High Resolution Search for Pentaquark Partner States in JLab/Hall A

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E04-012 Collaboration

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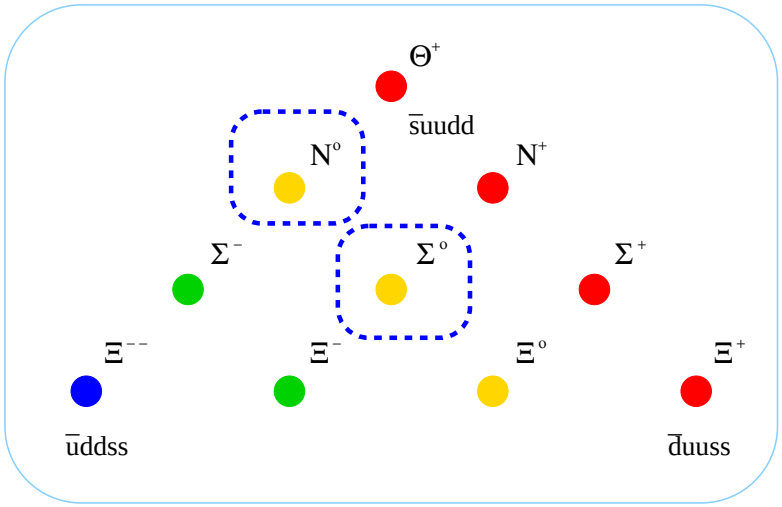
and the Hall A Collaboration

Motivation

Chiral Quark Soliton Model (Diakonov *et al.*, 1997) predicts an anti-decuplet of pentaquarks

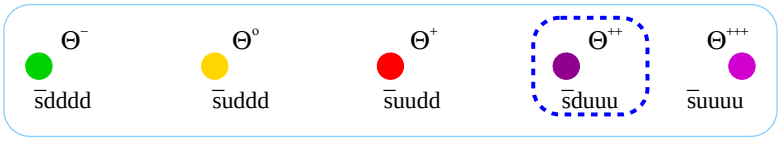
- Narrow ($\leq$ 30 MeV)
- Low mass ($\approx$ 1500-1800 MeV)
- $M = M_{\Theta+} + (1 - S) \times 107$ MeV



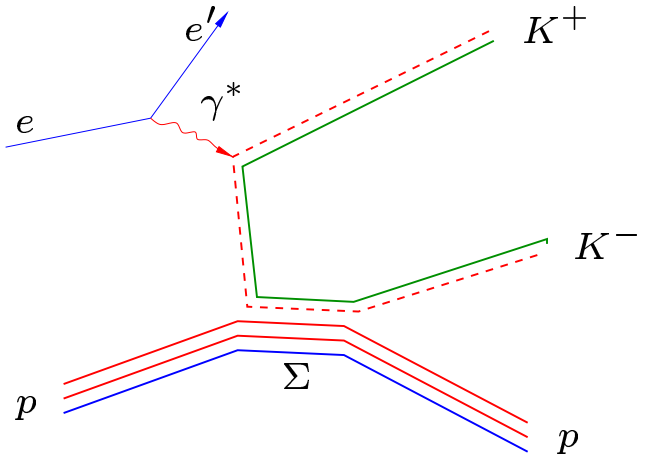
One of several alternative explanations of Θ^+: Isotensor multiplet (Capstick *et al.*, 2003)

- Explains narrow width in terms of isospin-violating strong decays
- Predicts different set of narrow (and exotic!) partners

State	Quark 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	



JLab Hall A Experiment E04-012



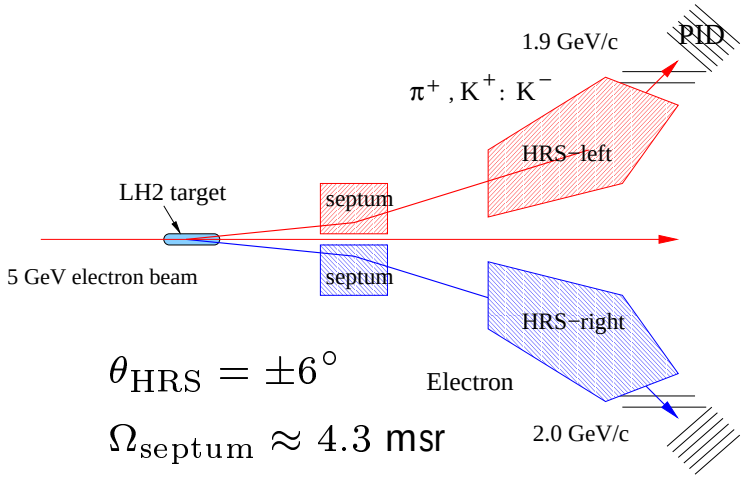
$p(e, e'K^+)\Sigma^\circ_{\overline{10}}$ $M(\Sigma^0)$ = 1530-1820 MeV

$p(e, e'K^-)\Theta^{++}$ $M(\Theta^{++})$ = 1500-1600 MeV

$p(e, e'\pi^+)N^\circ$ $M(N^0)$ = 1600-1830 MeV

$Q^2 \approx 0.1$ (GeV/c)^2

$\theta_{\gamma^* K(\pi)} \approx 6^\circ(7^\circ)$



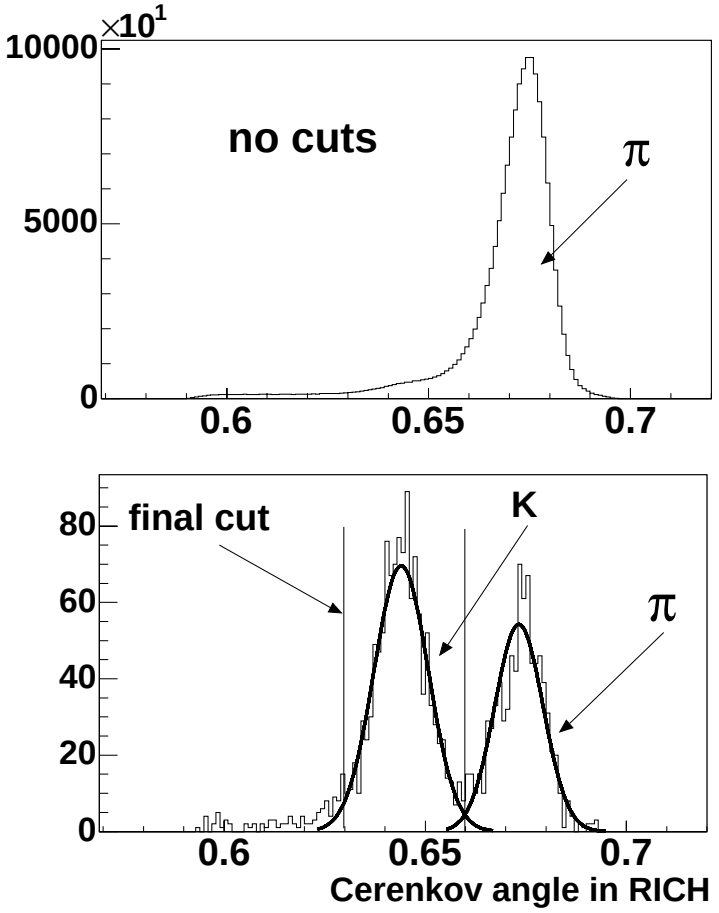
$\theta_{\mathrm{HRS}} = \pm 6^\circ$

$\Omega_{\mathrm{septum}} \approx 4.3$ msr

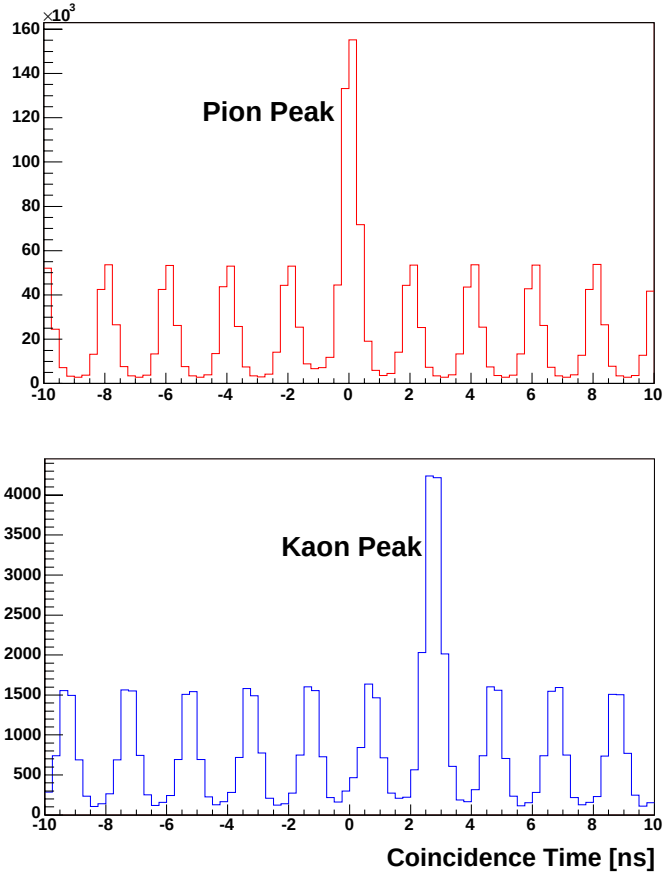
Particle ID

- Left HRS:
  - Two aerogels ($n = 1.015, 1055$)
  - RICH ($n = 1.30$)
  - Pion rejector (lead glass shower)
- Right HRS:
  - Gas Cherenkov (CO_2)
- Coincidence (ToF)

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



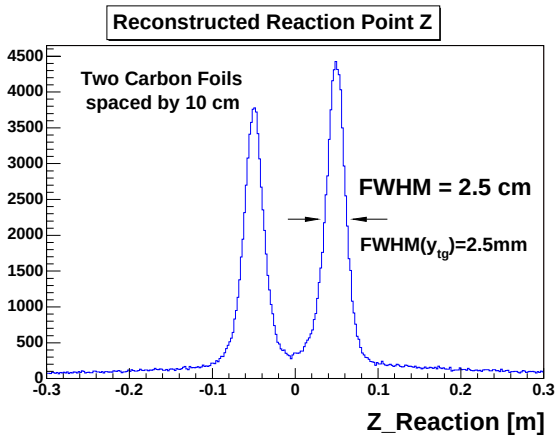
Coincidence System

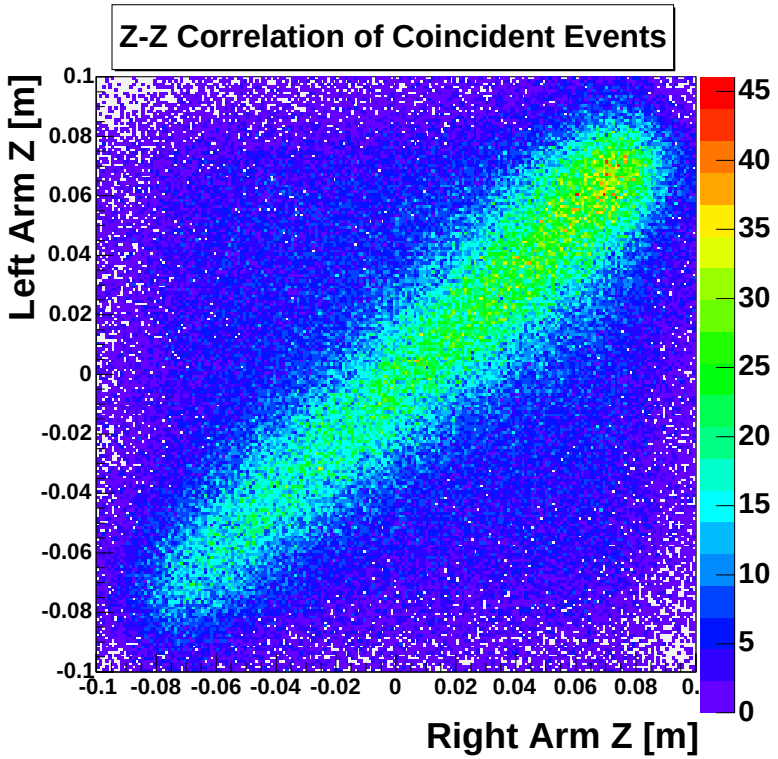


ToF resolution ≈ 600 ps FWHM

27 m flight path separates pion and kaon concidences by ≈ 2 ns at p = 2.0 GeV/c

Coincidence System (cont.)

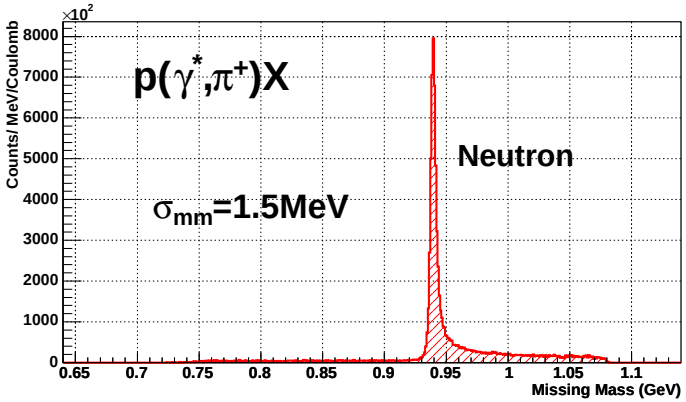


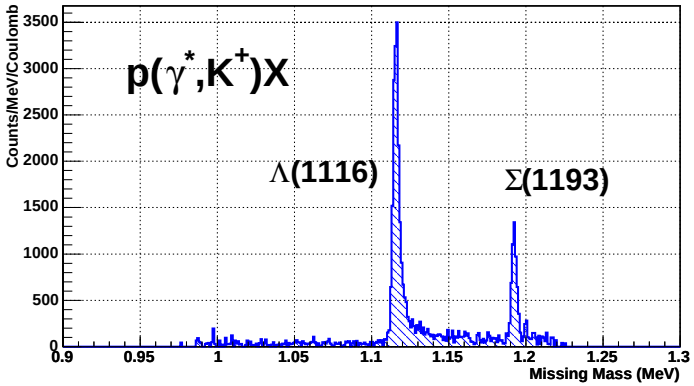


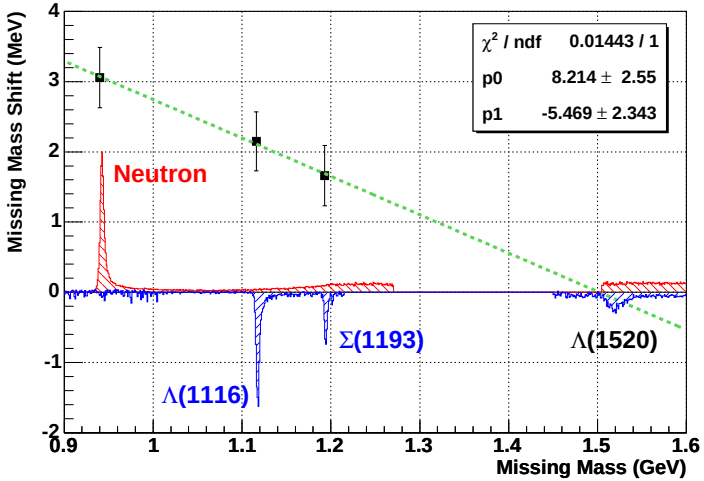
Vertex resolution ≈ 2.5 cm FWHM

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

Mass Resolution and Calibration







Resolution: ≈ 3.5 MeV FWHM

Absolute uncertainty: ≤ 3 MeV

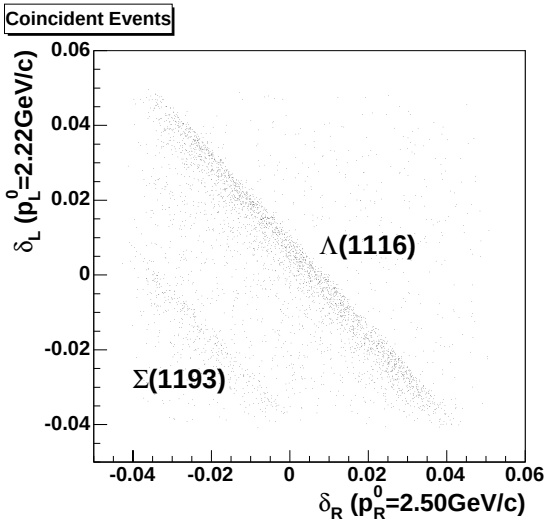
Assume zero offset in scan region

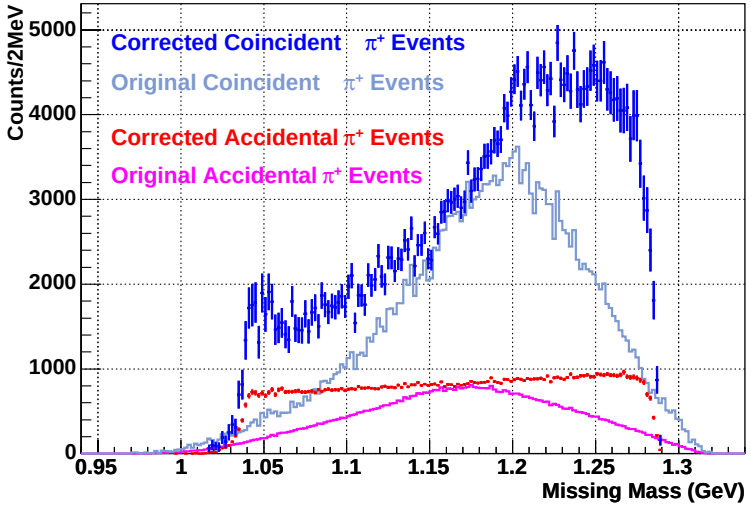
Acceptance Correction

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

$$M_X \approx \text{const} - E_{e'} - E_{\pi(K)}$$

Missing mass acceptance proportional to length of constant mass lines





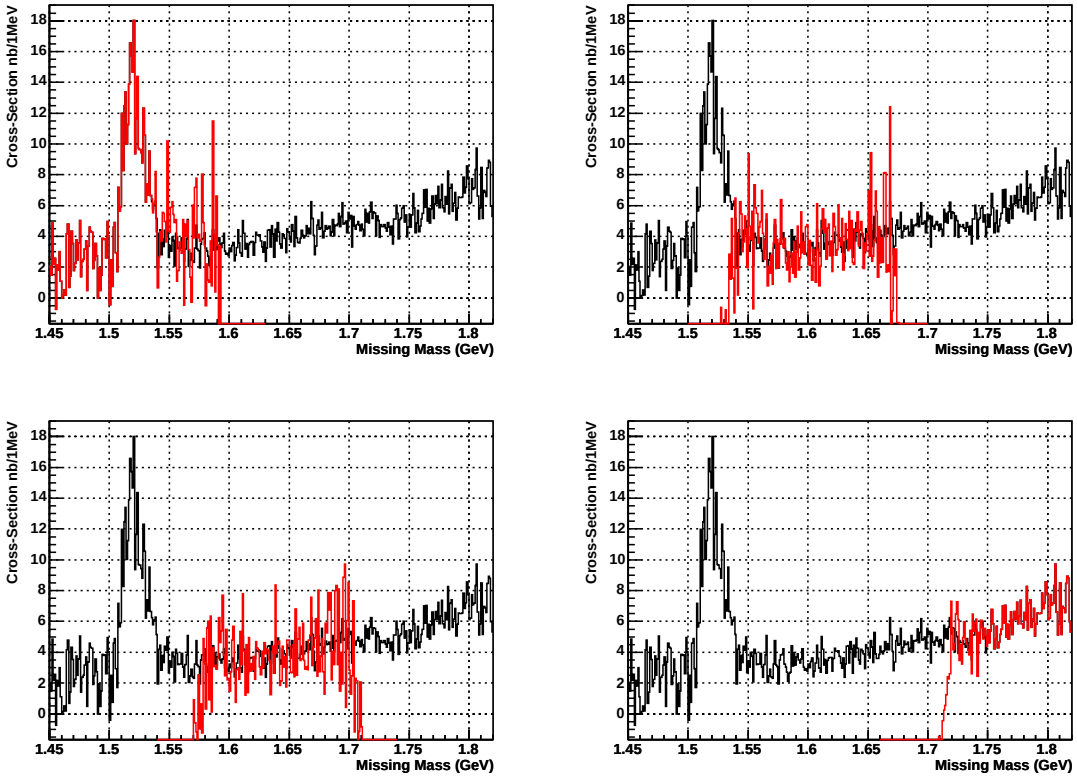
Combining Measurements

Example: Kin 4–7

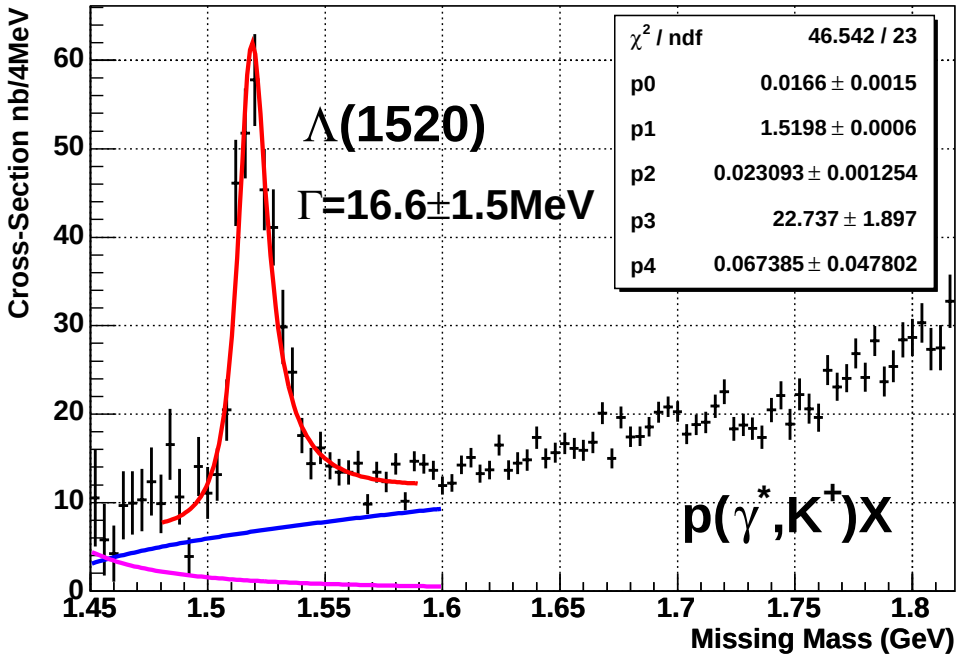
Combine different data sets after applying corrections

- Efficiencies
- Effective charge
- Acceptances

Transitions are smooth!



$\Lambda(1520)$ fit



$M = 1519.8 \pm 0.6$ MeV

$\Gamma = 16.6 \pm 1.5$ MeV

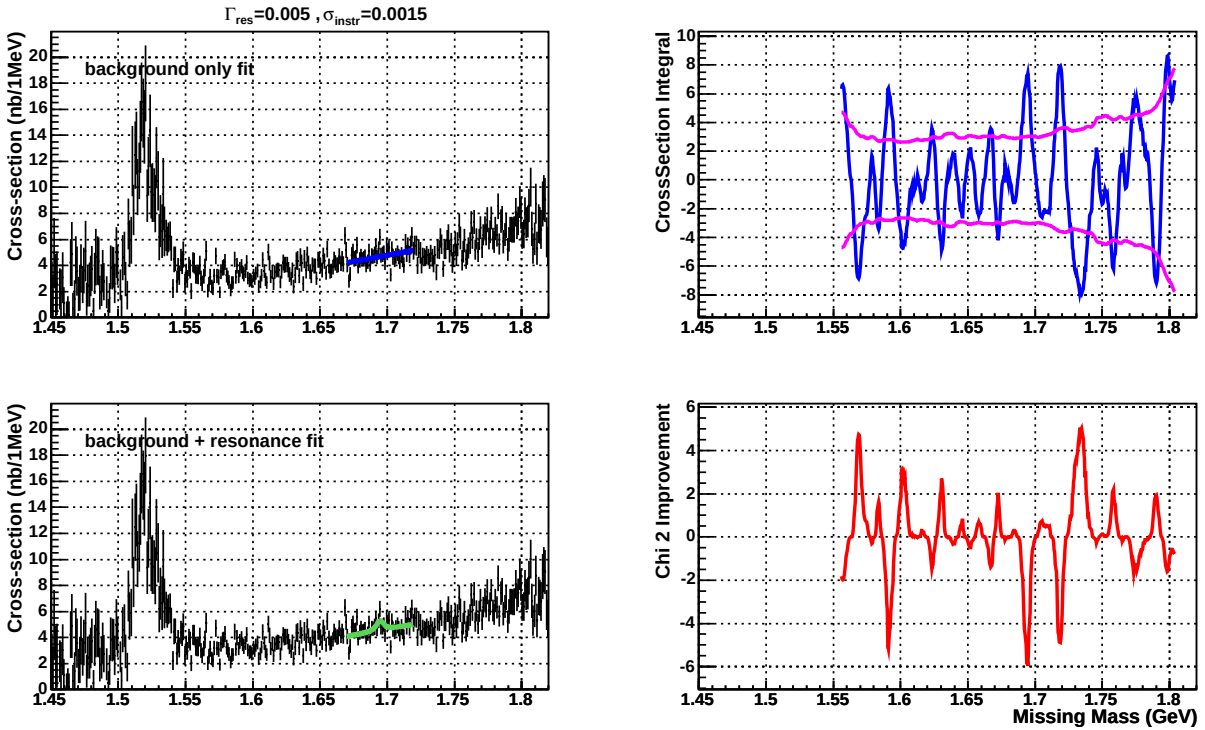
$\left.\frac{d\sigma}{d\Omega}\right|_{lab} (\gamma^* p \to \Lambda K) \approx 350$ nb

at $\theta_{\gamma^* K} \approx 6^\circ$

Background model: phase space plus tail from $\Lambda(1405)$

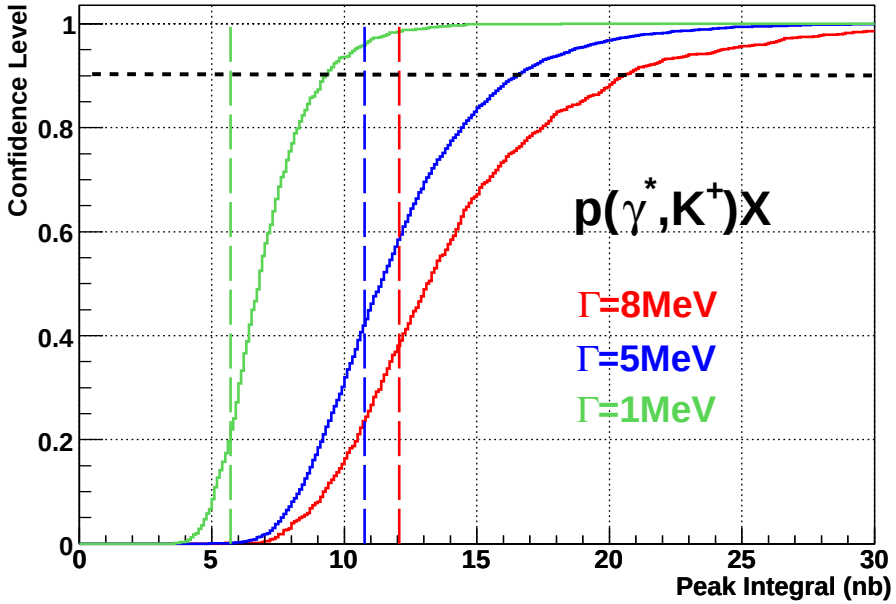
Search for Σ^0_{10} Partner

- Assume linear background in fitting region
- Breit-Wigner peak convoluted with Gaussian resolution (σ_{instr} = 1.5 MeV)
- Vary Breit-Wigner width, Γ = 1, 3, 5, 8 MeV



Monte Carlo Analysis of Statistical Significance

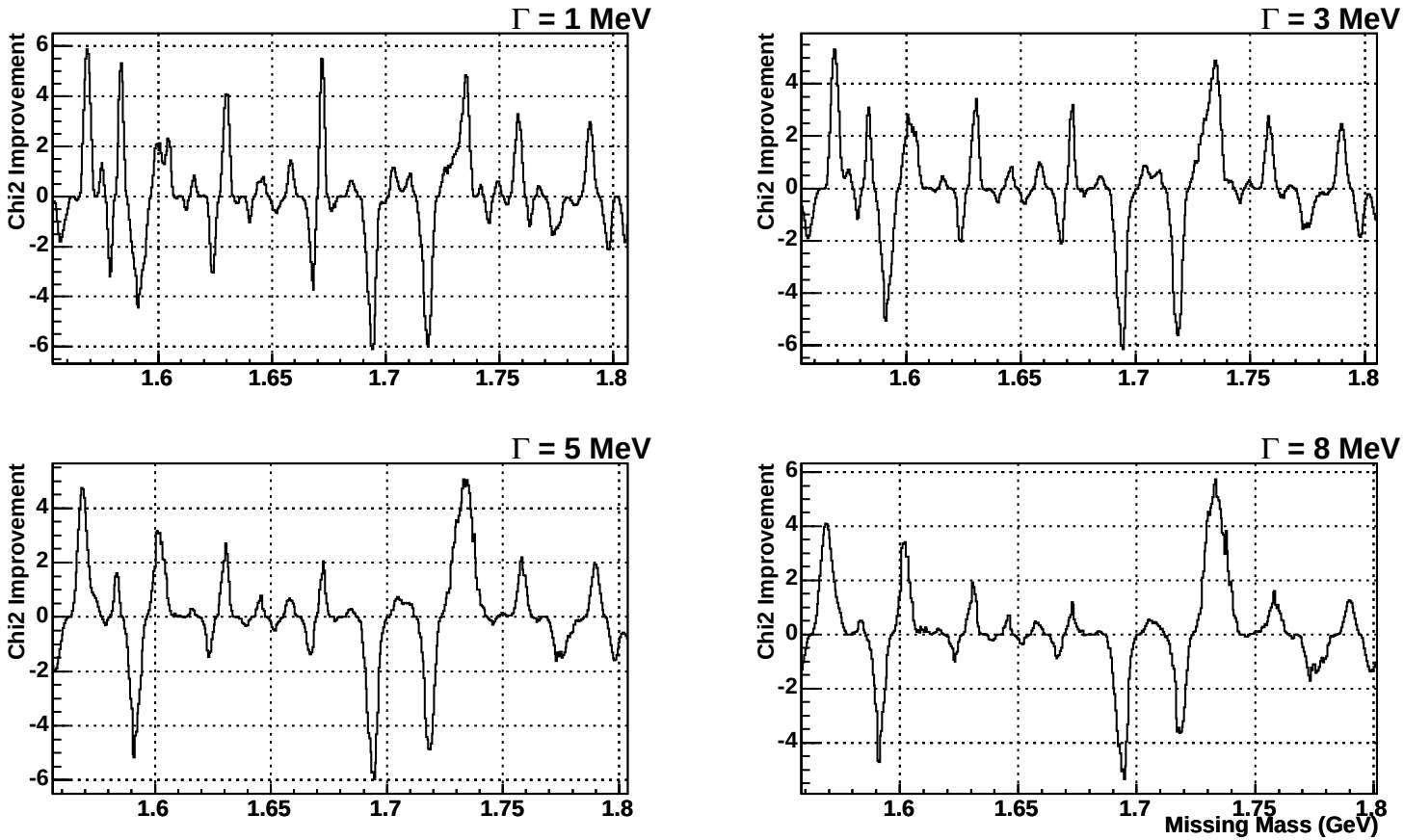
- Generate 1000 background-only spectra w/ statistics of the experiment
- Run peak search algorithm over each spectrum
- Find probability that background fluctuates above certain limit



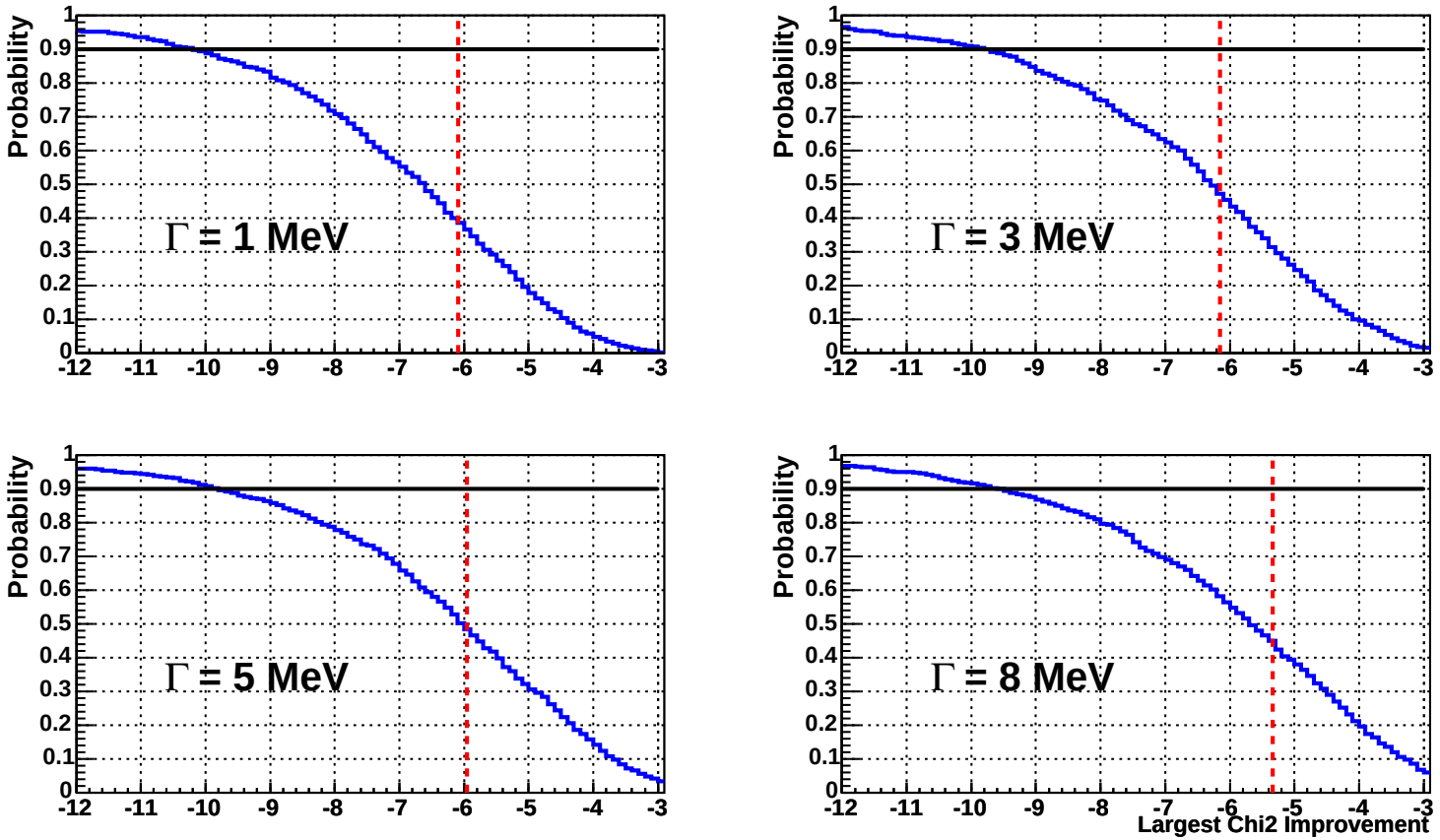
short-dashed: 90% confidence level that peak is NOT background

long-dashed: largest observed peak

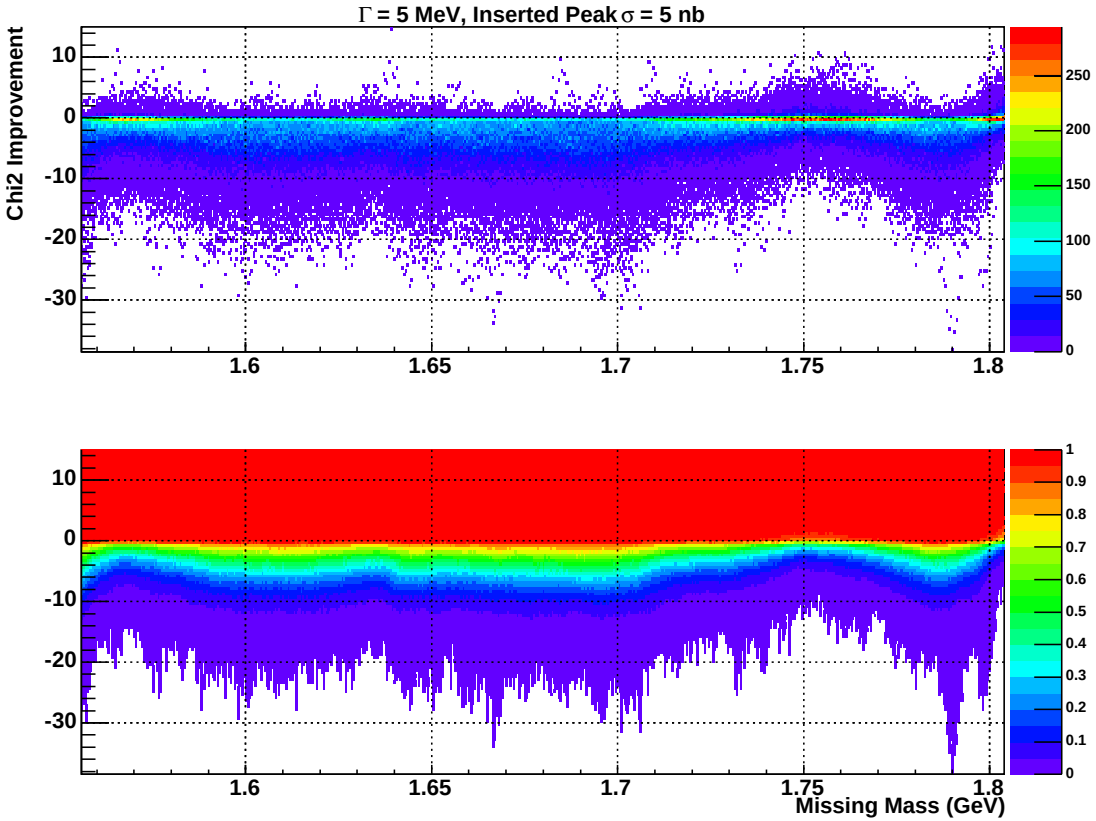
Detailed Σ^0_{10} Study: χ^2 Improvement



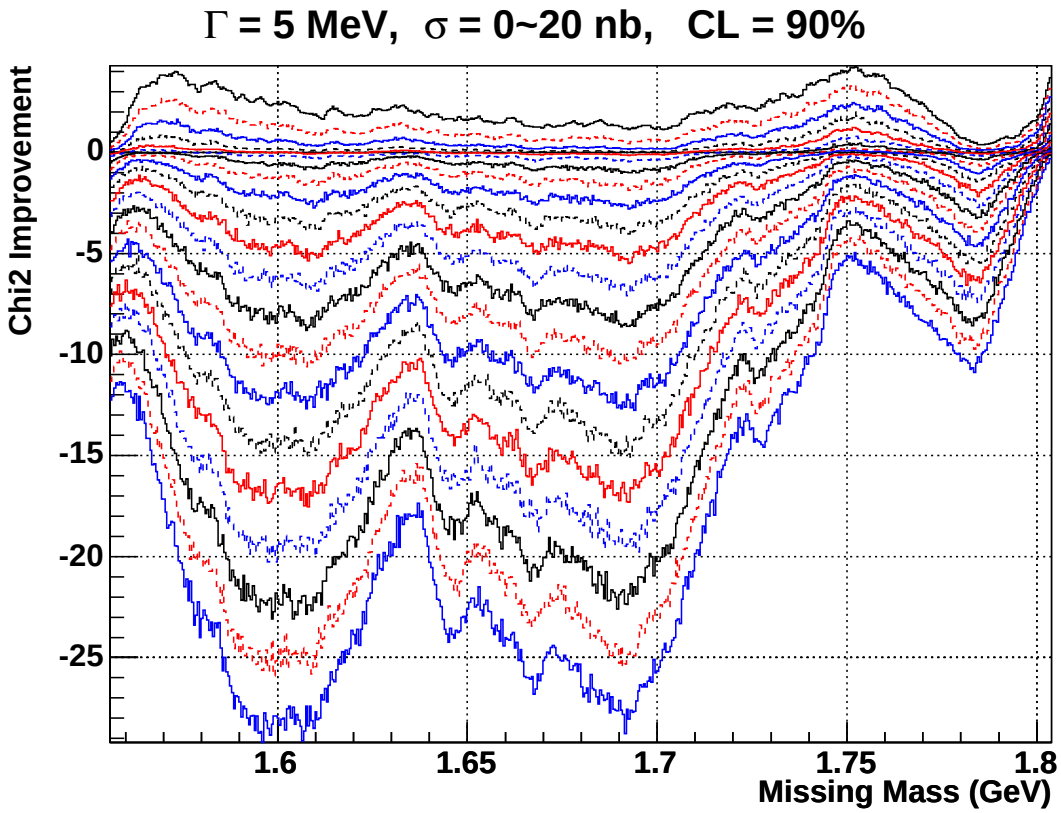
Σ^0_{10}: Significance of Background Fluctuations



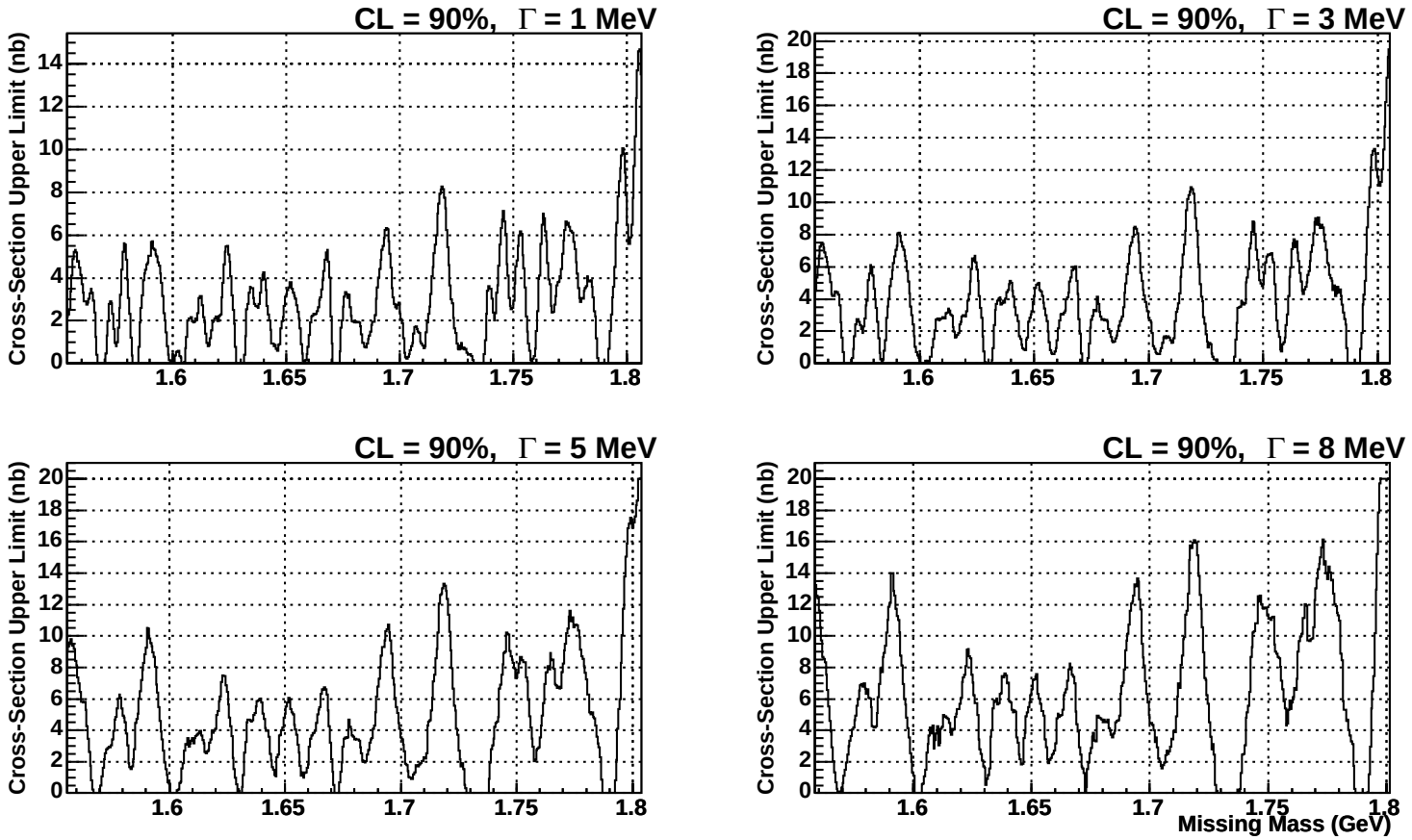
Σ^0_{10}: Peak Insertion Study



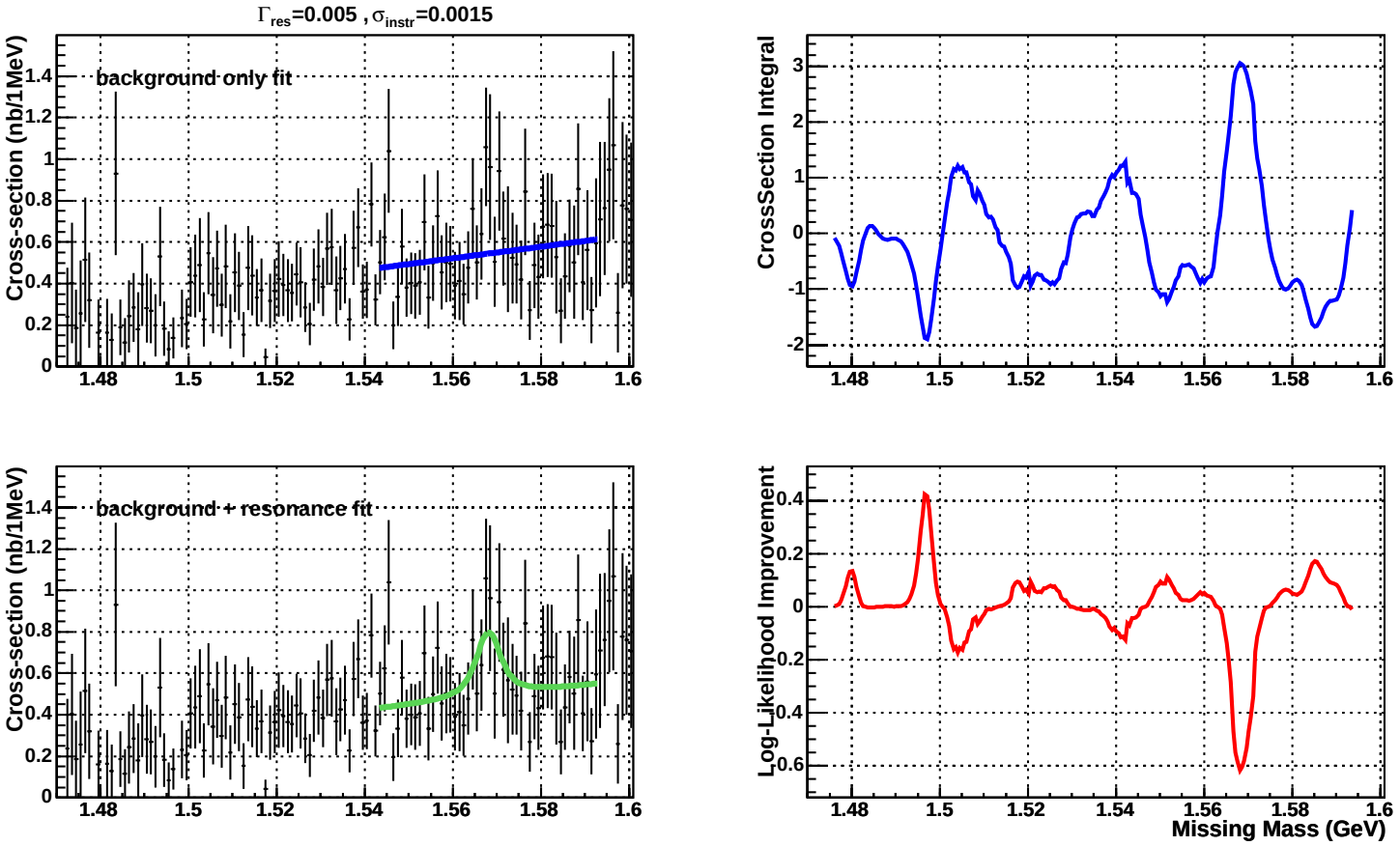
Σ^0_{10}: Confidence Level vs. Peak Amplitude



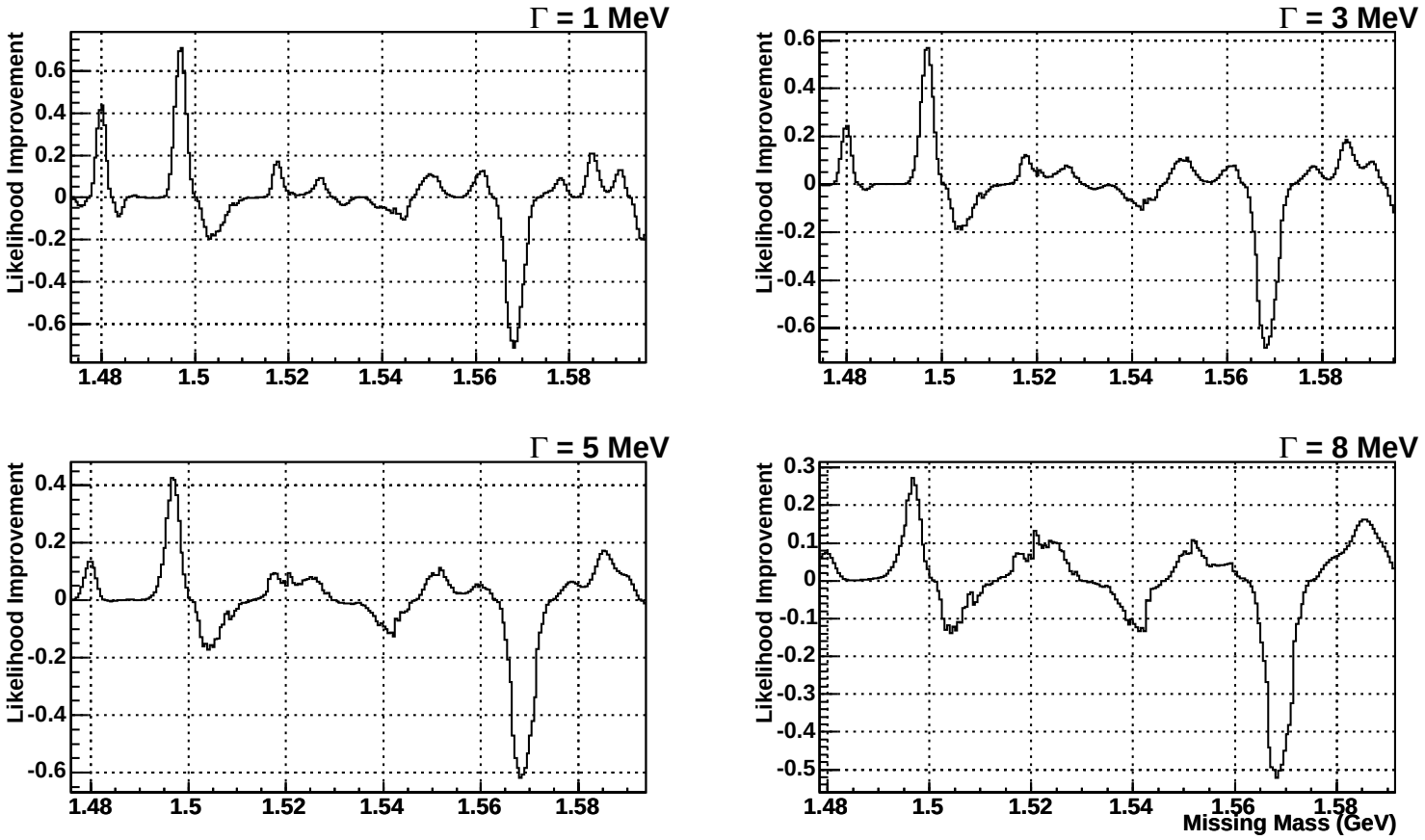
Σ^0_{10}: Cross Section Upper Limits



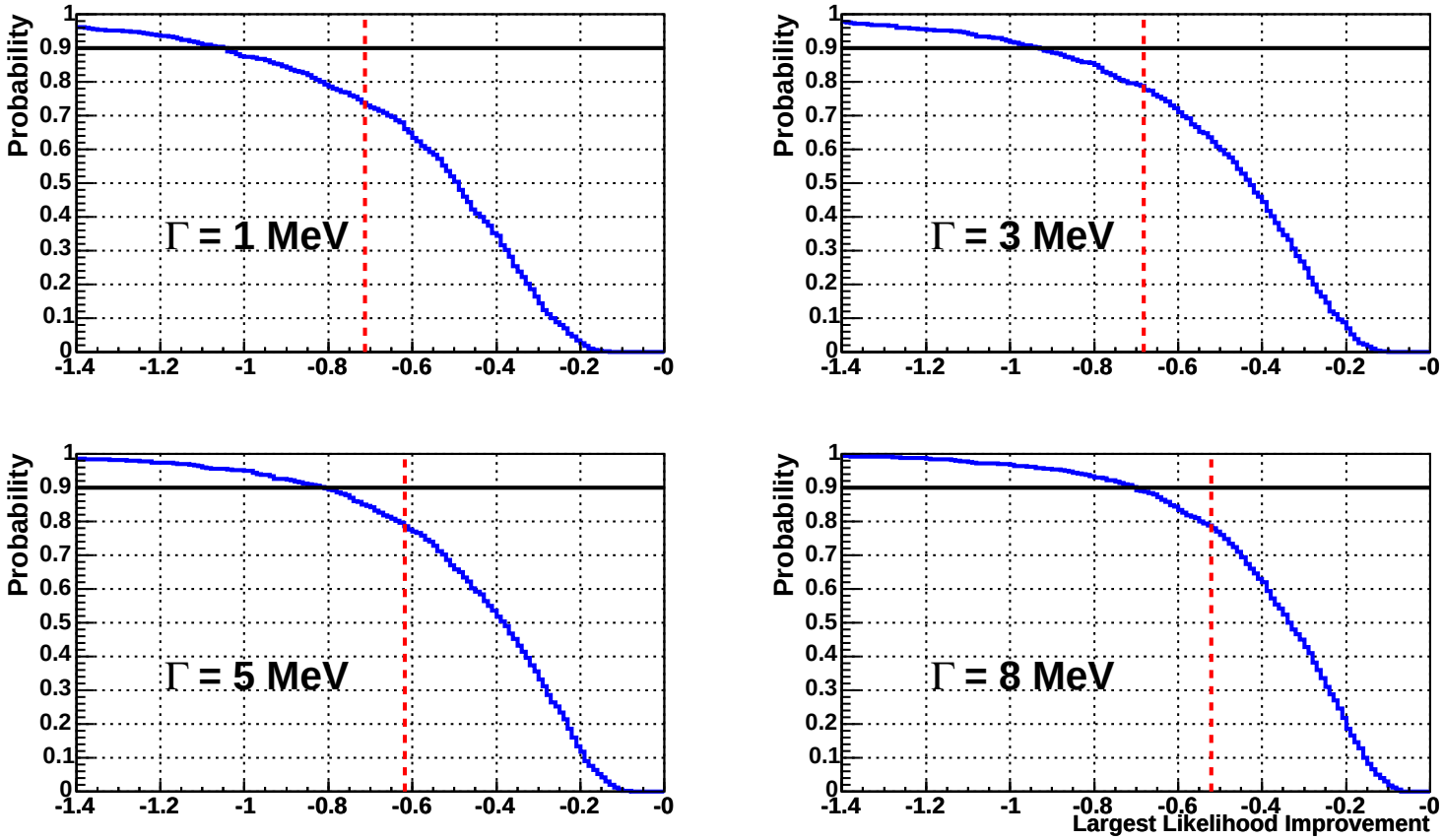
Search for Isotensor Partner Θ^{++}



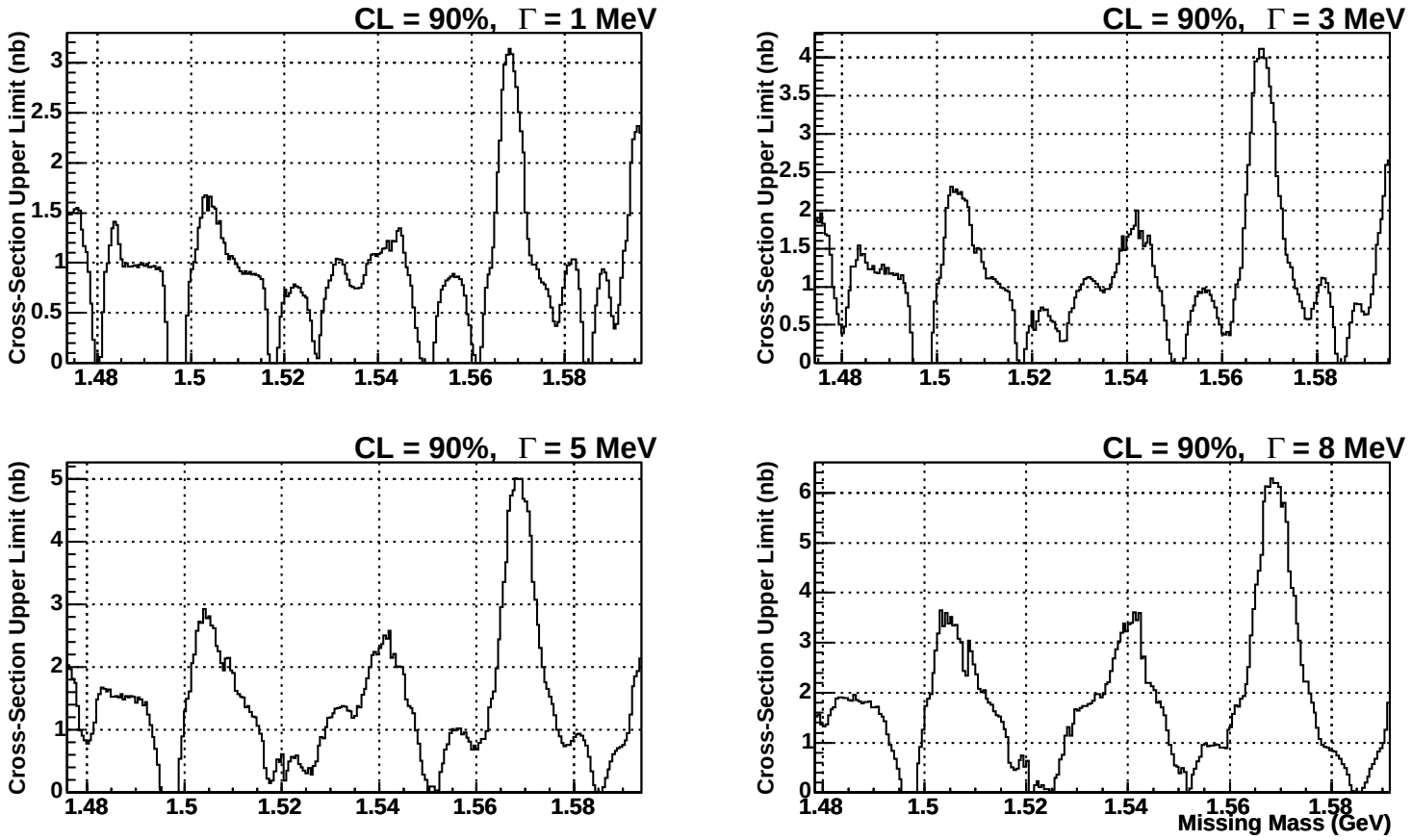
Θ^{++}: Likelihood Improvement



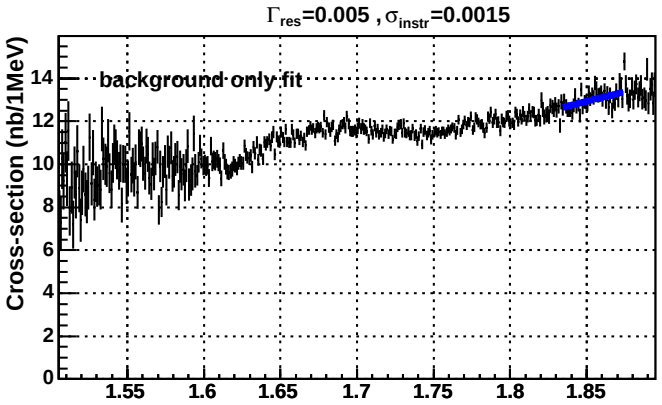
Θ^{++}: Significance of Background Fluctuations

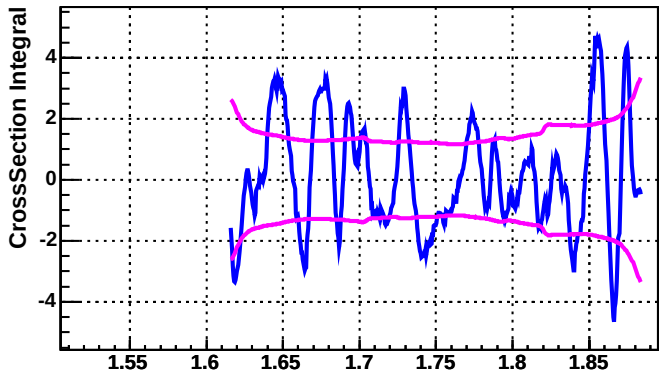


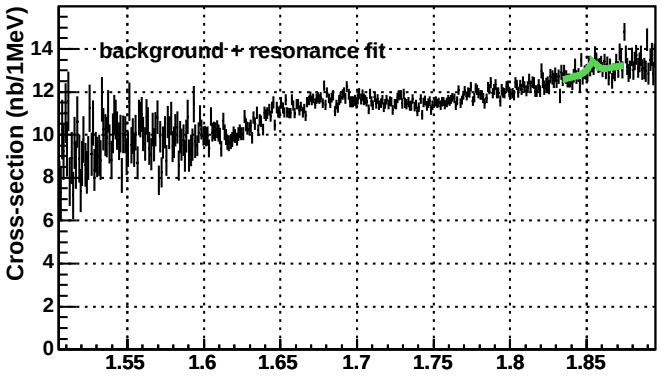
Θ^{++}: Cross Section Upper Limits

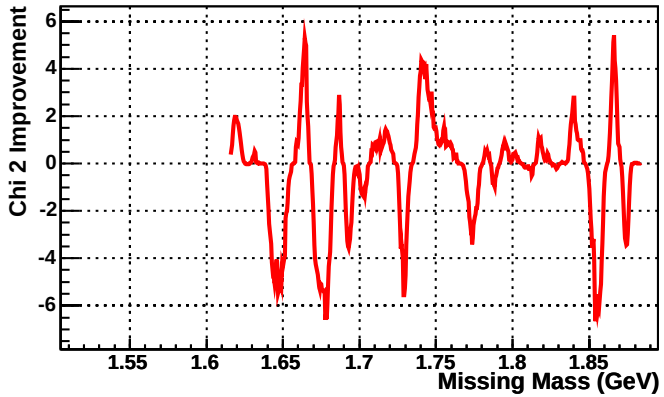


Search for Non-Strange N^0_{10} Partner

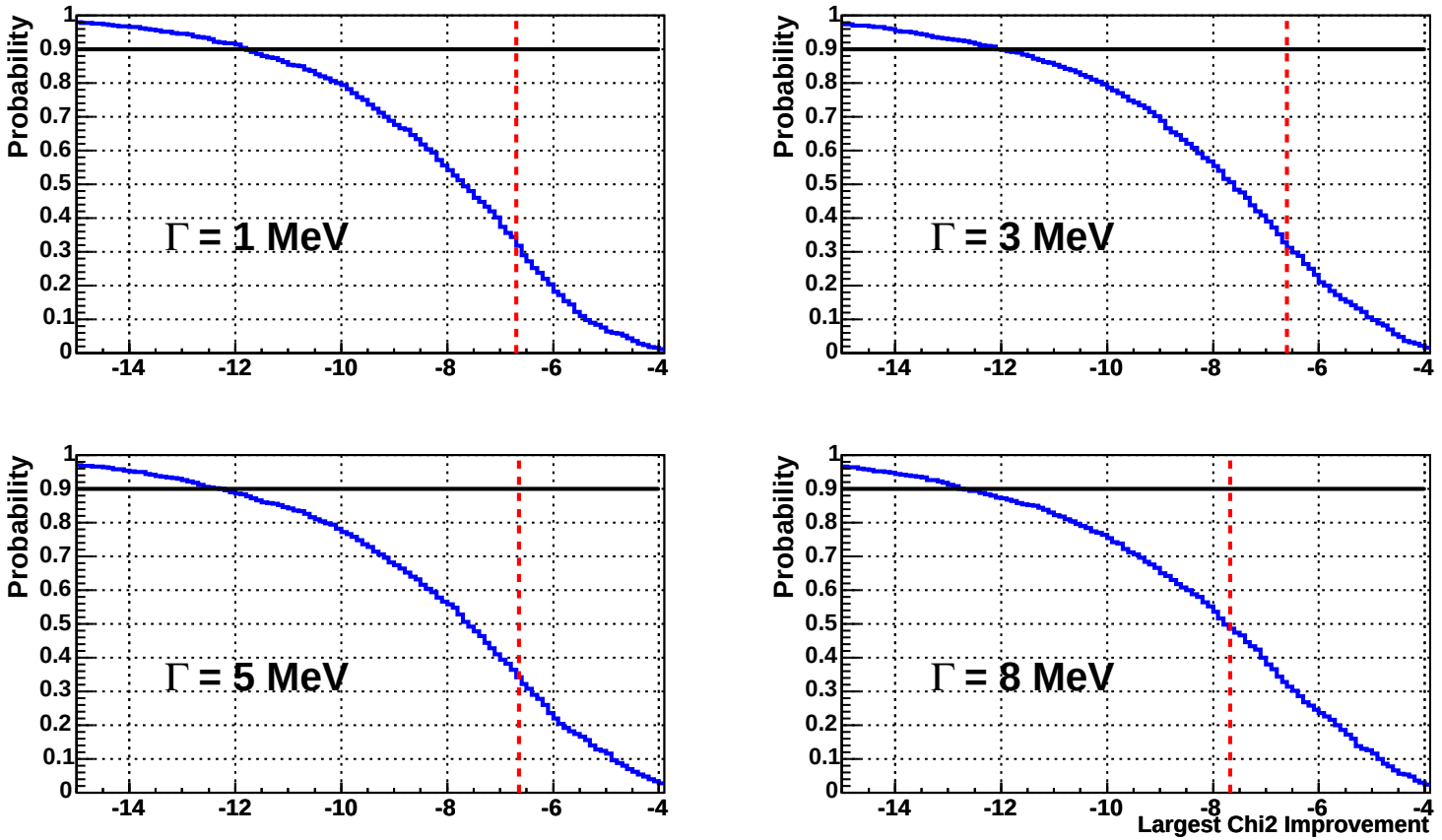




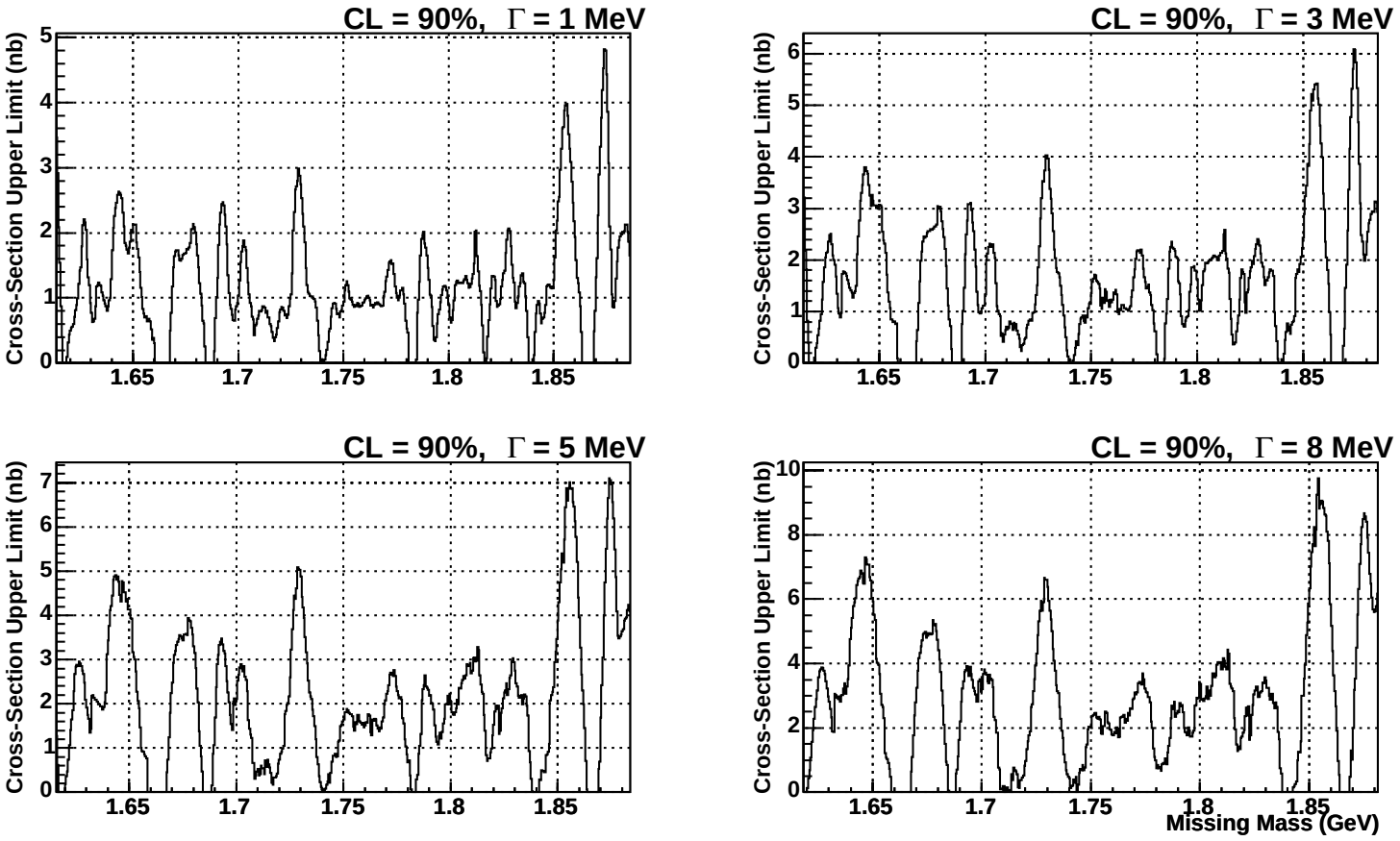




N^0_{10}: Significance of Background Fluctuations



N^0_{10}: Cross Section Upper Limits



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.
- We do not observe strong **narrow** Σ^0_{10} (Θ^{++}, N^0_{10}) resonances in the search region 1530-1820 (1500-1600, 1620-1860) MeV.
- Bumps seen are statistically consistent with background.
- For widths $\Gamma < 10$ MeV, we find 90% CL upper limits of
  - $\sigma < 16$ nb for Σ^0_{10}
  - $\sigma < 6$ nb for Θ^{++}
  - $\sigma < 10$ nb for N^0_{10}.

  NB: Differential cross sections at forward angles!
- Results still somewhat preliminary — final checks in progress.