受入
76-10-103
高工研図書室

CERN - EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Submitted to
Physics Letters B

CERN/EP/PHYS 76-44
30 June 1976

NEW DATA ON THE REACTION $K^-n \rightarrow (\Sigma\pi)^-$ AND A PARTIAL WAVE ANALYSIS OF $\bar{K}N \rightarrow \Sigma\pi$ IN THE ENERGY RANGE 1520-1745 MeV

V. HEPP(*)
CERN, European Organization for Nuclear Research, Geneva.

O. BRAUN, H.J. GRIMM(**), H. STRÖBELE, C. THÖL and T.J. THOUW
Institut für Hochenergiephysik der Universität Heidelberg

F. GANDINI(***), C. KIESLING, D.E. PLANE(+) and W. WITTEK
Max-Planck-Insitut für Physik und Astrophysik, München.

ABSTRACT

Differential cross sections and polarizations of the reactions $K^-n \rightarrow \Sigma^-\pi^0$ and $K^-n \rightarrow \Sigma^0\pi^-$ have been measured at K^- momenta between 680 and 840 MeV/c in a bubble chamber experiment at CERN. The data were used together with published results on the reactions $K^-p \rightarrow \Sigma\pi$ and $\bar{K}^0p \rightarrow \Sigma^0\pi^+$ in an energy-dependent partial wave analysis in the center of mass energy range from 1520 to 1745 MeV. A satisfactory fit was obtained with the well established resonances.

(*) On leave of absence from Heidelberg University.

(**) Now at GMD, Bonn.

(***) Now at IBM, Böblingen.

(+) Now at CERN, Geneva.

VH/mk

All recent partial wave analyses of $\bar{K}N$ two-body reactions covering the energy range between 1600 and 1700 MeV have agreed on the existence of three dominating resonances: $\Lambda(1670), 1/2^-)$, $\Lambda(1690, 3/2^-)$ and $\Sigma(1660), 3/2^-)$. Apart from minor discrepancies in the reported resonance parameters, these states are considered well established [1,2]. The evidence for additional resonances, mainly in the S and P waves, is much less convincing and the quoted values of the resonance parameters are widely spread.

Production experiments find two I = 1 states around 1660 MeV both having probably $J^P = 3/2^-$ [3]. It is not yet clear whether one of these states can be identified with the $\Sigma(1660, 3/2^-)$ observed in formation experiments [3,4].

Many difficulties in the partial wave analyses for energies below 1750 MeV arise from the fact that until now only scarce data on the pure I = 1 channels were available due to the lack of K^-d and $\bar{K}^0p$ experiments. It is interesting to note that in the energy range from 1515 to 1825 MeV there are five well established resonances with I = 0 but only two with I = 1.

In this paper we present new high statistics data on the I = 1 channels:

(1) $K^-n \to \Sigma^-\pi^0$ and (2) $K^-n \to \Sigma^0\pi^-$

for energies between 1600 and 1730 MeV.

The data are used in an energy dependent partial wave analysis of $\bar{K}N \to \Sigma\pi$ in the energy region 1520-1745 MeV. Apart from the $\Lambda(1520, 3/2^-)$, $\Sigma(1765, 5/2^-)$ $\Lambda(1830, 5/2^-)$ and $\Lambda(1815, 5/2^+)$, whose parameters were kept fixed, only the three established resonances mentioned above are required by the data. An inclusion of further resonances does not significantly improve the fit.

In this experiment about 700 000 pictures of K^-d interactions between 680 and 840 MeV/c were taken with the 81cm Saclay bubble chamber at the CERN PS. The results presented here are based on about 75% of the available statistics. Details of the experimental set-up, selection criteria and consistency checks of the data are given in ref. [4]. The partial and differential cross sections have been determined in the framework of the spectator model taking into account the Fermi motion of the target nucleon (see ref. [4,5]). A Glauber screening correction of 7% has been applied. This method of determining K^- nucleon cross sections from K^-d reactions was checked by comparing the cross sections for $K^-n \to \Lambda\pi^-$, $K^-p \to \Sigma^-\pi^+$, $\Lambda\pi^+\pi^-$ with the corresponding results from hydrogen experiments. Good agreement was found.

The polarization has been determined for reaction (2) $K^-n \to \Sigma^o\pi^-$ via the decay $\Sigma^o \to \Lambda\gamma$, by using the known dependence of the Λ polarization on the polar Σ^o decay angle.

The reactions (1) and (2) are equivalent both with respect to differential cross section and polarization (same I = 1 amplitude). We have verified the compatibility of the two differential cross sections. For the further analysis the angular distributions of reactions (1) and (2) were averaged. They will be labelled by $(\Sigma\pi)^-$ in the following.

Fig. 1b) shows the cross section divided by $4\pi\lambda\!\!\!^{-2}$ for $K^-n \to (\Sigma\pi)^-$, as measured in this experiment. In fig. 2 the normalized A and B coefficients for $(\Sigma\pi)^-$ are given, determined by the method of moments. The data point indicated by a triangle in these figures is the result of a recently published measurement of the reaction $\bar{K}^o p \to \Sigma^o\pi^+$ [6] which is described by the same I = 1 amplitude.

For an energy dependent partial wave analysis the data of this experiment were combined with results on $K^-p \to \Sigma\pi$ [7], [8], [9] and $K_L p \to \Sigma^o\pi^+$ [6] in the K momentum region between 400 and 900 MeV/c corresponding to a $\bar{K}N$ center of mass energy rang from 1522 to 1747 MeV. This energy interval was chosen in order to contain completely our data points and to constrain the $\Sigma\pi$-amplitudes by the well determined $\Lambda(1520)$ and $\Sigma(1765)$ resonances.

The amplitudes were parametrized according to:

$$T = T_{res} + T_{bg}$$

For the resonance amplitude T_{res} a Breit-Wigner form with energy dependent width was chosen [10]:

$$T_{res} = \frac{t}{\varepsilon - i} e^{i\phi}, \quad \varepsilon = \frac{2}{\Gamma(E)} (E_R - E)$$

The phase ϕ was left free in the fit. For the resonant amplitude t the sign convention of [11] was adopted. The energy dependence of the background amplitude T_{bg} was parametrized in terms of Legendre polynomials up to second order:

$$T_{bg} = A\, P_o(E') + B\, P_1(E') + C\, P_2(E') \text{ with the mapping:}$$
$$E' = (2E - E_{max} - E_{min})/(E_{max} - E_{min}),$$
$$E_{min} = 1522 \text{ MeV},\ E_{max} = 1747 \text{ MeV, i.e. } (-1 \leqslant E' \leqslant 1).$$

In the search for acceptable solutions we tried to keep the number of resonances as small as possible. It was found that the three established resonances $\Lambda(1670, 1/2^-)$, $\Lambda(1690, 3/2^-)$ and $\Sigma(1660, 3/2^-)$ were necessary and sufficient for an acceptable fit to the data.

We obtain a χ^2 of 1199 for 875 data points (A_o, A_n/A_o and B_n/A_o coefficients) corresponding to a χ^2 per degree of freedom of 1.46. Important contributions to the χ^2 come from the cross section measurements of the pure isospin reactions $K^-p \rightarrow \Sigma^o\pi^o$, $K^-n \rightarrow (\Sigma\pi)^-$ and $\bar{K}^op \rightarrow \Sigma^o\pi^+$. Figs 1 and 2 show the result of the fit (solid curves) in comparison with the cross section data of refs [7,8,9] for $K^-p \rightarrow \Sigma\pi$ (figs 1a,1c,1d), the results on $\bar{K}^o \rightarrow \Sigma^o\pi^+$ of ref [6] (triangles in figs 1b and 2) and our measurements on $K^-n \rightarrow (\Sigma\pi)^-$ (full circles in figs 1b and 2). Generally the data are well reproduced by the fit including our new data on $K^-n \rightarrow (\Sigma\pi)^-$ and those measurements which are not shown in the figures. It should be noted that the K^o_L data of ref. [13] on the reaction $K^op \rightarrow \Sigma^o\pi^+$ were not used in this analysis, since considerable inconsistencies were observed between the cross sections of $K^-p \rightarrow \Sigma^+\pi^-$, $K^-p \rightarrow \Sigma^-\pi^+$, $K^-p \rightarrow \Sigma^o\pi^o$, $K^-n \rightarrow (\Sigma\pi)^-$ and $K^op \rightarrow \Sigma^o\pi^+$ [12,13]. For a detailed discussion see ref. [4].

The Argand diagrams of the partial wave amplitudes are given in fig. 3. Table 1 summarises the result of the best solution. Parameters in parentheses have been kept fixed. The errors on the resonance parameters in the table indicate the spread of values obtained in the different fits that we have attempted. The resonance parameters obtained with our method are stable within the stated limits and are generally in good agreement with previous fits. However, we remark that the width of the $\Lambda(1670, 1/2^-)$ turns out to be larger than the world average. The width of the $\Lambda(1690, 3/2^-)$ is compatible with the results of other $\Sigma\pi$ analyses, but is still in disagreement with determinations from $\bar{K}N \rightarrow \bar{K}N$.

It is likely that at the present stage the inconsistencies in the data are more important than refinements of the adopted model.

A study of final state interactions in $K^-d \rightarrow YN\pi$ [4] suggests that the cross sections for $K^-n \rightarrow (\Sigma\pi)^-$ might be suppressed by 10-15% due to ΣN scattering. However, if we increase our measured cross sections by this amount, our solution remains essentially unchanged within the quoted errors. The new χ^2 drops from 1199 to 1188. The cross sections for $K_L p \rightarrow \Sigma^o\pi^+$ [13] remain incompatible with our solution and would contribute typically a χ^2 of 8.9 per data point.

Also an attempt was made to improve the quality of the fit by introducing additional resonances in the S and P waves claimed in the literature [1], [2]. However, in various searches no sizeable reduction in the χ^2 has been found. We conclude that with the method adopted here the published data on $\bar{K}N \rightarrow \Sigma\pi$ reactions are sufficiently well described by the established resonances.

Our fit may be compared with a recent phase shift analysis [2] in which for the pure I = 1 channel only $K_L p \rightarrow \Sigma^o\pi^+$ data were used [13], [6]. The cross section for the I = 0 reaction $K^-p \rightarrow \Sigma^o\pi^o$ was omitted in this study. The predictions of this fit are indicated in figs 1-3 by the dashed curves. The authors find a solution which is considerably different from our fit and fails to describe the cross sections for $K^-p \rightarrow \Sigma^o\pi^o$ and $K^-n \rightarrow (\Sigma\pi)^-$ from this experiment.

We thank R. Armenteros, M. Ferro-Luzzi and N. Schmitz for many informative discussions. We are grateful to R. Tripp for the generous provision of unpublished data. We also wish to thank the crews of the 81 cm Saclay bubble chamber and of the CERN PS for their collaborative efforts. We are indebted to the Rutherford-Imperial College groups for providing us with the results of their recent partial wave analysis.

REFERENCES

[1] For a review of $\bar{K}N$ partial wave analyses, D.E. Plane, Purdue Conference 1973, MPI report MPI-PAE/Exp. El 33.

[2] A.J. Van Horn et al., contribution paper F2-09 to Palermo Conference 1975.

G.P. Gopal et al., Rutherford laboratory preprint RL-75-182 (1975).

[3] J.J.M. Timmermans et al., Amsterdam-CERN-Nijmegen-Oxford Collaboration, contribution paper F2-07 to Palermo Conference 1975 and submitted to Nucl. Phys.

S.P. Apsell et al., Phys. Rev. 10D (1974) 1419.

P. Eberhard et al., Phys. Rev. 163 (1967) 1446 and LBL-2012 (1973).

[4] V. Hepp et al., CERN-Heidelberg-München Collaboration, to be submitted to Nucl. Phys. B.

[5] R.V. Reid Ann. Phys. 50 (1968) 411.

C. Alberi et al., Phys. Rev. Lett. 34 (1975) 503.

R.J. Glauber, Phys. Rev. 100 (1955) 242.

[6] Y. Cho et al., Phys. Lett. 60B (1976) 293.

[7] R. Armenteros et al., NP B8 (1968) 233 and NP B21 (1970) 15.

[8] M. Jones et al., Nucl. Phys. B90 (1975) 349.

[9] A. Barbaro-Galtieri, private communication to Mr. Ferro-Luzzi.

[10] See for example R. Armenteros et al., Nucl. Phys. B14 (1964) 95.

[11] R.D. Tripp et al., Phys. Rev. Lett. 21 (1968) 172.

[12] See for example: E. Burkhardt et al., Nucl. Phys. B99 (1975) 365.

[13] L. Bertanza et al., Rutherford Laboratory preprint RL-76-016 (1976) Birmingham-Edinburgh-Glasgow-Pisa-Rutherford Collaboration.

TABLE I

FITTED VALUES FOR THE RESONANCE PARAMETERS AND BACKGROUND COEFFICIENTS. THE PARAMETERS WITHIN SQUARE BRACKETS WERE KEPT FIXED

RESONANCES					Characteristics of the fit
Partial wave	Mass [MeV]	Width [MeV]	Resonant Amplitude	phase [rad]	
S01	1676 ± 2	43 ± 5	-0.29 ± 0.03	-0.06	No. of data points 875
D03	[1519]	[16]	[0.46]	[0.]	
D03	1688 ± 3	76 ± 8	-0.30 ± 0.03	0.08	No. of parameters 54
D13	1669 ± 6	53 ± 3	0.20 ± 0.01	0.30	No. of degrees of freedom 821
D05	[1825]	[94]	[-0.15]	[0.]	
D15	[1764]	[123]	[0.10]	[0.]	χ^2 1199
F05	[1820]	[83]	[-0.27]	[0.]	χ^2/ND 1.46

BACKGROUND						
Partial wave	Re(A)	Im(A)	Re(B)	Im(B)	Re(C)	Im(C)
S01	-0.266	0.136	0.100	-0.111	-	-
S11	0.058	0.253	-0.035	-0.114	0.043	-0.011
P01	0.070	-0.225	0.153	-0.049	-0.045	0.091
P11	0.003	-0.099	0.043	-0.069	-0.014	0.008
P03	0.104	0.079	0.050	0.019	0.015	-0.053
P13	0.081	0.007	-0.002	-0.005	0.024	-0.000
D03	-0.016	-0.032	0.025	0.013	-	-
D13	-0.024	-0.014	-0.000	-0.033	-	-

FIGURE CAPTIONS

Fig. 1 Cross sections divided by $4\pi\lambda^2$ as a function of the $\bar{K}N$ cm energy for the reactions:

(a) $K^- p \to \Sigma^+ \pi^-$ ref.[7,8,9]

(b) $K^- n \to (\Sigma\pi)^-$ and ref.[4]
$\bar{K}^o p \to \Sigma^o \pi^+$ ref.[6]

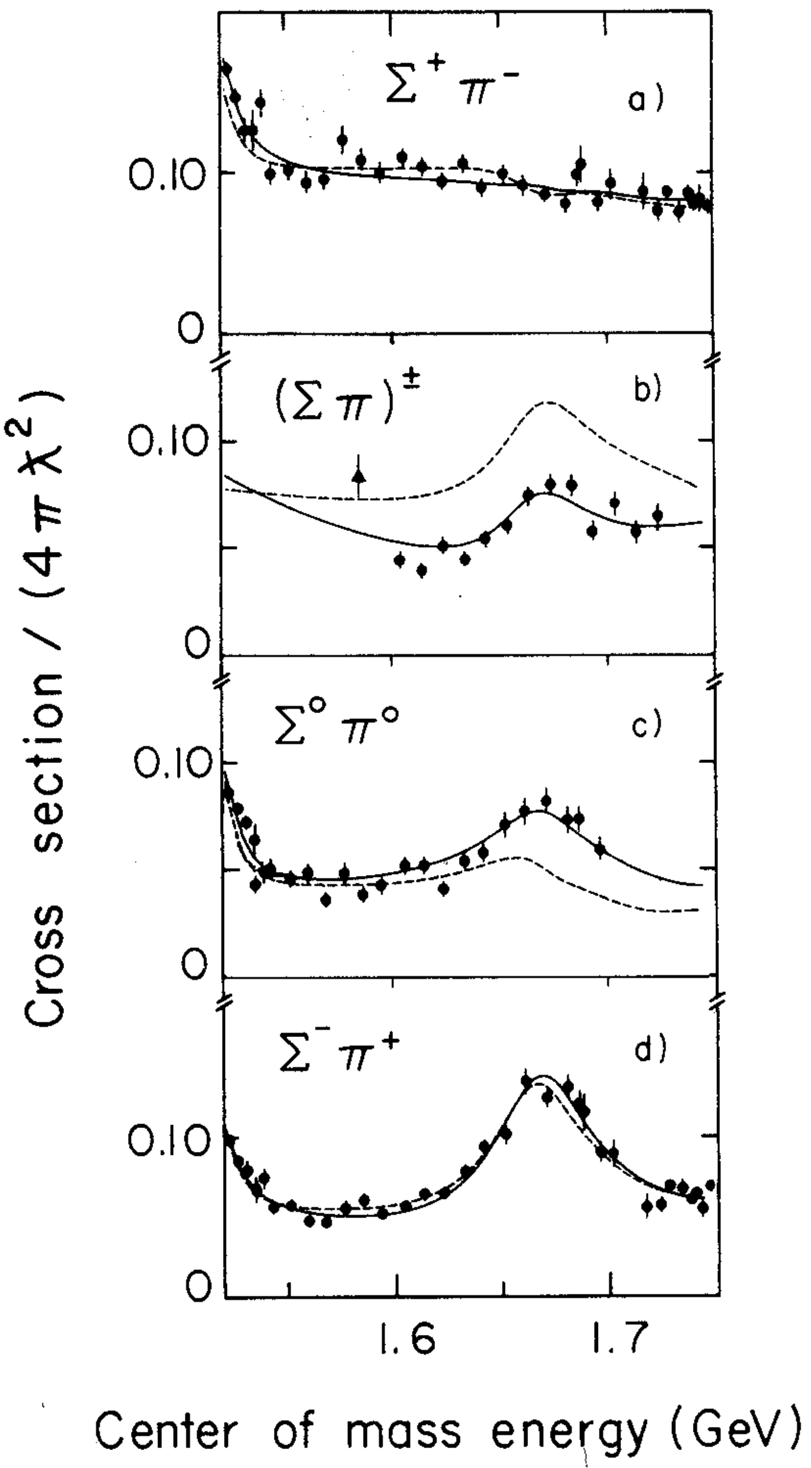
(c) $K^- p \to \Sigma^o \pi^o$ ref.[7, 9]

(d) $K^- p \to \Sigma^- \pi^+$ ref.[7,8,9]

The solid and dashed curves represent the result of this analysis and of ref. [2], respectively.

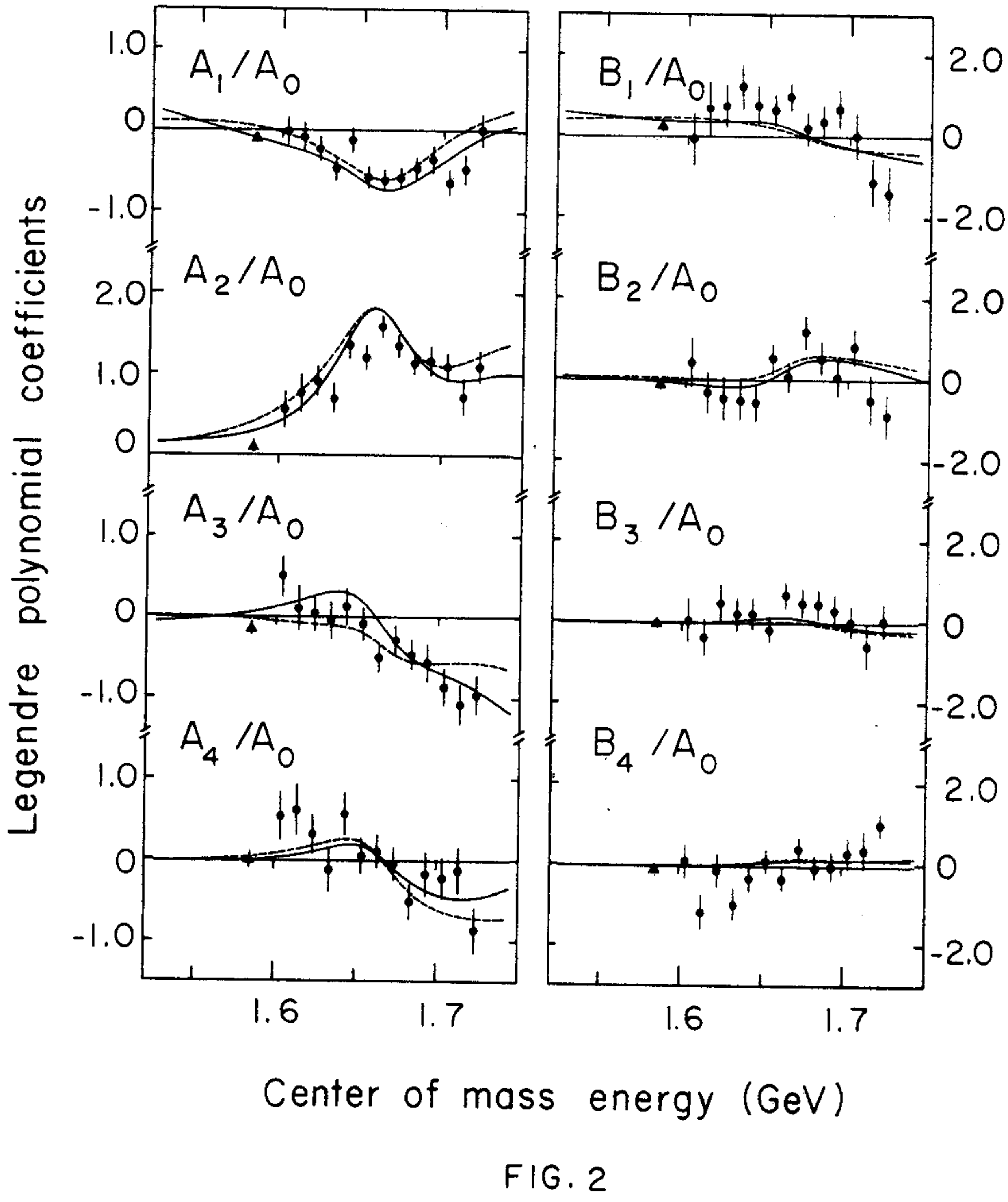
Fig. 2 Coefficients A_i/A_o and B_i/A_o (i = 1,2,3,4) for the reaction $K^- n \to (\Sigma\pi)^-$ as a function of the $K^- n$ CM energy. The solid and dashed curves represent the result of this analysis and of ref. [2], respectively.

Fig. 3 Argand diagrams for $\bar{K}N \to \Sigma\pi$ partial wave amplitudes. The solid and dashed curves represent the result of this analysis and of ref. [2], respectively. The arrows indicate the direction of increasing CM energy.



Σ⁺ π⁻
a)
(Σ π)±
b)
Σ° π°
c)
Σ⁻ π⁺
d)
0.10
0
Cross section / (4 π ƛ²)
1.6
1.7
Center of mass energy (GeV)

FIG. 1



Legendre polynomial coefficients
Center of mass energy (GeV)
A_1/A_0
A_2/A_0
A_3/A_0
A_4/A_0
B_1/A_0
B_2/A_0
B_3/A_0
B_4/A_0
1.6
1.7

FIG. 2