BEACH 2008
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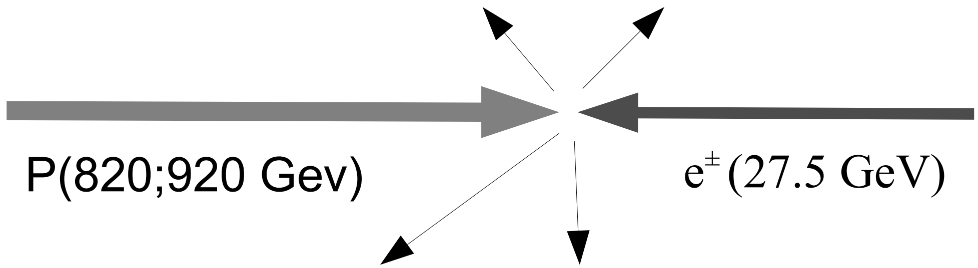
ITEP/DESY

Spectroscopy and Fragmentation results from HERA

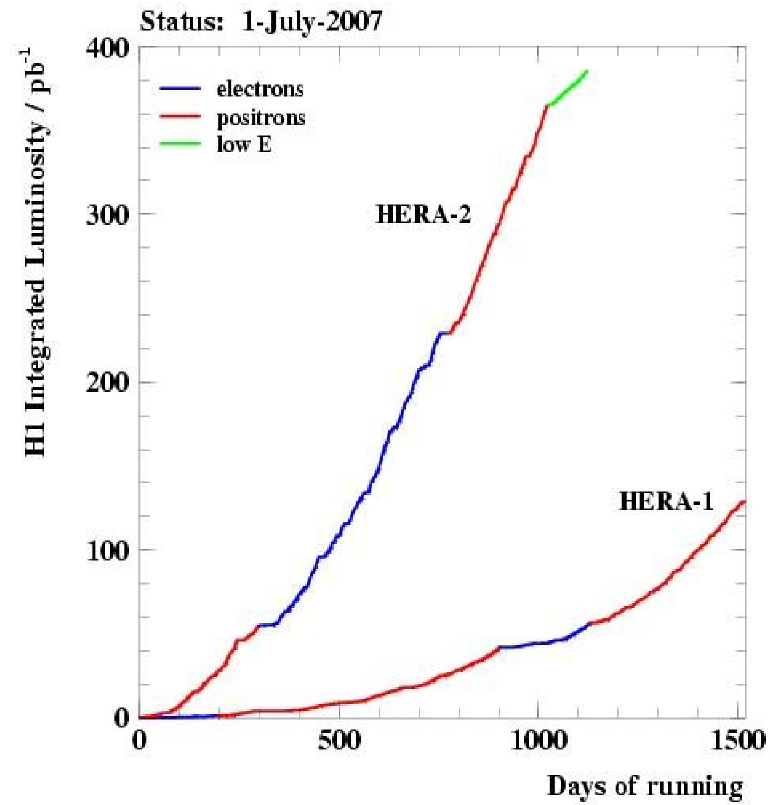
On behalf of the H1 and ZEUS Collaborations

Charged particle production
D* fragmentation
Strangeness production
Production of multi-quark states

HERA



Data taking periods:
HERA I : 1992-2000
HERAII : 2002-2007



~0.5 fb^{-1} per experiment

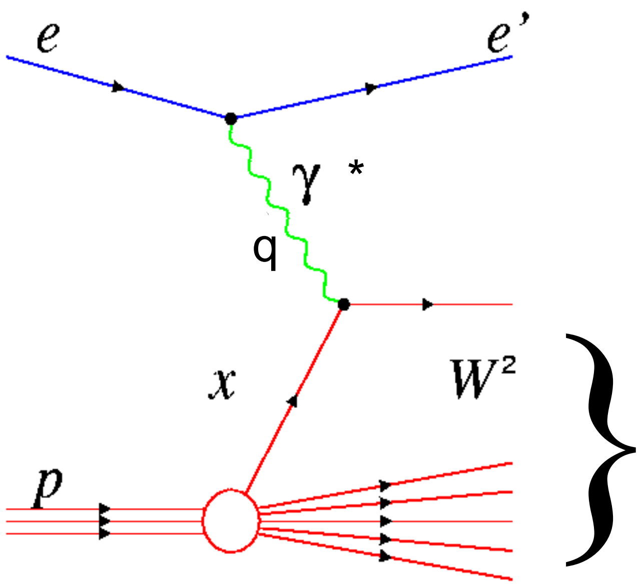
$e^{\pm}p$ - Kinematics

c.m. energy : $s^{1/2}$ = 301-319 GeV

hadronic energy : $W=m(\gamma^*p)$

photon virtuality : $Q^2 = -q^2$

inelasticity : $y = Q^2/(x_{Bj}\ s)$

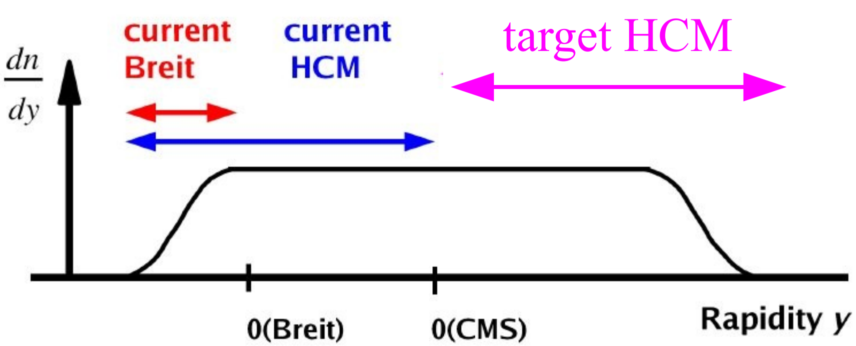


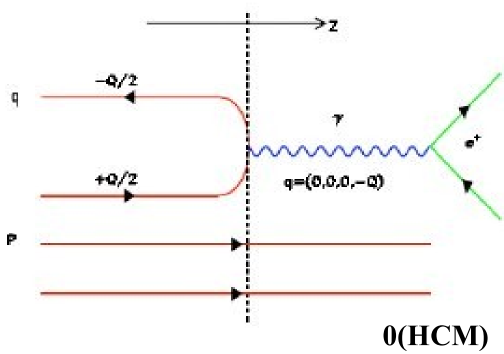
two regimes : $Q^2 \approx 0$ GeV^2 : **Photoproduction**
$Q^2 > 1$ GeV^2 : **Electroproduction (DIS)**

Fragmentation

HCM Frame

(hadronic centre-of-mass)





Breit Frame

Similarity expected between e^+e^- and ep in current regions of Breit or HCM Frames. Target regions should looks more like in pp collision.

To see the similarity you need to choose the proper variables:

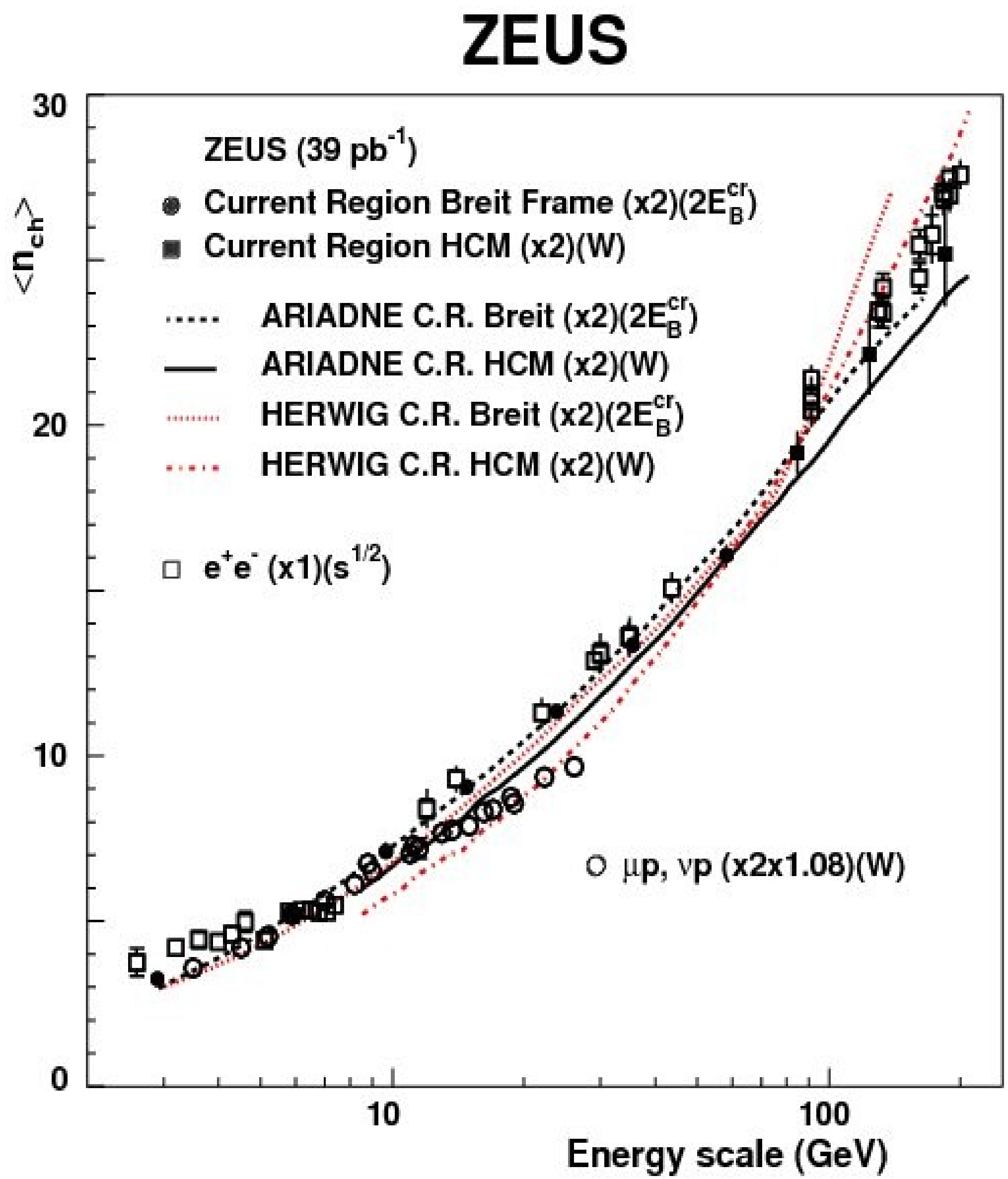
e^+e^- : $s^{1/2}$

ep (HCM) : W

ep (Breit Frame) : E^{cr}_B (available energy in the current region of Breit Frame)

Scaled momentum : $x_p = 2p_h/Q$ in ep (p_h/E_{beam} in ee)

Charged Particle Multiplicities



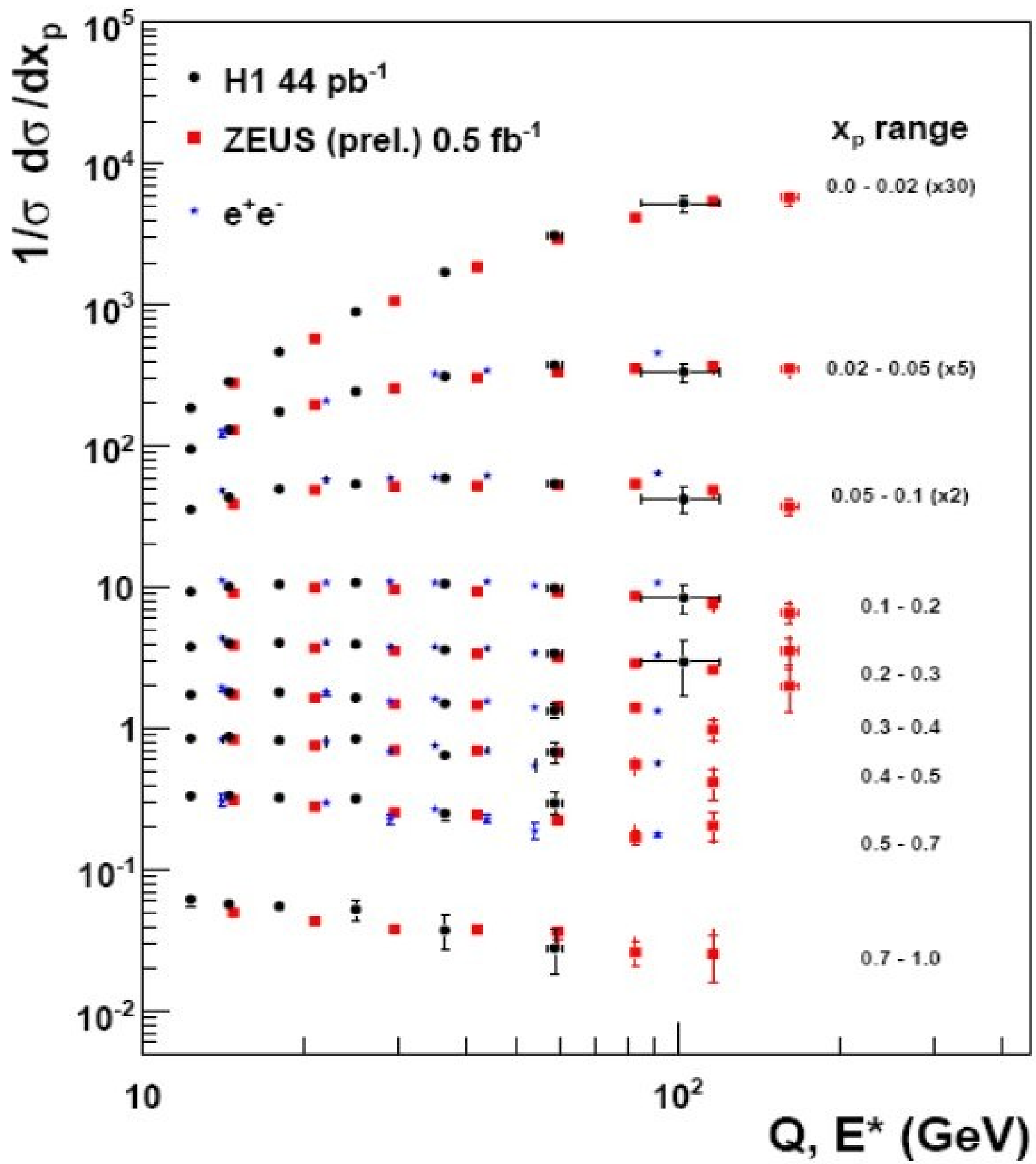
Breit Frame:

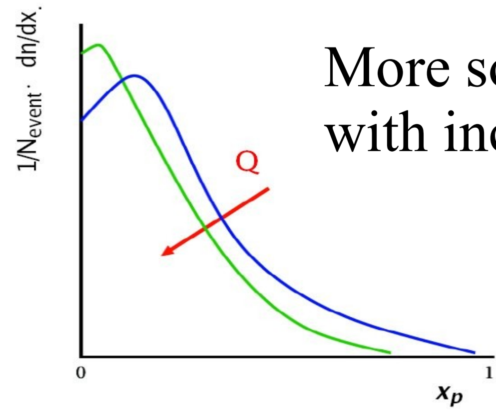
Good agreement between e^+e^- and ep data when $2{*}E^{cr}_{B}$ is used as energy scale

HCM Frame:

overall good agreement with e^+e^- and fixed target experiments when W is used as energy scale

Scaled Momentum Distributions



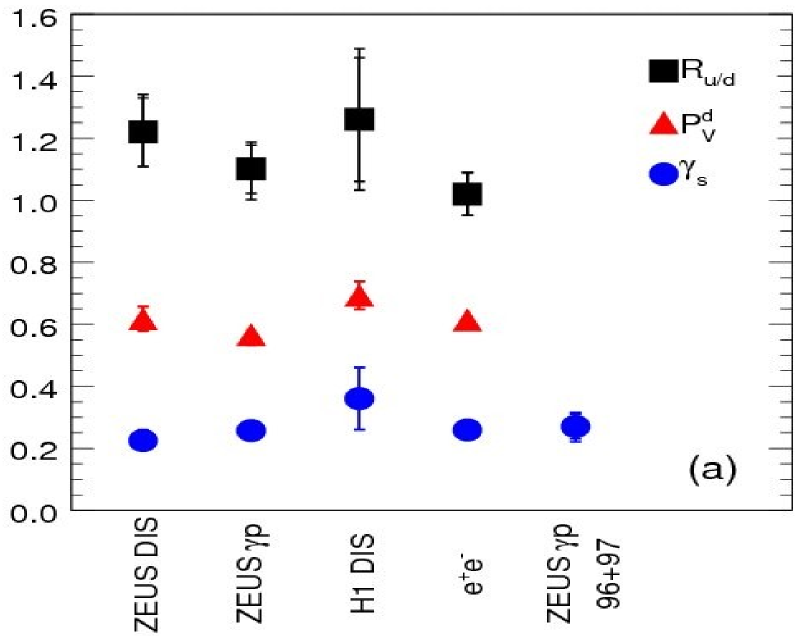


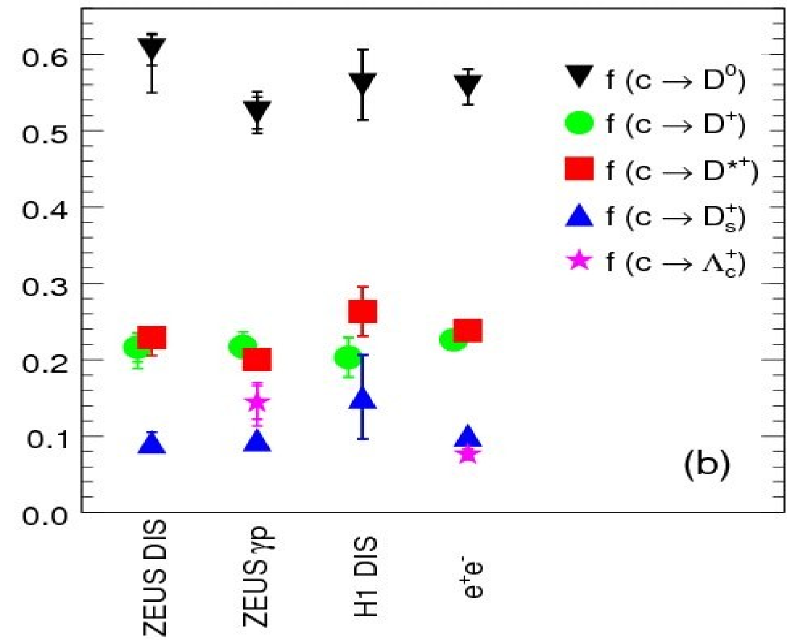
More softer particles with increasing energy

Agreement between e^+e^- and ep: supports the concept of quark fragmentation universality

Scaling violation is observed

Fragmentation of Charm Quarks I





Fragmentation ratios:

$R_{u/d} = (c\bar{u})/(c\bar{d})$

$P_v = V/(V+PS)$

$\gamma_s = (2c\bar{s})/(c\bar{d}+c\bar{u})$

Fragmentation fraction

$f(c \rightarrow D) = \sigma(D)/\sigma(c)^{tot}$

Measurements support universality of charm fragmentation

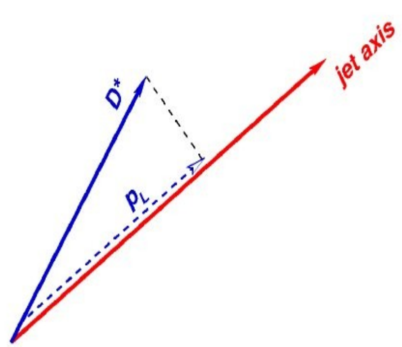
Fragmentation of Charm Quarks II

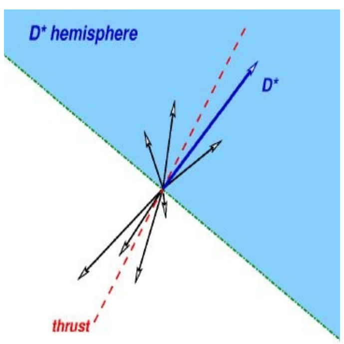
z – fraction of the D* momentum with respect to the charm quark.
for the e^+e^- - x_P
for ep two methods:

"jet" "hemisphere"

$$z_{jet} = \frac{(E+p_L)_{D^*}}{(E+p)_{jet}}$$

$$z_{hem} = \frac{(E+p_L)_{D^*}}{\sum_{hem}(E+p)_i}$$





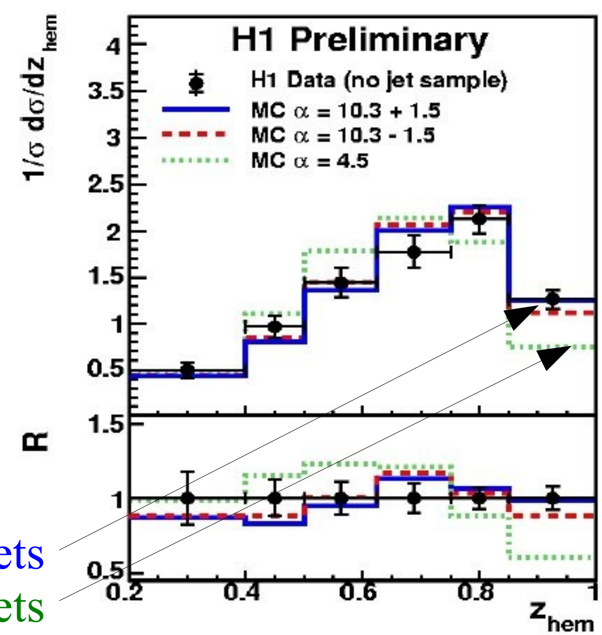
needs jet in the event

Applicable also to events without jet

Distributions for two methods are different, but resulting FF the same

Extracted parameter value agrees with e^+e^- : supports universality of FF

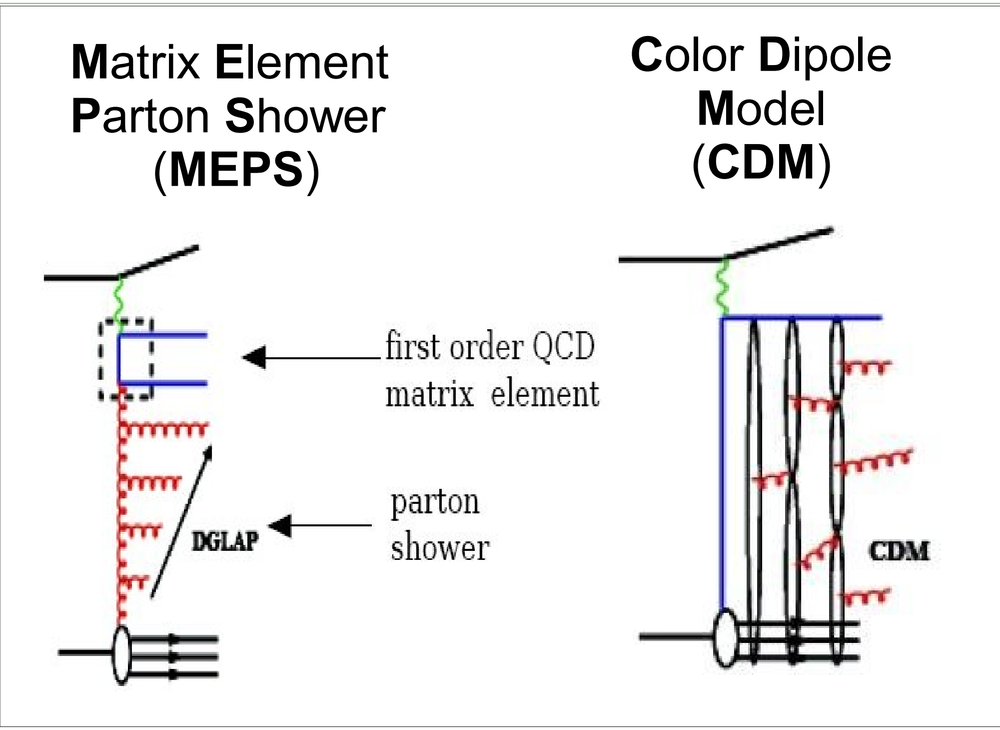
For events without hard scale in the event (no jet) : different FF needed



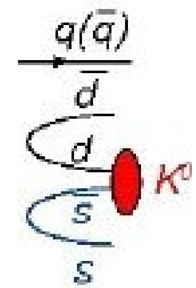
FF for events without jets
FF for event with jets

$D^H_Q(z) \propto z^\alpha(1-z)$ Kartvelishvili *et al*. parametrisation

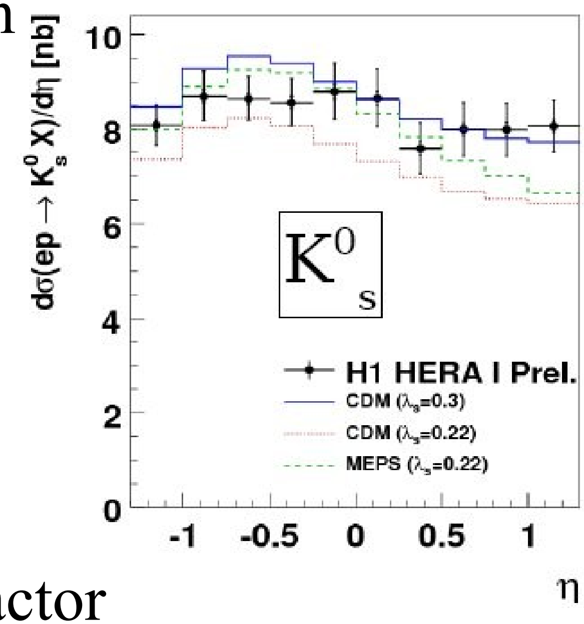
Strangeness production

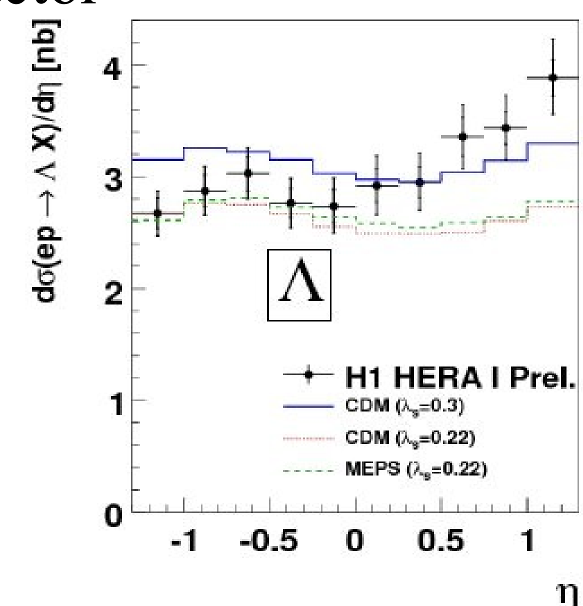


Hadronisation



$\lambda_s = P(s)/P(u)$
strangeness
suppression factor





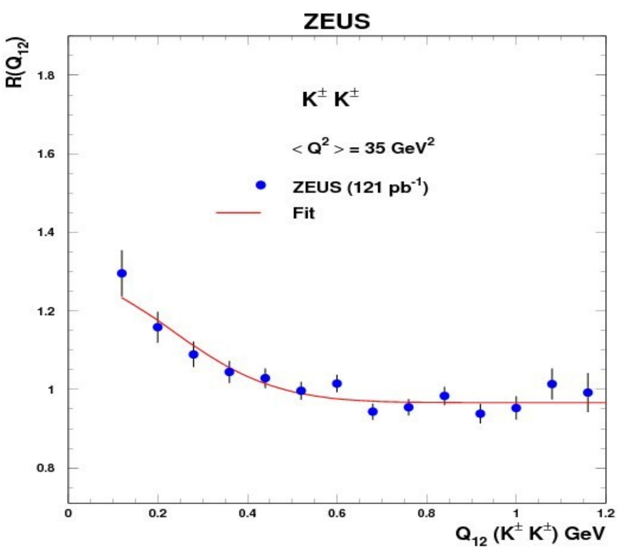
Neither MEPS nor CDM can describe the data with a single value of the λ_s parameter

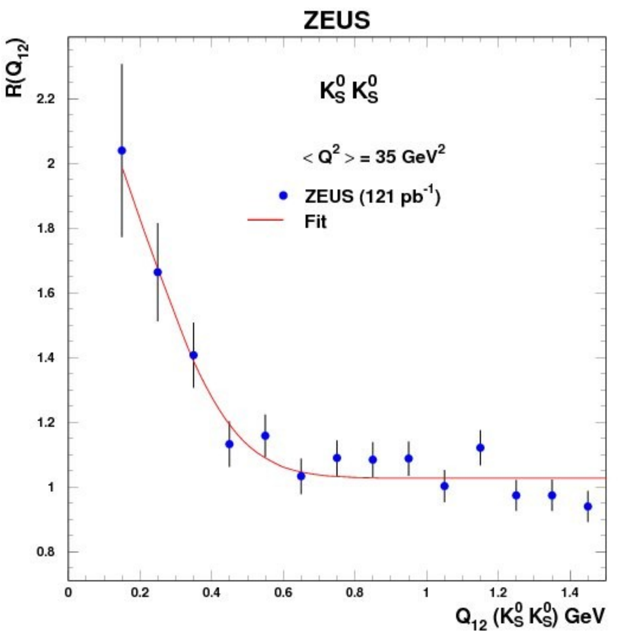
MEPS + (λ_s =0.22) – reasonable description of K^0 (and ratio of K^0 to charged particles)

MEPS + (λ_s =0.3) – close to Λ data

CDM + (λ_s =0.3) – K^0,Λ, but fails in details

Bose-Einstein Correlation in KK system





$R(Q_{12})=P(Q_{12})/P_0(Q_{12})$

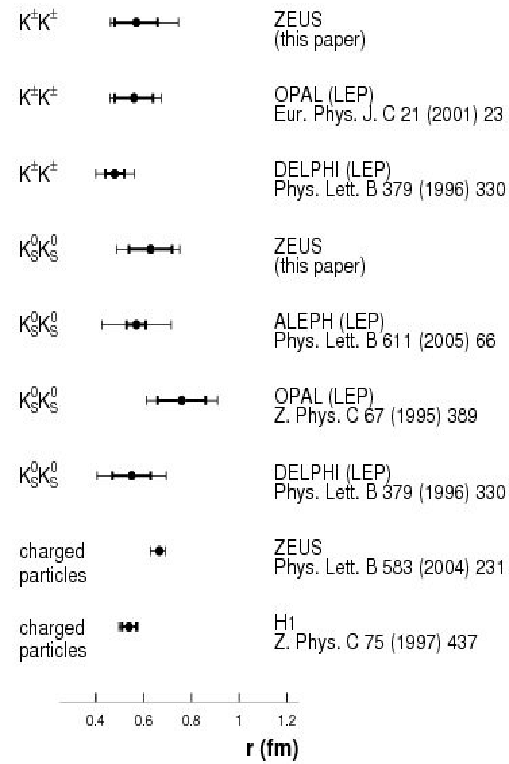
$Q_{12}^{\ 2} = -(p_1-p_2)^2 = (M_{KK}^{\ 2}-4M_K^{\ 2})$

Fit: $R(Q_{12})=1+\lambda\cdot\exp(-r^2Q_{12}^{\ 2})$

λ – strength of BEC

r – size of the source

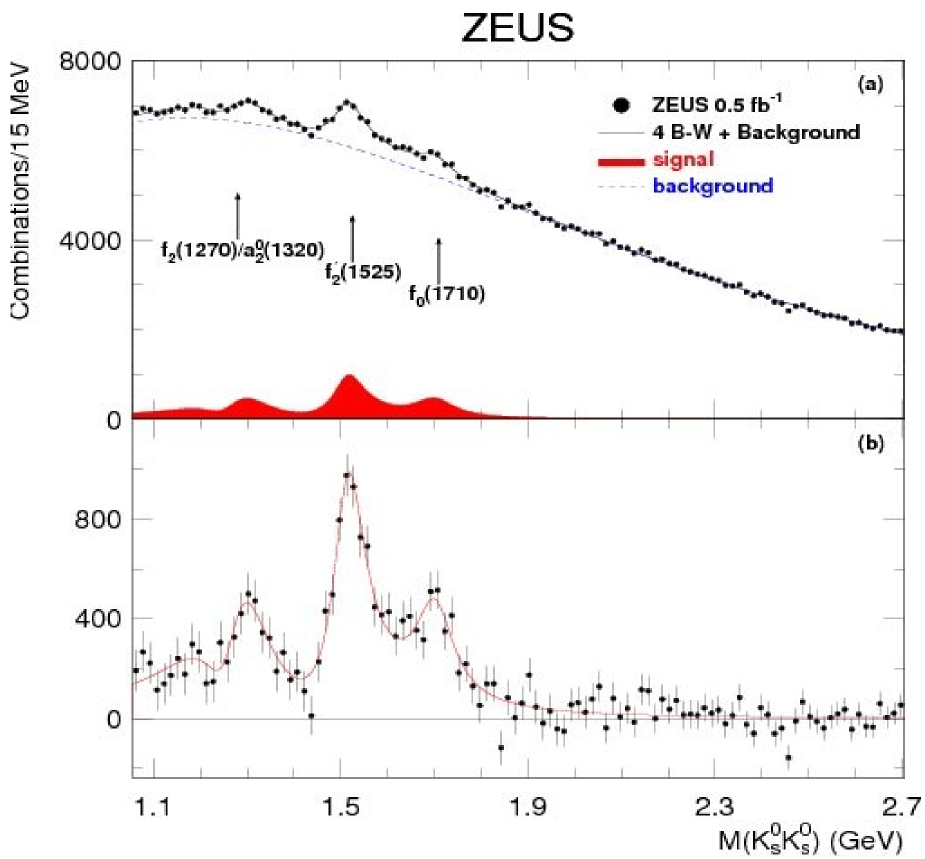
Measure $R(Q_{12})$ using event-mixing procedure (corrected with MC)

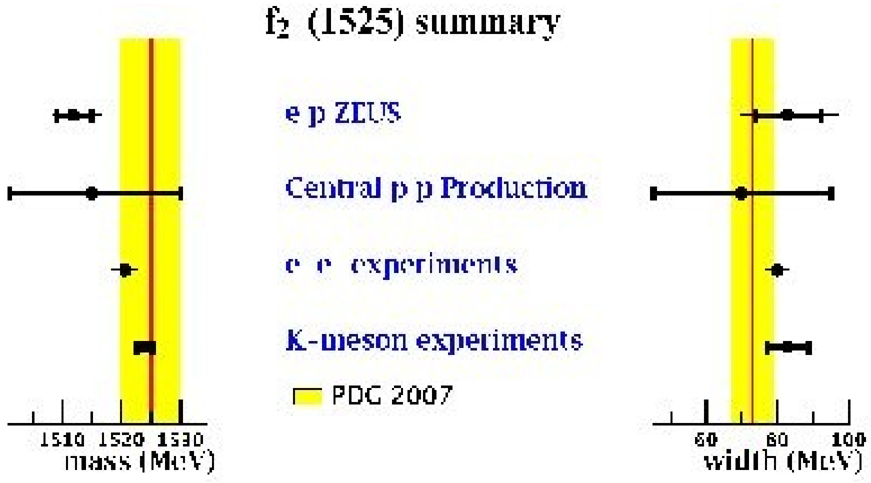


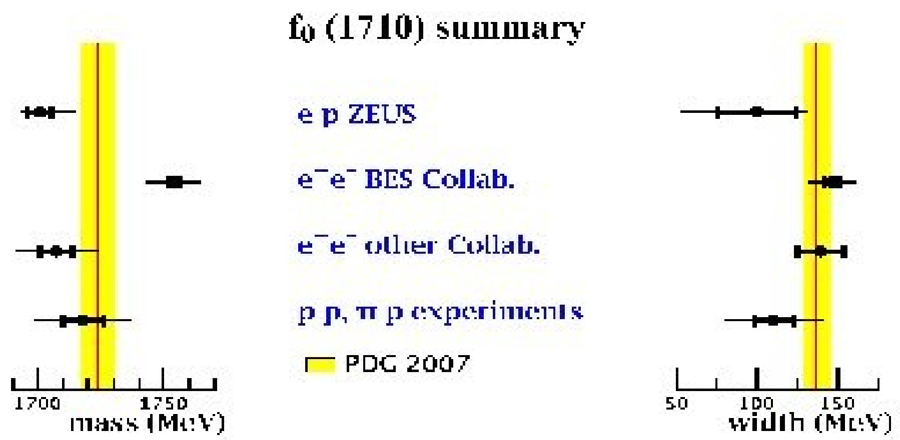
Consistent with the measurement of BEC for charged particles in DIS and kaons in e^+e^-

Spectroscopy

K^0K^0 - resonances







3 enhancements corresponding to $f_2(1270)/a_2(1320)$, $f'_2(1525)$ and $\underline{f_0(1710)}$

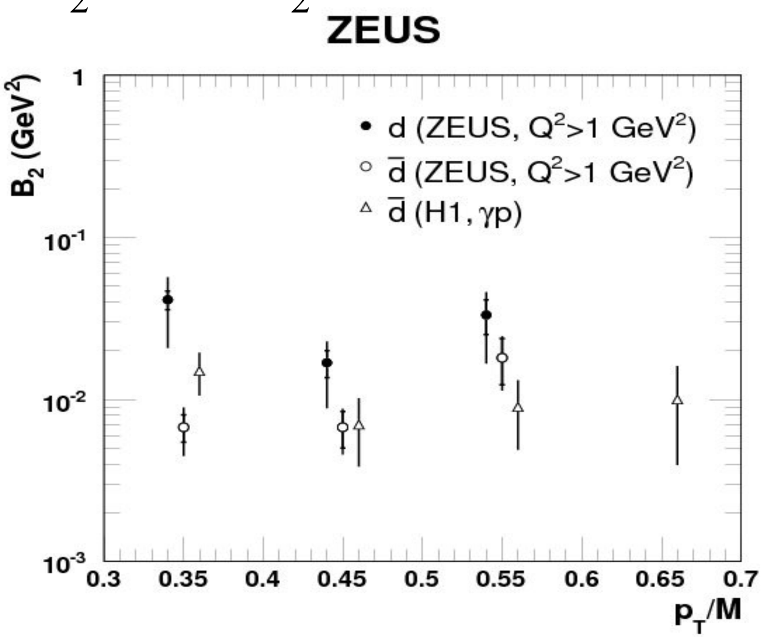
$f_0(1710)$ (5 σ significance) is the glueball candidate. (If not the same particle as observed in $\gamma\gamma \rightarrow K^0K^0$ (TASSO, L3))

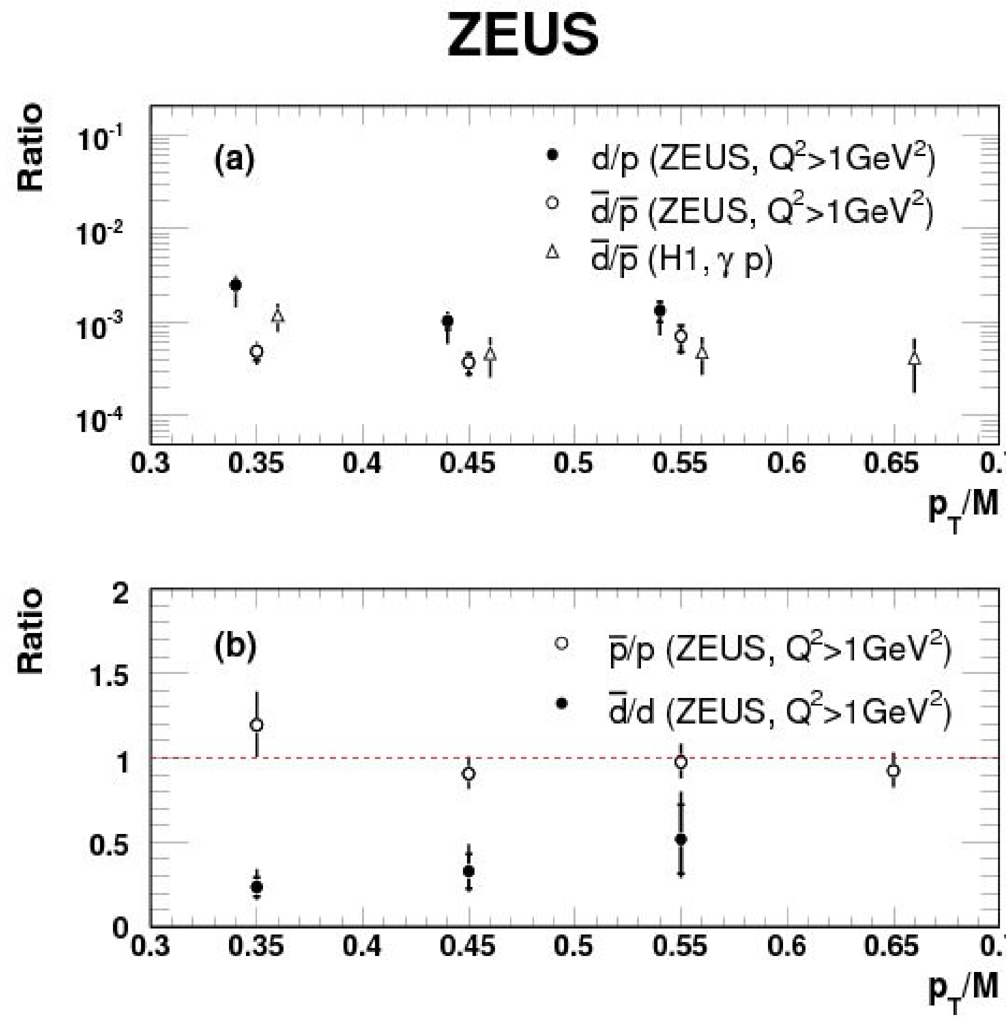
$\bar{d}/d$, $\bar{p}/p$ production

Coalescence model:

$$\frac{1}{\sigma}\frac{d^3\sigma(d)}{d^3p} = B_2\left(\frac{1}{\sigma}\frac{d^3\sigma(p)}{d^3p}\right)\left(\frac{1}{\sigma}\frac{d^3\sigma(n)}{d^3p}\right)$$

$B_2(d) = B_2(\bar{d})$ - expected





$$B_2(d) = (3.32 \pm 0.34^{+1.13}_{-1.55}) \cdot 10^{-2}$$
$$B_2(\bar{d}) = (0.89 \pm 0.14^{+0.19}_{-0.20}) \cdot 10^{-2}$$

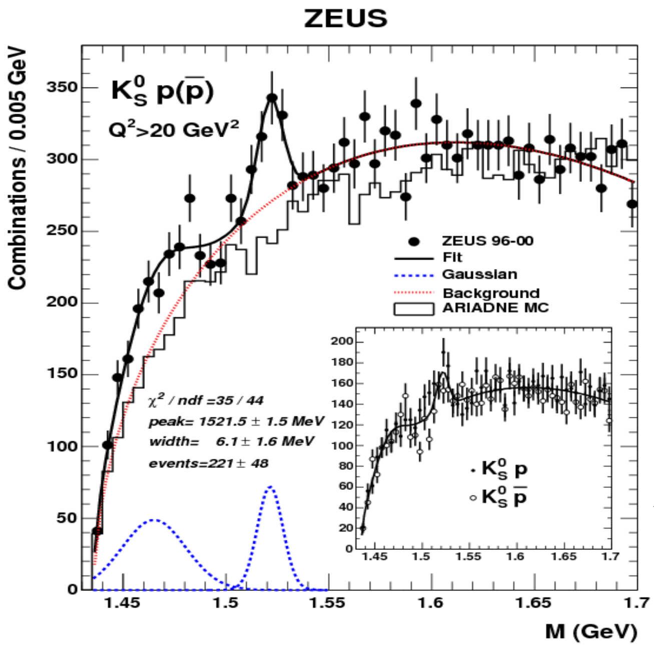
Enhanced production of multi-quark states?

Strange Pentaquark Θ^+

2004

2006

HERA I data

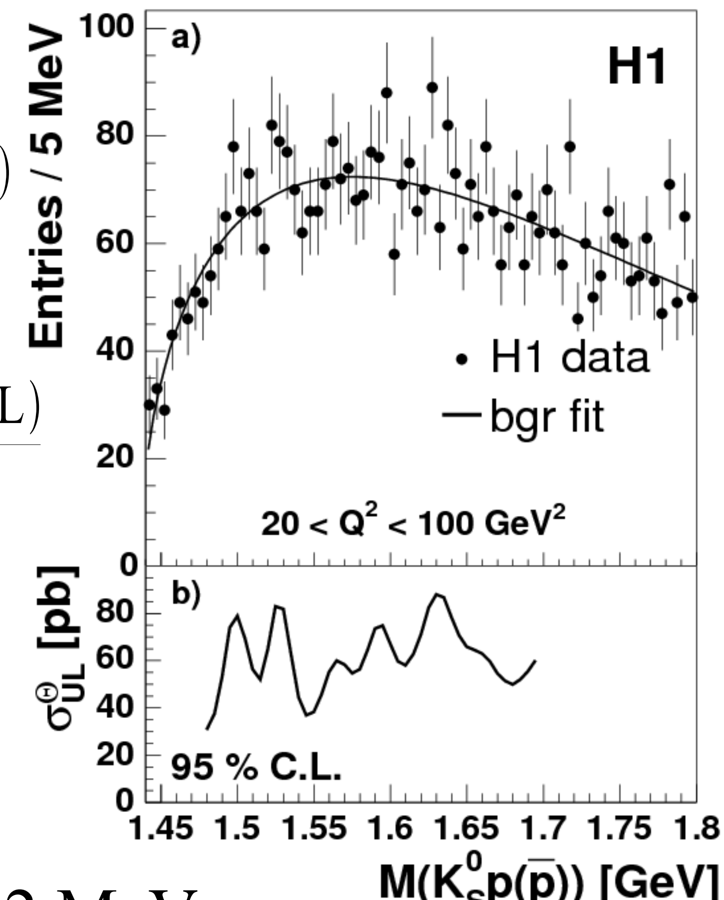


H1:
20.0 < Q^2 < 100.0 GeV^2
0.1 < y < 0.6

$$\sigma(M=1.52\,\mathrm{GeV})<72\,\mathrm{pb}\,(95\,\%\ \mathrm{CL})$$

(extrapolated to ZEUS y-region):

$$\sigma(M=1.52\,\mathrm{GeV})<100\,\mathrm{pb}\,(95\,\%\ \mathrm{CL})$$



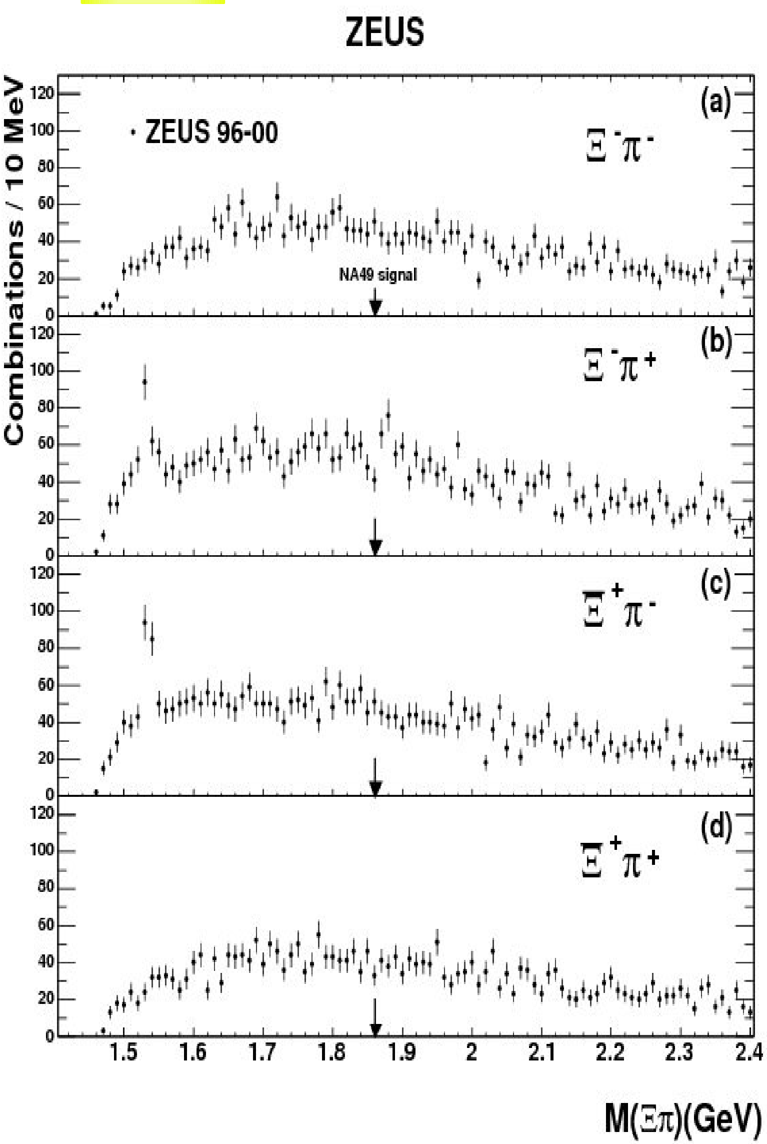
ZEUS : Q^2 > 20.0 GeV^2, 0.04 < y < 0.95

$$\sigma(e\,p\to e\,\theta\,X\to e\,K^0\,p\,X)=125\pm27\,(stat)^{+38}_{-28}\,(syst)\,\mathrm{pb}$$

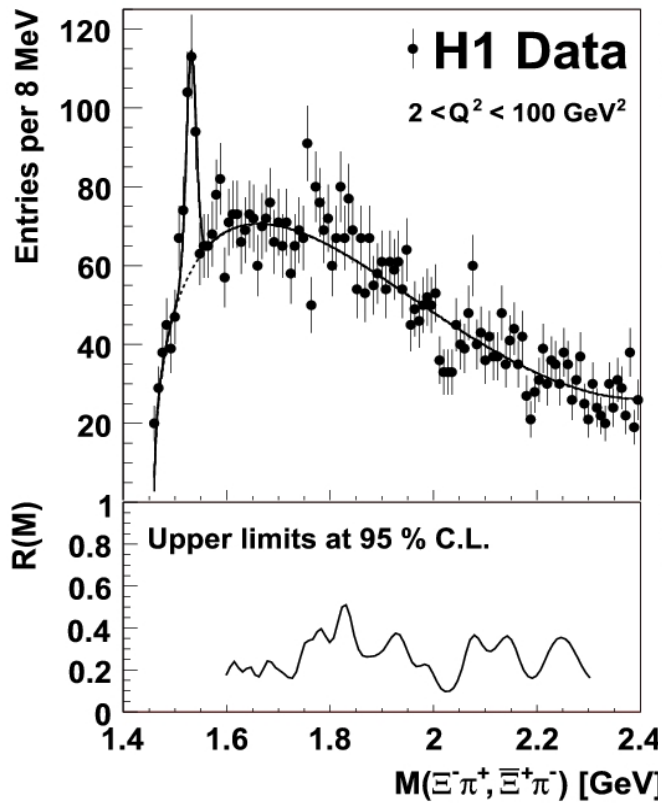
Positive signal in ZEUS data at 1522 MeV
No signal in H1, upper limit does not support ZEUS evidence
HERA II data will clarify this issue

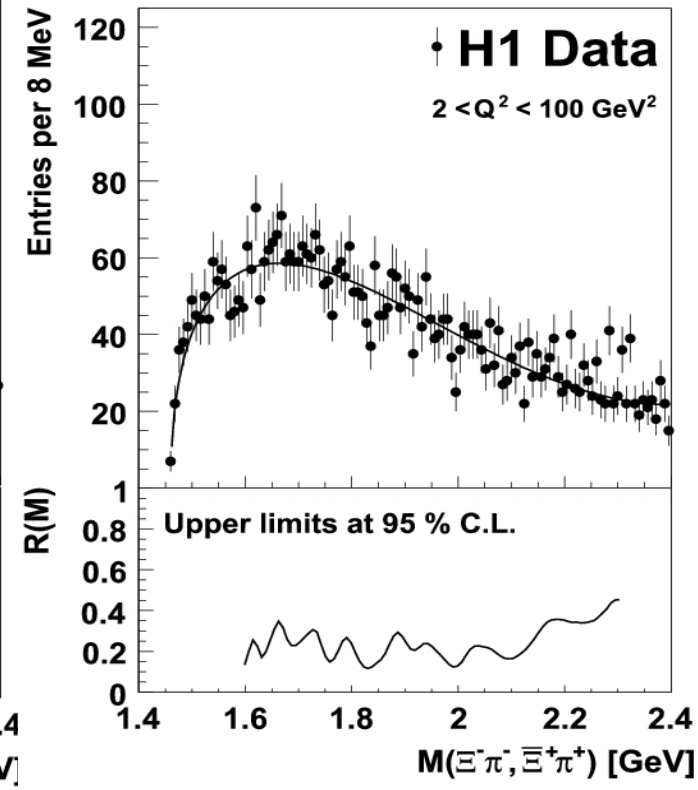
Double Strange Pentaquarks Ξ_{5q}

2005



2007

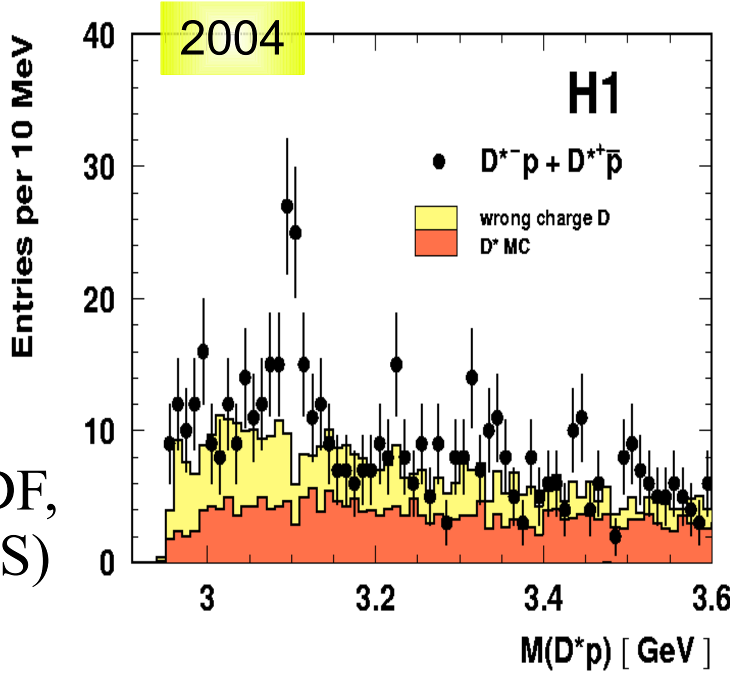


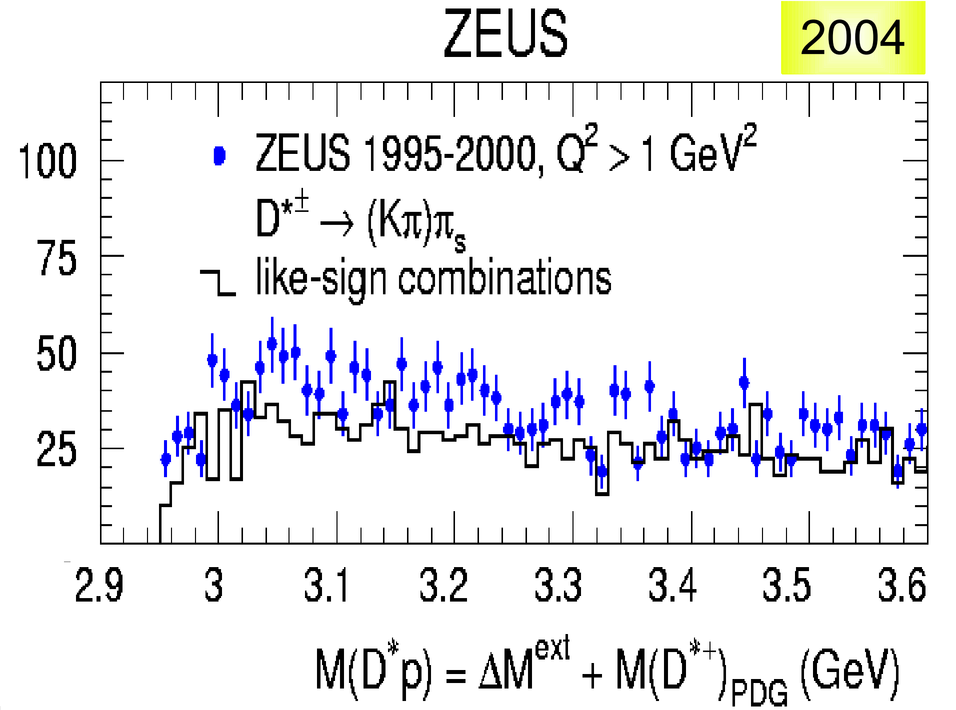


Known resonant state Ξ(1530) clearly seen
No signal at 1860 (NA49).
Upper limit relative to Ξ(1530)

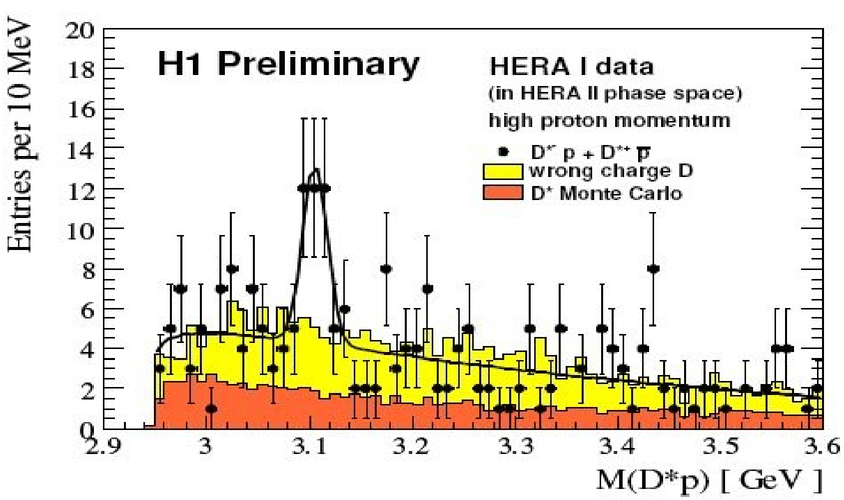
D*p resonance (charm PQ)

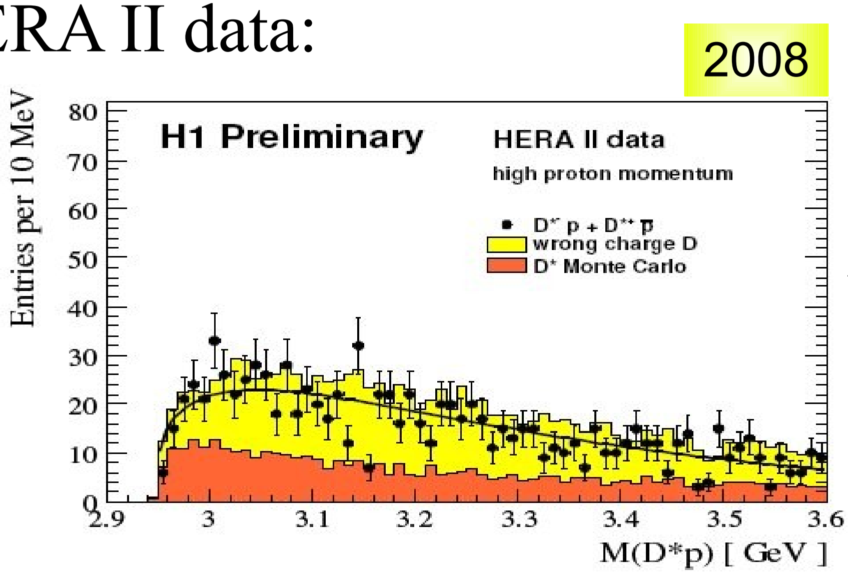
HERA I:
charming resonance in H1 data
no signal in ZEUS data
(and BaBar, CDF, ALEPH,FOCUS)





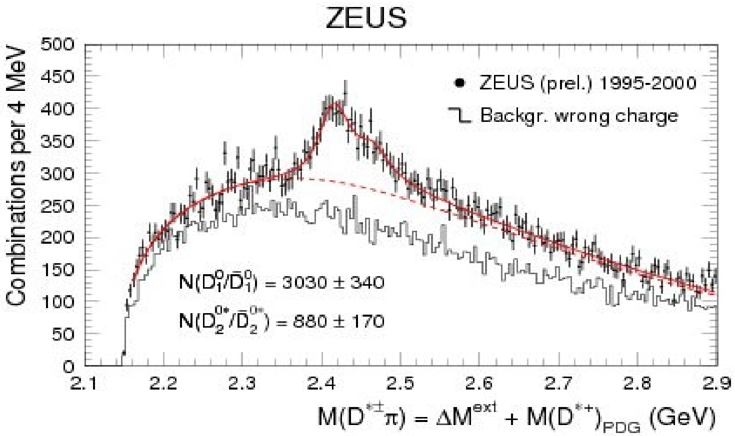
new analysis from H1 using HERA II data:



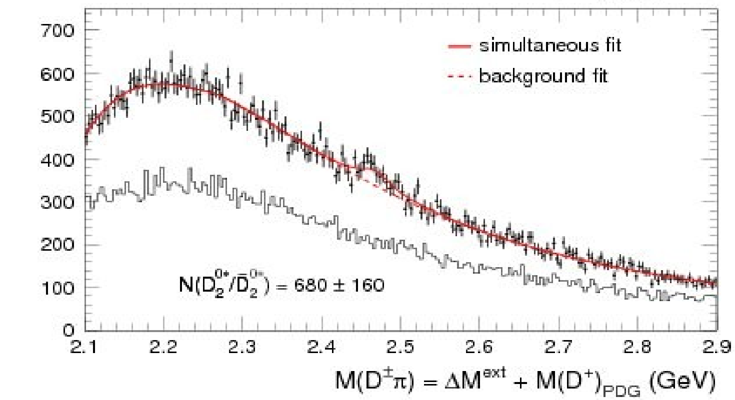


No excess in HERA II data

Excited charm and charm-strange mesons

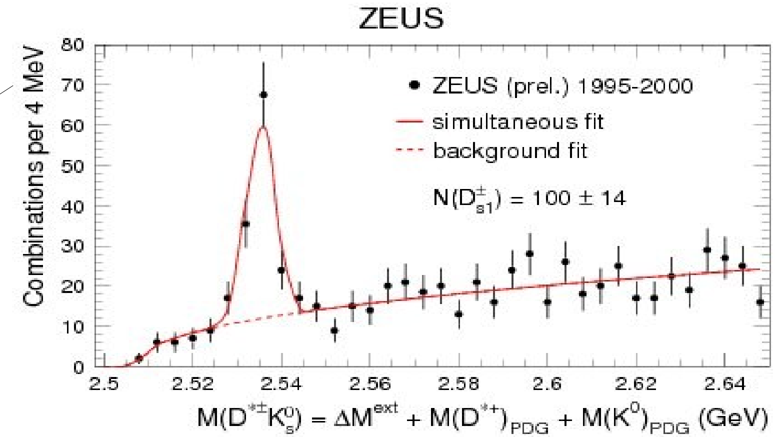


$D_1(2420)^0$ and $D_2^*(2460)^0$ in $D^{*+}\pi^-$

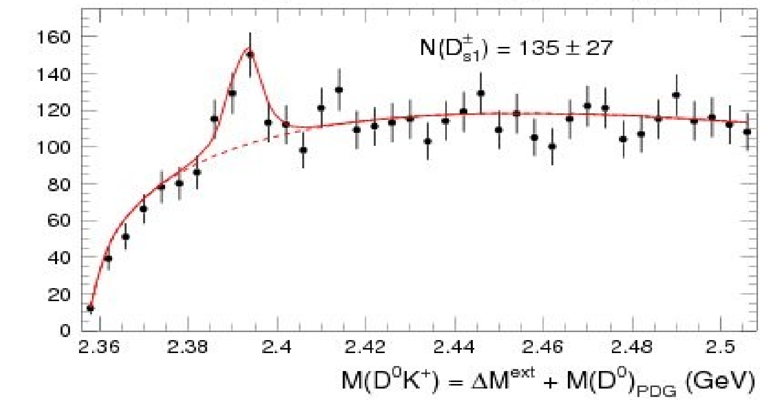


$D_2^*(2460)^0$ in $D^+\pi^-$

$D_{s1}(2536)^{\pm}$ in $D^{*\pm}K^0_s$



$D_{s1}(2536)^+$ in D^0K^+



$f(c \to D_1^{\,0}) = 3.5 \pm 0.4^{+0.4}_{-0.6} \pm 0.2\%$

$f(c \to D_2^{*0}) = 3.8 \pm 0.7 \pm 0.6 \pm 0.2\%$

$f(c \to D_{s1}^{\,+}) = 1.1 \pm 0.2 \pm 0.1 \pm 0.1\%$

Consistent with the e^+e^- measurements

Helicity measurements:

$R(D_1^0) = 6.1 \pm 2.3^{+2.0}_{-0.8}$ HQET:+3

$R(D_{s1}^+) = -0.74^{+0.23}_{-0.17}{}^{+0.06}_{-0.05}$

hardly consistent with 0 (CLEO conclusion)

Summary

Fragmentation:

Many similar features/consistent picture with e^+e^-
but some striking differences:

- charm fragmentation at threshold
- no simple picture for strangeness production
- enhanced production of deuterons

Spectroscopy:

Competitive with other world measurements:

- glueball candidate
- excited charm mesons
- pentaquarks (none in recent analyses, unfortunately)

Further exciting results in near future, with the HERA II data.