Notes on Elastic pp Polarimetry at High t for RHIC

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Recently Boris Kopeliovich suggested to use the elastic proton-proton scattering near $|t| \approx 1\ (\text{GeV/c})^2$ for absolute polarimetry. These notes contain our estimates on the subject, concerning the possibilities of its realization. The available data at the energies above 40 GeV in $|t| \approx 1.2 \pm 0.2\ (\text{GeV/c})^2$ interval reveals the asymmetry about $A \approx -(0.05 \div 0.10)$. Unfortunately these results have large errors and new precise asymmetry measurements are necessary in advance in order to use it for polarimetry. This could be achieved either with a polarized jet target or by measurement of the recoiled proton polarization, which is equal to the asymmetry in elastic processes. The recoiled proton polarization can be determined by their second scattering on carbon in a standard and calibrated polarimeter. The inspection of available experimental data on crossection and asymmetry leads to the conclusion that the "elastic" polarimetry at large momentum transferred is bounded to the energies above 40 GeV and relatively narrow t interval $\Delta t \sim 0.2\ (\text{GeV/c})^2$. Then we considered the principal features of the possible layouts separately for the measurement of the recoiled proton polarization and for the polarimetry itself. The instrumental restrictions are imposed by the elastic scattering kinematics and the properties of the carbon polarimeters. We also need a $\pm 90^\circ$ spin-rotator (solenoid) to cancel false asymmetries in the polarimeter. So the magnetic channel for the recoiled proton transportation to the polarimeter should include: a couple of wide aperture quadruple lenses near the target, a dipole magnet for the proton momentum measurement, another couple of lenses and a spin rotator. In order to select the events of elastic scattering the precision measurements of both recoiled and forward proton angles is necessary, since the angular correlations are the most powerful selection criteria in the case. For the available experimental data we estimated the counting rates. We calculated the event number and time required to achieve 5% precision in beam polarization. For the same conditions taking into account "figure of merit" of standard carbon polarimeters we obtained that the time required to measure the recoiled proton polarization is approximately 75 times more than the time required to measure the beam polarization itself. Using of polarized jet target with thickness $\rho > 10^{13}$ proton/cm^2 has several obvious advantages. We concluded that the absolute polarimetry based on elastic pp scattering near $|t| = 1\ (\text{GeV/c})^2$ is possible in the energy range $(40 \div 250)$ GeV, but requires large measurement times, particularly in the case of recoiled proton polarization analysis.

NOTES ON ELASTIC *pp* POLARIMETRY AT HIGH *t* FOR RHIC

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– Absolute polarimetry -- Boris Kopeliovich suggestion:

$$pp \to pp \text{ at } |t| = 1\ (GeV/c)^2$$

– Possibilities of realisation: our estimates

– Available data (fig. 1,2):

at $E > 40\ GeV/c$, $|t| = 1.2 \pm 0.2\ (GeV/c)^2$

$A \approx -(0.05\text{-}0.10)$, Large errors

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– New precise asymmetry measurement are necessary for polarimetry

– Two ways:
  - → Polarized jet target
  - → Recoil proton polarization ($\mathcal{P}$) measurement (Kopeliovich suggestion)

– For elastic scattering $\mathcal{P} = A$

– $\mathcal{P}$ via second scattering on carbon in a standard and calibrated polarimeter

– Figures: crossection and asymmetry

$d\sigma/dt$: strong dependence on t, 5 times in $\Delta t = 0.2\ (GeV/c)^2$

1 $\mu barn/(GeV/c)^2$ @ 50 GeV, 0.5 $\mu barn/(GeV/c)^2$ @ 200 GeV

At 24 GeV $A \approx 0$ near $|t| = 1\ (GeV/c)^2$.

I. Recoiled proton polarization measurements

Kinematics:

Polar angle of recoil proton has weak dependence on initial energy and could be fixed at $\theta = 60° \pm 20\ mrad$

Instrumental restrictions from properties of carbon polarimeters:

$$P_{rec} = (1\text{-}1.5)\ GeV/c, \quad A_C \approx 0.25$$

False asymmetries ≈ 0.002-0.005 or ≈ (10-25)% for $\mathcal{P}$ = 0.08

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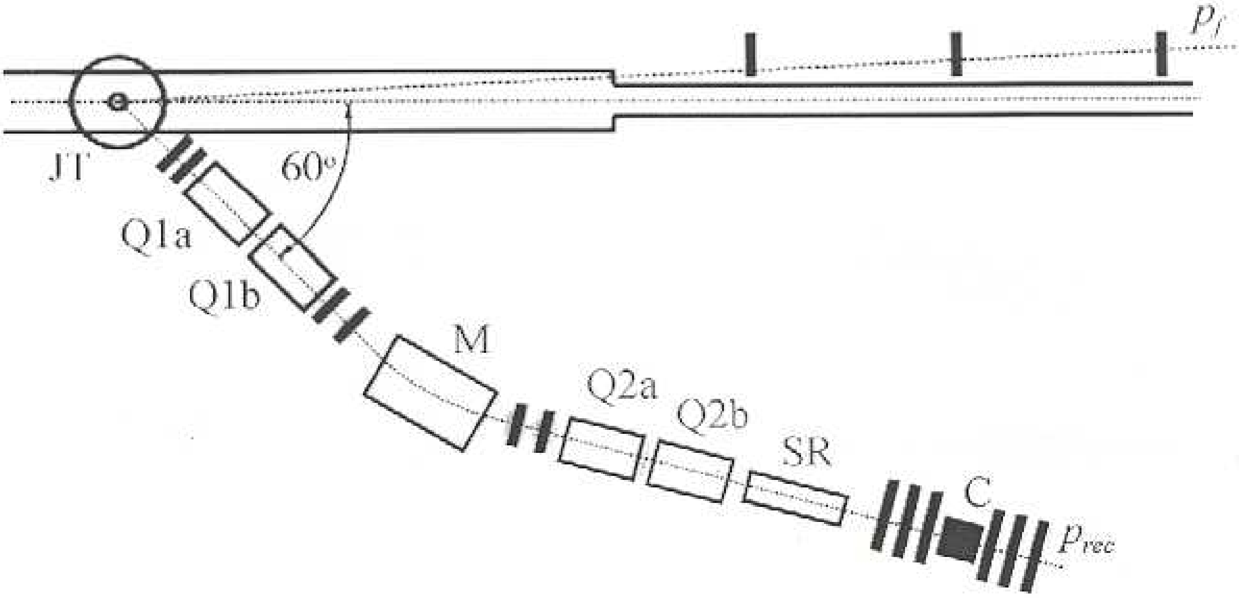
SPIN ROTATOR ± 90° (solenoid) for systematic error compensation

Magnetic channel:

- Couple of wide-aperture quadrupole lenses
- Dipole magnet
- Couple of lenses for focusing
- Spin rotator
- Polarimeter



Selection of elastic scattering:

The most powerful criteria – angular correlations

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Precise measurements of scattered and recoiled proton angles

Limitations → multiple scattering; → internal beam angular divergence

Measurement of recoiled proton momentum $\Delta P/P < 1\%$

Counting rates:

with $|t| = 1.2 \pm 0.1$ $(GeV/c)^2$, $\Delta\phi = 30°$, $I_b = 10^{11}$, $N_b = 60$, $\rho = 10^{15}$ p/cm^2 - target thickness

$n=8$ evt/c @ 50 GeV/c, $n = 4$ evt/c @ 200 GeV/c

Event number and time required:

"FIGURE OF MERIT" : analyzing power and polarimeter efficiency:

$$\Delta P = \frac{\sqrt{2}}{F\sqrt{N}}$$

For standard carbon polarimeter, for example:

POMME: $F^2 = 0.015$ @ $P_{rec} = 1.25$ GeV/c *NIM* **A288**, 1990, 379
ITEP: $F^2 = 0.015/1.1$ @ $P_{rec} = 1.35$ GeV/c

EVENT NUMBER: $8.3 \cdot 10^6$ (for $\mathcal{P} = 0.08$, stat. error 5%)

TIME REQUIRED: 300 hours @ 50 GeV, 600 hours @ 200 GeV.

It is strongly DESIRABLE to increase the target density (1-2) order of magnitude

BUT: possible problems with background due to excessive number of secondaries per bunch

Convenient formula for time estimations:

$$T_A = \frac{2}{\alpha^2 A^2 F^2 c\,(d\sigma / dt)},$$

$c = \Delta t \cdot (\Delta\phi/360°) \cdot \rho \cdot I_b \cdot N_b \cdot f$,
A – expected asymmetry,
$\alpha = \Delta A/A$ – required statistical accuracy,
f – collider frequency.

II. Beam polarization measurement

$$T_{P_b} = \frac{1}{\alpha^2 A^2 P_b{}^2 c\,(d\sigma / dt)\langle\cos\varphi\rangle^2} \quad (1)$$

$\langle\cos\varphi\rangle$ – averaged cosine to the scattering plane normal

At above conditions:

$$\frac{T_{P_b}}{T_A} = \frac{F^2}{2P_b{}^2\langle\cos\varphi\rangle^2} \approx \frac{1}{75}$$

$T_{Pb} = 4$ hours @ 50 GeV, $T_{Pb} = 8$ hours @ 200 GeV

III. Polarized hydrogen target

Time measurement formula similar to (1)

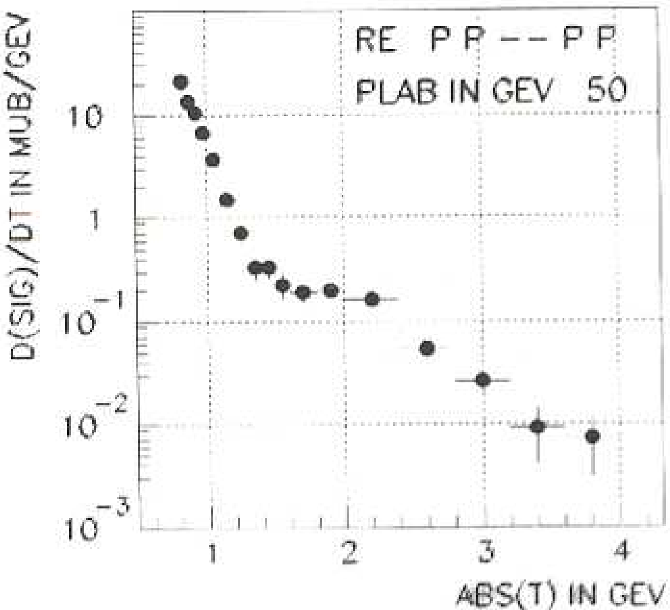
For polarized jet target with thickness 75 times LESS:
300 hours @ 50 GeV, 600 hours @ 200 GeV

Obvious advantages:

- The setup simplifies much, no second scattering required
- The same detector layout can be used for the measurements of both the asymmetry and beam polarization
- High target polarization values (up to 75%) result in essential raw asymmetries, thus decreasing the relative false asymmetries

IV. Conclusions.

The absolute polarimetry based on elastic *pp* scattering with large momentum transferred is possible in the energy range (40-250) GeV, but requires large measurement times due to low crossection and small asymmetry values, particularly in the case of the recoiled proton polarization analysis.



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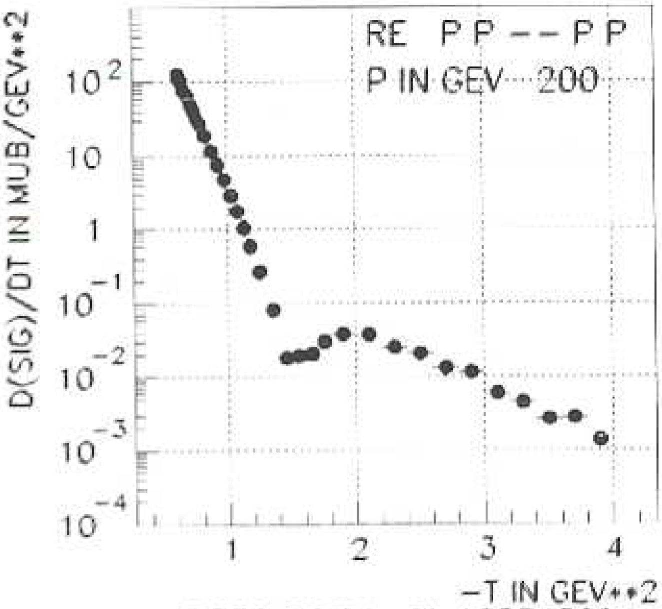

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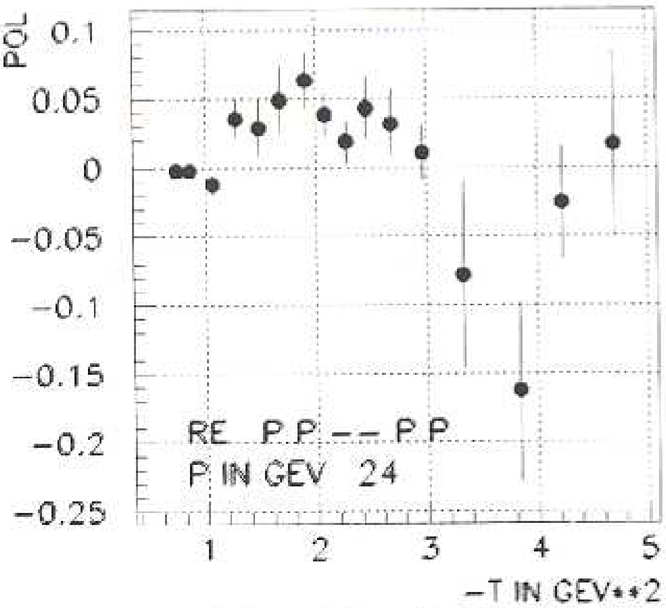

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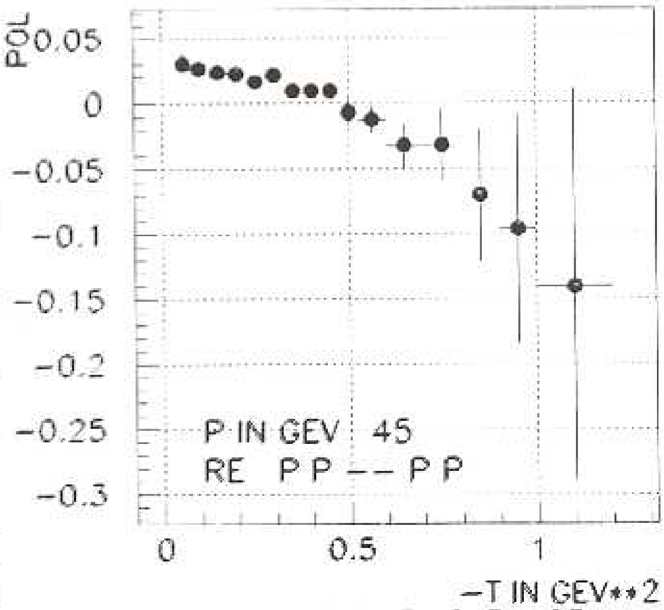

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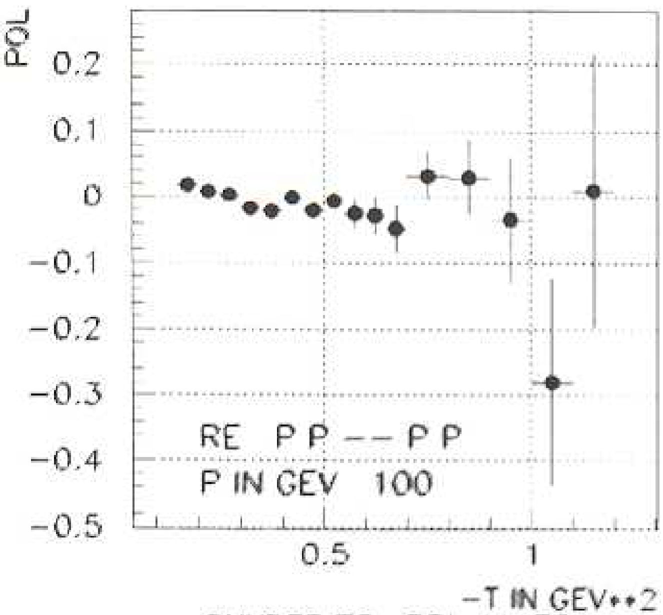

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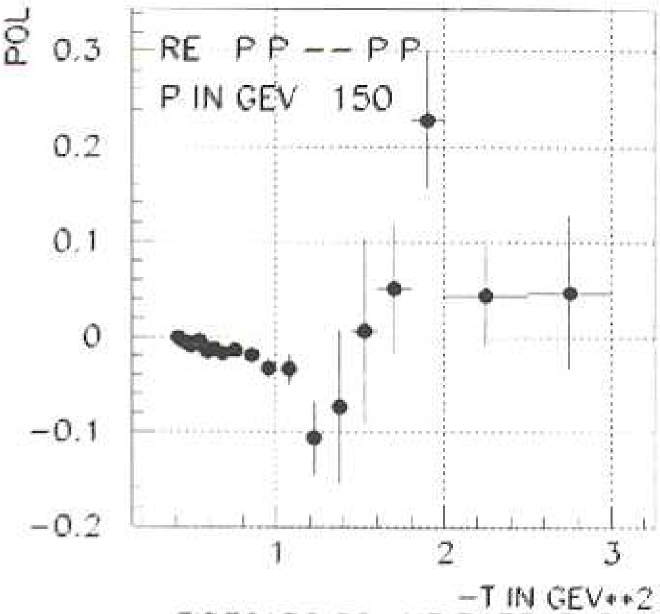

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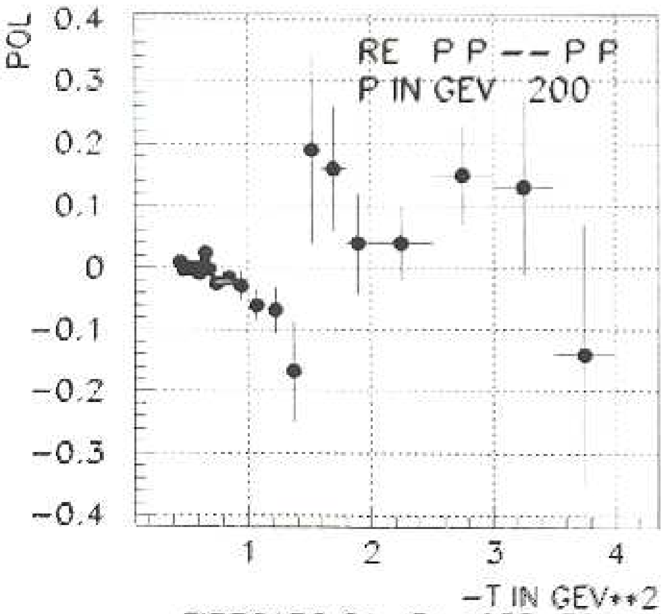

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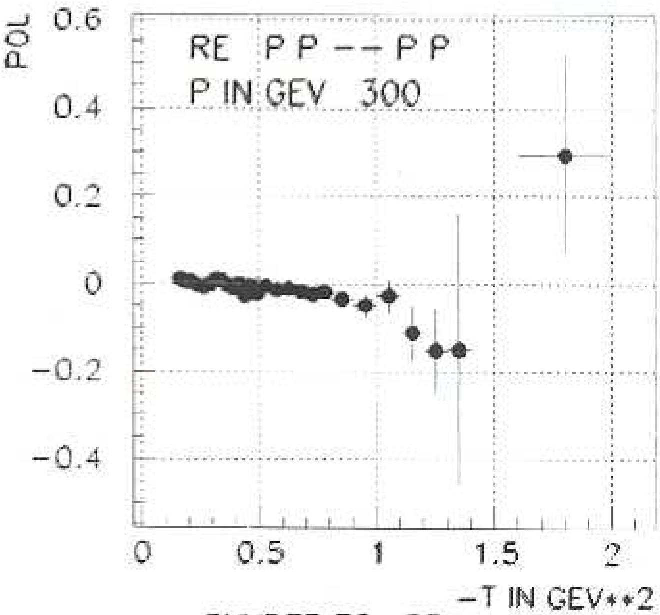

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