Charm Fragmentation and Excited Charm Meson Production at HERA

ICHEP2010, July 23, Paris
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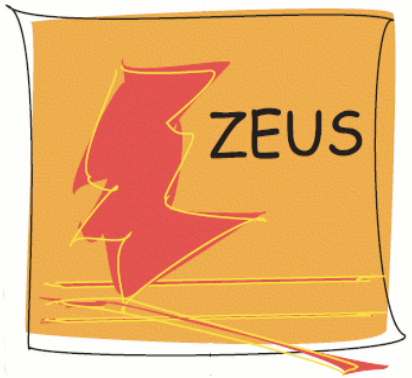
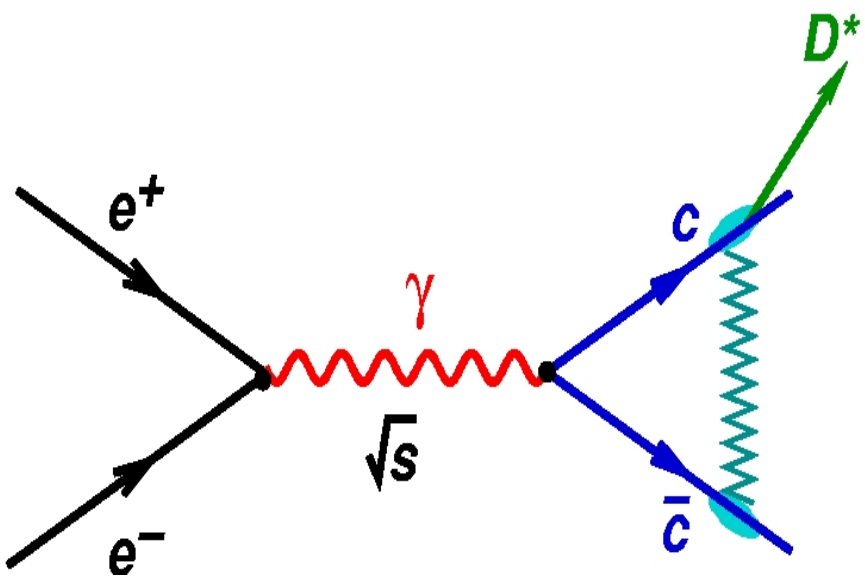
on behalf of



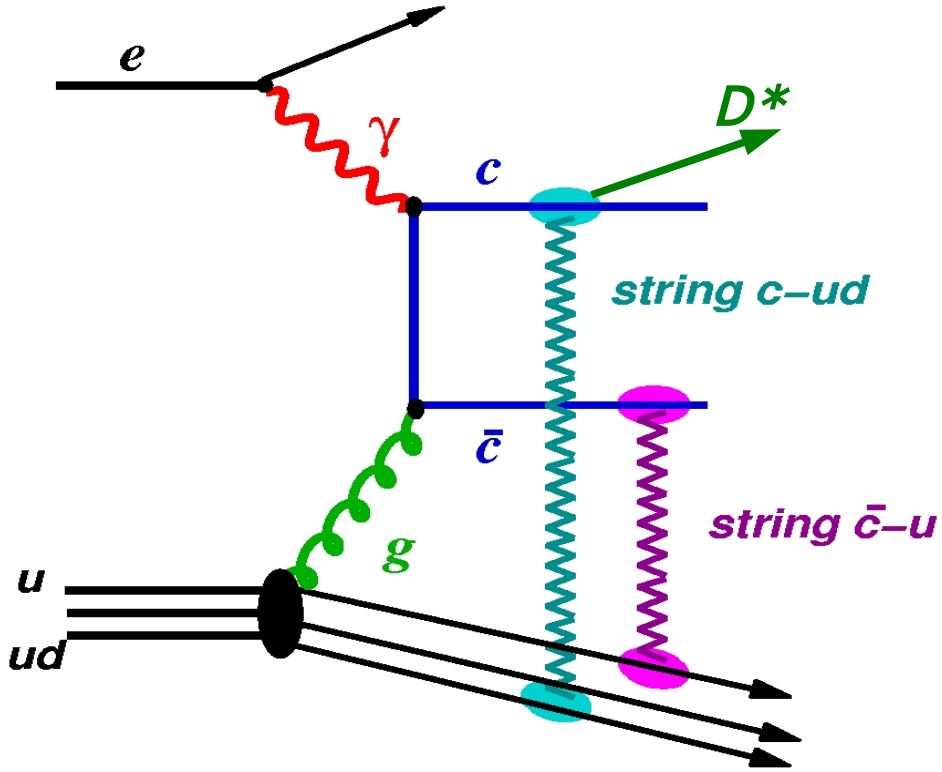
1. Charm Fragmentation: is it universal?

Observable **z**: Momentum fraction of c quark transferred to D* meson

e-e+



ep at HERA



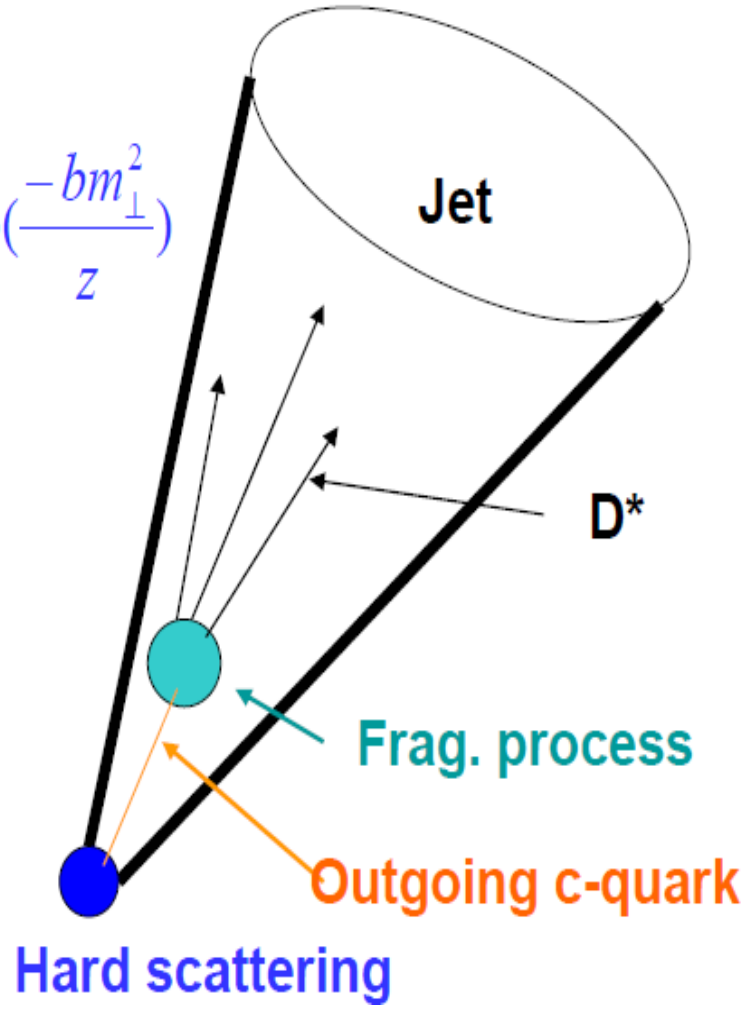
➔Probe different colour configurations
➔ Study at HERA over wide $p_T(c)$ range

Phenomenological models:

Peterson function: $f(z) \propto \frac{1}{[z(1-1/z-\varepsilon/(1-z))^2]}$

Kartvelishivili function: $f(z) \propto z^{\alpha}(1-z)$

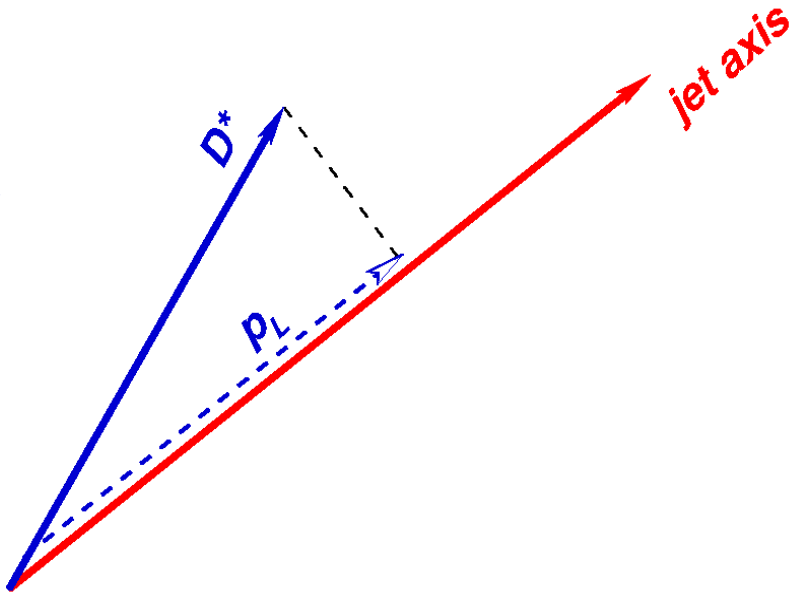
Bowler function: $f(z) \propto \frac{1}{z^{1+r_Q bm_Q^2}}(1-z)^a \exp(\frac{-bm_\perp^2}{z})$



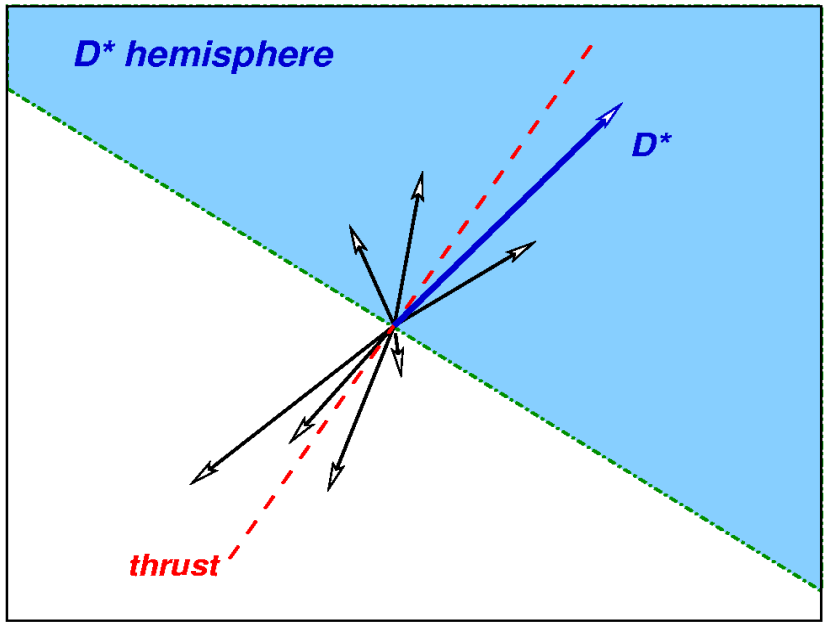
- Experimental definition e^+e^-:
  $z \sim E_{D^*}/E_{beam}$

Experimental definitions at HERA

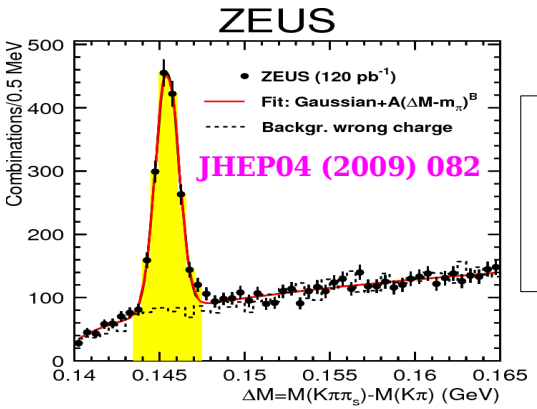
- Jet method (ZEUS, H1):
  energy of c-quark approximated by energy of reconstructed D* jet
  $z=(E+p_{||})_{D*}/(E+p)_{jet}$



- Hemisphere method (H1):
  energy of c-quark approximated by energy of reconstructed D*-hemisphere
  $z_{hem}=(E+p_{||})_{D*}/\Sigma(E+p)_i$

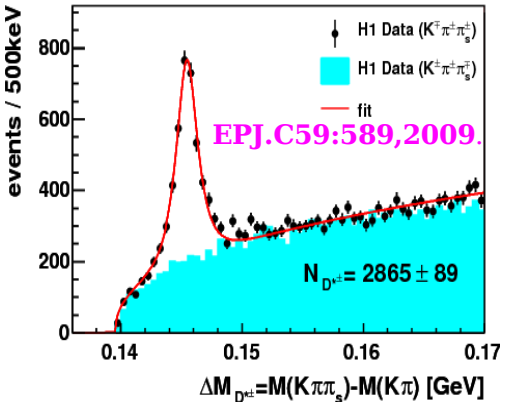


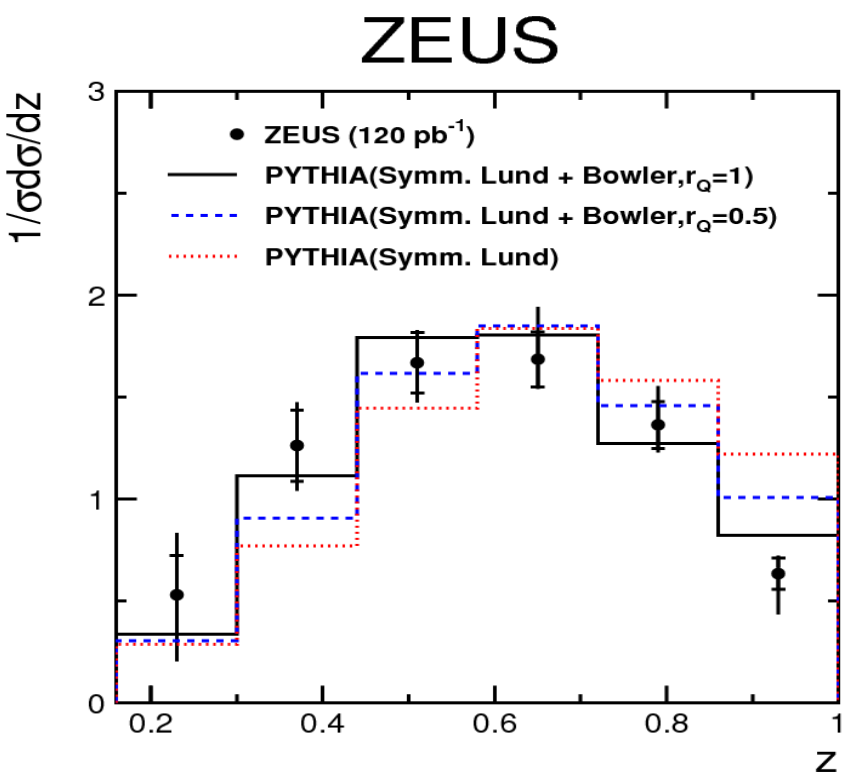
Results and comparison with LO+PS+Jetset (standard tunes) MC simulations

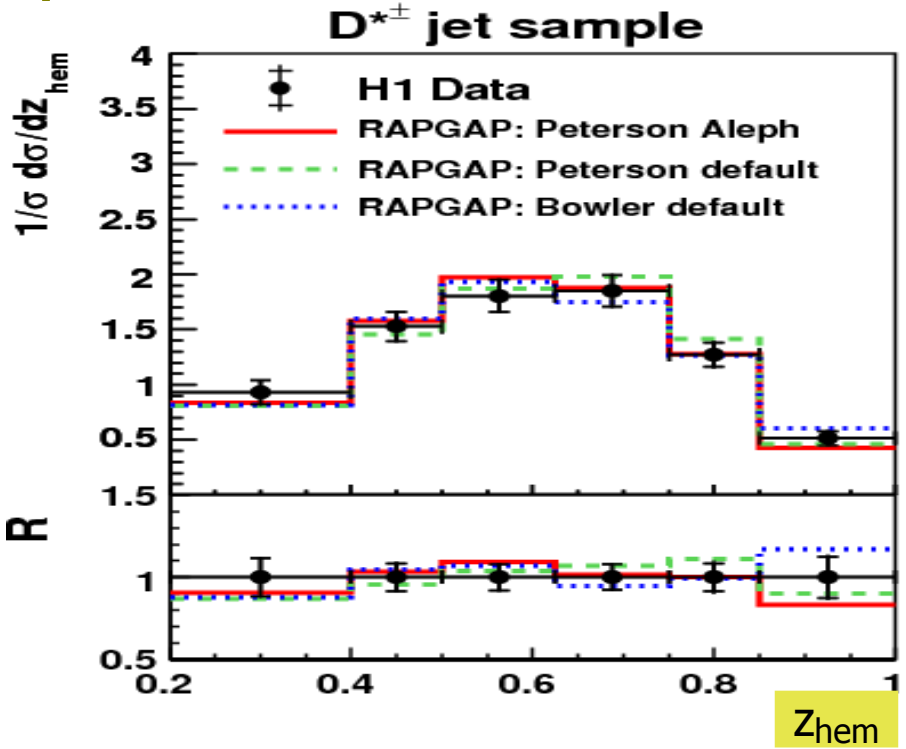


ZEUS:
$Q^2<1$ GeV^2
E_T(jet)>**9** GeV

H1:
$2<Q^2<100$ GeV^2
D^* Jet sample: E_T(jet)>**3** GeV
No jet sample



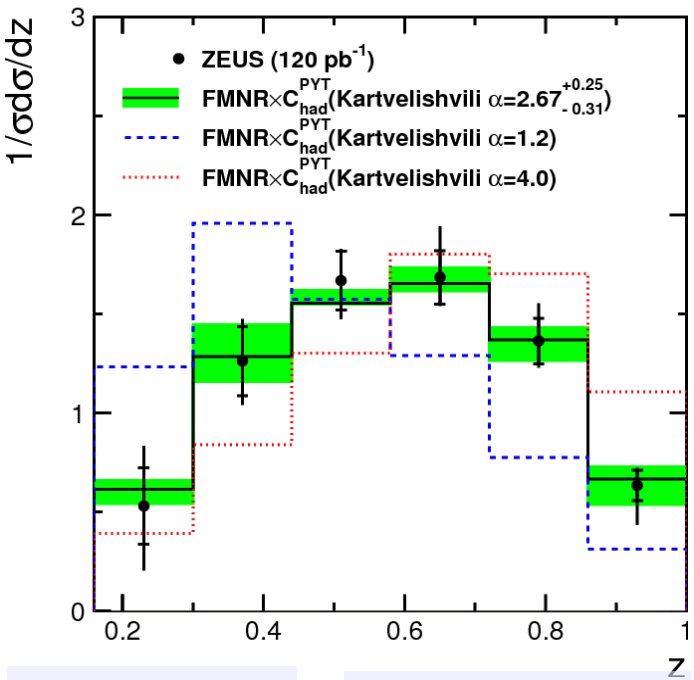




➔ HERA results agree with MC models with fragmentation tuned to e^+e^- data ⇒ universality

Results and Fits to NLO QCD

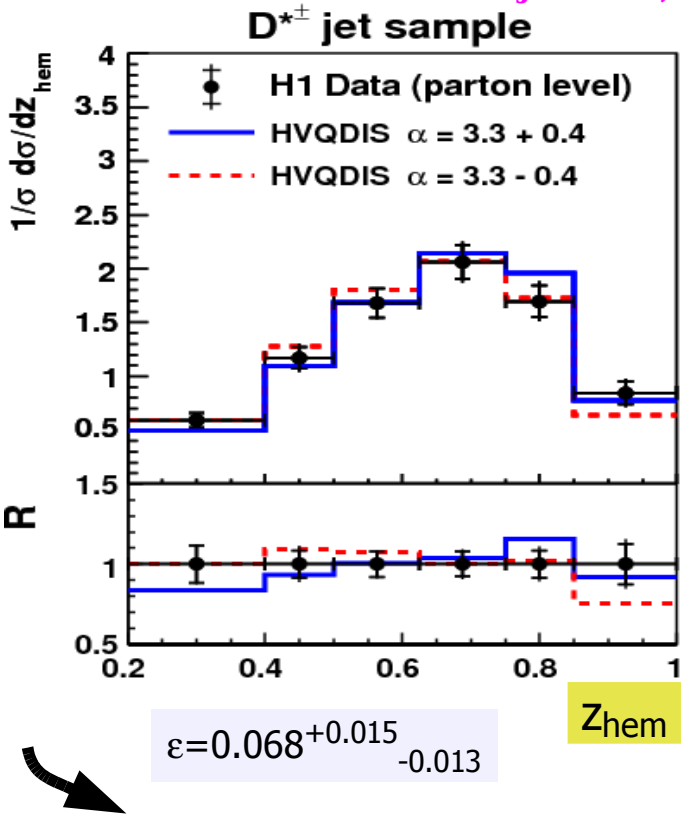
JHEP04 (2009) 082 ZEUS



Alternative fits with Peterson FF

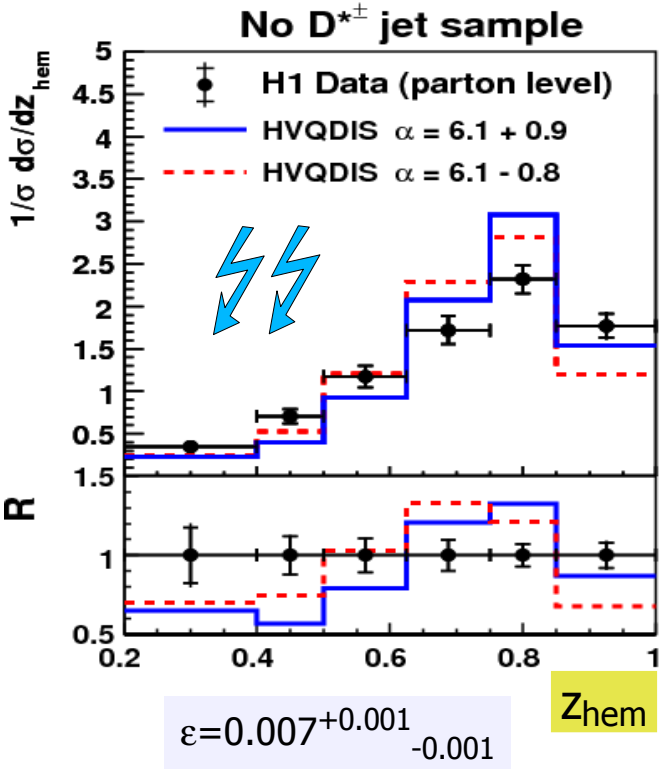
$\varepsilon=0.079^{+0.013}_{-0.009}$

EPJ.C59:589,2009.



$\varepsilon=0.068^{+0.015}_{-0.013}$

Especially sensitive to kinematic threshold

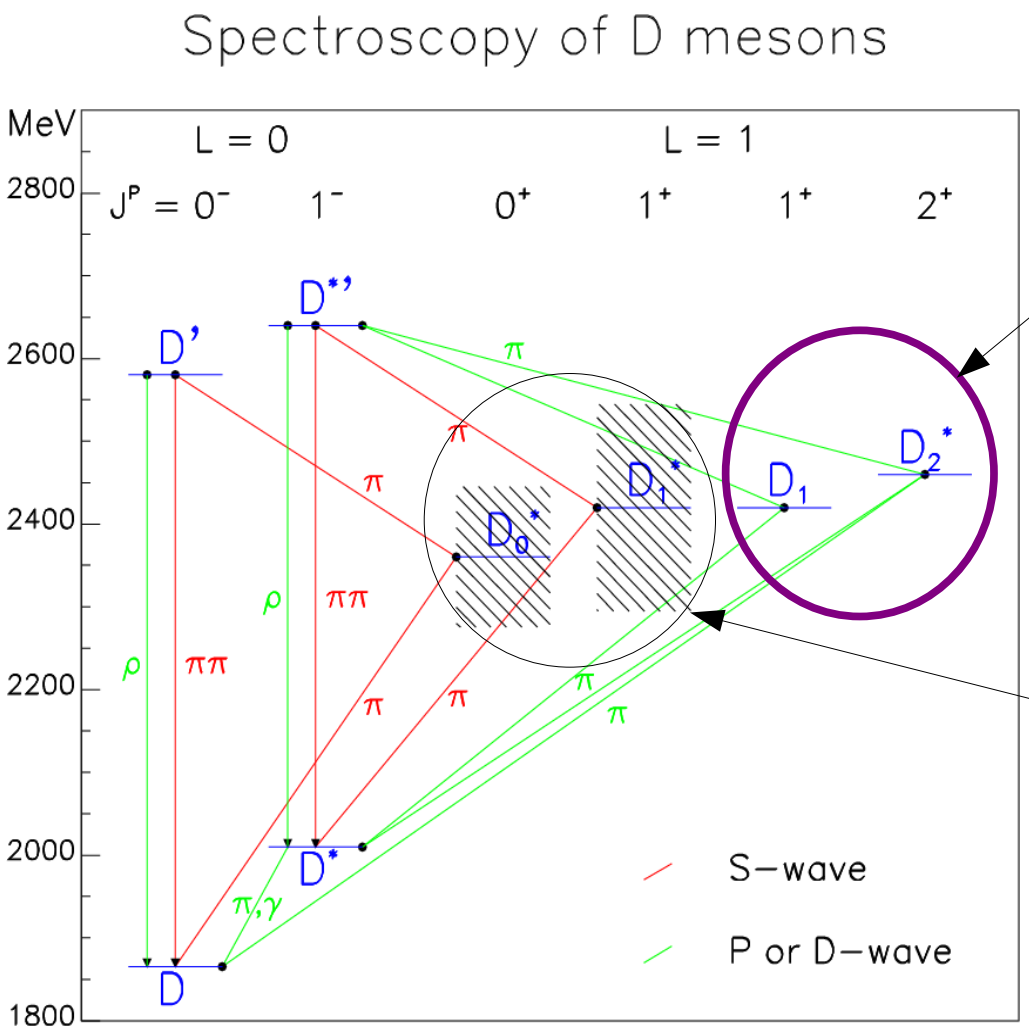


$\varepsilon=0.007^{+0.001}_{-0.001}$

Compare to typical value obtained from NLO fit to e+e- data: **ε =0.035** (Nucl.Phys.B565:245-266,2000)

- Jet samples vs NLO x Fragmentation functions: ⇒ fitted parameters somewhat different compared to parameters obtained from corresponding NLO fits to e^+e^- data (could be due to NLO being different/meaning different things for ep and ee)
- No D* jet sample ⇒ results differ! ⇒ need refined theory treatment at charm production threshold!

2. Excited charm mesons



HQET predicts 2 doublets of excited D mesons ($Q\bar{q}$) with L=1:

Doublet with $j=L+s_q = 3/2$

D-wave decays ⇒ narrow states

$D_1(2420)^0$ and $D_2^*(2460)^0$ known since ~1990, but parameters are being re-established, e.g. $\Gamma(D_2^{*0})$ updated significantly in PDG2006

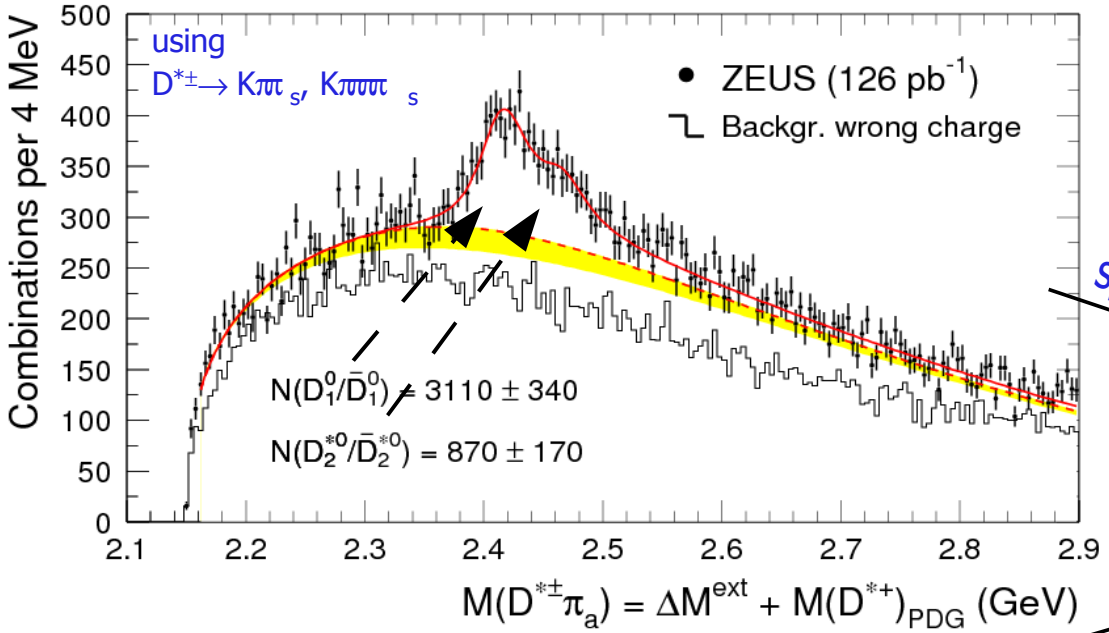
Doublet with $j=L+s_q = 1/2$

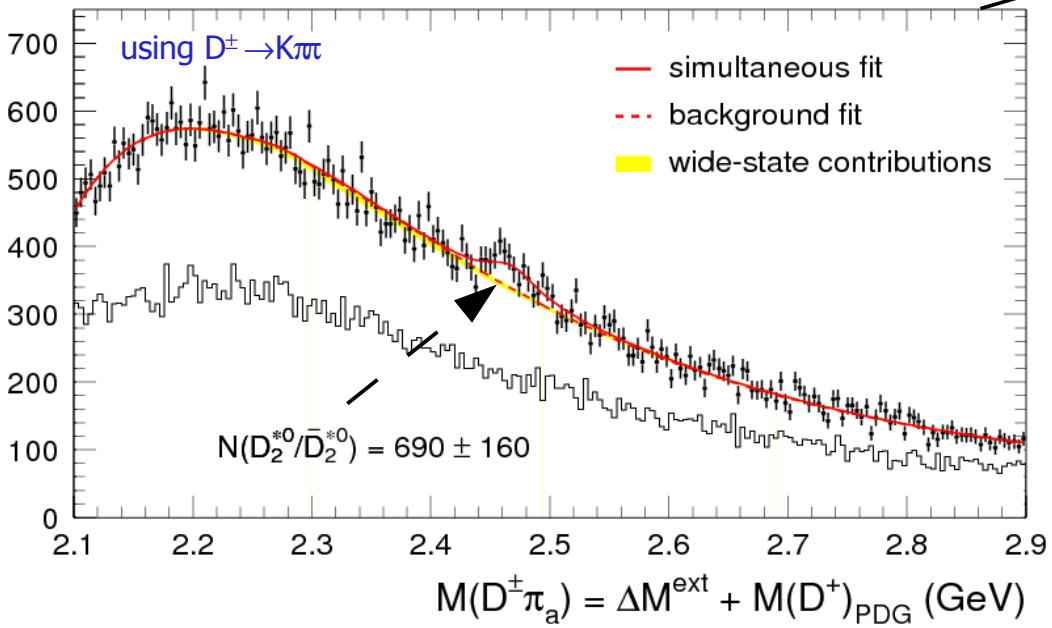
s-wave decays ⇒ wide states

Available results in PDG 2010:
Belle and Focus on $D_0^*(2400)^0$
Belle and Babar on $D_1(2430)^0$
large parameter uncertainties!

➔ What can we learn at HERA? ⇒ ZEUS studies on narrow $D_1(2420)^0$ and $D_2^*(2460)^0$ states

$M(D^{*\pm}\pi)$ and $M(D^{\pm}\pi)$ distributions in HERA I EPJ.C.60 (2009) 25-42





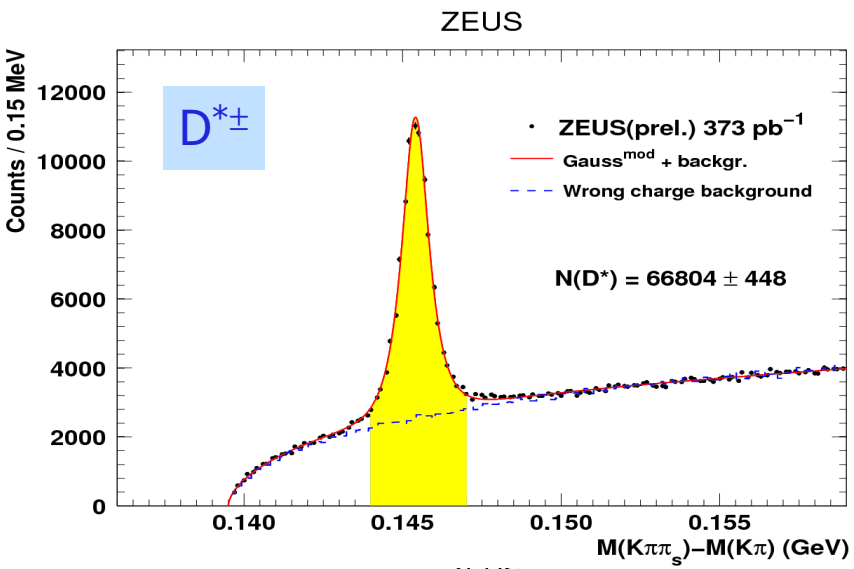
split signals in four helicity bins

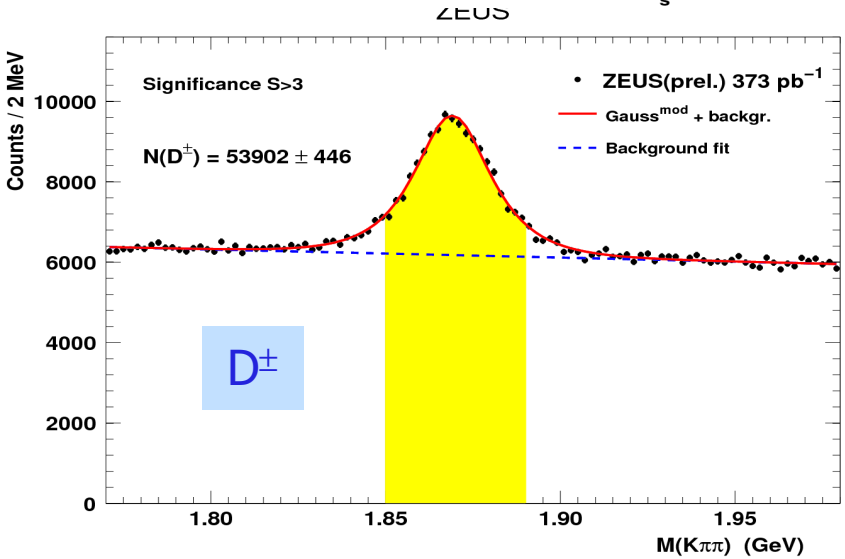
Simultaneous fit

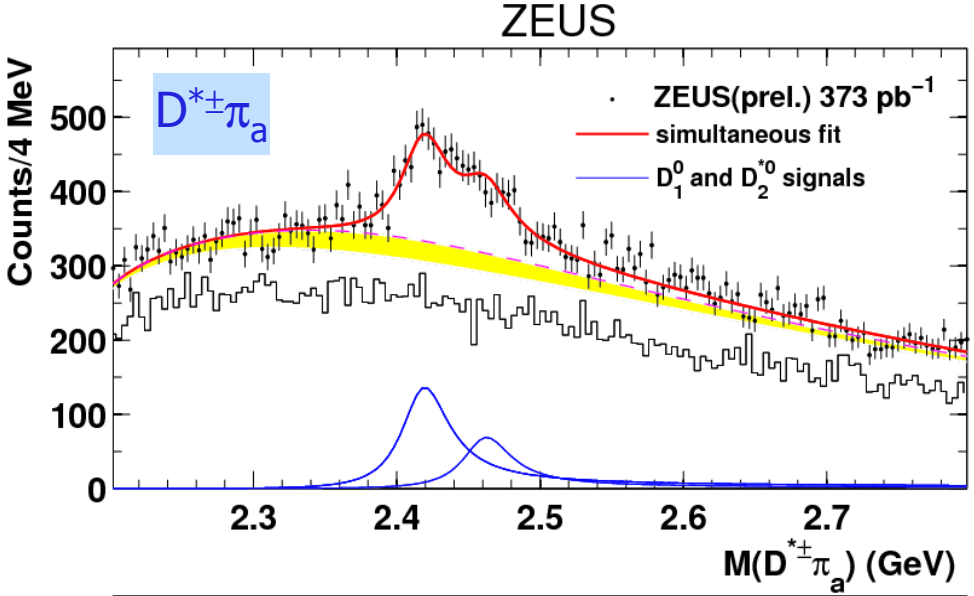
Fitted $D_1(2420)^0$ mass and helicity parameters agree well with other measurements, but width $\Gamma(D_1) = 53.2 \pm 7.1(stat)^{+3.3}_{-4.9}$ (syst.) MeV is higher than PDG average of 20.4 ±1.7 MeV

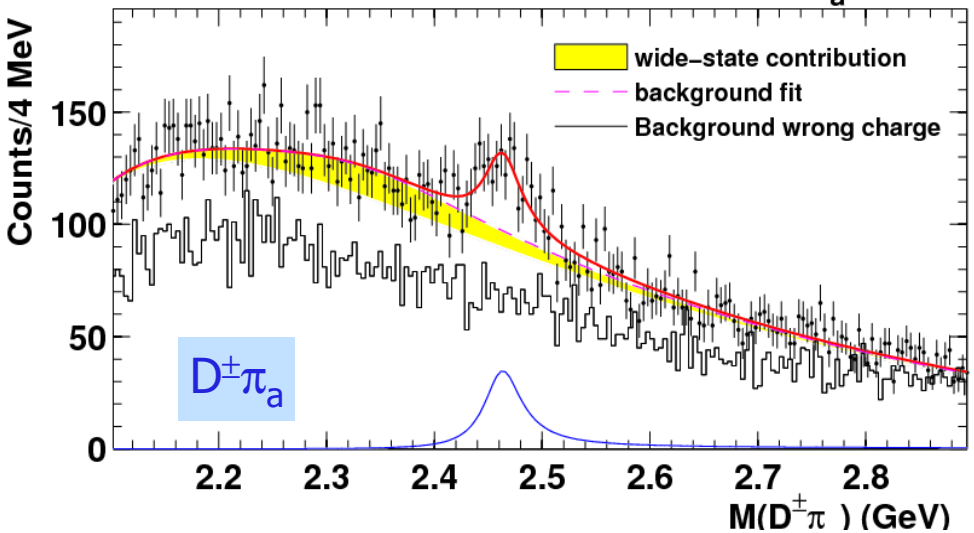
➔ Can we confirm with HERA II ?

HERA II: Mass peaks ZEUS PREL.10-016







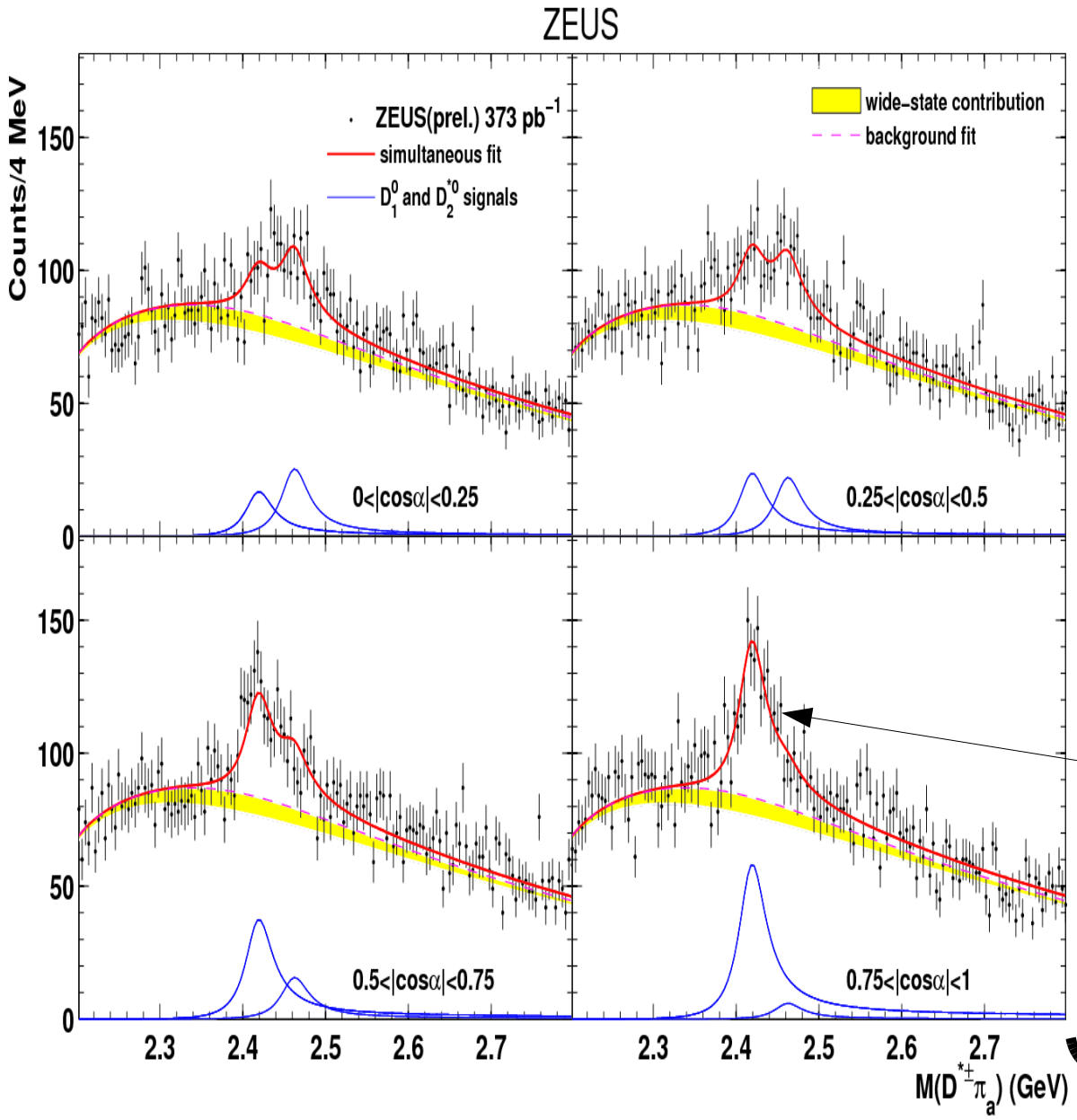


Improved $D^{\pm}$ signal in HERA II with lifetime tag (Si-tracker)

➔ Clear signals for $D_1(2420)^0$ and $D_2^*(2460)^0$

➔ Very well described by fit (described in the following)

HERA II: M($D^{*\pm}\pi$) in 4 helicity intervals ZEUS PREL.10-016



Helicity angle α – between π_s and π_a in $D^{*\pm}$ rest frame

$dN/d\cos\alpha \sim 1 + h\cos^2\alpha$, h=?

HQET predicts:

h = 3 for $D_1(2420)^0$

h = -1 for $D_2^*(2460)^0$

h = 0 for $D_1(2430)^0$ (wide state)

$D_1(2420)^0$ contributions increases with $|\cos\alpha|$, dominates bump for $|\cos\alpha|>0.75$

Make simultaneous χ^2 fit of these four and M($D^{\pm}\pi$) histograms

fix ($\Gamma(D_2^{*0})$ = 43 MeV and $h(D_2^{*0})$=-1)

D_1^0, D_2^{*0} fit results

	EPJ.C.60 (2009) 25-42 HERA I	ZEUS PREL.10-016 HERA II	PDG
$M(D_1^0)$ MeV	$2420.5 \pm 2.1 \pm 0.9$	$2422.2 \pm 1.7^{+1.2}_{-2.8}$	2422.3 ± 1.3
$\Gamma(D_1^0)$ MeV	$53.2 \pm 7.2^{+3.3}_{-4.9}$	$43.4 \pm 6.2^{+7.3}_{-10.4}$	20.4 ± 1.7
$h(D_1^0)$	$5.9^{+3.0+2.4}_{-1.7-1.0}$	$3.5^{+1.6+2.0}_{-1.0-0.8}$	
$M(D_2^{*0})$ MeV	$2469.1 \pm 3.7^{+1.2}_{-1.3}$	$2465.0 \pm 3.3^{+1.2}_{-2.9}$	2461.1 ± 1.6
$\Gamma(D_2^{*0})$ MeV	43 fixed	43 fixed	43 ± 4
$h(D_2^{*0})$	-1 fixed	-1 fixed	

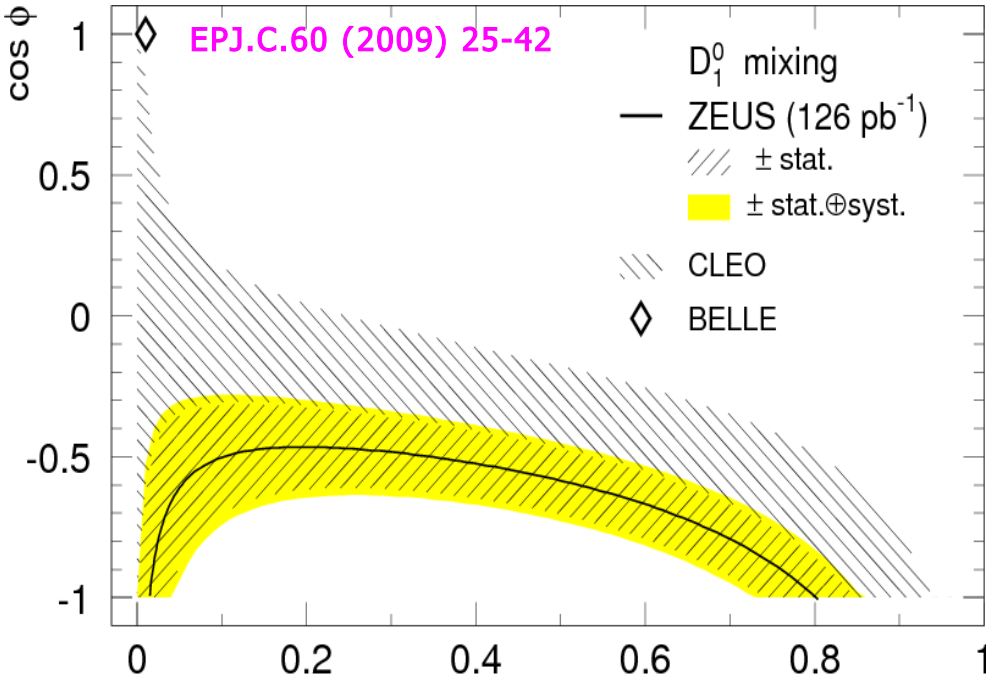
- ➔ HERA II prel. results confirm HERA I:
- ➔ Masses $M(D_1^0)$, $M(D_2^{*0})$: agree with PDG2008 values
- ➔ Helicity parameter $h(D_1^0)$:
  - ➔ inconsistent with pure S-wave decay, h=0
  - ➔ Consistent with HQET prediction for a pure D-wave decay, h=3
- ➔ Width $\Gamma(D_1(2420)^0)$: significantly above PDG2008 value

⇒ One possible explanation: larger s-wave admixture at ZEUS with respect to that in measurements with restricted phase space (e.g. Belle)

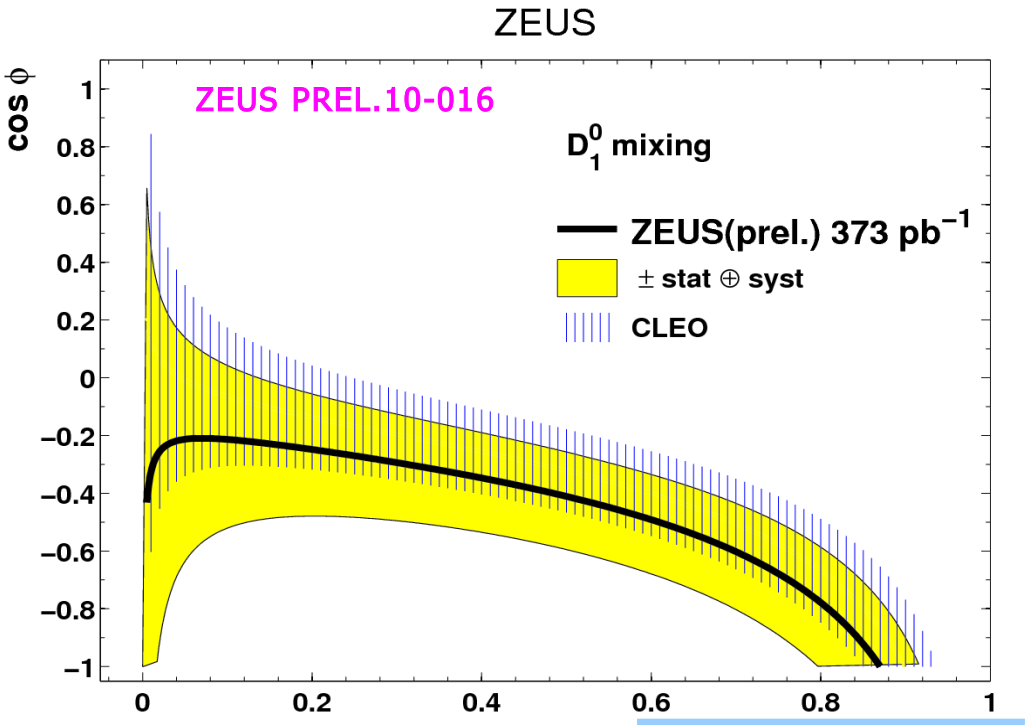
Mixing of D- and S-waves for $D_1(2420)^0$

Relative phase ϕ between D and S wave amplitudes can be expressed for given ratio of partial widths $r = \Gamma_S/(\Gamma_S+\Gamma_D)$ as function of measured helicity h

$$\cos\phi = \frac{(3-h)/(3+h) - r}{2\sqrt{2r(1-r)}}$$



$r = \Gamma_S/(\Gamma_S+\Gamma_D)$



$r = \Gamma_S/(\Gamma_S+\Gamma_D)$

➔ ZEUS measurements favour negative cos ϕ

Conclusion

1. Measurements of charm fragmentation function ($D^{*\pm}$) at HERA:

➔ For events with hard scale: results & parameters ~consistent with e^-e^+ data
⇒ Fragmentation 

➔ For events at kinematic threshold: ⇒ results & parameters differ,
poor description by NLO QCD + standard fragmentation functions
⇒ need for refined theory description

2. Excited charm mesons at HERA

➔ New HERA II results on $D_1(2420)^0$ and $D_2^*(2460)^0$ consistent with HERA I

➔ $\Gamma(D_1^0)$ is larger than in measurements at other colliders/environments
(larger S-wave admixture?)