Hyperon Polarization: WA89 (Preliminary)

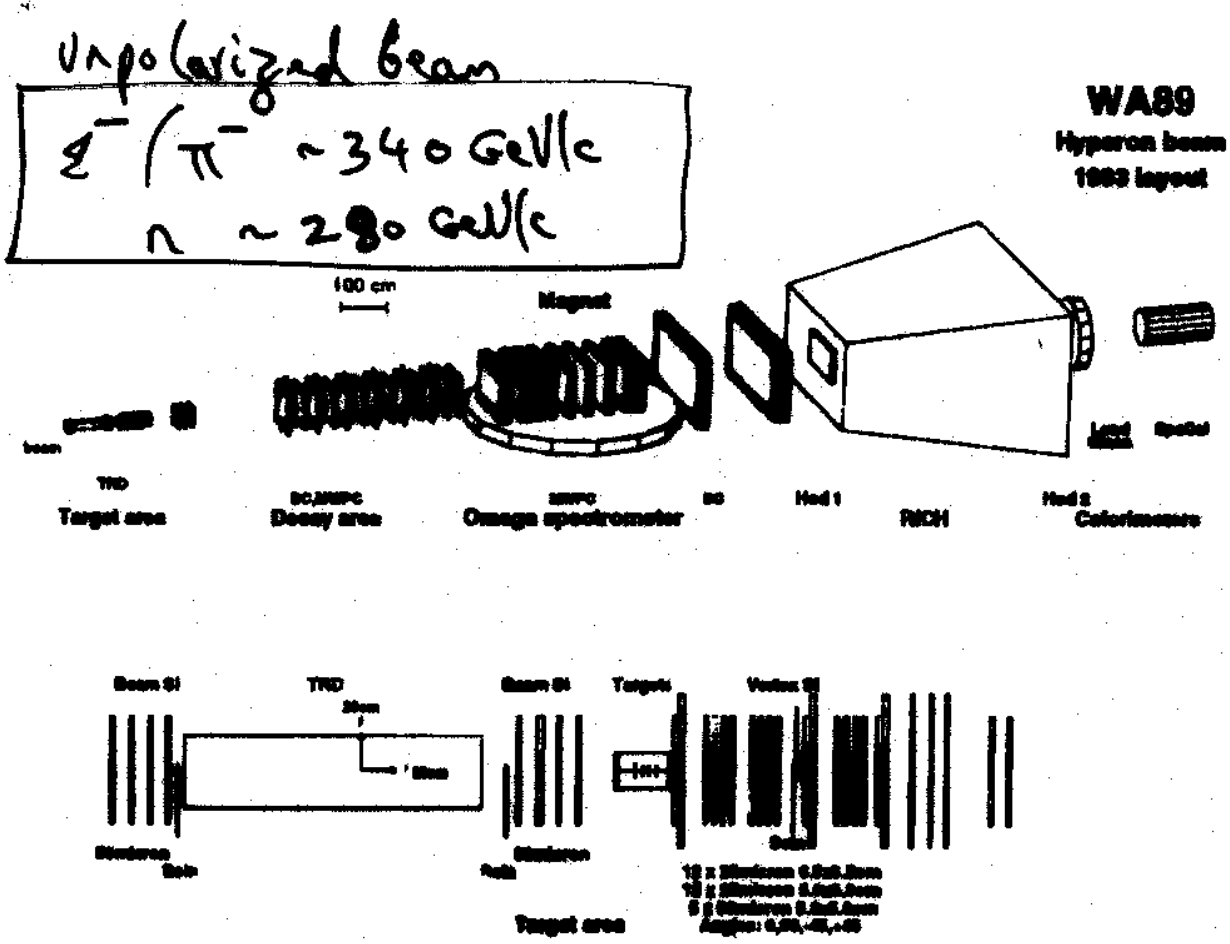


Fig. 1. Setup of the WA89 experiment in the 1995 run. The lower part shows an expanded view of the target area.

V J Smith, University of Bristol

Hyperon99 Symposium, Fermilab, Sept 28, 1999

$\Sigma^- N \to \Lambda X$

WA89 (1991) Polarization measurement

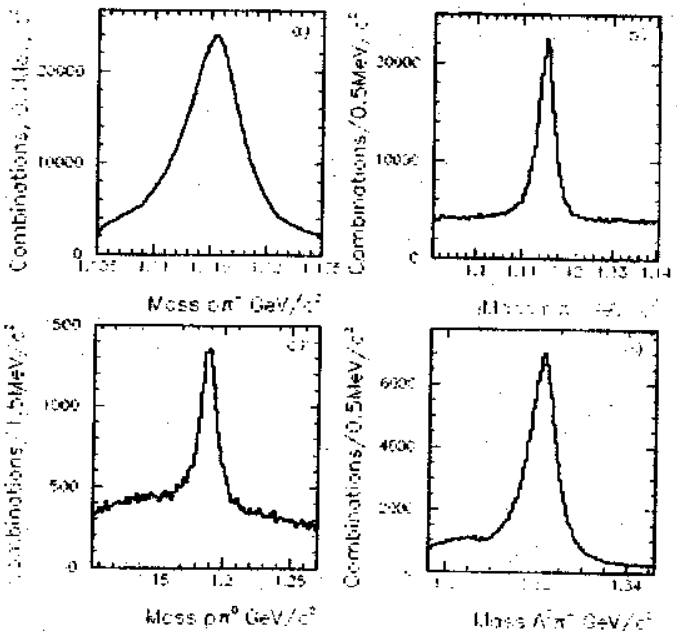


Figure 2: Invariant mass spectra of studied hyperons: a) Λ^0 , b) $\overline{\Lambda}^0$, c) Σ^+ (presented for a pa of the data sample used) and d) Ξ^-.

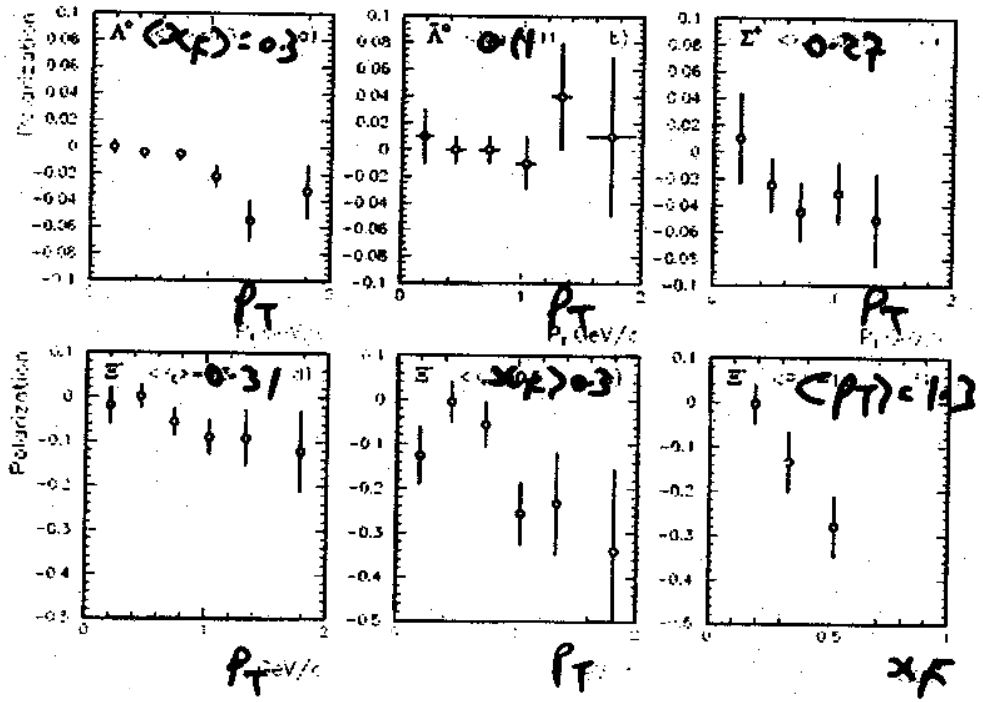


Figure 3: p_T dependence of the polarization of a) Λ^0 , b) $\overline{\Lambda}^0$, c) Σ^+ and d) Ξ^- measured for the full observed ranges of x_F (corresponding to mean values of x_F of 0.30 , 0.11 , 0.27 and 0.31, resp.). e) polarization of Ξ^- for $x_F > 0.3$, which corresponds to a mean value of x_F of 0.5. f) x_F dependence of the polarization of Ξ^- for $p_T > 0.9$ which corresponds to a mean value of p_T of 1.3. The errors indicated are statistical only.

Z.Phys.C A350,379 (1995)

WA89 - Preliminary

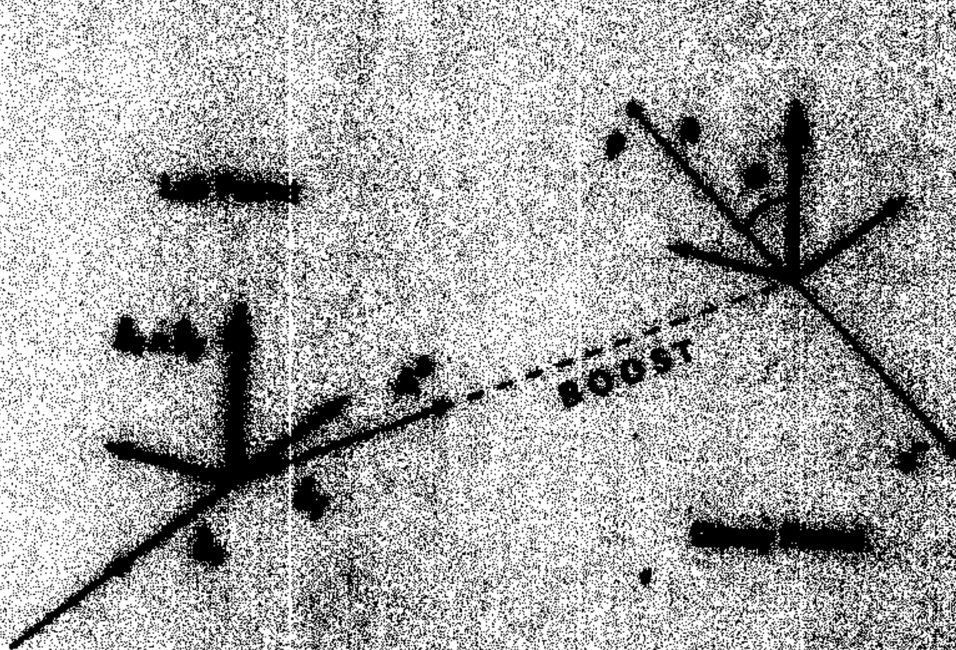
Inclusive Hyperon Polarisation Studies at the CERN SPS Hyperon Beam

David Michael Newbold

Abstract

Using data collected with the WA89 apparatus at the CERN SPS hyperon beam, the transverse polarisations of Λ^0, $\bar{\Lambda}^0$, Σ^+, Σ^0, Ξ^- and $\bar{\Omega}^+$ hyperons inclusively produced from an unpolarised -340GeV/c Σ^- hyperon beam were measured as a function of x_F and p_t. The polarisation of Λ^0 and $\bar{\Lambda}^0$ produced from a π^- beam of the same energy, and of Λ^0 and Σ^+ produced from an unpolarised neutron beam of 240GeV/c momentum, were also determined. The Λ^0 produced from the Σ^- beam were found to have a positive polarisation of around 10%. Σ^0 and Ξ^- produced from the Σ^- beam, and Λ^0 produced from neutrons, were found to have negative polarisation. All other measured polarisations were consistent with zero, except that of the $\bar{\Omega}^+$, which varied in sign with x_F.

A thesis submitted to the University of Bristol in accordance with the requirements of the degree of Doctor of Philosophy in the Faculty of Science, July 1998.



$N \propto (1 + \alpha P \cos\theta)$

[illegible] Ξ^- polarization ([illegible] Λ)

$P_\Lambda = -\frac{[illegible]}{[illegible]}\left(1 - [illegible]\right)$

For Ω^- polarization – 4 spin states
(density matrix [illegible])

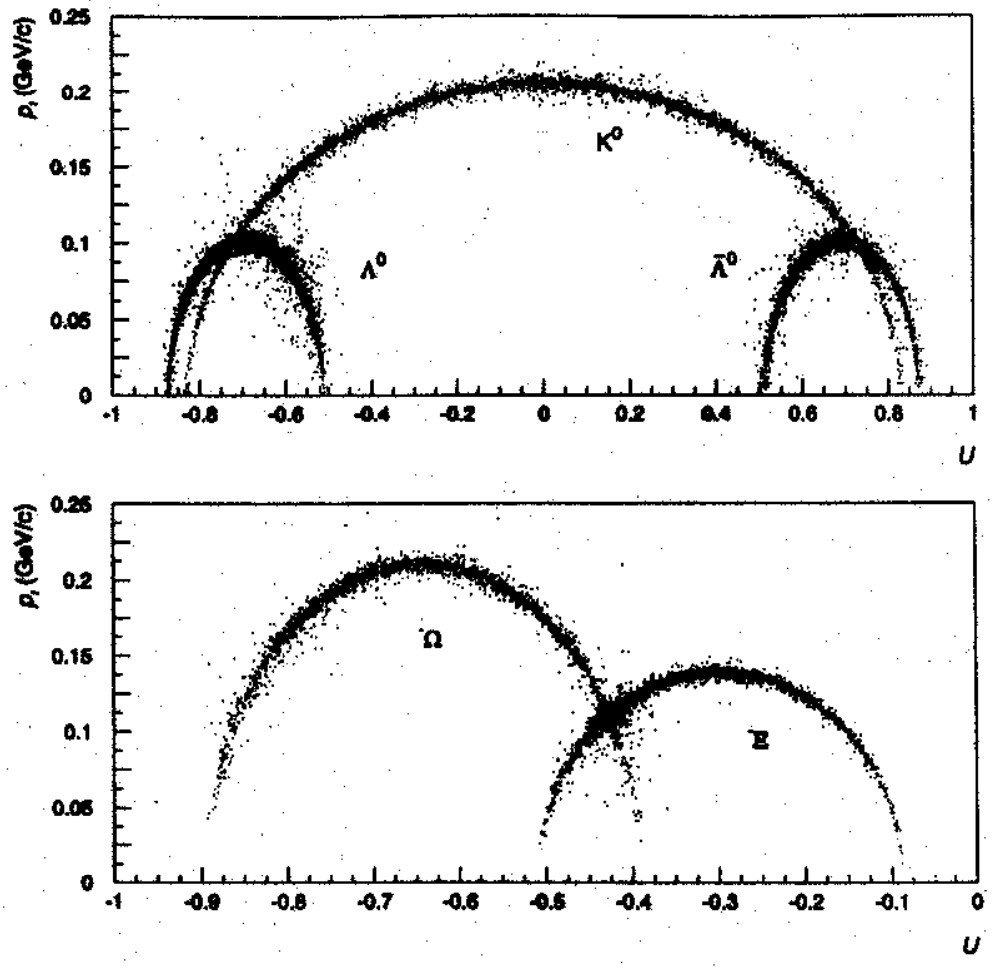
Vector polarization → transferred to daughter (spin ½)

$\vec{P}_\Lambda = \frac{1}{2(J+1)}\left[1 + (2J+1)\gamma_\Omega\right]\vec{P}_\Omega$

$\alpha_\Omega \approx 0 \Rightarrow \gamma_\Omega \approx 1$

	1993 dataset		1994 dataset		
	Σ^- beam	π^- beam	Σ^- beam	π^- beam	n beam
$\Lambda^0 \to p\pi^-$	1.86M	13.3k	1.82M	13.5k	86.4k
$\bar{\Lambda}^0 \to \bar{p}\pi^+$	19.4k	3.2k	33.9k	5.0k	–
$\Sigma^0 \to \Lambda^0\gamma$	83.5k	–	82.4k	–	–
$\Sigma^+ \to n\pi^+$	19.5k	–	98.2k	–	17.4k
$\Sigma^+ \to p\pi^-$	–	–	15.4k	–	–
$\Xi^- \to \Lambda^0\pi^-$	19.7k	–	36.4k	–	–
$\Omega^- \to \Lambda^0 K^-$	0.9k	–	1.9k	–	–
$K^0 \to \pi^+\pi^-$	0.59M	25.6k	0.56M	35.2k	34.8k

Table 6.1: Hyperon decay channels used in the polarisation studies. The entries indicate the number of events remaining after all selection cuts.



Bias-Cancelling vs Simulation.

Bias-Cancelling uses symmetry of apparatus
(eg about horizontal plane) (UPPER = LOWER)

WA89 acceptance symmetry was insufficient

Bias-cancelling works for $\cos\theta$ distributions of daughter baryon;
but not for spin-transfer (γ) + asymmetry of decay of daughter.

Bias-cancelling OK for acceptance effects;
but not for finite precision effects
(eg $\sigma(\cos\theta) \sim 0.2$ for n events
→ systematically reduces slope.)

$\Sigma^0 \to \Lambda\gamma$ not bias-cancelled
(iterative method used)

Of course, uncorrected bias, if small, will still be cancelled to first order...

WA89 Preliminary

K°

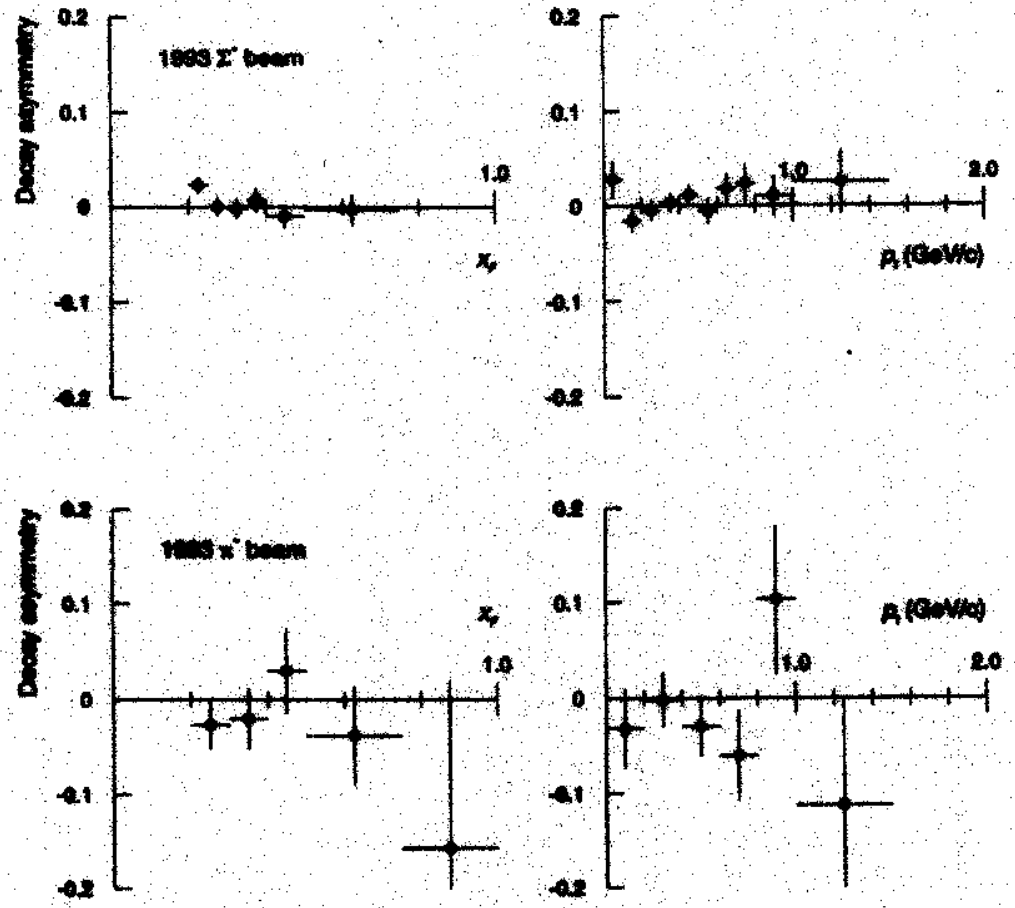


Figure 7.6: Decay asymmetry measurements for K^0 mesons produced from the 1993 Σ^- and π^- beams. Error bars indicate statistical uncertainties only.

indication of the correct performance of the polarisation measurement method. The maximum systematic bias intrinsic to the measurement method was estimated to be less than 2% in absolute polarisation; this number was used as the 'baseline' systematic error estimate for all other polarisation measurements, effectively indicating the degree of belief in the accuracy of the estimation technique.

7.4.2. Λ^0 polarisation

Figures 7.6 and 7.7 show the measured polarisation for Λ^0 produced from the 1994 Σ^-, π^- and neutron beams, and the 1993 Σ^- and π^- beams; the 1993 results have been corrected for beam cross-contamination. Note that the Σ^- results plotted here are corrected for the Σ^0 background (see Section 7.4.4). The vertical error bars indicate the statistical and systematic uncertainties on the measurements; the length of each bar between the horizontal cross-

WA89 Preliminary K^0

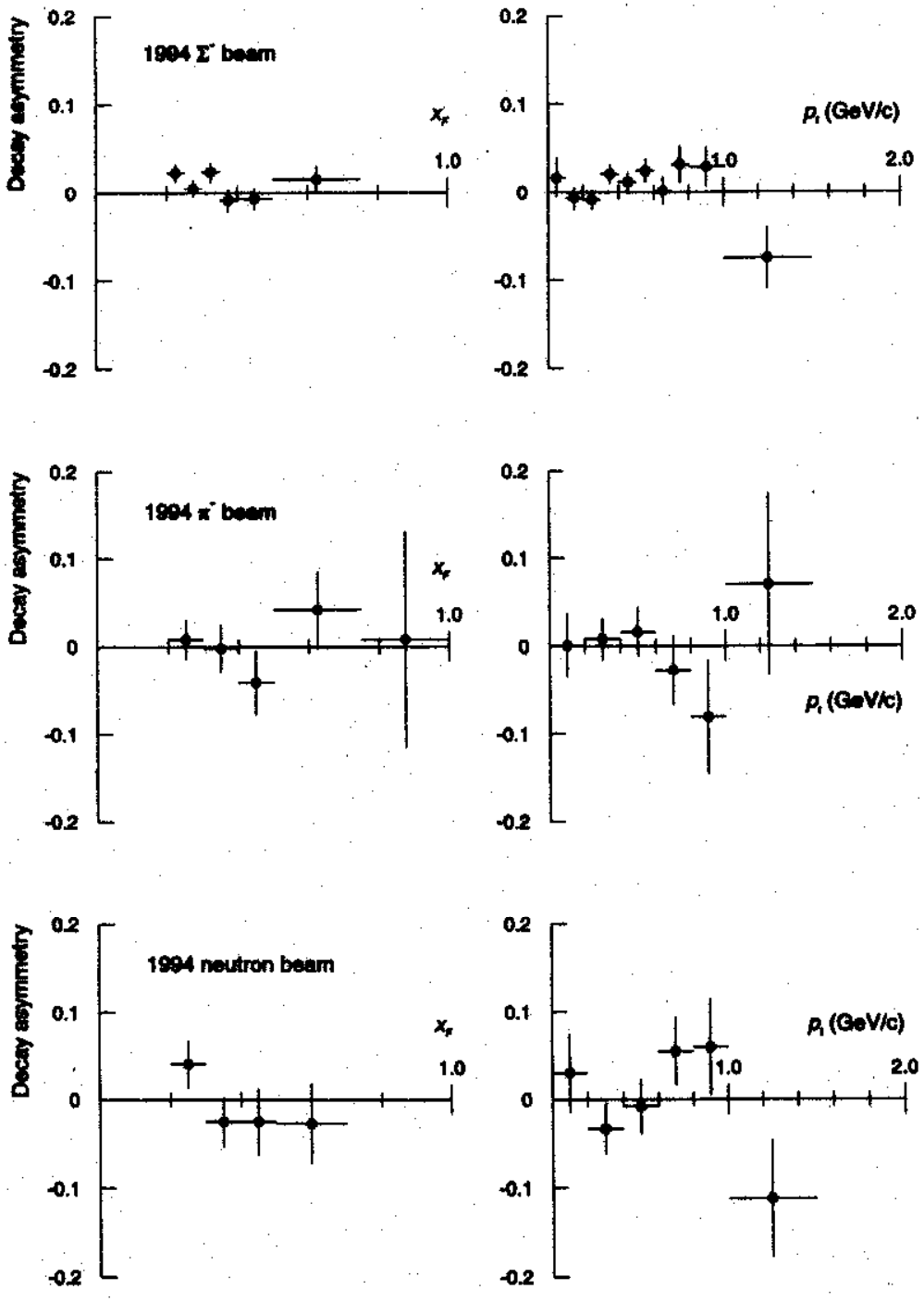


Figure 7.4: Decay asymmetry measurements for K^0 mesons produced from the 1994 Σ^-, π^- and neutron beams. Error bars indicate statistical uncertainties only.

WA89 (1994) Preliminary

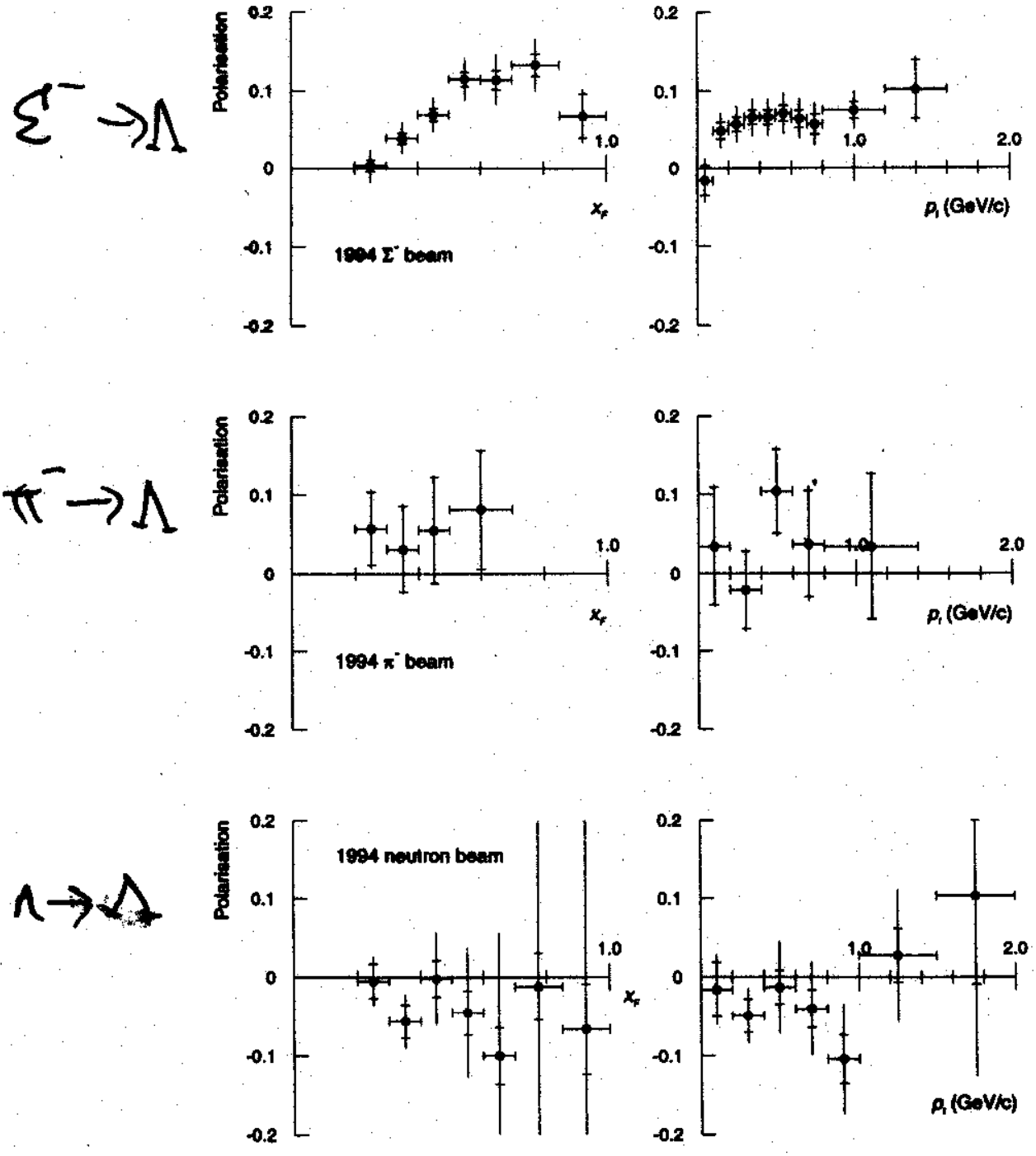


Figure 7.6: Polarisation measurements for Λ^0 produced from the 1994 Σ^-, π^- and neutron beams. The error bars within the cross-strokes indicate the statistical uncertainty, the whole length of the bars the combined statistical and systematic uncertainties. The Σ^- beam results are corrected for Σ^0 background.

WA89 (1993) Preliminary

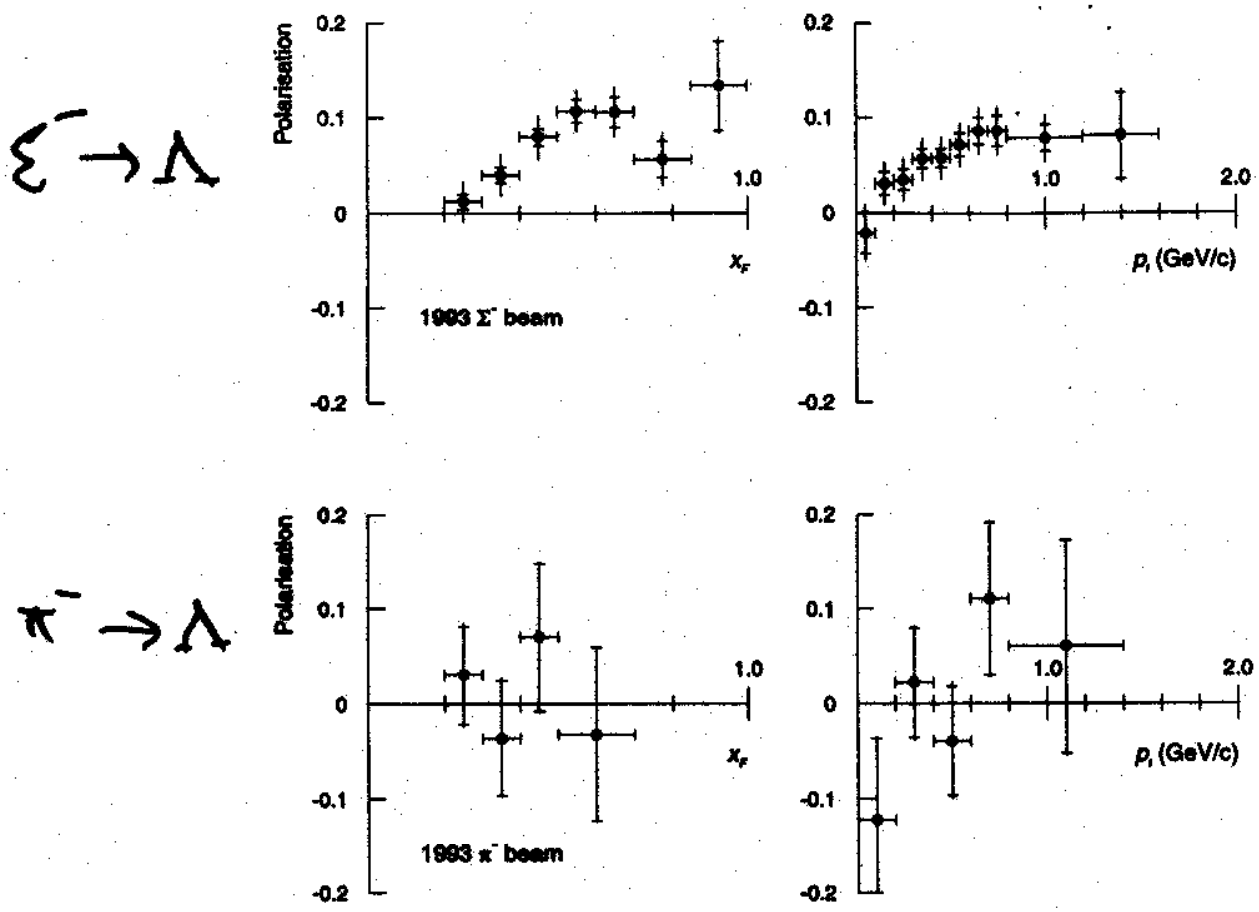


Figure 7.7: Polarisation measurements for Λ^0 produced from the 1993 Σ^- and π^- beams. The error bars within the cross-strokes indicate the statistical uncertainty, the whole length of the bars the combined statistical and systematic uncertainties. The Σ^- beam results are corrected for Σ^0 background.

The 1994 neutron beam data showed evidence of a negative Λ^0 polarisation. Th nificance of the results at large values of p_t was small, due to the overwhelming syste uncertainties associated with the background Λ^0 in the neutron beam. The number of ground Λ^0 was calculated from the measured Ξ^- contamination in the Σ^- beam, of a 1.5%; the Σ^- and Ξ^- have similar lab-frame lifetimes at high energies, and similar deca ematics. The Λ^0 production cross-sections from neutrons and Λ^0 at high energy are no known. The ratio of cross sections was therefore estimated from the measurements of production cross-sections from Σ^- and Ξ^- at similar energies [29, 30] (see Figure 2.5) the production of Ξ^- from Σ^- and the production of Λ^0 from neutrons involve the re ment of a *d* quark in the projectile by an *s* quark in the final-state particle, though th couplings between the initial and final states are not identical. For the highest bin in

WA89 $\Sigma^- \to \Lambda$ Preliminary

1993

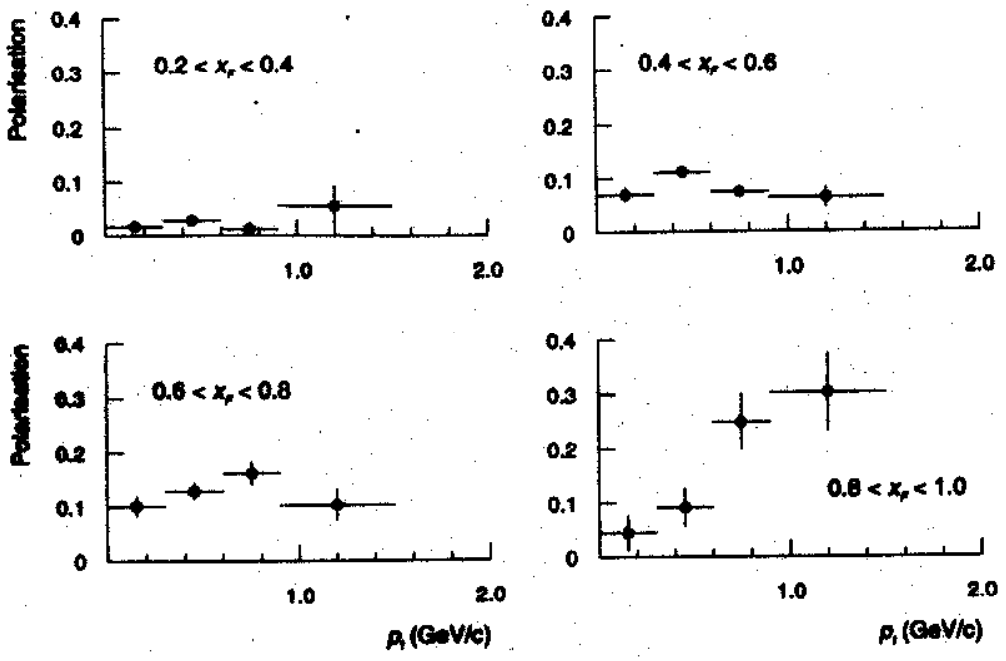


Figure 7.8: Detailed kinematic dependence of the polarisation of Λ^0 produced from the 1994 Σ^- beam. Only statistical errors are shown.

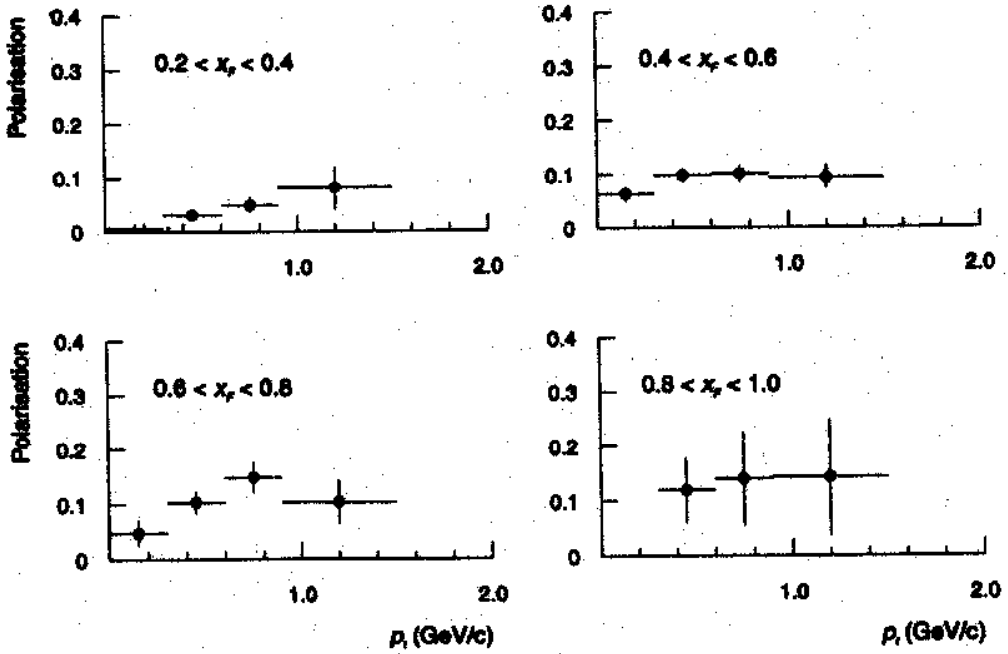


Figure 7.9: Detailed kinematic dependence of the polarisation of Λ^0 produced from the 1993 Σ^- beam. Only statistical errors are shown.

WA89 Preliminary

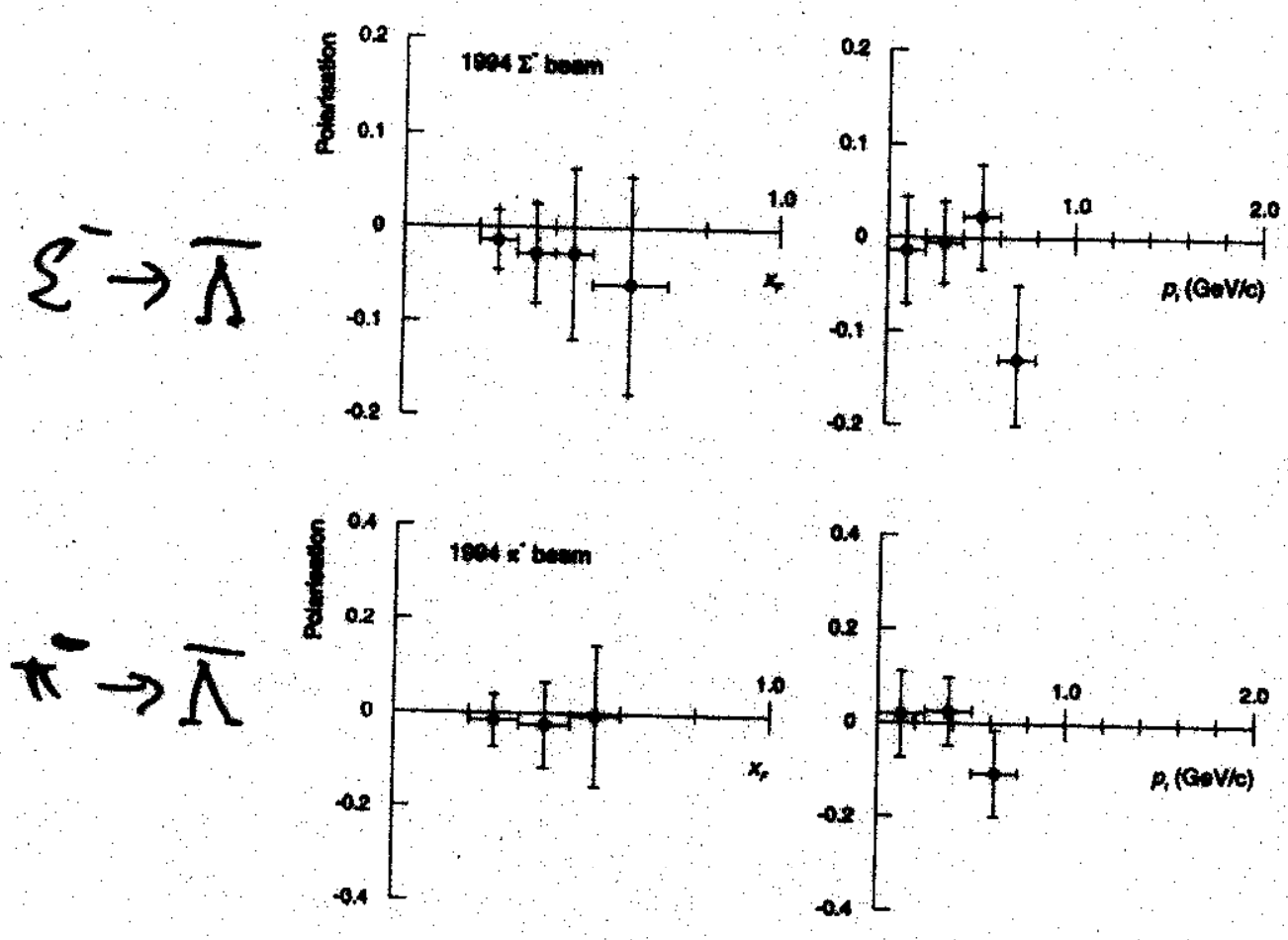


Figure 7.10: Polarisation measurements for $\bar{\Lambda}^0$ produced from the 1994 Σ^- and π^- beams.

number of Λ^0 produced from beam Λ^0 was estimated to exceed those produced from n trons by a factor of three or more; a measurement of polarisation was effectively impossib The systematic error on each p_t bin was calculated from the average x_F of its constitue events. A maximum negative polarisation of around 10% was observed at $p_t \approx 1.0$GeV/c

7.4.3. $\bar{\Lambda}^0$ polarisation

The results for $\bar{\Lambda}^0$ polarisation for the 1993 and 1994 Σ^- and π^- beams are shown in Figu 7.10 and 7.11. In all cases, the errors were dominated by the statistical uncertainty due to t low $\bar{\Lambda}^0$ production cross-section; the main contribution to the relatively small systema uncertainty was from coherent background due to K^0 decays. The results rule out any $\bar{\Lambda}$ polarisation of greater than a few percent, from either Σ^- or π^- beams.

WA89 Preliminary

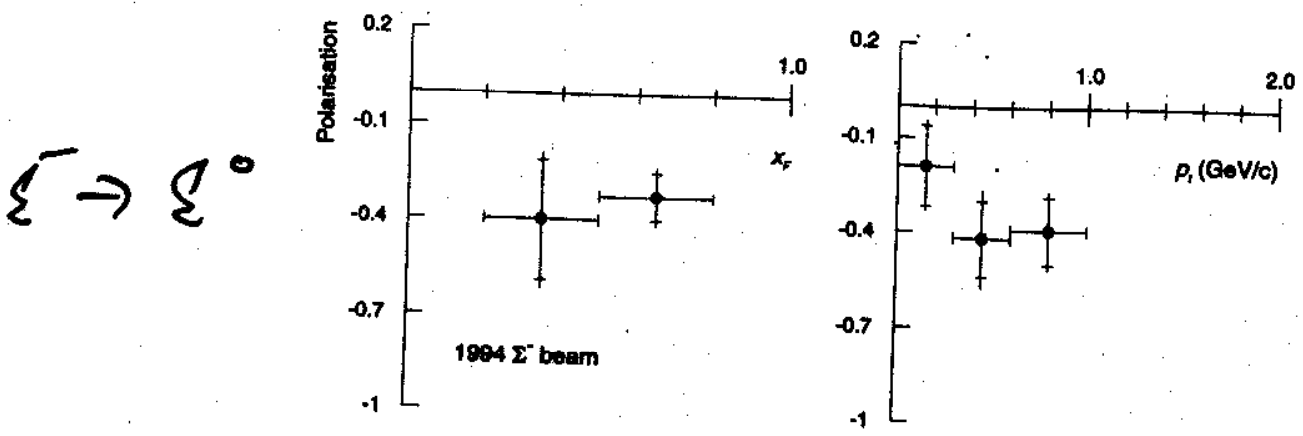


Figure 7.12: Polarisation measurements for Σ^0 produced from the 1994 Σ^- beam.

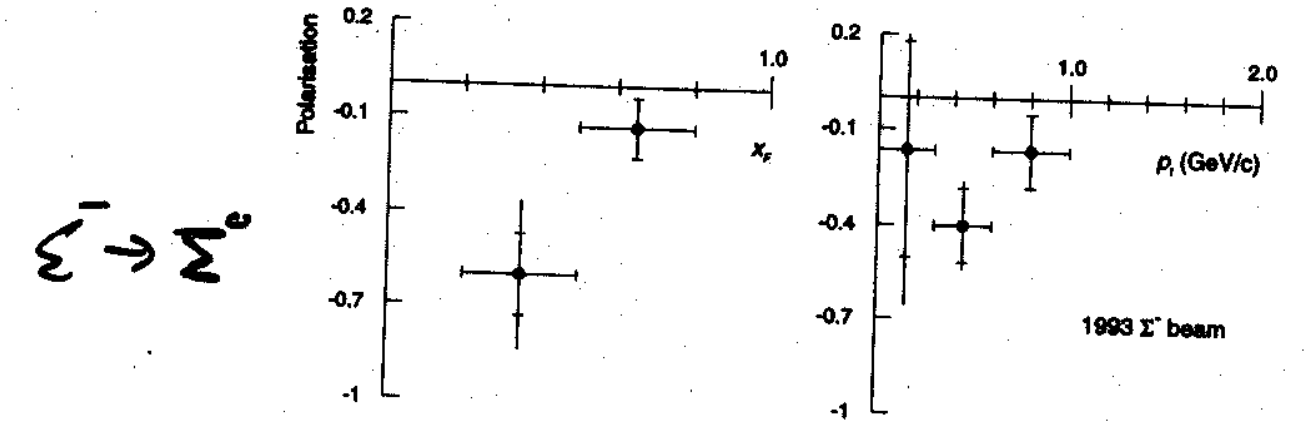


Figure 7.13: Polarisation measurements for Σ^0 produced from the 1993 Σ^- beam.

during the reconstruction was thus estimated to be $0.13 \pm 0.01(\text{stat.}) \pm 0.03(\text{syst.})$, averag over the whole kinematic range. Note that this number does not directly correspond to t ratio of production cross-sections for the two hyperons, as it takes into account only the c tamination of Λ^0 passing the selection cuts; since the x_F spectrum of decay product Λ^0 somewhat softer than that of the mother Σ^0, a large part of the daughter population was jected by the momentum cuts, and the ratio of cross-sections is expected to be somewh higher than the above figure. For the purposes of background subtraction, the average construction efficiencies and Σ^0 polarisation were calculated for each kinematic bin in t Λ^0 polarisation plots shown in Figures 7.6 and 7.7; since the number of data points for t Σ^0 polarisation were small, the measurements were interpolated by fitting a second- or thir order polynomial function to the plots in Figures 7.12 and 7.13, constrained to pass throu

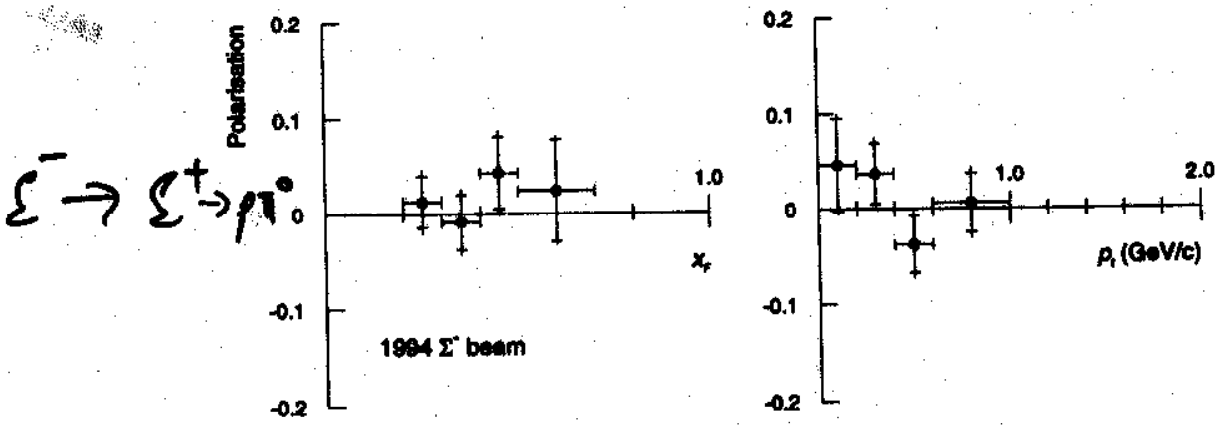
the point ($x_F = 0, p_t = 0$). The background subtraction was then performed assuming Equation A.33 to correctly describe the relationship between the Λ^0 and Σ^0 polarisations; the correlations between the systematic errors for the two sets of polarisation measurements were taken into account. Background subtraction was performed separately for the 1993 and 1994 datasets. The corrections to the Λ^0 polarisation measurements were generally found to be small compared to their errors.

7.4.5. Σ^+ polarisation

The polarisation of Σ^+ produced from the 1994 Σ^- beam, as measured through the proton decay channel, is plotted in Figure 7.14; the polarisation was consistent with zero except in one p_t bin. The errors on the measurements were dominated by statistical uncertainty, due to the low reconstruction efficiency for the $\Sigma^+ \rightarrow p\pi^0$ decay.

The results obtained using the neutron decay of the Σ^+ are shown in Figures 7.15 and 7.16. The results from both the 1993 and 1994 Σ^- beam data were consistent with those observed in the proton decay channel; the three sets of measurements were highly statistically compatible, and tend towards a small negative polarisation around $p_t \approx 0.5$GeV/c and large x_F; no definite statement could reasonably be made, however, except to say that the overall magnitude of the polarisation did not exceed a few percent. Results from the 1994 neutron beam are also shown in Figure 7.15; the polarisation was consistent with zero over the whole kinematic range.

WA89 Preliminary



$\Sigma^- \rightarrow \Sigma^+ \rightarrow p\pi^0$

Figure 7.14: Polarisation measurements for the proton decay channel of Σ^+ produced from the 1994 Σ^- beam.

WA89 Preliminary

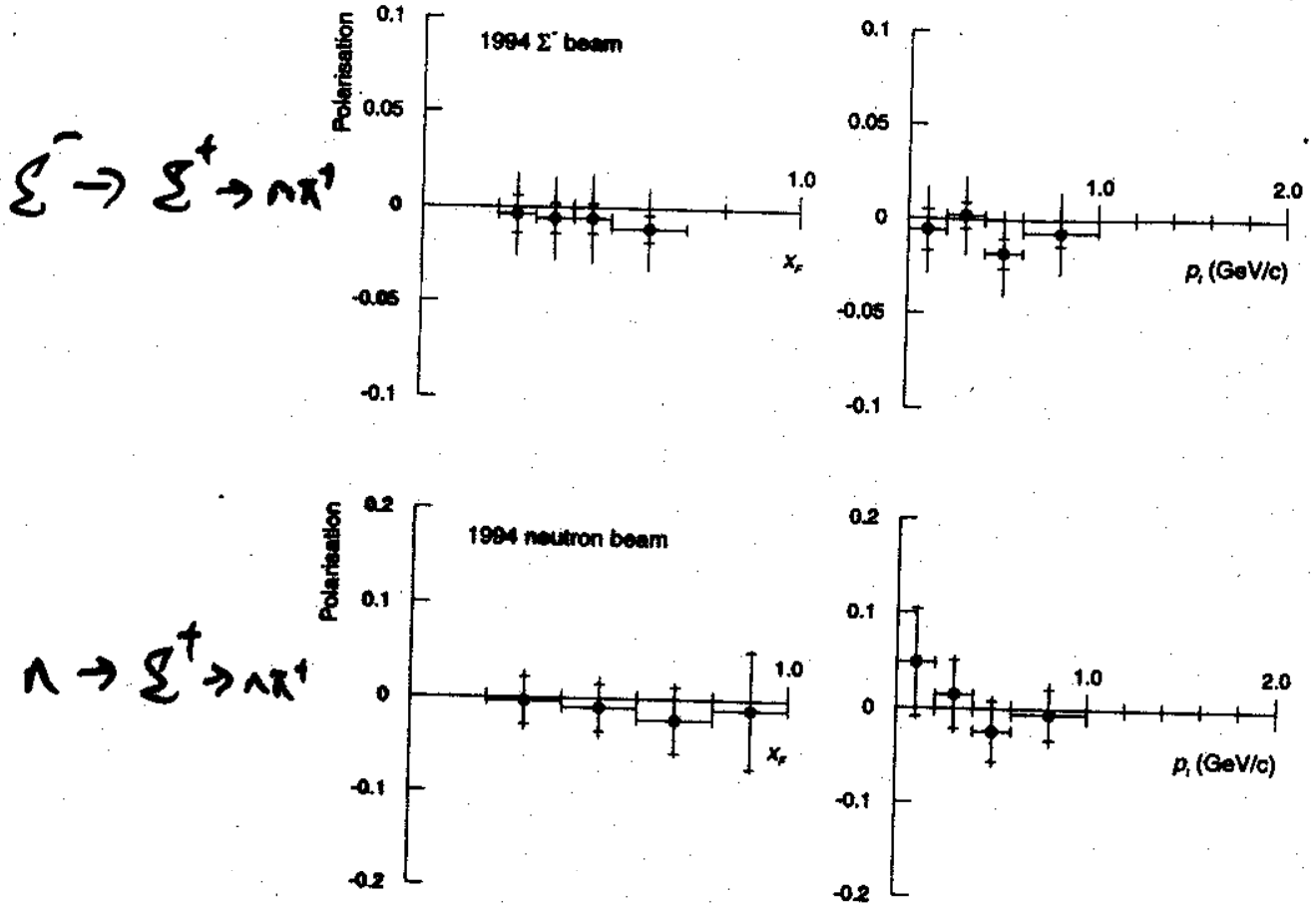


Figure 7.15: Polarisation measurements for the neutron decay channel of Σ^+ produced from the 1994 Σ^- and neutron beams.

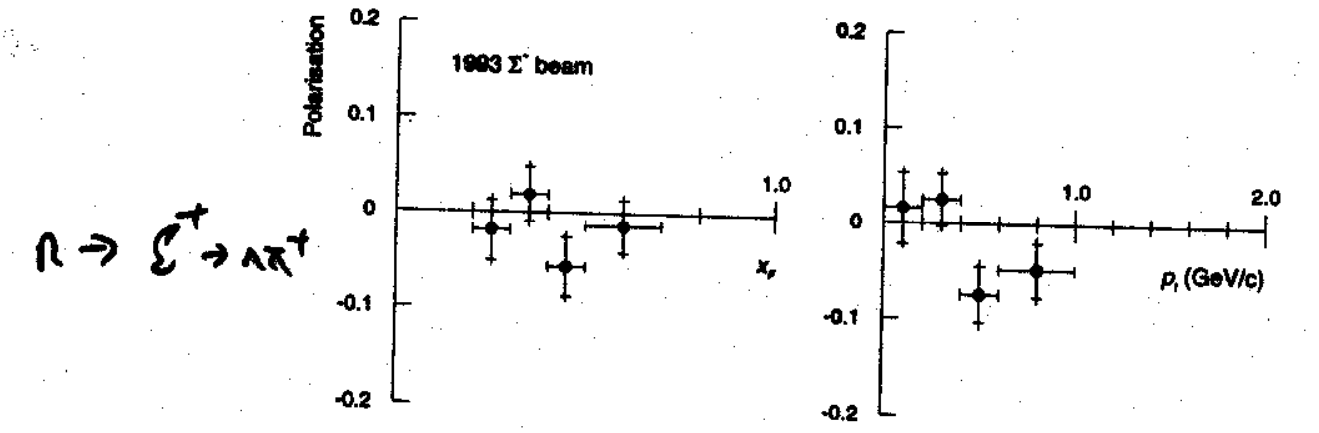


Figure 7.16: Polarisation measurements for the neutron decay channel of Σ^+ produced from the 1993 Σ^- beam.

WA89 $\Sigma^- \to \Xi^-$ polarization
Preliminary

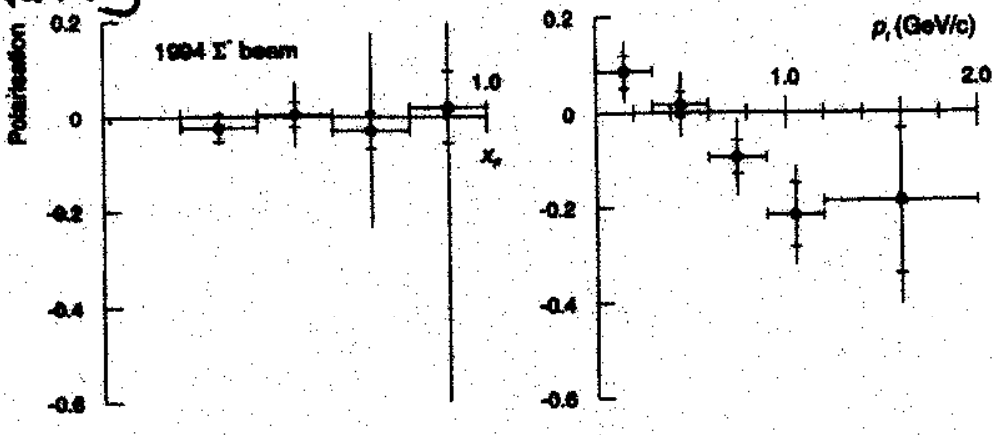


Figure 7.20: Polarisation measurements for Ξ^- produced from the 1994 Σ^- beam, obtained through measurement of the daughter Λ^0 polarisation.

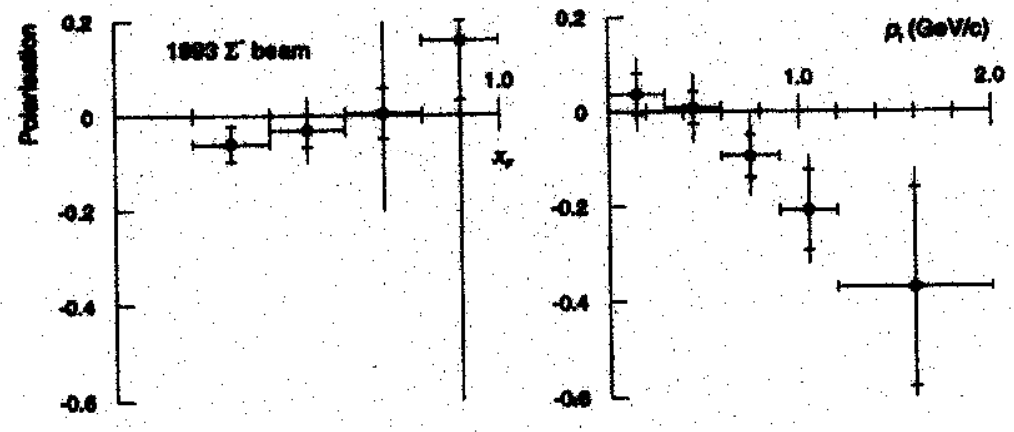


Figure 7.21: Polarisation measurements for Ξ^- produced from the 1993 Σ^- beam, obtained through measurement of the daughter Λ^0 polarisation.

extremely limited statistics of the Ω^- sample dominated the uncertainties of measurements. The systematic error was mainly due to the error on the Ω^- decay parameters; no attempt was made to estimate the systematic effects due to Ω^- production from background Ξ^- in the Σ^- beam, though these may have been significant.

WA89

$\bar{\Xi} \to \bar{\Omega}$

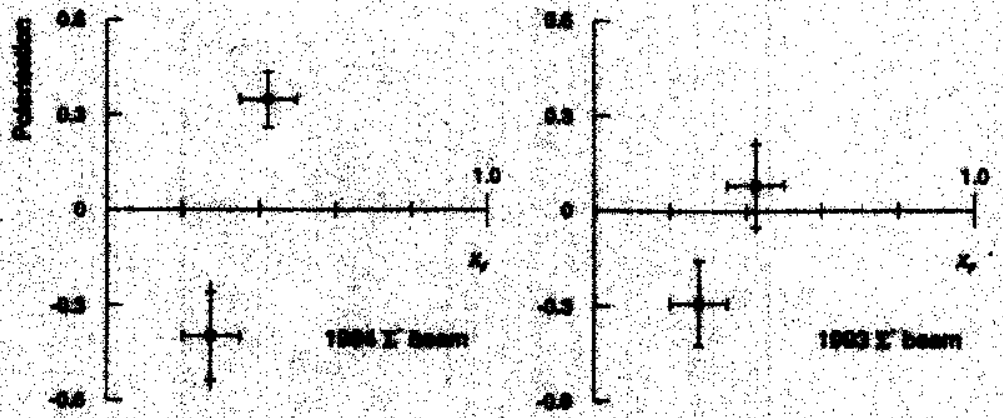
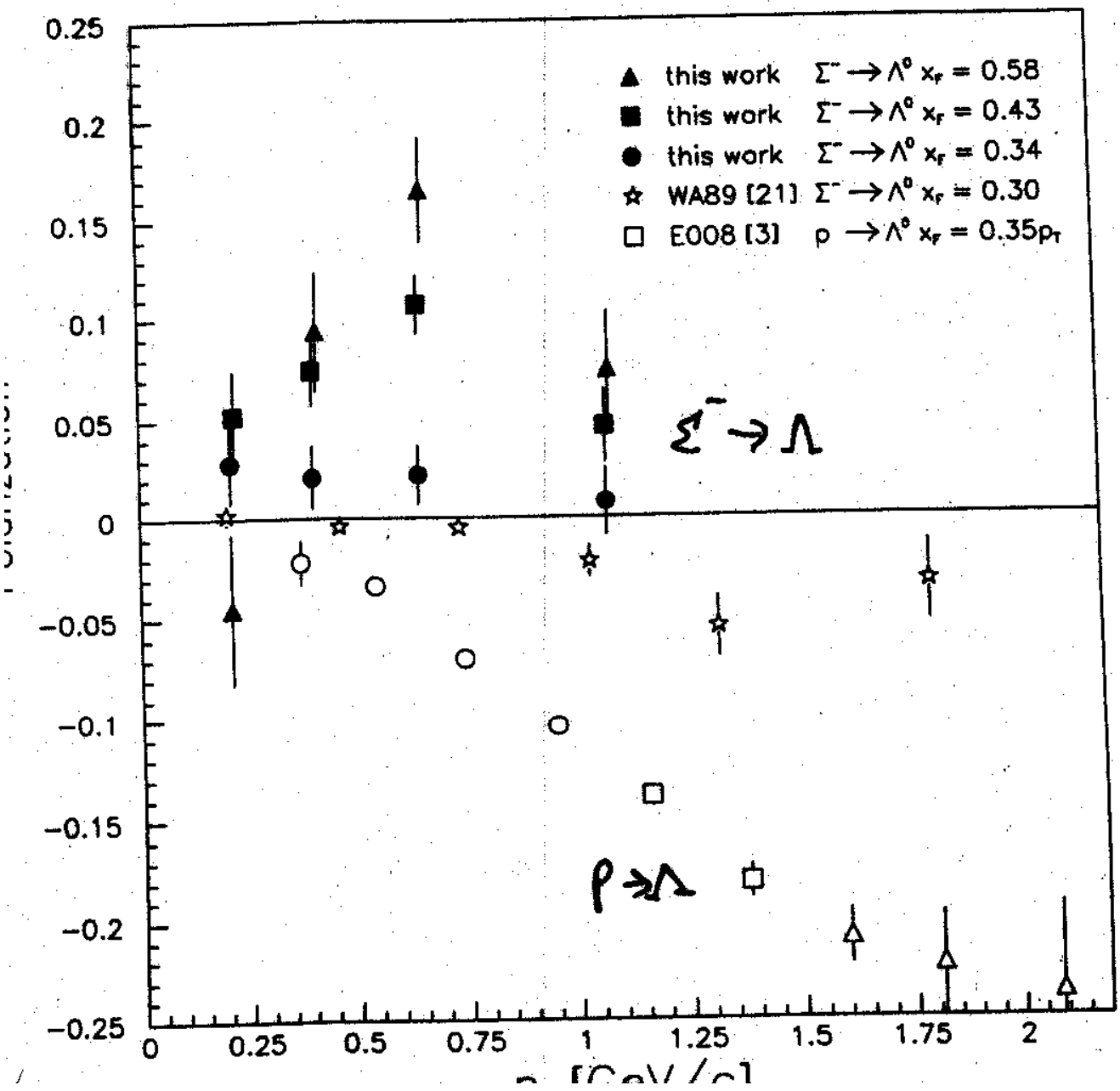


Figure 3.20: Polarization measurements for Ω^- produced from the 1994 and 1993 Σ^- beams, obtained through measurement of the daughter Λ^0 polarization.

E McCLIMENT – SELEX (E781)

$\Sigma^- (600\,GeV/c) + A \rightarrow \Lambda + X$



E McCLIMENT - SECEX (E781)

$\Sigma^- (600\,GeV/c) + A \rightarrow \Lambda + X$