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

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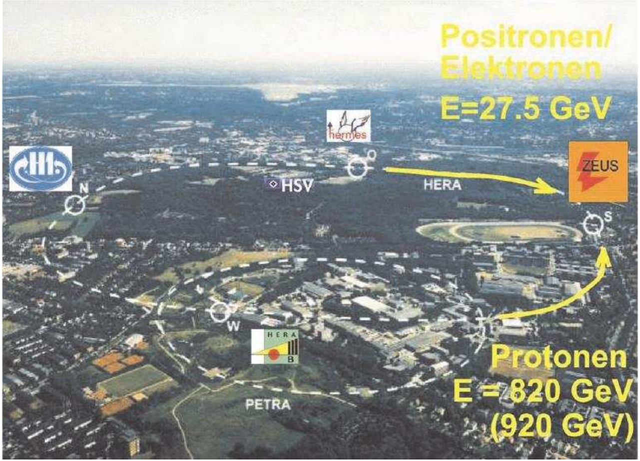
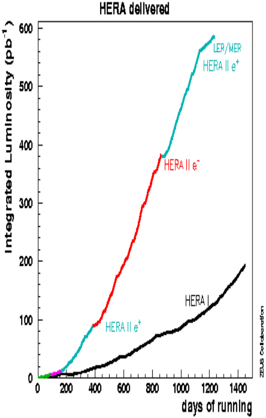
Outline

1. Introduction
2. $D_1^0(2420)$ and $D_2^{*0}(2460)$ spectroscopy and $D_1^0(2420)$ helicity analysis
3. Results
4. Conclusions

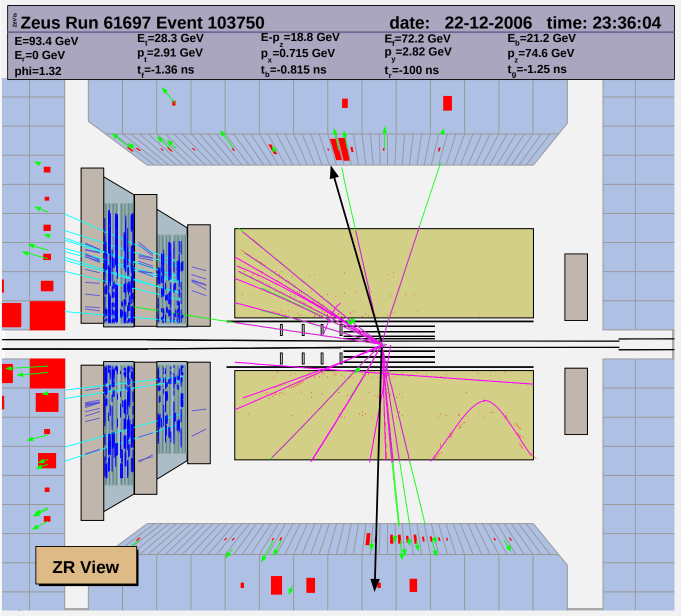
HERA Accelerator



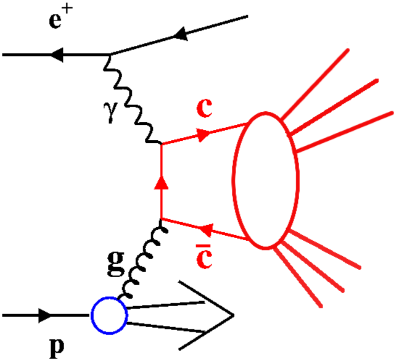


ZEUS taken: $\approx 126 pb^{-1}$ for HERA I, $\approx 370 pb^{-1}$ for HERA II.

The ZEUS Detector



Charm production at HERA



(c) Boson-Gluon-Fusion(LO)

Figure: BGF is a dominant process for charm production at HERA.

Motivation

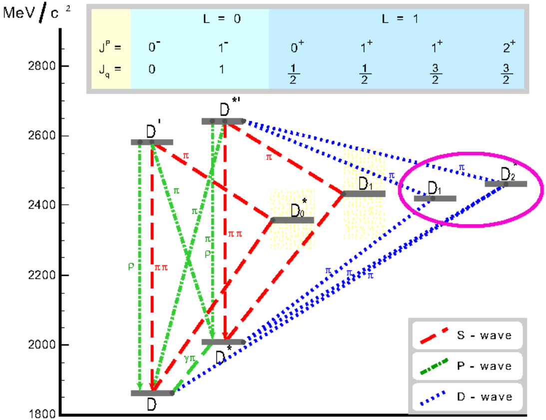
Many of excited D meson states were observed, but:

- some quantities of excited D mesons should be confirmed
- or are measured not precise enough
- some results from HERA I are in contradiction with world average results (PDG)

That is a motivation to measure:

- masses and widths
- quantum numbers
- fractions of decay waves

Spectrum of D mesons with L=0 and L=1 and their decays

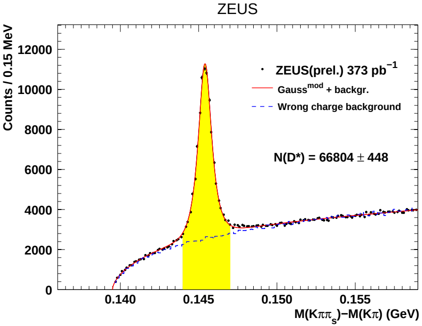


Note the mixing in decay waves.

Reconstructed decays:

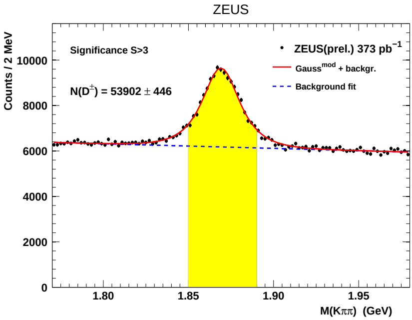
- $D_1^0(2420) \to \pi_a^{\mp} D^{*\pm};\ D^{*\pm} \to \pi_s^{\pm} D^0;\ D^0 \to K^{\mp}\pi^{\pm}$
- $D_2^{*0}(2460) \to \pi_a^{\mp} D^{*\pm};\ D^{*\pm} \to \pi_s^{\pm} D^0;\ D^0 \to K^{\mp}\pi^{\pm}$
- $D_2^{*0}(2460) \to \pi_a^{\mp} D^{\pm};\ D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm}$

$D^{*\pm}$ and $D^{\pm}$ signal reconstruction



$M(K\pi\pi_s) - M(K\pi)$ spectrum ($D^{*\pm}$ signal)

Δm technic used: $M(D^{*\pm}) - M(D^0)$



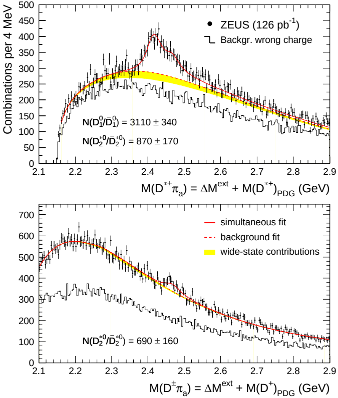
$M(K\pi\pi)$ spectrum ($D^{\pm}$ signal)

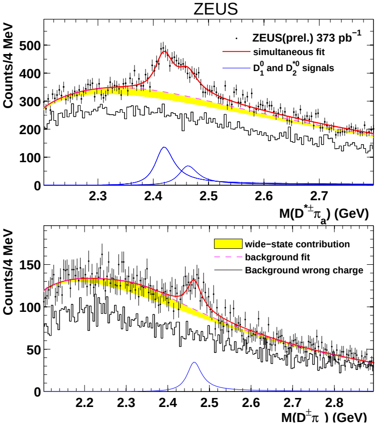
A cut on projected significance decay length S>3 used.

$$S = \frac{XY\ decay\ length\ projected\ onto\ momentum}{error\ of\ XY\ decay\ length\ in\ momentum\ direction}$$

$D_1^0(2420)$ and $D_2^{*0}(2460)$ signals from HERAI& HERAII

HERA I (published[1]) HERA II





HERA II vs. HERA I: much better $D^{\pm}\pi^{\mp}$ signal because of installed silicon tracker (MVD).

[1] ZEUS Collaboration; S. Chekanov et al. Production of excited charm and charm-strange mesons at HERA, DESY-08-093 (July 2008), European Physical Journal C 60 (2009) 25-42

S-D decay wave mixing measurement

For the general case of mixing D- and S- **decay waves** for mesons:

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

where

$\boldsymbol{r = \Gamma_S/(\Gamma_S + \Gamma_D)}$, $\Gamma_{S/D}$ is the S-/D-wave partial width,

$\boldsymbol{\phi}$ is the relative phase between the two amplitudes,

$\boldsymbol{\theta}$ is an angle between π_a and π_s in $D^{*\pm}$ rest frame.

This expression can be parametrised as:

$$dN/d(cos\theta) \approx 1 + h(r,\phi)cos^2\theta \quad (2)$$

HQET prediction:

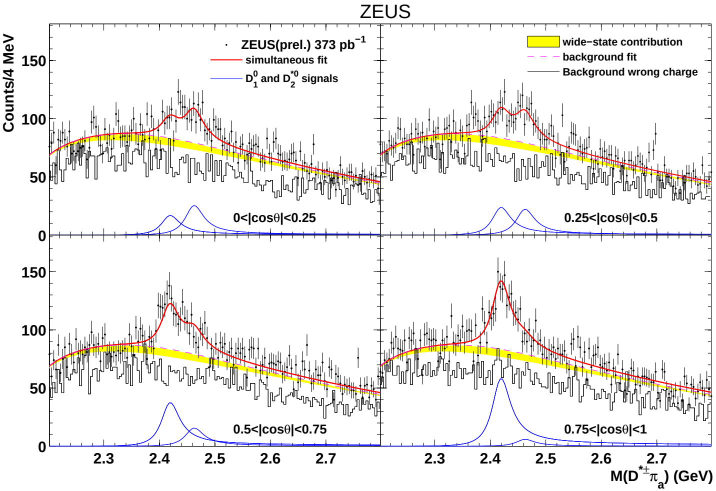
h=3 for $D_1^0(2420)$ pure D-wave

h=-1 for $D_2^{*0}(2460)$ pure D-wave

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

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

Simultaneous fit of mass spectra in $|cos\theta|$ bins



The fit includes the 4 $D^{*\pm}\pi_a^{\mp}$ helicity bins and the $D^{\pm}\pi^{\mp}$ spectrum.

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

	$HERAI$[1]	$HERAII$	$PDG2008$[2]	$BABAR$[3]
$M(D_1^0)$, MeV/c^2	$2420.5 \pm 2.1(stat)^{+0.9}_{-0.9}(syst)$	$2422.2 \pm 1.7(stat)^{+1.20}_{-2.8}(syst)$	2422.3 ± 1.3	$2420.1 \pm 0.1 \pm 0.8$
$\Gamma(D_1^0)$, MeV/c^2	$53.2 \pm 7.2(stat)^{+3.3}_{-4.9}(syst)$	$43.4 \pm 6.2(stat)^{+7.3}_{-10.4}(syst)$	20.4 ± 1.7	$31.4 \pm 0.5 \pm 1.3$
$h(D_1^0)$	$5.9^{+3.0}_{-1.7}(stat)^{+2.4}_{-1.0}(syst)$	$3.5^{+1.6}_{-1.0}(stat)^{+2.0}_{-0.8}(syst)$		5.72 ± 0.25
$M(D_2^{0*})$, MeV/c^2	$2469.1 \pm 3.7^{+1.2}_{-1.3}$	$2465.0 \pm 3.3(stat)^{+1.2}_{-2.9}(syst)$	2461.1 ± 1.6	$2462.2 \pm 0.1 \pm 0.8$
$\Gamma(D_2^{0*})$, MeV/c^2	$43(fixed)$	$43(fixed)$	43 ± 4	$50.5 \pm 0.6 \pm 0.7$
$h(D_2^{0*})$	$-1(fixed)$	$-1(fixed)$		

[2] The Review of Particle PhysicsC. Amsler et al. (Particle Data Group), Physics Letters B667, 1 (2008)

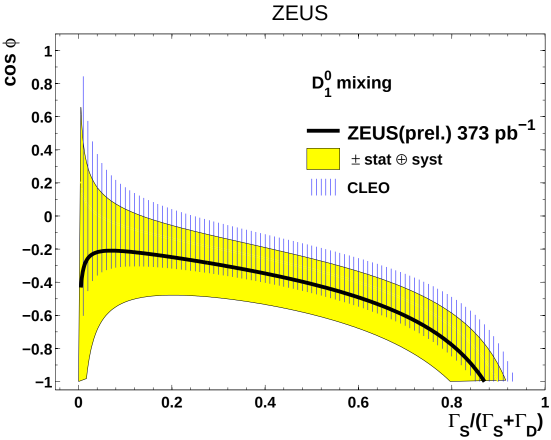
[3] BABAR Collaboration, P. del Amo Sanchez, et al, Observation of new resonances decaying to $D\pi$ and $D^*\pi$ in inclusive e^+e^- collisions near $\sqrt{s}$ =10.58 GeV, Phys.Rev.D82:111101, 2010

The S-D wave mixing parameters constrain D_1^0

$r = \Gamma_S/(\Gamma_S + \Gamma_D)$, where $\Gamma_{S/D}$ is the S-/D-wave partial width

ϕ is the relative phase between the two amplitudes

$$\cos\phi = \frac{(3-h)/(3+h) - r}{2\sqrt{2r(1-r)}}. \qquad (4)$$



Conclusions

- $D_1^0(2420)/D_2^{*0}(2460)$ signals measured in $D^{*\pm}\pi/D^{\pm}\pi$ spectra
- masses and widths were studied for $D_1^0(2420)$ and $D_2^{*0}(2460)$ mesons; S-D wave mixing was studied for $D_1^0(2420)$
  - $M(D_1^0)$ and $M(D_2^{*0})$ close to PDG
  - $\Gamma(D_1^0)$ is larger than PDG, which confirms HERA I and recent BABAR results
  - helicity analysis results are compatible with S-D wave mixing

$D^{*\pm}\pi$ and $D^{\pm}\pi$ mass spectra fit

The fit function components:

- relativistic Breit-Wigner functions multiplied by normalized helicity functions for $D_1^0(2420)$ and $D_2^{*0}(2460)$ signals in $D^{*\pm}\pi$ spectrum
- three parameter background $Ay^B e^{-yC}$ for $D^{\pm}\pi$ spectrum, where $y = M(D^{**}) - M(D^{*\pm})_{PDG} - M(\pi^+)_{PDG}$.
- relativistic Breit-Wigner function for $D_2^{*0}(2460)$ signal in $D^{\pm}\pi$ spectrum
- three parameter background $Ay^B e^{-yC}$ for $D^{\pm}\pi$ spectrum, where $y = M(D^{**}) - M(D^{+})_{PDG} - M(\pi^+)_{PDG}$.
- $D_2^{*0}(2400)$ and $D_1^0(2300)$ "wide" states

Extra sources

The picture on page 7:

Stefano Bianco, arXiv:hep-ex/0512073v3, 2006