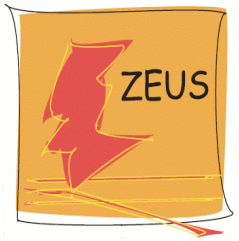
Heavy quark electroproduction and $F_2^{c\bar{c}}, F_2^{b\bar{b}}$



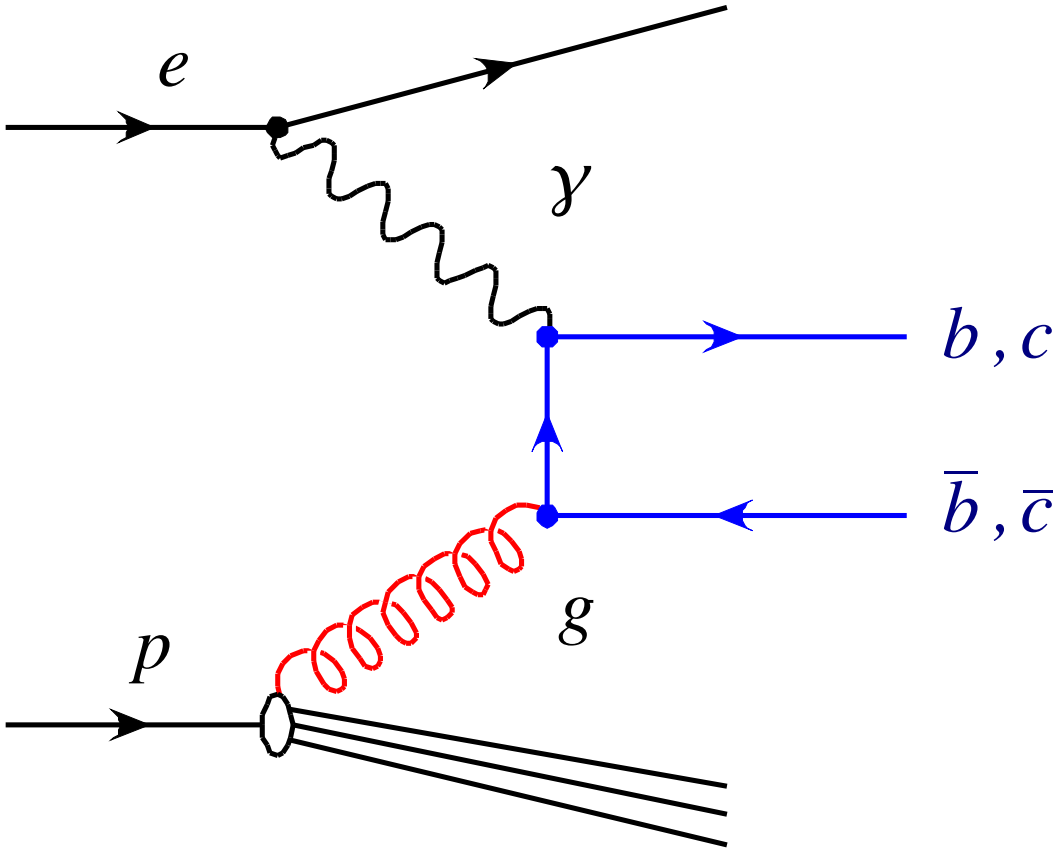
Katja Krüger, Universität Heidelberg
for the H1 and ZEUS Collaborations

- Production of Heavy Quarks
- Charm Cross Sections
- Charm Fragmentation
- Beauty Cross Sections
- HQ Contribution to Structure Function
- inelastic J/ψ production ➡ M. Juengst

34th International Conference on
High Energy Physics

July 29th, 2008 – August 5th, 2008
Philadelphia, PA

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

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

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

Predictions for Heavy Quark Production

NLO calculation:

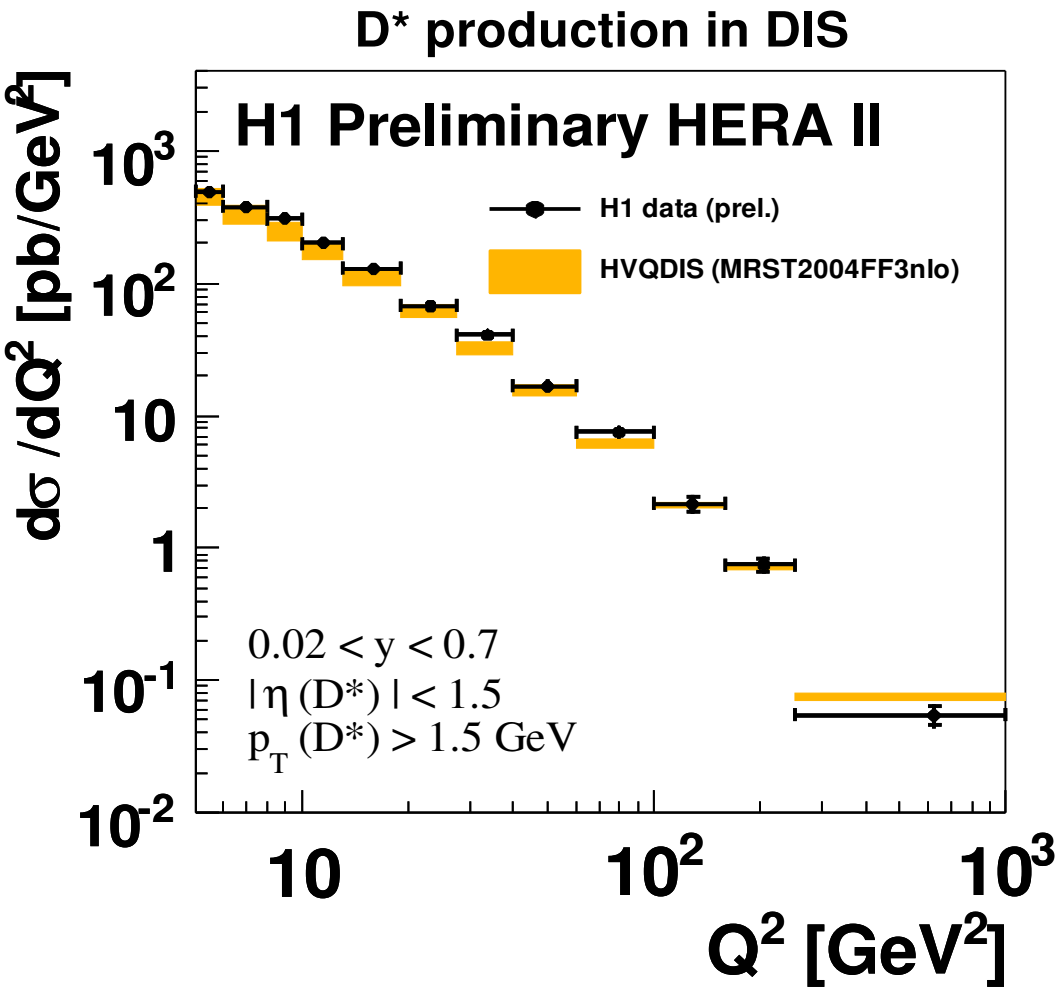
- HVQDIS:
  - fixed order, massive scheme (FFNS)
  - independent fragmentation for heavy hadrons
- FMNR: similar as HVQDIS, for photoproduction

Monte-Carlo: LO + Parton Shower:

- CASCADE:
  - k_T factorisation, CCFM evolution
  - Lund String fragmentation
- RAPGAP:
  - collinear factorisation, DGLAP evolution
  - Lund String fragmentation

D* Cross Section

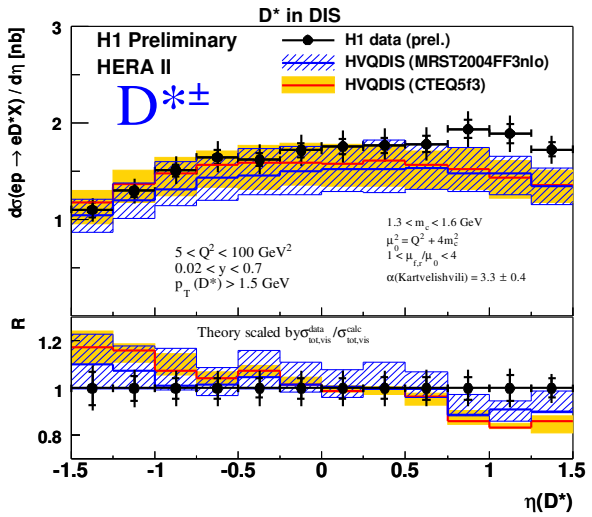
H1prelim-08-072
H1prelim-08-074



- full HERA II statistics (~350 pb^{-1})
- good description by NLO calculation (HVQDIS) in full measured Q^2 range
  - also at large Q^2, where massive approach not expected to be appropriate

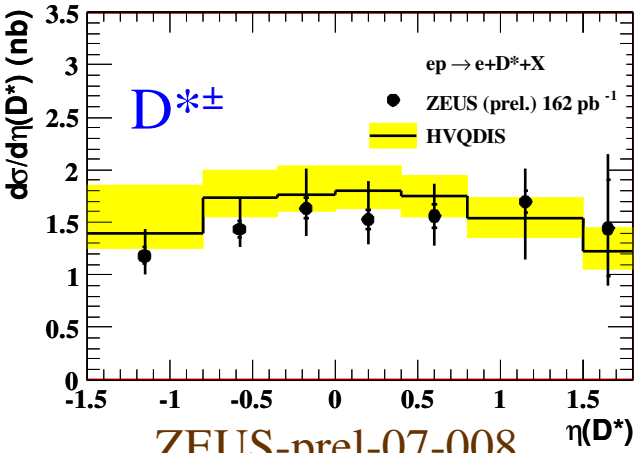
D Meson Cross Sections

H1prelim-08-072



- differential cross sections of several D mesons measured
- reasonably well described by HVQDIS
- double differential cross section in x and Q^2 allows extraction of $F_2^{c\bar{c}}$

ZEUS



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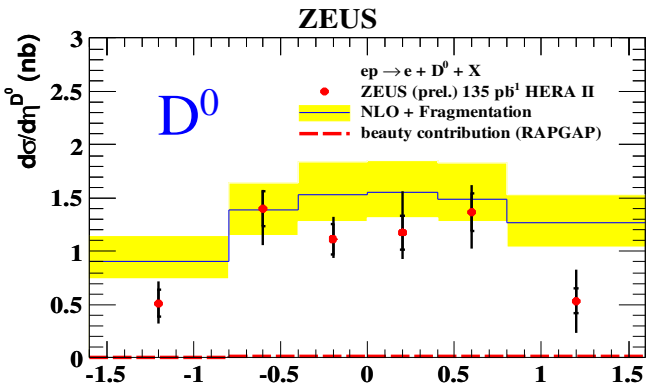
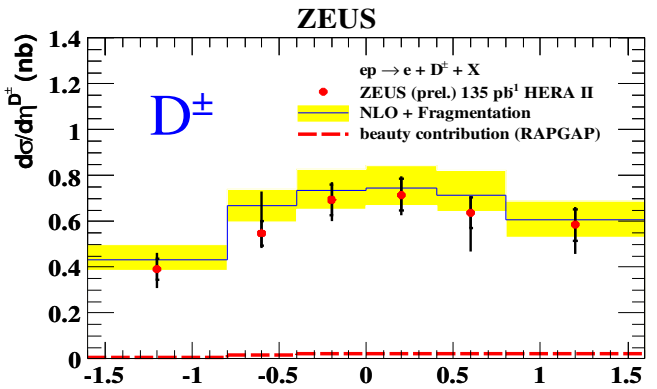


ZEUS-prel-07-034



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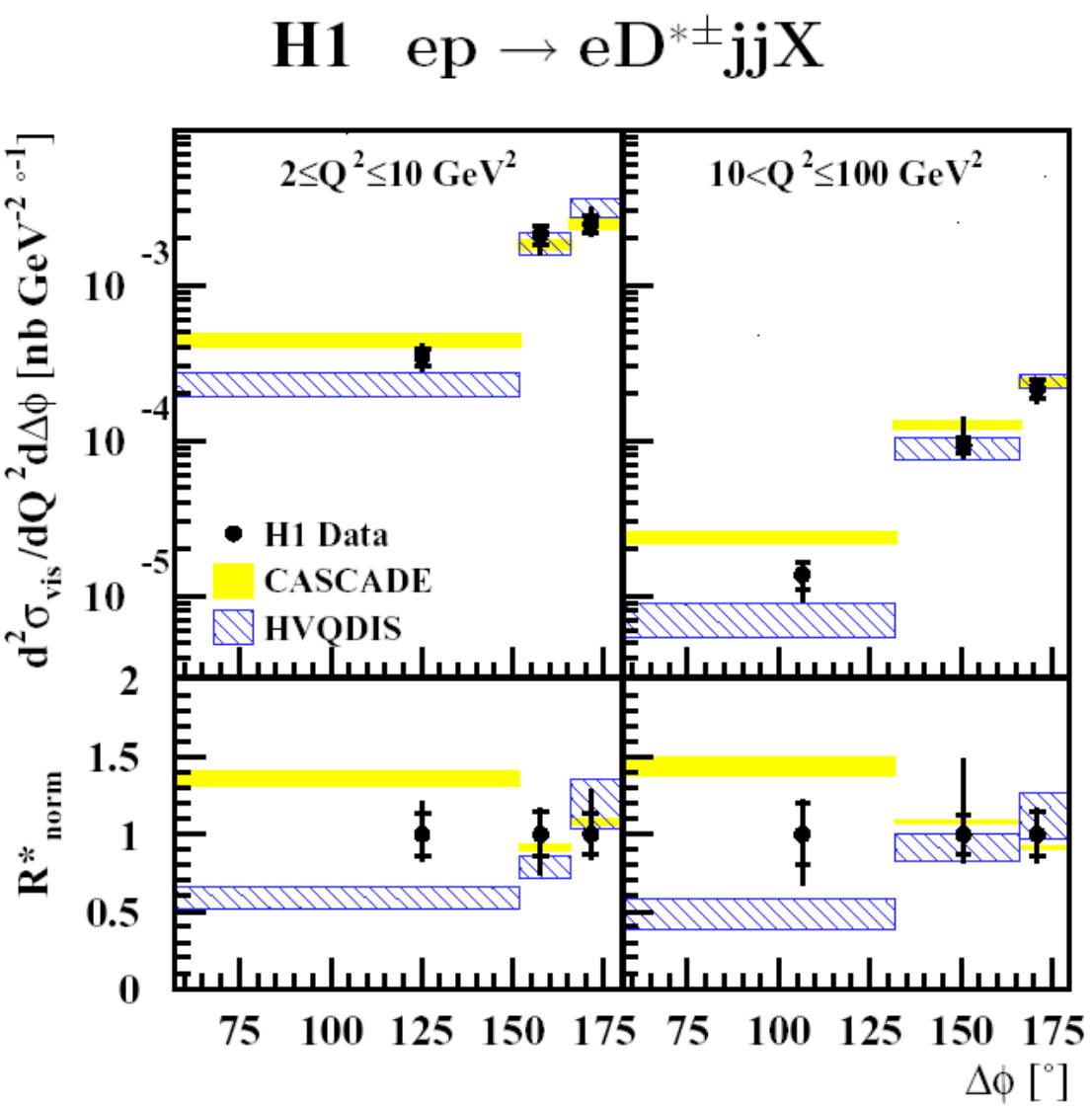
D* Mesons + Dijets



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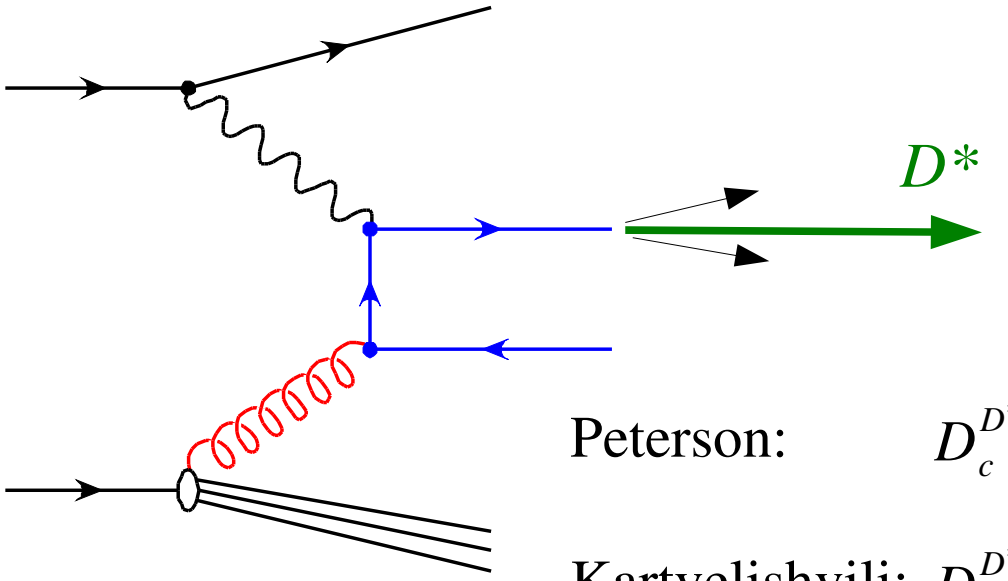
- measurement of D* tagged dijets allows to study two partons
- CASCADE (LO+PS) and HVQDIS (NLO) both describe the data reasonably well
- both have problems at small $\Delta\phi$

Charm Fragmentation

$$\sigma_{D^*} \propto f_{g/p} \otimes \hat{\sigma} \otimes D_c^{D^*}(z)$$

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

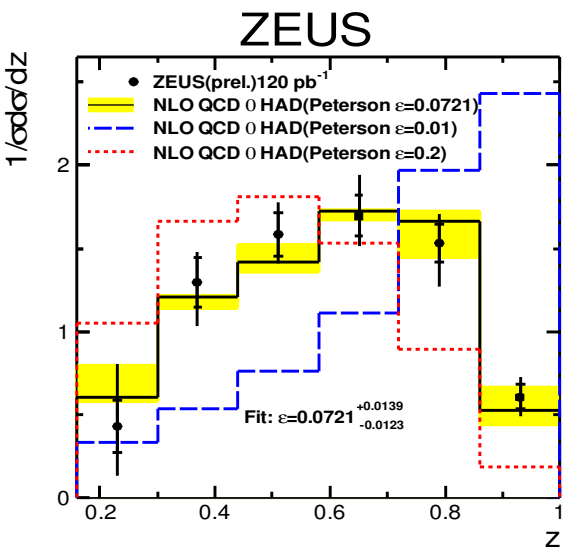


Peterson: $$D_c^{D^*}(z) \propto \frac{1}{z\left[1-(1/z)-\epsilon/(1-z)\right]^2}$$

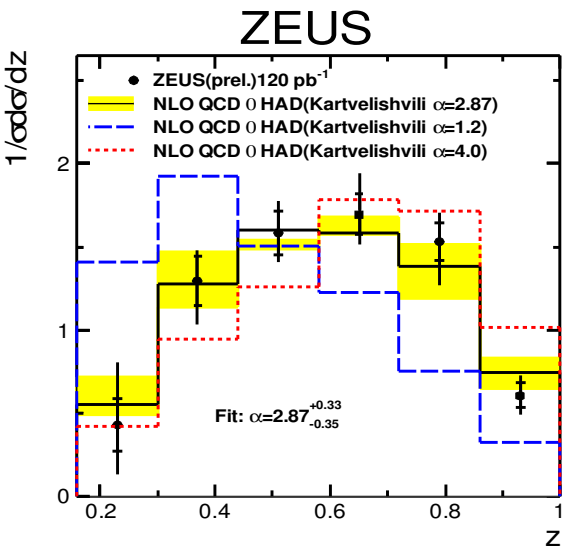
Kartvelishvili: $$D_c^{D^*}(z) \propto z^{\alpha}(1-z)$$

Fragmentation Function

ZEUS-prel-07-010

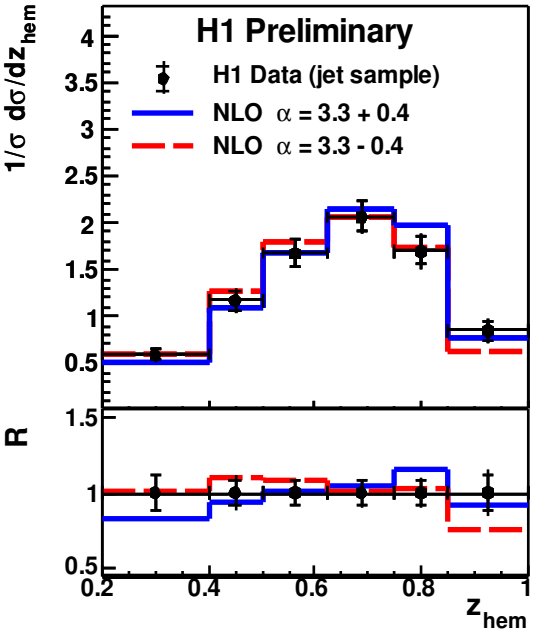


$p_{T,jet} > 9$ GeV



$p_{T,jet} > 9$ GeV

H1prelim-08-078

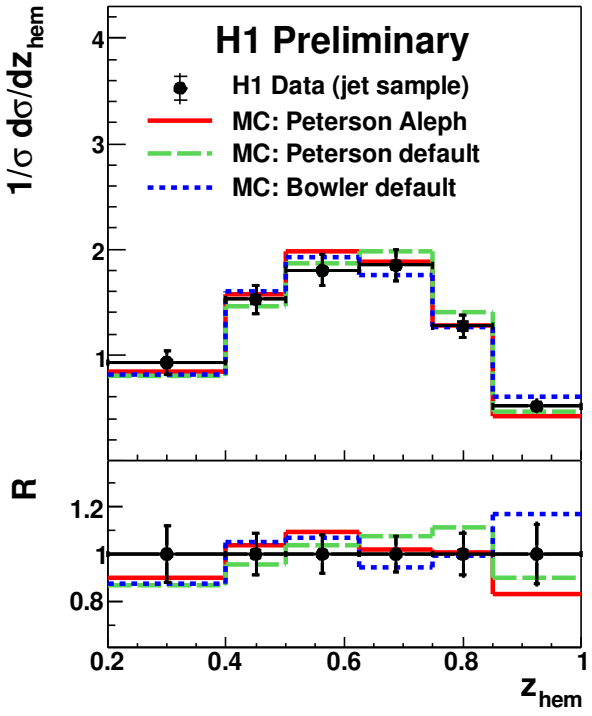


$p_{T,jet} > 3$ GeV

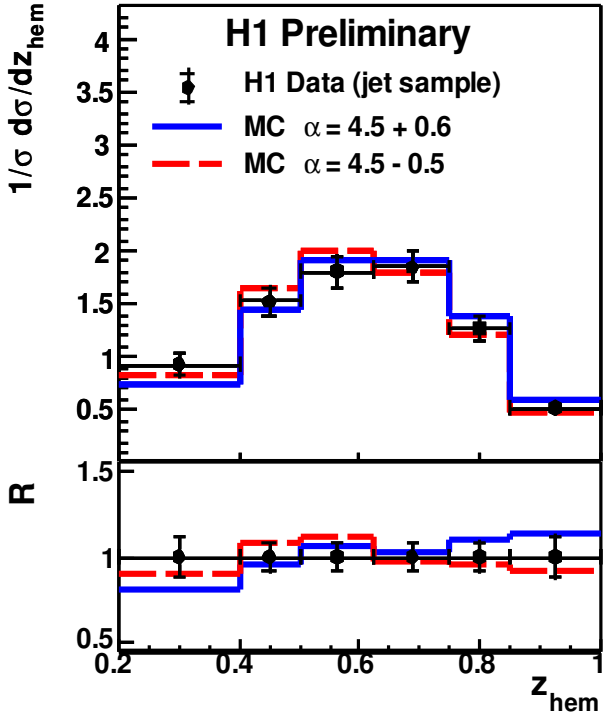
- data can be described by NLO calculation (FMNR/HVQDIS) with Peterson or Kartvelishvili fragmentation function
- reasonable agreement between ZEUS and H1 in jet sample

Fragmentation Function

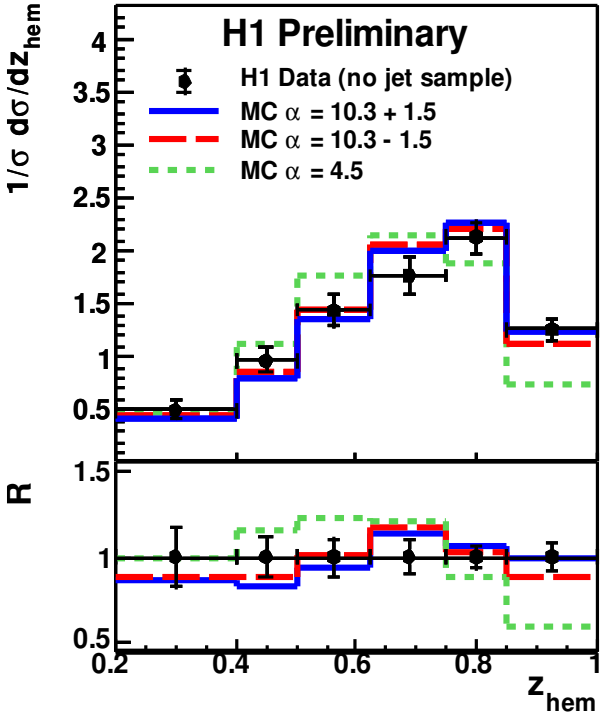
H1prelim-08-078



$p_{T,jet} > 3$ GeV



$p_{T,jet} > 3$ GeV

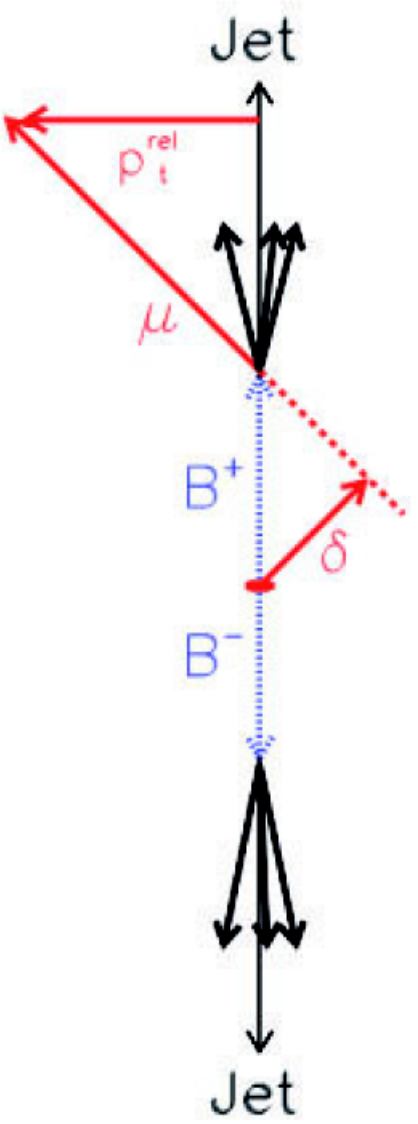


no jet

- RAPGAP MC: parameter consistent with e^+e^- measurements
- no-jet sample (low photon gluon centre-of-mass energy) needs harder fragmentation

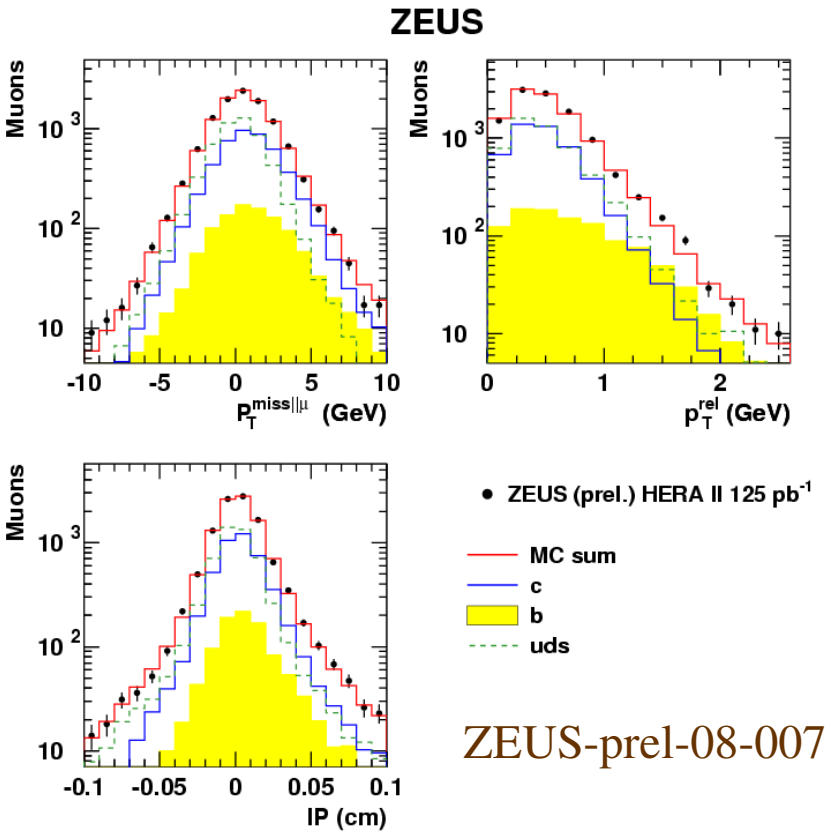
Measurements of Beauty Quarks

- beauty quarks rarely produced, only indirect detection methods
  - mass
    - transverse momentum p_T^{rel} relative to jet axis
  - lifetime
    - reconstruction of a secondary vertex
    - impact parameter δ
  - semileptonic decays (μ, e)



Beauty & Charm Cross Section

- combine the 3 methods
- use 3D fit to decompose into beauty, charm and light flavour



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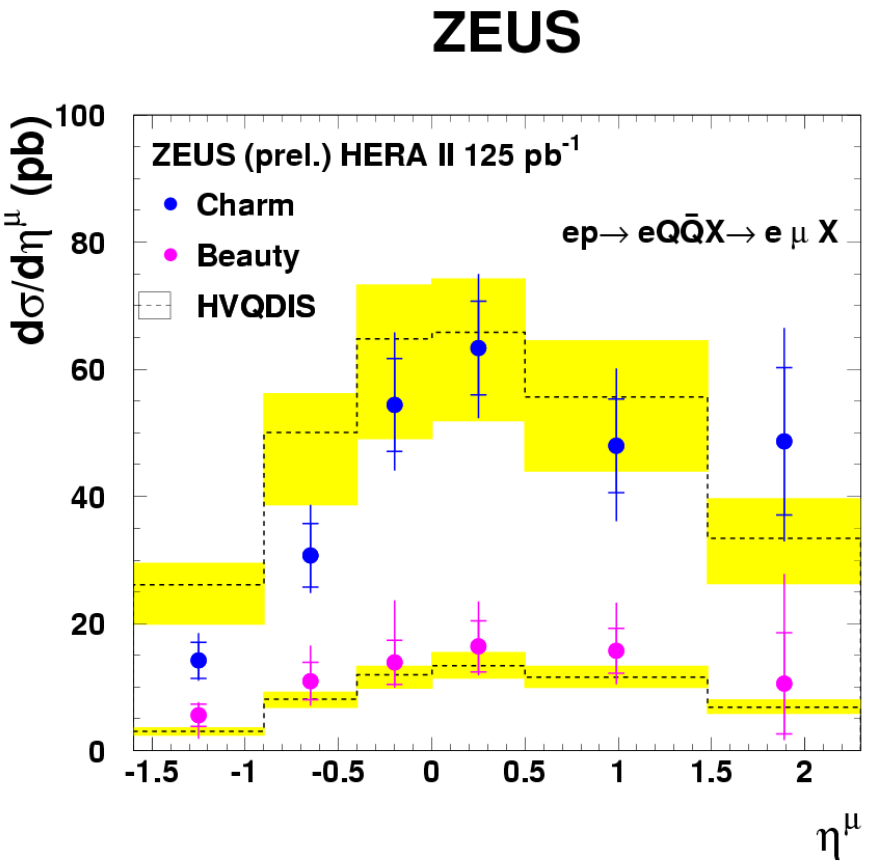


- reasonable description by NLO (HVQDIS)
- ➔ extract $F_{2,}^{c\,\bar{c}}\,F_2^{b\,\bar{b}}$

Inclusive Lifetime Analysis

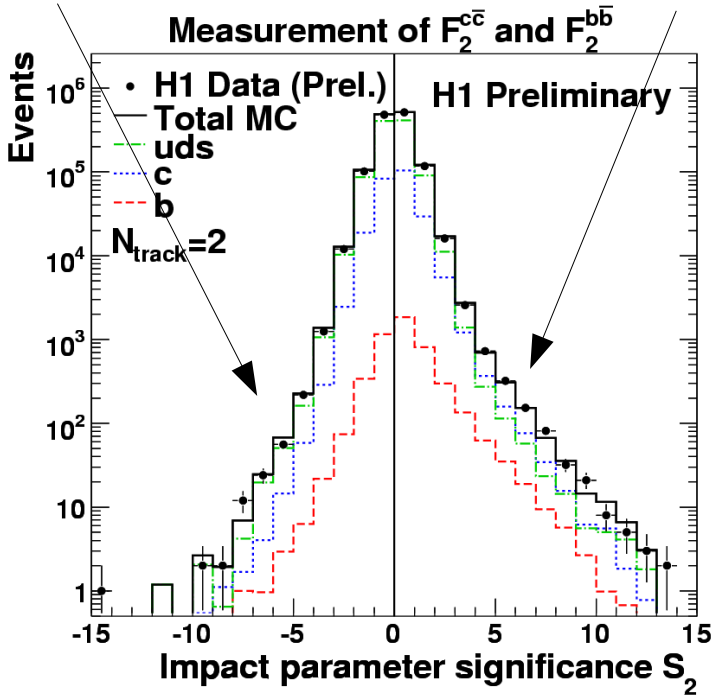
- inclusive analysis: use all tracks with hits in silicon detector
- studied variable: impact parameter significance: $S=\delta/\sigma(\delta)$
- improve separation power: use neural net for events with ≥ 3 tracks

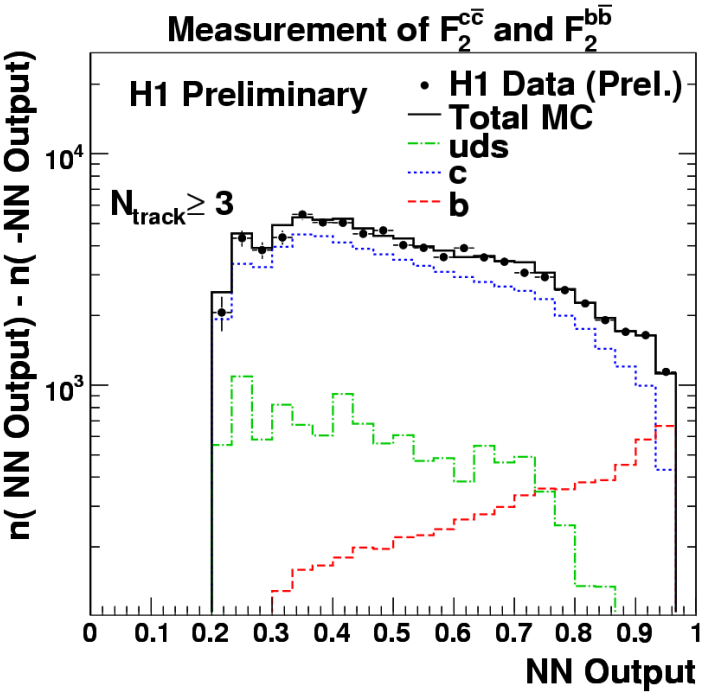
➔ up to 30% charm, some per mille to few % beauty

resolution

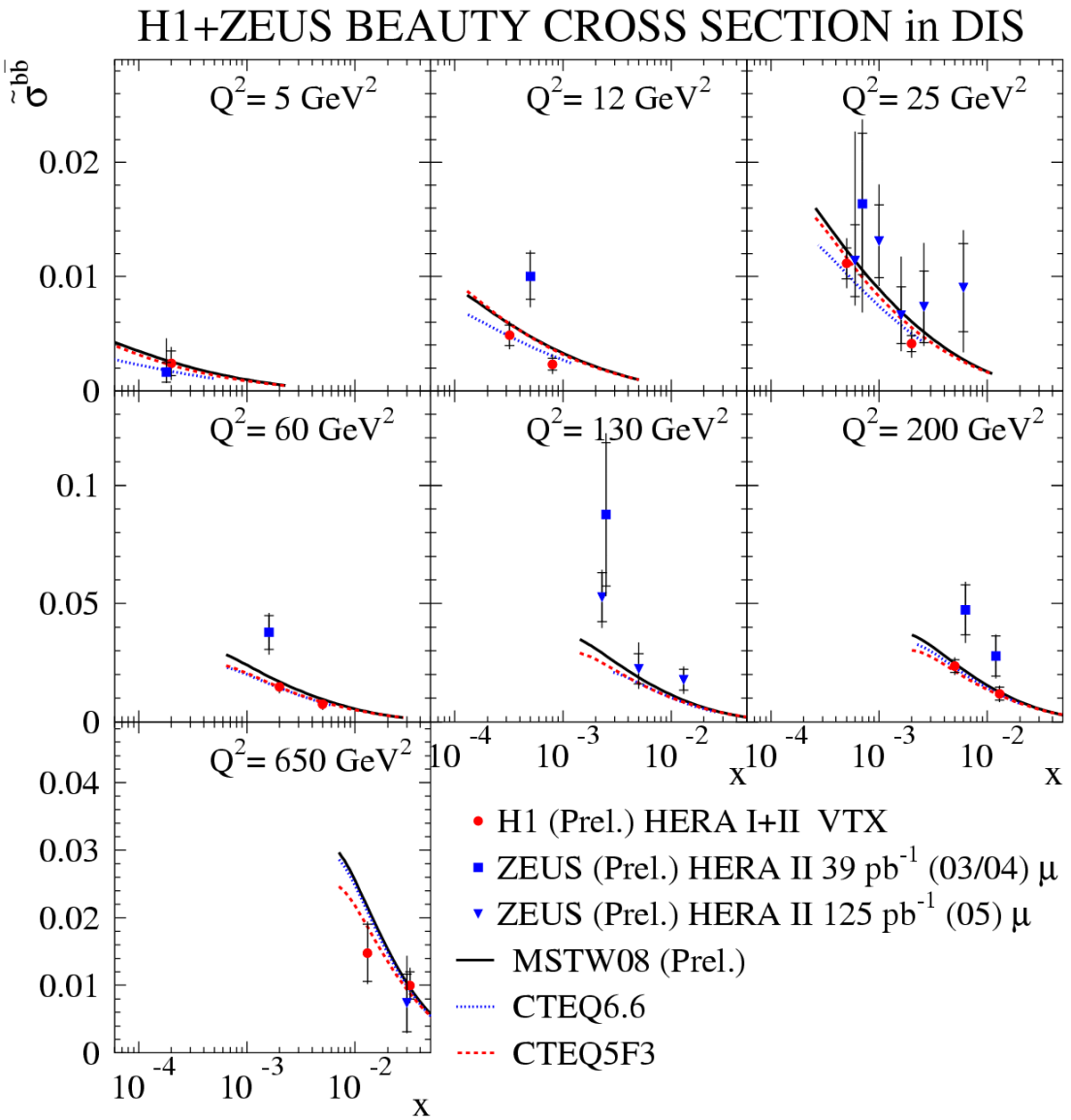
resolution & lifetime

H1prelim-08-173



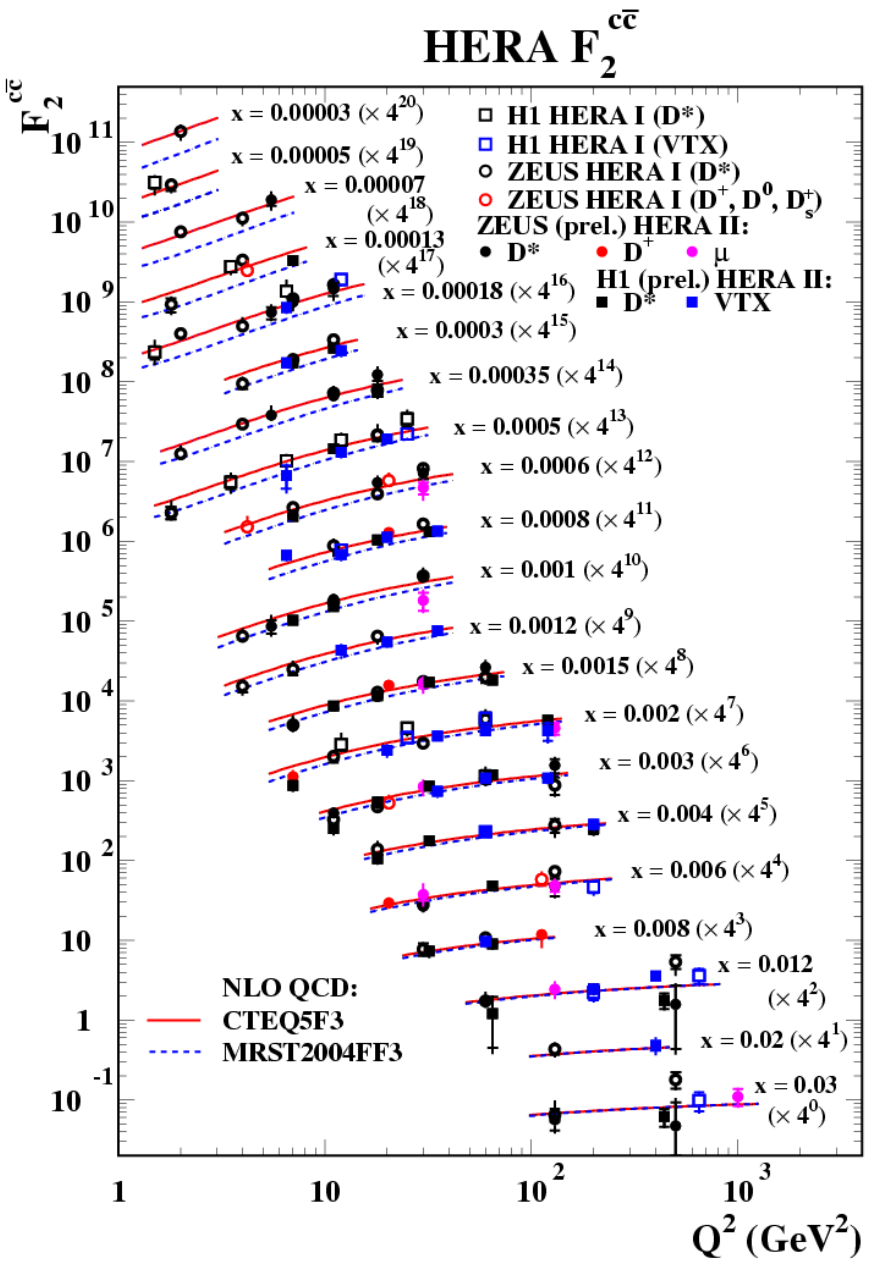


Measurements of $F_2^{b\bar{b}}$



- comparison of different analysis methods [acc.]
  - inclusive lifetime (H1 HERA I+II) [>90%]
  - μ p_T^{rel} (ZEUS HERA II) [20-35%]
  - μ p_T^{rel} + lifetime (ZEUS HERA II) [25-50%]
- experimental uncertainties decreasing with HERA I+II statistics

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

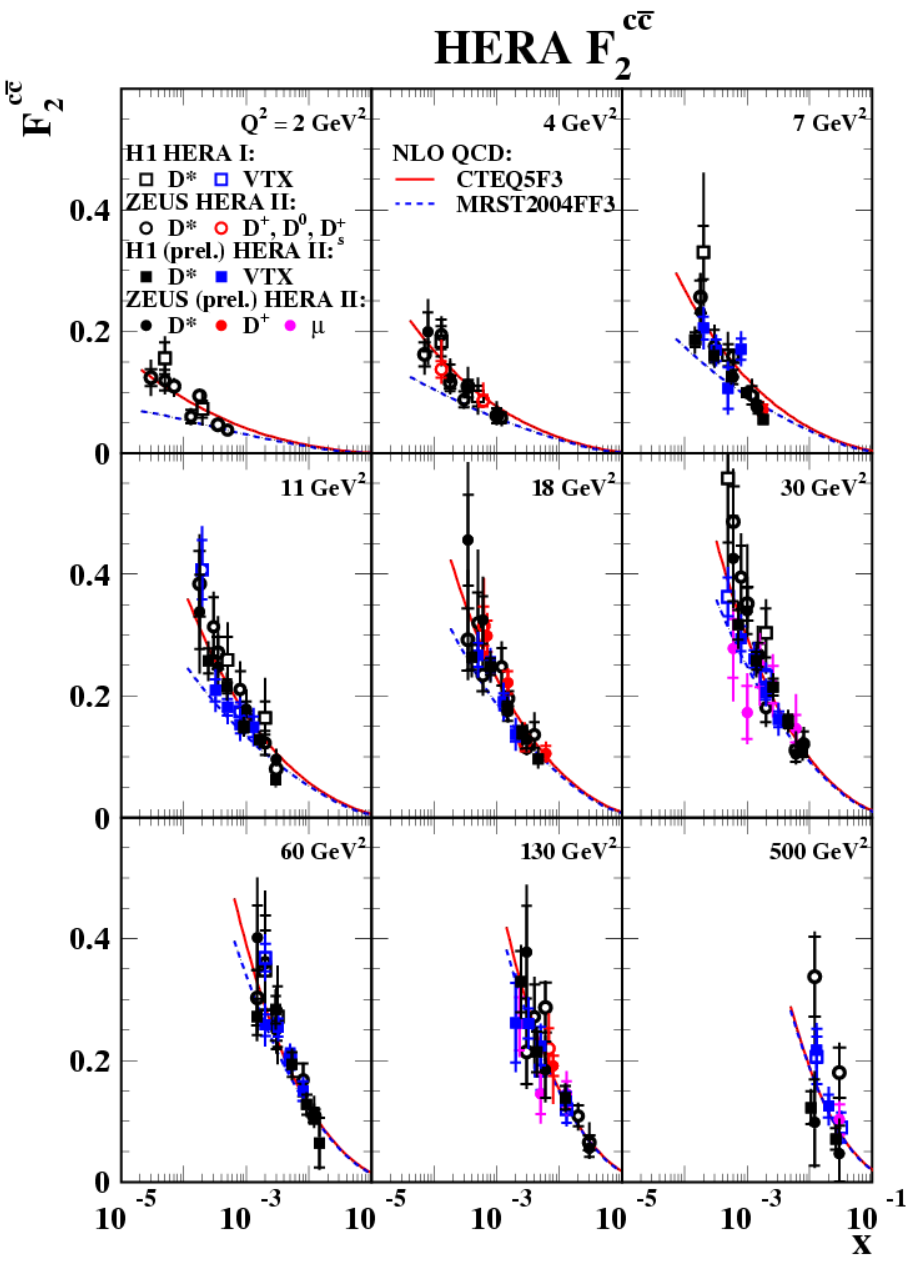


- comparison of different analysis methods [acceptance]
  - inclusive lifetime (H1 HERA I,II) [>70%]
  - μ p_T^{rel} + lifetime (ZEUS HERA II) [25-50%]
  - extrapolation of D*cross sections (H1, ZEUS HERA I,II) [20-70%]
  - D^+, D^0, D_s cross sections (ZEUS HERA I) [30-70%]
  - D^+ + lifetime (ZEUS HERA II) [30-70%]

➔ wealth of precise measurements

➔ theory predictions differ for $Q^2 \lesssim (2m_c)^2$

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



- different methods agree well
  - combination of measurements will improve precision
- strong rise towards low x at larger Q^2
- different inputs to the theoretical predictions:
  - parton densities
  - mass treatment

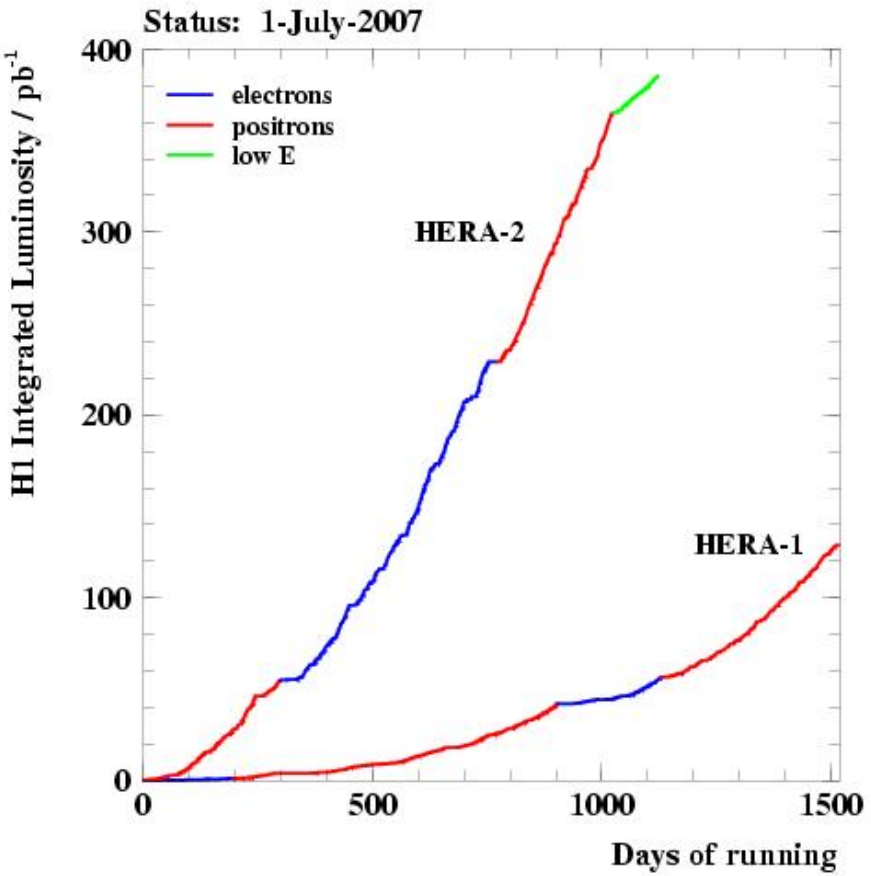
Conclusion

- wealth of new heavy quark measurements in electroproduction from HERA I and HERA II data
- extraction of F2c and F2b allows comparison of many different analysis techniques
- data are reasonably well described by NLO pQCD calculations
  - data distinguish between different theory calculations (mass treatment, PDFs)

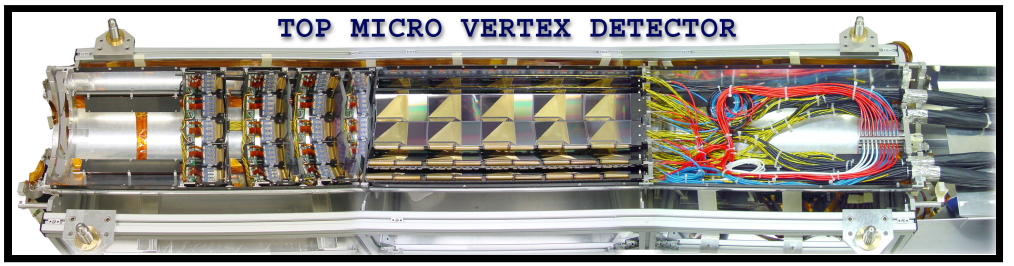
➔ final results with full HERA statistics expected soon!

Backup

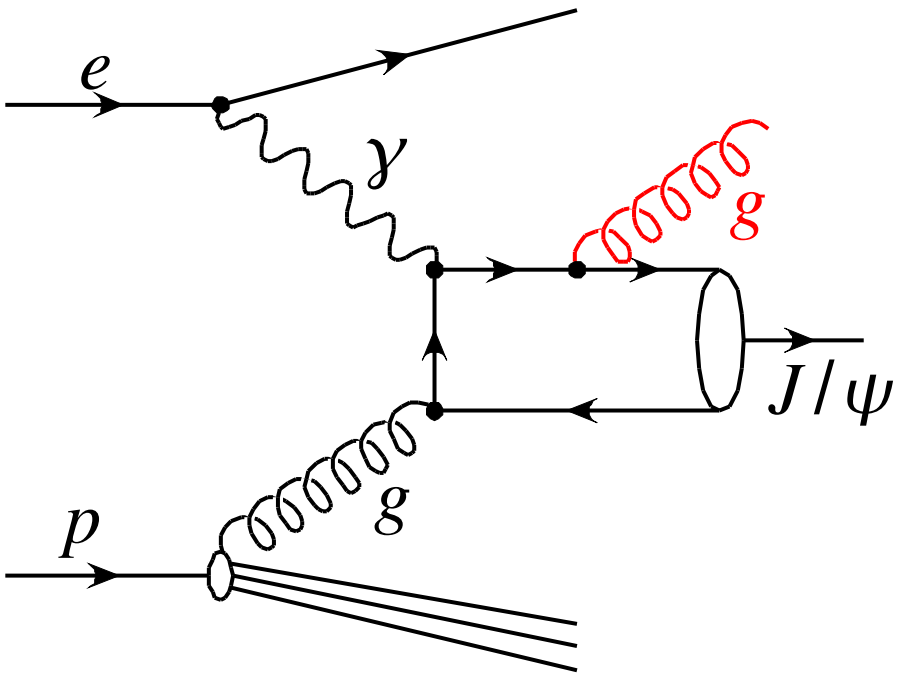
Available Data



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



Inelastic Electroproduction of J/ψ Mesons

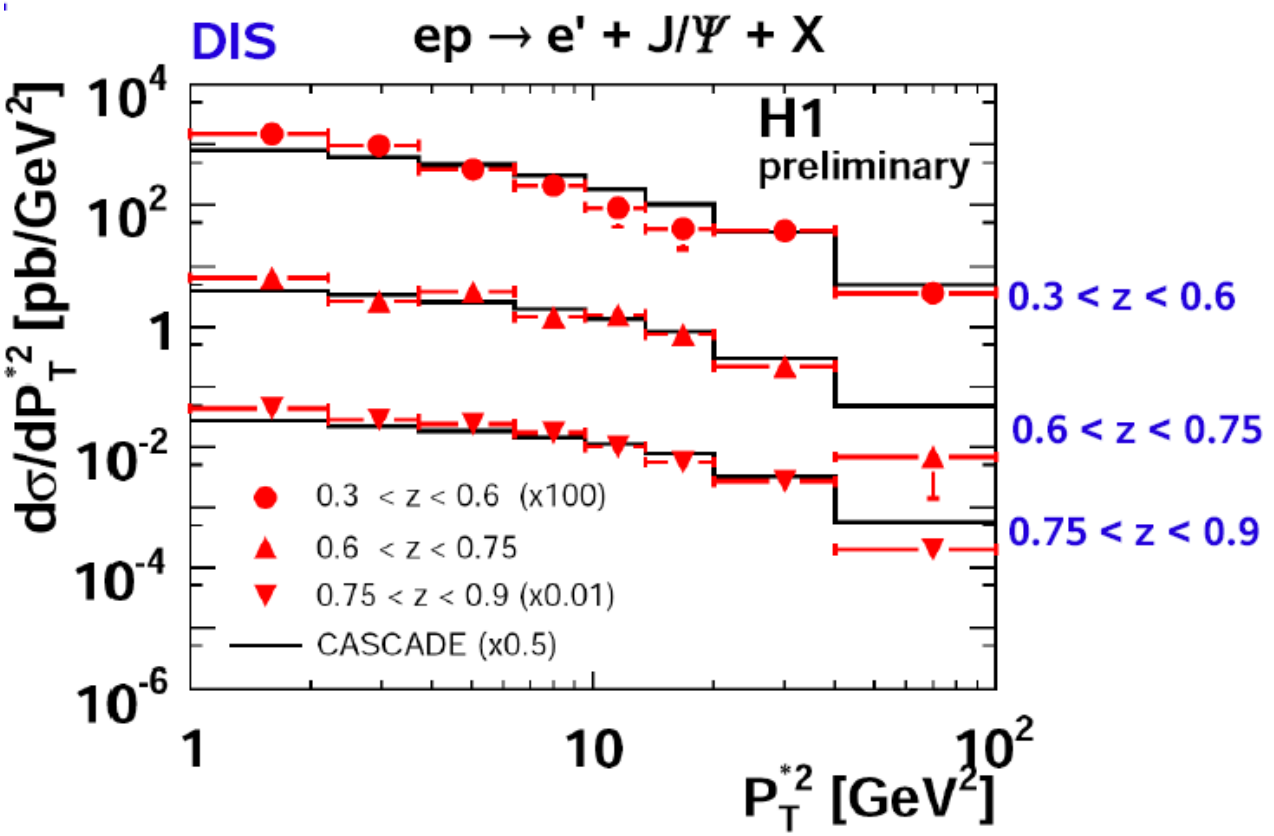


elasticity $z = \frac{E_\psi}{E_\gamma}$ in proton rest frame

several models to describe the transition $c\bar{c} \rightarrow J/\psi$

- Color Singlet Model: perturbative process („hard“ gluon)
  - MC: CASCADE
- Non-Relativistic QCD: non-perturbative process („soft“ gluons)

Inelastic Electroproduction of J/ψ Mesons



- similar p_T distribution in all z regions

➔ all z regions well described in shape by CSM Monte Carlo

➔ no additional NRQCD contributions needed