Search for Θ^{++} with CLAS

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Θ^+ Isospin

- Antidecuplet predicts I=0
- In 27-plet I=1
- In some models Θ^+ is isotensor (to suppress the strong decays)
- The question is what is the isospin of the Θ^+ (if real)?

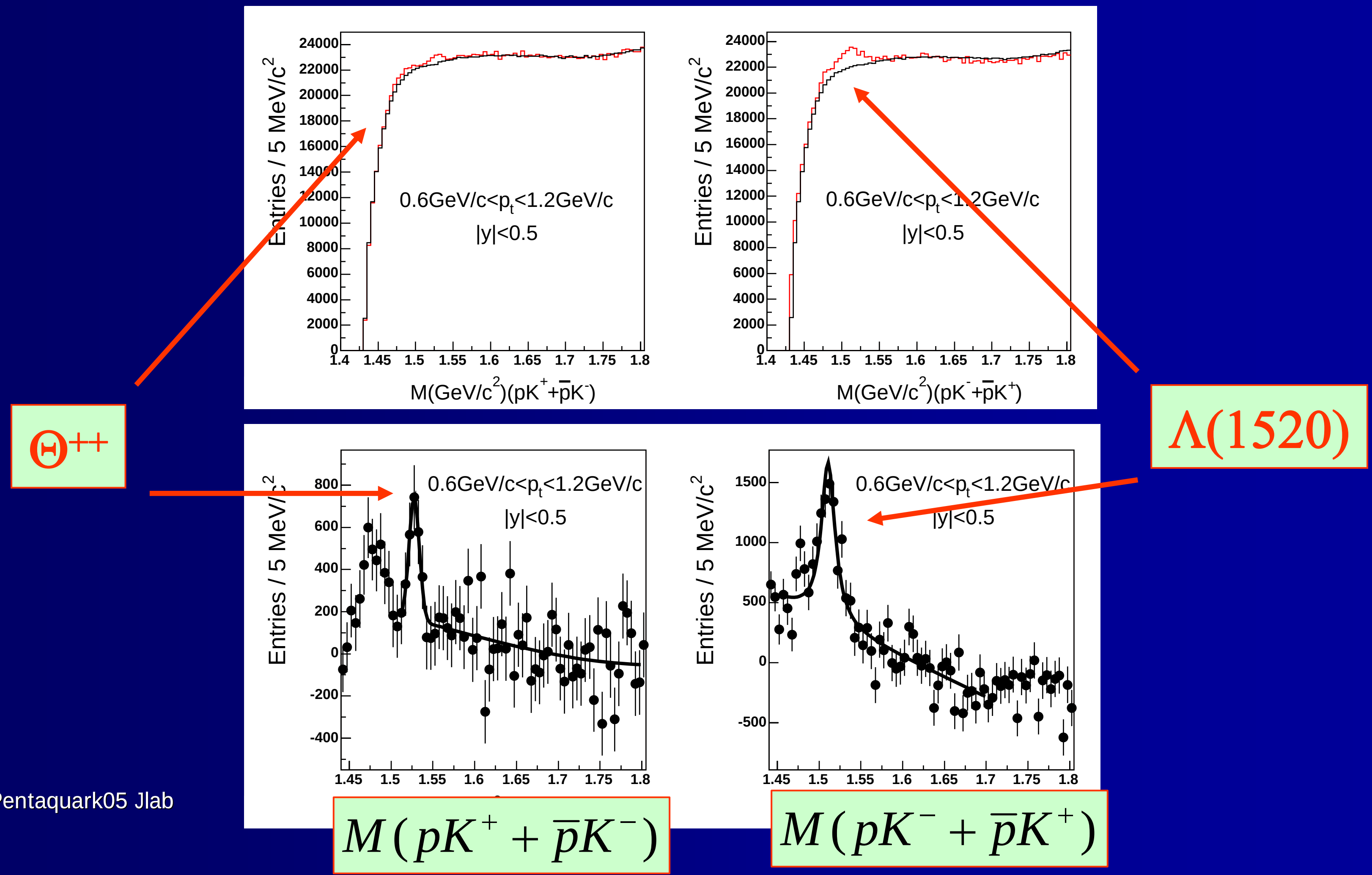
Search for Θ^{++}

- SAPHIR, CLAS, HERMES, ZEUS ...

  did not find signal in the pK^+ invariant mass spectra
- STAR found strong evidence (4.2 σ) for the Θ^{++} in d+Au collisions with M=1528 MeV
- The mass coincidence with the previously reported Θ^+ results suggests that the isotopic spin of the Θ^+ baryon is not zero

STAR: a Θ^{++} pentaquark?

d+Au Collisions



Search for Pentaquarks at Jlab

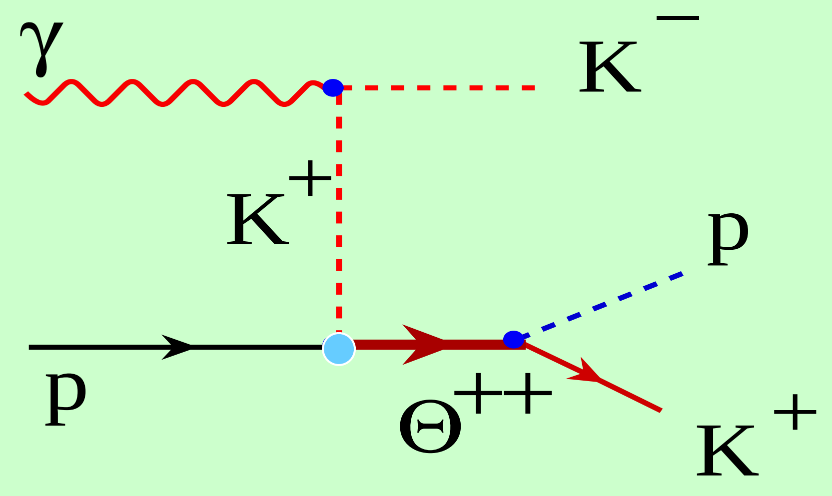
A comprehensive program to search for pentaquarks with high statistics and high resolution photoproduction experiments is in progress at Jefferson Lab

g10	deuteron	$E_\gamma \sim 1.0\text{–}3.5$ GeV	completed in 2004
Hall-A	Search for Θ^{++}, Σ^{0}		completed in 2004
	Search for Θ^{+}		planned for 2007
g11	proton	$E_\gamma \sim 1.6\text{–}3.8$ GeV	completed in 2004
eg3	deuteron	$E_\gamma \sim 4.0\text{–}5.4$ GeV	completed in 2005
Super-g	proton	$E_\gamma \sim 3.8 - 5.7$ GeV	planned for 2006/7

g11 experiment at Jlab

- High statistics and high resolution photoproduction experiment dedicated to search for pentaquarks.
- Maximum photon energy up to 3.8 GeV
- 6.9 10^{9} events collected with 70 pb^{-1} integrated luminosity

Search for Θ^{++}



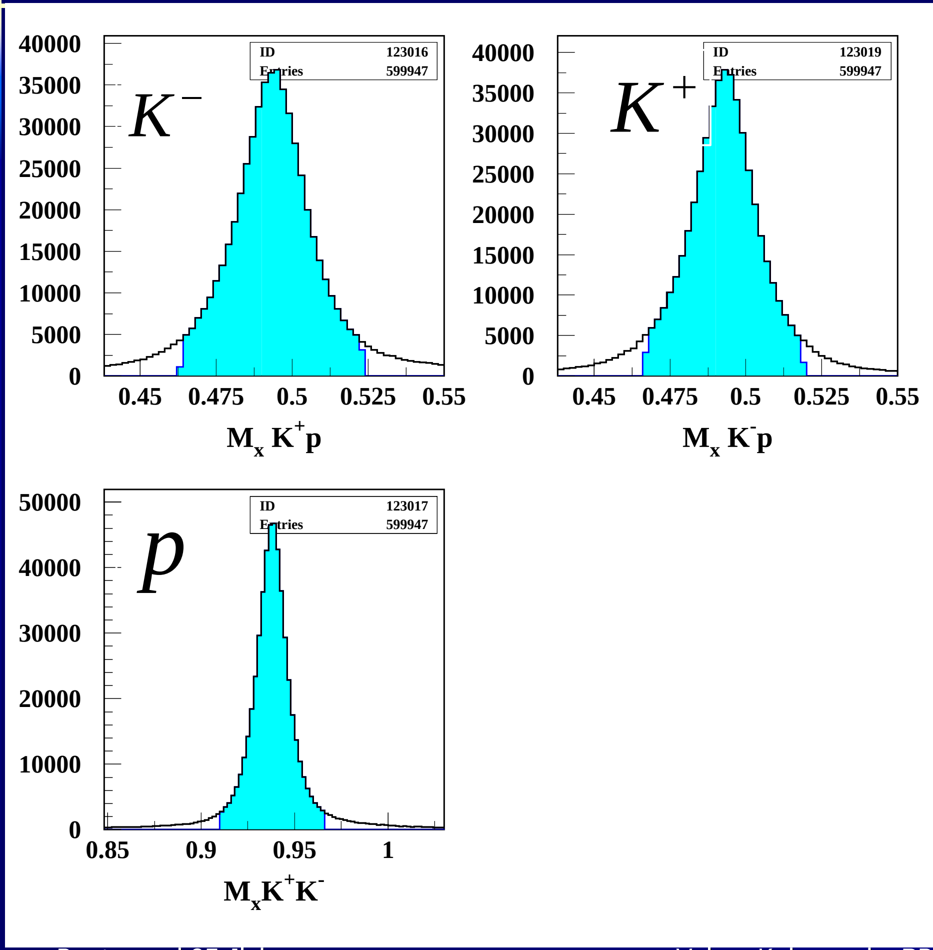
Reaction $\gamma p \rightarrow K^- K^+ p$

Two main topologies

- All three particles detected by CLAS
- Only p and K^+ detected and K^- reconstructed as missing particle
- The last method has an order of magnitude higher acceptance and full angular coverage

Missing Mass Spectra

proton, K^+ and K^- are detected

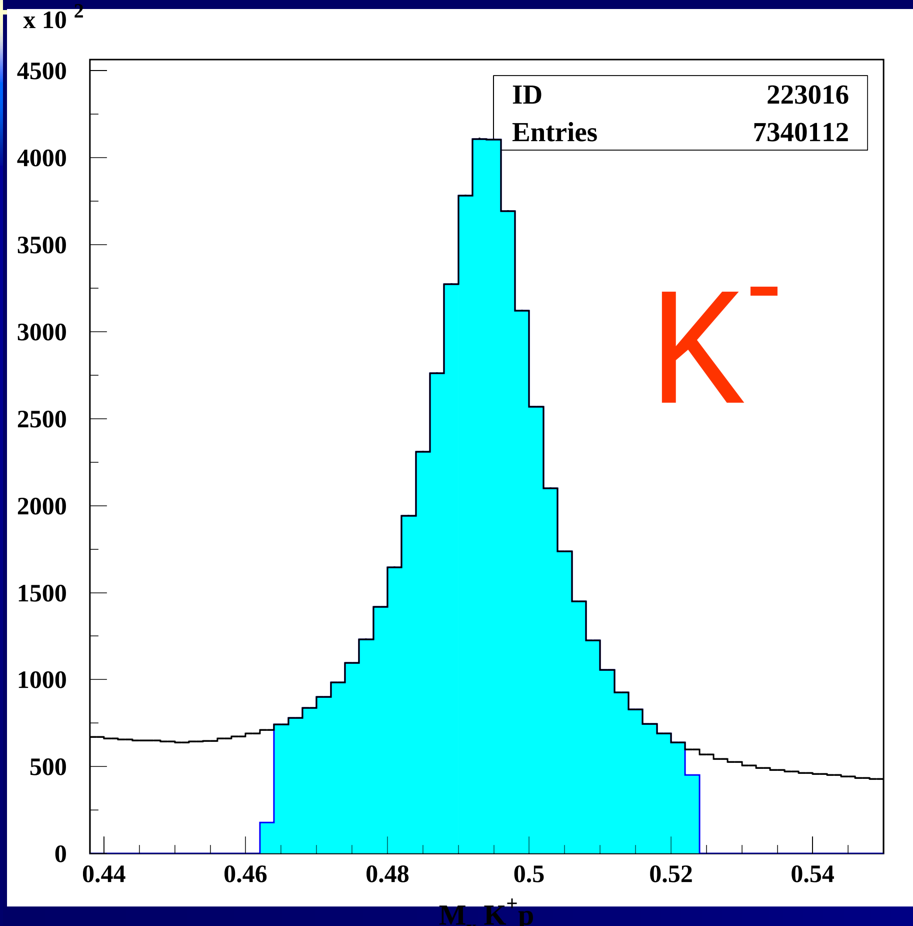


$$\gamma p \to K^- K^+ p$$

Very clean sample
No mis particle ID

Missing mass spectrum

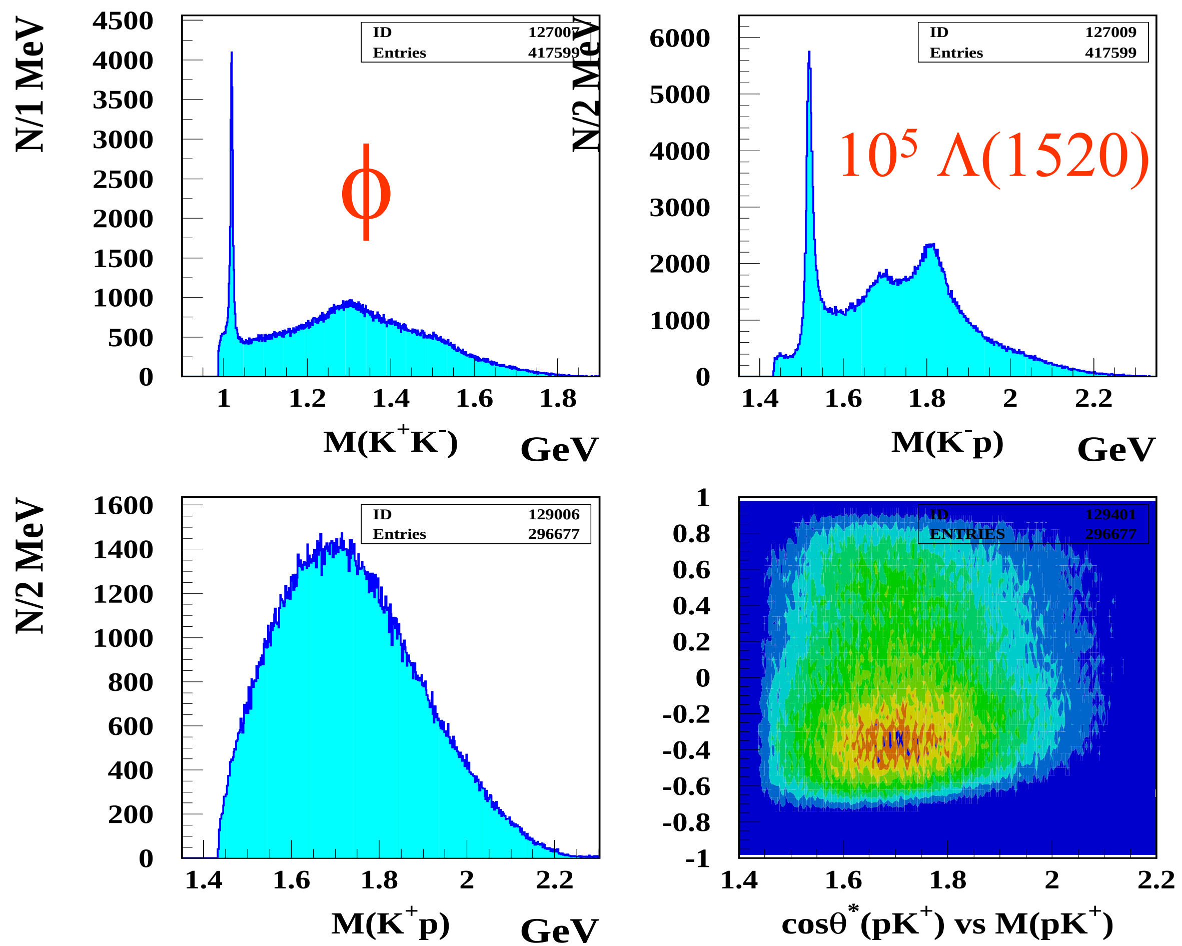
Only proton and K^+ detected

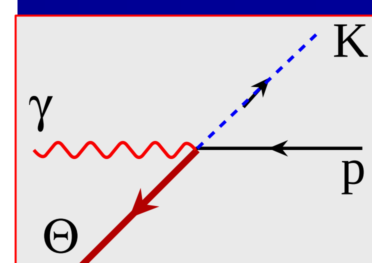


$$\gamma p \to (K^-)K^+ p$$

- K^- identified as a missing particle
- An order of magnitude larger acceptance
- Full angular coverage, no holes!

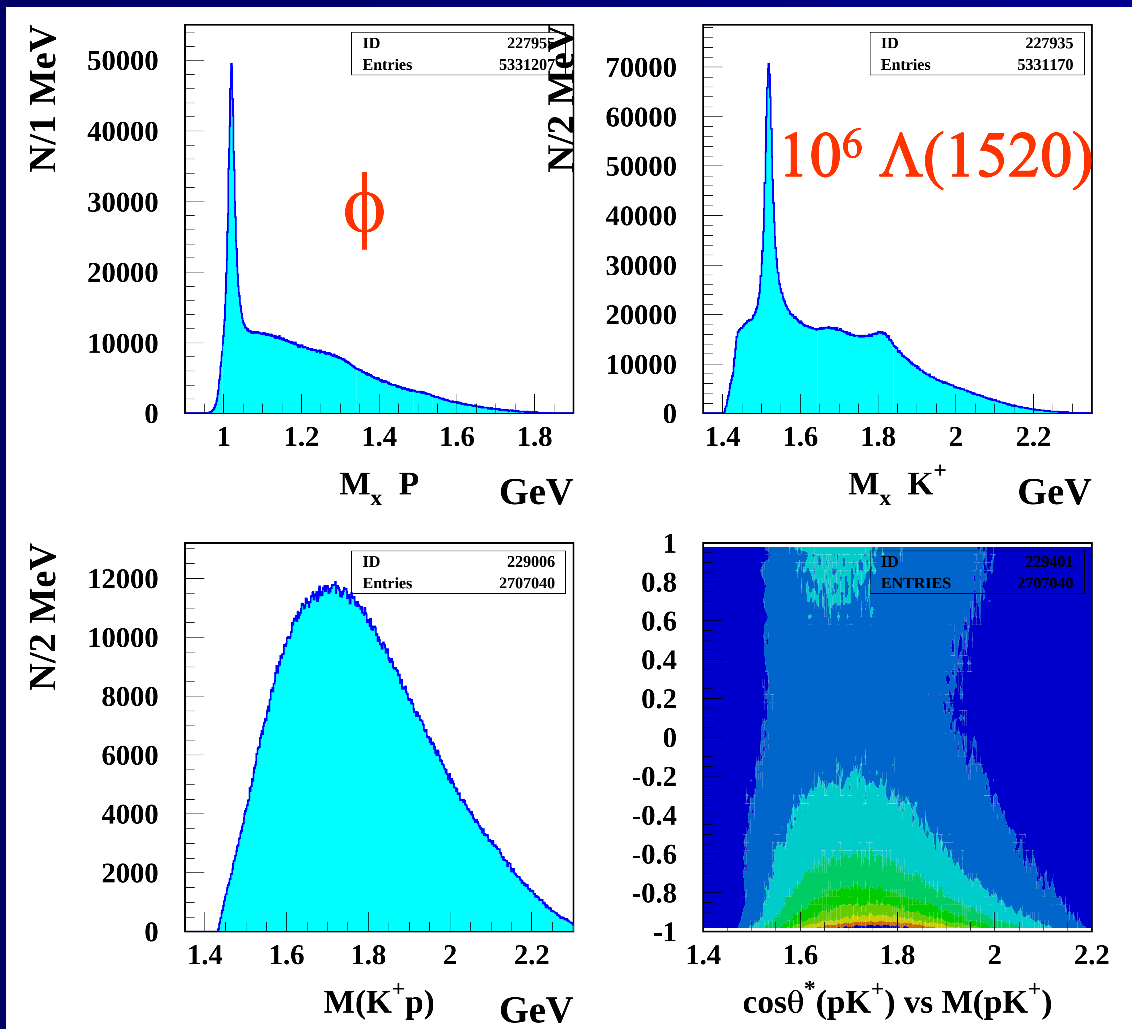
$\gamma p \to K^- K^+ p$ 10^5 Λ(1520)

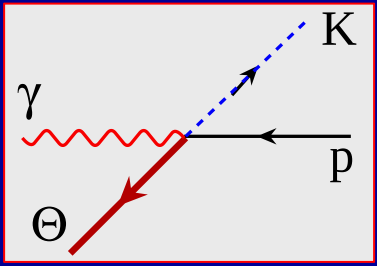




$$\gamma p \to (K^-)K^+ p$$

10^6 Λ(1520)

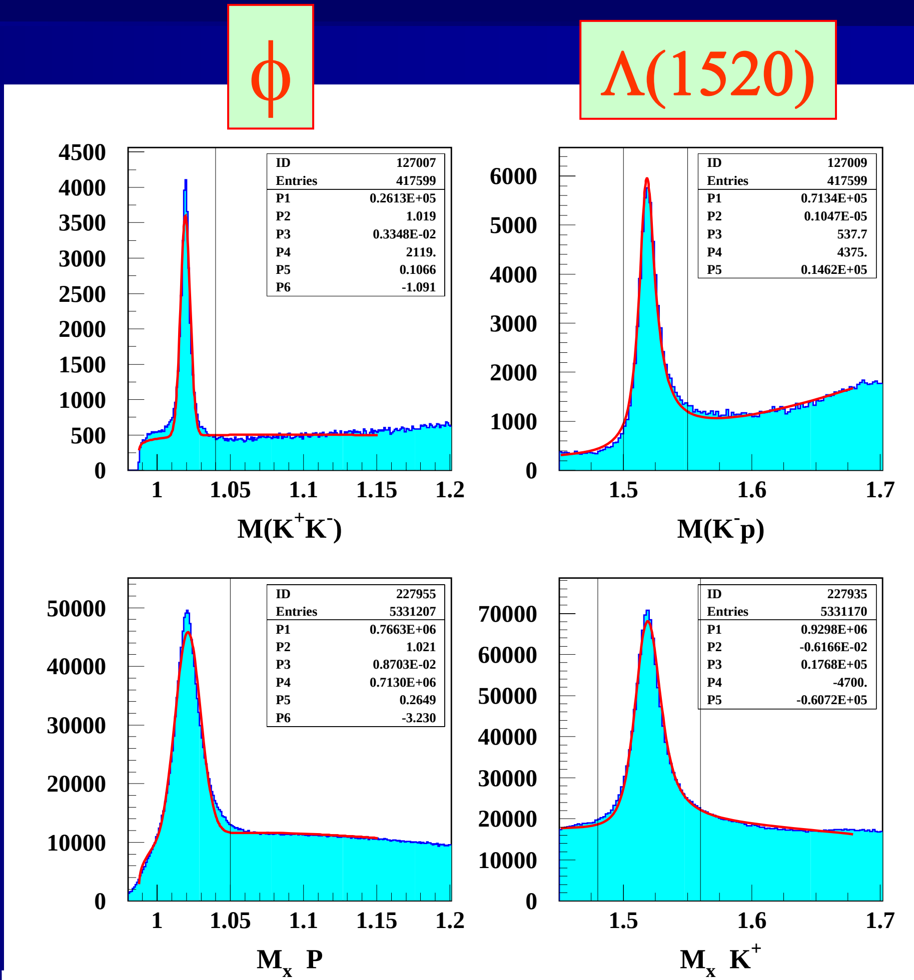




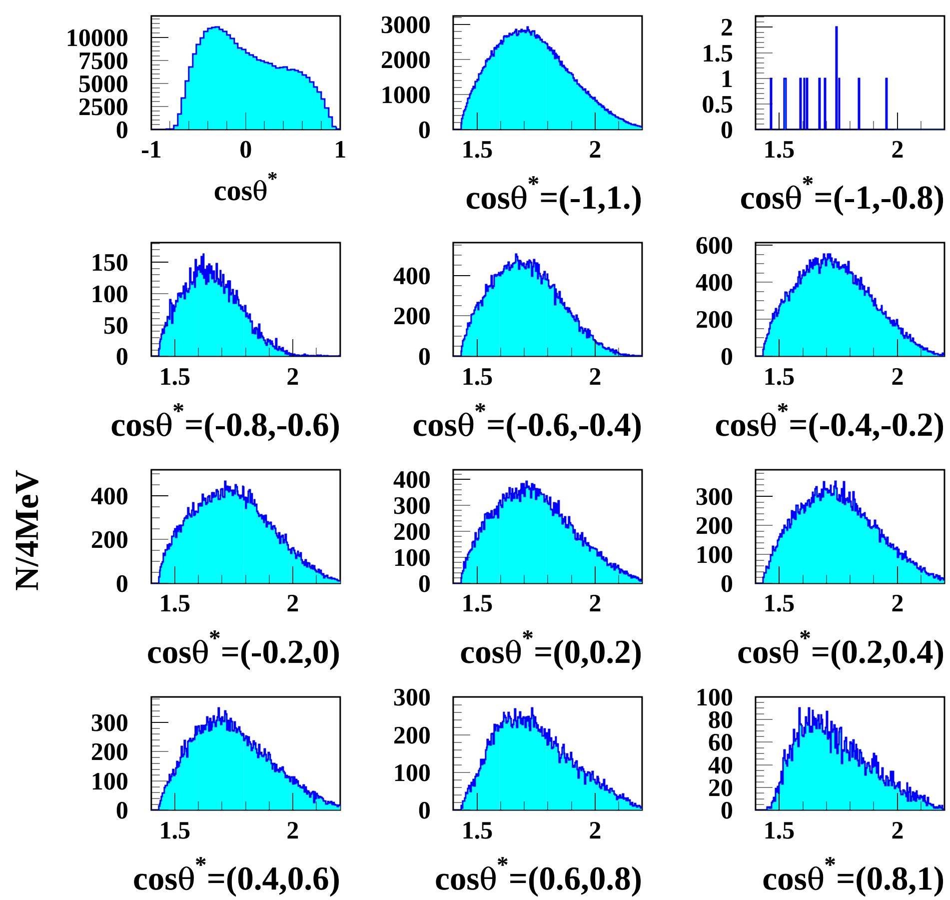
Cut ϕ and $\Lambda(1520)$ for the Θ^{++} search

$$\gamma p \rightarrow K^- K^+ p$$

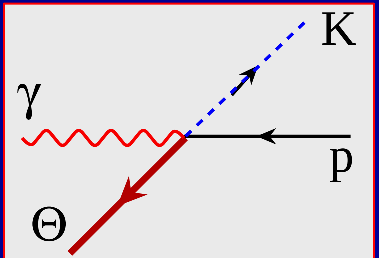
$$\gamma p \rightarrow (K^-) K^+ p$$



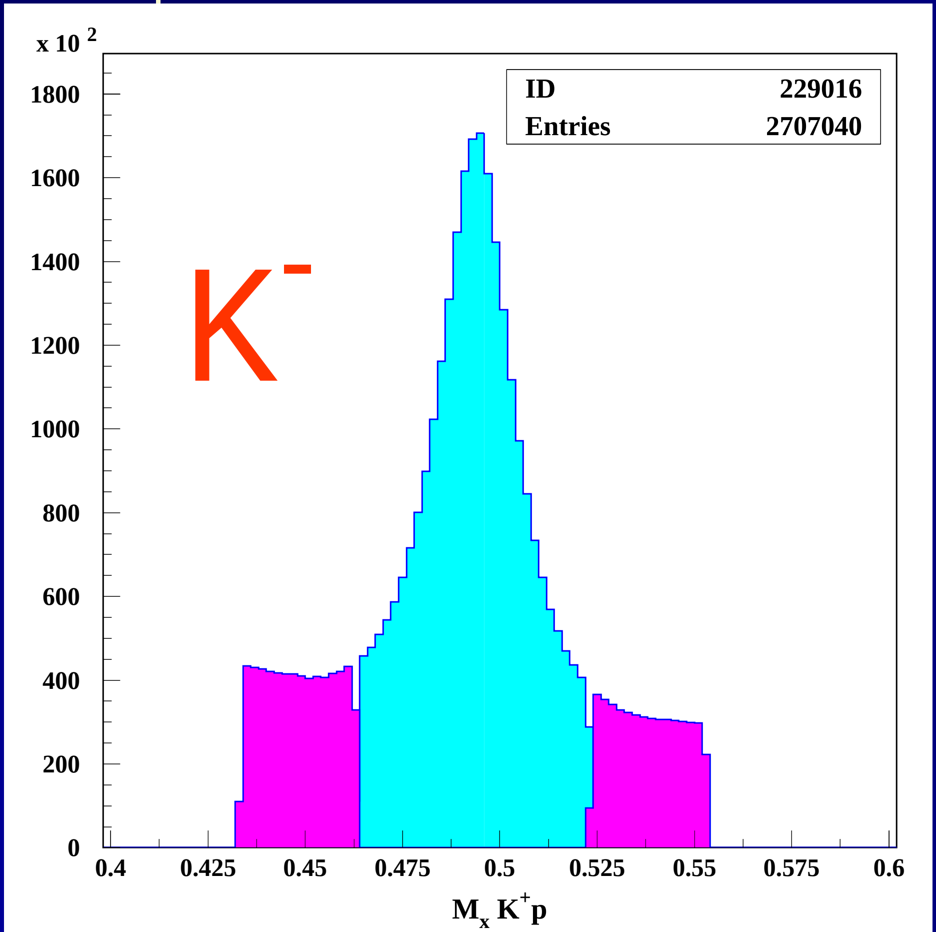
pK$^+$ Invariant mass spetra for different angles

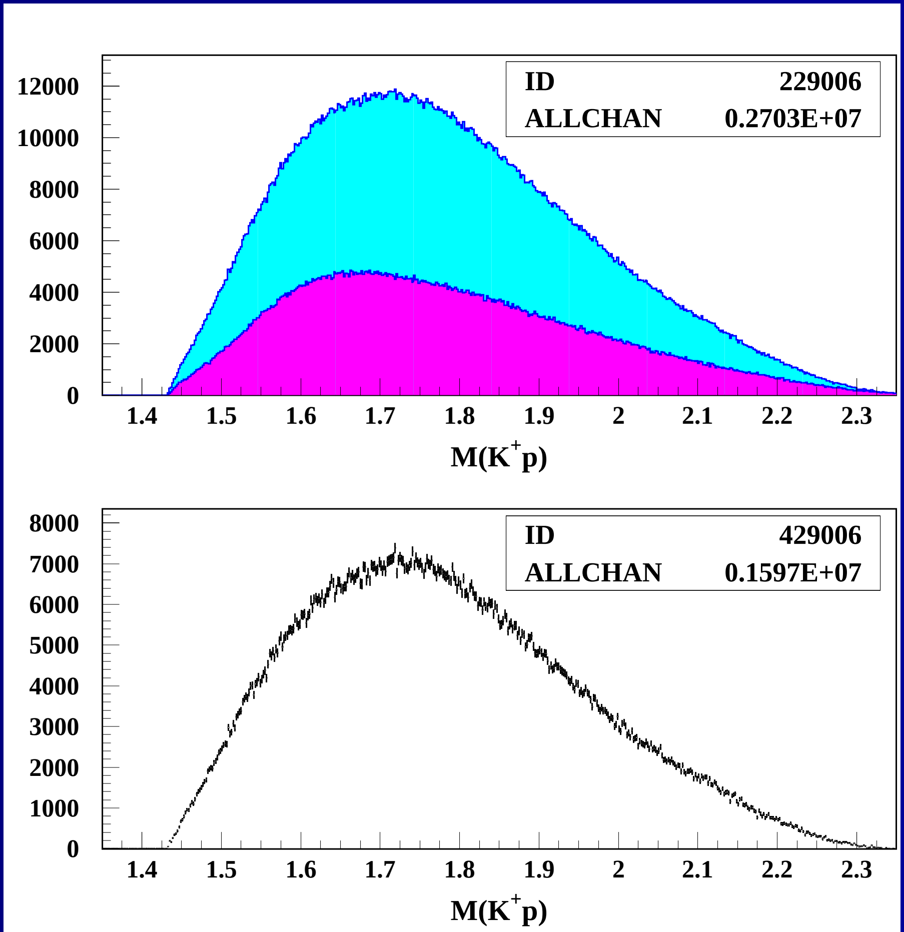


All three particles detected



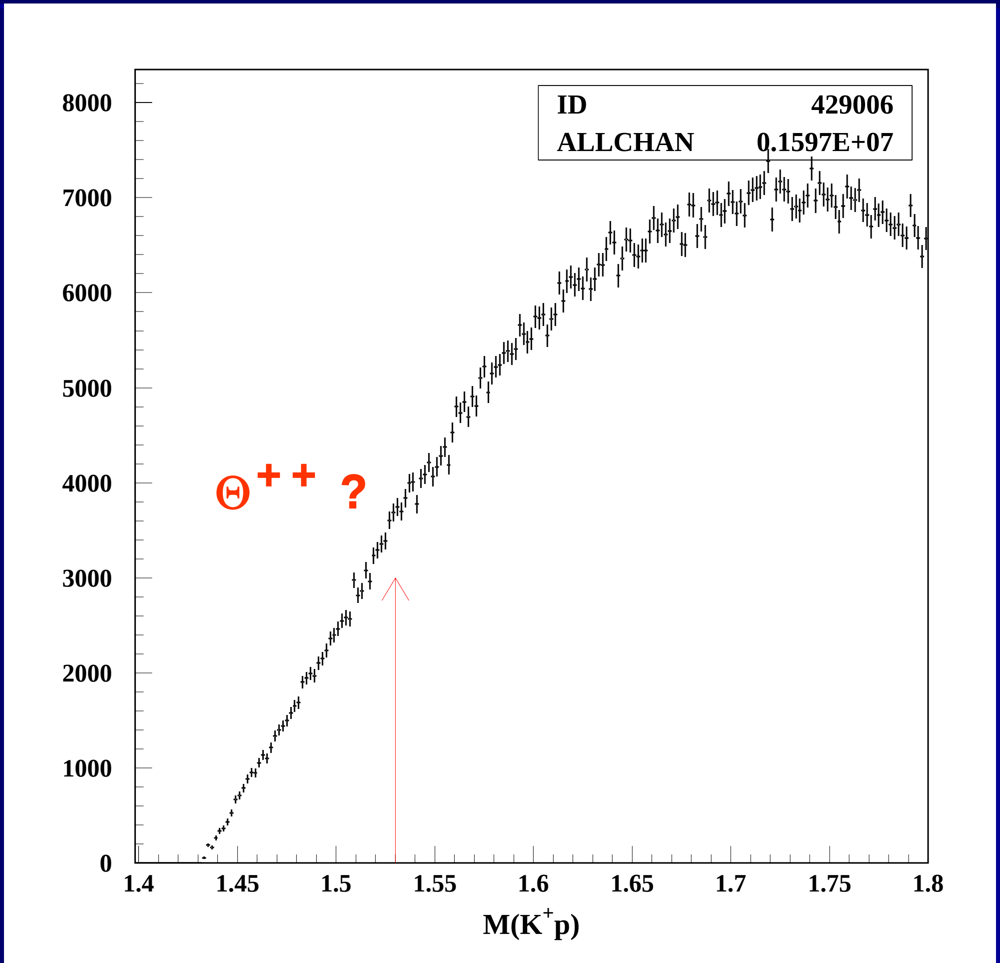
Side-band subtraction





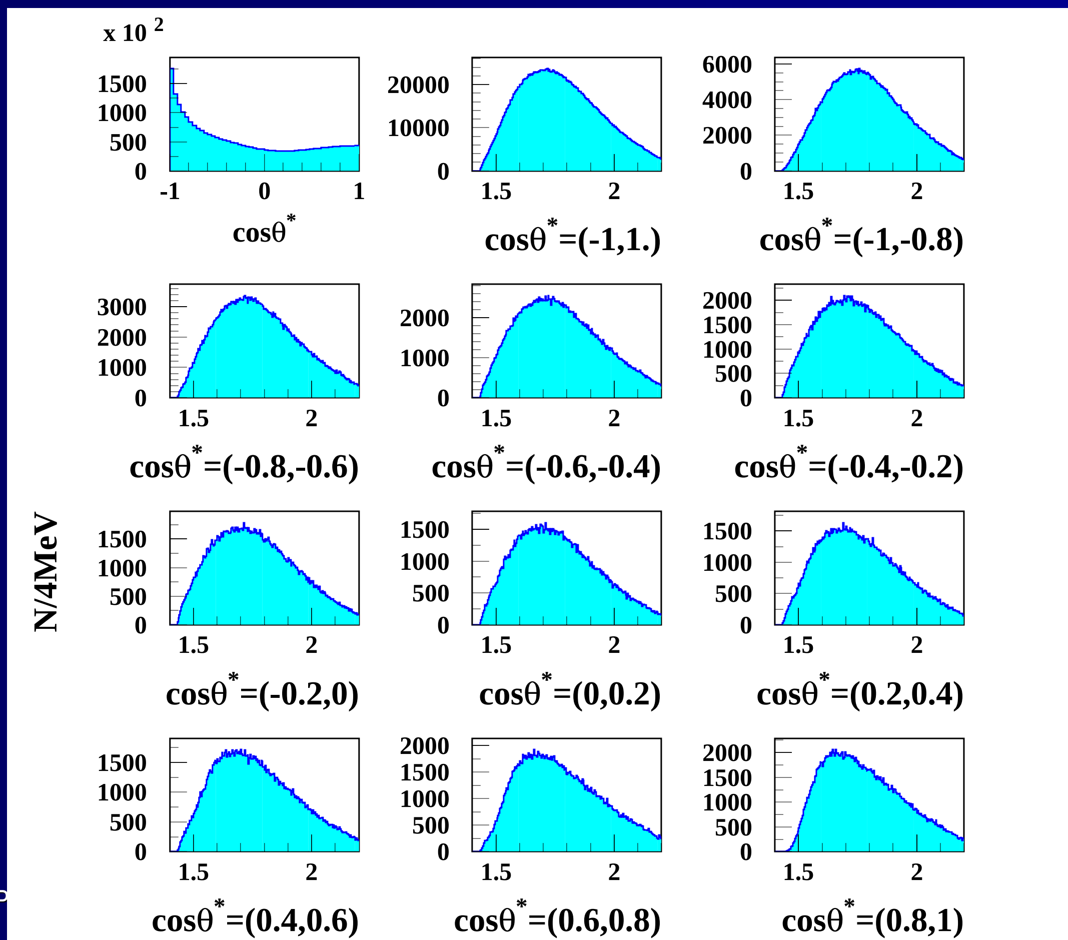
pK^+ Invariant Mass Spectrum

Events/ 2 MeV

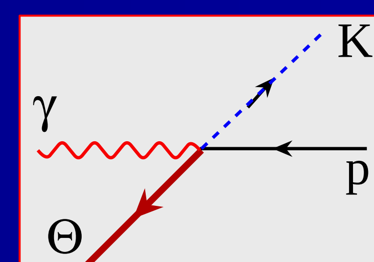


M(pK+)

pK^+ Invariant Mass Spetra for different angles



Only Proton and K+ detected



Θ^{++} Cross Section Upper Limit

- $\sigma^{95\%}$ based on the reference reaction

$$\gamma p \to K^{+}\Lambda(1520)$$

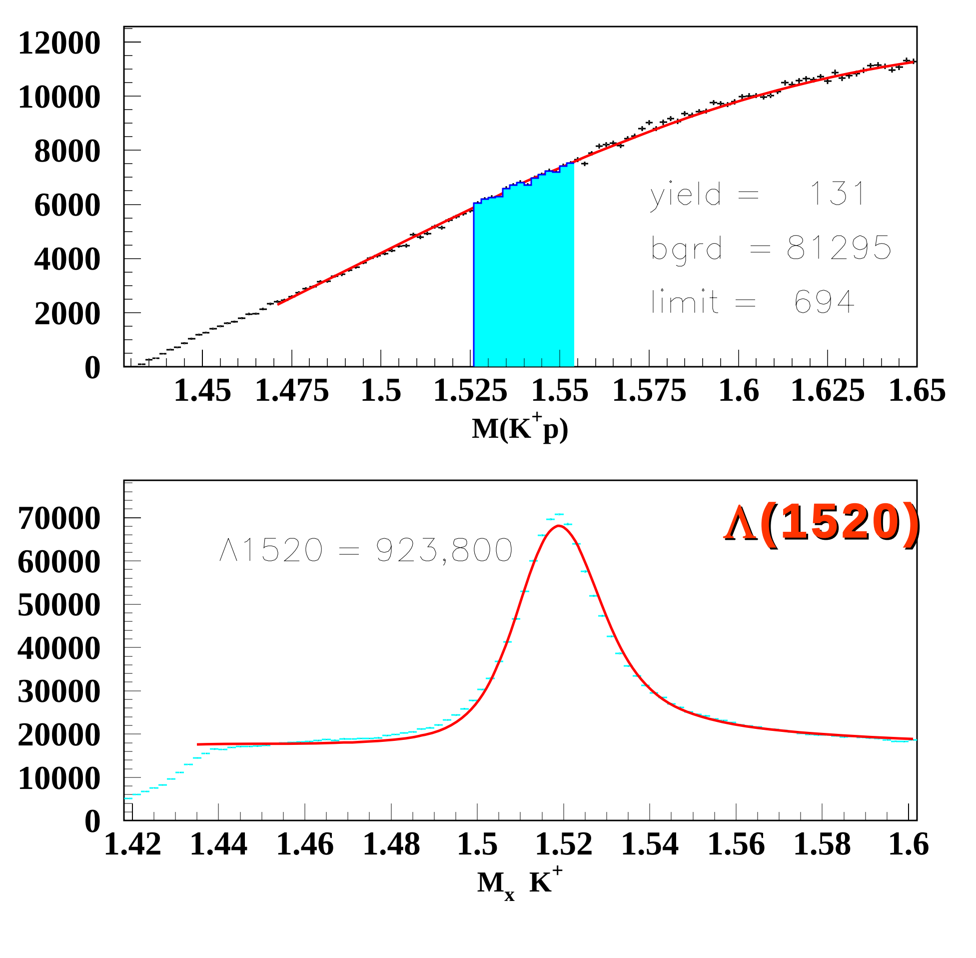
- Feldman-Cousins method for the estimation of the upper limit of the Θ^{++} yield

95% CL Upper Limit

$$\sigma_{\Theta^{++}}^{95\%} = \sigma(\Lambda 1520)\frac{Yield_{\Theta^{++}}^{95\%}}{N_{\Lambda 1520}}\frac{\varepsilon_{\Theta^{++}}}{\varepsilon_{\Lambda 1520}}\frac{BR(\Lambda \to pK^{-})}{BR(\Theta^{++} \to pK^{+})}$$

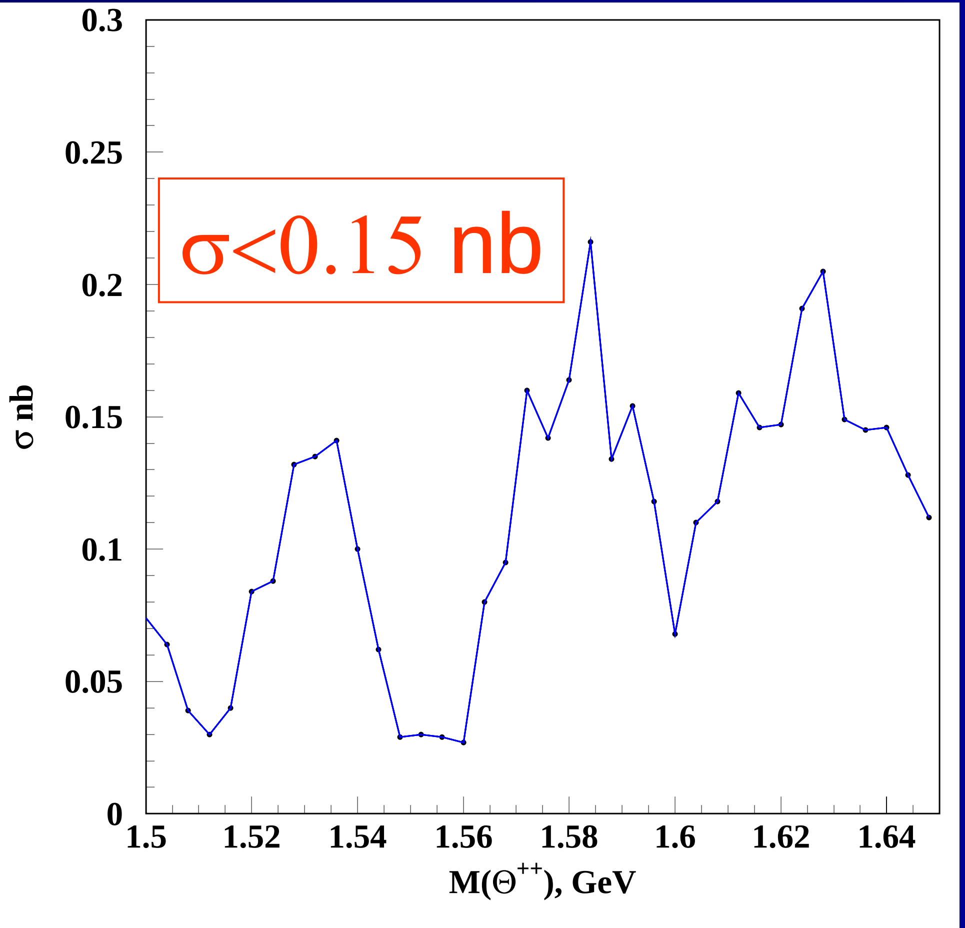
pK+ AND pK- MASS SPECTRA

$$\gamma p \rightarrow (K^-)K^+p$$

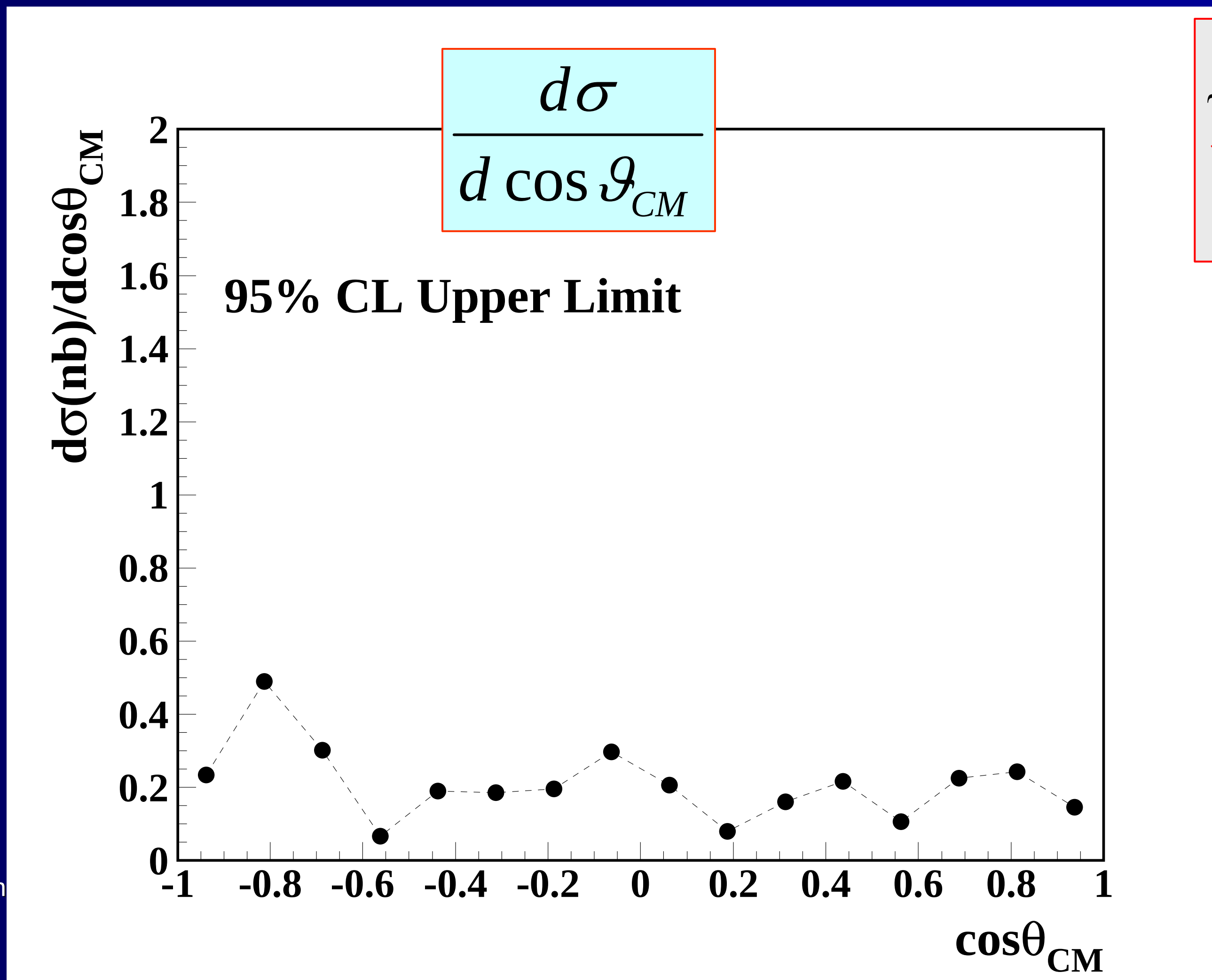


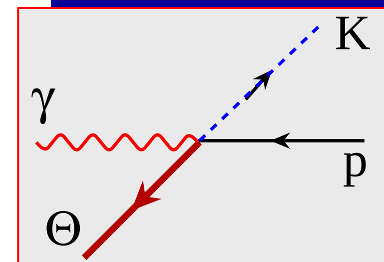
Upper Limit on Total Cross Section (95% CL)

$$\gamma p \rightarrow (K^-)\Theta^{++}$$

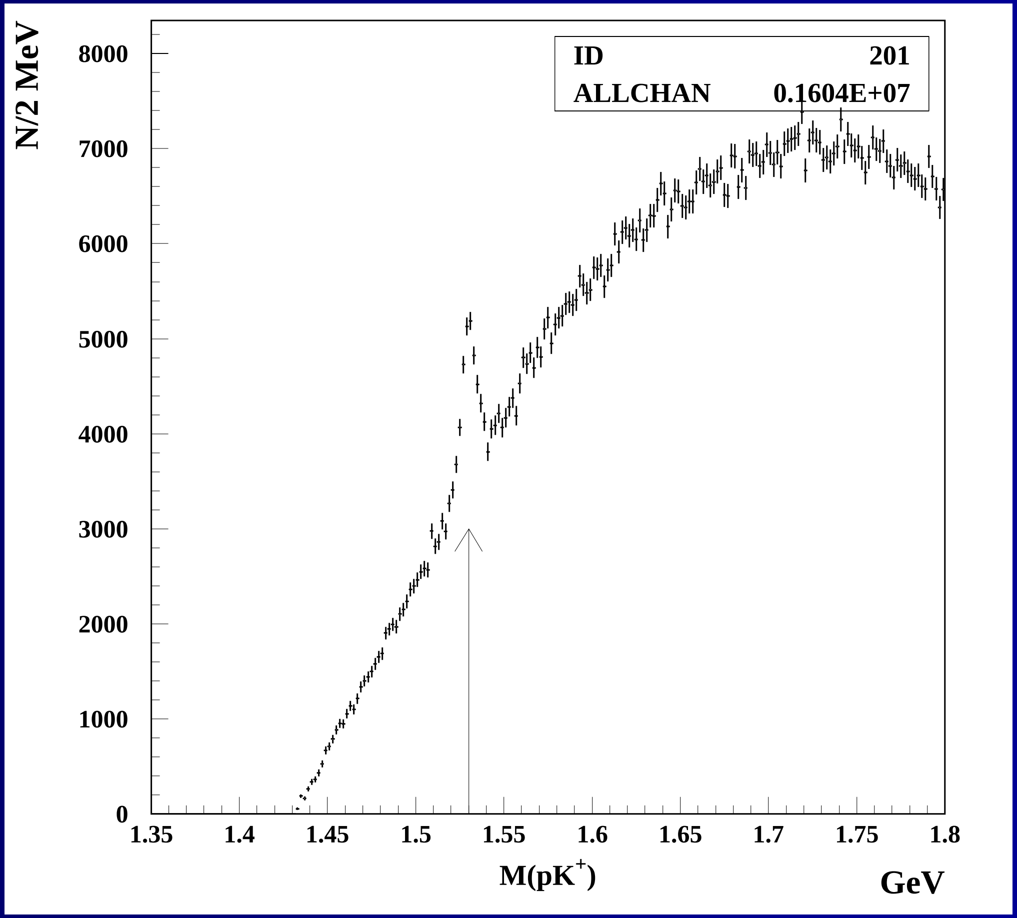


Upper limit on the differential cross section (95 % CL)





Simulated(!) 1 nb Θ^{++} signal

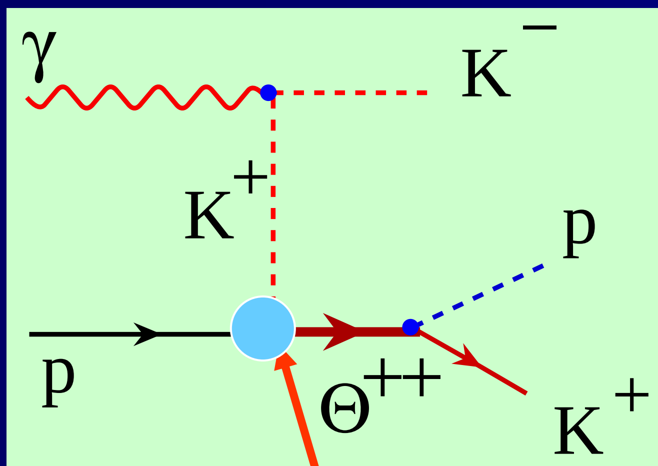


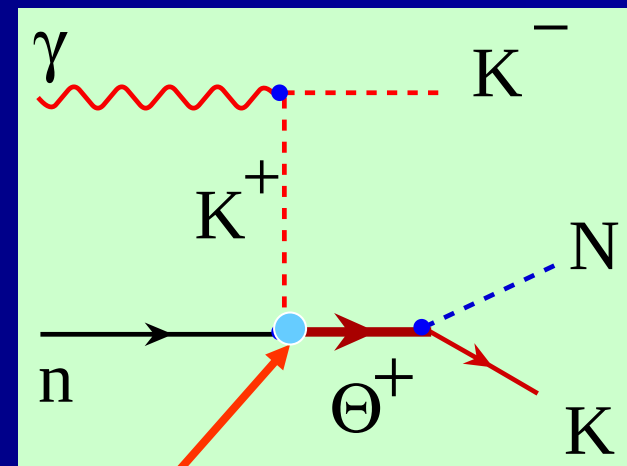
$\Theta^{++}/\Lambda(1520)$ Ratio

- The upper limit on the ratio of the photoproduction cross sections of Θ^{++} and $\Lambda(1520)$ from proton @ 95% CL

$$\frac{\Theta^{++}}{\Lambda(1520)} < 2.5 \cdot 10^{-4}$$

Theoretical estimation of the Θ^{++} total cross section





$$g(\theta^{++} p K^{+}) = \sqrt{2}\, g(\theta^{+} n K^{+})$$

$$\sigma(\gamma p \to K^{-}\theta^{++}) = 2\sigma(\gamma n \to K^{-}\theta^{+})$$

Regge model cross section

Γ_{Θ^+}=1 MeV , J^P=1/2$^+$

- In the threshold region Regge model predicts the photoproduction cross section from neutron:

$$\sigma(\gamma n \to K^- \theta^+) = 1 nb$$

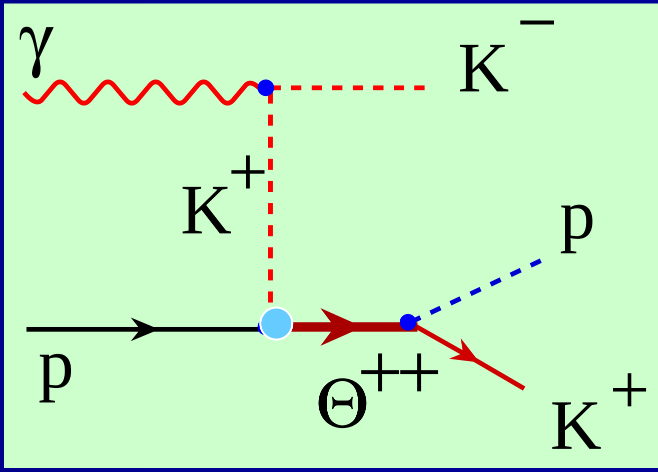
- It gives

$$\sigma(\gamma p \to K^- \theta^{++}) = 2\, nb$$

Total cross section and width

- Total cross section is proportional to the particle width.

$$\sigma \approx \Gamma_{\Theta}$$



- $$\Gamma = \frac{\sigma(nb)}{2} \ MeV$$

Upper limit on the Θ^{++} width (95% CL)

- Total Θ^{++} cross section upper limit at 95% CL is

$$\sigma(\Theta^{++}) < 0.15 \text{ nb}$$

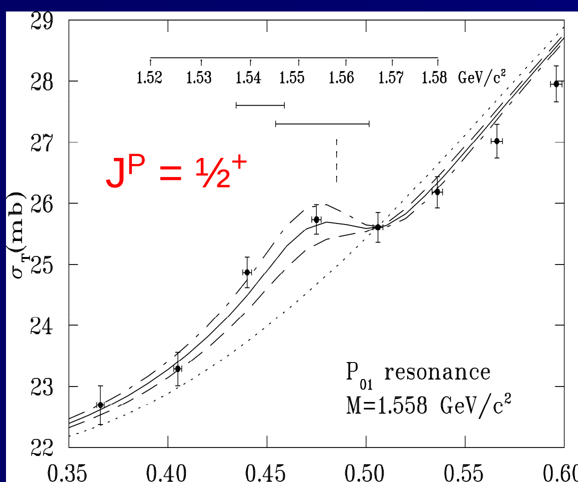
- Upper Limit on the Θ^{++} width is

$$\Gamma(\Theta^{++}) < 75 \text{ keV}$$

What do we know about the Θ^+ width?

Widths seen in experimental analyses are dominated by resolution effects.
More precise information is obtained in analyses with theoretical constraints.

DIANA, Phys. Atom. Nucl. 66,1715,(2003)	Γ_Θ <9 MeV
HERMES, PLB585, 213 (2004)	Γ_Θ = 17+/-9+/-3 MeV
S. Nussinov et al., hep-ph/0307357	Γ_Θ < 6 MeV (non-observation)
R. Arndt et al., PRC68, 42201 (2003)	Γ_Θ < 1 MeV (non-observation)
R. Cahn and G. Trilling, PRD69, 11401(2004)	Γ_Θ = 0.9 +/- 0.3MeV (from DIANA results)
A. Sibirtsev, et al., hep-ph/0405099 (2004)	Γ_Θ < 1 MeV ($K^+d \rightarrow K^0pp$)
W. Gibbs, nucl-th/0405024 (2004)	Γ_Θ = 0.9 +/-0.2 MeV (K^+d X)



$\Gamma(\Theta^+) \sim 1$ MeV

Is the Θ^+ isosinglet ?

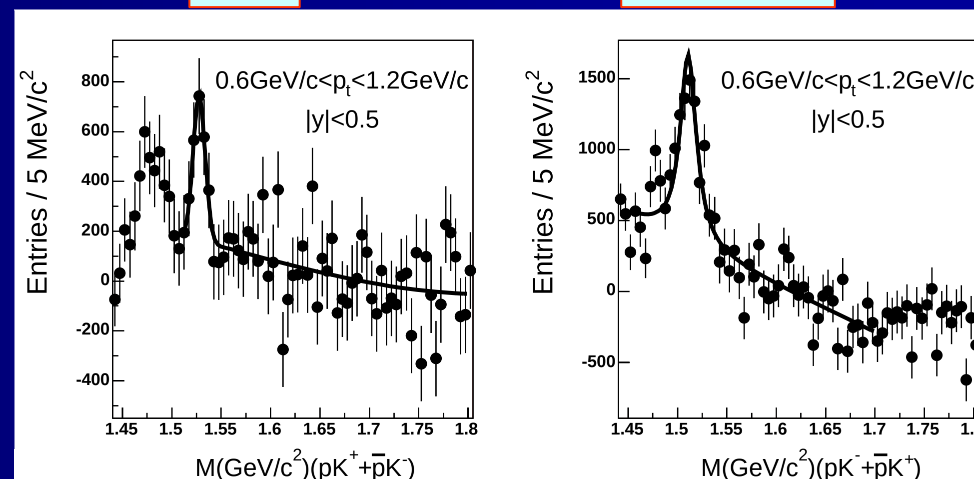
- g11 upper limit on the Θ^{++} width (Γ<75 keV) and the photoproduction cross section (σ<0.15 nb) would make the existence of such state highly unlikely
- Suppose that the Θ^+ width is of the order of 1 MeV that we would expect that Θ^{++} to be of the order of 1 MeV. Our result is incompatible with such a hypothesis.
- We conclude that either the Θ^+ has a remarkably small width or it must be isosinglet.

STAR – CLAS comparison

Θ^{++} $\Lambda(1520)$

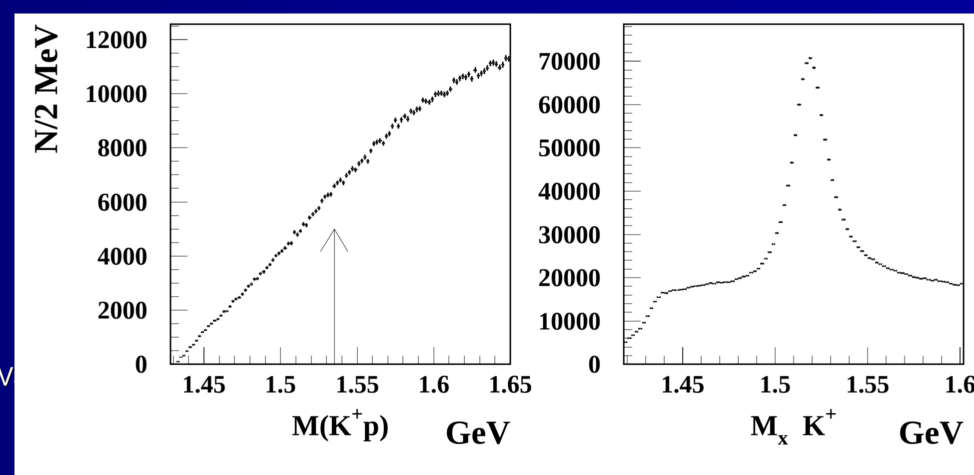
STAR:

$$\frac{\Theta^{++}}{\Lambda(1520)} = 0.4\%$$

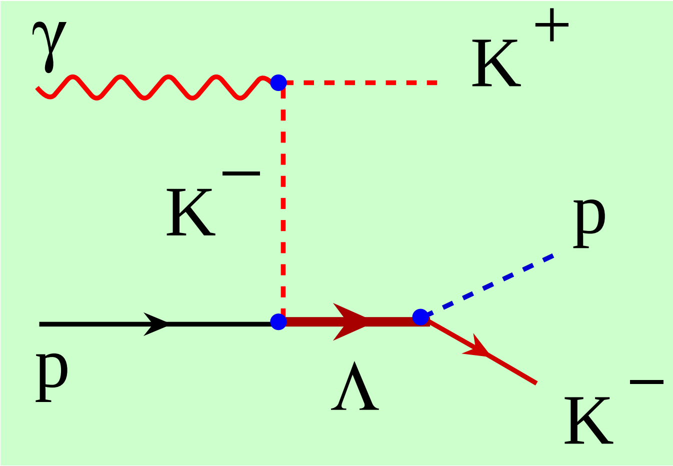


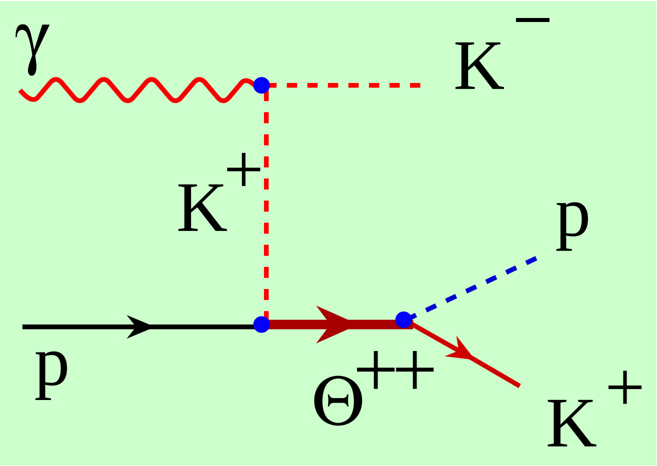
CLAS:

$$\frac{\Theta^{++}}{\Lambda(1520)} < 0.025\%$$



$\Lambda(1520)$ and Θ^{++} Production Mechanisms





Conclusion

- The reaction $\gamma p \rightarrow K^- K^+ p$ was studied at Jlab with photon energy 1.6-3.8 GeV to search for Θ^{++} state in the pK^+ decay mode
- No statistically significant evidence of Θ^{++} was found
- An upper limit $\sigma<0.15$ nb and $\Gamma<75$ keV (model dependent) at 95%CL were obtained for M=1.52-1.60 GeV
- $R=\Theta^{++}/\Lambda(1520) < 0.025\%$ @95%CL
- These low limits suggest that if the Θ^+ does exist it is isosinglet