UNIVERSITÉ PARIS-SUD

Institut de Physique Nucléaire

MEASUREMENT OF THE POLARIZATION PARAMETER IN $\pi^- p$ BACKWARD ELASTIC SCATTERING AT 6 GeV/c

CERN - IPN (ORSAY) - OXFORD UNIVERSITY
Collaboration

February 1973
IPN-HE 73 02

DIVISION
DES
HAUTES ENERGIES

91406-Orsay

MEASUREMENT OF THE POLARIZATION PARAMETER IN π^-p BACKWARD ELASTIC SCATTERING AT 6 GeV/c

CERN - I.P.N. Orsay - Oxford University Collaboration

L. Dick, Z. Janout*
CERN, Geneva, Switzerland

H. Aoi°, C. Caverzasio, A. Gonidec, K. Kuroda, A. Michalowicz,
M. Poulet, D. Sillou
Division des Hautes Energies, Institut de Physique Nucléaire,
91 Orsay, France.

D.G. Aschman, N.E. Booth, K. Green, C.M. Spencer+
Department of Nuclear Physics, Oxford University
Keble Road, Oxford, England

Abstract : The polarization parameter in π^-p elastic scattering has been measured in the backward angular region at an incident momentum of 6 GeV/c. The measurements cover the range of four momentum transfer $u = 0$ to -1 $(GeV/c)^2$, and were obtained with a high intensity pion beam, a butanol polarized proton target, and arrays of scintillation counter hodoscopes.

The polarization is different from zero, in contradiction to the prediction of the naive one trajectory Regge-exchange model. It increases positively with the four-momentum transfer u, reaching a maximum of about 0.4 at $u \approx -0.3$ $(GeV/c)^2$. It then decreases and becomes slightly negative beyond $u \approx -0.5$ $(GeV/c)^2$. This behaviour is not predicted by any baryon exchange model.

*Present Address : Fakulta Jaderna A. Fysikalne
Inzenyrska, stare Mestro,
Brehova ulice 7, Praha, CSR, Ceskoslovensko.

+Present Address : Laboratori Nazionali del CNEN, C.P. 70, Frascati, Italia.

°Present Address : HIRASAWA Nb. 15-1 ; 10,1 chome TAKASUZU,
HITACHI-SHI, IBARAKI, JAPAN.

I. INTRODUCTION

In a previous paper we reported results on π^+p backward scattering at 6 GeV/c [1]. In that paper we gave a detailed description of the method and the experimental apparatus, which with few changes were used for the π^-p experiment .

We have measured the polarization parameter in backward π^-p elastic scattering in order to find out how different it is from zero and the predictions of simple Regge models, and to try to obtain more information about baryon-exchange amplitudes. The incident momentum of 6 GeV/c is sufficiently high so that the interpretation should not be complicated by the effects of direct channel resonances, but not so high as to be experimentally unfeasible because of the rapid fall-off of the cross section with increasing momentum.

2. DESCRIPTION OF THE EXPERIMENT

The experiment was carried out at the CERN PS in the p_4 beam which yielded $\approx 2 \times 10^6$ π^- incident onto a CERN butanol polarized proton target [2] per machine burst. The target was 1.6 cm diameter x 3.8 cm long with an average polarisation P_T of the free protons of 0.70. The main features of the apparatus are shown in fig. 1. Scintillation counters S_1, S_2 and R formed the basic trigger. Not shown are lead-scintillator sandwich veto counters which were placed close to the target to reject particles produced outside the acceptance of the hodoscopes. These veto counters to a large extend rejected inelastic events. The threshold gas Cerenkov counters C_1 and C_2 identified incoming pions while C_4 and C_5 were used to reject events with forward-scattered pions. The counter C_7 was a large acceptance total-internal-reflection plexiglass Cerenkov counter [3] sensitive only to particles with $\beta \gtrsim 0.8$ and was used to help in the selection of backward scattered pions.

The scintillation hodoscopes determined two points on both the incident and backward-scattered particle trajectories, and one point on the trajectory of the forward-scattered particle. Details of their dimensions are given in ref. [1]. After each trigger the information from the hodoscopes and Cerenkov counters passed through a data acquisition system into an on-line IBM 360/44 computer. The computer wrote the events onto magnetic tape, and also carried out some on-line processing, the results of which were written onto another tape for later processing off-line. It also had the facility for on-line displays of various distributions which enabled checks of the reliability of the experiment to be made while data acquisition was in progress. A typical sequence of data taking was to make two runs of about two hours duration each for each sign of the target polarization, and so on.

3. DATA ANALYSIS

Each event which had only one particle in the hodoscopes H5, H6 and only one in H2, H3, H4, and which satisfied preselected criteria on the presence or absence of various Cerenkov signals was treated as a backward elastic scattering event. The value of u was calculated for each event from the position of the forward particle in H5, H6. From elastic scattering kinematics and the positions of the detected particles in H2 and H3, H4 the following quantities were calculated :

i) the deviation from coplanarity ε of the three particles (incident, scattered, recoil). For elastic events, $\varepsilon = 0$.

ii) the angular correlation $\Delta = \theta^{\pi}_{lab}$ (measured) - θ^{π}_{lab} (computed) where θ^{π}_{lab} (measured) is the angle of the backward scattered pion in the laboratory, and θ^{π}_{lab} (computed) is the value calculated from the measured angle of the forward scattered proton, assuming the event obeys elastic kinematics. Thus $\Delta = 0$ for an elastic event.

iii) The coordinate X along the beam axis of the reconstructed event. For a good event, X must lie within the geometrical limits of the target. (X could be reconstructed to an accuracy of 1.5 cm, while the length of the target was 3.9 cm).

Distributions of these quantities were made for various u bins and, after examination, cuts were made in two of the quantities, and then the distribution in the third one remade. Cuts in the X distributions eliminate background events originating from collisions in the entrance and exit walls of the target cryostat, and, because of the bending of the particles in the magnetic field of the target, reject backward-scattered particles with the wrong charge sign. Cuts in Δ eliminate most quasi-elastic and inelastic events.

We chose to make cuts in X and Δ first, and then to display the ε distributions. Two examples at $u = -0.15 \pm 0.03$, and $u = -0.75 \pm 0.09$ $(GeV/c)^2$ are shown in fig. 2. The elastic events stand out as a much sharper peak in

ε than the background. At small $|u|$ the background under the elastic peak is small ; however the signal-to-background ratio S/B decreases with increasing $|u|$ to about unity at $u = -0.75$. This change is mainly due to the factor of ≈ 10 decrease in $d\sigma/du$ over the range of u-values shown in fig. 2. The symbols 'UP' and 'DOWN' indicate the sign of the target polarization. Comparison of the UP/DOWN histograms shows, particularly in fig. 2a, the change in the number of elastic events when P_T is reversed, while the background remains the same.

The background was subtracted by a polynomial fit to the tails (ie. regions outside the elastic peak) which was interpolated into the region of the elastic peak. The ε distributions were chosen for the fitting, since for these the shape of the background is only weakly dependent upon u.

The relative normalization for the data taken with P_T up and down was obtained by using the coincidence C_1 C_2 as a monitor, and by requiring consistency in the numbers of events in the tails of the distributions, as described in detail in ref. [1].

4. EXPERIMENTAL RESULTS

The values of the polarization parameter P_o^- in backward π^-p elastic scattering at 6 GeV/c are given in table 1 and illustrated as a function of u in fig. 3. The errors quoted have been calculated by statistical considerations from the numbers of elastic and background events. Systematic errors in the monitoring and background subtraction combine to give an overall systematic error in the polarization parameter P_o of $\pm$ 0.03, including an error $|\Delta P_o/P_o| < 5\%$ from the uncertainty in the measurement of the target polarization.

The polarization parameter is small and positive at small u, rises to a maximum value of about 0.4 at $u \approx -0.3$, and appears to cross or become zero at $u \approx -0.5$. The data suggest a negative value of P_o beyond $u = -0.5$, but are also consistent with zero. In spite of the uncertainties due to the large errors, there is clear evidence for the existence of structure in the polarization.

A comparison of the π^-p polarization with the π^+p polarization [1] indicates that they are very different, as might be expected from the different behaviour of the background cross sections. This is in contrast to the forward scattering with its well-known mirror symmetry between the two polarizations.

5. DISCUSSION AND INTERPRETATION OF THE RESULTS

The polarization parameter P_o^- in π^-p backward elastic scattering is non zero and exhibits structure as a function of u. None of the existing baryon exchange models have predicted this result correctly. The models which are ruled out by this experiment are :

i) The simple Regge model with a single linear Δ_δ trajectory. The polarization must be zero in obvious contradiction with the data.

ii) Models with an imaginary contribution to the Δ_δ trajectory [4] ie.

$$\alpha(u) = a + bu + c\sqrt{u} .$$

This predicts a smooth polarization proportional to $\tanh(-i\pi c\sqrt{u})$ in contradiction with the data. However, two further assumptions are not eliminated : a more sophisticated u-dependence for the trajectory, or the superposition of a small imaginary contribution from another mechanism.

iii) The variety of models considered by Berger and Fox [5]. They made a series of fits to cross-section data with modified Regge pole models which included either weak absorptive cuts, strong cuts, or Carlitz-Kislinger type cuts. All these are in disagreement with our experimental results. Inclusion of the polarization data in the fitting procedure does not change this conclusion [6].

iv) The model of Halzen et al [7] based on a kinematic cut. This model predicts the sign of the π^-p polarization correctly and gives a zero at $u \approx -0.5$ $(GeV/c)^2$. This zero comes from a zero in the residue function, and the model gives a large negative polarization at large $|u|$ in disagreement with the data.

After the publication of our preliminary results,[8] a new generation of theoretical analysis has appeared. We discuss the qualitative features of some of these, and the mechanisms they invoke to explain the observed polarization, and compare some of them of our data. Apart from the fact that with π^-p polarization measurements we might hope to understand $I_u = \frac{3}{2}$ exchange which is isolated by π^-p backward elastic scattering, the $I_u = \frac{3}{2}$ exchange also contributes to π^+p and any previous interpretations of πN backward scattering are necessarily modified by our new results.

An interesting and simple treatment of πN backward scattering data has been carried out by Barger and Olsson [9], who used linear combinations of the πN differential cross-sections and polarizations to isolate the $I_u = \frac{1}{2}$ exchange contribution from the data. The same kind of analysis, using reasonable model-dependent hypotheses (for there are as yet not enough independent measurements to completely fix the πN amplitudes at 6 GeV/c) has been carried out by Ferro-Fontan [10], Minkowski [11], Hayot and Morel [12], and Storrow and Winbow [13].

These authors use the relations :

$$\sigma_N = \frac{1}{2}\,[3\,\sigma^+ + 3\,\sigma^\circ - \sigma^-] = |N_{++}|^2 + |N_{+-}|^2$$

$$\sigma_\Delta = \sigma^- = |\Delta_{++}|^2 + |\Delta_{+-}|^2$$

$$\sigma_{int} = \frac{1}{4}\,[3\,\sigma^+ - 6\,\sigma^\circ + \sigma^-] = \mathcal{R}e\,[\Delta_{++} N^*_{++} + \Delta_{+-} N^*_{+-}]$$

where the σ's are differential cross sections and where the superscripts + , - and $^\bullet$ refer to the reactions $\pi^+p \to p\pi^+$, $\pi^-p \to p\pi^-$ and $\pi^-p \to n\pi^\circ$ and the subscripts Δ and N refer to pure isospin values 3/2 and 1/2 in the u-channel and int. to the interference between the $I = 3/2$ (Δ_{++} , Δ_{+-}) and $I = 1/2$ (N_{++} , N_{+-}) helicity amplitudes. The polarization parameters (P) enter in the relations :

$$(P\sigma)_N = \frac{1}{2}\,[3(P\sigma)^+ + 3(P\sigma)^\circ - (P\sigma)^-] = -\,2\ \mathrm{Im}\ N^*_{++}\,N_{+-}$$

$$(P\sigma)_\Delta = (P\sigma)^- = -\,2\ \mathrm{Im}\ {}^*_{++}\ {}_{+-}$$

$$(P\sigma)_{int} = \frac{1}{2}\,[3(P\sigma)^+ - 6(P\sigma)^\circ + (P\sigma)^-] = -\,2\mathrm{Im}\ [\Delta^*_{++}N_{+-} - N^*_{++}\Delta_{+-}]$$

However without data on the charge exchange polarization parameter it is only possible to construct the combination :

$$(P\sigma)_N + \frac{1}{2}\,(P\sigma)_{int} = \frac{1}{4}\,[9(P\sigma)^+ - (P\sigma)^-]$$

These combinations of cross-section and polarization are plotted in figs. 4(a) and 4(b) using the π^-p polarization data of this experiment and our π^+p data [1] at GeV/c and the differential cross-section data of Owen et al [14] at 5.91 GeV/c. Some model-independent conclusions have already been made by Barger and Olsson [9] from similar plots. Figure 4 exhibits the smooth variation in both σ_Δ and $P\sigma_\Delta$ with u, but the considerable structure in σ_N , σ_{int} and $[(P\sigma)_N + \frac{1}{2}\,(P\sigma)_{int}]$. The latter quantities may all have quadratic zeros at $u \approx -0.15$ $(\text{GeV/c})^2$, but this is somewhat uncertain because of inconsistencies between the σ^+ measurements at 5.2 GeV/c [15], and those at 5.91 (GeV/c) [14]. If $I_u = \frac{1}{2}$ quantities vanish at $u \approx -0.15$ $(\text{GeV/c})^2$ then $P_+ = P_-$; our results are consistent with this relationship, but do not require it.

In spite of the lack of data needed to separate $(P\sigma)_N$ and $(P\sigma)_{int}$ it is never-the-less possible to put limits on these quantities using triangle inequalities from isospin invariance as has been shown by Dass et al [16]. The requirements of isospin invariance give :

$$\frac{1}{4}\left[3\sqrt{\sigma^+(1+P^+)} - \sqrt{\sigma^-(1+P^-)}\right]^2 \leq \sigma_N(1+P_N) \leq \frac{1}{4}\left[3\sqrt{\sigma^+(1+P^+)} + \sqrt{\sigma^-(1+P^-)}\right]^2$$

and $$\frac{1}{4}\left[3\sqrt{\sigma^+(1+P^+)} - \sqrt{\sigma^-(1-P^-)}\right]^2 \leq \sigma_N(1-P_N) \leq \sigma_N + \frac{1}{4}\left[3\sqrt{\sigma^+(1-P^+)} + \sqrt{\sigma^-(1=P^-)}\right]^2$$

and the more restrictive bounds :

$$\frac{1}{4}\left[3\sqrt{\sigma^+(1+P^+)} - \sqrt{\sigma^-(1+P^-)}\right]^2 - \sigma_N \leq (P\sigma)_N \leq \sigma_N + \frac{1}{4}\left[3\sqrt{\sigma^+(1-P^+)} - \sqrt{\sigma^-(1-P^-)}\right]^2$$

The derived bounds on $(P\sigma)_N$ and $(P\sigma)_{int}$ are plotted in fig. 5 and show that the large and negative polarization observed in $\pi^+ p \to p\pi^+$ arises almost entirely from the interference of $I_u = 1/2$ exchange with itself. The polarization from interference between $I_u = 1/2$ and $I_u = 3/2$ exchange is small at large u as might be expected in a region where $\sigma_N \gg \sigma_\Delta$. Figure 6 shows the bounds on the charge-exchange polarization. They are not very restrictive and can only rule out positive values of the polarization in the interval $-0.65 \leq u \leq -0.3$ $(\text{GeV/c})^2$.

We now turn to discuss some mechanisms which can give rise to the observed polarization in $\pi^- p$ backward elastic scattering at 6 GeV/c. Essentially all these mechanisms allow the $I_u = 3/2$ trajectory, the so-called Δ trajectory, to interfere with itself.

Barger and Olsson [9] envisage either a phase difference of 180° in Δ_{++} and Δ_{+-} , or else a zero of Δ_{++} or Δ_{+-} in both the real and imaginary parts, at $u \approx 0.4$.

Ferro-Fontan [10] has performed an amplitude analysis based on a small number of hypotheses. The result from his fit to our preliminary data is shown in fig. 7. The zero around $u = -0.5$ $(\text{GeV/c})^2$ is due to a phase difference of 180° between Δ_{+-} and Δ_{++}.

Minkowski [11] has investigated the structure of Regge residue functions for baryon exchange compatible with the absence of MacDowell parity doublets. Again fig. 7 shows the results of his fit to our preliminary data. The polarization results from an assumed Δ_δ ,Δ_β interference, and it is the Δ_β which prevents a dip appearing at $u = -1.8$ $(\mathrm{Gev/c})^2$ in the π^-p cross-section, where the Δ_δ has a wrong-signature nonsense zero.

Using the constraints of an isospin analysis, Hayot and Morel [12] have proposed a fit with an absorption model, which is also shown in fig. 7.

Storrow and Winbow [13] recently presented an extensive review of high energy backward πN scattering. Although no prediction for the π^-p polarization is given, they conclude that the Δ_δ Regge pole should be modified by strong cuts in the $I_u = 3/2$ exchange amplitudes.

Aye [17] has applied the ideas of the dual absorption model to backward scattering, and in a qualitative way has obtained agreement with both P^+ and P^-.

In conclusion we want to mention a very curious but possibly significant point. We can compare our results for the polarization in π^-p backward elastic scattering at 6 GeV/c to the polarization in the forward charge exchange reaction at comparable momenta [18,19]. These two reactions have been considered as key reactions in the phenomenology. Theoretically they should be simple because they are dominated by single exchanged objects : the ρ in the forward charge exchange scattering and the Δ_δ in the π^-p backward elastic scattering (the baryon exchange reaction is in fact a little more complicated due to the parity doublet problem and the ambiguities connected with this 20). In these two reactions the non-zero polarization is a source of difficulty for the Regge pole models. But we see from fig. 8 that the two results show similar behaviour as a function of the four-momentum transfer (t in the forward charge exchange, and $u-u_{min}$ in the backward elastic scattering). This fact is surprising. It may be coincidental and the similarity made more manifest by the non-negligible errors, or there could be a more fundamental dynamical reason.

We wish to thank M. Borghini and the members of his polarized proton target group at CERN : J. Conciencia, J.M. Rieubland, F. Udo, M. Uldry and J. Vermeulen for their invaluable assistance in setting up and runing the polarized target. We thank R. Bell who assisted in the writing of on-line programs and P. Scharff-Hansen who handled the hardware interfacing of the

IBM 360/44 computer to the experiment. We are indebted to J. Baze, D. Cronenberger, M. Givort, W. Huta, A. Looten, A. Kupferschmid and all the staff of the CERN and Orsay groups for their efficient technical assistance. We are also grateful to G. Gregoire who participated in the early stages of this work and to A. Gsponer for this participation in the measurements. One of us (Z. Janout) wishes to thank the IPN of Orsay for its hospitality and financial support, another (C.M. Spencer) wishes to thank the Science Research Council for a research student-ship, and another (D.G. Ashman) wishes to thank the University of Cape Town for a scholarship.

REFERENCES

1) L. Dick, Z. Janout, H. Aoi, C. Caverzasio, A. Gonidec, K. Kuroda, A. Michalowicz, M. Poulet, D. Sillou, D.G. Aschman, N.E. Booth, K. Green and C.M. Spencer, Nucl. Phys. B43 (1972) 522.

2) M. Borghini, P. Roubeau and C. Ryter, Nucl. Instr. 49 (1967) 248; S. Mango, O. Runolfsson and M. Borghini, Nucl. Instr. 72 (1969) 45; See also the Proceedings of the IInd International Conference on polarized targets, edited by G. Shapiro (Lawrence Berkeley Laboratory) Report LBL-500, 1971).

3) H. Aoi, Thèse de 3ème cycle, Paris, 1972.

4) J.D. Stack, Phys. Rev. Lett. 16 (1966) 286.

5) E.L. Berger and G.C. Fox, Nucl. Phys. B26 (1971) 1.

6) M. Evrad-Musette and C.M. Spencer (private communication) ; C.M. Spencer, D. Phil thesis (Oxford) 1972.

7) F. Halzen, A. Kumar, A.D. Martin and C. Michael, Phys. Lett. 32B (1970) III.

8) H. Aoi et al, Proceedings of the Amsterdam International Conference, edited by A.G. Tanner and M.J.G. Veltman (North-Holland Publishing Company, Amsterdam, 1971).

9) V. Barger and M.G. Olsson, Phys. Rev. D5 (1972) 2736.

10) C. Ferro-Fontan, CERN Preprint, TH 1490 (1972).

11) P. Minkowski, Nucl. Phys. B48 (1972) 247.

12) F. Hayot and A. Morel, Saclay Preprint, DPH T DOC 72-46 (1972).

13 J.K. Storrow and G.A. Winbow, Daresbury Nuclear Physics Laboratory Preprint DNPL/P132 (1972).

14) D.P. Owen, F.C. Peterson, J. Orear, A.L. Read, D.G. Ryan, D.H. White, A. Ashmore, C.J.S. Damerell, W.R. Frisken, R. Rubinstein, Phys. Rev. 181 (1969) 1794.

J.P. Boright, D.R. Bowen, D.E. Groom, J. Orear, D.P. Owen, A.J. Pawlicki, D.H. White, Phys. Rev. Lett. 24 (1970) 964 and Physics Letters 33B (1970) 615.

15) W.F. Baker, K. Berkelman, P.J. Carlson, G.P. Fisher, P. Fleury, D. Hartill, R. Kalbach, A. Lundby, S. Mukhin, R. Nierhaus, K.P. Pretzl and J. Woulds, Nucl. Phys. B25 (1971) 385.

16) G.V. Dass, J. Froyland, F. Halzen, A. Martin, C. Michael, J.P. Roy, Phys. Letters 36B (1971) 339 ;
L. Michel, Nuovo Cimento 22 (1961) 203 ;
R.J.N. Phillips, Nuovo Cimento 26 (1962) 103.

17) T.M. Aye, Imperial College Preprint ICTP/71/32 (1972).

18) P. Bonamy, P. Borgeaud, M. Crozon, J.P. Guillaud, O. Guisan, P.Le Du, P. Sonderegger, J.K. Bienlein, S. Mango, L. Paul, and H. Dinter, to be published.

19) D. Hill, P. Koehler, T. Novey, P. Rynes, B. Sandler, H. Spinka, A. Yokosawa, D. Eartly, K. Pretzl, G. Burleson, G. Hicks, C. Wilson, and W. Risk, to be published.

20) J.K. Storow and G.A. Winbow, Daresbury Nuclear Physics Laboratory Preprint DNPL/142 (1972).

Table 1

Experimental results for the polarization in $\pi^- p$ backward elastic scattering at 6 GeV/c

u $(GeV/c)^2$	P(u)
-0.03 ± 0.03	0.11 ± 0.09
-0.09 ± 0.03	0.18 ± 0.11
-0.15 ± 0.03	0.18 ± 0.07
-0.21 ± 0.03	0.20 ± 0.09
-0.27 ± 0.03	0.36 ± 0.09
-0.33 ± 0.03	0.39 ± 0.10
-0.39 ± 0.03	0.12 ± 0.13
-0.45 ± 0.03	0.02 ± 0.13
-0.51 ± 0.03	-0.09 ± 0.14
-0.60 ± 0.06	-0.21 ± 0.13
-0.75 ± 0.09	-0.16 ± 0.20
-0.93 ± 0.09	-0.19 ± 0.25

FIGURE CAPTIONS

1. Experimental arrangement for the polarization measurements in backward $\pi^{\pm}p$ elastic scattering at 6 GeV/c.

2. Distributions of coplanarity ε for the target polarization "UP", and "DOWN". The channel number 16 represents $\varepsilon = 0. \pm 20.$ mrad. Two subsets of data are shown :

   (a) , $u = -.15 \pm 0.3$ $(GeV/c)^2$

   (b) , $u = -.75 \pm 0.9$ $(GeV/c)^2$

3. Experimental results for the polarization parameter in $\pi^{-}p$ backward elastic scattering at 6 GeV/c.

4. Isospin decompositions at 6 GeV/c of a) σ_N , σ_Δ and $\sigma_{int.}$ and b) $(P\sigma)_\Delta$ and $(P\sigma)_N + \frac{1}{2}(P\sigma)_{int.}$

5. Constraints on the derived qualities $(P\sigma)_N$ and $(P\sigma)_{int.}$ from an isospin analysis. The curves are merely to guide the eye.

6. Isospin bounds on the polarization parameter in $\pi^{-}p$ backward charge exchange scattering at 6 GeV/c.

7. Some fitted curves to our preliminary results in $\pi^{-}p$ backward elastic scattering at 6 GeV/c. (———) : Ferro Fontan [10] (-----) ; Minkowski [11], (-·-·-): Hayot and Morel [12].

8. Polarization data from this experiment on $\pi^{-}p \rightarrow p\pi^{-}$ at 6 GeV/c and from the reaction $\pi^{-}p \rightarrow \pi^{\circ}n$ at 5 GeV/c and 8 GeV/c. Here u_{min} is the value of u at 180° scattering angle.

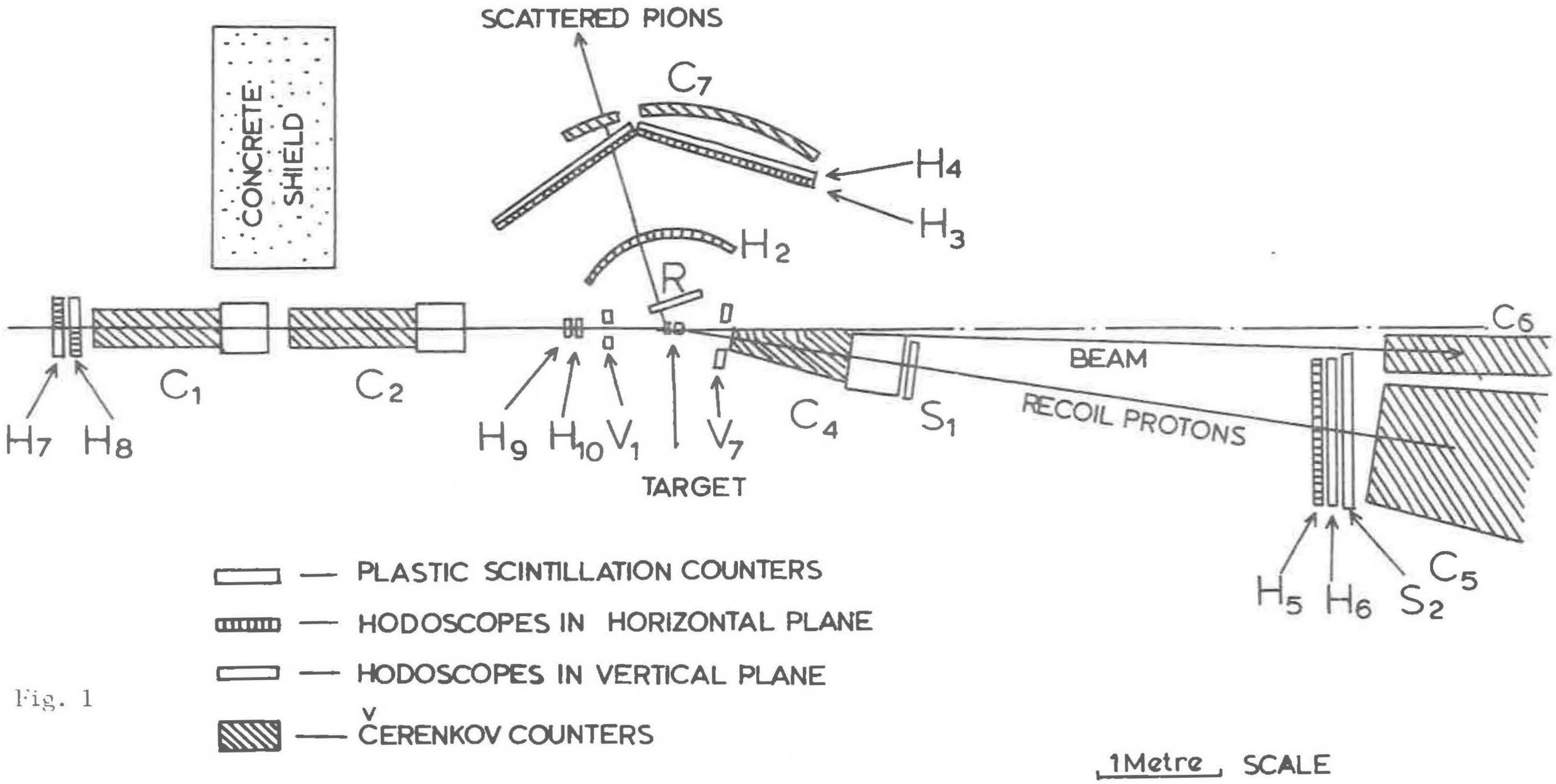
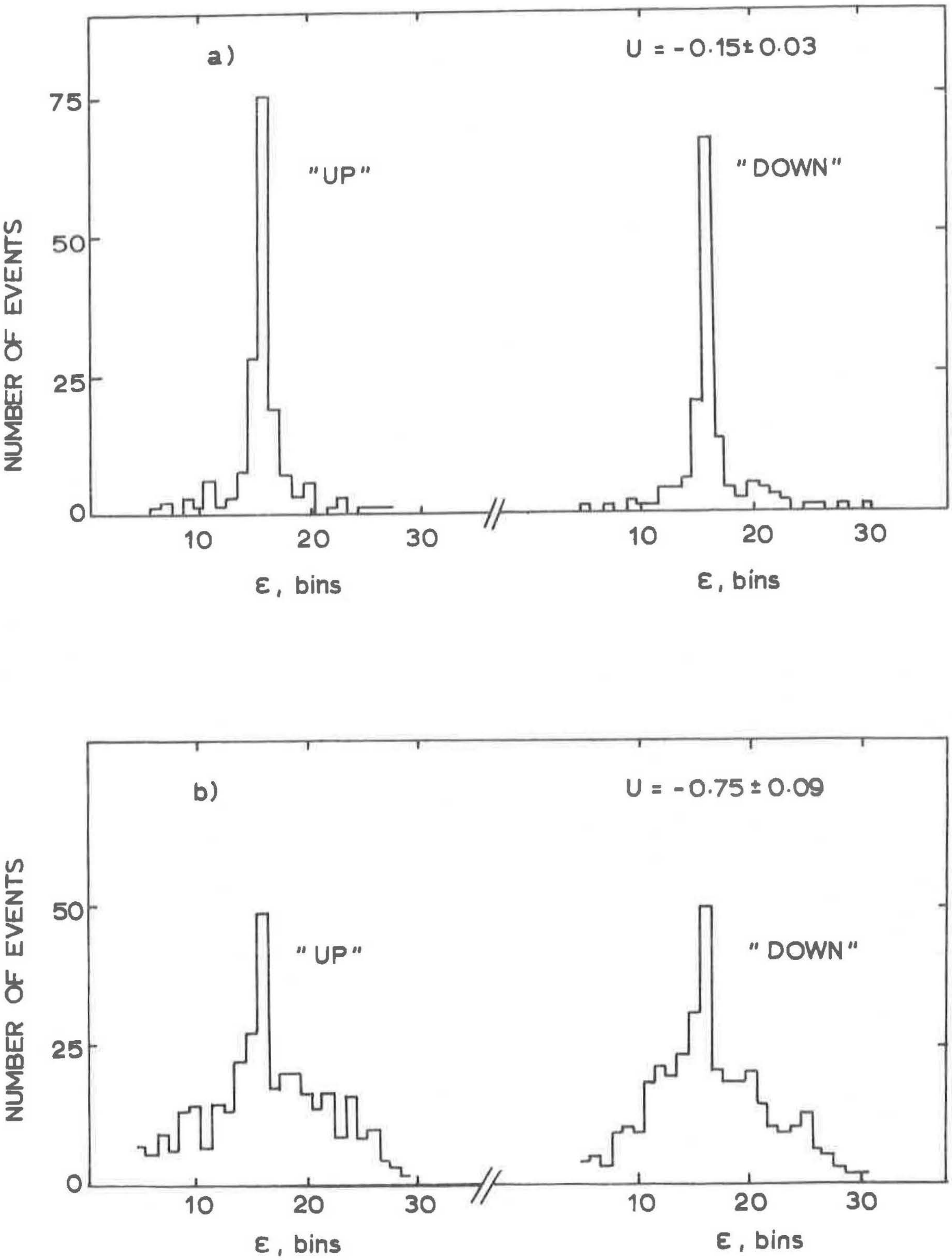
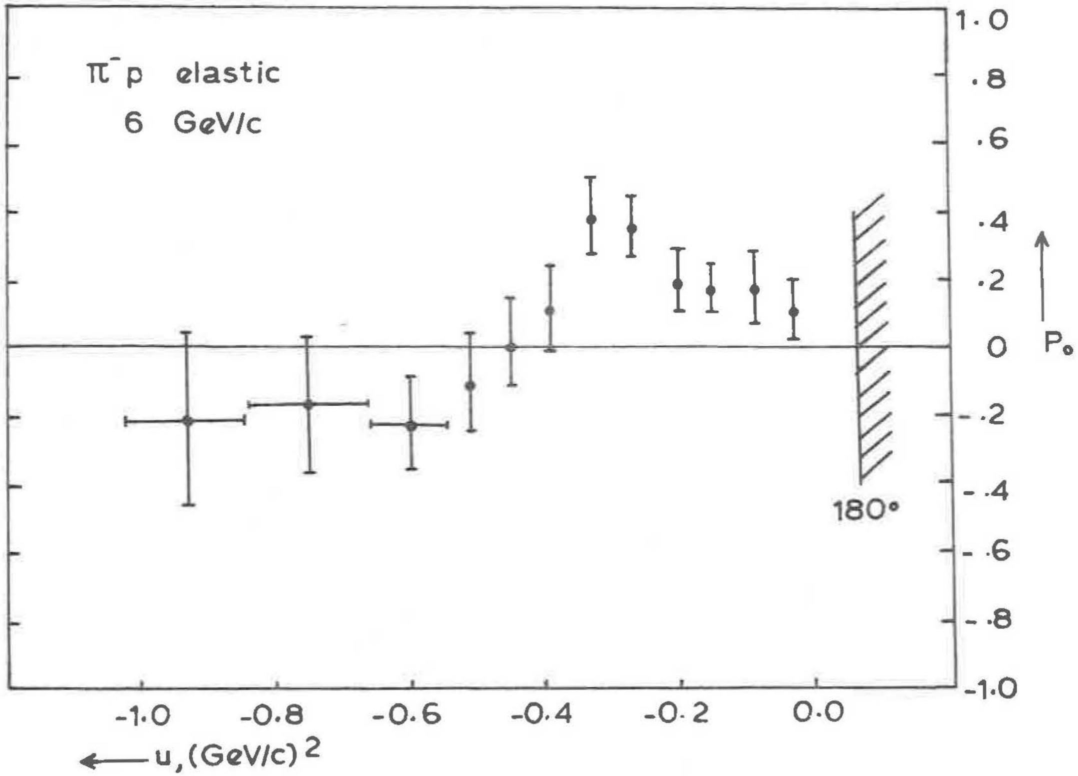

SCATTERED PIONS
CONCRETE SHIELD
C7
H4
H3
H2
R
C6
BEAM
C1
C2
H7
H8
H9
H10
V1
V7
TARGET
C4
S1
RECOIL PROTONS
H5
H6
S2
C5
PLASTIC SCINTILLATION COUNTERS
HODOSCOPES IN HORIZONTAL PLANE
HODOSCOPES IN VERTICAL PLANE
ČERENKOV COUNTERS
1Metre SCALE

Fig. 1



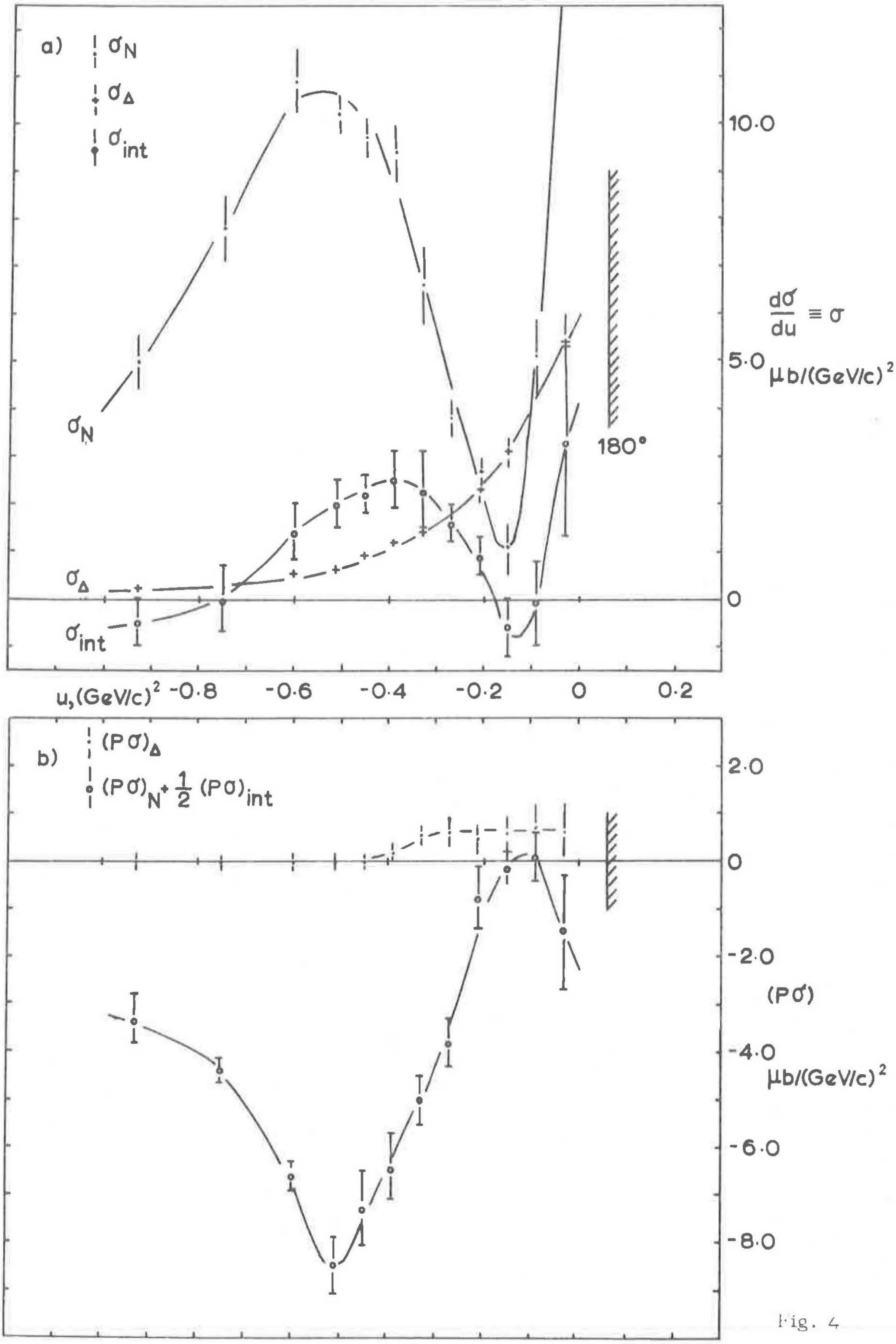
a)
U = -0.15 ± 0.03
75
50
25
0
NUMBER OF EVENTS
"UP"
"DOWN"
10
20
30
ε, bins
b)
U = -0.75 ± 0.09
"UP"
"DOWN"
ε, bins

Fig. 2



π⁻p elastic
6 GeV/c
1·0
·8
·6
·4
·2
0
-·2
-·4
-·6
-·8
-1·0
P₀
180°
-1·0
-0·8
-0·6
-0·4
-0·2
0·0
u, (GeV/c) 2

Fig. 3



a)
σ_N
σ_Δ
σ_{int}
10.0
5.0
0
$\frac{d\sigma}{du} \equiv \sigma$
$\mu b/(GeV/c)^2$
180°
u, $(GeV/c)^2$ -0.8 -0.6 -0.4 -0.2 0 0.2
b)
$(P\sigma)_\Delta$
$(P\sigma)_N + \frac{1}{2}(P\sigma)_{int}$
2.0
0
-2.0
$(P\sigma)$
-4.0
$\mu b/(GeV/c)^2$
-6.0
-8.0

Fig. 4

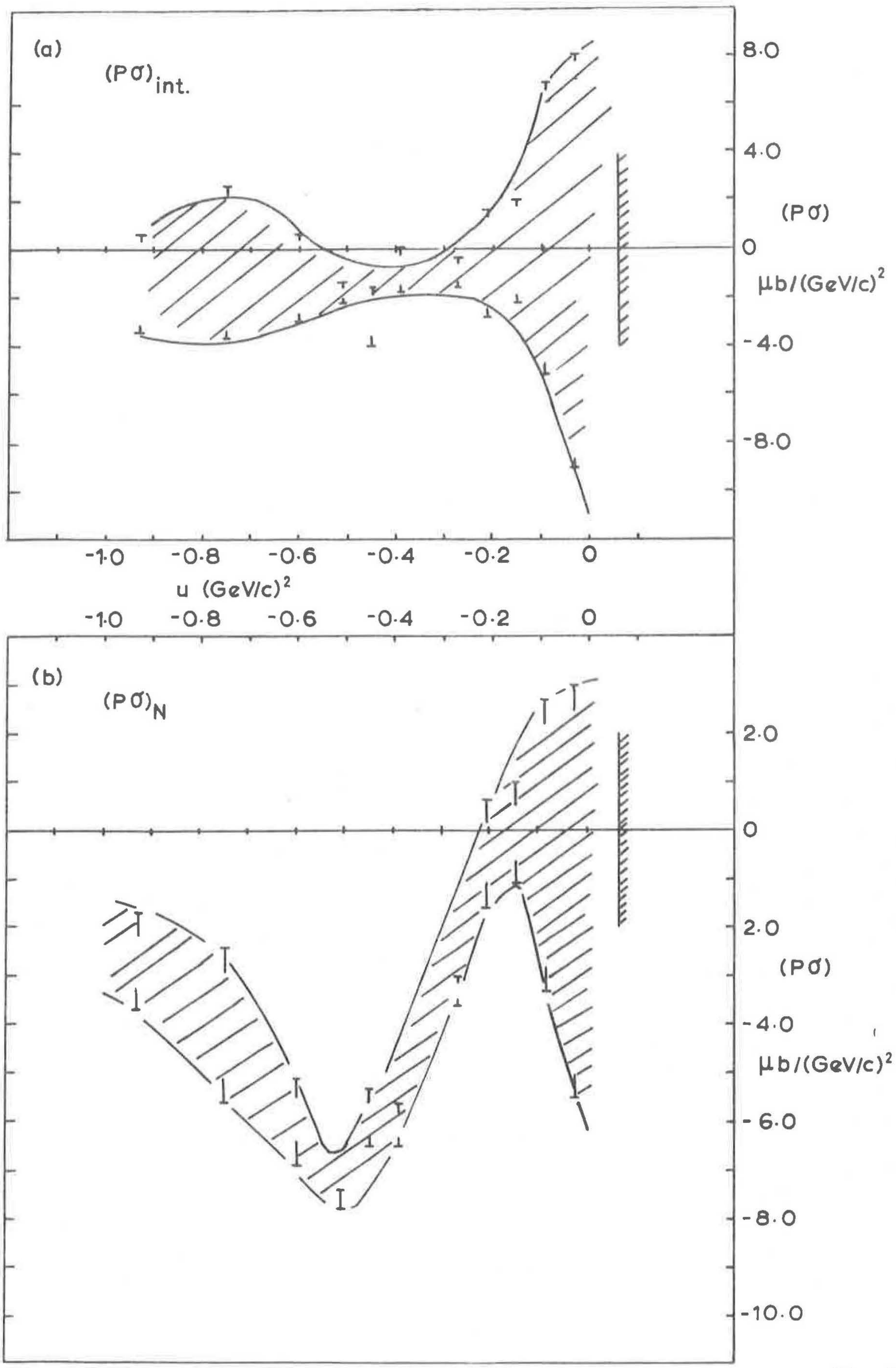

(a)
(Pσ)int.
8.0
4.0
(Pσ)
0
μb/(GeV/c)²
-4.0
-8.0
-1.0
-0.8
-0.6
-0.4
-0.2
0
u (GeV/c)²
(b)
(Pσ)N
2.0
0
2.0
(Pσ)
-4.0
μb/(GeV/c)²
-6.0
-8.0
-10.0

Fig. 5

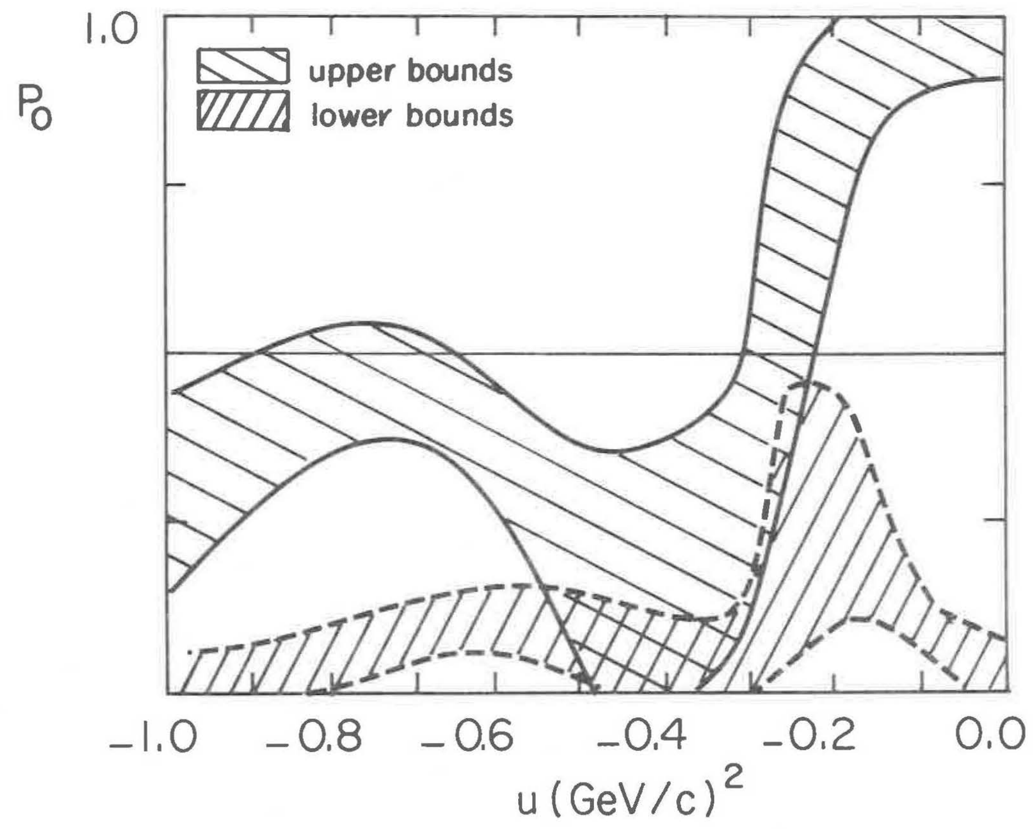


Fig. 6

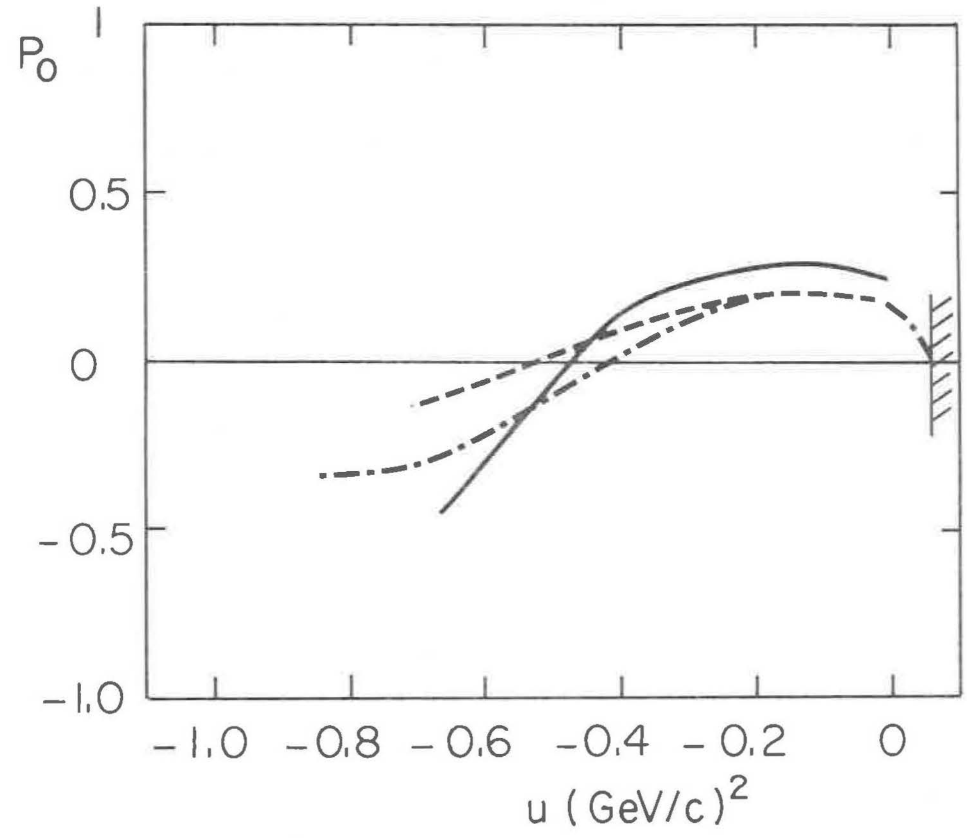


Fig. 7

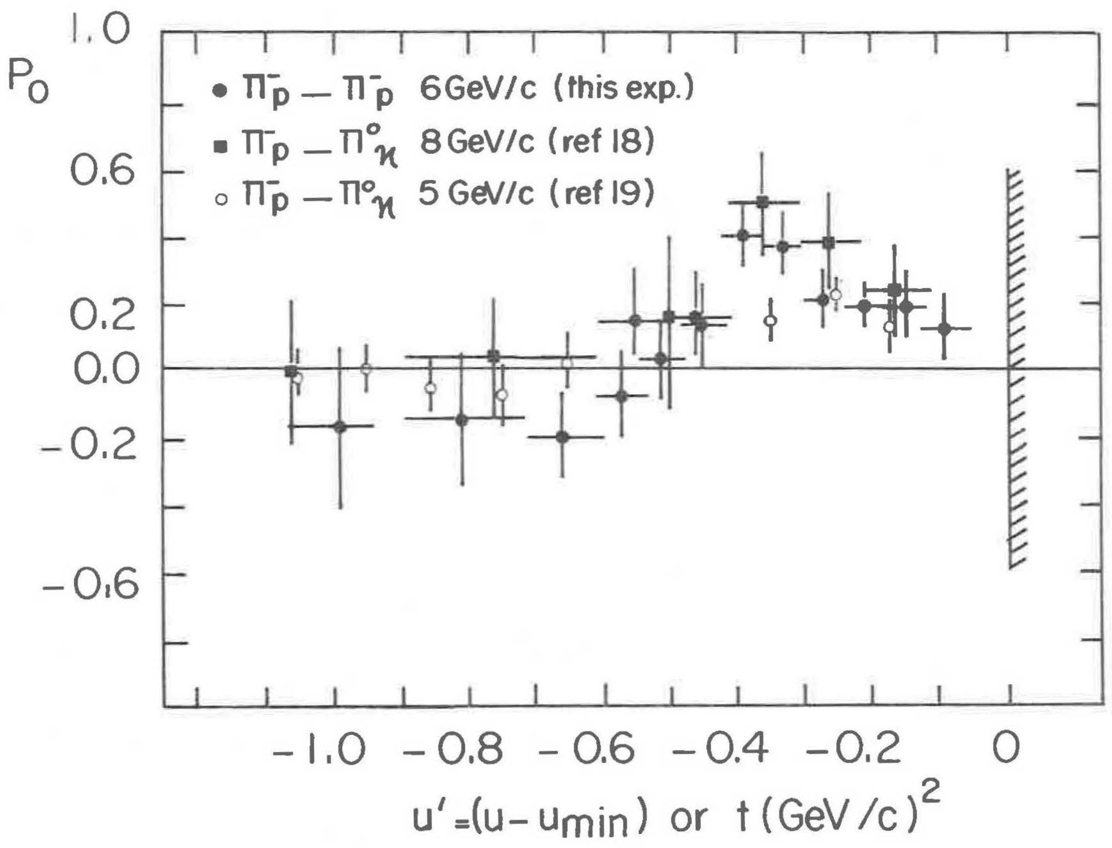

P_0
1.0
0.6
0.2
0.0
-0.2
-0.6
● $\pi^- p - \pi^- p$ 6 GeV/c (this exp.)
■ $\pi^- p - \pi^0 n$ 8 GeV/c (ref 18)
○ $\pi^- p - \pi^0 n$ 5 GeV/c (ref 19)
-1.0
-0.8
-0.6
-0.4
-0.2
0
$u' = (u - u_{min})$ or t $(GeV/c)^2$

Fig. 8