Lake Louise Winter Institute 2005
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Hadron Spectroscopy in ep Collisions at HERA

Bob Olivier – Birmingham Univ.

on behalf of

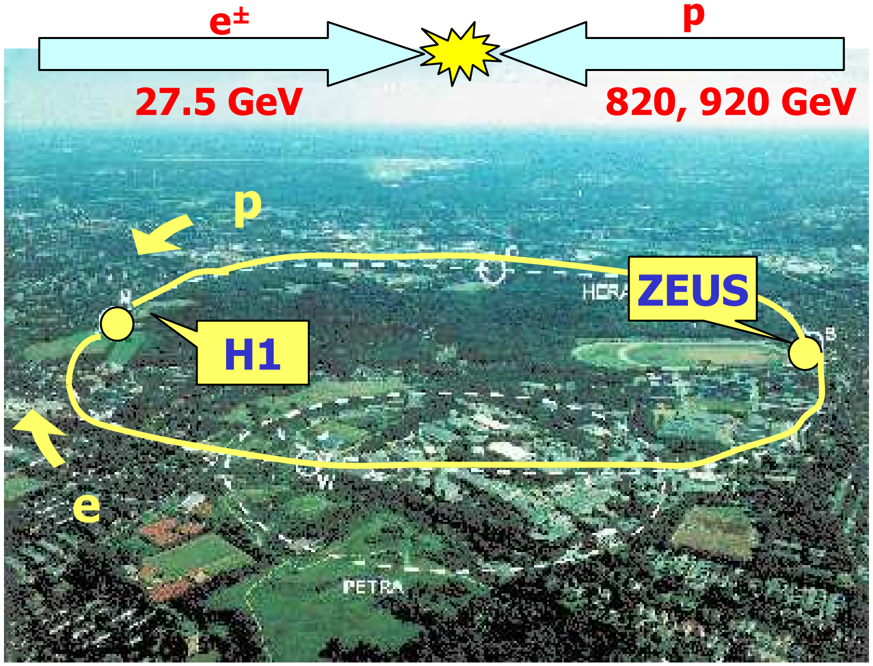
H1 and ZEUS Collaborations

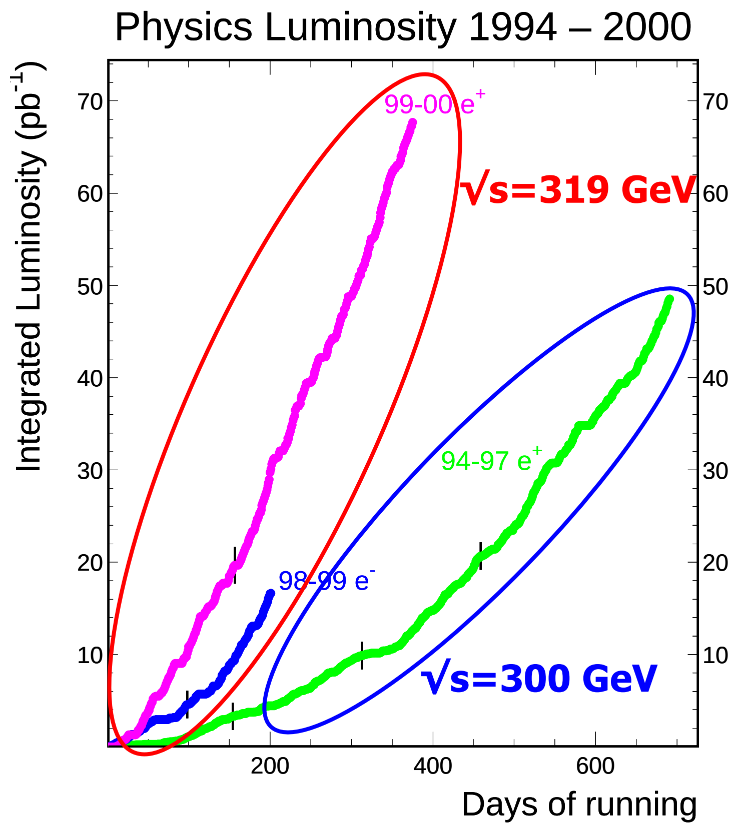
Search for Strange Pentaquarks θ^{+}, θ^{++}

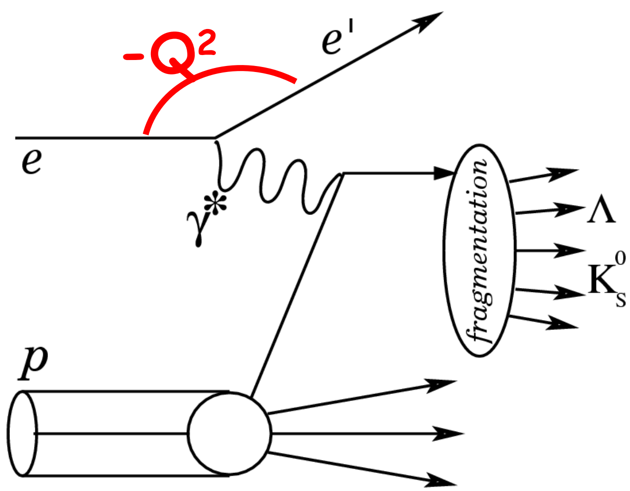
Search for Double Strange Pentaquarks Ξ^{--}

Search for Charm Pentaquark θ^{0}_{c}

The HERA Collider







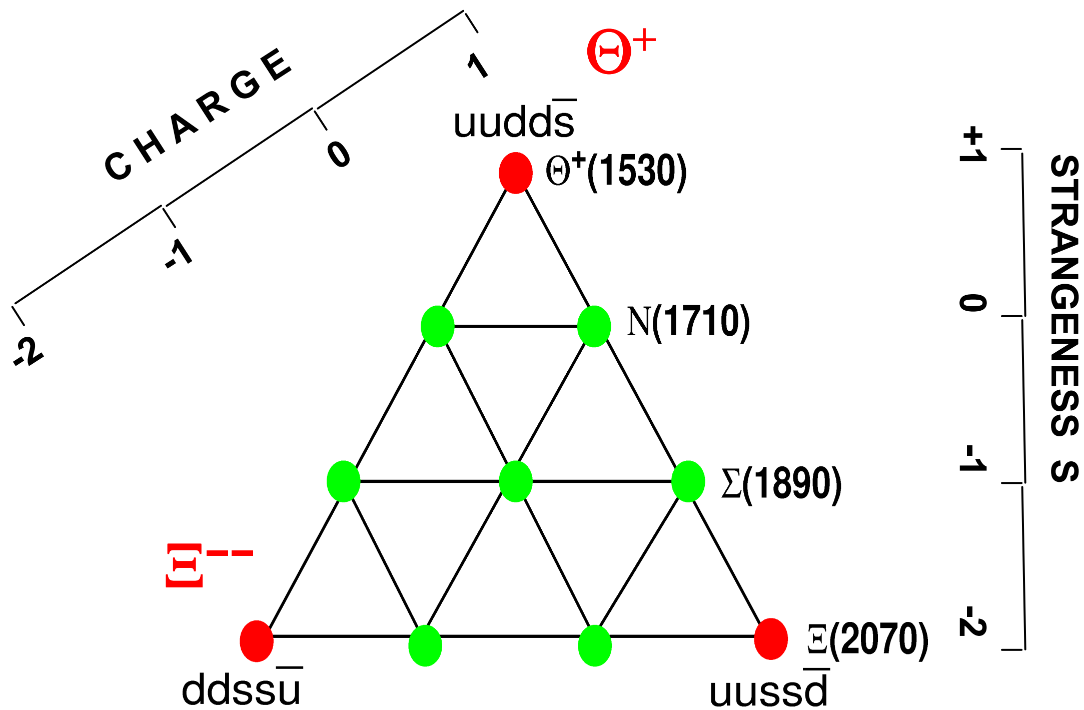
Q^2 : virtuality of exchanged boson

$Q^2 \sim 0$ GeV^2: photoproduction

$Q^2 > 1$ GeV^2: electro-production (DIS)

- HERA I data sample 94-00: L ≈ 120 pb^{-1} / experiment
- Two colliding experiments: ZEUS, H1
- HERA II data taking on-going

The *strange* Pentaquark anti-decuplet



QCD says no objection

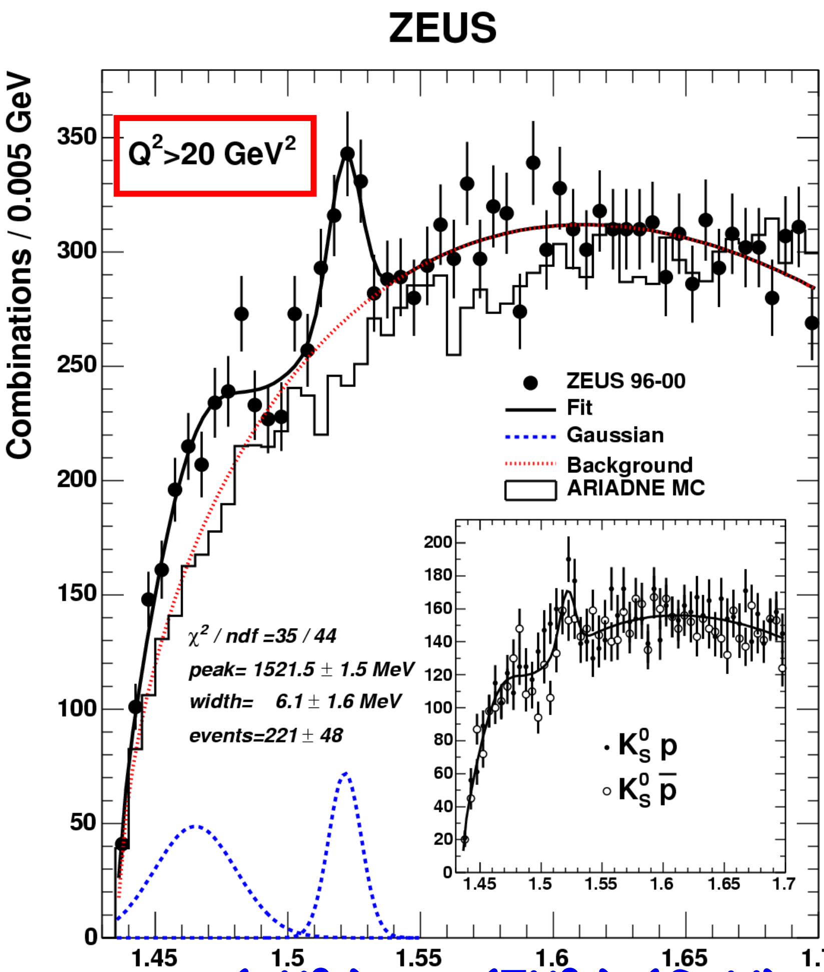
Proposed by Diakonov, Petrov, Polyakov in 1997:

- **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 θ⁺(1530) state**
- **Many positive results (mostly at low energy), many null results**

Search for $\theta^+ \to p\, K^0_s$ / $\theta^- \to \bar{p}\, K^0_s$ (ZEUS)

DIS sample (Q^2>1 GeV^2):

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



$m(pK^0_s)$, $m(\bar{p}K^0_s)$ (GeV)

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

Stat. Signif.: ~ 3.9 -4.6 σ

Γ: 8 ± 4 MeV

Differential cross-sections derived

Signal seen in both charges
(insert, $K^0{}_S$-antiproton fit, ~ 3 σ)

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

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

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

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

- **identify $K^{\pm}$, p (dE/dx)**

Λ(1520) $\rightarrow p K^{-}$ + c.c

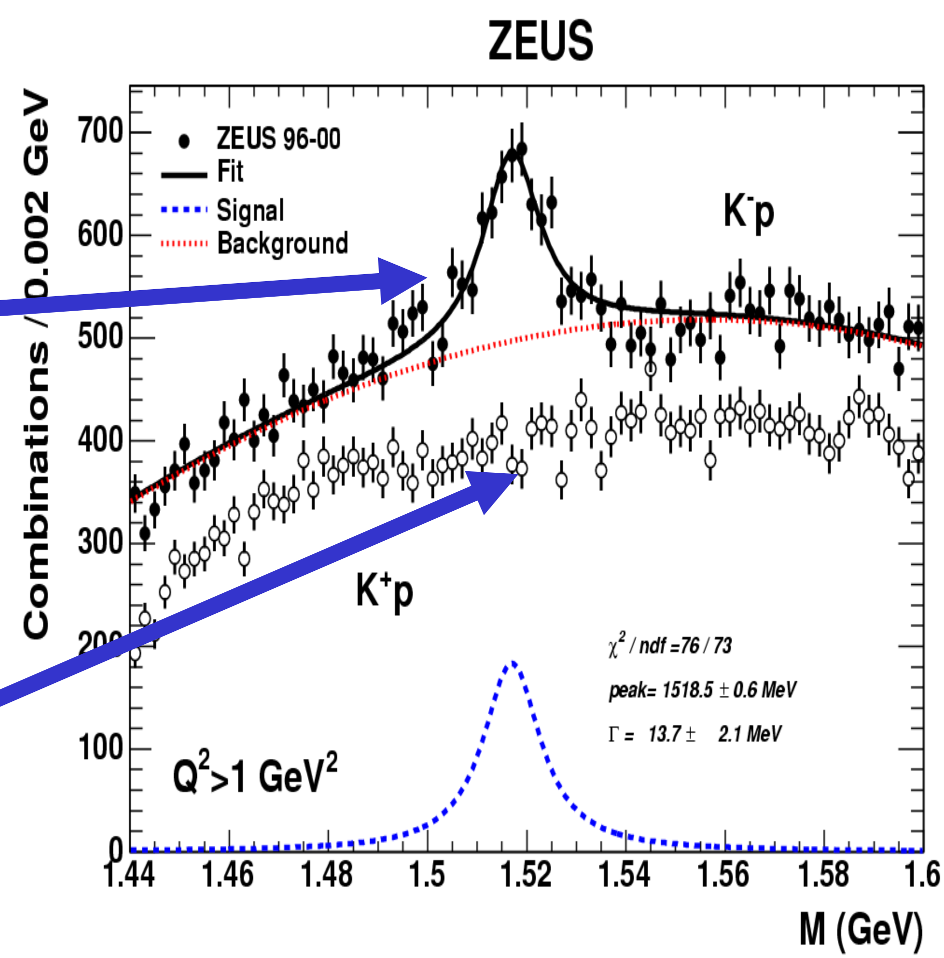
mass and natural width consistent with PDG:

M = 1519.5 ± 1.0 MeV

Γ = 15.6 ± 1.0 MeV

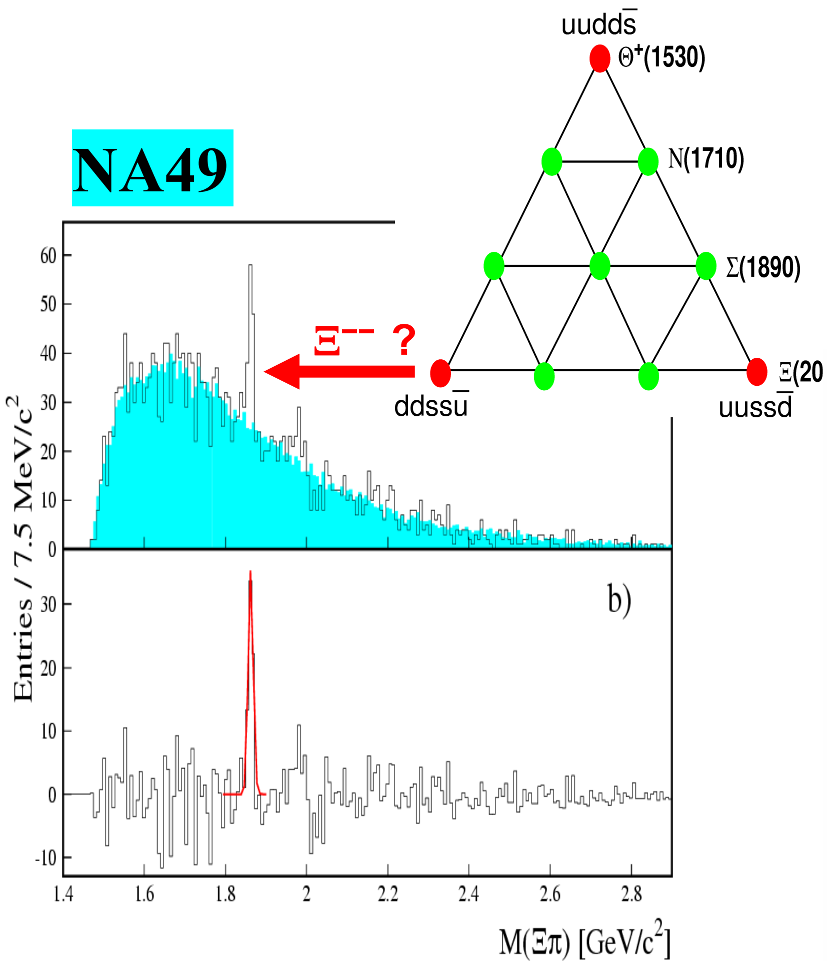
θ^{++}(1530) $\rightarrow p K^{+}$ + c.c

no evidence for hypothetical θ^{++}(1530)

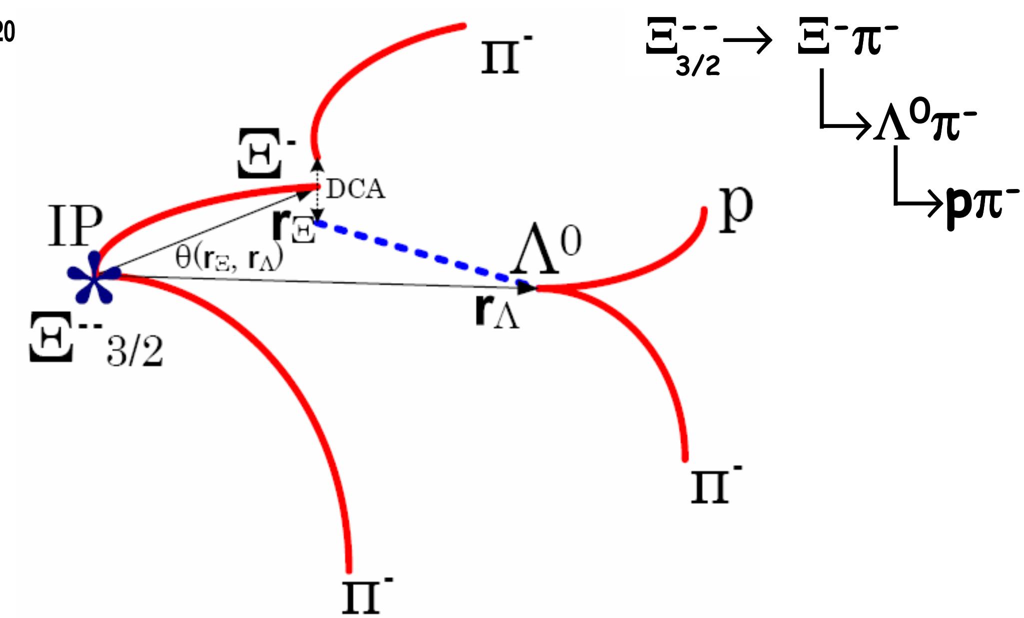


Search for Double Strange $\Xi_{3/2}^{--} \rightarrow \Xi^{-}\pi^{-}$

NA49 search for $\Xi_{3/2}^{--} \rightarrow \Xi^{-}\pi^{-}$
M = 1862 ± 2 MeV, ~3 σ

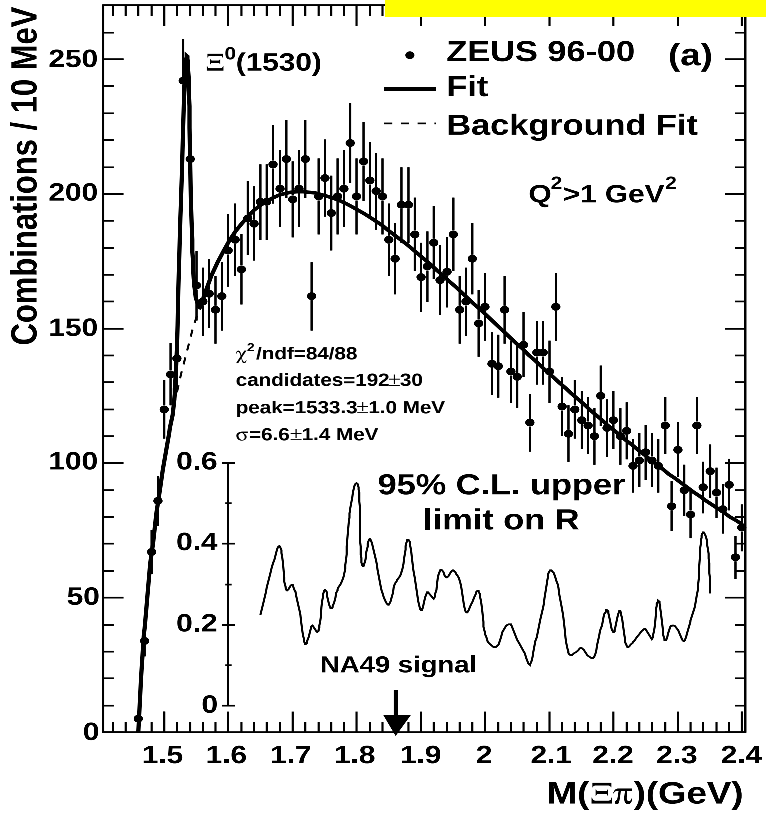


Similar analysis of NA49 repeated using ZEUS DIS data



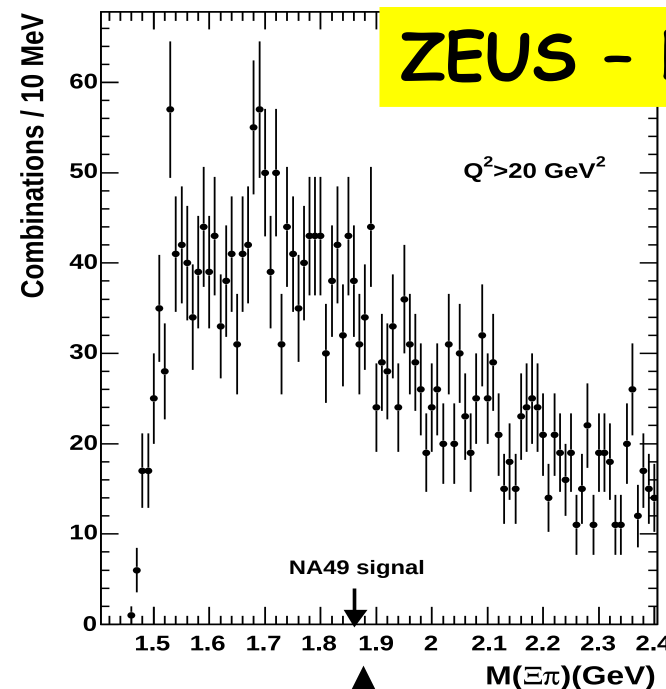
Search for Double Strange $\Xi^{--}_{3/2} \rightarrow \Xi^{-}\pi^{-}$

ZEUS - DIS.



NOTHING

ZEUS - high Q^2



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

The *charm* Pentaquark anti-decuplet

What about $\Theta^0_c \rightarrow D^{*-}p$?

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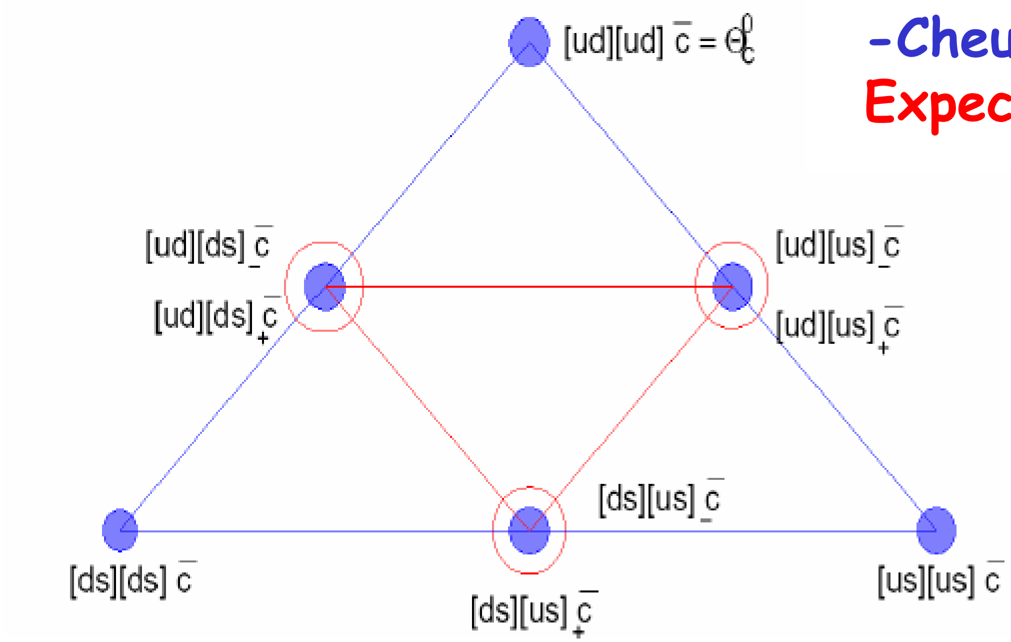


Many recent theoretical predictions:

- -Jaffe-Wilczek → M~2710 MeV
- -Wu-Ma → M~2704 MeV
- -Karliner-Lipkin → M~2985 MeV
- -Cheung → M~2938-2997 MeV

Expected width ~20 MeV

Decay modes:

- -M<2807 MeV θ^0_c+ → $\theta^+\pi^-$
- -M<2807 MeV θ^0_c+ → D^-p
- -M<2807 MeV θ^0_c+ → $D^{*-}p$

because of mass thresholds.

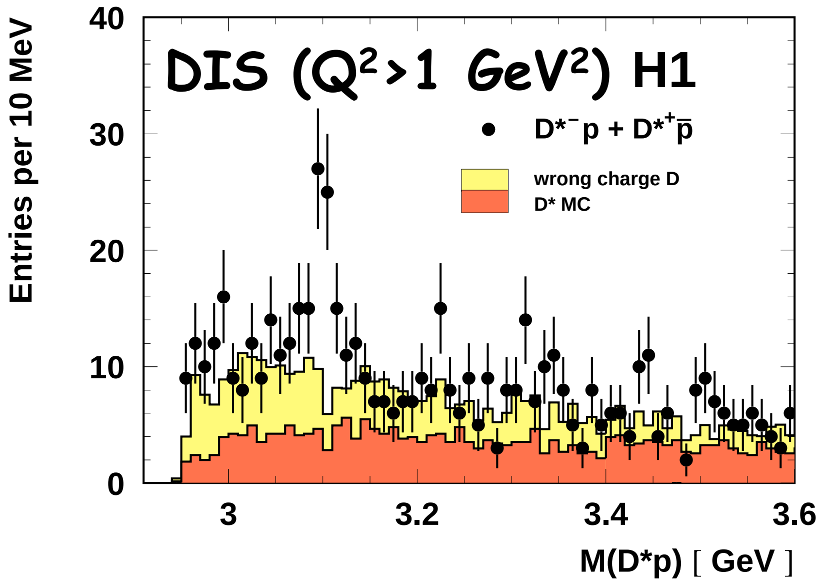
Main search decay channel:

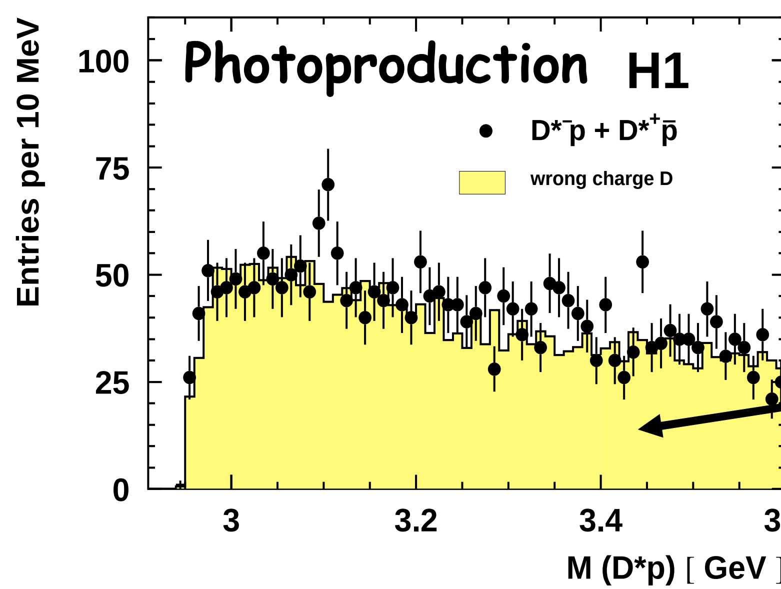
$\theta^0_c \rightarrow D^*p$

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

DIS and photoproduction samples

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





Non-charm background

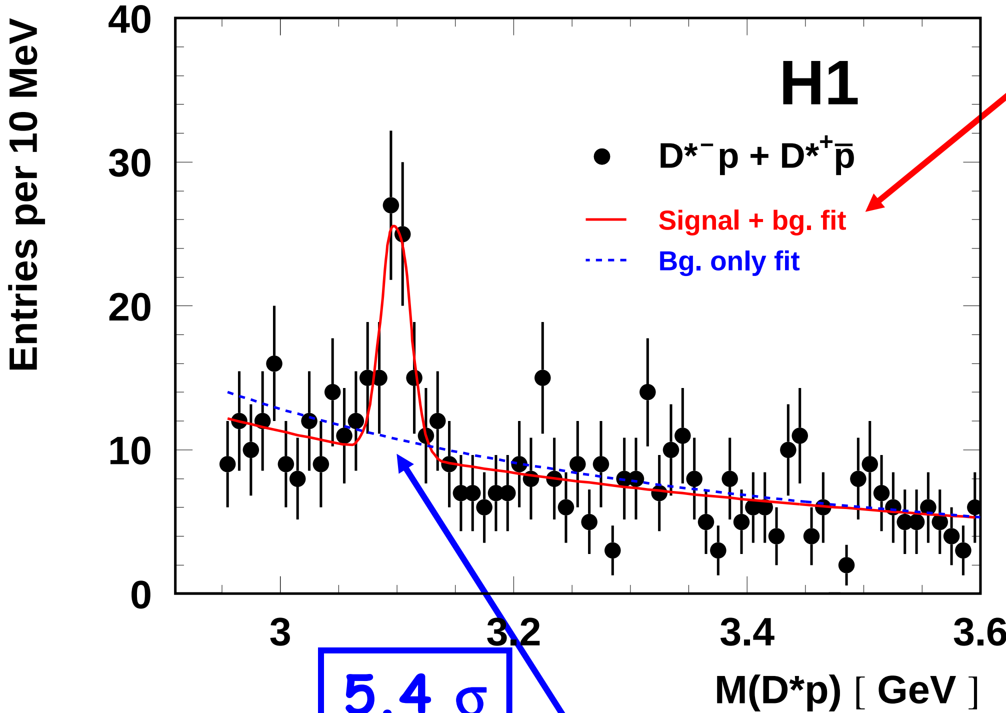
Signal at 3.1 GeV both in DIS and photoproduction samples

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

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

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

Significance estimatation



5.4 σ

Background + signal hypothesis:
Mass: 3099±3(stat)±5(sys) MeV
Width: 12 ± 3 MeV
(consistent with experimental resolution)

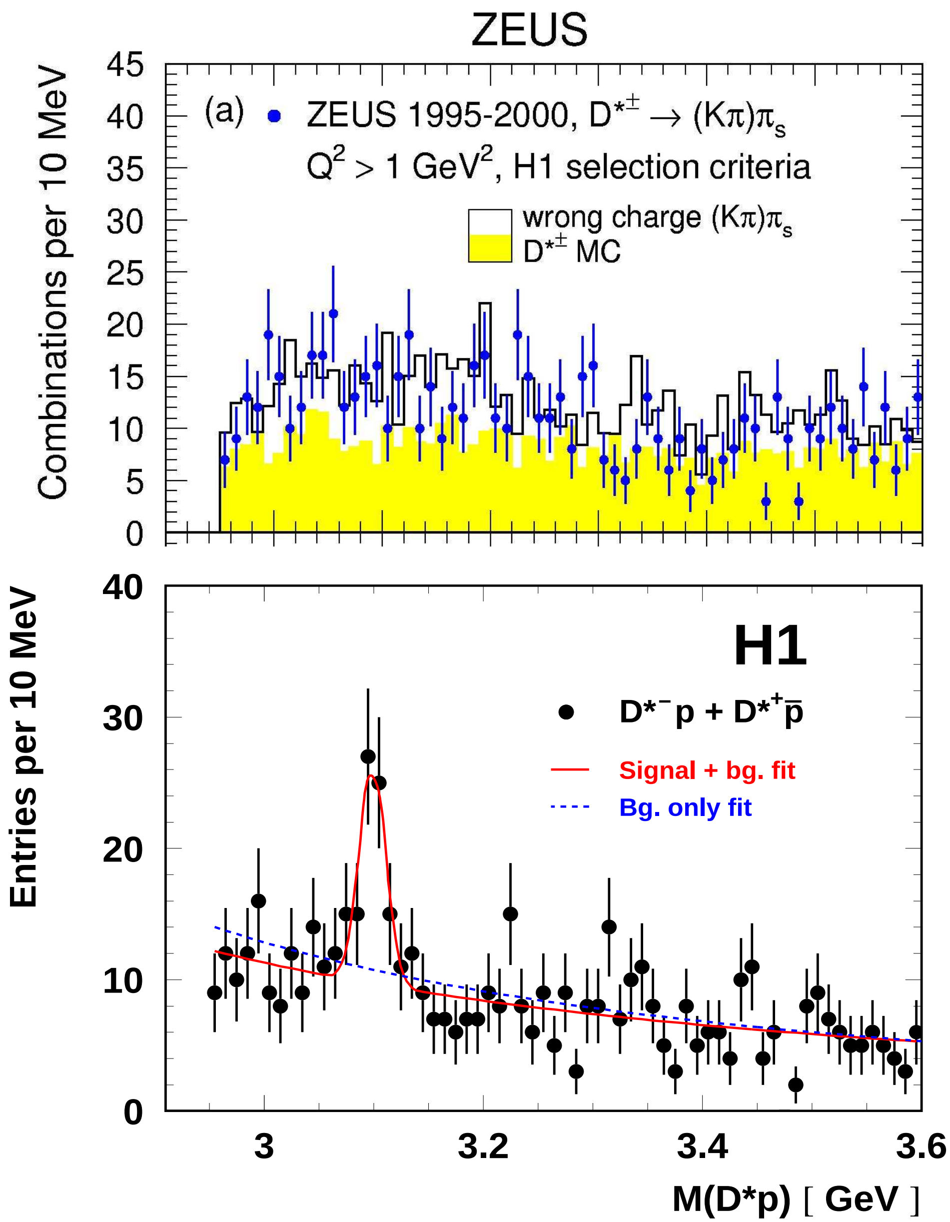
Numbers of signal and bg within 25 MeV:

N_b=45.0 ± 2.8
N_s=50.6 ± 11.2
(~1% of D* yield)

Background only hypothesis: N_b=51.7±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_θ/N_{D^*} :

< 0.0035 (ZEUS)

~ 0.01 (H1)

More quantitative comparisons require detector efficiency corrections

Conclusions

- θ^+(1530): evidence for a narrow baryonic state at mass 1521.5 decaying to $K^0{}_s p$ (ZEUS)
- θ^{++} (1530) : no evidence for a state decaying to K^+p (ZEUS)
- Ξ^{--} (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

Backup Slides

FAQ Pentaquarks: θ^+

- Q1: What's about H1 results?

Answer: there is no yet official result and work is ongoing.

- Q2: Why is the ZEUS signal not at small Q^2?

Answer: This is not understood in terms of standard fragmentation models. It may be a hint for a difference in PQ production compared due to standard K^0 production. There are differences between baryon and meson production. Why not also for PQs?

- Q3: Why is the θ^+ not seen in other high energy experiments?

Answer: There are large differences in standard baryon production between e^+e^-, ep and NN. The disagreement is even larger when considering the anti-deuteron production. We do not understand the standard fragmentation process well enough to conclude anything on consistency of PQ searches.

FAQ Pentaquarks: θ_c(1)

• Q1: Why is the H1 signal not confirmed by other experiments?

Answer: There are reasons for:

FOCUS: threshold effect

LEP: D* selection is anti-θ_c selection

CDF: no information available, may be trigger

BELLE: not in contradiction with H1. Limits too weak.

FAQ Pentaquarks: θ_c(2)

•Q2: Why is the H1 signal not confirmed by ZEUS?

Answer: Although H1 and ZEUS are looking at the same process, it is not clear whether the experiments can really be compared. Both experiments see only a small fraction of the $c\bar{c}$-phase space (about 20% at low Q^2). Due to trigger rate Zeus is unprescaled only for Q^2>20 GeV^2. Consequence: only 40% of the D*'s are from the DIS trigger in case of ZEUS, while 100% of the D*s in H1 are from the DIS trigger. For the DIS trigger Zeus has only 60% of H1 D* rate while Zeus luminosity is about a factor of 2 larger than H1. Zeus D*'s are coming from other triggers. It is not clear how these are mapping the D* phase space compared to the H1 trigger. The situation has to be clarified. Therefore H1 is going for acceptance corrected D*p yields (DIS05?) to see in which phase space region the events are produced.

FAQ Pentaquarks: θ_c(3)

- Q3: H1 claims a background fluctuation probability at 3.1 GeV of $4*10^{-8}$ but we do not know where it should be. What is the probability to find a fluctuation somewhere in this distribution?

Answer: This is less. Roughly a factor of 40 (mass-window). But H1 performed also a peak independent test for a signal in this distribution which looks for the change in the log likelihood of the fit for the signal+bg and the bg only hypotheses. This change corresponds to 6.2 sigma in favour of a signal in this distribution.