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HADRON SPIN-FLIP AT RHIC ENERGIES

July 21 - August 22, 1997

Organizers

Elliot Leader and T. L. Trueman

RIKEN BNL Research Center

Building 510, Brookhaven National Laboratory, Upton, NY 11973, USA

Volume 1 - Open Standards for Cascade Models for RHIC - BNL-64722

June 23-27, 1997 - Organizer - Miklos Gyulassy

Volume 2 - Perturbative QCD as a Probe of Hadron Structure - BNL-64723

July 14-25, 1997 - Organizers Robert Jaffe and George Sterman

DISCLAIMER

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Preface to the Series

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

For the first year, the Center will have only a Theory Group, with an Experimental Group to be structured later. The Theory Group will consist of about 12-15 Postdocs and Fellows, and plans to have an active Visiting Scientist program. A 0.6 teraflop parallel processor will be completed at the Center by the end of this year. In addition, the Center organizes workshops centered on specific problems in strong interactions.

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 a proceedings, which can therefore be available within a short time.

T.D. Lee
July 4, 1997

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INTRODUCTION

From July 21 to August 22, 1997 a working group sponsored by the RIKEN BNL Research Center was convened to consider "Hadron Spin-Flip at RHIC Energies." The original motivation for this arose from the importance of understanding the hadronic part of the proton-proton spin flip amplitude in using the Coulomb-Nuclear Interference for polarimetry. This is a very difficult, non-perturbative problem and it is not possible to make a calculation with controlled approximations, so a number of approaches were followed:

1. methods to extract the necessary information from past experiments and from RHIC experiments were examined;
2. phenomenological, Regge models - some of them very old - were reviewed;
3. the predictions of several non-perturbative theoretical models were evaluated;
4. the use of nuclei for the CNI experiment was quantitatively considered;
5. alternative methods of polarimetry were critically studied. These included Primikoff effect, large-t pp scattering, and pe double spin asymmetry.

The first talk of the working group by Elliot Leader was presented at the contemporaneous workshop on *Perturbative QCD as a Probe of Hadron Structure*, and his transparencies are included in that Workshop Proceedings. A selection of the others are included here.

There was also active participation in our work by Y. Makdisi, W. Guryn. G. Bunce, F. Paige, M. Tannenbaum and T. Rosen, all from BNL, and S. MacDowell, a visitor from Yale.

Several research papers based on this work are in preparation. Thanks to Elliot Leader, whose idea it was to convene this group, and to Kopeliovich, Soffer and Buttimore for their work and stimulating collaboration.

Thanks to Brookhaven National Laboratory and to the U.S. Department of Energy for providing the facilities to hold this workshop.

T.L. Trueman

Co-Organizer

Hadronic Spin-Flip Contribution to A_N

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The hadronic part of the p-p single flip amplitude ϕ_5 is the center of our investigation because the uncertainty in its value prevents the Coulomb-Nuclear-Interference (CNI) method from being a certain and precise absolute polarimeter. The first figure shows the measurable quantities that depend on ϕ_5 that involve only initial state polarization. The second figure shows the data from Fermilab E704. This is the only high energy data available in the region of t for which A_N is enhanced by the CNI effect. This is well fit by $\phi_5 = 0$, indicated in the figure by $\tau = 0$ but the error is ± 0.15. In this section $\tau = \sqrt{-t/m}\phi_5/\phi_1$. That fit is the best fit with Im τ constrained to be zero. If that constraint is lifted the best fit, also shown, has a much bigger error, $\pm.3$, and about the same χ^2.

The next figure shows the energy dependence of P at $t = -0.15$, the smallest value of t for which there is sufficient high energy data. The best fit to $a + b/\sqrt{p_L} + c/p_L$ gives a non-zero asymptotic value for P.

A_{NN} depends on ϕ_5 but it also depends sensitively on ϕ_2 and ϕ_4. If we assume that these last two vanish linearly with t, as would be the case with factorized Regge poles but is more general, then the parametrization shown is appropriate. The two pieces can cancel against each other simulating a pure CNI piece but with a shifted magnitude corresponding to the same shift in A_N. The size of A_{NN} is very small, probably unmeasurable at *pp2pp*.

There are big double-spin asymmetries in p-e scattering which are free of hadronic uncertainties. This has led Nurushev and collaborators to propose putting a proton beam onto a fixed polarized electron target. The symmetries are large only when the electron is longitudinally polarized, either A_{LL} or A_{SL}. The latter, relevant for transversely polarized beams, is shown in the last figure for $p_L = 100$ GeV/c and $p_L = 250$ GeV/c. The recoil electron energy is quite large, about 10 GeV/c and 55 GeV/c respectively and the recoil angle is about 2 mrad to the beam direction in both cases near the maximum asymmetry.

Measurable quantities depending on ϕ_5

$$\frac{d\sigma}{dt} = \frac{2\pi}{s^2}(|\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + |\phi_4|^2 + 4|\phi_5|^2)$$

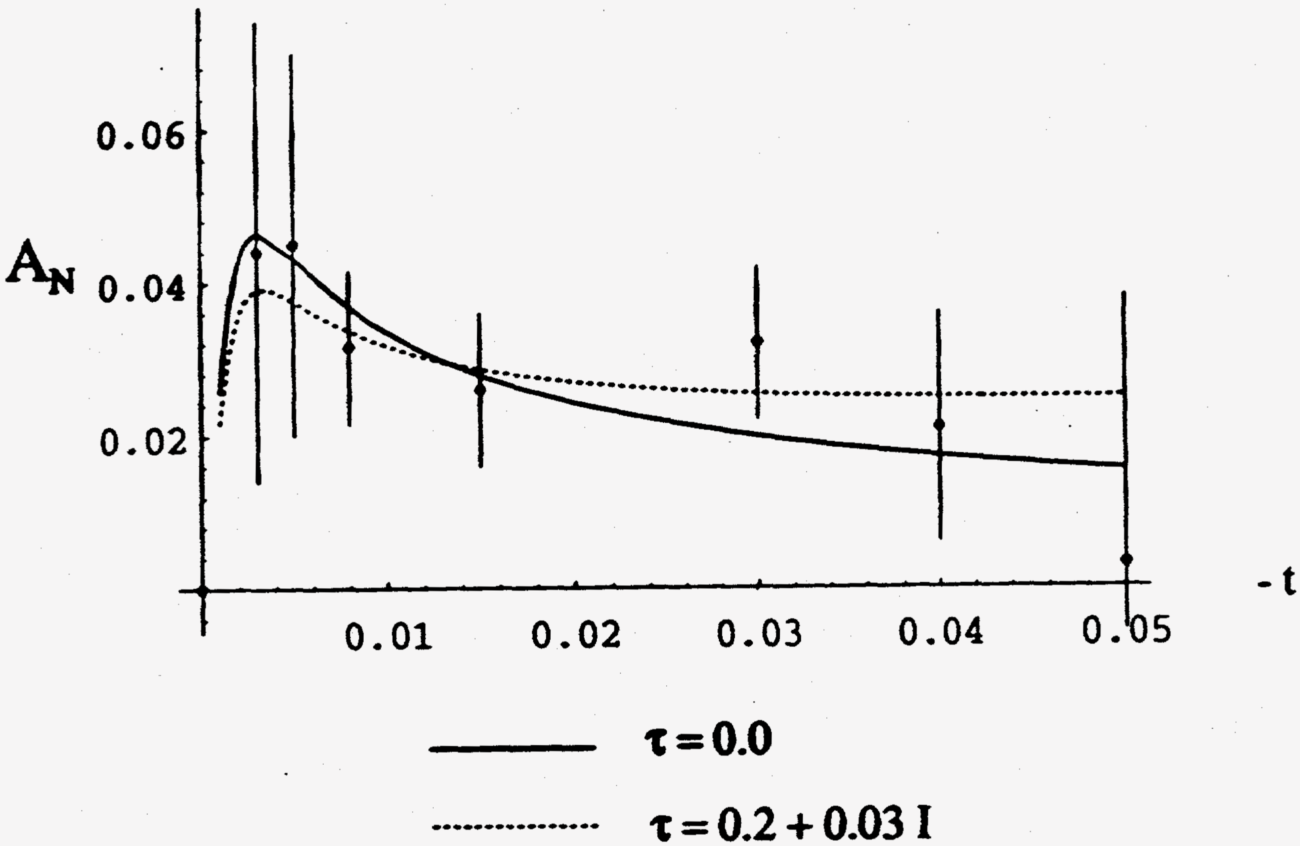
$$A_N \frac{d\sigma}{dt} = -\frac{4\pi}{s^2} Im(\phi_5^*(\phi_1 + \phi_2 + \phi_3 - \phi_4))$$

$$A_{NN} \frac{d\sigma}{dt} = \frac{4\pi}{s^2}(2|\phi_5|^2 + Re(\phi_1^*\phi_2 - \phi_3^*\phi_4))$$

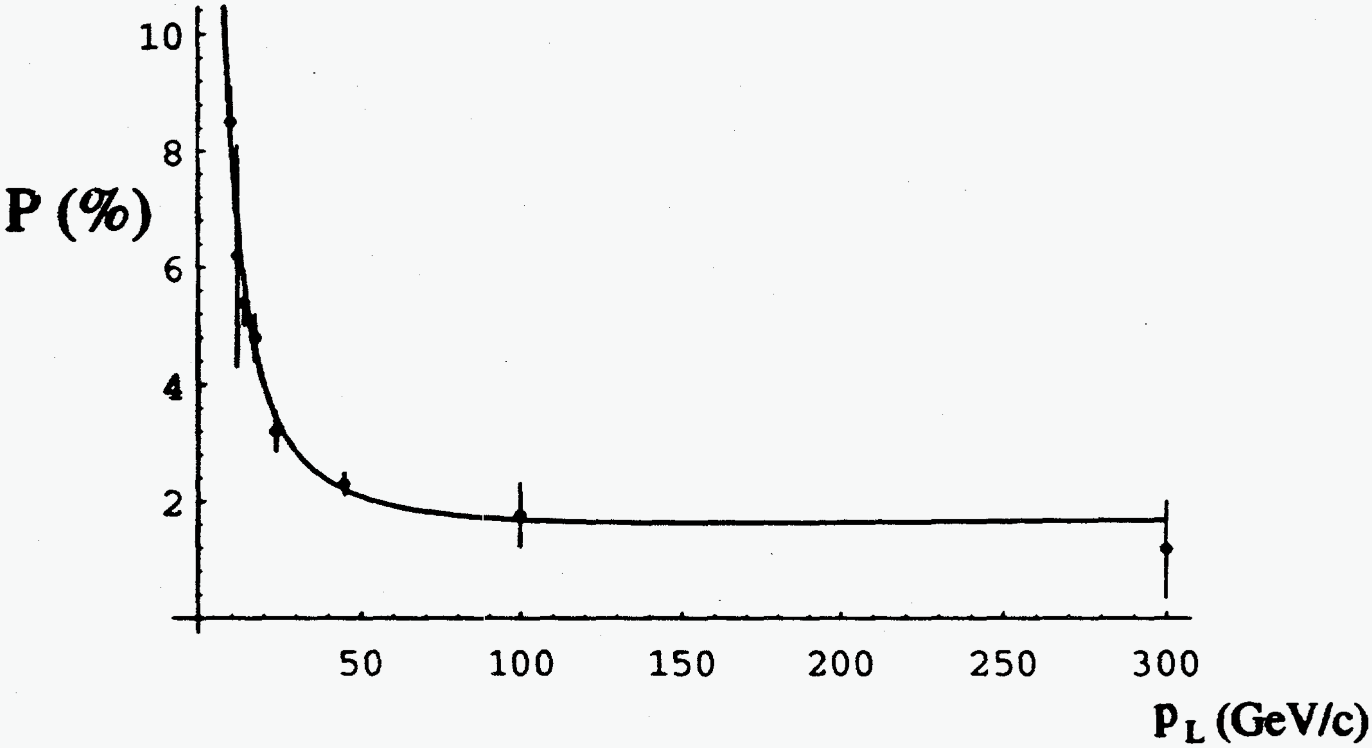
$$A_{SL} \frac{d\sigma}{dt} = \frac{4\pi}{s^2} Re(\phi_5^*(\phi_1 + \phi_2 - \phi_3 + \phi_4))$$

cf. Buttimore, Gotsman and Leader (1978)

Best fits to 704 data with and without Im(τ) = 0



Energy dependence of P at t = -0.15 GeV^2



Best fit gives asymptotic value 2.3±1.2

Pure CNI at 300 is 1.1

10 GeV Borghini 1971
11.8 GeV Kramer 1977
14 GeV Borghini 1971
17.5 GeV Borghini 1971
24 Gev Crabb 1977
45 GeV Gaudot 1976
100 GeV Snyder 1978
300 GeV Snyder 1978

A_{NN} for bounding spin-flip:

If $$Re(\phi_1^*\overset{h}{\phi_2} - \phi_3^*\overset{h}{\phi_4}) = 0$$

then

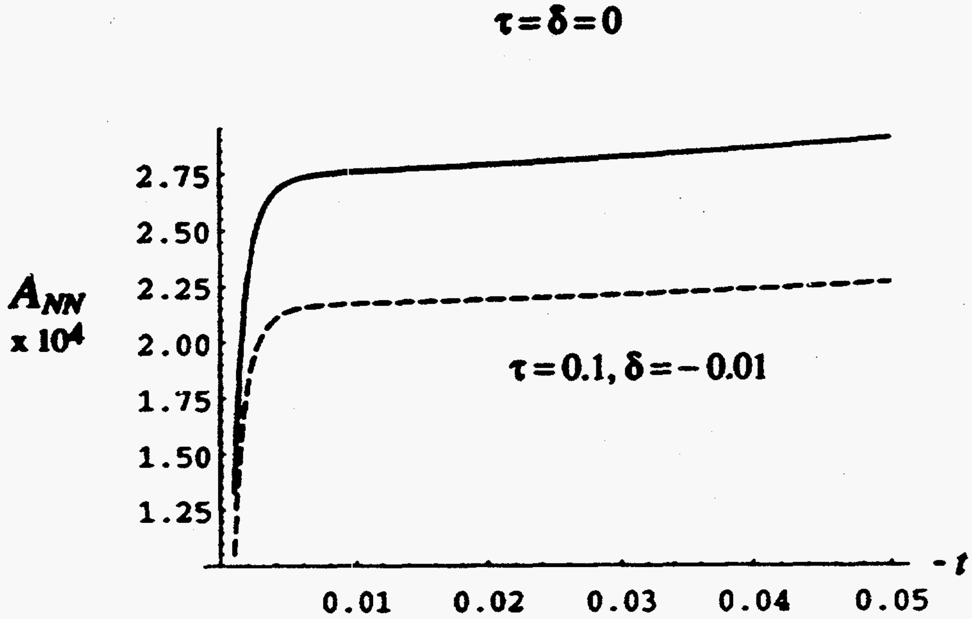
$$A_{NN} \approx -\sqrt{\frac{16\pi}{(1+\rho^2)\frac{d\sigma}{dt}}\frac{\alpha}{m^2}(\mu-1)(-\frac{(\mu-1)\rho}{4} + \rho Re\tau - Im\tau) - 2\frac{t}{m^2}|\tau|^2}$$

Small effect can be masked by very small δ:

$$\begin{aligned}\phi_1 &= \phi_3 \\ \phi_2 &= -\phi_4 = -\delta\frac{t}{m^2}\phi_1,\end{aligned}$$

Note that $A_{SL} = 0$ with this parametrization.

If $\delta = 0$ double spin asymmetry measures $P^2|\tau|^2$ and combined with single spin fixes P [illegible] to 2-fold ambiguity



$$P_{apparent}(\tau) = P_{true} \frac{A_N(\tau \neq 0)}{A_N(0)}$$

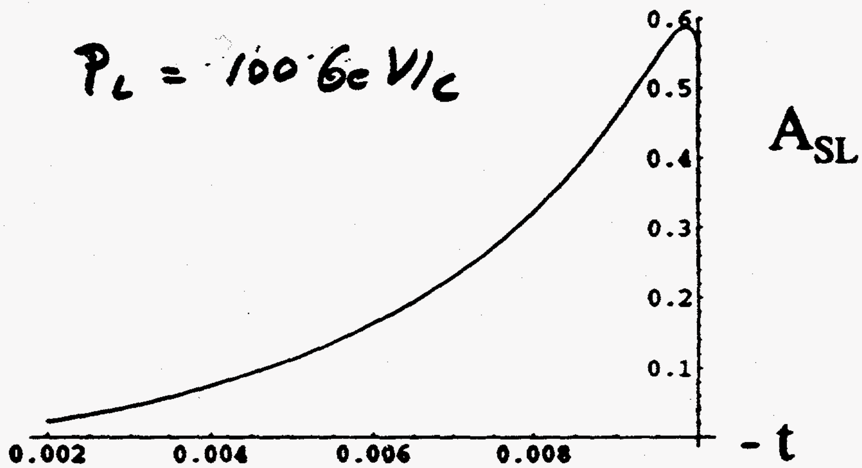
From A_N $\quad P_{app}(0.1)/P_{true} \simeq 0.9$

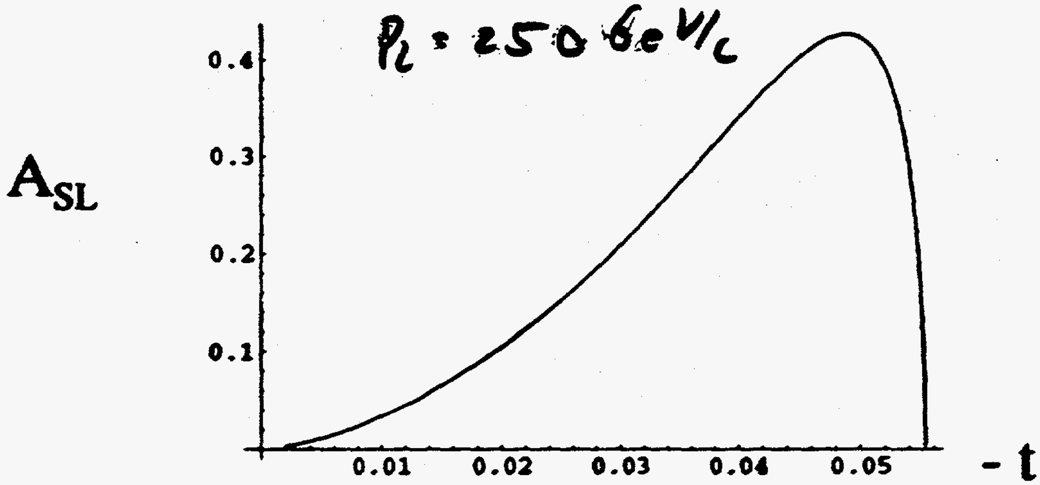
From A_{NN} $\quad \frac{P_{app}(0.1)}{P_{true}} = \sqrt{\frac{A_{NN}(0.1, -.01)}{A_{NN}(0)}}$

$$= \sqrt{0.8} \simeq 0.9$$

consistent!

p e double spin asymmetry





REVIEW OF POLARIZATION IN pp ELASTIC SCATTERING AT HIGH ENERGY AND PHENOMENOLOGY

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We start by recalling the difficulty of describing pp elastic scattering, which involves *five* complex helicity amplitudes $\phi_i(s,t)(i=1,\dots 5)$. So, for each kinematic point, center-of-mass energy and momentum transfer, the full knowledge of this reaction requires the extraction from the data of *nine* real numbers, since one overall phase remains undetermined. Indeed this implies the need of many measurements; most of the possible twenty five ones have never been done at high energies. At $p_{\rm lab} = 6$ GeV/c several spin observables have been measured at the ZGS (ANL) and we illustrate the method for an amplitude reconstruction. It leaves large uncertainties on the phase and the magnitude of the natural parity exchange amplitudes $\phi_1 - \phi_3$ and $\phi_2 + \phi_4$, which turn out to be the smallest ones. A rigorous positivity bound for $\mathrm{Im}\,\phi_2(s,0)$ has been derived long ago, which can be translated in terms of total cross sections in pure spin states, and it is obviously obeyed by the available data up to $p_{\rm lab} = 12$ GeV/c.

We also recall the present experimental situation at high energies for the single-spin asymmetry A_N which has been measured at CERN, BNL and FNAL up to $p_{\rm lab} = 300$ GeV/c. One should notice the scarcity and some lack of accuracy of these data which have explored only a limited range in momentum transfer. One observes that for $p_{\rm lab} < 25$ GeV/c or so at fixed t, A_N decreases with increasing energy but its behavior at higher energies remains unclear. A simple Regge picture is unable to describe properly these data but in the high energy region an impact picture approach is shown to be rather successful. This model introduces a small flip-coupling of the Pomeron such that its contribution to the single-flip amplitude $\phi_5^{\mathcal{P}}$ is non-zero and therefore it predicts that A_N does not vanish at very high energies. Here one should not forget that even if $\phi_5^{\mathcal{P}} = 0$, the effect of the Coulomb-Nuclear interference (CNI) introduces a *positive* shift of A_N of the order of 1% to 2% up to $|t| = 1\,\mathrm{GeV}^2$ or so. This is a sizeable effect when we compare it to the measured values. The magnitude and phase of ϕ_5 are crucial to decide if one can use this CNI effect in the very forward region ($t \gtrsim 10^{-3}\,\mathrm{GeV}^2$) to calibrate at RHIC the degree of polarization of a high energy polarized proton beam. According to the impact picture model $\phi_5^{\mathcal{P}}$ is so small in this region that it should not affect the pure CNI prediction.

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SPIN-FLIP FROM NON-PERTURBATIVE CHIRAL SYMMETRY BREAKING (M. ANSELMINO, S. FORTE PRL 71 (1993) 223)

MOTIVATION

THE SMALLNESS OF THE OBSERVED AXIAL CHARGE IN POL. DIS MIGHT BE DUE TO CHIRAL VIOLATING EFFECTS :
CAN INVOKE INSTANTON LIKE GLUONIC FIELD CONFIGURATIONS WHICH REDUCE THE AXIAL CHARGES CARRIED BY THE QUARKS

THEY PROPOSE TO CALCULATE AN EFFECTIVE HELICITY FLIP COUPLING DUE TO THE INTERACTION OF THESE ~~IN~~ INSTANTONLIKE GLUONIC FIELDS

FIRST RECALL THAT $\langle p,\lambda | j_5^\mu | p,\lambda\rangle = \lim_{q\to 0} G_A(q^2)\, s^\mu$

WE EXPECT $G_A(0) \sim 0.6$ AND EXP^{LY} $G_A(0)$ IS SMALLER
THE ANOMALY EQ. OF $\partial_\mu j_5^\mu$ IMPLIES

$$\lim_{q\to 0} i\, G_A(q^2)\, q_\mu \bar{u}_{\lambda'}(p')\gamma^\mu\gamma_5 u_\lambda(p) = \langle p,\lambda' | \Big\{ \frac{N_f}{8\pi^2} g^2\, \mathrm{Tr}\, \varepsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma} + \sum_f 2 i m_i \bar{\psi}_i \gamma_5 \psi_i \Big\} | p,\lambda\rangle$$

THE ANOMALY DENSITY IS PROPORTIONAL TO THE INSTANTON MINUS ANTI INSTANTON DENSITY $Q(x)$

$$\frac{N_f}{8\pi^2} g^2\, \mathrm{Tr}\, \varepsilon^{\mu\nu\rho\sigma} F_{\mu\nu}(x) F_{\rho\sigma}(x) = -2Q(x)$$

SO IT PRODUCES A DIRECT CONTRIBUTION FROM INSTANTONS TO NUCLEON AND WE CAN VIEW AS DEFINING AN EFFECTIVE COUPLING SUCH AS

$$\langle p,\lambda' | Q(x) | p,\lambda\rangle = -\lim_{q\to 0} i M_N\, G_A^{inst}(q^2)\, \bar{u}_{\lambda'}(p')\gamma_5 u_\lambda(p)$$

WHICH IS PURE HELICITY FLIP (NEED $\lambda = -\lambda'$)
$G_A^{inst.}(0)$ IS A UNIVERSAL CONST. WHICH TAKES CARE OF THE OBSERVED REDUCTION OF $G_A(0)$ FROM 0.6 TO 0.3 OR SO.

NOW A NON-VANISHING QUARK-QUARK-INSTANTON PROCESS IMPLIES THE NON VANISHING SAME PROCESS WITH n EXTRA GLUONS
THEREFORE ONE CAN ALSO CONSIDER HERE THE EXISTENCE OF NON DIRECT CONTRIBUTIONS WITH AN EFFECTIVE NUCLEON-NUCLEON-n GLUONS COUPLING

$$\langle p, \lambda'; g_1 \cdots g_n \mid p, \lambda \rangle = \lim_{q \to 0} i M_N G_A^{inst.}(q^2) \bar{u}_{\lambda'}(p) \gamma_5 u_\lambda(p) \prod_{i=1}^{n} \left[\left(\frac{2}{g_s}\right) \eta^{a_i}_{\mu_i \nu_i} k_i^{\mu_i} \rho^2 \right]$$

LET'S RECALL THAT $A_\mu^a(x) \sim \frac{2}{g_s} \eta^a_{\mu\nu} x_\nu \rho^2$

IS THE INSTANTON SOLUTION IN THE SO-CALLED SINGULAR GAUGE
$\eta^{a_i}_{\mu_i \nu_i}$ ARE THE 't HOOFT SYMBOLS , a_i COLOUR INDICES, $\mu_i \nu_i$ LORENTZ INDICES AND $k_i^{\mu_i}$ FOUR MOMENTUM OF g_i

ρ IS THE INSTANTON RADIUS WE SHOULD INTEGRATE OVER AND WILL TAKE A MEAN VALUE $\rho_0 \sim 0.5$ Fm.

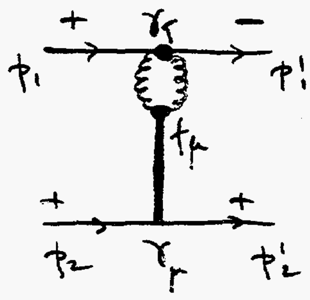
IF WE BELIEVE THAT THE NON-PERTURBATIVE POMERON IS ESSENTIALLY A TWO-GLUON STATE WE CAN HOPE FROM THAT TO CONSTRUCT A Φ_5.
THEY TAKE AS A REFERENCE THE D-L POMERON WHICH LEADS TO

$$\phi_3 = \phi_1 = \langle ++|++\rangle = \bar{u}_+(p_1')\gamma^\mu u_+(p_1)\left[3\beta D(t) F_1(t)\right]^2 \bar{u}_+(p_2')\gamma_\mu u_+(p_2)$$

$D(t)$ IS THE POMERON PROPAGATOR , $F_1(t)$ THE ELASTIC FORM FACTOR AND $\beta \sim 1.8\ \mathrm{GeV}^2$ A PHENOMENOLOGICAL COUPLING CONSTANT.

IN THIS CASE ϕ_5 READS (FACTORIZATION)

$$\phi_5 = \langle ++|+-\rangle = i M_N G_A^{\mathrm{inst}}(t)\, \bar{u}_+(p_1')\gamma_5 u_-(p_1) \left[\frac{2}{g_s}\right]^2 \langle f^\mu | k^2\rangle\, 3\beta D(t) F_1(t)\, \bar{u}_+(p_2')\gamma_\mu u_+(p_2)$$



f^μ IS THE POMERON WAVE FUNCTION AND $\langle f^\mu | k^2\rangle$ CAN BE TAKE AS THE AVERAGE SQUARE MOMENTUM OF GLUONS IN THE POMERON $\langle k^2\rangle$ (GLUON VIRTUALITY)

IF ONE USES THE STANDARD EXPRESSION FOR P WITH $\phi_2 = \phi_4 = 0$ ONE GETS IN THE LIMIT θ_{cm} SMALL

$$P = \sin\theta/2 \; 4\sqrt{2}\, G_A^{\mathrm{inst}}(-t)\, \frac{M_N \rho_0^4 \langle k^2\rangle}{3\beta F_1(t)\, g_s^2} + \cdots$$

SINCE $F_1(t) \xrightarrow[t\to 0]{} 1$ ONE GETS

$$P = P_0 \sin\theta/2 \quad \text{WITH} \quad P_0 = 4\sqrt{2}\,\frac{G_A^{\mathrm{inst}}(0) M_N \rho_0^4 \langle k^2\rangle}{3\beta g_s^2}$$

NUMERICAL ESTIMATE

THEY TAKE $G_A^{\mathrm{inst}}(0) \sim 0.5$, $\langle k^2\rangle = (0.4\ \mathrm{GeV})^2$ WHICH CORRESPONDS APPROXIMATELY TO $g_s \sim 2$ $(\alpha_s = g_s^2/4\pi)$

(SEE ESTIMATES)

$\Rightarrow \quad P_0 \sim 0.8$

<u>NOTE</u> CAN CHANGE THESE PARAMETERS $\langle k^2\rangle \nearrow$ $g_s \searrow$ AND $G_A^{\mathrm{inst}} \searrow$

WHAT DOES IT MEAN ??

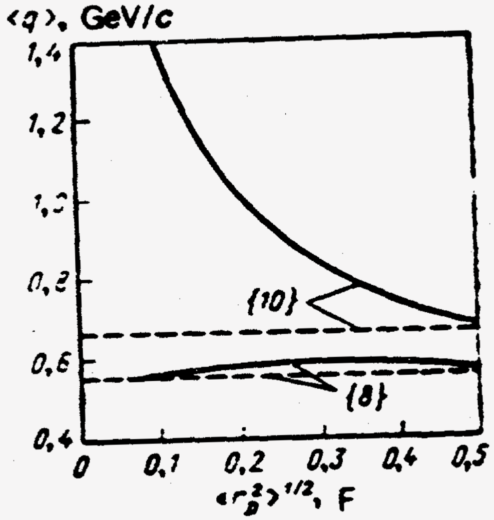
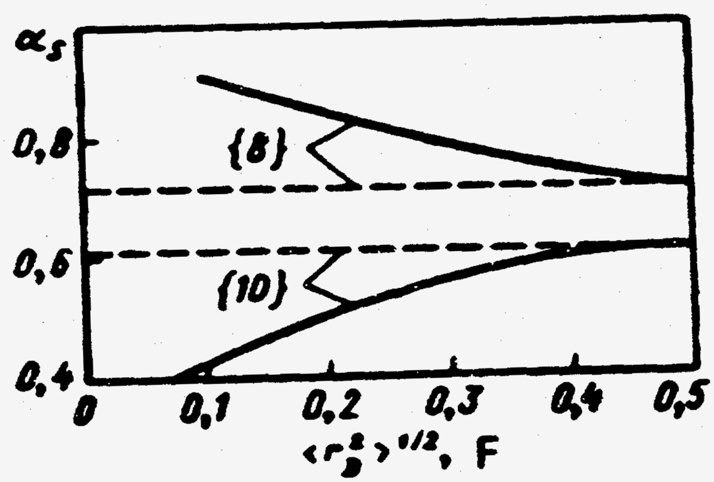


FIG. 11. Mean transverse momentum of the gluons in variant 1 ($|p\rangle = |uud\rangle$) (broken lines) and in variant 2 ($|p\rangle = |uD\rangle$) (continuous curves). The symbols {8} and {10} indicate that the averaging was performed for σ_{tot} or $\sigma_{\{10\}}$, respectively.



$$\alpha_s = \frac{g_s^2}{4\pi}$$

FIG. 12. Dependence of α_s in variants 1 and 2 on the diquark radius.

Sov. J. Part. Nucl. 22 (1991) 67

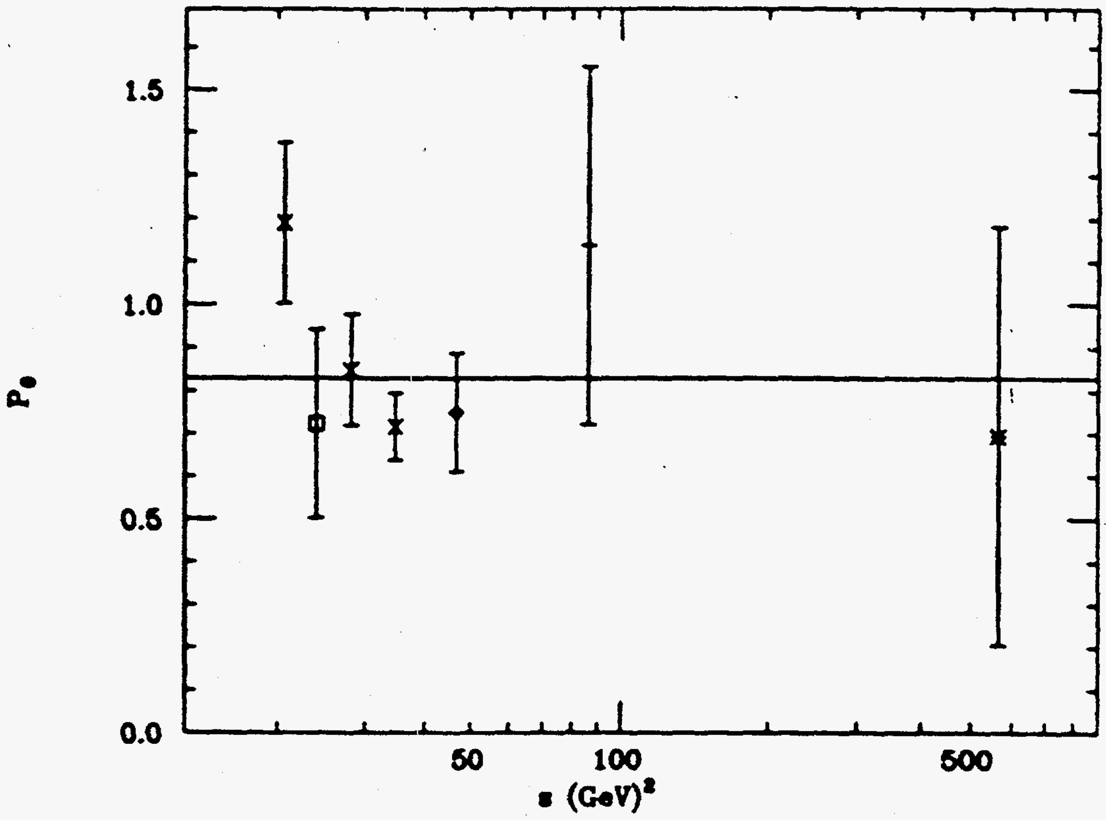


FIG. 2. The value of the forward polarization slope P_0 [Eq. (10)] vs s (in GeV^2). The crosses indicate data from Ref. [21]; the diamond, data from Ref. [22]; the square, data from Ref. [23]; the dash, data from Ref. [24]; and the star, data from Ref. [25]. The solid line is drawn through the mean value $P_0 = 0.83$.

FOR $\mathbb{P}$OMERON EXCH. WE EXPECT LIKE
FOR PHOTON EXCH. $\phi_5 \sim \sqrt{-t}\, f_{+-}(s)$ $\phi_1 = \phi_3 \sim f_{++}(s)$
$f_{+-}(s)$ AND $f_{++}(s)$ SAME ENERGY DEP.

$\Rightarrow$ $P \sim \sqrt{-t}$ NOT $P \sim \sin\theta/2$

THIS P_0 CORRESPONDS TO ρ-EXCHANGE SUCH THAT
$P \sim \sqrt{-t}\, \frac{1}{\sqrt{s}} \sim \sin\theta/2$
P_0 IS NOT THE $\mathbb{P}$ FLIP-COUPLING!

HOW LARGE IS THE POMERON - FLIP COUPLING TO THE NUCLEON ?

VARIOUS SOURCES OF INFORMATION

1- MODELS RELYING ON HIGH ENERGY pp POLARIZATION DATA ($p_{lab} \geq 45$ GeV/c)

* IMPACT PICTURE (BSW - 1979)

REMEMBER FOR $|t| < 1\,GeV^2$ 1% TO 2% OF A_N COMES FROM CNI

WE FIND THAT FOR 100 GeV/c AND 800 GeV/c

$$\mathrm{Re}\, r_5 \text{ and } \mathrm{Im}\, r_5 < 1\%$$

(RECALL $\phi_5 = r_5 \sqrt{\frac{-t}{m^2}}\, \mathrm{Im}\, \phi_+$)

PURE CNI WILL NOT BE AFFECTED BY $\phi_5^{Nucl} \neq 0$

* ANOTHER SIMPLE EIKONAL MODEL LEADS TO THE SAME CONCLUSION IF USE CORRECT DATA !!

2- MODELS RELYING ON ACCURATE A_N FOR $\pi^{\pm} p$

* B. KOPELIOVICH FITS $\Sigma = A_N(\pi^+) + A_N(\pi^-)$

$$\Sigma \sim \sqrt{\frac{-t}{m}}\, \lambda \left(\frac{\mathrm{Im}\, f_{++}}{\mathrm{Im}\, P_{++}} \right) \quad \text{WITH} \quad \lambda = \mathrm{Re}\, f_{+-} / \mathrm{Im}\, P_{++}$$

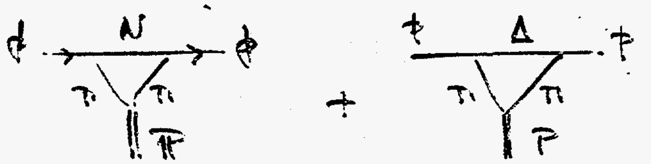
HE FINDS $\lambda = (0.05 \pm 0.01)$

* A. MARTIN and H. NAVELET (J. PHYS. G 4 (1978) 647)

USE LESS ACCURATE DATA AND GET $\lambda = -0.04 \pm$?

3. DYNAMICAL MODELS

* BORESKOV et al. (SOV. J. NUCL. PHYS. 27 (1978) 432)



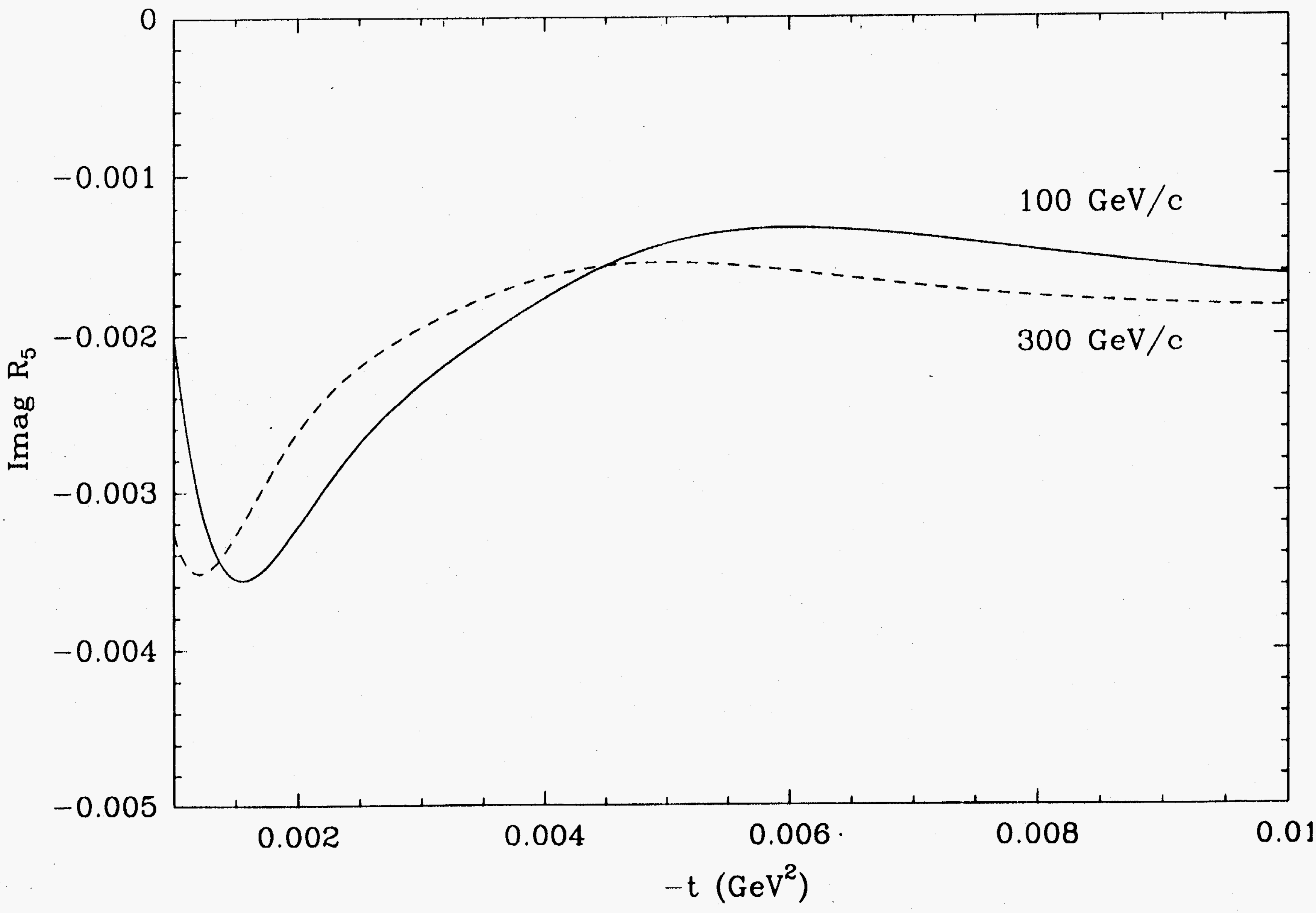
$T^0 \sim 3F_N + 2F_\Delta$

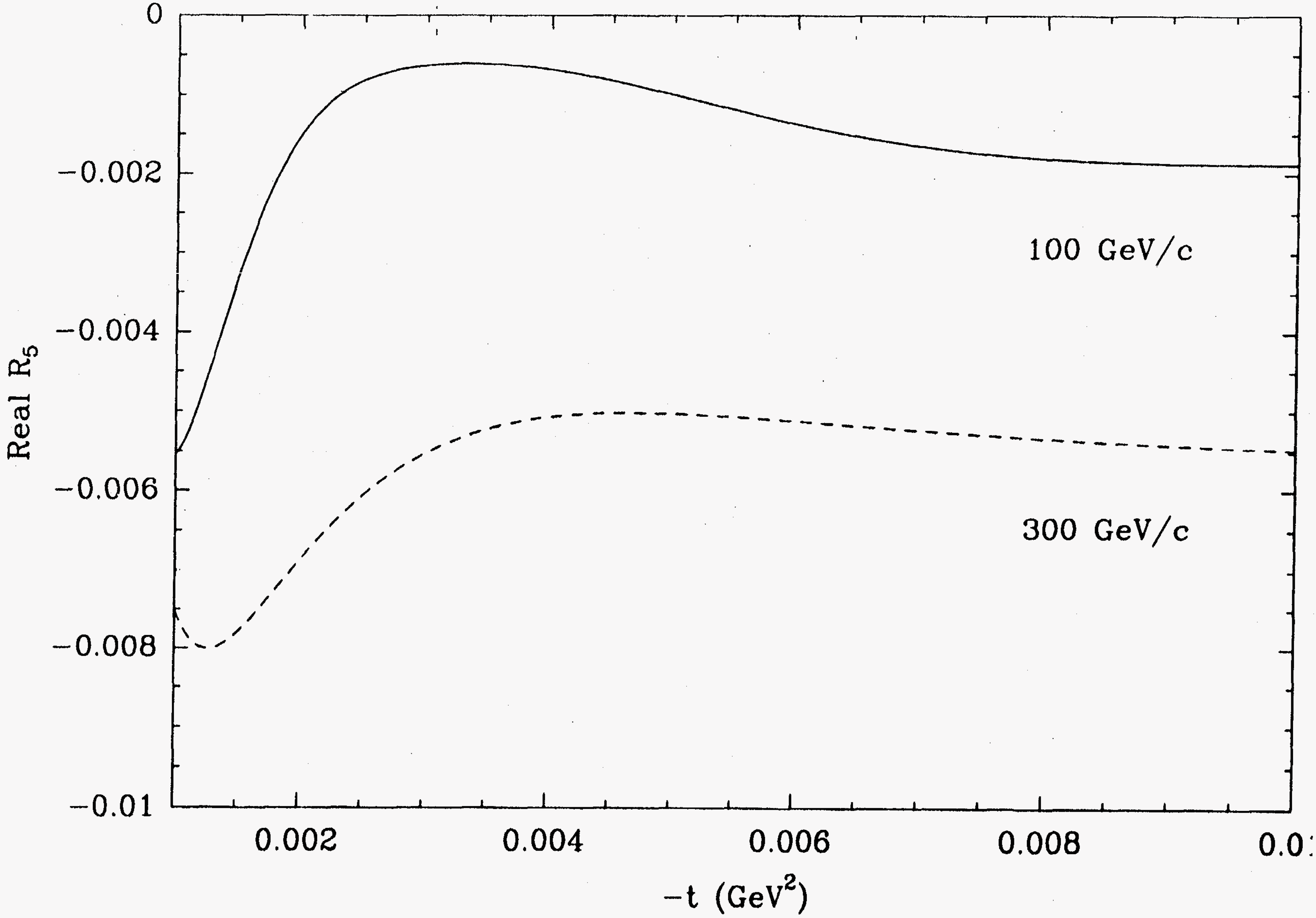
$T^1 \sim 2F_N - \frac{2}{3}F_\Delta$

FROM $\pi^\pm$ DATA GET A RESULT CONSISTANT WITH THE PREVIOUS ONES

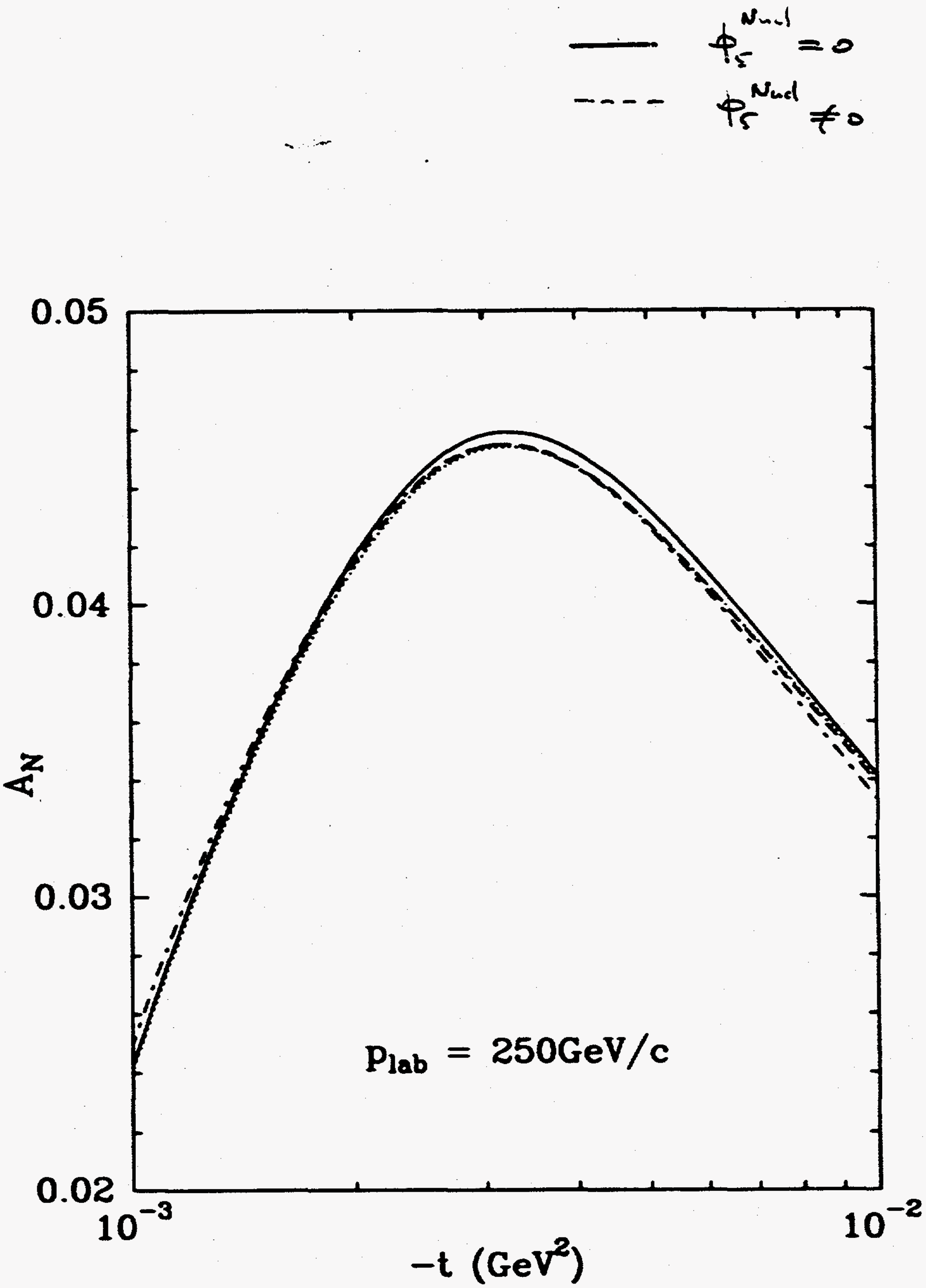
*

CAN EXPECT AN INTERFERENCE COMING FROM THE ODDERON (C = -1 , 3g) WHICH GENERATES A REAL PART FOR ϕ_r


0
−0.001
−0.002
−0.003
−0.004
−0.005
Imag R5
0.002
0.004
0.006
0.008
0.01
−t (GeV2)
100 GeV/c
300 GeV/c



0
−0.002
−0.004
−0.006
−0.008
−0.01
Real R5
100 GeV/c
300 GeV/c
0.002
0.004
0.006
0.008
0.01
−t (GeV2)


$\phi_5^{Nucl} = 0$
$\phi_5^{Nucl} \neq 0$
0.05
0.04
0.03
0.02
A_N
p_{lab} = 250GeV/c
10^{-3}
10^{-2}
$-t$ (GeV^2)

24 GeV/c

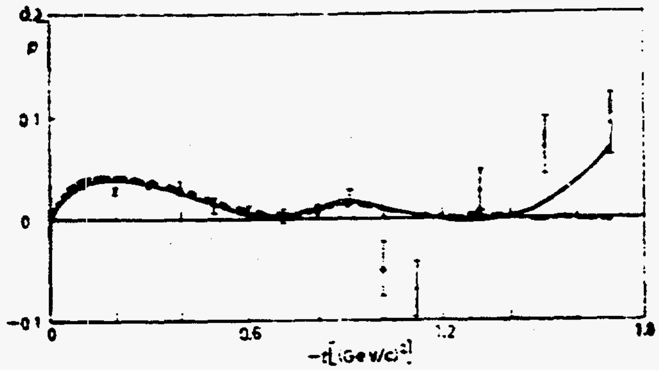


Fig. 1a). – Comparison of two-model calculations for the polarization in pp elastic scattering with experiment: at $p_{lab} = 24$ GeV/c (data from ref. (9)). The solid line is obtained by including a diffractive helicity flip component, the dashed line without that component.

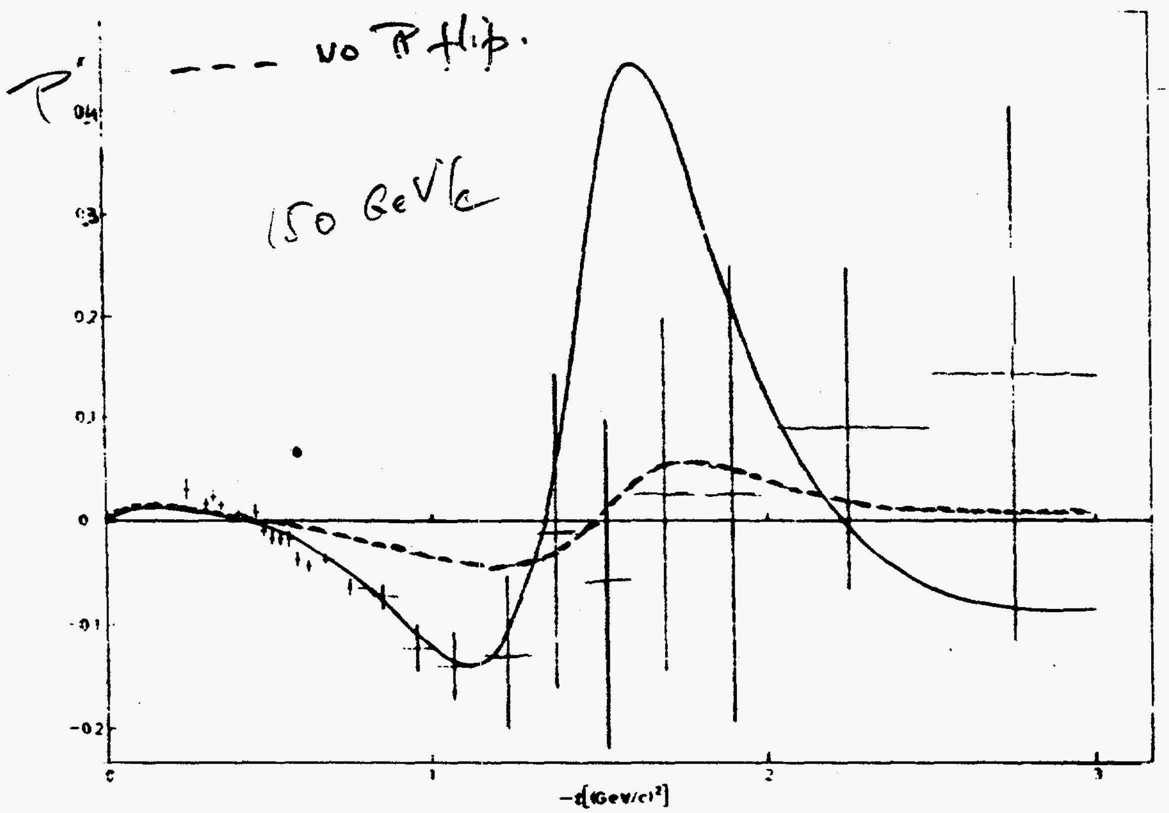
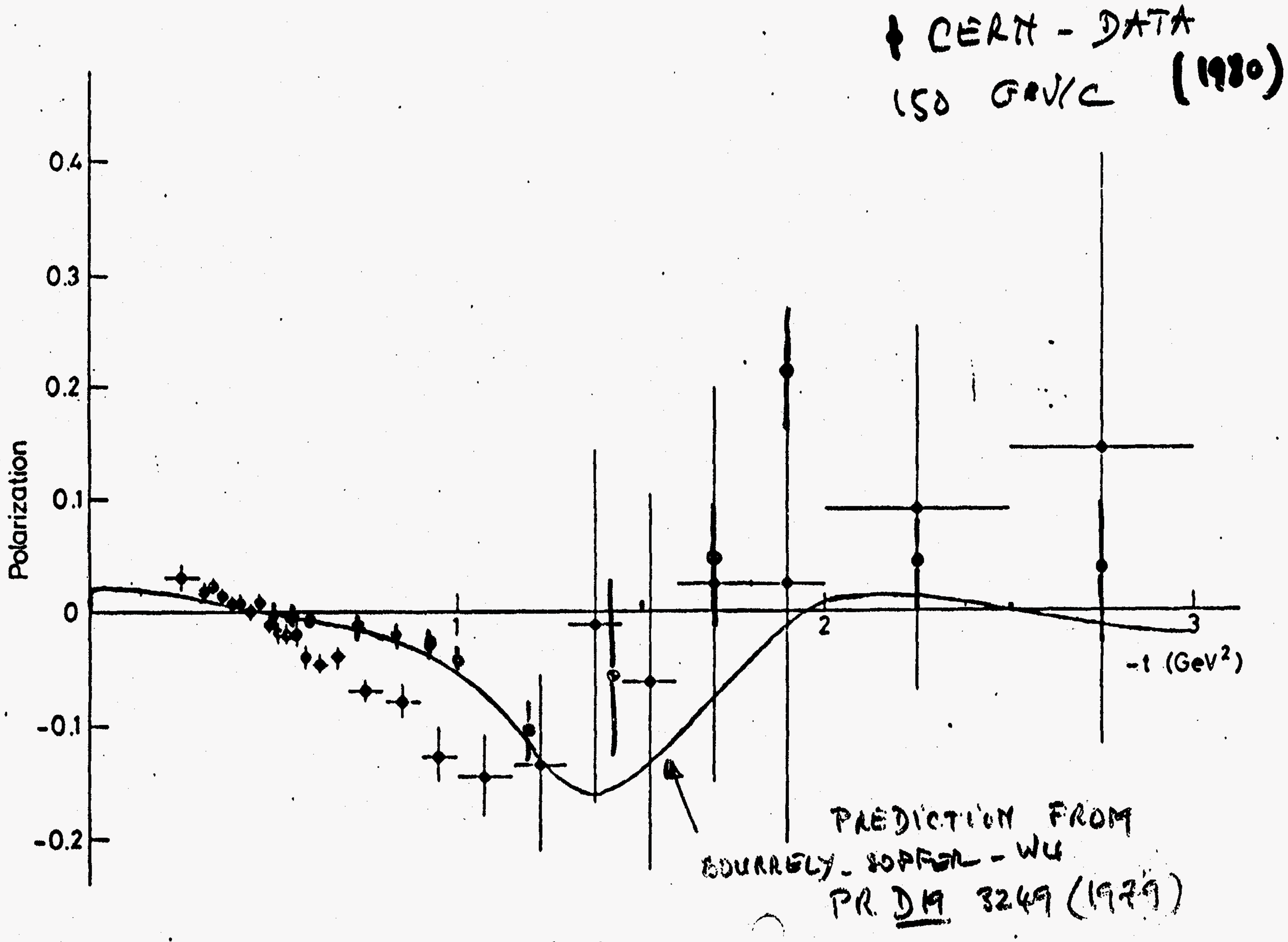


Fig. 1[illegible]). – Comparison of two-model calculations for the polarization in pp elastic scattering with experiment: at $p_{lab} = 150$ GeV/c (data from ref. (9)). The solid line is obtained by including a diffractive helicity flip component, the dashed line without that component.

H. GERHOLD and W. MAJEROTTO

Lett. Nuovo Cimento 23 (1978) 281

Coulomb Included



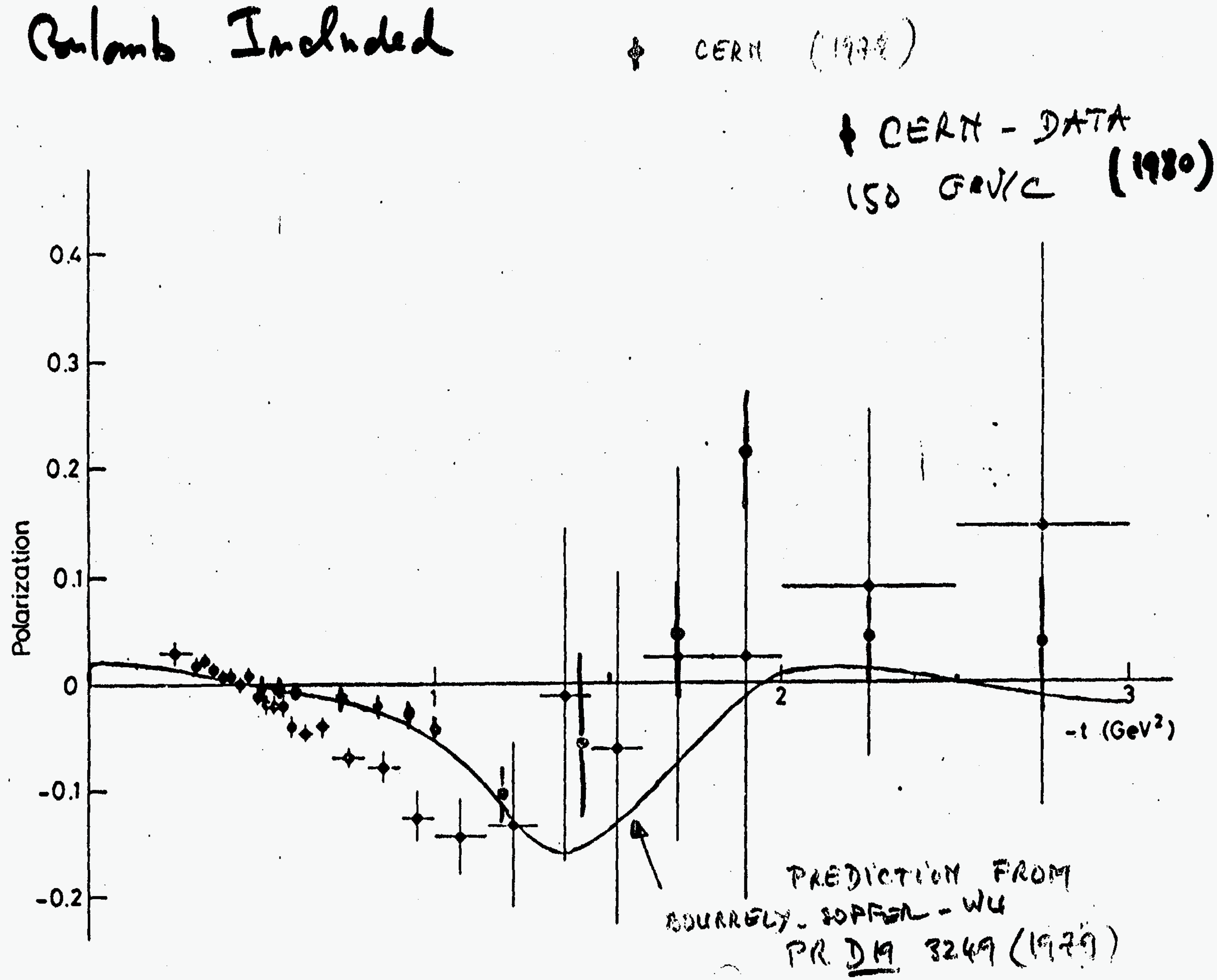

Coulomb Included
CERN
CERN - DATA
150 GeV/c (1980)
Polarization
0.4
0.3
0.2
0.1
0
-0.1
-0.2
1
2
3
-t (GeV²)
PREDICTION FROM
BOURRELY - SOFFER - WU
PR D19 3249 (1979)

Fig. 2

and the important momentum transfers are $|t| \approx 1/\ln(s/s_0)$. The spin-flip residue of the pomeron is proportional to $f_1(b_0)$, so that the spin-flip amplitude does not die away with increasing energy at fixed t.

Thus, the N and Δ contributions to the spin-flip residue of the $P(P')$ pole cancel to a great extent, whereas in the case of the amplitude with $I_t = 1$ (the ρ pole), to which the N and Δ contribute with opposite signs, a

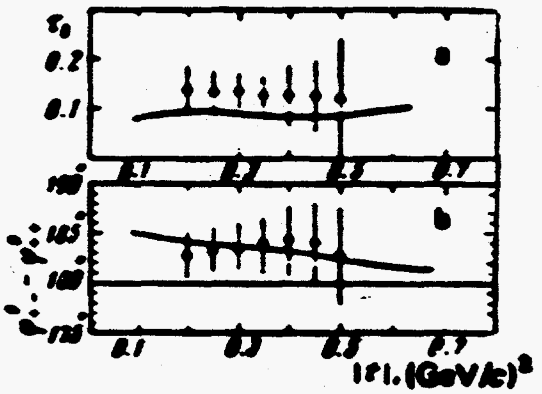


FIG. 11. a—The t-dependence of $\tau_0 = |T^0_{+-}\sqrt{s_0}/\sqrt{(-t)}/T^0_{++}|$; b—the t-dependence of the phase difference $\varphi^0_{+-} - \varphi^0_{++}$.

$S_0 = 1\ \mathrm{GeV}^2$

FROM $P(\pi^{\pm} p)$ DATA AT 40 GeV/c

Boreskov et al. 436

SOV. J. NUCL. PHYS. 27 (1978) 432

Attempts to improve the accuracy of the CNI analyzing power

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My survey of polarimeters was presented to the RIKEN BNL Workshop on *Perturbative QCD as a Probe of Hadron Structure* and a summary will appear in those proceedings. One of the most promising polarimeters is based on interference between electromagnetic and hadronic amplitudes. Its analyzing power A_N was thought to be exactly calculable, but it turns out that this claim rests upon the assumption that all hadronic helicity-flip amplitudes vanish at high energies and are negligible in the RHIC region. This assumption is probably a good approximate statement, but can not be proved rigorously.

Here I wish to explore to what extent one can learn about these helicity amplitudes from experiments at RHIC.

Surprisingly, it turns out that information useful to both the above can be obtained in principle from a study of the t-dependence of the cross-section asymmetries associated with A_N and A_{NN} at small t, **even when the beam polarization is unknown.** Alas, however, Nature conspires to make this method of little practical use. Nonetheless, in studying the structure of the contributions to A_N we have succeeded in simplifying its form so that it depends on only one unknown parameter, the imaginary part of the asymptotic part of the ϕ_5 amplitude.

We consider pp collisions in the collider mode at small momentum transfer when the bunch polarizations are arranged so that one can measure the cross-section asymmetries associated with A_N for each beam (one beam unpolarized) and with A_{NN} (both beams polarized).

We assume $\sigma_{\rm TOT}$ (hadronic) is known reasonably accurately. Let $P_{1,2}$ be the unknown, but non-zero, polarizations of the beams. The transparencies outline the main ideas of this approach and show why the method, in the end, fails to be of practical use.

Surprisingly seems can learn about hadronic helicity-flip via measurements with pold. beams, but without knowing value of pols $P_{1,2}$.

For very small t (Buttimore, Leader, Gotsman 1978)

$$\frac{d\sigma}{dt}\sqrt{-t}\,A_N = a_N + b_N t$$

$$\frac{d\sigma}{dt}\,t\,A_{NN} = a_{NN} + b_{NN} t$$

Tests $\Rightarrow$ valid for $|t| \leq 0.01$ GeV^2

$\Rightarrow$ no problem experimentally (≈ 40 bins of $\Delta t = 10^{-4}$)

Measured asymmetries are

$$P_{1,2}\sqrt{-t}\,A_N \frac{d\sigma}{dt} = P_{1,2}\left[a_N + b_N t\right]$$

$$P_1 P_2 \, t \, A_{NN} \frac{d\sigma}{dt} = P_1 P_2 \left[a_{NN} + b_{NN} t \right]$$

Measured slopes and intercepts of straight lines yields:

$$\frac{a_N}{b_N} = \frac{\left(P_{1,2}\, a_N\right)^{EXPT}}{\left(P_{1,2}\, b_N\right)^{EXPT}}$$

$$\frac{a_{NN}}{b_{NN}} = \frac{\left(P_1 P_2\, a_{NN}\right)^{EXPT}}{\left(P_1 P_2\, b_{NN}\right)^{EXPT}}$$

Thus P_1, P_2 cancel out. Also can use

$$\frac{a_N^2}{a_{NN}} = \frac{\left(P_1\, a_N\right)^{EXPT} \left(P_2\, a_N\right)^{EXPT}}{\left(P_1 P_2\, a_{NN}\right)^{EXPT}}$$

Coefficients a_N, b_N, a_{NN}, b_{NN} depend on 2 unknown hadronic ampls, ϕ_2 + ϕ_5. Seems to give 3 relations between 4 unknowns. But - - - .

i) Study of lower energy data $\Rightarrow$ only Im ϕ_2, Im ϕ_5 relevant asymptotically

ii) Theorem (Trueman, Peierls) $\Rightarrow$ Im $\phi_2 = 0$ at $t = 0$ for dominance of $PC = +1$ exchange

Consequences:

A_{NN} no good : $a_{NN} = 0$

But A_N measurement seems to be able to fix $\mathrm{Im}\, r_5$!

$$a_N = \frac{\kappa}{2} - \mathrm{Im}\, r_5$$

$$b_N = -\frac{\kappa}{2}(\beta_1 + \beta_2 + B/2) + \mathrm{Im}\, r_5 \left(2\beta_1 + b_5 + \frac{\kappa^2}{4m^2}\right)$$

where $\beta_{1,2}$ are slopes of e.m. $F_{1,2}(q^2)$

B = slope of $d\sigma/dt$

b_5 = slope of ϕ_5

Know $\beta_1 + \beta_2 + B/2 \approx 13\ \mathrm{GeV}^{-2}$

Also $\beta_1 \approx \beta_2$ and expect

$b_5 \approx B/2$

$$\therefore \left(2\beta_1 + b_5 + \frac{\kappa^2}{4m^2}\right) \approx \left(\beta_1 + \beta_2 + \frac{B}{2} + \frac{\kappa^2}{4m^2}\right)$$

$\varkappa$ = anomalous mag. mom

$\therefore \dfrac{\varkappa^2}{4m^2} \approx 1$

$\therefore$ difference between $\left(2\beta_1 + b_5 + \dfrac{\varkappa^2}{4m^2}\right)$

and $\left(\beta_1 + \beta_2 + \dfrac{B}{2}\right)$ is small;

also not accurately known.

Hence

$$b_N \approx \left(\beta_1 + \beta_2 + \frac{B}{2}\right)\left[-\frac{\varkappa}{2} + \mathrm{Im}\, r_5\right]$$

and $\mathrm{Im}\, r_5$ disappears in the

ratio $\dfrac{a_N}{b_N}$!

So method fails !

Positive side: We have much better idea of structure of A_N in CNI region at RHIC energies.

DISPERSION RELATION APPROACH TO SPIN FLIP

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1. The asymmetry A_N for elastic pp scattering in the Coulomb-Nuclear interference region at high energies may be expanded in powers of t according to

$$\frac{m}{\sqrt{-t}} A_N = \frac{(2\,\mathrm{Im}\, r_5 - \kappa_p)\, t_c/t + 2\rho\, \mathrm{Im}\, r_5 - 2\,\mathrm{Re}\, r_5}{1 + (t_c/t + \rho)^2}$$

where $t_c = 8\ \alpha\pi/\sigma_{\rm tot}$ corresponds to interference,

$$r_5 = \frac{m}{\sqrt{-t}} \quad \frac{2\phi_5}{\mathrm{Im}\,(\phi_1 + \phi_3)},$$

$$\rho = \frac{\mathrm{Re}\,(\phi_1 + \phi_3)}{\mathrm{Im}\,(\phi_1 + \phi_3)}$$

$$\kappa_p = \mu_p - 1 = 1.793.$$

An expression for somewhat larger values of $-t$ is given in equation (4) of PR 51, 3944 (1995). The amplitude ϕ_2 has been ignored here but will be included in item 3. The maximum A_N in the interference region is controlled by $\kappa_p - 2\,\mathrm{Im}\, r_5$.

2. A fit to the E704 data indicates that the hadronic helicity flip non-flip ratio
   a)

$$\mathrm{Im}\, r_5 = 15\% \pm 31\%$$

$$\mathrm{Re}\, r_5 = -2.5\% \pm 3.9\%$$

in the case where data in the interference region only is used.
   b)

$$\mathrm{Im}\, r_5 = 8\% \pm 14\%$$

$$\mathrm{Re}\, r_5 = -1.0\% \pm 0.4\%$$

in the case where the data in both the interference region and extending to $-t = 0.6(\mathrm{GeV/c})^2$ at laboratory momenta 150 to 300 (GeV/c) are employed.

We conclude that the real part of r_5 is sensitive to the larger $-t$ asymmetries A_N, as expected from the above expression where $\rho\, \mathrm{Im}\, r_5$ is more prominent at larger $-t$ values, ρ being small at the energies considered.

3. The hadronic double helicity flip amplitude $\phi_2 = \langle + + |\phi| - - \rangle$ does not necessarily vanish at $t = 0$ and, if not negligible, would appear in the numerator of the expression for $(m/\sqrt{-t})\, A_N$ in the form

$$[2\,\mathrm{Im}\, r_5 - \kappa_p\,(1 + \tfrac{1}{2}\,\mathrm{Im}\, r_2)]t_c/t + (2\rho + \mathrm{Re}\, r_5)\,\mathrm{Im}\, r_5 - (2 + \mathrm{Im}\, r_2)\,\mathrm{Re}\, r_5$$

The maximum of the asymmetry in the CNI region is now proportional to

$$\kappa_p\,(1 + \tfrac{1}{2}\,\mathrm{Im}\,r_2) - 2\,\mathrm{Im}\,r_5$$

so that either $I = \mathrm{Im}\,r_5$ or $-\xi = \mathrm{Im}\,r_2 = \Delta\sigma_{\mathrm{T}}/\sigma_{\mathrm{tot}}$, or both, may alter the maximum. Here $\Delta\sigma_{\mathrm{T}}$ refers to the difference between transversely polarized total cross sections.

4. Suppose that a maximum of the asymmetry in the CNI region is known experimentally. $\mathrm{Im}\,r_5$ and $\mathrm{Im}\,r_2$ contribute as we have seen. The rô le of ρ and the Bethe phase δ is non-negligible in this maximum. To first order, the contributions of such quantities is given in the table. Positive values of $\mathrm{Im}\,r_5$ and $\Delta\sigma_{\mathrm{T}}/\sigma_{\mathrm{tot}} = 2\xi$ decrease the maximum

RIKEN BNL RESEARCH CENTER 0.

Hadron Helicity-Flip at RHIC Energies

Dispersion relation approach to spin flip

N. H. Buttimore

1:30 pm July 28, 1997 Room 2-34 in 510

SUMMARY

1. Asymmetry A_N and ϕ_2
2. Rôle of $\mathrm{Im}\,\phi_5$ and $\mathrm{Re}\,\phi_5$ in A_N
3. Analyticity and helicity-flip
4. Bounds on hadronic spin flip
5. Conclusions

(2) For $s \geq 50\,\mathrm{GeV}^2$, A_N changes sign around $|t| \approx 0.3$ to $0.4\,(\mathrm{GeV}/c)^2$ from positive to negative and reaches a negative minimum followed by a sharp zero crossing in the region where the diffractive dip in the differential cross section develops around $|t| \approx 1.2\,(\mathrm{GeV}/c)^2$ and possibly remains positive at larger $|t|$ values.

These features have stimulated a number of speculations on the existence of a hadronic helicity single-flip contribution, ϕ_5^h, that does not necessarily decrease as $s^{-1/2}$.

Recent elastic pp scattering results at very small angles from Fermilab help to advance our understanding of the hadronic single-flip helicity amplitude. By using the polarized proton beam at Fermilab and scattering on a recoil-sensitive scintillator target, it was possible for the first time to measure the analyzing power of pp scattering at very small $|t|$ values $[1.5 \times 10^{-3} \leq |t| \leq 5.0 \times 10^{-2}\ (\mathrm{GeV}/c)^2]$ around 200 GeV/c [13]. This momentum transfer range was not accessible in other experiments that used unpolarized beams and polarized targets at comparably high energies. The data set around 200 GeV/c that we are considering in this study spans $1.5 \times 10^{-3} \leq |t| \leq 0.6\ (\mathrm{GeV}/c)^2$. Over this region, the asymmetry can be expressed as

$$A_N = \frac{\sqrt{-t}}{m}\,\frac{(\mu-1)z - 2zI + 2(\rho I - R)(1 + t/\tau)}{1 + (\rho - z)^2 - \frac{t}{2m^2}\{[(\mu-1)z - 2R]^2 + 4I^2\}} \tag{4}$$

where $z = t_c/(-t)$, $t_c = 8\pi\alpha/\sigma_{tot}$ and $I = \mathrm{Im}\, r_5$, $R = \mathrm{Re}\, r_5$.

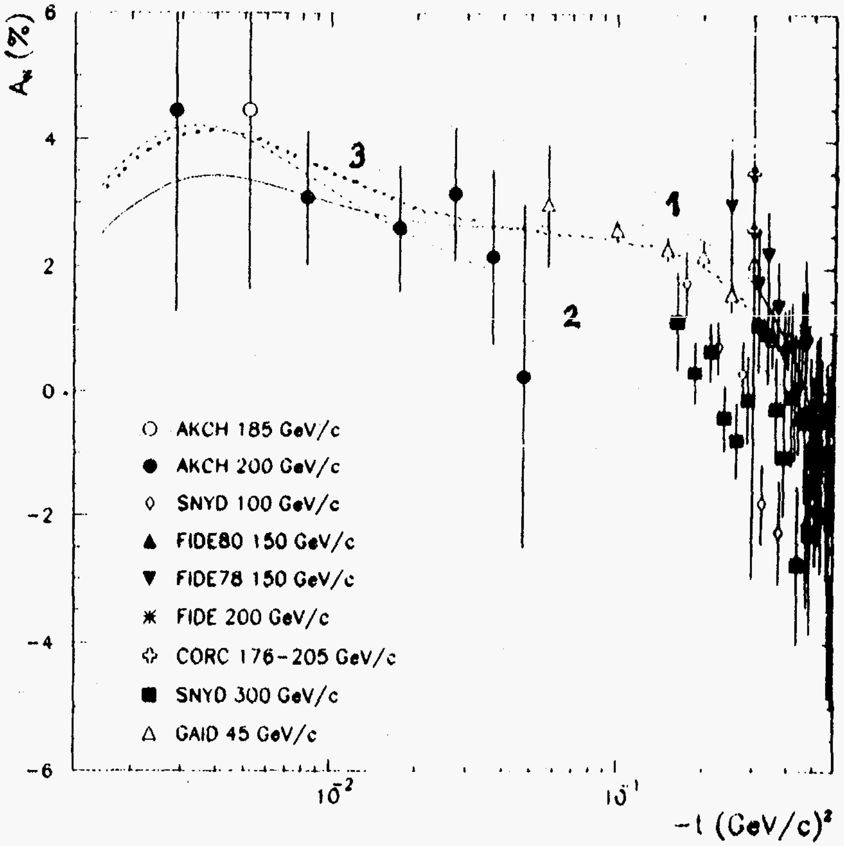


FIG. 1. The three curves represent the fits to the pp asymmetry data in the $1.5 \times 10^{-3} \leq |t| \leq 0.6\ (\mathrm{GeV}/c)^2$ range we have considered (see Table I). The solid line corresponds to 1, dashed to 2, and dotted to 3.

TABLE I. Results of the evaluation of the single-flip helicity amplitude for pp $\sigma_{tot} = 39$ mb and when an error equals zero it implies that the variable is fixed to a

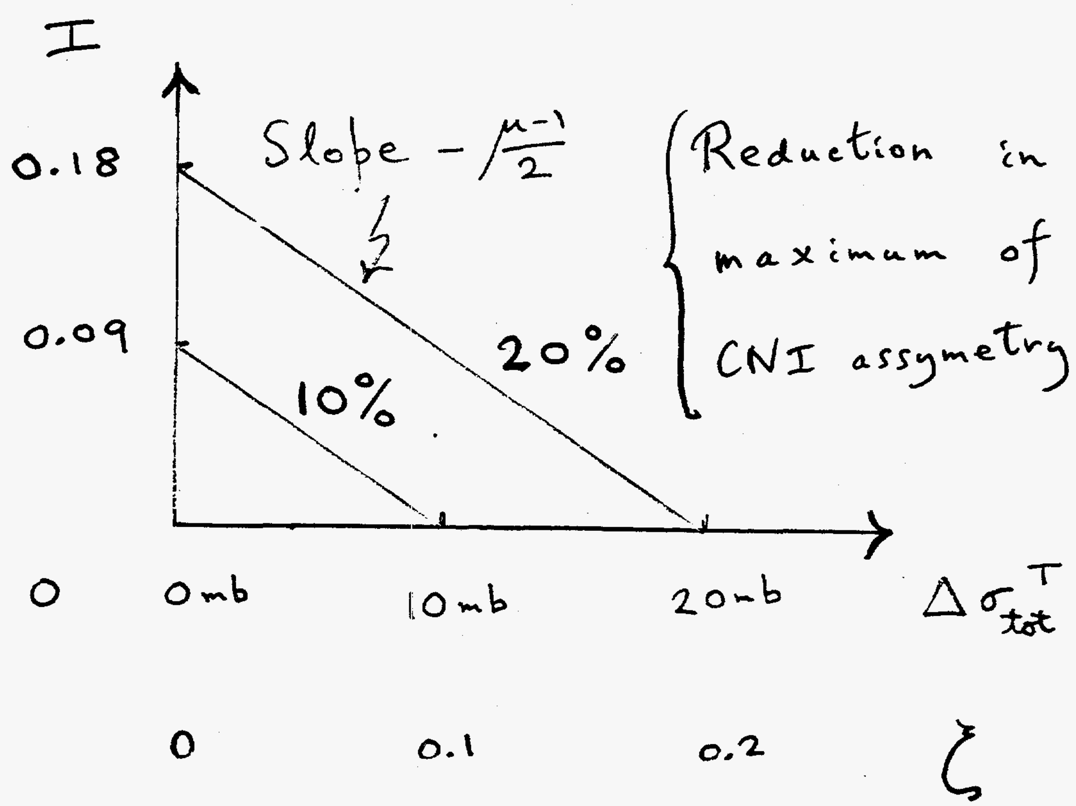
No.	R	I	τ [(GeV/c)^2]	ρ	P_L range (GeV/c)
1	-0.044 ± 0.013	0.295 ± 0.207	0.440 ± 0.018	-0.02	150–205
2	-0.010 ± 0.004	0.082 ± 0.138	0.285 ± 0.036	-0.02	150–300
3	-0.037 ± 0.022	0.078 ± 0.182	0.389 ± 0.017	-0.10	45–205
4	-0.025 ± 0.039	0.145 ± 0.311	0.450 ± 0.000	-0.02	185–200
5	-0.041 ± 0.002	0.000 ± 0.000	0.440 ± 0.009	-0.10	45–205
	-0.097 ± 0.002	0.500 ± 0.000	0.433 ± 0.009		
	-0.161 ± 0.003	1.000 ± 0.000	0.424 ± 0.012		

CNI only

2.

$\mathrm{Im}\,\phi_2$ and $\mathrm{Im}\,\phi_5$ in low $-t$ maximum of A_N [3.]

$$\frac{m}{\sqrt{-t}}\,\frac{\mathrm{Im}\,\phi_5}{\mathrm{Im}\,\phi_+} = I\,, \qquad \frac{-\,\mathrm{Im}\,\phi_2}{\mathrm{Im}\,(\phi_1+\phi_3)} = \zeta\,.$$



Since $\frac{\mu-1}{2}(1-\zeta) - I$ controls the maximum of the asymmetry A_N in the interference region, both I and $\zeta = \dfrac{\frac{1}{2}\Delta\sigma_{tot}^{T}}{\sigma_{tot}}$ may alter the maximum.

$R + iI$

$= \frac{m}{\sqrt{-t}} \cdot \frac{\phi_5}{\mathrm{Im}\,\phi_0}$

$\nu = \frac{\mu_p - 1}{2}$

$\nu = 0.896$

$\xi = \frac{\Delta\sigma_T}{2\sigma_{tot}}$

$4m\,A_{\max}/(\mu-1)\sqrt{3\sqrt{3}\,t_c}$	Parameter Value	Percent(%)	Asymmetry
1.0		100.00	4.60
$+(\sqrt{3}/2)\,\delta$	0.025	2.17	0.10
$+(\sqrt{3}/2)\,\rho$	0.10	8.66	0.40
$-(1/\nu)\,I$	0.08	-8.93	-0.41
$+(\sqrt{3}/2\nu)\,I\rho$	0.01	0.97	0.04
$-(\sqrt{3}/\nu)\,R$	-0.03	5.80	0.27
$+(\sqrt{3}/\nu)\,w_m$	0.001	0.19	0.01
$-(\sqrt{3}/2)\,w_e$	0.0025	-0.22	-0.01
$-\xi$	0.025	-2.50	-0.12
$-(3/4)\,\rho^2$	0.10	-0.75	-0.03
$-(3/4)\,\beta^2$	0.02	-0.02	-0.00

Though a ρ value of 0.1 contributes at a level of 8.7% it is a correction that may reliably be made. A positive value of ρ enhances the asymmetry maximum in pp elastic scattering.

A_N and the differential cross section should be fit to the respective data near the forward direction to determine β, R, and ξ, respecting the constraint

$$\beta^2 = \left(\frac{\Delta\sigma_L}{2\,\sigma_{tot}}\right)^2 (1 + \rho_-^2) + \frac{1}{2}\left(\frac{\Delta\sigma_T}{2\,\sigma_{tot}}\right)^2 (1 + \rho_2^2)$$

4.

For $NN \to NN$ D.V. Bugg, Nucl. Phys. B5, 29 (1968) writes a dispersion relation for

$$\lambda = \frac{\phi_5}{\sin\Theta} = -\frac{m}{\sqrt{s}}\left(\alpha + \beta + \frac{2\gamma}{\sin\theta}\right),$$

$\alpha, \beta, \gamma, \delta, \varepsilon$ being Goldberger, Nambu, Oehme amplitudes. In terms of s and u

$$\mathrm{Re}\,\lambda(s) - \sum_i \frac{\Gamma_i}{u-u_i} - \frac{1}{\pi}\int^{\infty} \frac{\mathrm{Im}\,\lambda(s')\,ds'}{s'-s} - \frac{1}{\pi}\int^{\infty}\frac{\mathrm{Im}\,\lambda(u')\,du'}{u'-u}$$

= same expression with s replaced by $4m^2$. Here $t = 0$, so that $u = 4m^2 - s$. A subtraction at threshold $s = 4m^2$ ensures convergence of $\int$'s. The unphysical cut from $u = 4m_\pi^2$ to $u = 4m^2$ has been approximated by a number of poles with coupling constants proportional to Γ_i.

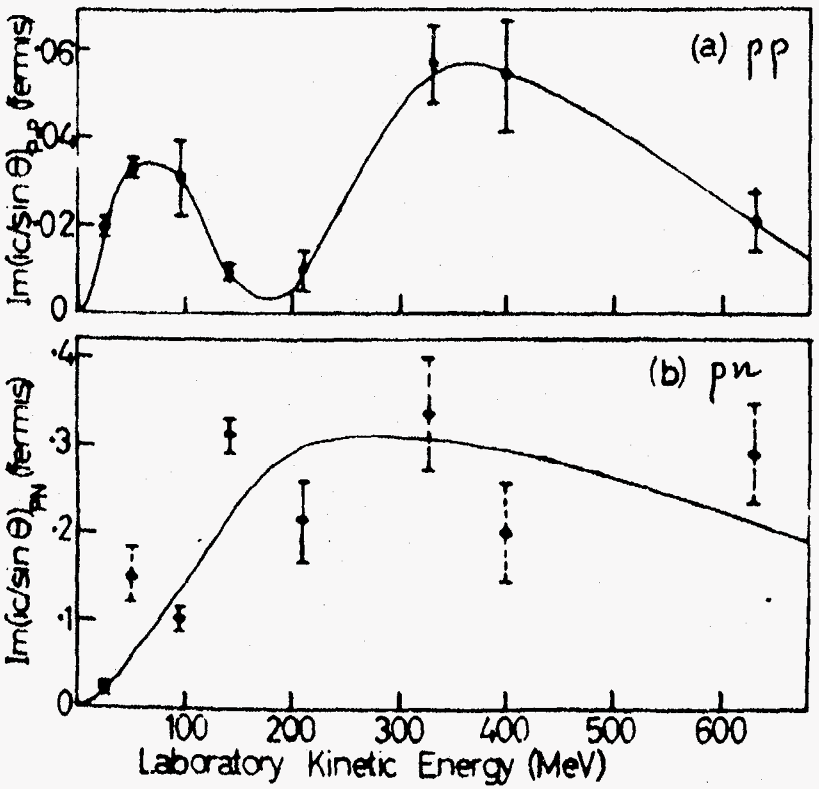


Fig. 3.

Fig. 1. The non-s-wave parts of Im ϵ_{pp} and Im β_{pp}. The continuous curve is a fit (by eye) to the former, and the dashed curve is a fit to the latter; these curves have been used in computing dispersion integrals.

Fig. 2. The non-s-wave parts of (a) Im ϵ_{pn} and (b) Im β_{pn}. The continuous curves are the empirical fits which have been used in computing dispersion integrals. The experimental points shown by broken lines are considered to be less reliable than the rest for reasons given in the text.

Fig. 3. (a) Im $(ic/\sin\theta)_{pp}$, (b) $(ic/\sin\theta)_{pn}$. The dashed curves are the empirical fits which have been used in computing dispersion integrals.

Polarimetry at high energies with pp elastic scattering

Boris KOPELIOVICH

Heidelberg/Dubna

Polarimetry at high energies with pp elastic scattering

Boris Kopeliovich
(Heidelberg / Dubna)

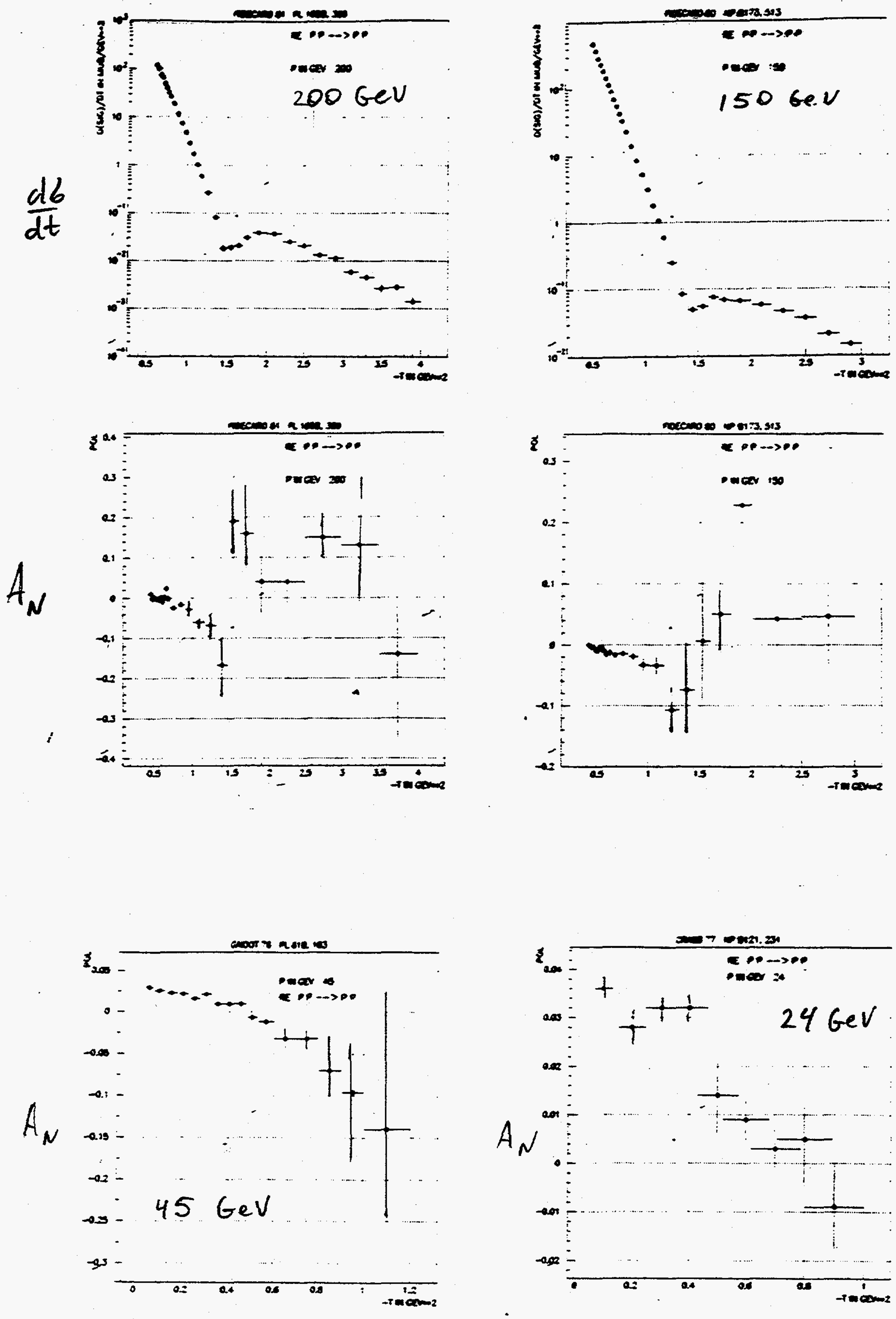
RIKEN-BNL Center
Aug. 1997

The analyzing power A_N of pp elastic scattering is known to vanish at high energies. This is because the spin-flip amplitude decreases with energy. There are, however, two regions (at least!) of momentum transfer, where A_N is nearly energy-independent and relatively large.

① $|t| \sim (10^{-3} - 10^{-2})\ \mathrm{GeV}^2$ Coulomb-Nuclear Interference (CNI)

The energy-independent electromagnetic spin-flip amplitude interferes with the hadronic non-flip amplitude.

② $|t| \sim (1 - 1.5)\ \mathrm{GeV}^2$ In this region the imaginary part of the hadronic spin-flip amplitude changes sign leading to the dip observed in the differential cross section. In the vicinity of the dip the hadronic spin non-flip amplitude is as small as the spin-flip one (at any energy!) providing a maximal polarization


dσ/dt
200 GeV
150 GeV
A_N
RE PP --> PP
45 GeV
24 GeV
-T IN GEV**2

① CNI polarimeter

B.K. & L. Lapidus 1974

N. Buttimore, E. Gotsman & E. Leader 1978

$$A_N(t) = A_N(t_p)\frac{4y^{3/2}}{3y^2+1}$$

$$y = |t|/t_p \; ; \quad t_p = \frac{8\sqrt{3}\pi\alpha}{\sigma_{tot}^{pp}}$$

$$A_N(t_p) = \frac{\sqrt{3}}{4}\frac{\sqrt{t_p}}{m_p}(\mu_p - 1)$$ Energy-independent reliably predicted

B.K. & B. Zakharov 1989

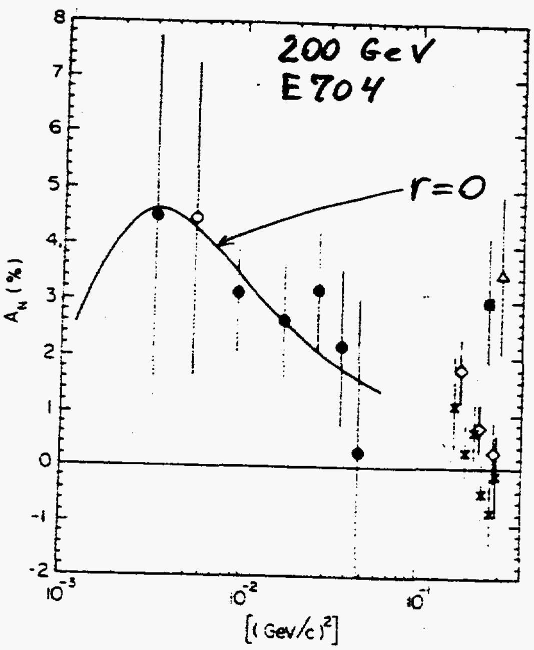
T.L. Trueman 1996

! Uncertanty due to the hadronic spin-flip

$$f_h(t) = f_0(t)\left(1 + r\,\frac{\sqrt{|t|}}{m_p}\vec{\sigma}\vec{n}\right)$$

$$A_N(t) = A_N(t)\Big|_{r=0}\left(1 - \frac{2r}{\mu_p - 1}\right)$$

hadronic spin-flip correction



One cannot use CNI as a polarimeter without any knowledge of **r**!

To what extend can we reduce the uncertainty of the CNI polarimetry using available infomation about **r** ?

★ Experimental information

● Polarization in elastic $\pi^\pm p$ scattering is due to interference of the Pomeron non-flip amplitude with Reggeon $(\rho+f)$ spin-flip, and vice versa.

The dominant ρ spin-flip term cancels in the sum

$$A_N^{\pi^+p}(t) + A_N^{\pi^-p}(t) = (r_{I\!P}+r_f)\,\frac{4\,ctg\left(\frac{\pi\alpha_f}{2}\right)R(s)}{\left(1+R(s)\right)^2} \qquad (*)$$

$R(s) = R\,(s/s_0)^{\alpha_f-\alpha_{I\!P}}$

$\alpha_{I\!P} = 1.1 + 0.25\,t$

$\alpha_f = 0.5 + 0.9\,t$

$r_{f,I\!P} = (f_{+-}/f_{++})_{f,I\!P}$

Fit to $\sigma_{tot}^{\pi^\pm p}$:

$R = 3.74 \pm 0.03$

Fit with (*) to the data on $A_N^{\pi^\pm p}(t)$ at energies $6 \div 14$ GeV results in

! $r_{I\!P} + r_f = \underline{0.059 \pm 0.008}$

B. K.
This workshop

In the model of f-dominance for the Pomeron $r_{I\!P} = r_f \Rightarrow r_{I\!P} \simeq 0.03$, otherwise, this result can be used as an upper limit for $r_p \leq 0.06$ (povided that r_p and r_f have the same sign) (and r_p is the same in pp and πp)

It is very improbable that $r_{I\!P}$ can increase more than by factor of 2 in the RHIC energy range.

B. K.

- CNI in pp elastic scattering

The E704 data, although with low statistics, put limits on a possible value of r, i.e. restrict the uncertainty of the CNI polarimetry

If r is imaginary $\mathrm{Im}\, r \lesssim 0.15$

For an arbitrary phase of r $\mathrm{Im}\, r \lesssim 0.3$

This ends up, respectively, with 15% or 30% error in the beam polarization measurement

T.L. Trueman this workshop

- CNI in pA elastic scattering

If $r = 0$, the CNI formulas look the same as for pp, except the replacement

$$t_p^{pA} = t_p^{pp}\left(Z\,\frac{\sigma_{tot}^{pp}}{\sigma_{tot}^{pA}}\right),$$ but $A_N^{pA}(t)$ changes sign at $|t| \sim 3/R_A^2$

For pC interaction $t_p^{pC} = 2.3 \cdot 10^{-3}\ \mathrm{GeV}^{-2}$

and in the maximum

$$A_N^{pC}(t_p^{pC}) = 0.039$$

If, however, $r \neq 0$ on should calculate r^{pA}, which may be different from r^{pp}.

! Amazingly, $r^{pA}(t) = r^{pp}(t)$, in Glauber approach, and even including the Gribov's inelastic shadowing corrections.

B. K. this workshop

Using the most precise E704 result for

$$A_N^{pC} = 0.024 \pm 0.09$$

we arrive at an estimate

$$r = 0.22 \pm 0.26$$

Summary E704

$$r = \begin{cases} 0.0 \pm 0.15 \\ \text{or} \\ 0.0 \pm 0.3 \\ 0.22 \pm 0.26 \end{cases}$$

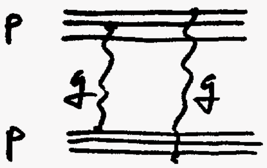
★ Theoretical expectations

- Perturbative QCD

The quark-gluon vertex $\bar{q}\gamma_\mu q$ conserves helicity. Therefore it is natural to expect $r \ll 1$ (naively, $r=0$).

However, the proton helicity ≠ the sum of the quark helicities, since they have transverse motion.

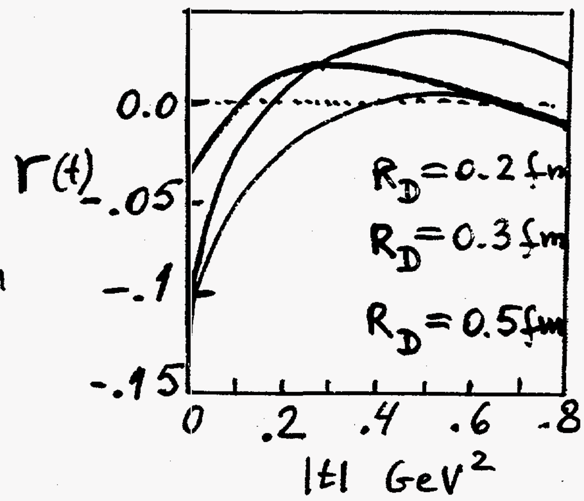
Evaluation in the double-gluon (Born) approximation



If the proton is a symmetric 3q-configuration, , $r=0$.

If, however, the dominant configuration contains a compact diquark with radius R_D, then $r \neq 0$

B. K. & B. Zakharov 1989



Expectation

$r \lesssim 0.1$

- Pion-exchange model for the Pomeron vertex

K. Boreskov, A. Grigoryan, A. Kaidalov & I. Levintov 1978

One can switch from the quark-gluon representation to the hadronic basis

Due to strong cancelation between N and Δ the Pomeron spin-flip is very small

$r = 0.06$

Conclusion: there is a nice consensus between available experimental data and theoretical predictions for the hadronic spin-flip at high energies

$r \lesssim 0.1$

This implies that CNI polarimeter has accuracy of about 10% even without calibration (i.e. measurement of r)

(2) Polarimetry with pp elastic scattering at $t = 1 - 1.5\ GeV^2$

Data for $A_N(t)$ in this region are available up to $E_{Lab} = 300\ GeV$ — B. K. this workshop

One can measure the left-right asymmetry on a fixed target at RHIC and use these data to evaluate roughly the beam polarization.

One can do, however, a much better job calibrating the polarimeter, making use of the relation

$$A_N(t) \equiv P_0(t)$$

The recoil proton in the fixed-target experiment has kinetic energy

$$E_{Kin} = -\frac{t}{2m_p}$$, what is only 500÷600 MeV

at this energy the analysing power is known to be large, a few tens percent, and one can easily measure the recoil proton polarization $P_0(t)$. This is quite a standard measurement usually performed with a carbon polarimeter, which can be precisely calibrated at a low-energy machine, i.g. at IUCF. The measurement of $P_0(t)$ can be done either at RHIC with unpolarized beam, or at other accelerators (CERN, FNAL)

The suggested polarimeter provides an absolute normalization of $A_N(t)$ and contains no uncertainty, which was not under control. The target may be either a proton jet, or a carbon foil. The counting rate is expected to be high, about 10^3 per minute

The uncertainty of the CNI palarimeter can be fixed, and one gets two polarimeters for selfcontrol W. Guryn

RIKEN BNL Center Symposium/Workshops

Title:	**Nonequilibrium Many-body Dynamics**
Organizers:	Miklos Gyulassy and Michael Creutz
Dates:	September 22-25, 1997

Title:	**Physics with Parallel Processors**
Organizers:	TBD
Dates:	January, 1998 (tentative)

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