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COMMISSIONING OF POLARIZED-PROTON AND-ANTIPROTON BEAMS AT FERMILAB§

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ABSTRACT

We describe the polarized-proton and polarized-antiproton beams up to 200 GeV/c at Fermilab. The beam line, called MP, consists of the 400-m long primary and 350-m long secondary beam line followed by 60-m long epxerimental hall. We discuss the characteristics of the polarized beams.

The Fermilab polarization projects are designated as E-581/704 initiated and carried out by an international collaboration, Argonne (U.S.), Fermilab (U.S.), Kyoto-Kyushu-Hiroshima-KEK (Japan), LAPP (France), Northwestern University (U.S.), Los Alamos Laboratory (U.S.), Rice (U.S.), Saclay (France), Serpukhov (U.S.S.R.), INFN Trieste (Italy), and University of Texas (U.S.).

INTRODUCTION

The physics objectives for the Fermilab polarized-beam facility up to 200 GeV/c are in part based upon the facts that there are already several experimental indications that spin effects are significant at high energy. They are i) measurements of π^0 production at high $p_\perp$($p_\perp$ > 2.0 GeV/c) in proton-proton

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at CERN and in $^-$-proton collisions at Serpukhov revealed sizeable asymmetries at 24 GeV/c and 40 GeV/c, respectively ii) hyperons produced at large x_F inclusively off nuclei and hydrogen at CERN, Fermilab, and ISR, were observed to have high polarizations iii) inelastic scattering of longitudinally polarized electrons on longitudinally polarized protons at SLAC yielded a large asymmetry, implying that proton helicity orientation is communicated to the constituent quarks.

Fermilab Polarized-Beam Facility

During the last decade, construction of a high-energy (above 100 GeV/c) polarized beam has been attempted. In order to avoid possible complications involving depolarization at high energies, polarized protons can be produced from decaying hyperons, lambdas or sigmas. The Fermilab polarized-beam facility was constructed and has been operational.

It has been shown that we can select protons or antiprotons at various momenta which are decaying around $\theta_{c.m.} = 90°$ from lambdas or antilambdas respectively.[1] We show how this scheme works.

The spin direction in the lambda center-of-mass (decay frame) is shown in Fig. 1. We note that spin direction is almost unchanged in transforming from the lambda-decay frame to the laboratory. Therefore protons or antiprotons decaying around $\theta_{c.m.} = 0°$ and 180° are longitudinally polarized ($\vec{L}$) while those with $\theta_{c.m.} = \pm 90°$ are transversely polarized ($\vec{N}$, up and down, or $\vec{S} = \vec{N} \times \vec{L}$) in the laboratory.

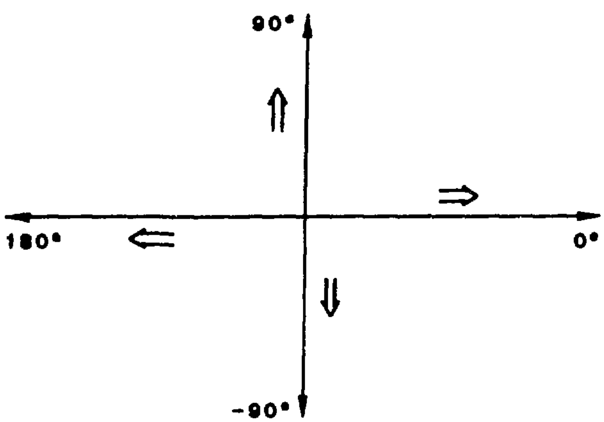

Fig. 1

Spin direction of protons vs. decay angles. The spin direction is indicated by => and $\hat{\Downarrow}$ symbols.

Protons or antiprotons with $\theta_{c.m.} = 90°$ and -90° have the opposite laboratory decay angles which are not zero. They can be distinguished from those decaying at $\theta_{c.m.} = 0°$ from lambda or antilambda with the production target as the source of the beam. Virtual sources for $|\theta_{c.m.}| = 90°$ particles are illustrated in Fig. 2. The spin direction, $\vec{N}$ or $\vec{S}$, should be chosen using the field direction of the sweeping magnets and bending magnets for the momentum selection, so that the spin direction is parallel to the field. The polarized beam line (up to 200 GeV/c) is shown in Fig. 3. Here we produce the $\vec{S}$ type beam before reaching the snake magnets which make fast reversal, typically every 10 spills, of the spin direction.[2]

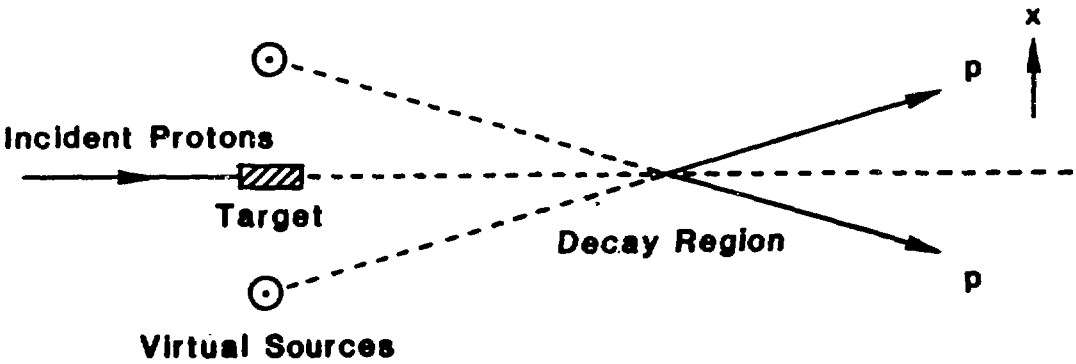

Figure 2 Virtual sources (top view).

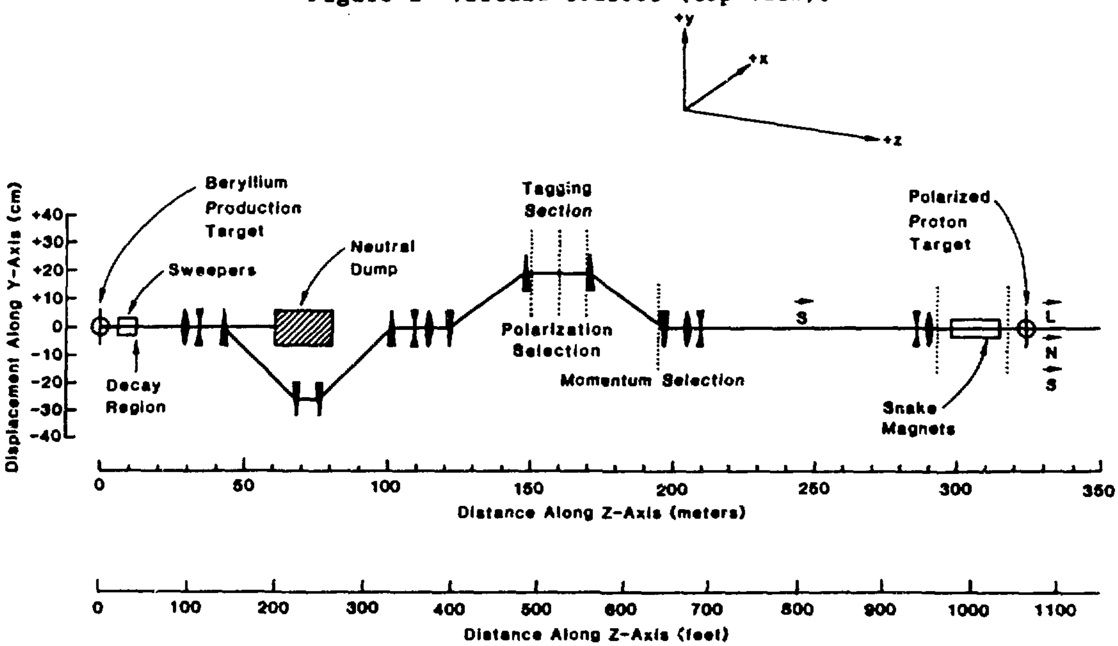

Figure 3 Side View of the Fermilab Polarized Beam (MP secondary beam).

Polarized protons from the virtual sources as shown in Fig. 2 are focused in the tagging section, where both the momentum and polarization are selected (see Fig. 3). The polarization is strongly related to the x position (x, y, z directions are indicated in Fig. 3) at the tagging section, and the average polarization, <P>, and $I\langle P\rangle^2$, where I represents actually measured beam intensity, are shown in Figs. 4 and 5 respectively with respect to x in mm.

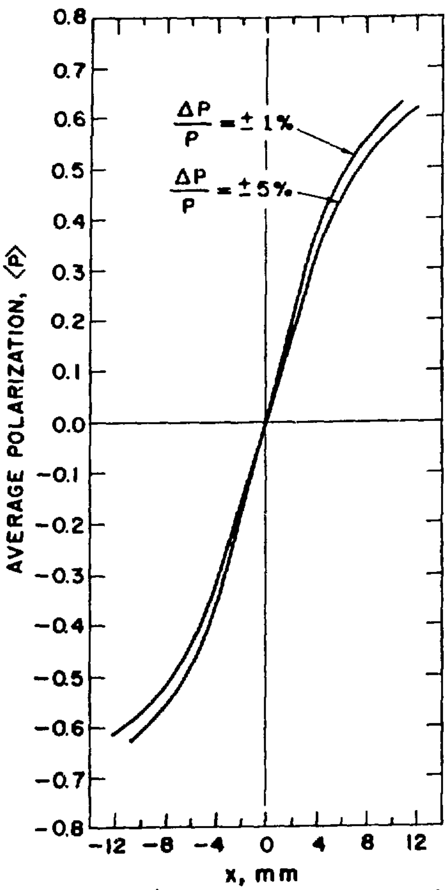

Figure 4 <P> vs. x in the Tagging Section

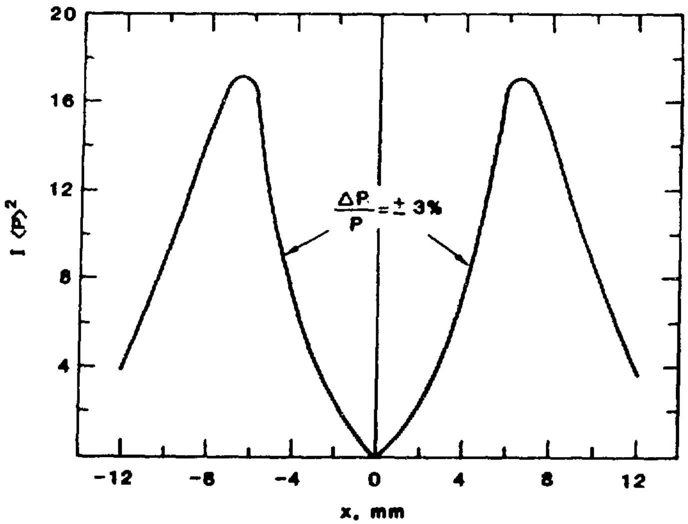

Figure 5 $I\langle P\rangle^2$ (arbitrary unit) vs. x in the Tagging Section

The beam line was actually operated at 800-GeV/c incident momentum. The intensities of total (not tagged) protons and antiprotons at 200 GeV/c were $1.5 \cdot 10^7$/spill (in addition $1.5 \cdot 10^6$ π's) and $1.5 \cdot 10^6$/spill (in addition $7.5 \cdot 10^6$ π's) respectively for incident protons with 10^{12}/spill. The intensities of tagged polarized beams with polarization higher than 40% are estimated to be about one half of the total. Two polarimeters were utilized to determine the polarization of the polarized beams. The results are being analyzed. We briefly describe these polarimeters.

1) Coulomb-Nuclear Polarimeter

This polarimeter is to measure the interference term of the non-flip amplitude and the electromagnetic spin-flip amplitude. The proton polarization arising from the interference is $P \approx 5\%$ at $|t| \approx 2 \cdot 10^{-3}$ $(GeV/c)^2$ and is energy independent.[3]

2) Primakoff-Effect Polarimeter

The diffractive dissociation of incoming high-energy proton into (πN) system by the Coulomb field of nuclei[4] is related to the low-energy photoproduction including the polarization effect.[5] This fact can be applicable to a polarimeter for high-energy polarized beams.[6] The process $pA \to pA\pi^{\circ}$ can be related via the Primakoff effect to low-energy photoproduction, i.e., $\gamma p \to \pi^{\circ} p$.

Results of measurements in $\gamma p^{\uparrow} \to \pi^{\circ} p$ at the γp kinetic energy of 600 MeV show that the photoproduction asymmetry is ~ 90% at $\theta_{c.m.} \approx 90^{\circ}$ and $m_{p\pi^{\circ}} = 1.4$ GeV/c^2.

Measurements of beam polarization at 200 GeV/c by these polarimeters were performed during November 1987 to January 1988. Preliminary results indicate that the beam polarization is consistent with the design values.

POLARIZED-BEAM PROGRAM

We describe the following experiments presently scheduled or planned using the Fermilab polarized-beam facility.

i) Measurements of the difference in total cross sections, $\Delta\sigma_L$(pp and $\bar{p}$p), and simultaneously a parity non-conservative experiment, $\Delta\sigma$ $(p^{\uparrow}p)$.

ii) Polarized beams on a hydrogen target at large $p_{\perp}$ or large x
$p^{\uparrow}p \to$ hadron $(\pi^{\circ}, \pi^{\pm}, \Lambda^{\circ}, \Sigma^{\circ}, q\ldots) + x$

iii) Longitudinally polarized beams and longitudinally polarized target
$p^{\uparrow}p^{\uparrow} \to$ hadron + x
$p^{\uparrow}p^{\uparrow} \to$ direct γ production, calorimeter trigger high-$p_{\perp}$, dimuon production

ENERGY UPGRADE

There is a plan to upgrade the present beam line up to 500 GeV/c by replacing the conventional quadrupole magnets with superconducting magnets.

REFERENCES

1. D. Underwood *et al.*, A Polarized Beam for the M-3 Line (Fermilab), ANL-HEP-PR-78-05.

2. D. G. Underwood, *Nucl. Inst. and Meth.* 173 (1980) 351.

3. For instance, C. Bourrely and J. Soffer, *Nuovo Cimento Lett.* 19 (1977) 569.

4. H. Primakoff, *Phys. Rev.* 81 (1951) 899; A. Halprin, C. M. Anderson, and H. Primakoff, *Phys. Rev* 152 (1966) 1295; L. Stodolsky, *Phys. Rev.* 144 (1966) 1145; G. Faldt, *Nucl. Phys.* B41 (1972) 125; B43 (1972) 591.

5. B. Margolis and G. H. Thomas, "High Energy Polarized Proton Beams", *AIP Conference Proceedings*, No. 42 (1978) p. 173.

6. D. G. Underwood, ANL-HEP-PR-77-56.