EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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PROPOSAL

To : Members of the EEC

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Subject : Measurement of the recoil proton polarization parameter in the backward $\pi^{\pm}p$ elastic scattering at high energies

1. INTRODUCTION

Among the simplest reactions which can proceed through the exchange of a single Regge pole, the $\pi^{-}p$ elastic scattering in the backward hemisphere looks very promising.

A measurement of the polarization parameter P_0 in the backward $\pi^{-}p$ elastic scattering would help to discriminate between the various hypotheses which were proposed: Regge cuts, imaginary part of the exchanged fermion trajectory, interference with other I = 3/2 poles, and so on.

It is worth recalling here that previous measurements[1] of $P_0(\pi^{+}p)$ are explained neither by a baryon exchange model with linear N_α and Δ_δ trajectories, nor by a pure resonance model including the Δ(1920), Δ(2420), and Δ(2850) resonances, and not even by an interference model combining baryon exchange and resonances[2,3] (Fig. 1).

On the other hand, data from a recent experiment on backward $\pi^{+}p$ elastic scattering were analysed using a sum of s-channel resonances. Good qualitative agreement has been found, thus supporting the idea of duality[4].

These reasons explain why we propose to measure the polarization parameter P_0 of the recoil nucleon in backward $\pi^{\pm}p$ elastic scattering at

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4, 6, and 10 GeV/c in the range $0 \leq |u| \leq 1$ (GeV/c)^2.

Typical differential cross-sections[5)] are shown in Figs. 2 and 3.

2. EXPERIMENTAL SET-UP

Figure 4 shows the momentum and lab. angle of the scattered pion versus u, the square of the invariant four-momentum transfer (from incident pion to outgoing proton) in the backward hemisphere.

The next figure (Fig. 5) sketches the corresponding asymptotic trajectories of the elastically scattered and recoil particles, taking into account the 25 kilogauss magnetic field of a polarized target. The field is oriented in such a way as to defocus the scattered pions.

Three hodoscopes will detect the backward scattered pions. At about 5 cm from the target a small counter array H_3 of 10 vertical scintillator strips (0.5 cm wide each) helps to resolve the finite size of the target (4.5 cm in length along the incident beam direction) on the scattered side.

The next two hodoscopes H_1 and H_2 will have vertical and horizontal scintillator strips.

The hodoscope H_2 is put at about 80 cm from the target, and H_1 lies in the field-free region 150 cm away from the magnet.

We plan to detect the recoil protons by the counter hodoscope H_4 located at a distance of 4 metres from the target.

The sizes of these hodoscopes H_2, H_3, and H_4 are listed in Table 1. They correspond to a centre-of-mass angular acceptance ranging from 140° to 171° or $0 \leq |u| \leq 1.0$ (GeV/c)^2, with a resolution Δu between 0.02 and 0.1 (GeV/c)^2. The azimuthal acceptance (vertical) is ±15°.

Two small hodoscopes H_5 and H_6 (not shown on the figure) are placed upstream and downstream from the polarized target, respectively. Since we intend to record the coordinates of, at most, four incident particles during the gate of the pattern units, H_5 and H_6 help us to find which incident particle interacted in the target.

3. BEAM CHARACTERISTICS

Taking into account the smallness of the backward πN cross-sections, we expect beam characteristics roughly similar to those of the present p_4 beam, i.e. a horizontal beam divergence less than ±5 mrad, a momentum bite of ±1%, and at least 2×10^6 pions per burst (independently of their charge).

A small x-y hodoscope H_5 is expected to give the direction of the incident particle.

4. POLARIZED TARGET

As for the present experiment, we will use a butanol polarized target, 4.5 cm in length along the beam line and 1.5×1.5 cm^2 across. We are planning to use the new ^{3}He refrigerator to get target polarizations of the order of 55% in a magnetic field of 25 kilogauss.

The use of the superconducting magnet, at present being developed at CERN, would allow an easy access to the central field region.

5. OTHER DETECTORS

The identification of the incident pions will be made by a set of two threshold Čerenkov counters. A third Čerenkov C_3 counter is put along the recoil proton trajectories. It will be used to veto all forward scattered pions. The requirement of a coincidence between a classical scintillator counter R, a set of anticoincidence counters V (not shown on the figure), and H_3 determine a fast trigger.

All hodoscopes will be of the same modular design that we are using now with the small XP 1110 photomultipliers.

6. BACKGROUND

There are two main sources of background: the first one comes from scatters off the complex nuclei in which secondaries are produced. Most of them are killed by the veto counters around the polarized target. The second source of background comes from production reactions that have cross-sections of the same order of magnitude[6)] as that of the elastic scattering in the backward hemisphere. They are mainly associated with productions of π^0's. Veto counters to kill them are at present under study.

7. DATA ACQUISITION

All hodoscope information, plus monitors and a set of single Čerenkov bits, will be stored in the same system of serial pattern units that we use in the present S59 experiment. A VARIAN 620-I computer is well suited to accommodate the small number of events we expect. Its main task will be to record the data on magnetic tapes and to check the performance of the experiment continuously. Each day we will need some priority time on one of the DD computers in order to make a more refined analysis. The final computations will be made at CERN.

An improvement to this solution would be a data link between the Varian 620-I and a computer such as the IBM 360/44 working in the PS Hall on a time-sharing basis and with several users. In that case, the total IBM 360/44 memory would have to be increased up to 64 K words at least.

8. COUNTING RATES, ESTIMATION OF PS TIME

In order to achieve rather accurate measurements, we made the following assumptions:

- The secondary beam intensity on the polarized target is of the order of 2×10^6 pions/burst at all energies and for both charges.
- The PS repetition rate is 2 sec.
- For all numerical values quoted below, we applied a safety factor of 1.75 to take into account the hodoscope efficiency, the beam structure, the fluctuations of beam intensity, background subtraction during analysis, and so on.

Table 2 shows some estimations of the machine time and the trigger rate per burst, for different incident momenta. Please note that this is the rate for elastic scatters on free protons, and that it does not take into account the so-called "complex nuclei events" and the various production processes.

The PS time requested is expressed in effective seven-day weeks. It has been computed assuming that the polarization P_0 is small everywhere. We would like to achieve a statistical accuracy of ±5% in $\pi^- p$ scattering near $|u| = 0.4\ (\text{GeV}/c)^2$ (Fig. 6a) and ±10% in $\pi^+ p$ scattering around $|u| = 0.15\ (\text{GeV}/c)^2$ (Fig. 6b). Our final estimate amounts to about 17 normal weeks of data taking.

Moreover, two weeks for testing the equipment in the experimental area will be required before taking data.

* * *

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4) R. Heinz et al., Third Topical Conference on Particle Physics, Hawaii University, August 1969, Report UH-511-57-69.

5) D. Owen et al., Report CNLS-50 (1969).
W. Baker et al., Nuclear Phys. B9, 249 (1969).

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Table 1

Hodoscope sizes

	H_3	H_2	H_1	H_4	H_5	H_6
Vertical strips						
Number	10	80	200	48	24	24
Length (cm)	2	40	80	60 max.	12	36
Width (cm)	0.5	0.5	1	1.25	0.5	1.5
Thickness (cm)	0.5	0.5	1	1	0.5	1.5
Horizontal strips						
Number	-	80	25	24	30	30
Length (cm)	-	40	200	60	15	45
Width (cm)	-	1	2	1°	0.5	1.5
Thickness (cm)	-	0.5	2	1	0.5	1.5

Table 2

Counting rate and accelerator time

Binning	$\pi^- p$	$\Delta u = \pm 0.05$	for	$\lvert u \rvert \leq 0.4$
		$\Delta u = \pm 0.10$		$\lvert u \rvert > 0.4$
	$\pi^+ p$	$\Delta u = \pm 0.03$	for	$\lvert u \rvert \leq 0.3$
		$\Delta u = \pm 0.05$		$\lvert u \rvert > 0.3$

	4 GeV/c		6 GeV/c		10 GeV/c	
	MT	ET	MT	ET	MT	ET
$\pi^+ p$	1	$\simeq$ 0.37	1.7	$\simeq$ 0.15	5.7	~ 0.05
$\pi^- p$	1	$\simeq$ 0.10	2.4	0.045	4.7	0.014

MT = machine time in effective seven-day weeks

ET = elastic trigger rate per burst

Figure captions

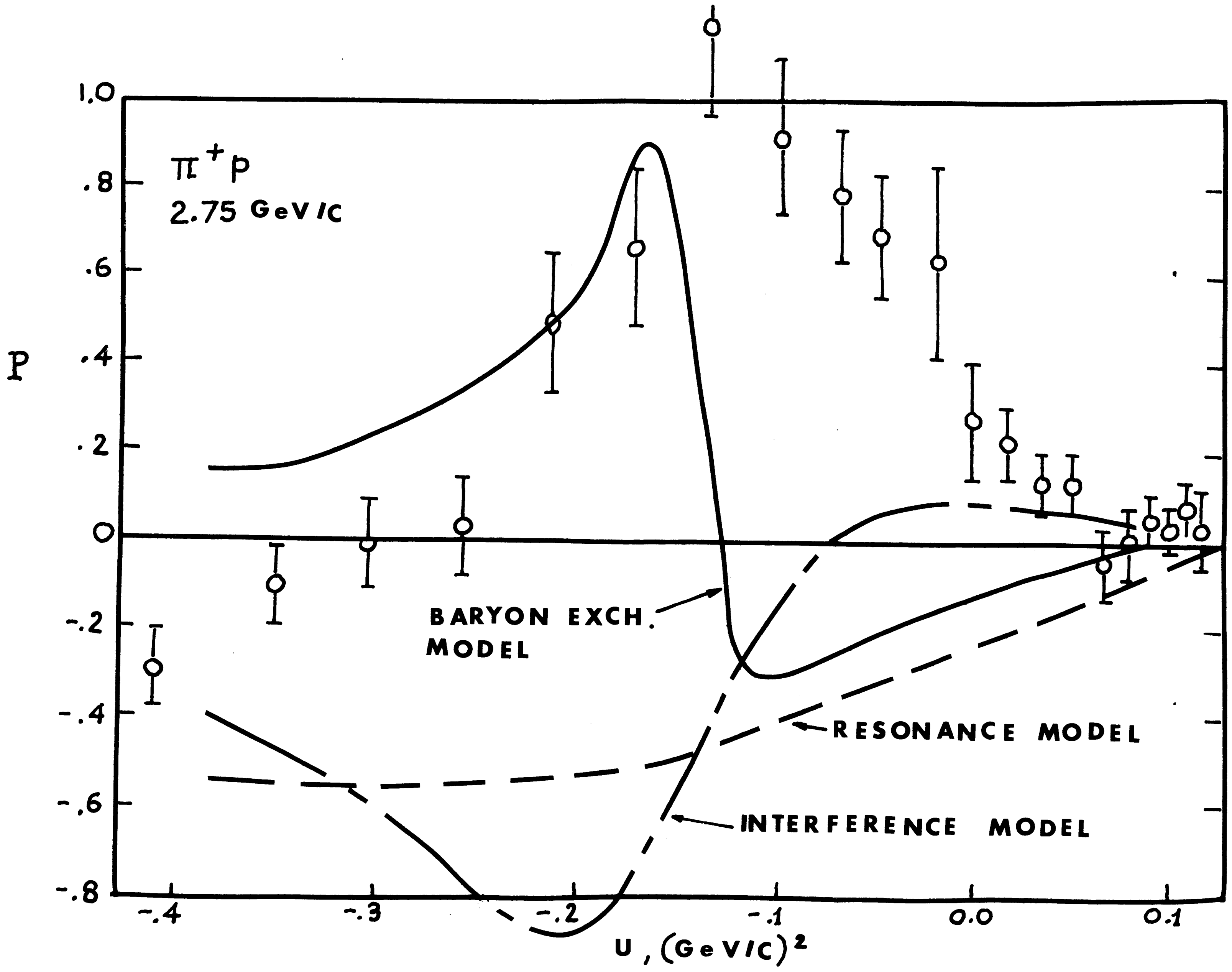
Fig. 1 : P_0 parameter in $\pi^+ p \rightarrow p\pi^+$ scattering at 2.75 GeV/c. The data points are from Ref. 1.

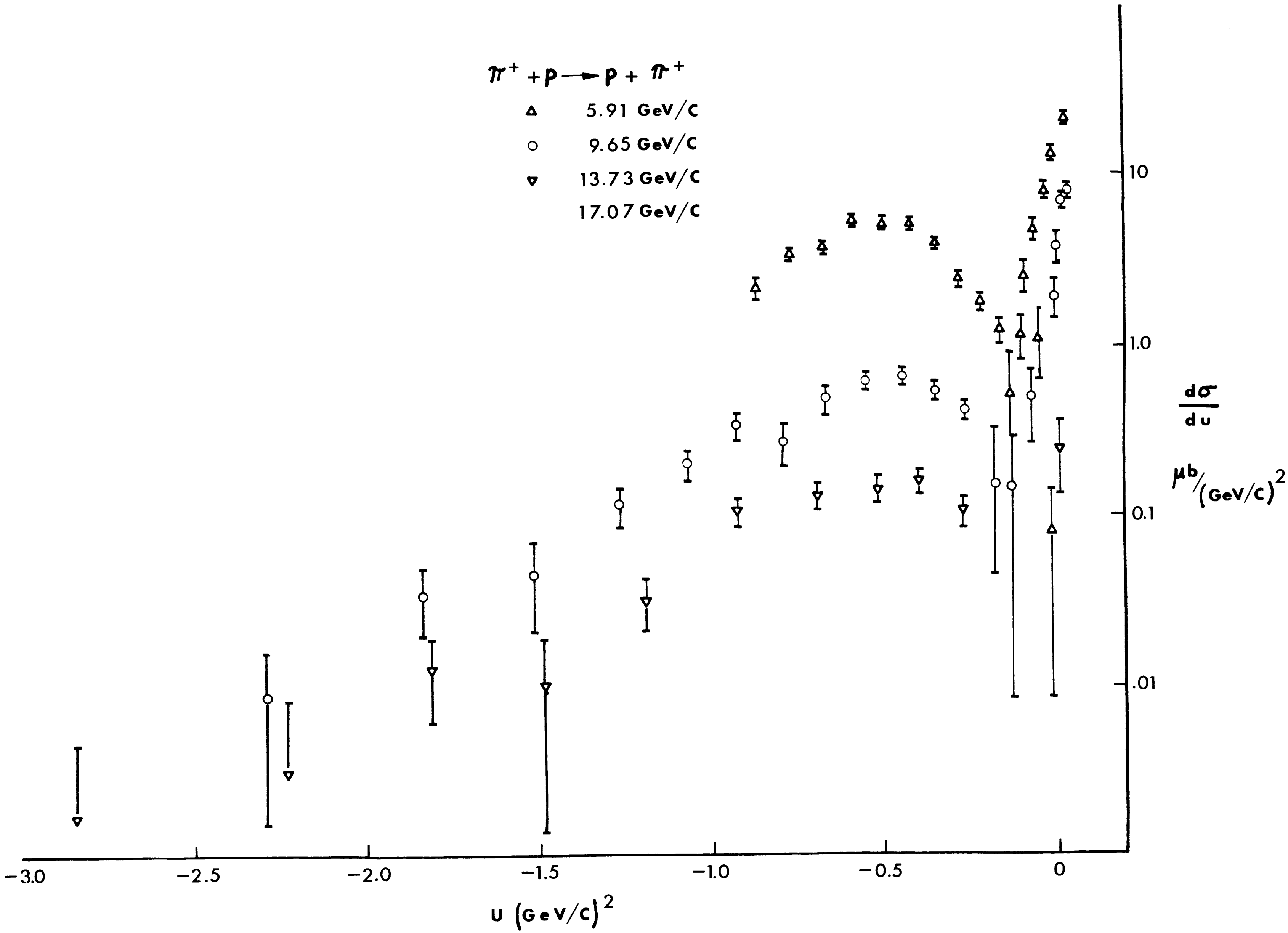
Fig. 2
Fig. 3 : Differential cross-sections for $\pi^\pm p \rightarrow \pi^\pm p$ elastic scattering at various momenta (Ref. 4).

Fig. 4 : Scattered pion lab. angle and momentum versus u at 4, 6, and 10 GeV/c.

Fig. 5 : Sketch of the proposed experimental set-up.

Fig. 6 : The computed statistical accuracy that we expect on the measurement of $P_0(\pi^\pm p)$.


P
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
π⁺p
2.75 GeV/C
BARYON EXCH.
MODEL
RESONANCE MODEL
INTERFERENCE MODEL
-.4
-.3
-.2
-.1
0.0
0.1
U, (GeV/C)²



$\pi^+ + p \rightarrow p + \pi^+$
5.91 GeV/C
9.65 GeV/C
13.73 GeV/C
17.07 GeV/C
10
1.0
0.1
.01
$\frac{d\sigma}{du}$
$\mu b/(GeV/c)^2$
−3.0
−2.5
−2.0
−1.5
−1.0
−0.5
0
$u\ (GeV/c)^2$

FIG 2

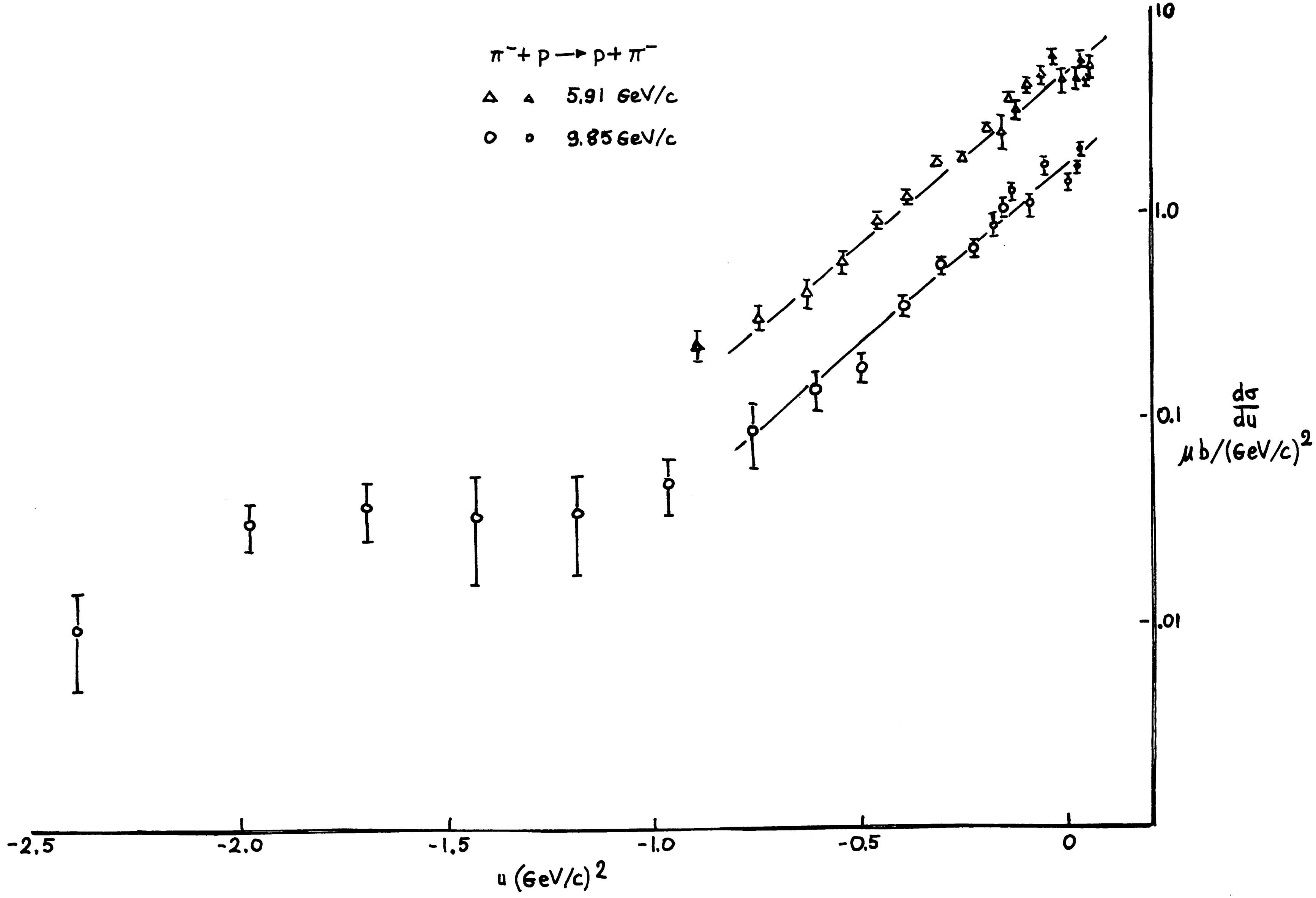
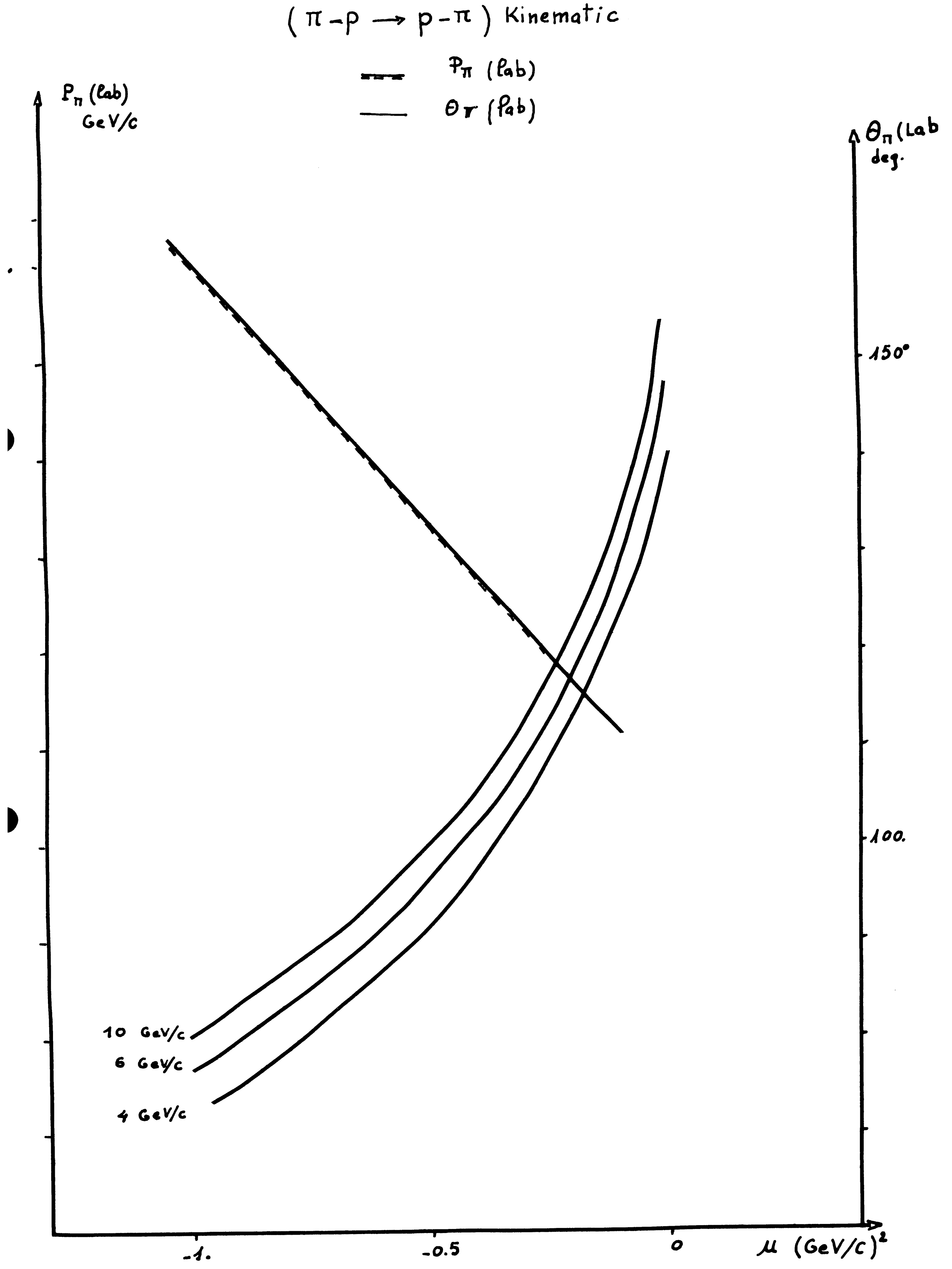

π⁻ + p → p + π⁻
5.91 GeV/c
9.85 GeV/c
10
1.0
0.1
.01
dσ/du
μb/(GeV/c)²
-2.5
-2.0
-1.5
-1.0
-0.5
0
u (GeV/c)²

FIG. 3



(π - p → p - π) Kinematic
P_π (lab)
θ_π (lab)
P_π (lab)
GeV/c
θ_π (Lab
deg.
150°
100.
10 GeV/c
6 GeV/c
4 GeV/c
-1.
-0.5
0
μ (GeV/c)²

Fig. 4

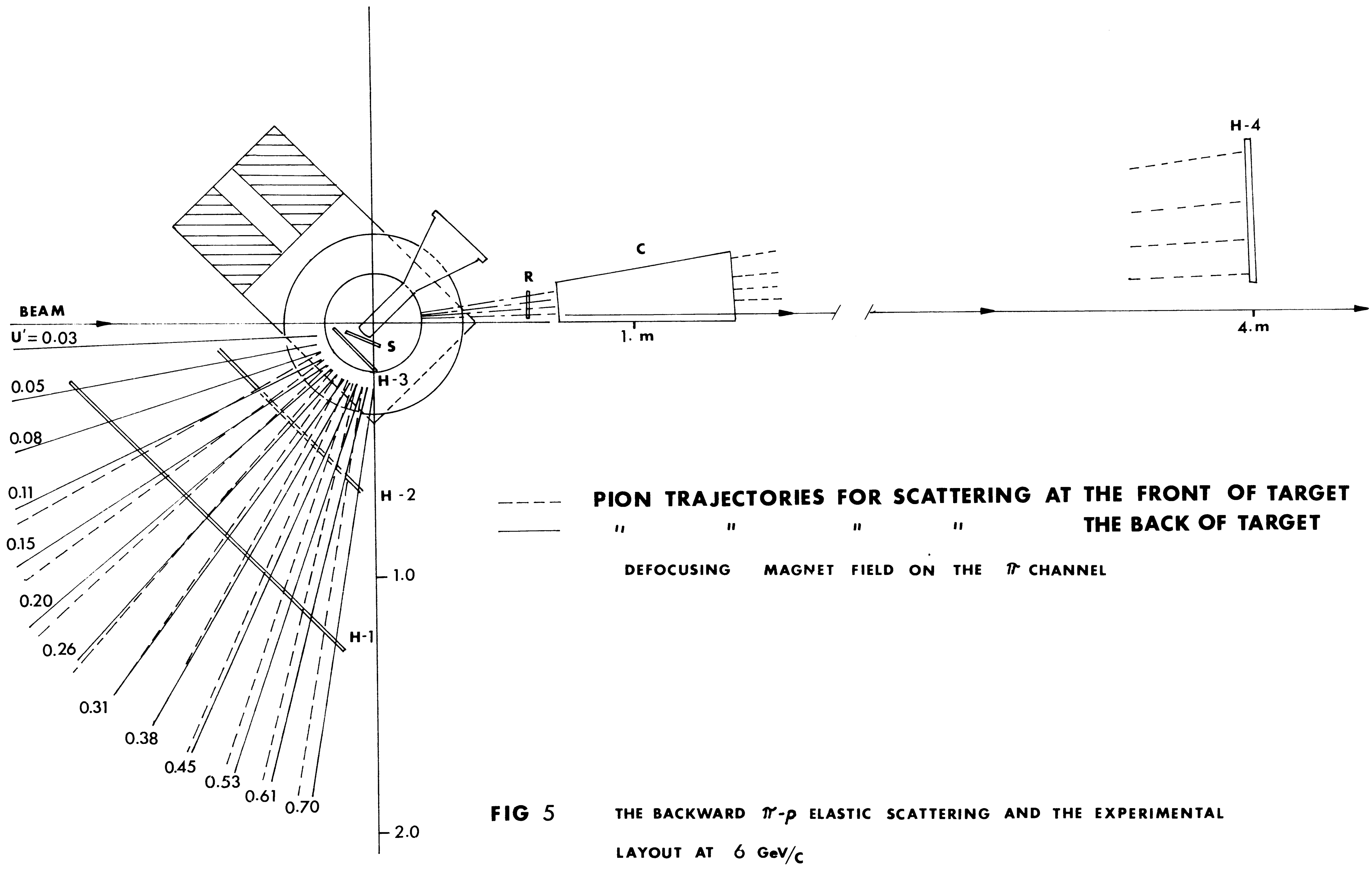


FIG 5 THE BACKWARD π-p ELASTIC SCATTERING AND THE EXPERIMENTAL LAYOUT AT 6 GeV/c

$\pi^- p \rightarrow p \pi^-$

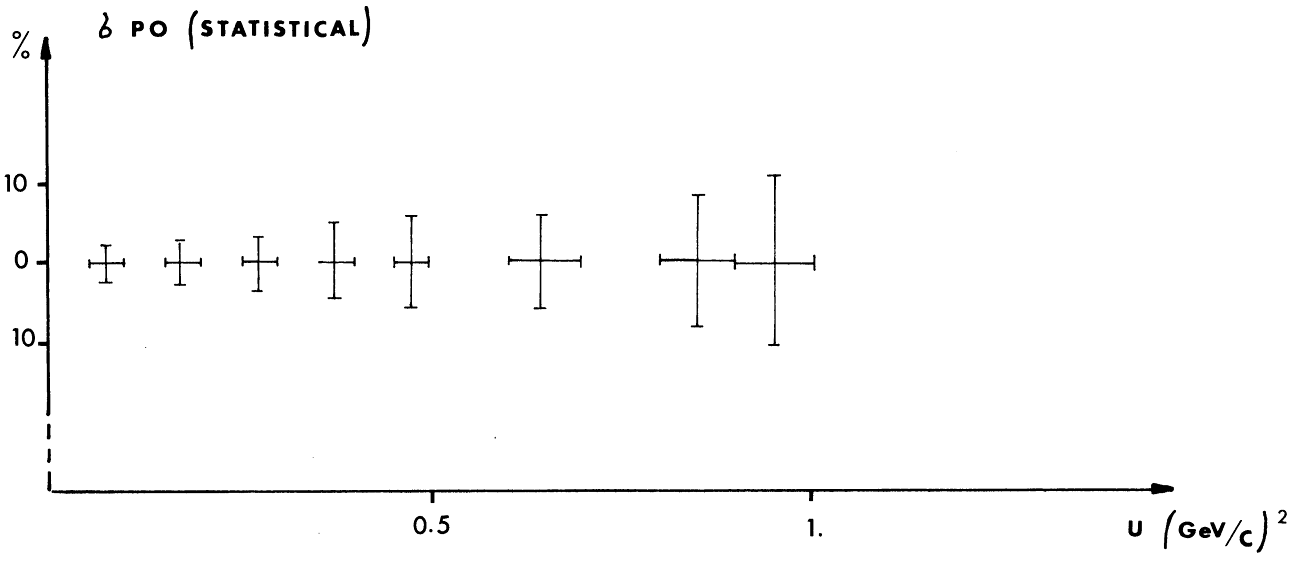


FIG 6a

$\pi^+ p \rightarrow p \pi^+$

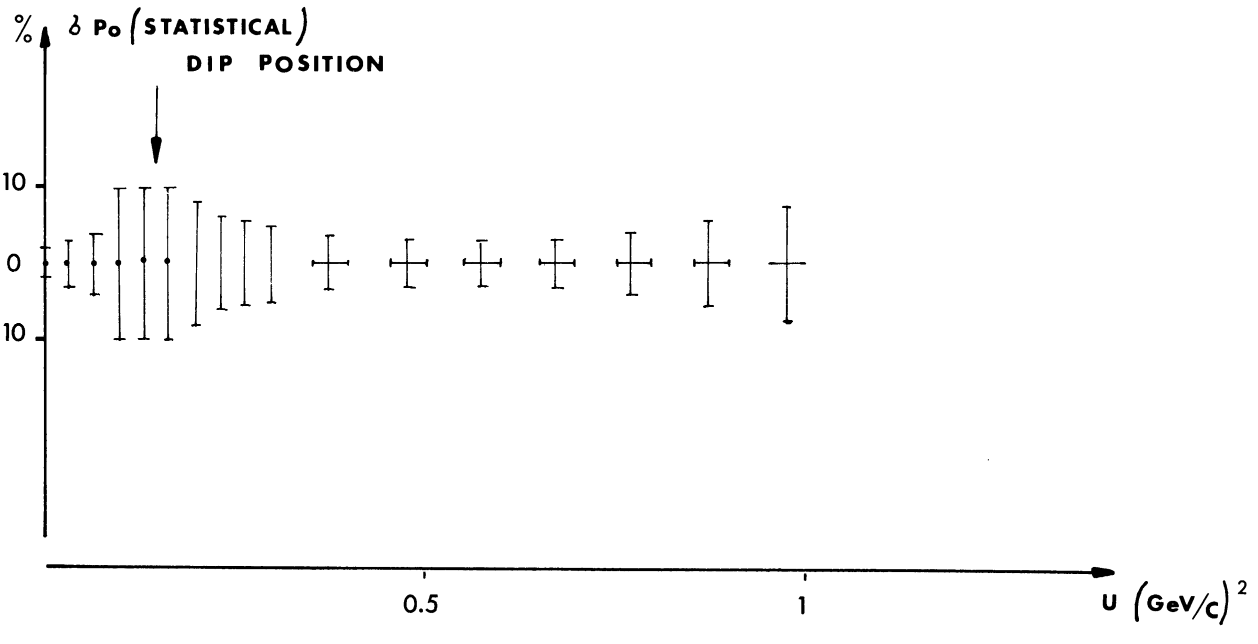


FIG 6b