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Pentaquark searches at FOCUS

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We find no evidence for high-energy photoproduction of pentaquarks at 1540 MeV/c^2, 1862 MeV/c^2, or 3099 MeV/c^2 using decay modes pK^0_S, $\Xi^-\pi^-$, and $D^{(*)-}p$, respectively.

1. Introduction

A 4–7 σ significant pentaquark with a mass of $\sim$1540 MeV/c^2 decaying to pK^0_S or nK^+ has been reported by ten experiments [1–10].Combining the mass measurements of these experiments we find $M = 1533.6 \pm 1.2\,\mathrm{MeV}/c^2$. The χ^2/dof for this averaging is 38.2/9 giving a confidence level of 1.6×10^{-5}, a 5.2 σ problem. Pentaquarks with two strange quarks [11] and with a charm quark [12] have also been reported.

FOCUS ran during the 1996–7 fixed-target run at Fermilab. A photon beam from brehmsstrahlung of a 300 GeV electron and positron beam impacts BeO targets. 16 silicon strip planes provide vertexing and tracking. Charged particles are tracked and momentum analyzed as they pass through up to two dipole magnets and up to five sets of multiwire proportional chambers. Three Čerenkov counters, two EM calorimeters, and two muon detectors identify particles. A hadronic trigger requiring $\sim$25 GeV of energy passed 7 billion events for reconstruction. Thus, these events are well above threshold for pentaquark production. Charge conjugates are assumed for these analyses and all pentaquarks are assumed to decay strongly.

2. Search for $\Theta(1540)^+ \to pK^0_S$

We search for $\Theta(1540)^+ \to pK^0_S$ and measure the production relative to two similar decays, $K^*(892)^+ \to K^0_S\pi^+$ and $\Sigma(1385)^\pm \to \Lambda^0\pi^\pm$. The data is from events with a reconstructed $K^0_S \to \pi^+\pi^-$ or $\Lambda^0 \to p\pi^-$ [13]. Selecting vee candidates within 2.5 σ of the nominal mass we obtain 63×10^6 K^0_S (8×10^6 Λ^0) candidates with 92% (96%) purity. The remaining good quality tracks must form a good vertex (CL > 1%).The proton candidate must pass stringent Čerenkov ID cuts, reducing the misidentification rate to $\sim$0. The $K^*(892)^-$ and $\Sigma(1385)^\pm$ are fit with a simple Breit-Wigner plus background of $aq^b \exp\left(cq + dq^2 + eq^3 + fq^4\right)$ where q is the energy release. We find $(8.29 \pm 0.01) \times 10^6$ $K^*(892)^-$, $(92 \pm 2) \times 10^3$ $\Sigma(1385)^+$, and $(146 \pm 3) \times 10^3$ $\Sigma(1385)^-$

*on behalf of the FOCUS Collaboration (http://www-focus.fnal.gov/)

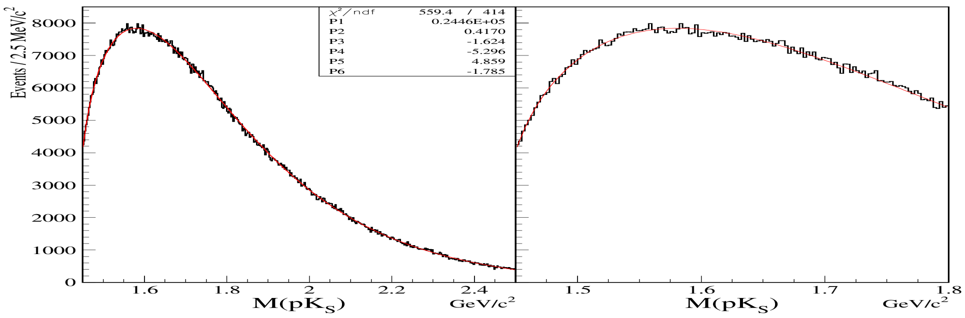

Fig. 1. Fit to $M(pK^0_S)$ in search for $\Theta(1540)^+ \to pK^0_S$.

signal events. No pentaquark evidence is seen in the the pK^0_S mass plot (Fig. 1). We obtain 95% CL limits on the yield by determing how much the fitted yield must be increased to change the log-likelihood by 1.92 (continually minimizing the background parameters). This procedure is performed with a Breit-Wigner width of 0 and 15 MeV/c^2, both with Gaussian resolution varying from 2.36–3.07 MeV/c^2. The maximum limit on the yield over the mass range 1.51–1.56 GeV/c^2 is 754 (2252) for Γ of 0 (15) MeV/c^2. To set cross section limits we generate pentaquarks the same as $\Sigma(1385)^+$. Using Pythia production and FOCUS MC simulation of $K^*(892)^-$, $\Sigma(1385)^\pm$, and $\Theta(1540)^+$ events we convert the yield limits into cross section ratio limits. For $1.51 < M < 1.56$ GeV/c^2, the 95% CL limit on the production of $\Theta(1540)^+$ relative to combined $\Sigma(1385)^+$ and $\Sigma(1385)^-$ is 0.7% (2.1%) for Γ of 0 (15) MeV/c^2. Relative to $K^*(892)^-$, the limit is 0.06% (0.17%) for Γ of 0 (15) MeV/c^2. We account for all branching ratios and assume $B(\Theta(1540)^+ \to pK^0_S) = 0.25$.

3. Search for $\phi(1860)^{--} \to \Xi^- \pi^-$

FOCUS reconstruction of $\Xi^- \to \Lambda^0 \pi^-$ is described in Ref. [13]. We select 800,000 Ξ^- candidates of which 75% are signal. We search for $\Xi(1530)^0 \to \Xi^-\pi^+$ and the $S = -2$ pentaquark candidate $\phi(1860)^{--} \to \Xi^-\pi^-$. We require the production and $\Xi^-\pi^\pm$ vertices have CL$\,>1\%$ and separated by less than 2σ. The pion candidate must have a Čerenkov signature consistent with a pion. We find 59391 ± 536 $\Xi(1530)^0$ events and no evidence for $\phi(1860)^{--}$ as shown in Fig. 2. The yield upper limit calculated at a mass of 1.862 GeV/c^2 is 114 (170) for Γ of 0 (15) MeV/c^2 with resolution $\sigma = 6.05$ MeV/c^2. Assuming production like $\Xi(1530)^0$ we find $\frac{\sigma(\phi(1860)^{--}) \times B(\phi(1860)^{--} \to \Xi^-\pi^-)}{\sigma(\Xi(1530)^0)} < 0.25\%\,(0.37\%)$ at 95% CL for Γ of 0 (15) MeV/c^2.

4. Search for $\Theta_c(3099)^0 \to D^{(*)-}p$

Using standard FOCUS charm reconstruction techniques we obtain a clean sample of $D^{*-} \to \overline{D}^0\pi^-$ ($\overline{D}^0 \to K^+\pi^-$) events and $D^- \to K^+\pi^-\pi^-$ events (Fig. 3). Combining 35821 ± 202 D^{*-} and 83940 ± 303 D^- candidates with a positively identified proton we find no evidence for a charm pentaquark as shown in Fig. 3.

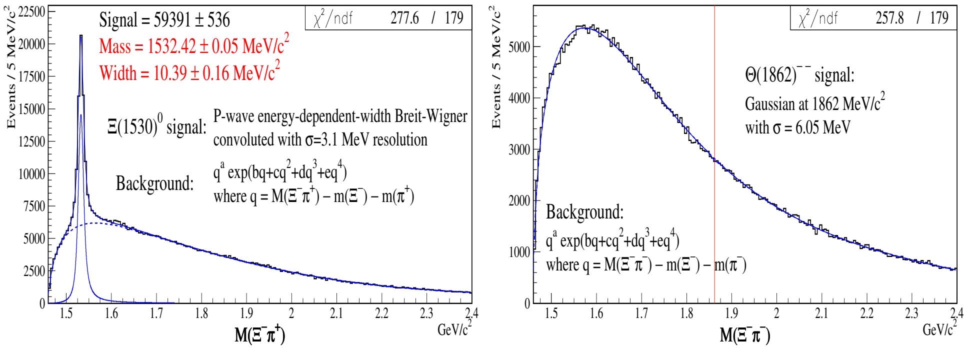

Fig. 2. Fits to $M(\Xi^-\pi^+)$ (left) for $\Xi(1530)^0$ and $M(\Xi^-\pi^-)$ for $\phi(1860)^{--}$.

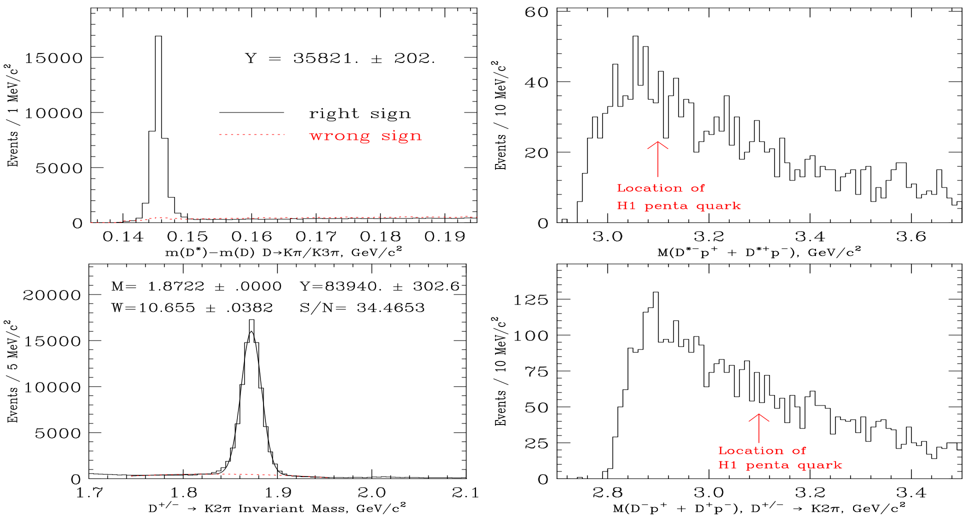

Fig. 3. We add a proton to the D^{*-} events and D^- events (left) to search for $\Theta_c(3099)$ (right).

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