Theoretical Summary

Glad it is not the Experimental Summary…

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Θ Status

not well, but not dead either

urgent challenges for theorists:

- LEPS vs CLAS

- reliable background estimate

"if you have to ask how much it costs, you can't afford it"

"if you have to ask how many σ, you shouldn't believe it"

Lipkin

- ordinary hadrons $\rightarrow$ $V(\bar{q}q)_1, \; V(qq)_{3^*}$
- no exp. info on $V(\bar{q}q)_8, \; V(qq)_6$
- no exp. info on states containing

  both qq and $\bar{q}q$
- exotics:

  $H(uuddss); \; \bar{c}uuds; \; (ud)(ud\bar{s}); \; \ldots$

simplest system with both qq and $\bar{q}q$

triquark:

ud : $(ud)_{3^*,0}$ attractive; $(ud)_{6,1}$ repulsive

$\bar{q}$ drastically changes the dynamics

the antiquark polarizes the scalar diquark:

$\longrightarrow$ $\bar{s}(ud)_{6,1}$ is the ground state

"beware of baryons bearing gifts"

crucial question:

Why some experiments see the Θ and others don't ?

two tests that can aid in understanding the data:

- resonance vs background test via angular distribution:

$$|p_K|^2 - |p_N|^2$$

- production mechanism test:
  momentum transfer distribution (cf. Nakano's talk)

soliton approach in large N_c context

- consistency of collective coordinate quantization?
- mixing of vibrational and rotational modes
- if Θ exists, so do its slightly heaver cousins:
  - J=3/2
  - 27-rep.
  - non manifestly exotics partners
- for large N_c and m_Q → ∞, the analogue of heavy pentaquark must exist
- how close is the real world with N_c=3 and m_q?

soliton model issues

- relation to QCD ? Is $N_c = 3$ large enough?
- consistency of derivative expansion ?
- model dependence
- Quantization
- SU(3) breaking: expansion in $\frac{m_s}{\Lambda_{\rm QCD}}$ or $\frac{\Lambda_{\rm QCD}}{m_s}$?

but also remarkable successes of these models (cf Kopeliovich talk)

baryon spectrum of Skyrme model

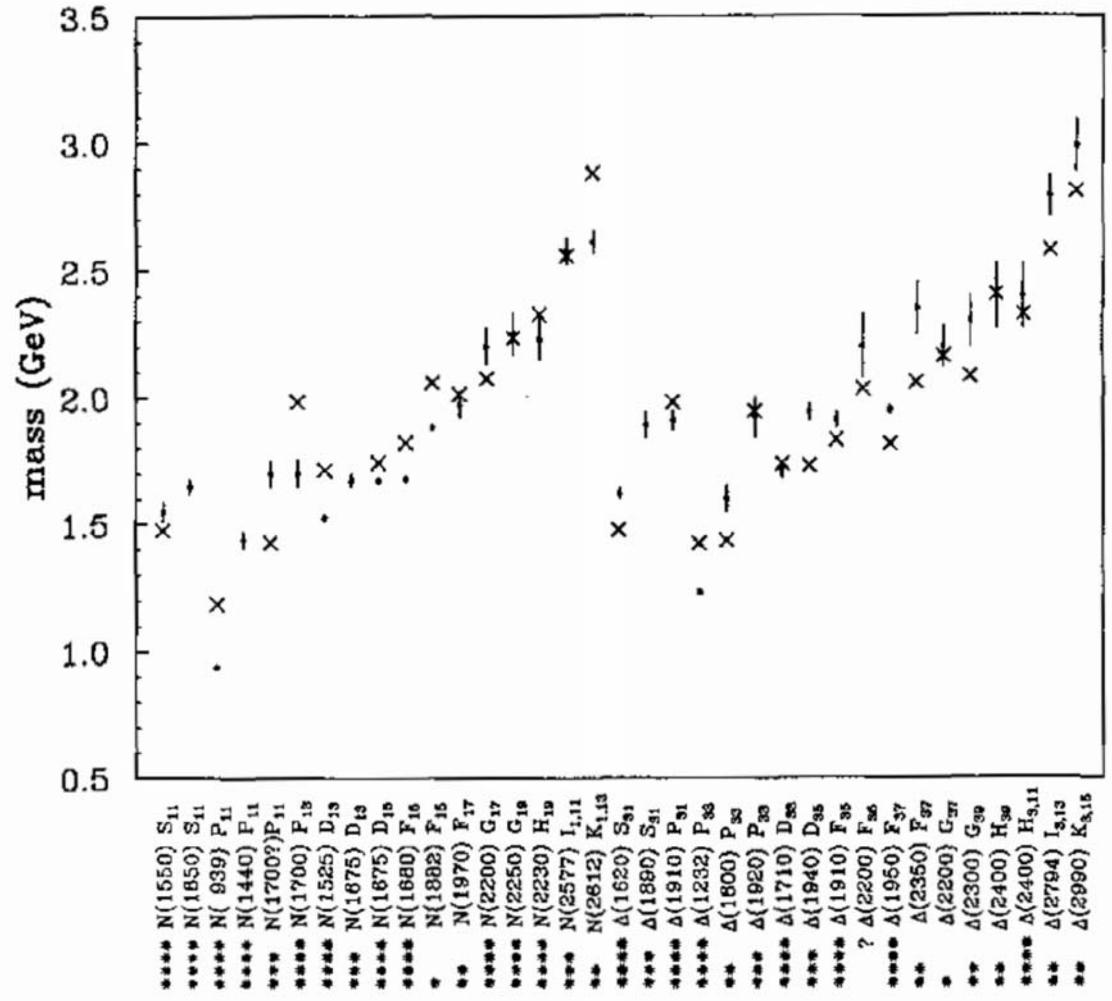

Fig. 6. Spectrum of N and Δ resonances: 3-flavor Skyrme model (crosses) *vs.* experiment (points with error bars) (from Ref. 9). Resonances are assigned stars according to the Particle Data Book. The Skyrme-model values for m_N and m_Δ are obtained from Eq. (9) of Ref. 3, using the "best fit" parameters of Ref. 9(e =4.79, f_π =150 MeV.)

M.K. & M.Mattis, 1984

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How Chiral Solitons Relate $\bar{K}N$ and πN Scattering

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Large-N arguments suggest that baryons correspond to soliton solutions of the optimal low-energy Lagrangean of QCD. Such solitons are characterized by a hedgehog symmetry which mixes isospin and space rotations. We show that this symmetry implies linear relations between experimental $\bar{K}N$ and πN elastic partial-wave scattering amplitudes. At least in one case these linear relations are satisfied with an extremely high accuracy.

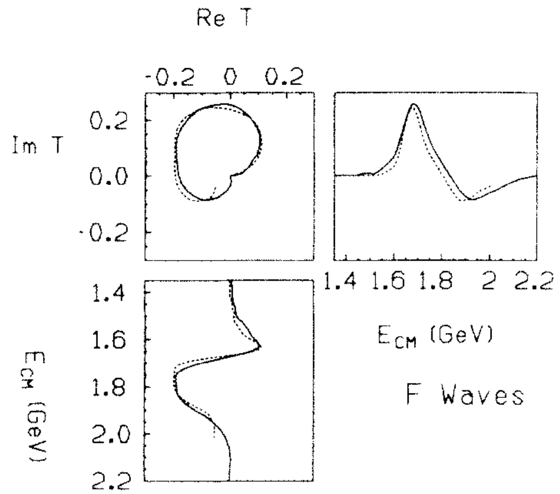


FIG. 1. Test of the linear relation (3) for F waves. The scattering matrix T is plotted both as function of energy and in Im(T) vs Re(T) representation. Continuous lines show the linear combination of F_{15} and F_{37} experimental πN amplitudes while dotted lines show the linear combination of F_{05} and F_{17} experimental $\bar{K}N$ amplitudes. $\bar{K}N$ amplitudes here and in Fig. 2 are shifted by $m_s \approx 150$ MeV.

I+J symmtery!

quark models

- what are the important light q correlations ?
- interplay of experiment, model and lattice
- exotics with heavy Q*: the new frontier
- lattice provides wonderful theoretical laboratory:
  - vary N_c and N_f
  - m_q dependence
  - light q correlations in presence of Q*

Θ from lattice

- in the long run – most reliable theoretical approach
- but not there yet, "at least two more years"
- disentangling KN from genuine resonance:
  → need careful V-dependence study
- quenching artifacts → need dynamical fermions
- Θ(uudds*) → need realistically light quarks
- heavy Q, e.g. Θ_c(uuddc*) → small lattice spacing
- spin and parity ?
  3/2+ deeply bound state !? (JLab-Adelaide)
- tetraquarks

critical open TH questions

- why some exps see Θ and others don't ?
- background computation
- possible production mechanisms ?
- if Θ exists – why is it so narrow ?
- PWA vs formation experiments ?! (Azimov)
- why forward (LEPS, ZEUS) ?
- energy and Q^2 dependence (cf BaBar plot)
- light q correlations: triquarks, diquarks ?
- optimal effective action ? (Hosaka)
- heavy Q exotics!

conclusions

many fascinating theoretical questions

but experimental situation baffling

the ball is clearly in the experimental court!

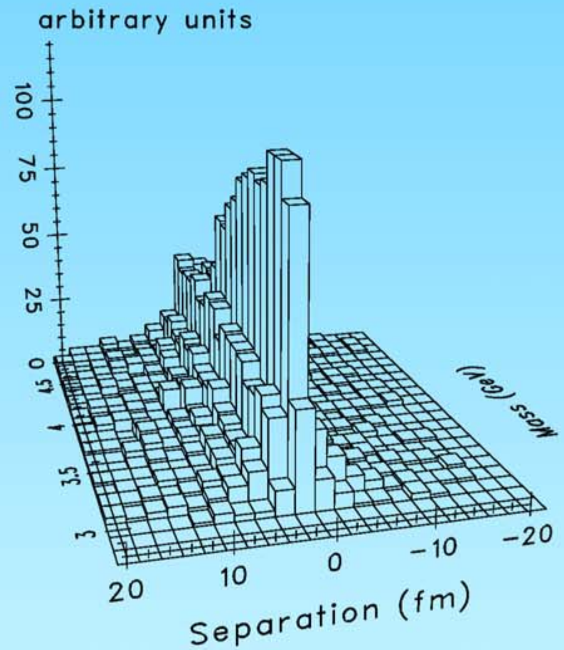
need more and higher stats experiments

gold plated experiment: K+ on nucleus

Coalescence model for Θ_c formation

B.R. Webber & MK, hep-ph/0409121

- Θ_c formed by coalescence of p and D^{*-}
- $\sigma(\Theta_c) = F_{co} \times$ number of pD^{*-} pairs
  $3050 < M(D^{*-}p) < 3150$ MeV, spacelike $0 < \Delta x < 2$ fm
- HERWIG MC:



- compare with H1 data $\Longrightarrow F_{co} \lesssim 10$
- apply to LEP: should have seen 25-40 Θ_c events per experiment
- apply to Tevatron: should have seen at least few $\times 10^4$ events

BaBar: hadron production rates vs mass

what is the dynamics that generates this pattern ?!