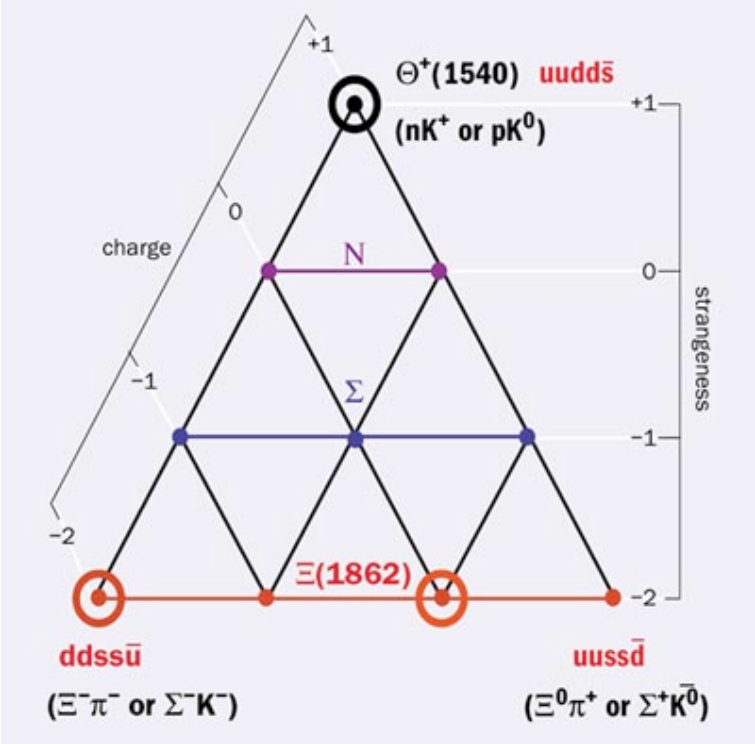
Strange Pentaquark Search with ZEUS

Zhenhai Ren (Columbia University)
for the ZEUS Collaboration

- Introduction
- × Ξ^{--} in $\Xi^{-}\pi^{-}$
- ✓ $\Theta^{+} \rightarrow K^{0}_{s}P$
- Some recent studies
- Conclusions



Introduction – Experimental Overview

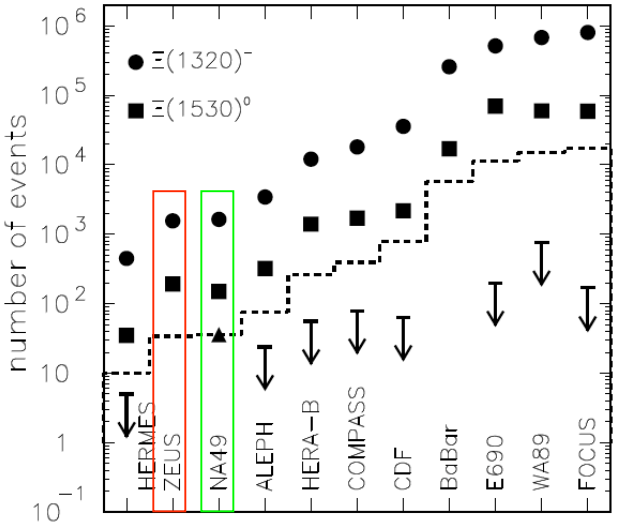
Θ^+ positive results

Group	Reaction	Mass (MeV)	Width (MeV)	σ's*
LEPS	$\gamma C \to K^+K^-X$	1540 ± 10	< 25	4.6
DIANA	$K^+Xe \to K^0pX$	1539 ± 2	< 9	4.4
CLAS	$\gamma d \to K^+K^-p(n)$	1542 ± 5	< 21	$5.2 \pm 0.6^\dagger$
SAPHIR	$\gamma d \to K^+K^0(n)$	1540 ± 6	< 25	4.8
ITEP	$\nu A \to K^0pX$	1533 ± 5	< 20	6.7
CLAS	$\gamma p \to \pi^+K^+K^-(n)$	1555 ± 10	< 26	7.8
HERMES	$e^+d \to K^0pX$	1526 ± 3	13 ± 9	~ 5
ZEUS	$e^+p \to e^+K^0pX$	1522 ± 3	8 ± 4	~ 5
COSY-TOF	$pp \to K^0p\Sigma^+$	1530 ± 5	< 18	4-6
SVD	$pA \to K^0pX$	1526 ± 5	< 24	5.6

Θ^+ negative results

Group	Reaction	Limit	Sensitivity?
BES	$e^+e^- \to J/\Psi \to \Theta\Theta$	$< 1.1 \times 10^{-5}$ B.R.	No*
Belle	$e^+e^- \to \bar{B}^0B^0 \to \bar{p}pK^0$	$< 2.3 \times 10^{-7}$ B.R.	Θ^{++}
BaBar	$e^+e^- \to \Upsilon(4S) \to pK^0X$	$< 1.0 \times 10^{-4}$ B.R.	??
HERA-B	$pA \to K^0pX$	$< 0.02 \times \Lambda^*$	No?
CDF	$p\bar{p} \to K^0pX$	$< 0.03 \times \Lambda^*$	No?
PHENIX	$Au + Au \to K^-\bar{n}X$	(not given)	??

Ξ^{--} results

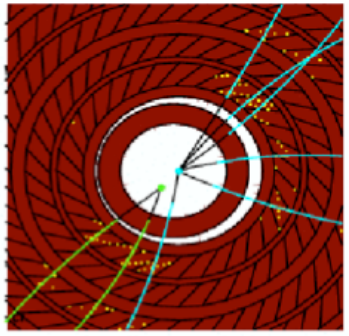


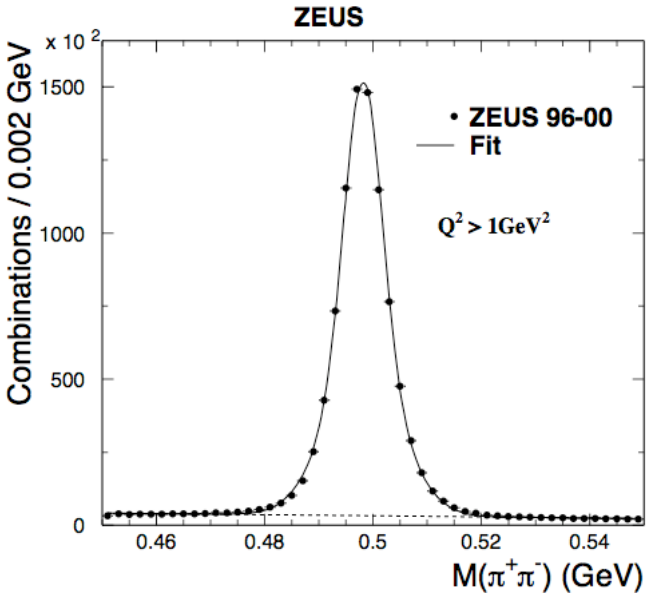
Goal of new ZEUS studies

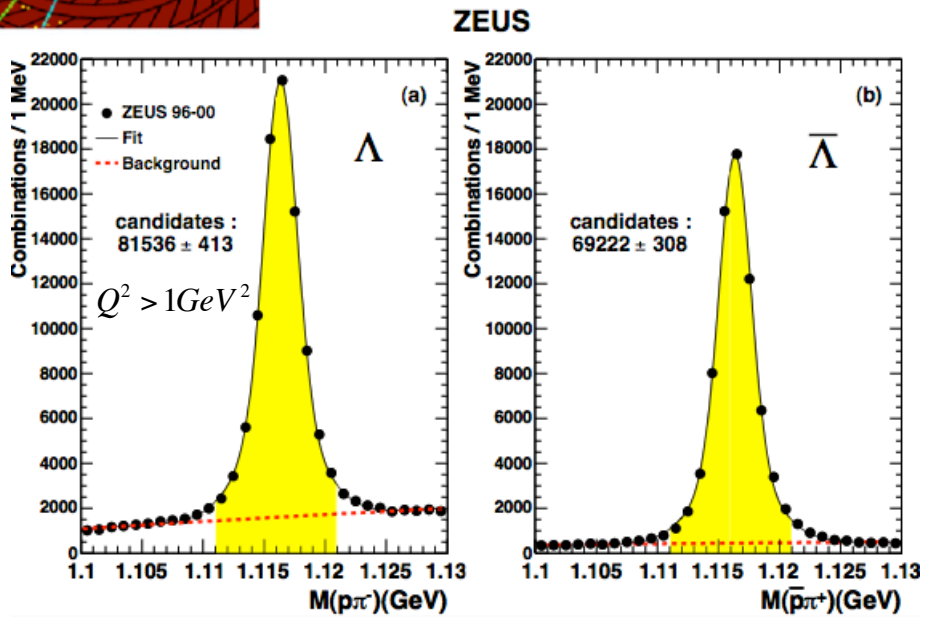
- Look at various kinematics regions
  - Understand the production mechanism?
- check statistical sensitivity to established states

K^0_s & Λ selection

- Data sample $\Rightarrow$ 121pb^{-1}
  - DIS : $Q^2 > 1$, 20 GeV^2
  - Photo production (PHP) : $Q^2 < 1$ GeV^2
- Selected by requiring displaced vertex with neutral charge — V0
- Clean signal with high statistics:
  - K^0_s
    - DIS : ~870K
    - PHP : ~4,400K
  - $\Lambda(\overline{\Lambda})$
    - DIS : ~81K(69K)
    - PHP : ~450K(380K)

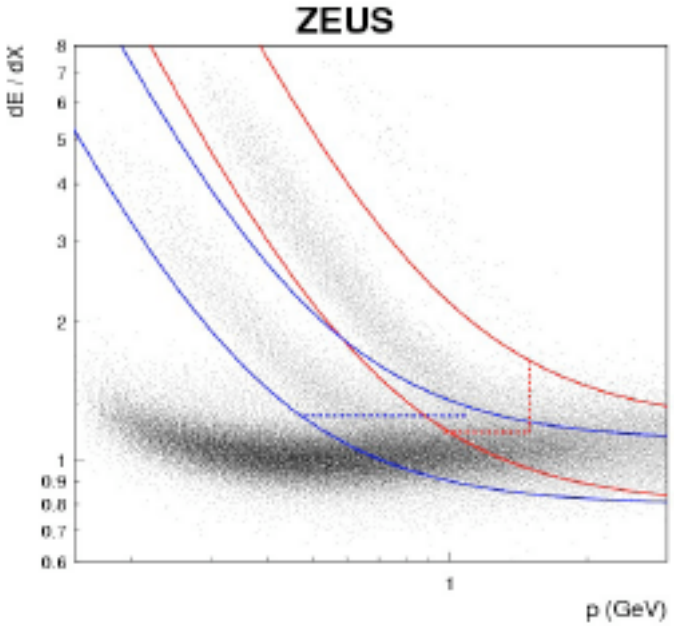






Particle identification using dE/dx

dE/dx – energy loss due to ionization measured by CTD



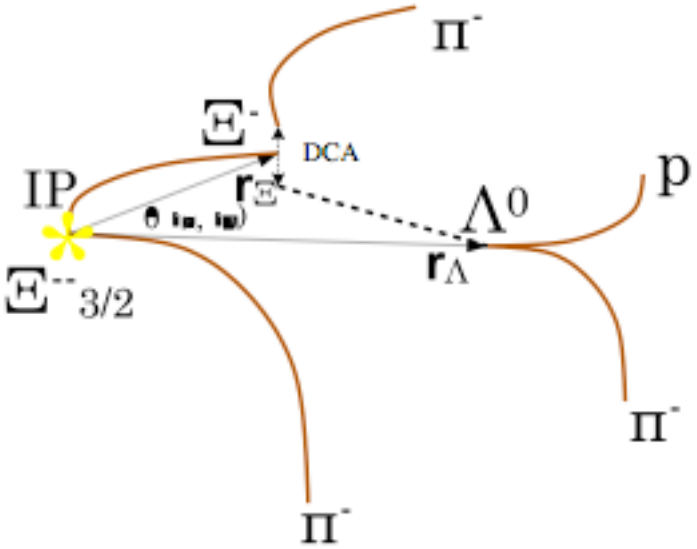
Band cut motivated by Bethe-Bloch equation

- Proton
  - Inside red band
  - dE/dx > 1.15 mips
  - P < 1.5 GeV
- $K^{\pm}$ meson
  - Inside blue band
  - dE/dx > 1.25 mips
- Pions
  - All tracks excluding proton & $K^{\pm}$ meson

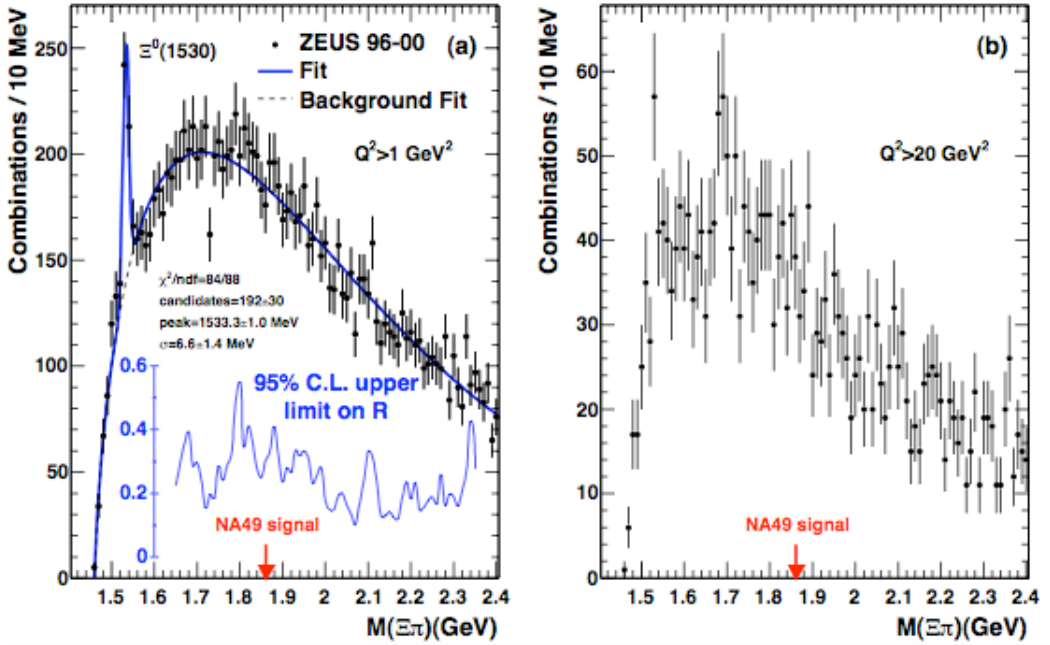
For proton and $K^{\pm}$ meson

- Relatively high purity, ~60%
- Phase space limited by cutting on track momentum

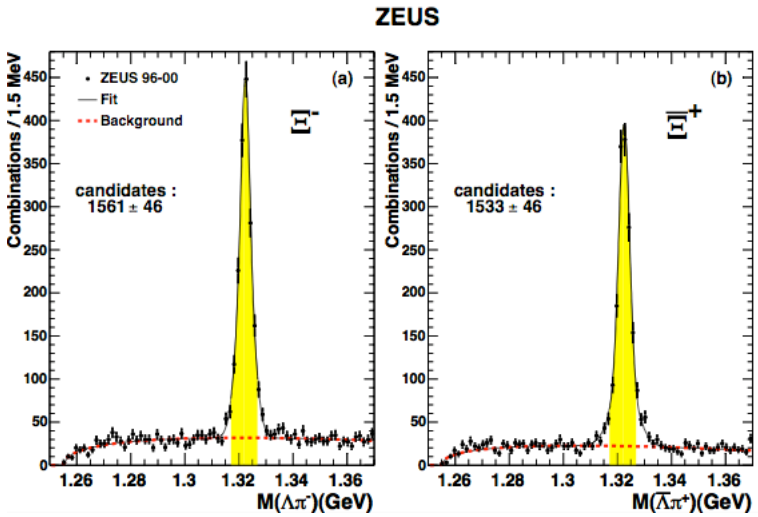
Non-observation of $\Xi^{--}(1860)$



ZEUS



ZEUS



- Both plots include all the 4 Ξ π combinations
- ✓ A known state $\Xi^0(1530)$ clearly observed
- × No signal found around the mass region where NA49 saw a signal
- 95% C.L. upper limits on

$$R = \frac{N_{\Xi^{--}}}{N_{\Xi^0}(1530)}$$

in mass range 1650-2350 MeV

  - Most of the acceptance effect largely cancel in the ratio

Observation of Θ^+

ZEUS Collaboration; S. Chekanov et al.
Physics Letters B 591 (2004) 7-22

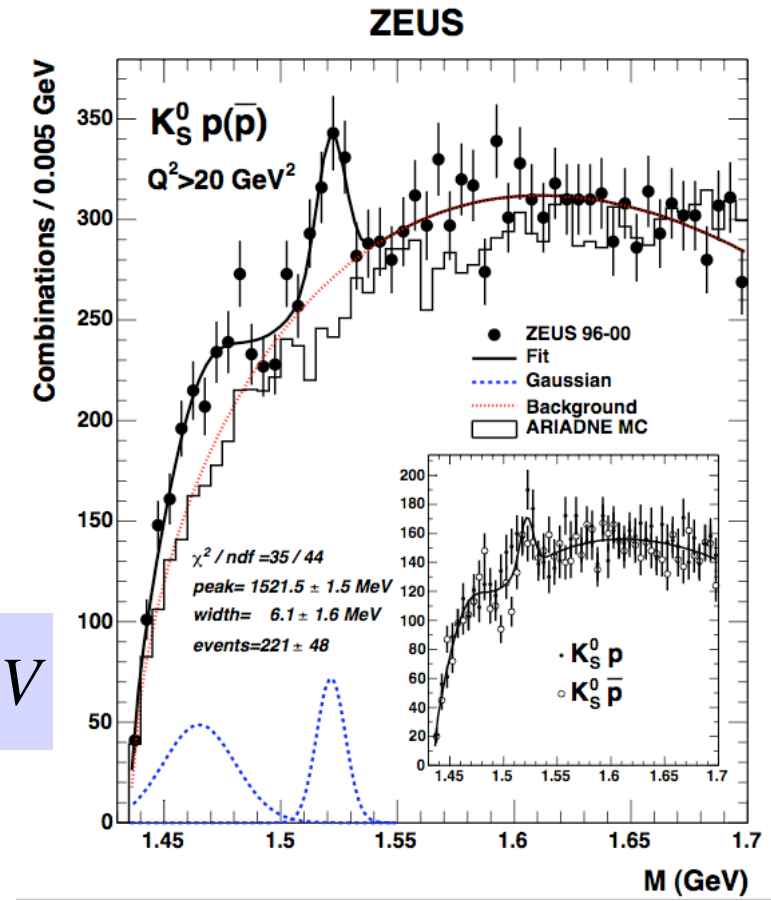
- Kinematics range

$$Q^2 > 20 GeV^2$$
$$P_T(\Theta^+) > 0.5 GeV, |\eta(\Theta^+)| < 1.5$$

- A signal with ~4.6 σ statistical significance was observed at

$$M = 1521.5 \pm 1.5(stat)^{+2.8}_{-1.7}(syst) MeV$$

- Gaussian width 6.1±1.5 MeV (experimental resolution ~2 MeV)

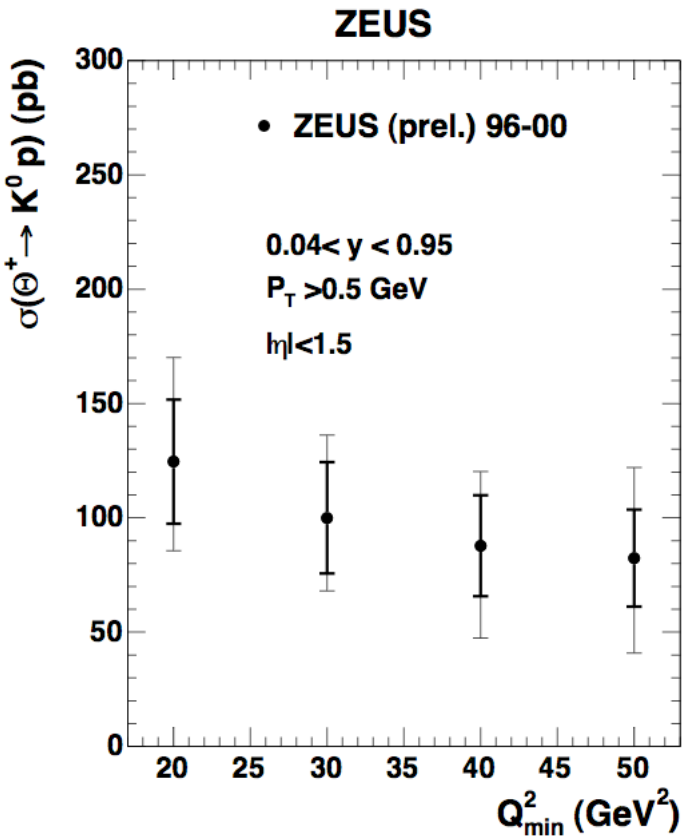


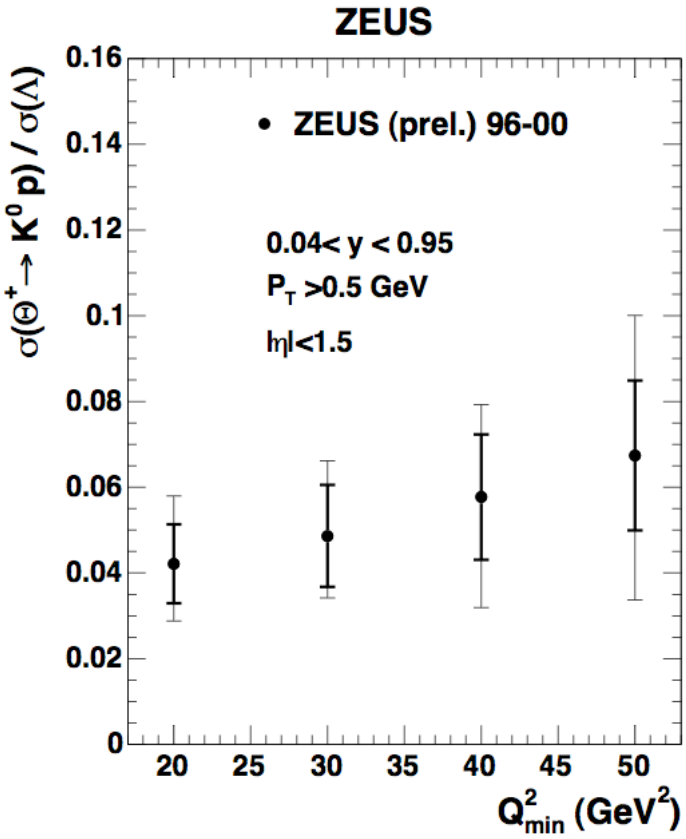
Main goal of new studies ⇨

- Why only at Q^2>20 GeV^2?
- Another Σ state?
- What is statistical sensitivity compared to other experiments?

Θ^+ cross sections and ratios ($\Theta^+ \to K^0 p$ / $\Lambda \to p\pi$)

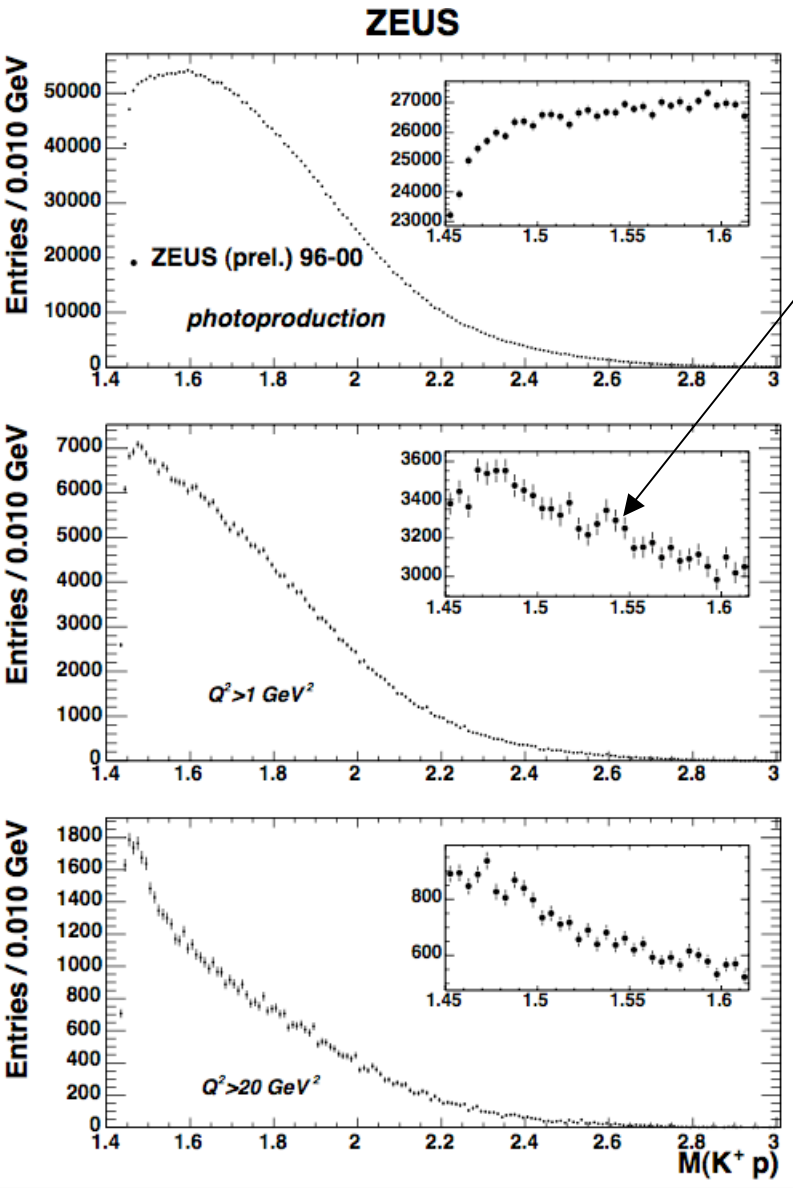
$$Q^2 > 20GeV \; P_T(\Theta^+) > 0.5GeV, |\eta(\Theta^+)| < 1.5$$





- $\sigma(\Theta^+) / \sigma(\Lambda)$ consistent with Q^2 independence
- Θ^+ kinematics was assumed to be the same as Σ state in MC— pure fragmentation
  - Could be too strong assumption (see below)

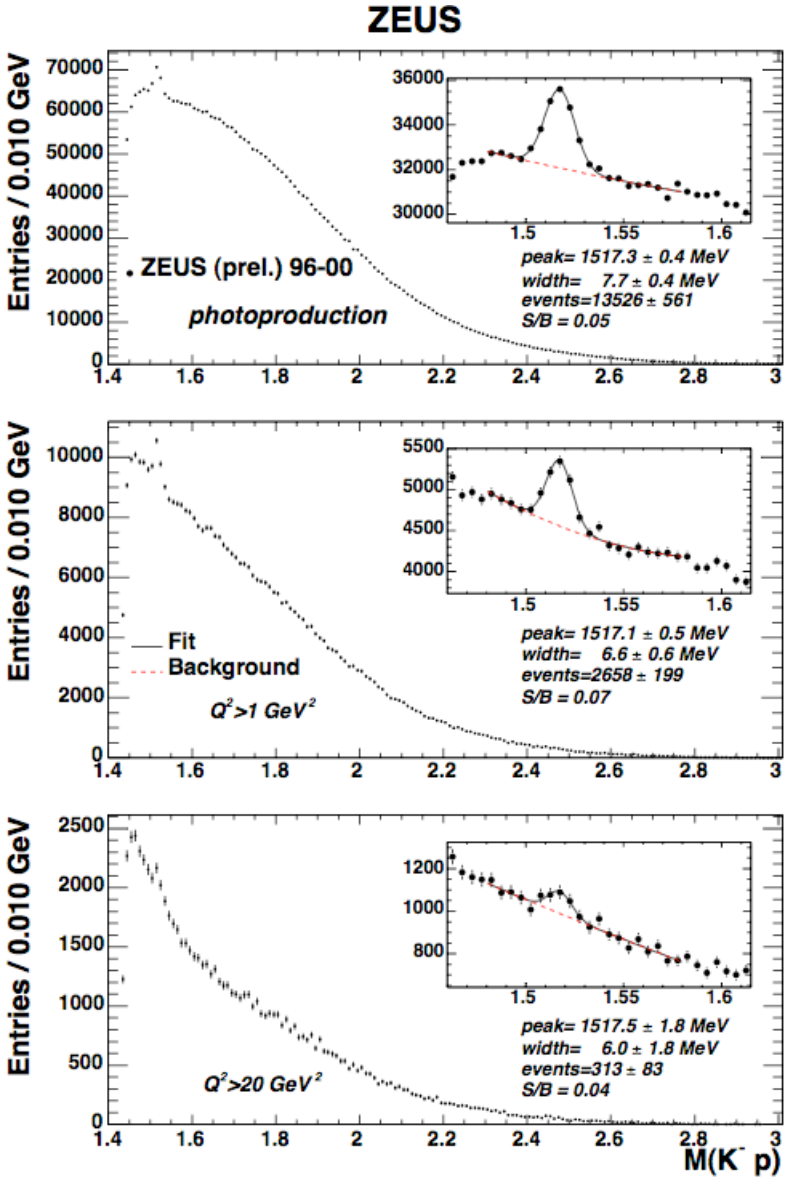
Θ^{++} in K^+p channel



Not statistically significant (~ 2.0 σ)

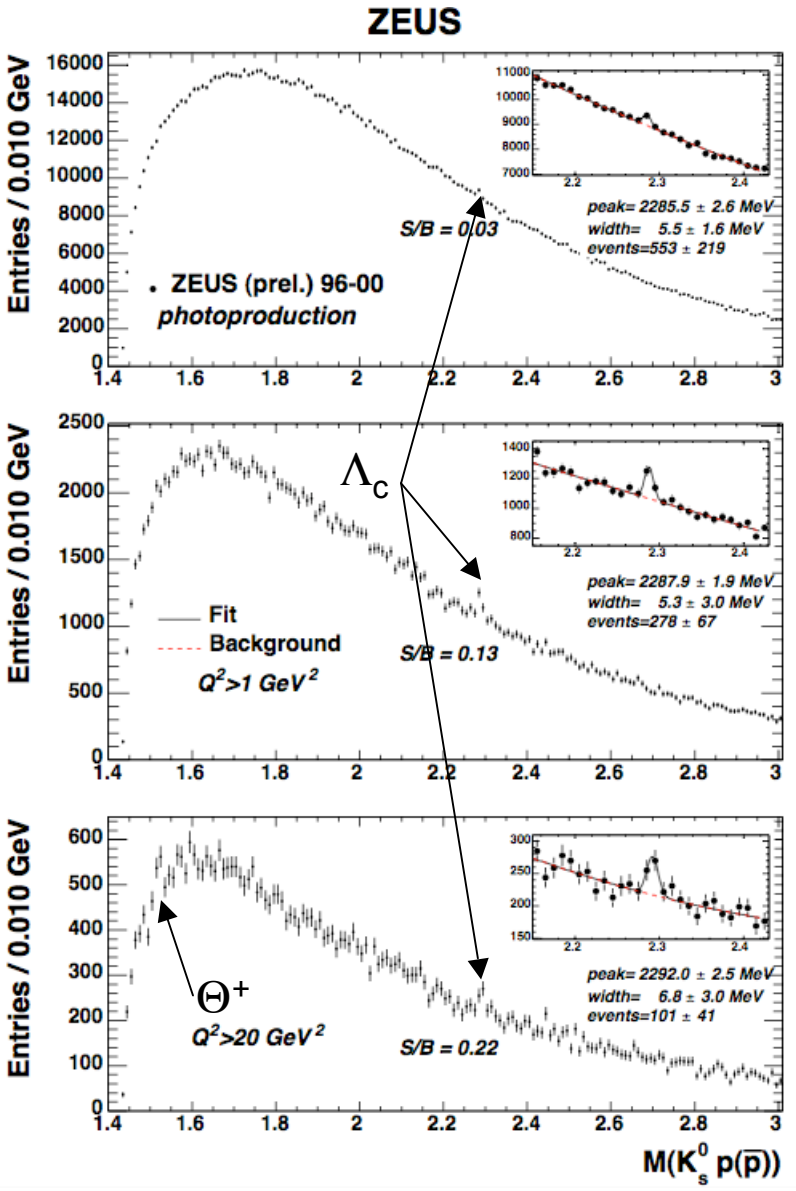
- × No Θ^{++} was observed
- Confirms previous ZEUS studies using statistics by a factor of ~10 larger
- Θ^+ is not isotensor

ZEUS sensitivity to known states : $\Lambda(1520) \rightarrow K^{-}p$



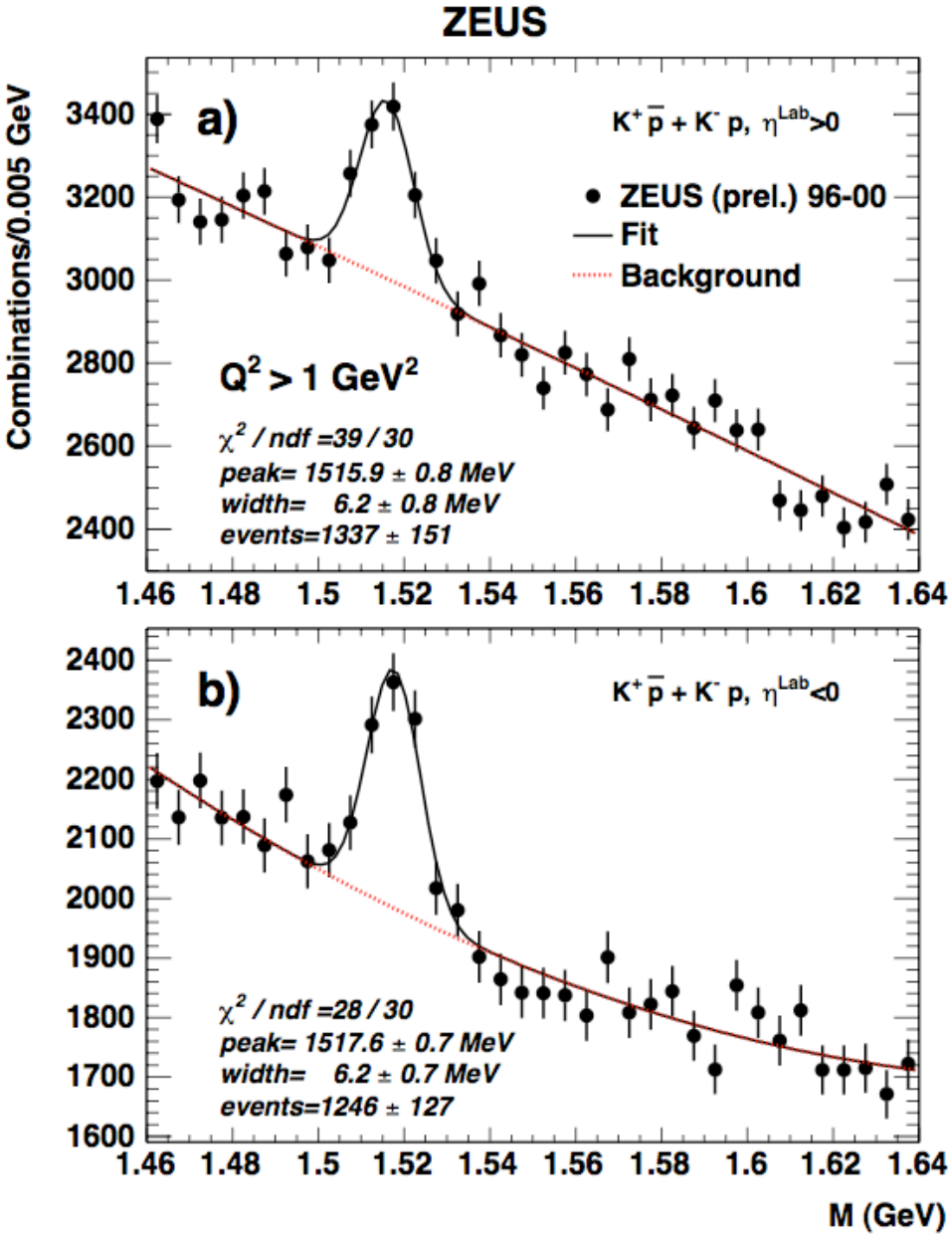
- $\Lambda(1520)$: clear signal with large statistics
  - Second largest statistics in colliding beam experiments (after BaBar)
- $\Lambda(1520)$: S/B remains the same with increasing Q^2
  - consistent with pure fragmentation from partonic string hadronisation as in $e^{+}e^{-}$

ZEUS sensitivity to known states : $\Lambda_c \rightarrow K^0_s p$



- Clean Λ_c signal (> 4σ at Q^2 > 1 GeV^2)
- S/B increases with Q^2
  - inconsistent with pure fragmentation production mechanism
  - consistent with boson gluon fusion(BGF) to $c\bar{c}$ hadronisation as for charm meson production
- S/B is the best for Q^2>20 GeV^2 (where Θ^+ was observed)
- May explain non-observation of Θ^+ in PHP and low Q^2 DIS

$\Lambda(1520)$: forward vs. rear

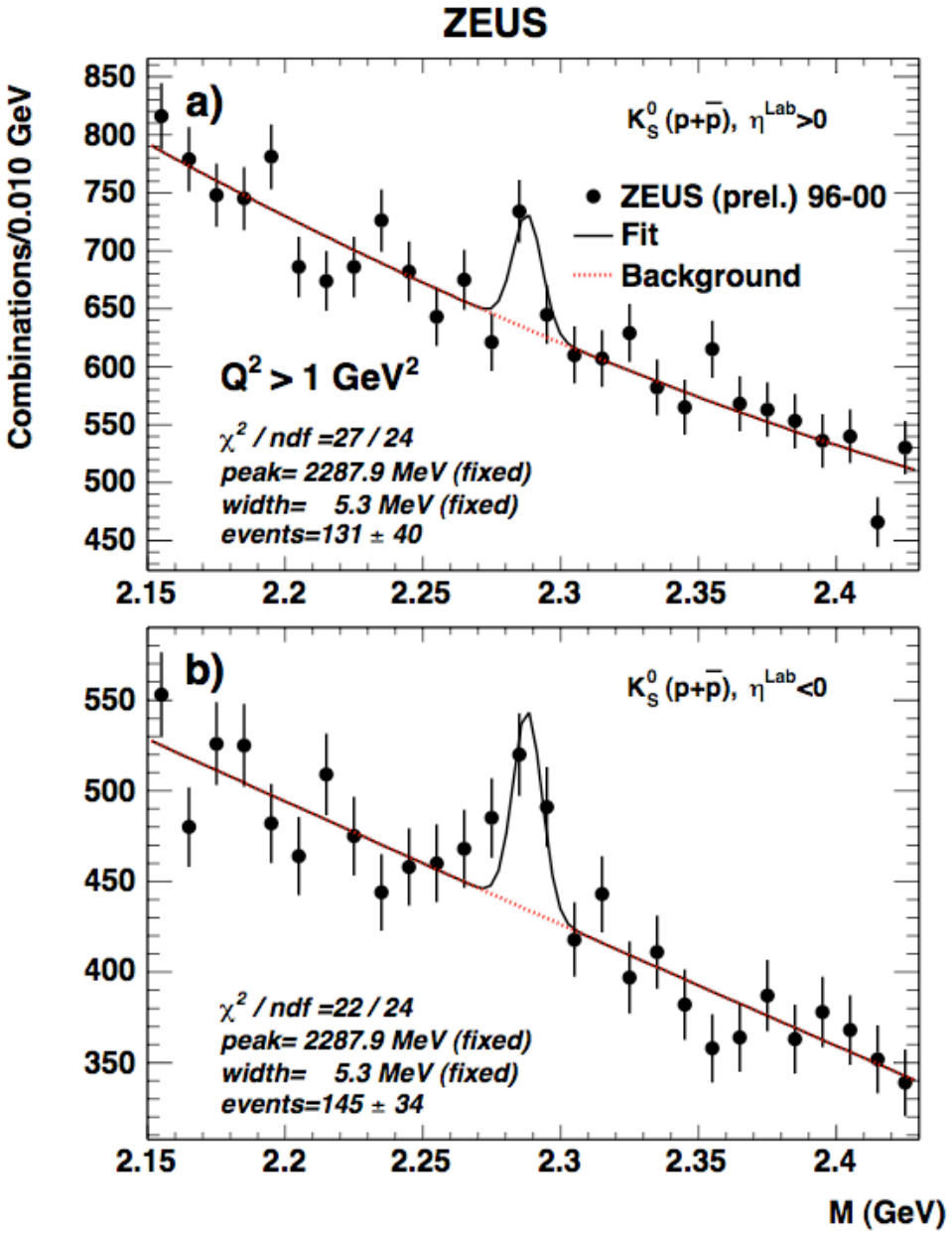


Forward region — the direction of the proton beam

Same production rate at forward and rear

Consistent with pure fragmentation

Λ_c : forward vs. rear

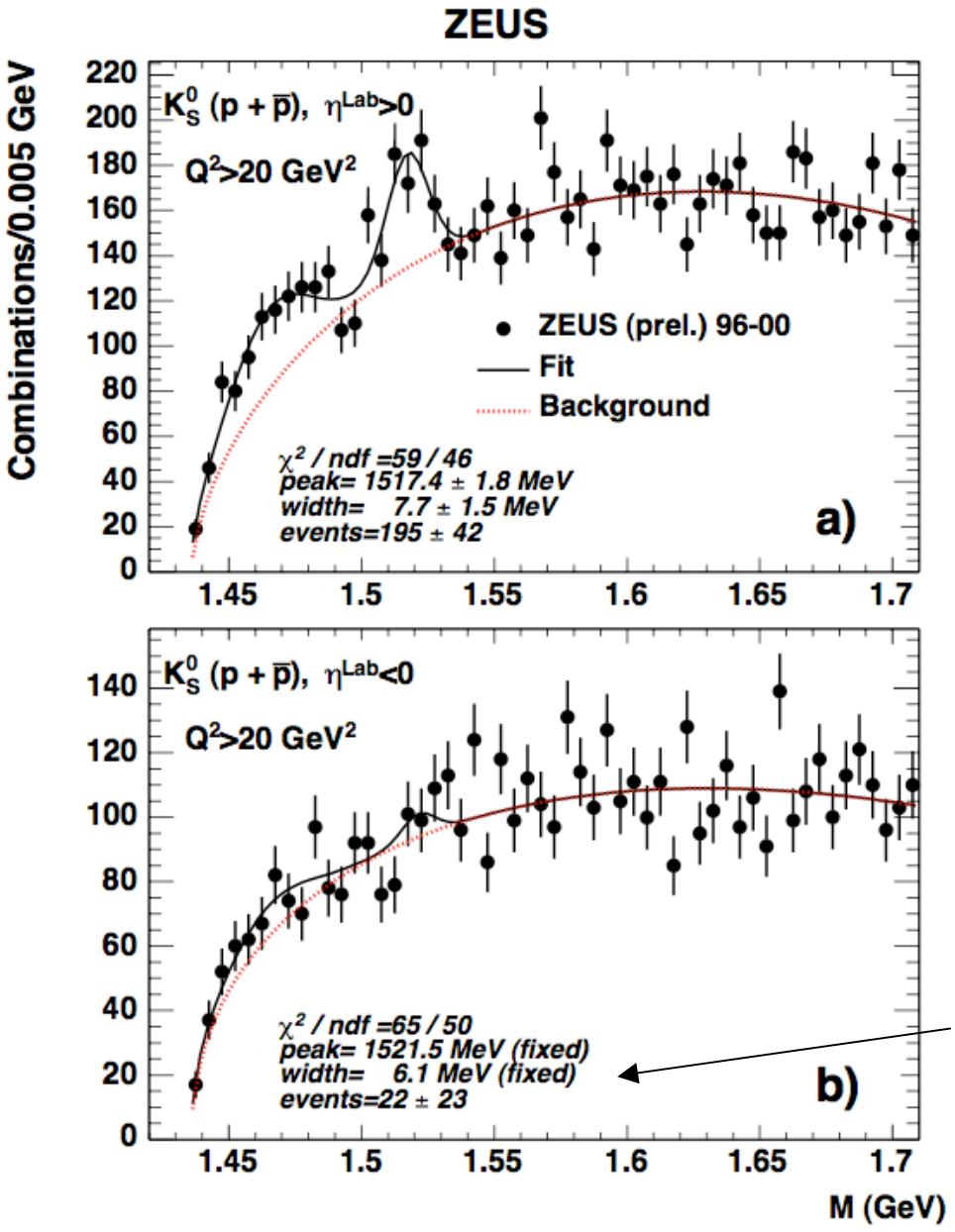


Consistent with same production rate at forward and rear

Consistent with BGF→$c\bar{c}$ production mechanism

Fit was done with peak position and width fixed to the sum plot

Θ^+ : forward vs. rear



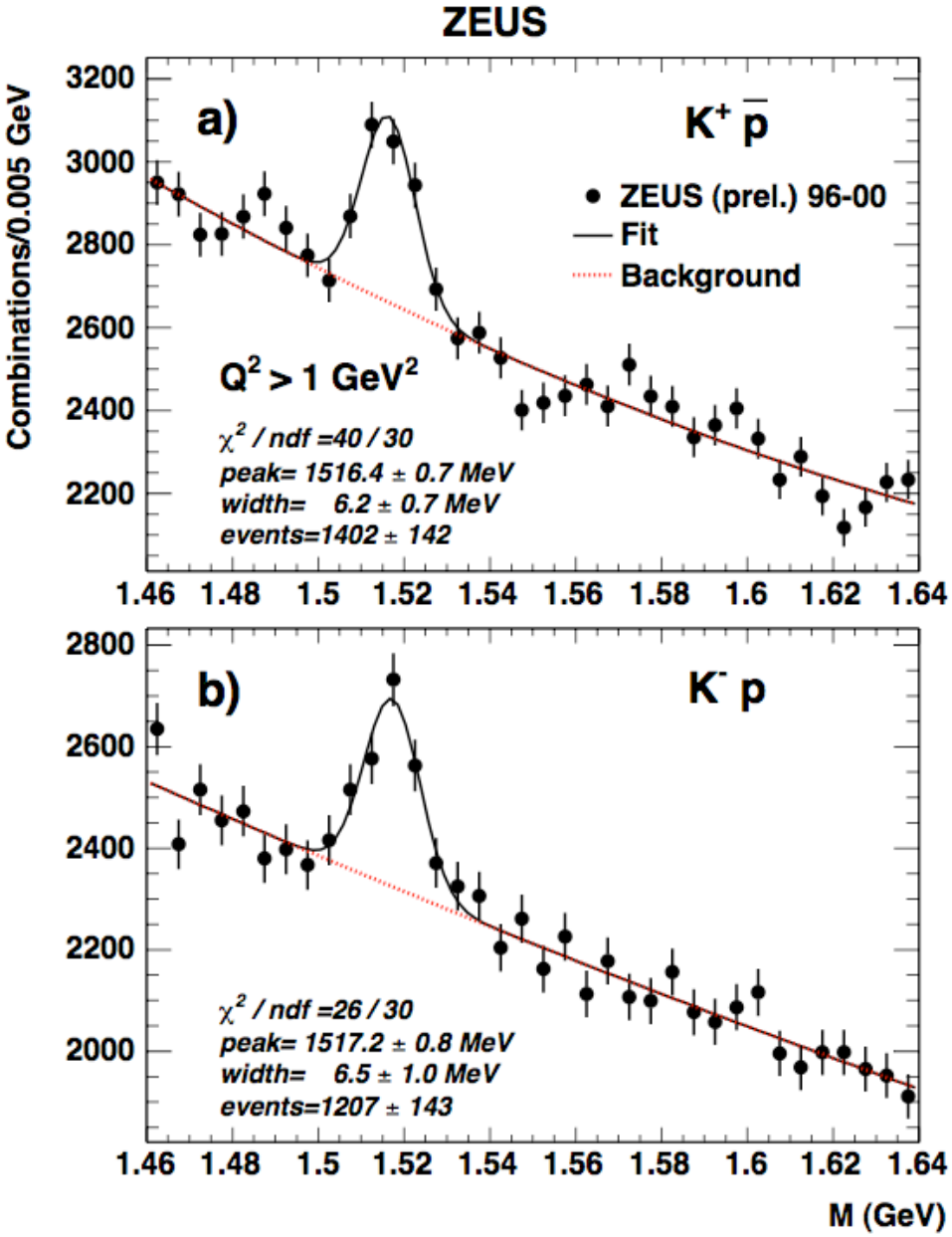
Production rate is higher at forward region than at rear region

- >3σ difference in number of events

Favors proton-remnant fragmentation origin

Fit was done with peak position and width fixed to the sum plot

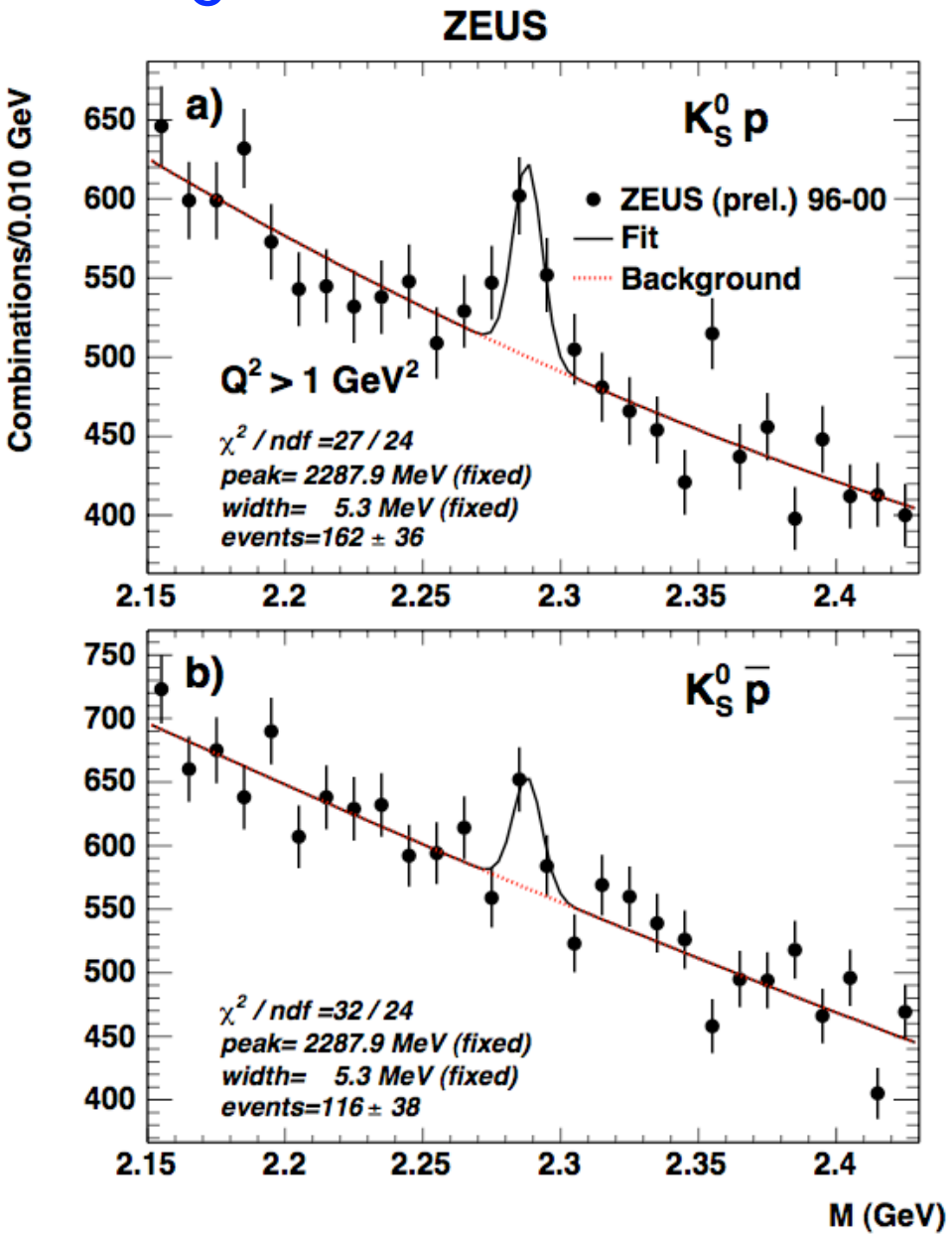
$\Lambda(1520)$: particle vs. anti-particle



Same production rate for particle and anti-particle

Consistent with pure fragmentation

Λ_c : particle vs. anti-particle

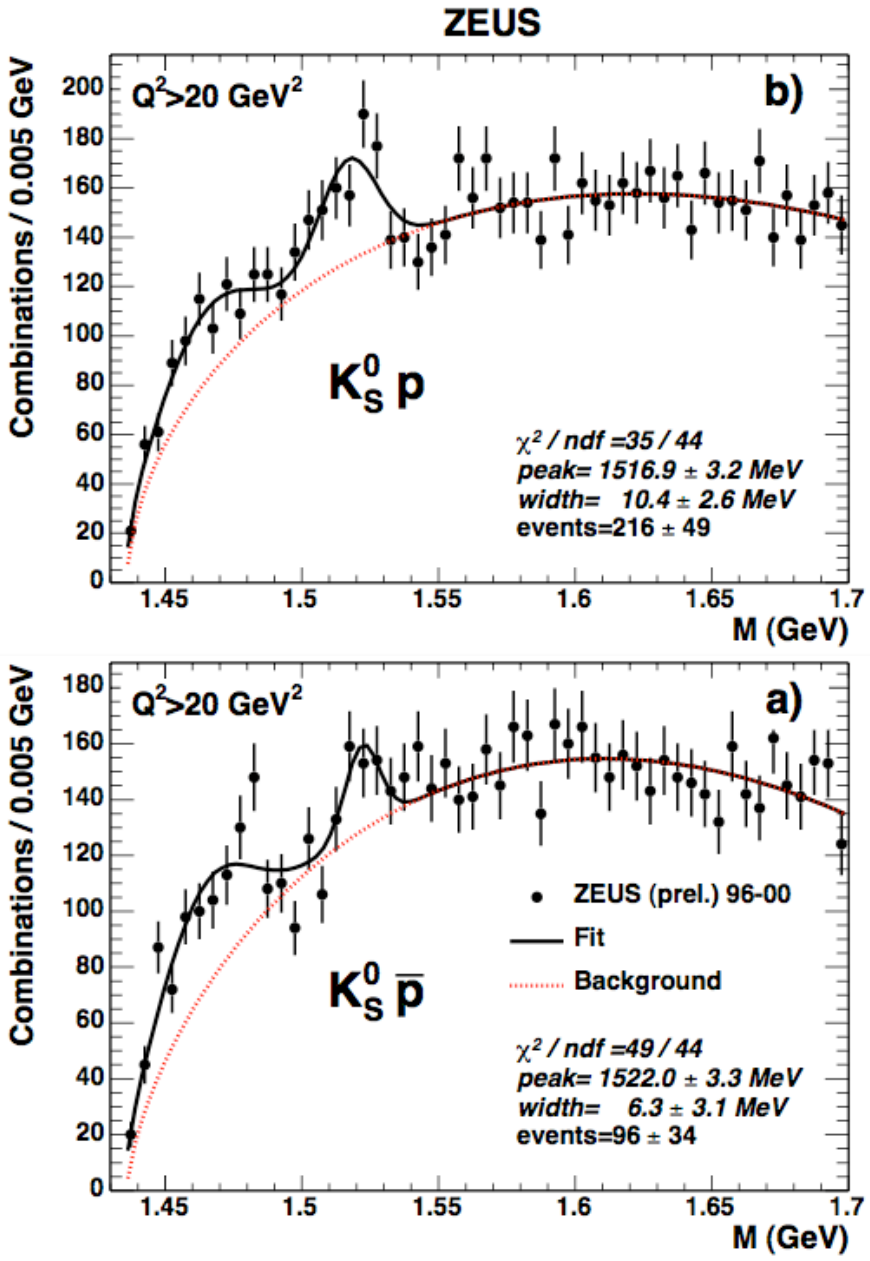


Consistent with same production rate for particle and anti-particle

Consistent with BGF→$c\bar{c}$ production mechanism

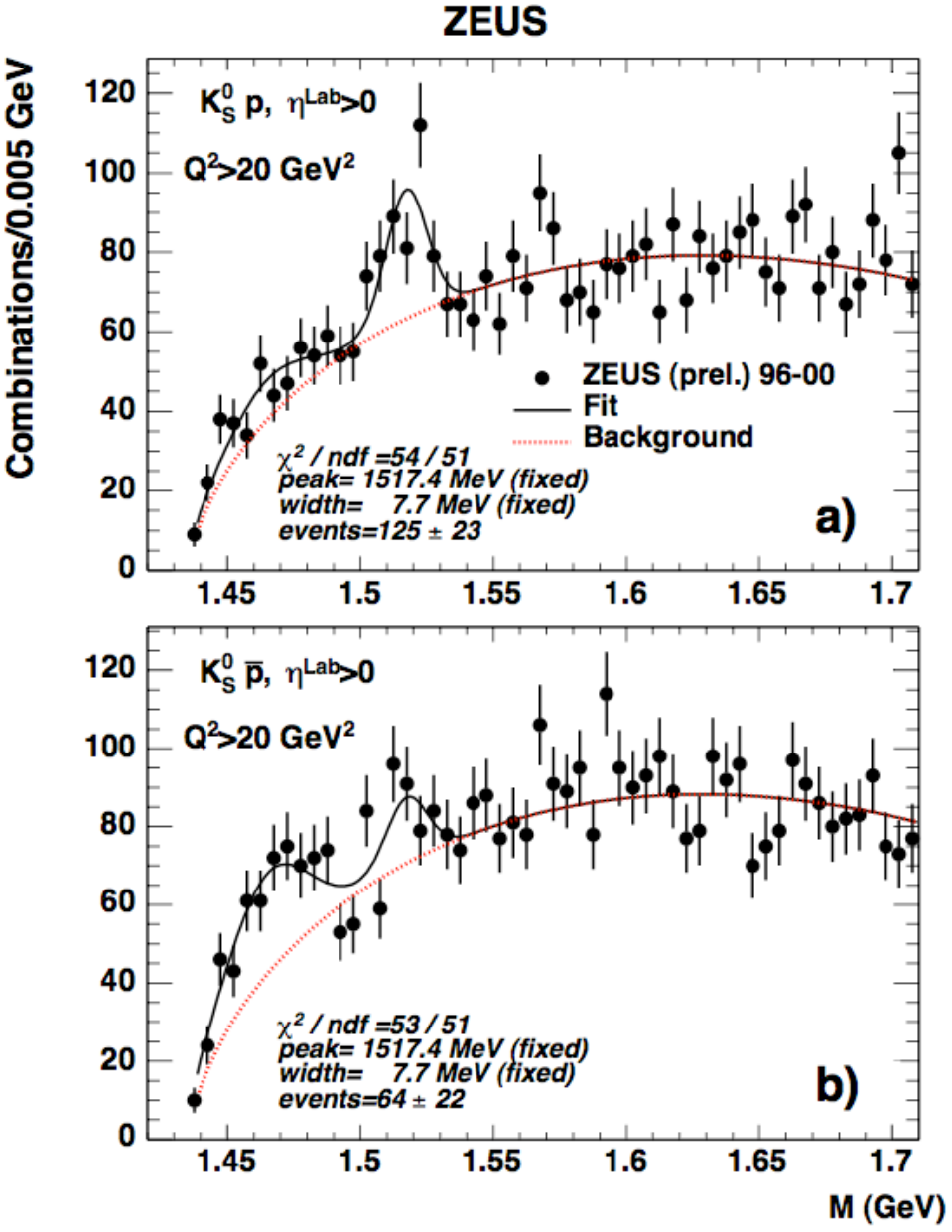
Fit was done with peak position and width fixed to the sum plot

Θ^+ : particle vs. anti-particle



- Data may indicate slightly more events for particle than for anti-particle
  - $<2\sigma$ difference
  - However, anti-particle data are also perfectly consistent with the background fit only
- May get clearer result if only look at forward region where S/B will be better

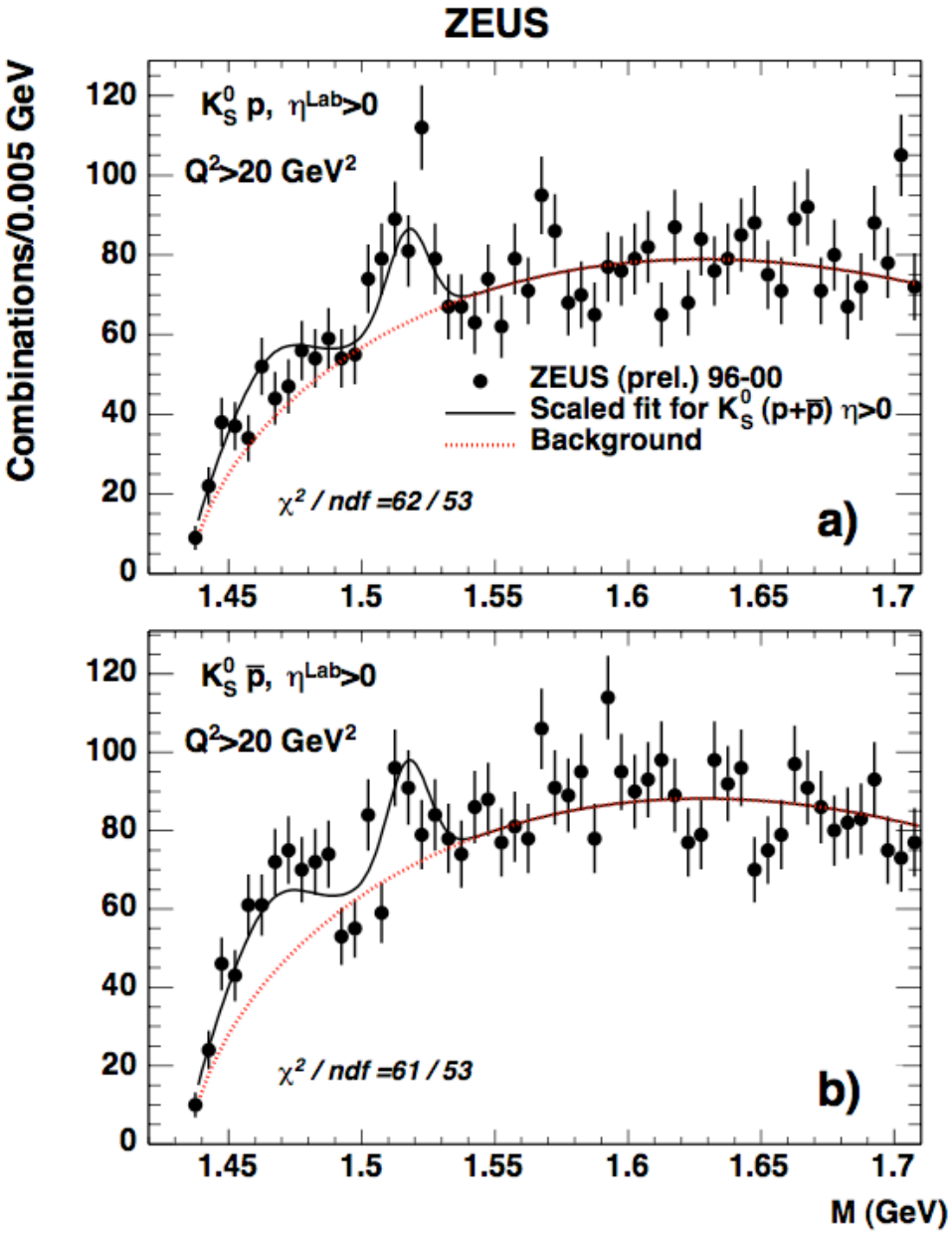
Θ^+ : particle vs. anti-particle in forward region



- > 5σ peak from the fit for particle channel
- Again only < 2σ difference by comparing events for particle with events for anti-particle

Fit was done with peak positions, peak widths and background shape fixed to the sum plot

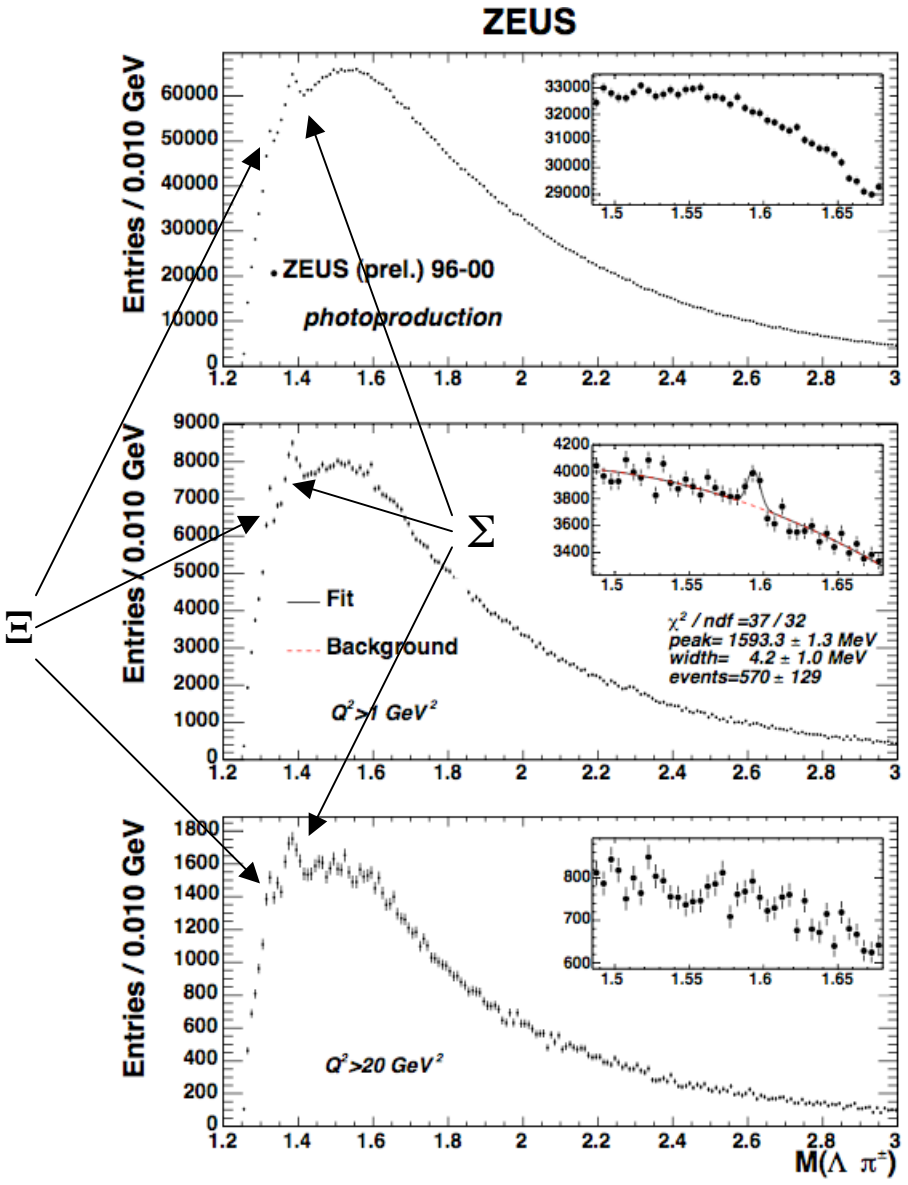
Θ^+ : particle vs. anti-particle in forward region



χ^2 check shows consistency for the same production rate in particle and anti-particle

Fit was done with the whole shape fixed to the sum plot

Θ^+ : another Σ state? Look at M($\Lambda\pi$)



- $\Sigma(1385)$ & Ξ clearly observed
- No signal around the mass where Θ^+ is observed
- A ~4.4σ peak at ~1600 MeV for $Q^2 > 1$ GeV^2
  - $\Sigma(1600)$ PDG state (**)?
  - Not reported by any colliding experiments
  - statistical significance is not high

Conclusion

- Published already
  - Non-observation of Ξ^{--} in $\Xi^{-}\pi^{-}$
  - Observation of $\Theta^{+} \rightarrow K^{0}_{s}P$
  - $\sigma(ep \rightarrow e\Theta + X) : 125 \pm 27(stat)^{+36}_{-28}(syst)\,pb$
- New results
  - $\Lambda(1520)$ production is consistent with pure fragmentation origin
    - S/B remains the same as Q^2 increases
    - Same production rate for forward/rear and particle/antiparticle
  - Λ_c production is not consistent with pure fragmentation — it can be produced by boson-gluon-fusion $BGF \rightarrow c\bar{c}$
    - S/B increases as Q^2 increases
    - Consistent with same production rate for forward/rear and particle/antiparticle
  - Θ^{+} May favor proton-remnant fragmentation origin
    - Production rate is higher at forward region than rear region
    - Production rate is higher for particle than for anti-particle
      - however the statistics is too small to make strong conclusion