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PHYSICS I

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# PROPOSAL TO STUDY LARGE-ANGLE Kp AND πp SCATTERING

by

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## 1. PROPOSED REACTIONS TO STUDY

We refer to our Letter of Intention[1] where we propose to study the following reactions, in order of priority:

| Reaction | Momentum GeV/c | Momentum transfer range $(GeV/c)^2$ | Geometry number |
|---|---|---|---|
| $K^{\pm}p \rightarrow pK^{\pm}$ | 8, 10, (15) | $-1 \lesssim u \lesssim 0$ | 1 |
| $\pi^{-}p \rightarrow p\pi^{-}$ | 6, 8 | $-4 \lesssim u \lesssim -1$ | 2 |
| $\pi^{-}p \rightarrow p\pi^{-}$ | 10, 15 | close to 180° | 3 |

The three geometries are shown in Fig. 1.

In addition, we may get as by-products to the above reactions:

| | |
|---|---|
| $\pi p \rightarrow pM$ | backward production of mesons |
| $\pi p \rightarrow YK$ | associated backward production |
| $Kp \rightarrow pK^{*}$ | backward production of mesons |
| $Kp \rightarrow Y\pi$ | production of hyperons |
| $K^{\pm}p \rightarrow K^{\pm}p$, $p^{-}p \rightarrow p^{-}p$ | forward scattering (across the second diffraction minimum). |

Our attitude is, of course, to reach first an understanding of the elastic reactions, and then to treat the inelastic channels.

### 1.2 Kp backward scattering

The backward scattering of $K^{\pm}p$ was first measured by the CERN-Saclay Group at 3.55 GeV/c [2], where the backward peak in $K^{+}p \rightarrow pK^{+}$ and the very small differential cross-section for $K^{-}p \rightarrow pK^{-}$ were first found. The results are indicated in Fig. 2, where the differential cross-sections at $u = 0$ and at 90° in the c.m.s. are plotted as a function of s. In the experiment we are running at present, we will obtain a value for $K^+p \to pK^+$ at 7 GeV/c. From preliminary analysis the cross-section seems to come out in the neighbourhood of the line for $\pi^+p$ in Fig. 2.

An experiment at BNL is now under way to measure $K^{\pm}p \to pK^{\pm}$ in the momentum range 1 to 3 GeV/c. As can be seen from Fig. 2, this is in the threshold region for the onset of the exchange mechanism. To our knowledge there is no high-energy experiment planned to study backward Kp scattering.

### 1.3 <u>$\pi p$ backward scattering</u>

The data on $\pi p$ scattering from the BNL-Cornell Group have been presented[3]. Their results for $\pi^-p \to p\pi^-$ are shown in Fig. 3. No other data will be available from this experiment since it has been removed from the experimental floor. The BNL-Cornell Group plans to measure the reaction $\pi^-p \to n\pi^0$ later this year.

We have focused our attention on three obviously outstanding problems in the case of $\pi^-p \to p\pi^-$ scattering:

i) We believe that there is a maximum in the differential cross-section at $u \sim -1.5$ $(GeV/c)^2$ which decreases with s (see Fig. 3). We would like to ascertain whether this maximum is there, and how it varies with s.

ii) Two different groups have measured the differential cross-section near 180°[3,4] at an incident momentum around 8 GeV/c. The results are controversial: one group finds a turnover in the differential cross-section, whereas the results from the other experiment give no such indication.

iii) In the region $-0.5 < u < 0$ $(GeV/c)^2$ existing data show irregularities, and the existence of dips cannot be excluded.

Finally, we would like to point out that the reaction $\pi^+p \to p\pi^+$ has not been well measured for $u \lesssim -1$ $(GeV/c)^2$. One may also question whether in this case there is a maximum at $u = -1.5$ $(GeV/c)^2$ which cannot be ruled out by the present data.

### 1.4 Inelastic reactions

We would like to mention here three different reactions:

i) $K^- p \rightarrow \Sigma^+ \pi^-$

This reaction is known to have a backward differential cross-section of the same magnitude as the backward elastic scattering $\pi^- p \rightarrow p\pi^-$ at lower incident momenta[5].

ii) $\pi^- p \rightarrow \rho^- p$

This reaction is known to have a backward differential cross-section of the same magnitude as the backward elastic scattering $\pi^- p \rightarrow p\pi^-$ at 8 GeV/c [4]. Our large aperture can give information on the decay distribution of the $\pi^-$ from the $\rho^-$ decay.

iii) Associated production:

$$\pi p \rightarrow \Sigma K .$$

From an experiment at CERN[6] it is known that the associated production $\pi^- p \rightarrow \Lambda K$ has a backward peak with a differential cross-section of about 1 $\mu b/(GeV/c)^2$ at 7 GeV/c.

## 2. EXPERIMENTAL SENSITIVITY

As a result of the experimental runs we have had to date, we have found that we can determine the elastic differential cross-section down to our present statistical limit (about 10 nb/sr for $\pi^+ p \rightarrow p\pi^+$) without being confused by inelastic processes. This should also be valid for other two-body reactions. So far we have used primary intensities of $10^5$ particles per burst in the $p_1$ beam. With an improved duty cycle we can increase the primary intensity. We also plan to rely on the hodoscope information in the incident beam, which again should make it possible for us to use higher intensities.

## 3. EXPERIMENTAL APPARATUS

Our experimental apparatus is at present being used in a production run in the $p_1$ beam in the East Hall. It consists of three wire spark-chamber telescopes surrounding a liquid-hydrogen target. In addition, there is a fourth telescope after an analysing magnet. The chambers are equipped with core read-out, and at present a total of about 14,000 cores are read out. The information from the wire spark chambers are read into an IBM 1800 computer, together with information from scalers and hodoscopes in the incident beam. The spark chambers are triggered with a system of scintillation and Čerenkov counters.

We foresee the following major changes:

i) Construction of a few larger spark chambers with an effective area of $0.8 \times 1.5$ m$^2$ for the telescope after the analysing magnet to increase our aperture.

ii) Recording of time-correlations between the scintillation counters. This would be particularly useful for measuring the velocities of the relatively slow, backward K mesons. These K mesons have a time-of-flight of more than 5 nsec from the target to the trigger counter.

iii) Inclusion, at a later stage, of a K-decay detector, which would make it possible to go to higher intensities. At an earlier date, some of us have operated a spark chamber experiment with $2 \times 10^6$ incident particles per burst[7)].

## 4. DATA HANDLING

The following tasks will be delegated to the IBM 1800.

i) Checking and monitoring spark chambers, hodoscopes, and counters. The size of the system (~ 30 spark chamber planes, ~ 5 hodoscope planes, ~ 40 counters) dictates a thorough supervision of each element, which can be most conveniently done by the computer. The IBM 1800 provides event-by-event indication of those errors that are immediately recognizable (e.g. unphysical wire numbers), and accumulation of data for error checking on a statistical basis (e.g. "core maps"). For the convenience of error tracing, several dump facilities are provided.

ii) Determination of experimental parameters. Efficiency and resolution for the different spark chamber and hodoscope planes are of interest, as well as beam position and beam shape. The computer can also provide some information on the coordinates, or at least check the supplied data for consistency.

iii) Analysis. Although we will not attempt a final analysis on a statistically significant sample of data on-line, we think it is of great interest to do some on-line analysis of a reasonable number of events, since only a successful reconstruction can provide the final test of the proper working conditions of the experiment. We have already some experience in vertex finding, and intend to investigate soon the on-line momentum determination by magnetic deflection. We will finally have to draw the line at error propagation with its associated inversion of big matrices. We are aware of the fact that for the detection of some systematic errors a more thorough evaluation should be done. We would be interested in using a data-link to one of the big machines, which we believe is the only way of providing ourselves with the necessary memory and computing power for a thorough error analysis.

All of the above-mentioned IBM 1800 programs are designed to be compatible with simultaneous buffering and tape-writing of experimental data. At least 20 events/burst can be accommodated.

For the final analysis we foresee the following change: the first phase of the analysis (which is concerned with track finding or pattern recognition) can be separated from the rest, and run off-line on the IBM 1800 during the normally long periods between experimental runs at the PS. Since this phase can be programmed in integer arithmetic, the IBM 1800 is not significantly slower than the big machines, but the work load taken away from them and shifted to an otherwise idling computer might be appreciable. The fitting program can only be run on the big machines; but it will also run faster, since all those events, which cannot be fitted because of insufficient track information, will no longer be contained on the input tape.

On the big machines we will also have to run some Monte Carlo programs for the optimization of geometries and for the evaluation of efficiencies, while we can Monte-Carlo-generate test-tapes for debugging and timing on the IBM 1800.

## 5. PREDICTED RESULTS

The geometries we have chosen were optimized by using a Monte Carlo program to evaluate event rates and the influence of background. We have estimated the cross-sections according to phenomenological models.

In the case of $K^+p \to pK^+$ we have assumed that the differential cross-sections at u = 0 follow the $\pi^+p$ line in Fig. 2. As to the angular distributions, we reason as follows: The underlying mechanism is probably hyperon exchange. Being of short range, the resulting angular distributions should be wider than for forward processes where meson exchange dominates. $\pi^-p$ backward scattering is typical, while $\pi^+p$ has a dip in the angular distribution due to an accidental zero in the scattering amplitude at u = -0.2, which makes the very backward peak extremely sharp. $K^+p$ is not expected to have such a zero, and we have therefore assumed that the angular distributions are similar to those for $\pi^-p$. Under these very tentative assumptions we have calculated the results of 100 hours running time at each momentum. They are given for geometry 1 in Fig. 4.

In the case of $K^-p \to pK^-$ we do not offer any guess. From the $K^+p \to pK^+$ curves we estimate that if the cross-section for $K^-p \to pK^-$ is a few per cent of $K^+p \to pK^+$, we should observe this process.

Geometry 1 is also suitable for high-energy $\pi^-p \to p\pi^-$ scattering up to momentum transfer u = -3, as seen in Fig. 4 (15 GeV/c curve).

Turning now to the maximum in $\pi^-p \to p\pi^-$ at u ~ -1.5, we give results of Monte Carlo calculations for the second geometry in Fig. 5.

Finally, the third geometry would give us the results in Fig. 6.

## 6. PROPOSED RUNNING SCHEDULE

Geometry 1

| | | |
|---|---|---|
| $K^+p \rightarrow pK^+$ | 8 GeV/c | 100 hrs |
| | 10 " | " |
| | (a run at 12-15 GeV/c if the PS is run at $\geq$ 25 GeV/c) | |
| $K^-p \rightarrow pK^-$ | 8 GeV/c | 100 hrs |
| | 10 " | " |
| $\pi^-p \rightarrow p\pi^-$ | 15 " | " |

Geometry 2

| | | |
|---|---|---|
| $\pi^-p \rightarrow p\pi^-$ | 6 " | " |
| | 8 " | " |

Geometry 3

| | | |
|---|---|---|
| $\pi^-p \rightarrow p\pi^-$ | 8 " | " |
| | 10 " | " |
| | 12 " | " |
| | 15 " if the PS is run at 25 GeV/c. | |

One should bear in mind that at the same time we collect information on inelastic processes, as discussed previously. We would like to defer to a later date an assessment of the results we may obtain for these reactions, which of course depends on the mass resolution in the chosen experimental set-up.

## REFERENCES

1) PH I/COM-68/2, 25 January 1968.

2) J. Banaigs et al., Physics Letters 24B, 317 (1967).

3) J. Orear et al., Topical Conference on High-Energy Collisions of Hadrons, CERN (January 15-18 1968) (to be published).

4) D. Edelstein et al., Proc.Int. Conference on Elementary Particles, Heidelberg (1967).

5) Birmingham, etc., Collaboration, Phys.Rev. 152, 1148 (1966).

6) M. Pepin et al., Physics Letters 26B, 35 (1967).

7) P. Blackall et al., Physics Letters 16, 336 (1965).

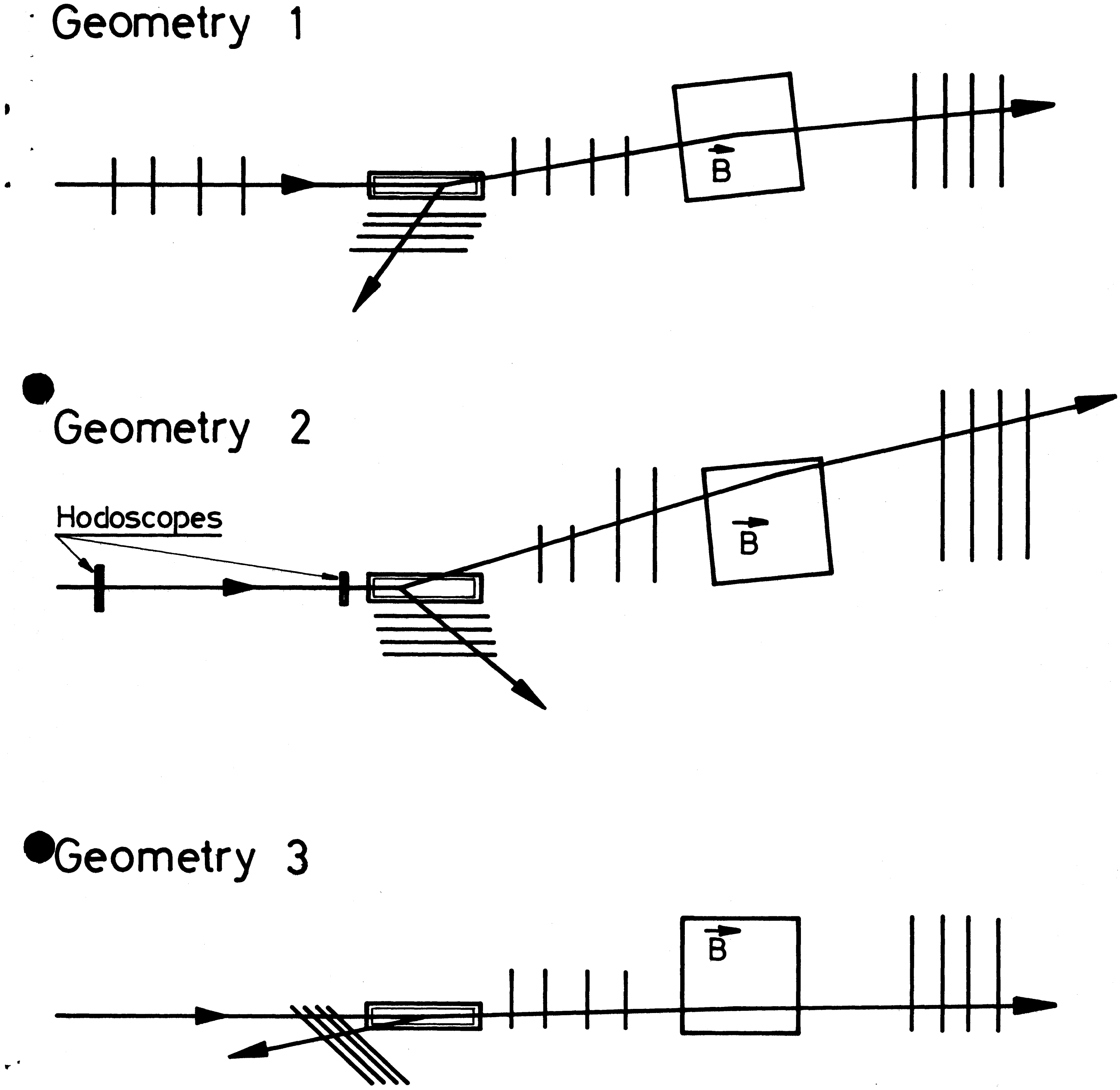



Fig. 1

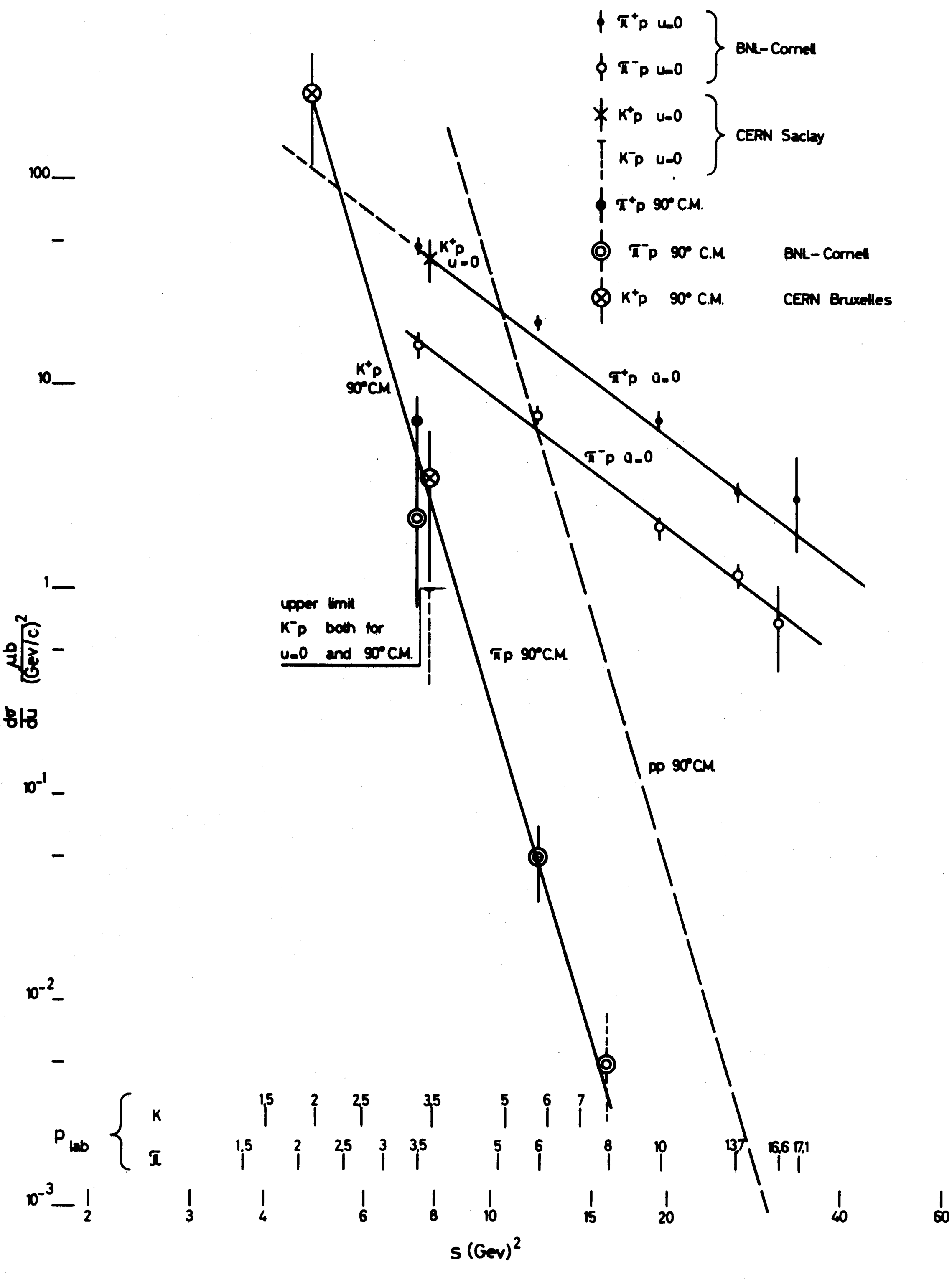
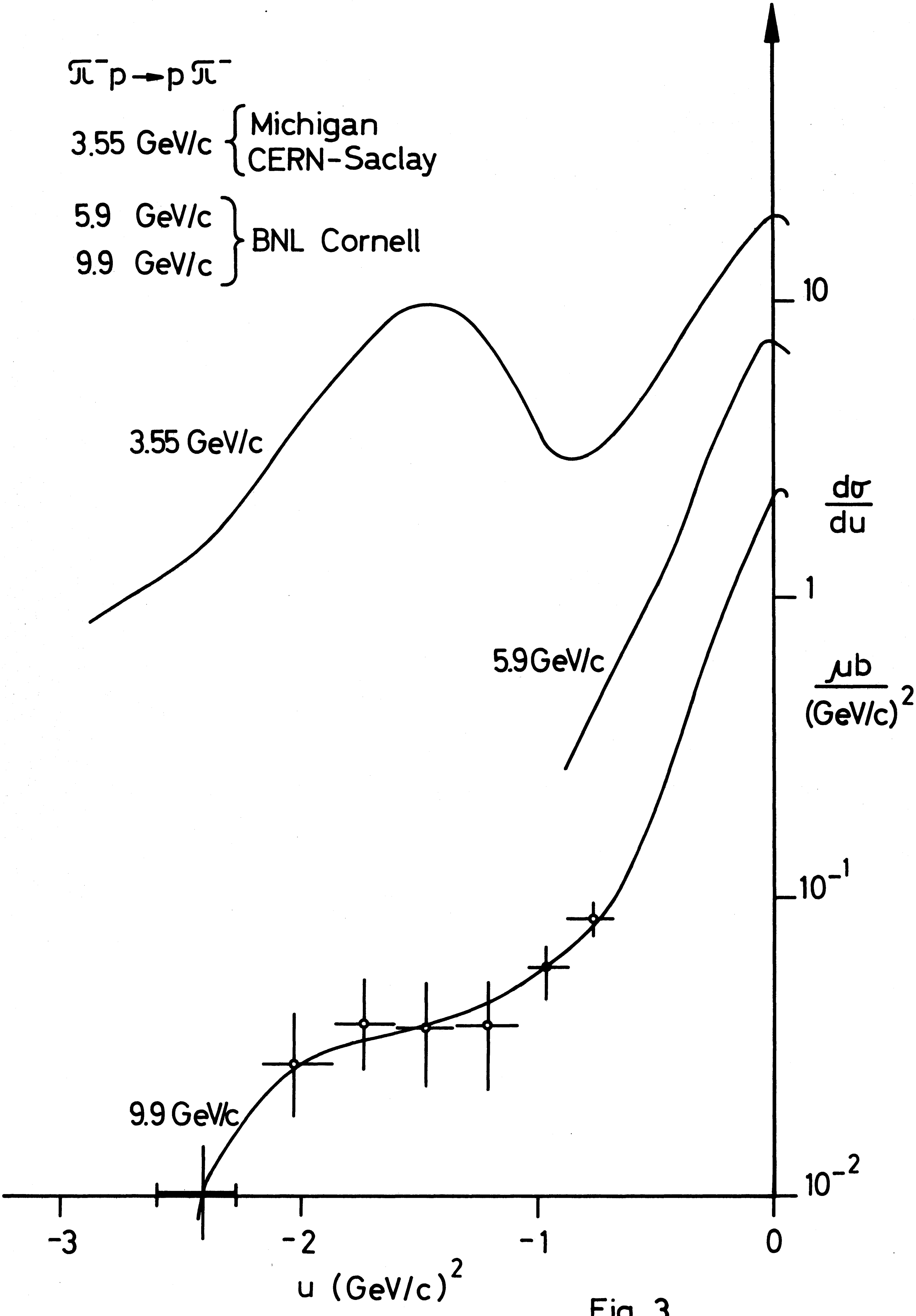


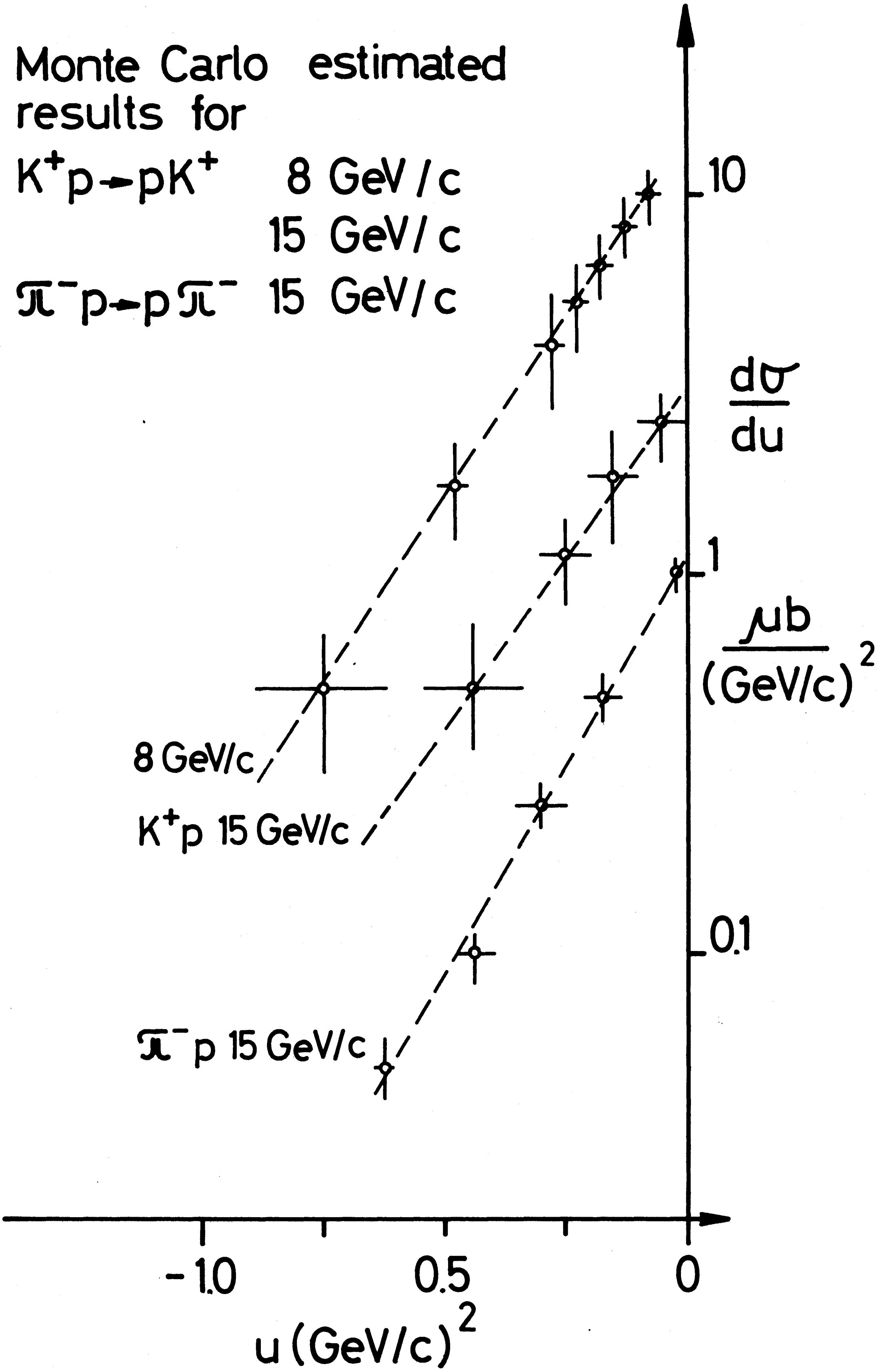

Fig.2 Log. $\frac{d\sigma}{du}$ vs log(s)

DIA 32746



π⁻p → p π⁻
3.55 GeV/c { Michigan
CERN-Saclay
5.9 GeV/c
9.9 GeV/c } BNL Cornell
3.55 GeV/c
5.9 GeV/c
9.9 GeV/c
10
1
10⁻¹
10⁻²
dσ/du
μb/(GeV/c)²
-3
-2
-1
0
u (GeV/c)²


Fig. 3



Monte Carlo estimated results for
K⁺p → pK⁺ 8 GeV/c
15 GeV/c
π⁻p → pπ⁻ 15 GeV/c
10
1
0.1
dσ/du
μb/(GeV/c)²
8 GeV/c
K⁺p 15 GeV/c
π⁻p 15 GeV/c
-1.0
0.5
0
u (GeV/c)²


Fig. 4

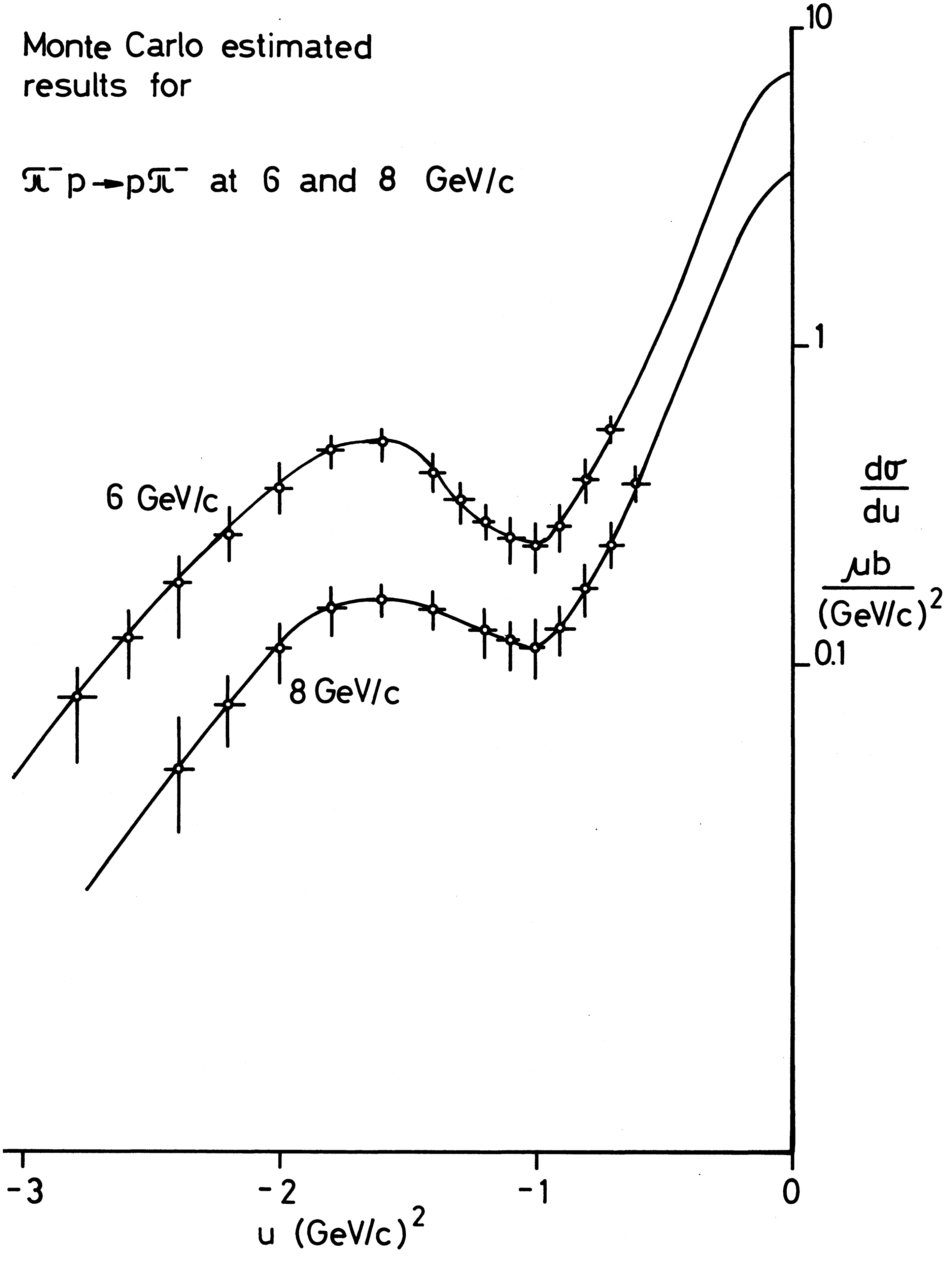

Monte Carlo estimated results for
$\pi^- p \rightarrow p \pi^-$ at 6 and 8 GeV/c
6 GeV/c
8 GeV/c
10
1
0.1
$\frac{d\sigma}{du}$
$\frac{\mu b}{(GeV/c)^2}$
-3
-2
-1
0
u $(GeV/c)^2$

Fig. 5

Monte Carlo estimated results for

$\pi^- p \to p \pi^-$ at 8, 12 and 15 GeV/c

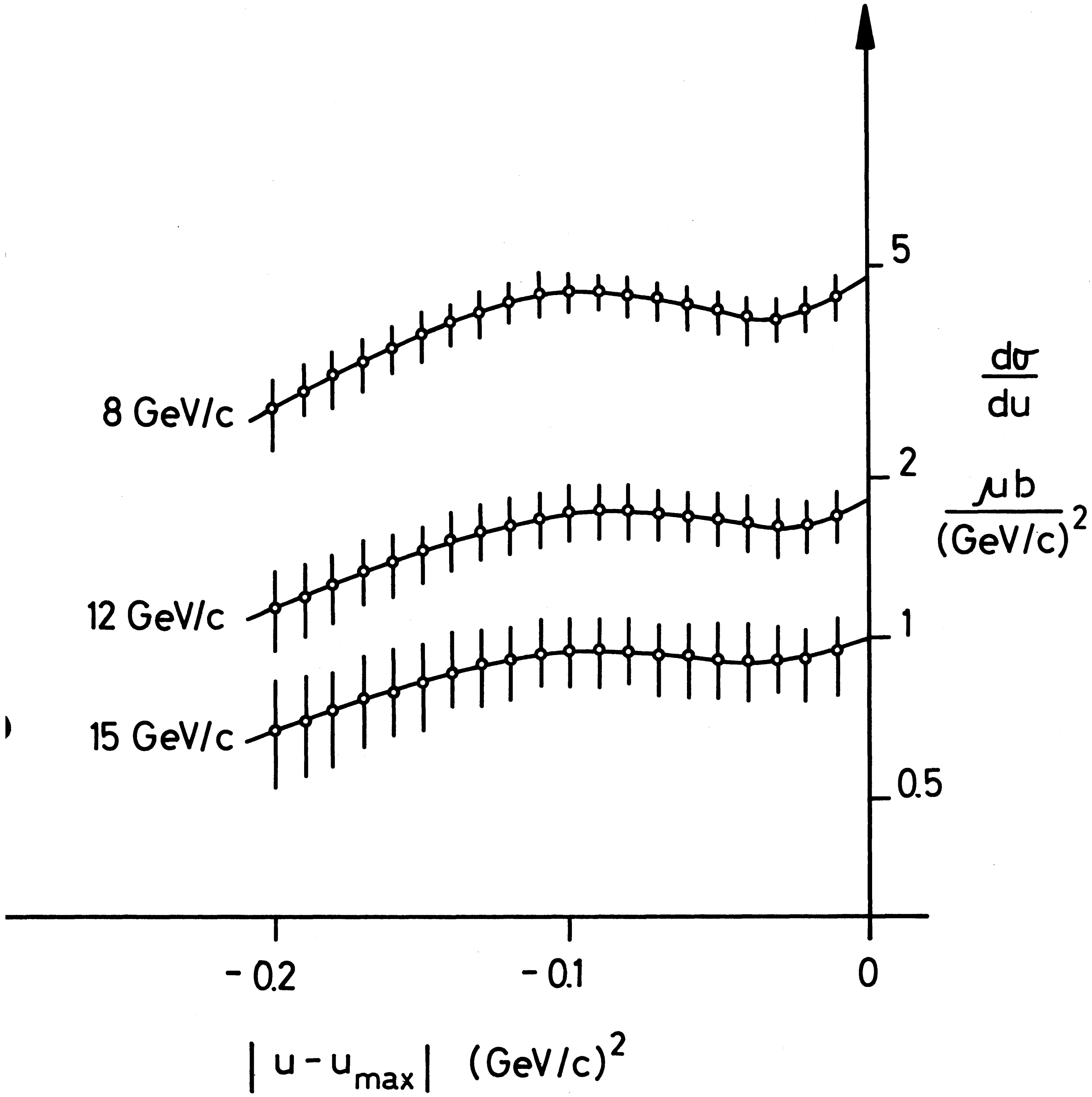



Fig. 6