Search for CHARM pentaquarks (ZEUS)

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O U T L I N E

- **I:** Introduction: Narrow pentaquarks
- **II:** The ZEUS $\Theta^{+}(1530)$ signal
- **III:** Zeus search for Charm pentaquark
- **IV:** Conclusions

Exotic Hadronic Pentaquarks

Observations of narrow hadronic states was reported during the last 2 years The significance was typically between 4-5σ. Some examples:

- Some low energy experiments reported observation of narrow exotic baryon state: $\Theta^+(1530) \rightarrow K^+n$ or K^0p with $S = +1$.
  CLAS coll., V. Kubarovsky et al., Phys.Rev.Lett.92,032001,2004, LEPS Coll.,at SPring8, Hermes Coll. A. Airapetian et al., Phys.Lett.B585,213,2004 (SEE updates of JLAB and CLAS results at this conference).
- ZEUS also reported observing $\Theta^+(1521)$ (see following plots).
  $\Theta^+(1530)$ cannot be made of 3 quarks but it can be made of 5 quarks $uudd\bar{s}$.
  Such Pentaquarks do not exist in the naive quark model, but QCD does not forbid 5-quark hadronic states
- Many other experiments have searched but have NOT seen the $\Theta^+(1520)$
- H1 reported in March 2004 the observation of a narrow charm pentaquark $\Theta_c^0(= uudd\bar{c}) \rightarrow D^{*\pm}p^{\mp}$ at 3.1 GeV (See update in DIS 05).
- Sept. 2004: ZEUS published the NON observation of $\Theta_c^0(3099)$

Many high statistics experiments searched but did NOT see the Θ_c^0.
Many theory papers discuss the new resonances.Example, Karliner + Lipkin hep-ph/0506084 suggest specific Θ_c^0 production mechanism. Hundreds of theory papers discuss the narrow resonances. No conclusions !

The $\Theta^{\pm}$ in the ZEUS experiment

To understand better the $\Theta^{\pm}$ in high-energy experiments one should :

- **Look at central rapidity region, dominated by hard fragmentation**
  $\rightarrow$ Little sensitivity to the proton remnant
- **See if pentaquarks are created in proton fragmentation region which have a net baryon number?**

ZEUS searched for $\Theta^{\pm} \rightarrow K_S^0 p(\bar{p})$ and saw a signal at 1521 MeV
S. Chekanov et al., Phys. Lett. B 591 (2004) 7

The entire ZEUS HERA-I DIS data was used $Q^2 > 1$ GeV^2 (121 pb^{-1})
$e^{\pm}p$ collisions: $E_e = 27.6$ GeV; $E_p = 820, 920$ GeV; $\sqrt{s} \approx 300, 318$ GeV

$\approx 867,000$ K_S^0 candidates with $\approx 6\%$ background

Select protons from primary tracks: define ionization dE/dx bands

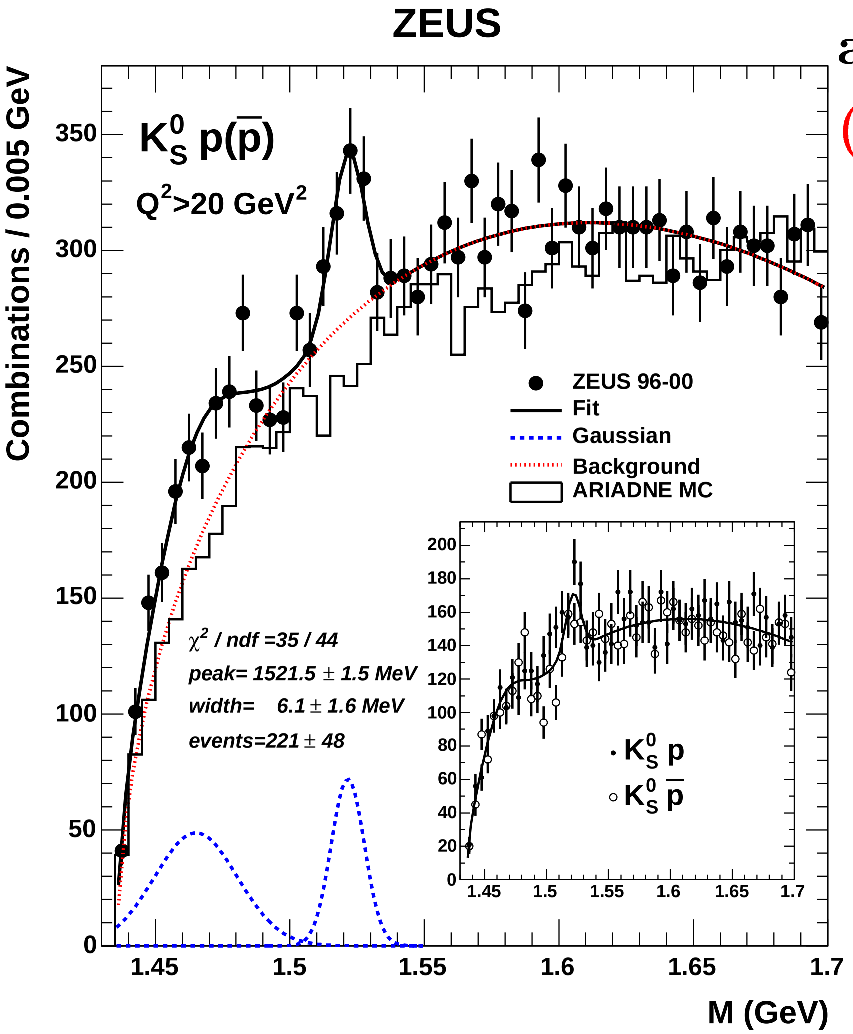
Cut on $dE/dx > 1.15$ mips, $P(p,\bar{p}) < 1.5$ GeV $\Rightarrow \approx 60\%$ proton purity

Check first reconstruction of $M(K^{\pm}p)$: Select p's and K's by dE/dx

See clean $\Lambda(1520) \rightarrow K^- p$. $N(\Lambda) \approx N(\bar{\Lambda}) \Rightarrow$ Main source - Fragmentation .
Also, ZEUS sees equal nos of $\Lambda(1520)$ in $\eta > 0$ and $\eta < 0$ (See following plots).

ZEUS published Results on $\Theta^{\pm}(1520)$

Fit the $M(K^0_S p)$ distribution to two Gaussians + threshold background function



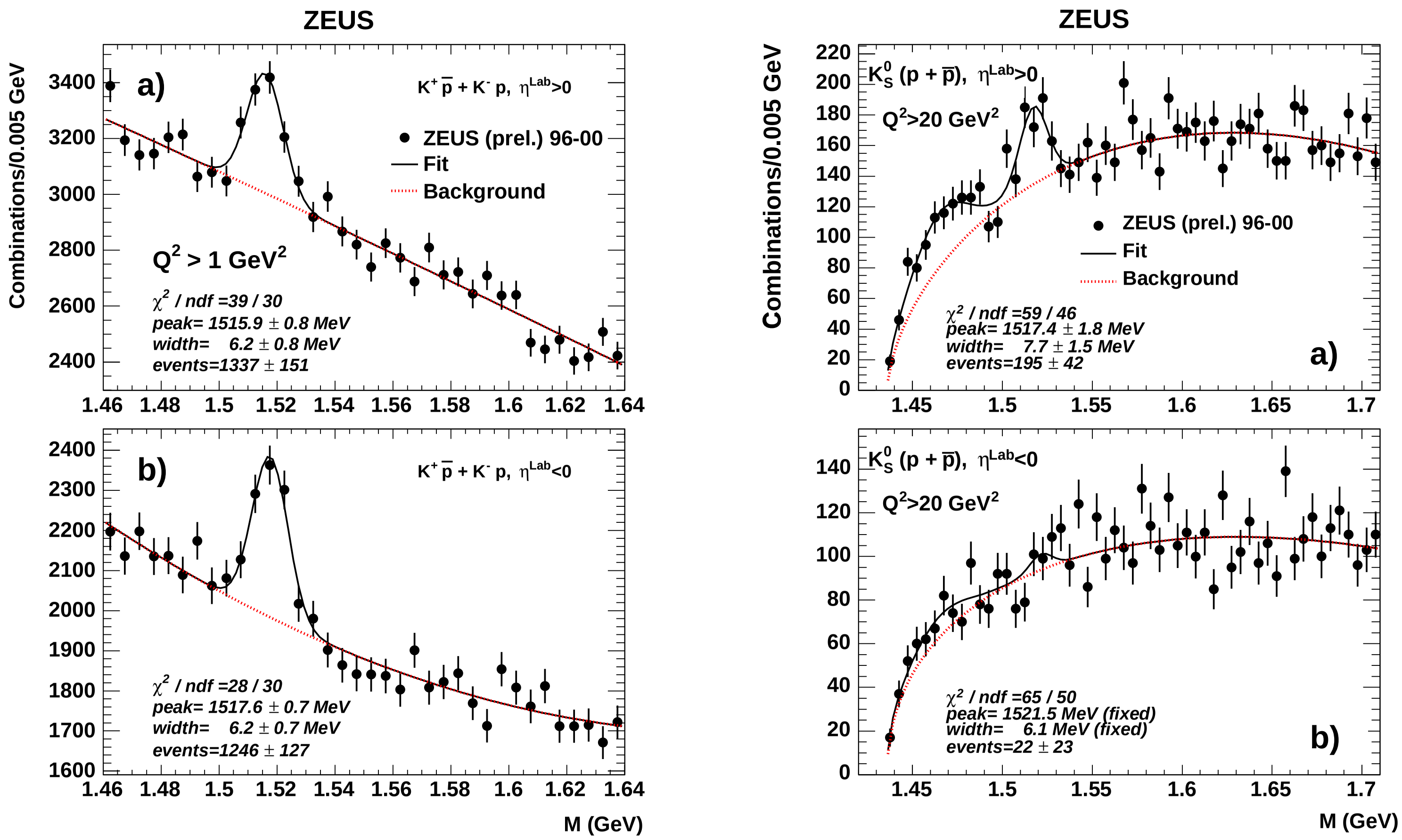
A narrow pK^0_S peak of $3.9 - 4.6$ s.d. is seen at 1521.5 MeV with a Gaussian width (6.1 ± 1.6 MeV) above but compatible with resolution (≈ 2 MeV). A convoluted Breit-Wigner function with a Gaussian fixed by experimental resolution yields $\Gamma = 8 \pm 4$ MeV

Probability of background fluctuating into signal in the range $1.5 - 1.56$ GeV is $< 6 \cdot 10^{-5}$

Signal seen in both charges (inset)

$K^0_S \bar{p}$ fit: 96 ± 34 (2.8 s.d.)

The ZEUS new analysis of $\Theta^+(1521)$



ZEUS (paper 05-013,LP2005) compared the $\Theta^\pm$ data with $\Lambda(1520)$ production

On the left plot the $\Lambda(1520)$ is shown for $\eta > 0$ and $\eta < 0$. The symmetry in the c.m.s is evident: NO PROTON REMNANT EFFECT is seen.

However the $\Theta^+(1521)$ production is mostly in the proton direction (upper R.H.S plot) $\Rightarrow$ hinting a DIFFERENT production mechanism !?

Charm Pentaquarks

If $\Theta^+ = uudd\bar{s}$ exists, heavy pentaquarks, such as $\Theta_c^0 = uudd\bar{c}$ should also exist

Several Theoretical Predictions:

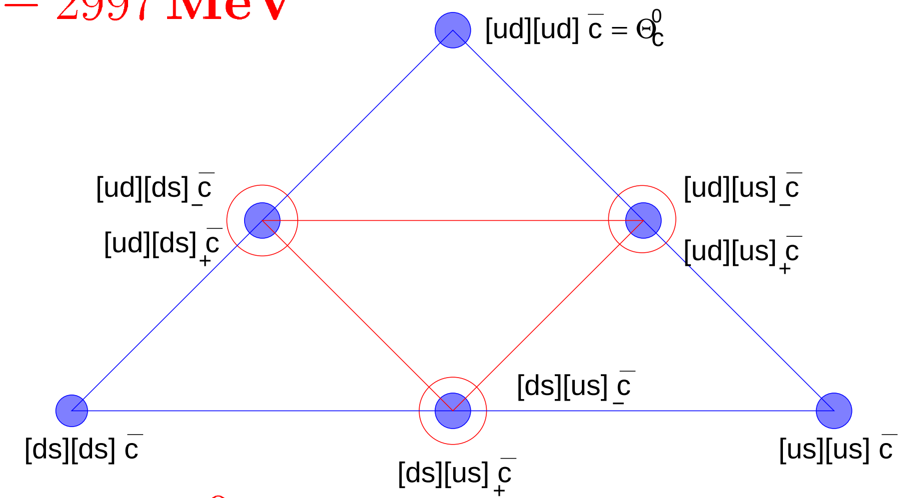
Jaffe-Wilczek (hep-ph/0307341); Wu-Ma (hep-ph/0402244):
$M(\Theta_c^0) \approx 2700$ **MeV** $\Rightarrow$ **too light to decay to** D **mesons**

Karliner-Lipkin (hep-ph/0307343):

$$M(\Theta_c^0) = 2985 \pm 50\,\textbf{MeV} \;;\; \Gamma(\Theta_c^0) \sim 21\,\textbf{MeV}$$

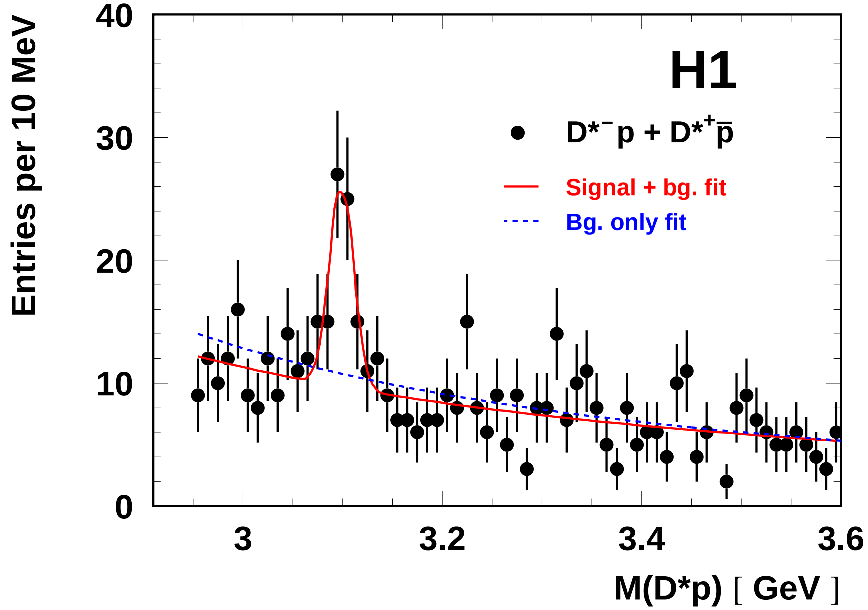
Cheung (hep-ph/0308176): $M(\Theta_c^0) = 2938 - 2997$ **MeV**
decays dominantly to $D^- p^+$ **or** $D^0 n$

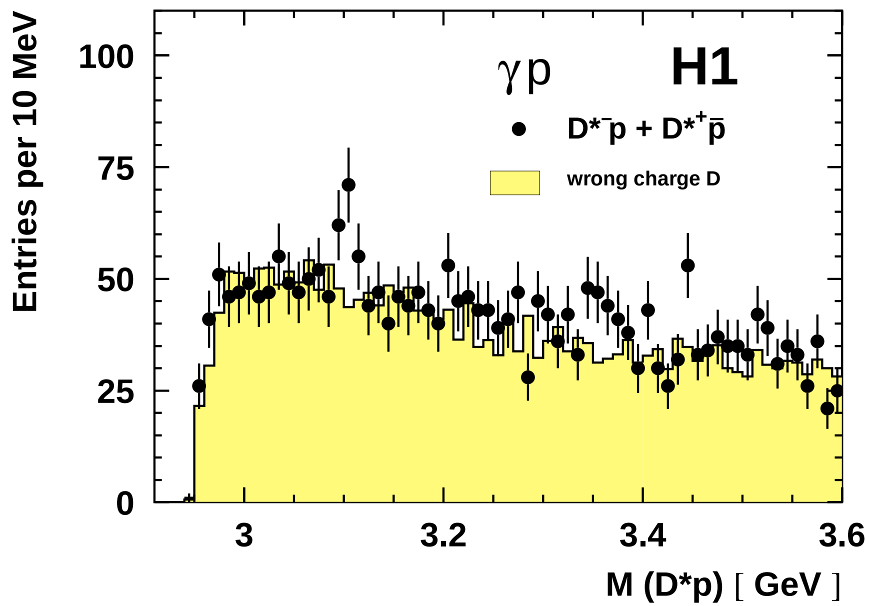
If $M(\Theta_c^0) > M(D^{*\pm}) + M(p) = 2948$ **MeV,**
Θ_c^0 **can decay to** $D^{*\pm} p$



H1 and ZEUS at HERA searched for Θ_c^0 signal in $M(D^{*-}p)$ (+ c.c.) spectra, where $D^{*+} \to D^0 \pi_s^+$ (+ c.c.)

The H1 Charm Pentaquark





In a DIS sample of ≈ 3400 $D^{*\pm}$ H1 reported observation of a narrow resonance in $M(D^{*-}p)$ (+ c.c.) in the D^0 decay mode $D^0 \to K^{\mp}\pi^{\pm}$ at a mass of $M = 3099 \pm 3(stat.) \pm 5(syst.)$ MeV

C. Atkas et al., Phys. Lett. B 588, 17 (2004); See K. Daum,update in DIS 05.

The measured Gaussian width $12 \pm 3(stat.)$ MeV
The quoted mass resolution (in talks) was about 7 MeV.

The signal in DIS consisted of 50.6 ± 11.2 events

Roughly 1% of the total D^* production rate.($(1.59 \pm 0.32)\%$, Reported DIS 05)

Signal also seen in photoproduction sample with $\approx$ same ratio to D^*

ZEUS search for the Θ_c^0 - D^* selection

All ZEUS HERA-I data was examined (126.5 pb^{-1})

The $D^{*\pm}(2010)$ mesons were identified using the two decay channels

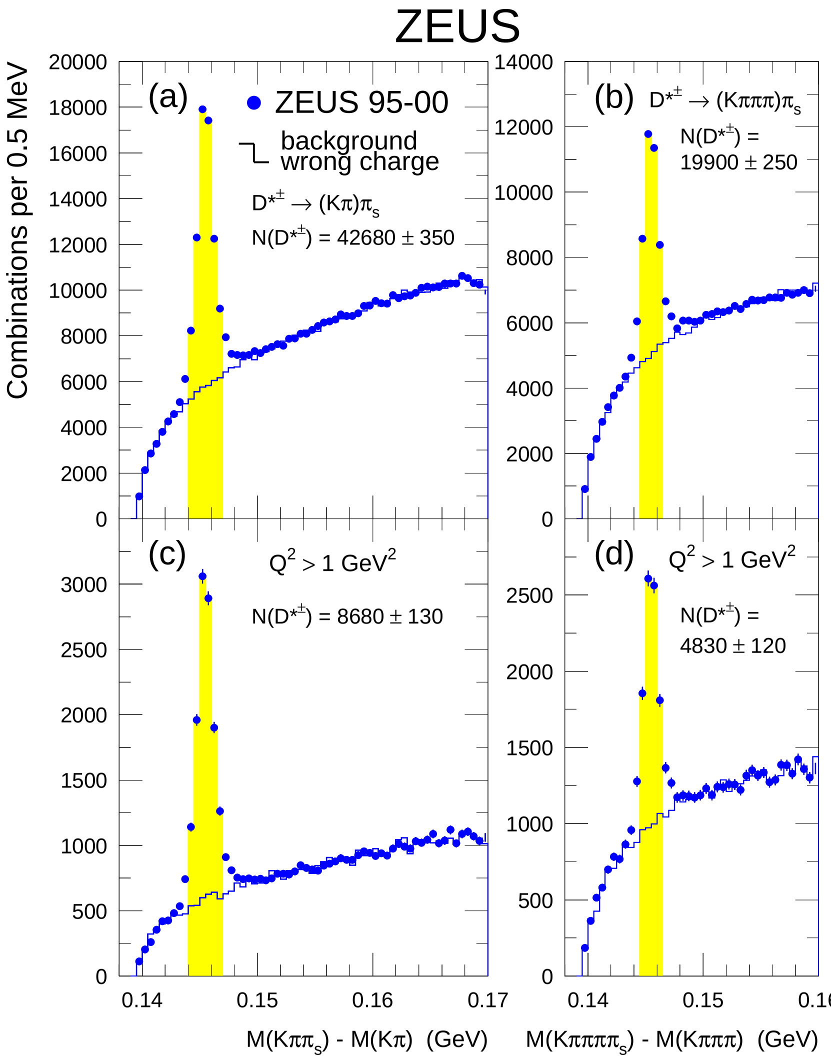
$$D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+)\pi_s^+ + (c.c.). \tag{1}$$

$$D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+\pi^+\pi^-)\pi_s^+ + (c.c.). \tag{2}$$

- **the mass difference $\Delta M = M(K\pi\pi_s) - M(K\pi)$ for channel (1) and $\Delta M = M(K\pi\pi\pi\pi_s) - M(K\pi\pi\pi)$ for channel (2) selected the D^* candidates. The D^* trigger efficiency was above 95%.**
- **Peaks at 145.5 MeV in $M(D^{*+}) - M(D^0)$ demonstrate the D^* signals. The wrong-charge combinations represent the background**
- **Cuts to reduce the combinatorial background:** $p_T(K,\pi) > 0.45\,\mathrm{GeV}$, $p_T(\pi_s) > 0.1\,\mathrm{GeV}$ **for channel (1), and** > 0.15 **for channel (2).**
- **Kinematic D^* region:** $-1.6 < \eta(D^*) < 1.6$, $p_T(D^*) > 1.35\mathrm{GeV}$ **or** $p_T(D^*) > 2.8\mathrm{GeV}$ **for channels (1) and (2) respectively.**
- **D^0 selection:** $1.83 < M(K\pi) < 1.90\,\mathrm{GeV},\ 0.144 < \Delta M < 0.147\mathrm{GeV}$

ZEUS search for the Θ_c^0

Publication: S. Chekanov et al., Eur.Phys.J.C 38 (2004) 29



$\Delta M = M(D^{*+}) - M(D^0) \sim m_\pi$

Clean D^* signals in 2 D^0 decay modes

$D^0 \to K^-\pi^+$; $D^0 \to K^-\pi^+\pi^+\pi^-$ **(+ c.c.)**

Θ_c^0 searched for with D^*'s from yellow bands $N(D^{*\pm}) \approx 62,000$

For the DIS sub-sample $Q^2 > 1$ **GeV^2**

$N(D^{*\pm}) \approx 13,500$

Proton selection: $P_T(p) > 0.15$ **GeV**

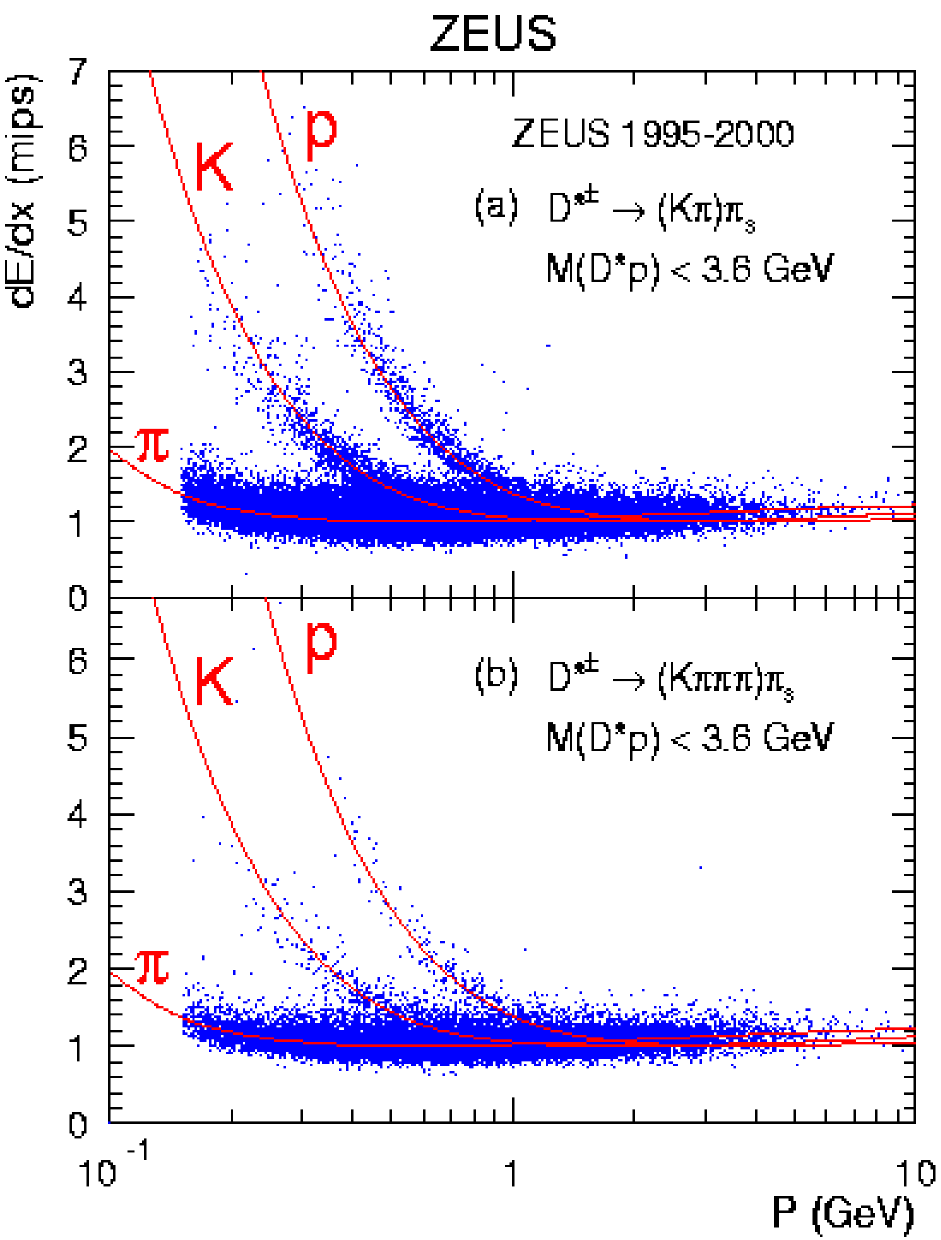
dE/dx applied for protons.

3 methods of p usage: (1) All Protons.

2) Low-P_p : $(dE/dx)_p$ **band;** $P < 1.35$ **GeV;** $dE/dx > 1.3$ **(Clean p's from dE/dx)**

3) High-P_p : $(dE/dx)_p$ **band;** $P > 2$ **GeV (Like H1 selection, without dE/dx cut)**

ZEUS search for the Θ_c^0: dE/dx



Plots of dE/dx for $M(D*p) < 3.6GeV.$

To ensure good dE/dx resolution at least 8 CTD hits were used.

P, K and π bands separated well at low momentum for both

D^0 decay modes:

$D^0 \to K^-\pi^+$ (+ c.c.)

$D^0 \to K^-\pi^+\pi^+\pi^-$ (+ c.c.)

ZEUS search for the Θ_c^0: use of dE/dx

A χ_1^2 method was used for dE/dx selection. (O.Deppe,PhD Thesis,1999)

For each particle, a χ_1^2 value that estimates the deviation of the measured dE/dx from the expectation was calculated as:

$$\chi_1^2 = \frac{[\ln(dE/dx) - \ln(dE/dx)_{\mathrm{expected}}]^2}{\sigma^2_{\ln(dE/dx)}}.$$

The resolution was parameterised empirically as $\sigma_{\ln(dE/dx)} = a/\sqrt{n}$, where n is the number of hits used for the dE/dx measurement and a is a constant determined from the sample of tagged protons. The χ_1^2 probability of the proton hypothesis, l_p, (l_p=0.0-1.0) is given by the probability for a proton to produce the observed or a larger value of χ_1^2.

The distribution of l_p for proton candidates shows a sharp peak at $l_p \sim 0$ and becomes relatively flat towards $l_p \sim 1$.

Cut to optimize the signal/background: $l_p > 0.15$.

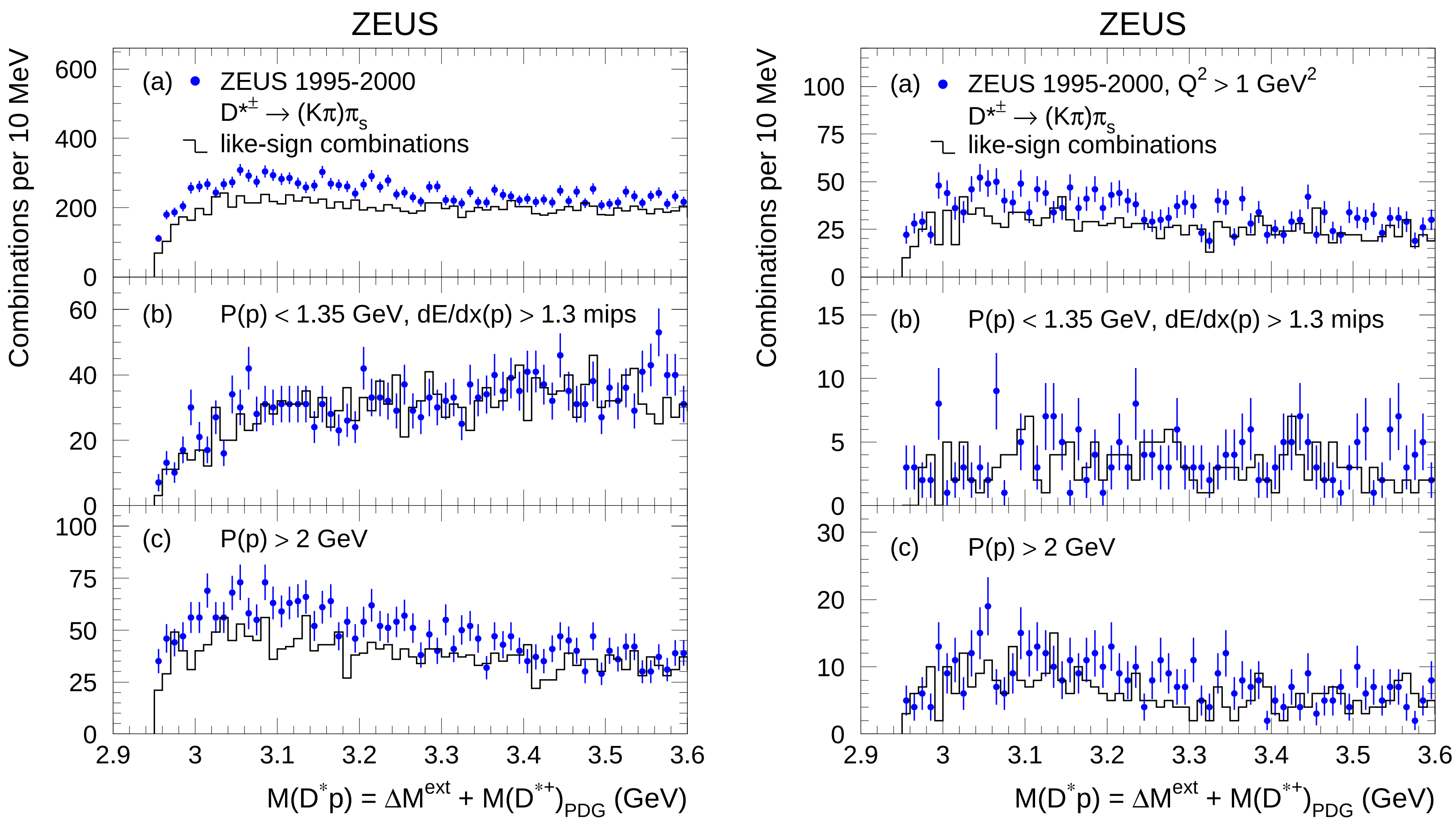
The acceptance of the protons before the cut l_p, was, using the Θ_c^0 MC, 85% and 89% for samples with D^*'s in channels (1) and (2), respectively.

After the cut $l_p > 0.15$ it became $(85.0 \pm 0.1)\%$, independent of the p momenta spectrum.

ZEUS $M(D^*p)$ spectra for the $D^0 \to K^-\pi^+$ channel

$$M(D^*p) = M(K\pi\pi_s p) - M(K\pi\pi_s) + M(D^{*+})_{\mathrm{PDG}}$$

full sample — **DIS sample**



All protons

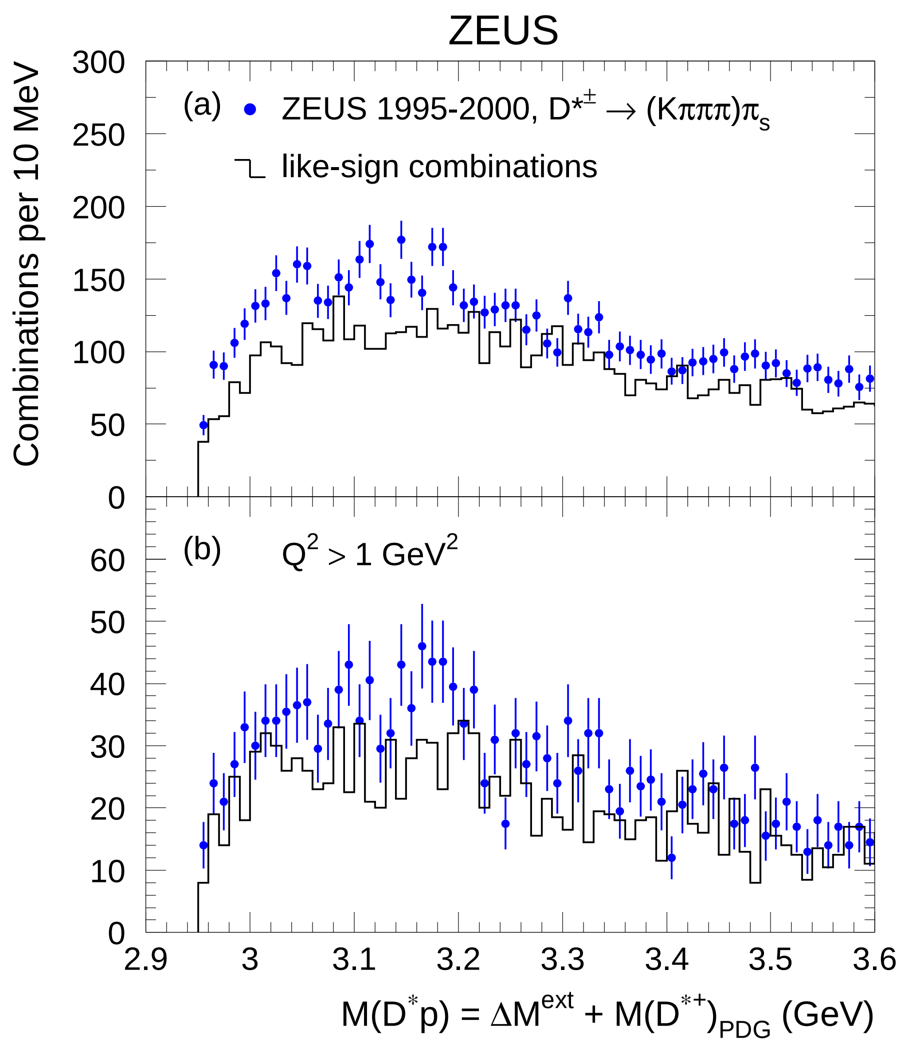
Low-P_p

High-P_p,no dE/dx

Histograms are like-sign combinations. Mass resolution from MC: 4 MeV.

No evidence for a Θ_c^0 signal at 3.1 GeV in the $D^0 \to K^-\pi^+$ channel.

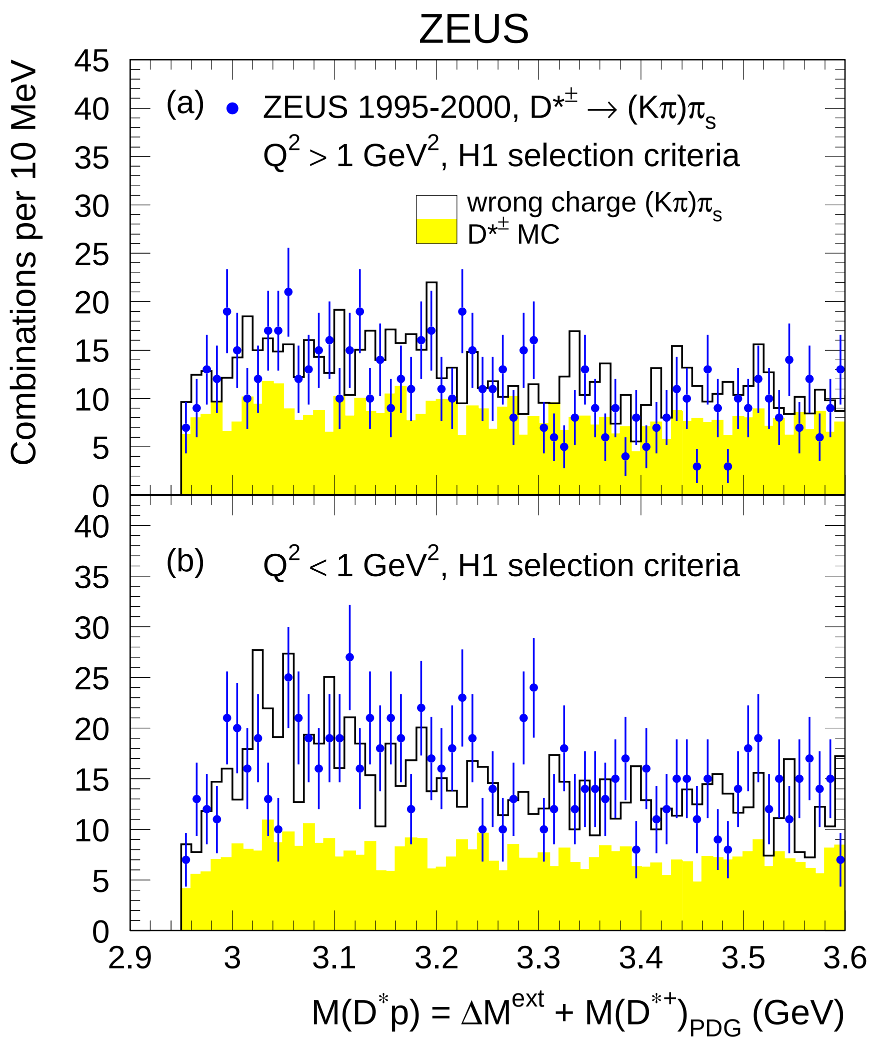
ZEUS $M(D^*p)$ spectra for the $D^0 \to K^-\pi^+\pi^+\pi^-$ channel



No evidence for Θ_c^0 also in the $D^0 \to K^-\pi^+\pi^+\pi^-$ channel.

ZEUS $M(D^*p)$ spectra $D^0 \to K^-\pi^+$ channel,H1 selection

The Θ_c^0 analysis was repeated using as far as possible the H1 cuts



ZEUS RATE relative to H1 is

proportional to relative D^* nos.

No evidence for Θ_c^0 using H1

ΔM and $D^0 \to K^-\pi^+$ cuts.

ZEUS upper limits for Θ_c^0 production I

Upper limits on the fraction of D^* mesons originating from the Θ_c^0 decays were set in the signal window $3.07 < M(D^*p) < 3.13$ GeV. This window covers the H1 measurement taking into account the uncertainties of the measured Θ_c^0 mass and width. The upper limits were calculated for the full D^*-meson samples obtained with D^* reconstructed in channels (1) and (2):

$$(1) D^0 \to K^-\pi^+ \qquad (2) D^0 \to K^-\pi^+\pi^+\pi^-$$

Each $M(D^*p)$ distribution was fitted outside the signal window to the functional form $x^a \exp(-bx + cx^2)$, where $x = \Delta M^{\text{ext}} - m_p$, m_p is the proton mass and:

$$\Delta M^{\text{ext}} = M(K\pi\pi_s p) - M(K\pi\pi_s) \text{ or } \Delta M^{\text{ext}} = M(K\pi\pi\pi\pi_s p) - M(K\pi\pi\pi\pi_s).$$

The fitted curves describe the $M(D^*p)$ distributions reasonably well in the whole range (see following Figures)

The number of reconstructed Θ_c^0 baryons was estimated by subtracting the background function, integrated over the signal window, from the observed number of candidates in the window. This number was divided by the number of reconstructed D^* mesons, yielding the fraction of D^* mesons originating from the Θ_c^0 decays: $R(\Theta_c^0 \to D^*p/D^*)$.

ZEUS upper limits for Θ_c^0 production II

The upper limits are the frequentist confidence bounds calculated for a Gaussian probability function (Feldman and Cousins,P.R.D57,3873(1998)).

The 95% C.L. upper limits on $R(\Theta_c^0 \to D^*p/D^*)$ are 0.29% and 0.33% for channels (1) and (2), respectively. The combined upper limit for both channels is 0.23%. The combined upper limit for DIS with $Q^2 > 1\mathrm{GeV}^2$ is 0.35%

To correct the fraction of D^* mesons originating from the Θ_c^0 decays for detector effects, we also calculated the relative acceptance of the above ratio R:

$$R^{cor}(\Theta_c^0 \to D^*p/D^*) = \frac{A(\Theta_c^0 \to D^*p)}{A^{\mathrm{inc}}(D^*)} = \frac{A^{\Theta_c^0}(D^*)}{A^{\mathrm{inc}}(D^*)} \cdot A(p) \cdot A(l_p > 0.15).$$

With the observed D^* mesons in ZEUS and H1 reported 1% Θ_c^0 production rate a signal of 626 Θ_c^0 baryons (995 for a 1.59% signal, quoted in DIS05) should have been CLEARLY seen our M(D^*p) plots !

Assuming Gaussian statistics, a 1% signal with the expected number of background events could produce 626 Θ_c^0 events in the signal window only in cases of statistical fluctuations larger than $9\,\sigma$. For our DIS ($Q^2 > 1\mathrm{GeV}^2$) sample the exclusion is about $5\,\sigma$.

A plot of such expected number of events is shown in the following figures and the detailed results of both channels are given in the following table

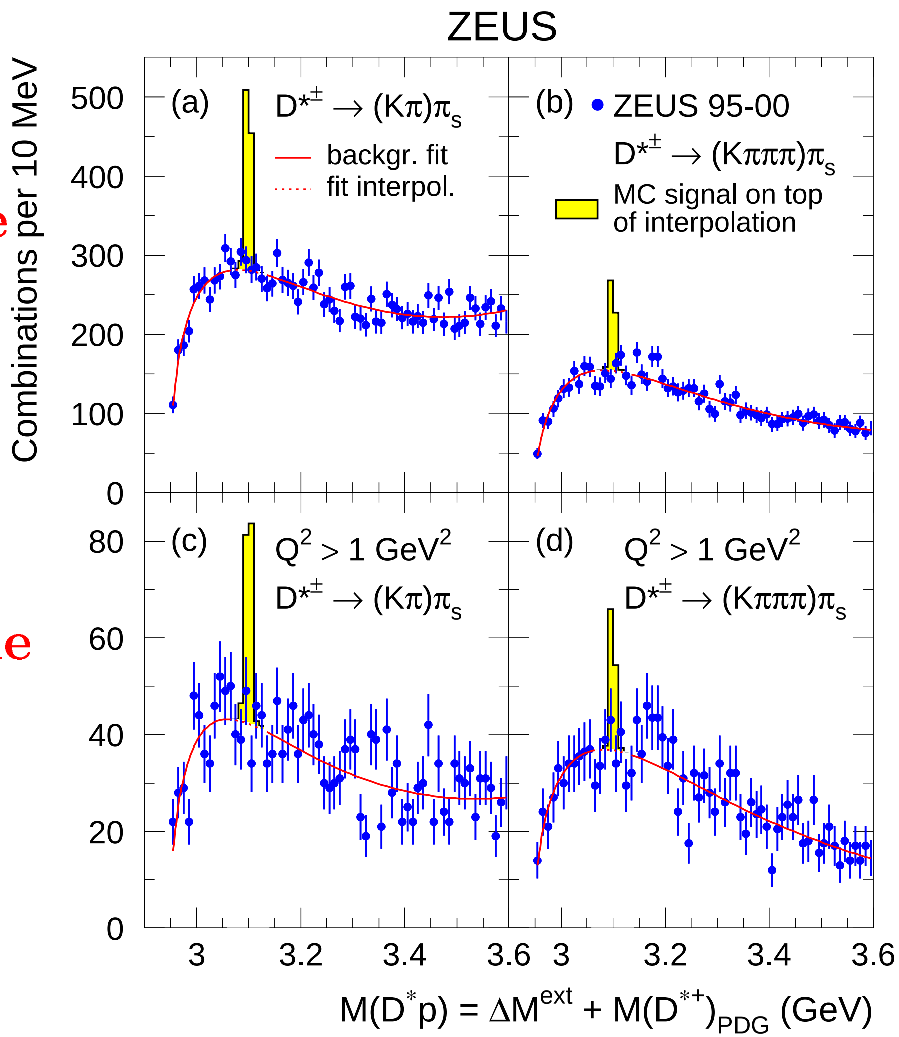
ZEUS upper limits for Θ_c^0 production III

$$M(D^*p) = M(K\pi\pi_s p) - M(K\pi\pi_s) + M(D^{*+})_{\rm PDG}$$

$D^0 \to K^-\pi^+ \qquad D^0 \to K^-\pi^+\pi^+\pi^-$

Full sample

DIS sample



Yellow histograms are MC Θ_c^0 signals normalized to $\Theta_c^0/D^* = 1\%$ after H1 on top of a background fit (solid curves)

95% **C.L. upper limits on $R(\Theta_c^0 \to D^*p/D^*)$ calculated in D^*p window 3.07-3.13GeV.**

A visible rate of $R = 1\%$ is excluded by 9 s.d. (5 s.d) for the full (DIS) sample.

$R < 0.23\%$ $(< 0.35\%)$ **for full (DIS) sample.**

Accepted-corrected limits: $< 0.37\% (< 0.51\%)$ **for full (DIS) sample.**

$f(c \to \Theta_c^0) \cdot B_{\Theta_c^0 \to D^*p} < 0.16\%$ $(< 0.19\%)$ **for the full (DIS) combined sample**

D^* decay channel	$(K\pi)\pi_s$	$(K\pi\pi\pi)\pi_s$	Both channels
Full data sample			
$N_{\rm window}$	1710	914	
$N_{\rm backgr}$	1678 ± 23	919 ± 19	
$N(D^*)$	42680 ± 350	19900 ± 250	
$R(\Theta_c^0 \to D^*p/D^*)$	$< 0.29\%$	$< 0.33\%$	$< 0.23\%$
$R^{\rm cor}(\Theta_c^0 \to D^*p/D^*)$	$< 0.47\%$	$< 0.50\%$	$< 0.37\%$
$f(c \to \Theta_c^0) \cdot B_{\Theta_c^0 \to D^*p}$	$< 0.18\%$	$< 0.33\%$	$< 0.16\%$
DIS with $Q^2 > 1{\rm GeV}^2$			
$N_{\rm window}$	252	220	
$N_{\rm backgr}$	252.8 ± 9.2	219.8 ± 8.8	
$N(D^*)$	8680 ± 130	4830 ± 120	
$R(\Theta_c^0 \to D^*p/D^*)$	$< 0.41\%$	$< 0.69\%$	$< 0.35\%$
$R^{\rm cor}(\Theta_c^0 \to D^*p/D^*)$	$< 0.59\%$	$< 1.06\%$	$< 0.51\%$
$f(c \to \Theta_c^0) \cdot B_{\Theta_c^0 \to D^*p}$	$< 0.20\%$	$< 0.56\%$	$< 0.19\%$
Photoproduction with $Q^2 < 1{\rm GeV}^2$			
$N_{\rm window}$	1458	695	
$N_{\rm backgr}$	1422 ± 21	694 ± 15	
$N(D^*)$	34000 ± 330	15070 ± 220	
$R(\Theta_c^0 \to D^*p/D^*)$	$< 0.36\%$	$< 0.40\%$	$< 0.29\%$
$R^{\rm cor}(\Theta_c^0 \to D^*p/D^*)$	$< 0.60\%$	$< 0.60\%$	$< 0.47\%$
$f(c \to \Theta_c^0) \cdot B_{\Theta_c^0 \to D^*p}$	$< 0.23\%$	$< 0.43\%$	$< 0.21\%$

Table 1: Numbers of the $M(D^*p)$ combinations in the signal window, $N_{\rm window}$; fit background estimations, $N_{\rm backgr}$; numbers of reconstructed D^* mesons, $N(D^*)$; 95% C.L. upper limits on the uncorrected, $R(\Theta_c^0 \to D^*p/D^*)$, and corrected, $R^{\rm cor}(\Theta_c^0 \to D^*p/D^*)$, fractions of D^* mesons originating from Θ_c^0 decays; and 95% C.L. upper limits on the product of the fraction of c quarks hadronising as a Θ_c^0 baryon, $f(c \to \Theta_c^0)$, and the branching ratio of the Θ_c^0 decay to D^*p, $B_{\Theta_c^0 \to D^*p}$. The results are shown for the full data sample, for DIS with $Q^2 > 1{\rm GeV}^2$ and for photoproduction with $Q^2 < 1{\rm GeV}^2$.

Summary of ZEUS search for Θ_c^0 in $e-p$ at HERA

ZEUS has searched for a resonance in the $D^{*\pm}p^{\mp}$ invariant-mass spectrum at HERA using an integrated luminosity of $126pb^{-1}$. The decay channels

$$D^0 \to K^-\pi^+ \qquad D^0 \to K^-\pi^+\pi^+\pi^- \ \textbf{(+c.c.)}$$

were used to identify $D^{*\pm}$ mesons.

No resonance structure was observed in the $M(D^{*\pm}p^{\mp})$ spectrum from more than $60\,000$ reconstructed $D^{*\pm}$ mesons. The upper limit on the fraction of D^* mesons originating from Θ_c^0 decays is 0.23% (95% C.L.). The upper limit for DIS with $Q^2 > 1\,\mathrm{GeV}^2$ is 0.35% (95% C.L.). Using the corrected ratios, R^{cor}, the limits become 0.37% and 0.51% respectively.

CONCLUSION : the ZEUS data are not compatible with the H1 report of Θ_c^0 baryon production in DIS and photoproduction, with a rate, in DIS, of roughly 1% of the D^* production rate.

FUTURE RESULTS FROM HIGH STATISTICS HERA II DATA MAY RESOLVE THE ZEUS/H1 Θ_c^0 DISCREPANCY

Spare: Repeating the Θ_c^0 analysis with the H1 cuts

The D^* in channel (1) $D^0 \to K^-\pi^+$ analysed using the H1 criteria:

(1). The minimum P_T of the D^* tracks were set to the H1 values.
(2). The cut $p_T(D^*)/E_T^{10} > 0.12$ was replaced by the cut $z(D^*) > 0.2$, where $z(D^*) = P \cdot p(D^*)/P \cdot q$ and P, $p(D^*)$ and q are the four-momenta of the incoming proton, the D^* meson and the exchanged photon. In the proton rest frame, $z(D^*)$ is the fraction of the photon energy carried by the $D^{*\pm}$ meson. The requirements on $M(K\pi)$ and ΔM were kept as in the nominal ZEUS analysis since they were determined by the mass resolution of the ZEUS CTD.
(3). The DIS events were selected with $Q^2 > 1\,\mathrm{GeV}^2$ and $0.05 < y < 0.7$, while the photoproduction events were selected with $Q^2 < 1\,\mathrm{GeV}^2$ and $0.2 < y < 0.8$
(4). The D^* candidates were required to have $-1.5 < \eta(D^*) < 1.0$ and $p_T(D^*) > 1.5\mathrm{GeV}$ or $p_T(D^*) > 2.0\mathrm{GeV}$ in DIS or photoproduction selections, respectively.
(5). No. of D^*'s became 5920 ± 90 and 11670 ± 140 for DIS and photoprod.
(6) The cut $l_p > 0.15$ was replaced by the H1 cut of normalised proton likelihood. P_p range $1.6 - 2.0\,\mathrm{GeV}$ was excluded for photoproduction.

NO $\Theta_c^0(3.1GeV)$ seen in the ZEUS data with the H1 CUTS.

Spare: Other pentaquark searches in e^+e^- annihilations

ALEPH sets upper limits of

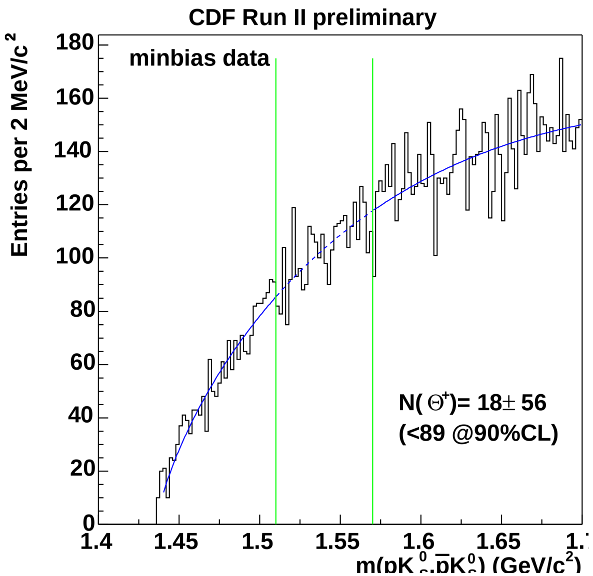
$$N(\Theta_c^0) \cdot BR(\Theta_c^0 \to D^{*-}p) < 6.3 \cdot 10^{-4}$$

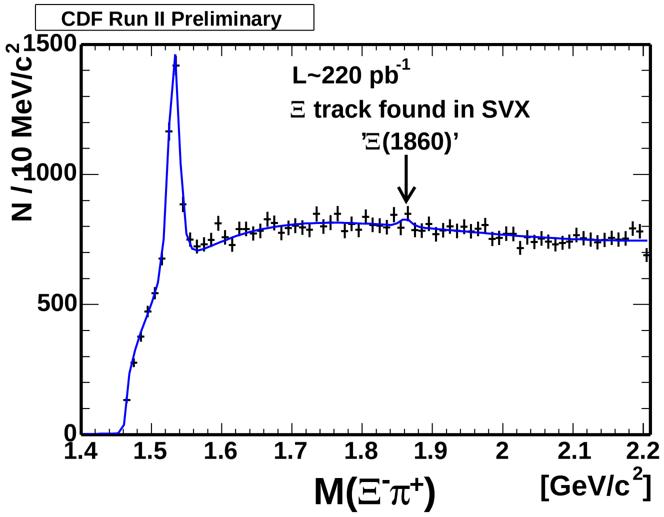
$$N(\Theta_c^0) \cdot BR(\Theta_c^0 \to D^{-}p) < 3.1 \cdot 10^{-3}$$

ALSO No evidence for $\Theta^+(1530), \Theta_c^0(3100)$ in DELPHI and OPAL at LEP as well as IN Belle and BaBar (see reports at this conference)

CONCLUSION: in e^+e^- annihilations neither the $\Theta^+(1530)$, nor $\Theta_c^0(3100)$ are seen !

Other pentaquark searches: CDF, in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ GeV

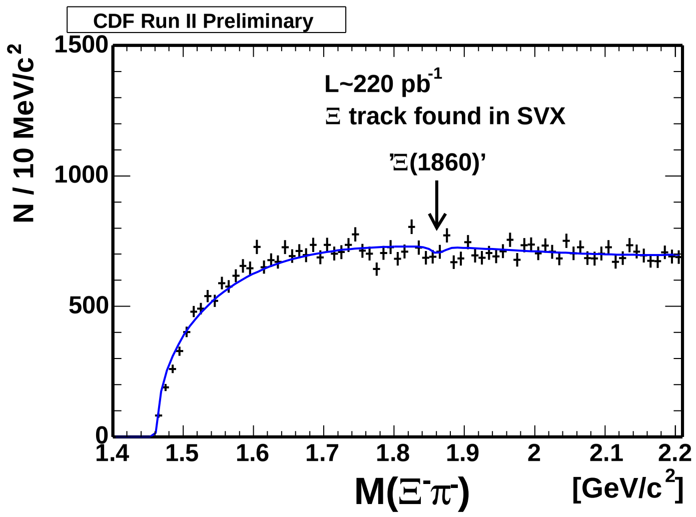


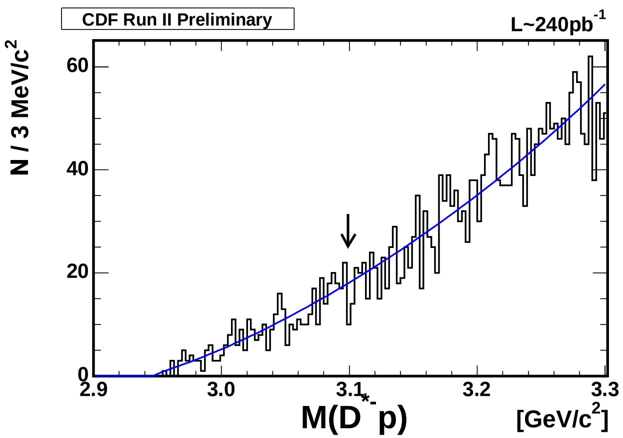


CDF Run II at the TEVATRON $(220\ \mathrm{pb}^{-1})$

No evidence for

$\Theta^+(1530)$, $\Xi^{--}(1862)$, $\Xi^0(1862)$, $\Theta_c(3099)$





CDF 90% C.L. limits:

$$BR(\Theta^+ \to pK^0_S) \cdot N(\Theta^+)/N(\Lambda(1520)) < 0.0034$$

$$BR(\Xi^0(1862) \to \Xi^-\pi^+) \cdot N(\Xi^0(1862))/N(\Xi^0(1530)) < 0.06$$

$$N(\Theta^0_c) \cdot BR(\Theta^0_c \to D^{*-}p) < 3.9 \cdot 10^{-5}$$

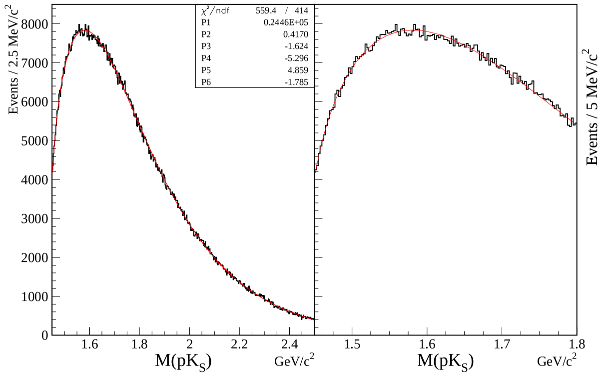
Other pentaquark searches: FOCUS

FOCUS: Fixed-target Fermilab experiment

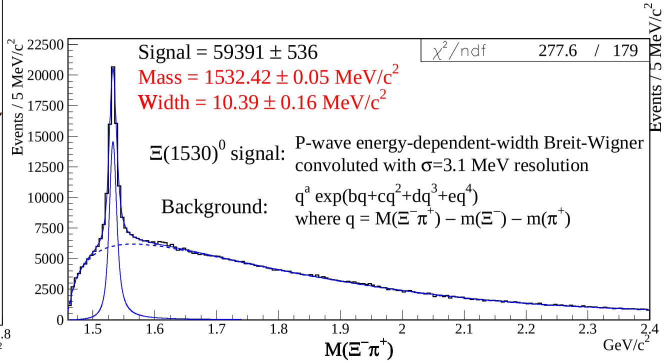
Photon beam from 300 GeV $e^{\pm}$ beam on BeO targets

Search for Θ^+, $\Xi(1862)$ and Θ_c^0 (hep-ex/0506013)

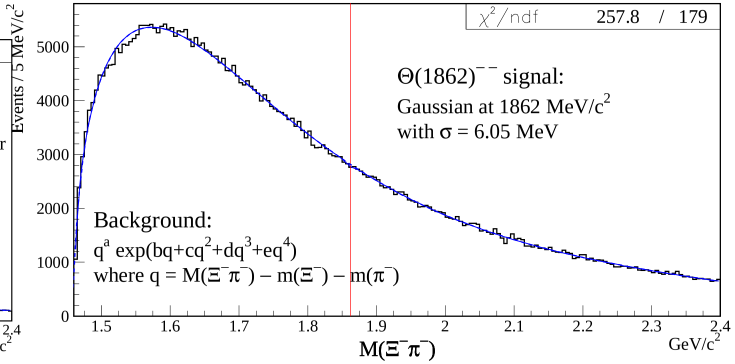
$\Theta^+(1530) \to pK_S^0$



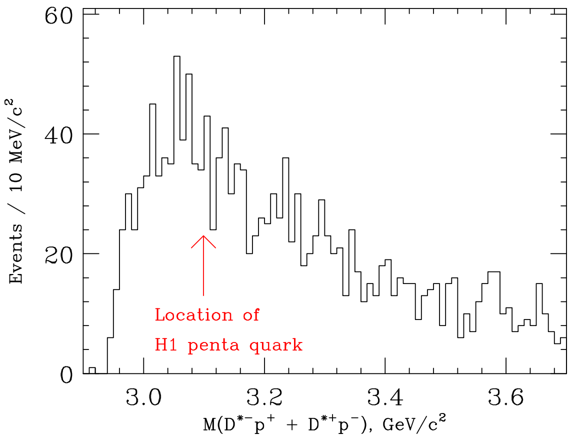
$\Xi^0(1862) \to \Xi^-\pi^+$



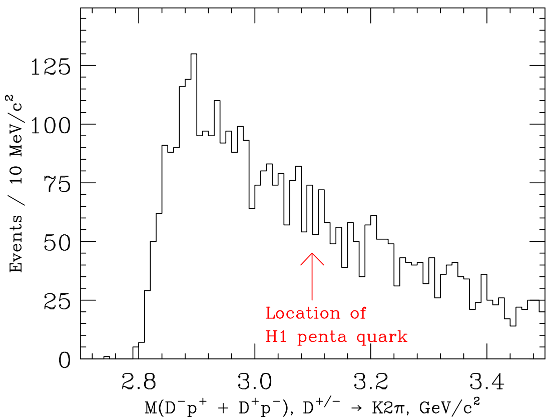
$\Xi^{--}(1862) \to \Xi^-\pi^-$



$\Theta_c^0(3099) \to D^{*-}p$



$\Theta_c^0(3099) \to D^-p$



Sample: 63 million K_S^0

800,000 Ξ^-

$\approx 60,000\ \Xi^0(1530)$

$\approx 36,000 D^{*-}$

$\approx 84,000 D^-$

No evidence for $\Theta^+(1530)$, $\Xi^{--}(1862)$, $\Xi^0(1862)$, $\Theta_c(3099)$

95% C.L. limits (assuming $BR(\Theta^+ \to pK_S^0) = 0.25$):

$\sigma(\Theta^+)/\sigma(\Sigma^{\pm}(1385)) < 2.1\%$; $\sigma(\Theta^+)/\sigma(K^{*-}(892)) < 0.17\%$

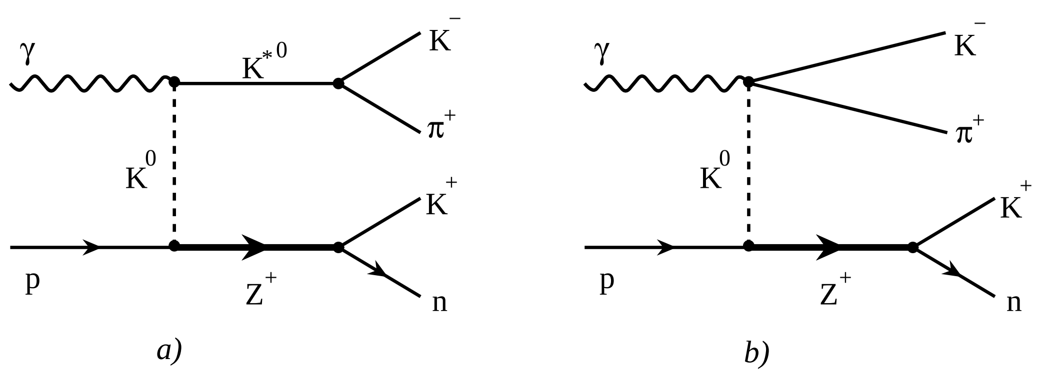
$\sigma(\Theta_c) \cdot BR(\Theta_c \to D^*p/\sigma(D^*) < 4.2 \cdot 10^{-4}$

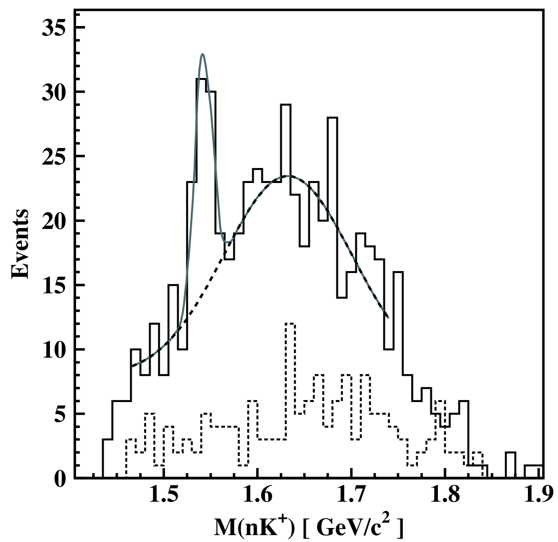
Old Results: the CLAS original report, JLab

CLAS Collaboration V. Kubarovsky et al., Phys.Rev.Lett.92,032001,2004) observed the Θ^+ in photoproduction using H_2 and D_2 targets. A report on the present CLAS results will be given in the Pentaquark session II tomorrow

The reactions studied were $\gamma d \to pnK^+K^-$ and $\gamma p \to nK^+K^-\pi^+$.

Possible Θ^+ production diagrams in H_2 via K exchange are:





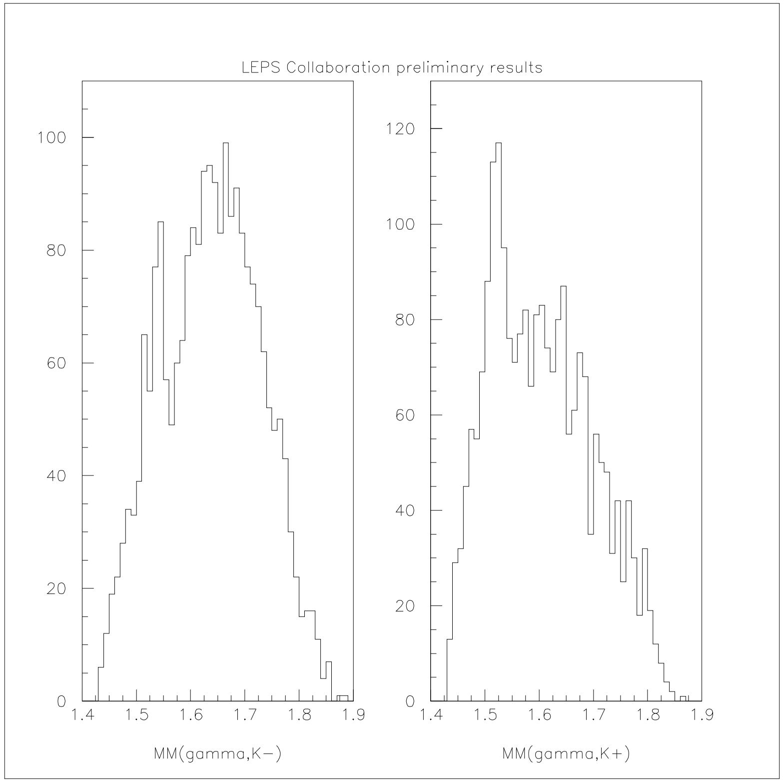
A peak of 5.2 s.d. is seen in $M(nK^+)$ from the D_2 target at $M = 1542$ MeV

The Θ^+ mass from 10 experiments is 1533.6, with χ^2/dof=38.2/9 (confidense level of 1.6x10^{-5}). See Lipkin + Karliner (hep-ph/0506084) for discusion of Θ^+ production mechanism.

The LEPS 2004 work at SPring8

Recent LEPS preliminary results for $\gamma n \to K^+K^-n$ using new data on deuteron target confirm the initial observation

Same event sample used for both plots. Same Fermi motion correction applied to both. Detector acceptance symmetric for both charged kaons.



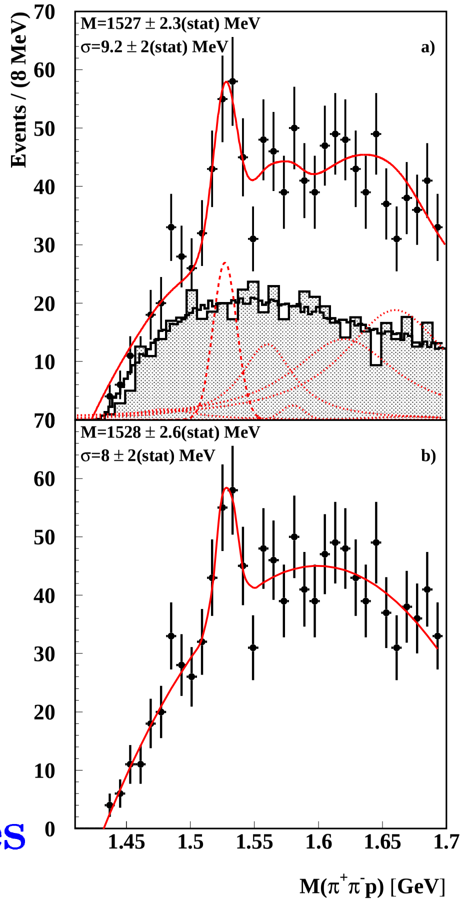
This is one of the most compelling positive results since it involves minimal kinematic cuts. Peaks are not due to kinematic reflection from $\phi \to K^+K^-$ peak. Applying same analysis procedure to mixed-event test $\Rightarrow$ No $\Lambda(1520)$ or Θ^+ peaks.

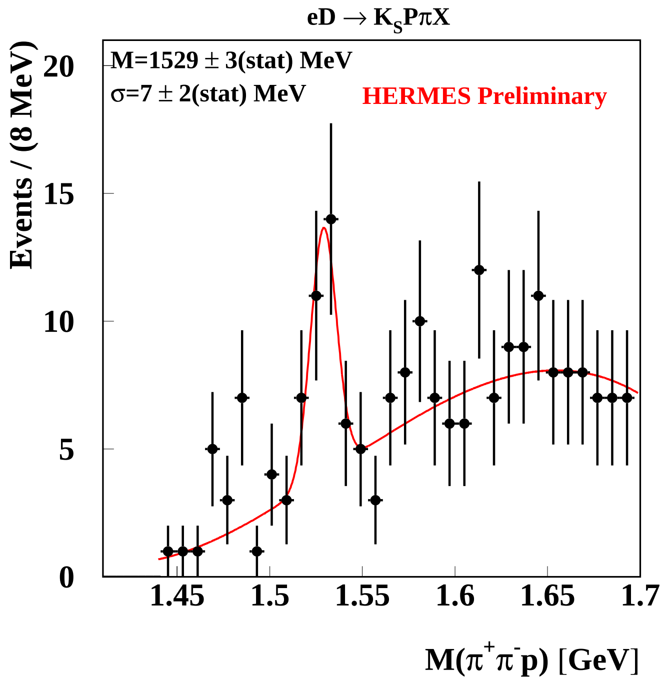
Analysis refinement in progress. Final results expected early 2005.

The HERMES experiment at HERA

The HERMES Collaboration searched for the Θ^+ in inclusive quasi-real photoproduction on deuterium in the decay chain $\Theta^+ \to pK_S^0$ (A. Airapetian et al., Phys.Lett.B585,213,2004). The virtual photons originated from the 27.6 GeV e^+ beam of the HERA storage ring.

A narrow pK_S^0 peak of ≈ 4 s.d. is seen at 1528 MeV with $\Gamma = 17 \pm 9$ MeV.
Shaded histogram is PYTHIA MC simulation.
Fit includes known baryon resonances (dotted lines).
$R_{\Lambda(1520)} \approx 1.6 - 3.5$





Signal/background improves from 1:3 to 2:1 (right plot) by requiring an extra π_3 and removing $K^{*\pm} \to K_S^0\pi_3^\pm$ and $\Lambda \to p\pi_3^-$ combinations. This removes 1)K_S's from ϕ's and $K^{*\pm}$'s; 2) protons from Λ's.