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Y^* SEARCH

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Y^* SEARCH

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In this talk I shall attempt to summarize the Y^* situation in the ~1600 to ~1900 MeV mass region. I shall concentrate on the lower partial waves (S, P_1, P_3, D_3), where we seem to be still a long way from having any sort of quantitative agreement among various partial wave analyses.

I. Data: Old and New

The "first generation" experiments which were nearly completed or well under way at the time of the Duke Conference on hyperons (April 1970) are summarized in Fig. 1.[1] The vast majority of $\bar{K}N$ formation experiments have utilized the bubble chamber. Such experiments have the advantage of seeing all relevant final states (in particular, K^0n, $\Lambda\pi$, $\Sigma\pi$) at once. On the other hand, they suffer from low statistics as compared to πN counter experiments at similar momenta. Even the find polarization measurements of the CERN-Holland group[2] come out on the short end when compared to similar πN experiments. The hard experimental reality of this situation is that K beams are simply much less intense than π beams at these low momenta. This fact must be borne in mind when we contrast our understanding of $\bar{K}N$ partial waves with those of πN.

The "second generation" experiments in progress are summarized in Fig. 2.[1] These new experiments should be quite useful in providing a more precise determination of the lower partial waves in the 1600 to 1900 MeV mass region.

The only new data relevant to the Y^* search presented to this conference is that of the Chicago-LBL (Ch-LBL) collaboration.[3] They report on some 90 000 events from the reactions $K^-p \to \bar{K}^0n$, $\Lambda\pi^0$ and $\Sigma^{\pm}\pi^{\mp}$. The data came from an exposure at nine momenta between 860 and 1000 MeV/c in the LBL 25" HBC. The quality of their data is shown in Figs. 3-5. The $\Lambda\pi$ statistics at nine momenta are nearly as good as the K^-p statistics of the CHS experiment at some 20 momenta. It should be mentioned that the curves shown are not Legendre polynomial fits but rather the results of single-channel, partial wave analyses performed by Ch-LBL. In addition to their new data, they also used in their analysis, data between 780 and 1220 MeV/c (1690-1900 MeV in mass) from the literature, including K^-p polarization data.[4] The overall fit is quite good, with χ^2/DF varying from 1.15 in the $\bar{K}N$ channel to 1.06 in the $\Lambda\pi$. This should be kept in mind when we compare their solutions with others in the same mass region.

II. Methods of Partial Wave Analyses

Below I shall compare six analyses which cover the 1690 to 1900 MeV mass region. First, however, I must summarize the various amplitude parametrizations used in these analyses.

1. Energy-dependent single-channel analyses

Each partial wave is assumed to be of the form

$$T_{\ell\pm,I} = a + b(p-p_0) + \frac{xe^{i\phi}}{\frac{2(E_R-E)}{\Gamma} - i} .$$

Here a and b are complex parameters and the background has been given some energy dependence (p is often taken as the laboratory momentum). These parameters and those of the resonance

$- x = \Gamma_{el}/\Gamma$ [or $(\Gamma_{el}\Gamma_{in})^{1/2}/\Gamma$]; E_R, Γ – are determined by fits to the data. The additional phase parameter ($e^{i\phi}$) expresses the well-known fact[5] that the resonance can be rotated relative to the background.

Comments:

a) In this approach, one channel is fit at a time

b) The range of energy in the fit must be restricted since the "linear" background eventually breaks unitarity.

c) The $S_{11}(1750)$ and $P_{03}(1860)$ which all analyses claim to see were first suggested[6] through the use of this approach.

d) The majority of the CHS collaboration (~1540 to ~1900 MeV), analyses and the Ch-LBL analysis use this method.

2. Energy dependent, coupled channel K-matrix

In this approach the K-matrix formalism is used

$$T_{\ell\pm,I} = K[1-iQK]^{-1},$$

where the channels are $\bar{K}N$, $\Lambda\pi$, $\Sigma\pi$ and usually an additional "junk" channel to account for three (or more) body final states. In the analysis of Kim[7] (~1430 to 1900 MeV) K is essentially given by an effective range expansion,

$$(Q^{\ell}K^{-1}Q^{\ell})_{ij} = M_{ij}^{(0)} + M_{ij}^{(1)}(E-E_0) + \cdots,$$

where the free parameters are the (symmetric) M_{ij}'s. In a new, preliminary analysis submitted to this conference, Lea, Oades, Martin and Moorhouse[8] (LOMM, ~1540 to 1900 MeV) have used

$$(Q^{-\ell}KQ^{-\ell})_{ij} = \sum_r \frac{\gamma_i^{(r)}\gamma_j^{(r)}}{E-E_r} \pm \gamma_i\gamma_j(E-E_0),$$

where the channel widths are given essentially by $\Gamma_i^{(r)} = q_i^{2\ell+1}(\gamma_i^{(r)})^2$.

Comments:

a) In this approach unitarity is insured so long as K is real symmetric. If three body final states are not too significant the "junk" channel approximation should be adequate.

b) In practice Kim fitted over energy intervals, $M^{(0)}$ for the (n+1)-interval being given by M for the nth interval.

c) For one resonance the expression of LOMM gives a factorizable Breit-Wigner in T. Unlike that of Kim, the LOMM parameterization permits them to introduce resonances one at a time. This particular approach may in fact be the most economic parameterization of more or less general applicability.

3. Energy-independent analyses – almost

Two energy-independent analyses have been attempted over the energy interval ~1540 to ~1900 MeV: that of the CERN-Heidelberg (CH) collaboration[9] and a more recent are by Langbein and Wagner[10] (LW). Both of these analyses impose some sort of multichannel unitarity constraint. In addition they both are not strictly energy independent in that the higher partial wave resonances (D_{15} and F_{15}) are included as Breit-Wigner resonances, acting in some sense as analysers for the lower partial waves.

III. Comparison of the Solutions

We may now compare the various solutions. Many of the discrepancies we see are due to the following factors:

1) Use of somewhat different data sets,

2) Different approaches to the partial wave analysis as discussed above.

While these differences may suggest that a comparison is unfair, it should be remembered that if the data were really good, minor

differences in the analyses ought still in principle to produce similar quantitative conclusions as to the behavior of the partial wave amplitudes.

The S_{11} waves for the KN, $\Sigma\pi$, and $\Lambda\pi$ channels are shown in Figs. 6-8. The CHS:ED analysis is a summary from Ref. 11; it should be considered as only a rough guide, since it represents the earliest attempt at determining the lower waves. While optimistically we might say there is some qualitative agreement among these solutions, it seems clear that we are still far from a good understanding of this wave.

Notice that the Ch-LBL analysis actually suggests two S_{11} resonances in the 1740 MeV mass region. The evidence for this comes primarily from their new data in the $\Sigma\pi$ and $\Lambda\pi$ channels. In particular they find—when only one S_{11} is included—two different solutions of similar χ^2 but with distinct resonance parameters. When they include both resonances, they find in fact that their fit becomes somewhat better. Although such evidence cannot be considered conclusive, it is clear that future analysis should examine this possibility. This is especially important in view of the fact that the $(\underline{70}, 1^-)$ representation of the quark model requires two S_{11} resonances in this mass region.

A similar situation exists in the D_{13} waves shown in Figs. 9-11. Again there is at best qualitative agreement among the solutions. Here, as before, the Ch-LBL analysis indicates the data could be quite consistent with the existence of two D_{13} states in the 1730 MeV region, provided they had very weak couplings to the $\bar{K}N$ channel. In this case, however, the improvement in χ^2 is not as impressive for either D_{13}. They mention this possibility only to provide limits

as to size of the resonant amplitudes which are consistent with the data at this energy.

In Table I, I have summarized the current situation with respect to Y^*'s in the lower partial waves. It should be noted that widths and couplings of these states often strongly disagree among these solutions even when the masses are comparable. The states in square brackets are generally accepted as well known.

Comments:

$\underline{S_{01}}$: The Ch-LBL analysis seems unable to find evidence for this state. The analyses which do see it are not unanimous about the elasticity, which ranges from ~0.2 to ~0.8 !

$\underline{P_{01}}$: There may be something near ~1750 MeV. The Ch-LBL analysis, however, only finds this effect in $\Sigma\pi$. Note that the other analyses are coupled channel.

$\underline{P_{03}}$: Everyone agrees that there is an effect in this wave, most likely at ~1860 MeV. This resonance was once thought to be F_{07}, but K^-p polarization data[2] seems to have definitely ruled out this spin.

$\underline{D_{03}}$: The $(\underline{70}, 1^-)$ representation of the quark model needs another D_{03} near 1800 MeV.

$\underline{S_{11}}$: Everyone finds at least one resonance at ~1750 MeV. LW and Kim find a second effect at ~1620 MeV. The Ch-LBL data are consistent with the existence of two resonances at ~1750 MeV.

$\underline{P_{11}}$: "Second generation" data in this region should determine whether the $P_{11}(1600)$ exists.

$\underline{P_{13}}$: Seems unlikely?

$\underline{D_{13}}$: This wave should be studied carefully. Again the new data should be quite useful here.

IV. The $Y^*(1405)$

Dalitz has suggested that the low-energy S_{01} wave be fit with a K-matrix of the form

$$K = K_b + \frac{CC^T}{E-E_0},$$

where K_b is a real, constant matrix, C a real, constant vector, and $E_0 \approx 1405$. With the presently available data it is possible to fit S_{01} with only the K_b term if one does not go too far above threshold. In this case, the $Y^*(1405)$ would be interpreted as a bound state of the $\bar{K}N$ system. A fit with the above parametrization ($C \neq 0$), however, would suggest that the $Y^*(1405)$ actually arises from forces in some higher-mass closed channel.

In a contribution to this conference, Dobson and McElhaney[12] argue that this issue cannot really be decided with available data. To determine better mass and width parameters for $Y^*(1405)$, Chao, Kraemer, Martin and Thomas[13] have included $\Sigma\pi$ production data in their K-matrix fit to low-energy $\bar{K}N$ data. They conclude that this must be done to constrain the $\pi\Sigma \to \pi\Sigma$ channel and thereby really determine the position of $Y^*(1405)$. The point I wish to make with regard to these analyses is that the low-energy $\bar{K}N$ formation data is not sufficiently precise to answer the question raised by Dalitz.

V. Conclusions

The Ch-LBL analysis (1690-1900 MeV) suggests the possibility of two S_{11} states in the ~1740 MeV region. This hypothesis is consistent with their new data (~1730-1794 MeV) for $\bar{K}^0 n$, $\Sigma\pi$, $\Lambda\pi$ final states, as well as with all older data available in this region. A similar possibility exists for the D_{13} partial wave. It is obvious that these states cannot be considered established until they are seen by other partial wave analyses which incude the new Ch-LBL data. On

the other hand, it is clear that future analyses should investigate the possibility of two resonances close in mass in the same partial wave. Reliable theoretical estimates of where such states are to be found could be useful in this difficult search, though they should not bias it.

The lower $\bar{K}N$ partial waves in the 1600-1900 MeV region are at best only qualitatively understood. Hopefully the "second generation" experiments may give us a more reliable quantative measure of them. In this region, the waves which need the closest objective scrutiny, in view of SU(3) and quark model[14] predictions, are the S_{01}, S_{11}, P_{11}, D_{13} and D_{03}. Of course, surprises in other waves should not be missed because of theoretical prejudice.

Even with new data, energy-independent analyses may still prove difficult to perform. In this event, an energy-dependent analysis using an economic parametrization—applicable over a broad energy range—such as that advocated by LOMM may be most reliable. Future analyses should cover as large an energy interval as is possible; continuity over broad energy regions may be our most powerful tool in ruling out spurious solutions.

Acknowledgments

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References

1. Figures 1 and 2 are from a reivew by M. Ferro-Luzzi, CERN/0:Ph. II/PHYS 71-9.

2. S. Andersson-Almehed et al., Nucl. Phys. B21 (1970)515; M. G Albrow et al., Nucl. Phys. B29(1971)413.

3. Chicago (R. Levi Setti) - LBL Collaboration, paper 938.

4. More precisely the data of Andersson-Almehed, 1970 (see Ref. 2) were included in the $\bar{K}N$ channel fit. The more recent data of Albrow, 1971 were found to be in excellent agreement with the fit, so much so that their inclusion in the fit would most likely not change the $\bar{K}N$ parameters quoted by Ch-LBL.

5. R. H. Dalitz, Ann. Rev. Nucl. Sci. 13, 339 (1963); C. J. Goebel and K. W. McVoy, Phys. Rev. 164, 1932 (1967).

6. B. Conforto et al., EFI 70-43 (August, 1970); also, B. Conforto et al., Nucl. Phys. B34 (1971) 41.

7. J. K. Kim, Phys. Rev. Letters 27, 356 (1971).

8. Lea, Oades, Martin, and Moorhouse, paper 627.

9. CH Collaboration, in Hyperon Resonances-70, ed. by E. C. Fowler (Moore Pub. Co., Durham, N. C., 1970).

10. Langbein and Wagner, Max-Planck-Institut für Physik und Astrophysik preprint; submitted to Nucl. Phys.

11. R. Levi Setti, rapporteur talk at the Lund International Conference on Particle Physics (1969).

12. Dobson and McElhaney, paper 101.

13. Chao, Kraemer, Martin and Thomas, paper 626.

14. R. H. Dalitz, talk presented at the Amsterdam conference on high energy physics.

Figure Captions

Fig. 1. "First generation" experiments: number of events/mb versus laboratory momentum. The superimposed dashed curve indicates the K^-p total cross section; the peak is at ~50 mb.

Fig. 2. "Second generation" experiments.

Fig. 3. Semi-log plots of $d\sigma/d\Omega$ versus the cosine of the c.m. scattering angle (K to π) for the new $K^-p \to \Lambda\pi^0$ data of the Ch-LBL (Ref. 3) collaboration. The dashed curve corresponds to their partial wave fit to the data.

Fig. 4. Same as Fig. 3, for the reaction $K^-p \to \Sigma^+\pi^-$.

Fig. 5. Same as Fig. 3, for the reaction $K^-p \to \bar{K}^0n$.

Fig. 6. The S_{11} partial wave for $\bar{K}N \to \bar{K}N$, a composite of recent solutions: CHS from Ref. 11; Ch-LBL from Ref. 3; Kim from Ref. 7; LOMM from Ref. 8; CH from Ref. 9; LW from Ref. 10. The labels EI and ED refer to whether the analyses were energy independent or energy dependent (see text).

Fig. 7. The S_{11} partial wave for $\bar{K}N \to \Sigma\pi$. (See caption to Fig. 6.)

Fig. 8. The S_{11} partial wave for $\bar{K}N \to \Lambda\pi$. (See caption to Fig. 6.)

Fig. 9. The D_{13} partial wave for $\bar{K}N \to \bar{K}N$. (See caption to Fig. 6.)

Fig. 10. The D_{13} partial wave for $KN \to \Sigma\pi$. (See caption to Fig. 6.)

Fig. 11. The D_{13} partial wave for $KN \to \Lambda\pi$. (See caption to Fig. 6.)

Table I. Lower wave resonant states claimed in recent partial wave analyses. States in brackets are "well known."

	New PWA			"Old" PWA	
	New Data				
	Ch-LBL	LOMM	LW	KIM	CH(S)
S_{01}	[1670] No 1830	[1668] –	[1640] 1830?	[1670] $1780_{\bar{K}N}$	[1670] 1870
P_{01}	$1744_{\Sigma\pi}$	–	1620 1780	1570 1755	1740-1800
P_{03}	$1885_{\bar{K}N}$	1863 Γ=340!	$1850_{\bar{K}N}$	1710?	1880
D_{03}	[1690]	[1690]	[1690]	[1690]	[1690]
S_{11}	1730 8 1750 10	1750	1630 1750	1620 1790	1750
P_{11}	–	1620	–	~1600	~1600
P_{13}	–	–	1840	–	~1700?
D_{13}	[1665] 1700 $\Lambda\pi$ 1752 $\Sigma\pi$	[1670] 1863 !	[1670]	[1670]	[1670]

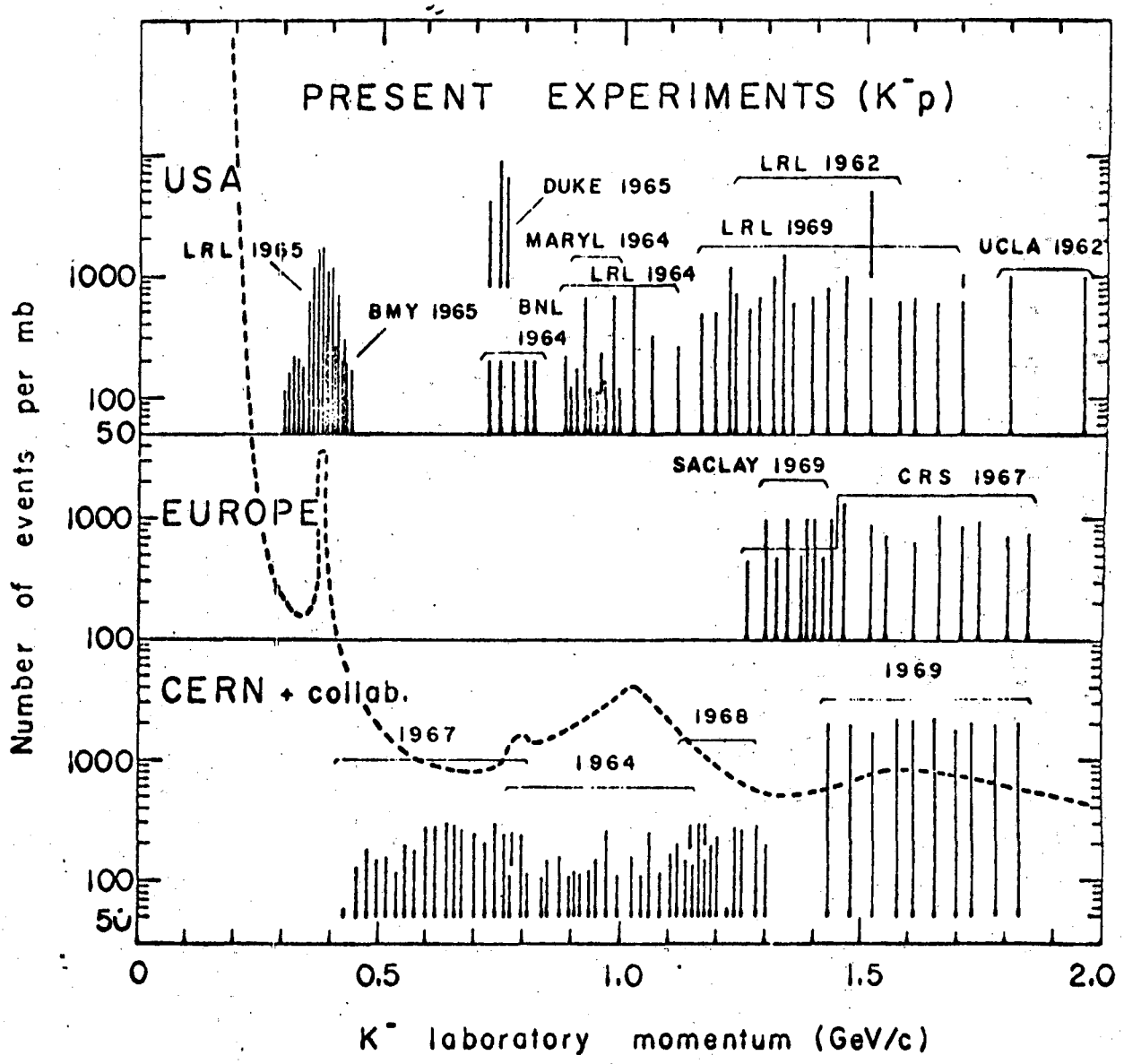

PRESENT EXPERIMENTS (K⁻p)
USA
LRL 1965
BMY 1965
DUKE 1965
BNL 1964
MARYL 1964
LRL 1964
LRL 1962
LRL 1969
UCLA 1962
EUROPE
SACLAY 1969
CRS 1967
CERN + collab.
1967
1964
1968
1969
1000
100
50
Number of events per mb
0
0.5
1.0
1.5
2.0
K⁻ laboratory momentum (GeV/c)

Fig. 1

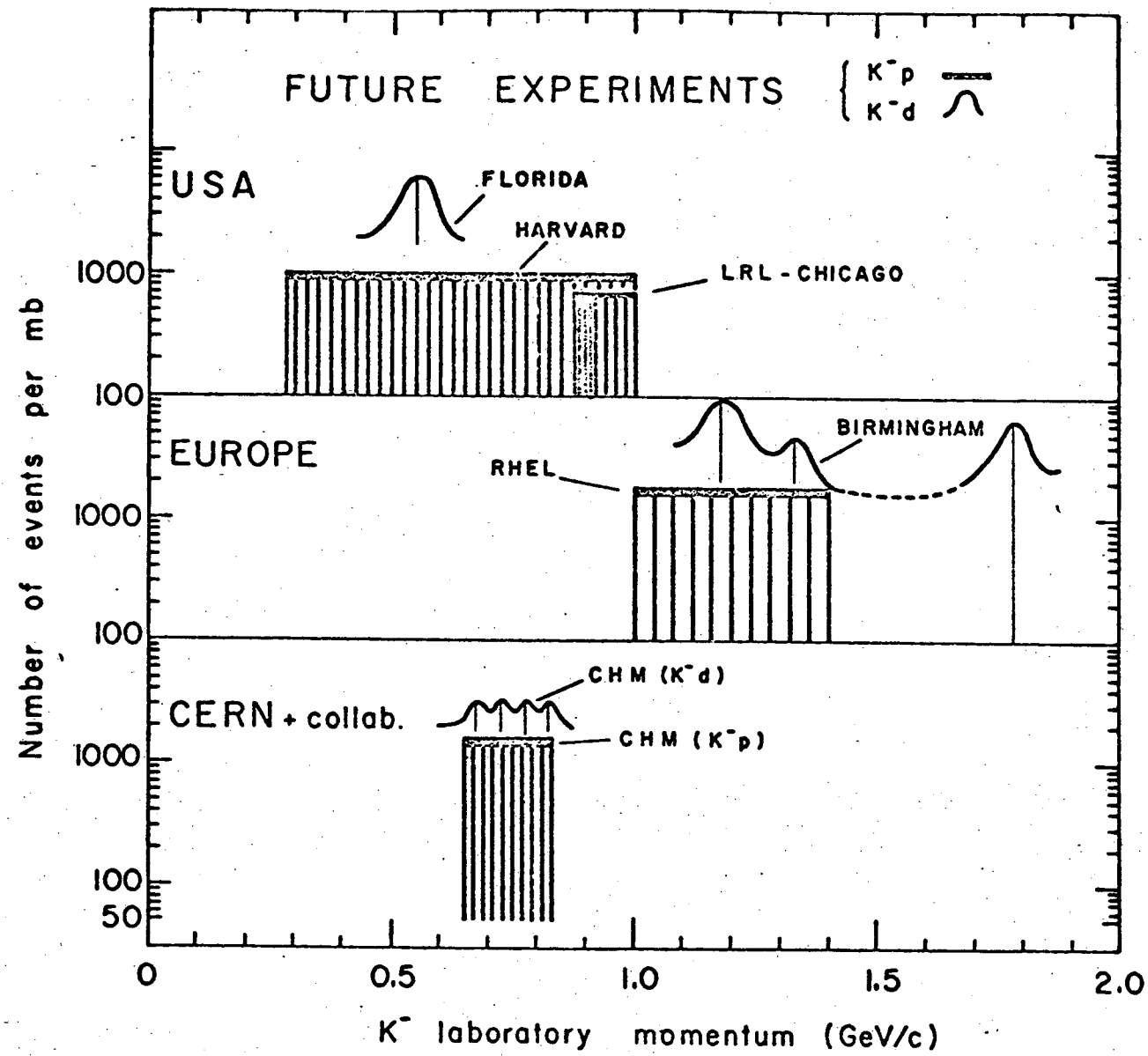
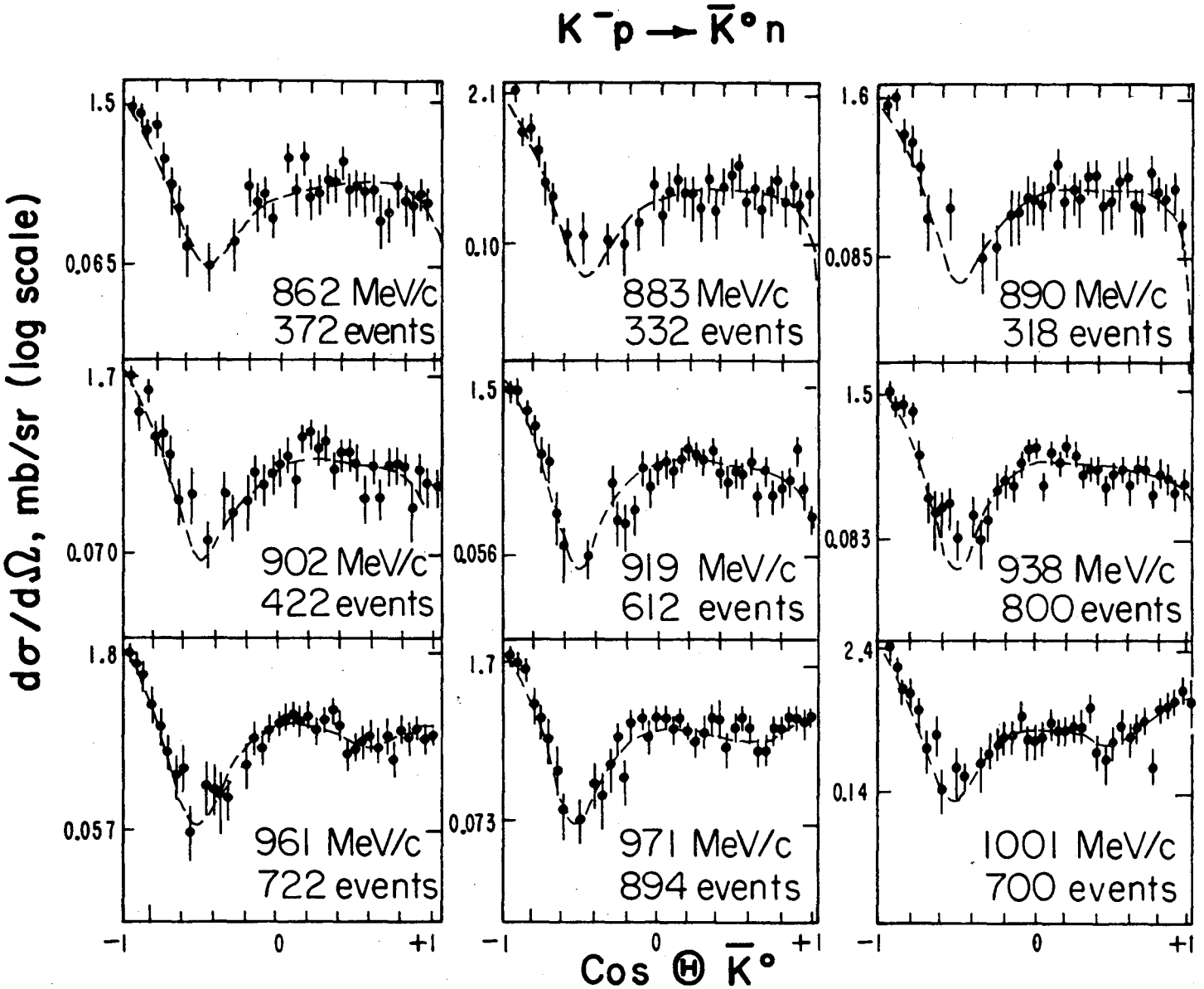

FUTURE EXPERIMENTS
K⁻p
K⁻d
USA
FLORIDA
HARVARD
LRL - CHICAGO
EUROPE
RHEL
BIRMINGHAM
CERN + collab.
CHM (K⁻d)
CHM (K⁻p)
Number of events per mb
1000
100
1000
100
1000
100
50
0
0.5
1.0
1.5
2.0
K⁻ laboratory momentum (GeV/c)

Fig. 2


K⁻p → K̄°n
dσ/dΩ, mb/sr (log scale)
862 MeV/c
372 events
883 MeV/c
332 events
890 MeV/c
318 events
902 MeV/c
422 events
919 MeV/c
612 events
938 MeV/c
800 events
961 MeV/c
722 events
971 MeV/c
894 events
1001 MeV/c
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Cos Θ K̄°
XBL7210-4149

Fig. 3

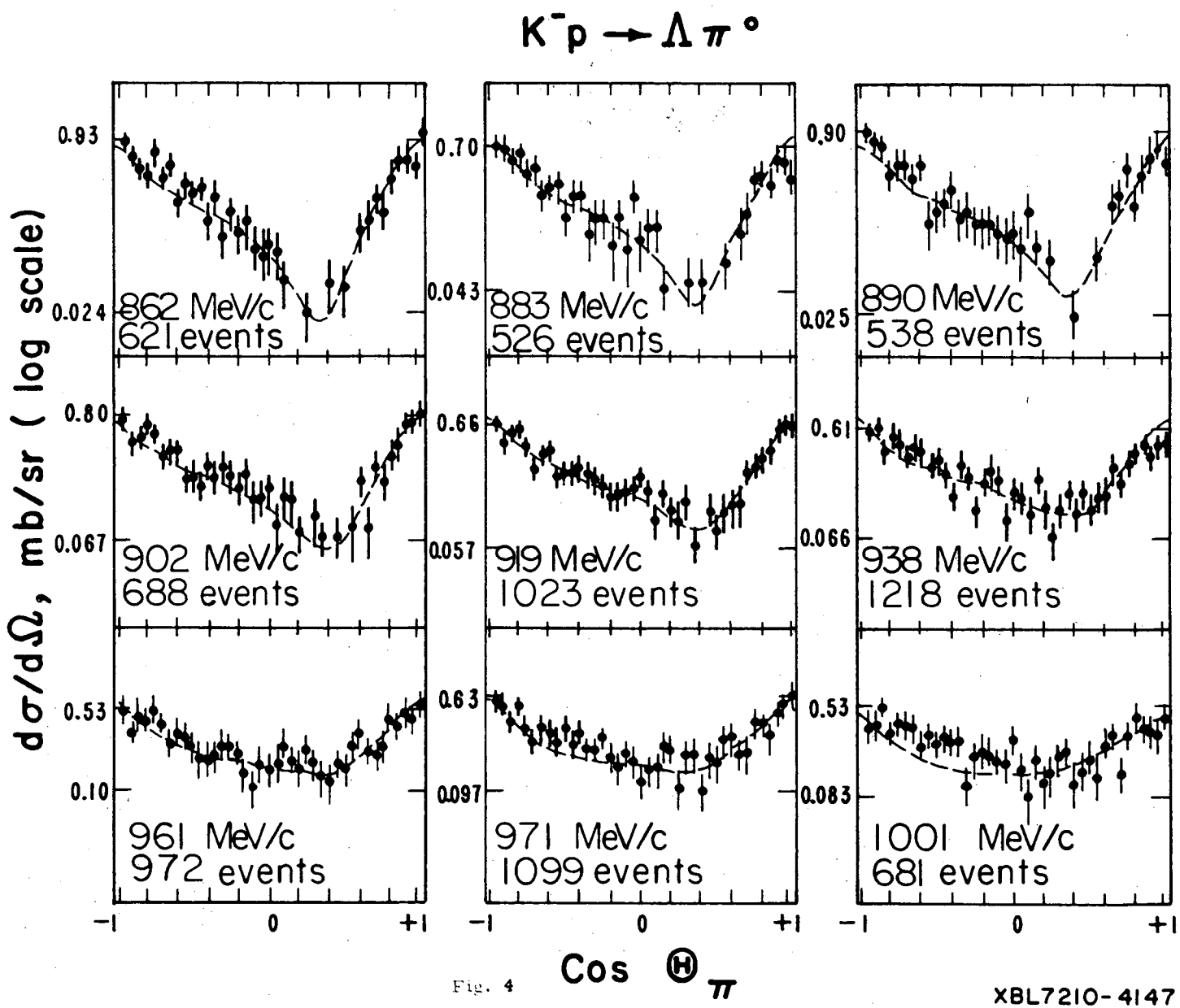

Fig. 4

XBL7210-4147

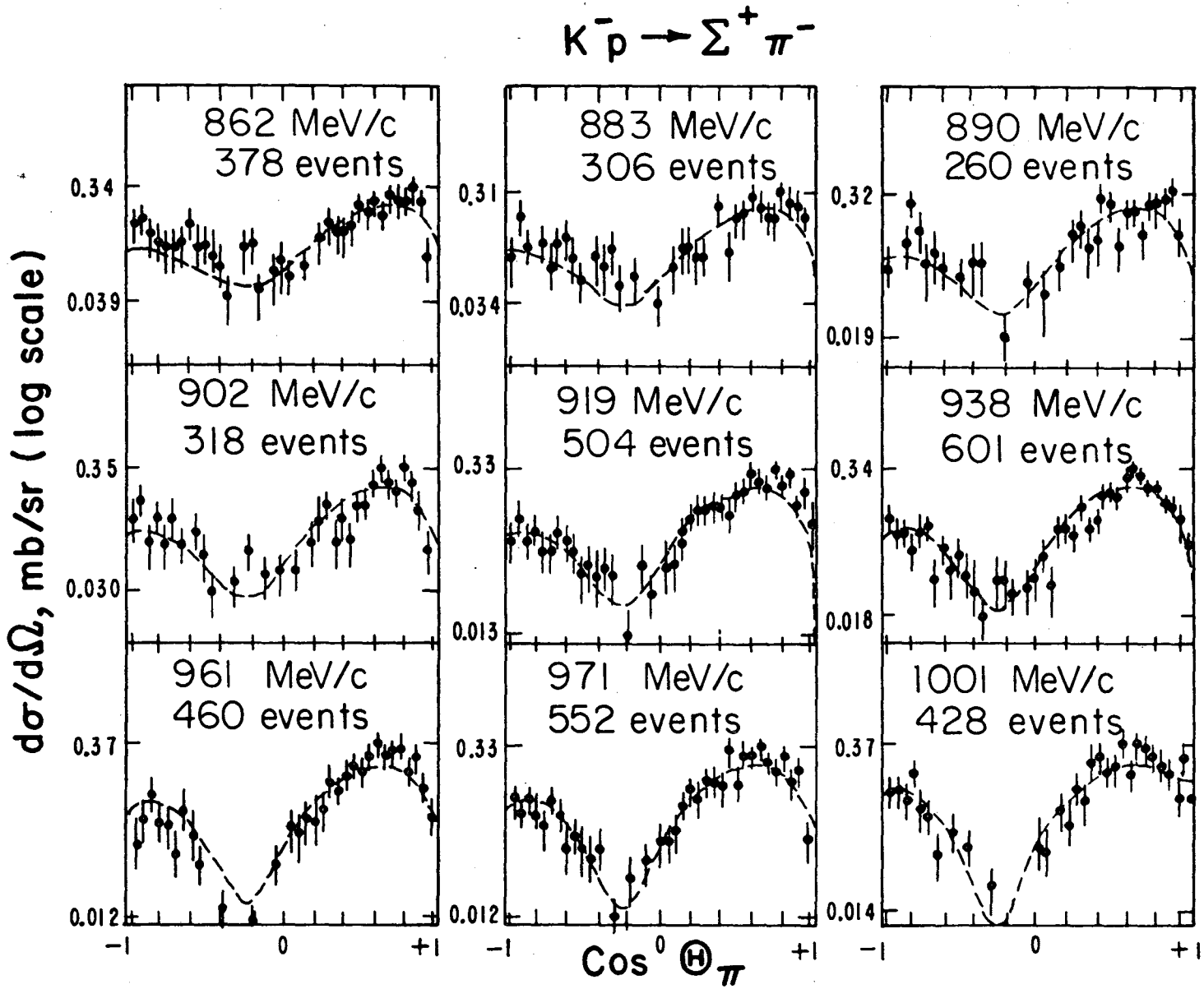

Fig. 5

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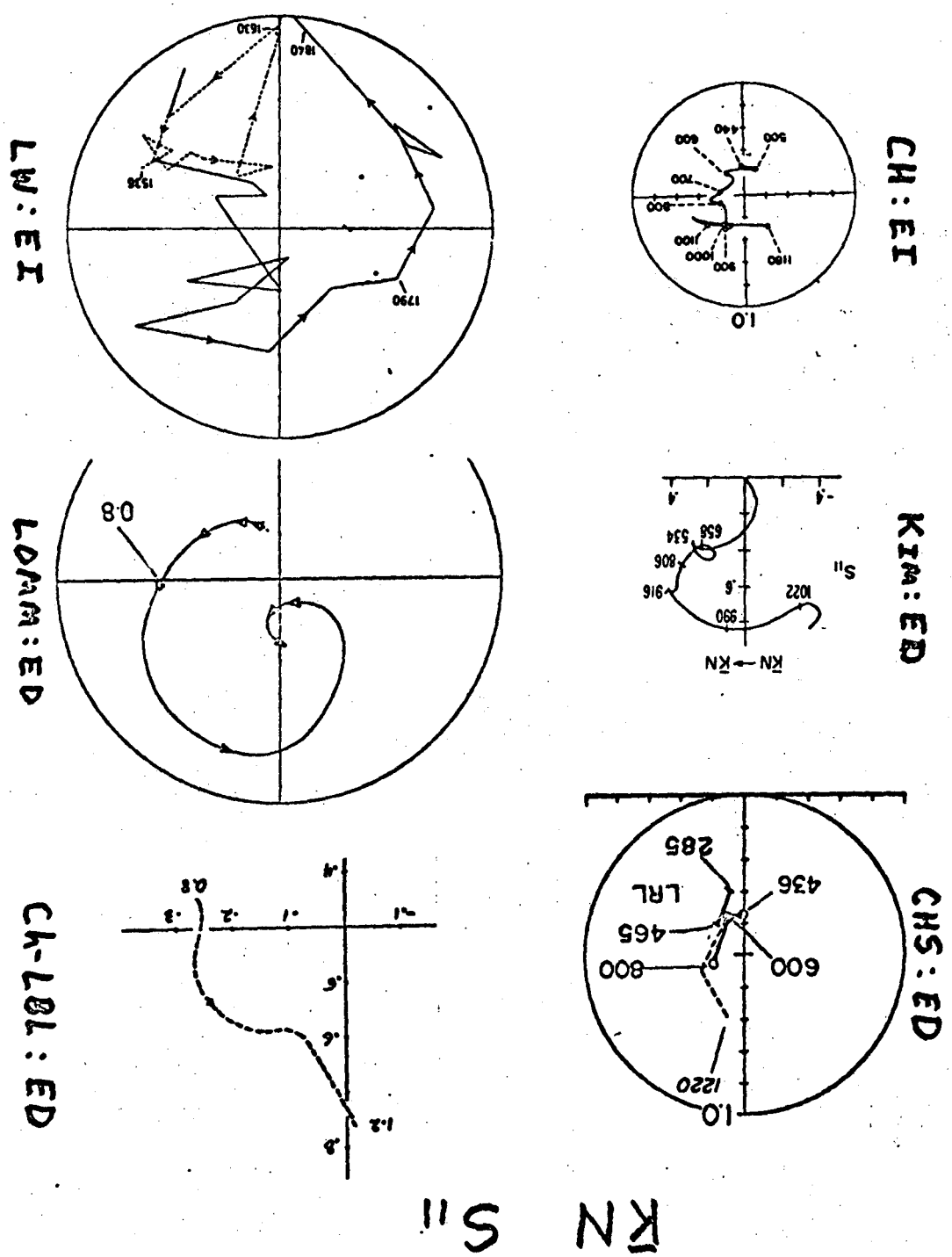
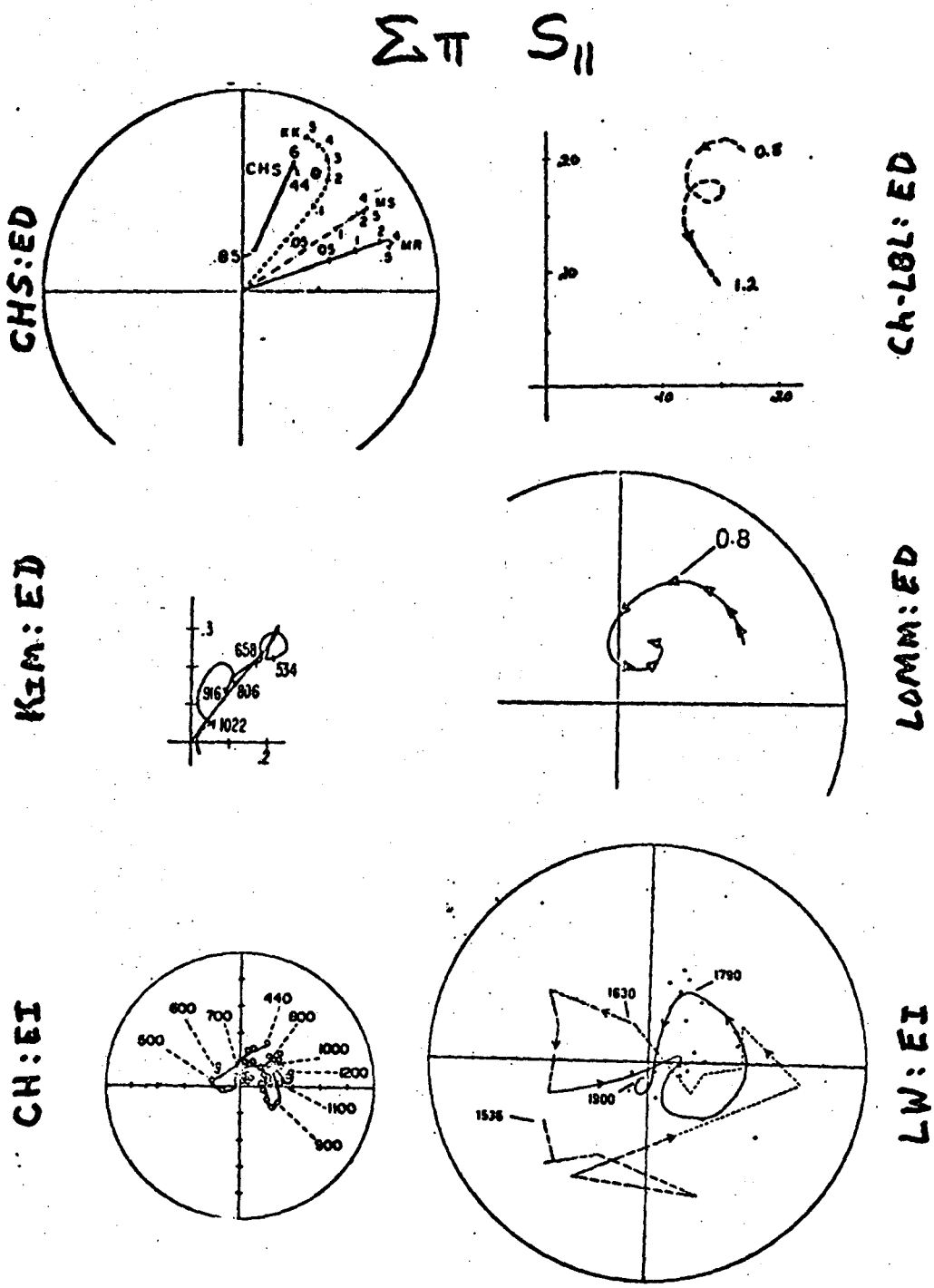


Fig. 6


Σπ S11
CHS:ED
CH-LBL:ED
KIM:ED
LOMM:ED
CH:EI
LW:EI
CHS
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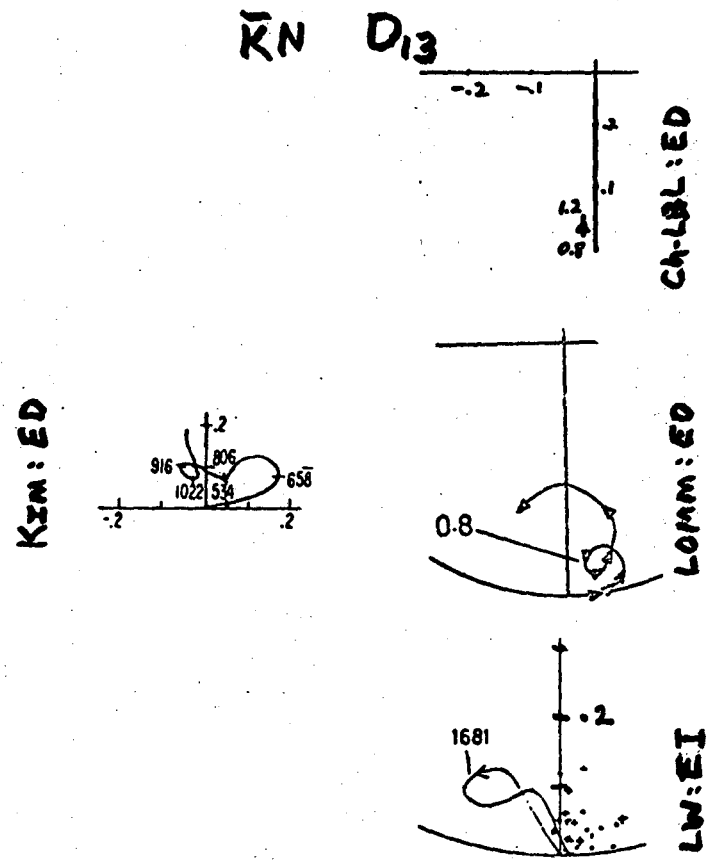
0.8
1.2
0.8
658
534
916
806
1022
1790
1630
1900
1536
440
600
700
800
500
1000
1200
1100
900

Fig. 7

Fig. 8


K̄N D13
Ch-LBL:ED
LOMM:ED
LW:EI
KIM:ED
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1022
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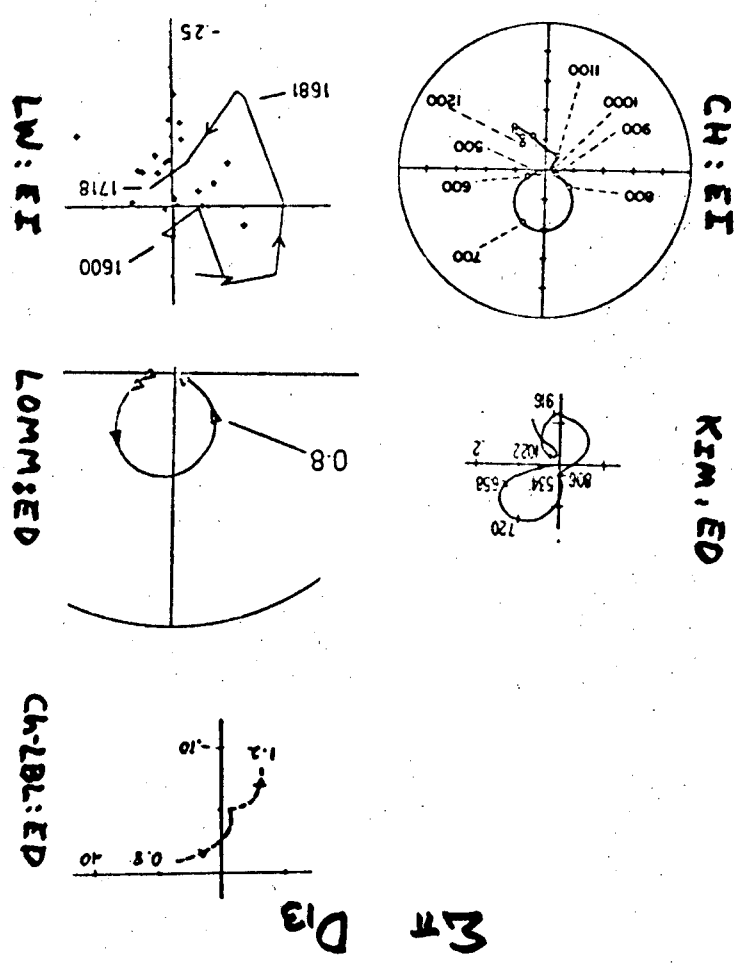
-.2
.1
1.2
0.8

Fig. 9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CH:EI
LOMM:ED
KIM,ED
Ch-LBL:ED
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1718
1600
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1100
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600
500
1200
916
1022
534
658
720
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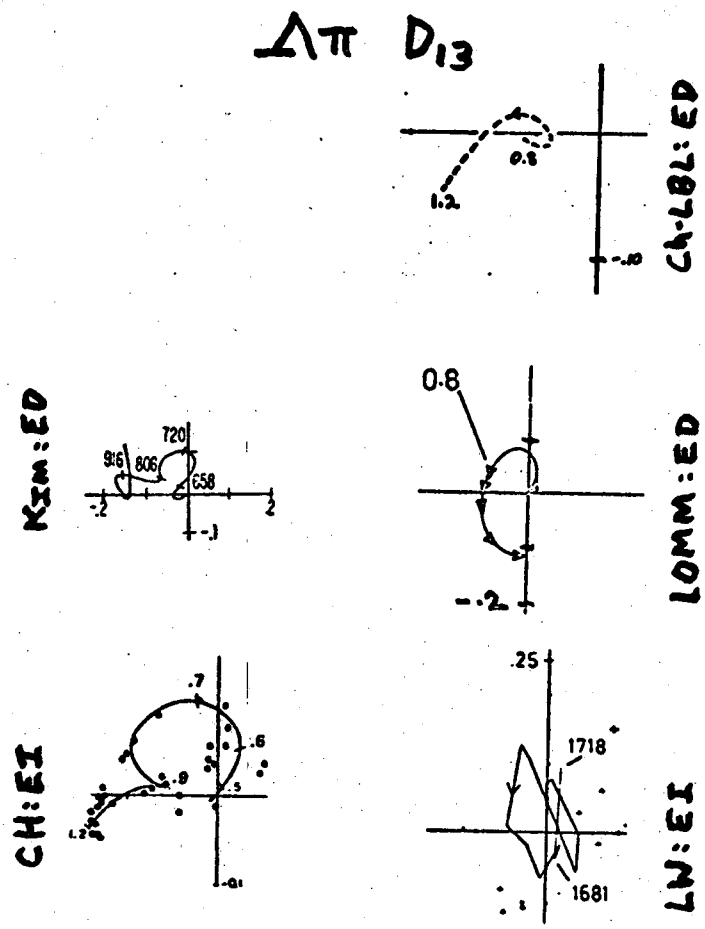
-.10
0.8
-.10

Fig. 10


Λπ D13
CH-LBL: ED
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1.2
-.10
KIM: ED
720
916
806
658
-.2
2
-.1
LOMM: ED
0.8
-.2
CH: EI
.7
.6
.9
.5
1.2
-0.1
LW: EI
.25
1718
1681

Fig. 11

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