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RHIC Spin Collaboration Meetings VIII, IX, X, XI

April 12, 2002
May 22, 2002
June 17, 2002
July 29, 2002

Organizer:

Brendan Fox

RIKEN BNL Research Center

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Preface to the Series

The RIKEN BNL Research Center (RBRC) was established in April 1997 at Brookhaven National Laboratory. It is funded by the "Rikagaku Kenkyusho" (RIKEN, The Institute of Physical and Chemical Research) of Japan. The Center is dedicated to the study of strong interactions, including spin physics, lattice QCD, and RHIC physics through the nurturing of a new generation of young physicists.

During the first year, the Center had only a Theory Group. In the second year, an Experimental Group was also established at the Center. At present, there are seven Fellows and seven Research Associates in these two groups. During the third year, we started a new Tenure Track Strong Interaction Theory RHIC Physics Fellow Program, with six positions in the first academic year, 1999-2000. This program had increased to include ten theorists and one experimentalist in academic year, 2001-2002. With recent graduations, the program presently has eight theorists and two experimentalists. Beginning last year a new RIKEN Spin Program (RSP) category was implemented at RBRC, presently comprising four RSP Researchers and five RSP Research Associates. In addition, RBRC has four RBRC Young Researchers.

The Center also has an active workshop program on strong interaction physics with each workshop focused on a specific physics problem. Each workshop speaker is encouraged to select a few of the most important transparencies from his or her presentation, accompanied by a page of explanation. This material is collected at the end of the workshop by the organizer to form proceedings, which can therefore be available within a short time. To date there are forty-nine proceeding volumes available.

The construction of a 0.6 teraflops parallel processor, dedicated to lattice QCD, begun at the Center on February 19, 1998, was completed on August 28, 1998. A 10 teraflops QCDOC computer in under development and expected to be completed in JFY 2003.

T. D. Lee
November 22, 2002

*Work performed under the auspices of U.S.D.O.E. Contract No. DE-AC02-98CH10886.

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SUMMARY

B. Fox, RBRC
April 12, 2002

for
RHIC Spin Collaboration Meeting VIII
RIKEN BNL Research Center

Since its inception, the RHIC Spin Collaboration (RSC) has held semi-regular meetings each year to discuss the physics possibilities and the operational details of the program. Having collected our first data sample of polarized proton-proton collisions in Run02 of RHIC, we are now in the process of examining the performance of both the accelerator and the experiments. From this evaluation, we not only aim to formulate a consensus plan for polarized proton-proton during Run03 of RHIC but also to look more forward into the future to ensure the success of the spin program.

In the second meeting of this series (which took place at BNL on April 12, 2002), we focused on Run02 polarization issues. This meeting opened with a presentation by Thomas Roser about his reflections on the outcome from the RHIC retreat during which the Run02 performance was evaluated. Of particular importance, Thomas pointed out that, with the expected beam time and his estimates for machine-tuning requirements, the experiments should limit their beam requests to two or three programs.

Following this presentation, we had a series of presentations which addressed the polarization performance as the beam traversed through the accelerator complex. Starting with the OPPIS source, Anatoli Zelenski reported that the source consistently produced pulses of 1×10^{12} protons with 70% polarization during the run. This polarization was, however, lower than had been expected following the August, 2001 studies which had indicated that 80% polarization was achievable. It was realized that this deficit might arise from unpolarized molecular hydrogen contaminating the polarized atomic hydrogen beam. Over the last three months, he has modified the source to filter out the molecular hydrogen. The resulting source now delivers 80% polarization. He feels that, with further work, it will be possible to increase the source to 85%, but did not speculate about the time scale for realizing such an improvement.[1]

From the source, the polarized protons are delivered to the AGS Booster ring where they are accelerated from 200 MeV to 1.5 GeV. Leif Ahrens reported on the polarization performance of the booster. He told us that there were few resonances which are crossed in the booster during ramping and that it is well known how to cross these resonance without losing polarization. So, there should be no polarization losses in the booster. Since the booster does not have a polarimeter, the polarization losses in it are evaluated by measuring the polarization in the AGS just after the beam is injected into it and comparing this measurement with the polarization in the source or the polarimeter at the end of the 200 MeV LINAC. As expected, these measurements showed that there was no loss of polarization in the booster.

Out of the booster, the beam enters the AGS where it is accelerated to the RHIC injection energy of 24 GeV ($G\gamma = 46.5$). Mei Bai reported on the polarization performance in the AGS. During ramping, the polarization dropped from an injection value of around 70% down to 20 to 30%. Losses were higher than expected because of the slow ramping rate of the AGS. However, measurements at different points in the ramp call into question the understanding of the spin model for the AGS because the losses at some resonances, in particular the $24\text{-}\nu_y$ weak resonance, were higher than would have been expected based on the model. Work is still underway to understand how the weak resonance could have such a large effect.[2]

Out of the AGS, the beam is injected into RHIC. Osamu Jinnouchi presented the latest

[1]For an update on this issue, see Anatoli's presentation at the September meeting.
[2]For an update on this work, please see Haixin Huang's talk at the May meeting.

status of the offline analysis of the data from the RHIC polarimeter. During the run, the polarimeter operated quite well. At this stage in the offline analysis, he has been aiming to understand its performance. This work included applying an energy correction to account for the approximately 20% drop in the gain of the silicon detectors during the course of the run. The cause for this gain loss is presently under study. Even with this correction, the non-zero y-component observed in the yellow ring near the end of the run remains and thus is still unexplained. He also took a first and very preliminary look at the time dependence of the polarization within a fill. He sees that the polarization is maintained or decreases by, at most, 15% of the measured value at the beginning of the fill. He intends to continue these studies when he has further improved his understanding of the polarimeter.

And, finally, Vadim Ptitsyn presented the current understanding of the polarization performance within RHIC. The two Siberian snakes operated well during the run and, with them, it is expected that the spin tune will be held at 1/2 during the entire ramp. In this way, the standard resonances do not affect the polarization. However, the snakes introduce new resonances which need to be avoided by controlling the betatron tune during the ramp. In Run02, the polarization retention on the ramp was good in yellow for the most part but, in blue, was not as good. The cause of this difference is still under study.

B. Fox
19 April 2002

RHIC Status and Plans

T. Roser, BNL
April 12, 2002

for
RHIC Spin Collaboration Meeting VIII
RIKEN BNL Research Center

RHIC Status and Plans

Brief summary of RHIC RUN2001/2

Plans and goals for RUN2003

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Thomas Roser
RHIC Retreat
March 5-7, 2002

FY2001 - 02 RHIC Gold Parameters

- **55 - 56 bunches** per ring ✓ (110 bunches per ring tested, intensity limited).
- **7.5 $\times$ 10^8 Au/bunch @ storage energy** (intensity limited during acceleration)
- **1 $\times$ 10^9 Au/bunch achieved @ injection** ✓
- **Longitudinal emittance**: 0.5 eVs/nucleon/bunch (0.3-0.6 Design) ✓
- **Transverse emittance** at storage: **15 π μm** (norm, 95%) ✓
- **Storage energy: 100 GeV/ amu** (γ = **107.4**) ✓ **10 GeV / amu** (γ=**10.5**) ✓
- **Lattice with β^* squeeze during acceleration ramp:**
  - β^* = 3 m and 10m @ all IP at injection ✓
  - β^*= 1 m @ 8 and 2 m @ 2, 6 and 10 o'clock at storage ✓
- **Peak Luminosity: 5 $\times$ 10^{26} cm^{-2}** s^{-1} (2.5 $\times$ design average) ✓
- **Bunch length: 5ns** (200 Mhz operational, diamond length: σ = 20 cm) ✓

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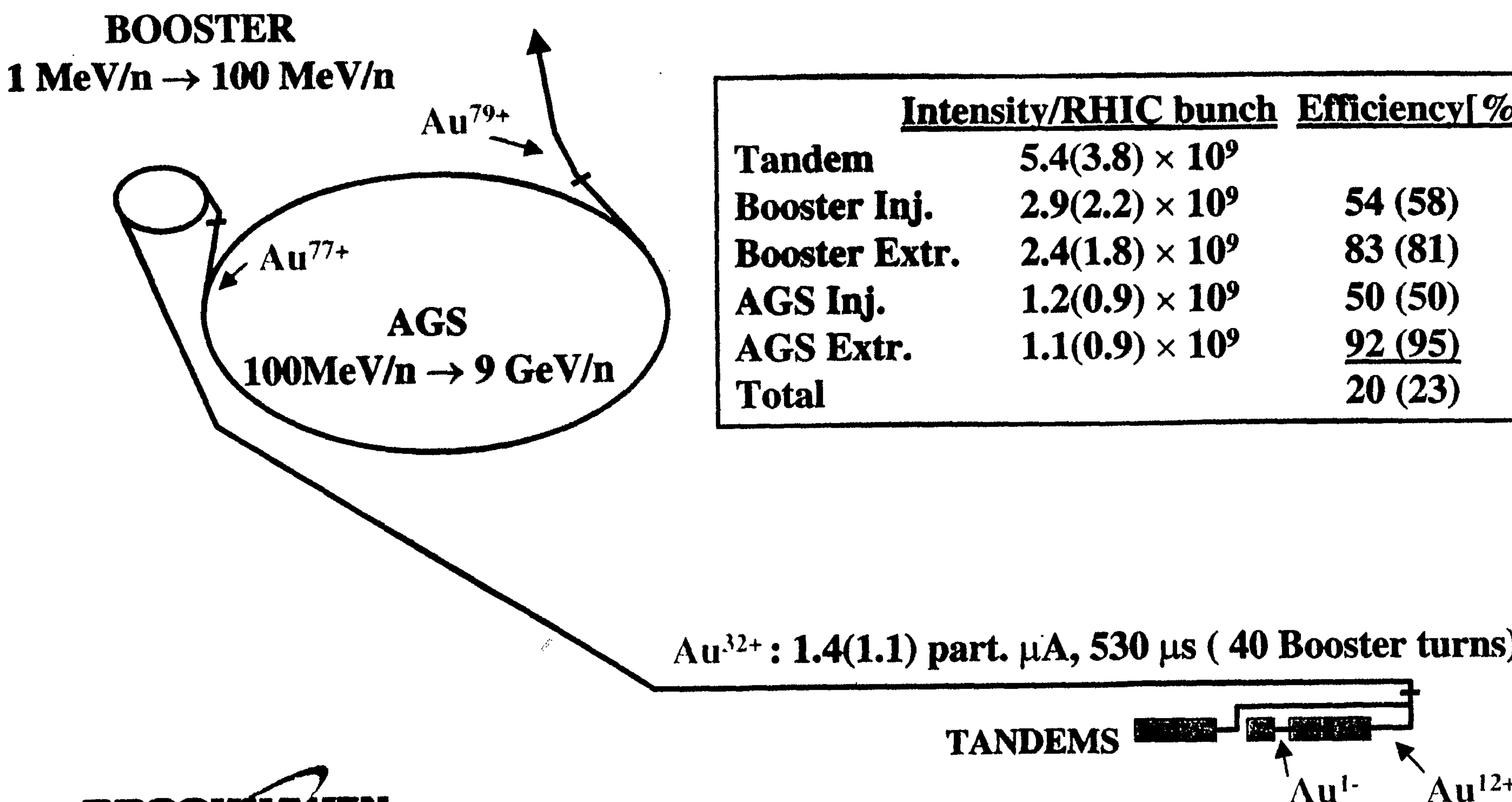
Au Injector Performance (needs update)

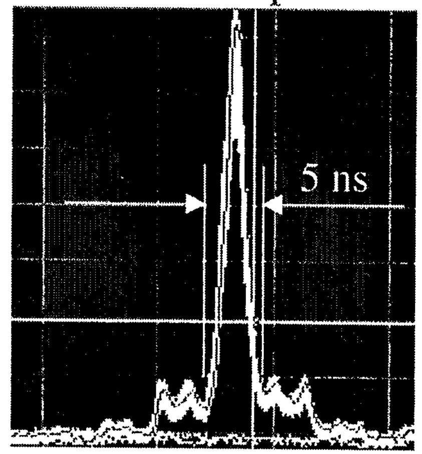


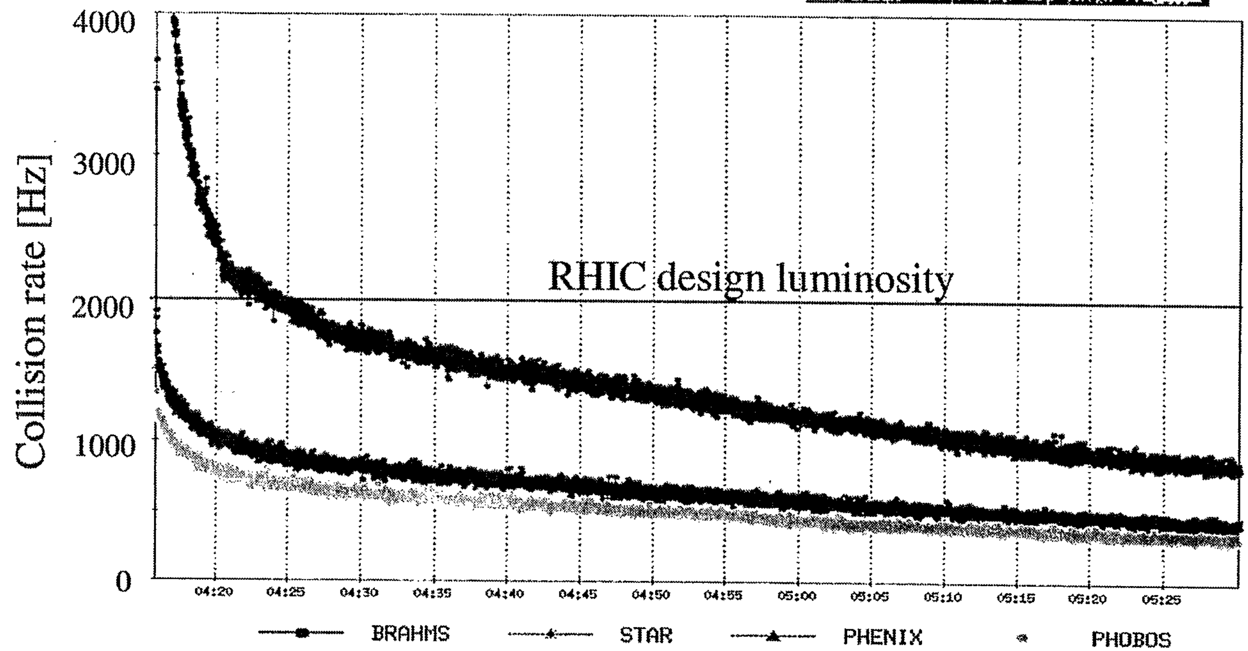
	Intensity/RHIC bunch	Efficiency[%]
Tandem	$5.4(3.8) \times 10^9$	
Booster Inj.	$2.9(2.2) \times 10^9$	54 (58)
Booster Extr.	$2.4(1.8) \times 10^9$	83 (81)
AGS Inj.	$1.2(0.9) \times 10^9$	50 (50)
AGS Extr.	$1.1(0.9) \times 10^9$	92 (95)
Total		20 (23)

RHIC performance

- Collisions at RHIC design beam energy (100 GeV/nucl)
- 200 MHz rf system operational
  - 5 ns bunch length and an interaction region with $\sigma \sim 25$ cm
- Luminosity exceeding RHIC design luminosity of 2×10^{26} cm^{-2} s^{-1}
- 40% availability is limiting total integrated luminosity

RHIC bunch profile





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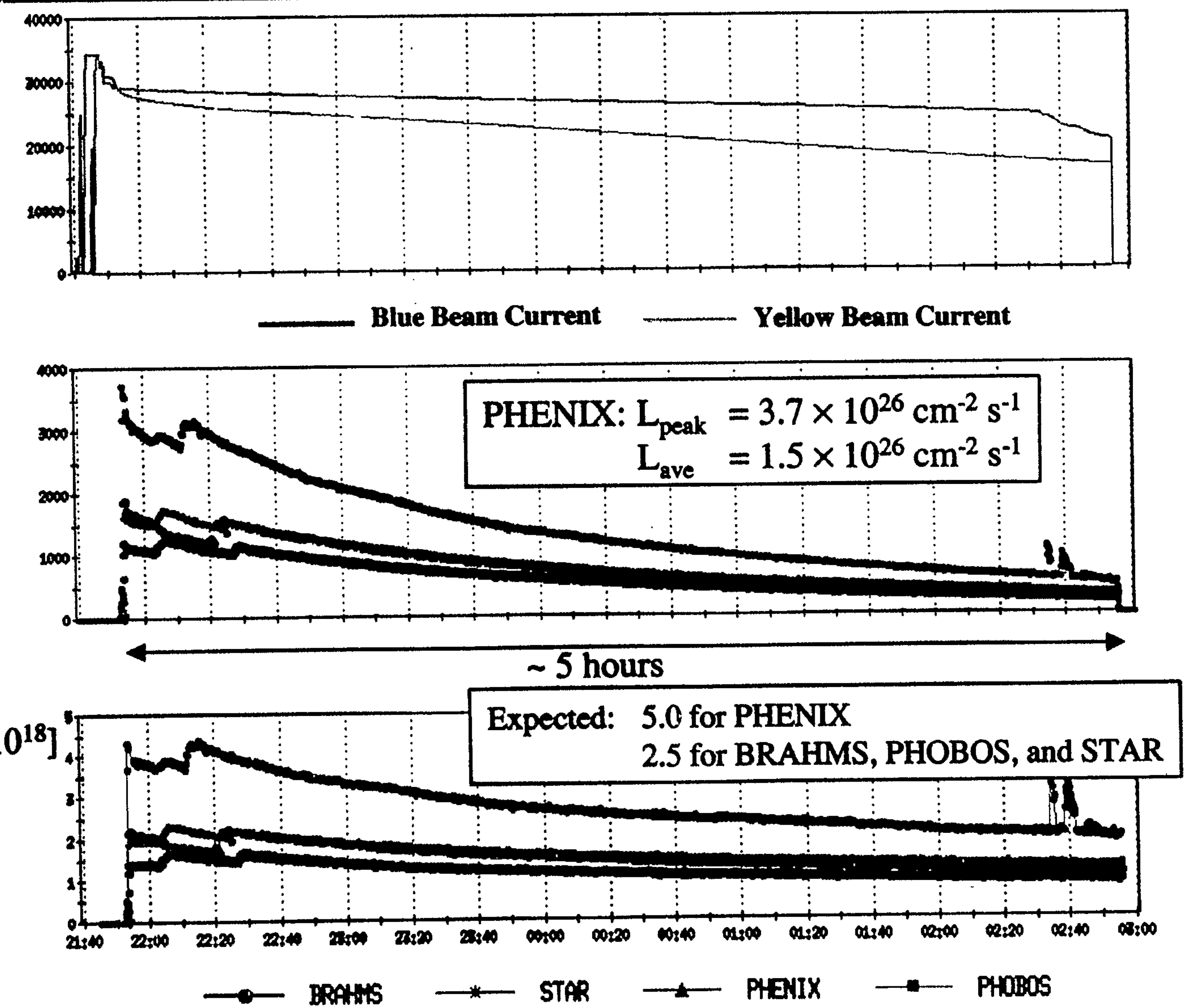
"Typical Store" # 1812

Beam currents [x10^6 ions]

Collision rate [Hz]

Specific luminosity [Hz/10^{18}]



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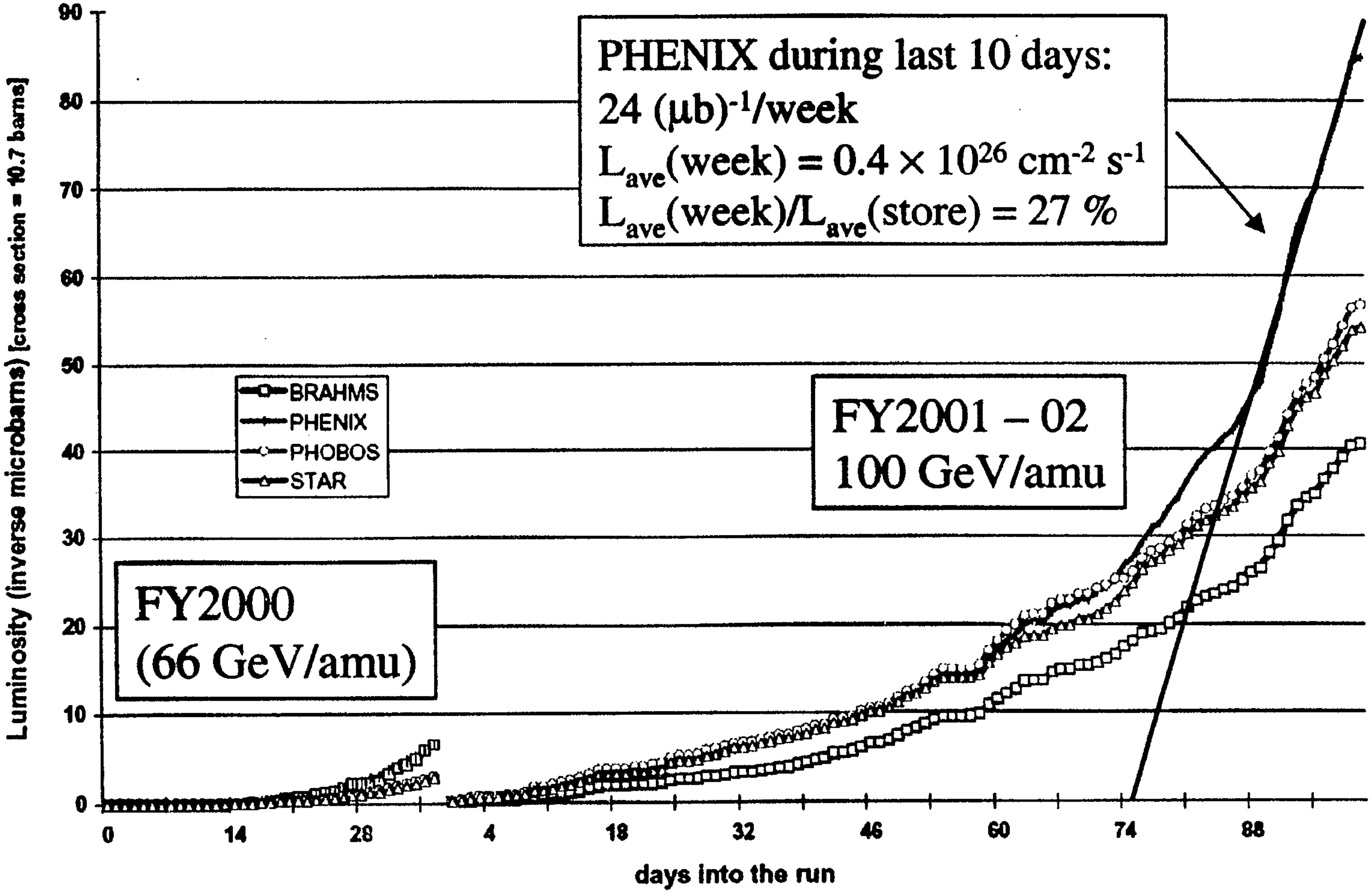
Integrated Au-Au luminosity



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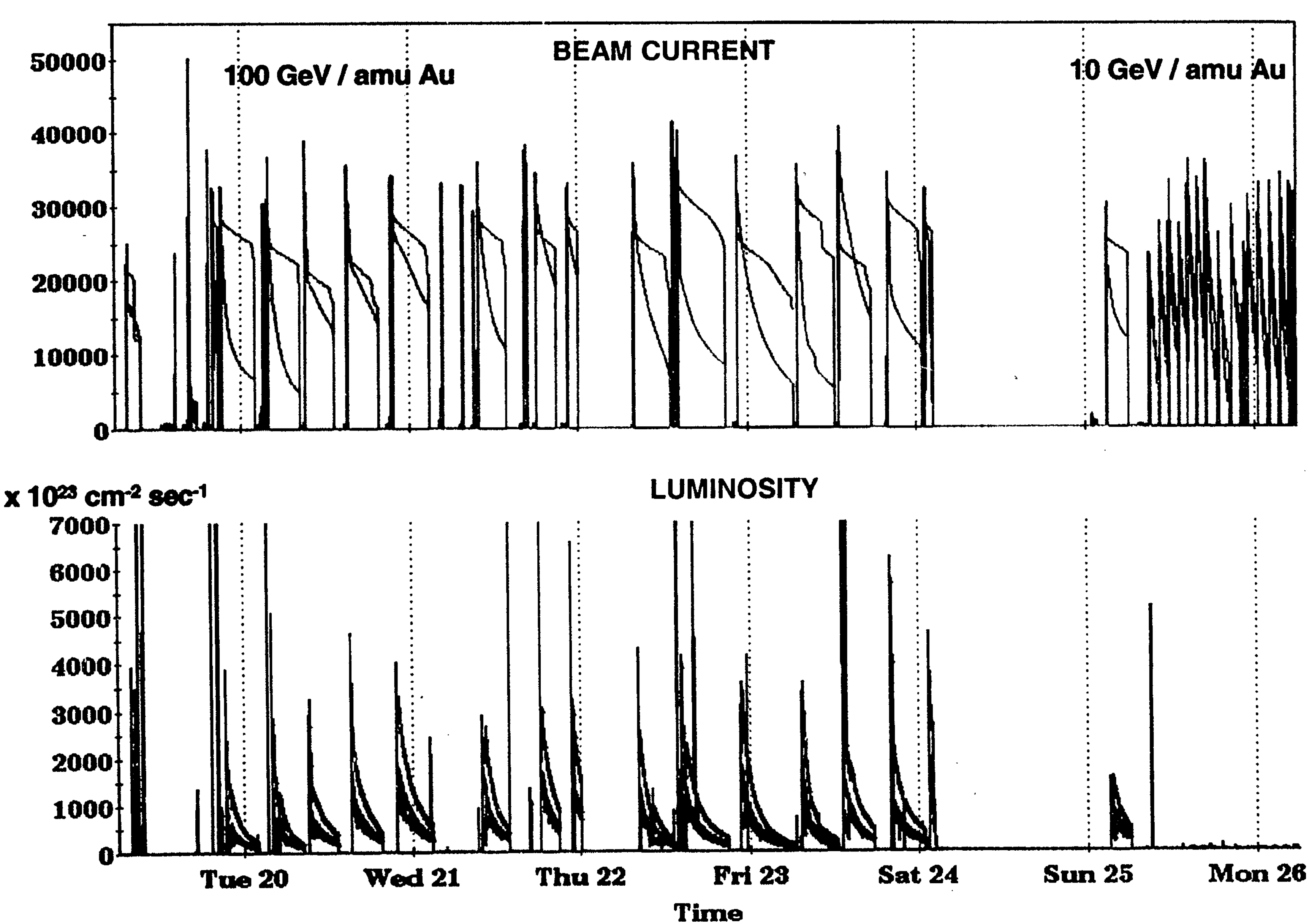
RHIC Performance

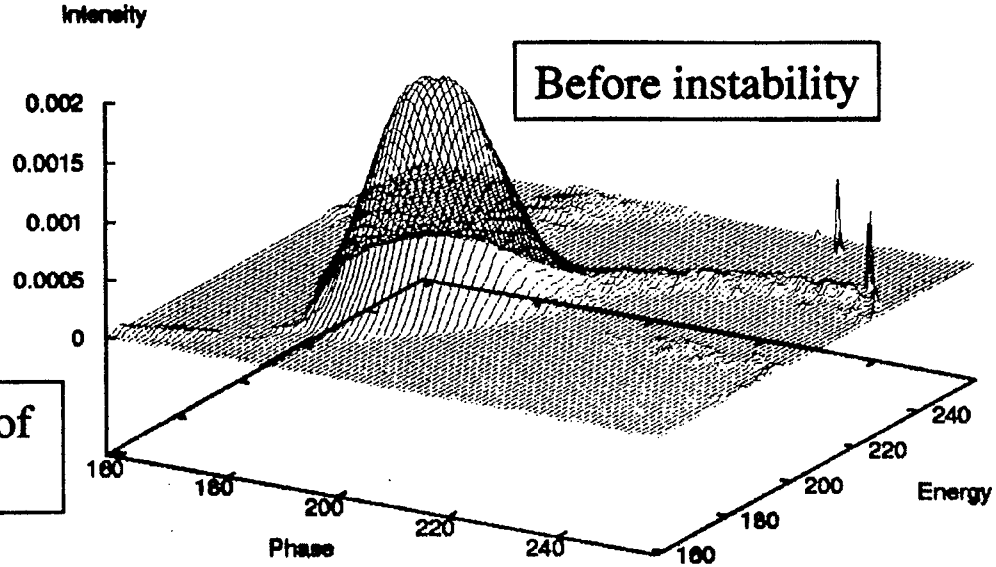


Transverse instabilities in RHIC

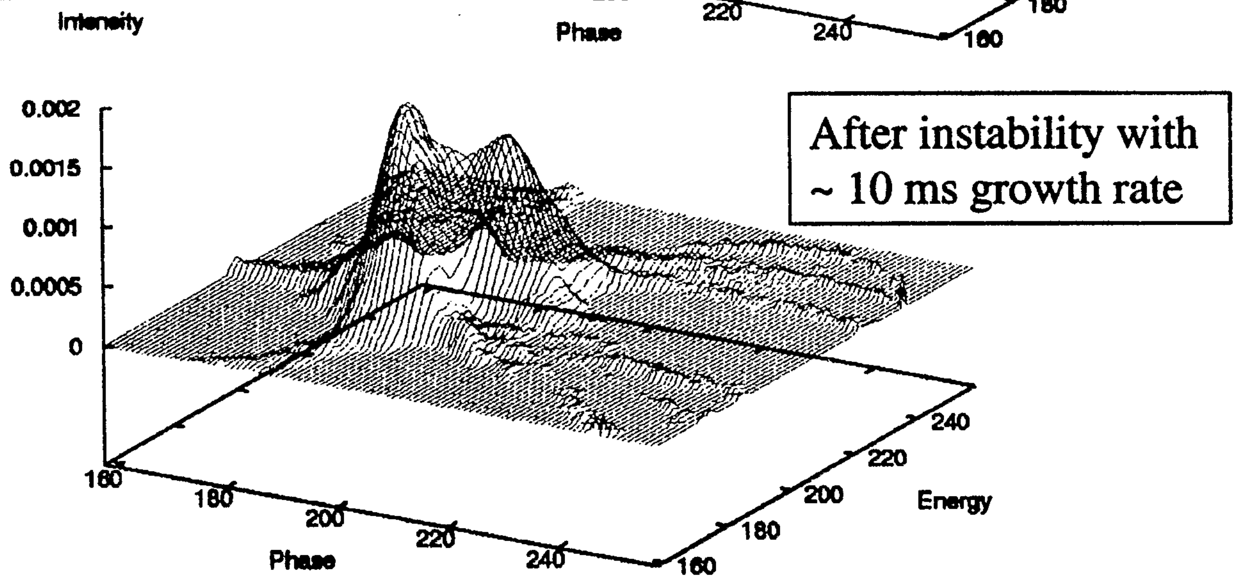
High sensitivity around transition

Effect of vacuum chamber impedance, electron cloud (?)

Cures: beam-beam tune spread, **octupoles,** transverse dampers, rf quad, …



Tomographic reconstruction of 2D bunch density



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RHIC intensity limitations

- Single- and multi-bunch instabilities
  - **Effect of vacuum chamber impedance, electron cloud (?)**
- Intensity limitation due to vacuum break-down
  - **Limited to about 40×10^9 Au/ring**
    - **Electron cloud ? Ion or electron desorbtion ?**
- Intra-Beam Scattering (IBS) (only Au)
  - **Transverse and longitudinal emittance growth**
  - **Eventually will need electron cooling (see below)**
- Beam-beam tune shift and spread
  - **First strong-strong hadron collider (after ISR)**

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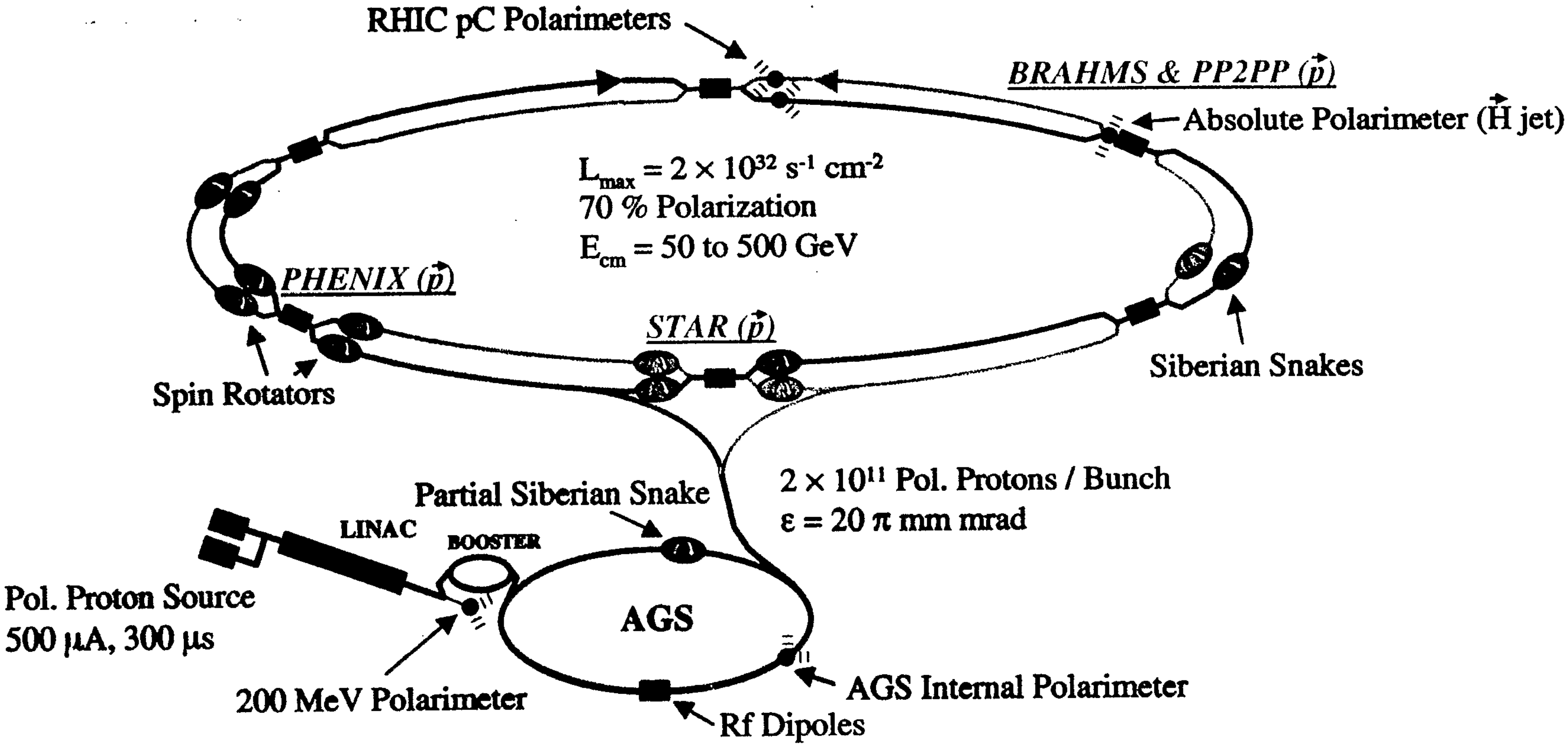
Polarized Proton Collisions in RHIC



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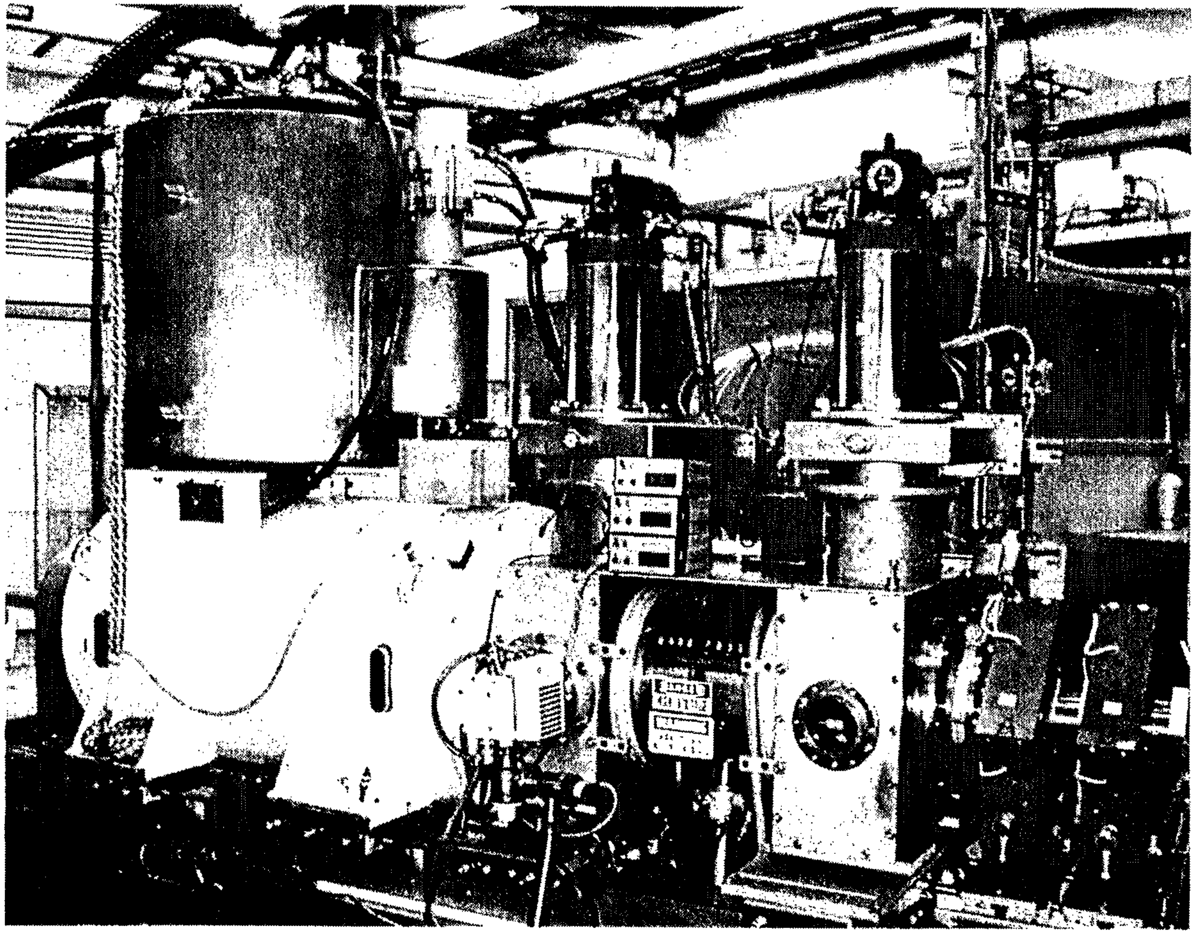
High intensity polarized H^- source



KEK OPPIS
upgraded at TRIUMF

75 - 80 % Polarization

15×10^{11} protons/pulse
at source

6×10^{11} protons/pulse
at end of LINAC

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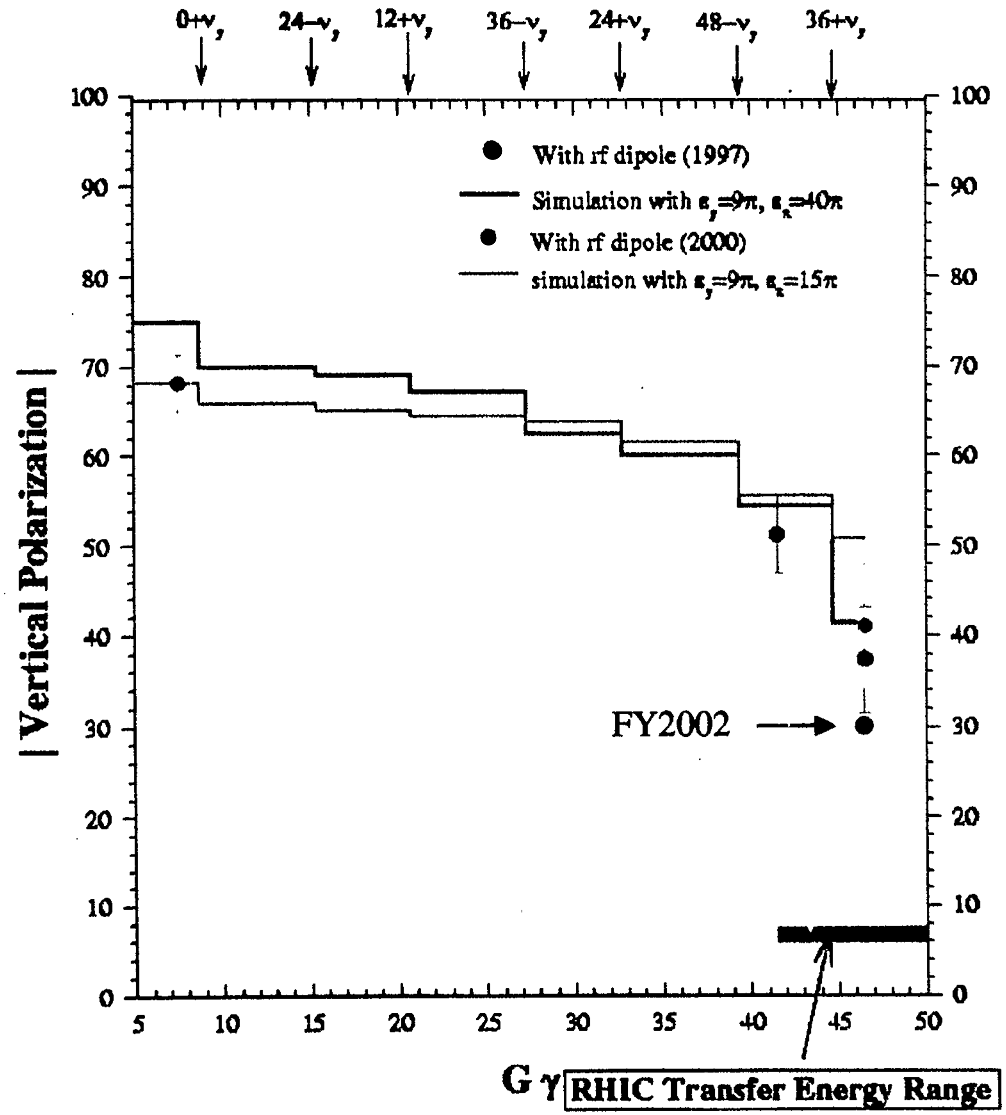
Proton polarization at the AGS

- Full spin flip at all imperfection resonances using partial Siberian snake
- Full spin flip at strong intrinsic resonances using rf dipole
- Remaining polarization loss from coupling and weak intrinsic resonances
- Larger polarization loss in FY2002 due to lower ramp-rate motor-generator and higher bunch intensity (?)



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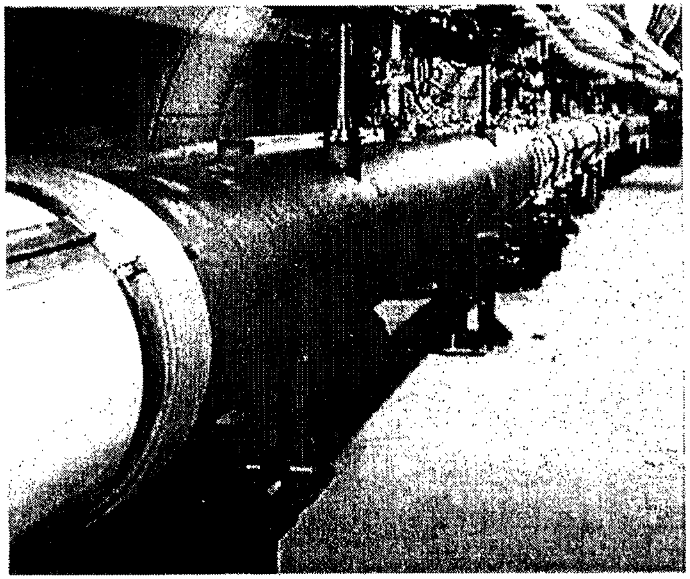
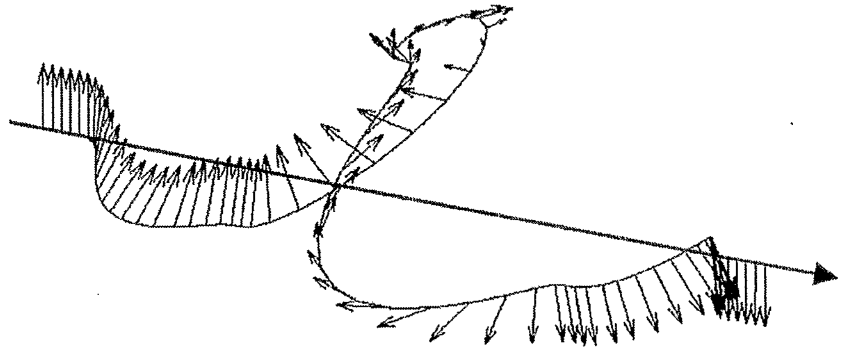
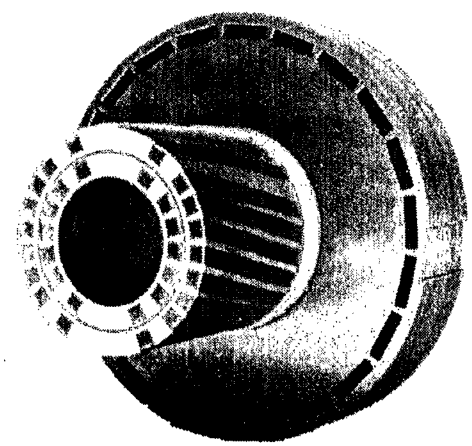
First Siberian Snake in RHIC Tunnel

Siberian Snake: 4 superconducting helical dipoles, 4Tesla,
2.4 m long with full 360° twist





Funded by RIKEN, Japan
Designed and constructed at BNL



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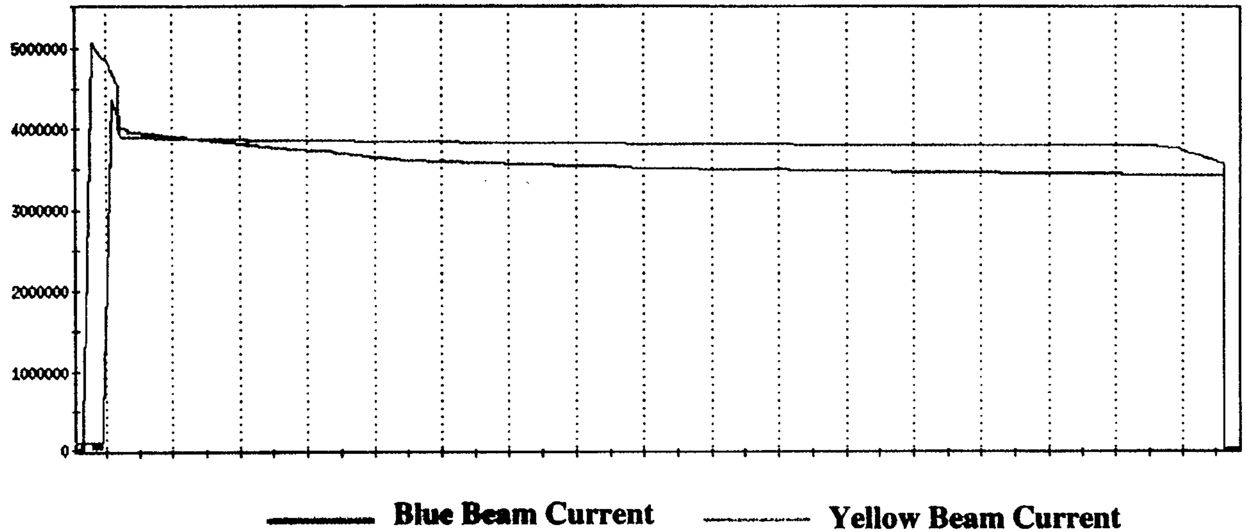
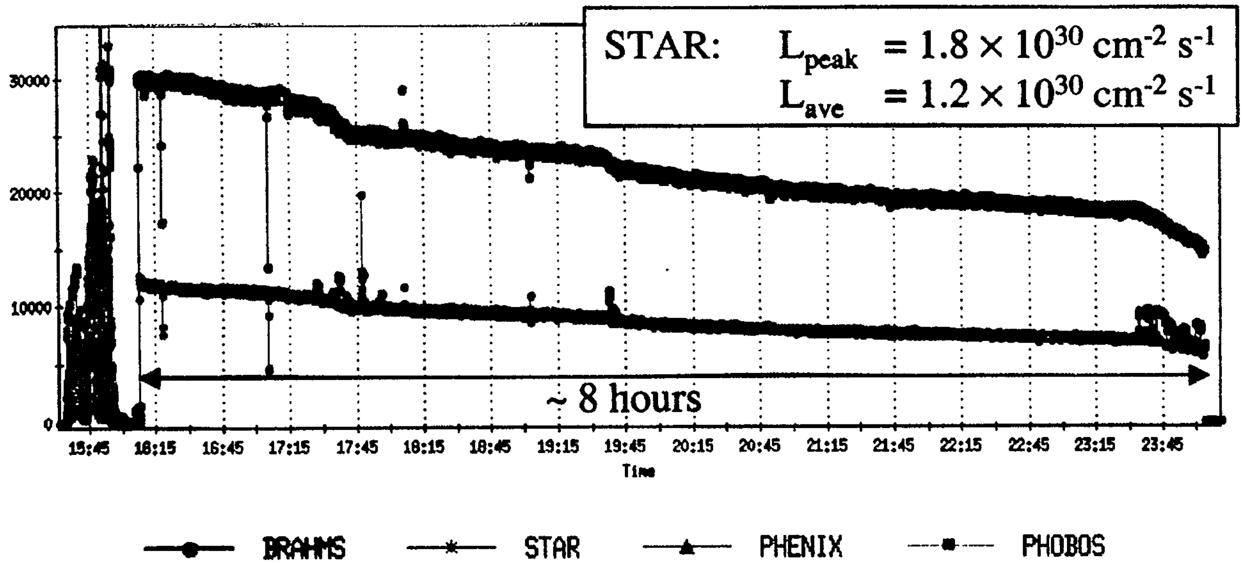
“Typical Store” # 2304

Beam currents [$\times 10^6$ ions]



Collision rate [Hz]

Vernier scans:
STAR: $10^4 \rightarrow 0.6 \times 10^{30}$ cm^{-2} s^{-1}
PHENIX: $10^4 \rightarrow 1.6 \times 10^{30}$ cm^{-2} s^{-1}



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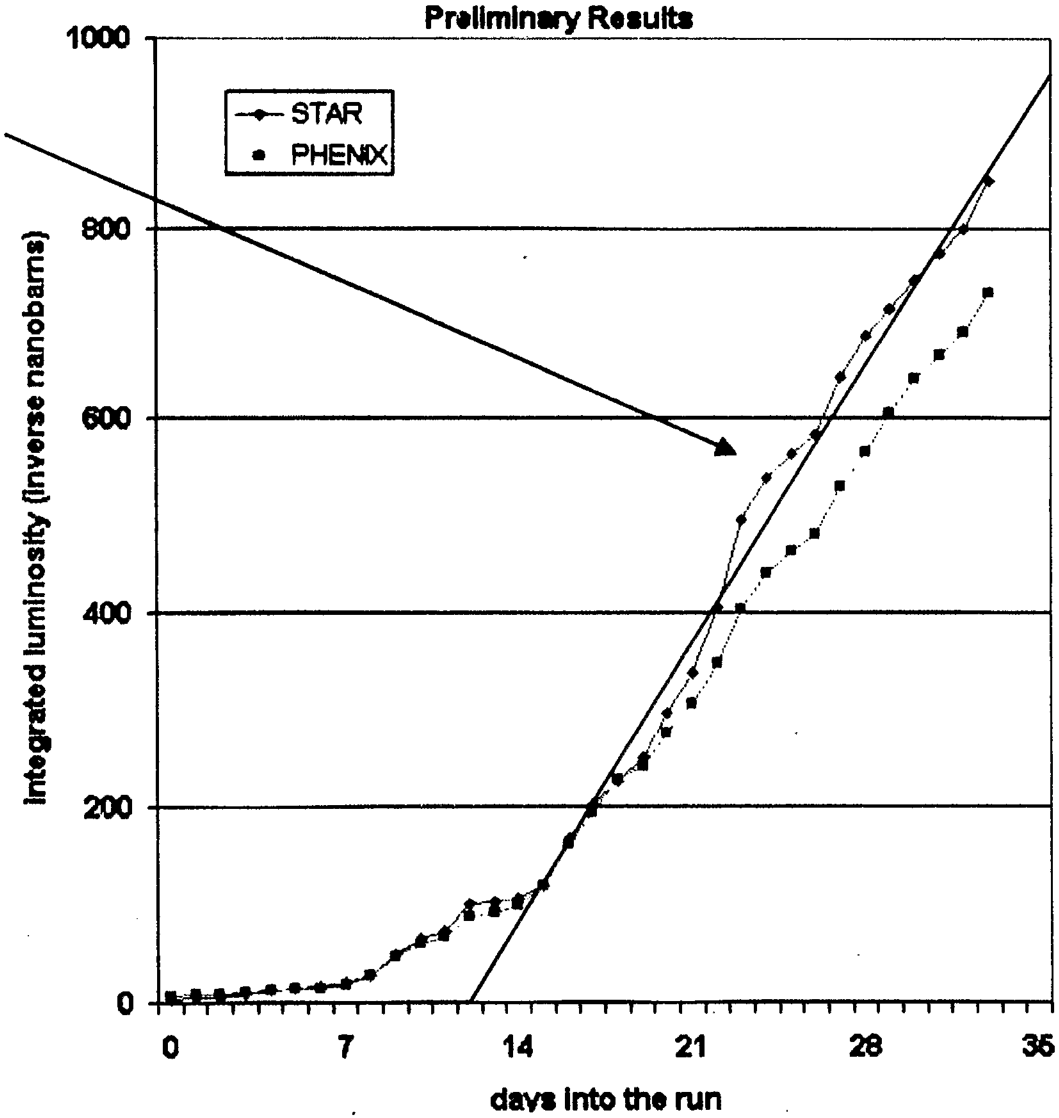
Integrated p - p luminosity

STAR during last 20 days:
290 $(nb)^{-1}$/week
$L_{ave}(week) = 0.5 \times 10^{30}\ cm^{-2}\ s^{-1}$
$L_{ave}(week)/L_{ave}(store) = 42\ \%$



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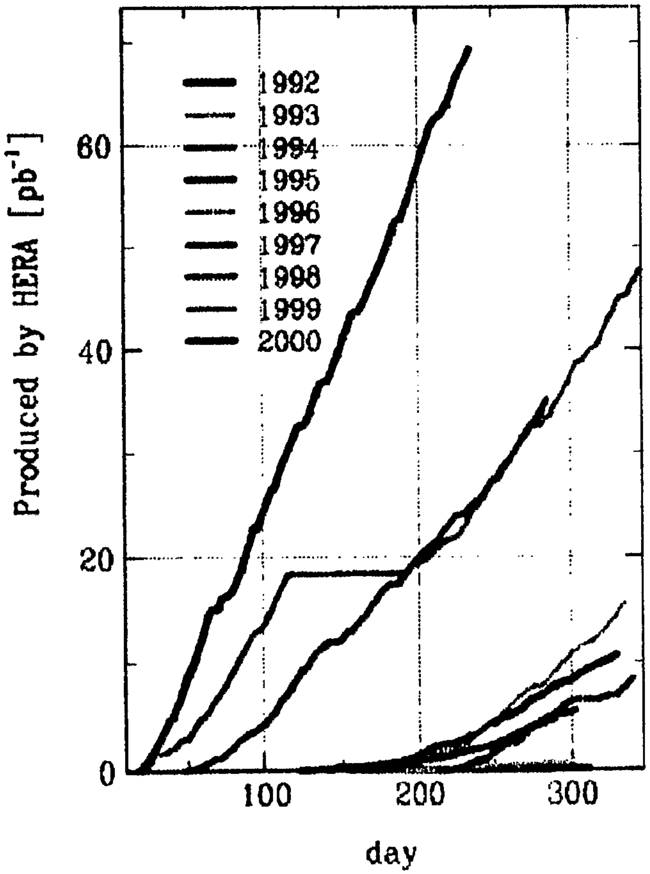
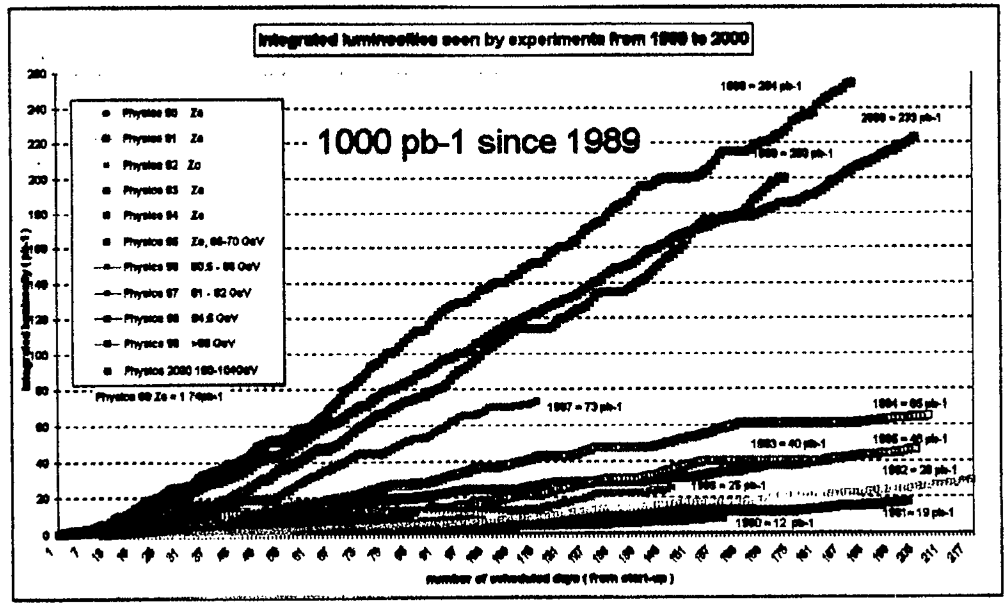
Results from first RHIC polarized proton run

- 55 bunches per ring with 0.8×10^{11} p↑/bunch
- Charge/bunch and total charge higher than with gold beams
- Lattice with constant β* of 3 m during ramp
- Peak luminosity at beginning of store: 1.5×10^{30} cm^{-2} s^{-1}
- Energy/beam: 100 GeV
- Beam polarization ~ 25 %
  RHIC polarimeters work reliably
- Little if any depolarization in RHIC during acceleration and store
  Siberian Snakes work
- ~ 60 % polarization loss in AGS; aggravated by lower ramp-rate from Westinghouse motor-generator
- **Strong Siberian snake in AGS (~ 30 % of full snake) could avoid all depolarization in the AGS**

HERA and LEP luminosity evolutions





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RUN2003 Goals (~ 3-4 weeks into run)

- Prepare for four modes; all with:
  Energy/beam: 100 GeV/nucl., diamond length: $\sigma = 20$ cm, L_{ave}(week)/L_{ave}(store) = 40 %

Mode	# bunches	Ions/bunch [$\times 10^9$]	β^* [m]	Emittance [$\pi\mu$m]	L_{peak} [$cm^{-2}s^{-1}$]	L_{ave}(store) [$cm^{-2}s^{-1}$]	L_{ave} (week) [$week^{-1}$]
Au-Au	56	1	1	15-40	14×10^{26}	3×10^{26}	70 $(\mu b)^{-1}$
(p↑-p↑)*	112	100	1	25	16×10^{30}	10×10^{30}	2.8$(pb)^{-1}$
d-Au	56	100(d), 1(Au)	2	20	5×10^{28}	2×10^{28}	5 $(nb)^{-1}$
Si-Si	56	7	1	20	5×10^{28}	2×10^{28}	5 $(nb)^{-1}$

* Beam polarization ≥ 50 %; Acceleration test to 250 GeV

- New hardware installed and to be commissioned:
  - All eight spin rotators for PHENIX and STAR

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RUN2003 Integrated Luminosity Estimate

Estimate for integrated luminosity for 29 week FY2003 run (starting October 1, 2002):

- 4 weeks cool down, 1 week warm-up, 2 weeks setup (for each mode), 3 weeks ramp up (for each mode): →
  29 weeks of cryo ops.: 2 modes: 7 weeks at "final" luminosity / mode
  3 modes: 3 weeks at "final" luminosity / mode
  4 modes: 1 week at "final" luminosity / mode
- Minimum: performance at end of FY2001/02 run
- Maximum: luminosities from previous slide

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Mode	L_{ave} (week) [$week^{-1}$]	Int. Lumi. 2 modes	Int. Lumi. 3 modes	L_{ave} (week) [$week^{-1}$]	Int. Lumi. 2 modes	Int. Lumi. 3 modes
Au-Au	$24(\mu b)^{-1}$	$168(\mu b)^{-1}$	$72(\mu b)^{-1}$	$70 (\mu b)^{-1}$	$490(\mu b)^{-1}$	$210(\mu b)^{-1}$
(p↑-p↑)*	$0.3(pb)^{-1}$	$2.1(pb)^{-1}$	$0.9(pb)^{-1}$	$2.8(pb)^{-1}$	$19.6(pb)^{-1}$	$8.4(pb)^{-1}$
d-Au	?	?	?	$5 (nb)^{-1}$	$35 (nb)^{-1}$	$15 (nb)^{-1}$
Si-Si	?	?	?	$5 (nb)^{-1}$	$35 (nb)^{-1}$	$15 (nb)^{-1}$

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POLARIZED SOURCE

PERFORMANCE IN 2001-02 RUN

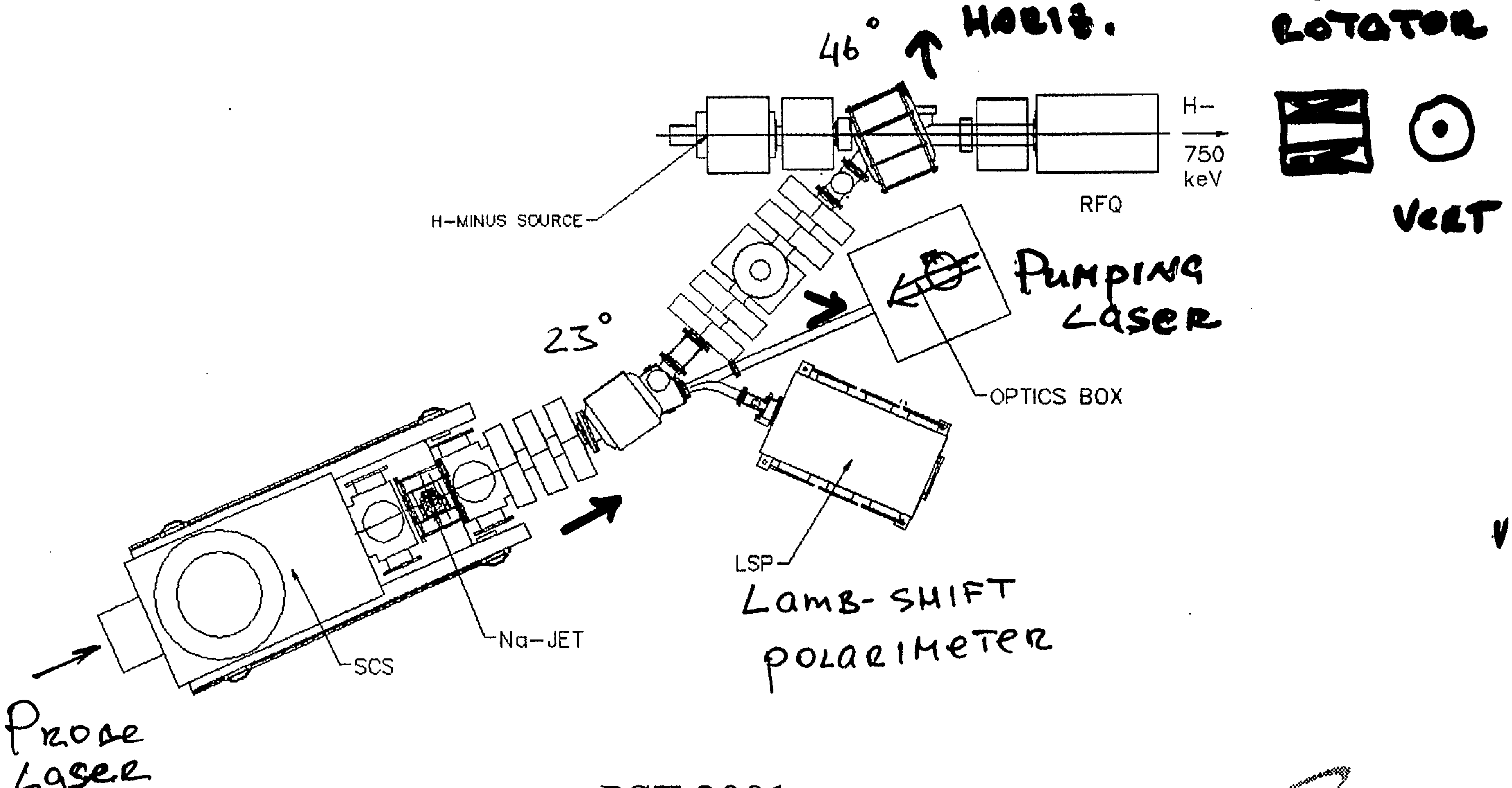
AND FUTURE PLANS

ANATOLI ZELENSKI

April 12, 2002

1. OPPIS INJECTOR
2. SOURCE OPERATION
3. 200 MeV POLARIMETER
4. POLARIZATION MEASUREMENTS DURING THE RUN
5. POLARIZATION DIAGNOSTICS UPGRATE
6. PLANS

The polarized RHIC injector layout



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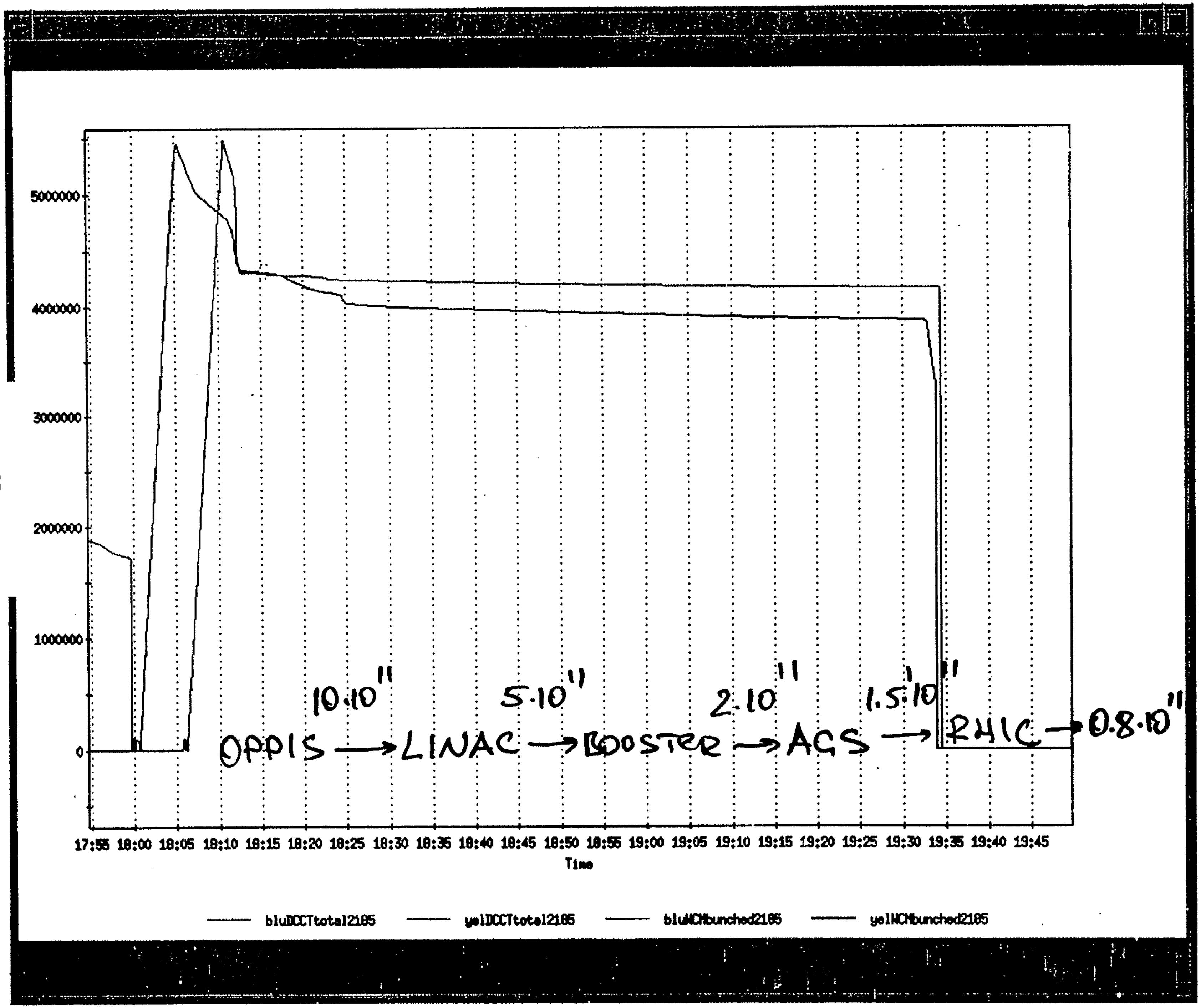
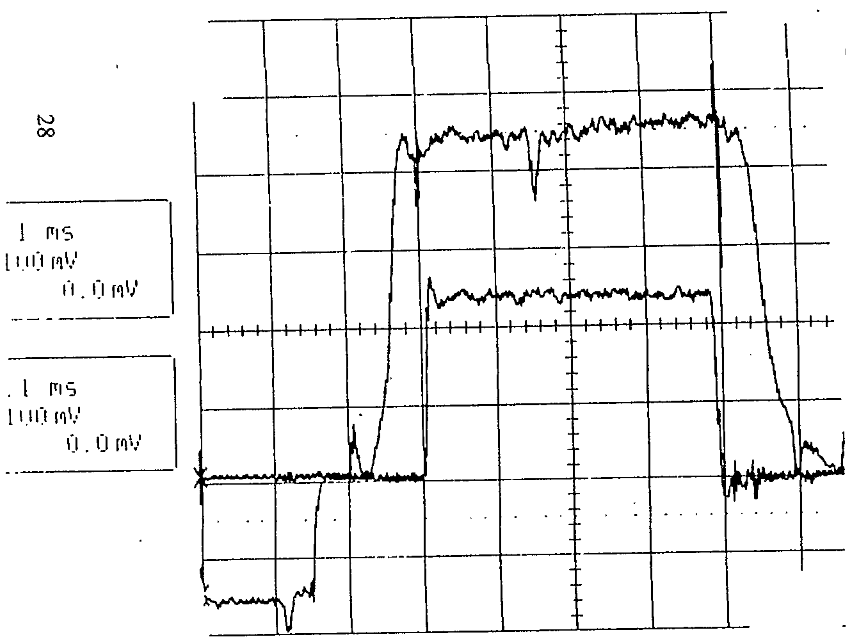


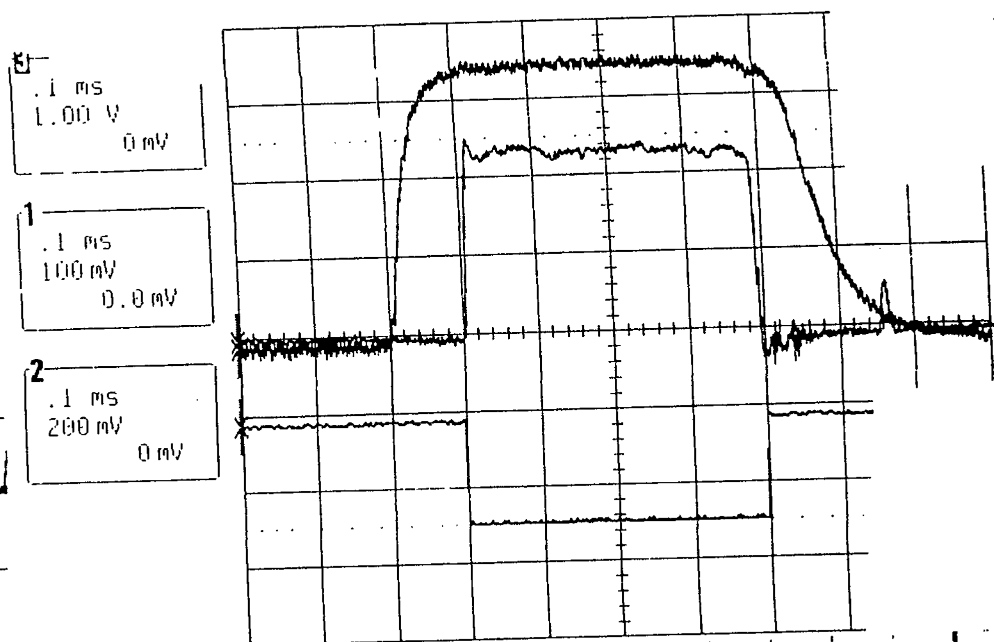
5000000
4000000
3000000
2000000
1000000
0
17:55 18:00 18:05 18:10 18:15 18:20 18:25 18:30 18:35 18:40 18:45 18:50 18:55 19:00 19:05 19:10 19:15 19:20 19:25 19:30 19:35 19:40 19:45
Time
bluDCCTtotal2185
yelDCCTtotal2185
bluWCMbunched2185
yelWCMbunched2185
10·10^11 5·10^11 2·10^11 1.5·10^11
OPPIS → LINAC → BOOSTER → AGS → RHIC → 0.8·10^11

θ = 157.1°   AB = 327   L2-470   TRG-240

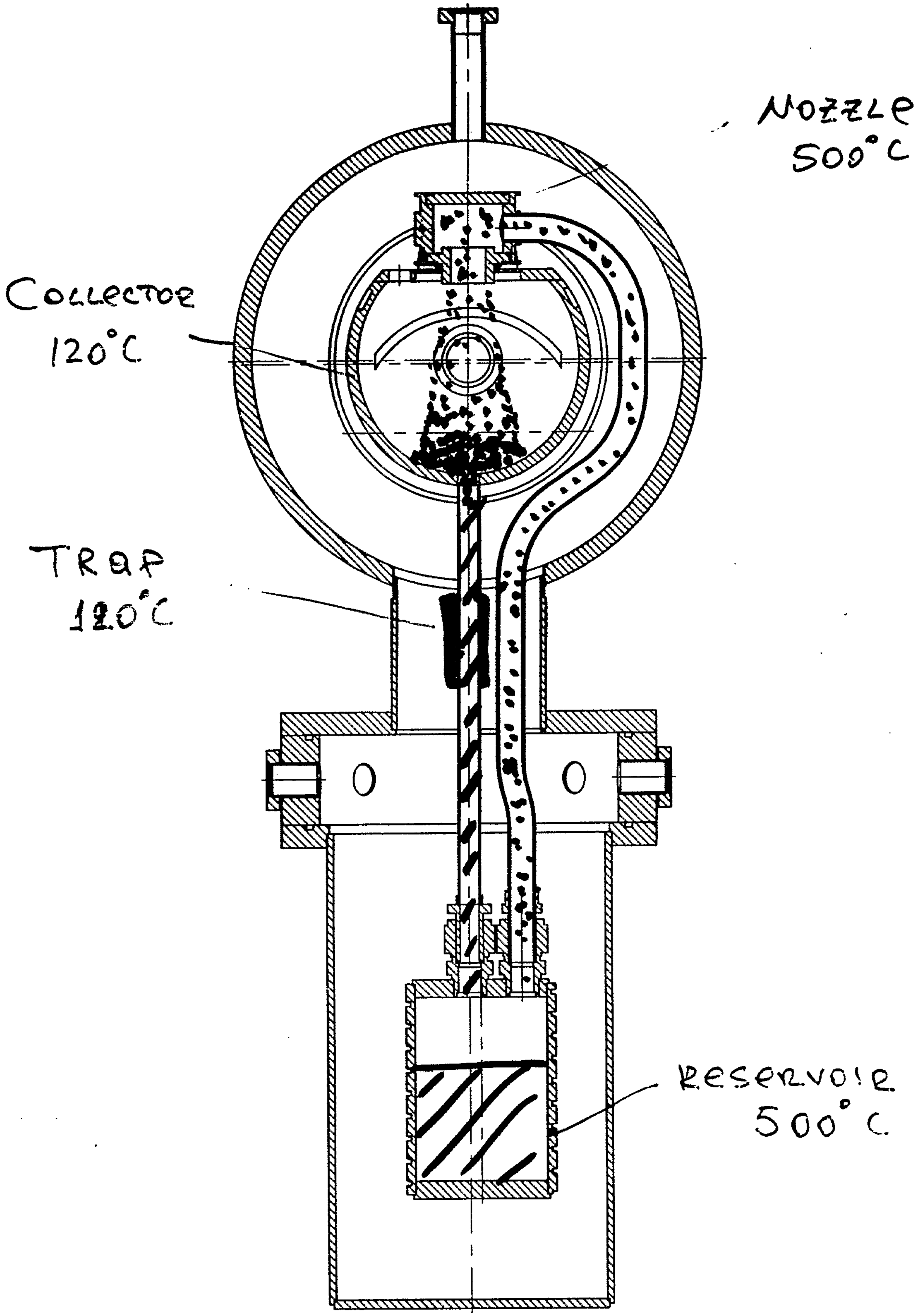
ECR- 59mA (U3-139)

Booster, inj 5800
AGS exp 2000 (1955)

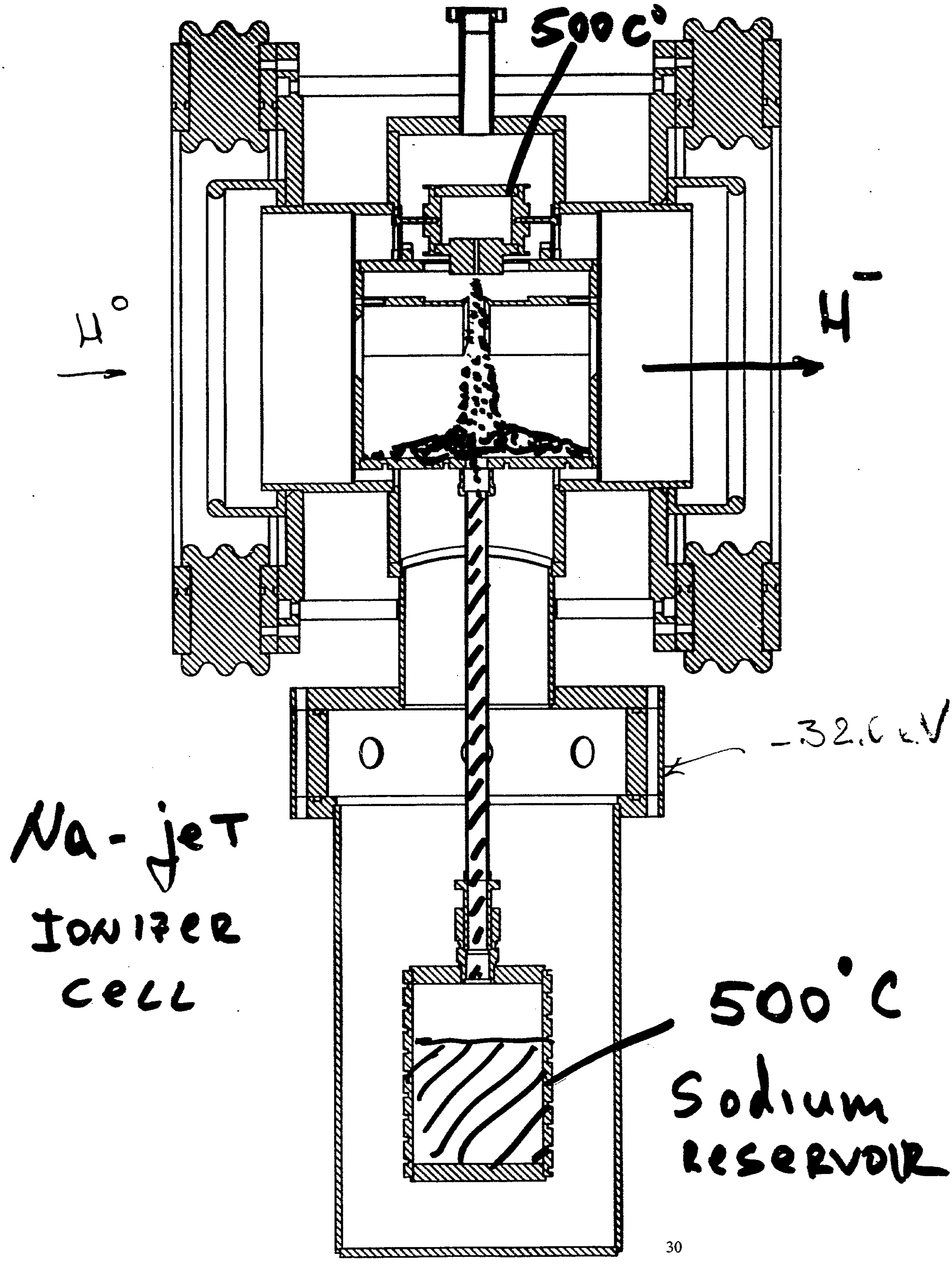




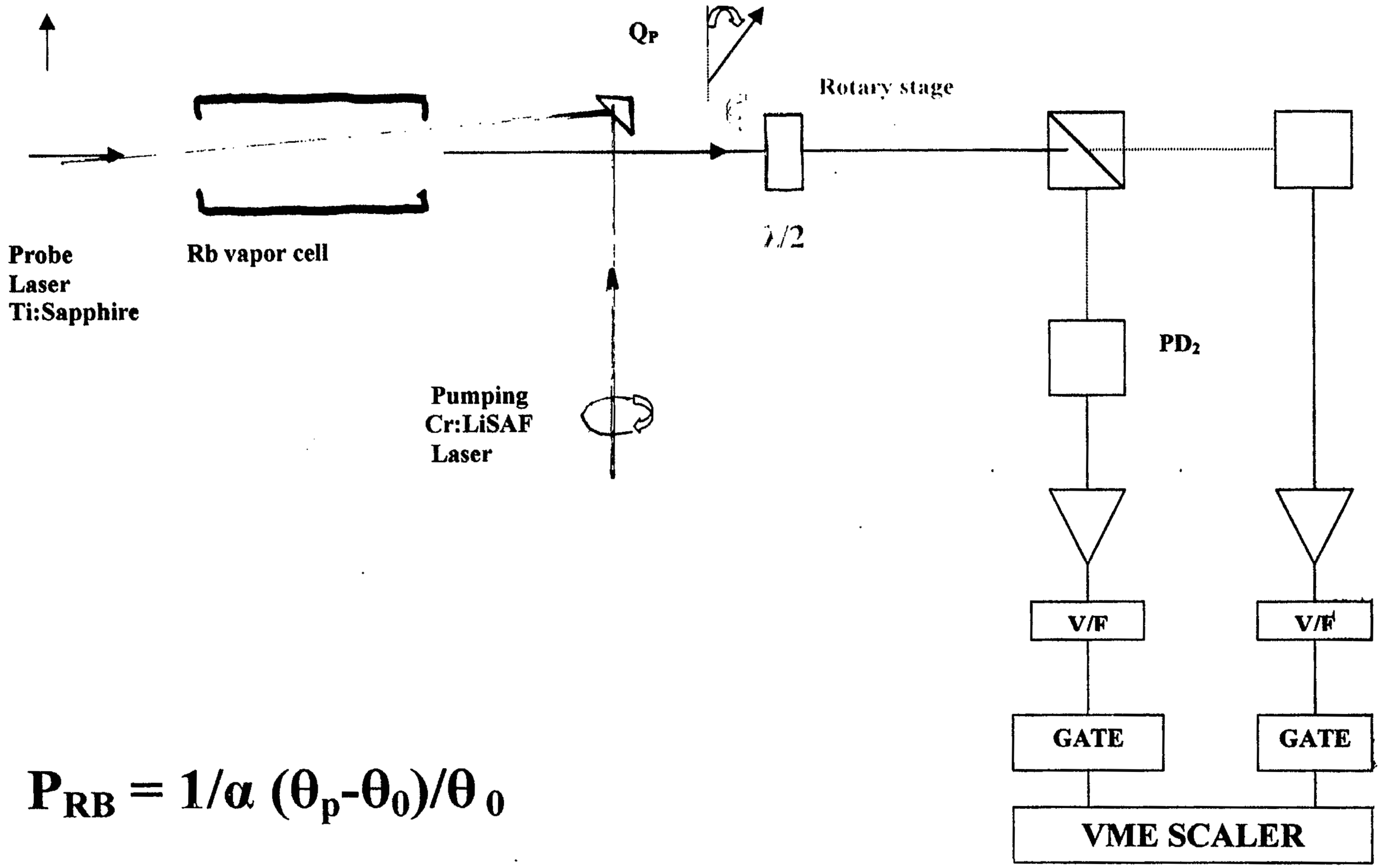
Laser trigger adjustment.



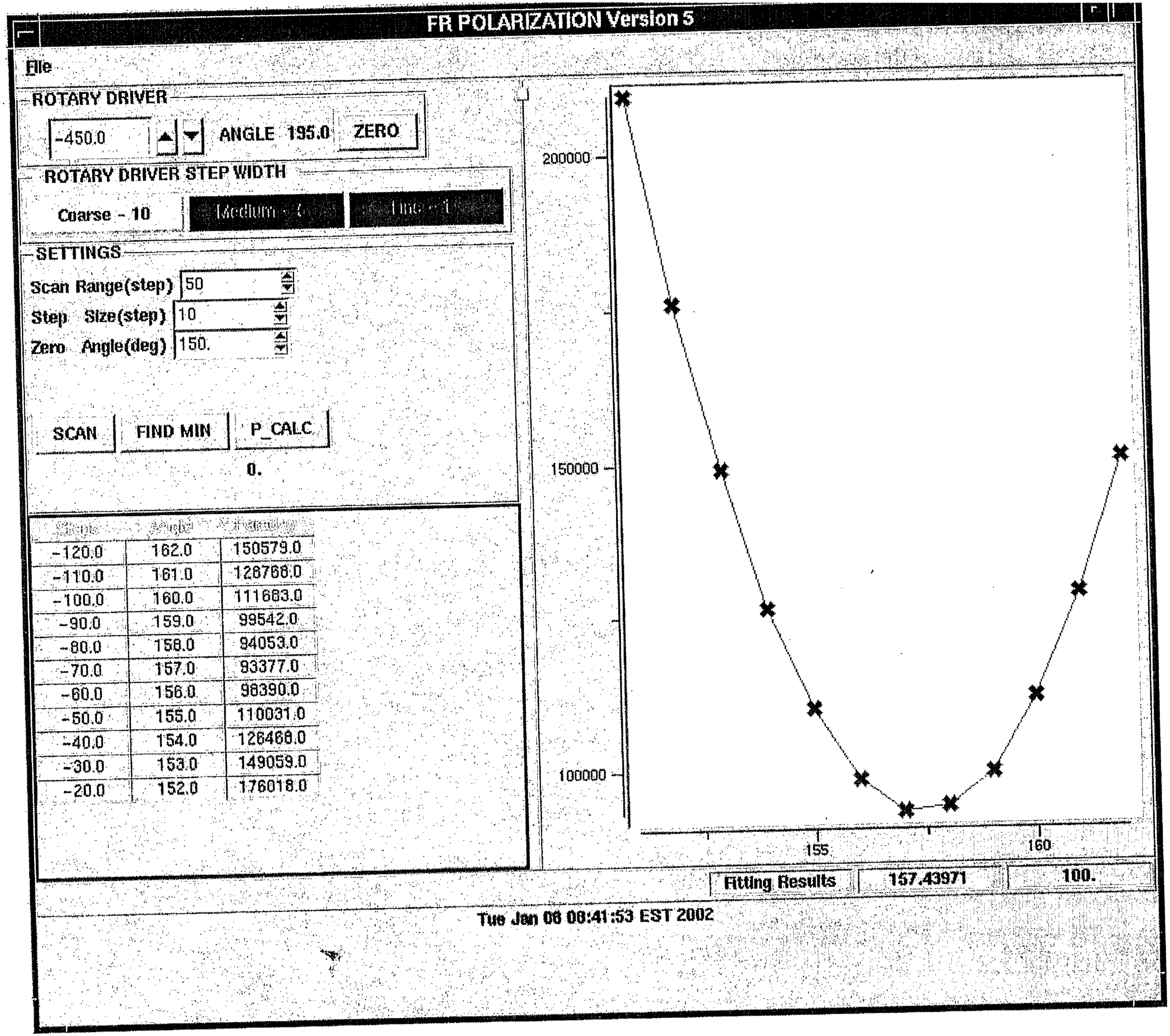
SECTION B–B


500C°
H°
H⁻
-32.0 kV
Na-jeT
IONIZER
CeLL
500°C
Sodium
RESERVOIR

Rb POLARIZATION MEASUREMENT BY FARADEY ROTATION TECHNIQUE



$$P_{RB} = 1/\alpha\ (\theta_p-\theta_0)/\theta_0$$


FR POLARIZATION Version 5
File
ROTARY DRIVER
-450.0
ANGLE 195.0
ZERO
ROTARY DRIVER STEP WIDTH
Coarse - 10
SETTINGS
Scan Range(step) 50
Step Size(step) 10
Zero Angle(deg) 150.
SCAN
FIND MIN
P_CALC
0.
-120.0 162.0 150579.0
-110.0 161.0 128768.0
-100.0 160.0 111683.0
-90.0 159.0 99542.0
-80.0 158.0 94053.0
-70.0 157.0 93377.0
-60.0 156.0 98390.0
-50.0 155.0 110031.0
-40.0 154.0 126468.0
-30.0 153.0 149059.0
-20.0 152.0 176018.0
200000
150000
100000
155
160
Fitting Results
157.43971
100.
Tue Jan 08 08:41:53 EST 2002

RUBIDIUM POLARIZATION MEASUREMENT – Ver. 10

STATUS:

PROCESSING

START | STOP | CLEAR | SAVE | PRINT | RESTART | EXIT

READING

PD1+	PD2+	PD1-	PD2-	CLK+	CLK-	(th-45)	RbPOL.
0	0	485	302.0	0	1781	-13.3	-95.0
215	678.0	0	0	1781	0	27.2	97.4
0	0	518	308.0	0	1781	-14.5	-100.6
211	668.0	0	0	1780	0	27.3	97.7
366	474.0	0	0	1780	0	7.0	1.7
0	0	490	303.0	0	1781	-13.5	-95.9
213	673.0	0	0	1780	0	27.2	97.4
0	0	474	301.0	0	1780	-12.8	-92.6
210	669.0	0	0	1780	0	27.4	98.2
0	0	491	304.0	0	1781	-13.5	-95.7
218	680.0	0	0	1780	0	27.1	96.6
0	0	506	306.0	0	1780	-14.1	-98.5
212	674.0	0	0	1780	0	27.4	98.0
0	0	503	305.0	0	1780	-14.0	-98.2
220	686.0	0	0	1780	0	27.1	96.6
0	0	503	305.0	0	1781	-14.0	-98.2
208	665.0	0	0	1780	0	27.5	98.5
0	0	484	303.0	0	1780	-13.2	-94.3
217	681.0	0	0	1780	0	27.1	96.9
0	0	488	303.0	0	1780	-13.4	-95.3
214	675.0	0	0	1781	0	27.2	97.4
0	0	490	304.0	0	1780	-13.4	-95.5
229	704.0	0	0	1780	0	26.8	95.2
0	0	490	303.0	0	1780	-13.5	-95.9
0	0	367	475.0	0	1781	7.0	1.5
209	666.0	0	0	1780	0	27.4	98.2
0	0	473	301.0	0	1781	-12.8	-92.4
204	658.0	0	0	1780	0	27.6	99.0
0	0	488	302.0	0	1781	-13.5	-95.8

21st

41st

AVERAGING

Theta_0: 6.7 Asymmetry : 0.99

Alpha : 3.15 Offset : 220.0

NUMBER OF PULSES (+,-): 174 157

<theta+> <theta-> : 23.4 +/- 7.4 -11.4 +/- 6.6

COUNT RATES (PD1+,PD2+,PD1-,PD2-) : 238.9 631.0 472.4 319.2

POLARIZATION (P+,dP+,P-,dP-): 62.34 +/- 0.2 -84.92 +/- 0.1

Sun Jan 20 11:01:51 EST 2002

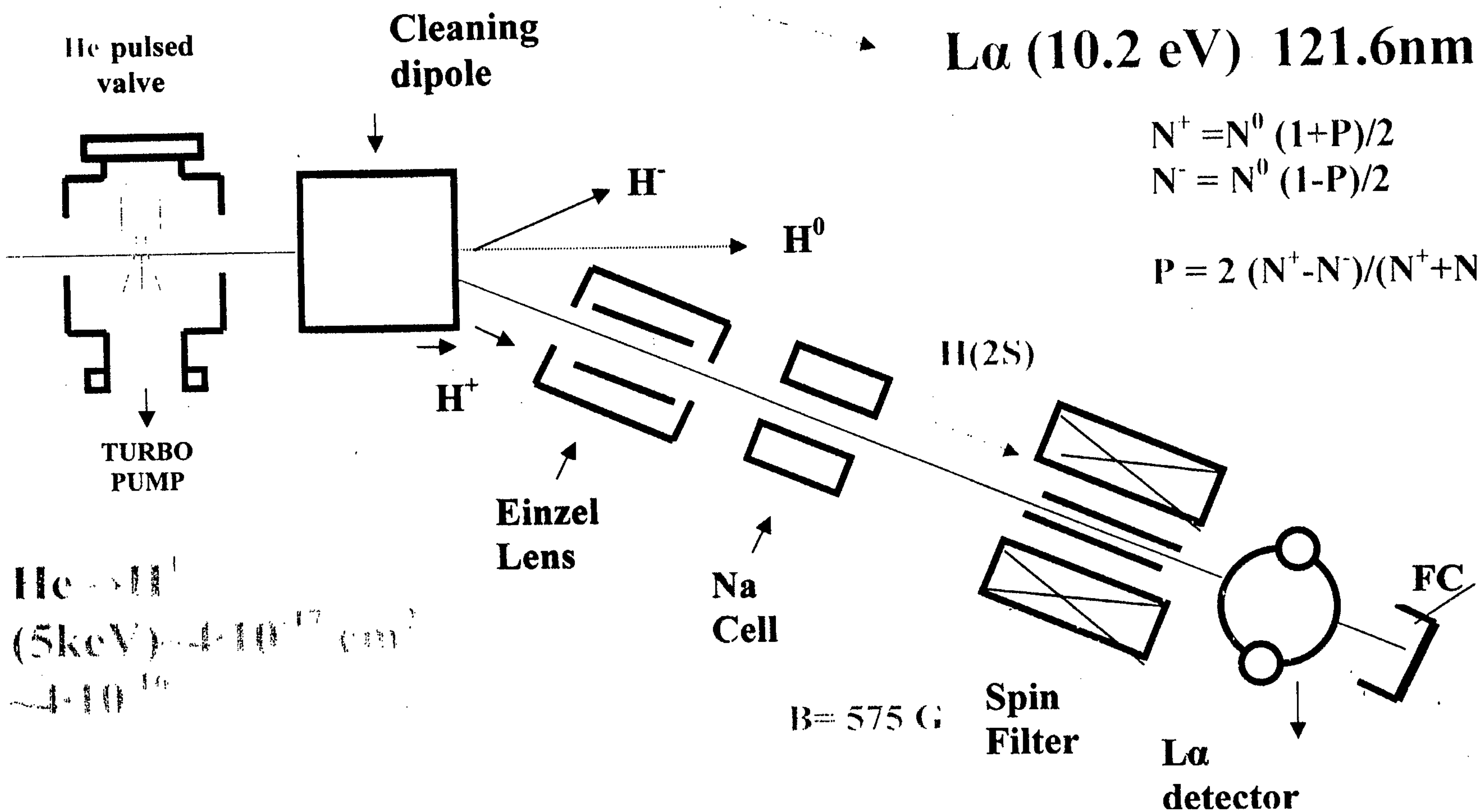
LAMB – SHIFT POLARIMETER

$\vec{H}^- \xrightarrow{(He)} \vec{H}^+ \xrightarrow{Na} H(2s)$ ⟶ **Lα (10.2 eV) 121.6nm**

$N^+ = N^0 (1+P)/2$

$N^- = N^0 (1-P)/2$

$P = 2 (N^+ - N^-)/(N^+ + N$



-+ He → H+

-+ (5keV) ~4·10^-17 cm^2

-0 ~4·10^-16

LAMB-SHIFT POLARIMETER with ANALYSIS Ver 2

STATUS:

PROCESSING

START | STOP | CLEAR | SAVE | EXIT

READING

PULSE	MCP+	MCP-	CLK+	CLK-	POL
22445	38.0	0.0	1336.0	0.0	-1.05
22446	0.0	125.0	0.0	1336.0	-1.087485
22447	46.0	0.0	1336.0	0.0	-0.9239766
22448	0.0	106.0	0.0	1336.0	-0.7894737
22449	53.0	0.0	1336.0	0.0	-0.6666667
22450	0.0	103.0	0.0	1336.0	-0.6410256
22451	46.0	0.0	1335.0	0.0	-0.7651007
22452	0.0	116.0	0.0	1336.0	-0.8641975
22453	38.0	0.0	1336.0	0.0	-1.012987
22454	0.0	92.0	0.0	1336.0	-0.8307692
22455	57.0	0.0	1335.0	0.0	-0.4697987
22456	0.0	124.0	0.0	1336.0	-0.7403315
22457	49.0	0.0	1336.0	0.0	-0.867052
22458	0.0	104.0	0.0	1336.0	-0.7189542
22459	40.0	0.0	1336.0	0.0	-0.8888889
22460	0.0	99.0	0.0	1336.0	-0.8489209
22461	57.0	0.0	1336.0	0.0	-0.5384615
22462	0.0	106.0	0.0	1336.0	-0.6181818

AVERAGING

N+_min: 1 — N+_max: 1000

N-_min: 1 — N-_max: 1000

NUMBER OF PULSES (+,-): 131 130

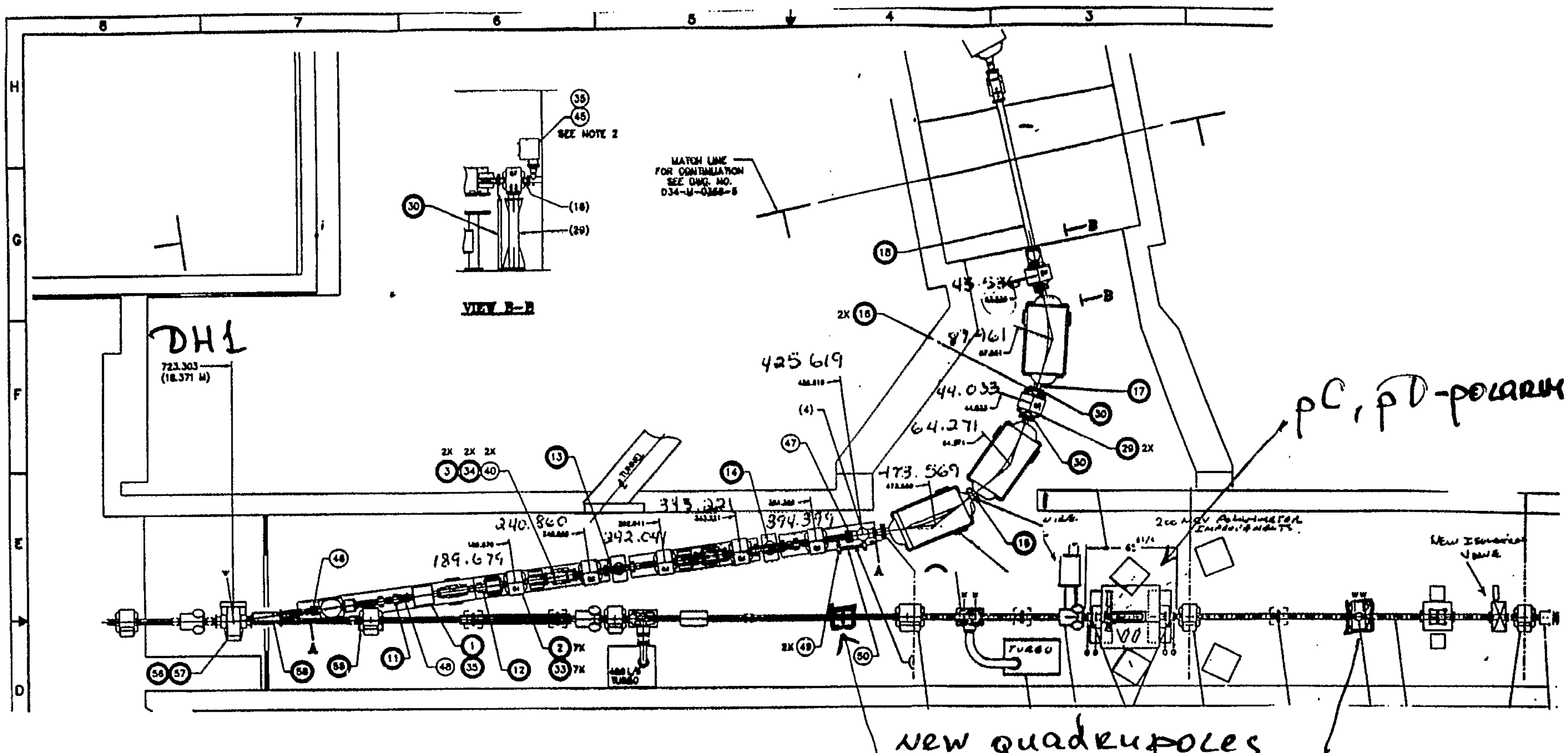
COUNTING RATE (N+,N-): 42.32824 97.44615

POLARIZATION (P,dP): -0.7886697 0.01363932

ANALYZING

ANALYZE POLARIZATION | RESTART

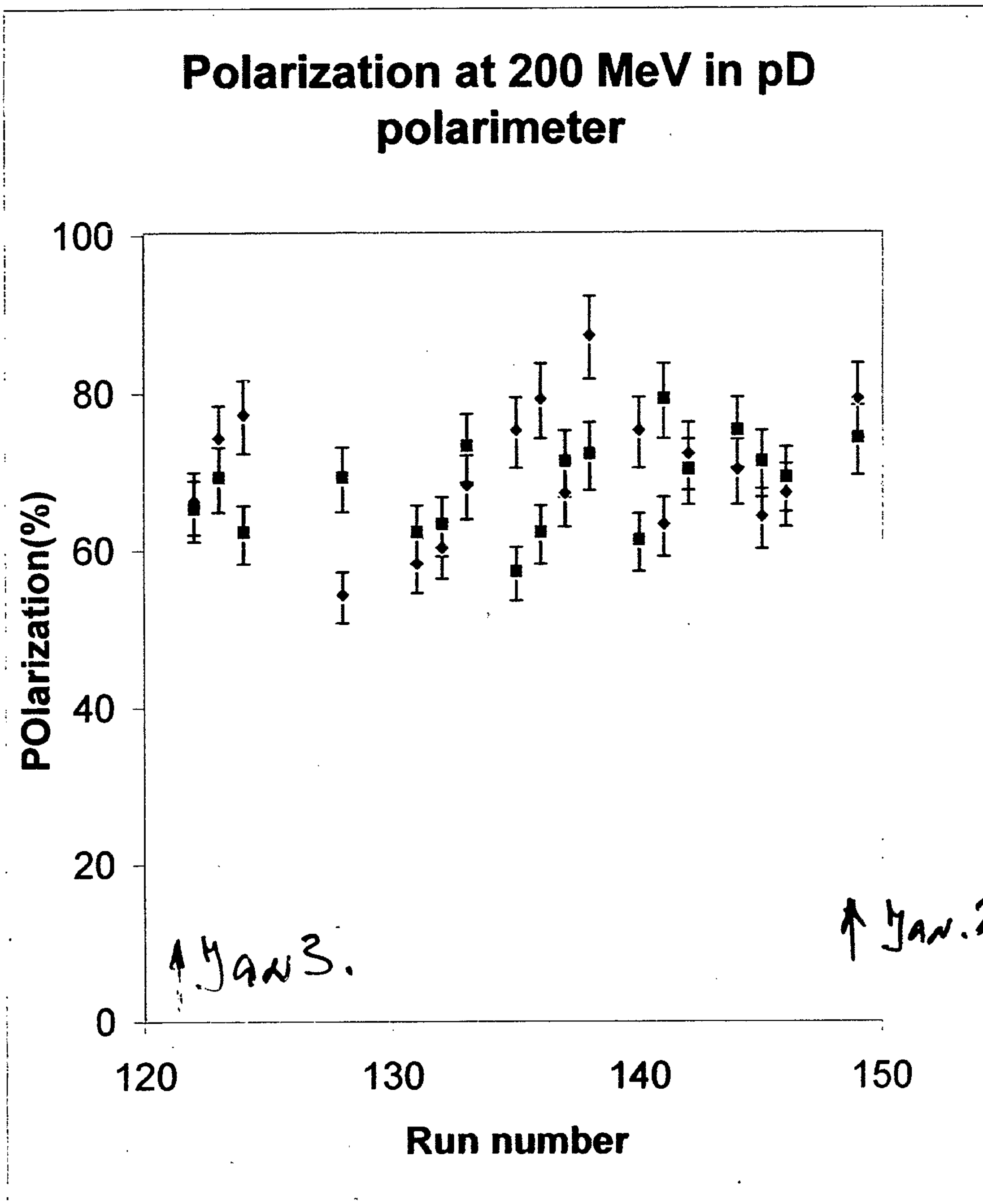
200 MeV polarimeter in HEBT



A. Zelenski

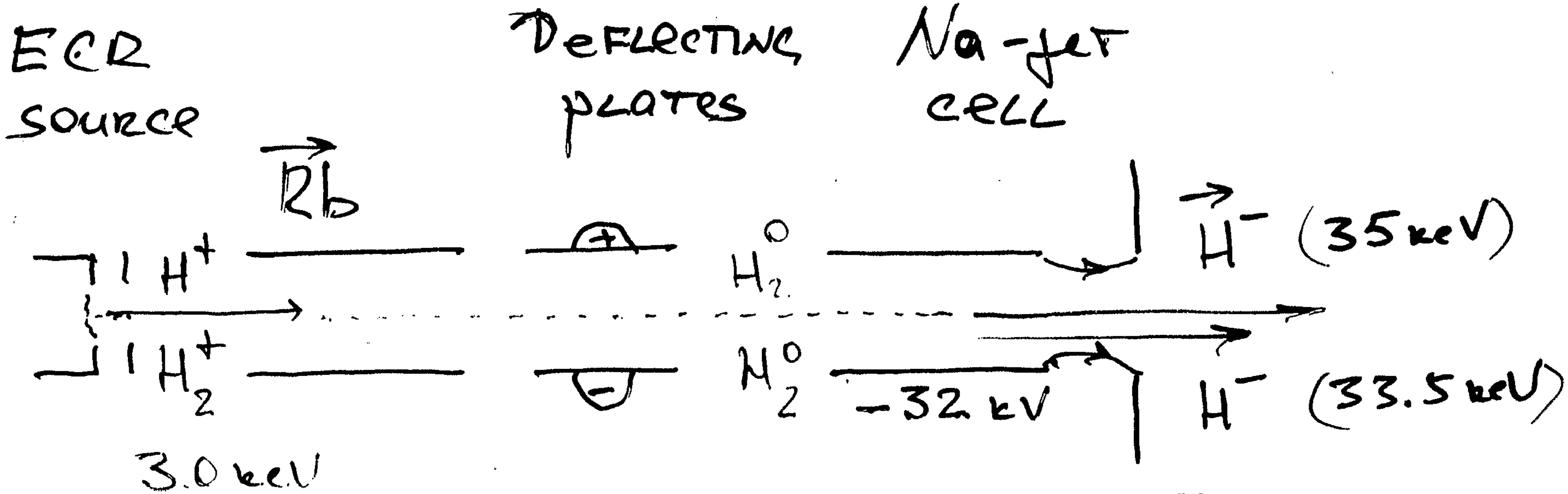
PST 2001

BROOKHAVEN NATIONAL LABORATORY



Ed Stephenson analysis for Dec. 01 run

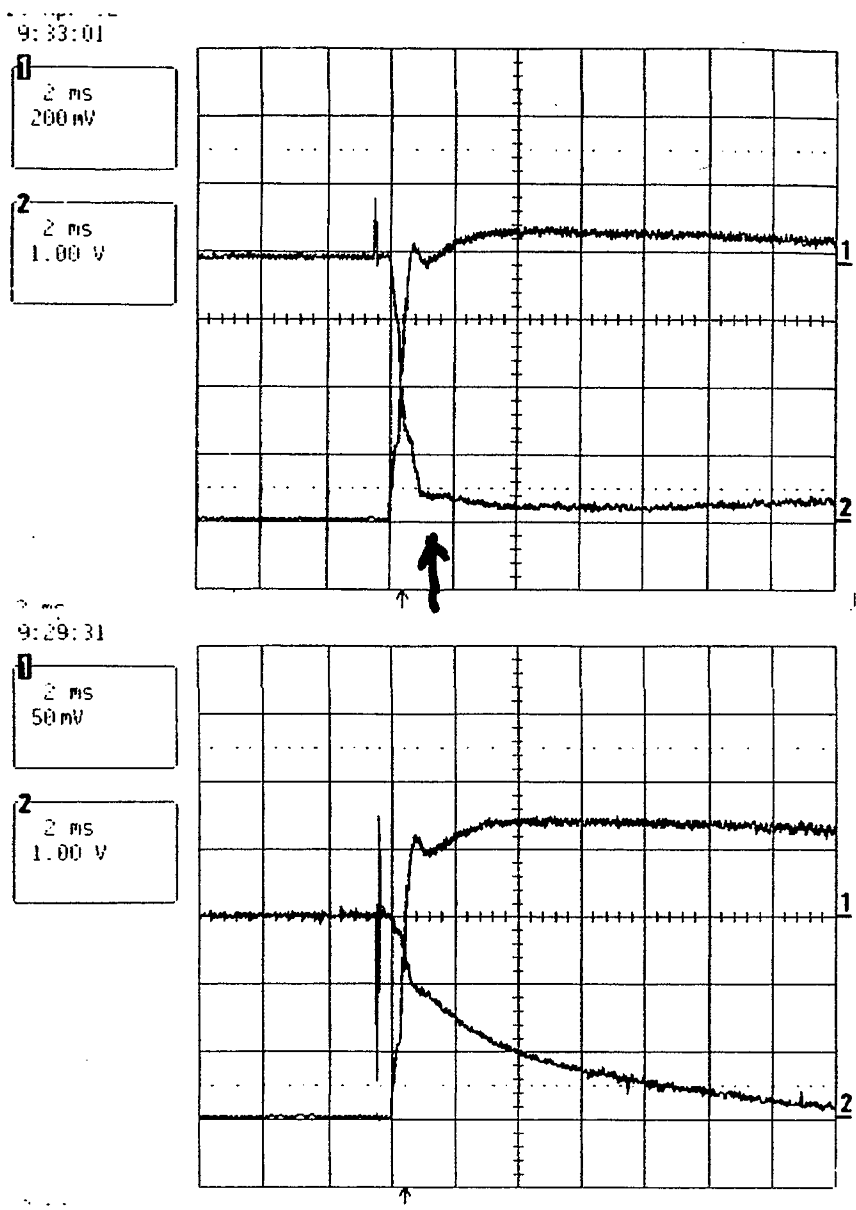
POLARIZATION DILUTION due TO MOLECULAR H_2^+ IONS FROM THE ECR SOURCE.



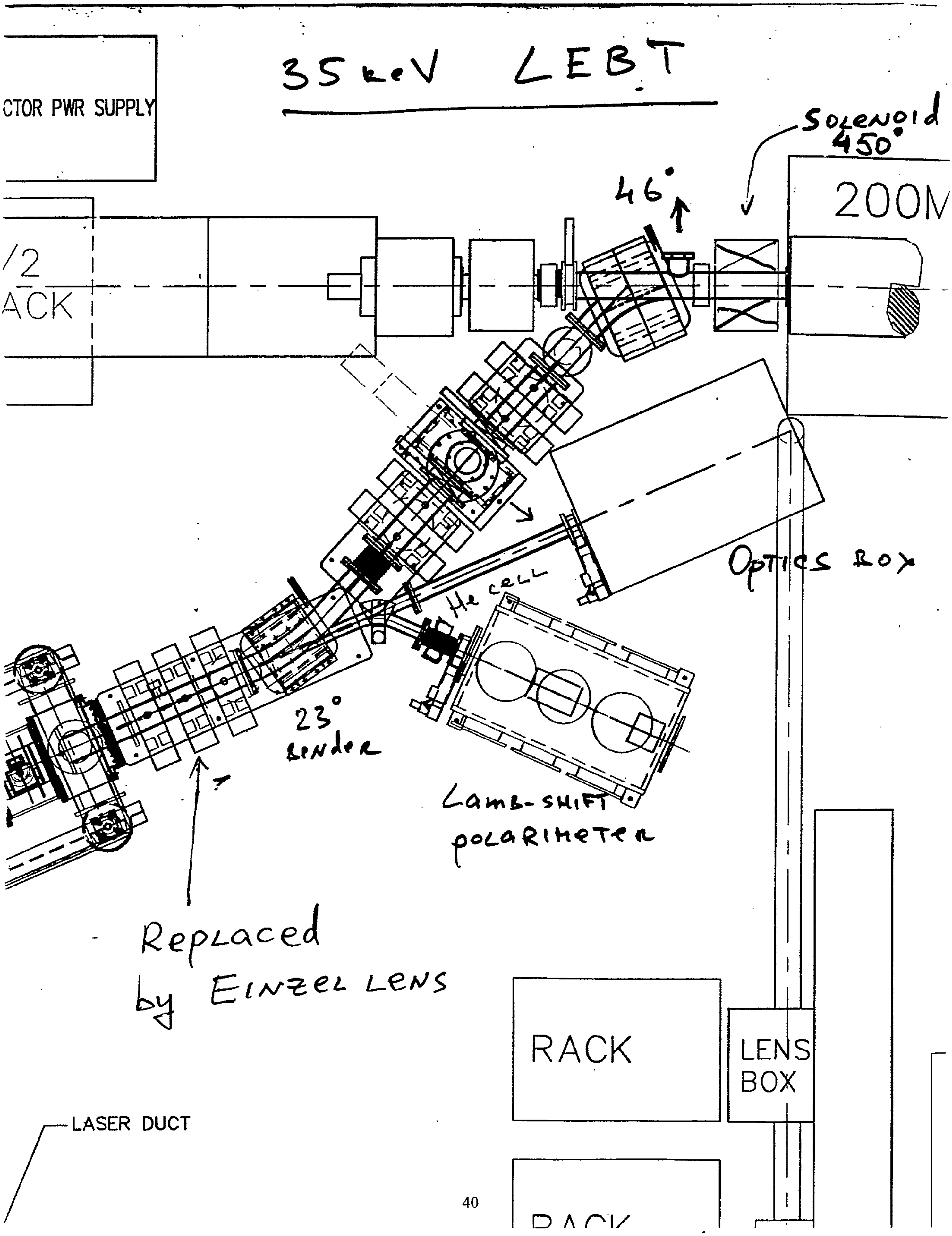
$$H^0 + Na \rightarrow H^- \ (3\ keV)$$

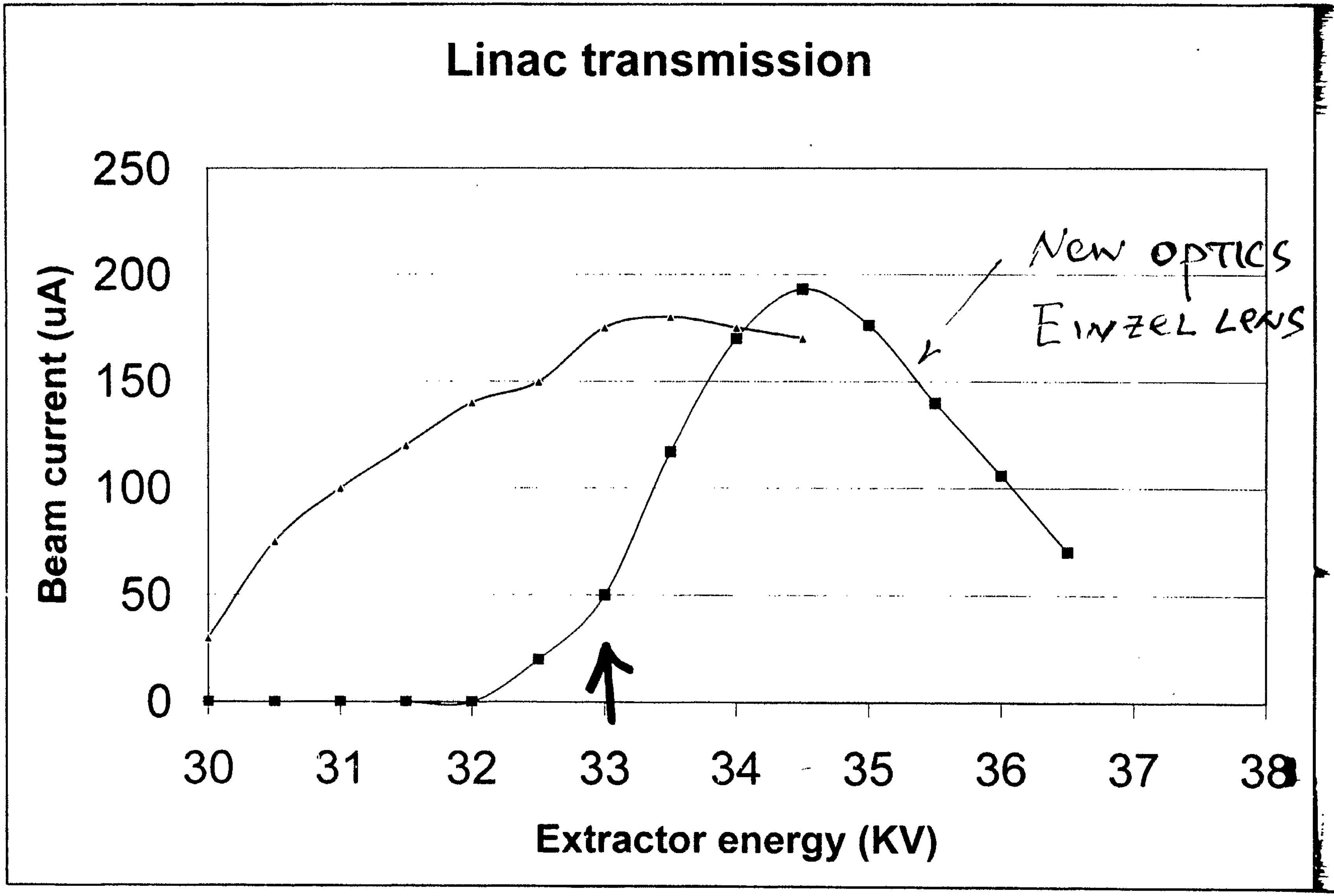
$$H_2^0 + Na \rightarrow H^- + H^0$$

1.5 keV → H^- 1.5 keV



Pulsed ECR operation


35 keV LEBT
CTOR PWR SUPPLY
/2
ACK
46°
Solenoid
450°
200M
Optics Box
He cell
23°
Bender
Lamb-shift
polarimeter
Replaced
by Einzel lens
RACK
LENS
BOX
LASER DUCT
RACK


Linac transmission
Beam current (uA)
250
200
150
100
50
0
30
31
32
33
34
35
36
37
38
Extractor energy (KV)
New optics
Einzel lens

200 MeV POLARIMETER(12 degree-accidental)

STATUS:

PROCESSING

START | STOP | SAVE | EXIT

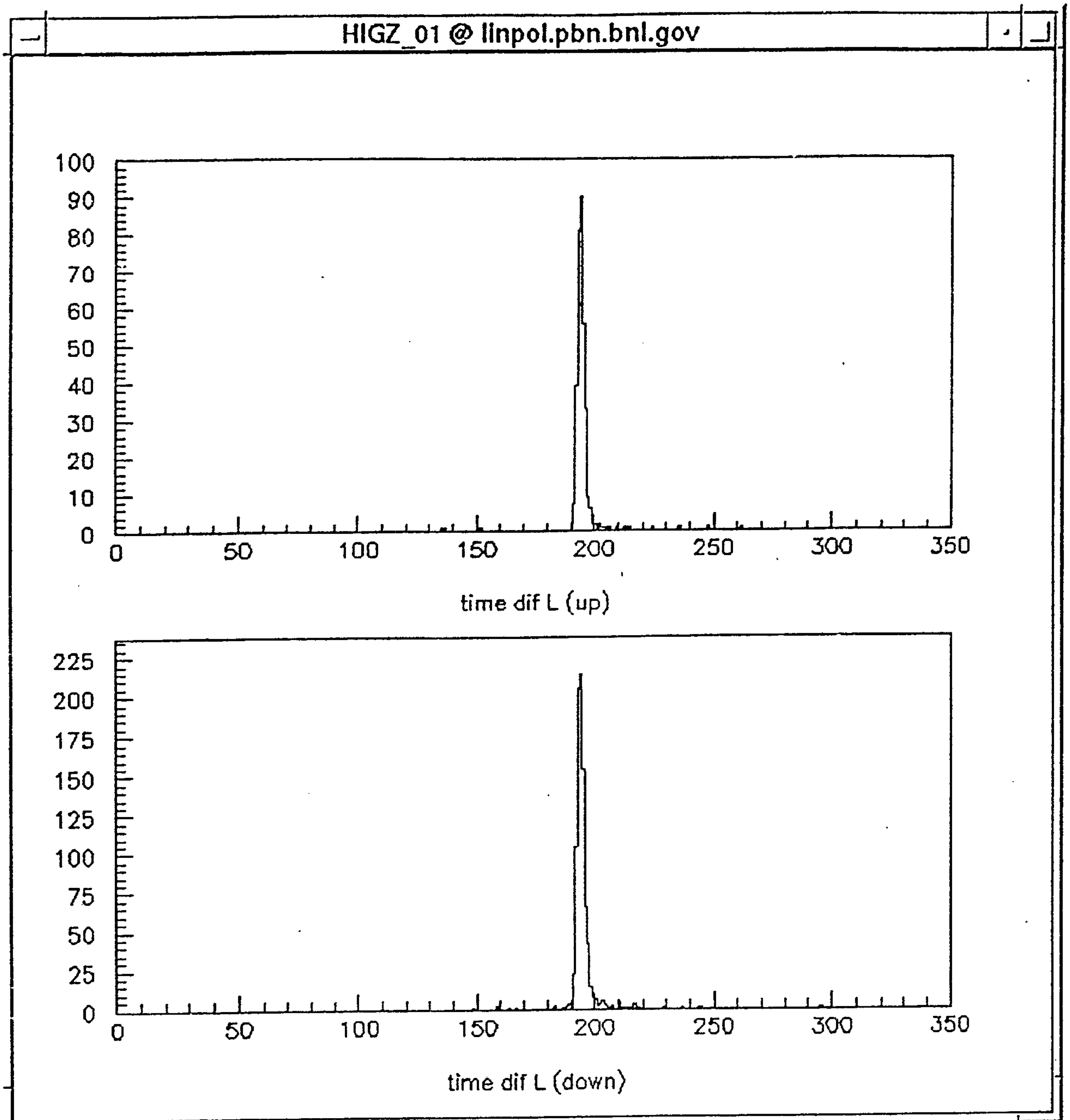
READING

PULSE	LEFT	RIGHT	CLK+	CLK-	POL.	ACC_L	ACC_R
196	2.0	22.0	0.0	1336.0		0.0	0.0
197	17.0	11.0	1336.0	0.0	-0.9833	0.0	0.0
198	5.0	28.0	0.0	1336.0		0.0	0.0
199	27.0	12.0	1336.0	0.0	-0.904	0.0	0.0
200	12.0	24.0	0.0	1336.0		0.0	0.0
201	24.0	8.0	1336.0	0.0	-0.6777	0.0	0.0
202	10.0	19.0	0.0	1335.0		0.0	0.0
203	24.0	10.0	1336.0	0.0	-0.5839	0.0	0.0
204	4.0	29.0	0.0	1335.0		0.0	0.0
205	33.0	7.0	1336.0	0.0	-1.142	0.0	0.0
206	5.0	25.0	0.0	1336.0		0.0	0.0
207	21.0	7.0	1336.0	0.0	-0.9509	0.0	0.0
208	3.0	24.0	0.0	1336.0		0.0	0.0
209	21.0	9.0	1336.0	0.0	-1.007	0.0	0.0
210	7.0	24.0	0.0	1335.0		0.0	0.0
211	27.0	9.0	1336.0	0.0	-0.8463	0.0	0.0
212	12.0	20.0	0.0	1336.0		0.0	0.0
213	32.0	7.0	1336.0	0.0	-0.7551	0.0	0.0
214	8.0	25.0	0.0	1336.0		0.0	0.0
215	28.0	7.0	1336.0	0.0	-0.9017	0.0	0.0
216	9.0	29.0	0.0	1336.0		0.0	0.0
217	18.0	6.0	1336.0	0.0	-0.828	0.0	0.0
218	3.0	27.0	0.0	1335.0		0.0	0.0
219	29.0	9.0	1336.0	0.0	-1.108	0.0	0.0
220	6.0	23.0	0.0	1336.0		0.0	0.0
221	23.0	7.0	1336.0	0.0	-0.9038	0.0	0.0
222	7.0	30.0	0.0	1336.0		0.0	0.0
223	26.0	12.0	1336.0	0.0	-0.8159	0.0	0.0

Left arm events (+,-):	2651.0	790.0
Right arm events(+,-):	974.0	2875.0
POLARIZATION (P,dP):	-0.8352	0.01622

RESET

Sat Apr 06 22:30:23 EST 2002




```
PAW-E950: '[24]'>
PAW-E950: '[24]'> vec/create out(6)
 *** VECTOR/CREATE OUT(6): existing vector OUT(6) replaced
PAW-E950: '[25]'>
PAW-E950: '[25]'> for/call asym.f(327,798,844,321)
  polarization -0.8558564     +-  0.3714243E-01
PAW-E950: '[26]'>
```

Anatoli,

Included here is the analysis of runs 158 through 162. The polarization is definitely higher, as you will see from the average at the bottom.

Here are the peak sums with background subtracted:

RN4	LU4	LD4	RU4	RD4
***	***	***	***	***
158	128	251	284	103
159	272	636	578	247
160	140	272	267	110
161	327	798	844	321
162	439	981	988	403

Here are the asymmetries and polarizations:

RN4	EPS	DEPS	P	DP
***	*******	*******	******	*******
158	-.39854	.033267	.78608	.065616
159	-.40105	.02203	.79102	.043453
160	-.3694	.033204	.72861	.065491
161	-.43392	.018831	.85586	.037142
162	-.40131	.017284	.79153	.03409

} 82.0 ± 2.5 (161–162)

<158-162> = 80.3 ± 2.0 %

Here is the average polarization:

PBAR = .80332 DPBAR = .019686

It would have been nice to have seen the ratio to the p+C again. I should mention that rates seemed to be lower this time, and the

POLARIZATION

	ΔP	April 6-7 run
Pulsed ECR operation	**3 – 5 %**	+
Lower ECR beam energy	**2 – 3 %**	
LEBT optics optimization for E/2 beam component suppression	**3 – 5 %**	+
Polarization direction alignment	**1 - 2 %**	
OPPIS optimization (superconducting solenoid, lasers, Sona transition)	**3 – 5 %**	+
Polarimeters. Systematic errors.	**3 – 5 %**	
		+ 10 %

GOAL : Stable operation, P > 80 % for 2002-03 run.

200 MeV POLARIMETERS

Vacuum system upgrade.

Pulsed DH1 operation.

Beam profile monitor.

High-rate detectors.

Polarized Protons and the Booster

L. Ahrens, BNL
April 12, 2002

for
RHIC Spin Collaboration Meeting VIII
RIKEN BNL Research Center

Polarized Protons and the Booster

Background:

injected beam - from the Linac at 200 MeV kinetic energy. $G\gamma = (1.793)*(1.213) = 2.175$
extracted beam – at 1.5 GeV kinetic, $\gamma = 2.6$, $G\gamma = 4.66$

depolarizing resonances considered:

imperfections:

$G\gamma = 3$
$G\gamma = 4$

intrinsic:

$G\gamma = \nu_v$

There is not a polarimeter in the Booster. The relevant polarization measurements are made in the AGS.

Status:

The **imperfections** at n=3 and n=4 are explored and corrected by varying the phase and amplitude of the relevant vertical correction magnetic harmonic field. The resonances can be made strong enough to flip the sign of the polarization measured in the AGS. These two resonances are corrected (rather than flipped). The required corrections are a small fraction of the correction magnet capabilities. Periodically during the run checks are made that the applied magnetic harmonics are still active.

The **intrinsic** is far enough above the extraction energy to cause no harm to the beam polarization. The vertical betatron tune is set to about 4.9, putting the resonance well above extraction energy ($G\gamma = 4.66$). This assertion was tested experimentally during the previous (Sep, 2000) RHIC run (when the polarization measured early in the AGS acceleration cycle was anomalously low) by reducing the vertical tune until an effect was seen on the polarization measured in the AGS. There was a wide margin before any effect was seen, and a significant effect was seen given adequate reduction.

Present Understanding of the AGS Polarization and its Simulation

Mei Bai

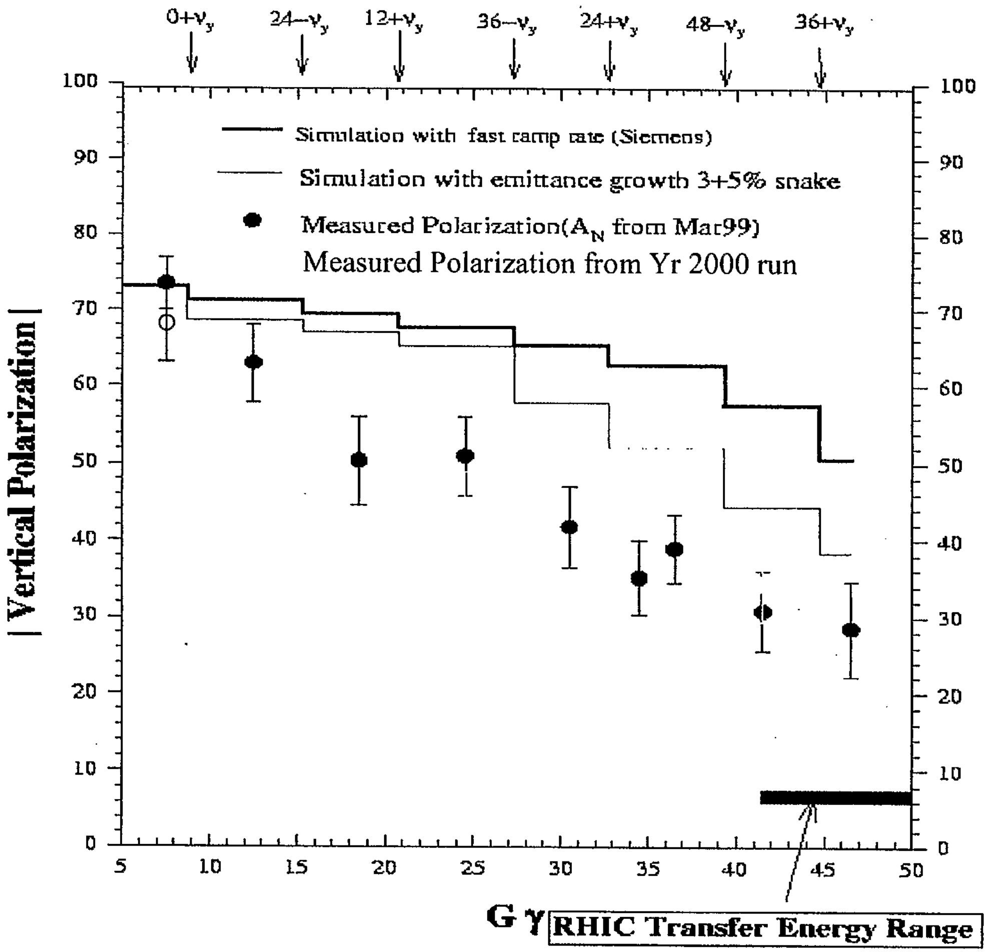
Brookhaven National Laboratory

April 12, 2002

- AGS setup for the RHIC pp 2002 run
  - slow acceleration rate with the westinghouse power supply
  - hybrid snake, i.e. ramp from 3% to 5% between $0+\nu_y$ and $36+\nu_y$.
  - large vertical coherent betatron oscillation induced by Ac dipole at $0+\nu_y$, $12+\nu_y$ and $36\pm\nu_y$

- we reached
  - source polarization reached 0.70
  - polarization at $G\gamma$=7.5 measured as 0.70
  - 0.2~ 0.3 polarization at the AGS extraction energy

- outstanding problems
  - significant polarization loss at the weak intrinsic resonances and coupling resonances
  - AGS J10 bump modulating at 60Hz and 360Hz
  - beam emittance blowup
  - it was very difficult to tune the polarization with the existing polarimeter



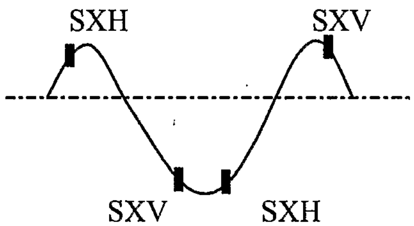
Puzzle:

significant polarization got lost between $0+\nu_y$ and $12+\nu_y$ with $24-\nu_y$ in-between.

Hypothesis:

1. Stronger resonance
2. Synchrotron motion. Since this resonance is very close to the AGS transition, the momentum spread can be large and may cause beam crossing through this resonance multiple times.

- AGS J10 bump power supply

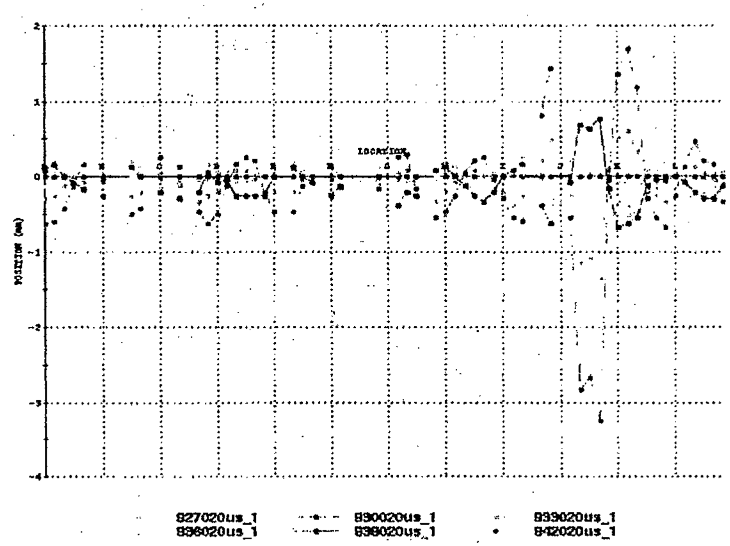


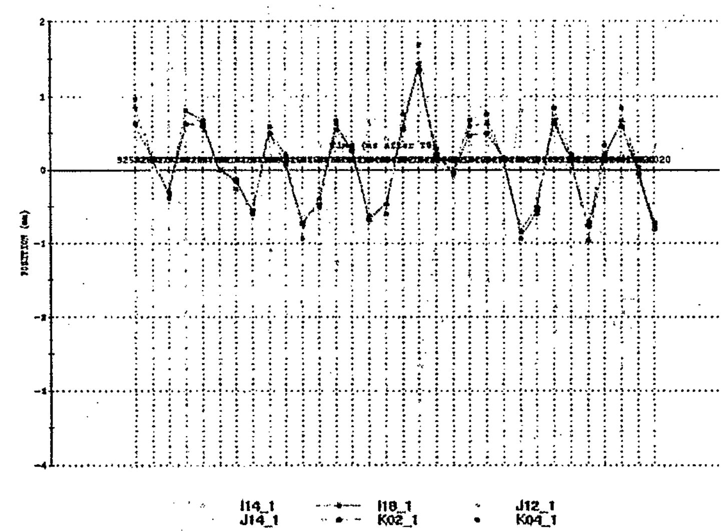
causes the horizontal bump being modulated at 60 Hz and 360Hz.

resonance	Isxh(Amp)	Isxv(Amp)
$0+\nu_y$	5.0	14.5
$12+\nu_y$	2.15	6.25
$36-\nu_y$	2.8	6.4
$36+\nu_y$	10.0	5.5

- $\Delta\nu_{x,y} < 0.001$

- no direct evidence of its impact on spin

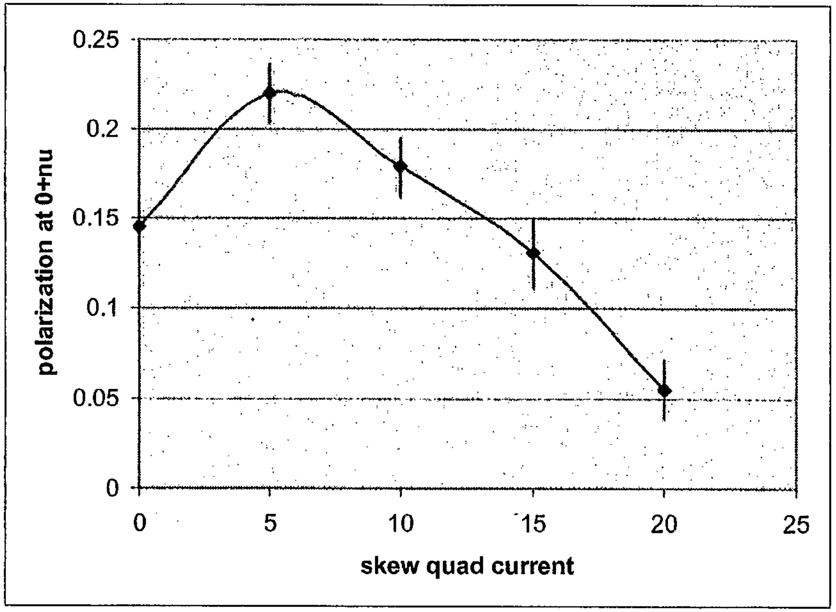


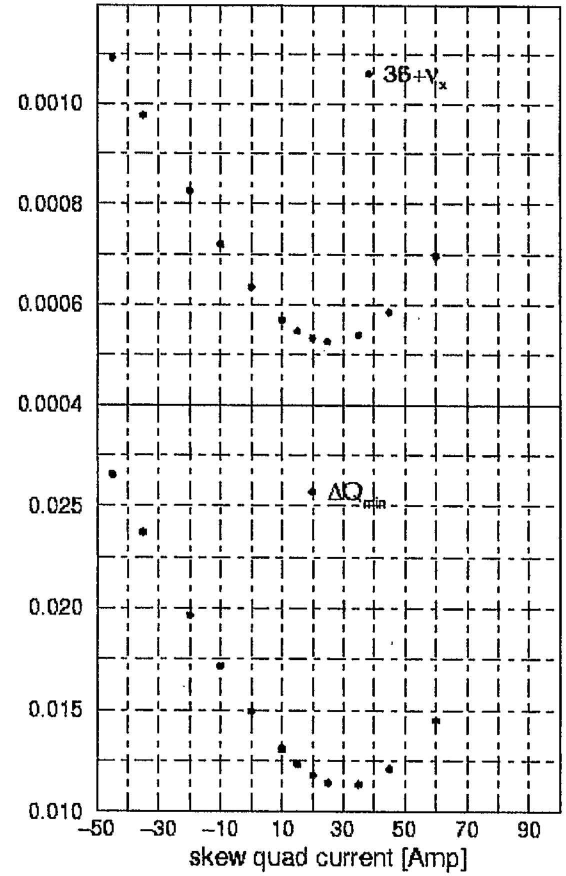


- AGS intrinsic and coupling spin resonance

intrinsic resonance	resonance strgenth	p_f/p_i westing house	p_f/p_I Siemens
$0+\nu_y$	0.006345	-0.681, 1.0	-0.450, 1.0
$24-\nu_y$	0.000246	0.984	0.992
$12+\nu_y$	0.002241	0.207, 1.0	0.505, 1.0
$36-\nu_y$	0.005685	-0.618, 1.0	-0.358, 1.0
$24+\nu_y$	0.000317	0.974	0.987
$48-\nu_y$	0.000568	0.919	0.959
$36+\nu_y$	0.011248	-0.886, 1.0	-0.784, 1.0
		0.881	0.936
Coupling resonance			
$0+\nu_x$	0.000479	0.942	0.970
$12+\nu_x$	0.000178	0.992	0.996
$36-\nu_x$	0.00069	0.883	0.940
$36+\nu_x$	0.001391	0.596	0.775
		0.492	0.704
		0.433	0.659

- using skew quads to reduce the strength of the coupling resonance





- agenda for preparing the next run

  - understand 24 - ν_y, what is the effect of the synchrotron motion?
  - Tracking studies of the coupling resonance
  - upgrading the AGS ac dipole system aiming for reliability, user- -friendly and PPM-users
  - install an CNI polarimeter in the AGS

  - twice faster acceleration rate with Siemens back
  - CNI polarimeter will allow us to have quick and reliable measurement
  - use octupoles to correct high order resonances to reduce beam loss at $0+\nu_y$, $12+\nu_y$ and $36\pm\nu_y$ where the ac dipole is excited

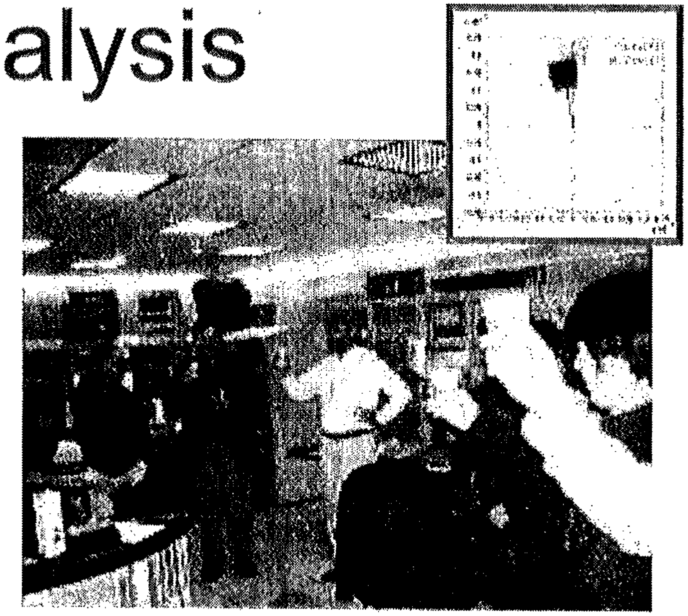
Update on the Status of the RHIC Polarimeter Analysis

O. Jinnouchi, RIKEN
April 12, 2002

for
RHIC Spin Collaboration Meeting VIII
RIKEN BNL Research Center

Update on the status of the RHIC polarimeter analysis

Contents
- About offline analysis
- Understanding of the existing systematic
- Stability of the beam polarization

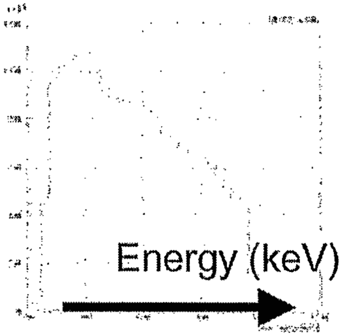


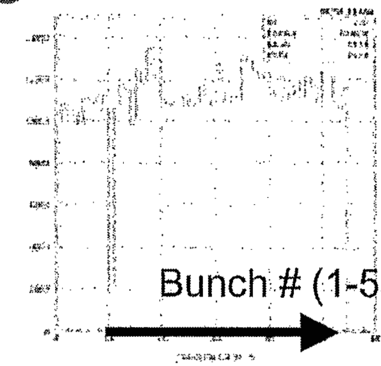
Osamu Jinnouchi (RIKEN)

Our interests and tasks

- Interests
  - Fully understand the systematic of the polarimeter results
  - Confirm if any depolarization during the long store exists
  - -t dependence of the asymmetry
    and cross sections (slope) (←not contained in this talk)
- Tasks
  - Distributions of asymmetry values by version control
    - Including several offline corrections
      - Energy scale, Energy loss correction
      - Excluding bad strips, etc.
  - Systematic study
    - Understanding of the false asymmetries
      - Some measurements have the
        discrepancy X90 ←→ X45
        Y components in Yellow ring (1/18/02~)
    - Stability of the polarization during the stores

What is available in our data set for offline analysis





independent

60

Spin sorted ADC histogram for each strip (1-72)
- Up (+)
- Down (-)
- 0-pol

⇓

- Energy loss correction (Target & dead layer)
- Energy scale correction
- Strip selection

Bunch dist. histogram for each strip (1-72)
With spin bit pattern from V124

⇓

- Bunch by bunch polarization
- Strip selection
- Bunch selection

Already distributed asymmetry info

- Several versions of the asymmetry values have been revised and distributed in the form of spread sheets
- The analysis is basically based on the spin sorted energy spectrums, where the re-definition of the energy cut is capable
- Providing many kinds of run conditions
- Assign the flag for validity of the each measurement
- Current situation

  -t range is defined as

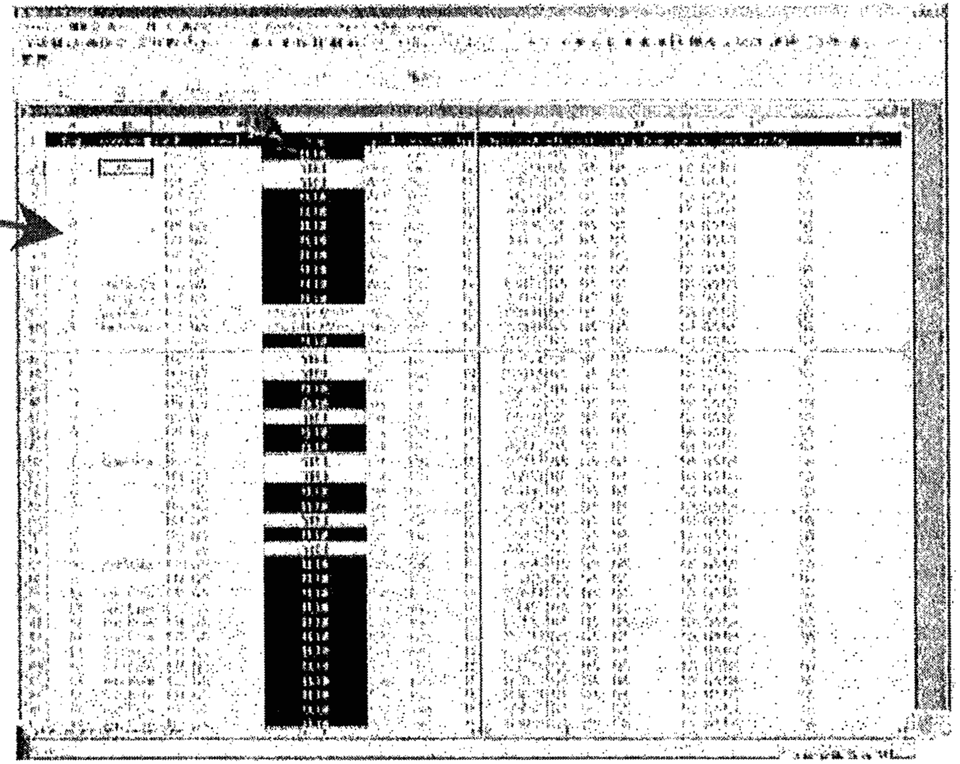
  Analyzing power Ver 2.0 (by J. Tojo)

  Ver 1.0 (distributed)

  target+dead layer correction

  Ver 1.1 (ready but not announced)

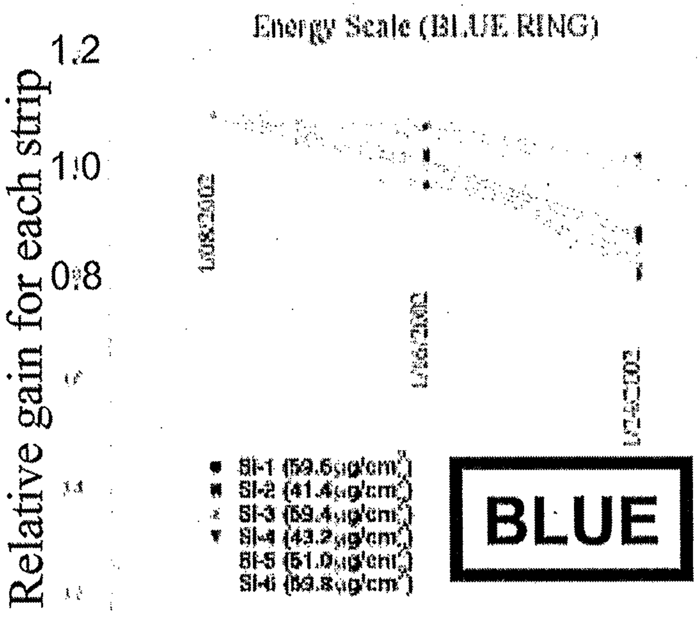
  energy scale correction

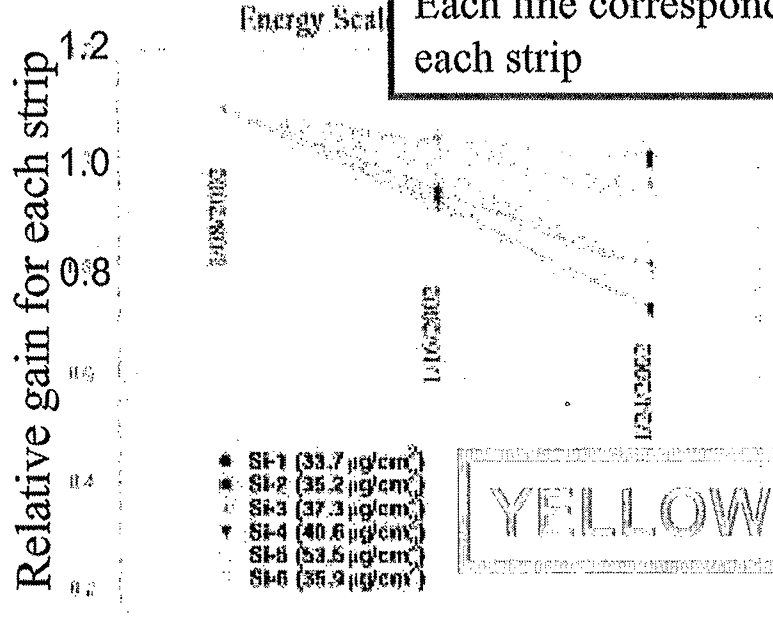


http://spin.riken.bnl.gov/exp/pcpol

Energy scale corrections

Each line corresponds to each strip

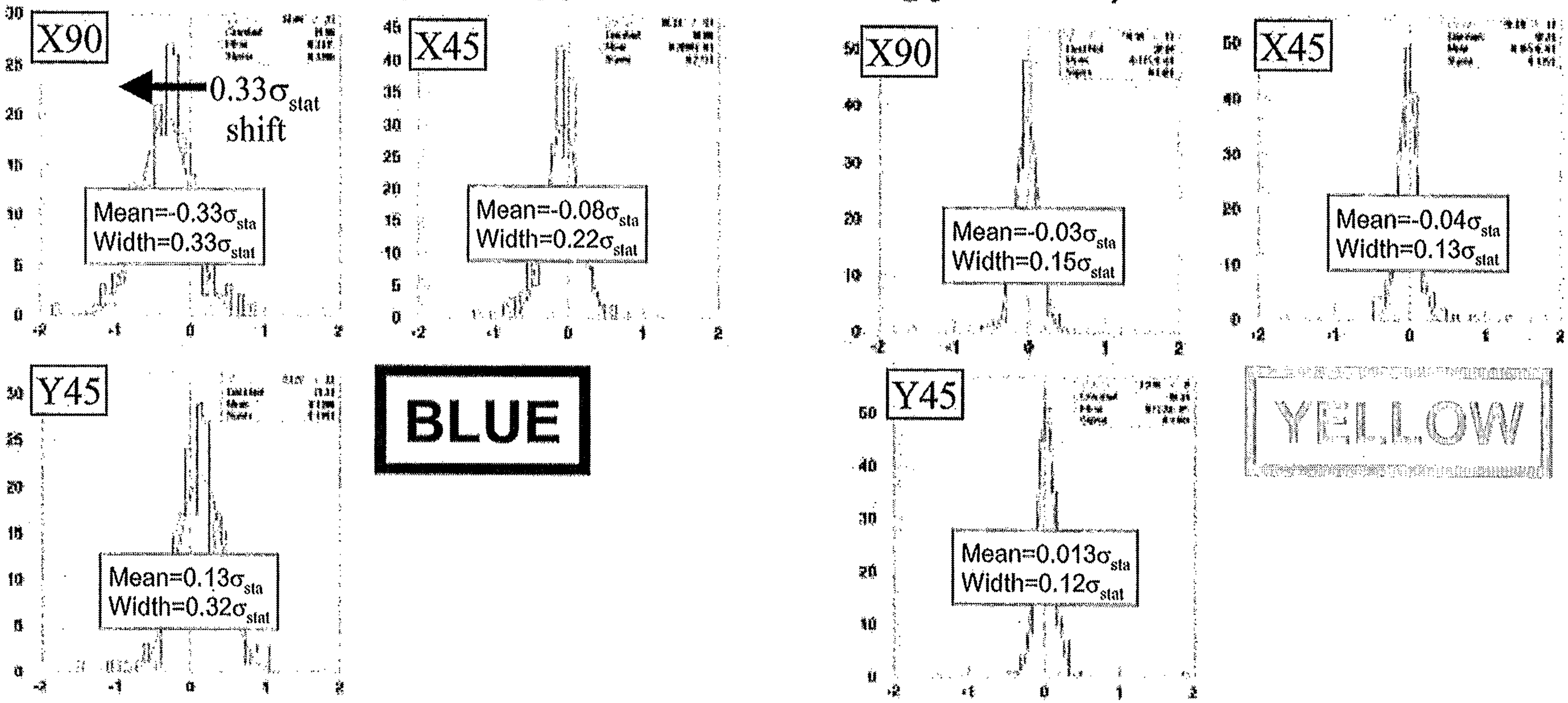




- Re-calibration measurements are performed at 1/8, 1/16 and 1/24(run end)
- Strips from same detector behave in like wise
- No correlation with the dead layer thickness
- The corrections are made with linear interpolation for each strip after the first recalibration

Results after the corrections

(energy loss & energy scale)

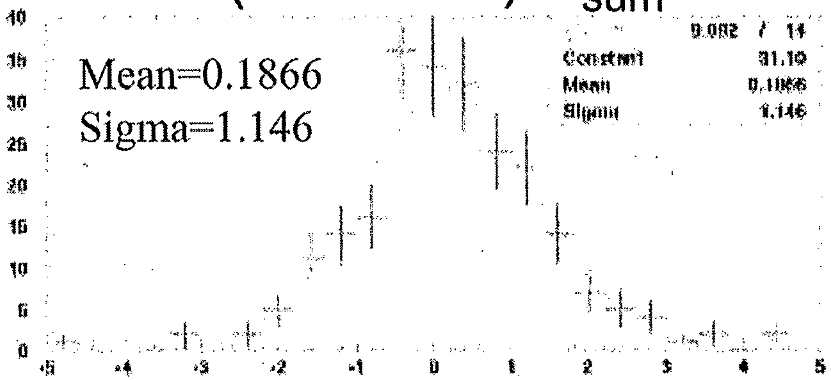


(After-Before)/σ_{stat} plots

- Deviations stemming from the corrections are symmetric and well below the statistical error bars, except blue X90 which has been slightly shifted

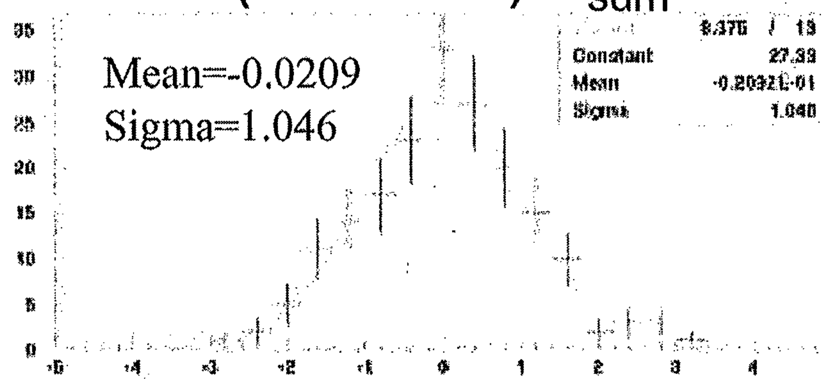
Significance of the X90,X45 separation

$(X90\text{-}X45)/\sigma_{sum}$



BLUE

$(X90\text{-}X45)/\sigma_{sum}$



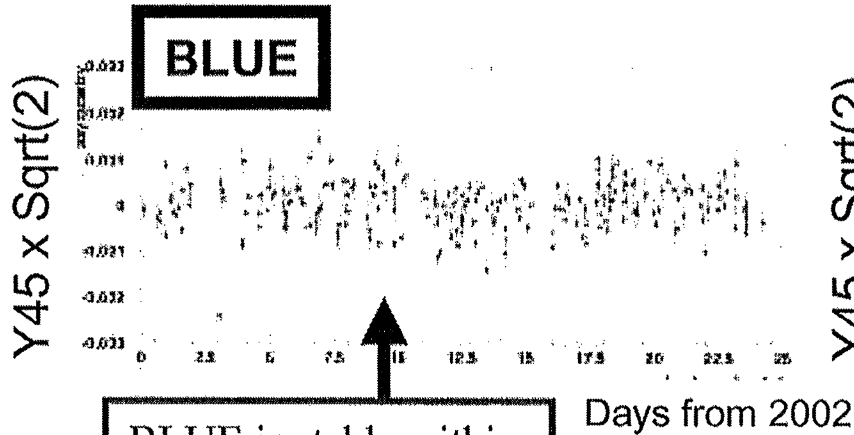
YELLOW

- The degree of separation is in good agreement with the statistical fluctuation of the measurements
- At the level of statistics that we have, the statistical errors still dominate over the systematic
- The average of X90 and X45 (equivalently Xlsq) **can be considered trustworthy**

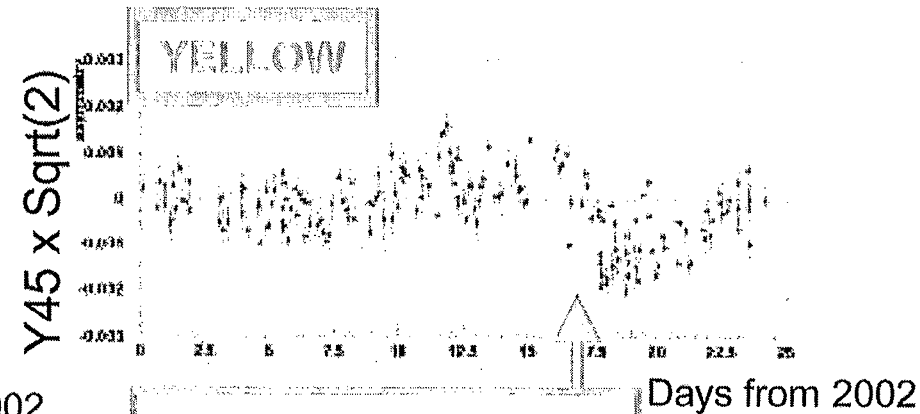
$$\sigma_{sum} = \sqrt{\sigma^2_{X90stat} + \sigma^2_{X45stat}}$$

Used data set 1/1-1/24

Still remaining Y components



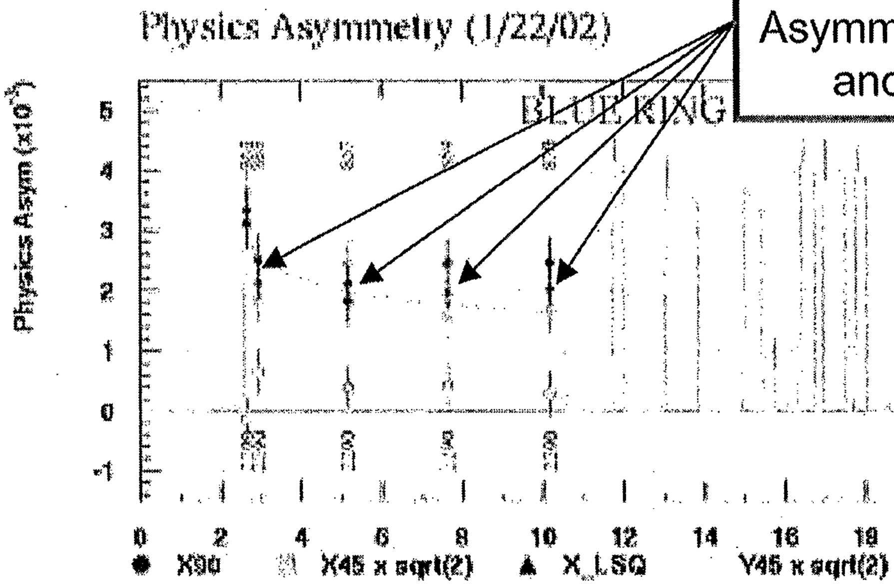
BLUE is stable within statistical errors



YELLOW systematically deviates from zero.

- The energy corrections has not improved the Y-components anomalies in yellow
- The study starting from the bunch distribution histograms are on going. Comparison with WCM (wall current monitor) is also shows a quite interesting feature, though no conclusion was delivered so far.

Polarization stability during the store



Asymmetry A[0],A[1],,,
and beam intensity B[0],B[1],,,

To see the tendency, the values are normalized as A[n] / A[0]

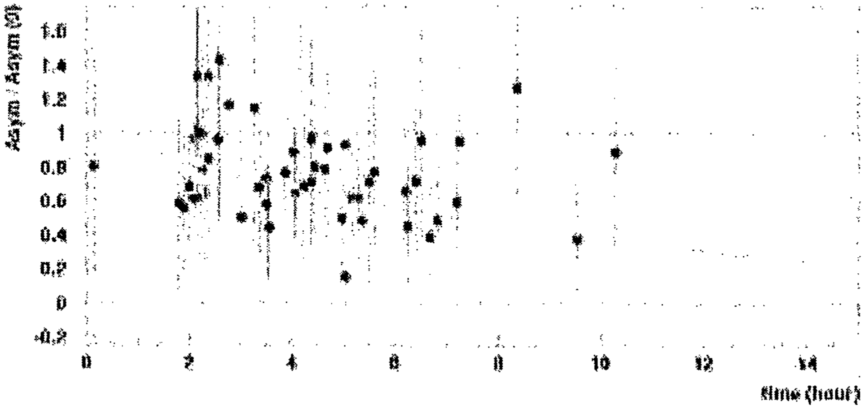
Used fill ID
2147,2153,2161,2162,2173,
2175,2178,2181,2185,2187,
2201,2208,2212,2233,2244,
2246,2251,2258,2266,2269,
2275,2277,2281,2290,2301

- Choose the fill which satisfies following conditions
  - There is a measurement immediately after the ramp
  - Store > 4 hours
  - 1st measurement has asymmetry > 1.0×10^{-3}
  - The data after Jan. 4th
- Taking the ratio against the 1st measurement
- Is there any correlation with beam intensity ?

Asymmetry as a function of store time

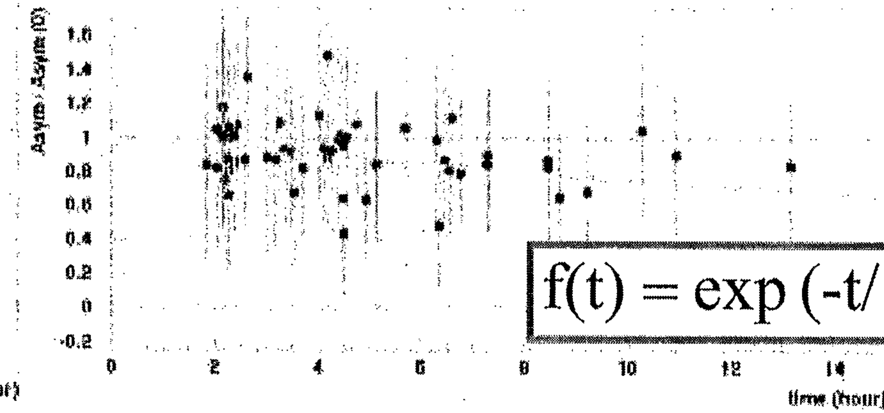
6.9 x 10^{10} turns

BLUE $\tau = 10.3^{+2.8}_{-2.0}$ hours



2.4 x 10^{11} turns

YELLOW $\tau = 35.2^{+32.1}_{-12.1}$ hours

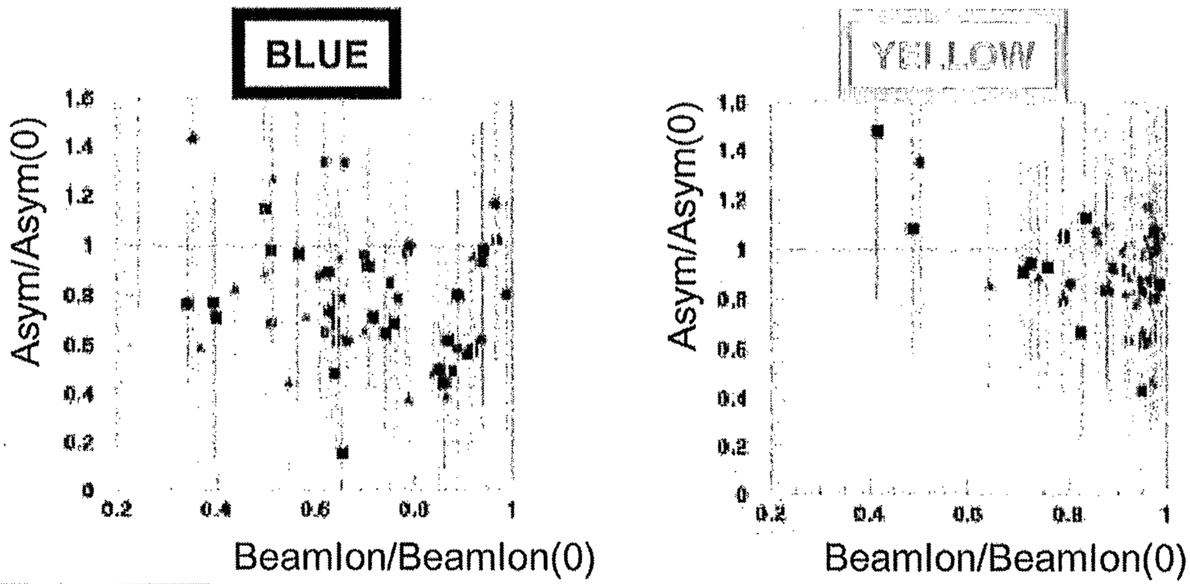


$f(t) = \exp(-t/\tau)$

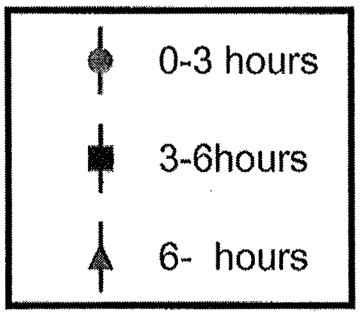
Time starting from the first measurement at flattop (hour)

- We assume the exponential decay function from unit=1 at time=0 although we do not have any particular reason
- Using Xlsq values (asymmetry value calculated with fit)
- Exponential curves fit well, showing long lifetime in yellow, while blue has rather short lifetime
- Statistically, they are depolarizing during the store

Asymmetry .vs. beam intensity

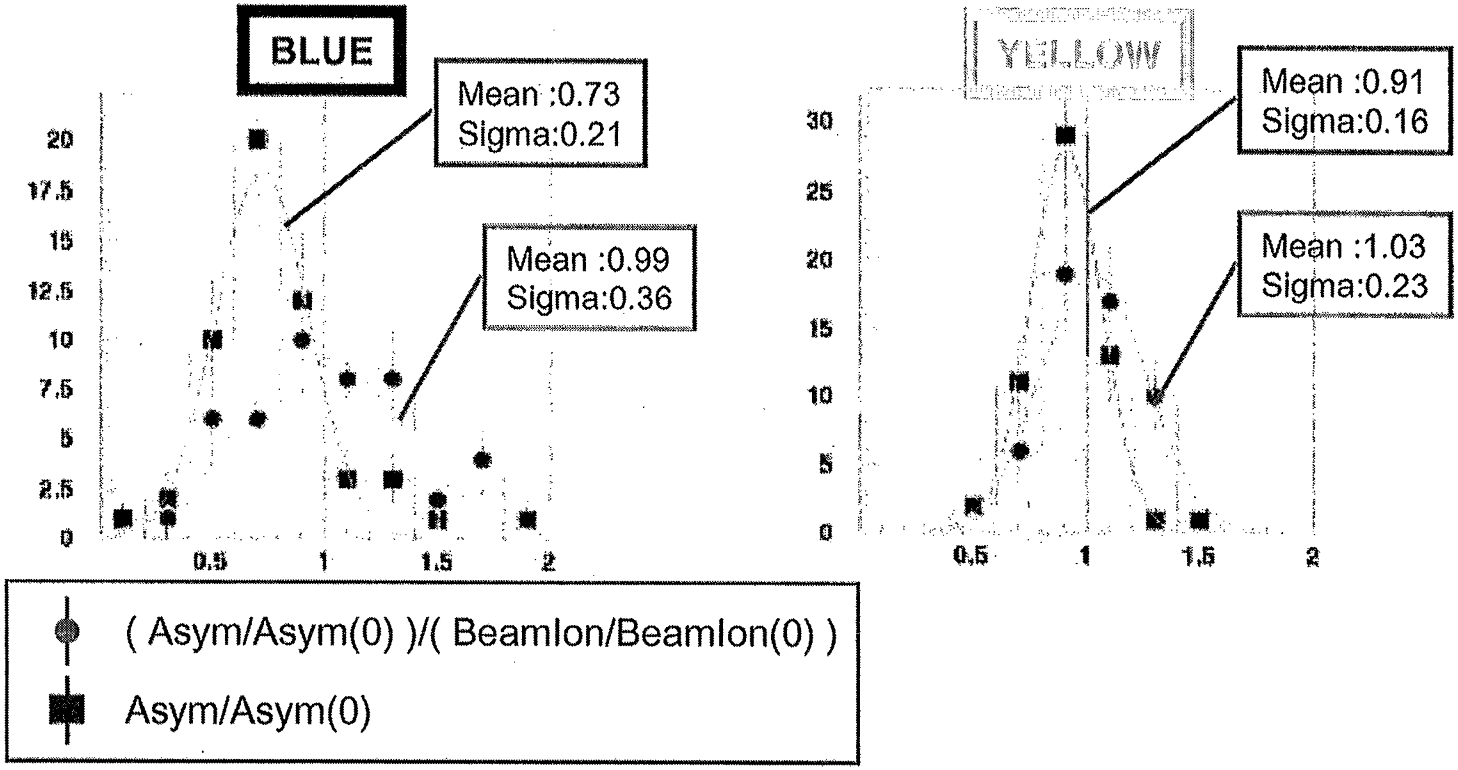


68



- The correlation between the lifetime of the asymmetry and beam intensity is not clear due to the large statistical error bars
- However by comparing blue and yellow, the correspondence is found, i.e.
  asymmetry decays ←→
  beam intensity decays

Asymmetry .vs. beam intensity (2)



- By taking the ratio, the distributions show the peak structures around 1 with larger width on both ring
- Statistically, the decay of the asymmetry and the decay of the beam intensity behave in similar way

Remaining tasks

Needless to say, there are so many....

- On going study for Y-component anomalies
- Bunch by bunch polarization study
  - Using 10 successive runs (with 0 pol bits) taken at polarimeter dedicated run time
  - The polarizations of the plus and negative spin bit bunches are equal ?
- Estimation of the systematic error originating from the false spin bit pattern
- Polarimeter dedicated run data with WFD AT mode
  - -t dependent asymmetry with x8 good energy resolution
  - Cross section (slope) study
  - Detailed study on the WFD signal shape
- ....

Summary and Outlook

- Systematic study
  - Separation between X90 and X45 looks reasonable within a statistical error bar
  - Y-component anomalies are still under study
- Stability of the asymmetry during the same fill
  - The asymmetry has the lifetime
    - Blue : 10.3 hour Yellow:35 hour
- Several measurements are needed for more precise determinations?
  - Current statistics (20Mevents) corresponds to about 5% error for 0.004 asymmetry

Update on the understanding of the polarization in RHIC

V.Ptitsyn

RHIC Polarization Setup

- 2 Siberian Snakes per ring hold the spin tune ½ all the way up during the acceleration
- The vertical tune was chosen at 0.23, between 2 high−order spin resonances:
  - 1/4=0.25 ; depends on vertical orbit
  - 3/14=0.2143; exists even without orbit errors
- The special vertical orbit, "really" flat was used as the ideal orbit
  - Made from measured misalignment data (3 years old).
  - The goal number for vertical orbit correction was 0.5mm rms
  - No measured orbit data in defocusing quads

The vertical tune was put between two higher order spin resonances

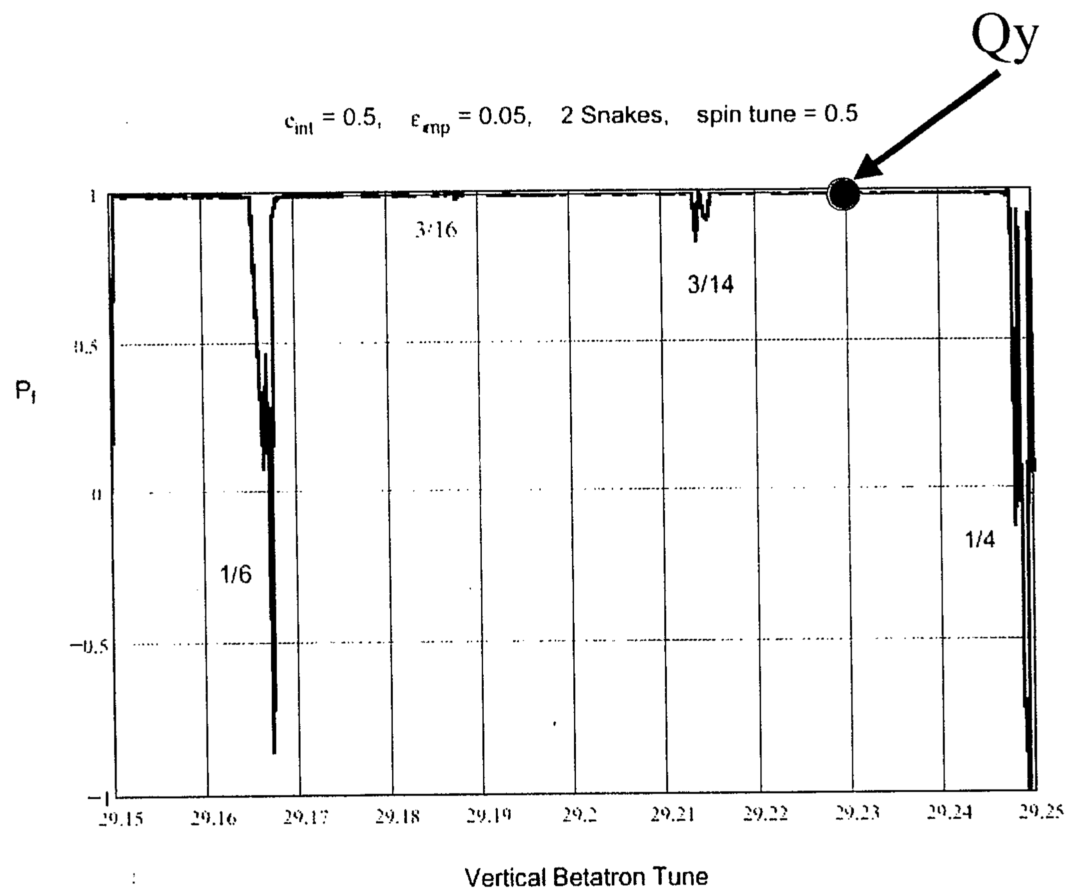
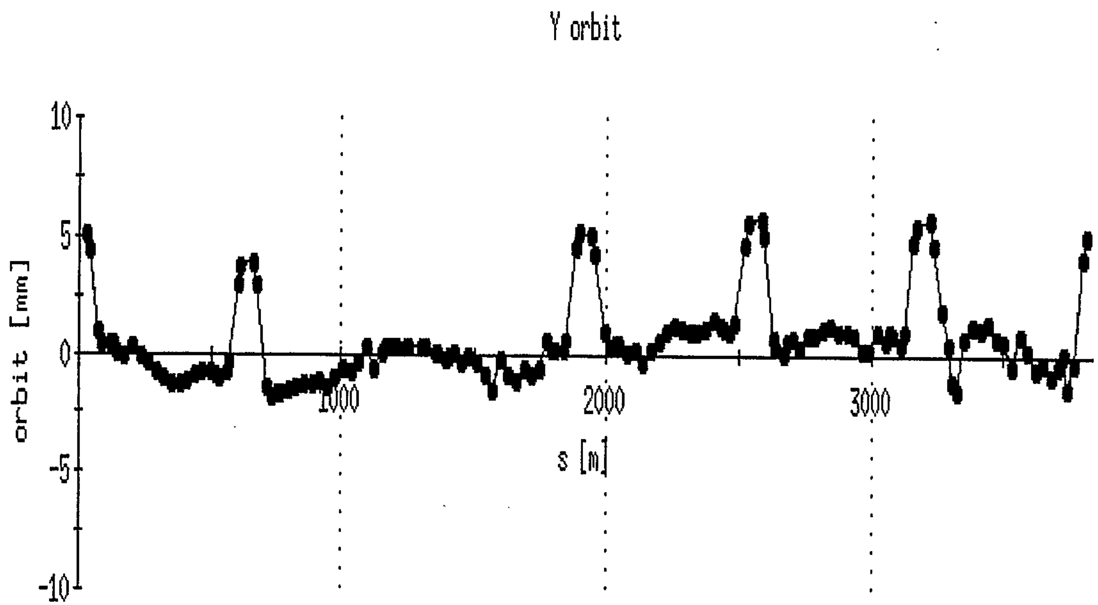


Figure 5.3: Vertical component of the polarization after acceleration through a strong intrinsic resonance and a moderate imperfection resonance shown as a function of the vertical betatron tune.

Ideal Blue orbit for polarized protons
(with vertical separation bumps included)



Data

Orbit Statistics:

	mean	rms	|max|	Nbpms
X:	0	0	0	0
Y:	-0.0471	0.87751	1.53676	69

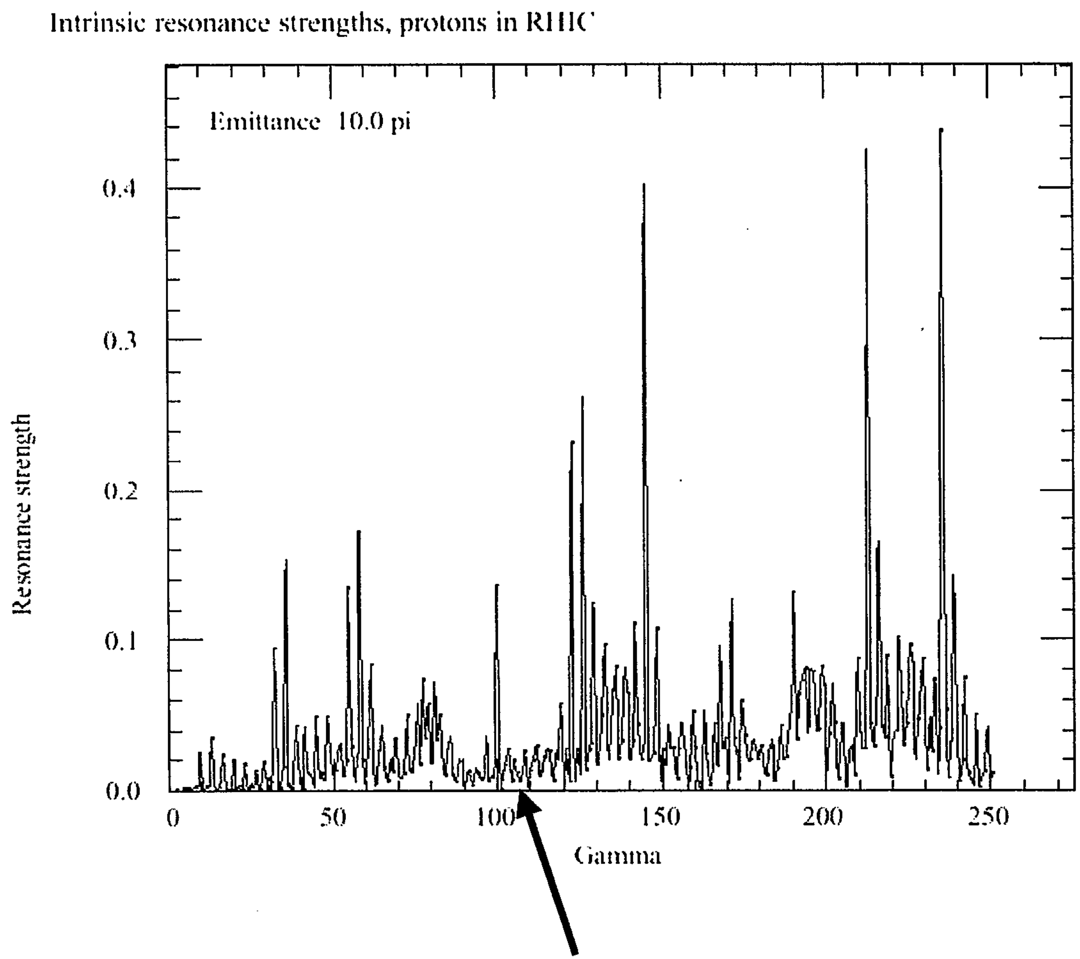
√

∨ Displayed Region

∧ Arcs

Polarization preservation

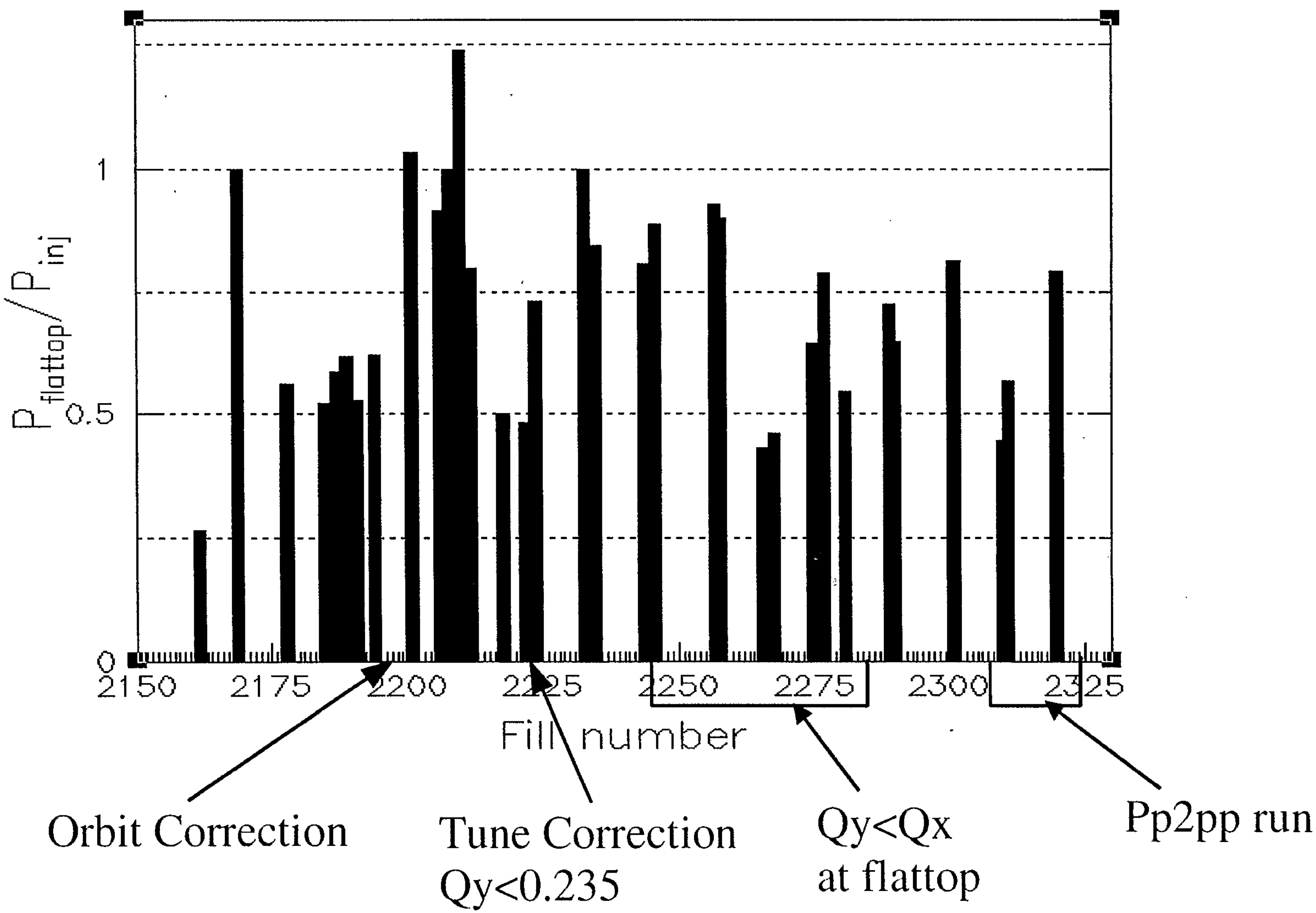
- The intrinsic resonances: 4 dangerous zones on the ramp
  - Special attention to the tunes and orbits at these zones
- Yellow polarization transmission was good the most of time
- Blue polarization transmission required more attention and periodical corrections
  - Mostly tune corrections



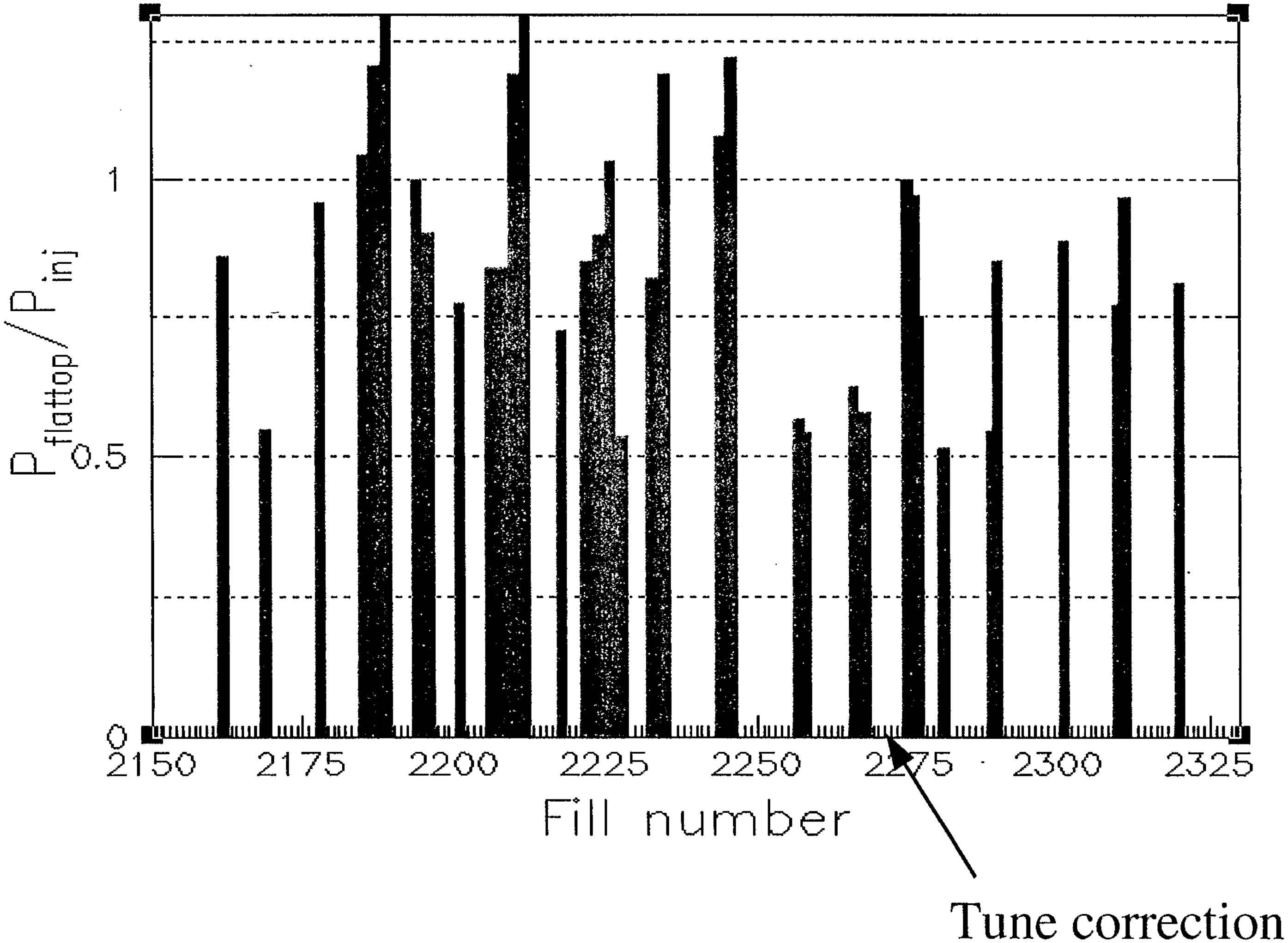
The flattop energy this run

Note that the emittance was more than 2 times larger this run with the resonance strength increasing as the square root of the vertical emittance

Blue polarization transmission on the ramps



Yellow polarization transmission on the ramps

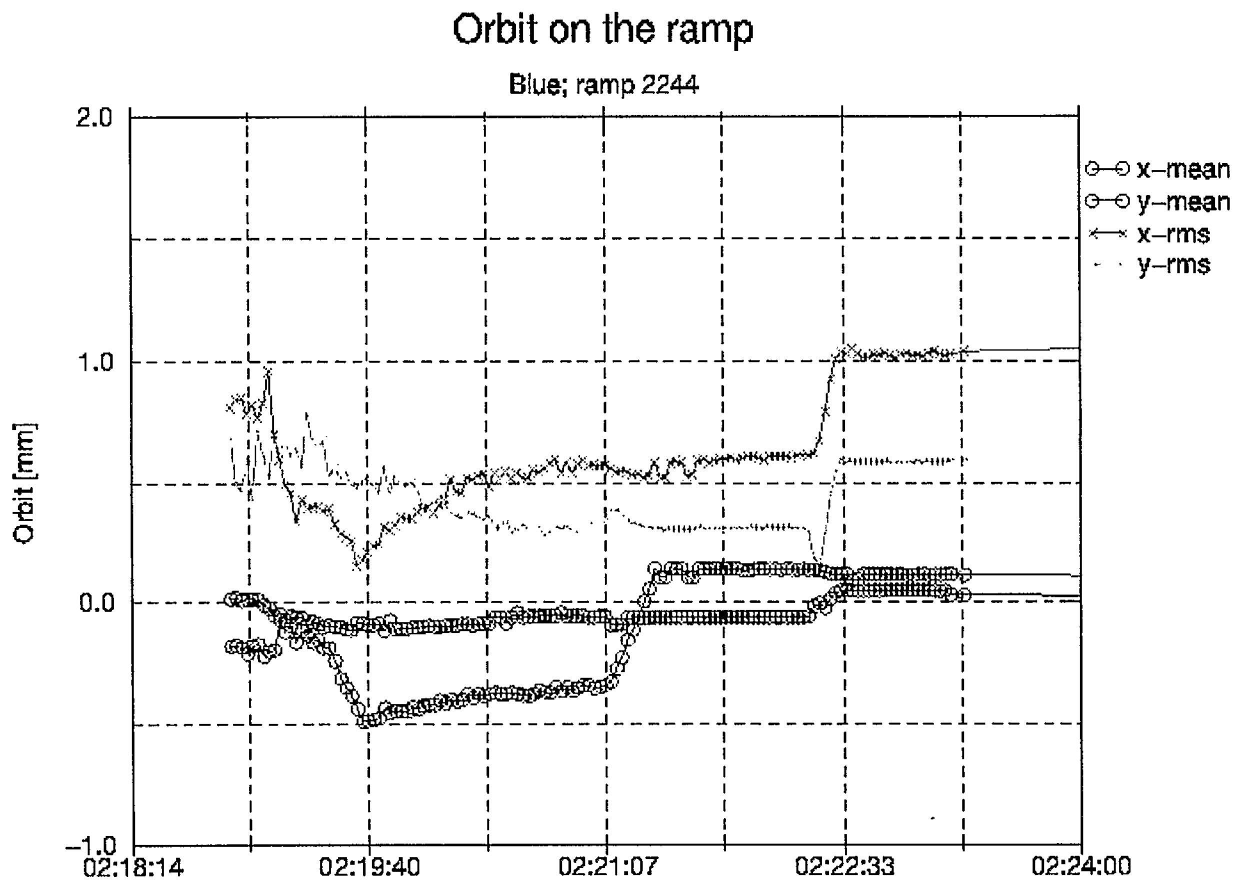


08

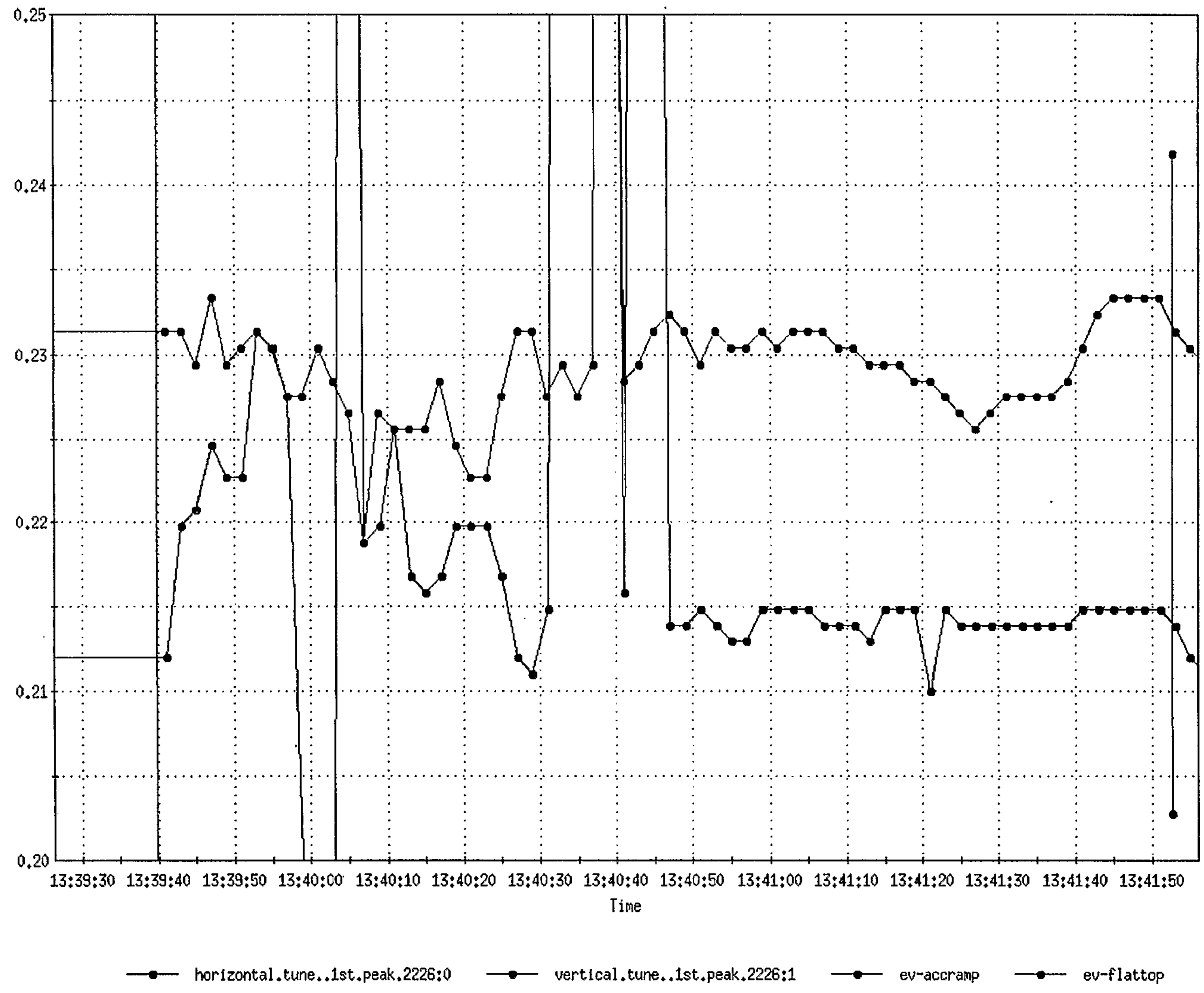
The empirical rules for the ramp:

- Keep the vertical tune below 0.235
  - Total polarization loss when Qy exceeded 0.245 at the end of the ramp was observed
- Horizontal tune + coupling might be important too
- Keep the orbit rms below 1mm
  - Blue depolarization was observed with the horiz.orbit rms higher than 1.5 mm
- The polarization deterioration at the store was observed when the vertical and horizontal tunes were switched in Yellow.
  - Qy close to 3/14 resonance

Beam orbit rms/mean along the ramp



Betatron tunes on the ramp (Blue)

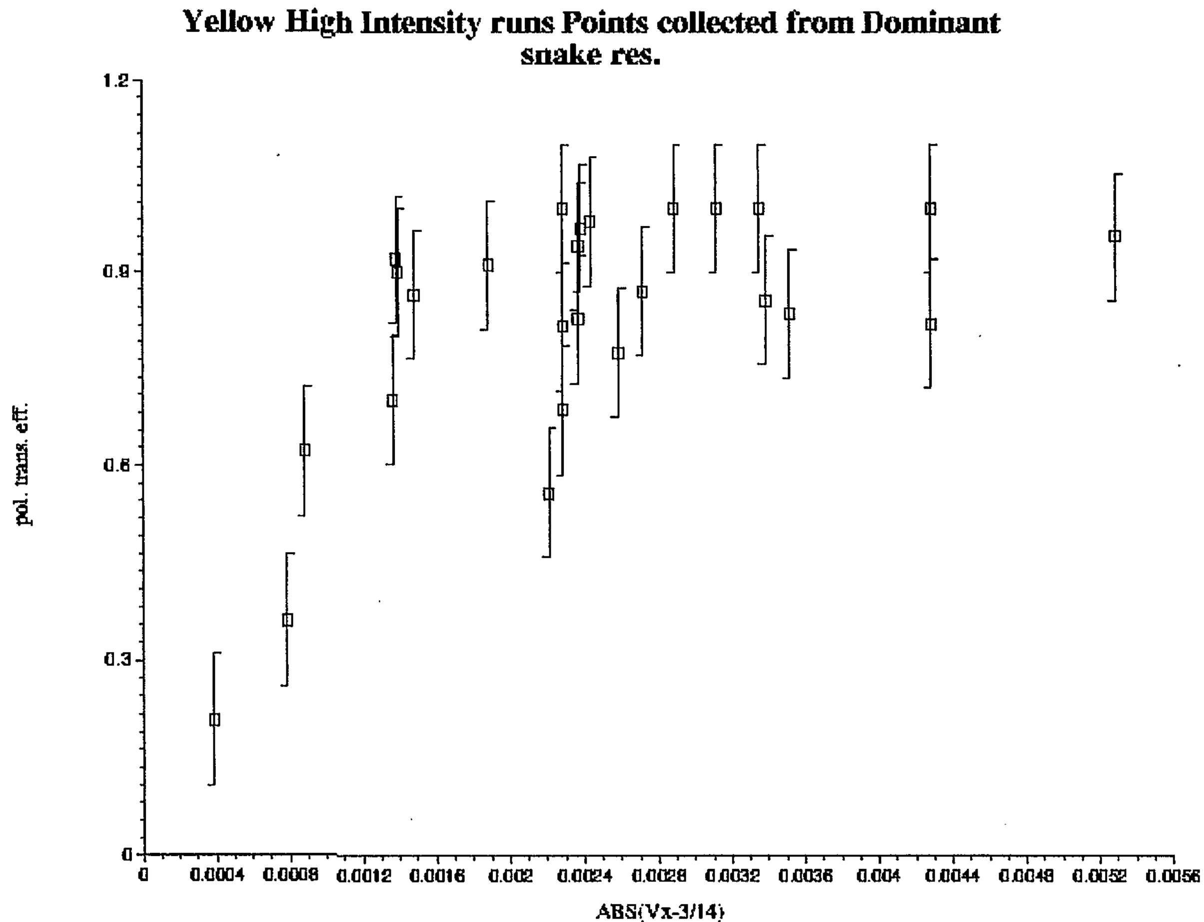


The Polarization Analysis

- The search for correlations between the polarization and tunes, orbits, coupling, emmittances is underway
  - The horiz. tune should be kept away from 3/14 (V.Ranjbar)
  - Was Blue worse than Yellow because of different emmittances? Or the goal orbits?
  - The Blue orbit more critical than Yellow
- The spin (SPINK) tracking to reproduce observed depolarizing effects and to study them (A.Luccio)

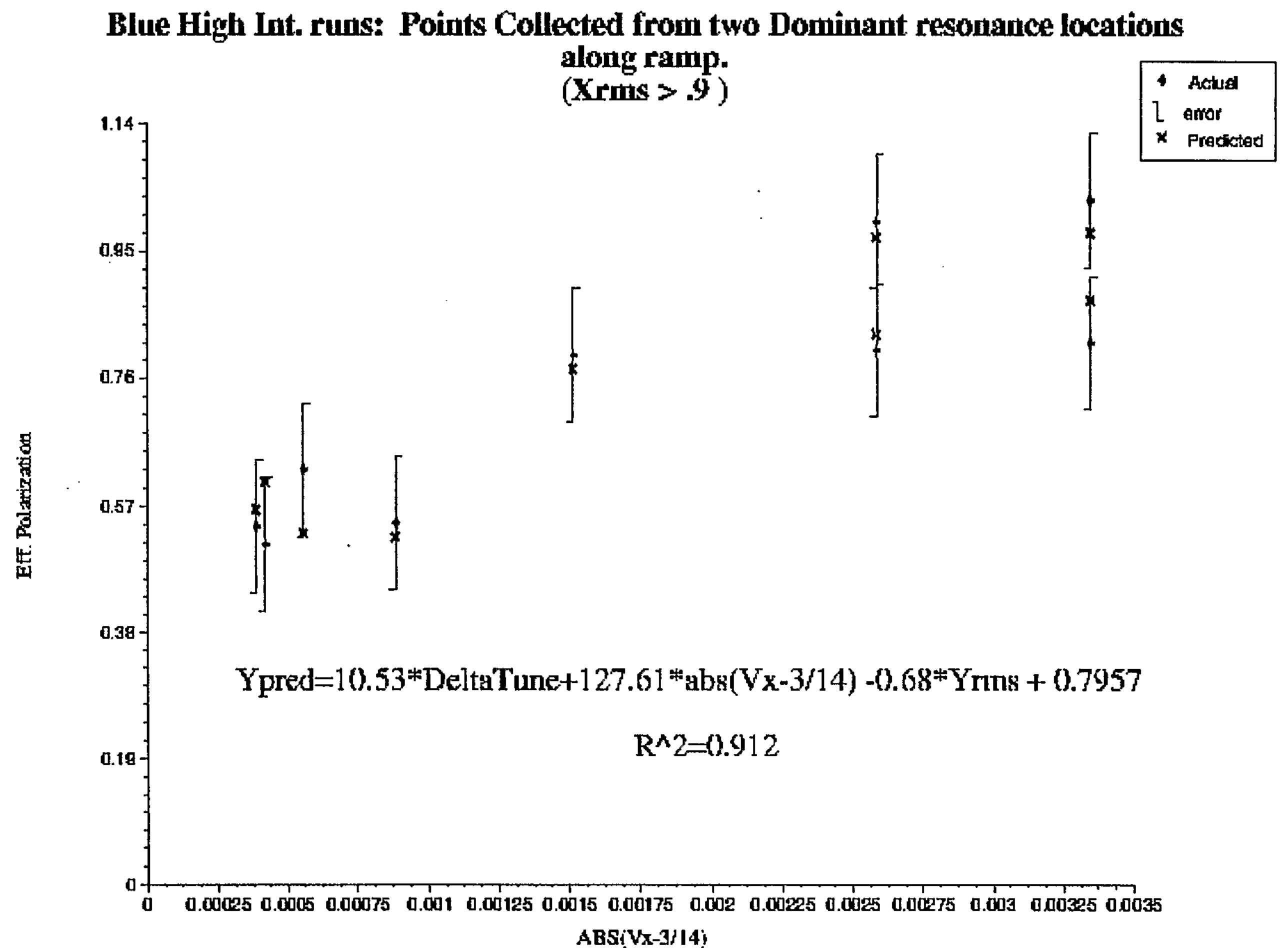
The run data shows depolarisation by 3/14 resonance caused by coupling inYellow

(V.Ranjbar)

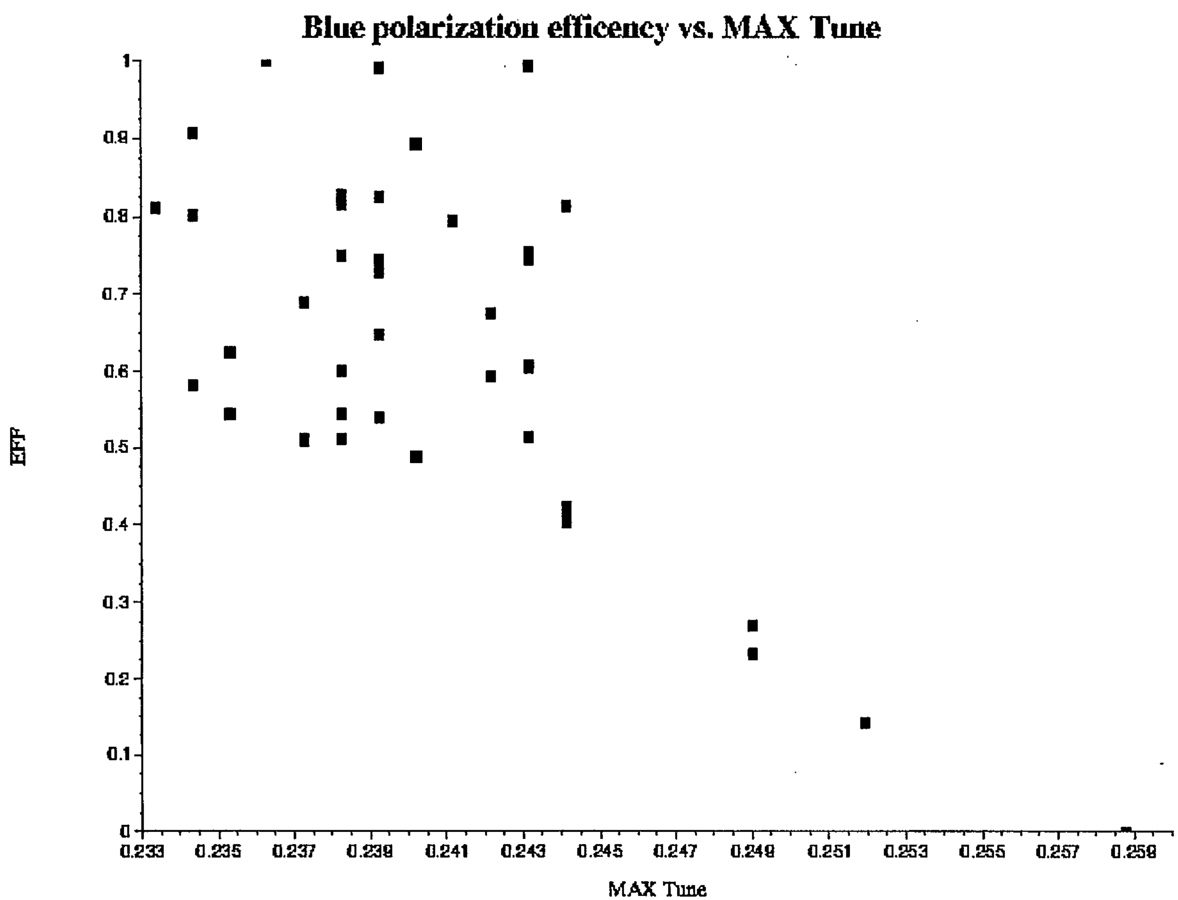


Blue data for the 3/14 resonance
The resonance was not so pronounced as in Yellow

(V.Ranjbar)

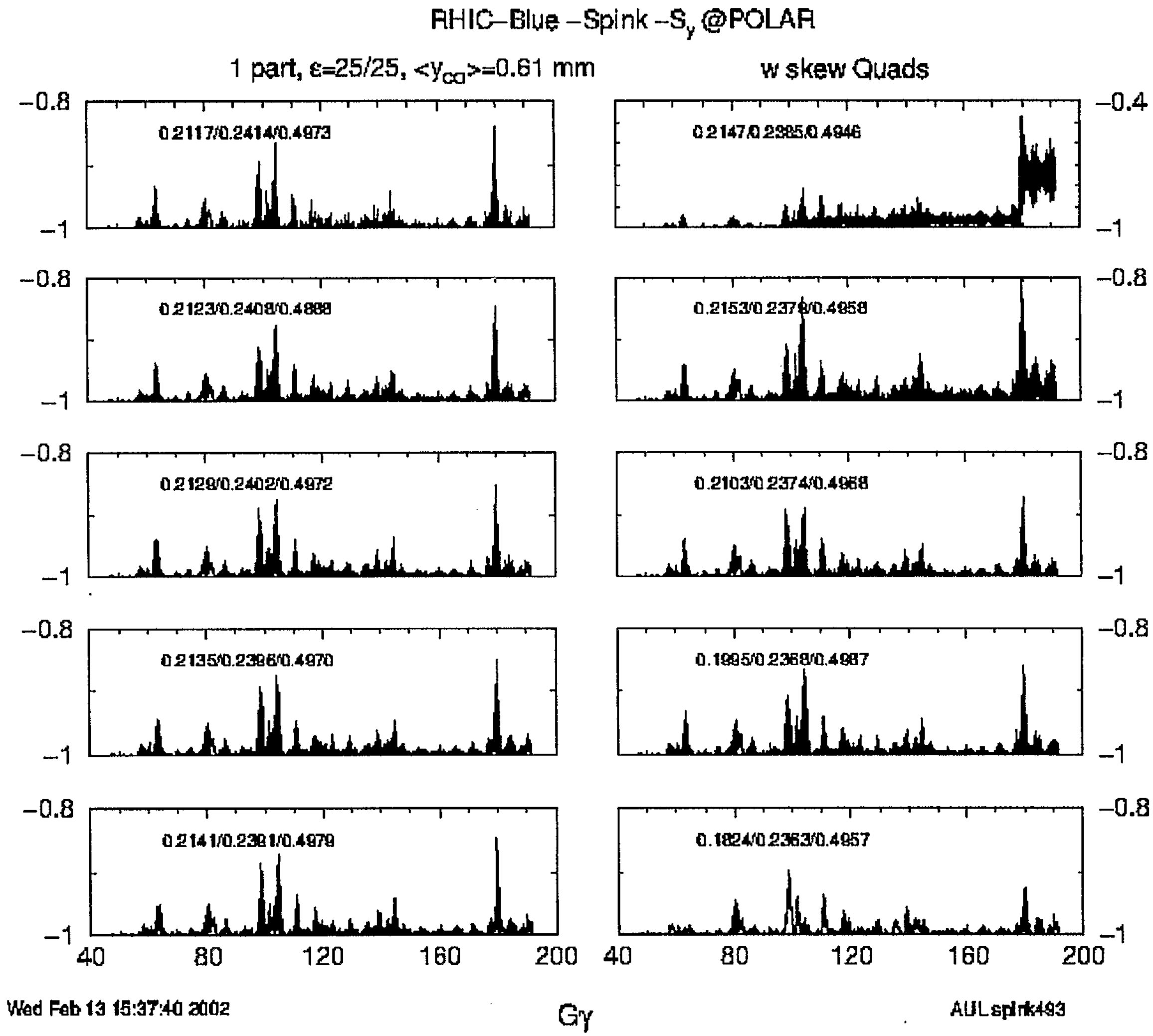


¼ spin resonance (with vertical betatron tune) (V.Ranjbar)



SPINK modeling of 3/14 resonance in the presence of betatron coupling

(A.Luccio)



Next Run

- Higher energy–> stronger resonances
- The goal orbit needs to be revisited
  - Newly measured misalignment data
  - Analysis of the corrector strengths
  - Coupling and dynamic aperture from the ideal orbit going off center in quads and sextupoles.
- Better beam control on the ramp would be necessary
  - Tune feedback
  - Improved orbit correction (below 0.4mm rms)
  - Coupling control on the ramps

RHIC Spin Collaboration Meeting VIII
April 12, 2002
RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting VIII
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RIKEN BNL Research Center

RHIC Spin Collaboration Meeting VIII

April 12, 2002

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

*******AGENDA*******

Morning Session

09:00 - 09:30	Reflections from the RHIC Retreat...........................	T. Roser
09:30 - 10:15	Performance & Future for the Polarized Source...........	A. Zelenski
10:15 – 10:45	Performance of the Booster....................................	L. Ahrens
10:45 – 11:00	Coffee Break	
11:00 – 12:00	Present Understanding of the AGS Polarization and Its Simulation..	M. Bai
12:00 – 13:00	*Lunch*	

Afternoon Session

13:00 – 13:45	Update on the Status of the RHIC Polarimeter Analysis....	O. Jinnouchi
13:45 - 14:30	Update on the Understanding of the Polarization in RHIC..	V. Ptitsyn
14:30	Coffee Break & Discussion	

SUMMARY

B. Fox, RBRC
May 22, 2002

for
RHIC Spin Collaboration Meeting IX
RIKEN BNL Research Center

Since its inception, the RHIC Spin Collaboration (RSC) has held semi-regular meetings each year to discuss the physics possibilities and the operational details of the program. Having collected our first data sample of polarized proton-proton collisions in Run02 of RHIC, we are now in the process of examining the performance of both the accelerator and the experiments. From this evaluation, we not only aim to formulate a consensus plan for polarized proton-proton during Run03 of RHIC but also to look more forward into the future to ensure the success of the spin program.

In the third meeting of this series (which took place at BNL on May 22, 2002), we focused on three, more immediate topics:

- luminosity performance at the experiments,
- the status of the local polarimetry test efforts from PHENIX and STAR, and
- a discussion of the proposals for Run-03 from the three spin experiments.[1]

In addition, there was an update presentation on the analysis of the RHIC CNI polarimeter data from Run-02.

To start the luminosity discussion, Gerry Bunce summarized his comments at previous RSC meetings on the importance of the relative luminosity measurement for spin measurements. Since the bunches are prepared and accelerated separately, they will inherently have different characteristics. If the polarization state remains fixed, these differences could result in a false asymmetry if, for example, the luminosity of the parallel and anti-parallel bunches are different. This difference – called the relative luminosity – thus needs to be measured and then used when computing the spin asymmetry. In order to keep the systematic error in the asymmetry on the order of 10^{-3}, the relative luminosity should be measured to a precision of 10^{-4}. This level of precision requires a detector which monitors a high-rate process in order to collect the statistics needed for this precision. Effects such as saturation, accidentals, beam gas/scraping, and sensitivity to the vertex distribution could result in a mis-measurement of the relative luminosity. Corrections of the relative luminosity for these effects are likely not possible because of the required precision. And, finally, the monitored process ideally should not have any polarization dependence.

Following Gerry's talk, Joanna Kiryluk presented the status of the luminosity analysis underway at STAR using the data from the beam-beam counters (BBCs) which had been installed for the Run-02 proton-proton run. In this presentation, she presented preliminary results from the van der Meer scan that indicated that the peak luminosity at STAR was on the order of $10^{30}/\mathrm{cm}^2\cdot\mathrm{s}$ with an error bar which was estimated to be in the range of 15 to 25%. For spin measurements, she showed that the STAR luminosity data corroborated the observation from the RHIC CNI polarimeter that bunch 11 in each beam is anomolous.[2] She then showed that, after removing this bunch, the relative luminosity was measured with

[1]Subsequent to this meeting, it was realized that, with the addition of bunch-sorted luminosity scalers (such as the scalers which were developed by STAR for spin), the BRAHMS experiment would be able to measure $A_N(\pi)$ at forward rapidity over a large p_t range. Such a measurement will be performed by BRAHMS in Run-03.

[2]It has been since been learned that bunch 11 in each beam is used by the tune-measurement system, so the machine group is not surprised that it is an anomoly.

a precision of up to 10^{-3} by the BBCs by comparing the transverse asymmetry computed by the square-root formula with that computed with the luminosity normalized formula. In addition, she notes that, from the data collected with the BBC counters, there is a slight (10^{-3}) transverse asymmetry – an observation which, if confirmed by further analysis, would provide STAR with an already operational local polarimeter.

On the same topic, Yuji Goto presented the plan for evaluating the relative luminosity error at PHENIX.[3] Unlike at STAR, PHENIX has several luminosity detectors in the experiment and thus can compare the response of one against the other to evaluate their performance as relative luminosity monitors. In this talk, Yuji showed some initial results from this work – notably, confirming the "Bunch-11" problem seen by STAR and the CNI polarimeter – and outlined the analysis plan for the data.

And, finally, to close out this portion of the program, Thomas Roser presented the luminosity goals in Run-03. In this presentation, he recounted the performance of the machine for Au-Au and p-p running in Run-02 and, based upon this performance, estimated that the luminosity expectations for Run-03. Specifically, he expects something in the neighborhood of $\sim$2.8 pb^{-1}/week for proton-proton running. Folding in an efficiency of 50% for the experiments, we decided that we should use $\sim$1.0 pb^{-1}/week as a reference luminosity when estimating the physics output from a spin run as part of Run-03.

The final presentation of the morning session was an update on the CNI polarimeter by Osamu Jinnouchi. With the data collected on January 23rd during the dedicated polarimeter fill, the polarization of the individual bunches was computed with the square root asymmetry formula using the unpolarized bunches as the reference. After observing markedly different polarizations for the up and down bunches based on this analysis, Osamu realized that the first bunch, which was one of the three unpolarized bunches, exhibited non-zero and wildly fluctuating asymmetries when matched with either of the other two unpolarized bunches. Further investigation showed that this behavior occurred in all fills. Omitting this anomolous bunch from his analysis, he found that the polarizations for the up and the down bunches were much more consistent, but still these studies need to be pursued a bit further before it is reasonable to draw any definite conclusions from these data.

In the afternoon session, Les Bland presented a first look at the analysis of the data from the forward pion detector (FPD) installed for the Run-02 proton-proton run at STAR. The aim of this effort was to measure the cross section and the transverse asymmetry for π° production at forward rapidity (x_f between 0.3 and 0.6) with a p_t of $\sim$1.5 GeV/c. This detector setup consisted of the prototype for the STAR end-cap calorimeter for the left-arm and arrays of lead-glass detectors (obtained from E704) for the top, bottom, and right arms. At this point, the analysis has verified that the detectors worked as expected and they are now working on extracting both the cross section and the transverse asymmetry. It is hoped that this analysis will be finalized by September for the Spin 2002 conference.

And, finally, there was a discussion of the Run-03 plans from the three main spin experiments. Matthias Grosse-Perdekamp presented a summary of the detector performance at PHENIX in Run-02, including a first look at the absolute π° cross section result from an online analysis by Sasha Bazilevsky and an estimate for the precision of the A_N measurement from

[3]The results of this analysis were presented by Takehiro Kawabata during the September meeting and the transperencies from his talk have been included in a later section of these proceedings.

these data. He then showed that we could make a significant measurement of ΔG in Run-03 in the π° channel if the polarization was $\geq 40\%$ and the recorded, integrated luminosity was ≥ 3 pb^{-1}. With this result as our main goal, PHENIX will likely ask for a proton-proton run as part of Run-03.

Geary Eppley then presented the thoughts on Run-03 for the STAR spin group. He informed us that STAR also was leaning towards requesting a proton-proton run as part of their beam proposal because the spin group feels that it can improve the $A_N(\pi^{\circ})$ from the FPD (discussed early by Les) by increasing both the statistics and the kinematic coverage and also start a ΔG measurement using the jet+X channel. In addition, he emphasized the need for continuity in the spin program. So, as with PHENIX, STAR will likely ask for a spin run.

To close this discussion, Stephen Bueltmann presented the Run-03 plans for the pp2pp experiment. To open, he summarized the performance of pp2pp in Run-02. In this run, they had 4 Roman pots (2 on each side of the IP) instrumented with silicon microstrip detectors and trigger scintillators to cover a range in momentum transfer from 4×10^{-3} to 0.03 (GeV/c)^2. With this setup, they were able to collect $\sim$400k elastic events during the dedicated running at $\beta^* = 10$ m. He showed a first (x,y) distribution for hits in one of these detectors. The analysis of these data is still under way.[4] For Run-03, they plan to adjust the detectors to extend their momentum transfer acceptance down to $\sim 2\times10^{-3}$ and, with a 2-3 day run at $\sim$10 times the Run-02 luminosity, collect 2 to 3 million elastic triggers. With these data, they would be able to measure the cross section to $\sim$3% and A_N with a statistic precision of 0.002; however, it should be noted that, within the collaboration, discussions of the conditions and the duration of a run during Run-03 are still ongoing.

B. Fox
22 May 2002

[4]In the June meeting, Stephen Bueltmann made a presentation on the analysis of these data.

On Relative Luminosity at RHIC

G. Bunce

May 22, 2002

for
RHIC Spin Collaboration Meeting IX
RIKEN BNL Research Center

22 May 02
RHIC Spin Mtg.
G. Bunce

On Relative Luminosity at RHIC

① Absolute luminosity → cross sections
→ important to compare to theory
⇒ understand parton subprocesses
→ need to 1% to 10% level

② Relative luminosity → asymmetries
→ normalize (++) crossings to (+−)

$$A_{LL} = \frac{1}{P^2} \frac{N_{++} - \mathbf{R} N_{+-}}{N_{++} + \mathbf{R} N_{+-}}$$

$$\mathbf{R} = \frac{L_{++}}{L_{+-}} = \frac{k L'_{++}}{k L'_{+-}}$$

$L'_{++ \atop +-}$ = relative luminosity

→ need to 10^{-3} to 10^{-4} level

(3) At RHIC, L'_{++}, L'_{+-} will be measured by counts in a luminosity monitor

$$R = \frac{L'_{++}}{L'_{+-}} \approx 1 \; ; \quad L'_{++}, L'_{+-} \text{ are } \underline{\text{counts}},$$

$$\Delta L'^{2}_{++} = L'_{++}$$

$$L' = L'_{++} + L'_{+-}$$

$$\boxed{\Delta A_{LL} \approx \frac{1}{P^2}\sqrt{\frac{1}{N} + \frac{1}{L'}}}$$

For many RHIC measurements, for example A_{LL} for π^0 production, the raw asymmetry will have a statistical error of $\sim 10^{-3}$:

$$\Delta A_{LL} \times P^2 \Big|_{\pi^0 \text{ stats}} = \frac{1}{\sqrt{N_{\pi^0}}} \approx 10^{-3}$$

⇒ **<u>want $L' \gg 10^6$</u>**

⇒ **systematic error in L'_{++}, L'_{+-} <u>also at this level</u> $\ll 10^{-3}$**

⇒ **monitors <u>free of polarization dependence</u> to this level**

④ + − + − X + + − −

→   ←

→| |← ~100 ns spacing

→ polarization signs flip every 100 ns

⇒ apparatus variation vs. time will not be important

but

→ each bunch is prepared and accelerated, stored independently

⇒ $\boxed{L'_{++} \neq L'_{+-}}$

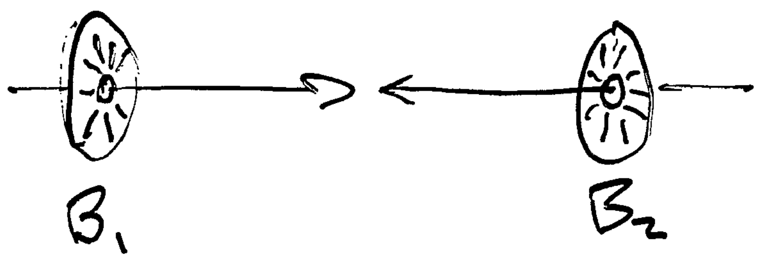
⑤ strategies

- flip spins on 1 ring at a time, frequently (++ crossing → +− crossing)
- relative luminosity monitors

(− recog so that different bunches collide)

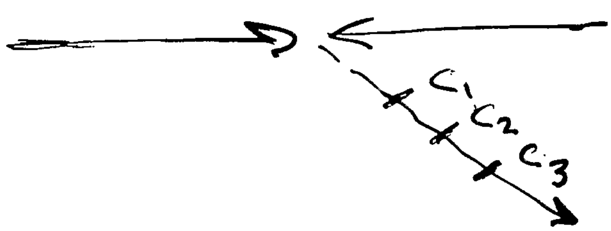
⑥ Typical luminosity ~~monitors~~

beam-beam counters



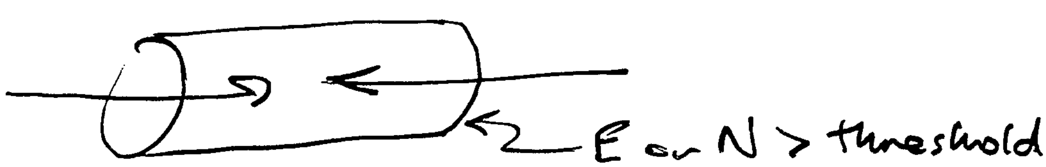
$$L'_{++} = \sum_{\substack{\text{crossings}\\ ++}} B_1 \cdot B_2$$

counter telescopes



$$L'_{++} = \sum_{++} C_1 \cdot C_2 \cdot C_3$$

global (or local) energy or multiplicity



$$L'_{++} = \sum_{++} E > E_T \quad \text{or} \quad L'_{++} = \sum_{++} E \ (\text{or } N)$$

(7) Issues to study for each monitor

- **saturation**
  - if $\Delta L'|_{\text{per cross}} = 1$, study requirement on acceptance (efficiency of getting a $\Delta L' = 1$ for a collision) vs. luminosity
    - if accept. × collision rate is large (>10^{-2} ?), monitor will count 1 hit too often when there are 2 collisions for a crossing
- **accidentals**
  - if $B_{\text{singles}} \gg B_1 \cdot B_2$, and probability of 2 collisions in 1 crossing is high ⇒ extra counts
- **beam effects** (not from collisions)
  - beam-gas, scraping
    → base-line counts
- **L' vs. σ** (different sensitivity to vertex...)
  - L' measures different "luminosity" than σ

(7) cont. — issues for monitors

— polarization dependence

- multiple luminosity monitors, compare 1 vs. 2 ...

(8) <u>But</u>: all of these "issues" are only important if they affect (++) vs. (+-) crossings differently.

<u>However</u>: <u>each</u> can generate a false asymmetry!

One clear conclusion: **spin-flipping is crucial.**

Luminosity at STAR

Joanna Kiryluk, UCLA
May 22, 2002

for
RHIC Spin Collaboration Meeting IX
RIKEN BNL Research Center

Luminosity at STAR

Joanna Kiryluk, UCLA

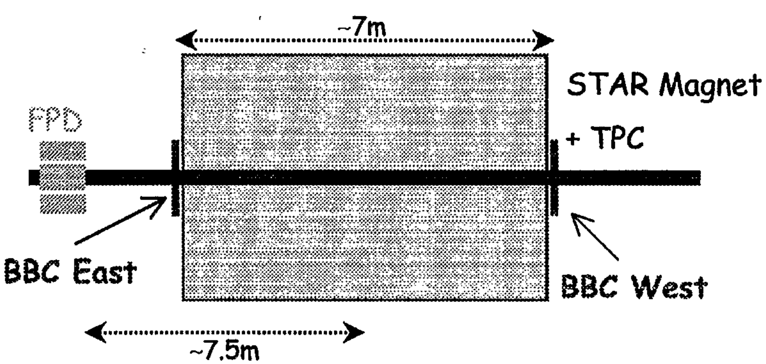
Rhic Spin Collaboration Meeting, BNL May22

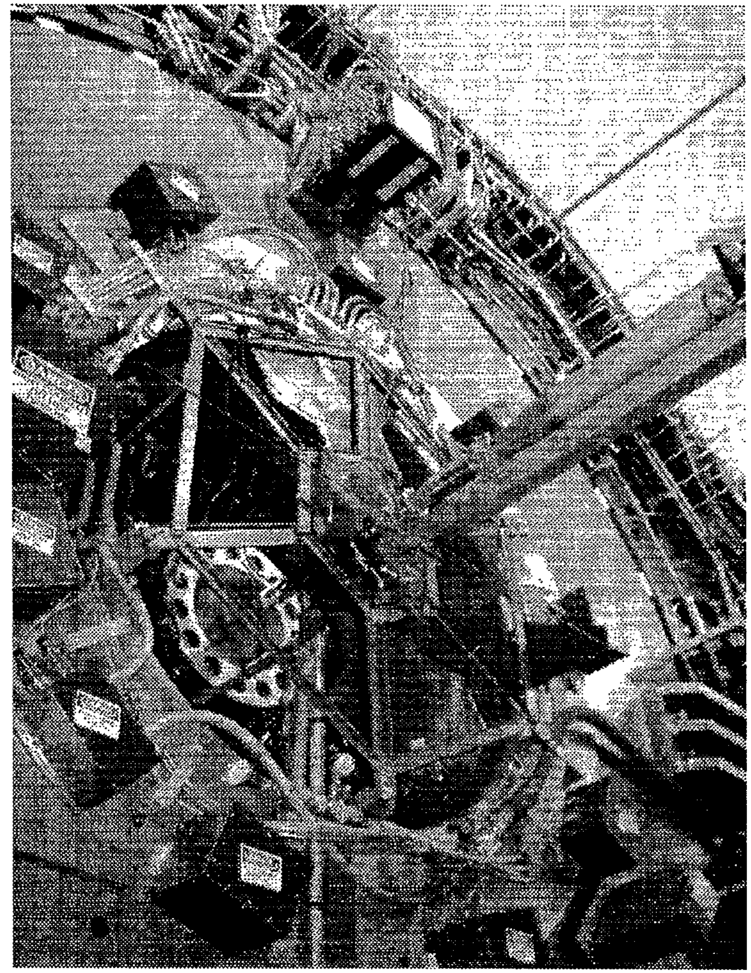
1. STAR detector upgrade (BBC + scaler boards) for luminosity measurement in FY02/FY03
2. Luminosity monitoring
3. Relative luminosity measurement
4. Single spin asymmetries from the BBC scaler data
5. Summary

I Upgrade of STAR detector for luminosity measurement in pp run FY02/FY03

1. Beam-Beam Counters (BBC)
   Scintillator annullus installed around the beam pipe, on the east and west poletips of STAR magnet at ±3.5m from IR ($2 < |\eta| < 5$)

2. Scaler Board System



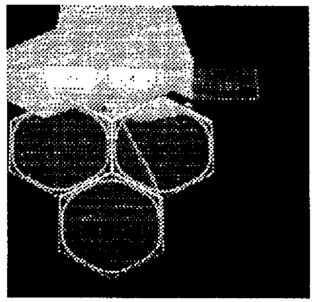


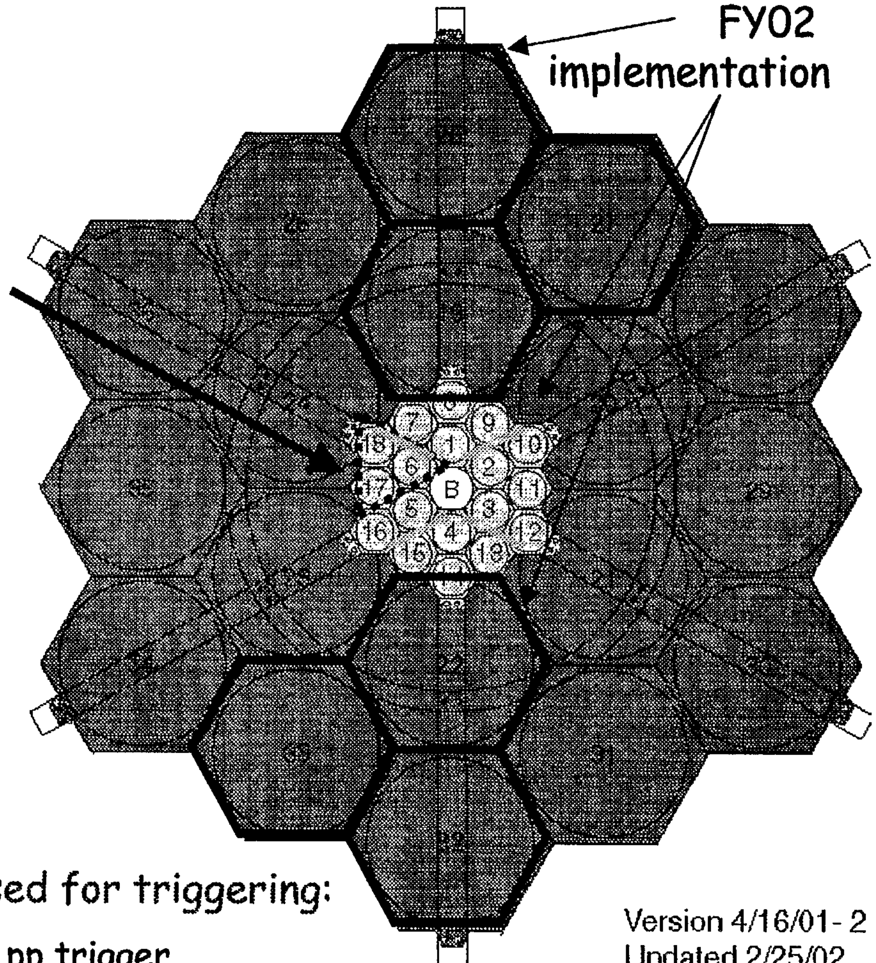
1. Beam-Beam Counters (BBC)

Small hexagonal annulus:

- inner (outer) diameter 9.6cm (48cm); of 18 pixels (6 inner + 12 outer);
- 8PMT: 4 PMT/η ring -> azimuthal segmentation (Top, Bottom, North, South)
- all pixels in place in FY02 covered $3.3 < |\eta| < 5.0$

-1 cm thick scintillator SCSN81 (Kuraray)
-4 optical fibers for light collection
- 1,2 or 3 tiles connected to a PMT
-15 photoelectron/MIP





Large hexagonal annulus:

-inner (outer) diameter 38cm (193cm) of 18 pixels (6 inner + 12 outer)

-1/3 in place, to be completed for FY03. It will cover $2.1 < |\eta| < 3.3$

Only small annuli have timing information, thus used for triggering:

East*West coincidences condition in each of pp trigger

FY02/FY03 BBC Plans

- Complete construction of large hexagonal tiles
  - ➢ purchase/construct wave-length shifting fiber optics
  - ➢ assemble/test remaining large hexagonal tile triplets
- Extend PMT readout of hexagonal pixels:
  - ➢ 16 PMT for small hexagonal annulus
    - → evaluate/purchase fast, 'green-extended' PMT
    - → purchase/construct clear-fiber optical cables
  - ➢ 8 PMT for large hexagonal annulus
    - → design/construct PMT box for mounting atop STAR magnet
- Implement 48-channels of CDB/DSM for pulse-height readout
- Implement 32-channels of CDB/DSM for timing readout (small hexagons only)
- Develop 6U VME time-to-amplitude converter (based on CAMAC design/components)
- Employ LeCroy 1440 HV system / interface to STAR slow controls system

2. Scaler Board System

1 BBC E•W
2 BBC E
3 BBC W
4 BBC W.Etop
5 BBC W.Ebot
6 BBC W.Enorth
7 BBC W.Esouth
8 BBC Wtop.Eany
9 BBC Wbot.Eany
10 BBC Wnorth.Eany
11 BBC Wsouth.Eany
12 BBC Enorth
13 BBC Esouth
14 BBC Etop
15 BBC Ebot
16 CTB-M1
17 CTB-M2
18 BX1
19 BX2
20 BX3
21 BX4
22 BX5
23 BX6
24 BX7

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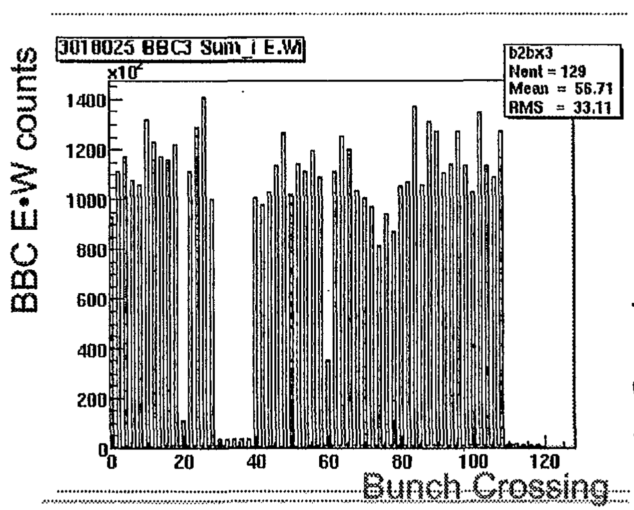
- Each scaler board has 24 input bits:
  For pp spin run:
  24 = 7(bunch crossing) + 17(physics inputs) -> $2^{17}=10^5$
  or 24 = 4 (spin index) + 20(physics inputs) -> $2^{20}=10^6$

- Input bit pattern (information from fast detectors like BBC, ZDC, FPD, CTB, EMC) recorded for each RHIC Strobe received

- FY03 - up to 10 scaler boards,
decision which detector(s) to use and bit mapping to be made

<- example of the BBC scaler bits used in FY02

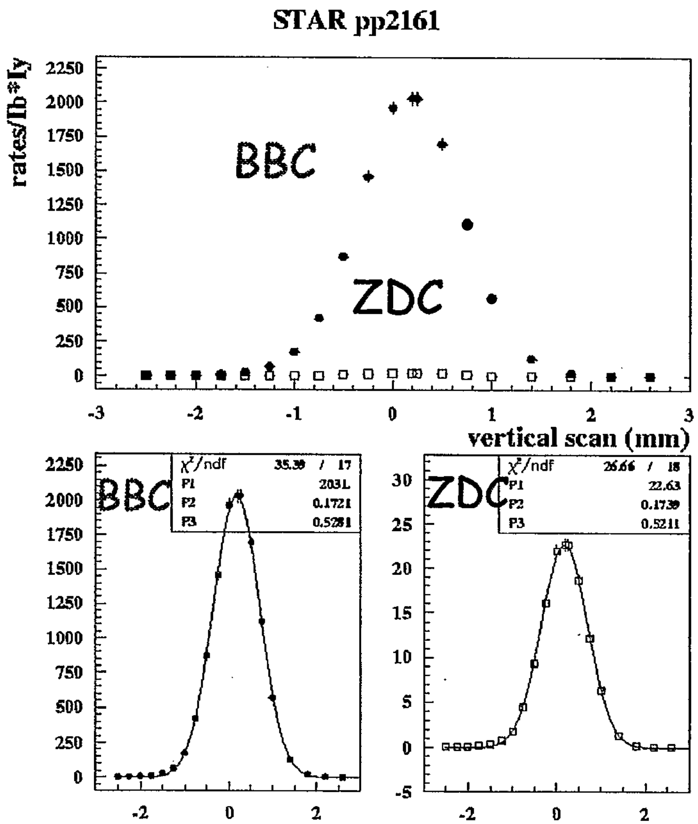


Run 3018025, fill 2251

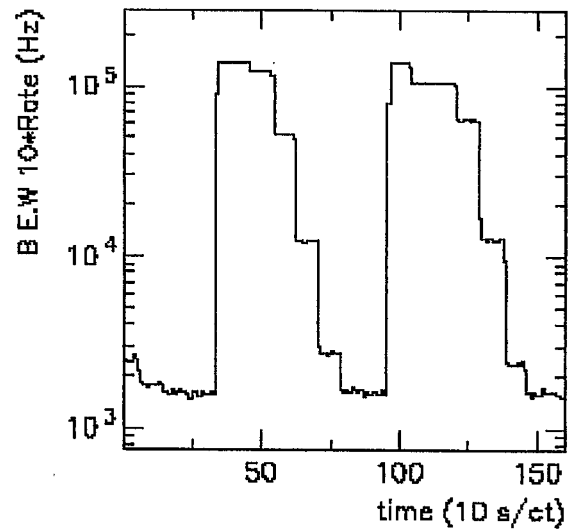
<- To determine the relative luminosity of bunch crossings with different polarization directions.

II Luminosity monitoring

Scalar info sent to RHIC to enable MCR
to steer beam at STAR



Absolute normalization from BBC E.W:



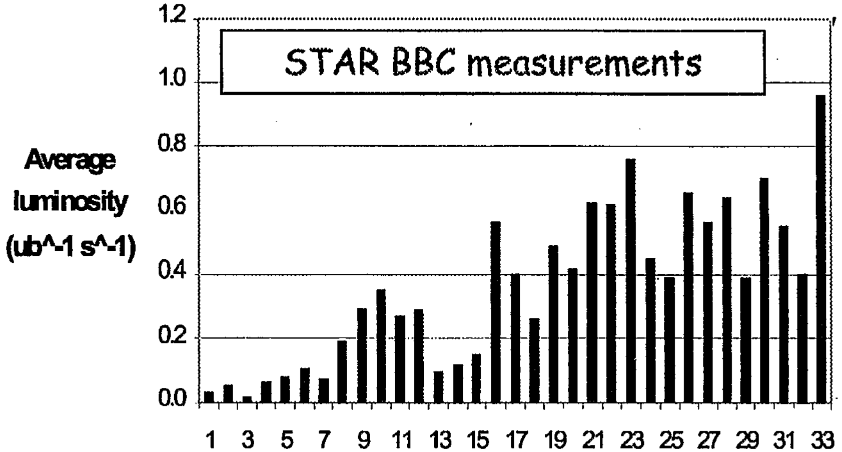
- BBC E•W coincidence rate vs time during a **Van der Meer scan** that determines the beam size, and hence the luminosity, by controlled relative steering of the colliding beams.

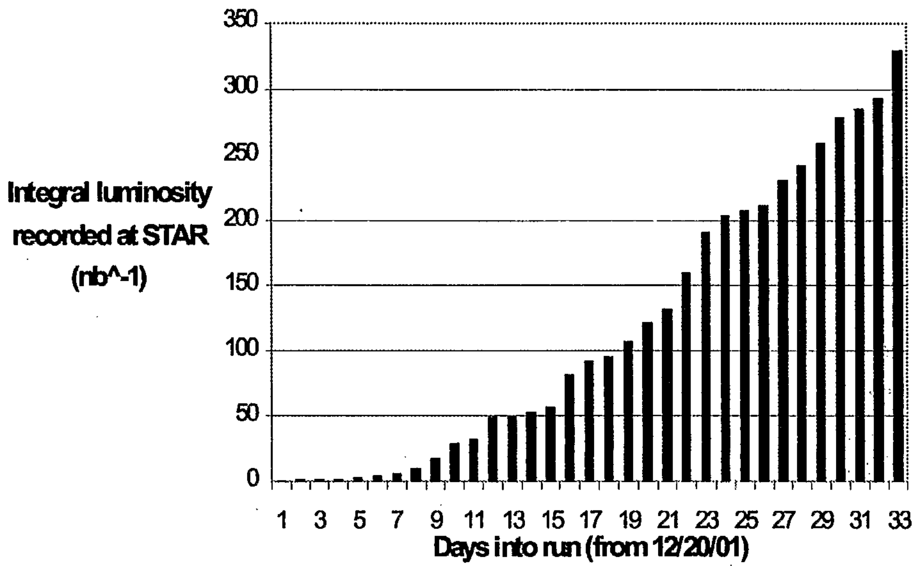
From simulations: BBC "sees" 40% of total pp cross section,

Rate of 20 kHz ~ Luminosity of 10^{30} cm^{-2} s^{-1} ; agreement up to 15%

Plot(s) from Angelika Drees

FY02 Polarized Proton Run Luminosity





- RHIC can deliver 10^{30} cm^{-2} s^{-1}
- Integrated luminosity@STAR ~ 325 nb^{-1}

III Relative luminosity measurement

To measure relative luminosity of bunch crossings with different polarization directions with good statistical accuracy,
one needs process/detector with
- high rates and
- no (or small) polarization dependence

$$\delta \frac{\mathcal{L}^{\uparrow}}{\mathcal{L}^{\downarrow}} << P \times A_N$$

<u>Transverse Single Spin Asymmetries</u>

1. Left-Right symmetric detector

This method works only with transverse polarization

$$\varepsilon_1 = P_{Y(B)} \times A_N = \frac{\sqrt{L^{\uparrow}R^{\downarrow}} - \sqrt{L^{\downarrow}R^{\uparrow}}}{\sqrt{L^{\uparrow}R^{\downarrow}} + \sqrt{L^{\downarrow}R^{\uparrow}}}$$

$L(R)^i$ – spin dependent yields from Left (Right) detector, where $i = \uparrow, \downarrow$ and $L^i\ (R^i) = N^{i\uparrow} + N^{i\downarrow}$
$P_{Y(B)}$ – beam polarization

2. Non-symmetric detector

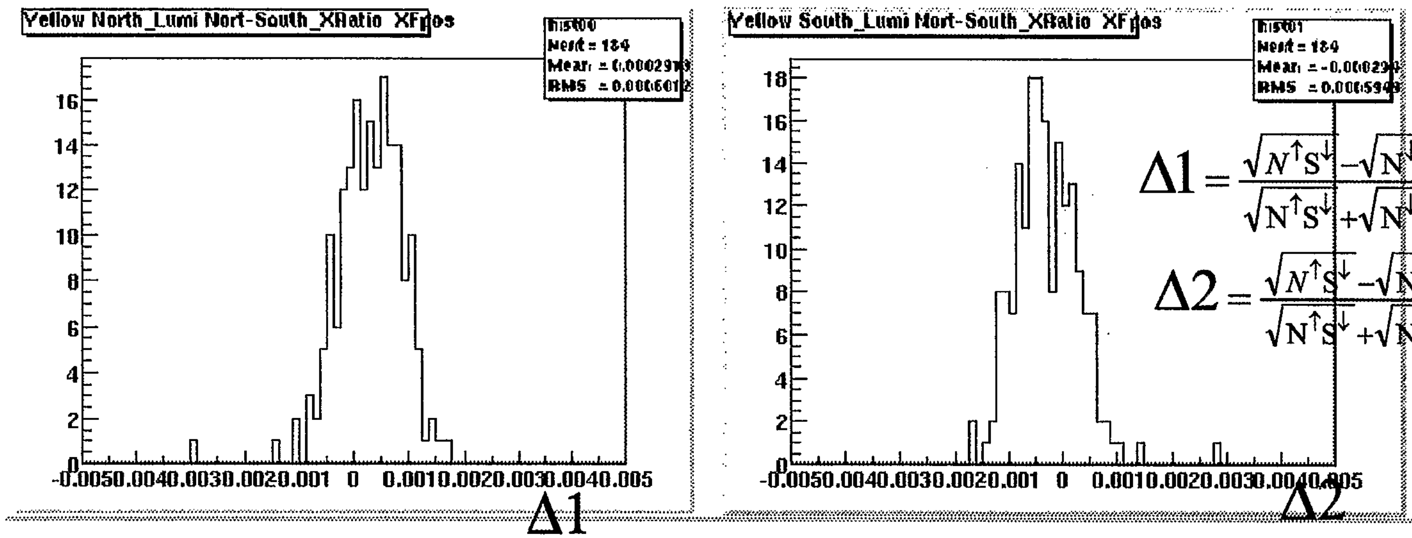
This method will be used when beam(s) are polarized longitudinally (next year) A_{LL}

$$\varepsilon_2 = P_{Y(B)} \times A_N = \frac{N^{\uparrow}/\mathcal{L}^{\uparrow} - N^{\downarrow}/\mathcal{L}^{\downarrow}}{N^{\uparrow}/\mathcal{L}^{\uparrow} + N^{\downarrow}/\mathcal{L}^{\downarrow}}$$

where: N^i – spin dependent yields, requires the $\mathcal{L}^i$ – corresponding luminosity measurements

Statistical significance: $P^2 \cdot \int \mathcal{L} dt$

- Single spin asymmetry calculated using counts from North/South BBC East detector, Yellow beam polarized (example)
- Comparison of 2 methods of single spin asymmetry calculation : ε_1 and ε_2 (North/South)



$$\Delta 1 = \frac{\sqrt{N^{\uparrow}S^{\downarrow}} - \sqrt{N^{\downarrow}S^{\uparrow}}}{\sqrt{N^{\uparrow}S^{\downarrow}} + \sqrt{N^{\downarrow}S^{\uparrow}}} - \left(\frac{N^{\uparrow}/\mathcal{L}^{\uparrow} - N^{\downarrow}/\mathcal{L}^{\downarrow}}{N^{\uparrow}/\mathcal{L}^{\uparrow} + N^{\downarrow}/\mathcal{L}^{\downarrow}} \right)$$

$$\Delta 2 = \frac{\sqrt{N^{\uparrow}S^{\downarrow}} - \sqrt{N^{\downarrow}S^{\uparrow}}}{\sqrt{N^{\uparrow}S^{\downarrow}} + \sqrt{N^{\downarrow}S^{\uparrow}}} - \left(\frac{S^{\uparrow}/\mathcal{L}^{\uparrow} - S^{\downarrow}/\mathcal{L}^{\downarrow}}{S^{\uparrow}/\mathcal{L}^{\uparrow} + S^{\downarrow}/\mathcal{L}^{\downarrow}} \right)$$

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Conclusion: Relative luminosity known up to 10^{-3}

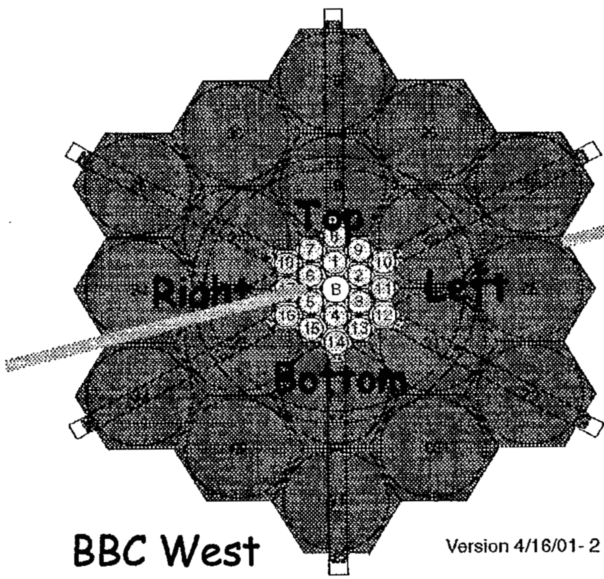
Results from the charged leading particle analysis (midrapidity, TPC) supports this conclusion - no spin effects observed in pp-> h + X up tp 10^{-3}

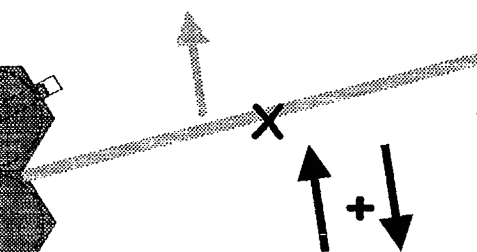
Now we want to check if there is any spin dependence in the process(es) for which we measure the relative luminosity with the BBC:
Transverse single spin asymmetries calculation with BBC counters (possible Due to an azimuthal segmentation: left-right-top-bottom)

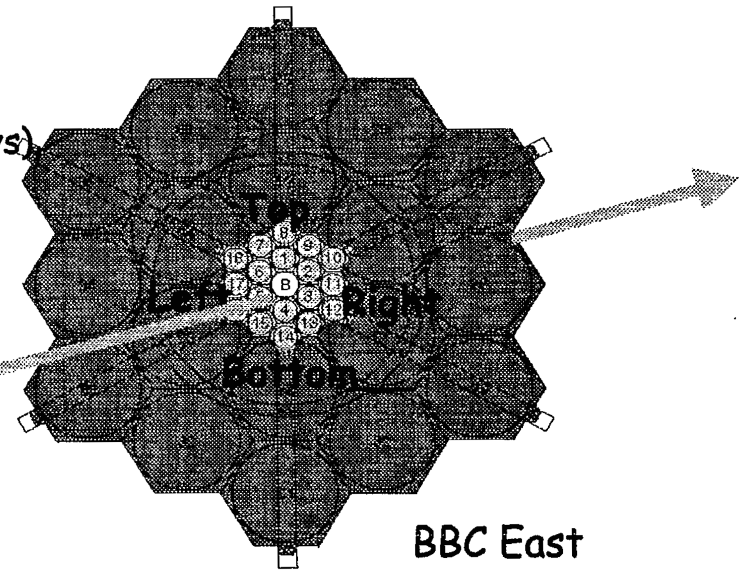
IV Transverse Single Spin Asymmetries from the BBC scaler data

L(R) - number of counts in Left (Right) or Top (Bottom)
in the BBC East or BBC West (small annuli)

Scaler data analyzed for runs 3011001-3023073 (12 days)
$N = 8 \times 10^9$ events



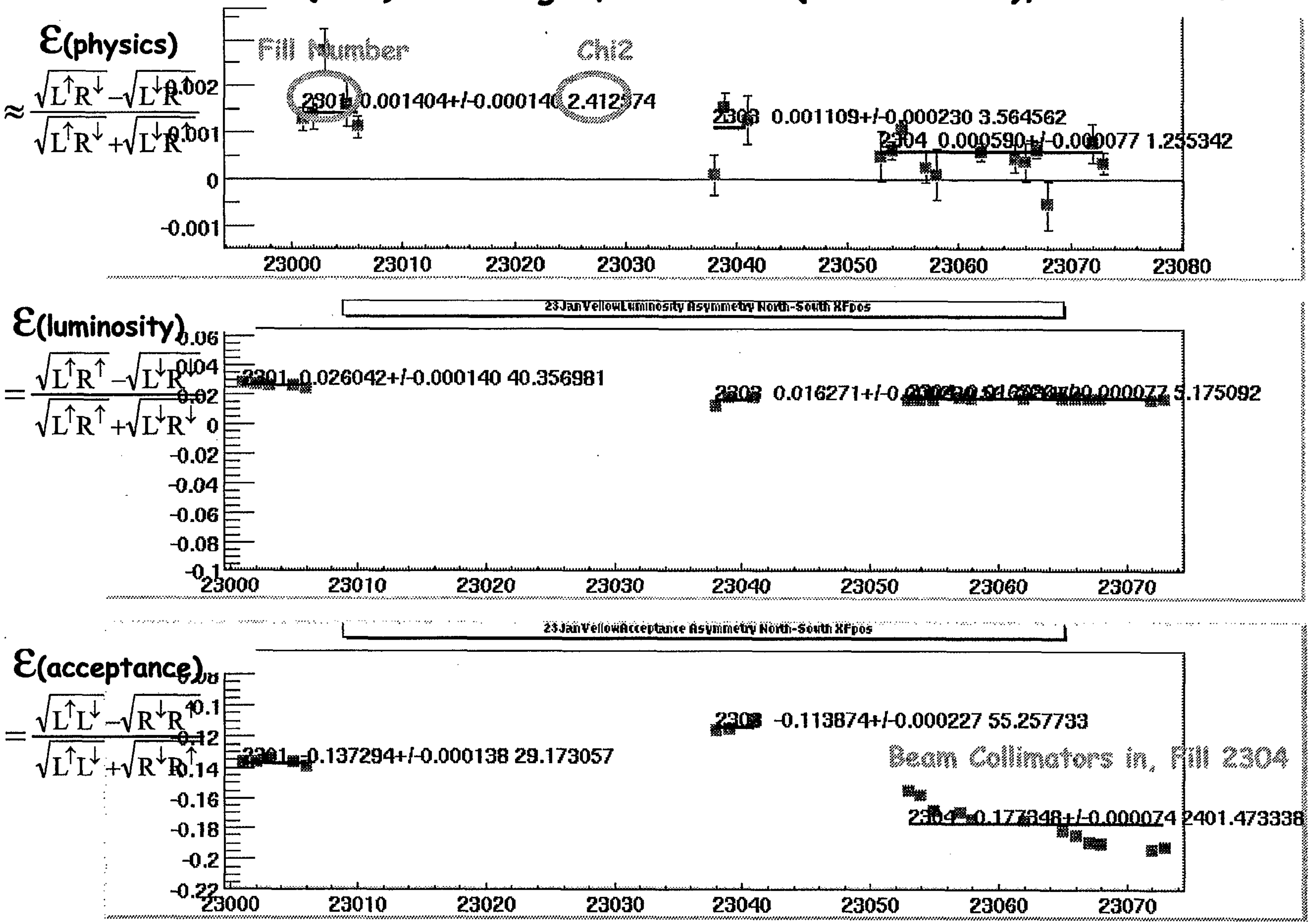


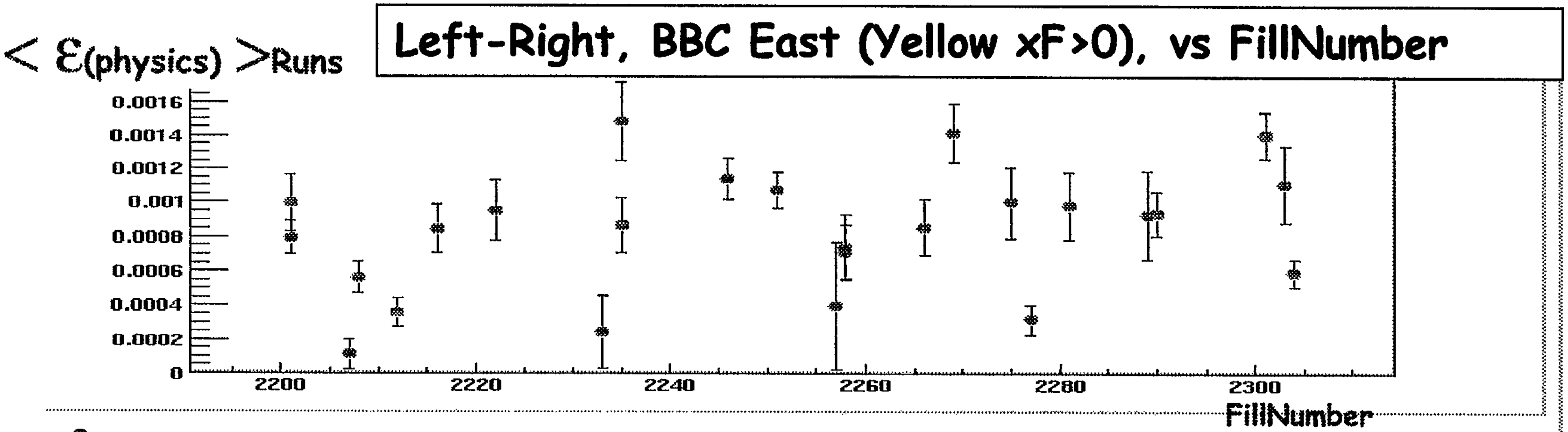


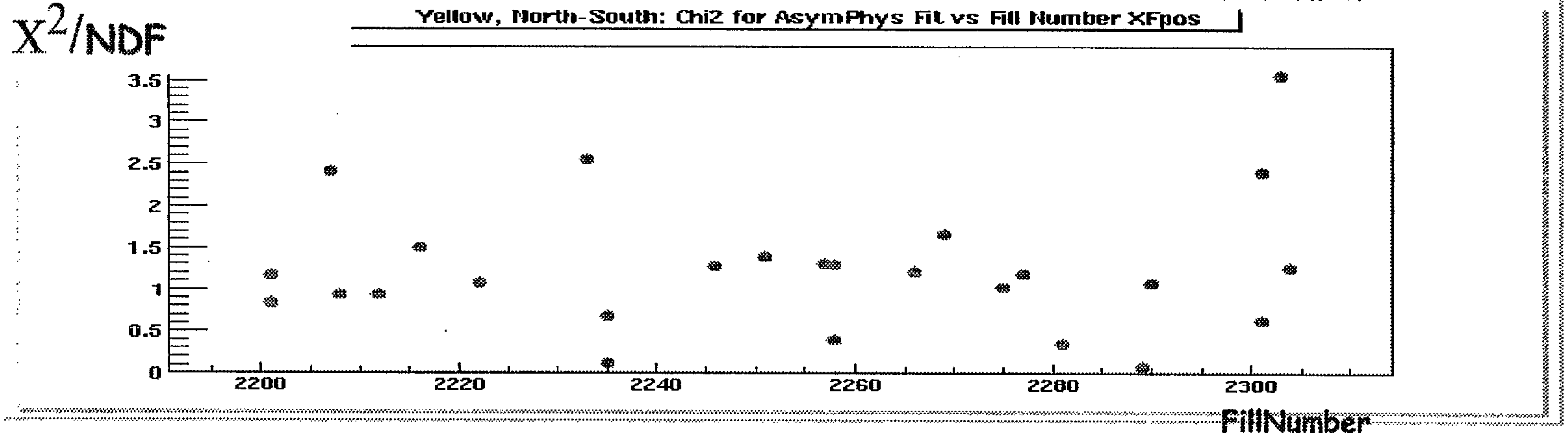
Example: Yellow beam polarized (sum over Blue polarization states).
Calculate ε (xratio) using counts from

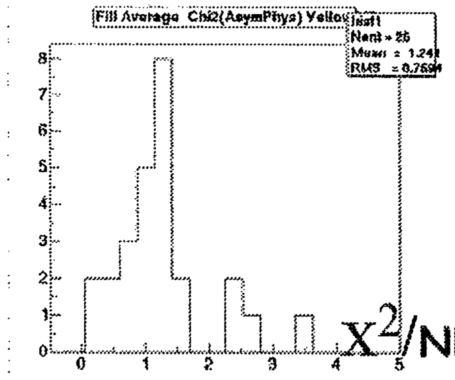
1. BBC counters on the East side of STAR ($xF > 0$)
   - Left and Right
   - Top and Bottom
2. BBC counters on the West side of STAR ($xF < 0$)
   - Left and Right
   - Top and Bottom

ε(BBC) Left-Right, BBC East (Yellow xF>0), vs RunNumber



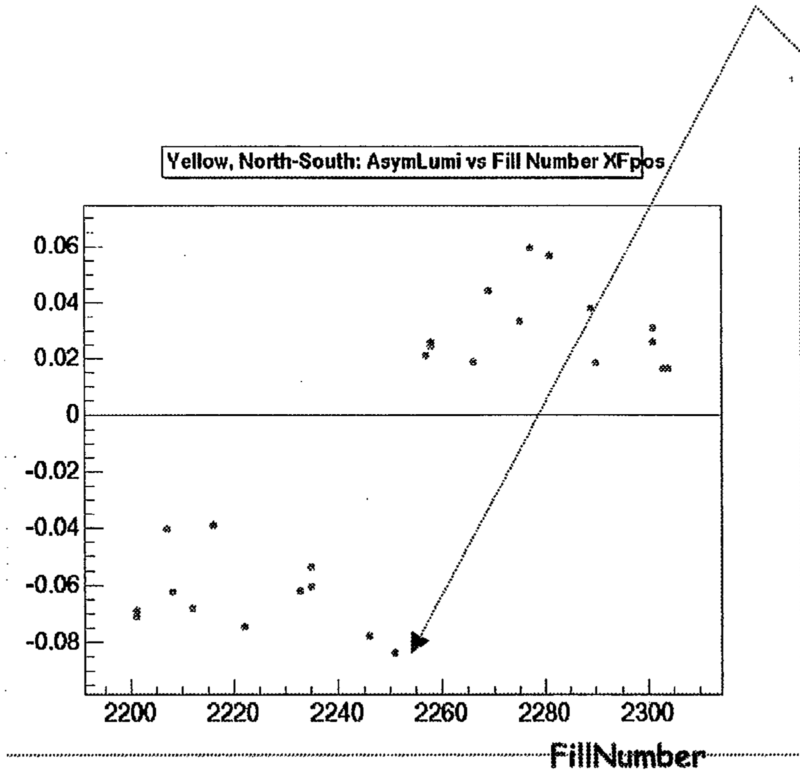


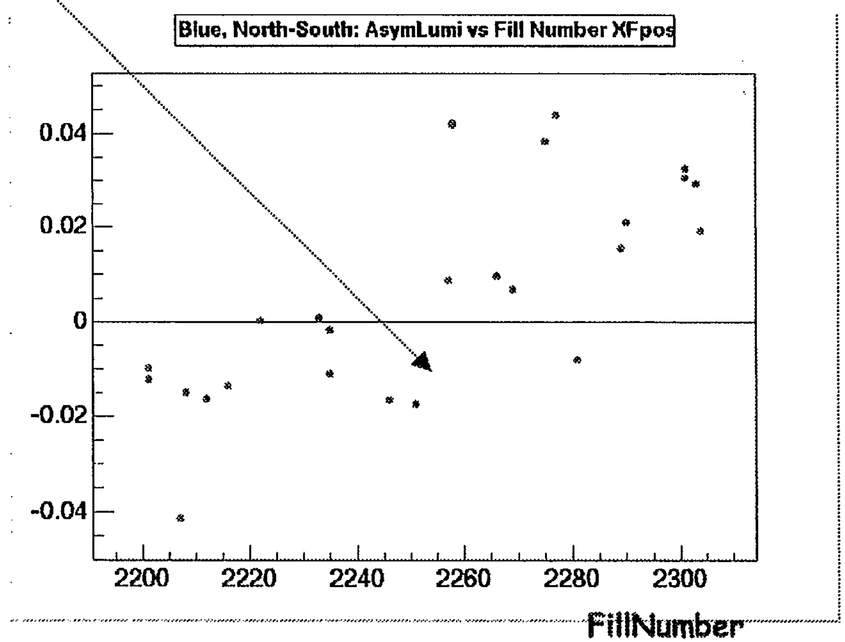




χ^2/NDF - consistent with 1 , no evidence for beam depolarization during RHIC fill

Luminosity asymmetries: larger for Yellow than for Blue
(sign changed when fill pattern changed)





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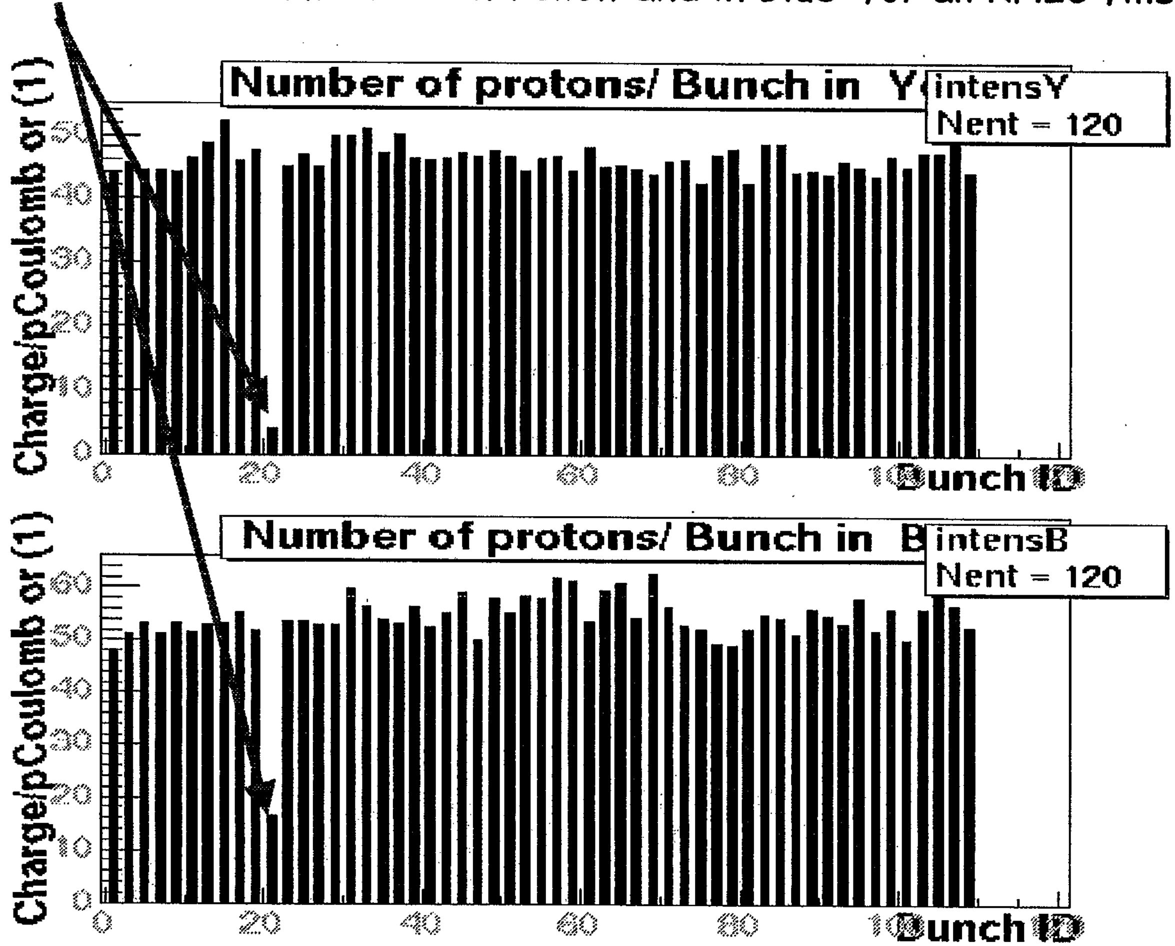
Bunch luminosity:

Weak bunch number 11 in Yellow and in Blue for all RHIC fills ("test" bunches)



Run 3023039, Fill 2303

Two test bunches result in two weak bunch crossings at STAR with the same spin orientations:
Yellow^Up-Blue^Down -> increase of false asymmetries

Run 3023039, lasted 2280 sec, Fill 2303

- Time integration for W*E
- Time average for Y*B

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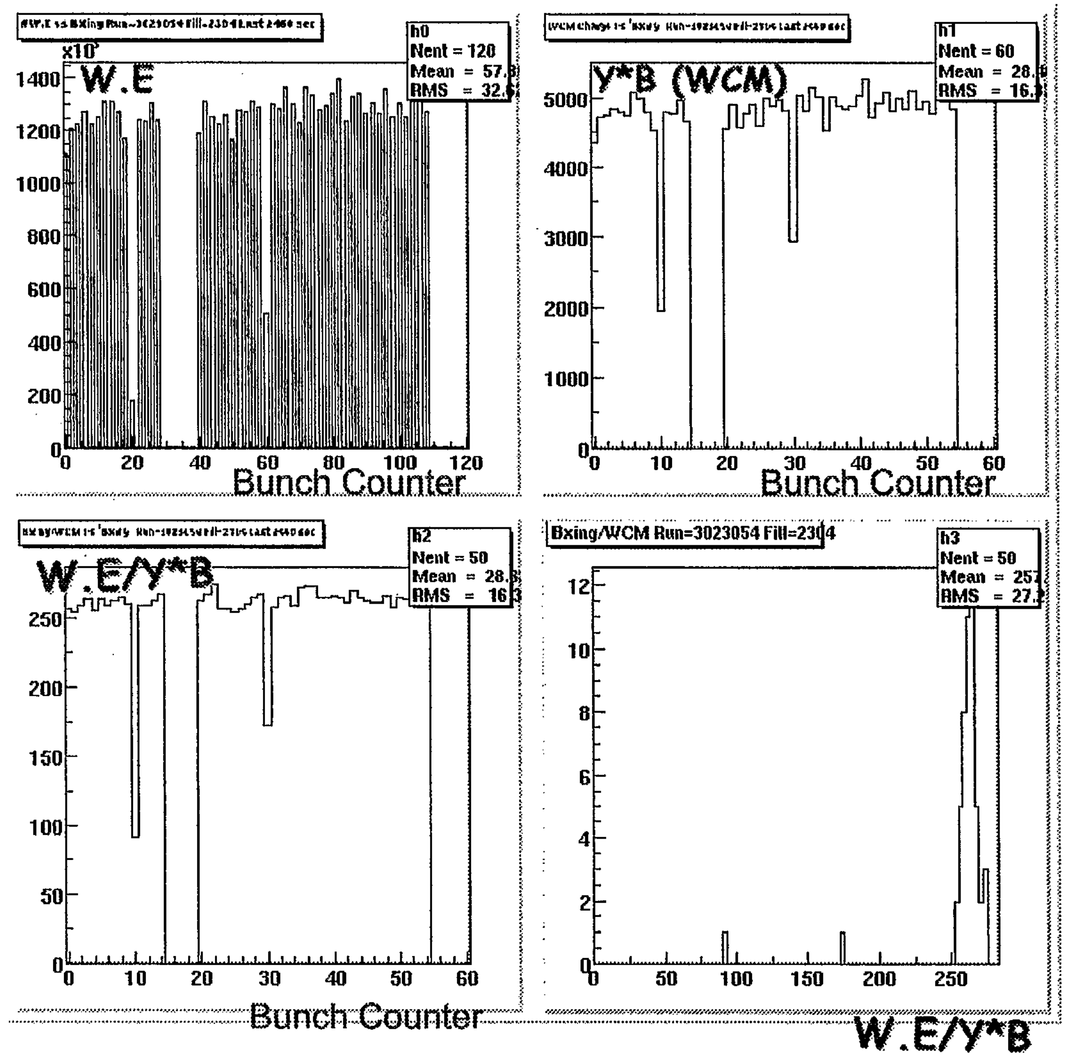
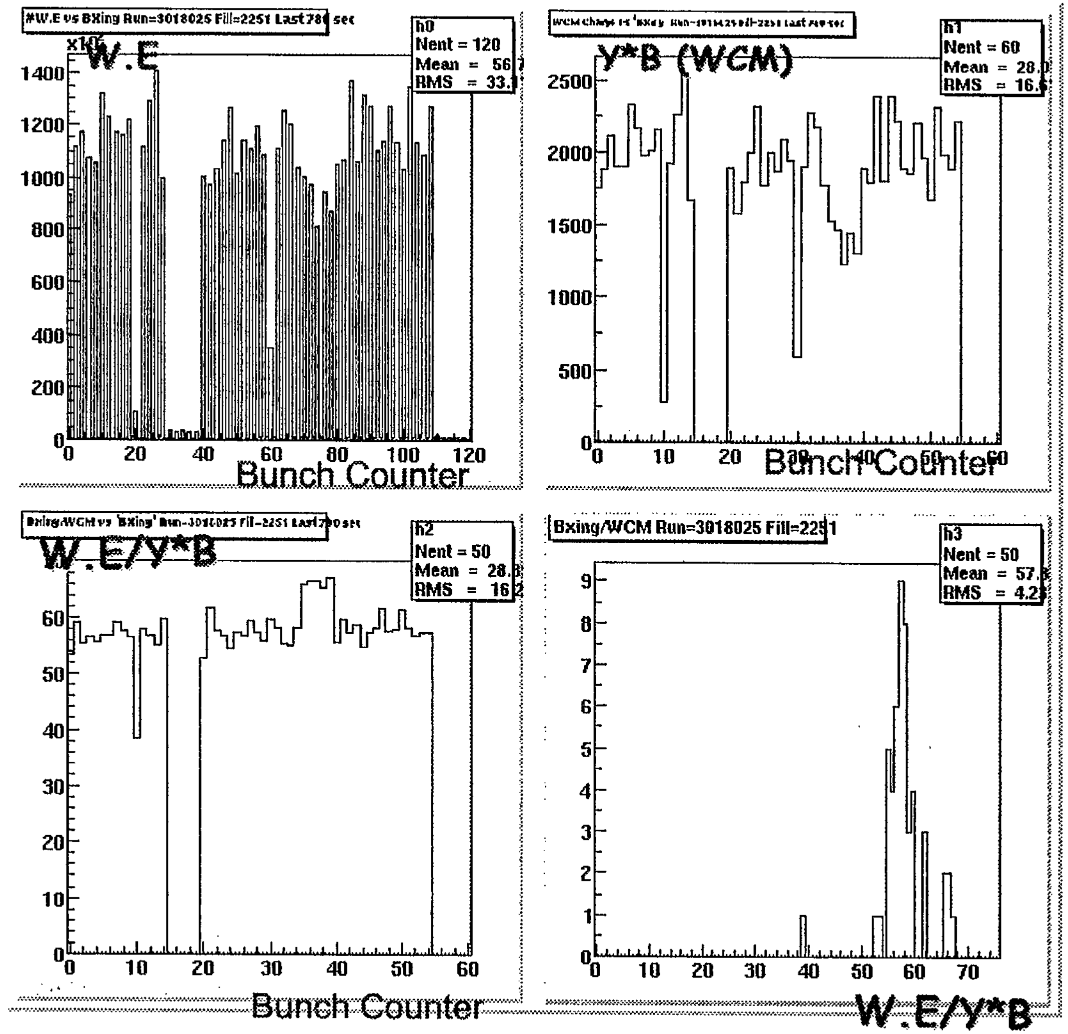
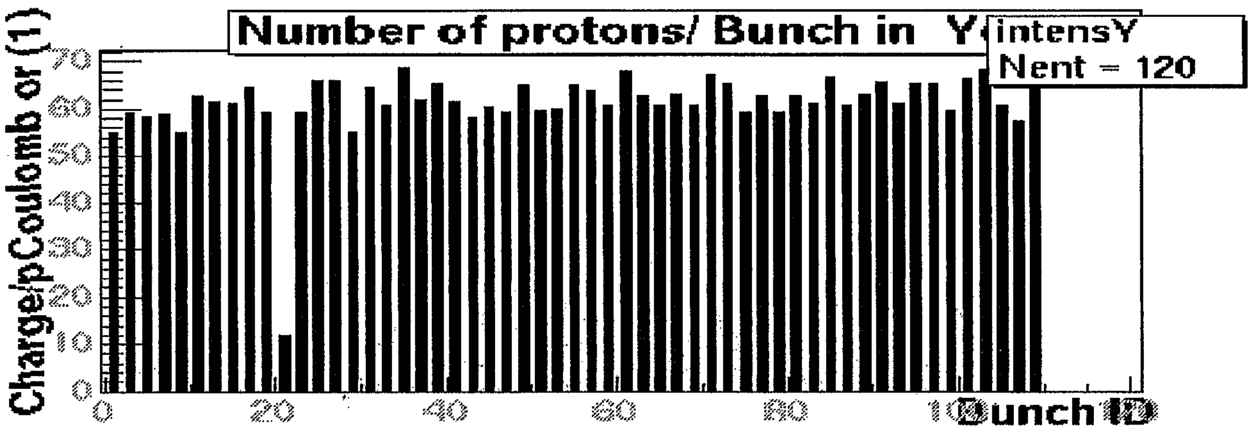


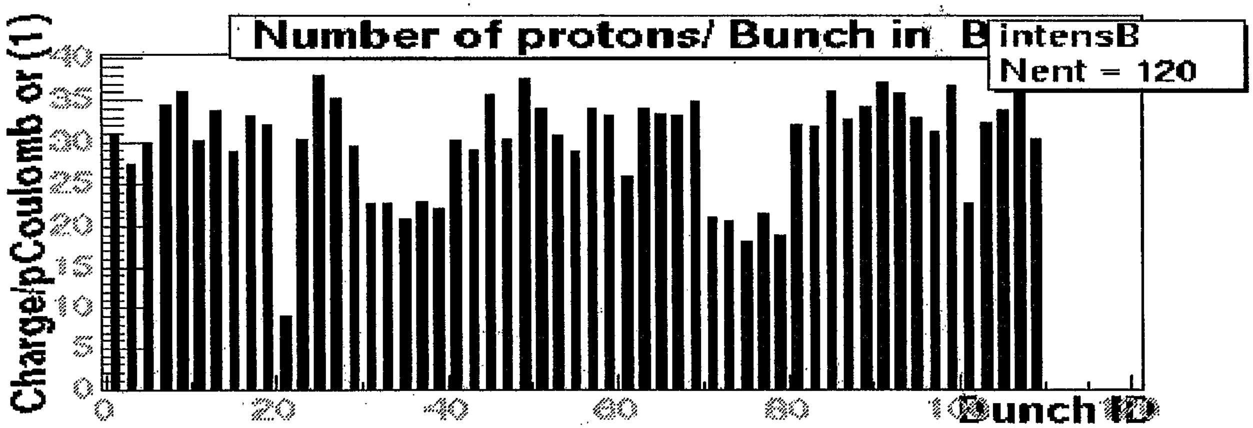
- Specific luminosity looks fine for ~50% fills (Jan11 - Jan23)

Run 3018025, lasted 780 sec,
Fill 2251



A "structure" seen for 5 bunch crossings in ~ 50% fills (Jan11 - Jan23 checked)
- a problem with Blue beam. List of fills:
2233, 2235, 2244, 2246, 2251, 2266, 2269, 2275, 2289, 2301, 2303





Run 3018025, Fill 2251

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Summary:

1. Relative luminosity known up to 10^{-3}
2. Spin effects seen in BBC (East) scaler data (if real) are very small, of the order of 10^{-3}, thus suitable for relative luminosity measurements
3. False asymmetries: both detector and accelerator

Further work needed:

- time dependence of false asymmetries,
- beam-gas background,
- bunch selections ...

Luminosity at PHENIX

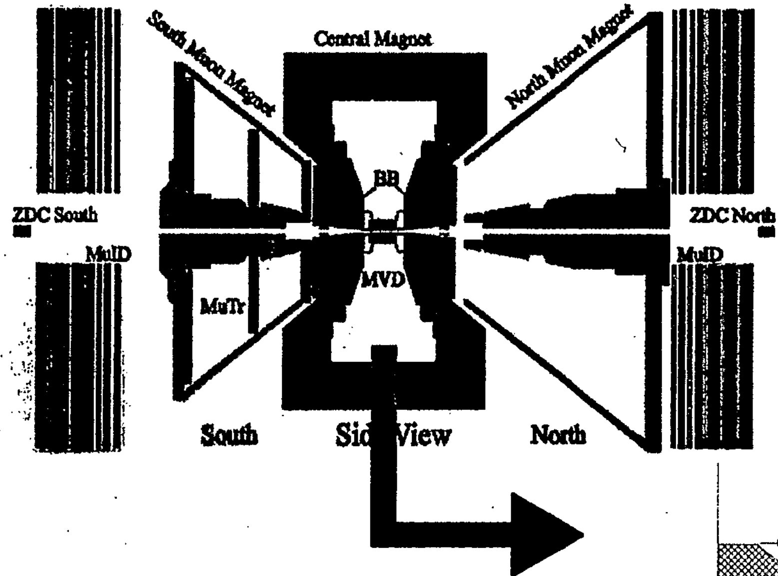
RSC Meeting

May 22, 2002

Yuji Goto (RIKEN/RBRC)

Instruments

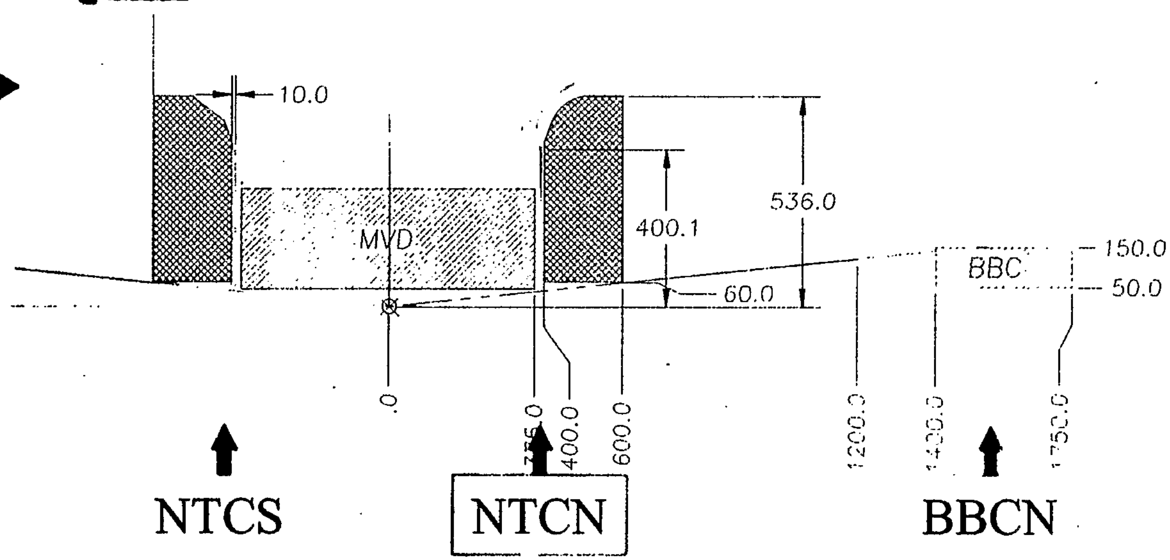
- crossing-by-crossing scalers
  - for 120 crossings (60 crossings this year)
  - BBC / BBC⊕NTC_{wide} (min.bias trigger) / NTC_{narrow} / ZDC
  - live time only



min.bias trigger:

NTC_{wide}	~63%
BBC	~51%
BBC⊕NTC_{wide}	~74%

of inelastic reactions



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Instruments

- scalers & spin-sorted scalers
  - BBC / BBC⊕NTC_{wide} (min.bias trigger) / NTC_{narrow}(spin-sorted) / ZDC(spin-sorted)
  - raw / live / pre-scaled
- beam current information
  - CDEV
  - for blue beam and yellow beam
  - raw data only (no live time cut)
- vertex information
  - vertex counters

Relative luminosity

- no critical item for A_N measurement in run-2

$$A_N = \frac{1}{P}\frac{\sqrt{N_{\uparrow L}N_{\downarrow R}} - \sqrt{N_{\downarrow L}N_{\uparrow R}}}{\sqrt{N_{\uparrow L}N_{\downarrow R}} + \sqrt{N_{\downarrow L}N_{\uparrow R}}}$$

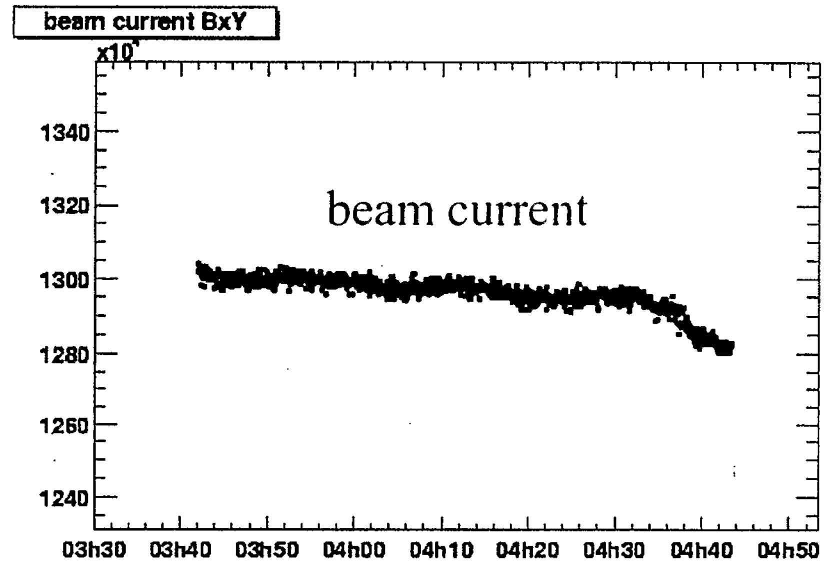
- important for A_{LL} measurement in run-3
  - 10^{-4} level precision required for sub-% level asymmetry measurement

$$A_{LL} = \frac{1}{P_B P_Y}\frac{N_{++}/L_{++} - N_{+-}/L_{+-}}{N_{++}/L_{++} + N_{+-}/L_{+-}}$$

- normalization in the cross section measurement (as well as absolute luminosity)
  - stability of each luminosity monitor ?
  - which is the best ?

Relative luminosity

- beam current / scaler raw / scaler live
  - – live/raw ratio ?
  - – stability ?
  - ➔ crossing-by-crossing analysis
  - ➔ vertex cut ?



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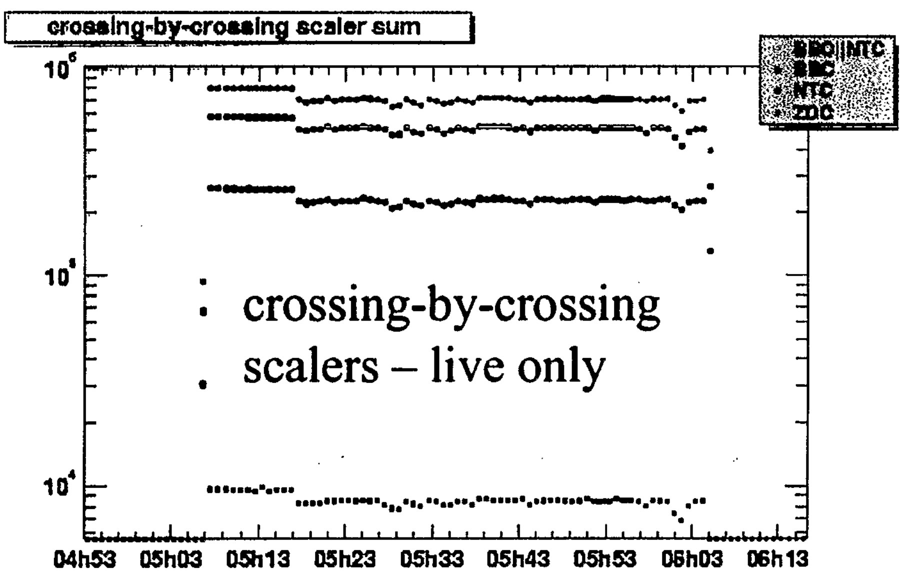
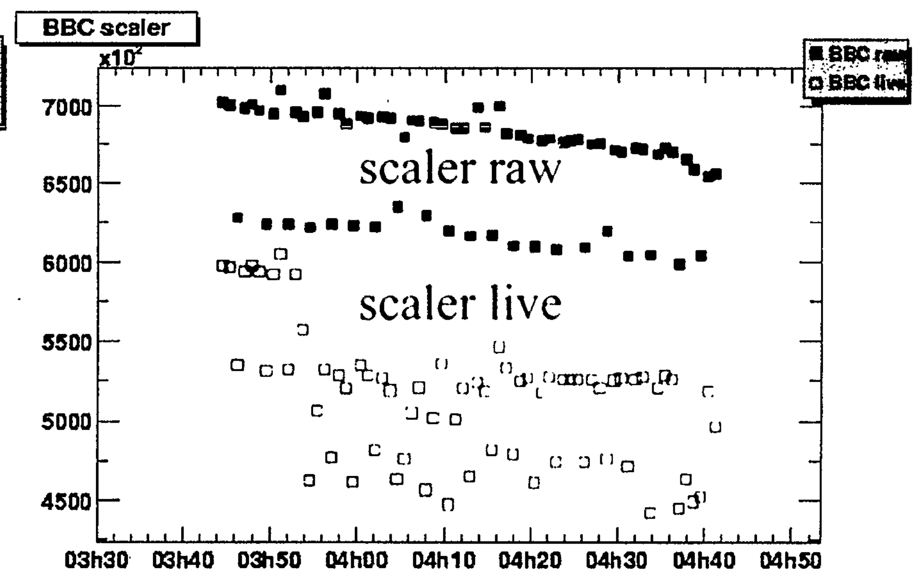
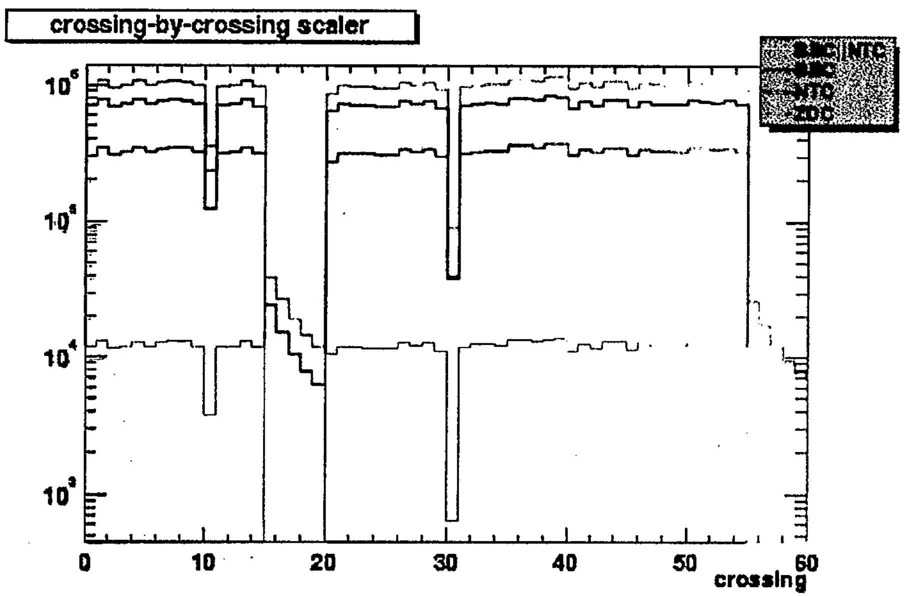
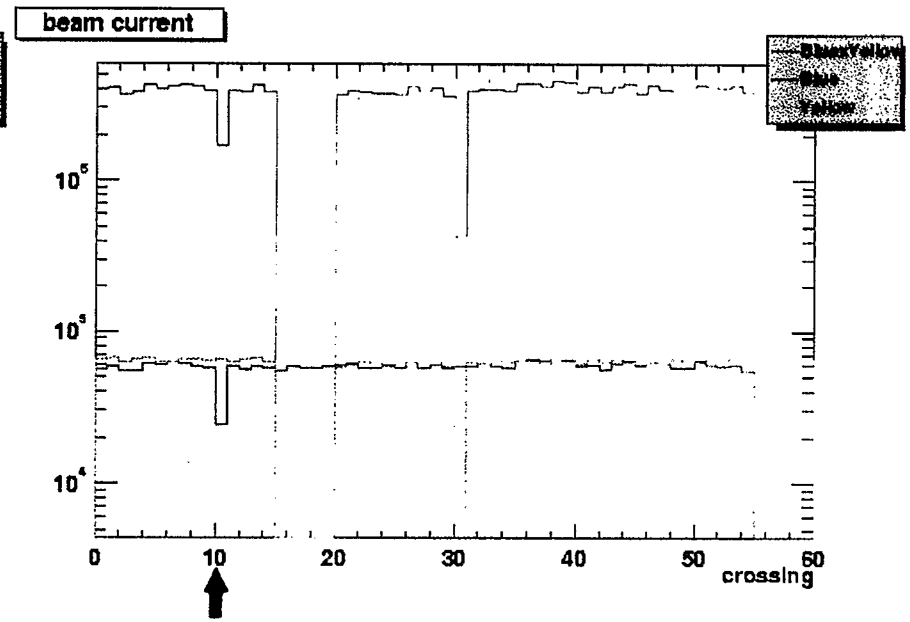




Relative luminosity

- crossing-by-crossing analysis
  - ratio between scalers, time dependence should be studied



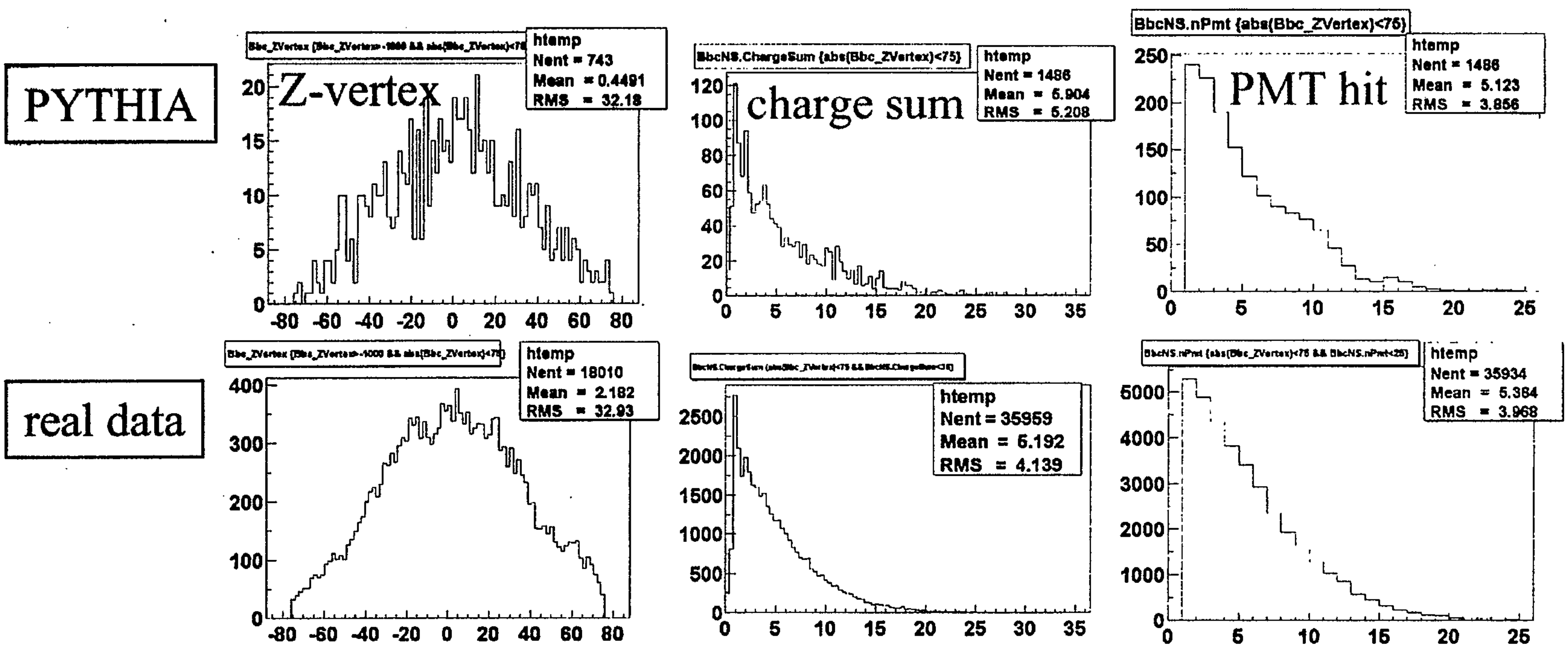


blue: bunch#10

yellow: bunch#10
large emittance
for chromaticity study

Absolute luminosity

- normalization in the cross section measurement
  - comparison of real data and simulation (PYTHIA etc.) to understand BBC/NTC efficiencies (and those of ZDC, …)
    - preliminary study by Hiroki Sato
      - NTC_{wide} ~63%, BBC ~51%, $BBC \oplus NTC_{wide}$ ~74% of inelastic reactions
    - detector responses need to be understood



Outlook

- absolute luminosity
  - efficiency study
    - real data study with clock trigger and non-min.biased EMCal trigger
    - simulation (PYTHIA etc.)
    - BBC charge/hit polar angle distribution
- relative luminosity
  - crossing-by-crossing analysis
    - time dependence
    - vertex cut
  - stability evaluation
    - database to provide integrated luminosity with error estimations

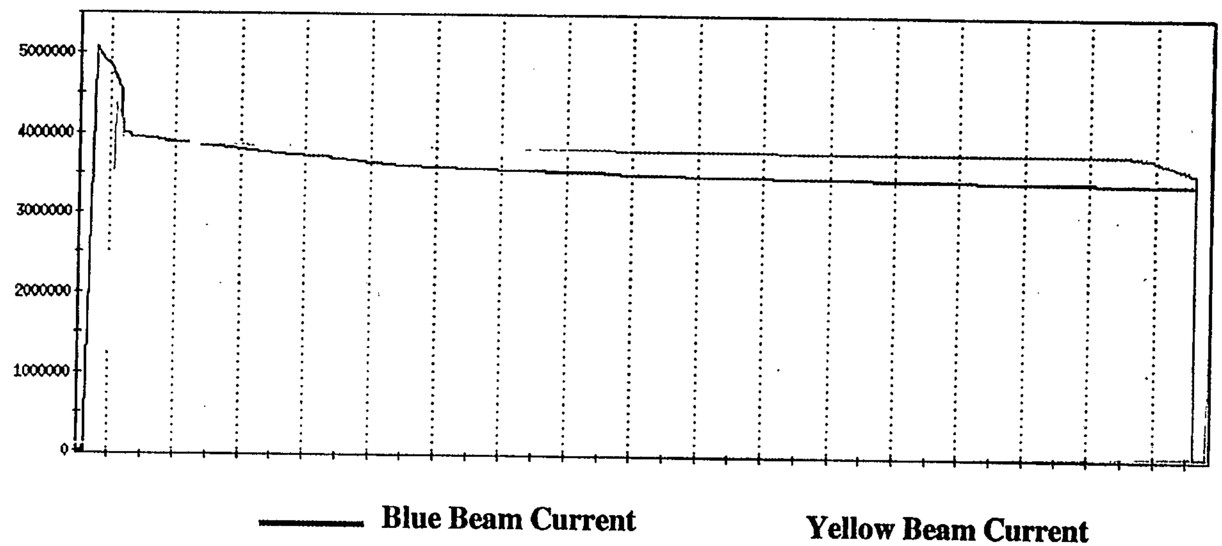
Luminosity from the Machine Perspective

T. Roser
May 22, 2002

for
RHIC Spin Collaboration Meeting IX
RIKEN BNL Research Center

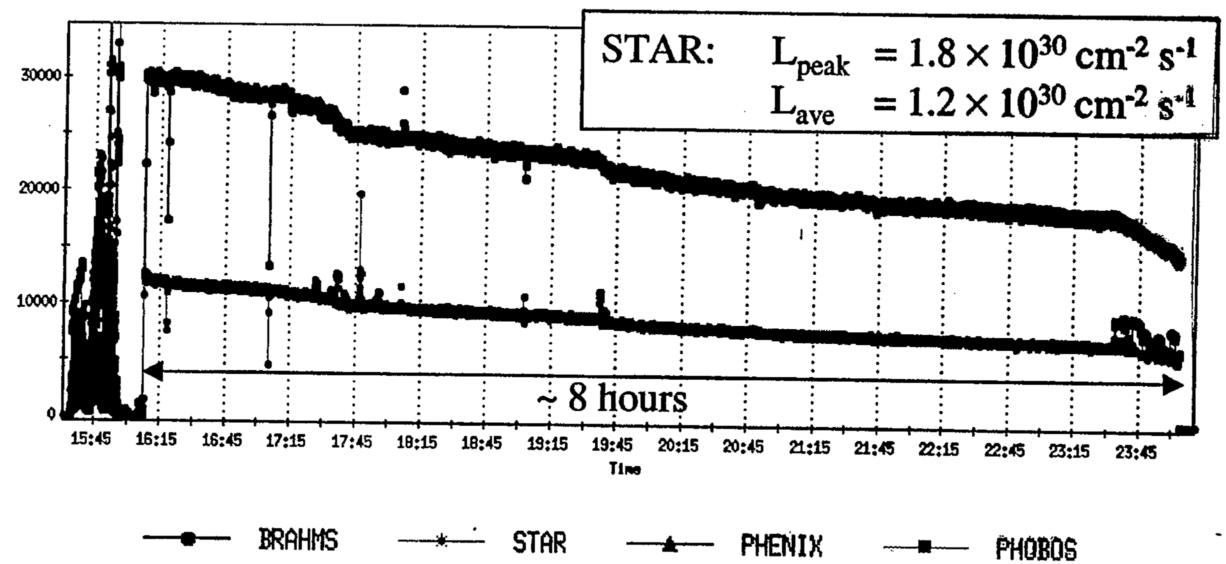
"Typical Store" # 2304

Beam currents [× 10^6 ions]



Collision rate [Hz]

Vernier scans:
STAR: $10^4 \rightarrow 0.6 \times 10^{30}$ cm^{-2} s^{-1}
PHENIX: $10^4 \rightarrow 1.6 \times 10^{30}$ cm^{-2} s^{-1}



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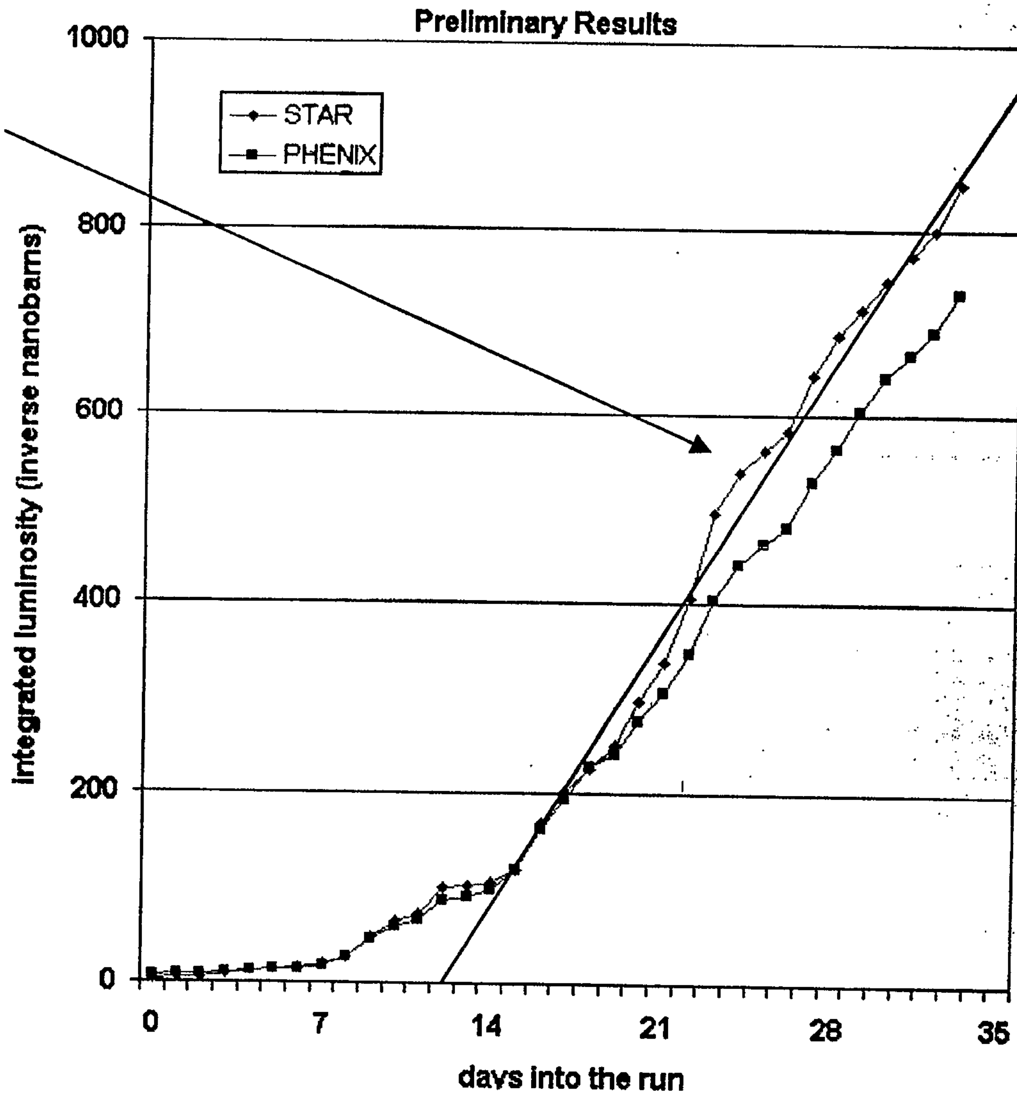
Integrated p - p luminosity

STAR during last 20 days:
290 $(nb)^{-1}$/week
$L_{ave}(week) = 0.5 \times 10^{30}\ cm^{-2}\ s^{-1}$
$L_{ave}(week)/L_{ave}(store) = 42\ \%$



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RUN2003 <u>Goals</u> (~ 3-4 weeks into run)

- Prepare for four modes; all with:
  Energy/beam: 100 GeV/nucl., diamond length: $\sigma = 20$ cm, L_{ave}(week)/L_{ave}(store) = 40 %

Mode	# bunches	Ions/bunch [$\times 10^9$]	β^* [m]	Emittance [$\pi\mu$m]	L_{peak} [$cm^{-2}s^{-1}$]	L_{ave}(store) [$cm^{-2}s^{-1}$]	L_{ave} (week) [$week^{-1}$]
Au-Au	56	1	1	15-40	14×10^{26}	3×10^{26}	70 $(\mu b)^{-1}$
($p\uparrow$-$p\uparrow$)*	112	100	1	25	16×10^{30}	10×10^{30}	2.8 $(pb)^{-1}$
d-Au	56	100(d), 1(Au)	2	20	5×10^{28}	2×10^{28}	5 $(nb)^{-1}$
Si-Si	56	7	1	20	5×10^{28}	2×10^{28}	5 $(nb)^{-1}$

* Beam polarization ≥ 50 %; Acceleration test to 250 GeV

- New hardware installed and to be commissioned:
  - All eight spin rotators for PHENIX and STAR

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RUN2003 Integrated Luminosity Estimate

Estimate for integrated luminosity for 29 week FY2003 run (starting October 1, 2002):

- 4 weeks cool down, 1 week warm-up, 2 weeks setup (for each mode),
  3 weeks ramp up (for each mode): →
  29 weeks of cryo ops.: 2 modes: 7 weeks at "final" luminosity / mode
  3 modes: 3 weeks at "final" luminosity / mode
  4 modes: 1 week at "final" luminosity / mode
- Minimum: performance at end of FY2001/02 run
- Maximum: luminosities from previous slide

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Mode	L_{ave} (week) [week^{-1}]	Int. Lumi. 2 modes	Int. Lumi. 3 modes	L_{ave} (week) [week^{-1}]	Int. Lumi. 2 modes	Int. Lumi. 3 modes
Au-Au	24(μb)$^{-1}$	168(μb)$^{-1}$	72(μb)$^{-1}$	70 (μb)$^{-1}$	490(μb)$^{-1}$	210(μb)$^{-1}$
(p↑-p↑)*	0.3(pb)$^{-1}$	2.1(pb)$^{-1}$	0.9(pb)$^{-1}$	2.8(pb)$^{-1}$	19.6(pb)$^{-1}$	8.4(pb)$^{-1}$
d-Au	?	?	?	5 (nb)$^{-1}$	35 (nb)$^{-1}$	15 (nb)$^{-1}$
Si-Si	?	?	?	5 (nb)$^{-1}$	35 (nb)$^{-1}$	15 (nb)$^{-1}$

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Update on the CNI Polarimeter Results for RUN 02

Osamu Jinnouchi

May 22, 2002

for

RHIC Spin Collaboration Meeting IX

RIKEN BNL Research Center

Update on the CNI polarimeter results for Run02

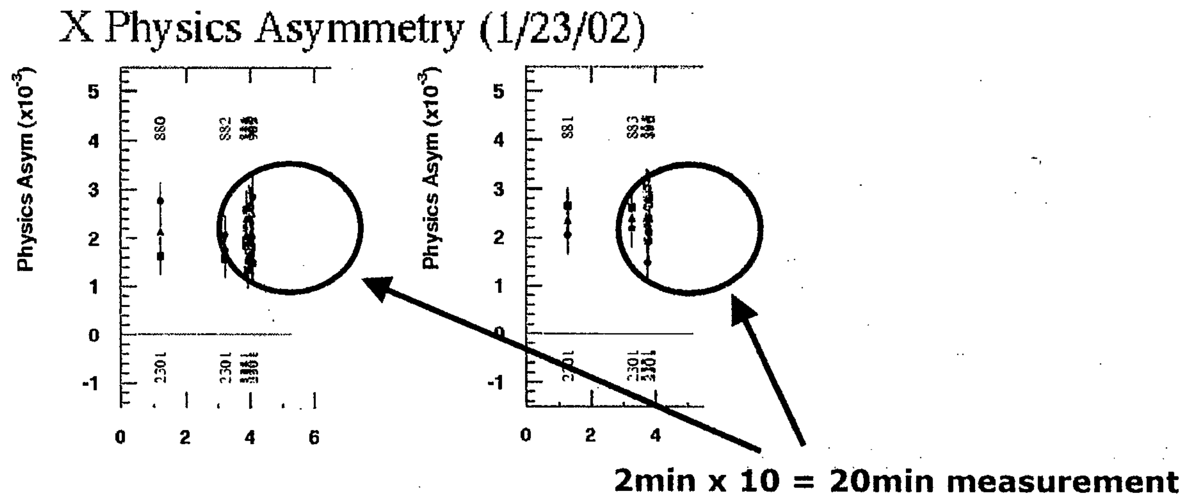
Osamu Jinnouchi

1. Bunch-by-bunch polarization study
2. Profiles of 0-pol bunches

1. Bunch by bunch polarization study

- Interests
  - for spin physics analysis
    - Luminosity weighted polarization info (bunch per bunch polarization) is needed
    - Each detector sees different bunch combinations (clockwise ,anti-clockwise)
      - STAR (i,i+20) 6 o'clock
      - PHENIX,pp2pp,BRAHMS (i,i+40) 2 or 8 o'clock
      - PHOBOS (i,i) 10 o'clock
  - for machine physicists
    - Bunch profile
      - Is there any weird bunches?
      - Polarization profile within 55-bunches

Polarimeter dedicated run



- ☐ 10 successive measurements at the end of store for both rings (fill ID :2301 Jan. 23th, 02)
- ☐ The data can be summed up to gain statistics
- ☐ 0-pol bunches are available
  - ■ (3-bunches 1^{st},21^{st},41^{st})

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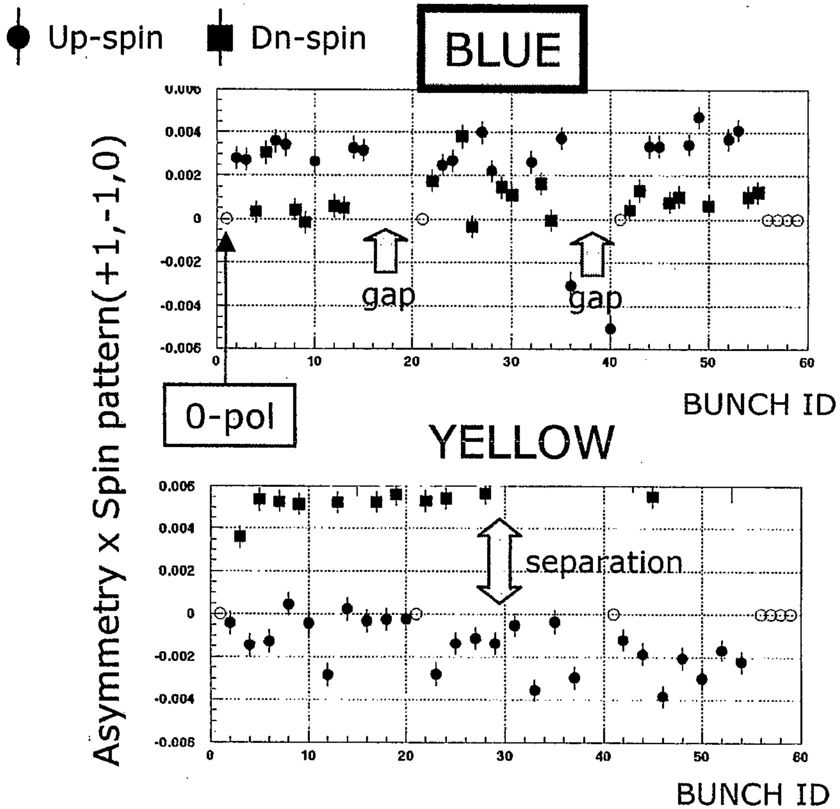
Bunch by bunch asymmetry

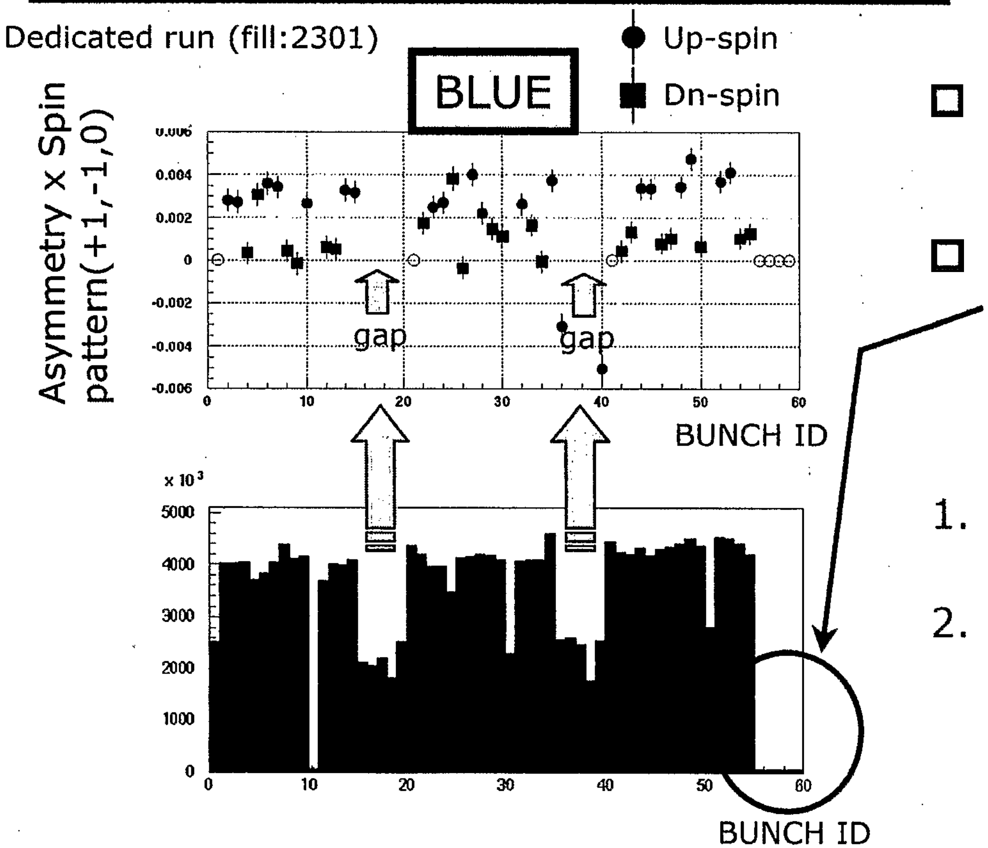
Naive calculation shows terrible distributions



- Good statistics
- Used square-root formula
- The values are averages of X90 and X45

1. Origin of gaps
2. Separation of Plus spin and Minus spin
   - → can we trust 0-pol bunches ?

Origin of gaps



Bunch luminosity at RHIC polarimeter

- Location of the gaps are corresponding to small population bunches
- There are hits on the empty bunches (56-60th)
  → Found out that several strips are noisy

1. Noisy strips can be excluded from calculation
2. How about other normal fills?

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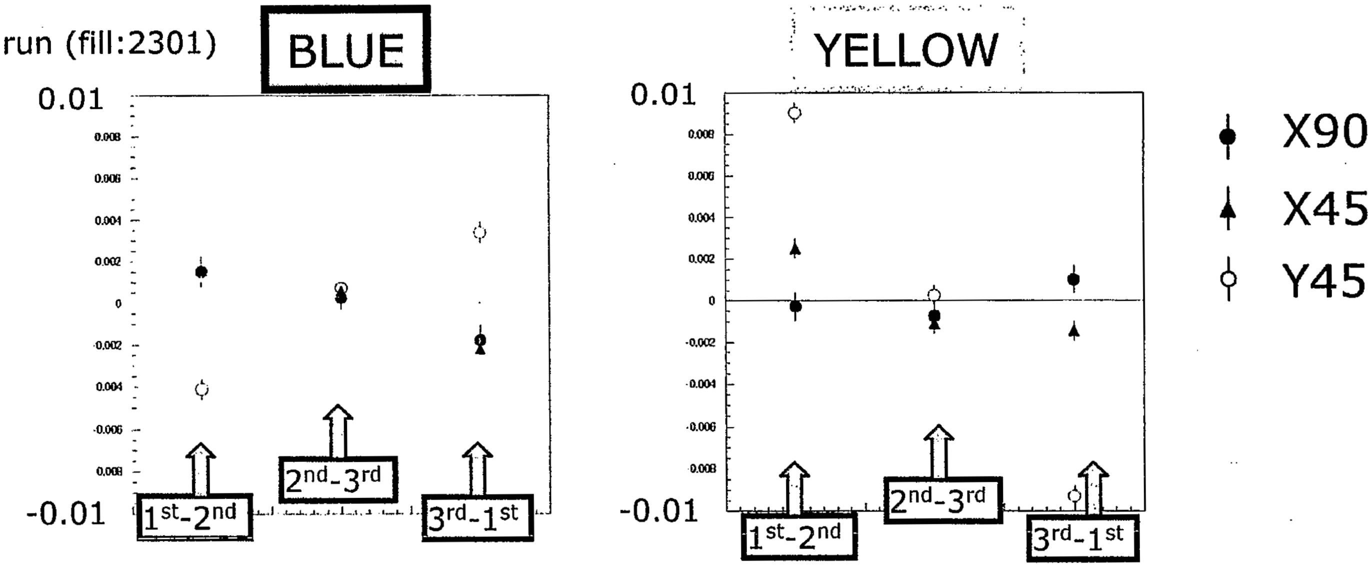
Consistency between 0-pol bunches

Dedicated run (fill:2301)

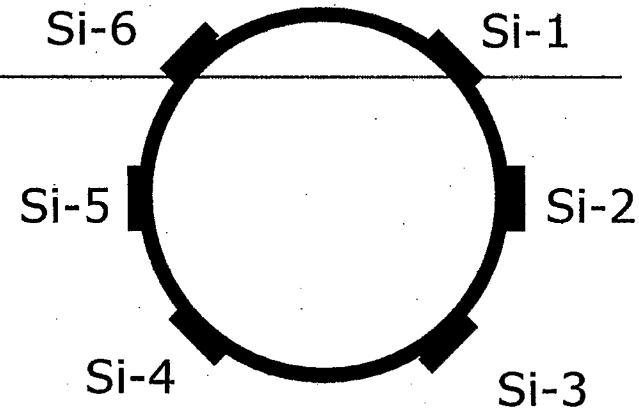


Square-root asymmetries

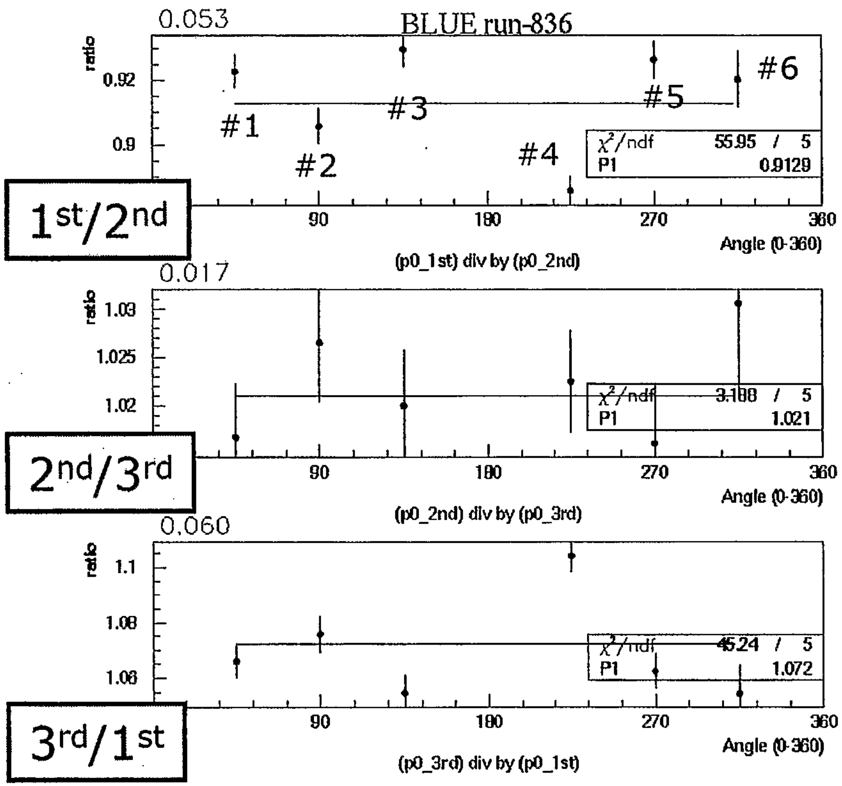
- Triplets turned out to be identical twins (2nd – 3rd pair)
- Y components are rather large (vertical target)
- Generating false asymmetries of comparable size

1. How about other fills?

Luminosity ratio

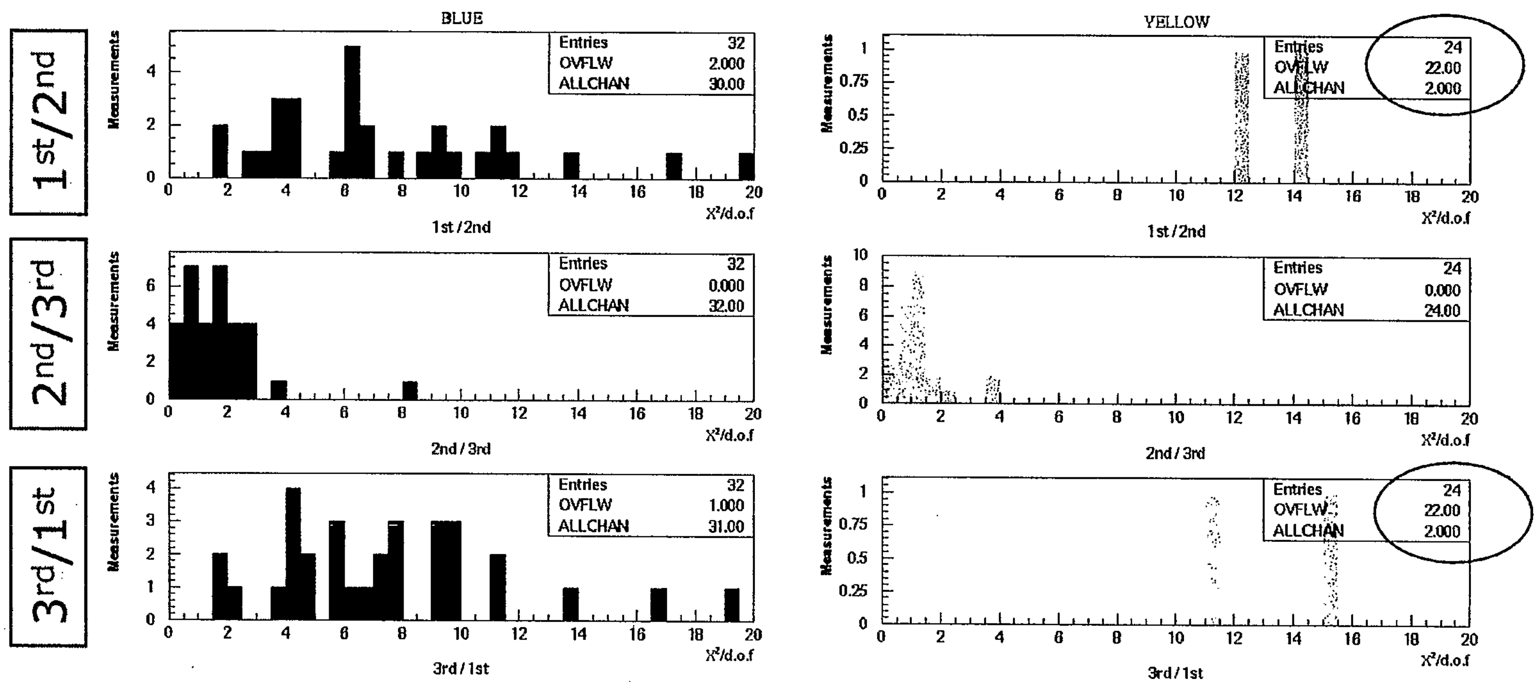


Count ratio for each detector



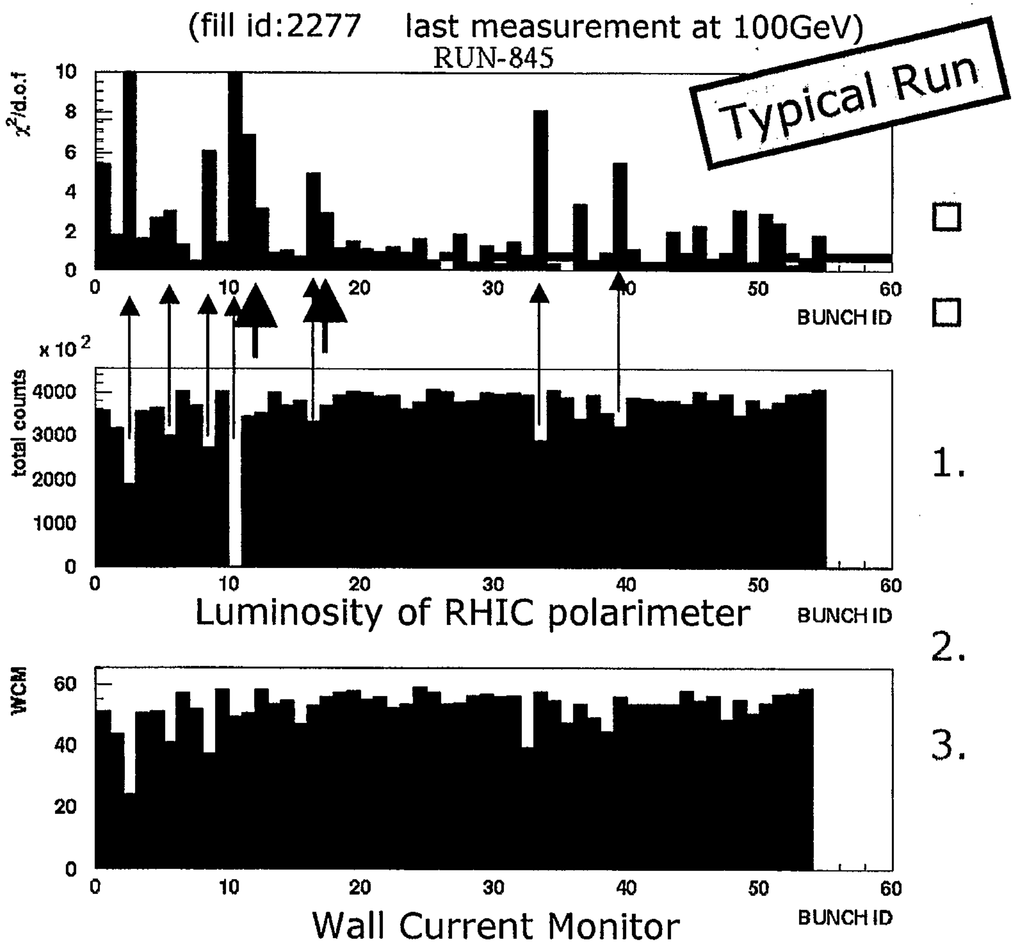
- Typical run (fill ID:2277)
- Supposed to be flat if two bunches are identical
- Fit with horizontal line and yield reduced chi-square

Luminosity ratio (cont'd)



- Reduced Chi-square dists. for all the fills including 0-pol bunches (fill id: 2277~ last)
- Generally 1st 0-pol bunch is strange

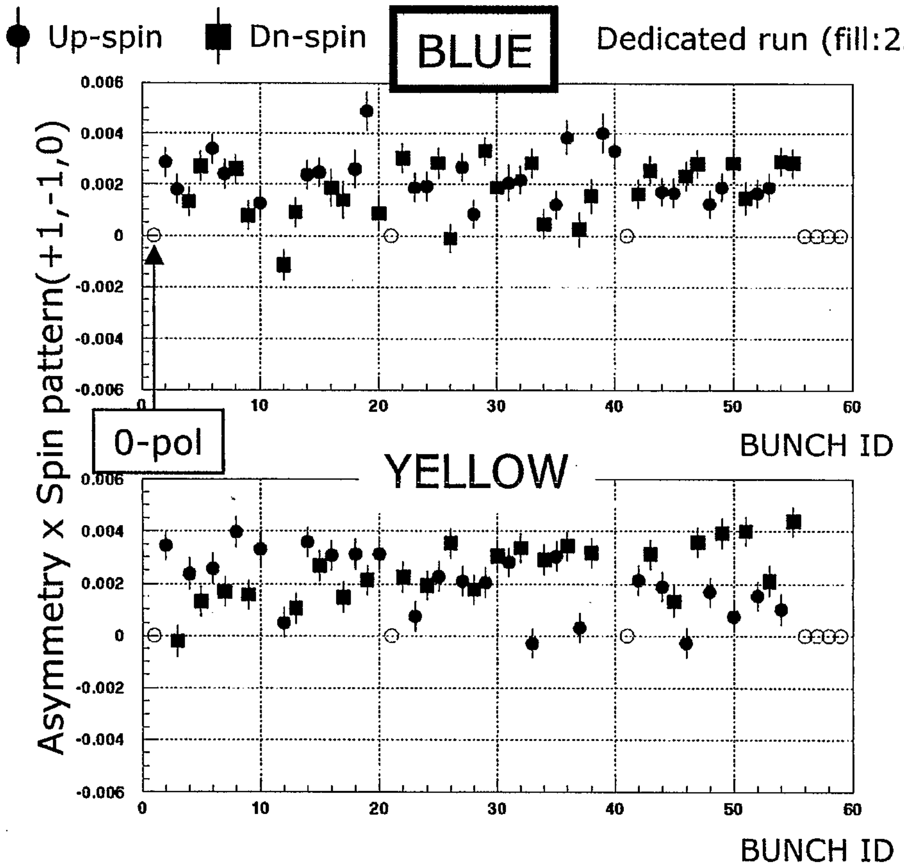
Bunch profile



- Similar analysis applied for polarized bunches
- Fitting with Sin function instead of flat constant

1. Luminosity ratio is getting worse at low populated bunches, which would result in false asymmetry
2. Adjacent bunches are also affected
3. Need a criteria to throw away those weird bunches

Improved bunch by bunch asymmetry



- Exclude noisy strips
  - Gaps disappeared
- Use combined 0-pol (2nd and 3rd)
  - Separation disappeared

1. Still some bunches behave strange
   - low populated bunches introduce false asymmetries
2. Tendency *up* drops and *down* grows in yellow
   - Need further study

Summary

- 1st 0-pol bunch is strange
  - Tail effect of the kicker field?

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- Low populated bunches will create false asymmetries
  - Need certain criteria to throw them away (fitting χ^2 is a good candidate)

Status of STAR Local Polarimeter

L. C. Bland, BNL
May 22, 2002

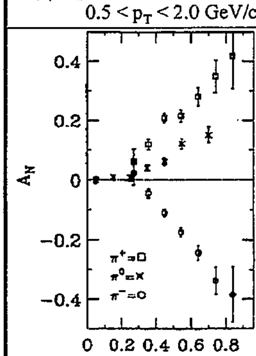
for
RHIC Spin Collaboration Meeting IX
RIKEN BNL Research Center

Status of STAR Local Polarimeter

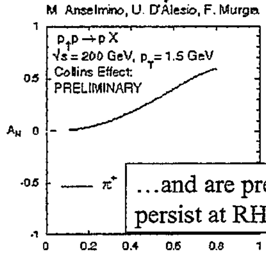
- A brief summary: why forward pions?
- What's it like in the forward direction?
- How things worked…
- Plans and proposals

L.C. Bland
BNL

$p_\uparrow + p \rightarrow \pi + X$, $\sqrt{s} = 20$ GeV, $0.5 < p_T < 2.0$ GeV/c



M. Anselmino, U. D'Alesio, F. Murgia



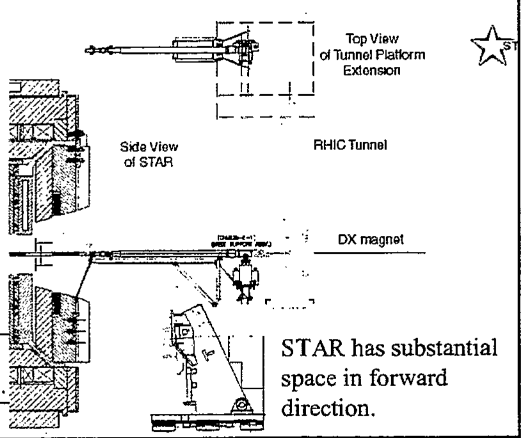
…and are predicted to persist at RHIC energies.

Why Forward Pions?

E704 effect

Non-zero values of A_N have been observed in FNAL E704..

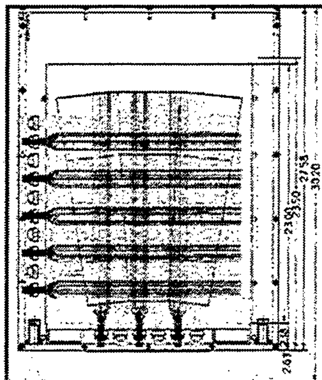
[D.L. Adams, et al. Phys. Lett. B261 (1991) 201]

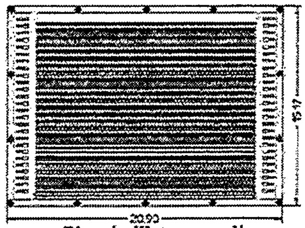


STAR has substantial space in forward direction.

1

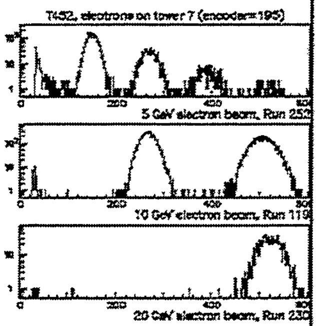
The opportunity...

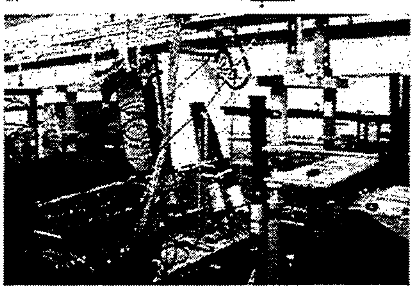




Pb-scintillator sampling calorimeter with scintillator-strip **shower maximum detector**

Tests of a prototype endcap calorimeter had been ongoing at SLAC...

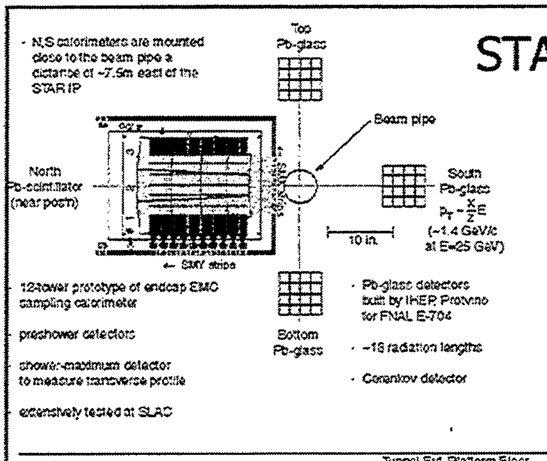


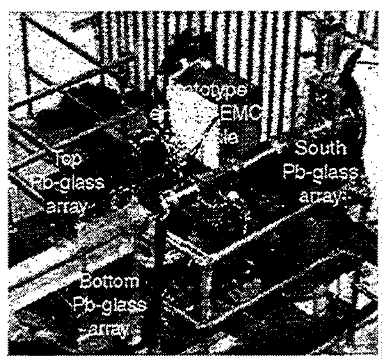


T-438/452 setup at SLAC

...a 'perfect' forward π^0 detector for STAR?

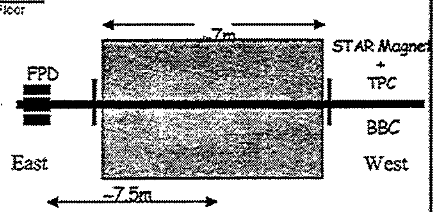
STAR Prototype FPD





Prototype endcap EMC was pretty close to perfect as a π^0 detector, but ***was not a polarimeter*** because it was a single arm detector.

⇒ Supplement with Pb-glass detectors from IHEP, Protvino (built for E-704).

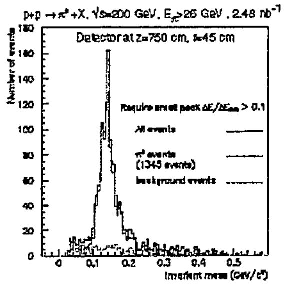


2

FPD Simulations for Transverse asymmetry measurement

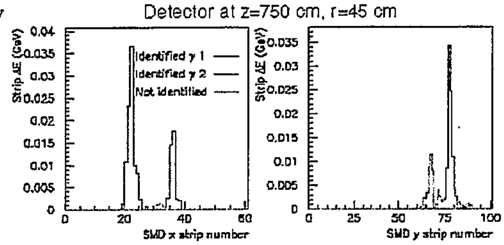
STAR spin

Use electromagnetic calorimeter (EMC) + shower maximum detector (SMD) to reconstruct $\pi^0 \rightarrow \gamma\gamma$ decays up to $E_\pi \sim 50$ GeV



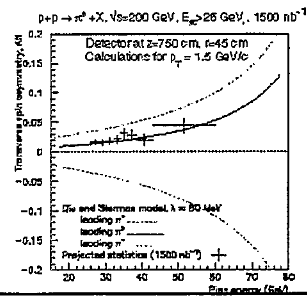
SMD provides good $\gamma\gamma$ opening angle measurement and crude single g energy measurement
$\Rightarrow$ **π^0 reconstruction.**

p+p $\rightarrow \pi^0$+X single event, $\sqrt{s}$=200 GeV, E_π=37.6 GeV
Simulated SMD profile
Detector at z=750 cm, r=45 cm



Expect single-spin asymmetry (A_N) to be significant for π^0 with large x_F and moderate p_T.

$\Rightarrow$ Make first measurement of a polarization observable at RHIC

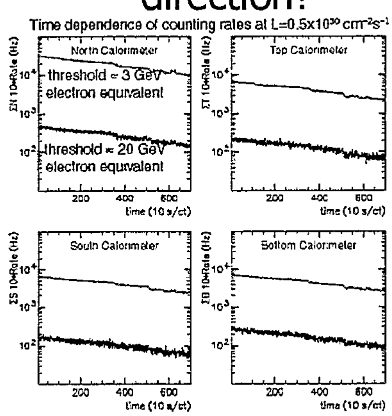


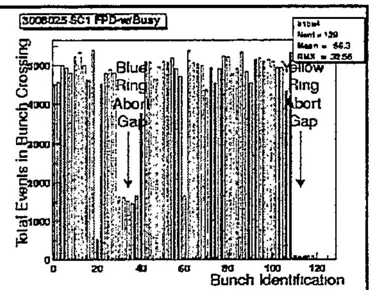
1 year ago:

'expected' $L = 5\times10^{30}$ cm^{-2} s^{-1} and P_{beam}=50%

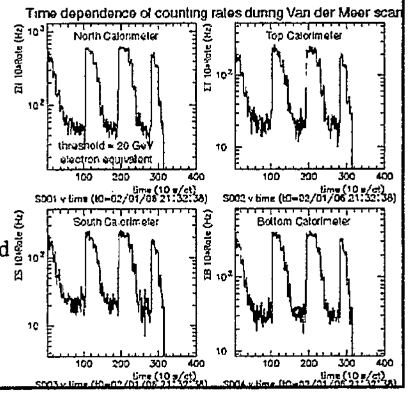
What's it like in the forward direction?

Time dependence of counting rates at $L=0.5\times10^{30}$ $cm^{-2}s^{-1}$





Time dependence of counting rates during Van der Meer scan



- Counting rates of ~50(10) Hz for E>20 GeV at L=0.5×10^{30} $cm^{-2}s^{-1}$ and ~100× higher at 3 GeV threshold
- Beam-gas background mostly from Yellow ring
- Signal:background (without BBC coincidence) can be 10:1 and can also be much worse $\Rightarrow$ use BBC.

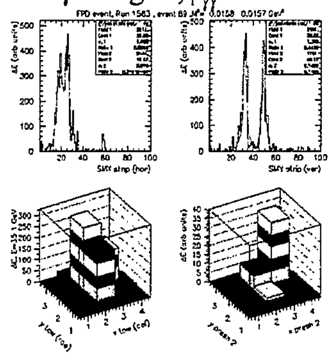
3

Forward Pi0 Detector: π^0 mesons

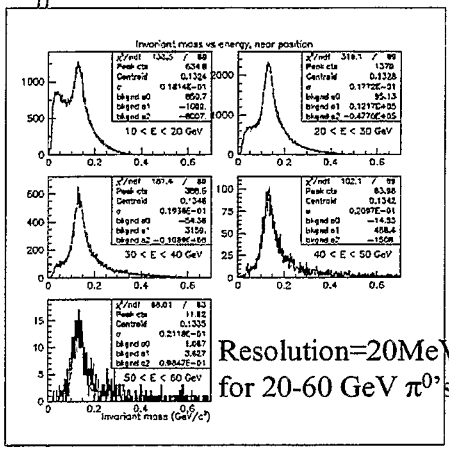
North arm of FPD = prototype Endcap EMC

Reconstruction:

- Etot from towers
- γ energies, $\phi_{\gamma\gamma}$ from SMD



$M_{\gamma\gamma}$ vs. Etot:

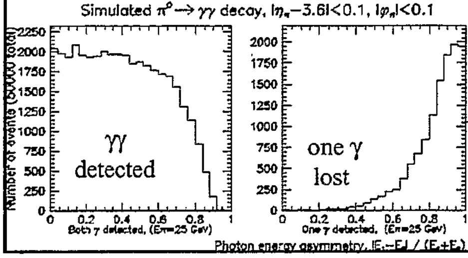


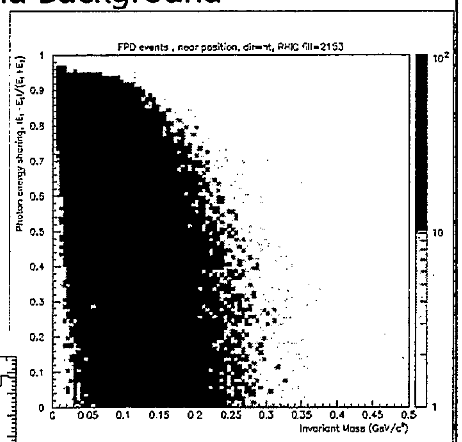
Total number of π^0's in standalone sample = 1.5M

Mass vs. $\gamma\gamma$ Energy Sharing Correlation

Acceptance and Background

- $\gamma\gamma$ energy sharing ($|z|$) related to opening angle.
- distribution is uniform since π^0 has J=0.
- large energy asymmetry related to large diphoton opening angle.
- for $|z|<0.5$, get uniform distribution.
- most of the small M background comes from large $|z|$.





Toward QM02: π^0 cross section

(G.Rakness for STAR)

- Input towards global analysis of E704 + HERMES spin asymmetry data
  ⇒ Collins fragmentation ⊗ transversity

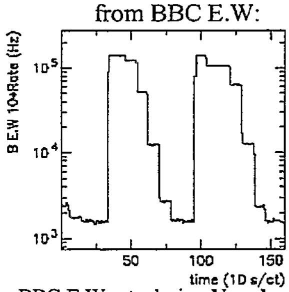
- Towards understanding of π^0 production from d+Au
  ⇒ possible first measurement of gluon shadowing

Abstract to QM02 for $pp \rightarrow \pi^0 X$ cross sections
at $\sqrt{s} = 200$ GeV

Two positions: near ⇒ $3.4 < \eta < 4.0$
far ⇒ $3.1 < \eta < 3.5$
$\sim 0.2 < x_F < 0.6$

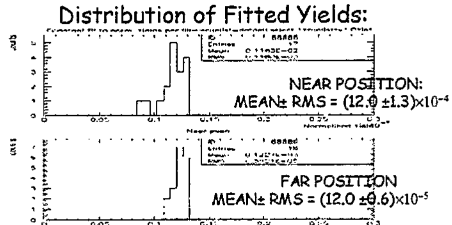
Towards a cross section...

Absolute normalization from BBC E.W:



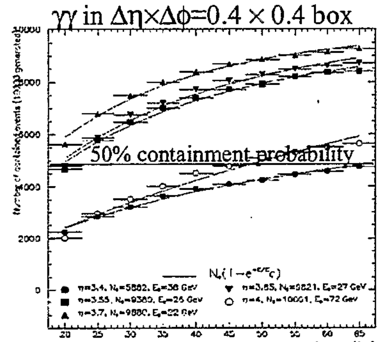
BBC E.W rate during **Van der Meer scan**

Distribution of Fitted Yields:



⇒ Yield stable w/in 10% for each pos'n

$\gamma\gamma$ in $\Delta\eta \times \Delta\phi = 0.4 \times 0.4$ box



Still need to establish reconstruction efficiencies from existing simulations

Physics Motivations for a Forward π^0 Detector for STAR

- Topic I: Tuning STAR Spin Rotators
- Topic II: Spin Physics in the Forward Direction
- Topic III: Probing the color glass condensate in d-Au collision

Proposed for Next Run

Left/right symmetric calorimeters $\Rightarrow \pi^0$

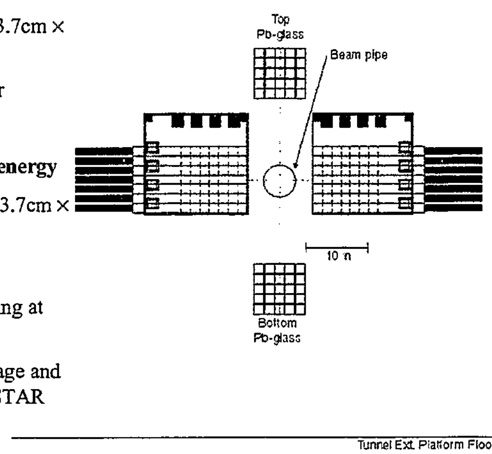
- Pb-glass calorimeter: two 7x7 matrices of 3.7cm × 3.7cm × 45 cm Pb-glass detectors
- Scintillator strip shower maximum detector
- 7-element Pb-glass preshower detector

Up/down symmetric calorimeters $\Rightarrow$ total energy

- Pb-glass calorimeter: two 5x5 matrices of 3.7cm × 3.7cm × 45 cm Pb-glass detectors

Readout electronics

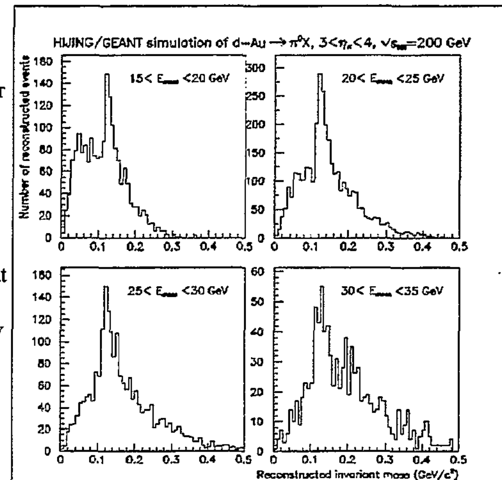
- employ existing design 8-bit ADC's operating at RHIC clock frequency.
- employ existing design of FPGA (data-storage and manipulation, DSM) boards for interface to STAR trigger.



Probing gluon densities in heavy nuclei

- Search for predicted modification of p_T dependence of large rapidity π yield in d-Au collisions from gluon saturation effects (Dumitru and Jalilian-Marian, hep-ph/0204028)

- HIJING/GEANT simulations show that we can reconstruct π^0 in d-Au collisions. Will be able to reduce the background by tuning the reconstruction algorithm $\Rightarrow$ utilize calorimeter segmentation to discriminate π^0 from additional particles incident on calorimeter.



Summary

- Large rapidity π^0 detection works.
- Possibly large transverse spin effects, but further work is needed to establish consistency of left/right results.
- A proposal will be submitted to build forward π^0 polarimeters for STAR.
- Forward π^0 detection also of interest to probe gluon density in heavy nucleus in d-Au collisions.

Local Polarimeter Analysis Status Report from PHENIX/IP12

Please see summary

B. Fox

May 22, 2002

for

RHIC Spin Collaboration Meeting IX

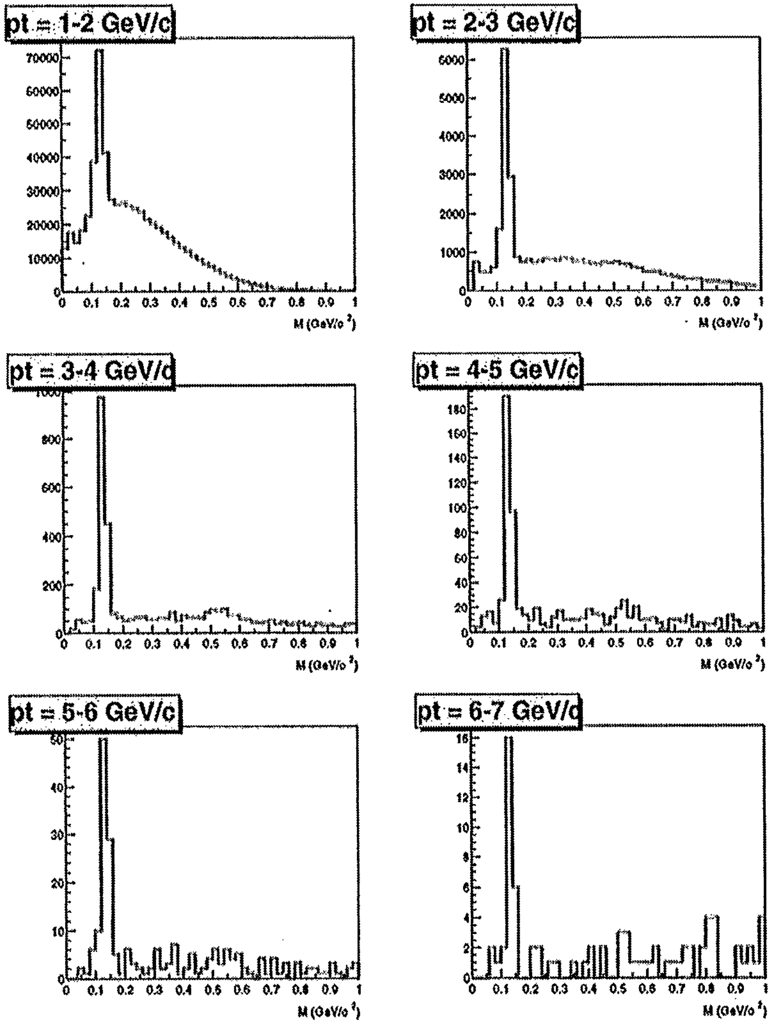
RIKEN BNL Research Center

Spin Plans for RUN 03 from PHENIX

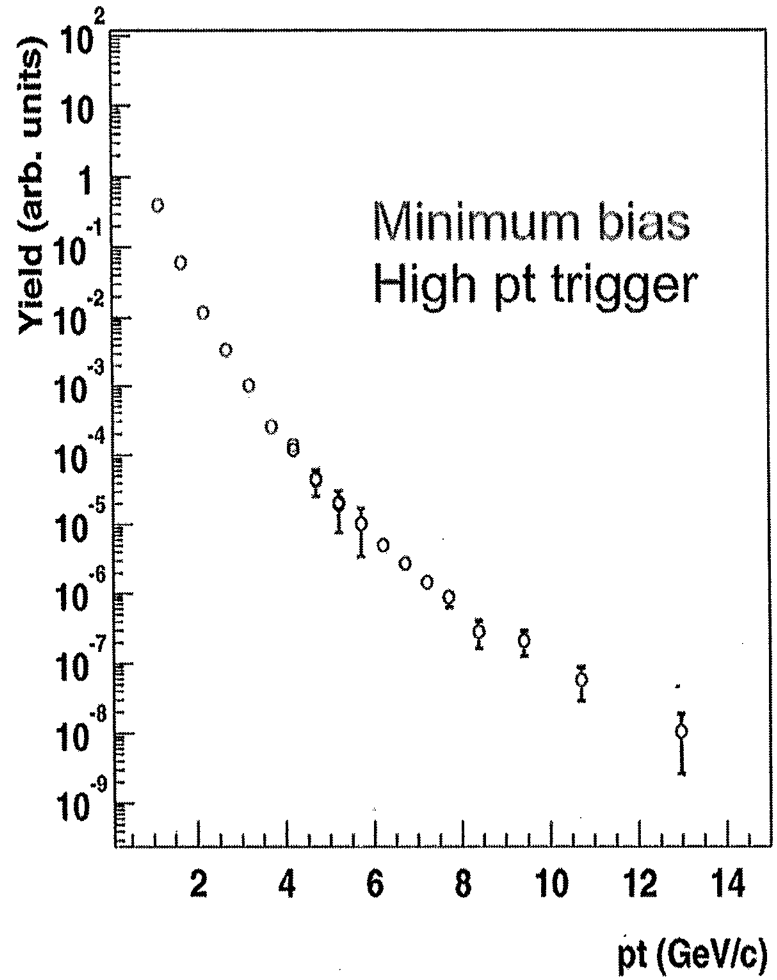
M. Grosse Perdekamp
May 22, 2002

for
RHIC Spin Collaboration Meeting IX
RIKEN BNL Research Center

EMC + EMC lvl1 Trigger Performance in RUN 02



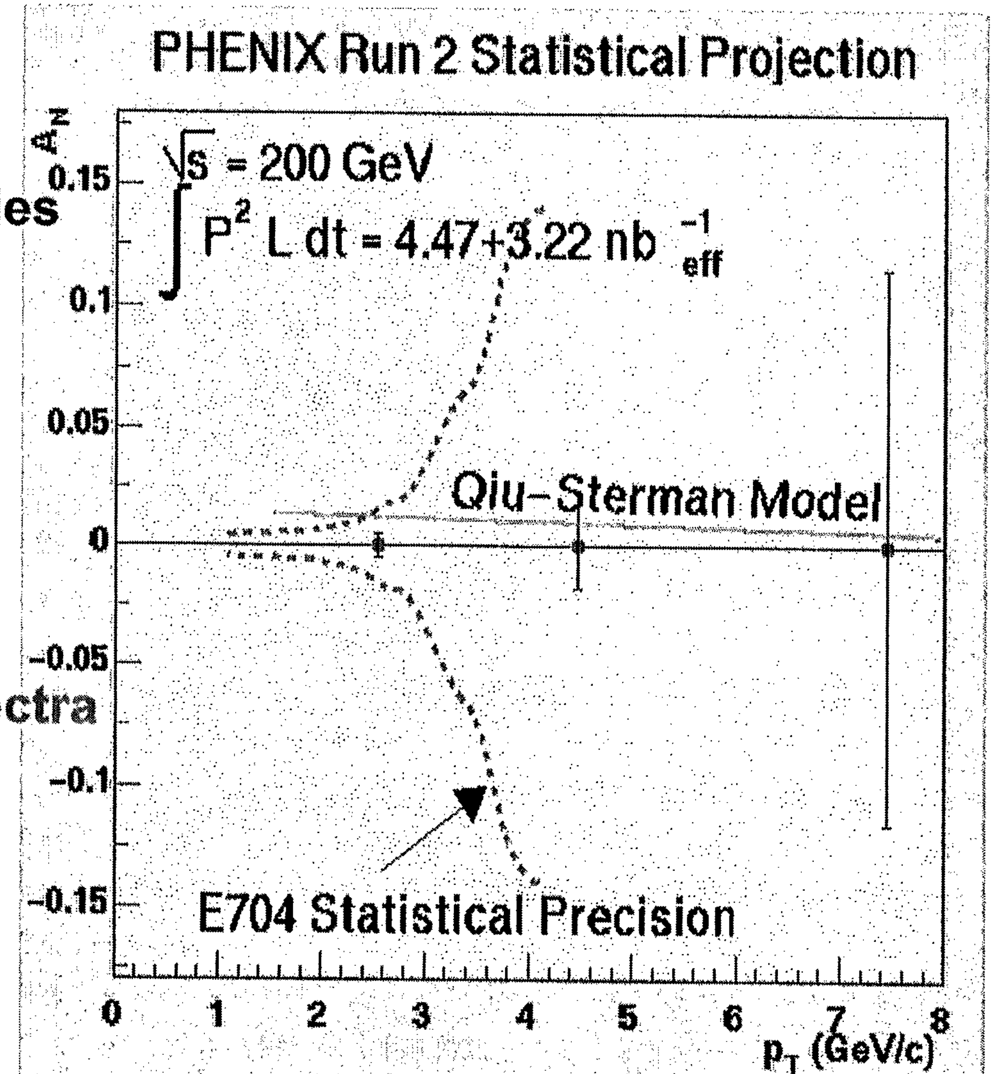
From Sasha Bazilevsky



Spin PWG Physics Goals from Run 02 Data

From Naohito Saito

- **Measure single spin asymmetries for identified particles**
- **Test to which level NLO QCD describes inclusive hadron spectra**



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Rates for run 03

Peak luminosity: $1.6\text{x}10^{31}\text{cm}^{-2}\text{s}^{-1}$ ==> Peak Rates into Level 1 500kHz

Bandwidth into Event builder/DCM ==> 5kHz (?)

Need rejection of about 500 at level 1: Thresholds between 2-3 GeV

Integrated Luminosity from RHIC ==> 2.8pb^{-1}/week

Integrated Luminosity with PHENIX up ==> 1.0pb^{-1}/week

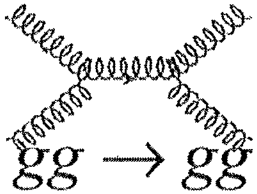
Write $3\text{x}10^{9}$ events corresponding to 120 days of production on CCJ

Matthias Grosse Perdekamp

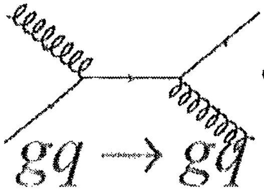
May 22, 2002

Sensitivity of inclusive π^0 spectra to ΔG

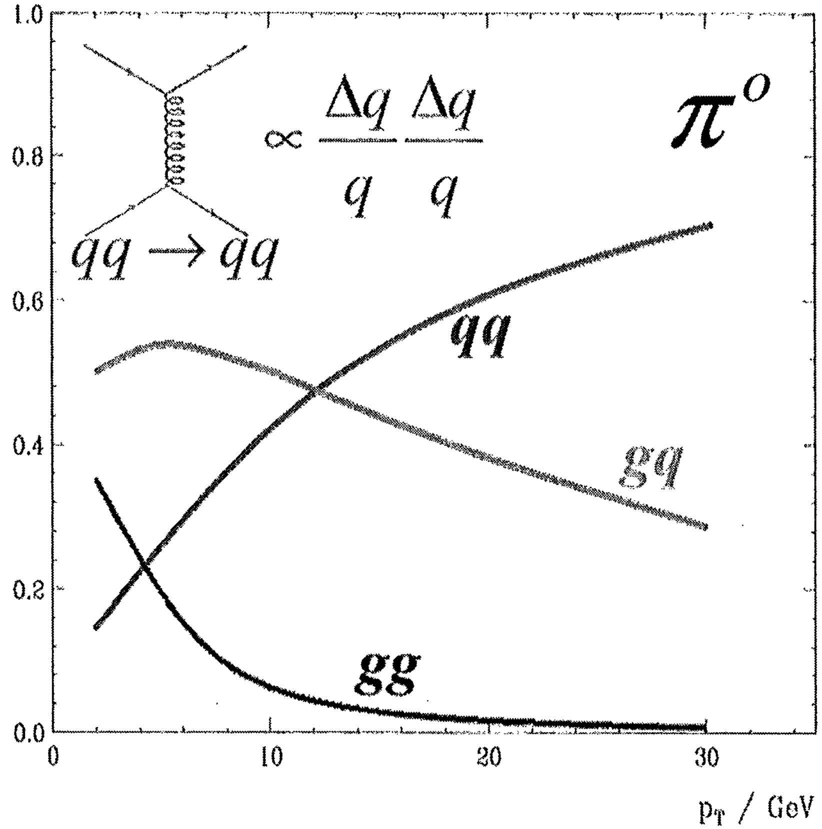
W. Vogelsang and M. Stratmann

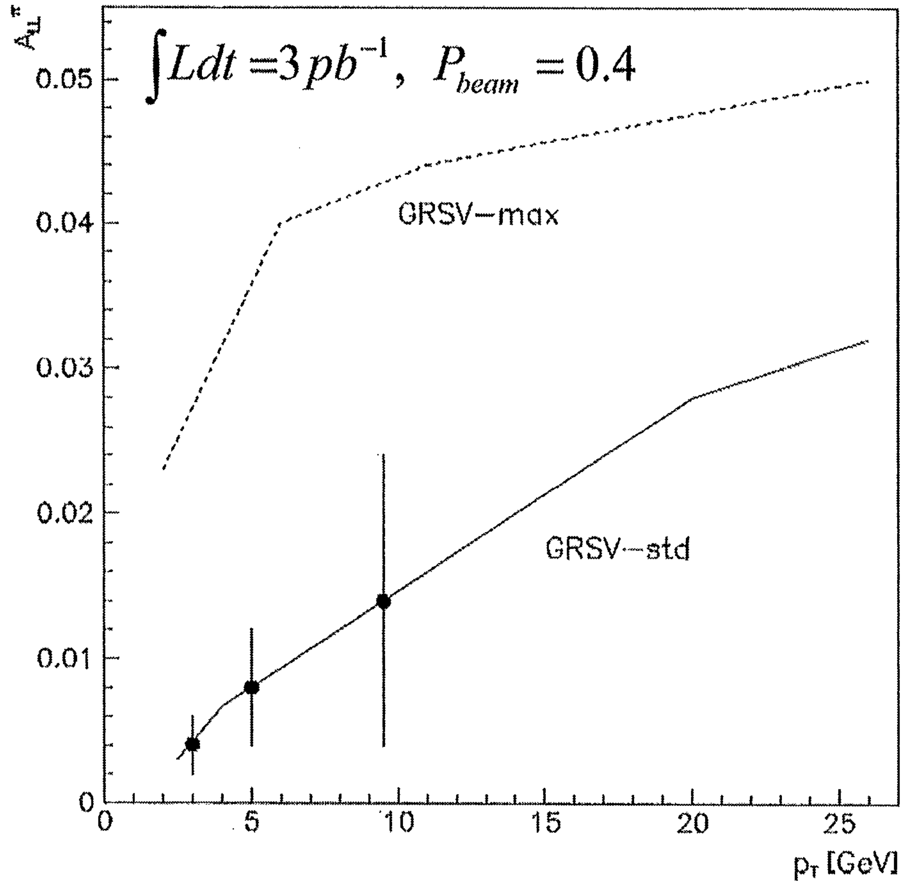


$$\propto \frac{\Delta G}{G}\frac{\Delta G}{G}$$



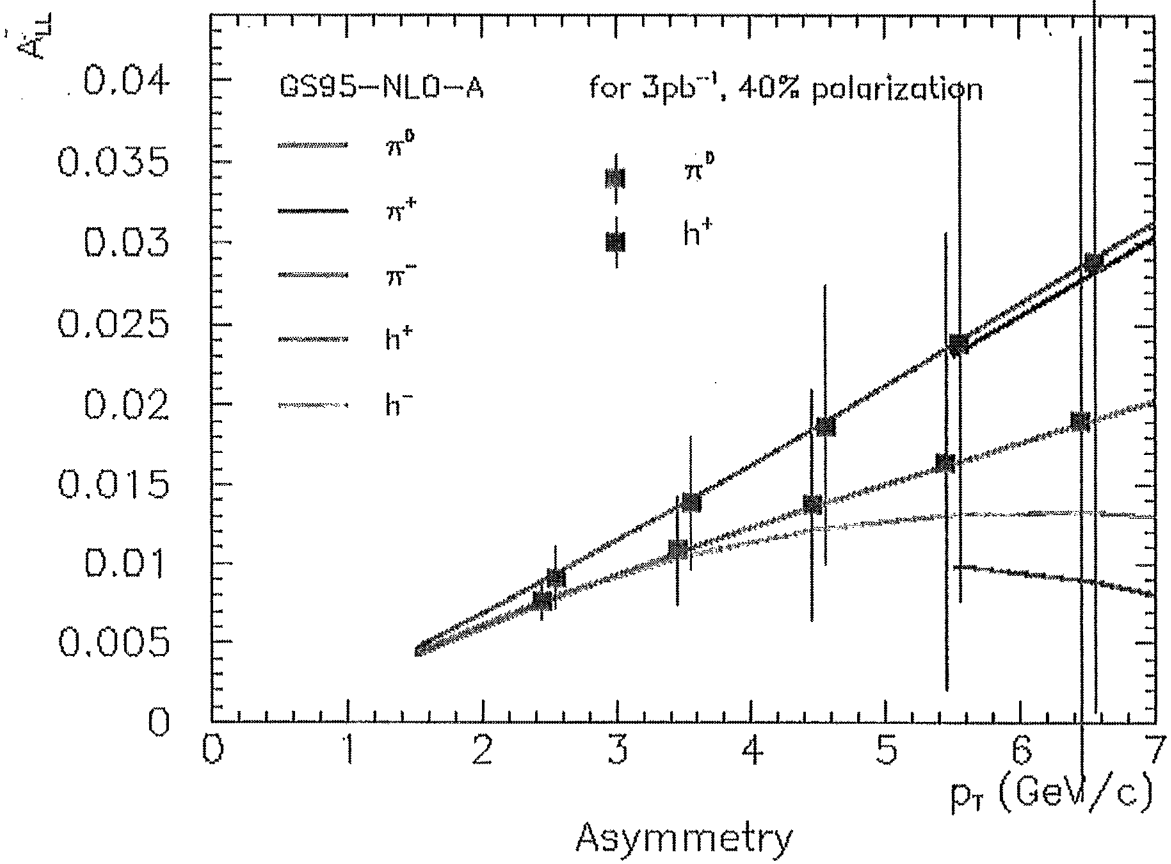
$$\propto \frac{\Delta q}{q}\frac{\Delta G}{G}$$





Sensitivity of inclusive chargehadron spectrato ΔG

Y. Goto



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Model dependence

W. Vogelsang

- Evidence that pQCD fits data for colliders down to p_T=2 GeV. This can be further studied using RHIC pp data from runs 02 (and 03).

- Charged and neutral pion spectra are sensitive to the Gluon Polarization.

- Input distributions:
  - o Differences in the fragmentation functions will largely cancel in the asymmetry.
  - o Variations in the unpolarized parton distributions have little effect on the asymmetry.
  - o Significant experimental input: pdfs: SLAC, CERN-M2, HERA, ffs: EMC, LEP, HERMES

Summary

o **5 weeks of spin commissioning**

o **3 weeks of physics with longitudinal polarization**

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Measurement of gluon polarization in inclusive hadron production

Operate PHENIX at 10 times higher luminosity

o **Physics run should be contingent on demonstrated P_{AGS}>40%**

Spin Plans for RUN 03 from STAR

G. Eppley, Rice University
May 22, 2002

for
RHIC Spin Collaboration Meeting IX
RIKEN BNL Research Center

RHIC Spin Meeting
BNL
May 22, 2002

Projected STAR Spin Beam Use Request

G. Eppley
Rice University

Questions for an opening discussion:

1) What is the goal of having BUR discussion at a RHIC Spin meeting at the time?

2) How will this inform C-AD and help them better plan for the FY03 run?

3)What will be different this year form a beam use perspective?

> transverse vs. longitudinal is not a STAR vs. PHENIX issue this year
> integrated Ldt is not a beam use issue this year, or at least shouldn't be
> number of days of pp running is possibly an issue this year

Why run pp in FY03?

1. Commissioning RHIC and detector spin components is a difficult, step-by-step process. Missing a year will put us a year behind. We are not likely to catch up by having longer runs in subsequent years.
2. The sense of the STAR spin group is that keeping spin commissioning moving forward is more important than any particular physics goal for this year. It is essential for the "health" of the spin community that this happen. The young people involved can not be expected to wait two years between runs.

Run Priorities

1. Commissioning

   P_AGS > 0.4 , P^2_RHIC > 0.1
   Rotataors
   A/C dipole
   Down-ramp
   10^31
   Other C-AD beam development

2. Transverse Polarization

   Measure A_T sufficient for tuning the rotators
   Measure A_T in forward pi0production, 1 pb^-1

3. Longitudinal Polarization

   Measure A_LL in pp => jet + X, 3 pb^-1

pp2pp Running Plan for Year-2 (2003)

Stephen Bültmann

May 22, 2002

for

RHIC Spin Collaboration Meeting IX

RIKEN BNL Research Center

pp2pp Running Plan for Year-2 (2003)

Elastic and Total Cross-Section Measurements in Polarized Proton-Proton Scattering

Stephen Bültmann
For the pp2pp Collaboration

Outline of the Talk

1. Short Introduction
2. Summary of Year-1 Run
3. Plan for Run in 2003

pp2pp Physics Programme

Primary Goal:

Study of total and elastic cross-sections in polarized proton-proton scattering over a large kinematic range

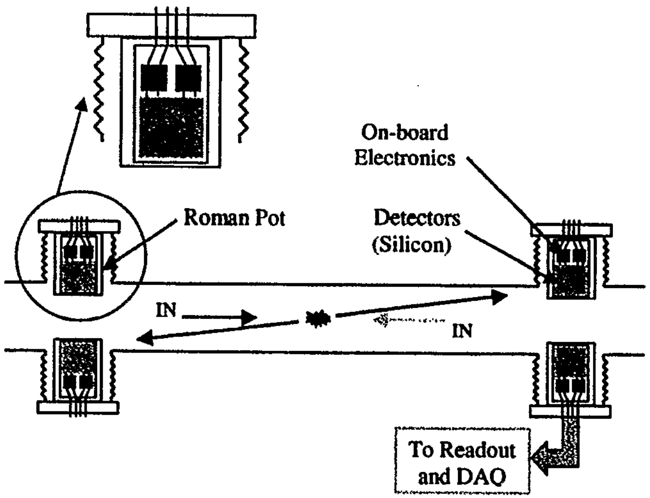
$$50 \leq \sqrt{s} \leq 500 \text{ GeV}/c$$

$$4 \cdot 10^{-4} \leq |t| \leq 1.5 \text{ (GeV}/c)^2$$

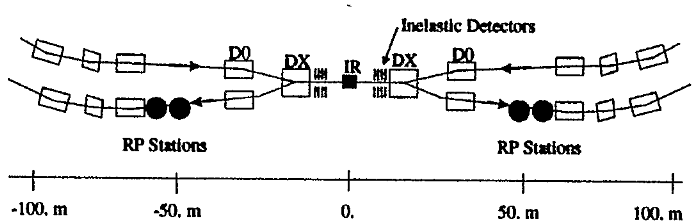
Measure

- Kinematic dependence of σ_{tot} and $d\sigma_{el}/dt$
- s dependence of nuclear slope parameter, b
- Ratio of real to imaginary part of forward scattering amplitude, ρ
- Spin asymmetries A_N, A_{NN}, A_{LL}

pp2pp Detectors in Year-1 (2002)

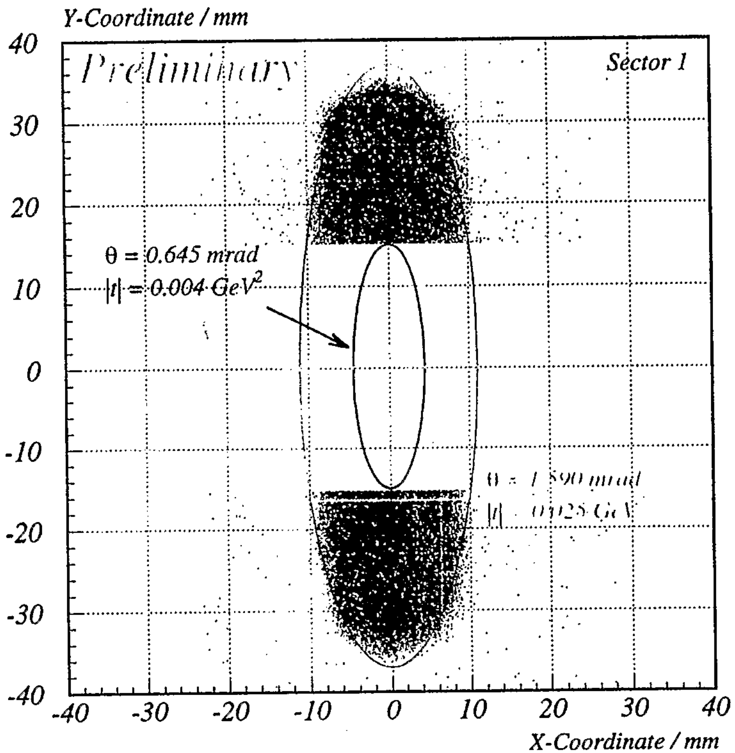


RHIC Intersection Region with PP2PP Basic CB Setup



Conditions during Run in Year-1 (2002)

- 4 Roman Pots total equipped, each with
  - 2 X silicon microstrip detectors
  - 2 Y silicon microstrip detectors
  - 1 trigger scintillator (8 mm thick)
- 15 mm proximity of first detector strip to beam covering $4 \cdot 10^{-3} \le |t| \le 0.03$ (GeV/c)^2
- 4 planes of inelastic scintillator counters on either side of the IP (covering $2.4 < |\eta| < 5.3$)
- Average beam intensity of $4.4 \cdot 10^{11}$ protons in either ring with 55 bunches $\Rightarrow$ $L \approx 1.2 \cdot 10^{28}$ cm^{-2} sec^{-1}
- Special tune of $\beta^* = 10$ m
- Beam emittance reduced to about 12 π mm · mrad via scrapping
- Collected about 400,000 elastic triggers



Plan for Run in Year-2 (2003)

- Replace silicon detectors to improve efficiency and coverage
- Have 4 fully equipped Roman Pot Stations
- Reduce minimum distance of detectors from beam to reach lower t_{min} increasing coverage to **$2\text{-}3\cdot10^{-3} \leq |t| \leq 0.03\ (\mathrm{GeV}/c)^2$**
- Increase maximum allowed intensity to $\sim10^{12}$ protons per beam (safety issue) ?
- Include Van-der-Meer scans for luminosity determination
- Collect about 2-3 million elastic triggers to reduce statistical error
- Achieve accuracy $\delta A_N \approx 0.002$ and $\Delta\sigma_{tot} \approx 3\%$
- Need 1 day commissioning and 2-3 days for data taking (depending on beam efficiency, 50% ?)

RHIC Spin Collaboration Meeting IX
May 22, 2002
RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting IX
May 22, 2002
RIKEN BNL Research Center

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RIKEN BNL Research Center

RHIC Spin Collaboration Meeting IX

May 22, 2002

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

*******AGENDA*******

Morning Session

09:00 - 09:30 General Luminosity Issues .... G. Bunce

09:30 - 10:00 Luminosity at STAR.. J. Kiryluk

10:00 – 10:30 Luminosity at PHENIX... Y. Goto

10:30 – 11:00 Luminosity from the Machine Perspective.................... T. Roser

11:00 – 11:15 Coffee

11:15 – 12:00 Update on the CNI Polarimeter Results for RUN 02......... O. Jinnouchi

12:00 Lunch

14:30 Coffee

Afternoon Session

14:30 - 15:00 Local Polarimeter Analysis Status Report from STAR..... L. Bland

15:00 - 15:30 Local Polarimeter Analysis Status Report from PHENIX/IP12.. B. Fox

15:30 – 16:00 Spin Plans for RUN 03 from PHENIX........................ M. Grosse Perdekamp

16:00 – 16:30 Spin Plans for RUN 03 from STAR........................... G. Eppley

16:30 – 17:00 Spin Plans for RUN 03 from pp2pp........................... S. Bueltmann

Next Meeting ~ Monday, June 17, 2002 small seminar room, BNL Physics Bldg. 510

SUMMARY

B. Fox, RBRC
June 17, 2002

for
RHIC Spin Collaboration Meeting X
RIKEN BNL Research Center

Since its inception, the RHIC Spin Collaboration (RSC) has held semi-regular meetings each year to discuss the physics possibilities and the operational details of the program. Having collected our first data sample of polarized proton-proton collisions in Run02 of RHIC, we are now in the process of examining the performance of both the accelerator and the experiments. From this evaluation, we not only aim to formulate a consensus plan for polarized proton-proton during Run03 of RHIC but also to look more forward into the future to ensure the success of the spin program.

In the fourth meeting of this series (which took place at BNL on June 17, 2002), we focused on the latter. Specifically, we heard reports on the status of the following efforts:

- a polarized hydrogen jet target experiment in RHIC,
- a CNI polarimeter for the AGS, and
- a spin flipper for RHIC.

In addition, because of its central role to all spin analysis for Run-02, there was an update presentation on the status of the RHIC CNI polarimeter analysis.

The polarized jet target effort aims to measure the absolute beam polarization via elastic proton-proton scattering from a polarized proton target so that the more rapid measurements from RHIC CNI polarimeters can be absolutely calibrated at flattop energies. For this purpose, a jet target will be installed at the 12:00 interaction point. This target will be fed with polarized hydrogen by an atomic beam source (ABS) which is presently being designed. The particles from beam scattering will be detected in an array of silicon detectors. To open this meeting, Tom Wise discussed the current status of the design of the target and the interfacing of it to the RHIC ring. The most troublesome aspect of this effort had been the magnet design because the magnet needs to provide an uniform holding field in order to avoid depolarizing the target by resonances with the bunched beam, yet also must not significantly deflect the recoil protons since the scattering angle of these protons is determined from position measurements made outside of the field region. A nice design by Wuzheng Meng with two concentric Helmholtz coils sandwiching an iron core was presented and is considered to be nearly final. By powering the coils with oppositely directed current, the field in the region through which target atoms transverse is uniform, yet the momentum kick given to scattered particles is largely canceled because the $\int B \cdot dr$ is nearly zero. Sandro Bravar then presented a status report on the design of the experiment for detecting the recoil protons. The setup would consist of silicon strip detectors using the same readout electronics as the CNI polarimeters and, as mentioned, positioned outside of the target magnet. These detectors would measure the scattering angle and energy of the recoil proton to isolate the signal from background particles. The left-right asymmetry of the signal particles would then be measured to determine the beam polarization. And, finally, Yousef Makdisi presented a timeline for the project. The goal is to have this setup in place by October, 2003 so that the experiment can be commissioned during RHIC Run-04.

Prior to the presentation on the AGS polarimeter, Haixin Huang presented an update on the offline analysis of the AGS polarization data from Run-02. First, the AGS polarimeter had been upgraded with additional forward arms so that inclusive proton-proton scattering could be measured at 3 different energies. During the run, however, time constraints allowed for a measurement at only one energy (corresponding to Gγ of 7.5, the first "large" resonance above the AGS injection energy of $\sim$3 GeV). The polarization determined from this measurement was in agreement with the polarization measured by the 200 MeV polarimeter in the LINAC. The mystery of the low asymmetry measured at this energy in September 2000 remains. Second, following up on the presentation by Mei Bai in the April meeting, further studies have been done to try to understand the loss of polarization at the 24-ν_y weak resonance. Looking at past runs, Haixin showed that, during the last time when the slow ramp rate was used (April, 1994), they also observed a polarization loss at this resonance. However, like now, they did not understand this loss. Presently, he speculated that this loss may be a result of the slow ramp rate and thus would resolve itself for Run-03. And, finally, he pointed out that the emittance growth (which tends to increase polarization loss at resonances) was definitely observed in the AGS during Run-02 even when the the AC dipole was not operating. If this effect is also a result of the slow ramp rate, we can expect it to be improved for Run-03. Certainly, it will be something which will be studied as part of the AGS commissioning effort for polarized proton running.

To provide faster feedback about polarization during tuning of the AGS, a CNI polarimeter will be installed in the AGS and made operational for Run-03. Jeff Woods presented the status of this effort. The design of this polarimeter is the same as the 90° components of the RHIC polarimeter, except that the detectors are positioned further from the beam since the beam bunches are longer in the AGS than in RHIC. To a large extent, this effort is piggy-backing on the development effort for the RHIC CNI polarimeters. However, one new concern for this effort is the pickup of electronic noise from the AGS. Effort is underway to understand this noise and to design a shield or grounding arrangement which eliminates it. In addition, the carbon target for it will be longer and wider but of the same thickness as the one used for RHIC and is being manufactured by Indiana. The expected installation time for the polarimeter is September, 2002.

To open the afternoon session, Dave Underwood presented some further analysis of the polarization trends seen during a fill using the online polarization results from the RHIC polarimeter. This work indicates that, at first glance, the blue beam was losing polarization during the course of the fill and maybe (though, definitely, not clearly) the yellow was also losing polarization.

Presently, in RHIC, the polarization orientation of each bunch is determined at the source. So, under unfavorable circumstances, differences between bunches could be correlated with polarization and thus, as in the case of the relative luminosity, give rise to false asymmetries. This problem can be minimized by flipping the spin of the bunches in RHIC. For this reason, a spin flipper was designed, built, and installed in RHIC for Run-02. During this run, this device was commissioned. Mei Bai presented the results on the analysis of this commissioning effort. In the blue ring, she was able to flip the spin twice without losing all of the polarization. The efficiency of the flipper was $\sim$67%. In yellow beam, however, the polarization was completely lost on the first flip. She suspects that this total loss (as well as perhaps the inefficiency seen in the blue) was due to the snakes not being tuned perfectly. More studies will be done on this device as part of the commissioning effort for Run-03.

Stephen Bueltmann presented a status report on the analysis of the data collected by pp2pp experiment during their dedicated fill. After introducing the (spin-) physics programme of the experiment, he outlined the principle of the measurement. Because of the small elastic scattering angle, the scattered protons are in the vicinity of the beam and are subject to the beam transport magnets. It was emphasized was that the addition of Roman Pot detectors at 3 m downstream of the existing setup would eliminate the dependence on the scattering vertex perpendicular to the beam momentum by measuring the angle of the scattered protons in the detection area. The performance of the silicon detectors was discussed by showing a spectrum of the energy deposited by protons. A method of calculating the silicon detector efficiency was explained and the result as a function of strip number shown for two detectors. For 14 out of 16 detectors, the average efficiency is above 0.95, resulting in a position detection efficiency of above 0.99 when combining the detectors. The running conditions for the low intensity fill, resulting in 14 hours of data, were reviewed. A total of about 300k elastic events were recorded. The positions of the scattered protons were shown and the shift of the position due to the roll of a quadrupole magnet pointed out. The correlation between coordinates measured for the two scattered protons showed a very clear band of elastically scattered protons and very low background. Finally, accuracy estimates for the measurement of the analyzing power under different conditions, like beam polarization, detector position with respect to the beam, *etc.*, were given.

And, to close the meeting, Werner Vogelsang gave an introduction to QCD resummation. Very inelastic hadronic reactions are probes of nucleon structure since they may be described in terms of a partonic hard scattering in which a constituent of the nucleon participates. Such hard-scattering cross sections are amenable to QCD perturbation theory. Often, low orders in perturbation theory suffice to obtain a good description of the process. However, the situation is different if the partonic cross section is probed near an exclusive limit of phase space, where it develops large logarithmic terms associated with soft-gluon emission. An example is the Drell-Yan cross section at low measured transverse momentum of the Drell-Yan boson. It is possible in many cases to take into account ("resum") the large logarithmic corrections to all orders of perturbation theory. Recent progress presented by Vogelsang includes the development of a more general resummation formalism, and the application of resummation to single-inclusive cross sections and to spin asymmetries.

Vogelsang also presented new studies for transverse double-spin asymmetries for direct-photon and jet production at RHIC, showing that these processes will be very promising tools for a direct measurement of transversity at RHIC.

B. Fox
17 June 2002

Status Report on the Jet Target

T. Wise, Univ. of Wisconsin
June 17, 2002

for
RHIC Spin Collaboration Meeting X
RIKEN BNL Research Center

JET TARGET STATUS JUNE17 02

Quick review of idea

Jet H target of known polarization		$\lvert Q \rvert \approx 0.9$
P beam of unknown polarization		$\lvert P \rvert \approx 0.5$?
Unknown Ay	0.03 (~~≈0.6~~ expected for p-p elastics)	

Method relies on $Ay_{beam} = Ay_{target}$

WORKING GROUP EXISTS -not a formal collaboration

CURRENT MEMBERS on project in no particular order:

[Mail list is **much** longer]

WISCONSIN	T. WISE	
	W. HAEBERLI	
	M. CHAPMAN	tech support
IUCF	E. STEPHENSON	
BNL	A. BRAVAR	
	G. BUNCE	
	G. MAHLER	
	W. MENG	
	Y. MAKDISI	
	A. ZELINSKI	

To assist in near future:

Don Barton

D. Hseuh

STRATEGY

1) MEASURE JET POLARIZATION WITH BRP
   (to ≈ 1% hopefully) also expect $Q\downarrow \neq Q\uparrow$

2) GENERATE 8 YIELDS NEAR 90°
   by rotating through $Q\downarrow,\uparrow$, $P\downarrow,\uparrow$

Example

$$Y_{L\uparrow\uparrow} = I_\uparrow t\, \varepsilon_L \sigma_0 \left[1 + P_\uparrow A_Y + Q_\uparrow A_Y + A_{YY} P_\uparrow Q_\uparrow\right]$$

6 unknowns: $\frac{I_\uparrow}{I_\downarrow}$, $\frac{\varepsilon_L}{\varepsilon_R}$, $P_\uparrow$, $P_\downarrow$, A_{YY}, A_Y ← we can measure

NOTE: $t\downarrow = t\uparrow = t$

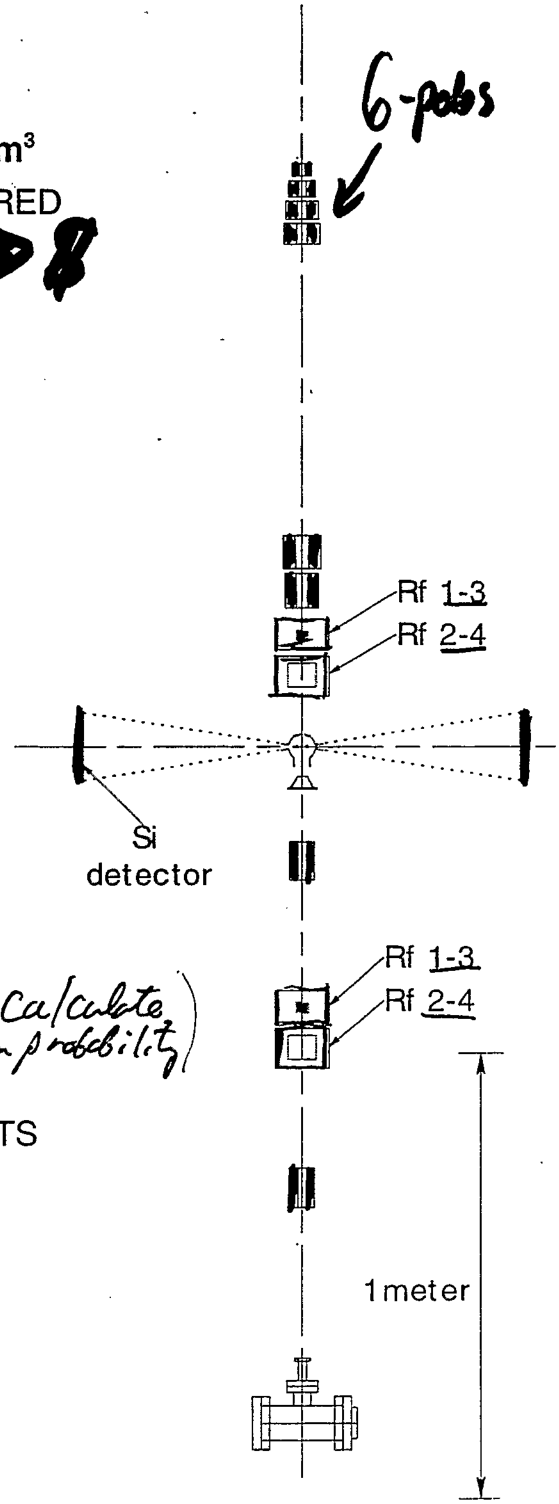
target constant to $<10^{-4}$ level

We expect $I\downarrow \neq I\uparrow$
and $P\downarrow \neq P\uparrow$

An independent measurement of beam Luminosity is helpful but not required.

DESIGN ISSUES

1) • JET NOT A POINT TARGET
   9mm long with density **7×10^{11} atom/cm^3**
2) LONG 50-80cm SILICON ARMS REQUIRED
   for bunch separation and resolution. → 8
3) VERTICAL JET ORIENTATION
4) • TARGET GUIDE FIELD
   a) 0.1 T with **$\Delta B/B = 6 \times 10^{-3}$**
   b) 60mm free aperture
   c) no zero crossing along JET path
   d) low Bdl from JET to Si detectors
   e) low stray field at rf transitions
5) JET HAS H_2 DILUTION
   -need to measure
6) HIGH JET GAS LOAD
   a) 1.6×10^{-3} mbar-liter/s H_2
   b) must capture ≈ 99% of JET
   c) geometry makes pumping difficult
7) RESONANCES –special BRP mode
   to observe resonances (Theory student? Calculate transition probability)
8) • 2:00 REGION IS CROWDED
9) • COMPATABILITY WITH EXPERIMENTS
   We want to run jet during heavy ions
   OR rapidly remove from ring (and install)



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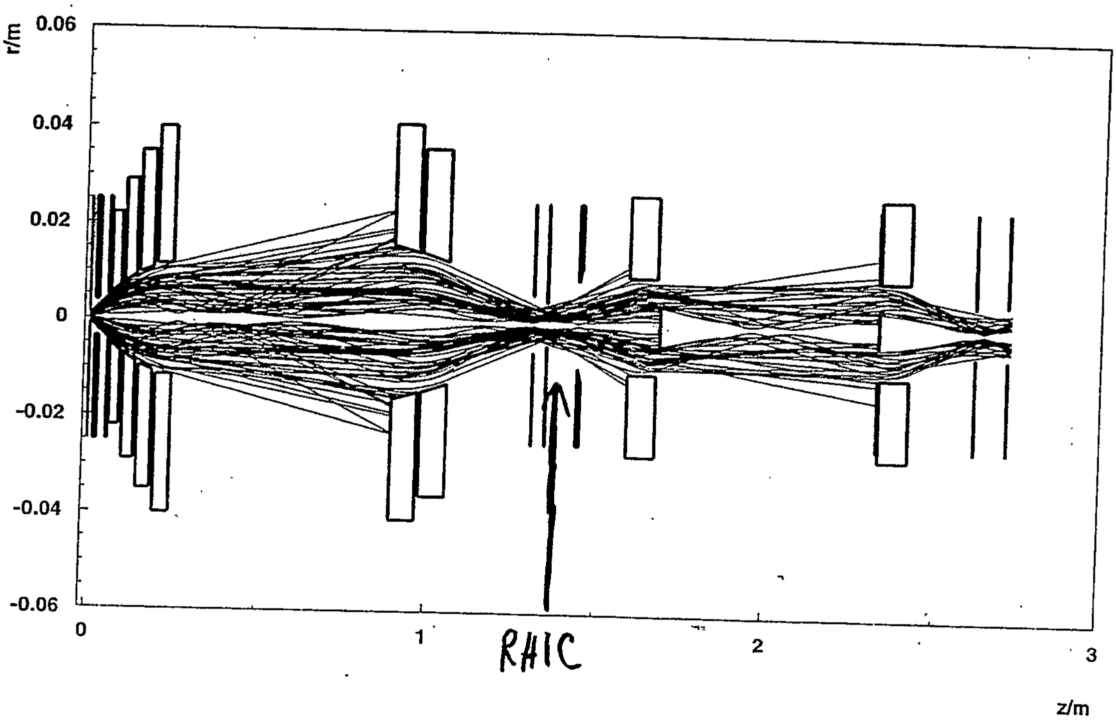

50 starting rays, State 1 entire path

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TARGET MAGNET

WHY 0.1T WITH UNIFORMITY $\Delta B/B = 6\times10^{-3}$?

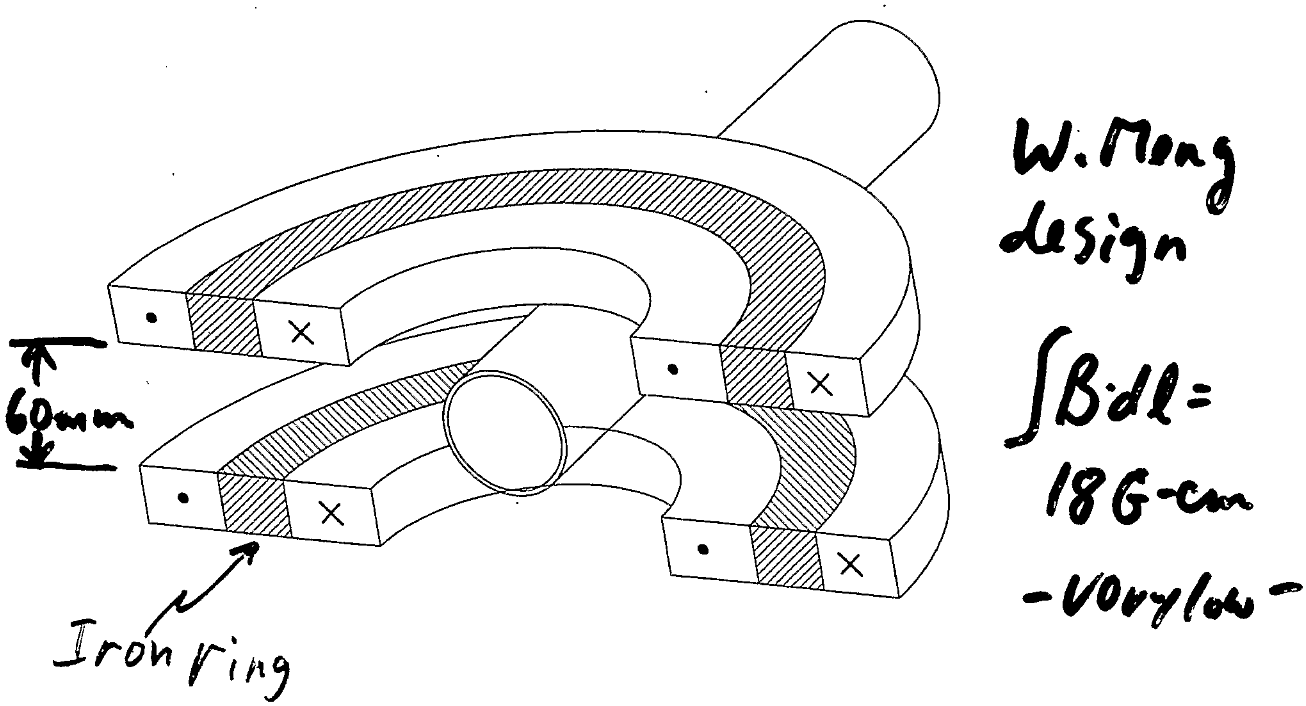
MAXIMUM INTENSITY REQUIRES 2 HYPERFINE STATES

P+ (1+4) or P- (2+3)

$$|P| = \left(1 + \frac{x}{\sqrt{1+x^2}}\right)/2 \approx 0.95 \text{ @ } 0.1T \quad (x = 2)$$

DEPOLARIZING RESONANCES. We need uniformity to slip between closely spaced resonances

4-COIL DESIGN WITH IRON RING MINIMIZES ∫ Bdl FOR ESCAPING RECOIL PROTONS



HERMES Resonances
also 1↔2 + 3↔4

H. Kolster thesis

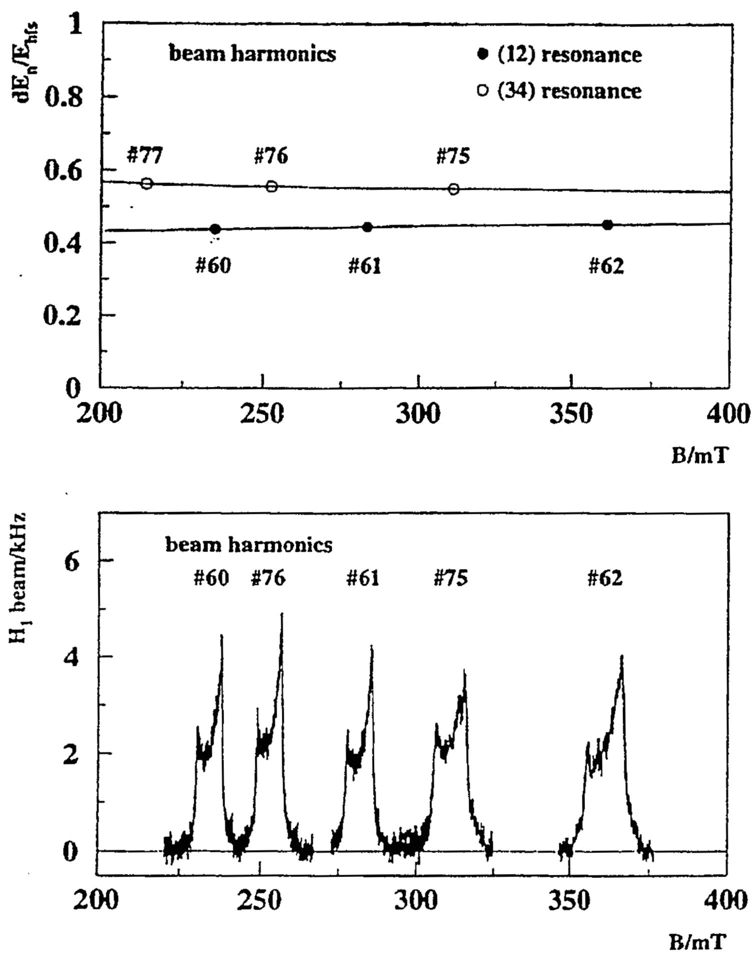
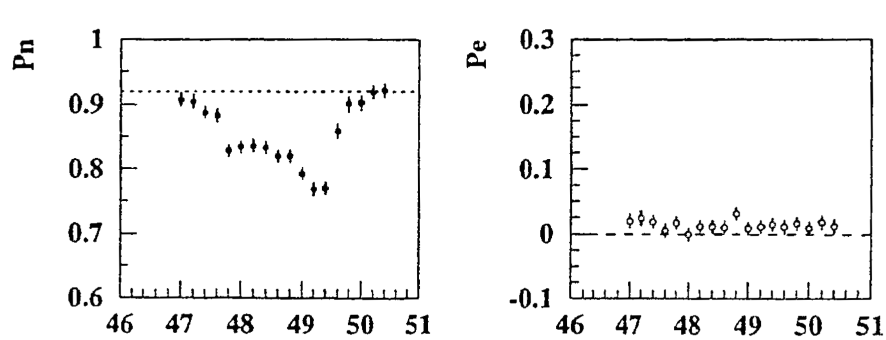


Fig. 6.4:
Upper graph:
The expected position of the resonances derived from the Fourier spectrum of the beam. The number of the beam harmonics is plotted next to the data points.
Lower graph:
Measured positions of the resonances versus the average magnetic field in the target cell. The HERMES operating point of $B = 335\,\mathrm{mT}$ lies in between two resonances.



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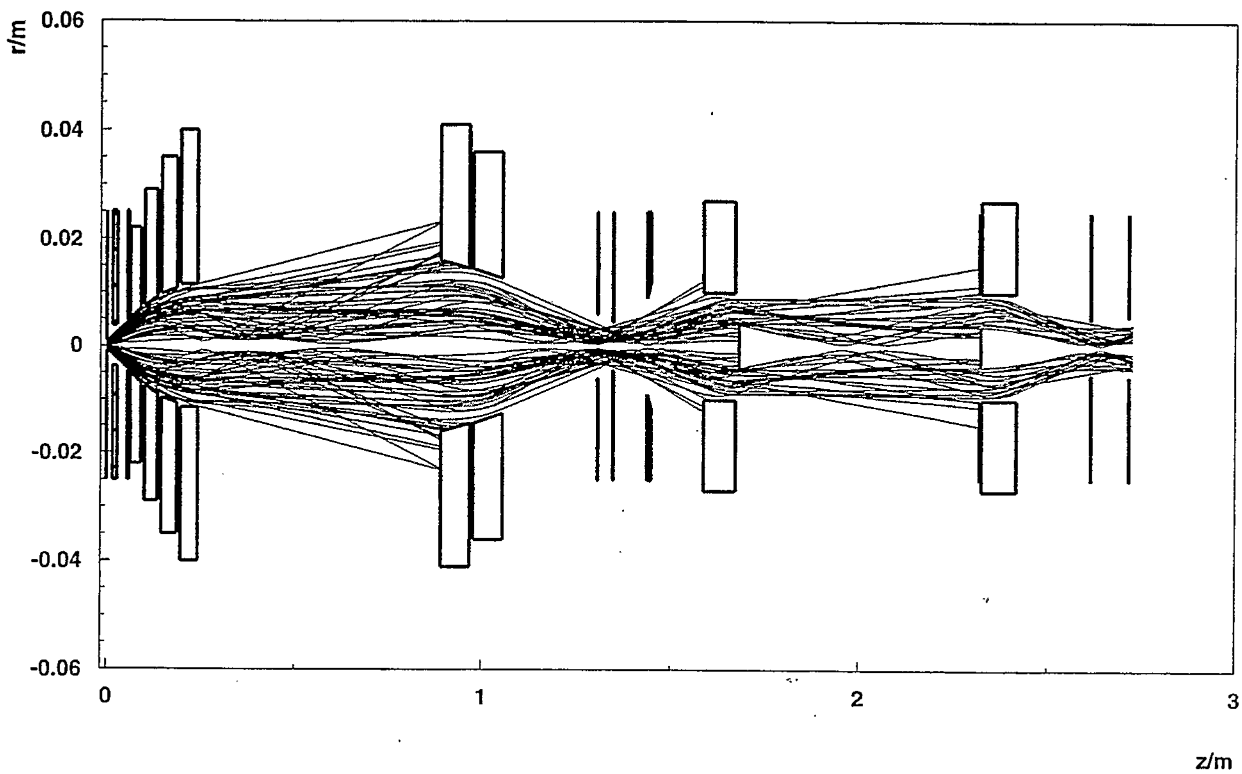

50 starting rays, state 1 entire path

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TARGET MAGNET

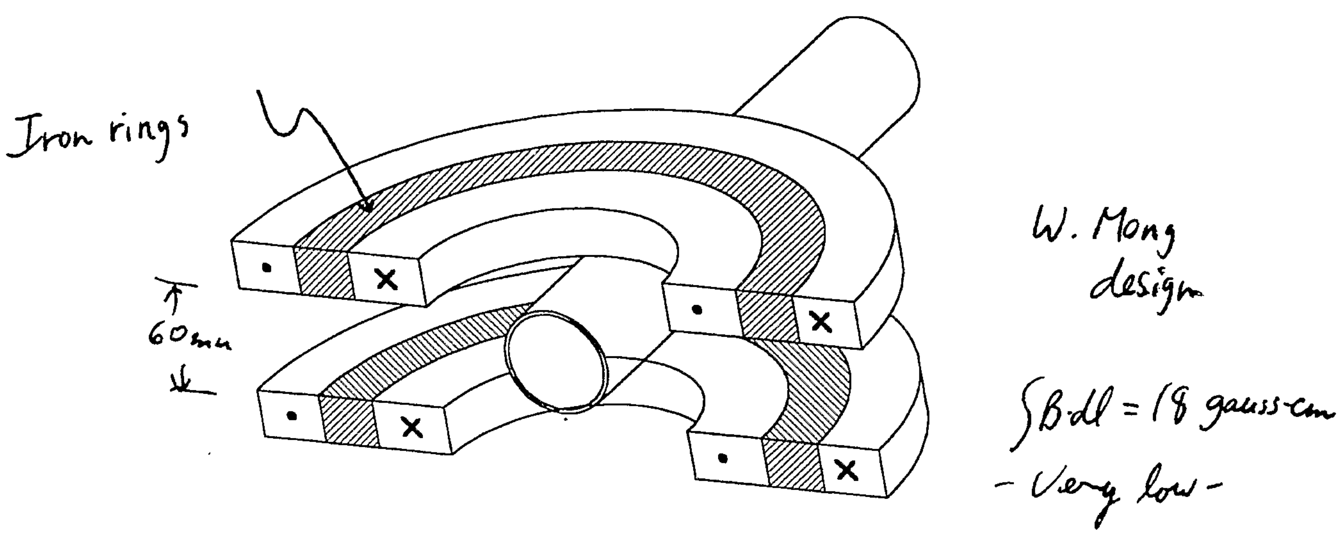
Why 0.1 T with $\frac{\Delta B}{B} \sim 5 \times 10^{-3}$?

a) Maximum JET intensity requires 2 hyperfine states: $p^{+}(1+4)$, $p^{-}(2+3)$

$$|P| = \left(1 + \frac{x}{\sqrt{1+x^2}}\right)/2 \simeq 0.95 \text{ @ } 0.1\,T$$

b) depolarizing resonances
need uniformity to avoid 1–2 or 3–4 resonance.
at $B \geq 0.1\,T$ all others are avoided at any uniformity.

4-coil design with Iron minimizes $\int B \cdot dl$ for recoils



HERMES Resonances
also 1↔2 + 3↔4

H. Kolston
thesis

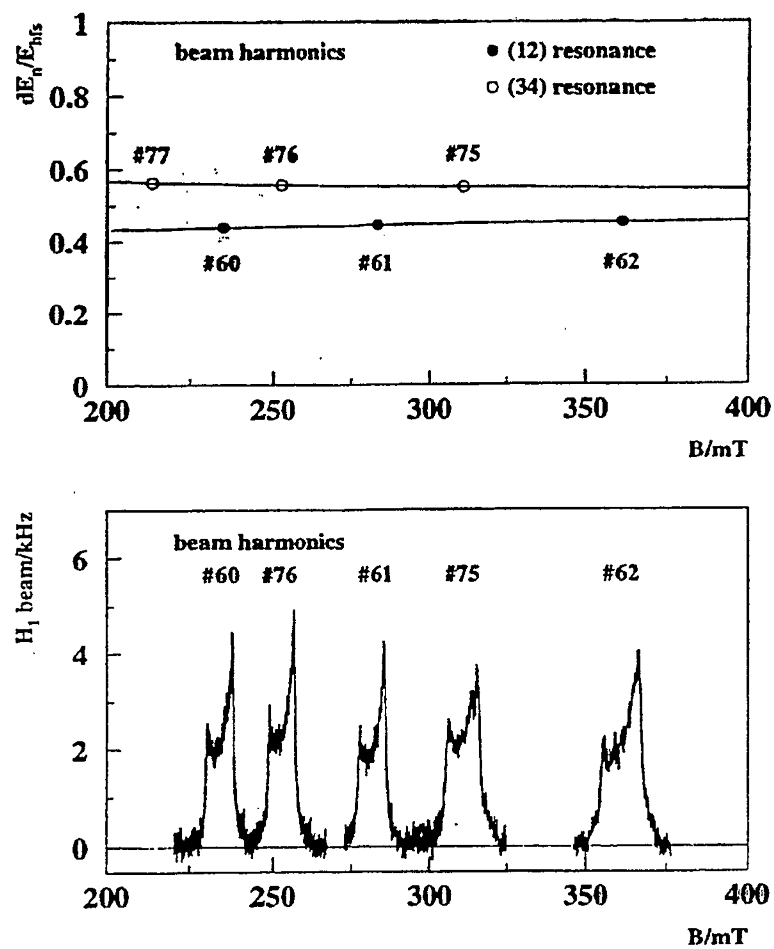
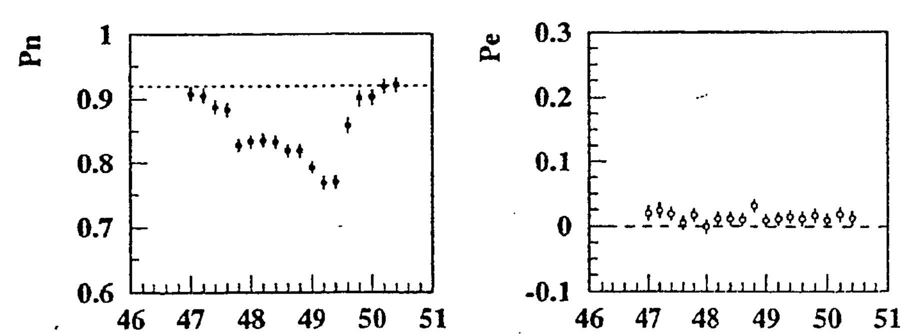
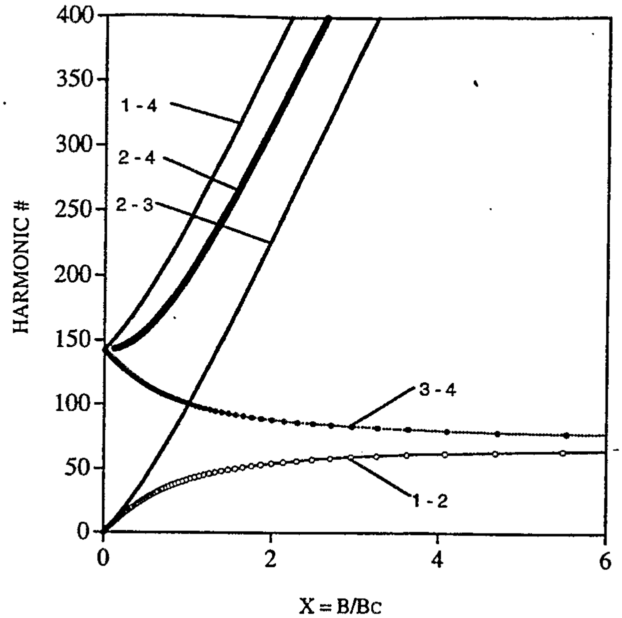


Fig. 6.4:
Upper graph:
The expected position of the resonances derived from the Fourier spectrum of the beam. The number of the beam harmonics is plotted next to the data points.
Lower graph:
Measured positions of the resonances versus the average magnetic field in the target cell. The HERMES operating point of $B = 335\,\mathrm{mT}$ lies in between two resonances.



Beam ↑
HARMONIC #

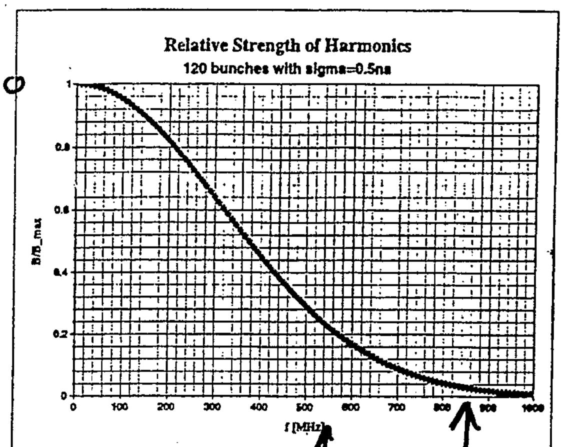


Calculated field values for resonances 1 − 2
+ 3 − 4
~~2 − 3~~, ~~2 − 4~~, ~~1 − 4~~ } gone at 0.1T

Relative
Strength
B/B_MAX

1.0

0



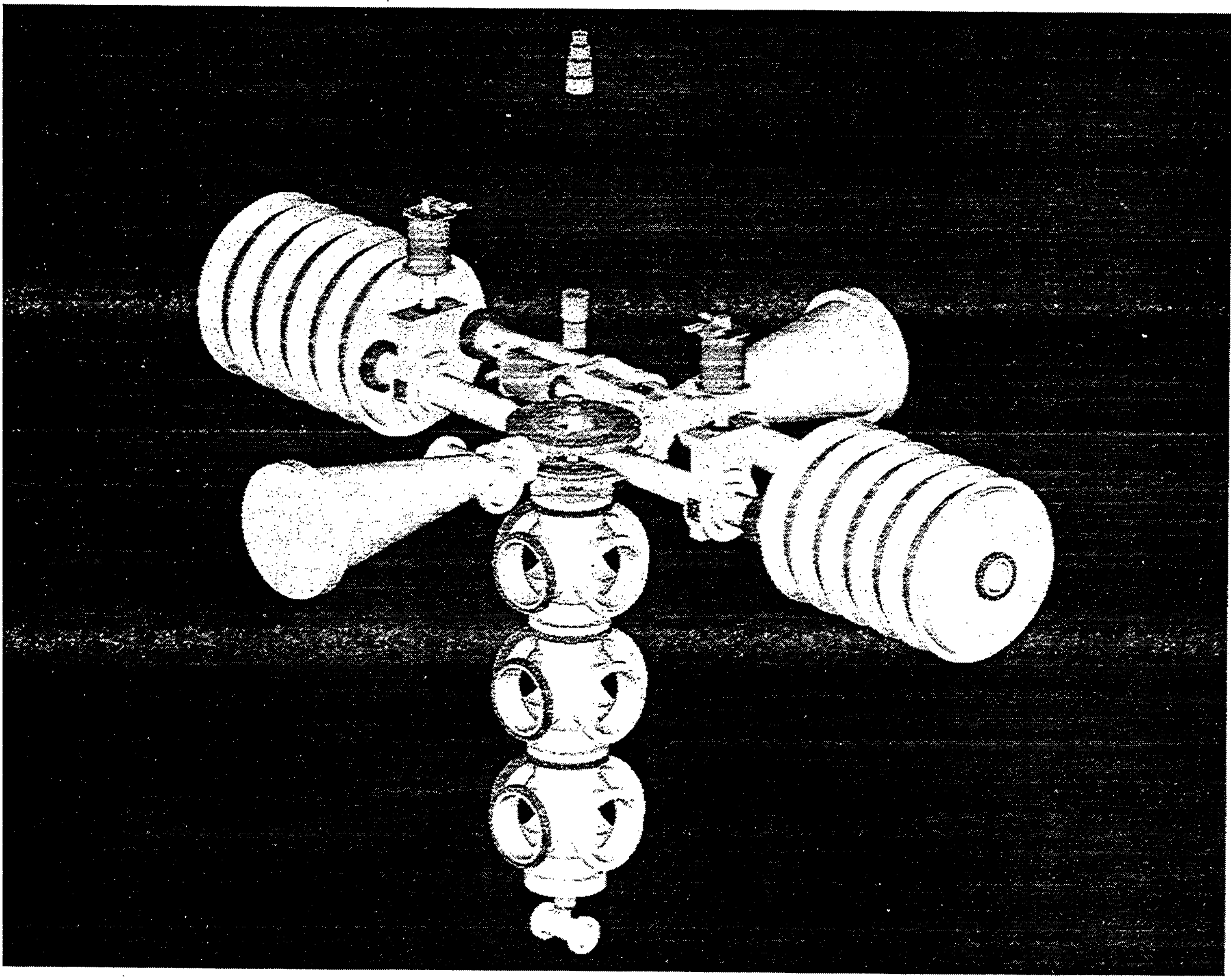
← from
T. Rosen
+
W. MacKay

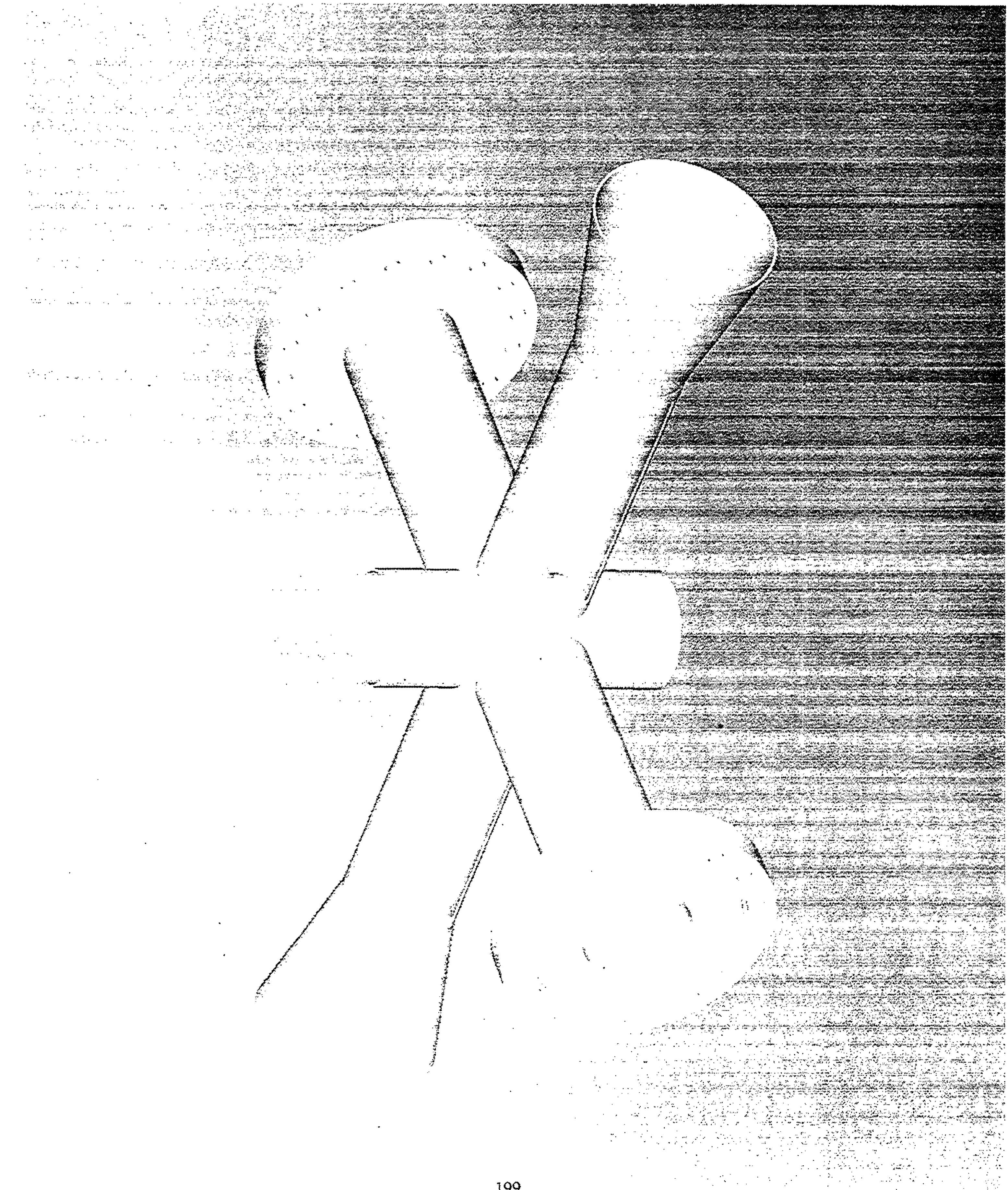
Figure 12. Relative power spectrum for the RHIC proton bunch field.

1−2 3−4
n = 100

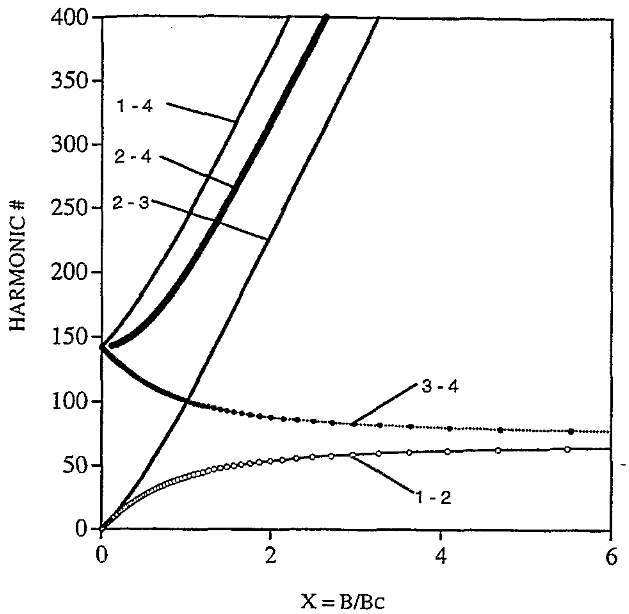
Harmonic # ⟶

RHIC Bunch field depolarization
Calculations.





Beam ↑
HARMONIC #

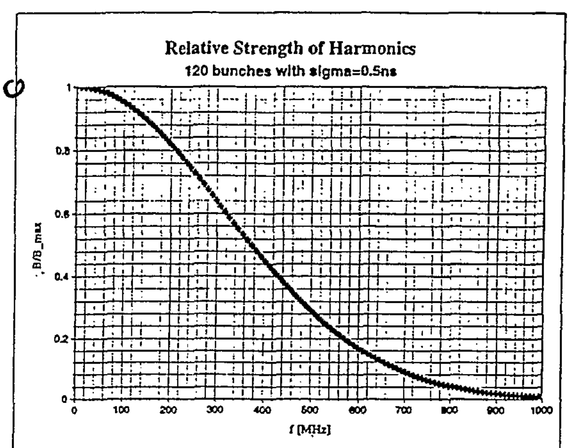


Calculated field values for resonances 1 – 2
+ 3 – 4
~~2 – 3~~
~~2 – 4~~
~~1 – 4~~

Relative Strength
B/B

1.0

0

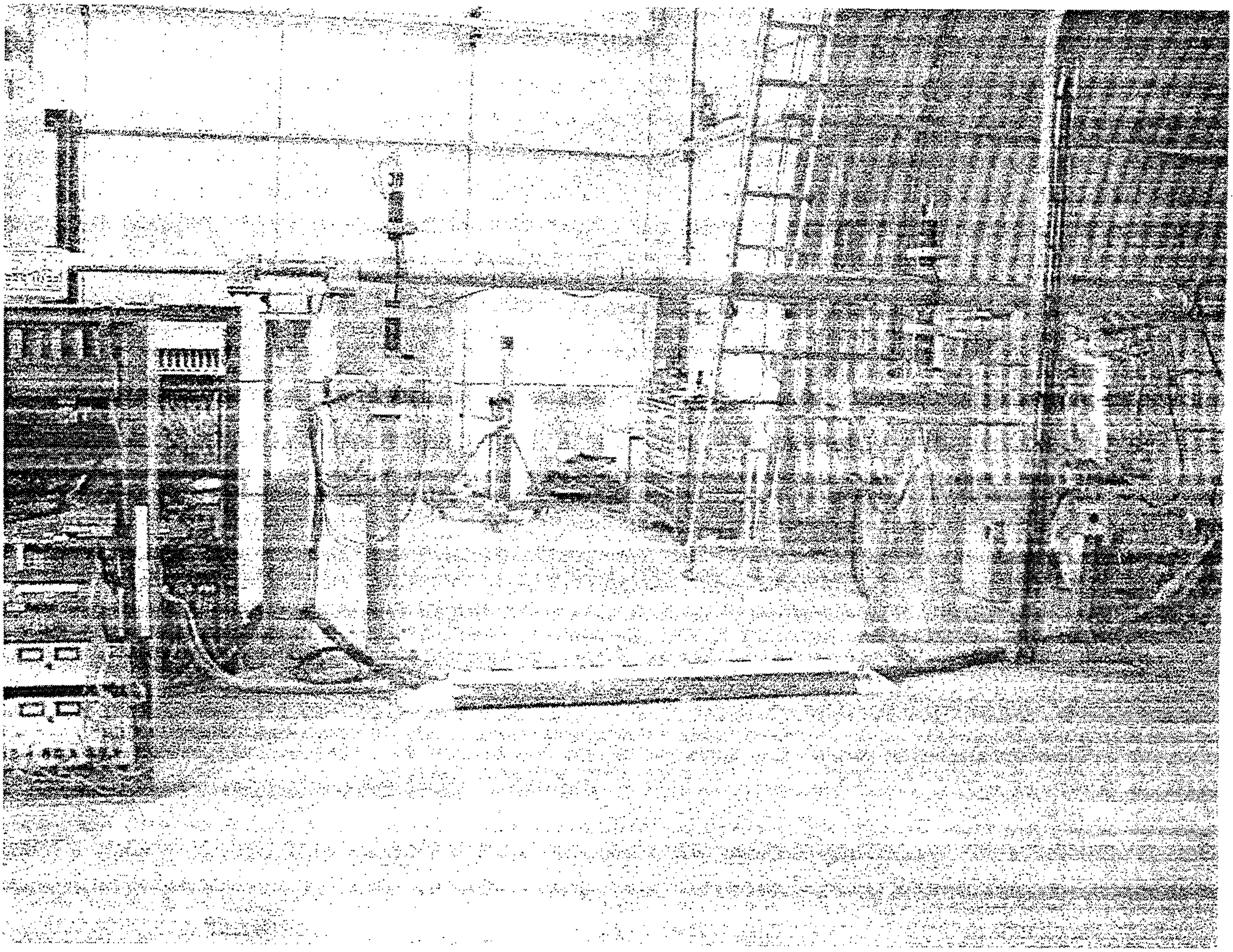


← from T. Rosser + W. MacKay

Figure 12. Relative power spectrum for the RHIC proton bunch field.

Harmonic # → n = 100

RHIC Bunch field depolarization Calculations



REMAINING DESIGN ISSUES

1) MAGNETIC SHIELDING OF Rf TRANSITIONS
   3-D calculations by W. Meng
   correction coils could possibly be needed
2) MEASUREMENT OF H_2 DILUTION OF JET
3) DETECTION LIMIT OF BRP
   Test bench under construction at Wisconsin
4) CAREFUL ESTIMATE OF Si BACKGROUNDS --next talk
5) FINAL DECISION ON JET LOCATION on agenda of JET collaboration meeting June 25
6) BEAM-LINE PUMPING a proposal is under development with BNL vacuum group
7) MECHANICAL MOUNTING AND ALIGNMENT and WIRING/PLUMBING -- how to make compatible with rapid move from staging area to ring?

*** WE ARE NOT YET READY FOR DETAIL ***
DRAWINGS TO BE MADE

al Pazik ?

OTHER TASKS

- COUNTING HOUSE -need cost +arrange for construction

- UTILITIES AND CABLING
  - not yet detailed
  - 40 meter cables

- ANALYSIS SOFTWARE
  - algorithms are known
  - BRP software in progress
  - Si data use existing waveform digitizers from Carbon target

- CONTROLS
  - just beginning
  - preliminary list exists
  - need to time coordinate Si and BRP data

Status Report on the Jet Experiment

A. Bravar, BNL
June 17, 2002

for
RHIC Spin Collaboration Meeting X
RIKEN BNL Research Center

The RHIC Absolute Polarimeter: CNI + Polarized Gas Jet-Target

Alessandro Bravar *et al.*
RHIC Spin Coll. Meeting

- Introduction
- Elastic pp kinematics
- Setup
- Backgrounds
- MonteCarlo Studies
- Recoil detector

Jun 17, 2002

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Method

Choose a process with large σ and known A_N
$\Rightarrow$ *pp* elastic scattering in CNI region
Current knowledge on A_N (exp & theo) to poor for
$\Delta P_{beam} / P_{beam} < 0.05$

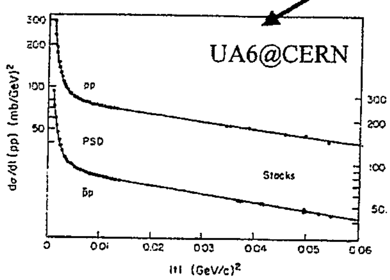
Measure A_N to required accuracy of $\Delta A_N < 10^{-3}$ with unpolarized beam and polarized target ($\Rightarrow \Delta P_{targ} / P_{targ} < 0.02$)

then measure P_{beam} using A_N with polarized beam and unpolarized target
$\Delta P_{beam} / P_{beam} \sim \sqrt{2}\, \Delta A_N / A_N$ (some systematics counts twice)

or Transfer target polarization to beam polarization:
i.e. Measure ratio of spin asymmetries with beam and target polarized
$\Delta P_{beam} / P_{beam} \sim \Delta A_N / A_N$ (some systematics cancels)

NB *Self-Calibration* works with elastic scattering only

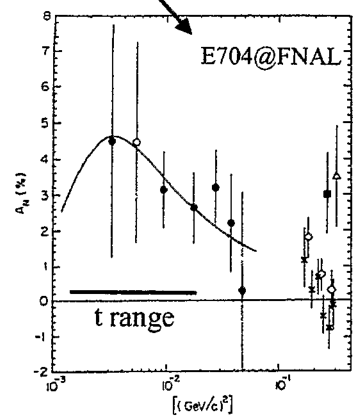
Elastic *pp* $d\sigma / dt$ & A_N



$0.001 < |t| < 0.02$ GeV^2

$<\sigma> = 3$ mbarn

$<A_N> > 0.03$



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RATES

BEAM	TARGET
2×10^{11} p / bunch 120 bunches 78 kHz	3×10^{11} atoms / cm^2

L $= 2\ 10^{11} \times 120 \times 78\ 10^3 \times 3\ 10^{11} = 5.6\ 10^{29}$ cm^{-2}s^{-1}

$= 4.7\ 10^{27}$ cm^{-2}s^{-1} / bunch

N = **L** $<\sigma>$ *acc* ($\Delta\varphi = 30°/2\pi$) *eff* (50%) = 70 evt s^{-1}

~ 0.5 evt s^{-1} / bunch

in 12 hours can collect 3×10^6 events

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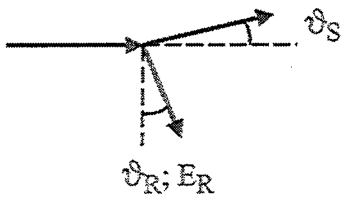
Kinematics



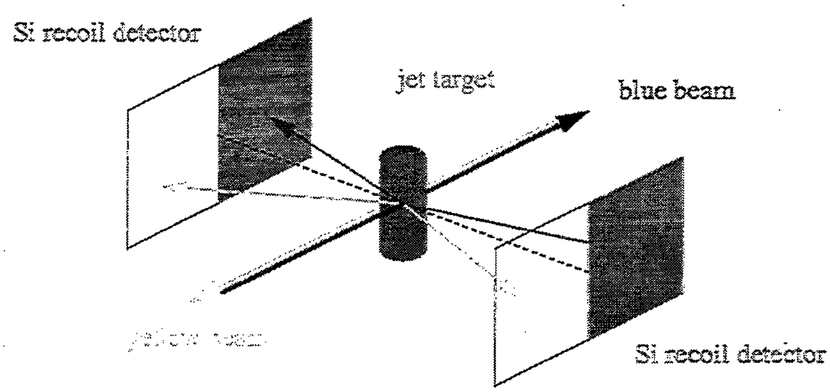
t : 0.001 – 0.02 GeV^2
ϑ_R : 1 – 5 degrees
T_{kin} : 0.5 – 10 MeV
p_R : 30 – 140 MeV

Essentially only 1 free parameter: t (+ φ) ⇒
elastic *pp* kinematics fully constrained by recoil proton !

$$\sin\vartheta_R \approx \left(1+\frac{m_p}{p_{beam}}\right)\frac{\sqrt{|t|}}{2m_p} \qquad t=-2m_pT_{kin}$$

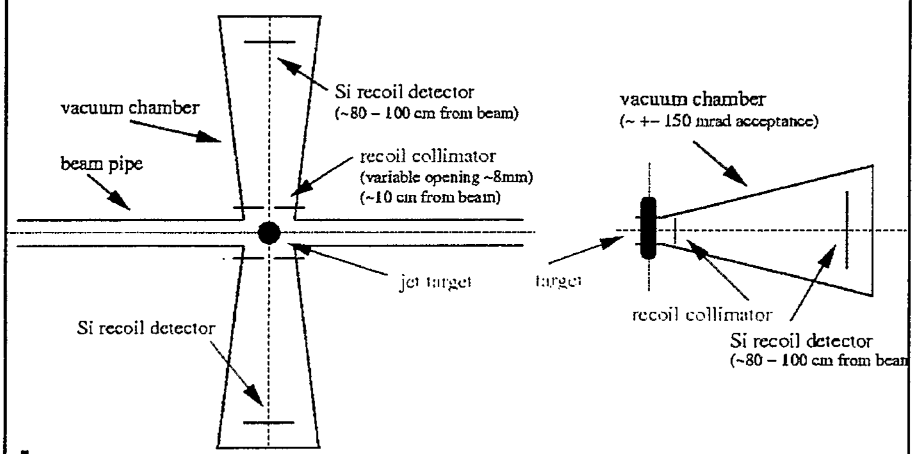
measure position and energy of recoil ⇒ ϑ_R and t

Setup



energy → t
position → ϑ_R
time

Setup: top view side view



MonteCarlo Studies

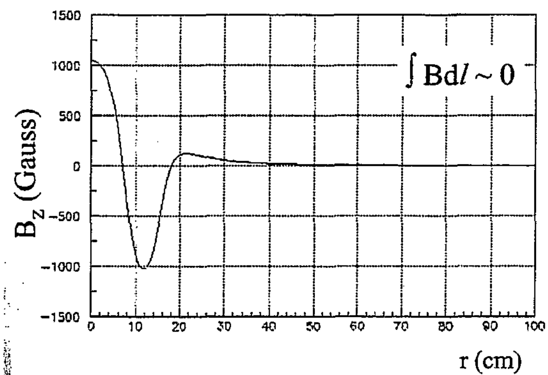
Inputs:

- *pp* elastic cross section (differential)
- jet target profile (T. Wise)
- target holding magnetic field (W. Meng)

Outputs:

- design of recoil spectrometer
- resolution of recoil spetrometer M_X and ϑ_R
- separation of elastic *pp* from non-elastic *pp* (background)

Jet-target holding field

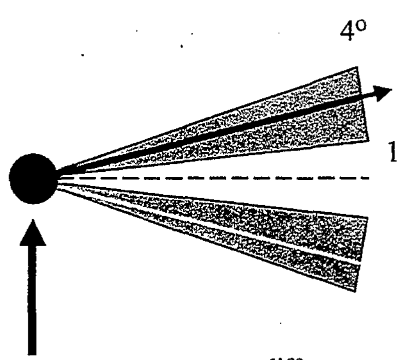


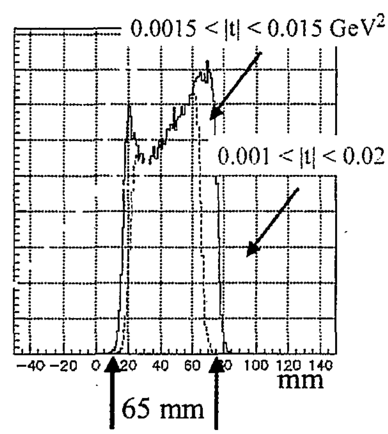
almost no effect on recoil proton trajectories

left – right hit profiles almost identical

left – right acceptance almost equal

Recoil hit profiles @ 100 cm





diff. x-sect.
kinematics
target profile

Background: We can live with it !

Mainly three sources of background:

- Beam – gas interactions: at 10^{-9} torr, ~ 10^{7} atoms / cm^3
- Proton dissociation $pp \rightarrow Xp$
- Beam – residual jet-target gas interactions (suppress with collimator)

Acceptable level of background:

$$A_N^{mes} = A_N - \left(A_N - A_N^{BG}\right) \cdot R \qquad R = \frac{N^{BG}}{N^S + N^{BG}}$$

$$\Delta A_N < 10^{-3} \;\Rightarrow\; \left|A_N - A_N^{BG}\right| \cdot R < 10^{-3}$$

For $A_N^{BG} \sim 10\%$ (0%), $R \sim 1\%$ (3%) acceptable

Otherwise Background Subtraction

For $R \sim 5\%$ (2%) $\rightarrow$ $\Delta R \sim 5\%$ (2%) OK for $A_N^{BG} \sim 30\%$

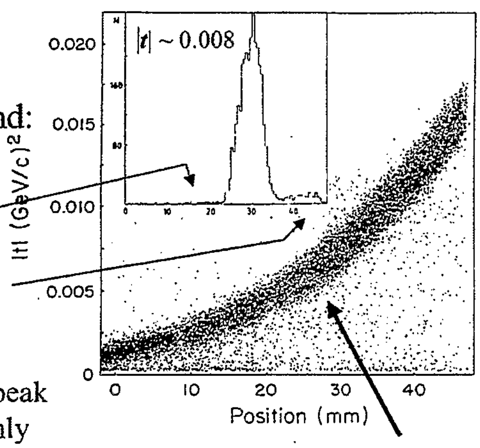
For $R \sim 2\%$ $\rightarrow$ $\Delta R \sim 10\%$ OK for $A_N^{BG} \sim 30\%$

|t| vs pos. from UA6 $\rightarrow$ background

two sources of background:

a) beam gas interactions
few %

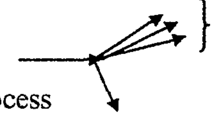
b) beam proton dissociation
few % below elastic peak



less than 5 % below elastic peak using the recoil technique only

elastic *pp*

$pp \to Xp$ Dissociation



Kinematically quite different from elastic process

$$\sin\vartheta_R^{Xp} = \frac{M_X^2 - m_p^2}{2p_b\sqrt{|t|}} + \sin\vartheta_R^{el} \; > \; \sin\vartheta_R^{el}$$

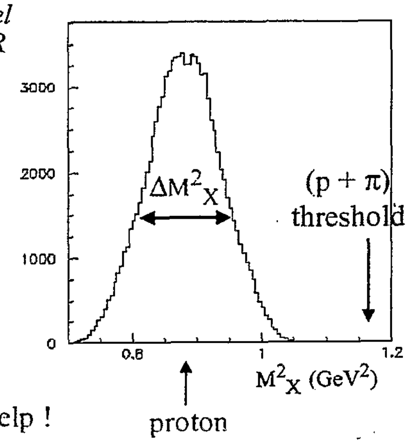
Suppresion of $pp \to Xp$ depends on how well one can reconstruct M_X

$$\Delta M_X^2 \approx 2p_b\sqrt{|t|}\Delta\vartheta_R$$

if $\Delta M_X^2 << (m_p + m_\pi)^2 - m_p^2$ OK

resolution on ϑ_R depends on
distance from target and
target profile

NB at threshold coplanarity doesn't help !



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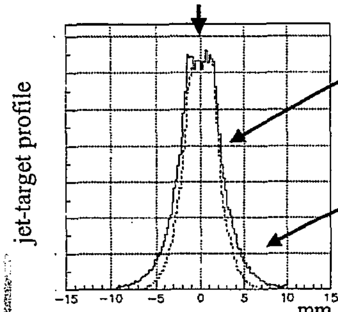
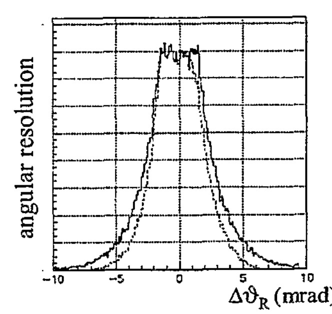
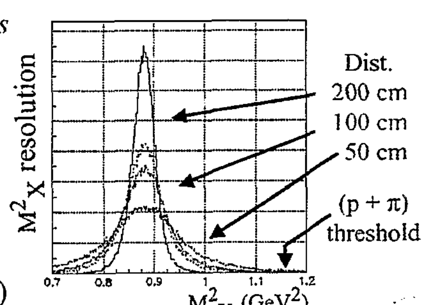
resolution

ΔM_X and $\Delta\vartheta_R$ depend on jet-target profile







1 free parameter to choose:
distance from jet-target
(could also narrow target profile)

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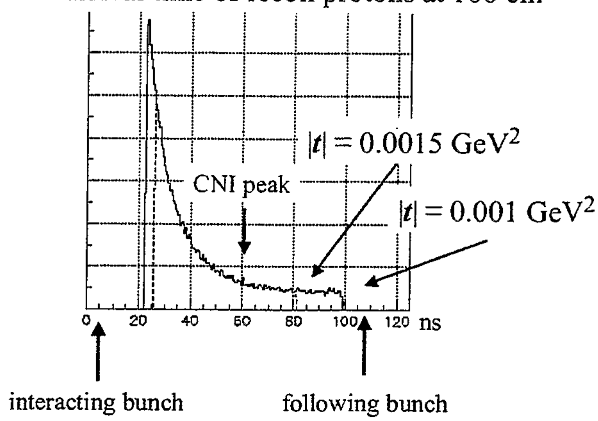
time of flight

arrival time of recoil protons at 100 cm



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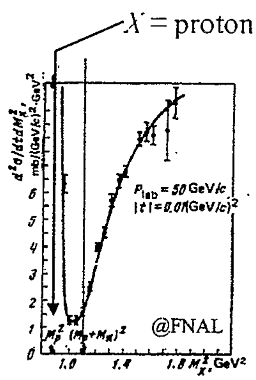
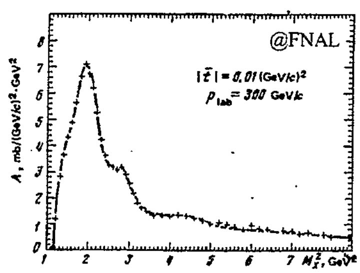
$\Delta\sigma$ / dM^2_X





σ (*elastic*) ~ 100 x σ ($pp \to Xp$) at threshold !

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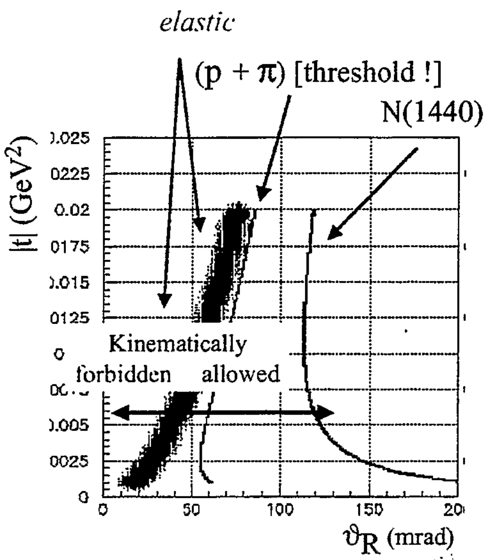
t vs ϑ_R

reconstructed from:
1. deposited energy
2. hit position

recoil spectrometer resolutions:

$\Delta\vartheta_R$ = targ. ext. / dist.
~ 3 mrad

$|t| = 2\, m_p\, T_{kin}$
$\Delta\, T_{kin} < 100$ keV



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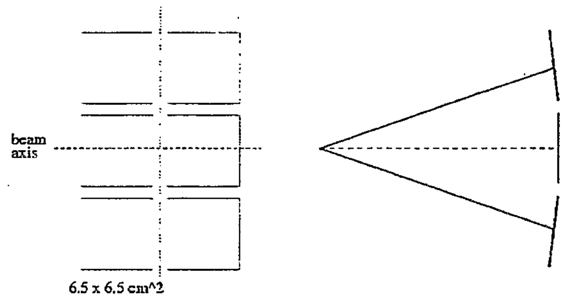
Si Recoil Detector



Requirements
- good energy resolution
  $\Delta E < 0.1$ MeV
- space resolution
  $\Delta x \sim$ few mm
- time resolution
  $\Delta t \sim 1$ (2) ns

horizontal segmentation ~ 4 mm (16 ch.)
vertical segmentation ~ 8 mm (8 ch.) ⇒ $\delta\varphi \sim 10$ mrad

thickness: 0.5 mm ⇒ stops up to 8 MeV protons
veto for faster protons?

under development (Inst. Div. @ BNL)

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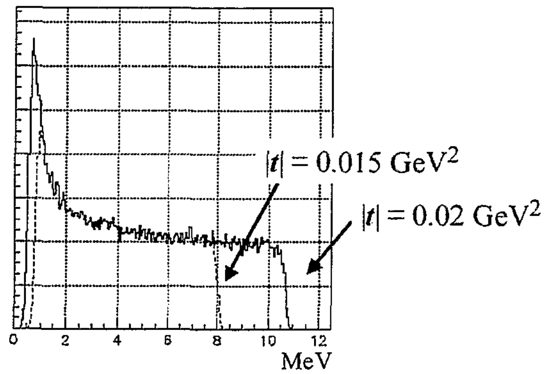
Energy deposited in Si detector



mip in 0.5 mm of Si deposits 150 keV
lowest energy protons (t = 0.001 GeV^2, T_{kin} = 0.5 MeV)
~ 3 mip signal
signal / noise comfortable

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Readout

2 x 144 channels

Similar to RHIC pC polarimeters
- preamplifier boards just outside of vacuum chamber
- signal transport to counting room with coaxial cables or optical fibers
- shapers (amplifier boards)
- Wave Form Digitizers (Satish @ Yale)

Low Rate
- can record waveform for each event

Under development (Inst. Div. @ BNL)

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Summary

Comfortable statistics (3×10^6 events in ~ 12 hours)

$\Delta p_{beam} / p_{beam} < 5\%$

⇒ $\Delta A_N < 10^{-3}$ ... feasible, but $\Delta p_{targ} / p_{targ} \sim 2\%$ & bkg < few %

Background under control (not too bad !)

- Roman pots not necessary in CNI region
  useful for background studies

Recoil detector based on existing technology

Readout similar to RHIC pC polarimeters

Recoil detector and readout electronics under development, first prototypes this fall

Additional MonteCarlo studies under way

Asymmetry Extraction under study

Timeline Discussion

Y. Makdisi, BNL
June 17, 2002

for
RHIC Spin Collaboration Meeting X
RIKEN BNL Research Center

Makdisi 6/17/02

Polarized Jet Target

Game Plan, Schedules, Funding issues

Boundary Conditions:

- Funding began in earnest this fiscal year from the following sources:

Reprogrammed Medium energy physics:	$ 75k
RHIC Detector capital funds	$300k
Direct DOE NP funds	$275k
Totals	$650k

- DOE NP may be able to provide some additional funding this FY.
- We have requested another $500 (conventional const)
  $200 (RHIC compatible Controls)

The Promise:

- Design, contruct, test, the Jet awat from RHIC
- Install the Jet in the tunnel by the beginning of the Run October 2003

The plan:

- Run on all cylinders with parallel efforts where possible

Wisconsin

Overall design/ Coordination
Sextupoles completed and RFQ placed with vendors
RF systems purchased and tested w/ Wisc. Source
Breit Rabi designed built and tested w/ Wisc. Source

BNL C-AD

Holding field magnet design and build
Magnetic measurements / (w/ RF units?)
ABS/ BRP/ Target chamber vacuum housing and support
Over all mechanical systems and pumping
Dissociator, design construction and testing

BNL-Spin phys/RBRC/Instrumentation/ IUCF/Yale

Silicon recoil detectors and testing

BNL- Spin phys/ ITEP /Yale

DAQ

The schedule Milestones

- Funding started February 2002
- Design and construction of various components/ testing by January 2003
- Develop a test bench at the BNL – LINAC area August 2002
- Start work on the Jet controls November 2002 for delivery May/June 2003
- Subsystems arrive at BNL in the January/ February, 2003
- Assemble and test jet components at the LINAC through August 2003
- Conventional construction and support
- Move Jet in one piece from LINAC and Install in RHIC September 2003

Manpower at BNL C-AD

- Overall mechanical design and assembly
  - Lead mechanical engineer (George Mahler) onboard
  - Design shop support as required
- Magnetic field analysis
  - Wuzheng Meng
  - Magnet measurement group
- LINAC/ injector group
  - Anatoli Zelenski, physicist
  - Russian technical help (two people)
  - Engineering, John Ritter
  - Technical support (1/2 FTE as needed)

  Design and build the dissociator
  Prepare the test bench at the LINAC
  Help with the assembly and testing

  Group will assume responsibility to operate and maintain the jet

- C-AD Vacuum
  - Dick Hseuh (engineering design and consultation)
  - Engineering to design the vacuum controls

- Controls Group

  Engineering to develop and integrate the jet controls

- Beam Instrumentation group
  - Technician support as required during installation at RHIC

Goals:

- Install in RHIC, provide an early calibration of the local polarimeters to the 10% level.
- Refine and improve to attain the 5% absolute beam polarization calibration.

Update on the AGS Polarization Offline Analysis

H. Huang, BNL
June 17, 2002

for
RHIC Spin Collaboration Meeting X
RIKEN BNL Research Center

AGS Polarization Analysis

Calibration runs for $G\gamma=7.5$

Partial snake to overcome 0+ ν_y

Spin tracking for all intrinsic resonances

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Calibration of AGS polarimeter at $G\gamma = 7.5$

Two forward arms were installed to detect inclusive p-p scattering for several low energies: $G\gamma = 4.7, 7.5, 13.5$. Combined with the recoil arms, we can select elastic scattering. The purpose is to solve the puzzle of injection beam polarization. Due to the limited time, only $G\gamma = 7.5$ detectors were used.

1. Polarization measured at $G\gamma = 7.5$ agreed with 200 MeV measurements.
2. We still do not have explanation for the low asymmetry measured at $G\gamma = 7.5$ in Sep. 2000.

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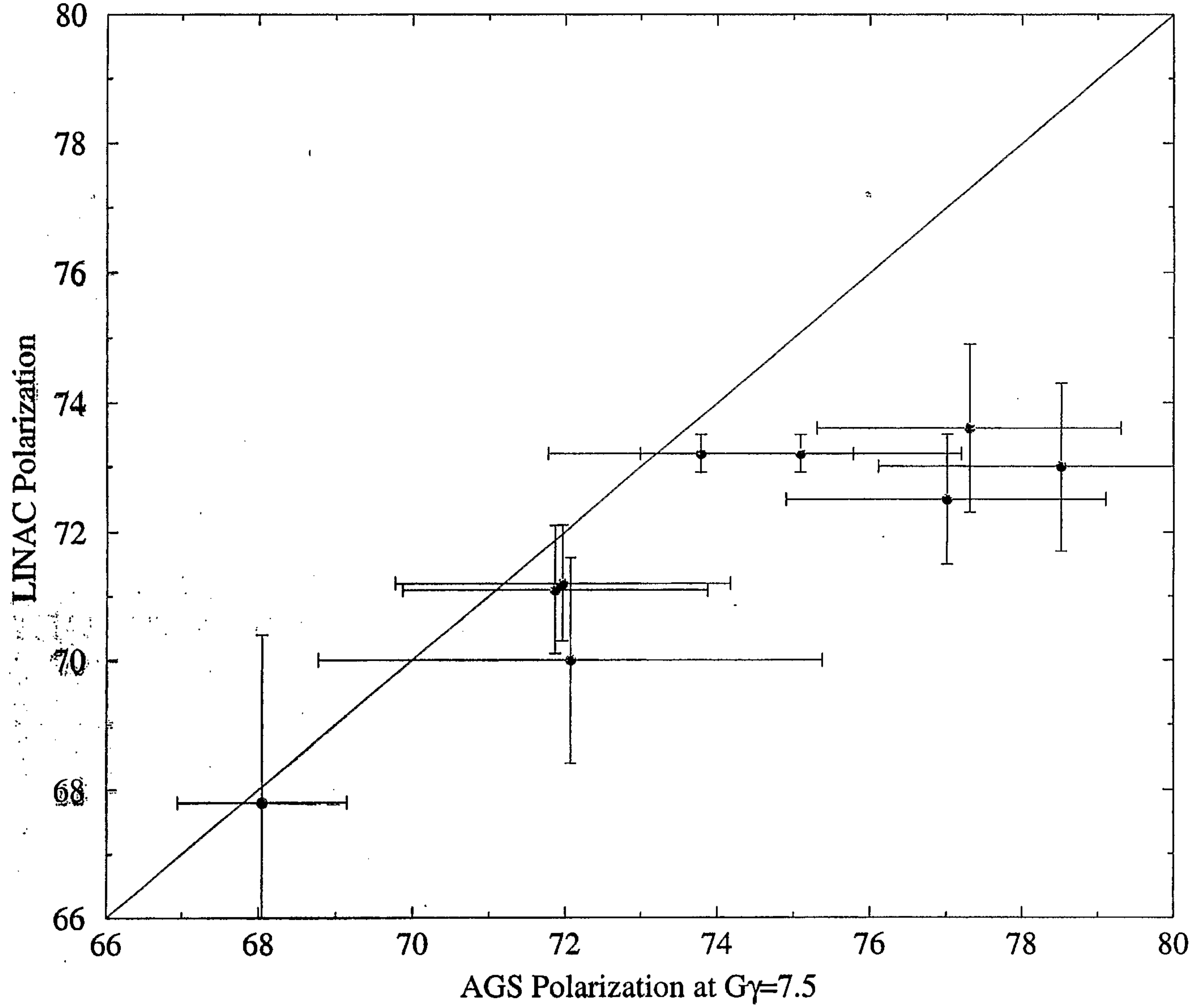
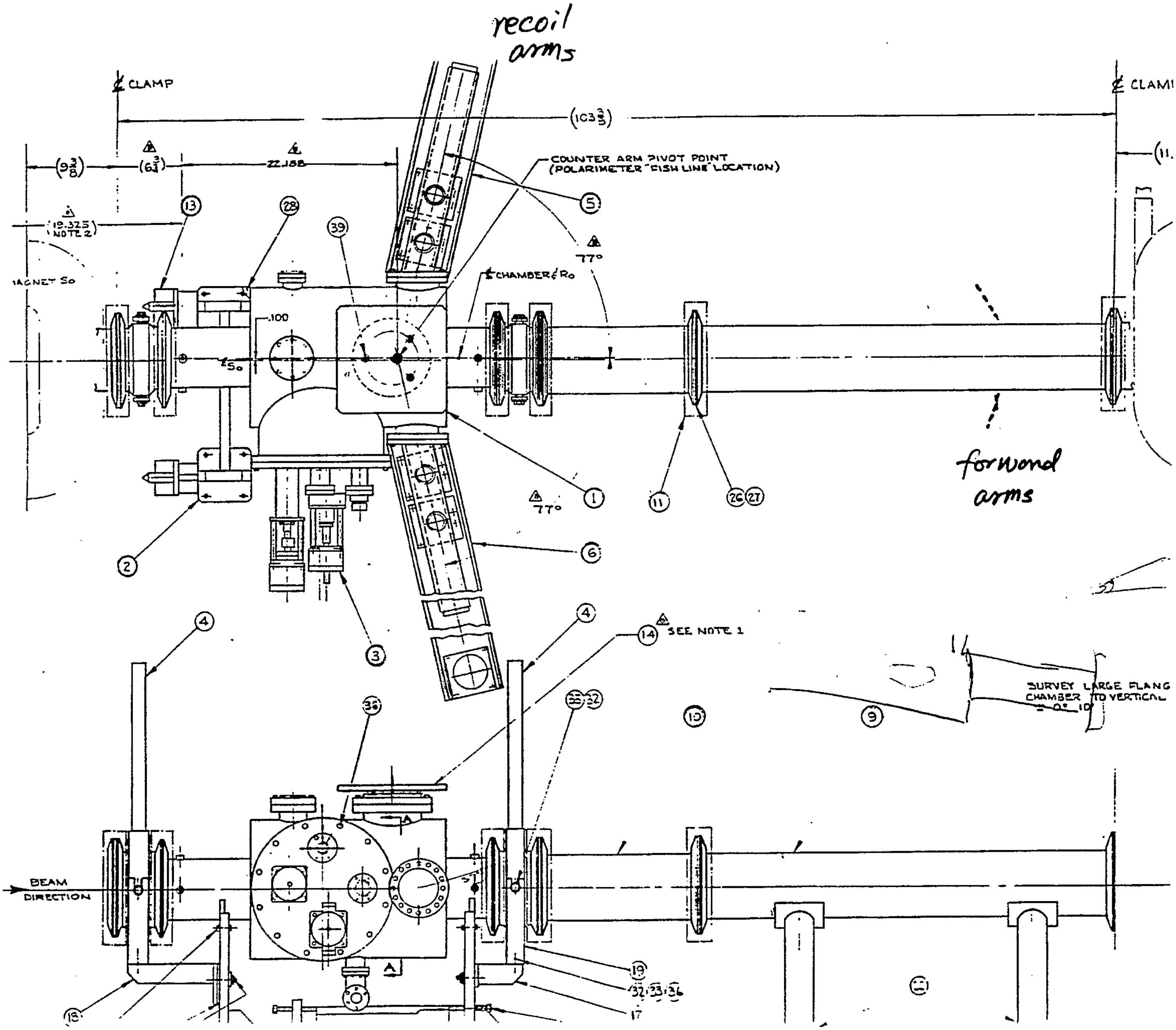

LINAC Polarization
AGS Polarization at Gγ=7.5
80
78
76
74
72
70
68
66
66
68
70
72
74
76
78
80

C-20 E880 polarimeter

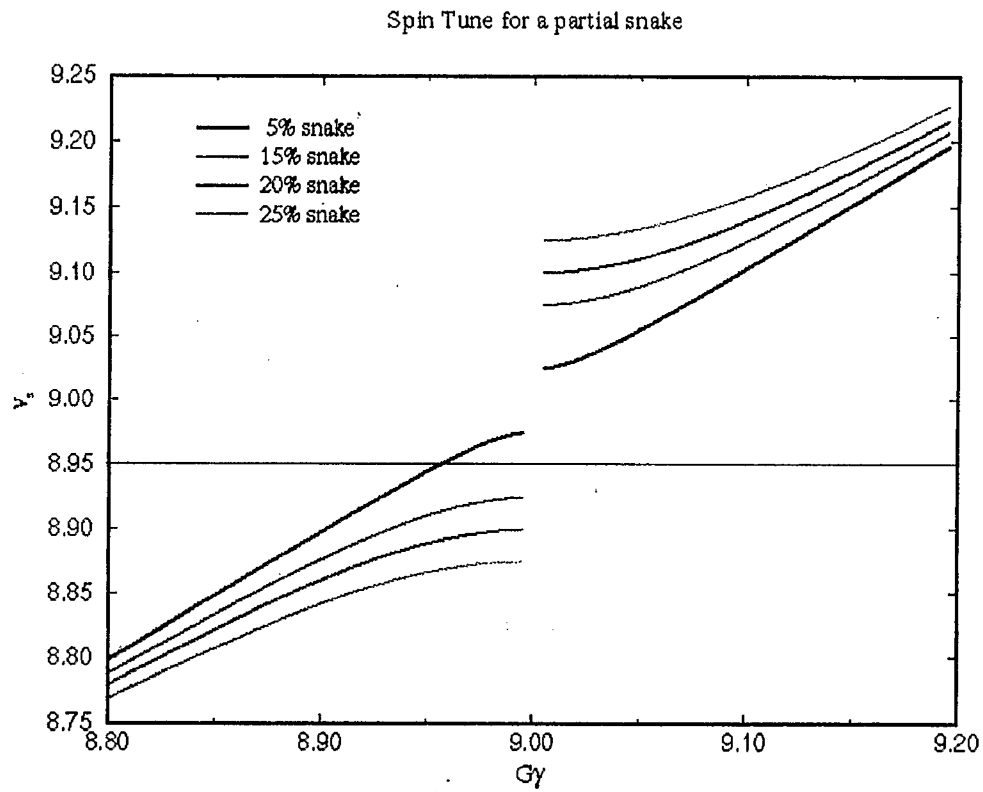


beam pipe thickness 0.109 in (0.28 cm) diameter 7 in.

available space ~ 2 meters

How a strong snake works

- The stronger the snake, the larger the spin tune gap when $G\gamma=N$. When the snake is strong enough so we can put betatron tune in the gap, then the resonance condition will never be met.
- In a different view, The snake acts as a resonance at $G\gamma=N$. If the intrinsic resonance is overpowered by the snake, then full spin flip can be achieved.



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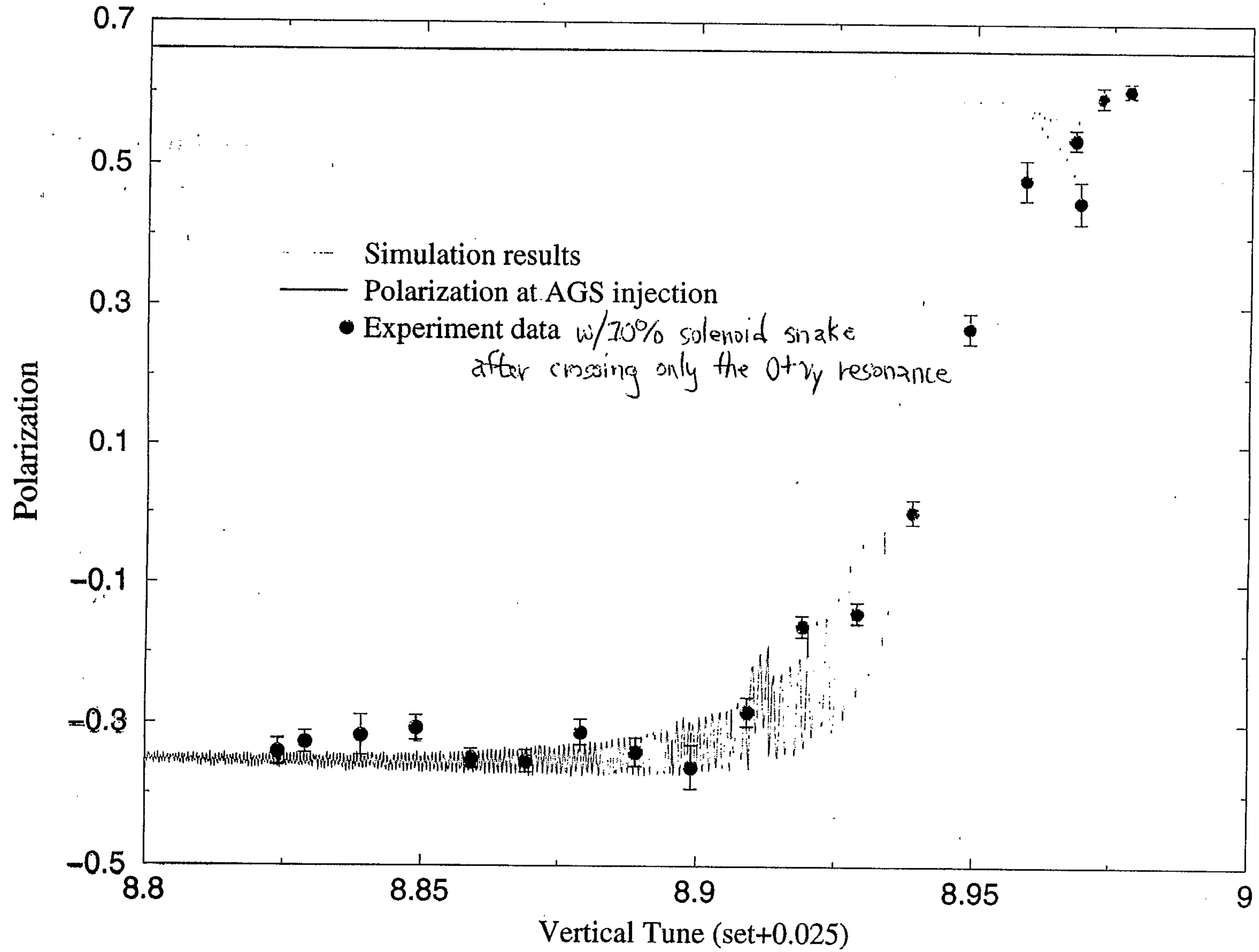
Polarization
0.7
0.5
0.3
0.1
−0.1
−0.3
−0.5
8.8
8.85
8.9
8.95
9
Vertical Tune (set+0.025)
Simulation results
Polarization at AGS injection
Experiment data w/70% solenoid snake
after crossing only the 0+νy resonance

Emittance and Ramp Rate

There is emittance growth in the AGS even without AC dipole.
---AtR beam profile measurements.
---Careful beam profile study with AGS IPM.

There were three runs with beam accelerated to $G\gamma$=46.5:
Nov. 97, Sep. 00, and Jan. 02.

The spin tracking shows agreement with Nov. 97 and Sept. 00 runs.
These two runs used fast ramp (Siemans).

There is discrepancy in Jan. 02. The polarization measurements suggest polarization loss around $0+\nu_y$ and $24-\nu_y$. Similar mystery happened for slow ramp case in April 94.

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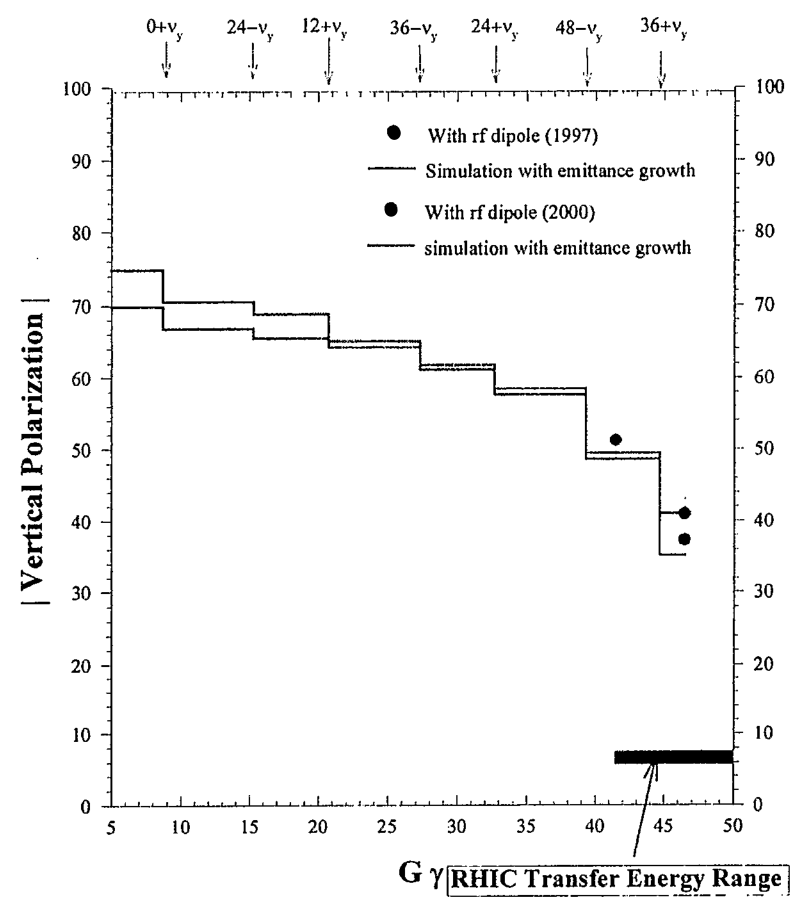
AGS Performance in 97 and 00

Red line: Simulation with 1997 running conditions, 75% as input from LINAC. Betatron tune separation 0.15 except 36+ν_y and 48-ν_y with 0.13. Horizontal emittance was big: ~40π.

Green line: Simulation with 2000 commissioning conditions, 70% as input from LINAC. Betatron tune separation 0.15 except 36+ν_y with 0.11. Horizontal emittance was reduced: 15 π at injection and 22π at extraction.

ν_x=8.85, ν_y=8.70 for both years.



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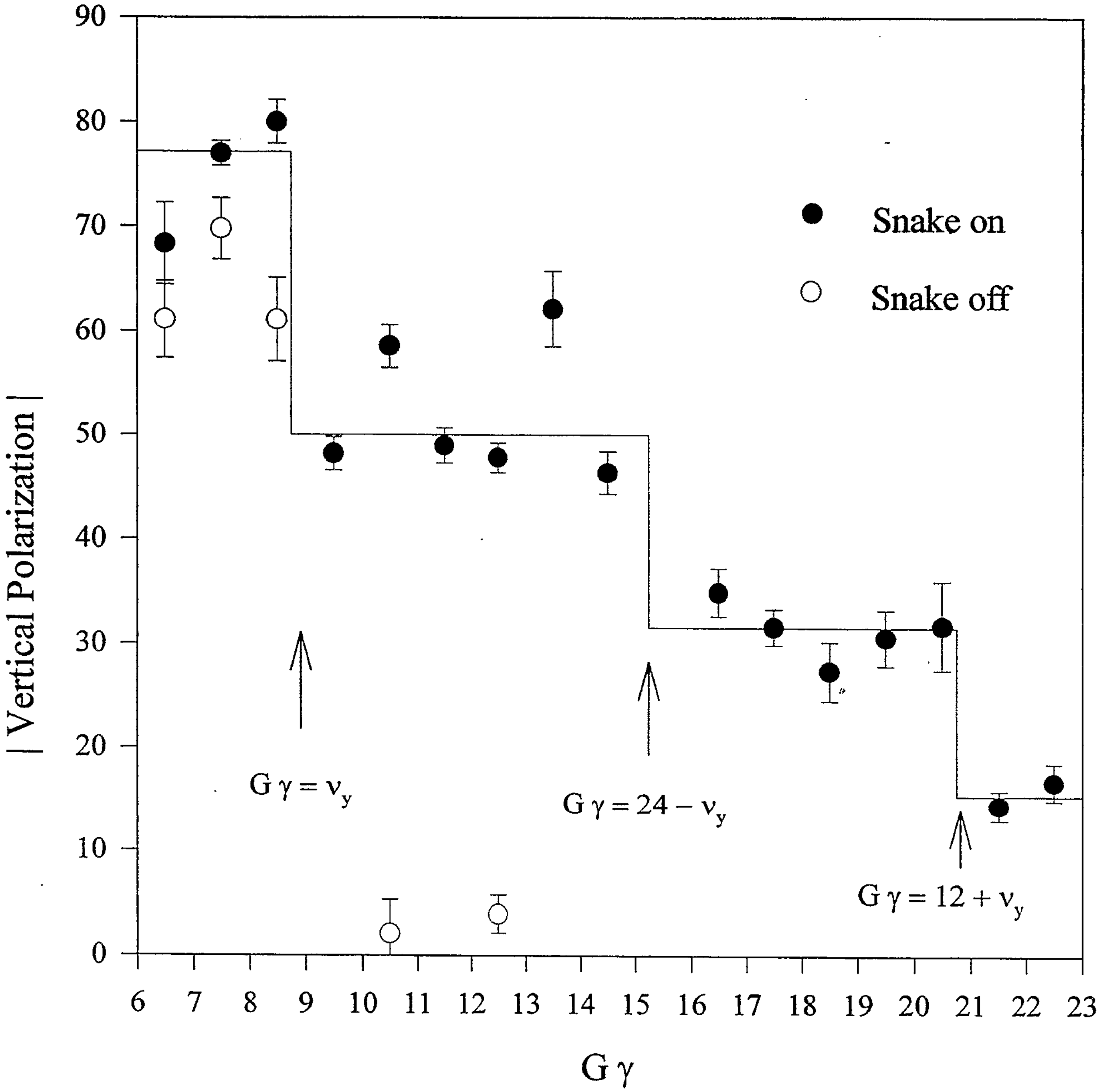
E880 April 1994 Run

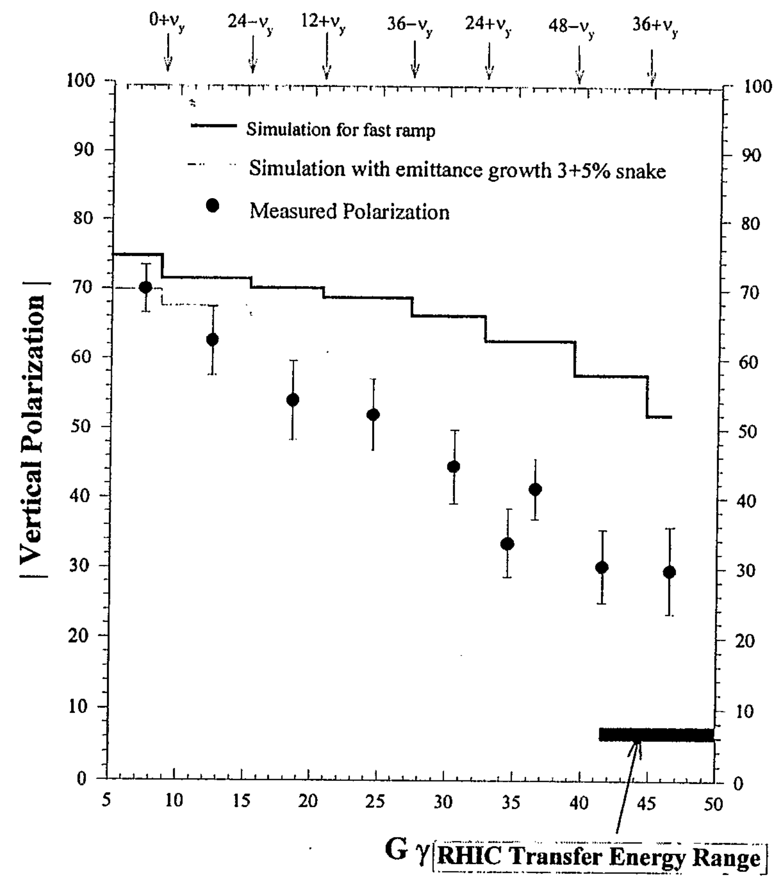


AGS Performance in 02

Red line: Simulation with 2002 running conditions, 70% as input from LINAC. Emittance taken as measured.

ν_x =8.70, ν_y =8.80 for most resonance except 36+ ν_y with ν_x =8.68, ν_y =8.90 and ac dipole not fired.

Blue line: use sept. 00 running condition except more tune separation at 36+ ν_y and good betatron tunes for 48-ν_y.



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Depolarization around $0+\nu_y$ and $24-\nu_y$

1. A stronger resonance at $24-\nu_y$.
2. Synchrotron motion . Since this resonance is very close to the AGS transition, the momentum spread can be large and may cause beam crossing through this resonance multiple times.
3. J10 bump power supply noise.

These will be the focus of spin tracking study in the coming month.

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Status Report on the New AGS CNI Polarimeter

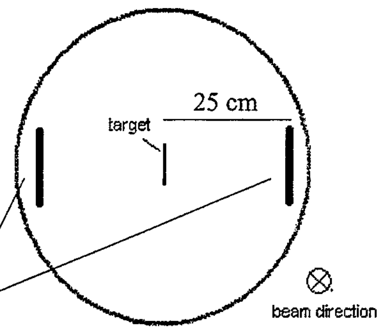
Jeff Wood, UCLA
for the
AGS Polarimeter Group

Outline

- New polarimeter
  - What is it?
  - Why do we need it?
- Hardware
  - What we have
  - What we need
- Noise Study
  - Noise in the AGS environment
  - Test with new chamber
- To Do List
- Summary and Outlook

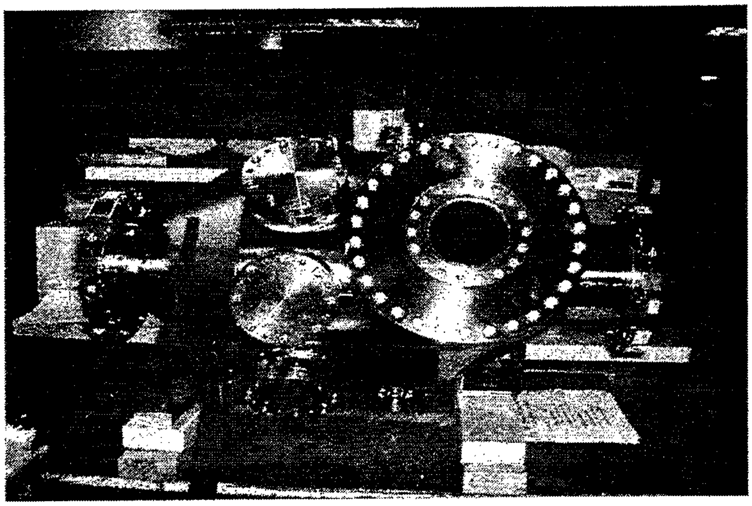
AGS CNI Polarimeter

- What is it?
  - pC elastic scattering in CNI region
  - Similar to RHIC polarimeters
  - Left/right Si strip detectors



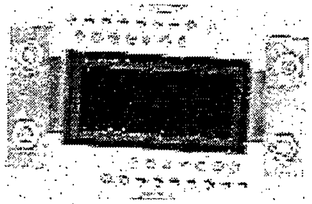
- Why do we need it?
  - Fast pol. measurements (.
  - Provide information for AGS tuning
  - Locate where polarization losses occur

Polarimeter Chamber

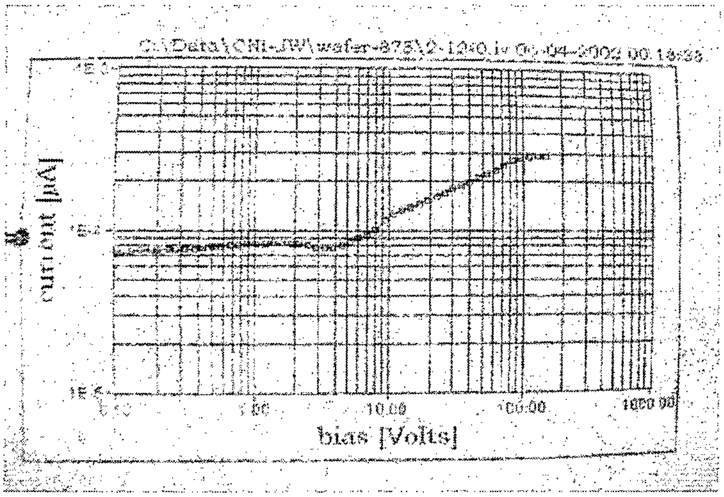


- Now sitting in bldg. 919A
- Stand being machined @ UCLA

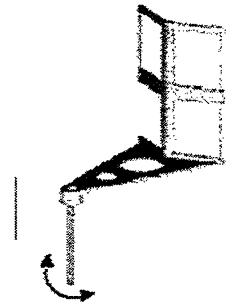
Si Strip Detectors



- Need for next run: 2 + spares
- Have: 15 (w/ acceptable leakage current)

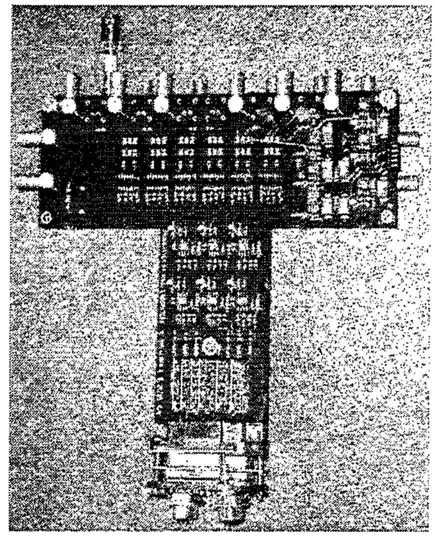


Target



- Current RHIC target
  - Width = 11.6 m
  - Thickness = 5 □g/cm2
  - Length = 3 cm
- New target being developed – Bill Lozowski, IUCF
  - Wider □ increased rates
  - Longer □ wider beam at AGS injection
- Motor and drives for target have been ordered
- Learning to develop targets @ BNL for future

Electronics

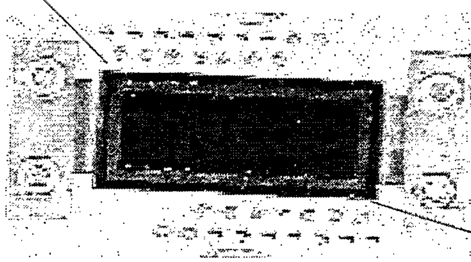


- Pre-amp pc boards
  - Need: 4 + spares
  - Have: 1 used for bench tests
- Pre-amp cards
  - Need: 24 + spares
  - Have: 30
- Shapers
  - Need: 24 channels
  - Have: 1 used for bench test & noise study
- WFD
  - Need: 6 modules (4 ch/module)
  - 12 new modules being built @ Yale – ready 9/02
    - Memory upgrade ⇒ μεασυρε ωηιλε αχχελερατινγ

AGS Noise Study

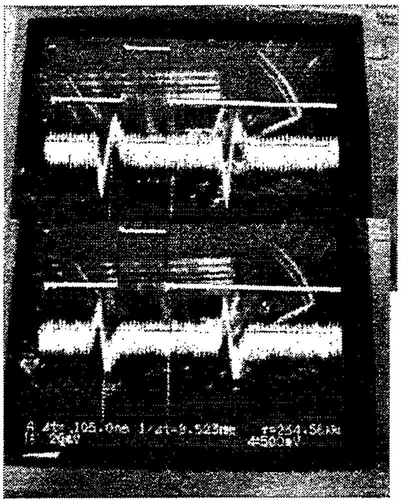
- Si detector & pre-amp board installed in AGS
  - E880 polarimeter chamber in C15
  - During high intensity proton run
    - 6 bunch mode
    - I_{beam} = 6 Tp/bunch
    - I_{beam} = 0.25 Tp/bunch by request

Wire bonding for strips 1-6

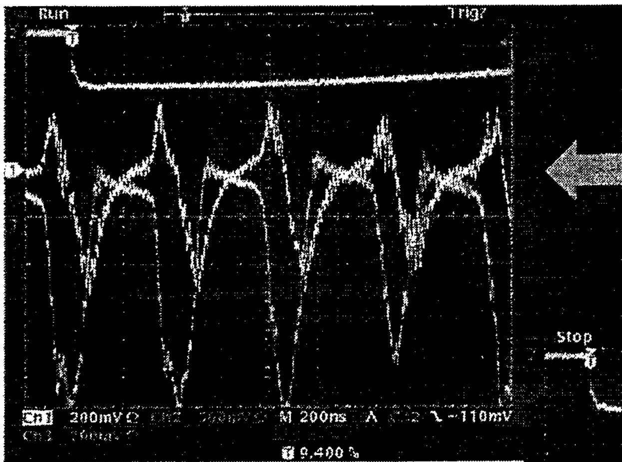


strips 7-12

Bunch reflection seen in RHIC

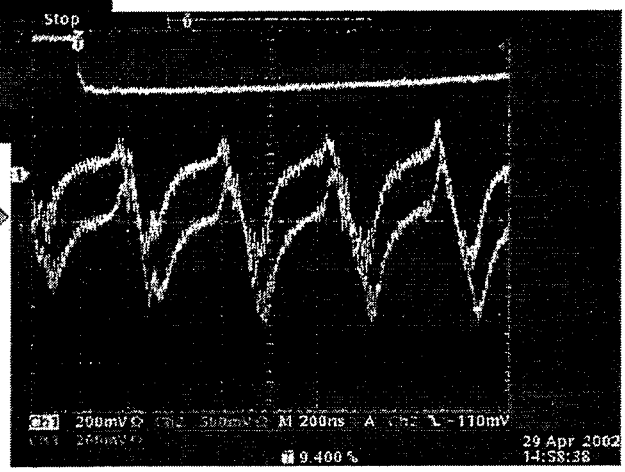


Output from pre-amps:



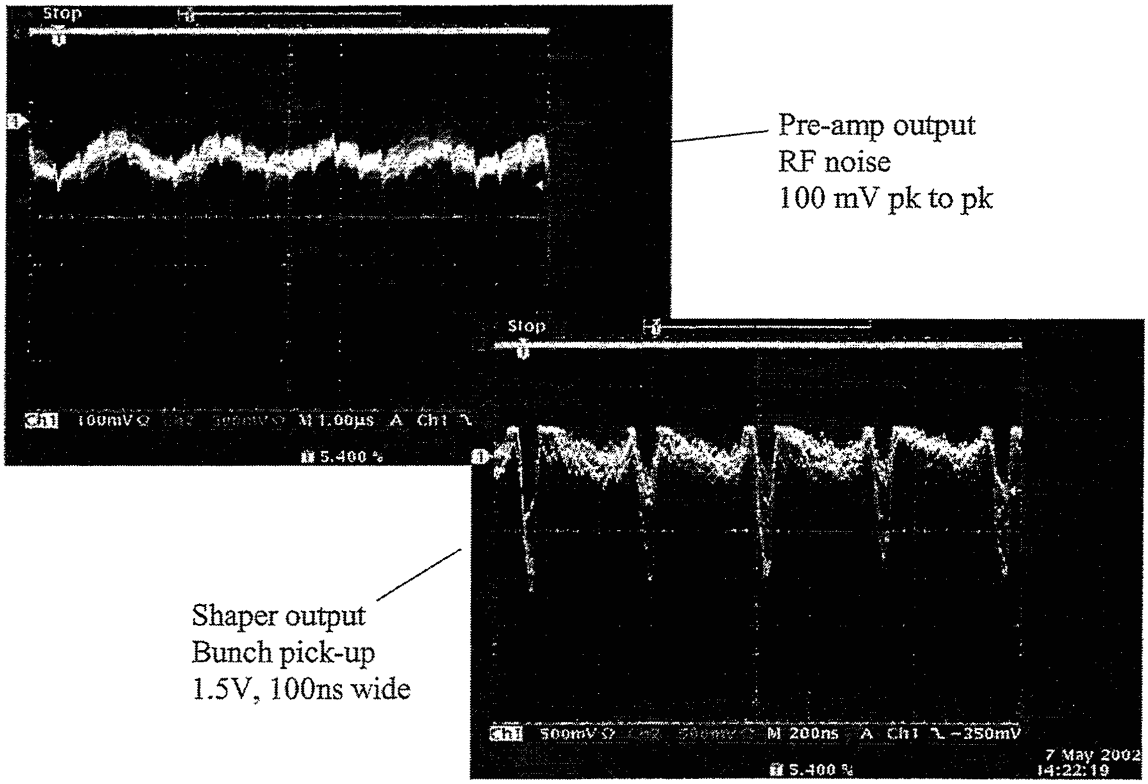
800 mV pk to pk
Strip 7 1V pk to pk

600 mV pk to pk
Strip 6



Bi-polar structure seen in RHIC not present.

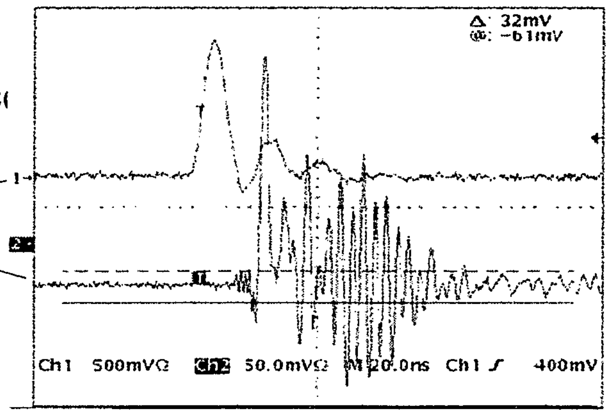
Lower intensity (1.5Tp/6 bunches)



AGS Chamber Test

- Send current pulse through chamber
  - V_{pulse} 1.5V, width □ 15ns
- Signal induced on detector
  - Vreflect □ 200mV, width w/ ringing □ 60ns

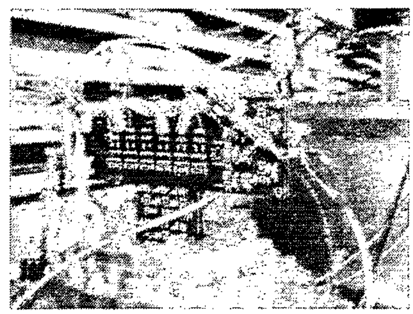
- No Vbias dependenc
- No shielding, yet



On-going studies
being performed
by Roger Connolly

Still To Do

- Design feedback circuit for noise subtraction (E950 - advice from Doug Fields)
- Design, fabricate shielding for pre-amp electronics
- Assemble, install and make it work



Summary - Hardware

- Chamber √
- Si strip detectors √
- Target - R&D on-going
- Electronics
  - Pre-amp pc boards - need to order more
  - Pre-amp cards √
  - Shapers - need to order more
  - WFD - ready 9/02

Summary – Noise Reduction

- Still learning from chamber bench tests
- More work planned for noise reduction
  - Noise subtraction circuit
  - Electronics shielding

Outlook

Expect to be ready for installation 9/02

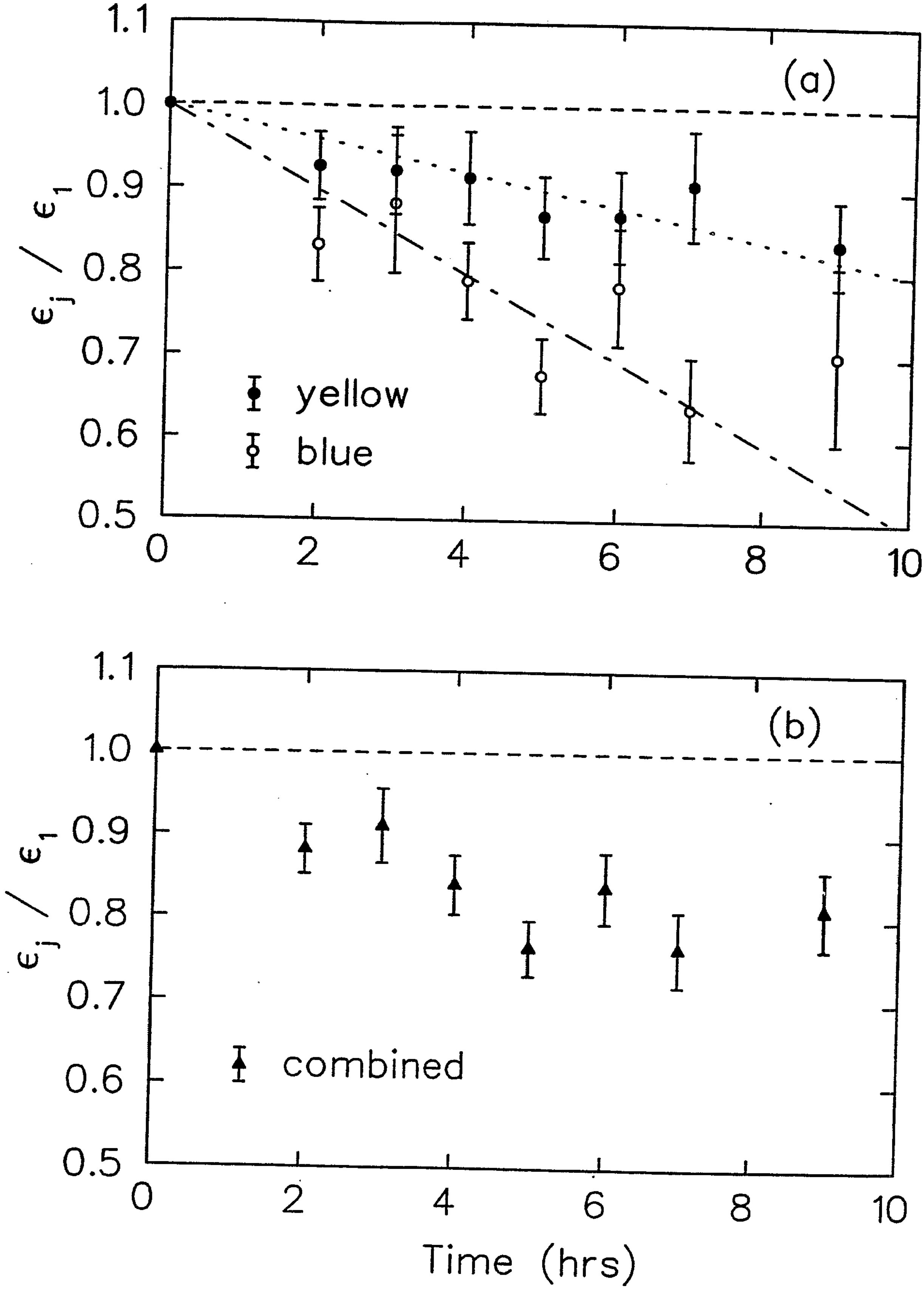
Some RHIC Polarimeter Analysis

by ANL People and Others

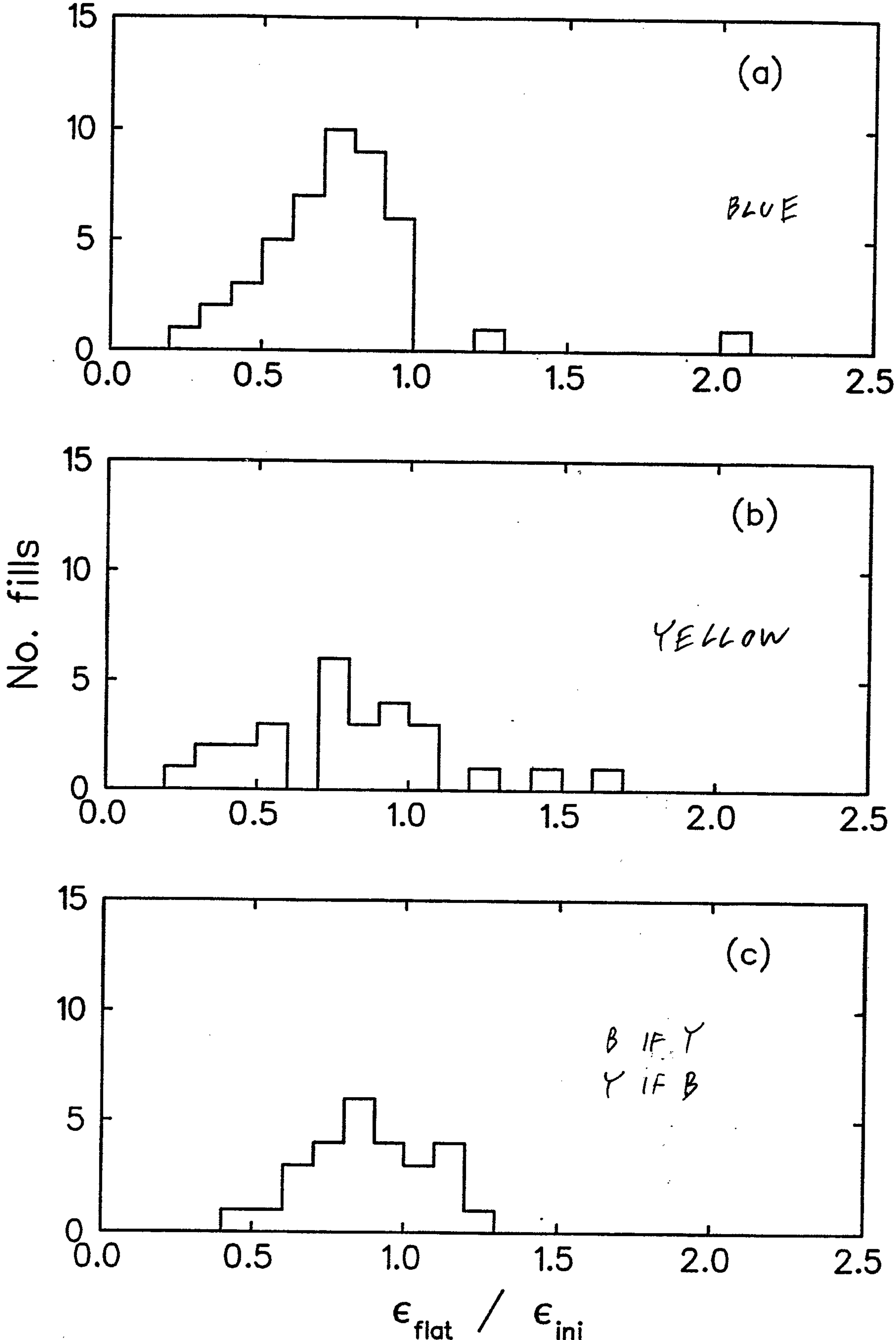
Presented by
D. Underwood

RSC
BNL
June 17, 2002

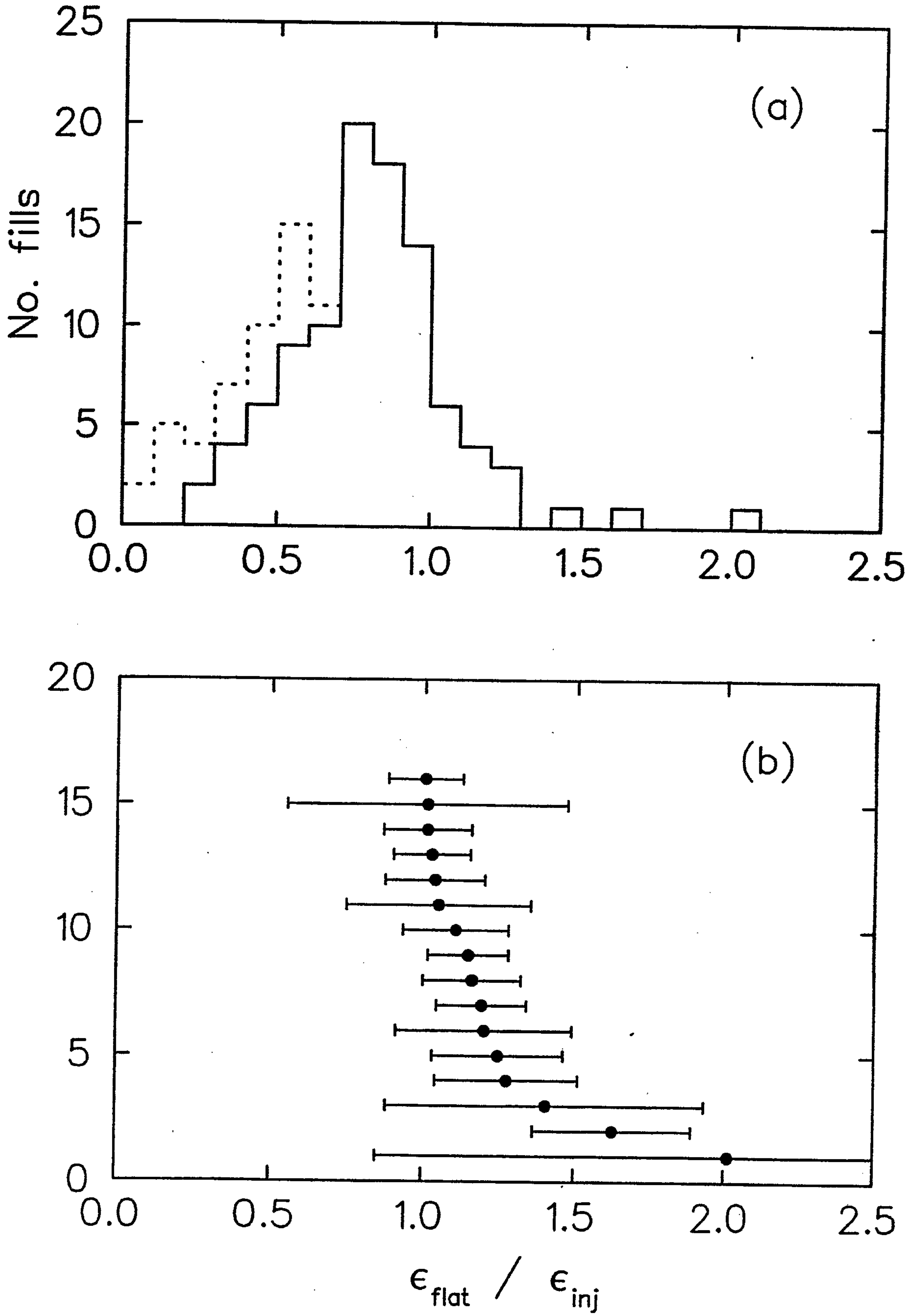
RATIO OF MEASURED CNI ASYMMETRIES DURING STORES TO THE FIRST MEASUREMENT AT FLATTOP



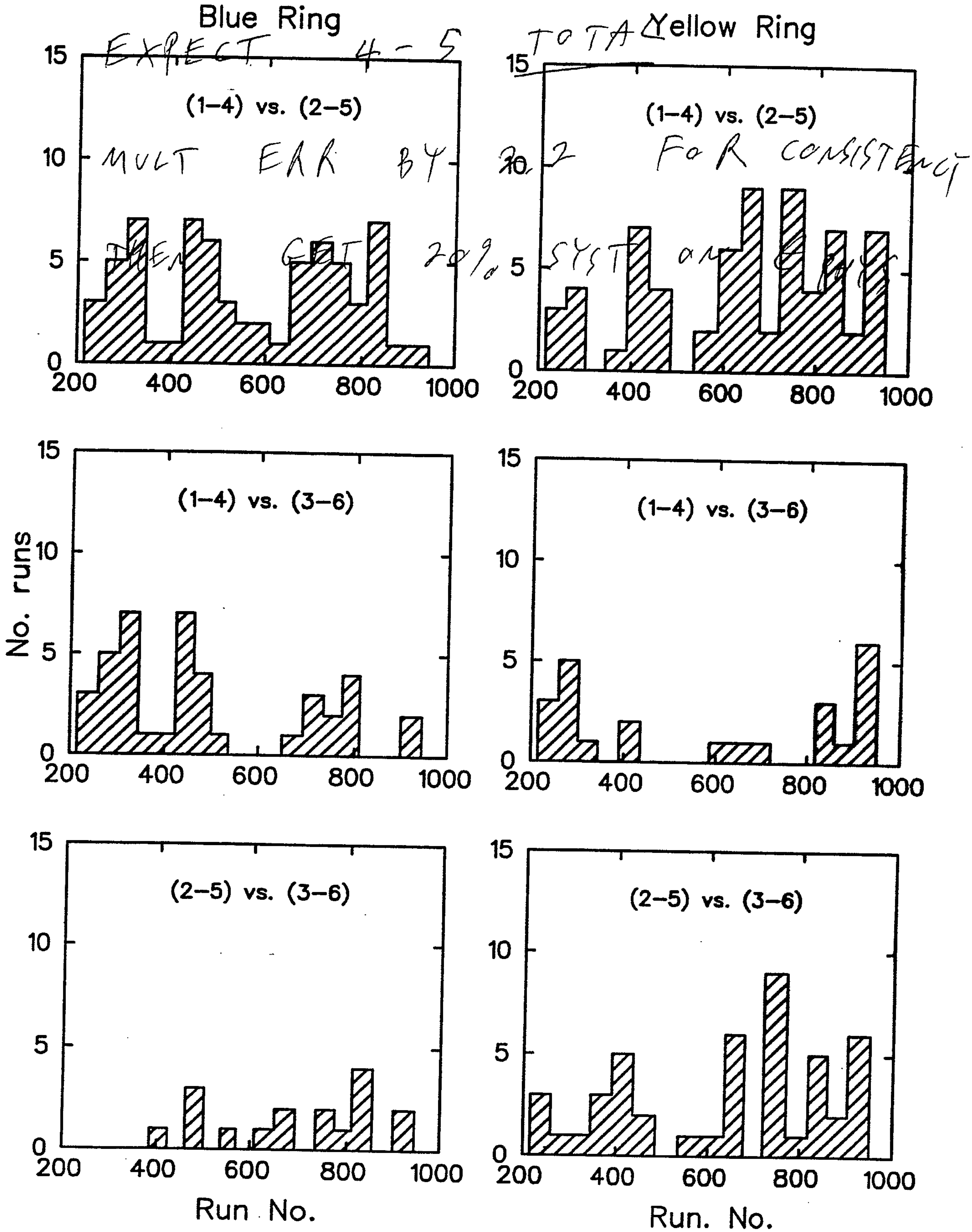
RATIO OF CNI ASYMMETRY AT FLATTOP (≤3 MEAS)
TO ASYMMETRY AT INJECTION



RATIO OF CNI ASYMMETRY AT FLATTOP TO ASYMMETRY AT INJECTION



NUMBER OF 4 σ DEVIATIONS OF ϵ_{LUM} PER 20 RUNS



Conclusions

1) Evidence for depolarization during store.
   Much more in Blue Ring. (5% per hour)

2) Evidence that Analyzing Power of CNI polarimeter
 is larger at Flattop (100 GeV)
 than at Injection energy (24 GeV)
Could be as much as 20% larger.

3) Evidence that there are Systematic Errors
 in a CNI measurement
(Luminosity Asymmetry)
far outside statistical expectations.

These occur over all running times.

These could also be present in the Physics Asymmetry
 at the 20% level.

RHIC Spin Flipper Commissioning Results and Future Plans

M. Bai, BNL
June 17, 2002

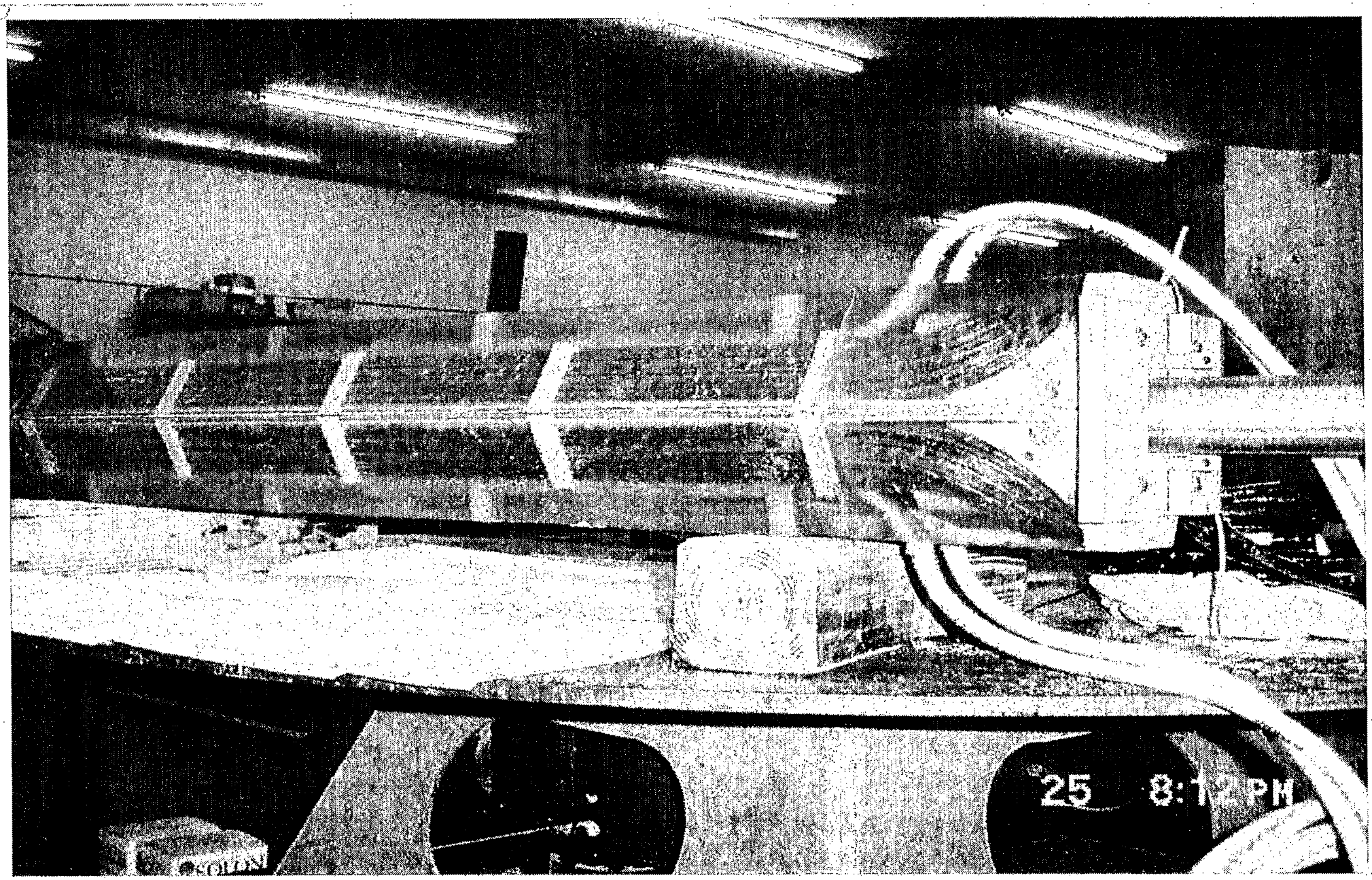
for
RHIC Spin Collaboration Meeting X
RIKEN BNL Research Center

RHIC Spin Flipper Commissiong Results and Future Plans

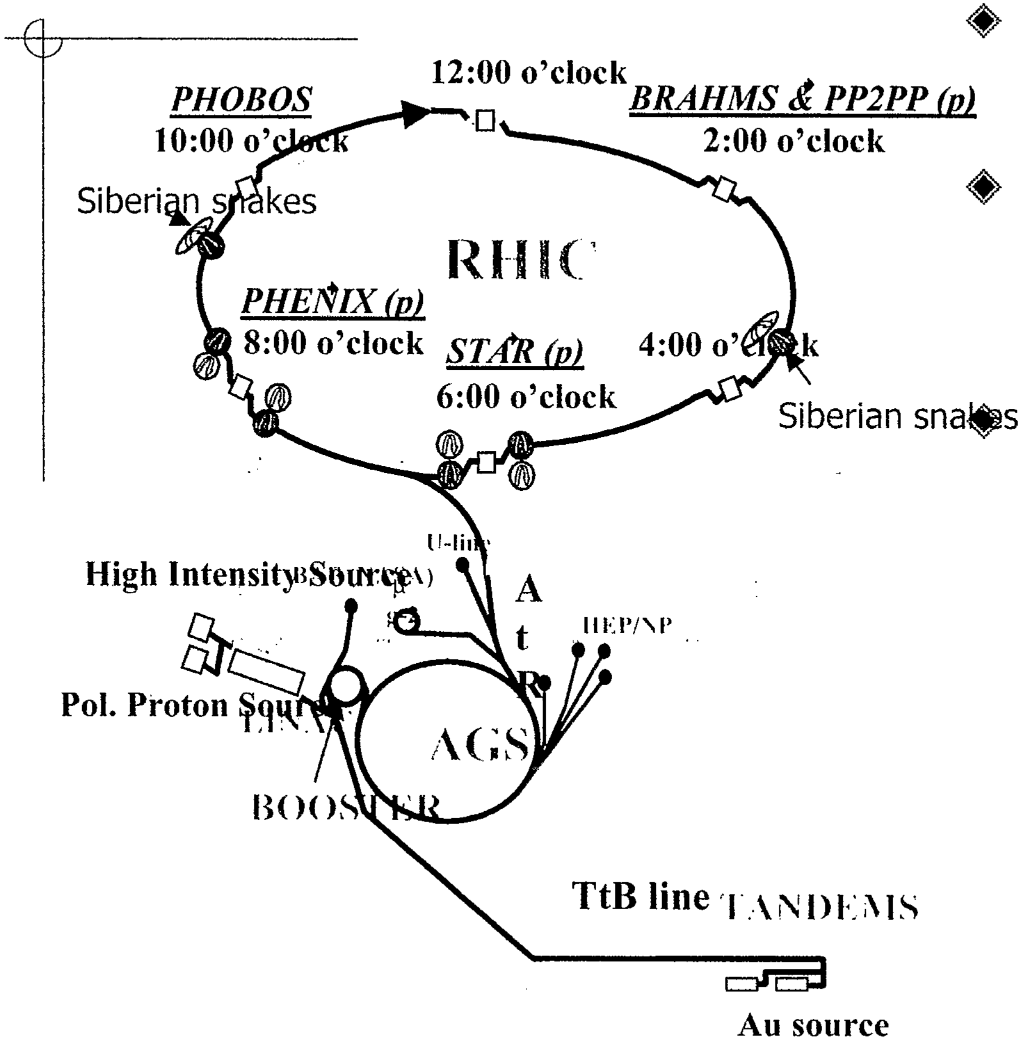
RSC Meeting, June 17 2002, Mei Bai

- RHIC polarized proton setup
- Spin manipulation using a dipole with horizontal oscillating magnetic field
- Rhic spin flipper commissioning
- Future plans

RHIC spin flipper



RHIC polarized proton setup



- Two full snakes apart from each other by 180° in phase
- Stable spin direction in which the spin precesses around is vertical.
- Spin precession frequency

$$\nu_s = \frac{1}{\pi}\left|\mu_1 - \mu_2\right|$$

$\mu_{1,2}$ is the angle between the snake axis and the beam direction

and is independent of beam energy. In RHIC, the two snakes' axes are perpendicular to each other and the nominal spin tune is 1/2.

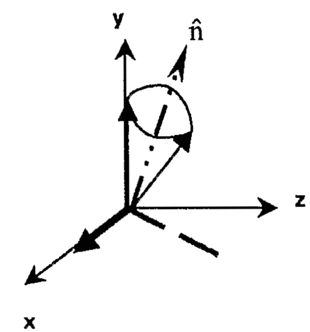
Spin motion in the presence of the ac dipole

- Thomas BMT equation

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S} = -\frac{e}{\gamma m}(1 + G\gamma)\vec{B}_\perp \times \vec{S}$$

where

$$\vec{B}_\perp = B_m \cos \nu_m \theta \, \hat{x}$$



A spin resonance then happens when $\nu_s = \nu_m$

The strength of this resonance is

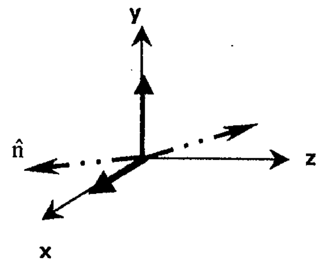
$$\varepsilon = \frac{1}{4\pi}(1 + G\gamma)\frac{B_m L}{B\rho}$$

For $B_m L$=100 Gauss-m and 100 GeV/c pp, the resonance strength is 0.00046.

Spin manipulation using ac dipole

- In the frame which rotates at the same frequency as the drive frequency, the stable spin direction becomes

$$\hat{n} = \frac{\delta}{\lambda}\hat{e}_3 + \frac{\varepsilon}{\lambda}\hat{e}_1$$

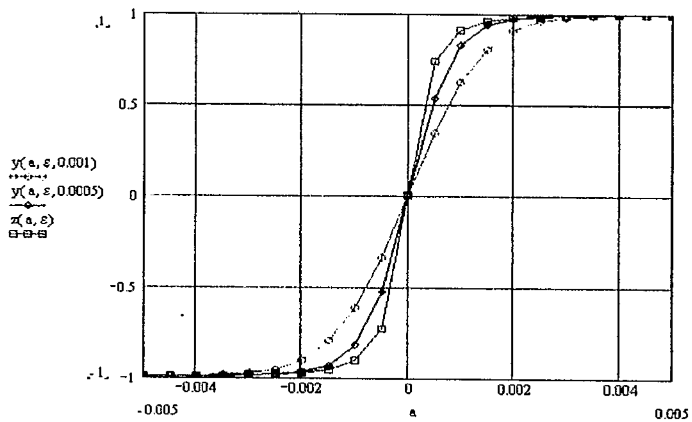


where: $\delta = \nu_m - \nu_s$ and $\lambda = \sqrt{\delta^2 + \varepsilon^2}$

- fixed drive frequency

$$P_f = P_i\left(1 - 2\frac{|\varepsilon|^2}{\lambda^2}\sin^2\left(\frac{\lambda}{2}2\pi f_0 \Delta t\right)\right)$$

-- measure the spin tune



- crossing through the resonance

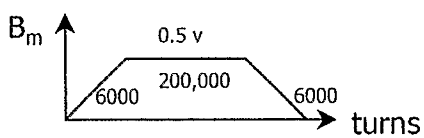
$$P_f = P_i\left(2e^{-\frac{\pi|\varepsilon|^2}{2\alpha}} - 1\right)$$ -- spin flipping

where $\alpha = \frac{|\nu_b - \nu_e|}{2\pi f_0 \Delta t}$; time to achieve 99.9% spin flip ≥ 1 sec

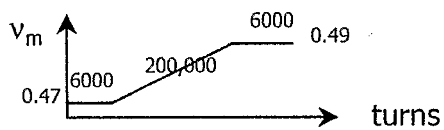
Spin flipper commissioning
------- Blue Ring

- **Setup:**
  - snake:
    - inner current=325.06A
    - outter current=106.11A

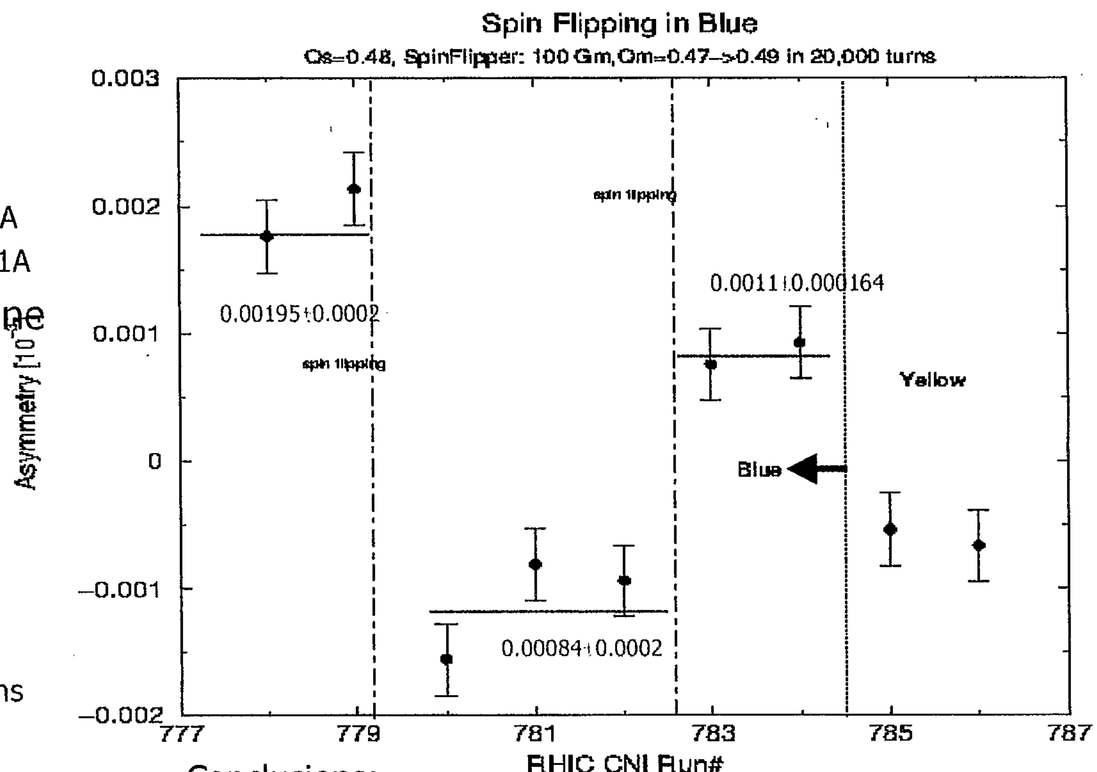
    the predicted spin tune equals to 0.48.
  - Spin flipper:
    - amplitude:



    - frequency



$\alpha = 1.6\times10^{-7}$



Conclusions:

- spin flip efficiency η

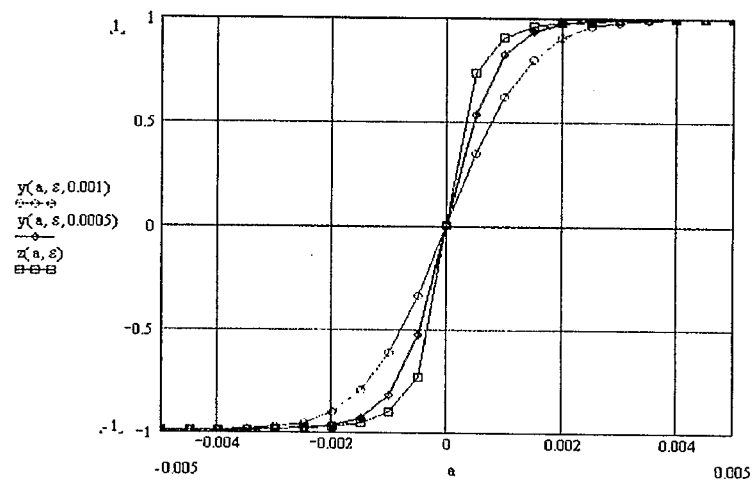
  $P_2 = P_1\eta = P_0\eta^2$ $\eta \approx 0.66$
- yellow beam

  The fact that we measured negative asymmetry after we spin-flipped twice in Blue is very hard to understand. This is also consistent with the fact that the yellow beam was actually fully depolarized. while we were spin flipping the blue beam. This suggests that the yellow beam spin tune is away from 0.5.

Spin flipper commissioning

------- Blue Ring (continue)

- Effect of Spin tune spread
  - spin tune spread:
    - particles with different betatron oscillation amplitude have different spin precession tune
  - to achieve full spin flip, spin tune spread should be less than the spir flipper tune sweeping range.

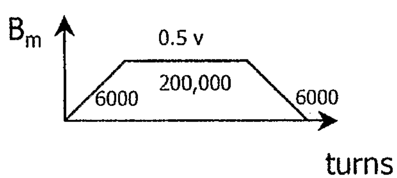


- Spin precession tune too close to the resonance during the amplitude ramping

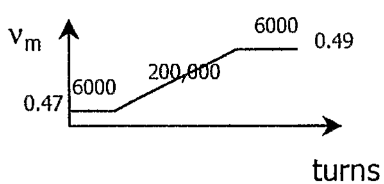
Spin flipper commissioning

- ◈ Setup:
  - snake:
    - inner current=106.9A
    - outer current=323.5A

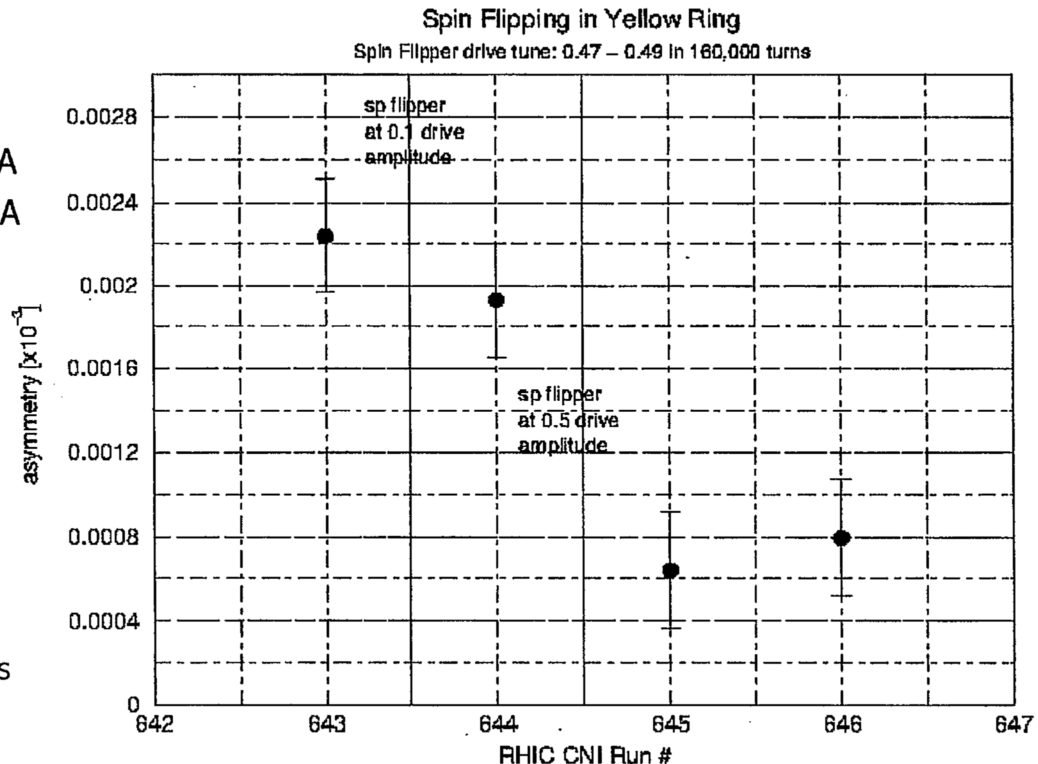
    predicted spin tune equals to 0.48.
  - Spin flipper:
    - amplitude:



    - frequency:



$\alpha = 2.0\times10^{-7}$



Conclusions:

No spin flip was achieved in Yellow. Instead, the yellow beam was partially depolarized. This could be because spin tune with the snake setting of (inner106.9A, outer323.5A) doesn't equal to 0.48.

Problems during RHIC pp 2002

- Spin flipper
  - The ± 0.2mm coherent betatron oscillation caused snake quench twice at injection due to the limitation of the aperture.
  - The resolution of the snake WFG.
- No spin tune measurement
- Not enough time

Plans for the next run

- Measure the spin flipping efficiency in both blue and yellow ring
  - this allows us to assess how well the spin flipper behaves
  - prefer to do the measurement at store.
  - No new instrumentation is needed provided the RHIC CNI polarimeter will be available

- Measure the spin precession tune to calibrate the snake setting
  - The alternative way to measure the spin tune by measuring the beam polarization before and after turning on the ac dipole at a fixed frequency is to measure the asymmetry while sweeping the ac dipole frequency. The zero crossing of the measured asymmetry is where the spin tune locates. However, this requires to upgrade the current RHIC CNI polarimeter to allow one to measure the beam polarization continuously in couple of seconds.

Status of the pp2pp Experiment

S. Bültmann, BNL
June 17, 2002

for
RHIC Spin Collaboration Meeting X
RIKEN BNL Research Center

Status of the pp2pp Experiment

Stephen Bültmann

Brookhaven National Laboratory

For the pp2pp Collaboration

- Introduction
- Formalism
- Experimental Setup
- Silicon Detector Performance
- Preliminary Results
- Planning for Year-2003 Running

RHIC Spin Collaboration Meeting June 17, 2002

Spin Physics with pp2pp (2)

Single spin asymmetry A_N may be used for polarimetry in RHIC

Measure t- and φ-dependence   later also s-dependence

$$A_N(t) = \frac{1}{P_{blue} \cdot \cos\varphi} \; \frac{N_{\uparrow\uparrow}(t) - N_{\downarrow\downarrow}(t) + N_{\uparrow\downarrow}(t) - N_{\downarrow\uparrow}(t)}{N_{\uparrow\uparrow}(t) + N_{\downarrow\downarrow}(t) + N_{\uparrow\downarrow}(t) + N_{\downarrow\uparrow}(t)}$$

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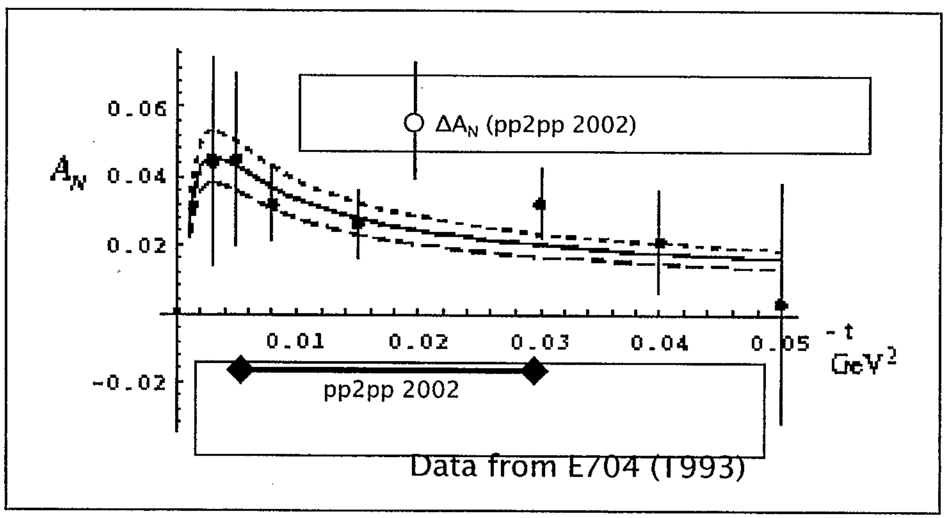


$$N(t) = \frac{dN}{dt}$$

φ = Azimuth

P_{blue} = Beam Polarization

N.H. Buttimore, B.Z. Kopeliovich, E. Leader, J. Soffer, T.L. Trueman, "The Spin Dependence of High-Energy Proton Scattering", PRD 59, 114010 (1999)

Principle of Measurement

Transport of beam and scattered protons defined by transport matrix

$$\begin{pmatrix} x \\ x' \end{pmatrix} = M_x \begin{pmatrix} x_0 \\ x_0' \end{pmatrix} = \begin{pmatrix} a_{11} & L_{eff} \\ a_{12} & a_{22} \end{pmatrix} \begin{pmatrix} x_0 \\ x_0' \end{pmatrix}$$

(one for each coordinate: x, y)

This results in two equations (where x_0 can be eliminated)

$$x = a_{11}\, x_0 + L_{eff}\, x_0' \rightarrow$$ Optimize so that a_{11} small and L_{eff} large

$$x' = a_{12}\, x_0 + a_{22}\, x_0'$$

Design $M_x = \begin{pmatrix} -0.75 & 6.98 \\ -0.06 & -0.73 \end{pmatrix}$

$M_y = \begin{pmatrix} 0.02 & 23.29 \\ -0.04 & -0.66 \end{pmatrix}$

x : Position at Detector
x' : Angle at Detector
x_0 : Position at Interaction Point
x_0': Scattering Angle at IP

Principle of Measurement (3)

Measurement of x and x' at Roman Pot location enables determination of scattering angle x_0' without knowledge of x_0 :

$$x_0' = \frac{x - (a_{11}/a_{12})\,x'}{L_{eff} - (a_{11}/a_{12})\,a_{22}}$$

But, need two Roman Pot stations at both tunnel locations :

With x_0' (min) = 0.6 mrad $\rightarrow$ $x' \approx 0.4$ mrad

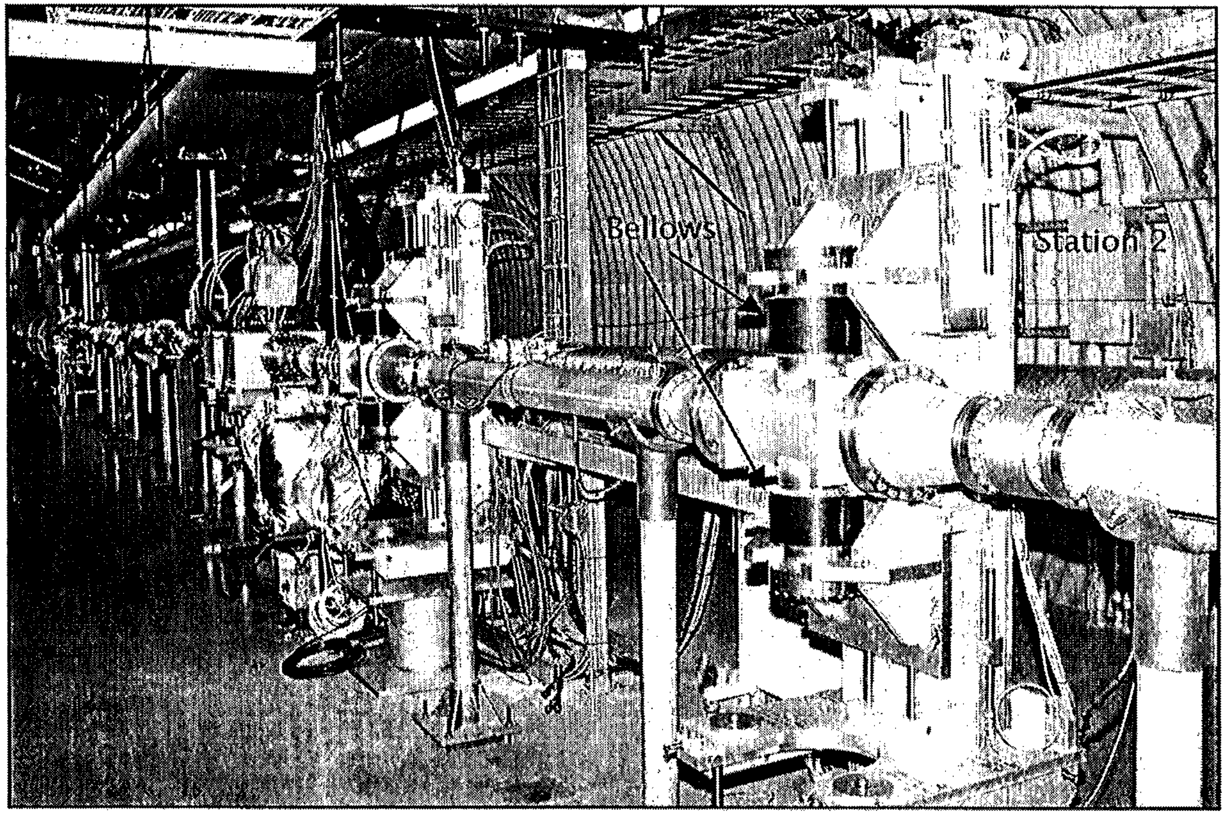
$\rightarrow$ $\Delta x > 1.2$ mm for a distance of ~ 3 m between stations

x : Position at Detector
x' : Angle at Detector
x_0 : Position at Interaction Point
x_0' : Scattering Angle at IP

Roman Pot Stations at RHIC

Detector Package
consists of
2 x-silicon planes
2 y-silicon planes
1 trigger scintillator

Active area of silicon
covers 7.5 x 4.5 cm^2



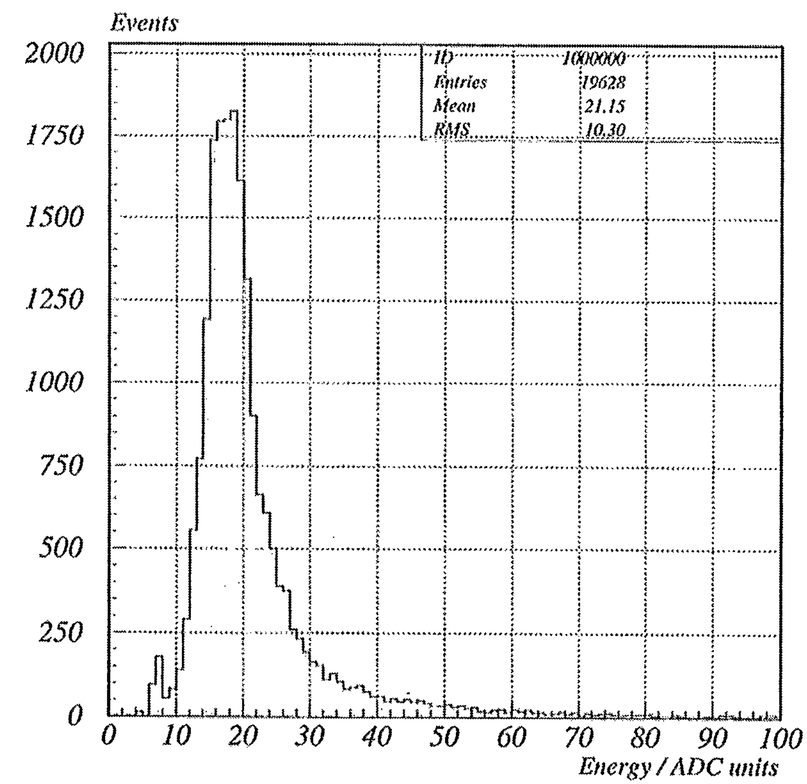
Two Roman Pot Stations installed in each Sector
(One Station equipped with Detector Package)

Silicon Microstrip Detector

100 GeV proton loses about 200 keV in silicon

Corresponds to 58,000 electron-hole pairs

SN ratio ≈ 11
(for detector shown on right)



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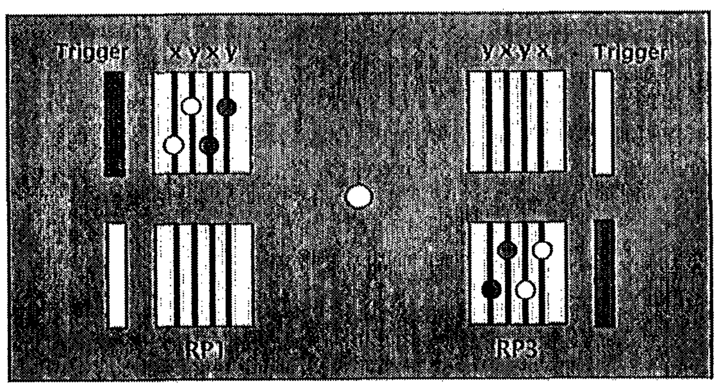
Elastic Event Selection Criteria

Exactly one hit for each coordinate one either side of IP in one of the two elastic arms

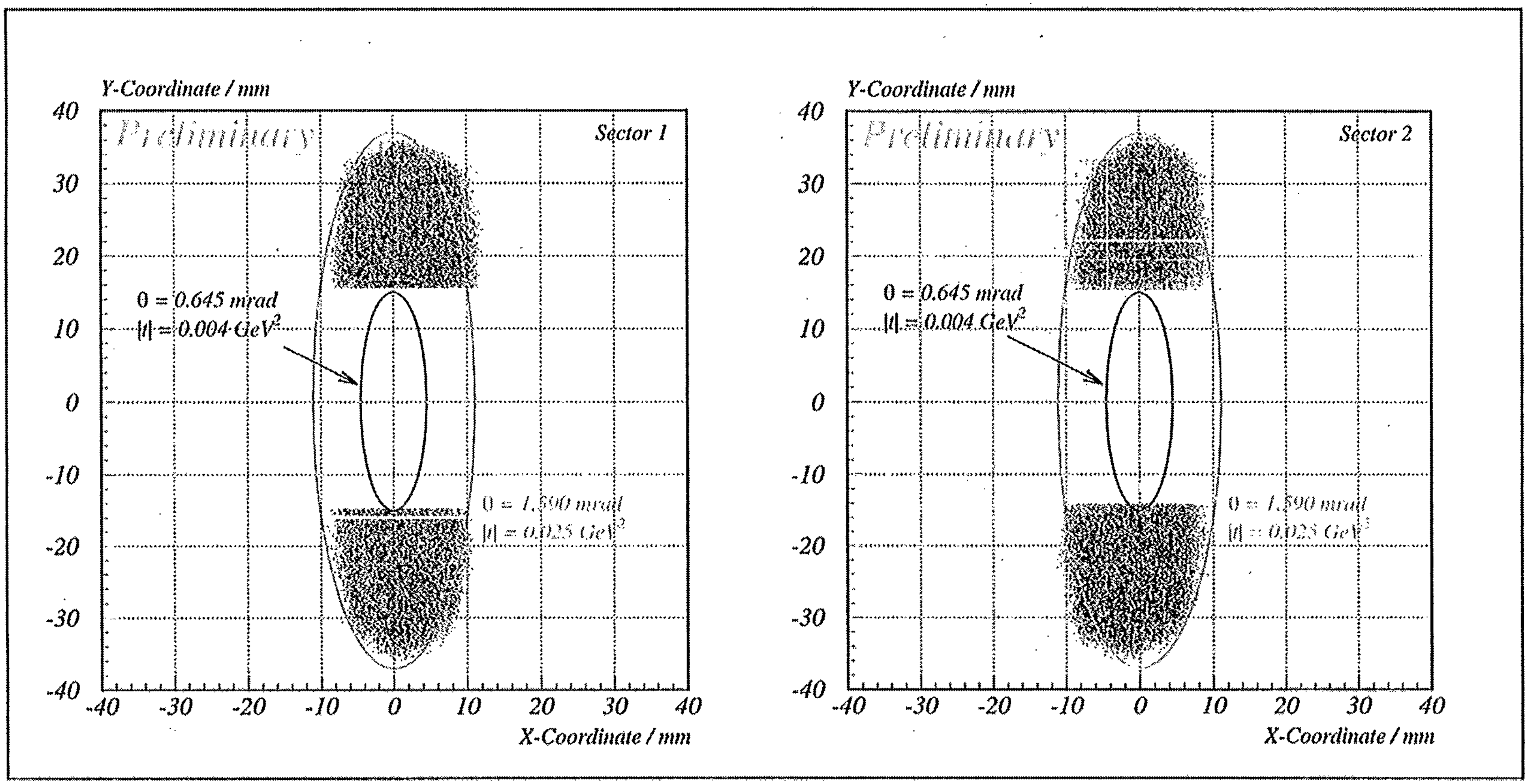
Cuts

- Difference between each coordinate within RP less than 1.5 strips
- No veto counter with hit
- No elastic trigger from diagonal elastic arm
- Less than 3 hits in silicon planes of diagonal elastic arm



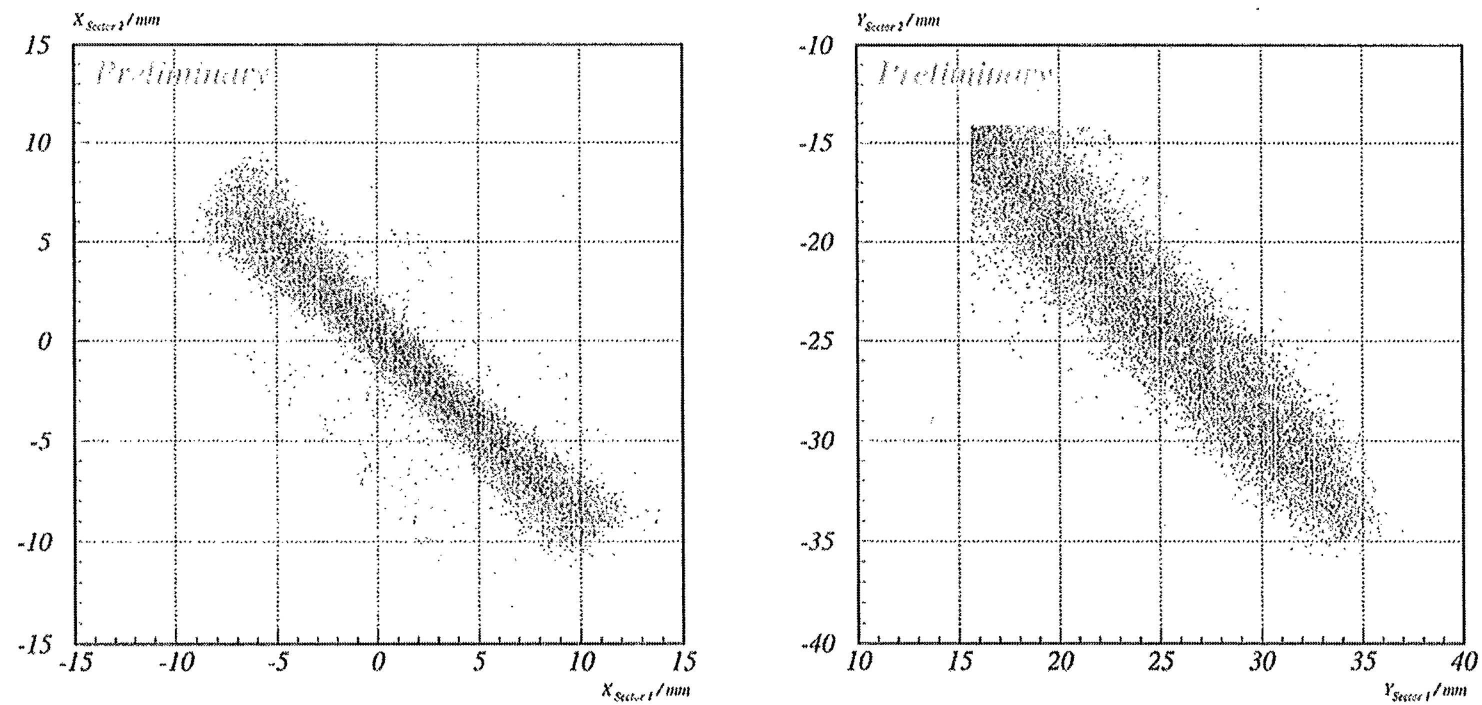
Elastic Hit Pattern

Raw hit distribution without final alignment



Collinearity Plots

Elastic arm with higher efficiency



Running Conditions in 2002

Closest approach of first detector strip to beam about

$15\sigma_{beam} \rightarrow t_{min} = -4 \cdot 10^{-3}\ \mathrm{GeV}^2$

Observed count rate $\dot{N}_{elastic} = \sigma_{el} \cdot \mathcal{L} \cdot \Delta\varphi = 12\ \mathrm{sec}^{-1}$

with $\sigma_{el} \approx 1.8$ mb $\quad (5 \cdot 10^{-3}\ \mathrm{GeV}^2 \leq |t| \leq 2.5 \cdot 10^{-2}\ \mathrm{GeV}^2)$

$$\mathcal{L} = \frac{3}{2} \frac{\nu N_B N^2}{\epsilon \beta^*} (\beta\gamma) = 1.1 \cdot 10^{28} \frac{1}{\mathrm{cm}^2\ \mathrm{sec}}$$

$\Delta\varphi = 0.60$ Integrated azimuthal coverage

$\beta^* = 10$ m
$N_B = 55$ bunches
$\nu = 78.2$ kHz
$\beta\gamma = 106.6$
$N = 7.8 \cdot 10^9\ p^+$/bunch
$\epsilon = 12\,\pi \cdot 10^{-6}$ rad m

Conclusions

We had a successful engineering run in 2002

Next Steps in Analysis Effort

- Full Simulation of Beam Transport to
  - Understand Elastic Event Hit Pattern
  - Calculate Acceptance
- Efficiency Calculation
- Asymmetries and Slope B

Next Steps for Experiment Preparation

- Need Full Roman Pot Station Setup

Recent results in QCD resummation, and on A_{TT}

Werner Vogelsang
RIKEN-BNL Research Center
and Nuclear Theory, BNL

RSC meeting, June 17, 2002

work with A. Kulesza, E. Laenen, G. Sterman
J. Soffer, M. Stratmann

Outline :

I. Introduction : why resum ?

II. Soft emission in QED

III. In QCD . . .

IV. "Joint" resummation

V. Resummation for polarized scattering

VI. (Old and) new results on A_{TT}

I. Introduction : why resum ?

QCD at short distances

- prerequisite : asymptotic freedom $\Rightarrow$ pert. theory

- **"infrared safe" observables**

$$Q^2\,\sigma_{\text{phys}}(Q) \;=\; \sum_n c_n\,\alpha_s^n(Q) \;+\; \mathcal{O}\left(\frac{1}{Q^p}\right)$$

examples : $e^+e^- \to$ hadrons, jets, event shapes, ...

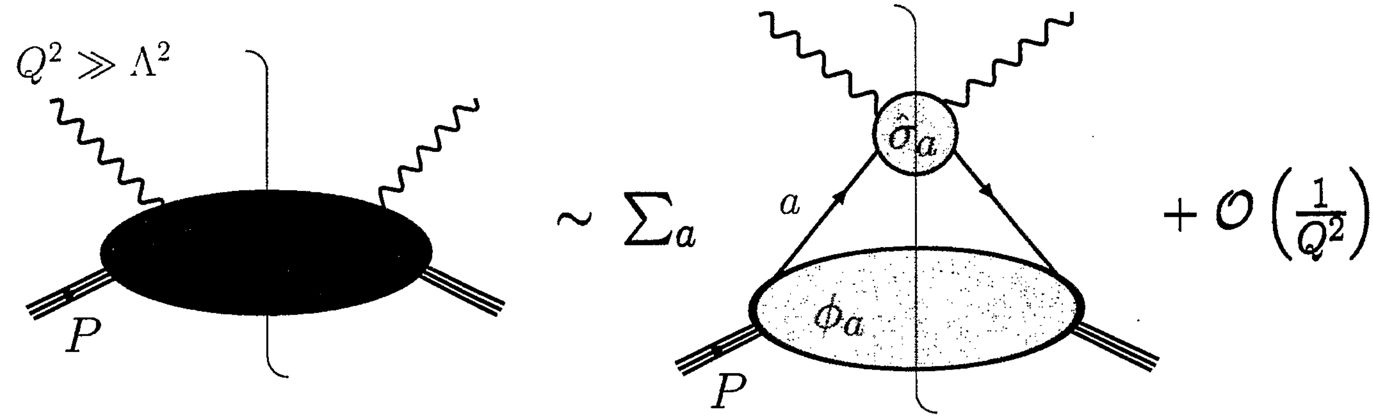
- extension : **"factorizable" observables**

$$Q^2\,\sigma_{\text{phys}}(Q,m) \;=\; \mathcal{H}\left(\frac{Q}{\mu},\alpha_s(\mu)\right)\otimes\mathcal{S}\left(\frac{\mu}{m},\alpha_s(\mu)\right)+\mathcal{O}\left(\frac{1}{Q^p}\right)$$

  - short-distance "hard" part $\mathcal{H}$: perturbative, specific to process
  - long-distance "soft" part $\mathcal{S}$: incalculable (at present), universal
  - μ – factorization scale

examples : DIS $ep \to e'X$, $p\bar{p} \to$ jets + X, γ + X, ...

example : deeply-inelastic scattering



$$F_2 \;\sim\; \sum_a \int_x^1 \frac{d\xi}{\xi}\, \widehat{\sigma}_a\left(\frac{x}{\xi}, \frac{Q}{\mu}, \alpha_s(\mu)\right)\; \phi_a\left(\xi, \frac{\mu}{m}, \alpha_s(\mu)\right)$$

$$\equiv\; \sum_a \widehat{\sigma}_a \otimes \phi_a$$

- PDF's $\longleftrightarrow$ operator matrix elements :

e.g. $$q(\xi) \;=\; \frac{1}{4\pi}\int dy^-\, e^{iy^-\xi P}\, \langle P,S\,|\,\overline{\psi}(0)\,\gamma^+\,\psi\left(0,y^-,\mathbf{0}_\perp\right)\,|\,P,S\rangle$$

$\longrightarrow$ nucleon structure

- factorization theorems :
  extension to $pp \to$ jet $+\, X$, Drell-Yan, etc.

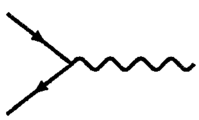
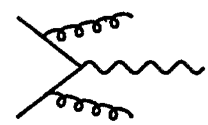
(Sterman,Libby; Ellis et al.; Amati et al.; Curci et al.; Collins,Soper,Sterman; Bauer,Fleming,Pirjol,Rothstein,Stewart)

The full picture : e.g. $pp \to ZX$

$$\sigma_{pp}^{Z} = \sum_{a,b} \phi_a(\mu) \otimes \phi_b(\mu) \otimes \hat{\sigma}_{ab}^{Z}\left(\frac{M_Z}{\mu}, \alpha_s(\mu)\right)$$

- perturbative cross sections :

$$\hat{\sigma}\left(\frac{M_Z}{\mu}, \alpha_s(\mu)\right) = \hat{\sigma}^{(0)} + \alpha_s(\mu)\,\hat{\sigma}^{(1)}\left(\frac{M_Z}{\mu}\right) + (\alpha_s(\mu))^2\,\hat{\sigma}^{(2)}\left(\frac{M_Z}{\mu}\right) + \ldots$$

 LO NLO  NNLO 

to be calculated for each process !

- "DGLAP" evolution of PDF's :

$$\mu \frac{\partial}{\partial \mu} \phi_i(\mu) = \sum_j \phi_j(\mu) \otimes \gamma_{ij}(\alpha_s(\mu))$$

$$\gamma_{ij}(\alpha_s) = \frac{\alpha_s}{2\pi}\gamma_{ij}^{(0)} + \left(\frac{\alpha_s}{2\pi}\right)^2 \gamma_{ij}^{(1)} + \left(\frac{\alpha_s}{2\pi}\right)^3 \gamma_{ij}^{(2)} + \ldots$$

LO NLO NNLO

universal (= same in all processes)

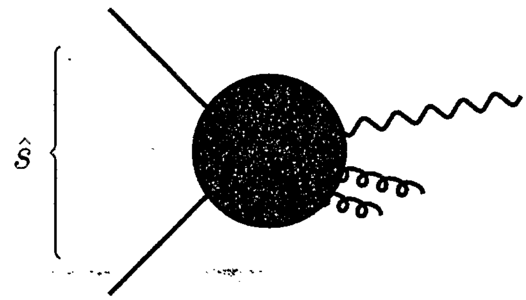
"state-of-the-art" : NLO

" fixed-order perturbation theory "

Despite presence of large scale Q, and despite being infrared-finite :

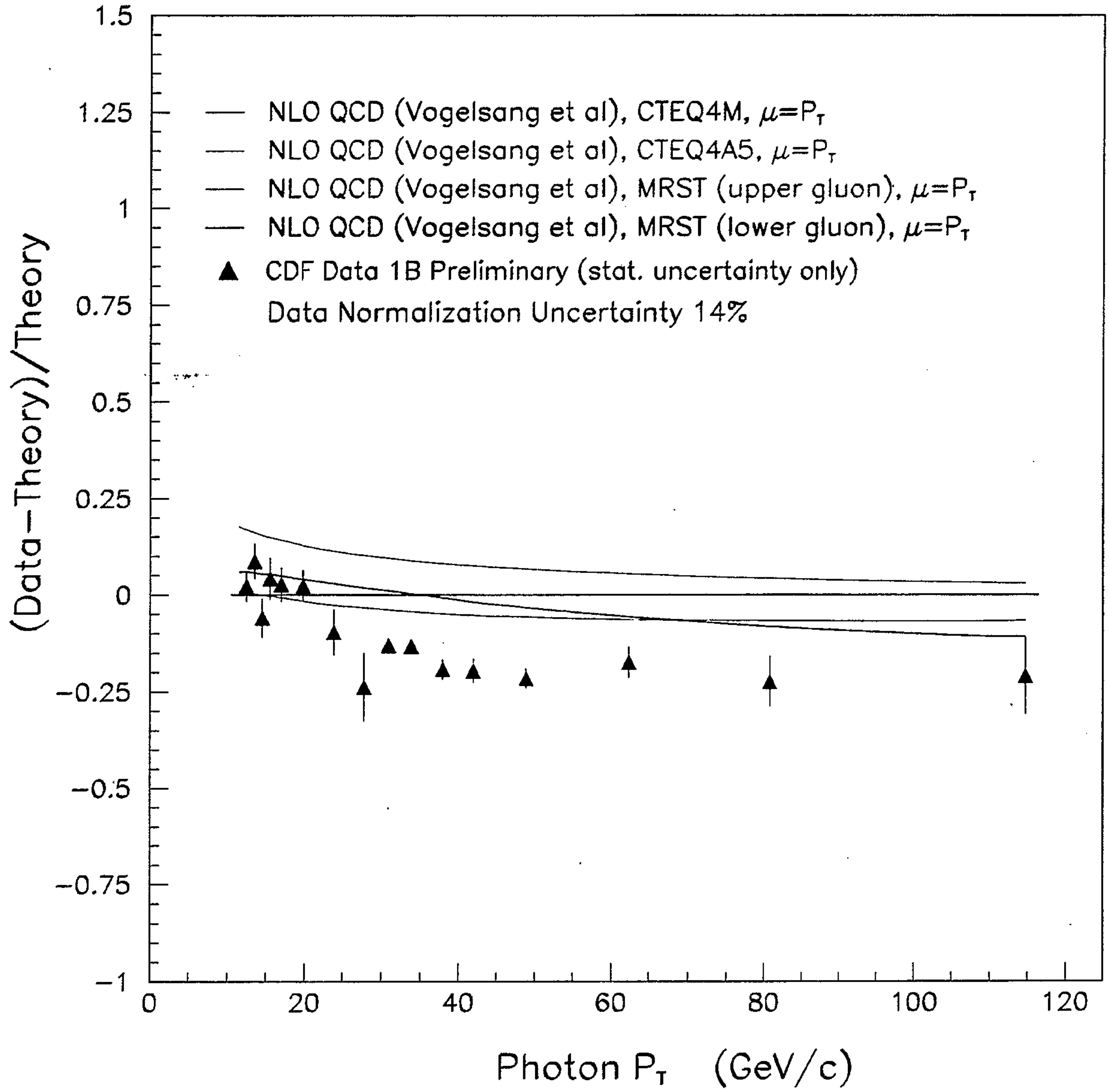
fixed-order perturbation theory for $\widehat{\sigma}$ may not always be adequate

- example : Z production via $q\bar{q} \to Z + X$



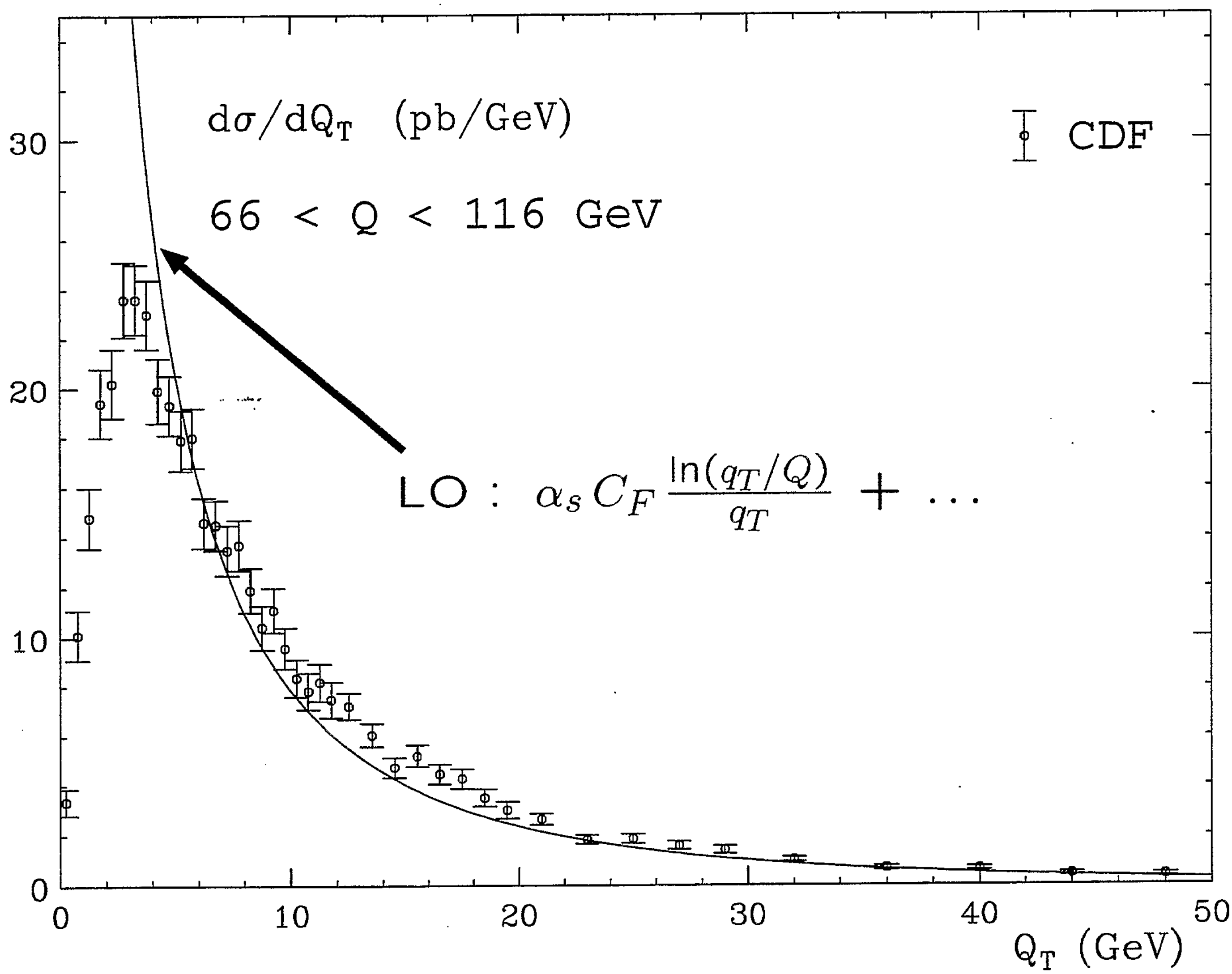
- when $\widehat{s} \to Q^2$: $\quad \widehat{\sigma} \sim \alpha_s^k \frac{\ln^{2k-1}(\widehat{s}-Q^2)}{\widehat{s}-Q^2} + \ldots$
- "threshold logs" – just enough partonic energy
- origin : suppression of gluon radiation
- when $q_T \to 0$: $\quad \frac{d\widehat{\sigma}}{dq_T} \sim \alpha_s^k \frac{\ln^{2k-1}(q_T/Q)}{q_T} + \ldots$
- "q_T logs" – recoil against soft radiation
- real-virtual IR cancellations leave large logs $\to$ may spoil expansion in $\alpha_s(Q)$
- such corrections associated with soft and/or collinear emission
  $\to$ can often be treated to all orders
- = resummation !

CDF, Run-1B



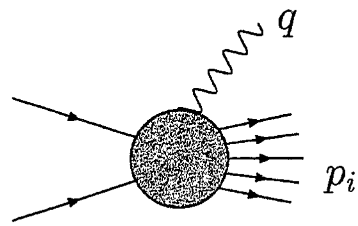
– a case for resummation ?

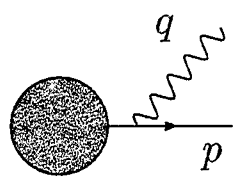
Classic Example : Transverse-momentum distribution of Z bosons at the Tevatron



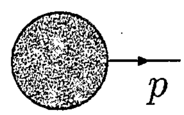
II : Soft emission in QED

$M^\mu(p_1,\dots,p_k;q) =$





$\approx_{q\to 0}$



$\cdot\ e\,\frac{p^\mu}{p\cdot q}\,\epsilon_\mu(q)$

$\Uparrow$

eikonal factor

- single emission off all legs :

$$|M(p_1,\dots,p_k;q)|^2 \approx_{q\to 0} |M(p_1,\dots,p_k)|^2 \cdot d\rho_1(q)$$

$$d\rho_1(q) = \frac{\alpha}{\pi} \sum_{\text{legs } k} e_k^2 \frac{d\omega}{\omega} \frac{d\theta_{kq}^2}{\theta_{kq}^2}$$

- n soft photons emitted:

$$d\rho_n(q_1,\dots q_n) = \frac{1}{n!} \prod_{i=1}^{n} d\rho_1(q_i)$$

$$d\rho_n(q_1, \ldots q_n) = \frac{1}{n!} \prod_{i=1}^{n} d\rho_1(q_i)$$

- factorization of dynamics
- exponentiation *if* photon phase space symmetric
- sometimes achievable by integral transforms :

$$\delta\Big(2P\cdot\sum_j k_j - m^2\Big) = \frac{1}{2\pi\, i\, Q^2} \int_C dN\, \mathrm{e}^{-N\left(2P\cdot\sum_j k_j - m^2\right)/Q^2}$$

$$\delta\Big(\vec{q}_T - \sum_j \vec{k}_T^j\Big) = \frac{1}{(2\pi)^2} \int d^2 b\, \mathrm{e}^{i\vec{b}\cdot\left(\vec{q}_T - \sum_j \vec{k}_T^j\right)}$$

- $\Rightarrow$ phase space factorizes :
  "factorization of kinematics"

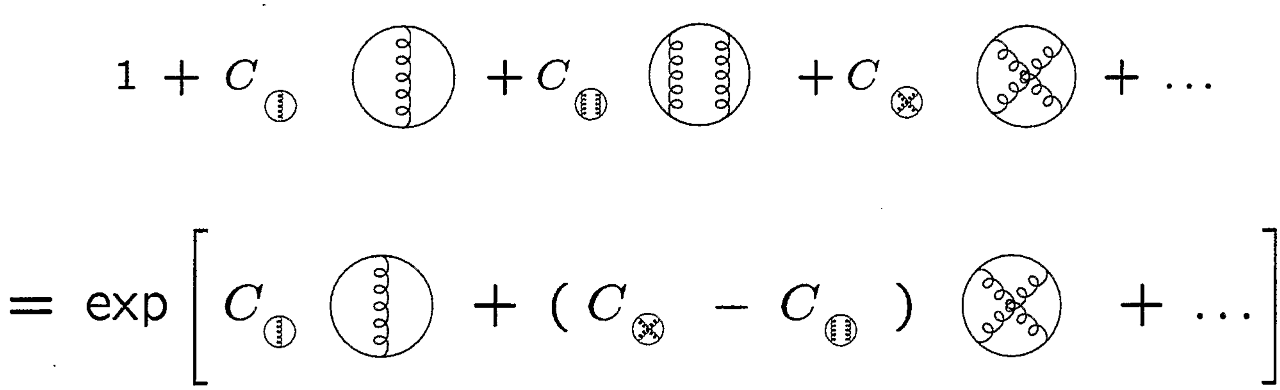
III. In QCD ...

- an emitted soft gluon carries color :

$$|M(\{p_i\}, q\rangle \approx_{q\to 0} \epsilon_\mu(q)\, \mathcal{J}_a^\mu\, |M(\{p_i\})\rangle$$

$$\mathcal{J}_a^\mu(q) = \sum_i T_a^i \frac{p_i^\mu}{p_i \cdot q} \qquad \text{matrix}$$

- still, eikonal cross sections exponentiate in terms of "webs" (Gatheral; Frenkel, Taylor) schematically :



- in addition, running coupling

IV : "Joint" resummation

Laenen, Sterman, WV :

logarithms at threshold and at $q_T = 0$ can be resummed *simultaneously*

- "jointly" resummed cross section :

$$\frac{d\sigma^{\rm res}}{dQ^2\, dq_T^2} \propto \sum_q \int_C dN \left(\frac{Q^2}{S}\right)^{-N} \int d^2{\rm b}\ {\rm e}^{-i\,\tilde{\rm q}_T\cdot\tilde{\rm b}}\ f_q^N(Q)\ f_{\bar q}^N(Q)$$

$$\times\ \exp\left\{2\int_0^{Q^2}\frac{dk_\perp^2}{k_\perp^2}A_a(\alpha_s(k_\perp^2))\left[J_0(b\,k_\perp)\,K_0\left(\frac{2Nk_\perp}{Q}\right)+\ln\left(\frac{\bar N k_\perp}{Q}\right)\right]\right\}$$

  - *two* inverse transforms (N, b)
  - exponent approximated by

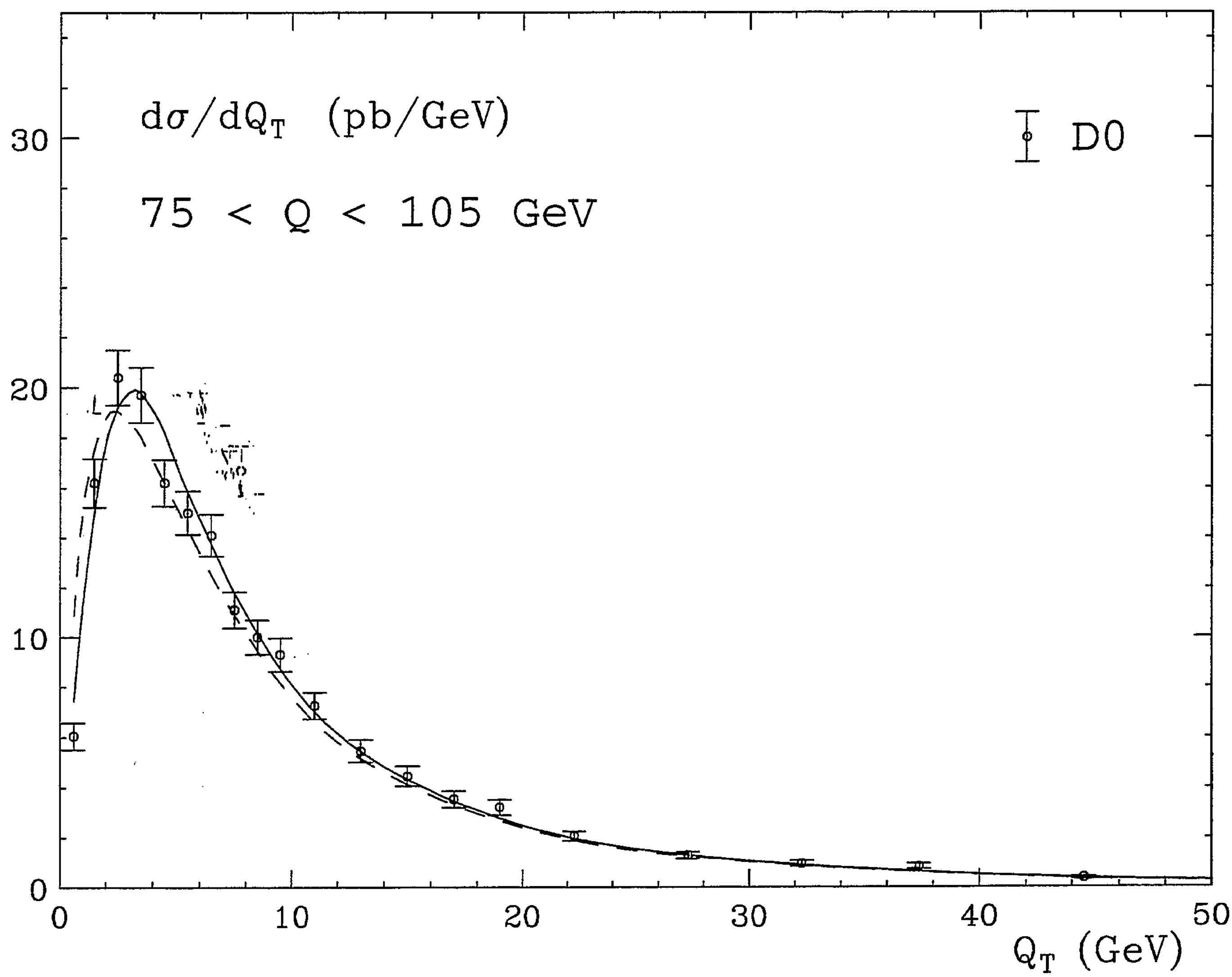
$$2\int_{Q^2/\chi^2}^{Q^2}\frac{dk_\perp^2}{k_\perp^2}A_q\left(\alpha_s(k_\perp^2)\right)\ \ln\left(\frac{k_\perp \bar N}{Q}\right)$$

$$\chi \equiv \chi(\bar N,\bar b) = \bar b + \frac{\bar N}{1+\bar b/4\bar N}$$

  - at very low $q_T \to 0$: expect non-pert. effects exponent gives guide to form of corrections :

$$\sim \left(\frac{b^2}{4}-\frac{N^2}{Q^2}\right)\int_0^\lambda dk_\perp\,k_\perp\ \alpha_s(k_\perp^2)\ \ln\left(\frac{Nk_\perp}{Q}\right)$$

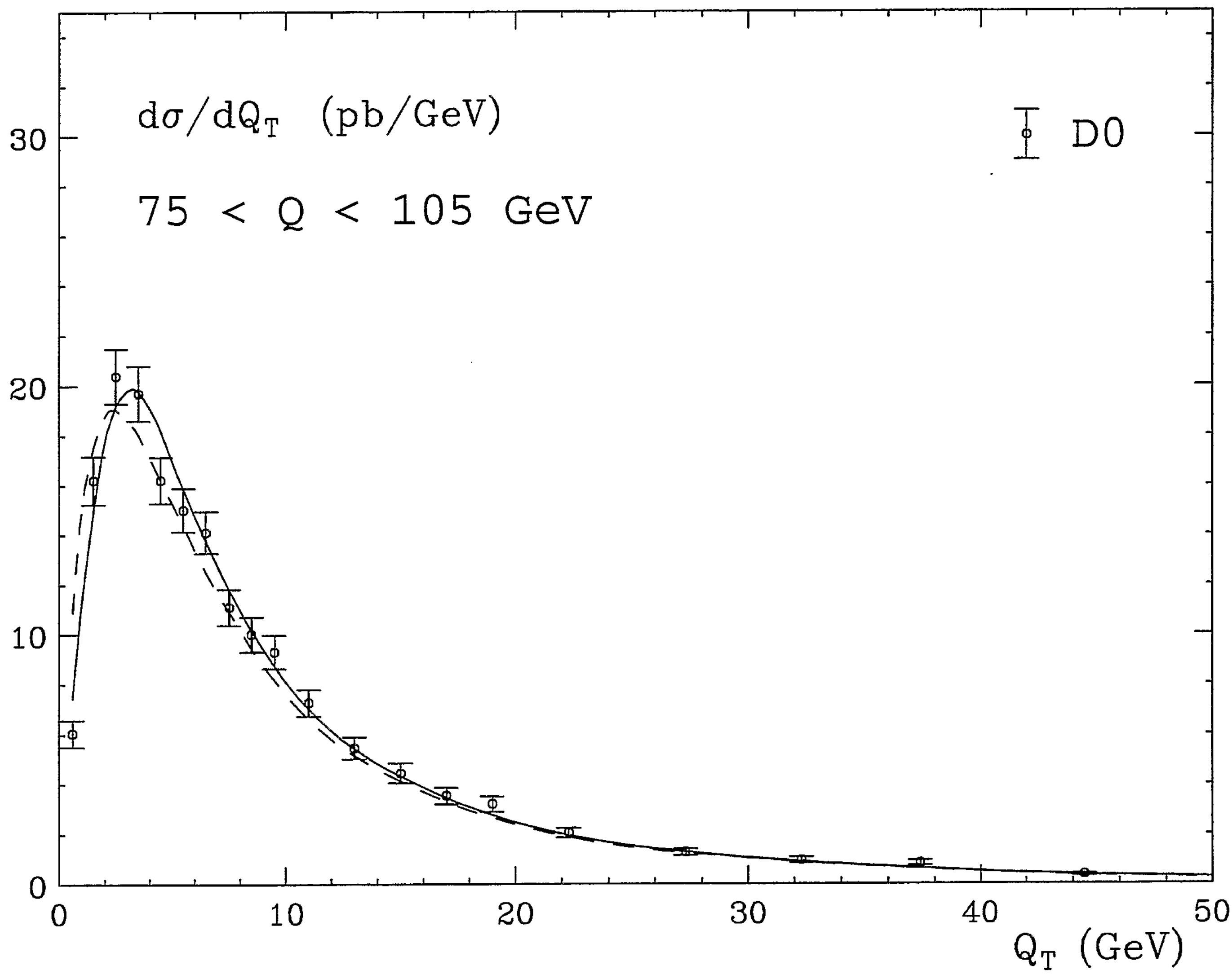
(Kulesza, Sterman, WV)
(CTEQ5M pdfs)



dashed : "purely perturbative" resummed

solid : Gaussian smearing $-g\,b^2$ with $g = 0.8$ GeV^2

(Kulesza,Sterman,WV)
(CTEQ5M pdfs)



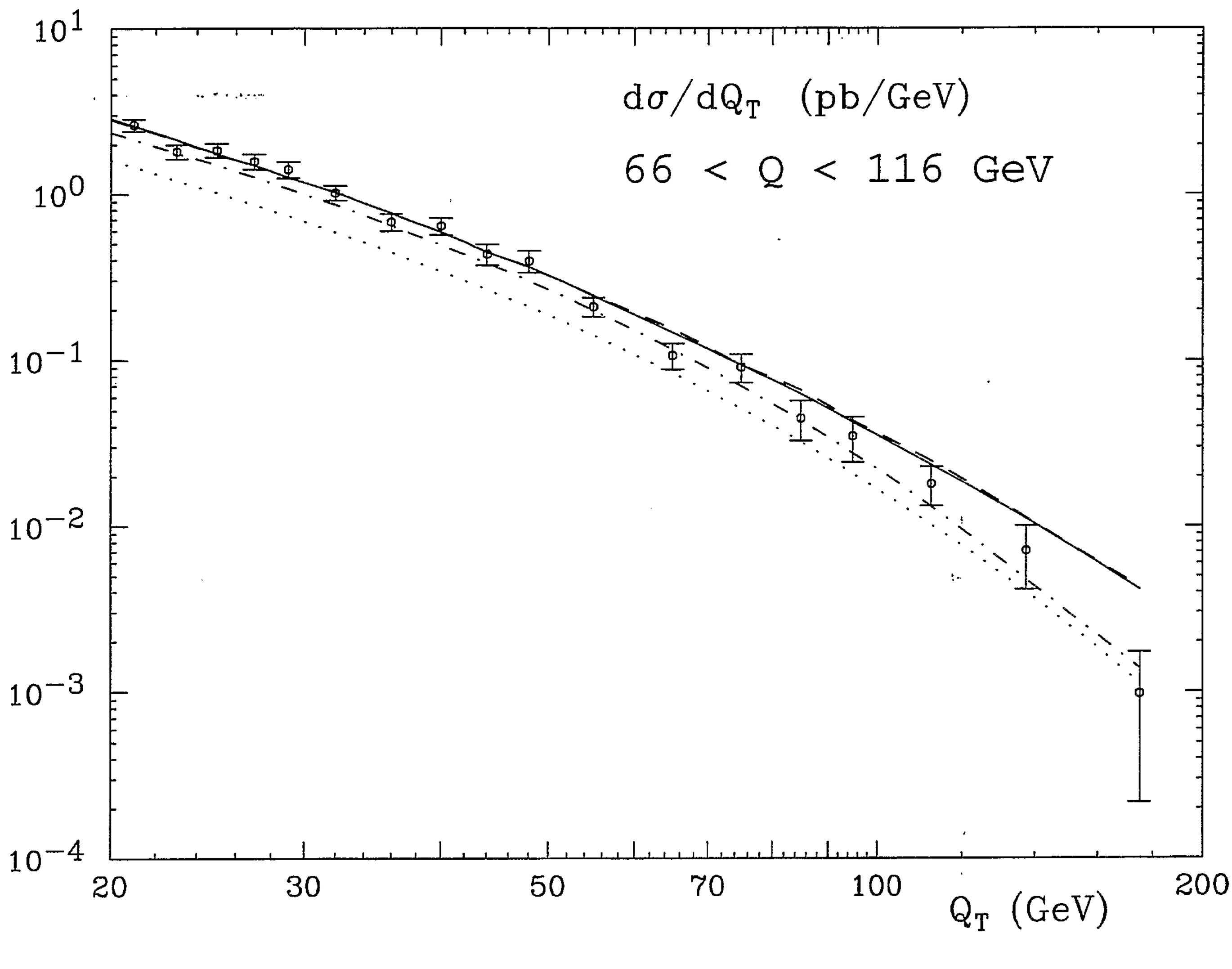
dashed : "purely perturbative" resummed

solid : Gaussian smearing $-g\,b^2$ with $g = 0.8$ GeV^2

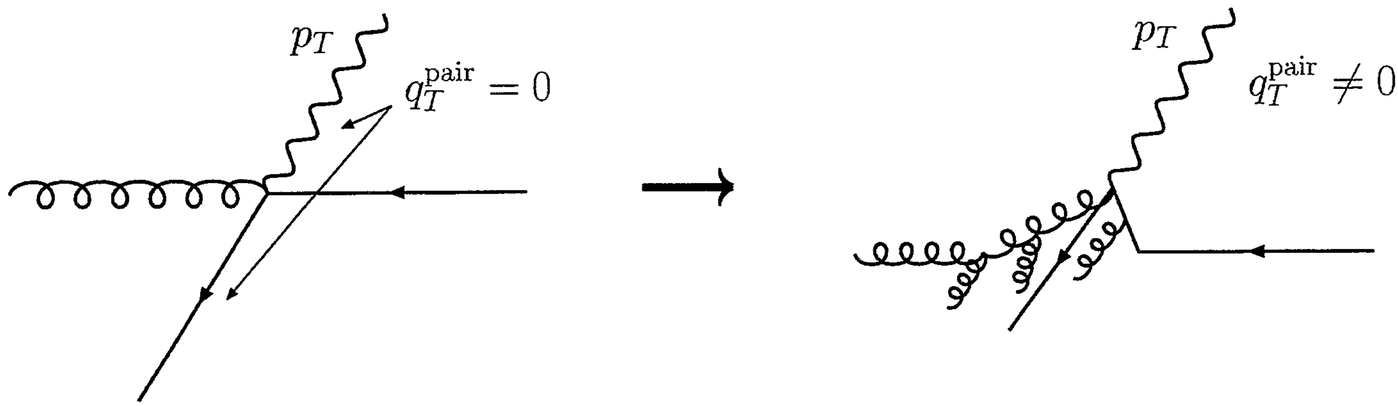
- at large $q_T \sim Q$, expect resummation to fail
fixed-order more appropriate
"matching" :

$$\frac{d\sigma}{dQ^2 dq_T^2} = \frac{d\sigma^{\rm res}}{dQ^2 dq_T^2} - \underbrace{\frac{d\sigma^{\rm exp(k)}}{dQ^2 dq_T^2}}_{\text{expansion of res.}} + \underbrace{\frac{d\sigma^{\rm fixed(k)}}{dQ^2 dq_T^2}}_{\text{fixed o.}}$$

$\rightarrow$ no double-counting



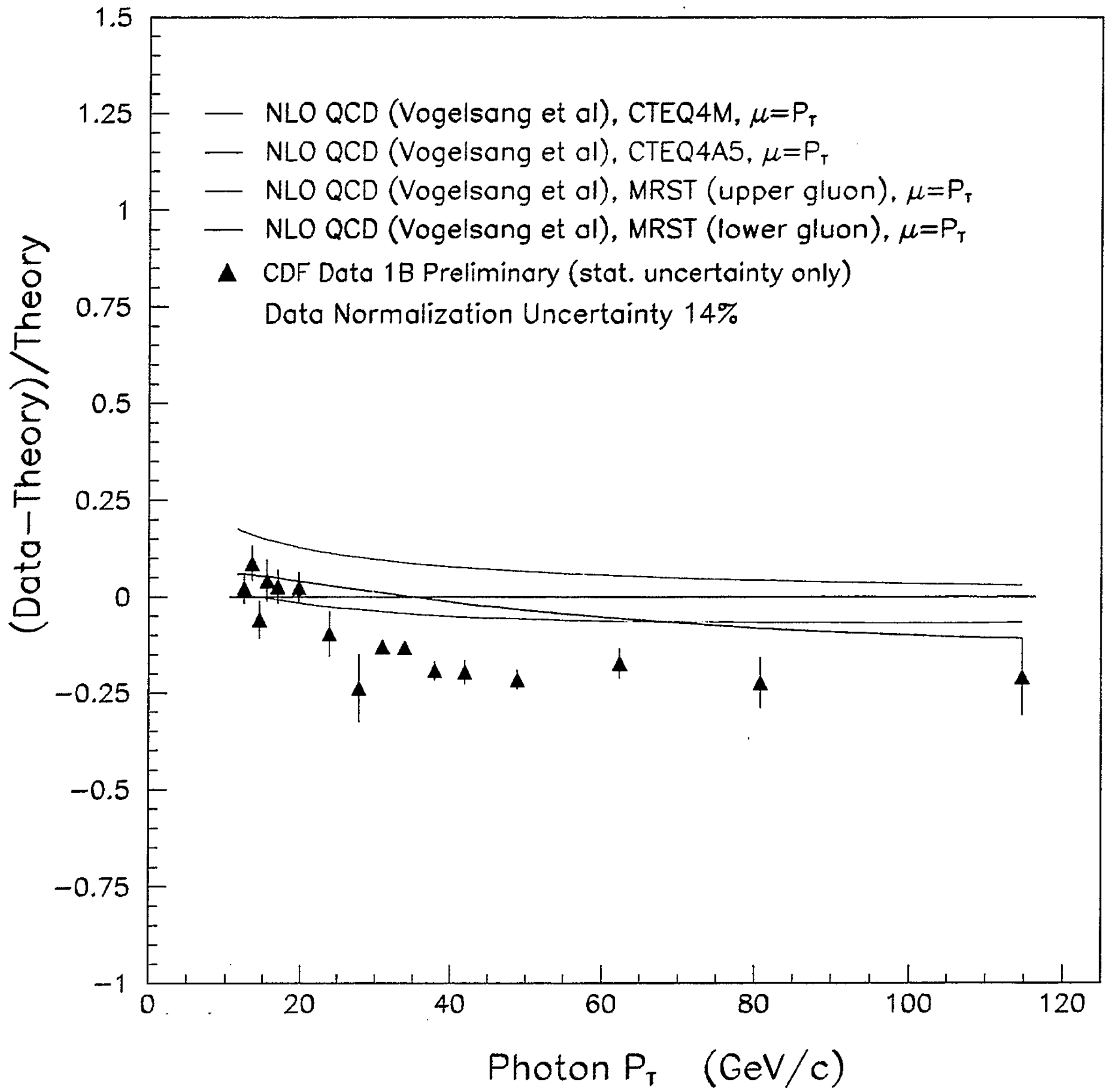
- extension to single-inclusive cross sections , for example direct photons $pp \to \gamma X$



  * motivated by phenomenologically observed "intrinsic-k_T smearing" (Apanasevich et al.)
  * q_T and/or "joint" resummations for photons : Laenen,Sterman,WV; Li; Fink,Owens

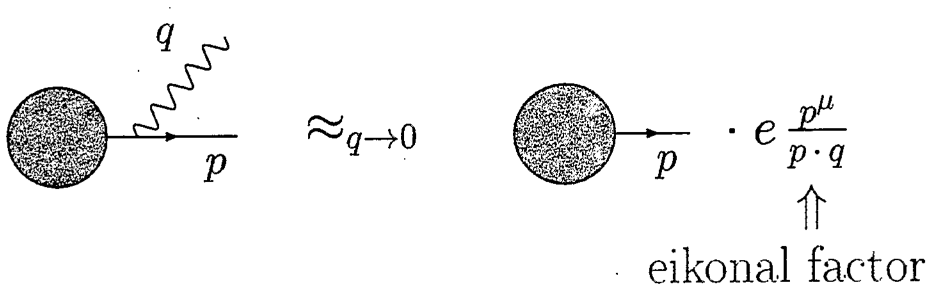
- phenomenological studies of these ideas in progress
- large effects likely, promising
- need to put "matching" on firmer basis
- non-perturbative effects also here

CDF, Run-1B

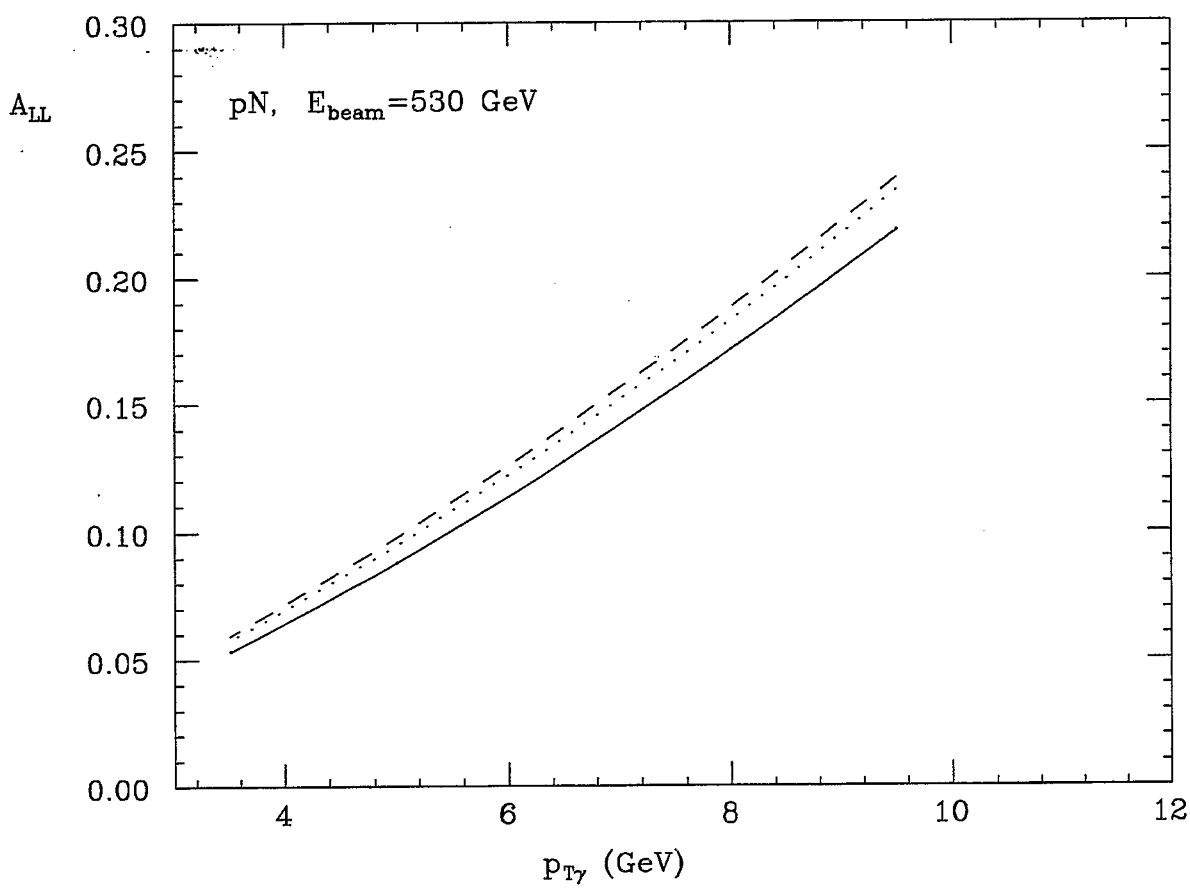


1.5
1.25
1
0.75
0.5
0.25
0
−0.25
−0.5
−0.75
−1
(Data−Theory)/Theory
NLO QCD (Vogelsang et al), CTEQ4M, μ=P_T
NLO QCD (Vogelsang et al), CTEQ4A5, μ=P_T
NLO QCD (Vogelsang et al), MRST (upper gluon), μ=P_T
NLO QCD (Vogelsang et al), MRST (lower gluon), μ=P_T
CDF Data 1B Preliminary (stat. uncertainty only)
Data Normalization Uncertainty 14%
0
20
40
60
80
100
120
Photon P_T (GeV/c)

V. Resummation for polarized scattering



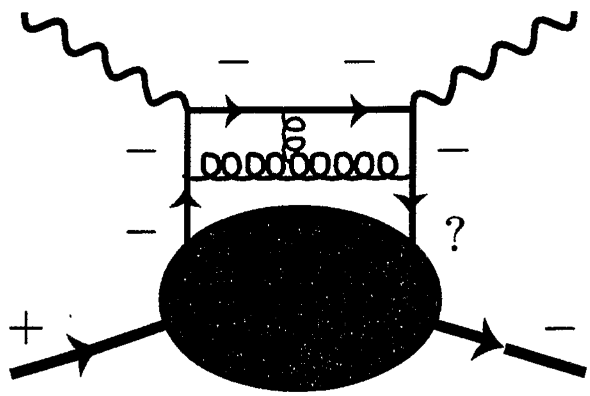
eikonal factor : spin-*in*dependent



- dotted : LO, dashed : NLO
- solid : threshold-resummed

VI. New results for A_{TT}

Helicity flip required $\Rightarrow$ δq not in incl. DIS :



Possibilities (among others) :

- Collins effect, interference fragmentation, etc.
  - require independent measurement of a fragmentation function
  - often not the only mechanism involved (see recently Brodsky, Hwang, Schmidt; Collins)

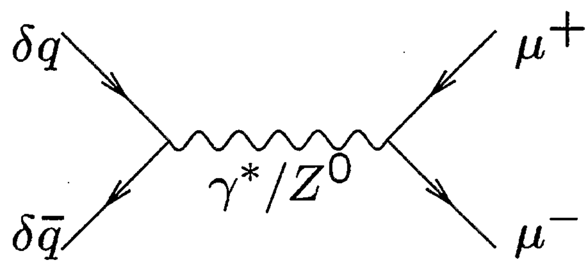
- collisions of transversely pol. protons at RHIC

$$A_{TT} = \frac{d\sigma^{p^\uparrow p^\uparrow} - d\sigma^{p^\uparrow p^\downarrow}}{d\sigma^{p^\uparrow p^\uparrow} + d\sigma^{p^\uparrow p^\downarrow}}$$

Drell-Yan dimuon production, $pp \to \mu^+\mu^- X$

$+$: LO $q\bar{q} \to \gamma^* \to \mu^+\mu^-$

$-$: presumably $\delta\bar{q}$ small



- dir. photons, jets, inclusive hadrons,... :

  Re-emphasize : A_{TT} is expected small,
  "$A_{TT} \ll A_{LL}$" (Jaffe, Saito)

  – no gluon transversity, however, gluon contribution to unpolarized cross section !

  – relevant hard scattering cross sections typically color-suppressed

  – Soffer's inequality limits size of δq

  + rates can be substantial

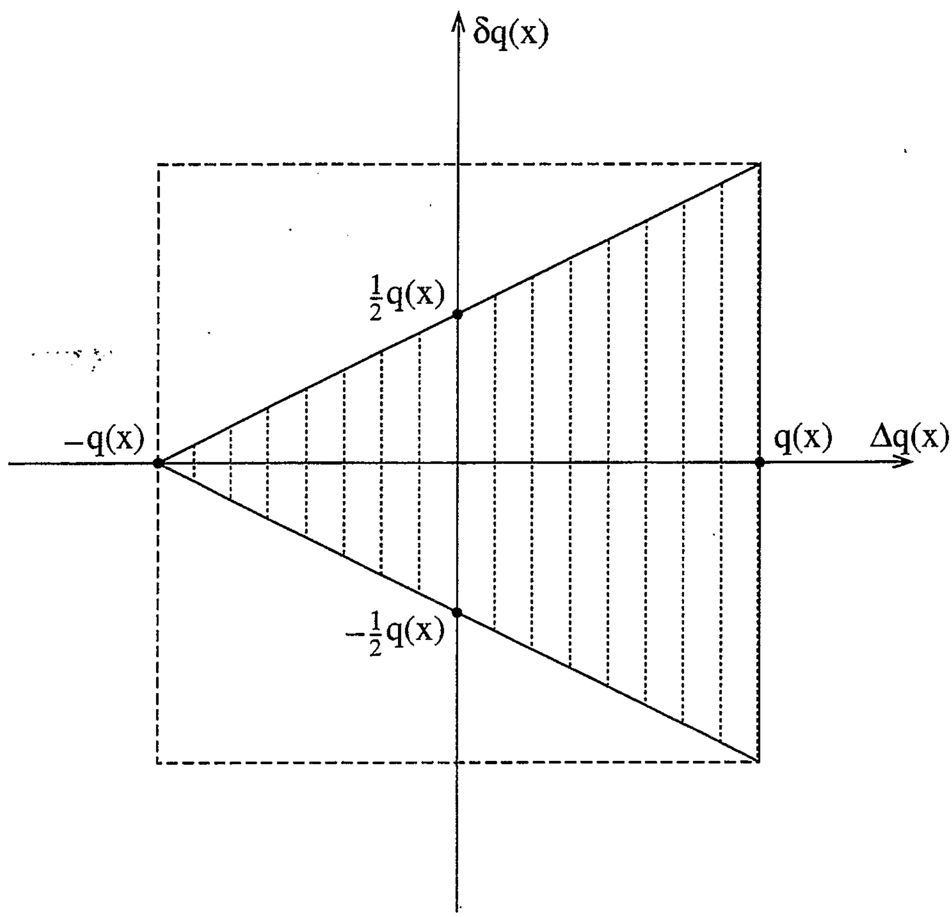
  ⇒ small asymmetries *may* be measurable

- estimate "upper bounds" on A_{TT} by saturating Soffer's inequality at $\mu_0 \sim 0.6$ GeV (Soffer, Stratmann, WV)

- "hard to imagine" that A_{TT} could be much bigger !

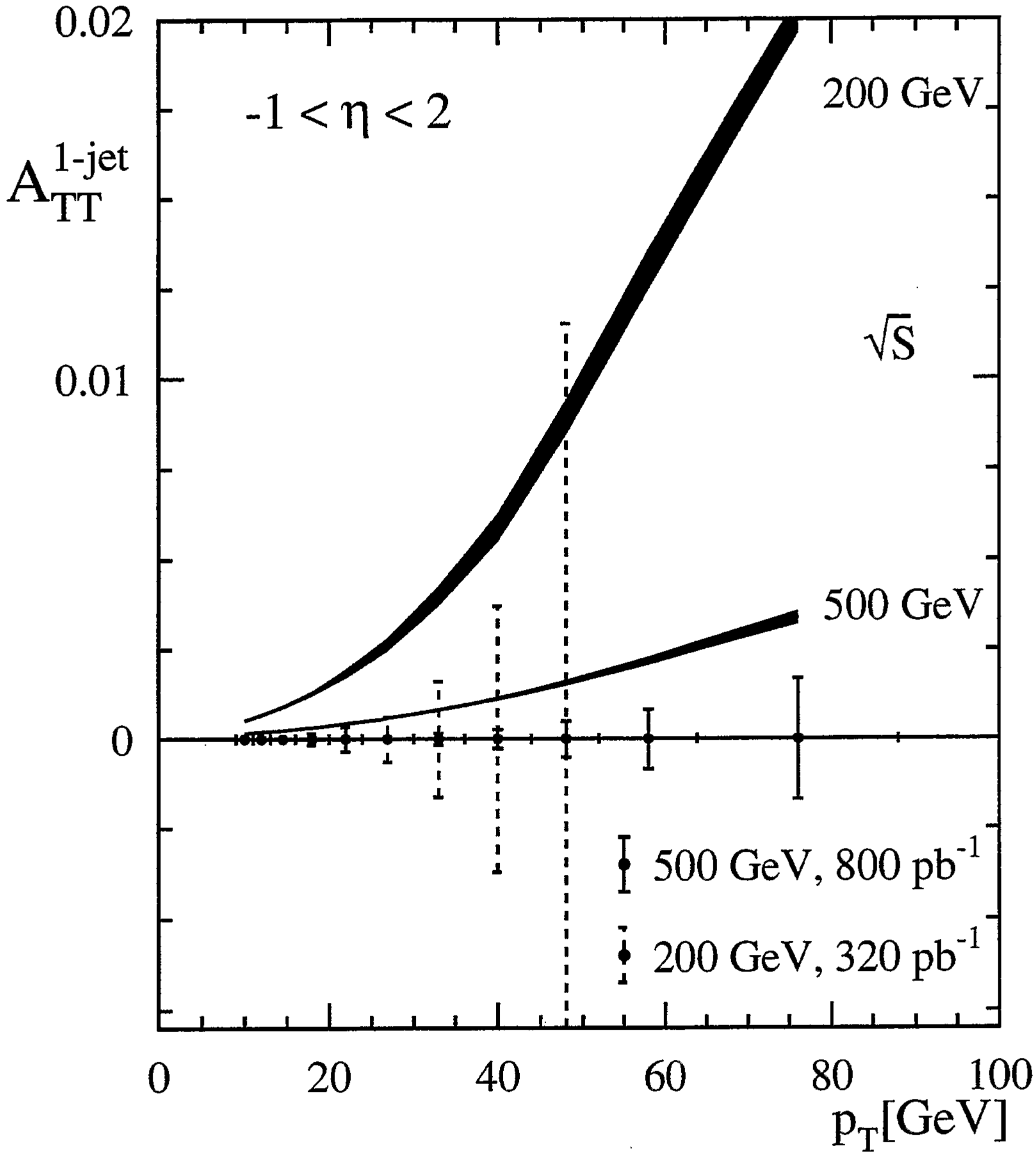
From helicity structure :
Soffer's inequality

$$2\,|\delta q(x,\mu)| \;\leq\; q(x,\mu) + \Delta q(x,\mu)$$

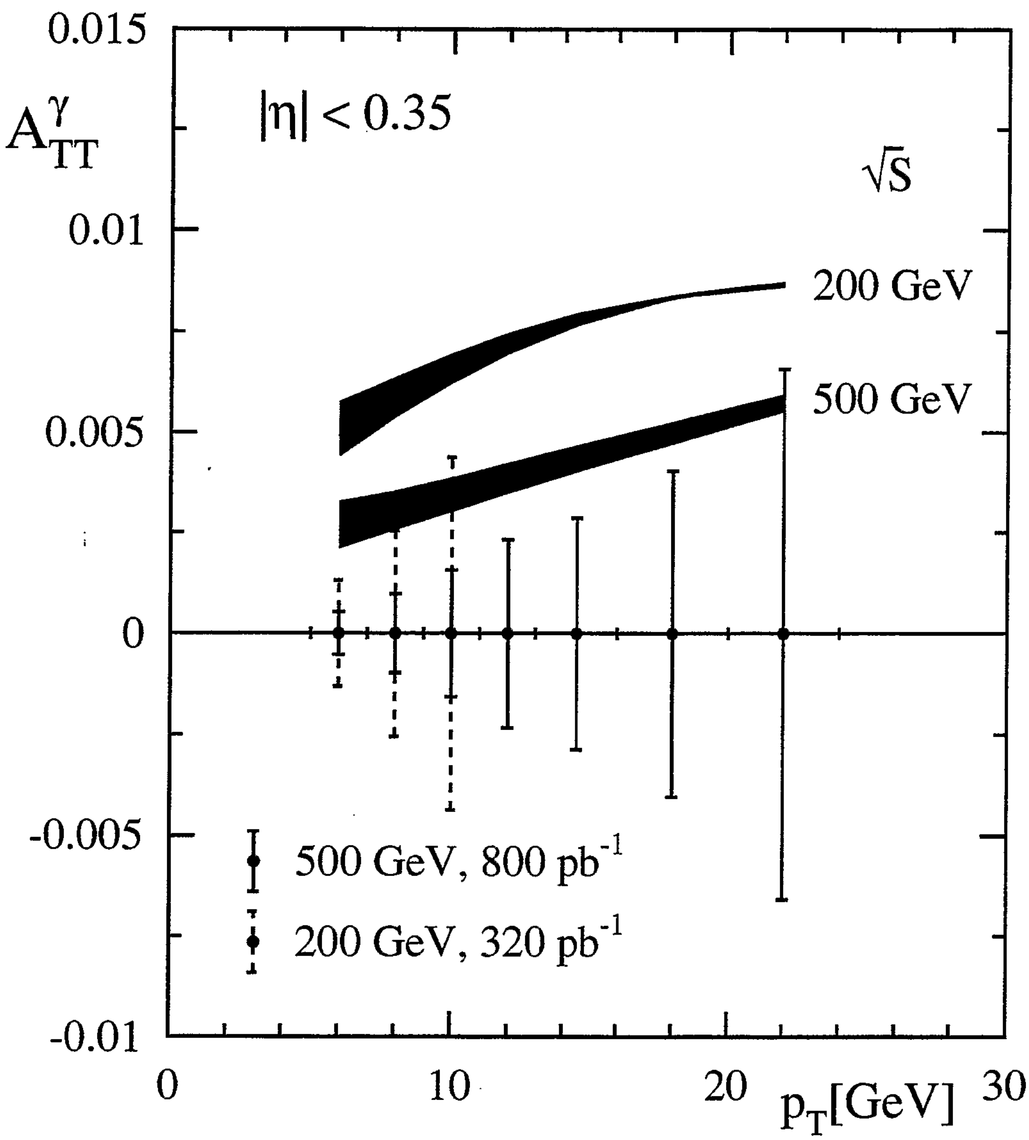


- for all flavors
- constraint for models for transversity
- preserved under QCD evolution
  (Barone; Bourrely,Soffer,Teryaev;
  Martin,Schäfer,Stratmann,WV)

(Soffer,Stratmann,WV)



(Soffer,Stratmann,WV)



RHIC Spin Collaboration Meeting X
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RIKEN BNL Research Center

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Not in attendance but will be sent proceedings:

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Geary Eppley	Rice University MS 315 6100 Main St. Houston, TX 77005	eppley@physics.rice.edu
Waldo Mackay	BNL - CAD Bldg. 1005S Upton, N.Y. 11973-5000	waldo@bnl.gov
Vahid Ranjbar	BNL Bldg. 911B Upton, N.Y. 11973-5000	vranjbar@indiana.edu

RIKEN BNL Research Center

RHIC Spin Collaboration Meeting X

June 17, 2002

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

*******AGENDA*******

Morning Session

09:00 - 09:45 Status Report on the Jet Target.. T. Wise

09:45 - 10:15 Status Report on the Jet Experiment.............................. S. Bravar

10:15 – 10:30 Timeline Discussion.. Y. Makdisi

10:30 – 10:45 Coffee Break

10:45 – 11:30 Update on the AGS Polarization Offline Analysis............ H. Huang

11:30 – 12:00 Status Report on the New AGS CNI Polarimeter.............. J. Wood

12:00 Lunch

Afternoon Session

13:00 – 13:30 Presentation on Some RHIC Polarization Analysis........... D. Underwood

13:30 - 14:15 Analysis of the Spin Flipper & Its Future Use.................. M. Bai

14:15 – 15:00 Analysis Progress Report from pp2pp.............................. S. Bueltmann

15:00 – 15:15 Coffee Break

15:15 – 16:00 Theory Talk... W. Vogelsang

Next Meeting ~ Monday, July 8, 2002 Small Seminar Room, BNL Physics Bldg. 510

SUMMARY

B. Fox, RBRC

July 29, 2002

for

RHIC Spin Collaboration Meeting XI

RIKEN BNL Research Center

Since its inception, the RHIC Spin Collaboration (RSC) has held semi-regular meetings each year to discuss the physics possibilities and the operational details of the program. Having collected our first data sample of polarized proton-proton collisions in Run02 of RHIC, we are now in the process of examining the performance of both the accelerator and the experiments. From this evaluation, we not only aim to formulate a consensus plan for polarized proton-proton during Run03 of RHIC but also to look more forward into the future to ensure the success of the spin program.

In the fifth meeting of this series (which took place at BNL on July 29, 2002), we focused on the former since the beam-use requests from the experiments were due in early August. Accordingly, we had presentations on three of the critical issues for spin running in RHIC Run-03:

- RHIC polarization issues,
- Commissioning of the new spin rotators, and
- Absolute luminosity.

Following these presentations, we had an open discussion about the beam use proposal. In addition, there was a presentation on a proposal to measure the analysing powers of the CNI polarimeter at AGS energies.

To open the meeting, Osamu Jinnouchi presented an update on the offline analysis of the CNI polarimeter data from Run-02. Following up on the work presented in the May meeting, Osamu showed that the increase in the noise was caused by the gain drop in the silicon. Instead of cutting the noisy strips in his analysis, he performed a background subtraction by using the counts observed for "abort gap" bunches as a measure for this noise. In the yellow beam, he showed that the polarization exhibits a bunch-to-bunch dependence – specifically, the polarization of up bunches go up with bunch number, whereas the down bunches go down. At this time, this trend is not understood.

Vahid Ranibar then presented his results on depolarization in RHIC during ramping. In RHIC, the intrinsic, imperfection, and coupled resonances have no effect because the two Siberian snakes keep the tune at 1/2, independent of energy. However, the snakes give rise to so-called snake resonances. During the ramp to 100 GeV, there are three such resonances – Q_y at 3/16, 3/14, and 1/4 – which need to be avoided while ramping. During Run-02, the vertical tune was kept well above the 3/16 resonances, but did come close to the 3/14 and 1/4 resonances. These resonanaces were slightly displaced from their nominal values because, as seen by the survey, the machine was not as flat as it was initially thought. In particular, there was a sizeable dip ($\sim$ 5 mm) at IP12. From plots of the polarization versus the tune separation from the 3/14 and from the 1/4 resonance points, it's clear that both resonances were affecting the beam polarization. The 3/14 looked like the more frequent problem during the run. This fact may explain the observation (as presented by Dave Underwood in the June meeting) that the CNI analyzing power at flattop energy appeared to differ at the 20% level from the value at injection energy. For the next year, the new knowledge of the alignment of the machine will be propagated into the tune calculation and thus this situation will likely be avoided.

As suggested by Vahid, the polarization would be better retained if we could control the tune on the ramp. Such control is possible when the tune feedback system (commonly referred to as the phase-lock loop or PLL system) is operating during the ramp. Peter Cameron presented a report on the commissioning and the performance of this system during Run-02. In this system, one bunch is given a nudge with each revolution of the beam and, via an rf pickup, the response of the beam is measured. The beam tune can then be computed from this information. To control the tune, the measurement is fed back to the magnet control system to tweak the current in correction coils so that the tune remains unchanged during the ramp. During Run-02, the system suffered from several problems: locking onto satellite bunches instead of the main bunches, the control system was not quite mature enough for non-experts to operate the system, and the feedback circuit was a bit too simple. Nevertheless, the system – when operated by an expert – was often able to control and stabilize the tune as the Au beams were being ramped. For proton-proton running, however, there were initially several failures of the system. Subsequently, these failures have been attributed to chromoticity broadening. But, at the time, the system was not studied further because of other demands on the commissioning effort. It is expected that the various problems will be surmounted by the beginning of Run-03 so that the system can be routinely operated throughout the run. The operation of this system is also required for performing the downramp.

In Run-03, both PHENIX and STAR will have spin rotators installed and operational around their IPs. As part of the commissioning for Run-03, these rotators need to be calibrated. Thus, there needs to be a means to measure the transverse component of the polarization at the interaction points. For PHENIX,[1] Abhay Desphande presented the results for the measurements which were performed at IP12 in Run-02 in the hopes of locating a process with both a sufficient rate and a non-zero analyzing power to provide a feasible method for doing local polarimetry. In this effort, forward production of neutral particles (neutrons, photons, and neutral pions) were studied with an electromagnetic calorimeter and a hadron calorimeter positioned behind the DX magnet on the blue and yellow beam, respectively. At this time, the analysis shows a large (on the order of 10%) analyzing power for neutrons, no analyzing power for pions, and at most a small analyzing power for photons. PHENIX plans to use the neutrons to determine the orientation of the polarization vector by adding shower maximum detectors to the existing zero-degree calorimeters (ZDC).

Following Abhay's presentation, Waldo Mackay closed the morning session with a status report on the installation of the spin rotators and a first look at the commissioning plan for them. The installation of the rotators in the RHIC ring is on schedule and presently well past the halfway point. The main tasks which remain are the cabling of the magnets to the cooling system, the magnet power supplies, and the quench circuits. Both tasks are expected to be finished on schedule. The commissioning plan is to take some data at the experiments first with the spin rotators off so that the performance of the local polarimeters can be verified. Then, Waldo would turn on the rotators so that, in principle, the spin would be aligned radially. A measurement by the local polarimeters at STAR and PHENIX would then verify the orientation of the polarization. From this point onwards, the commissioning effort would depend upon what is learned. Once the spin rotators have been commissioned, their setting will be set during physics running from measurements of the deflection of the beam made by

[1] The STAR local polarimeter effort was discussed by Les Bland during the May RSC meeting.

beam position monitors situated at the center of each rotator.

The afternoon session was opened by Angelika Drees with a presentation of the analysis of the data from the van der Meer/vernier scans performed with protons during Run-02. To compute the luminosity from machine parameters alone, the most difficult property to determine is the transverse size of the overlap between the two beams at the interaction point (IP). At RHIC, this overlap size can be directly measured using van der Meer or vernier scans. In these scans, one of the beams is systematically moved across the other beam along one axis. By monitoring the collision rates using the experiment's min-bias trigger and measuring the positions of the two beams using the beam position monitors, the width of the overlap is measured along one axis. The width of the overlap region along the orthogonal axis is then determined by repeating the scan with displacements along this axis. In her presentation, Angelika showed that the ZDC cross section was, within statistics, the same at PHENIX and STAR in the fills for which scans were done at both IRs. She also presented the preliminary cross section results from the BBC counters at PHENIX.

Since the geometry of the detectors at each IP imposes an event configuration cut on the cross section, it is necessary to investigate the extent to which the experiments understand such effects. This effort provides a means to estimate the systematic error in the luminosity measurement. Yuji Goto presented a status report on the PHENIX efforts to study this issue.[2] Since PHENIX imposes a vertex cut in its trigger counters, the effective luminosity is smaller than the machine luminosity. The correction for this effect was estimated from data which had been collected without this cut. In addition, the limited acceptance of the trigger counters ($3.0<\eta<3.9$) biases the cross section measurement done via the van der Meer scan. This effect was estimated using a PYTHIA Monte Carlo. At present, the analysis results in a cross section of 40 mb, somewhat smaller than the inelastic cross section predicted in PYTHIA (42 mb). However, for this analysis, we presently estimate that the error is between 10 and 20%. In the upcoming month, we plan to finalize the error estimate and investigate the agreement of PYTHIA with our measured data. Yuji also showed the measured π° p_t spectra released by PHENIX for QM. The agreement of the perturbative QCD (pQCD) calculation with these data is remarkable and thus supports the use of pQCD for interpreting our future longitudinal asymmetry measurements.

Likewise, STAR has worked to understand the infleuence of their detector geometry on the luminosity measurement. Les Bland provided an update on the status of this analysis. STAR, like PHENIX, needs to estimate the acceptance bias of their trigger counters. They, like PHENIX, are using a PYTHIA Monte Carlo to generate the events. They then use a simplified response functions for their detectors to complete the simulation. Les showed that, in this simulation, although the hit distributions for each counter agree qualitatively with data, they tend to fall more rapidly at low and high multiciplicity than the data does. These differences are likely arising from from the simplified response function and the neglection secondaries in the Monte Carlo. He then summarized the status of the forward π° detector analysis which they are presently finalizing.[3]

For the pp2pp experiment, Ron Gill presented a progress report on their absolute lumi-

[2]The complete discussion of this analysis (including final results) was presented by Sergei Belikov during the October meeting.

[3]For details of the goals of this work, see Les Bland's talk during the May meeting.

nosity analysis. In pp2pp, the luminosity is monitored using the count rate in their inelastic detectors. Positioned at ± 20 m from the IP, these detectors cover the pseudo-rapidity range (η) from 2.5 to 5.5 using four sets of quadrant-segmented scintillator paddles. Since each set is separated from the other by ~ 2 m in z, a crude TOF measurement can be done to determine the direction of the particles which pass through the counters. This measurement can discriminate between beam-gas or beam-scraping events and beam-beam events. By using information from only one side of the IP, they hope to reduce the bias of the trigger on their data selection. During their dedicated fill in Run-02, however, pp2pp had set up their trigger so that it required a coincidence between the set of counters on each side of the IP. From these data, Ron reported that a single side measurement could separate the beam-beam events from the other background events. He used these events, along with a cross section estimate from PYTHIA, to determine a luminosity at pp2pp.

To close off the presentations, Rob Hobb talked about the goals and plans for a possible measurement of the CNI analyzing powers at several energy points over the range which the AGS operates. From the E950 experiment, this analyzing power is only known at one energy – namely 22 GeV which is near the transfer energy to RHIC – but with an error of $\sim 30\%$. To make the most use of the CNI polarimeter presently being installed in the AGS, it would be best not only to improve the precision of this result but also to know the analyzing power at or near all of the spin resonances in the AGS. Without a dedicated experiment, it will only be possible to cross check the CNI analysing power with the "standard" AGS polarimeter at low energy in the AGS, leaving room for uncertainty over the mid-range of energy. So, to fill this gap in our knowledge, Rob presented a proposal to install a jet experiment on one of the AGS exit lines and, similar to the jet target effort underway at RHIC, make a measurement of the analyzing power of the AGS.

B. Fox
29 July 2002

Update on the RHIC Polarization Analysis

O. Jinnouchi, RBRC
July 29, 2002

for
RHIC Spin Collaboration Meeting XI
RIKEN BNL Research Center

Update on the RHIC Polarization Analysis

7/29/2002 RSC meeting

Osamu Jinnouchi

Contents

- ☐ Bunch-by-bunch polarization study

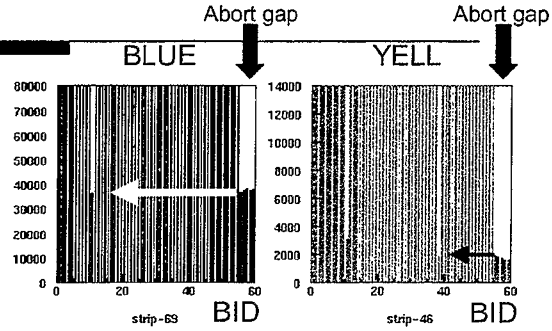
Reminder

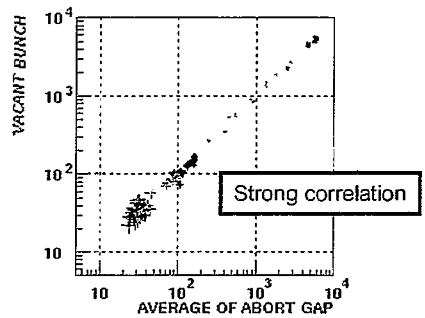
- ☐ *From my last presentation,*
  1. *1^{st} 0-pol bunch behaves strange*
     - ☐ *use 2^{nd} and 3^{rd} 0-pol bunches*
  2. *Low populated bunches create unphysical counts ratio between 6-Si detectors*
     - ☐ *Fitting χ^2 for the ratio distribution can be a criteria for choosing good bunches*
- ☐ *Other concerns*
  - ☐ *Robust strip selections will create large acceptance asymmetries*
  - ☐ *systematic effects (Asymmetry of Up (down) spin bit went up (down))*

Strip selections

Use Dedicated run (fill:2301)

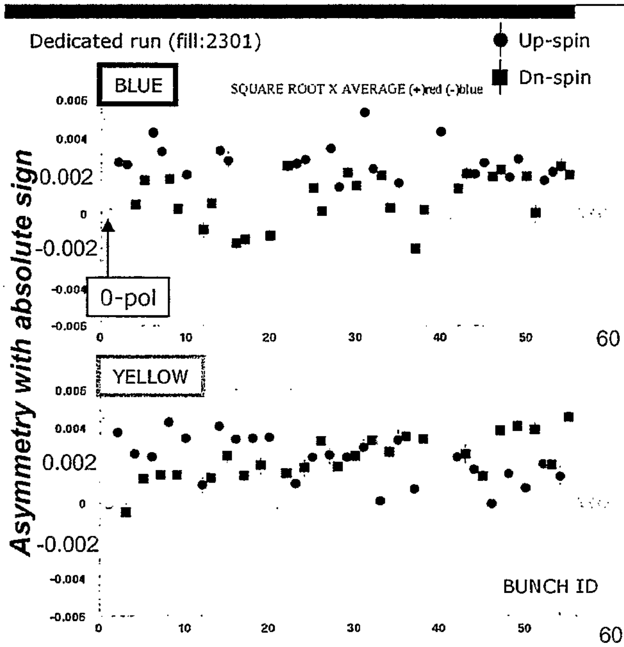
- ☐ *In order to avoid the acceptance asymmetry distortion, the noisy strips are going to be used in the analysis*
- ☐ *Background level for each strip is estimated with the number of counts in the abort gap*
- ☐ *Assuming that the backgrounds are flat with respect to the bunch distribution, average of the number of counts in abort gap is subtracted for each strip*





Bunch by bunch asymmetry

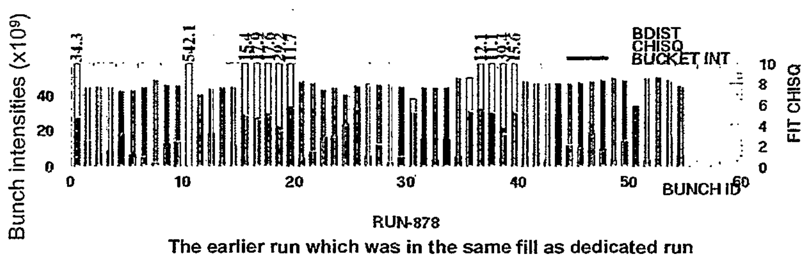
Dedicated run (fill:2301)



- *Taking bunch-by-bunch asymmetries with background subtraction*
- *1st 0-pol bunch is not used*

1. *For BLUE*
   - ☐ *Large gaps are due to the unphysical detector ratio*
   - ☐ *Some criteria to discard those runs are needed*
2. *For YELLOW*
   - ■ *Down spin bit is going up*
   - ■ *Up spin bit is going down*

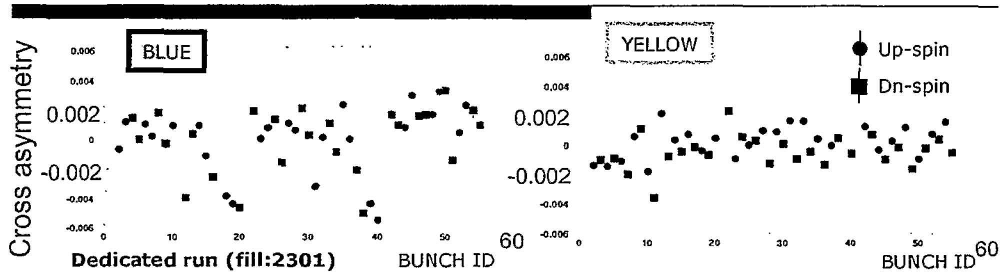
Fit χ^2 as a bunch selection criteria

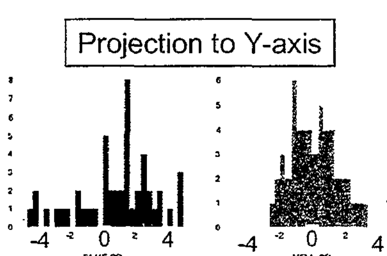


The earlier run which was in the same fill as dedicated run

- *The luminosity ratio with respect to the 0-pol bunch for each detector is fitted with sinϕ function (ϕ dependence of A_N)*
- *Fit χ^2 is obtained for every bunches*
- *Fit χ^2 surely indicates the bad bunches, however it is hard to determine the criteria line (χ^2=2,3,?)*
- *The normal bunches can easily get the higher fitting χ^2*

Cross (forbidden) asymmetry as a criteria parameter



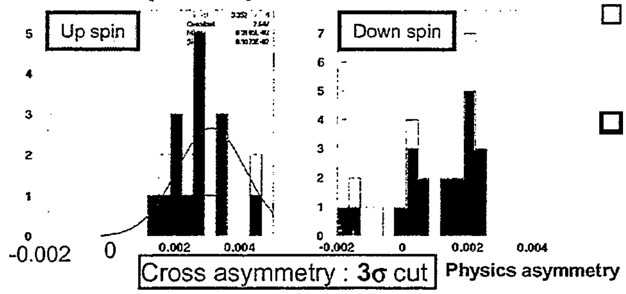


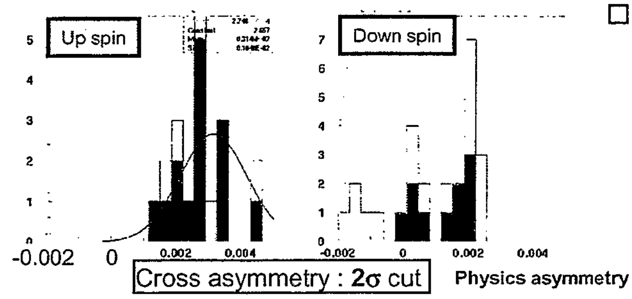
Significance plot [Asymmetry/$\sigma_{stat.}$]

- *Cross asymmetry is taken btw i-th bunch and 0-pol bunch*
- *45 degree detectors are used forbidden combination (1x4-2x5)*
- *Basically the cross asymmetry corresponds to the fit χ^2*
- *Criteria is determined by significance*

Blue: physics asymmetry after bunch selection

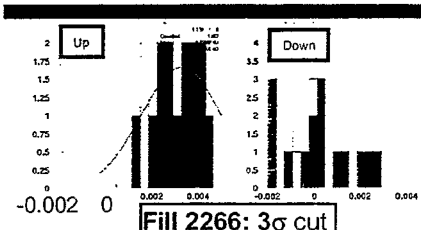
Dedicated run (fill:2301)

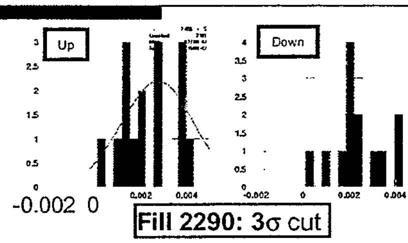


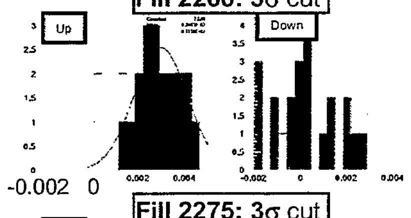


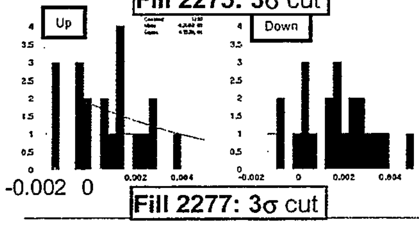
- *Up spins are rather stable with wide distribution (35% fluctuation)*
- *Down spins are unstable with strong dependence on cut condition*
- *It would be better to take a look at other fills*

Other fills (for Blue)





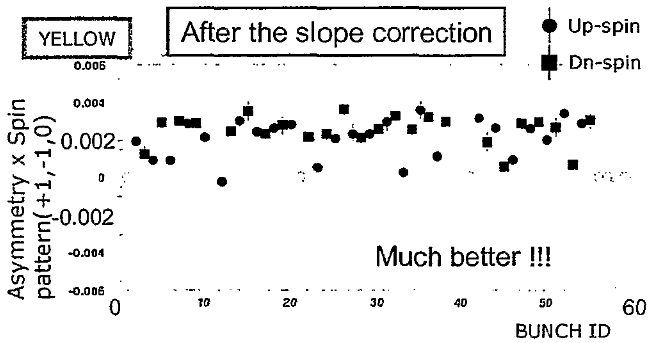


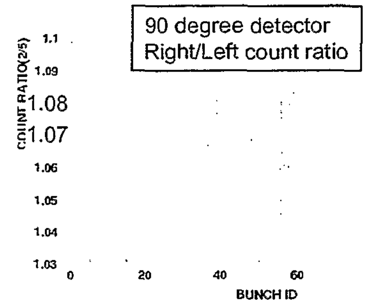


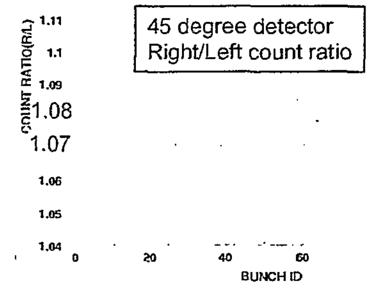
- Add up 4-5 runs during the same fill
- Generally physics asymmetries for Blue ring are widely distributed

(Yellow) Shifting of the counts (left → right)

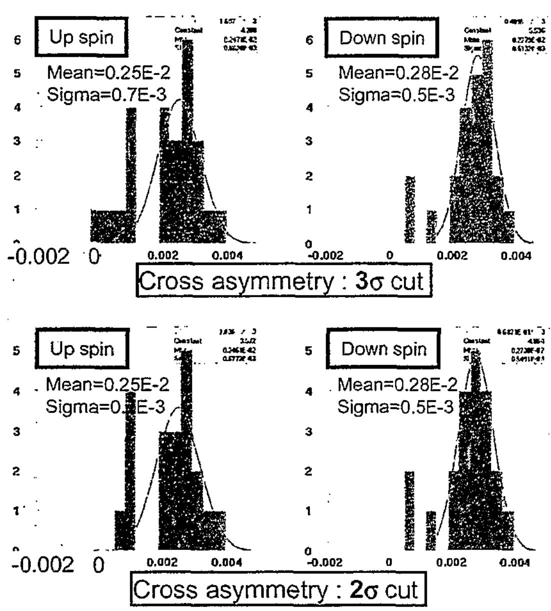
- Absolute asymmetry values for yellow is shifting towards minus on both spin signs
- The ratio Right/Left is decreasing linearly as a function of bunch ID
- Although the reason for the behavior is unknown, the slope correction is possible







Yellow: physics asymmetry after bunch selection

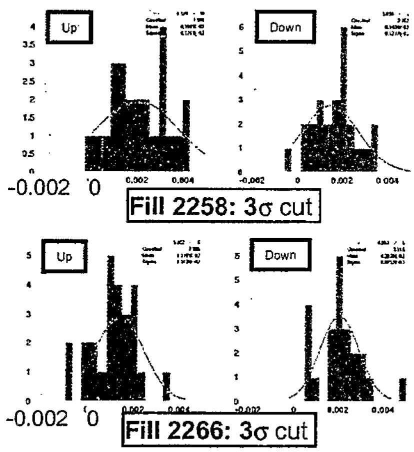


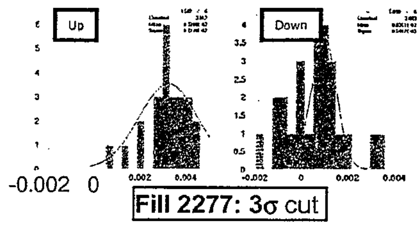
- Both spins are stable with variation of cut condition
- Distribution widths are relatively 20~30% for both rings
- Expected statistical fluctuation is

$$\frac{1}{\sqrt{200M/55}} = 0.53\times10^{-3}$$

- The outliers are found around zero even after the cross asymmetry cut, indicating some of the bunches lose polarization(?)

Other fills (for Yellow)





- ☐ 4-5 runs (20M events each) are added up
- ☐ Estimated error is ~0.8E-3
- ☐ Some fills are stable both in up and down spin
- ☐ Some fills show up-down separation
- ☐ Some fills need slope correction

Summary

- ☐ The bunch-by-bunch polarization is estimated with cross asymmetry cut
- ☐ For BLUE:
  - ■ still needed to be struggling with both on dedicated run and normal runs
- ☐ For Yellow:
  - ■ slope correction needed (beam position change?)
  - ■ Bunch-by-bunch asymmetry fluctuations are comparable with the statistical error
    - ☐ Can we say that

    intensity weighted polarization =

    luminosity weighted polarization ?

Understanding of the Beam Depolarization on the RHIC Ramp

V. Ranjbar, BNL
July 29, 2002

for
RHIC Spin Collaboration Meeting XI
RIKEN BNL Research Center

Depolarization along the RHIC ramp

Overview

- Review Spin Resonance
- Consider relevant snakes Resonance during 2002 run
- Examine Imperfection, Intrinsic and Coupled spin resonance in RHIC
- A Case for 3/14th coupled snake resonance
- Fitting a simple coupled snake spin Resonance model

Review of Spin Resonance

With out snakes the spin precesses Gg times each period. Depolarization occurs when:

- Gg = integer ⟶ Imperfection
- Gg = N±Qy ⟶ Intrinsic
- Gg = N±Qx ⟶ Coupled

Imperfection Resonance strength depend:

- Y closed orbit distortions
- Lattice periodicity
- Acceleration rate, vertical emittance

Intrinsic Resonance strength depend:

- Lattice periodicity
- Vertical and Horizontal tune
- Acceleration rate, vertical emittance

Coupled Spin Resonance depend on:

- Lattice periodicity
- Strength of global coupling
  - skew and solenoidal fields
  - $|Qx-Qy|$
- Acceleration rate, Horizontal emittance

The introduction of a snake forces the spin tune to be 1/2 and thus energy independent. In this way the imperfection, intrinsic and coupled spin resonance condition can be avoided. However this introduces a new "snake" resonance condition given by:

$$\delta Qy = (Qs \pm k)/\mathbf{l}$$

where **l**= order of resonance

l=odd ⟶ Odd Snake Resonance

- Associated intrinsic or coupled spin resonance strength, acceleration rate

l=even ⟶ Even Snake Resonance

- Associated intrinsic or coupled spin resonance strength, acceleration rate
- Imperfection resonance strength

-Splits resonance by

$$|\Delta Q_y| \le \frac{1}{l} \left| \frac{1}{\pi} \arcsin\left[\sin^2\left(\frac{\pi \varepsilon_{imp}}{N_s}\right) \right] \right|$$

Relevant Snake Resonance During the 2002 run

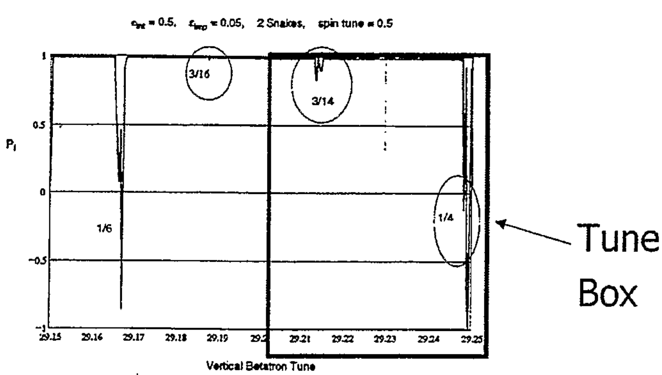


Figure 5.3: Vertical component of the polarization after acceleration through a strong intrinsic resonance and a moderate imperfection resonance shown as a function of the vertical betatron tune.

Imperfection, Intrinsic and coupled spin resonance in RHIC

From recent survey Data we can see that

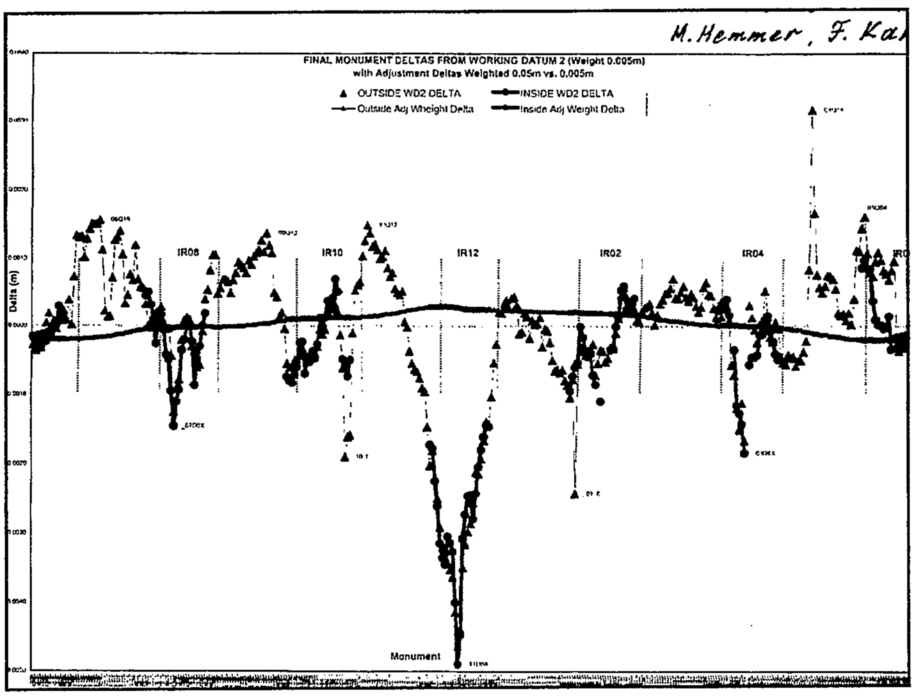
Y(co) max < 5 mm

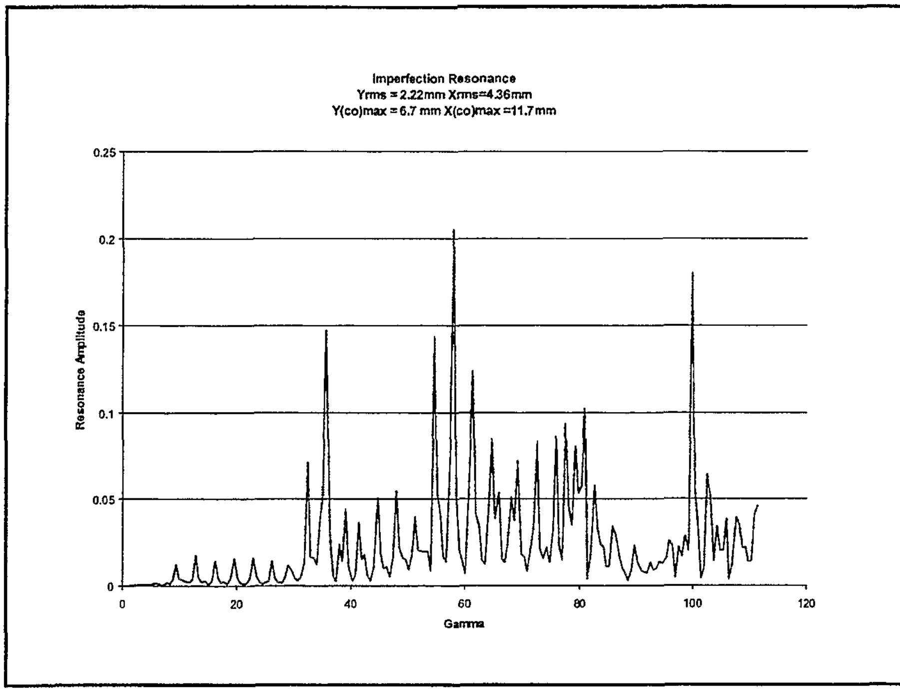
In the Energy range of the ramp this places

$|\epsilon|$max < 0.2

Which for the even snake resonance:

- 1/4 - 0.0076=0.242
- 3/16 +0.0019= 0.189





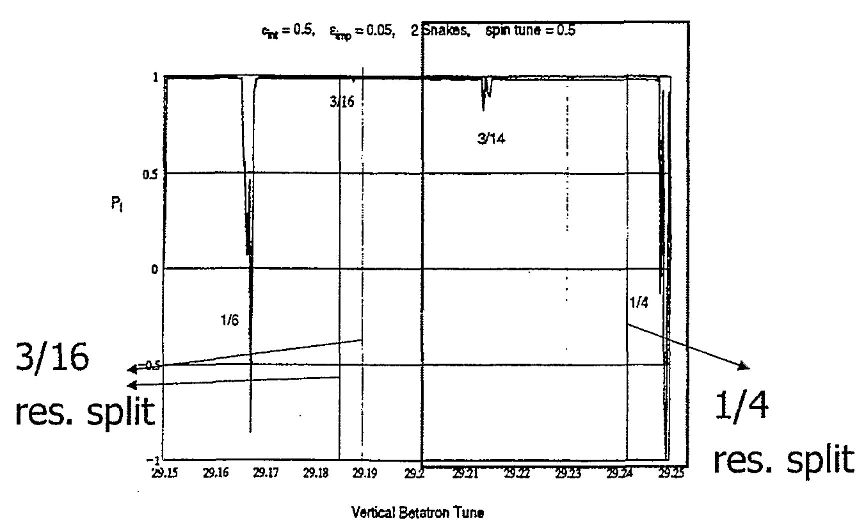
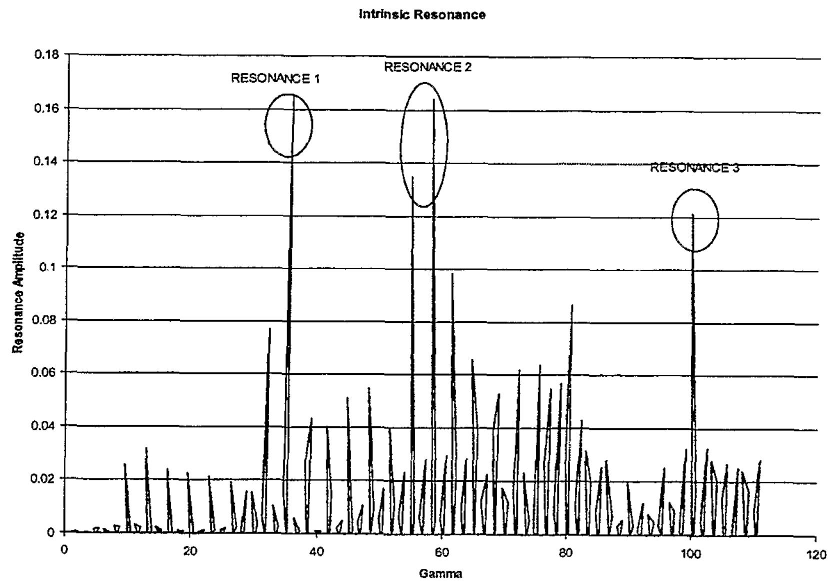


Figure 5.3: Vertical component of the polarization after acceleration through a strong intrinsic resonance and a moderate imperfection resonance shown as a function of the vertical betatron tune.



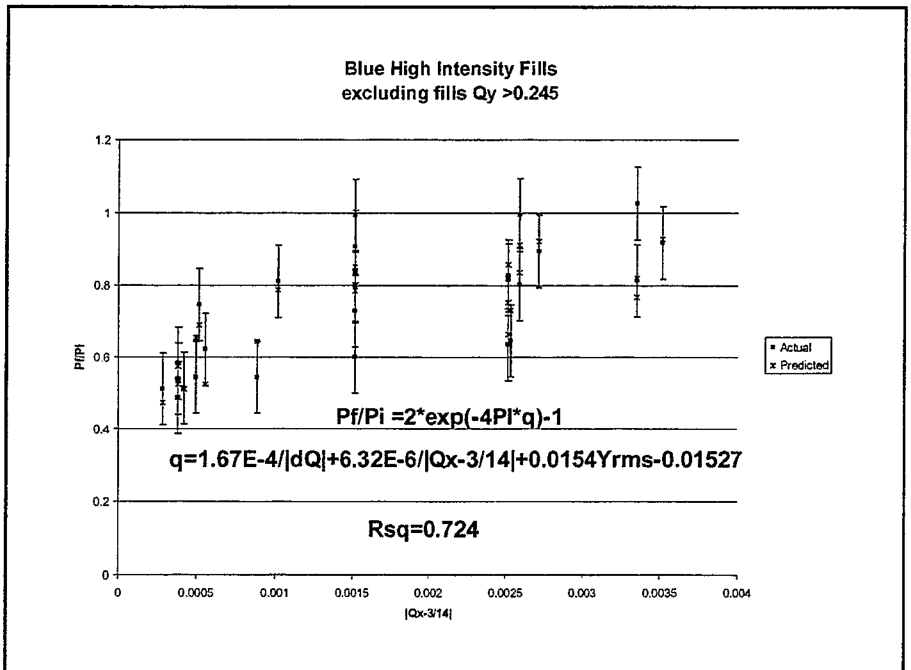
A Case for the 3/14 and 1/4 Snake Resonance

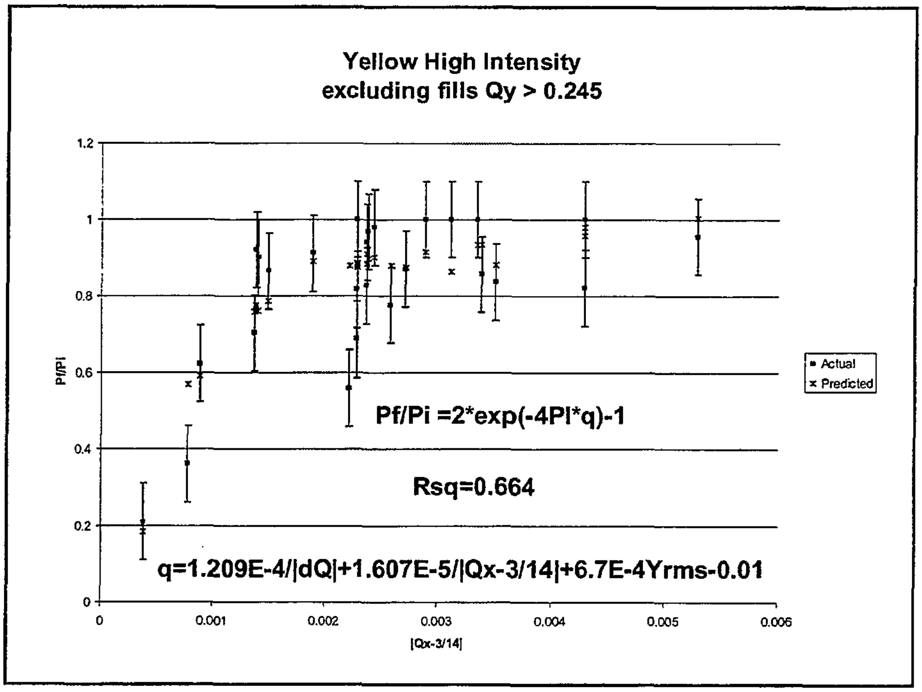
- Since our vertical tune was kept well above 3/14 depolarization could only come from 1/4 resonance
- However our Horizontal tune did cross the 3/14 tune and Strong coupling known to exist
- Since intrinsic Resonance < 0.2 numerical simulations in the past rule out the effect of higher order resonance

Fitting a simple coupled snake spin Resonance model

Data Sorting:

- For 3/14 snake resonance fit we excluded any fills with Qy > 0.245
- From these collected tune and orbit data for the three major intrinsic resonance locations along the ramp
- From these Picked the Resonance with min |Qx-3/14| value.



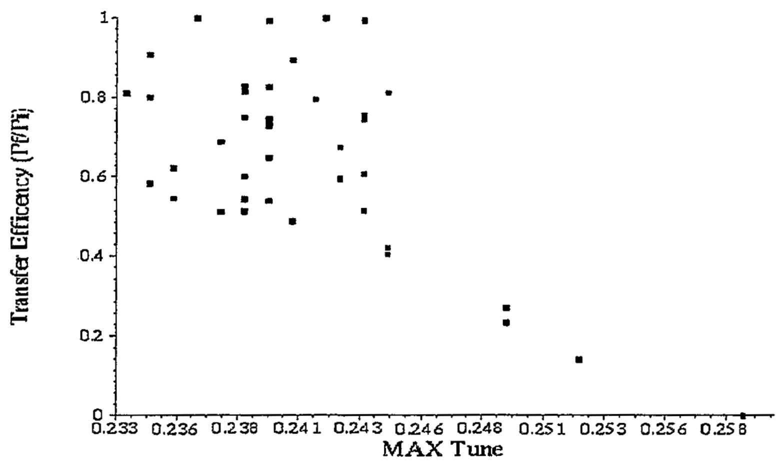


To understand the variability of these coefficients versus Blue Rsq=0.724 and Yellow Rsq=0.663

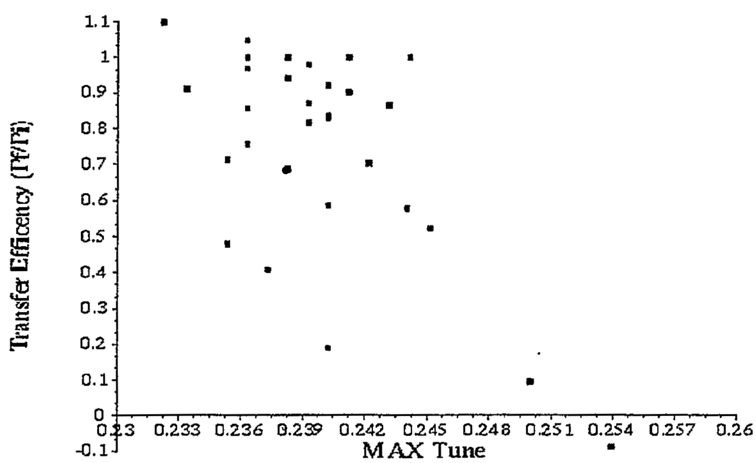
- Swapping term by term in Blue for Yellow
  - 0.715,0.676,0.597,0.724
- Swapping term by term in Yellow for Blue
  - 0.663,0.643,0.426,0.663
- Largest variability due to the Yrms term

  -could be due to old orbit data

Blue 1/4 snake Resonance



Yellow 1/4 snake resonance



Conclusion

To avoid Depolarization we suggest

- Correction of vertical closed orbit
- Better tune control to avoid 3/14 and keep tune separated
- Try to better De-couple machine

Status of and Commissioning Plans for the Phased-Lock Loop

P. Cameron, BNL

July 29, 2002

for

RHIC Spin Collaboration Meeting XI

RIKEN BNL Research Center

Goals for RHIC 2003

- Tune Feedback day one
- Chromaticity feedforward day one
- Supporting diagnostics (tune, chromaticity, coupling) in good order
- Operation from MCR via control system

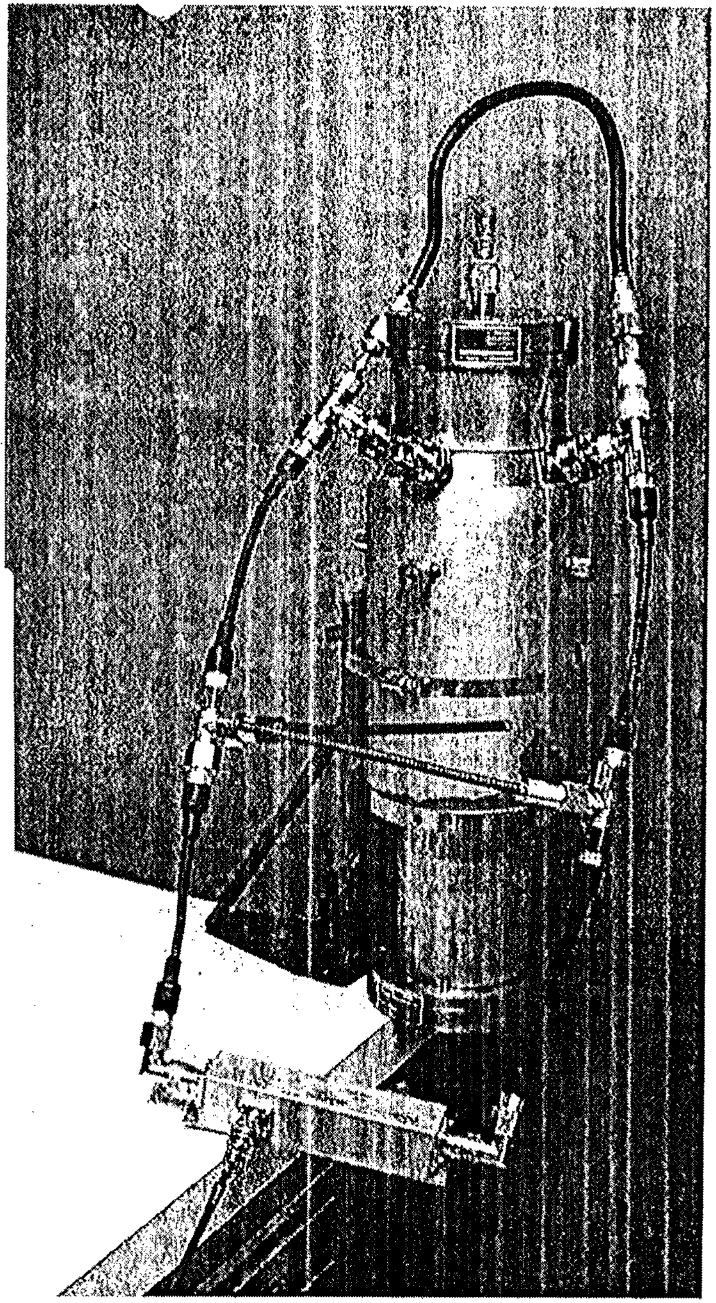
Definitions

- ① Tune Feedback
  - Ramp development tool
  - Normal operations?
- ② 'Day One' - see commissioning plan
- ③ Operational - 'it works'
  - The Specialist's definition - works when the specialist is present
  - The Physicist's definition - works when the physicist is present
  - The Operator's definition - When it breaks you call the physicist/specialist

333

Responsibilities

- Definition of System Requirements
  - Accelerator Physics - Drees, Pilat, Peggs,…
  - Power Supplies - Schultheiss
  - Instrumentation - Cameron
- PLL - Cameron
- Magnet Control - Schultheiss
- Simulation - Schultheiss, Peggs, Pilat, Malitsky,..
- Controls - Marusic, van Zeijts, Tepikian,…



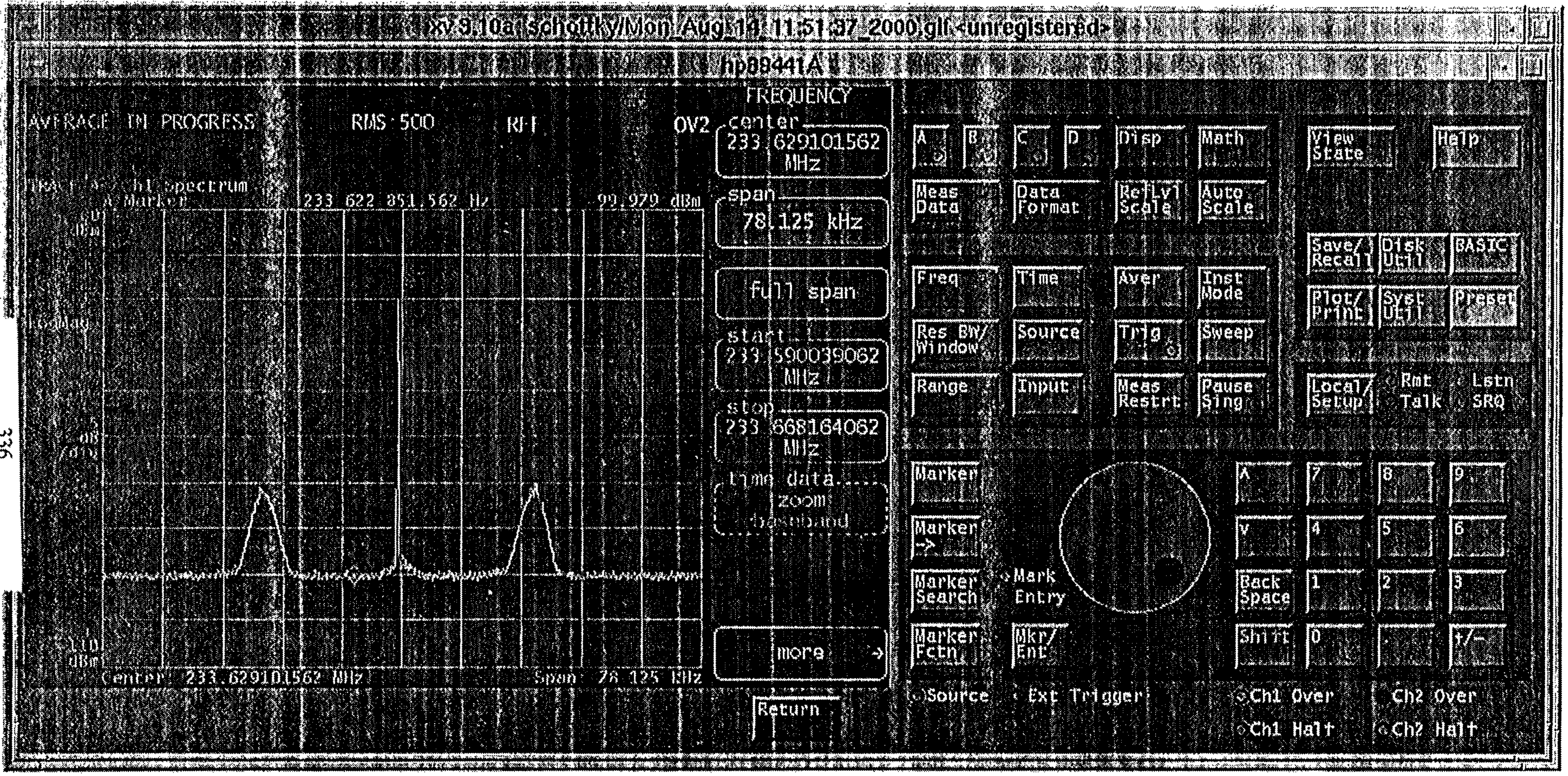
Resonant BPM

Beam Instrumentation
BIW02
Workshop

- M. Kesselman et al - PAC 2001
- Stub-tuned 1/4 wave resonator
- Simulated in Spice
- frequency ~ 240MHz (8.5xRF)
- Q_{loaded} ~ 100 optimal coupling
- In-tunnel hybrid for Σ and Δ
- Resonate difference mode - not sum mode signal at revolution line
- Moveable - minimize difference mode signal at revolution line
- Resonate above coherent spectrum

AT INJECTION

SPAN 78 KHZ   5 dB/div



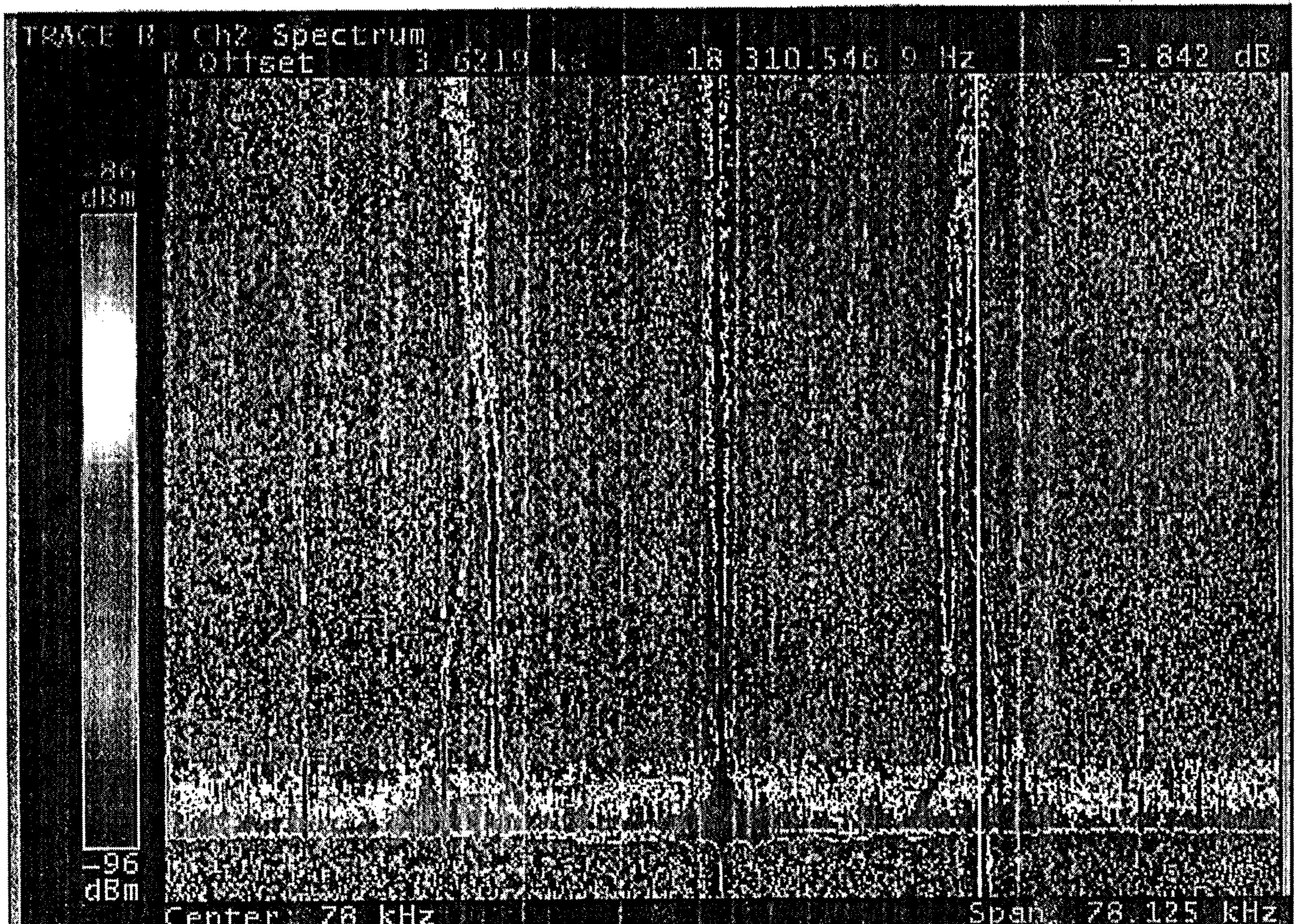
336

$\Delta f \simeq \eta N \frac{\Delta p}{p} = 237 \times 10^6 \times 7\times 10^{-3} \times 10^{-3}$ FWHM

~ 1-2 KHZ FWHM   ~ 4 KHZ MEASURED

LF Schottky on the Ramp

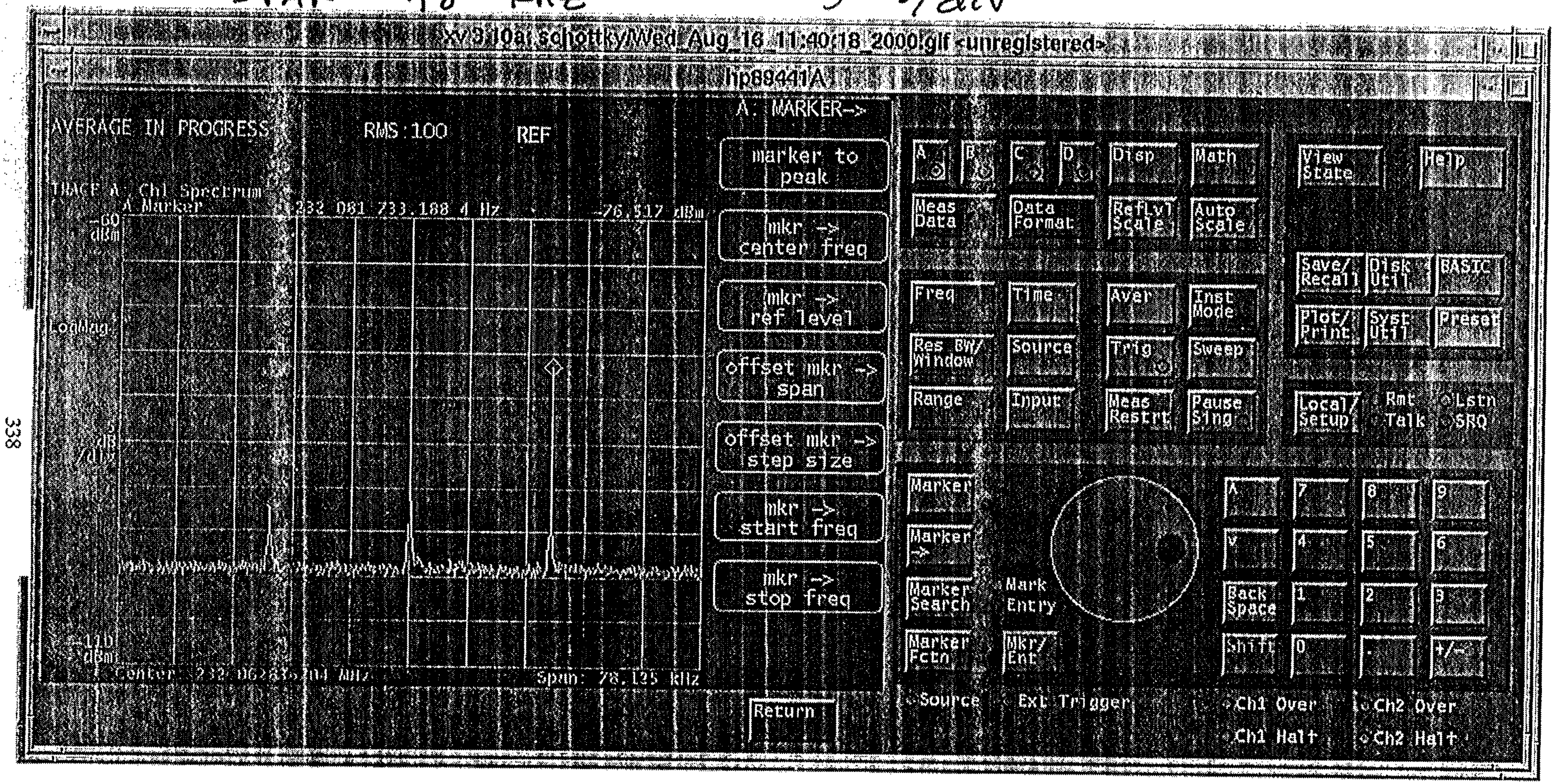
Injection



Transition

STORE

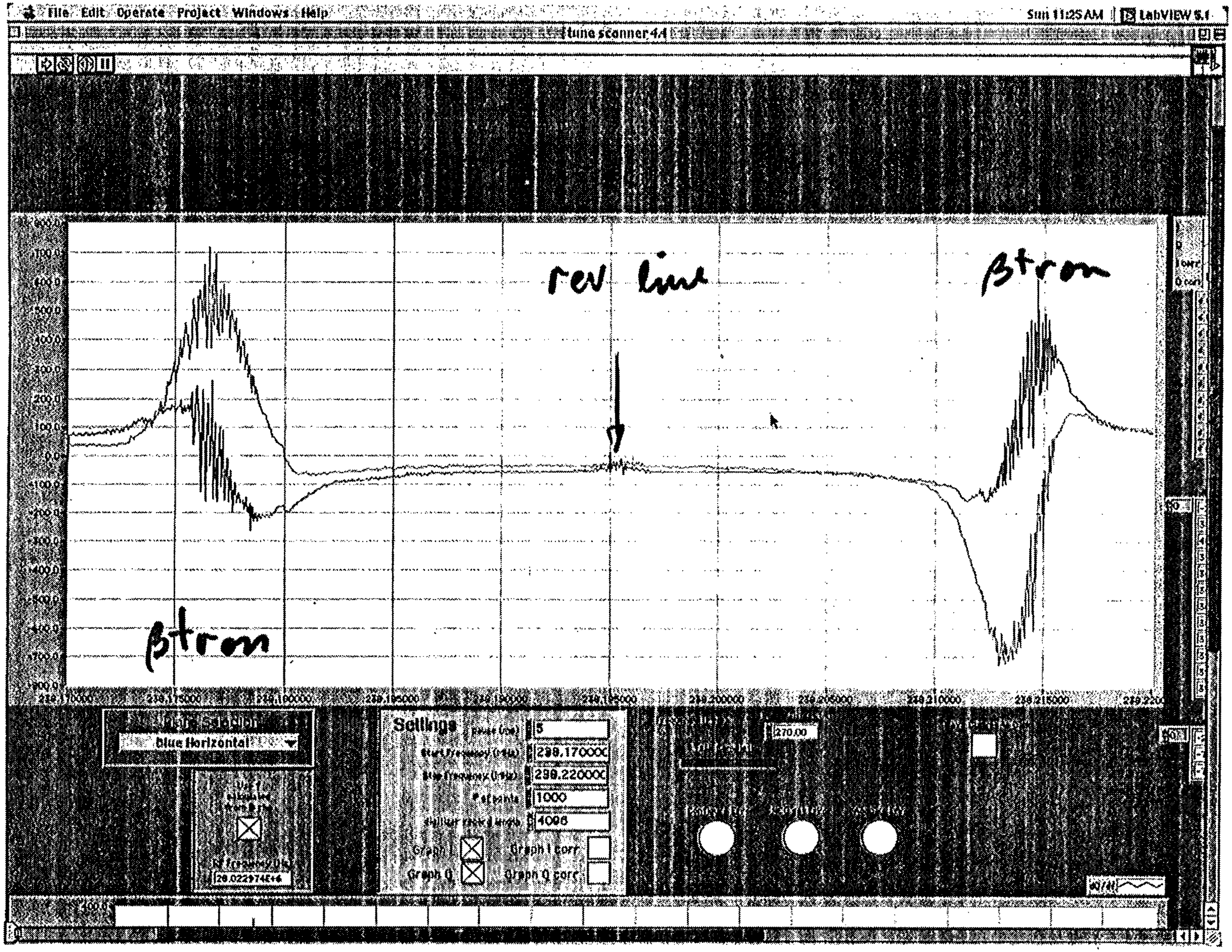
SPAN 78 KHZ 5 dB/div



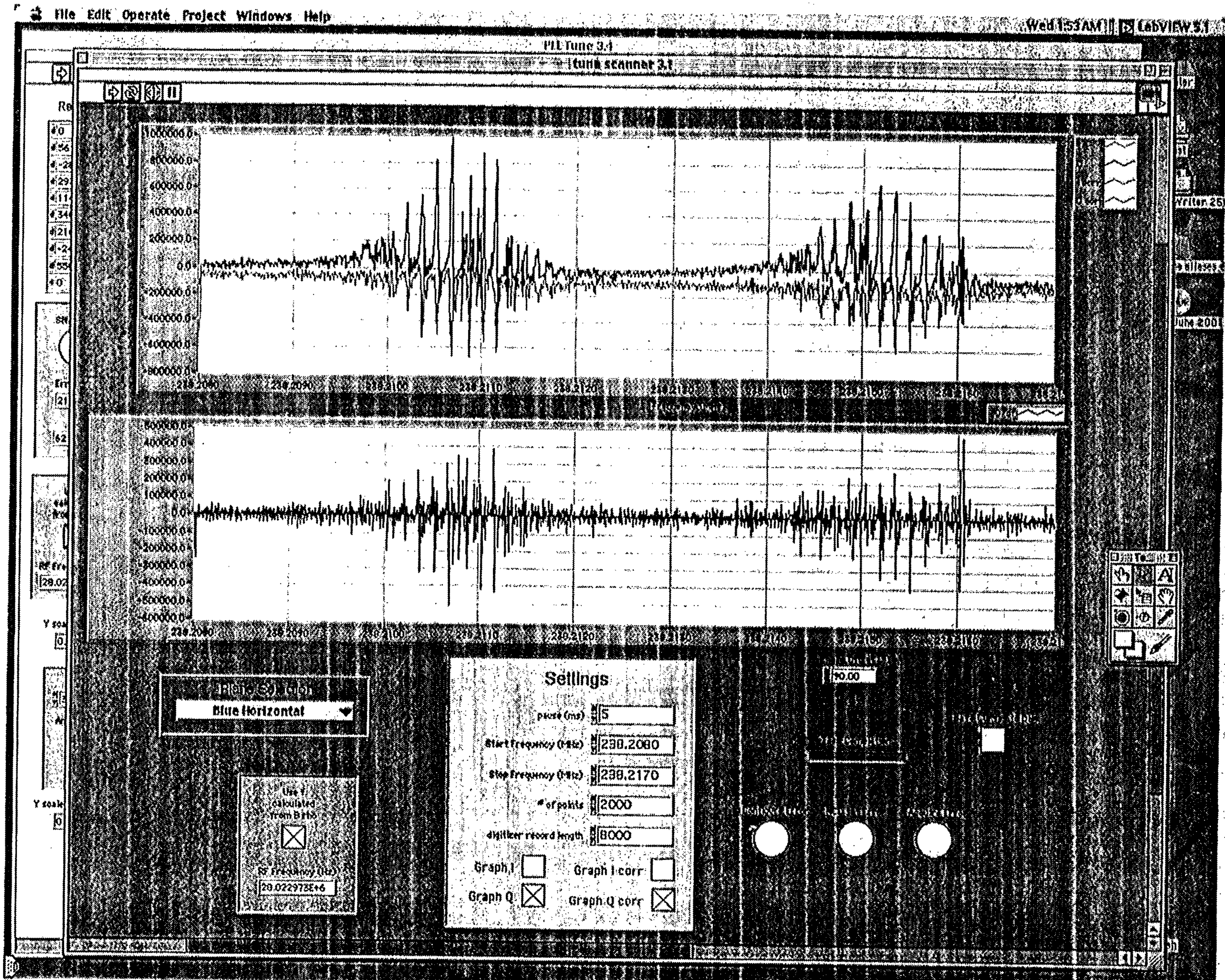
338

SIGNAL + 15 dB

S/N + 25 dB

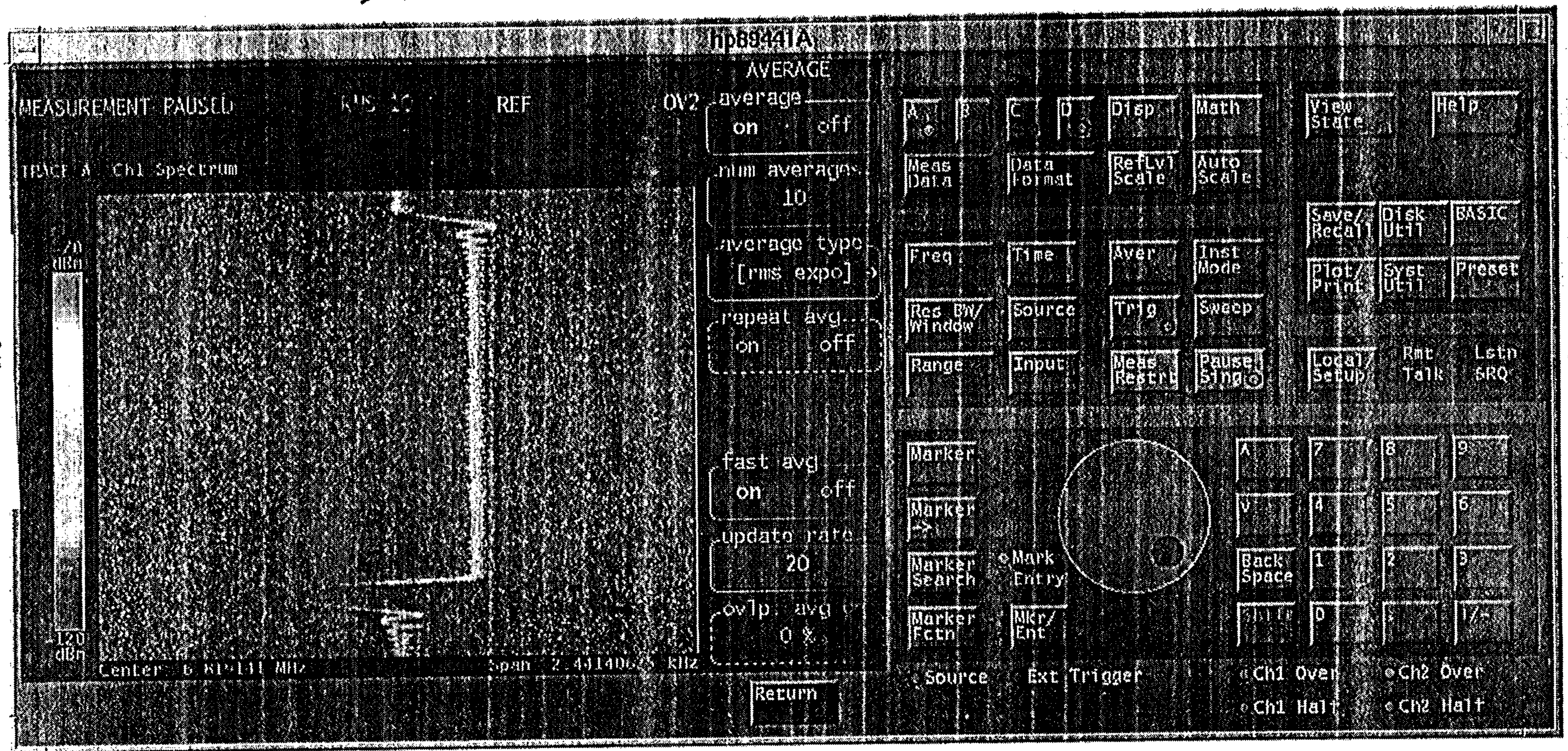

File Edit Operate Project Windows Help
Sun 11:25 AM
LabVIEW 5.1
rev line
βtron
βtron
Settings
Blue Horizontal
5
238.170000
238.220000
1000
4096
270.00
Graph I
Graph Q
Graph I corr
Graph Q corr

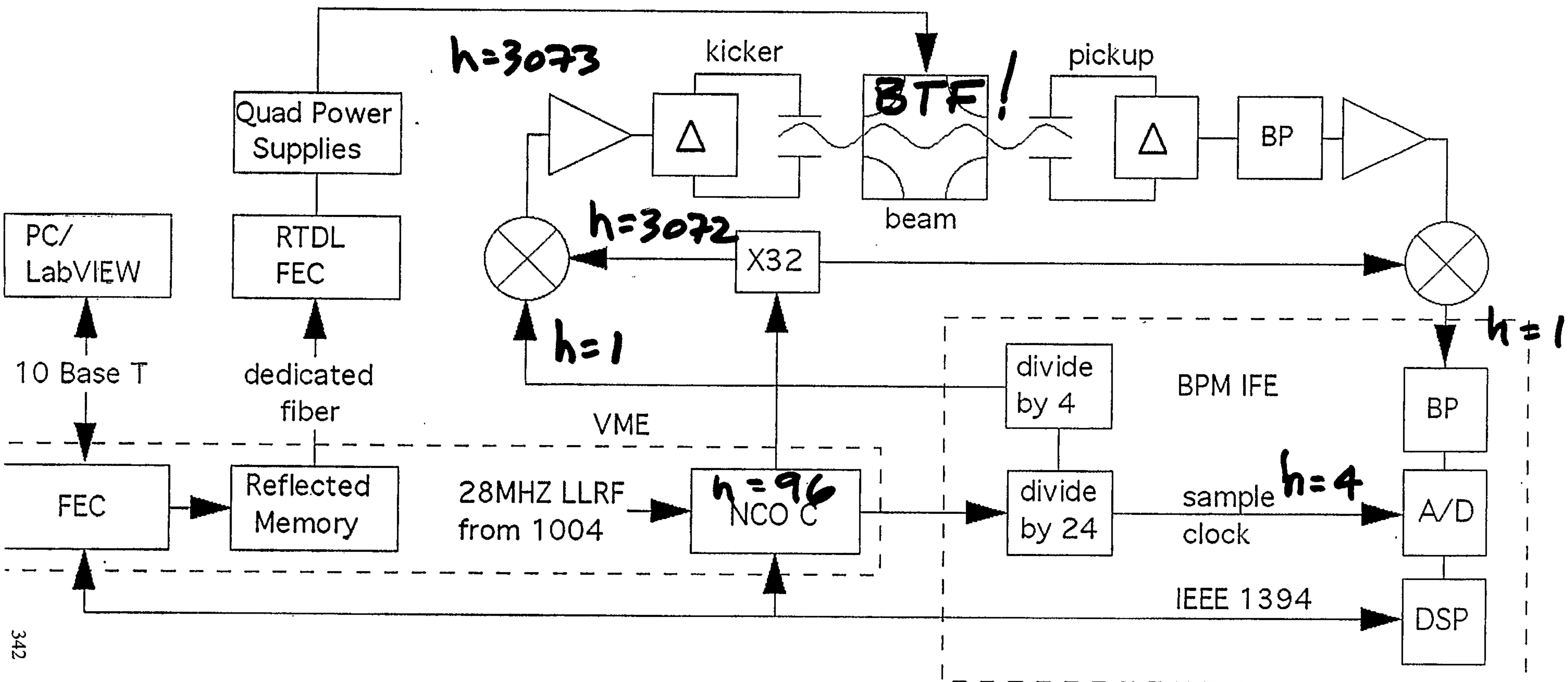
W/ LOW LOOP GAIN YOU LOCK ON SATELLITE → PRECISION

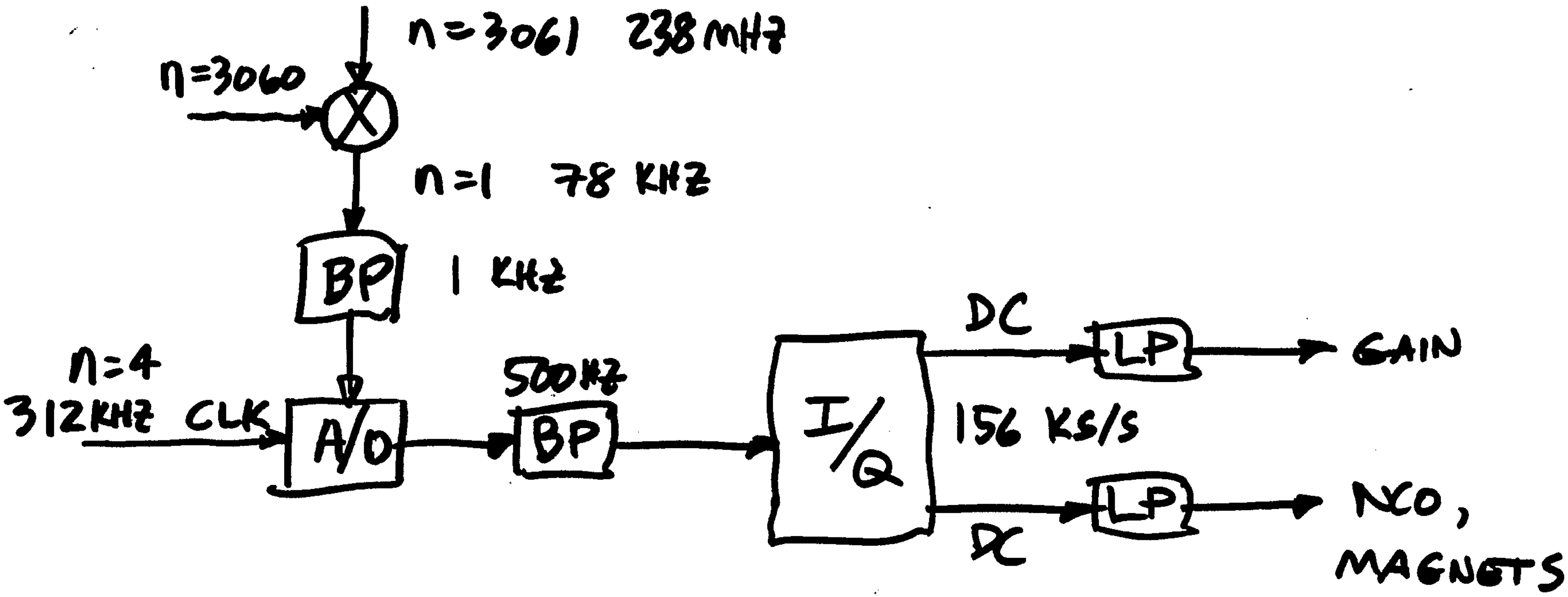


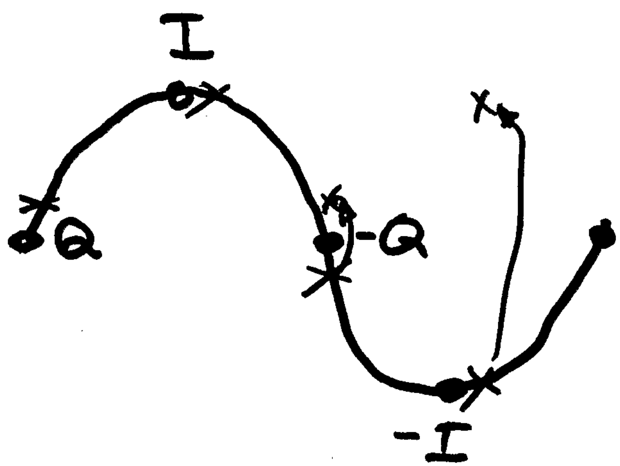
340

SPAN = 2.4 KHz

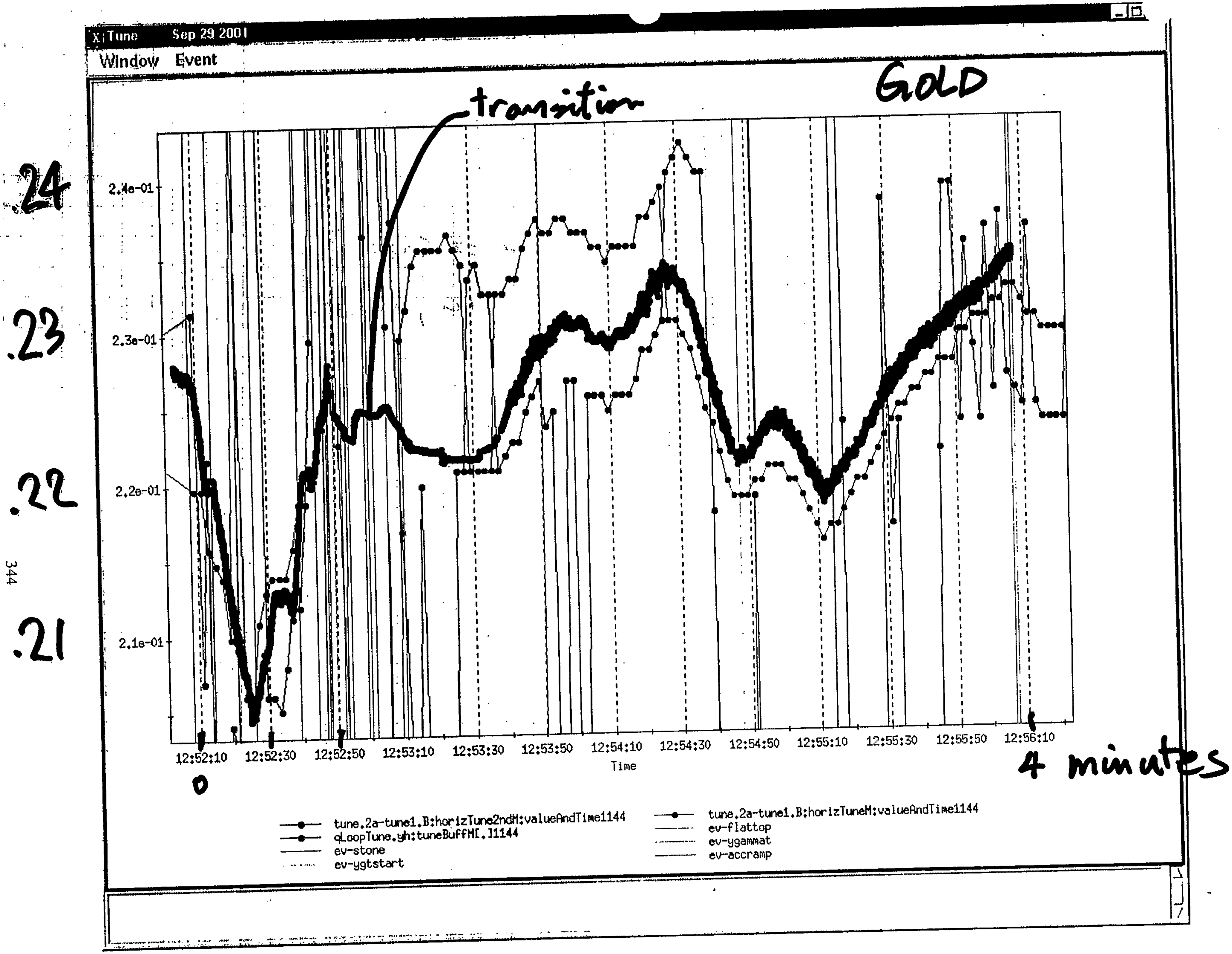
~~~60Hz artifact?~~



$\Delta f \sim 300$ Hz $\Rightarrow \Delta q \sim .004$

measurement accuracy ~ a few 10^{-4}

SQ1 lockin HP DC FM sig. gen. kick ~ 1 mW
~~~


h=3073
kicker
BTF!
pickup
Quad Power Supplies
Δ
Δ
BP
beam
h=3072
X32
PC/ LabVIEW
RTDL FEC
h=1
h=1
10 Base T
dedicated fiber
divide by 4
BPM IFE
BP
VME
FEC
Reflected Memory
28MHZ LLRF from 1004
h=96
NCO C
divide by 24
sample clock
h=4
A/D
IEEE 1394
DSP





I/Q DEMODULATION
(RECTIFICATION)


XiTune Sep 29 2001
Window Event
GOLD
transition
.24
.23
.22
.21
2.4e-01
2.3e-01
2.2e-01
2.1e-01
12:52:10
12:52:30
12:52:50
12:53:10
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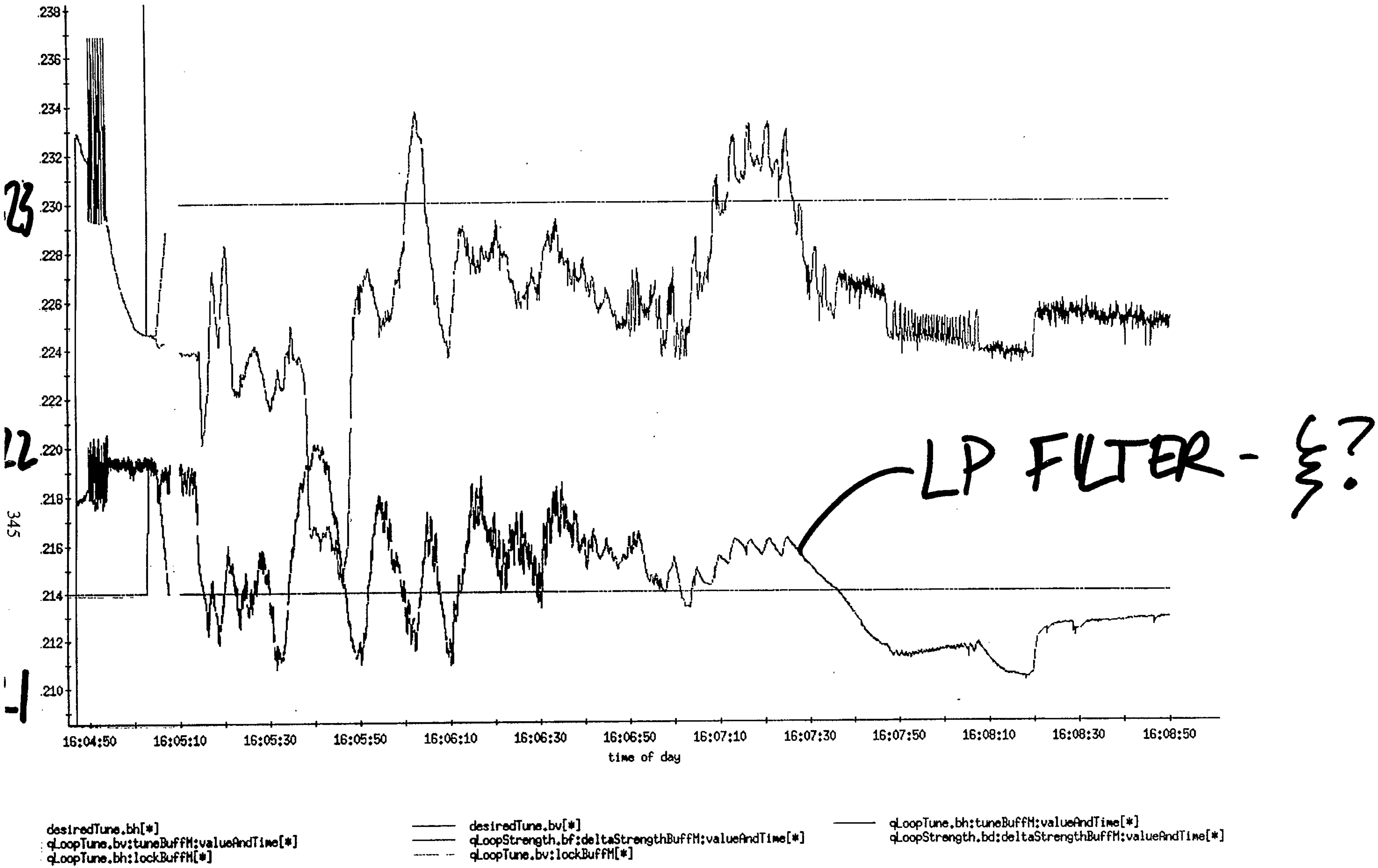
12:55:50
12:56:10
Time
0
4 minutes
tune.2a-tune1.B:horizTune2ndM:valueAndTime1144
qLoopTune.yh:tuneBuffMI.J1144
ev-stone
ev-ygtstart
tune.2a-tune1.B:horizTuneM:valueAndTime1144
ev-flattop
ev-ygammat
ev-accramp


.238
.236
.234
.232
.230
.228
.226
.224
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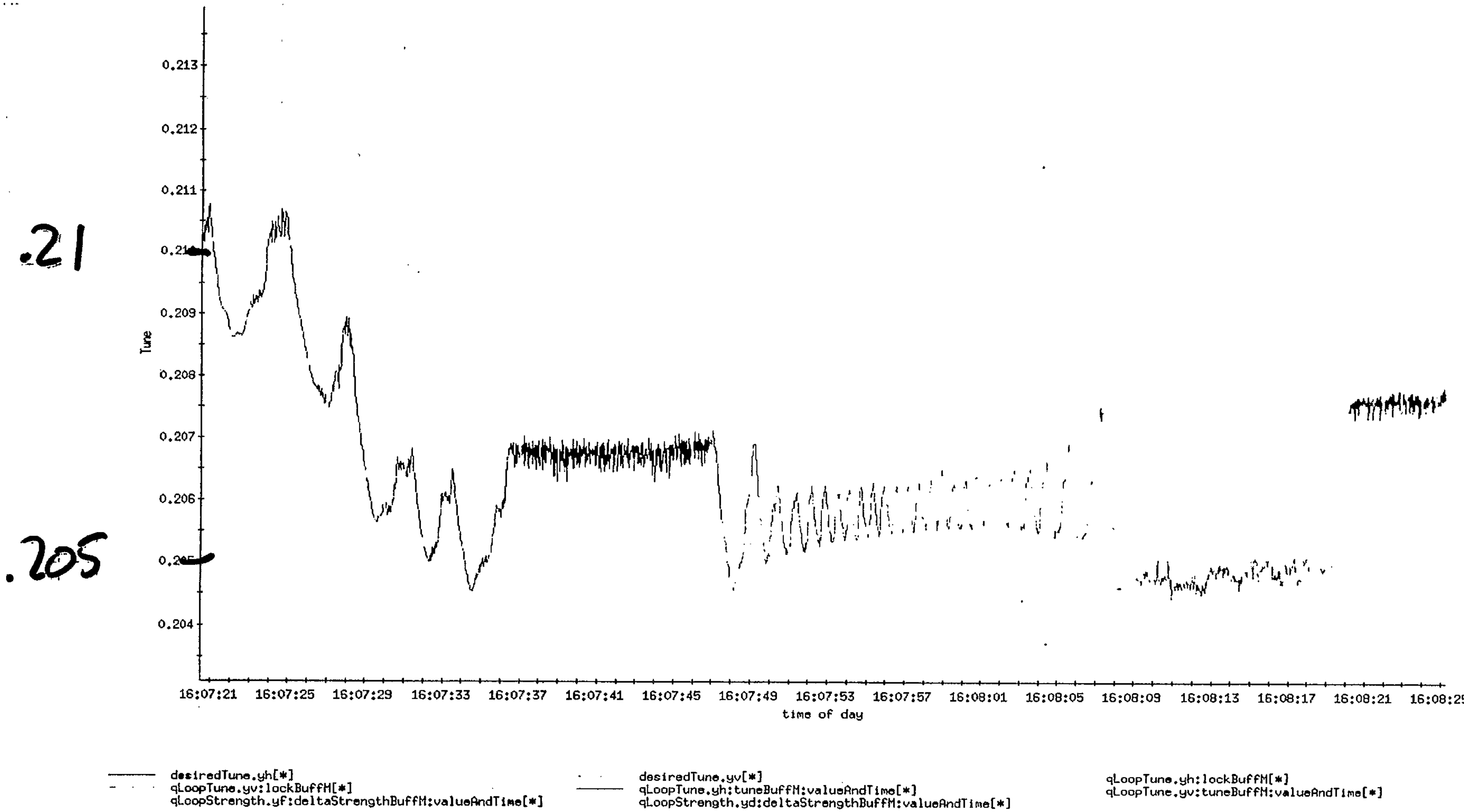
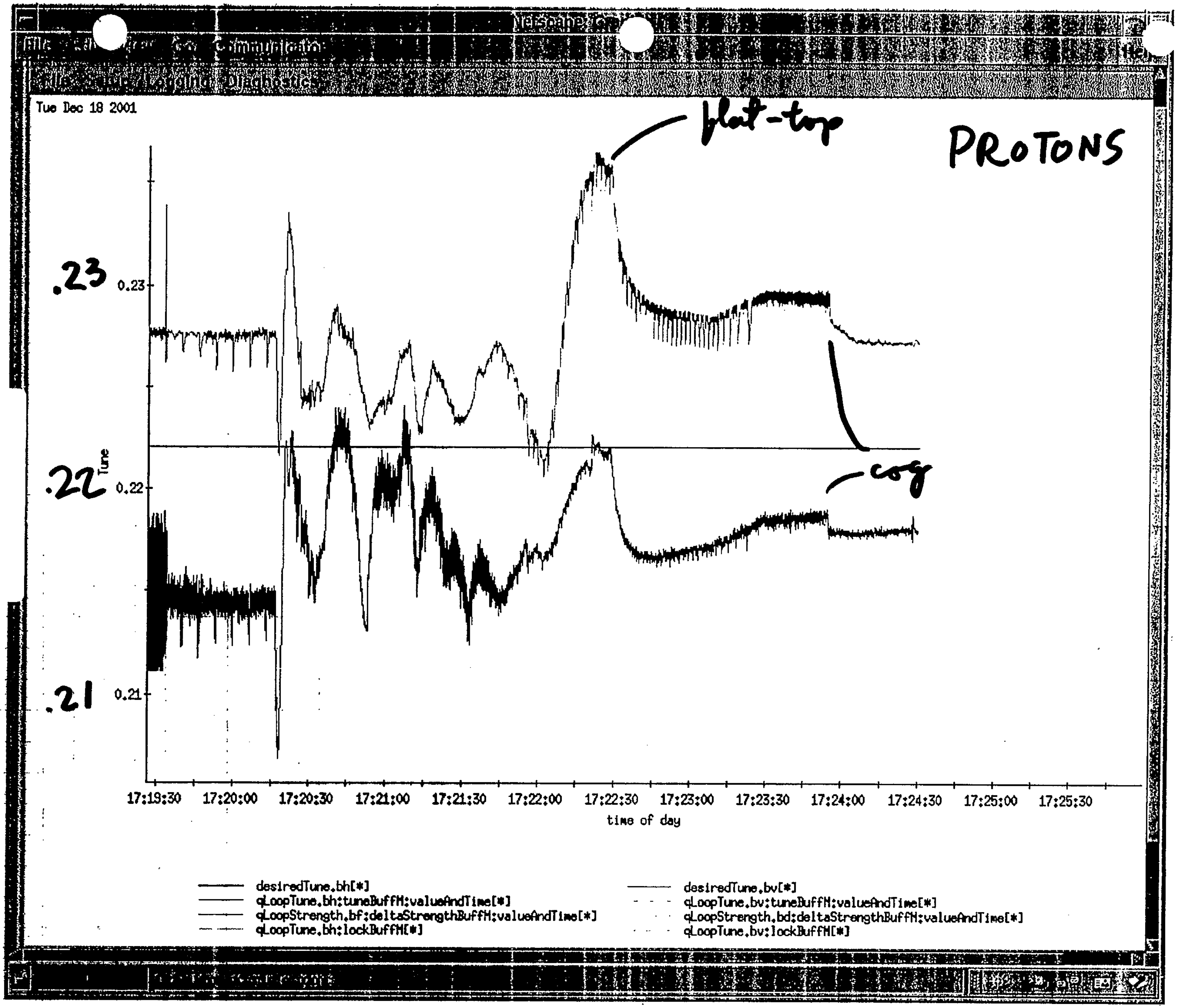
.220
.218
.216
.214
.212
.210
16:04:50
16:05:10
16:05:30
16:05:50
16:06:10
16:06:30
16:06:50
16:07:10
16:07:30
16:07:50
16:08:10
16:08:30
16:08:50
time of day
LP FILTER - ξ?
desiredTune.bh[*]
qLoopTune.bv:tuneBuffM:valueAndTime[*]
qLoopTune.bh:lockBuffM[*]
desiredTune.bv[*]
qLoopStrength.bf:deltaStrengthBuffM:valueAndTime[*]
qLoopTune.bv:lockBuffM[*]
qLoopTune.bh:tuneBuffM:valueAndTime[*]
qLoopStrength.bd:deltaStrengthBuffM:valueAndTime[*]

345

~.002 Beam-Beam Tune Shift Yellow



346


Tue Dec 18 2001
flat-top
PROTONS
.23
0.23
.22
Tune
0.22
cog
.21
0.21
17:19:30
17:20:00
17:20:30
17:21:00
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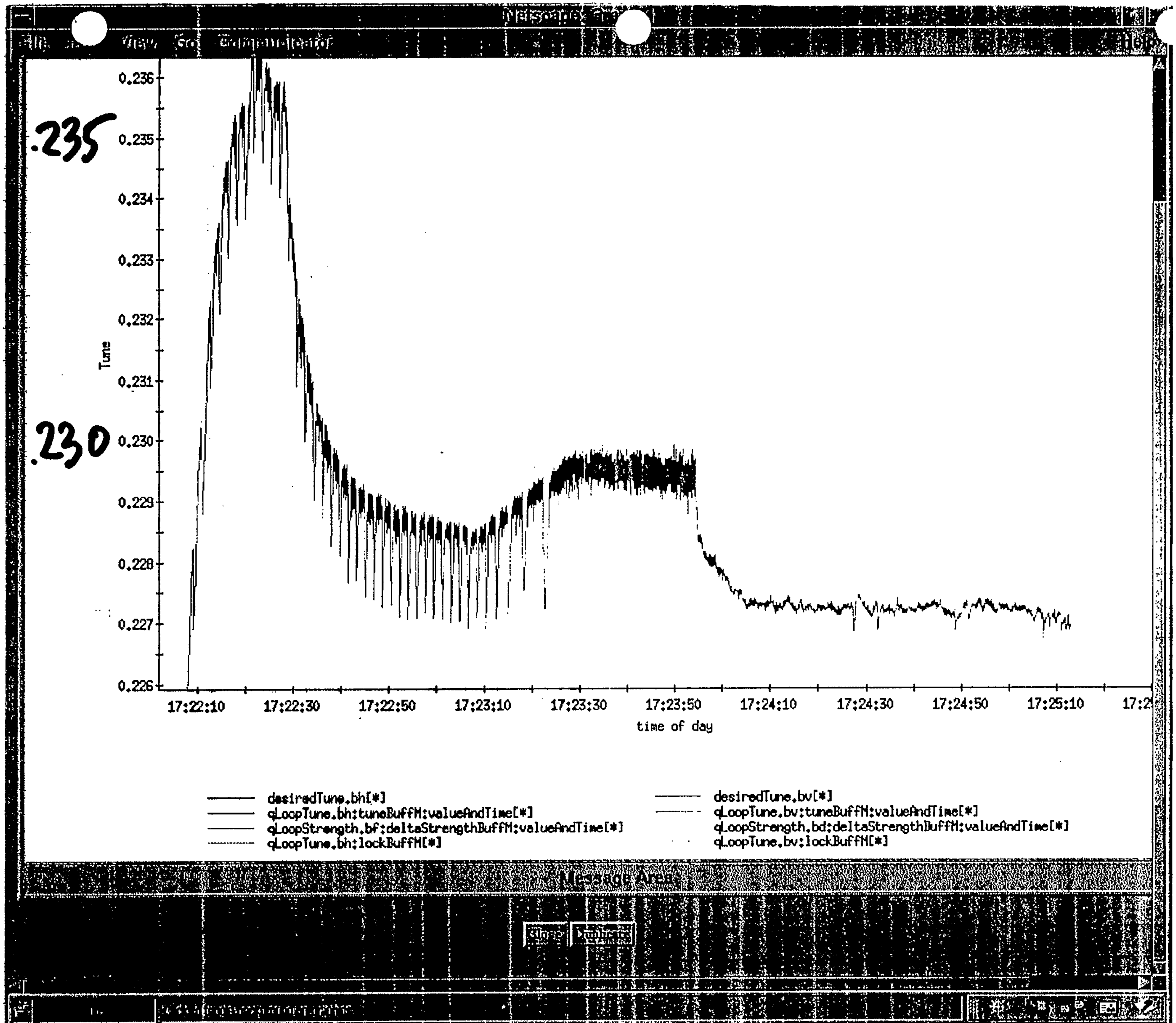
17:24:00
17:24:30
17:25:00
17:25:30
time of day
desiredTune.bh[*]
qLoopTune.bh:tuneBuffM:valueAndTime[*]
qLoopStrength.bf:deltaStrengthBuffM:valueAndTime[*]
qLoopTune.bh:lockBuffM[*]
desiredTune.bv[*]
qLoopTune.bv:tuneBuffM:valueAndTime[*]
qLoopStrength.bd:deltaStrengthBuffM:valueAndTime[*]
qLoopTune.bv:lockBuffM[*]



.235
.230
0.236
0.235
0.234
0.233
0.232
0.231
0.230
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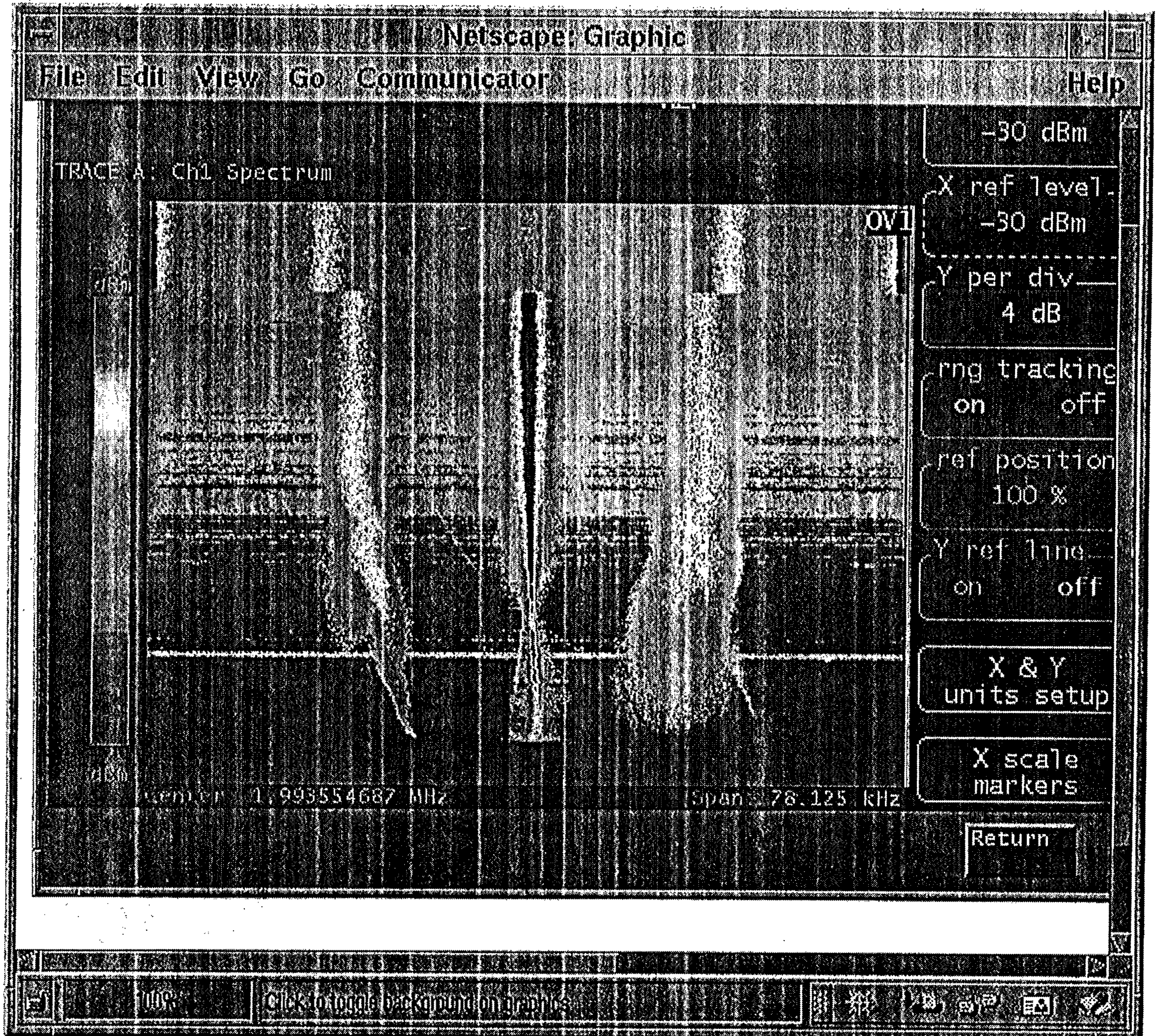
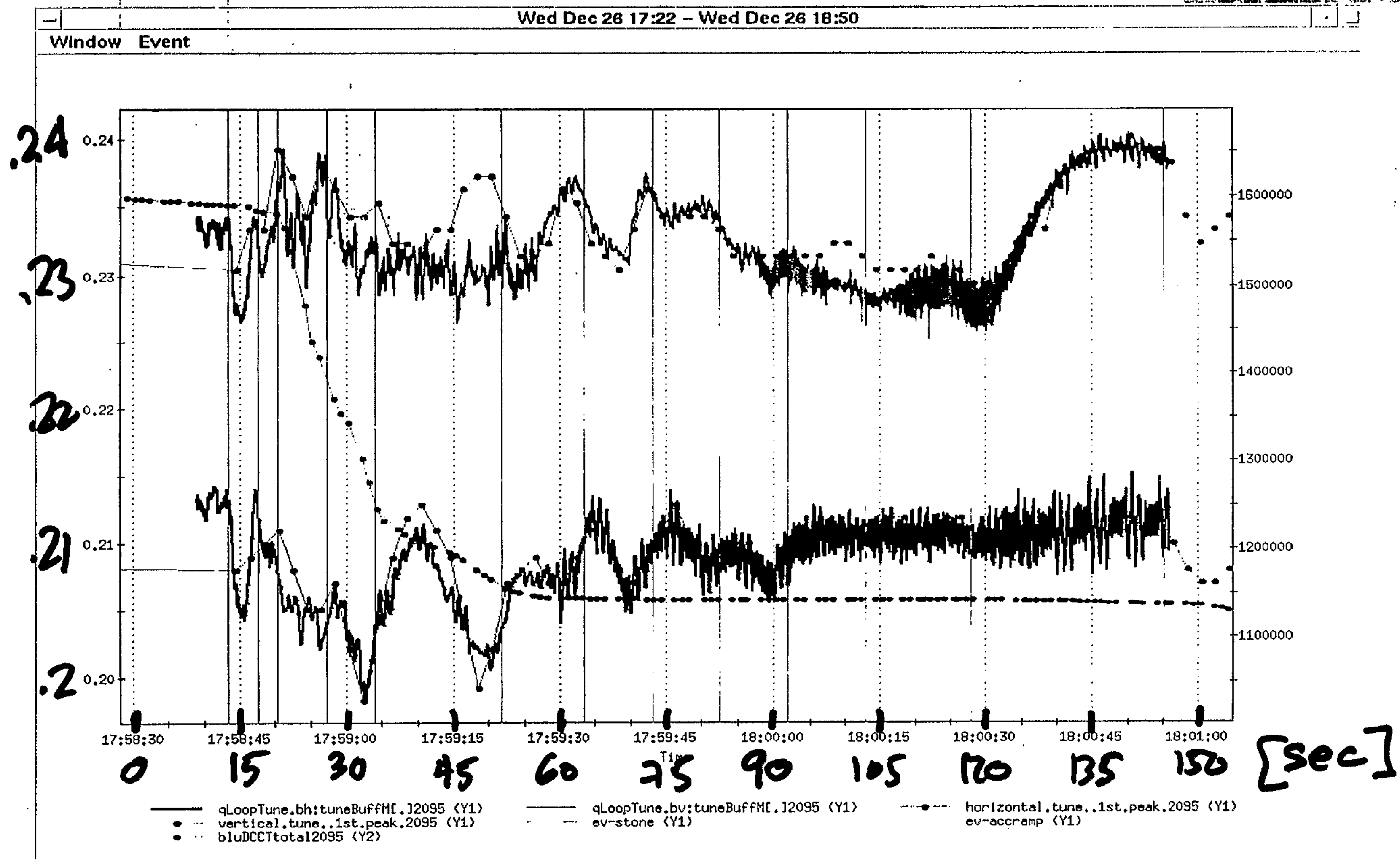
0.228
0.227
0.226
Tune
17:22:10
17:22:30
17:22:50
17:23:10
17:23:30
17:23:50
17:24:10
17:24:30
17:24:50
17:25:10
time of day
desiredTune.bh[*]
qLoopTune.bh:tuneBuffM:valueAndTime[*]
qLoopStrength.bf:deltaStrengthBuffM:valueAndTime[*]
qLoopTune.bh:lockBuffM[*]
desiredTune.bv[*]
qLoopTune.bv:tuneBuffM:valueAndTime[*]
qLoopStrength.bd:deltaStrengthBuffM:valueAndTime[*]
qLoopTune.bv:lockBuffM[*]
Message Area



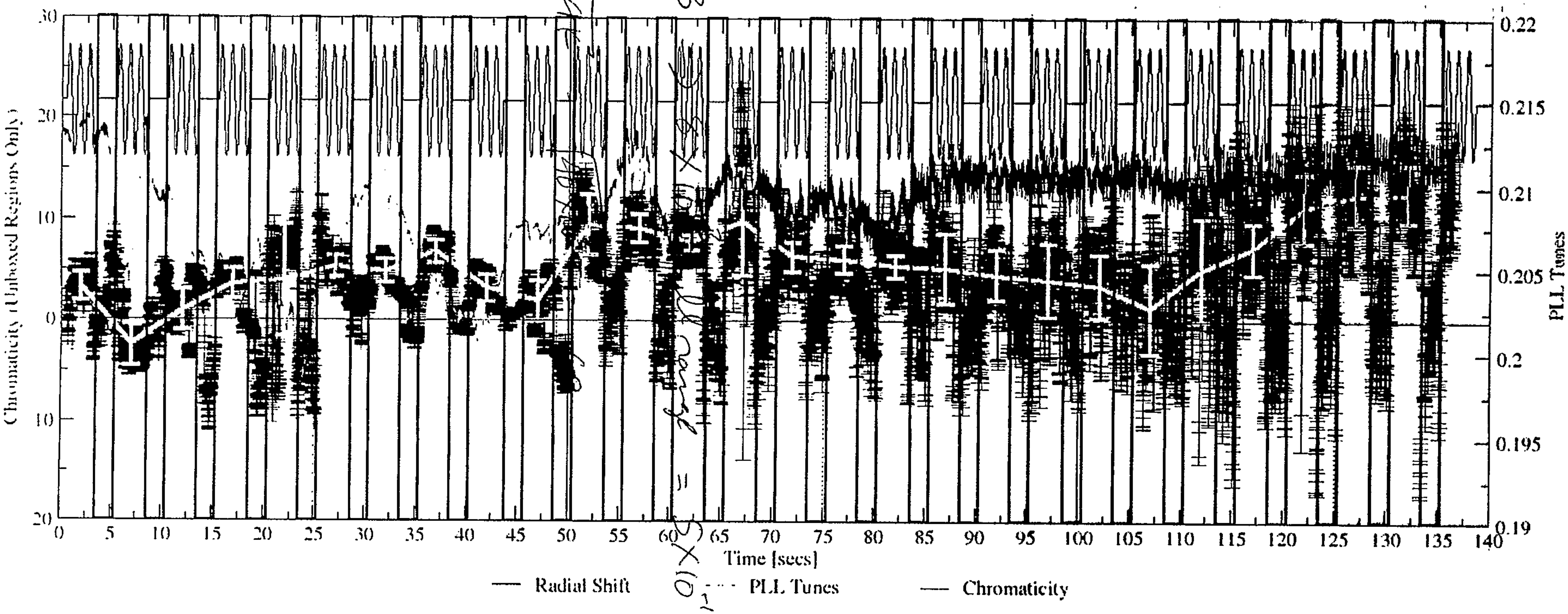
HF SCHOTTKY DOWN RAMP

Radial Modulation on the Ramp



350

$\Delta R = 200\mu$ $\quad \Delta p/p \sim 1.8 \times 10^{-4}$



Lessons Learned about PLL/TF

- Good approach
  - resonant pickup give sensitivity
  - above coherent spectrum gives clean spectrum, small kick OK
  - Mix to harmonic 1 permits effective analog filtering (revolution lines!)
  - Synchronous x4 digitizer clock for I/Q demodulation - simple
- Landau damping effective except near transition (protons)
- RF Leakage requires careful attention - 1/4 heliax connectors, resonant BPM capacitive trimmers,...
- Ramp phase compensation (cables give >3pi) not a problem
- Reliable autolock at constant phase is essential
- Filter, filter, filter,…
- Chromaticity control (feedforward? feedback?) is ESSENTIAL
- Coupling correction is highly desirable

Where We Stand with PLL/TF

- We could run TF with present system during RHIC 2003
- State of the art in accuracy ($<10^{-5}$) and resolution (a few 10^{-6})
- Autolock in good shape – ran unattended for last month of run
- Up Ramps after 'lessons learned' - 4 of 5, failure due to chrom
- Down Ramps - Four attempted, none successful due to chrom
- By end of run system was stable, repeatable, reliable specialist tool
- Qloop stable with ARTUS kicking, agreement is generally good, understood in terms of chromaticity and coupling when it is not
- Results with radial modulation for chromaticity are encouraging, but not convincing.

PLL Status - Goals

- PLL is not a Diagnostic, but rather a system needed to commission an operating mode (ie d-Au, Au-Au, p-p, downramp,…
- Goal is fast and efficient ramp development
- Improve the S/N
  - Signals are ~ 10^{-15} watt!
  - Vertical plane was problematic - β functions
  - DSP limitations - filtering, communications,…
- Reduce ‘expert’ dependency
  - Not so far from this last run

PLL Status - Methods

- Move Pickups and kickers to larger β
- Move processing from BPM IFE to VME DSP
  - Better communications (no more ethernet/1394/sederta/VME)
  - Faster - improved digital filtering, processing gain
- Move Control from LabVIEW/Mac to LabVIEW/Sun
  - System will be run from MCR, familiarity will propagate quickly

Improvements from last run

- Common Mode rejection - MBPM position control, better preamps, h=3060 to h=3148/49, fix obstruction,… - 5dB?
- Oversampling processing gain - 455KHz - 7dB?
- Improved analog and digital filtering - 5dB? More?
- PUEs at larger beta, 3/8 heliax - 2dB?
- For ramp development don't care about emittance growth - 10dB?
- Operation from MCR
- Improved phase compensation
- Matrix Inversion, PLL/Beam Model
- Improved Diagnostics - ARTUS, Schottky's, Coupling,…

Status of Improvements

- Common Mode rejection
  - MBPM position control - Angelika
  - better preamps - done
  - h=3060 to h=3148/49 - done
  - fix obstruction - not yet
- DSP Improvements
  - Pentek DSPs in house, running in VXWorks, interfaced to digitizer
  - DSP code from IFE ported to Pentek DSP - debugging
- Improved analog filtering - 455KHz ceramic filters
- PUEs at larger beta - in progress
- Operation from MCR - LabVIEW running on Sun, new ADO parameters,…
- Matrix Inversion, PLL/Beam Model - in progress
- Improved Diagnostics - ARTUS, Schottky's, Coupling - in progress

Commissioning Plan

- Single plane running on resonator - early to mid-August
- First dry run - Single plane system integration from MCR
- Second dry run - All planes,…
- With beam single bunch - concurrent w/ BPM timing, RF,…
    - PLL/Diagnostics/Applications Commissioning - dedicated time
    - Phase zero, Phase compensation, Autolock
    - Comparison with ARTUS, Schottky,…
    - Loop gain, filter BW, AGC,…
    - Coupling, Chromaticity - how to measure, effect on PLL,…
    - Magnet transfer function
    - Close magnet loop, ramp?
- Six bunches

Update on the 12:00 Local Polarimeter Measurement

A. Deshpande, RBRC

July 29, 2002

for

RHIC Spin Collaboration Meeting XI

RIKEN BNL Research Center

Phenix Local Polarimeter

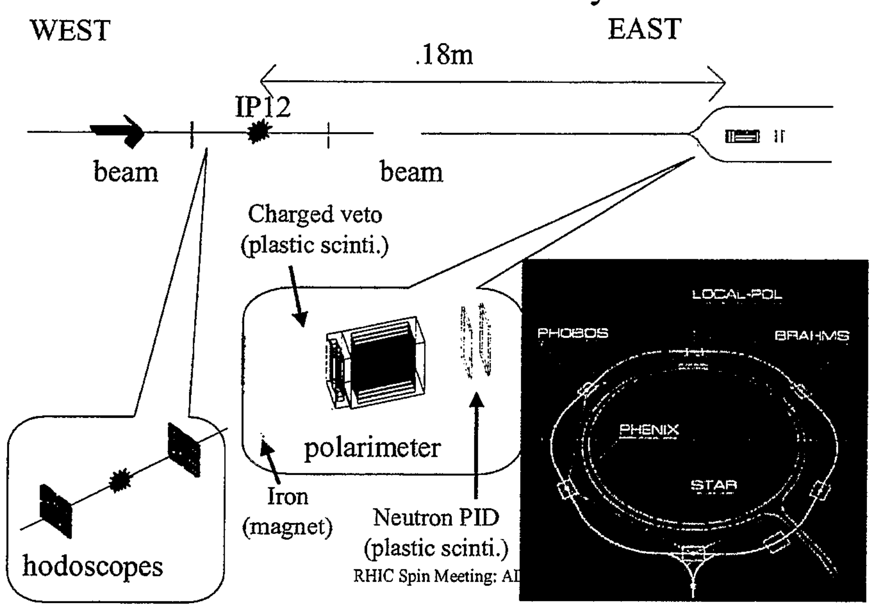
UPDATE

Abhay Deshpande
For
Manabu Togawa & Yoshinori Fukao
IP12 Local Polarimeter Collaboration
Slides based on recent talk by Naohito Saito at BNL

Summary

- Reminder of the experimental setup
- East Side Story: Lead Tungstate Electromagnetic Calorimeter
  * Particle ID (g vs. n) purities and efficiencies
    -- Pythia & GEANT dependence
  * Detector Asymmetries
    -- Independent of Physics asymmetries
  * Analyzing power extraction
  * Remaining mysteries...??
- West Side Story: Zero Degree Calorimeter
  * Calibrated using cosmics
  * Asymmetry observed for neutrons
- Comparison of EMCal & ZDC ... in progress.

Where abouts…. and lay out…



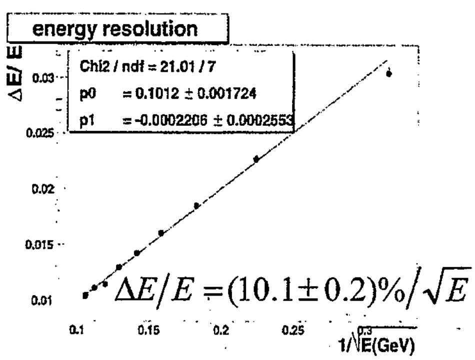
RHIC Spin Meeting: A

Calorimeter Performance

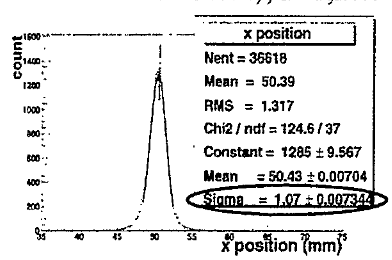
Energy & Position resolution measured at test beam measurement at SLAC FFTB August 2001: (n X 10 GeV electron beam); n=1,2…

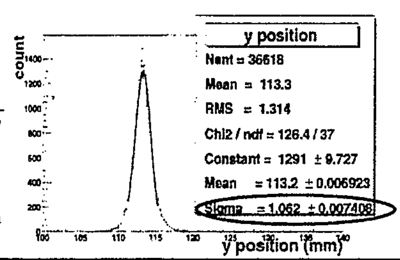
Position resolution: ~1.1 mm

Energy resolution:



$\Delta E/E = (10.1 \pm 0.2)\% / \sqrt{E}$

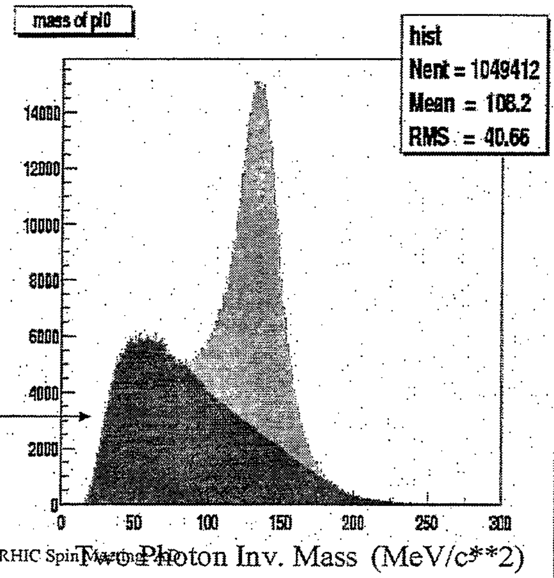




7/29/02 RHIC Spin Meetin

Invariant Mass Distribution: $M_{\gamma\gamma}$

- $\pi 0$ signal clearly visible
- Used to refine tower by tower calibration



7/29/02

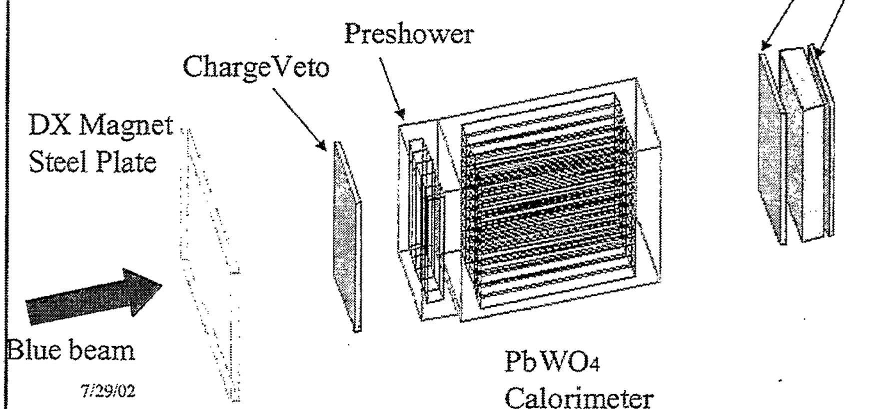
RHIC Spin Meeting

Particle Identification

EAST

$$\gamma = \overline{\text{ChVeto}} \otimes \overline{\text{N1}} \otimes \overline{\text{N2}}$$

$$n = \overline{\text{ChVeto}} \otimes \text{N1} \otimes \text{N2}$$



7/29/02

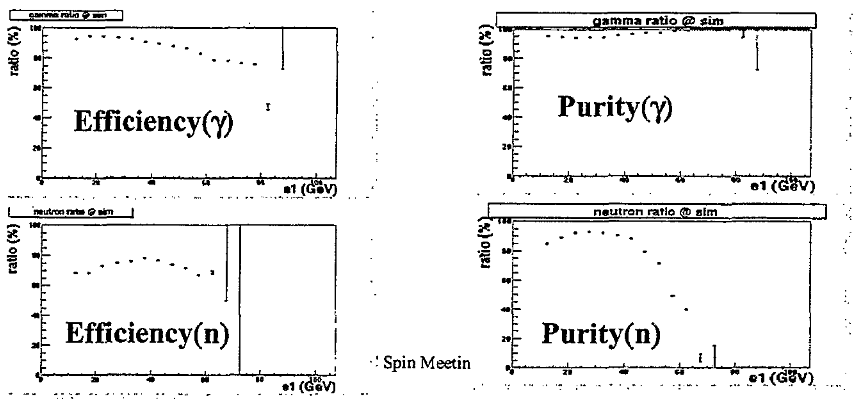
3

Efficiency & Purity: MC Study

EAST

$$\text{Effciency}(\gamma) = \frac{\#\text{ of } \gamma\text{'s identified as } \gamma}{\#\text{ of injected } \gamma\text{'s}}$$

$$\text{Purity}(\gamma) = \frac{\#\text{ of Real } \gamma \text{ (known, MC)}}{\#\text{ of Clusters Identified as } \gamma}$$



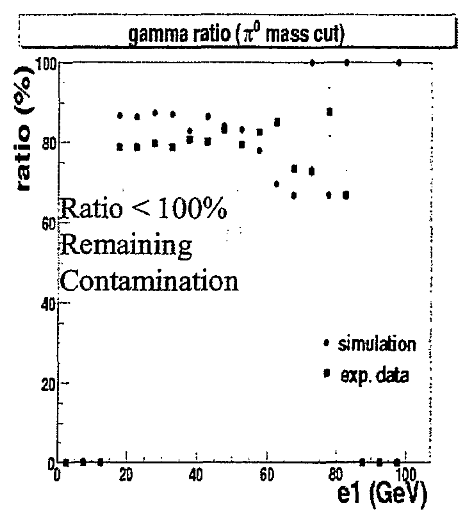
Particle ID in Data vs. Simulation

EAST

- Data: Need pure photon sample
  - → Photon enriched sample with pi0 mass cut.

$$R = \frac{\#\text{of clusters identified as } \gamma}{\#\text{of clusters which form } \pi^0}$$

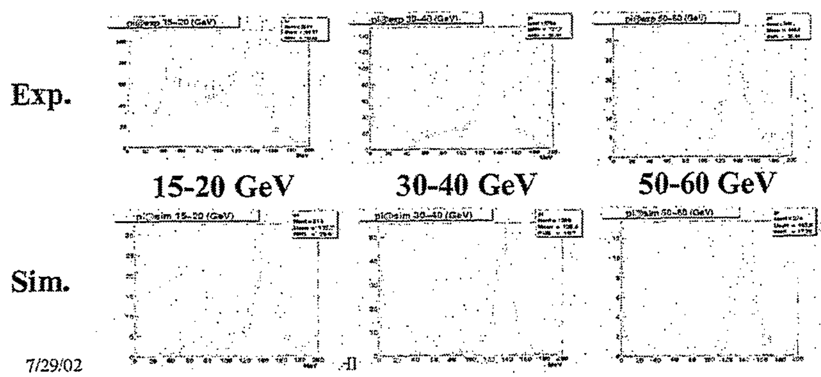
- Contamination at low energies
  - → Pythia-6 employed
    - n/γ → 1:1
    - 10% n contamination in γ
    - 25% g contamination in n
  - → Depends also on hadron shower development
    - → Geisha and Fluka available
      Fluka gives a better agremennt with data.



Contamination in γ and $\pi 0$ samples...

EAST

- Significant Difference in Combinatorial Background
  - Slightly higher number of clusters in exp. Data
  - Lower Energy shows worse χ^2 distribution in exp. Data
  - → Contamination should be studies as a function of Energy



7/29/02

Compare Data vs. MC

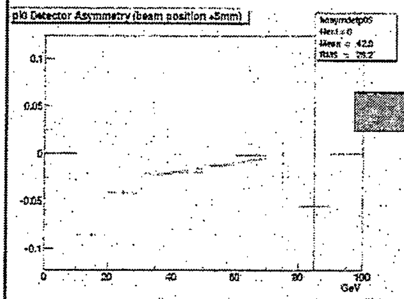
- PYTHIA: Photon Source
  - PYTHIA says 95% of photons originate in π^0
  - Compared Following Ratio:9.6%(exp) vs 11.7%(sim)

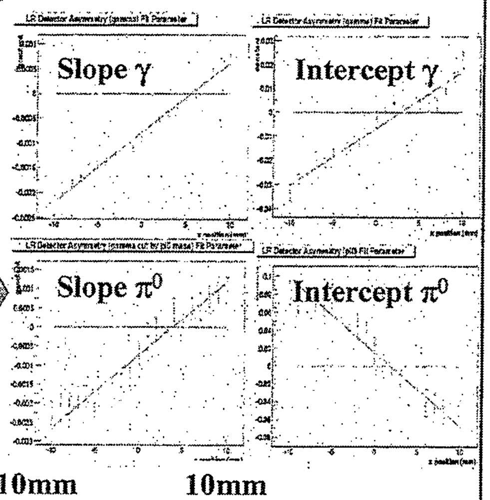
$$R = \frac{\#\text{ of } \pi^0\text{s}(E_1 > 20\text{GeV} \,\&\&\, E_2 > 20\text{GeV})}{\#\text{ of Photons } (E > 40\text{ GeV})}$$

- GEANT: Hadron Shower Algorithm
  - GHEISHA vs FLUKA
  - Compared identified γ/n
    - 64:36 (exp)
    - 78:22 (GHEISHA) vs 67:33 (FLUKA)
  - PYTHIA dependence is not eliminated yet i.e. no other generator has been tried...

Detector & Physics Asymmetries

- Detector Asymmetry is very sensitive to Beam Position
  - Extract Slope and Intercept from Detector Asymmetry as a function of Energy
  - Minimize Both Slope and Intercept → Around +5mm





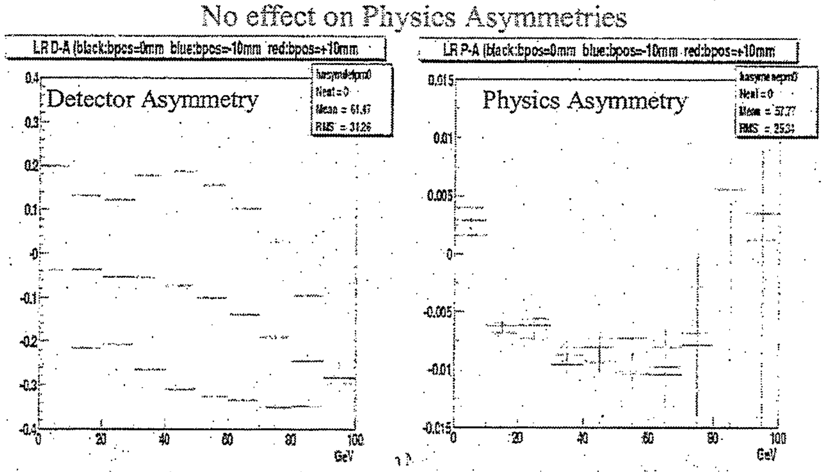
Detector & Physics Asymmetries for Neutrons

All Asymmetries calculated using the SQRT formula

EAST

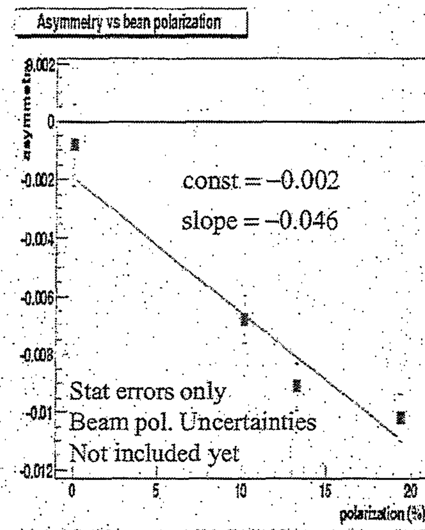
10mm change in center imparts a 20% variation in DA;

No effect on Physics Asymmetries



Neutron Asymmetry: Correlation with polarization

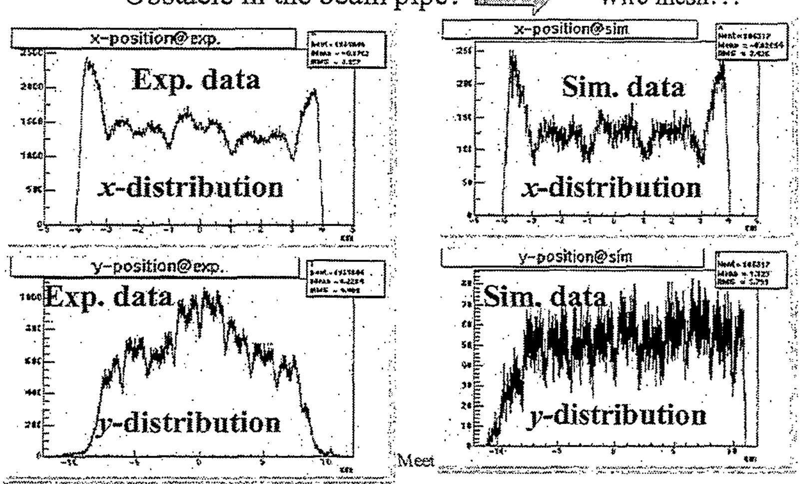
- Clear correlation observed
  Neutron deposited energy > 20 GeV
- Analyzing power is ~5%
  Slope = -4.6% \pm 0.8%
- Simple average: -5.9%
- Beam polarization uncertainties
  → simple average vs. lumi weighted
  → RHIC pol. Systematics, unknown analyzing power at 200 GeV
- Photon Contamination in neutron samples



7/29/02 RHIC Spin Meeting: AD 13

Spatial Distribution Data vs. MC

- X distribution for data/MC matching is fine
- Y distribution: seems peaked at the center
- Obstacle in the beam pipe? ⇨ Wire mesh???



7

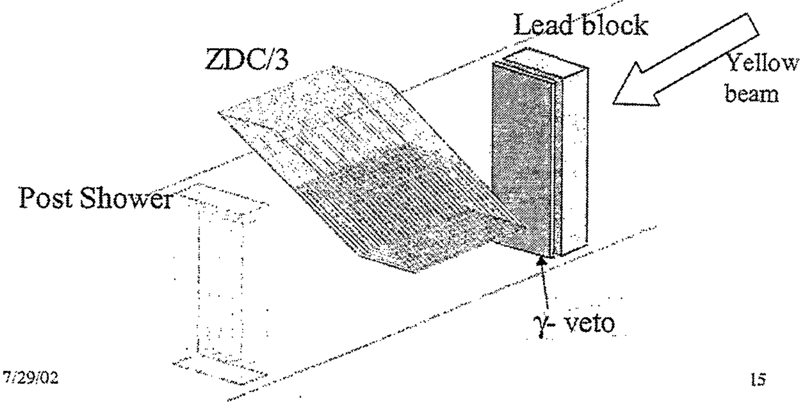
The WEST Side story…. ZDC/3

Setup: Lead block + g veto + ZDC/3 + Post shower

→ Pb block + g-veto provide excellent γ rejection (<0.1%)

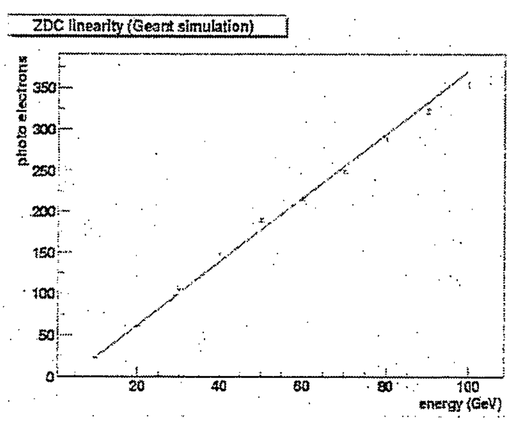
→ ZDC/3 provides good energy resolution

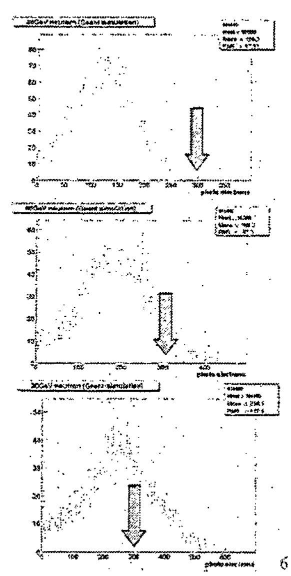
→ Post shower provides satisfactory x resolution



ZDC response to neutrons

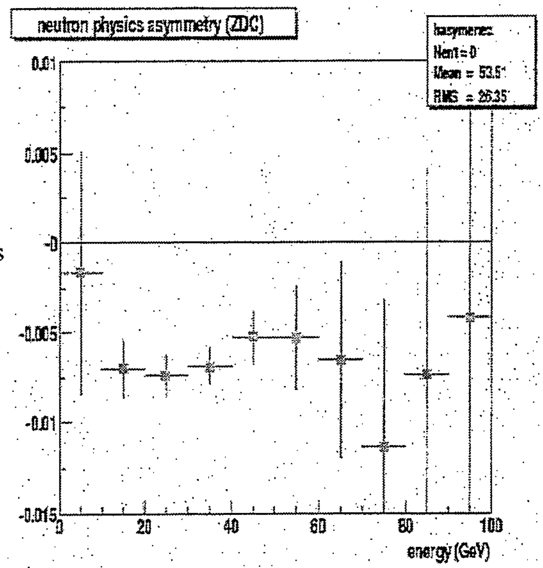
- Modest non-linearity in neutron energy response





ZDC/3 Asymmetry for neutrons !

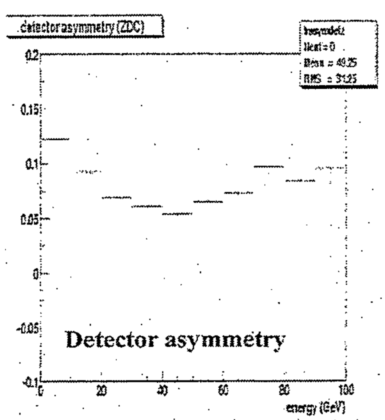
- Updated results
  - Run523-541; 19 runs
  - Left: < -5 mm
  - Right: > + 5mm
  - Gamma Veto < 0.6 MeV
  - Collision trigger ONLY
  - 2.7M "neutron" samples
  - Analyzing Power is consistent with EMCal side?
    - EMCal +/-π/4 $\int_{-\pi/4}^{\pi/4}\cos\theta d\theta / \int_{-\pi/4}^{\pi/4} d\theta = 0.90$
    - ZDC +/-π/2 $\int_{-\pi/2}^{\pi/2}\cos\theta d\theta / \int_{-\pi/2}^{\pi/2} d\theta = 0.64$

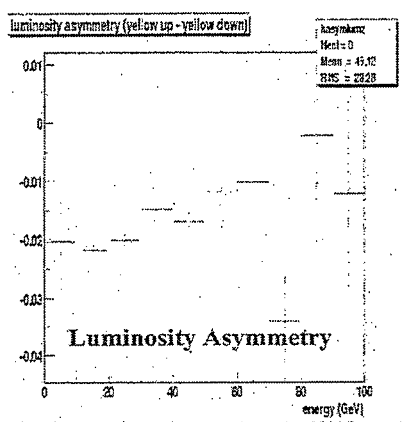


7/29/02

Detector & Luminosity Asymmetries

- Find:
  - Detector Asymmetry < 10%
  - Luminosity Asymmetry < 2%





7/29/02 RHIC Spin Meeting: AD 18

Comparison: $PbWO_4$ vs. ZDC/3

- Neutron asymmetry diluted by:
  → Photon contamination (25% in PbWO4) and <1% in ZDC
- Integration over azymuthal angle
  → PbW04: 0.90 and ZDC: 0.64
  → Detailed GEANT underway

- Presently:
  Analyzing power: A differs by > 4 σ
  PbWO4 : A = -8.7% +/- 0.5
  ZDC/3 : A = -5.0 +/- 0.5

To Do....

- Refine current studies:
  → finalize PID, PYTHIA, GEANT
  → Understand the correct dilution factors
  → User better RHIC polarization values (Account for the yellow, blue beam analyzing powers, lumi weighted vs. intensity weighted)
- 1st Draft for publication....Within a month or so...

Status of and Commissioning Plans for the Spin Rotators

W. Mackay, BNL

July 29, 2002

for

RHIC Spin Collaboration Meeting XI

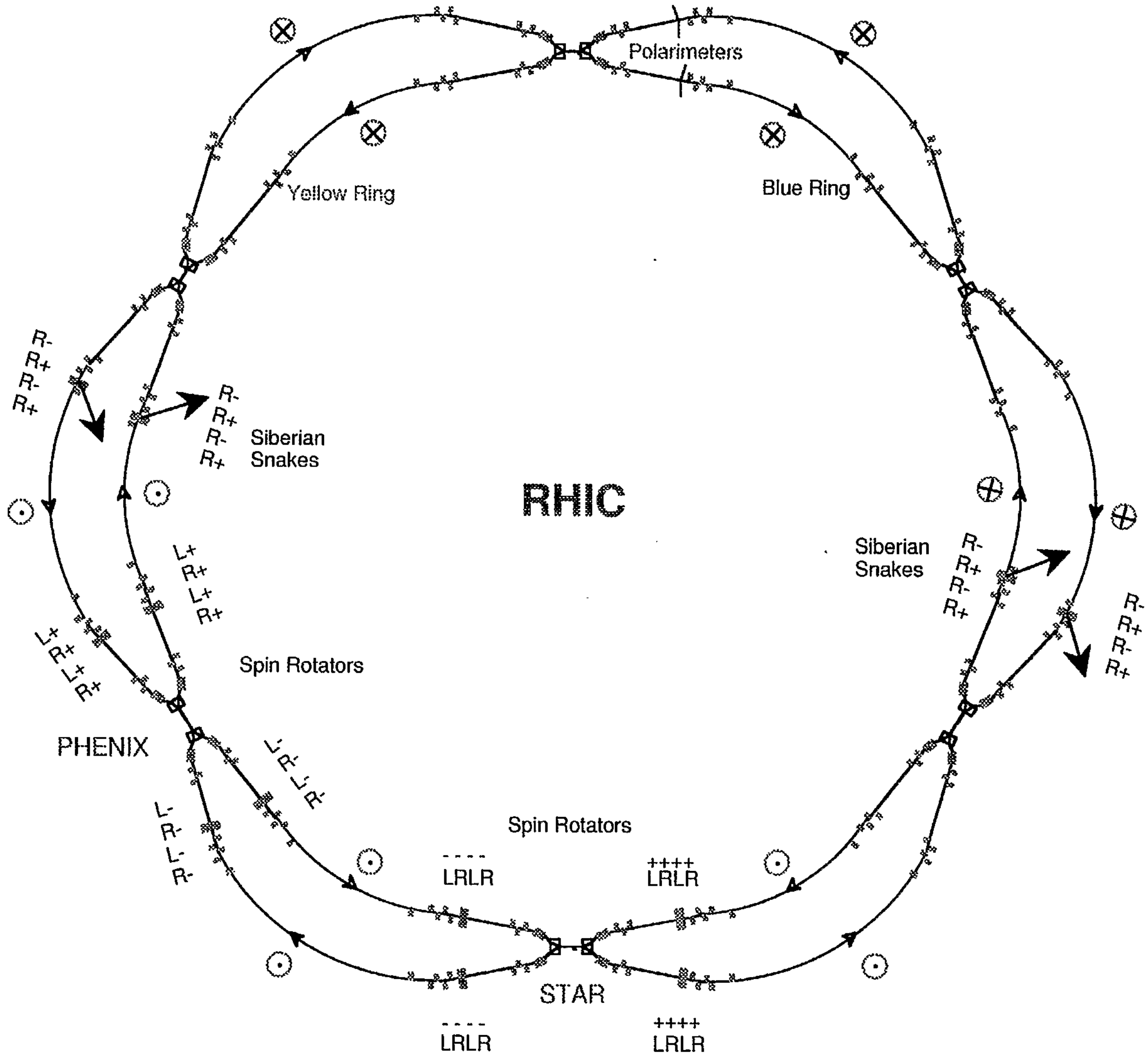
RIKEN BNL Research Center

Status of Spin Rotators

- Rotators:
  - All eight rotators installed in tunnel.
  - Six (WTC) warm-to-cold transitions completed.
    - Two WTC's on 7 o'clock side of PHENIX are not yet closed.
  - 4 of eight remain to be leak checked.
  - No high pressure check has been done yet.
  - Cables not yet connected
  - Loss monitors yet to be installed.
  - WTC's and interconnects need to be painted.
- Power supplies:
  - All rotator supplies installed and tested into shorted loads in alcoves.
  - Installation of quench circuits to start in about a week.
  - Tests with quench circuits and shorted loads at magnets will follow.
  - Final tests require cold magnets.

BROOKHAVEN
NATIONAL LABORATORY

Waldo MacKay
RHIC Spin: 29 July, 2002

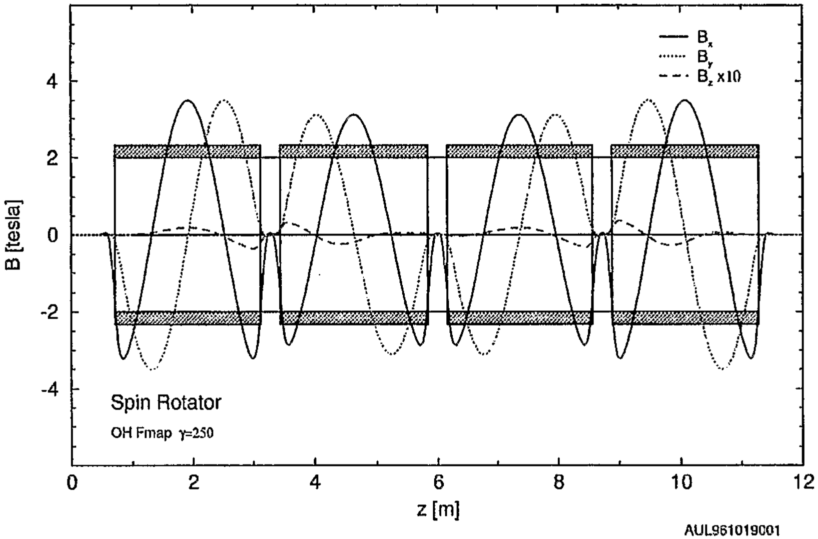


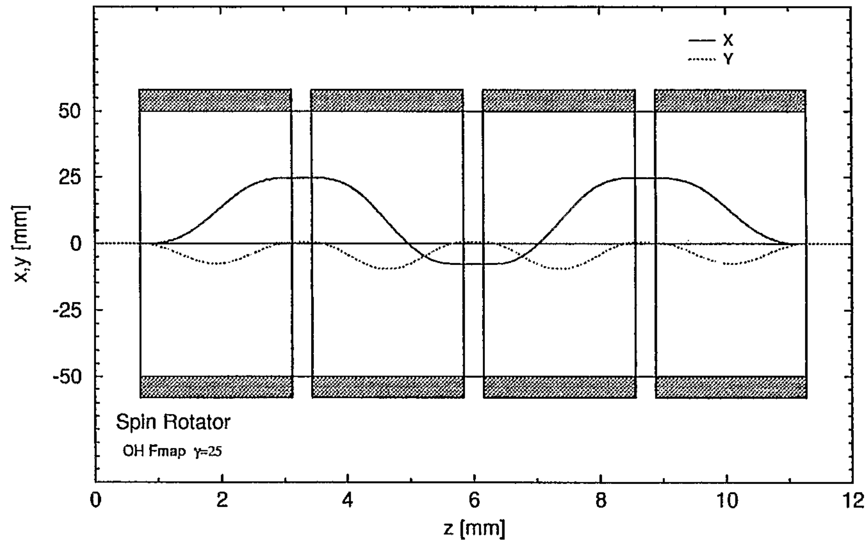

```
Rotators = Hor field (at ends), + = radially out, - = radially in
Snakes   = Ver field (at ends), + = up,           - = down
```

BROOKHAVEN NATIONAL LABORATORY

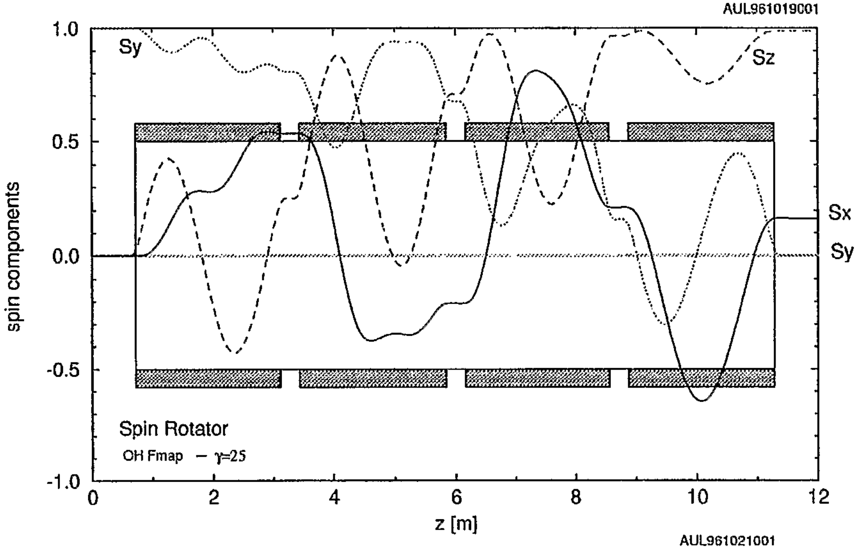
Waldo MacKay
RHIC Spin: 29 July, 2002

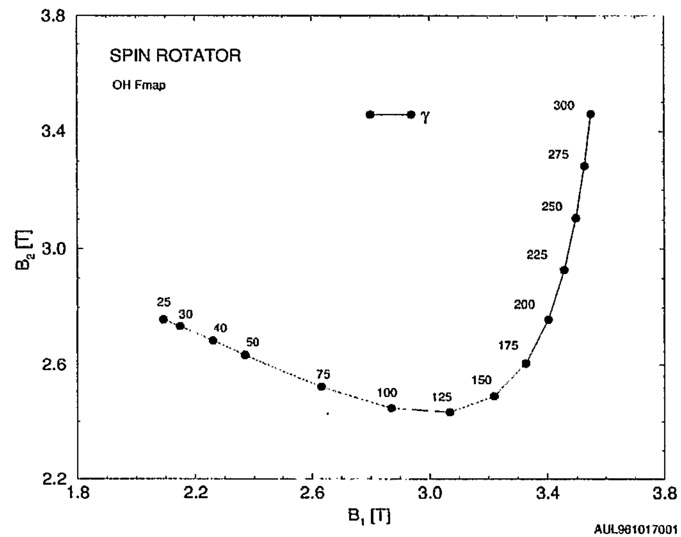
Operation of Rotator





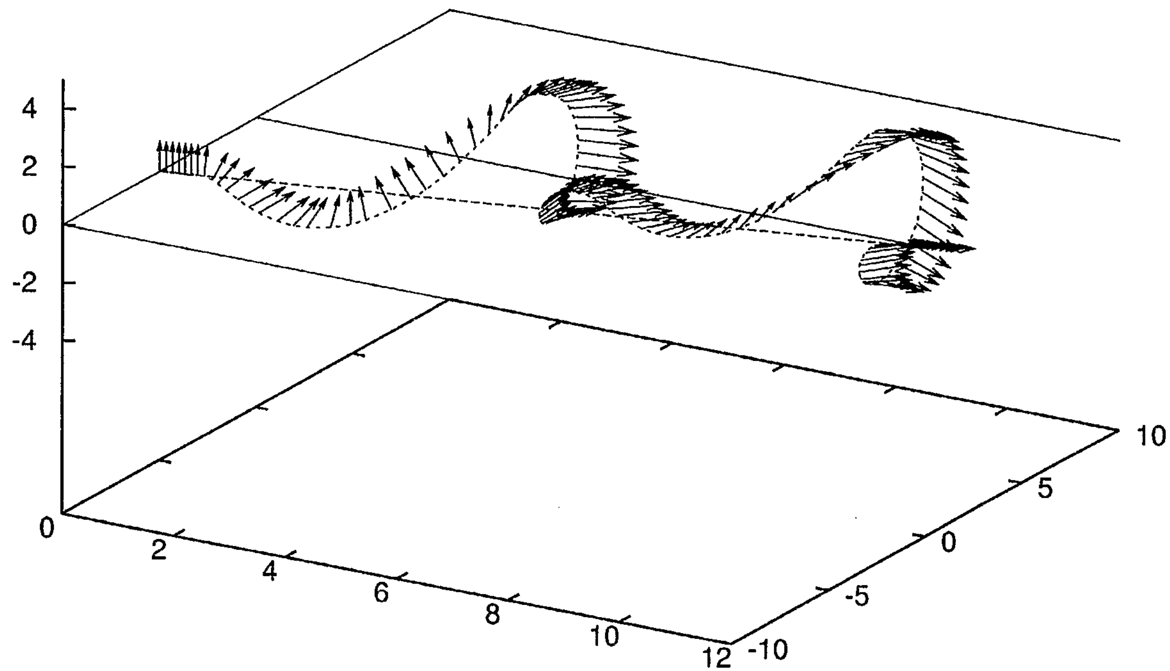
374

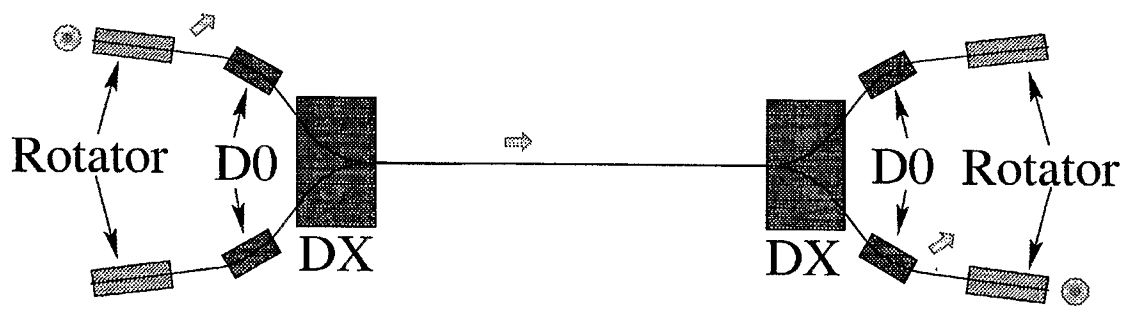


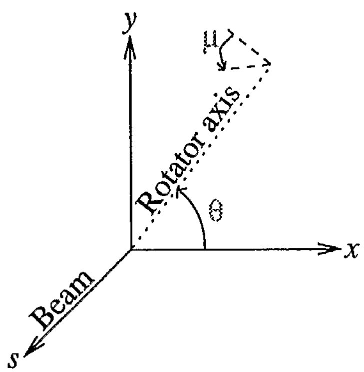


Helical Spin Rotators

375

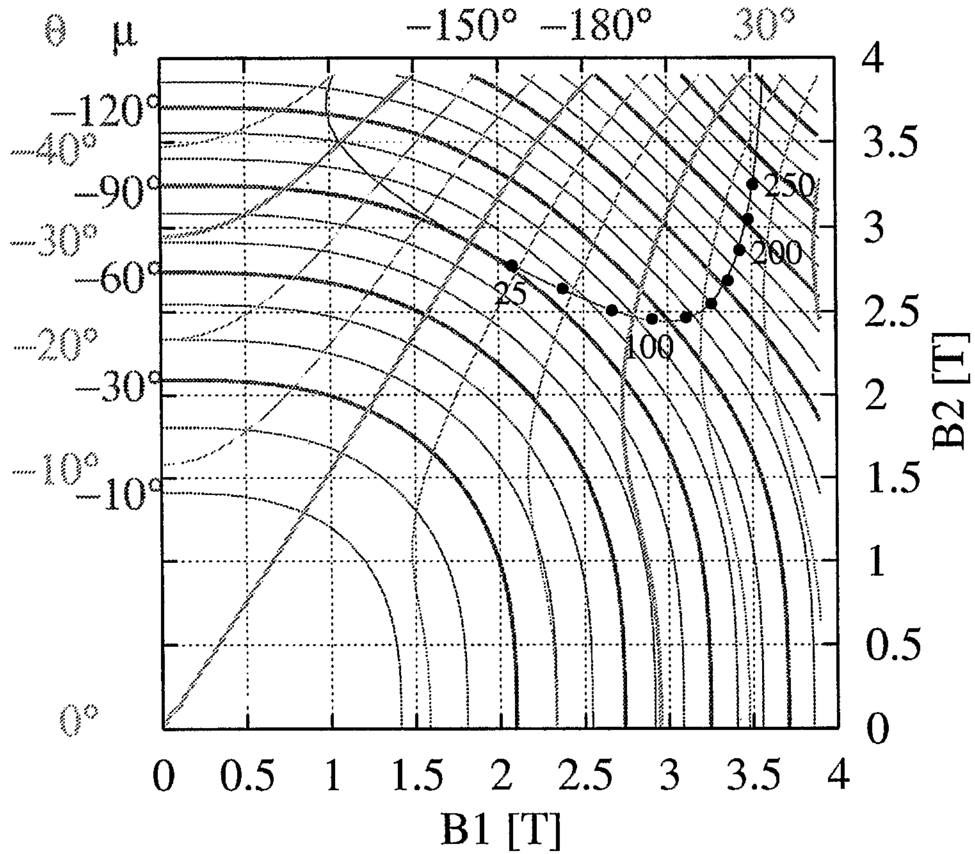






The rotation axis of the spin rotator is in the x-y plane at an angle θ from the vertical. The spin is rotated by the angle μ around the rotation axis.

Rotation Angles for a Helical Spin Rotator



Note: Purple contour for rotation into horizontal plane. Black dots show settings for RHIC energies in increments of 25 GeV from 25 to 250 GeV.

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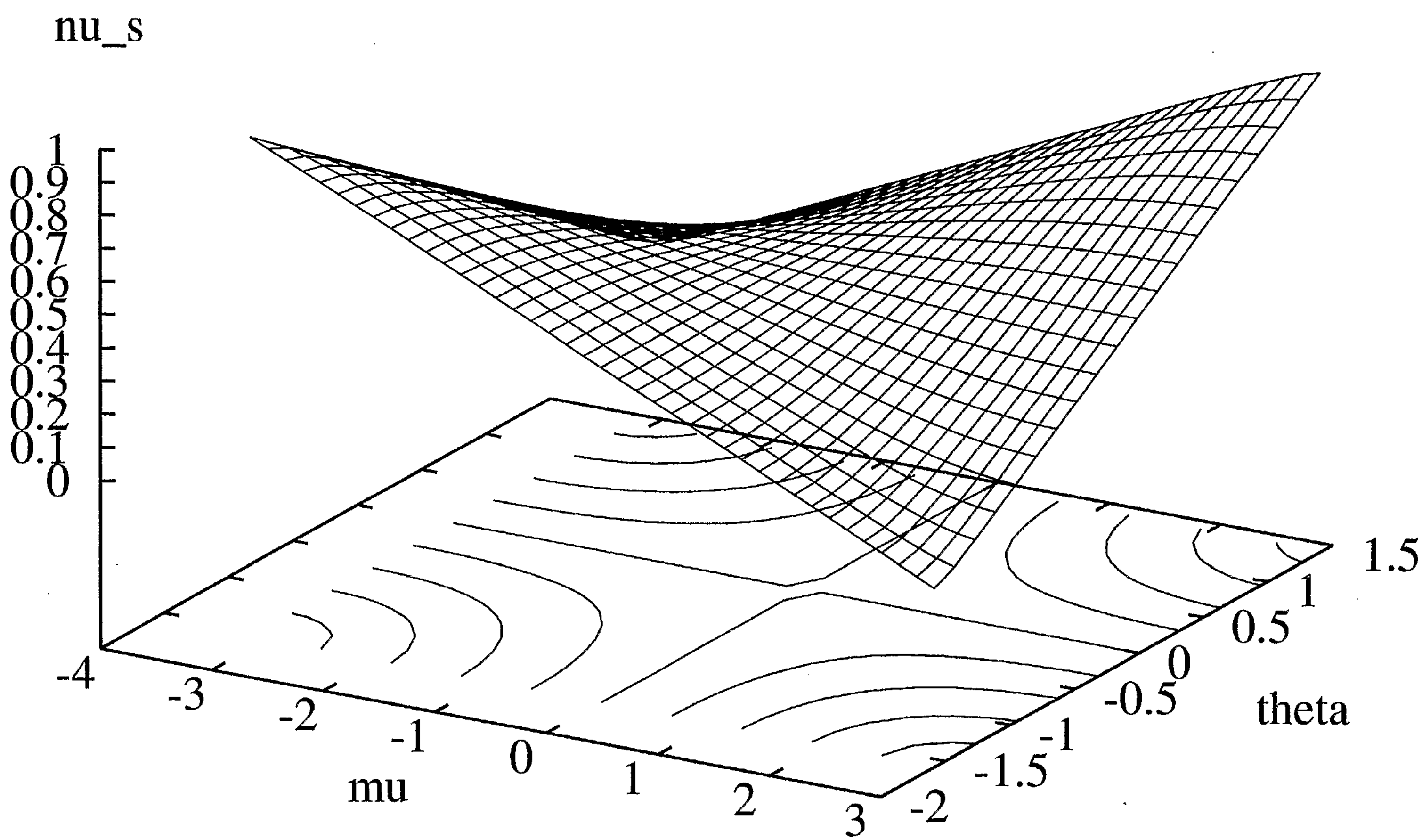
Spin tune: 2 full snakes, 1 rotator



Note: Contours are in steps of $\Delta\nu_s = 0.1$. $\cos(\pi\nu_s) = -\sin\theta\sin\frac{\mu}{2}$

Understanding of RHIC Absolute Luminosity in pp

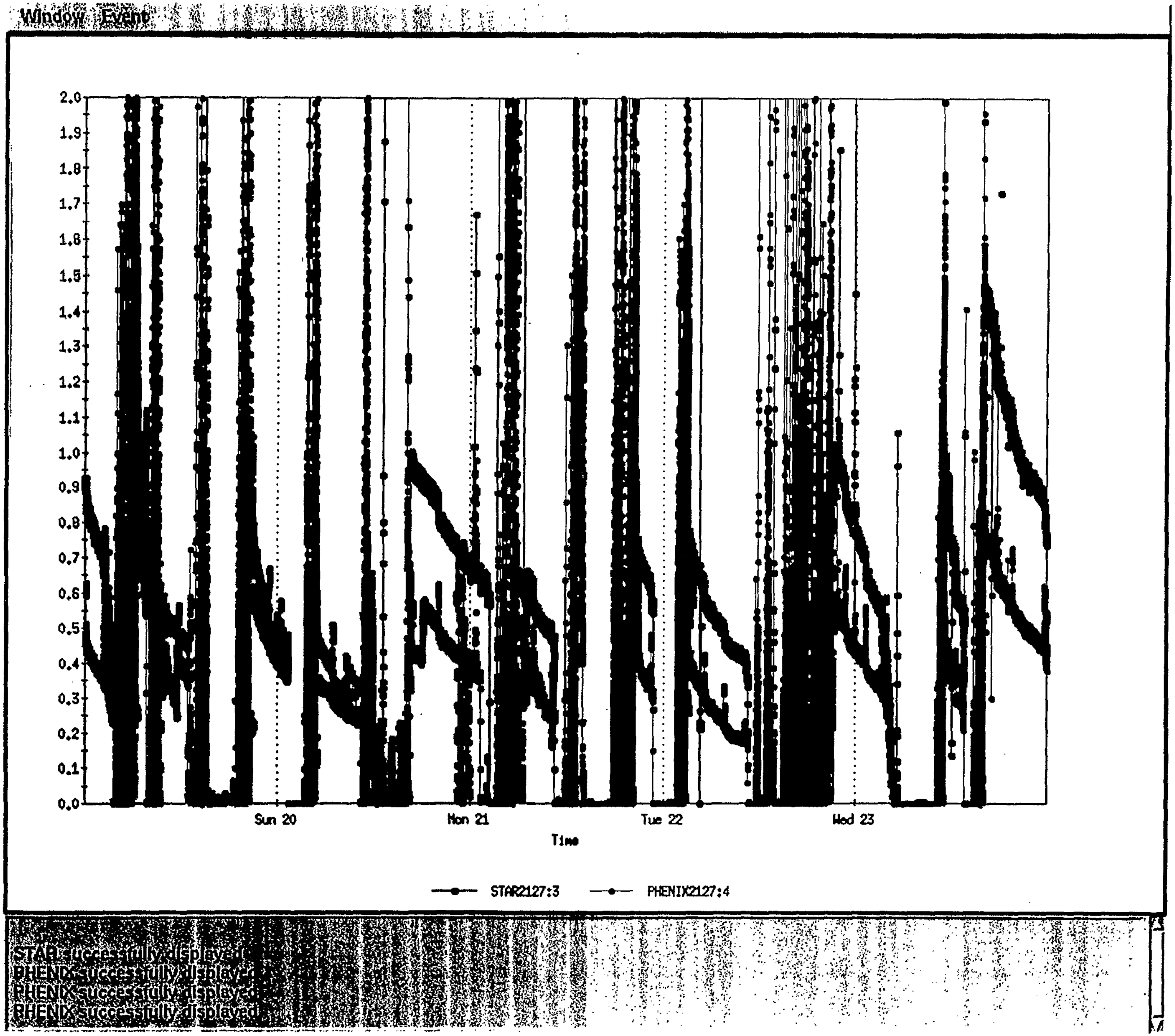
A. Drees, BNL
July 29, 2002

for
RHIC Spin Collaboration Meeting XI
RIKEN BNL Research Center

Luminosity during RHIC PP_FY02 Run

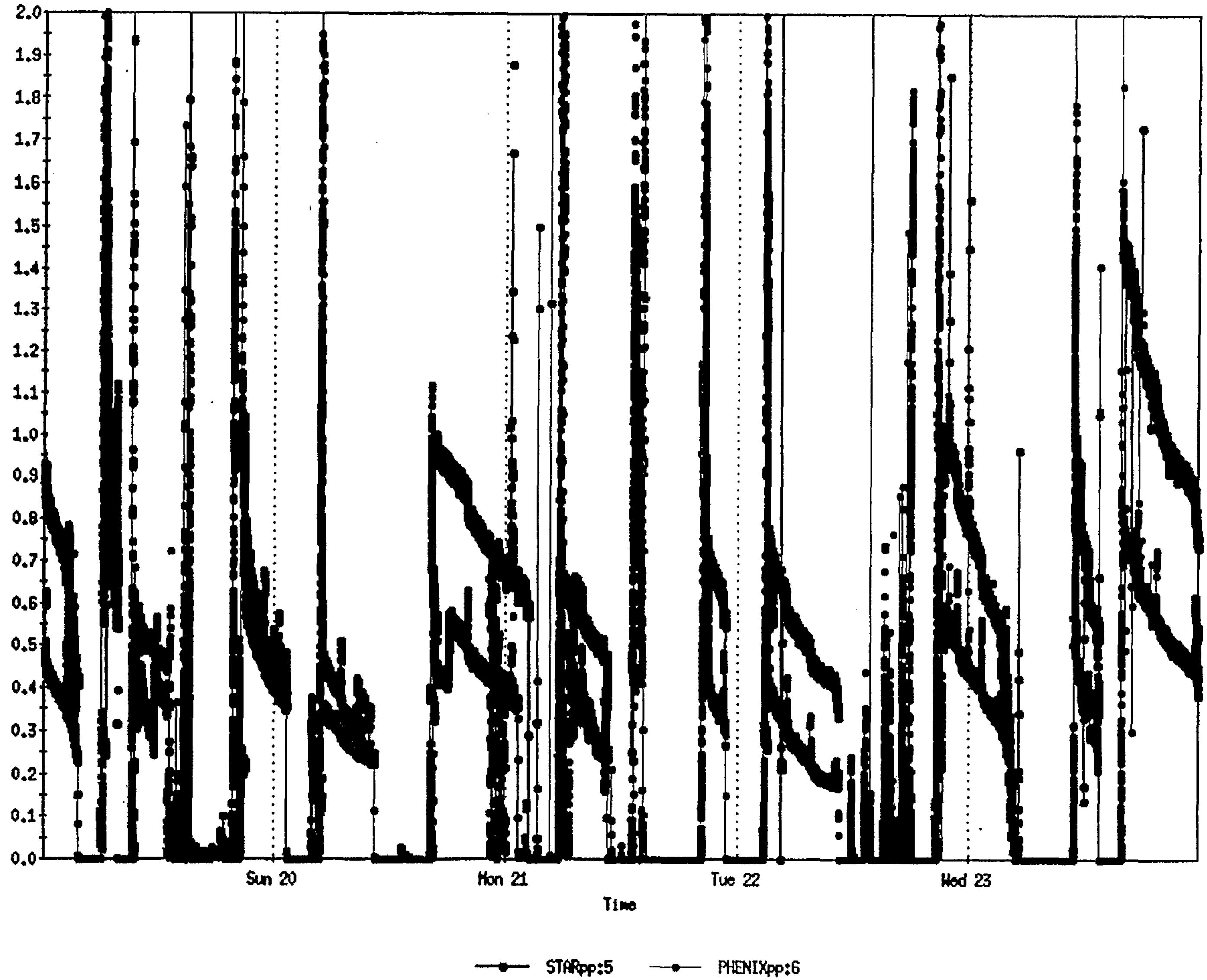
Issues:

* Background/Noise
  => during monitoring
  => during Vernier Scans
* Detector Acceptance
  => Vernier Scans (some results)
  => cross section normalization
* Comparability IR<->IR
  => ZDCs

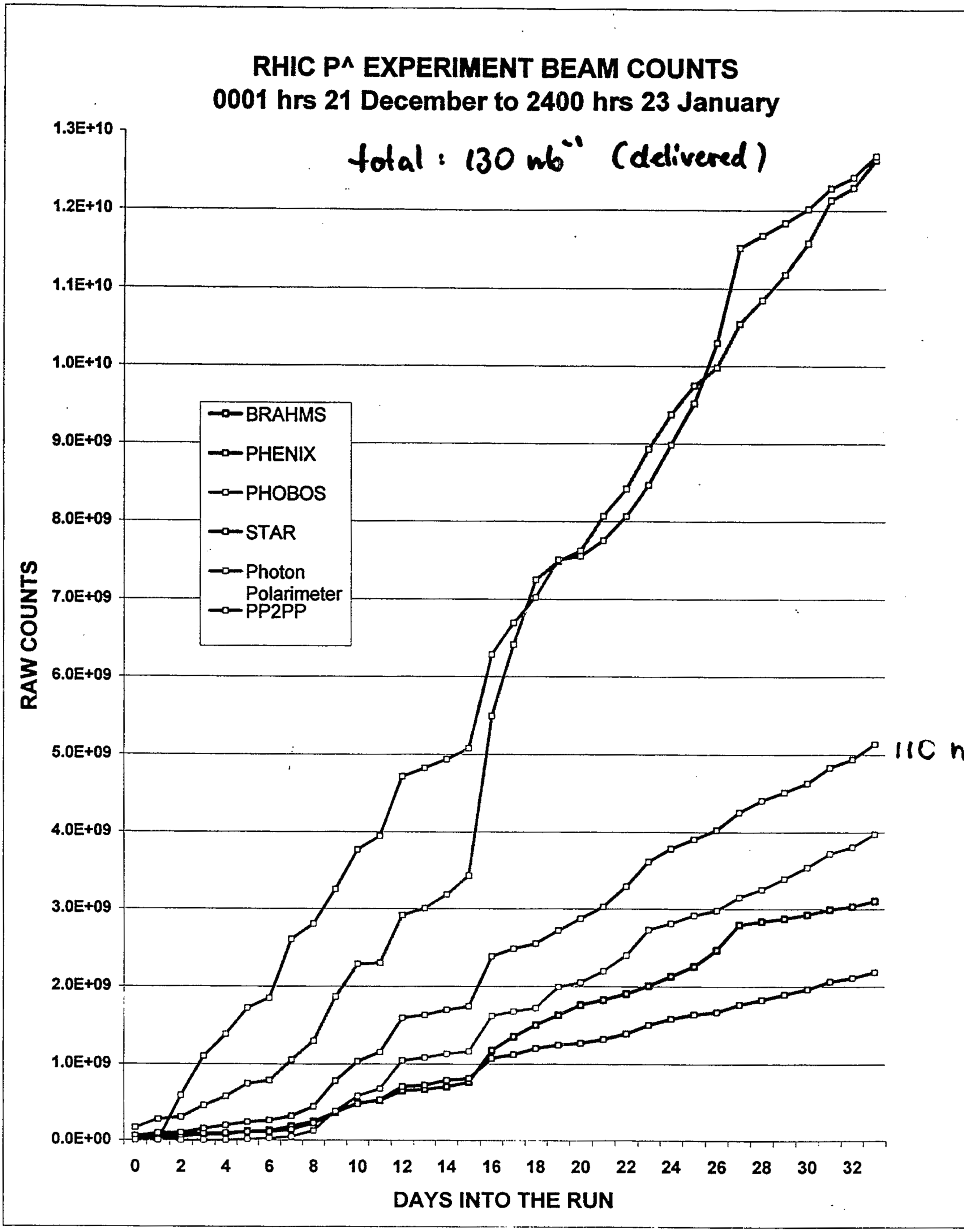

Window Event
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Sun 20
Mon 21
Tue 22
Wed 23
Time
STAR2127:3
PHENIX2127:4
STAR successfully displayed
PHENIX successfully displayed
PHENIX successfully displayed
PHENIX successfully displayed

Printed: Mon Jul 29 12:59:24 2002

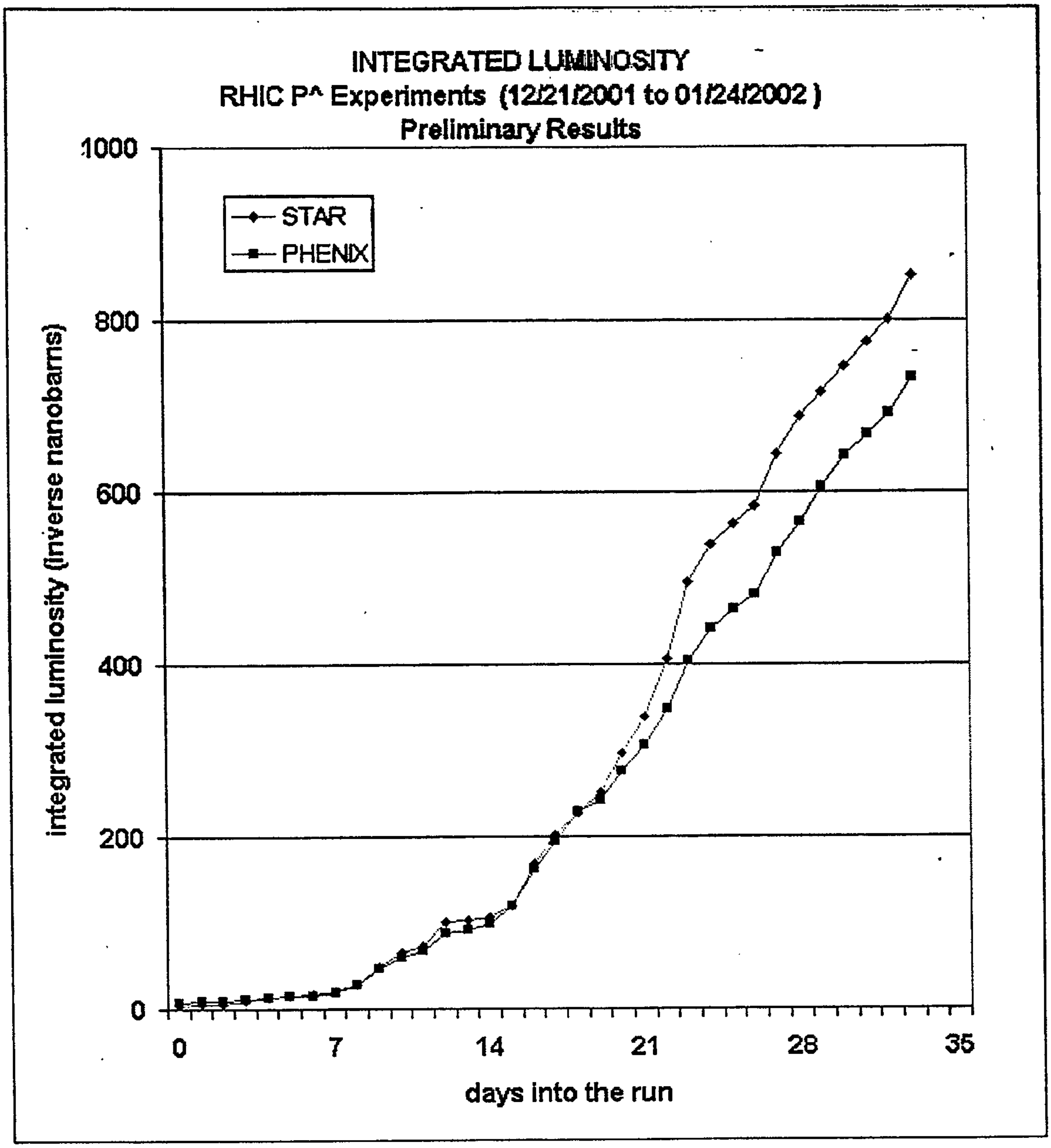
Window Event



STARpp successfully displayed
PHENIXpp successfully displayed
PHENIXpp successfully displayed
PHENIXpp successfully displayed

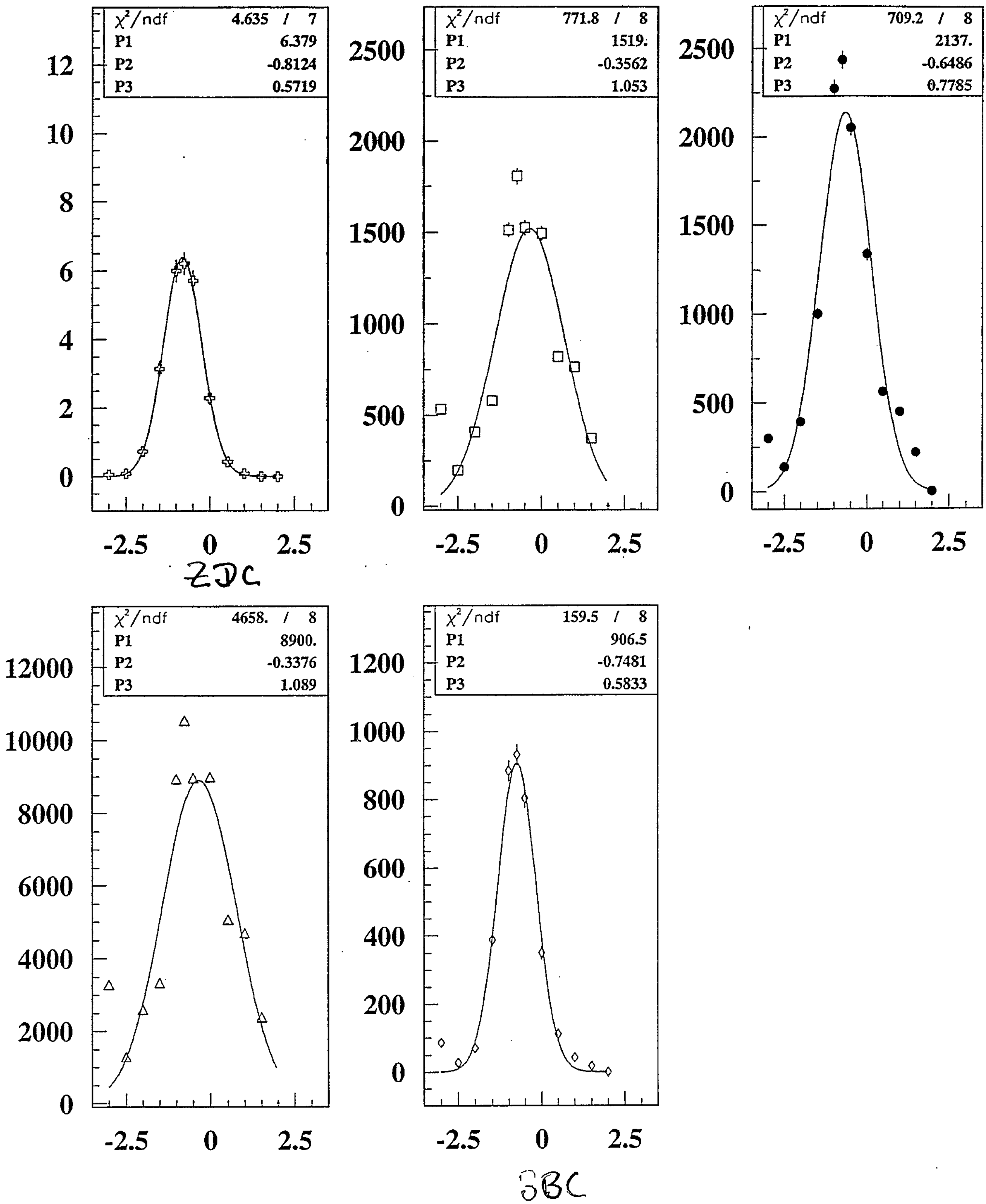


RHIC P^ EXPERIMENT BEAM COUNTS
0001 hrs 21 December to 2400 hrs 23 January
total : 130 nb⁻¹ (delivered)
110 nb⁻¹
BRAHMS
PHENIX
PHOBOS
STAR
Photon Polarimeter
PP2PP
RAW COUNTS
DAYS INTO THE RUN
1.3E+10
1.2E+10
1.1E+10
1.0E+10
9.0E+09
8.0E+09
7.0E+09
6.0E+09
5.0E+09
4.0E+09
3.0E+09
2.0E+09
1.0E+09
0.0E+00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32


INTEGRATED LUMINOSITY
RHIC P^ Experiments (12/21/2001 to 01/24/2002)
Preliminary Results
STAR
PHENIX
integrated luminosity (inverse nanobarns)
1000
800
600
400
200
0
0
7
14
21
28
35
days into the run

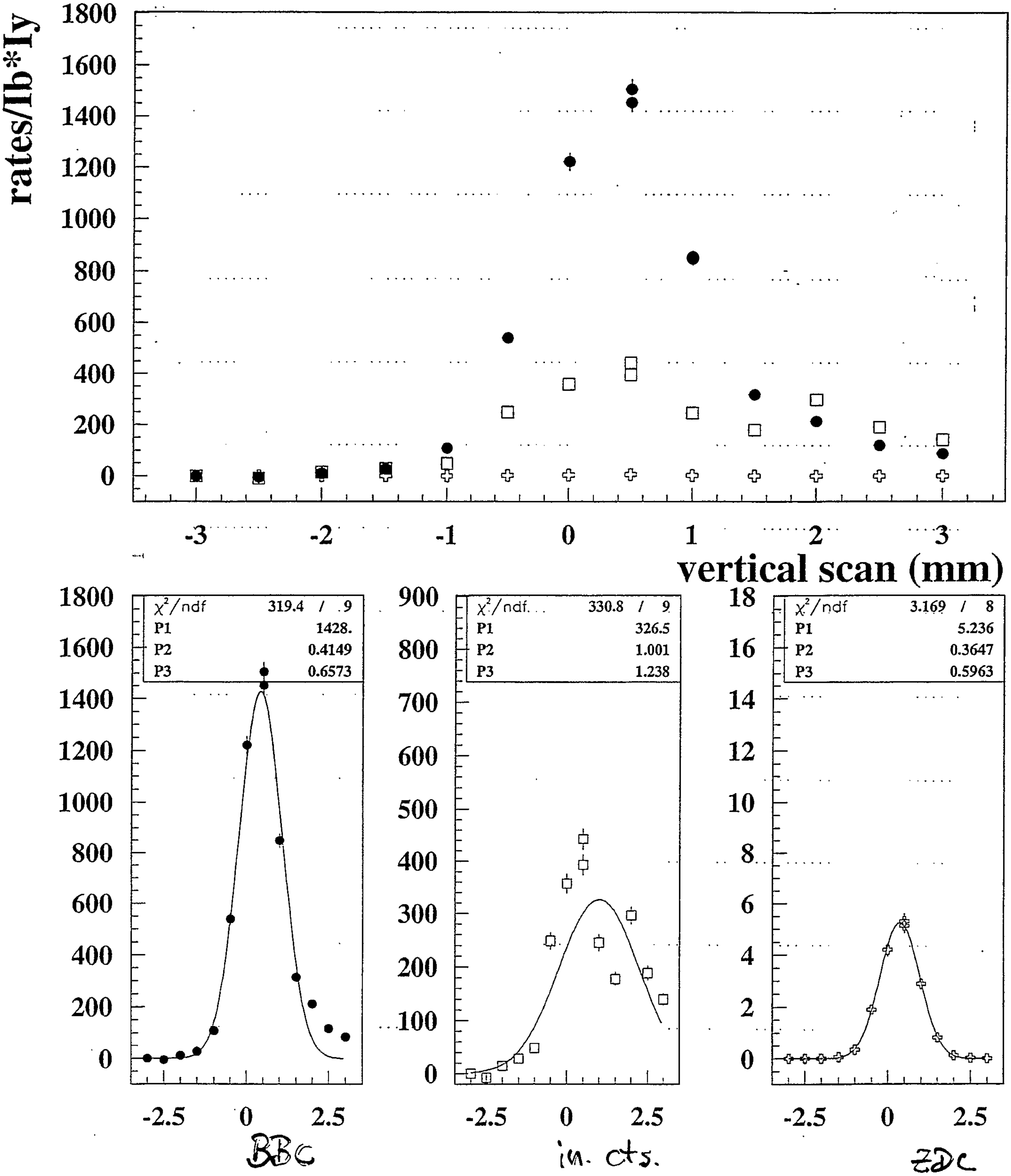
c nb⁻¹

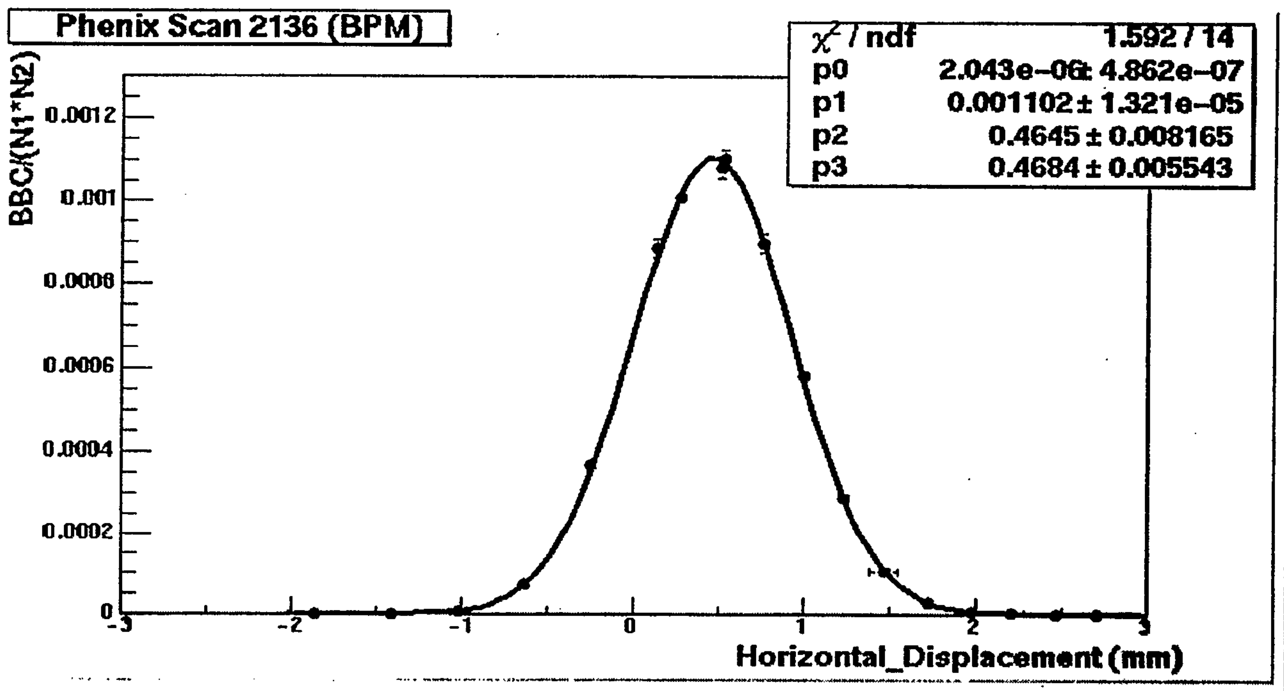
IR2 pp2233 V



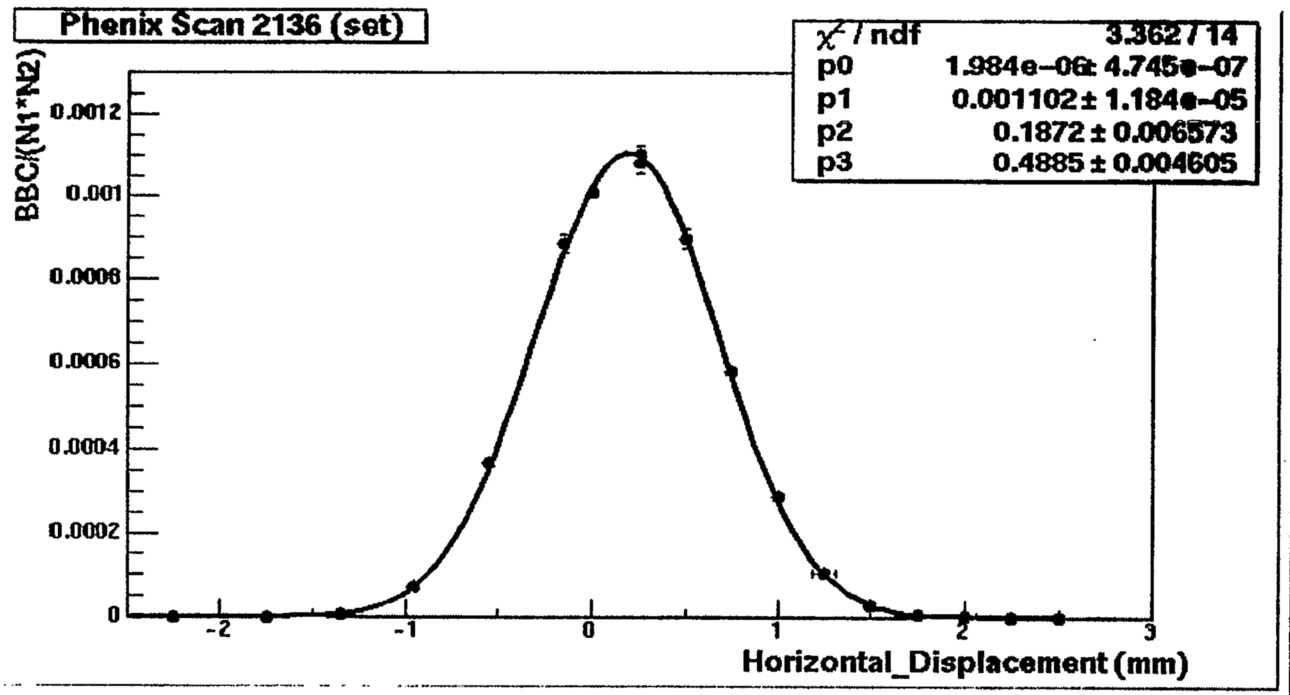
χ²/ndf 4.635 / 7
P1 6.379
P2 -0.8124
P3 0.5719
ZDC
χ²/ndf 771.8 / 8
P1 1519.
P2 -0.3562
P3 1.053
χ²/ndf 709.2 / 8
P1 2137.
P2 -0.6486
P3 0.7785
χ²/ndf 4658. / 8
P1 8900.
P2 -0.3376
P3 1.089
χ²/ndf 159.5 / 8
P1 906.5
P2 -0.7481
P3 0.5833
BBC

BRAHMS pp2193

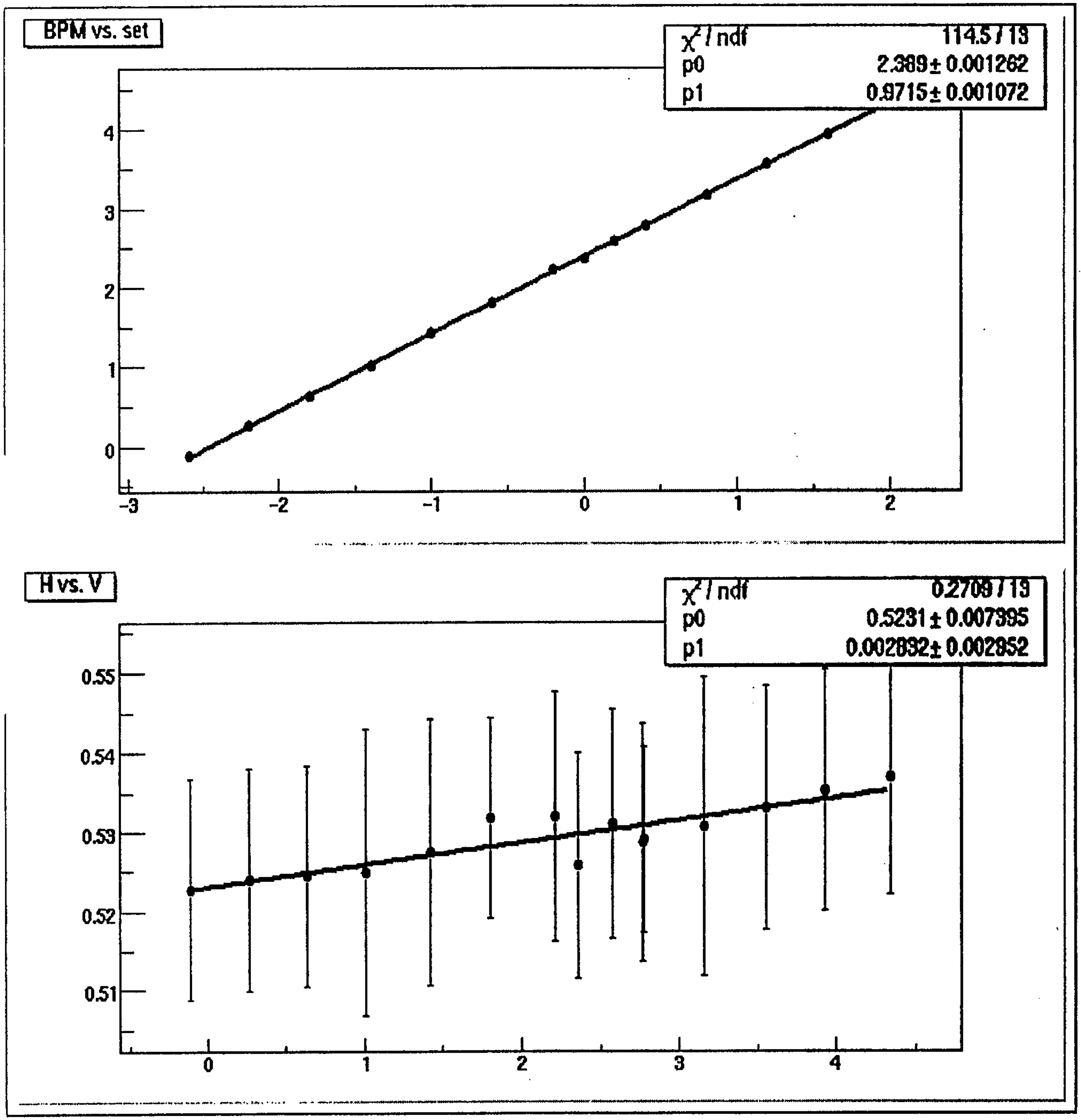




BPM =(BPM_7+BPM_8)/2 measured by horizontal DX BPMs



Set = from model

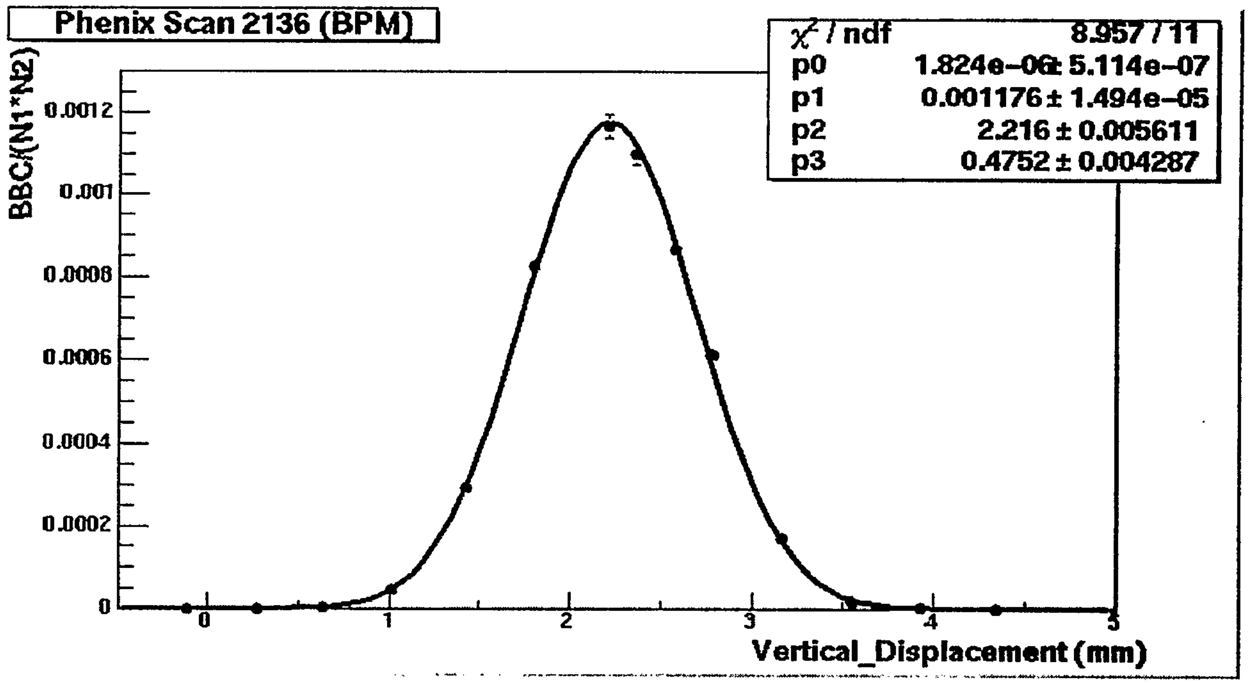


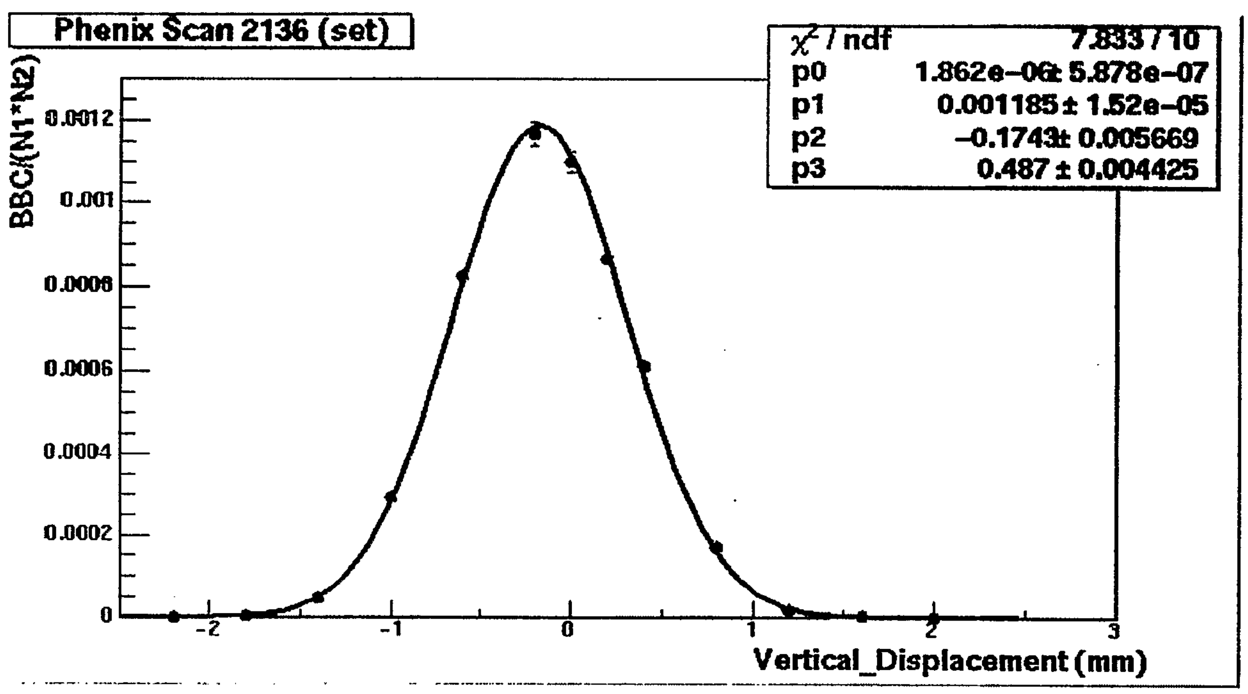
about 3% "contraction"

expected for $\beta^* = 3$m

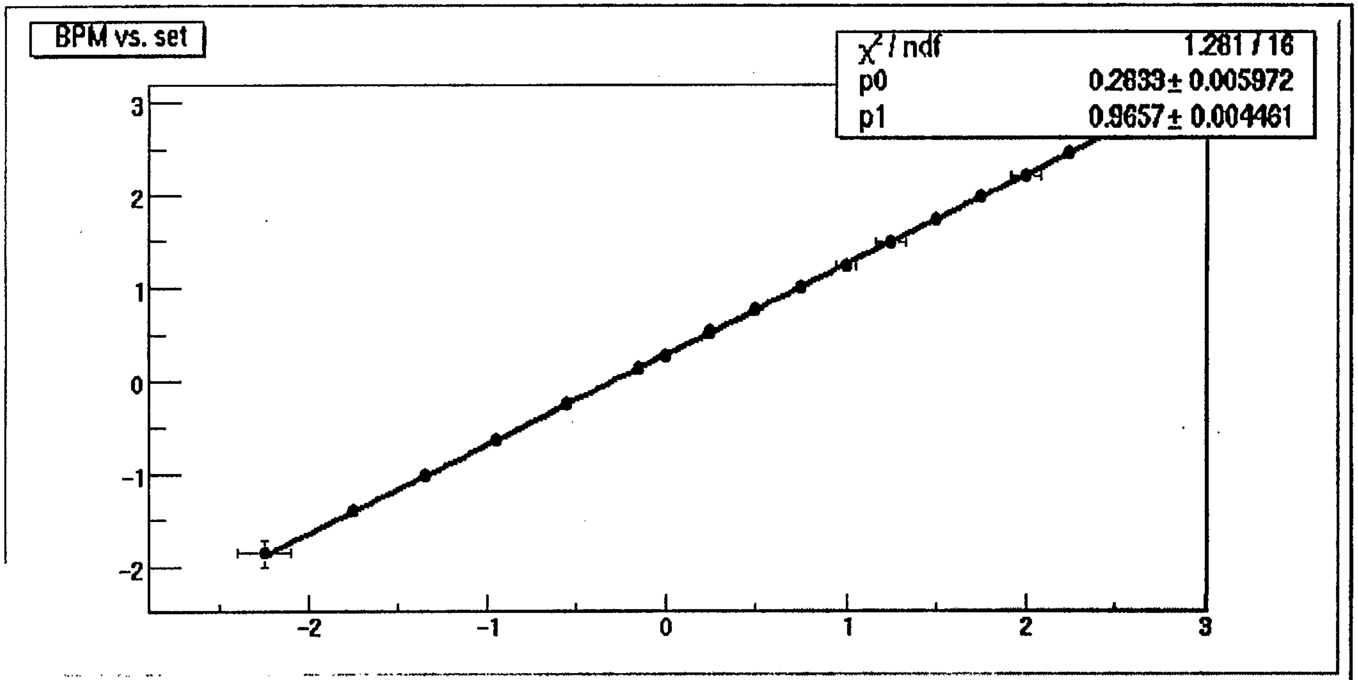
H = (BPM7+BPM8)/2
V = (BPM7+BPM8)/2

about 20 µm drifts
in other plane during
the H scan measured



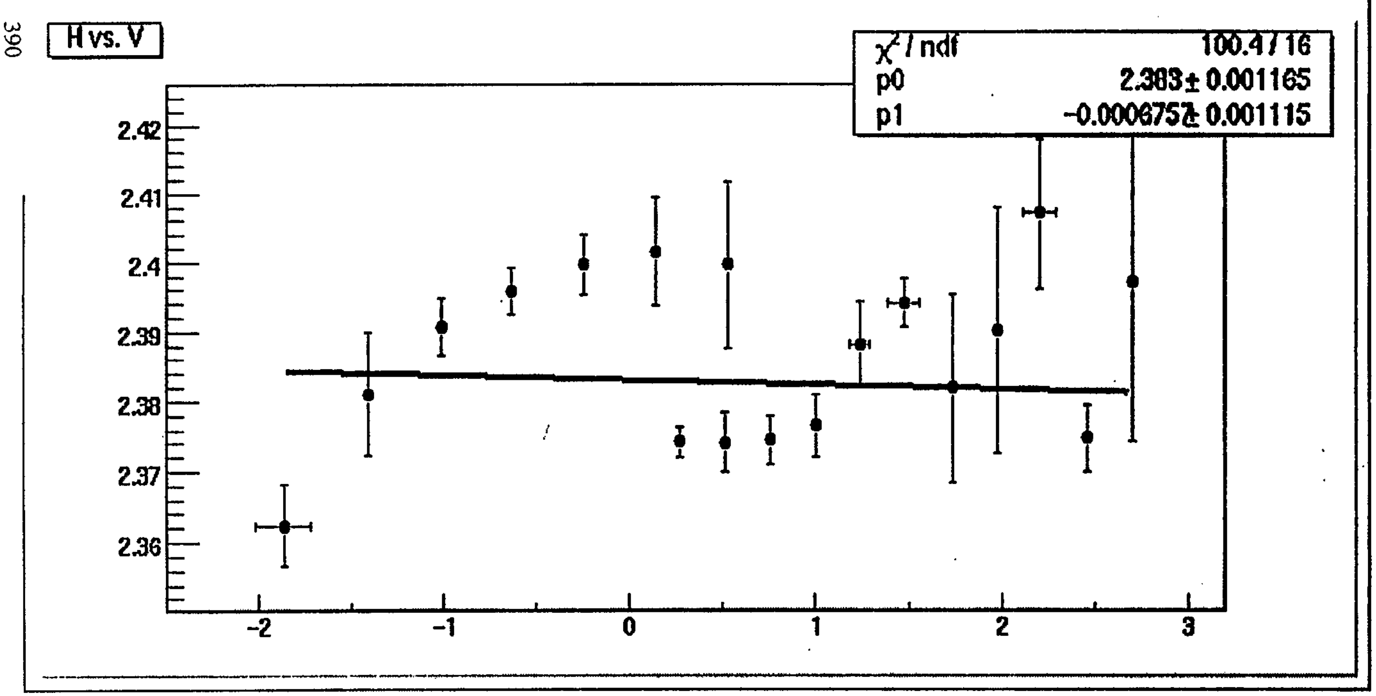


BPM =(BPM_7+BPM_8)/2 measured by vertical DX BPMs



about 3% "contraction"

expected for β* = 3m



H = (BPM7+BPM8)/2
V = (BPM7+BPM8)/2

about 50 μm drifts
in other plane during
the V scan measured

don't understand
distribution yet

IR<–>IR

<u>Vernier Scan during fill 2161 with ZDC data:</u>

σ_{ZDC}(STAR) = 0.33 ± 0.05 mbarn

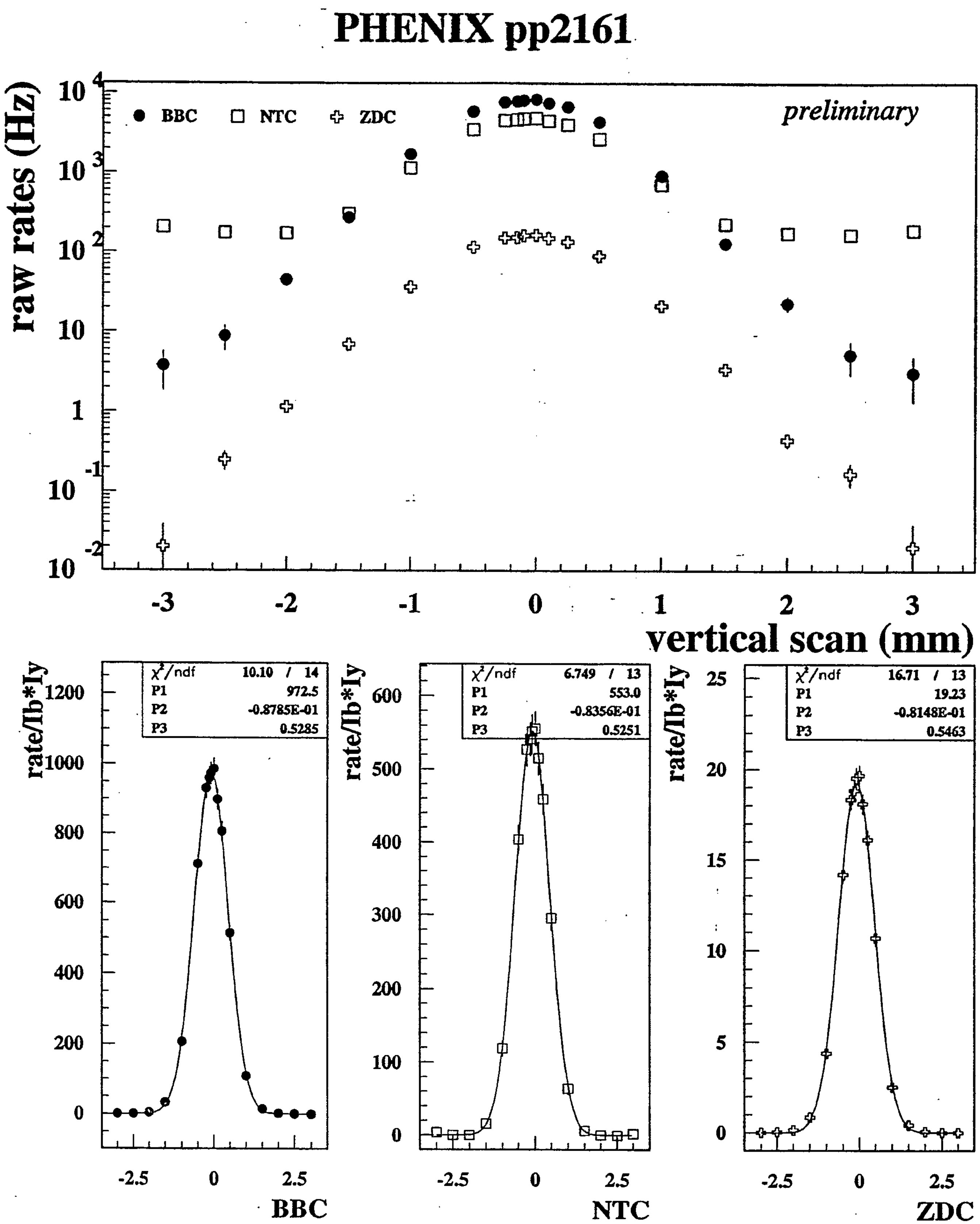
σ_{ZDC}(PHENIX) = 0.30 ± 0.05 mbarn

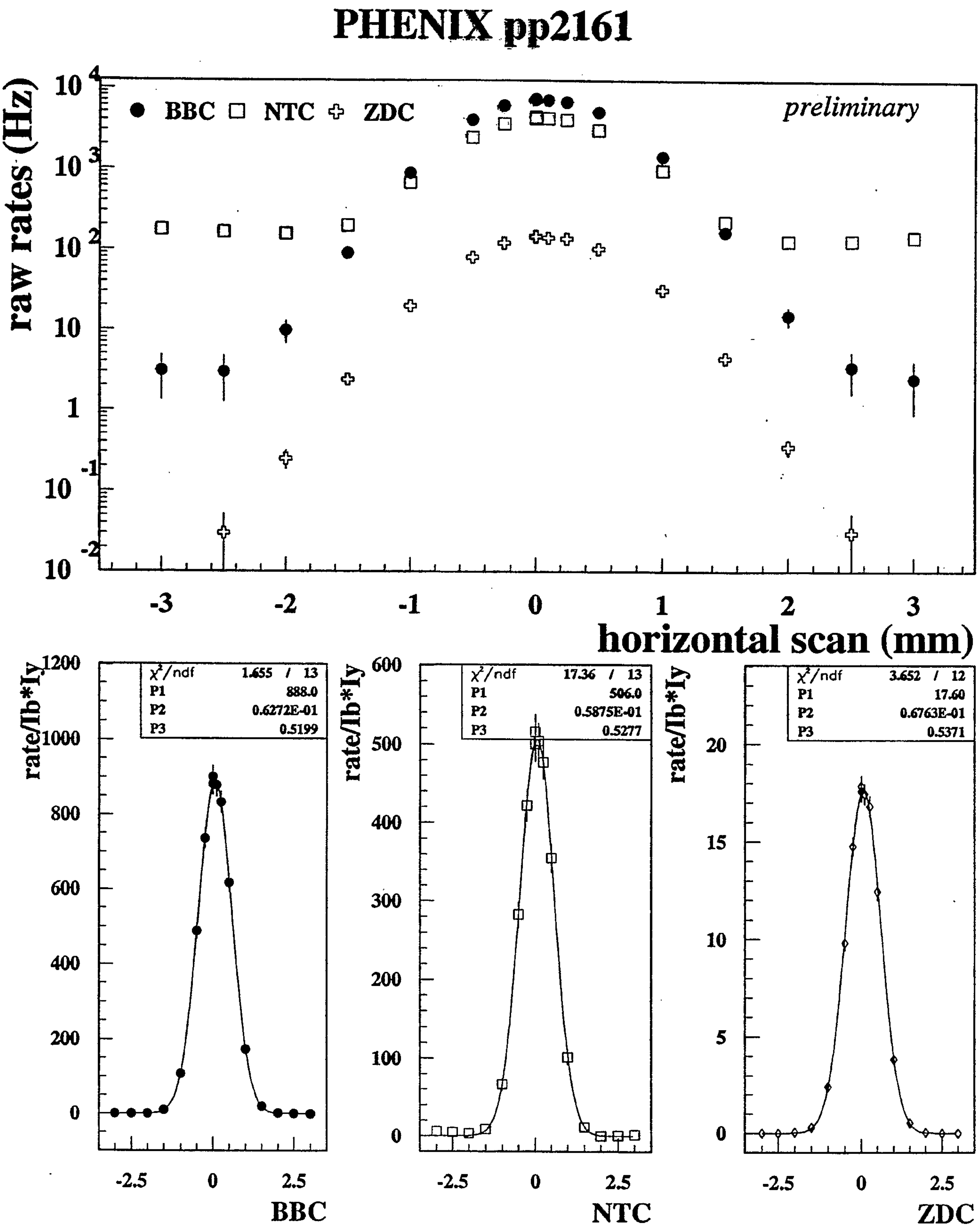
consistent within (stat.!) errors

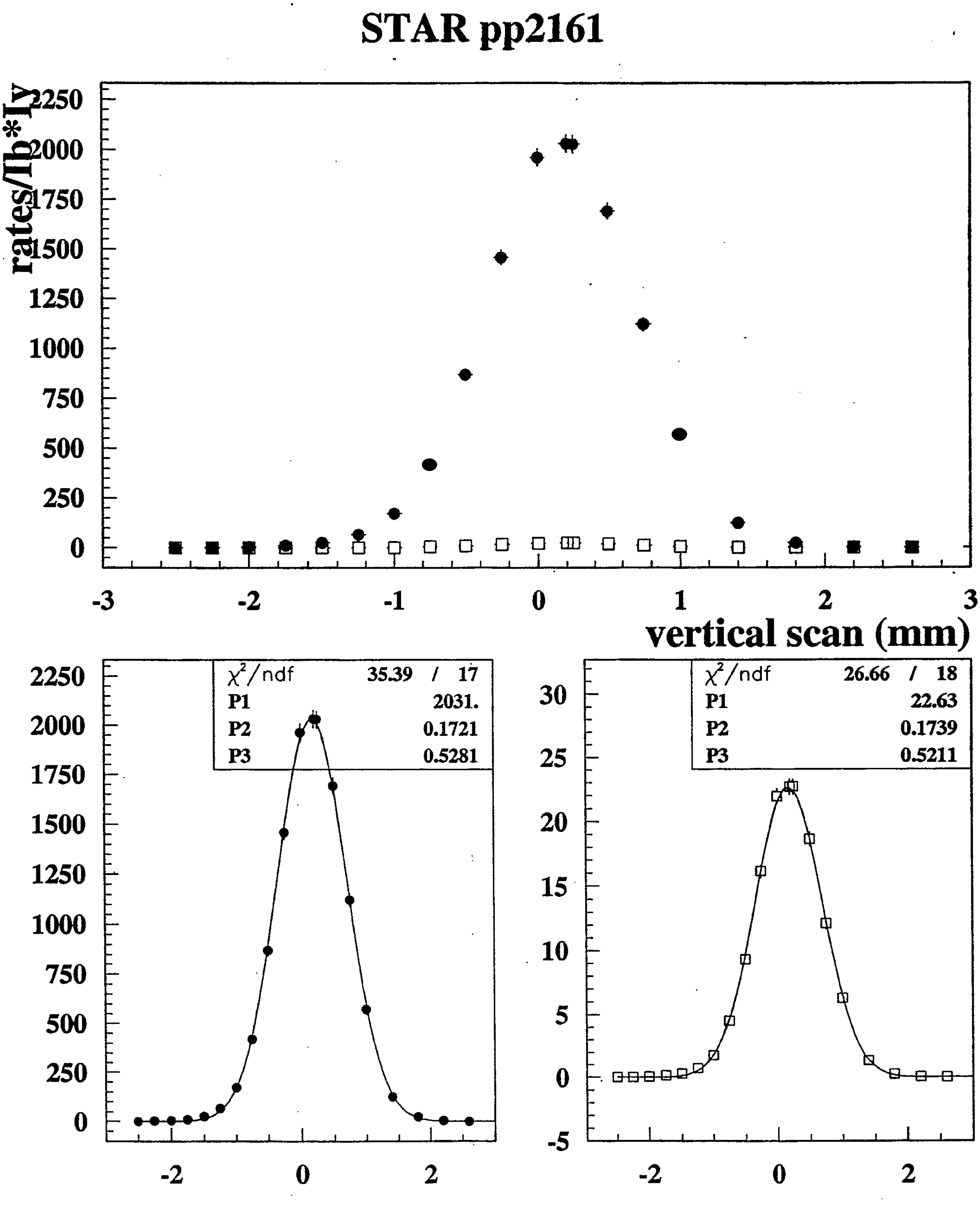
Luminosity from Scan:

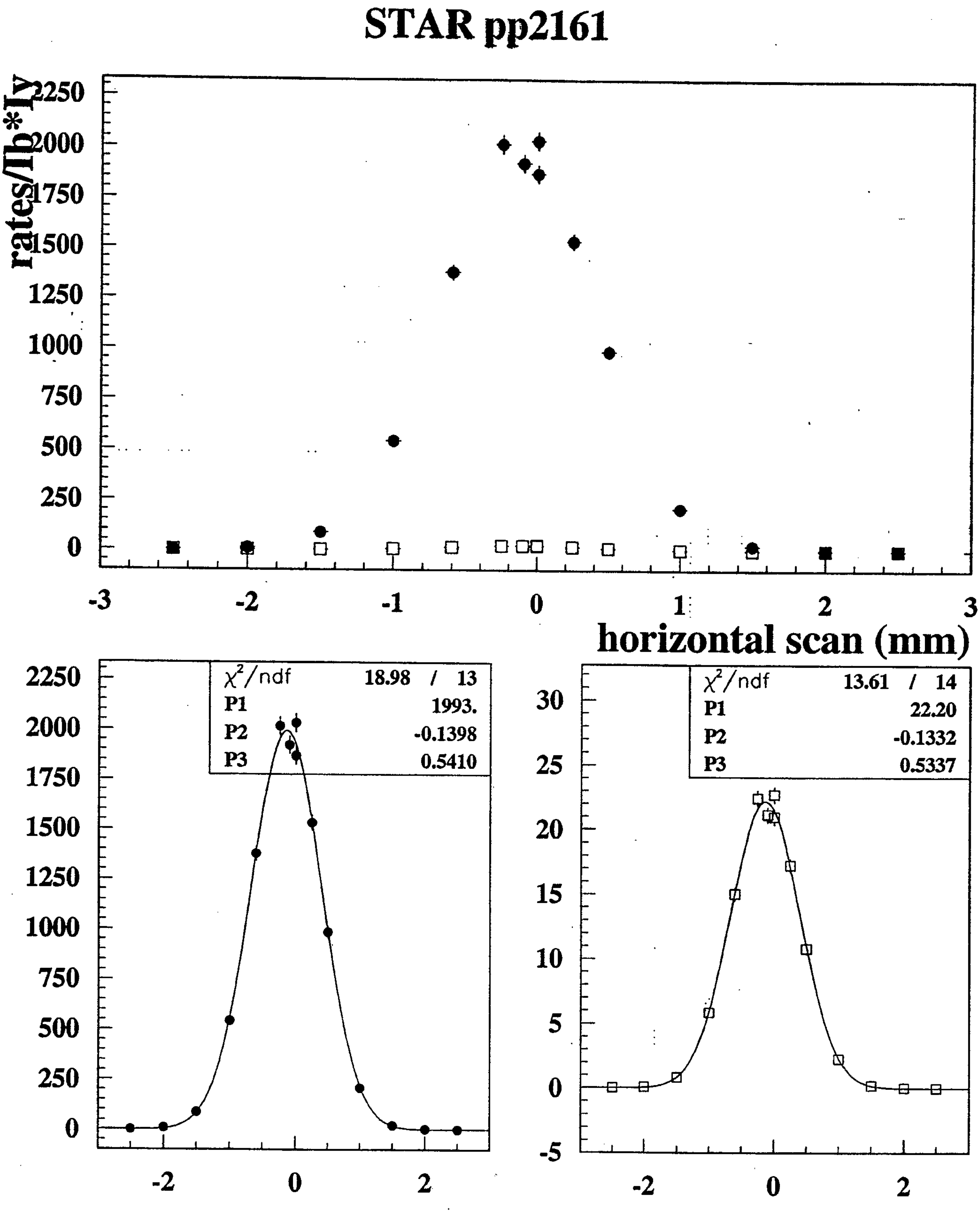
STAR: 0.6 ± 0.1 10^{30} cm^{-2} s^{-1}

PHENIX: 0.54 ± 0.1 10^{30} cm^{-2} s^{-1}


PHENIX pp2161
raw rates (Hz)
BBC
NTC
ZDC
preliminary
vertical scan (mm)
rate/Ib*Iy
χ²/ndf 10.10 / 14
P1 972.5
P2 -0.8785E-01
P3 0.5285
BBC
χ²/ndf 6.749 / 13
P1 553.0
P2 -0.8356E-01
P3 0.5251
NTC
χ²/ndf 16.71 / 13
P1 19.23
P2 -0.8148E-01
P3 0.5463
ZDC


PHENIX pp2161
BBC NTC ZDC
preliminary
raw rates (Hz)
horizontal scan (mm)
rate/Ib*Iy
χ²/ndf 1.655 / 13
P1 888.0
P2 0.6272E-01
P3 0.5199
BBC
χ²/ndf 17.36 / 13
P1 506.0
P2 0.5875E-01
P3 0.5277
NTC
χ²/ndf 3.652 / 12
P1 17.60
P2 0.6763E-01
P3 0.5371
ZDC


STAR pp2161
rates/Ib*Iy
vertical scan (mm)
χ²/ndf 35.39 / 17
P1 2031.
P2 0.1721
P3 0.5281
χ²/ndf 26.66 / 18
P1 22.63
P2 0.1739
P3 0.5211


STAR pp2161
rates/Ib*Iy
horizontal scan (mm)
χ²/ndf 18.98 / 13
P1 1993.
P2 -0.1398
P3 0.5410
χ²/ndf 13.61 / 14
P1 22.20
P2 -0.1332
P3 0.5337

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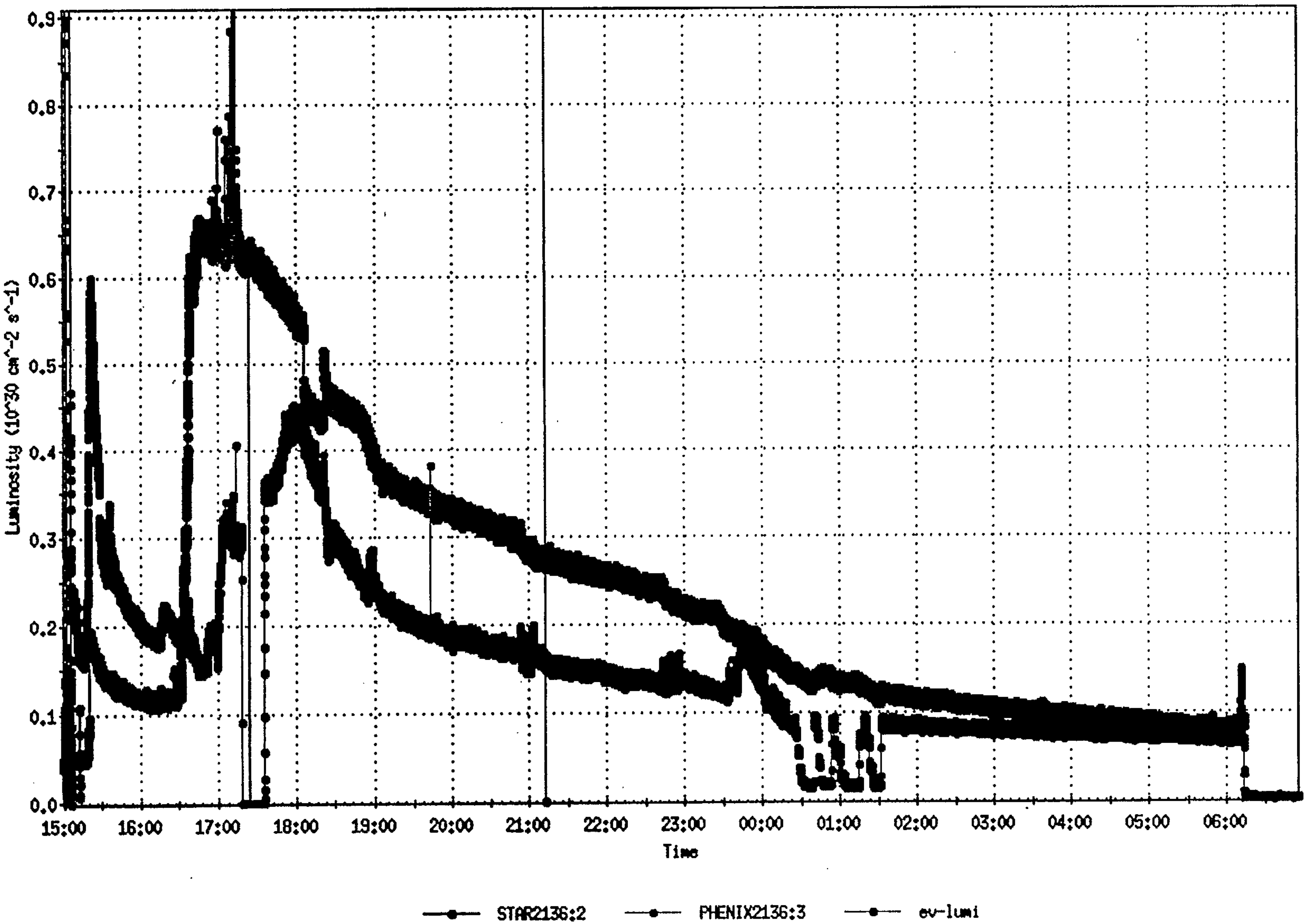
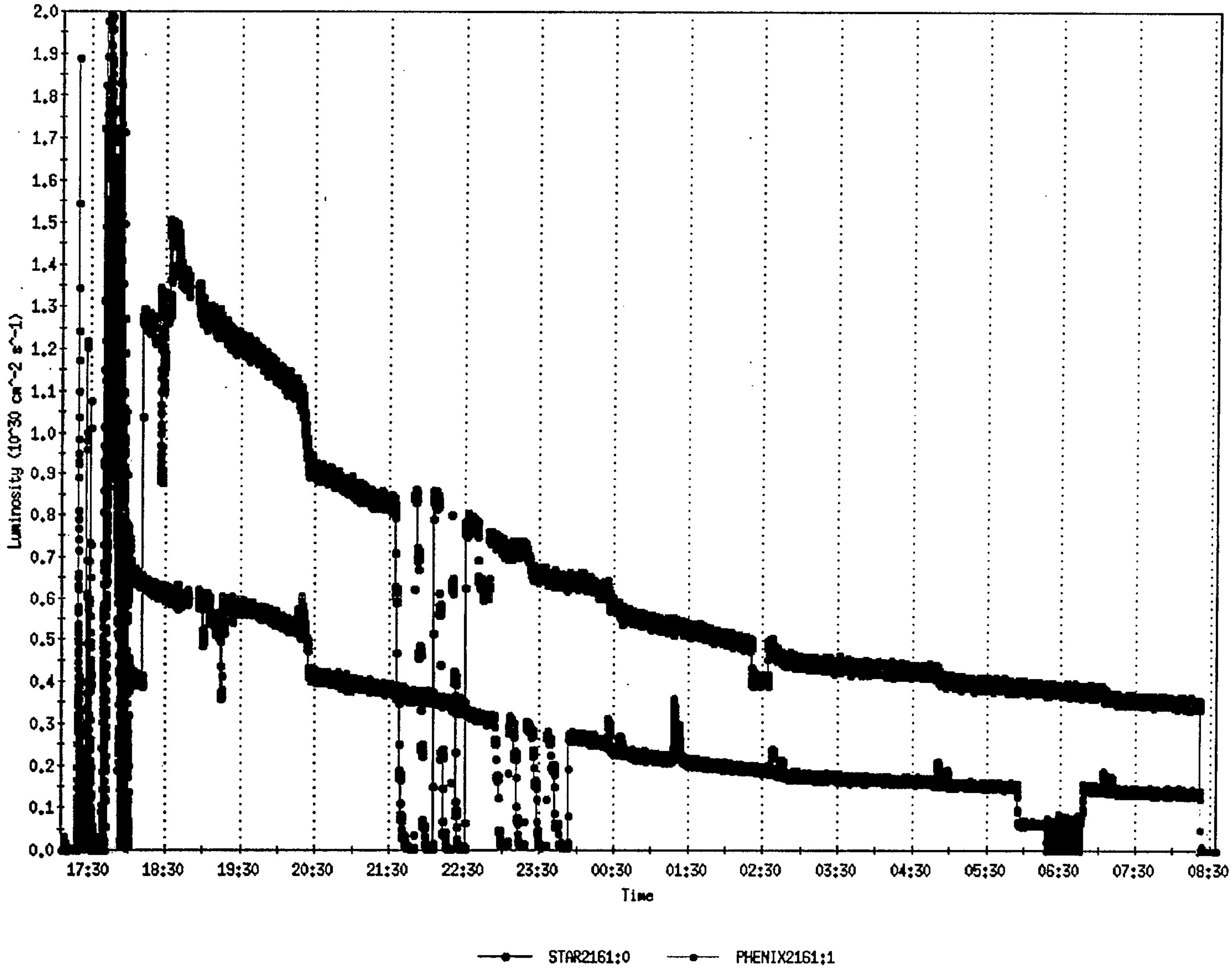


STAR successfully displayed
PHENIX successfully displayed
PHENIX successfully displayed
PHENIX successfully displayed

Printed: Mon Jul 29 11:03:21 2002

Window - Event



STAR successfully displayed
PHENIX successfully displayed
PHENIX successfully displayed
PHENIX successfully displayed

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Understanding of the Absolute Luminosity at PHENIX

RSC Meeting

July 29, 2002

Yuji Goto (RIKEN/RBRC)

Vernier scan analysis

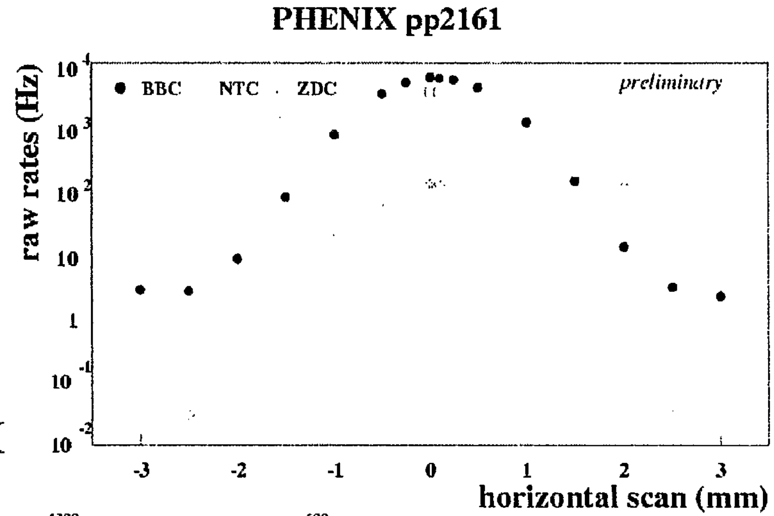
- 2 vernier scans at PHENIX
  - fill 2136
    - Jan 3 0:30-1:20
    - σ_{BBC}=12.3mb
      - σ_X=0.485mm σ_Y=0.485mm

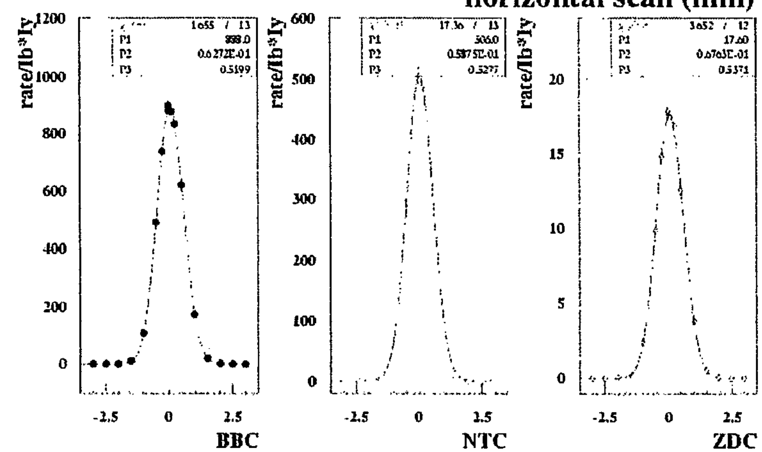
    ➔11.5mb with measured position

    ➔12.5mb with current product at PHENIX
  - fill 2160
    - Jan 6 22:50-23:55
    - σ_{BBC}=12.1mb
      - σ_X=0.520mm σ_Y=0.529mm

    ➔11.3mb with measured position

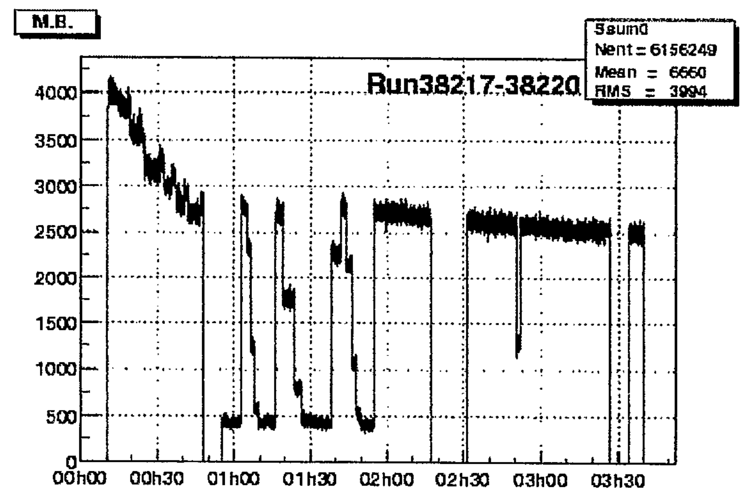
    ➔12.6mb with current product at PHENIX
    - σ_{NTCn}=7.0mb
    - σ_{ZDC}=0.25mb

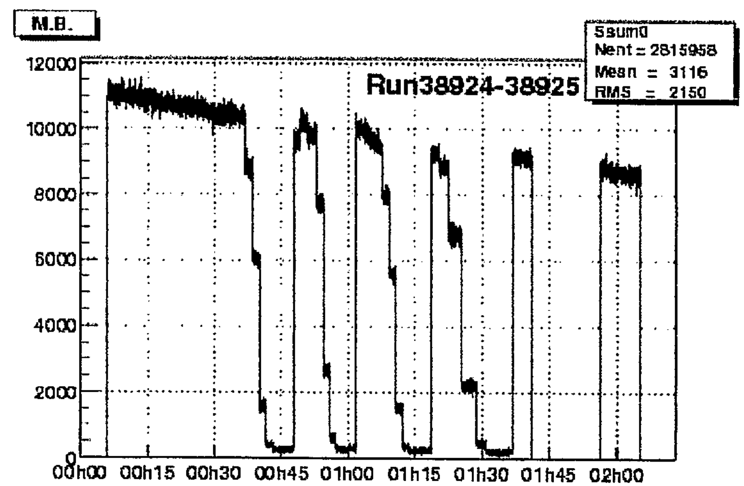




Vernier scan analysis

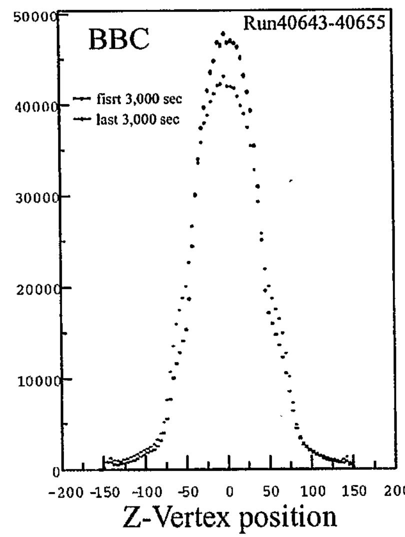
- 2 vernier scans at PHENIX
  - fill 2136
    - Jan 3 0:30-1:20
    - PHENIX run 38218
  - fill 2160
    - Jan 6 22:50-23:55
    - PHENIX run 38924
- Corrections
  - to evaluate inelastic cross section
  - BBC efficiency
    - PYTHIA/GEANT simulation
  - BBCLL1 vertex cut
    - |z| < 75cm cut
    - vertex distribution dependent
    - evaluated with measured vertex distribution

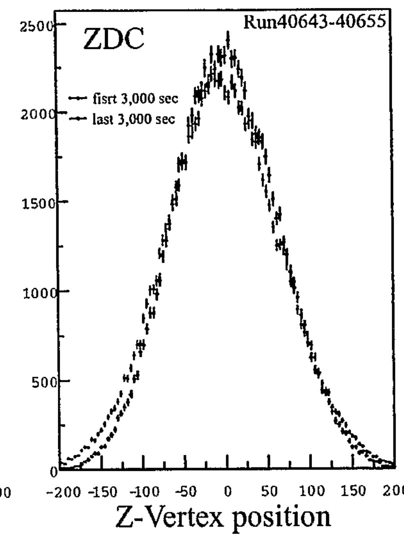


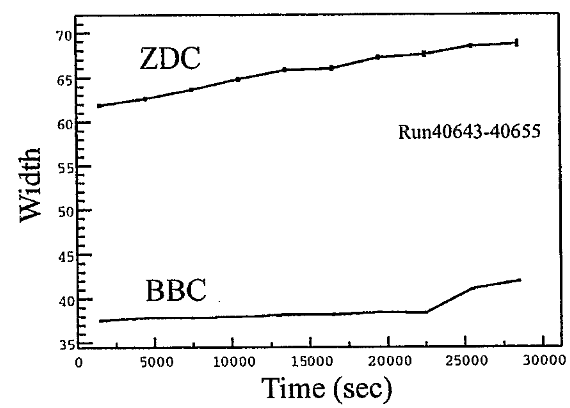


Vernier scan analysis

- Corrections
  - vertex distribution
    - changing in a fill
    - ZDC vertex in vernier scan period: σ = 50–70cm

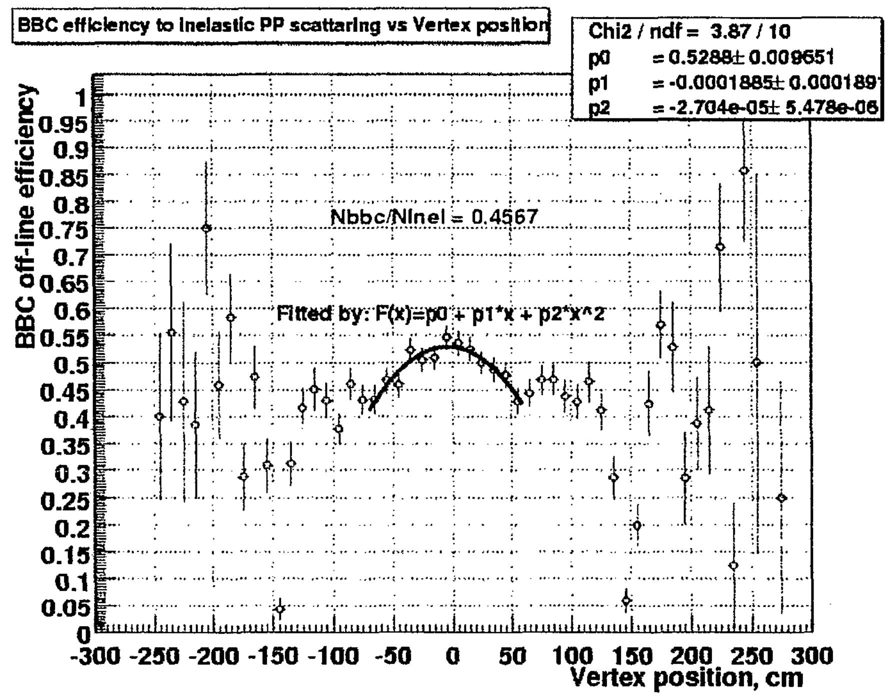






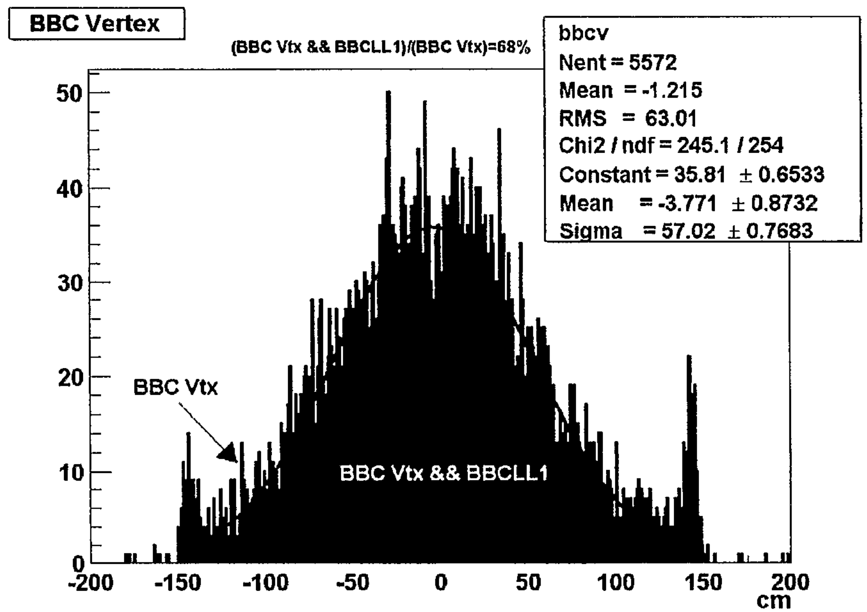
Vernier scan analysis

- Corrections
  - BBC efficiency
    - PYTHIA/GEANT simulation
    - 46% for $|z| < 75$cm with $\sigma_{BBC} =$ 60–80cm
    - stable at $z = 0$
      - 51% for $|z| < 40$cm
    - error evaluation ??
      - need to understand PYTHIA event structure in forward direction



Vernier scan analysis

- Corrections
  - BBCLL1 vertex cut
    - uncertainty in beam-gas background subtraction with BBCLL1 no vertex cut trigger
      - 68–72%
    - uncertainty in BBCLL1 ↔ BBC offline with clock trigger
      - 63%
    - 68 ± 5%



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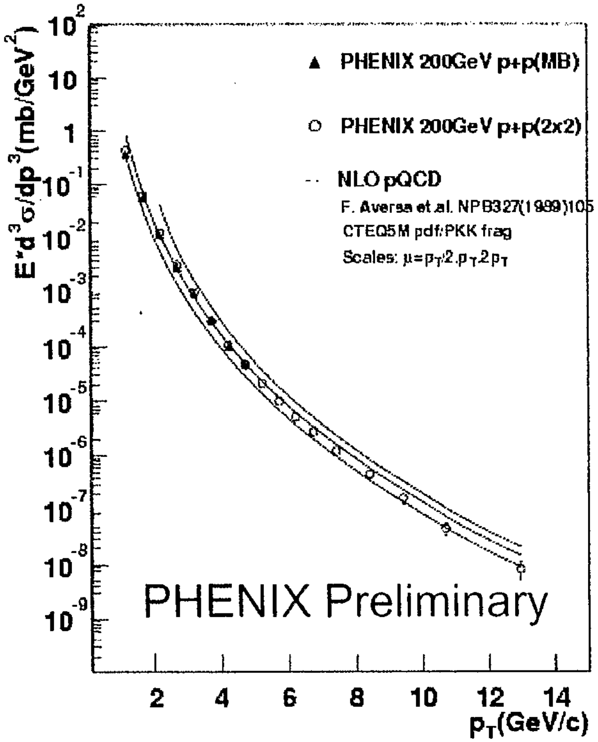
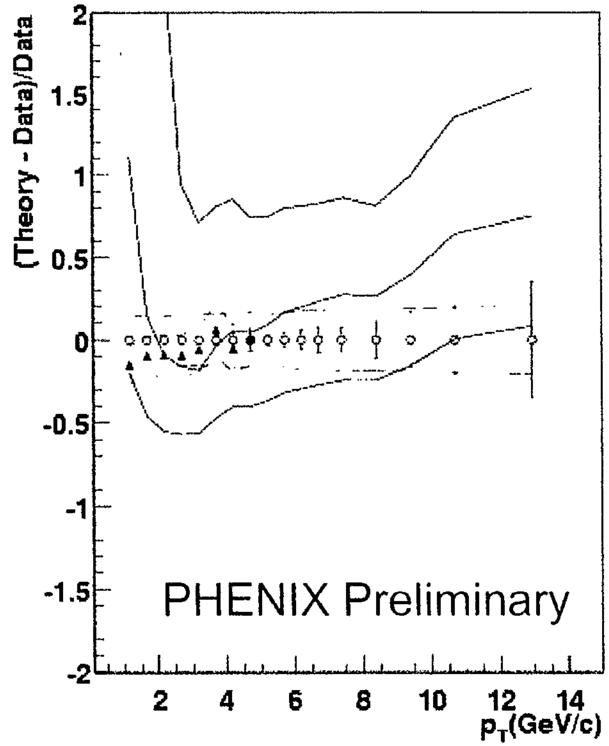
Vernier scan analysis

- Inelastic cross section evaluation
  - $\sigma_{inel} = 12.5 / 0.46 / 0.68 = 40$ mb
  - in PYTHIA / PDG: 42mb
  - 5% difference
- Error evaluation
  - vernier scans
    - offset correction ~3%
    - hourglass effect ~3%
  - corrections at PHENIX
    - BBC efficiency ??
    - BBC vertex cut ~7%
  - 10% level error

π^0 *analysis*

- Cross section measurement
  - based on $|z| < 30$cm cut
    - $\sigma_\pi(p_T) = N_\pi(p_T)[|z| < 30\text{cm}] / L[|z| < 30\text{cm}]$
    - $L[|z| < 30\text{cm}] = \sigma_{inel} \cdot \varepsilon$
    - $\varepsilon = 51\%$ for BBC at $z = 0$





Summary

- In our π^0 measurement, systematic uncertainties except in absolute luminosity is 15–20%
- We expect our absolute luminosity measurement has 10% level precision
- Anything else ?

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Understanding of the Absolute Luminosity at STAR

L. Bland, BNL
July 29, 2002

for
RHIC Spin Collaboration Meeting XI
RIKEN BNL Research Center

Towards ^ Understanding Absolute Luminosity for pp Collisions at STAR

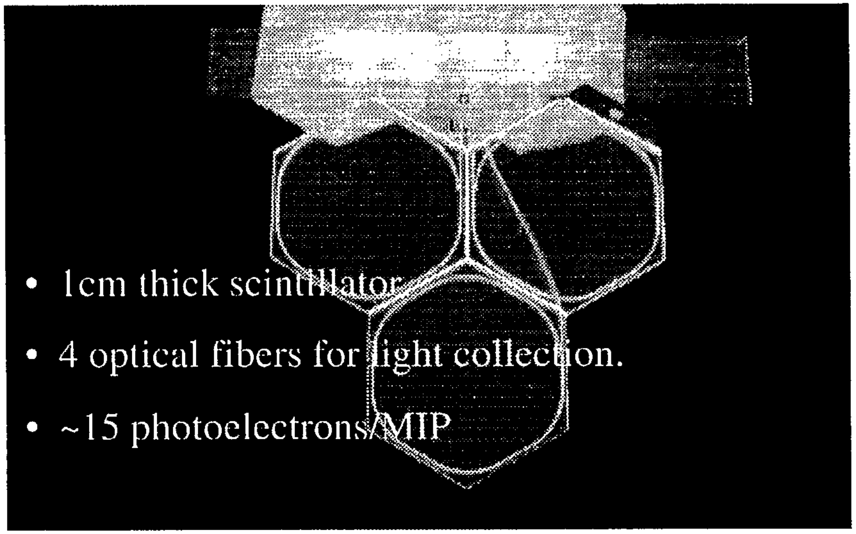
STAR beam-beam counters (BBC) (with J. Kiryluk)

- Description of BBC
- Comparison of data to simple model
- Backgrounds

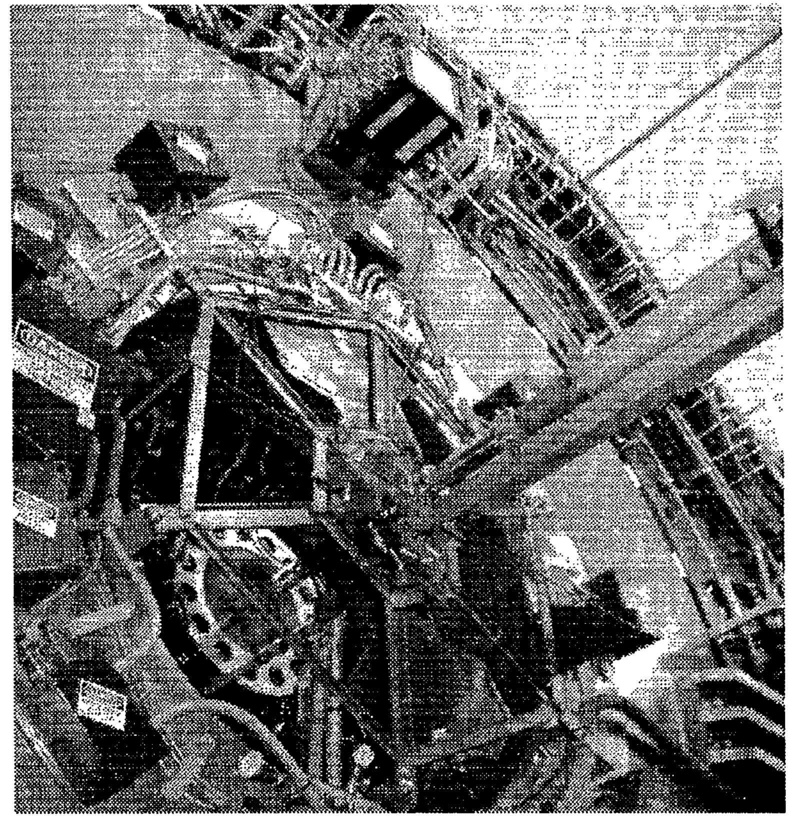
Towards determination of large-η π^0 cross section (G. Rakness)

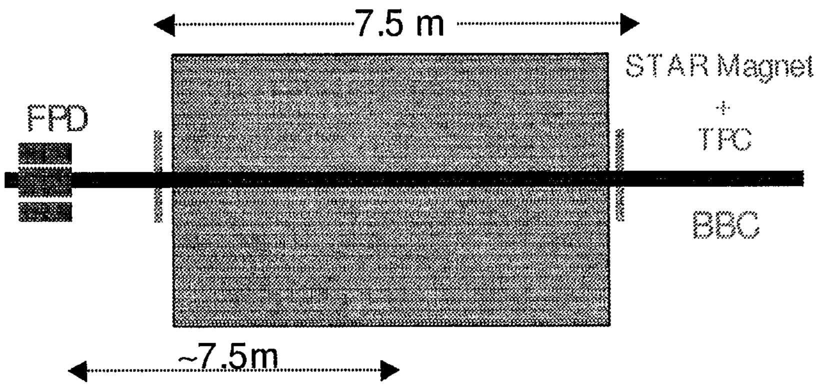
L.C. Bland
BNL

STAR Beam-Beam Counter (BBC)



- 1cm thick scintillator.
- 4 optical fibers for light collection.
- ~15 photoelectrons/MIP



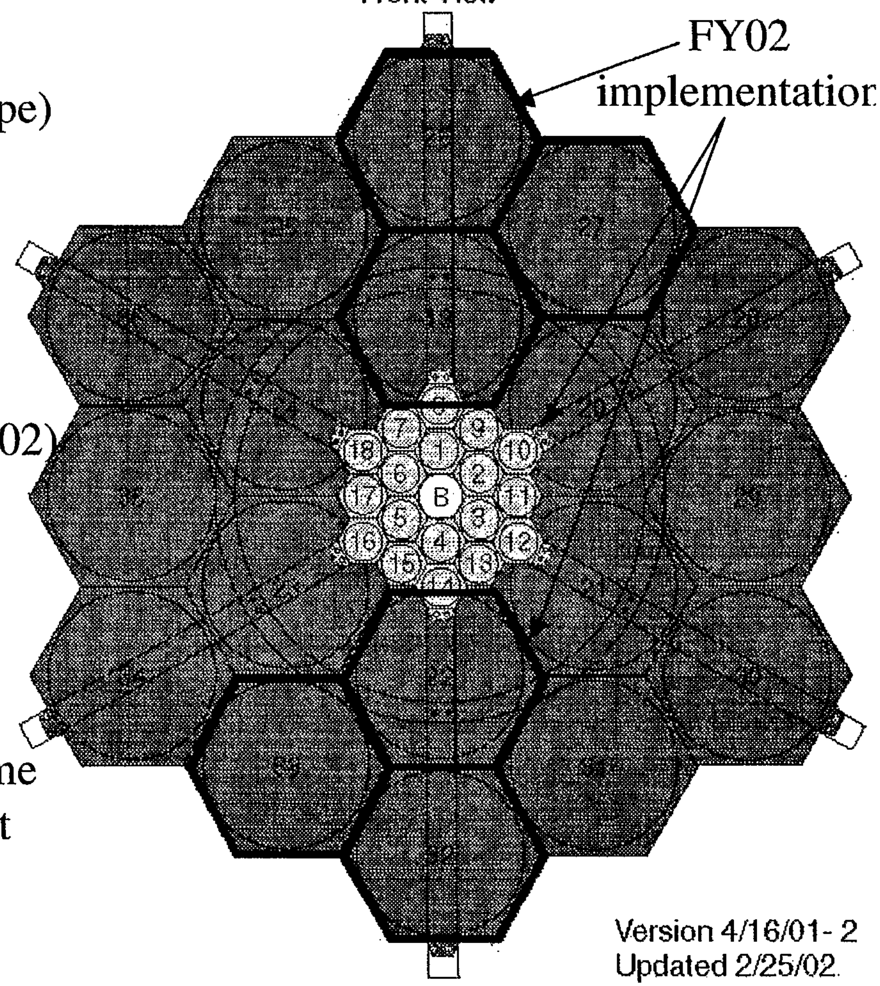


- BNL, UCLA, Penn State and Wayne State involved in project
- BBC scintillator annulus installed on west poletip of STAR magnet. Similar annulus installed on east poletip of magnet.
- BBC E•W coincidences defined STAR triggers and monitored luminosity for different polarization states ($\mathbf{L}_{\uparrow/\downarrow}$).

Scintillator Annuli

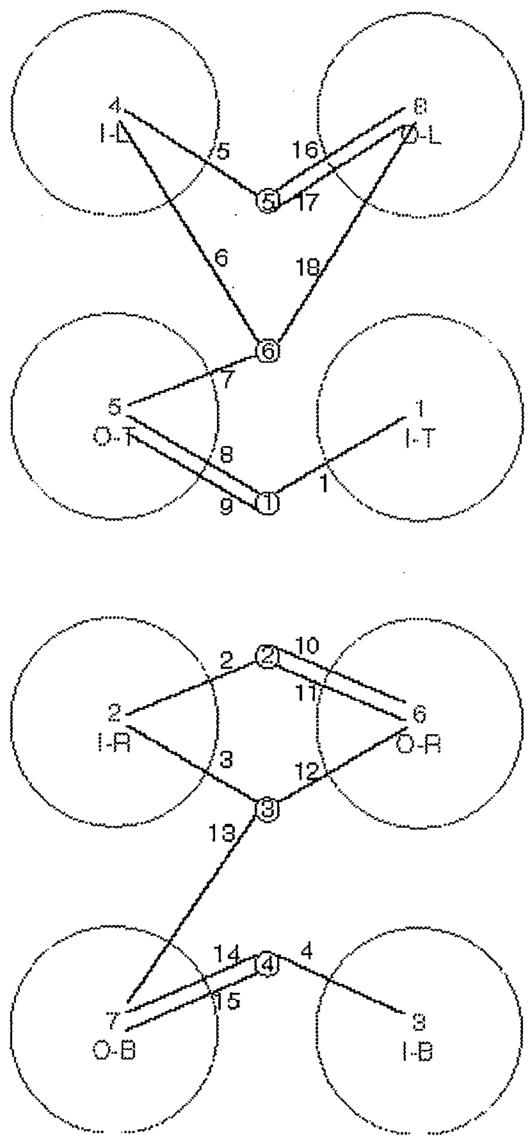
- All scintillator is 1cm thick SCSN81 (Kuraray)
- Small hexagonal annulus (complete for FY02)
  - o 9.6 cm ID (1 cm clearance around beam pipe)
  - o 48 cm OD $\Rightarrow$ $3.5 < \eta < 5.0$
  - o 18 total pixels (6 inner + 12 outer)
  - o 4 PMT/eta ring $\Rightarrow$ azimuthal segmentation
- Large hexagonal annulus (30% complete for FY02)
  - o 38 cm ID
  - o 193 cm OD
  - o 18 total pixels, only 6 installed for run
- Annuli are supported by fiber-glass channel frame attached to the STAR poletips on the east and west sides.

STAR Beam-Beam Counter Schematic
Front View



Fiber to PMT Mapping for Small Hex Tiles

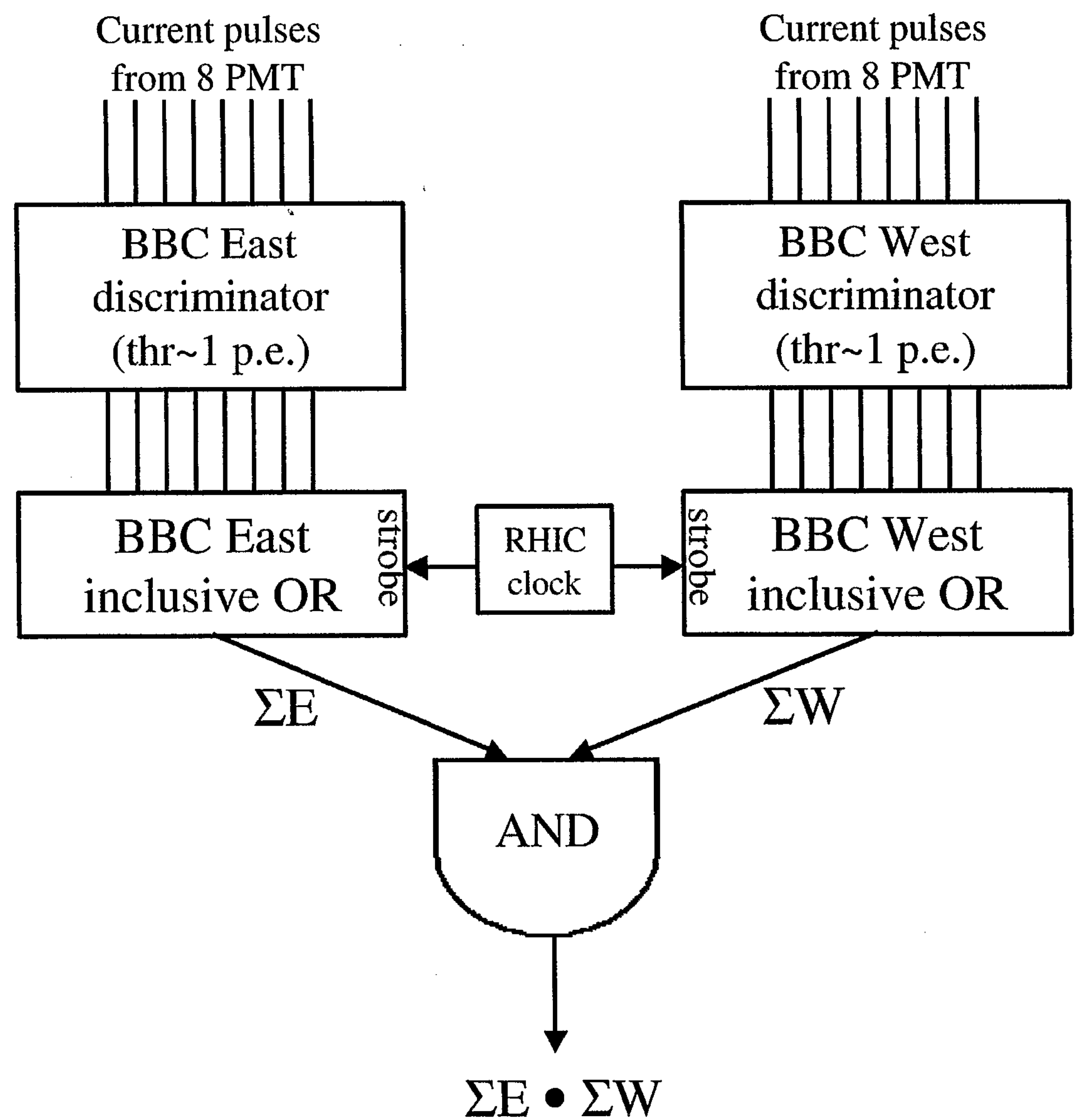
Red	PMT number
Blue	Fiber bundle number (from triplet)
Black	Tile number (each line = 4 fibers)



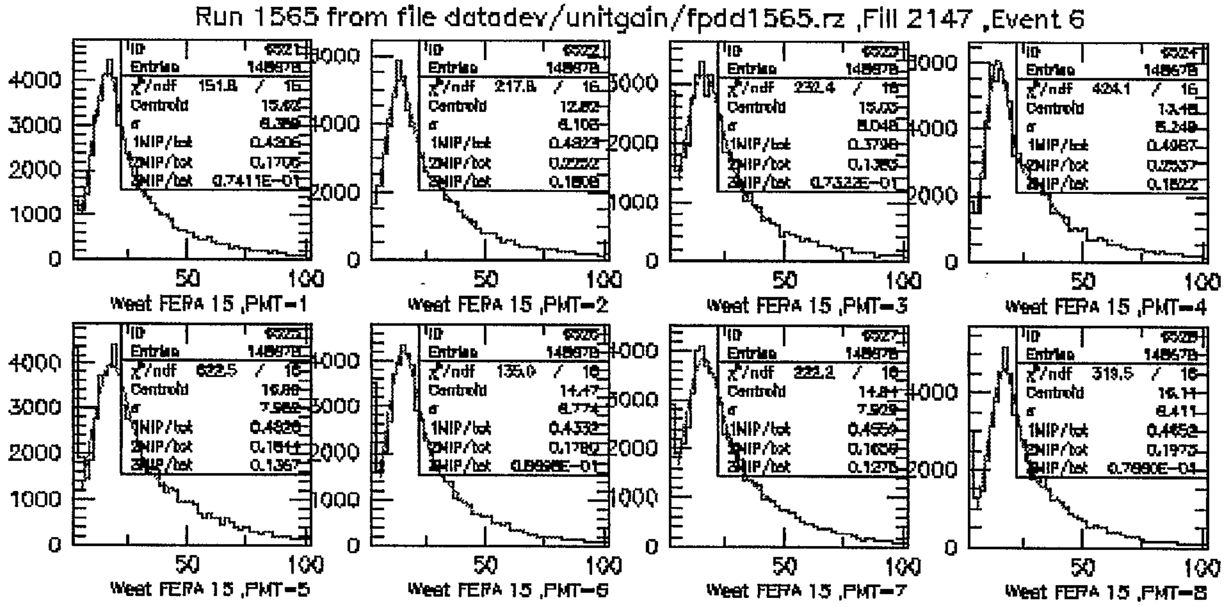
Fiber to PMT Mapping for FY02 pp Run

- 4 PMT's used to collect light from each tile annulus (inner=I; outer=O).
- Preserved azimuthal segmentation of individual tile rings (left=L; top=T; right=R; bottom=B).
- Similar mapping planned for future implementation of large hex tiles ⇒ use clear fiber bundles from FY02 small hex tile readout.

Schematic BBC Trigger Logic

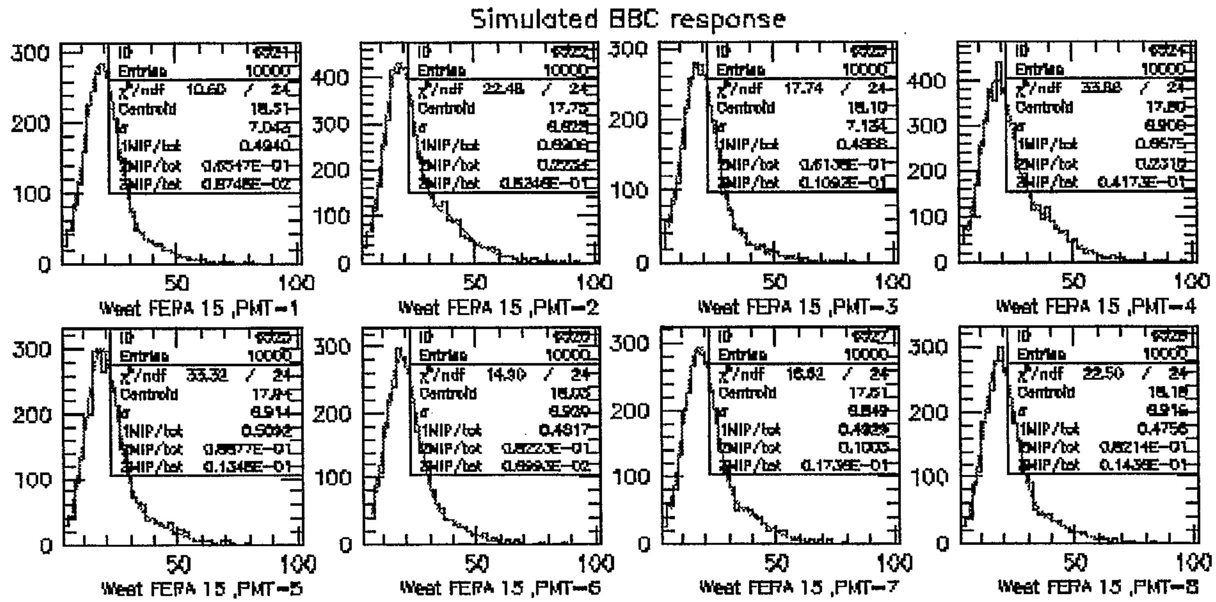


ADC Distributions for Min-Bias Events



- Prominent peak from minimum ionizing particle (MIP).
- PMT gains found to be stable throughout run.
- Represent spectra as sum of Gaussians: $\sum_n \frac{a_n}{\sqrt{2n\pi}\sigma_1} e^{-\frac{1}{2}\left(\frac{x-nx_1}{\sqrt{n}\sigma_1}\right)^2}$
  - o underpredicts large amplitudes (require Landau tail)
  - o single MIP peak has ~ equal amplitude for all PMT

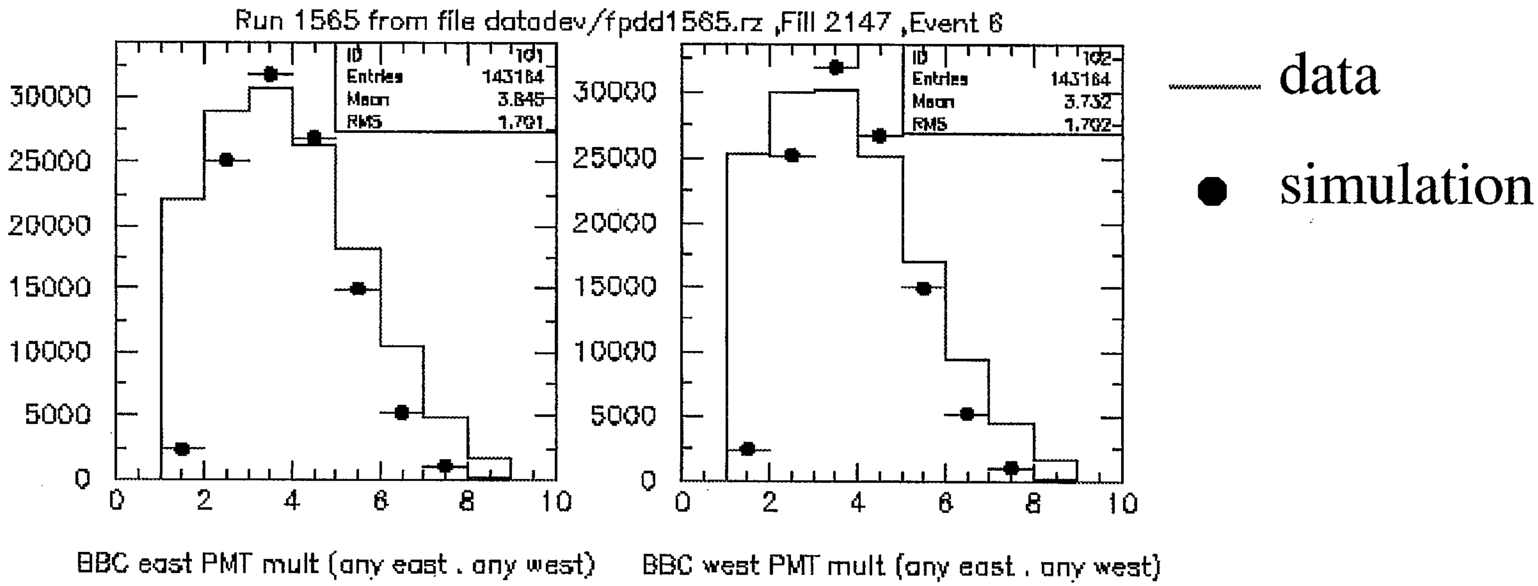
Simulated ADC Distributions



- Generate PYTHIA events and transport particles to hexagonal tiles.
- Assume Gaussian response for minimum ionizing particle (MIP). Assumes single MIP from γ, to account for $\sim 1X_0$ of material between IP and BBC
- Comparison to data:
  - o qualitative agreement with data
  - o overpredicts single MIP fraction of PMT 2,4 (inner L/R tiles).
  - o underpredicts large amplitude events (Landau tail).

$\Rightarrow$ Require full GEANT simulation to obtain quantitative agreement

Hit PMT Multiplicity Distribution

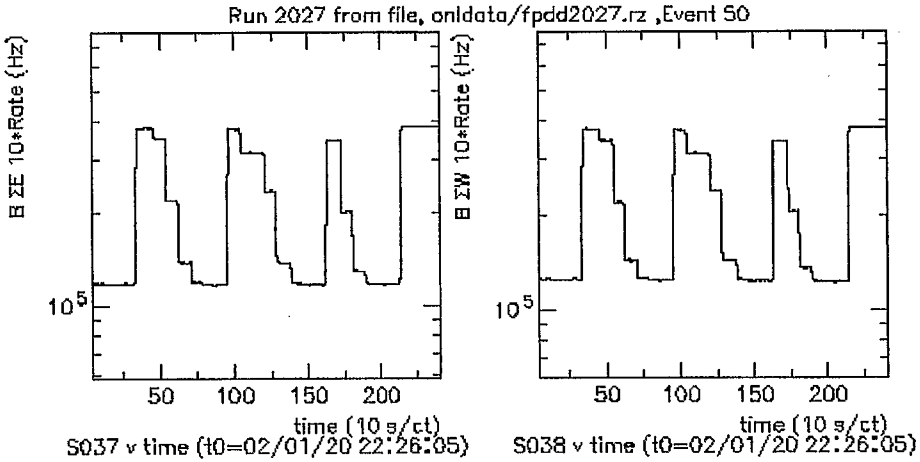


• Qualitative agreement with simple simulation. Most probable hit PMT multiplicity is accounted for.

• Large disagreement with single PMT hits for both east and west.

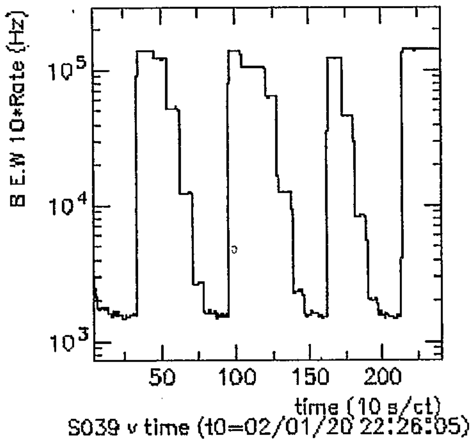
• Large multiplicities not accounted for by simple model. Require full GEANT simulation to include secondary production.

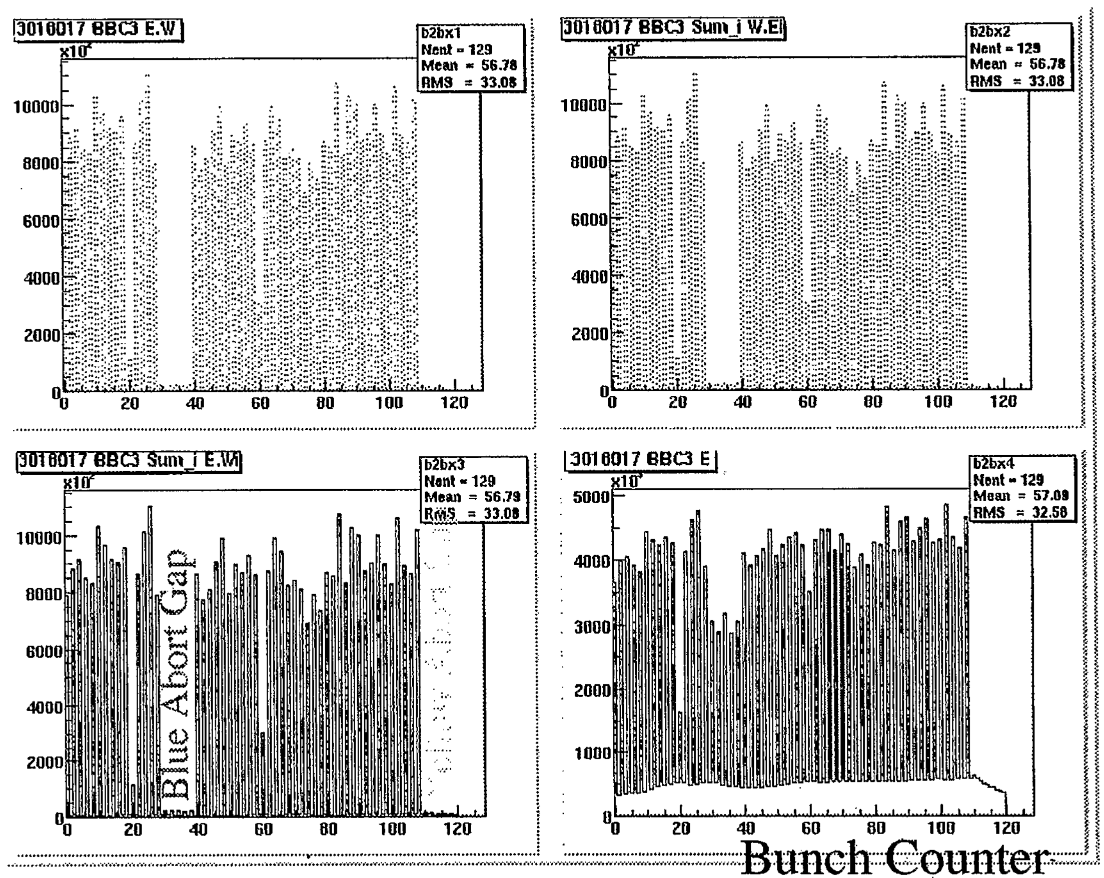
BBC Backgrounds



Measure time dependence of count rate from BBC for data collected during Van der Meer scan conducted at STAR for RHIC fill 2277.

⇒ ~1% background for no collisions





Continuously monitor total number of ΣE • ΣW counts versus bunch counter using STAR bunch crossing scalers. From abort gap yields, get ~1% background.

Simulated Acceptance of BBC

$$\varepsilon = \frac{N_{trig}}{N_{gen}}$$

Uses Gaussian distribution for interaction diamond (σ_z=70 cm) and beam line coincident with detector symmetry axis.

	charged only	charged + γ
Non-elastic, non-single diffractive	0.65	0.84
Includes elastic, single diffractive	0.42	0.54

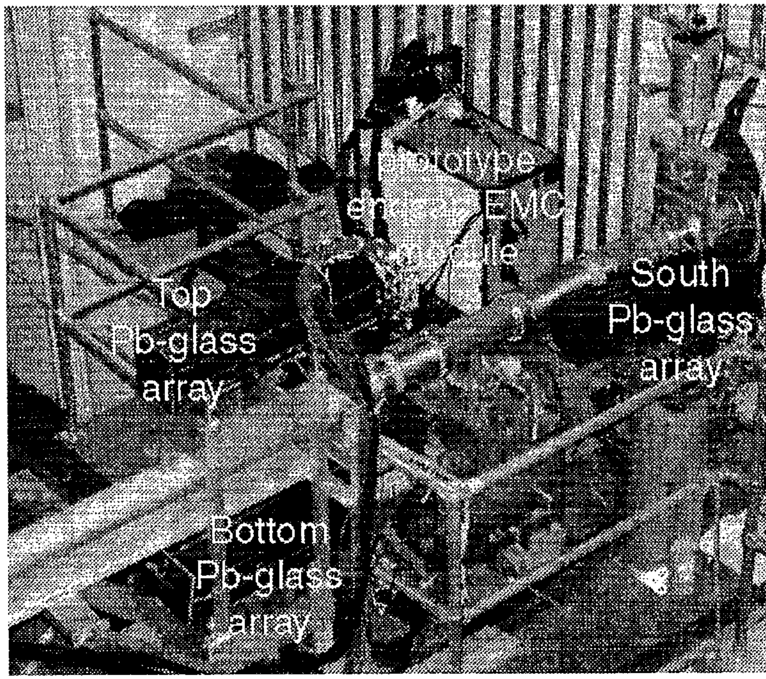
Find that acceptance efficiencies are:

- independent of diamond size
- independent of transverse beam position

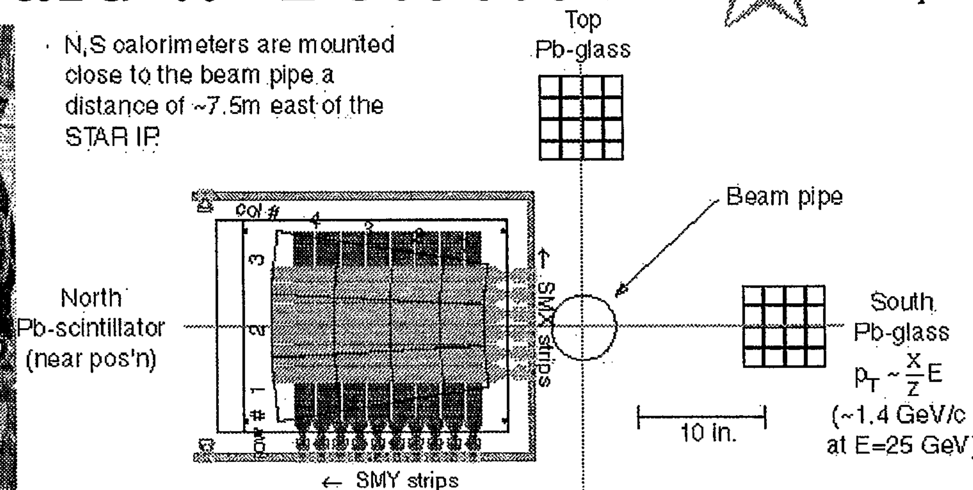
(NOTE: azimuthal acceptance asymmetry strongly depends on beam position relative to detector axis.)

STAR Forward π^0 Detector

STAR spin

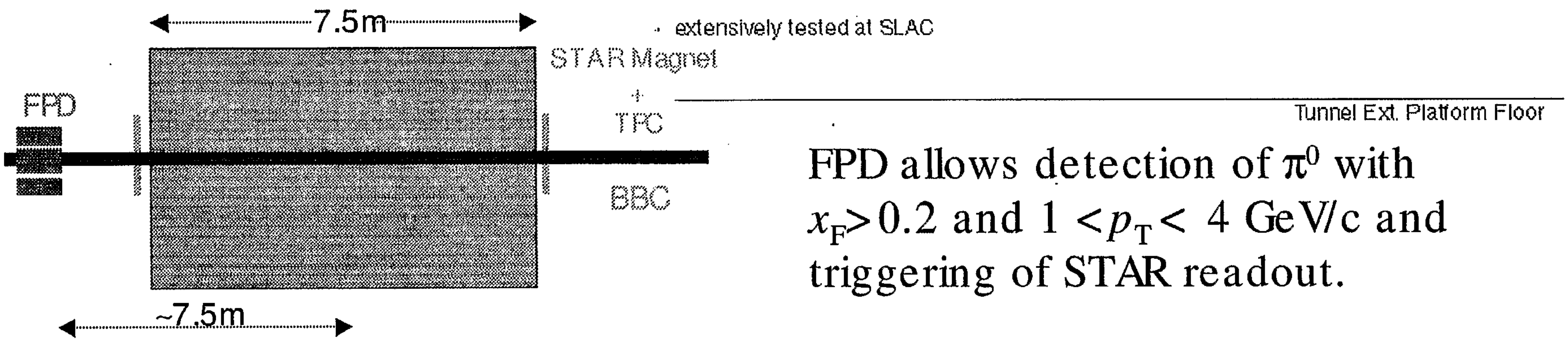


- N,S calorimeters are mounted close to the beam pipe a distance of ~7.5m east of the STAR IP.



- 12-tower prototype of endcap EMC sampling calorimeter
- preshower detectors
- shower-maximum detector to measure transverse profile
- extensively tested at SLAC

- Pb-glass detectors built by IHEP, Protvino for FNAL E-704
- ~18 radiation lengths
- Cerenkov detector



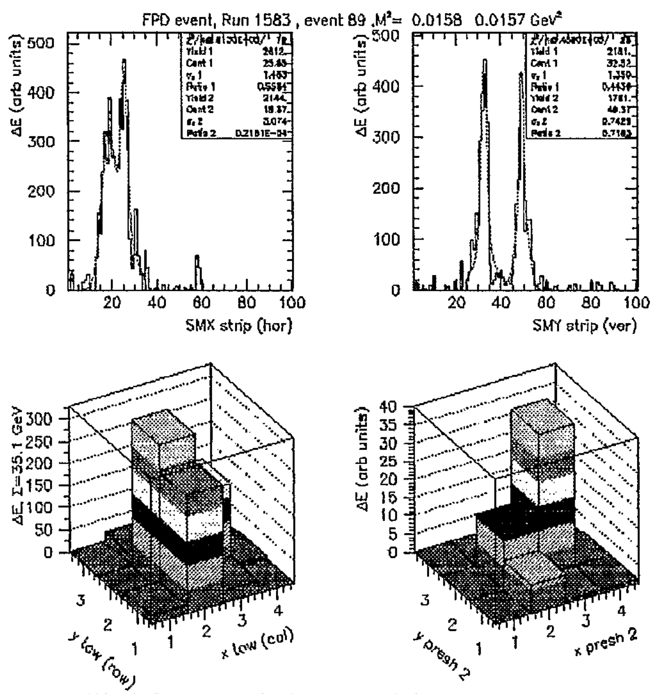
FPD allows detection of π^0 with $x_F > 0.2$ and $1 < p_T < 4$ GeV/c and triggering of STAR readout.

π^0 signal extraction

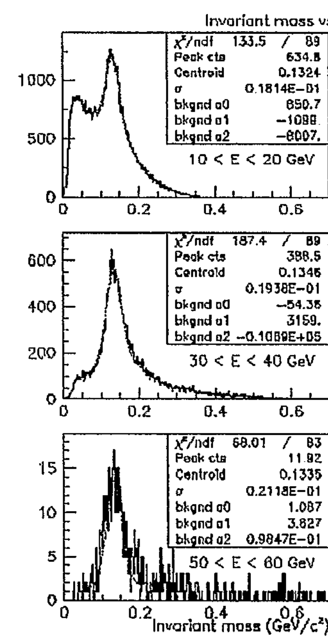
$$M_{\gamma\gamma} = E_{tot}\ \mathrm{sqrt}(1-z_\gamma^2)\ \sin(\phi_{\gamma\gamma}/2)$$

- E_{tot}=sum over towers ($\delta E/E$=17%/sqrt(E))
- γ separation from centroid separation of two peaks
- z_γ=|E1-E2|/(E1+E2) from relative yield in two peaks in SMD profile distribution ($\delta E/E$=30%/sqrt(E))
- Assume Z_{vertex}=750cm

Single event analysis:



Results in π^0 as a function of E_π:



σ_π=20 MeV/c^2 for E_π=10-60 GeV...

G. Rakness (IUCF), Quark Matter 02

Simulation of pEEMC in STAR

Use simulation for background and efficiency correction…

Scheme:

- Events generated with PYTHIA (min bias)
- Events stored if >25 GeV pointing to "box"
- Full PYTHIA record included with events
- GEANT simulation of pEEMC
- Reconstruct using algorithm applied to data

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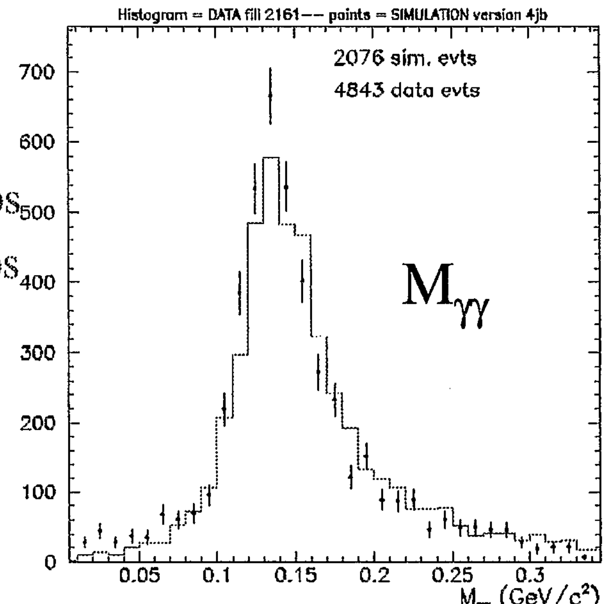
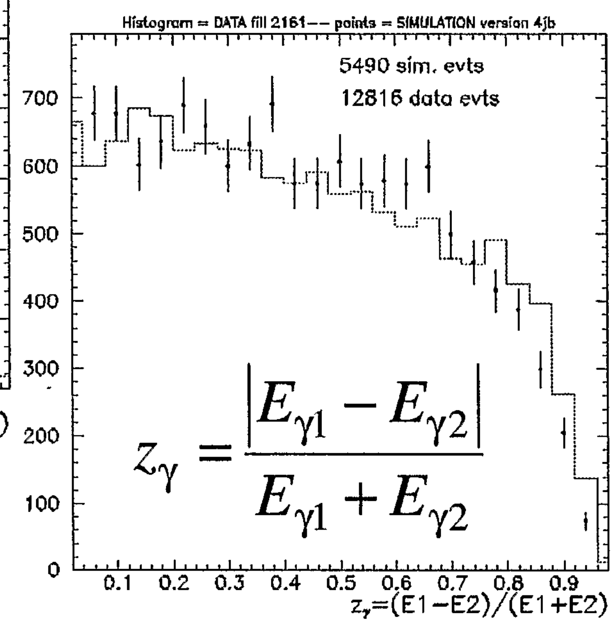
Cuts applied:

- E_{tow}>31 GeV
- 13 < SMD-Y centroid < 90 strips
  12 < SMD-X centroid < 48 strips
- SMD-X or SMD-Y > 1 peak
- z_γ<0.3



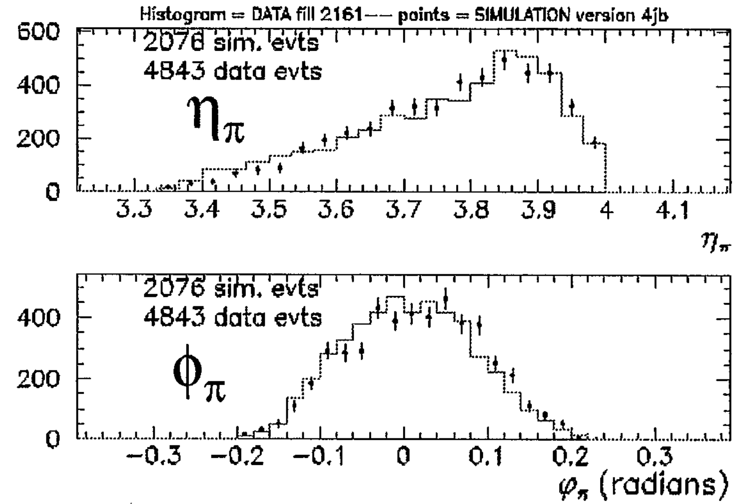
- Histogram = data
- Points = simulation norm. to data

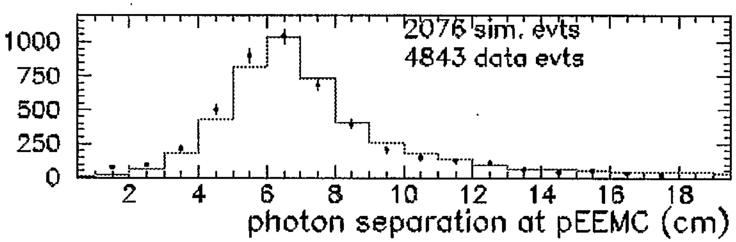


$$z_\gamma = \frac{\left|E_{\gamma1} - E_{\gamma2}\right|}{E_{\gamma1} + E_{\gamma2}}$$

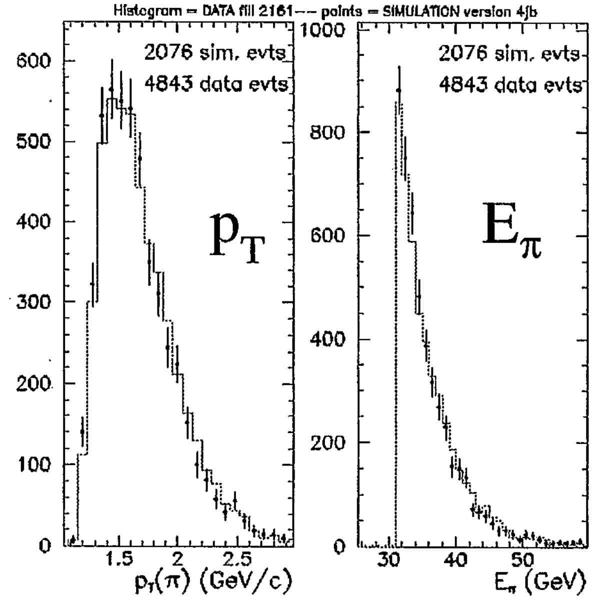
Simulation of pEEMC (cont.)

Angular variables:





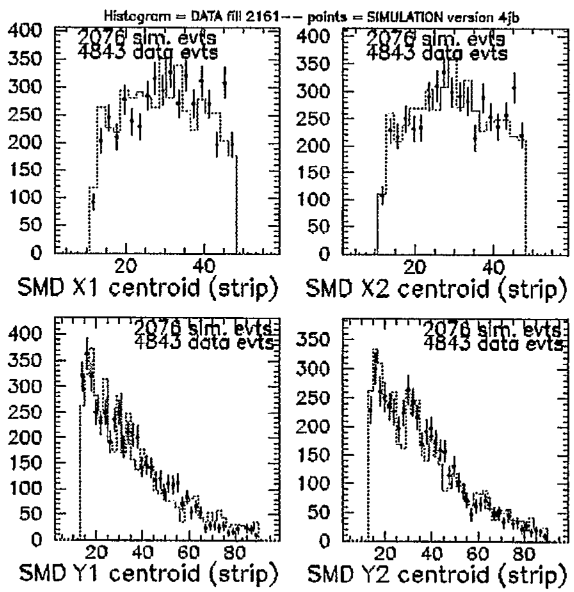
Photon separation at pEEMC



Single photon positions:

vertical

horizontal

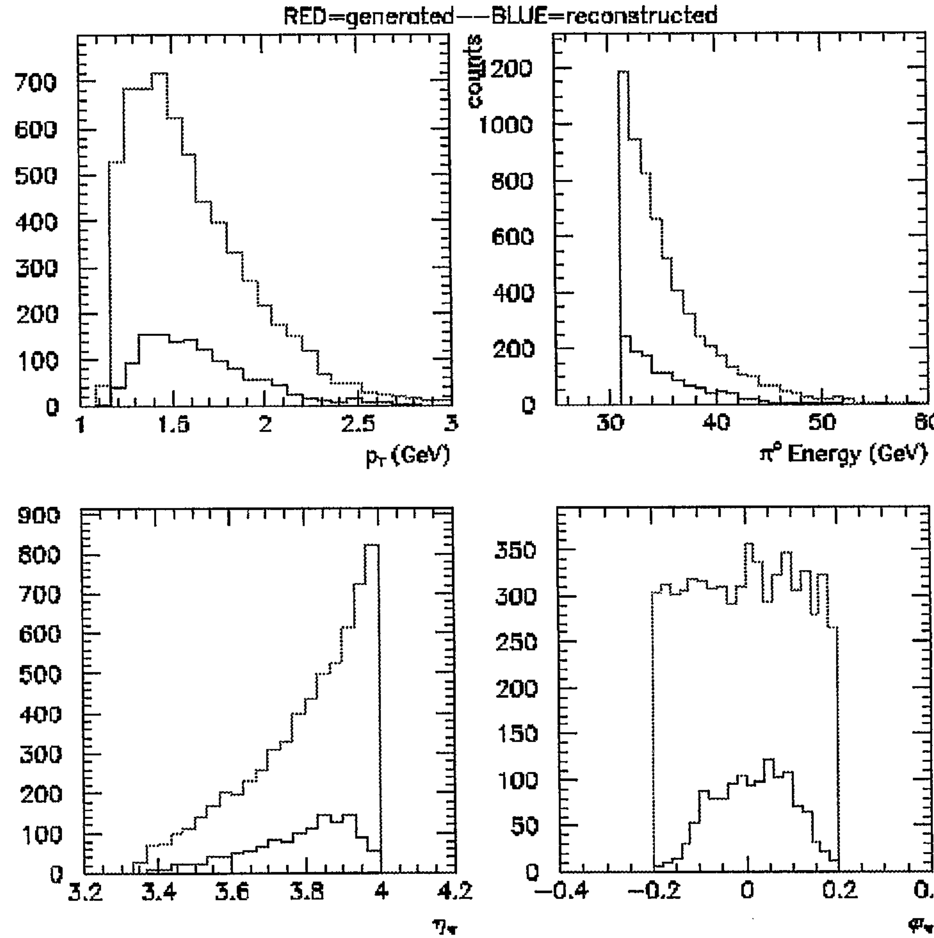


Simulation describes data and general features understood…

G. Rakness (IUCF), Quark Matter 02

Efficiency/Acceptance Correction Performed with Monte Carlo Simulation

- Red= π^0 simulated events generated into "box" defined by η and ϕ
- Blue=full PYTHIA simulated events reconstructed with identical fit model and cuts as used for data



Correction to be performed simultaneously as a function of p_T and η...

Summary:

Well on our way to extracting differential π^0 cross-section…

- Signal extraction—robust
- Livetime/luminosity correction—yields stable to ~15%

Simulations describe signal and background well:

- Background shape/magnitude—amount of background dependent on z_γ cut, correction to be performed, systematic uncertainty to be estimated

Efficiency/acceptance correction— size of correction dependent on z_γ cut, correction to be performed vs. p_T and η, syst. uncertainty to be estimated

- Absolute angle uncertainty from beam position monitors from accelerator physicists—transverse position to ~few mm
- Absolute energy scale from π^0 mass—effect from uncertainty on absolute knowledge of z-vertex <1%, stability to be determined
- Absolute normalization uncertainty from comparison of van der Meer scan with estimated Beam-Beam Counter acceptance of $\sigma_{tot}(pp)$

Understanding of the Absolute Luminosity at pp2pp

R. Gill, BNL
July 29, 2002

for
RHIC Spin Collaboration Meeting XI
RIKEN BNL Research Center

Understanding of the Absolute Luminosity at pp2pp – Inelastic Detectors

- Veto or Clean-up Elastic Events
- Measure Luminosity at IR
- Run Conditions...
  - Scraped beam →
    - ~4.8×10^{11} p in 55 bunches, each ring
    - $\beta^* = 10$ m, $\varepsilon = 12\pi$ μrad·m
    - $L_{eff} = \frac{3}{2}\frac{v_{rev} N_B N^2}{\varepsilon\beta^*}(\beta\gamma)$
  - >12 hours beam time
  - Collected ~3×10^5 elastic events

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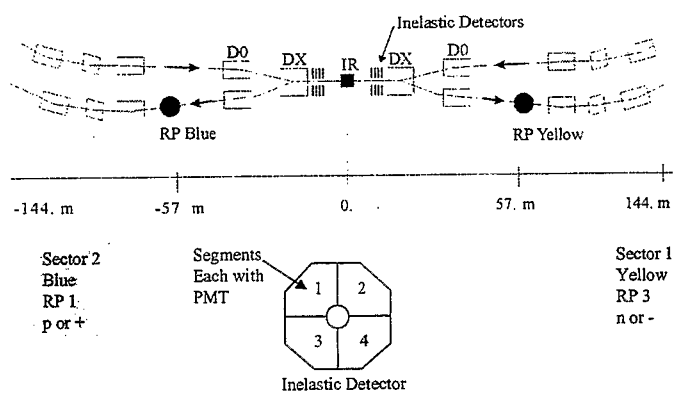
pp2pp Inelastic Detectors

Layout of the PP2PP Experiment at RHIC



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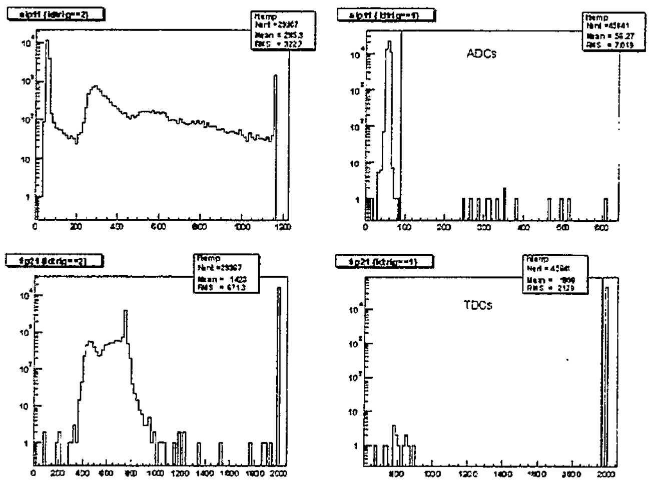
ADC & TDC Pedestals



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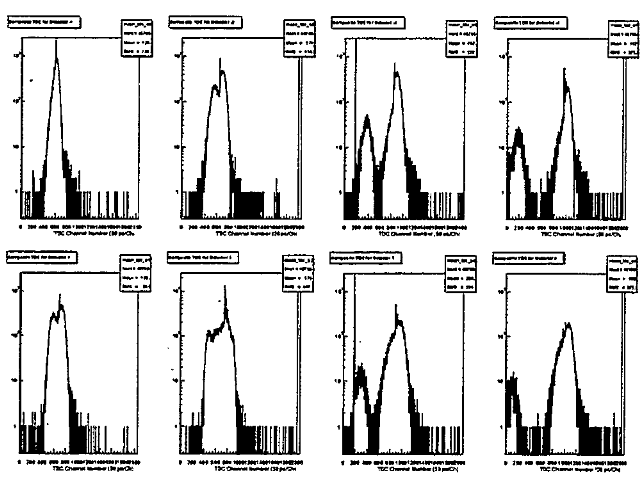
Inelastic TDCs

"Raw" Inelastic TDCs – no cuts applied



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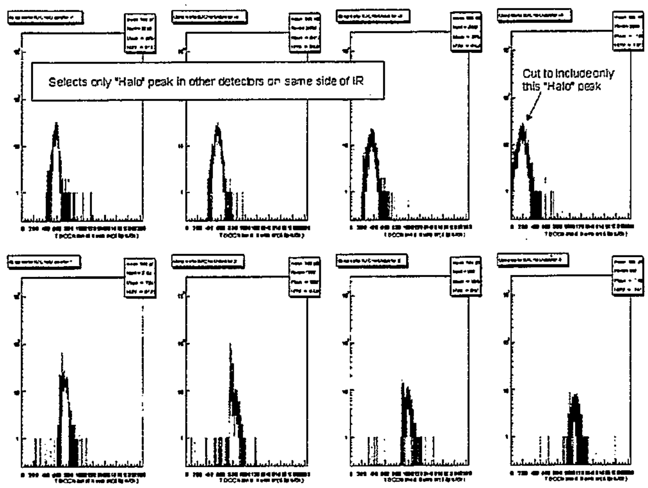
Cuts to Remove Halo Events



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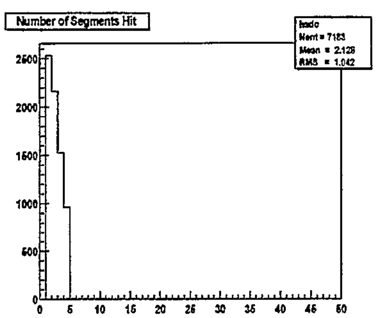
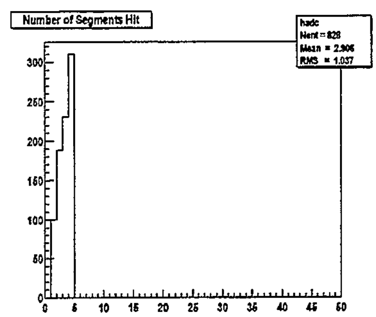
Inelastic Event Correlations

Event Multiplicity for Detector 4n.



Cut selects "Normal" TDC in Detector 4n, segment 1 and looks at hits in other segments of the same detector.



Cut selects "Halo" TDC in Detector 4n, segment 1 and looks at hits in other segments of the same detector.

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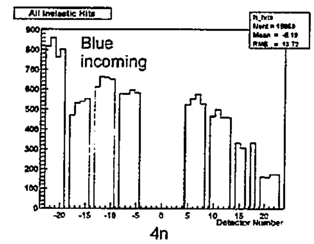
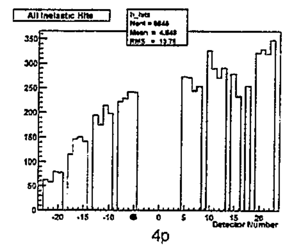
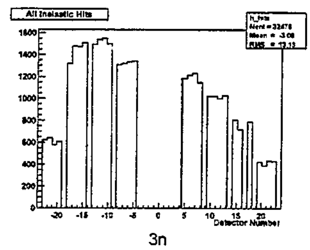
Halo Hit Patterns

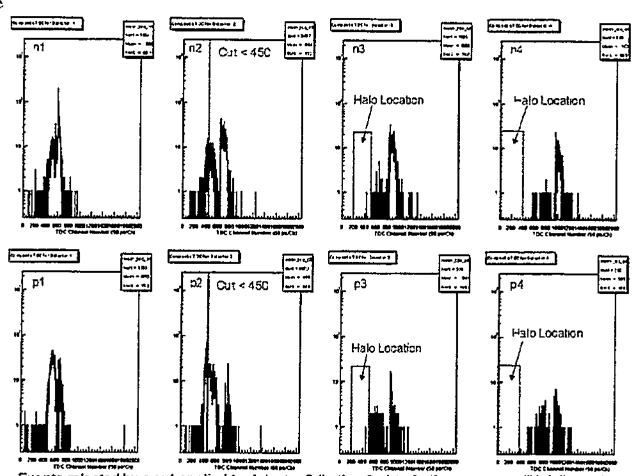






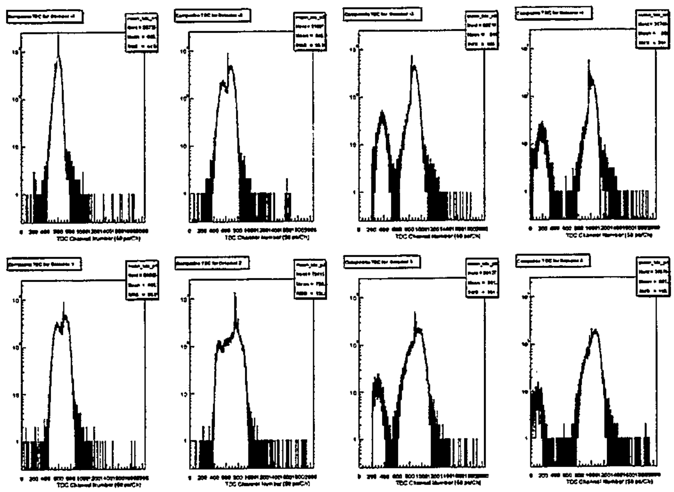
Cuts on the "Halo" TDC peak of the indicated detector. A hit in any segment produces a projection of the events in any other detector segment.

Cut at Halo Overlap



Events *rejected* by a cut applied to detector 2 (both p & n) to further suppress "Halo" events. This cut is not evidently effective, and would reduce events by ~2%.

All Events Excluding Pedestals



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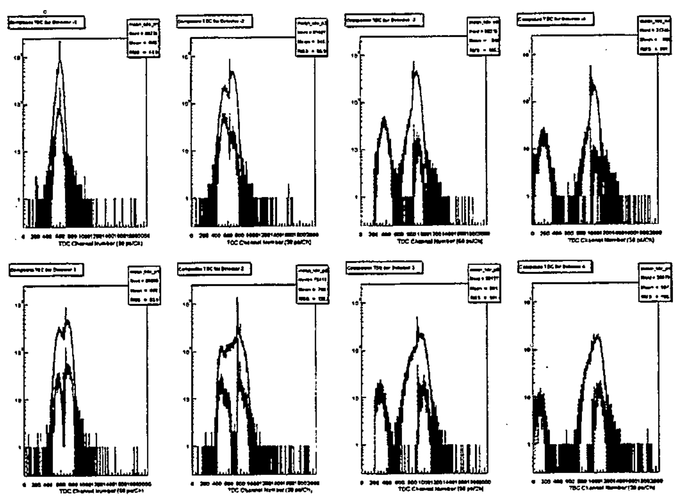
All & Rejected Events



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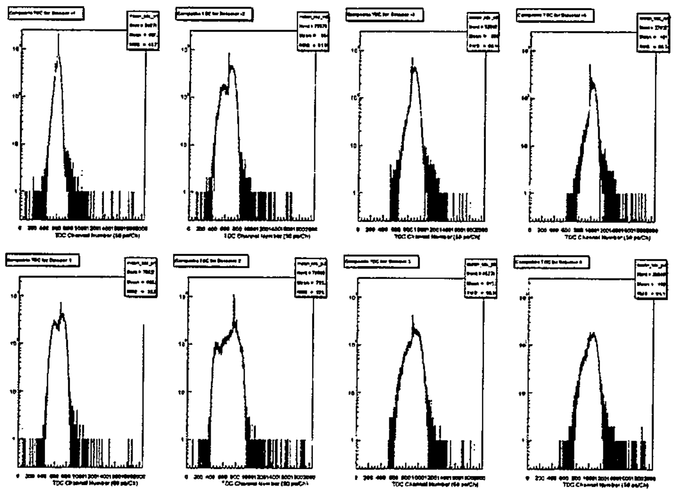
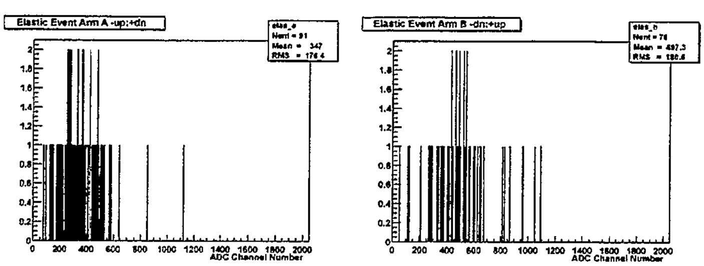
Accepted Inelastic Events

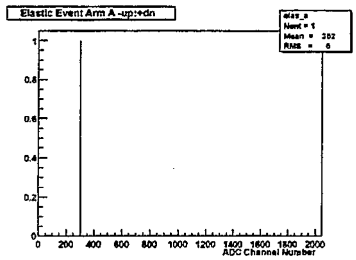


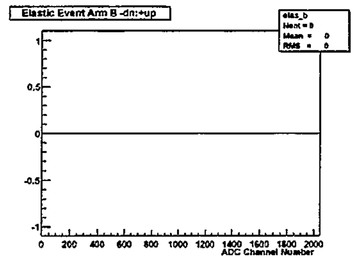
Elastic ⇔ Inelastic Events



- Events that Elastic scintillators (alone) would select
- But, the event also satisfies the Inelastic Cuts
- 91 in "Arm A", 76 in "Arm B" out of ~30K elastic events ⇒ Veto these events

Elastic ⇔ Halo Events





- Elastic events correlated with Inelastic "Halo" events
- Only <u>one</u> event in this category!

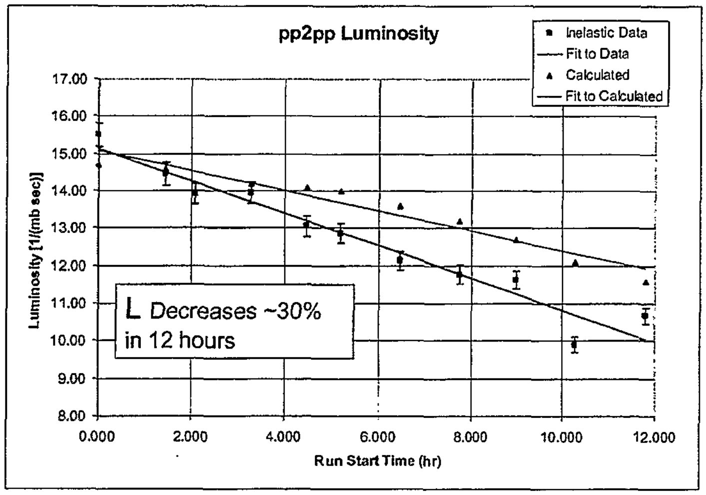
Luminosity for pp2pp

$$L_{eff}(mb^{-1}sec^{-1}) = \frac{50 \cdot N_{inelastic}}{31(mb) \cdot \Delta t(sec)}$$

- $\sigma_{inelastic}$ = 31 mb for $2.5 \leq \eta \leq 5.5$ (PYTHIA simulations) requiring a track in both "arms"
- Inelastic triggers had a prescale factor of 50

Time (hr)	Inelastic Event Rate (sec^{-1})	Inelastic $L_{eff}(mb^{-1}sec^{-1})$	Calculated $L_{eff}(mb^{-1}sec^{-1})$
0	9.61 ±0.07	15.50±0.32	14.7
5.2	7.96 ±0.05	12.85 ±0.26	14.0
11.8	6.61 ±0.04	10.16 ±0.21	11.6

Luminosity for pp2pp



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Summary...

- L can be Determined by Inelastic Counters
- L Decreases During Fill (~30%/12 hr)
- Incoming Beam Contributes to Events
- Refined Simulations & Analysis Continues

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Proposed Measurement of pp Analyzing Power at the AGS

R. Hobbs, University of New Mexico

July 29, 2002

for

RHIC Spin Collaboration Meeting XI

RIKEN BNL Research Center

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Proposal for a polarized target p-p Polarimeter

Robert Hobbs
University of New Mexico

for the RHIC Spin Collaboration

RSC Brookhaven meeting – July 29, 2002

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Outline

- Motivation
- Principle
- Setup
- Monte Carlo
- Rates

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Motivation 1

- Spin physics based on polarization
  - a=AP, we use A to measure P
  - Only have A(24 GeV) with large uncertainty
- Solution
  - Solution gas-jet target (2004)
  - Better A uncertainty (2003)

July 29, 2002

R. Hobbs
University of New Mexico

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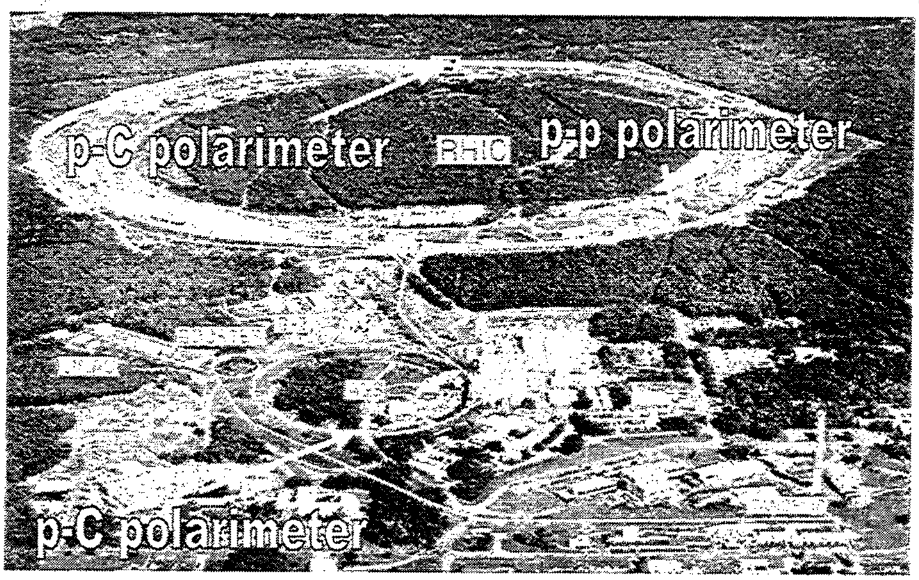

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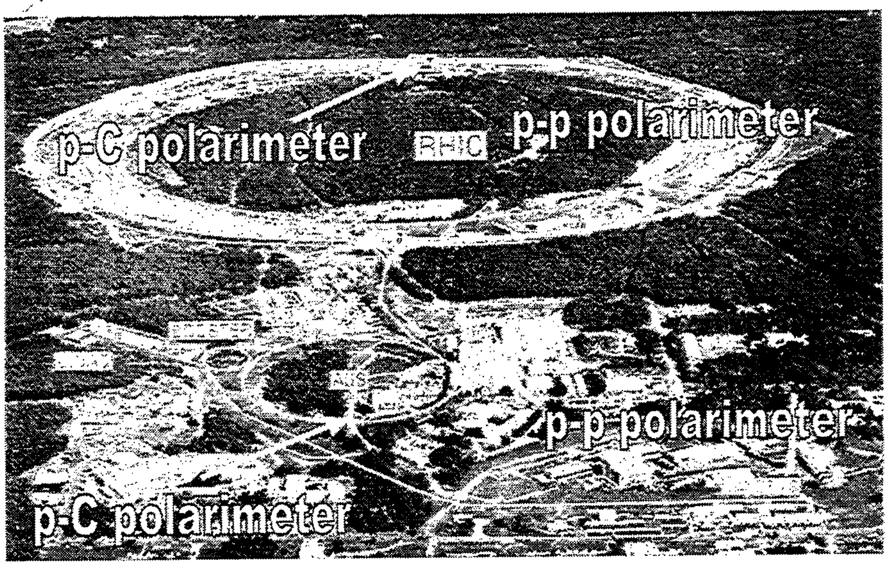

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$p^{\Uparrow}$ on polarized target

\+ $p^{\Downarrow}$ on polarized target

= p on polarized p

⇨ Lorentz boost to obtain A(p-p)

⇨ measure P from a=PA

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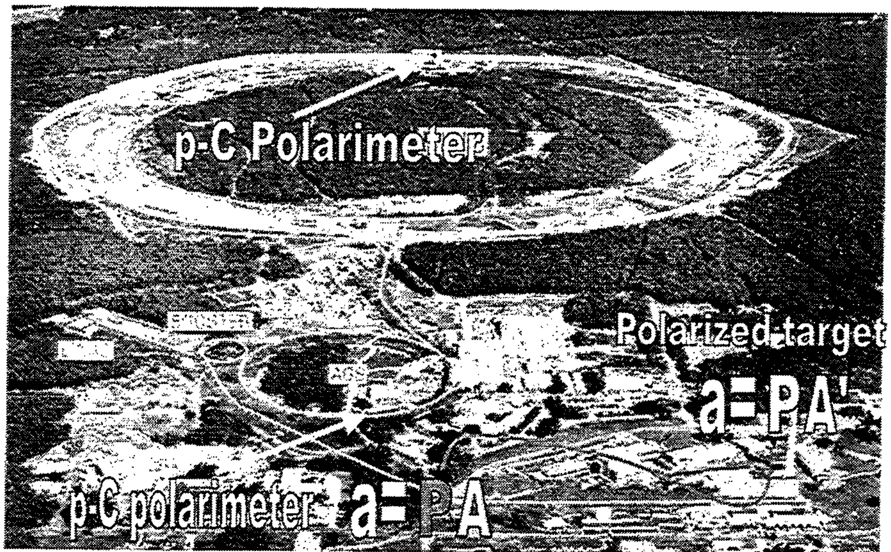

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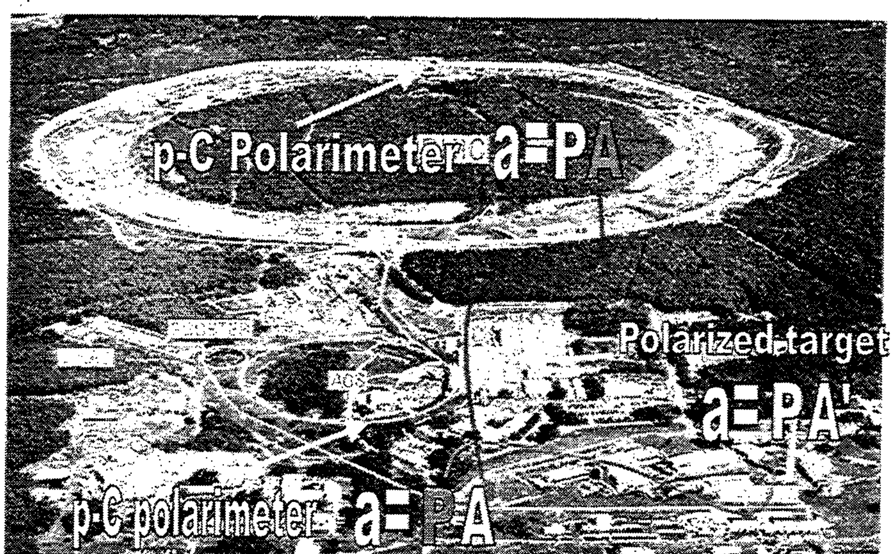

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More accurate but still wrong energy

- Acceleration/deceleration
- Map of A: fit to models

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Motivation 2

- Understand loss of polarization
  - From 75% (200MeV) to 40% (200GeV)

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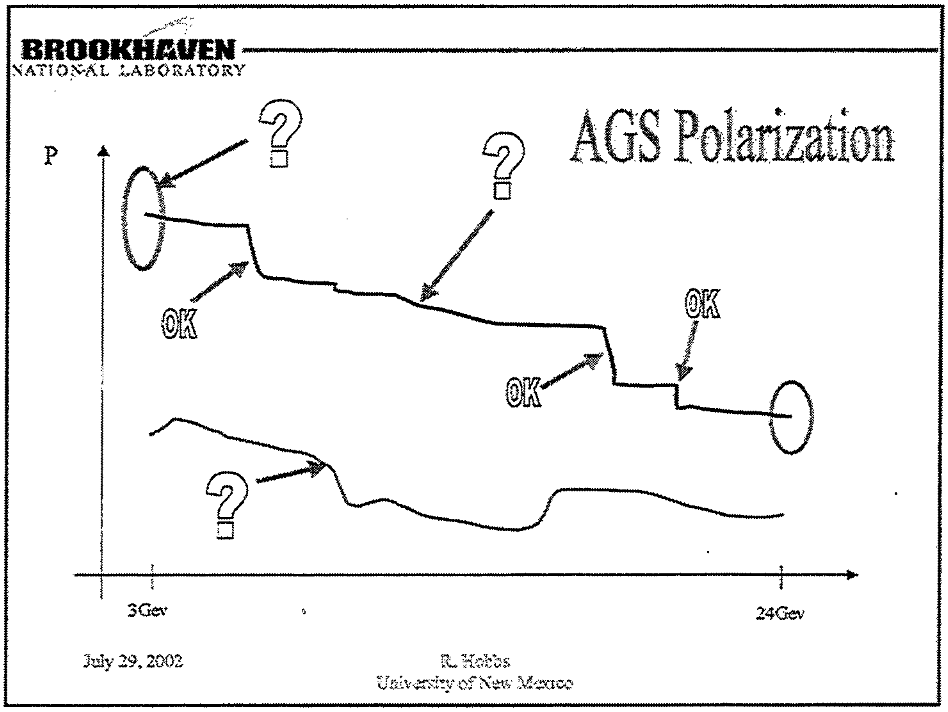
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AGS Polarization
P
?
?
OK
OK
OK
?
3Gev
24Gev
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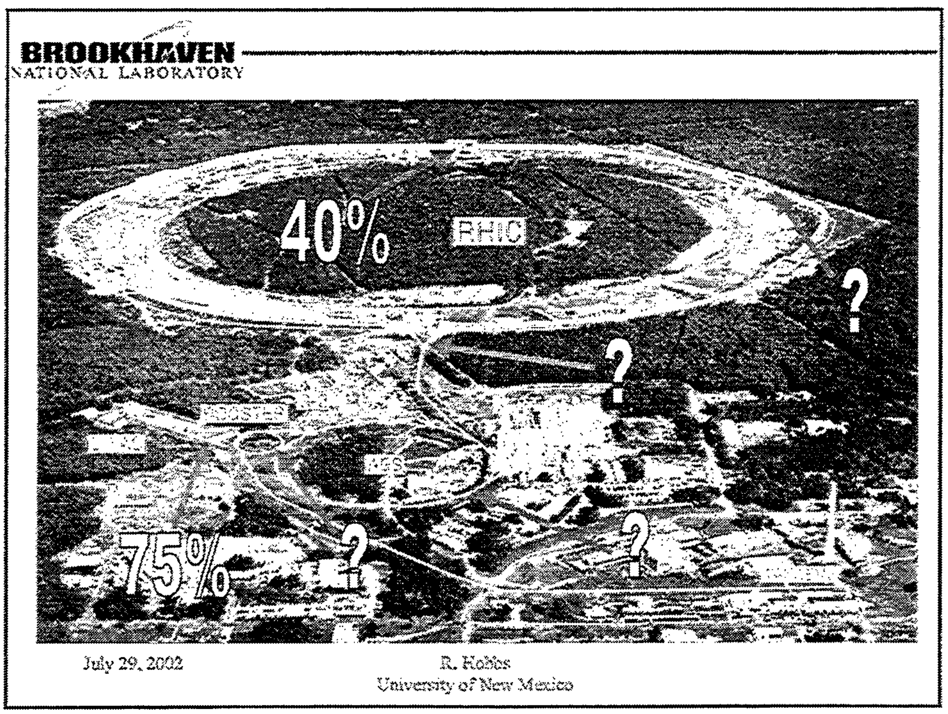
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40%
RHIC
?
?
75%
?
?
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In short

- Extracted beam polarized target polarimeter, in conjunction with AGS p-C polarimeter
  - Use own Analyzing power to provide polarization.
  - P-C polarimeter measures A (p-C)
  - Have map (3Gev-24GeV) of A (p-C)

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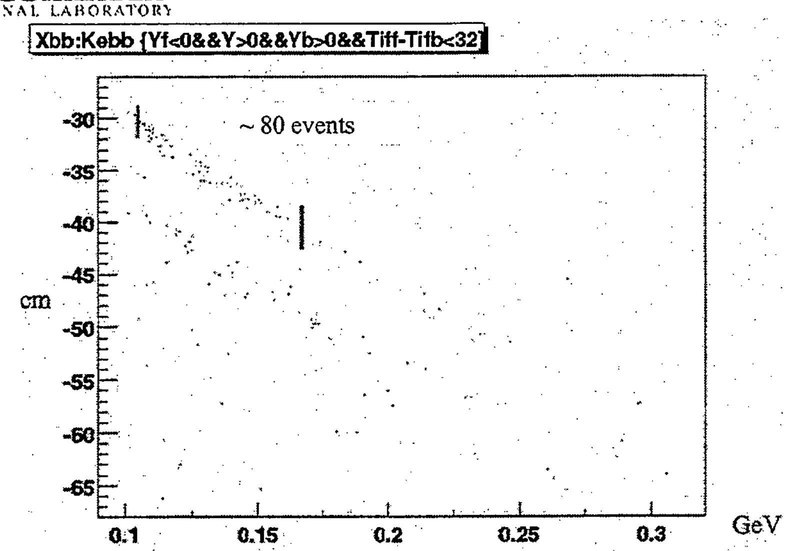

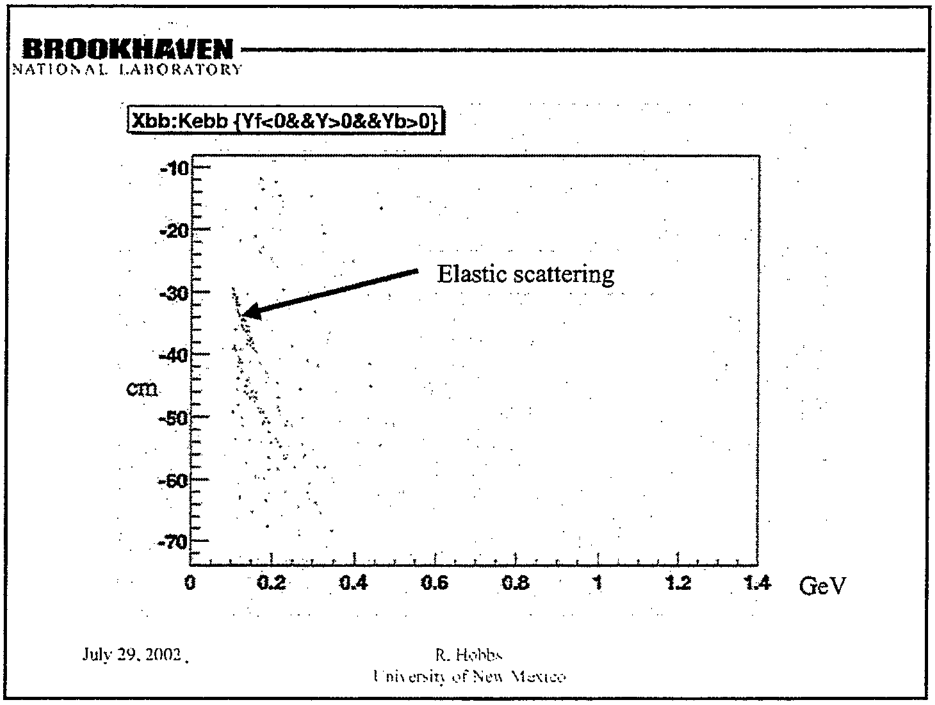
BROOKHAVEN
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Xbb:Kebb {Yf<0&&Y>0&&Yb>0}
Elastic scattering
cm
-10
-20
-30
-40
-50
-60
-70
0
0.2
0.4
0.6
0.8
1
1.2
1.4
GeV
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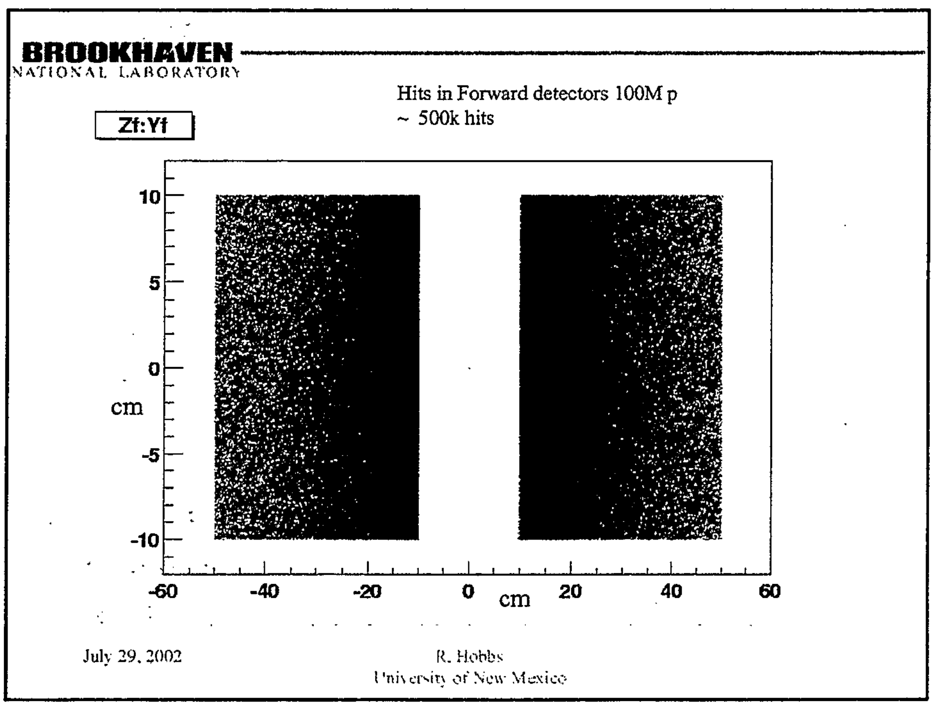
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Hits in Forward detectors 100M p
~ 500k hits
Zf:Yf
10
5
0
cm
-5
-10
-60
-40
-20
0
cm
20
40
60
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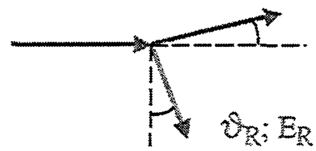
Kinematics



t : 0.22 – 0.38 GeV^2
ϑ_R : 13 – 15 degrees
T_{kin} : 110 – 170 MeV
p_R : 470 – 590 MeV

Essentially only 1 free parameter: t (+ φ) ⇒
elastic *pp* kinematics fully constrained by recoil proton !

$$\sin \vartheta_R \approx \left(1+\frac{m_p}{p_{beam}}\right)\frac{\sqrt{|t|}}{2m_p}$$

$$t=-2m_p T_{kin}$$

measure position and energy of recoil ⇒ and

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Setup

- Polarized Ammonia target in 2.5T magnetic field
  - Recoil (x2) silicon detectors or hodoscopes
  - Use x (angle) vs. Ke (momentum transfer)
  - Collimators

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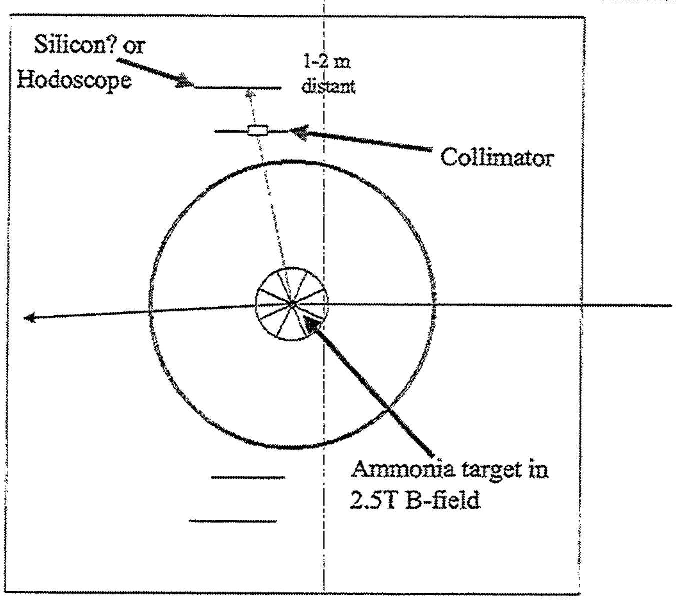

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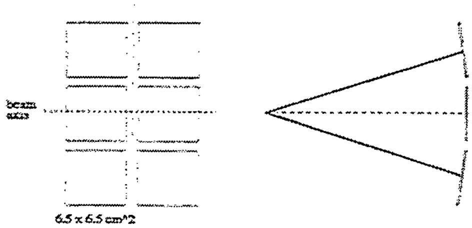
Detectors?



Requirements

- good energy resolution
  $\Delta E < 0.1$ MeV
- handle large statistics
- space resolution
  $\Delta x \sim$ few mm
- time resolution
  $\Delta t \sim 1$ (2) ns

horizontal segmentation ~ 4 mm (16 ch.)
vertical segmentation ~ 8 mm (8 ch.) $\Rightarrow \delta\varphi \sim 10$ mrad

thickness: 0.5 mm $\Rightarrow$ stops up to 8 MeV protons
veto for faster protons?

under development (Inst. Div. @ BNL)

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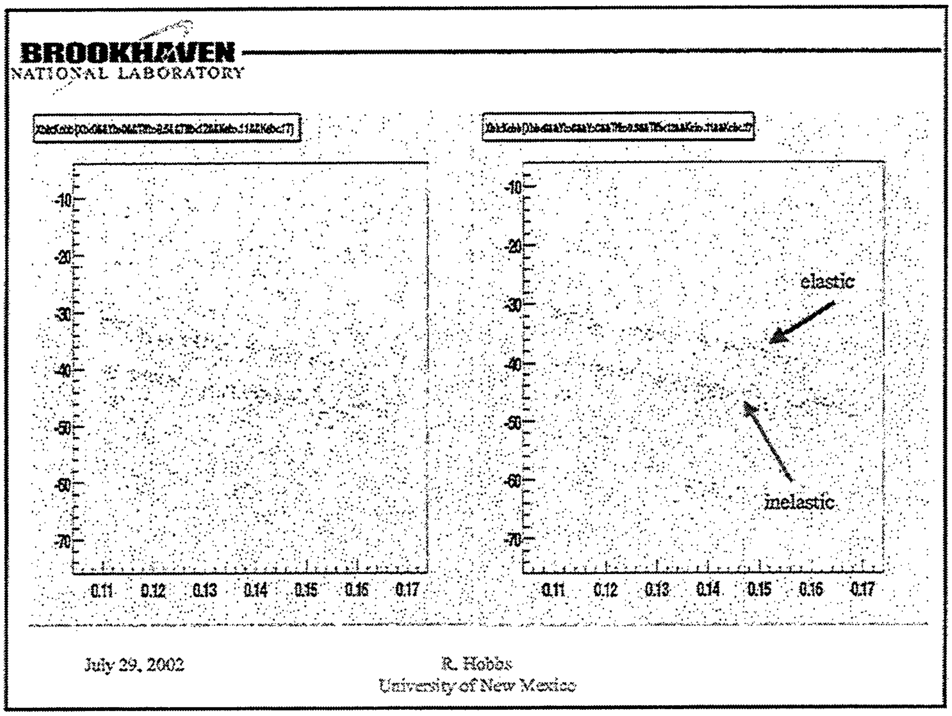
BROOKHAVEN
NATIONAL LABORATORY
-10
-20
-30
-40
-50
-60
-70
0.11
0.12
0.13
0.14
0.15
0.16
0.17
elastic
inelastic
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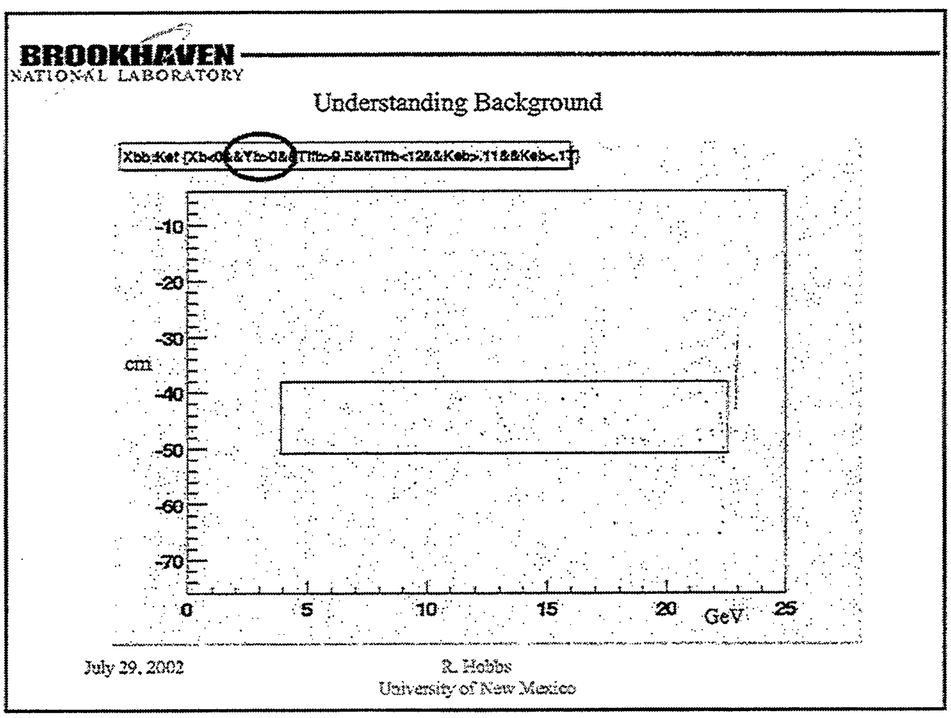
BROOKHAVEN
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Understanding Background
cm
-10
-20
-30
-40
-50
-60
-70
0
5
10
15
20
GeV
25
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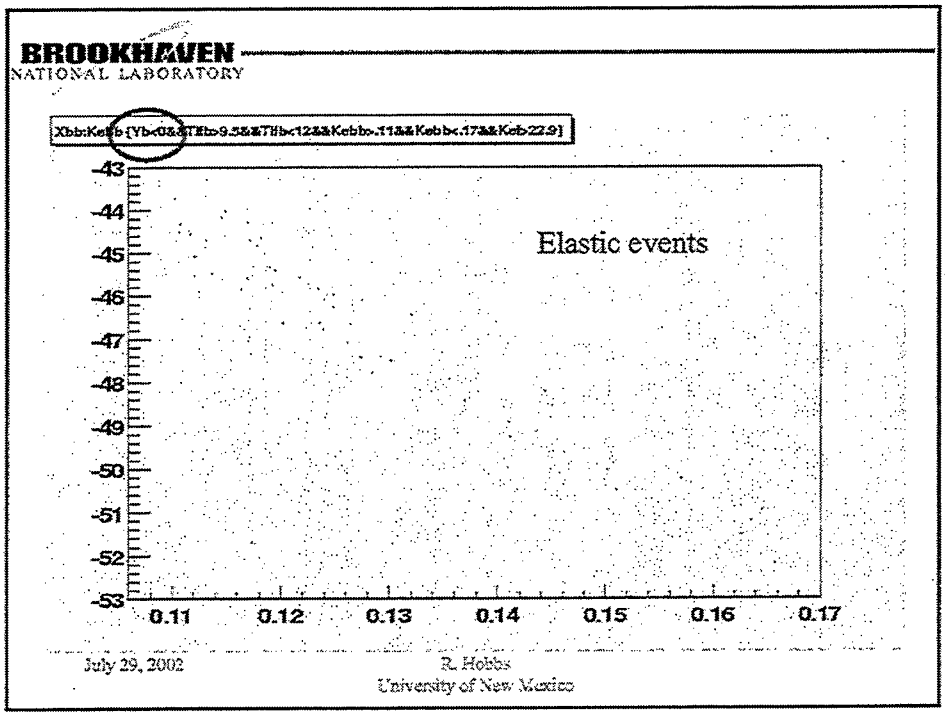
BROOKHAVEN
NATIONAL LABORATORY
Elastic events
-43
-44
-45
-46
-47
-48
-49
-50
-51
-52
-53
0.11
0.12
0.13
0.14
0.15
0.16
0.17
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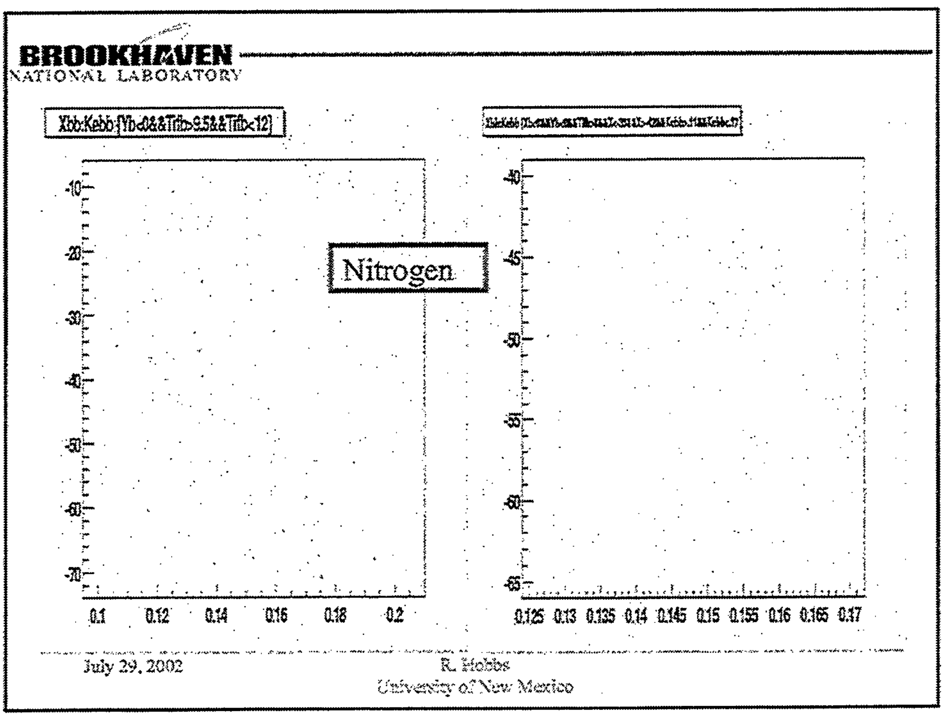
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Xbb:Kebb {Yb<0&&Tfib>9.5&&Tfib<12}
Nitrogen
-10
-20
-30
-40
-50
-60
-70
0.1
0.12
0.14
0.16
0.18
0.2
-40
-45
-50
-55
-60
-65
0.125
0.13
0.135
0.14
0.145
0.15
0.155
0.16
0.165
0.17
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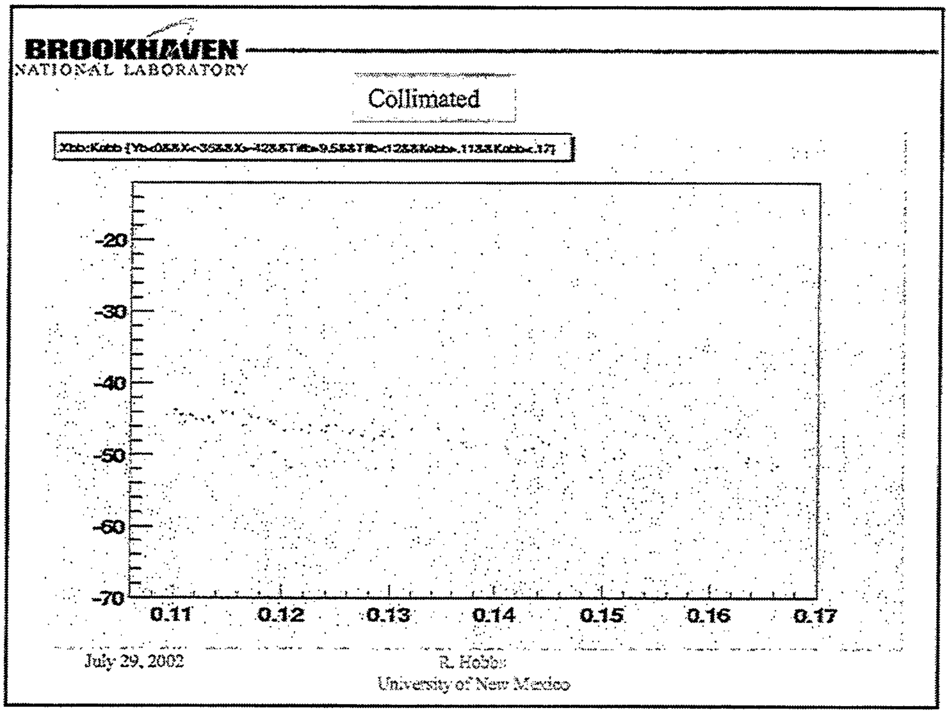
BROOKHAVEN
NATIONAL LABORATORY
Collimated
-20
-30
-40
-50
-60
-70
0.11
0.12
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0.15
0.16
0.17
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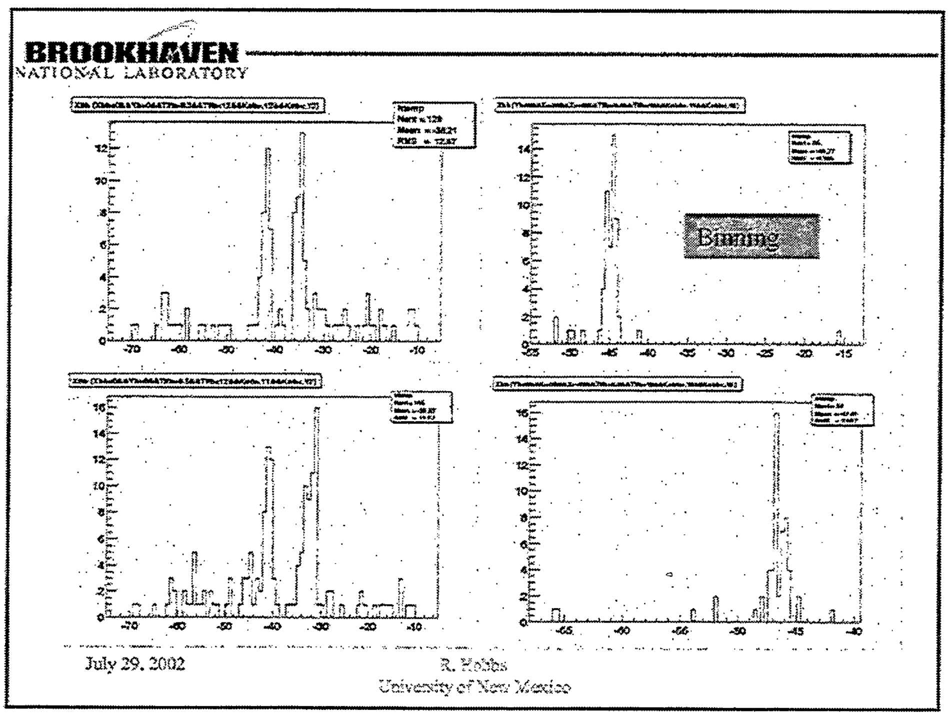
BROOKHAVEN
NATIONAL LABORATORY
Binning
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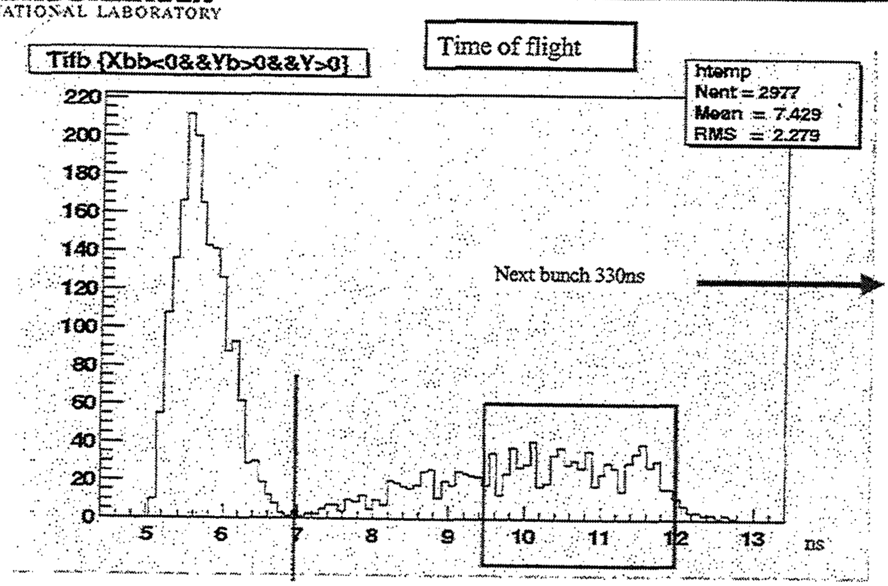

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RATES

BEAM	TARGET
1.2×10^{10} p / spill 1 spill/ 4 sec	2.0×10^{23} atoms / cm^2

- L $=1.2\ 10^{10} \times 2.0\ 10^{23} = 2.4\ 10^{33}\ cm^{-2}s^{-1}$
- N = **L** $<\sigma>$ $(5.0\ 10^{-27})$ *acc* (0.01) *eff* (50%) = 20000 evt s^{-1}
- in 8 hours can collect $1.4\ 10^{8}$ events (M.C: 24000 evt s^{-1})

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RHIC Spin Collaboration Meeting XI
July 29, 2002
RIKEN BNL Research Center

LIST OF REGISTERED PARTICIPANTS

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RHIC Spin Collaboration Meeting XI
July 29, 2002
RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting XI

July 29, 2002

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Not in attendance but will be sent proceedings:

NAME	AFFILIATION AND ADDRESS	E-MAIL ADDRESS
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RHIC Spin Collaboration Meeting XI

July 29, 2002

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

*****AGENDA*****

Morning Session

09:00 - 09:45 Update on the RHIC Polarization Analysis.................... O. Jinnouchi

09:45 - 10:15 Understanding of the Beam Depolarization on the RHIC Ramp.. V. Ranjbar

10:15 – 11:00 Status of and Commissioning Plans for the Phased-Lock Loop.. P. Cameron

11:00 – 11:15 Coffee Break

11:15 – 11:45 Update on the 12:00 Local Polarimeter Measurement....... A. Deshpande

11:45 – 12:15 Status of and Commissioning Plans for the Spin Rotators... W. Mackay

12:15 Lunch

Afternoon Session

13:00 – 13:30 Understanding of RHIC Absolute Luminosity in pp........ A. Drees

13:30 - 14:00 Understanding of the Absolute Luminosity at PHENIX... Y. Goto

14:00 – 14:45 Understanding of the Absolute Luminosity at STAR...... L. Bland

14:45 – 15:05 Understanding of the Absolute Luminosity at pp2pp....... R. Gill

15:05 – 15:15 Coffee Break

15:15 – 15:45 Proposed Measurement of pp Analyzing Power at the AGS... R. Hobbs

15:45 – 16:30 Discussion of the Beam Use Proposal Between the Various Experiment and the Machine Group.................. All

Next Meeting ~ Monday, August 5, 2002 Cancelled

Additional RIKEN BNL Research Center Proceedings:

Volume 49 – RBRC Scientific Review Committee Meeting – BNL-52679
Volume 48 – RHIC Spin Collaboration Meeting XIV – BNL-
Volume 47 – RHIC Spin Collaboration Meetings XII, XIII – BNL-
Volume 46 – Large-Scale Computations in Nuclear Physics using the QCDOC – BNL-52678
Volume 45 – Summer Program: Current and Future Directions at RHIC – BNL-71035
Volume 44 – RHIC Spin Collaboration Meetings VIII, IX, X, XI – BNL-
Volume 43 – RIKEN Winter School – Quark-Gluon Structure of the Nucleon and QCD – BNL-52672
Volume 42 – Baryon Dynamics at RHIC – BNL-52669
Volume 41 – Hadron Structure from Lattice QCD – BNL-52674
Volume 40 – Theory Studies for RHIC-Spin – BNL-52662
Volume 39 – RHIC Spin Collaboration Meeting VII – BNL-52659
Volume 38 – RBRC Scientific Review Committee Meeting – BNL-52649
Volume 37 – RHIC Spin Collaboration Meeting VI (Part 2) – BNL-52660
Volume 36 – RHIC Spin Collaboration Meeting VI – BNL-52642
Volume 35 – RIKEN Winter School – Quarks, Hadrons and Nuclei – QCD Hard Processes and the Nucleon Spin – BNL-52643
Volume 34 – High Energy QCD: Beyond the Pomeron – BNL-52641
Volume 33 – Spin Physics at RHIC in Year-1 and Beyond – BNL-52635
Volume 32 – RHIC Spin Physics V – BNL-52628
Volume 31 – RHIC Spin Physics III & IV Polarized Partons at High Q^2 Region – BNL-52617
Volume 30 – RBRC Scientific Review Committee Meeting – BNL-52603
Volume 29 – Future Transversity Measurements – BNL-52612
Volume 28 – Equilibrium & Non-Equilibrium Aspects of Hot, Dense QCD – BNL-52613
Volume 27 – Predictions and Uncertainties for RHIC Spin Physics & Event Generator for RHIC Spin Physics III – Towards Precision Spin Physics at RHIC – BNL-52596
Volume 26 – Circum-Pan-Pacific RIKEN Symposium on High Energy Spin Physics – BNL-52588
Volume 25 – RHIC Spin – BNL-52581
Volume 24 – Physics Society of Japan Biannual Meeting Symposium on QCD Physics at RIKEN BNL Research Center – BNL-52578
Volume 23 – Coulomb and Pion-Asymmetry Polarimetry and Hadronic Spin Dependence at RHIC Energies – BNL-52589
Volume 22 – OSCAR II: Predictions for RHIC – BNL-52591
Volume 21 – RBRC Scientific Review Committee Meeting – BNL-52568
Volume 20 – Gauge-Invariant Variables in Gauge Theories – BNL-52590
Volume 19 – Numerical Algorithms at Non-Zero Chemical Potential – BNL-52573
Volume 18 – Event Generator for RHIC Spin Physics – BNL-52571

Additional RIKEN BNL Research Center Proceedings:

Volume 17 – Hard Parton Physics in High-Energy Nuclear Collisions – BNL-52574

Volume 16 – RIKEN Winter School - Structure of Hadrons - Introduction to QCD Hard Processes – BNL-52569

Volume 15 – QCD Phase Transitions – BNL-52561

Volume 14 – Quantum Fields In and Out of Equilibrium – BNL-52560

Volume 13 – Physics of the 1 Teraflop RIKEN-BNL-Columbia QCD Project First Anniversary Celebration – BNL-66299

Volume 12 – Quarkonium Production in Relativistic Nuclear Collisions – BNL-52559

Volume 11 – Event Generator for RHIC Spin Physics – BNL-66116

Volume 10 – Physics of Polarimetry at RHIC – BNL-65926

Volume 9 – High Density Matter in AGS, SPS and RHIC Collisions – BNL-65762

Volume 8 – Fermion Frontiers in Vector Lattice Gauge Theories – BNL-65634

Volume 7 – RHIC Spin Physics – BNL-65615

Volume 6 – Quarks and Gluons in the Nucleon – BNL-65234

Volume 5 – Color Superconductivity, Instantons and Parity (Non?)-Conservation at High Baryon Density – BNL-65105

Volume 4 – Inauguration Ceremony, September 22 and Non -Equilibrium Many Body Dynamics – BNL-64912

Volume 3 – Hadron Spin-Flip at RHIC Energies – BNL-64724

Volume 2 – Perturbative QCD as a Probe of Hadron Structure – BNL-64723

Volume 1 – Open Standards for Cascade Models for RHIC – BNL-64722

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RIKEN BNL RESEARCH CENTER

RHIC Spin Collaboration Meetings VIII, IX, X, XI

April 12, 2002 ~ May 22, 2002 ~ June 17, 2002 ~ July 29, 2002

Li Keran

Nuclei as heavy as bulls
Through collision
Generate new states of matter.
T.D. Lee

Speakers:

L. Ahrens	M. Bai	L. Bland	S. Bravar	S. Bueltmann
G. Bunce	P. Cameron	A. Deshpande	A. Drees	G. Eppley
B. Fox	R. Gill	Y. Goto	M. Grosse Perdekamp	R. Hobbs
H. Huang	O. Jinnouchi	J. Kiryluk	W. Mackay	Y. Makdisi
V. Ptitsyn	V. Ranjbar	T. Roser	D. Underwood	W. Vogelsang
T. Wise	J. Wood	A. Zelenski		

Organizer: Brendan Fox