EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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PHYSICS I

ELECTRONICS EXPERIMENTS COMMITTEE

STATUS AND INTENTIONS
KAON/ANTIPROTON-POLARIZED PROTON EXPERIMENT

by

S. Andersson, C. Daum, F.C. Erné, J.P. Lagnaux,

J.C. Sens and F. Udo

(CERN/Holland team)

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

4 February 1969

MEMORANDUM

To : The members of the EEC

From : S. Andersson, C. Daum, F.C. Erné, J.P. Lagnaux, J.C. Sens and F. Udo (CERN/Holland team)

Re : Status and intentions kaon/antiproton-polarized proton experiment

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The purpose of this note is twofold:

1) to inform the EEC of what has been done so far in this experiment;

2) to indicate the intentions of the group for the remainder of the experiment, in particular in connection with the butanol polarized target which will shortly replace the present LMM target.

STATUS OF THE EXPERIMENT

The equipment consists of counter hodoscopes to measure the polar and azimuthal angles of the scattered particle and the recoil proton. The incident particles ($\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$) are identified by gas Cherenkov counters and time-of-flight signals. Time-of-flight is also used on part of the hodoscopes to improve the precision on the very forward part of the angular distribution and to resolve "elastically" scattered events, in angular regions where a measurement of angles alone is insufficient. The equipment is supervised by a computer on-line which checks for counter failures, monitors the time-of-flight devices and preselects the data before storage on tape.

The experiment started on October 23, 1968 with one week of beam survey in the new q_7 beam, followed (up to 7 February 1969) by three weeks of production with 15-20% on PS target # 8, two weeks with 30-35%, and one parasitic week with 1%. Approximately 90% of the total allocated time has been used for production runs.

In this time 22 angular distributions and polarization will have been measured*):

P (GeV/c)	Data taking time (hours)	Background corrected events K^-	$\bar{p}$	π^-	K^+	p
1.10	80	7000	2000	8000	-	-
1.16	80	←in progress →			-	-
1.22	75	7500	2000	8500	-	-
1.22	102	-	-	-	4500	-
1.22	7	-	-	-	-	12000
1.30	70	8500	1900	8000	-	-
1.75	140	13000	4000	20000	-	-
2.50	167	9000	4000	9000	-	-
2.50	73	-	-	-	6000	-
2.50	4	-	-	-	-	6000

A sample of the results obtained so far is shown in Fig. 1. The limited statistics on the $\bar{p}$ data is due to the low $\bar{p}$ rate in the beam and to the sharp drop of the differential cross-section with angle. The precision of the $K^{\pm}$, π^-, p data is adequate for further analysis. The 1.75 GeV/c data were taken to provide a link with data of our previous experiment, and to improve the accuracy of the previous $\bar{p}$ data at a momentum where structure is seen in the $\bar{p}p$ total cross-section. The data at 2.5 GeV/c, near the upper end of the range of momenta in q_7 were taken to permit a Regge type analysis on the $\bar{p}$ and K^+ data, and to obtain a new K^- polarization in a region where further resonances are thought to be present. In the region 1.1 to 1.3 GeV/c data on negative particles were collected at

*) In the negative beam the K^-, $\bar{p}$, and π^- are taken simultaneously; π^- are admitted for ~ 1 msec per (200 msec) burst to avoid loss of K^- and $\bar{p}$ by dead-time in the data transfer. In the K^+ runs, both protons and pions have been suppressed; proton data are then taken in separate, typically four-hour long runs.
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No π^+ data (~ 4 hours/run) have been taken as yet. Simultaneous K^+, p, π^+ data-taking would be possible but requires some additional electronics.

four momenta. In this region there should be strong resonance effects for K^-, while the $\bar{p}$ data are not expected to vary much with incident momentum. The $\bar{p}$ data at these four momenta can therefore be summed; since the $K^-/\bar{p}$ ratio in this region is ~ 3, this will result in comparable statistics in the summed $\bar{p}$ and the separate K^- spectra. Finally, the K^+ data at 1.22 GeV/c can be combined with an accurate differential cross-section measurement (bubble chambers, Goldhaber/Trilling group) at the same momentum in a phase shift analysis.

In a systematic investigation of this sort it is obvious that no immediate conclusions can be drawn from the limited data listed above. Exceptions are the K^+ data at 1.22 GeV/c, which provide good evidence against a I = 1 Z* resonance, thereby supporting the "simple" quark model, and the K^+ data at 2.5 GeV/c which contain information on the helicity flip amplitudes of the exchanged Regge poles. These conclusions have been submitted for publication. A preprint is enclosed.

STATUS OF LOW-ENERGY ELASTIC REACTIONS

Although the experiment has been intended primarily for $\bar{p}p$ elastic scattering, it is clear from the results obtained so far, that the present set-up is sufficiently flexible and reliable to enable a detailed study of the other elastic reactions between ~ 1 and ~ 3GeV/c as well.

The present status of information on these reactions can be summarized very briefly as follows:

- K^+: no polarization distributions, apart from the 1,22 and 2,5 GeV/c data quoted above (preprint) are available. From angular distributions and inelastic reactions (all bubble chamber work) it appears that the K^+-nucleon system can be described with only a few partial waves (S, P, D up to ~ 1.5 GeV/c); hence there is some hope for a conclusive phaseshift analysis, without the numerous ambiguities of e.g. the K^--nucleon system. The interest lies firstly in establishing whether there are any resonances (at the bumps in σ_T or elsewhere); as is well known S = + 1 baryon resonances are incompatible with the "simple" quarkmodel. Furthermore, at higher momenta ($\gtrsim$ 2 GeV/c) the system is "asymptotoc" and can be compared with Regge predictions.

- K^-: polarizations have been measured at 8 momenta between 1.0 and 1.4 GeV/c (NIMROD) and at 19 momenta between 1.4 and 2.4 GeV/c (this group, previous experiment). Two resonances ($2030(7/2^+)$ and $2100(7/2)^-$; $2350(9/2^+$ or $7/2^-)$ is faint) are clearly present in the data; to detect the other known (nine are predicted in 1 - 3 GeV/c) or new resonances more accuracy is required in particular between 1.0 and 1.4 GeV/c. The points at 1.10, 1.16, 1.22 and 1.30 GeV/c quoted above have been taken for this purpose. Between 2.5 and 3.0 GeV/c, where 2 bumps occur in σ_T, no polarizations have been measured yet.

- $\bar{p}$: polarizations have been measured at 1.75, 2.15, 2.4 and 3.0 GeV/c (this group, byproduct of previous K^- experiment) with poor accuracy. The 1.75 GeV/c data have now been improved and new points have been obtained at 2.5 GeV/c and in the 1.10 - 1.30 GeV/c region. The polarizations are positive at small t, up to the first minimum in the differential cross-section. From there on the structure is varying with momentum.

- $\pi^\pm$: here, polarizations have been measured at a large number of momenta and hence the present experiment can only fill in gaps or improve the accuracy. The discrepancies between the different phase shift analysis groups (Berkeley, CERN, Saclay) show the need for more data in the region $\sim$1 to 2 GeV/c where CERN (Lovelace et al.) finds nine new resonances. The latter group has suggested various specific momenta where more data would solve ambiguities. It is hoped that this feedback between the two groups will effectively clarify the situation. Typical data taking times for $\pi^\pm$ runs are $\sim$ 5 hours.

- p : polarizations have been measured at many momenta. Running times $\sim$ 5 hours per momentum. Diffraction model fits the data. Large spacing between momenta is possibly sufficient.

CONTINUATION OF THE EXPERIMENT

We should like to ask for an extension of the experiment up to the shutdown in September 1969. The arguments are:

1) As outlined above the set up is adequate for the whole range of momenta of the q_7 beam and for any elastic reaction ($K^{\pm}$, $\pi^{\pm}$, $p^{\pm}$).

2) As summarized above there is much quantitative work to be done; accurate polarization data can provide strong constraints both in the search for resonances and the verification of diffraction (Regge) theories.

3) The q_7 beam is free; to our knowledge no one has asked for it.

4) The PS target 8 feeds q_7 and q_8. As long as q_8 is still in use, q_7 can run in parallel (as at present); in any case 20 - 30% on 8 is adequate except for $\pi^{\pm}$ and p runs for which a few percent on 8 is sufficient if no $K^{\pm}$ or $\bar{p}$ data are taken in parallel. There is thus plenty of intensity left for target 1.

The time up to September would be used as follows:

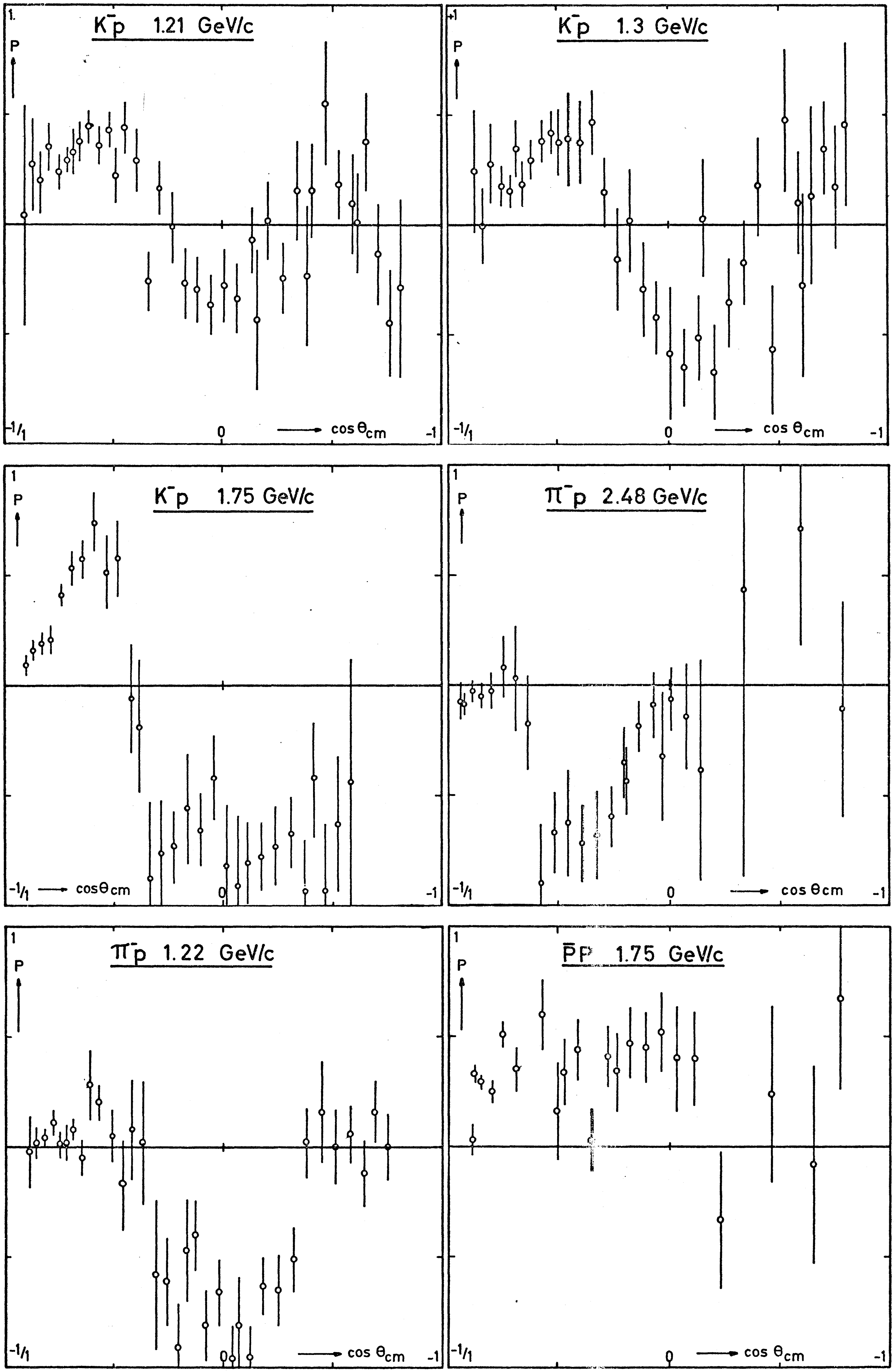
a) Installation of the butanol polarized target. With this target the minimum measurable $d\sigma/d\Omega$ will be reduced from $\sim$ 50 μb/sr to $\lesssim$ 10 μb/sr; this will enable us to obtain the large angle polarizations at high momenta where the cross sections are low. The installation is provisionally planned for the period February 24 - March 13.

b) 4 weeks with emphasis on K^+ in the region 1.0 - 1.5 GeV/c to obtain sufficient data for a phaseshift analysis.

c) 4-5 weeks with emphasis on K^+ and K^- between 2.5 and 3.0 GeV/c, here, no data exist, the rates are high, the distinction between particles in the beam is straight forward and the region of confusion between elastic and reverse-elastic scattering is small.

d) $\pi^{\pm}$ and $p^{\pm}$ data are taken in parallel with b) and c); during periods that only a small percentage on 8 would be available, additional $\pi^{\pm}$ and p data would be collected.

At present 10 weeks of South Hall operation have been scheduled up to September 1969. This time is sufficient (and leaves a sligh reserve for breakdowns) to carry out the indicated programme of measurements.


K⁻p 1.21 GeV/c
K⁻p 1.3 GeV/c
K⁻p 1.75 GeV/c
π⁻p 2.48 GeV/c
π⁻p 1.22 GeV/c
p̄p 1.75 GeV/c
P
cos θcm
1
-1/1
0
-1

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ELASTIC SCATTERING OF POSITIVE KAONS ON POLARIZED PROTONS AT 1.22 AND 2.48 GeV/c

S. Andersson*), C. Daum, F.C. Erné**)
J.P. Lagnaux***), J.C. Sens**) and F. Udo**)
CERN, Geneva, Switzerland

ABSTRACT

Polarization angular distributions of K^+p elastic scattering have been measured at 1.22 and 2.48 GeV/c. Over the measured range of -t the polarization is generally large and positive. The data at 1.22 GeV/c solve an ambiguity in a recently published phase-shift analysis favouring the solution which requires no resonance in the K^+p system.

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*) Visitor from the Institute of Physics, University of Lund, Sweden.

**) Visitor from the Foundation for Fundamental Research of Matter (F.O.M.), The Netherlands.

***) Visitor from the Institut Interuniversitaire des Sciences Nucléaires, Bruxelles.

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S. Andersson*), C. Daum, F.C. Erné**)
J.P. Lagnaux***), J.C. Sens**) and F. Udo**)

CERN, Geneva, Switzerland

At present, there is accumulating evidence that the structure seen in K^+p total cross-sections around 1.3 GeV/c incident momentum by Cool et al.[1a] and by Bugg et al.[1b] are not due to the formation of baryonic resonances Z^* with $S = +1$. Bland et al.[2] have shown that the energy variation of the total cross-section between 0.8 and 3.6 GeV/c is well reproduced by adding the monotonically falling elastic cross-section, the cross-section for single-pion production $\sigma(KN\pi)$ which rises rapidly above the N^* threshold and then saturates, and the cross-section for two-pion production $\sigma(KN\pi\pi)$, which rises abruptly above 1.6 GeV/c, the K^*N^* threshold. Bassompierre et al.[3] have investigated the effective mass distributions KN, K^*N, KN^*, and $KN\pi$ into which a Z^* might decay, in the reaction $K^+p \rightarrow K + N + m\pi$ ($m = 1, 2, 3, 4$) at 3.0, 3.5, and 5.0 GeV/c and find no evidence for Z^*'s. The same data subjected to a missing-mass-type analysis ($K^+p \rightarrow Z^* + n\pi$) show again no bump in the mass region 1.8 to 2.0 GeV. A phase-shift analysis of elastic K^+p data below 1 GeV/c by Bland et al.[2] is consistent with non-resonant behaviour of the partial waves, although this would not completely rule out a resonance structure in the suspected mass region ~ 0.15 GeV higher up. Evidence in favour of Z^*'s is claimed by a photoproduction experiment[4] in which three bumps are seen which,

*) Visitor from the Institute of Physics, University of Lund, Sweden.

**) Visitor from the Foundation for Fundamental Research of Matter (F.O.M.), The Netherlands.

***) Visitor from the Institut Interuniversitaire des Sciences Nucléaires, Bruxelles.

however, disagree either in mass or in I-spin with the structures in the total cross-section. Furthermore, in a phase-shift analysis by Lea et al.[5] on K^+p data below 1.5 GeV/c, two sets of solutions are obtained of which one is consistent with a T = 1, J = ½ resonance at 2020 MeV. In the phase-shift analysis of both Ref. 2 and Ref. 5, the calculated polarizations are quite different for the various solutions and thus provide a sensitive means of distinguishing between them. The polarization data at 1.22 GeV/c, reported below, are in excellent agreement with the prediction obtained from the non-resonant solution of Ref. 5, and thus provide further evidence against any Z* with I = 1 in this mass region. As is well known, a S = +1, I = 1 resonance requires a {27} representation in SU(3), which cannot be obtained from a simple three-quark system.

At momenta above ~ 1.5 GeV/c the K^+p system, from all present evidence, rapidly approaches its asymptotic limit. Total, elastic, single [$\sigma(KN\pi)$] and double [$\sigma(KN\pi\pi)$] pion production cross-sections, the momentum dependence of the slope of the diffraction peak, and the momentum dependence of the N* and K* density matrix elements of the inelastic channels, all level off somewhere between ~ 1.5 and ~ 5 GeV/c [2,6]. Regge-pole predictions for differential cross-sections, with parameters obtained from fits to data above ~ 6 GeV/c, appear to hold reasonably well down to ~ 1.2 GeV/c [2,6]. The polarization data at 2.48 GeV/c discussed below can therefore be compared with one particular "asymptotic" model, the optical Regge model of Arnold and Blackmon[7]; the data favour the relative sign of the ρ and A_2 helicity flip Regge amplitudes to be negative in this model.

The K^+ data have been obtained in an unseparated beam by recording coincidences between elastically-scattered kaons and recoil protons in counter hodoscopes placed around an LMN-type polarized target (polarization ~ 63%) in which the direction of the spin of the free protons was reversed every ~ 10 hours. The rate of kaons focused on the target was ≈ 2000 per burst at 1.22 GeV/c and ≈ 8000 per burst at 2.48 GeV/c. Data were collected for ≈ 110 hours at 1.22 GeV/c and for ≈ 65 hours at 2.48 GeV/c. The apparatus was an improved version of the one used earlier and described in Ref. 8, the principle differences being: a) an improved angular resolution [2° in both the polar (ϑ) and azimuthal (φ) direction] obtained by doubling the number of φ counters, using overlapping ϑ counters and placing them all at twice the distance from the target; b) identification of kaons in the (unseparated) beam by tagging the beam particles by a combination of time-of-flight and gas Čerenkov counter signals; c) separation, by time-of-flight tagging, of "elastically" scattered from "reverse-elastically" scattered events (with the scattered kaon and recoil proton interchanged) in the angular region where a measurement of angles alone cannot make this distinction ("region of confusion"); and d) the use of on-line computing to preselect the data and monitor the apparatus.

The procedure followed in the analysis is the same as the one described in detail in Ref. 8, except for the additional time-of-flight information, which enabled us to resolve the region of confusion in the data at 1.22 GeV/c. In this region, which extends from ~ +0.3 to -0.15 in cos $\vartheta_{c.m.}$, the time difference Δt was measured between the time of arrival of one particle in the left hodoscope and that of the other particle in the right hodoscope. The events then fall into two classes, those with positive Δt, corresponding to a kaon left/proton right configuration, and those with negative Δt for the opposite case. At 1.22 GeV/c, the difference in Δt for the two classes is typically 2.6 nsec, the resolution of the circuit 1.0 nsec. At 2.48 GeV/c where the region of confusion extends from $\approx$ 0.3 to $\approx$ -0.2 in cos $\vartheta_{c.m.}$, the difference in Δt is typically 0.5 nsec, too small to be detectable with the circuitry used; hence the lack of data in the central part of the angular range at 2.48 GeV/c. The backward cross-sections are too small to produce measurable asymmetries with the number of events taken in this experiment.

The results are presented in Table 1 and Figs. 1 and 2. The data points with spacings less than 0.035 in cos $\vartheta_{c.m.}$ have been replaced by their weighted averages. The errors are statistical only; an error common to all points and due to an uncertainty of 0.03 in the calibration of the target polarization is not included in the table and figures. The Basel Convention has been followed in choosing the sign of the polarization.

The data at 1.22 GeV/c show a large positive polarization over the entire angular interval. In Fig. 1 they are compared with the phase-shift solutions of Ref. 5. This analysis has been performed on total cross-sections, inelastic cross-sections, differential elastic cross-sections, and computed real parts of the forward scattering amplitudes between 140 and 1495 MeV/c, and the polarization data (4 points at 910 MeV/c, 3 points at 778 MeV/c) available prior to the present experiment. In essence, two solutions emerge, one with resonance behaviour in the P_{11} wave near 1.5 GeV/c, the other with a purely elastic P_{11} wave. The predictions for the polarization at 1.2 GeV/c for these two cases are indicated in Fig. 1. It is seen that although the polarization data included in the fit were not able to prevent this ambiguity from arising, the present data clearly favour the non-resonant solution.

In Fig. 2 the data at 2.48 GeV/c and small t are compared with a prediction at 2.6 GeV/c of the optical Regge model of Arnold et al.[7,10], considered as representative for several hybrid models, recently proposed[9]. The main assumptions in this model are a fixed Pomeranchuk pole, linear trajectories and helicity flip amplitudes for the I = 1 exchanges (ρ, A_2) only; a free parameter is the relative sign of these two amplitudes. As pointed out in Ref. 10, the Schmid analogy relating Regge amplitudes to direct channel resonances would suggest a negative sign in the absence of any resonances. This choice is indeed favoured by the data, although the agreement between experimental points and the calculation is far from excellent.

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REFERENCES

1a) R.L. Cool, G. Giacomelli, T.F. Kycia, B.A. Leontić, K.K. Li, A. Lundby and J. Teiger, Phys. Rev. Letters 17, 102 (1966).

1b) D.V. Bugg, R.S. Gilmore, K.M. Knight, D.C. Salter, G.H. Stafford, E.J.N. Wilson, J.D. Davies, J.D. Dowell, P.M. Hattersbey, R.J. Homer, A.W. O'Dell, A.A. Carter, R.J. Tapper and K.F. Riley, Phys. Rev. 168, 1466 (1968).

2) R.W. Bland, G. Goldhaber, B.H. Hall, J.A. Kadyk, V.H. Seeger, G.H. Trilling and C.G. Wohl, UCRL-18323.

3) G. Bassompierre, Y. Goldschmidt-Clermont, A. Grant, V.P. Henri, R. Jennings, B. Jongejans, D. Linglin, F. Muller, J.M. Perreau, R. Sekulin, W. de Baere, J. Debaisieux, P. Dufour, F. Grard, J. Heughebaert, L. Pape, P. Peeters, F. Verbeure and R. Windmolders, Phys. Letters 27 B, 468 (1968).

4) J. Tyson, J.S. Greenberg, V.W. Hughes, D.C. Lu, R.C. Minehart, S. Mori and J.E. Rothberg, Phys. Rev. Letters 19, 255 (1967).

5) A.T. Lea, B.R. Martin and G.C. Oades, Phys. Rev. 165, 1770 (1968).

6) W. de Baere, J. Debaisieux, P. Dufour, F. Grard, J. Heughebaert, L. Pape, P. Peeters, F. Verbeure, R. Windmolders, R. George, Y. Goldschmidt-Clermont, V.P. Henri, B. Jongejans, D.W.G. Leith, A. Moisseev, F. Muller, J.M. Perreau and V. Yarba, Nuovo Cimento 45, 885 (1966).

7) R.C. Arnold and M.L. Blackmon, ANL/HEP 6814; R.C. Arnold, Phys. Rev 153, 1523 (1967).

8) C. Daum, F.C. Erné, J.P. Lagnaux, J.C. Sens, M. Steuer and F. Udo, Nucl. Phys. B6, 273 (1968).

9) Chan Hong Mo, Proc. 14th Int. Conf. on High-Energy Physics, Vienna, (1968) (CERN, Geneva, 1968), p. 391.

10) M.L. Blackmon and G.R. Goldstein, ANL/HEP 6819.

Table 1

Polarization in elastic K^+p scattering at 1.22 and 2.48 GeV/c

Incident momentum: 1.22 GeV/c c.m. momentum : 0.602 GeV/c			Incident momentum: 2.48 GeV/c c.m. momentum: 0.963 GeV/c		
$\cos\vartheta_{c.m.}$	$-t$ $(GeV/c)^2$	p	$\cos\vartheta_{c.m.}$	$-t$ $(GeV/c)^2$	p
0.83	0.12	0.63 ± 0.11	0.93	0.13	0.49 ± 0.13
0.77	0.16	0.71 ± 0.07	0.90	0.19	0.53 ± 0.06
0.70	0.21	0.76 ± 0.06	0.87	0.24	0.51 ± 0.05
0.60	0.28	0.84 ± 0.05	0.81	0.35	0.64 ± 0.06
0.50	0.36	0.71 ± 0.07	0.76	0.44	0.50 ± 0.06
0.39	0.44	0.86 ± 0.07	0.71	0.54	0.45 ± 0.08
0.32	0.49	0.80 ± 0.10	0.65	0.65	0.49 ± 0.08
0.25	0.54	0.88 ± 0.09	0.61	0.72	0.40 ± 0.13
0.18	0.59	0.64 ± 0.09	0.57	0.80	0.48 ± 0.11
0.12	0.64	0.96 ± 0.12	0.50	0.93	0.67 ± 0.12
0.05	0.68	0.74 ± 0.11	0.44	1.04	0.28 ± 0.19
-0.01	0.72	0.85 ± 0.12	0.37	1.17	0.28 ± 0.18
-0.07	0.77	0.88 ± 0.14	0.31	1.28	0.43 ± 0.25
-0.16	0.84	0.57 ± 0.11			
-0.26	0.90	0.57 ± 0.13			
-0.35	0.97	0.41 ± 0.15			
-0.46	1.05	0.11 ± 0.16			
-0.55	1.11	0.27 ± 0.12			
-0.66	1.20	0.14 ± 0.16			
-0.74	1.25	0.01 ± 0.15			
-0.82	1.31	0.05 ± 0.22			

Figure captions

Fig. 1 : Polarization in K^+p elastic scattering at 1.22 GeV/c. The dashed line is the prediction of Ref. 5, at 1.2 GeV/c, for the no-resonance case (group IV in Ref. 5). The solid line is the prediction of Ref. 5 for one of the solutions with resonance behaviour in P_{11} (group I in Ref. 5). The other solution is similar to this one.

Fig. 2 : Polarization in K^+p elastic scattering at 2.48 GeV/c. The solid (dashed) line is the prediction of Ref. 10, at 2.6 GeV/c, for positive (negative) relative sign of the ρ and A_2 helicity flip amplitudes.

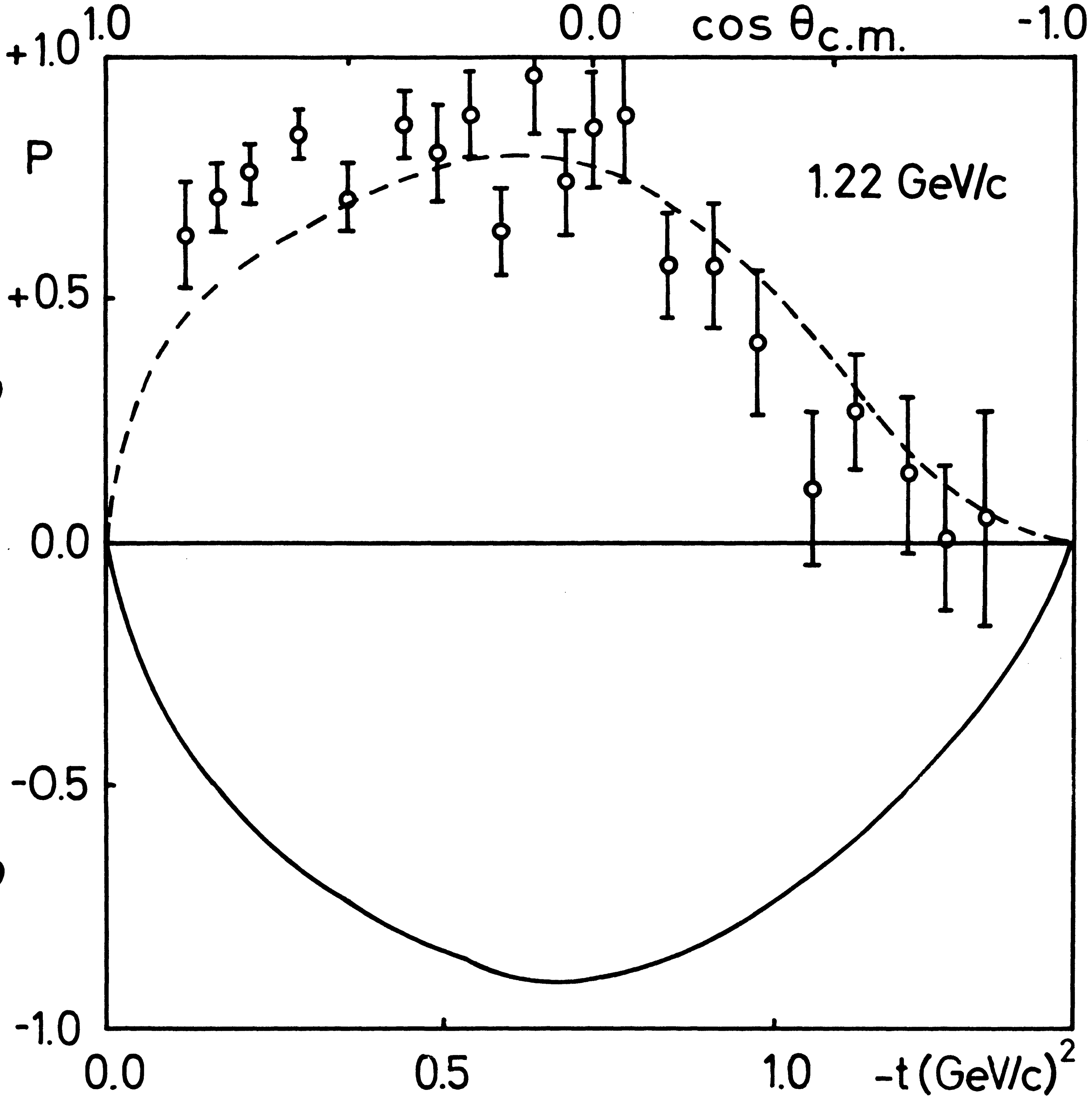

Fig. 1

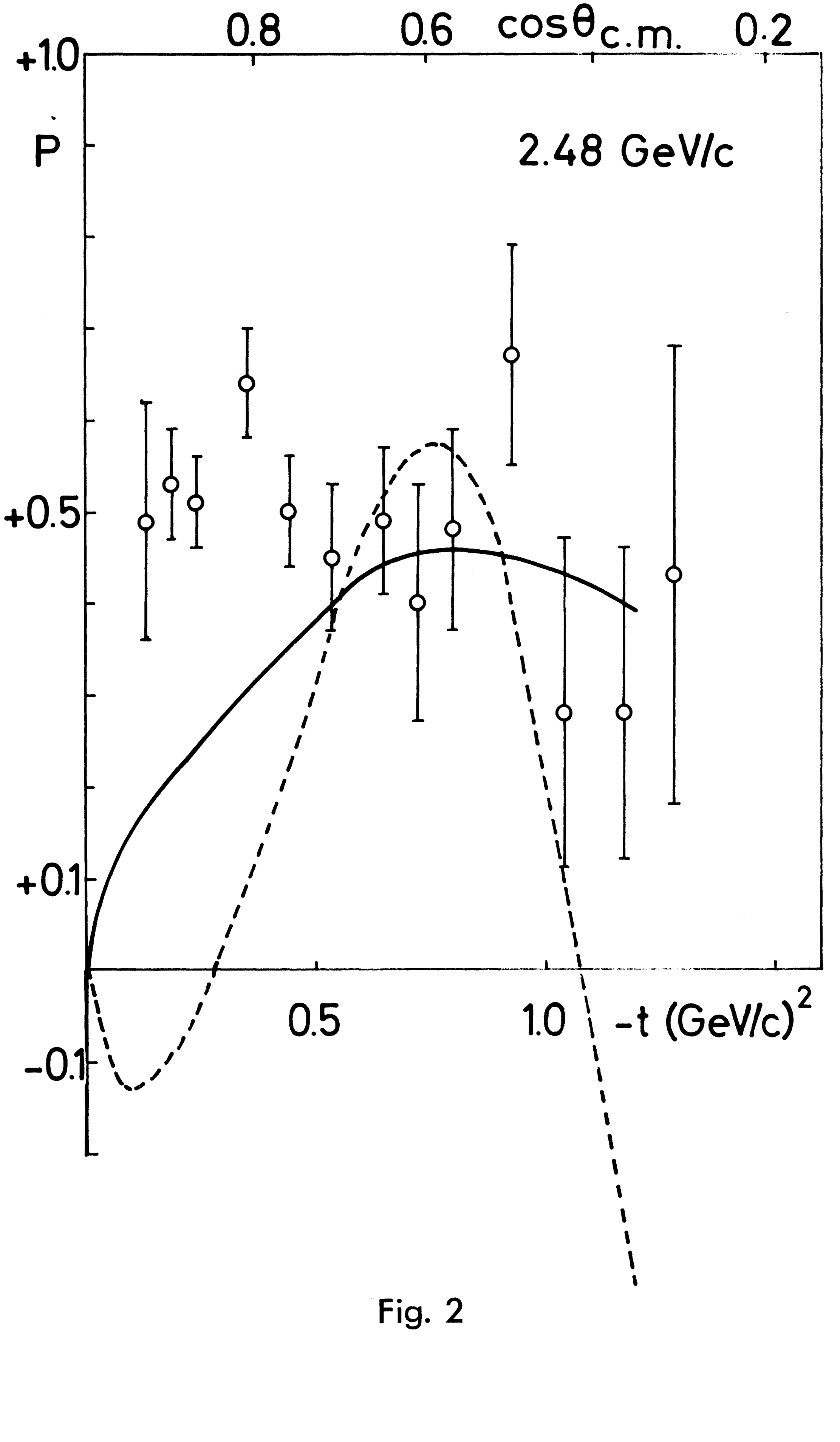

Fig. 2