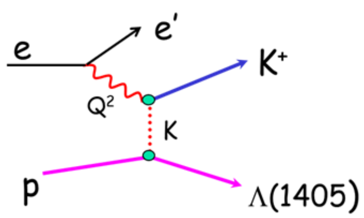
First Observation of the Λ(1405) Line Shape in Electroproduction

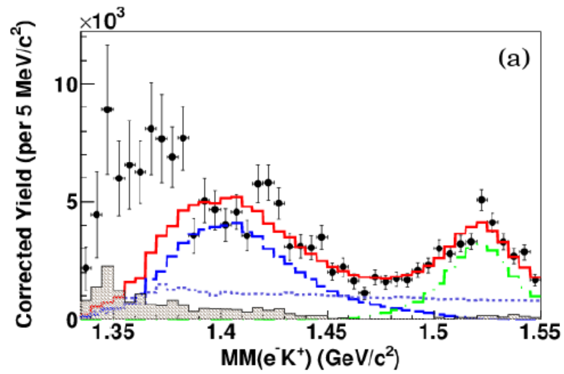
The mass distributions or "line shapes" of resonant states can reveal information about their internal structure. We consider the case of the Λ(1405), a peculiar state that for many years has defied detailed explanation. Although it has its place in the standard quark model, it may not be a simple 3-quark baryon, but rather a mixed state with one or more molecular-like interactions that couple together the octet baryons and pseudo-scalar mesons. Its line shape in *photo*production was shown recently at CLAS to be described neither by a simple Breit-Wigner shape, nor by a line shape expected in a coupled-channel model incorporating the Σπ and the $N\bar{K}$ baryon-meson states.

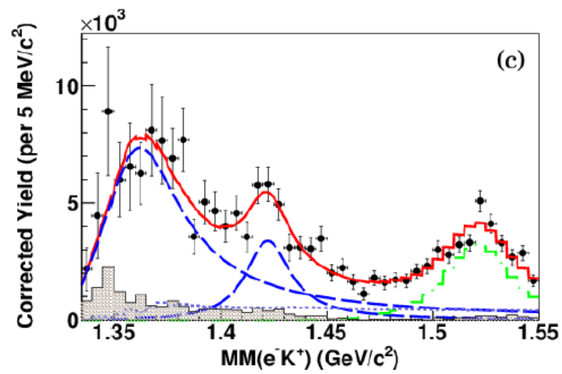


The experiment summarized here [1] was the first to detect the Λ(1405) when it was created through interaction of an electron beam with a proton target. This reaction can be pictured as a virtual, off-shell photon with 4-momentum *Q* (see small figure) indirectly making this hyperon in conjunction with a K meson to conserve the strangeness quantum number. The idea of the experiment was to see how similar or different the Λ(1405) "looks" when the photon is off shell compared to when it is on shell or "real." In particular, there are theoretical models in which the Λ(1405) is a coherent mix of two isospin zero poles located at somewhat different masses. Each pole is predicted to couple with different strength to the measured Σπ final state. Is there evidence for this? This experiment is the first to look in *electro*production.

More precisely, electroproduction of K^+ Λ(1405) off the proton was studied by using data from CLAS at Jefferson Lab in the range $1.0 < Q^2 < 3.0$ $(\mathrm{GeV/c})^2$. The analysis used the decay channels $\Sigma^+\pi^-$ of the Λ (1405) and $p\pi^0$ of the Σ^+. Neither the standard (PDG) resonance parameters, nor free parameters fitting to a single Breit-Wigner resonance reproduce the measured line shape. The top figure shows the data for the range $1.5 < Q^2 < 3.0$ GeV^2 integrated over all kaon angles. One sees the Λ(1405) and Λ(1520). A fit of the missing mass $MM(e^-K^+)$ is shown, with the solid red line as the overall fit, the dash-dotted green lines around 1.52 $\mathrm{GeV/c^2}$ are from the Λ(1520) simulation. The dashed blue lines is from the Λ(1405) simulation parametrized by PDG values for the position and width using a relativistic Breit-Wigner function. The dotted purple lines show the summed background contributions mainly from nonresonant KΣπ production. The shadowed histogram at the bottom shows the estimated systematic uncertainty. The red curve is clearly quite a poor match to the data. In the lower plot, showing the same data, the fit to the 1405 region was modeled with two freely-varying Breit-Wigner functions. This results in a much better fit, which suggests that the structure of the Λ(1405) state, as revealed in this reaction, is more complex than a single resonance distribution.

The fitted line shape corresponds approximately to predictions of a two-pole meson-baryon picture of the Λ(1405), with a lower mass pole near 1368 $\mathrm{MeV/c^2}$ and a higher mass pole near 1423 $\mathrm{MeV/c^2}$. Furthermore, it is shown in the paper that with increasing photon virtuality the mass distribution shifts toward the higher mass pole.





So far these data from CLAS are the world's only look at electroproduction of the Λ(1405). No theoretical predictions exist. Since now data exist, we believe it is time to make an attempt to compute this observable.

[1] H.Y. Lu, R. A. Schumacher *et al.* (CLAS Collaboration), *First Observation of the Λ(1405) Line Shape in Electroproduction* , Physical Review C **88**, 045202 (2013).