E04-012: High Resolution Search for $\Theta^+(1540)$ Partners

Status Report

Jens-Ole Hansen

Hall A Collaboration Meeting

16 December 2004

E04-012 Collaboration

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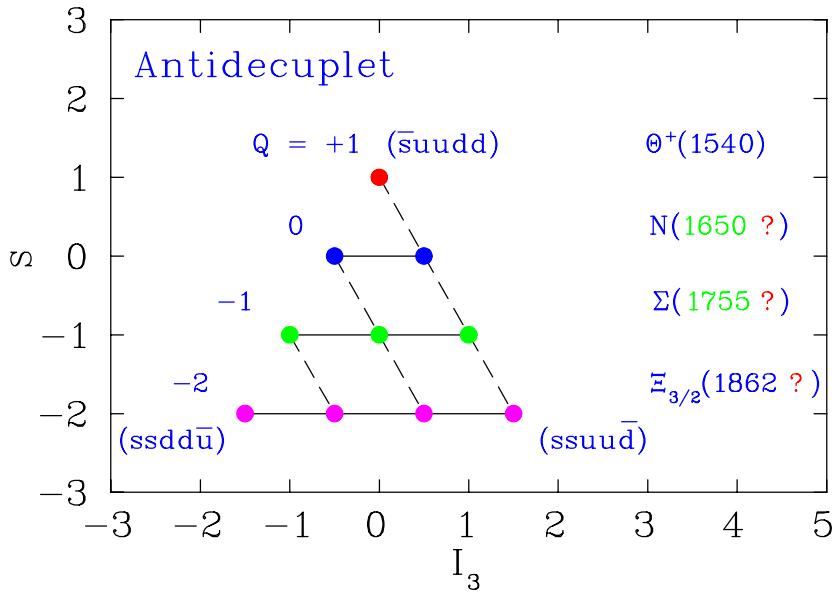
and the Hall A Collaboration

Pentaquark Models

- Chiral Quark Soliton Model (Diakonov *et al.*, 1997) predicts an anti-decuplet of pentaquarks
  - Narrow ($\leq$ 30 MeV)
  - Low mass: $M = M_{\Theta^+(1540)} + (1 - S) \times 107$ MeV



- One of several alternative explanations of Θ^+:
  Isotensor multiplet (Capstick *et al.*, 2003)
  - Explains narrow width in terms of isospin-violating strong decays
  - Predicts different set of narrow (and exotic!) partners

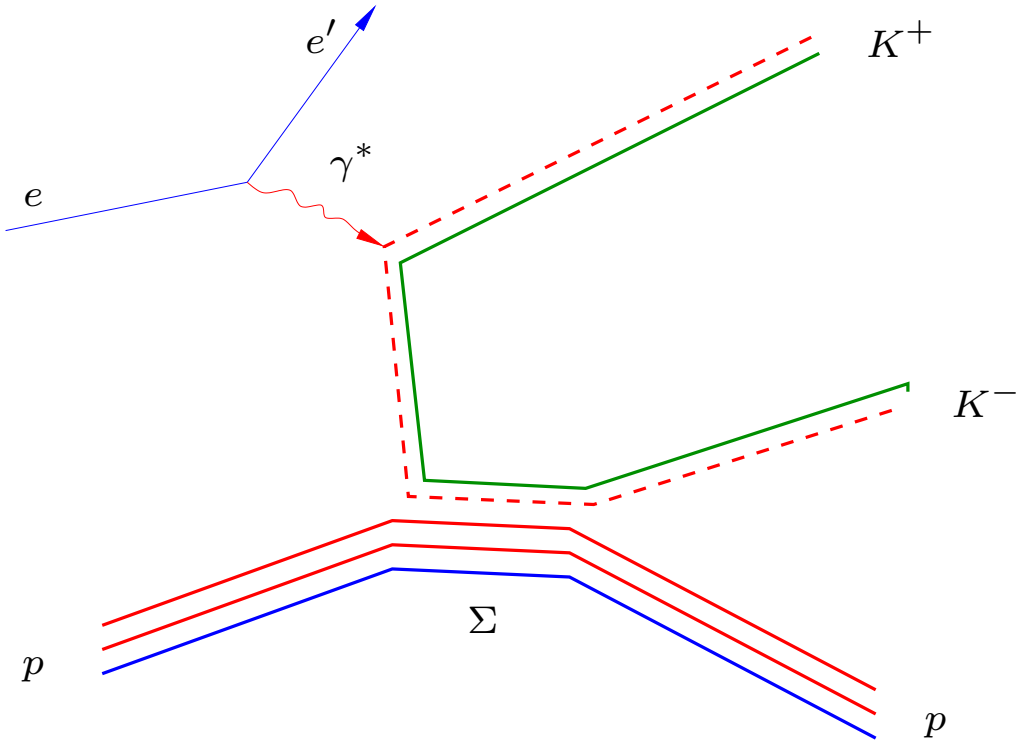
State	Content	I_z	Strong decay modes
Θ^-	$dddd\bar{s}$	-2	
Θ^0	$uddd\bar{s}$	-1	nK^0
Θ^+	$uudd\bar{s}$	0	nK^+,pK^0
Θ^{++}	$uuud\bar{s}$	1	pK^+
Θ^{+++}	$uuuu\bar{s}$	2	

Knowledge about Θ^+ Partners

- Mass spectrum in Chiral Soliton Model: $M = M_{\Theta^+} + (1 - S) \times 107$ MeV
- Different mass spectra predicted by different models
- Various predictions for widths. E.g. $\Gamma_{\Sigma^0} \approx 3$–$40$ MeV
- Partial wave analysis by Arndt *et al.* (2003):
  $M_{N^*} = 1680$ or 1730 MeV; $\Gamma_{N^*} < 30$ MeV; $\Gamma_{\Xi_{3/2}} < 3$ MeV

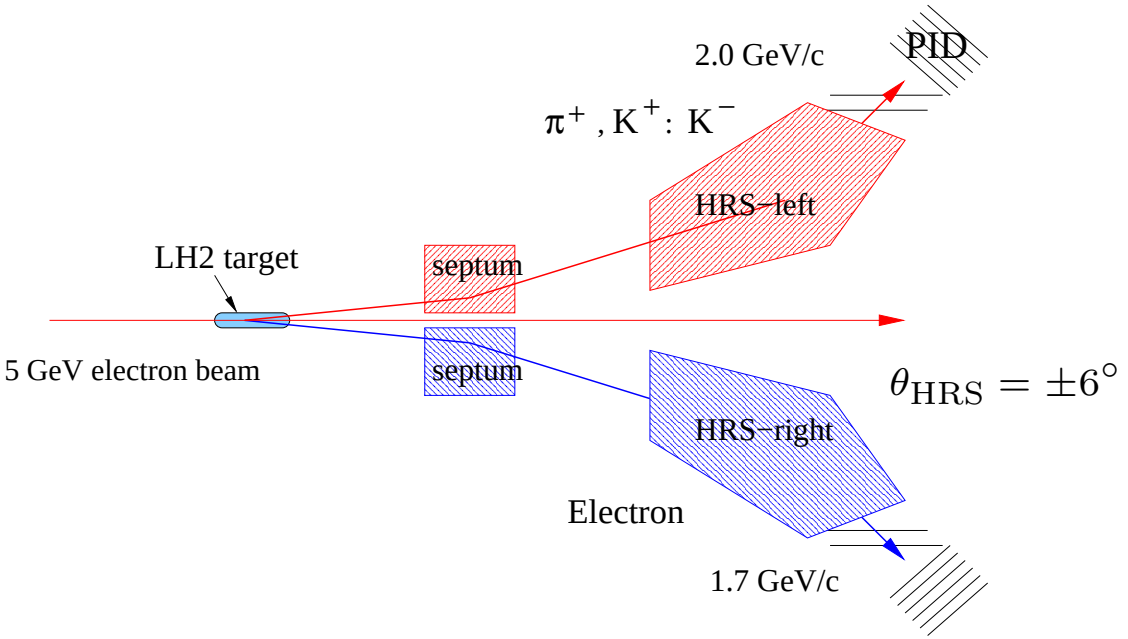
- Various facilities (CLAS, HERMES, etc.) have carried out search for Θ^{++} — no conclusive results
- Narrow $\Xi^{--}_{3/2}$ state reported by NA49 with $M = 1862$ MeV. Other exps. report non-observation.
- Signal of non-strange member of antidecuplet seen in $\gamma n \to K\Lambda(\Sigma)$ at $M \approx 1680$ MeV at GRAAL (preliminary result)

Production Reaction



Assume low-t dominance

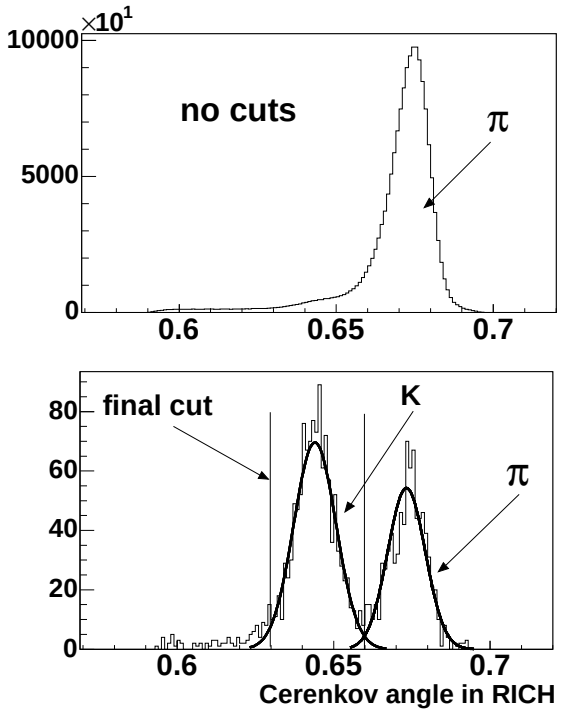
JLab Experiment E04-012



- $H(e, e'K^+)\Sigma^\circ_{\overline{10}}$ — search for strange narrow resonance in the range 1530-1820 MeV
- $H(e, e'K^-)\Theta^{++}$ —- search for an exotic state in the range 1500-1600 MeV
- $H(e, e'\pi^+)N^\circ$ — search for non-strange narrow resonance in the range 1600-1830 MeV

Particle ID

- Gas Cherenkov in HRS-right
- Two aerogels, pion rejector, and RICH in HRS-left
- coincidence time (ToF) cut

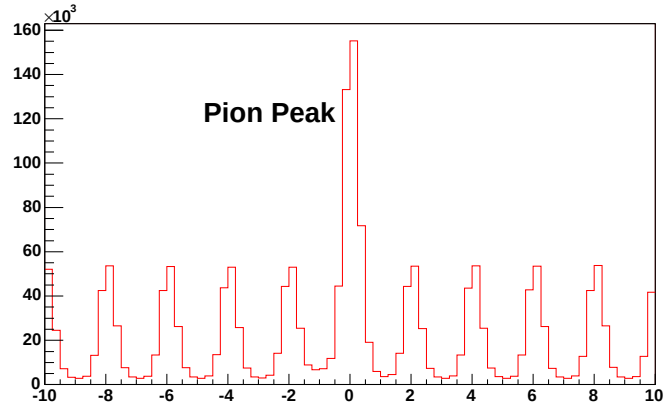


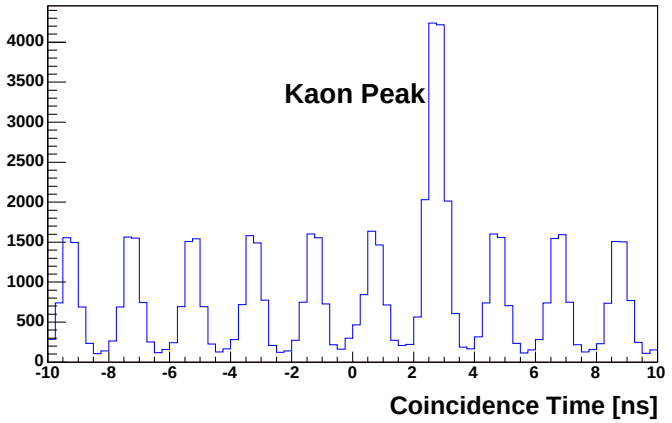
π rejection $\approx 3 \cdot 10^4$. Final K/π ratio > 20

Coincidence System

ToF resolution $\approx$ 600 ps FWHM

Pion and kaon concidences separated by $>$ 2.5 ns.

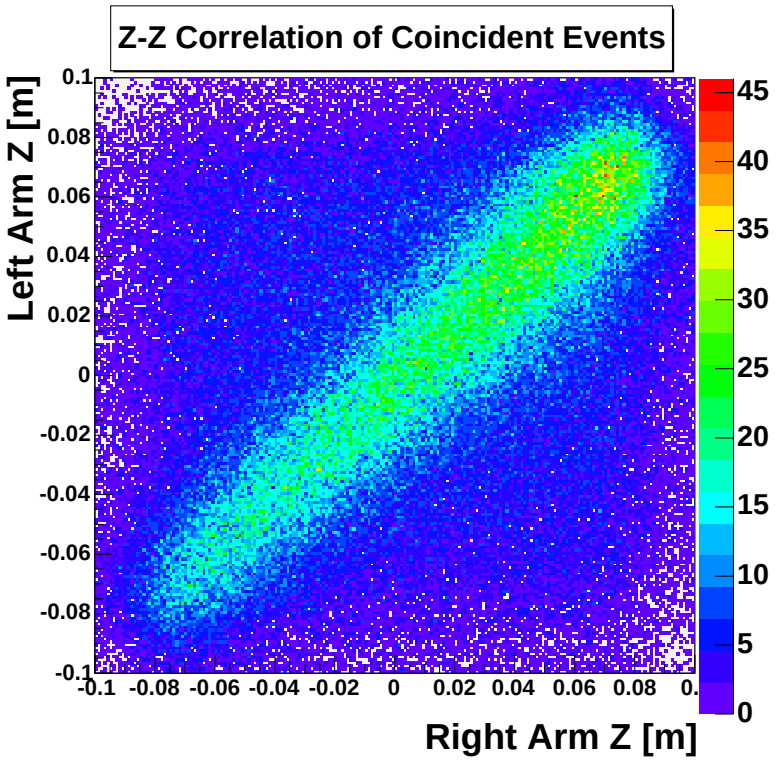




Coincidence System (cont.)

Vertex resolution $\approx$ 2.5 cm FWHM

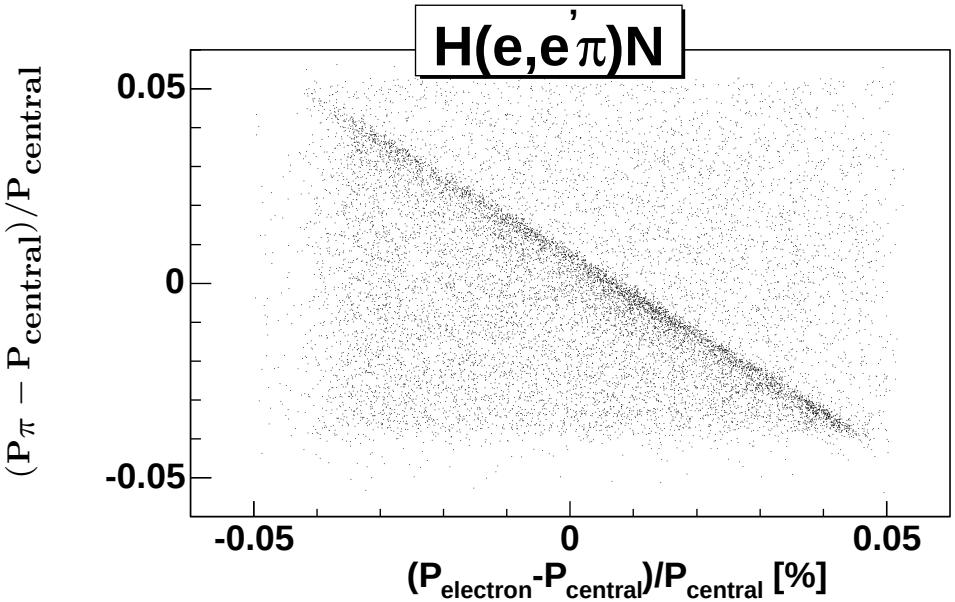
With 15 cm extended target, vertex cut reduces accidental background by a factor of 2.



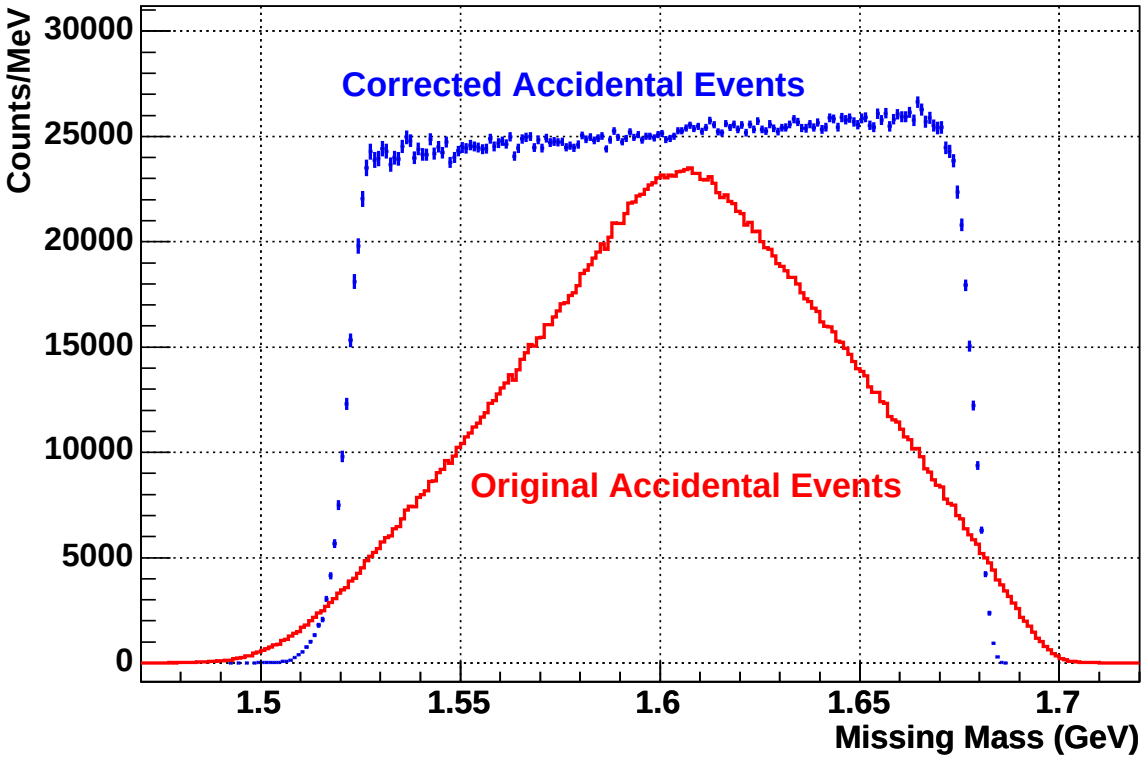
Missing Mass Technique

$$e + p \rightarrow e' + \pi^+(K^\pm) + X$$

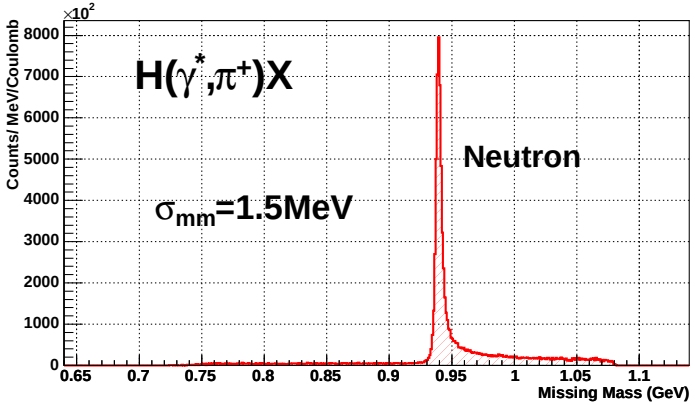
$$M_X = \sqrt{(P^\mu_{miss})^2} \approx C - E_{e'} - E_{\pi(K)}$$

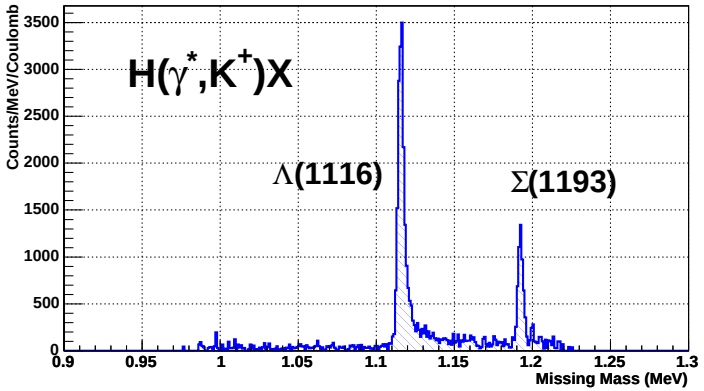


Acceptance Correction



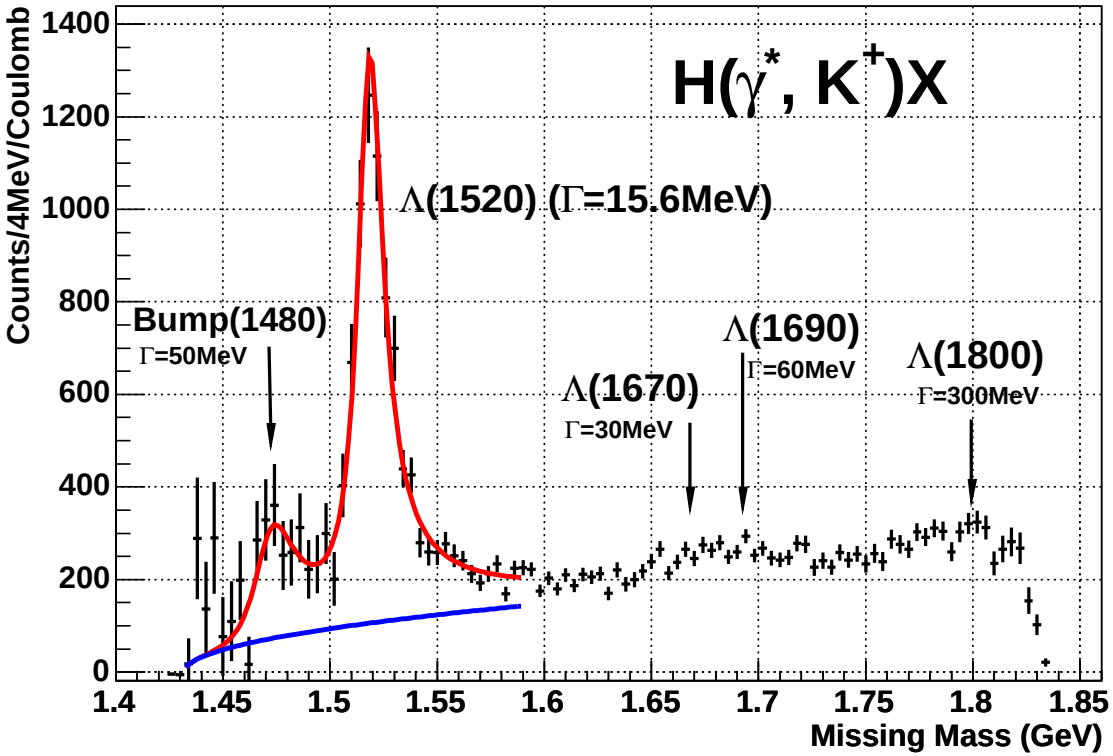
Mass Resolution and Calibration





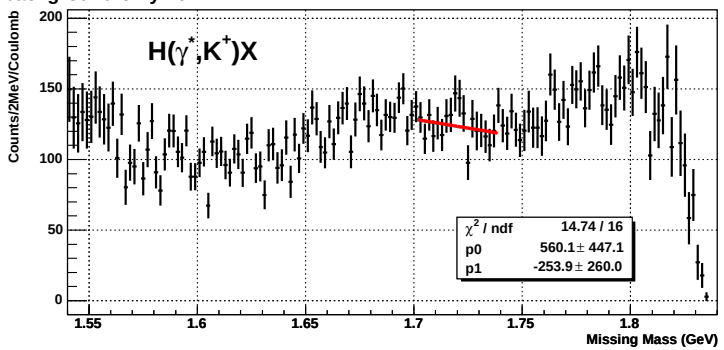
$\Lambda(1520)$ and $H(e,e'K^+)X$ scan

PRELIMINARY

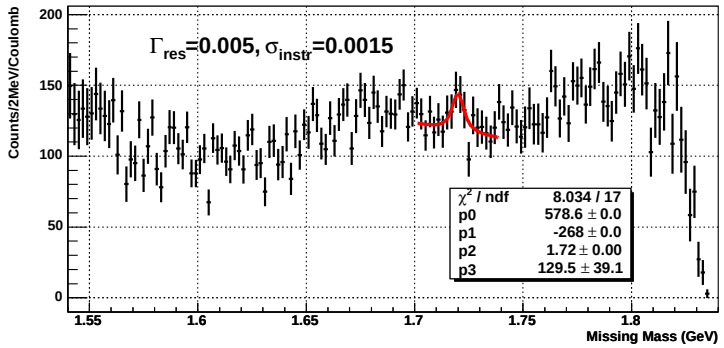


Search for Σ^0_{10} Partner

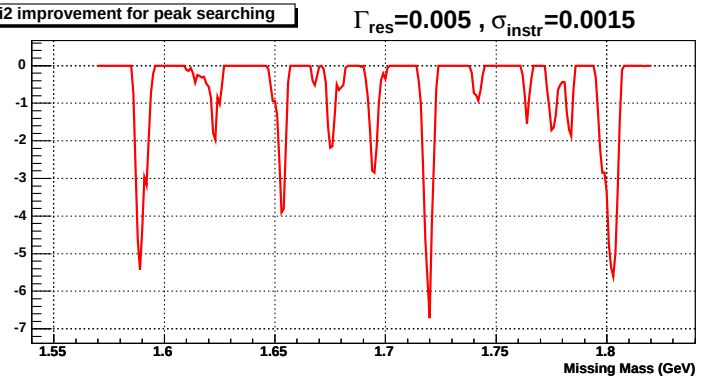
background only fit



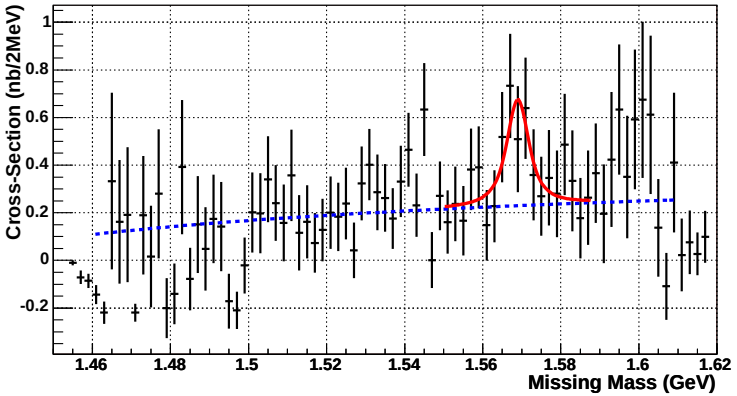
background + resonance fit

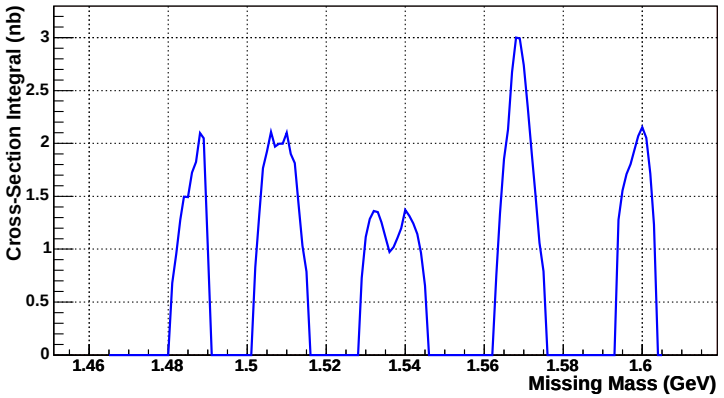


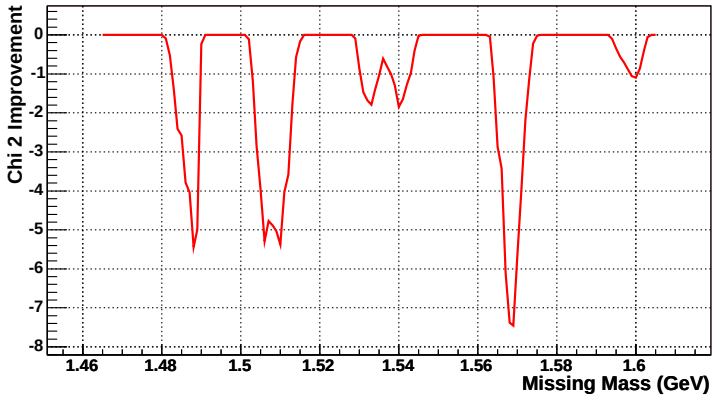
Chi2 improvement for peak searching



Search for Isotensor Partner Θ^{++}







Preliminary Results for Σ^0_{10} and Θ^{++}

For $E_{\gamma^*} \approx 3\ \mathrm{GeV}, \quad Q^2 \approx 0.2\ (\mathrm{GeV/c})^2, \quad \theta^{cm}_{\gamma^* K} < 20^\circ$

- **Σ^0_{10} search:**

  90% CL limit for a $\Gamma = 5$ MeV state in the region 1570-1820 MeV:

  $$\frac{\sigma_{\gamma^* p \to K^+ \Sigma^0}}{\sigma_{\gamma^* p \to K^+ \Lambda(1520)}} < 1.7\%$$

  If

  $$\sigma_{\gamma^* p \to K^+ \Lambda(1520)} \approx 300\ \mathrm{nb}$$

  then

  $$\sigma_{\gamma^* p \to K^+ \Sigma^0} < 5\ \mathrm{nb}$$

- **Θ^{++} search:**

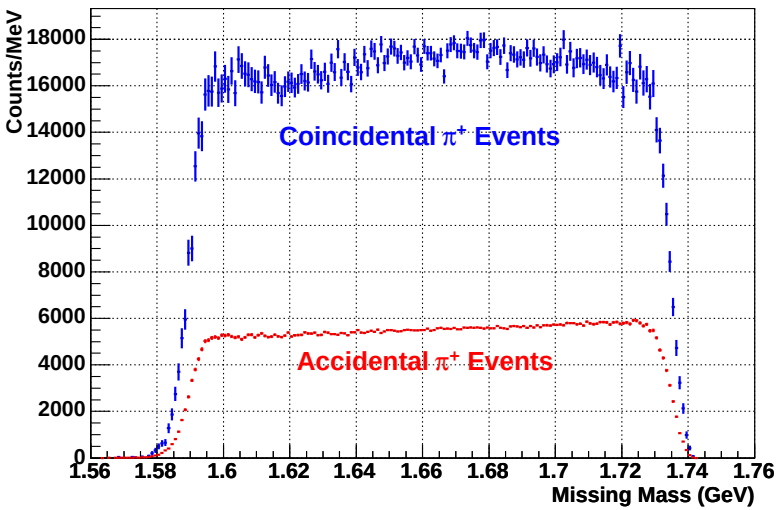
  90% CL limit for a $\Gamma = 5$ MeV state in the region 1500-1600 MeV:

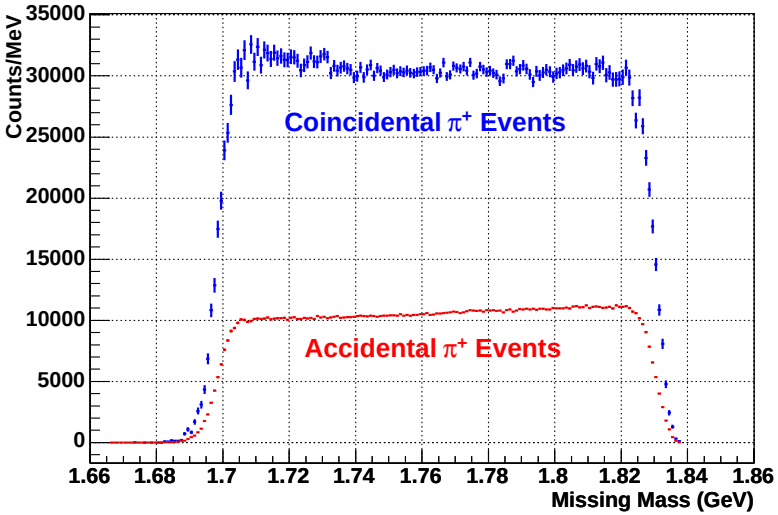
  $$\frac{\sigma_{\gamma^* p \to K^- \Theta^{++}}}{\sigma_{\gamma^* p \to K^+ \Lambda(1520)}} < 1.0\%$$

  $$\sigma_{\gamma^* p \to K^- \Theta^{++}} < 3\ \mathrm{nb}$$

Cf. reported value of $\sigma_{\gamma^* p \to K^0 \Theta^+} \approx 50$ nb.

Search for Non-Strange $N\frac{0}{10}$ Partner





To Do

Analysis:

- Efficiencies, esp. trigger
- Background modeling
- Cross-sections for Σ^0 and N^0 kinematics

Publications:

- Draft of Θ^{++} search results ready in January
- Σ^0 and N^0 searches to be published separately

Conclusions

- E04-012 carried out high resolution search for narrow exotic states in the missing mass region 1500-1820 MeV in kaon electroproduction at forward angles.
- Several small peaks observed, but not statistically significant.
- We do not observe strong narrow Σ^0_{10} (Θ^{++}) resonances in the search region 1570-1820 (1500-1600) MeV. For widths $\Gamma < 10$ MeV, we place an upper limit of $\sigma < 5$ nb, i.e. less than 10% of the reported Θ^+ cross section.
- Analysis still ongoing, esp. of N^0 search.
- First publication in preparation.