EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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PHYSICS I

ELECTRONICS EXPERIMENTS COMMITTEE

LARGE MOMENTUM-TRANSFER SCATTERING (Experiment S53)

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P. Fleury, D. Hartill, R. Kalbach, A. Lundby,
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In this short report we present some characteristics of our experiment and some preliminary results. We believe that the experiment is now running very satisfactorily, with an extensive on-line monitoring and analysis of the data.

We have made a preliminary analysis of a part of the data which we have collected on $K^{\pm}p$, $\pi^{\pm}p$, and $\bar{p}p$ backward and near-forward scattering. Table 1 contains information on the energies and momentum-transfers we have covered, and in Table 2 is indicated the time we have used in setting up the beam and running the experiment. We have chosen first to analyse the $K^{+}p$ and $\pi^{+}p$ backward data, and conclude the following.

$K^{+}p$ has a backward peak at 7 GeV/c with a differential cross-section $(d\sigma/du)_{u=0} \simeq 3\ \mu b/(GeV/c)^2$. Together with data at lower momenta (see Fig. 1), the variation with s is roughly $(d\sigma/du)_{u=0} \propto s^{-3}$, which is faster than that for $\pi^{\pm}p$. We call attention to the fact that the hyperon Regge trajectories run lower than the nucleon trajectories. The intercept at u=0 of, for example, the Λ_{α} trajectory is roughly at $\alpha \simeq -0.5$, which would give $(d\sigma/du)_{u=0} \propto s^{2\alpha-2} = s^{-3}$. During the next run we intend to make a measurement at 5 GeV/c in order to verify this relationship.

The slope of the backward peak in $K^{+}p \to pK^{+}$ (see Fig. 2) seems to be somewhat steeper than that for $\pi^{-}p \to p\pi^{-}$, but by no means as steep as $\pi^{+}p \to p\pi^{+}$ (see Fig. 3). In this experiment we cover for the first time in one geometry the region across the dip at $u \simeq -0.2$ for $\pi^{+}p \to p\pi^{+}$, and preliminary results are seen in Fig. 3.

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1. EXPERIMENTAL ARRANGEMENT

Our experimental apparatus is illustrated in Fig. 4. 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 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 (see Appendix B) in the incident beam. The spark chambers are triggered with a system of scintillation and Čerenkov counters as indicated in the figure.

2. DATA HANDLING

Appendix A contains a description of the on-line data-handling facilities with illustrations of some of the outputs. We call attention to Samples 8 and 9 among the illustrations which contain histograms of beam profiles and resolutions of the spark chambers.

A simplified flow diagram for the off-line analysis of the data is shown in Fig. 5. The events are filtered according to some simple criteria, and a two-constraint kinematic fit is made to those events which pass the filter. The elastic scattering events are selected on the basis of the goodness of the fit, together with the momentum measurement of the forward scattered particle.

The amount of computing time used in analysis depends on the quality of the data. An upper limit for the CDC 6600 central processor time required per event is given in the table below:

Filter programme	36 msec
Kinematic fit and momentum determination	260 msec

This means an analysis rate of at least 30 per sec for backward scattering, when the major part of the total computer time used is in the filtering.

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Table 1

Reaction	Momentum	Momentum transfers		Momentum	Momentum transfers	
$K^+p \to pK^+$	7 GeV/c	$-1 \lesssim u \lesssim 0$	$-1.5 \lesssim t \lesssim -0.2$			
$K^-p \to pK^-$	"	"	"	12 GeV/c	$-2 \lesssim u \lesssim 0$	$-2 \lesssim t \lesssim -0.2$
$\pi^+p \to p\pi^+$	"	"				
$\pi^-p \to p\pi^-$	"	"		"	"	"
$\bar{p}p \to p\bar{p}$	"		"	"		"

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Table 2.

Experiment S 53 Large Angle Scattering. Running time obtained.

Date	Cond.	Running time hrs		Work done on the floor
		all.	obtained	
March -67	1/1	300	250	Setup and first operation of a counter beam from an external production target. See NP 67-7
July -67	1/1	130	110	Further beam studies. First operation of a wire chamber telescope on-line.
Sept -67	1/5	28	22	Test of wire chamber telescope
Nov -67	1/5	31	28	Test of wire chamber telescopes
Dec -67	1/1	320	248	datataking
Jan -68	1/1	330	300	datataking
Feb -68	1/1	330	250	datataking

TOSCA - TEST PROGRAM FOR ON-LINE SPARK CHAMBER DATA ANALYSIS

This program is a set of core-loads that are resident on the disk and that can be loaded one at a time into core memory for execution.

TOSCA provides for:

1) reading scalers, parameter and pattern units, scintillation counter hodoscopes, and wire chambers;
buffering these data;
and writing them on magnetic tape for off-line analysis and on the disk scratch area for on-line analysis;

2) several test and analysis functions on the data written on the disk;

3) executing these functions in an off-line mode from data on magnetic tape;

4) simulating elastic scattering events with a random-number generator and writing them on magnetic tape;

5) several utility functions for tape handling and changing parameters used by the test and analysis routines.

The operator directs the activities of TOSCA in two ways:

1) by control cards read by the card-reader;

2) by setting sense, program and data-entry switches.

The following control cards are recognized by TOSCA:

Mode-selecting control cards

1) ∅START - Puts the machine into on-line run mode;

2) ∅ SIMULATION - The simulator is called to generate elastic scattering events using a random-number generator;

3) ∅ PLAYBACK - All test and analysis functions are executed in an off-line mode from magnetic tape;

Control cards that select
test or analysis functions

4) ∅ COREMAP - A counter is kept for each chamber plane and sense amplifier and for each chamber plane and address group. At the end of accumulation, the contents of these counters are printed. Several dump options are under the control of data switches.

5) ∅ BEAM PROFILE - Two histograms are produced representing the horizontal and vertical intensity distribution of the beam.

6) ∅ RESOLUTION - Four histograms are printed from which conclusions can be drawn as to:

the resolution of the spark chambers,
their geometrical alignment,
and the disturbance of track finding by accidentals.

7) ∅ VERTEX - The first steps of an analysis program are executed. The details of the printed output are under the control of data switches.

8) ∅ HODOSCOPES - A hodoscope test program.

9) ∅ MAGNET - A magnet tracking program.

10) ∅ LOOK - Numerical and graphical output concerning spark patterns.

Utility function-selecting control cards

11) ∅ REWIND - The data tape is rewound.

12) ∅ SKIP FILE - A file on the data tape is skipped.

13) ∅ PARAMETERS - Parameters used by the test and analysis core loads are read from data cards.

14) ∅ LABEL - A header record is written on magnetic tape gives a file description of the data which follow.

15) ∅ ENDFILE - An end-of-file is written on magnetic tape (except when in playback mode), no data are admitted from the read-out box (until the next ∅ START card is read).

The sequence in which the control cards are read is not arbitrary, and an interlock system is provided to avoid operator errors. It is necessary to read the parameters before any test or analysis function can be executed. Every file on magnetic tape should start with a header record and end with an end-of-file mark.

There is a 16th control card - $ CONTINUE; its action is the same as that of $ START (it puts the machine into on-line run mode), but it by-passes the interlock-system, and is used only in cases of hang-ups, when the file label has been written and the parameters are read.

Several sample print-outs which are enclosed illustrate the action of the different control cards and data switches.

Sample 1 is the listing of a deck of cards, on which parameter data are punched.

If this deck is read following the control card $ PARAMETERS, the print-out shown in sample 2 will be produced, and parameter information will be stored in a common region that is available to all core-loads.

Sample 3 shows a print-out of the dump routine.

NTA is the trigger number (A for absolute, the corresponding count is reset only when a file label is written on magnetic tape). The next word is the count of all data words transmitted for that trigger. The first 16 words read, representing parameter unit, scaler, and pattern unit data, are printed in hexadecimal; the following words should be hodoscope or spark chamber data; they are unpacked into plane addresses and wire numbers (or element numbers) and then printed.

The dump routine is always entered when data switch 14 is up; it is entered only in case of errors if sense switch 13 is up.

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Since the 16 hexadecimal words are somewhat difficult to interpret, the scaler and pattern unit data are also available in another form, shown in sample 4. To get this print-out, control card ∅ COREMAP must have been read and data switch 12 must be up.

The mnemonics used have the following meaning:

S	scintillation counter beam
SUR	S, ungated, random
SU	S, ungated
BK	K beam
BKR	K beam, random
T	time (in 100 μsec since beginning of burst)
N	burst number
B	beam
ENA	event, no antis
ERA	event, random antis
R01 to R10	right trigger (fence) counters
L01 to L12	left trigger (fence) counters
C1,C2,C3	Čerenkov counters
AB	anticoincidence counter around the beam
AS	anticoincidence counters around the spark chambers
AT	anticoincidence counters around the target.

Sample 5 shows the print-out which occurs at the end of a COREMAP run. NT is the number of triggers accumulated, the other mnemonics are the same. The numbers which are printed refer only to those scalers that are reset after reading; the accumulating counters are kept in the 1800. The pattern units have counters for each bit.

For the accumulation of the core-map a counter is kept for each chamber plane and address group, and for each chamber plane and sense amplifier.

At the end of a core-map run, first the contents of the counters referring to address groups, then the contents of the counters referring to sense amplifiers are printed. Failures of individual cores will not be found, but sense amplifier or address driver defects will become apparent.

Most of the test and analysis programs attempt track finding: a group of three or four sparks in three or four different parallel telescope planes that lie on a straight line within the resolution of the chambers is considered to be a track. A spark might correspond to one core and one data word, or to several adjacent cores and several data words.

Sample 6 shows the print-out that occurs during track-finding if data switch 1 is up.

The number of sparks found in each of the 32 chamber planes is printed on the left, the wire number of the spark centre times 2 is printed on the right.

The print-out shown in sample 7 is produced if data switch 2 is up. For each track found is printed:

L the number of the telescope

K (=1 for planes measuring an x-coordinate -- with vertical wires;
 = 2 for planes measuring y-coordinate -- with horizontal wires)

J a code number [=5 for 4 spark tracks,
 =N(N=1, 4) for tracks without a spark in plane N].

Then follow the x- or y-coordinates of the sparks contributing to the tracks, which are 0 if there is no spark in a plane (0 can also be a legitimate spark coordinate -- which it is -- and can be found out by looking at J).

The output from a beam profile run is shown in sample 8. The first histogram gives the horizontal intensity distribution, the second histogram the vertical intensity distribution. The scale of the abscissa is in millimetres.

PZ = 2800 means that the profile is taken at z = 2800 mm in the laboratory coordinate system. The origin of the abscissa corresponds respectively to x = 0 and y = 0 in the laboratory coordinate system.

The RESOLUTION core-load produces, at the end of accumulation, four histograms shown in sample 9. The scale of the abscissa is one-tenth of a millimetre. The histograms represent the distribution of the sparks in the two inner chambers of a telescope (2 and 3, x and y) around the line through the centre of the sparks in the outer chambers (1 and 4).

The spark chamber resolution can be inferred from the width of the distribution; a high background indicates that there are many accidentals; and if the centre of the distribution does not occur at the origin, it means that there is some inconsistency in the spark-chamber coordinates read from the parameter cards.

Sample 10 shows some print-out from the VERTEX core-load. After successful track-finding in both projections of the three first telescopes, the program looks for a two-prong vertex formed by tracks in telescopes 1 and 2. If the distance between two tracks is less than RPV1 (resolution parameter vertex 1, read by the PARAMETER input subroutine from a data card), it is assumed that a two-prong vertex has been found.

If data switch 3 is up, the vertex coordinates are printed, preceded by R1, the square of the distance between the two tracks (in millimetres).

For each two-prong vertex found, the program proceeds to look for three-prong vertices. The distance between the two-prong vertex and the third track must be smaller than RPV2. If data switch 4 is up, the vertex coordinates are printed, preceded by R2, the square of the distance between the two-prong vertex and the track in telescope 3.

For each three-prong vertex found, the program determines if the vertex is in the target, and if the coplanarity is smaller than RPC.

The print-out of the coplanarity and the final vertex coordinates is under the control of data switches 5 and 6, respectively.

Sample 11 finally shows again a print-out from the VERTEX core-load but with most data switches up at the same time to obtain a print-out from many stages of the analysis.

Magnetic tape output:

The input of data from the experiment and the output on magnetic tape is an interrupt job that has always higher priority than any test or analysis program.

At least 10 events can be input into a buffer, which is (e.g. at end of burst) output on magnetic tape.

One record contains 1700 words, each of which is (after the addition of two half-word parity bits) broken up into three six-bit bytes, that are written (after the addition of another parity bit) on seven-track half-inch tape and 800 bits/inch in odd parity.

These records are read by the 6600 (6400) in FORTRAN (binary) as 510 central memory words.

An Ascent routine then removes the half-word parity bits and unpacks each record into 1700 CM words.

File description records are written in 1800 EBCDIC, and there is another Ascent routine for the conversion into 6600 (6400) printer code.

The same records are written on the first six sectors of the scratch area of the disk, but only if these sectors have been read before by the test and analysis programs.

Most of the arithmetic done on the 1800 is programmed in FORTRAN, and there are only short assembler-language subroutines for the unpacking of words or for double precision integer arithmetic. (The compiler admits extended precision, floating point operations, but restricts integers to 15 bits + sign.)

In addition to input-output, most of the program sequence control is written in assembler language.

Some core-loads do just one job, other core-loads handle several control cards, and there are activities that require two core-loads, e.g. the core-load that accumulates histograms for a RESOLUTION run has not enough space left to output these histograms, and another core-load is called.

Some additions have recently been incorporated into the vertex program.

One gives the deflection angle of the scattered particle and its **energy**, computed under the assumptions that it is a π, a K, and a p.

Another gives the deflection of the proton in the magnet behind telescope 3.

APPENDIX B

HODOSCOPES

In this experiment we are using three hodoscopes with altogether 58 elements of different sizes (hodoscope I contains 12 elements in the x-plane with 3 mm width, 3 mm thickness and 40 mm length; hodoscope II contains 11 elements in the x-plane and 5 elements in the y-plane with 14 mm width, 2 mm thickness, 70 mm and 154 mm length, respectively; hodoscope III contains 12 elements in the x-plane and 20 elements in the y-plane with 3 mm width, 3 mm thickness, 60 mm and 36 mm length, respectively). Hodoscope I at the momentum slit contains only elements to measure horizontal deflections, while hodoscope III at the target and hodoscope II after the incoming beam spectrometer contain horizontal and vertical elements, which allow us to determine the momentum and also the direction of the incoming particles to an accuracy of ±1 mrad. We reconstruct tracks from the hodoscope information and compare them with those found from the incident beam chambers.

The momentum determination of the incident particles by hodoscopes is of the order of $\Delta p/p = \pm 0.3\% \rightarrow \pm 0.4\%$. An on-line program gives us the possibility of checking, during the experiment, the operating conditions of each individual hodoscope element, and also gives us efficiency information for each plane and for the whole hodoscope-telescope. It also prints out beam profiles at various points along the beam line.

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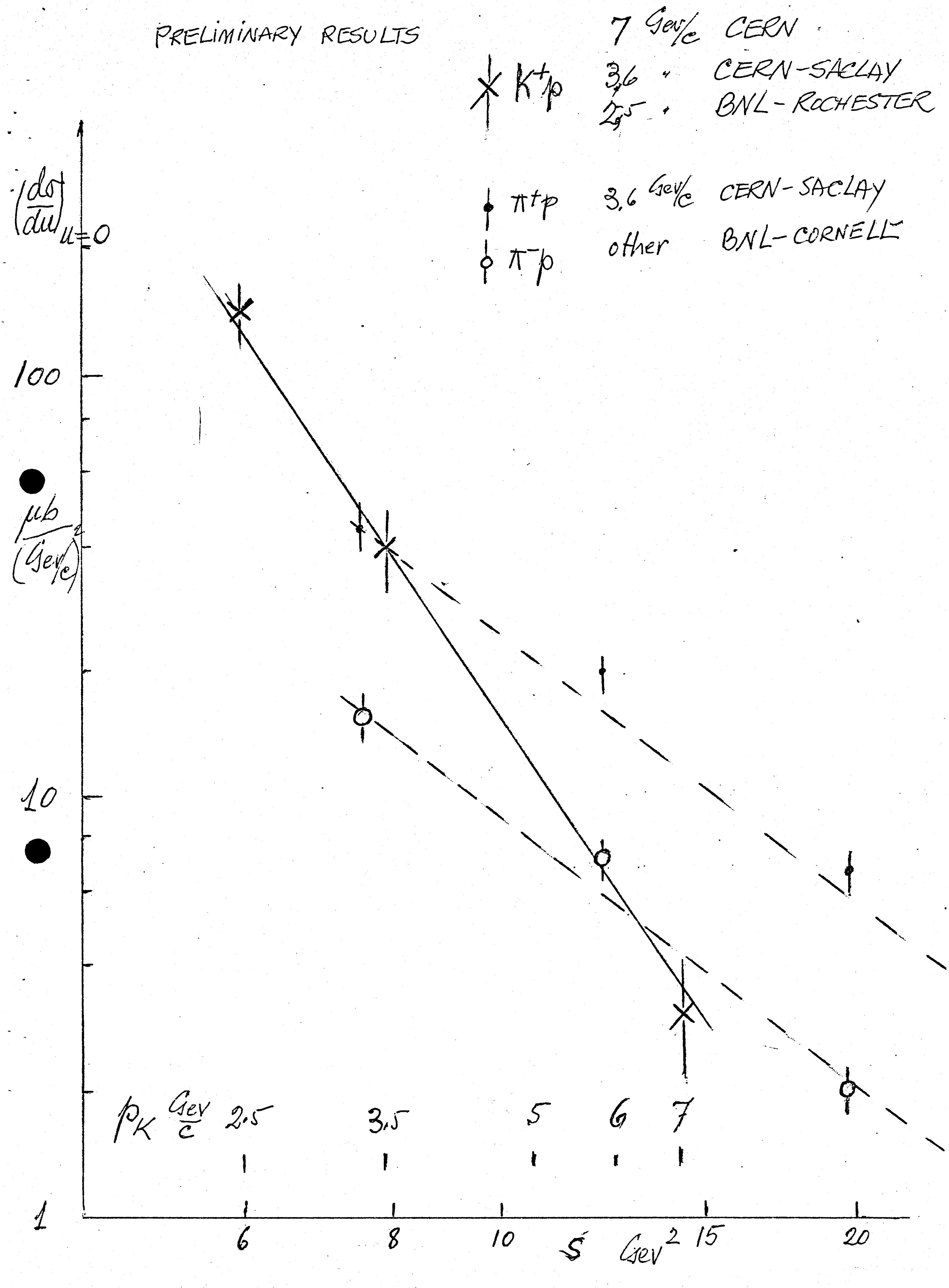

PRELIMINARY RESULTS
7 GeV/c CERN
K+p 3,6 " CERN-SACLAY
2,5 " BNL-ROCHESTER
π+p 3,6 GeV/c CERN-SACLAY
π−p other BNL-CORNELL
(dσ/du)u=0
μb/(GeV/c)²
100
10
1
pK GeV/c 2.5 3.5 5 6 7
6
8
10
15
20
s GeV²

FIG. 1

PRELIMINARY RESULTS

$K^+p \to pK^+$

7 GeV/c.

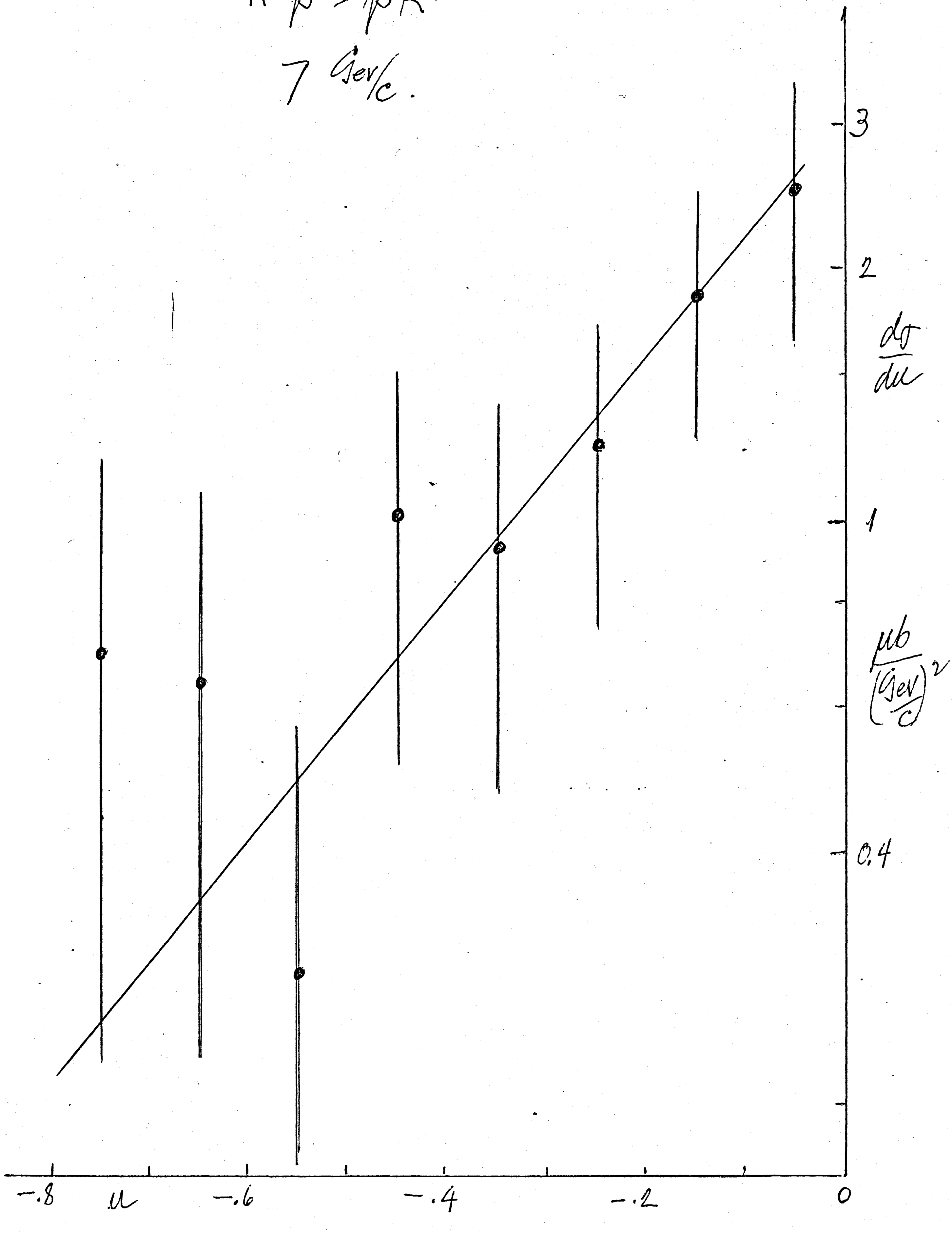


FIG. 2.

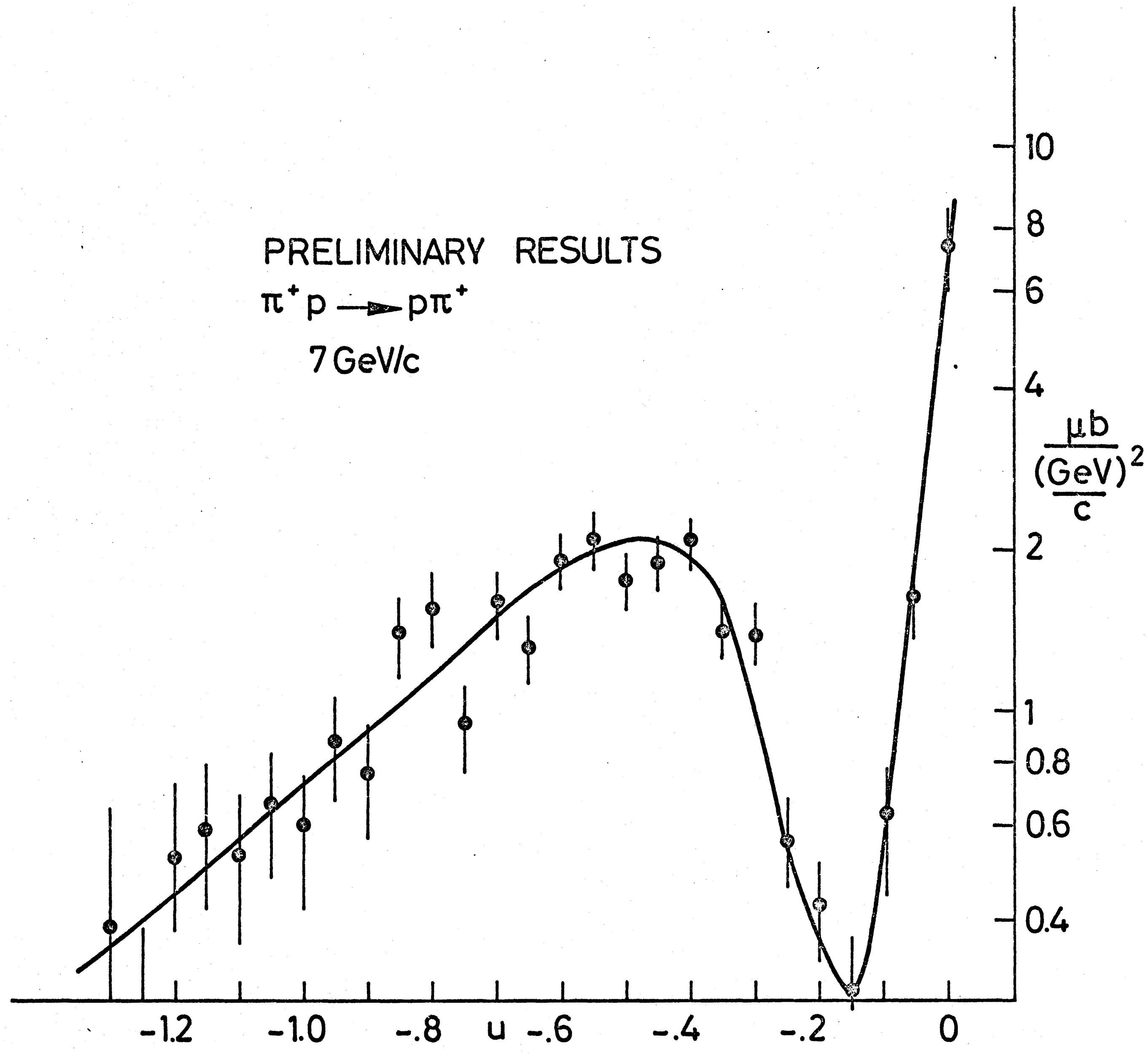
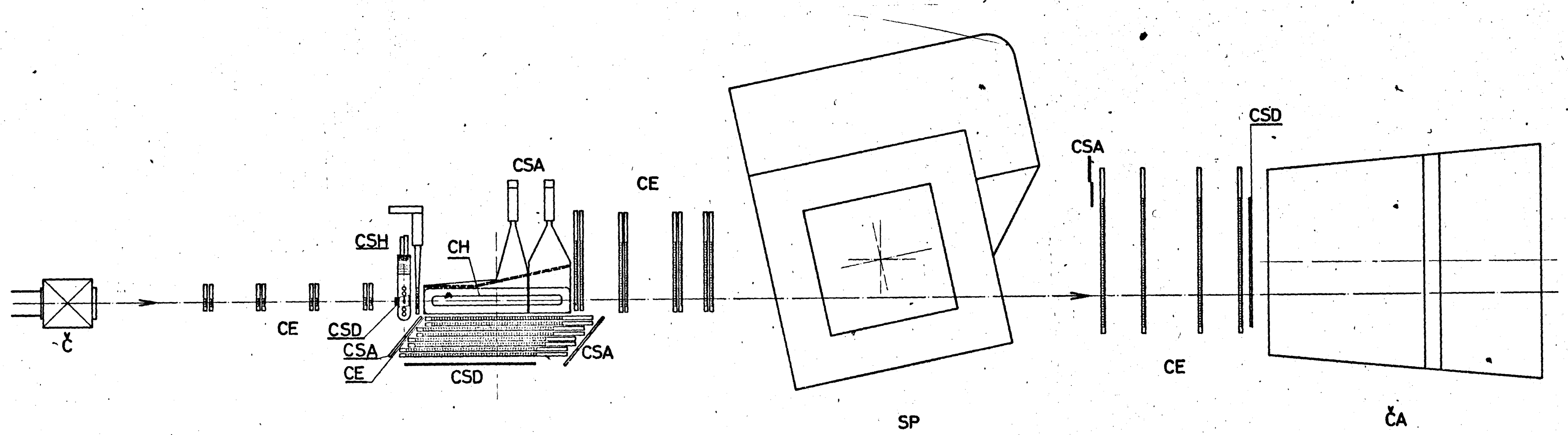

PRELIMINARY RESULTS
π⁺p → pπ⁺
7 GeV/c
10
8
6
4
μb / (GeV/c)²
2
1
0.8
0.6
0.4
-1.2
-1.0
-.8
u
-.6
-.4
-.2
0

FIG.3



Č : Compteur Čérenkov
ČA : Compteur Čérenkov (anticoïncidence)
CE : Chambre à étincelles à fils
CSH : Compteurs à scintillation (Hodoscopes)
CSD : Compteurs à scintillation (déclenchement)
CSA : Compteurs à scintillation (anticoïncidence)
SP : Aimant spectromètre
CH : Cible à hydrogène

Fig. 4.

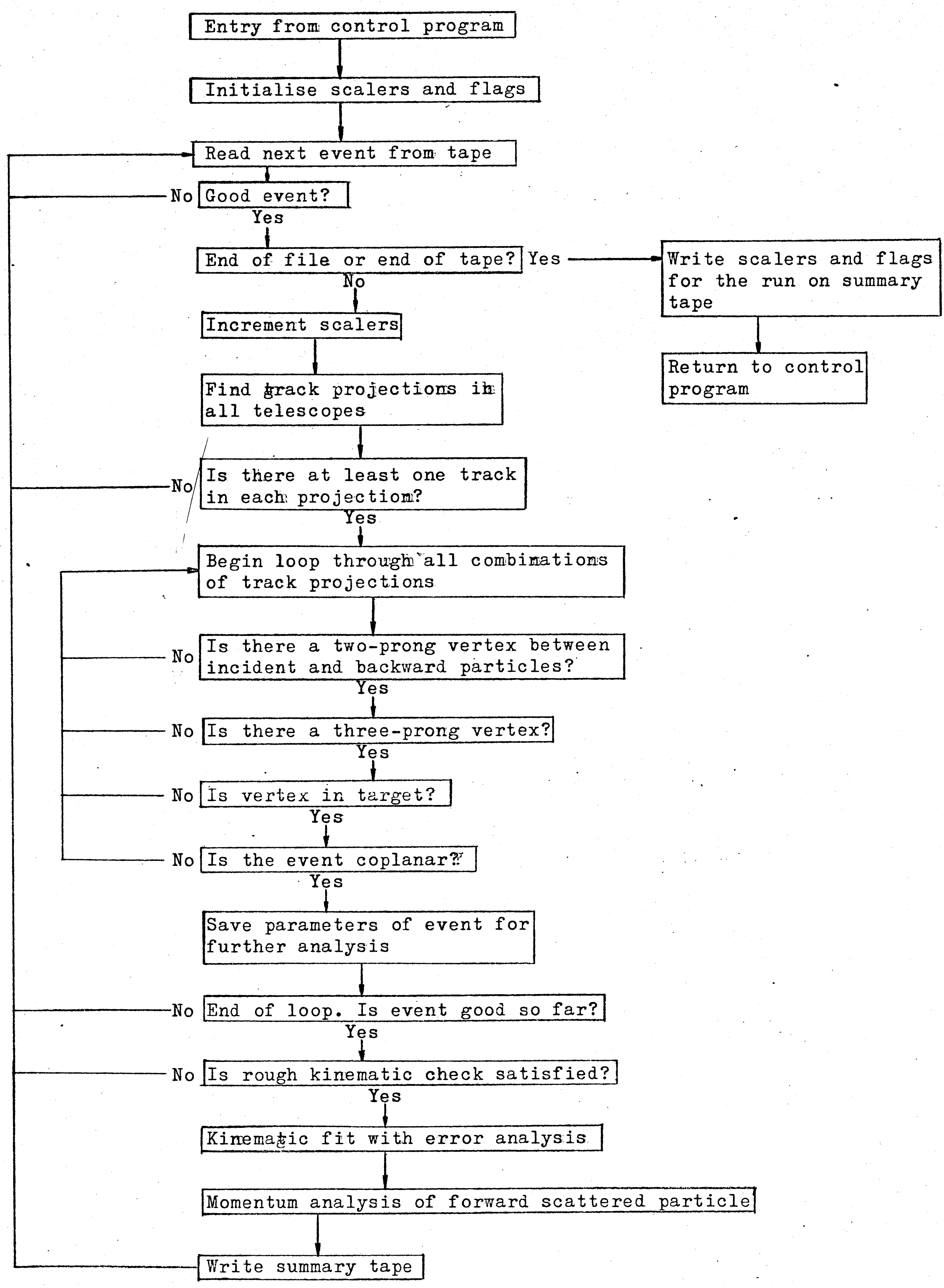
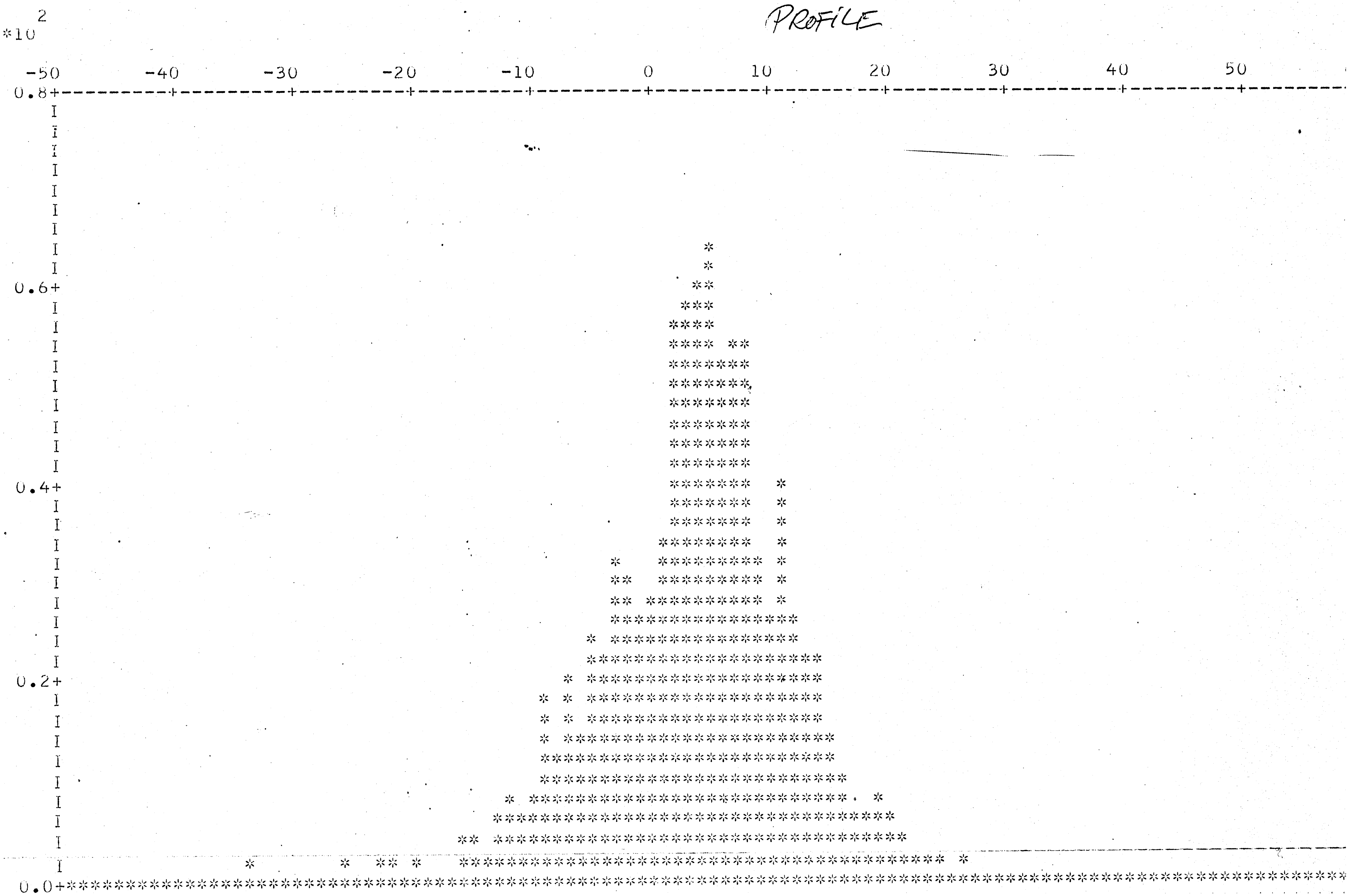
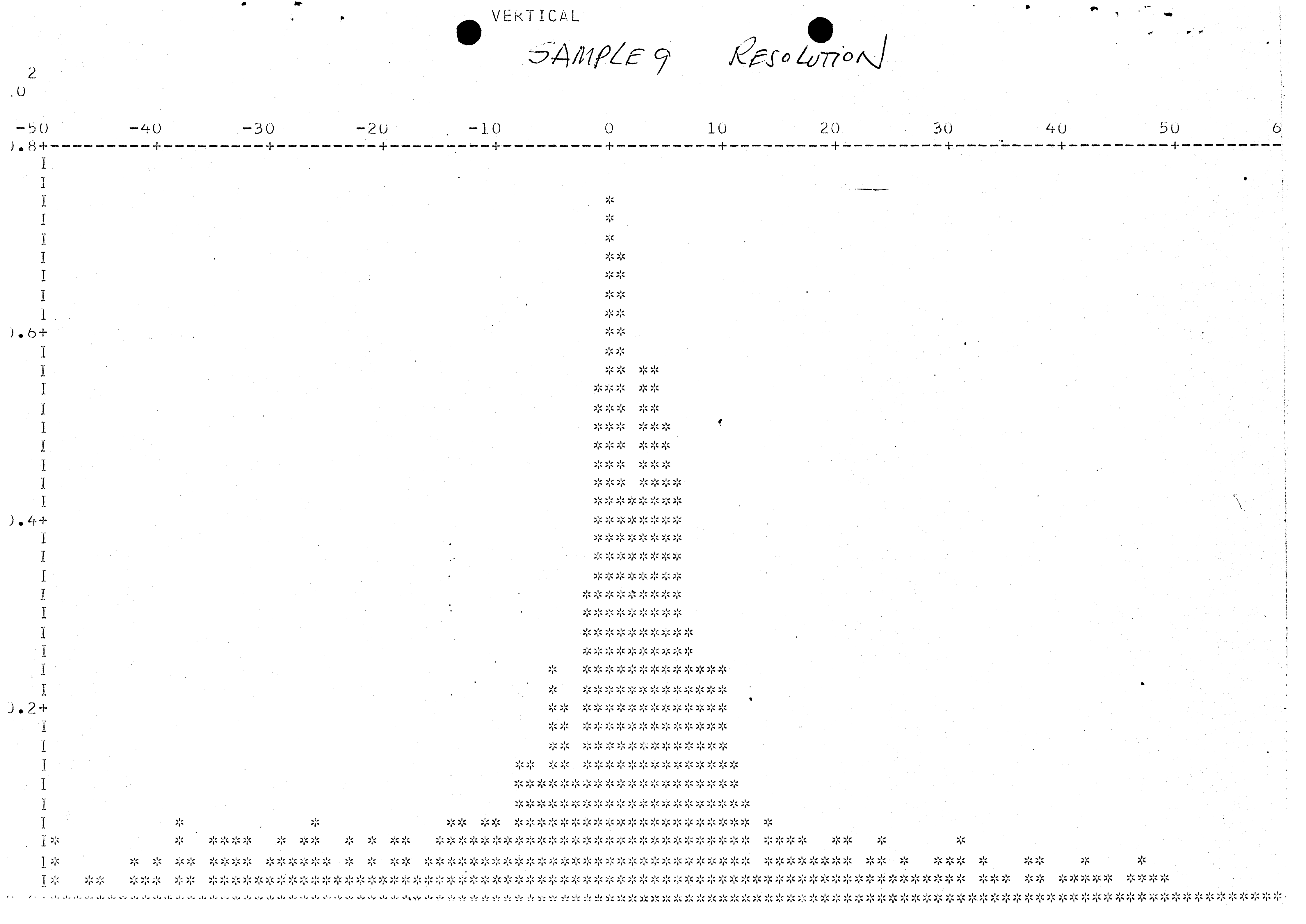

Entry from control program
Initialise scalers and flags
Read next event from tape
No
Good event?
Yes
End of file or end of tape?
Yes
Write scalers and flags for the run on summary tape
Return to control program
No
Increment scalers
Find track projections in all telescopes
No
Is there at least one track in each projection?
Yes
Begin loop through all combinations of track projections
No
Is there a two-prong vertex between incident and backward particles?
Yes
No
Is there a three-prong vertex?
Yes
No
Is vertex in target?
Yes
No
Is the event coplanar?
Yes
Save parameters of event for further analysis
No
End of loop. Is event good so far?
Yes
No
Is rough kinematic check satisfied?
Yes
Kinematic fit with error analysis
Momentum analysis of forward scattered particle
Write summary tape

Fig. 5

NC3 = 0


SAMPLE 8 BEAM
PROFILE
*10^2
-50
-40
-30
-20
-10
0
10
20
30
40
50
0.8
0.6
0.4
0.2
0.0


VERTICAL
SAMPLE 9 RESOLUTION
2
.0
-50
-40
-30
-20
-10
0
10
20
30
40
50
6
).8
).6
).4
).2