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HIGH MASS BARYONS IN PION PHOTOPRODUCTION

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Abstract

A Regge model was employed in a global analysis of the world data on π^+ and π^- photoproduction at photon energies from 3 to 8 GeV. In this energy region the resonance contributions are expected to be negligible so that the available experimental results allows to determine the non-resonant part of the reaction amplitude reliably. This amplitude is then used to predict observables for photon energies below 3 GeV. Differences between the predictions and data in this energy region are systematicall examined as possible signals for the presence of high mass baryons. The analysis of differential cross section for negative pion photoproduction, obtained recently at JLab, indicates resonance structures above an invariant energy of 2 GeV.

A rough inspection of the excited baryon spectrum given by the Particle Data Group [1] suggests an impressive regularity for nucleon and Delta states with the masses above $\simeq$1.8 GeV. The states with the same spin but opposite parity are almost degenerate. At the same time, a parity doubling was not observed for the well established low lying baryons.

One can ask why parity doubling was not discovered for low mass baryons and what is the QCD symmetry behind this phenomenon? It was proposed [2–5] that parity doubling might reflect the restoration of spontaneously broken chiral symmetry of QCD. These considerations are not the only way to explain the apparent doubling phenomenon. It was shown in the framework of a covariant constituent quark model [6], that the instanton induced multi-fermion interaction leads to a lowering of selected states that accidentally become degenerate with their parity partners.

Unfortunately some of the doublet partners for the baryons with masses above 2 GeV have not been detected yet. Therefore the crucial question of whether the parity doubling of the high mass baryons has systematic nature

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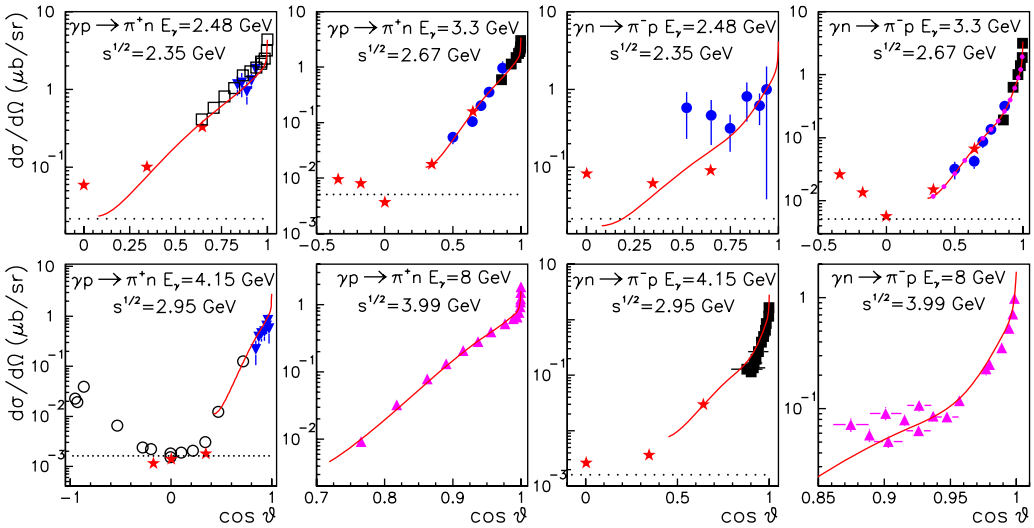

Figure 1: Angular spectra for π^+ and π^- photoproduction at different photon energies E_γ and invariant collision energies $\sqrt{s}$. The symbols show the data compiled in Ref. [7]. The stars are results from JLab Hall A Collaboration [8, 9]. The solid lines show the Regge calculations [7], while the dashed lines are the results obtained with the dimensional counting rule [10].

remains open. Indeed, the generation of the excited baryon spectrum is one of the unsolved puzzles of QCD that explicitly involves such fundamental properties as chiral symmetry and confinement.

The spectroscopy of high lying baryons is a non-trivial problem. In this energy region the background contribution dominates the reaction, which substantially complicates data evaluation and extraction of the resonance properties. To resolve the problem it was proposed [7] to construct the non-resonant part of the reaction amplitude and to fix it at high energies. Here the resonance contributions are expected to be negligible so that the available experimental results on differential cross sections and polarization observables allows to determine the non-resonant amplitude reliably. This amplitude is then used to predict observables at lower energies. The method was applied in the analysis of πN scattering and π photoproduction.

The analysis of the π^+ and π^- photoproduction indicates some surprising results that are presented here. In order to fix the non-resonance part of the reaction amplitude the Regge model with absorptive corrections was employed in a global evaluation of the world data available at photon energies

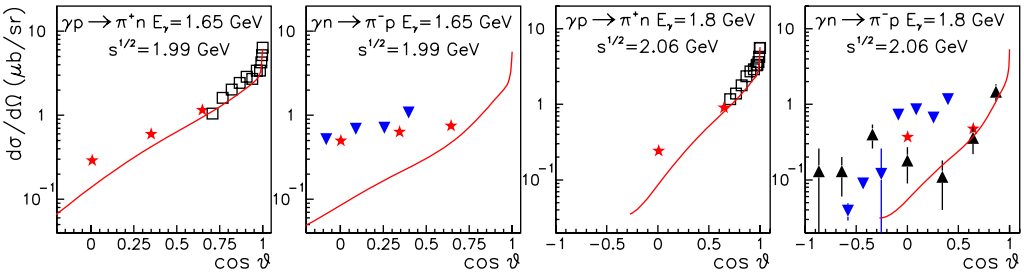

Figure 2: Angular spectra for π^+ and π^--photoproduction at different photon energies E_γ and invariant collision energies $\sqrt{s}$. The symbols show the data compiled in Ref. [7]. The stars are results from JLab Hall A Collaboration [8, 9]. The solid lines show the Regge calculations from Ref. [7].

from 3 to 8 GeV. The details of the calculations and systematic comparison with data are given in Ref. [7].

The solid lines in Fig.1 show the results obtained with the Regge calculations [7]. Note that in general the model is applicable at squared four momentum transfer $|t|<2$ GeV^2 and the solid lines are shown for that range of t. It is clear that the calculations well reproduce differential cross sections at forward angles. Here the stars are most recent results from JLab Hall A Collaboration [8, 9]. It is important that JLab measurements cover large range of angles and overlap with the data available previously. These new results are in reasonable agreement with Regge calculations at forward angles and indicate some additional contribution at large angles.

Part of such additional contribution at large $|t|>2$ GeV^2 or large angles might come from the direct interaction of photon with the quark of the nucleon. The main feature of this direct interaction is that the reaction amplitude is almost independent of t and the energy dependence of the reaction cross sections is driven by the total number of elementary fields in the initial and final states. The interaction can be modeled by perturbative QCD and the dashed lines in Fig.1 show the results obtained with the Dimensional Counting Rule [10].

Fig.1 illustrates that at invariant energies $\sqrt{s}<3$ GeV the differential cross sections, especially for π^- photoproduction, variate with angle and thus disagree with DCR expectations. Such angular dependence is typical for the excited baryon contribution. However to identify resonance excitation it is necessary to measure the spectra within the full angular range.

Now the non-resonant amplitude fixed at high energies can be used to predict observables for photon energies below 3 GeV. The differences between the predictions and data in this energy region might indicate the presence of excited baryons. Fig.2 shows angular spectra for π^+ and π^--photoproduction at invariant collision energies $\sqrt{s}\simeq 2$ GeV. While the positive pion data are reasonably described by Regge calculations, the π^- photoproduction results are in strong disagreement with the predictions. Note that old as well as new JLab negative pion data indicate likewise the presence of resonance structures.

Obviously further evaluation of high lying excited baryons requires the precise measurements on differential cross sections and polarization observables that cover full angular range and scan the photon energy above $\simeq 1.6$ GeV. Presented analysis [7] illustrates that single pion photoproduction is crucial tool to study the excited baryon spectrum. And finally to resolve the current puzzle of QCD.

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