

Ohio University workshop on
photo- and electro-production of one and two pions

Workshop Summary

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- ★ Definition and importance of the N^* "problem"
- ★ Lots of beautiful experimental data
- ★ State-of-the-art theory
 - consensus
 - issues to be resolved
- ★ Where do we go from here?



Definition of the N^* “problem” (??)

- ★ “the treatment of multi-particle final states in a manner consistent with the **constraints of unitarity and analyticity** □ are essential for a reliable interpretation” of JLab data (*proposal for the establishment of an N^* analysis center at JLab*)
- ★ the problem is two-fold:
 1. to develop an effective **partial wave theory** that can be used to analyze two and three body final states in a model independent way, and
 2. to extract N^* masses and widths, **undressed by pion rescattering**, from the analyzed data (**maybe only widths**)
- ★ the masses and widths can then be interpreted as “bare” masses and coupling constants suitable for comparison with a quark based theory that neglects pion rescattering effects (IF we choose a SCHEME)

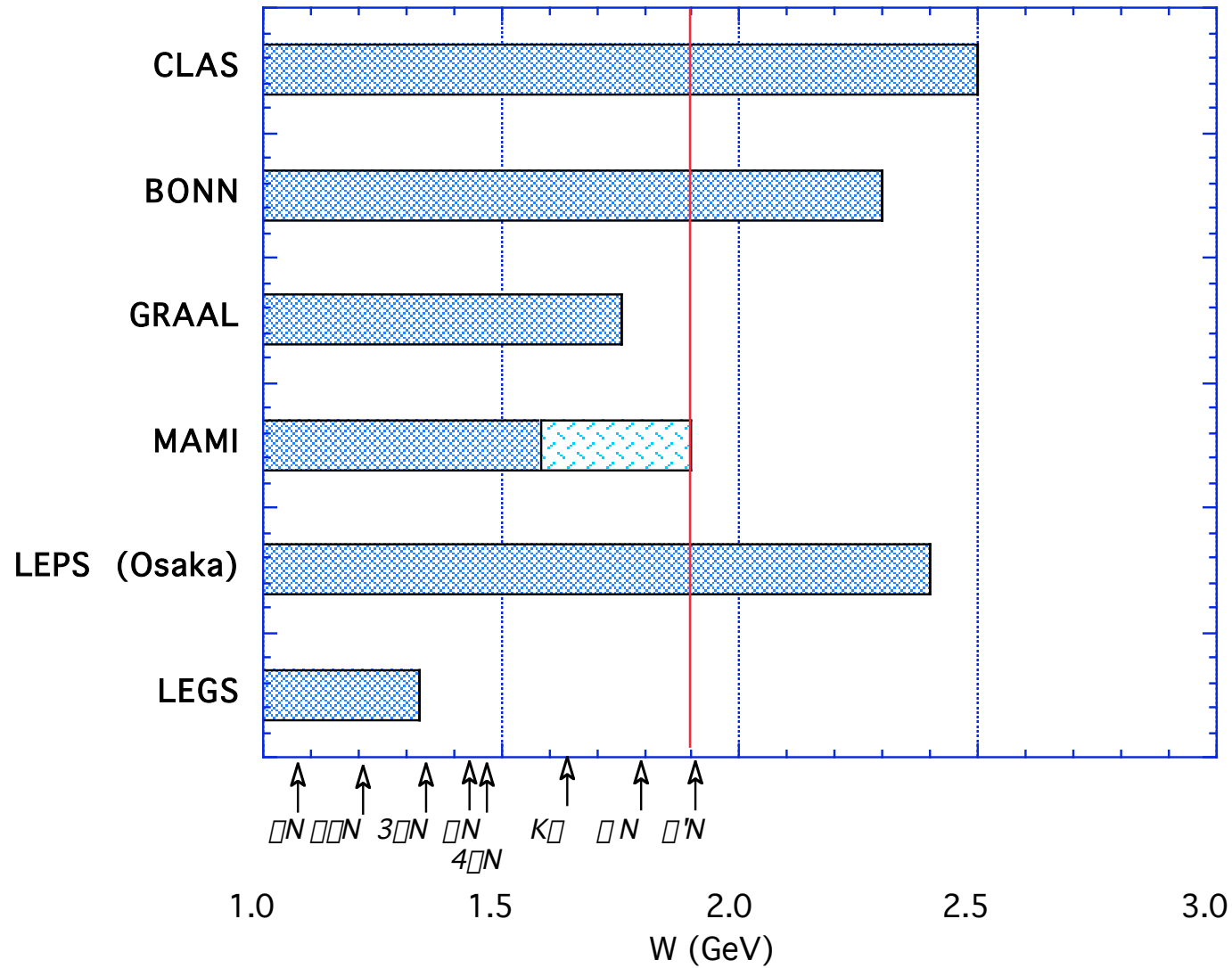


LOTS of beautiful experimental data -- can theory match it?

- ★ assume $3\pi N$ channel can be neglected, or replaced by simplified $\pi\pi$ contribution (?)
 - it is 15 - 20% of the total cross section at $W \approx 1.9 \text{ GeV}$
- ★ present analyses (MAID and SAID) lack state-of-the-art sophistication
 - damping of Born terms
 - treatment of $L \geq L_{\text{max}}$ contributions
 - consistent treatment of resonance and background (unitarity and gauge invariance)
 - inclusion of all coupled channels in the range of $W \approx 2 \text{ GeV}$
 - ◆ 2 body: $\pi N, \pi N, \pi N, \pi N, K\pi, K\pi$
 - ◆ 3 body: $\pi\pi N, \pi\pi N, \pi K\pi, \pi K\pi$
- ★ at the moment, $\pi\pi N \rightarrow a + b$ may be enough (coupled channel working group)
- ★ Do we need to do partial waves?
- ★ But; is there a theory [theory "flow": Beane]?



Reach of electromagnetic facilities (from Steve Dytman)



Publish the data even if the analysis is incomplete!



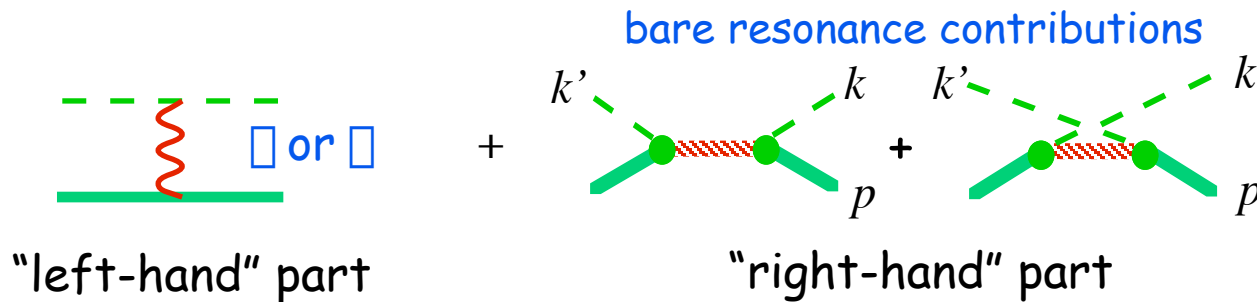
State-of-the-art theoretical tools that *must* be included in a serious “solution” to the N^* problem

- ★ dynamical coupled channel equations for the hadronic sector that treat background and bare resonance contributions *together* in a systematic way (to insure *unitarity and analyticity*)
 - Bethe-Salpeter equation, or spectator equation, or unitary transformation of the Hamiltonian [Lee] (which one ?)
 - do NOT settle for a K matrix approach
- ★ treatment of higher spin states using pure projection operators [*al la* Pascalutsa and Phillips] -- *a nice recent advance*
- ★ extension to include photon couplings in a phenomenological, but gauge invariant way [*al la* Riska and Gross (87), or Krewald, or Scholten] -- *old ideas previously ignored*. BUT: use of these ideas may work only for specific equations
- ★ regularization through subtraction at the N (for $S=0$) or Δ (for $S=1$) poles to insure crossing symmetry at one point [Nieves and Lutz] -- *a nice new idea*
- ★ low energy through *ChPt*



Issues to be resolved (1): CHOICE OF DRIVING TERMS

- Driving terms are $V = V_L + V_R$, where



- make BOTH left and right-hand parts general.

$$V_L = c_1 + \frac{c_2}{c_3 t} \quad \left\{ \begin{array}{l} \text{where the } c_i \text{ are parameters (recall that only the "tail"} \\ \text{of the left-hand side can be fixed, and this is largely} \\ \text{insensitive to the number and location of poles)} \end{array} \right.$$

$$V_R = \sum_i \frac{g_i^2 \prod_i^{(s)}(p+k)}{m_{0i}^2 \prod_i (p+k)^2} + \frac{g_i^2 \prod_i^{(s)}(p-k')}{m_{0i}^2 \prod_i (p-k')^2}$$

where g_i and m_{0i} are bare resonance parameters



Issues to be resolved (2):

REGULARIZATION PROCEDURE

- ★ is one subtraction enough?
- ★ where should the subtraction be done?
- ★ are form factors necessary? When coupled channels are included, form factor masses may be larger [Nakayama]
- ★ how is the regularization combined with the equation we will use?

WHAT CAN LARGE N_c TELL US [QCD working group]?



Where do we go from here?

- ★ Are we serious?
 - do we really agree on anything? If so, what?
 - will we act as if we agree [all adopt the agreed-upon methods]?
 - will we share computer codes?
- ★ How will we resolve our disagreements?
 - what calculations will resolve the issues?
 - what are our assignments?
 - when is our homework due?
- ★ How will we develop the new "standard" analysis code?
- ★ What about three particle final states - not discussed here?

- ★ SUPPORT THE JLAB PWA CONNECTION!!



End



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