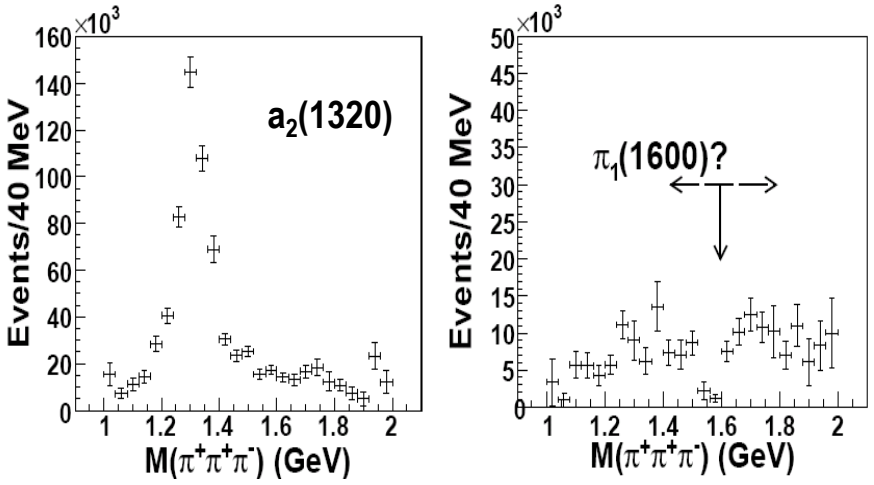
The Search for Exotic Mesons in $\pi^+\pi^+\pi^-$ Photoproduction on protons

The question of whether or not hadrons outside the scope of the constituent quark model (CQM) exist speaks directly to the fullness of our understanding of QCD. However, mesons not composed of a quark-anti-quark pair (exotic mesons) have proven difficult to distinguish from the many conventional states that populate the meson spectra. For this reason, much attention has been focused on those states with manifestly exotic J^{PC} quantum numbers. A q-qbar meson with orbital angular momentum l and total spin s must have $P = (-1)^{l+1}$ and $C = (-1)^{l+s}$. Thus a resonance with $J^{PC} = 0^{--}$, 0^{+-}, 1^{-+}, 2^{+-}, etc., must be exotic. Such a state could be a gluonic excitation (qqg) or glueball (2g, 3g,..), or a 4-quark state. The self interacting nature of the gluon within QCD allows for resonant states with a (qqg) configuration, where the gluonic degree of freedom gives rise to a spectrum of additional states outside the CQM. The observation of mesons, with an explicit excitation of the gluonic degree of freedom, is an important test of the predicting power of QCD at intermediate energies. There is evidence for a state with $J^{PC} = 1^{-+}$, the $\pi_1(1600)$, in the reaction $\pi^-p \rightarrow \pi^+\pi^+\pi^-p$ at 18.1 GeV by the Brookhaven E852 experiment.[1] The existence of the $\pi_1(1600)$ has been confirmed by the same experiment in other channels such as $\eta'\pi$.[2]

It has long been anticipated that photoproduction may be a better production mechanism for these hybrid mesons. The present experiment was performed at Jefferson Lab with CLAS. Results from the PWA are shown in the figure. A prominent wave observed is $J^{PC} = 2^{++}$ (a_2). The $a_2(1320)$ is observed in the $(\rho\pi)_D$ wave at the expected mass and width (l.h.s.). The a_2 cross section was measured to be 0.81 ± 0.25 μb. However, no clear resonant structure was observed in the exotic $J^{PC}=1^{-+}$ partial wave (r.h.s.), this distribution was used to estimate an upper limit to the $\pi_1(1600)$ cross section. Using the mass of 1597 MeV and the width of 340 MeV as measured by Ref. [2], we estimated an upper limit for the $\pi_1(1600)$ of 13.5 nb at a 95% confidence level, less than 2% of the $a_2(1320)$, in sharp disagreement with the predicted strengths for photoproduction of a $J^{PC}=1^{-+}$ exotic gluonic meson.



[1] G.S. Adams, et al., Phys.Rev.Lett.81:5760-5763,1998.

[2] E. I. Ivanov, et al., Phys.Rev.Lett.86:3977-3980,2001.