Heavy Flavour Production in *ep* Collisions

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- HERA and Production of Heavy Quarks
- Inclusive Measurements
- Heavy Meson Cross Sections

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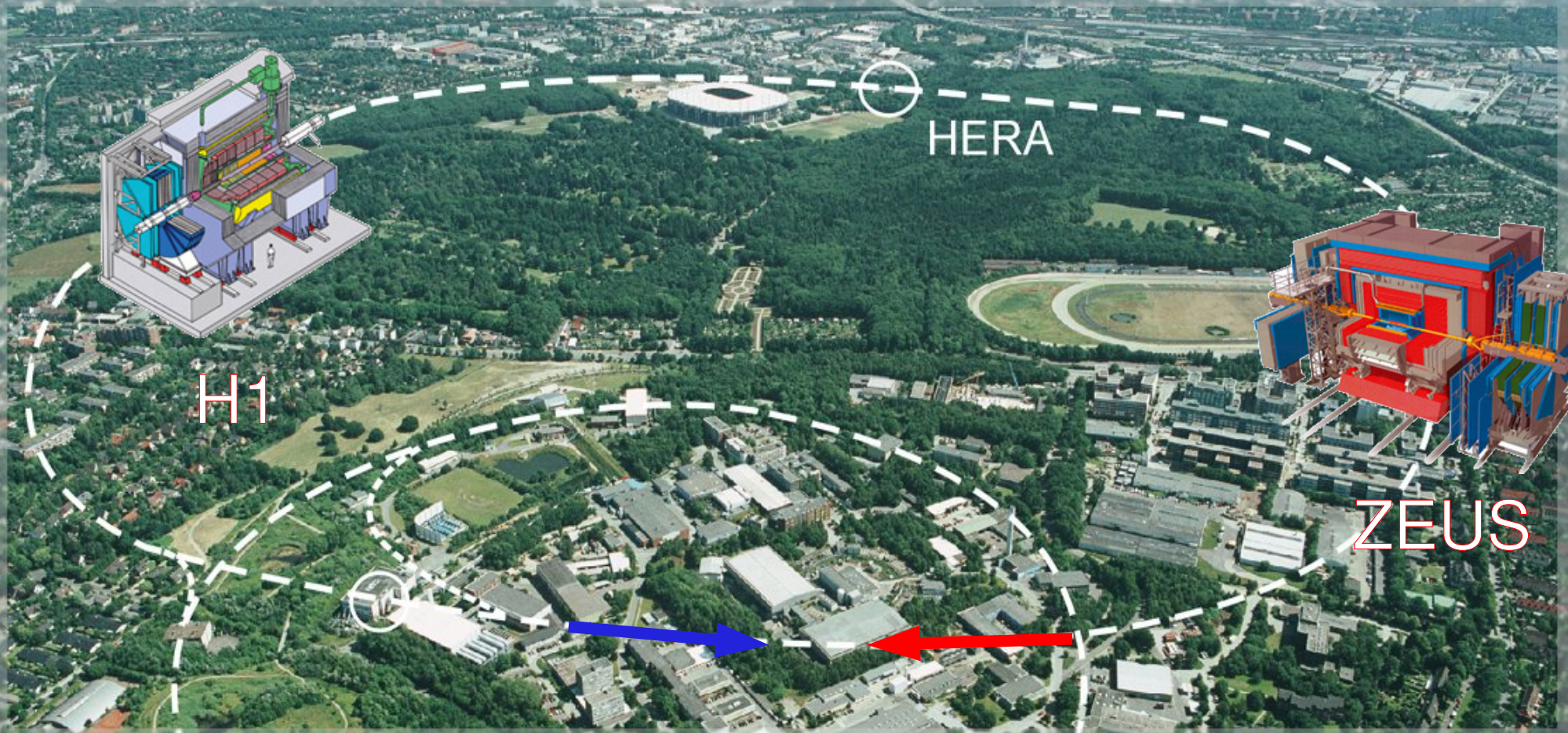
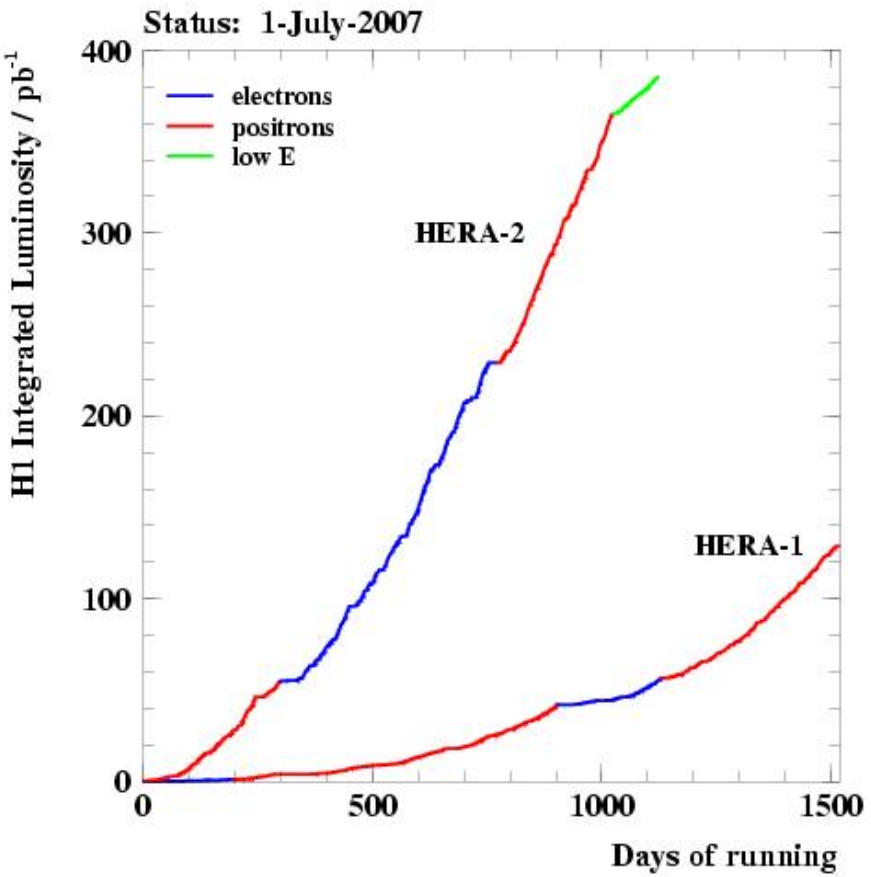
Berkeley, CA

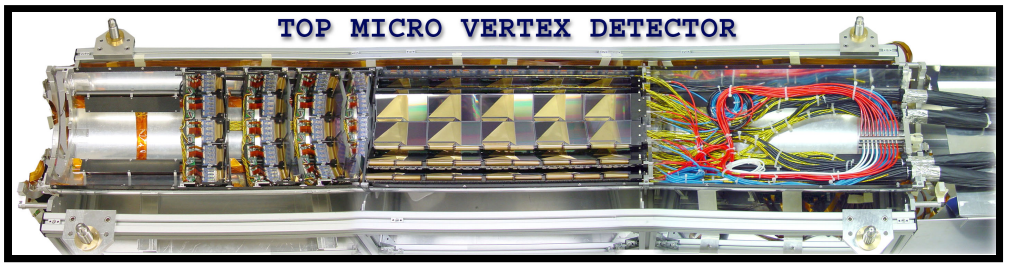
Electron-Proton-Collisions at HERA



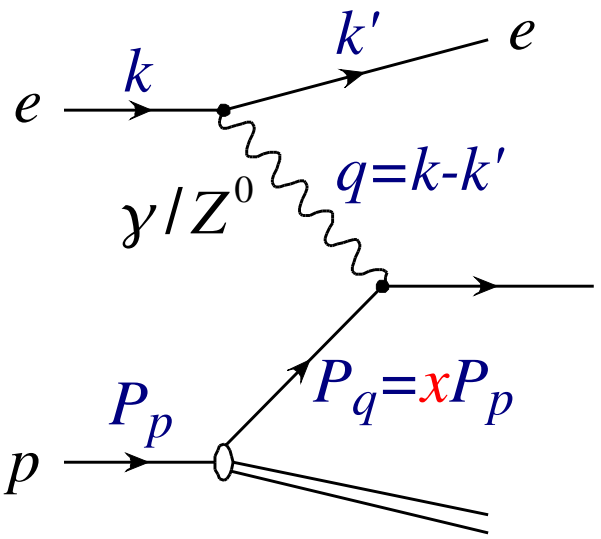
Available Data



- in total ~500 pb^{-1} of high energy data collected per experiment
- luminosity upgrade in 2001
  - detectors adjusted
  - ZEUS: new MicroVertex-Detector



Inclusive DIS & Structure Functions



$Q^2 = -q^2$

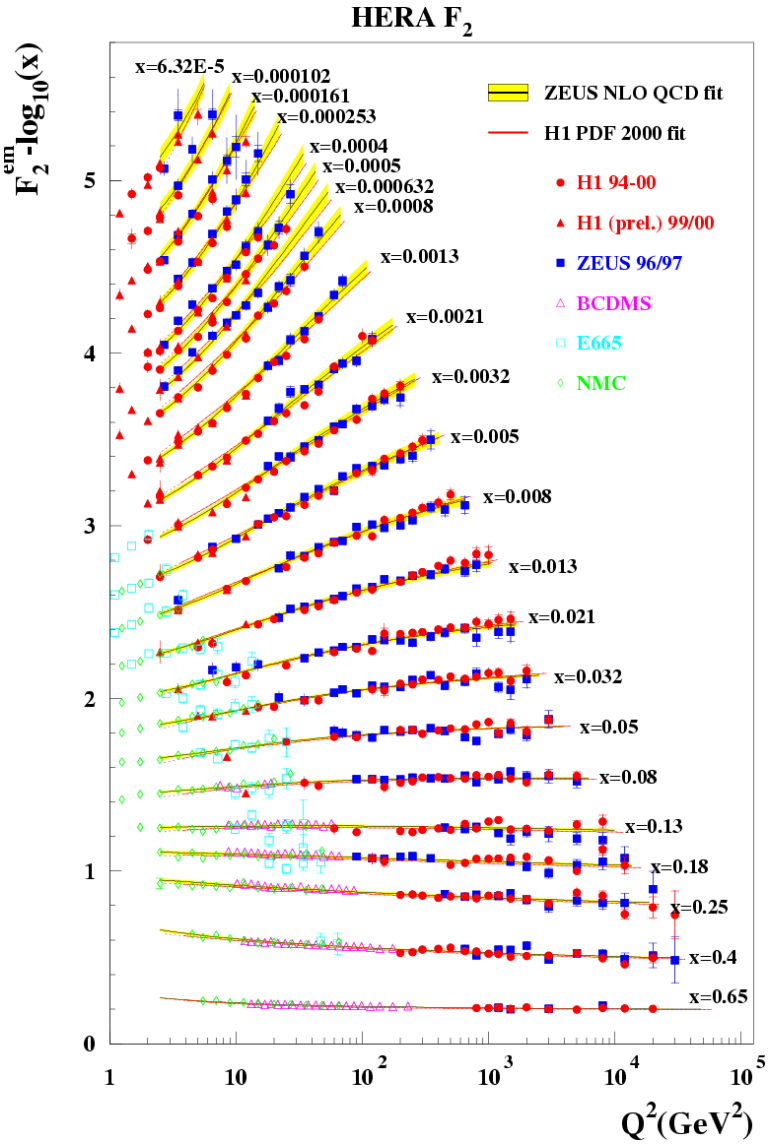
$Q^2 > 1\,\mathrm{GeV}^2$: Deep Inelastic Scattering

$Q^2 \approx 0\,\mathrm{GeV}^2$: Photoproduction

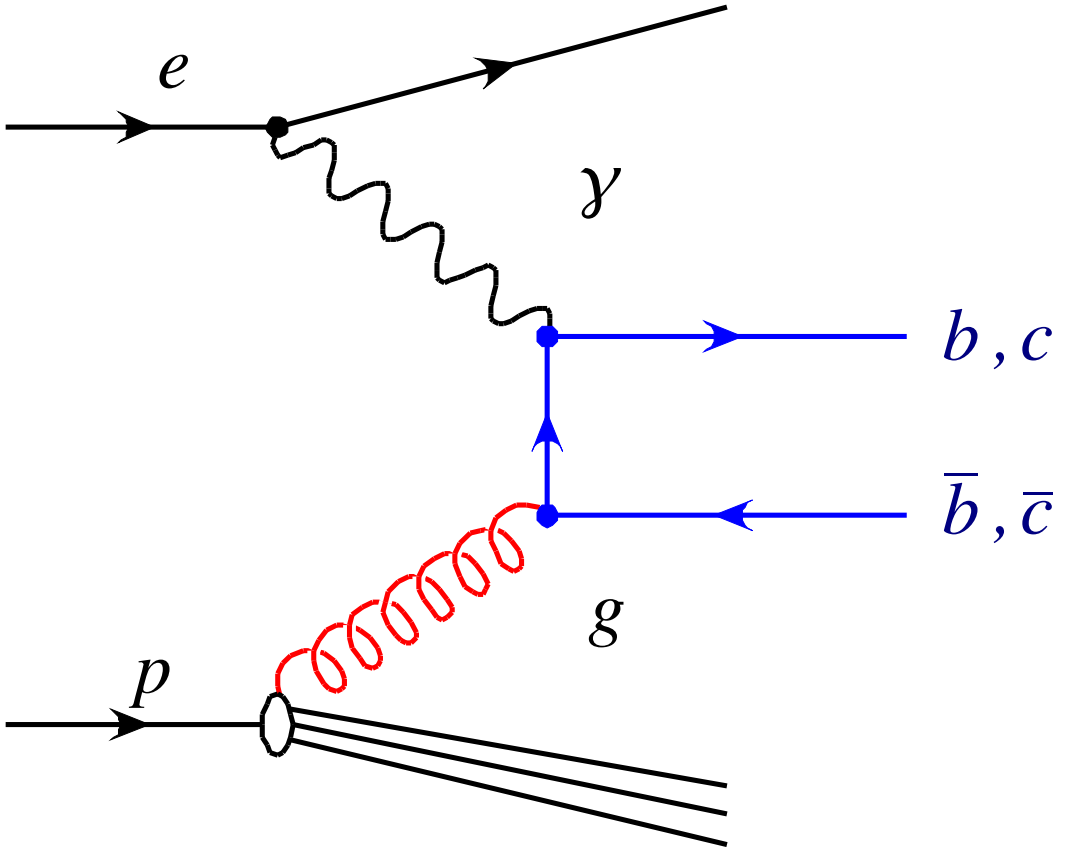
$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{Q^4} Y_+ \left[F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2) \right]$$

for low Q^2 with $Y_+ = (1+(1-y)^2)$

- directly sensitive to quark content of the proton
- gluons only seen in scaling violations



Production of Heavy Quarks



predominantly via boson gluon fusion

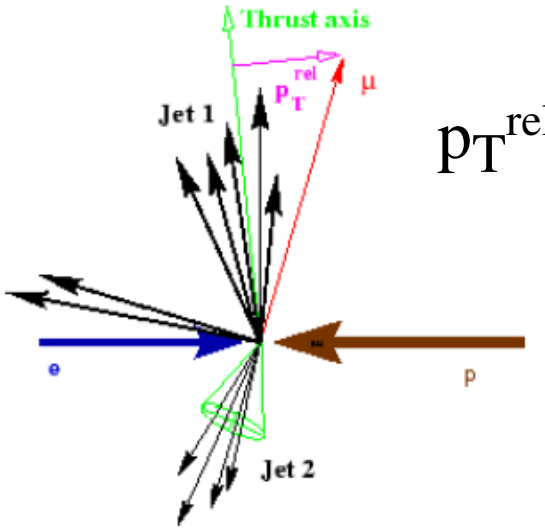
large quark mass allows pQCD calculations

directly sensitive to gluon density in the proton

heavy quark contribution to structure function

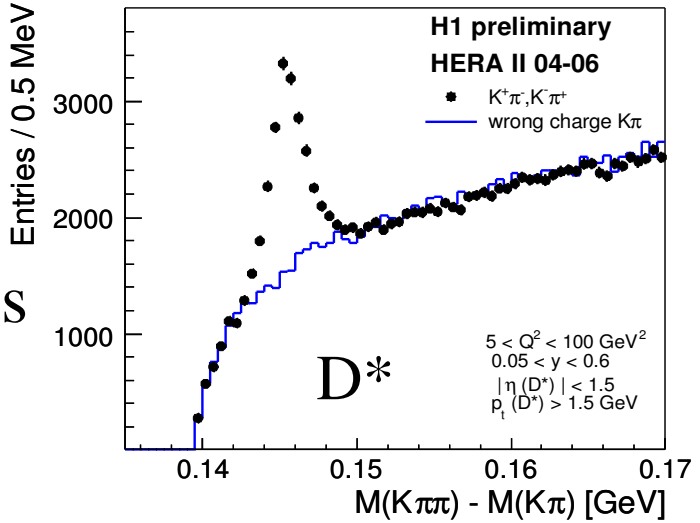
$$\frac{d^2\sigma^{b\bar{b}}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{Q^4} Y_+ \left[F_2^{b\bar{b}}(x,Q^2) - \frac{y^2}{Y_+} F_L^{b\bar{b}}(x,Q^2) \right]$$

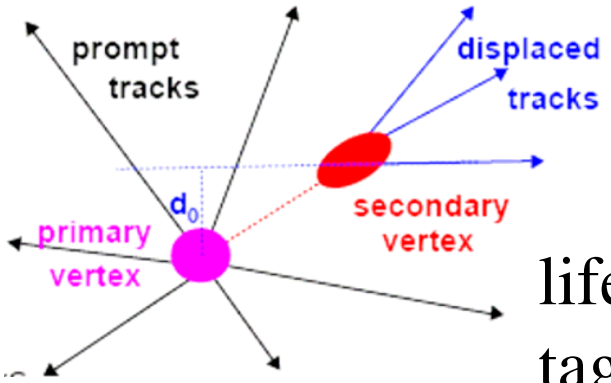
Tagging of Heavy Quarks



p_T^{rel}

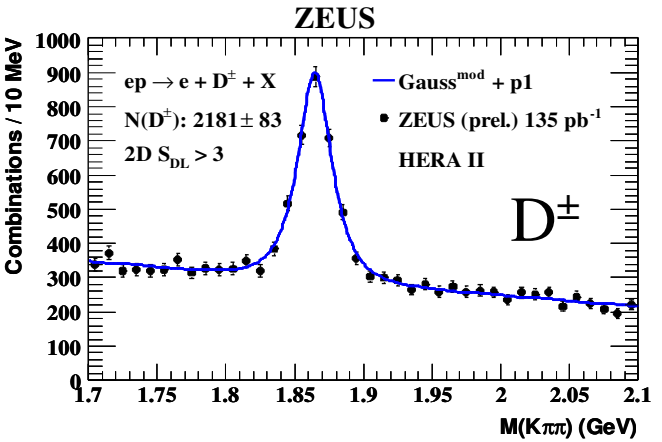
resonances (charm)





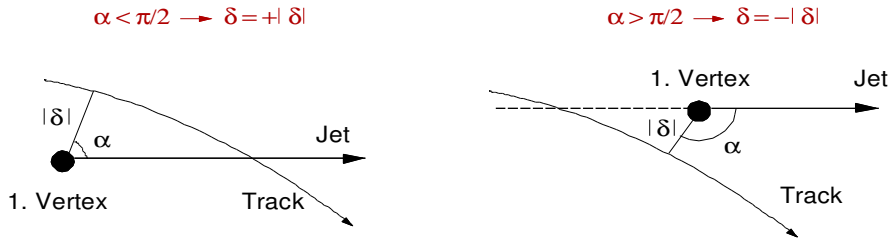
lifetime tagging

resonance + lifetime tagging



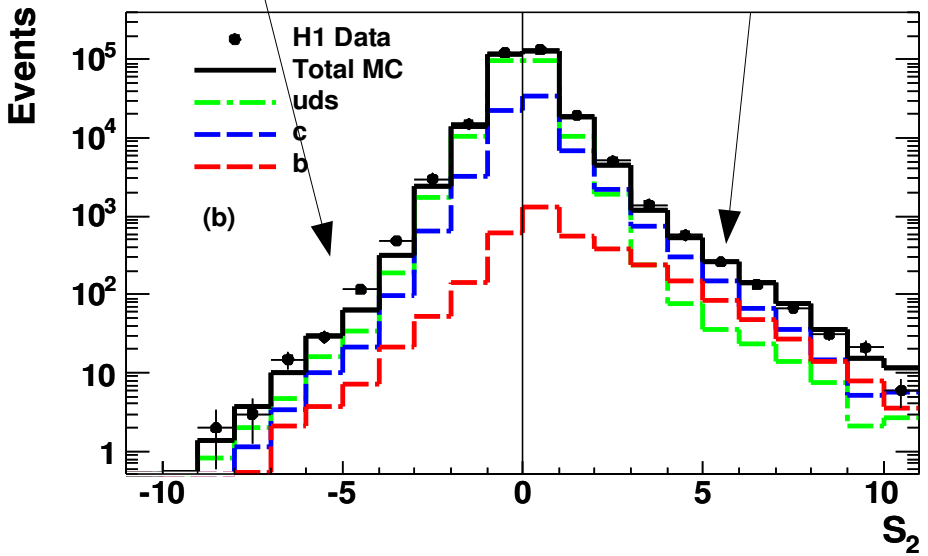
Inclusive Lifetime Tagging

signed impact parameter δ



resolution

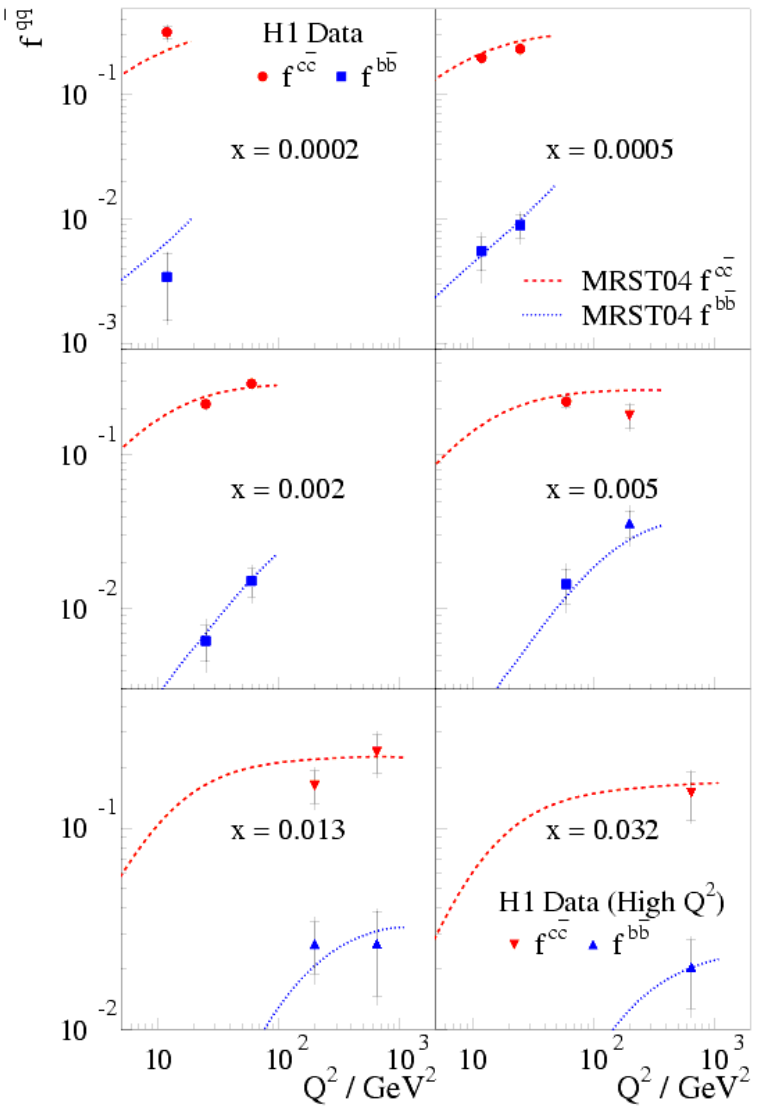
resolution & lifetime



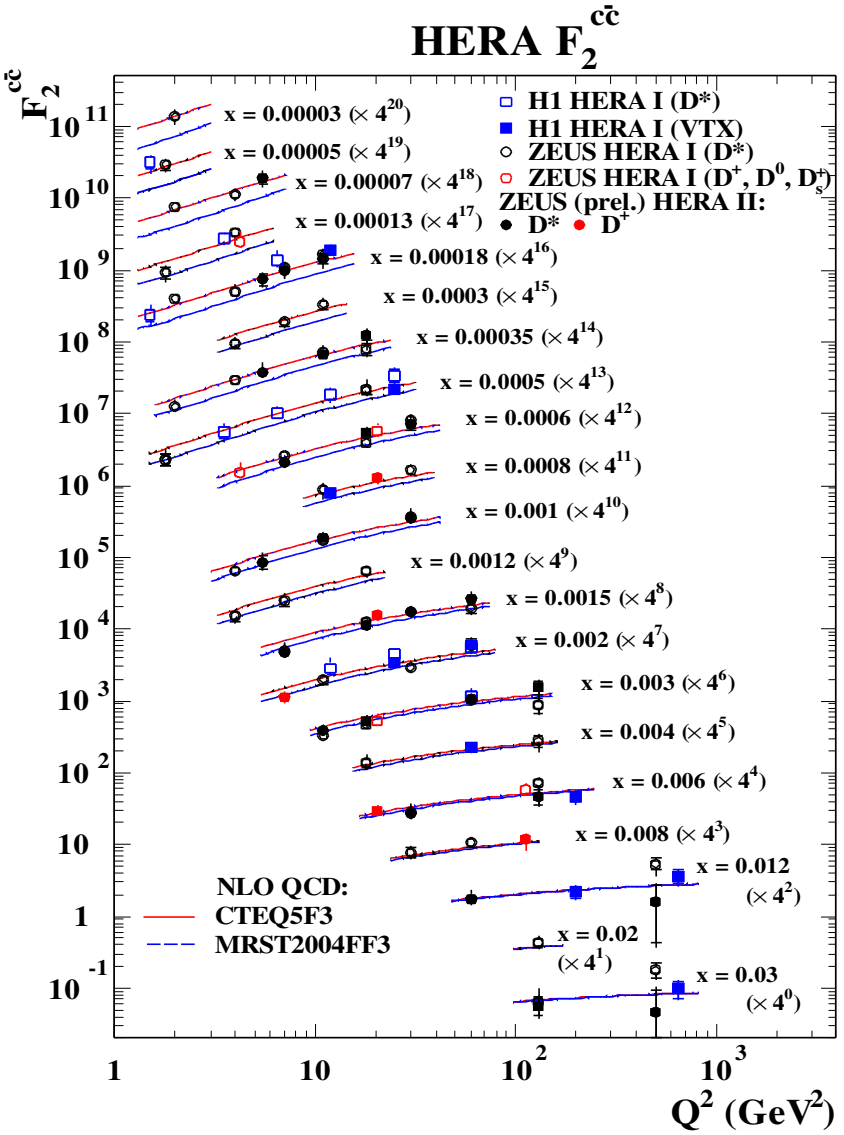
- both experiments have silicon vertex detectors
- inclusive method: use all tracks
- study significance of the (signed) impact parameter: $S = \delta / \sigma(\delta)$
- allows separation of beauty, charm and light quarks

Contribution to the Cross Section

- large charm fraction (up to ~30%)
- small beauty fraction (‰ to few %)
- charm and beauty thresholds
- reasonable description by theory

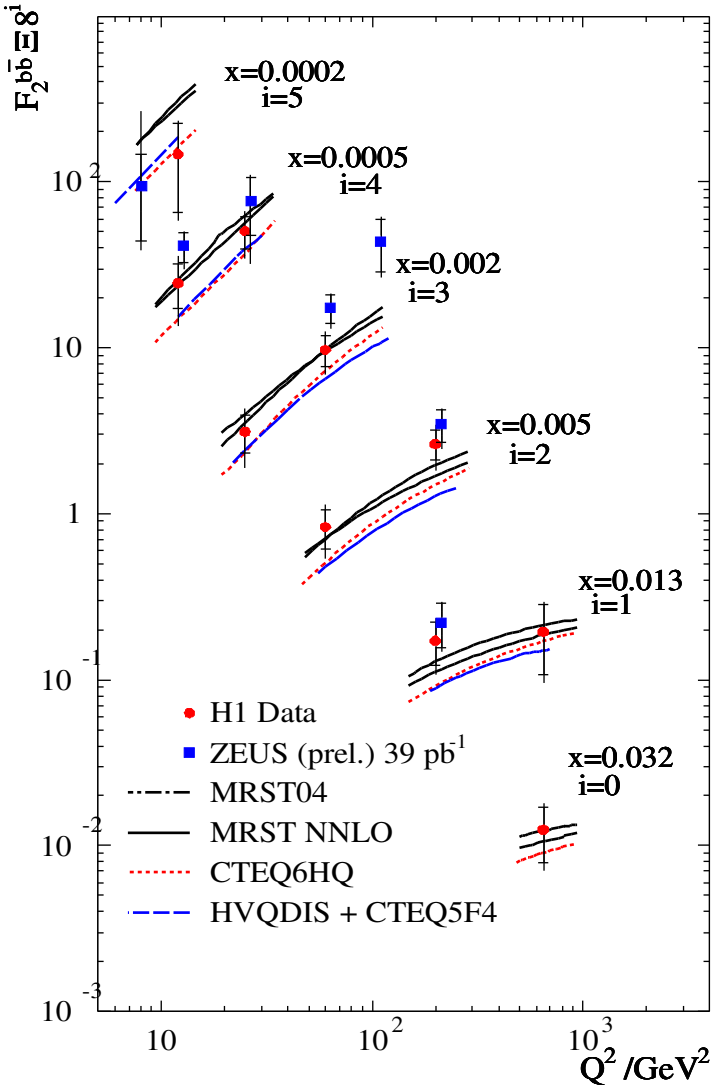


$F_2^{c\bar{c}}$



- all available measurements agree
  - inclusive lifetime
  - resonances: D*, $D^{\pm}$, D^0, D_S
- strong scaling violations
- sensitivity to parton densities (small x)

$F_2^{b\bar{b}}$

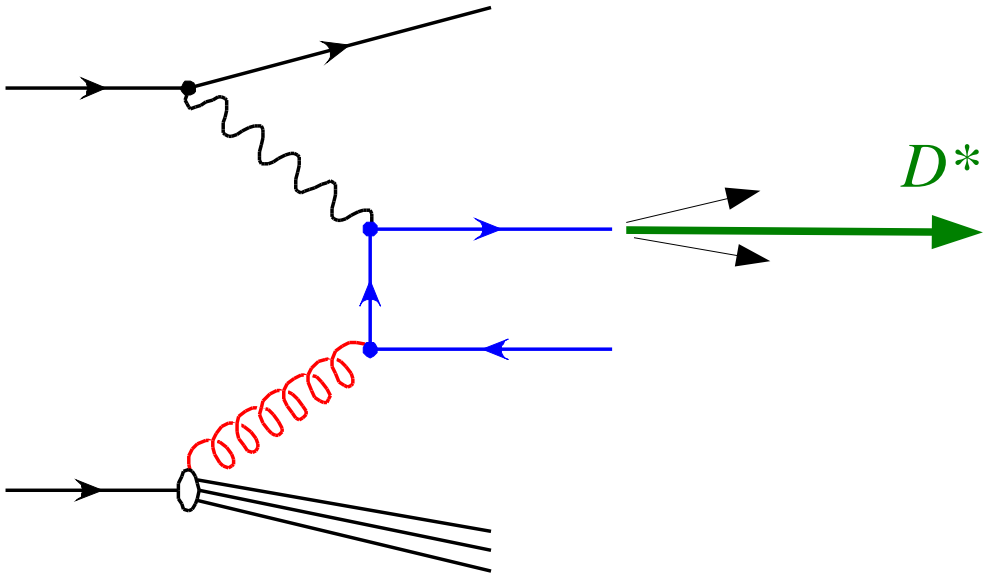


- worlds first $F_2^{b\bar{b}}$ measurements:
  - inclusive lifetime (H1)
  - p_T^{rel} (ZEUS)
- NNLO calculation
- experimental errors too large to distinguish theories/PDFs
- much larger datasets (factor 3-10) available

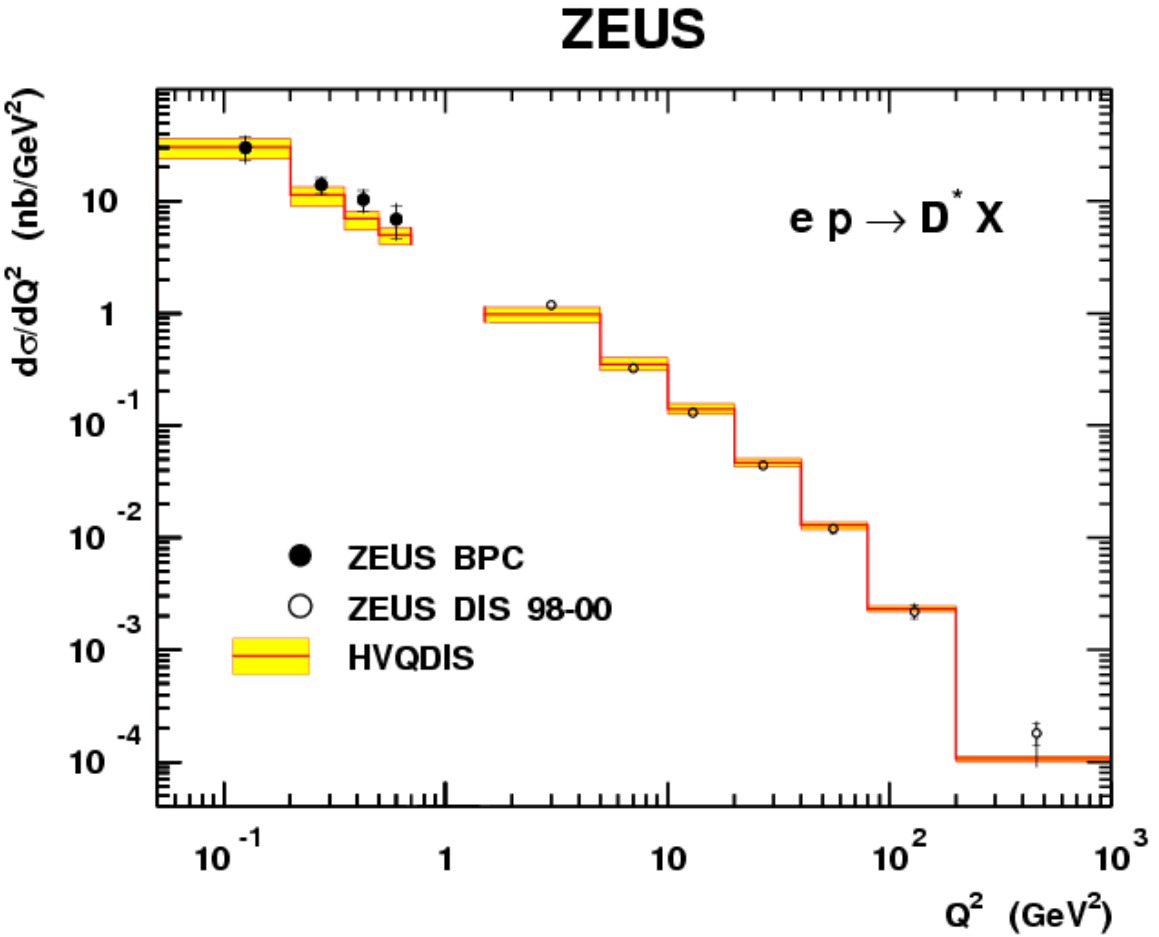
Heavy Meson Cross Sections

$$\sigma_{D^*} \sim f_{g/p}(x,\mu) \otimes \hat{\sigma}(x,\mu) \otimes D_c^{D^*}(x,\mu)$$

parton density function (non-perturbative)	parton scattering cross section (perturbative)	fragmentation function (non-perturbative)



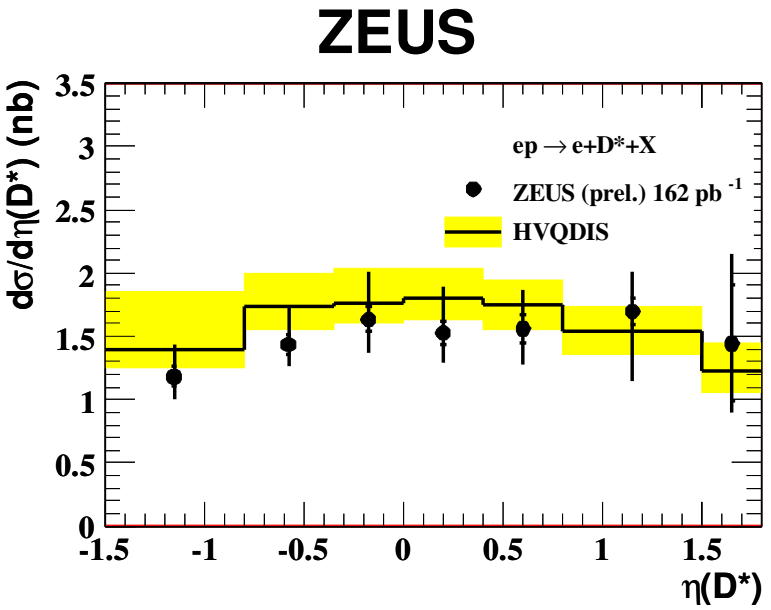
D* Cross Section

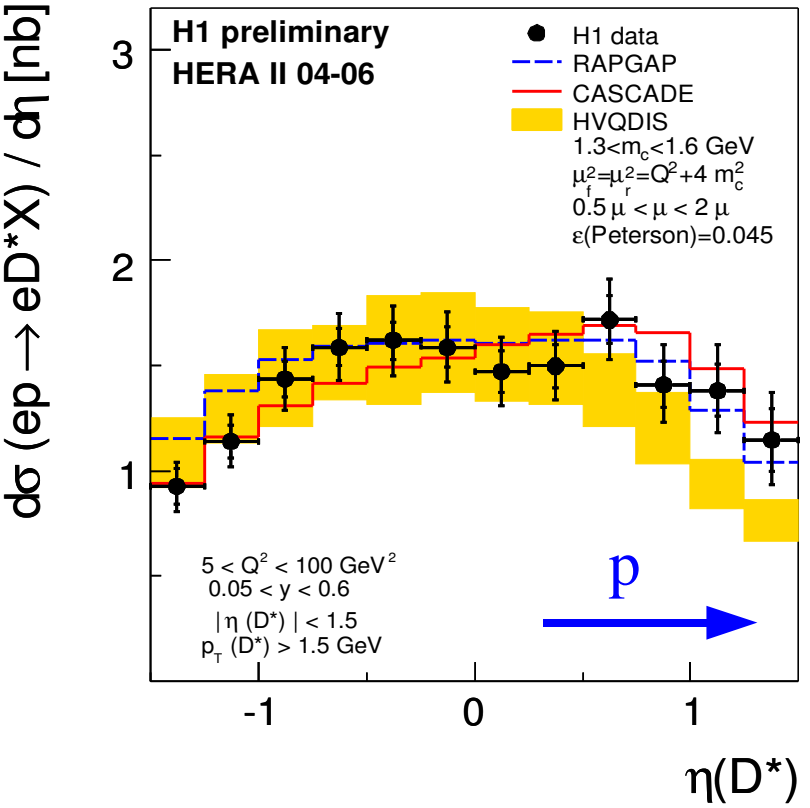


good description by NLO calculation (HVQDIS) in full measured Q^2 range (more than 4 orders of magnitude)

D* Cross Sections

$$\eta = -\ln\tan(\theta/2)$$



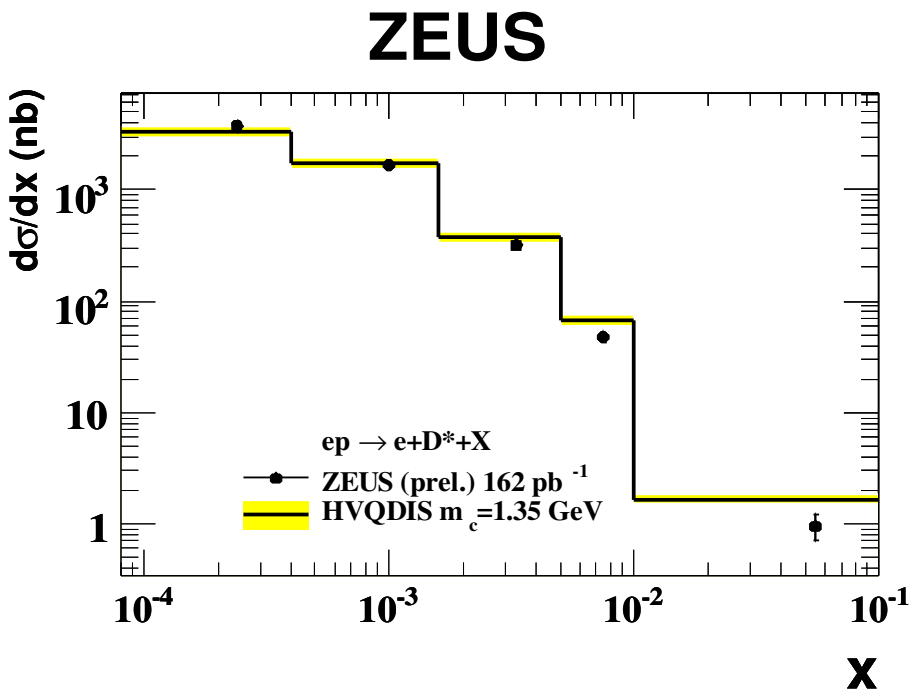


ZEUS and H1 data in agreement

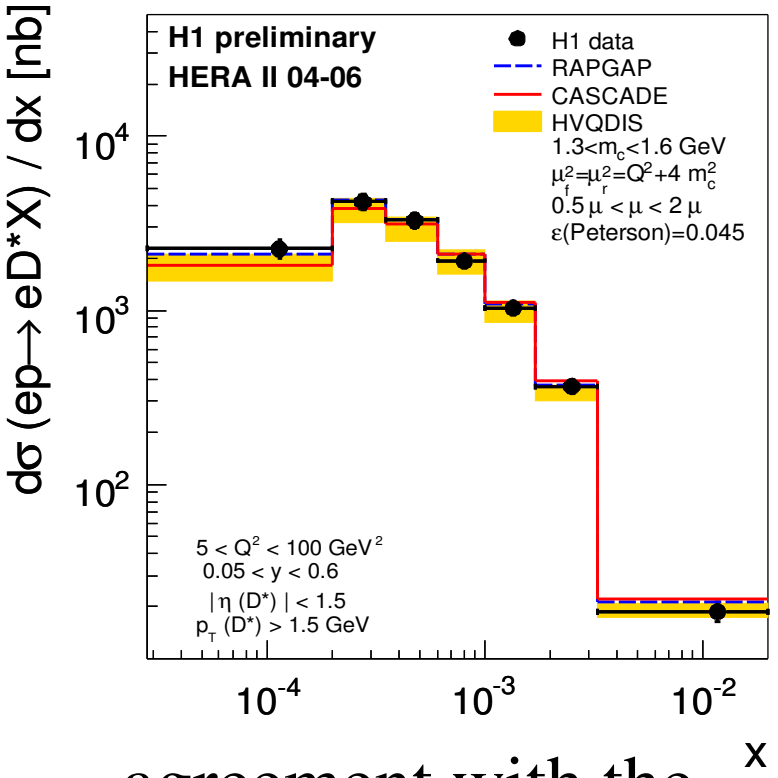
HVQDIS with ZEUS pdf agrees with data

deficit in proton direction with CTEQ5F3

D* Cross Sections



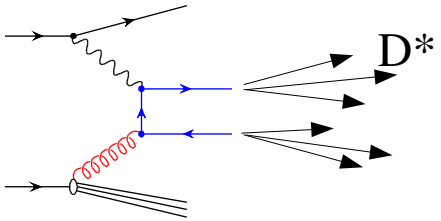
HVQDIS with ZEUS pdf too high at large x



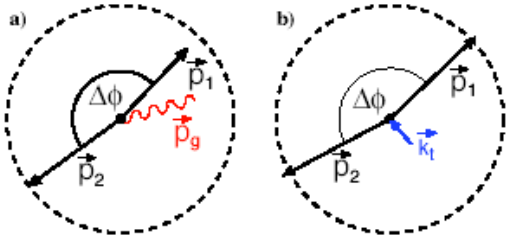
agreement with the data with CTEQ5F3

➔ in general good description, sensitivity to pdfs, fragmentation, ...

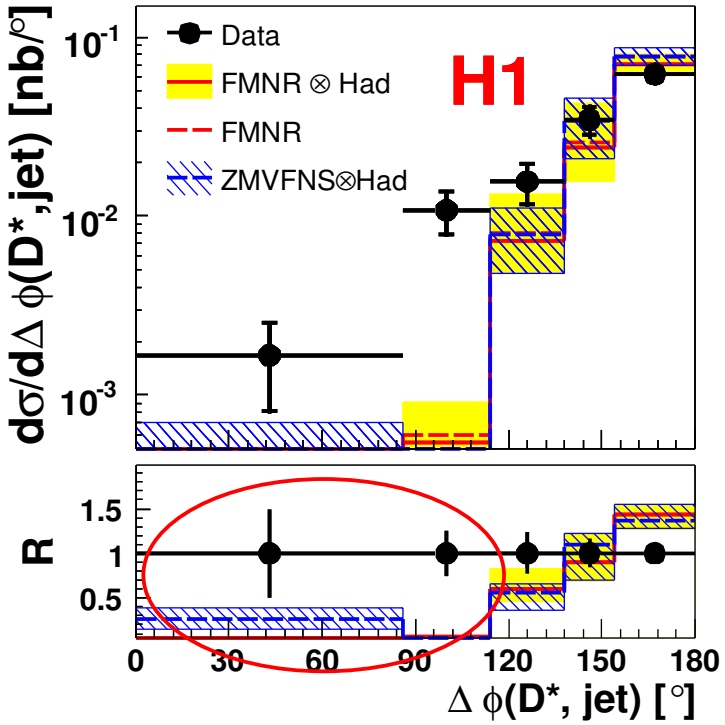
Azimuthal Correlations in D* Events



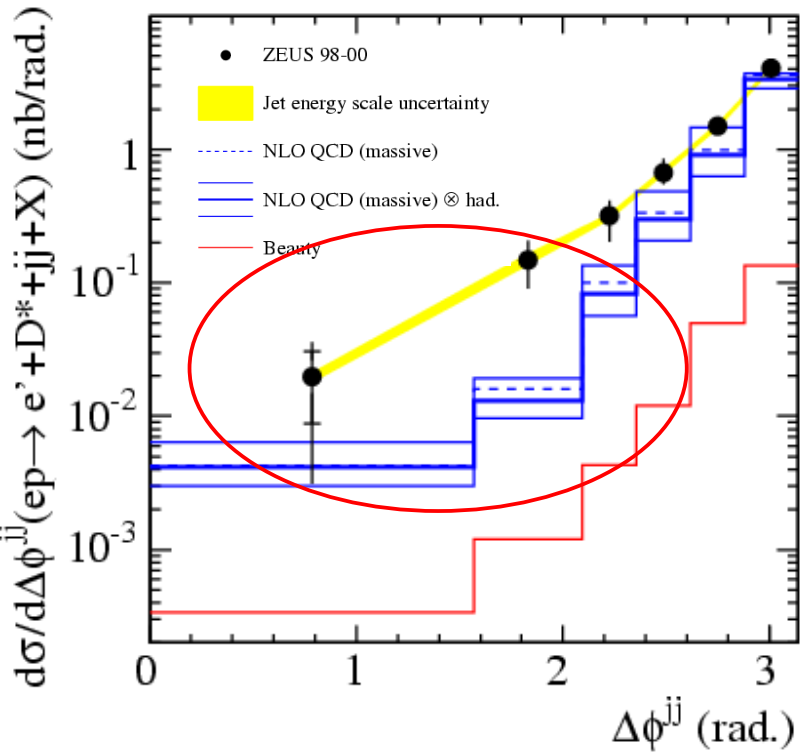
azimuthal correlation between two jets or the D* and a second jet



γp: D* + other jet

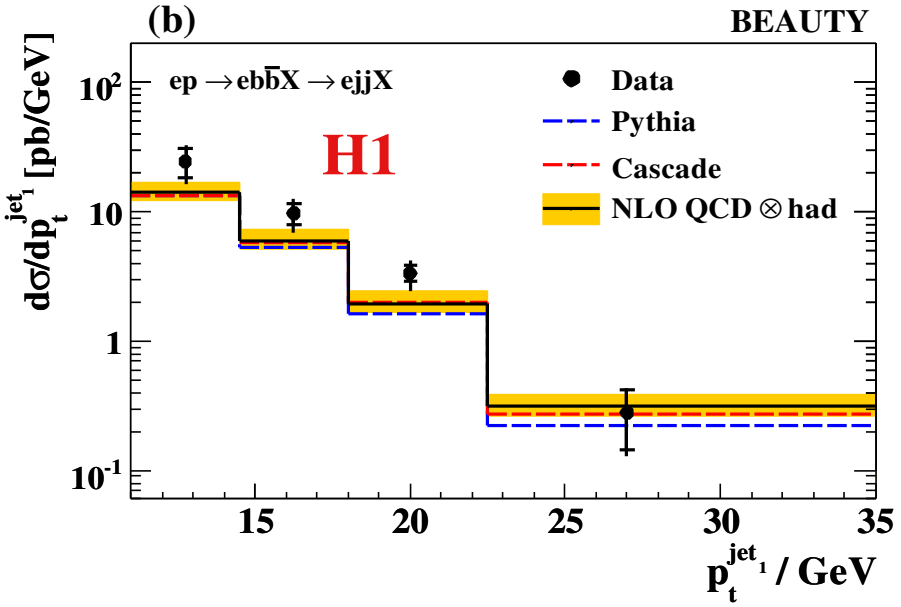


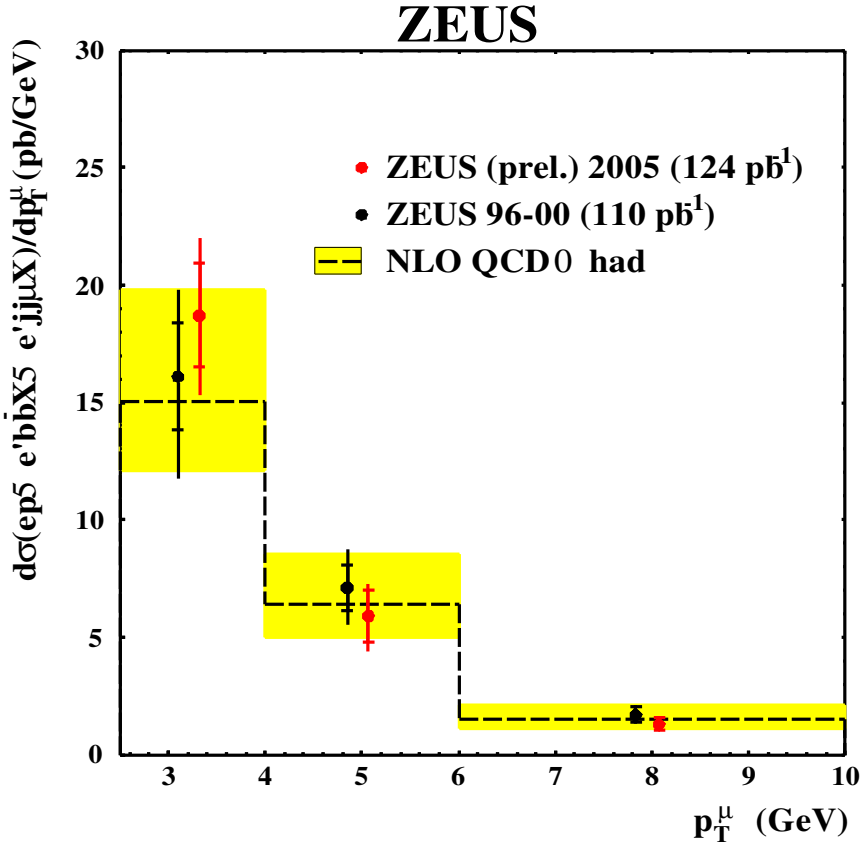
ZEUS



contributions beyond NLO (FMNR) needed

Differential Beauty Cross Sections

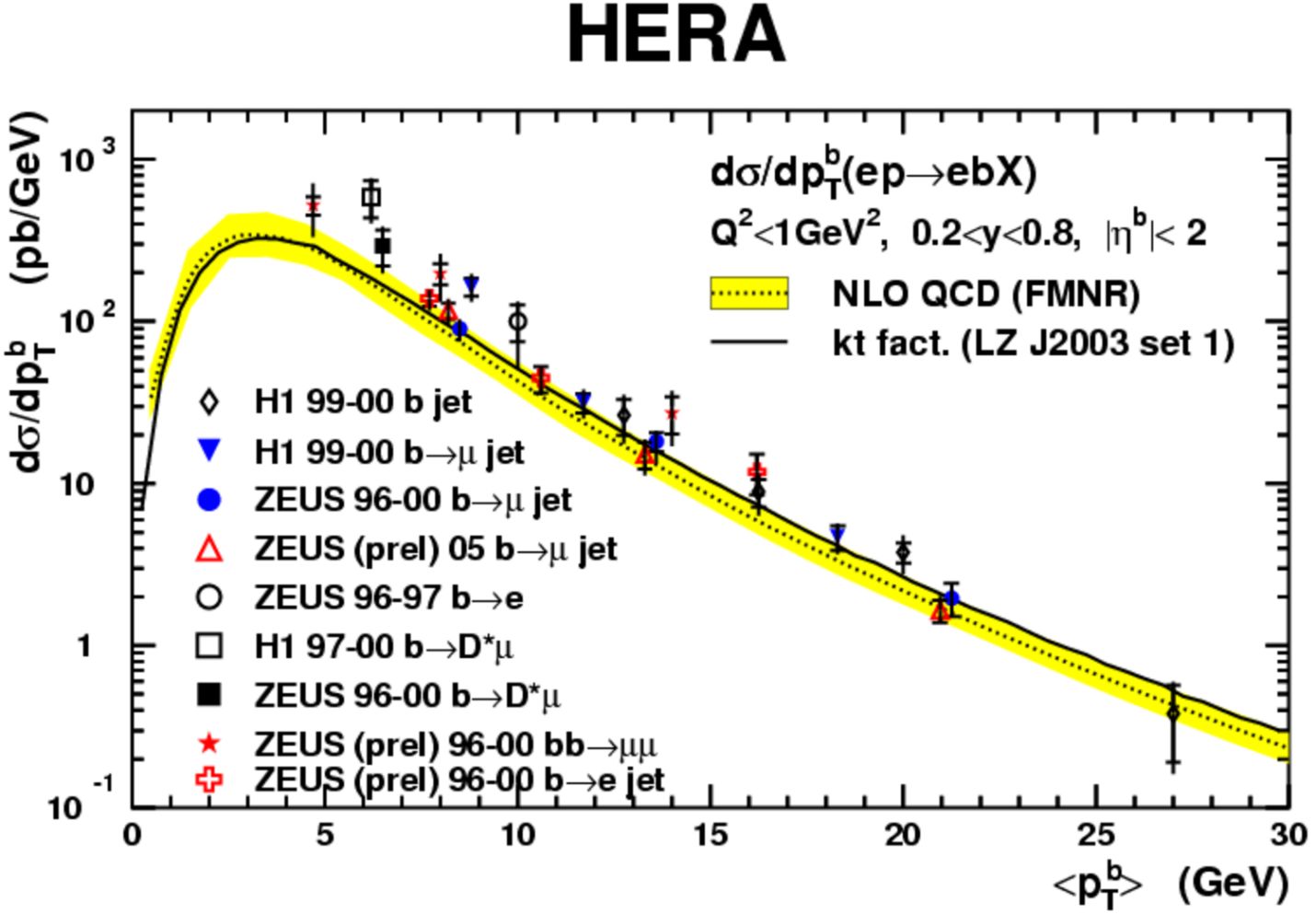




- examples for different taggings:
  - inclusive lifetime tag in dijet events (H1)
  - p_T^{rel} & lifetime for dijets with muons (ZEUS)

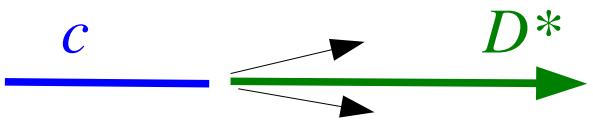
➔ NLO (FMNR) agrees reasonably well with the data

Compilation of Beauty Photoproduction

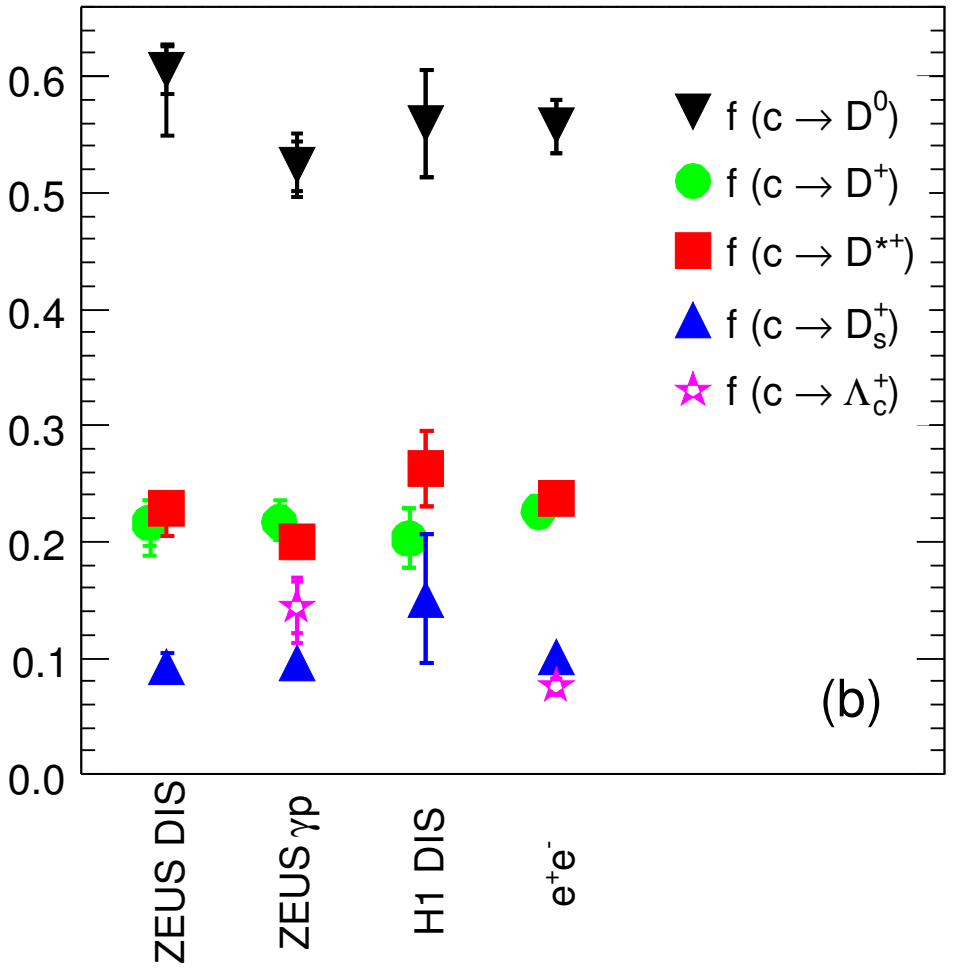


➔ reasonable agreement of NLO with data

Fragmentation Fractions



- fraction of *c* quarks hadronising as a particular *D* meson
- agreement between HERA experiments and e^+e^- data

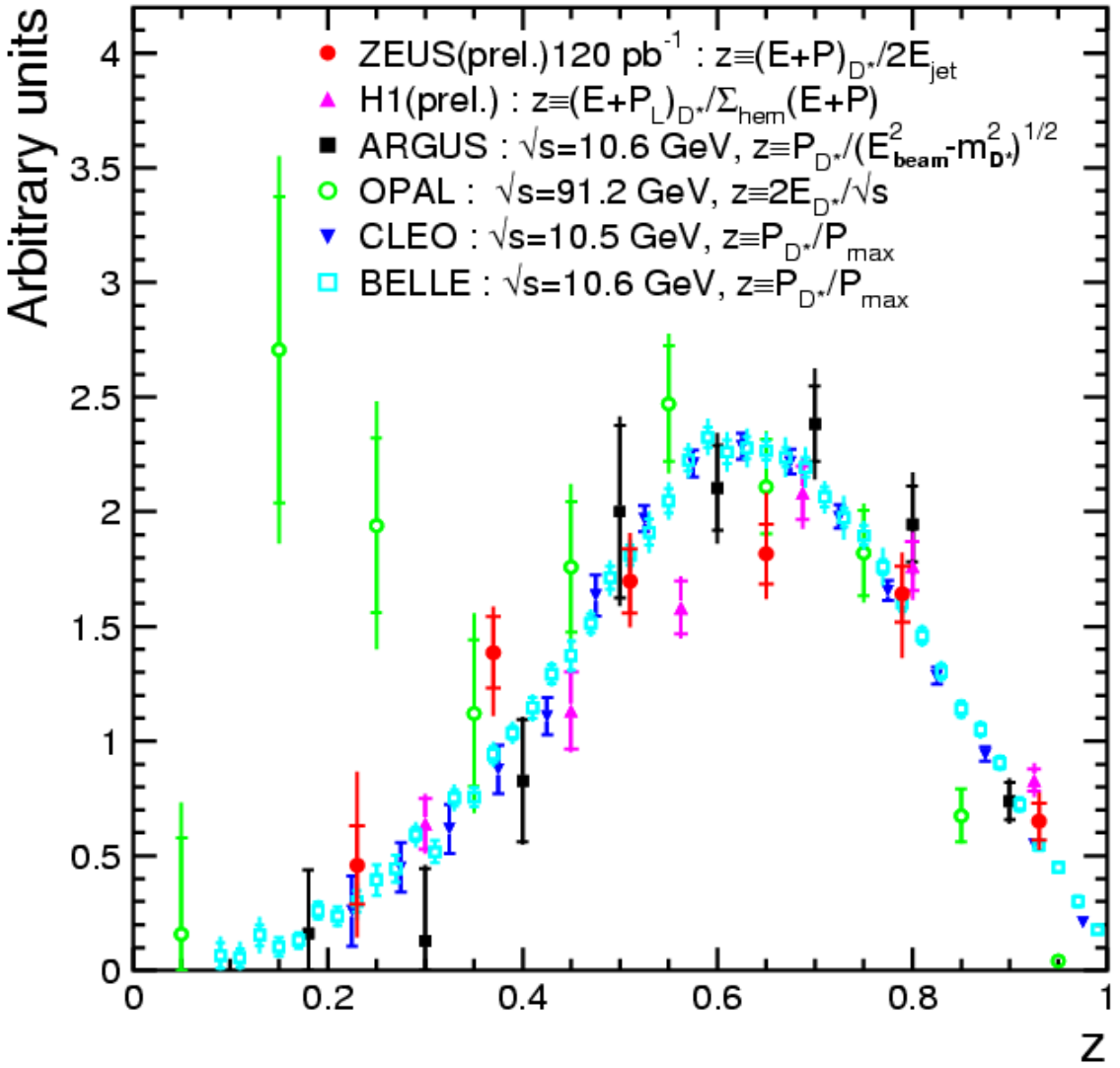


Fragmentation Function

energy transfer: $z = \frac{E_{D^*}}{E_c}$

- ZEUS: $z=(E+P)_{D^*}/2E_{jet}$
- H1: $z=(E+P_L)_{D^*}/\Sigma_{hem}(E+P)$
- ARGUS: $\sqrt{s}$=10.6 GeV
- OPAL: $\sqrt{s}$=91.2 GeV
- CLEO: $\sqrt{s}$=10.5 GeV
- BELLE: $\sqrt{s}$=10.6 GeV

➔ spectra similar to e^+e^- data



Conclusions

- heavy flavour production at HERA allows to study
  - gluon density in the proton
  - pQCD calculations
- in general reasonable description of the data by NLO calculations
- sensitivity to parameters (fragmentation function)

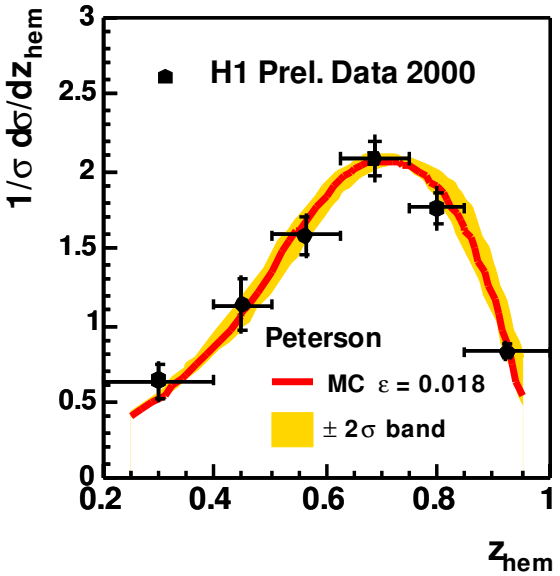
➔ outlook: analyses using full HERA statistics

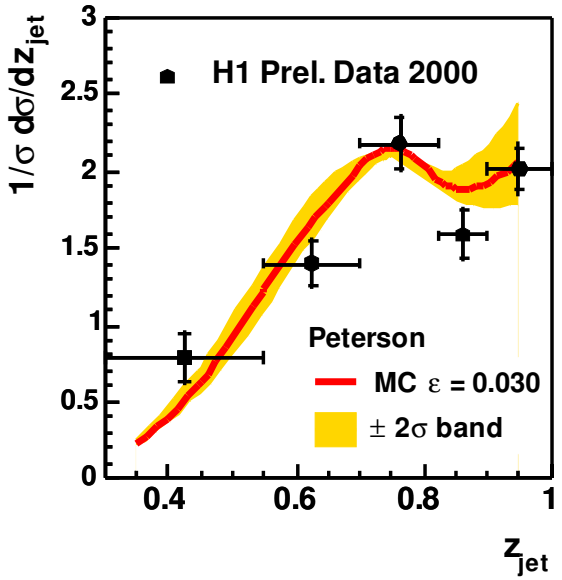
Backup

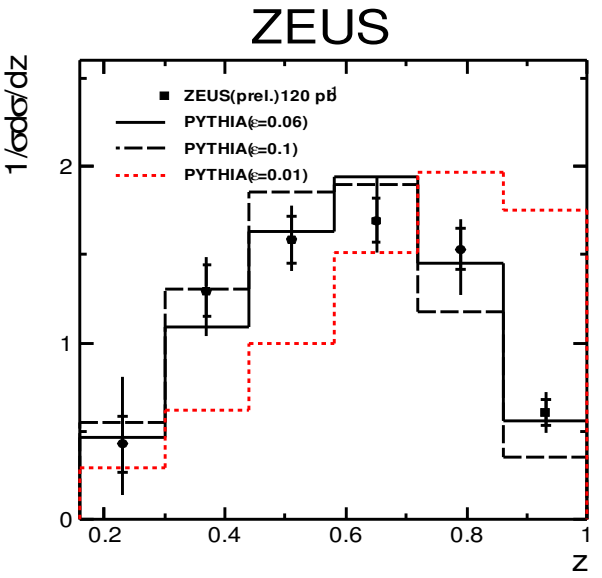
Fragmentation Function

energy transfer: $z = \frac{E_{D^*}}{E_c}$

Peterson: $D_c^{D^*}(z) \sim \frac{1}{z\left(1 - 1/z - \varepsilon/(1-z)\right)^2}$







no jet cut

$\varepsilon = 0.018 \pm 0.004$

$p_{t,jet} > 3$ GeV

$\varepsilon = 0.030^{+0.006}_{-0.005}$

$E_{t,jet} > 9$ GeV

$\varepsilon = 0.064 \pm 0.006^{+0.011}_{-0.008}$

➔ scale dependence of the fragmentation function