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PHYSICS I
ELECTRONICS EXPERIMENTS COMMITTEE

PROPOSAL

for

An Experiment to measure $K^{\pm}$ and $\bar{p}$ scattering on polarised protons in the 1.0 - 5.0 GeV/c region

by

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24.11.1967

To : The E.E.C.

From : S. Andersson, C. Daum, F. Erné, J.P. Lagnaux, J.C. Sens, F. Udo.

Herewith we submit a proposal for an experiment at the PS. The principle features are indicated below.

- It is proposed to measure $K^{\pm}$ and $\bar{p}$ scattering on polarised protons in the 1.0 - 5.0 GeV/c region.

- It is suggested to start with $\bar{p}$ p, 1.0 - 2.0 GeV/c in the short beam from PS target # 8, and to continue with $(K^{-}+\bar{p})$ p and $K^{+}p$ from 2.5 to 5.0 GeV/c in the long beam from target # 8. In this manner for at least part of the experiment PS target # 8 is shared with one of the other proposed experiments for the long # 8 beam; hence this arrangement is to be preferred over other solutions such as using the long # 8 beam (where the usable $\bar{p}$ rate is higher than in the short #8 beam) for the entire experiment.

- It is suggested to incorporate into the experiment the recent advances made in polarised target work and superconducting magnet design. We ask for approval of the construction of a 50 KGauss magnet for this and other future polarised target experiments. Setting up in the short beam with target sharing on # 8 will provide the desired conditions for testing the new equipment under experimental conditions.

NP/161/mk 23.11.1967

PROPOSAL FOR AN EXPERIMENT

To : E.E.C.

From : S. Andersson, C. Daum, F. Erné, J.P. Lagnaux, J.C. Sens, F. Udo.

Re : $K^{\pm}$ and $\bar{p}$ scattering on polarised protons, 1.0 - 5.0 GeV/c

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INTRODUCTION

We propose to extend the previous measurements of the angular distributions of cross sections and polarisations of K^- and $\bar{p}$ elastic scattering on polarised protons.

We propose to measure :

1) K^-p elastic scattering + polarisation in the region 2.5 - 5.0 GeV/c
2) K^+p elastic scattering + polarisation at a few energies in the same momentum region.
3) $\bar{p}$ p elastic scattering + polarisation in the region 1.0 - 5.0 GeV/c.

At present the following counter experiments on polarisations in $K^{\pm}$, $\bar{p}$ scattering in the region of 1.0 - 5.0 GeV/c have been completed or are in progress :

a)	Nimrod	K^-p	1.1 - 1.4 GeV/c	(ready)
b)	CERN	K^-p	1.4 - 2.4 GeV/c	(ready)
c)	Argonne	K^+p	1.0 - 2.0 GeV/c	(scheduled for early 1968)
d)	Brookhaven	K^+p	1.4 - 2.4 GeV/c	(approved)
e)	CERN	$\bar{p}$ p	1.75/3.10/2.40/3.00 GeV/c	(ready)

The proposed experiment is, with several improvements in the experimental technique, a continuation of our earlier work mentioned above.

The K^-p experimental data show clearly the presence of the resonances at 2035 and 2100 MeV; spins and parities of these resonances have been deduced from the data. The smaller elasticities of the resonances at 2260 and 2340 MeV near the upper and of the momentum range covered in the previous experiment complicate the analysis. More data above the resonance energies would provide sensitive constraints in a search for the spins and parities of these resonances. The earlier K^-p work has further more revealed, that at small values of t the polarisation can not be fitted with the parameters of the P, P', ρ, A_2 and ω trajectories, obtained by fitting the Regge pole motel to scattering data at high energy.

The reasons for continuing the K^-p investigation at higher incident momenta are then the following :

1) To clarify the structure in the 2.0 - 3.0 GeV/c region. Apart from the 2260 and 2340 resonances mentioned above there are structures at 2450 and 2595 and possibly others not seen in the total cross section data. The resonances seem to become less and less elastic with increasing momenta, so that the precision of the proposed experiment must be increased over that of the previous experiment.

2) To investigate the behaviour of the polarisation at small t values by continuing the experiment in an energy region where the Regge pole model should become applicable.

It is of interest to compare K^-p with K^+p data because

a) The same trajectories contribute with different combinations of sign; there should thus be a difference between the K^-p and K^+p differential cross sections and polarisations at small values of t.

b) The presence of many resonances in the K^-p system and the presence of a few or no resonances in the K^+p system should be visible in strong structure in the direct channel for

K^-p scattering and in the backward peak in the K^+p scattering.

Concerning $\bar{p}$ p, recent Brookhaven data on total cross sections in $\bar{p}$ p and $\bar{p}$ d show the structures, at 1.32 GeV/c (2190 MeV mass), 1.76 GeV/c (2345 MeV) and 1.86 GeV/c (2380 MeV). These structures can all three be interpreted as threshold effects (of the 1236 and 1400 MeV nucleon isobars) or as resonances; in the latter case the 2190 and 2380 MeV structures can be tentatively identified with the structures found by Chikovani et al. at approximately these energies (although the widths are very different in the two experiments).

In view of this interesting situation we have in the previous experiment measured the $\bar{p}$ p elastic differential cross sections and polarisations at four momenta. It was found that there is large positive polarisation over most of the angular region at 1.75 GeV/c, but many more measurements in this momentum region are necessary before quantitative conclusions can be reached. For this reason we propose to continue the $\bar{p}$ p data taking in the 1.0 - 2.0 GeV/c region.

From our data at the three remaining momenta (2.15, 2.40 and 3.00 GeV/c) it appears that the polarisation is decreasing towards higher energies and is always positive with small t region, contrary to Regge pole predictions. It is thus of importance to continue the $\bar{p}$ p data taking towards energies 2.5 GeV/c. No extra PS time is involved in taking $\bar{p}$ p data 2.5 GeV/c, since in an unseparated beam K^-p and $\bar{p}$ p data are obtained simultaneously by tagging the incident particle.

APPARATUS

The apparatus is substantially the same as the one used in the previous experiment, i.e. hodoscopes of counters forthe determination of the polar and azimuthal angles of the scattered and recoil particles and the electronic requirement that one and only one particle has scattered into the left and one and only one into the right hodoscopes with respect of the incident beam. The coplanarity requirements, being too complex for electronic treatment, are imposed in subsequent computer analysis of the stored data.

Several modifications to the system used before are necessary; they stem partly from experience gained in the previous experiment, partly from the particular requirements of this energy region and the fact that here also K^+ is considered in the design. They are :

1) The angular resolution will be improved by increasing the distance between target and counters. This improves the distinction between free and bound proton events.

2) Extensive use will be made of time of flight information 1) to separate elastic from reversed elastic events in the angular regions where a measurement of angles alone will not remove this ambiguity; 2) to improve the accuracy of the very forward ($|t| < 0.3$ $(GeV/c)^2$) region by measuring the flight time of the slow proton at large angles; 3) to reduce the background for the backward region where the cross sections are < 20 $\mu b/sr$.

3) The monitoring of the experiment in the production phase will be improved by use of the IBM 1800 on-line, thus reducing losses due to failures and errors.

4) The beam electronics will be made faster; this will allow for a higher maximum flux of beam particles (mostly protons and/or pions) to pass through the apparatus; in the upper part of the previously studied momentum region the rate of data taking was limited by the electronics, rather than by the available flux from the PS.

Figure 1 shows an outline of the proposed set up. Ninety counters are placed in the angular interval $-90° < \theta_L < +90°$.

Kinematics tells us, that limiting the counter hodoscope to this angular region we reach scattering angles with $\cos \theta_{cm} > -0.85$.

The azimuthal acceptance is 20° divided in bins of 2° at each side by 10 counters. The radius of the counter system is 114 cm.

The backward scattering range ($-0.92 > \cos \theta_{cm} > -0.99$) will be measured by a separate counter system, located between 100° and 155° in conjunction with a $\check{C}$ counter viewing the corresponding angular range for the recoil proton ($-4° < \theta_L < -9°$).

The counters A and B serve to measure time of flight. This is necessary to disentangle the left-right confusions for the K^+p scattering. Counter A is placed in such a way, that the arrival of a kaon there is coincident with the corresponding proton in counter B.

Figure 2 shows the differences in arrival times in the θ counters over the whole angular range.

Because of the special arrangement of the counters A and B both types of events (kaon left, proton right versus proton left, kaon right) have now a characteristic difference in time of arrival ($\geq 1,2$ nsec) in these counters. In the forward direction the differences in flight time for different scattering angles become so large, that a determination of the scattering angle of the event via time of flight becomes more accurate, than the geometrical determination, in particular at higher energies. In principle one then measures with a constant accuracy on the t scale. This way of measuring the angles has the additional advantage that it is not influenced by the uncertainty in interaction point in the target and by the effects of multiple scattering on the trajectory of the particle.

THE BEAM

Concerning the beam required for this experiment, there are several possibilities.

1) The K^-, K^+ and $\bar{p}$ scattering > 2.5 GeV/c can only be done in the long beam from target # 8. The rates for this beam are given in tables 1 and 2 for the case of full flux on the target, and for the case where the upper limit tolerated by the electronics is 10^6 particles through the equipment per burst.

It appears that when running on K^- and $\bar{p}$ (the data are taken simultaneously) the optimum fraction of beam on target # 8 ranges from ∽ 30 to 45 % (for 10^{12} protons/burst). Increasing this percentage does not speed up the experiment further. When running on K^+ the optimum fraction ranges from ∽ 10 to 20 %.

2) The $\bar{p}$ scattering in the range 1.0-2.0 GeV/c (K^+ is not proposed, since at Argonne this experiment is scheduled for early 1968; K^- has been done at Nimrod and by this group recently) can be done in the m_{4b} beam, in the long beam from # 8, or in the short beam from # 8. The rates for the long beam from # 8 are given in tables 1 and 2. The rates in the m_{4b} beam are comparable to those for the long beam from # 8. The rates for the short beam from # 8 are given in table 3. The rates have been calculated from an empirical formula of Ranft [1]. It is apparent that all these beams are of comparable quality for the performance of the experiment.

1) P.S. handbook M6 page 8.

RATE OF EVENTS; REQUIRED PS TIME

From the (scarce) data on differential cross sections in the region 2.5 - 5.0 GeV/c it appears that a sensitivity of

10 events per $\Delta \cos \theta^* = 0.05$ per μb/sr is required to arrive at meaningful conclusions in the analysis. Scaling with the aid of data from the previous experiment, we obtain that 100 events per $\Delta \cos \theta^* = 0.05$ in a region where the differential cross section is 10 μb/sr require 3×10^9 incident kaons. For an average of 10^4 kaons/burst and a burst rate of 3000 per hour this requires 100 hours per momentum. With an overall efficiency of ~ 70 % and data taking at 10 momenta this leads to approximately 10 PS weeks as the time required for running in the long beam from # 8 between 2.5 and 5.0 GeV/c.

For the $\bar{p}$ p data in the range 1.0 - 2.0 GeV/c approximately 5 PS weeks are required to complete a set of 15 momenta in the short # 8 beam. It may be noted that several other experiments have been scheduled for the long # 8 beam, while the short # 8 beam is at present free. For the $\bar{p}$ p at 1.0 - 2.0 GeV/c the short # 8 beam is thus to be preferred over the other possibilities mentioned above : the use of target # 8 becomes more efficient and somewhat more time is available for running in the improved set up.

The background is caused by elastic scattering on bound protons and to a lesser extent by inelastic reactions with one charged particle going to the right hand telescopes, and one charged particle going to the left hand telescopes. In the region of low cross sections (~ 10 - 20 μb/sr) both sources of background are about equally important. Their intensity is estimated by extrapolating the variation with incident momentum of the background in the previous experiment to the 2.5 -5.0 GeV/c region. With an improved angular resolution (see 1) above) this results in 100 - 150 background events for 100 elastic events at the 10 μb/sr) level. This is a factor two better than the previous experiment.

LMN TARGET VERSUS ALCOHOL TARGET

The required PS time indicated above is based on the use of a LMN-type polarised target. The use of an alcohol target at 50 KGauss, which has an estimated polarisation of 50 %, will reduce this time by a factor two to three, due to the difference in density of free protons (0.07 g/cm^3 for LMN, 0.14 g/cm^3 for alcohol) and the improved ratio of bound/free proton events (∽ 5.5 for LMN, ∽ 1.5 for alcohol). It will in addition reduce the required number of magnetic tapes and the computer time required for the analysis by a factor of two to three.

A point not yet investigated is the effect of the fringe field of such a magnet on the detectors. If this can be handled the construction of a 50 KGauss superconducting coil would be of great advantage to this experiment.

REQUIRED COMPUTER TIME

At this stage we can not make an reliable estimate concerning the computer time needed. An upper limit is of the order of 100 hrs 6600 - equivalent per year. It is envisaged to spread the load over the CDC 6600, the IBM 360/44, the IBM 1800 of our group, and possible outside computers.

TABLE 1

Negative particle fluxes in Q x beam from # 8

Beam data

Length of beam : 40 m

Production angle : .12 rad

Acceptance : .22 msterad

Momentum bin : ± 1 %

A 10^{12} protons on target, 75 % target efficiency

Sec.Mom	N_{π^-}	$N_{\bar{p}}$	N_{K^-}	% beam
1.00 GeV/c	0.98×10^6	4000	360	100
1.50	1.95×10^6	8600	3500	100
2.00	2.75×10^6	13600	11000	100
2.50	3.23×10^6	17900	21300	100
3.00	3.38×10^6	21000	31000	100
4.00	3.0×10^6	21000	42000	100
5.00	2.1×10^6	17000	39000	100

B Beam limited to 10^6 particles per burst above 2.5 GeV/c *

1.00	1×10^6	4000	360	100
1.50	2×10^6	8600	3500	100
2.50	3.2×10^6	13600	11000	100
3.00	10^6	6300	9300	30.
4.00	10^6	7000	14000	33.
5.00	10^6	8500	19000	50.

* Below 2.50 GeV/c the separator is effective.

TABLE 2

Positive beam fluxes in Q x beam from #8

Beam data

Length of beam : 40 m

Production angle : 0.12 rad

Acceptance : 0.22 msr

Momentum bin : ± 1 %

A 10^{12} protons on target, 75 % target efficiency.

Sec. Mom.	N_{π^+}	$N_{\bar{p}}$	N_{K^+}	% beam
2.50 GeV/c	4.0×10^6	3.0×10^6	56000	100
3.00	4.3×10^6	4.0×10^6	90000	100
4.00	4.0×10^6	5.3×10^6	150000	100
5.00	3.1×10^6	5.7×10^6	170000	100

B Beam limited to 10^6 particles per burst

2.50 GeV/c	0.57×10^6	0.42×10^6	8000	14
3.00	0.59×10^6	0.41×10^6	12000	14
4.0C	0.43×10^6	0.57×10^6	16000	11
5.00	0.35×10^6	0.64×10^6	19000	11

TABLE 3

Negative beam fluxes in K x beam from target 8

Beam data

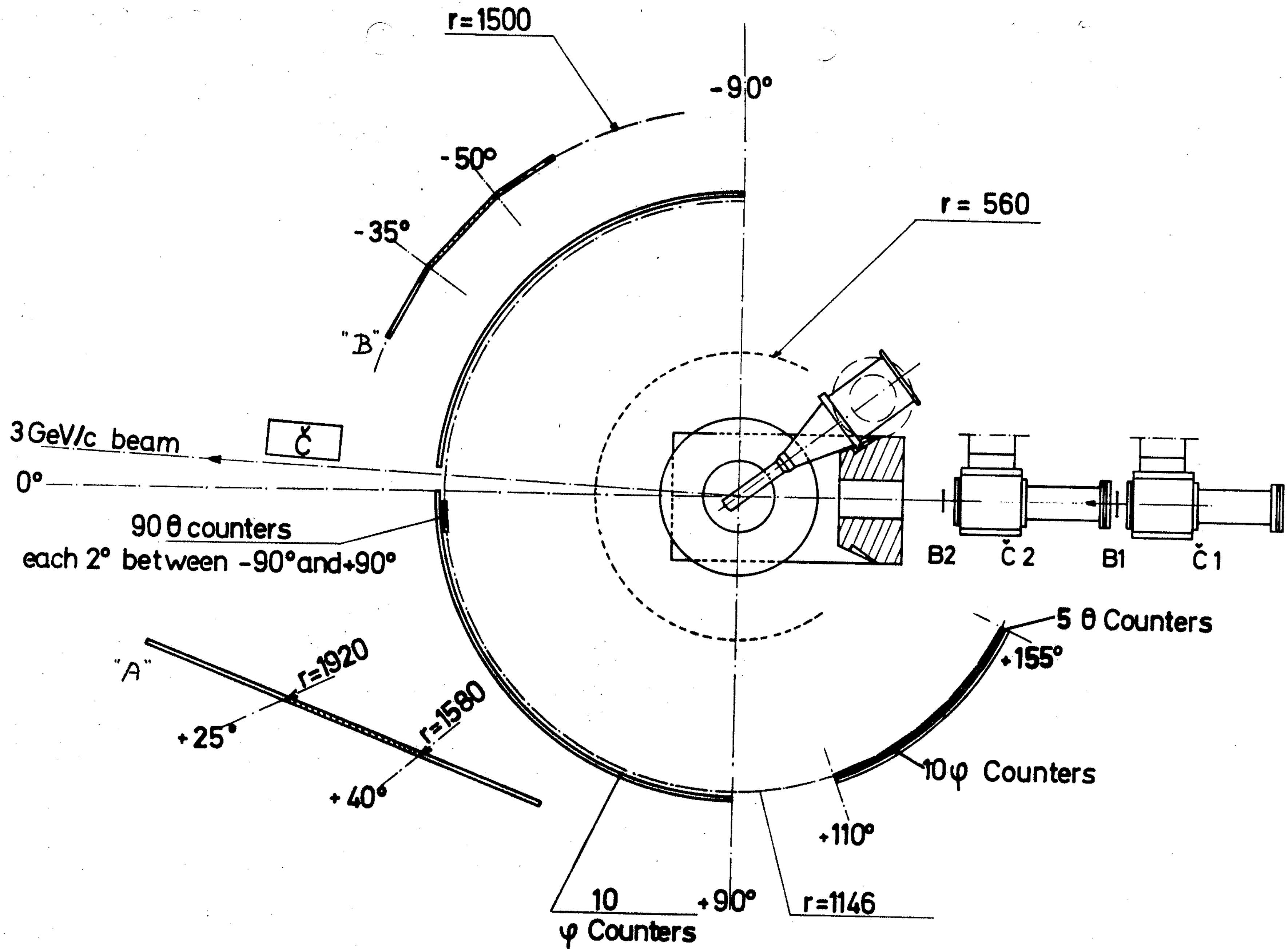
Length of beam :	17 m
Production angle :	0.26 rad
Acceptance :	0.30 msr
Momentum bin :	$\pm$ 1 %

A 10^{12} protons on target, 75 % target efficiency

Sec. Mom.	N_{π^-}	$N_{\bar{p}}$	N_{K^-}	% beam
0.80 GeV/c	0.90×10^6	2400	3000	100
1.00	1.1×10^6	3400	6600	100
1.50	1.4×10^6	5300	17000	100
2.00	1.2×10^6	5900	23000	100
2.50	$.9 \times 10^6$	5400	23000	100

B Beam limited to 10^6 particles per burst

Sec. Mom.	N_{π^-}	$N_{\bar{p}}$	N_{K^-}	% beam
0.80	0.9×10^6	24000	3000	100
1.00	10^6	3100	6000	90
1.50	10^6	3700	12000	70
2.00	10^6	4700	18000	80
2.50	10^6	5400	23000	100



APPARATUS ELASTIC SCATTERING EXPERIMENT

DIFFERENCE IN ARRIVAL TIME OF THE TWO PARTICLES OF ONE ELASTIC $K^{+}p$ SCATTERING AFTER ONE METER.

INCIDENT MOMENTUM 2.50 GeV/c

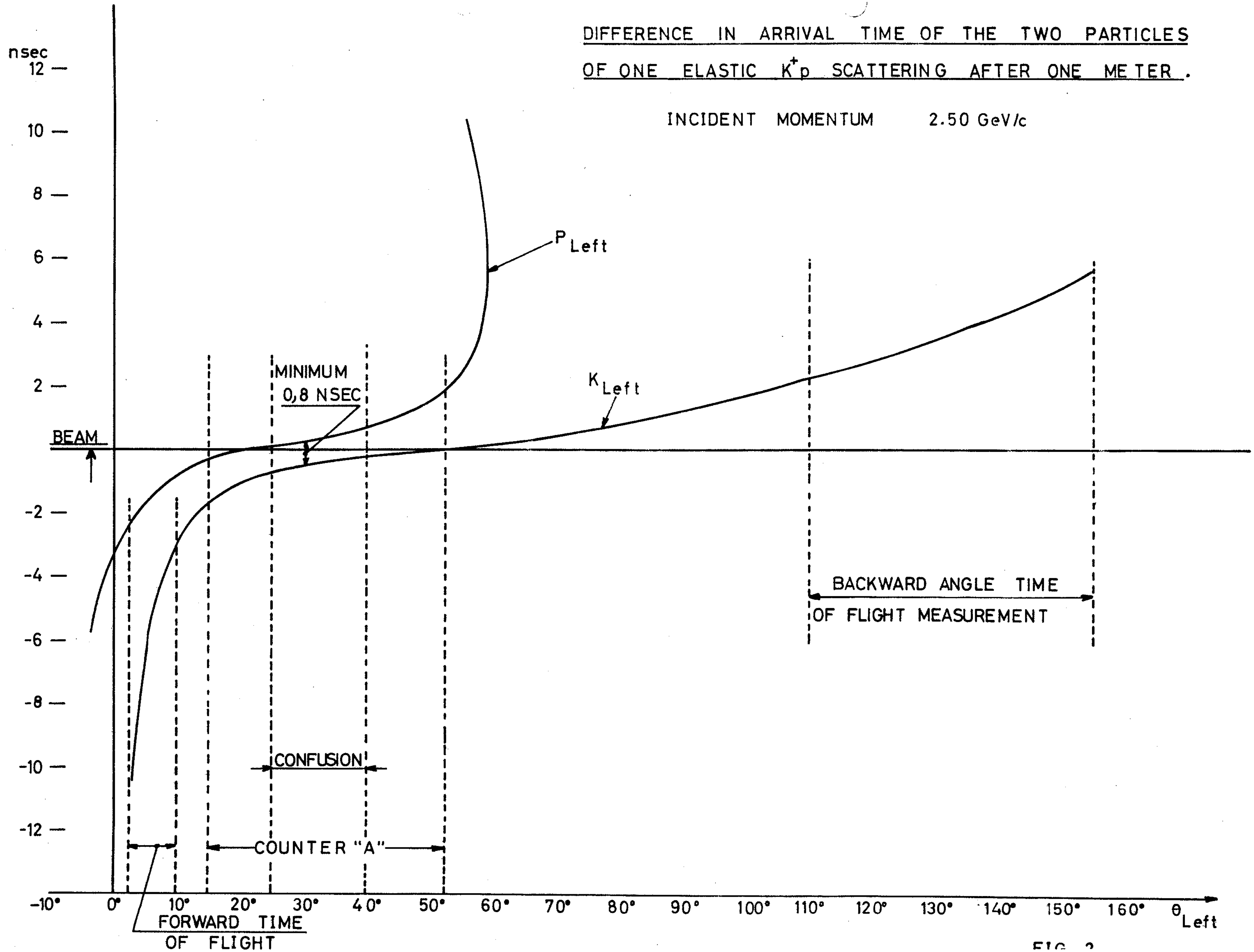


FIG. 2