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Hadron Spectroscopy in ep Collisions at HERA

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on behalf of
H1 and ZEUS collaborations

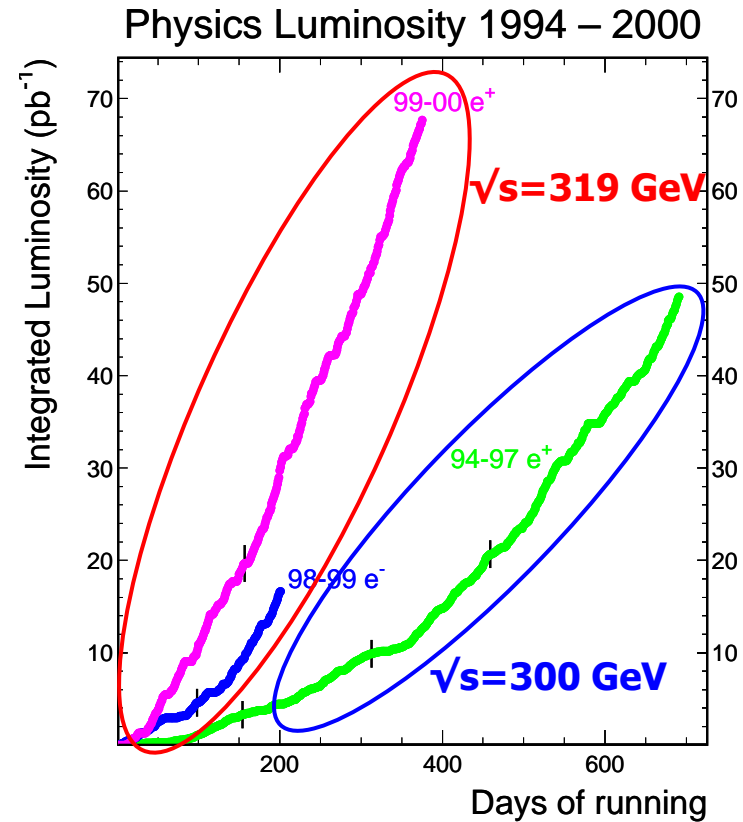
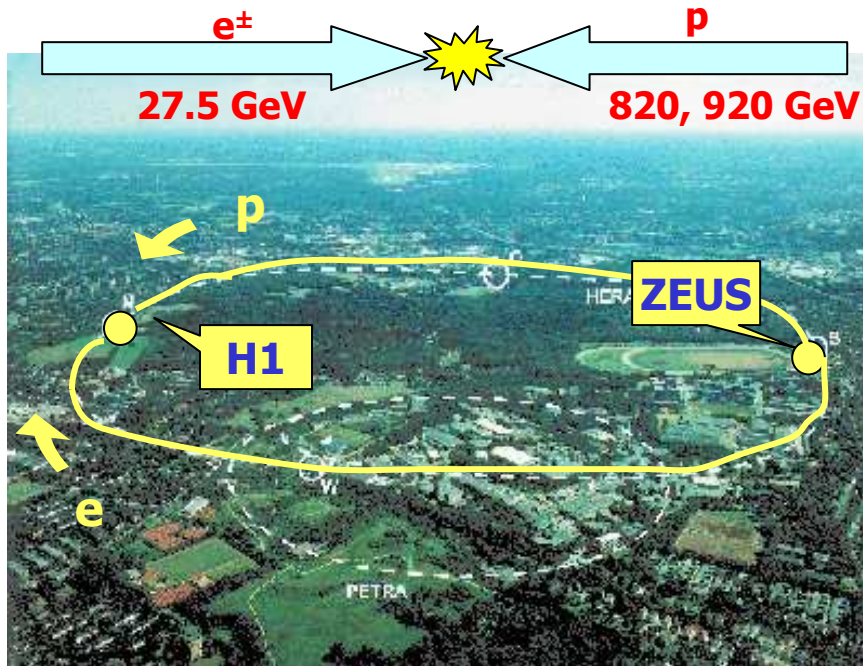


Search for Strange Pentaquarks θ^+ , θ^{++}

Search for Double Strange Pentaquarks Ξ^{--}

Search for Charm Pentaquark θ_c^0

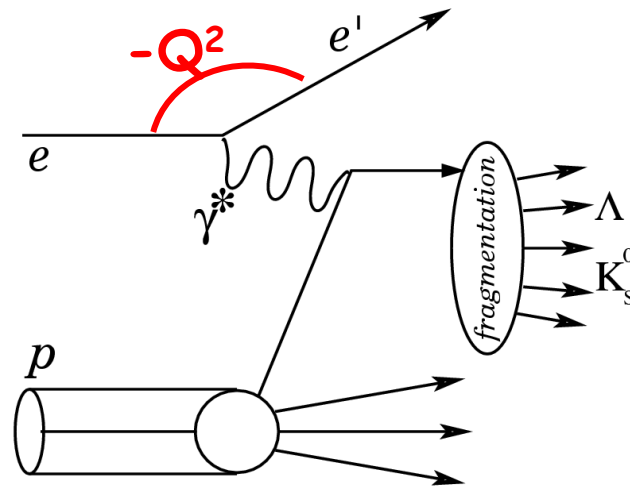
The HERA Collider



Q^2 : virtuality of exchanged Boson

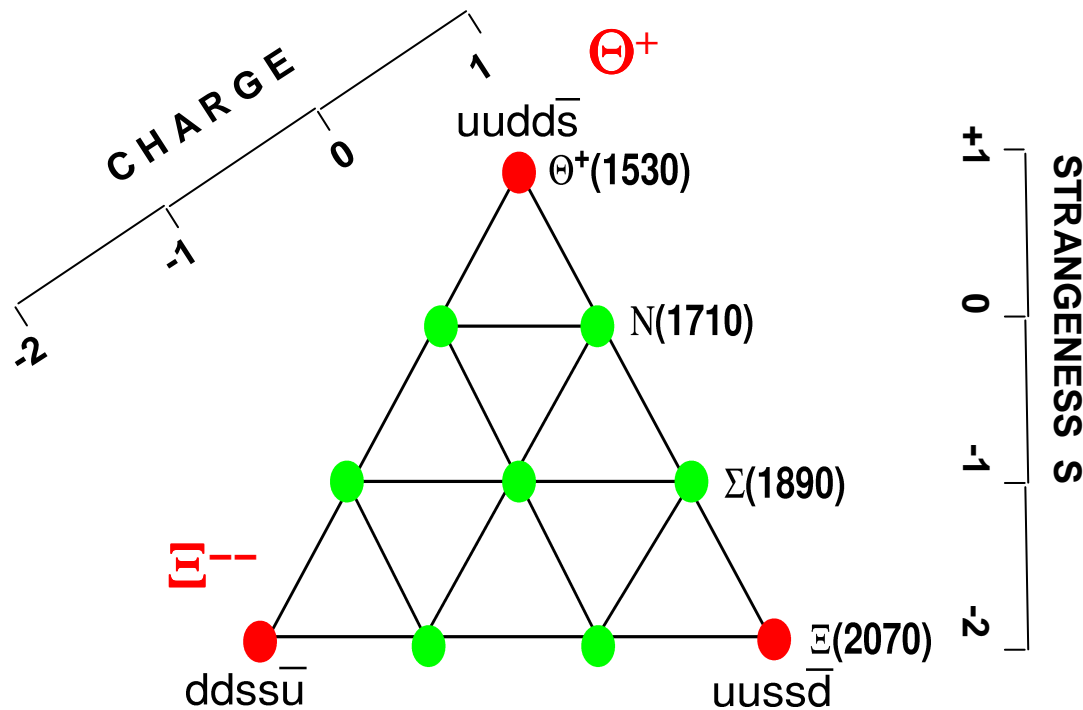
$Q^2 \sim 0 \text{ GeV}^2$: photoproduction

$Q^2 > 1 \text{ GeV}^2$: electro-production (DIS)



- HERA I data sample: $L \approx 120 \text{ pb}^{-1}$ / experiment
- Two colliding experiments: ZEUS, H1
- HERA II data taking on-going

The *strange* Pentaquark anti-decuplet



QCD says no objection

Proposed by Diakonov, Petrov, Polyakov in 1997:

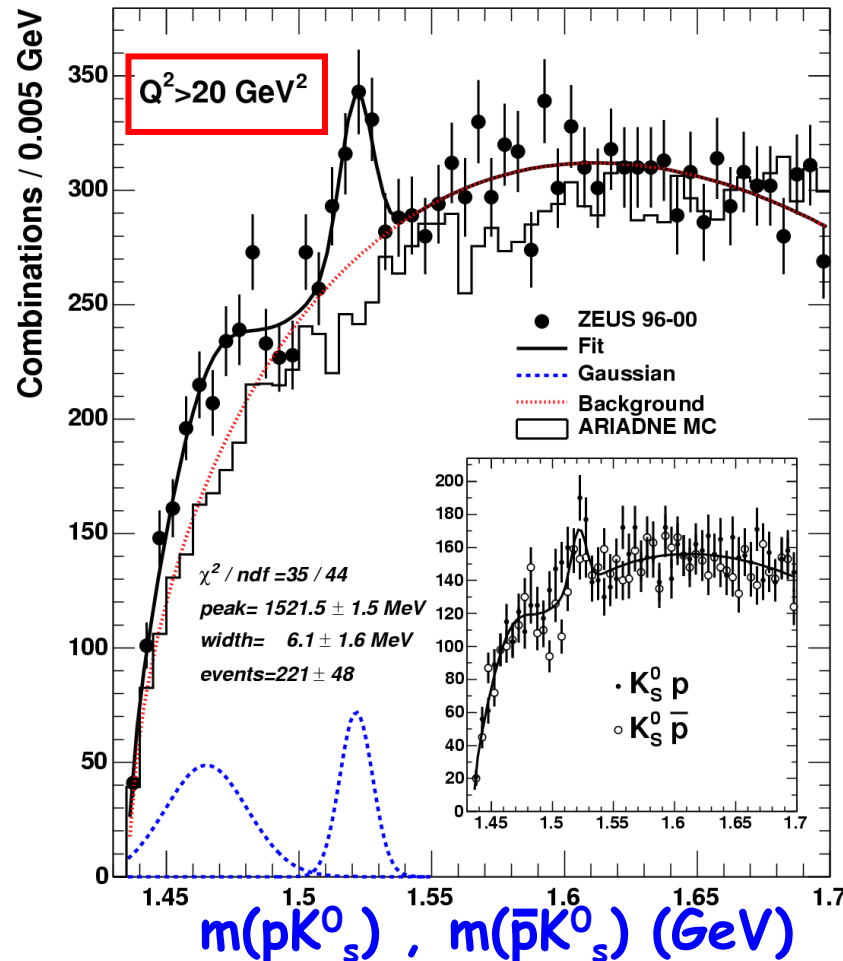
- 3 exotic baryons at corners, exotic quantum numbers which can not be explained by 3 quarks
- Prediction of a width less than 15 MeV for the $\Theta^+(1530)$ state
- Many positive results (mostly at low energy), many null results

Search for $\theta^+ \rightarrow p K_s^0$ / $\theta^- \rightarrow \bar{p} K_s^0$ (ZEUS)

DIS sample ($Q^2 > 1 \text{ GeV}^2$):

- identify $K_s^0 \rightarrow \pi^+\pi^-$ (secondary vertex)
- identify p, \bar{p} (dE/dx)

ZEUS



Peak = 1521.5 ± 1.5 (stat)
 $+2.8-1.7$ (sys) MeV

Stat. Signif.: $\sim 3.9 - 4.6 \sigma$

$\Gamma: 8 \pm 4 \text{ MeV}$

Differential cross-sections derived

Signal seen in both charges
 (insert, K_s^0 -antiproton fit, $\sim 3 \sigma$)

If interpreted as $\theta^+ + \theta^-$
 \Rightarrow antipentaquark ?

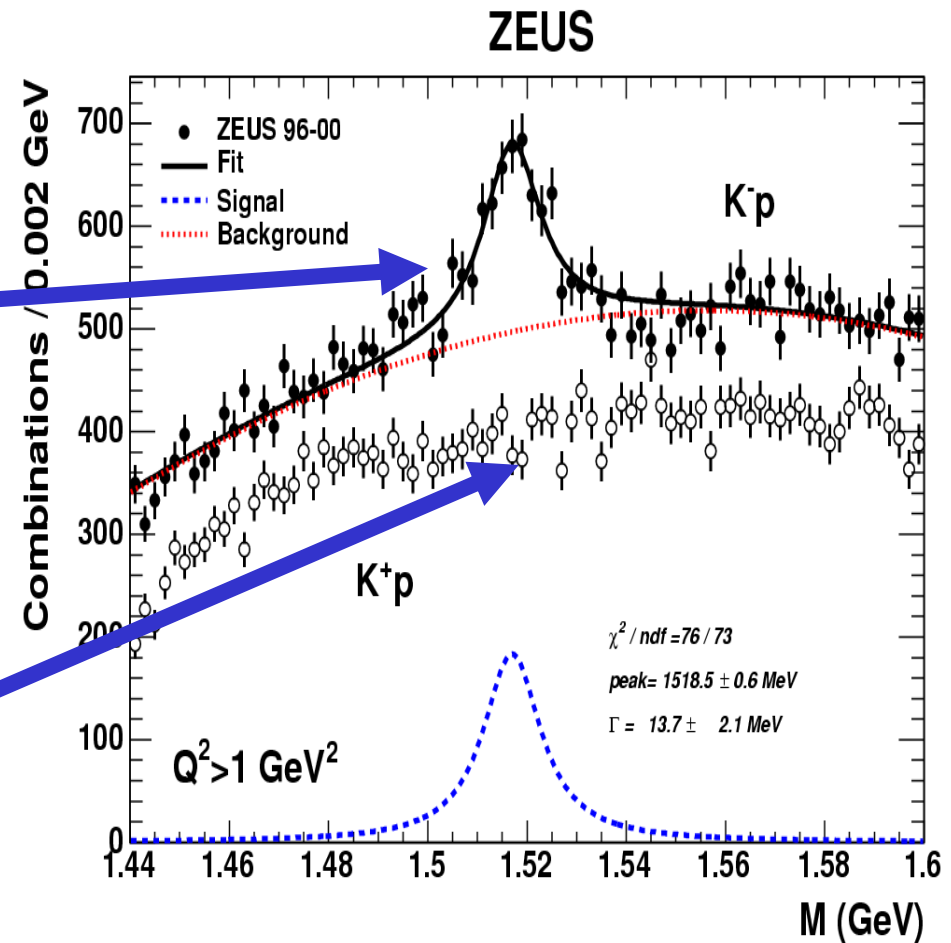
Search for $\theta^{++} \rightarrow K^+ p + c.c.$

Is θ^+ member of a $I=1$ triplet: $(\theta^0, \theta^+, \theta^{++})$?

Search for $\theta^{++} \rightarrow K^+ p + c.c.$
 • identify K^\pm, p (dE/dx)

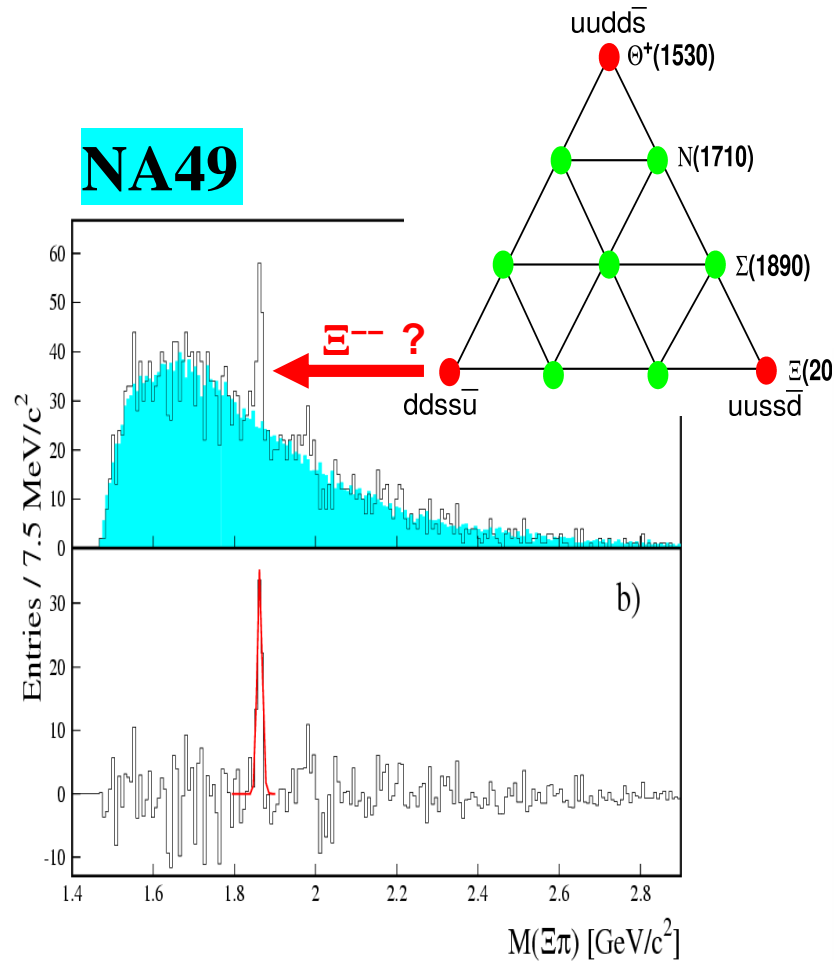
$\Lambda(1520) \rightarrow p K^- + c.c.$
 mass and natural width
 consistent with PDG:
 $M = 1519.5 \pm 1.0 \text{ MeV}$
 $\Gamma = 15.6 \pm 1.0 \text{ MeV}$

$\theta^{++}(1530) \rightarrow p K^+ + c.c.$
 no evidence for
 hypothetical $\theta^{++}(1530)$

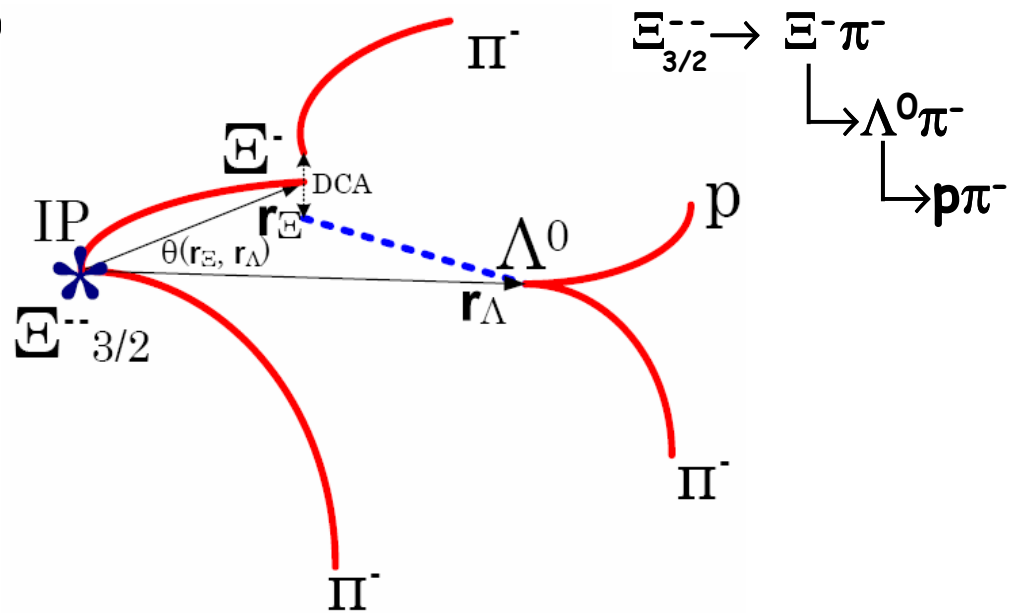


Search for Double Strange $\Xi_{3/2}^{--} \rightarrow \Xi^- \pi^-$

NA49 search for $\Xi_{3/2}^{--} \rightarrow \Xi^- \pi^-$
 $M = 1862 \pm 2 \text{ MeV}, \sim 3 \sigma$

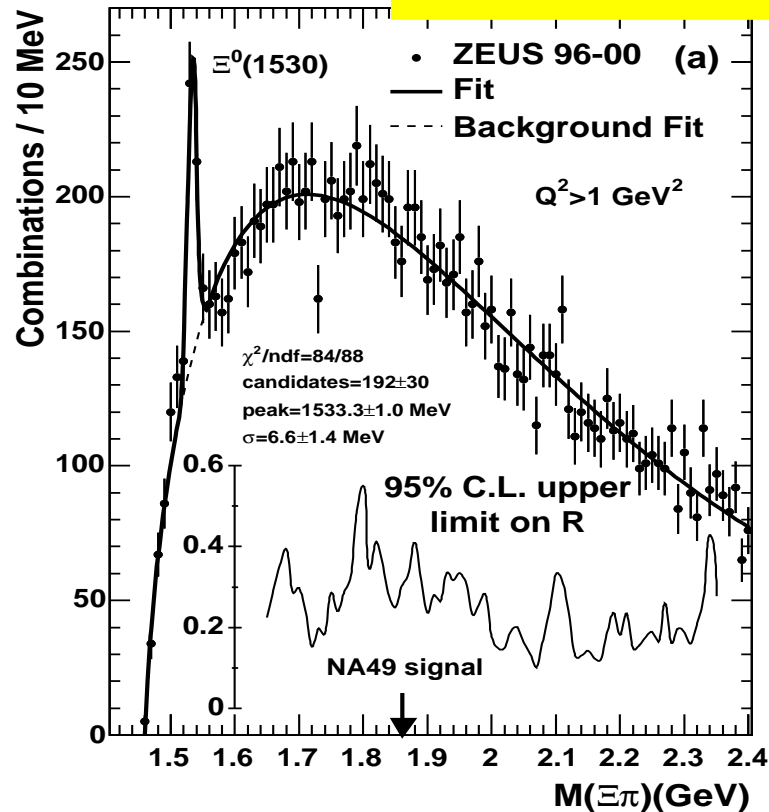


Similar analysis of NA49 repeated using **ZEUS DIS** data



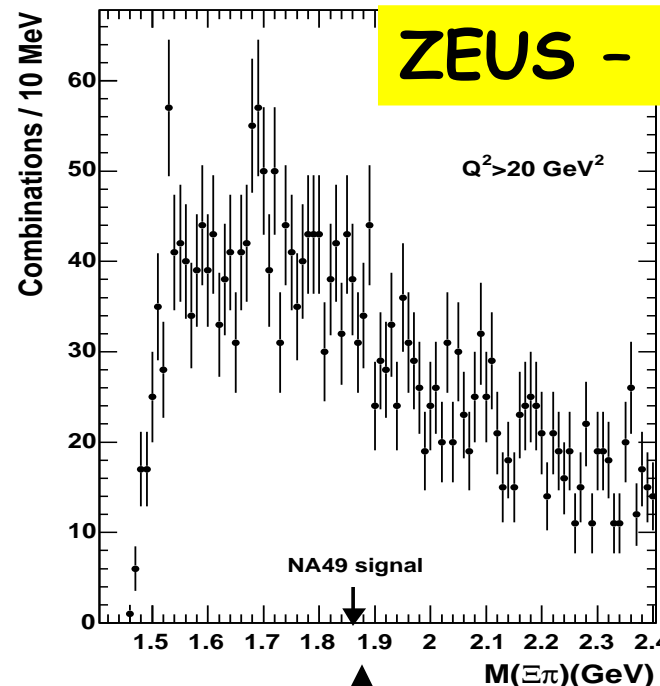
Search for Double Strange $\Xi_{3/2}^{--} \rightarrow \Xi^- \pi^-$

ZEUS - DIS.



NOTHING

ZEUS - high Q^2

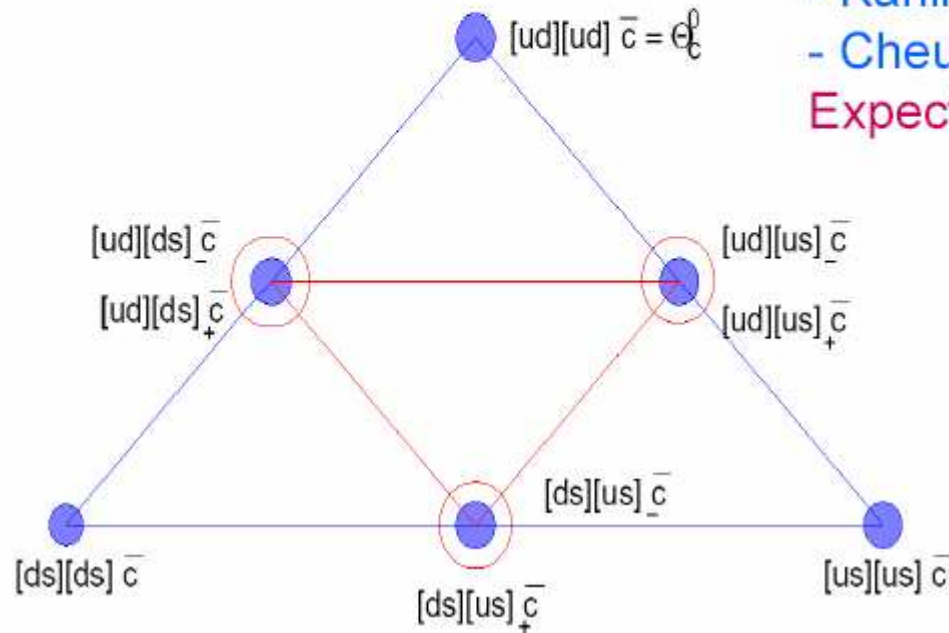


- Clean $\Xi(1530) P_{13}$
- **No pentaquark signal, even for $Q^2 > 20 \text{ GeV}^2$**
- Different production mechanism ?

The *charm* Pentaquark anti-decuplet

What about $\Theta_c^0 \rightarrow D^{*+} p$?

$uudd\bar{c}$



Many recent theoretical predictions:

- Jaffe-Wilczek $\rightarrow M \sim 2710$ MeV
- Wu-Ma $\rightarrow M \sim 2704$ MeV
- Karliner-Lipkin $\rightarrow M \sim 2985$ MeV
- Cheung $\rightarrow M \sim 2938-2997$ MeV

Expected width ~ 20 MeV

Decay modes:

- $M < 2807$ MeV $\theta_c^0 \rightarrow \theta^+ \pi^-$
- $M < 2948$ MeV $\theta_c^0 \rightarrow D^- p$
- $M > 2948$ MeV $\theta_c^0 \rightarrow D^{*+} p$

because of mass thresholds.

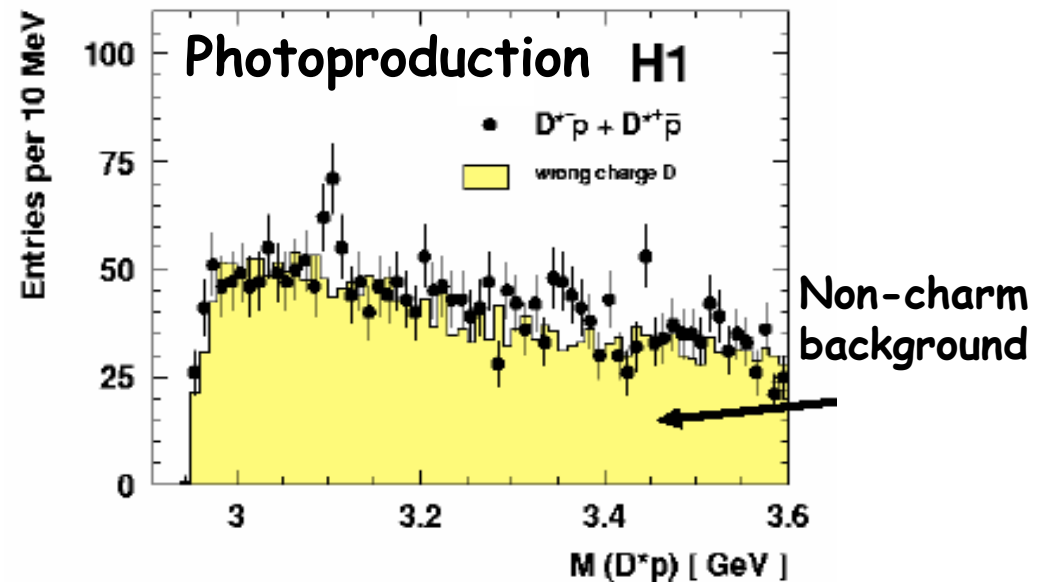
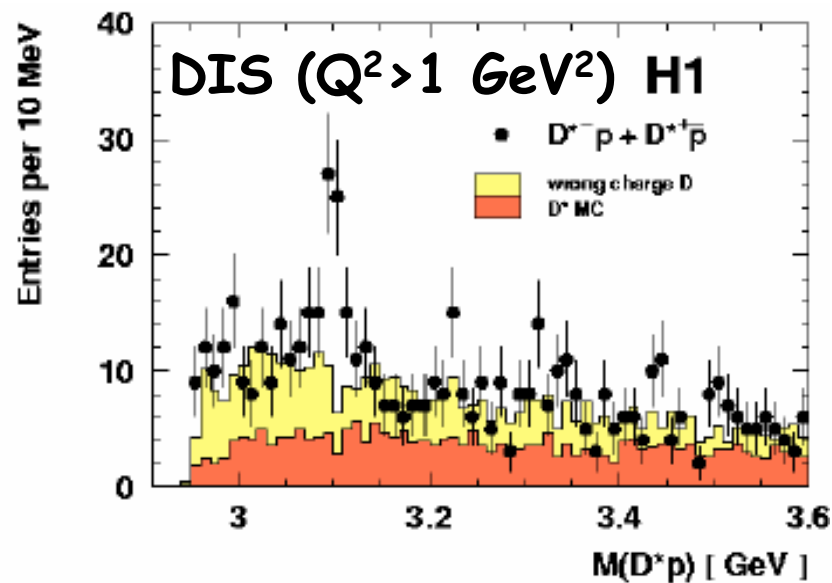
Main search decay channel :

$$\theta_c^0 \rightarrow D^{*+} p$$

Search for charmed PQ, $\theta_c \rightarrow D^*p$, in H1

DIS and photoproduction samples

- $D^{*+} \rightarrow D^0 \pi_s^+ \rightarrow (K^- \pi^+) \pi_s^+$
- identify p (dE/dx)



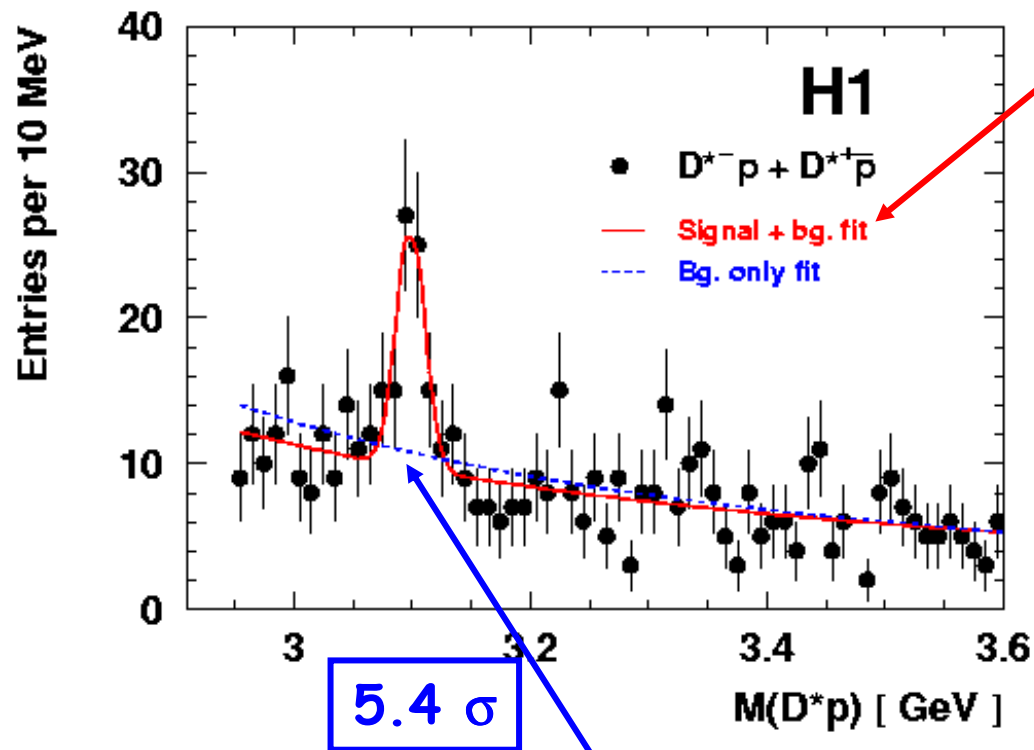
Signal at 3.1 GeV both in DIS and photoproduction samples

Data well described (except in the 3.1 GeV region) by

- Non-charm background
- D^* combined with random p

Search for charmed PQ, $\theta_c \rightarrow D^*p$, in H1

Significance estimation



Background + signal hypothesis:
Mass: $3099 \pm 3(\text{stat}) \pm 5(\text{sys})$ MeV
Width: 12 ± 3 MeV
(consistent with experimental resolution)

Numbers of signal and bg
within 25 MeV:

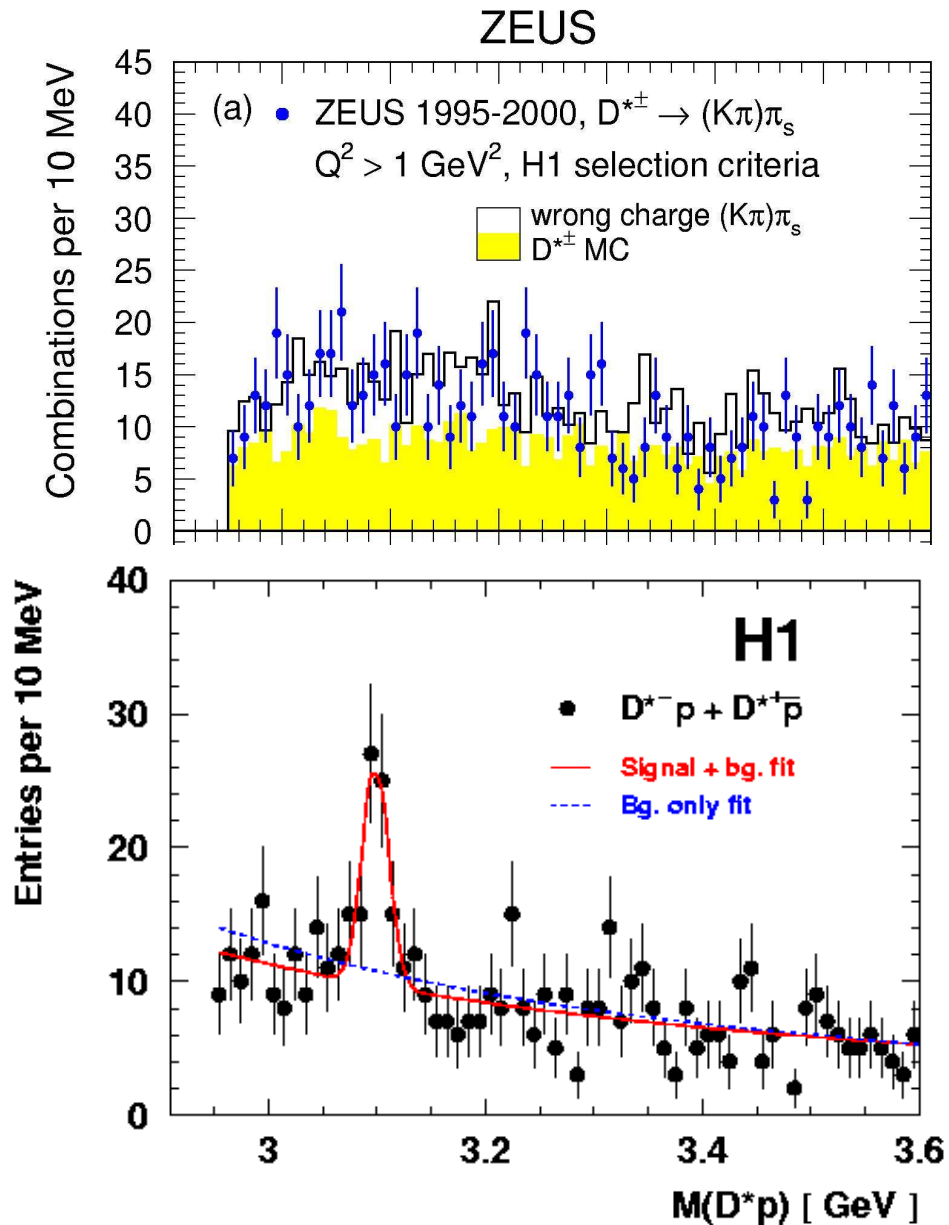
$$N_b = 45.0 \pm 2.8$$
$$N_s = 50.6 \pm 11.2$$

(~1% of D^* yield)

Background only hypothesis: $N_b = 51.7 \pm 2.7$

Background fluctuation probability: 4×10^{-8} (Poisson) = 5.4 σ (Gauss)

Search for $\theta_c \rightarrow D^*p$: H1 / ZEUS



Comparison of H1 and ZEUS
in similar phase space region

ZEUS didn't observe θ_c signal
in a DIS data sample 1.7 times
of H1 data sample
(neither in photoproduction)

Observation of ZEUS and H1
are not compatible

$$N_{\theta} / N_{D^*} :$$

$$< 0.0035 \text{ (ZEUS)}$$

$$\sim 0.01 \text{ (H1)}$$

More quantitative comparisons
require detector efficiency corrections

Conclusions

- $\theta^+(1530)$: evidence for a narrow baryonic state at mass 1521.5 decaying to $K^0_s p$ (ZEUS)
- $\theta^{++}(1530)$: no evidence for a state decaying to $K^+ p$ (ZEUS)
- $\Xi^{--}(1860)$: no evidence for a state decaying to $\Xi^- \pi^-$ (ZEUS)
- $\theta^0_c(3100)$: seen by H1, but not confirmed by ZEUS (H1, ZEUS)

Overall HERA (and world) situation unclear

- Need more results: θ^+ , θ^{++} , Ξ^{--} (H1)
- Need more final states: $\Lambda^0 K^0$?
- Need more statistics: HERA 2