Search for PentaQuark Partners: JLab E04-012

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Jefferson Lab Hall A Collaboration Meeting

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Collaboration

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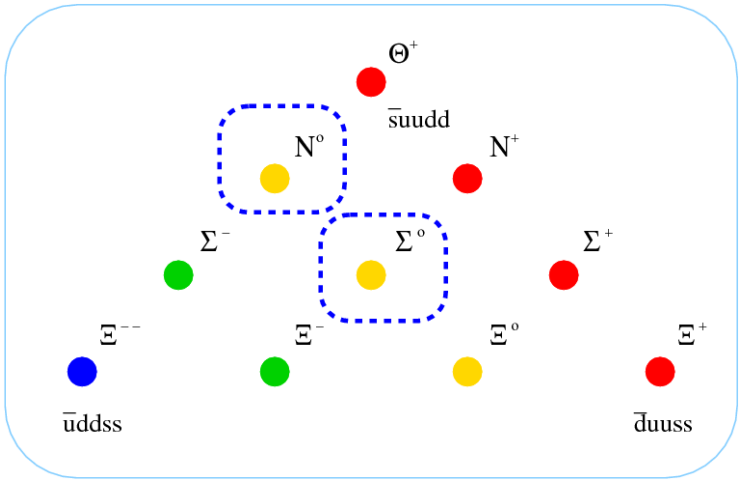
and the Hall A Collaboration

PentaQuark Model

- Chiral Quark Soliton Model (Diakonov *et al.*, 1997) predicts an anti-decuplet of pentaquarks
  - Narrow (1~8 MeV)
  - Low mass (1530 MeV)
  - $M = M_{\Theta^+} + (1 - S) \cdot 107 MeV$



$M(\Theta^+) \approx 1540 MeV$ *

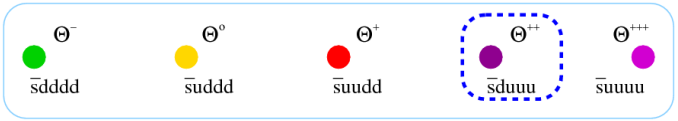
$M(\mathrm{N}) \approx 1650 MeV$?

$M(\Sigma) \approx 1755 MeV$?

$M(\Xi) \approx 1862 MeV$ *

PentaQuark Model (cont.)

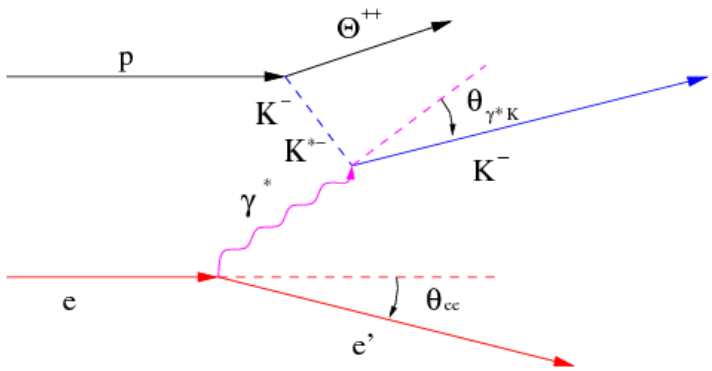
- One of several alternative explanations of Θ^{++} Isotensor multiplet (Capstick *et al.*, 2003)



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

Partn-ers	I_3	Strong Decay modes
Θ^-	-2	
Θ^o	-1	n K^o
Θ^+	0	n K^+, p K^o
Θ^{++}	1	p K^+
Θ^{+++}	2	

Hall A Experiment E04-012



$H(e,e'K^+)\Sigma^o_{10}$ 1550 – 1820 *MeV*

$H(e,e'K^+)\Theta^{++}$ 1460 – 1600 *MeV*

$H(e,e'K^+)N^o$ 1510 – 1900 *MeV*

Beam Energy : 5.0 GeV

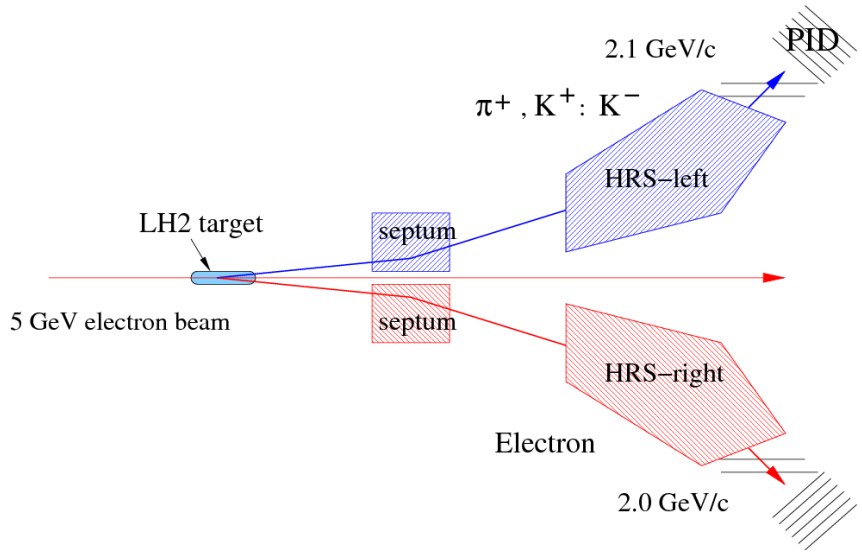
Left and Right HRS angle : 6°

Left Arm Momentum : ~ 2.0 *GeV/c*

Right Arm Momentum : ~ 1.7*GeV/c*

Q2 : ~ 0.1 (*GeV/c*)2

$\theta_{\gamma^* K(\pi)}$:~ 2(6)°

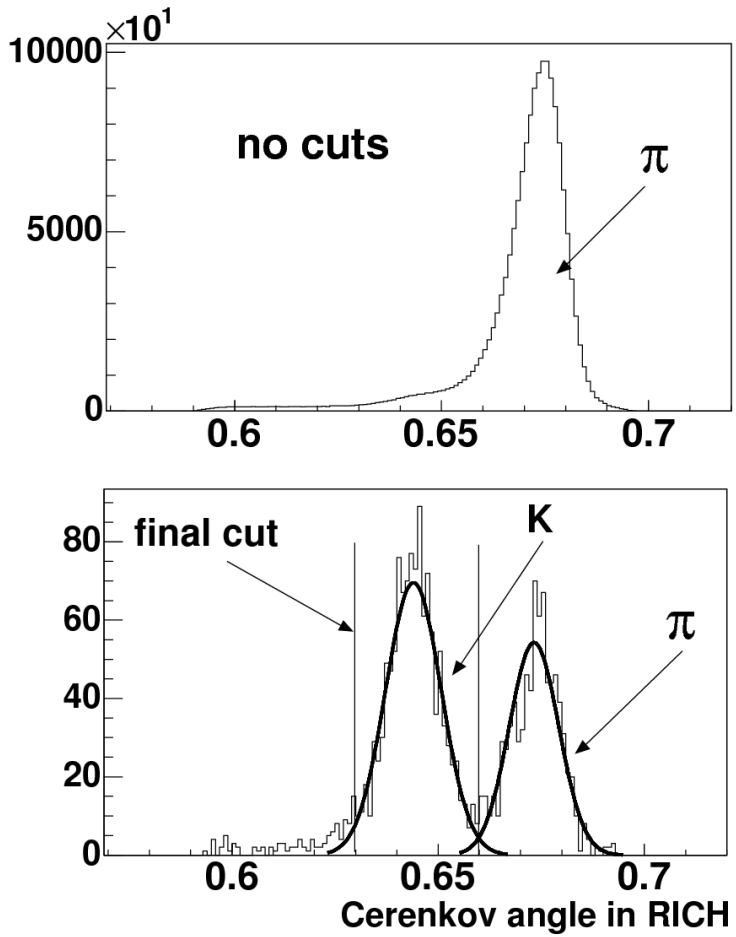


PID System

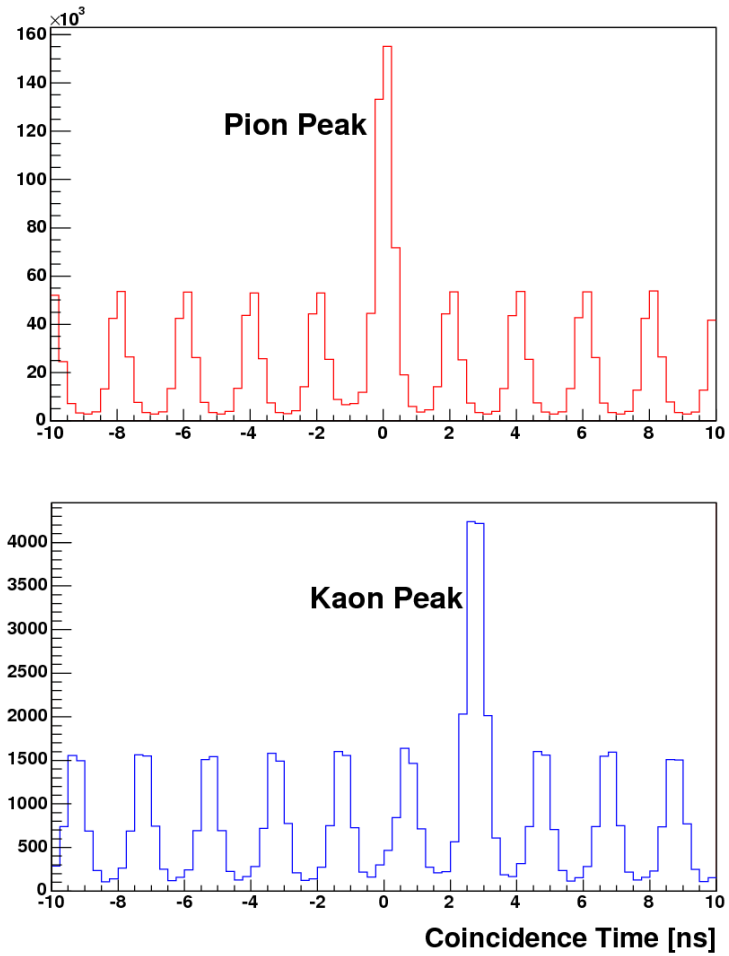
- Left Arm:
  - Aerogel 1 (n = 1.015)
  - Aerogel 2 (n = 1.055)
  - RICH (n = 1.30)
  - Pion Rejector
- Right Arm:
  - Gas Cherenkov
- Coincidence

π Rejection $\approx 3 \cdot 10^4$

Final K/ π ratio > 20



Coincidence System

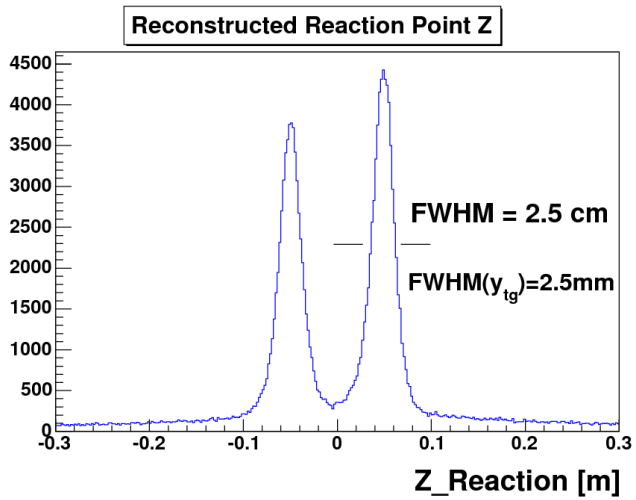


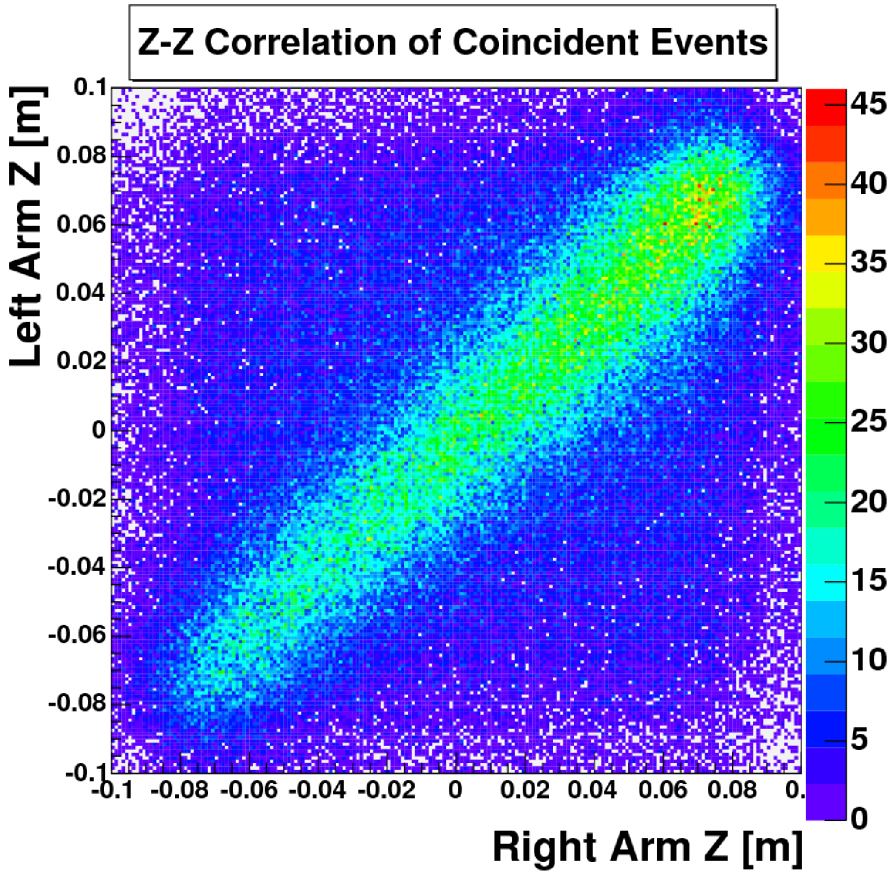
TOF Resolution :

FWHM ≈ 600 ps

CT difference for 2.0 GeV/c Pion and Kaon after 27 m travel is around 2 ns

Coincidence System (cont.)



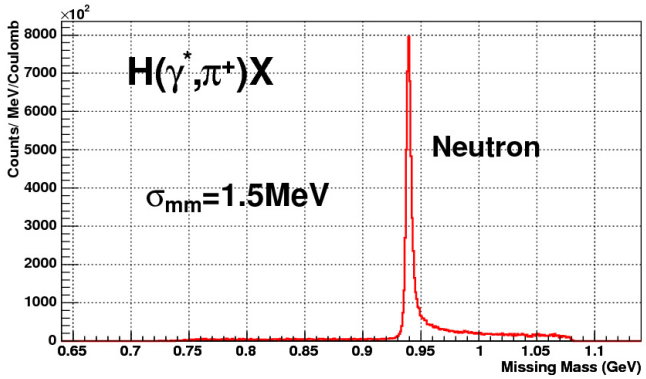


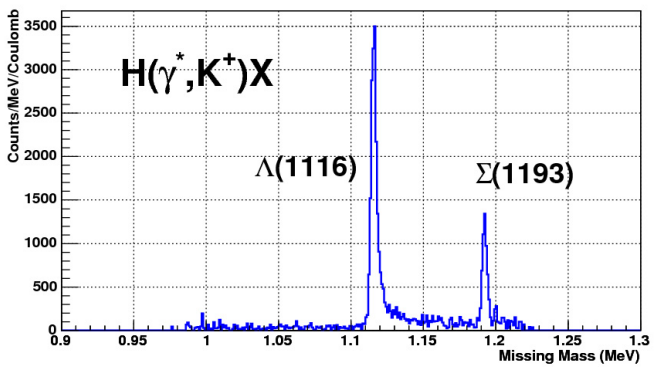
Reaction z Resolution:

FWHM ≈ 2.5 cm

Using a **15** cm extended Target allows us to reduce accidental background through a **5** cm cut by a factor of **2**

High Resolution and Mass Calibration

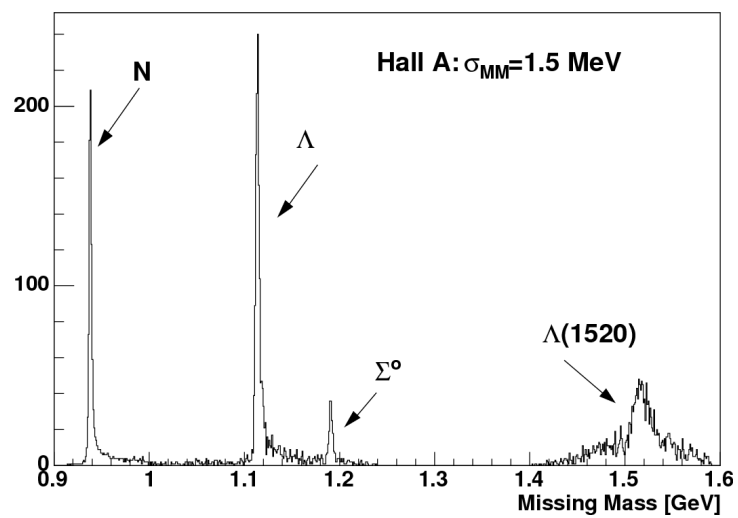




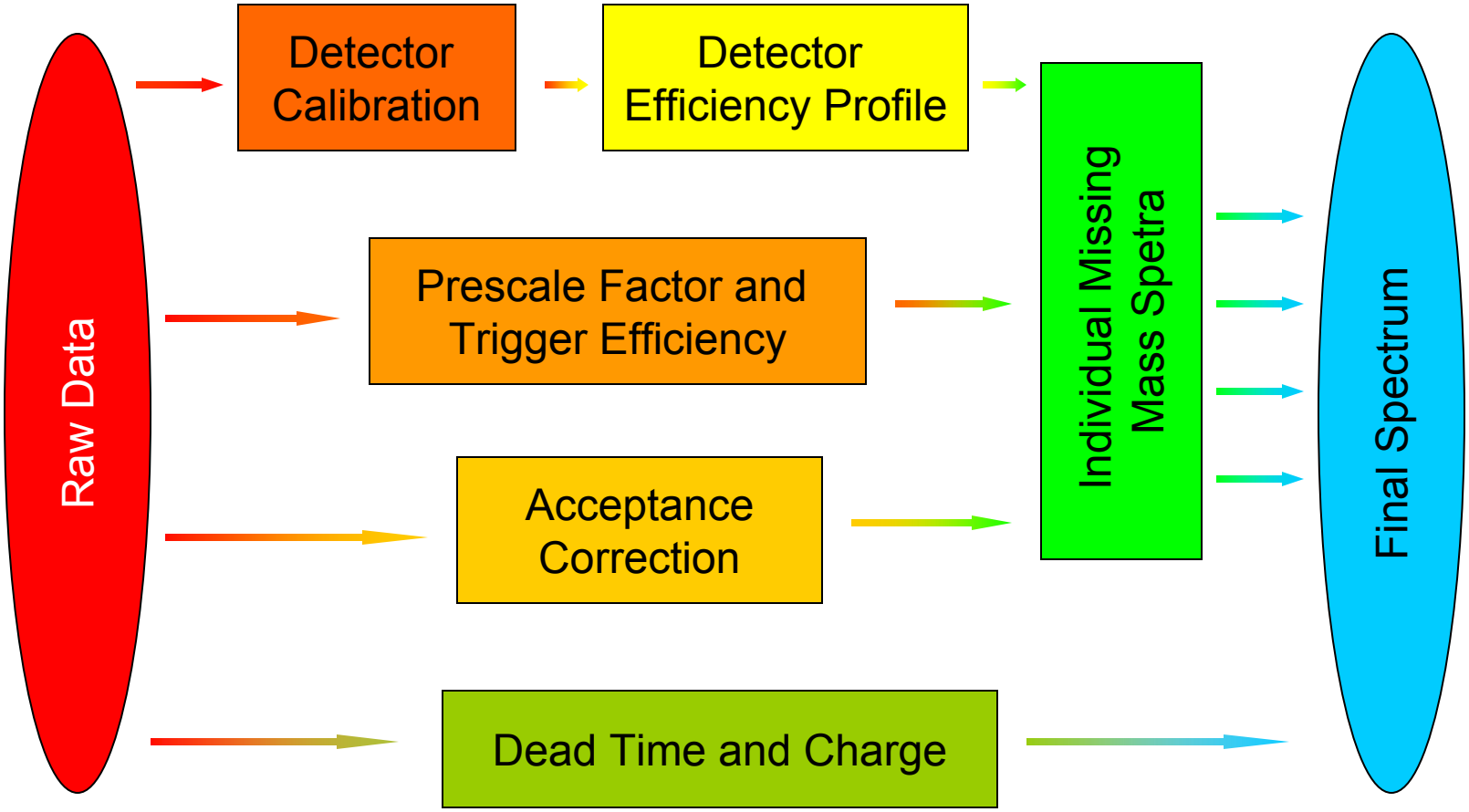
Missing Mass Resolution

$\sigma_{mm} = 1.5\ MeV$

Mass Uncertainty < 1 *MeV*

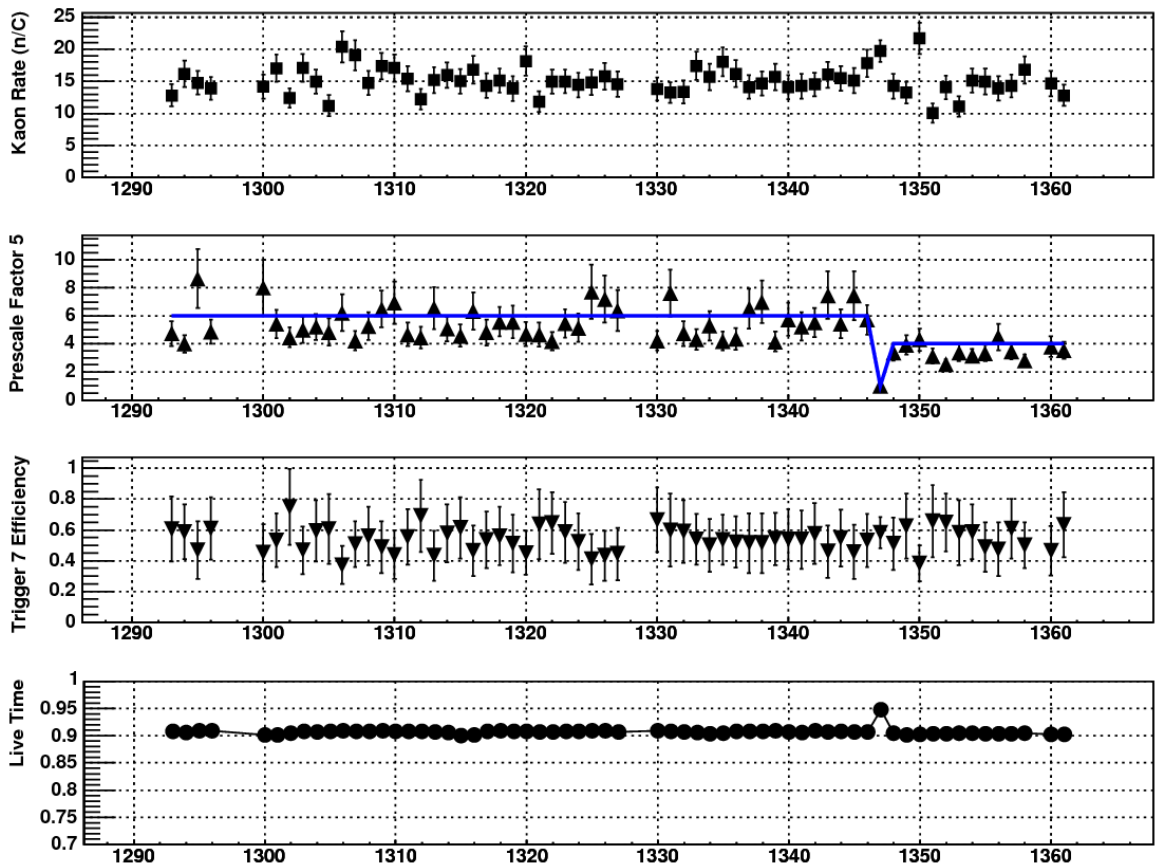


Analysis Step by Step



Data Quality

- The Uniformity of Kaon rate run by run shows the good quality of our data



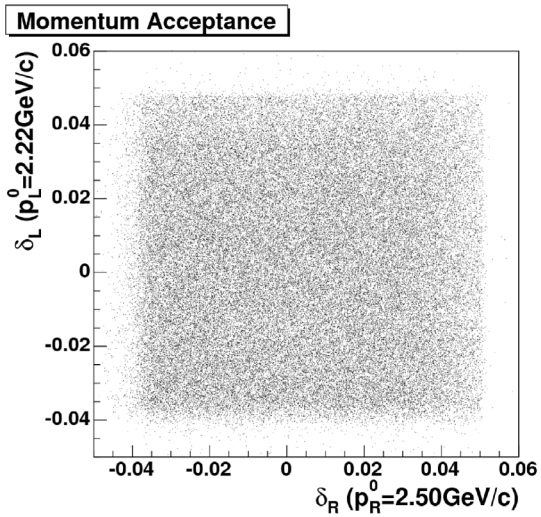
Kaon Rate

Prescale Factor of Trigger 5

Trigger 7 Efficiency

Live Time

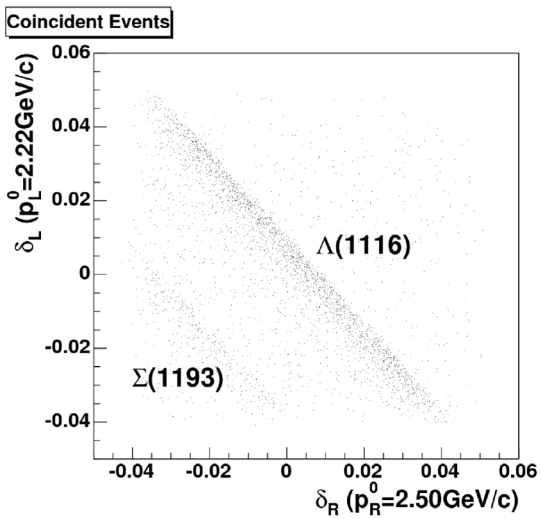
Acceptance Correction at 6°

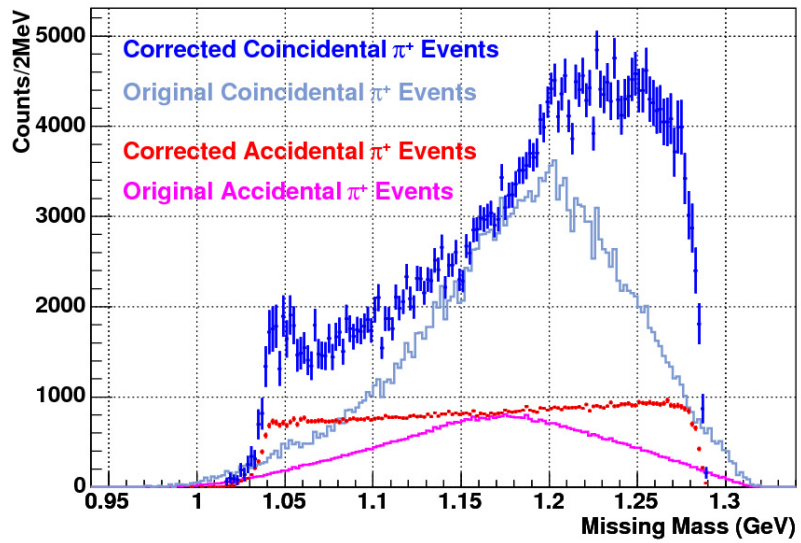


$$e + p \rightarrow e' + \pi^{\pm}(K^{\pm}) + X$$

$$M_X \approx C - P_{e'} - P_{\pi(K)}$$

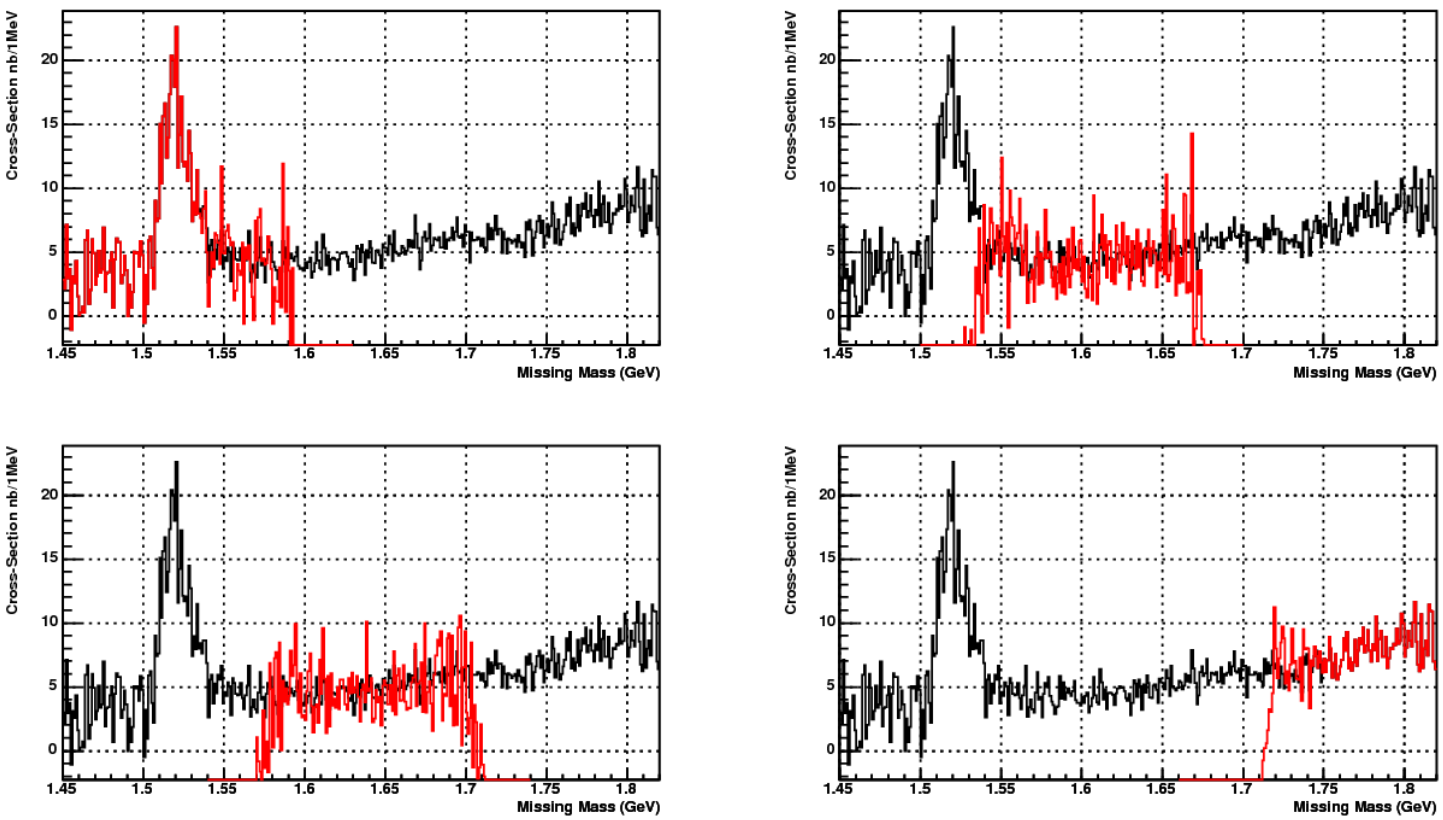
Missing Mass Acceptance is proportional to the Length in 2D momentum acceptance plot



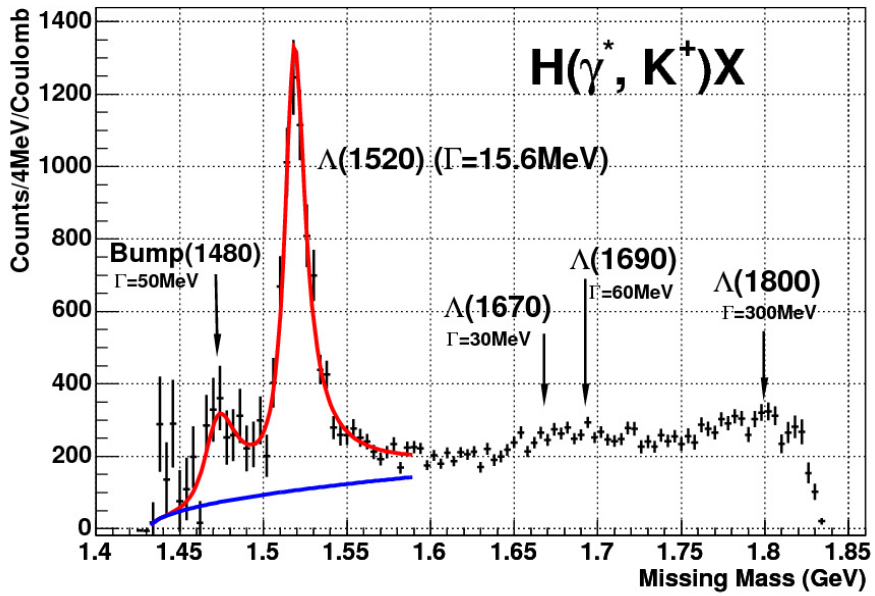


Combine Kinematics Settings

Effective charges are taken account in Missing Mass Combination, red curves show different settings



Parameters of Λ°_{1520}



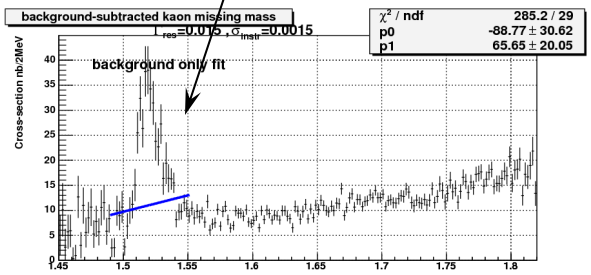
$$M = 1520.2 \pm 0.5\ MeV/c^2$$

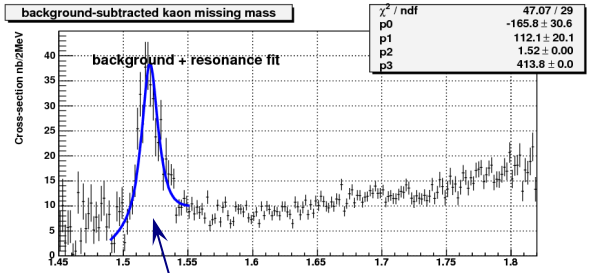
$$\Gamma = 16.6 \pm 1.3\ MeV/c^2$$

$$\frac{d\sigma}{d\Omega}\Big|_{Lab}(\gamma^* p \rightarrow \Lambda K) \approx 350nb \qquad \theta_{\gamma^* K} :\sim 2^{\circ}$$

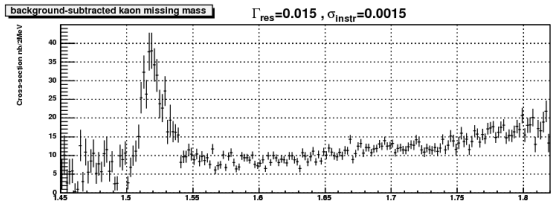
Chi Square Peak Search

Background fit

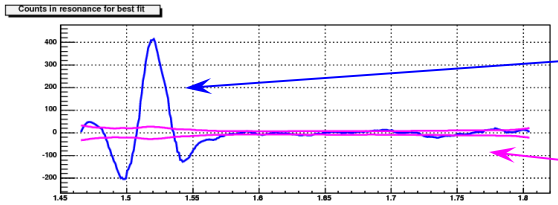




Background + Resonance

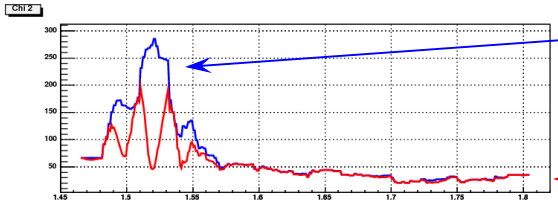


Missing Mass Spectrum



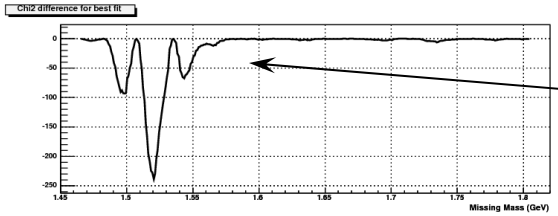
Resonance Cross-Section

Fit Error



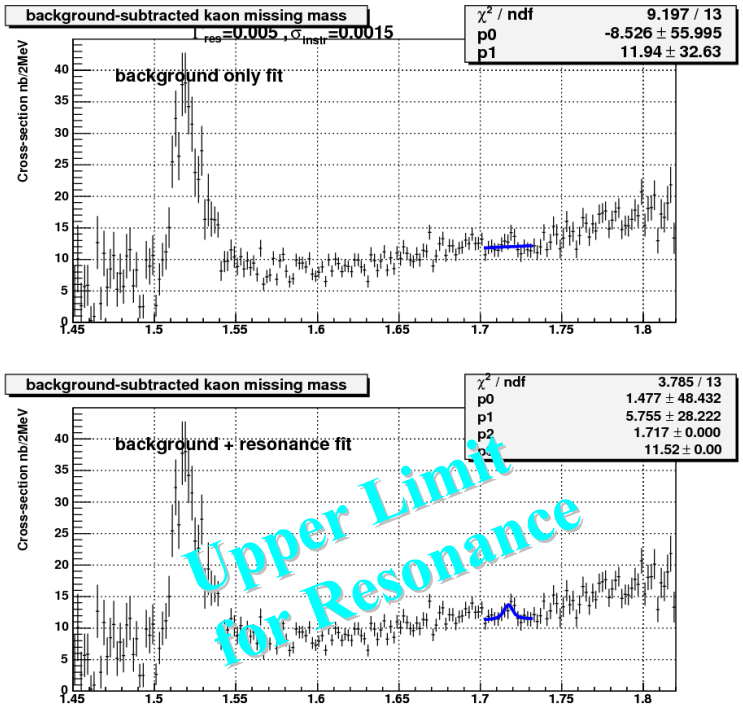
Chi^2 of Background

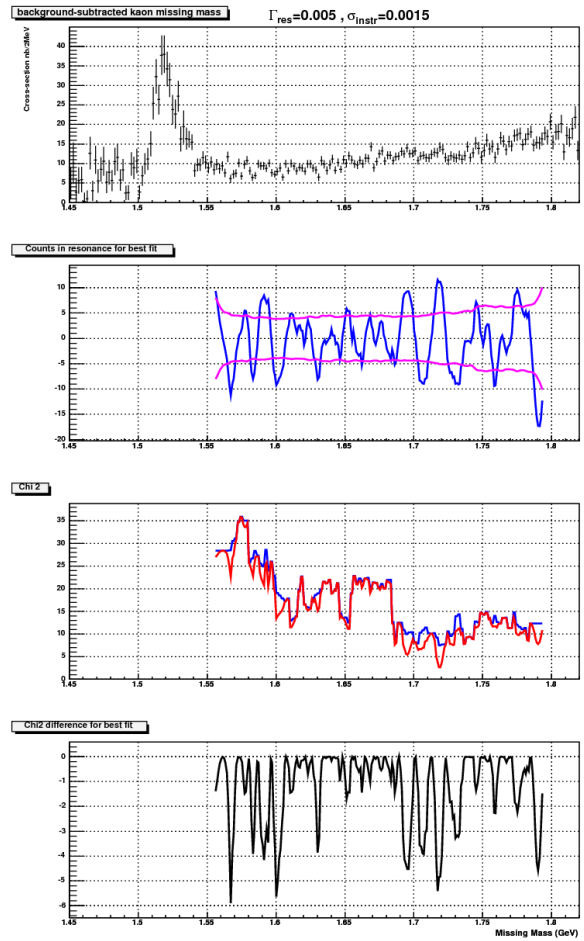
Chi^2 of Bg. + Res.



Chi^2 Improvement

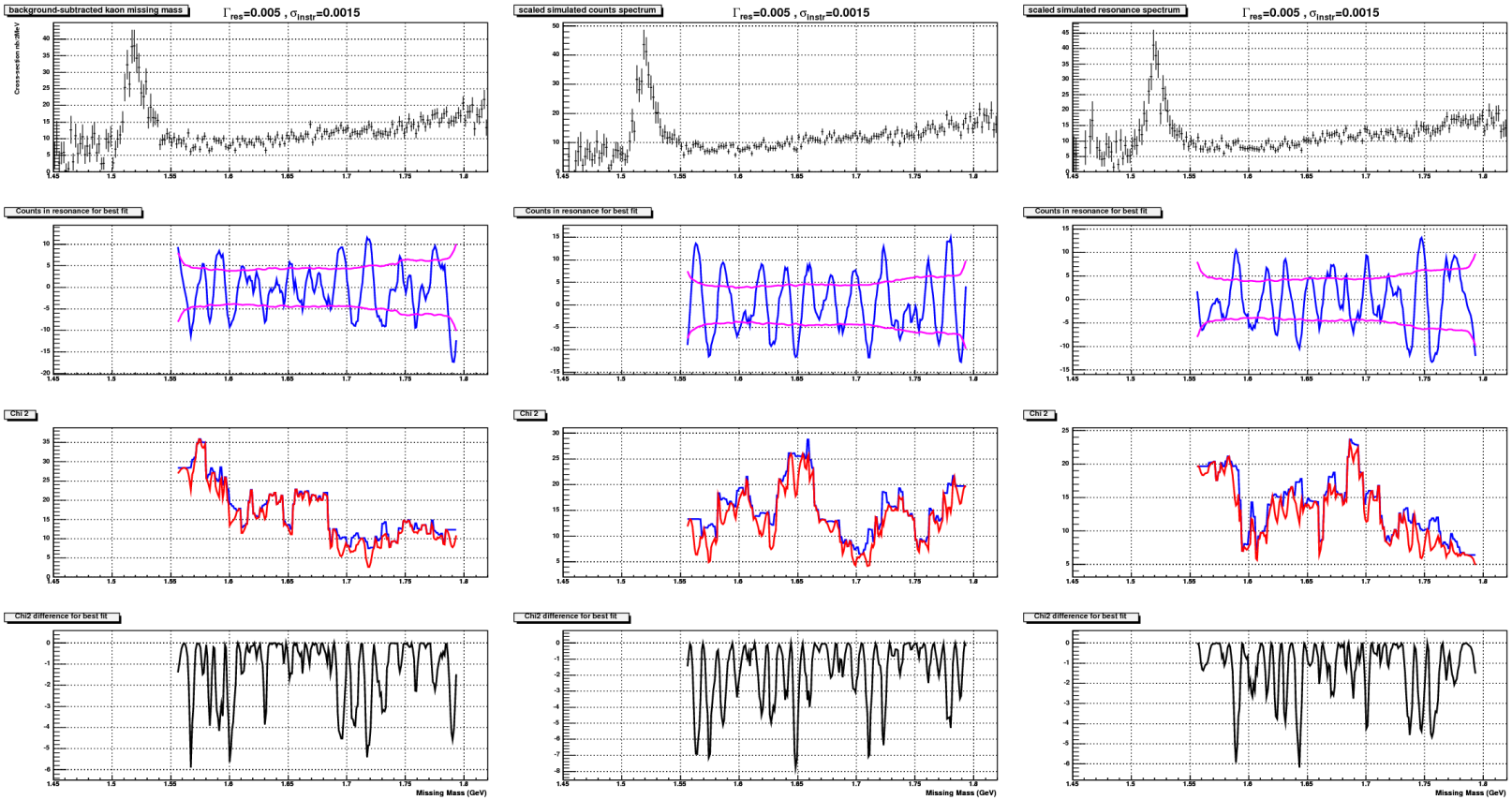
$\Sigma^{\circ}_{\overline{10}}$ Search





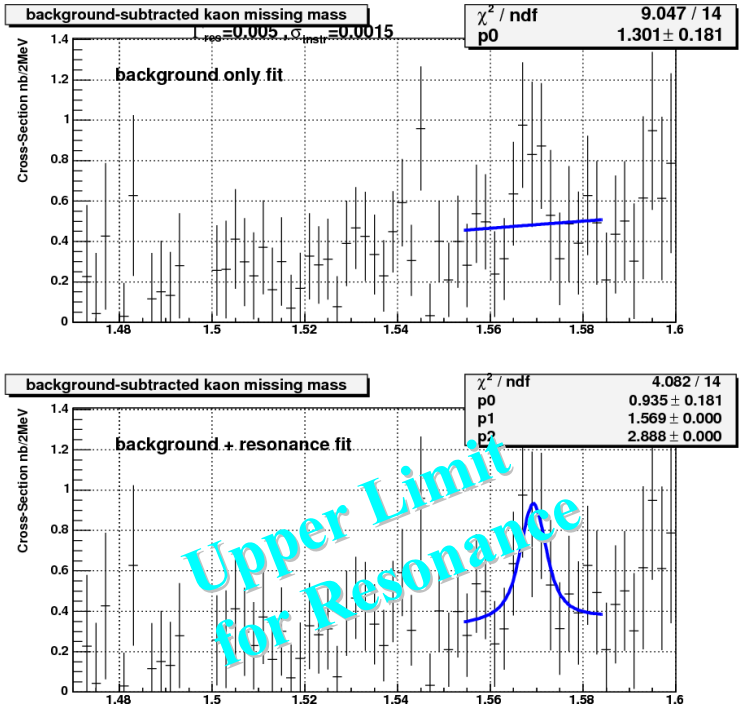
$$\frac{d\sigma}{d\Omega}(\gamma^* p \rightarrow \Sigma^{\circ} K^{+})\big|_{\theta=2^{\circ}} < 11nb$$

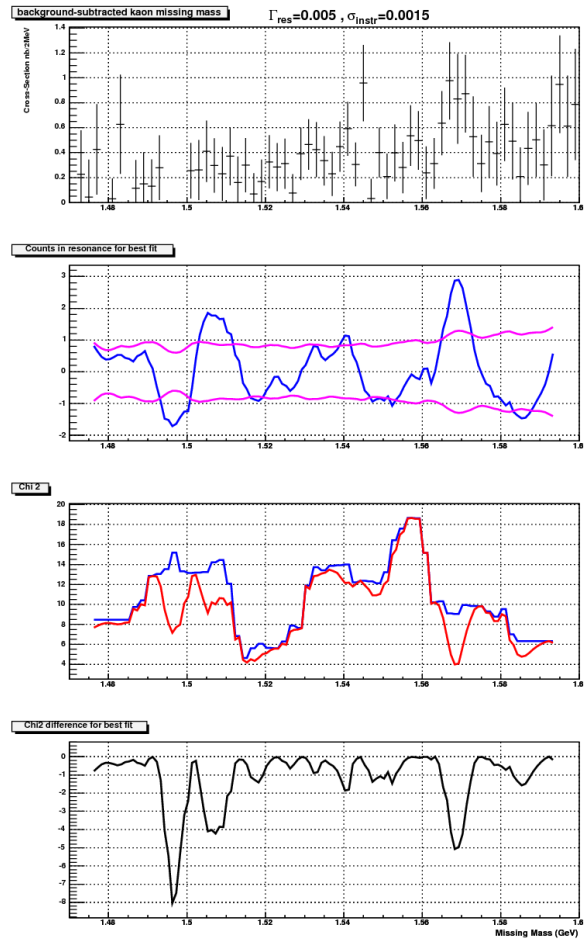
Spectrum Monte-Carlo



One Spectrum has a 5 nb peak, can you find it?

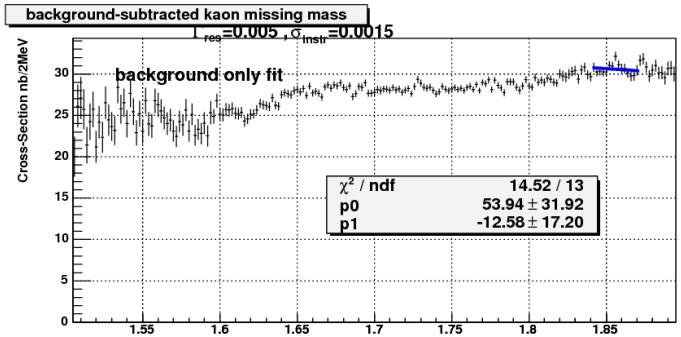
Θ^{++} Search

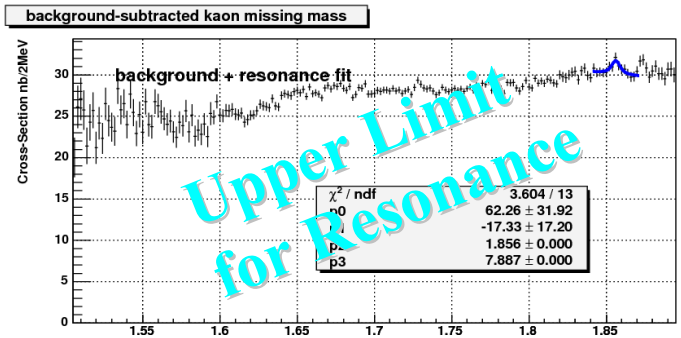


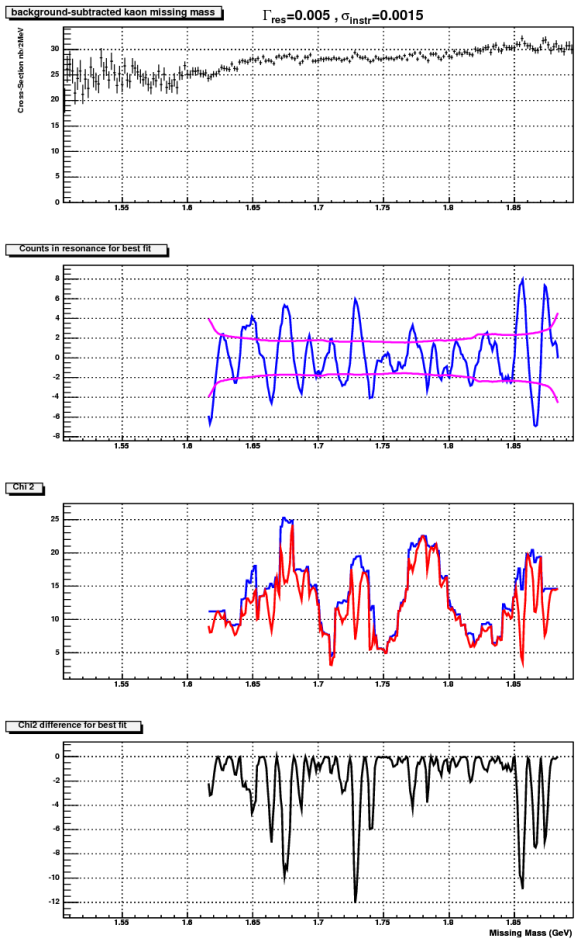


$$\frac{d\sigma}{d\Omega}(\gamma^* p \rightarrow \Theta^{++}K^-)\Big|_{\theta=2^\circ} < 3nb$$

$N^{\circ}_{\overline{10}}$ Search







$$\frac{d\sigma}{d\Omega}(\gamma^* p \rightarrow N^{\circ}\pi^+)\Big|_{\theta=6^{\circ}} < 8nb$$

Summary

- Preliminary Upper Limit for Σ^0

$$\frac{\sigma_{\gamma^* p \to \Sigma^\circ K^+}}{\sigma_{\gamma^* p \to \Lambda^\circ(1520) K^+}} < 3.1\% \qquad \frac{d\sigma_{\gamma^* p \to \Sigma^\circ K^+}}{d\Omega} < 11nb$$

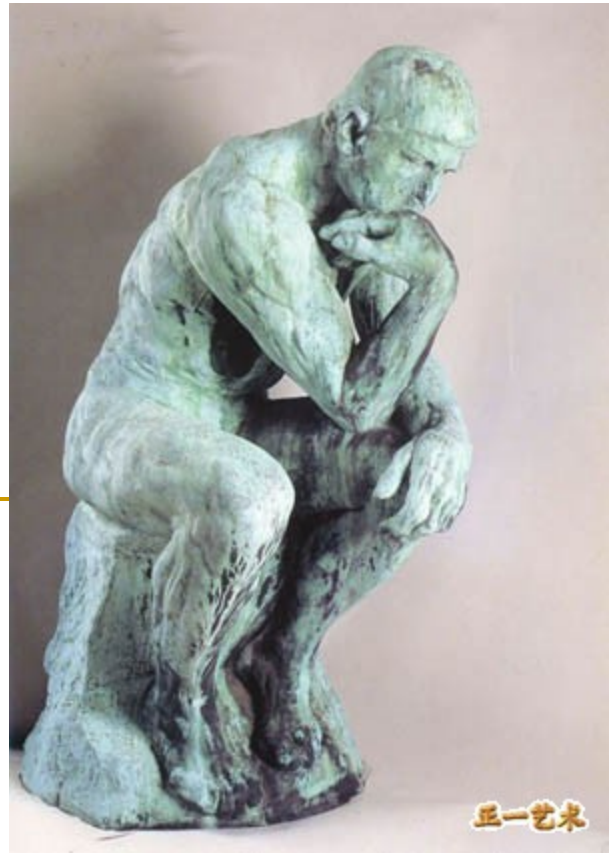
- Preliminary Upper Limit for Θ^{++}

$$\frac{\sigma_{\gamma^* p \to \Theta^{++} K^-}}{\sigma_{\gamma^* p \to \Lambda^\circ(1520) K^+}} < 0.9\% \qquad \frac{d\sigma_{\gamma^* p \to \Theta^{++} K^-}}{d\Omega} < 3nb$$

- Preliminary Upper Limit for N^0

$$\frac{\sigma_{\gamma^* p \to N^0 \pi^+}}{\sigma_{\gamma^* p \to \Lambda^\circ(1520) K^+}} < 2.3\% \qquad \frac{d\sigma_{\gamma^* p \to N^0 \pi^+}}{d\Omega} < 8nb$$

To be or not to be?



Final Results coming soon…

Knowledge about Θ^+ partners

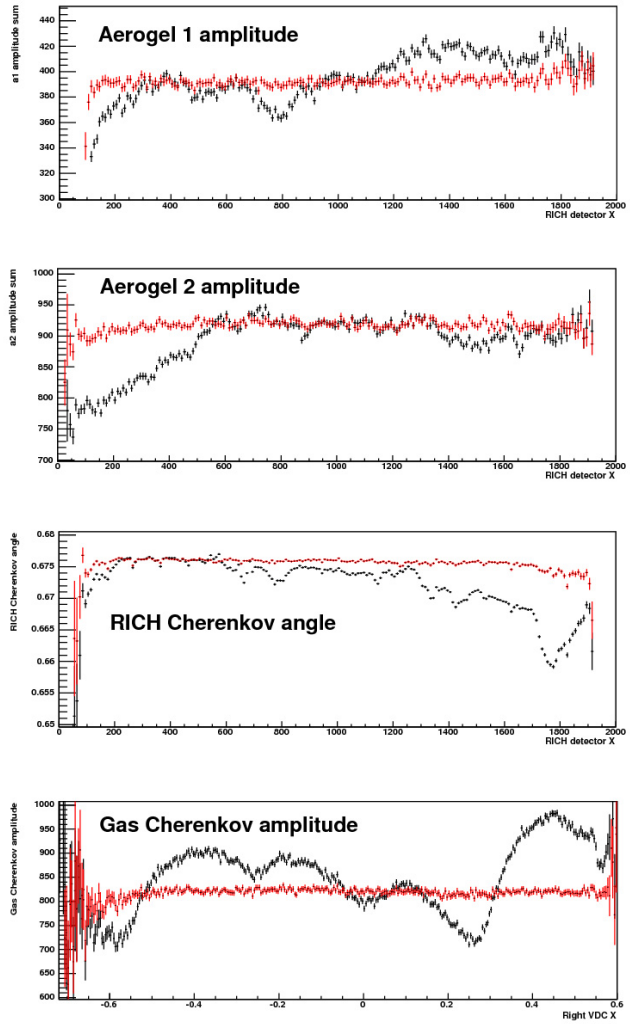
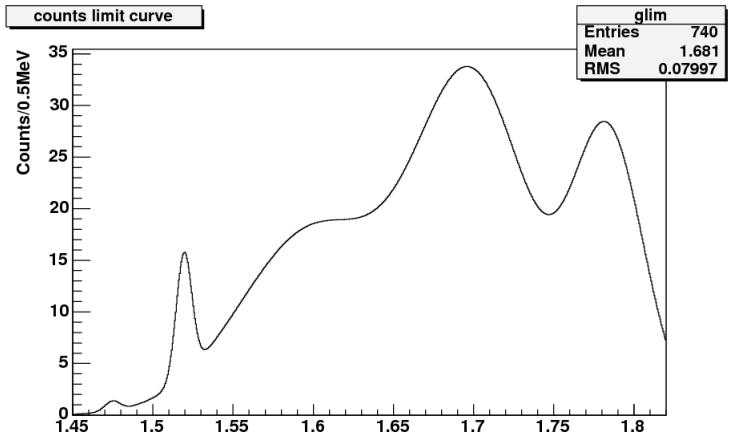
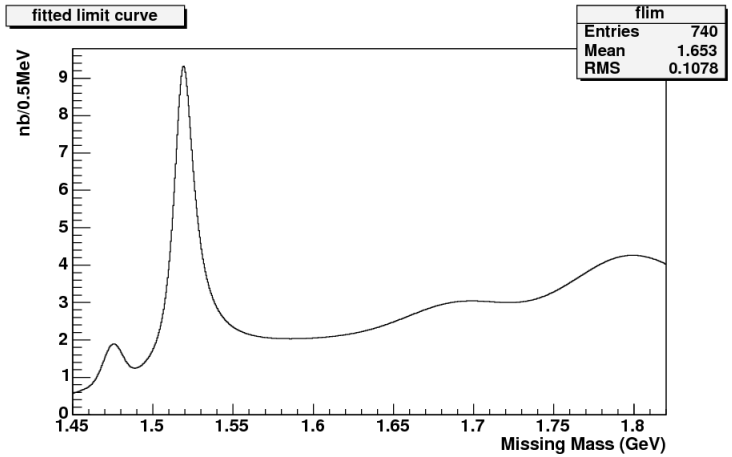
- $M = M_{\Theta^+} + (1-S)\cdot 107 MeV$ (x Soliton Model)
- Various Predictions for width, e.g. $\Gamma_{\Sigma^o} \approx$ 3 – 40 *MeV*
- Partial wave analysis by Arndt *et al.* (2003):

  M_{N^*} = 1680 or 1730 *MeV*

  Γ_{N^*} < 30 *MeV*

  $\Gamma_{\Xi_{3/2}}$ < 3 *MeV*
- Various facilities (CLAS, HERMES, etc.) have carried out search for Θ^{++}, no conclusive observations yet
- Signal of non-strange member of antidecuplet seen in $\gamma n \to K\Lambda(\Sigma)$ with *M* = 1680 *MeV* at GRAAL (preliminary)
- Narrow $\Xi^{--}_{3/2}$ reported by NA49 with *M* = 1862 *MeV*

Detector Correction



Monte-Carlo Simulation