

Production of the excited charm mesons D_1^0 and D_2^{*0} at HERA

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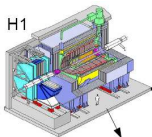
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on behalf of the **ZEUS** Collaboration

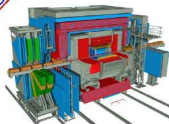
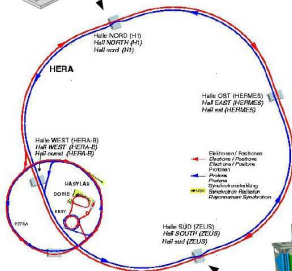
July 22, 2011

EPS – HEP 2011, Grenoble, Rhône-Alpes France July 21-27 2011



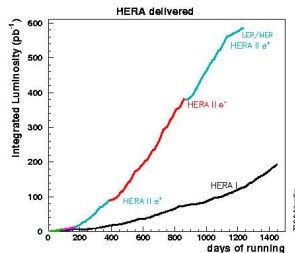


HERA collider



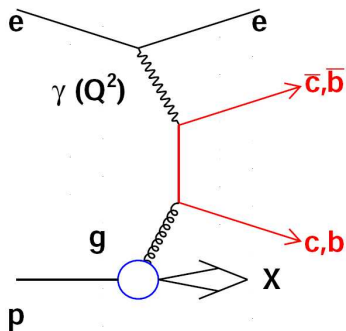
ZEUS

- Protons 920 GeV
- Electrons and positrons 27.6 GeV
- Operational: 1992 - 2007
- Two collider experiments: H1 and ZEUS
- ~500 pb^{-1} per experiment accumulated during HERA I and HERA II running periods



Luminosity

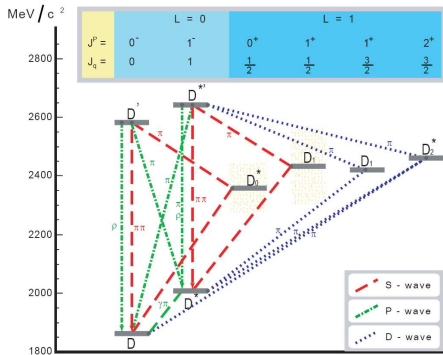
- HERA I: $\approx 126 \text{pb}^{-1}$
- HERA II: $\approx 370 \text{pb}^{-1}$



BGF (LO)

- Predominantly via Boson-Gluon Fusion (BGF)
- Well established ground state charm mesons D and D^*
- Charm cross section is high enough to study excited D mesons (EDM)

Theoretical predictions of EDMs



Godfrey and Isgur, 1985 (Heavy Quark Effective Theory **HQET**) – prediction of EDM states

- **Known 1P narrow** D_1, D_2^* states ($\Gamma \sim 30\text{MeV}$):
 - $D_1(2420) - J^\pi = 1^+$
 - $D_2^*(2460) - J^\pi = 2^+$
- **Poorly known 1P wide** D_0^*, D_1 states ($\Gamma \sim 300\text{MeV}$):
 - $D_0^*(2400) - J^\pi = 0^+$
 - $D_1(2430) - J^\pi = 1^+$
- **Poorly known or unknown** orbitally and radially excited states $D', D^{*'}$

$$D^{**} \rightarrow D^* \rightarrow D^0$$

$$D_1(2420)^0 \rightarrow D^{*\pm} \pi_a^\mp$$

$$D^{*\pm} \rightarrow D^0 \pi_s^\pm$$

$$D^0 \rightarrow K^\mp \pi^\pm$$

$$D_2^*(2460)^0 \rightarrow D^{*\pm} \pi_a^\mp$$

$$D^{*\pm} \rightarrow D^0 \pi_s^\pm$$

$$D^0 \rightarrow K^\mp \pi^\pm$$

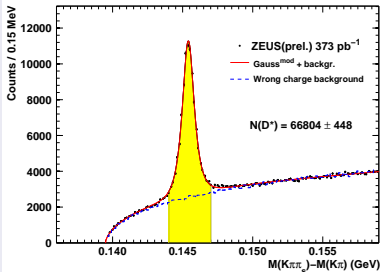
$$D^{**} \rightarrow D^\pm$$

$$D_2^*(2460)^0 \rightarrow D^\pm \pi_a^\mp$$

$$D^\pm \rightarrow K^\mp \pi^\pm \pi^\pm$$

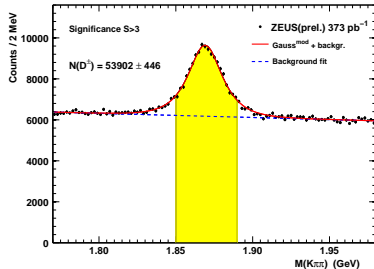
$$D^{*\pm} \rightarrow D^0(K\pi)\pi_s$$

ZEUS

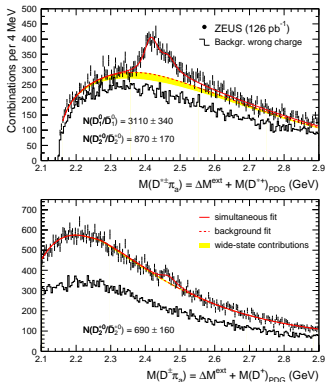


$$D^\pm \rightarrow K\pi\pi$$

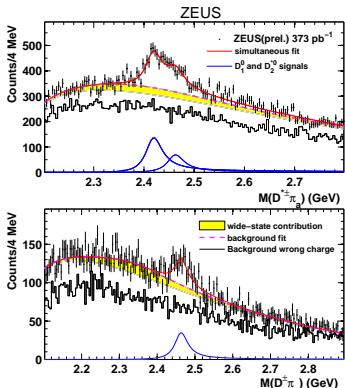
ZEUS



HERA I



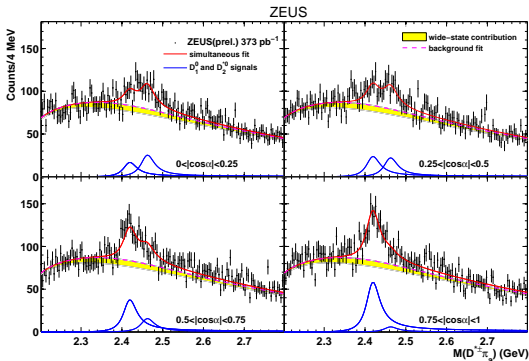
HERA II (prelim)



- Published: DESY-08-093; EPJ C 60(2009)25-45
- $D^{**} \rightarrow D^* \rightarrow D^0(K\pi), D^0(K\pi\pi\pi)$

- $D^{\pm}\pi$ signal – much better because of installed micro-vertex detector (MVD)
- $D^{**} \rightarrow D^* \rightarrow D^0(K\pi)$

Simultaneous fit of $D^*\pi$ mass spectra in 4 helicity bins



- Fitted $D_1(2420)^0$ and $D_2^*(2460)^0$ signals – relativistic Breit-Wigner functions ($\bar{L} = 2$)
- Fitted wide state, $D_1(2430)^0$ – relativistic Breit-Wigner functions (mass and width fixed according to PDG, $L = 0$)

- Helicity angular parametrisation

$$\frac{dN}{d \cos \alpha} \propto 1 + h \cos^2 \alpha$$

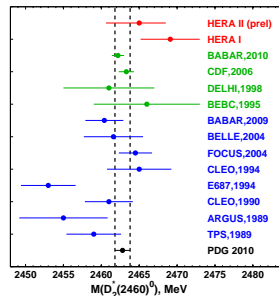
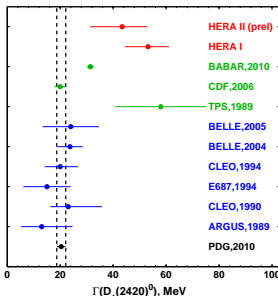
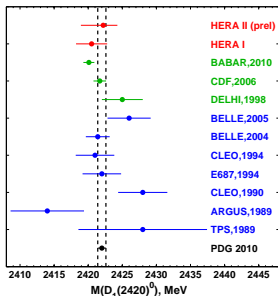
- α – an angle between π_a and π_s momenta in the $D^{*\pm}$ rest frame
- h – helicity parameter

- HQET predicts:

- $h = 3$ for the 1^+ ($j = 3/2$):
 $D_1(2420)^0$ (pure D -wave)
- $h = -1$ for the 2^+ ($j = 3/2$):
 $D_2^*(2460)^0$ (pure D -wave)
- $h = 0$ for the 1^+ ($j = 1/2$):
wide $D_1(2430)^0$ (pure S -wave)

$D_1(2420)^0$ and $D_2^*(2460)^0$ fit results and comparison

Parameter	HERA I	HERA II (prelim)	BABAR,2010	PDG,2010	PDG,2011
$M(D_1^0)$, MeV	$2420.5 \pm 2.1(stat) \pm 0.9(syst)$	$2422.2 \pm 1.7(stat)_{-2.8}^{+1.2}(syst)$	$2420.1 \pm 0.1(stat) \pm 0.8(syst)$	2422.0 ± 0.6	2421.3 ± 0.6
$\Gamma(D_1^0)$, MeV	$53.2 \pm 7.2(stat)_{-4.9}^{+3.3}(syst)$	$43.4 \pm 6.2(stat)_{-10.4}^{+7.3}(syst)$	$31.4 \pm 0.5(stat) \pm 1.3(syst)$	20.4 ± 1.7	27.1 ± 2.7
$h(D_1^0)$	$5.9_{-1.7}^{+3.0}(stat)_{-1.0}^{+2.4}(syst)$	$3.5_{-1.0}^{+1.6}(stat)_{-0.8}^{+2.0}(syst)$	5.72 ± 0.25	–	5.72 ± 0.25
$M(D_2^{*0})$, MeV	$2469.1 \pm 3.7(stat)_{-1.3}^{+1.2}(syst)$	$2465.0 \pm 3.3(stat)_{-2.9}^{+1.2}(syst)$	$2462.2 \pm 0.1(stat) \pm 0.8(syst)$	2462.8 ± 1.0	2462.6 ± 0.7
$\Gamma(D_2^{*0})$, MeV	43 (fixed)	43 (fixed)	$50.5 \pm 0.6(stat) \pm 0.7(syst)$	42.9 ± 3.1	49.0 ± 1.4
$h(D_2^{*0})$	-1 (fixed)	-1 (fixed)	-1	–	–



Points: blue – included into PDG2010 averaging, green and red (ZEUS) – not included

The general case of D - and S -wave mixing of 1^+ state:

$$\frac{dN}{d \cos \alpha} \propto r + (1 - r)(1 + 3 \cos^2 \alpha)/2 + \sqrt{2r(1 - r)} \cos \phi (1 - 3 \cos^2 \alpha),$$

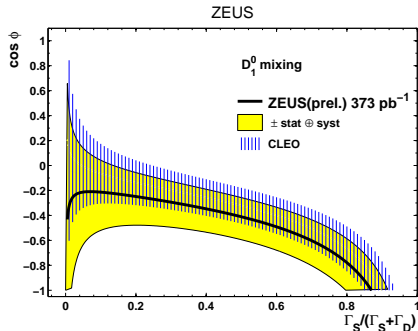
where

- $r = \frac{\Gamma_S}{\Gamma_S + \Gamma_D}$

- ϕ – the relative phase between two amplitudes

$\cos \phi$ can be expressed in terms of r and the measured helicity parameter, h :

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



- The production of the excited charm mesons $D_1(2420)^0$ and $D_2^*(2460)^0$ in ep collisions was measured with the ZEUS detector at HERA using an integrated luminosity of 373 pb^{-1} (HERAII)
- The masses, widths and helicity parameters of these resonances were determined and compared with previous measurements, with theoretical expectations and with published ZEUS results of an independent sample with an integrated luminosity of 126 pb^{-1} (HERAI)
- The measured $D_1(2420)^0$ width is found to be above the world average value in both cases, consistent with a recent BaBar high-statistics result
- The measured $D_1(2420)^0$ helicity parameter allows for some mixing of S - and D -waves in its decay to $D^*\pi$ however the result is also consistent with the prediction for a pure D -wave decay