

Beauty and Charm at HERA

by
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On the behalf of H1 and ZEUS Collaborations

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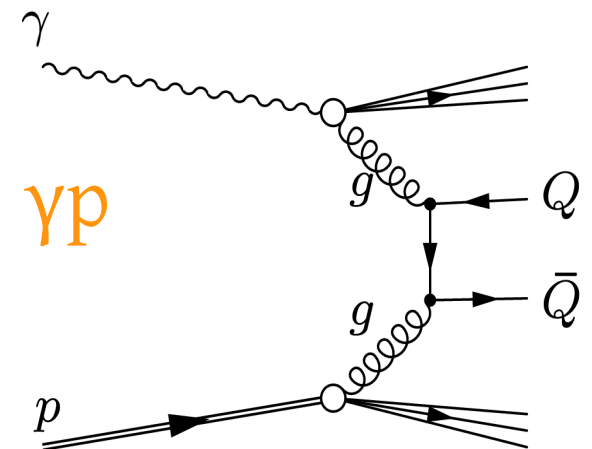
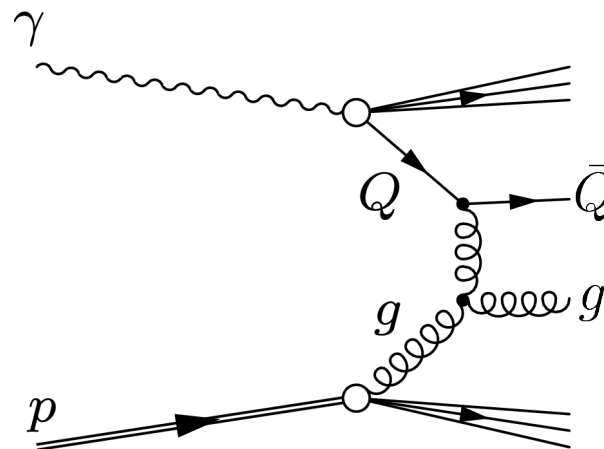
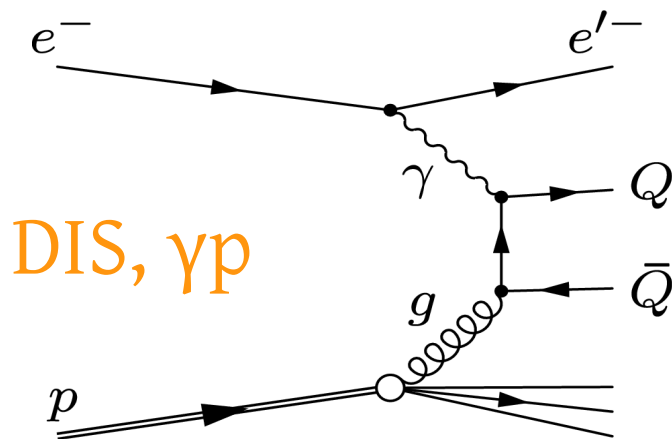


Content

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

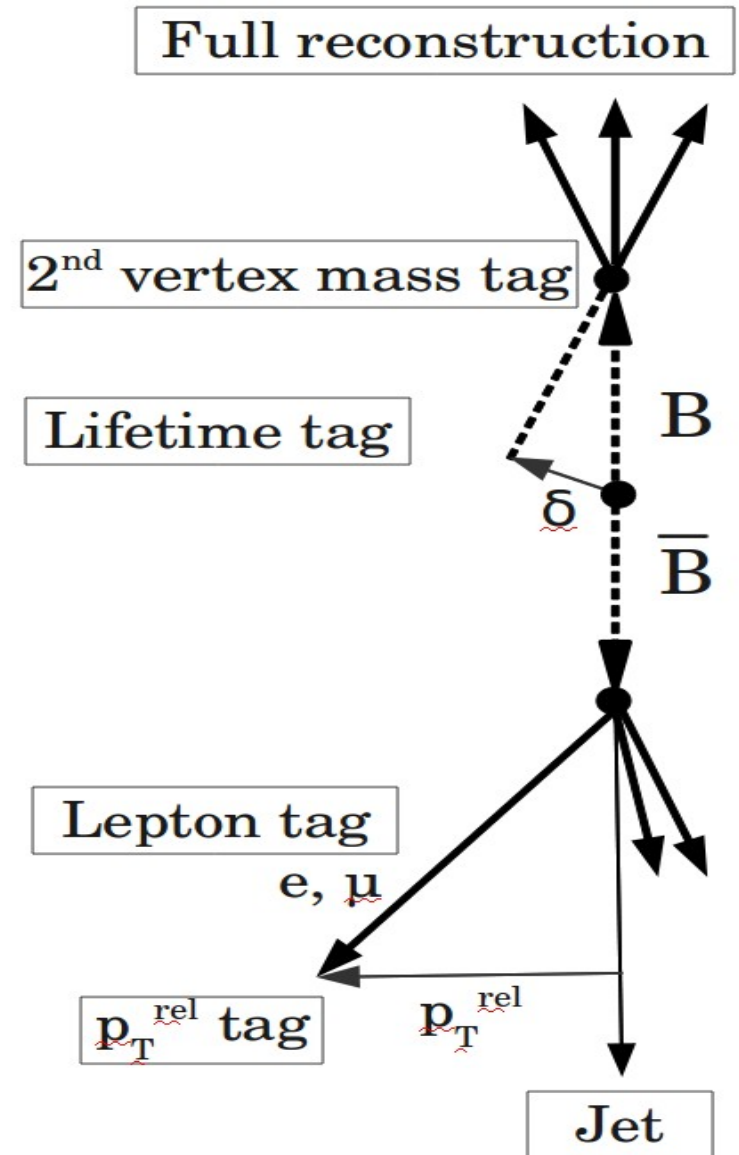
Production Mechanism

- 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

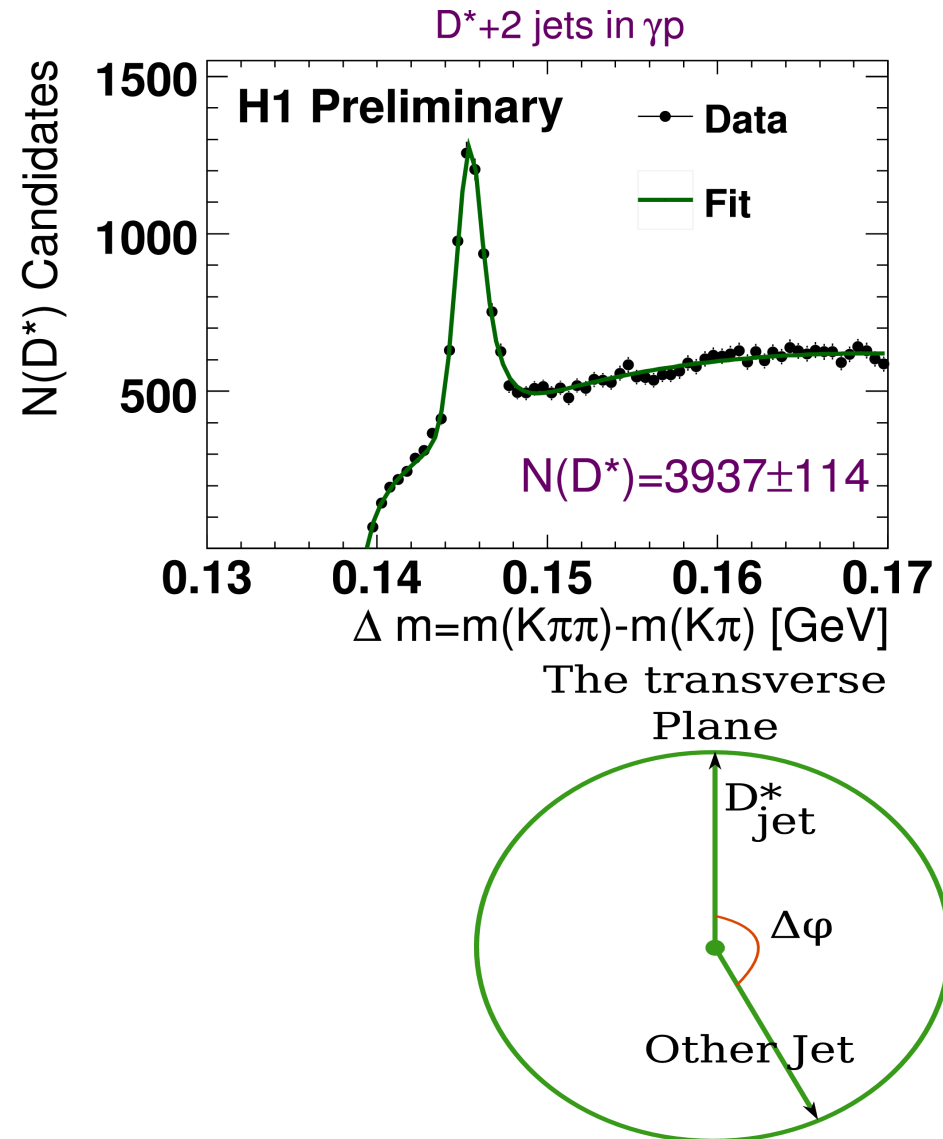
- Full reconstruction of D mesons:
- (Semi)leptonic decays and (or) jets:
 - $Q \longrightarrow e(\mu) + X$
 - The relative p_T of a lepton with respect to a jet axis p_T^{rel}
- Long lifetime:
 - Displaced secondary vertices
 - Track impact parameter and displaced secondary vertices



Results from
 γp

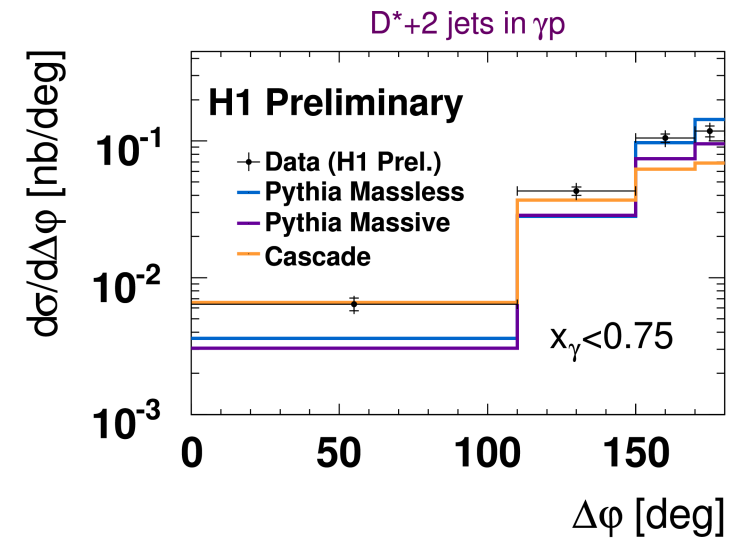
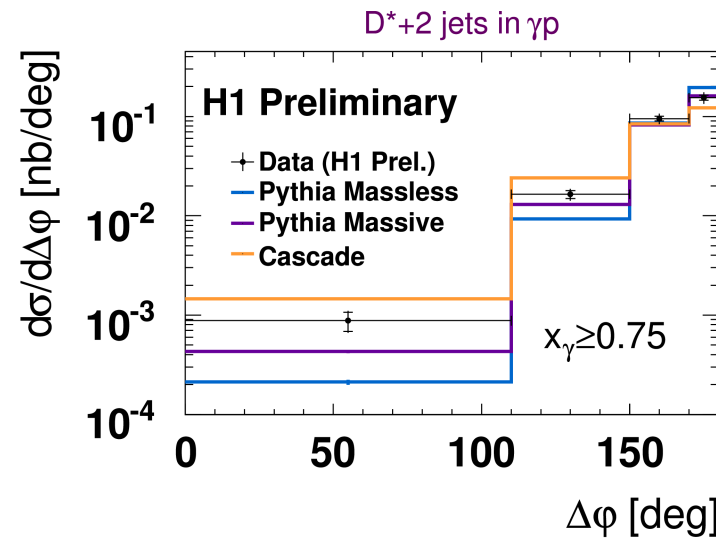
D* with Jets

- HERAII 06/07 $e^+ \mathcal{L} \approx 90\text{pb}^{-1}$
- $D^{*\pm} \rightarrow D^0 \pi_{slow}^{\pm} \rightarrow (K^{\mp} \pi^{\pm}) \pi_{slow}^{\pm}$
- 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

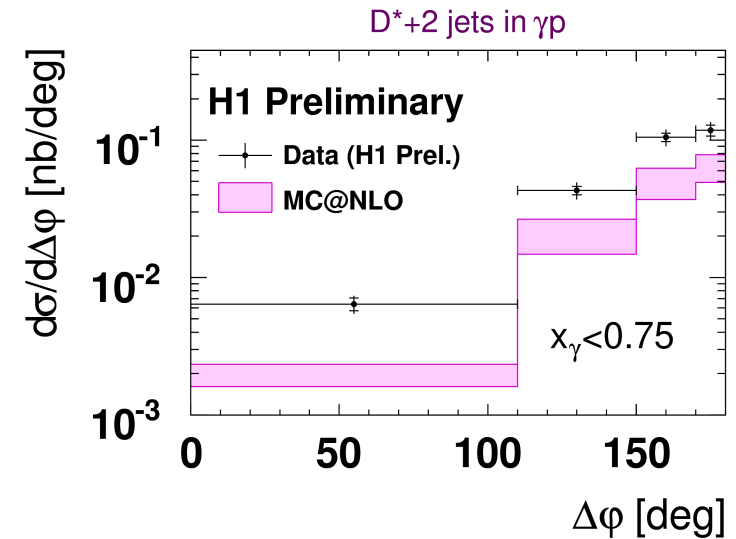
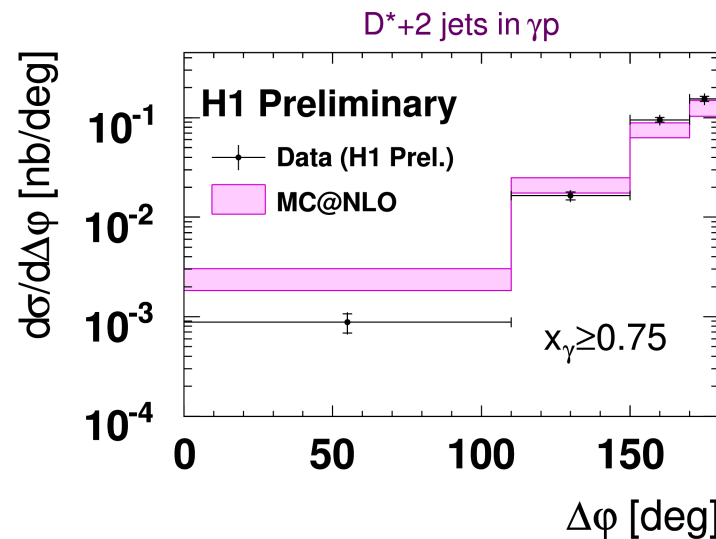


D* with Jets

- Pythia and Cascade give different shapes than the data



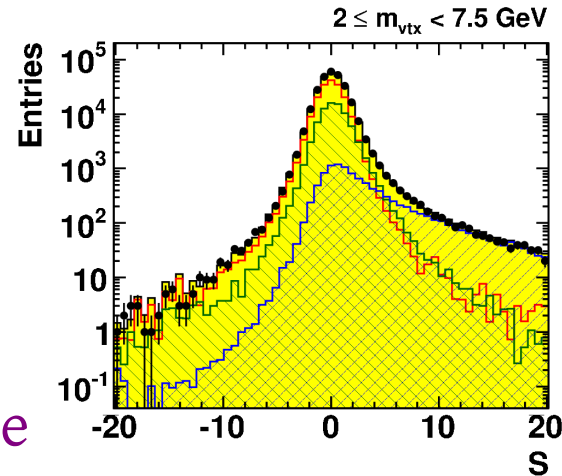
- MC@NLO:
 - Normalisation problem at low x_γ
 - Best shapes predictions



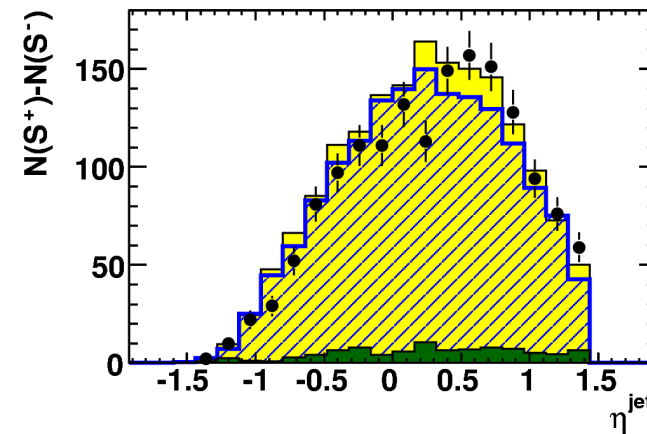
$$x_\gamma = \frac{\sum (E - p_z)_{jets}}{(E - p_z)_{tot}}$$

Inclusive Heavy-flavour Jets

- HERAII 05e-
- 2 Jets $p_T^{\text{jet}} > 6(7)\text{GeV}$
- 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



- ZEUS 133 pb⁻¹
- PYTHIA (lf+c+b)
- PYTHIA (lf)
- PYTHIA (c)
- PYTHIA (b)

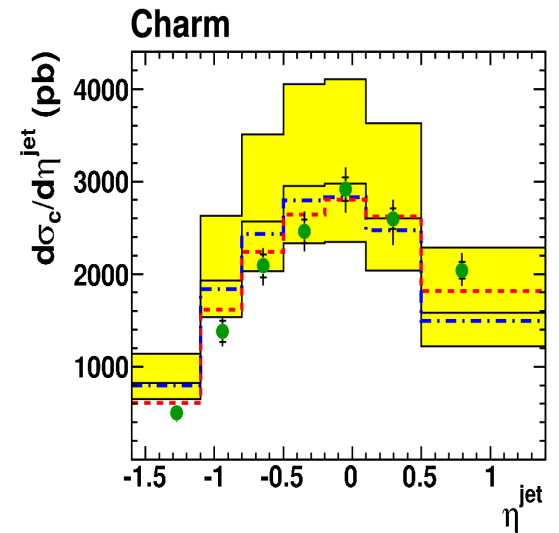
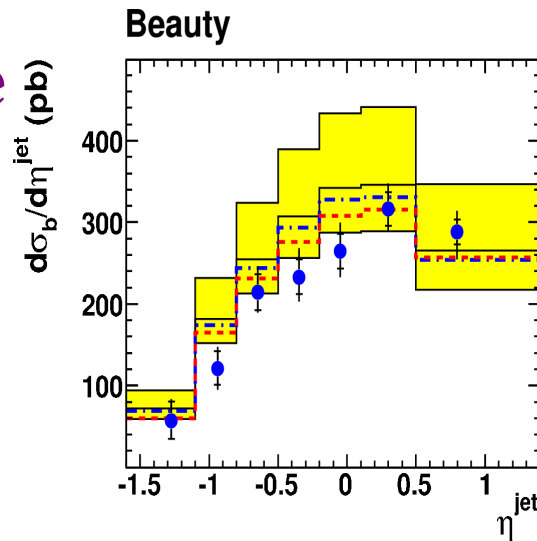
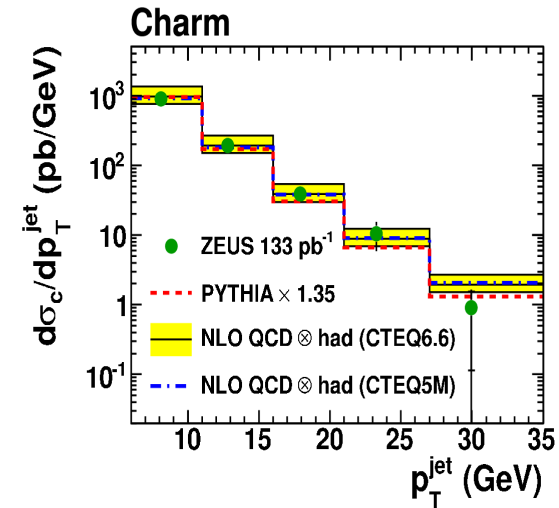
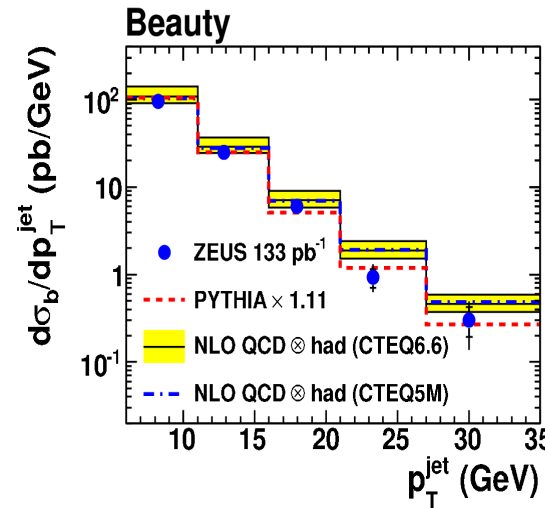


Inclusive Heavy-flavour Jets

ZEUS

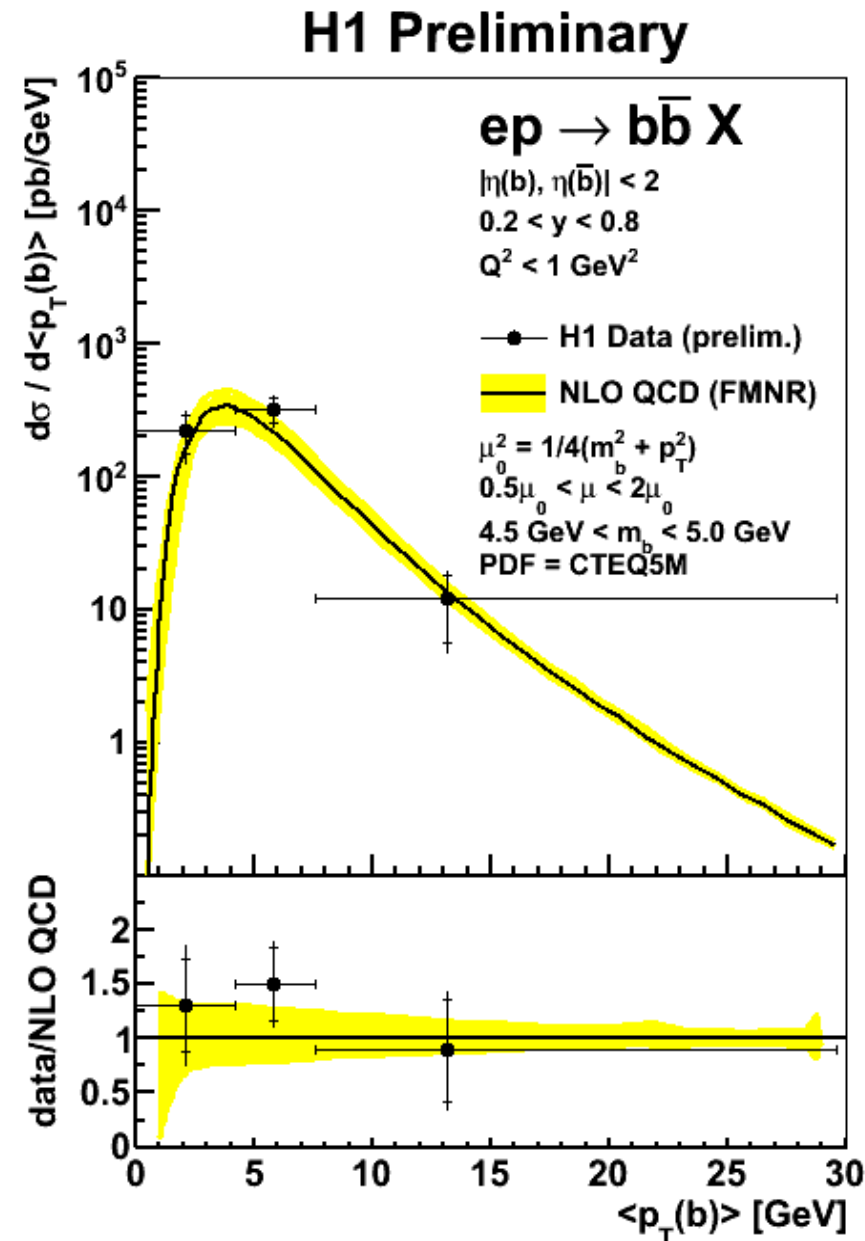
Jet cross sections well reproduced by NLO QCD (FMNR)

Small sensitivity to the proton pdf



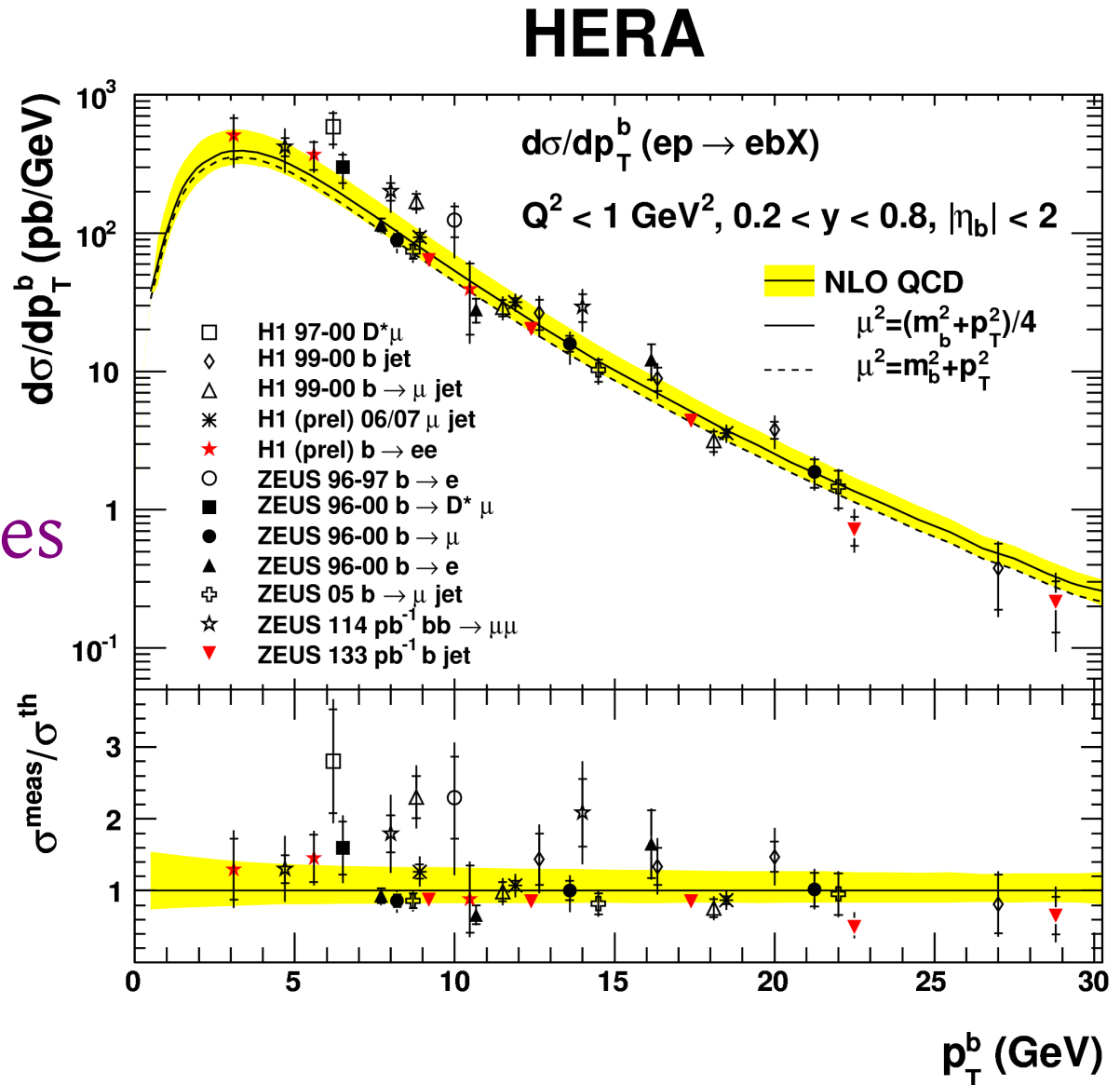
Beauty at the Threshold

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



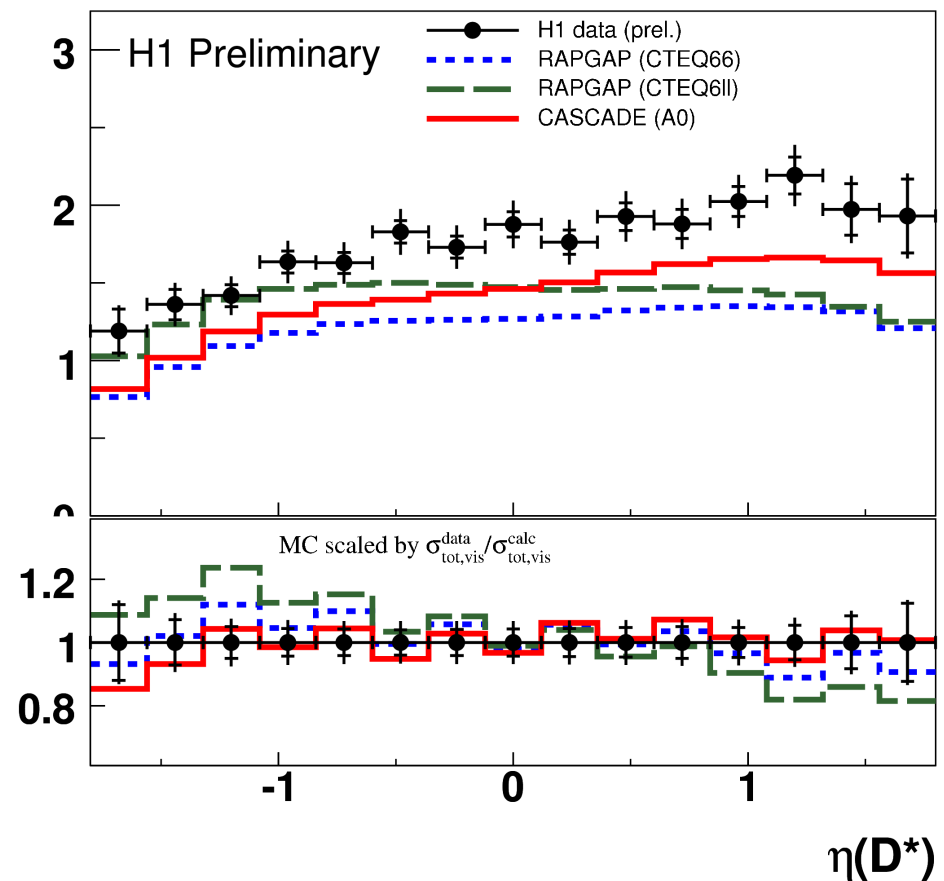
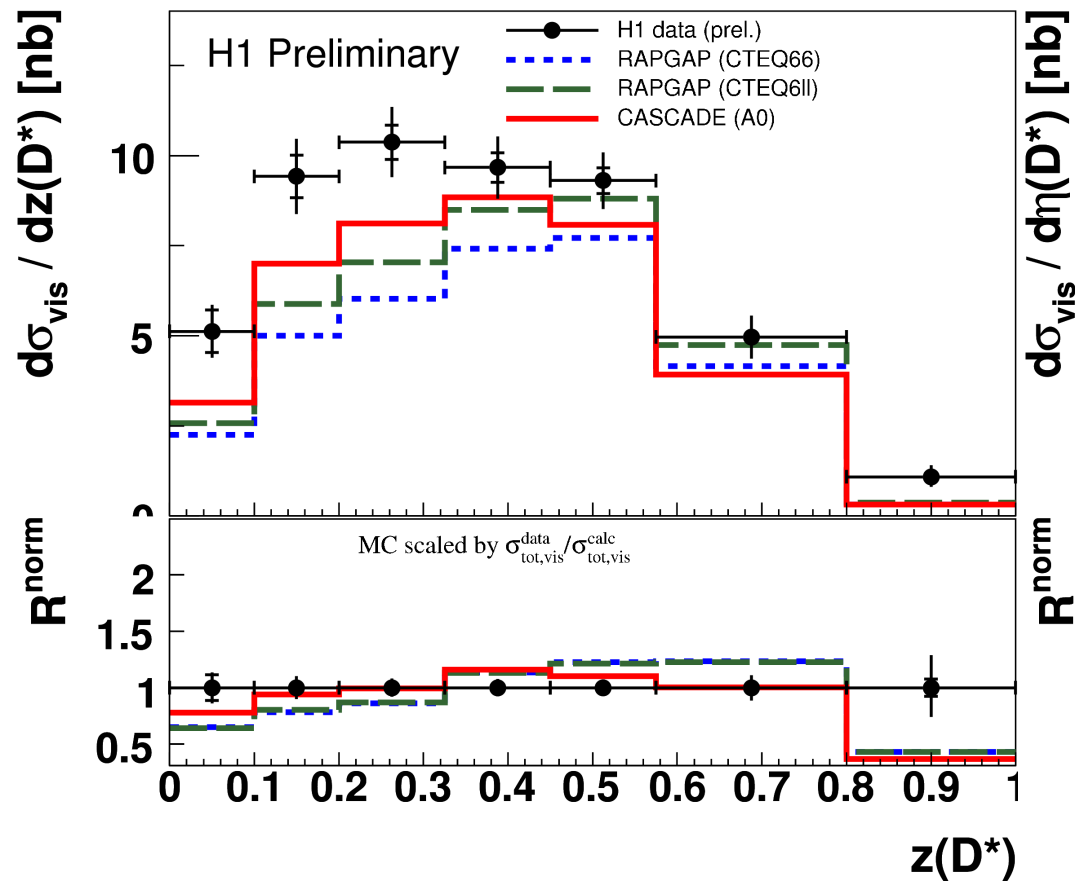
Summary on Beauty at HERA in γp

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



Results from DIS

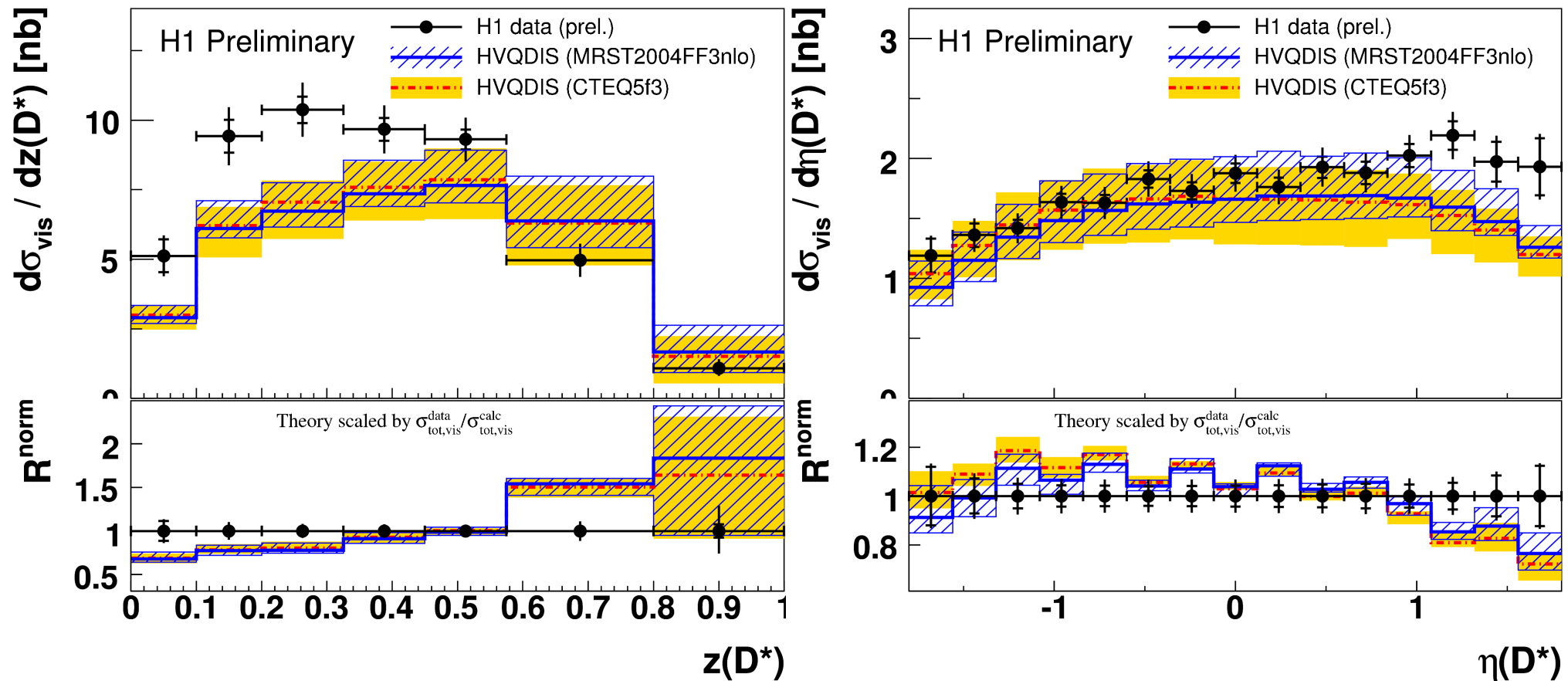
D^* in DIS



• Full HERAII data set $\mathcal{L} \approx 350\text{pb}^{-1}$

• $z(D^*)$ is the longitudinal momentum fraction of the photon carried by the D^*

D^* in DIS

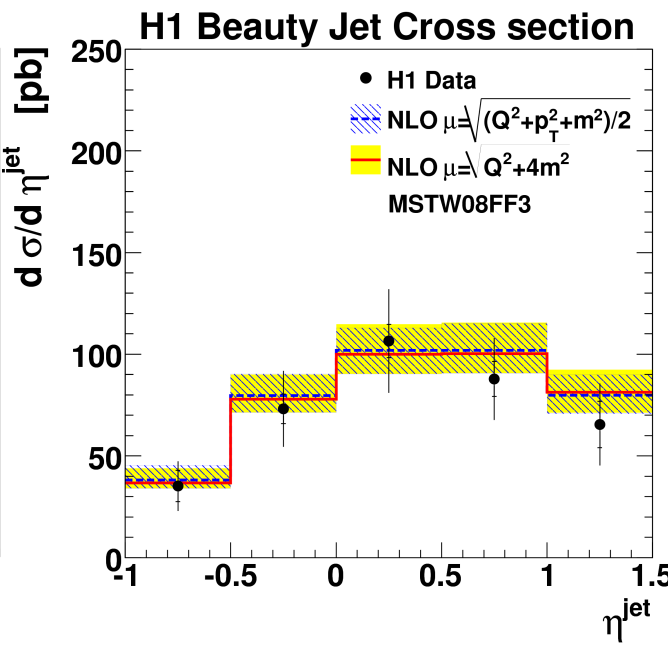
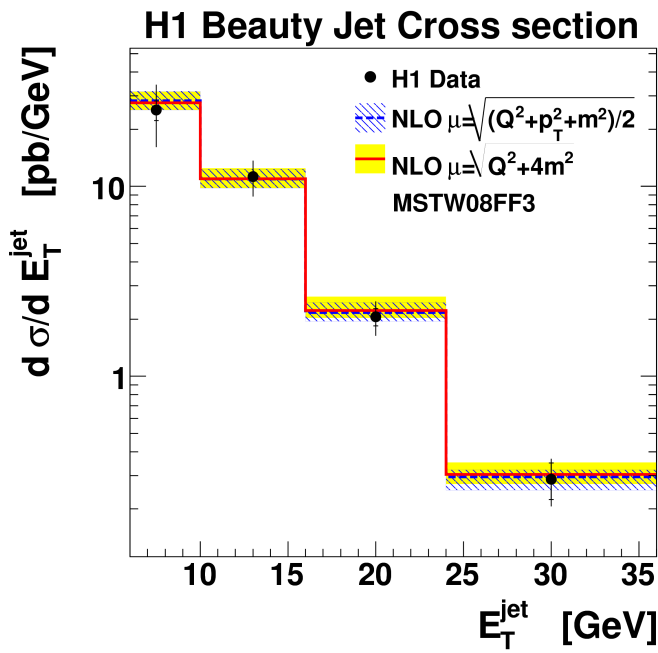
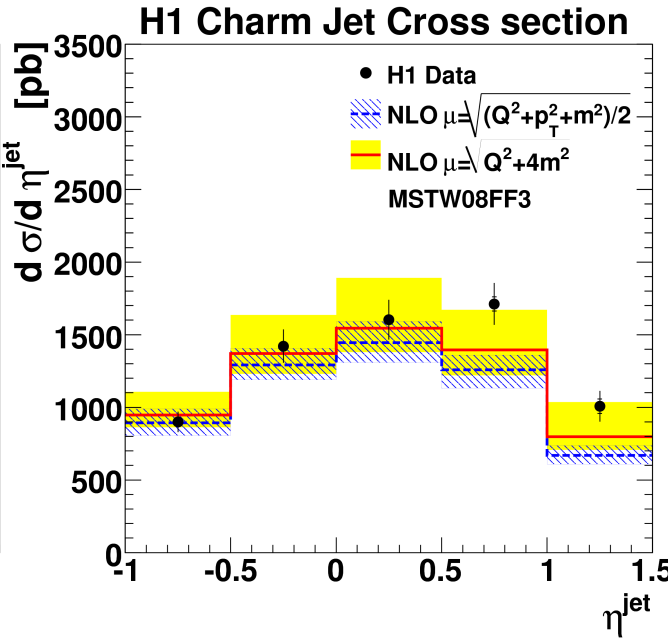
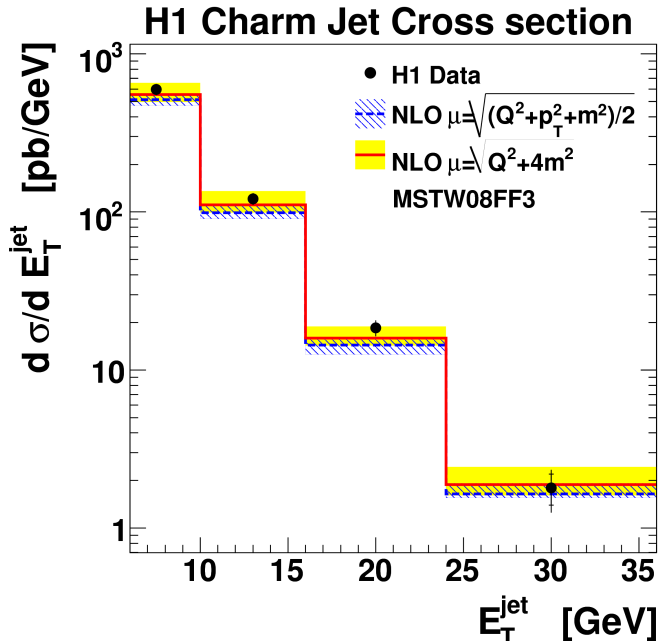


Comparison to NLO (HVQDIS)

Reasonably well reproduced $\eta(D^*)$, wrong $z(D^*)$

Charm and Beauty Jets

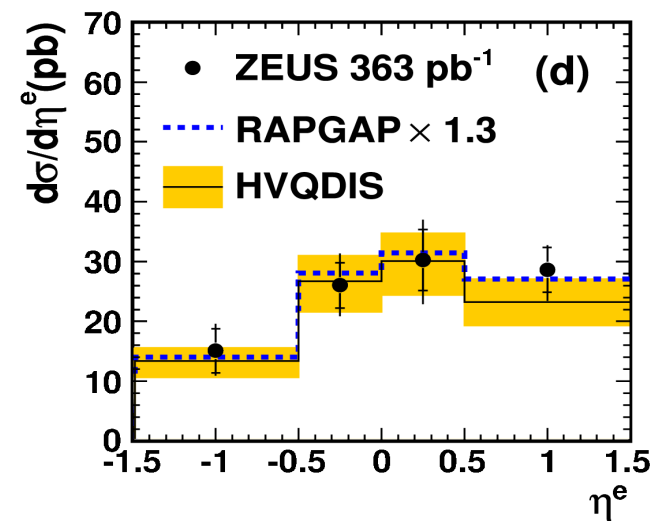
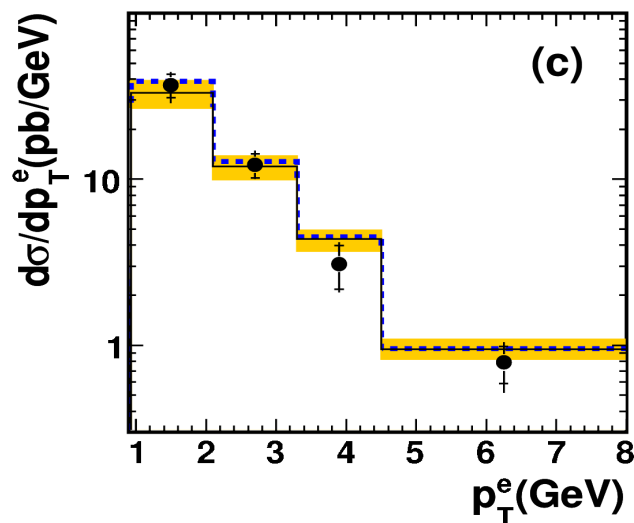
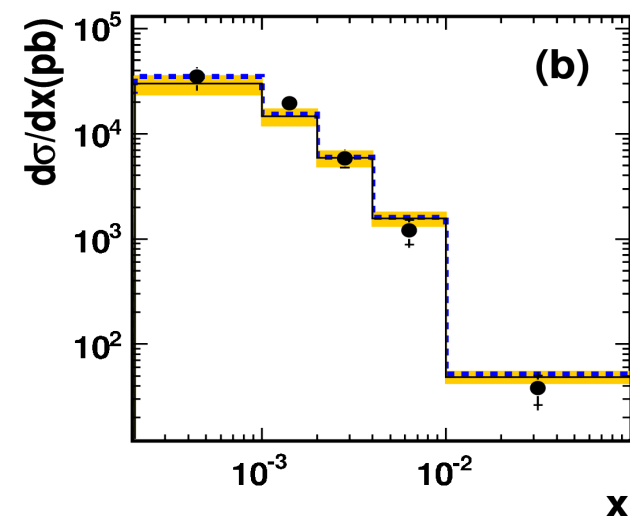
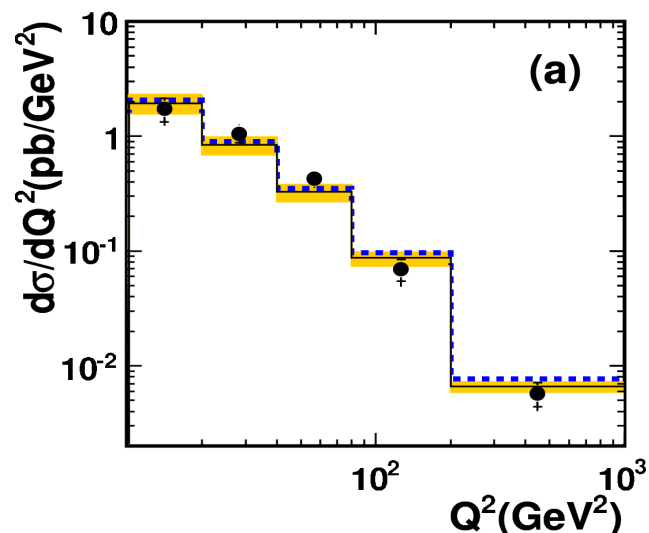
- $\mathcal{L} \approx 190\text{pb}^{-1}$
- $E_t^{(*)} > 6\text{GeV}$
- Jets in:
 - Lab frame
 - Breit frame
- Good description by NLO(HVQDIS)



Beauty Using Exclusive Electrons

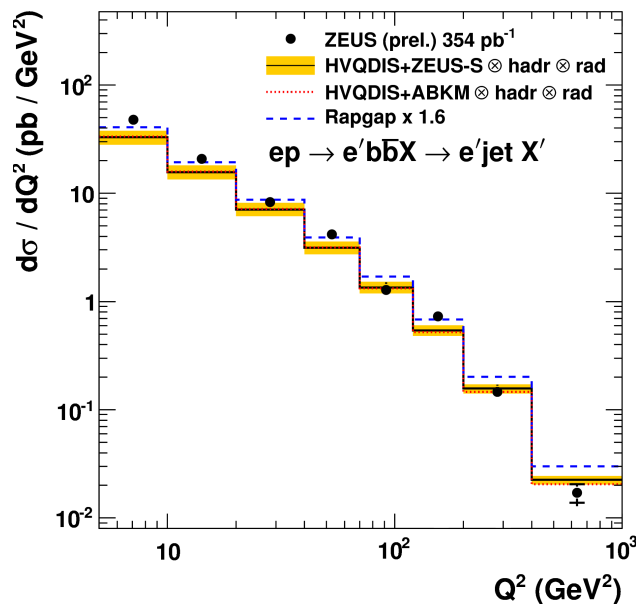
ZEUS

- $ep \rightarrow e' b \bar{b} \rightarrow e' e X$
- The electron is associated to a jet:
 $p_T > 2.5 \text{ GeV}$
- Several variables used to identify the electrons from beauty decays
- Data well reproduced by NLO
- Scaling factor for Rapgap

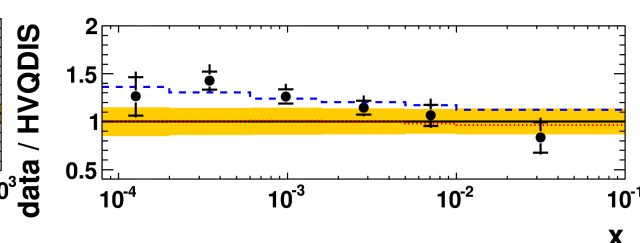
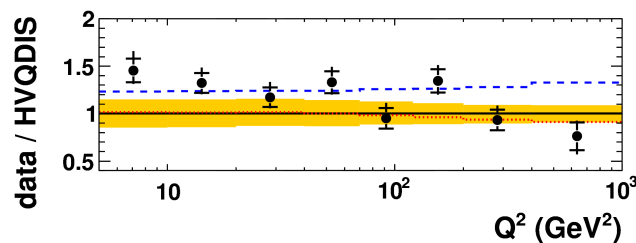
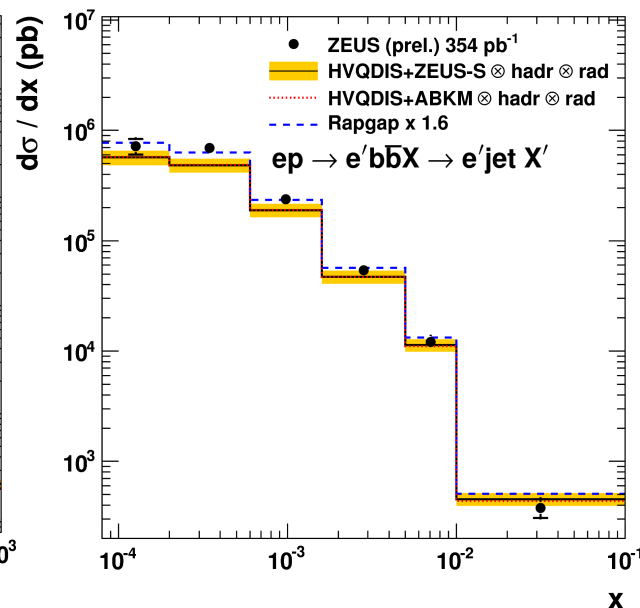


Beauty using Jets and Secondary Vertices

ZEUS



ZEUS



Small difference between different proton pdfs

Reasonable description of the cross sections

Double differential cross sections in (x, Q^2) are used to determine the beauty contribution to F_2

The Beauty Contribution to the Proton Structure

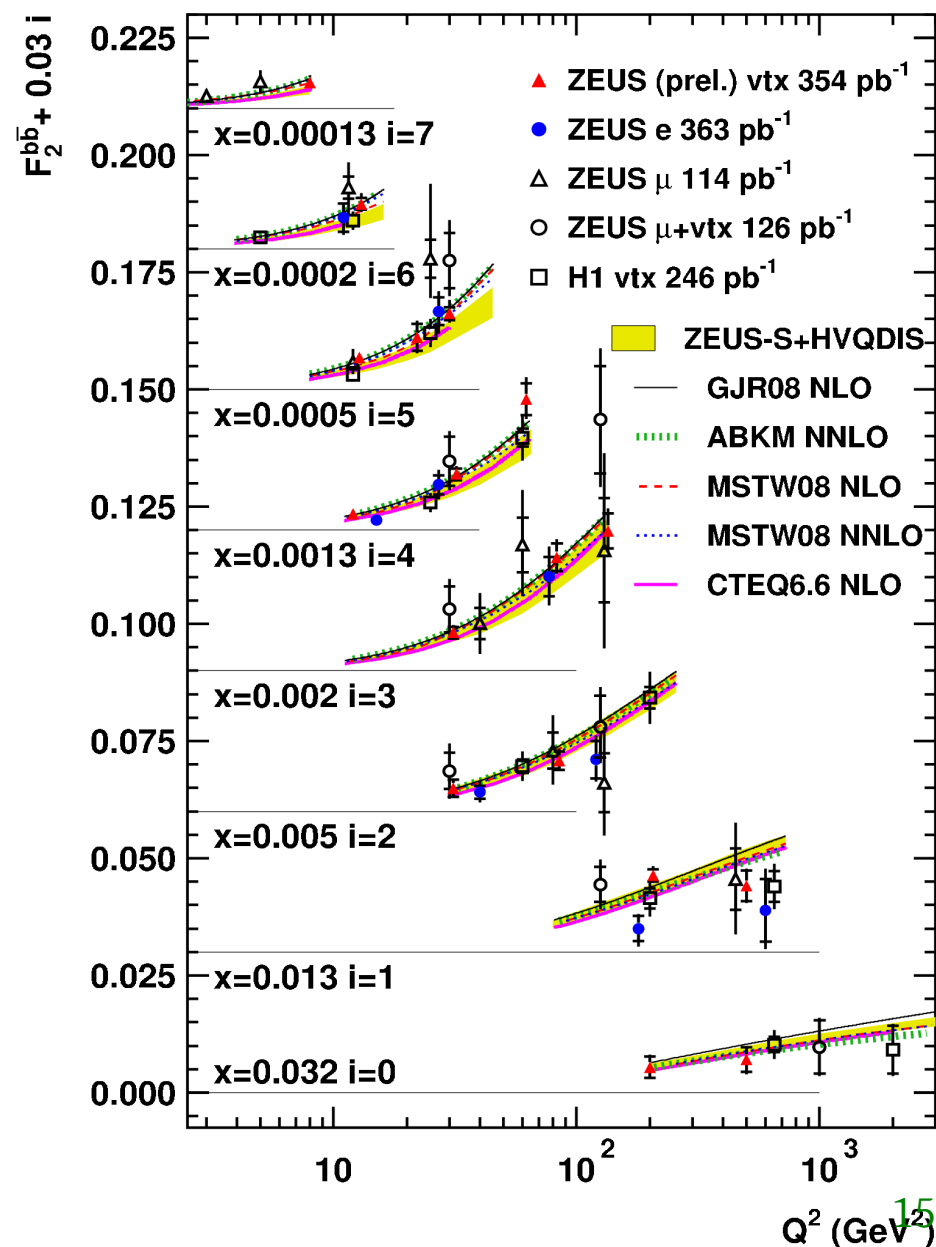
ZEUS

$$\frac{d^2 \sigma^{b\bar{b}}}{dx dQ^2} \approx \frac{2\pi\alpha_{em}^2}{xQ^4} \left[1 + (1-y)^2 F_2^{b\bar{b}} \right]$$

Consistent picture:

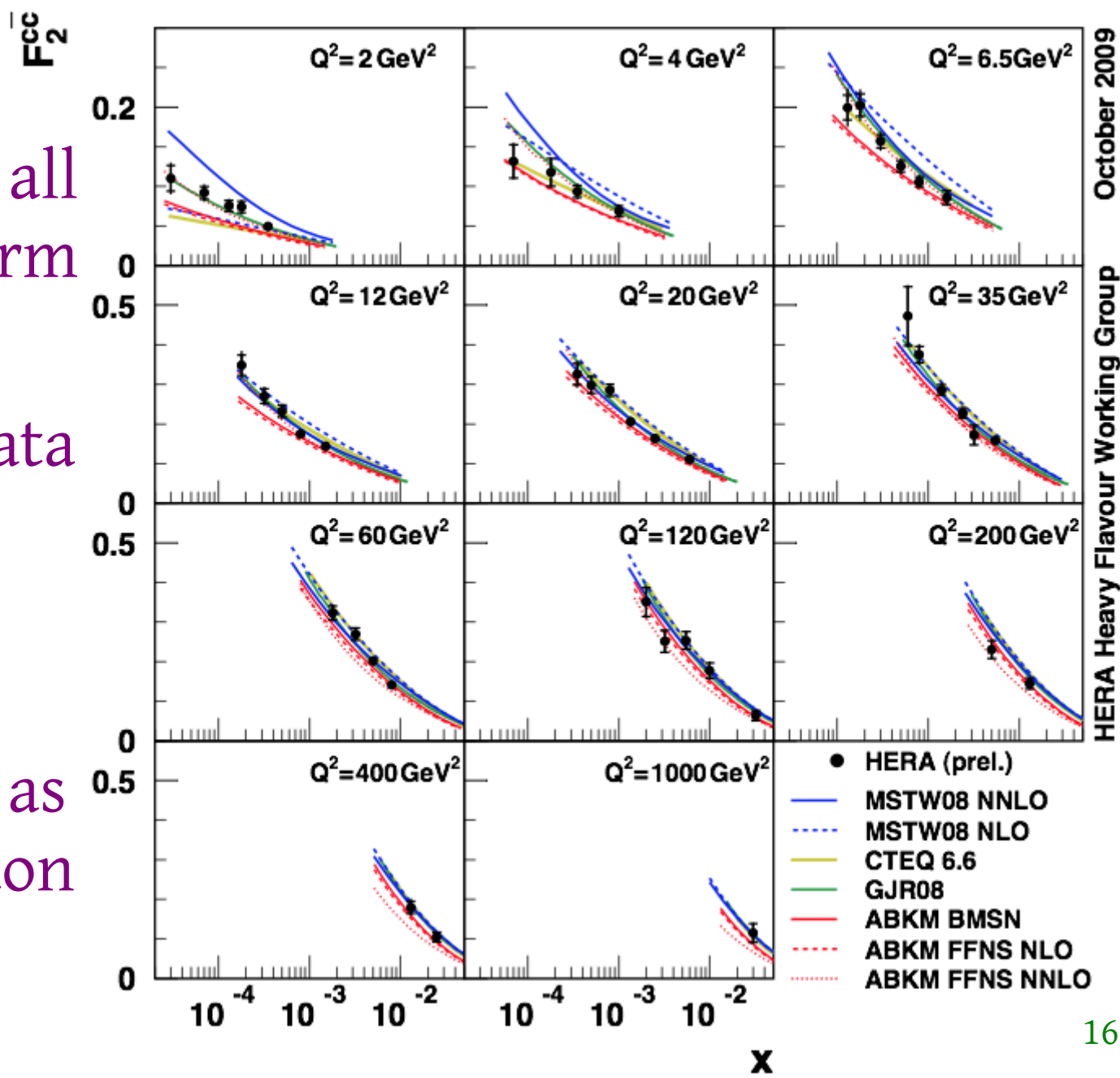
Good agreement within experimental procedures

NLO and NNLO give a good description



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