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PARTIAL-WAVE ANALYSIS AND SPECTROSCOPY. FROM πN SCATTERING TO PION-ELECTROPRODUCTION

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Abstract

We have analysed data from πN elastic scattering along with single pion photo- and electroproduction. The main focus is the study of low-lying resonances. Here we concentrate on some difficulties associated with resonance identification, in particular the Roper and higher P_{11} states.

1 Introduction

Many of our fits to scattering data have been motivated by ongoing studies of the N^* properties [1]. Most of these require, as input, amplitudes extracted from elastic πN scattering data [2, 3]. Our pion photoproduction multipoles are determined using a K-matrix formalism, based upon πN partial-wave amplitudes [4, 5]. Futher, the electroproduction analysis is anchored to our $Q^2 = 0$ photoproduction results, with additional factors intended to account for the Q^2 variation [6].

One of the most convincing ways to study the spectroscopy of non-strange baryons is through πN partial-wave analysis (PWA). The main sources of the Review of Particle Physics (RPP) N^* Listings [1] are the PWA of the KH, CMB, and GW/VPI groups. The analysis of πN scattering data is still crucial in this respect.

In πN PWA, we found resonances through a search for poles in the complex energy plane. These were not put in by hand, contrary to the Breit-Wigner (BW) parameterization. We have also given the results of a BW parameterization, mapping $\chi^2[W_R, \Gamma]$ while searching all other partial-wave parameters. Some subjectivity is involved, such as: (i) energy binning, (ii)

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the strength of constraints, and (iii) the choice of partial waves to be searched. We should stress that the standard PWA reveals resonances with widths of order 100 MeV, but not too wide ($\Gamma > 500$ MeV) or possessing too small a branching ratio (BR $< 4\%$), tending (by construction) to miss narrow resonances with $\Gamma < 30$ MeV. The partial waves of solution KA84 [7] and the single-energy solutions (SES) associated with our SP06 results agree reasonably well over the full range of SP06 (Figs. 4–7 from [2]). However, this does not lead to agreement on the resonance content. For instance, our study [2] does not support several N^* and Δ^* reported by PDG [1]. It is important here to remember that during last 20 years, πN database has increased by a factor of 3–4.

2 P_{11} Puzzle

These states have been controversial for many years. The prominent N(1440)P_{11} resonance is clearly evident in both KH and GW/VPI analyses (Figs. 4–7 from [2]), but occurs very near the $\pi\Delta$, ηN, and ρN thresholds (Fig. 8 from [3]), making a BW fit questionable. The N(1440) is the single resonance which manifests itself through two poles on different Riemann sheets (with respect to the $\pi\Delta$-cut). Due to the nearby $\pi\Delta$ threshold, both P_{11} poles are not far from physical region. There is a shift between pole positions at two sheets, due to a non-zero jump at the $\pi\Delta$-cut. Our conclusion is that a simple BW parametrization cannot account for such complicated structure.

There is recent evidence for a direct measurement of the N(1440) (at BES in $e^+e^- \to J/\psi \to p\pi^-\overline{n} + n\pi^+\overline{p}$ [8], at SATURNE II in $\alpha p \to \alpha' X$ [9], at Uppsala in $pp \to np\pi^+$ [10], and at JLab in $ep \to e'X$ [11]). They found peaks different from the BW interpretation of πN elastic scattering. This could indicate that a difference is due to the complex structure descibed above.

Indeed, the P_{11} partial wave wraps around the center of the Argand diagram (Fig. 1). As a result, small changes in the amplitude can produce large changes in the phase, though these changes have little influence on the fit to data. For the πN elastic scattering, we conclude that there is no sensetivity to resonance in P_{11} above 1500 MeV except possible states with small Γ_{el} [12].

In fitting the electroproduction database, we extrapolate from the relatively well determined $Q^2 = 0$ point. The photoproduction multipoles can be parametrized using a form containing the Born terms and phenomenological pieces maintaining the correct threshold behavior and Watson's theorem

below the two-pion production threshold. The πN T-matrix connects each multipole to structure found in the elastic scattering analysis.

The difference between MAID and GW/VPI amplitudes tends to be small but resonance content may be essentially different (Figs. 13 and 14 from [5]).

Ongoing fits incorporate all available electroproduction data, with modifications to our fitting procedure implemented as necessary. Useful comparisons will require those involved in this effort to make available all amplitudes obtained in any new determination of R_{EM} and R_{SM}. A major database problem is that most data are from unpolarized measurements. There are no $\pi^0 n$ data and very few $\pi^- p$ data (no polarized measurements). This does not allow a determination of the neutron couplings.

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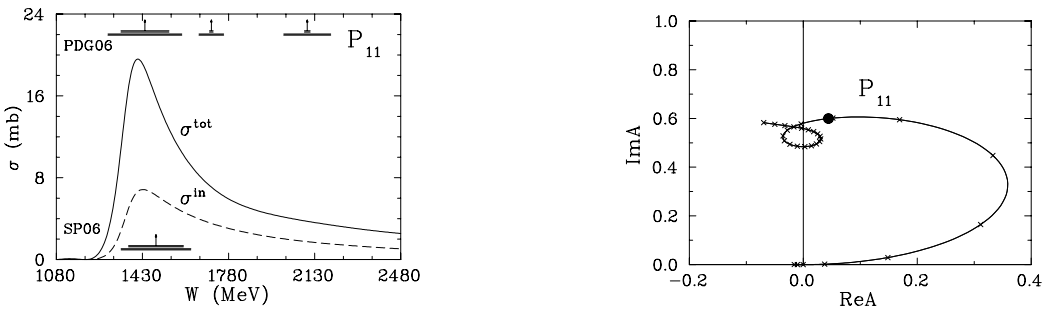

Figure 1: Left panel: P_{11} contribution to total cross sections. Vertical arrows indicate resonance W_R values and horizontal bars show full Γ and partial $\Gamma_{\pi N}$ widths. The lower BW resonance symbols are associated with the SP06 values; upper symbols give PDG values. Right panel: Argand plot for partial-wave amplitude from threshold (1080 MeV) to W = 2.5 GeV. Crosses indicate 50 MeV steps in W. Solid circle corresponds to BW W_R.

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