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Fluxes and Background from $\Sigma^+ \rightarrow$ Polarized Proton at Fermilab *

David C. Carey
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, Illinois 60510

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I. Introduction

The decay of a Σ^+ hyperon produces a proton whose polarization is correlated with its momentum in the hyperon center of mass. The positive charge of the hyperon allows momentum selection both on it and on the proton. A beam of longitudinally polarized protons can be produced, by backward decays in the center of mass. The Λ hyperon being neutral, does not allow momentum selection. Transversely polarized protons, produced by the decay of Λ particles must be identified by tagging hodoscopes at an intermediate focus in the proton beam line.

The use of Σ^+ hyperons to produce polarized protons was first suggested by Rafil Rzaev, a visitor to Fermilab from Serpukhov. He was primarily concerned with the existing 200 GeV polarized beam in the Fermilab meson area.[1] Since then interest has been shown in polarized protons by other experimental collaborations. These experiments are at the ends of beam lines in existing tunnels. These tunnels are curved and are well suited to a Σ^+ produced polarized proton beam which has a net bend. The expected fluxes and backgrounds for the beam are given below.

II. Targetting Scheme for Σ^+

The targetting scheme for Σ^+ is illustrated in figure 1. The magnets shown are set to bend 310 GeV Σ^+ by 12 mr onto the axis of the polarized proton beam. The 800 GeV incident protons are deflected only 4.2 mr toward a beam dump.

The polarized proton beam is tuned to a momentum of 200 GeV/c and is unchanged from its use with Λ hyperons. The protons resulting from the Σ^+ decay have a momentum which ranges from 65 to 96 percent of the Σ^+ momentum. By setting the proton momentum to the lower end of this range, we select only backward decays in the center of mass. No particles of any momentum, directly produced at the target can reach the end of the polarized proton channel.

The masses of the two hyperons are comparable but the Σ^+ decays about three times as rapidly as the Λ. At 310 GeV the decay length of the Σ^+ is 6.3 meters, while that of the Λ is 22 meters. Essentially all protons are produced before the Σ^+ particles reach the first optical element of the beam.

The branching ratio of Λ into protons is higher than that of Σ^+ into protons by a factor which is no larger than are the uncertainties in flux estimates. The correlation of polarization with decay direction for a Σ^+ hyperon is 98 %. For a Λ hyperon it is only 65 %. Selection of a momentum fraction of 65 percent produces backward polarized protons.

The use of the Siberian snake at the end of the beam line allows the transformation of any direction of polarization into any other direction. The two transverse polarization modes can then be alternated by reversing the fields of the snake magnets. Any systematic effects associated with asymmetric beam line acceptances will thereby be reduced.

III. The Resulting Beam

In the Σ^+ produced beam the average polarization was calculated to be 63 percent. The flux is approximately 10 percent of the proton flux for the Λ produced beam. However, in the Λ produced beam the maximum polarization of 50% is achieved for only about 10% of the tagged flux. This means that the maximally polarized flux is close to being equal for the two different beam lines. The Σ^+ production was estimated by combining measured ratios of Σ^+ to π at 400 GeV with scaled π^+ production rates at 200 GeV.[2] The production rates of the Σ^+ and Λ appear to be equal to the accuracy that flux estimates can be made. A variety of background processes produce other particles. The major processes are given in table I. The fluxes given are for $3 \cdot 10^{12}$ 800 GeV protons incident on a half interaction length target.

The flux for Λ producing polarized protons is also given. Since only about 10 percent of this flux is close to 50 percent polarization, the useful polarized proton fluxes from Λ and Σ^+ decay are comparable.

	Momentum Fraction	Rate
$\Sigma^+ \to p$	65 - 96 %	$2.7 \cdot 10^6$
$\Sigma^+ \to \pi^+$	4 - 35 %	$1.2 \cdot 10^5$
p, π^+ direct	100 %	0
$K^+ \to \pi^+$	9 - 92 %	$8 \cdot 10^4$
$\pi^+ \to \mu^+$	57 - 100 %	$4.4 \cdot 10^6$
$K^+ \to \mu^+$	4 - 100 %	0
$\Lambda \to p$		$3.1 \cdot 10^7$

$3 \cdot 10^{12}$ protons incident on 1/2 interaction length target
($1.2 \cdot 10^{12}$ interacting protons)
Table I. Competing Processes

The flux estimates given in this paper were made using the 13.5 kilogauss sweeping magnet presently in the polarized proton facility. However, 35 kilogauss fields have been achieved in the Fermilab charged hyperon facility. By increasing the field of the first bending magnet to 35 kG, we can reduce its length from 9.6 m to 3.7 m at 200 GeV. The flux then increases to $9.6 \cdot 10^6$ under the same conditions as above. Increasing the beam energy now requires increasing the length of this first magnet since the field cannot be increased. At 500 GeV it will again have a length of 9.6 m. Using a 35 kG magnet the flux as a function of energy is:

Energy	Flux
200	$9.6 \cdot 10^6$
250	$1.24 \cdot 10^7$
300	$1.36 \cdot 10^7$
350	$1.30 \cdot 10^7$
400	$1.08 \cdot 10^7$

References

(1) D.G. Underwood, this conference; F.C. Luehring, this conference.

(2) A.E. Brenner et al, Experimental Study of Single-Particle Inclusive Hadron Scattering and Associated Multiplicities, Physical Review D 26, 1497 (1982). T.R. Cardello et al, Charged-Hyperon Production by 400-Gev Protons, Physical Review 32, 1 (1985). J. Lach and L. Pondrom, Hyperon Beam Physics, Annual Review of Nuclear and Particle Science 29, 203 (1979). Pondrom, Lee G., Hyperon Experiments at Fermilab, Physics Reports 122, 58 (1985).

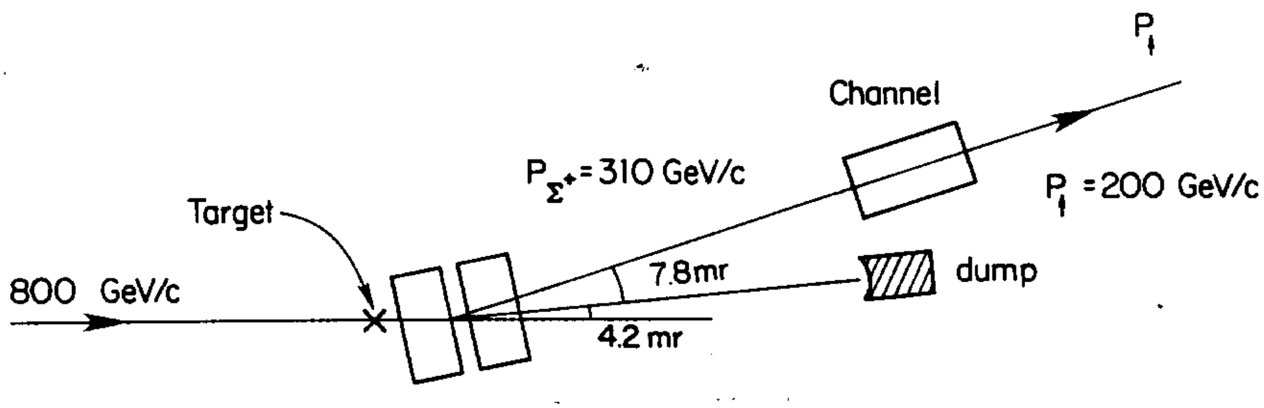

Figure 1. The targetting scheme for Σ^+.