POLARIZATION OF Σ^+ AND $\overline{\Sigma}^-$ HYPERONS PRODUCED BY 800 GeV/c PROTONS (E761 experiment, FNAL)

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The fact that hyperons inclusively produced by high energy protons have significant polarization was first discovered at Fermilab about seventeen years ago. This experiment and subsequent ones showed that Λ^0 were produced polarized while $\overline{\Lambda}^0$ had no polarization

in the same kinematical region. These polarizations have generally been attributed to peripheral mechanisms in which some of the proton valence quarks assimilate a strange quark from the sea to form a polarized hyperon. The $\overline{\Lambda}^0$ does not contain any of the valence quarks of the proton projectile and that might explain the absence of polarization in this case.

The conjecture that the more quarks incorporated from the sea reduces the produced hyperon polarization seemed to be confirmed by measurements of the polarization of $\Sigma^{\pm}$, Ξ^- and Ω^- hyperons. However, recent measurements of Ξ^- and $\overline{\Xi}^+$ polarizations using an 800 GeV/c proton beam indicate that both are polarized with the same sign and similar magnitudes. This differs dramatically from the behavior of the $\Lambda^-/\overline{\Lambda}^0$ system and confounds the interpretation as being attributable to peripheral mechanisms. In this experiment we investigated the $\Sigma^+/\overline{\Sigma}^-$ system in the hope of shedding more light on these polarization mechanisms. These measurements [1] were performed as a part of a Fermilab experiment (E761) which was designed to measure the asymmetry parameter [2, 3] in the decay $\Sigma^+ \to p\gamma$.

Fig.1 shows the relevant parts of the E761 apparatus located in the Proton Center beam line at Fermilab. The configuration and experimental resolutions are the same as in the asymmetry parameter measurement [2, 3] and all of these data were collected during that run. This study used the $\Sigma^+ \to p\pi^0(\overline{\Sigma}^- \to \bar{p}\pi^0)$ decay mode for analysis of the $\Sigma^+(\overline{\Sigma}^-)$ polarization.

The apparatus, shown in Fig.1, included a hyperon spectrometer, a baryon spectrometer and a photon spectrometer. The geometrical acceptance of the apparatus was 85% for both decays occured in a decay region (Fig.1) defined from SSD3 to PWC A. Protons of 800 GeV/c were steered and focused onto the hyperon production target. The charged hyperon beam originated from a 1 interaction length Cu target in the upstream end of a 7.3 m long hyperon magnet which imparted a transverse momentum of about -7.5 GeV/c to the 375 GeV/c hyperon beam. The targeting angle was varied over the range ± 5 mrad in either the horizontal or vertical plane. This allowed for hyperons to be produced, in a controlled manner, with their respective polarization directions either parallel or perpendicular to the vertical magnetic field of the hyperon magnet. The currents in all of the magnets could be reversed, thus allowing selection of positive or negative beam.

The mode [4] responsible for 52% of the Σ^+ decays, $\Sigma^+ \to p\pi^0$, was identified by measuring the vector momentum of the Σ^+ in the hyperon spectrometer and that of the proton in the baryon spectrometer. This decay mode has a large asymmetry parameter [4], $\alpha = -0.980 \pm 0.016$, making it sensitive analyzer of polarization. In the negative beam the identification of the $\overline{\Sigma}^- \to \bar{p}\pi^0$ was accomplished in a similar manner.

Fig.2a shows a mass squared distribution (M_X^2) of the missing neutral particle (X^0) for the hypothesis $\Sigma^+ \to pX^0$ after offline selections of events. The centre and width of the π^0 signal are in agreement with the expected position and resolution. Fig.2b shows the equivalent distribution for the negative beam. The small background from the kaon decays at high M_X^2 and the even smaller background from radiative decays at low M_X^2 do not significantly affect our polarization measurements.

Approximately equal amounts of data were collected at pairs of targeting angles as shown in Table. The targeting angles were of equal magnitude but opposite signs, thus allowing the polarization to be periodically reversed to separate the asymmetry from instrumental biases.

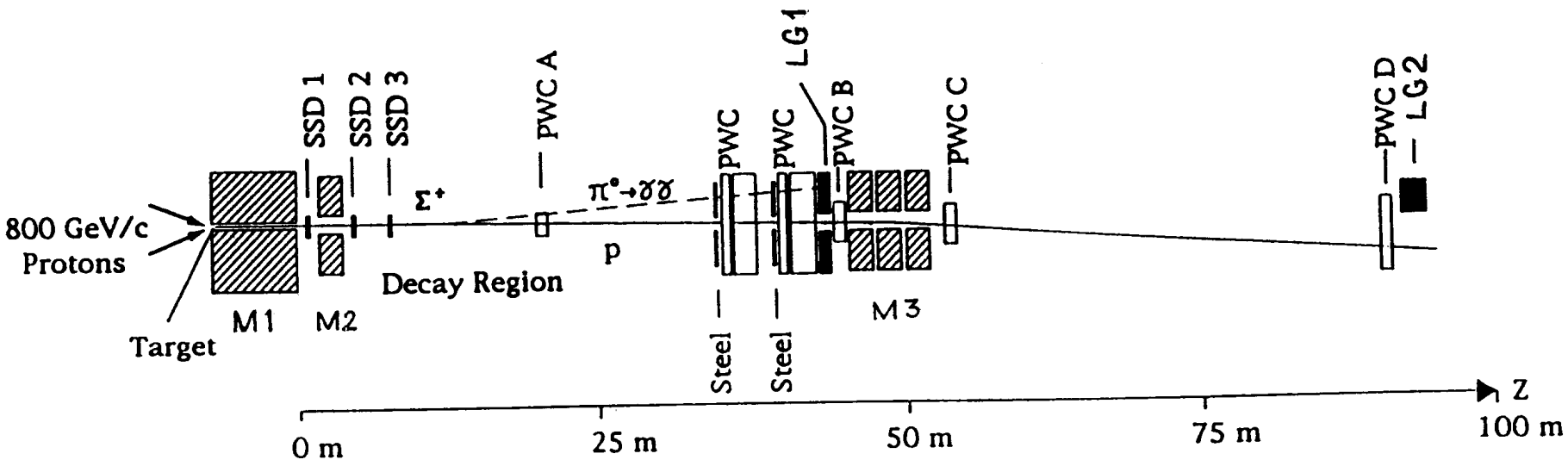

Fig.1. Plan view of the apparatus.
Hyperon magnet — M1
Hyperon spectrometer — dipole magnet M2, silicon strip detectors SSD1, SSD2, SSD3
Baryon spectrometer — dipole magnets M3, multiwire proportional chambers PWC A, PWC B, PWC C,PWC D
Photon spectrometer — lead glass LG1, LG2

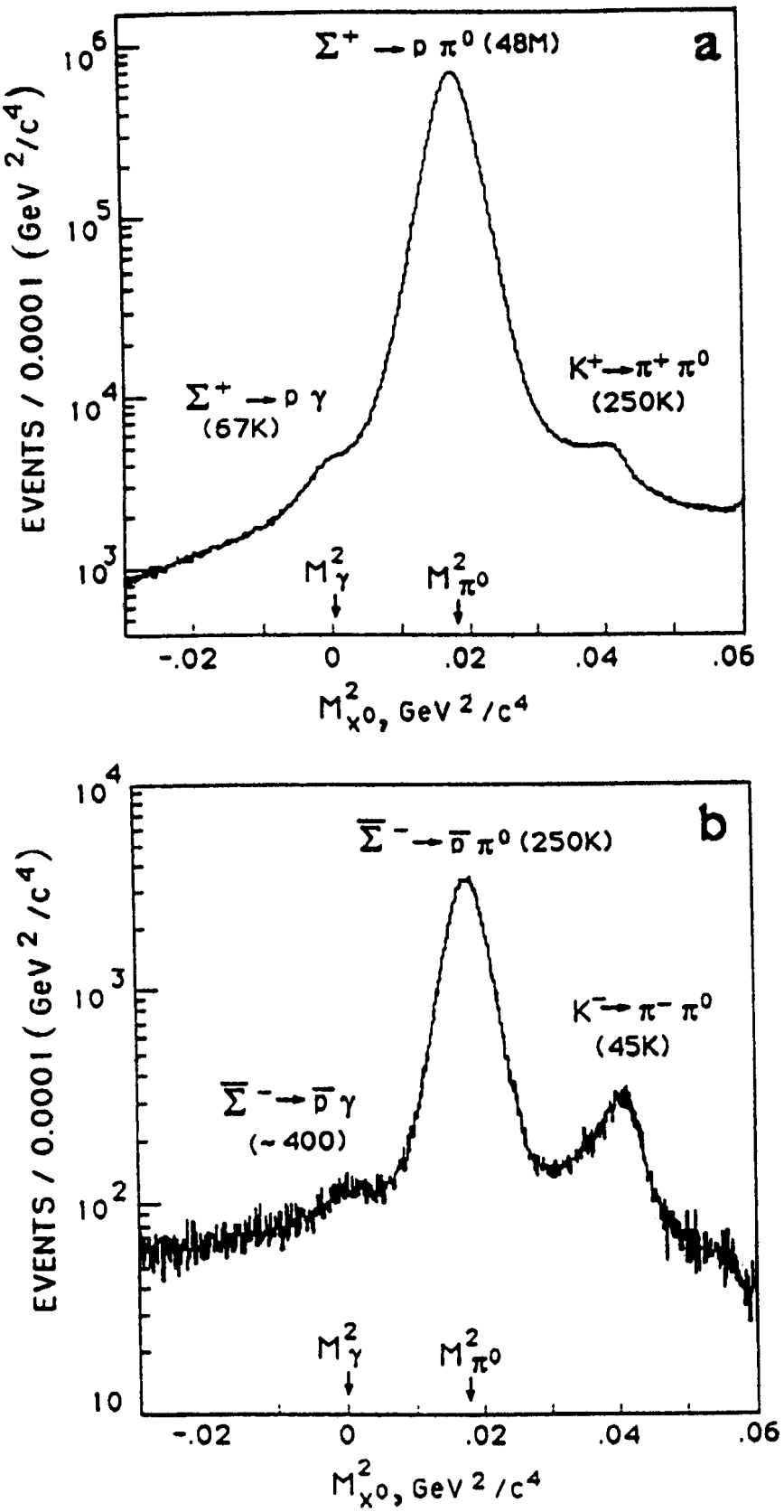

Fig.2. Event distributions of the mass squared of the missing neutral particle X^0 for the hypothesis: a)$\Sigma^+ \to pX^0$; b) $\overline{\Sigma}^- \to \overline{p}\overline{X}^0$

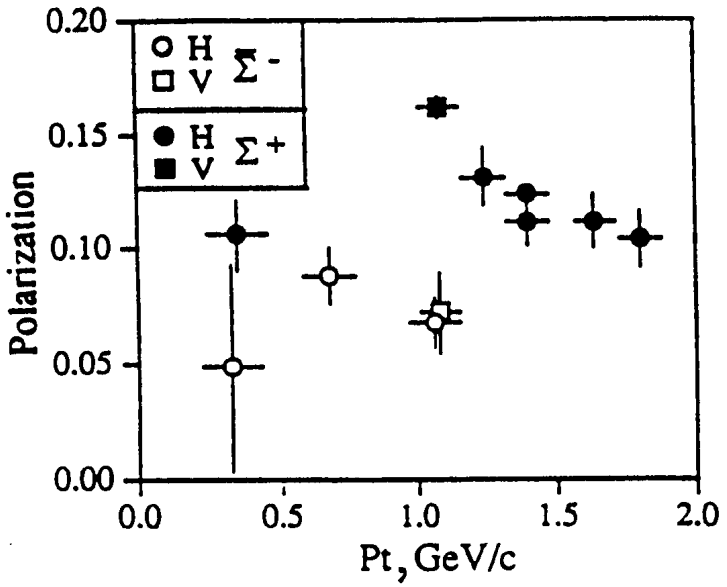

Fig.3. Comparison of polarizations for Σ^+ and $\overline{\Sigma}^-$ as a function of P_t from this experiment. H — data from horizontal targeting, V — data from vertical targeting

Table

Experimental data

Mode	Particle	Angle, mrad	Events	P_t, GeV/c	Polarization
H	$\overline{\Sigma}^-$	±2.8	28957	1.07±0.09	0.068±0.011
H	$\overline{\Sigma}^-$	±1.8	23630	0.68±0.09	0.088±0.011
H	$\overline{\Sigma}^-$	±0.9	1554	0.33±0.10	0.048±0.045
V	$\overline{\Sigma}^-$	±2.9	11806	1.07±0.07	0.072±0.017
H	Σ^+	±4.8	23744	1.80±0.07	0.104±0.011
H	Σ^+	±4.3	23173	1.64±0.07	0.112±0.012
H	Σ^+	±3.7	43225	1.40±0.07	0.112±0.010
H	Σ^+	±3.7	12573218	1.40±0.07	0.124±0.001
H	Σ^+	±3.3	20351	1.24±0.08	0.131±0.012
H	Σ^+	±0.9	14134	0.35±0.10	0.106±0.015
V	Σ^+	±2.9	249863	1.08±0.07	0.163±0.004

In Table we included Σ^+ and $\overline{\Sigma}^-$ data from both horizontal (H) and vertical (V) targeting. The measurement of the asymmetry parameter [2] in the decay $\Sigma^+ \to p\gamma$ included a large data sample of $\Sigma^+ \to p\pi^0$ decays which were also used for a measurement of polarization at ±3.7 mrad. In Table the quoted uncertainty in the polarization is statistical. The systematic uncertainties, which we estimated as 0.0032, were combined in quadrature with the statistical uncertainty and are included in Fig.3.

From Table, it is clear that both the Σ^+ and $\overline{\Sigma}^-$ are produced polarized. At similar values of P_t the polarizations have the same sign but different magnitudes. These polarizations are plotted in Fig.3 as functions of P_t. This observation is similar to the recent Fermilab results which showed that both Ξ^- and $\overline{\Xi}^+$ are polarized with about the same magnitude. This

would indicate that the polarization of antihyperons is a common phenomenon, and we should now turn our attention to why the $\overline{\Lambda}^0$ are not produced polarized.

One can see the Σ^+ polarization increasing with P_t, reaching a maximum at P_t = 1 GeV/c, and then decreasing. This is the first clear experimental indication that high energy hyperon polarization decreases at large P_t. The $\overline{\Sigma^-}$ polarization data are consistent with a similar behavior.

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