Resonance Search and Particle Production at HERA

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on behalf of the
H1 and ZEUS Collaborations

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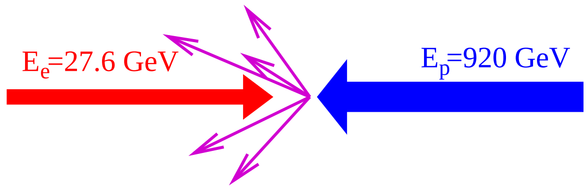
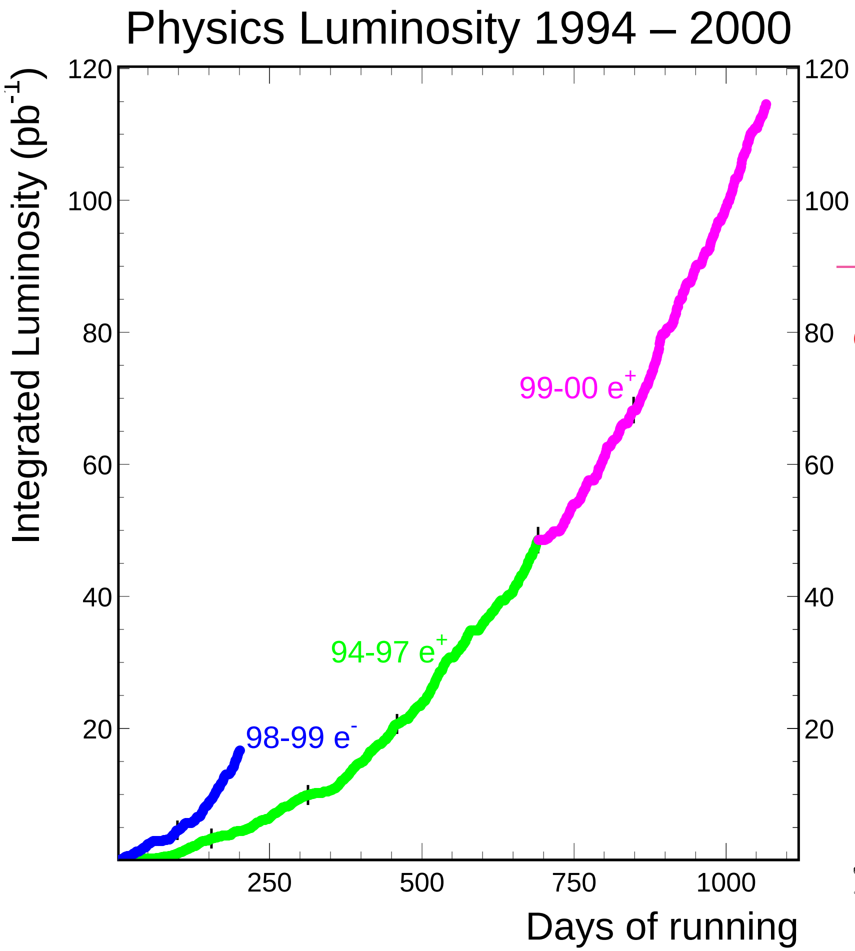
O U T L I N E

- Introduction
- Search for $\Theta^+ \to K_s^0 p$,$K_s^0 \overline{p}$ in DIS
- Search for exotic decay to $\Xi\pi$ in DIS
- Production of d,$\overline{d}$ in DIS
- Production of K_s^0,Λ,$\overline{\Lambda}$
- Excited Charm Mesons
- Summary

HERA Machine



	HERA I	HERA II
	1992-2000	2003-2007
$\sqrt{s}$	318 **(300)**	318 **GeV**
$\mathcal{L}$	$1.5 \cdot 10^{31}$	$7 \cdot 10^{31}\, cm^{-2}\, s^{-1}$
$\mathcal{L}_{int}$	0.1	$\sim 0.4\, fb^{-1}$



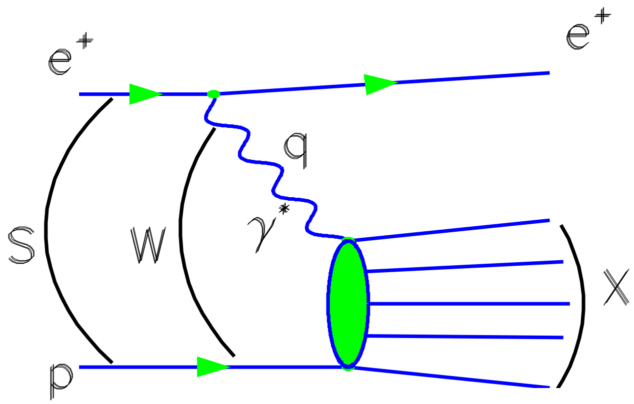
H1, ZEUS : $> 100\,$pb^{-1} each

$$e(k) + p(P) \rightarrow e(k') + X \qquad s = (P+k)^2$$

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

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

DIS $\quad Q^2 > 1,5\, GeV^2$

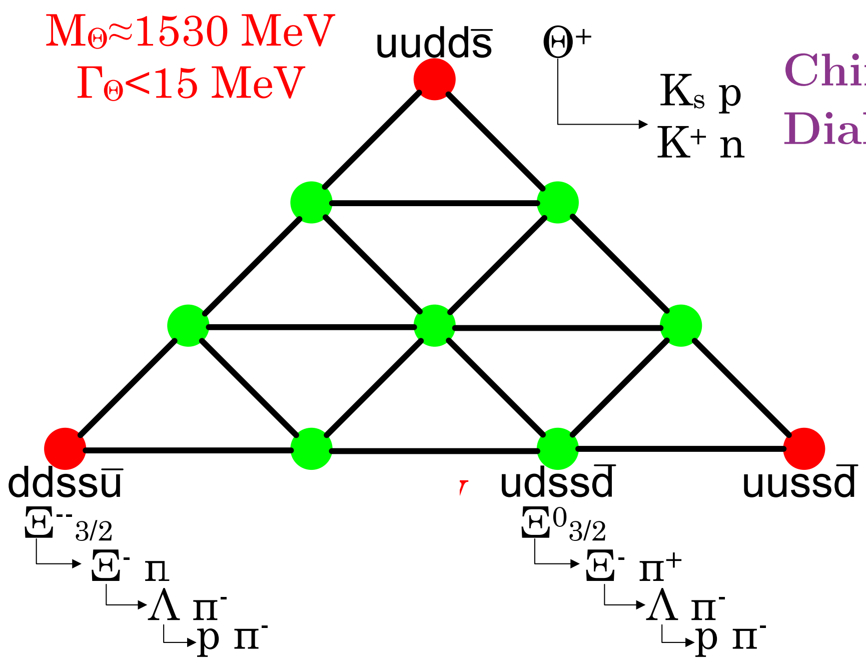


$$W^2 = (P+q)^2$$

$$y = \frac{qP}{kP} \cong \frac{W^2+Q^2}{s}$$

$$x = \frac{Q^2}{2qP} \cong \frac{Q^2}{sy}$$

Strange Pentaquarks



Chiral Soliton Model predicts Exotic Baryon Anti-Decuplet
Diakonov, Petrov, Polyakov (hep-ph/9703373)

$\Theta^+ \rightarrow K^+ n$ exotic (S=B=+1) Seen by LEPS, SAPHIR

$M_\Theta \approx 1540 MeV$

Not seen by CLAS, BES, PHENIX

$\Theta^+ \rightarrow K_s^0 p$ non-exotic Seen by DIANA, HERMES, νBC, SVD, ZEUS, ITEP

$M_\Theta = 1520 - 1540 MeV$

Not seen by BES, BaBar, Belle, HERA-B, CDF,

ALEPH, DELPHI, L3, SPHINX, HyperCP,

FOCUS, E690, COMPASS, COSY-TOF, H1

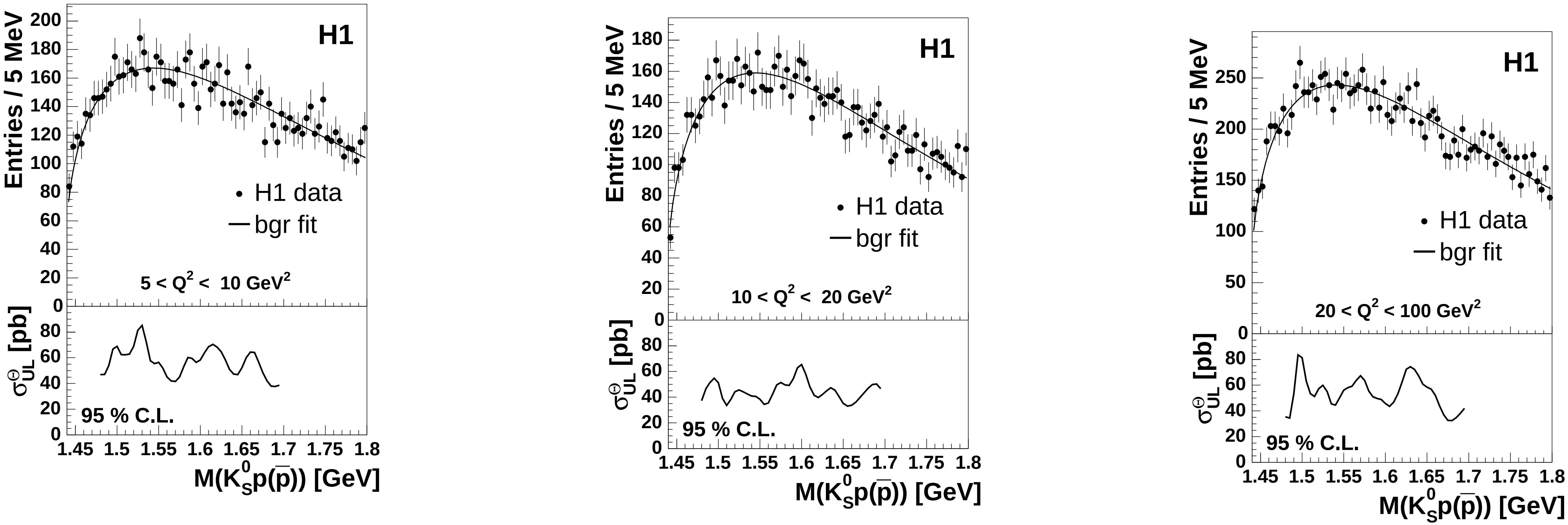
H1 Strange Pentaquark Search

$\mathcal{L}_{int}$: 74pb^{-1} 1996-2000, $5 < Q^2 < 100\, GeV^2$, $0.1 < y < 0.6$

Choose K_s^0 for $0.475 < M_{\pi^+\pi^-} < 0.515$ GeV

Select proton by ionization loss probability

Look in range $1.48 < M(K_s^0 p\ (\bar{p})) < 1.70$ GeV

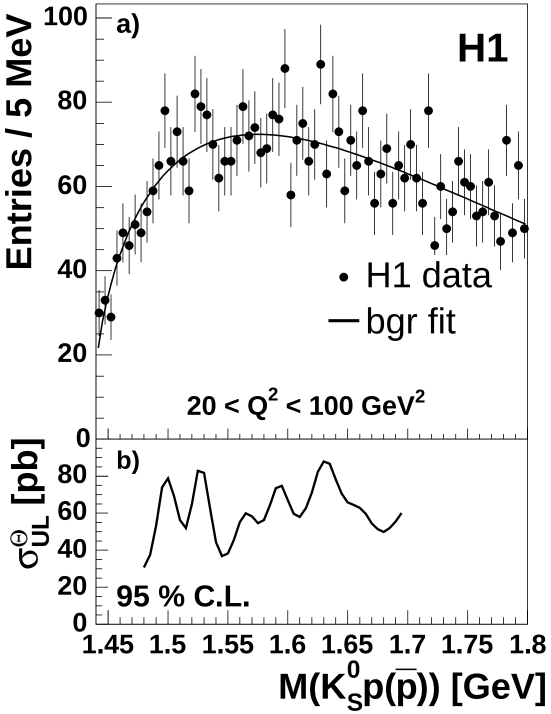


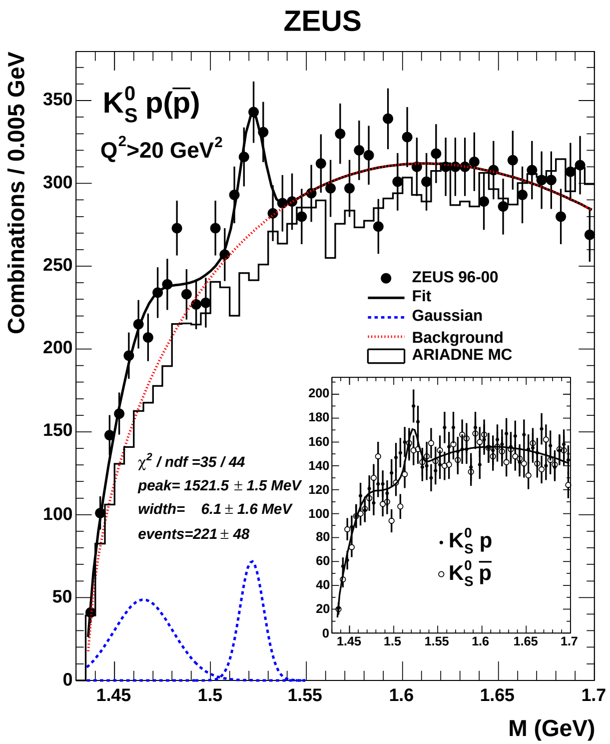
Similar upper limits for K_s^0p and $K_s^0\bar{p}$ separately.

Strange Pentaquark

H1: $\sigma(ep \rightarrow e\Theta^+ X)$ x $BR(\Theta^+ \rightarrow K^0 p) < 30 - 90$ pb

Imitate ZEUS analysis: $20 < Q^2 < 100\,GeV^2$, $p(p) < 1.5\,GeV$





	H1	ZEUS(prelim.)
$\mathcal{L}_{int}$	74 pb^{-1}	121 pb^{-1}
$\sigma(ep \rightarrow e\Theta^+ X \rightarrow eK^0 pX)$	< 72 pb (95% CL)	$125 \pm 27^{+36}_{-28}$ pb

H1 limit not inconsistent with ZEUS result

Double Strange Pentaquark Search

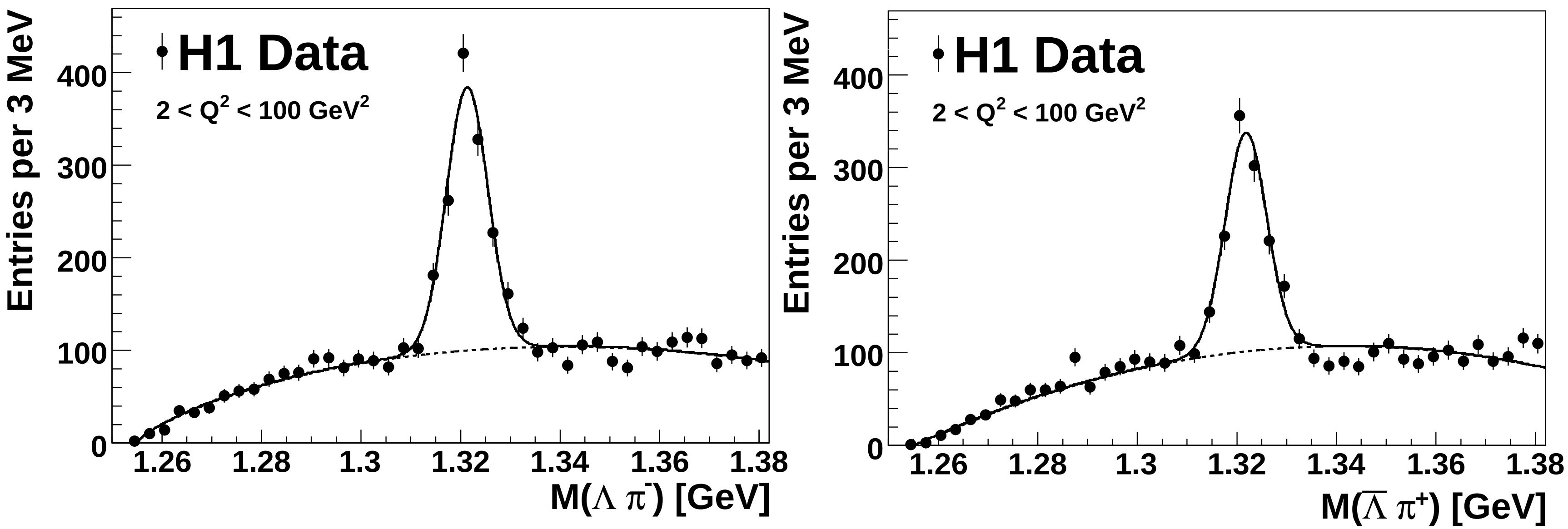
NA49: $M(\Xi^{--})(S=-2, I_3=-3/2) = 1862\, MeV$
$M(\Xi^{0})(S=-2, I_3=+1/2) = 1864\, MeV$

Not seen by WA89,ALEPH,BES,HERA-B,HERMES,ZEUS

$\mathcal{L}_{int}(H1)$: $101\mathrm{pb}^{-1}$ 1996-2000

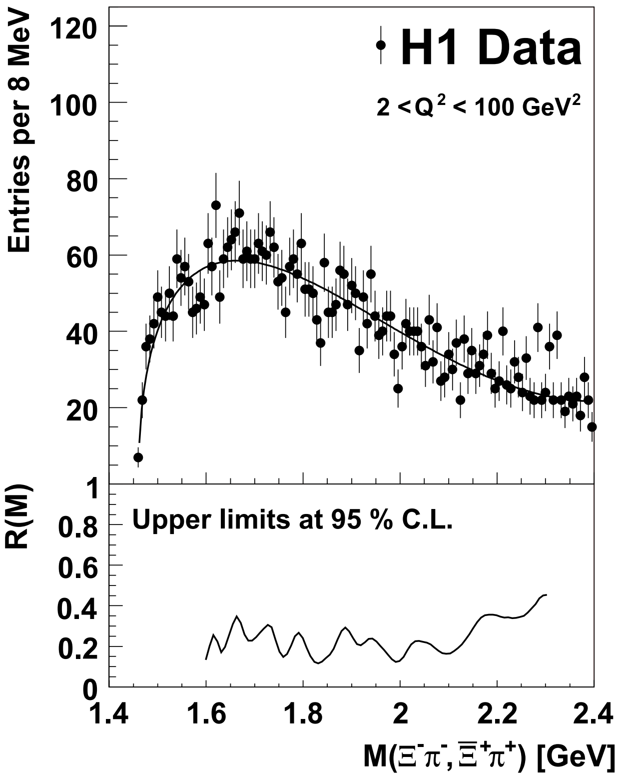
$2 < Q^2 < 100\, GeV^2, \quad 0.05 < y < 0.7$

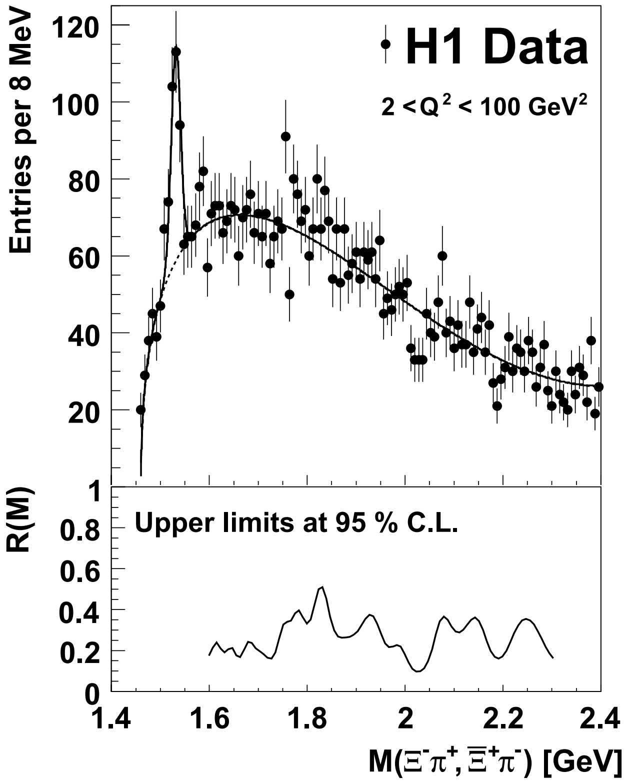
Decay Chain: $\Xi^{--} \rightarrow \Xi^- \pi^- \rightarrow \Lambda\pi^-\pi^- \rightarrow p\pi^-\pi^-\pi^-$
$\Xi^{0} \rightarrow \Xi^- \pi^+ \rightarrow \Lambda\pi^-\pi^+ \rightarrow p\pi^-\pi^-\pi^+$

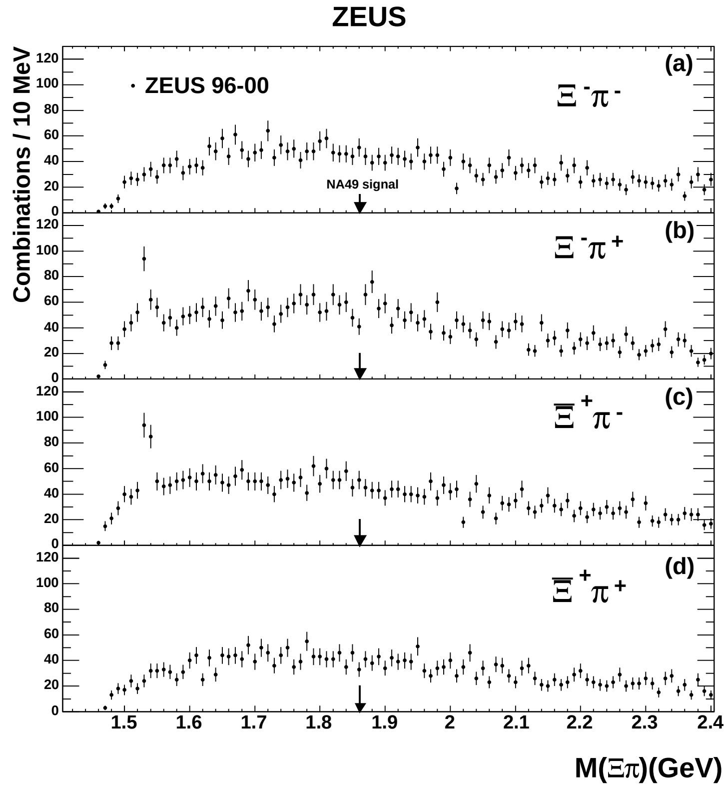


Double Strange Pentaquark Search

Look in mass range M(1600-2300) MeV See $\Xi^0(1530)$







$$\text{H1,ZEUS:}\ \frac{N(\Xi^{--})}{N(\Xi^0(1530))} < 12 - 45\%, 10 - 50\% \qquad 95\%\ \text{CL}$$

$$\text{H1,ZEUS:}\ \frac{N(\Xi^{0})}{N(\Xi^0(1530))} < 10 - 50\%, 10 - 50\% \qquad 95\%\ \text{CL}$$

Anti(Deuteron) Production in DIS

$\mathcal{L}_{int}(ZEUS)$: 120pb^{-1} 1996-2000, $Q^2 > 1\,GeV^2$

Heavy ion collisions use coalescence model for d production.

Used for $d(\bar{d})$ production in $pp, \gamma p, e^+e^-$ interactions.

Assume baryons uncorrelated, $\sigma_n = \sigma_p$

$$\frac{1}{\sigma_{tot}}\frac{E_d d^3\sigma_d}{dp_d^3} = B_2\left(\frac{1}{\sigma_{tot}}\frac{E_p d^3\sigma_p}{dp_p^3}\right)^2$$

$$B_2 \sim \frac{1}{Volume\ of\ fragmentation\ region\ emitting\ the\ particles}$$

Central rapidity region $|y| < 0.4 \quad 0.3 < p_t/M < 0.7$

Require ≥ 1 track with $dE/dx > 2.5\,mips$

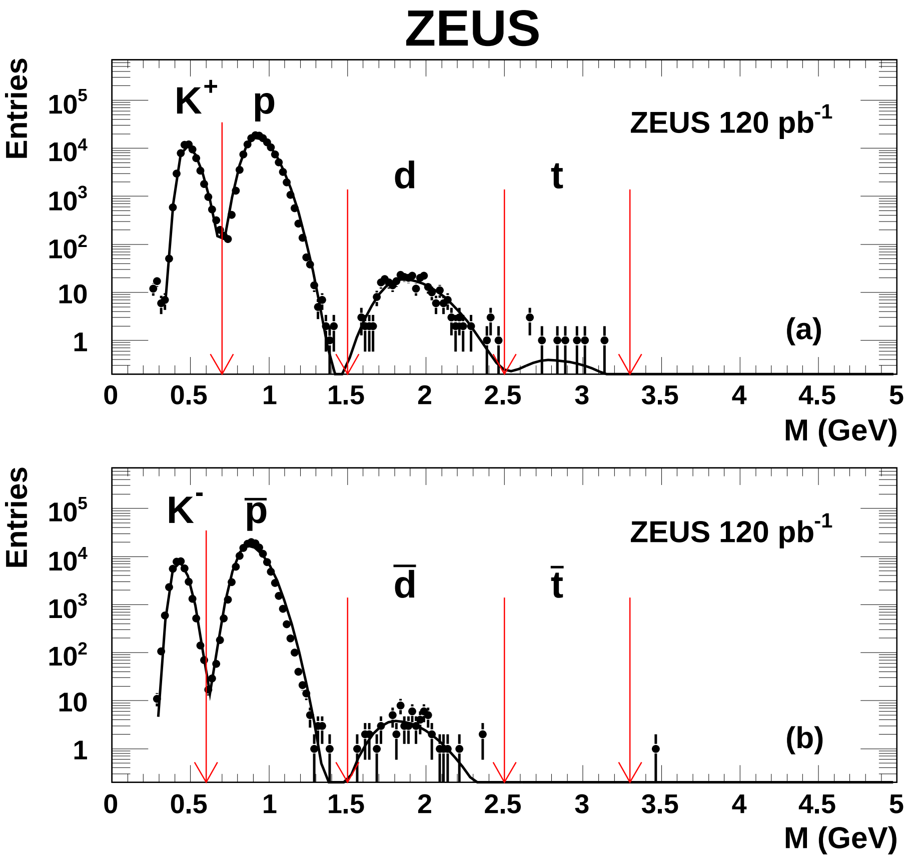
Enhances fraction of events with ≥ 1 particle with mass $> M(\pi)$

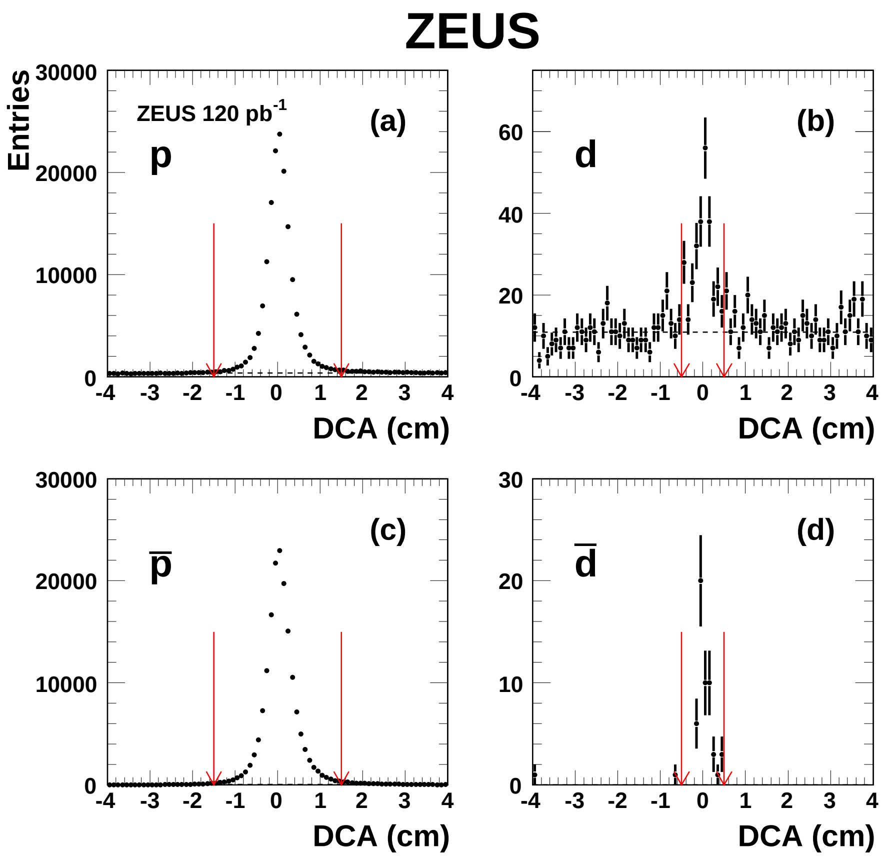
Distance of Closest Approach, z Distance from Vertex cuts

Then sideband subtraction to remove beam gas events

Anti(Deuteron) Production in DIS

Masses from track momentum,energy loss with Bethe-Bloch

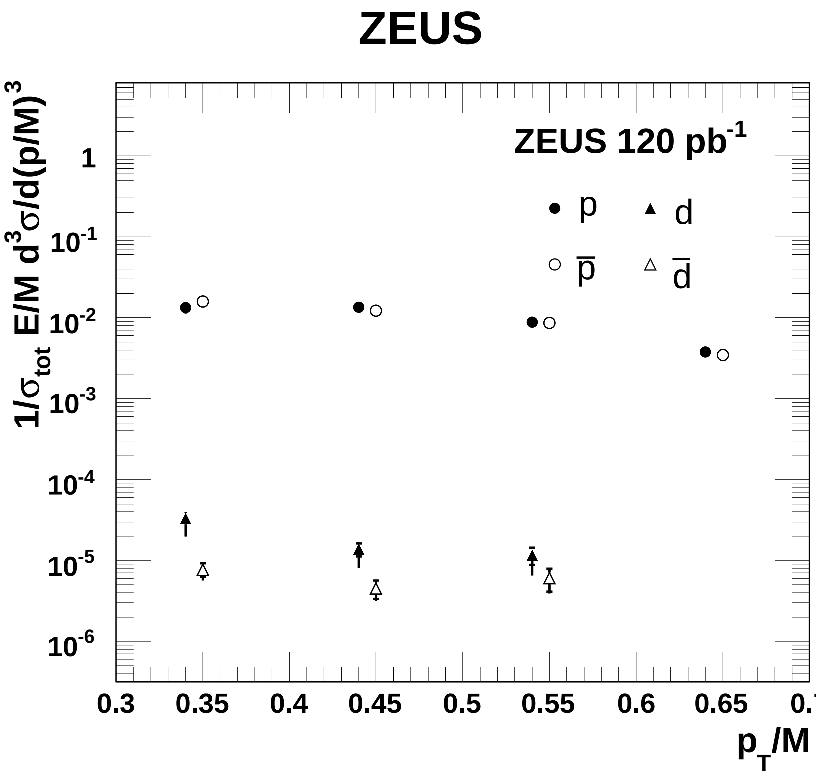


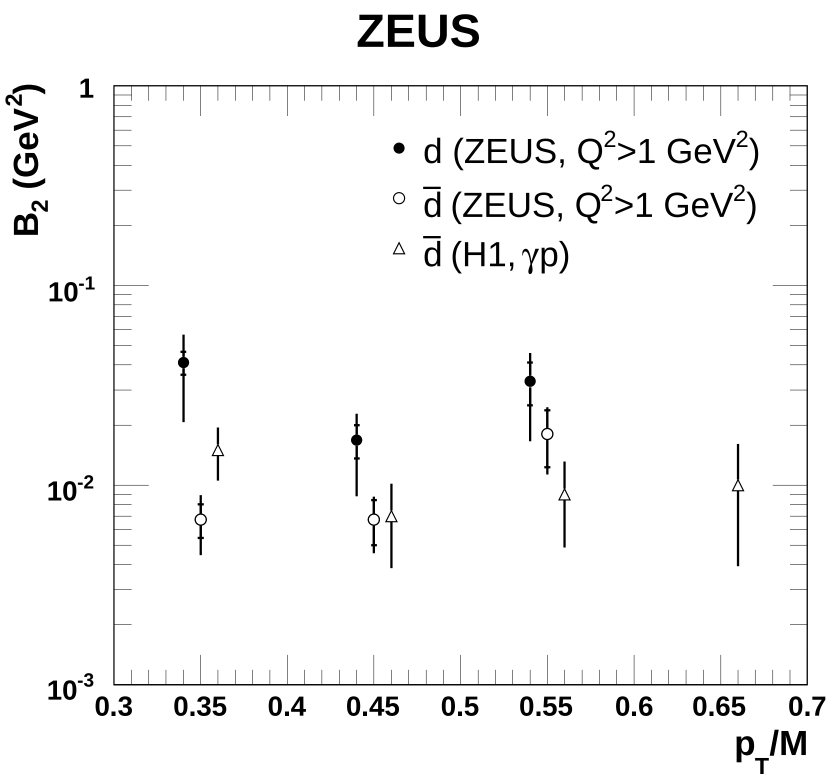


$N(d) = 177 \pm 17 \quad N(\overline{d}) = 53 \pm 7$

$p(\overline{p})$ **rate corrected for** $\Lambda(\overline{\Lambda})$ **decays**

Anti(Deuteron) Production in DIS





$\sigma(\bar{d}) < \sigma(d)$

B_2 **larger than in heavy ions and** e^+e^-

B_2 **DIS compatible with photoproduction**

$$\frac{1}{\sigma_{tot}}\frac{E_d d^3\sigma_d}{dp_d^3} = B_2\left(\frac{1}{\sigma_{tot}}\frac{E_p d^3\sigma_p}{dp_p^3}\right)^2 \Rightarrow R(\bar{d}/d) = R(\bar{p}/p)^2$$ **Not Satisfied**

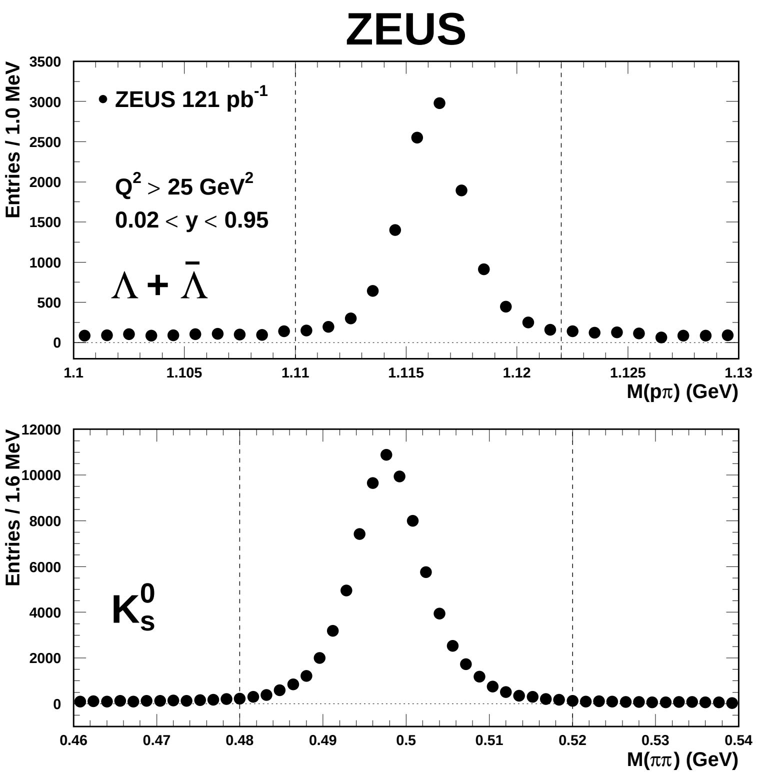
No d **or** $\bar{d}$ **in current Breit frame region. Doesn't contradict** e^+e^-

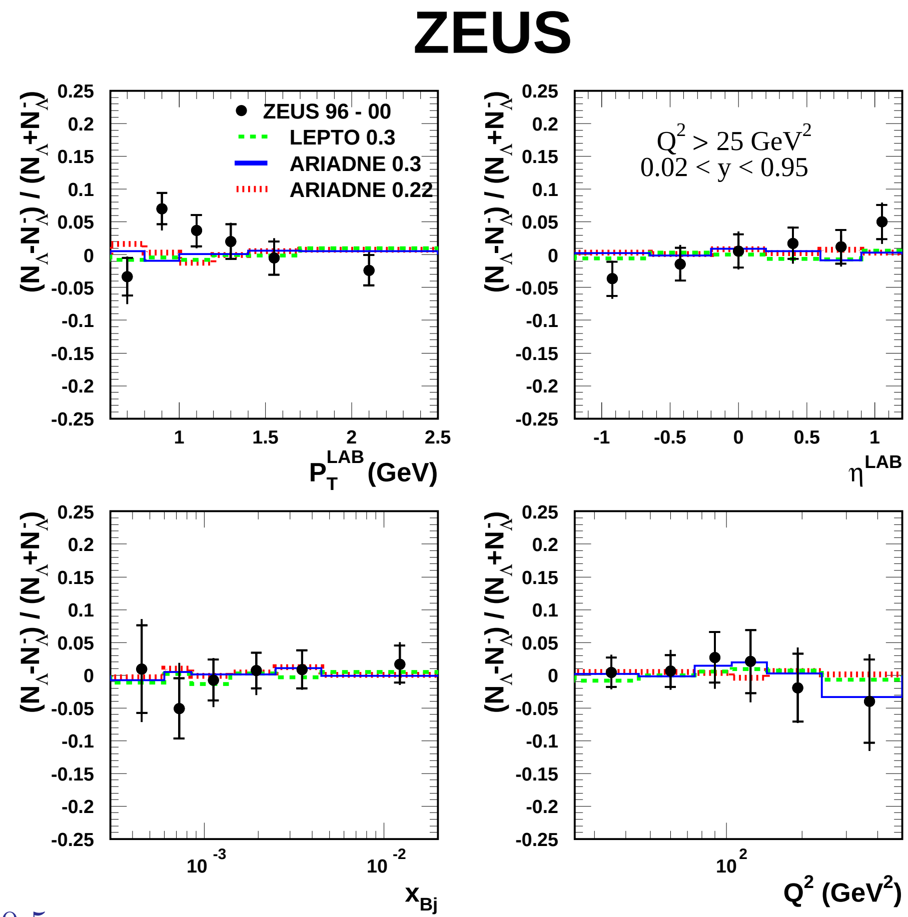
ZEUS Neutral Strange Particle Production

$\mathcal{L}_{int}(ZEUS): 121\mathbf{pb}^{-1}$ **1996-2000,** $5 < Q^2 < 25\,GeV^2$, $0.02 < y < 0.95$

$Q^2 > 25\,GeV^2$, $0.02 < y < 0.95$

Baryon-Antibaryon Asymmetry: $A = (N(\Lambda) - N(\overline{\Lambda}))/(N(\Lambda) + N(\overline{\Lambda}))$





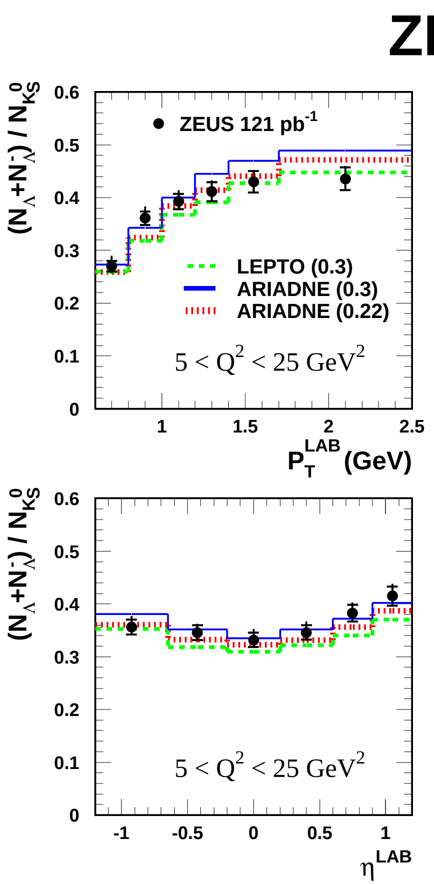
$Q^2 > 25\,GeV^2$: $A = 0.3 \pm 1.3^{+0.5}_{-0.8}\%$

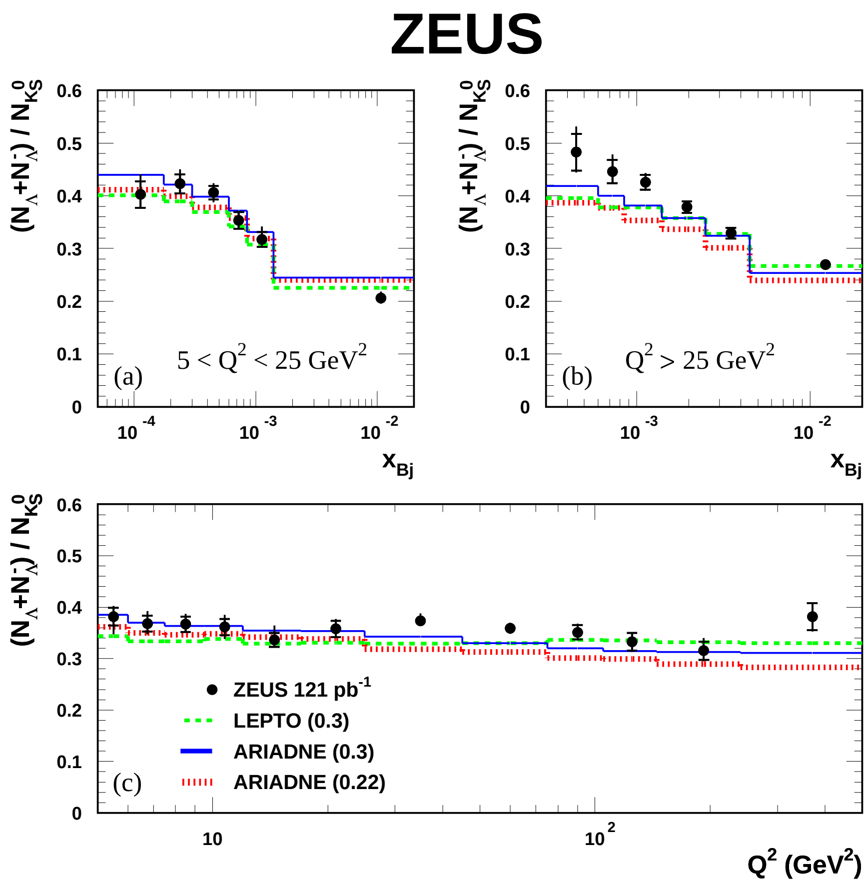
$5 < Q^2 < 25\,GeV^2$: $A = 1.2 \pm 1.6^{+0.7}_{-2.1}\%$

Consistent with No Asymmetry

ZEUS Neutral Strange Particle Production

Baryon-to-Meson Ratio: $R = (N(\Lambda) + N(\overline{\Lambda}))/N(K_s^0)$





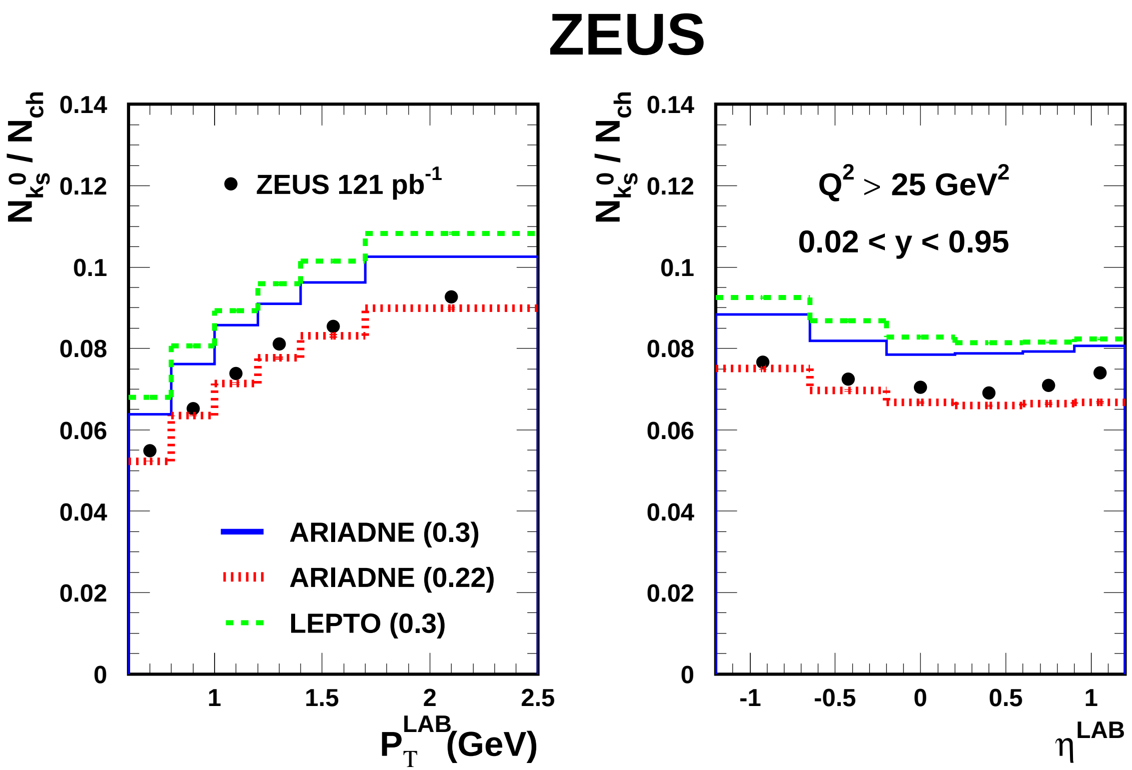
R increases with p_t | **R decreases with x_{Bj}**

R increases in forward η region | **$R \sim$ constant in Q^2**

Data and Monte Carlo disagree for high Q^2 at low x_{Bj}

ZEUS Neutral Strange Particle Production

Strange-to-Charged Particle Ratio: $T = N(K_s^0)/N_{charged}$

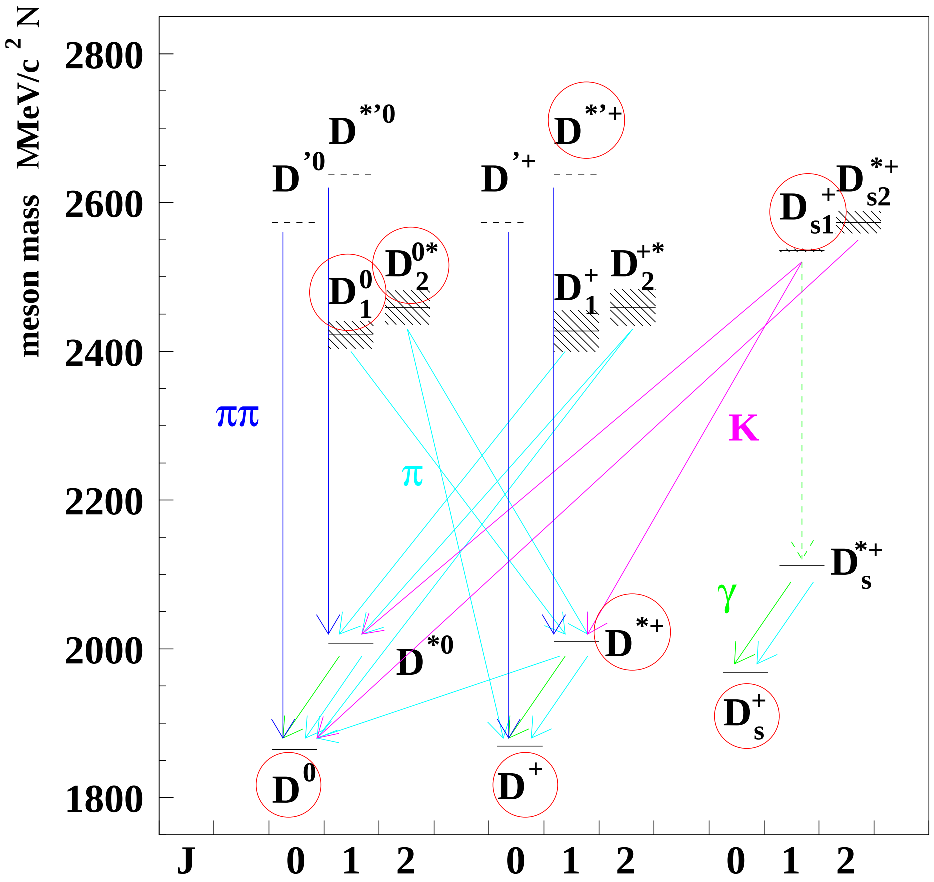


T increases with p_t

$T \sim$ constant in η

Strange Suppression Factor Prefers $\lambda_s = 0.22$ over 0.3

ZEUS(Prelim.) Excited Charm Mesons



Look at $D_1^0 \to D^{*\pm}\pi^{\mp}, D_2^{*0} \to D^{\pm}\pi^{\mp}$

$D_{s1}^{\pm} \to D^{*\pm}K_s^0, D^{*0}K^{\pm}$

Extract charm fragmentation fractions:

$f(c \to D_1^0), f(c \to D_2^{*0}), f(c \to D_{s1}^{\pm})$

And Branching Fractions:

$\frac{B(D_2^{*0}\to D^+\pi^-)}{B(D_2^{*0}\to D^{*+}\pi^-)}, \frac{B(D_{s1}^+\to D^{*0}K^+)}{B(D_{s1}^-\to D^{*+}K^0)}$

Using $f(c \to D^{*\pm}), f(c \to D^{\pm}), f(c \to D^0)$

And Measured Ratios:

$R(\frac{D_1^0\to D^{*+}\pi^-}{D^{*+}}), R(\frac{D_2^{*0}\to D^{*+}\pi^-}{D^{*+}}), R(\frac{D_2^{*0}\to D^+\pi^-}{D^+}), R(\frac{D_{s1}^+\to D^{*+}K^0}{D^{*+}}), R(\frac{D_{s1}^+\to D^{*0}K^+}{D^0})$

Heavy Quark Effective Theory(HQET): Helicity parameter,H

$\frac{dN}{dcos\theta} \sim 1 + Hcos^2\alpha,\ H = 3(-1)$ **for** $J^P = 1^+(2^+)$ **from** $j = 3/2$ **doublet**

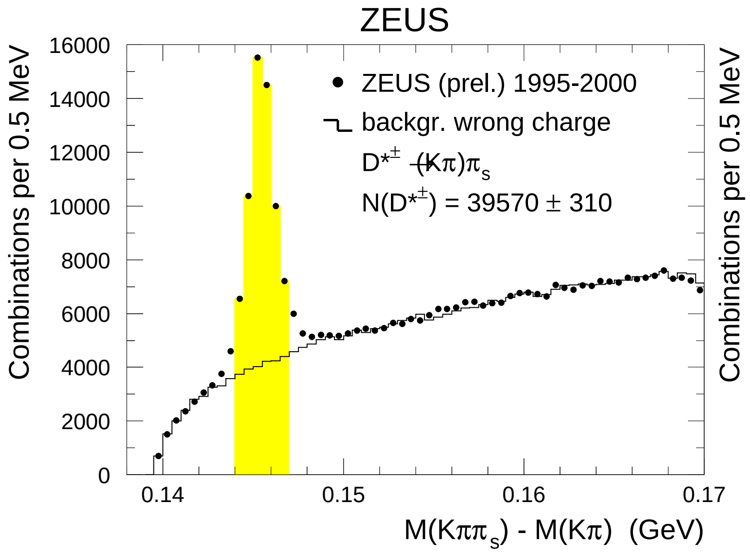
α **: Angle in** $D^{*\pm}$ **rest frame between extra** $\pi^{\mp}(K_s^0)$ **and** π_s $(D^{*\pm} \to D^0\pi_s)$

ZEUS(Prelim.) Excited Charm Mesons

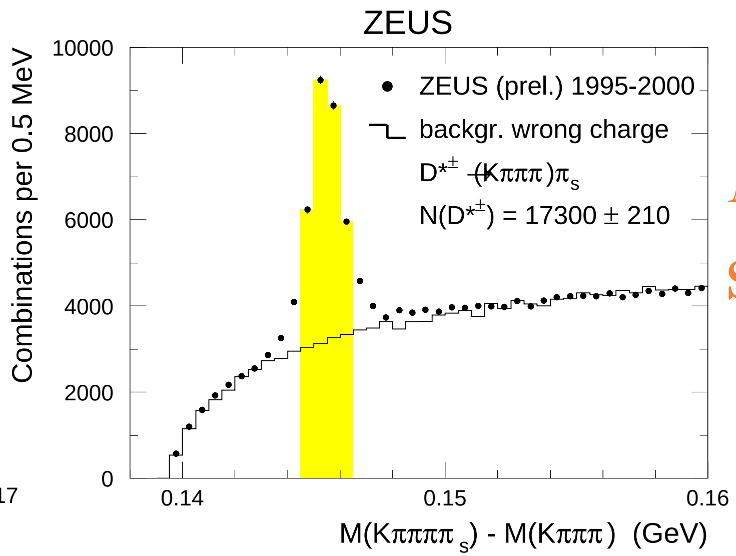
$\mathcal{L}_{int}: 126\mathrm{pb}^{-1}$ **1995-2000** **Full phase space; DIS + γp events**

Use $D^{*+} \rightarrow D^0\pi^+, D^0 \rightarrow K^-\pi^+, K^-\pi^+\pi^+\pi^- + cc$

$D^{*\pm}$



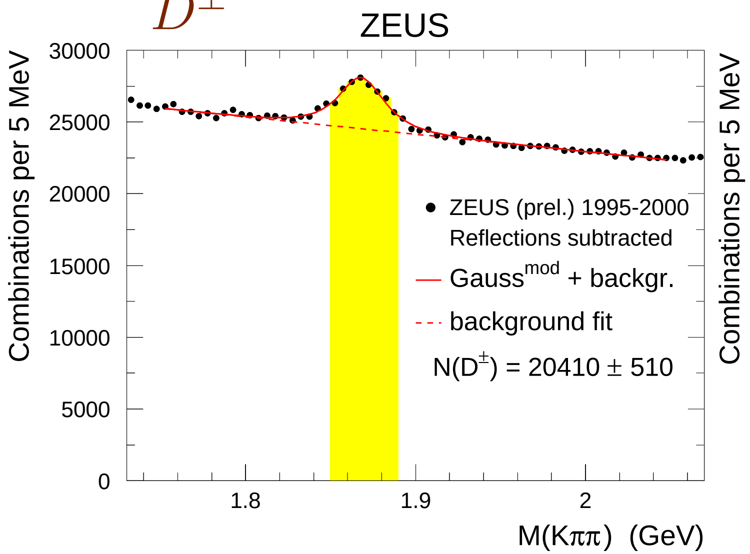
$D^{*\pm}$



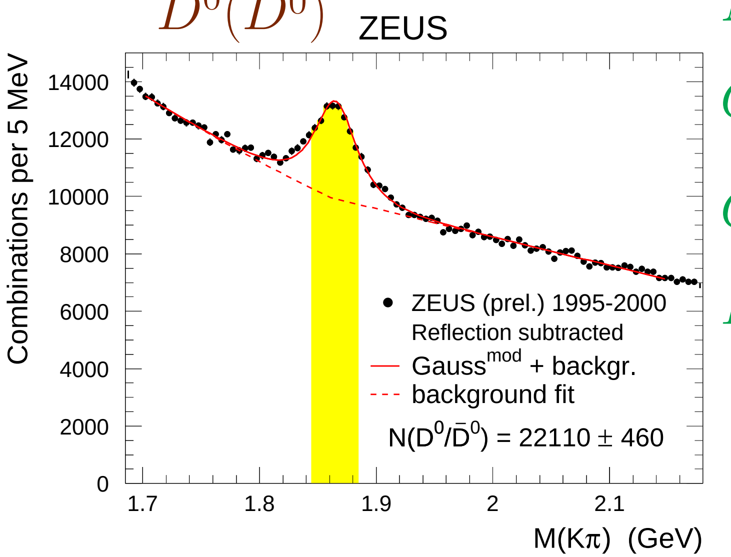
$N(D^{*\pm})$ **from**

Signal - Wrong Charge Bkgd

$D^{\pm}$



$D^0(\overline{D^0})$



$N(D^0), N(D^{\pm})$ **from fit to**

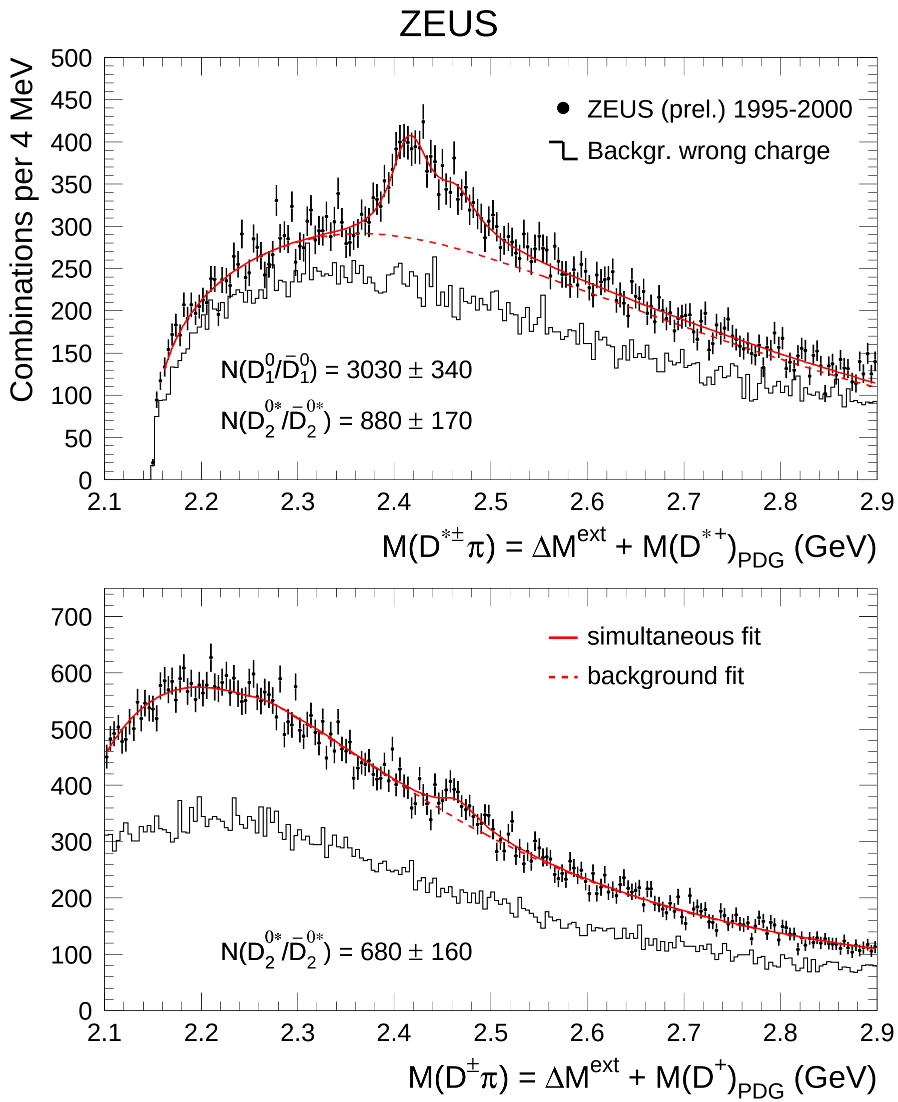
$Gauss^{mod}$ **+ Bkgd**

$Gauss^{mod} \sim exp(-0.5x^{1+\frac{1}{(1+0.5x)}})$

D^0 **not from** $D^{*\pm}$ **decays**

ZEUS(Prelim.) Excited Charm Mesons

Combine charged $D^*(D)$ with π of opposite charge, π_e



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

$p_t(D^{*\pm}) > 1.35GeV, \; |\eta(D^{*\pm})| < 1.6$

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

$p_t(D^{*\pm}) > 2.80GeV, \; |\eta(D^{*\pm})| < 1.6$

Plot contains sum of $K\pi$ and $K\pi\pi\pi$ $D^{*\pm}$ decays

Difficult to separate D_1^0 from D_2^{*0}

$\Delta M^{ext} = M(K\pi\pi\pi_e) - M(K\pi\pi)$

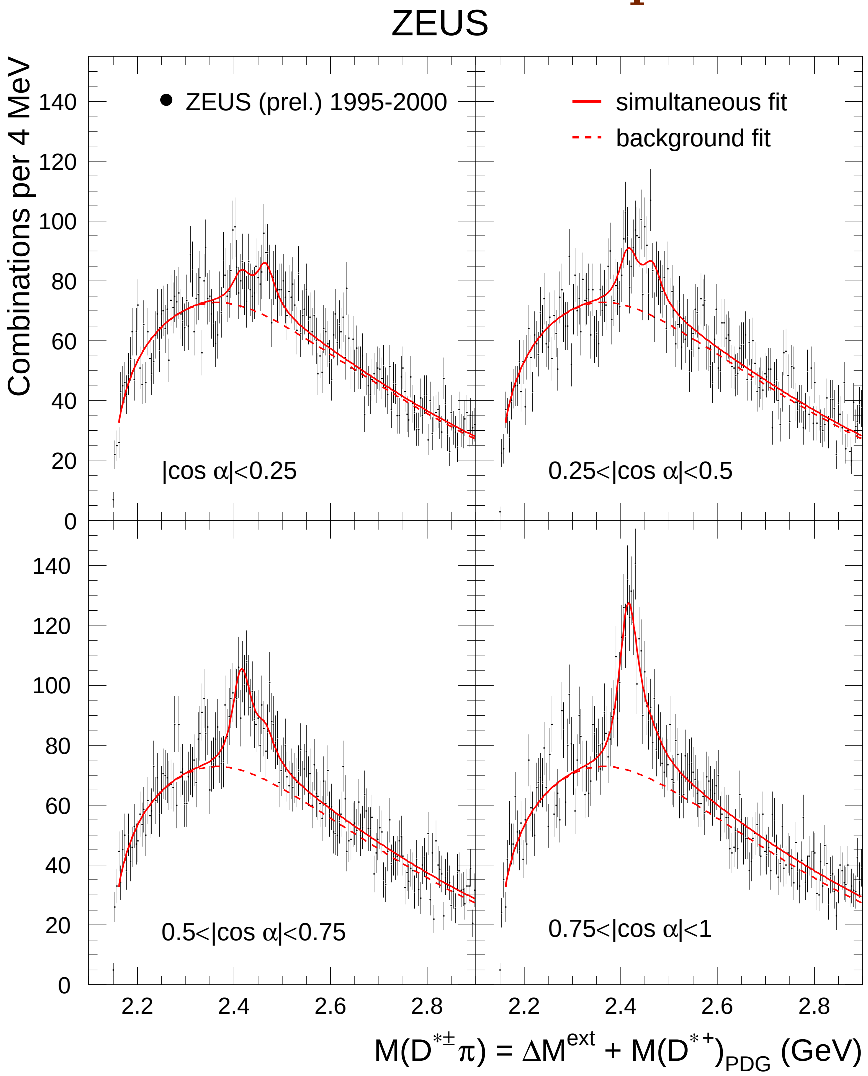
$p_t(D^{\pm}) > 2.80GeV, \; |\eta(D^{\pm})| < 1.6$

From Spin-Parity $D^{\pm}\pi^{\mp}$ only from D_2^{*0} decay

ZEUS(Prelim.) Excited Charm Mesons

Simultaneous fit to 4 helicity $M(D^{*\pm}\pi^{\mp})$ histograms and $M(D^{\pm}\pi^{\mp})$ histogram

χ^2 Fit to variable width relativistic Breit-Wigner function convoluted with experimental resolution + background function



In high $\cos(\alpha)$ bin almost all D_1^0

$M(D_1^0) = 2419.8 \pm 2.0^{+0.8}_{-1.0}\, MeV$ **(Prel.)**

$M(D_2^{*0}) = 2468.4 \pm 3.6^{+1.1}_{-1.3}\, MeV$ **(Prel.)**

$\Gamma(D_1^0) = 51.6 \pm 7.0^{+1.9}_{-4.1}\, MeV$ **(Prel.)**

$\Gamma(D_2^{*0}) = 43 MeV$ **(PDG)**

$H(D_1^0) = 6.1 \pm 2.3^{+2.0}_{-0.8}$ **(Prel.)**

$H(D_2^{*0}) = -1\, (J^P = 2^+$ **state)**

$R(\frac{D_1^0 \rightarrow D^{*+}\pi^-}{D^{*+}}), R(\frac{D_2^{*0} \rightarrow D^{*+}\pi^-}{D^{*+}}), R(\frac{D_2^{*0} \rightarrow D^{+}\pi^-}{D^{+}})$

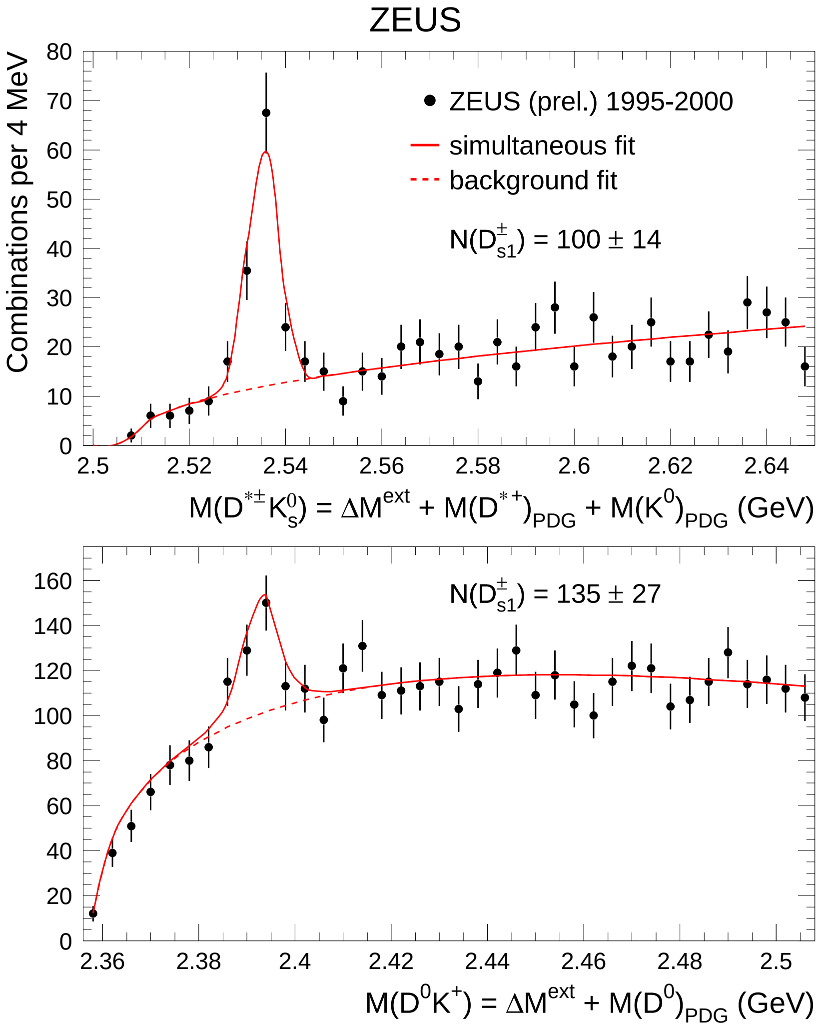
Extrapolated to full kinematic phase space yields:

$$\frac{B(D_2^{*0} \rightarrow D^+\pi^-)}{B(D_2^{*0} \rightarrow D^{*+}\pi^-)} = 2.7 \pm 0.8(stat.) \pm 0.6(syst.) \pm 0.1(ext.)\%$$ **(Prel.)**, 2.3 ± 0.6 **(PDG06)**

ZEUS(Prelim.) Excited Charm Strange Mesons

Simultaneous fit of $M(D^{*\pm}K_s^0), M(D^0K^{\pm})$ and $cos(\alpha)$ distributions

Gaussian ($Gauss^{mod}$ for $M(D^0K^{\pm})$ + background unbinned liklihood fit



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

$$p_t(D^{*\pm}) > 1.35GeV, \quad |\eta(D^{*\pm})| < 1.6$$

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

$$p_t(D^{*\pm}) > 2.80GeV, \quad |\eta(D^{*\pm})| < 1.6$$

Plot contains sum of $K\pi$ and $K\pi\pi\pi$ $D^{*\pm}$ decays

$$M(D_{s1}) = 2535.3^{+0.44}_{-0.41}(stat.)^{+0.09}_{-0.08}(syst.)\, MeV$$ **(Prel.)**

$$H(D_{s1}) = -0.74^{+0.23}_{-0.17}(stat.)^{+0.06}_{-0.05}(syst.)$$ **(Prel.)**

$$\Delta M^{ext} = M(K\pi K^{\pm}) - M(K\pi)$$

$$p_t(D^0) > 2.80GeV, \quad |\eta(D^0)| < 1.6$$

$$R\left(\frac{D_{s1}^+ \to D^{*+}K^0}{D^{*+}}\right), \quad R\left(\frac{D_{s1}^+ \to D^{*0}K^+}{D^0}\right)$$

Extrapolated to full kinematic phase space yields:

$$\frac{B(D_{s1}^+ \to D^{*0}K^+)}{B(D_{s1}^+ \to D^{*+}K^0)} = 2.2 \pm 0.6(stat.)^{+0.4}_{-0.5}(syst.) \pm 0.1(ext.)\%$$ **(Prel.),** 1.27 ± 0.21 **(PDG06)**

ZEUS(Prelim.) Excited Charm Mesons

	$f(c \to D_1^0)(\%)$	$f(c \to D_2^{*0})(\%)$	$f(c \to D_{s1}^{\pm})(\%)$
ZEUS	$3.5 \pm 0.4^{+0.4}_{-0.6} \pm 0.2$	$3.8 \pm 0.7^{+0.6}_{-0.6} \pm 0.2$	$1.1 \pm 0.2^{+0.1}_{-0.1} \pm 0.1$ **(all Prel.)**
CLEO	1.8 ± 0.3	1.9 ± 0.3	
OPAL	2.1 ± 0.8	5.92 ± 2.6	$1.6 \pm 0.4 \pm 0.3$
ALEPH			$0.94 \pm 0.22 \pm 0.07$

CLEO measured smaller resonance widths,OPAL used PDG values

CLEO and OPAL used non relativistic Breit Wigner functions in their fits

Helicity Parameter, $H\ (D_{s1}^{\pm})$

ZEUS	$-0.74^{+0.23}_{-0.17}(stat.)^{+0.06}_{-0.05}(syst.)$ **(Prel.)**
CLEO	$-0.23^{+0.40}_{-0.32}$
Belle(prelim.)	-0.70 ± 0.03

$H = 0 \Rightarrow J^P = 1^+$ **(if pure S wave),** $H = -1 \Rightarrow J^P = 1^-$ **or** 2^+

Possible (S,D) wave mixing of $D_{s1}^{\pm}(2536)$ **with** $D_{s1}^{\pm}(2460)$ **if both are** $J^P = 1^+$

Summary

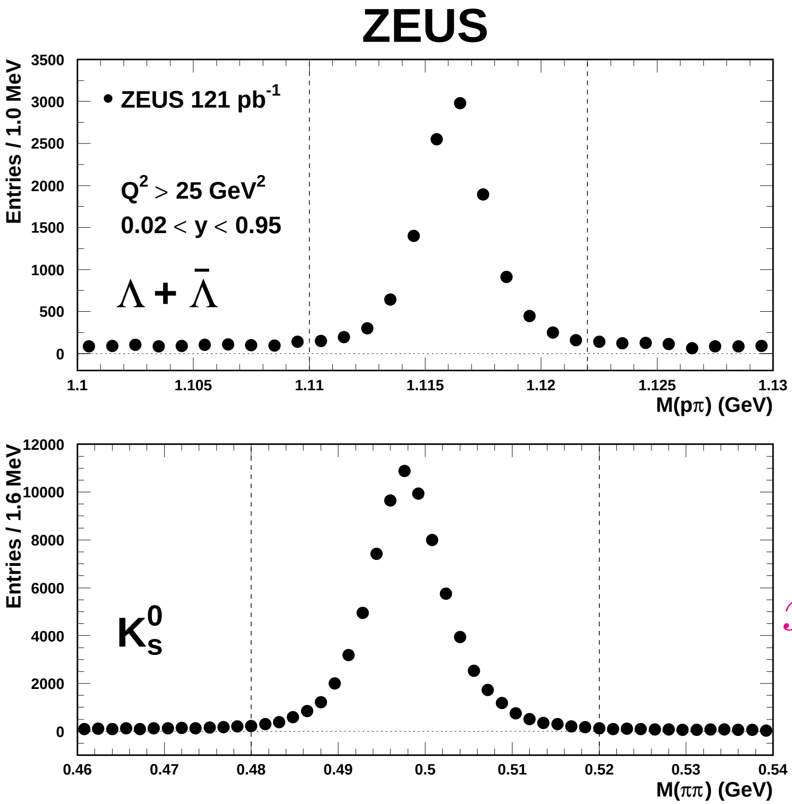
- **H1:** $\sigma(ep \rightarrow e\Theta^{+}X)$ **x** $BR(\Theta^{+} \rightarrow K^{0}p) < 30 - 90$ **pb**
- **H1,ZEUS:** $\frac{N(\Xi^{--})}{N(\Xi^{0}(1530))} < 12 - 45\%, 10 - 50\%$ **95% CL**
- **H1,ZEUS:** $\frac{N(\Xi^{0})}{N(\Xi^{0}(1530))} < 10 - 50\%, 10 - 50\%$ **95% CL**
- **ZEUS:** $R(\overline{d}/d) \neq R(\overline{p}/p)^{2}$ **in central region of** ep **DIS**
- **ZEUS:**$A = (N(\Lambda) - N(\overline{\Lambda}))/(N(\Lambda) + N(\overline{\Lambda}))$ **consistent with** 0
- **ZEUS:**$R = (N(\Lambda) + N(\overline{\Lambda}))/N(K_{s}^{0})$ **Data** $\neq$ **MC at high** Q^{2} **,low** x_{Bj}
- **ZEUS:**$T = N(K_{s}^{0})/N_{charged}$ **Favors** $\lambda_{s} = 0.22$ **over** 0.30
- **ZEUS:Measured** $f(c \rightarrow D_{1}^{0}), f(c \rightarrow D_{2}^{*0}), f(c \rightarrow D_{s1}^{\pm})$
- **ZEUS:Helicity Parameter doesn't favor a pure** $J^{P} = 1^{+}$, **S wave,** $D_{s1}^{\pm}(2536)$ **state**
  May be mixed with a $J^{P} = 1^{+}$ $D_{sj}^{\pm}(2460)$ **state**
- **Above Topics to be Continued in HERA II analysis**

Backup: ZEUS Neutral Strange Particle Production

$\mathcal{L}_{int}(ZEUS): 121\mathbf{pb}^{-1}$ **1996-2000,** $5 < Q^2 < 25\, GeV^2$, $0.02 < y < 0.95$

$Q^2 > 25\, GeV^2$, $0.02 < y < 0.95$

$Q^2 < 1\, GeV^2$, $0.20 < y < 0.85$



$0.6 < p_t(K_s^0, \Lambda, \overline{\Lambda}) < 2.5\, GeV$

$|\eta(K_s^0, \Lambda, \overline{\Lambda})| < 1.2$

For $Q^2 < 1$ require:

≥ 2 **jets with** $E_T^{jet} > 5\, GeV$, $|\eta^{jet}| < 2.4$

$$x_\gamma^{OBS} = \frac{\Sigma E_T^{jet} e^{-\eta^{jet}}}{2 y_{JB} E_e^{beam}}$$ (Σ **over 2 highest** E_T^{jet})

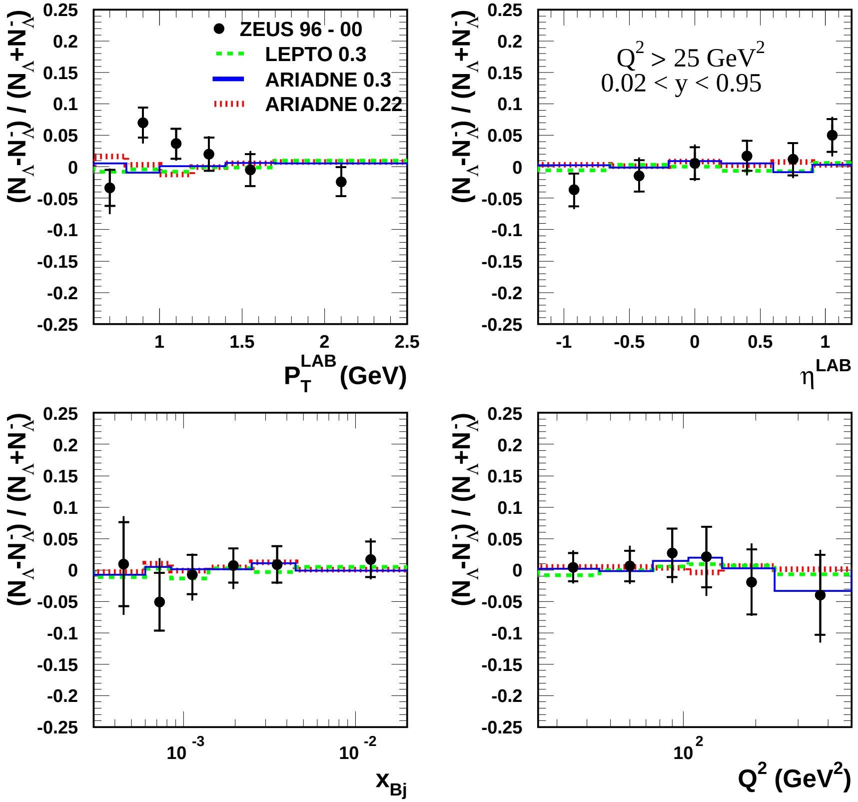
Two Samples: $x_\gamma^{OBS} > 0.75$ **(direct-enriched)**

$x_\gamma^{OBS} < 0.75$ **(resolved-enriched)**

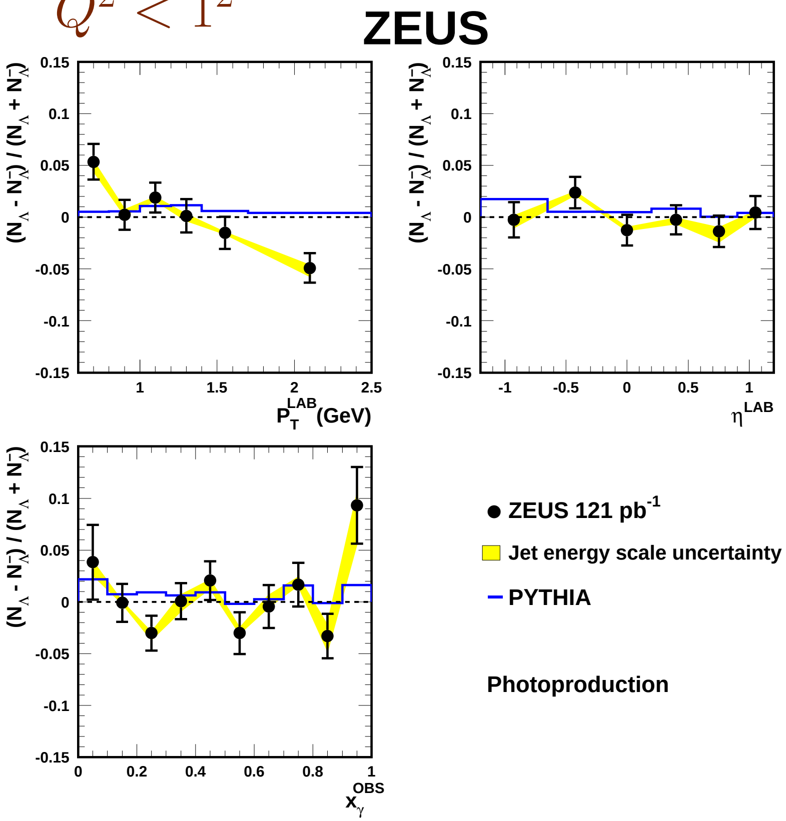
Backup: ZEUS Neutral Strange Particle Production

Baryon-Antibaryon Asymmetry: $A = (N(\Lambda) - N(\overline{\Lambda}))/(N(\Lambda) + N(\overline{\Lambda}))$

$Q^2 > 25\,GeV^2$ **ZEUS**



$Q^2 < 1^2$



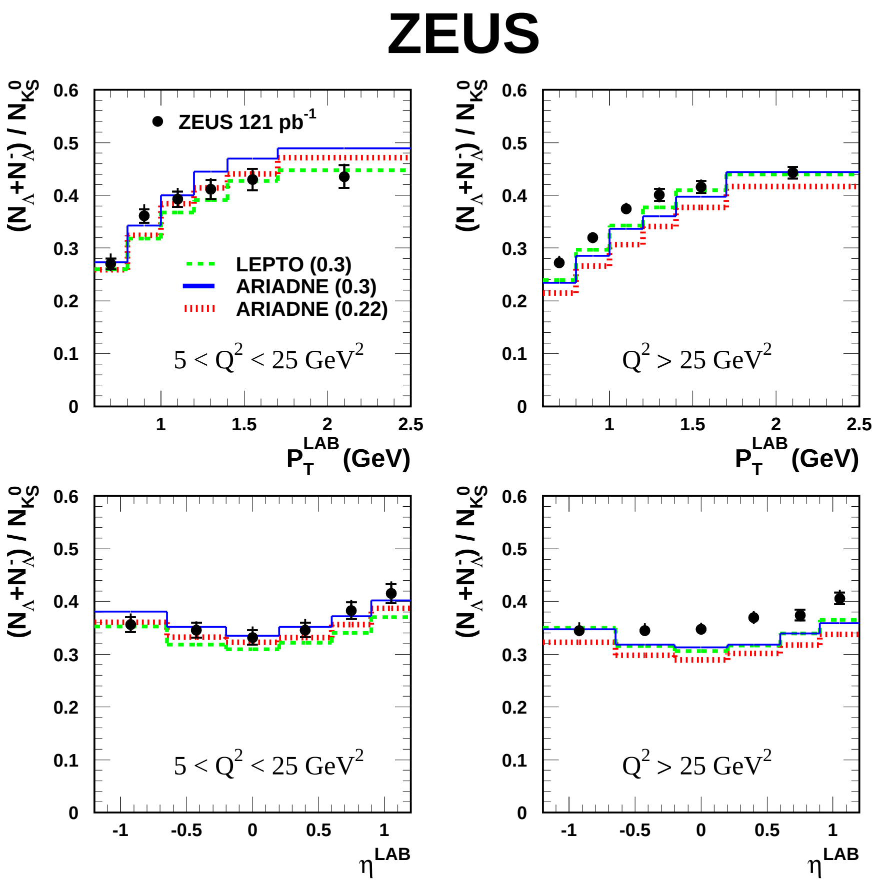
$Q^2 > 25\,GeV^2$: $A = 0.3 \pm 1.3^{+0.5}_{-0.8}\%$ $\quad Q^2 < 1\,GeV^2$: $A = -0.07 \pm 0.6^{+1.0}_{-1.0}\%$

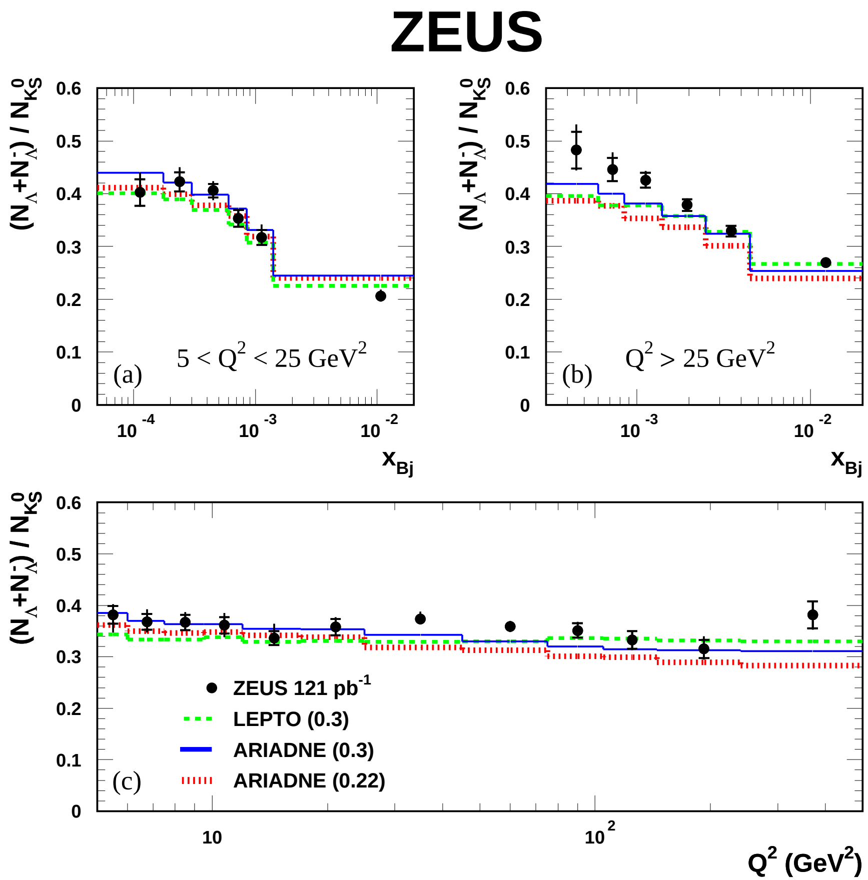
$5 < Q^2 < 25\,GeV^2$: $A = 1.2 \pm 1.6^{+0.7}_{-2.1}\%$

Consistent with No Asymmetry

Backup: ZEUS Neutral Strange Particle Production

Baryon-to-Meson Ratio: $R = (N(\Lambda) + N(\overline{\Lambda}))/N(K_s^0)$





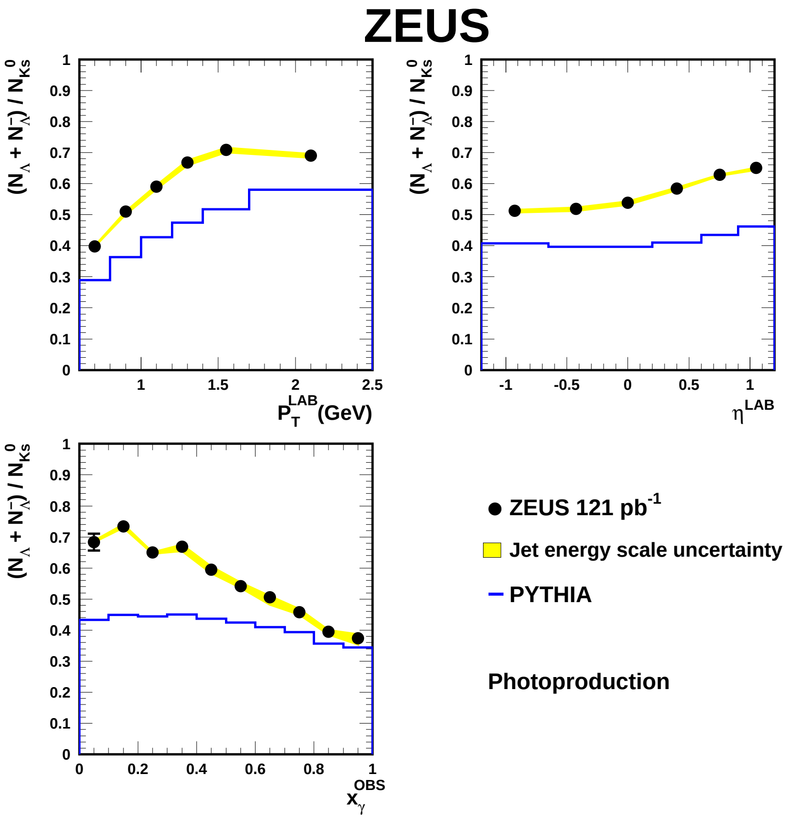
DIS(γp) : R increases with p_t **R decreases with x_{Bj}**

DIS(γp) : R increases in forward η region **$R \sim$ constant in Q^2**

DIS: Data and Monte Carlo disagree for high Q^2 at low x_{Bj}

Backup: ZEUS Neutral Strange Particle Production

Baryon-to-Meson Ratio: $R = (N(\Lambda) + N(\overline{\Lambda}))/N(K_s^0)$



γp: R increases with p_t R increases in forward η region

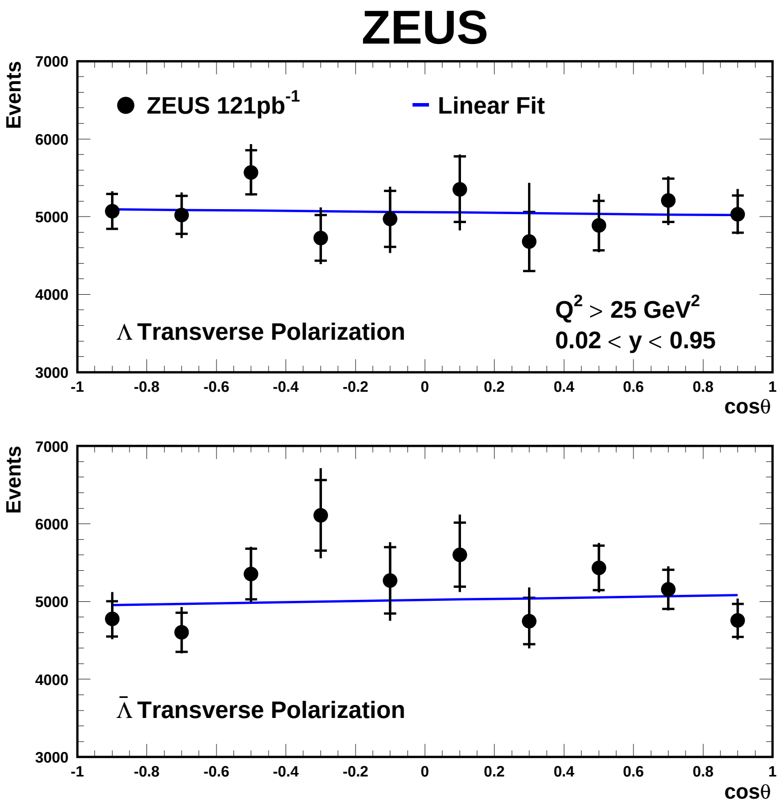
γp: Data and Monte Carlo disagree, especially for resolved γp

γp: R in direct-enhanced region similar to e^+e^- production

Backup: ZEUS Neutral Strange Particle Production

Transverse Polarization(P): $\frac{1}{N}\frac{dN}{dcos\theta} = \frac{1}{2}(1 + \alpha P^{\Lambda} cos\theta)$

$$= \frac{1}{2}(1 - \alpha P^{\overline{\Lambda}} cos\theta)$$



Decay Asymmetry Parameter $\alpha = 0.642 \pm 0.013$

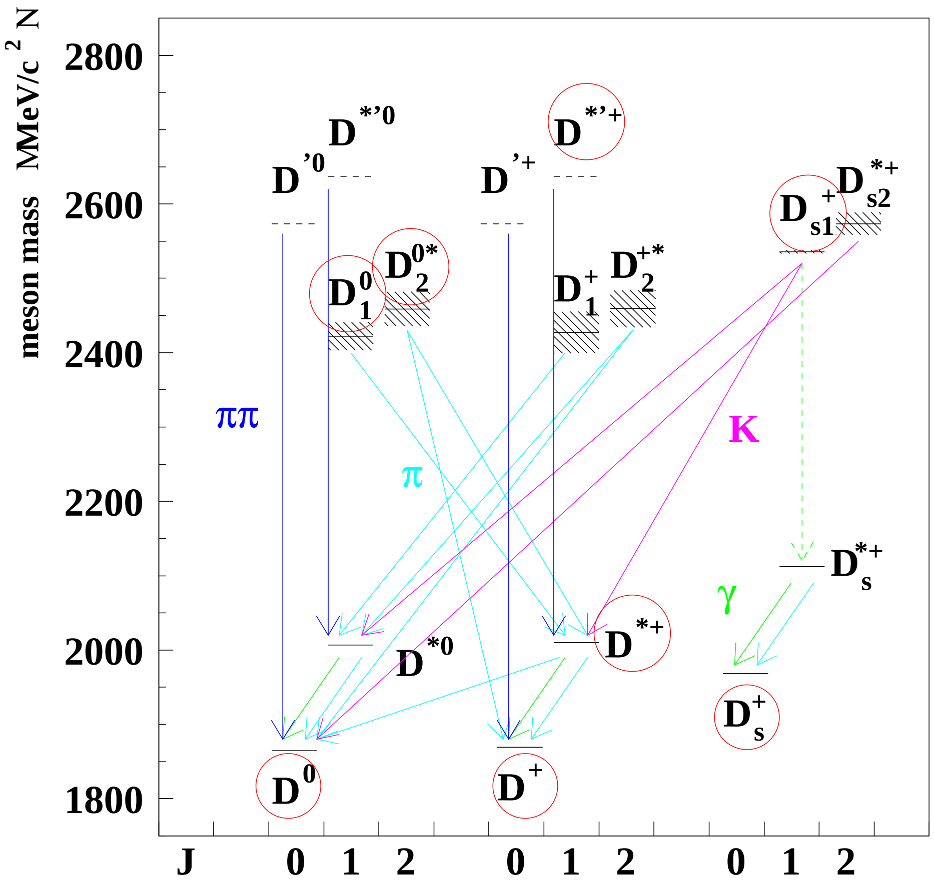
θ**: Angle between** p ($\overline{p}$) **in** Λ **rest frame and** $k_e^{beam}\mathbf{x}k_{\Lambda}$

Polarization(%)

	High Q^2 DIS	Low Q^2 DIS	γp
Λ	$-1.3 \pm 4.3^{+4.0}_{-0.8}$	$-4.0 \pm 5.3^{+4.7}_{-4.0}$	-2.4 ± 2.2
$\overline{\Lambda}$	$-2.2 \pm 4.2^{+2.3}_{-1.3}$	$-8.5 \pm 5.5^{+4.7}_{-2.1}$	-5.8 ± 2.2

Consistent With No Transverse Polarization

Backup: ZEUS Excited Charm Mesons



$D^0, D^\pm, D^{0*}, D^{*\pm}, D_s$ **copiously produced**

Look at $D_1^0 \to D^{*\pm}\pi^\mp, D_2^{*0} \to D^\pm\pi^\mp$

$D_{s1}^\pm \to D^{*\pm}K_s^0, D^{*0}K^\pm$

Extract charm fragmentation functions:

$f(c \to D_1^0), f(c \to D_2^{*0}), f(c \to D_{s1}^\pm)$

From production ratios:

$R(\frac{D_1^0 \to D^{*+}\pi^-}{D^{*+}}), R(\frac{D_2^{*0} \to D^{*+}\pi^-}{D^{*+}}), R(\frac{D_2^{*0} \to D^+\pi^-}{D^+})$

$R(\frac{D_{s1}^+ \to D^{*+}K^0}{D^{*+}}), R(\frac{D_{s1}^+ \to D^{*0}K^+}{D^0})$

Using ZEUS measured values of:

$f(c \to D^{*\pm}), f(c \to D^\pm), f(c \to D^0)$

Heavy Quark Effective Theory(HQET): Helicity parameter, H

$\frac{dN}{dcos\theta} \sim 1 + Hcos^2\alpha,\ H = 3(-1)$ **for** $J^P = 1^+(2^+)$ **from** $j = 3/2$ **doublet**

α **: Angle in** $D^{*\pm}$ **rest frame between extra** $\pi^\mp(K_s^0)$ **and** π_s $(D^{*\pm} \to D^0\pi_s)$

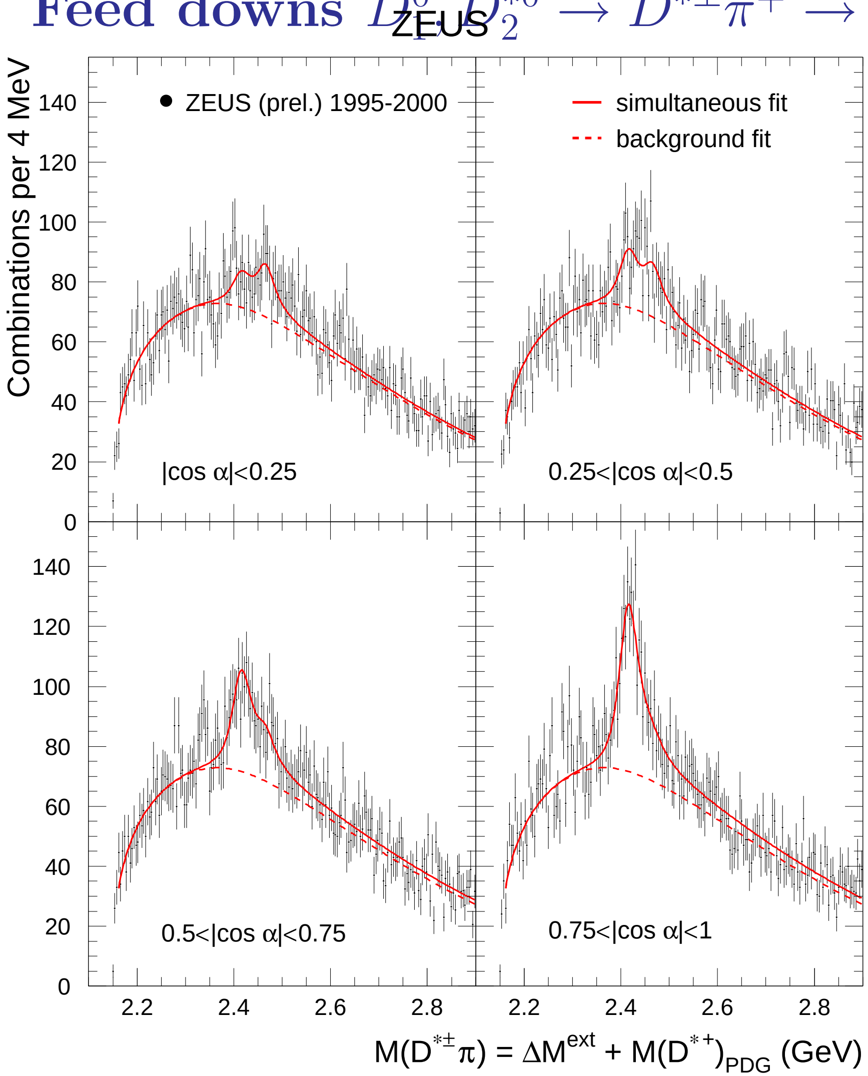
Backup: ZEUS Excited Charm Mesons

Simultaneous to fit 4 helicity $M(D^{*\pm}\pi^{\mp})$ **histograms and** $M(D^{\pm}\pi^{\mp})$ **histogram**

χ^2 **Fit to variable width relativistic Breit-Wigner function**

convoluted with experimental resolution + background function

Feed downs $D_1^0, D_2^{*0} \to D^{*\pm}\pi^{\mp} \to D^{\pm}\pi^{\mp}$ **+ neutrals,wide** $D_1^0(2430), D_0^{*0}(2400)$ **included**



In high $\cos(\alpha)$ **bin almost all** D_1^0

$M(D_1^0) = 2419.8 \pm 2.0^{+0.8}_{-1.0}\, MeV, M(D_2^{*0}) = 2468.4 \pm 3.6^{+1.1}_{-1.3}$

$\Gamma(D_1^0) = 51.6 \pm 7.0^{+1.9}_{-4.1}\, MeV, \Gamma(D_2^{*0}) = 43 MeV$ **(PDG)**

$H(D_1^0) = 6.1 \pm 2.3^{+2.0}_{-0.8}, H(D_2^{*0}) = -1\,(J^P = 2^+$ **state)**

Extrapolated to full kinematic phase space

$R(\frac{D_1^0 \to D^{*+}\pi^-}{D^{*+}}) = 11.7 \pm 1.3(stat.)^{+0.9}_{-1.4}(syst.)^{+0.4}_{-0.3}(ext.)\%$

$R(\frac{D_2^{*0} \to D^{*+}\pi^-}{D^{*+}}) = 3.4 \pm 0.6(stat.)^{+0.4}_{-0.5}(syst.)^{+0.2}_{-0.2}(ext.)\%$

$R(\frac{D_2^{*0} \to D^{+}\pi^-}{D^{+}}) = 8.6 \pm 2.1(stat.)^{+1.2}_{-1.4}(syst.)^{+0.3}_{-0.3}(ext.)\%$

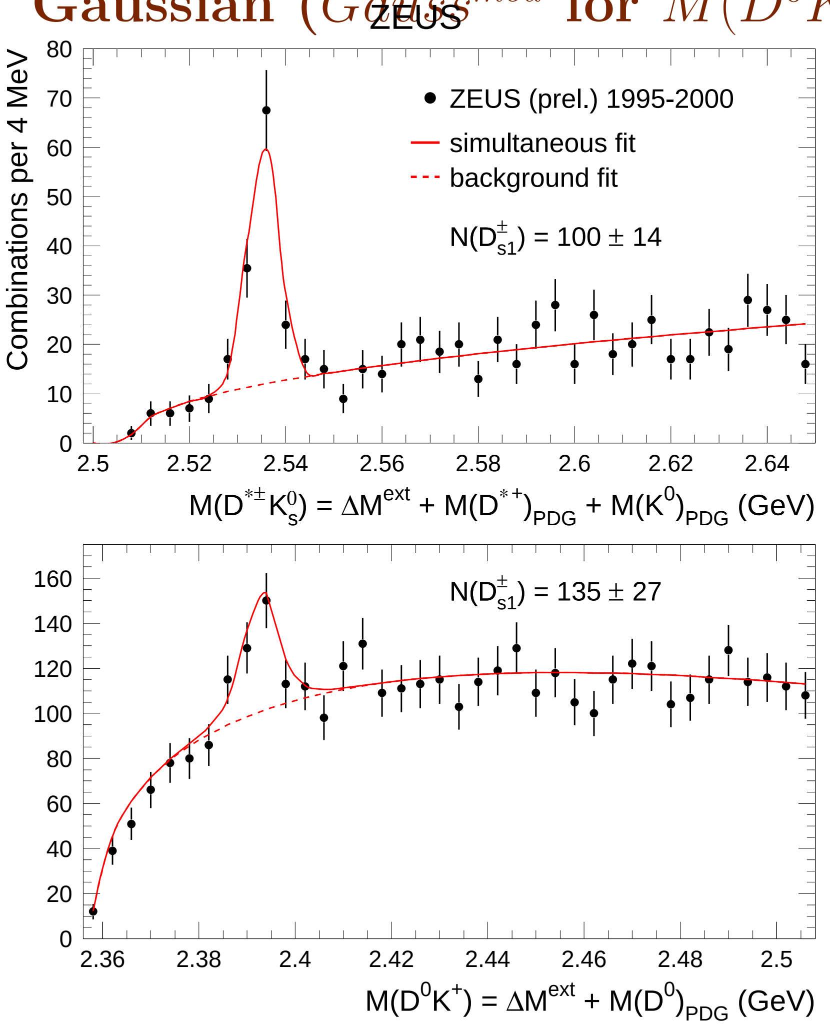
Branching Ratio, B, $(2.3 \pm 0.6$ **(PDG06)**$)$

$\frac{B(D_2^{*0} \to D^+\pi^-)}{B(D_2^{*0} \to D^{*+}\pi^-)} = 2.7 \pm 0.8(stat.) \pm 0.6(syst.) \pm 0.1(ext.)\%$

Backup: ZEUS Excited Charm Strange Mesons

Simultaneous fit of $M(D^{*\pm}K_s^0), M(D^0K^\pm)$ and $cos(\alpha)$ distributions

Gaussian ($Gauss^{mod}$ for $M(D^0K^\pm)$) + background unbinned liklihood fit



$\Delta M^{ext} = M(K\pi\pi_s\pi^+\pi^-) - M(K\pi\pi_s), p_t(D^{*\pm})$

$p_t(D^{*\pm}) > 1.35GeV, |\eta(D^{*\pm})| < 1.6$

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

$p_t(D^{*\pm}) > 2.80GeV, |\eta(D^{*\pm})| < 1.6$

Plot contains sum of $K\pi$ and $K\pi\pi\pi$ $D^{*\pm}$ decays

$M(D_{s1}) = 2535.3^{+0.44}_{-0.41}(stat.)^{+0.09}_{-0.8}(syst.)\ MeV$

$H(D_{s1}) = -0.74^{+0.23}_{-0.17}(stat.)^{+0.06}_{-0.5}(syst.)$

$\Delta M^{ext} = M(K\pi K^\pm) - M(K\pi)$

$p_t(D^0) > 2.80GeV/c, \quad |\eta(D^0)| < 1.6$

Extrapolated to full kinematic phase space

$R(\frac{D_{s1}^+ \to D^{*+}K^0}{D^{*+}}) = 1.7 \pm 0.33(stat.)^{+0.1}_{-0.1}(syst.)^{+0.1}_{-0.1}(ext.)\%$

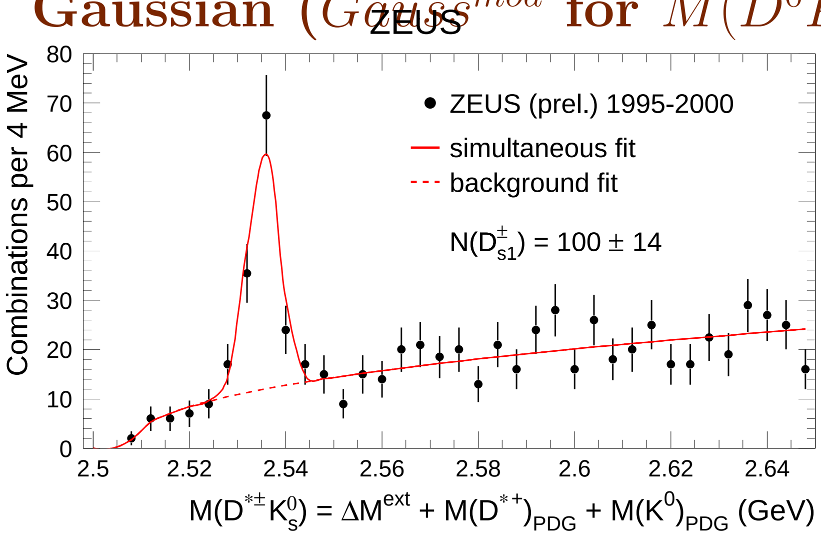
$R(\frac{D_{s1}^+ \to D^{*0}K^+}{D^0}) = 1.9 \pm 0.4(stat.)^{+0.1}_{-0.2}(syst.)^{+0.2}_{-0.1}(ext.)\%$

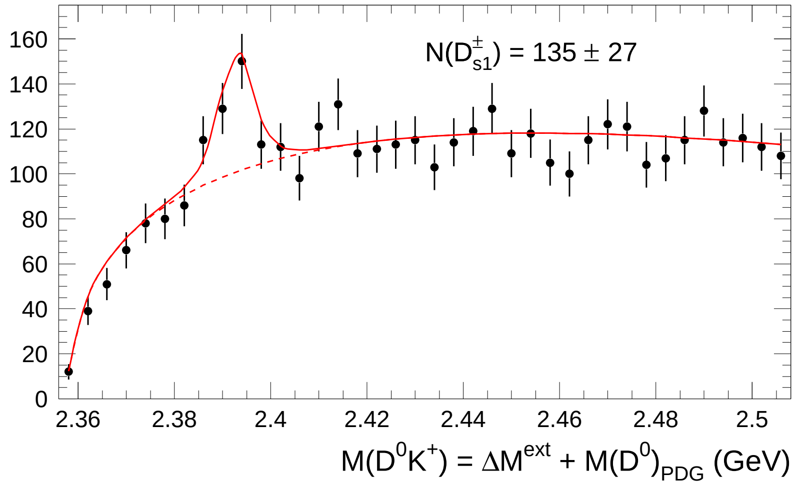
$\frac{B(D_{s1}^+ \to D^{*0}K^+)}{B(D_{s1}^+ \to D^{*+}K^0)} = 2.2 \pm 0.6(stat.)^{+0.4}_{-0.5}(syst.) \pm 0.1(ext.)\%, \quad 1.27 \pm 0.21$ **(PDG06)**

Backup: ZEUS Excited Charm Strange Mesons

Simultaneous fit of $M(D^{*\pm}K_s^0), M(D^0K^\pm)$ and $cos(\alpha)$ distributions

Gaussian ($Gauss^{mod}$ for $M(D^0K^\pm)$) + background unbinned liklihood fit





$\Delta M^{ext} = M(K\pi\pi_s\pi^+\pi^-) - M(K\pi\pi_s), p_t(D^{*\pm})$

$p_t(D^{*\pm}) > 1.35GeV, |\eta(D^{*\pm})| < 1.6$

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

$p_t(D^{*\pm}) > 2.80GeV, |\eta(D^{*\pm})| < 1.6$

Plot contains sum of $K\pi$ and $K\pi\pi\pi$ $D^{*\pm}$ decays

$M(D_{s1}) = 2535.3^{+0.44}_{-0.41}(stat.)^{+0.09}_{-0.8}(syst.)\ MeV$

$H(D_{s1}) = -0.74^{+0.23}_{-0.17}(stat.)^{+0.06}_{-0.5}(syst.)$

$\Delta M^{ext} = M(K\pi K^\pm) - M(K\pi)$

$p_t(D^0) > 2.80GeV/c, \quad |\eta(D^0)| < 1.6$

Extrapolated to full kinematic phase space

$R(\frac{D_{s1}^\pm \to D^{*\pm}K_s^0}{D^{*\pm}}) = 1.7 \pm 0.33(stat.)^{+0.1}_{-0.1}(syst.)^{+0.1}_{-0.1}(ext.)\%$

$R(\frac{D_{s1}^\pm \to D^{*0}K^\pm}{D^0}) = 1.9 \pm 0.4(stat.)^{+0.1}_{-0.2}(syst.)^{+0.2}_{-0.1}(ext.)\%$

$\frac{B(D_{s1}^\pm \to D^{*0}K^\pm)}{B(D_{s1}^\pm \to D^{*\pm}K_s^0)} = 2.2 \pm 0.6(stat.)^{+0.4}_{-0.5}(syst.) \pm 0.1(ext.)\%, \quad 1.27 \pm 0.21$ **(PDG06)**

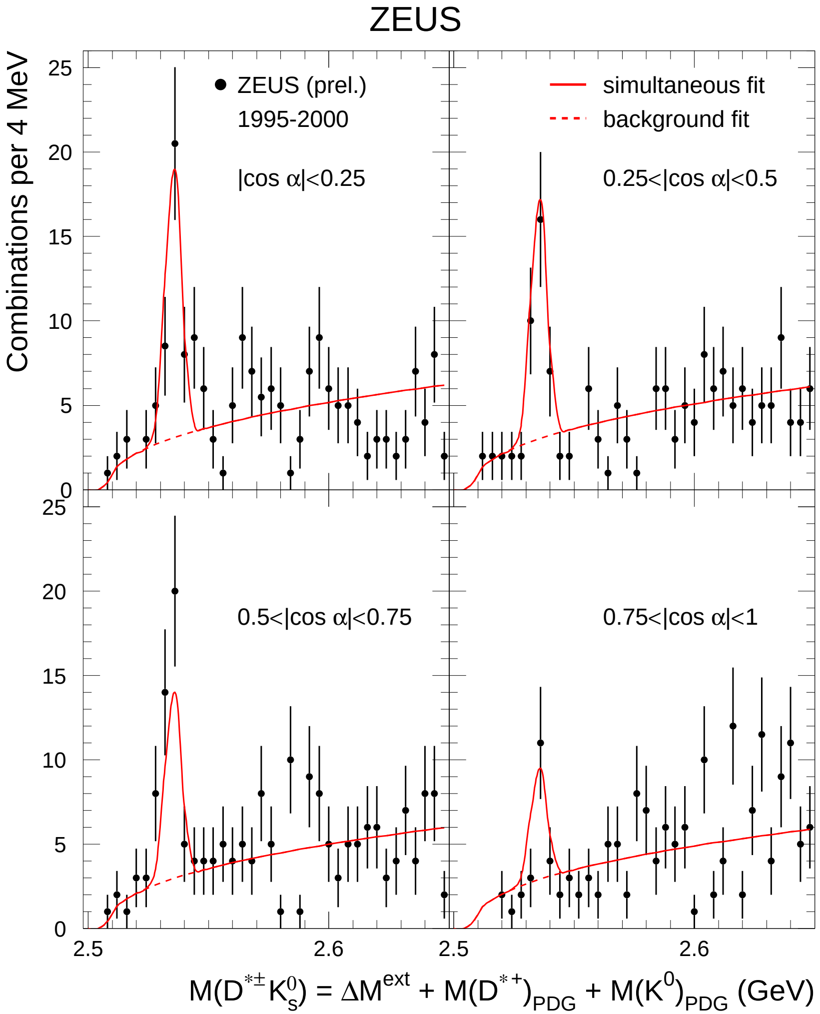
Backup: Summary

- **H1:** $\sigma(ep \to e\Theta^+ X)$ **x** $BR(\Theta^+ \to K^0 p) < 30 - 90$ **pb**
- **H1,ZEUS:** $\frac{N(\Xi^{--})}{N(\Xi^0(1530))} < 12 - 45\%, 10 - 50\%$ **95% CL**
- **H1,ZEUS:** $\frac{N(\Xi^0)}{N(\Xi^0(1530))} < 10 - 50\%, 10 - 50\%$ **95% CL**
- $R(\overline{d}/\overline{p})$ **in ZEUS DIS,H1 in** γp **agree**
- **ZEUS:** $R(\overline{d}/d) \neq R(\overline{p}/p)^2$ **in central region of** ep **DIS**
- **ZEUS:**$A = (N(\Lambda) - N(\overline{\Lambda}))/(N(\Lambda) + N(\overline{\Lambda}))$ **consistent with** 0
- **ZEUS:**$R = (N(\Lambda) + N(\overline{\Lambda}))/N(K_s^0)$ **Data,MC** $\neq$ **high** Q^2 **,low** x_{Bj}
- **ZEUS(**γp**),**R**: MC** $\neq$ **Data for resolved,as** e^+e^- **in direct enriched**
- **ZEUS:DIS:Favors** $\lambda_s = 0.22$ **over** 0.30, γp**:** $\lambda_s = 0.30$ **does'nt fit data**
- **ZEUS:**Λ, $\overline{\Lambda}$ **consistent with no transverse polarization**
- **ZEUS:Measured** $f(c \to D_1^0), f(c \to D_2^{*0}), f(c \to D_{s1}^{\pm})$
- **ZEUS:Helicity Parameter doesn't favor** $J^P = 1^+$ $D_{s1}^{\pm}(2536)$ **state**

Backup: Charm Pentaquark

	H1 prel.	**ZEUS**	**ZEUS,** $Q^2 > 1\,GeV^2$
corrected rate	$1.59 \pm 0.33^{+0.33}_{-0.45}\%$	$< 0.37\%$ (95% **C.L.**)	$< 0.51\%$ (95% **C.L.**)

Backup: ZEUS Excited Charm Strange Mesons



Backup: References

ZEUS Collaboration; S. Chekanov et al.

Measurement of K_s^0, Λ,$\overline{\Lambda}$ Production at HERA

European Physical Journal C 51 (2007) 1-23

ZEUS Collaboration; S. Chekanov et al.

Measurement of (anti)deuteron and (anti)proton production in DIS at HERA

DESY-07-070 (May 2007),accepted by Nuclear Physics B

ZEUS Collaboration; S. Chekanov et al.

Evidence for a narrow baryonic state decaying to $K_s^0\overline{p}$ in deep inelastic scattering at HERA

Physics Letters B 591 (2004) 7-22

ZEUS Collaboration; S. Chekanov et al.

Search for a narrow charmed baryonic state decaying to $D^{*+}\ \overline{p}$ in ep collisions at HERA

European Physical Journal C 38 (2004) 29-41

H1 Collab., A. Aktas et al., hep-ex/0704.3594, To be submitted to Phys. Lett. B ,04/07

Search for Baryonic Resonances Decaying to $\Xi\pi$ in Deep-Inelastic Scattering at HERA

H1 Collab., A. Aktas et al., Phys. Lett. B 639 (2006) 202

Search for a Narrow Baryonic Resonance Decaying to $K_s^0 p$ or $K_s^0\ \overline{p}$ in Deep Inelastic Scattering at HERA

H1 Collab., A. Aktas et al., Eur. Phys. J. C36 (2004) 413-423

Measurement of Anti-Deuteron Production and a Search for Heavy Stable Charged Particles at HERA

H1 Collab., C. Adloff et al., Z. Phys. C76 (1997) 213

Photoproduction of K^0 and Λ at HERA and a Comparison with Deep Inelastic Scattering

Backup: References

CLEO Coll., P. Avery et al.,Phys. Lett. B 331, 236 (1994)

OPAL Coll., K. Ackerstaff et al.,Z. Phys. C 76, 425 (1997)

ALEPH Coll., A. Heister et al.,Phys. Lett. B 526, 34 (2002)

CLEO Coll., J.P. Alexander et al.,Phys. Lett. B 303, 337 (1993)

BELLE Coll., K. Abe et al.,(hep-ex/0507030)

Backup: Charm Pentaquark

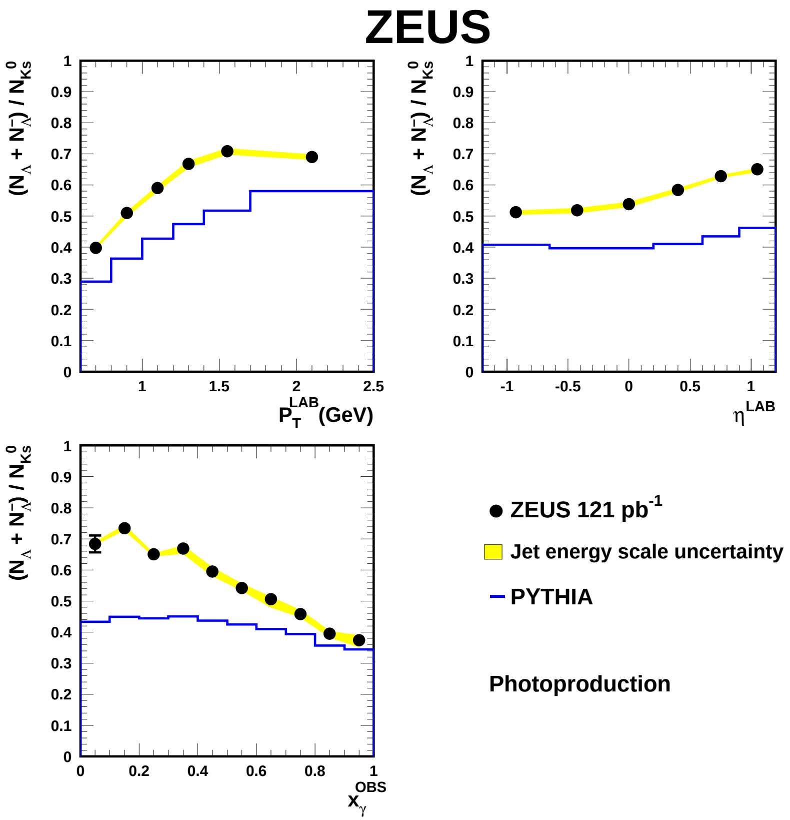
	H1 prel.	**ZEUS**	**ZEUS,** $Q^2 > 1\,GeV^2$
corrected rate	$1.59 \pm 0.33^{+0.33}_{-0.45}\%$	$< 0.37\%$ (95% **C.L.**)	$< 0.51\%$ (95% **C.L.**)

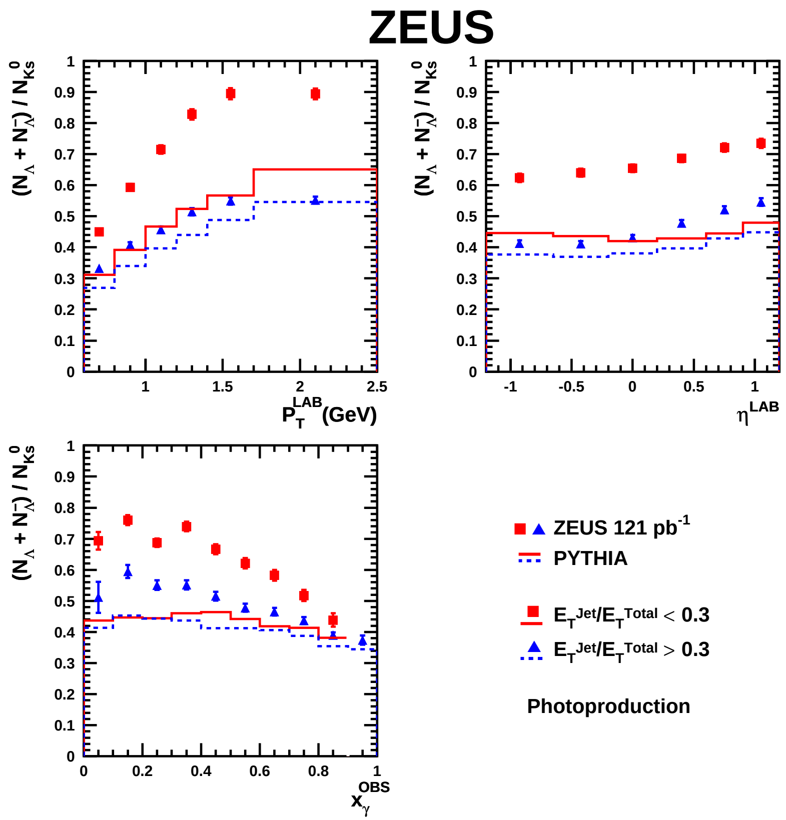
$M(D_1^0) = 2419.8 \pm 2.0^{+0.8}_{-1.0}\,MeV$	2422.3 ± 1.3	**(PDG)**
$M(D_2^{*0}) = 2468.4 \pm 3.6^{+1.1}_{-1.3}\,MeV$	2461.1 ± 2.1	**(PDG)**
$\Gamma(D_1^0) = 51.6 \pm 7.0^{+1.9}_{-4.1}\,MeV$	20.4 ± 2.1	**(PDG)**
$H(D_1^0) = 6.1 \pm 2.3^{+2.0}_{-0.8}$	$3(J^P = 1^+$ **state)**	
$M(D_{s1}) = 2535.3^{+0.44}_{-0.41}(stat.)^{+0.09}_{-0.8}(syst.)\,MeV$	2535.2 ± 0.29	**(PDG)**

ZEUS Neutral Strange Particle Production

Baryon-to-Meson Ratio γp : $R = (N(\Lambda) + N(\bar{\Lambda}))/N(K_s^0)$

$Q^2 < 1GeV^2, \geq 2$ **jets with** $E_T^{jet} > 5\,GeV$, $|\eta^{jet}| < 2.4$



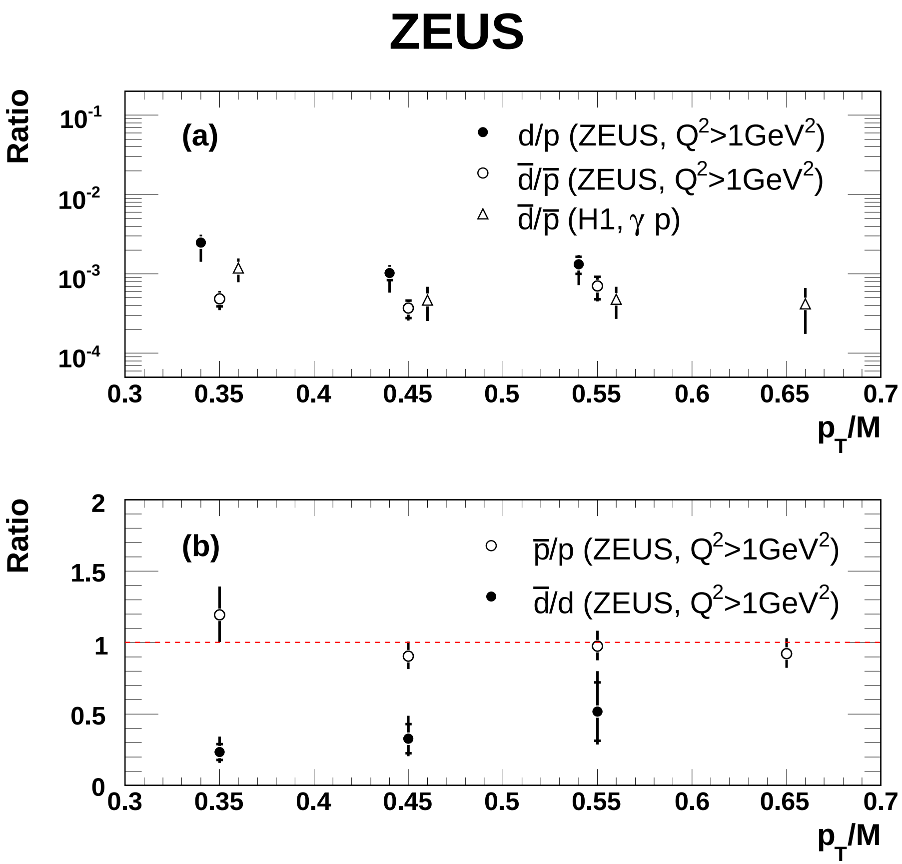


$x_\gamma^{OBS} = \frac{\Sigma E_T^{jet} e^{-\eta^{jet}}}{2 y_{JB} E_e^{beam}}$ **(Σ over 2 highest E_T^{jet}), R larger for fireball enriched**

R larger for resolved (small x_γ^{OBS}), R also larger in heavy ion collisions

Relatively more gluons produced in fireball and heavy ion collisions

Anti(Deuteron) Production in DIS



$R(\overline{d}/\overline{p})$ **in ZEUS DIS,H1 in** γp **agree**

$R(\overline{p}/p) \simeq 1$ **q,g jet hadronisation**

$$\frac{1}{\sigma_{tot}}\frac{E_d d^3\sigma_d}{dp_d^3} = B_2\left(\frac{1}{\sigma_{tot}}\frac{E_p d^3\sigma_p}{dp_p^3}\right)^2 \Rightarrow R(\overline{d}/d) = R(\overline{p}/p)^2$$

Ratio not satisfied in central region of ep **DIS**

Ratio $\simeq$ **satisfied at RHIC and** pA **fixed target expts.**