Beauty and Charm at HERA

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On the behalf of H1 and ZEUS Collaborations

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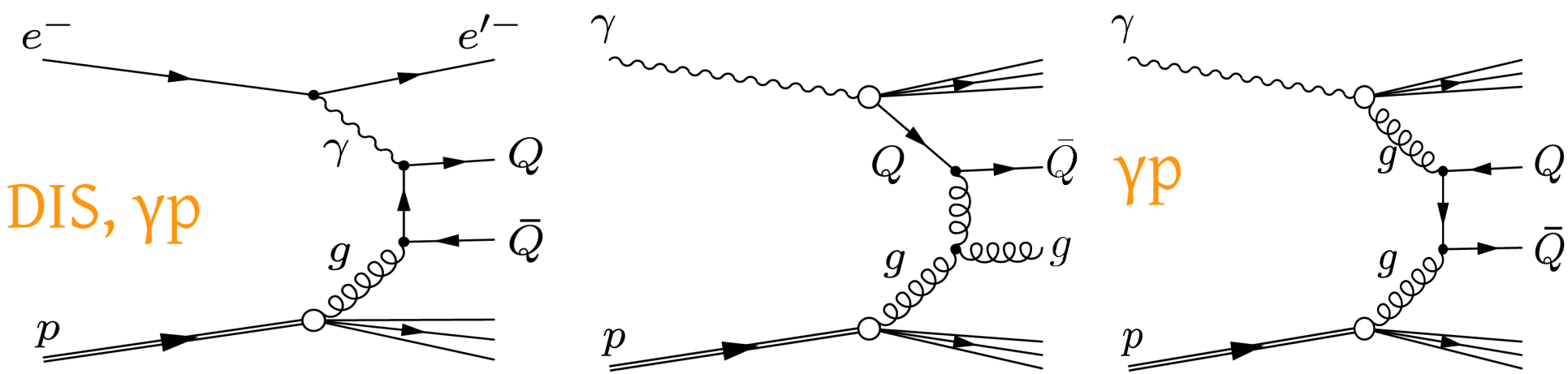
Content

- Heavy Quark Production at HERA
- Tagging
- Results from photoproduction
- Results from DIS

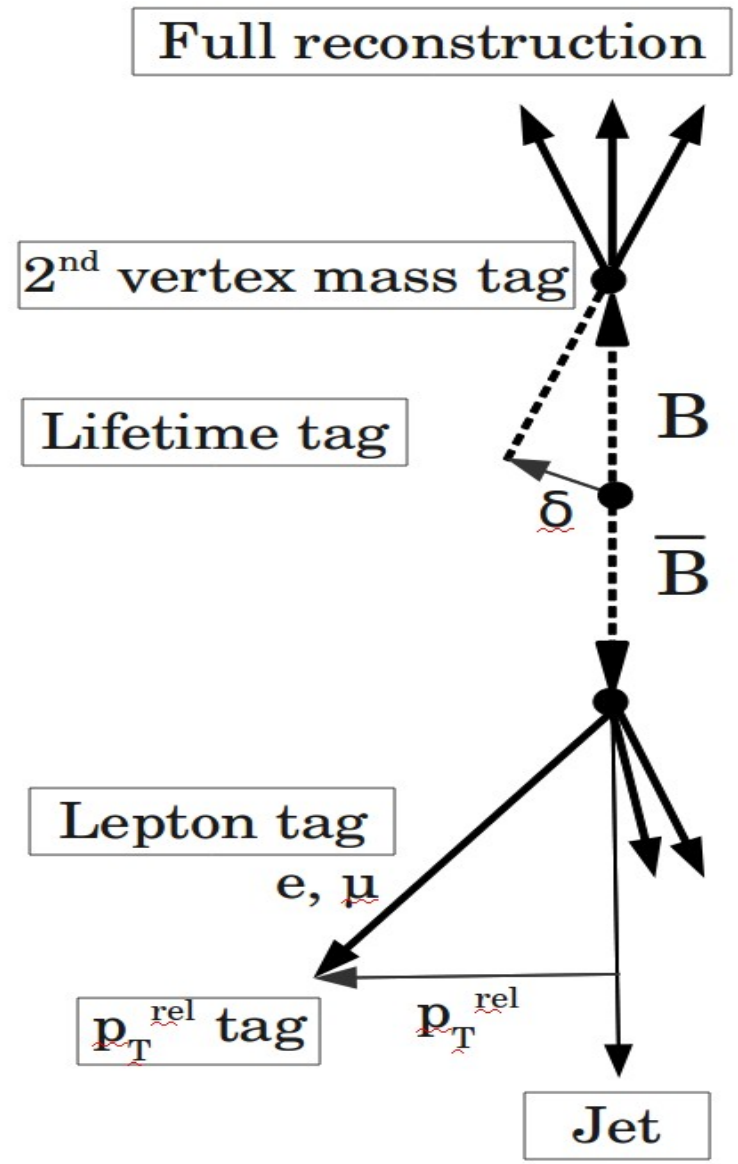
Production Mechanism

- Dominant production mechanism: Boson-gluon Fusion, sensitivity to the gluon content of the proton
- Applicability of pQCD can be tested down to very low scales Q^2, p_{T} : $m_Q^2 \gg \Lambda_{QCD}^2$, multiscale problem
- Significant contribution from resolved photons in photoproduction (γp)



Experimental Tag

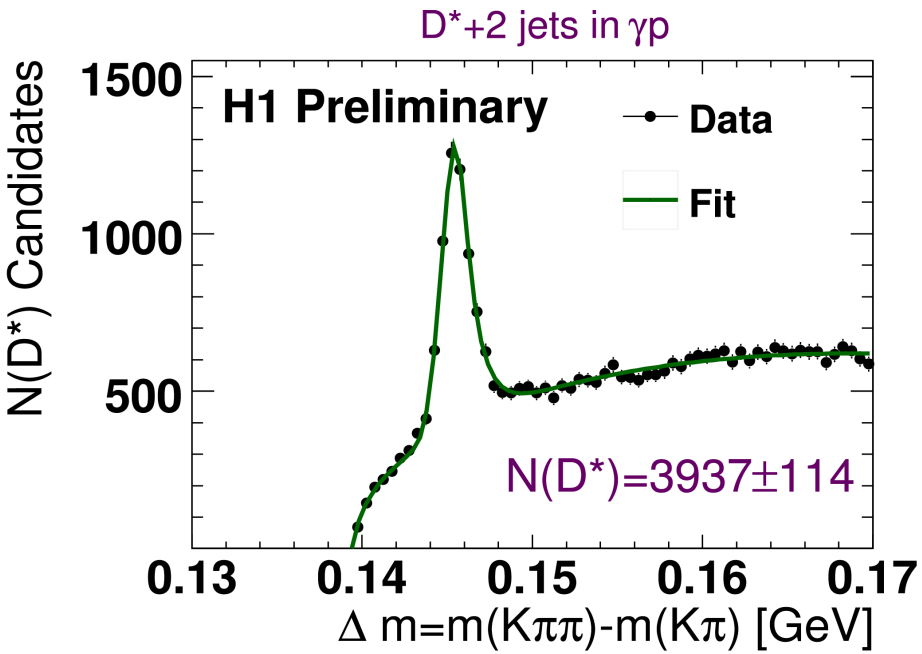
- Full reconstruction of D mesons:
- (Semi)leptonic decays and (or) jets:
  - $Q \longrightarrow e(\mu) + X$
  - The relative p_{T} of a lepton with respect to a jet axis $p_{\mathrm{T}}^{\mathrm{rel}}$
- Long lifetime:
  - Displaced secondary vertices
  - Track impact parameter and displaced secondary vertices

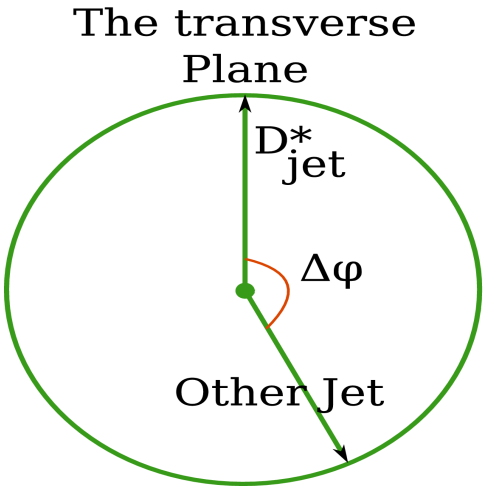


Results from γp

D* with Jets

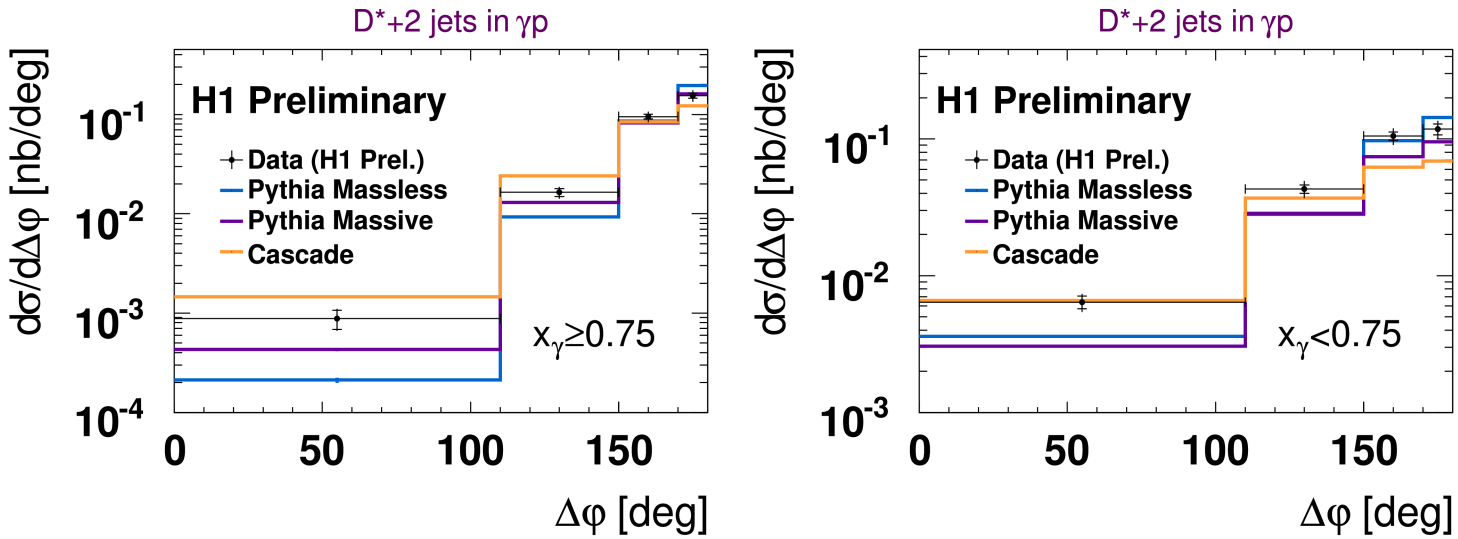
- HERAII 06/07 e+ $\mathcal{L} \approx 90\mathrm{pb}^{-1}$
- $D^{*\pm} \to D^0 \pi^{\pm}_{slow} \to \left(K^{\mp}\pi^{\pm}\right) \pi^{\pm}_{slow}$
- D* jet identified, second hard parton tagged via "Other jet"
- Study the correlations between the jets
- Models:
  - Pythia (DGLAP) and Cascade (CCFM): different parton dynamics
  - MC@NLO: FMNR + Herwig



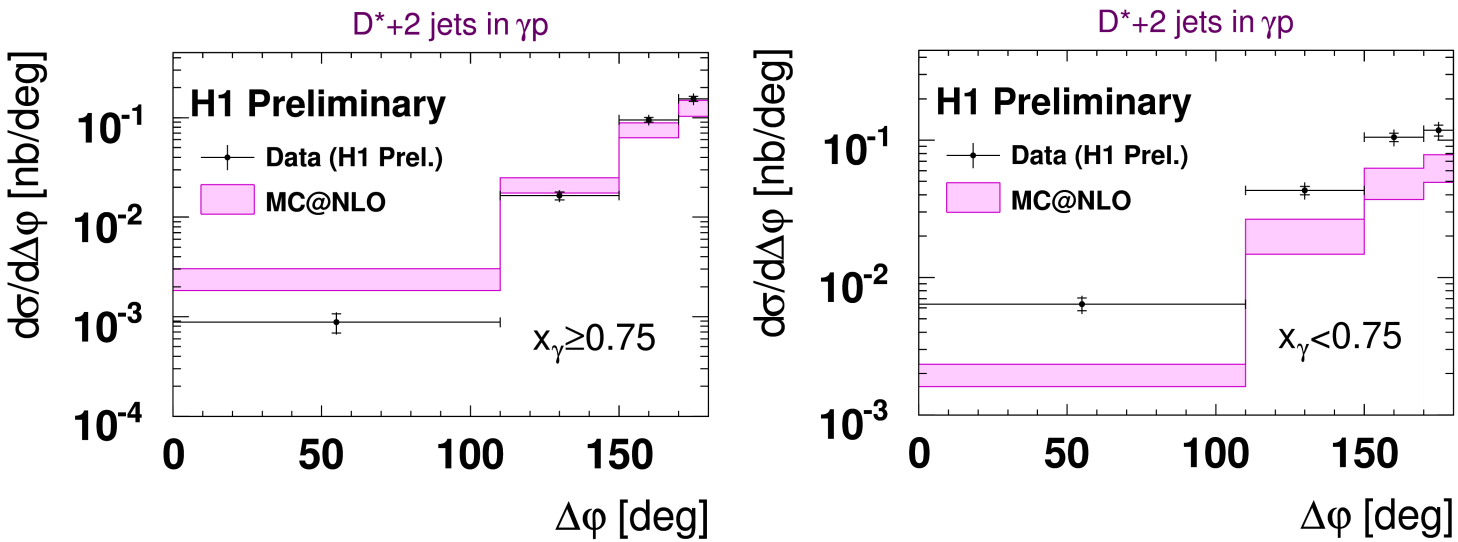


D* with Jets

- Pythia and Cascade give different shapes than the data



- MC@NLO:
  - Normalisation problem at low x_γ
  - Best shapes predictions



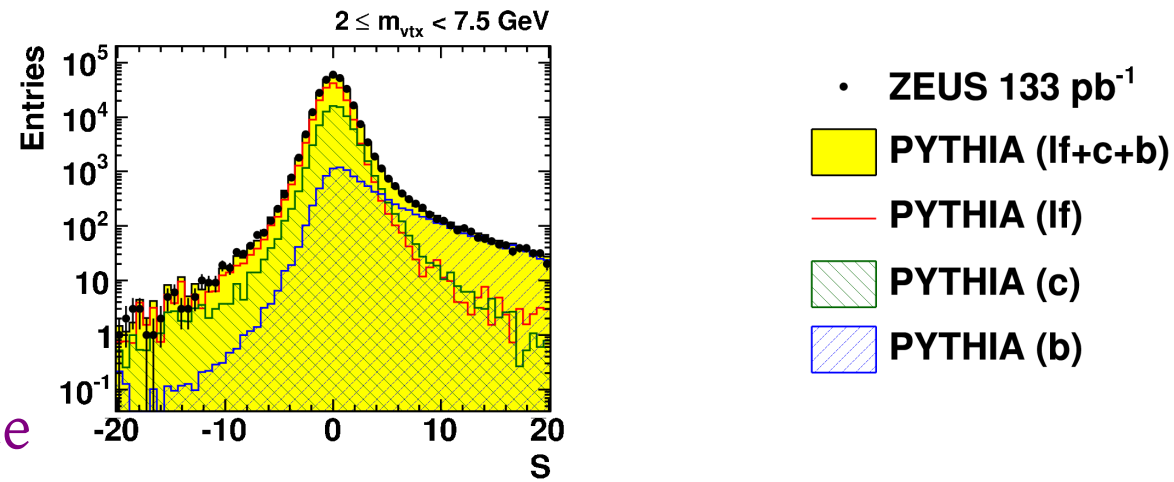
$$x_\gamma = \frac{\sum (E - p_z)_{jets}}{(E - p_z)_{tot}}$$

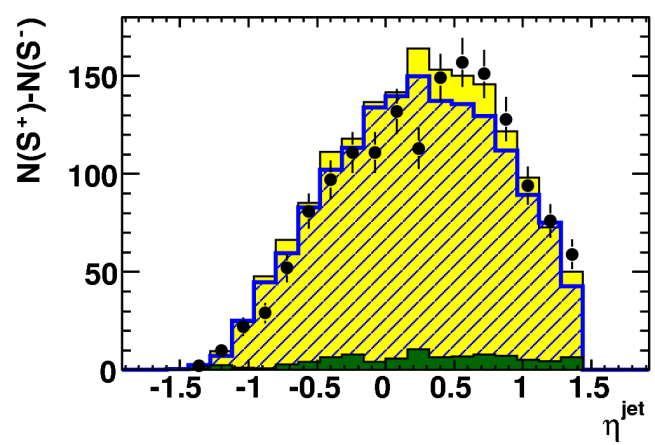
Accepted by EPJ C,
DESY-11-067

ZEUS

Inclusive Heavy-flavour Jets

- HERAII 05e-
- 2 Jets $p_{\mathrm{T}}^{\mathrm{jet}} > 6(7)\mathrm{GeV}$
- HQ separation
  - Decay length significance
    - $S = L/\Delta L$
  - Mass of the track associated to the secondary vertex
- Almost pure b sample (>90%) after S>8
- Good description by MC





Accepted by EPJ C,
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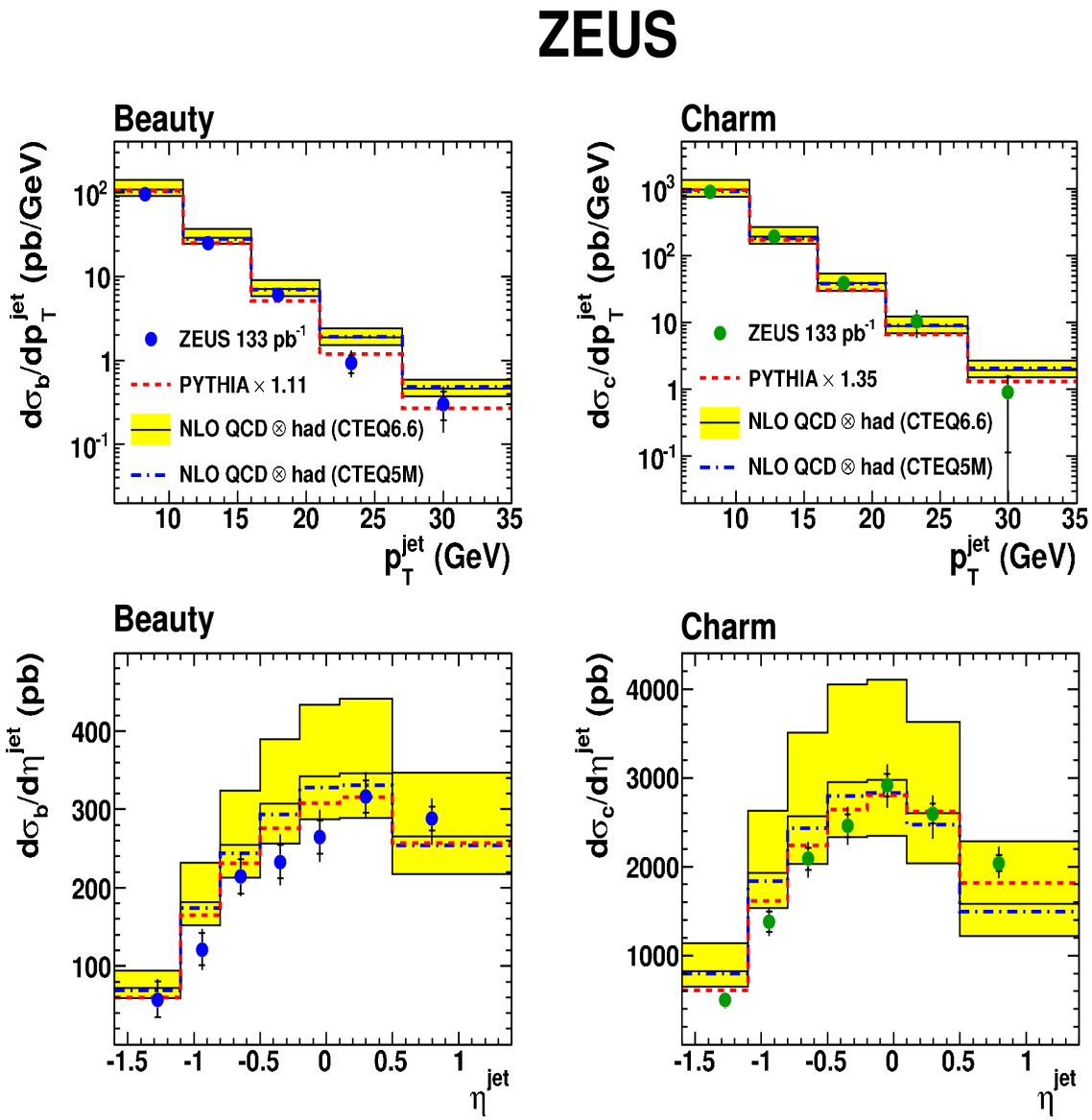
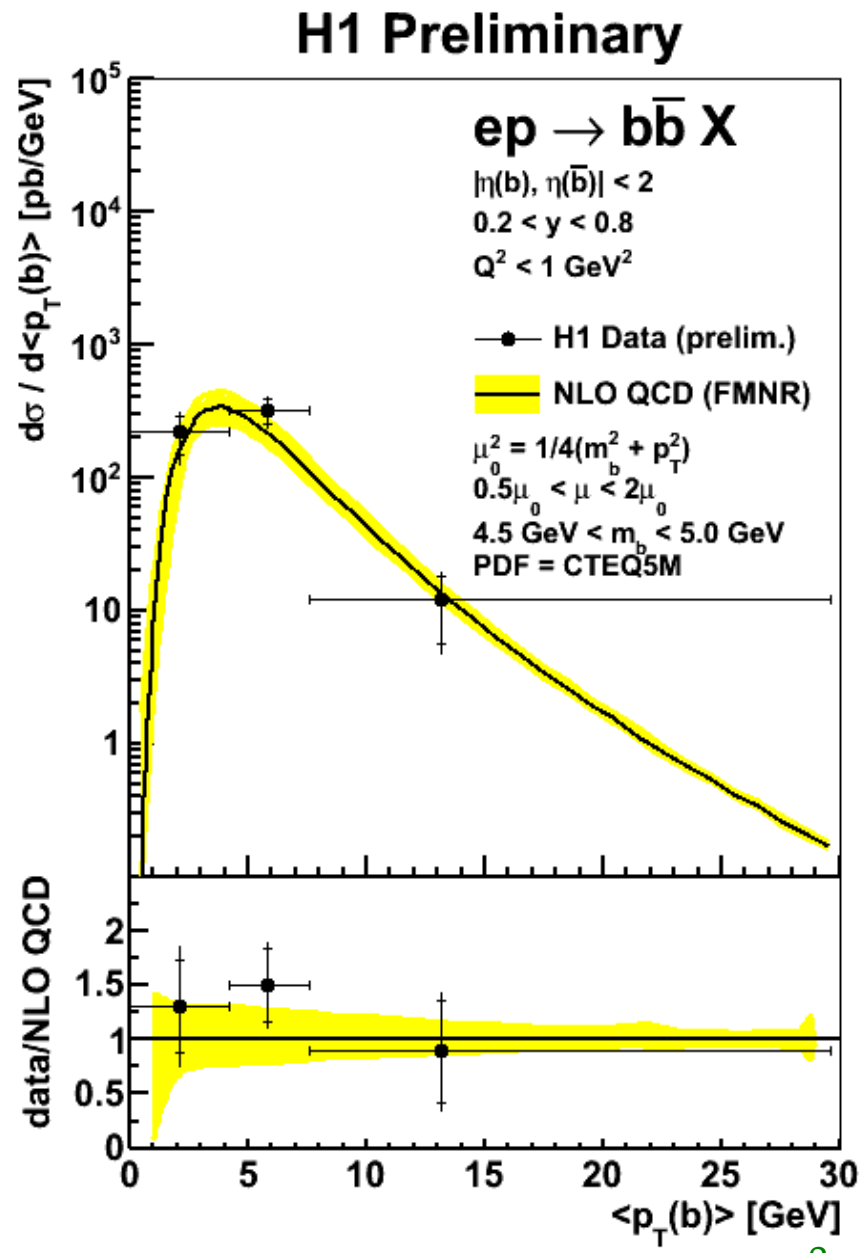
Inclusive Heavy-flavour Jets

- Jet cross sections well reproduced by NLO QCD (FMNR)
  - Small sensitivity to the proton pdf



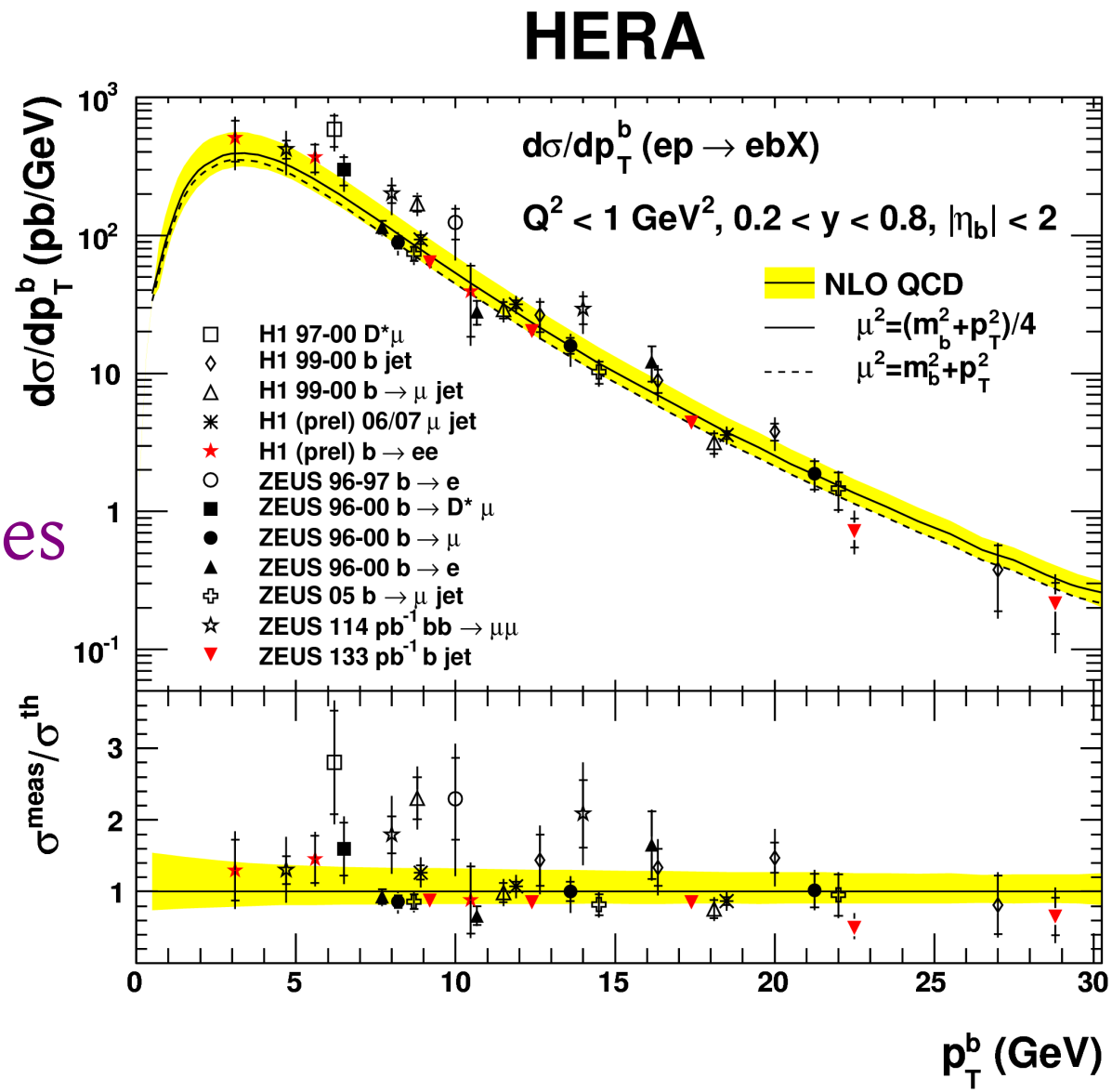
Beauty at the Threshold

- HERAII $\mathcal{L} = 46\mathrm{pb}^{-1}$
- Access to very low p_{T}^{e}
- Excellent electron-pion discriminator
- Results:
  - The lowest $p_{\mathrm{T}}(b)$ measurement at HERA
  - Good description of the data from FMNR



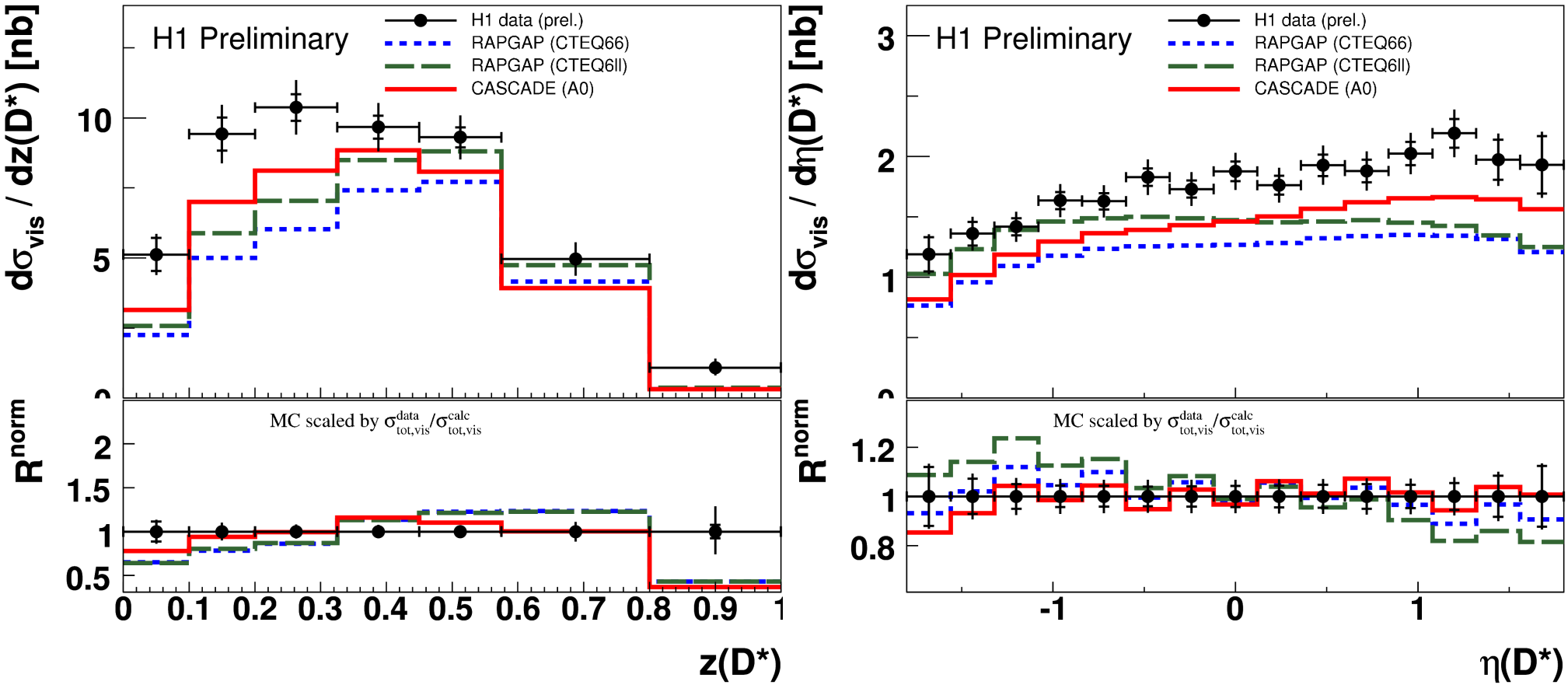
Summary on Beauty at HERA in γp

- Good agreement among the HERA experiments
- NLO (FMNR) provides reasonable description of the $p_T(b)$ spectrum



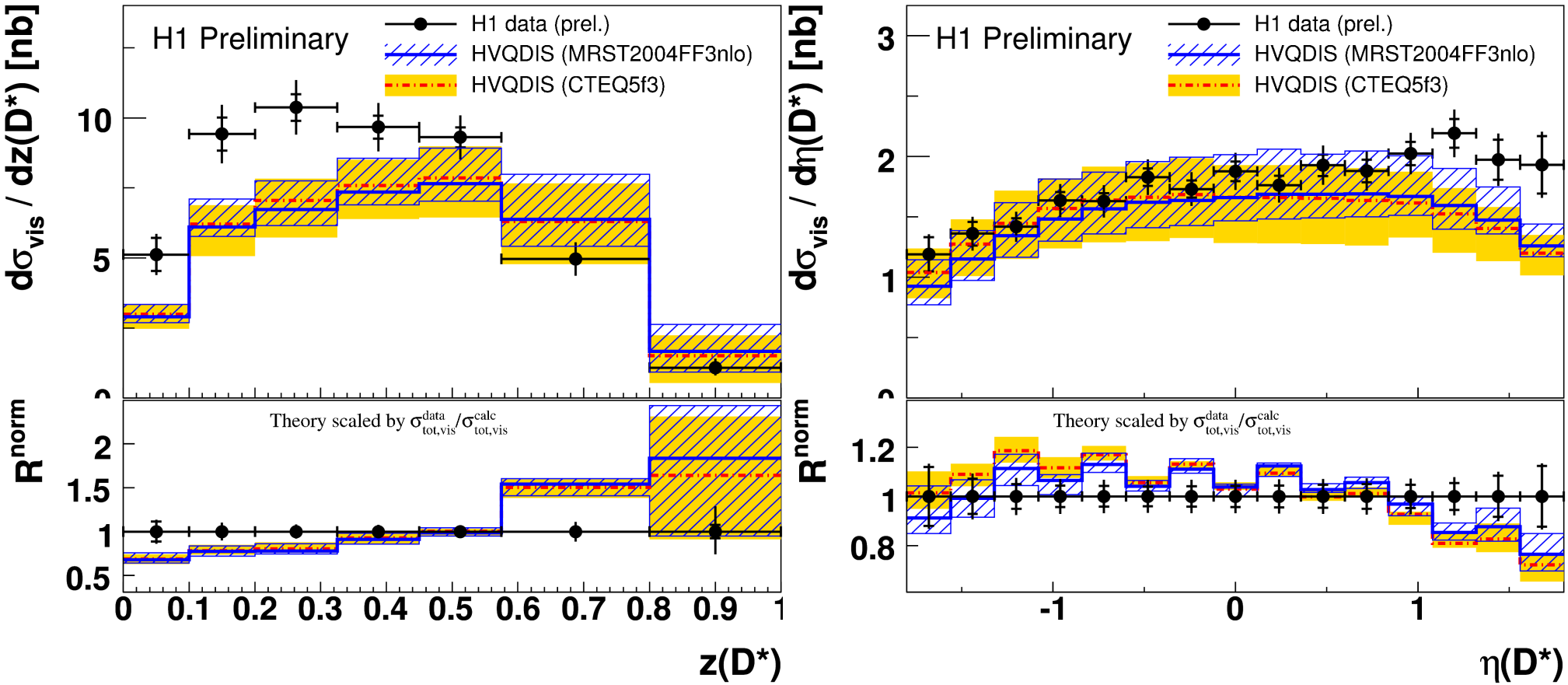
Results from DIS

D* in DIS



- Full HERAII data set $\mathcal{L} \approx 350\mathrm{pb}^{-1}$
- $z(D^*)$ is the longitudinal momentum fraction of the photon carried by the D*

D* in DIS



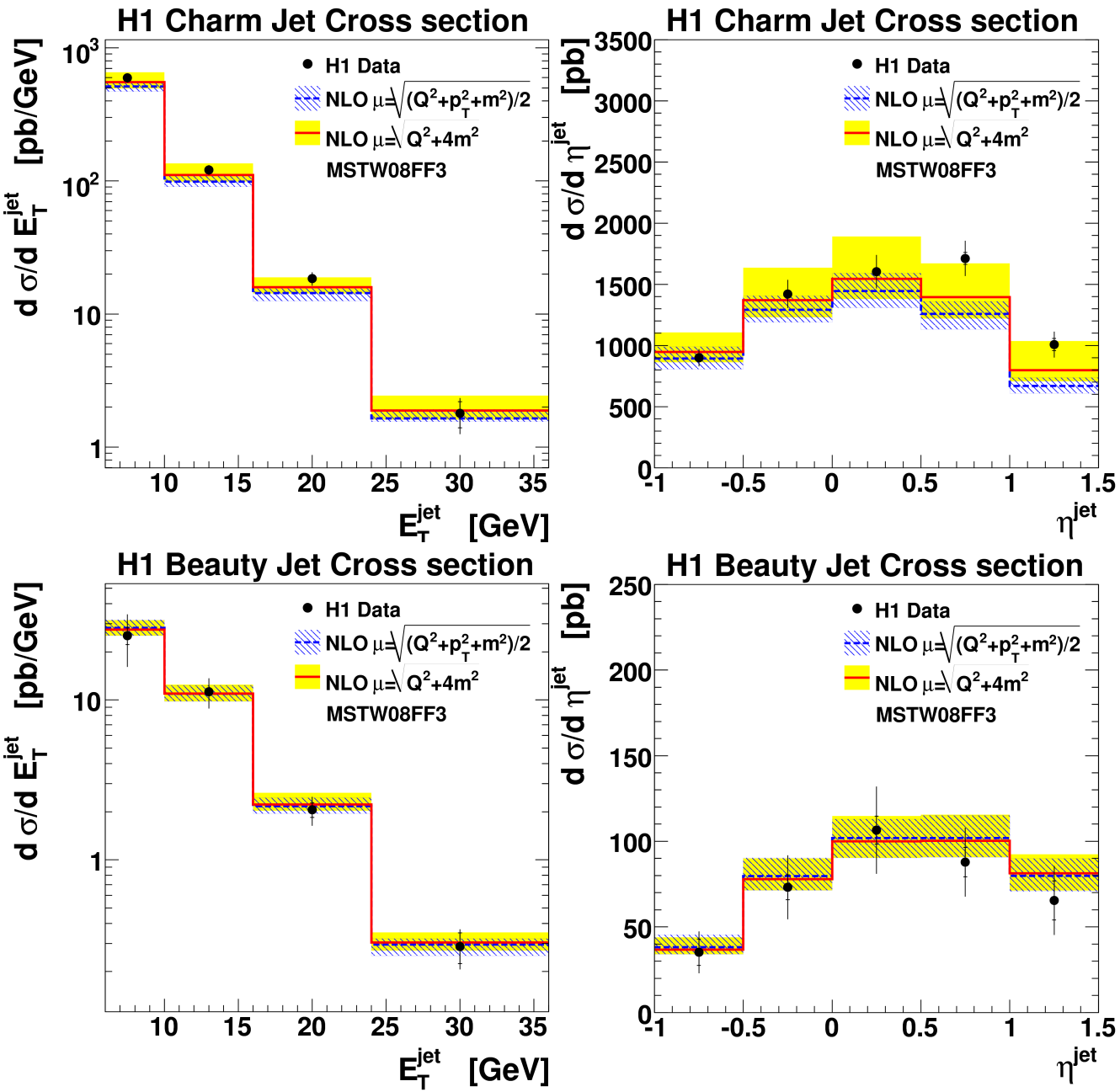
- Comparison to NLO (HVQDIS)
  - Reasonably well reproduced $\eta(D^*)$, wrong $z(D^*)$

Eur.Phys.J. C71 (2011) 1509

H1

Charm and Beauty Jets

- $\mathcal{L} \approx 190\mathrm{pb}^{-1}$
- $E_t^{(*)} > 6\mathrm{GeV}$
- Jets in:
  - Lab frame and Breit frame
- Good description by NLO(HVQDIS)



Eur.Phys.J.C71:1573,2011

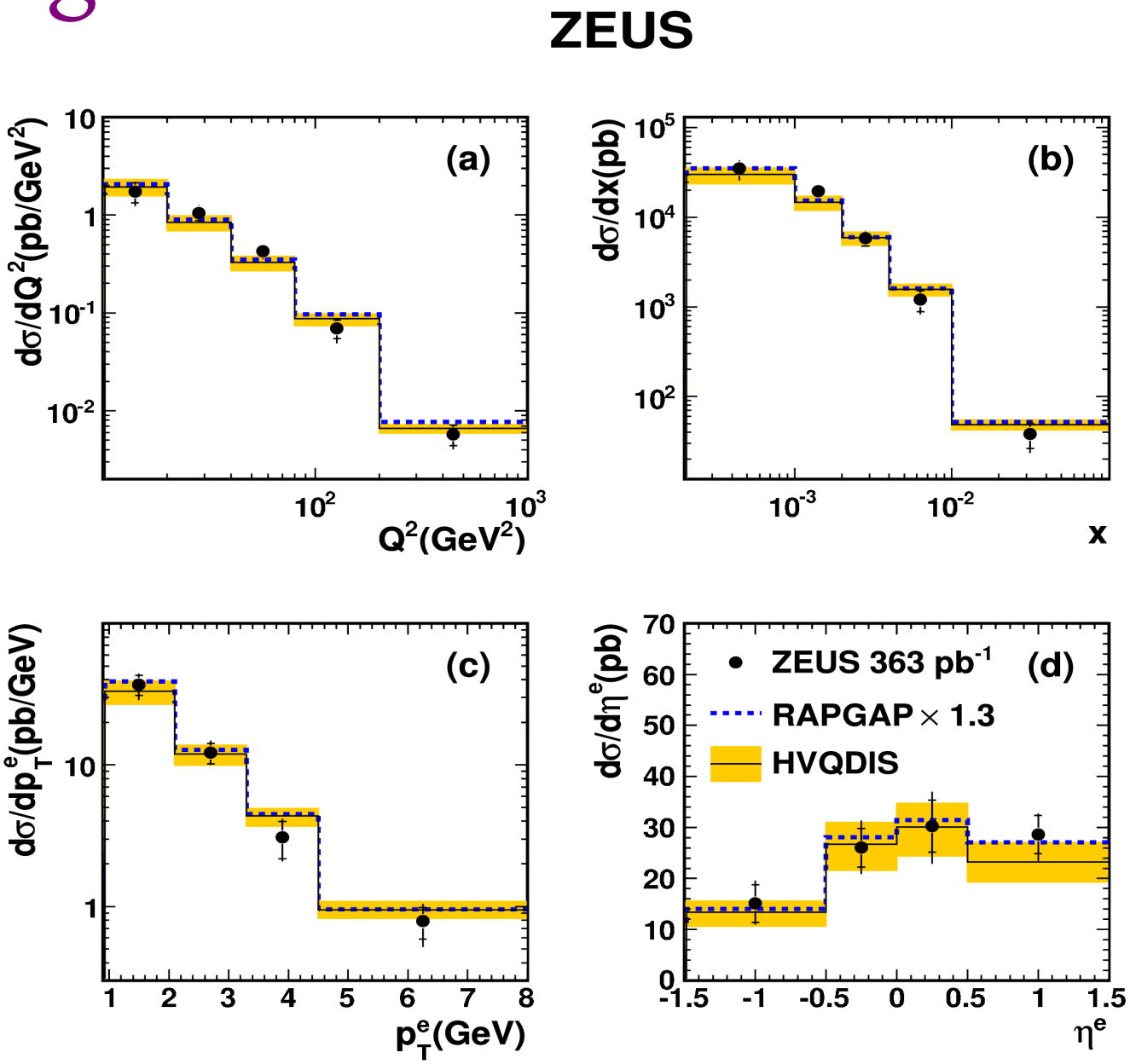
ZEUS

Beauty Using Exclusive Electrons

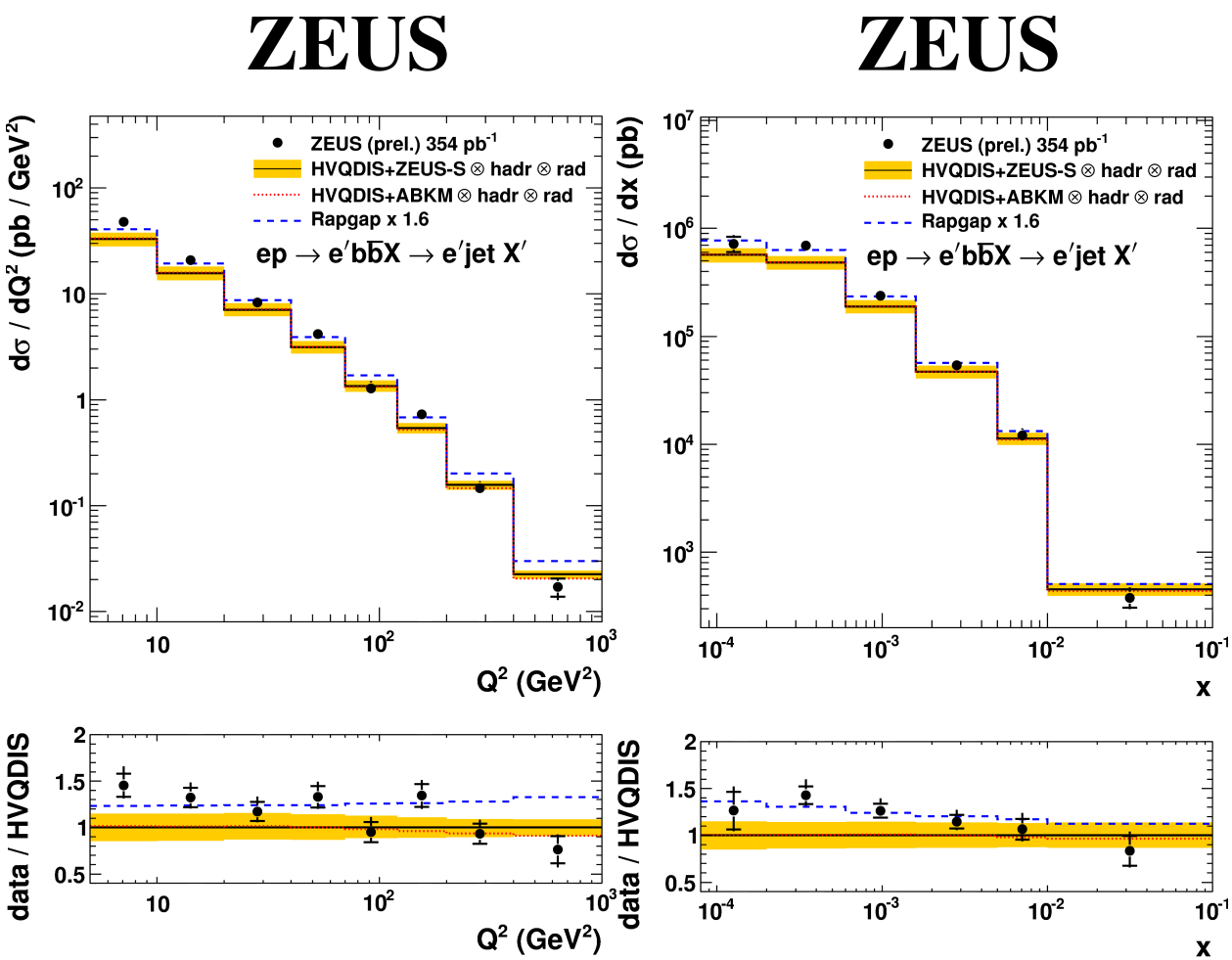
- $ep \to e' b\bar{b} \to e' e X$
- The electron is associated to a jet:

  $p_{\mathrm{T}} > 2.5\mathrm{GeV}$

- Several variables used to identify the electrons from beauty decays
- Data well reproduced by NLO
  - Scaling factor for Rapgap



Beauty using Jets and Secondary Vertices



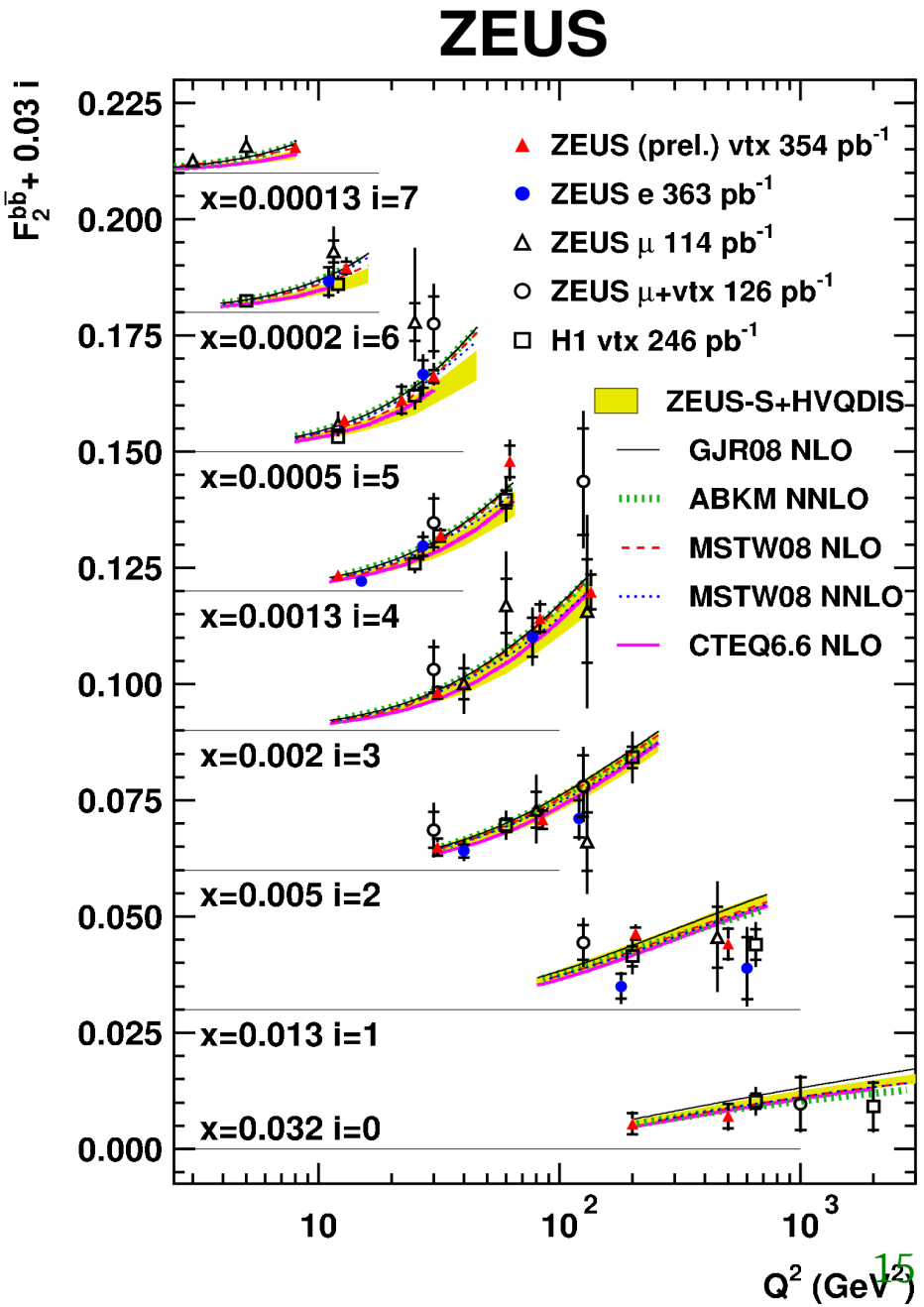
- Small difference between different proton pdfs
  - Reasonable description of the cross sections
  - Double differential cross sections in (x,Q2) are used to determine the beauty contribution to F_2

Eur.Phys.J.C65:89-109,2010
Eur.Phys.J.C71:1573, 2011, ZEUS-prel-10-004

H1+ZEUS

The Beauty Contribution to the Proton Structure

- $$\frac{\mathrm{d}^2\,\sigma^{b\bar{b}}}{\mathrm{d}\,x\,\mathrm{d}\,Q^2} \approx \frac{2\pi\alpha_{em}^2}{xQ^4}\left[1+(1-y)^2 F_2^{b\bar{b}}\right]$$
- Consistent picture:
  - Good agreement within experimental procedures
  - NLO and NNLO give a good description

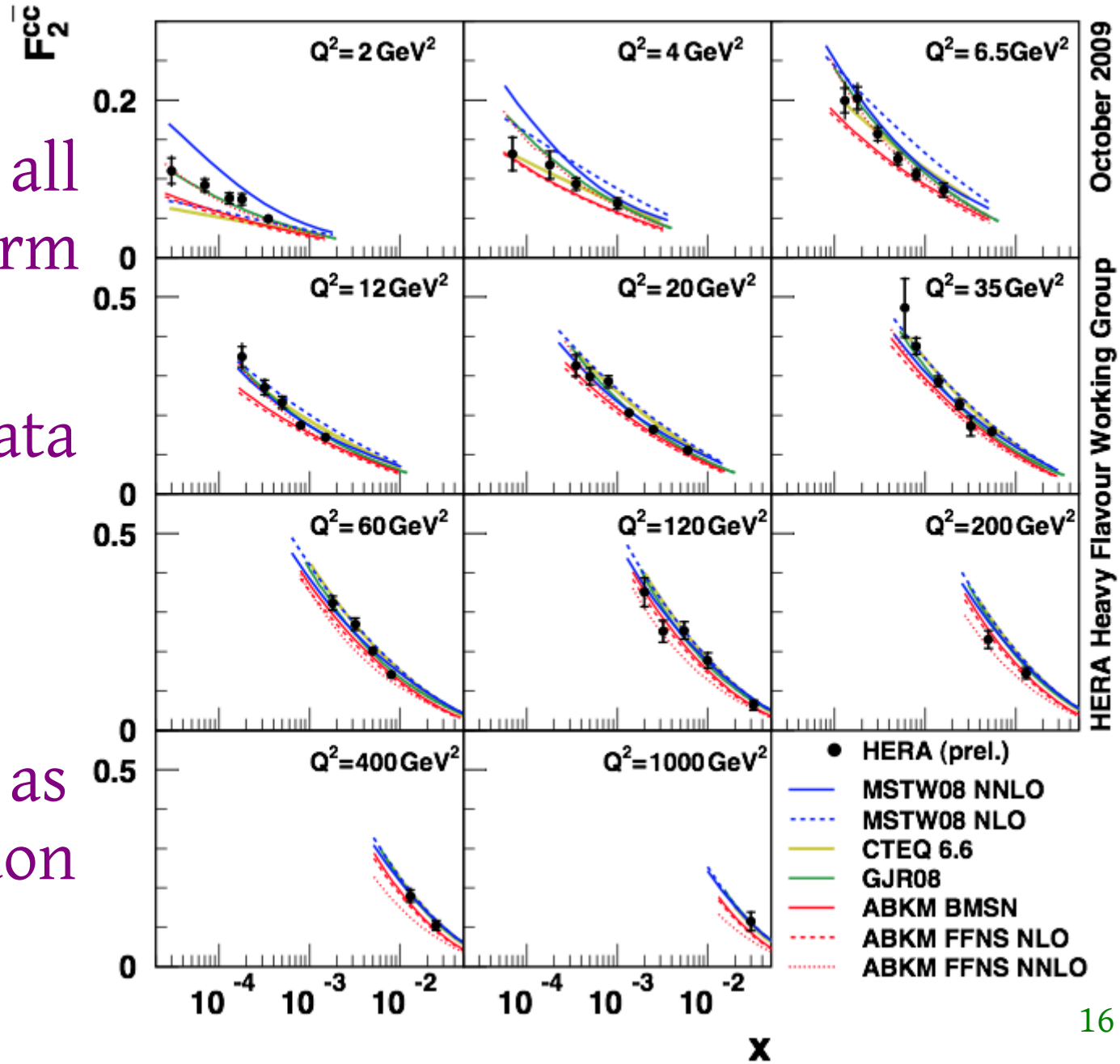


H1prelim-10-143
ZEUS-prel-10-019

H1+ZEUS

The Charm Contribution to the Proton Structure

- Combination of all H1 and Zeus charm data
- High precision data
- The data are sensitive to the different heavy quark treatment as well as to the gluon densities



Concluding Remarks

- Heavy flavour physics at HERA provides an excellent testing ground for pQCD
- High precision data with well understood detectors
- Different experimental techniques were presented and cross checked against one another and compared to a wide range of LO and NLO predictions:
  - Excellent agreement within the experiments and the measurements
  - Reasonable description of the data by up-to-date NLO QCD models