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 3pN channel can be neglected, or replaced by simplified ΔN contribution (?)
  • it is 15 - 20% of the total cross section at W≥ 1.9 GeV
★ present analyses (MAID and SAID) lack state-of-the-art sophistication
  • damping of Born terms
  • treatment of L≥Lmax contributions
  • consistent treatment of resonance and background (unitarity and gauge invariance)
  • inclusion of all coupled channels in the range of W≤ 2 GeV
    ♦ 2 body: 2pN, ΔN, ΔN, KN, K⁻, K⁺
    ♦ 3 body: 3pN, 3pN, ΔK⁺, ΔK⁻
★ at the moment, 4pN → 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)

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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 \(\pi\) (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

  \[ V_L = c_1 + \frac{c_2}{c_3} \frac{t}{t} \]

  where the $c_i$ are parameters (recall that only the “tail” of the left-hand side can be fixed, and this is largely insensitive to the number and location of poles)

  \[ V_R = \sum \frac{g_i^2}{m_{0i}^2} \frac{(p + k)^2}{(p + k')^2} \]

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

- make BOTH left and right-hand parts general.
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