POLARIMETER WORKING GROUP - SUMMARY

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In previous workshops and other discussions[1-3] of polarimeters at high energy several reactions have been identified as being likely processes for use in an absolute polarimeter. The Polarimeter Working Group considered these processes as candidates for operation at 20 TeV and how well they met the requirements for an operational absolute polarimeter. The basic requirements for an absolute polarimeter were:

a) A large known (or calculable) analyzing power (or other spin variable) and large cross section.
b) Minimum beam disturbance for continuous monitoring of the beam polarization.
c) A simple process with a clear event signature.
d) A simple apparatus. It should be remembered that in a collider with both beams polarized, two identical polarimeters will be needed.

These requirements are best met by a few electromagnetic interactions. Of course it may well turn out that other reactions (e.g. hyperon production[4]) have large spin effects and can be used as relative polarimeters for monitoring specific experiments.

The processes considered for an absolute polarimeter were, in order of viability :

1) Coulomb-Nuclear Interference in pp elastic scattering at very small momentum transfer.

It has been pointed out by Buttimore et al.[5] and Kopeliovich and Lapidus[6] that in pp elastic scattering at very small -t ($\sim 3 \times 10^{-3}(\text{GeV/c})^2$) there should be significant polarization ($\sim$ 5%) arising from the interference between the hadronic non-flip amplitude and the electromagnetic spin flip amplitude. This has been discussed further by K. Kuroda[2] and at this workshop by A. Penzo.

In the formalism of Buttimore et al. the polarization is a maximum at a t value given by

$$t_p = \sqrt{3}\,\frac{8\pi\alpha}{\sigma_{TOT}} , \tag{1}$$

with a polarization $P(t_p)$ given by

$$P(t_p) = \sqrt{3}\,\frac{(\mu-1)}{4m}\,|t_p|^{1/2} \quad . \qquad (2)$$

The polarization varies with t according to

$$P(t) = P(t_p)\,\frac{4z^{3/2}}{3z^2+1} \quad , \qquad (3)$$

where $z = \frac{|t|}{|t_p|}$.

This is plotted in Fig. 1.

For an SSC proton beam of 20 TeV incident on a fixed target $\sqrt{s}$ = 200 GeV and then $\sigma_{TOT} \approx 50$ mb.

This gives

$$-t_p \approx 2.5 \times 10^{-3}\ (\text{GeV/c})^2$$

and $P(t_p) = .04$.

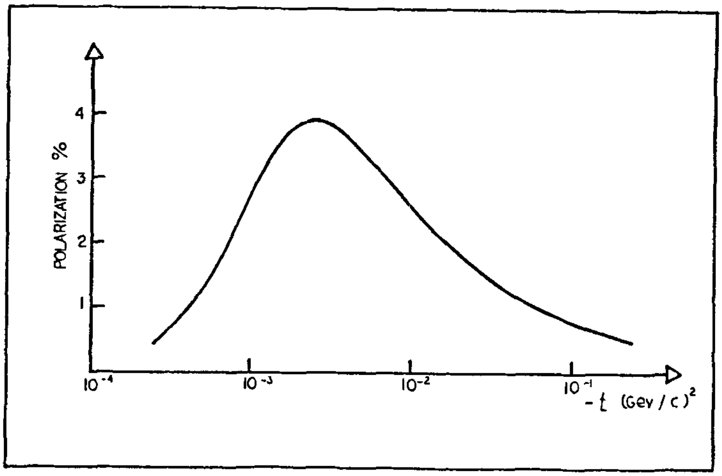

Fig. 1. Polarization in the Coulomb Nuclear Interference Region at 20 TeV.

To estimate the rates we assumed the SSC design intensity (10^{14} protons circulating) and a hydrogen jet target to give a luminosity of ~ 10^{32} cm^{-2} sec^{-1}. The elastic cross section for $.001 < -t < .02$ $(\text{GeV/c})^2$ is about 1 mb giving ~ 10^5 events/sec. Since ~ 6×10^6 events are required to measure the beam polarization to ±.01 with an analyzing power of .04 a one minute measurement would suffice.

The essential kinematics are shown in Table I.

Table I

$-t$ $(\mathrm{GeV}/c)^2$	T_{RECOIL} MeV	θ_{RECOIL} Deg.	$\theta_{\mathrm{FORWARD}}$ μr
.001	.5	89	1.5
.02	10	86	7

The measurements could be achieved with the use of solid state detectors. Good energy and position measurements could be made on the recoil particle but the detection of the forward particle, because of the proximity of any detector to the beam, will be difficult. However a possible layout is shown in Fig. 2 if a high β straight section of at least 1 km in length can be utilized.

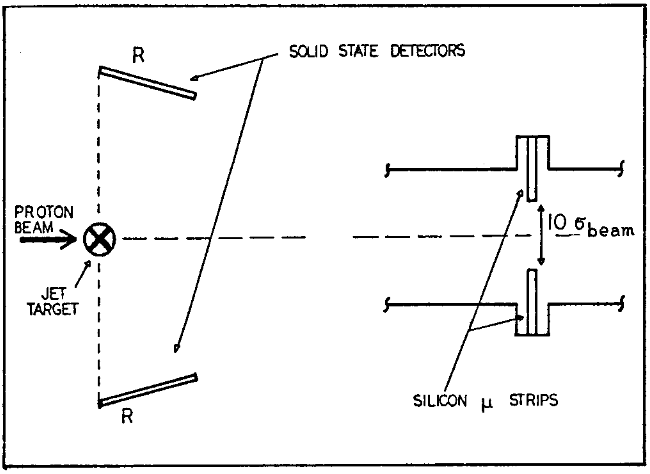

Fig. 2. Schematic for polarimeter in Coulomb Nuclear Interference region.

The problems of operating the forward detectors so close to the beam (e.g. radiation damage) may make it necessary to operate the polarimeter with the recoil detectors alone. In this case the discrimination against inelastics is less effective and there will be some dilution of the analyzing power. However it was noted that at several 100 GeV/c[7] the diffractive dissociation of protons is less than 10% of the elastic signal. A calibration of the polarimeter could be made by using a polarized jet instead of a normal gas jet.

Finally A. Penzo reported on a test of the principle of the Coulomb Nuclear Interference polarimeter using a 0.7 - 2 GeV/c extracted polarized beam at SATURNE. Analysis is still continuing but an effect has been seen. The group was encouraged to repeat the test using the polarized beam at the Brookhaven AGS.

2) Coulomb Diffractive Dissociation or Primakoff Polarimeter

The use of the process $p_{\uparrow} + Pb \to Pb + p + \pi^{\circ}$ in a polarimeter was suggested by D. Underwood.[8] The process is related to low energy photoproduction through the Primakoff effect[9] as shown in Fig. 3.

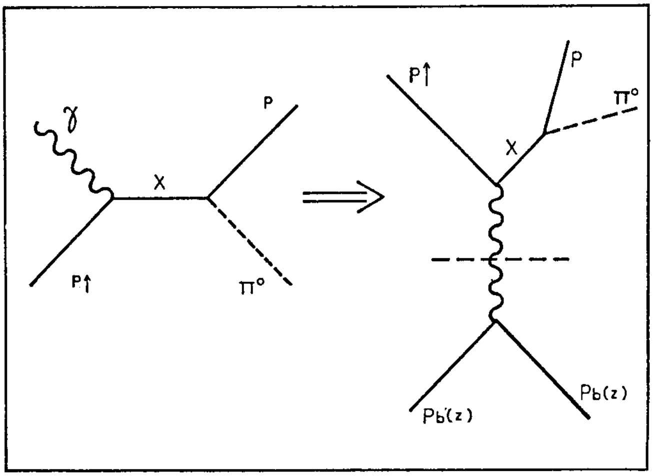

Fig. 3. Diagrams showing relation of Coulomb Diffractive dissociation to Photoproduction.

There is data[10] at the relevant γ energies (~ 600 MeV) which show analyzing powers of ~ 80%. Coupled with a large usable cross section (~ 5 mb) and a clean trigger this is an attractive candidate for an absolute polarization measurement. The disadvantages for use as a polarimeter at the SSC are the need for a lead target and a high resolution reconstruction of the π° and proton.

D. Underwood discussed the experimental aspects of such a polarimeter comparing the parameters for the SSC and a similar measurement to be carried out in a 200 GeV polarized beam at Fermilab.[11] These are shown in Table II.

Table II. Detector Geometry assuming
$M_{N^*} \sim 1400$ and θ_{cm} $(N^*) = 70°$ to 110°

Energy	Distance	$E_{\pi^0 MIN}$	$E_{\pi^0 MAX}$	E_{PMIN}	θ_{PMAX}
200 GeV	16 m	38 GeV	78 GeV	122 GeV	3×10^{-3}r
20 TeV	1600 m	3.8 TeV	7.8 TeV	12.2 TeV	3×10^{-5}r

	$\Delta\theta_{\pi^0}$	ΔE_{π^0}	$\Delta\theta_p$	ΔE_p
200 GeV	2×10^{-4}	3%	5×10^{-5}	2%
20 TeV	2×10^{-6}	3%	5×10^{-7}	2%

The polarimeter would consist of a proton calorimeter surrounded by a lead glass γ_{π^0} calorimeter installed in a high β section with a ~ 2000 m straight section.

The layout is shown schematically in Fig. 4.

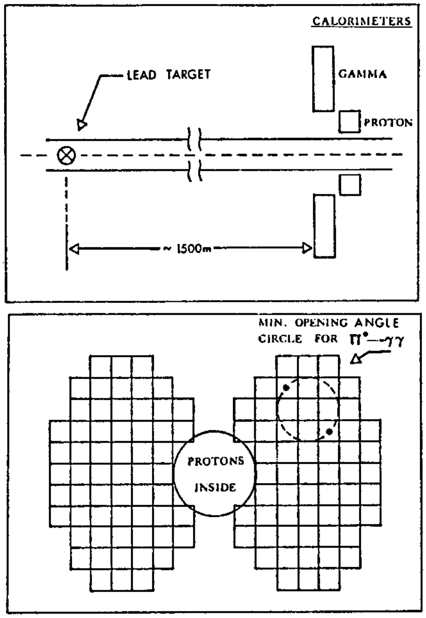

Fig. 4. Possible Primakoff Polarimeter Layout.

The only form of the lead target considered, a lead coated carbon fiber, probably would not work for very long because of the temperatures which the carbon could reach when exposed to the beam. A more promising approach would be to consider some form of lead "jet".

3) $p\uparrow + e\uparrow$ Elastic Scattering

QED calculations by Kobayashi[12] have shown that the double spin asymmetry A_{LL} is large at large q^2 and high energy in electron proton elastic scattering. At this workshop R. Prepost discussed the usefulness of this process in an absolute polarization measurement.

The main problem is that the proton form factor suppresses the cross section enough that it forces the requirement that the detection be done at as low a q^2 as possible in order to get a reasonable scattering rate. Unfortunately $A_{LL} \to 0$ as $q^2 \to 0$.

However, assuming a measurement at $q^2 \lesssim 1.0\ (\mathrm{GeV/c})^2$ then $A_{LL} \approx .075$ and the integrated cross section is $\approx 7 \times 10^{-33}\ \mathrm{cm}^2$. The electron target was assumed to have the parameters of 10^{10} electrons/bunch at 20 MHz with electron polarizations of 50%. Further it was assumed that each electron sees the whole proton bunch. Then, for a proton beam size of 0.2 mm the luminosity is $\sim 5 \times 10^{31}\ \mathrm{sec}^{-1}\ \mathrm{cm}^{-2}$ giving 0.35 events/sec.

A measurement of the beam polarization to ± 10% would take 4 hours which is unacceptable. An increase in the luminosity by a factor of 400 would mean that the ± 10% measurement could be made in about half a minute. However it was not clear whether such an increase could be achieved.

Due to the marginal nature of this reaction for polarimetry, questions about the interaction region, detectors and inelastic scattering were not addressed.

4) Compton Polarimeter

The use of backscattered circularly polarized laser photons for analyzing the longitudinal polarization of high energy beams was discussed by H. Steiner.

For high energy electron beams this is a powerful technique and at the SLC maximum asymmetries of 70-80% are expected when the relative spin directions of $\lambda \sim 500$ nm photons and 50 GeV electrons are reversed. In a head-on collision the electron loses about 2/3 of its energy to the photon. At the SLC counting rates are also large allowing statistically significant results in a few minutes.

Unfortunately, the method cannot be used for 20 TeV protons at the SSC. The crucial parameter which determines both the maximum asymmetry and the maximum fractional momentum transfer to the proton is $4k\gamma/m_p$, where $k \approx 2.5$ eV (photon energy) ,

$$\gamma = 2 \times 10^4 \text{ and } m_p = \text{proton mass} \quad .$$

At the SSC, $4k\gamma/m_p \approx 2 \times 10^{-4}$ compared with 2 at SLC. Further the Compton cross section is down by $(m_p/m_e)^2$.

The low asymmetry (2×10^{-4}) and low cross section ($\sim 10^{-31}$ cm^2) makes this method unsuitable for a polarimeter at the SSC.

CONCLUSIONS

The main conclusion of the workshop was that the two reactions identified earlier[2] as likely polarimeter processes at several hundred GeV/c are still good candidates at 20 TeV. The Coulomb Nuclear Interference and Diffractive Dissociation reactions, 1) and 2) discussed above, will be measured soon at 200 GeV/c in the external polarized beam at Fermilab.[11]

Other reactions which have substantial spin effects at lower energies may maintain these effects to higher energies and then may be used as relative polarimeters for monitoring experiments. Hyperon spin effects and polarization in meson inclusive production also will be measured at 200 GeV/c and should provide a better basis for extrapolation to 20 TeV. Of the other reactions, $p\uparrow + e\uparrow$ elastic scattering was considered to be marginal relying on the optimization of various parameters for it to be viable. The Compton polarimeter was considered not to be a candidate for a 20 TeV polarized proton beam.

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