XXII. International Workshop on Deep-Inelastic Scattering and Related Subjects

Measurement of D* photoproduction at three different centre-of-mass energies at HERA

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on behalf of the
ZEUS collaboration

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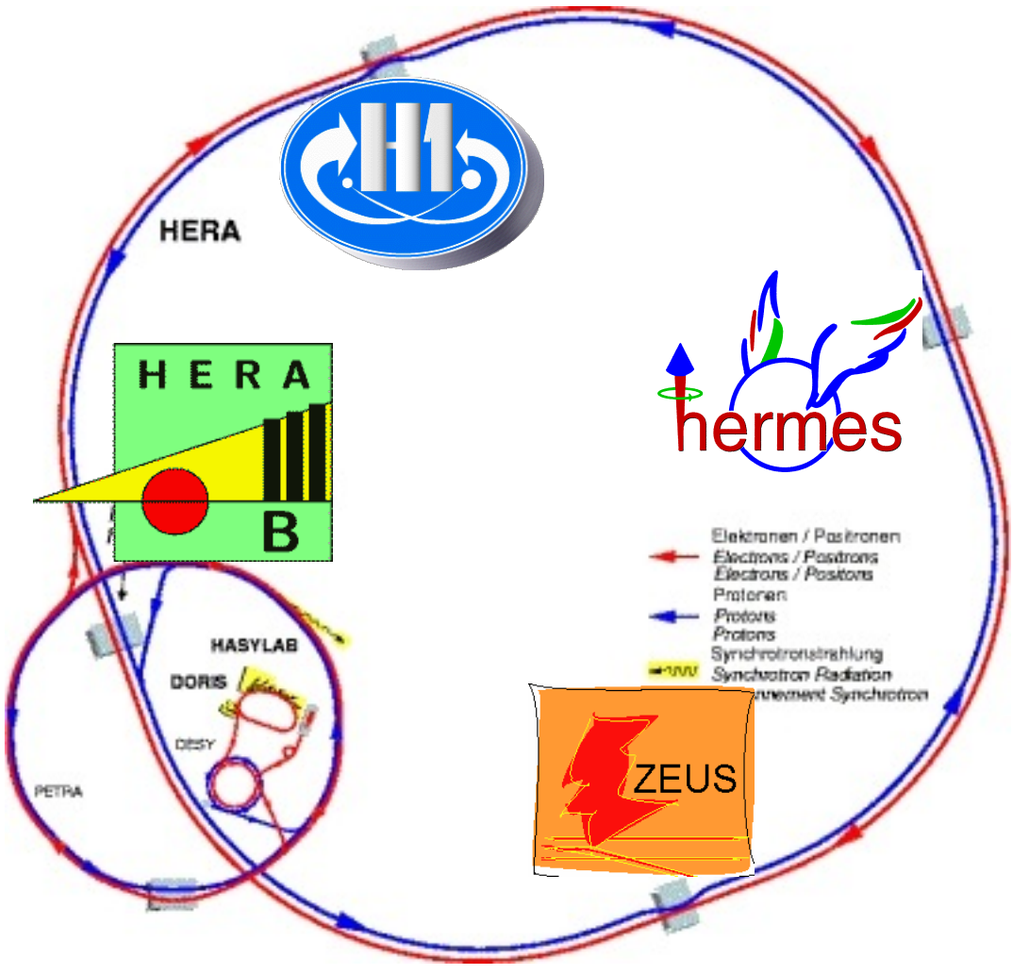
Outline

- **Introduction**
  - HERA accelerator
  - ZEUS detector
  - Heavy flavour production
- **Measurement of $D^{*\pm}$ meson production**
  - Event selection and D* signal extraction
  - Comparison data and MC
  - Centre-of-mass energy dependence of the ratios of the visible cross section
- **Summary**

The HERA ep collider (1992 - 2007)



- located at Hamburg, Germany;
- operated during 1992-2007;
- two data-taking periods:
  - ➡ HERA I (1992-2000)
  - ➡ HERA II (2003-2007)

Four interaction regions:

H1, ZEUS, HERMES and HERA-B

HERA operated with 4 different proton beam energies (E_p):

HERA II:

- **920 GeV** - High Energy Run (HER);
- **575 GeV** - Middle Energy Run (MER);
- **460 GeV** - Low Energy Run (LER);

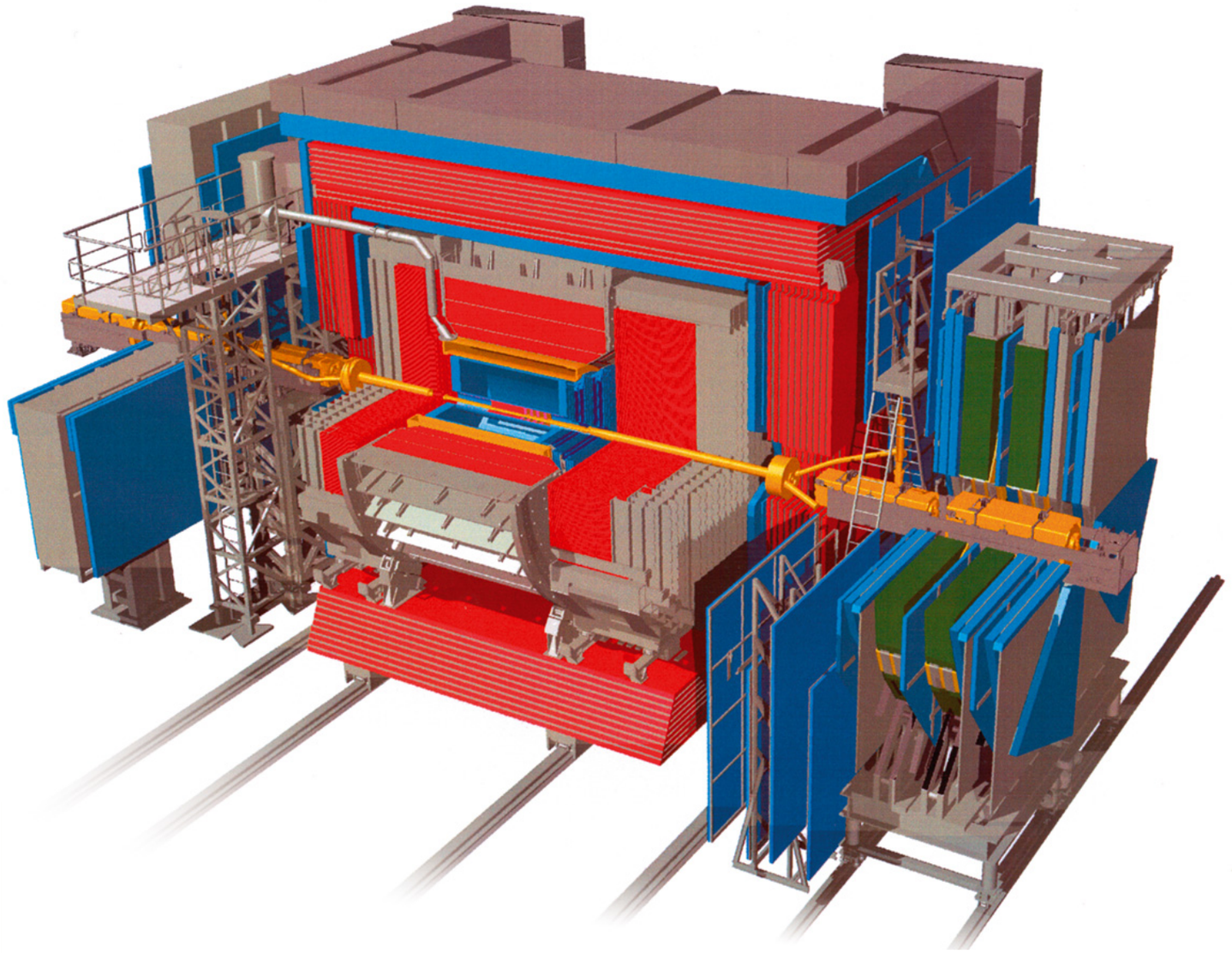
HERA I:

- 1992-1997 years - energy **820 GeV**;

and electron beam energy (E_e): 27.5 GeV

ZEUS detector

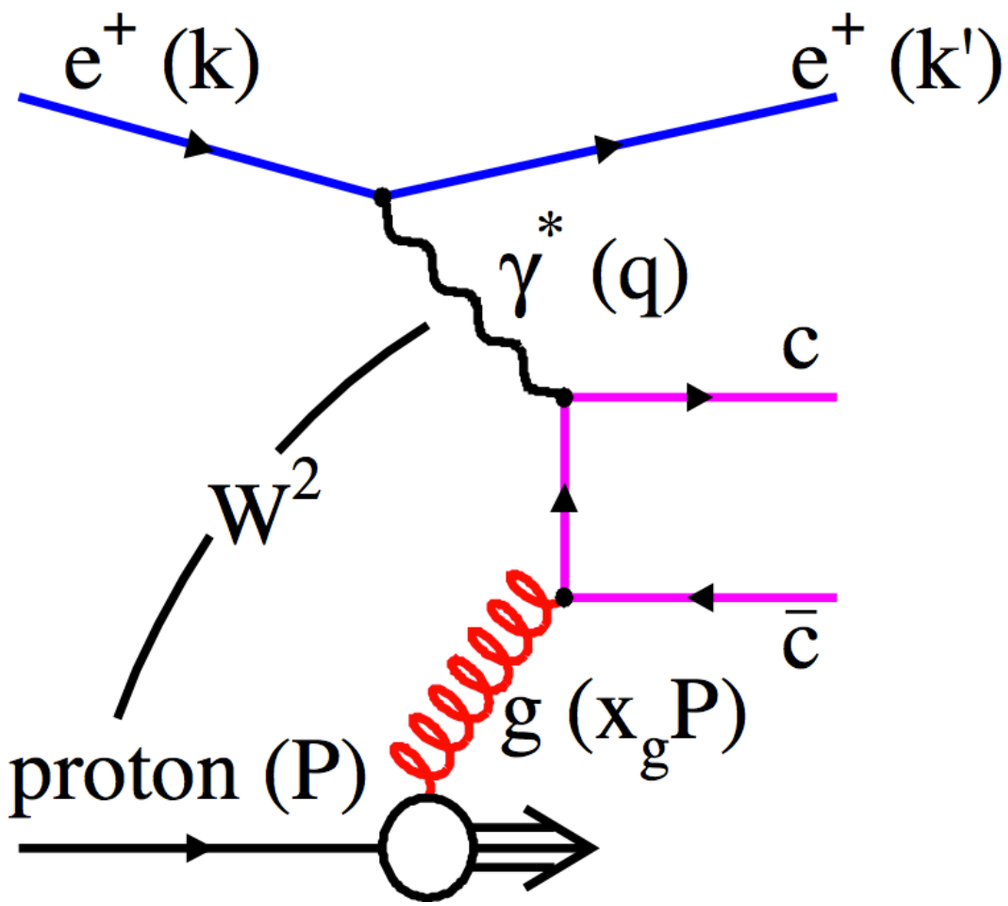
- Micro-Vertex silicon detector
- Central Tracking detector
- Uranium Calorimeter



- Collected ~ 0.5 fb^{-1} of integrated luminosity by each of ZEUS and H1

Heavy Flavor Production

- Charm and beauty quarks are produced at HERA mainly through the photon-gluon fusion process → sensitive to the gluon density in the proton



- The large masses of the c and b quarks provide (additional) hard scales for pQCD calculations

- Q^2 – virtuality of the exchanged photon

$$Q^2 = -q^2 = -(k - k')^2$$

- **x** – Bjorken scaling variable: $x = \frac{Q^2}{2P \cdot q}$

- **y** – inelasticity: $y = \frac{P \cdot k}{P \cdot q}$

- **s** – centre-of-mass energy: $s = (k + P)^2$

$Q^2 < 1\ \mathrm{GeV}^2$ - **Photoproduction:**

- Quasi-real photon exchanged
- No scattered electron in detector

Motivation

Heavy quark production provides an opportunity to study perturbative QCD.

Investigate the dependence of charm production on the ep centre-of-mass energy and compare with NLO QCD.

This will enhance confidence in the use of NLO QCD predictions for the LHeC.

Variation of cross section on √s should be sensitive to the gluon distribution in the proton.

Event selection

Measurement of charm contained D* meson production by the full reconstruction of the decay :

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

- ☑ ZEUS, 2006/2007 years;
- ☑ Photoproduction ($\mathbf{Q^2 < 1\ GeV^2}$)
- ☑ Phase Space:

$130 < \mathbf{W_{HER}} < 285$ GeV

$103 < \mathbf{W_{MER}} < 225$ GeV

$92 < \mathbf{W_{LER}} < 201$ GeV

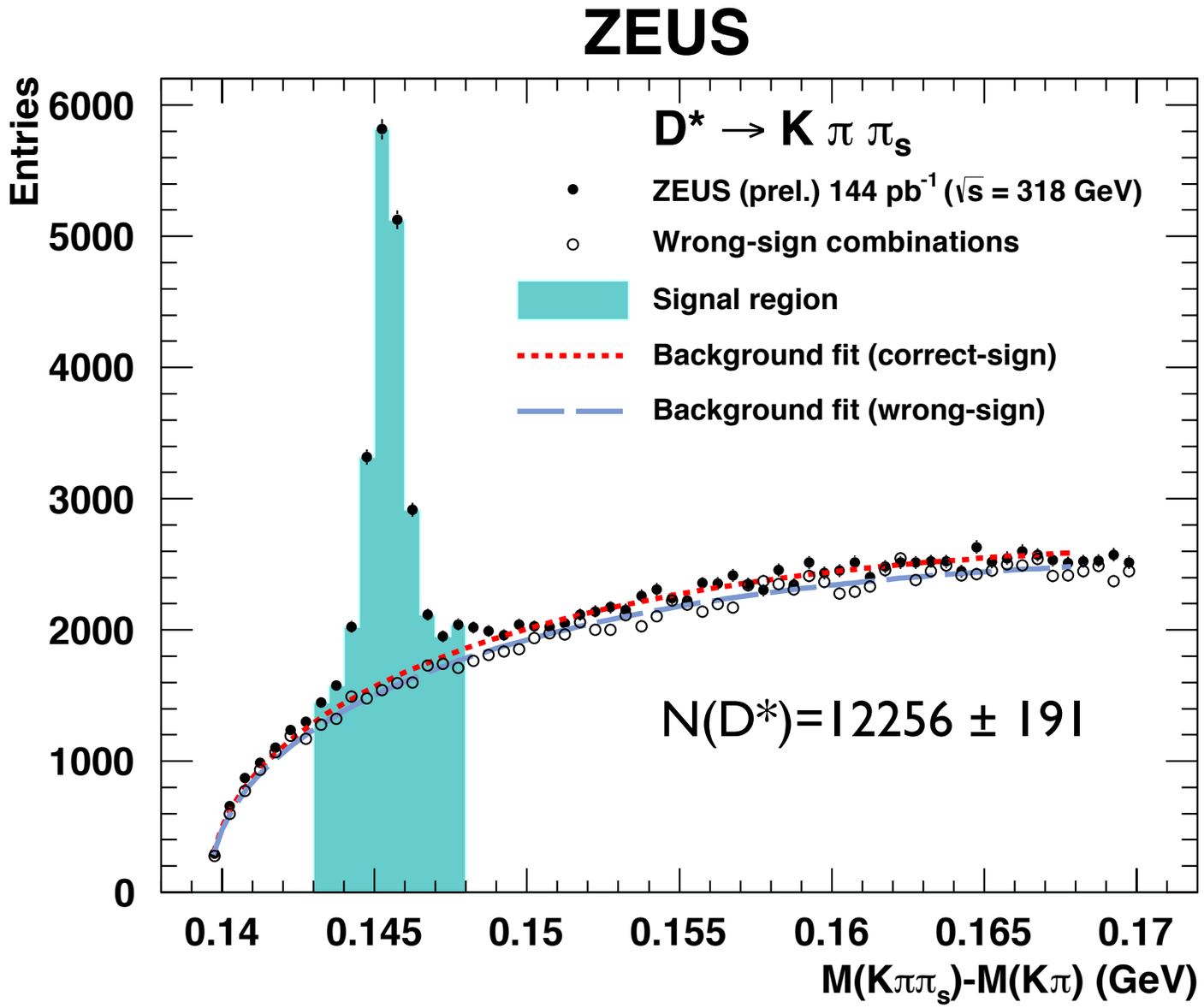
$0.167 < \mathbf{y} < 0.802$

$1.9 < \mathbf{p_T(D^*)} < 20$ GeV

$\mathbf{|\eta(D^*)|} < 1.6$

D* signal extraction

- The background estimation was obtained by fitting simultaneously correct-sign and wrong-sign distribution in the range $\Delta M < 0.168$ GeV;
- Fit was done with Granet function for **WS:** $G(x) = Ax^B e^{-Cx}$; $x = (\Delta M - m_\pi)$ and with Granet multiplied by normalization factor (D) for **CS:** $G' = D \cdot G(x)$;



- Number of D*:

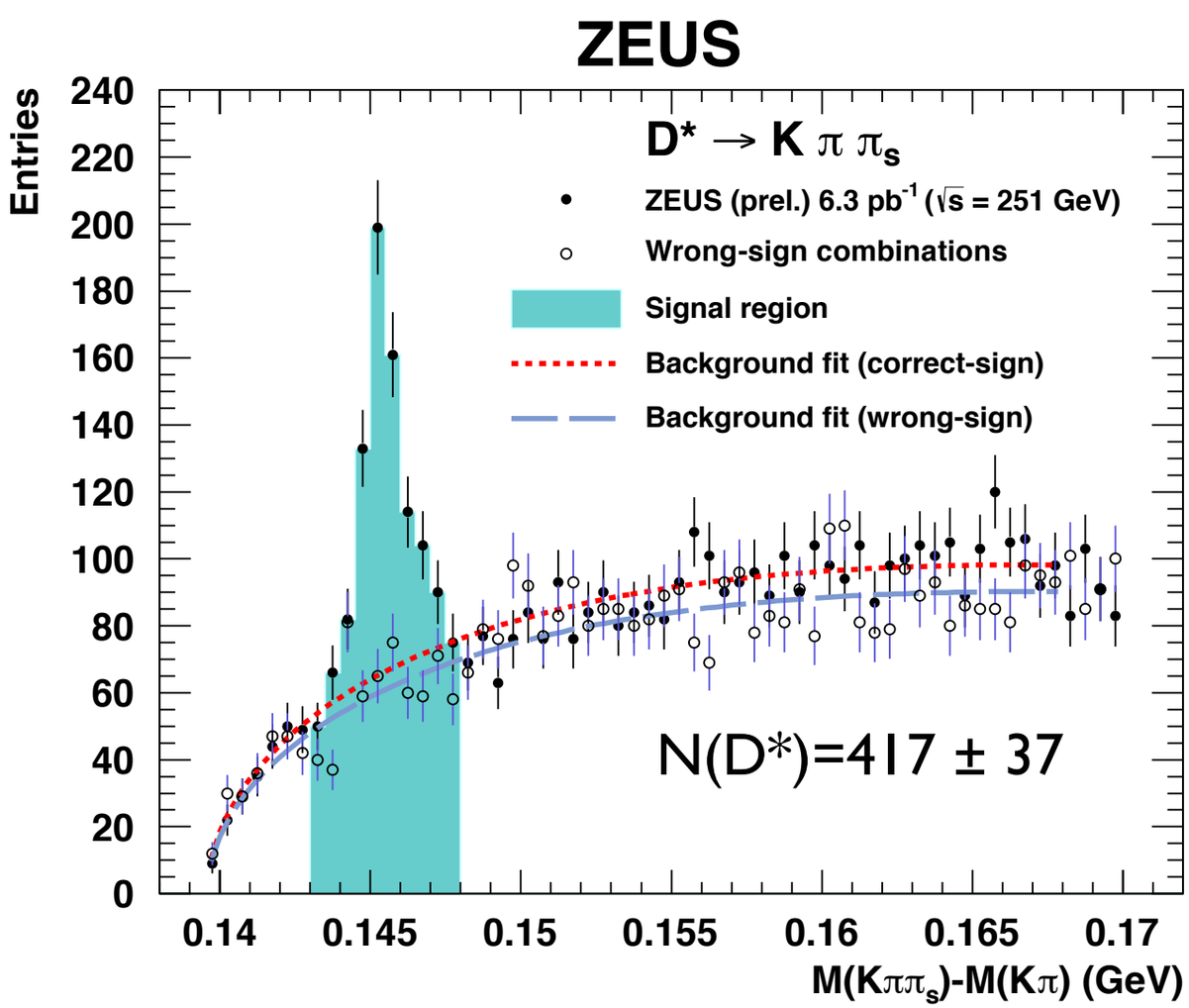
$$N^{D*} = \sum_{y1}^{y2} N_{CS} - \int_{y1}^{y2} G'(y)dy;$$

$$y1 = 0.143; y2 = 0.148$$

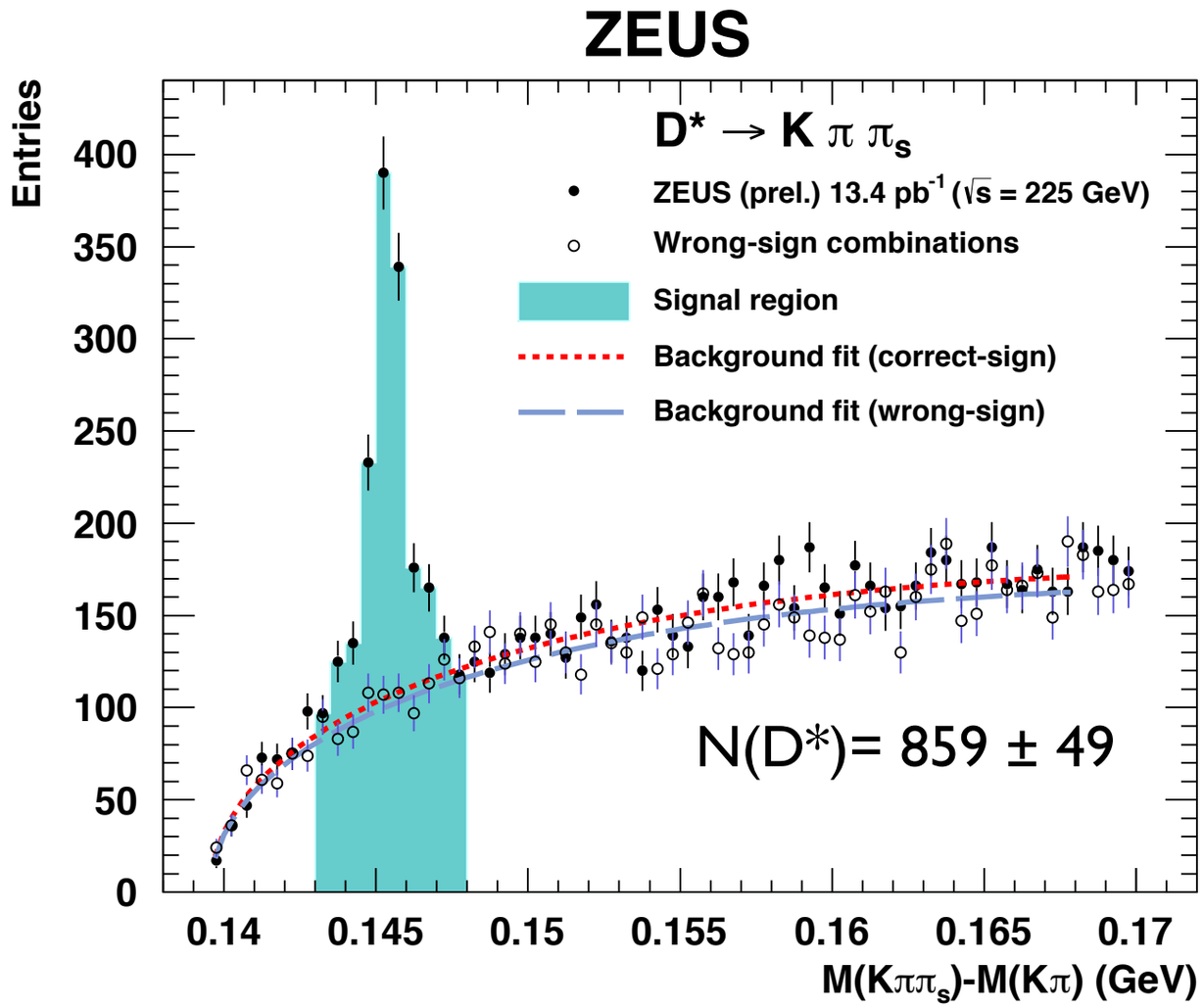
HER: L=144pb^{-1}

The distribution of the Δ(M) for data for MER&LER

MER: L=6.3pb^{-1}

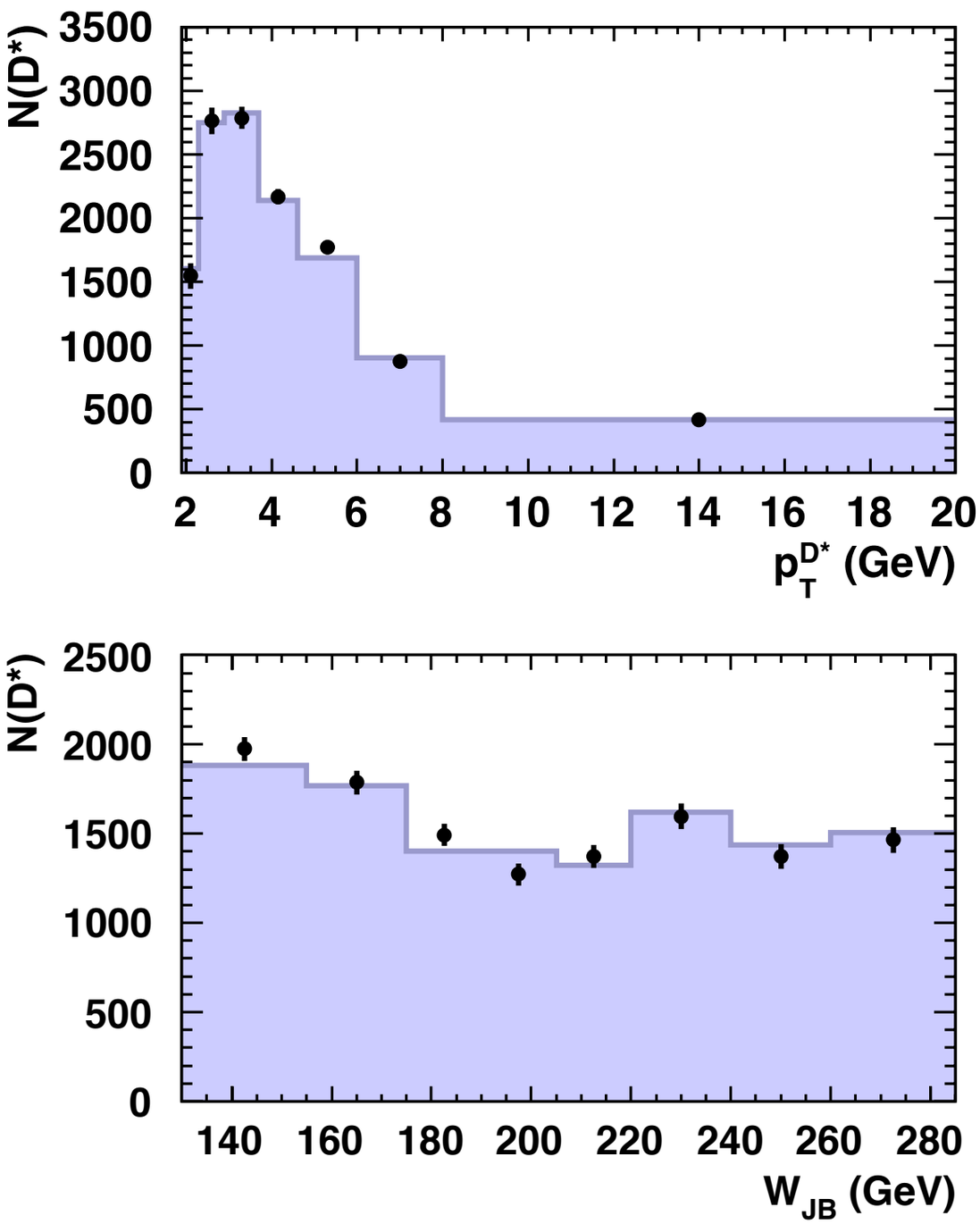


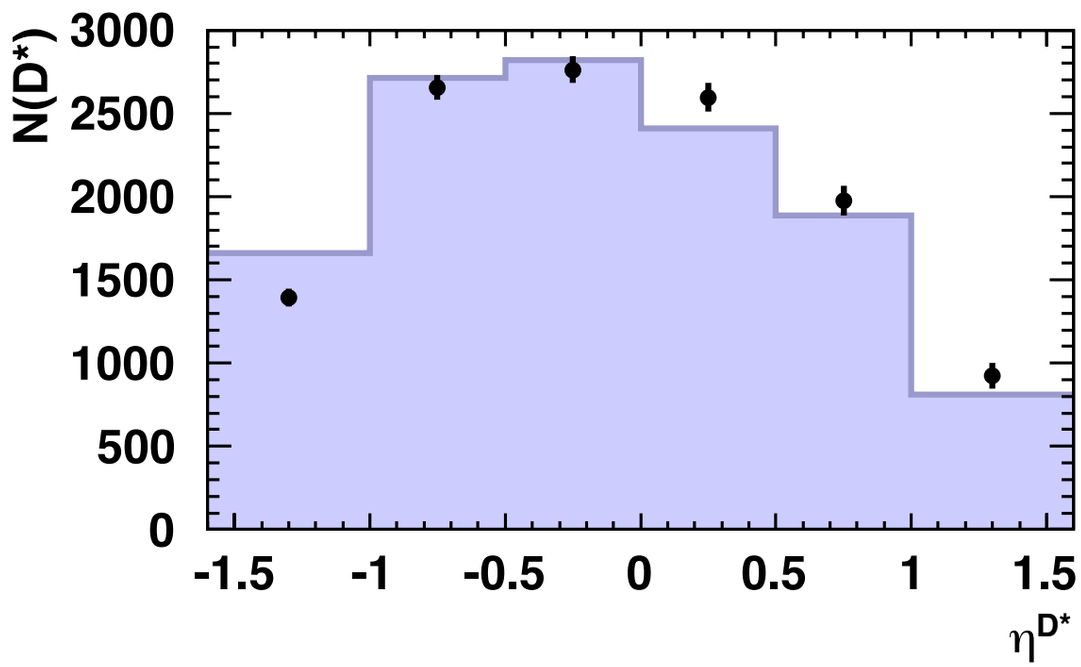
LER: L=13.4pb^{-1}



Control plots for HER

ZEUS





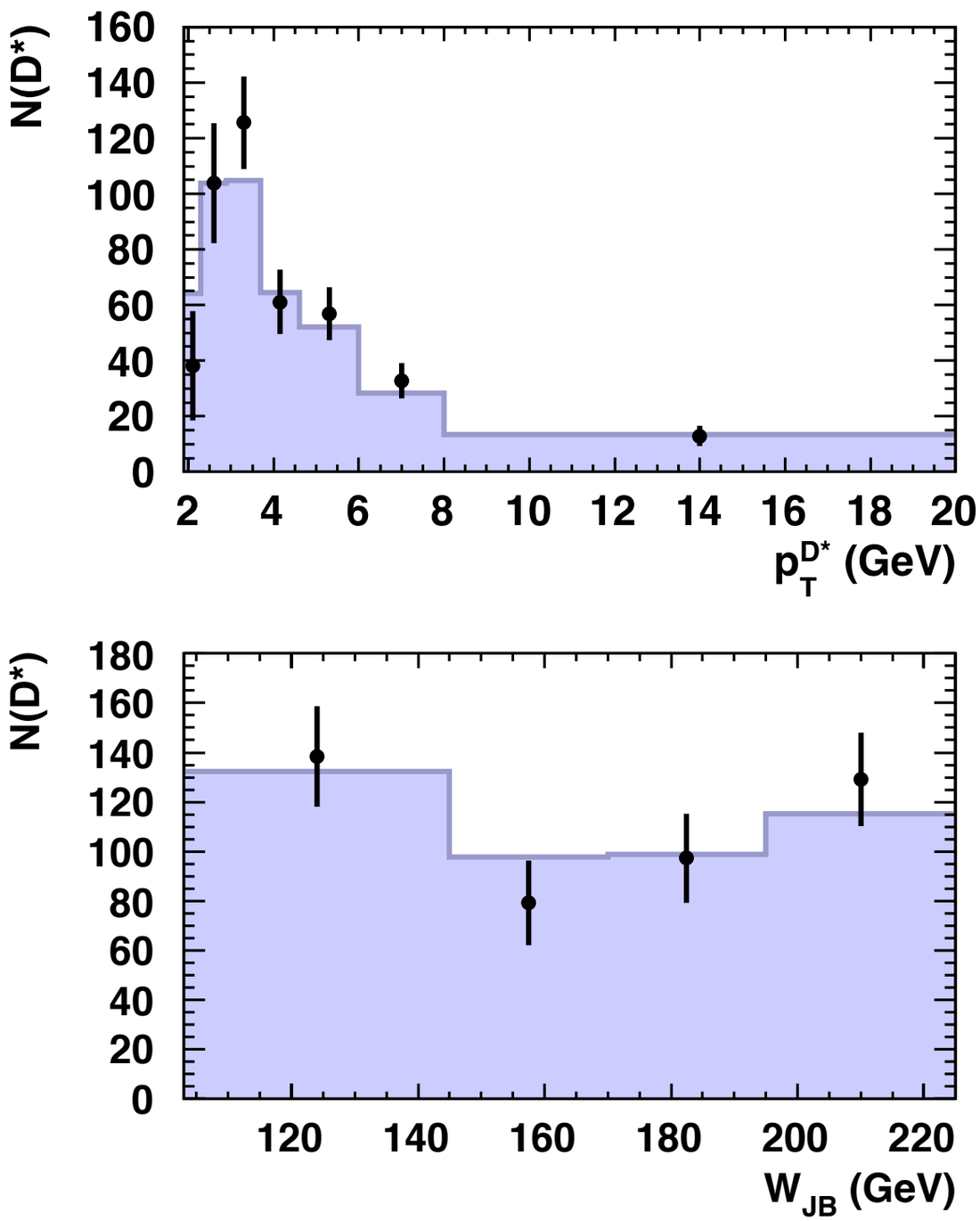
ZEUS (prel.) 144 pb^{-1} ($\sqrt{s}$ = 318 GeV)

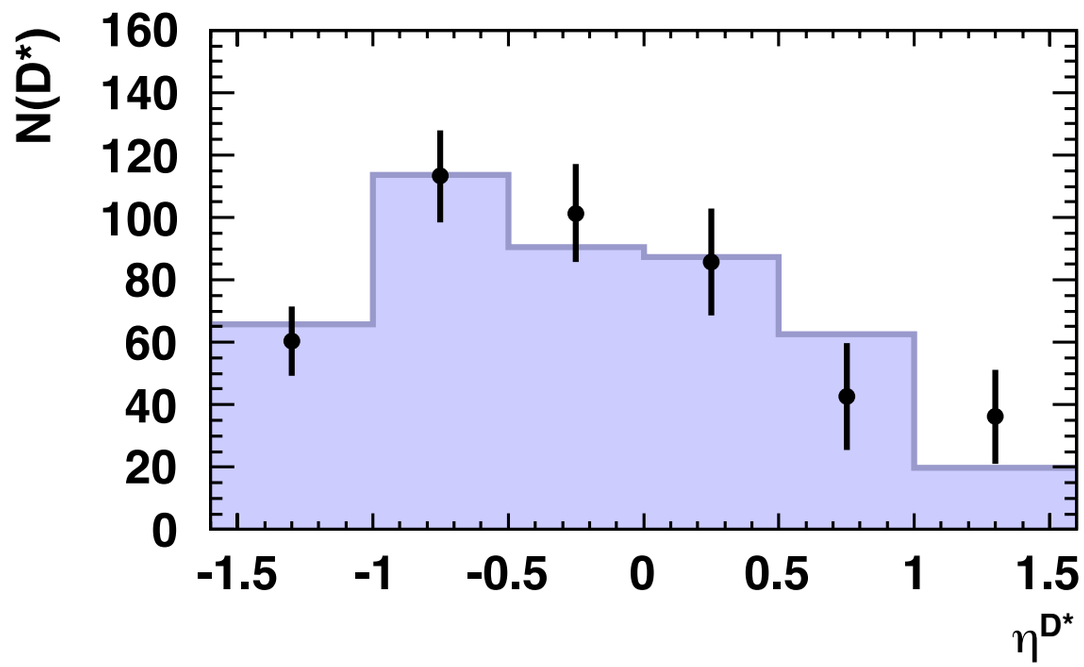
Pythia

MC gives a good enough description of the data to be used for the acceptance corrections

Control plots for MER

ZEUS





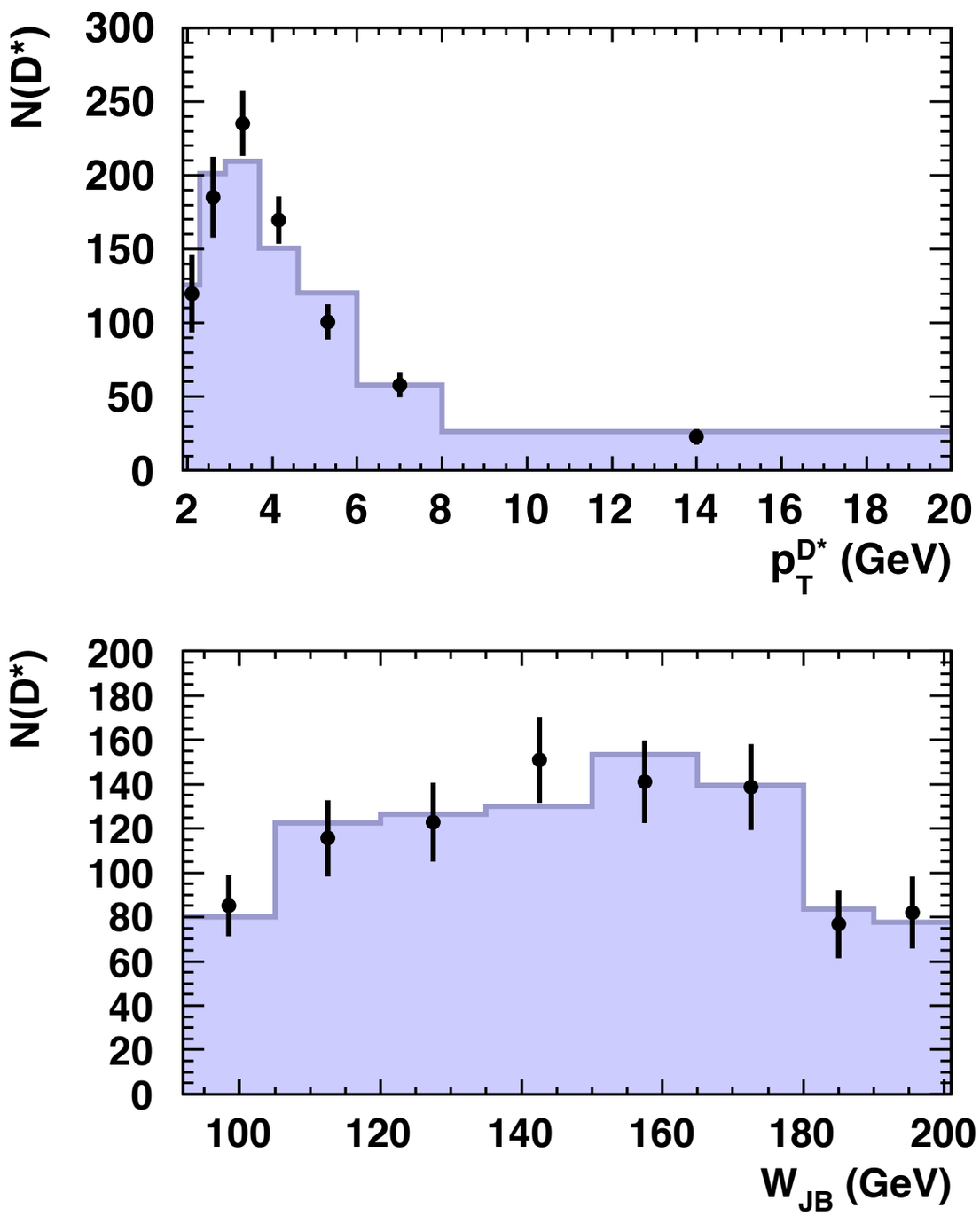
ZEUS (prel.) 6.3 pb^{-1} ($\sqrt{s}$ = 251 GeV)

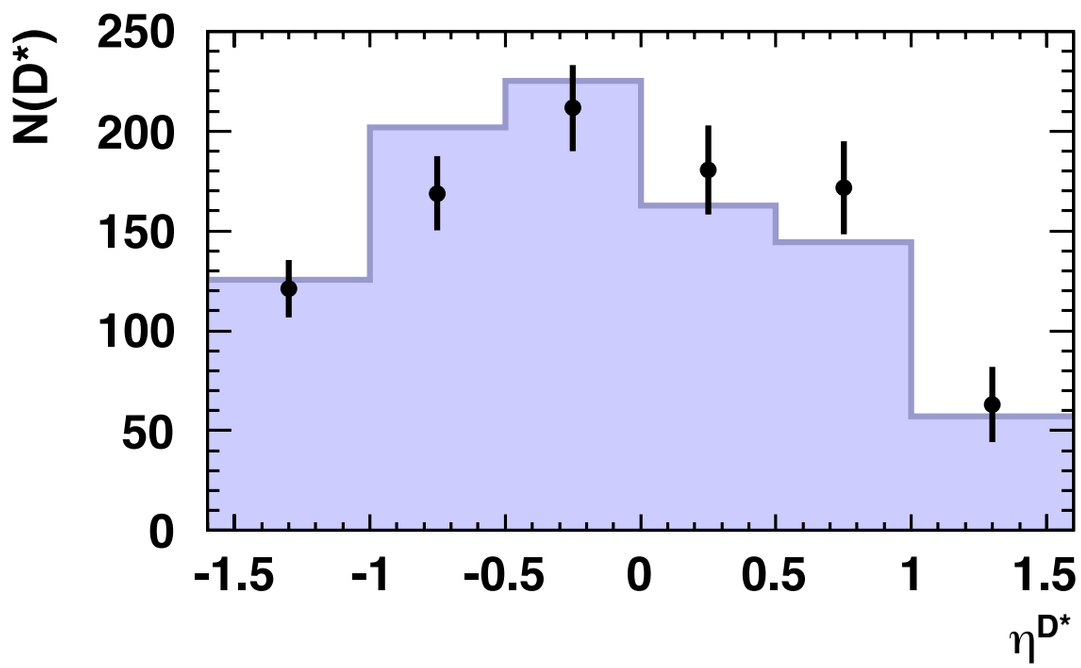
Pythia

MC gives a good enough description of the data to be used for the acceptance corrections

Control plots for LER

ZEUS





ZEUS (prel.) 13.4 pb^{-1} ($\sqrt{s}$ = 225 GeV)

Pythia

MC gives a good enough description of the data to be used for the acceptance corrections

Cross section definition

Visible cross section: $\sigma_{vis.}(D^*) = \dfrac{N^{data}(D^*)}{L \cdot Br \cdot \alpha}$

Where L - luminosity, $Br = \mathrm{B}(\mathrm{D}^* \to \mathrm{D}^0\pi) \times \mathrm{B}(\mathrm{D}^0 \to K\pi) = 0.0263$ - branching ratio,
α - detector acceptance

Ratio of the visible cross section:

$$R_\sigma = \frac{\sigma_i}{\sigma_{HER}}, i = HER, MER, LER$$

- **Measurement of ratios provide cancellation of few courses of systematic uncertainties, both in data and theoretical predictions;**
- **The total systematics are about ±5% in data and a few % in theory;**

NLO QCD prediction (FMNR)

➡**NLO QCD calculation of charm photoproduction was developed by Frixione et al.**

Fixed-flavor-number scheme (FFNS):

- **the number of active flavours is fixed (only the light quarks u, d, s and the gluon are included in the proton);**
- **takes heavy quark masses into account;**
- **reliable in the region** $Q^2 \sim m_c^2$

Parameter settings for NLO QCD calculation:

Strong coupling constant : $\alpha_s(M_Z) = 0.118$,

mass of c quarks: m =1.5 GeV

Fragmentation fraction f(c->D*)=0.237

PDFs : proton - ZEUS-S FFNS

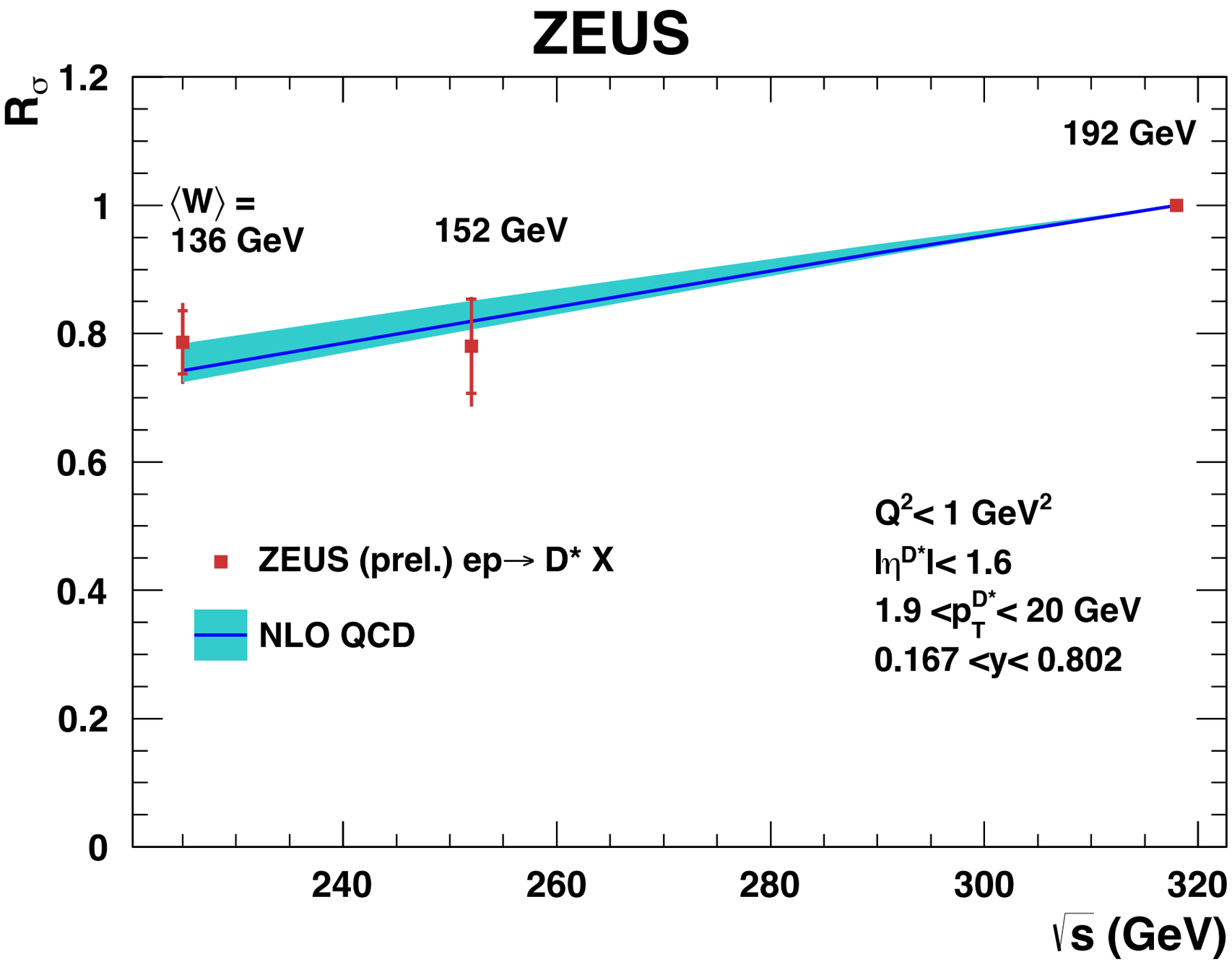
photon - GRV-G HO

Peterson fragmentation function: $\varepsilon = 0.079$

Scales were set to $\mu = \sqrt{m_c^2 + \hat{p}_T^2}$

The predictions uncertainties were obtained through variation of the setting parameters

Result: Ratios of the visible total cross section



⟨**W**⟩ - mean value of the W from generated MC;

➡ The data increases with increasing ep centre-of-mass energy.

➡ This behaviour is predicted well by NLO QCD.

Summary

- The dependence of D* photoproduction on the ep centre-of-mass energy is measured for the first time at HERA.
- The D* cross sections increase with √s.
- This is predicted well by perturbative QCD, demonstrating consistency of the gluon distribution probed here with that extracted in fits to the proton PDFs and enhancing confidence in predictions for future higher energy ep colliders.

Thank you for your attention!