Search for Pentaquarks in Jefferson Lab Hall A

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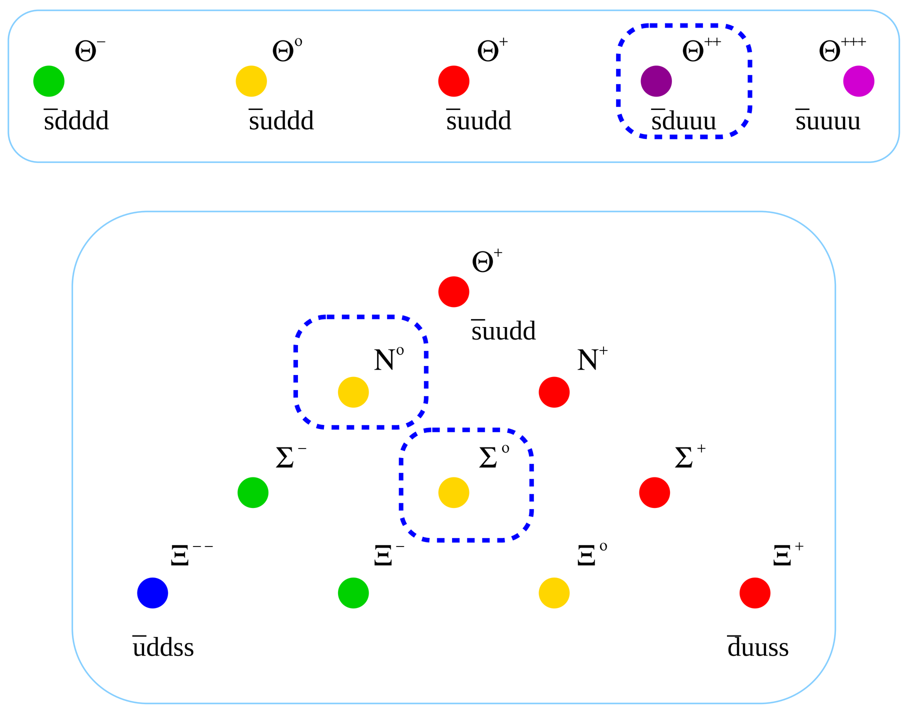
Predictions of Pentaquarks

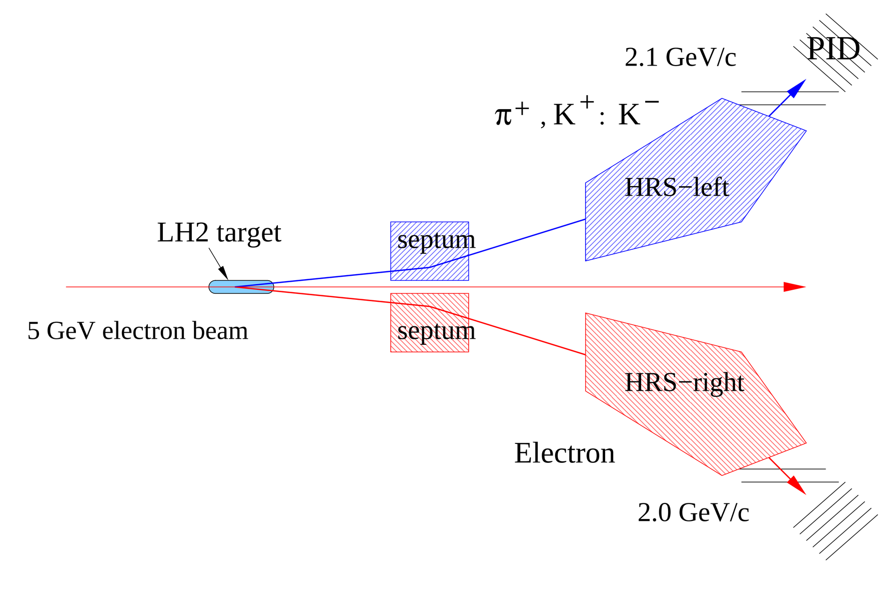


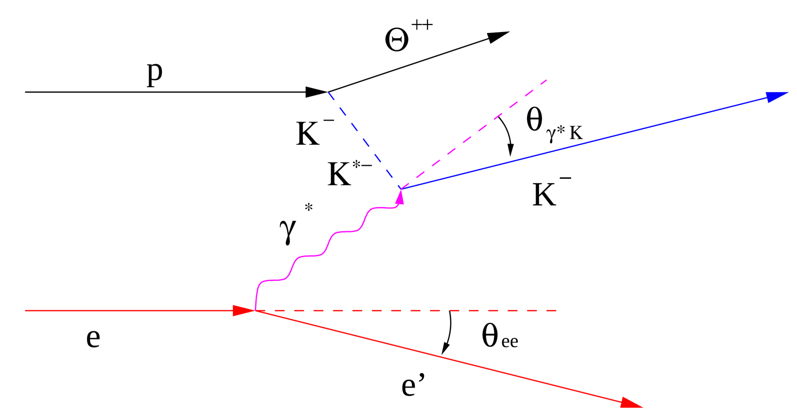
In 1997, according to soliton model D. Diaknov et al. predicted a $SU(3)_F$ flavor antidecuplet of pentaquarks. In the antidecuplet, what attracts people most is a narrow ($5\ MeV$), exotic state, $\Theta^+(1540)$, which has quark component $uudd\bar{s}$. Following observations have shown the quite high possibility of its existance. However, in our experiment, the interests were focused on Θ^+'s partners: $N^0(1650)$ and $\Sigma^0(1760)$, and they can be used to verify the existance of such antidecuplet. Also, if the Θ^+ has non-zero isospin we're anticipating to discover it's isospin partners, so here we also selected a strong interaction channel for the Θ^{++}. The pentaquarks we searched in the experiment are circled by blue dots.

Experiment Setup

Two High Resolution Spectrometers were used and they provided us a very good missing mass resolution, around 3.5 MeV FWHM, which made the experiment very sensitive to narrow resonances. A 5 GeV electron beam was used with 15 cm LH2 cryogenic target. The interactions are following

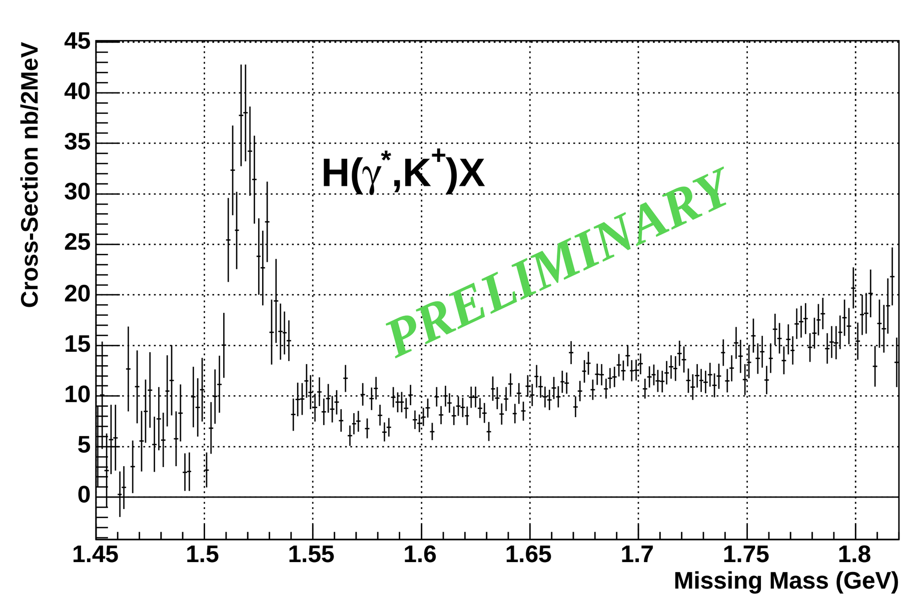
$$H(e,\ K^-\ e')\Theta^{++}$$
$$H(e,\ K^+\ e')\Sigma^0_{\overline{10}}$$
$$H(e,\ \pi^+\ e')N^0_{\overline{10}}$$

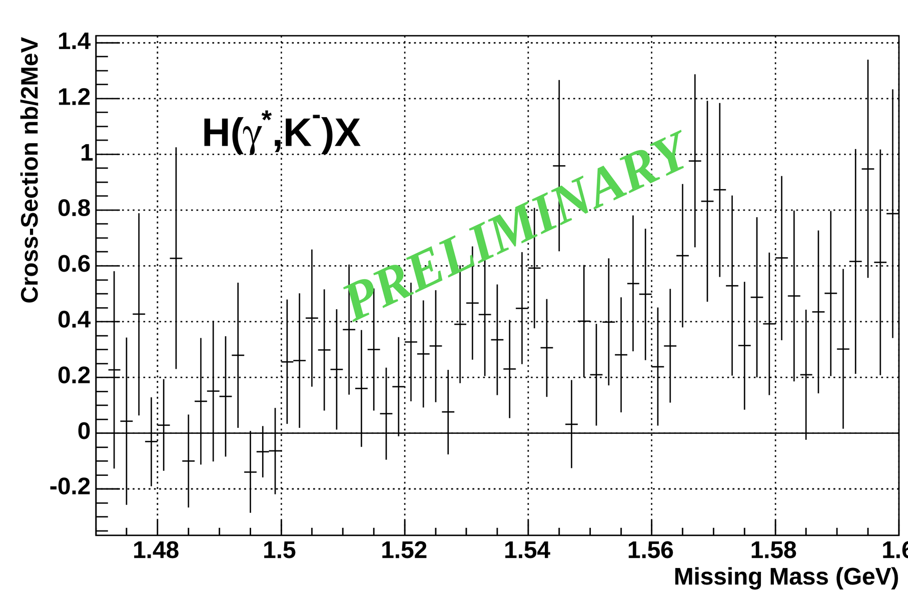


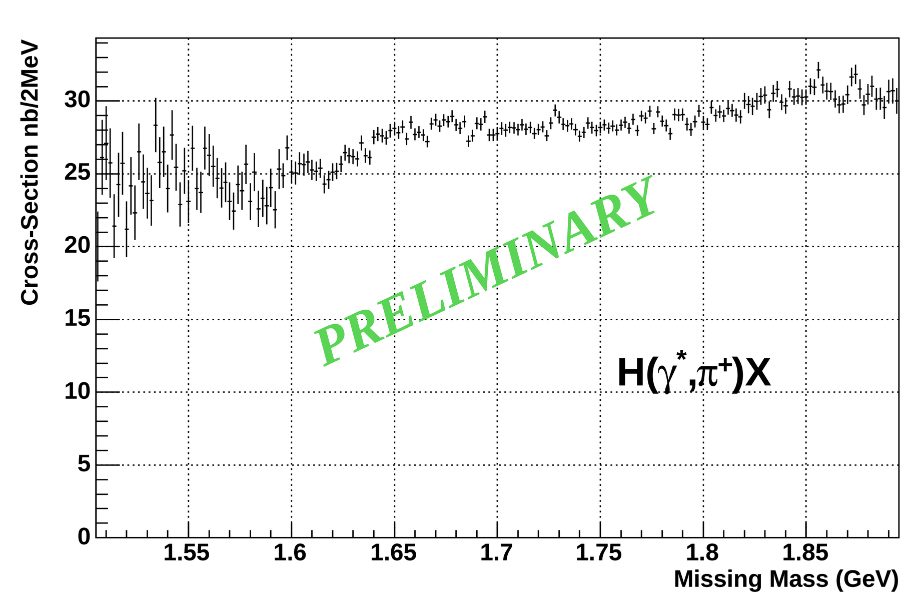


The kaons and pions were detected in the HRS-left at a central angle of 6° with a septum magnet. The scattered electrons were detected in the HRS-right at a central angle of 6° with another septum magnet. The polarity of HRS-left was positive for the $\Sigma^0_{\overline{10}}$ and $N^0_{\overline{10}}$, and negative for the Θ^{++}.

Cross-Section Spectra







According to accumulated luminosity and other efficiency factors, we combined the acceptance corrected spectra from different kinematic settings and normalized the scale into cross-section. In left hand side, from top to bottom there are missing mass spectra for Σ^0, Θ^{++}, N^0 search. In the Σ^0 spectrum, the properties of a known big resonance $\Lambda^0(1520)$ have also been measured. Note that some spectra may have negtive values because of accidental background substraction.

Kinematic Parameters

$$E_\gamma\ =\ 3\ GeV,\ Q^2\ \sim\ 0.1\ (GeV/c)^2,\ \theta^{Lab(CM)}_{\gamma K(\pi)}\ \sim\ 2(6)^\circ$$

Parameters of $\Lambda^0(1520)$

$$M_{\Lambda^0(1520)}\ =\ 1520.2\ \pm\ 0.5\ MeV$$
$$\Gamma_{\Lambda^0(1520)}\ =\ 16.6\ \pm\ 1.3\ MeV$$
$$\frac{d\sigma}{d\Omega_K}|_{Lab}(\gamma p \to \Lambda^0 K^+)\ \approx\ 350\ nb$$

Cross-Section Upper Limits for Pentaquarks

Since there's **NO SIGNIFICENT NARROW PEAK** found in our searching range, the upper limits in Lab system for differential scross-sections of 5 MeV resonances are given: (**PRELIMINARY**)

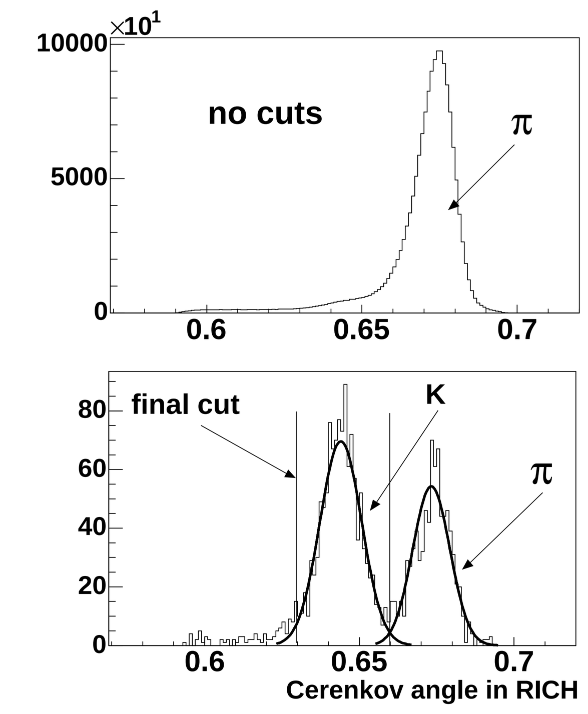
$$\frac{d\sigma}{d\Omega_K}(\gamma p \to \Sigma^0 K^+)\ <\ 11\ nb\ =\ 3.1\%\ \frac{d\sigma}{d\Omega}(\Lambda(1520))$$
$$\frac{d\sigma}{d\Omega_K}(\gamma p \to \Theta^{++} K^-)\ <\ 3\ nb\ =\ 0.9\%\ \frac{d\sigma}{d\Omega}(\Lambda(1520))$$
$$\frac{d\sigma}{d\Omega_K}(\gamma p \to N^0 K^+)\ <\ 8\ nb\ =\ 2.3\%\ \frac{d\sigma}{d\Omega}(\Lambda(1520))$$

Particle Identification

AEROGEL Detectors

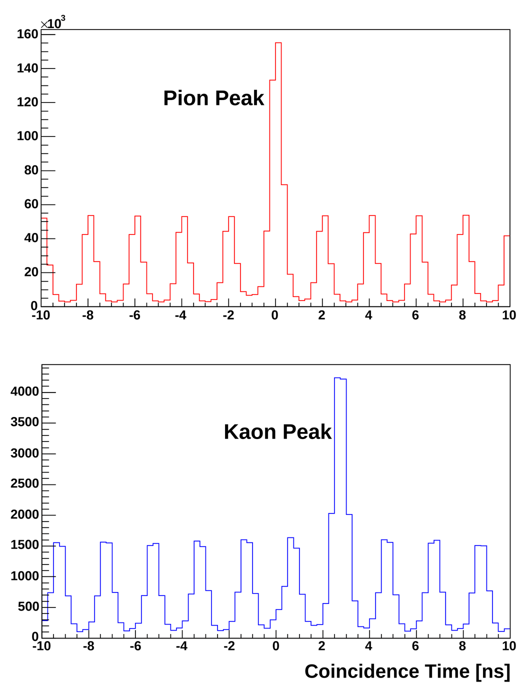
In HRS-left we used 3 Cerenkov detectors to identify particles. Two of them are amplitude detectors using AEROGEL with index 1.015 and 1.055. So the thresholds of Cerenkov radiation in these detectors are 2.84(0.803) GeV/c for kaons(pions) and 2.8(0.415) GeV/c for protons(pions) repectively.

RICH Detector



The third detector measuring the angle of Cerenkov radiation is called RICH. It has a very good angle resolution of 5 mrad(σ). Accompanied by a radiator of index n = 1.3, it allows us to identify kaons from pions clearly up to 3 GeV/c momentum.

Coincidence Time

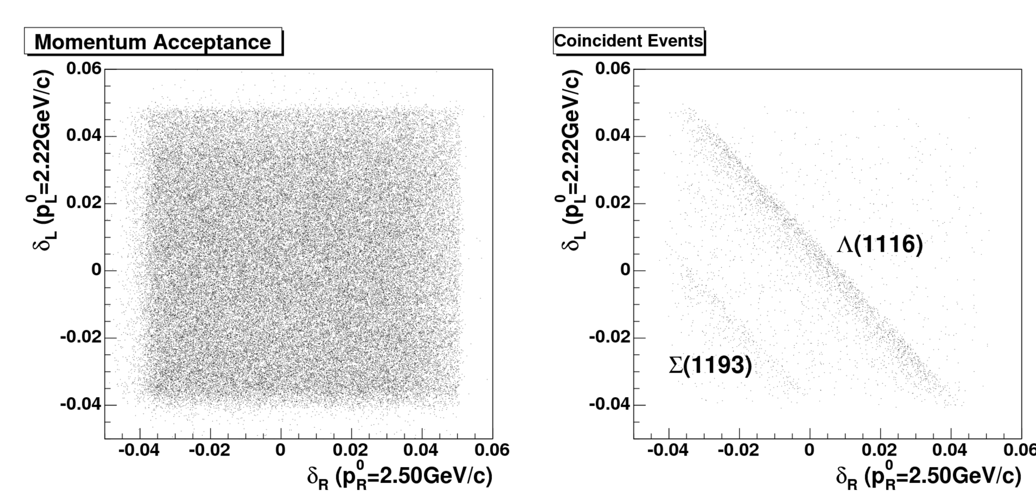


With the help of RICH detector, Aerogel 1, Aerogel 2, and other conventional Hall A PID detectors: Pion Rejector and Gas Cherenkov, we can clearly identify the kaon peak in the coincidence time spectrum.

Acceptance Correction

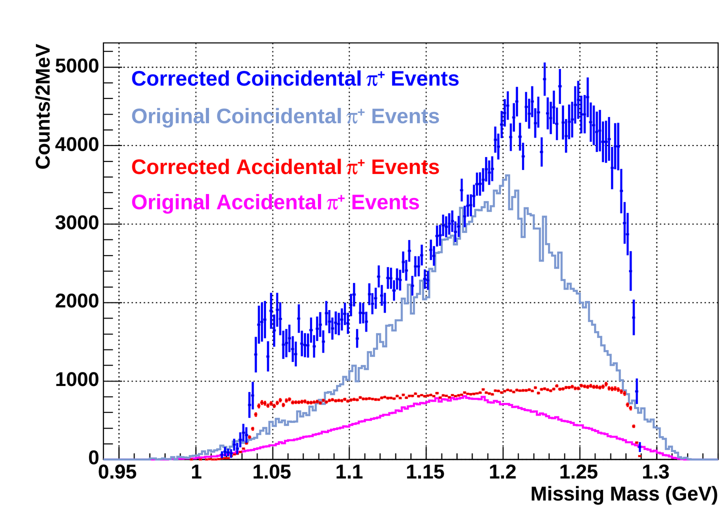
Missing Mass at Forward Angle

$$M_X = \sqrt{(p^\mu_e + M - p^\mu_{e'} - p^\mu_{K(\pi)})^2} \approx C' - p^0_R\delta_R - p^0_L\delta_L$$



For particular missing mass, it's a straight line in the momentum acceptance and $\Delta E'$ is proportional to the length in the 2-dimensional acceptance plot.

Momentum Acceptance Correction



With above knowledge, we are able to normalize the missing mass spectrum and calculate cross-section $\frac{d^3\sigma}{dE' d\Omega_e d\Omega_{K(\pi)}}$. The plot shows the pion missing mass spectra after such correction: the triangle shape of accidental events has been removed and the resonance $\Delta(1232)$ got its proper shape.