

# Pentaquark '05

## Experimental Summary

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QuickTime™ and a  
TIFF (Uncompressed) decompressor  
are needed to see this picture.

Sunset...?

## Quotes about pentaquarks by distinguished Americans.

“...the reports of my death are exaggerated.”

...Mark Twain

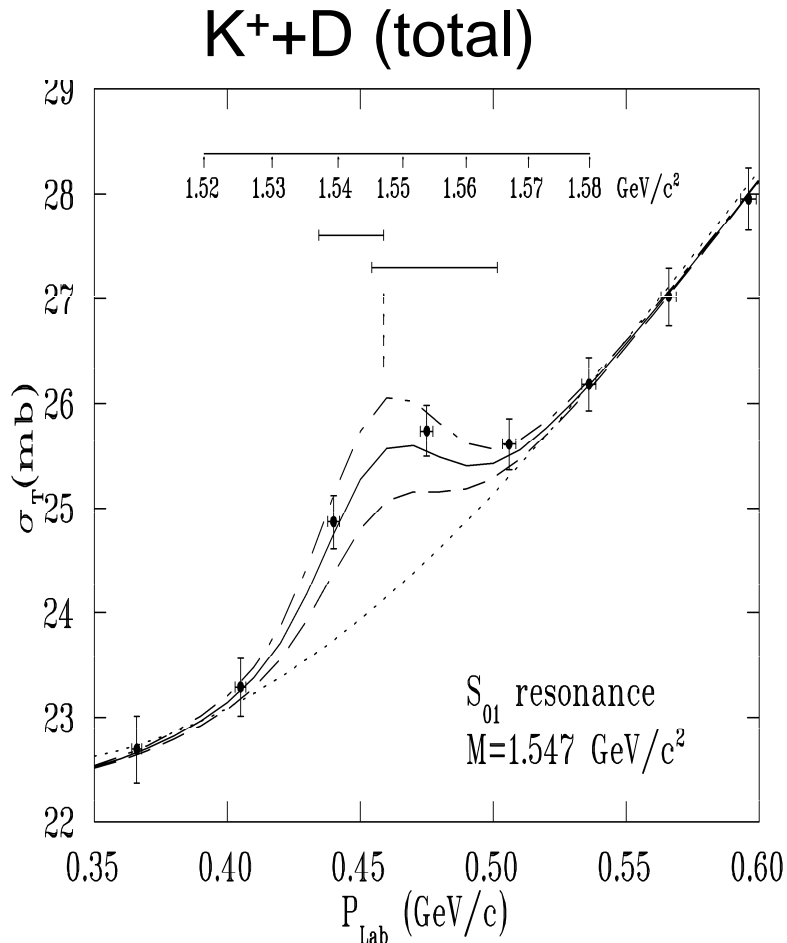
“It ain’t over ’till it’s over.”

...Yogi Berra

# Searches for $\Theta^+$

# Kaon Scattering

The most direct experiments for exciting pentaquarks would be with kaon beams for which there is a surprising dearth of data. The most cited positive signals are from Bowen et al (1970), which actually used kaon beams.

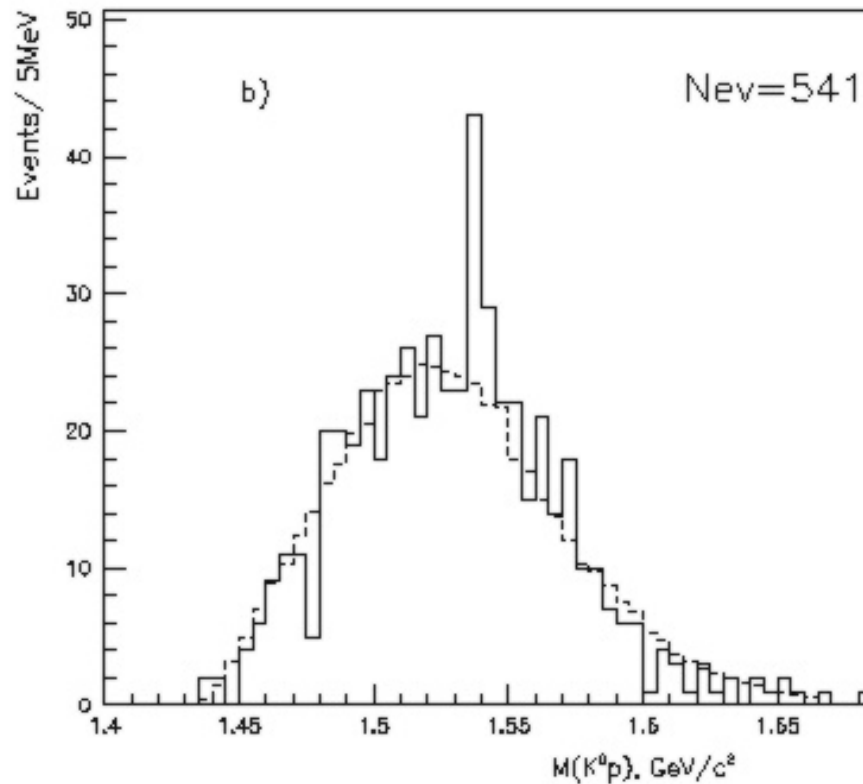


The consensus now is that the upper limit on the width is less than 1 MeV.

$$\Gamma_{\ominus} < 1 \text{ MeV}$$

# Kaon Scattering

## DIANA/ITEP



Secondary kaons produced in the detector materials and then interacting within bubble chamber.

# Belle

$$e^+e^- \rightarrow K^{+/-} X, \quad K^{+/-} A \rightarrow pK^0, pK^-$$

Low energy kaon scattering, observe  $pK_S$  pairs

Secondary kaons scattering with the rest of the detector structure.  
Dubbed "Detector Tomography"

Inclusive production upper limit

$$\frac{\sigma(KN \rightarrow \Theta(1540)^+ X)}{\sigma(KN \rightarrow \Lambda(1520) X)} < 2.5\% \text{ at the 90\% C.L.}$$

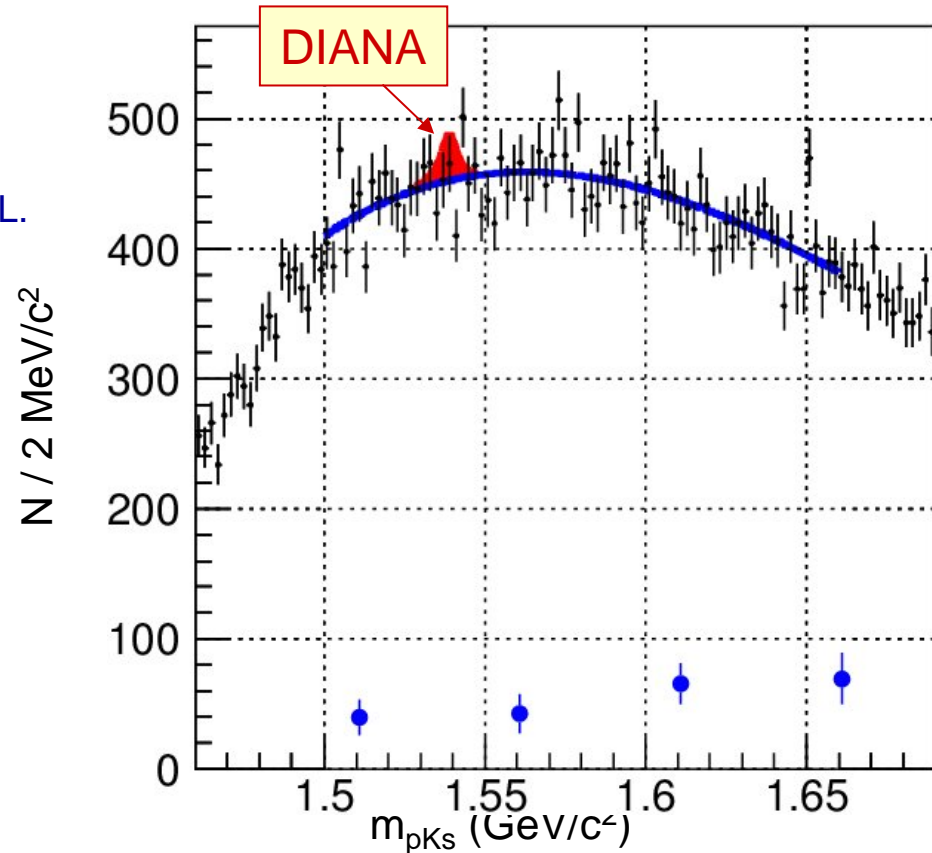
Exclusive production upper limits

$$\Gamma_{\Theta^+} < 0.64 \text{ MeV at the 90\% C.L.}$$

Similar sensitivity to DIANA;

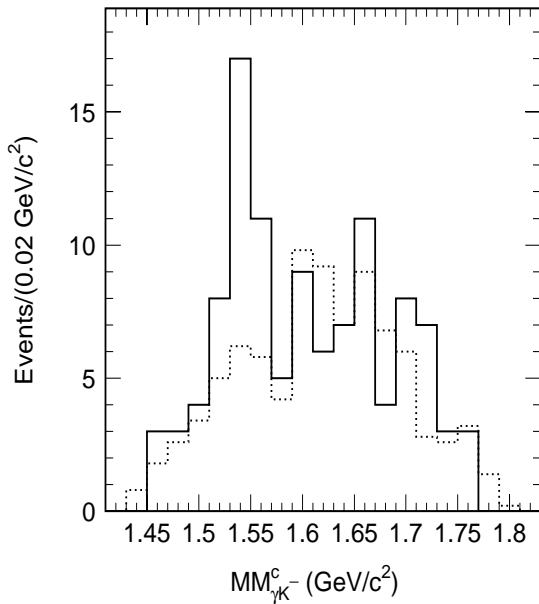
do not support their evidence.

$\Gamma_{\Theta^+} < 1.0 \text{ MeV}$  for wide range  
of possible  $\Theta^+$  masses.

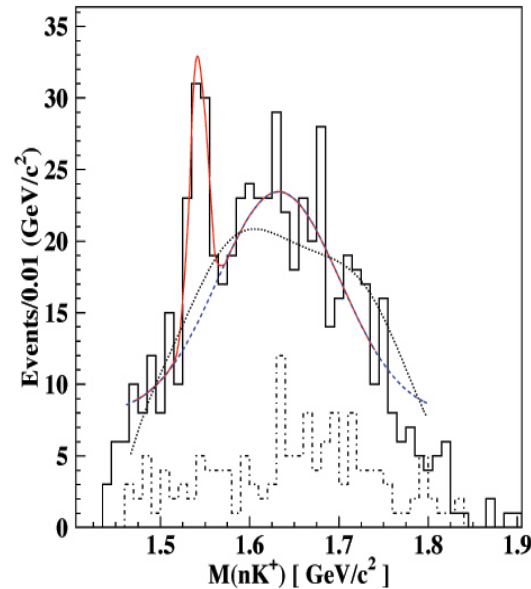


# Early Photon Experiments on neutron targets (deuterons)

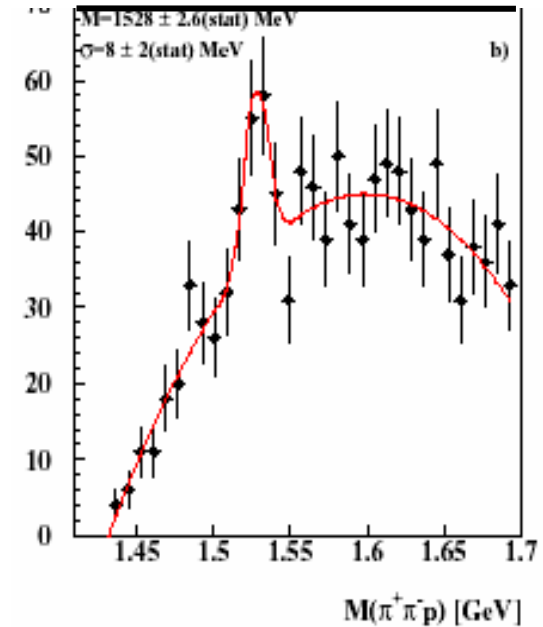
*Spring8*



*JLab*



*HERMES*

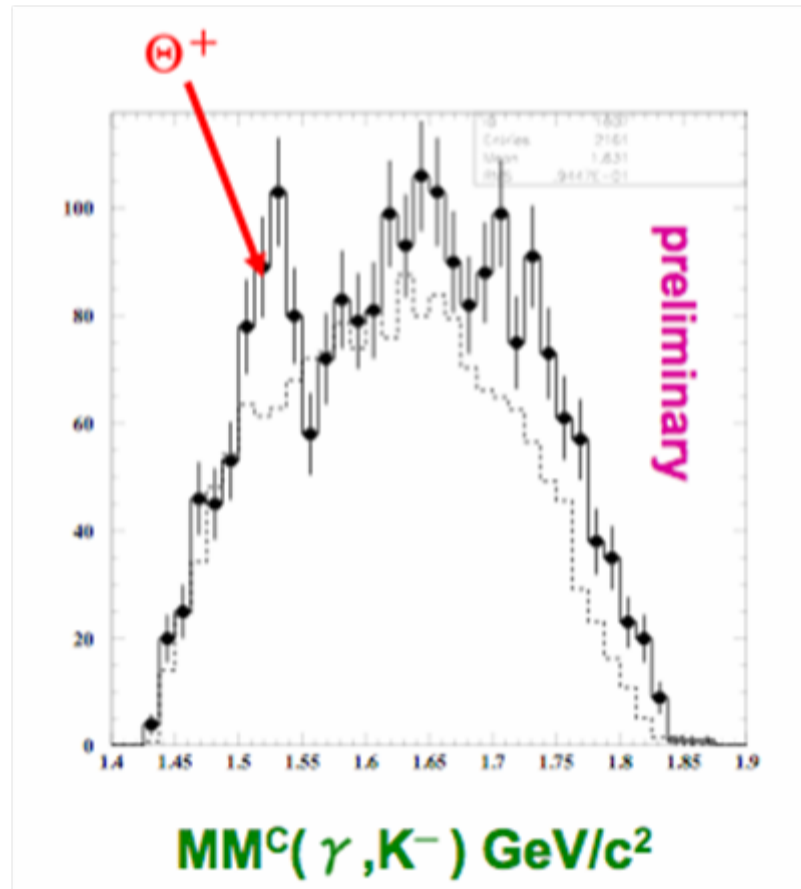


What is new since then?



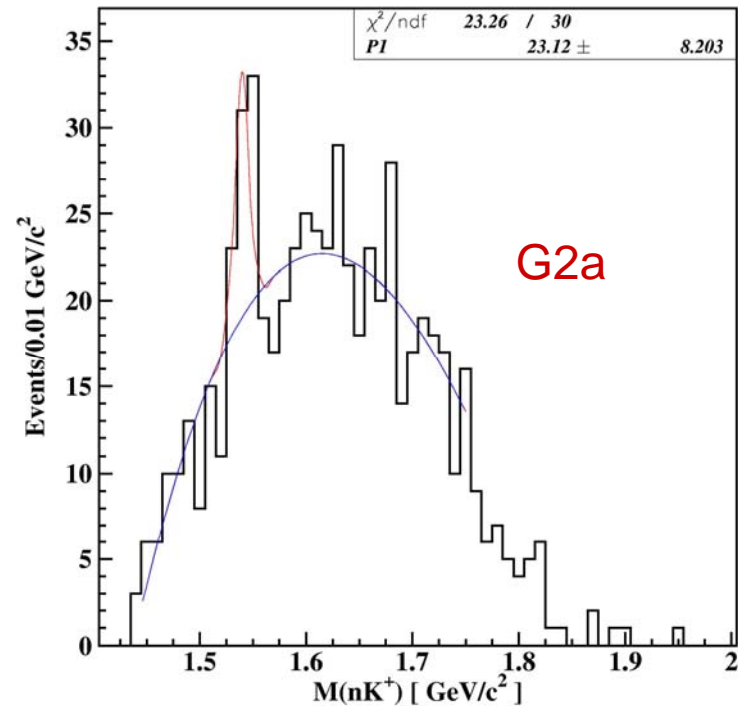
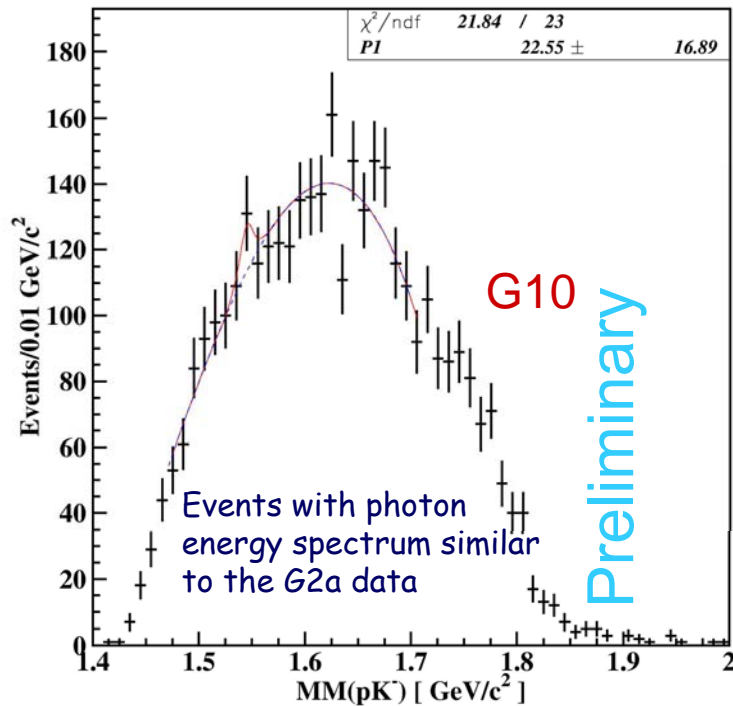
# LEPS

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



# JLab g10

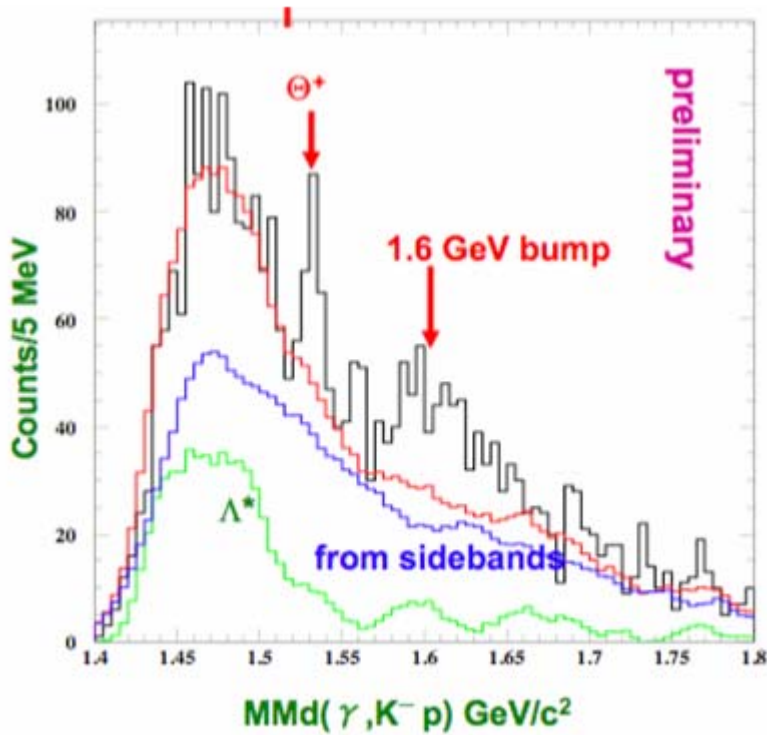
Repeated original experiment with  
order of magnitude greater statistics.



(Model dependent cross section upper limit for the  $\gamma d \rightarrow pK^- \Theta^+$ )

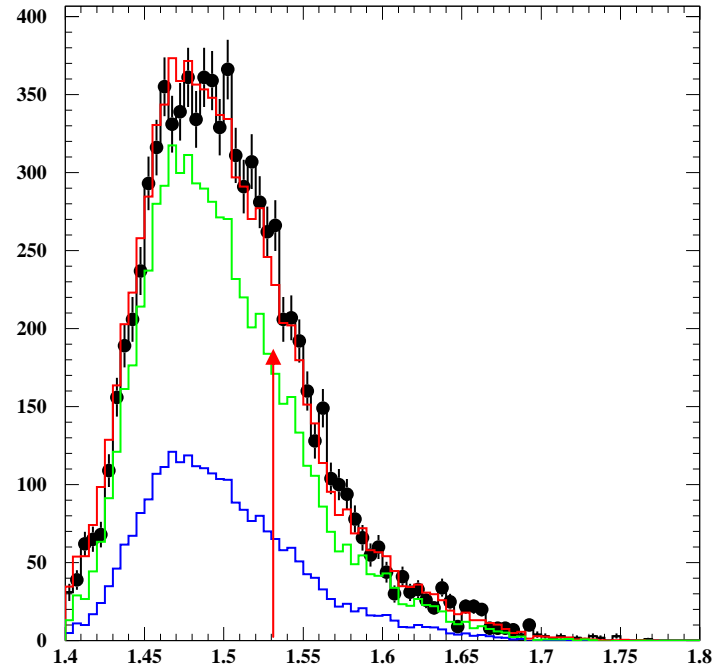
# LEPS

$$\gamma d \rightarrow \Theta^+ \Lambda^*(1520)$$



$\sim 5 \sigma$  excess near  $1.53 \text{ GeV}^2/c^2$

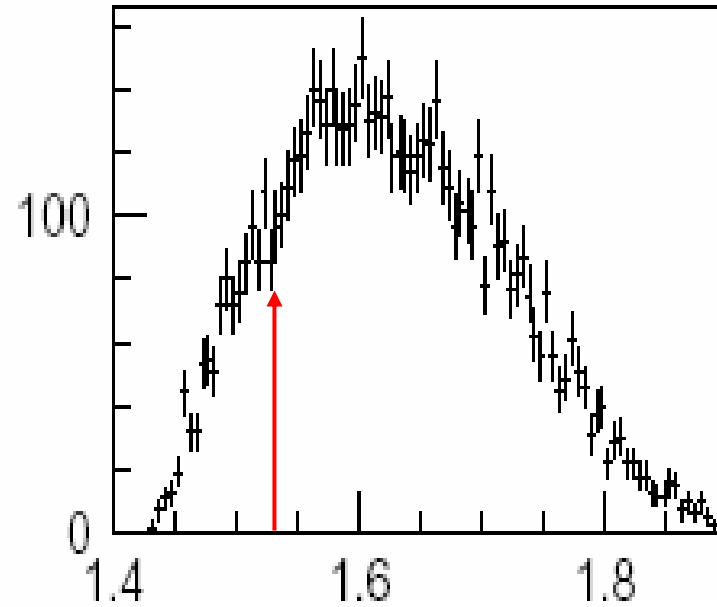
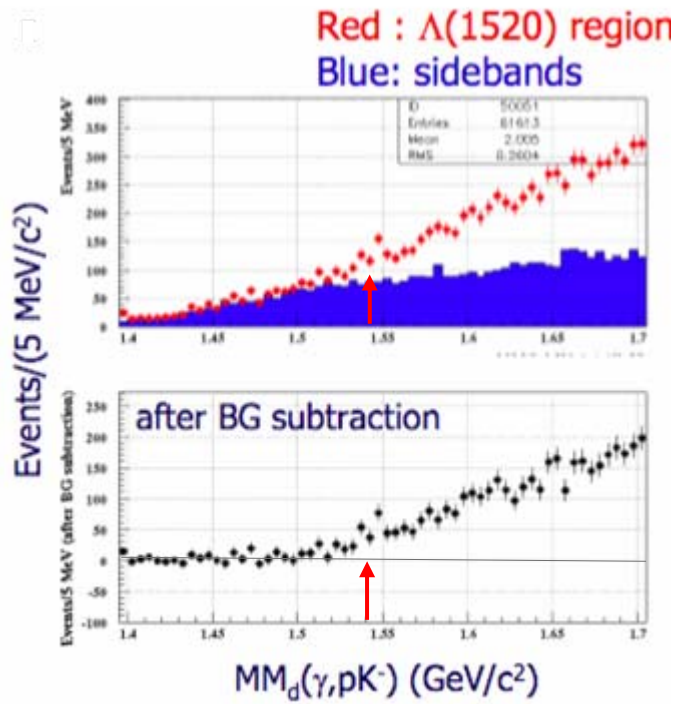
$$\gamma d \rightarrow \Theta^+ \Lambda(1116)$$



No excess near  $1.53 \text{ GeV}^2/c^2$

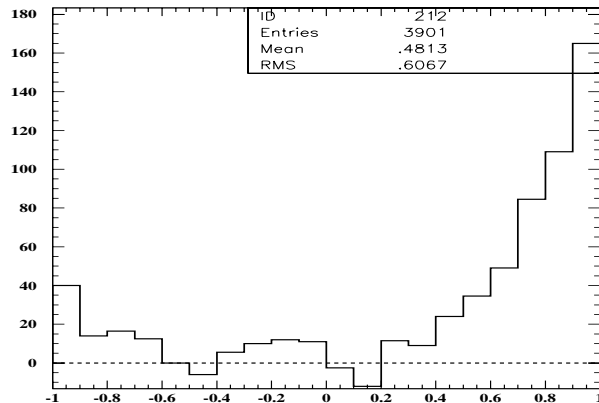
$$\gamma d \rightarrow \Theta^+ \Lambda^*(1520)$$

$$\gamma d \rightarrow \Theta^+ \Lambda(1116)$$

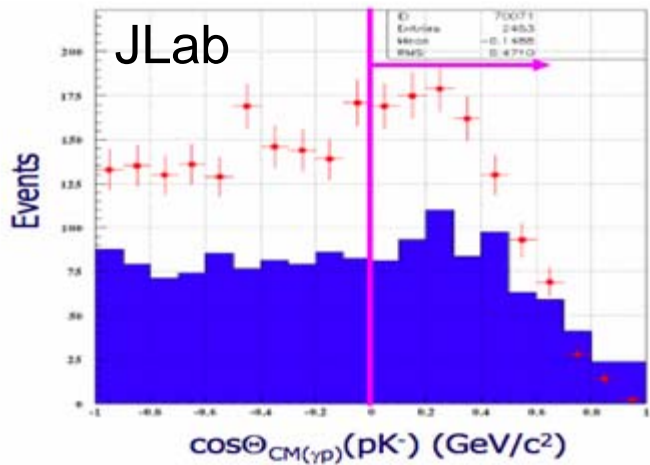


# $\Lambda(1520)$ angular distribution

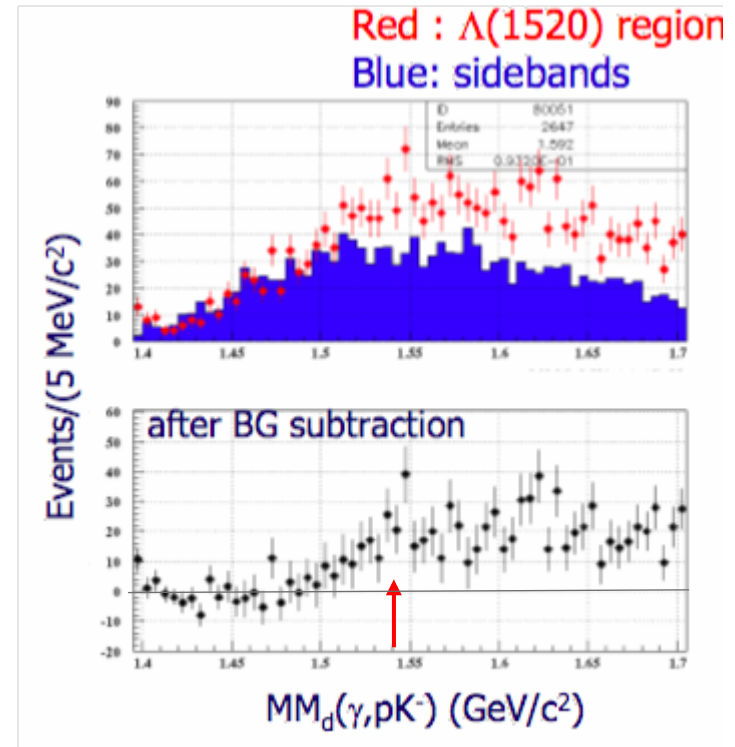
LEPS



$\text{Cos } \Theta_{Kp}$  in CMS

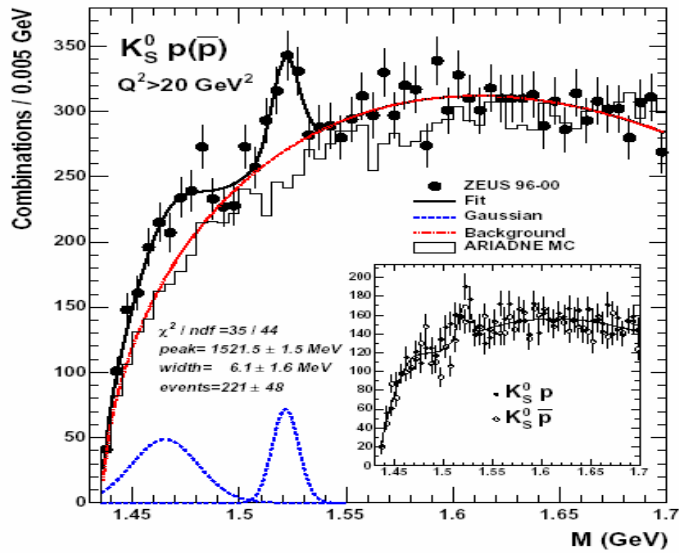


Cut at  $\text{cos } \theta > 0$



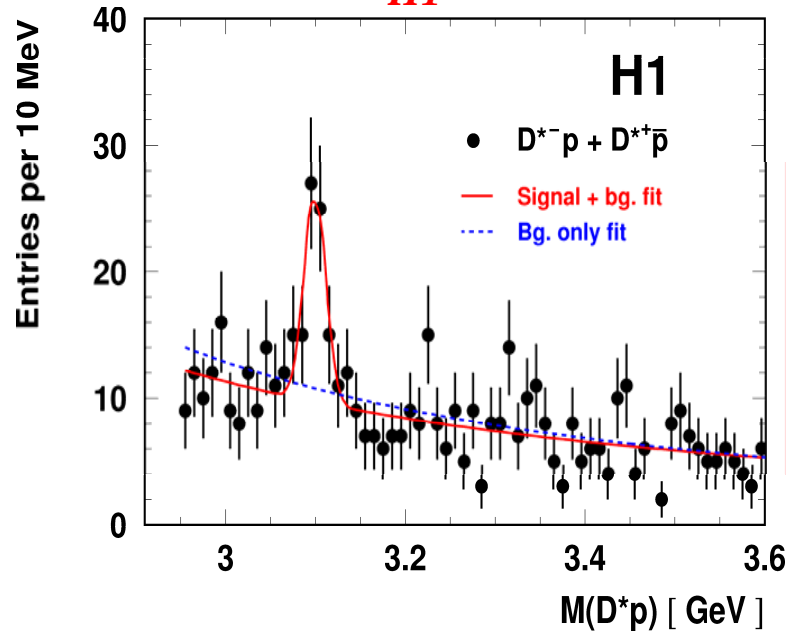
# HERA

**ZEUS**



Zeus doesn't see  $\Theta_c$

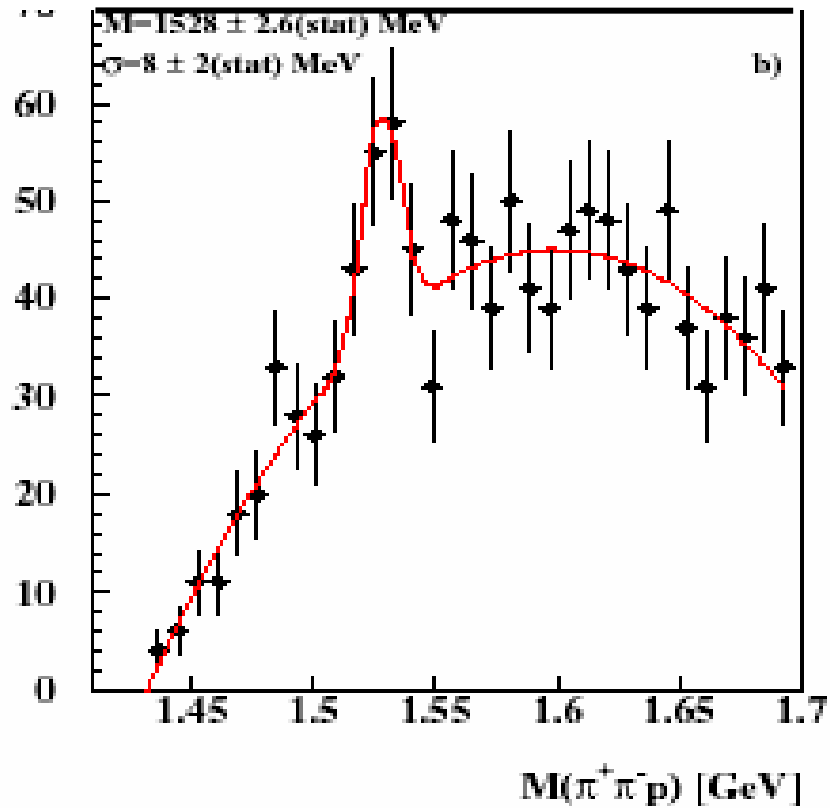
**H1**



H1 doesn't see  $\Theta^+$

# HERMES

$$e^+d \rightarrow K_S^0 p + X$$



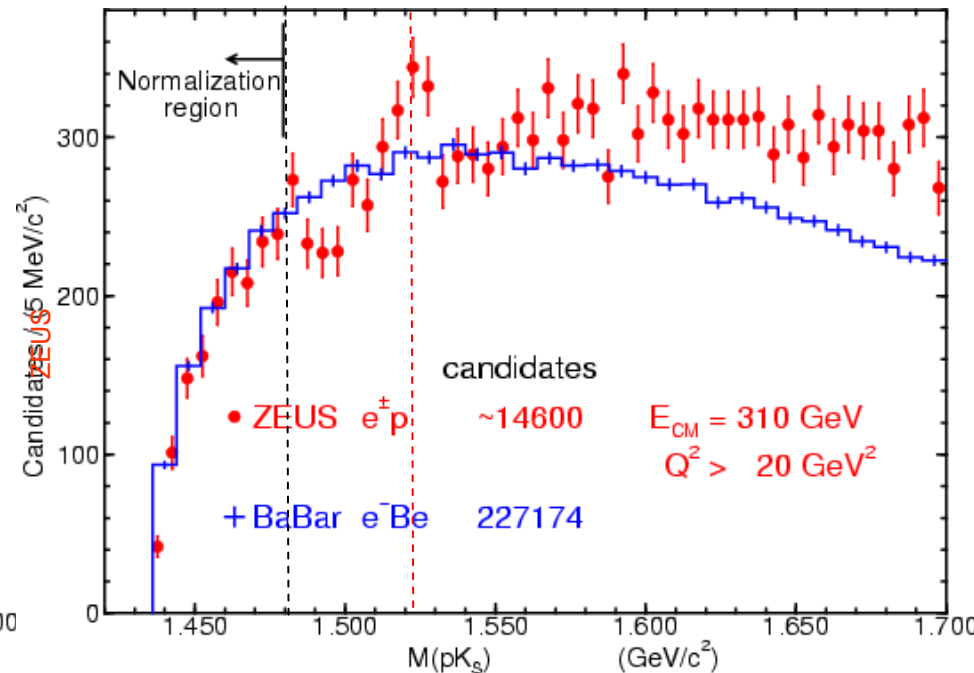
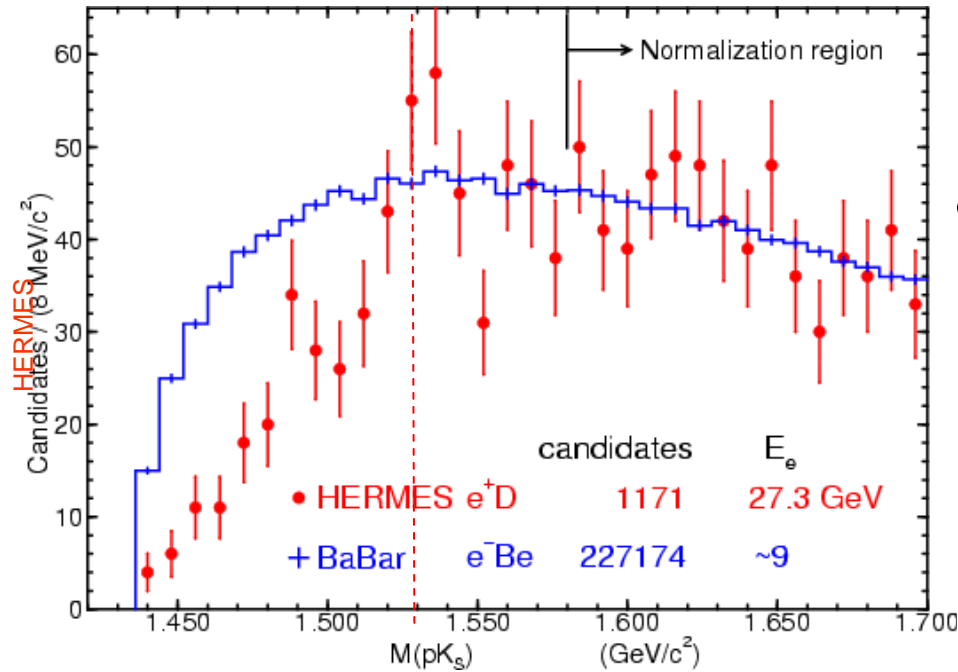
5 times more statistics expected in new run.

# BaBar

Electron and scattering from beam pipe - e-Be

Comparison with  
HERMES ( $e^+d \rightarrow K_S^0 p + X$ )

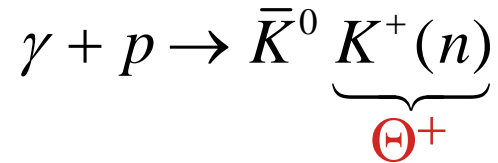
Comparison with  
ZEUS ( $e^-p \rightarrow e^- K_S^0 p + X$ )



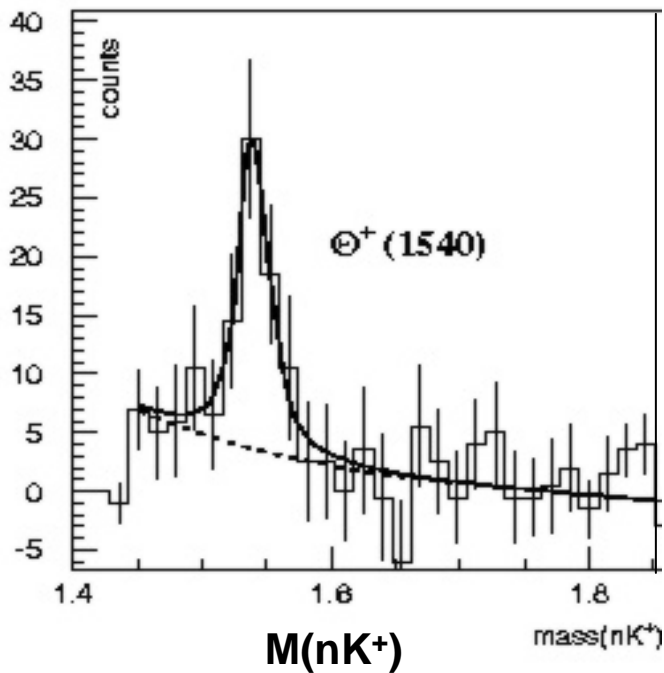
BaBar disagrees with both HERMES and Zeus



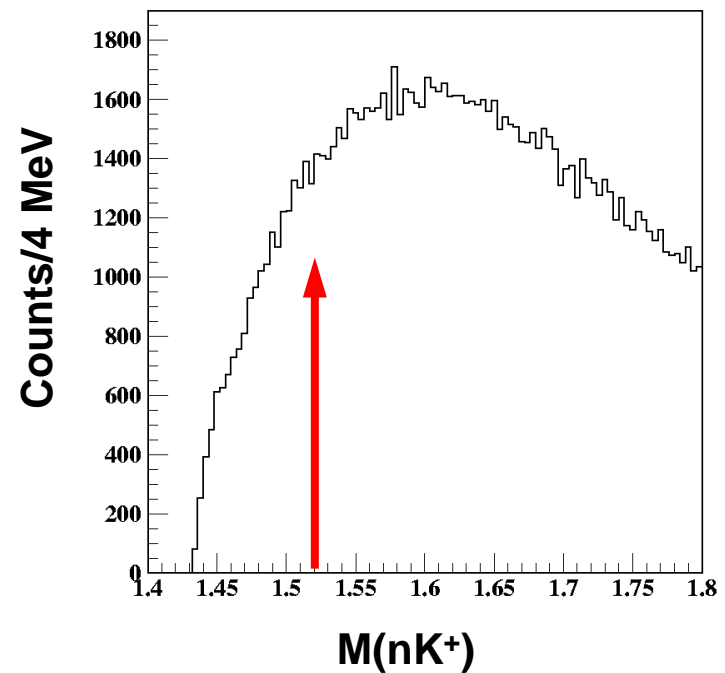
# Photoproduction on protons



ELSA

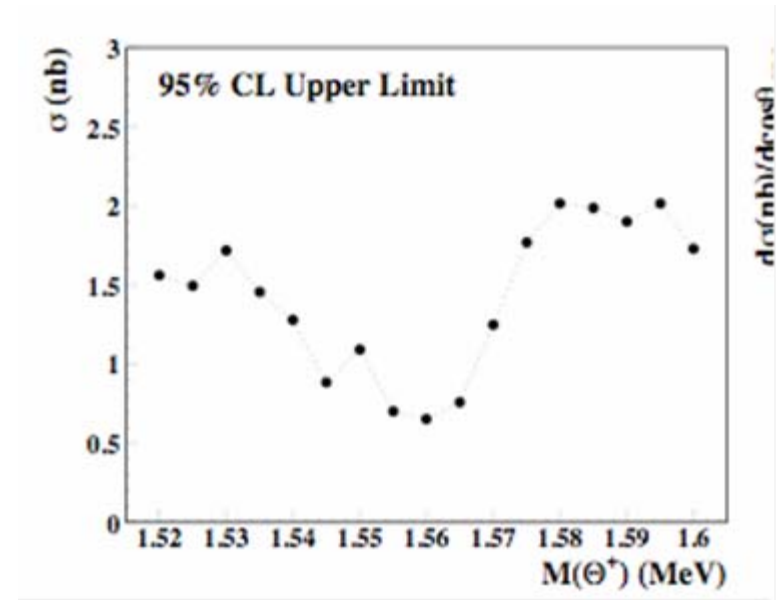
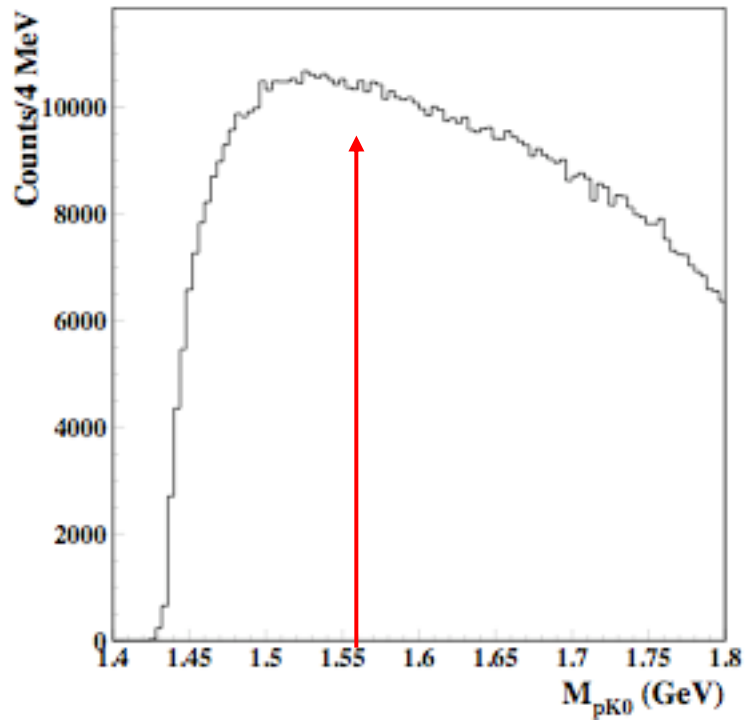
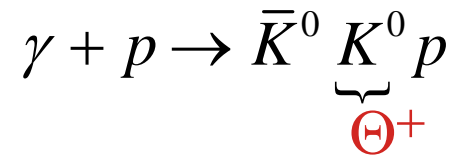


JLAB

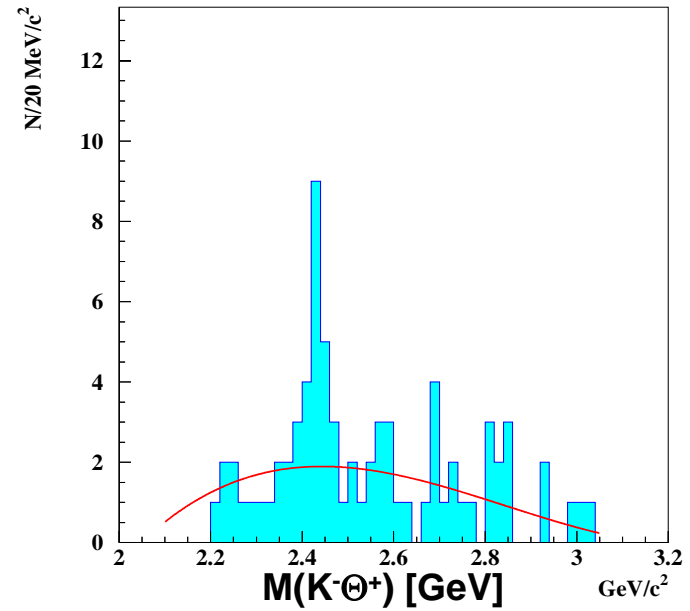
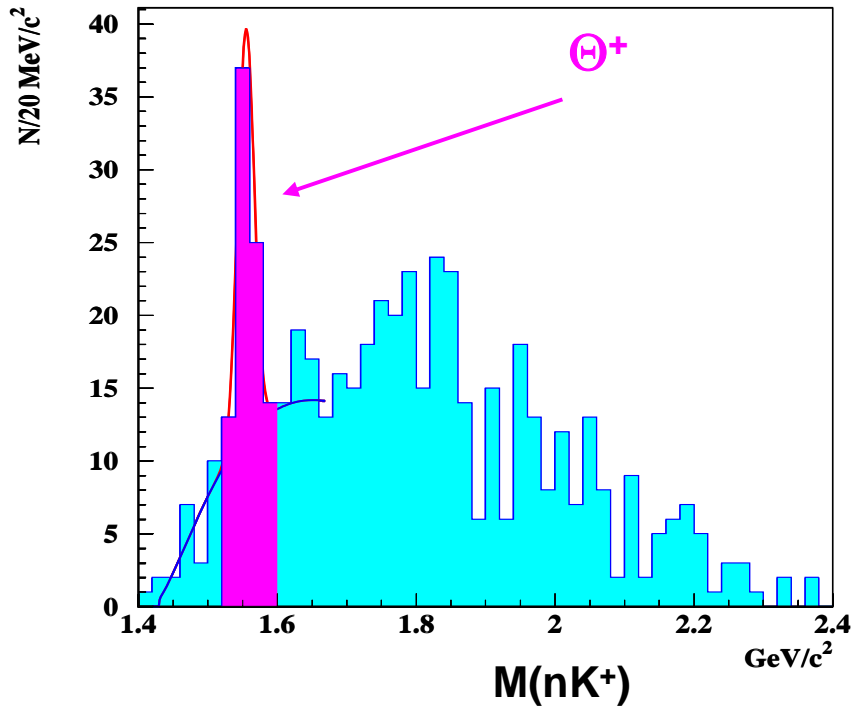


$$\sigma_{\gamma p \rightarrow \Theta^+ \bar{K}^0} < 2 \text{ nb}$$

# CLAS g11



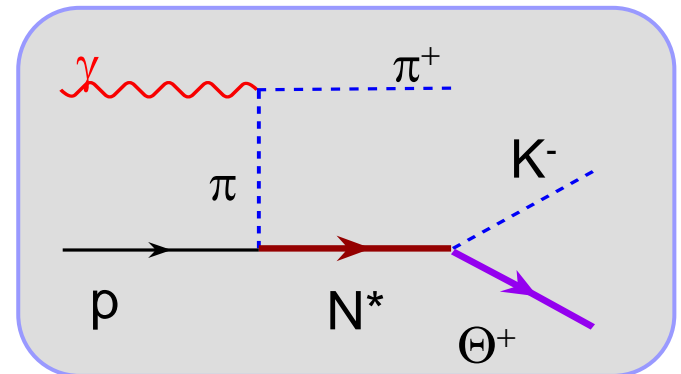
# CLAS $\gamma p \rightarrow \pi^+ k^- k^+ (n) \rightarrow \pi^+ k^- \Theta^+$



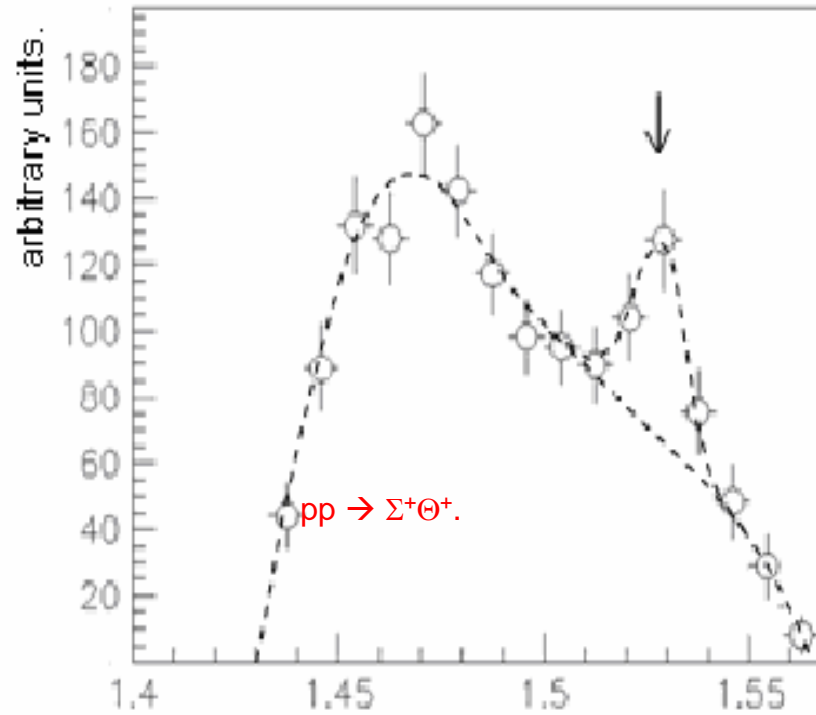
$$E_\gamma = 4.8 - 5.6 \text{ GeV}$$

$$\cos(\theta_\pi^*) > 0.8$$

Will be run with order of magnitude  
More statistics.



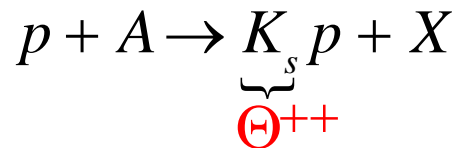
# COSY-TOF



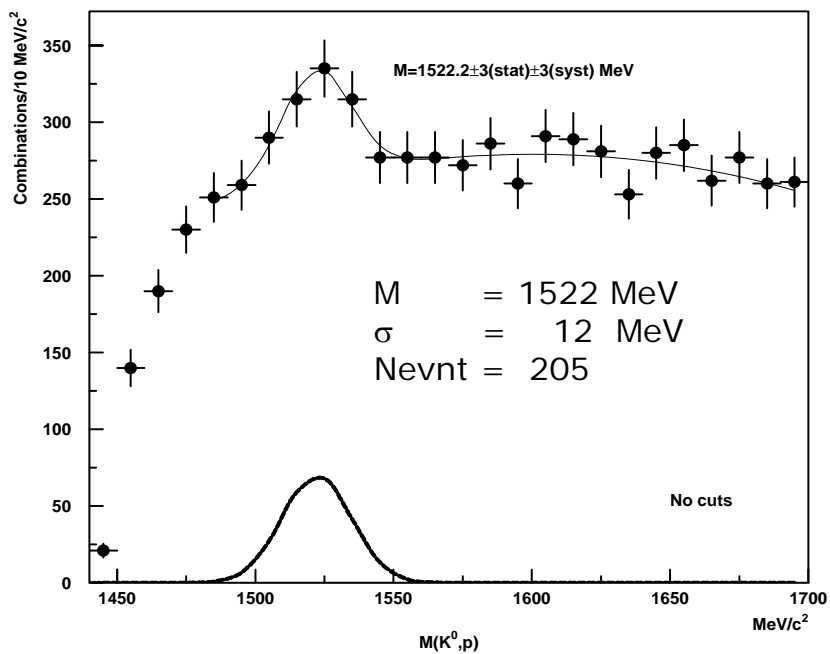
5 times more data (to appear soon)

# SVD-2

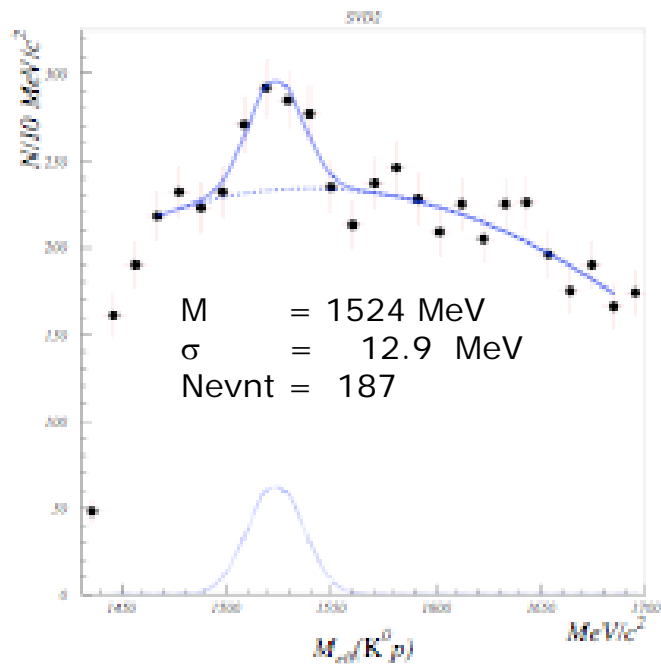
## New Analysis



2 independent data sets for  $K_s$  decay inside and outside their vertex detector.



$K_s$  decay inside vertex detector



$K_s$  decay outside vertex detector

Signal improves by factor 8.

# Searches for $\Theta^{++}$

# JLAB Hall A

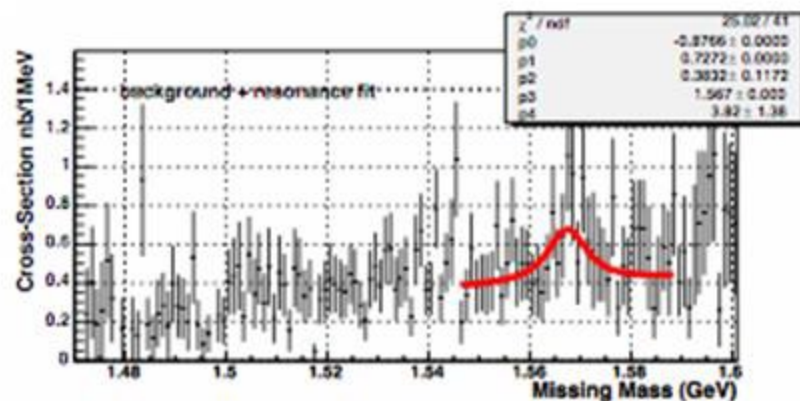
## $H(e, e' K^+) X$

### High resolution Hall A

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

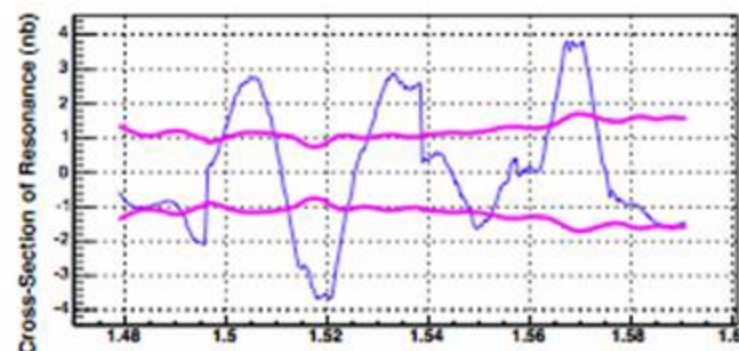
$$p(e, e' K^-) \Theta^{++} \quad M(\Theta^{++}) = 1500-1600 \text{ MeV}$$

$$p(e, e' \pi^+) N^0 \quad M(N^0) = 1600-1830 \text{ MeV}$$

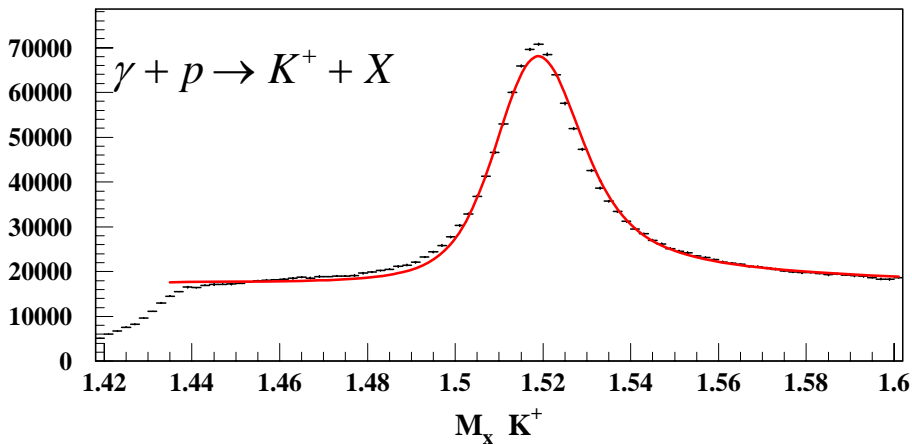
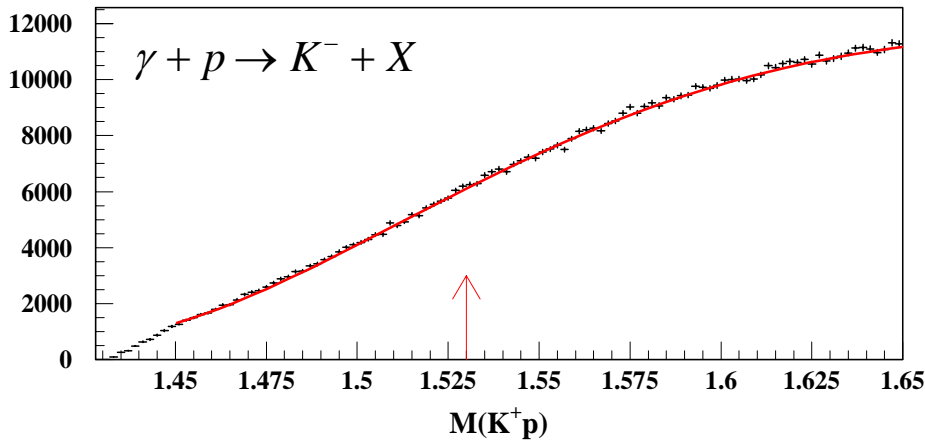
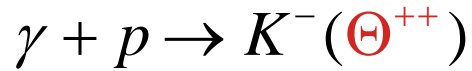


Upper limit for  $\Theta^{++}$

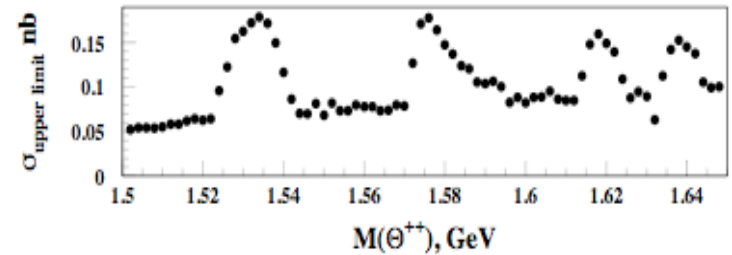
< 1nb (in narrow kinematics)



# Jlab. CLAS exp g11



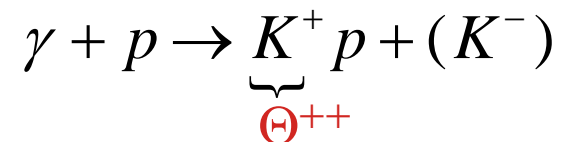
Cross section upper limit



$$\sigma_{(95)} < 0.15 \text{ nb}$$

$$\Gamma < 100 \text{ KeV}$$

Also studied

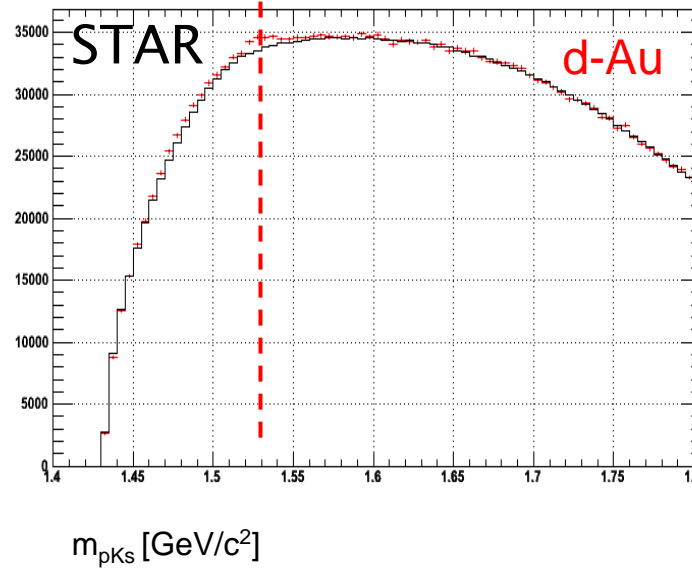
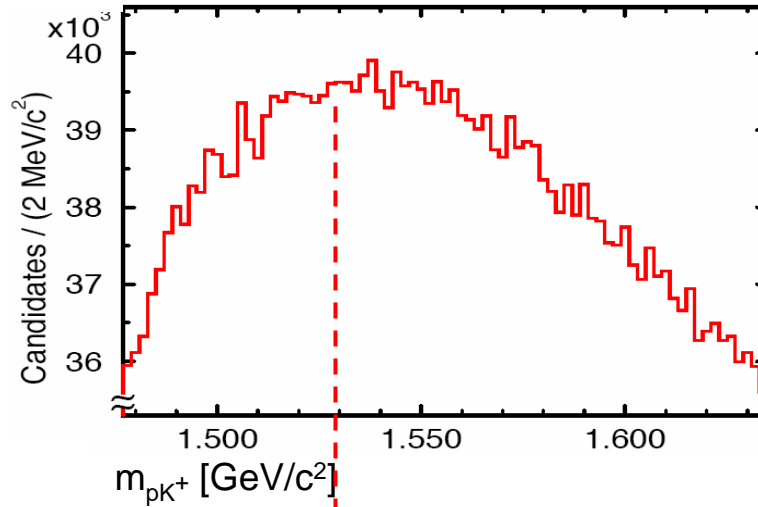




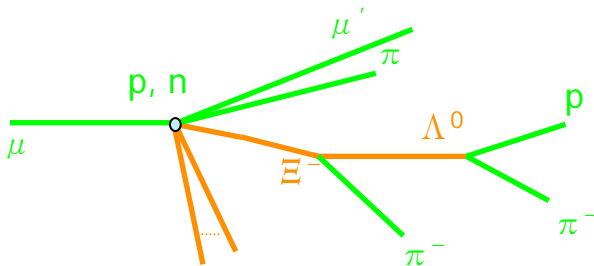


*BaBar*

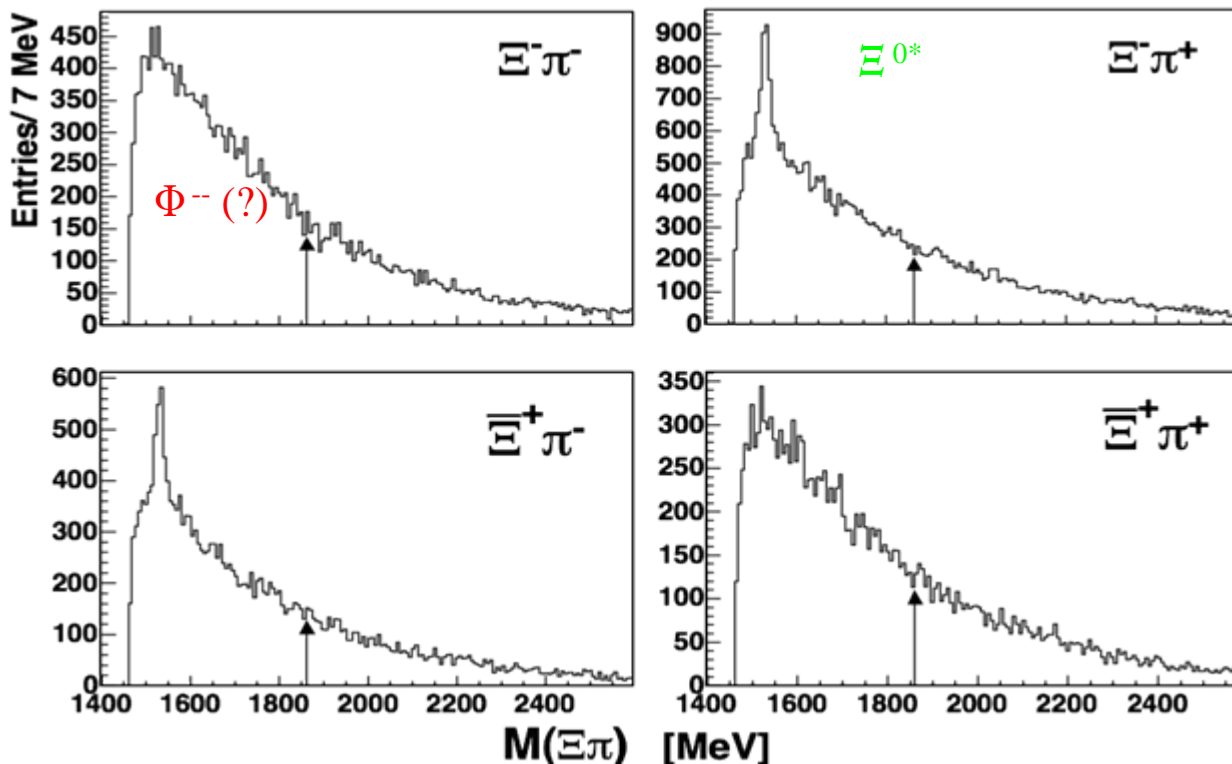
e+Be



# $\Xi_5$ searches



# COMPASS



No other lab has been able to reproduce NA(49)

New results expected from Jlab eg3 and g12

# Fermi Lab

CDF, SELEX, FOCUS, HYPERCP, E690, E791...

- High energy inclusive experiments.
- Huge body of impressive data. Lots of statistics.
- No sign of any exotic:  $\Theta^+$ ,  $\Theta^{++}$ ,  $\Theta^0_c$ ,  $\Xi_5^{--}$ , etc.
- Upper limits typically  $<1\%$  of normal states.

But:

- Lots of combinatoric backgrounds.
- With 5 quarks one might expect the signals to have even smaller relative cross sections compared to “normal” baryons.

## At this point what can we say?

- The situation cannot be put into *any neat package*.
- New very high quality exclusive experiments from CLAS have repeated earlier experiments at ELSA and CLAS, and contradicted earlier positive observations.
- There have been new positive reports from SVD and LEPS.
- Beyond that there is a lot of overwhelming negative evidence which appear to push the observed pentaquark signals into narrower corners.

# Prognosis

Many large scale experiments, with both positive and negative signals, are part of large experiments. Given the current plans vis-à-vis Fermi Lab, HERA, BaBar, COMPASS they probably will not be repeated or tested with large increases in statistics.

Still, there are a considerable number of plans to repeat earlier experiments with large increases in statistics.

Examples are:

- LEPS
- HERMES
- JLAB eg3
- JLAB g12
- Jlab Hall A
- COSY
- Zeus

Thus, we can expect new definitive results for several more years.

## Further quotes about pentaquarks by distinguished Americans.

“The  $\Theta$  pentaquark is not in good health, but it is still alive”

...Volker Burkert, Milos '05

“The vital signs are even weaker now, but ....”

...PS Pentaquark '05



# Pentaquark Vital Signs

