HADRON PHYSICS WITH HADRON BEAMS

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"Hadron Physics" (HP) means studying the spectroscopy, structure and binary reactions of hadrons as a subject of intrinsic value. "Hadron Beams" (HB) are pi's, K's, pbars at P(lab) ~ 1-30 GeV/c. Today only Protvino operates in this mode; Brookhaven has potential for the lower half-range (D6 line); and JHF is a great hope for the future.

The importance of HB for HP we see by surveying the 2000 edition of the PDG: > 90% of its hadronic data came from reactions of HB on hadron targets. Despite popularity of electron machines today their productivity for HP has yet to be established.

A significant impetus for renewed experiments in spectroscopy is the recent indication that "radial" hadronic excitations do seem to justify Veneziano's model with cognate states all having only one universal slope: dm^2/dn =~ 1.04 GeV^2, where m = resonance mass, n = radial quantum number. Examples will be given from the light meson domain - and surprisingly, from the lowest baryons.

This development is just in its infancy and it invites a massive pursuit. Results should be expedited if the slope above is valid to a few percent, guiding further searches. Such a program looks like needing 3 or more independent laboratories, each developing its own HPHB innovations and checking each other's conclusions.

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Construction of a Crossing-Simmetric, Regge-Behaved Amplitude for Linearly Rising Trajectories.

G. Veneziano (*)

CERN - Geneva

(ricevuto il 29 Luglio 1968)

Crossing has been the first ingredient used to make Regge theory a predictive concept in high-energy physics. However, a complete and satisfactory way of imposing crossing and crossed-channel unitarity is still lacking. We can look at the recent investigations on the properties of Reggeization at $t=0$ as giving a first encouraging set of results along this line of thinking ([1]). A technically different approach, based on superconvergence, has been also recently investigated ([2]), and the possibility of a self-consistent determination of the physical parameters, through the use of sum rules, has been stressed.

In this note we propose a quite simple expression for the relativistic scattering amplitude, that obeys the requirements of Regge asymptotics and crossing symmetry in the case of linearly rising trajectories. Its explicit form is suggested by the work of ref. ([3]) and contains only a few free parameters ([**]).

Our expression contains automatically Regge poles in families of parallel trajectories (at all t) with residue in definite ratios. It furthermore satisfies the conditions of superconvergence ([4]) and exhibits in a nice fashion the duality between Regge poles and resonances in the scattering amplitude.

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Empirical light meson trajectories: radial $^3P_2$, $^3P_0$, $^3F_2$

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Abstract

Candidate light meson states are selected to form linear trajectories in squared mass m^2 vs. radial excitation number N. The most numerous candidates have $J^{PC} = (\text{even})^{++}$ and $J \leqslant 2$: namely, $^3P_2$, $^3P_0$ and $^3F_2$. About 40 states are assembled into 11 trajectories distinguished by four flavors: f, a, K and f'; no candidates appeared for $^3F_2: K$. From these data the universal slope of the Veneziano model emerges as $A = dm^2/dN = 1.04 \pm 0.01$ GeV^2.

PACS: 14.40
Keywords: Light mesons; Radial trajectories; Universal slope

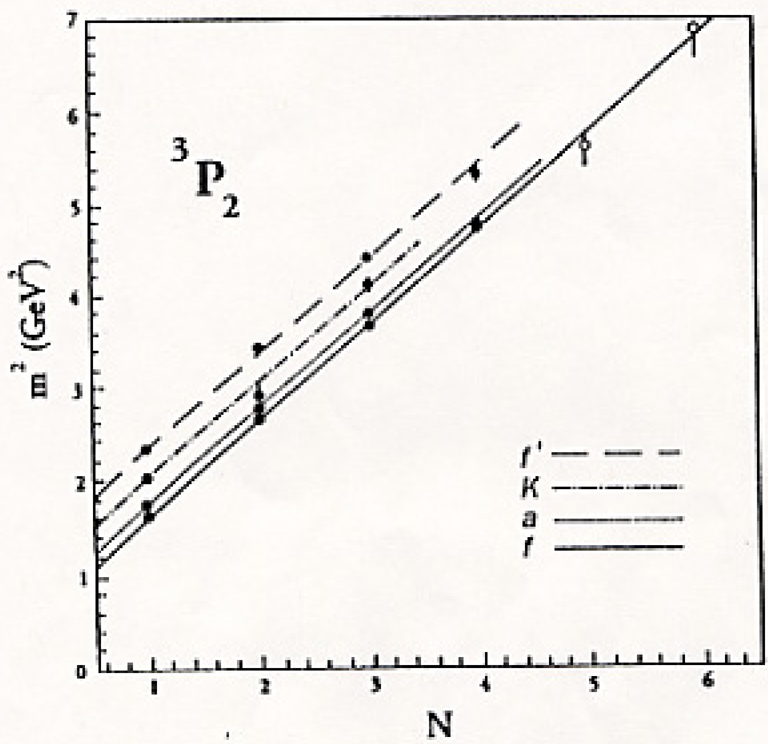


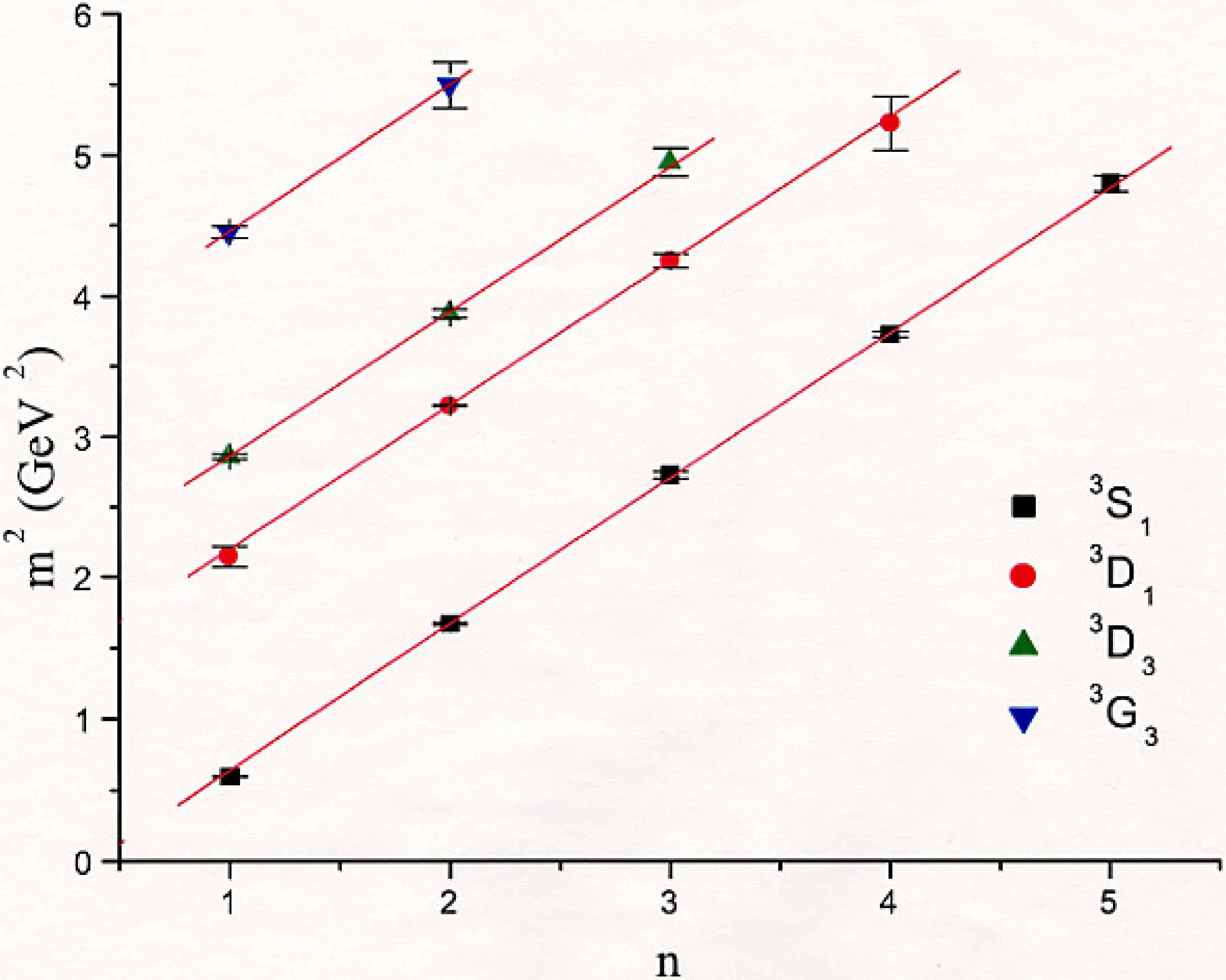
Fig. 1. Radial trajectories for $^3P_2$.

Table 4
Slope parameter summary

	f	a	K	f'	
P_0	1.0406 ± 0.0153	1.0720 ± 0.0290	1.0380 ± 0.1189	1.0134 ± 0.0270	(1.0412 ± 0.0120)
P_2	1.0444 ± 0.0079	1.0373 ± 0.0155	1.0503 ± 0.0366	1.0420 ± 0.0229	(1.0431 ± 0.0066)
F_2	1.0434 ± 0.0365	1.0076 ± 0.0434		1.0090 ± 0.1212	(1.0298 ± 0.0272)
	(1.0440 ± 0069)	(1.0416 ± 0.0130)	(1.0492 ± 0.0350)	(1.0296 ± 0.0173)	(1.0420 ± 0.0057)

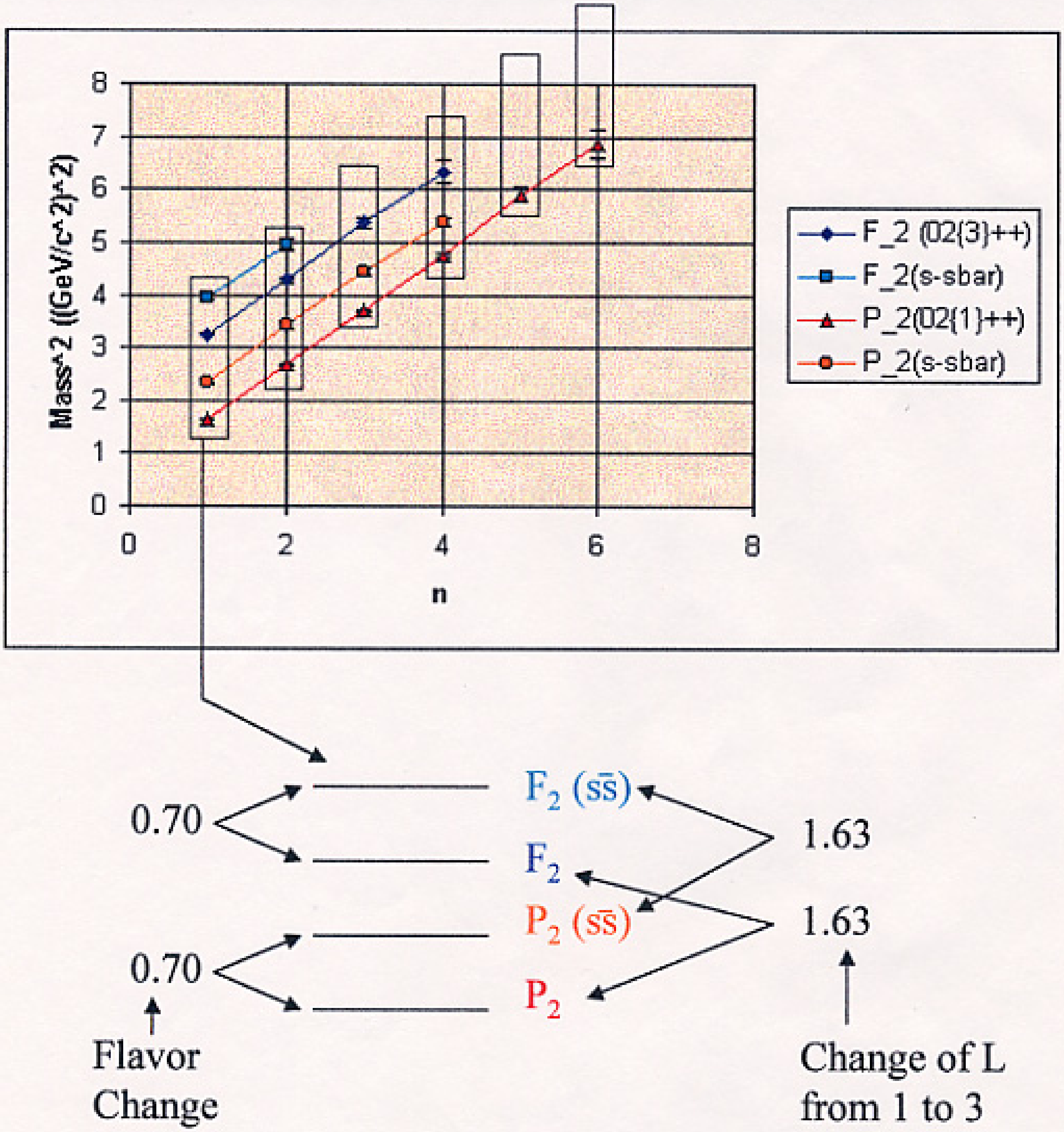
Table 5
Rare and missing states

Missing states	m	Single citations	m
$4\,^3P_2 : K$	2295 ± 47	$4\,^3P_2 : a$	2186 ± 27
$3\,^3P_0 : a$	1762 ± 19	$4\,^3P_0 : a$	2025 ± 30
$1\,^3P_0 : K$	1123 ± 73	$2\,^3F_2 : a$	2060 ± 20
$4\,^3P_0 : K$	2083 ± 70	$4\,^3F_2 : f$	2517 ± 44
$3\,^3P_0 : f'$	1882 ± 14		
$4\,^3F_2 : a$	2461 ± 35		
$3\,^3F_2 : f'$	2420 ± 46		



m^2 (GeV^2)
n
0
1
2
3
4
5
6
1
2
3
4
5
$^3S_1$
$^3D_1$
$^3D_3$
$^3G_3$

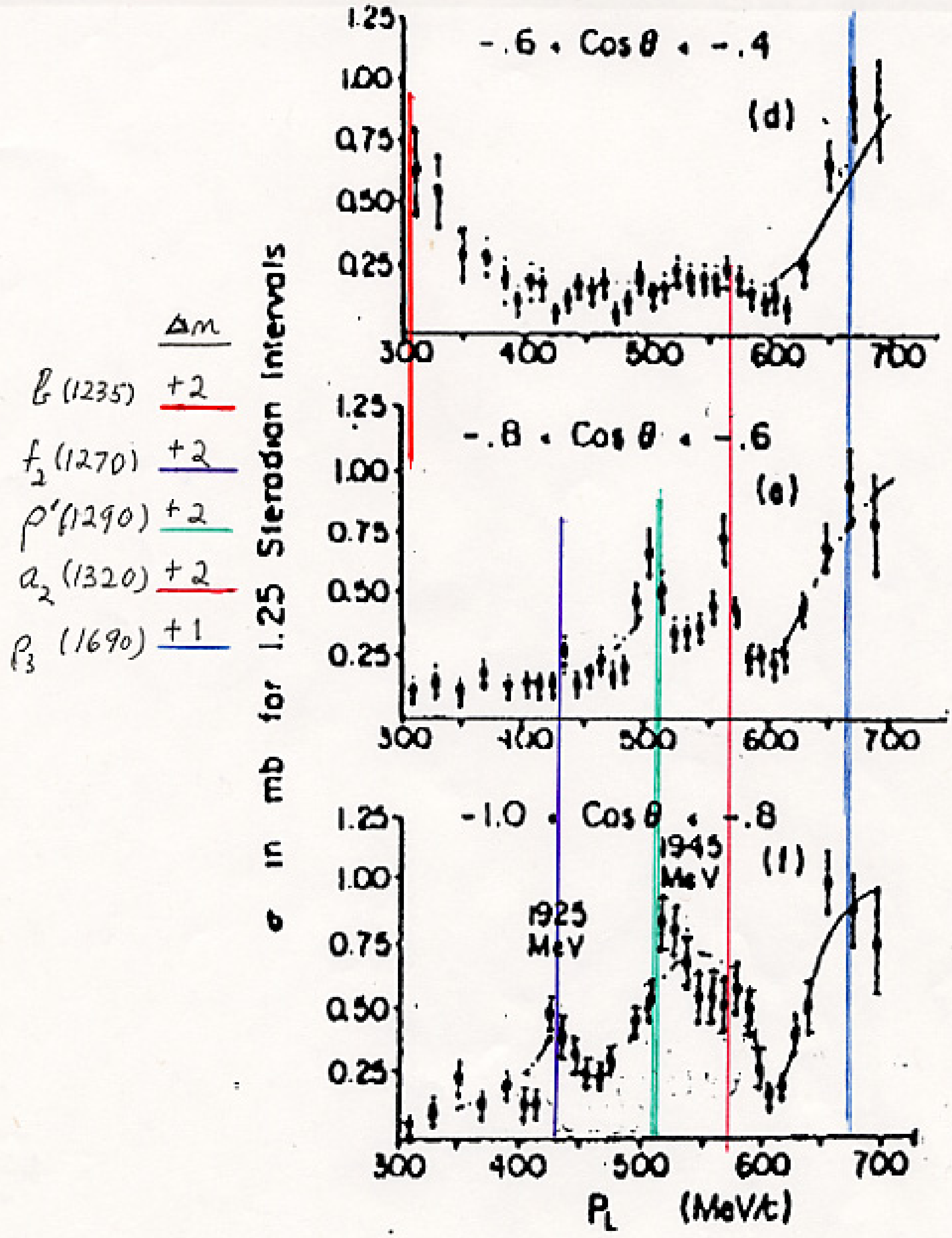
The "Template" Idea:



Shifting the template by units of n and A yields mass predictions for undiscovered meson resonances.

BACKSCATTERING OF $p\bar{p}$

D. Cline, et al. Phys. Rev. Lett. 21, 1268 (1968)



$\pi^- p \to \pi^0 \pi^0 n$

@ 9 GeV

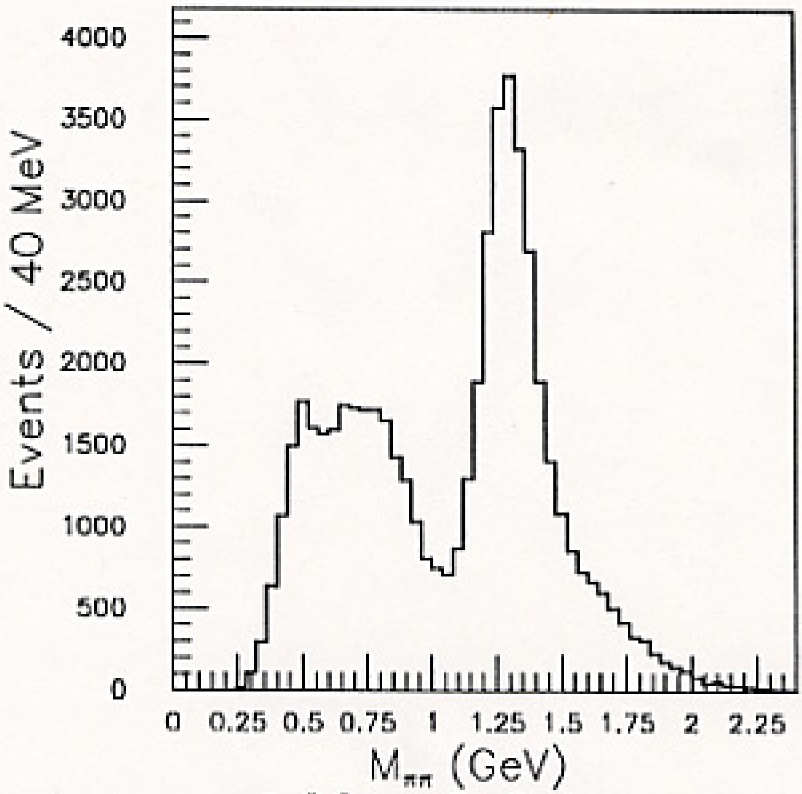


Figure 1. Acceptance corrected $\pi^0\pi^0$ mass distribution

Fermilab E791 $m(\sigma) = 478 \pm 29$ MeV

$\Gamma(\sigma) = 324 \pm 47$

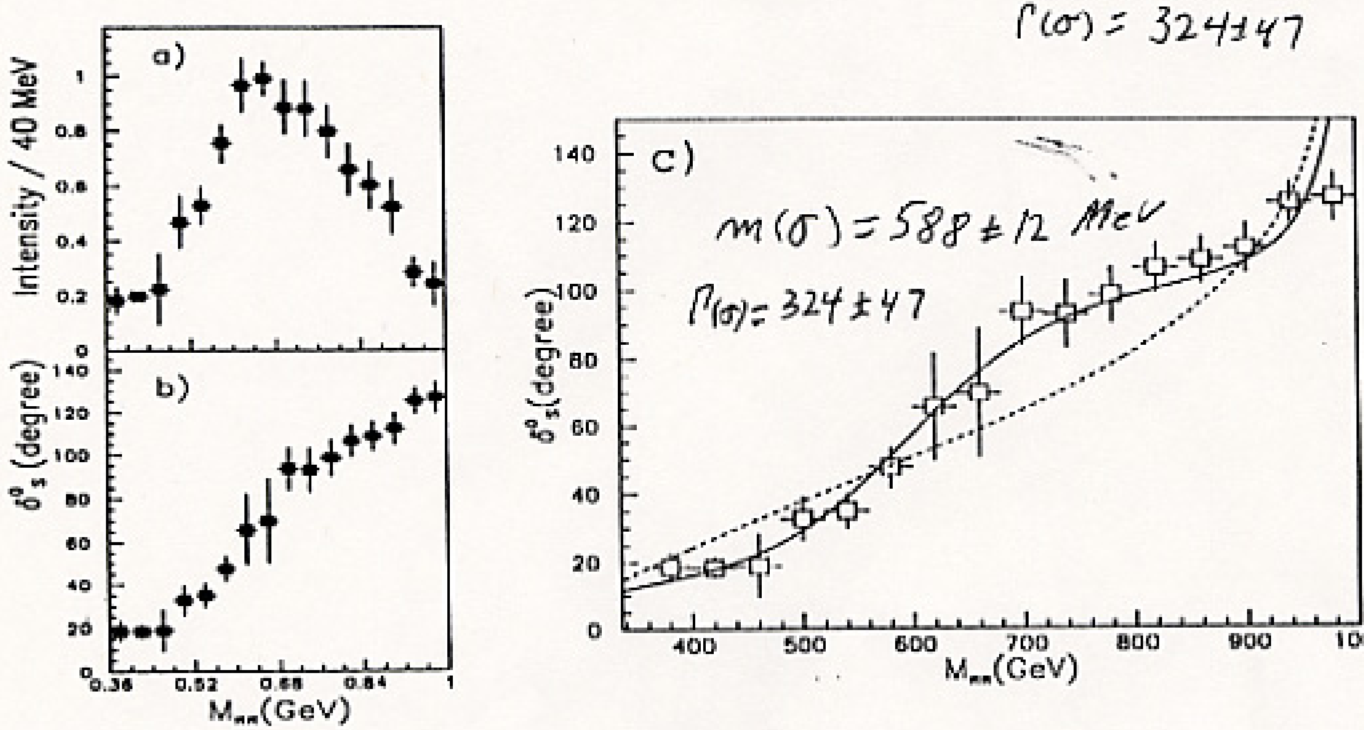


Figure 4. a) Normalized intensity of S wave amplitude squared below 1 GeV, b) S wave $\pi^0\pi^0$ scattering phase shift δ^0_S below $K\bar{K}$ threshold and c) the result of fitting by the IA method with the hard core (solid line) and without it. (dotted line).

$D^+ \to K^- \pi^+ \pi^+$

$m(\kappa) = 797 \pm 46$ MeV, $\Gamma(\kappa) = 410 \pm 98$ MeV

Light Meson Physics from Charm Decays at Fermilab E791

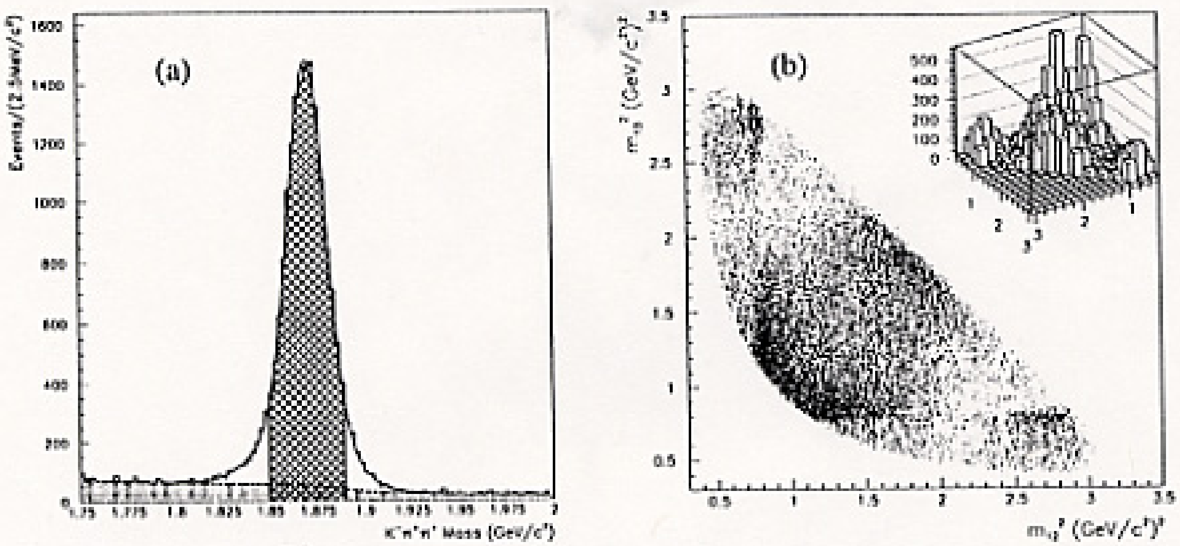


FIGURE 1. (a) The $K^-\pi^+\pi^+$ invariant mass spectrum. The filled area is background; (b) Dalitz plot corresponding to the events in the dashed area of (a).

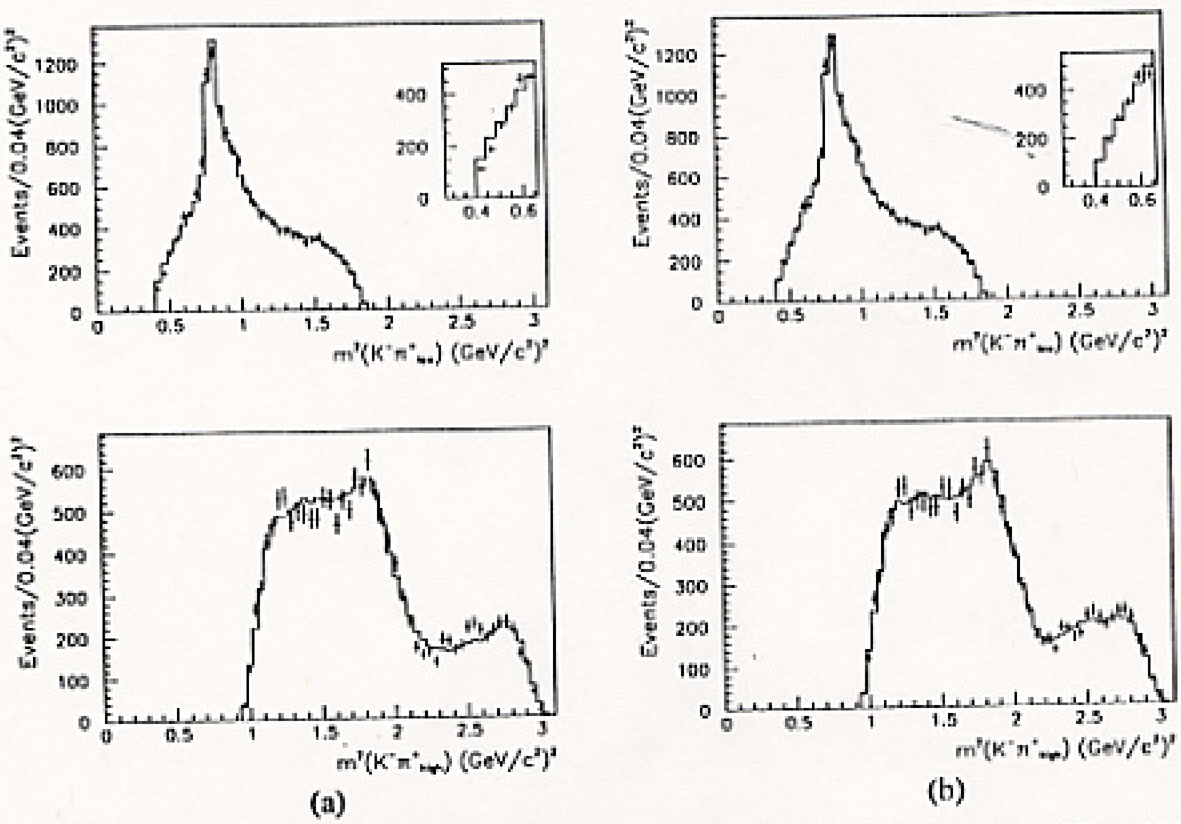


FIGURE 2. $m^2(K\pi_{low})$ and $m^2(K\pi_{high})$ projections for data (error bars) and fast MC (solid line): (a) fit to Model A, without κ, and (b) fit to Model B, with κ.

Figure 8 – Radial baryons for ^{2}8 states.

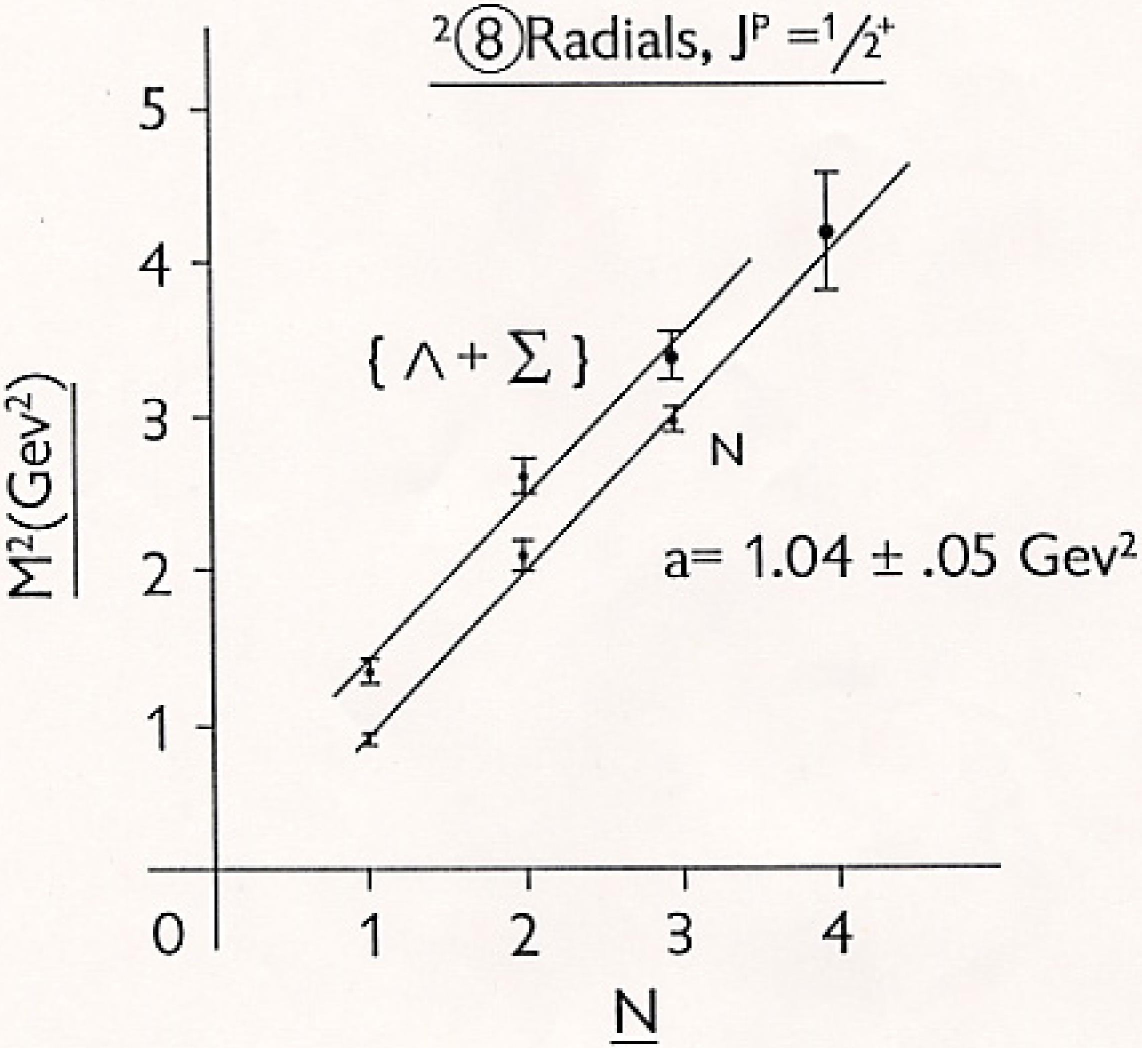
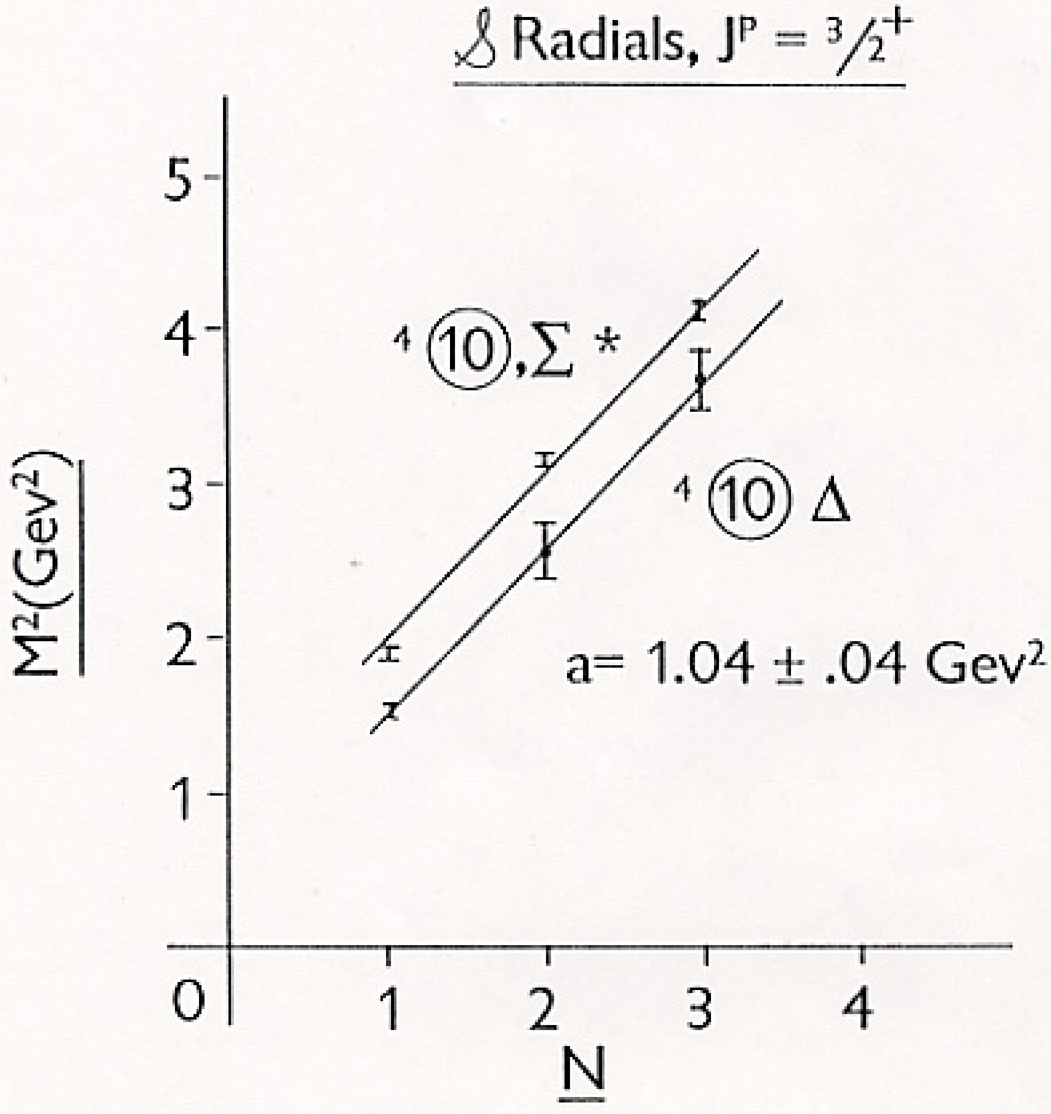
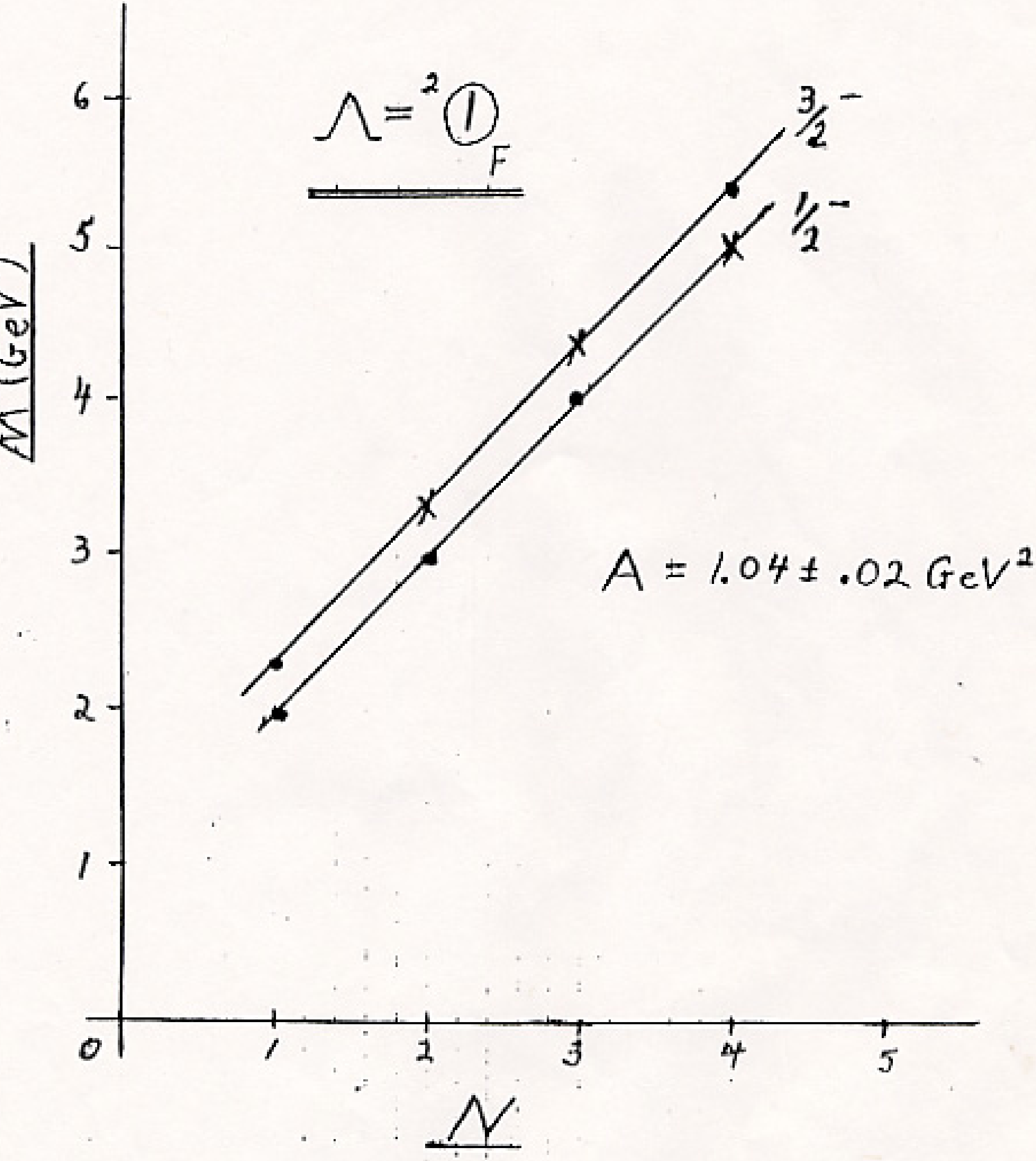


Figure 6 – Radial baryons for $\mathcal{S}$ configuration.





Λ = ²(1)F
3/2⁻
1/2⁻
A = 1.04 ± .02 GeV²
M²(GeV²)
0
1
2
3
4
5
6
N

KAON SUPPLEMENT(1)

The radial exciation slope

$$dm^2/dN = 1.04 \pm .01\ GeV^2 \tag{1}$$

obtained for $^3P_2$, $^3P_0$ and $^3F_2$ light mesons is tempting to apply to baryons. Because baryons contain two independent radial coordinates, their radial excitations may be expected in general to display complexities. In special cases of particularly simple baryon radial functions, however, the excited states may display at least a branch that again follows Eq. (1).

A possible candidate is the $1/2^-$, $3/2^-$ pair of baryons $\Lambda(1420)$, $\Lambda(1509)$ as the ground state of such a simple system. These states are best assigned the SU3 flavor singlet configuration 1_F . Applying Eq. (1) to this pair results in the following table, plotted in the accompanying figure.

The D6 line can reach the first and probably second unknown (x) resonance in the table. Because of the expected precision of their mass estimates, the two regions could be explored at ~ 150 hours apiece with K^- beam at $p_L \sim 1050$, 1700 MeV/c.

TOTAL: 300 hrs.

Radial $\Lambda = {}^2 1_F$ trajectories for L=1

	S_1			D_3		
N	m	m^2	Ref.	m	m^2	Ref.
1	1406.5 ± 4	1.978 ± .011	PDG	1519.5 ± 1	2.309 ± .003	PDG
2	1723 ± 20	2.969 ± .069	a	1817 ± 24	3.300 ± .080	x
3	2030 ± 30	4.121 ± .122	b	2110 ± 30	4.452 ± .129	x
4	2260 ± 21	5.103 ± .095	x	2331 ± 17	5.434 ± .086	PDG
$A_S = 1.041 \pm .0281$ $B_S = .937 \pm .0320$				$A_D = 1.041 \pm .0200$ $B_D = 1.268 \pm .0256$		
$\chi^2/df = .19$				$\chi^2/df = .14$		

$$\Delta B = B_D - B_S = .331 \pm .041 = 3\sigma \cdot L$$

Units: m in MeV, m^2 in GeV^2.

Linear fit: $m^2 = AN + B$

a) M. Alston-Garnjost *et al.*, Phys. Rev. D *18*, 182 (1978); Phys. Rev. Lett *38*, 1007 (1977).

b) W. Cameron *et al.*, Nucl. Phys. B *146*, 327 (1978).

x) Calculated by use of constant displacement $\Delta B = .331 \pm .041\ GeV^2$

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Partial-wave analysis of K^+-nucleon scattering

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(Received 21 February 1992)

We have analyzed the available kaon-nucleon elastic-scattering data with laboratory kinetic energies below 2650 MeV. We present the results of an energy-dependent analysis and a set of energy-independent analyses over this energy range. Our isoscalar amplitudes cover the region from threshold to 1100 MeV. The isovector amplitudes extend to 2650 MeV. Scattering lengths have been extracted. We also give pole positions and residues for resonancelike structures found in the P_{01}, D_{03}, P_{13}, and D_{15} partial waves. We compare our results to those from previous analyses.

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TABLE IV. Pole positions and residues from the energy-dependent solution SP92.

Amplitude	Result	Position (MeV) Re W	$-$Im W	Residue (MeV) (modulus)
P_{01}	Pole	1831	95	25
D_{03}	Pole	1788	170	42
P_{13}	Pole	1811	118	19
D_{15}	Pole	2074	253	16

single-energy solutions of Hashimoto, and Martin and Oades, with the exception of the G_{09} wave of Martin and Oades.

A. Resonance poles

Poles are associated with each of the partial-wave amplitudes that display a counterclockwise looping behavior