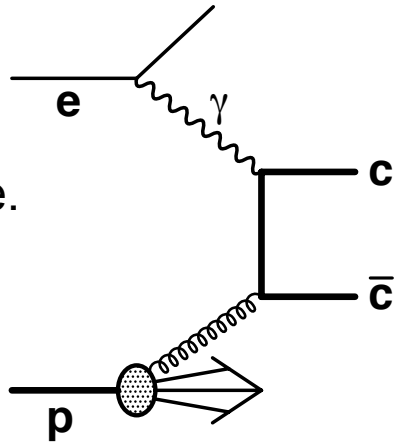
Measurement of D^* photoproduction at three different centre-of-mass energies at HERA

Matthew Wing (UCL/DESY/Univ. Hamburg)
on behalf of the ZEUS Collaboration

- Motivation and HERA and running
- Reconstruction of D^* mesons
- Energy dependence of D^* cross sections
- Summary

See: ZEUS Coll.,
JHEP **10** (2014) 003.

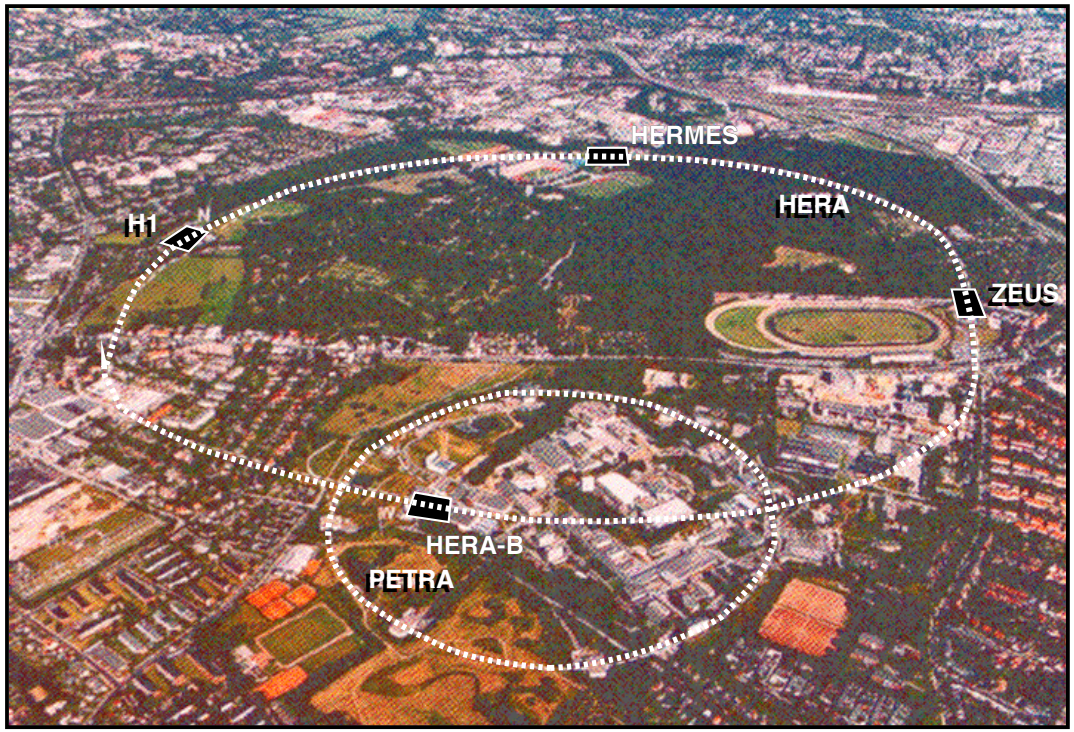
Motivation

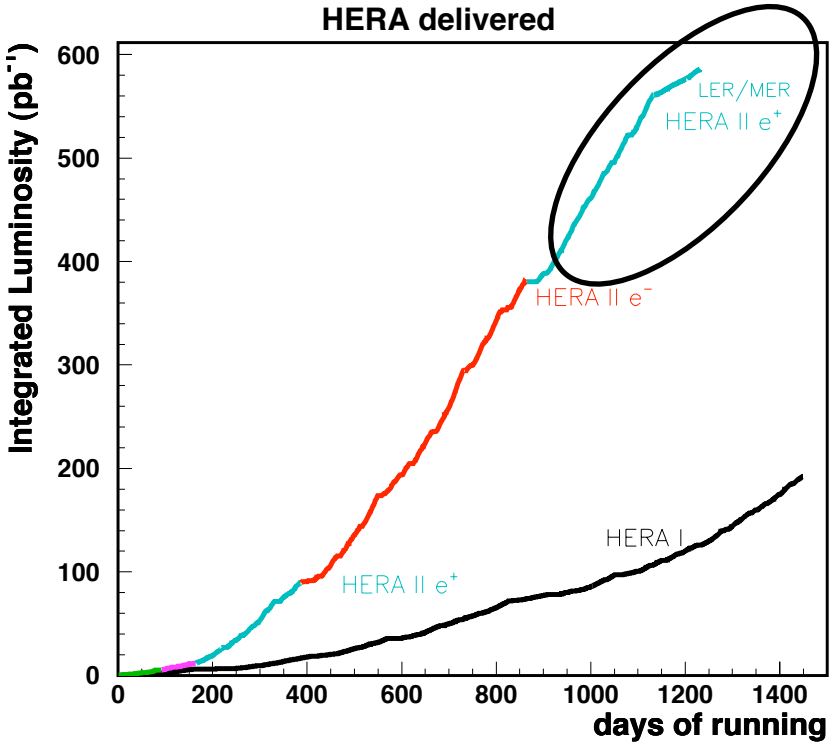


- Charm production is a rich testing ground for perturbative QCD.
  - Expect reliable predictions as charm mass provides hard scale.
  - Production at HERA dominated by boson–gluon fusion.
  - Hence sensitivity to gluon density in proton.

- Previously measured charm production at a single *ep* centre-of-mass energy.
  - Now measure dependence of charm production on *ep* centre-of-mass energy.
  - Sensitive to gluon distribution in proton as different values of *x* are proved.
  - Normalise to highest energy measurement leading to cancellation of systematic uncertainties in data and theory.

HERA and running





Bulk of *ep* running at HERA at E_p = *920 GeV*, but other data taken with E_e = *27.5 GeV* kept constant:

- High-energy run (HER) $E_p = 920$ GeV, $\sqrt{s} = 318$ GeV
- Medium-energy run (MER) $E_p = 575$ GeV, $\sqrt{s} = 251$ GeV
- Low-energy run (LER) $E_p = 460$ GeV, $\sqrt{s} = 225$ GeV

Data selection

Select D^* mesons in golden decay channel:

$$D^{*+} \rightarrow D^0 + \pi_s^+ \rightarrow (K^- \pi^+) + \pi_s^+ \text{ (+c.c.)}$$

With transverse momentum, $1.9\ p_T(D^*) < 20\ GeV$ and pseudorapidity, $|\eta(D^*)| < 1.6$

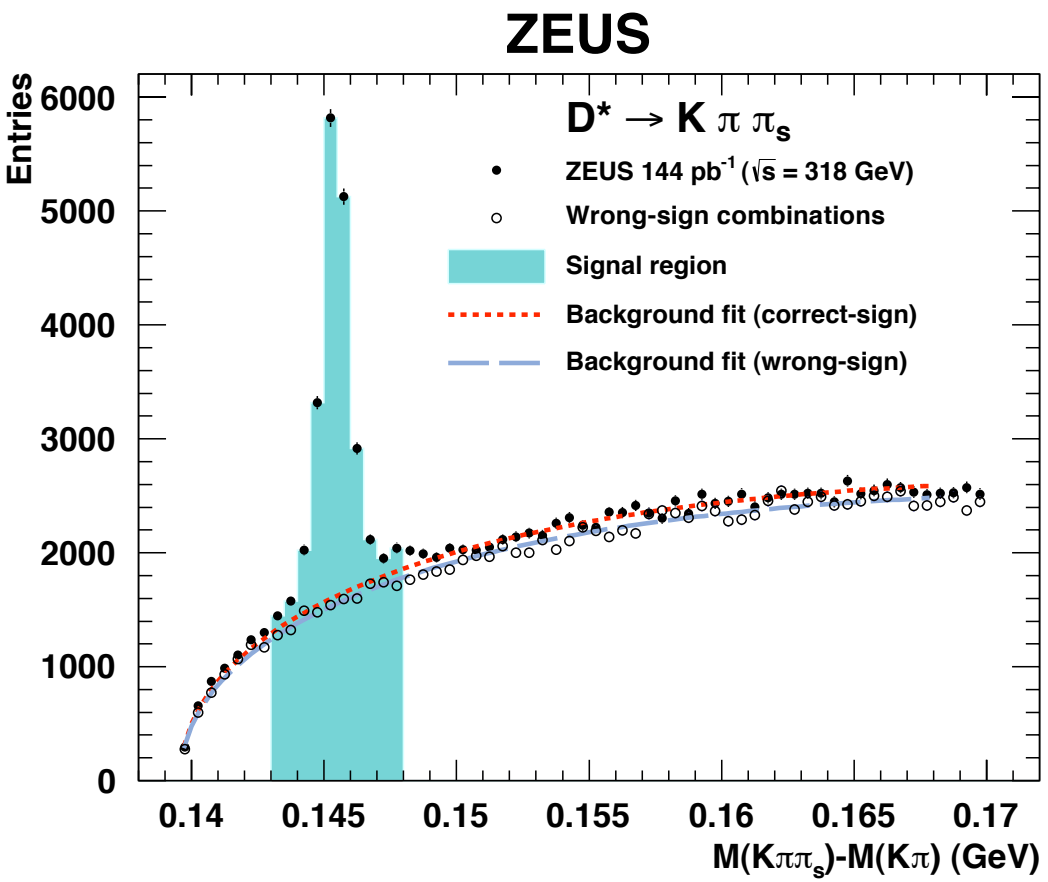
Choose photoproduction events with photon virtuality, $Q^2 < 1\ GeV^2$ and photon–proton centre-of-mass energies ($W^2 = y \cdot s$),

$130 < W_{HER} < 285\ GeV$
$103 < W_{MER} < 225\ GeV$ i.e. the same region in y, $0.167 < y < 0.802$
$92 < W_{LER} < 201\ GeV$

Use ZEUS 2006−7 data where we have different centre-of-mass energy data under the same detector conditions.

*D** signal for HER data

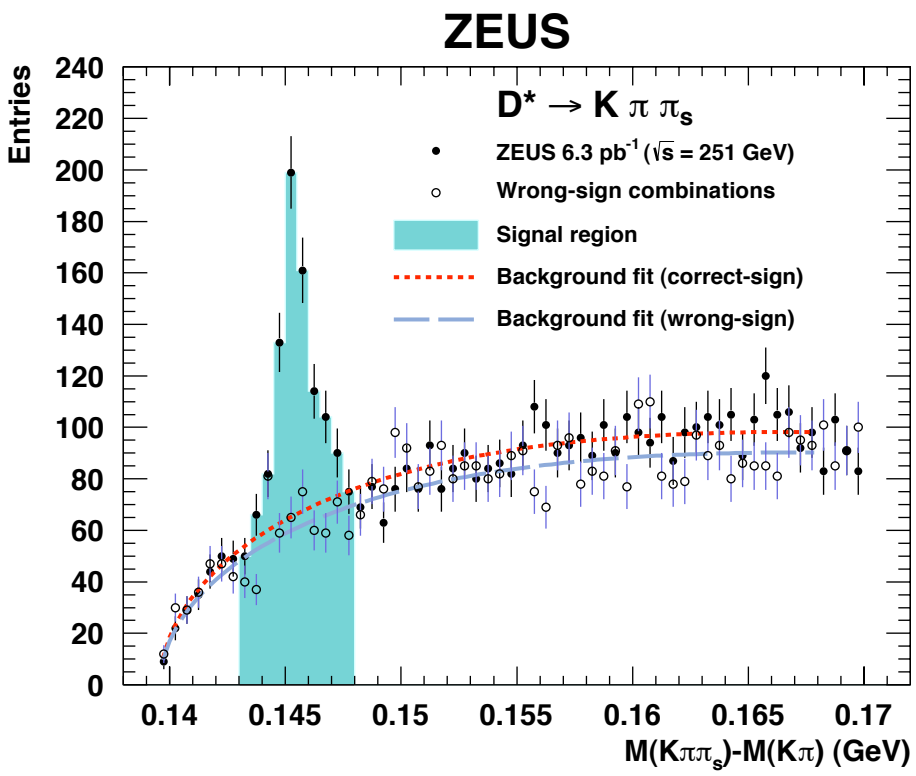
- Background estimation obtained by simultaneous fit to correct-sign and wrong-sign distributions for $\Delta M < 0.168$ GeV.
- Fit done with Granet function for wrong-sign, $G(x) = A\, x^B\, e^{-Cx}$; $x = \Delta M - m_\pi$.
- And $G' = D\, G(x)$ for correct-sign.
- Correct-sign background estimate subtracted from number of candidates for $0.143 < \Delta M < 0.148$ GeV.
- Clear *D** signal with low background.

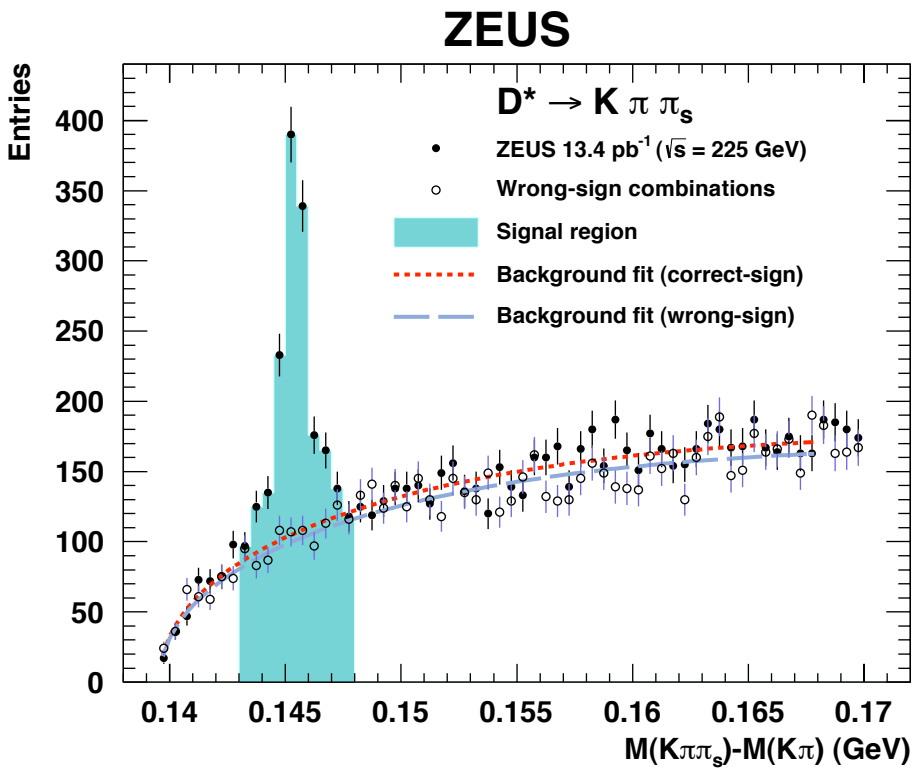


HER data:

- $L = 144\ pb^{-1}$
- $N = 12256 \pm 191$

D^* signals for MER and LER data





MER data:

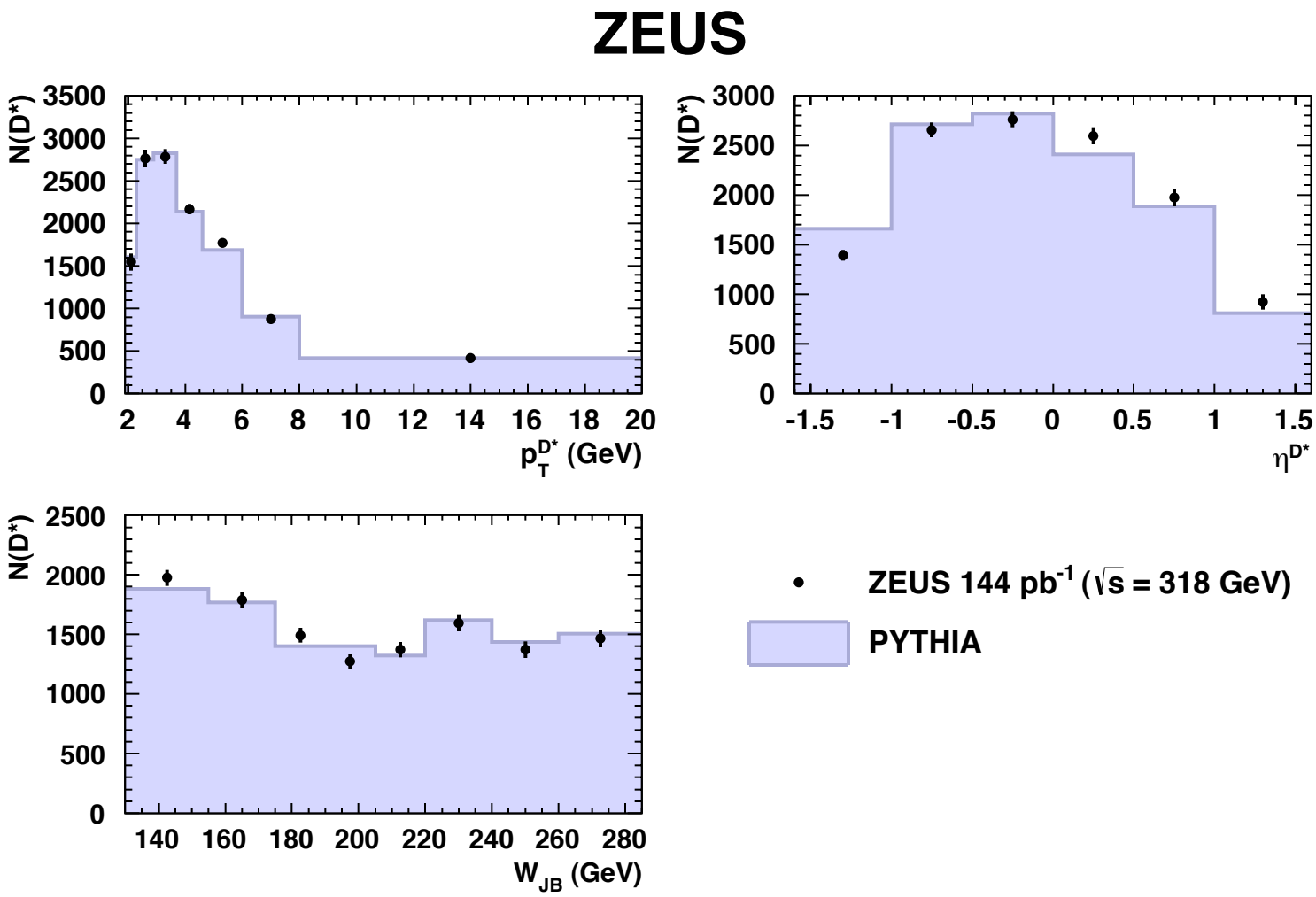
- $L = 6.3\ pb^{-1}$
- $N = 417 \pm 37$

LER data:

- $L = 13.4\ pb^{-1}$
- $N = 859 \pm 49$

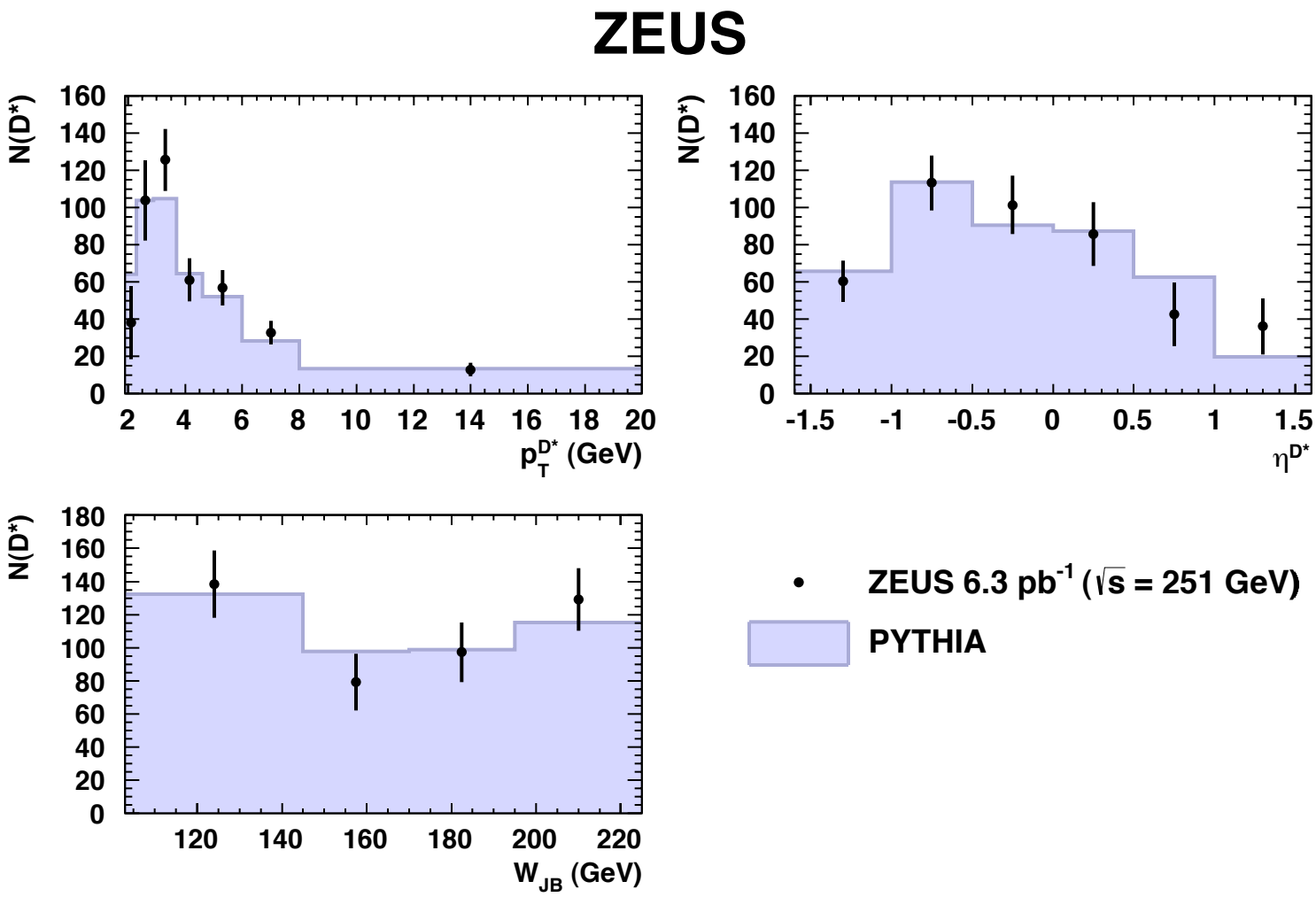
Clear signals, with relatively low background in both running periods.

Control plots for HER



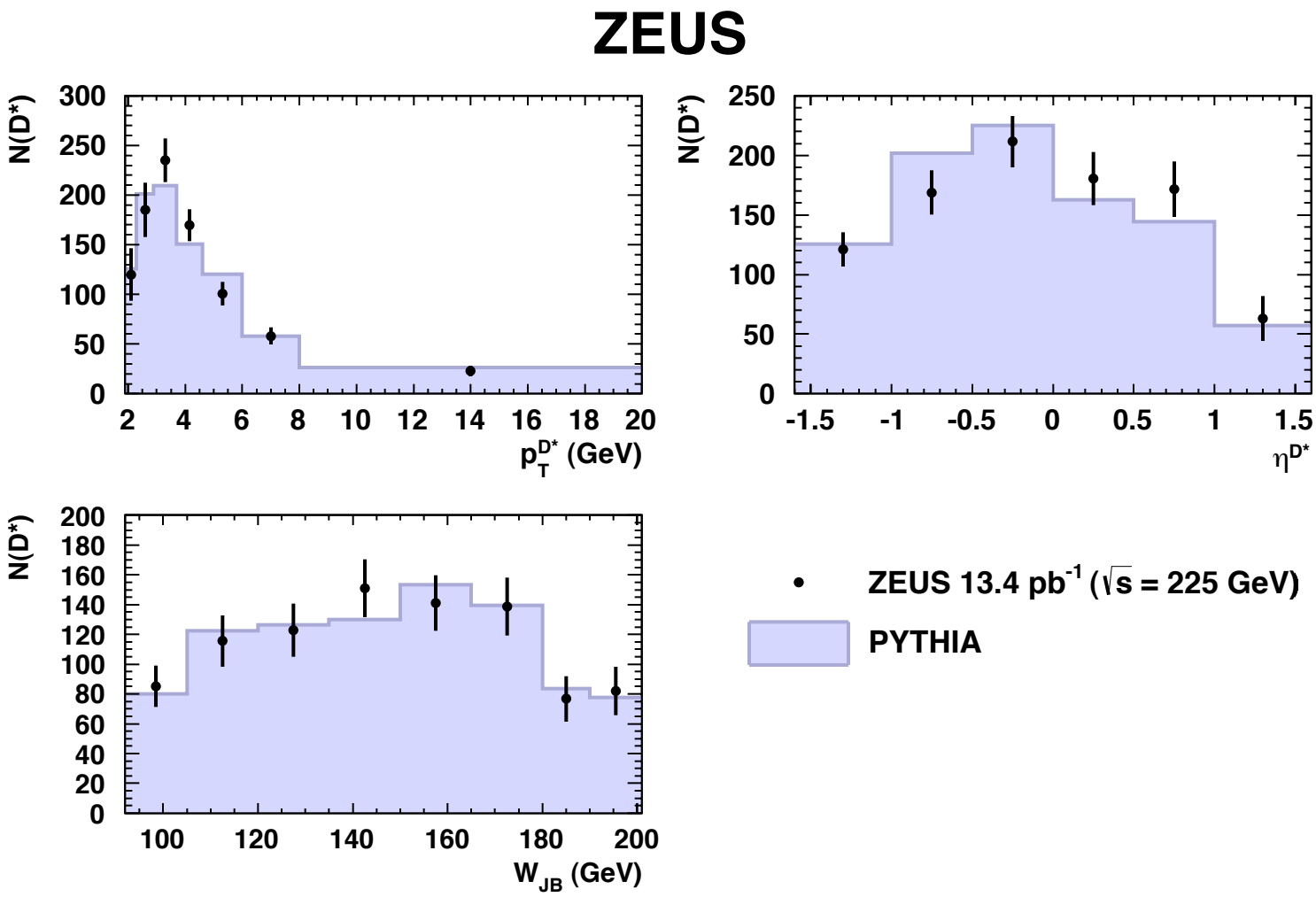
Reasonable description of the data by PYTHIA; can use for correction to cross section.

Control plots for MER



Reasonable description of the data by PYTHIA; can use for correction to cross section.

Control plots for LER



Reasonable description of the data by PYTHIA; can use for correction to cross section.

Measurement of D^* cross sections

$$\sigma_{\text{vis}} = \frac{N^{D^*}_{\text{data}}}{\mathcal{A} \cdot BR \cdot \mathcal{L}},$$

$$R_\sigma^{\text{HER,MER,LER}} = \sigma_{\text{vis}}^{\text{HER,MER,LER}} / \sigma_{\text{vis}}^{\text{HER}}.$$

Kinematic range:

- $Q^2 < 1\ GeV^2$
- $0.167 < y < 0.802$
- $1.9\ p_T(D^*) < 20\ GeV$
- $|\eta(D^*)| < 1.6$

- N is number of D^* mesons
- $\mathcal{A}$ is the acceptance
- BR is the branching fraction
- $\mathcal{L}$ is the luminosity

Total systematic uncertainty on data about ±5 %, dominated by reweighting of MC and background determination.

However significant reduction as calculating normalised cross sections.

NLO QCD predictions

Calculations for charm production uses a fixed-flavour number scheme at NLO QCD from Frixione et al.

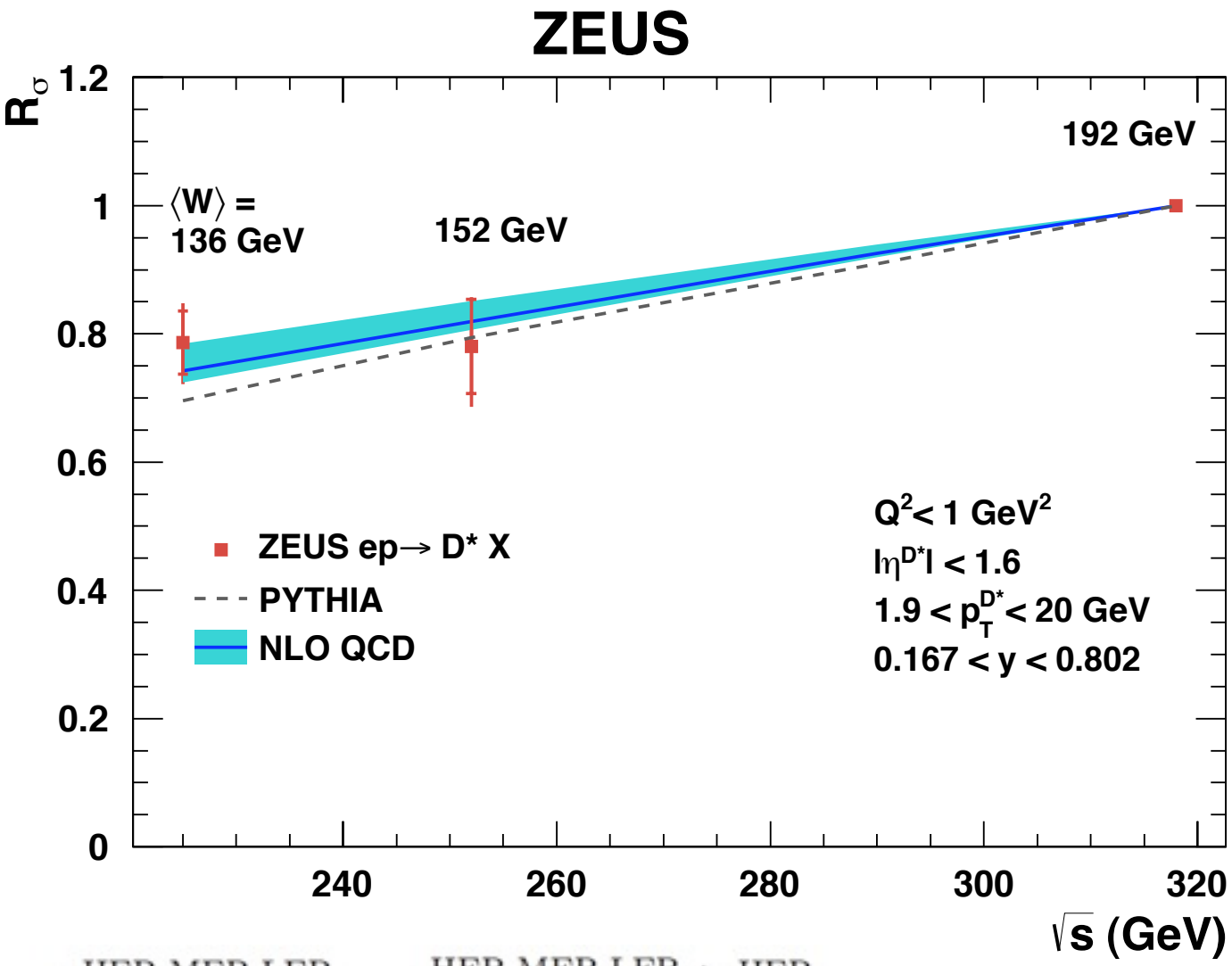
- Number of active flavours fixed: *u*, *d*, *s* and *g* included in the proton PDFs.
- Heavy quarks produced in the hard interaction.
- Expected to be reliable for scale around ~ m_c.

Parameters and variations:

- Renormalisation and factorisation scales, $\mu = \sqrt{(m_c^2 + p_T^2)}$; changed independently to *0.5* and *2* times this value.
- Charm mass, m_c = *1.5 GeV*; changed to *1.35* and *1.65 GeV*.
- Proton PDF ZEUS-S FFNS, photon PDF GRV-G HO; proton PDF changed to ABM11.
- Peterson fragmentation with ε = *0.079*; changed to *0.006* and *0.092*.
- Strong coupling, α_s = *0.118* for five flavours.

Uncertainty dominated by scale changes, but still only *2−5 %* on normalised cross sections.

Energy dependence of D^* cross sections



$$R_\sigma^{\mathrm{HER,MER,LER}} = \sigma_{\mathrm{vis}}^{\mathrm{HER,MER,LER}} / \sigma_{\mathrm{vis}}^{\mathrm{HER}}.$$

- Cross sections for LER and MER are compatible.
- Both are significantly smaller than the HER cross section.
- Behaviour predicted well by PYTHIA and NLO QCD.
- Compatibility of gluon distribution in the proton.
- More confidence in calculations used for e.g. LHeC.

Summary

• Dependence of the charm cross section on the *ep* centre-of-mass energy measured for the first time at HERA.

• The cross sections, normalised to the highest $\sqrt{s}$, increase with increasing $\sqrt{s}$.

• The behaviour is predicted well by perturbative QCD.

• Adds confidence in the use of pQCD predictions for higher-energy projects, e.g. LHeC.

• Demonstrates the consistency of gluon distribution probed here with that extracted in PDF fits.