BNL-71118-2003
Formal Report

Proceedings of RIKEN BNL Research Center Workshop Volume 47

RHIC Spin Collaboration Meetings XII and XIII

September 16, 2002
October 22, 2002

Organizer:

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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
September 16, 2002

for
RHIC Spin Collaboration Meeting XII
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. During the PAC meeting on August 29, 2002, the beam use proposal with a four week, polarized proton physics run was approved as part of the plan for Run-03. So, we meet at BNL on September 16, 2002 to discuss the concrete plans for this proton-proton run.

To open the meeting, Thomas Roser presented the machine plans for Run-03. The run will begin with deuteron-gold beams. During this time, work will be done between fills to understand and improve upon the polarization of the protons in the AGS. It is hoped that, with the addition of the new CNI polarimeter in the AGS, improved tune feed-back in RHIC, and the use of the Siemens instead of Westinghouse power supply in the AGS, that it will be possible to achieve a polarization of 50%, maybe a bit more. The luminosity for proton-proton collisions at the interaction regions should be an order of magnitude larger than it was last year because the number of bunches will be doubled, the focussing at the IPs reduced to $\beta^* = 1$ m, losses of ions during ramping should be reduced with the tune-lock (PLL) system operating, and finally the storage rf should reduce the vertex region to $\sim \pm 40$ cm. Later, Leif Ahrens presented a timeline for the startup of the machine. Specifically, in October, the AGS should see the first beam, probably deuterons and gold. In early November, the cool-down of RHIC should start so that RHIC is ready for beam in the first week of December. Most of the month of December will be spent tuning up RHIC for deuteron-gold collisions. Once that has been accomplished, the dA physics program will commence and the polarization commissioning work for the AGS will be underway. By this time, it is hoped that the new CNI polarimeter will have been commissioned using deuterons.

Between Leif's and Thomas's talk, Anatoli gave an update on the status of the polarized proton source. Proceeding to tackle the molecular component problem[1], he reports that he now sees proton polarization of $> 80\%$ in both the Lamb shift polarimeter and the 200 MeV polarimeter – it should be noted that this is an increase from $\sim 70\%$ during Run-02 – with $\sim 5 \times 10^{11}$ ions per pulse.

To close out the morning session, Jeff Wood gave an update on the progress of the new CNI polarimeter. At this time, the main technical concern is noise pickup from the passing bunches in the AGS. Tests have been done by running a pulse of appropriate shape and magnitude down a wire which was placed down the center of the polarimeter pipe and the measuring the pick-up on the silicon detectors. In this arrangement, they saw ~ 60 mV (peak-to-peak) noise. This noise was reduced to ~ 10 mV by shielding the preamplier box. Thoughts are now focusing on how to do a noise subtraction. Presently, they are planning to install the device in the AGS by mid-October and this work seems to be on schedule. After installation, there is then a significant amount of commissioning work which needs to done. There is some hope that this work can be done when deuterium beams are in the AGS starting in early December.

To open the afternoon session, we discussed the feasibility of frequently recogging the beams during a fill. This recogging will reduce the systematic error in the relative luminosity by averaging out bunch-to-bunch differences which are not understood. To start this discussion, Mike Brennan informed us that the recogging was technically possible as long as the common

---

[1] For a detailed discussion of this matter, see Anatoli's take in April, 2002 proceedings.

rf was not operating. Further, it is expected that the common rf is not needed to squeeze the longitudinal size of bunches. Wolfram Fischer then talked about the effects, perhaps adverse, of such recogging on the beam. To begin with, he told us that, when the beams are recogged, the tunes change. So, we will need to define acceptable operating ranges so that the beam is not lost. How this effects the polarization would also need to be considered. Second, the recogging might increase the longitudinal and transverse emittance of the beam, resulting in a loss of luminosity at the experiments. Of particular concern with respect to polarization issues, there is an increased likelihood for debunching some of the beam. And, finally, we can expect that recogging will impact the lifetime. So, we decided that, for the time being, recogging would be investigated during commissioning but not used during the physics run.

Takehiro Kawabata talked about the present results of the relative luminosity analysis for PHENIX. At PHENIX, there are several luminosity detectors and thus we can compare the response of one against the others to evaluate each of their performance as a monitor for the relative luminosity. First, he showed that, within a fill, all of the detectors indicated that the specific luminosity varied from bunch to bunch by about 2 to 5%. Then, he looked at the ratios of relative luminosity measurement for the different detectors. By randomizing the polarization assignment for the bunches, he determined that the spread in the relative luminosity between different detectors had an error which, in a good fill, was $\sim$0.3% larger than it would be if the fluctuations in the luminosity measurements were only statistical in nature. In other fills, it was seen that this systematic error could be significantly worse. By averaging the data from all of the fills, he reported that the systematic error of the relative luminosity measurement at PHENIX was $\sim$0.2% in the Run-02 dataset. He then made some effort to identify the source of this non-statistical behavior by correlating the fluctations in the relative luminosity measurements to beam parameters. He then showed that there is perhaps a slight time-dependence within a fill. In addition, he found that there was a slight correlation between the non-statistical fluctuations and the width of the vertex distribution; the latter was determined from the width of the vertex distribution for ZDC trigger events since, in PHENIX, this is the only source of events for which there was no vertex cut applied by the trigger.

To finish the meeting, we had an open discussion of the experiment needs for Run-03.

B. Fox
16 September 2002

RHIC Machine Status and Plans

T. Roser, BNL
September 16, 2002

for
RHIC Spin Collaboration Meeting XII
RIKEN BNL Research Center

RHIC Machine Status and Plans

Brief summary of RHIC RUN2001/2

Plans and goals for RUN2003 / RUN2004

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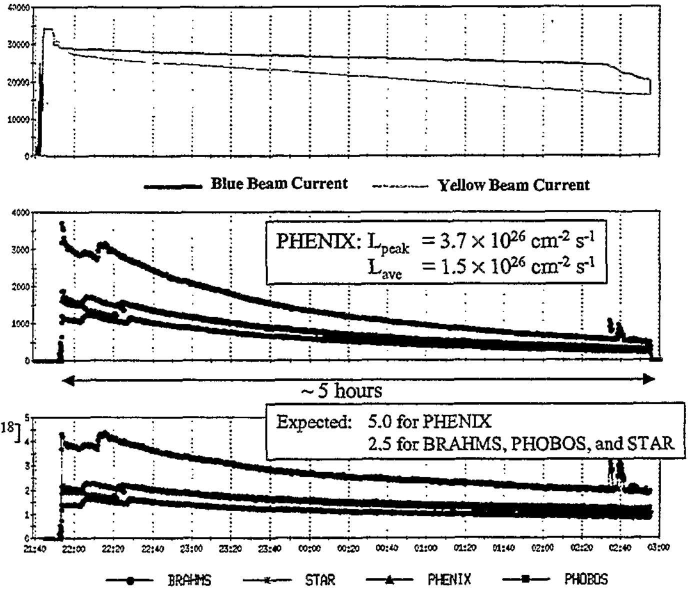
NATIONAL LABORATORY

Thomas Roser
RSC Meeting
September 16, 2002

"Typical Au Store" # 1812



Beam currents [x10^6 ions]

Collision rate [Hz]

PHENIX: $L_{peak} = 3.7 \times 10^{26}$ cm^{-2} s^{-1}
$L_{ave} = 1.5 \times 10^{26}$ cm^{-2} s^{-1}

~ 5 hours

Specific luminosity [Hz/10^{18}]

Expected: 5.0 for PHENIX
2.5 for BRAHMS, PHOBOS, and STAR

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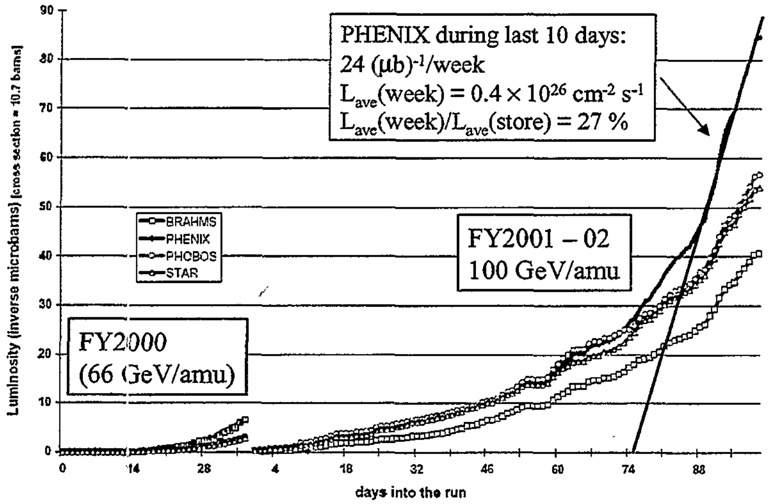
NATIONAL LABORATORY

Integrated Au-Au luminosity



PHENIX during last 10 days:
24 $(\mu b)^{-1}$/week
$L_{ave}(\text{week}) = 0.4 \times 10^{26}\ \text{cm}^{-2}\ \text{s}^{-1}$
$L_{ave}(\text{week})/L_{ave}(\text{store}) = 27\ \%$

FY2001 – 02
100 GeV/amu

FY2000
(66 GeV/amu)

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RHIC R&D Challenges and Developments

- Intensity limitation for gold due to vacuum break-down (HI)
- Single- and multi-bunch instabilities (HI & PP)
- Tune feedback (PLL) (HI & PP)
- "Flat" orbits to avoid depolarization (PP)
- Intra-Beam Scattering (IBS) (HI)
  - Determines RHIC Au performance
  - Eventually will need electron cooling (see below)

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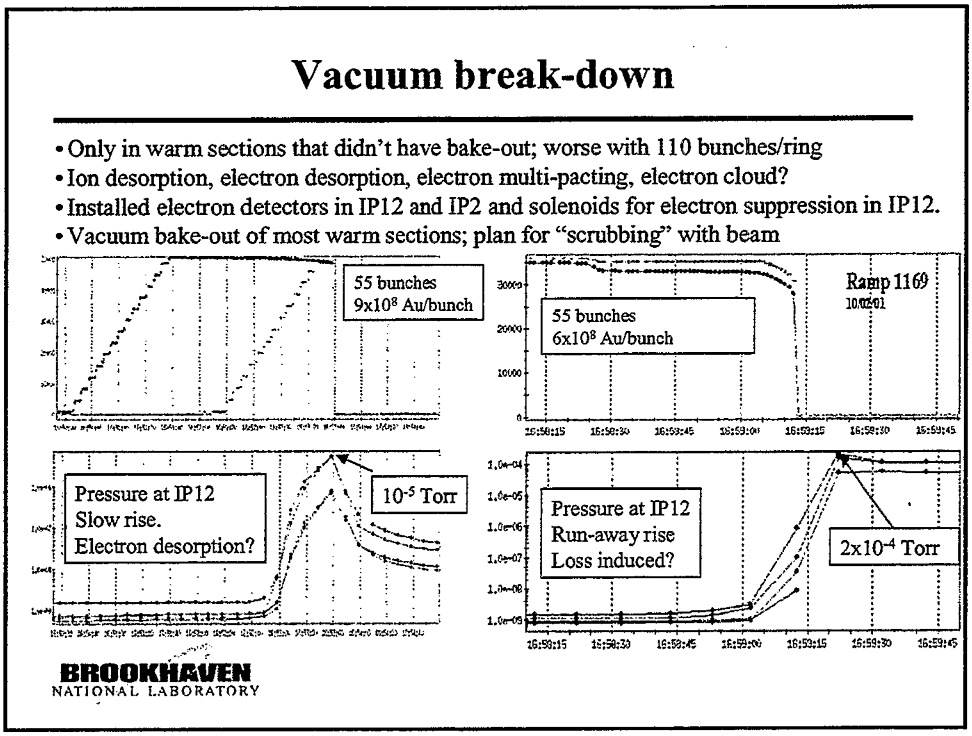

Vacuum break-down

- Only in warm sections that didn't have bake-out; worse with 110 bunches/ring
- Ion desorption, electron desorption, electron multi-pacting, electron cloud?
- Installed electron detectors in IP12 and IP2 and solenoids for electron suppression in IP12.
- Vacuum bake-out of most warm sections; plan for "scrubbing" with beam

55 bunches
$9x10^8$ Au/bunch

55 bunches
$6x10^8$ Au/bunch

Ramp 1169
10/02/01

Pressure at IP12
Slow rise.
Electron desorption?

10^{-5} Torr

Pressure at IP12
Run-away rise
Loss induced?

$2x10^{-4}$ Torr

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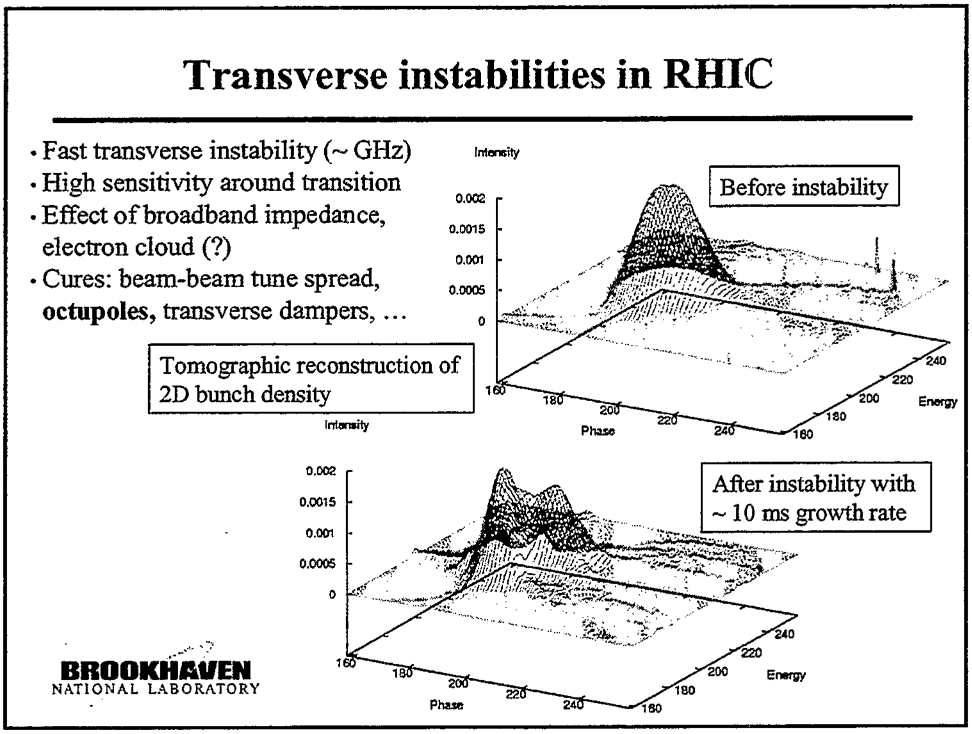

Transverse instabilities in RHIC

- Fast transverse instability (~ GHz)
- High sensitivity around transition
- Effect of broadband impedance, electron cloud (?)
- Cures: beam-beam tune spread, **octupoles**, transverse dampers, ...

Before instability

Tomographic reconstruction of 2D bunch density

After instability with ~ 10 ms growth rate

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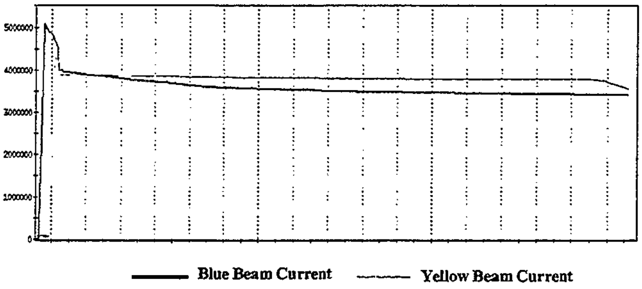
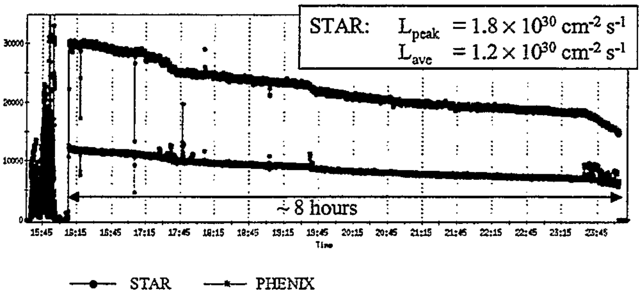
“Typical Proton Store” # 2304

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}



STAR: $L_{peak} = 1.8 \times 10^{30}$ cm^{-2} s^{-1}
$L_{ave} = 1.2 \times 10^{30}$ cm^{-2} s^{-1}

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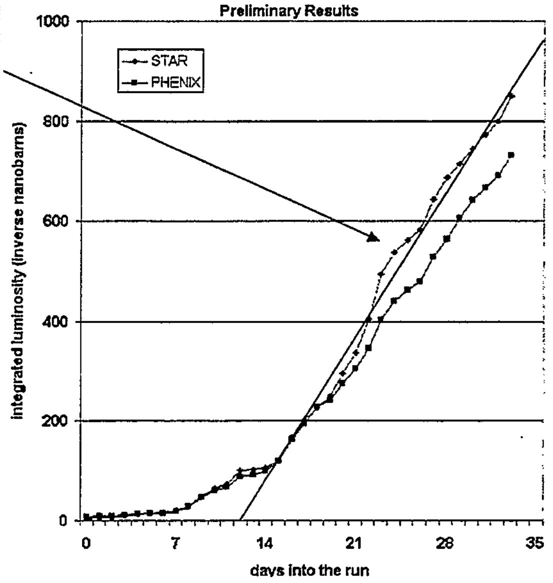
Integrated p - p luminosity

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



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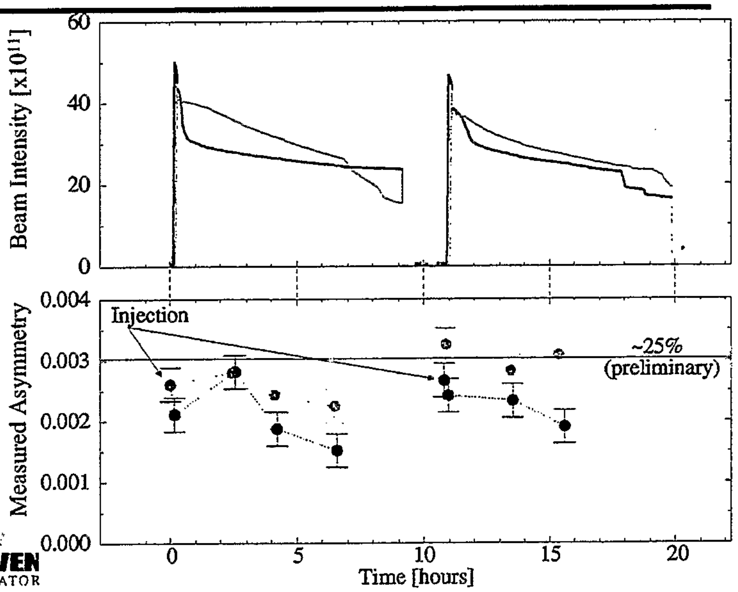
RHIC Beam Polarization



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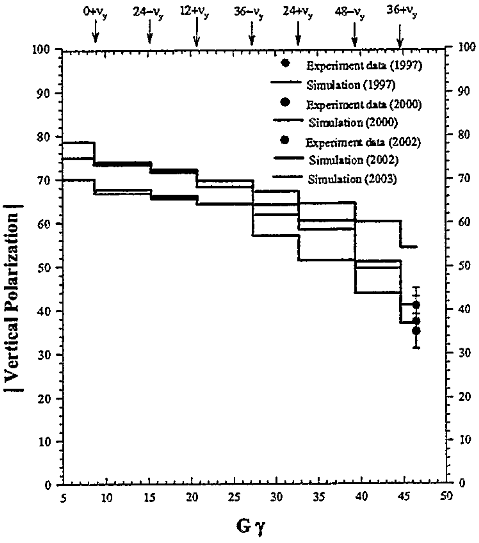
Proton polarization at the AGS

- 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
- With high ramp rate MG, higher source polarization, and new AGS pC polarimeter expect more than 50 % AGS polarization
- To avoid all depolarization in AGS build strong AGS helical Siberian snake! (Installation in 2004)



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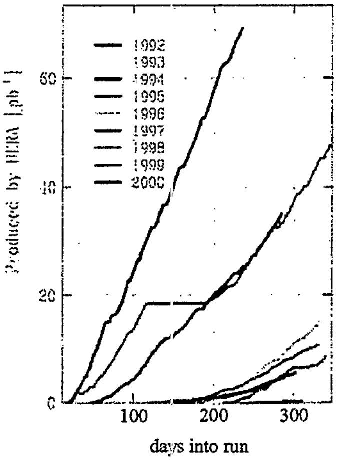
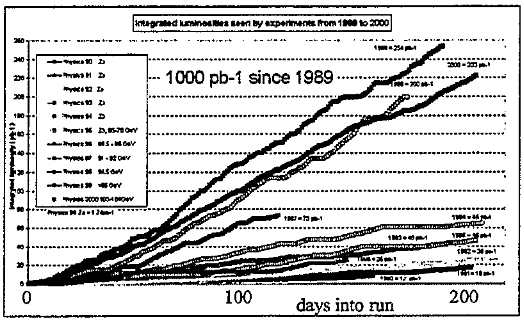
HERA and LEP luminosity evolutions





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 $(\mu b)^{-1}$
$(p\uparrow$-$p\uparrow)$*	112	100	1	25	16×10^{30}	10×10^{30}	2.8$(pb)^{-1}$
d-Au	56	80(d), 1(Au)	2	20	4×10^{28}	1.6×10^{28}	4 $(nb)^{-1}$
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

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.: d-Au: 11 weeks at "final" luminosity
  p-p: 3 weeks at "final" luminosity
- Minimum: performance at end of FY2001/02 run
- Maximum: luminosities from previous slide

Mode	L_{ave}(week) [$week^{-1}$]	Int. Lumi.	L_{ave}(week) [$week^{-1}$]	Int. Lumi.
($p\uparrow$-$p\uparrow$)	$0.3(pb)^{-1}$	$0.9(pb)^{-1}$	$2.8(pb)^{-1}$	$8.4(pb)^{-1}$
d-Au	?	?	$4\ (nb)^{-1}$	$44\ (nb)^{-1}$

RUN2004 Tentative Runplan

For 29 week FY2004 run:

- 2 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.: Au - Au: 12(11) weeks at "final" luminosity
  p - p: 4(3) weeks at "final" luminosity

POLARIZATION OPTIMIZATION STUDIES IN THE RHIC OPTICALLY-PUMPED POLARIZED ION SOURCE.

A.Zelenski[1], J.Alessi [1], B.Briscoe[1], V.Klenov [2], S.Kokhanovski[2], A.Kponou[1],
V.LoDestro[1], D.Raparia[1], J.Ritter[1], E.Steffenson[3], V.Zubets[2]

(1) Brookhaven National Laboratory, Upton, New York 11973
(2) Institute of Nuclear Research, Moscow, Russia
(3) Indiana University Cyclotron Facility, Bloomington, Indiana

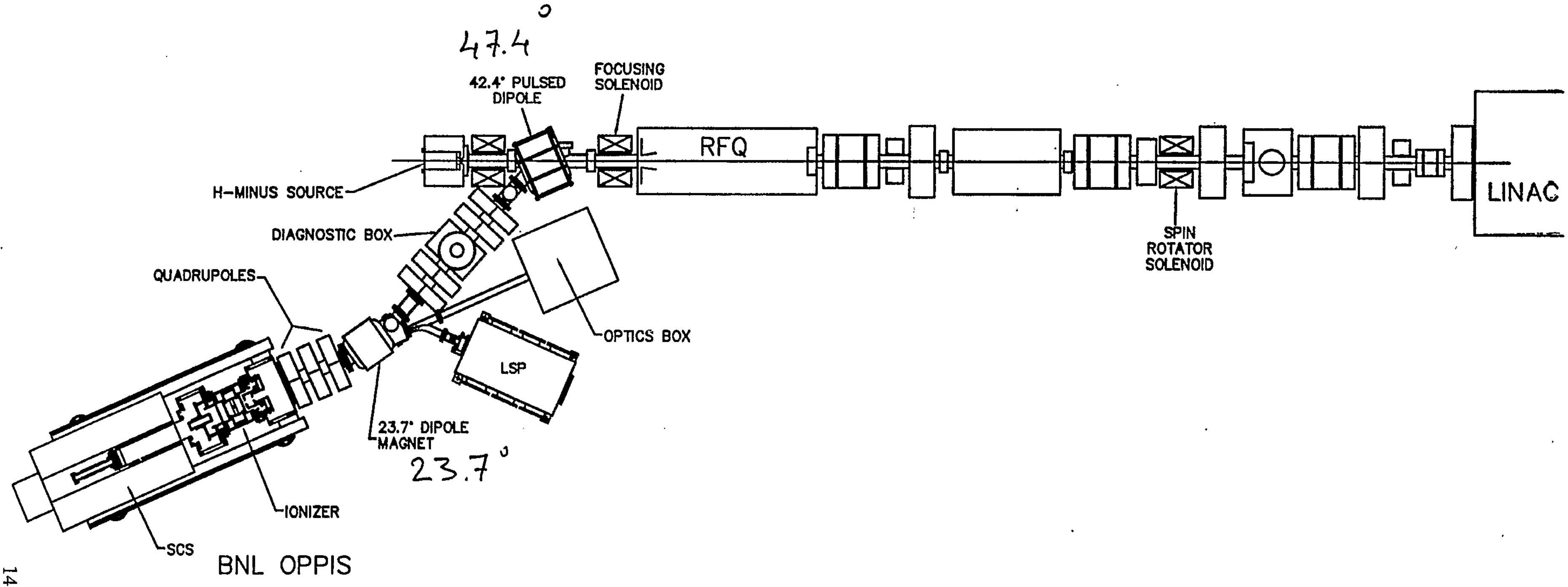
ABSTRACT

The performance of the RHIC Optically-Pumped Polarized H^- Ion Source (OPPIS) in the 2000-2002 runs for AGS and RHIC is reviewed. The OPPIS met the RHIC requirements for the beam intensity with the reliable delivery of about 500 μA polarized H- ion current in 400 μs pulse duration (current can be increased to over 1.0 mA, if necessary). The beam intensity after the linac at 200 MeV was $(5\text{-}6)\cdot10^{11}$ H^-/pulse, which is sufficient to obtain the required $2\cdot10^{11}$ polarized protons per bunch in RHIC. A Lamb-shift type polarimeter was used for polarization measurements and optimization at a source energy of 2.6-3.0 keV (extraction voltage turned off). A proton polarization of 80% was measured in the Lamb-shift polarimeter, after OPPIS-parameter optimization. At that time the presence of a half-energy beam component coming from dissociation of H_2^+ molecular-ions was observed. The molecular ions are produced in the ECR (Electron Cyclotron Resonance) primary proton source. This component can be as high as 20%, and the polarization is significantly lower than polarization of the main beam. At the 35 keV extraction energy, this component has 33.5 keV, and is matched into the RFQ and accelerated along with the full energy ions, reducing the beam polarization. The molecular-ions can be reduced to about 5% by the ECR source-operation optimization. They can be suppressed further by optimization of the extraction optics and by use of a decelerating einzel lens in 35 keV LEBT line. As a result, the proton polarization of the accelerated beam was increased to over 80%, as measured in a 200 MeV proton-deuterium polarimeter. The polarimeter upgrade will be also discussed, which includes the high-current polarization measurements and continuous polarization monitoring (by interleaving beam pulses injected to Booster with the pulses transported to the polarimeter).

RHIC SPIN COLLABORATION MEETING

September 16, 2002

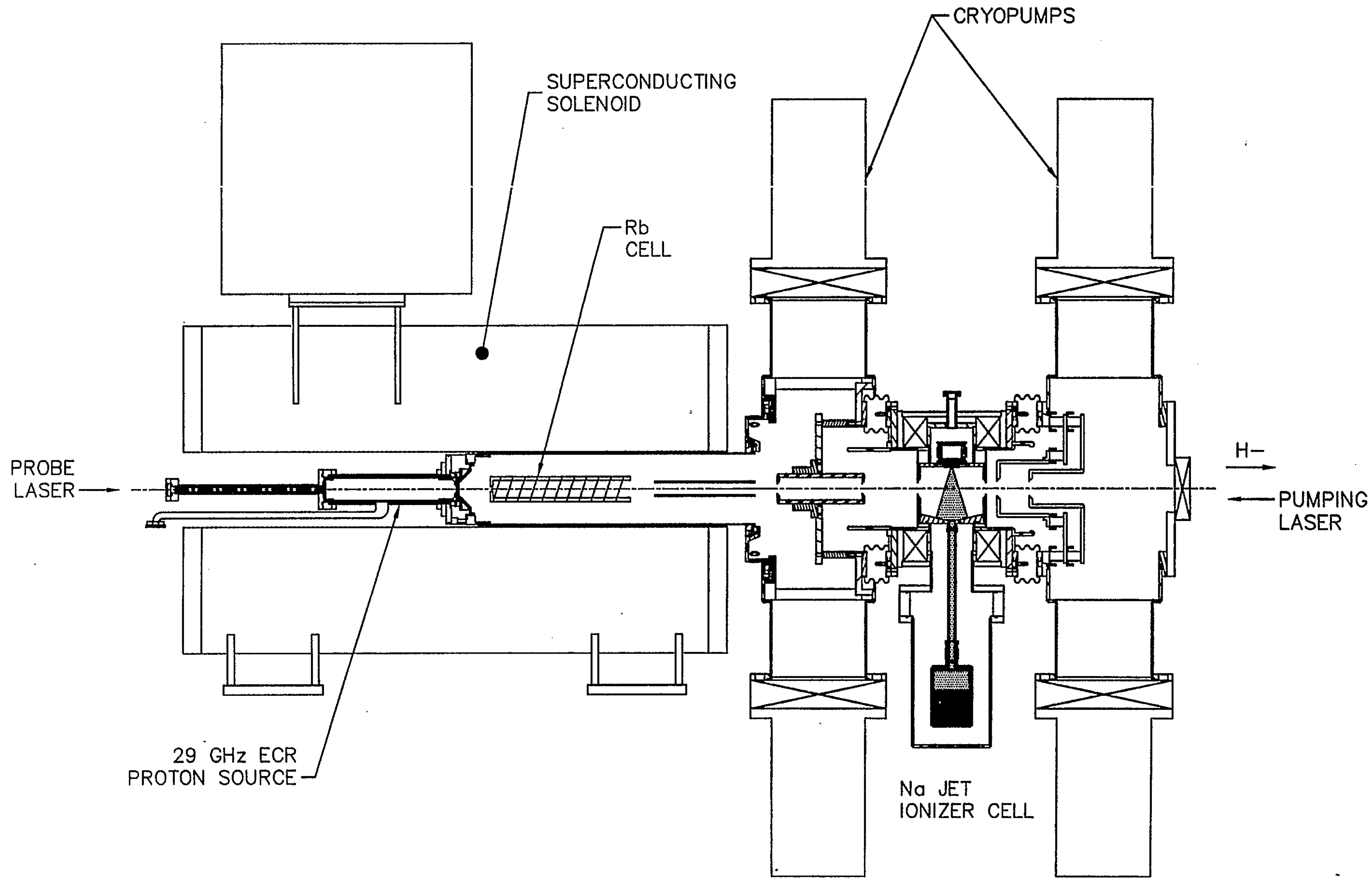
POLARIZED SOURCE LAYOUT AT THE LINAC INJECTOR



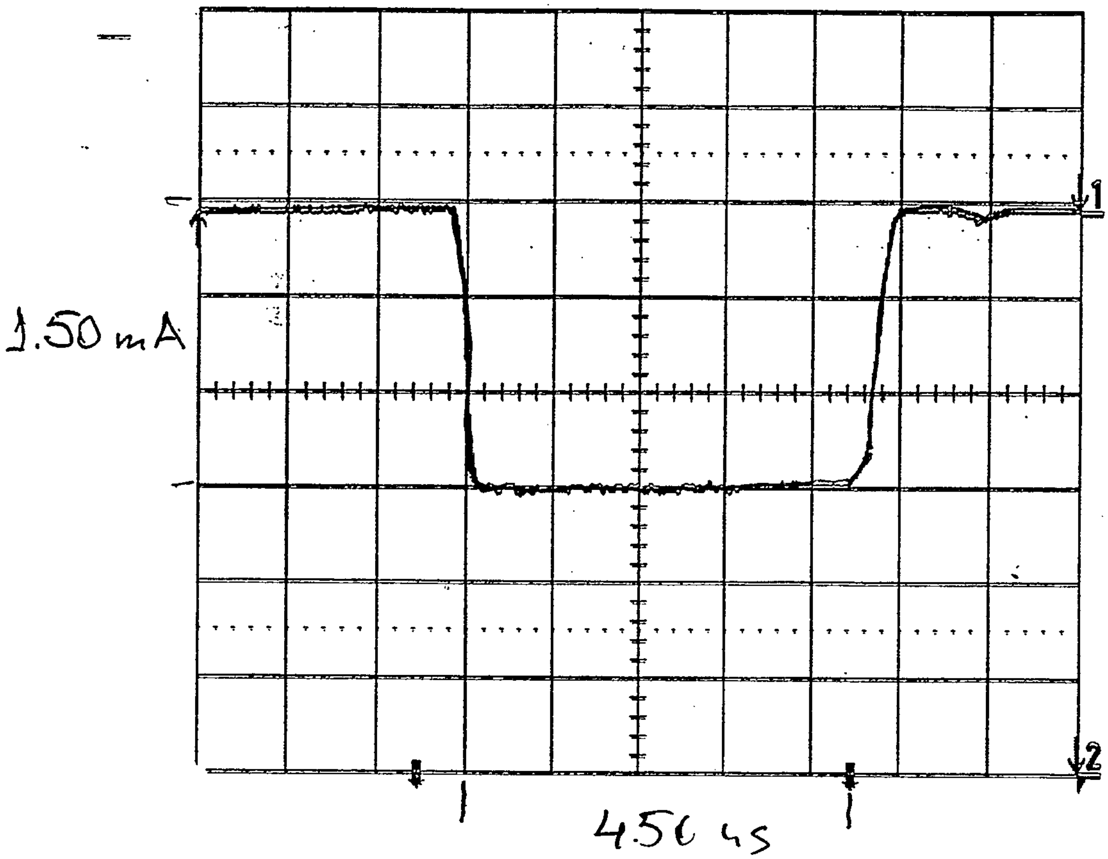
Allows interleaving of 1mA polarized H– beam and 100 mA unpolarized beam on pulse–to–pulse basis.

Longitudinal polarization out of the source converted to vertical polarization at the linac entrance.

RHIC OPTICALLY PUMPED POLARIZED H- SOURCE

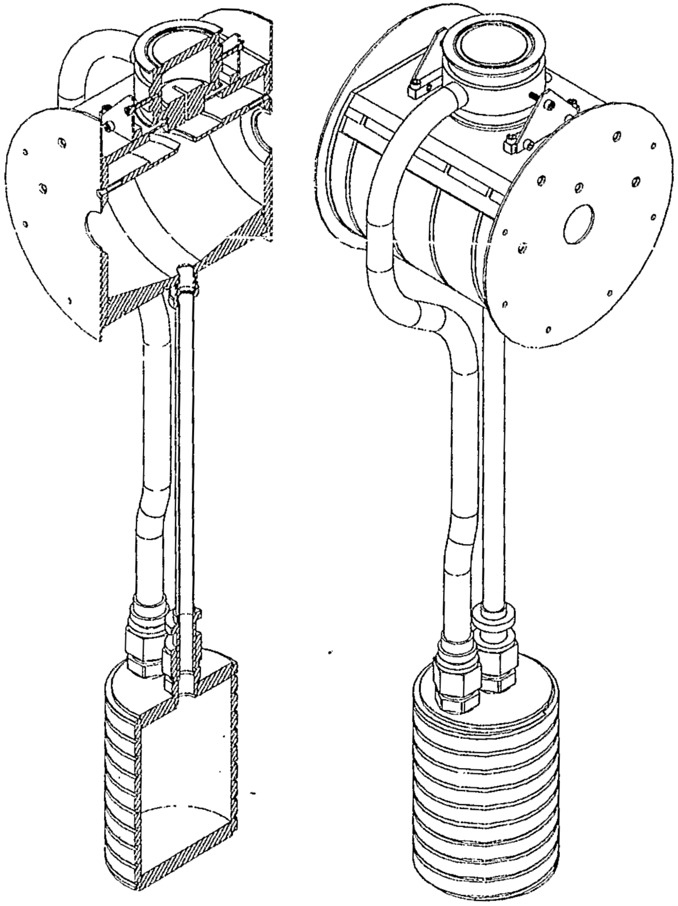


H- current pulse in 35 keV LEBT FC



Vertical current scale is 500 uA/div.

Horizontal scale is 100 us/div.



- Na ionizer cell at high voltage - avoided the need to have the entire source sit on a high voltage platform

- Low Na loss, despite the large aperture

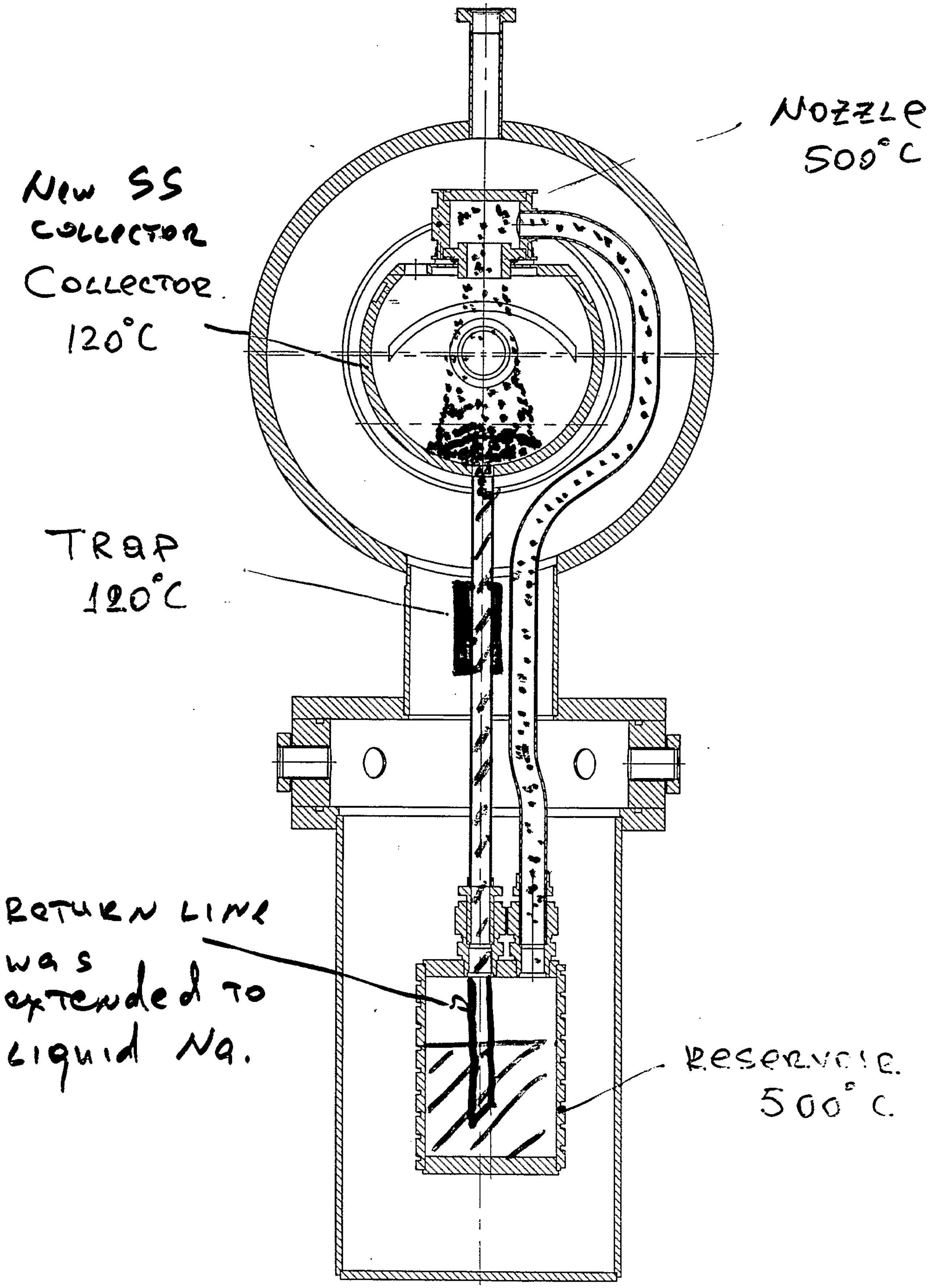
- Reservoir is loaded with 150 g of sodium metal

- Reservoir and jet nozzle are operated at a temperature of 530 C.

- Sodium vapor density is ~10^{17} atoms/cm^3, resulting in a vapor jet with an effective thickness of ~5×10^{14} atoms/cm^2, sufficient for saturation of the H^- yield.

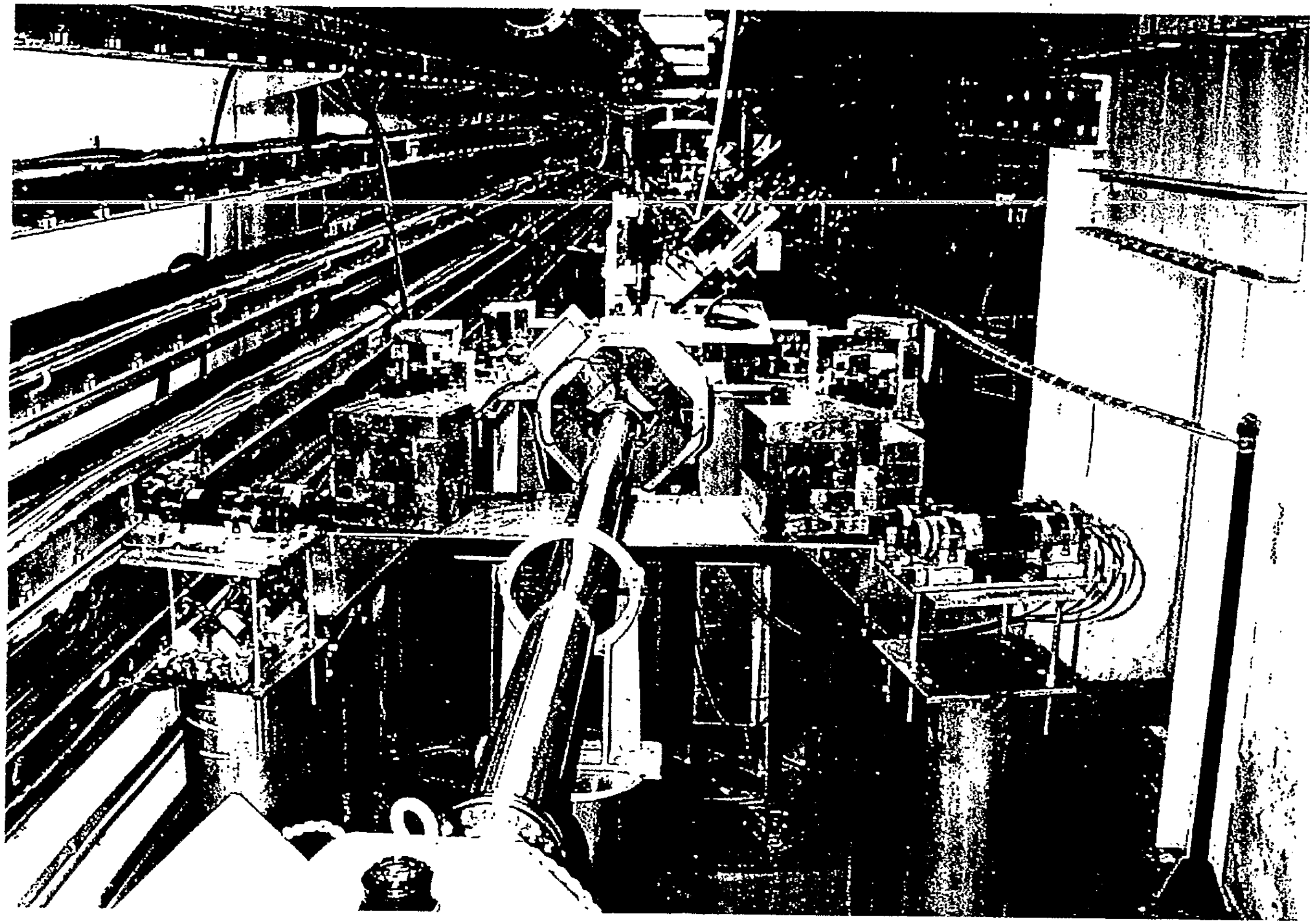
- Although the entire 150 g circulates in ~3 hours, the cell provides continuous, stable operation for 1-2 months.

- The Na loss has proven to be much less than with the previous oven-type cell.

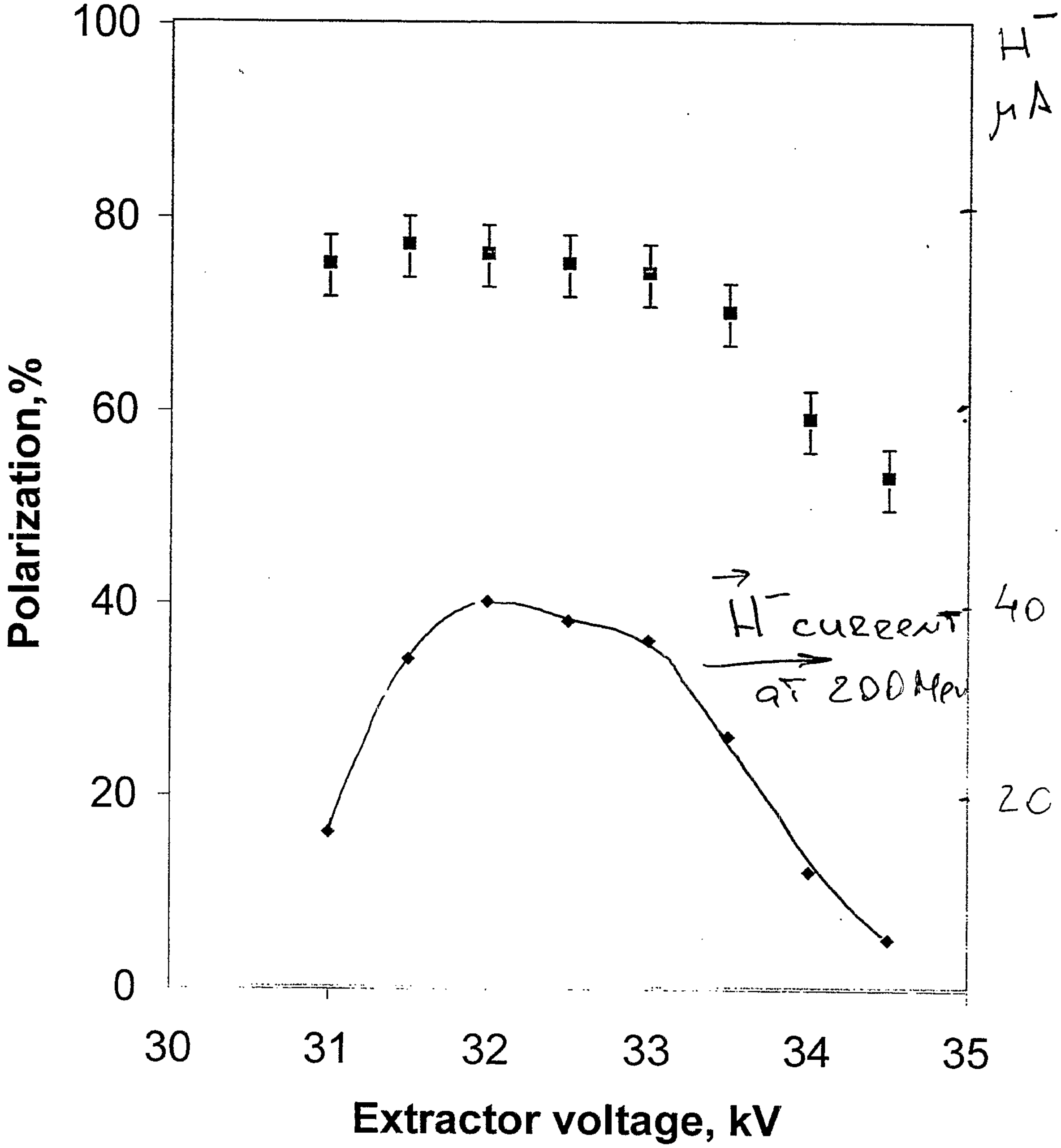

NOZZLE
500°C
NEW SS COLLECTOR
COLLECTOR
120°C
TRAP
120°C
RETURN LINE was extended to liquid Na.
RESERVOIR
500° C.

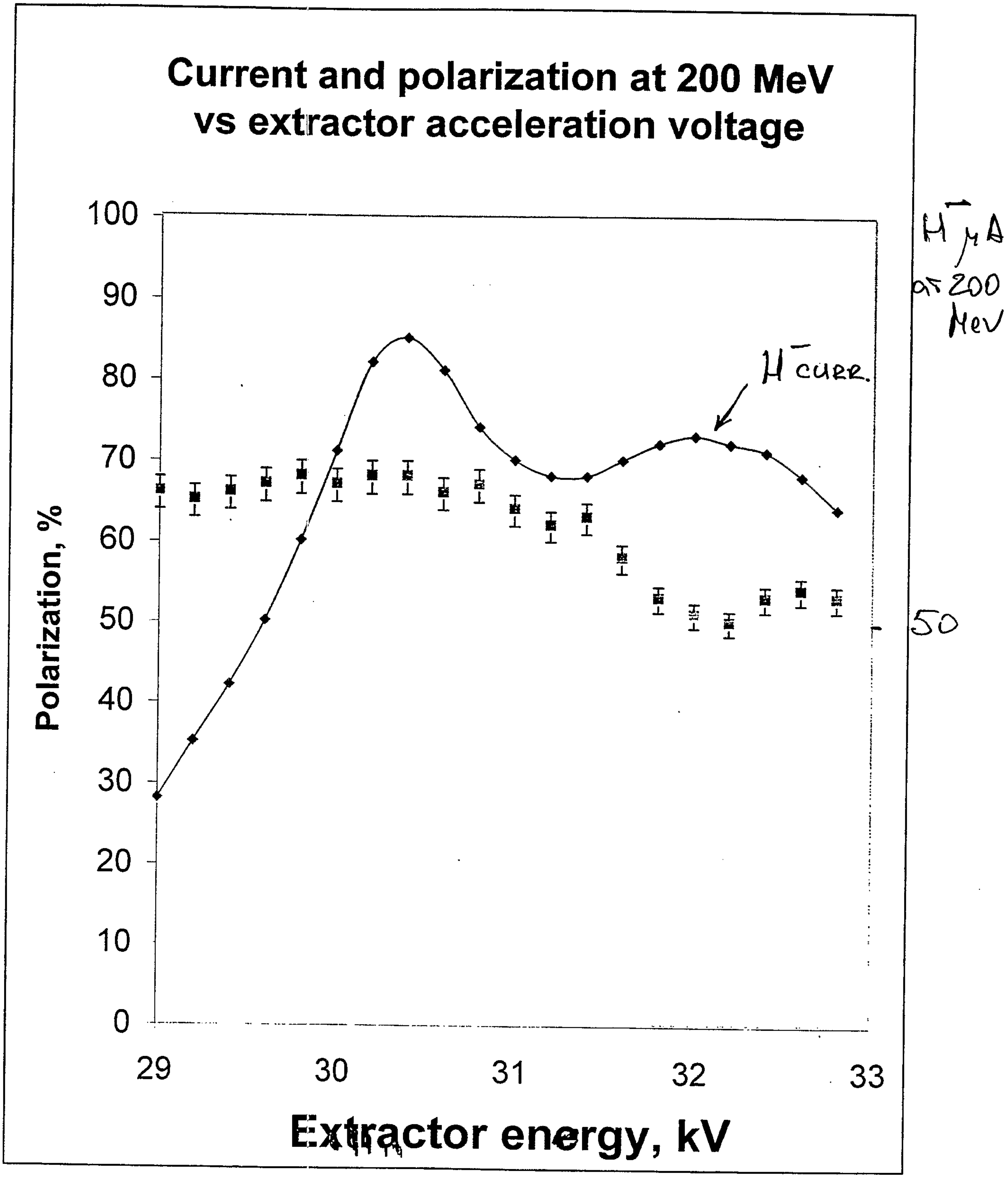
SECTION B–B

200 MeV pD, pC polarimeter



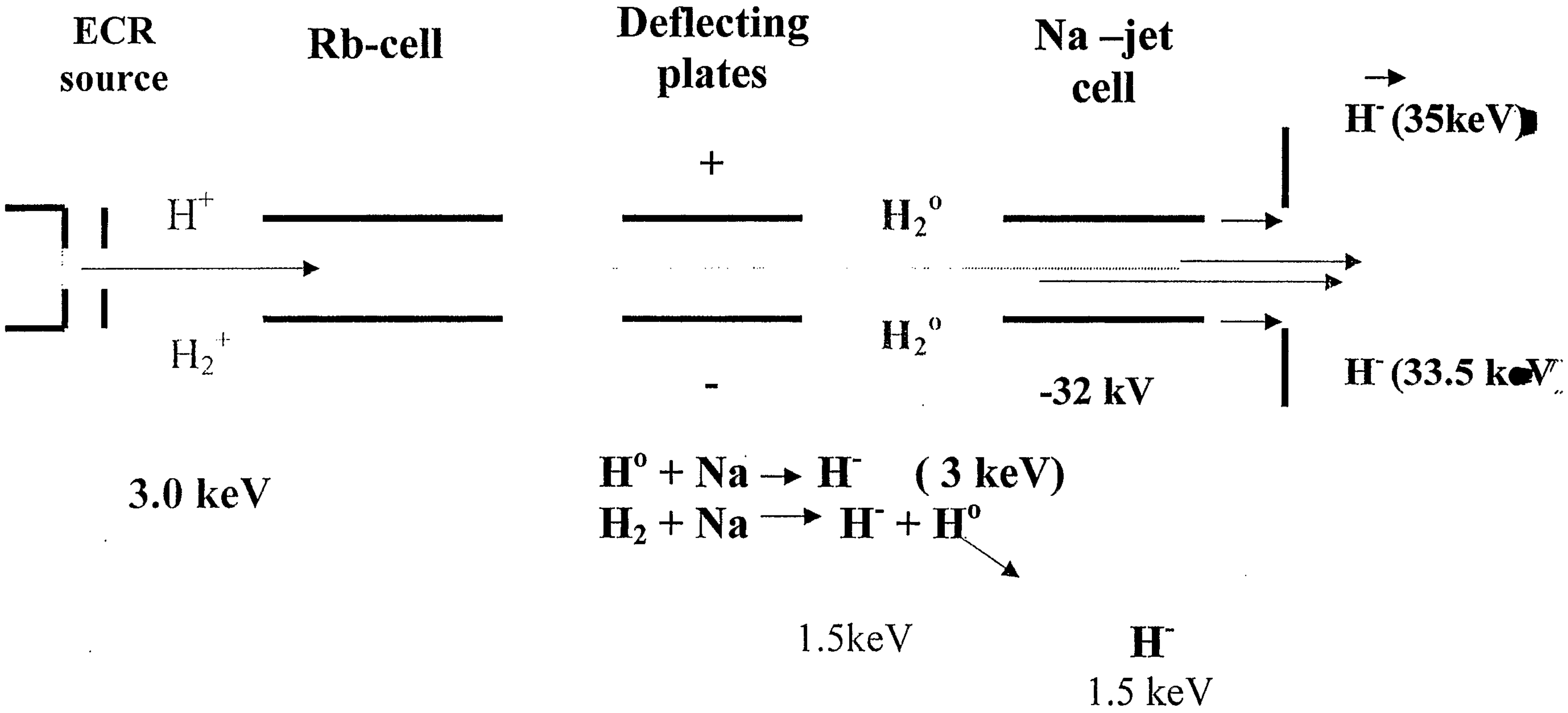
Current and polarization vs extractor voltage





Current and polarization at 200 MeV vs extractor acceleration voltage

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



ECR source

Rb-cell

Deflecting plates

Na –jet cell

H^+

H_2^+

+

-

H_2^o

H_2^o

-32 kV

$\rightarrow$ H^- **(35keV)**

H^- **(33.5 keV)**

3.0 keV

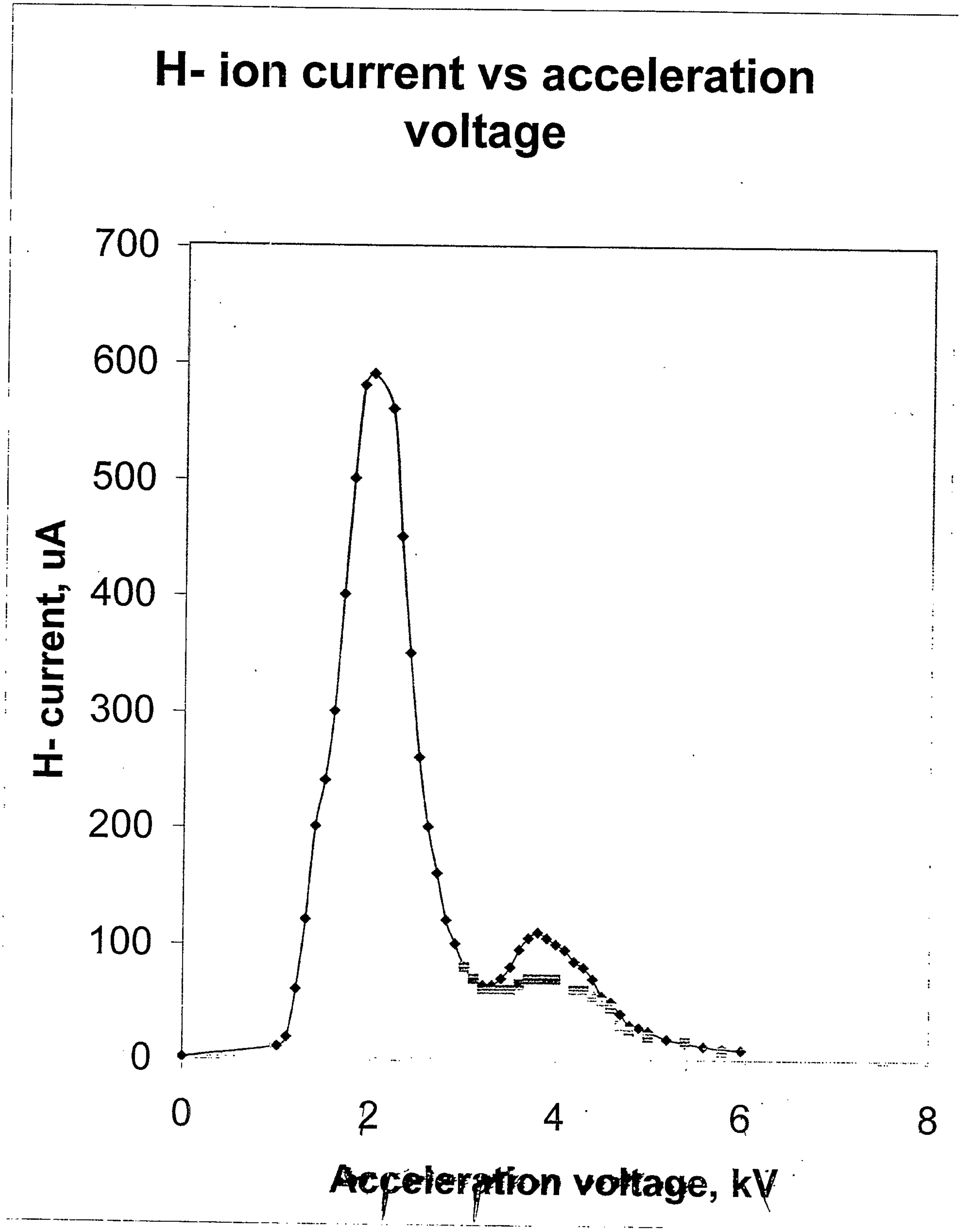
$H^o + Na \rightarrow H^-$ **(3 keV)**

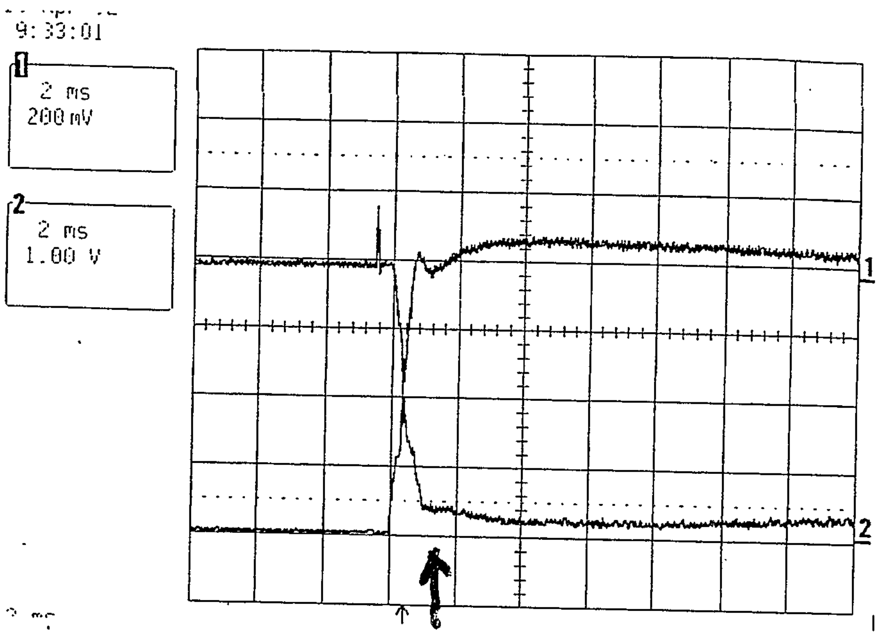
$H_2 + Na \longrightarrow H^- + H^o$

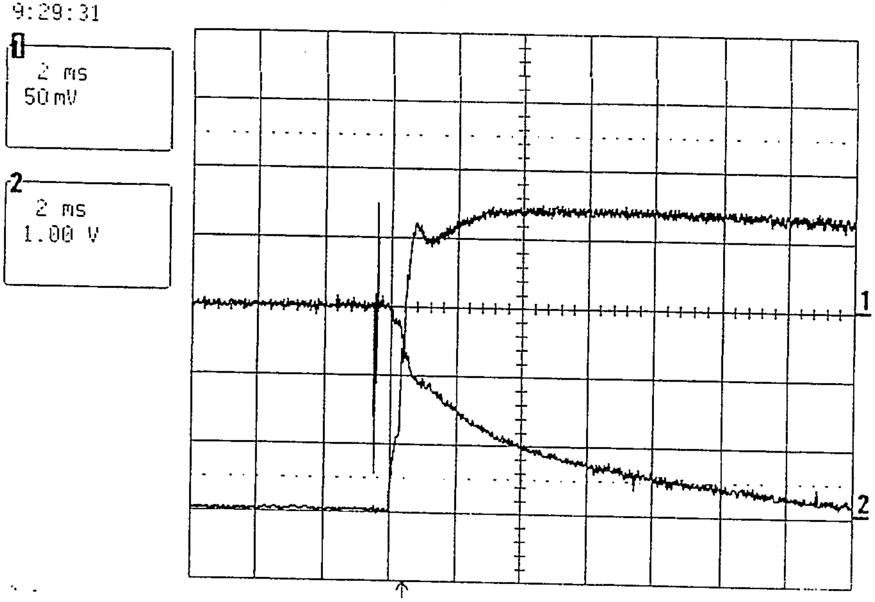
1.5keV

H^-

1.5 keV

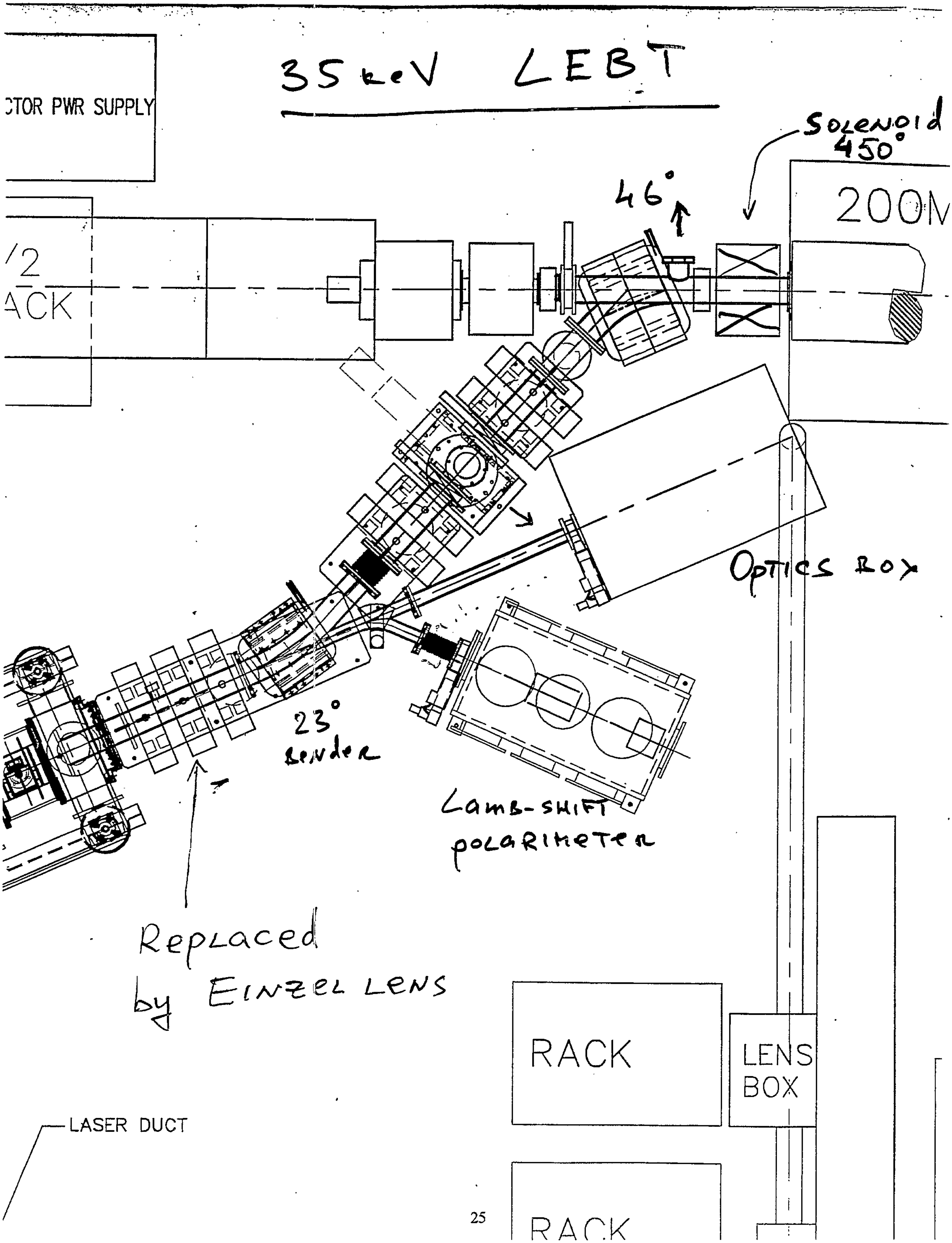

H- ion current vs acceleration voltage
H- current, uA
700
600
500
400
300
200
100
0
0
2
4
6
8
Acceleration voltage, kV

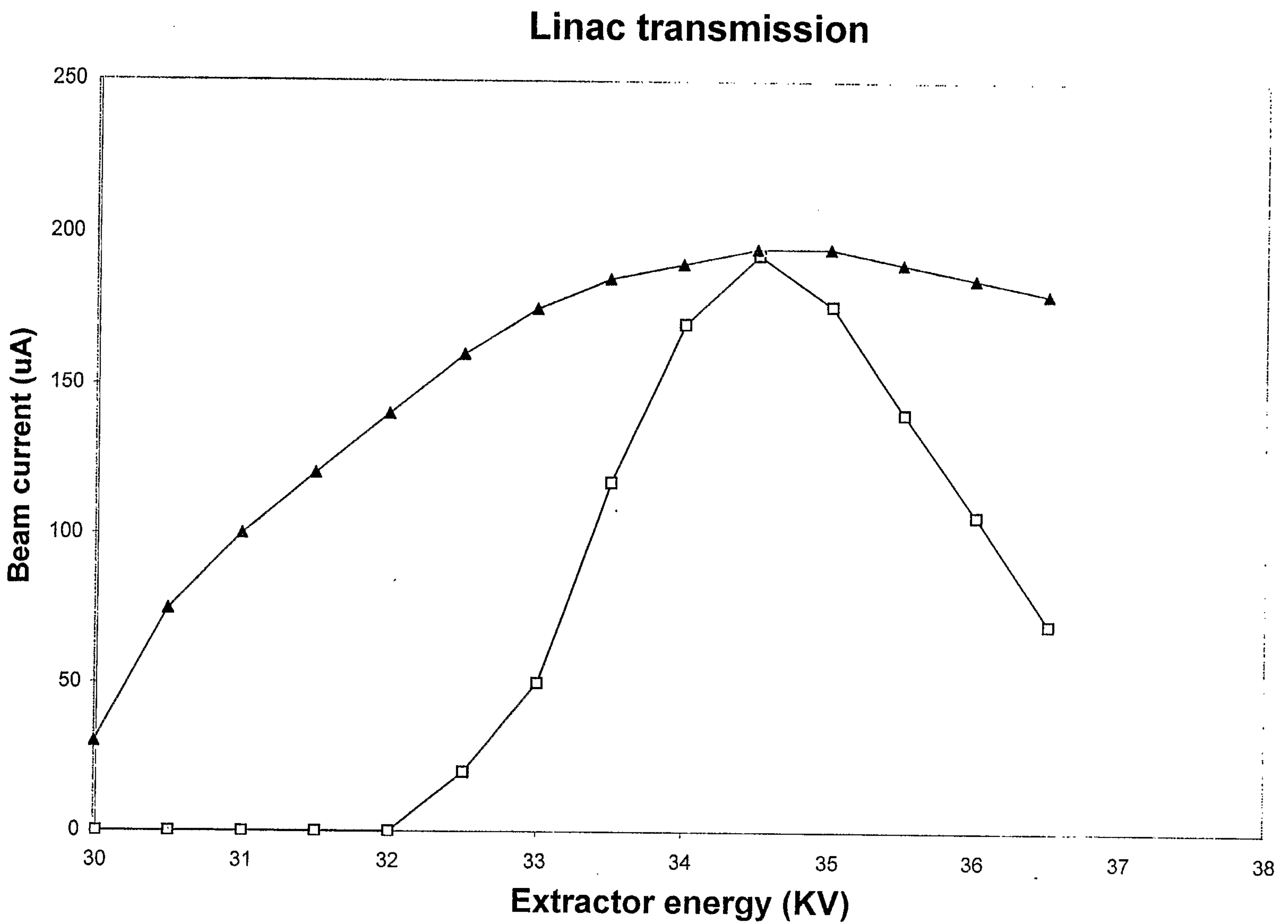


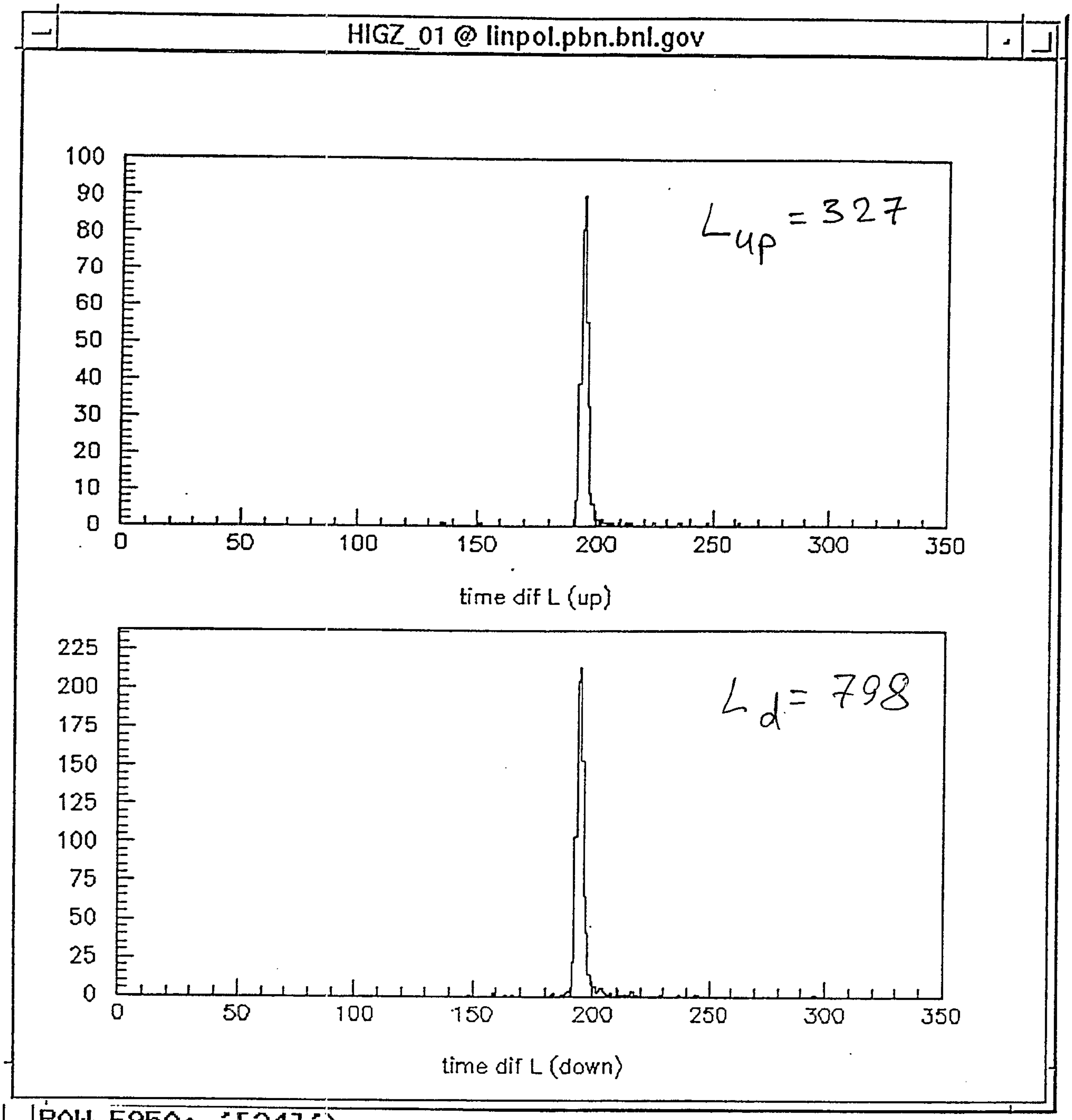


Pulsed ECR operation

35 keV LEBT


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


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

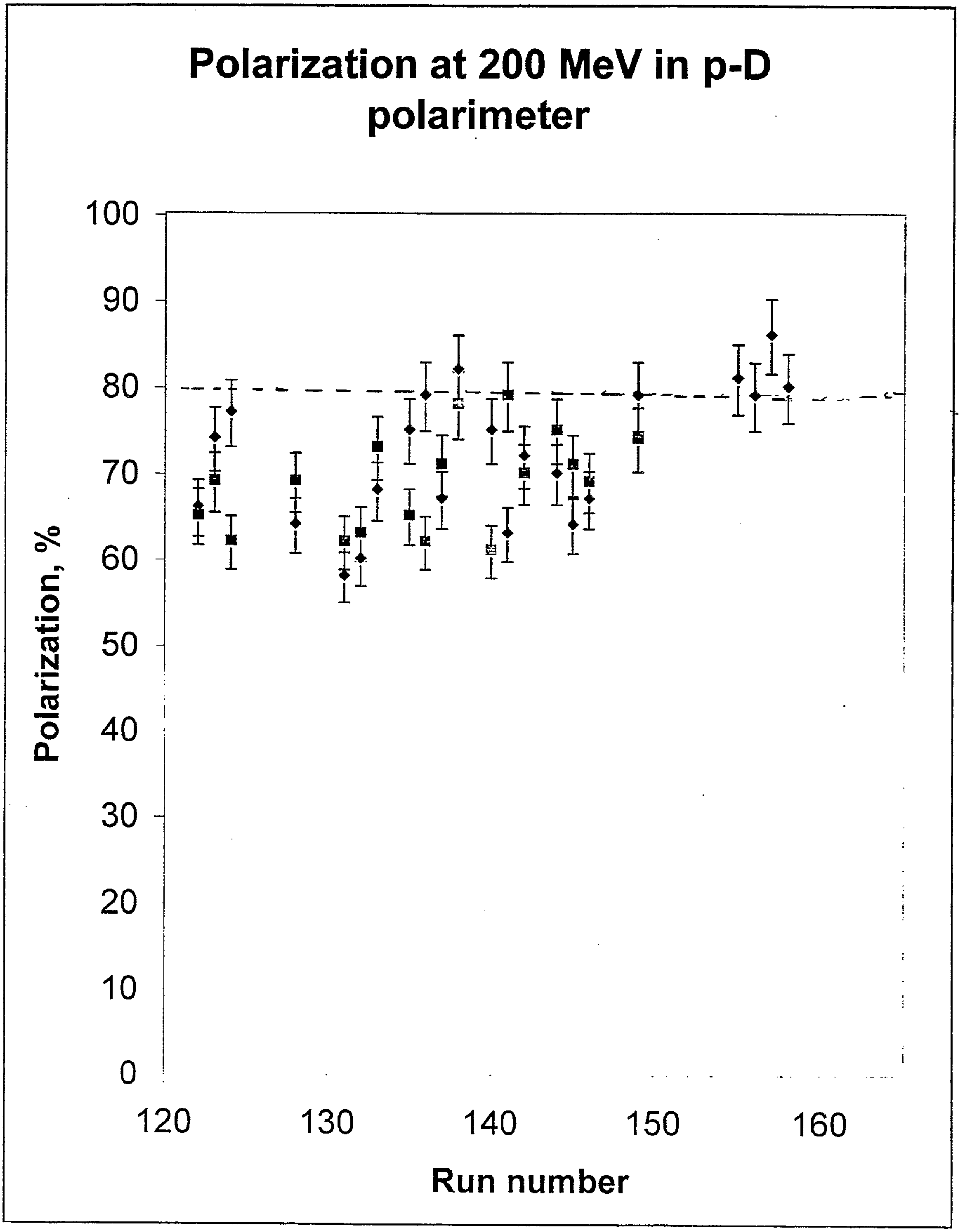


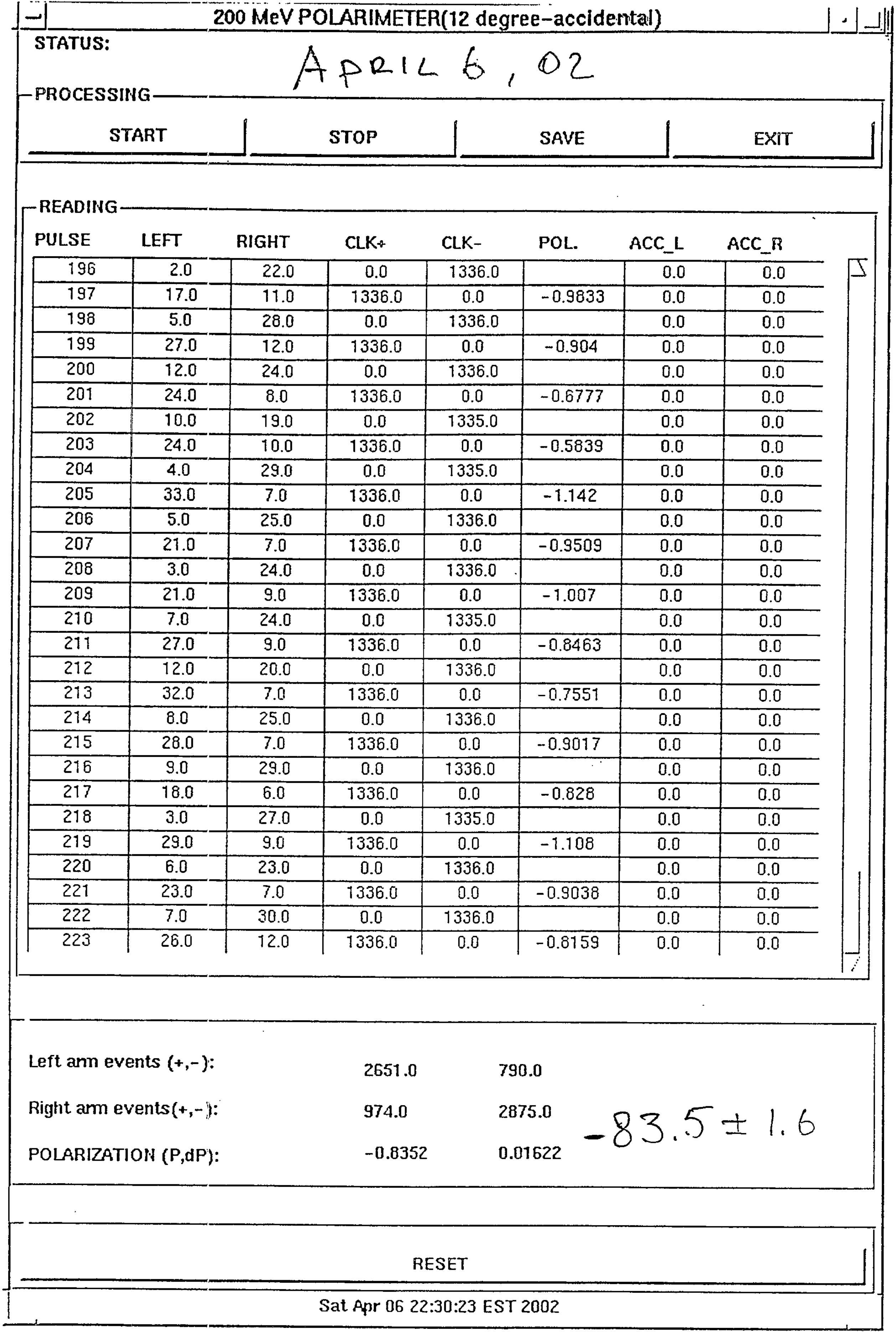
$L_{up} = 327$

$L_d = 798$

```
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]'>
```

$A_{p\gamma} = 0.507 \pm 0.002$


Polarization at 200 MeV in p-D polarimeter
Polarization, %
100
90
80
70
60
50
40
30
20
10
0
120
130
140
150
160
Run number



200 MeV POLARIMETER(12 degree-accidental)

STATUS:

April 6, 02

PROCESSING

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

-83.5 ± 1.6

Sat Apr 06 22:30:23 EST 2002

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 %**	
		+ 16 %

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

CONCLUSIONS

The RHIC OPPIS status:

The ECR proton source has been optimized for high (up to 1.6 mA) current production. Molecular ion H_2^+ admixture was reduced to about 5%.

The Na-jet ionizer cell operation is very stable. The cell worked continuously trouble-free for two months in the last run. A spare cell is near completion.

The 35 LEBT optics was optimized to suppress molecular ion polarization dilution.

A 200 MeV p-Carbon plarimeter was upgraded for high current operation and continuous polarization monitoring. A new p-D polarimeter has been built for p-Carbon polarimeter calibration.

Proton polarization in excess of 80% was measured at 200 MeV after reduction of molecular ion admixture.

Source repetition rate was increased to 6 2/3 Hz.

Problems:

Stable long-term source operation at 75-80% has to be demonstrated. Some polarization losses are expected at high repetition rate.

Higher > 85 % polarization is feasible in the optically-pumped sources and still has to be achieved in the RHIC OPPIS.

The high repetition rate of a 6 2/3 Hz might be required only during AGS polarization optimization and switch between 1 Hz and 6 2/3 Hz has to be developed.

CONCLUSIONS

The new BNL polarized source now produces about 3 times our design goal for intensity meeting RHIC requirements. It easily produces > 1 mA of H^- with polarization in excess of 75%. 50% of the source output is transported to 200 MeV. The source produces very flat beam pulses, and is very stable. It has been able to operate for 2 weeks between scheduled maintenance periods, and maintenance can sometimes be "transparent" to the RHIC spin program when done during an 8 hour period of stored beam.

AGS Commissioning Plans for Run03

L. Ahrens, BNL

September 16, 2002

for

RHIC Spin Collaboration Meeting XII

RIKEN BNL Research Center

Transparancies:

1: Schedule

2: Source/Linac

3: Booster

4: AGS

5: Observations Plans

6: Haixin's polarization plot

Schedule: 7 Oct 02 gold beam in Booster (Booster recommish)

15 Oct 02 gold/ deuterium beam in AGS with Siemens Motor/Generator
(how long AGS available – not clear, maybe not long – a week?) BAF (Booster Accelerator Facility) commissioning will compete making AGS beam harder to come by.

4 Nov 02 Iron in AGS (NASA biology run)

21Nov 02 Injectors setup for RHIC injection

1 Dec 02 RHIC Blue cold, deuterium into Blue. fill, fill, fill or fill and ramp, fill and ramp. no resting spaces.(but deuterium always in the AGS, and most of that beam doesn't go into RHIC. Probably could be available as another User – if Operations has any space in their head.

Yellow – gold into Yellow. probably no deuterium for a while. Then working on collisions.

comments: Injectors very busy just trying to deliver to RHIC (Au and d) – optimizing injector performance; little time for messing, but deuterium accelerating in AGS some fraction of the time - more if we have trouble d, less if deuterium a piece of cake relative to gold, in which case we will be working on gold behind RHIC.

mid Dec 02 Polarized protons in Linac, into HEBT to the 200 MeV polarimeter.

January 03 RHIC into physics runs (d,Au), injectors "mode switch" to polarized protons during stores. Plan for 3 (is there a constraint?) weeks of running in this pattern. This is the pre-run run.

Issues:

Linac:

200 MeV operation:

access into HEBT competes with Au/d operation (?)

measure 200 MeV polarization with 7Hz source pulse rate vs historic slow (1 Hz) pulsing.

(Anatoli Zelinsky +) Need the fast repetition rate if want to fill AGS with 6 bunches – for the internal polarimeter.

"commission" the 750 KeV chopper with beam from the polarized source. (Zelinski, Alessi, Brennan, Brisco, Zeno)

(issue: longitudinal emittance – last year ran Booster at h=2, two bunches accelerated, equally populated with beam and used only one of these, just to get a smaller beam in longitudinal phase space (.7 eVsec/n). The chopper which 'chops' the beam in time as it enters the Linac was ineffective for beam coming from the polarized source. This was (is) not understood. If the beam can be chopped, we have better control over the longitudinal phase space. Go back to h=1 operation. But also need smaller momentum spread out of Linac. Alessi has a program to attack this – at least gaining better understanding of the situation – diagnostics commissioning etc.

Booster:

Booster is the “easy” measurer of the longitudinal quality of the Linac beam. Can we inject into Booster before January?

Some serious orbit distortions possible due to the BAF construction. Reopens the possibility of losing polarization in Booster. (Equilibrium orbit measuring system being commissioned.)

The test will be polarization at AGS injection (1.5 GeV kinetic or slightly higher). Polarization should equal 200 MeV measurement. Old polarimeter.

Booster tune control, tune measurements all required for BAF commissioning so should already be there. Standard drill to optimize – or show degradation if move (4th 5th orbit harmonics, vertical betatron tune) away from optimal.

AGS:

changes:

1) back to the higher acceleration rate of the Siemens motor-generator set.
2) new magnet hardware for the (ac dipole/tune meter) both vertical and horizontal.
3) CNI Polarimeter

any immediate acceleration strategy changes?
nope. Set up as in last Siemens (higher acceleration rate) run (2000) – well nearly (betatron tune space).

comments:

unpolarized work:

satisfactory calibration of the (magnetic field measuring system / AGS average orbit measurement) last run. This cal should be redone during the RHIC setup period, and we should set the ac dipole intervals with the best confidence yet – not that we won't try to check with timing scans.

Equilibrium orbit correction – nothing new, but simplify if possible.

where should we live in tune space?

Two remotely-switchable frequencies now possible for the vertical ac dipole (~ betatron tune of 8.8) – choice fixes the vertical tune to be just above or just below the tune associated with this frequency, and horizontal tune on the other side. (Limited head room 8.5 – 9 or less)

Where can we go in tune space (without beam loss ... without emittance growth) (skew sextupole resonance line Qy+2Qx=26?) Understanding this is valuable prework for later polarization optimization.

observations and plans:

1) The presence of quality polarization (asymmetry) measurements will make a huge difference.

2) If in addition we can make these measurements while we are ramping (without having to introduce magnet porches) that will make another huge difference. It will remove the gnawing suspicion that something "else" has changes upstream in the acceleration process, and hence that the effect you see isn't really associated with the change you just made.

therefore : once we reestablish polarization in AGS (if not before) give commissioning of the CNI polarimeter highest priority.

Then get into systematic studies to tune polarization.

> tune space locations (at each intrinsic resonance) – affects emittances and hence polarization loss at intrinsic resonances
>
> intensity dependence of final polarization
> ? associated with emittance growth?
>
> Snake strength during acceleration cycle– is there any optimization to be done?
>
> Mei's explorations with quad pulsing and octupole pulsing on the plate – when we have good polarization measurements.
>
> relevant experience from last run?
>
> More convenient/automatic logging (hopefully) to help us keep track of what we have done.

Update on the AGS CNI Polarimeter

J. Wood, UCLA
September 16, 2002

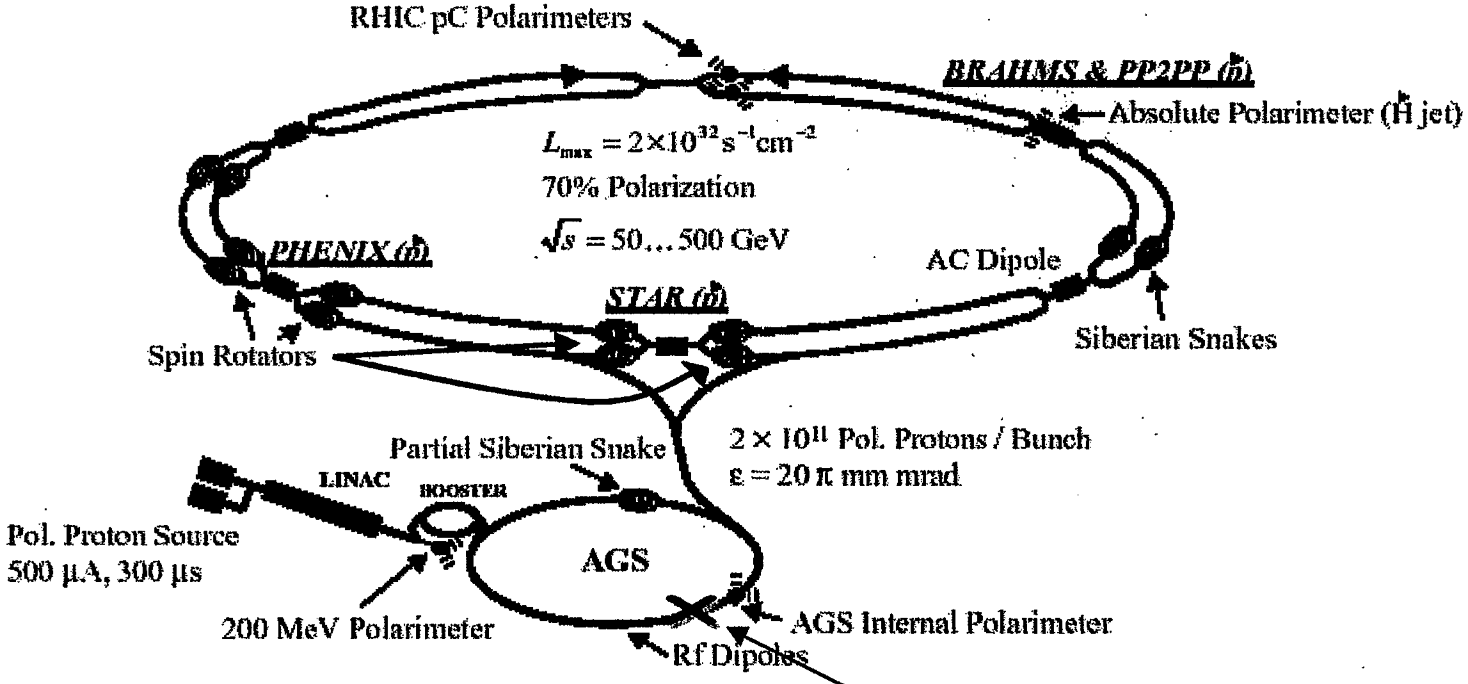
for
RHIC Spin Collaboration Meeting XII
RIKEN BNL Research Center

Update on the AGS CNI Polarimeter

- Overview of CNI polarimeter
  - Kinematics
  - Set up
  - Features
- AGS noise study update
- Schedule for installation and operation

Jeff Wood, UCLA
for the
AGS Polarimeter Group

RHIC Spin Layout



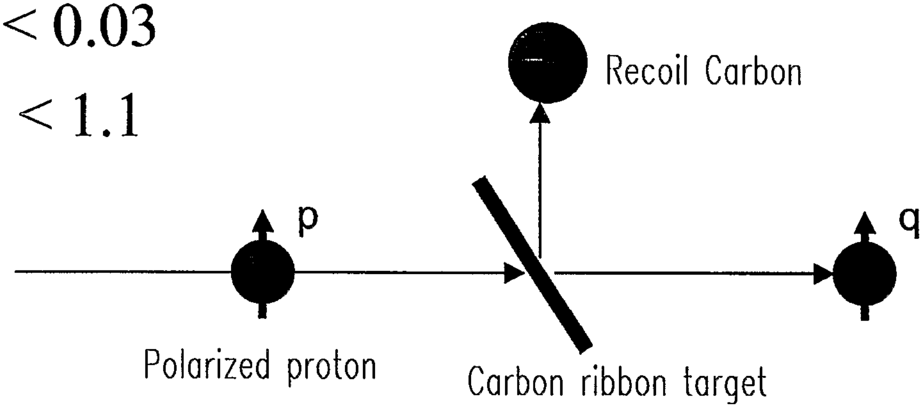
New AGS pC CNI Polarimeter

Kinematics of pC CNI Polarimeter

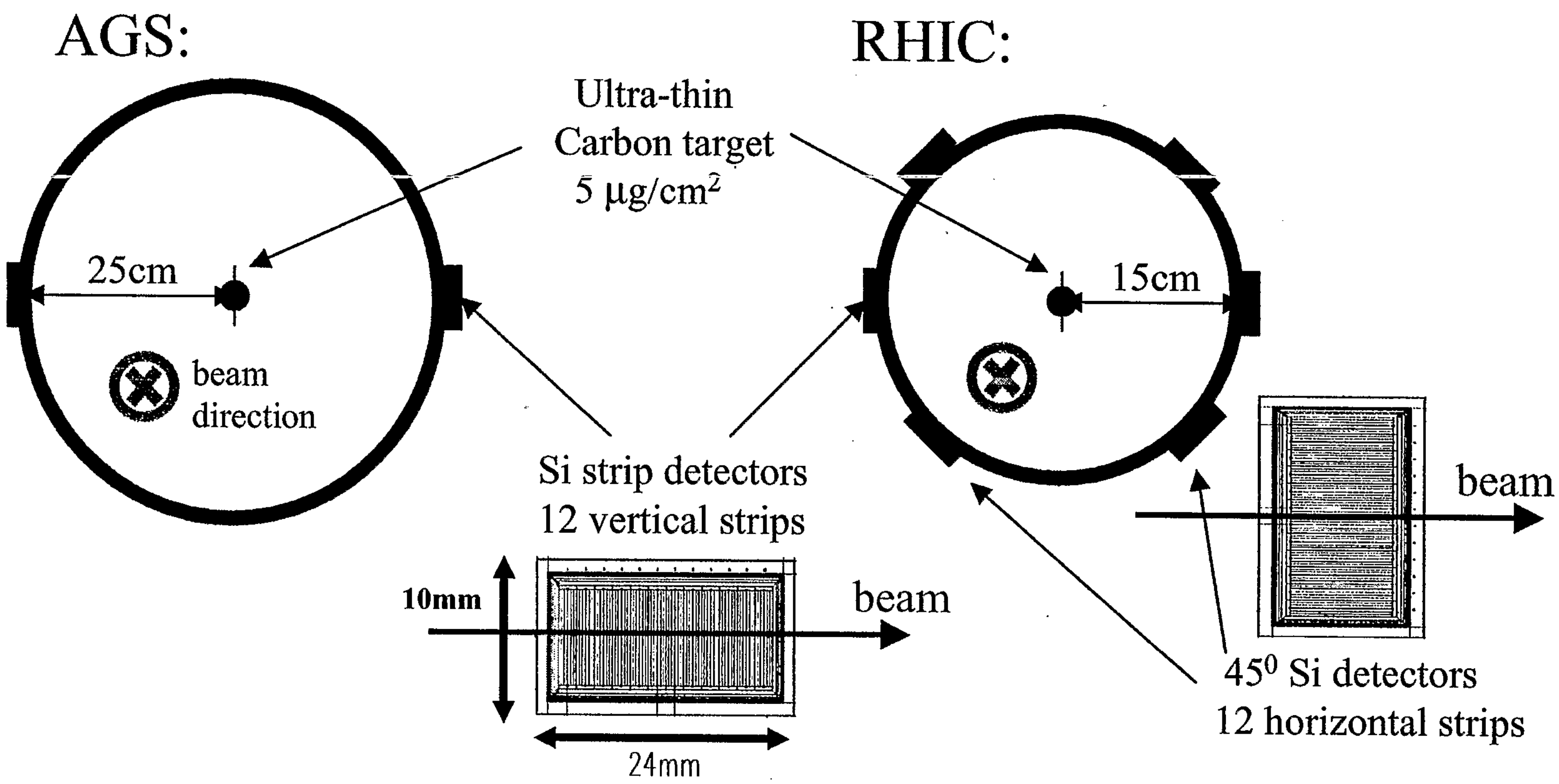
pC elastic scattering in the Coulomb-Nuclear Interference (CNI) region

- $A_N \propto Im(\phi^{h}_{non-flip} \times \phi^{em*}_{flip})$
- Measure recoil Carbons at ~90 deg.
- Calculate left-right asymmetry
- Kinematic range:
  - $0.003 < -t \ (GeV/c)^2 < 0.03$
  - $0.1 < T_{recoil\ C} \ (MeV) < 1.1$
  - $60 < tof \ (ns) < 170$

$-t = (p - q)^2$



Experimental Setup



AGS:

RHIC:

Ultra-thin
Carbon target
5 μg/cm^2

25cm

15cm

beam
direction

Si strip detectors
12 vertical strips

10mm

24mm

beam

beam

45^0 Si detectors
12 horizontal strips

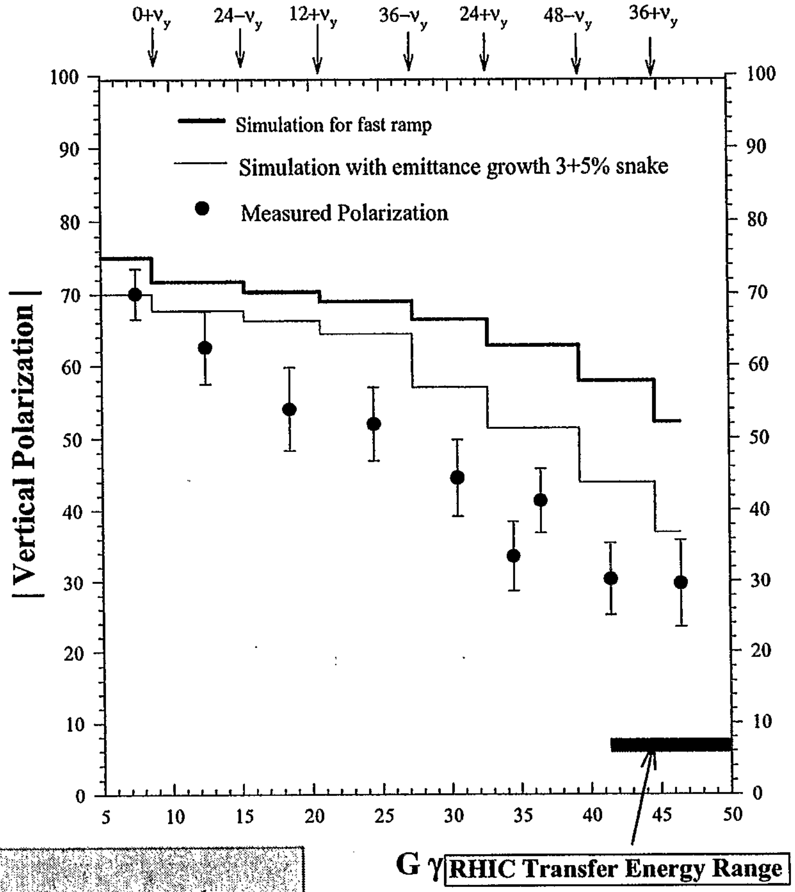
- thin carbon target is moved into the beam for measurements
- AGS target width: 600 μm RHIC: 5 μm

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.

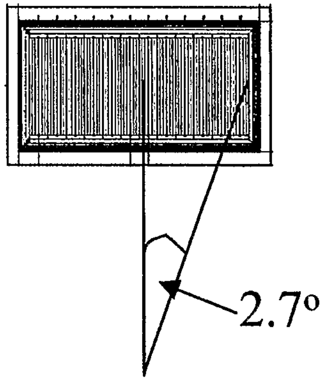
Blue line: Simulation with fast ramp rate and more tune separation at 36+ ν_y and good betatron tunes for 48-ν_y.



New polarimeter is expected to help avoid polarization losses

New AGS CNI Polarimeter will help

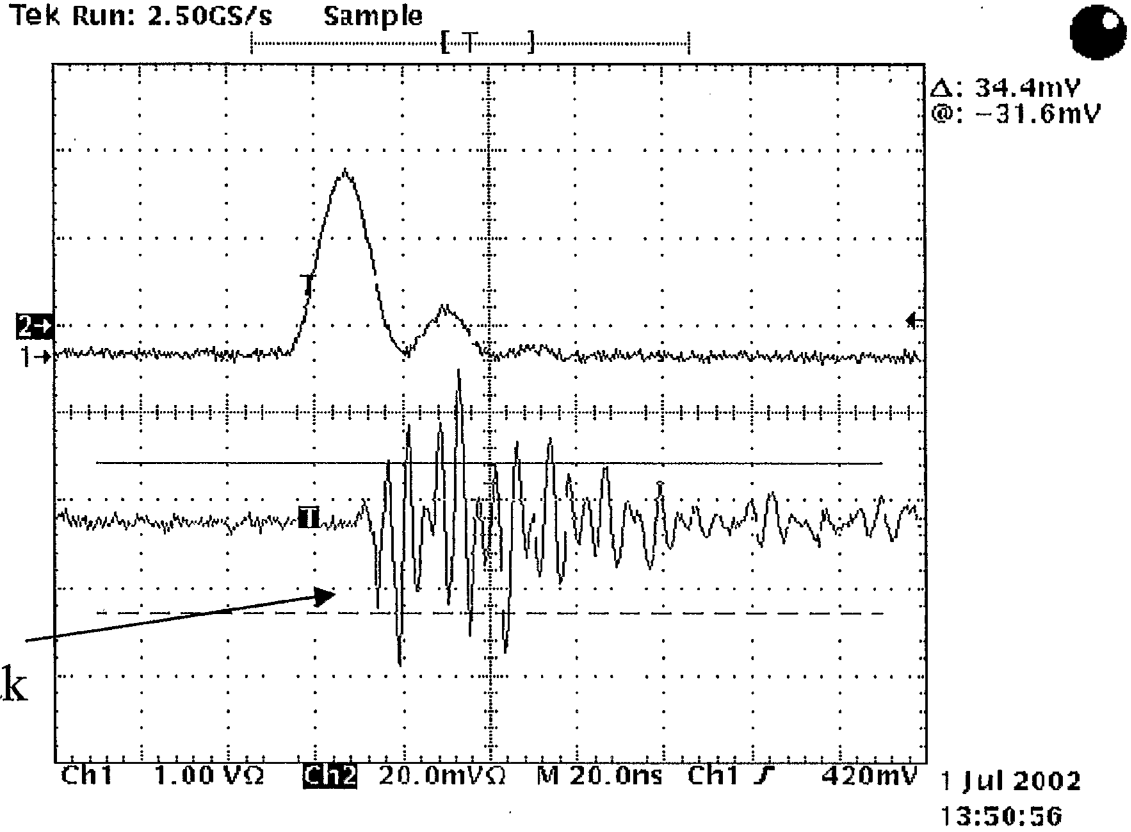
- Fast feedback for machine tuning
  - No dead time
  - ~1M events/s (with 6 bunches in AGS)
- Ability to measure during the ramp
  - Can measure 2 ms bins with several ramps
- Detector acceptance throughout AGS momentum range ($2.27 < p_{beam}$ (GeV/c) < 24.32)



Acceptance:
$90^{\circ} +/- 2.7^{\circ}$
Worst case recoil angle:
$\theta_{recoil} = 88^{\circ}$
(at p=2.27, -t=0.03)

Update on AGS Noise Study

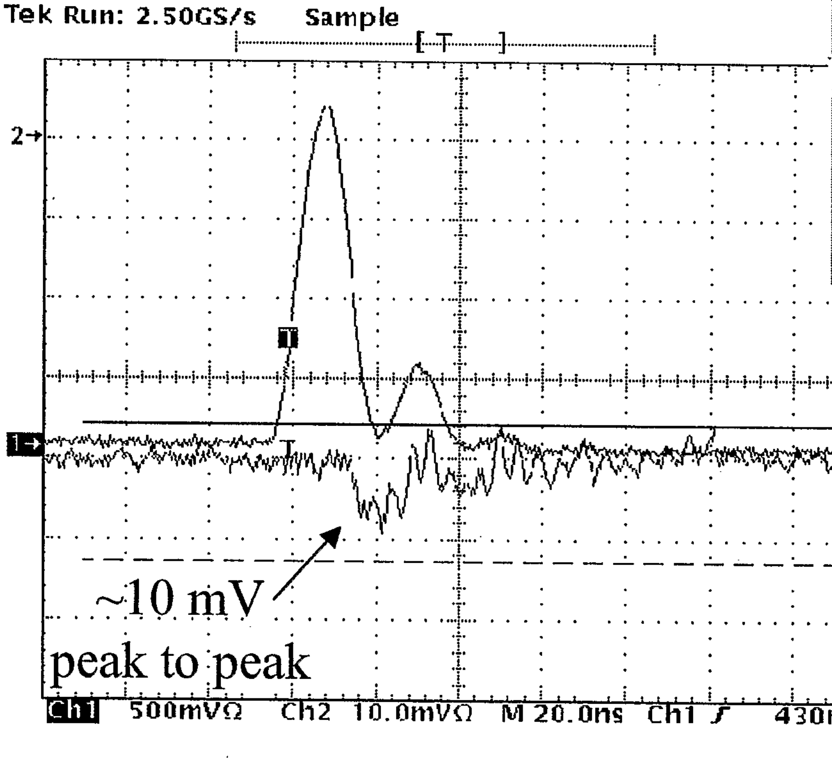
- Reflection signal from passing bunches seen in RHIC and AGS
- Pulsed wire tests
  - Current pulse sent through chamber
  - Signal induced on detector



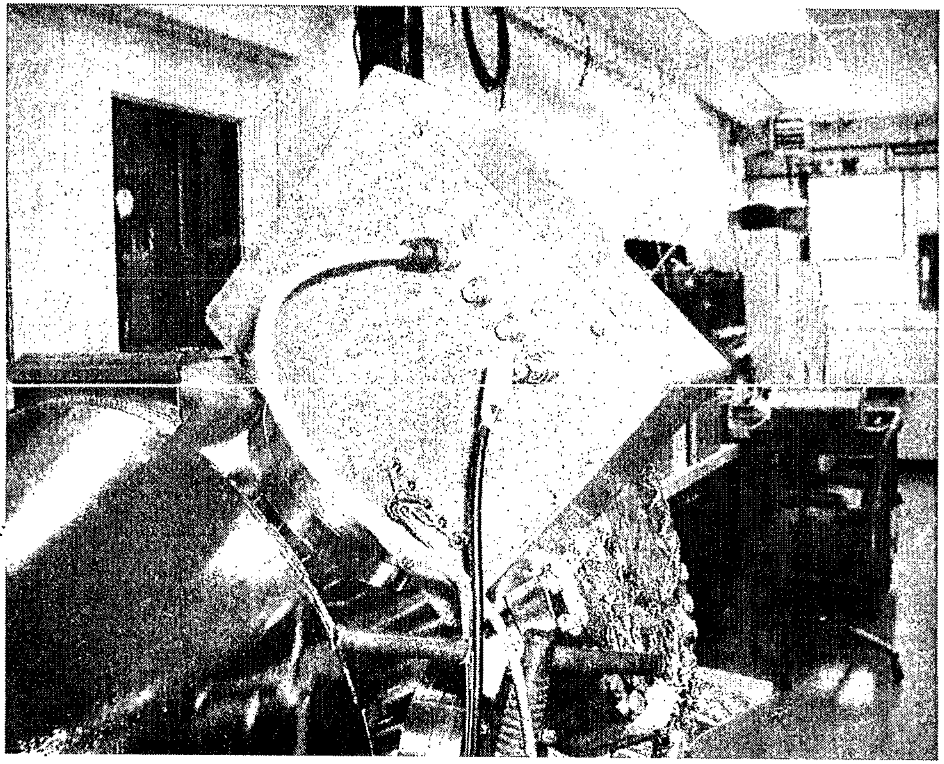
~60 mV
peak to peak

Shielding Box

Addition of shield box reduces signal size



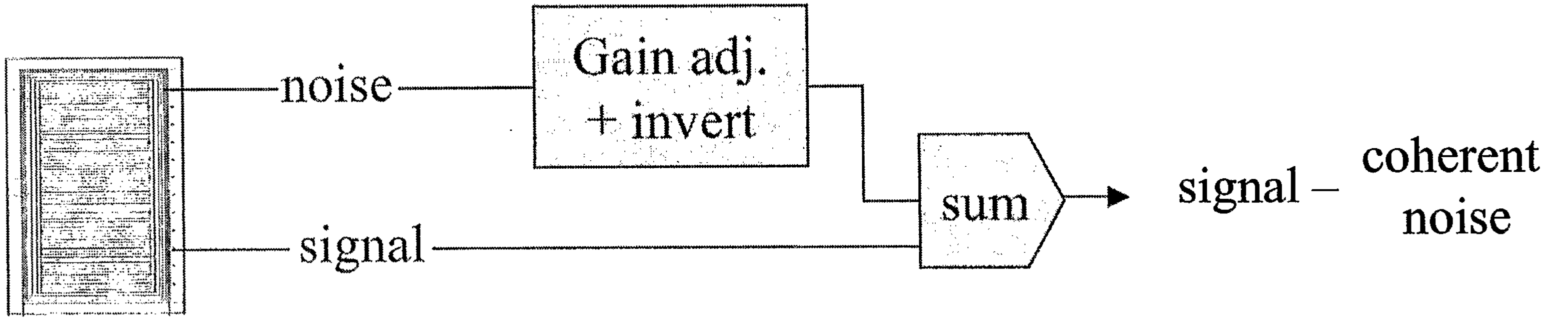
~10 mV peak to peak



- Effect on measurement is minor
  - signal persists for ~60 ns

RSC meeting 9/16/02

Noise Subtraction



noise

Gain adj.
+ invert

signal

sum

signal – coherent noise

- Build a new module based on experience from E950

  Or
- Use WFD – if possible

Noise difference between left and right
may cause problems

Installation Schedule

First beam in AGS scheduled for 10/15

- Installation of chamber must be complete
  - Chamber itself – motor tests complete 9/15
  - Detectors – ready
  - Preamps – arriving end of Sept.
  - Cables – pulled first week in Oct.
  - Targets – delivered from IUCF by end of Sept.

Commission/Operation Schedule

- Set up DAQ
  - New WFD modules – arrive mid-Nov.
  - Program WFDs – Nov./Dec.
  - Shapers, Bias Volt. Supply, etc. – in hand
- May try dC scattering during RHIC commissioning in Dec.
- First pol. p in AGS – Jan.

Summary

- AGS CNI pol. will provide fast feedback for machine tuning
  - Minimize polarization loss
- Noise studies look promising
- Installation by 10/15
- Polarized p beam in Jan.

Recogging: Technical Details

Please see summary

M. Brennan, BNL
September 16, 2002

for
RHIC Spin Collaboration Meeting XII
RIKEN BNL Research Center

Frequent Recogging: Effects on the Beam

W. Fischer, BNL
September 16, 2002

for
RHIC Spin Collaboration Meeting XII
RIKEN BNL Research Center

FREQUENT RECOGGING: EFFECTS ON THE BEAM

Wolfram Fischer

BROOKHAVEN
NATIONAL LABORATORY

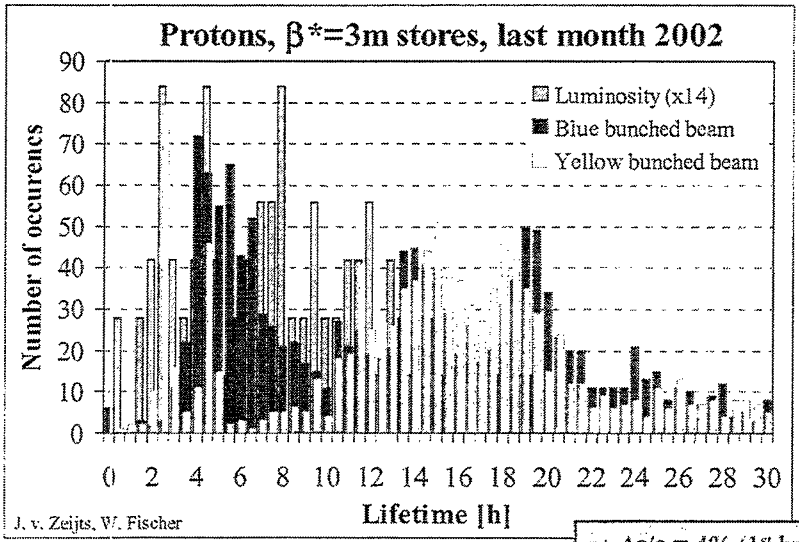
RHIC Spin Collaboration Meeting
19 September 2002

Contents

Introduction

- Assumptions:
  - Proton beams at $\gamma = 260$, 56(112) bunches
  - $N_b = 10^{11}$, $\varepsilon_N = 20\mu m \rightarrow \xi_{beam\text{-}beam} = 0.0037$ / IP
  - Store length of 7 hours
  - Recogging (worst case)
    - Every 2 min
    - By 6(3) buckets
- Expect adverse effects on:
  - Integrated luminosity Ldt
    → try to estimate $\Delta Ldt = (Ldt)_{recogging} / (Ldt)$
  - Polarization (→ A. Luccio, V. Ptitsyn, V. Ranjbar)

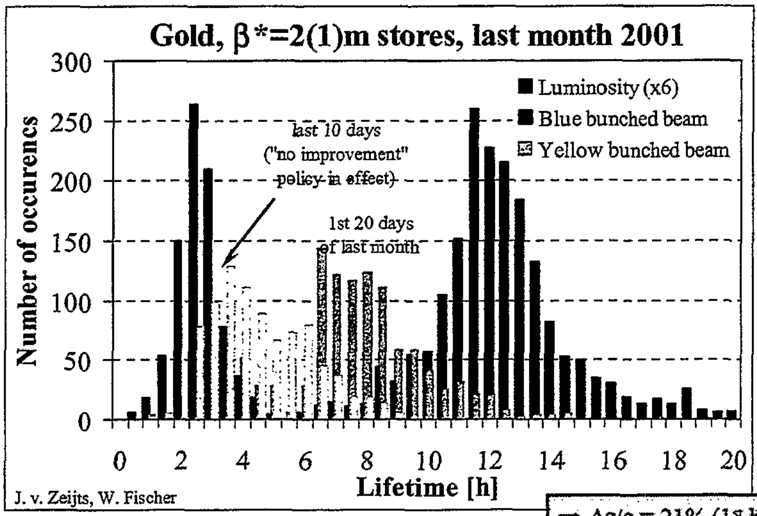
Run 2001 lifetimes – p



J. v. Zeijts, W. Fischer

⇒ $\Delta\varepsilon/\varepsilon = 4\%$ (1st hour)
rms = 5%

Run 2001 lifetimes – Au



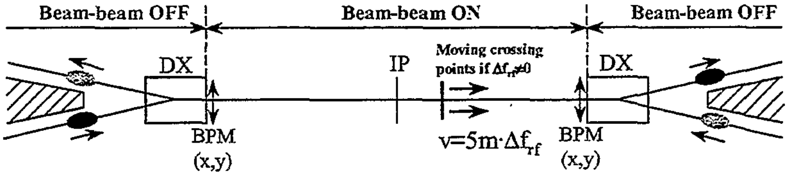
J. v. Zeijts, W. Fischer

⇒ $\Delta\varepsilon/\varepsilon = 21\%$ (1st hour)
rms = 13%

Wolfram Fischer

Cogging effects

- Cogging moves the collision points longitudinally
- Beyond DX magnets and with crossing angles (intentional or unintentional) transverse beam separation changes
  → Transverse tunes change (beam-beam interaction)



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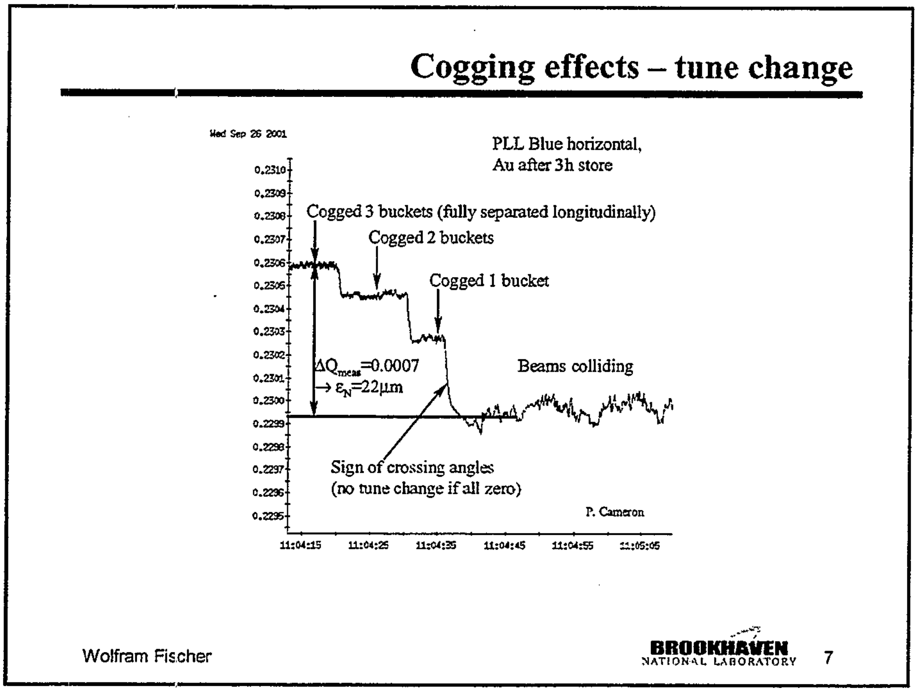

Cogging effects – tune change

PLL Blue horizontal,
Au after 3h store

Cogged 3 buckets (fully separated longitudinally)

Cogged 2 buckets

Cogged 1 bucket

ΔQ_{meas}=0.0007
→ ε_N=22μm

Beams colliding

Sign of crossing angles
(no tune change if all zero)

P. Cameron

Wolfram Fischer

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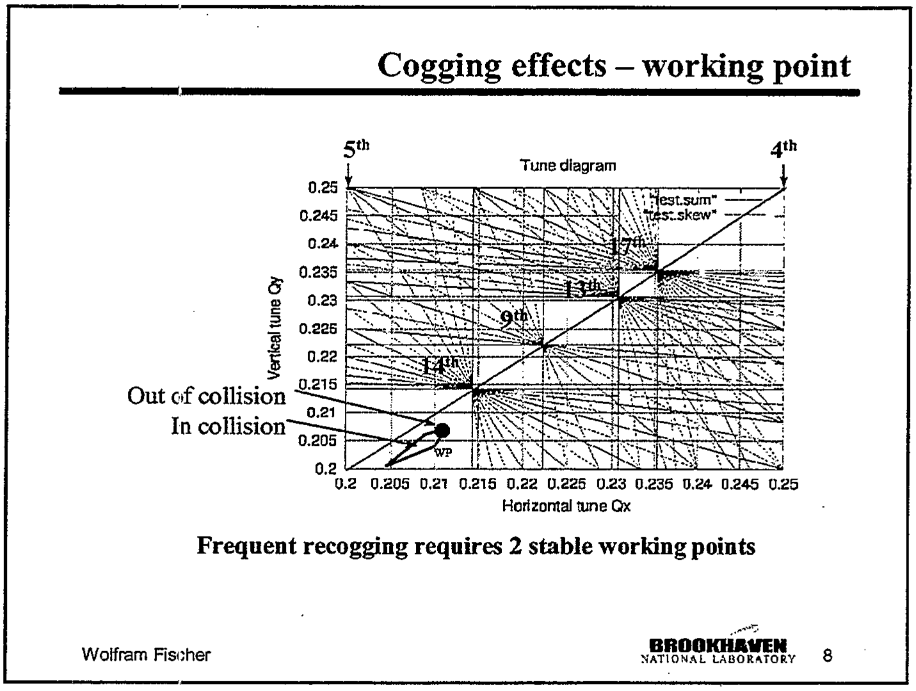

Cogging effects – working point

Out of collision

In collision

Frequent recogging requires 2 stable working points

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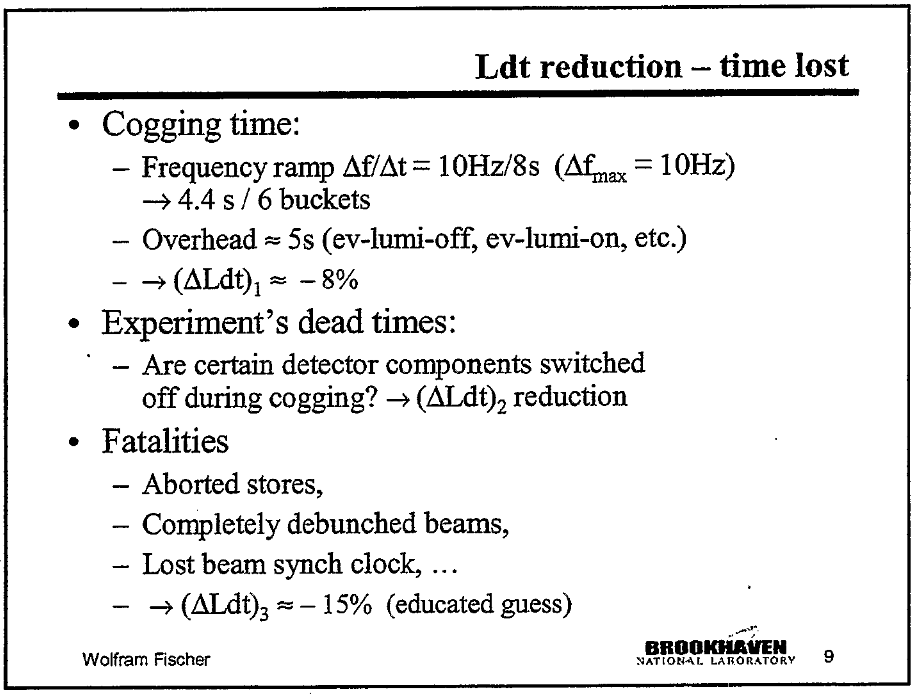
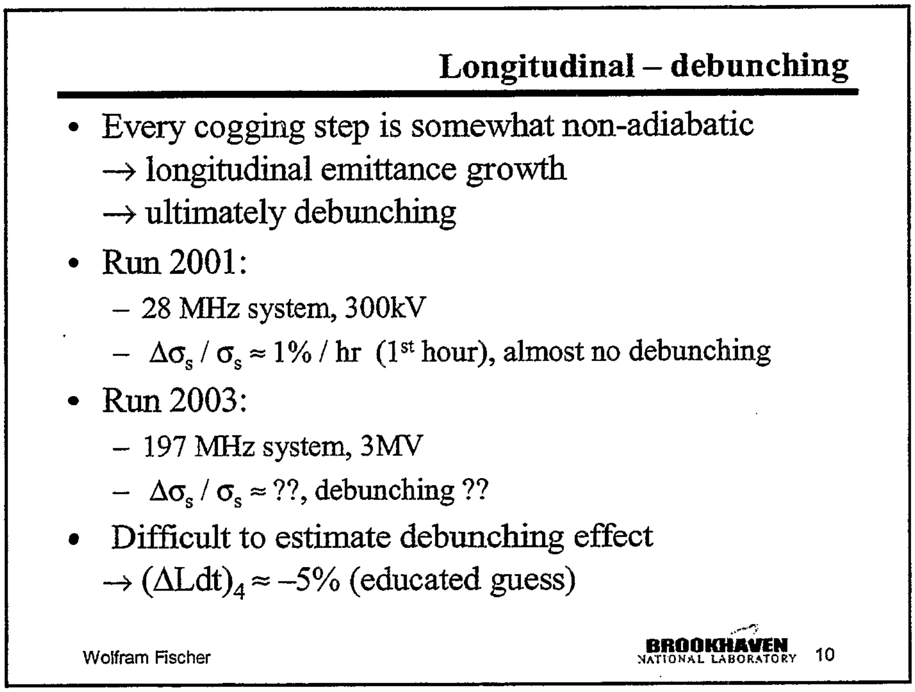


Ldt reduction – time lost

- Cogging time:
  - Frequency ramp $\Delta f/\Delta t = 10\text{Hz}/8\text{s}$ ($\Delta f_{max} = 10\text{Hz}$) → 4.4 s / 6 buckets
  - Overhead ≈ 5s (ev-lumi-off, ev-lumi-on, etc.)
  - → $(\Delta \text{Ldt})_1 \approx -8\%$
- Experiment's dead times:
  - Are certain detector components switched off during cogging? → $(\Delta \text{Ldt})_2$ reduction
- Fatalities
  - Aborted stores,
  - Completely debunched beams,
  - Lost beam synch clock, …
  - → $(\Delta \text{Ldt})_3 \approx -15\%$ (educated guess)



Longitudinal – debunching

- Every cogging step is somewhat non-adiabatic
  → longitudinal emittance growth
  → ultimately debunching
- Run 2001:
  - 28 MHz system, 300kV
  - $\Delta\sigma_s / \sigma_s \approx 1\%$ / hr (1st hour), almost no debunching
- Run 2003:
  - 197 MHz system, 3MV
  - $\Delta\sigma_s / \sigma_s \approx$??, debunching ??
- Difficult to estimate debunching effect
  → $(\Delta \text{Ldt})_4 \approx -5\%$ (educated guess)

Transverse – luminosity lifetime

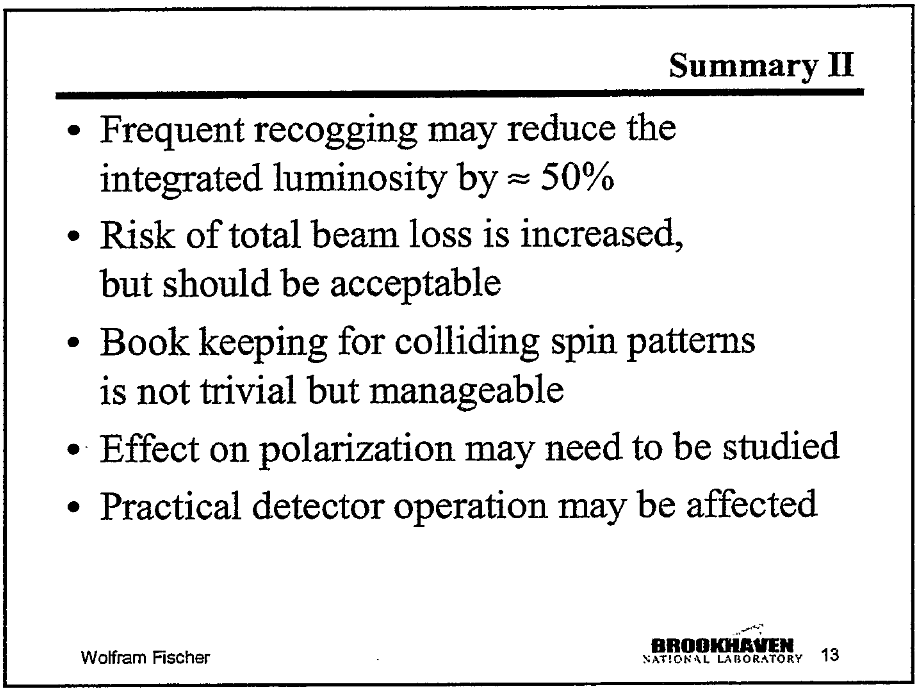
- Run 2001:
  - Small tune changes (of order $\sim\xi$) could result in dramatic changes in beam lifetime with $\beta^*=2(1)$m lattice (Yellow)
- Run 2003:
  - Expect beam lifetime improvements for Run 2002 with nonlinear IR correction
  - Assume 30% beam lifetime reduction in uncogged state $I(t) = I_0 \exp(T_1/\tau_1)\exp(T_2/\tau_2) \ldots \rightarrow (\Delta Ldt)_5 \approx -10\%$
  - Emittance growth from recogging, difficult to estimate → $(\Delta Ldt)_6 \approx -5\%$ (educated guess)

Summary I

Effect	**(ΔLdt)**
Cogging time	– 8%
Fatalities	– 15%
Debunching	– 5%
Beam lifetime	– 10%
Emittance growth	– 5%
Total	**– 65%**

$$(\Delta Ldt)_{tot} = \Pi\ [1 - (\Delta Ldt)_i]$$

Not considered:
- Additional experiments dead time for cogging
- Loss in polarization



Summary II

- Frequent recogging may reduce the integrated luminosity by ≈ 50%
- Risk of total beam loss is increased, but should be acceptable
- Book keeping for colliding spin patterns is not trivial but manageable
- Effect on polarization may need to be studied
- Practical detector operation may be affected

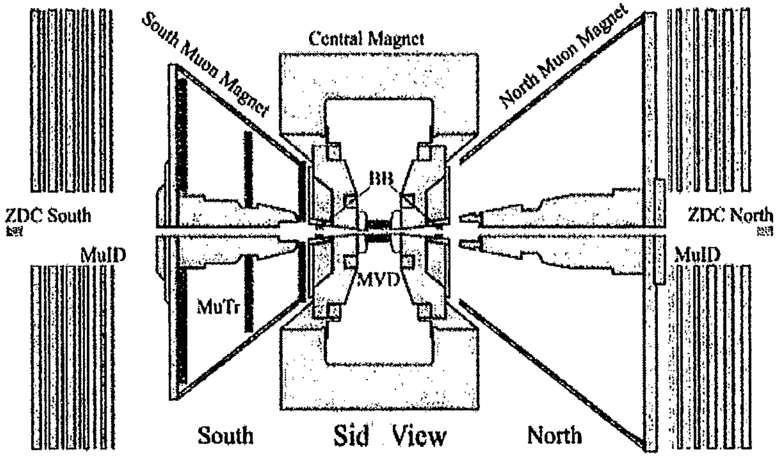
Wolfram Fischer

BROOKHAVEN NATIONAL LABORATORY

Relative Luminosity Analysis from PHENIX

RIKEN BNL Research Center
KAWABATA TAKAHIRO

Instruments



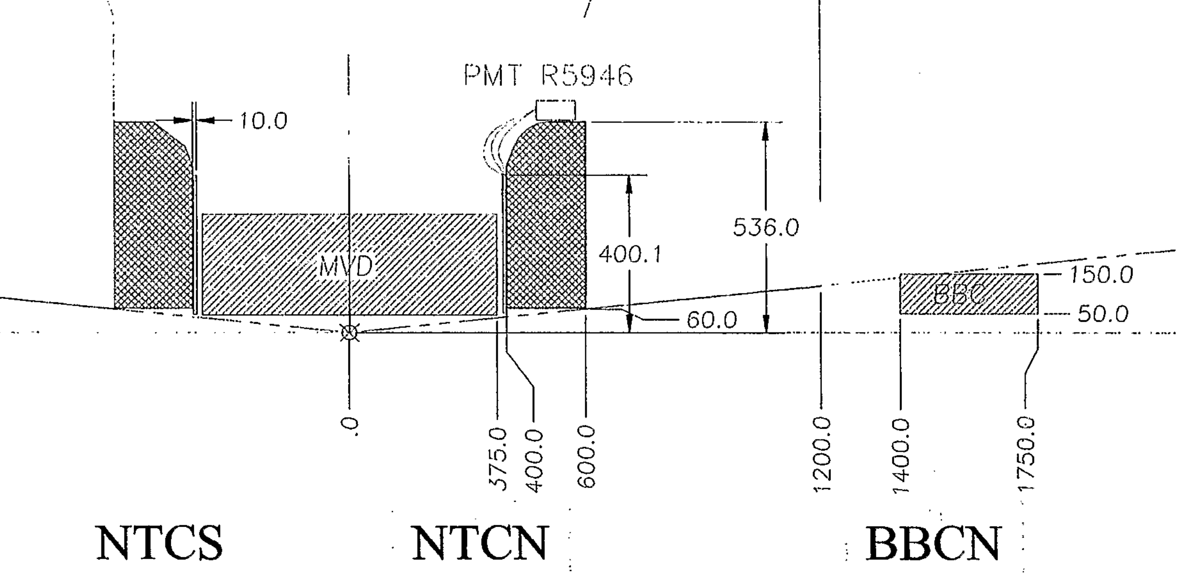
GL1P scaler

- crossing-by-crossing scalers
  for 120 crossings
  (60 crossings in run 2)
- live time only
- consists of 4 channels

M.B. (BBCLL1⊕NTCwide)
$\text{NTC}_{\text{narrow}}$ / BBCLL1 / ZDC (N&S)

Luminosity monitors

BBCLL1 (|Z| < 75 cm)
NTC_{wide}
$\text{NTC}_{\text{narrow}}$ (|Z| < 40 cm)
ZDC



Relative luminosity

- no critical item for A_N measurement in run-2

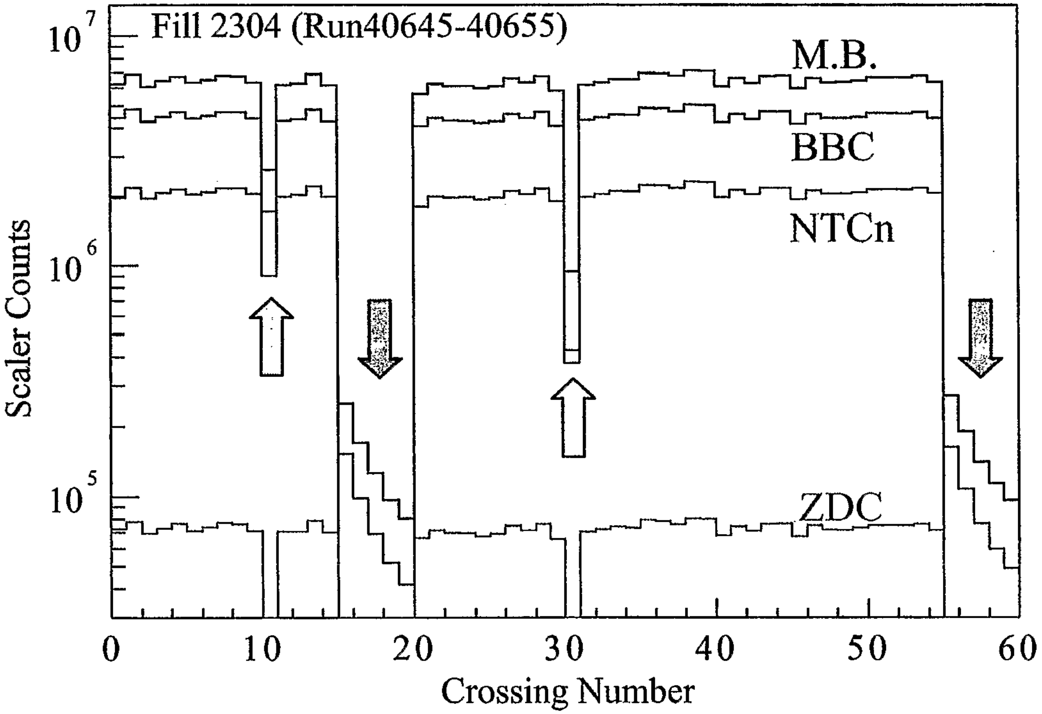
$$A_N = \frac{1}{P} \frac{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} - \sqrt{N_L^{\downarrow} N_R^{\uparrow}}}{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} + \sqrt{N_L^{\downarrow} N_R^{\uparrow}}}$$

- 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 stability of each luminosity monitor ?
  - which is the best ?

Scaler Counts



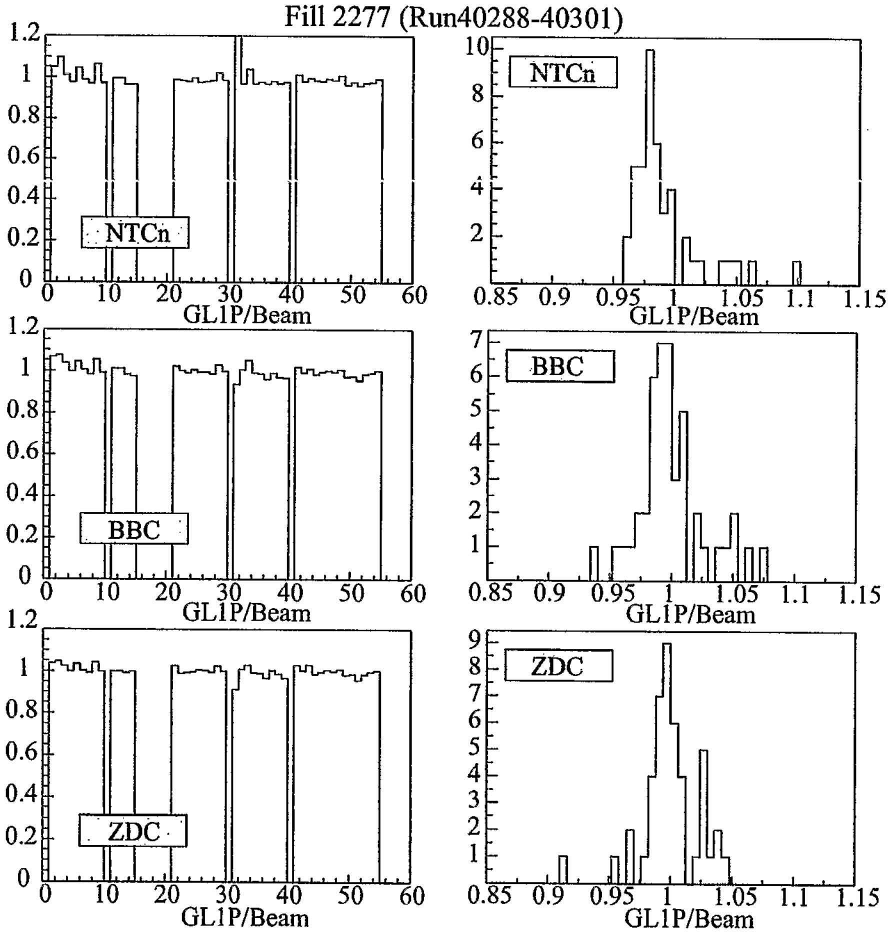
GL1P counts vs Crossing number

- #10 and #30 … large emittance
- #15-19 … abort gap (Yellow)
- #55-59 … abort gap (Blue)

Only NTC counts beam-gas events.

ZDC has low statistics.

Specific Luminosity

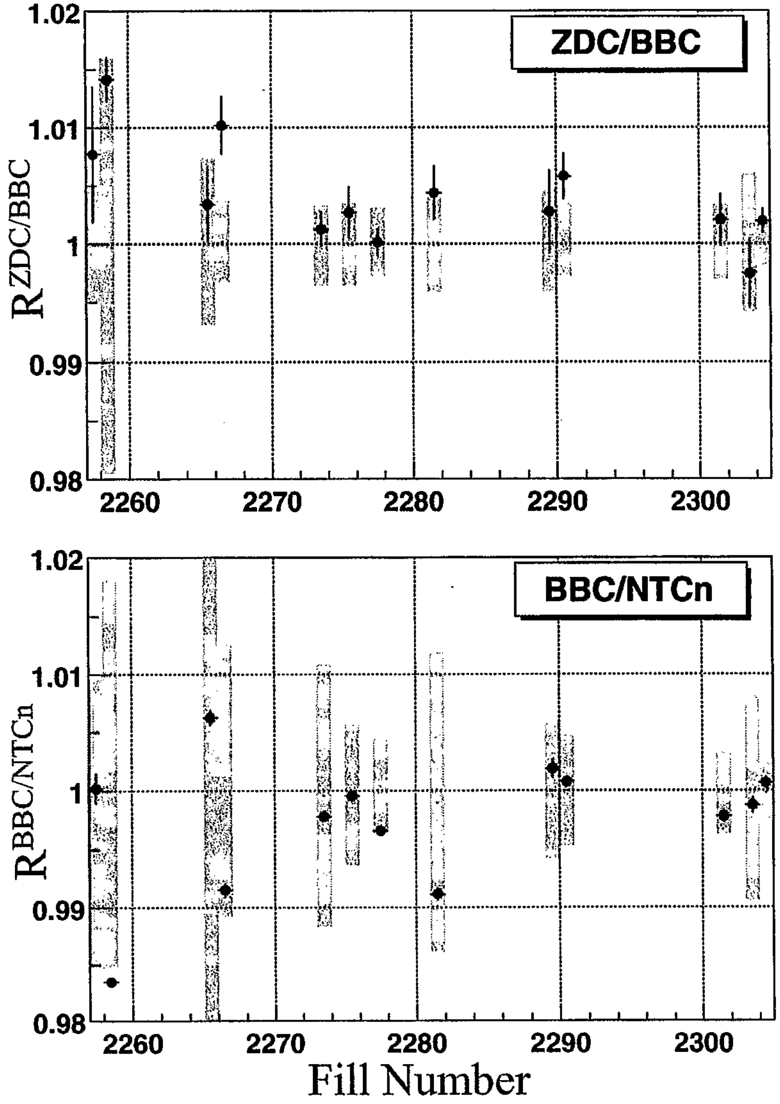


- •Specific Luminosity

$$\text{(specific luminosity)} = \frac{\text{(number of counts)}}{\text{(Beam intensity)}}$$

- •Normalized and plotted as
  a function of crossing number
- •Specific luminosity fluctuates by 2-5%.
- •NTCn is less stable.
  - only NTC counts beam-gas events.
- •ZDC has low statistics.

Systematic Error on Relative Luminosity



Ratio between GL1P channels must be one.

$$R^{XY} = \frac{L^X_{++}/L^X_{+-}}{L^Y_{++}/L^Y_{+-}}$$

$(X, Y = M.B., BBC, NTC_n, ZDC)$

- Shown with the statistical errors by solid circles and lines.

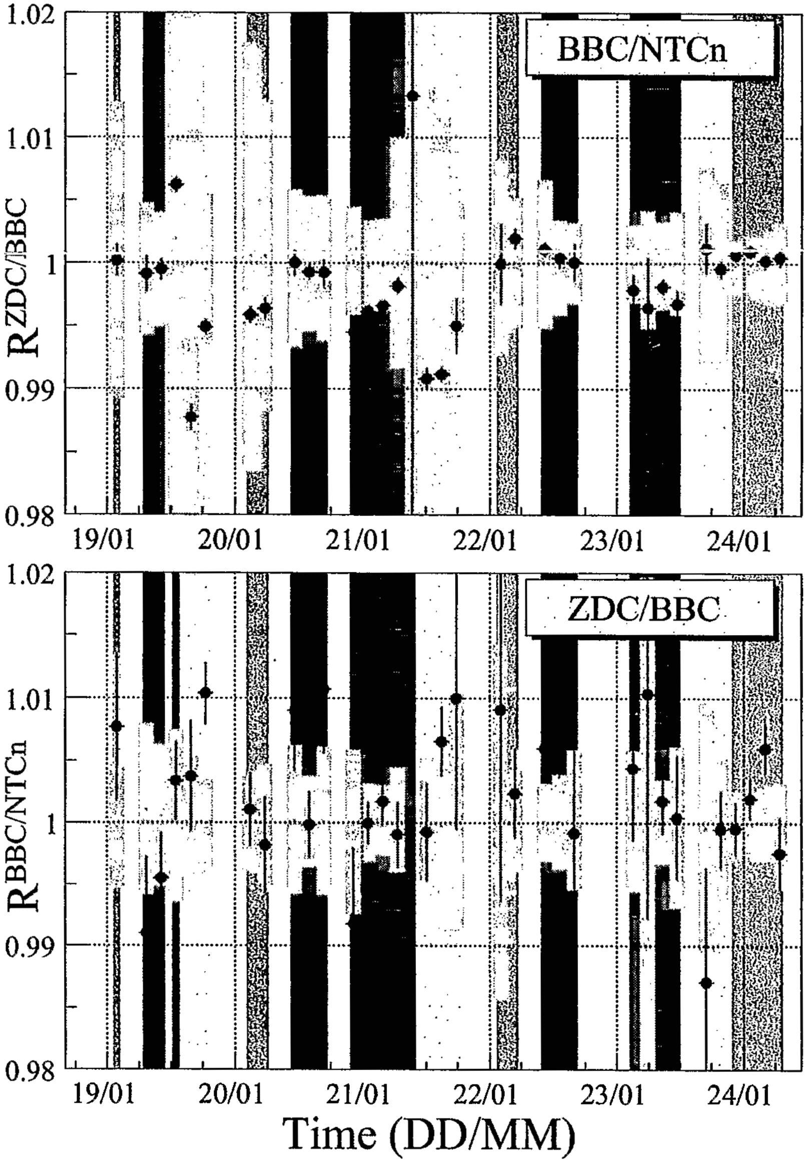
Evaluate R^{XY}_{AB} for random classification.

- All bunches were randomly sorted into Group A and B.
- Repeat the calculation 400 times.
- Shown by shaded area.

Systematic error has fill dependence.

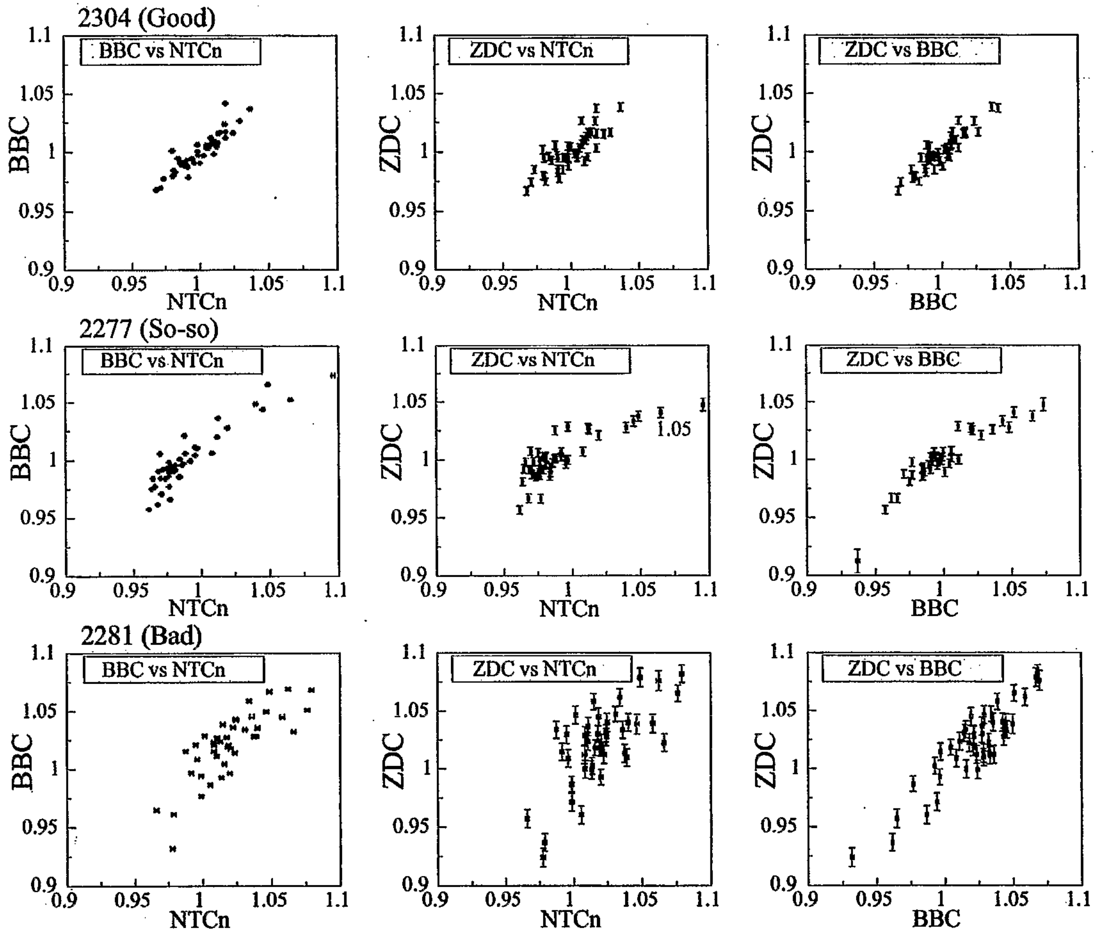
- ~0.3% for good fill.
- Improve by adding all fills up to ~0.2%.

Time Dependence



- Spin relative luminosity R^{XY} is plotted as a function of time.
  - solid lines .. Statistical error
  - shaded region
    .. Systematic + Statistical
- Each point shows 10,000-sec time slot.
- Background colors indicate fills.
- R^{XY} has a fill dependence.

Correlation between Specific Luminosities



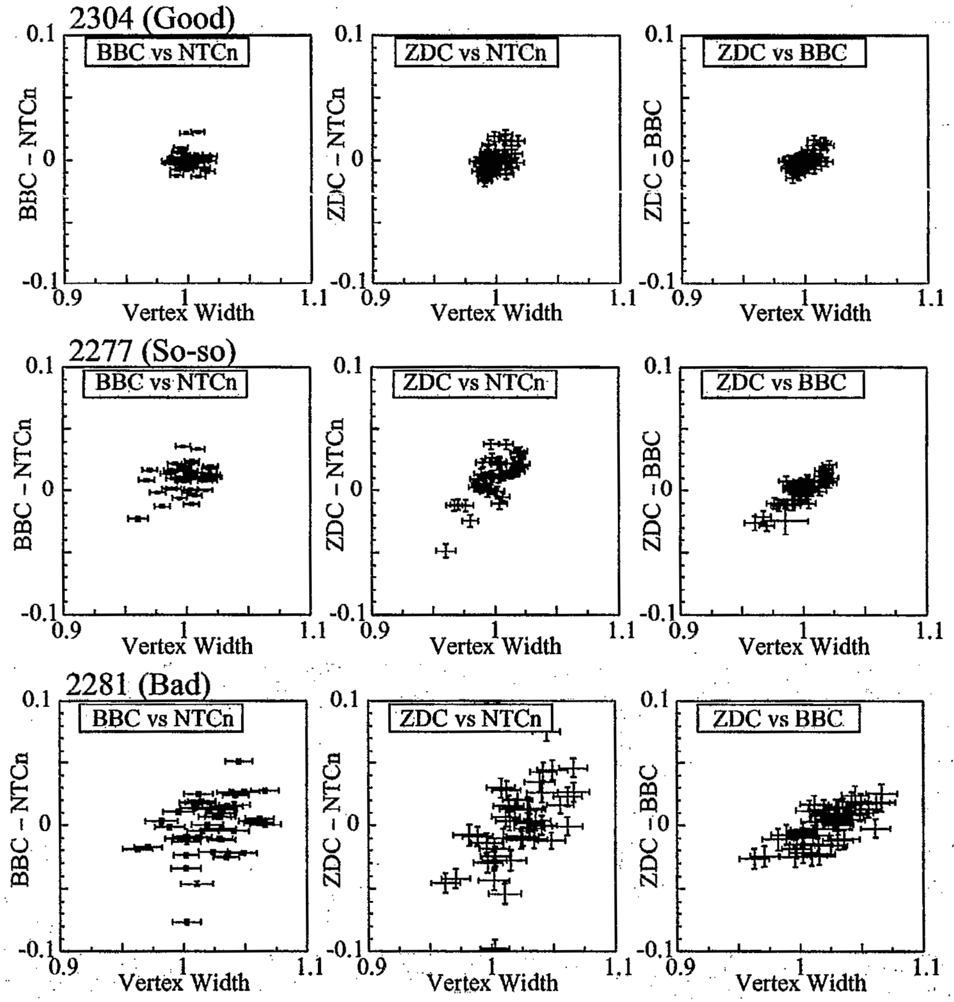
- Correlation between spe. lumi. are plotted.

$$(\text{specific luminosity}) = \frac{(\text{number of counts})}{(\text{Beam intensity})}$$

- Fluctuation of spe. lumi. is not important.
- Systematic errors depend on widths of loci.

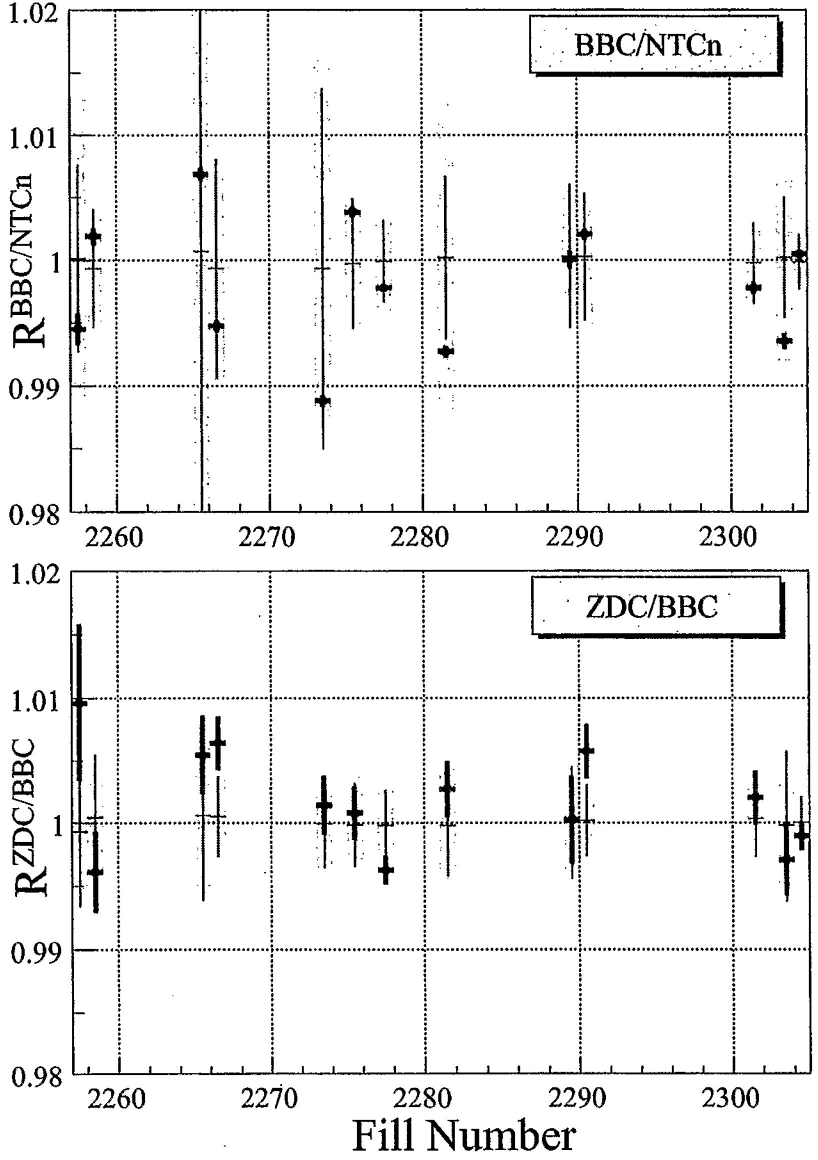
$$(\text{systematic error}) \propto (\text{spe. lumi. a}) - (\text{spe. lumi. b})$$

Dependence on Z-vertex width



- Differences in specific luminosities are plotted as a function of the Z-vertex wdith.
- Dependence on Z-vertex width is not clear.
- Bunch selection by Z-vertex width did not work well.

Bunch Selection



Several bunches with the bad spe. lumi. are excluded

- shaded region …. before the selection
- black line …. after the selection
- red line … statistical error
- solid circle … R^{XY}

Bunch sel. slightly improves bad fills, but not good fills.

Results on R^{XY} are ….

- NTCn/M.B.	…	1.0005 +/− 0.10%
- BBC/M.B.	…	0.9974 +/− 0.36%
- ZDC/M.B.	…	0.9981 +/− 0.37%
- BBC/NTCn	…	0.9969 +/− 0.41%
- ZDC/NTCn	…	0.9975 +/− 0.44%
- ZDC/BBC	…	1.0007 +/− 0.15%

by summing up Run40117-40655.

Summary

- GL1P data from PHENIX were analyzed for relative luminosity study.
- Systematic error has a fill dependence.
  - ~0.3% for good fill,
    0.15% for Run40117-40655
  - Small dependence on Z-vertex width
  - Slightly improved by bunch selection
- Procedure for fill diagnosis should be established.

RHIC Spin Collaboration Meeting XII

September 16, 2002

RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting XII
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RHIC Spin Collaboration Meeting XII
September 16, 2002
RIKEN BNL Research Center

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RIKEN BNL Research Center

RHIC Spin Collaboration Meeting XII

September 16, 2002

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

*****AGENDA*****

Morning Session

09:00 - 09:45	Machine Plans for Run03..	T. Roser
09:45 - 10:30	Update on the Source..	A. Zelenski
10:30 – 10:45	Coffee Break	
10:45 – 11:30	AGS Commissioning Plans for Run03..........................	L. Ahrens
11:30 – 12:15	Update on the AGS Polarimeter................................	J. Wood

12:15 Lunch

Afternoon Session

13:00 – 13:45	Recogging: Technical Details................................	M. Brennan
13:45 - 14:30	Recogging: Effect on the Beam..............................	W. Fischer
14:30 – 14:45	Coffee Break	
14:45 – 15:30	Relative Luminosity Analysis from PHENIX................	T. Kawabata
15:30 – 16:15	General Discussion about Experiment Needs for Run03...	All

~ are time shift possible?
~ do we have a plan for controlling the beam backgrounds?
~ 200 MHz rF, will it be operational?
~ special runs to cross check the AGS & RHIC polarimeters?
~ other questions?

Next Meeting ~ Tuesday, October 22, 2002 BNL Physics Bldg. 510, Small Seminar Room

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22 October 2002

A Summary of the RHIC Spin Collaboration Workshop

October 22, 2002

G. Bunce

This workshop, a monthly one day meeting to discuss the spin program, covered the ongoing analysis and presentations of data from the 2001/2 spin run, and preparations for the 2003 spin run.

For the ongoing analysis, many studies of the systematic errors in the polarimeter data have now been made, and we are close to deciding on a "standard" systematic error, to be used by experiments in articles on their results. Osamu Jinnouchi presented these studies. An important issue for the presentation of our results is the fact that the analyzing power of our RHIC polarmeter is not known at 100 GeV. The "standard" to use for absolute polarization at 100 GeV was discussed. It will be important to report cross sections as well as spin asymmetries. Cross sections require an absolute luminosity from vernier scans of one beam across the other. The status of analyzing these scans was given by Angelika Drees, and PHENIX studies for the cross section were presented by Sergei Belikov.

A major issue for the 2001/2 run was the low AGS polarization. We are preparing an AGS run to try to increase the polarization, and this is scheduled for January 2003. The RHIC spin run is scheduled for April-May 2003. Leif Ahrens discussed preparations for the AGS. A major difficulty last year was a slow ramp rate in the AGS, from using the backup power supply while the normal supply, from Siemens, was being repaired. The Siemens supply was tested and then connected to the AGS just after this meeting, so we expect we will have the faster ramp rate for the 2003 run. Also, a new CNI polarimeter is being installed for the AGS, which will allow fast and precise polarization measurements to give quick feedback to the polarization studies. There will be a workshop in Ann Arbor on the AGS polarization November 7-9.

Osamu Jinnouchi described improvements for the RHIC polarimeters for 2003, based on the studies of the 2001/2 data. An important addition is to be able to calibrate the energy response of the silicon detectors automatically. Last year, ^{241}Am alpha sources were installed and used, but only weekly because attenuators had to be inserted by hand for the calibration. The RHIC polarimeter data acquisition is based on a novel wave form digitizer (WFD) which is based on ADC chips used for laptop screens. The wave forms from the silicon strips are digitized every 2.4 ns and sent to an onboard FPGA Xilinx chip, the pulse height and time relative to the RHIC rf clock is obtained, a selection is made for carbon recoils, and the data is collected into histograms for each silicon strip and for each proton bunch. Satish Dhawan described the WFDs, which will be used also for the AGS polarimeter and for the polarized hydrogen jet experiment being prepared for 2004.

For the 2003 run, both STAR and PHENIX will run with longitudinal polarization, obtaining the first data sensitive to the gluon polarization in protons. These measurements will be from asymmetries corresponding to whether the helicities of the two beams are parallel or anti-parallel. To measure this asymmetry, we must normalize our data to the parallel and anti-parallel luminosities. These luminosities can be different for each crossing due to differences in the bunches—emittance and/or intensity. Mei Bai described plans for a spin-flipper which can reverse the polarization of one ring. This is very important for the experiments, since it flips the relationship between parallel and anti-parallel helicities for each crossing. We expect that the spin flipper should greatly reduce systematic errors in the measurements. We discussed the procedure—notifying the experiments, and changing the spin pattern broadcast by RHIC to the experiments. Polarimeter measurements will be taken before and after using the spin flipper. The steps involve detuning the Siberian Snakes in the ring we are flipping, applying the rf dipole at IP4 (the spin flipper), and then retuning the Snakes. The Snakes are slow devices, so that the time required will be minutes. We discussed leaving the Snakes detuned, and flipping only one ring. Although this would then take just seconds, we decided that it will be important to have all combinations of spin states for each crossing. We need to decide on the notification procedure.

Werner Vogelsang described new results from next to leading order calculations for our proposed measurements of gluon polarization, using jets and pions. A new paper has just been completed,

http://arxiv.org/abs/hep-ph/0211007

They find that the NLO spin results have very little dependence on the theoretical factorization scale, giving a more robust prediction from QCD.

There will be a review of the polarized jet experiment to measure the absolute polarization for RHIC, November 18-19. The next RHIC Spin Workshop will be in early December, but needs to be scheduled.

Status Report on the AGS Preparation

L. Ahrens, BNL
October 22, 2002

for
RHIC Spin Collaboration Meeting XIII
RIKEN BNL Research Center

22Oct02 RSC meeting L. Ahrens

Revisit my transparencies from last RSC meeting (additions: bold italics)

Schedule: 7 Oct 02 gold beam in Booster (Booster recommish)

DONE, Worked very well

15 Oct 02 gold/ deuterium beam in AGS with Siemens Motor/Generator

In Process. Started with Westinghouse, but Siemens to come this week. Au in AGS, d in Booster. Plan: d in AGS starting this Saturday, 26Oct for a few days.

4 Nov 02 Iron in AGS (NASA biology run)

21Nov 02 Injectors setup for RHIC injection

1 Dec 02 RHIC Blue cold, deuterium into Blue. fill, fill, fill or fill and ramp, fill and ramp. no resting spaces.(but deuterium always in the AGS, and most of that beam doesn't go into RHIC. Probably could be available as another User – if Operations has any space in their head.

Yellow – gold into Yellow. probably no deuterium for a while. Then working on collisions.

mid Dec 02 Polarized protons in Linac, into HEBT to the 200 MeV polarimeter.

January 03 RHIC into physics runs (d,Au), injectors "mode switch" to polarized protons during stores. Plan for 3 (is there a constraint?) weeks of running in this pattern. This is the pre-run run.

Issues:

Linac:

200 MeV operation:

access into HEBT competes with Au/d operation (?)

a proposal to redefine boundaries to Radiation Areas is being presented to the RSC (that's the radiation safety committee) which would make this access more convenient. So work in progress.

measure 200 MeV polarization with 7Hz source pulse rate vs historic slow (1 Hz) pulsing.

(Anatoli Zelinsky +) Need the fast repetition rate if want to fill AGS with 6 bunches – for the internal polarimeter.

"commission" the 750 KeV chopper with beam from the polarized source. (Zelinski, Alessi, Brennan, Brisco, Zeno)

(issue: longitudinal emittance – last year ran Booster at h=2, two bunches accelerated, equally populated with beam and used only one of these, just to get a smaller beam in longitudinal phase space (.7 eVsec/n). The chopper which 'chops' the beam in time as it enters the Linac was ineffective for beam coming from the polarized source. This was (is) not understood. If the beam can be chopped, we have better control over the longitudinal phase space. Go back to h=1 operation. But also need smaller momentum spread out of Linac. Alessi has a program to attack this – at least gaining better understanding of the situation – diagnostics commissioning etc.

Booster:

Booster is the "easy" measurer of the longitudinal quality of the Linac beam. Can we inject into Booster before January?

Some serious orbit distortions possible due to the BAF construction. Reopens the possibility of losing polarization in Booster. (Equilibrium orbit measuring system being commissioned.)

Equilibrium Orbit measuring system still being put together. This is an 'unessential' diagnostic system, so struggles for priority.

The test will be polarization at AGS injection (1.5 GeV kinetic or slightly higher). Polarization should equal 200 MeV measurement. Old polarimeter.

Booster tune control, tune measurements all required for BAF commissioning so should already be there. Standard drill to optimize – or show degradation if move (4th 5th orbit harmonics, vertical betatron tune) away from optimal.

AGS:

changes:

1) back to the higher acceleration rate of the Siemens motor-generator set.
2) new magnet hardware for the (ac dipole/tune meter) both vertical and horizontal.

Tune Meter/ ac Dipole installed (pic), not yet powered. AC dipole has two remotely switchable frequency choices. (Mei)

3) CNI Polarimeter

CNI polarimeter installed in AGS (pics). System about ready to comment on the issue of beam noise. (Haixin)

any immediate acceleration strategy changes?
nope. Set up as in last Siemens (higher acceleration rate) run (2000) – well nearly (betatron tune space).

comments:

unpolarized work:

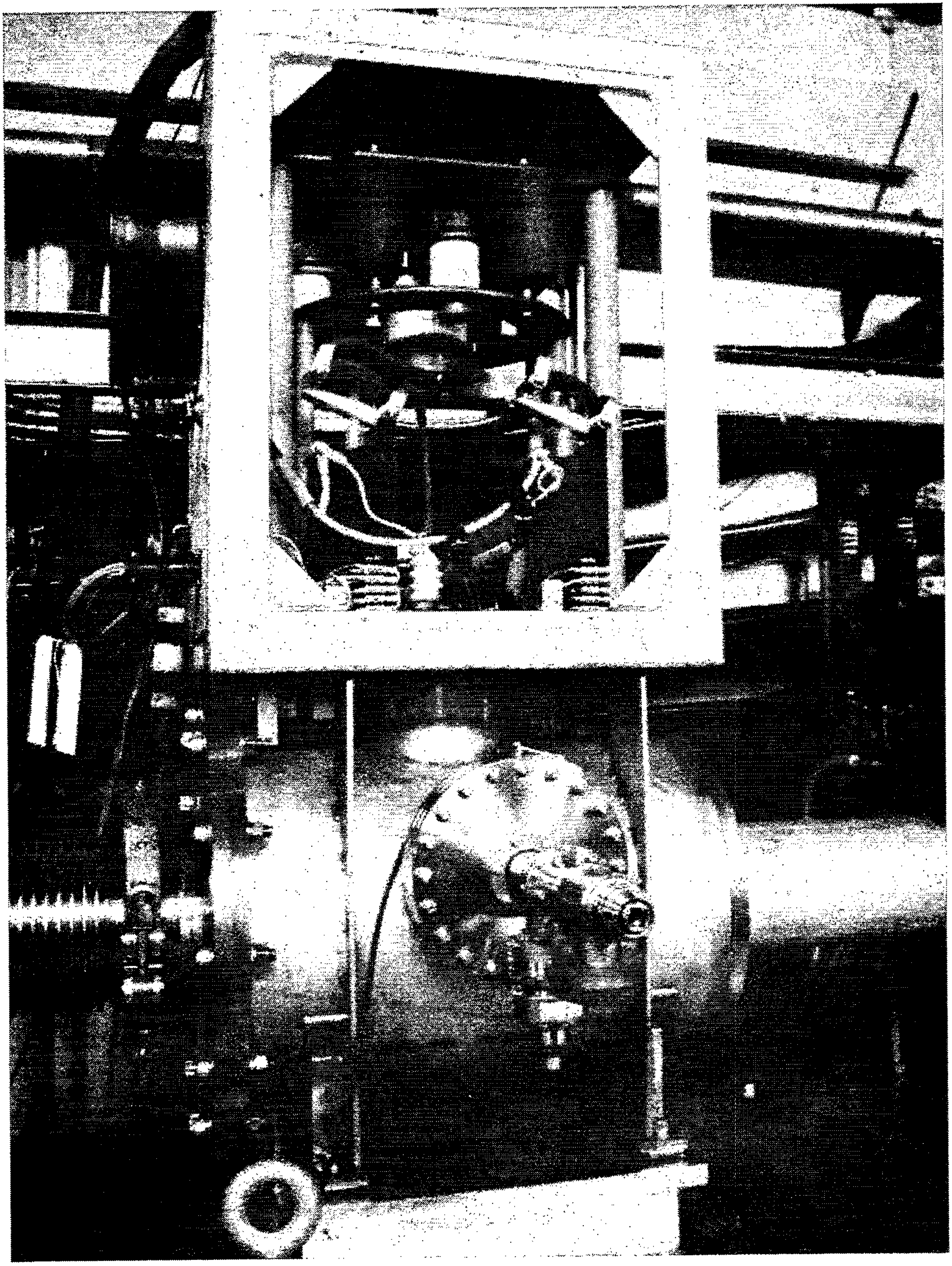
satisfactory calibration of the (magnetic field measuring system / AGS average orbit measurement) last run. This cal should be redone during the RHIC setup period, and we should set the ac dipole intervals with the best confidence yet – not that we won't try to check with timing scans.

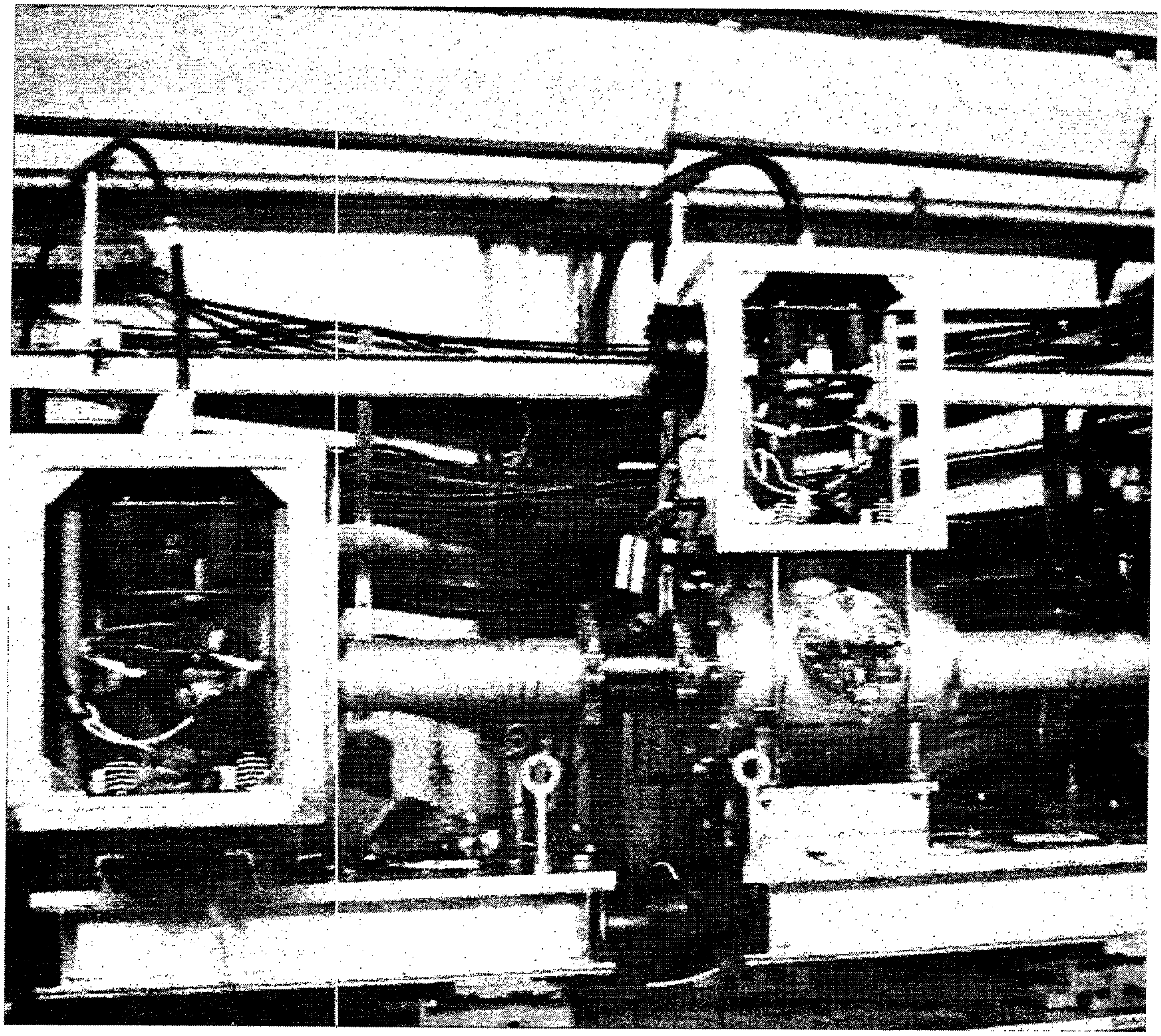
Equilibrium orbit correction – nothing new, but simplify if possible.

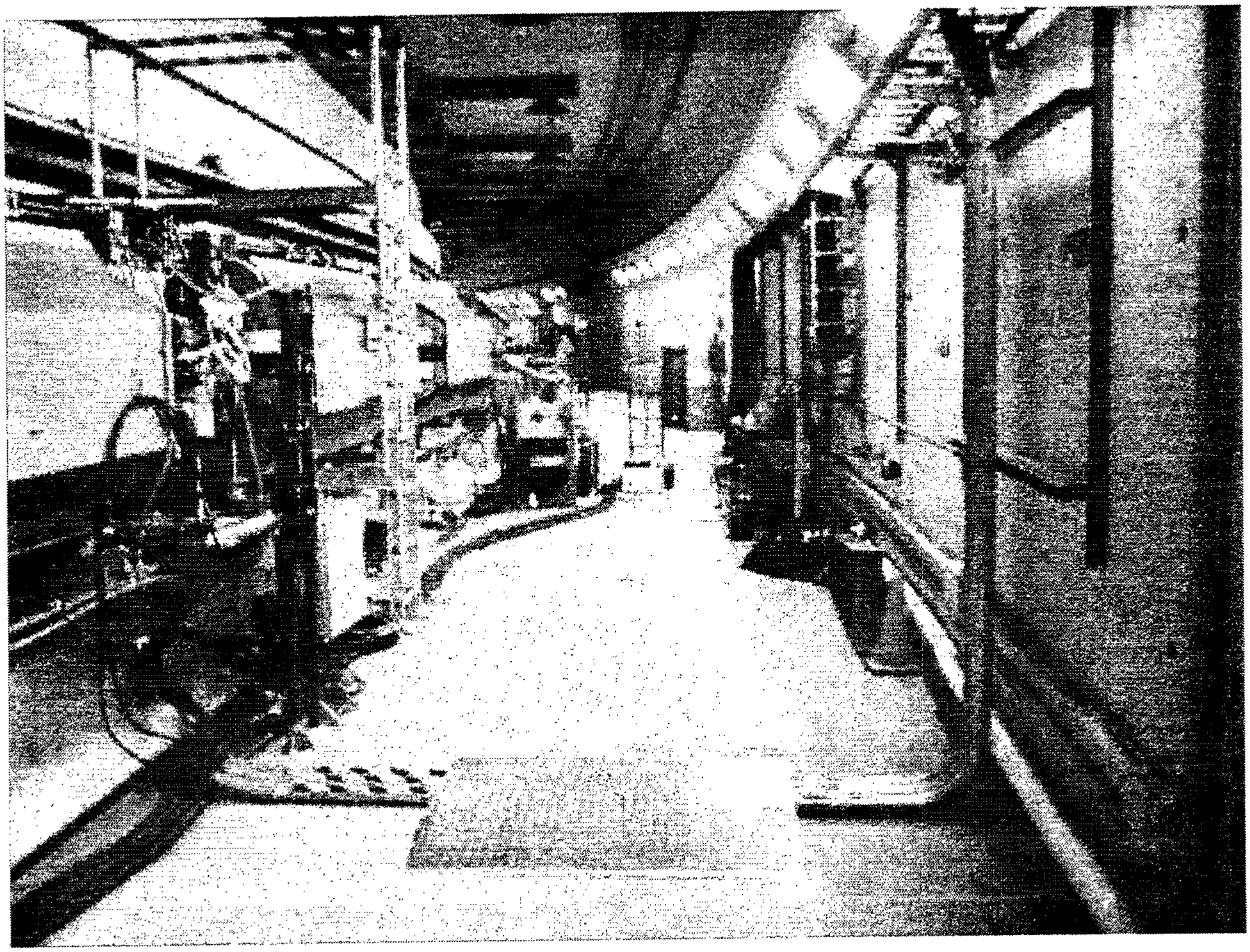
where should we live in tune space?

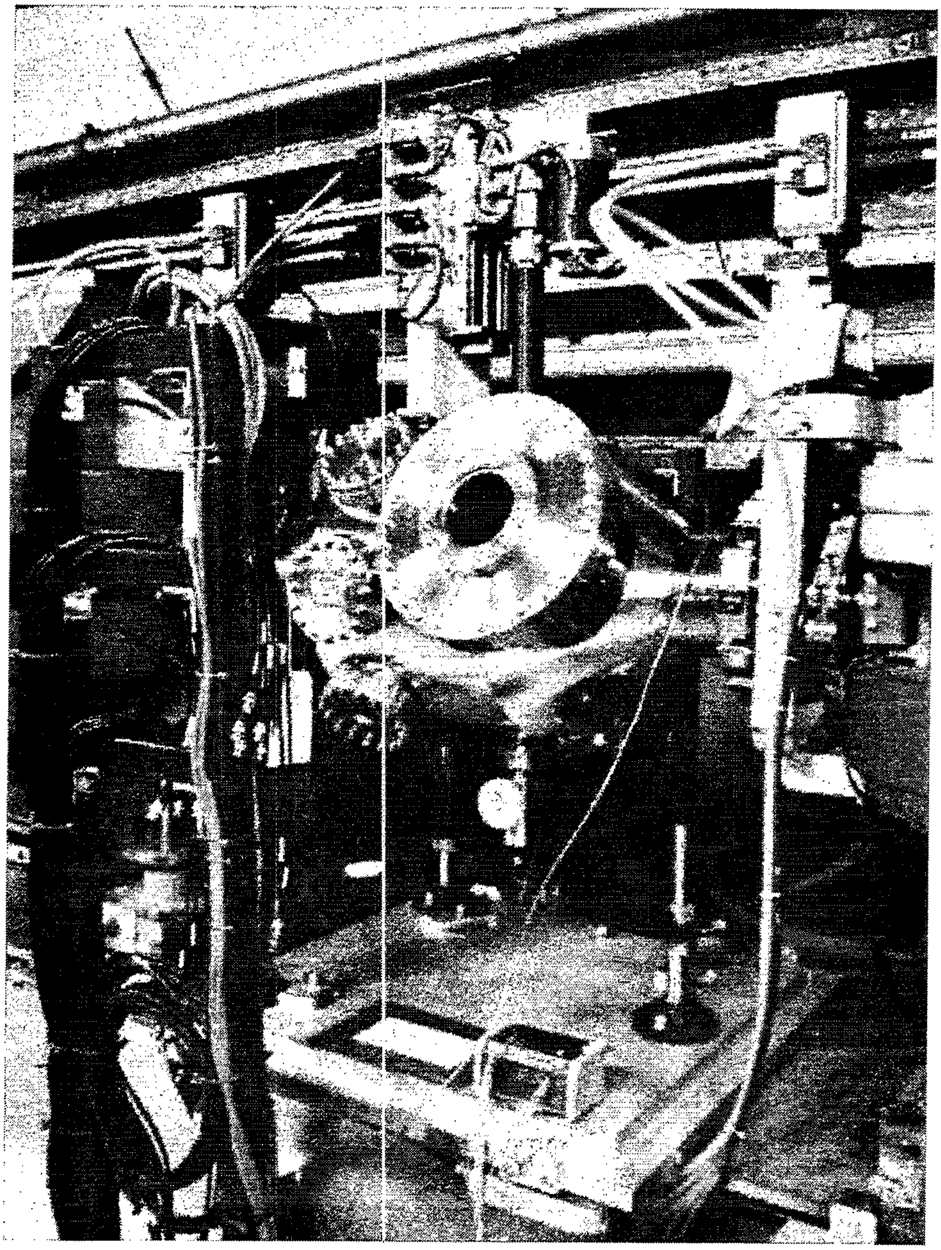
Where can we go in tune space (without beam loss ... without emittance growth) (skew sextupole resonance line Qy+2Qx=26?) Understanding this is valuable prework for later polarization optimization.
(Not attacked yet)

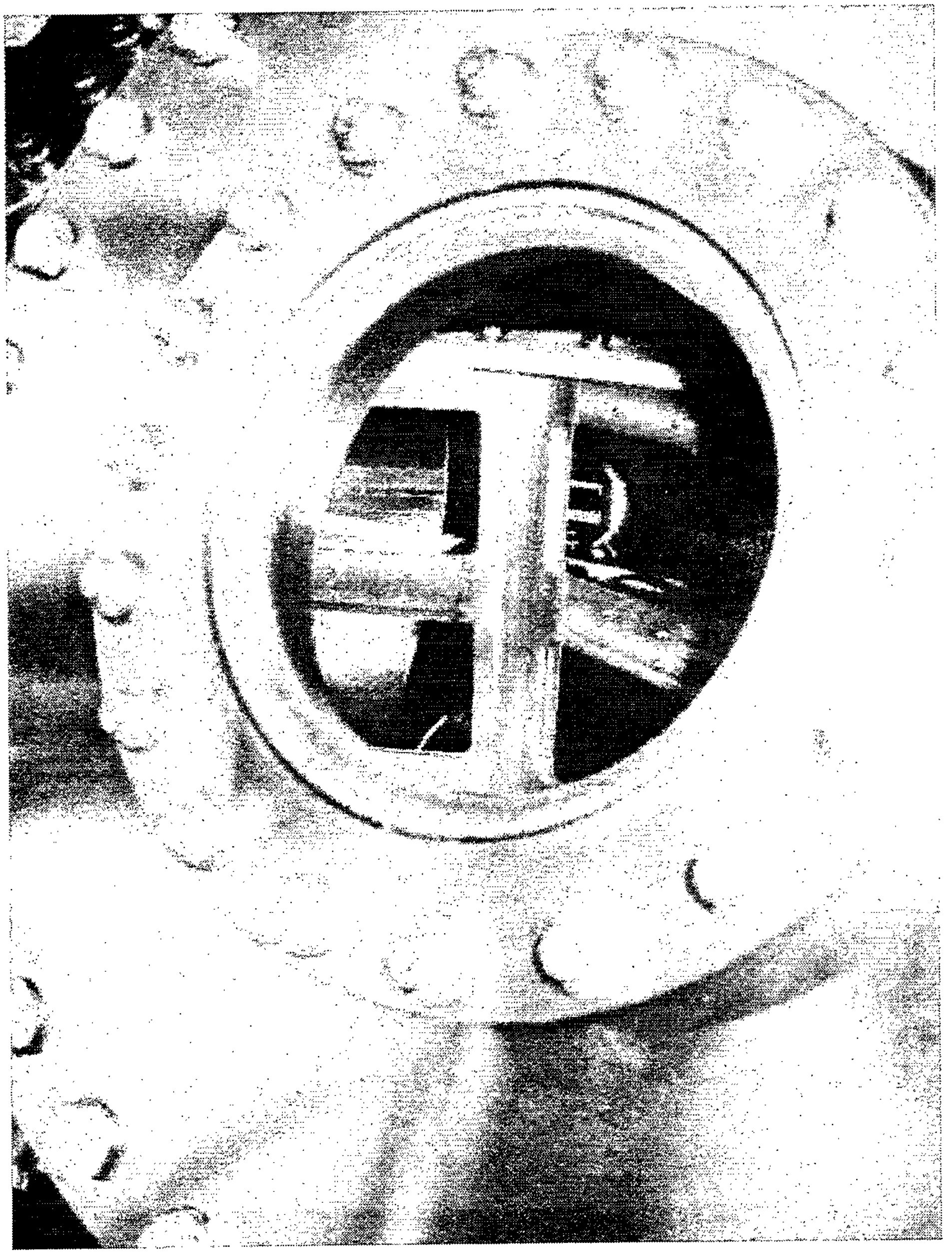
Workshop: AGS Polarization Upgrades in early November: stay tuned











Update on the Run-02 RHIC Polarimeter Analysis

O. Jinnouchi, RBRC
October 22, 2002

for
RHIC Spin Collaboration Meeting XIII
RIKEN BNL Research Center

Update on the Run-02 RHIC polarimeter analysis

Systematic Error Estimation for the CNI polarimeter

Outline:
- Subdividing into Categories
- Run by run fluctuations of false asymmetries
- Effect of noise correction

RHIC Collaboration Meeting 10/22/2002
Osamu Jinnouchi

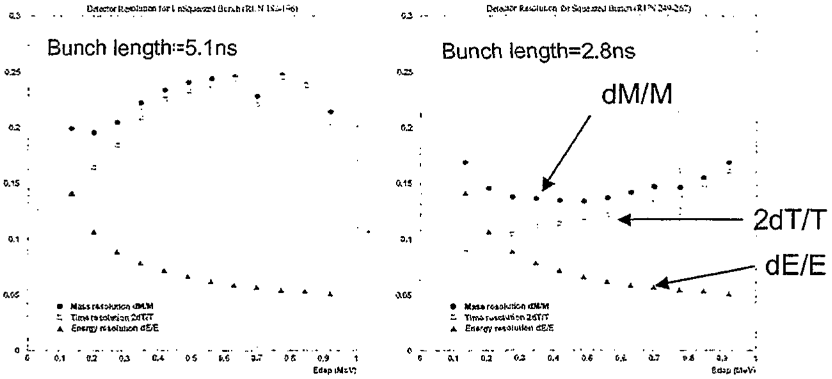
Systematic errors for CNI polarimeter

- ☐ There were discussions (meetings) to estimate the possible systematic errors for CNI polarimeter
- ☐ Roughly there are two categories of errors
  - ■ Hardware oriented intrinsic errors (like those J.Tojo estimated for the E950 data) → *constant type*
    - ☐ *Page 3*
    - ☐ *Need some time*
  - ■ Systematic errors which can be estimated from false asymmetry distributions → *point by point type*
    - ☐ *Page 5*
    - ☐ *Several kinds of distributions, supposed to be strongly correlated → take into account only the biggest contribution*

Systematic error sources common to E950

- ☐ Raw asymmetry errors
  - Cut dependence (banana cut quality) → will take time
  - Background from alpha particles, etc. → maybe negligible
  - Acceptance/Luminosity asymmetry propagation → maybe negligible
- ☐ *-t* definition errors
  - *-t* is defined only by *energy*
    - ☐ *Relative contribution is known from data-2000 (page 4)*
  - Energy scale/loss corrections
    - → *Estimated in asymmetry distribution section*
- ☐ Error propagation from E950
  - Large but scaling effect → *neglect for the current purpose*

Relative contribution for mass resolution



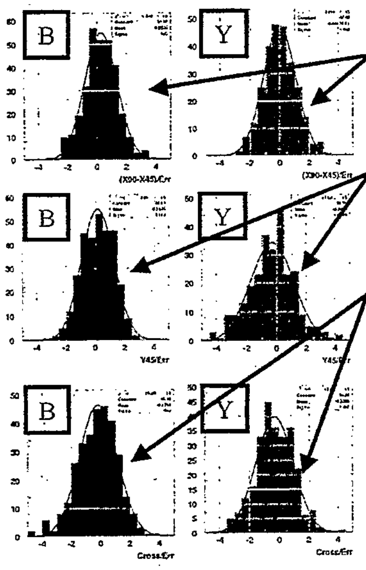
- ☐ The data is from RHIC polarimeter commissioning-2000
- ☐ To be exact *-t* must be the weighted mean of –t defined by Energy and Time of the recoil carbons
- ☐ With the bunch length ~ 5ns, *-t* can be determined only by energy information

Systematic errors assessable with distributions

- ☐ Known origin
  - ■ Effect of energy scale/loss correction
    - ☐ 0.7%(Blue), 0.4%(Yellow) in absolute polarization scale
  - ■ Effect of the bunch selection
    - ☐ 1.5% in absolute polarization scale in maximum
- ☐ Unknown origin
  - ■ False asymmetries
    - ☐ (X90-X45)/σ_{stat} → plots
    - ☐ Y-components → plots
    - ☐ Cross asymmetry → plots
    - ☐ Forced un-polarized artificial spin bit pattern → plots
  - ■ From χ^2/ndf distributions → plots

False asymmetry distributions

(data Dec.22th-End, no energy correction, bunch selection level-2 (tight cut))



(X90-X45)/Err
- Mean 0.25(B) / -0.02(Y)
- Sigma 1.11(B)/ 1.10(Y)

Y45/Err
- Mean 0.16(B) / -0.30(Y)
- Sigma 1.11(B)/ 1.43(Y)

Cross/Err
- Mean -0.17(B) / -0.32(Y)
- Sigma 1.30(B)/ 1.26(Y)

σ_B, σ_Y : statistical errors
σ_B =2.5% σ_Y=2.7%

→ B:0.47σ_B / Y: 0.45σ_Y

→ B: 0.47σ_B / Y: 1.01σ_Y

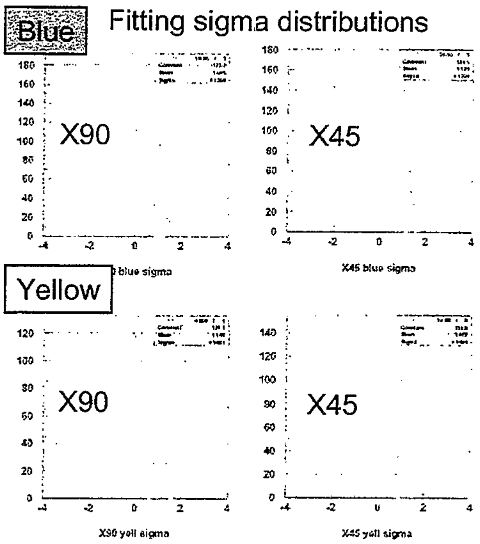
→ B: 0.83σ_B / Y: 0.76σ_Y

The size of systematic error is estimated with this relation, assuming leftover after subtracting the statistical contribution can be attributed to systematic errors.

$$\sigma_{systematic} = \sqrt{\sigma^2_{observed} - \sigma^2_{statistics}}$$

Randomized spin bit patterns

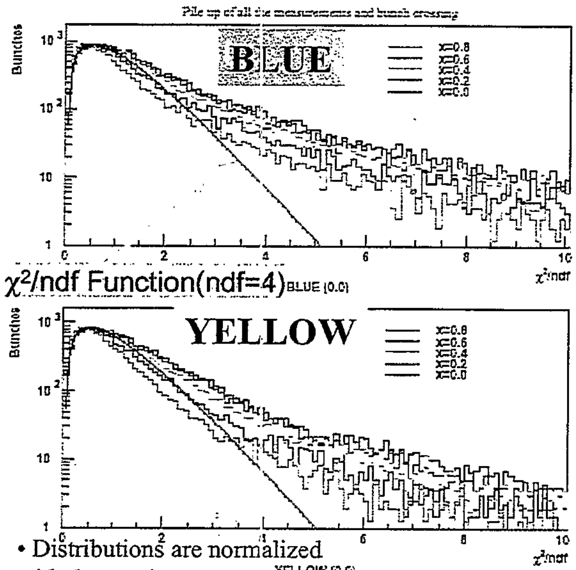
Fitting sigma distributions



- ☐ Basic idea is to see the distribution of physics asymmetries with forced un-polarized spin bit pattern
- ☐ Random combinations of un-polarized spin bit patterns are iteratively tried for each CNI run
- ☐ Left plots shows the Gaussian sigma distribution from the fittings to each measurement

Blue
X90 → 0.45σ
X45 → 0.51σ
Yellow
X90 → 0.56σ
X45 → 0.39σ

Scaled χ^2/ndf distributions



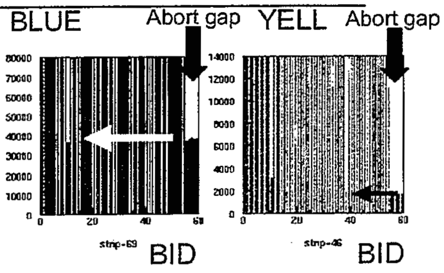
- Distributions are normalized with the maximum contents

- ☐ Sin function fit to the detector ratio (phi asymmetry fit) yields fit χ^2/ndf
- ☐ χ^2/ndf is scaled with assumed systematic error level
- ☐ "f" looks to be 0.4-0.6, this is comparable with the other systematic errors

$$\chi^2 = \sum_{\text{detector}} \left(\frac{(x_i - \bar{x}_i)^2}{\sigma_{stat}^2 + \sigma_{sys}^2} \right)$$

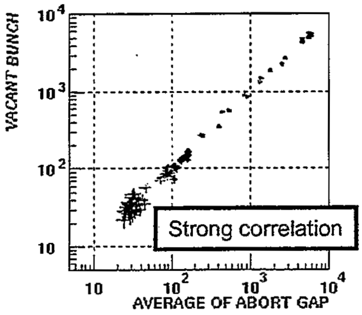
$$= \frac{1}{(1+f^2)} \sum_{\text{detector}} \left(\frac{(x_i - \bar{x}_i)^2}{\sigma_{stat}^2} \right)$$

Credibility of the noise correction



- ☐ Noisy strips are observed towards the end of the run, due to the energy scale change of Si detectors
- ☐ The size of noise is estimated from the number of events in abort gap
- ☐ There is a concern that the de-bunched beam might make same effect at abort gap

- ☐ From next page, it is known the de-bunch effect and the noise effect can be clearly separated



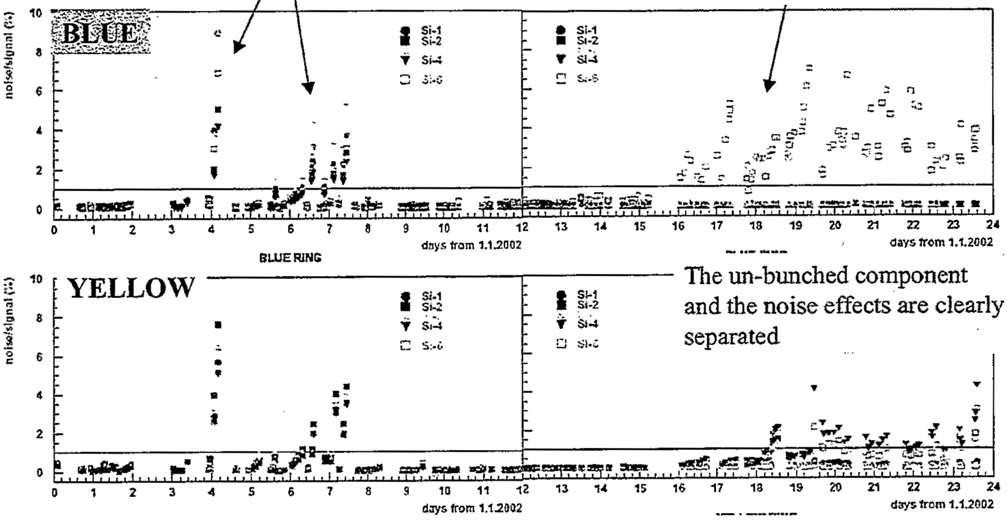
Strong correlation

Effect of de-bunched & noise

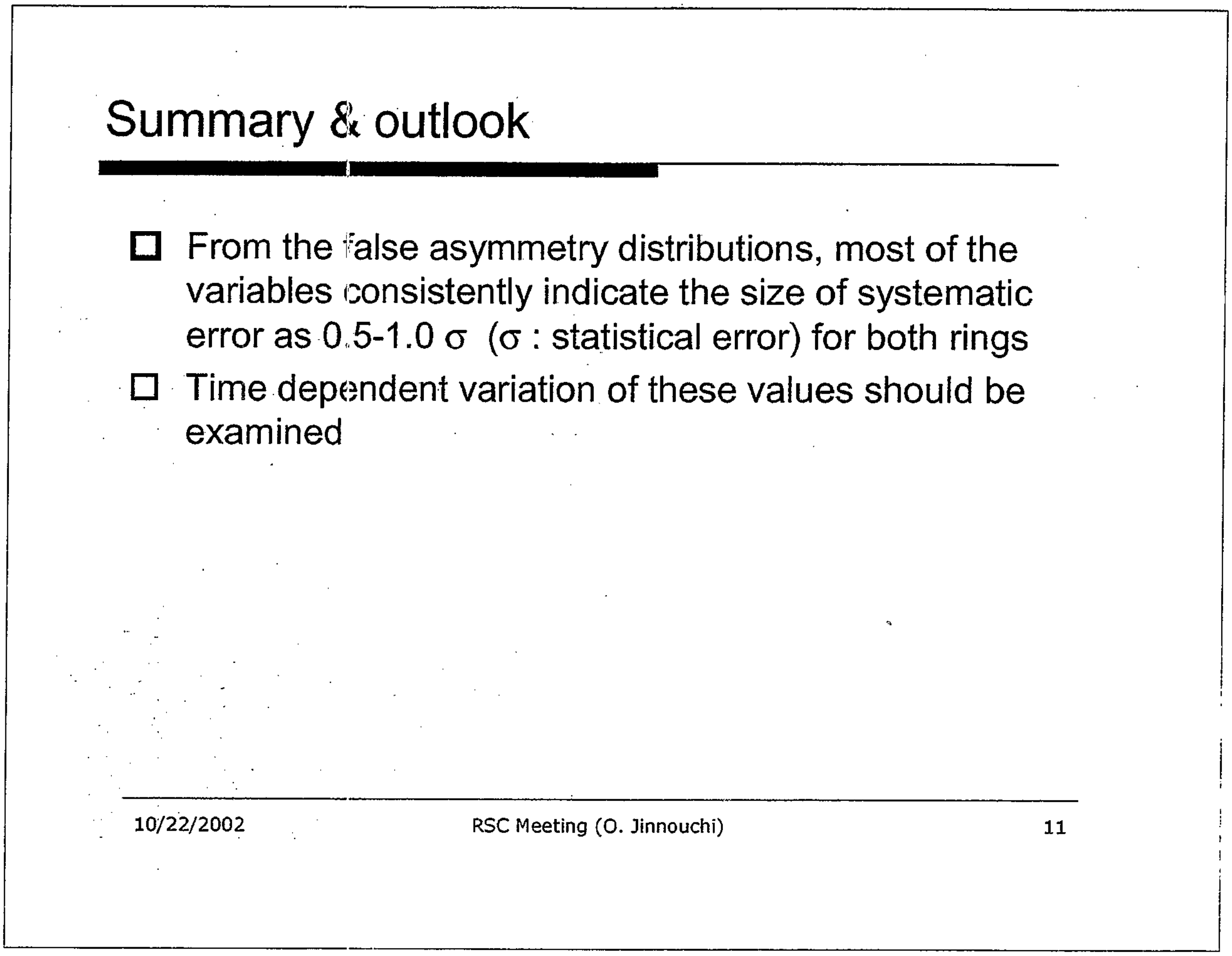
The ratios (5abort/55normal)*55/5*100 are plotted as the detector average

All the detectors (strips) are counting at abort gap
They are corresponding to STAR de-bunched beam monitor DB

Some strips became largely noisy while the other rest remain silent, Because of real noise effect



The un-bunched component and the noise effects are clearly separated



Summary & outlook

- From the false asymmetry distributions, most of the variables consistently indicate the size of systematic error as 0.5-1.0 σ (σ : statistical error) for both rings
- Time dependent variation of these values should be examined

Discussion on Beam Polarization for Run 2 Papers

O. Jinnouchi (RBRC), L. Bland (BNL), and
G. Bunce (RBRC/BNL)

October 22, 2002

for
RHIC Spin Collaboration Meeting XIII
RIKEN BNL Research Center

22 Oct. 2002

Discussion on Beam Polarization for Run 2 Papers

O. Jinnouchi, L. Bland, G. Bunce

There are expected to be several papers from the first RHIC spin run, including observed asymmetries (forward π^0 at STAR, very forward neutrons at IP12) and some null results for asymmetries (very forward π^0s at IP12, charged hadrons at mid rapidity at STAR). PHENIX mid rapidity π^0 asymmetries are still being analyzed. To present these results as physics asymmetries, we need to decide on what to use for the beam polarization. We would like to use one approach for all RHIC results.

We have two issues to resolve: what do we use for the absolute beam polarization at 100 GeV, and what systematic error should we assign to the polarimeter measurements?

For the absolute beam polarization, we do not have a measured analyzing power for proton-carbon elastics in the CNI region at 100 GeV. From AGS experiments E950 (J. Tojo et al., PRL 89, 052302 (2002)), and E925 (C.E. Allgower et al., PR D65, 092008 (2002)), we have the analyzing power for a 22 GeV polarized proton beam, for the proton-carbon CNI polarimeter. For the –t range used in the RHIC polarimeters, this is $A_N = 0.013 +/- 0.0015$. Jungi Tojo will write a RHIC Spin Note that we will use (after reaching an understanding on the approach and error) on the extraction of A_N from the E950 data. (Note that he presented his extraction of the analyzing power for the RHIC polarimeters at two of our RHIC Spin Collaboration meetings in January 2002.)

We discussed presenting asymmetries measured by the experiments with 2 vertical axes. The left axis would give the raw asymmetry, and the right axis A_N, where we use the analyzing power for the polarimeters at 100 GeV = analyzing power at 24 GeV. We state in the paper that the analyzing power has not yet been measured at 100 GeV, and refer to the O. Jinnouchi et al. Spin2002 paper on the RHIC polarimetry.

For the systematic errors for the polarimetry, Osamu has presented several approaches to estimate/measure them. Looking at comparisons between the measurements with the 90° and 45^0 polarimeter detectors, from various false asymmetry studies, and from a sin ϕ fit to the data from the 6 polarimeter detectors, he finds a systematic error between (0.5 to 1) x $\sigma_{\text{Statistical}}$ for each measurement. The measurement statistical error is $\Delta\varepsilon=2 \times 10^{-4}$ for 20 M events. (ε is the raw asymmetry, $\varepsilon=P \times A_N$) For $A_N=.013$, the range of systematic error is $\Delta P = (0.8 \text{ to } 1.6) \times 10^{-2}$ per measurement. We propose to use the larger estimate, or $\sigma_{\text{Systematic}} = 1 \times \sigma_{\text{Statistical}}$ for each measurement. This systematic error adds in quadrature to the statistical error for each measurement. This implies that, after many measurements, the combined statistical and systematic error on the average polarization is greatly reduced. We need to discuss what evidence we have that this systematic error is indeed random, and how we should quote an overall systematic error for the beam polarization, from the measurements. This systematic error is for false asymmetry in the polarimeter measurement, and does not include the systematic error from A_N.

A number of other issues were raised. These included possible pile up or other intensity dependence of the measurement, and whether fill-dependence of false asymmetries is observed. There were 5 fills which showed significant debunching which would affect the time of flight measurement of the polarimeter. Luminosity asymmetries being different for different detectors was mentioned, but this issue may have been addressed with the χ^2 test done for the luminosity of the six detectors for each bunch. This test resulted in identifying several bad bunches which were removed from the analysis. Also a few silicon strips were noisy, and the noise was subtracted based on a measurement in the abort gap. (This also led to the identification of the fills with significant debunching.) Finally, the bunches identified as anomalous have been shown to have anomalous specific luminosity at STAR (see studies by Johanna Kiryluk, Spin 2002 and RHIC Spin Collaboration meetings) and PHENIX (see RSC presentation by Takahiro Kawabata).

We also decided that the Spin2002 polarimeter article (O. Jinnouchi et al.) will present the systematic errors to be used by the experiments for presentation of their results from the 2002 polarized proton run.

Plans for the Run-03 RHIC Polarimeter

O. Jinnouchi, RBRC

October 22, 2002

for

RHIC Spin Collaboration Meeting XIII

RIKEN BNL Research Center

Plans for the Run-03 RHIC polarimeter

Outline:
- Plans for hardware improvements
- WFD and Data Format issues
- Proposal for Special dedicated run

RHIC Collaboration Meeting 10/22/2002

Osamu Jinnouchi

Experiences from the run-02

- As a polarization monitor, the most important feature required for RHIC polarimeter is its *operational stability*
- The energy scale change was the worst thing ! We observed significant gain drop towards the end of the run-02
- The possible solutions for this issue are,
  - → Regularly monitor the energy scale by frequent calibration
  - → Suppress the scale drop with the hardware improvement

- The upgrades of WFD programming and the improvements of the data format will extend the physics availability
- Polarimeter dedicated time slots were very useful to understand the systematic of the detector and the beam properties

Monitoring of the energy scale

Problem of the last run:

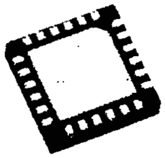
- Calibration with ^{251}Am source (5.5MeV) needs signal reduction by a factor of 1/10
- Putting in/out attenuators for 48 channels (required 4hours job) limited the frequency of the measurement → once per week

Creating a New patch panel
Requirements

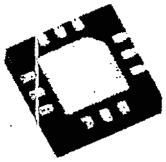
- multiplexer and attenuator
- Blue(48ch) ←→ Yellow (48ch) switch required
- remote controllable attenuation is desirable for a long term operation
- variable attenuation 1/2, 1/5 are also useful for large $-t$ measurements

---

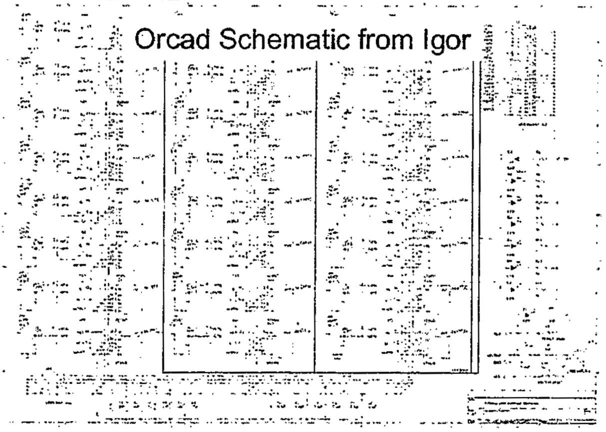
New patch panel (plan.)



attenuator



switch



Orcad Schematic from Igor

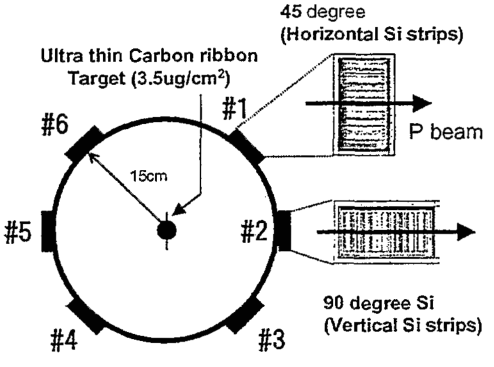
- ☐ The patch panel which satisfies such a condition will be made
- ☐ One board contains 24ch; 3 boards will be used for RHIC polarimeter
- ☐ Bench test will soon be done with the evaluation boards

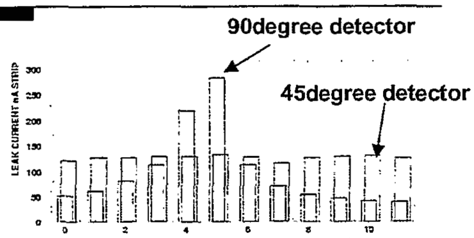
In order to suppress the Si gain drop

- ☐ Major reason for the gain drop was the leakage current of Si (worst case 8μA; normally << 1μA)
- ☐ Direct current measurements showed the large currents are
  - ■ Partially from Radiation Damage of Si (~1μA)
  - ■ Rests are from electronics origin (unknown)
- ☐ Radiation damage came from target (next page)
- ☐ No need to concern about dA run, as we learned from AuAu run

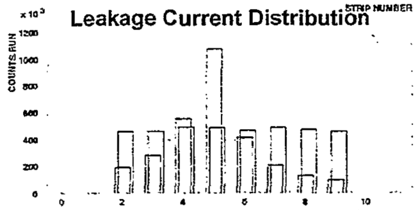
- ☐ Replacement of all the Si to new ones→ now 10/21,10/23
- ☐ Change the bias register 10Mohm→1Mohm to reduce the bias drop and keep the effective bias voltage at default value (100V)

Direct leakage current measurements





Leakage Current Distribution



Counts Distribution

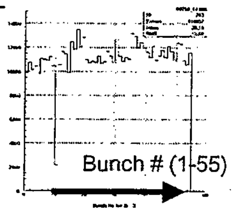
Strip # 1→12

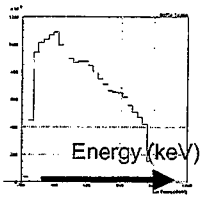
- ☐ Direct measurement with actual detectors in RHIC was carried out recently

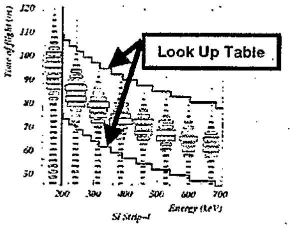
Data Format (at previous run)

- Data set obtained at previous run was not sufficient for an offline analysis
- Data set for normal measurement
  - Bunch histograms (60bin x 72ch)
  - Spin sorted Energy histograms (64bin x 3 pat x 72ch)
  - Look up table boundary ...
  - 2D-mode (AT-mode) (8x32matrix x 72ch)

  - 1 file size 170kB → was easy to handle
- Problems
  - Bunch and Energy information was independent
  - 2D-mode was not spin sorted







Data format for run-03

- Data format and size are depending on the WFD programming (or vice versa)
- Tentative plan is to store both
  - usual scaler histograms
  - Event by event AT-mode data
    - 6 bytes per event (Energy,Integral,TOF,Bunch,Channel,Status)
    - 120MB/run for 20M events → feasible 192MB/48ch with WFD SDRAM
    - Need to get the large RAID disks for storage
    - Data readout is performed at once after the measurement
- Good features
  - Store also the events outside of Look Up Table
  - Store the outlier events with wider $-t$ range

Proposal for the special dedicated run

- During dA run period
  - dC→dC elastic process, almost same kinematics as proton is expected
  - Timing adjustment, new daq system test, online monitor development are possible
  - RF,Clock,V124, dummy bit patterns are available
- During polarized pp run
  - Energy calibration runs – each fill or each day
  - High statistic measurement – several times
  - Beam profile scan with carbon target

Summary

- Calibration runs will become more easy
- Effort to suppress the leakage current

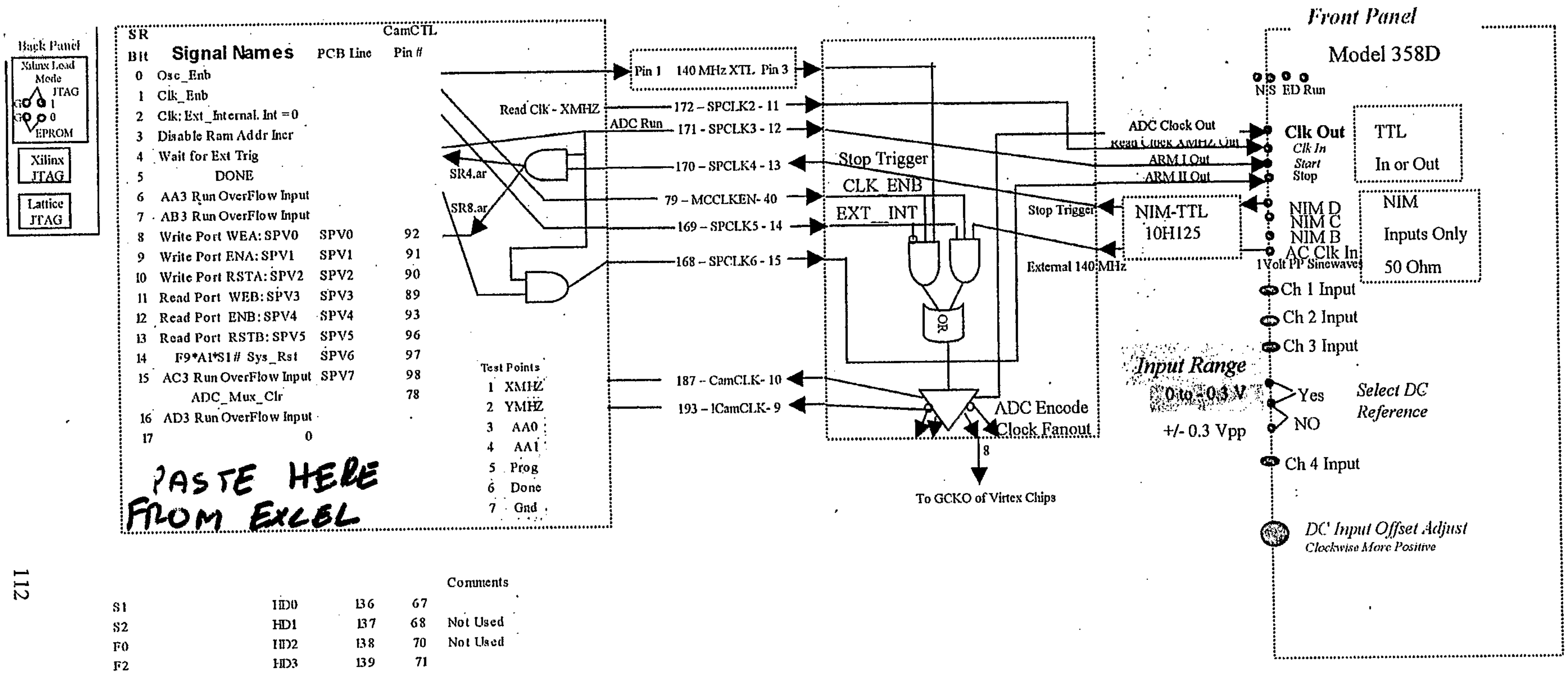
  → better data quality is expected
- Data format will be larger and a new offline analysis approach will be possible
- The special runs are strongly required

CNI Waveform Digitizer

S. Dhawan, Yale

October 22, 2002

for
RHIC Spin Collaboration Meeting XIII
RIKEN BNL Research Center



				Comments
S1	HD0	136	67	
S2	HD1	137	68	Not Used
F0	HD2	138	70	Not Used
F2	HD3	139	71	
F16	HD4	140	72	
F17	HD5	141	73	Not Used
BA1	HD6	142	74	
BA2	HD7	143	78	

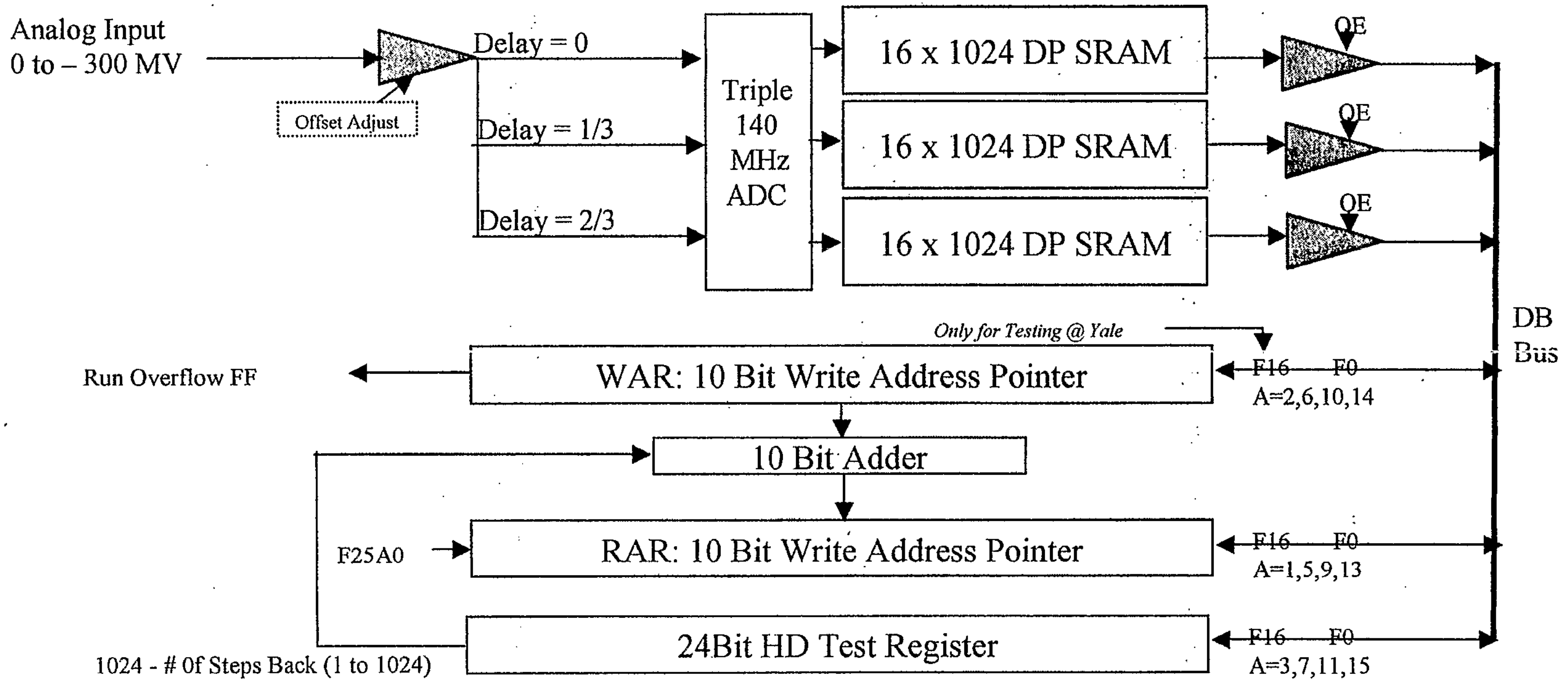
8 - GCKO-92 Virtex

Load HD Register

S. DHAWAN

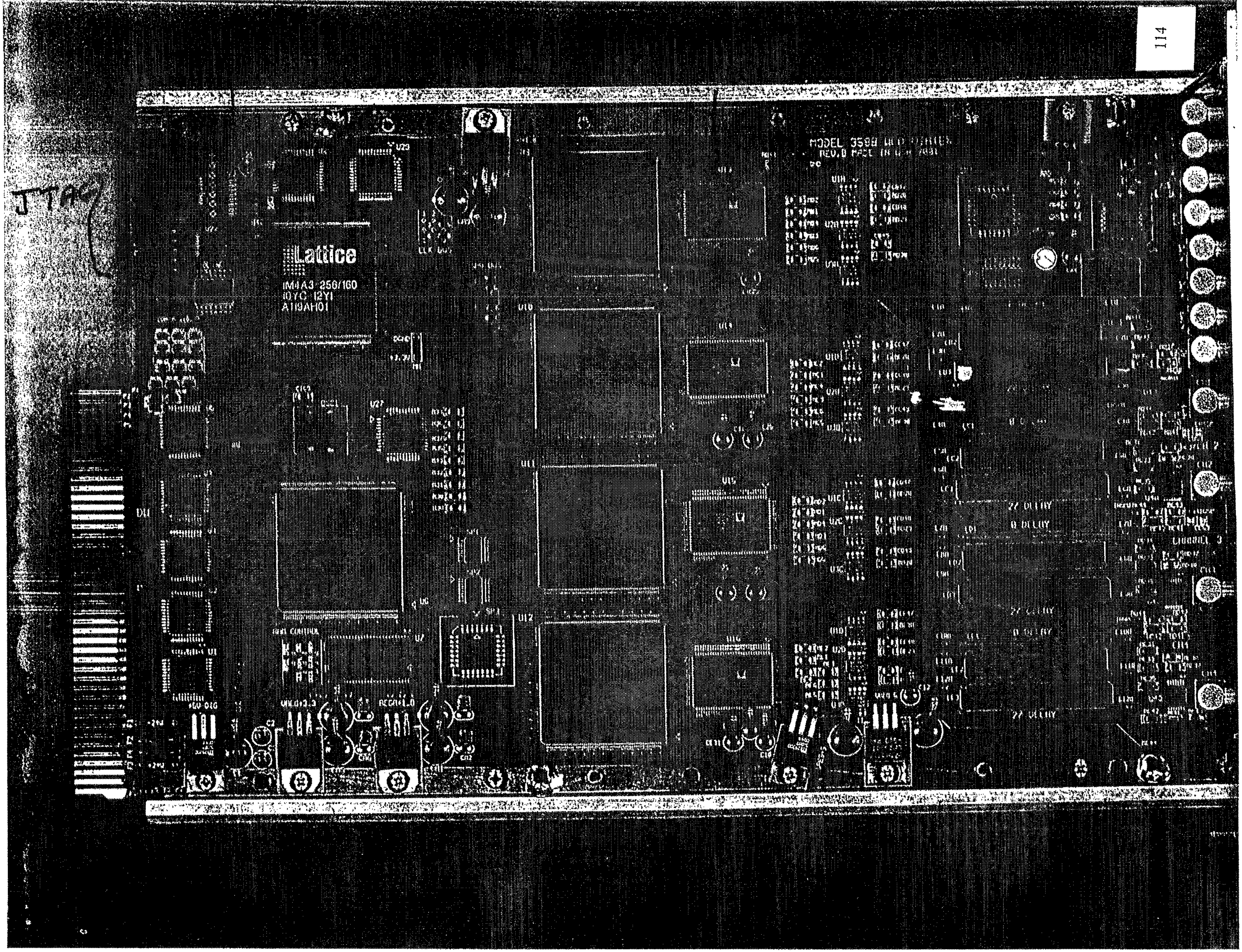
[illegible]

Model 358D PSI

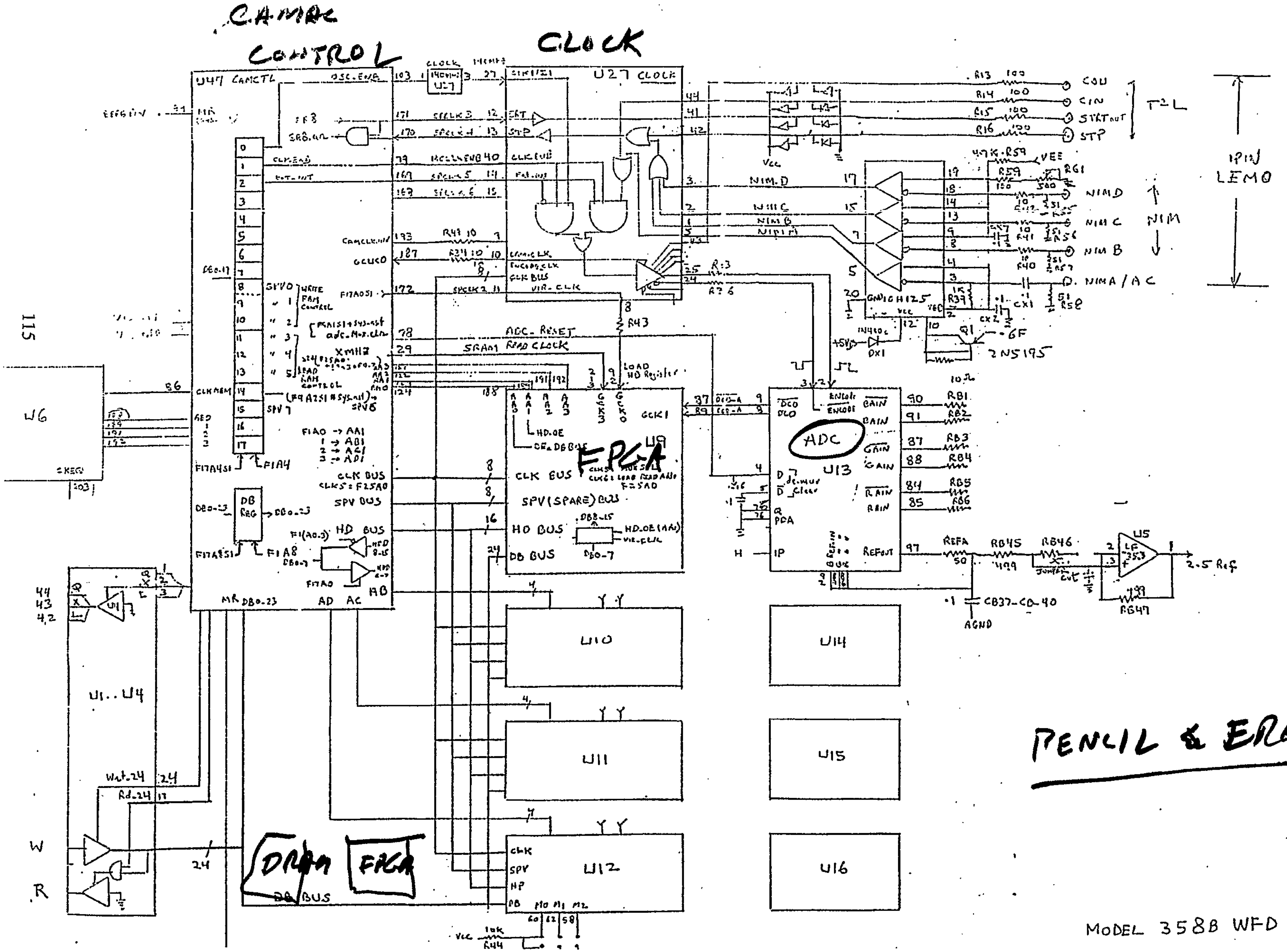


Xilinx Block

WFD Model 358D_PSI Yale University 19 Sept 2002 5 AM


Lattice
M4A3-256/160
10YC-12YI
A119AH01
MODEL 3598
REV.D
22 DELAY
0 DELAY
CHANNEL 3

JTAG



PENCIL & ERASER

MODEL 358B WFD

25-Sep-02	**Model 358D_ PSI**									Data Format											Yale University
10:00 AM																					
		Sampling Time			*S2*								*S1*								
		Byte			D2								D1								
Function Code																					
Write	Read	Subaddr																			
			17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
F16	F0	4*(Ch#- -1)+1									|	|	|	|	|	|	|	|	|	|	Memory Read Address
F16	F0	4*(Ch#- -1)+2									|	|	|	|	|	|	|	|	|	|	Memory Write Address
F16	F0	4*(Ch#- -1)+3	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	24 Bit HD Test Register
	F2	4*(Ch#- -1)+1	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	Blue Delay = 0
	F2	4*(Ch#- -1)+2																			Green Delay = 1/3 Cycle
	F2	4*(Ch#- -1)+3																			Red Delay = 2/3 Cycle
	18 Bit Status Register		17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
					7	*6*	*5*	*4*	*3*	*2*	*1*	*0*								osc_enb	
			0	Run OVF Ch# D	Run OVF Ch# C				WEA			WEA	Run OVF Ch# B	Run OVF Ch# A	Done				clk_enb		
F17	F1	A4						ENA			ENA							clk_ext			
		A4					RSTA			RSTA							Disable Ram addr Incr.				
										Write DP RAM						Wait for Ext Trig					
							Read DP RAM														
								1			1	1							1	1	
			131072	65536	32768	16384	8192	4096	2048	1024	512	256	128	64	32	16	8	4	2	1	Weight
			0	0	0	0	0	4096	0	0	512	256	0	0	0	0	0	0	2	1	4867

17-Sep-02 Model 358_ PSI

5:00 PM

CamCTL

CAMAC Commands

F	A	S	Command	Pin # U47	Pin # Virtex	Name of Signal	Function	# of Bits		
			Read db0-db23			*Data OE*	*Read 24 bits*	*24*		
			Write db0-db23			*Wrt_Enb*	*Write 24 bits*	*24*		
2	1		Read dout0-dout15	161	100	AA0	~~Read ADC Blue 16 bits (AA0): Channel A *Incr Addr*~~	16	CLK5, CLK6 is Mux Select	
2	2		Read dout0-dout15	124	186		~~Read ADC Green 16 bits (AA0): Channel A~~	16	Pass Dataway A1 & A2	
2	3		Read dout0-dout15	161	100		~~Read ADC Red 16 bits (AA0): Channel A~~	16		
2	5		Read dout0-dout15	120	188	AB0	Read ADC Blue 16 bits (AB0): Channel B *Incr Addr*	16		
2	6		Read dout0-dout15	161	100		Read ADC Green 16 bits (AB0): Channel B	16		
2	7		Read dout0-dout15	114	188		Read ADC Red 16 bits (AB0): Channel B	16		
2	9		Read dout0-dout15	161	100	AC0	Read ADC Blue 16 bits (AC0): Channel C *Incr Addr*	16		
2	10		Read dout0-dout15	107	188		Read ADC Green 16 bits (AC0): Channel C	16		
2	11		Read dout0-dout15				Read ADC Red 16 bits (AC0): Channel C	16		
2	13		Read dout0-dout15			AD0	Read ADC Blue 16 bits (AD0): Channel D *Incr Addr*	16		
2	14		Read dout0-dout15				Read ADC Green 16 bits (AD0): Channel D	16		
2	15		Read dout0-dout15				Read ADC Red 16 bits (AD0): Channel D	16		
0	1		Read dout0-dout10				Read Memory RAR 10 bits: Channel A	10		
0	2		Read dout0-dout10				Read Memory WAR 10 bits: Channel A	10		
0	3		*Read db0-db23*				Read HD Test Register/Counter 24 bits: Channel A	24		
0	5		Read dout0-dout10				Read Memory RAR 10 bits: Channel B	12		
0	6		Read dout0-dout10				Read Memory WAR 10 bits: Channel B	10		
0	7		*Read db0-db23*				Read HD Test Register/Counter 24 bits: Channel B	24		
0	9		Read dout0-dout10				Read Memory RAR 10 bits: Channel C	10		
0	10		Read dout0-dout10				Read Memory WAR 10 bits: Channel C	10		
0	11		*Read db0-db23*				Read HD Test Register/Counter 24 bits: Channel C	24		
0	13		Read dout0-dout10				Read Memory RAR 10 bits: Channel D	10		
0	14		Read dout0-dout10				Read Memory WAR 10 bits: Channel D	10		
0	15		*Read db0-db23*				Read HD Test Register/Counter 24 bits: Channel D	24		
16	1		Write dout0-dout10			AA1	Write Memory RAR 10 bits: Channel A	10		
16	2		Write dout0-dout10				Write Memory WAR 10 bits: Channel A	10		
16	3		*Write db0-db23*				Write HD Test Register/Counter 24 bits: Channel A	24		
16	5		Write dout0-dout10				Write Memory RAR 10 bits: Channel B	10		
16	6		Write dout0-dout10				Write Memory WAR 10 bits: Channel B	10		
16	7		*Write db0-db23*				Write HD Test Register/Counter 24 bits: Channel B	24		
16	9		Write dout0-dout10				Write Memory RAR 10 bits: Channel C	10		
16	10		Write dout0-dout10				Write Memory WAR 10 bits: Channel C	10		
16	11		*Write db0-db23*				Write HD Test Register/Counter 24 bits. Channel C	24		
16	13		Write dout0-dout10				Write Memory RAR 10 bits: Channel D	10		
16	14		Write dout0-dout10				Write Memory WAR 10 bits: Channel D	10		
16	15		*Write db0-db23*				Write HD Test Register/Counter 24 bits: Channel D	24		
1	8		Read db0-db23				Read db Test Register	24		
17	8	1	Write db0-db23				Write db Address Register	24		
1	4						Read Status Register	8		
17	4	1					Write Status Register	H/L		
						sr0	osc_Enb	1		
						sr1	clk_enb	1		
						sr2	clk_ext_int: int =0 ext = 1	0		
						sr3	Disable Ram addr Incr.			
						sr4	Wait for Ext Trig			
						sr5	Recording Time OverFlow Channel B		AB3	Read Only
						sr6	Recording Time OverFlow Channel C		AC3	Read Only
						sr7	Recording Time OverFlow Channel D		AD3	Read Only
				92	138	sr8	spv0 Cleared by Lemo_STP	1	WEA	Write DP RAM
				91	139	sr9	spv1	1	ENA	Write DP RAM
				90	140	sr10	spv2	0	WCLK	Write DP RAM
				89	141	sr11	spv3	0	WEA	Read DP RAM
				93	184	sr12	spv4	1	ENA	Read DP RAM
				96	185	sr13	spv5	0	RCLK	Read DP RAM
				97	186	sr14	spv6			
				98	187	sr15	Recording Time OverFlow Channel A		AA3	Read Only
						sr16				
						sr17				
						sr18				
25	0	2		193	213	XMHZ	Add to Read Clk: XMHZ			
25	0			160	101	clk6	Load Read Address from Write Address			
9	1	1	+sys_rst	103		adc_pin4	demux_clr of all ADC's			
9	2	1	+sys_rst	97	186	spv6	Clear Virtex Test counters & Read Pointers			
9	0	1		86	6		sys_rst			
Z		2								
C		1								
8	0						Test LAM Q=1 if Request present			
10	0						Clear LAM Source FF			
24	0	1					Clear ED FF to disable LAM Mask			
26	0	1					Set ED FF to enable LAM Mask			
27	0						Test LAM Source Q=1 if LAM Source=1			

10/212002

2:00 PM

Parts List M358D

#	Qty/ PCB	Description	Manf.	Part #	Order #	Unit Price	Cost Per Board	Qty For 21 Boards	Inventory	Needed	Order qty	Extended Price
1	5	FPGA	Xilinx	XCV200E- 6 PQ240C	*INS 072301*	$ 76.55	$ 382.75	105	0	105	110	$ 8,420.50
2	2	jtagPROM	Xilinx	XC18V04VQ44C	*INS 072301*	$ 26.60	$ 53	42	10	32	36	$ 957.60
3	4	ADC	ADI	AD9483KS-140	FAI 092702	$ 27.00	$ 108	84	11	73	80	$ 2,160.00
4	12	Diff Amp	ADI	AD8131AR	FAI 092702	$ 2.69	$ 32	252	30	222	250	$ 672.50
5	4	Driver Amp	TI	THS6022CPWP	*INS 072301*	$ 3.31	$ 13	84	16	68	60	$ 198.60
6	1	DRAM	Micron	MT48LC16M16A2TG-75	AV 072301	$ 7.15	$ 7	21	0	21	25	$ 178.75
7	1	CamCTL	Lattice	M4A3-256/160-10Y	AV 072301	$ 20.90	$ 21	21	6	15	24	$ 501.60
8	5	Dataway Drv	Lattice	M4A5-64/32-10VC	AV 072301	$ 3.65	$ 18	105	45	60	100	$ 225.00
9	1	Clock Driver	Lattice	M4A3-32/32-5VC	AV 072301	$ 2.25	$ 2	21	2	19	25	$ 56.25
10	1	Oscillator 140 MHz	Fox	JITO-2-PC3AE-140	Quick Order	$ 4.54	$ 5	21	12	9	25	$ 113.50
11	1	MM74H423AM	Fairchild/Phil	PHISN74HC123D	*FAI*	$ 0.19	$ 0	21	100	79	0	$ -
12	1	74 LCX 244T	ST/Fairchild	FSCSN74 LCX 244	*FAI052201*	$ 0.22	$ 0	21	100	79	0	$ -
13	1	MECL-TTL	Motorola	MC10H125FN	FAI 092702	$ 2.49	$ 2	21	9	12	20	$ 49.80
14	2	Fuse 3Amps		LF251003	*FAI 051401*	$ 0.18	$ 0	42	60	18	0	$ -
15	2	1.8 V Regulator 1.5A	ST	LD1086V18		$ 2.00	$ 4	42	135	93	0	$ -
16	1	3.3 V Regulator 1.5A	ST	LD1086V33		$ 2.00	$ 0	21	20	1	25	$ 5.75
17	2	5 V Regulator 3.0A	Micrel	MIC29300-5.0BT	FAI 092702	$ 2.49	$ 5	42	40	2	50	$ 124.50
18	1	. -5 V Regulator 1.0A	NSC	LM2990T-5.0		$ 2.00	$ 2	21	32	11	0	$ -
19	1	2N5195 PNP		2N5195	*FAI 051401*	$ 0.40	$ 0	21	100	79	0	$ 40.00
20	12	LEMO Right Angle	LemoUSA			$ 6.00	$ 72	252	46	206	300	
21	1	JTAG Lattice Connector			*Digikey:MHD10K·*	$ 1.00	$ 1	21	8	13	15	
22	1	JTAG Xilinx Connector			*Newark*	$ 1.00	$ 1	21	46	25		
23	1	Offset Connector				$ 0.50	$ 1	21	6	15	20	
24	6	LED			*FAI 051401*	$ 0.13	$ 1	126	54	72	100	$ 12.50
25	1	PC Board				$100.00	$ 100	21	0	21	0	$ -
26	1	Assembly				$200.00	$ 200	21		21	4	$ 800.00
27	1	Front Panel				$ 30.00	$ 30	21	0	21	5	$ 150.00
28	2	Rails	Techni Fab	P3208		$ 4.25	$ 9	42		42	50	$ 212.50
29	2	Ferrite SMT 1806 6A 60 Ohms		HI 1806T600R	*DK072301*	$ 0.26	$ 0.510	42	200	158	250	$ 63.75
30	8	Diodes Case LL34		592-RLS4154 or RLS92	*MS072301*	$ 0.046	$ 0.368	168	50	118		
31	220	.1 uF 1206	Xicom		*Mouser: 140-CC502Z104M*	$ 0.026	$ 5.720	4620	0	4620		
32	20	15uF 10V				$ 0.22	$ 4.400	420				
33	1	10Turn 50K Pot 3006P	Bourns	3006P-503-ND	*DK072301*	$ 1.58	$ 1.575	21	0		10	
34	1	1Turn 500 Pot 3329P	Bourns			$ 1.00	$ 1.000	21				
35	1	TPStrip - 7 Female	Berg			$ 0.40	$ 0.400	21				
36	1	Misc SMD Components				$ 25.00	$ 25.000	21				
						Total =	**$1,110.153**					**$ 14,943**

21-Oct-02
1:30 PM

Model 358D WFD

Price Quotes

Quantity = 25

PC Boards

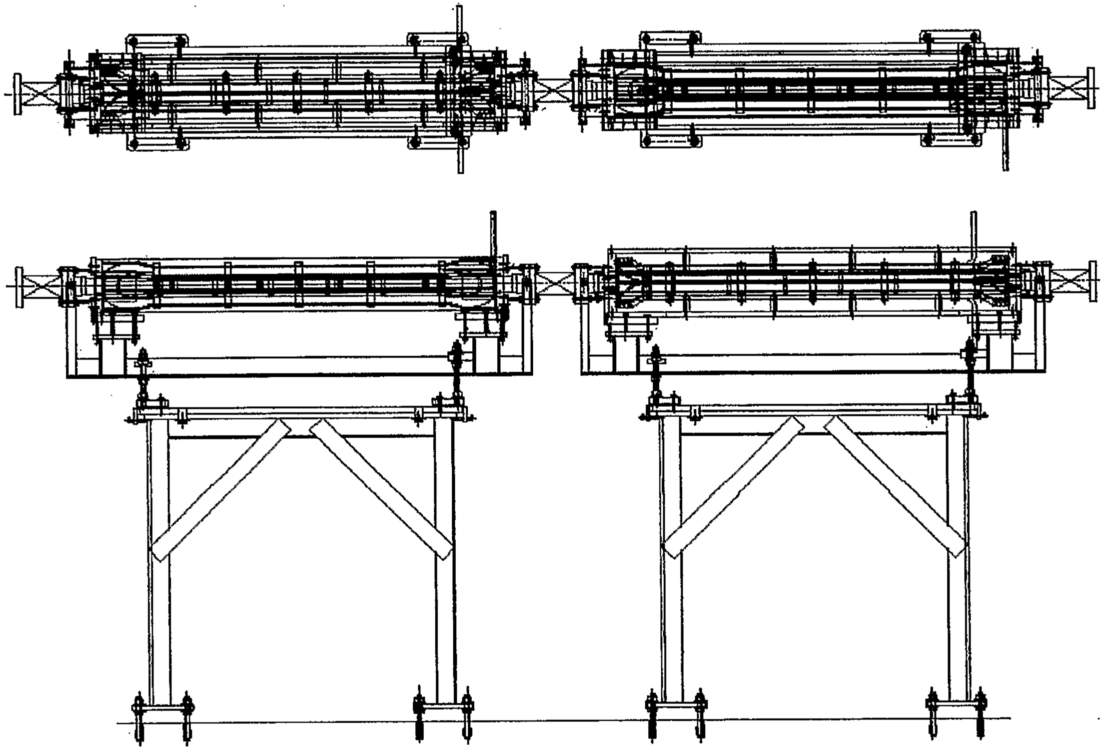
	Tooling	Test	Total Tooling	25Piece Price	Total $
Advanced Circuits	$474	$389.56	$863.56	$106.54	$3,527.06
Electro Pac Inc.	$595.00	$1,827.09	$2,422.09	$72.00	$4,222.09
Pronto Circuits	$480.00	$800.00	$1,280.00	$72.00	$3,080.00
		Assembly			
Argos Trans Data			$1,147.00	$161.49	$5,184.25
Interplex Technologies Corp.					

Status Report and Run-03 Plans for the Spin Flipper

M. Bai, BNL
October 22, 2002

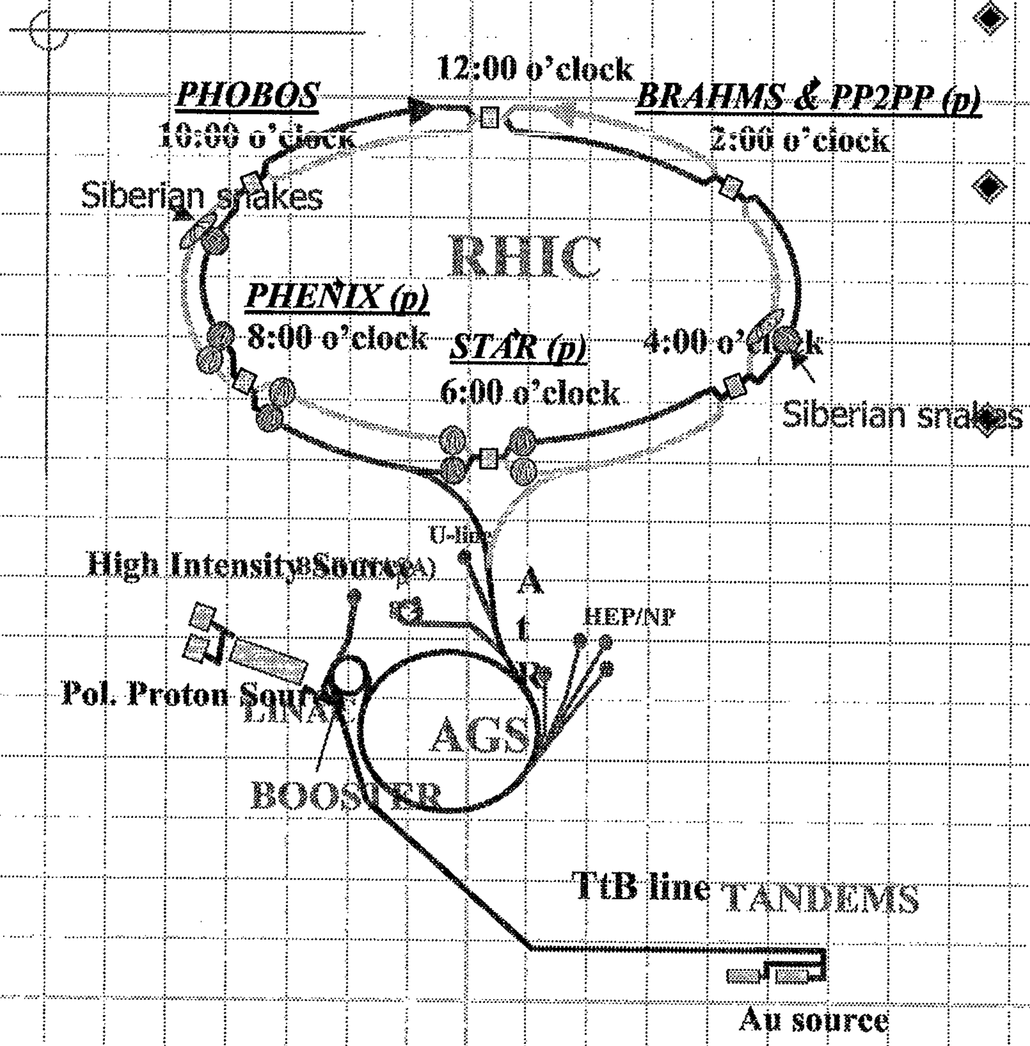
for
RHIC Spin Collaboration Meeting XIII
RIKEN BNL Research Center

RHIC spin flipper status



Rhic spin collaboration meeting
M. Bai Oct. 22,2002

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.

Rhic AC dipole status

- The spin flipper(vertical ac dipole) was installed and operated during rhic_pp_2002 run.
- The horizontal ac dipole will be installed mid of Nov.
- The horizontal ac dipole will use the existing set of capacitors.
- A new set of power amplifiers are purchased.
- Two new sets of capacitors are purchased for the spin flipper. A Roth relay is also purchased to allow one to remotely switch the vertical ac dipole between the spin flipper mode(37.5kHz) and betatron coherence excitation mode(64kHz).
- The horizontal ac dipole, the capacitors and the power amplifiers are currently under bench measurement. They will be installed after the measurement.
- A new waveform generator will be installed. This will allow us to generate a sinusoidal waveform according to the rf frequency frequency

Plans for the next run

- Commissioning phase
  - Goal: achieve >99% spin flip
  - Measure the spin flipping efficiency as a function of spin flipper strength
  - Measure the spin flipping efficiency as a function of resonance crossing rate
  - Measure the spin flipping efficiency as a function of the frequency sweeping range
  - prefer to do the measurement at injection if aperture permits
  - Measure the efficiency at storage
- Operation phase
  - An application is preferred to consolidate the spin flipping prosedures:
    - Detune the snake axis
    - Setup the spin flipper
    - Run the spin flipper

- 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.

Report on the Absolute Luminosity Analysis in Run-02 and Plans for Run-03

A. Drees, BNL

October 22, 2002

for

RHIC Spin Collaboration Meeting XIII
RIKEN BNL Research Center

Results from Vernier Scans in RHIC from 2001/02 Au–Au and pp Operation

Angelika Drees, BNL C–AD, Zhangbu Xu, BNL STAR, Haibin Zhang, Yale University

- What are Vernier Scans?
- The Method
- Data and Analysis
- Results from Au–Au (2001)
- Results from pp (2001/2002)
- Summary

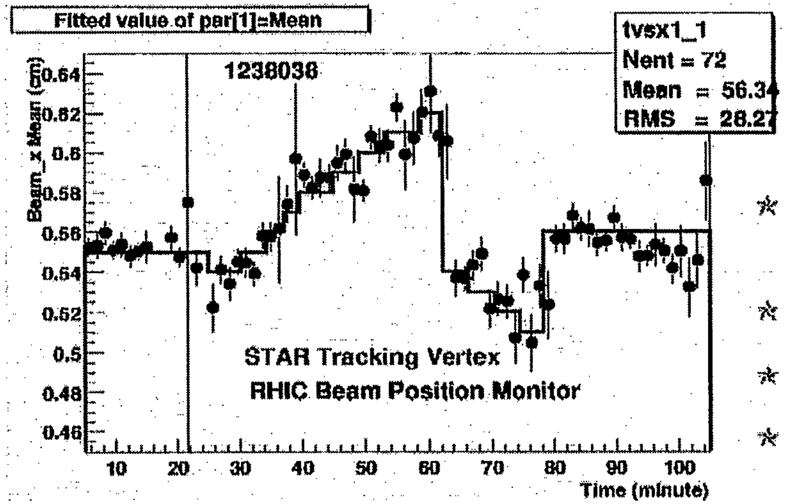
What are Vernier Scans?

Van–der–Meer Scans or Vernier Scans are done by stepwise sweeping one beam across the other while measuring collision rates as a function of beam displacement. This is done in both planes.

Needed basic instrumentation: the ZDCs or other collision monitors (BBC ...) at the various IRs, corrector magnet control to apply 4–bump at IR, DX Beam Position Monitors (BPM) and beam current measurements from Wall Current Monitor (WCM).

A Gauss function is fitted to the result yielding the maximum rates (R_x^{max}, R_y^{max}) the location of the maximums (x_{max}, y_{max}) and the effective beam widths (σ_x, σ_y) in both planes.

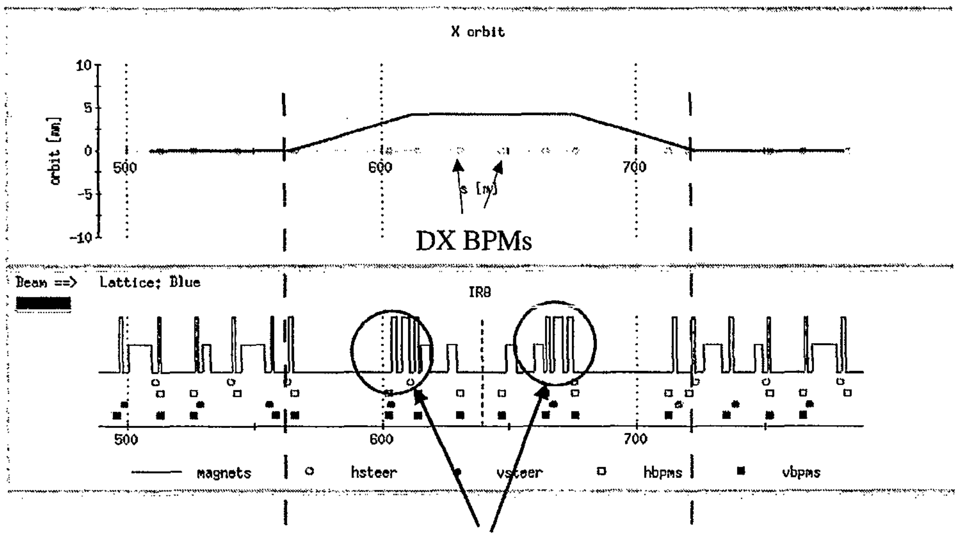
The Method



STAR reconstructed vertex during a horizontal scan in 2000 (arbitrary offset added to adjust both data sets).

- **Sweeping blue or yellow beam**
- **Stepsize: 100–500 μm**
- **approx. 2 min./point**
- **good agreement with STAR data**

Method: IR bumps



DX BPMs

Hcorr

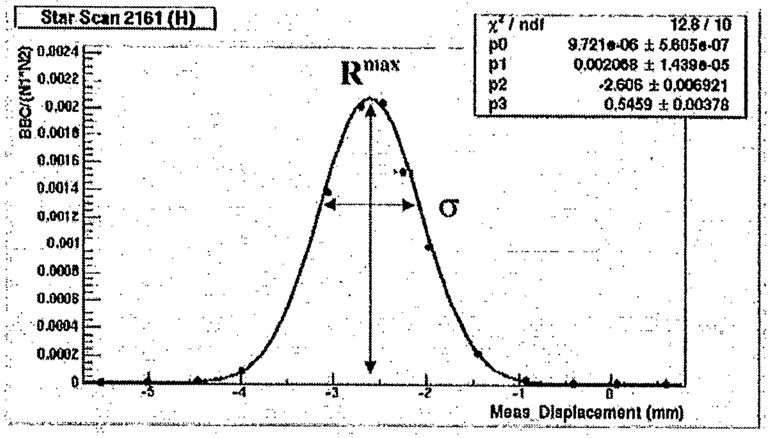
Triplet with skew quads

Hcorr

New in 2001–02: skew quads in triplets!
Different optics (b*) required different corrector settings.

Available Data from Scans

	Fill number	IR2	date	β*	comment
Au–Au	1056	STAR	9/21/01	5 m	
	1090	PHENIX	9/25/01	5 m	problem with gh8 bpr
	1153	PHENIX	10/1/01	5 m	problem with gh8 bpr
	1413	STAR	10/22/01	2 m	
	1646	PHENIX	11/6/01	1 m	problem with gh8 bpr
	1717	STAR	11/11/01	2 m	no bpm
	1717	PHENIX	11/11/01	1 m	no bpm
	1763	STAR	11/15/01	2 m	
	1766	PHENIX	11/16/01	1 m	problem with gh8 bpr
pp	2119	STAR	12/30/01	3 m	horiz. only, no ZDC
	2136	PHENIX	1/3/02	3 m	no ZDC
	2161	STAR	1/6/02	3 m	
	2161	PHENIX	1/6/02	3 m	
	2193	STAR	1/10/02	3 m	no bpm
	2193	IR2	1/11/02	3 m	one side bpm
	2233	IR2	1/15/02	3 m	one side bpm
	2277	STAR	1/20/02	3 m	
	2277	PHENIX	1/20/02	3 m	



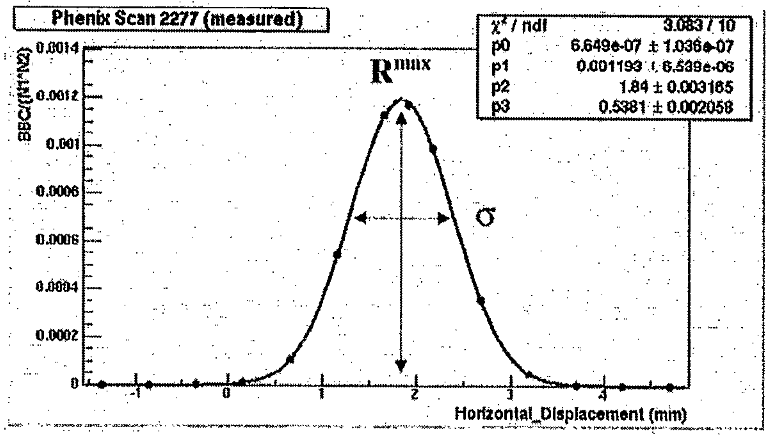
- ✯ do both planes (varying order)
- ✯ approx. 30 min. / scan
- ✯ fit Gauss function to data
- ✯ reasonable x2/ndf
- ✯ get fit parameters to calculate luminosity and cross section

$$\sigma_{(Au+Au)} = R^{max}\, 2\pi \sigma_x \sigma_y k_b / f_{rev}$$

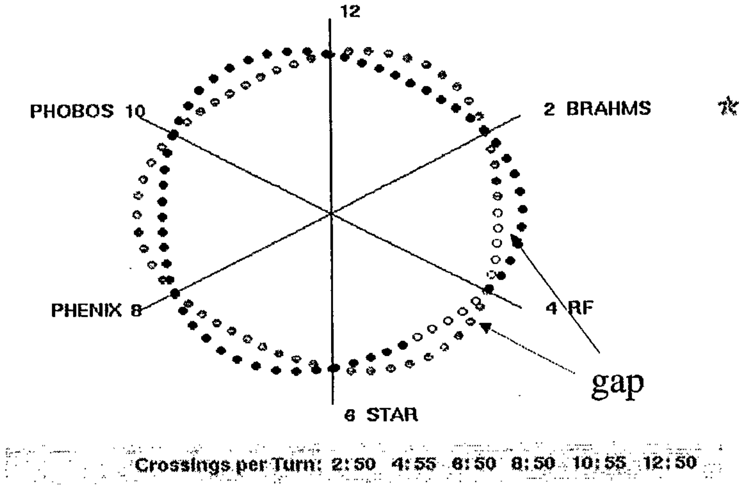
$\sigma_x \sigma_y$: horz./vert. profiles

k_b : number of bunches

f_{rev} : revolution frequency



Correction: Fill Pattern



- Total beam current has to be corrected for actual colliding pairs of bunches at the IRs.

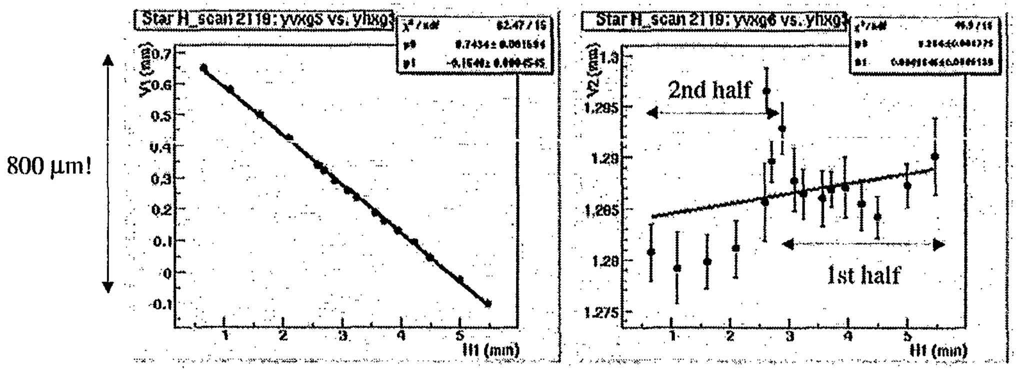
- With 55 bunches (and 60 bunch pattern) this is 9% (5 out of 55) at all IPs except IR8 and IR2 (Au–Au) or IR4 and IR10 (pp). Correction varies from fill to fill slightly.

Coupling and Model Corrections at STAR

✯ **model correction** (meas. displacement vs. set value):

- Au–Au: $(H_1+H_2)/2 = 6\%$, $(V_1+V_2)/2 = -4\%$ (β^* 2m)
- pp: $(H_1+H_2)/2 = 2\%$, $(V_1+V_2)/2 = -3\%$ (β^* 3m)

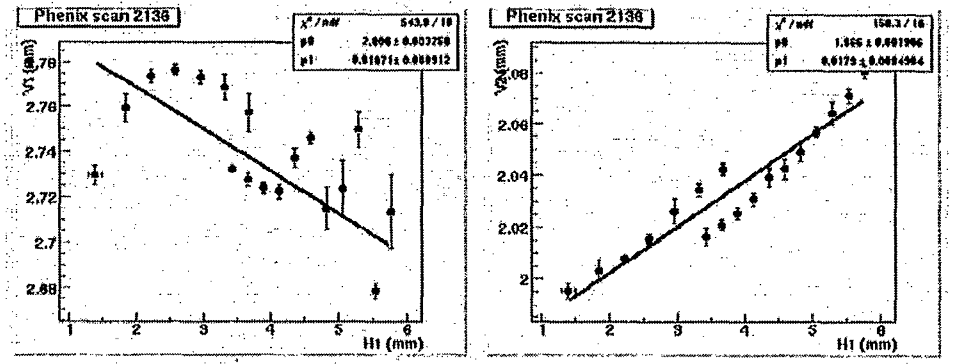
✯ **coupling** (scan induces changes in the other plane):



- shows non–linearities and hysteresis effects (corrector magnets)
- varies by one order of magnitude from fill to fill:
  at z=0: from 2 μm/mm to 70 μm/mm!
- depends on corrector magnets and skew quad settings –> check

Coupling at PHENIX

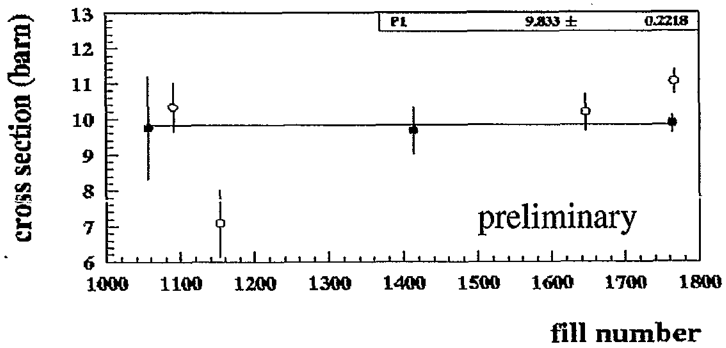
- **model correction** (meas. displacement vs. set value):
  - Au–Au: $(H_1+H_2)/2 = 18\%$, $(V_1+V_2)/2 < 2\%$ (β^* 1m) (only 1 fill)
  - pp: $(H_1+H_2)/2 < 2\%$, $(V_1+V_2)/2 < 1\%$ (β^* 3m)
- **coupling** (scan induces changes in the other plane):



  - shows non–linearities and hysteresis effects
  - smaller fill to fill variations (pp):
    at z=0: from −5 µm/mm to 3 µm/mm!

Au–Au: Results from run 2001:

Only STAR data (red circles) used. PHENIX data (open circles) not included.



Preliminary total cross sections from the 2001 Au–Au data (200 GeV), corrected for fill pattern, statistical error bars shown

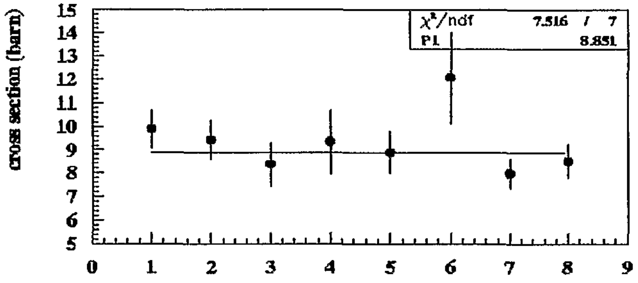
preliminary:

Total cross section @ 200 GeV: σ_{Au+Au} **= 9.8 +/– 0.2 (stat.) barn +/– 1.2 (sys.) barn**

compare to:

Total cross section @ 130 GeV: σ_{Au+Au} **= 8.9 +/– 0.3 (stat.) +/– 0.6 (syst.) barn**

AU–AU: Results from previous run (2000)



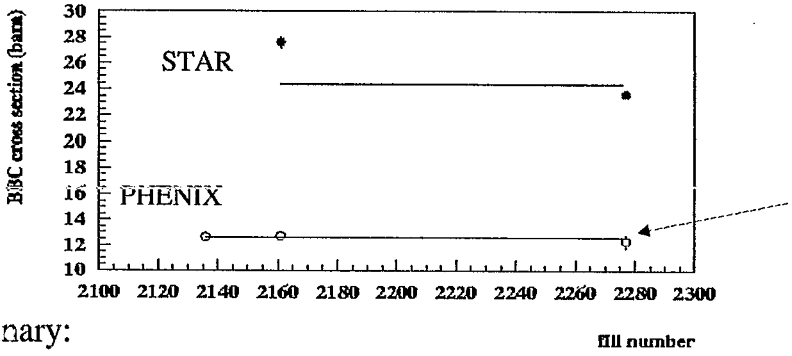
cross section as function of scan id in run 2000

Final total cross sections in the year 2000 (130 GeV) after correction (statistical errors shown).

Total cross section @ 130 GeV:

σ_{Au+Au} **= 8.9 +/– 0.3 (stat.) +/– 0.6 (syst.) barn**

pp: Preliminary Results from Run 2002



corrected for
bunch length
variation

Preliminary:

BBC: different detectors at IR6 and IR8:

$\sigma_{\mathrm{BBC,PHENIX}}$ **= 12.6 +/– 0.1 (stat) +/– 1.0** (syst) and

$\sigma_{\mathrm{BBC,STAR}}$ **= 24.4 +/– 0.2 barn (stat)**

ZDC: consistent results from PHENIX and STAR scans:

cross–section for pp @ 200 GeV: σ_{zdc} **= 0.28 +/– 0.01 (stat) barn**

Summary

- Vernier Scans are a powerful tool for both, EP and AP.
- Situation in 2001–02 was more difficult due to b–squeezing and the use of skew quads, probably corrector saturation.

- ***Preliminary*** results for cross sections:
  - ZDC (Au–Au): **9.8 +/– 0.2 (stat.) +/– 1.2 (sys.) barn**
  - PHENIX–BBC (pp): **12.6 +/– 0.1 (stat) +/– 1.0 (syst) barn**
  - STAR–BBC (pp): **24.4 +/– 0.2 (stat) barn**
  - ZDC (pp): **0.28 +/– 0.01 (stat) barn**

- More corrections need to be done and numbers might change slightly.
- Systematic errors need some more work and analysis.

Report on the PHENIX Trigger Efficiency Used in Absolute Luminosity Analysis for Run-02

S. Belikov, BNL/ISU
October 22, 2002

for
RHIC Spin Collaboration Meeting XIII
RIKEN BNL Research Center

Absolute Luminosity Measurement in PP RUN 2002 at PHENIX

Sergey Belikov, Iowa State University,
for PHENIX collaboration

Content

Introduction

- Determine total inelastic cross section in PP interactions at √S=200 GeV.

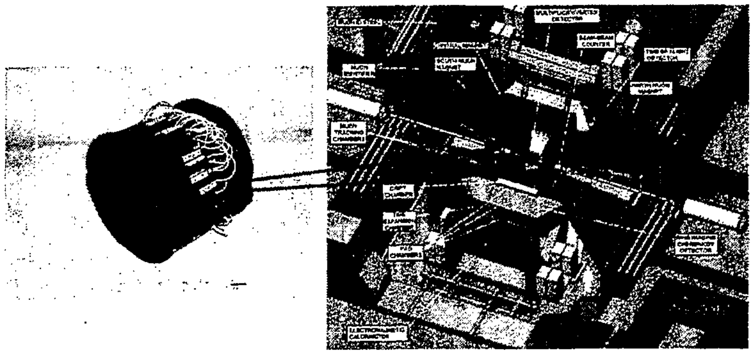
During van der Meer scan PHENIX supplied signals from 3 independent detectors:

1. Zero Degree Calorimeter (~ 1-2% efficiency, too low statistic for analysis).
2. Normalization Trigger Counters (too sensitive to a background).
3. Beam Beam Counters with Local Level 1 trigger subsystem (effectively cuts background, efficiency ~ 50%).

In this analysis only BBC LL1 trigger was used.

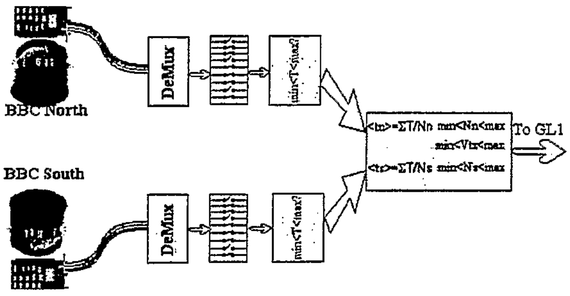
Beam – Beam Counters

- Two arms at ± 1.5 m from the PHENIX center.
- 64 PMTs in each arm.
- PMT has 3 cm thick quartz window – detects Cherenkov light.
- Flash ADCs convert signals to digits on each beam crossing.
- Timing data are processed by the BBC Local Level 1 Trigger System.



BBC LL1 operation

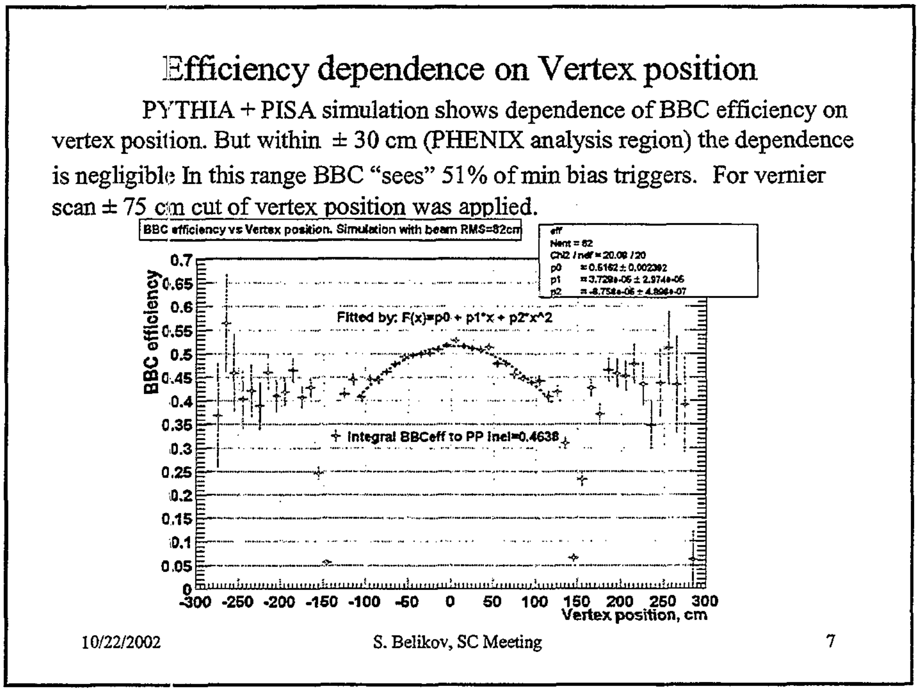
1. Converts input bits into channel time values
2. Masks off bad channels
3. Checks time range for each channel
4. Determines number of hits in each arm
5. Calculates average arm time
6. For each arm checks if number of hits is in range
7. Checks if Vertex is in range
8. Result of the last two checks and FEM Unreliable signal are used as an input into 4->2 Look Up Table that creates 2 output bits for GL1



BBC Efficiency calculation

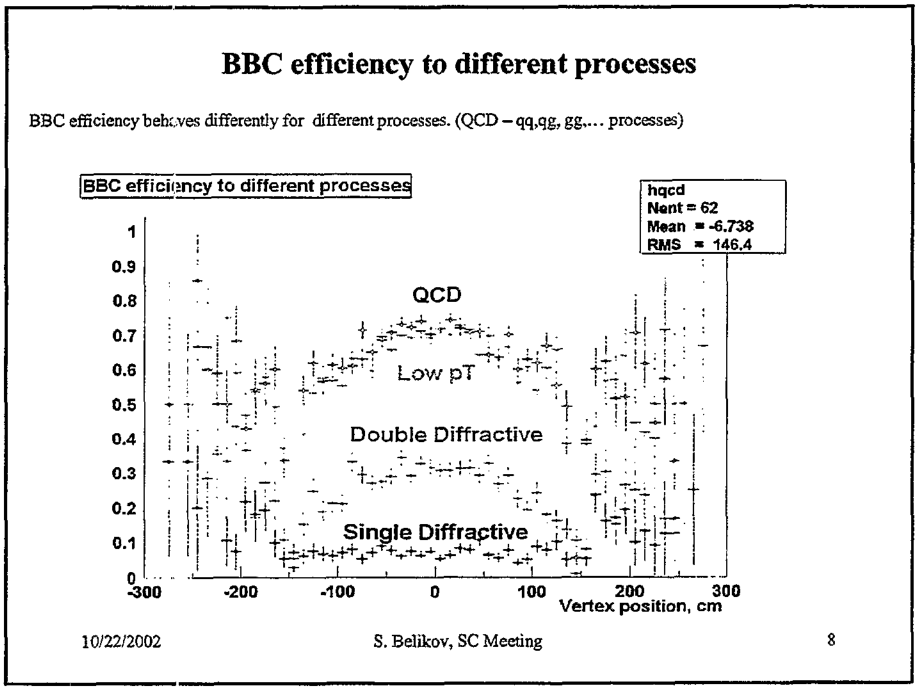
In principle it is possible to simulate both BBC and LL1, but we decided to split the task:

1. Simulate BBC and find out their efficiency to all PP inelastic processes.
2. Determine BBC LL1 efficiency directly from data accumulated during van der Meer/vernier scan. This permits to avoid systematic error introduced by pedestals drift, etc.



Efficiency dependence on Vertex position

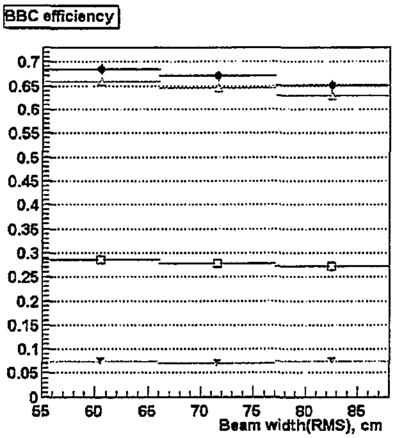
PYTHIA + PISA simulation shows dependence of BBC efficiency on vertex position. But within ± 30 cm (PHENIX analysis region) the dependence is negligible In this range BBC "sees" 51% of min bias triggers. For vernier scan ± 75 cm cut of vertex position was applied.

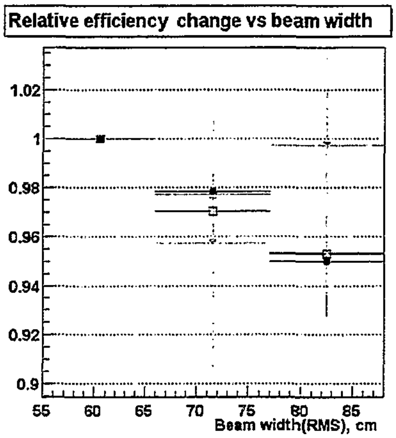


BBC efficiency to different processes

BBC efficiency behaves differently for different processes. (QCD – qq,qg, gg,… processes)

BBC efficiency dependence on bunch width

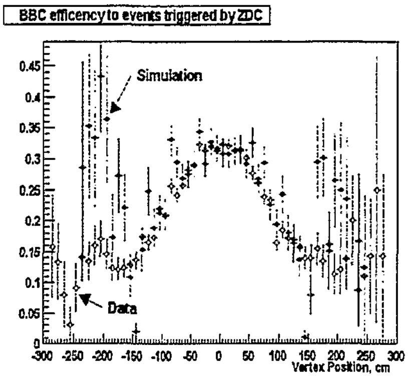




Comparison with experimental data

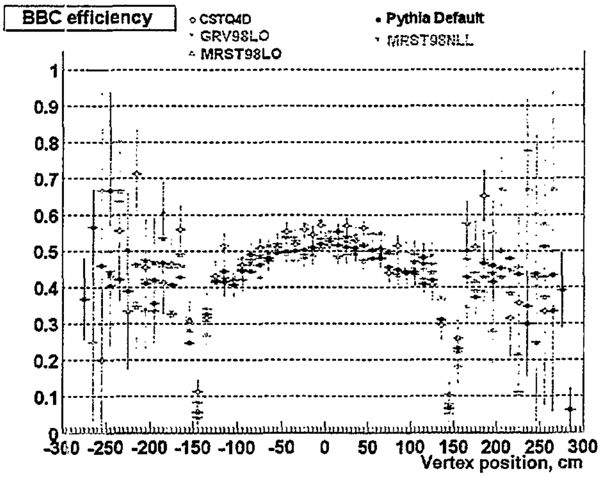
- In PHENIX by selecting events triggered by ZDC we can measure BBC efficiency and can compare it with our simulation. As you can see we have good enough agreement in +/- 150 cm region, but our simulation definitely exaggerates BBC efficiency outside this region. Integral (+/- 300 cm range) BBC efficiency extracted from the data is 5% lower then that obtained from simulation.
Reason: inaccuracy in the simulation of the Cherenkov light propagation when charged particle hit PMT from back.

- Would be better to use narrower vertices range, ± 140 cm. Advantages: less sensitive to background. Disadvantage: more sensitive to the bunch length.
- Integral BBC efficiency in the ± 140 cm is **BBCeff=0.437**



Dependence on Parton Distribution Function model

Five functions were used to estimate systematic error. PDF variation introduces 2% systematic error.



LL1 efficiency

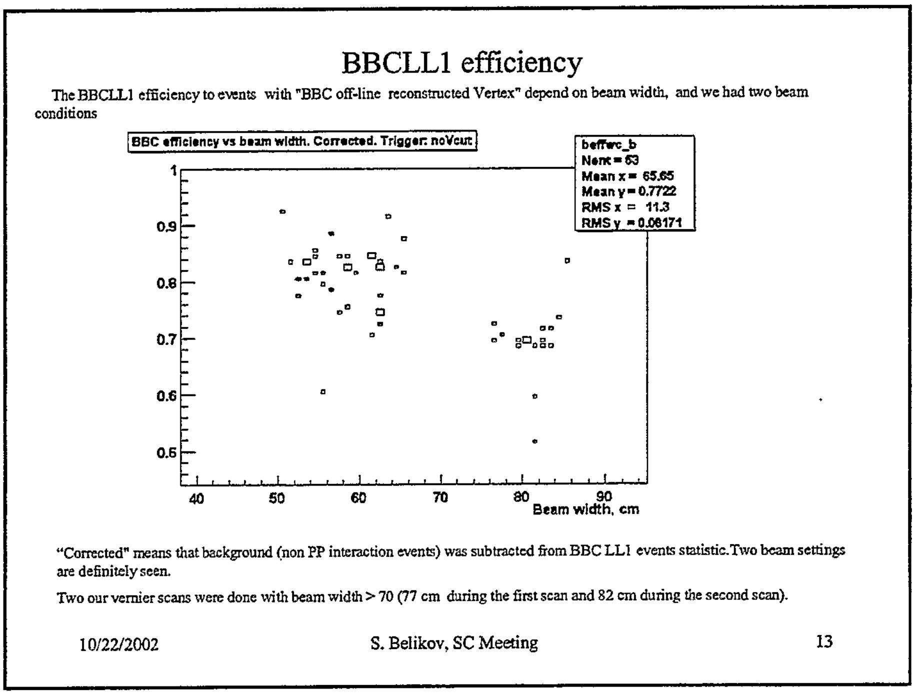
- To determine BBC LL1 efficiency two triggers were used:

1. Clock trigger – distributed randomly in time (not biased, but low statistic)
2. BBC LL1 without vertex cut (high statistic, but biased)

To estimate BBCLL1 trigger background we sorted all events triggered by BBCLL1 into 4 groups according to beams fill patterns:

1. Yellow empty, Blue empty
2. Yellow empty, Blue filled
3. Yellow filled, Blue empty
4. Yellow filled, Blue filled.

First 3 groups were used for background estimation. It is worth to mention that the background to BBCLL1 triggered events in most runs is ~ 0.1%

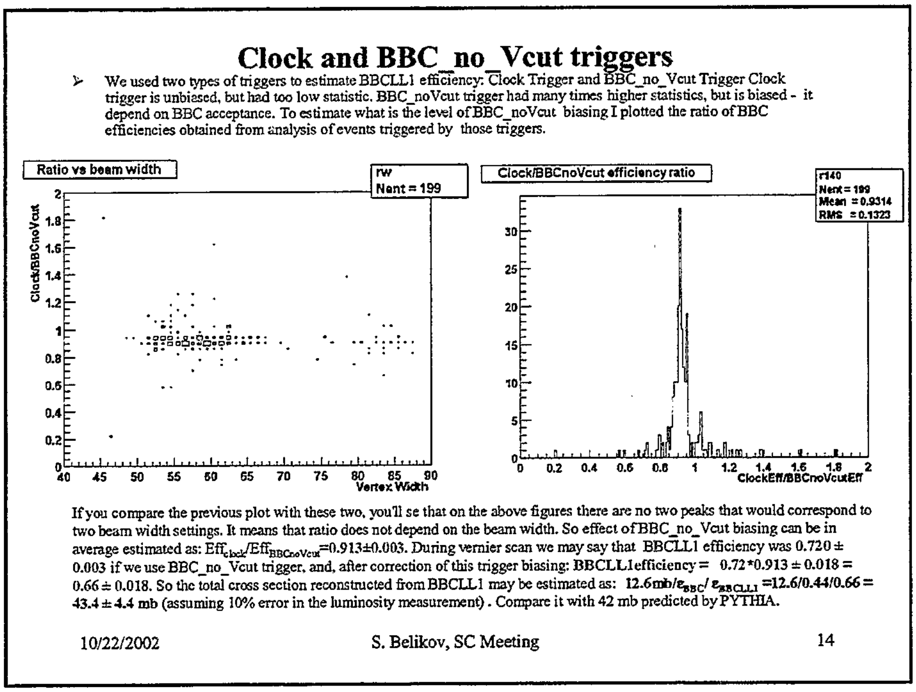


BBCLL1 efficiency

The BBCLL1 efficiency to events with "BBC off-line reconstructed Vertex" depend on beam width, and we had two beam conditions

"Corrected" means that background (non PP interaction events) was subtracted from BBC LL1 events statistic.Two beam settings are definitely seen.

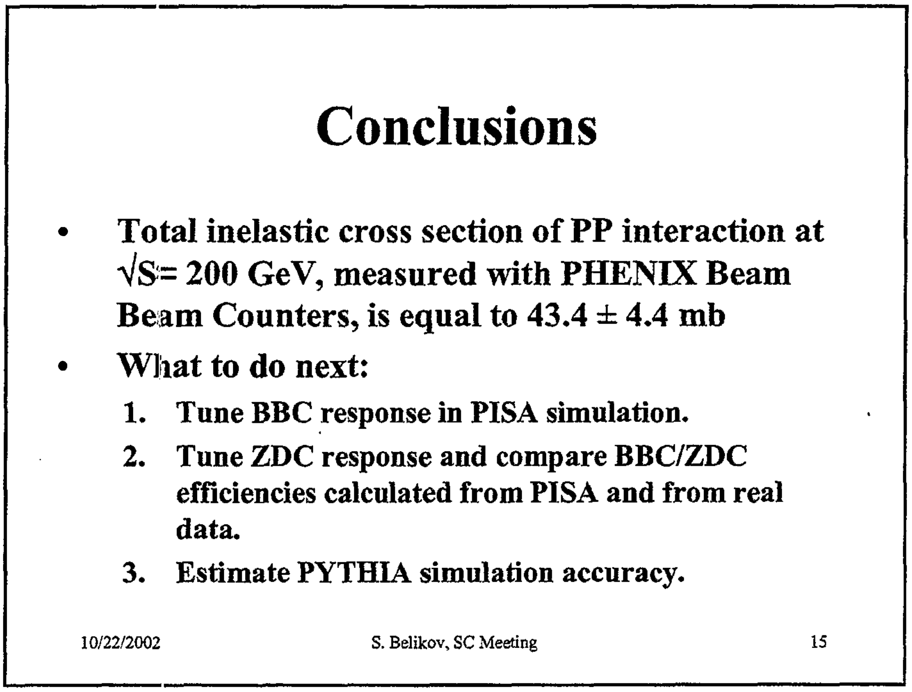
Two our vernier scans were done with beam width > 70 (77 cm during the first scan and 82 cm during the second scan).



Clock and BBC_no_Vcut triggers

- We used two types of triggers to estimate BBCLL1 efficiency: Clock Trigger and BBC_no_Vcut Trigger Clock trigger is unbiased, but had too low statistic. BBC_noVcut trigger had many times higher statistics, but is biased - it depend on BBC acceptance. To estimate what is the level of BBC_noVcut biasing I plotted the ratio of BBC efficiencies obtained from analysis of events triggered by those triggers.

If you compare the previous plot with these two, you'll se that on the above figures there are no two peaks that would correspond to two beam width settings. It means that ratio does not depend on the beam width. So effect of BBC_no_Vcut biasing can be in average estimated as: $Eff_{clock}/Eff_{BBCnoVcut}=0.913\pm0.003$. During vernier scan we may say that BBCLL1 efficiency was 0.720 ± 0.003 if we use BBC_no_Vcut trigger, and, after correction of this trigger biasing: **BBCLL1efficiency = 0.72*0.913 ± 0.018 = 0.66 ± 0.018**. So the total cross section reconstructed from BBCLL1 may be estimated as: **$12.6mb/\varepsilon_{BBC}/\varepsilon_{BBCLL1}=12.6/0.44/0.66=$ 43.4 ± 4.4 mb** (assuming 10% error in the luminosity measurement). Compare it with 42 mb predicted by PYTHIA.



Conclusions

- **Total inelastic cross section of PP interaction at $\sqrt{S}$= 200 GeV, measured with PHENIX Beam Beam Counters, is equal to 43.4 ± 4.4 mb**
- **What to do next:**
    1. **Tune BBC response in PISA simulation.**
    2. **Tune ZDC response and compare BBC/ZDC efficiencies calculated from PISA and from real data.**
    3. **Estimate PYTHIA simulation accuracy.**

RSC meeting, 10/22/02

NLO QCD Corrections to A_{LL}^{π}

Werner Vogelsang (RBRC/BNL)

collaboration with :

Barbara Jäger (Regensburg)

Marco Stratmann (Regensburg)

- **Accessing Δg at RHIC**
- **NLO QCD Corrections to A_{LL}^{π}**
- **Results**

major goal of RHIC spin program: measure $\Delta g(x)$

key advantages of RHIC:

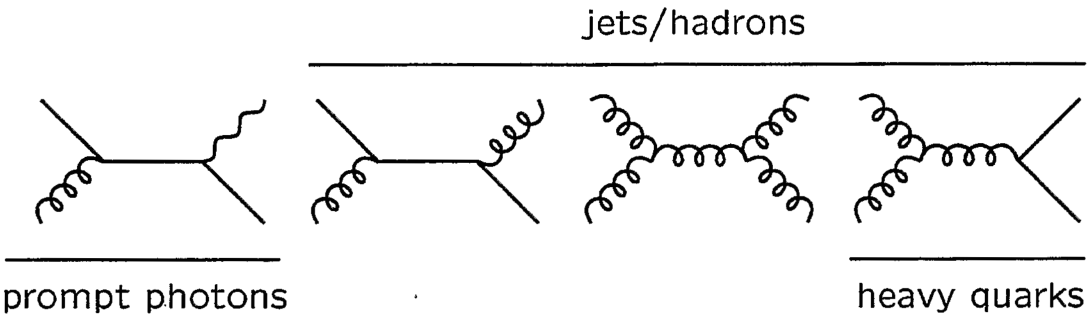
- Δg can be probed in *various* processes

  → can verify universality of pol. pdfs for the 1st time

  $\updownarrow$

  foundation for predictive power of pQCD

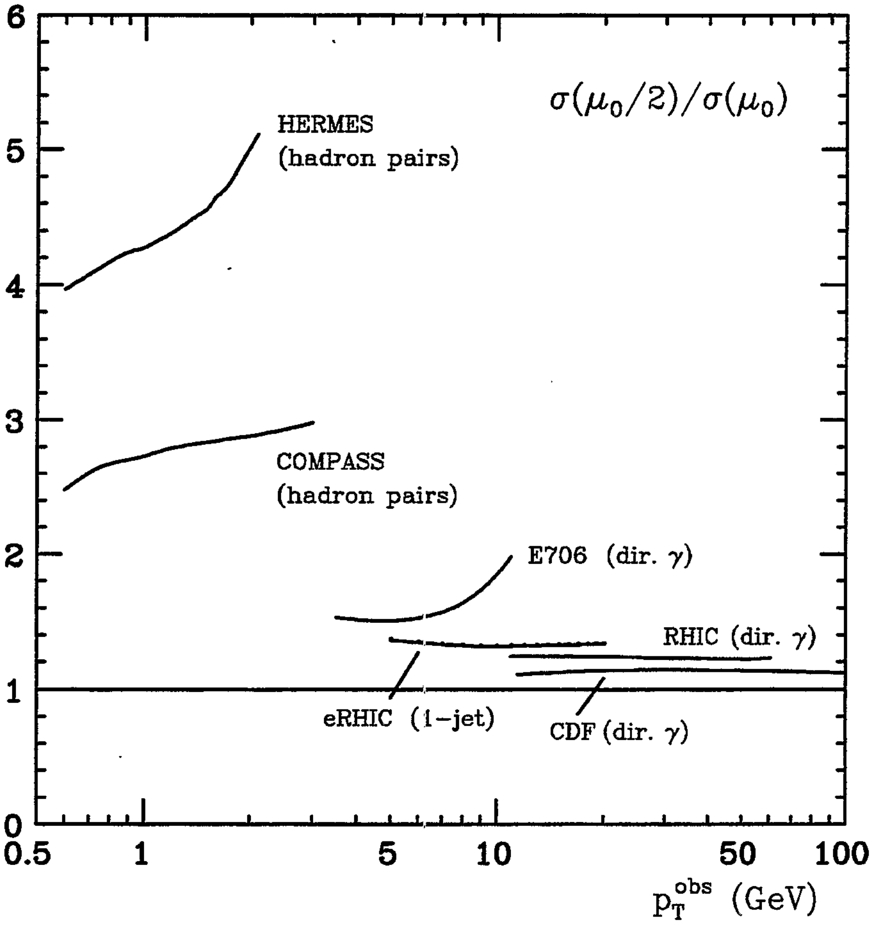
  candidates with a *dominant* gluon contribution in LO:



- large c.m.s. energy $\sqrt{S}$ → high p_T accessible

  → pQCD should be applicable

scale dependence ↔ measure for reliability of pQCD:



← ratio of x-secs for two choices of μ should be $\simeq 1$

↑ ↑

× ✓

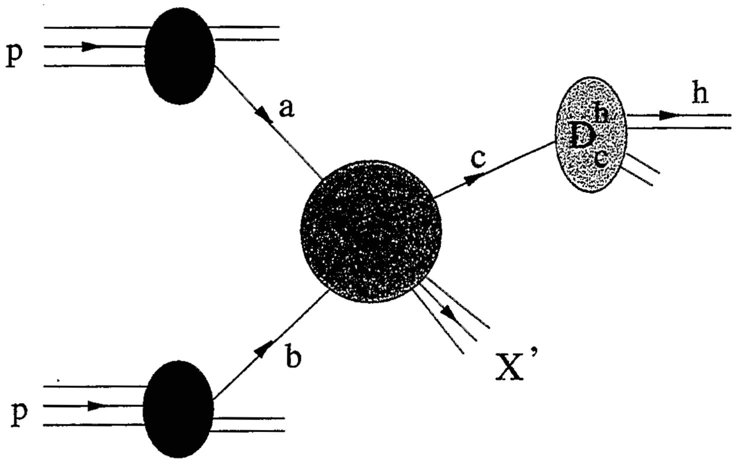
general framework for inclusive-pion production:

starting point: factorization theorem

Libby, Sterman; Ellis et al.; Collins et al.; ...

requirement: a hard scale, e.g., pions with high-p_T

$$d\sigma = \left| \quad \right|^2 + \mathcal{O}\left(\frac{\lambda}{p_T}\right)^n$$



long-distance

from exp.; μ-dep.: $d\sigma/d\mu = 0$ (pQCD)

↓ ↓ ↓

$$\boxed{\frac{d\sigma^{pp\to\pi X}}{dp_T} = \sum_{abc}\int dx_a\, dx_b\, dz_c\, f_a(x_a,\mu)\, f_b(x_b,\mu)\, D_c^{\pi}(z_c,\mu) \times \frac{d\hat{\sigma}^{ab\to cX'}}{dp_T}(x_aP_a, x_bP_b, P^{\pi}/z_c,\mu) + \text{Power corr.}}$$

↑

short-distance

pQCD: power series in α_s

- scale $\mu \sim p_T$: separates long- and short-dist. physics
- formula valid for polarized case as well :

$f(x,\mu_f) \to \Delta f(x,\mu_f)$ and $d\hat{\sigma}/dp_T \to d\Delta\hat{\sigma}/dp_T$

experimentally relevant: double-spin asymmetry

$$\boxed{A^{\pi}_{\mathrm{LL}} \equiv \frac{d\sigma^{pp\to\pi X'}(++) - d\sigma^{pp\to\pi X'}(+-)}{d\sigma^{pp\to\pi X'}(++) + d\sigma^{pp\to\pi X'}(+-)}}$$

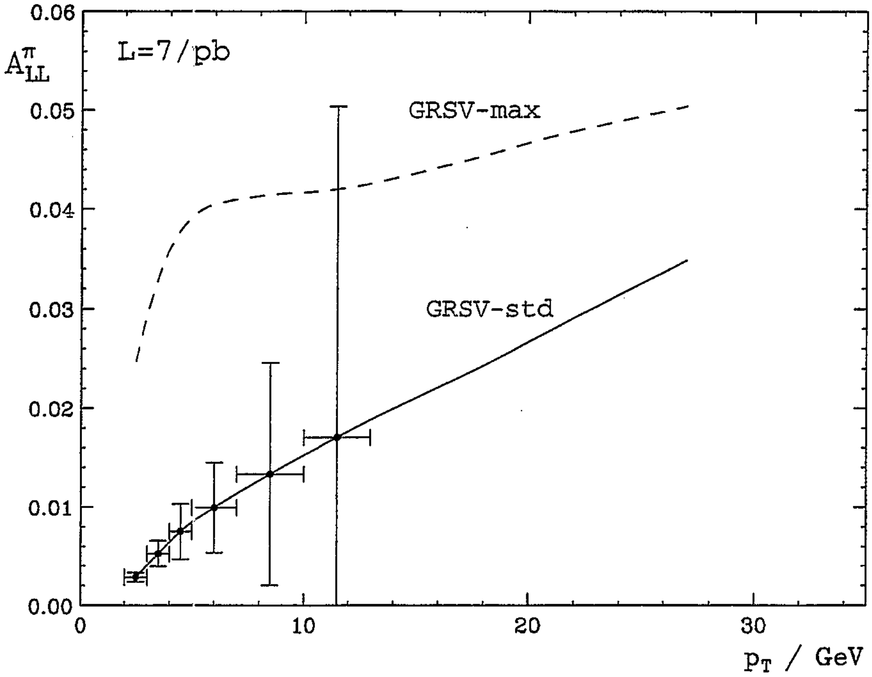
↑↑ ↑↑

helicities of colliding protons

LO prediction for $A^{\pi}_{\mathrm{LL}}(p_T^{\pi})$ at $\sqrt{S} = 200\,\mathrm{GeV}$:

very moderate luminosity!

↓

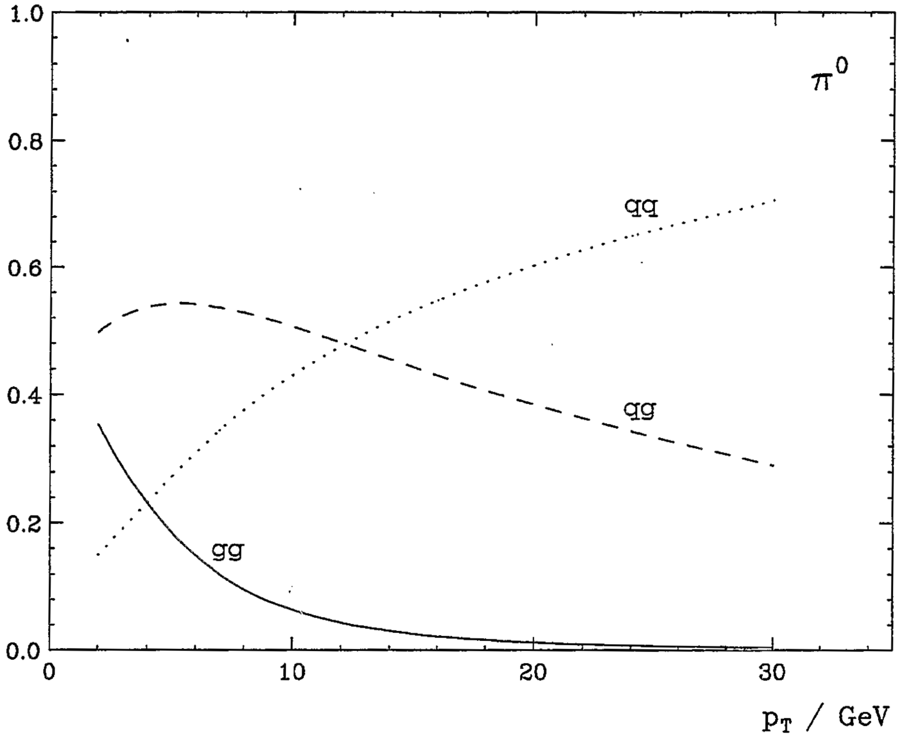


estimate of statistical errors: $\delta A \simeq \frac{1}{P_1 P_2} \times \frac{1}{\sqrt{\mathcal{L}\sigma_{\mathrm{bin}}\varepsilon_{\mathrm{eff}}}}$

[with $P_1 = P_2 = 0.5$ (beam pol.) and $\varepsilon_{\mathrm{eff}} = 1$ (detection efficiency)]

sensitivity to Δg (with $\mathcal{L} = 7/\mathrm{pb}$!) → very promising breakdown into contributions from different subprocesses:

$d\sigma^{\pi^0}/dp_T$ ($\sqrt{S} = 200\,\mathrm{GeV}$)



[unpol. NLO: Aversa et al.; pdfs: CTEQ5M; frag-fcts: Kretzer]

→ gluon-induced processes relevant up to large p_T

polarized: $qq/qg/gg$ ratio depends strongly on Δg

NLO pQCD hard scattering works well at colliders →

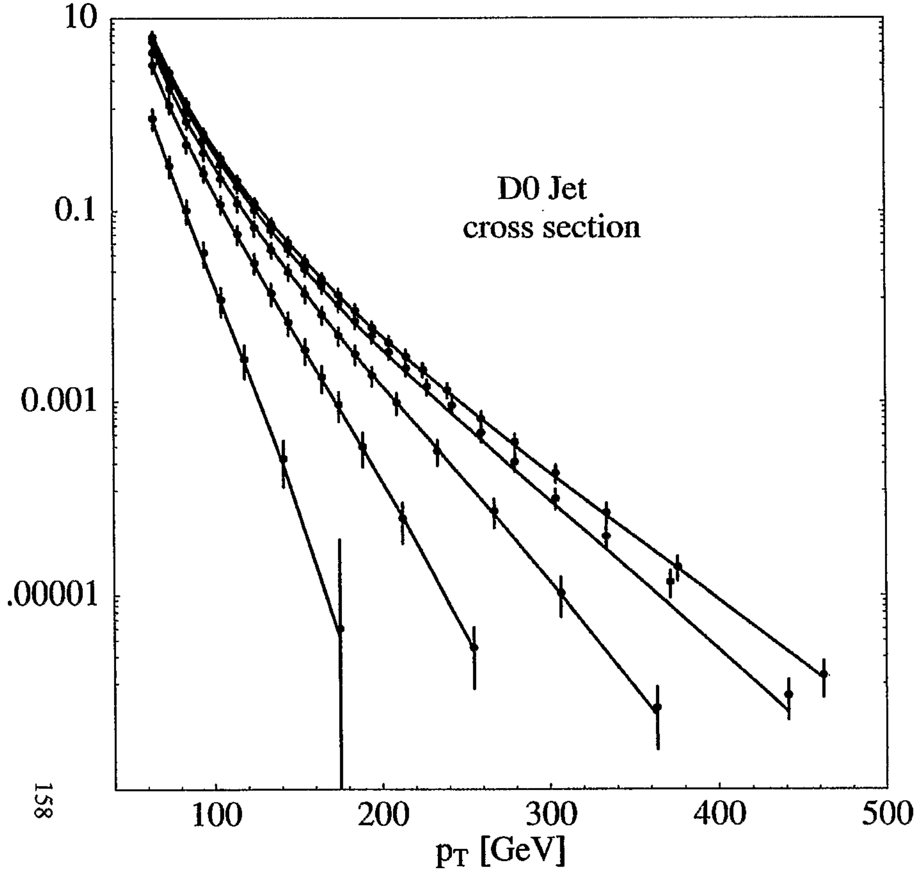
in general, NLO QCD corrections are a must :

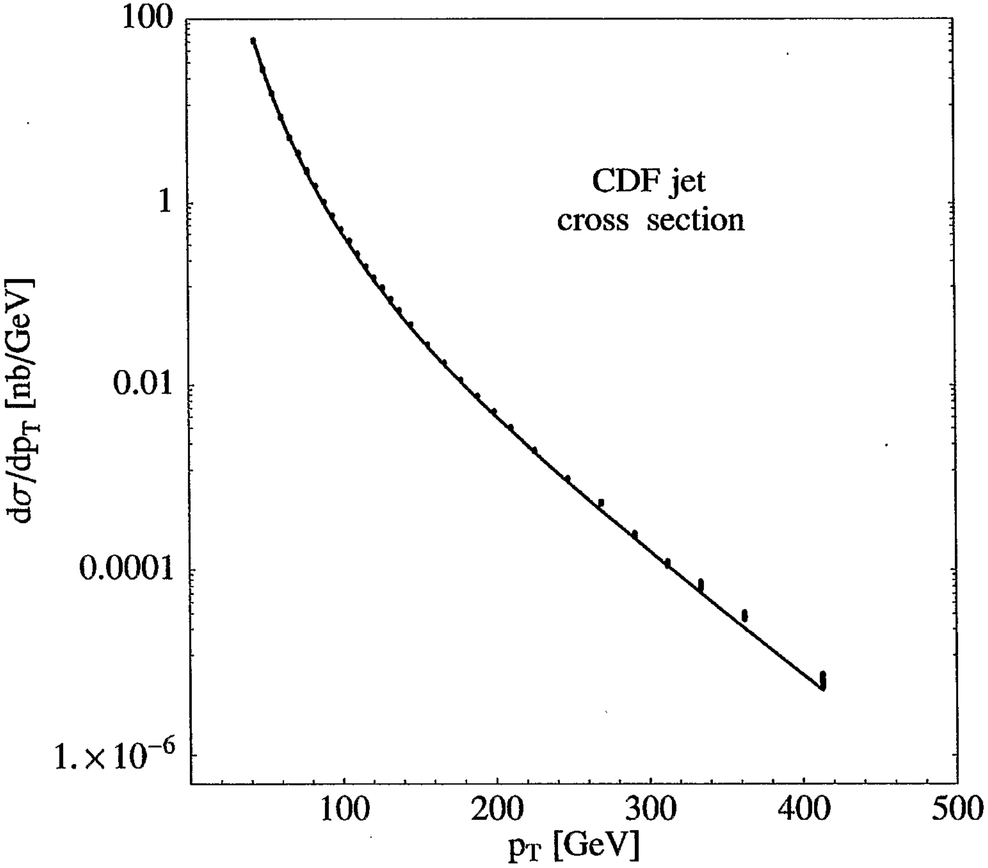
$$\mu \frac{\mathrm{d}}{\mathrm{d}\mu} d\sigma_{\text{phys}} = 0$$

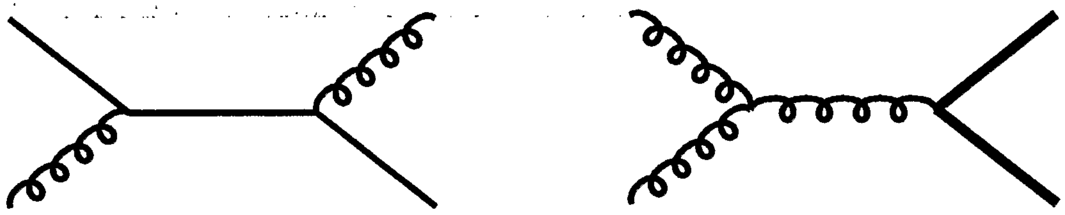
- however, ≠ 0 in truncated preturbation theory
- dependence on unphysical scale μ strong in LO

  → sizable theoretical uncertainties
- QCD corrections often important,
  in particular for polarized cross section
- more reliable angular / p_T distributions, jet def., . . .

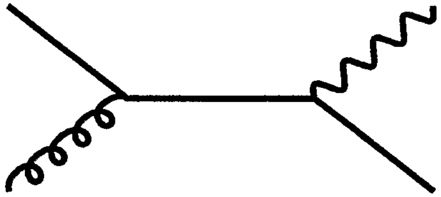
Example : High-p_T jets at the Tevatron :

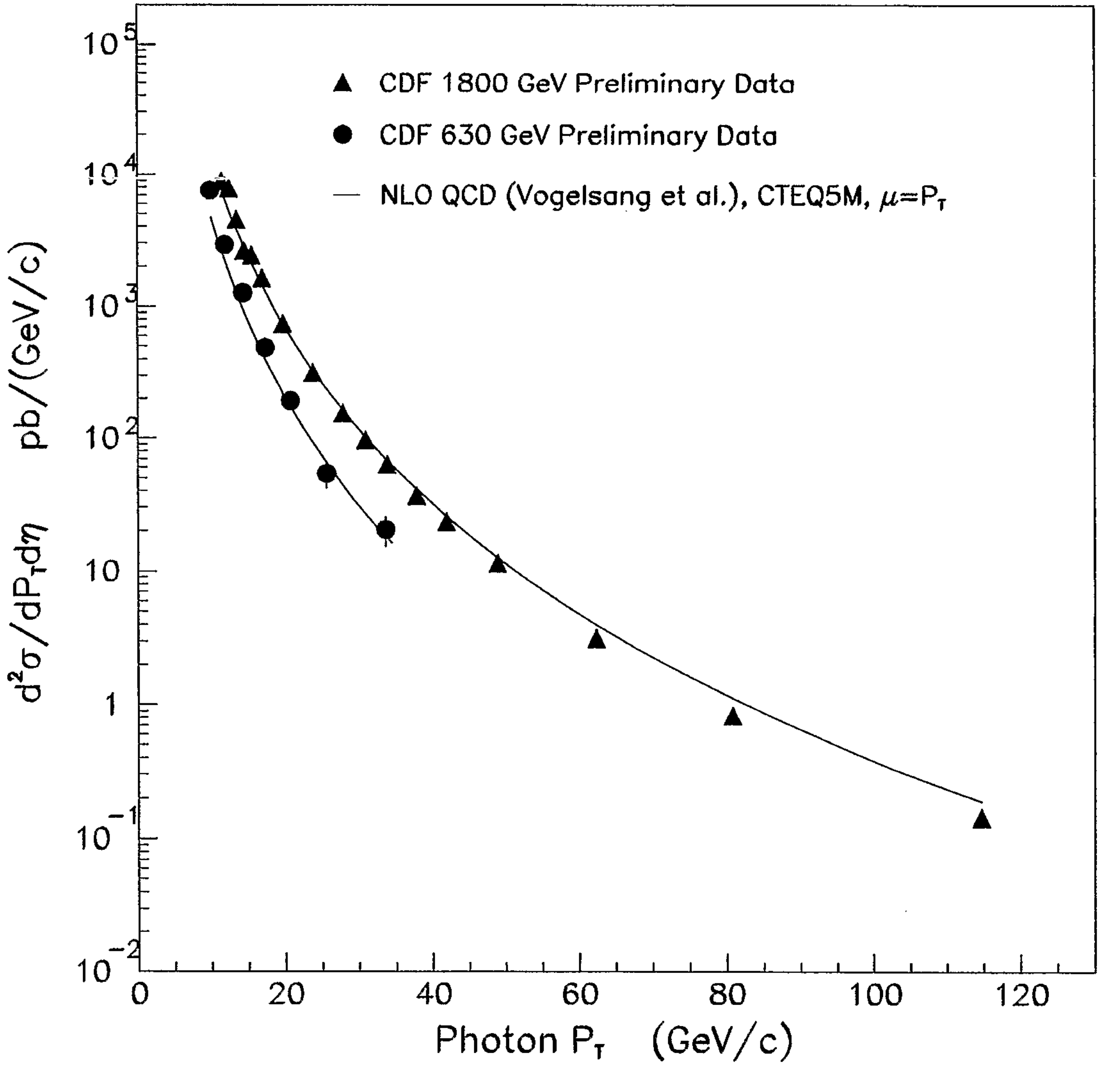






Example : High-p_T photons at the Tevatron :

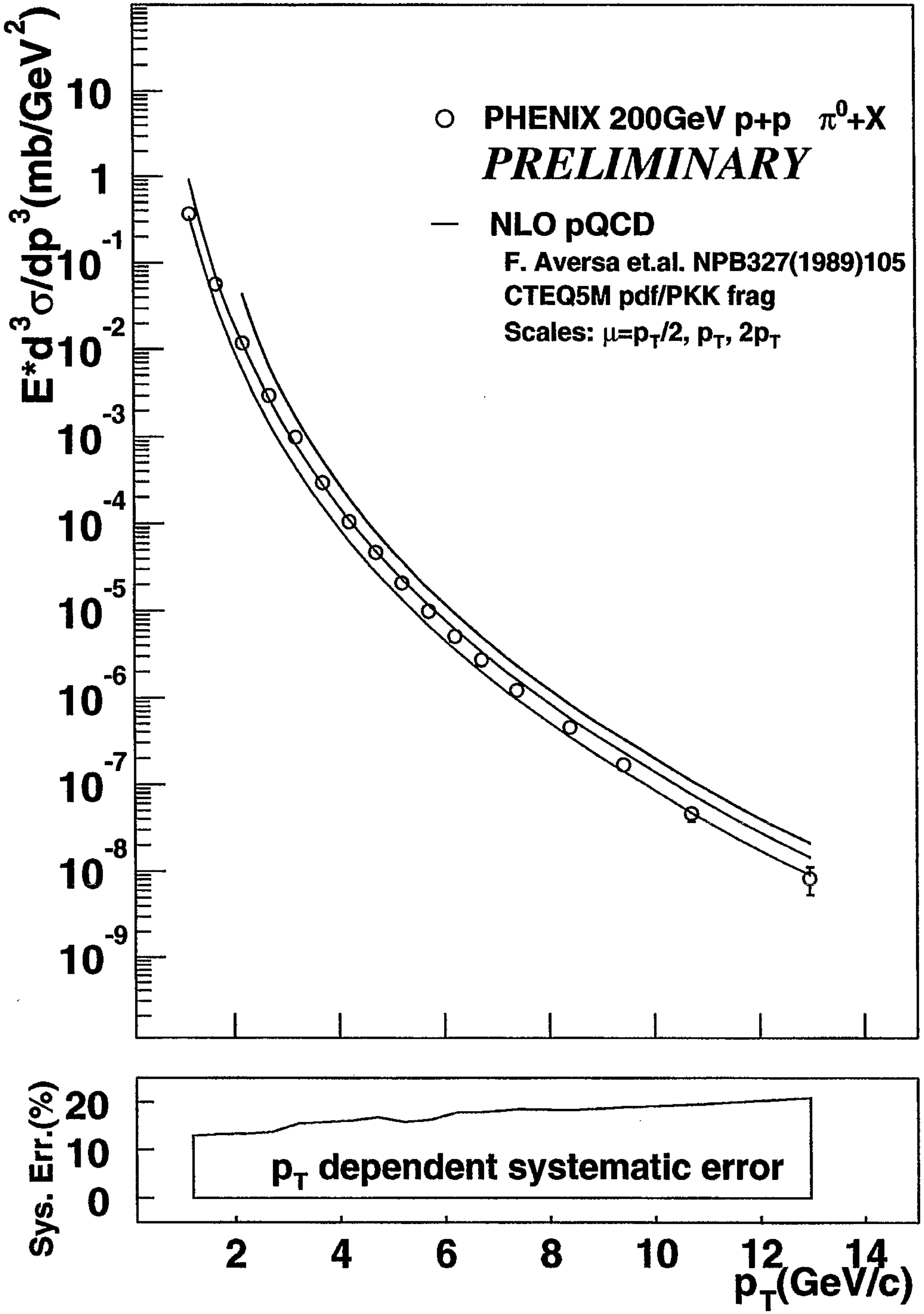




AND :

$pp \to \pi^0 X$ by PHENIX

(±30% normalization unc.)



NLO QCD corrections to $\mathrm{A}_{\mathrm{LL}}^{\pi}$ - outline:

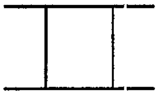
at $\mathcal{O}(\alpha_s^2)$ one has:

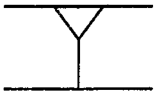
all LO $2 \to 2$  parton-parton scattering processes

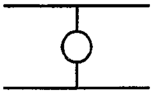
unpol.: 4 processes $qq' \to qq'$, $qq \to qq$, $q\bar{q} \to gg$, $gg \to gg$
all other processes related by crossing
(however, need $\vec{q}\vec{g} \to qg$ etc.)

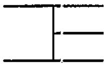
at $\mathcal{O}(\alpha_s^3)$ one has:

(1) 1-loop (virtual) corrections to all LO processes


'box'


'vertex'


'selfenergy'

(2) all $2 \to 3$  parton-parton scattering processes

$qq' \to qq'g$, $q\bar{q} \to ggg$, $gg \to ggg$, etc.

all contributions separately singular
$\Rightarrow$ choose $d = 4 - 2\epsilon$ dimensions

Two strategies for NLO calculations :

(1) 'Monte-Carlo approach'

✓ different observables, exp. cuts
✓ "smaller amount of work"
× delicate numerics
× relatively slow in evaluation
→ D. de Florian

$$I = \lim_{\epsilon \to 0} \left(\int_0^1 \frac{dx}{x} x^{\epsilon} F(x) - \frac{1}{\epsilon} F(0) \right)$$

$$I = F(0) \ln \delta + \int_\delta^1 \frac{dx}{x} F(x)$$

"slicing method"

$$I = \int_0^1 \frac{dx}{x} \left[F(x) - F(0) \right]$$

"subtraction method"

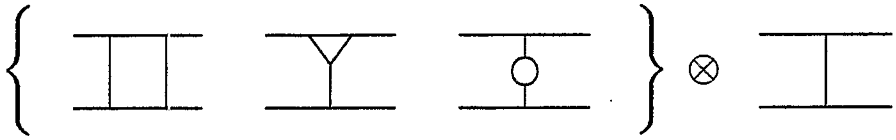
(previous application : $\vec{p}\vec{p} \to$ jets$X$ de Florian, Frixione, Signer, WV)

(2) 'analytical method'

× 'only' single-incl. cross section
✓ numerically stable
✓ fast → useful for global fits
→ our approach
(previous application : $\vec{p}\vec{p} \to \gamma X$ Gordon, WV; Contogouris et al.)

technical details (I) - 1-loop virtual corrections:

$\mathcal{O}(\alpha_s^3)$: only interference of 1-loop and Born amplitudes contributes:



IR+UV divergencies → work in $4-2\varepsilon$ dimensions

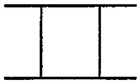
can extensively make use of available results

we use two different methods:

(1) renormalized propagators and vertices

Nowak, Praszalowicz, Slominski

UV-divergent → tabulated in NPS



UV-finite → calculate from scratch

(2) one-loop renormalized helicity amplitudes

Kunszt, Signer, Trocsanyi

some 'gymnastics' required to obtain desired results [e.g., 'color-linked matrix elements' Kunszt, Soper]

✓ results for methods (1) and (2) fully agree

✓ unpolarized results agree with Ellis, Sexton

technical details (II) - $2 \to 3$ contributions:

aim: calculation of *single-inclusive* pion cross section:

e.g. $gg \to q \ (\bar{q}g)$
↗ ↖
fragments: $q \to \pi X$ integrated out

phase space integration performed in rest frame of the two unobserved partons

↘ (parametrized by two angles $\theta_{1,2}$)

$$d\Delta\hat{\sigma}_{2\to 3} \sim \ldots \int d\theta_1 d\theta_2 \sin^{1-2\varepsilon}\theta_1 \sin^{-2\varepsilon}\theta_2 \, |\Delta M_{2\to 3}|^2$$

calculation requires extensive partial fractioning to get

$$I^{(k,l)} = \int \frac{d\theta_1 \ \sin^{1-2\varepsilon}\theta_1 \ d\theta_2 \ \sin^{-2\varepsilon}\theta_2}{(1+\cos\theta_1)^k (1 + A\cos\theta_1 + B\sin\theta_1\cos\theta_2)^l}$$

which can be done *analytically*

subtlety in polarized calculation: γ_5 in $4-2\varepsilon$ dimensions

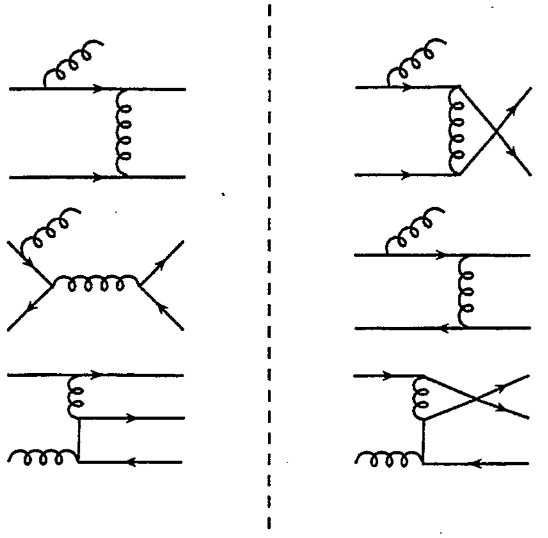
- γ_5 (and $\epsilon_{\mu\nu\rho\sigma}$) are genuine 4-dim. → use HVBM prescription :

$\{\gamma^\mu, \gamma_5\} = 0 \quad (\mu = 0,1,2,3) \qquad [\gamma^\mu, \gamma_5] = 0$ otherwise

✓ all $2 \to 3$ matrix elements computed ...
(agreement unpol. case with Ellis, Sexton)

✓ ... and integrated

some typical NLO $2 \to 3$ Feynman diagrams:



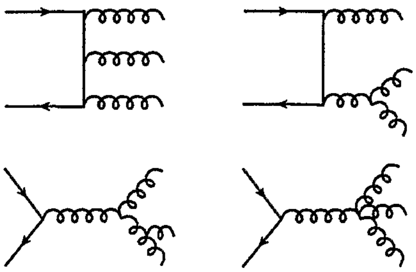
different flavors $q \neq q'$

identical flavors $q = q'$

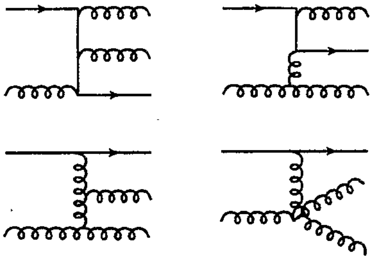
$qq' \to qq'g$

$q\bar{q} \to q'\bar{q}'g$

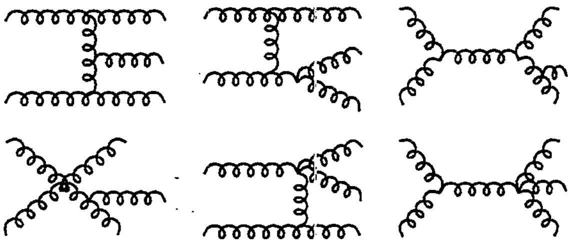
$qg \to qq'\bar{q}'$



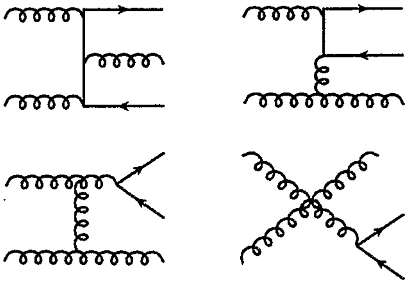
$q\bar{q} \to ggg$



$qg \to qgg$



$gg \to ggg$



$gg \to q\bar{q}g$

technical details (III) - cancellation of divergencies:

final step: adding up all real and virtual contributions

before taking the limit $\varepsilon \to 0$ all poles have to cancel:

UV $1/\varepsilon$-singularities

removed by renormalization of α_s

introduce arbitrary renormalization scale μ_r

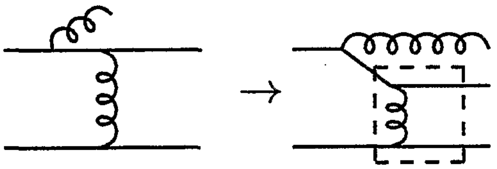
IR singularities ($1/\varepsilon^2$, $1/\varepsilon$)

cancel in sum of 1-loop and $2 \to 3$ contributions

collinear $1/\varepsilon$-singularities

have to be removed by factorization

e.g.:



$\sim \frac{1}{\varepsilon} \int dx \Delta P_{qq}(x) \Delta\hat{\sigma}_{qq\to qq}$

introduce two arbitrary factorization scales μ_f and μ'_f

initial-/final-state singularities

$\swarrow \qquad \searrow$

$\Delta f(x, \mu_f) \qquad D_f^{\pi}(z, \mu_{f'})$

Final answer finite ! → good check of results

final results (I) - $\mathcal{O}(\alpha_s^3)$ parton-parton processes:

16 different inclusive cross sections contribute:

fragmenting parton
↓

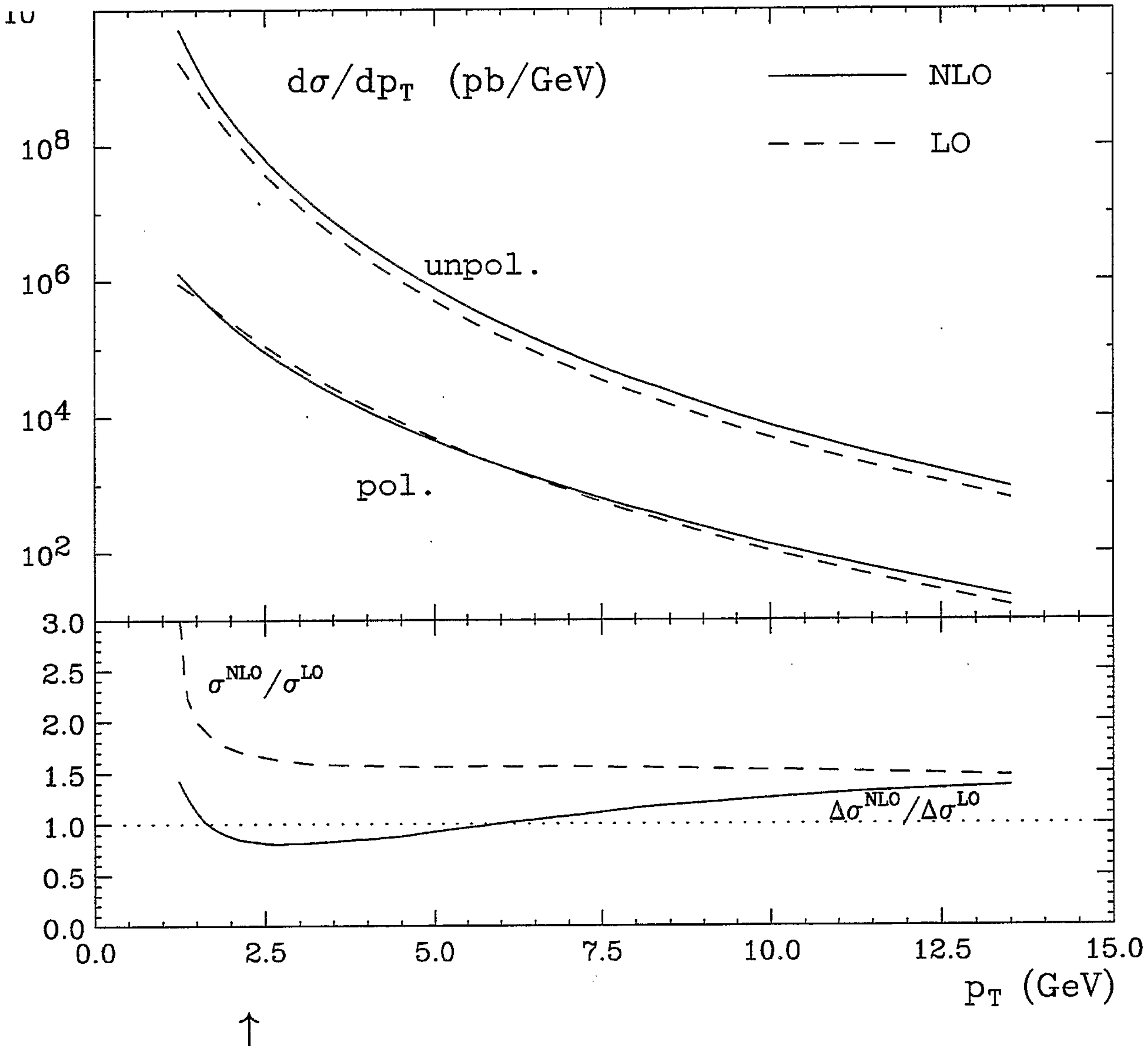
$$\begin{array}{lcl}
qq' & \to & q+X \\
 & \to & g+X \\
q\bar{q}' & \to & q+X \\
 & \to & g+X \\
q\bar{q} & \to & q'+X \\
 & \to & q+X \\
 & \to & g+X \\
qq & \to & q+X \\
 & \to & g+X \\
qg & \to & q'+X \\
 & \to & \bar{q}'+X \\
 & \to & \bar{q}+X \\
 & \to & q+X \\
 & \to & g+X \\
gg & \to & g+X \\
 & \to & q+X
\end{array}$$

✓: all done & unpol. results agree with Aversa et al.

⇒ full NLO results available

final results (II) - importance of NLO corrections:

$\sqrt{S} = 200\,\text{GeV}$



lower part: K-factor: $\sigma^{\text{NLO}}/\sigma^{\text{LO}}$, $\Delta\sigma^{\text{NLO}}/\Delta\sigma^{\text{LO}}$

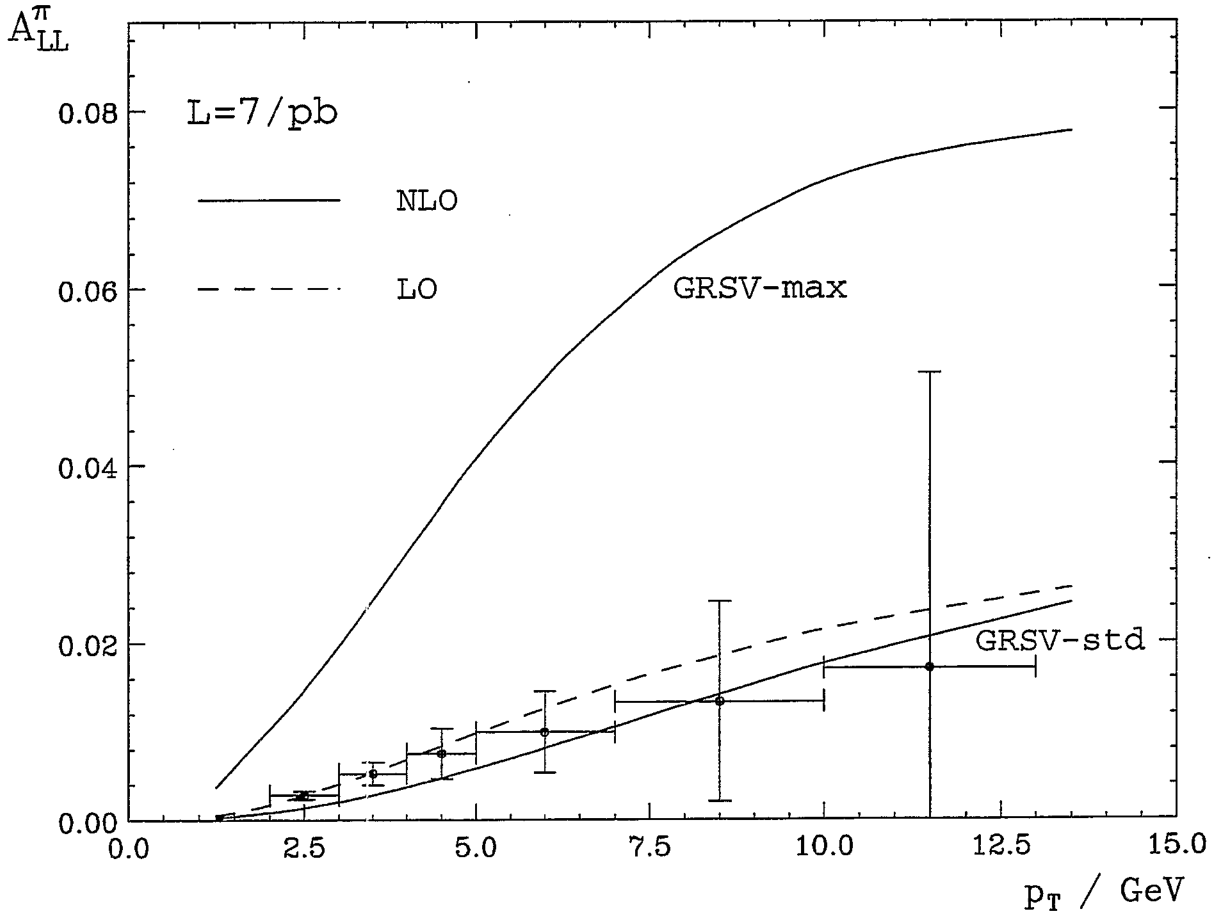
pdfs: CTEQ 5M (unpol.), GRSV std. (pol.)
frag. fcts: KKP

final results (III) - A_{LL}^{π} in NLO:

very moderate luminosity!

↓

$\sqrt{S} = 200\,\mathrm{GeV}$



pdfs: CTEQ 5M (unpol.), GRSV std. (pol.)

frag. fcts: KKP

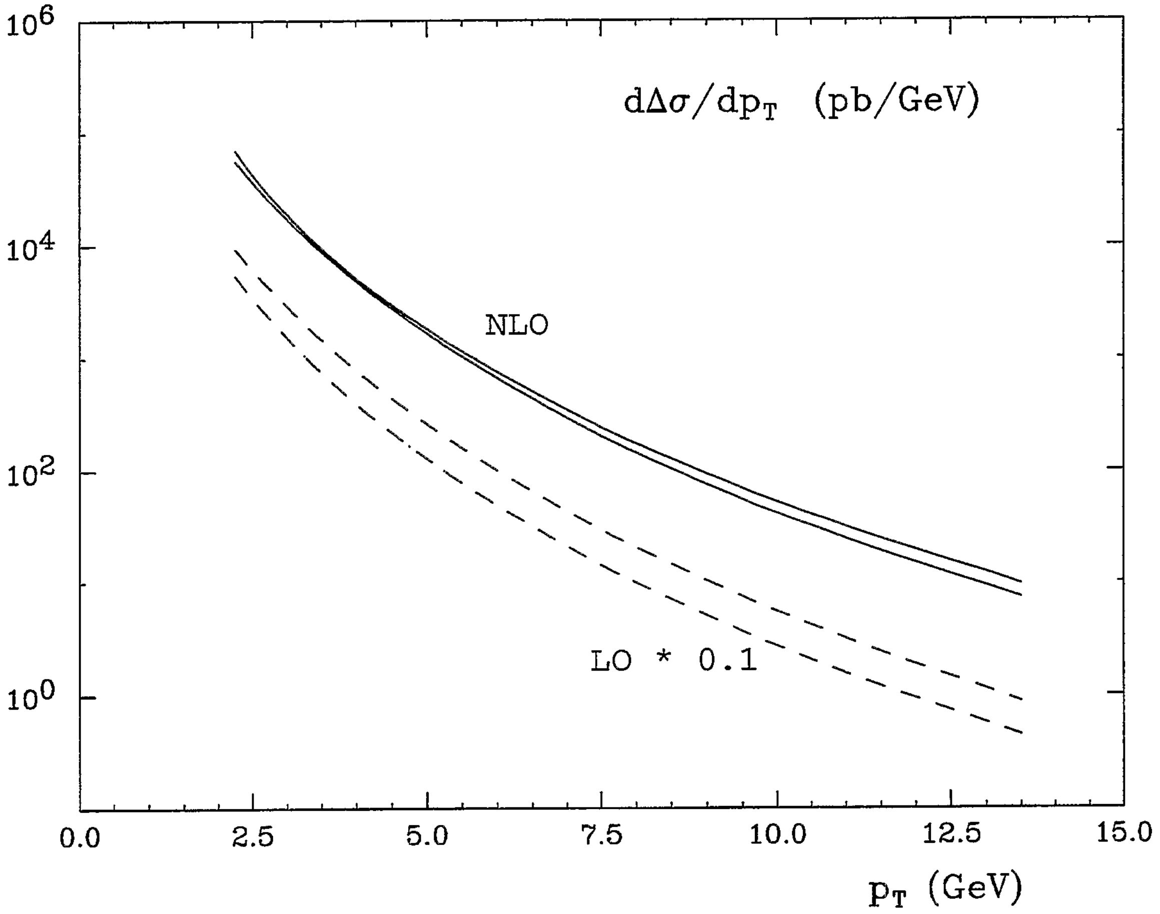
estimate of statistical errors: $\delta A \simeq \frac{1}{P_1 P_2} \times \frac{1}{\sqrt{\mathcal{L}\sigma_{\mathrm{bin}}\varepsilon_{\mathrm{eff}}}}$

[with $P_1 = P_2 = 0.4$ (beam pol.) and $\varepsilon_{\mathrm{eff}} = 1$ (detection efficiency)]

good sensitivity to Δg even with $\mathcal{L} = 7/\mathrm{pb}$!

final results (IV) - scale dependence:

$\sqrt{S} = 200\,\mathrm{GeV}$



variation of scales: $\mu_f = \mu'_f = \mu_r = p_T \ldots 2p_T$

pdfs: GRSV std.; frag. fcts: Kretzer

$\Downarrow$

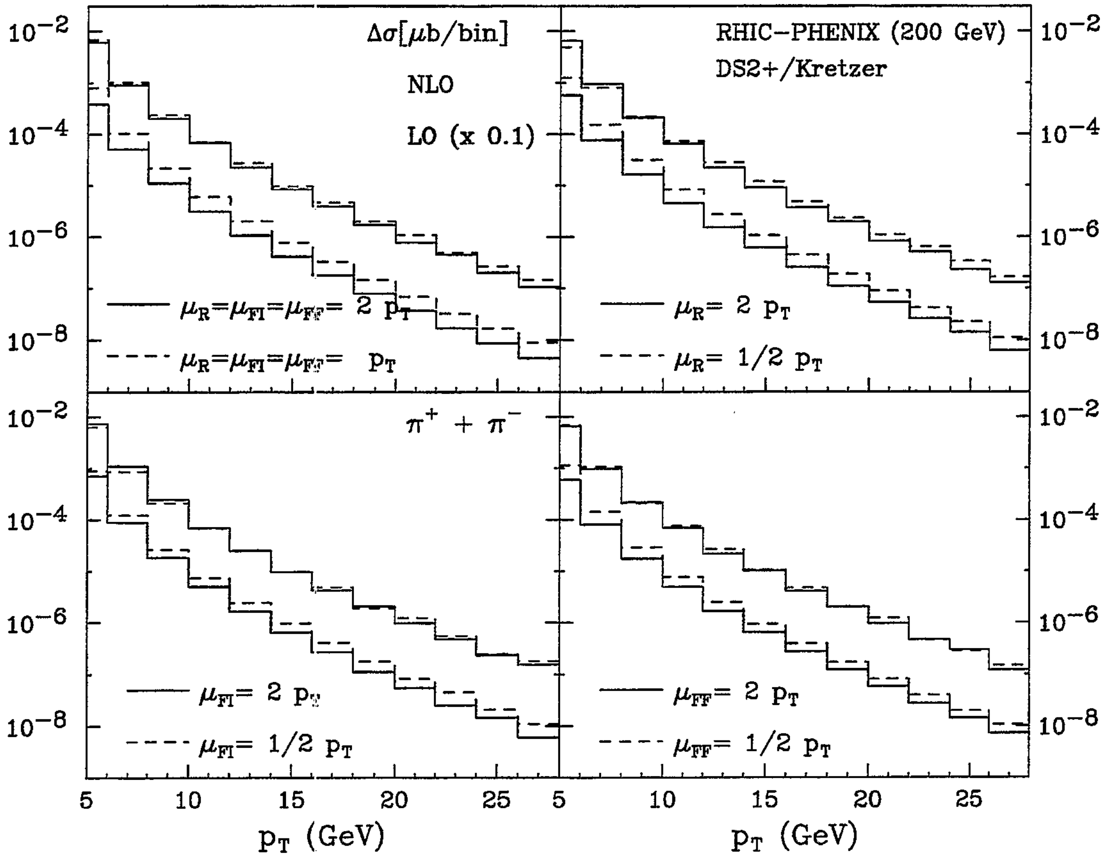
NLO results much more reliable

comparison with other calculations :

also very recently:

NLO QCD MC-code for hadron production at RHIC

D. de Florian



[from de Florian's talk at "Current and future directions at RHIC"]

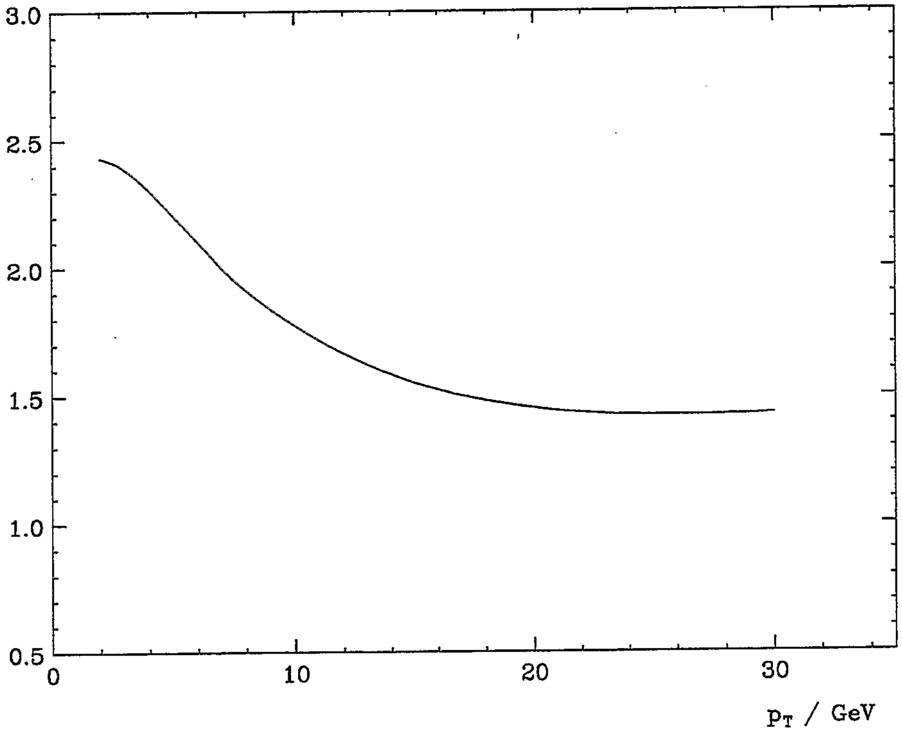
so far:

gross features of both calculations look very similar

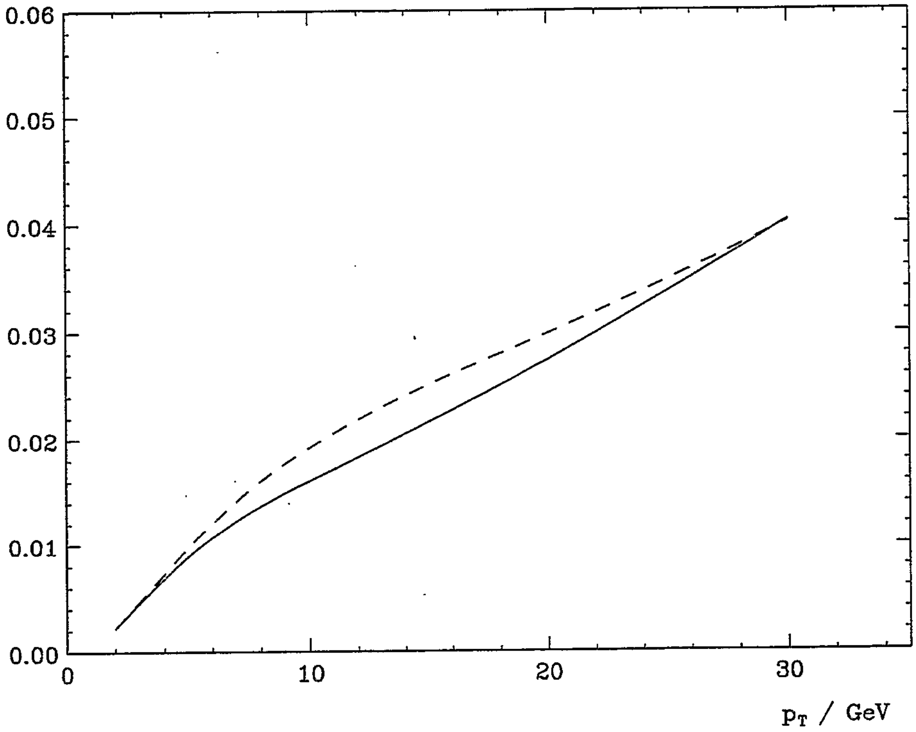
- detailed comparisons are under way
- more quantitative results will be available soon

dependence of $\frac{d\sigma}{dp_T}$ and A^{π}_{LL} on fragmentation functions:

$d\sigma^{KKP}/d\sigma^{Kretzer}$



$A^{\pi}_{\mathrm{LL}}(p_T)$ (dashed: KKP; solid: Kretzer)



RHIC Spin Collaboration Meeting XIII

October 22, 2002

RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting XIII
October 22, 2002
RIKEN BNL Research Center

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RHIC Spin Collaboration Meeting XIII
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Not in attendance but will be sent proceedings:

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RIKEN BNL Research Center

RHIC Spin Collaboration Meeting XIII

October 22, 2002

Small Seminar Room, Physics Dept., Brookhaven National Laboratory

*****AGENDA*****

Morning Session

09:00 – 09:45	Status Report on the AGS Preparation	L. Ahrens
09:45 – 10:30	Update on the Run-02 RHIC Polarimeter Analysis	O. Jinnouchi
10:30 – 10:45	Discussion of Beam Polarization for Papers from Run-02	G. Bunce/L. Bland
10:45 – 11:00	Coffee Break	
11:00 – 11:45	Plans for the Run-03 RHIC Polarimeter	O. Jinnouchi
11:45 – 12:15	CNI Waveform Digitizer	S. Dhawan

12:15 *Lunch*

Afternoon Session

13:00 – 13:45	Status Report and Run-03 Plans for the Spin Flipper	M. Bai
13:45 - 14:30	Report on the Absolute Luminosity Analysis in Run-02 and Plans for Run-03	A. Drees
14:30 – 15:00	Report on the PHENIX Trigger Efficiency Used in Absolute Luminosity Analysis for Run-02	S. Belikov
15:00 – 15:15	Coffee Break	
15:15 – 16:00	Next-to-Leading Order A_LL(pi) Calculations	W. Vogelsang

Next Meeting ~ Monday, November 18, 2002 ~
BNL Physics Bldg. 510, Small Seminar Room

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 XII and XIII

September 16, 2002 ~ October 22, 2002

Li Keran

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Nuclei as heavy as bulls
Through collision
Generate new states of matter.
T.D. Lee

Speakers:

L. Ahrens
M. Bai
S. Belikov
L. Bland
M. Brennan
G. Bunce
S. Dhawan
A. Drees
W. Fischer
O. Jinnouchi
T. Kawabata
T. Roser
W. Vogelsang
J. Wood
A. Zelenski

Organizer: Brendan Fox