Spectroscopy and pentaquarks at ZEUS-H1

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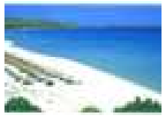
Quark Confinement and the Hadron Spectrum VI

September 21-25, 2004, Tanka Village, Italy



O U T L I N E :

QCD explorer and charm factory HERA

Spectroscopy of light mesons

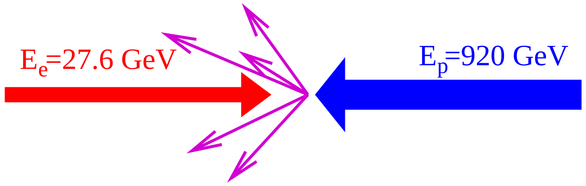
Spectroscopy of charmed mesons

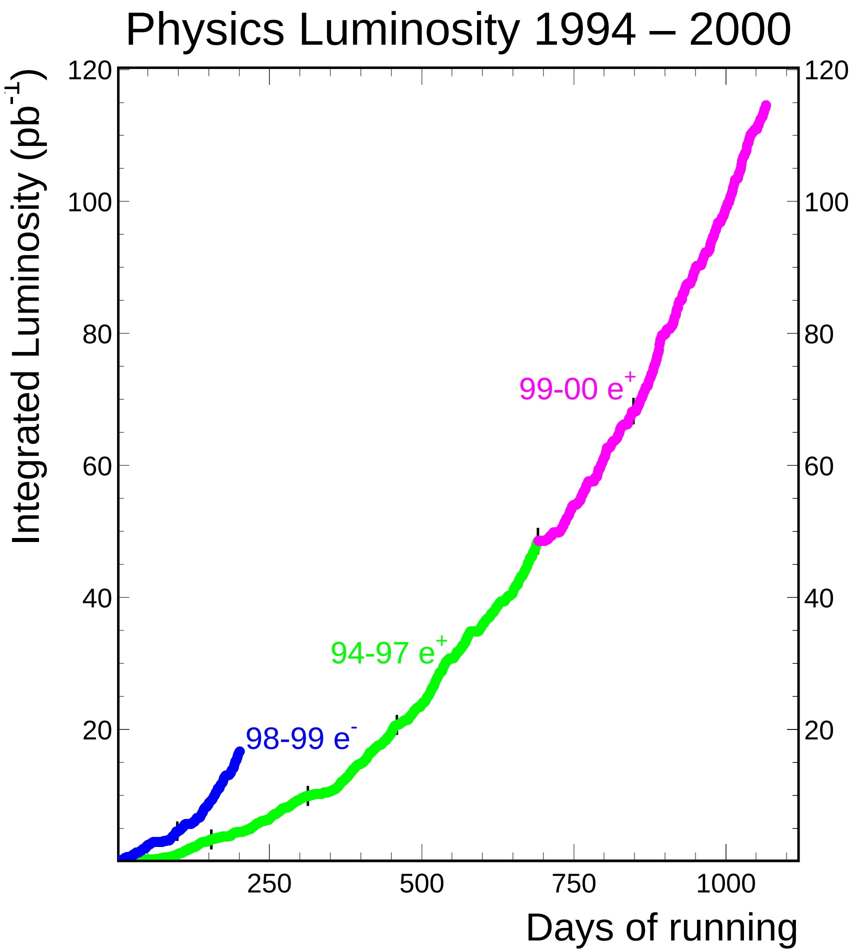
Strange pentaquarks

Charmed pentaquarks

Summary and Outlook

HERA $\longrightarrow$ HERA II





H1, ZEUS : $> 100\,$pb^{-1} each

	HERA	**HERA II**
	1992-2000	**2003-2006/7**
$\sqrt{s}$	320 (**300**)	320 **GeV**
$\mathcal{L}$	$1.5 \cdot 10^{31}$	$7 \cdot 10^{31}\, cm^{-2}\, s^{-1}$
$\mathcal{L}_{int}$	0.1	$0.5\, fb^{-1}$
beam spot	150×30	$80 \times 20\, \mu m^2$

$e^{\pm}$ **long. pol.** $(\approx 60\%)$

$\sigma_{c\bar{c}} \approx \ 1\,\mu\mathbf{b} \Longrightarrow 10^8$ **events** $(\mathcal{L}_{int} = 0.1\, f\mathbf{b}^{-1})$

$\sigma_{b\bar{b}} \approx 10\,\mathbf{nb} \Longrightarrow 10^6$ **events** $(\mathcal{L}_{int} = 0.1\, f\mathbf{b}^{-1})$

"QCD explorer" HERA

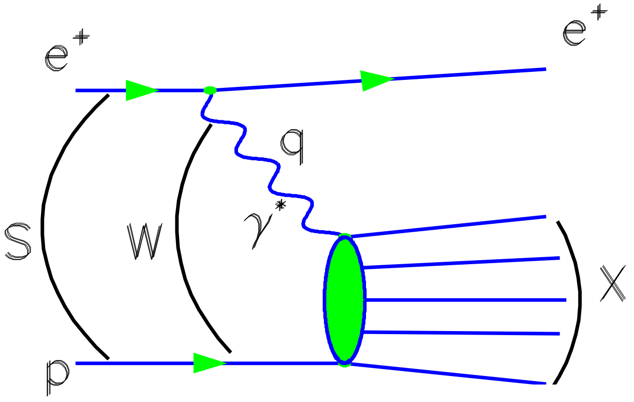
tests (p)QCD predictions

"Charm factory" HERA

studies charm fragmentation

Kinematic variables and charm production

$e(k) + p(P) \to e(k') + X$



$$s = (P + k)^2$$

$$Q^2 = -q^2 = -(k - k')^2$$

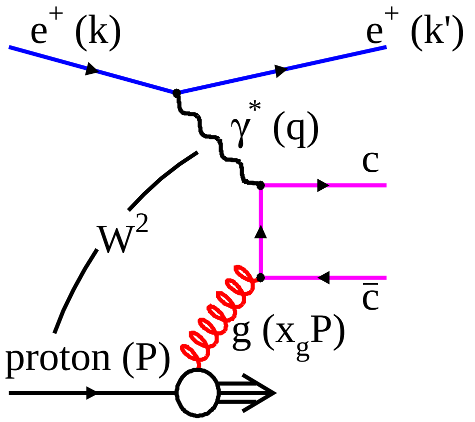
Photoproduction $\quad Q^2 \simeq 0\,GeV^2$

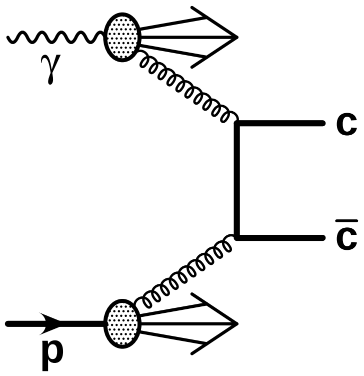
DIS $\quad Q^2 > 1\,GeV^2$

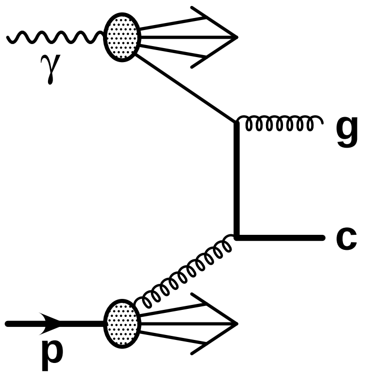
$$W^2 = (P + q)^2$$

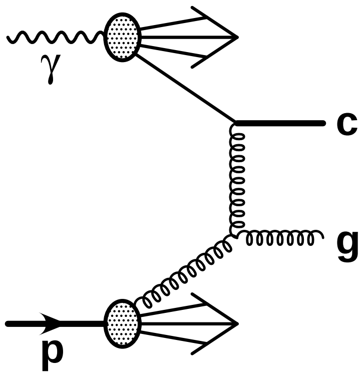
$$y = \frac{q \cdot P}{k \cdot P} \cong \frac{W^2}{s} \qquad x \cong \frac{Q^2}{sy}$$

Charm production:

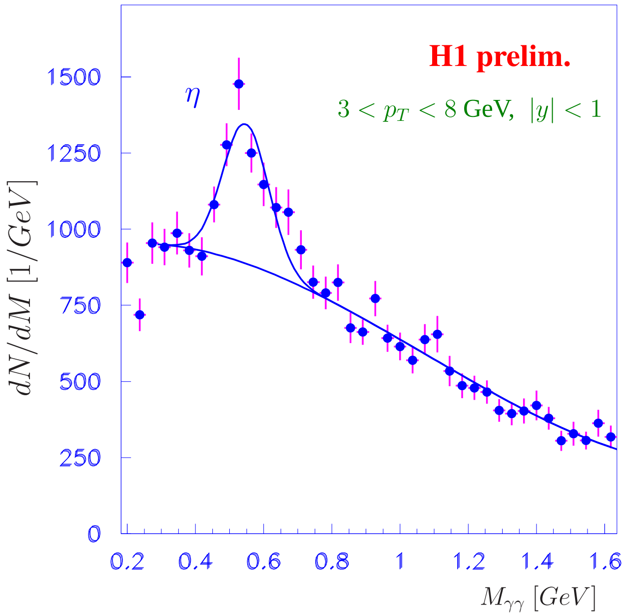


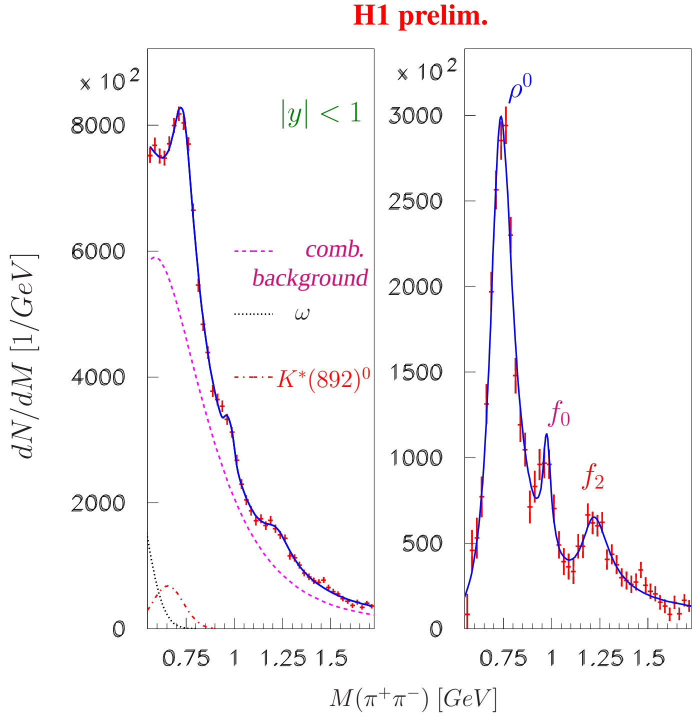


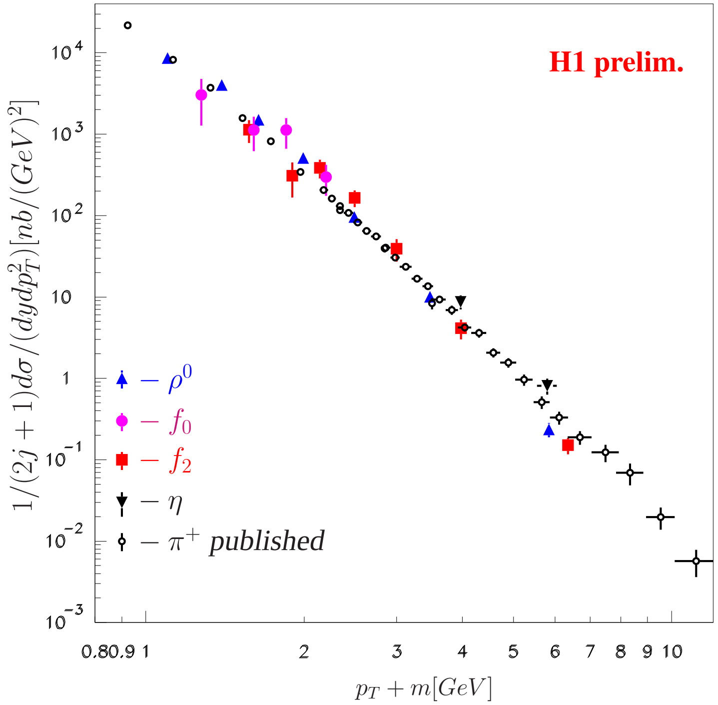




Light mesons in $M(\gamma\gamma)$ and $M(\pi^+\pi^-)$







Inclusive photoproduction of η, ρ^0, $f_0(980)$ and $f_2(1270)$ at $W \sim 210$ GeV

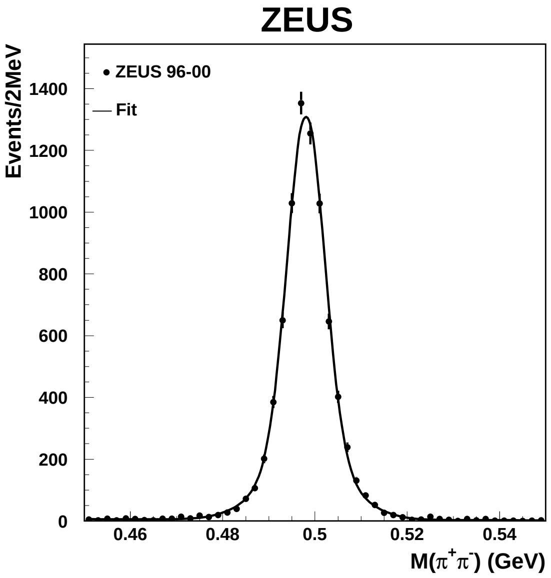
$\Longleftarrow$ **Similar behavior vs $p_T + m$ of pions and heavier light mesons**

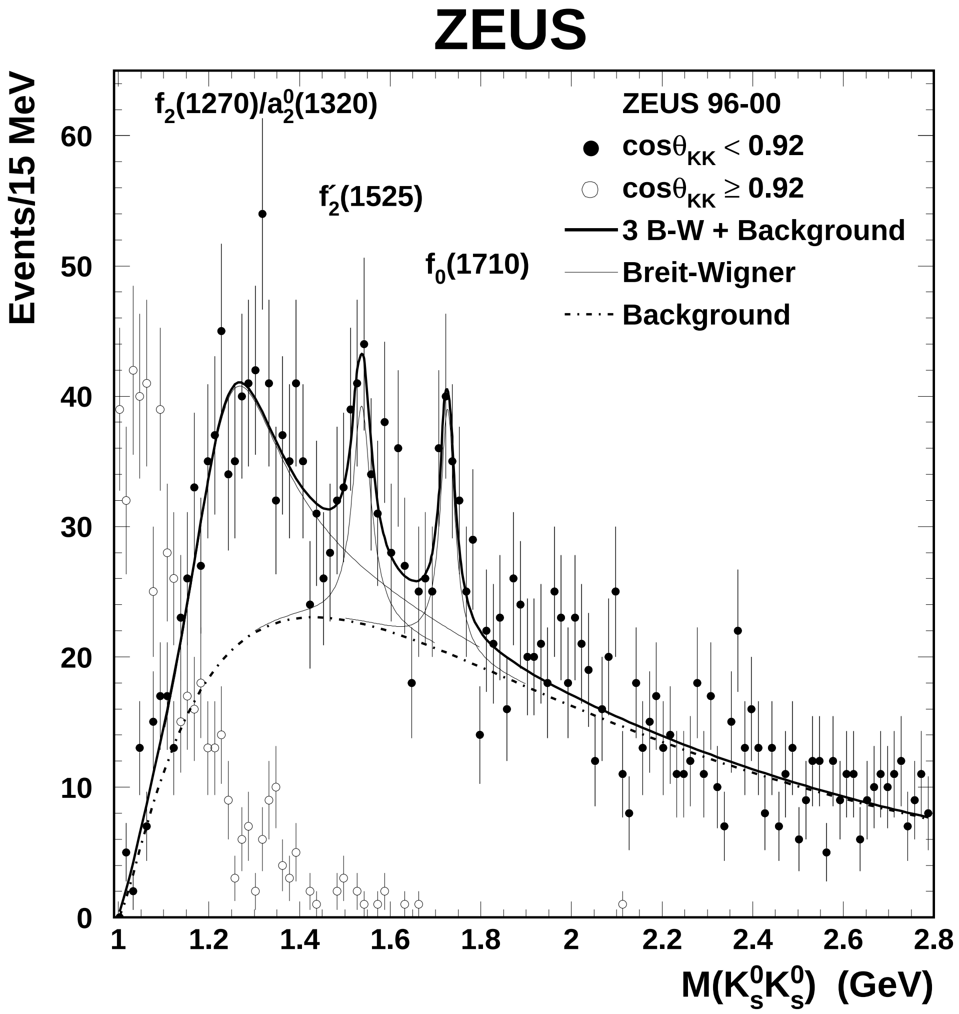
$\Longrightarrow$ **suggest similar production mechanism in q/g fragmentation**

Light mesons in $M(K^0_s K^0_s)$

$Q^2 \gtrsim 1\,\mathrm{GeV}^2,\ 50 < W < 250\,\mathrm{GeV}$

K^0_s are well identified using
the displaced secondary vertices $\Longrightarrow$





$\Longleftarrow$

threshold enhancement ($f_0(980)/a_0(980)$?)

contribution from $f_2(1270)/a^0_2(1320)$

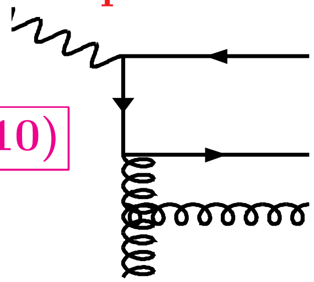
$f'_2(1525)$ (fit agrees with PDF)

$f_0(1710)$ (narrower but agrees with PDF)

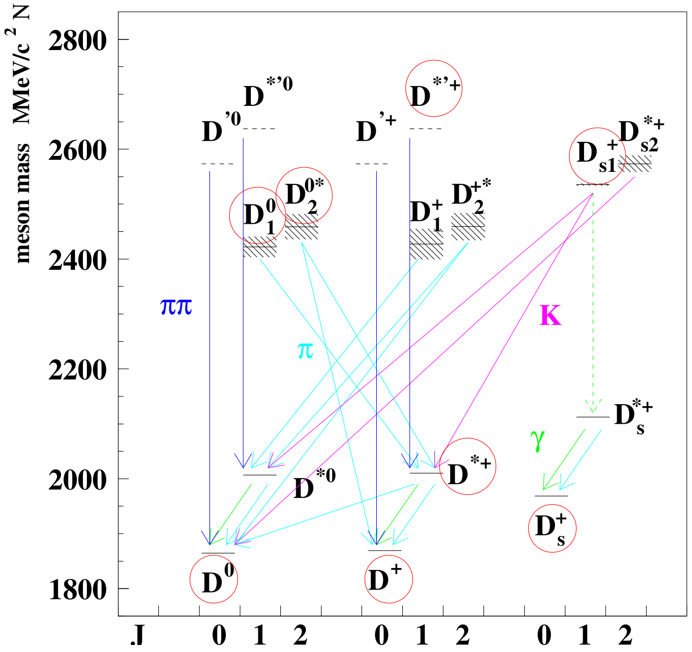
$M = 1726 \pm 7\,\mathrm{MeV},\ \Gamma = 38^{+20}_{-14}\,\mathrm{MeV}$

produced in the region where sizeable
initial state gluon radiation is expected

additional hint for large
gluonic component of $f_0(1710)$



Study of excited D mesons at HERA



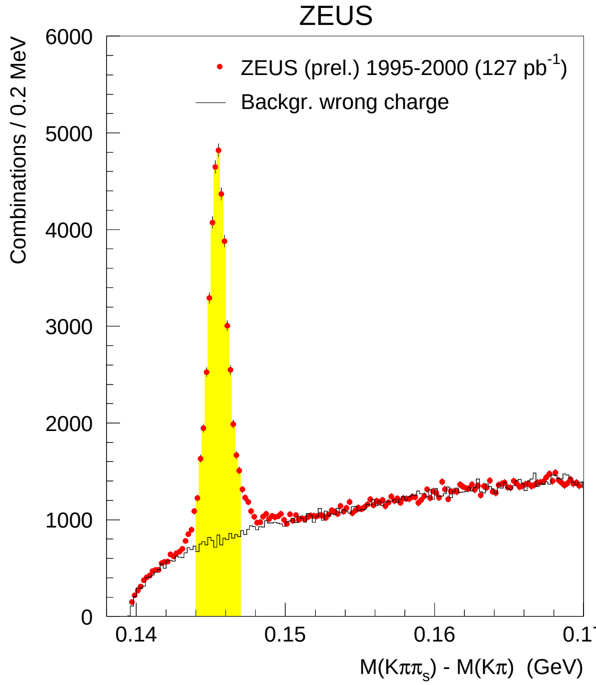
Orbitally excited:

1) $D_1^0, D_2^{*0} \to D^{*+}\pi^-$ (+ c.c.)

2) $D_{s1}^+ \to D^{*+}K^0$ (+ c.c.)

Search for radially excited:

3) $D^{*\prime +} \to D^{*+}\pi^+\pi^-$ (+ c.c.)



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

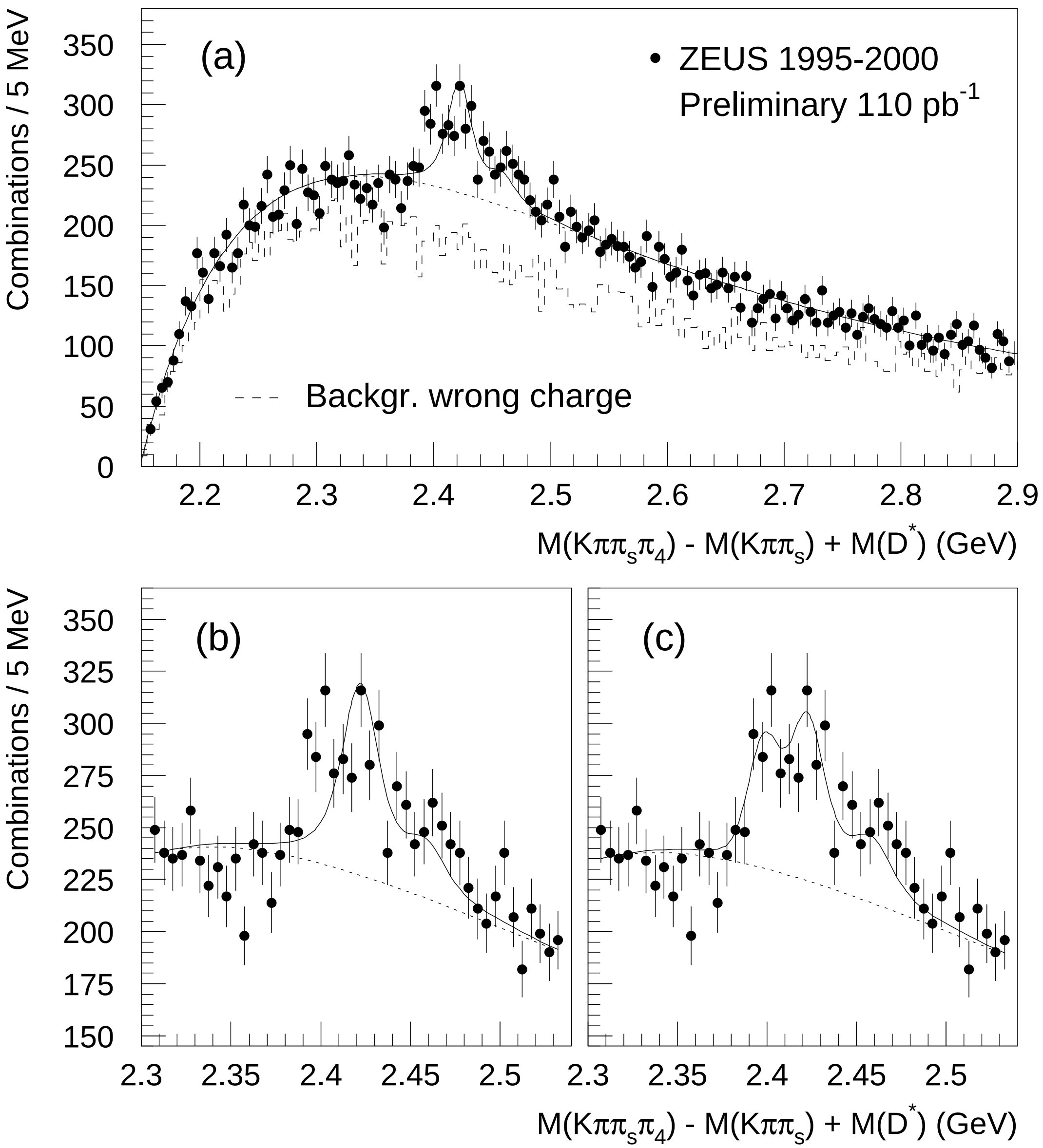
$\Delta M = M(D^{*+}) - M(D^0) \sim m_\pi$

$P_\perp^{D^*} > 2\,\mathrm{GeV}$ and $-1.5 < \eta^{D^*} < 1.5$

In the yellow band under background:

$$\boxed{N(D^{*\pm}) = 31350 \pm 240}$$

Orbitally excited P-wave D mesons



$D_1^0(2420), D_2^{*0}(2460) \to D^{*\pm}\pi^{\mp}$

$\Delta M^{ext} = M(K\pi\pi_S\pi_4) - M(K\pi\pi_s)$

2-dimensional fit with fixed M, Γ, resolution and helicity distr. :

$\frac{dN}{d\cos\alpha} \propto 1+3\cos^2\alpha \quad (1^+, L+s = 3/2)$

$\frac{dN}{d\cos\alpha} \propto 1-\cos^2\alpha \quad (2^+, L+s = 3/2)$

helicity angle α : between π_4 and π_s in $D^{*\pm}$ rest frame

$N(D_1^0) = 526 \pm 65$

$N(D_2^{*0}) = 203 \pm 60$

Additional narrow bump ?

$N = 211 \pm 49$

$M = 2398.1 \pm 2.1(\text{stat.})^{+1.6}_{-0.8}(\text{syst.})$ MeV

New D meson ? Interference ?

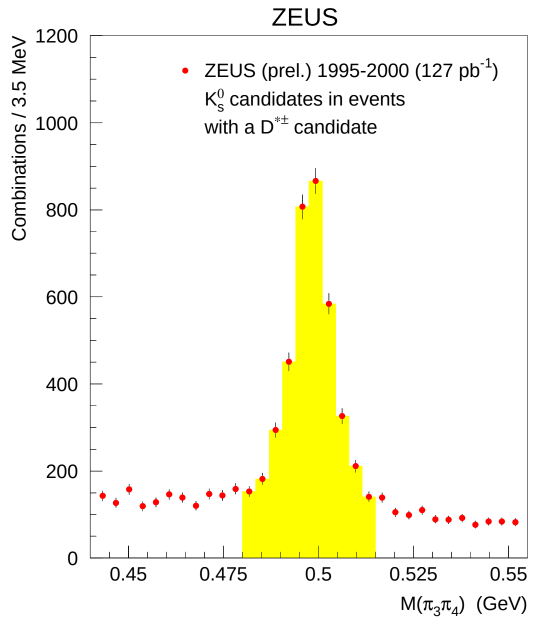
Charm-strange $D_{s1}^{\pm}(2536)$ meson

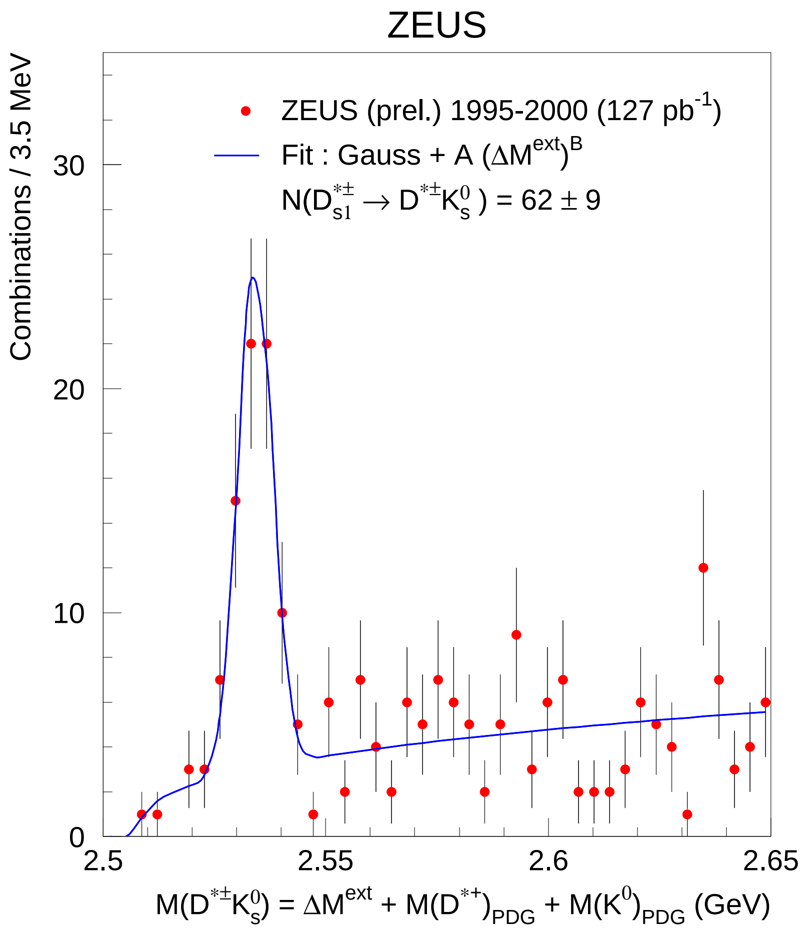
$D_{s1}^{\pm}(2536) \rightarrow D^{*\pm} K_s^0 \ , \quad K_s^0 \rightarrow \pi^+ \pi^-$

$\Delta M^{ext} = M(K\pi\pi_S\pi_3\pi_4) - M(K\pi\pi_s) - M(\pi_3\pi_4)$

$N(D_{s1}^+) = 62.3 \pm 9.3$

$M(D_{s1}^+) = 2534.2 \pm 0.6 \pm 0.5\,\mathrm{MeV} \quad (\sim M_{\mathrm{PDG}})$





Helicity angle α : between K_s^0 and π_s in $D^{*\pm}$ r.f.

Fit to a form : $1 + R\cos^2\alpha$

$\boxed{R = -0.53 \pm 0.32(\mathrm{stat.})^{+0.05}_{-0.14}(\mathrm{syst.})}$ (ZEUS prel.)

CLEO $(D_{s1}^+ \rightarrow D^{*0}K^+)$: $R = -0.23^{+0.40}_{-0.32}$

ZEUS : consistent with $R = 0$, i.e. $J^P = 1^+$

does not contradict to $R = -1$

expected for $J^P = 1^-,\ 2^+$

Fragmentation fractions for excited D mesons

Using world average for $f(c \to D^{*+})$:

	$f(c \to D_1^0)$ [%]	$f(c \to D_2^{*0})$ [%]	$f(c \to D_{s1}^+)$ [%]
ZEUS (prel.)	$1.46 \pm 0.18^{+0.33}_{-0.27} \pm 0.06$	$2.00 \pm 0.58^{+1.40}_{-0.48} \pm 0.41$	$1.24 \pm 0.18^{+0.08}_{-0.06} \pm 0.14$
CLEO	1.8 ± 0.3	1.9 ± 0.3	
OPAL	2.1 ± 0.8	5.2 ± 2.6	$1.6 \pm 0.4 \pm 0.3$
ALEPH	1.6 ± 0.5	4.7 ± 1.0	$0.94 \pm 0.22 \pm 0.07$
DELPHI	1.9 ± 0.4	4.7 ± 1.3	

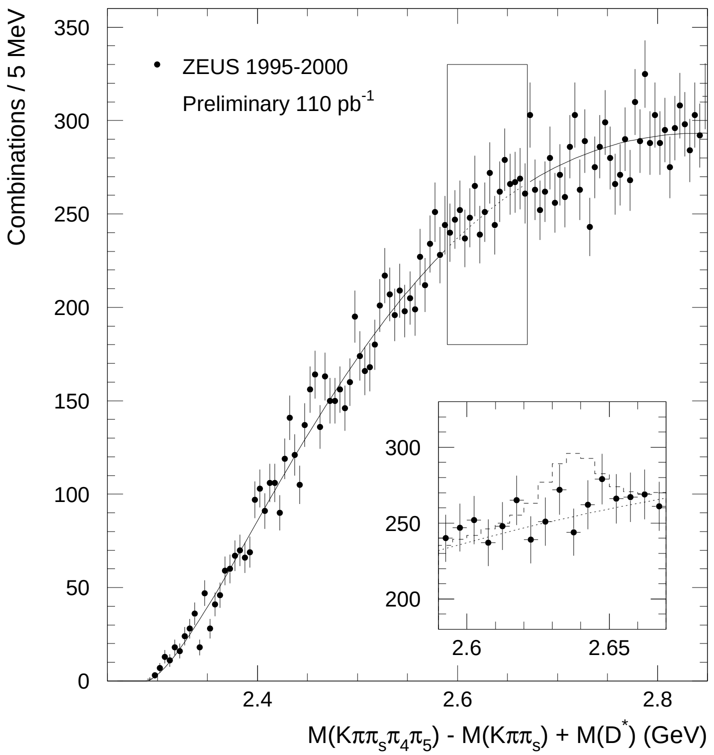
1) the same amounts of excited D mesons in e^+e^- and ep data

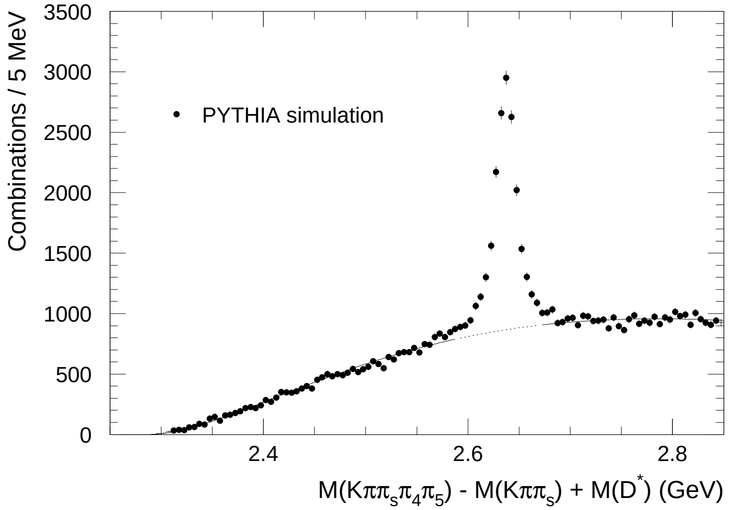
2) situation with $f(c \to D_2^{*0})$ is not clear

3) $f(c \to D_{s1}^+)$ is twice as large as the expectation :

$\gamma_s \times f(c \to D_1^0) \approx 0.3 \times 2\% = 0.6\%$ Why ?

Search for radially excited $D^{*\prime\pm}$ meson





$\underline{D^{*\prime\pm} \rightarrow D^{*\pm}\pi^+\pi^-}$

Observed by DELPHI ($\sim 5\sigma$): $M = 2637\,\text{MeV}$
$\Gamma < 15\,\text{MeV}$

CLEO and OPAL did not confirm

$\Longleftarrow$ ZEUS search

$\Delta M^{ext} = M(K\pi\pi_S\pi_4\pi_5) - M(K\pi\pi_s)$

Search window: $2.59 < \Delta M^{ext} + M(D^{*+}) < 2.67\,\text{GeV}$

covers both predictions and DELPHI's observation

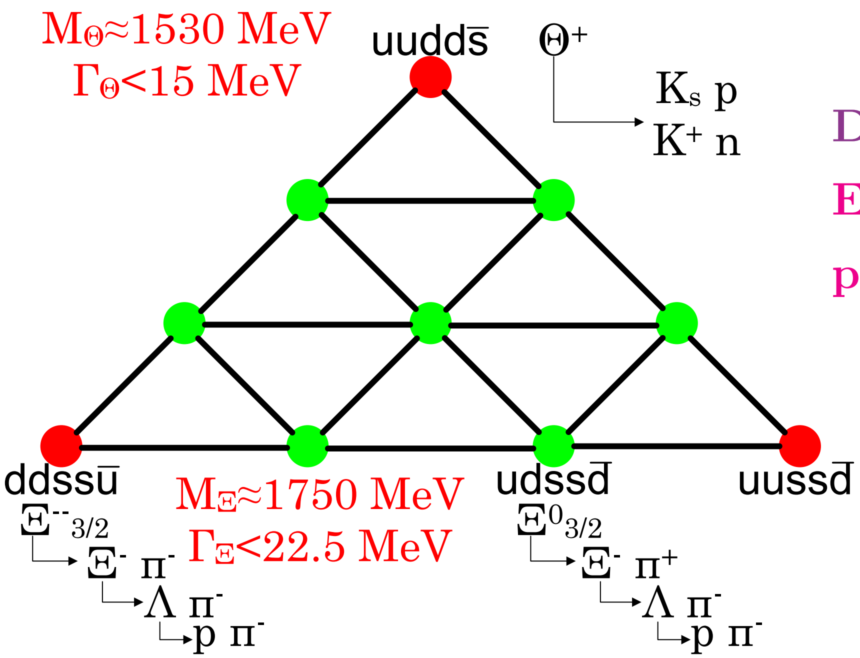
after backgr. subtraction: "$N(D^{*\prime\pm})$"$= 91 \pm 75$

Using world average for $f(c \rightarrow D^{*+})$:

$f(c \rightarrow D^{*\prime+}) \cdot B_{D^{*\prime+} \rightarrow D^{*+}\pi^+\pi^-} < 0.7\%$ (95% C.L.)
(ZEUS prel.)

somewhat stronger than the 0.9% limit
obtained by OPAL

Strange pentaquarks



Diakonov, Petrov, Polyakov (hep-ph/9703373)

Exotic Anti-Decuplet of Baryons:

predictions from Chiral Solitons

exotic (S=B=+1) narrow baryon $\Theta^+ \to K^+ n$ observed by LEPS, CLAS, SAPHIR

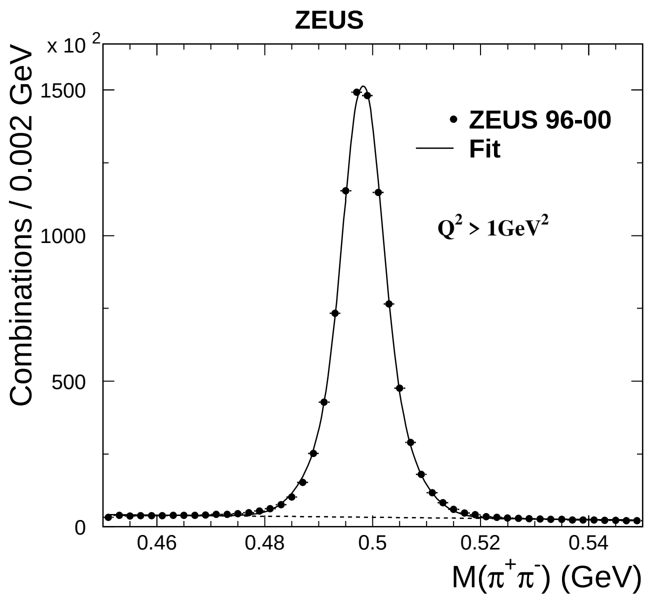
non-exotic decay mode $\Theta^+ \to K^0_s p$ seen by DIANA, HERMES, COSY-TOF, ...

negative results from BES, HERA-B, CDF, ALEPH, DELPHI, L3, BABAR, BELLE

only one observation in collider experiment: ZEUS, PLB 591 (2004) 7

- observed in $\Theta^+ \to K^0_s p$
- central production (q/g fragmentation)
- both pentaquark and anti-pentaquark

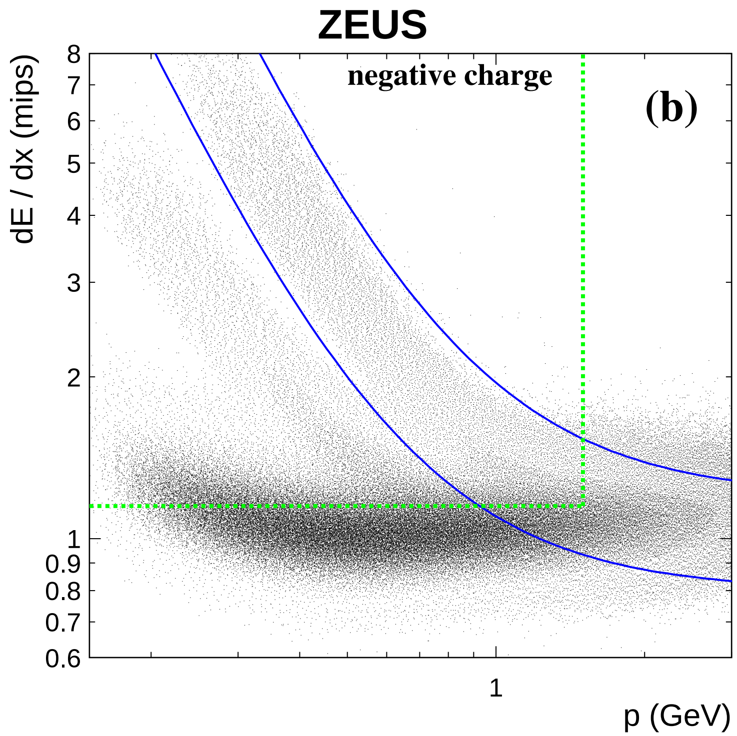
K_s^0 and p ($\bar{p}$) identification



$Q^2 > 1\,\mathbf{GeV}^2$

870 000 $K_s^0 \to \pi^+\pi^-$ **from sec. vertices**

$p_T(K_s^0) > 0.3\,\mathbf{GeV}$, $|\eta(K_s^0)| < 1.5$



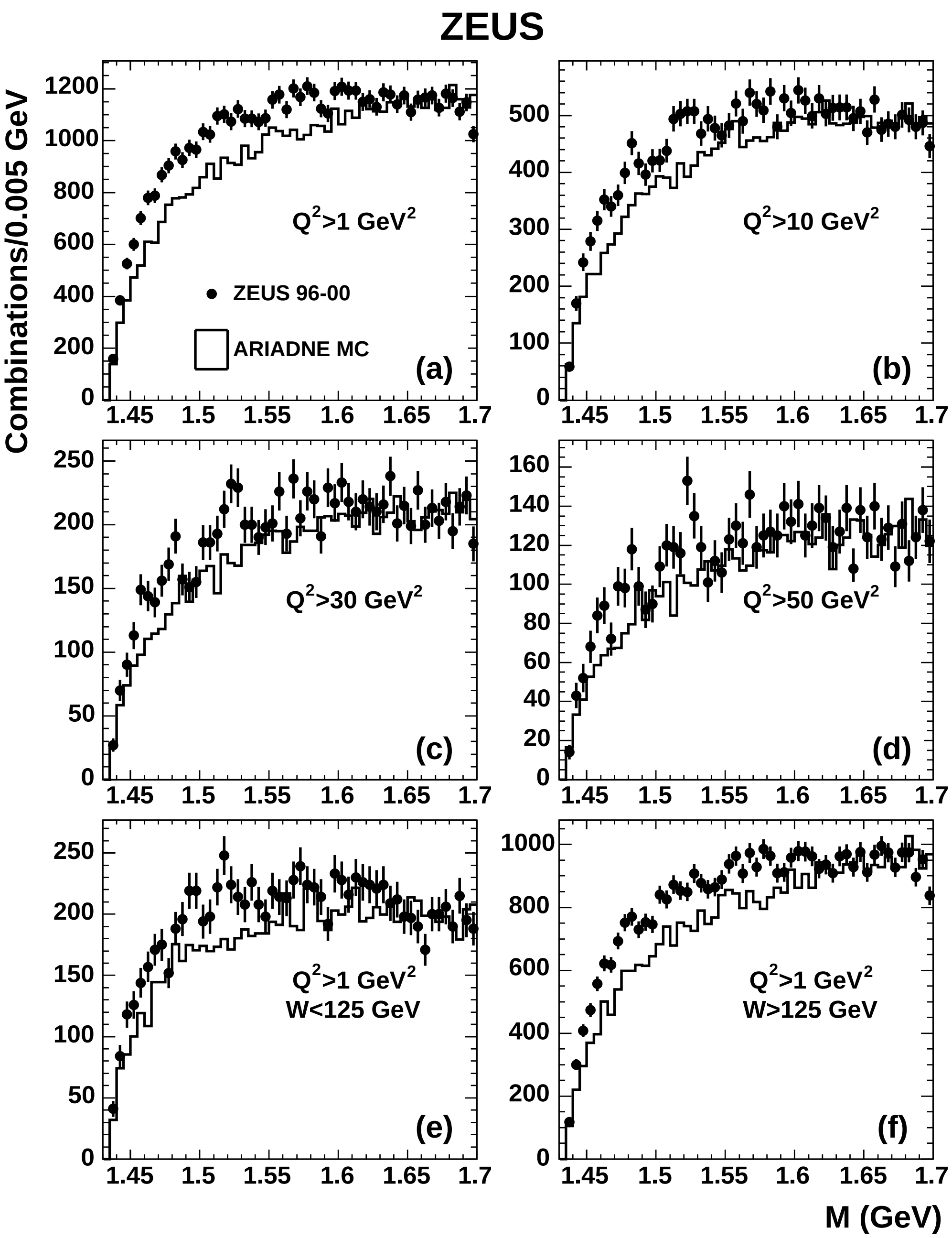
both p **and** $\bar{p}$

wide dE/dx **band tuned using tagged protons from** Λ^0

$dE/dx > 1.15\,\mathbf{mips}$, $P(p) < 1.5\,\mathbf{GeV}$

60% **proton purity**

$M(K^0_s p(\bar{p}))$



large background

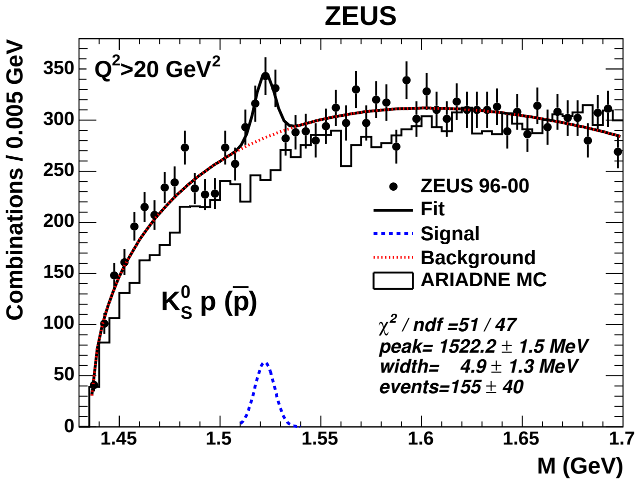
signal becomes visible for $Q^2 > 10\,\mathrm{GeV}^2$

ARIADNE (JETSET) MC (normalized to data above $1.65\,\mathrm{GeV}$) does not reproduce the shape.

$\Sigma(1480)$, $\Sigma(1560)$ bumps ?

for $Q^2 > 1\,\mathrm{GeV}^2$, signal is visible for $W < 125\,\mathrm{GeV}$

$M(K_s^0 p(\bar{p}))$ for $Q^2 > 20\,\mathrm{GeV}^2$

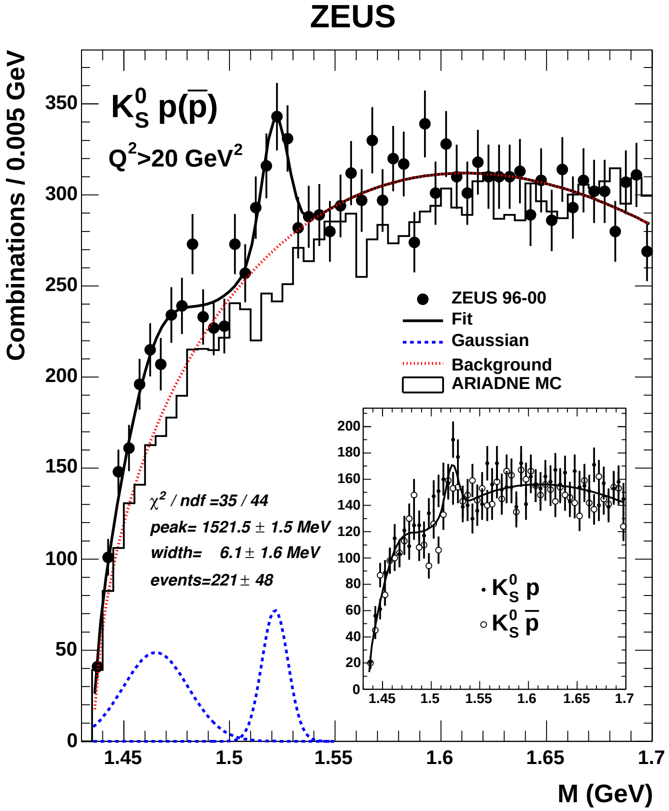


$Q^2 > 20\,\mathrm{GeV}^2$ **: best signal identification**

Fit with Gaussian + background (3 par.)

$N = 155 \pm 40$, $M = 1522.2 \pm 1.5\,\mathrm{MeV}$

width compatible with resolution



Fit with 2nd Gaussian for (Σ ?) bump around $1465\,\mathrm{MeV}$

$N = 221 \pm 48$, $M = 1521.5 \pm 1.5\,\mathrm{MeV}$

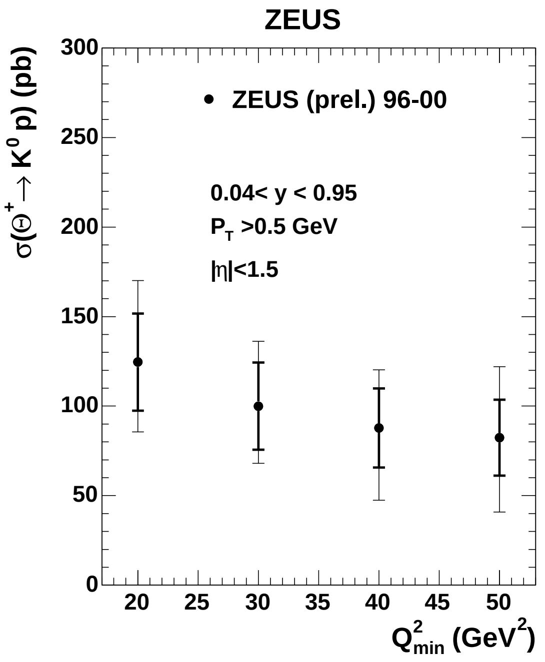
width compatible with resolution

For BW: $\Gamma = 8 \pm 4$ **(stat.) MeV**

$\Longleftarrow$ **signal seen in both charges**

$N(\Theta^- \to K_s^0 \bar{p}) = 96 \pm 34$

Θ^+ cross section and rate w.r.t. Λ^0

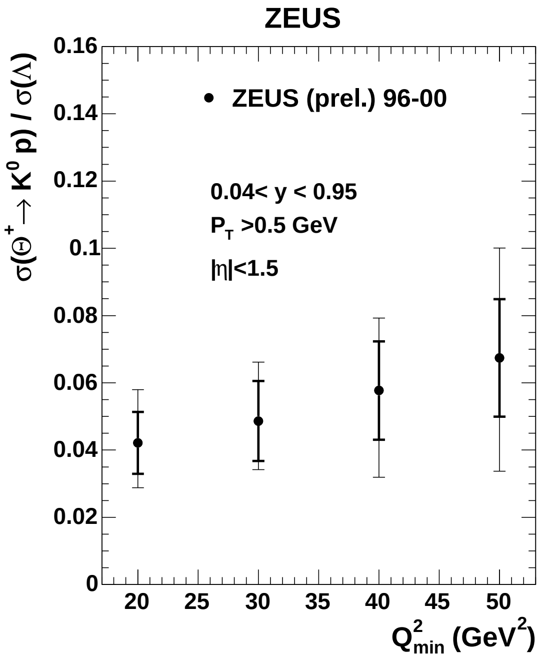


$\Theta^\pm$ cross section in the visible range:

$$Q^2 > 20\,\mathbf{GeV}^2,\ 0.04 < y < 0.95$$

$$p_T(\Theta^\pm) > 0.5\,\mathbf{GeV},\ |\eta(\Theta^\pm)| < 1.5$$

$$\sigma(ep \to e\Theta^+ X \to eK^0 pX) = 125 \pm 27^{+37}_{-28}\,\mathbf{pb}$$



rate compared to Λ^0:

$$R = \sigma(\Theta^+ \to K^0 p)/\sigma(\Lambda^0) = 4.2 \pm 0.9^{+1.2}_{-0.9}\,\%$$

but limits from:

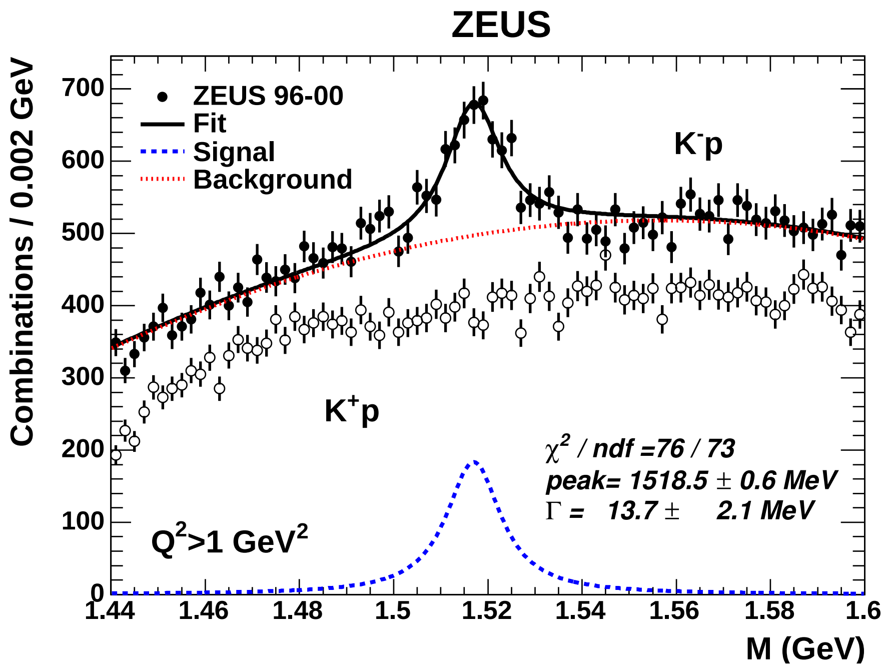
HERA-B: $R < 0.46\,\%$

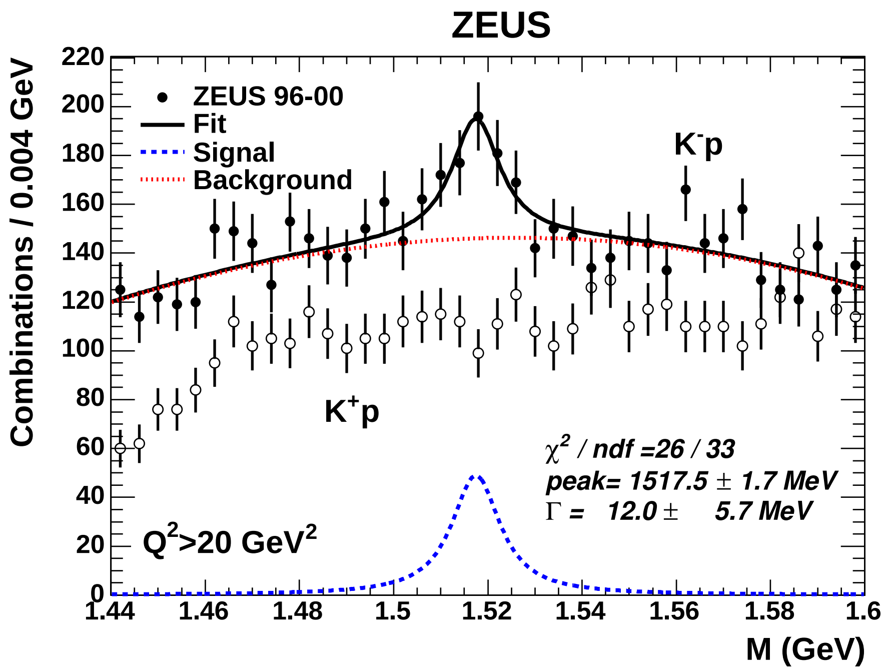
$(R(\Theta^+/\Lambda^0) < 0.92\,\%$ **and** $B(\Theta \to K^0 p) = 1/2)$

ALEPH: $R < 0.4\,\%$

$(R(\Theta^+/Z) < 0.29\,\%,\ B(\Theta \to K^0 p) = 1/2$ **and** $R(\Lambda^0/Z) = 39\%)$

Θ^0, Θ^{++} from $I=1$ triplet ?





For NK bound state,
both $I=0,1$ are possible

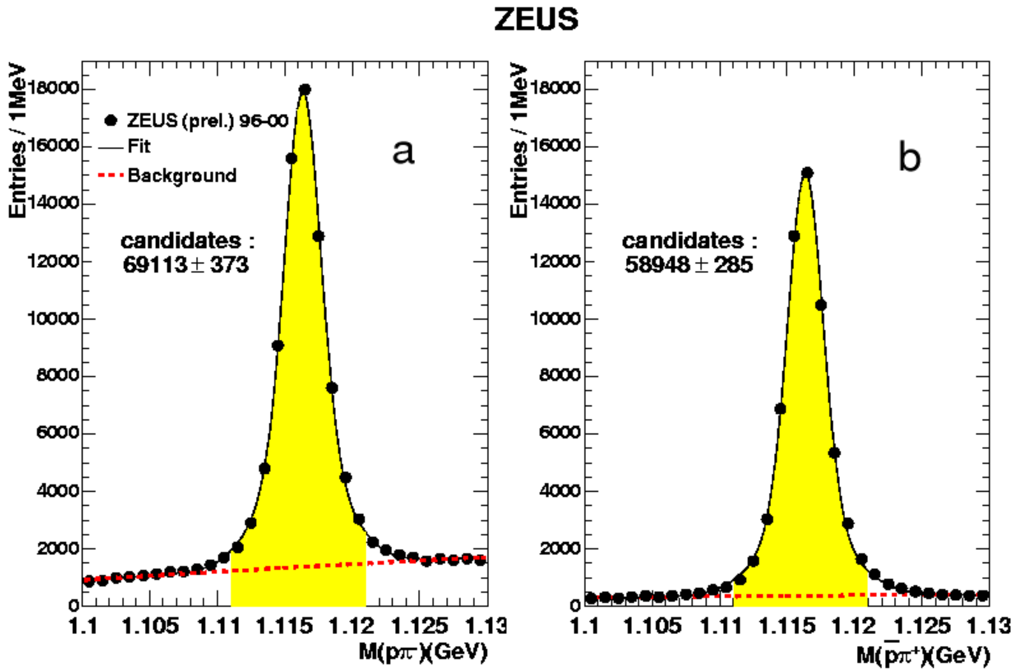
$I=1$: triplet Θ^0, Θ^+, Θ^{++}

$\Longleftarrow$ **search for $\Theta^{++} \to K^+p$ (+c.c.)**
no signal

known $\Lambda(1520)$ baryon in K^-p (+c.c.)

$\Longleftarrow$ **no Θ^{++} signal for $Q^2 < 20\,\mathrm{GeV}^2$**
as well

Search for pentaquarks with $S = \pm 2$

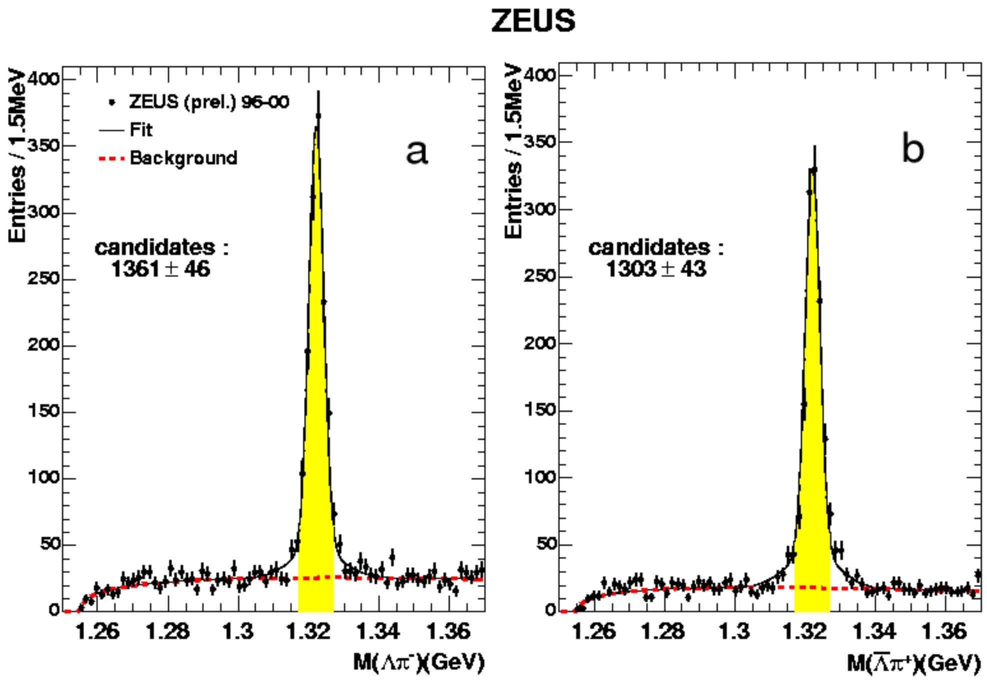


$\Xi_{5q}^{--,0} \rightarrow \Xi\pi$ **observed by NA49**

ZEUS search in DIS, $Q^2 > 1\,$**GeV**^{2}

$\Lambda^0 \rightarrow p\pi^-$ **(+c.c.) are well identified using the displaced vertices**

$\Longleftarrow \sim 130000$ **candidates**

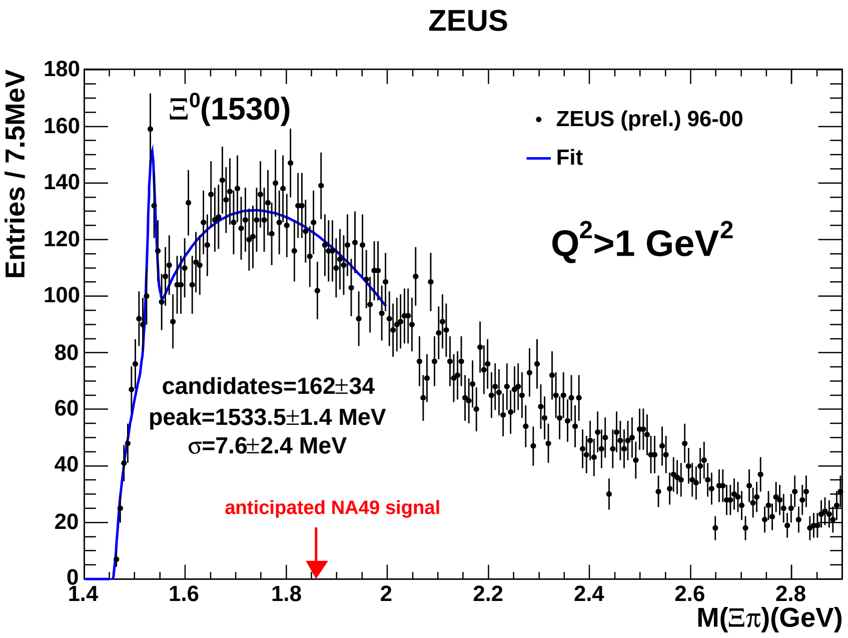


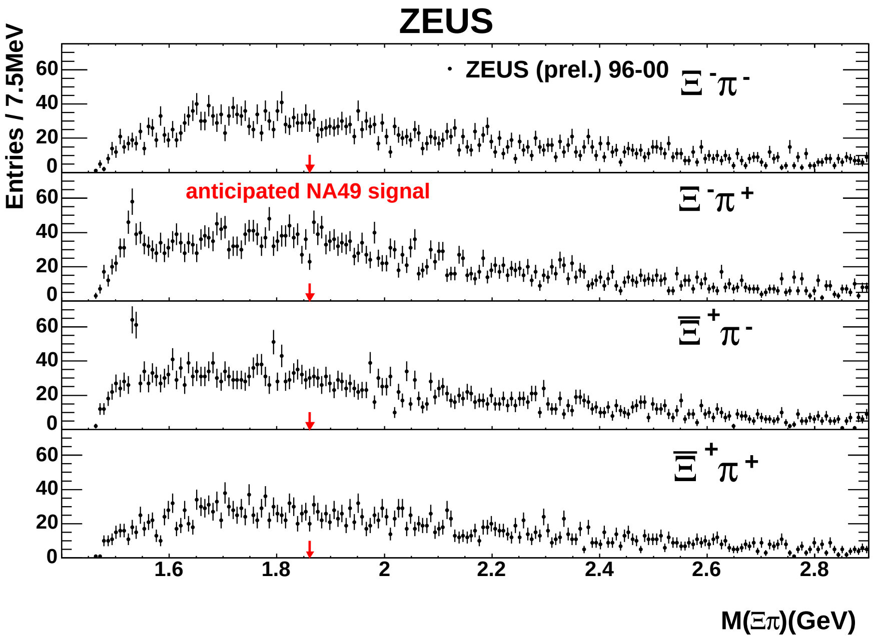
Combining with additional track

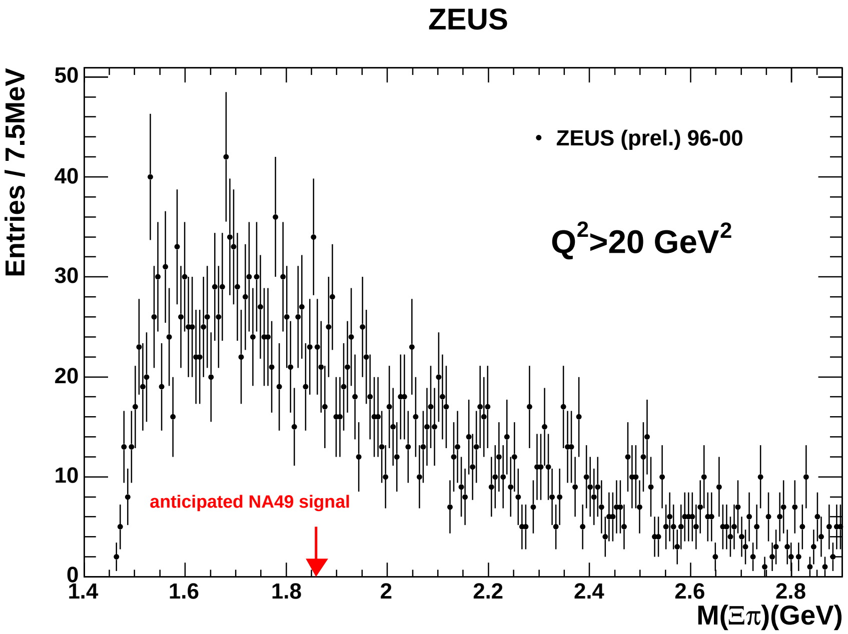
$\Xi^- \rightarrow \Lambda^0\pi^-$ **(+c.c.)**

$\Longleftarrow \sim 2600$ **candidates**

$M(\Xi\pi)$ for $Q^2 > 1\,\mathrm{GeV}^2$ and $Q^2 > 20\,\mathrm{GeV}^2$







known $\Xi^0(1530) \to \Xi^-\pi^+$ is well visible

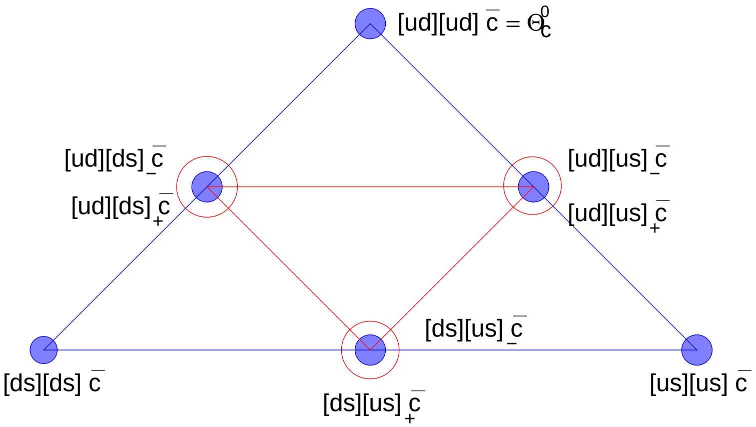
No Ξ_{5q} signal in all charge combinations

$\Longleftarrow$ No signal for $Q^2 > 20\,\mathrm{GeV}^2$

Note: ZEUS studies central production

NA49 covers forward production

Charmed pentaquarks



What about $\Theta_c^0 = (ud)^2\bar{c}$?

Jaffe-Wilczek (hep-ph/0307341): $M(\Theta_c^0) = 2710\,\mathbf{MeV}$

Such Θ_c^0 would be too light to decay to D mesons
can decay weakly to $\Theta^+\pi^-$

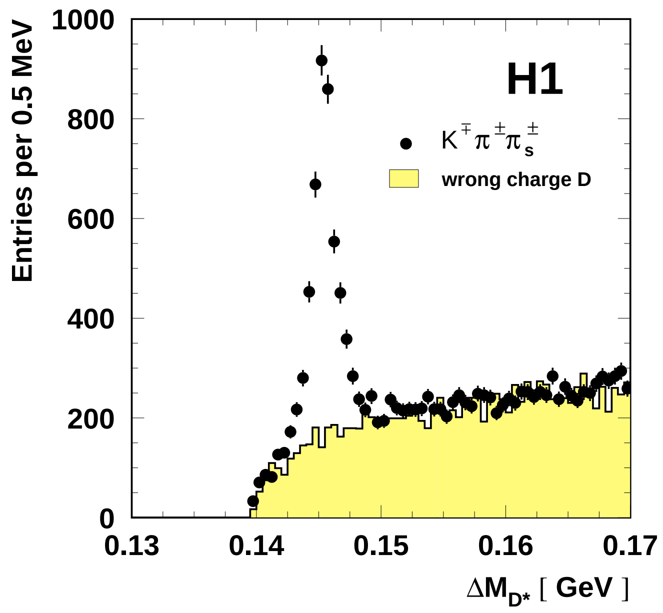
Karliner-Lipkin (hep-ph/0307343): $M(\Theta_c^0) = 2985 \pm 50\,\mathbf{MeV}$
$\Gamma(\Theta_c^0) \sim 21\,\mathbf{MeV}$

Such Θ_c^0 would decay to $D^{(*)-}p$ (+ c.c.)

H1 (hep-ex/0403017) observed a signal in $M(D^{*-}p)$ **(+ c.c.)** spectra

negative results from **ZEUS (hep-ex/0409033)**, **ALEPH, FOCUS, CDF, CLEO, BABAR, ...**

$D^{*\pm}$ reconstruction and $p(\bar{p})$ identification, H1



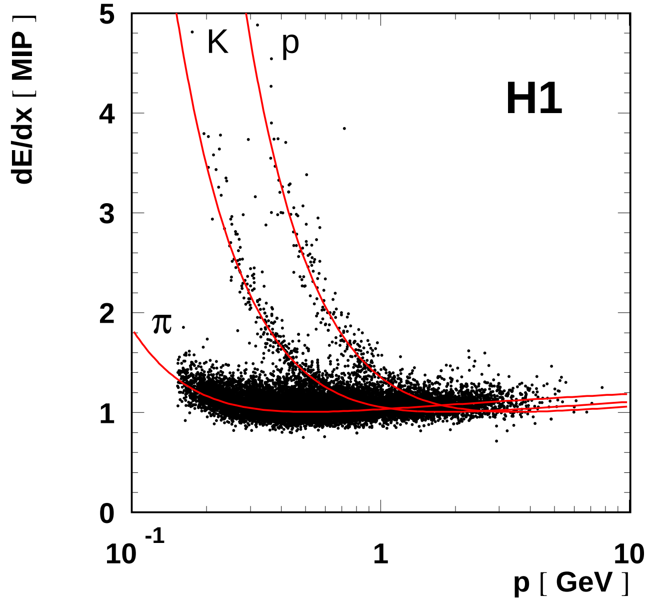
H1 96-00 data ($75\,\mathrm{pb}^{-1}$)

$Q^2 > 1\,\mathbf{GeV}^2$, $0.05 < y < 0.7$

$P_T(D^{*\pm}) > 1.5\,\mathbf{GeV}$, $-1.5 < \eta(D^{*\pm}) < 1.0$

$N(D^{*\pm}) \sim 3400$

(for $Q^2 < 1\,\mathbf{GeV}^2$ **:** $N(D^{*\pm}) \sim 4900$**)**



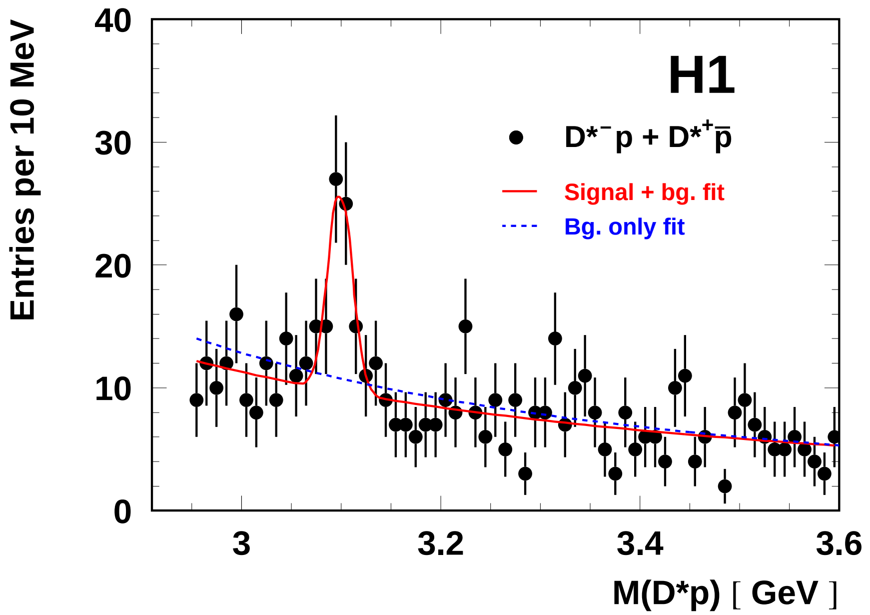
dE/dx **for** $p(\bar{p})$ **identification**

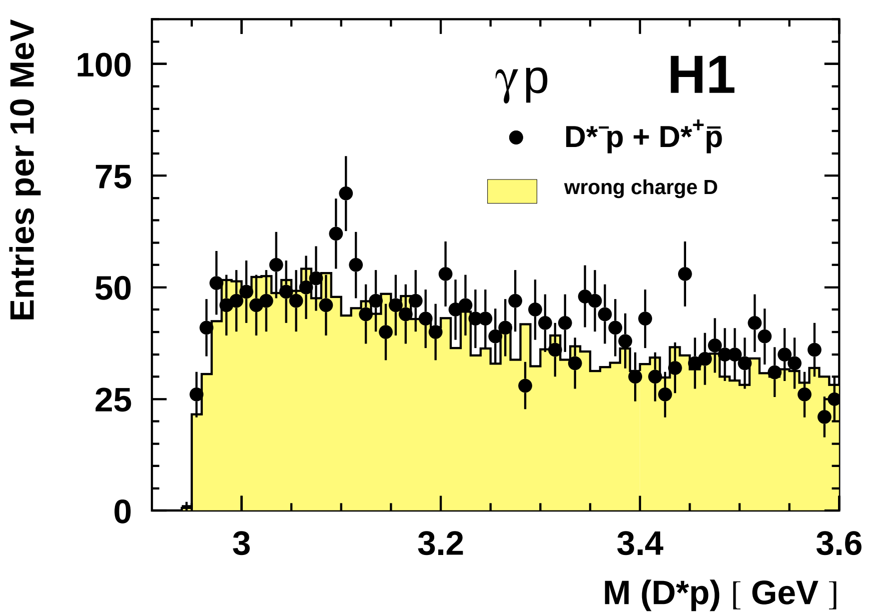
resolution $\sim 8\%$

Normalised likelihood for PID:

$L(p) + L(K) + L(\pi) = 1$

$M(D^*p)$ in DIS and photoproduction





Clean signal in DIS (in both $D^{*+}\bar{p}$ and $D^{*-}p$)

Signal for $Q^2 < 1\,\mathrm{GeV}^2$ at the same mass

Fit Gaussian + background (2 par.):

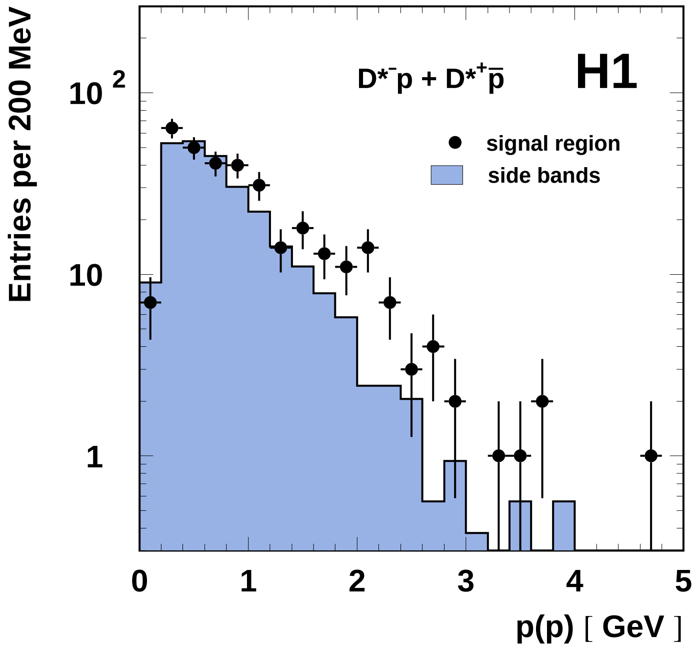
$$N(\Theta_c^0) = 50.6 \pm 11.2$$

$$M(\Theta_c^0) = 3099 \pm 3(stat.) \pm 5(syst.)\,\mathbf{MeV}$$

$$\sigma(\Theta_c^0) = 12 \pm 3\,\mathbf{MeV}$$ **(consist. with resolution)**

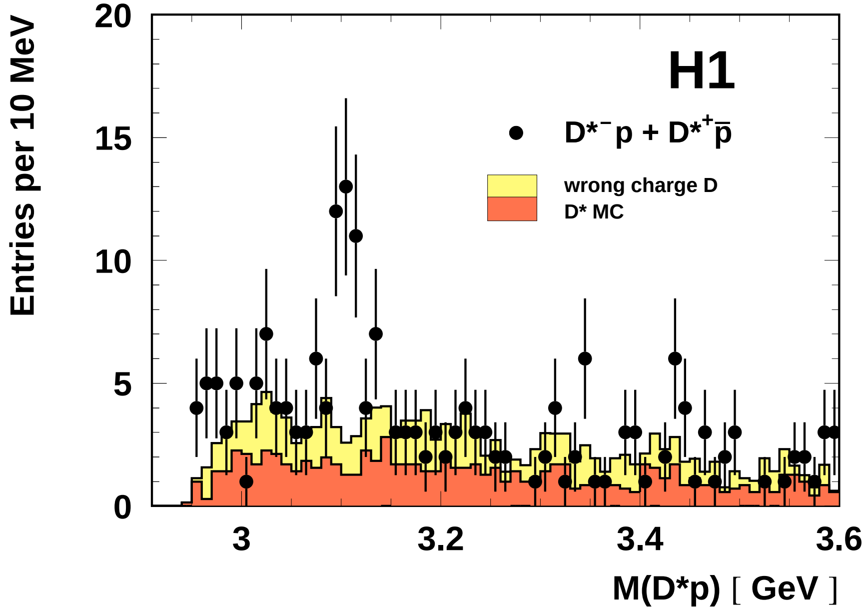
visible rate $R(\Theta_c^0 \to D^*p/D^*) = 1.46 \pm 0.32\,\%$ (prel.) or "roughly 1%" (paper)

$M(D^*p)$ for large proton momenta



particles taken as protons
w/o dE/dx requirements

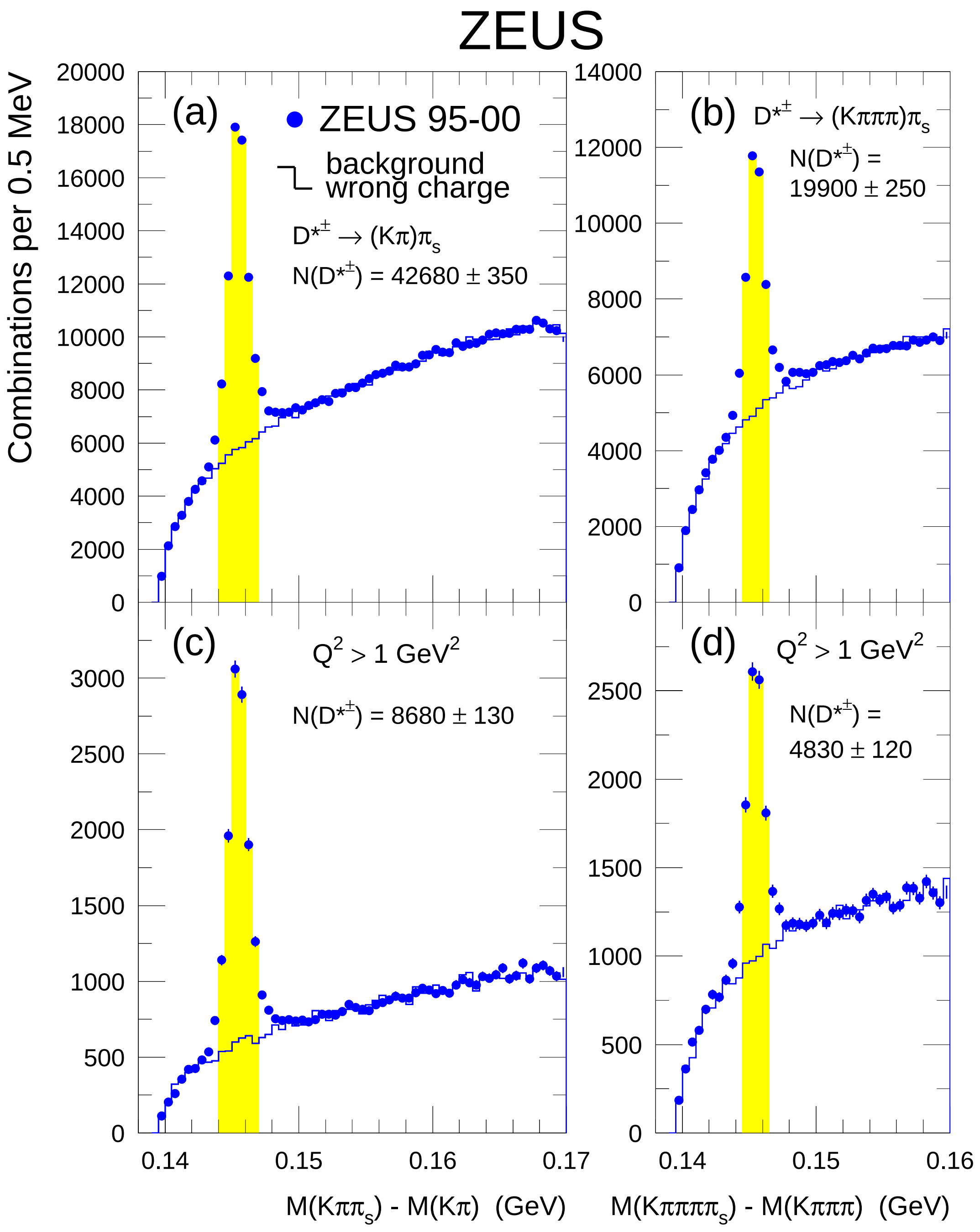
"protons" from signal region
$(3.085 < M(D^*p) < 3.115\,$GeV)
have harder momentum distribution
than "protons" from side bands



For $P(p) > 2\,$GeV,
clean signal is seen
even w/o use of dE/dx

$\Longleftarrow$ background is well described
by 2-component model

$D^{*\pm}$ reconstruction, ZEUS



95-00 data $(126\,\mathrm{pb}^{-1})$

two D^* decay channels:

$D^{*+} \rightarrow D^0\,\pi_s^+ \rightarrow (K^-\,\pi^+)\,\pi_s^+$

$D^{*+} \rightarrow D^0\,\pi_s^+ \rightarrow (K^-\,\pi^+\,\pi^+\,\pi^-)\,\pi_s^+$

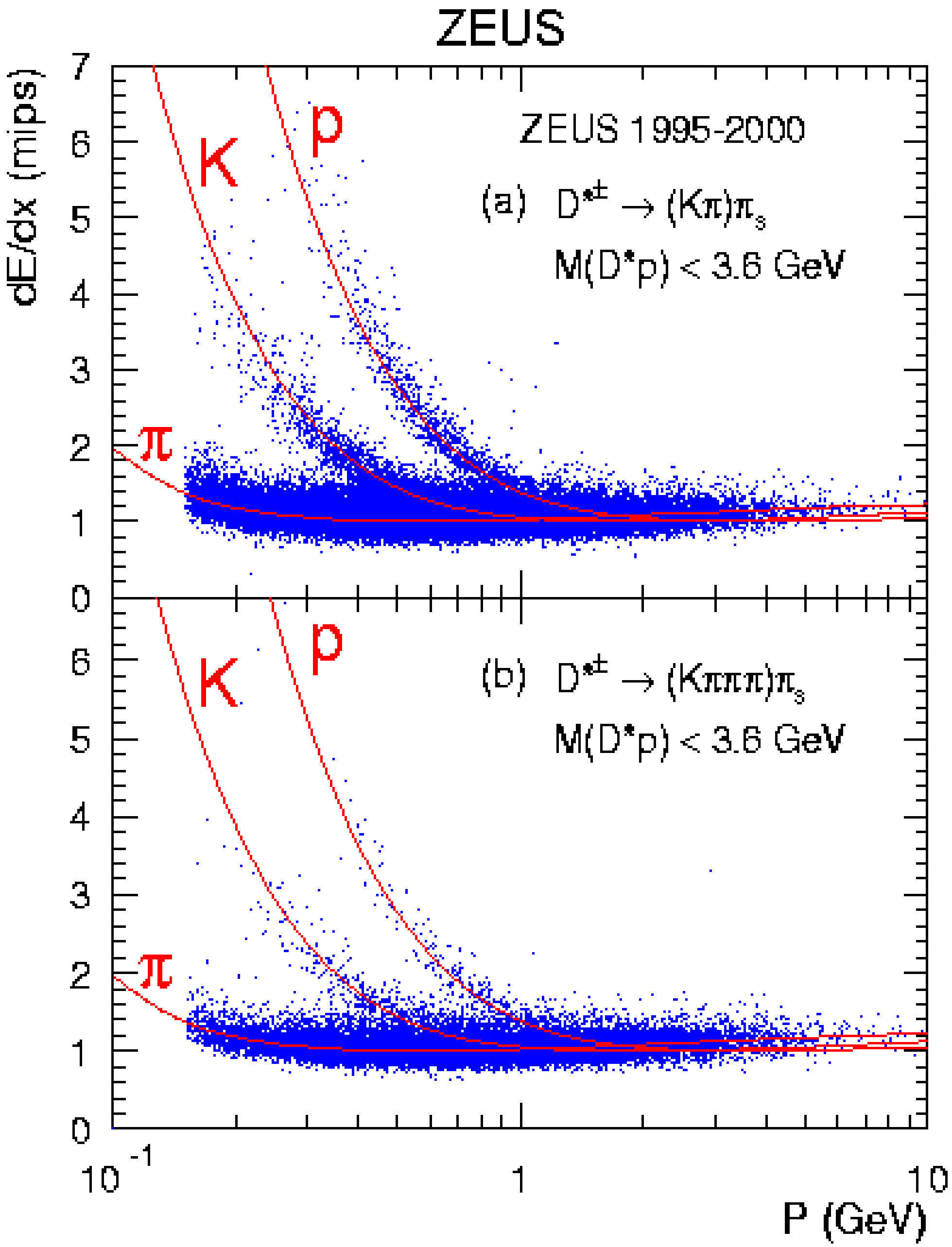
- $p_T(D^*) > 1.35$ **GeV for** $(K\pi)\pi_s$
- $p_T(D^*) > 2.8$ **GeV for** $(K\pi\pi\pi)\pi_s$
- $|\eta(D^*)| < 1.6$ **for both channels**

Yellow bands used for Θ_c^0 search:

$N(D^*) \sim 62500$, **full sample**

$N(D^*) \sim 13500$, $Q^2 > 1\,\mathbf{GeV}^2$

$p(\bar{p})$ identification, ZEUS



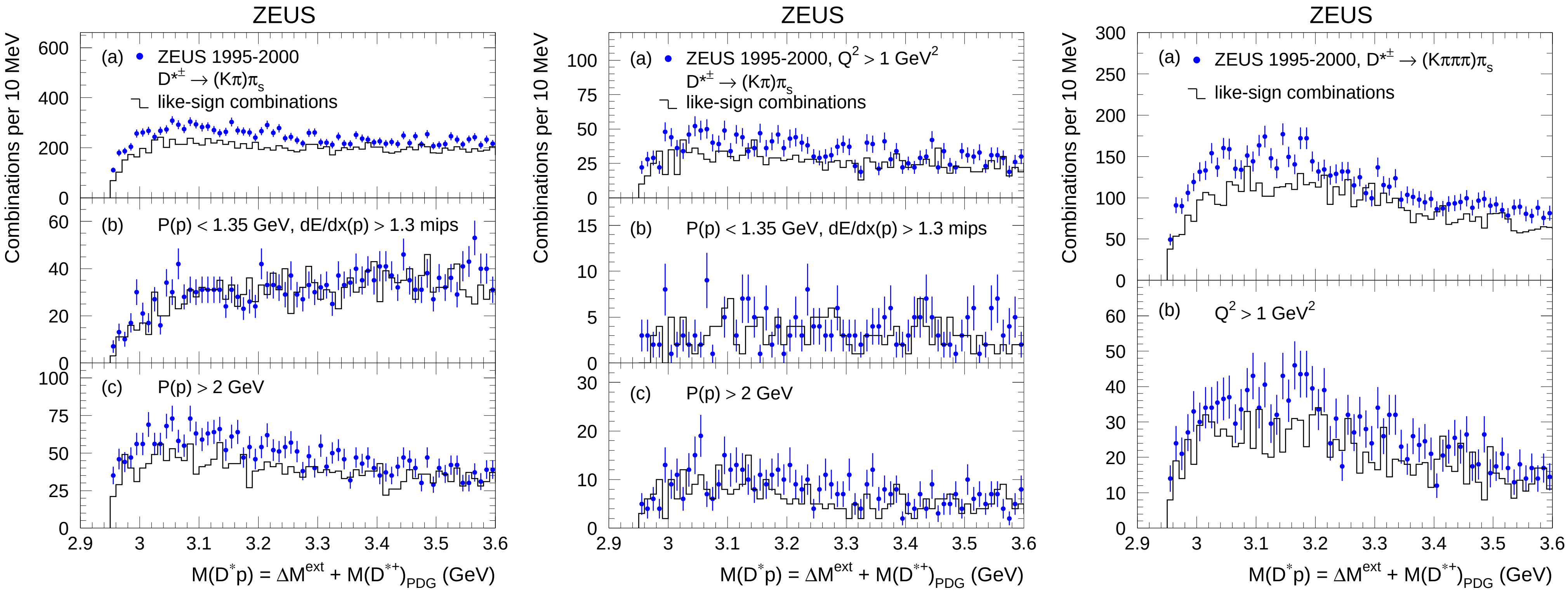
improved dE/dx calibration
w.r.t. Θ^+ analysis

resolution $\sim 9\%$

param. tuned using tagged $p(\bar{p})$
from Λ^0 decays

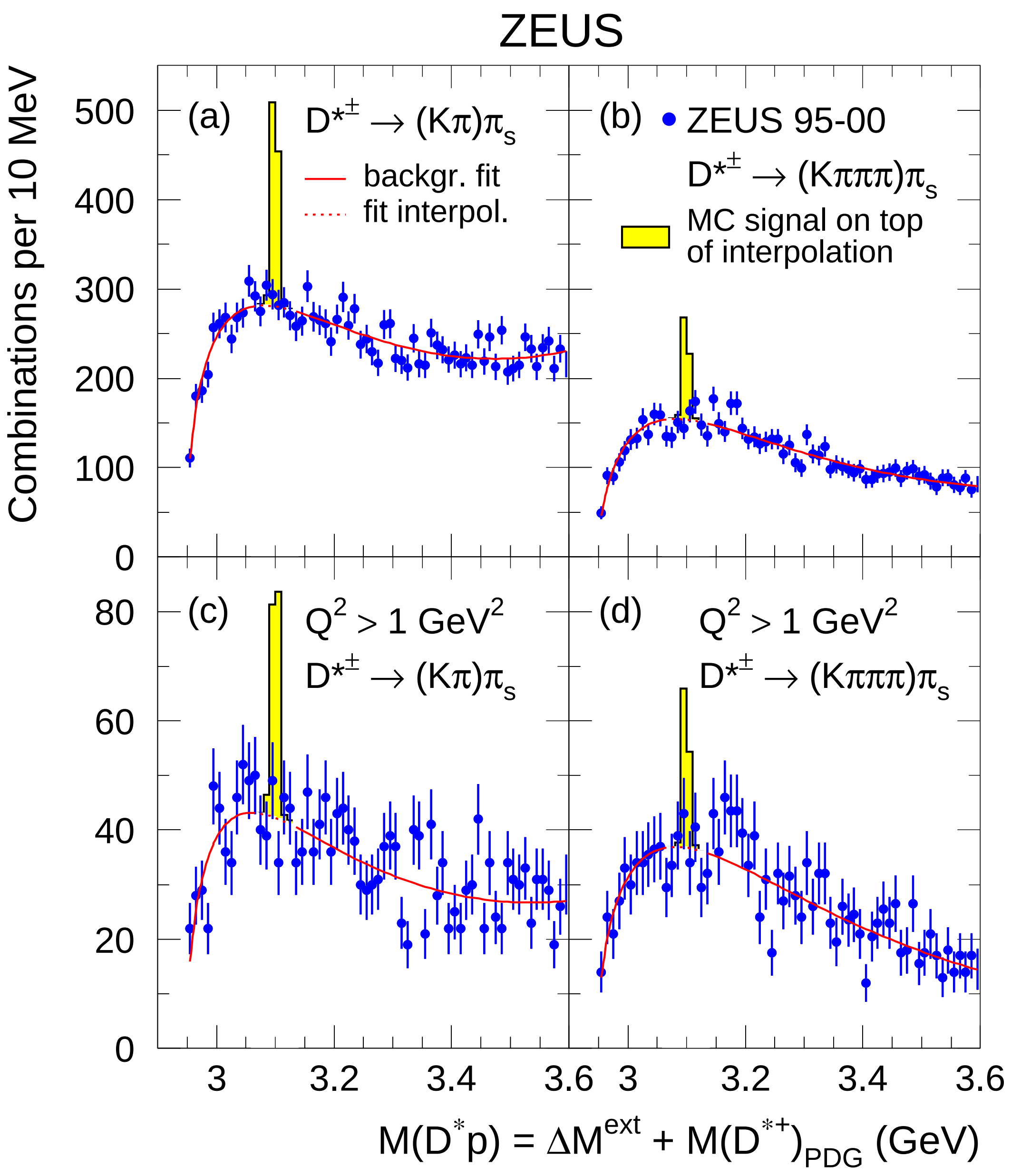
to select $p(\bar{p})$ candidates
$Prob(\chi^2) > 0.15$
$A(Prob(\chi^2) > 0.15) = 85.0 \pm 0.1\,\%$

$M(D^*p)$, ZEUS



no signal in either distribution

Limits on Θ_c^0 rate



yellow signals: MC signals normalised to 1% of obs. D^*

1% visible rate is excluded

at 9 σ for full sample
at 5 σ for $Q^2 > 1$ GeV^2

95% C.L. upper limits:

visible rate $R(\Theta_c^0 \to D^*p/D^*)$

$< 0.23\%$ for full sample
$< 0.35\%$ for $Q^2 > 1$ GeV^2

acceptance corrected rate

$< 0.37\%$ for full sample
$< 0.51\%$ for $Q^2 > 1$ GeV^2

$f(c \to \Theta_c^0) \times B(\Theta_c^0 \to D^*p)$

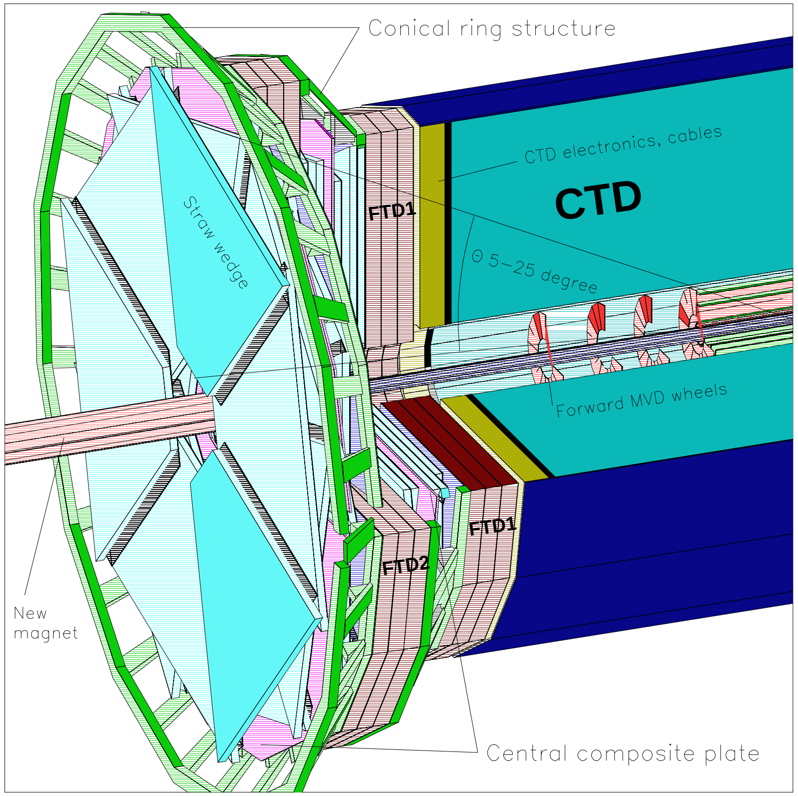
$< 0.16\%$ for full sample
$< 0.19\%$ for $Q^2 > 1$ GeV^2

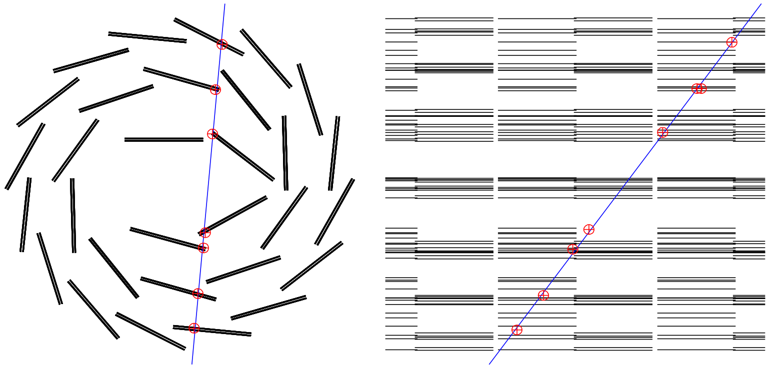
Summary

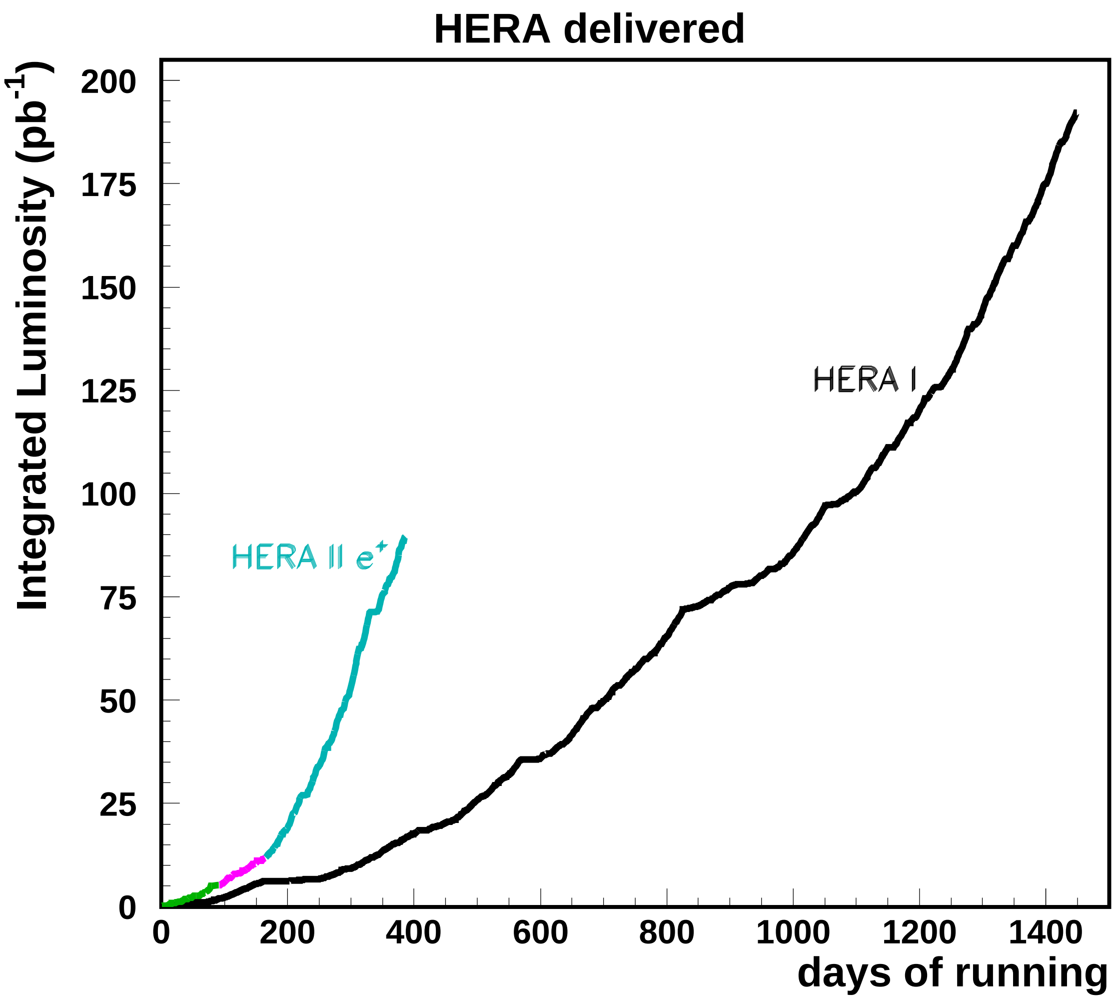
HERA produces competitive results on hadron spectroscopy and pentaquark searches

- $f_0(1710)$ **production in gluon-rich region of phase space. Additional hint for its gluonic content.**
- $D_1^0(2420)$, $D_2^{*0}(2460)$, $D_{s1}^{\pm}(2536)$ **clearly seen.**
  $f(c \to D^{*\prime +}) \cdot B_{D^{*\prime +} \to D^{*+}\pi^+\pi^-} < 0.7\% \quad (95\% \quad \text{C.L.})$,
  slightly better than limit from OPAL
- $\Theta^+ \to K_s^0 p$ **production observed in high-**Q^2 **DIS,**
  $R(\Theta^+/\Lambda^0)$ **larger than limits from ALEPH, HERA-B**
- **no signature of** $\Xi_{5q}^{--,0} \to \Xi\pi$
  although sensitivity is similar to NA49
- **H1 and ZEUS results on** $\Theta_c^0 \to D^*p$ **disagree.**
  Using larger statistics, ZEUS does not see a signal observed by H1

Outlook

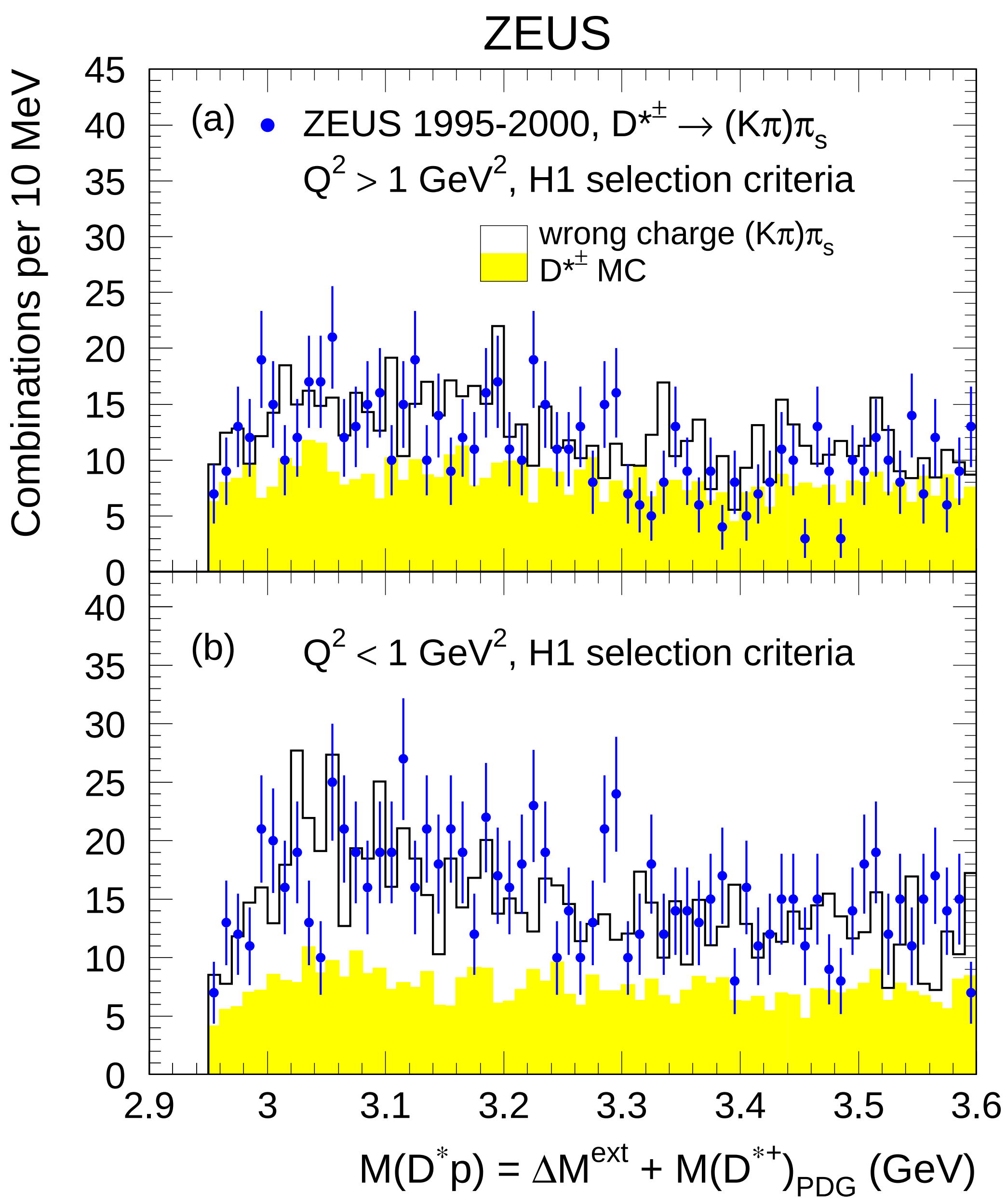


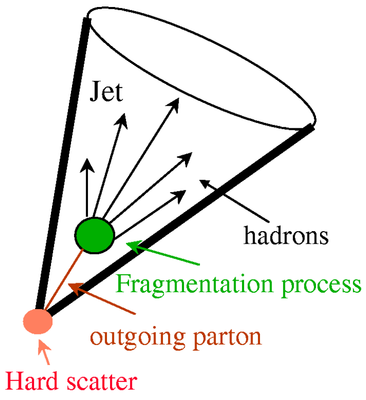




HERA II collecting data

Backup: ZEUS $M(D^*p)$ with H1 selection criteria





Charm fragmentation issues

Important to study charm fragmentation to find :

1) What is the proper parameterisation for the fractional transfer of c-quark energy/momentum to a given D-meson (**z**) ?
   fragmentation function, $f(z)$

2) Are u and d quarks produced equally ? $R_{u/d} = \frac{c\bar{u}}{c\bar{d}}$

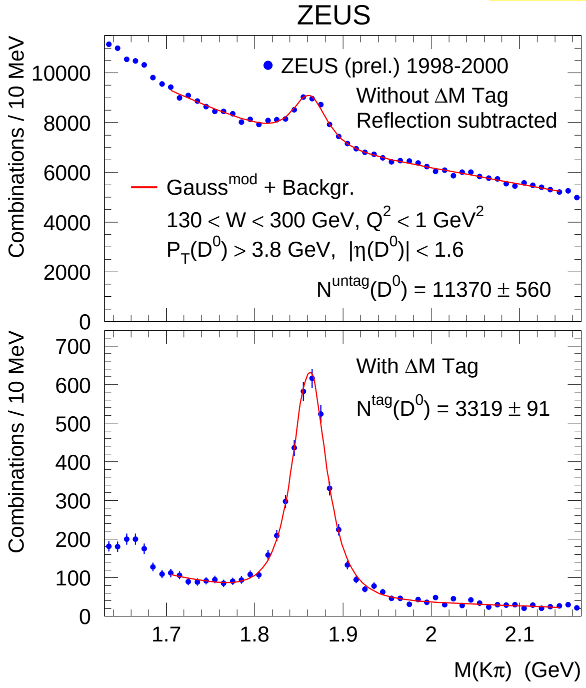
3) What is the s-quark production suppression ? $\gamma_s = \frac{2\,c\bar{s}}{c\bar{d}+c\bar{u}}$

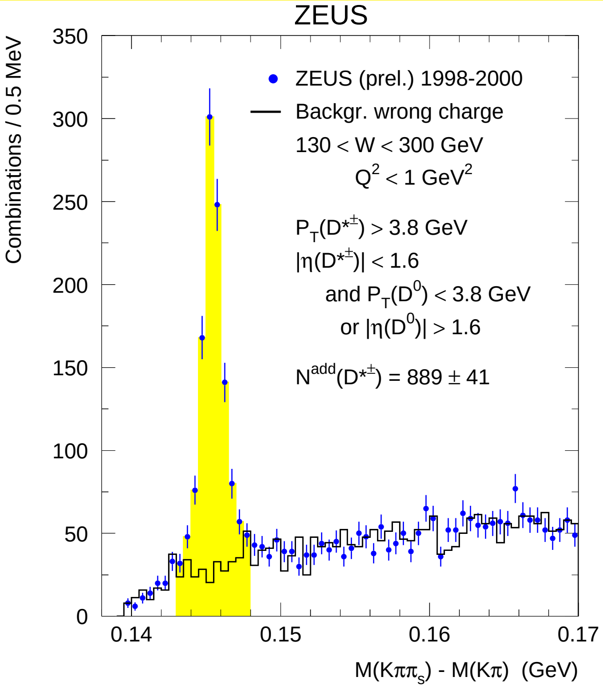
4) Are vector (D^*) and pseudoscalar (D) mesons produced as predicted by spin counting ? $P_{\rm v} = \frac{V}{V+PS}$ $(= 0.75\ ?)$

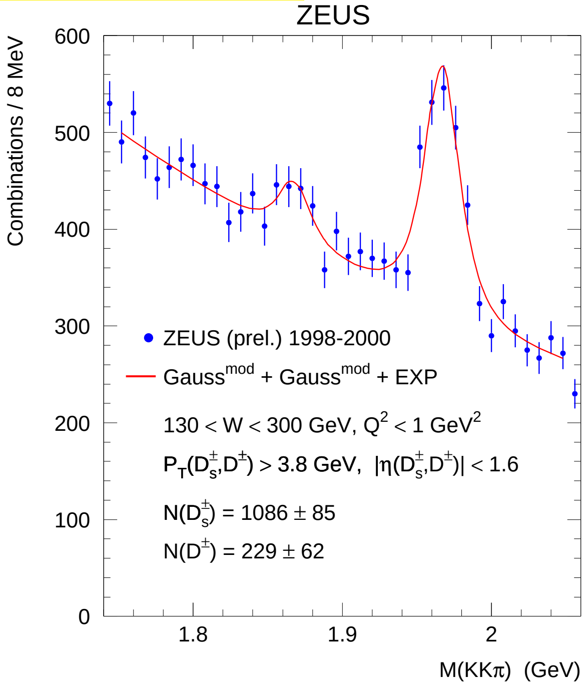
5) What are the relative **fragmentation fractions** of charm hadrons ?
   $f(c \to D) = \frac{N(D)}{N(c)} = \frac{\sigma(D)}{\sum_{\rm all}\sigma(D)}$

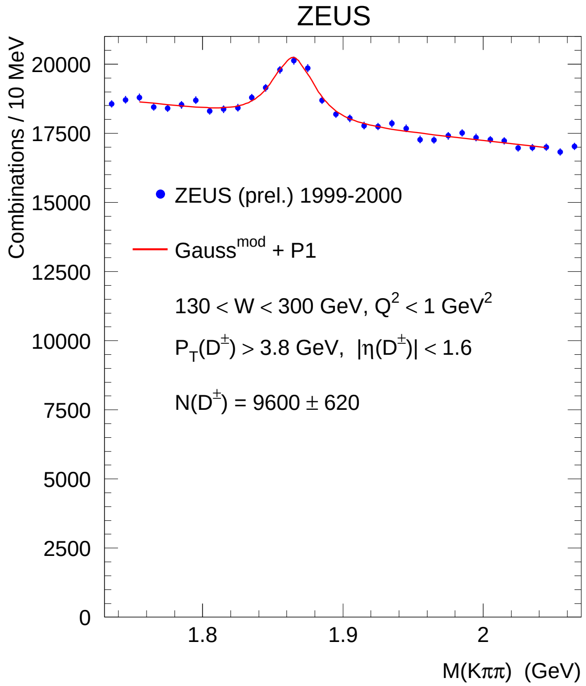
6) Are these functions, ratios and fractions universal ?
   compare HERA results with those in e^+e^- annihilations

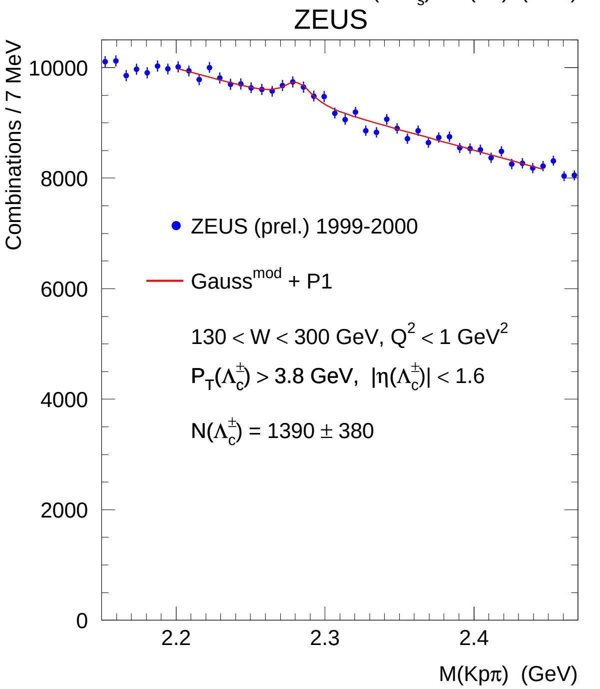
D^0, $D^{*\pm}$, $D_s^\pm$, $D^\pm$ and $\Lambda_c^\pm$ signals











Kinematic range:

$P_T(D,\Lambda) > 3.8\,\textbf{GeV},\ |\eta(D,\Lambda)| < 1.6$

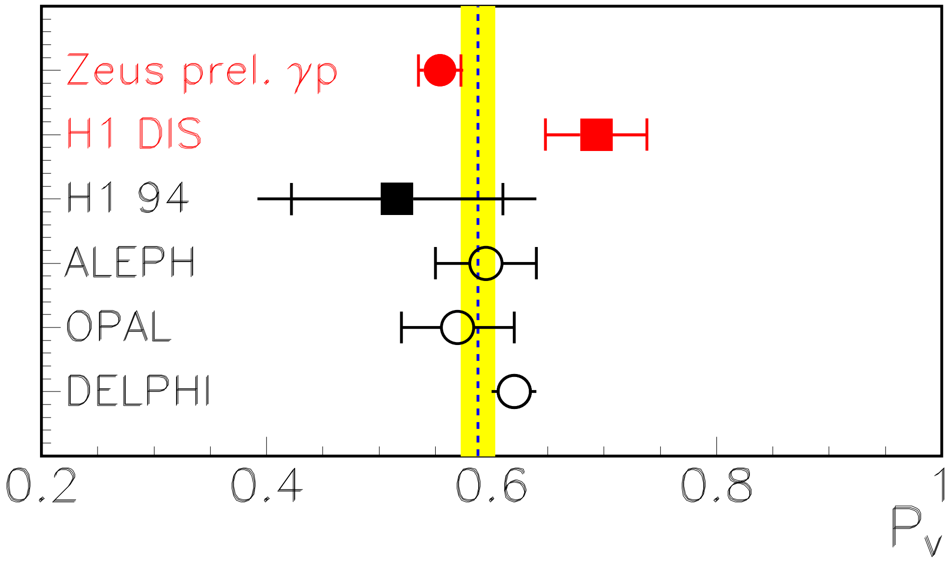
$130 < W < 280\,\textbf{GeV},\ Q^2 < 1\,\textbf{GeV}^2$

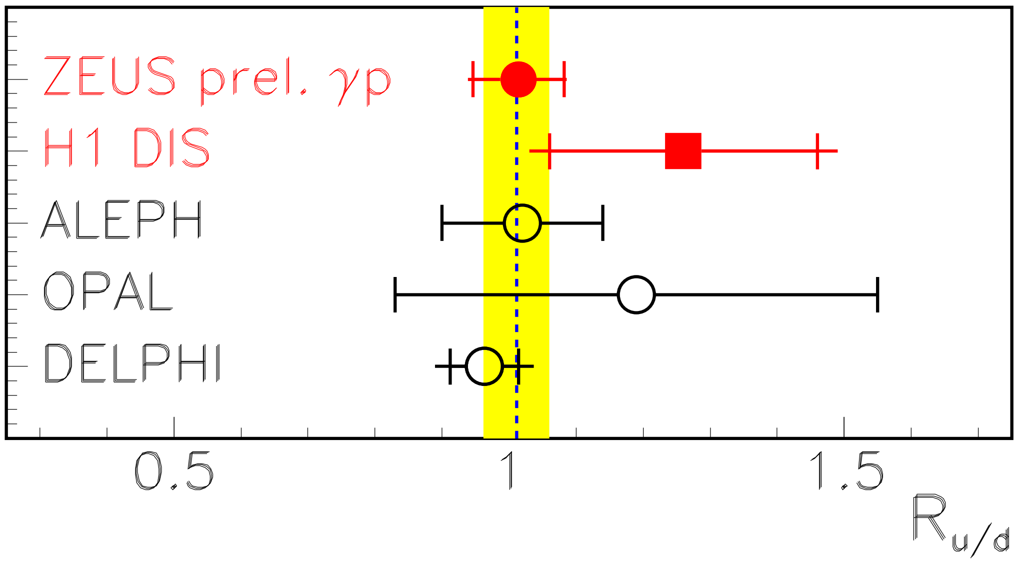
"Measured" x-sections:

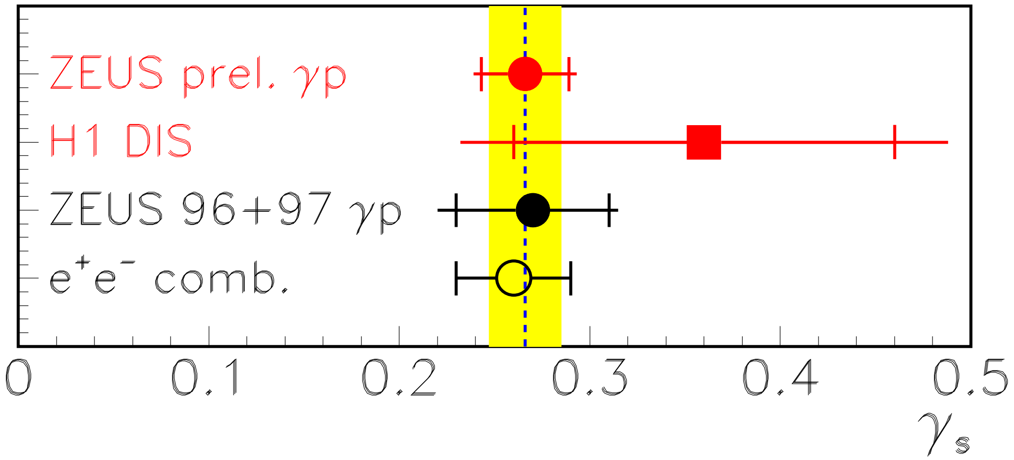
$\sigma^{\rm untag}(D^0),\ \sigma^{\rm tag}(D^0),\ \sigma^{\rm add}(D^{*\pm})$

$\sigma(D_s^\pm),\ \sigma(D^\pm),\ \sigma(\Lambda_c^\pm)$

Fragmentation ratios







Fragmentation fractions

ZEUS prel. (γp) $P_T(D,\Lambda_c) > 3.8$ **GeV**, $\lvert\eta(D,\Lambda_c)\rvert < 1.6$	Combined e^+e^- data	H1 (DIS)
$\boxed{f(c \to D^+) = 0.249 \pm 0.014^{+0.004}_{-0.008}}$	0.232 ± 0.010	$0.202 \pm 0.020^{+0.045\,+0.029}_{-0.033\,-0.021}$
$\boxed{f(c \to D^0) = 0.557 \pm 0.019^{+0.005}_{-0.013}}$	0.549 ± 0.023	$0.658 \pm 0.054^{+0.117\,+0.086}_{-0.142\,-0.048}$
$\boxed{f(c \to D_s^+) = 0.107 \pm 0.009 \pm 0.005}$	0.101 ± 0.009	$0.156 \pm 0.043^{+0.036\,+0.050}_{-0.035\,-0.046}$
$\boxed{f(c \to \Lambda_c^+) = 0.076 \pm 0.020^{+0.017}_{-0.001}}$	0.076 ± 0.007	
$\boxed{f(c \to D^{*+}) = 0.223 \pm 0.009^{+0.003}_{-0.005}}$	0.235 ± 0.007	$0.263 \pm 0.019^{+0.056\,+0.031}_{-0.042\,-0.022}$

charm fragmentation fractions are universal

we use correct normalization for pQCD predictions

HERA measurements confirm universality
of charm fragmentation

Summary for charm fragmentation

measurement of charm fragmentation function ($D^{*\pm}$) :

PYTHIA with Bowler and Peterson fragmentation functions provide good description; $\epsilon = 0.064 \pm 0.006^{+0.011}_{-0.008}$ **(ZEUS prel.)**

this leading-logarithm Monte Carlo fit to ZEUS data agrees with LL fit to ARGUS data performed by Nason and Oleari

measurement of charm fragmentation ratios :

u **and** d **quarks are produced equally in charm fragmentation**

s**-quark production suppressed by factor** $3-4$ **in** c**-fragmentation**

$P_{\mathrm{v}} \neq 0.75 \quad \Longrightarrow$ **naive spin counting does not work for charm**

measurement of charm fragmentation fractions :

charm fragmentation fractions measured in $e^{\pm}p$ **and** $e^{+}e^{-}$ **collisions are in reasonable agreement**

study of excited D mesons :

the same amounts of excited D **mesons in** $e^{+}e^{-}$ **and** ep **data**

the strongest world limit: $f(c \to D^{*\prime +}) \cdot B_{D^{*\prime +} \to D^{*+}\pi^{+}\pi^{-}} < 0.7\% \quad (95\% \;\; \mathrm{C.L.})$

open questions: a narrow bump in $D^{*\pm}\pi^{\mp}$ **spectrum;** D_{s1}^{+} **helicity distribution; precise value of** $f(c \to D_{2}^{*0})$**; "too large"** $f(c \to D_{s1}^{+})$ **value**