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POLARIZATION OF ANTIPROTONS BY ANTIPROTON DECAY

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Several participants in this workshop expressed the following questions and problems:

1) How will polarized antiproton beams be produced at Fermilab?
2) How is the polarization of antiproton beams determined?
3) Can this beam be used for the Fermilab collider?

I will attempt to describe the results of this working group.

I. POLARIZED ANTIPROTON BEAMS AT FERMILAB

First, let me review the earlier design of the polarized-proton beam at CERN.[1] The idea then was to select high-momentum protons which were forward decaying, around $\theta_{c.m.} = 0°$, from lambdas near the highest momentum point of the lambda production spectrum. These protons were longitudinally polarized, as I will explain later. However, this method could not be applied to antiprotons since antilambdas are produced at much lower momenta than the incident momentum of protons striking a production target.

It has been shown that we can select protons or antiprotons which are decaying around $\theta_{c.m.} = 90°$.[2] We will see how this scheme works.

The polarization of antiprotons comes from parity violating decays of antilambdas, and the measured polarization was 64%.[3] The spin direction in the antilambda center-of-mass frame (decay frame) is shown in Fig. 1.

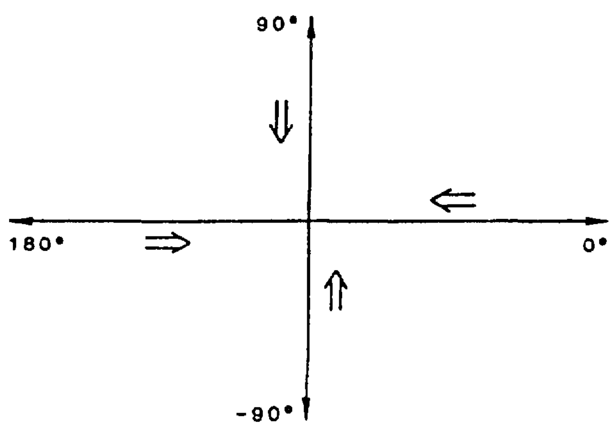

Figure 1
Spin direction of antiprotons vs. decay angles. The spin direction is indicated by ‡ and ↑↑ symbols.

We note that spin direction is almost unchanged in transforming from the lambda decay frame to the laboratory. Therefore antiprotons with $\theta_{c.m.} = 0°$ and 180° are longitudinally polarized ($\vec{L}$) while those with $\theta_{c.m.} = 90°$ are transversely polarized ($\vec{N}$ or $\vec{S}$) in the laboratory. Since antiprotons with $\theta_{c.m.} = 0°$ and 180° move in the same direction (lab decay angle = 0°) in the laboratory, there are no

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longitudinally polarized beams at momenta which are much less than the incident proton momentum.

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 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 bending magnet, so that the spin direction is parallel to the field. The polarized beam line (up to 200 GeV/c) at Fermilab is shown in Fig. 3. Here we produce the $\vec{S}$ type beam. The estimated intensities of polarized antiprotons with beam polarization of 45% produced by 400-GeV/c and 1000-GeV/c incident protons are shown in Fig. 4.

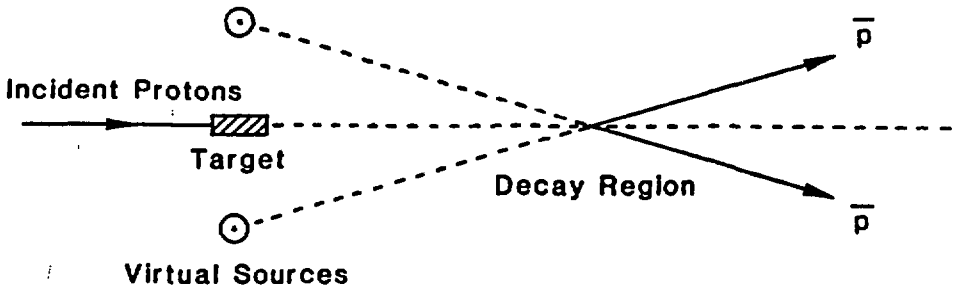

Figure 2 Virtual Sources

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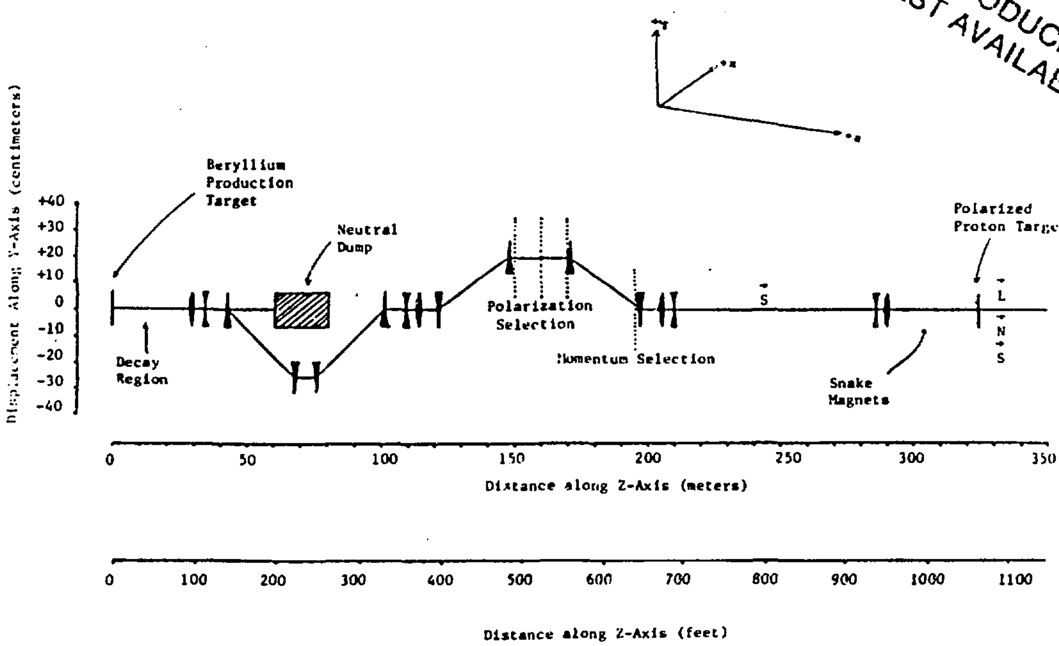

Figure 3 Side View of Fermilab Polarized Beam

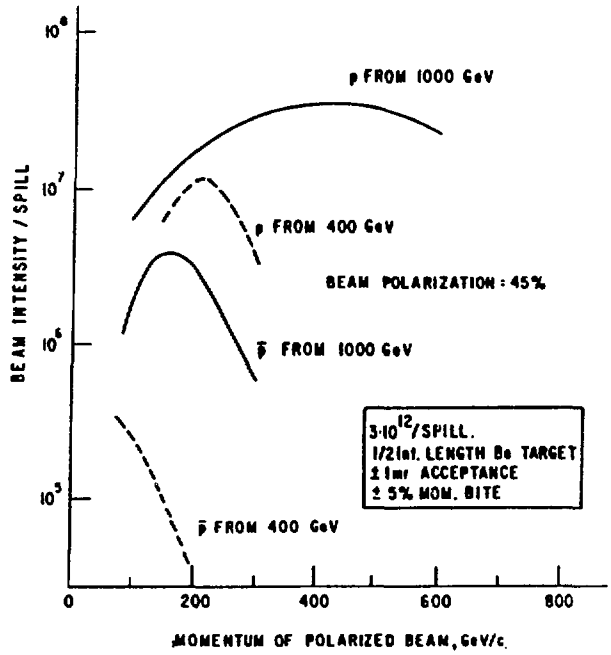

Figure 4

Polarized Antiproton-Beam Intensity

II. HIGH-ENERGY $\bar{p}$ POLARIMETERS

We describe here polarimeters in the Fermilab E-581 proposal. Two promising polarimeters are as follows:

i) Coulomb-Nuclear Polarimeter

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

ii) Primakoff-Effect Polarimeter

This is to apply the results of the low-energy processes, which are related to the low-momenta high energy reactions. The diffractive dissociation of incoming proton into (πN) system by the Coulomb field[4] of nuclei seems the most promising channel as proposed by Underwood.[5] This scheme is shown in Fig. 5. The process $pA \rightarrow pA\pi^\circ$ can be related via the Primakoff effect to low-energy photoproduction, i.e., $\gamma p \rightarrow \pi^\circ p$. The amplitude ψ for diffractive production from a nucleus with charge Z and atomic number A can be written as:

$$\int |\psi|^2 \, d\phi = \frac{Z^2\alpha}{p_\perp^2} \left(\frac{2M_A}{s_{\pi p} - m_p^2}\right)^2 \left(A \cdot \frac{d\sigma}{d\Omega}\right)_{\gamma p \rightarrow \pi^0 p},$$

where A is the photoproduction asymmetry at the given value of $p_\perp$ and $s_{\pi p}$. Asymmetries at the γp kinetic energy of 600 MeV are as large as 60%.

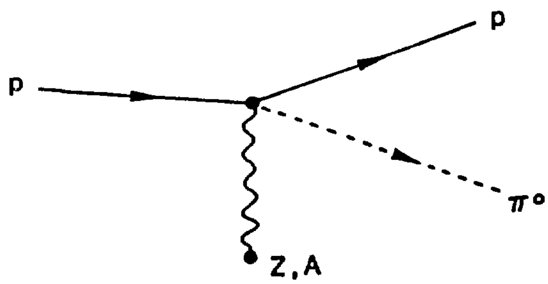

Figure 5 Primakoff Effect

III. 8.9 GeV/c Polarized Antiprotons (Fermilab Accumulator Ring)

According to S. van der Meer's talk on the antiproton accumulator, polarized antiprotons entering an accumulator ring have practically no depolarization effect in the ring.

Then we need to investigate how effectively we can produce polarized antiprotons before the accumulator. Assuming we apply a similar method as described in Section I, 8.9 GeV/c polarized antiprotons are from decays of antilambdas produced by protons above 120 GeV/c on a production target. The decay distance is around 0.7 ± 0.2 m, and this produces a virtual image size of ± 1mm. The acceptance of the accumulator ring is 20 π mm-mrad and then the acceptable beam divergence becomes ± 10 mrad. The emittance of polarized antiproton beam entering the accumulator ring can be as shown in Fig. 6 with respect to the position of production target located at x = 0.

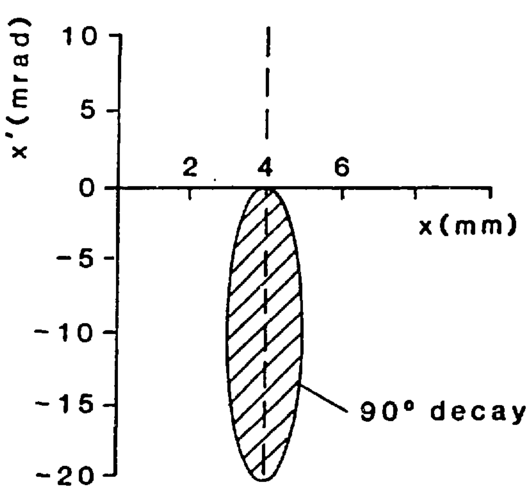

Figure 6 Example of the Emittance of Polarized Beam

We roughly estimate up to 10^6 $\overline{p}^{\uparrow}$/spill with $3 \cdot 10^{12}$/spill incident protons on the production target. The optimization of the intensity as well as detailed design of the beam line should be followed.

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