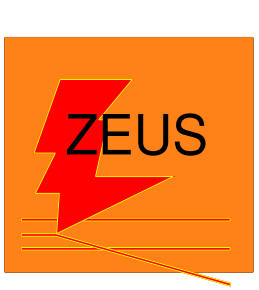
F_2^{cc} measurement at HERA



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on behalf of the ZEUS and H1 Collaborations

Europhysics Conference on High Energy Physics

EPS HEP 2007

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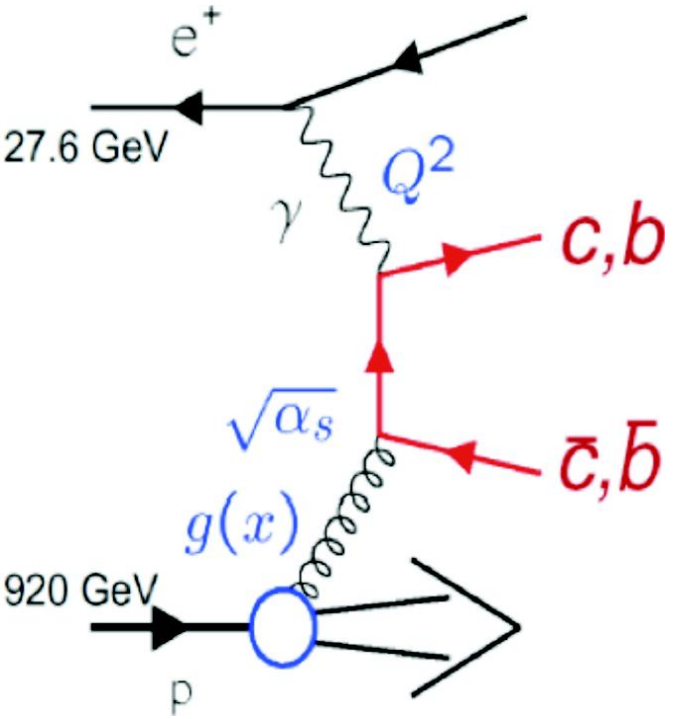
Motivations

At HERA, in lepton-proton collisions, charm can be studied in a wide kinematic region, for transverse momentum, p_T^c, from 1 to some tens GeV, and photon virtuality, Q^2, from 0 to 1000 GeV^2. *The DIS regime corresponds to a photon virtuality greater than few GeV^2 (scattered lepton seen in the detector).*

At these photon virtualities, charm production is dominated by the boson-gluon fusion process, $\gamma g \rightarrow c\bar{c}$, since resolved photon processes are suppressed.

This process is directly sensitive to the gluon content of the proton.



Theoretical models: NLO QCD

- Massive approach (Fixed Flavour Number Scheme)
- *(PHP: S. Frixione et al, FMNR, DIS: Harris and Smith, HVQDIS)*:
- heavy quark has mass, most appropriate for $Q^2 \sim M_Q^2$;
- number of active flavours in the proton is 3 (u,d,s);
- c and b are produced perturbatively in the hard subprocess;
- If $Q^2 >> M_Q^2$, large $\ln(Q^2/M_Q^2)$ appear.

Massless approach:

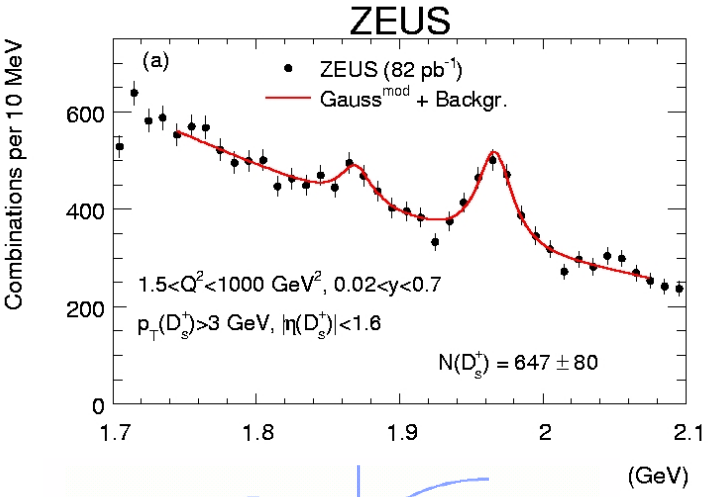
(B. Kniehl et al.)

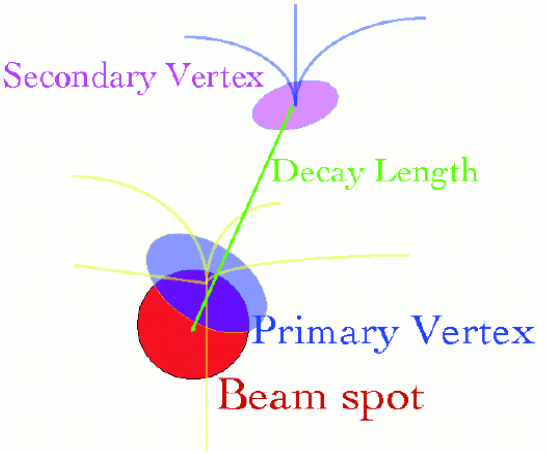
- heavy flavour masses are neglected, resummation is valid for $Q^2 >> M_Q^2$;
- number of flavours increases across threshold, HQ densities are zero below threshold.

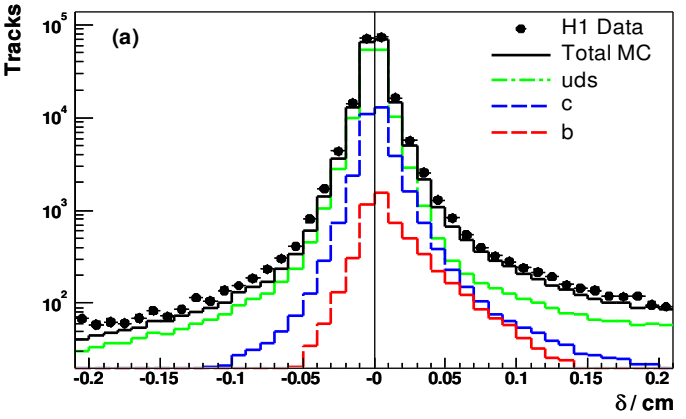
Combined approach *(M. Cacciari et al.)* (Variable Flavour Number Scheme)

Experimental methods

- Charm is tagged via the reconstruction of D mesons in the final state (D^*, D^+, D^0, D_s)
  - For long living particles, like D^+, the secondary vertex of the decay can be reconstructed, and a cleaner signal can be retrieved by requiring it to be well reconstructed.
  - In this case, an extrapolation to the full phase space of the D meson is needed to evaluate F_2^{cc} .
- Charm can also be tagged inclusively, by selecting events with tracks significantly displaced from the primary vertex.
  - The extrapolation is in this case much smaller, since the large majority of the charm events have tracks significantly displaced from the primary event vertex, that can be reconstructed by the vertex detectors.







$D^* \to K\pi\pi$

Golden mode: can be double tagged by the slow pion and the D^0 in the final state.

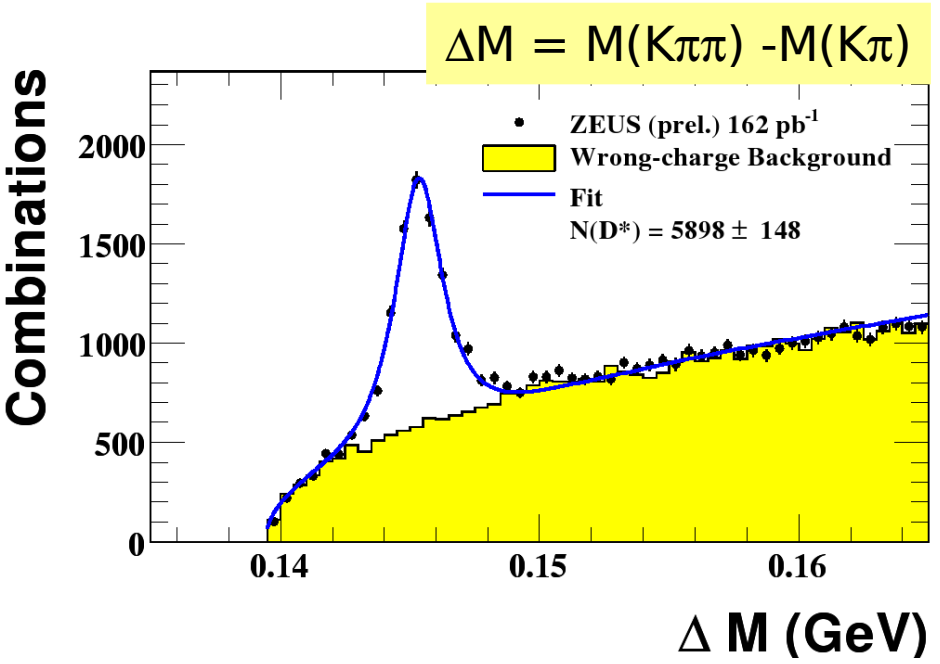
Kinematic region:

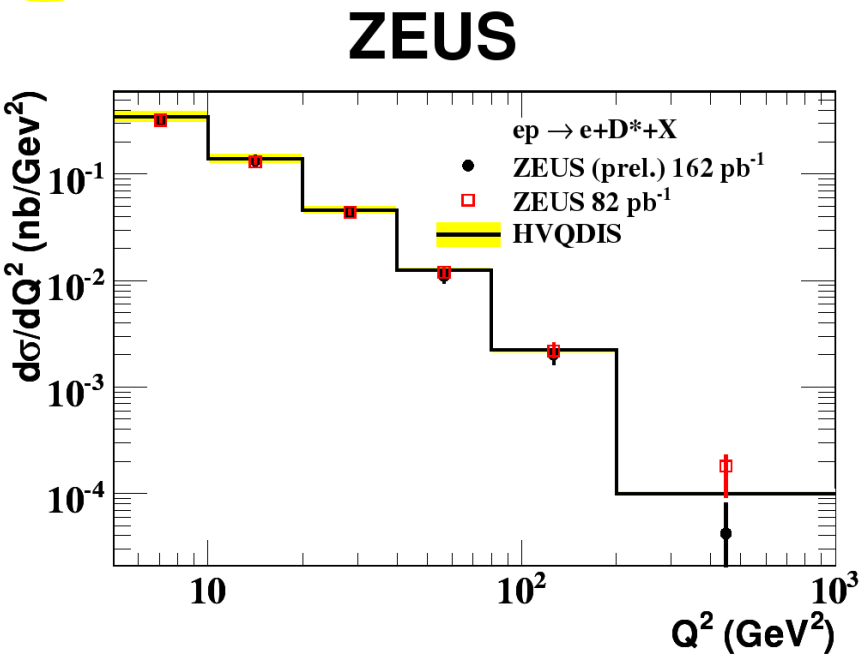
$5 < Q^2 < 1000\ \mathrm{GeV}^2$

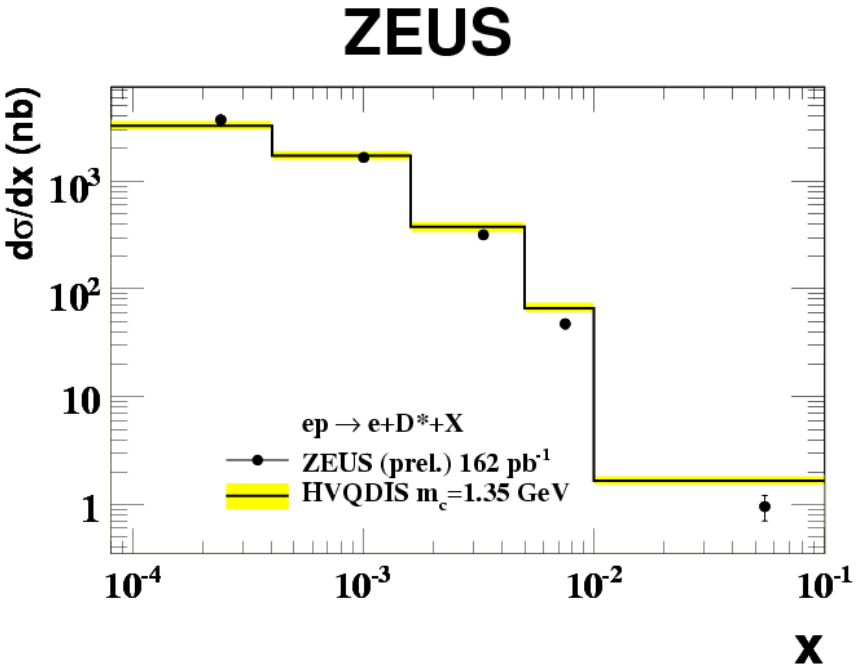
$0.02 < y < 0.7$

$|\eta(D*)| < 1.5$

$1.5 < p_T(D*) < 15\ \mathrm{GeV}$

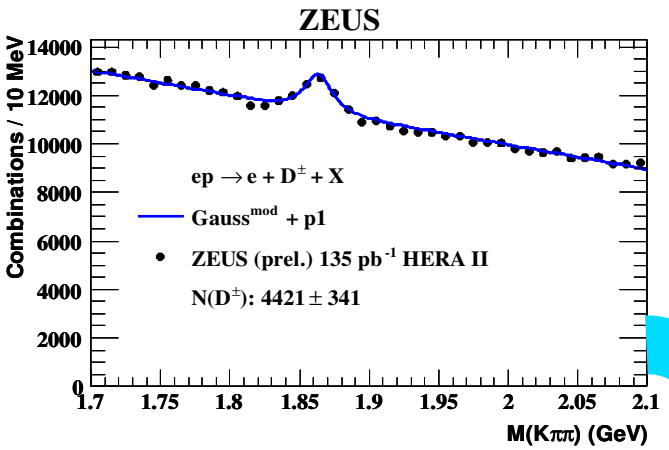


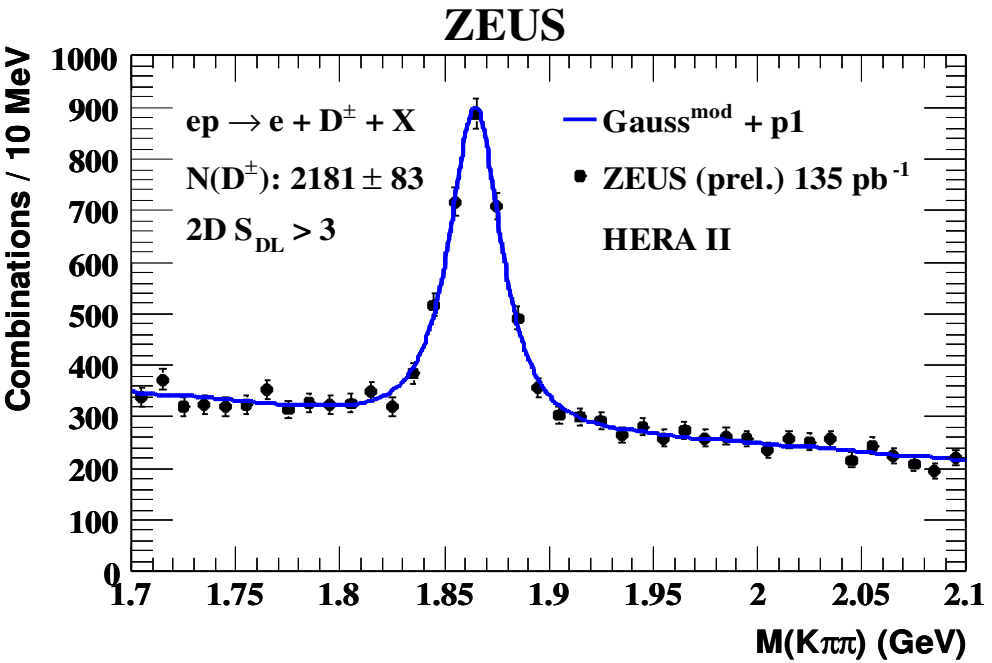


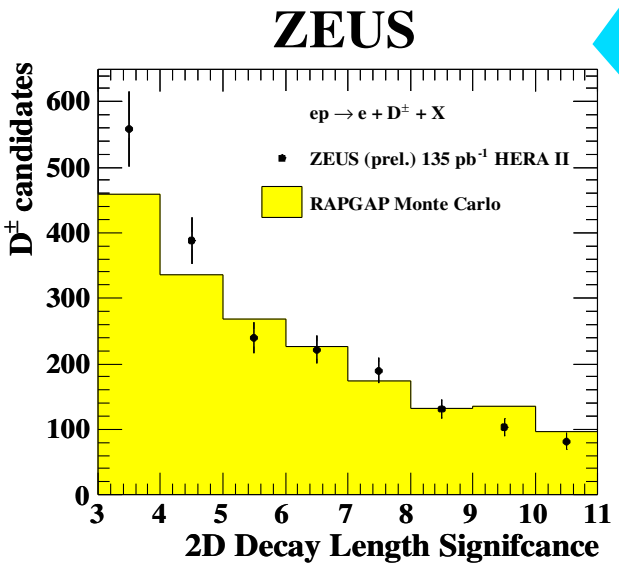


$D^+ \to K^- \pi^+ \pi^+$

The D^+ has a long lifetime: better S/N ratio can be obtained by cutting on the significance of the decay length of the three decay products.





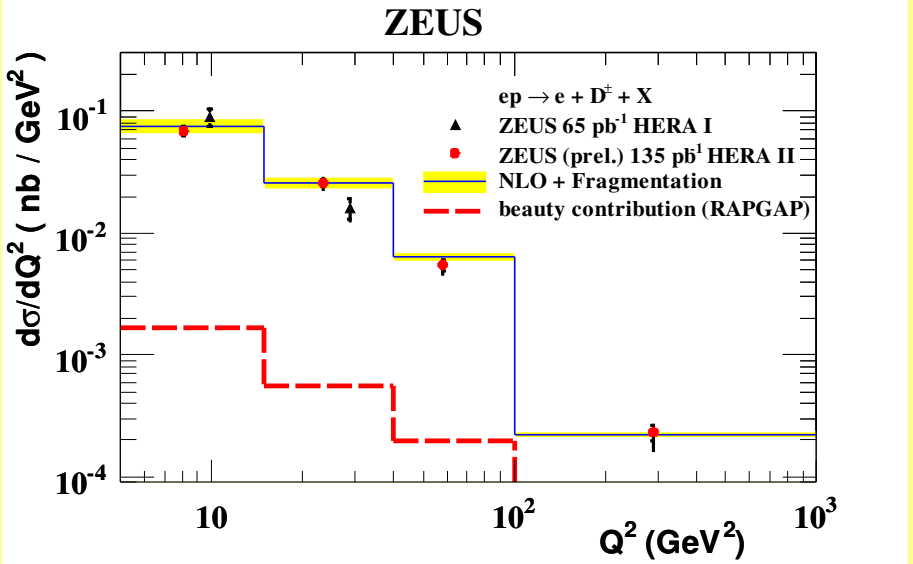


By requiring the decay length significance to be > 3,

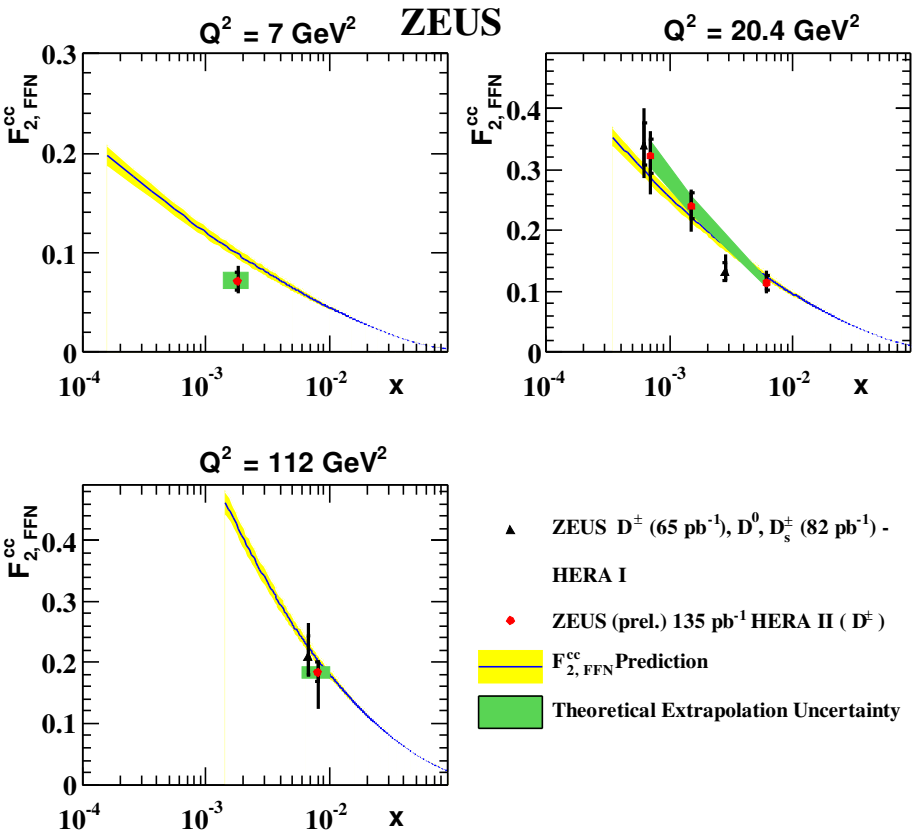
the statistical error goes from 7.7% to 3.8%

F_2^{cc} in bins of Q^2

The error is reduced with respect to the previous HERAI measurement.



HVQDIS is used for the extrapolation to the full D^+ phase space.

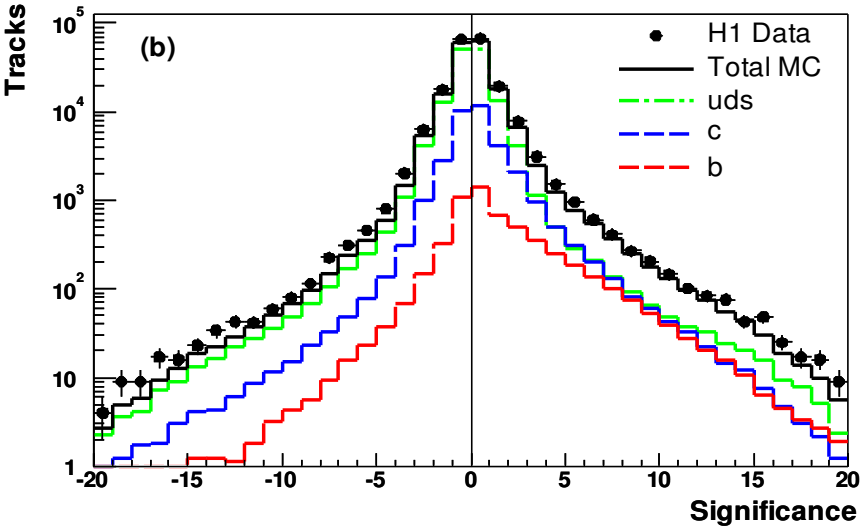


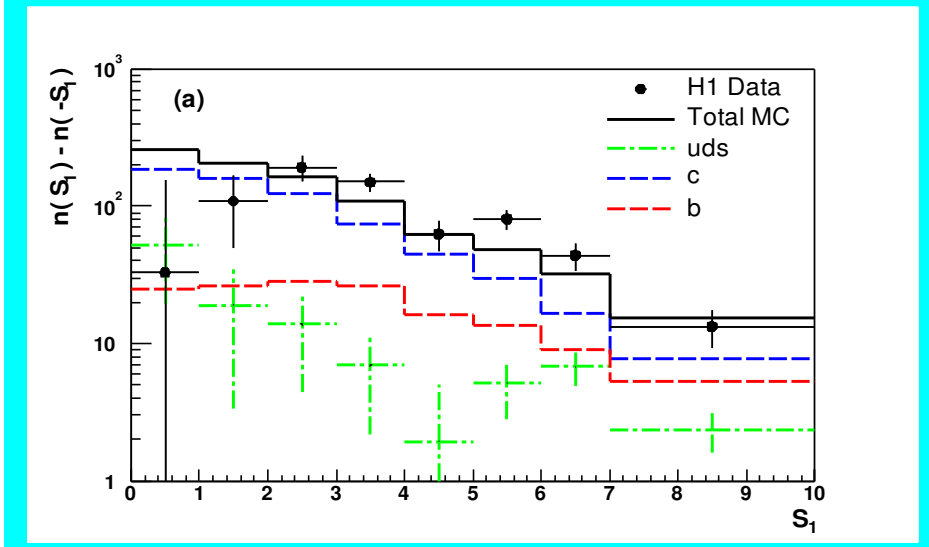
The charm contribution to F_2 has been determined and has comparable precision to that of the HERAI measurement with three mesons.

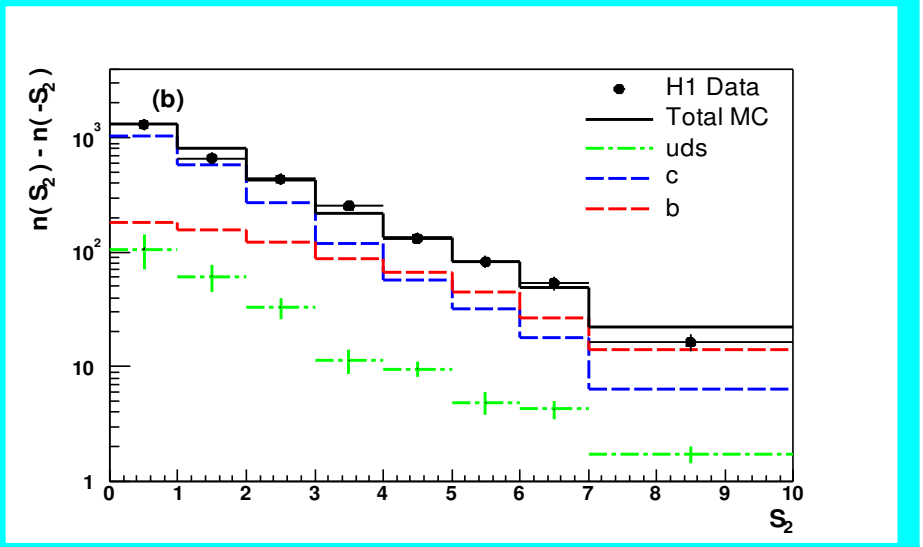
F_2^{cc} from inclusive charm tagging

Charm can be identified also using the impact parameter (IP) of the tracks with respect to the primary event vertex.

The most powerful tool to separate beauty, charm and background is the significance of the IP of the tracks.

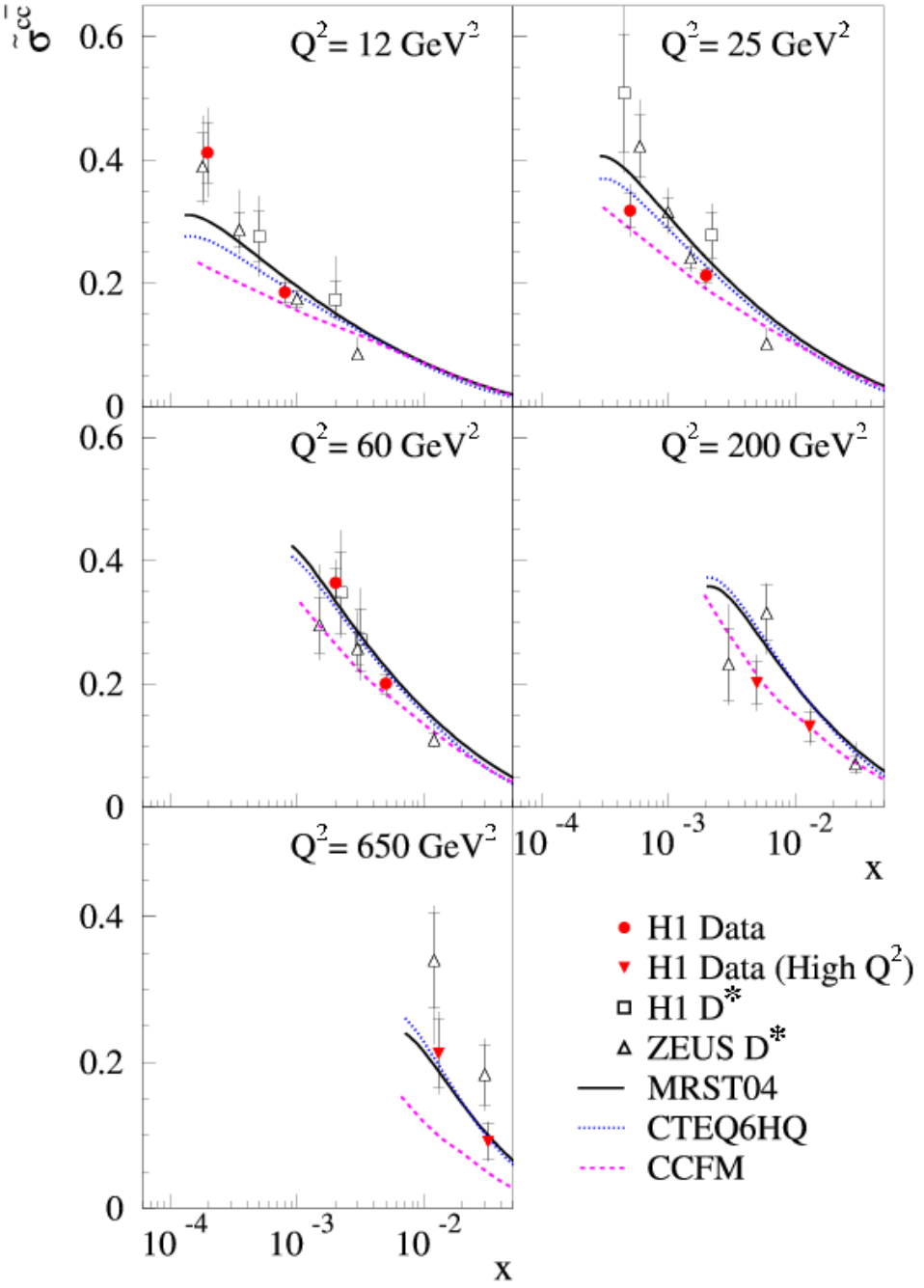






A high purity sample of charm and beauty is obtained after subtracting the reflected light flavour contribution.

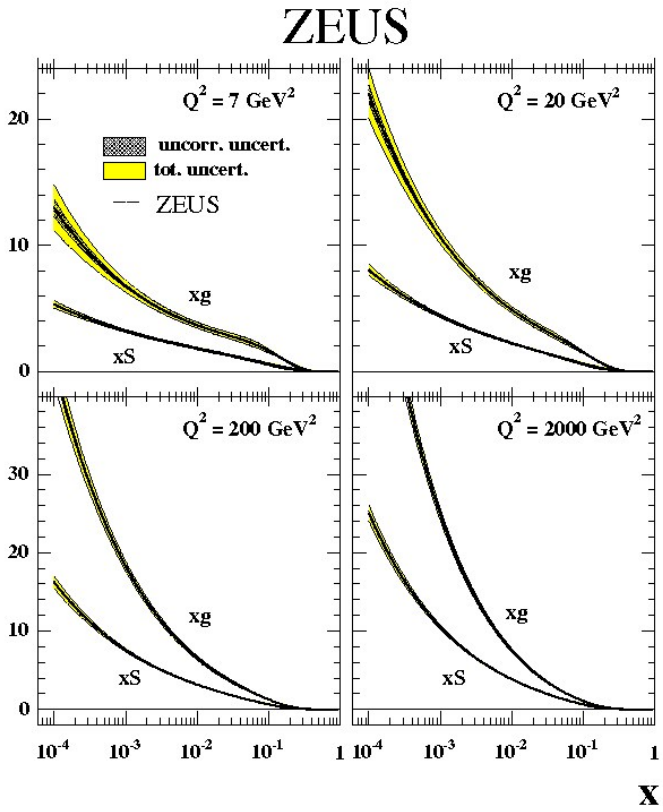
F_2^{cc} in bins of Q^2



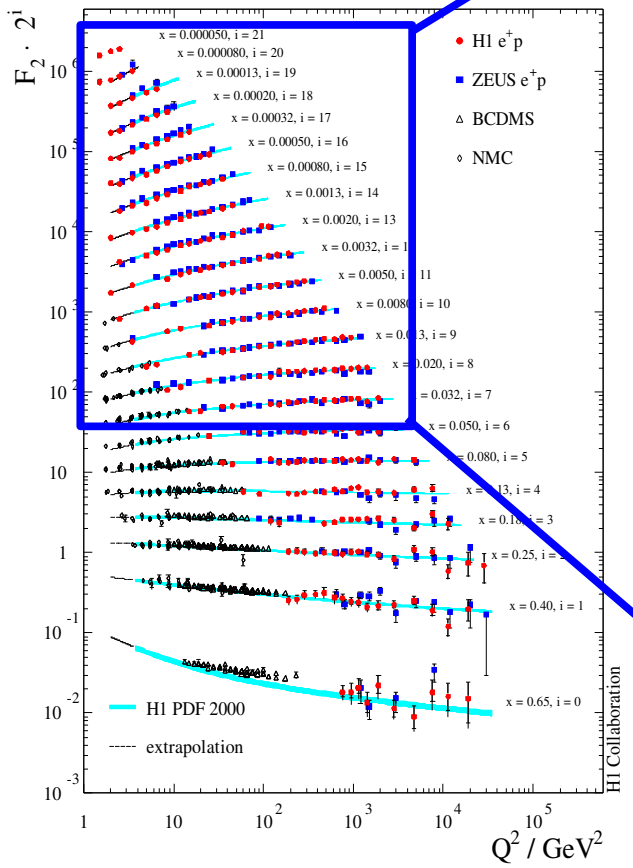
The charm contribution to the proton structure function is determined in a wide range in x and Q^2.

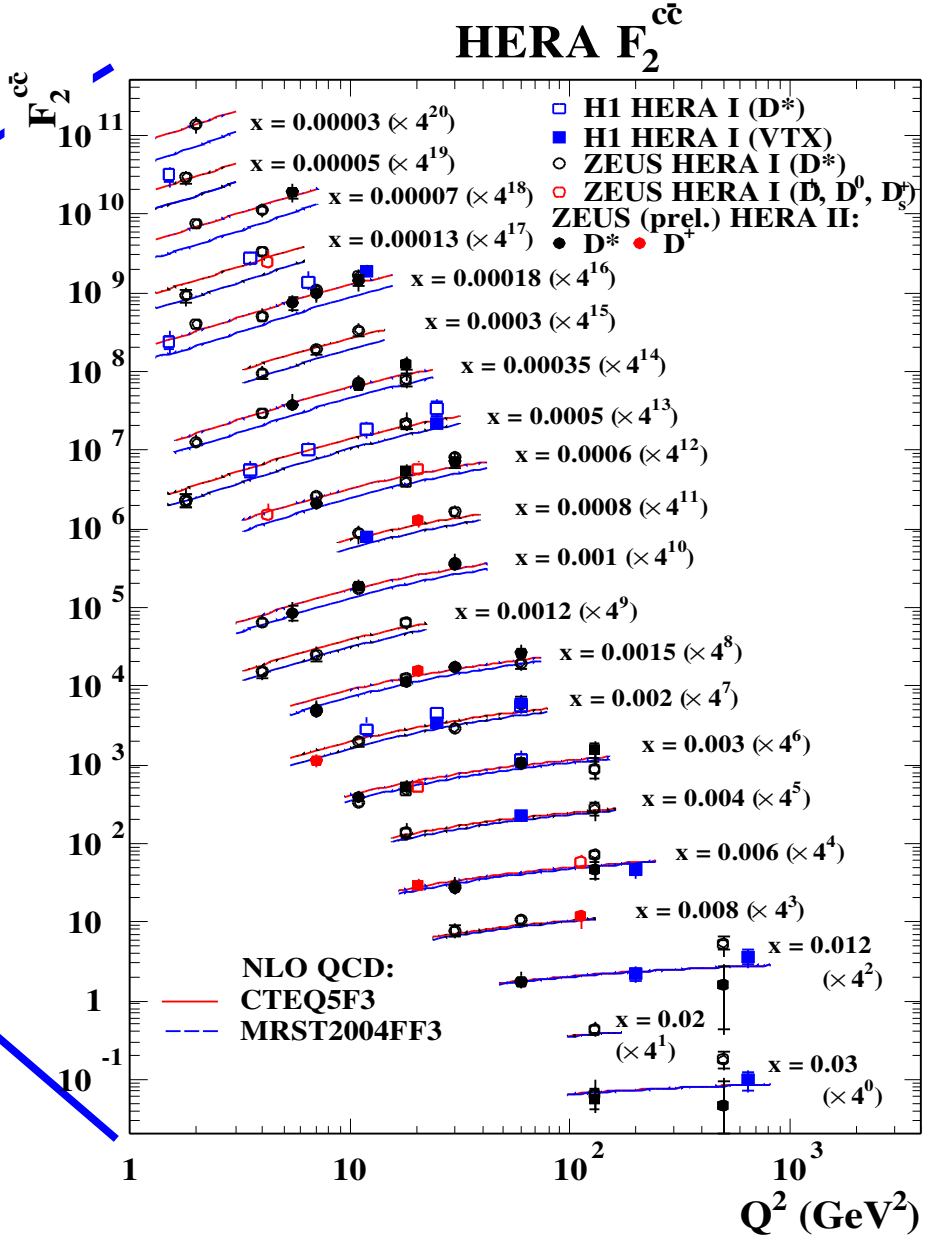
Agreement is found between the measurement and the QCD predictions at NLO, within the measurement error.

With smaller errors, it should be possible to distinguish between different gluon densities.



F_2^{cc}





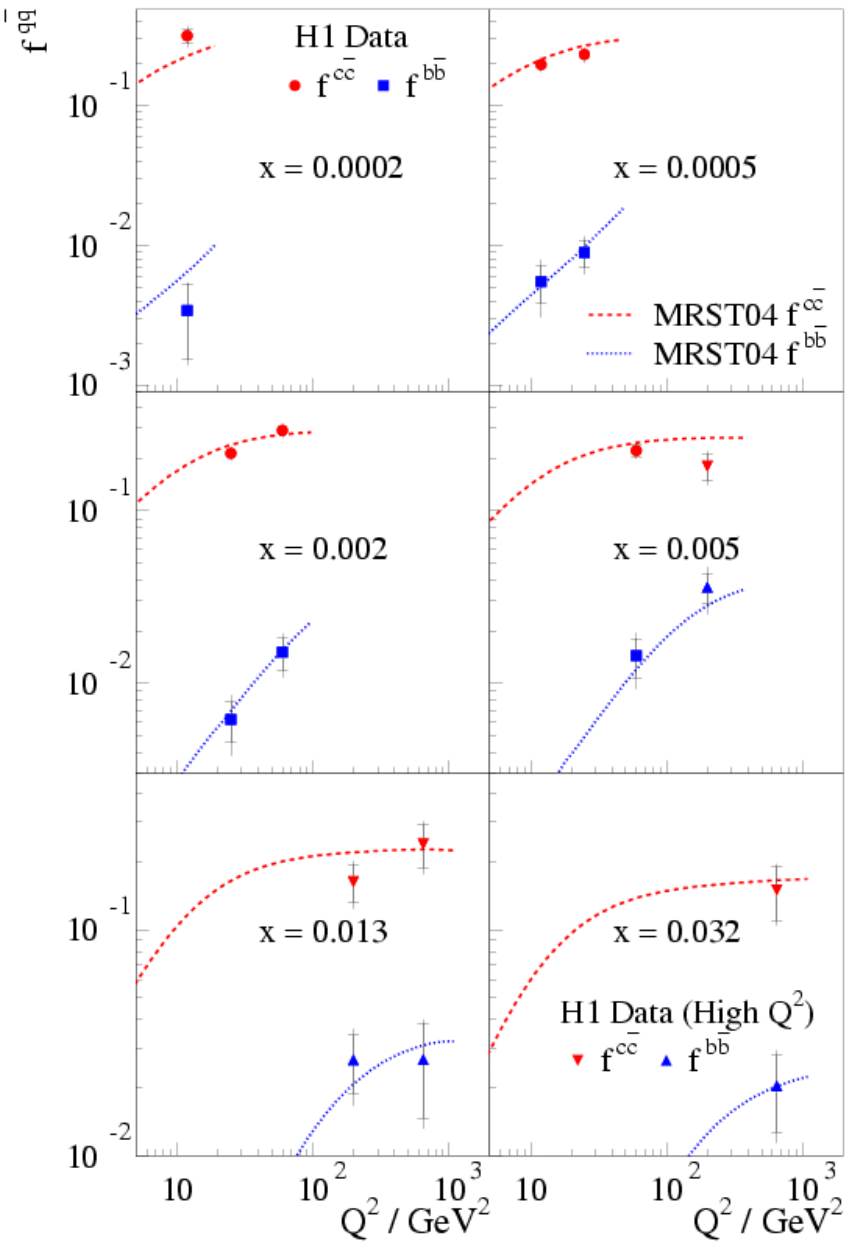
Scaling violation observed at low x.
The measurement can distinguish between different gluon distributions.
ZEUS and H1 measurements are in good agreement.

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

The charm (and beauty) contributions are presented as the fractional contribution to the total ep cross section.

charm contribution is of the order of 20%

beauty contribution is of the order of few percent.



Conclusions and outlook

- The charm contribution to the proton structure functions, F_2, is measured at HERA using different techniques, basing on D meson tagging and lifetime measurements.
- The two collaborations, ZEUS and H1, using very different methods for the analysis, implying different extrapolations factors, agree on the results.
- The precision of the measurement is improving, and the measurement appears to be able to distinguish between the different gluon densities provided by theorists.
- The use of the whole HERA data sample can help in constraining the gluon density in the proton.

Backup slides

Bibliography

- H1 Coll., Eur. Phys. J. C45 (2006) 23-33 , July 2005.
- H1 Coll., Eur. Phys. J. C40 (2005) 349-359 , November 04.
- ZEUS Coll., Phys. Rev. D 69 (2004) 012004, August 03.

F_2^{cc} extraction: ZEUS and H1

$$\frac{d^2\sigma^{c\bar{c}}(x,Q^2)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\{[1+(1-y)^2]F_2^{c\bar{c}}(x,Q^2) - y^2 F_L^{c\bar{c}}(x,Q^2)\}$$

ZEUS extracts F_2^{cc} from *D* mesons cross sections, using HVQDIS to extrapolate to the full meson phase space:

$$F_{2,\mathrm{meas}}^{c\bar{c}}(x_i,Q_i^2) = \frac{\sigma_{i,\mathrm{meas}}(ep\to D^*X)}{\sigma_{i,\mathrm{theo}}(ep\to D^*X)} F_{2,\mathrm{theo}}^{c\bar{c}}(x_i,Q_i^2)$$

H1 measures charm inclusively:

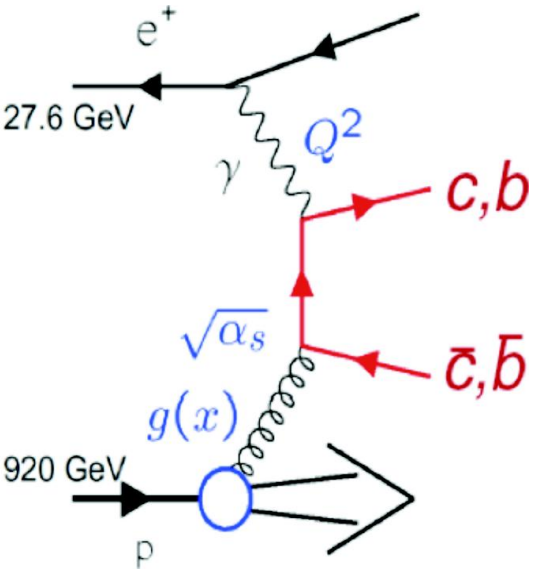
$$\tilde{\sigma}^{c\bar{c}}(x,Q^2) = \tilde{\sigma}(x,Q^2)\frac{P_c N_c^{\mathrm{MCgen}}}{P_c N_c^{\mathrm{MCgen}} + P_b N_b^{\mathrm{MCgen}} + P_l N_l^{\mathrm{MCgen}}}\delta_{\mathrm{BCC}}$$

where Pc,b,l are the fraction of charm, beauty, LF from the fit and $\tilde{\sigma}$ is the inclusive reduced cross section.

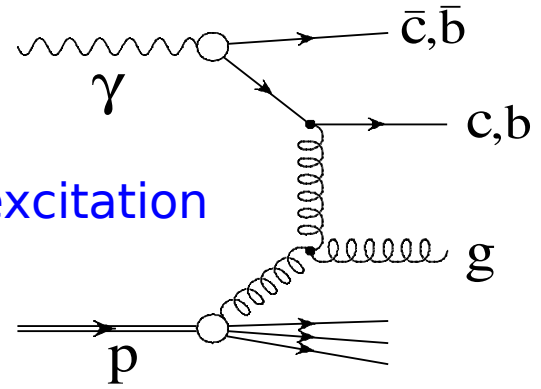
Production mechanism

The main process contributing to HFL production at HERA is boson-gluon fusion (BGF): $\gamma p \rightarrow Q\bar{Q}$. This is directly sensitive to the gluon content of the proton.

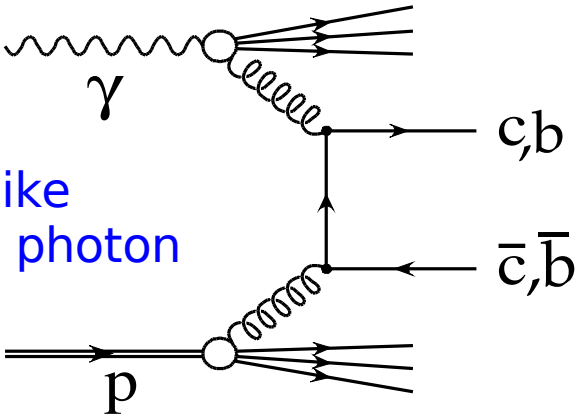
There are also other processes contributing: resolved photon (a parton is extracted from the photon) and flavour excitation.



Charm, beauty excitation



Hadron-like resolved photon



ZEUS: NLO QCD predictions

The HVQDIS program has been used, which evaluates cross sections for heavy quark production at NLO in the fixed flavour number scheme.

Quantity	Value	Variation
Renormalisation & Factorisation scale (μ_R, μ_F)	$\mu_R = m_F = \sqrt{Q^2 + 4M_c^2}$	$2\sqrt{Q^2 + 4M_\chi^2}$ Larger of: $\frac{1}{2}\sqrt{Q^2 + 4M_\chi^2}$ and $2M_c$
Peterson Parameter (ε)	0.035	± 0.015
Charm Mass (M_c)	1.35 GeV	±0.15 GeV
Input PDF	ZEUS NLO PDF	Upper and lower predictions of ZEUS NLO PDF.

Theoretical models: Monte Carlo

Data are compared with different Monte Carlo models and next-to-leading order QCD predictions:

- PYTHIA, RAPGAP: LO+LL parton shower QCD predictions.
  - Parton evolution simulated according to the collinear approximation (DGLAP). Higher order effects are simulated with LL parton showers;
  - BGF+resolved photon: charm is massive;
  - flavour excitation: charm is massless.
- CASCADE: gluon density unintegrated in the gluon transverse momentum (k_t):
  - higher order QCD corrections are simulated with initial state parton showers, based on CCFM evolution;
  - the simulated process is BGF, and the charm is considered as massive.

Theoretical models: NLO QCD

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- *(PHP: S. Frixione et al, FMNR, DIS: Harris and Smith, HVQDIS)*:
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(B. Kniehl et al.)

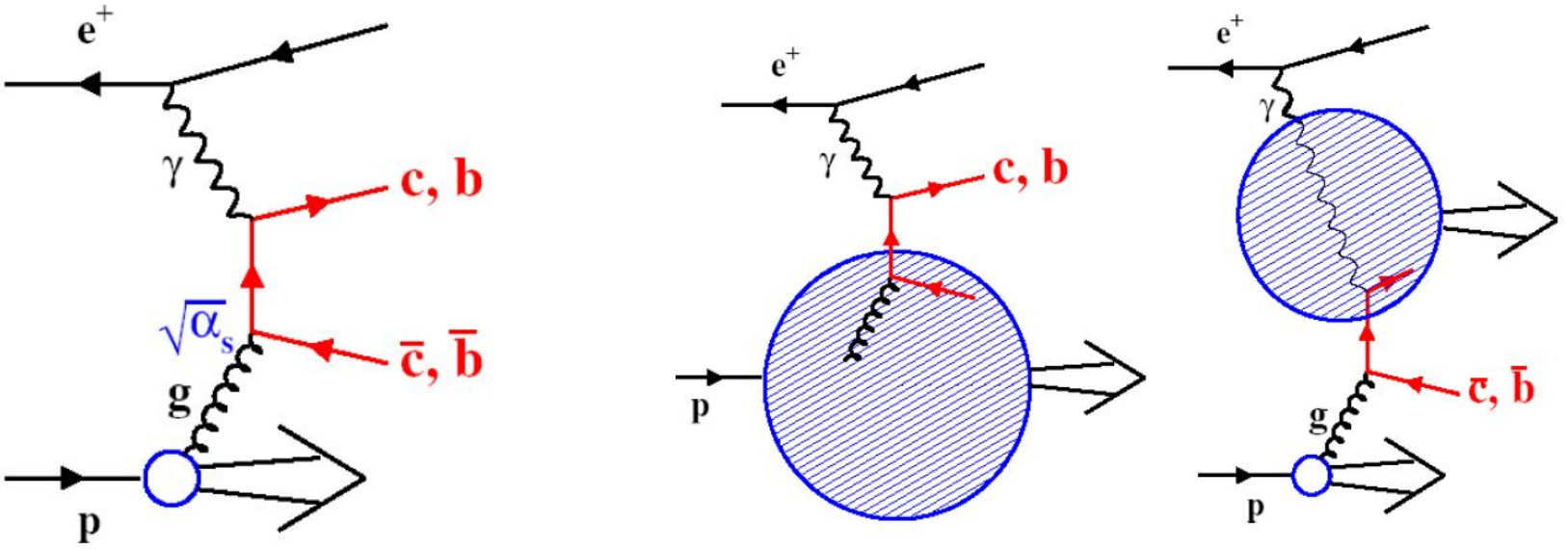
- heavy flavour masses are neglected, resummation is valid for $Q^2 >> M_Q^2$;
- number of flavours increases across threshold, HQ densities are zero below threshold.

Combined approach *(M. Cacciari et al.)* (Variable Flavour Number Scheme)

Theoretical models: NLO QCD (cont'd)

Variable Flavour Number Scheme:

- combines massive and massless approach;
- massive approach around threshold ($Q^2 \sim M_Q^2$), resummation of $\ln(Q^2/M_Q^2)$ at large Q^2.



F_2^{cc}

The precision of the measurement of F^2_{cc} is improving.

The effect of the different gluon densities is quite relevant at low Q2, low x.

The possibility to constrain the gluon density by using the whole HERAII statistics should be investigated.