Charm with ZEUS HERA-II data

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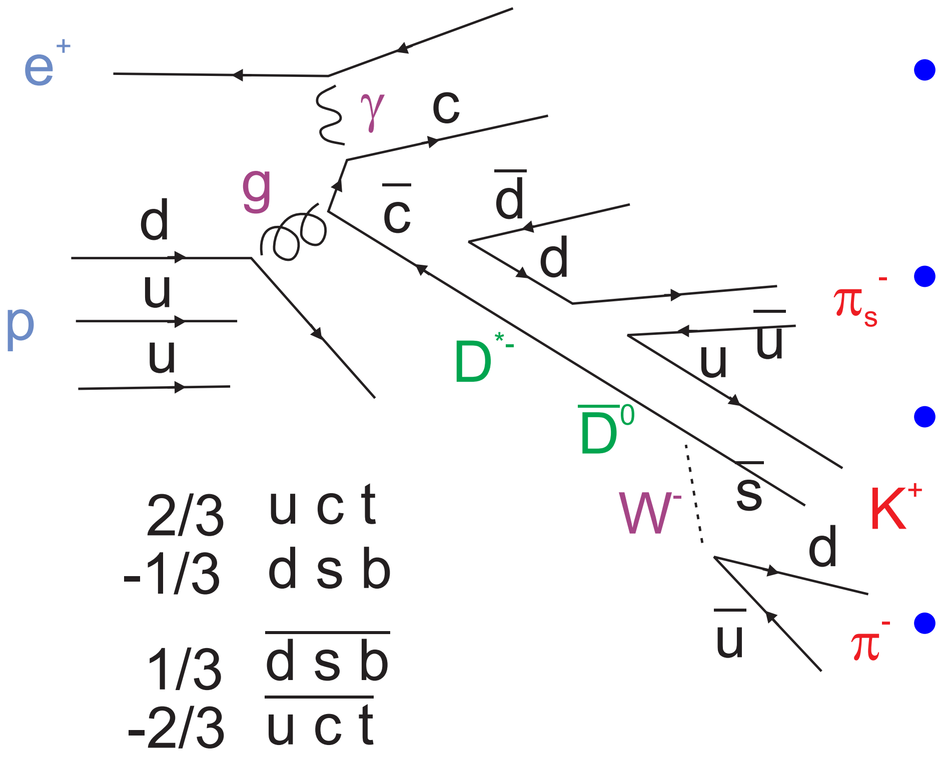
DIS 2006 – 21th April 2006 – HF-2

Outline:

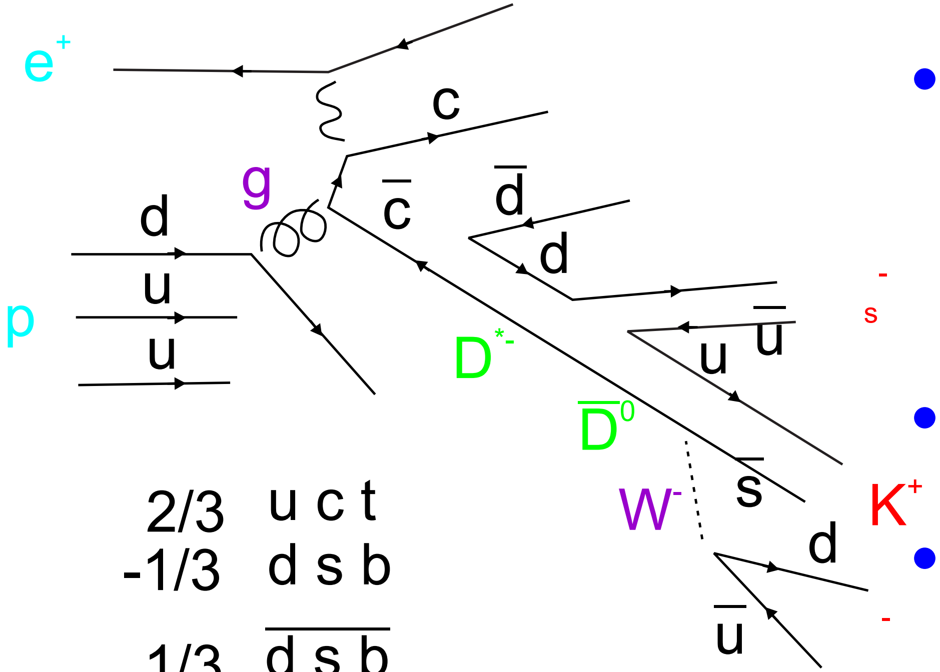
- $D^{*\pm}$ mesons in deep inelastic scattering
- D^{0} decay length significance
- $D^{\pm}$ mesons in deep inelastic scattering

Charm search with $D^{*\pm}(2010) \rightarrow D^0(K^{\mp} + \pi^{\pm}) + \pi_s$



- Boson Gluon Fusion is the dominant process in DIS – gluon sensitivity
- open charm pair production
- fragmentation $\mathcal{F}(c, \bar{c} \rightarrow D^{*\pm}) = 0.197 \pm 0.012$
- charm deexcitation: Zweig rule - strong interaction, short lifetime $\mathcal{B}(D^{*\pm} \rightarrow D^0 \pi_s^{\pm}) = 0.677 \pm 0.005$

Charm search with $D^{*\pm}(2010) \rightarrow D^0(K^{\mp} + \pi^{\pm}) + \pi_s$



2/3	u c t
-1/3	d s b
1/3	$\overline{\text{d s b}}$
-2/3	$\overline{\text{u c t}}$

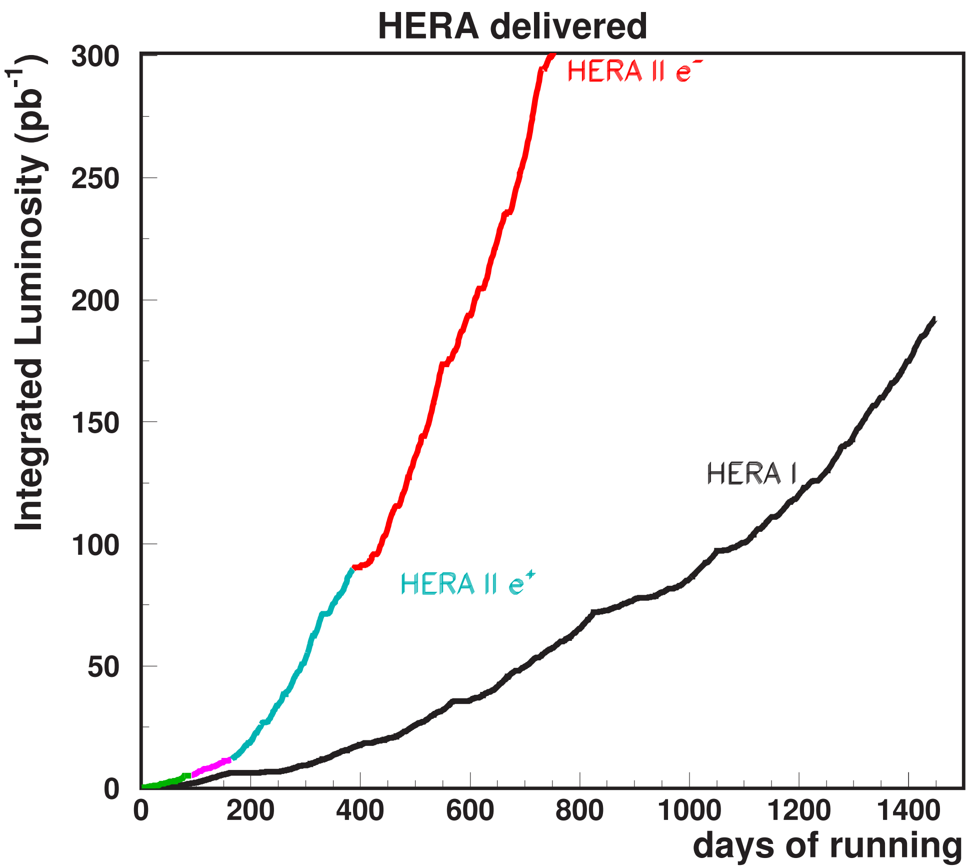
- charm ground state to strange state: weak interaction, longer lifetime $\mathcal{B}(D^{*\pm} \rightarrow D^0\pi_s^{\pm}) \times \mathcal{B}(D^0 \rightarrow K^{\mp}\pi^{\pm}) = 0.0380 \pm 0.0009$
- $\mathcal{F} \times \mathcal{B} = (0.51 \pm 0.13)\,\%$
- all elementary forces relevant for particle physics covered
- small phase space of about $6\,\mathrm{MeV}$ for slow $\pi_s^{\pm}$ limited by mass difference

HERA II

- HERA I 1996 - 2000,
  HERA II 2002 - 2007

- new elements are micro vertex detector (MVD) and straw tube tracker (STT) in HERA II

- gated ZEUS data $\mathcal{L}(e^+p) = 41\,\mathrm{pb}^{-1}$ and $\mathcal{L}(e^-p) \approx 160\,\mathrm{pb}^{-1}$ in HERA II



Selection criteria for $D^{*\pm}(2010) \rightarrow D^0(K^{\mp} + \pi^{\pm}) + \pi_s^{\pm}$

mass calculations done with all track combinations and mass assignment

primary vertex tracks

mass cuts:

$1.80\,\text{GeV} < M(D^0) < 1.92\,\text{GeV}$

$0.143\,\text{GeV} < \Delta M < 0.148\,\text{GeV}$

$\Delta M = M(K^{\mp}\,\pi^{\pm}\,\pi_s^{\pm}) - M(K^{\mp}\,\pi^{\pm})$

DIS cuts:

$5\,\text{GeV}^2 < Q^2 < 1000\,\text{GeV}^2$

$0.02 < y < 0.7$

$D^{*\pm}$ kinematic cuts:

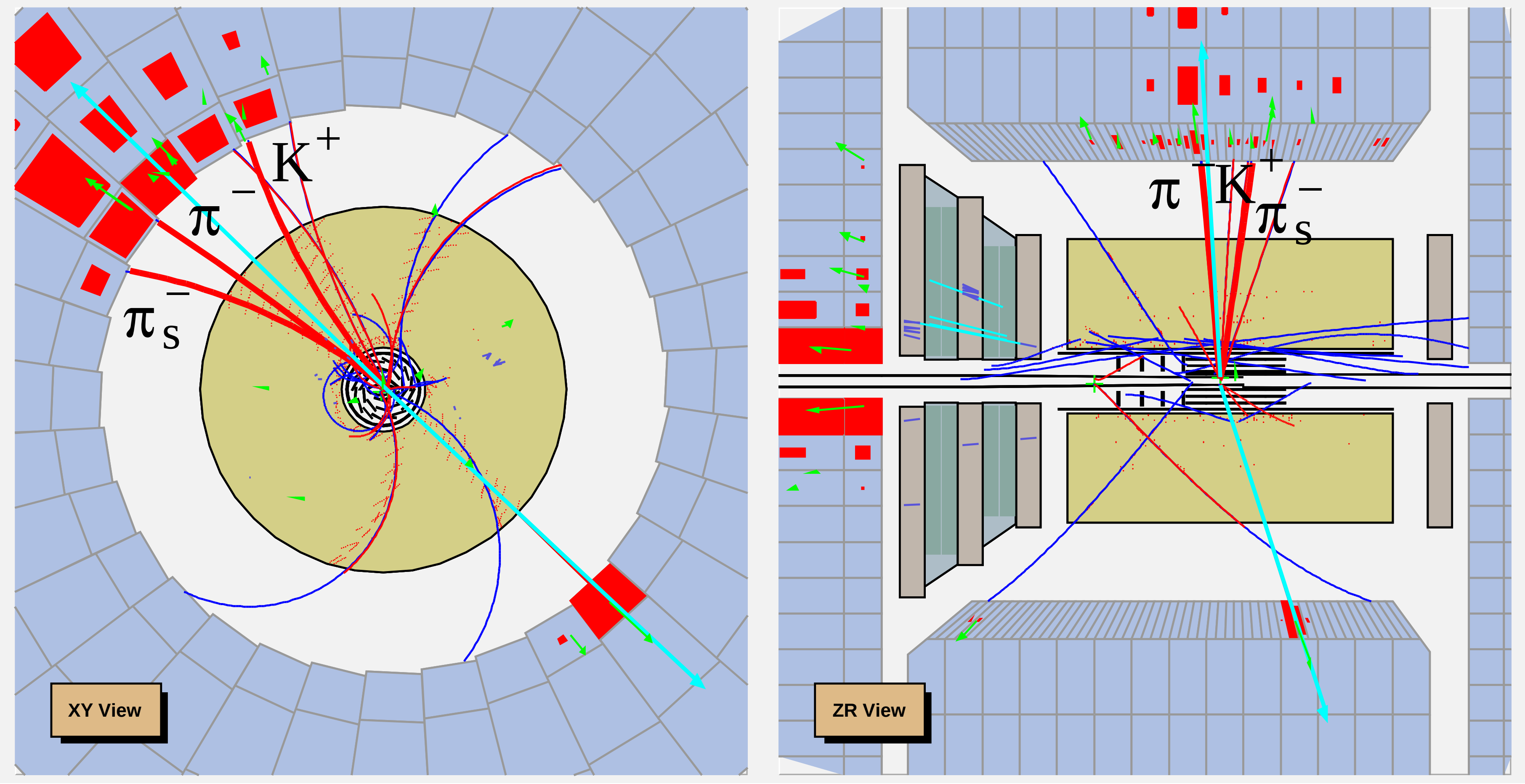
$1.5\,\text{GeV} < p_{\text{T}}(D^{*\pm}) < 15\,\text{GeV}$

$p_{\text{T}}(\text{K}) > 0.4\,\text{GeV}$

$p_{\text{T}}(\pi) > 0.4\,\text{GeV}$

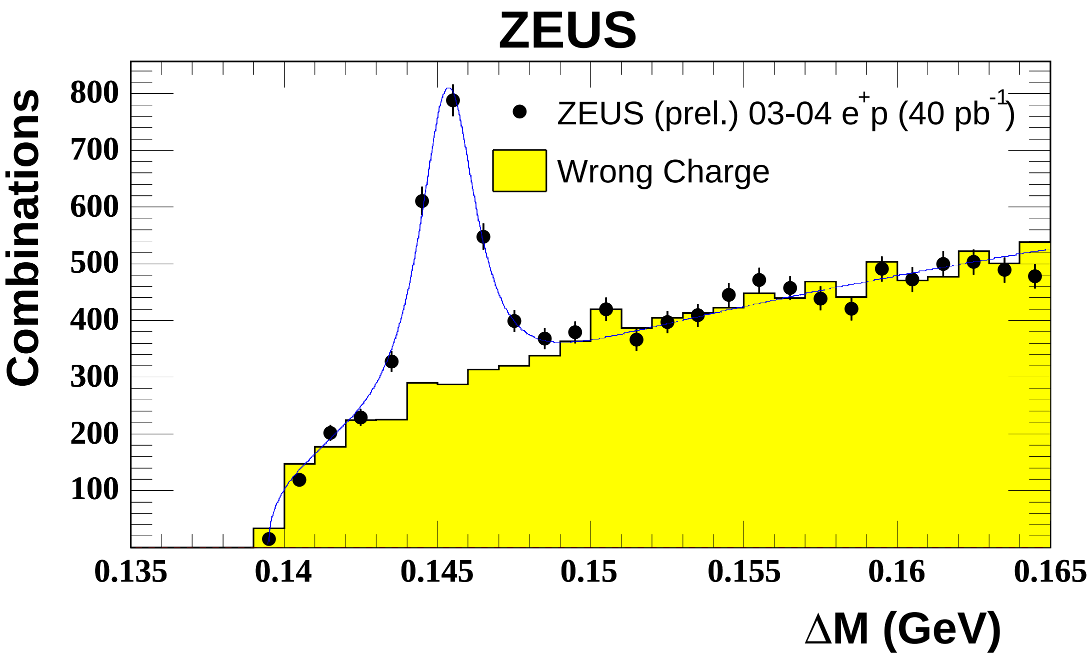
$p_{\text{T}}(\pi_s) > 0.12\,\text{GeV}$

$-1.5 < \eta_{D^{*\pm}} < 1.5$



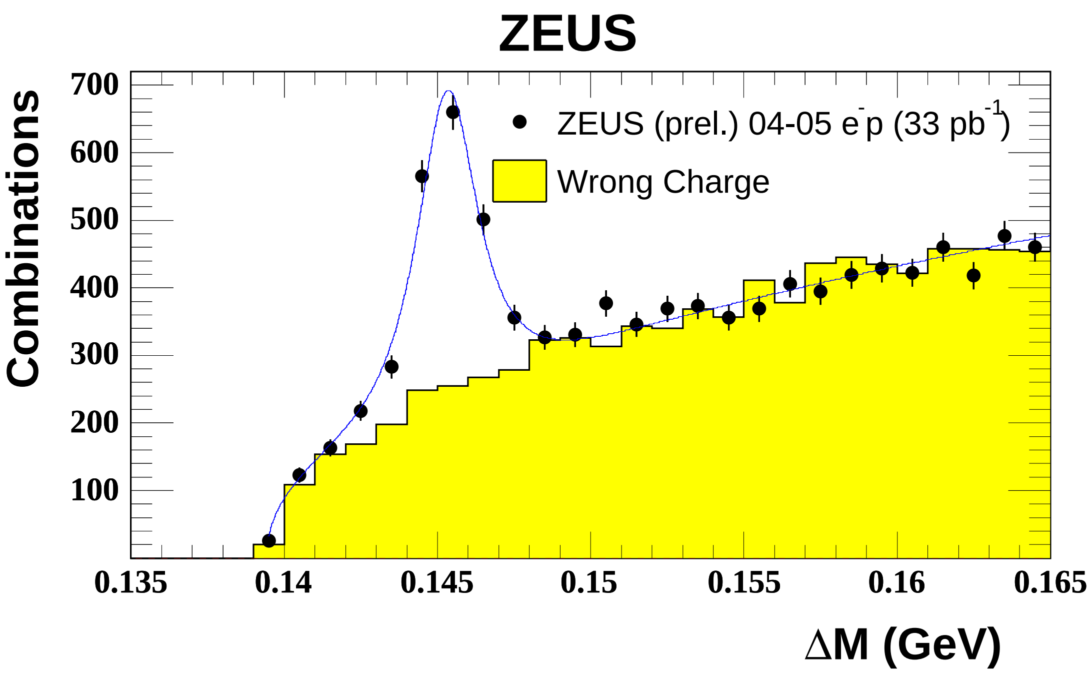
$$Q^2 = 918\,\mathrm{GeV}^2 \quad y = 0.39 \quad p_T(D^{*-}) = 10.3\,\mathrm{GeV} \quad \eta(D^{*-}) = 0.06$$
$$p_T(K^+) = 1.5\,\mathrm{GeV} \quad p_T(\pi^-) = 7.9\,\mathrm{GeV} \quad p_T(\pi_s^-) = 1.1\,\mathrm{GeV}$$

Positron scattering: $e^+ + p \to D^{*\pm} + X$



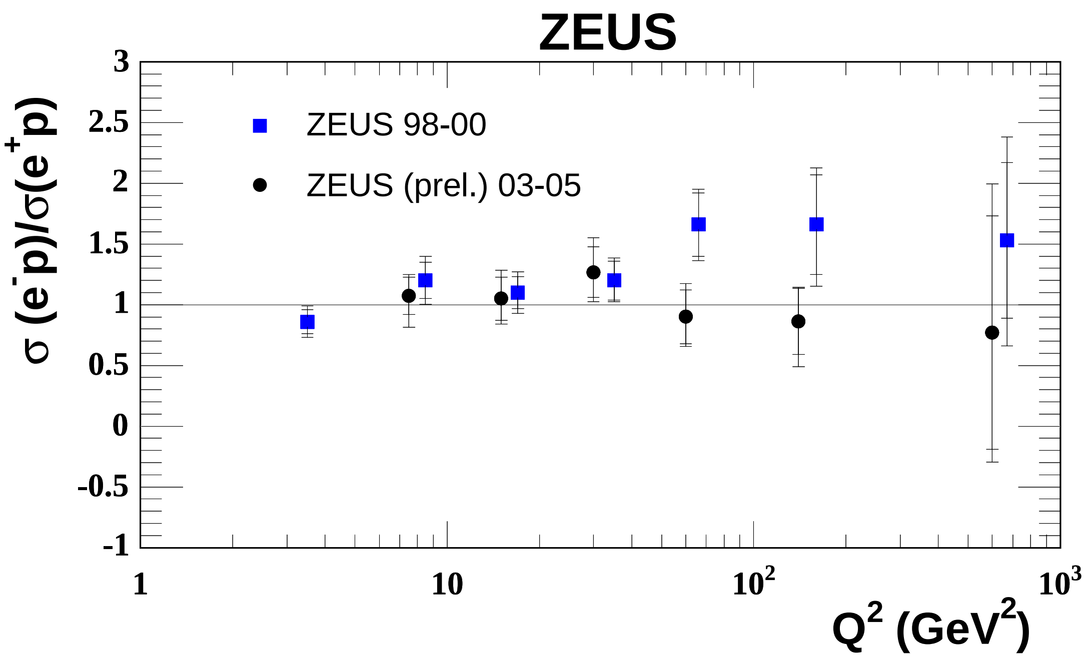
- subtraction of correlated errors gives a narrow signal
- invariant mass difference peaks around the rest mass of π_s $(139\,\mathrm{MeV})$ plus its kinematic energy
- background subtraction method to get the number of candidates $N_{rec} = N_{sig} - N_{back}$
- luminosity $\mathcal{L} = 40\,\mathrm{pb}^{-1}$

Electron scattering: $e^- + p \to D^{*\pm} + X$



- luminosity $\mathcal{L} = 33\,\mathrm{pb}^{-1} \to$ only a fraction of the current data

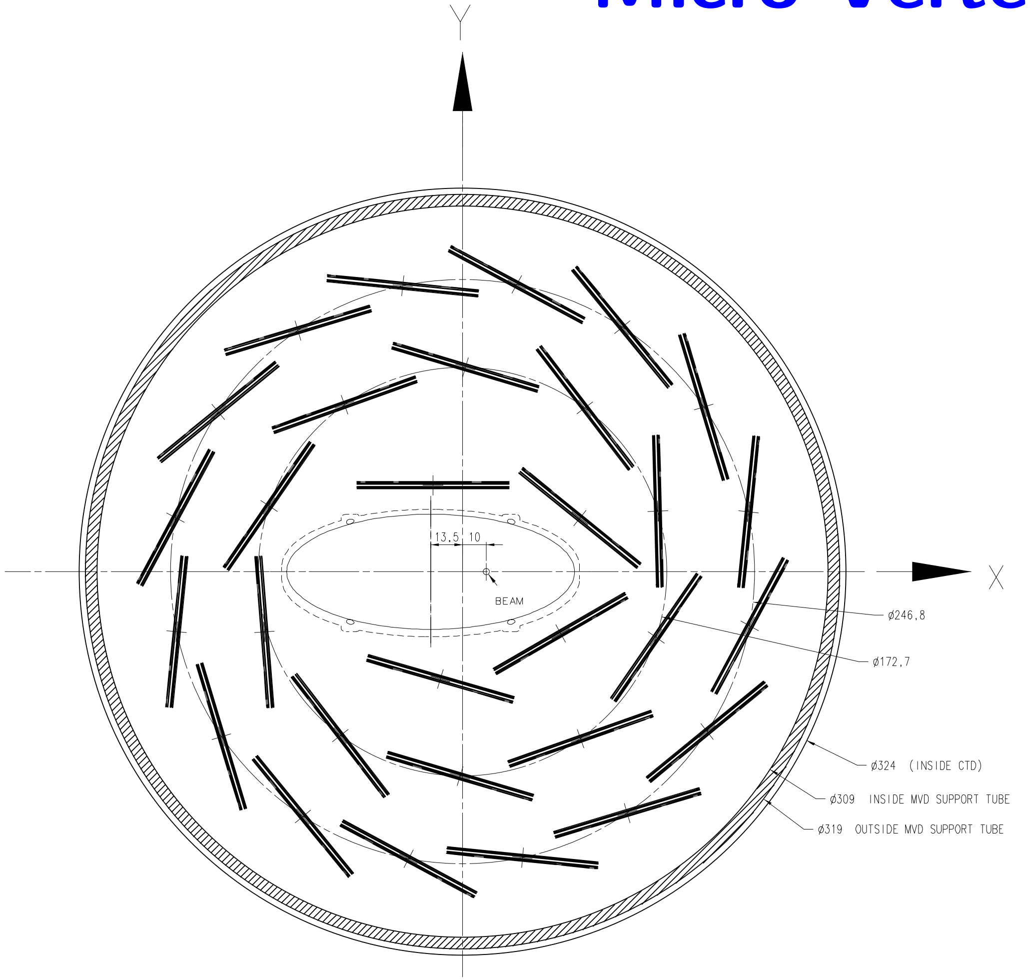
Ratio between $\sigma(e^- p)$ and $\sigma(e^+ p)$ cross-sections



- lower limit in Q^2 shifted from $1.5\,\mathrm{GeV}^2$ to $5\,\mathrm{GeV}^2$
- HERA I data in Phys. Rev. D69: 012004, 2004 (hep-ex/0308068) given in blue $\mathcal{L}(e^- p) = 17\,\mathrm{pb}^{-1}$; $\mathcal{L}(e^+ p) = 65\,\mathrm{pb}^{-1}$
- HERA II data confirms that the excess in HERA I data was a statistical fluctuation

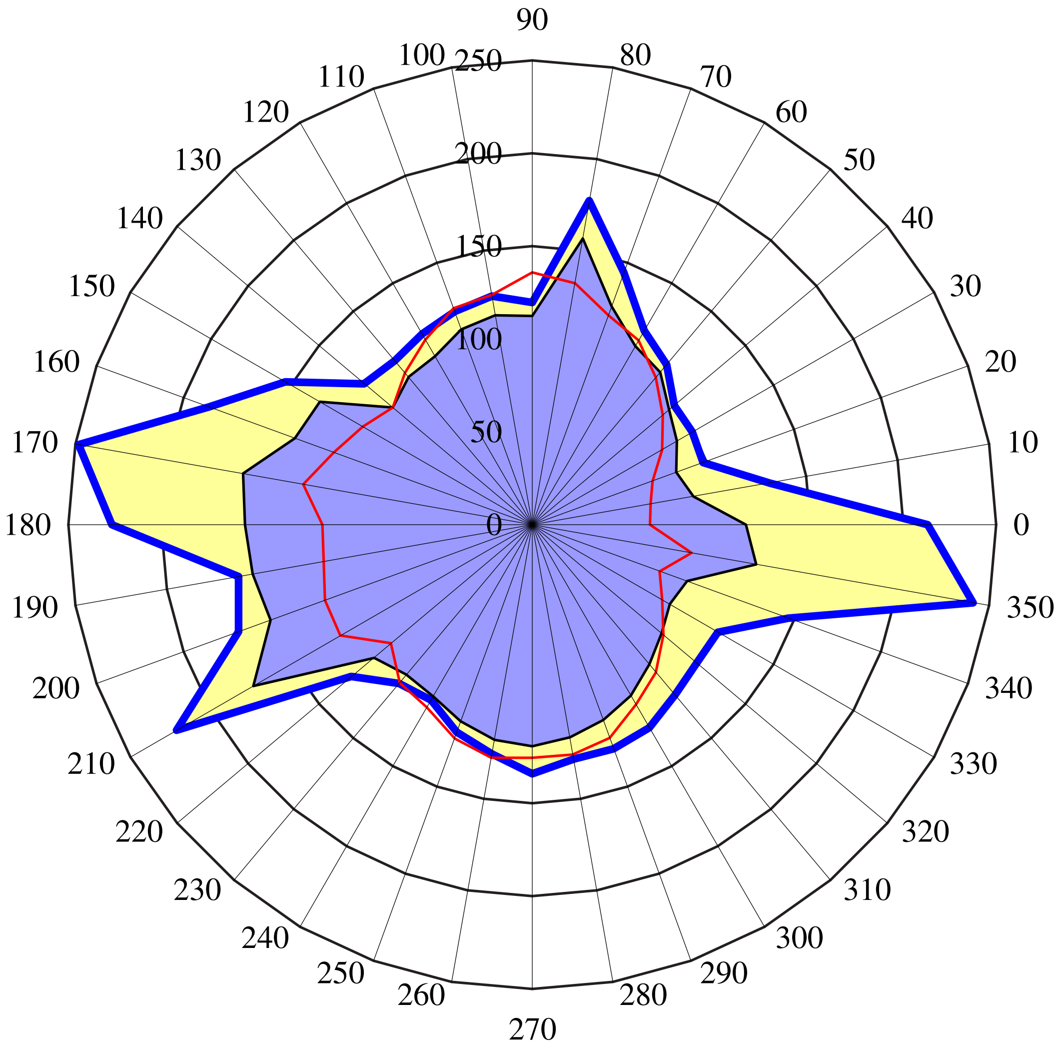
$\Rightarrow$ charm is produced equally in $e^+ p$ and $e^- p$ collisions

Micro Vertex Detector



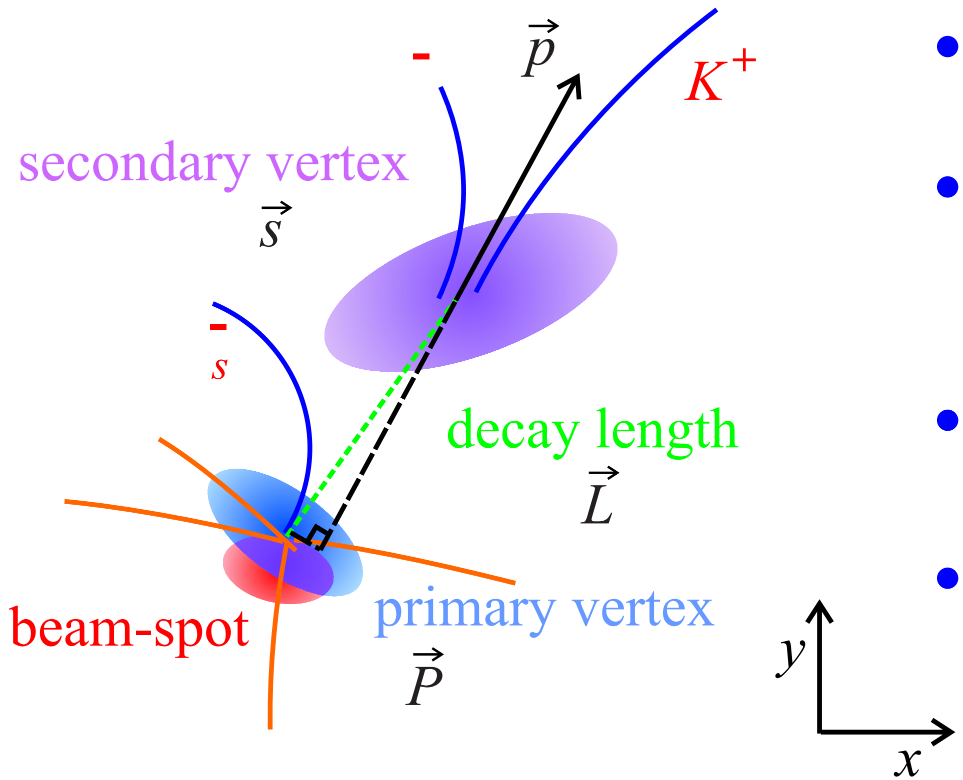
- two/ three barrel layers and four forward wheels
- $20\,\mu\mathrm{m}$ intrinsic hit resolution
- impact parameter resolution of about $100\,\mu\mathrm{m}$ is required for efficient charm tagging $\Rightarrow$ alignment accuracy of $20\,\mu\mathrm{m}$ needed

MVD alignment



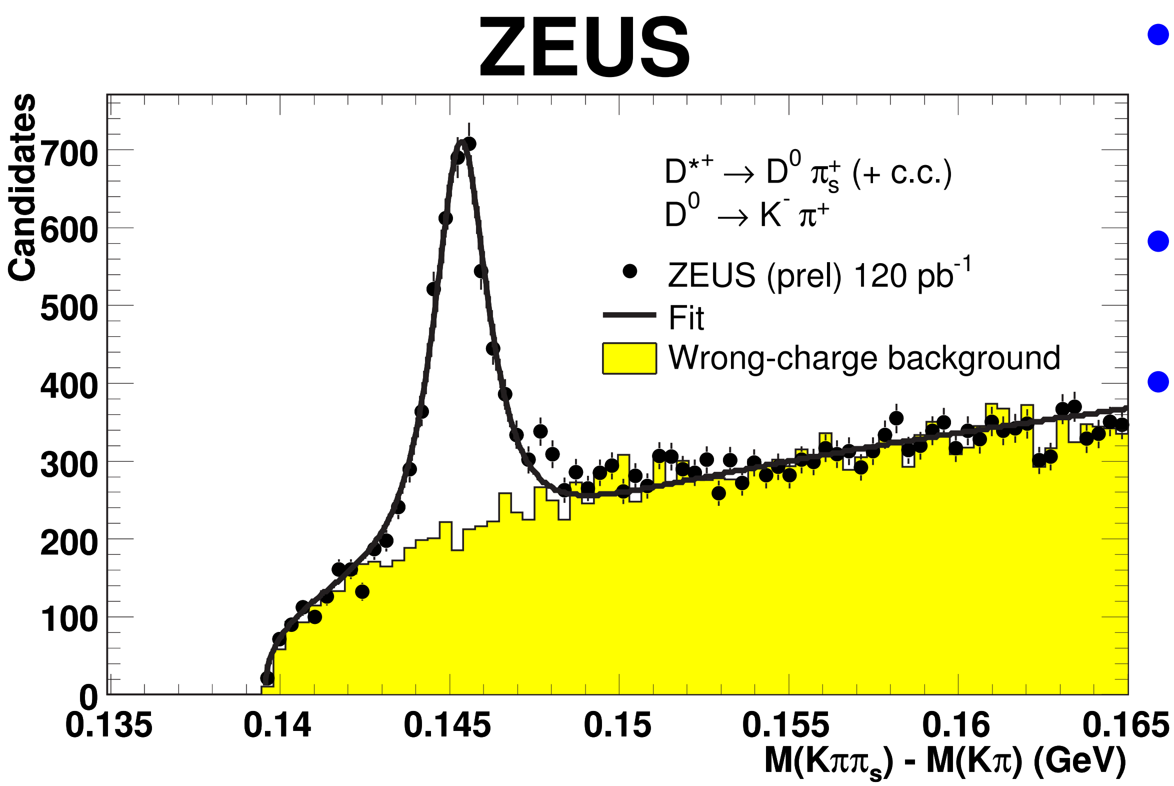
- impact parameter w.r.p. beam-spot in microns vs ϕ for high momentum tracks $p_T > 3\,\mathrm{GeV}$ in central region $|\eta| < 1$ of good quality min. 4 MVD hits $\Rightarrow$ natural spread of tracks in interaction region covered
- cosmic alignment in yellow
- ep collision tracks used for alignment in blue
- good agreement with MC given in red

Decay length significance



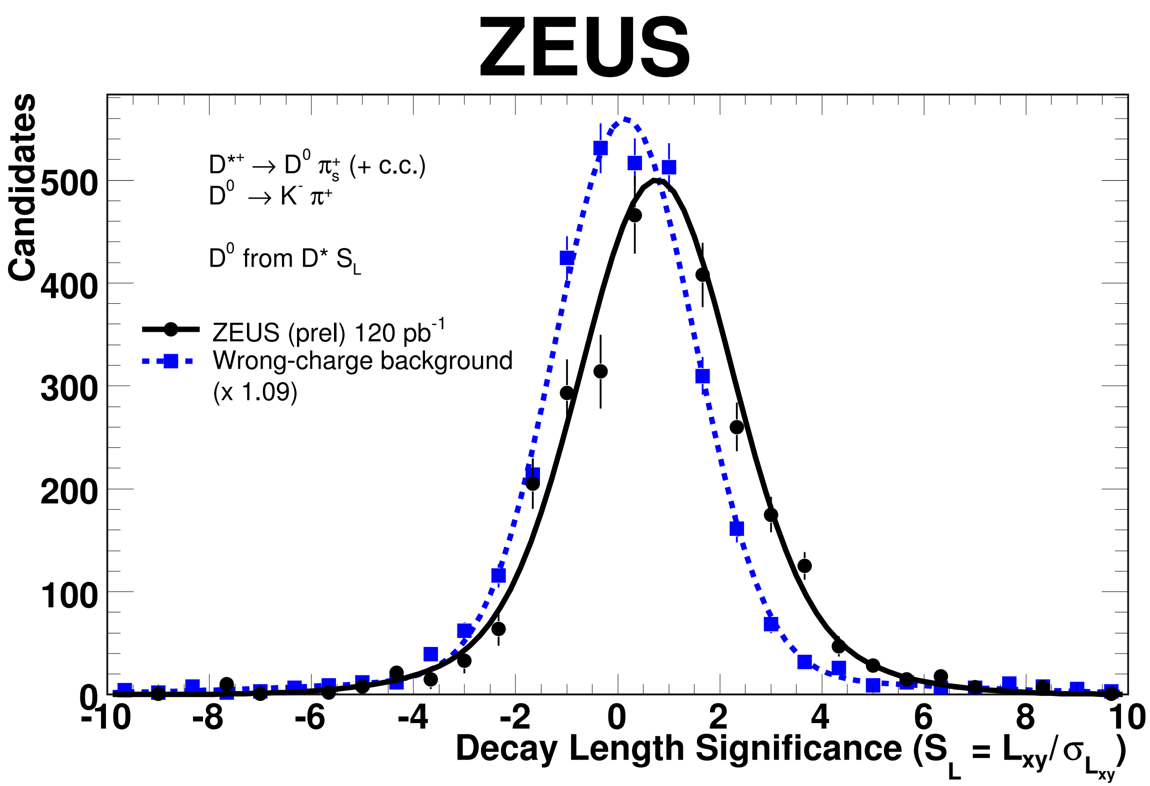
- decay length $\vec{L} = \vec{s} - \vec{P}$
- projection onto momentum in 2D
  $L_{xy} = \frac{(\vec{s}-\vec{P})\cdot\vec{p}(D^0)}{p_T(D^0)}$
- significance $s_L = \frac{L}{\sigma_L}$
- $\vec{P}$ = beam-spot gives higher precision than $\vec{P}$ = primary vertex

More data ...

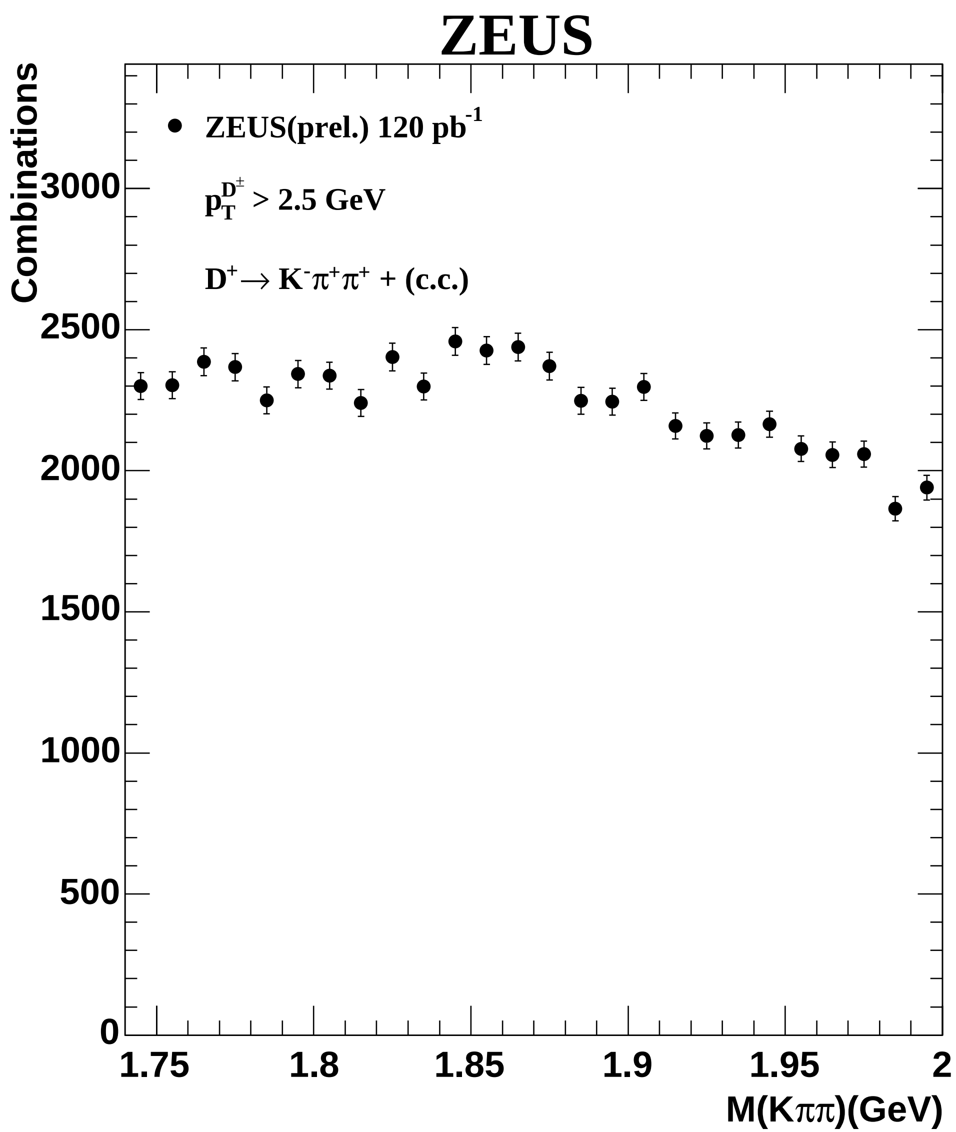


- current 2005 data added for the signal
- $\mathcal{L}(e^- p) = 120\,\mathrm{pb}^{-1}$
- signal width improved from $0.93\,\mathrm{MeV}$ to $0.76\,\mathrm{MeV}$ because of improved track fits

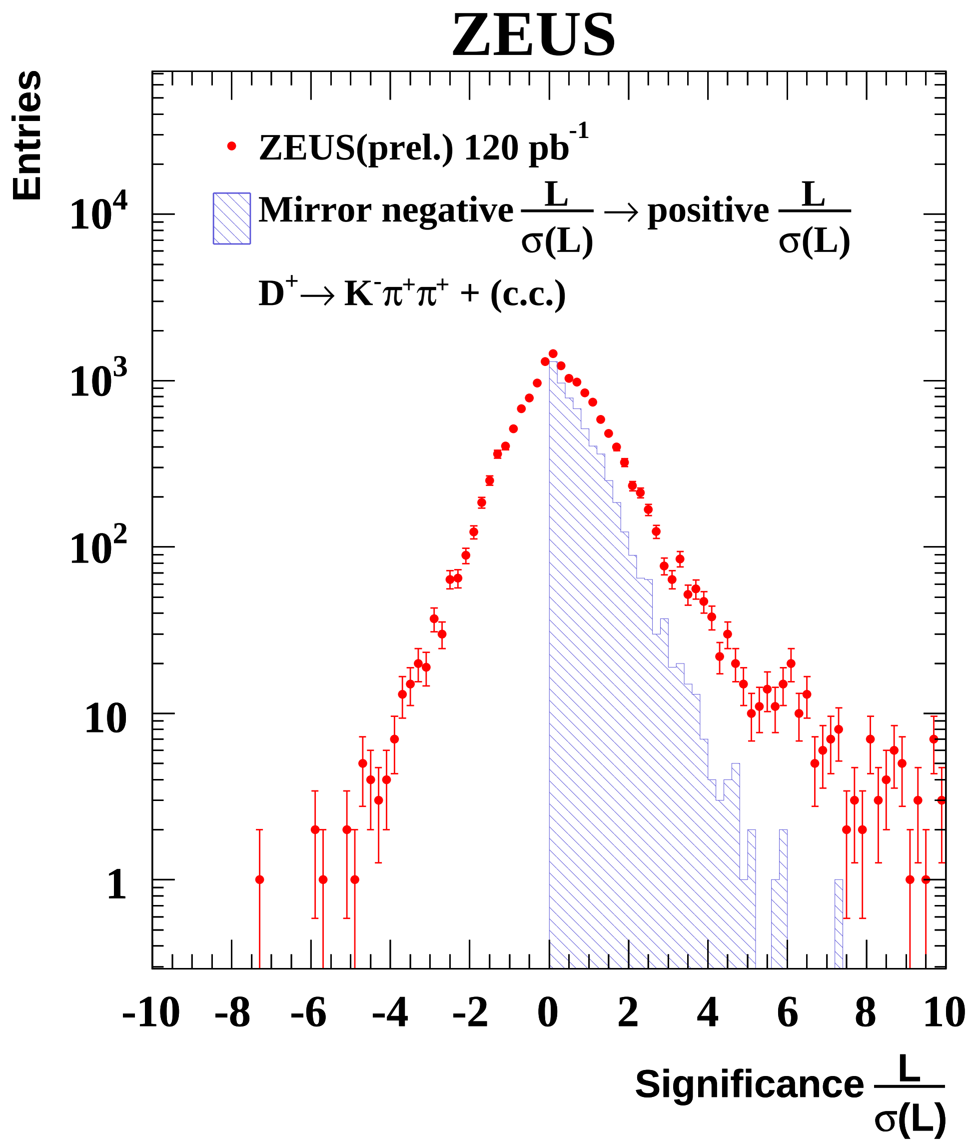
Decay length significance II



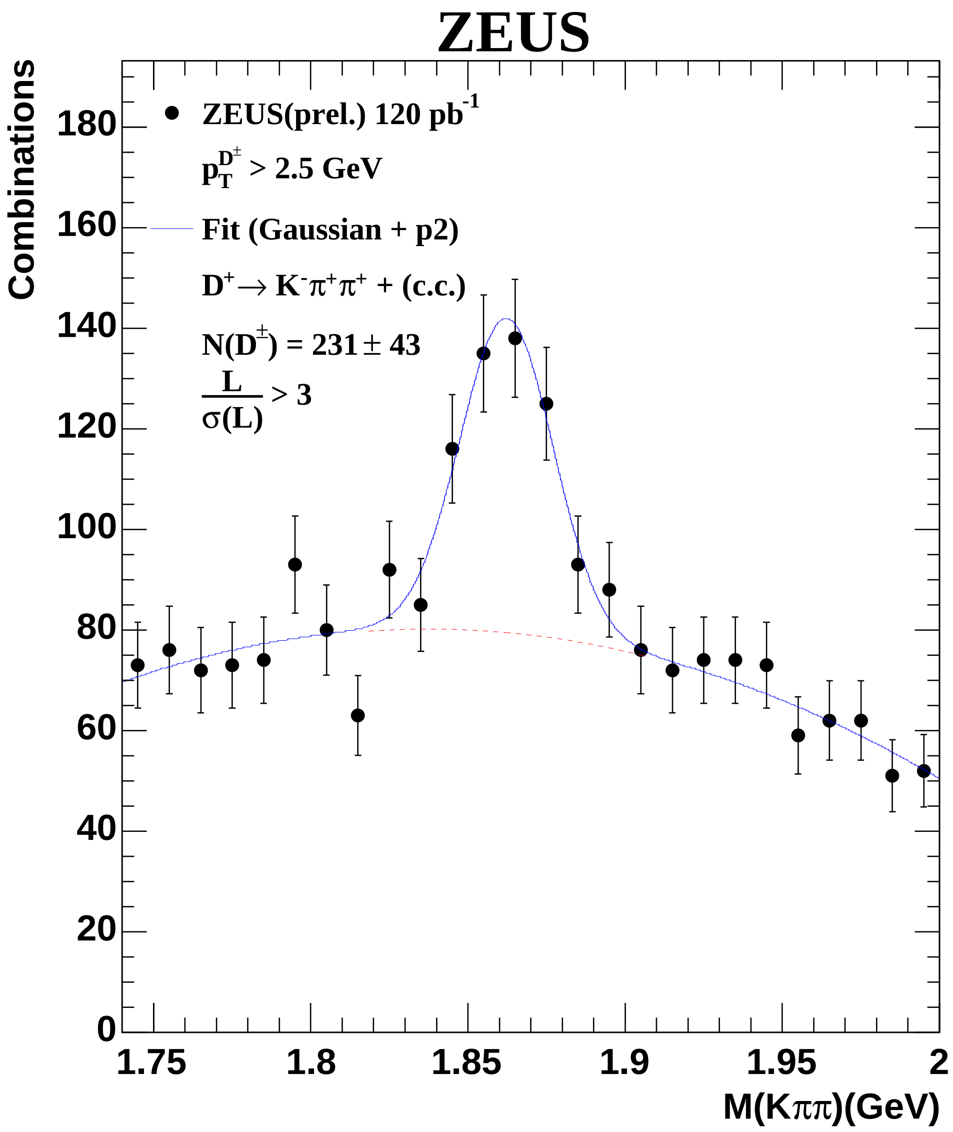
- D^0s taken from $D^{*\pm}$s
- wrong-charge background normalized to signal
- shift seen because of decay length $c\tau = 123\,\mu\mathrm{m}$
- exponential decay length distribution hidden by resolution effects, what is not a surprise



- same DIS cuts as for $D^{*\pm}s$
  $p_T(D^{\pm}) > 2.5\,\mathrm{GeV}$
  $p_T(K^{\mp}) > 0.65\,\mathrm{GeV}$
  $p_T(\pi^{\pm}) > 0.45\,\mathrm{GeV}$
- additional quality cut min. 4 MVD hits
- hardly any signal visible
- lifetime longer: $c\tau = 314\,\mu\mathrm{m}$

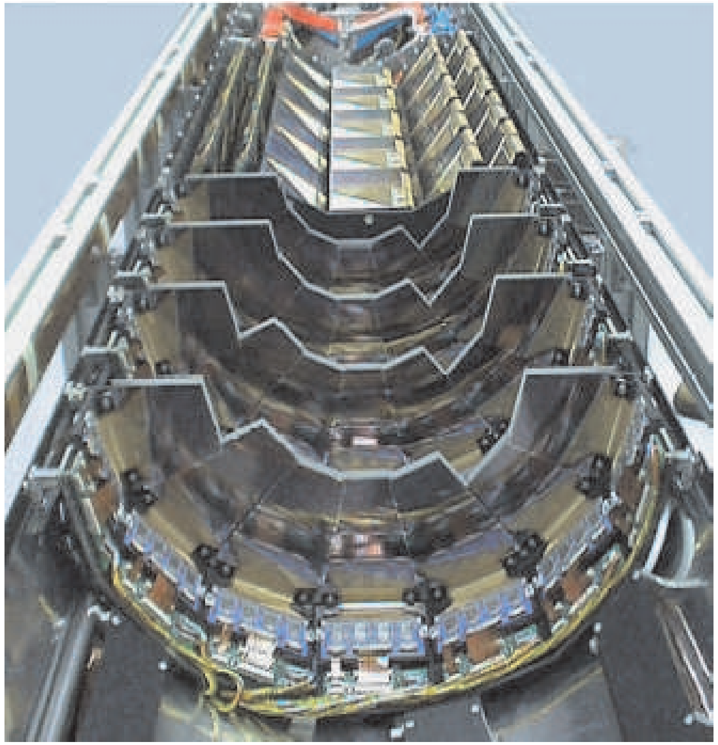


- negative side mirrored to the left $\Rightarrow$ enhancement
- signed decay length $L = |\vec{L}| \text{sign}(\vec{L} \cdot \vec{p}_{D^{\pm}})$
- cut $\frac{L}{\sigma(L)} > 3$ is used to enrich the signal



- big improvement
- background reduced by a factor of 30

Summary and outlook



- $D^{*\pm}$ cross-section ratio: HERA II data confirms that the excess in HERA I data was a statistical fluctuation
- decay length of D^0s from $D^{*\pm}s$ visible in decay length significance plot and could be used to clean up the signal
- further use of decay length significance for untagged D^0s
- decay length significance cut useful to reduce $\frac{s}{\sqrt{b}}$ for $D^\pm$ production