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K'p--> xi""""^ BETWEEN 1730 MeV AND 2150 MeV

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program, FOG, the kinematic fitting program, CLOUDY, and the logical selection program, FAIR. Ambiguities were looked at on the scan table and either resolved or sent back for remeasure. The throughput efficiencies, percentage of events believed to be good sigmas currently available for analysis, are about 92% for the early batch and 79-82% for the more recent data. The remeasures for the latter have been completed but are not used here.

The normalization for the recent batch was based on a count of beam tracks that decayed via the three-prong tau mode. Although the cross sections for the earlier batch have been published previously,[1] they tended to be lower than other published values.[2] We have renormalized this set of data based on the beam count used in the Vee topology for the same film.[3]

Before beginning any analysis, we studied the lifetime of the sigmas and the decay angle in the helicity frame. In this way we determined the appropriate cuts and weights to compensate for events subject to scanning bias. The lifetimes determined for both sigmas are in agreement with recent determinations with much greater statistics.[4]

RESULTS

We have obtained from our data the following information: cross sections for both channels, angular distributions for both channels, and polarizations for the $\Sigma^+\pi^-$ channel. Where possible we obtained the distributions in twenty equal bins of the production cosine, but because of limited statistics we generally had to combine bins. Polarization information can be obtained only from the proton decay of the positive sigma.

We have obtained the angular distributions and cross sections using only the pion decay modes; for high momentum sigmas the decay proton is constrained to the small decay angles frequently missed by scanners. This scanning bias does not affect the determination of the polarization. For each bin in the production cosine, the polarization is

$$P(\cos\,\theta) = \frac{3}{\alpha N} \sum \cos\,\chi_i$$

where N is the number of events in the bin and the angle, χ_i, for each event is measured between the direction of the proton in the sigma center of mass and the production normal, $\hat{k} \times \hat{\pi}$, with $\alpha = -1$.

Events satisfying all cuts were weighted individually. Average weights in each angular distribution bin were never more than about 1.6 and averaged about 1.35. Weights for the cross sections, where a significant azimuthal cut was applied, were typically about 2.

We have expanded the distributions in the Legendre series and the associated Legendre series[5]

$$I = \frac{d\sigma}{d\Omega} = \lambda\!\!\!^{-2} \sum_m A_m P_m\,(\cos\,\theta)$$

$$IP = \lambda\!\!\!^{-2} \sum_m B_m P_m^1\,(\cos\,\theta)$$

The structure in the cross section is more noticeable after the kinematic factor, $\lambda\!\!\!^{-2}$, has been removed, so we have plotted in Fig. 1 the A_o's from our data along with those in a recent review article.[6] The values in the Σ^+ channel are in very good agreement. In the Σ^- channel our data indicate a major enhancement which is shifted to higher momenta than that in the review.

Of particular interest to us is the center-of-mass energy region between 1850 and 2000 Mev. There are well-known resonances both above and below this region:

$I = 0$	$J^P = 5/2^+$	at	1815 Mev
$I = 0$	$J^P = 5/2^-$	at	1830 Mev
$I = 1$	$J^P = 7/2^+$	at	2030 Mev
$I = 0$	$J^P = 7/2^-$	at	2100 Mev

However, this energy region has not been as thoroughly studied. A resonance has been reported in the $I = 1$, $J^P = 5/2^+$ state at 1915 Mev.[8] This is a candidate to fill out the $5/2^+$ recurrence of the $1/2^+$ baryon octet. We have included in Fig. 2 the coefficients which seem to show definite structure in this region. These are A_2 and A_3 in the Σ^- channel, and A_2 and B_3 in the Σ^+ channel, all of which seem to have extrema centered in the vicinity of 1900-1920 Mev. Other coefficients are monotonic within errors in this region.

THE ANALYSIS

We have used a conventional partial wave analysis in which the angular distribution and polarization may be represented[5]

$$\frac{d\sigma}{d\Omega} = I = |f|^2 + |g|^2$$

$$I\vec{P} = 2\,\mathrm{Re}\,(f^* g)\,\hat{n}$$

where $\hat{n}$ is the production normal we have used, and

$$f(\theta) = \lambda \sum_{\ell}[(\ell + 1)\; T_{\ell}^{+} + T_{\ell}^{-}]\; P_{\ell}$$

$$g(\theta) = i\; \lambda \sin\theta \sum_{\ell} [T_{\ell}^{+} - T_{\ell}^{-}]\; \frac{dP_{\ell}}{d\cos\theta}$$

The waves, T, are differentiated by their orbital angular momentum quantum number, ℓ, and parity state $\pm$. We shall refer to them according to the standard convention specifying orbital state by the letter, isospin state by its integral value, and spin by twice its half integral value. Thus F05 refers to the $5/2^{+}$ state in I = 0, which resonates around 1815 Mev.

Thus far we have tried only energy-dependent fits in which we fit a series of energies simultaneously. Single energy fits would be preferable but the nature of our data makes this impractical. At a single energy the number of data points is severely limited, and our data require high order waves, increasing the number of parameters to be considered. We have used only two types of parameterization, resonant and polar background.

The resonant parameterization takes the form:

$$T(E) = \frac{A\; D_1 \frac{\gamma}{2}\; e^{i\phi}}{(E_R - E)\; -\; i\; D_2 \frac{\gamma}{2}}$$

Here A is the amplitude of the wave, E_R is the resonant energy, $\gamma/2$ is the reduced half width, and ϕ is a relative phase. The energy dependence of the width is contained in the terms D_1 and D_2, based on the formula of Glashow and Rosenfeld.[9]

We have chosen to represent the background with a form in which the magnitude and phase of the wave may vary independently

$$T(k) = (A + Bk)e^{i(C + Dk)}$$

Here k is the center-of-mass momentum in the elastic channel. In general, this parameterization gives a position and derivative of the magnitude and phase. In particular, it can take on, within an energy span not greater than one width, the general appearance of a resonance. Thus, in fact, when we began our analysis we included only F05 as resonant, but this polar representation suggested first the D05 and then the D15 as purely resonant. We emphasize that this parameterization is not intended to be valid over a broad energy region. We suspect that any parameterization may break down over too broad a range; therefore, we prefer to work within limited, overlapping regions and then to iron out inconsistencies. In this way we hope the data will suggest a broad parameterization not readily foreseen.

Our best fits are summarized in Table I with the resonance parameters listed in Table II. All waves below D5, in both isospins, are represented by polar backgrounds. The parenthetical number for a resonance indicates the number of free parameters. In all our best fits, all parameters were free to vary except, usually, the relative phase of the F05 resonance.* We have tried fitting both the Legendre coefficients and the distributions directly. The fits to the coefficients had confidence levels two to three times greater than those for fitting the distributions with the same parameterization. Several waves consistently violate the Wigner condition for causality in our best fits.[5] The worst violation for each

* On two occasions (including fit c) when even this parameter was free, the fit showed marked improvement; apparently the fitting procedure used this variable as a convenient route for adjusting many relative phases.

fit is indicated in Table I, where the motion of the phase is given in radians per pion mass. We intend to study this problem further.

In the energy region between 1733 and 1865 MeV, our data indicate that coefficients above A_5 are consistent with zero. Fit A shows that the data does not require F7. Above this region the A6 becomes significant, but only in the $\pi^+\Sigma^-$ channel. We have tried adding F15 and F17 to account for this; Fits B and C show some slight improvement over Fit A and prefer a resonant parameterization for the D15. The resonance parameters are in general agreement with previous determinations.[6,7] However, our data distinctly prefer a narrow width for the D05. Also, the D15 has a lower mass than generally accepted.

We have gotten one significant fit in the energy region from 1844 to 2001 MeV, listed as Fit D in Table I. The higher mass for the F05, which was parameterized as purely resonant, may indicate the presence of background in this wave. In Fig. 3 we have rotated this fit so the D05 and F05 waves retain a crude continuity with their counterparts in Fit B. The F15 and F17 move in a manner consistent with resonances reported elsewhere,[6,7] having masses of 1910 and 2030 MeV respectively. Both waves havethe same relative phases as the D05 and F05 at these energies, which agrees with the results of others.[6] Assuming the F15 is dominated by the $\Sigma(1910)$, we obtain from this fit an amplitude of .14 ± .05 (in the notation of Ref. 6, t = -.14). If we use an elasticity for the F15 resonance of .10,[7] we find that the branching fraction into the $\Sigma\pi$ channel is .20.

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TABLE I.

Summary of best fits to data in two energy regions. The type of parameterization is either resonant (number of variables given) or polar background. All waves below D5 have polar background in both isospins. The last two columns indicate wave with worst violation of Wigner condition; the rate of change of the phase is given in radians per pion mass.

Fit	Data	Energies†	Parameterization D05	D15	F05	F15	F17	χ^2	DF	Causality Violation	
A	Distributions	1.733-1.865	R(4)	P	R(3)	-	-	266.2	244	S11	-2.5
B	Coefficients	1.733-1.865	R(4)	R(4)	R(3)	P	P	88.7	89	P13	-1.8
C	Distributions	1.733-1.865	R(4)	R(4)	R(4)	P	P	247.0	235	P11	-3.0
D	Coefficients	1.844-2.001	P	P	R(3)	P	P	97.3	89	P11	-5.5

TABLE II.

List of resonance parameters for the fits given in Table I. $\gamma/2$ is the reduced half-width. $D_2(E_R)$ is the full width energy dependence evaluated at the resonant energy. Their product is the normally quoted half-width.

Resonance	Fit	E_R †	$D_2(E_R)\gamma/2$ †	Amplitude	Relative Phase
F05	A	1.831	.048	.316	[3.14]
	B	1.822	.046	.285	[3.14]
	C	1.832	.047	.311	3.14
	D	1.893	.101	.262	[3.14]
D05	A	1.831	.036	.122	3.47
	B	1.832	.028	.127	3.61
	C	1.824	.029	.125	3.25
D15	B	1.738	.050	.079	-.53
	C	1.756	.078	.068	-.40

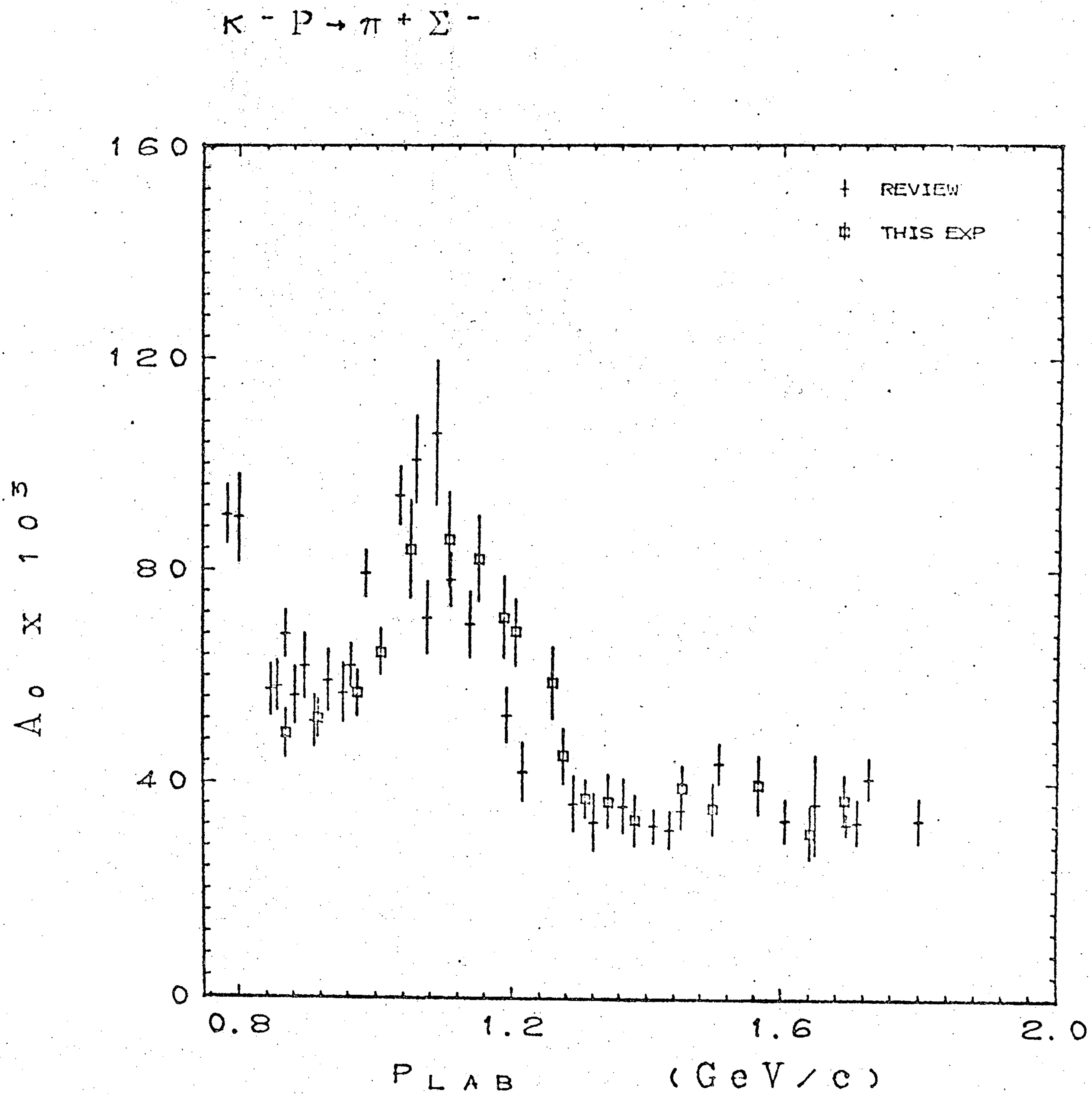
† Energies in GeV

FIGURE CAPTIONS

Fig. 1. The A_0's obtained from our data are compared to those taken from Ref. 6. a) The data for the channel $K^- p \to \pi^+ \Sigma^-$. b) The data for the channel $K^- p \to \pi^- \Sigma^+$.

Fig. 2. The coefficients in our data which show structure in the region from 1850 to 2000 Mev (indicated by horizontal bars). All other coefficients are monotonic within errors through this particular region.

Fig. 3. Solid curves are the high order waves from Fit D in Table I. These have been rotated so that the D05 and F05 retain some continuity with their counterparts in Fit B, given by the dashed curves. The energy range of the dashed curves is 1798 to 1844 Mev; that for the solid curves is 1844 to 2001 Mev. The arrow is located at 1920 Mev.



$K^- P \to \pi^+ \Sigma^-$
REVIEW
THIS EXP
160
120
80
40
0
0.8
1.2
1.6
2.0
$A_0 \times 10^3$
P_{LAB} (GeV/c)

Fig. 1A

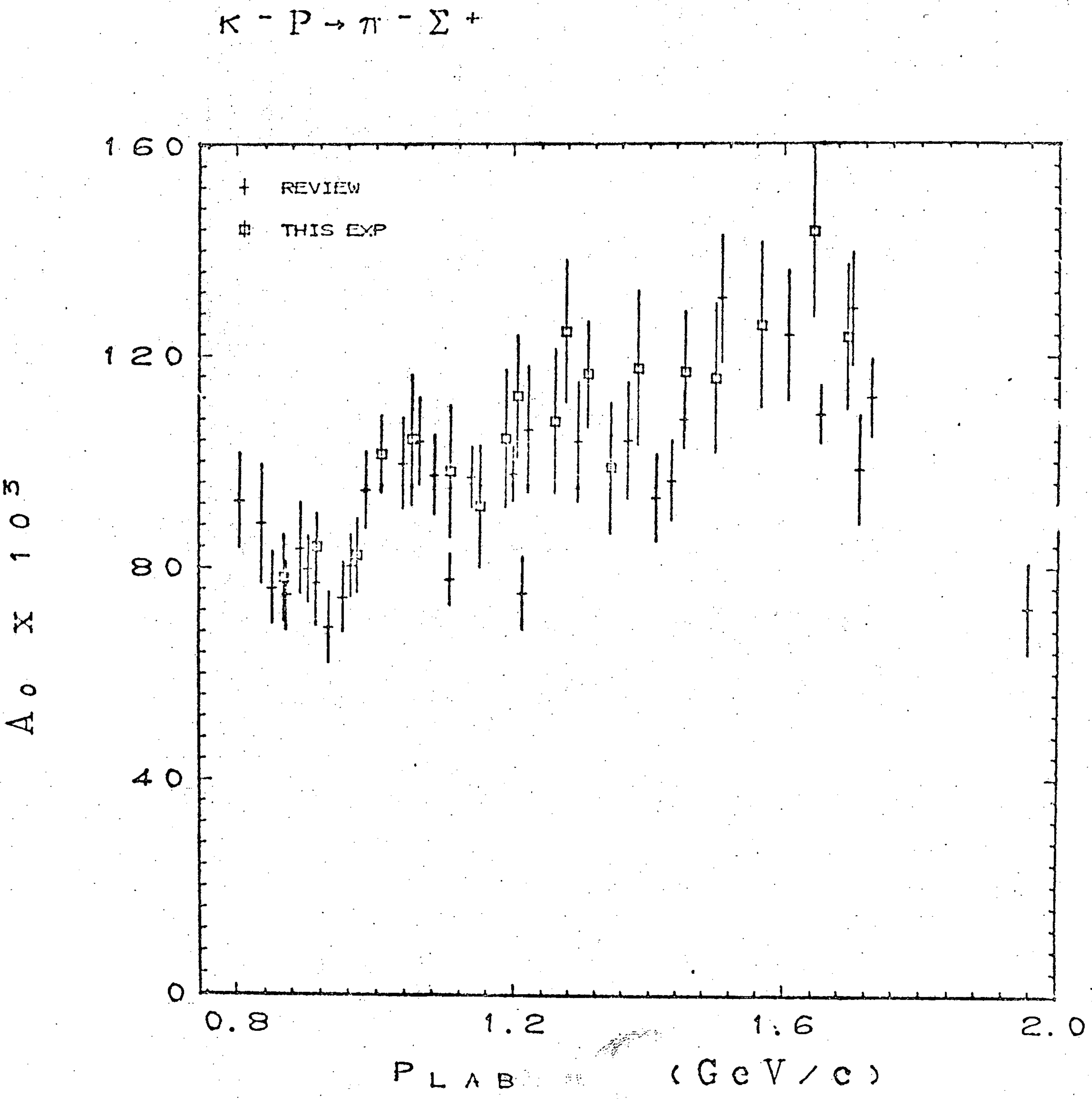

K⁻P → π⁻Σ⁺
160
120
80
40
0
0.8
1.2
1.6
2.0
REVIEW
THIS EXP
A₀ x 10³
P LAB (GeV/c)

Fig. 1B

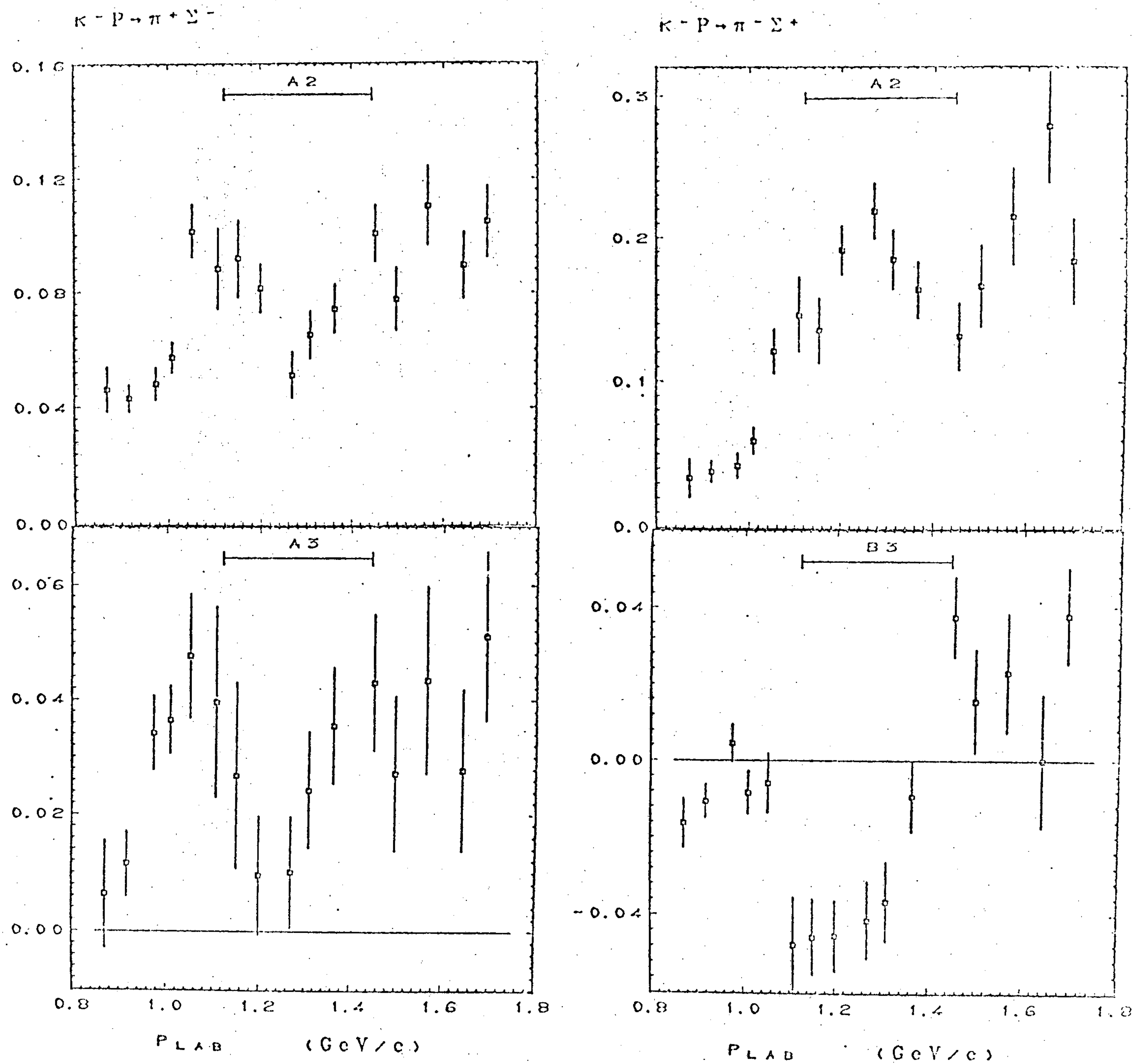

K⁻P → π⁺Σ⁻
K⁻P → π⁻Σ⁺
A2
A3
A2
B3
0.16
0.12
0.08
0.04
0.00
0.06
0.04
0.02
0.00
0.3
0.2
0.1
0.0
0.04
0.00
-0.04
0.8 1.0 1.2 1.4 1.6 1.8
P LAB (GeV/c)

Fig. 2

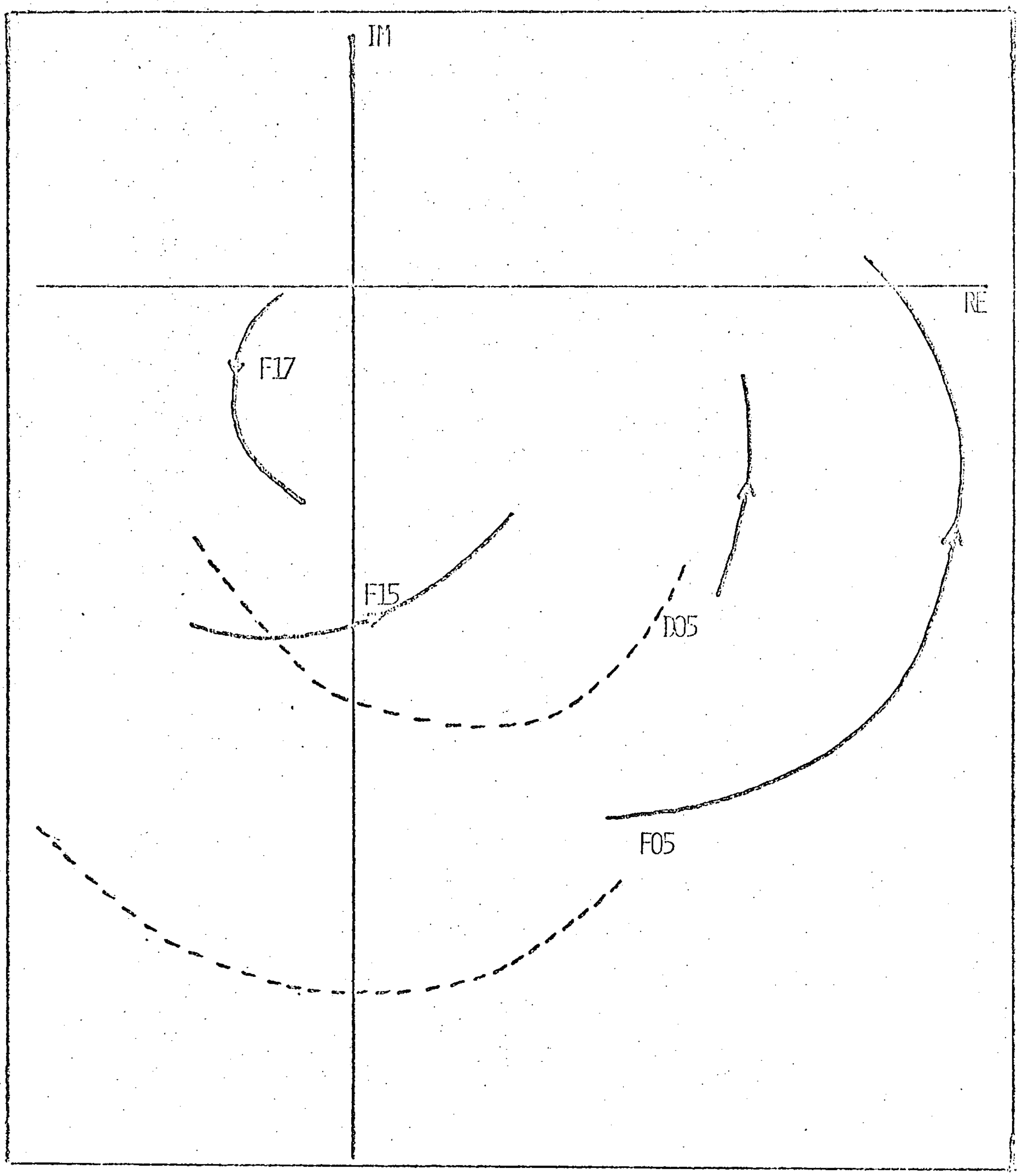


Fig. 3

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