HELMHOLTZ GEMEINSCHAFT

DESY

Measurement of F^c_2 and F^b_2 in DIS using vertex reconstruction at H1. Combined F^c_2 at H1.

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European Physics Symposium EPS 2009 Krakow

Heavy quark tagging via vertex reconstruction

Tagging of c,b using properties of c-,b- hadrons:

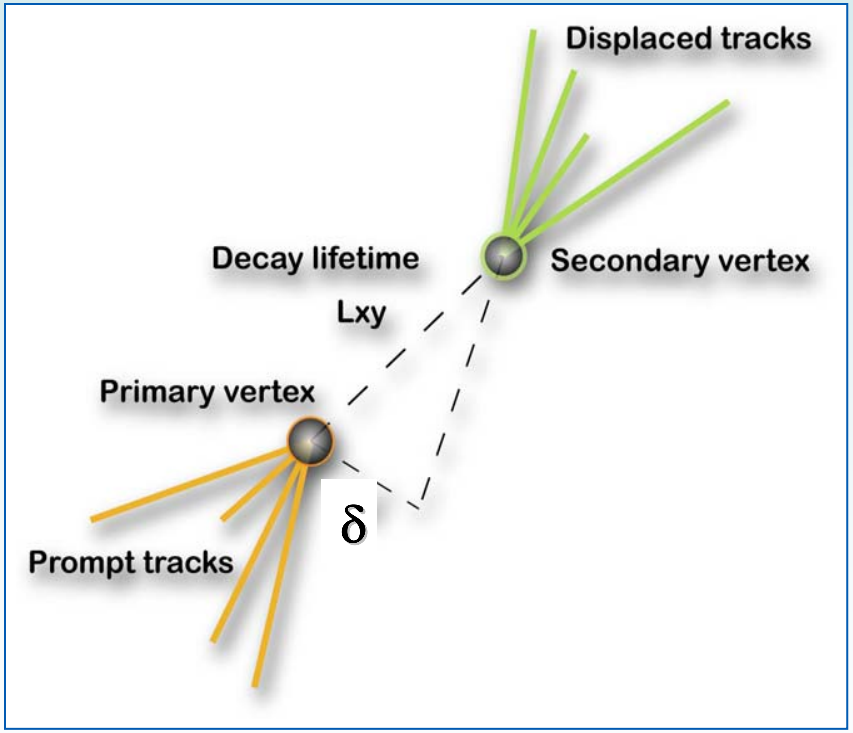
- track multiplicity

- long lifetime

Experimentally reconstruct:

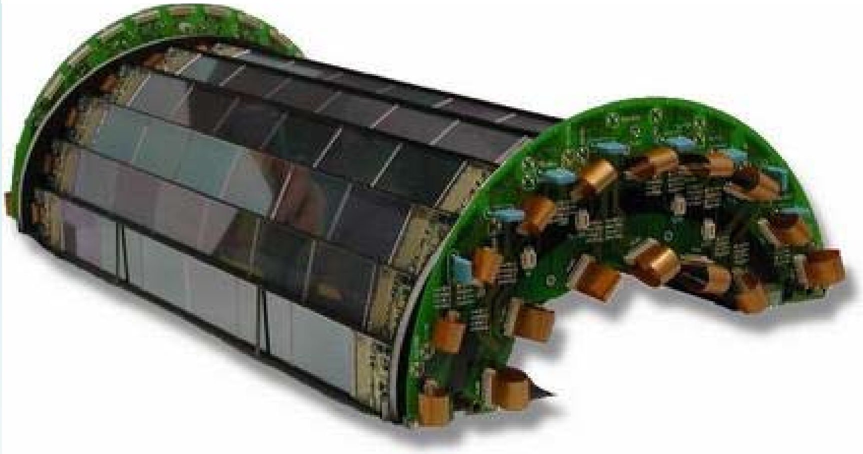
- secondary vertex,
- transverse decay length L_{xy}
- impact parameter δ
- significance $S = \delta/\sigma(\delta)$,

$$S_L = L_{xy}/\sigma(L_{xy})$$



Heavy quark tagging using H1 vertex detector

H1 Central Silicon Tracker (CST)



acceptance ($30^o < \theta < 150^o$)

2 layers of double sided strips

δ resolution for hits in both layers:

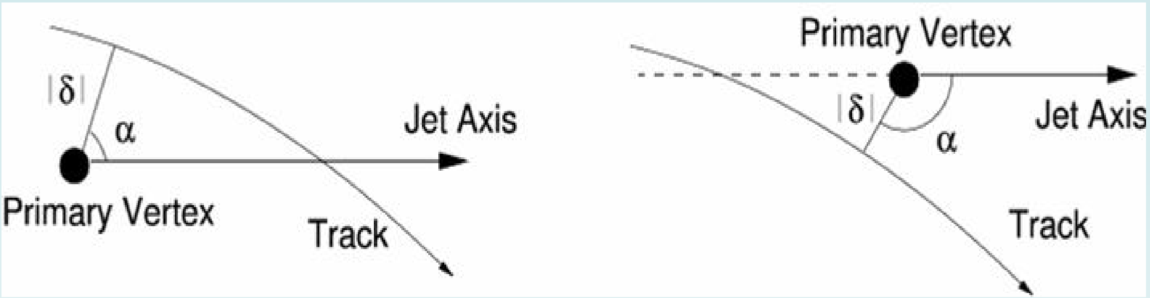
$$33\ \mu m \oplus 90\ \mu m / p_T [GeV]$$

Presented analysis: *DESY-09-096, hep-ex/09072643*

Data 2006-2007, $L = 189\ pb^{-1}$

Kinematical range: $5 < Q^2 < 650\ GeV^2$, $0.0002 < x < 0.032$

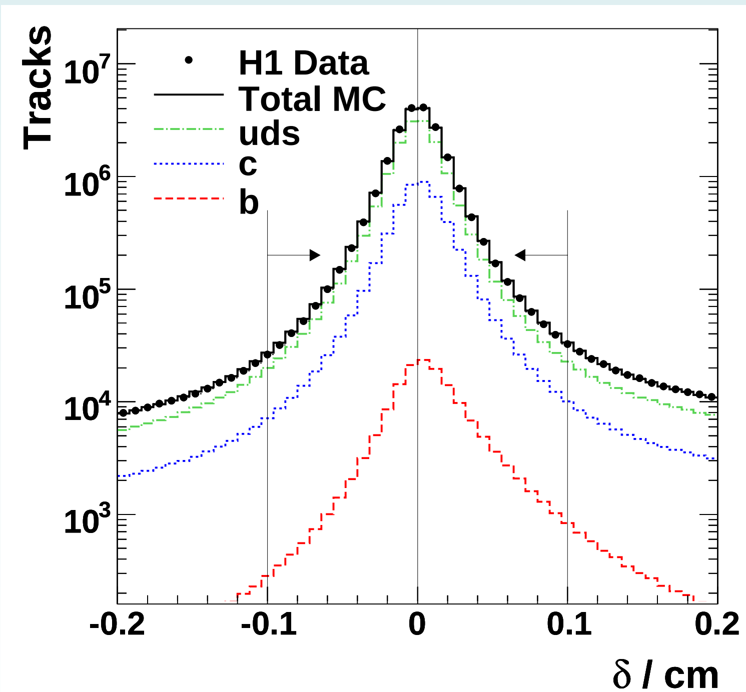
Impact parameter and Significance

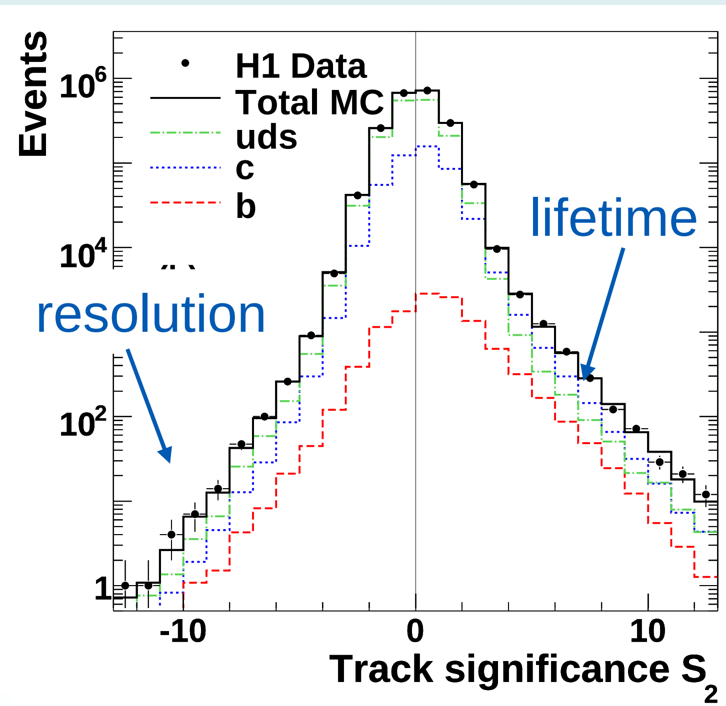


δ signed according to quark azimuthal angle:

$\alpha < 90°$: $\delta = +|\delta|$

$\alpha > 90°$: $\delta = -|\delta|$



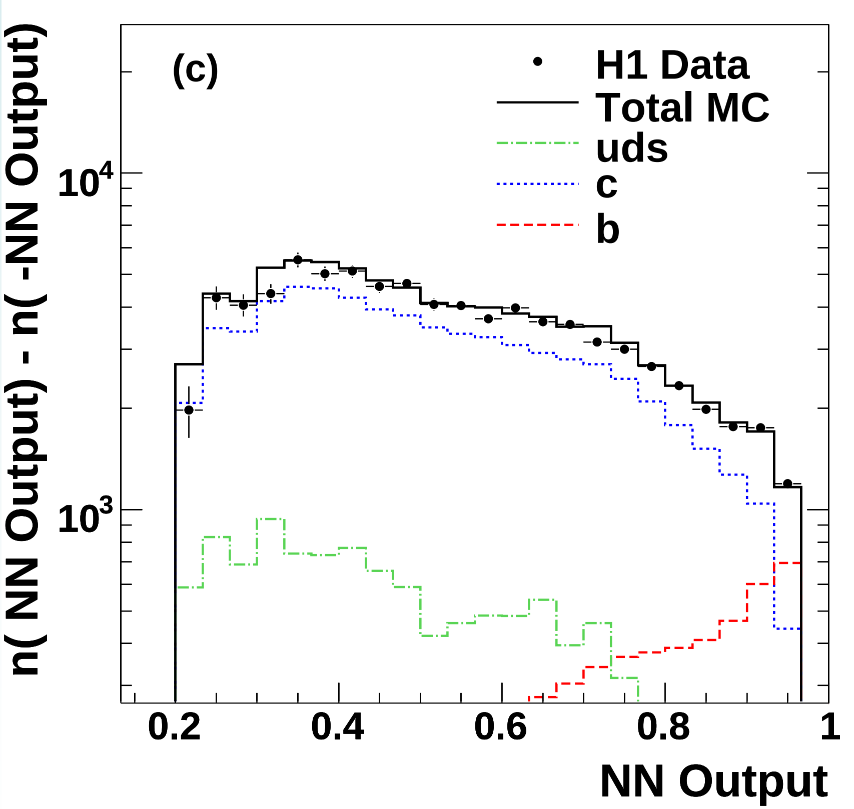


S_1 (S_2) : highest (2-nd highest) $|S|$

Measurement strategy

Inclusive measurement: use all tracks with hits in CST, p_T>0.3 GeV

Improve *c,b* separation: use neural network (NN) for $N_{tracks} \geq 3$



c-, b- fractions from fit of significances and NN output

Reduced cross section and F_2^{HQ}

Result of the fit converted to reduced cross section:

$$\sigma_{red}^{c\bar{c}}(x,Q^2) = \frac{d^2\sigma^{c\bar{c}}}{dxdQ^2} \cdot \frac{xQ^4}{2\pi\alpha^2(1+(1-y)^2)}$$

use:

$$\sigma_{red}^{c\bar{c}}(x,Q^2) = \sigma_{red}(x,Q^2) \cdot \frac{\rho_c \cdot N_c^{MC}}{\rho_c \cdot N_c^{MC} + \rho_b \cdot N_b^{MC} + \rho_{uds} \cdot N_{uds}^{MC}} \cdot \delta_{BCC}$$

Quark fractions ρ_c, ρ_b, ρ_{uds}:

fit to S_1, S_2, NN output in (x,Q^2) bins using Monte Carlo templates

Normalization:

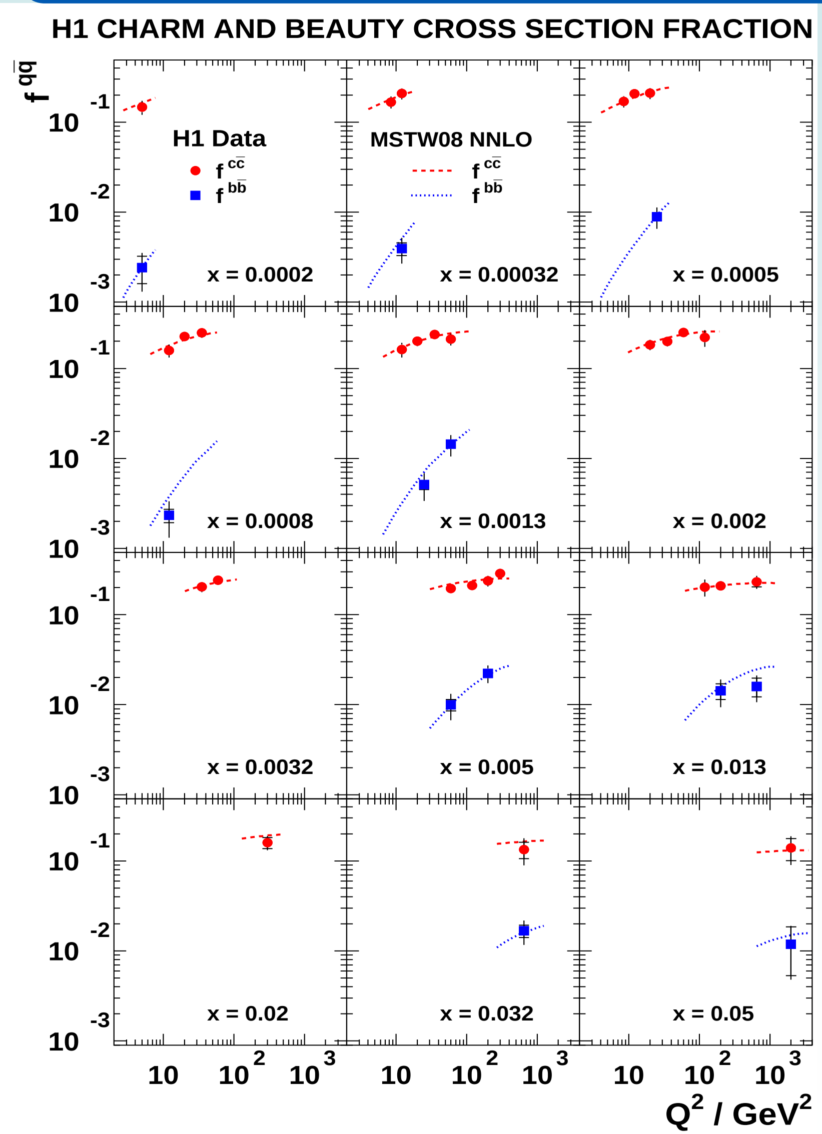
H1 inclusive reduced cross section $\sigma_{red}(x,Q^2)$ *hep-ex/0012053, 0304003*

Bin center corrections δ_{BCC}: via FFNS NLO calculation

Connection to F^c_2:

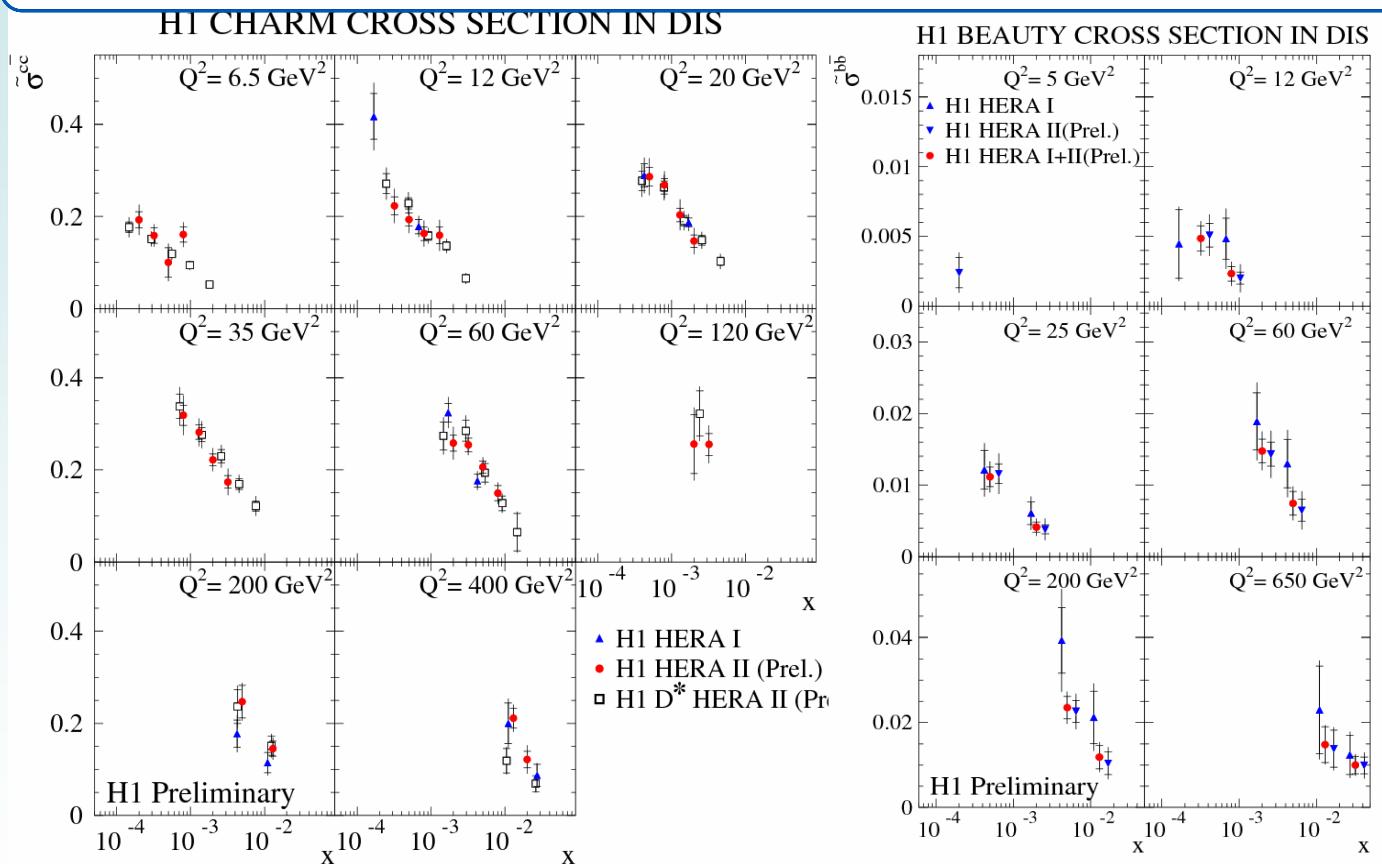
$$\sigma_{red}^{c\bar{c}} = F_2^{c\bar{c}} - \frac{y^2}{1+(1-y)^2} F_L^{c\bar{c}}$$

Charm and beauty fractions



- charm fraction up to 30%
- beauty fraction ~1% at most
- mass thresholds visible
- reasonable description by QCD

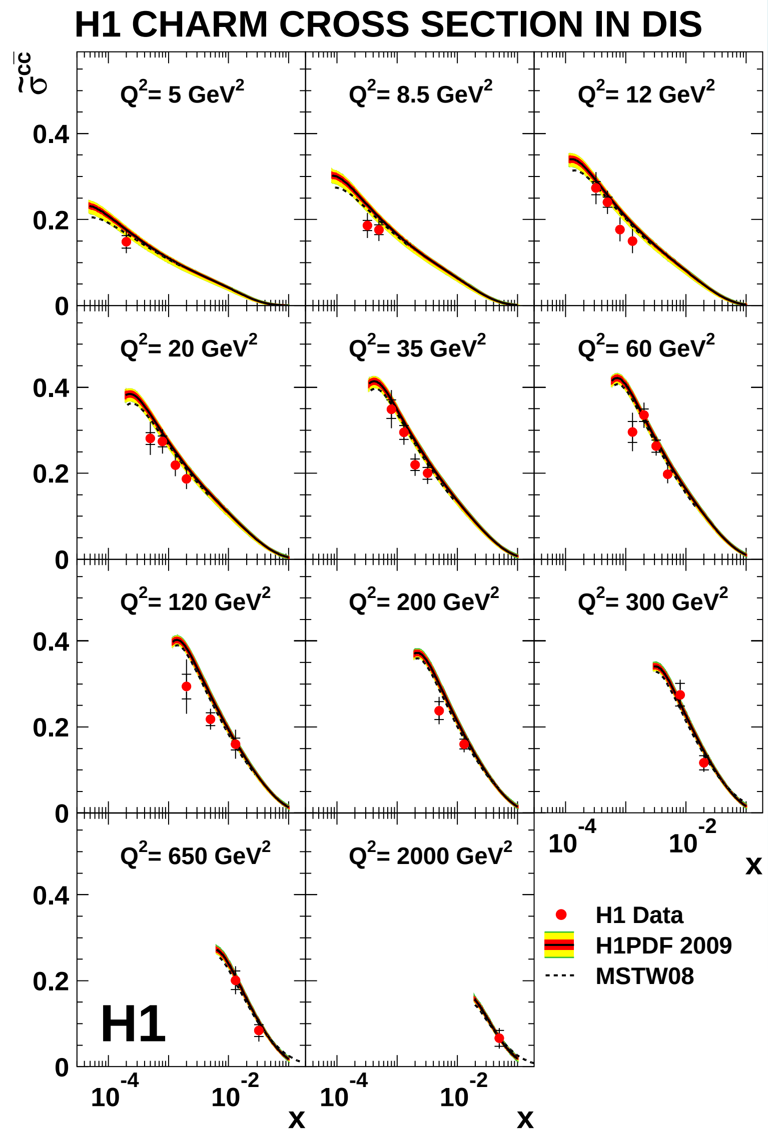
Charm and Beauty reduced cross sections

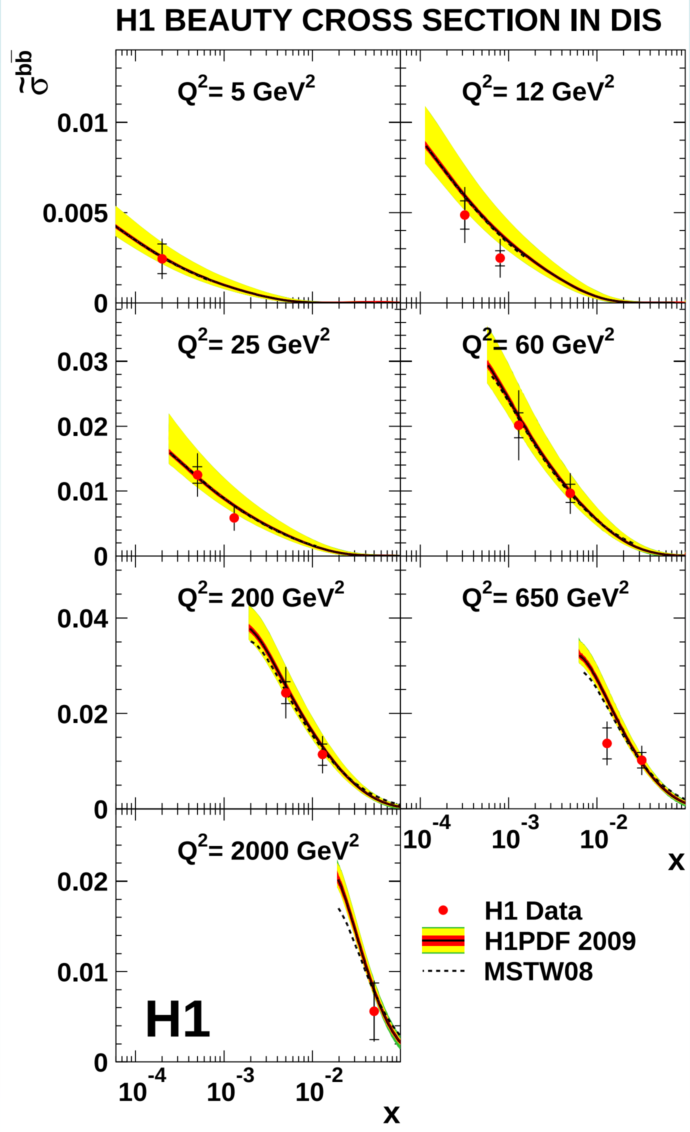


charm & beauty: new data agree with previous measurements

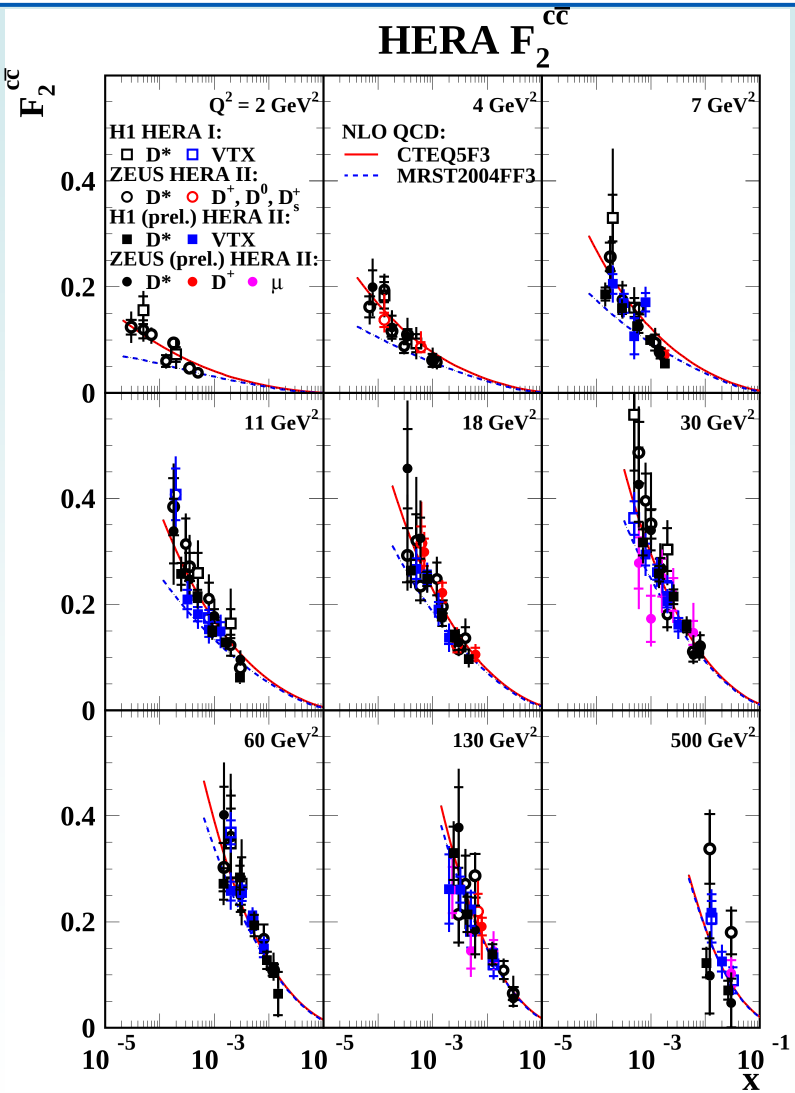
charm cross sections agree with D* reconstruction method

F_2^c, F_2^b vs predictions from global fits





HERA F^c_2 measurement: precision



Plenty of measurements:

- different precision
- different systematics
- (partially) different phase space

Make the message more conclusive:

- combine different tag methods

Get more distinction power btw models

Start: recent measurement of H1

Result:

Currently most precise F^c_2

H1prelim-08-174

Averaging procedure: input

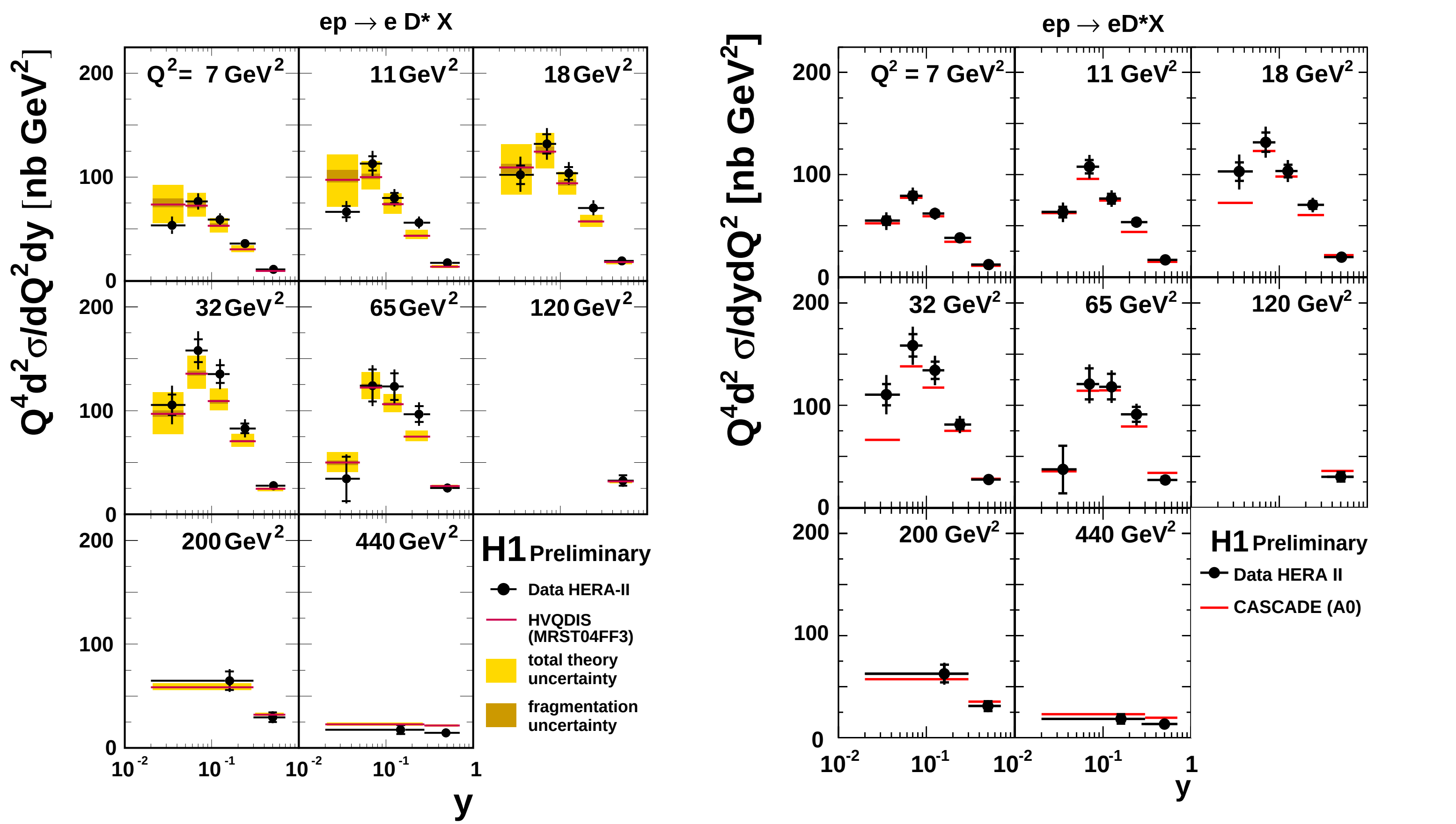
- Data in combination:
  - H1 D* HERA-II F^c_2 (talk by K. Daum)
  - H1 displaced track HERA-II σ_{red} ,

    F^c_2 obtained from reduced cross section using NLO FFNs

- Measurements at different x and Q^2:
  - point swimming to the common grid using FFNS NLO DGLAP, PDF MRST04FF, m_c=1.43 GeV

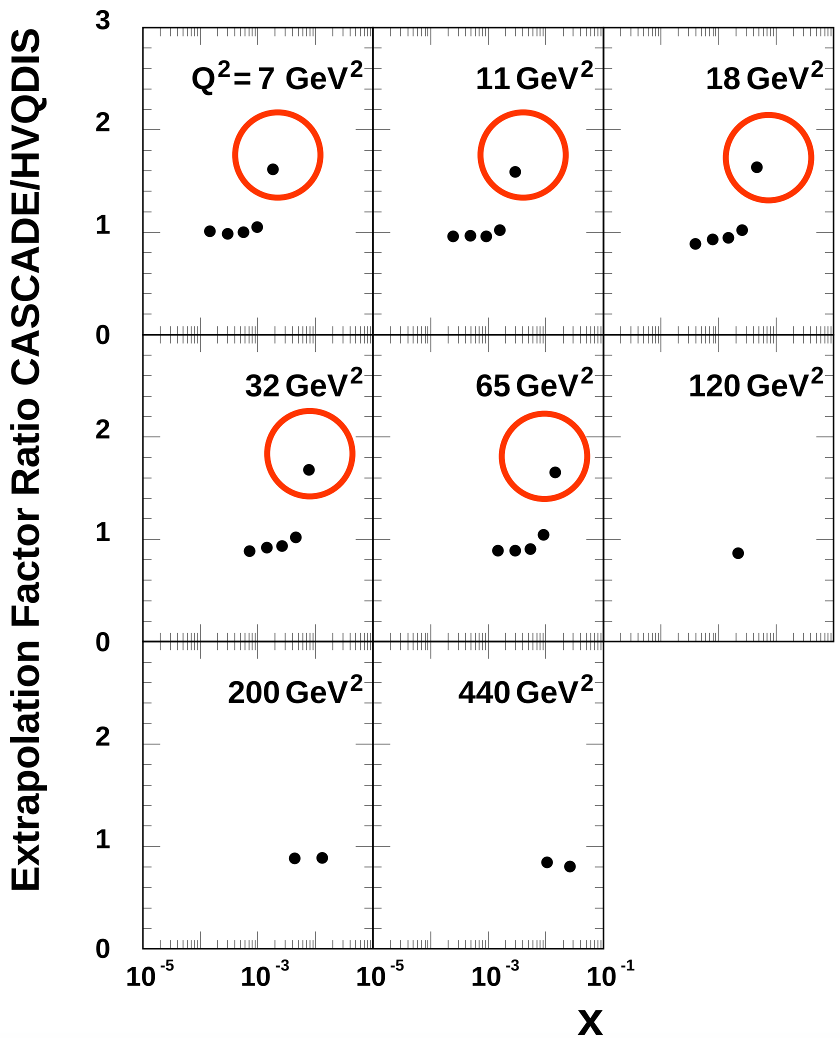
- Correlation of experimental uncertainties taken into account
  - 20 sources of point-to-point systematic correlations
  - 3 correlated sources between the methods

Note on extrapolation in D* measurement



Lowest y (highest x) overestimated by NLO, underestimated by CASCADE

Note on extrapolation in D* measurement



Extrapolation factors ($\sigma_{tot}/\sigma_{vis}$)

differ in NLO vs CASCADE:

3%-6% (low x) -100% (high x)

Differences in the models:

- LO+PS vs NLO
- Evolution
- Hadronization

More studies have to be done

Highest x points not included in the combination procedure

Difference accounted for as an additional model uncertainty

Averaging Procedure: definition

$$\chi^2(M^{i,true},\Delta\alpha_j)=\sum\frac{\left[M^{i,true}-\left(M^i+\sum_j\frac{\partial M^i}{\partial\alpha_j}\frac{M^{i,true}}{M_i}\Delta\alpha_j\right)\right]^2}{\left(\sigma_i\frac{M^{i,true}}{M_i}\right)^2}+\sum_j\frac{\left(\Delta\alpha_j\right)^2}{\sigma^2_{\alpha_j}}$$

M^i measured central values

σ_i statistical + uncorrelated systematic error

$\sigma_{\alpha j}$ – correlated systematic error

$dM^i/d\alpha_j$ – sensitivity of data *i* to systematic uncertainty *j*

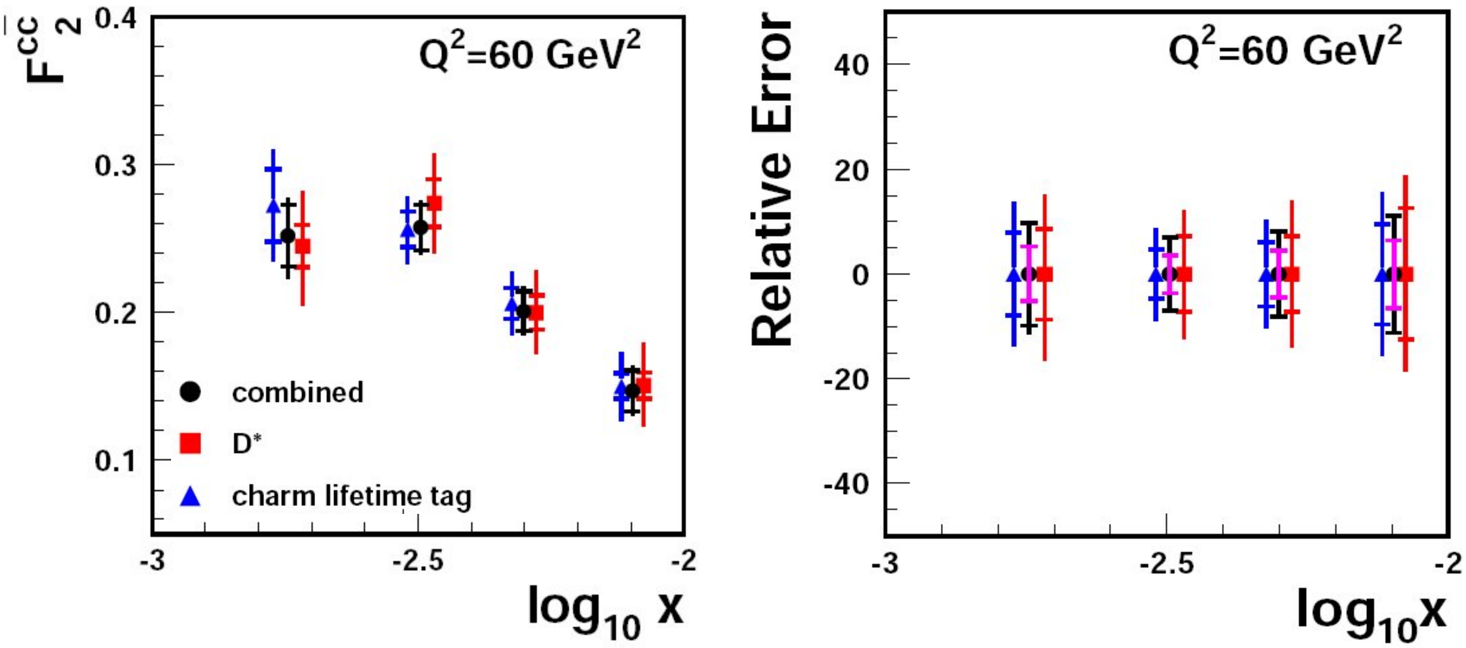
$M^{i,true}$ - fitted combined data D* + LTT

$\Delta\alpha_j$ – fitted shifts of correlated uncertainties

More details yesterday by V. Radescu

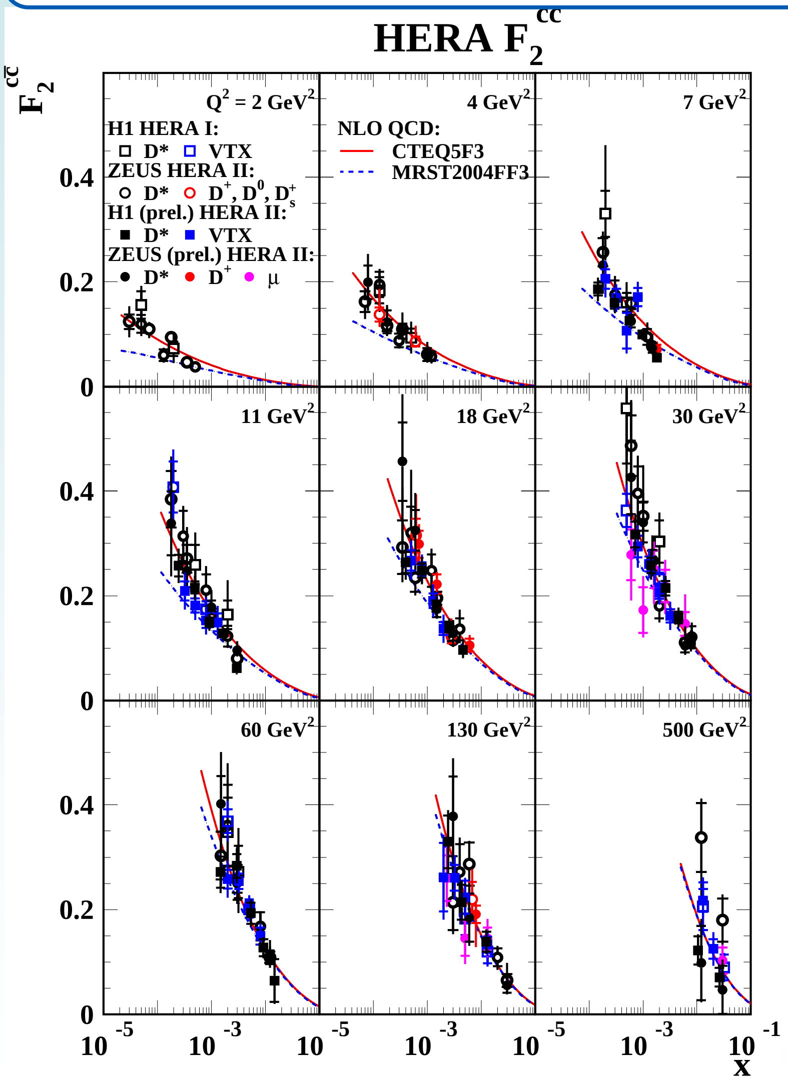
Results: improvement in precision

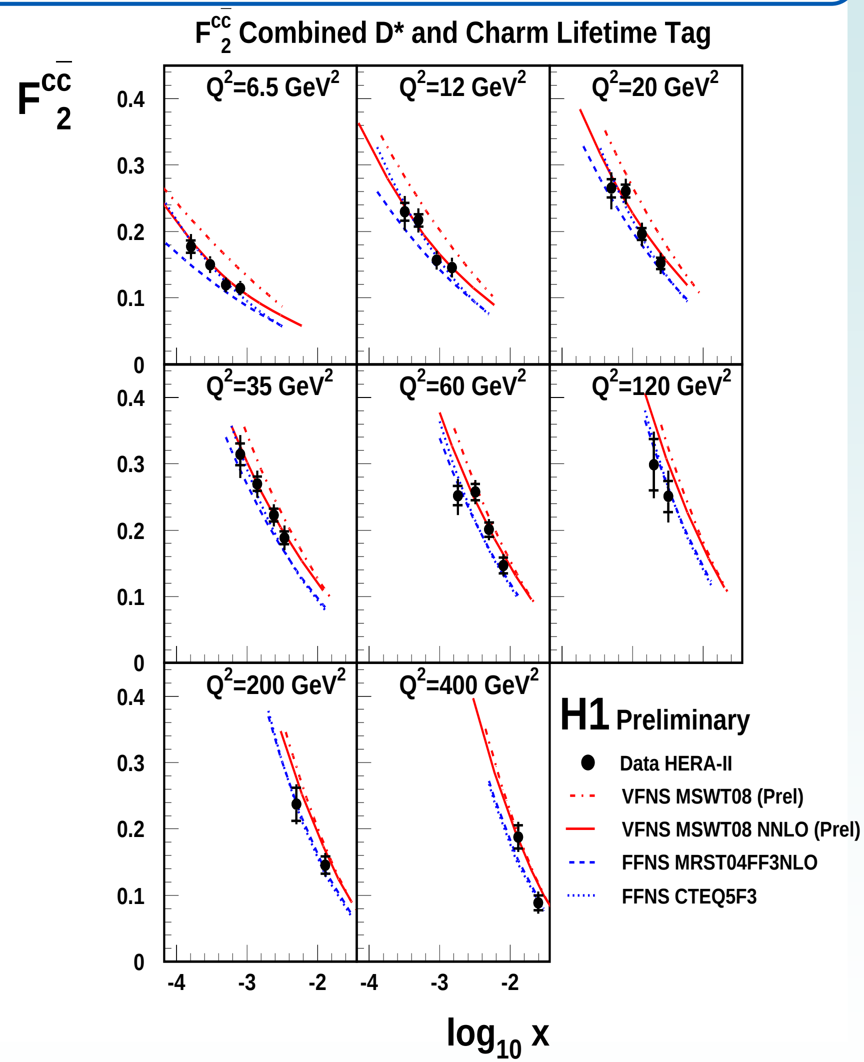
H1 Preliminary F^c_2 combined D* and Charm Lifetime Tag



- Most gain (50%) where D* and vertex measurements similar precise
- Overall improvement in precision (10-50%)
- Results stable wrt. variation of systematics treatment, χ^2 = 26/25

Results: test different QCD models





High precision measurement - distinction power wrt. different QCD models

Conclusion/Outlook

- extraction of F^c_2 allows to compare different measurement techniques
- extra precision can be gained from combination
- data are described by (N)NLO pQCD calculations
- precision of D* measurement will further improve
- more improvement possible by H1 + ZEUS combination
- final data will help to constrain theory mass treatments and PDFs

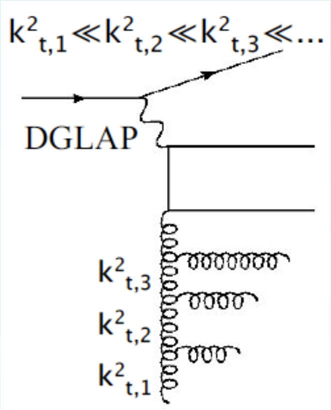
BACK UP

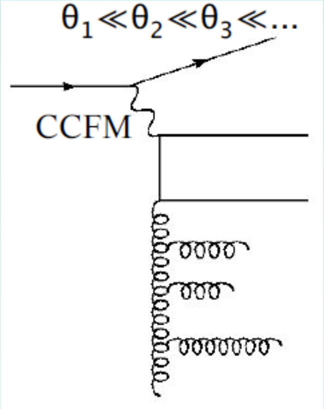
Models of heavy quark production at HERA

Event Generators: LO ME + Parton Showers

proton structure (parton densities):

- RAPGAP, PYTHIA: DGLAP evolution
- CASCADE: CCFM evolution





pQCD calculations: due to multi-scale problem (m_{HQ}, p_T, Q^2) several approaches:

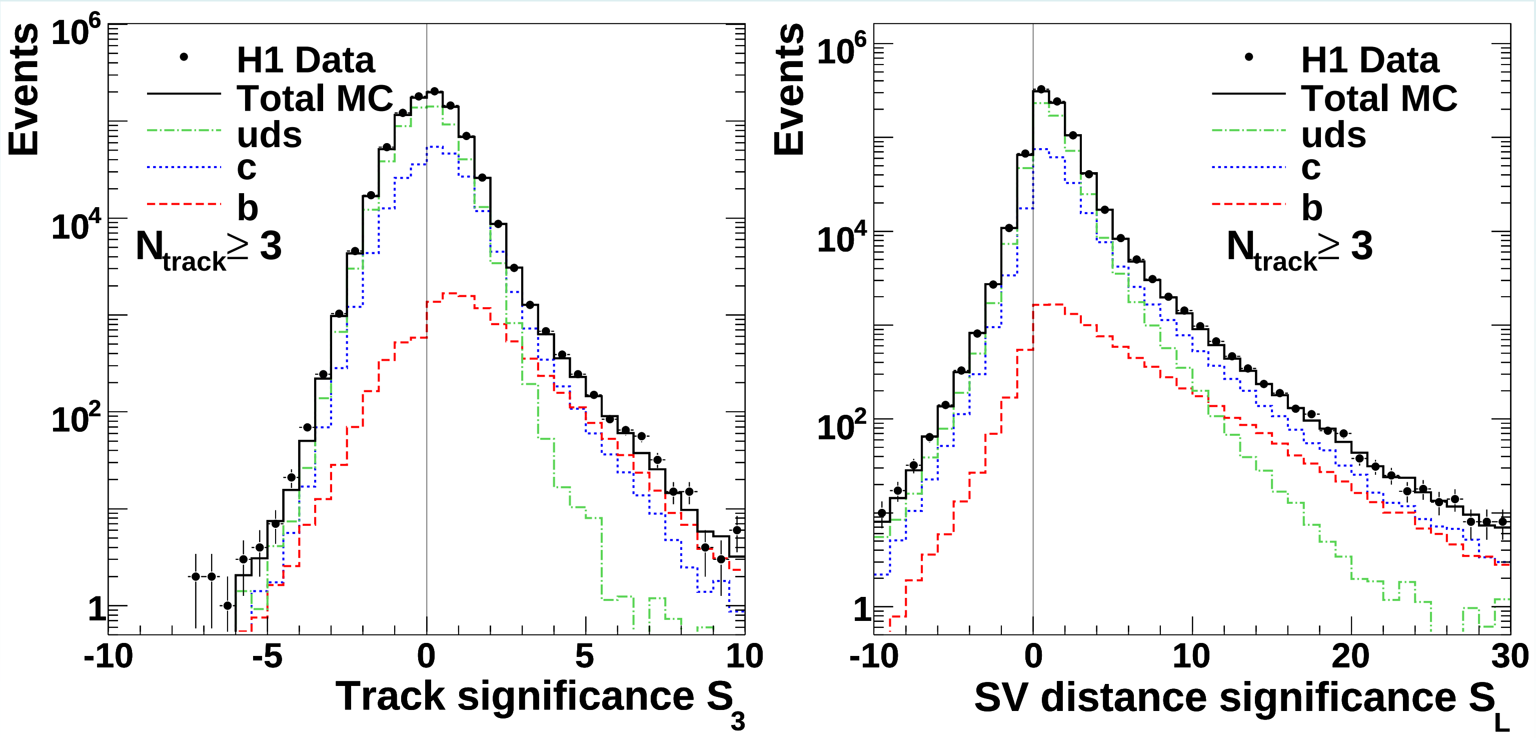
- massless (ZM-VFNS) HQ exist in the proton, reliable for $Q^2 >> m^2_{HQ}$
- massive (FFNS) HQ dynamically produced in BGF, reliable for $Q^2 \sim m^2_{HQ}$
  - NLO program for DIS (Q^2>2 GeV) HVQDIS
  - NLO program for photoproduction ($Q^2 \sim 0$): FMNR
- GM-VFNS: combination of massless and massive schemes:
  - NLO program for HQ in photoproduction
  - Used in the latest PDF fits by HERA, CTEQ, MSTW

Measurement strategy

Inclusive measurement: use all tracks with hits in CST, $p_T > 0.3\ GeV$

Improve *c,b* separation: use neural network (NN) for $N_{tracks} \geq 3$

NN Inputs: S_1, S_2, S_3, S_L, 1st (2nd) highest track p_T, N_{tracks} , N^{SV}_{tracks}

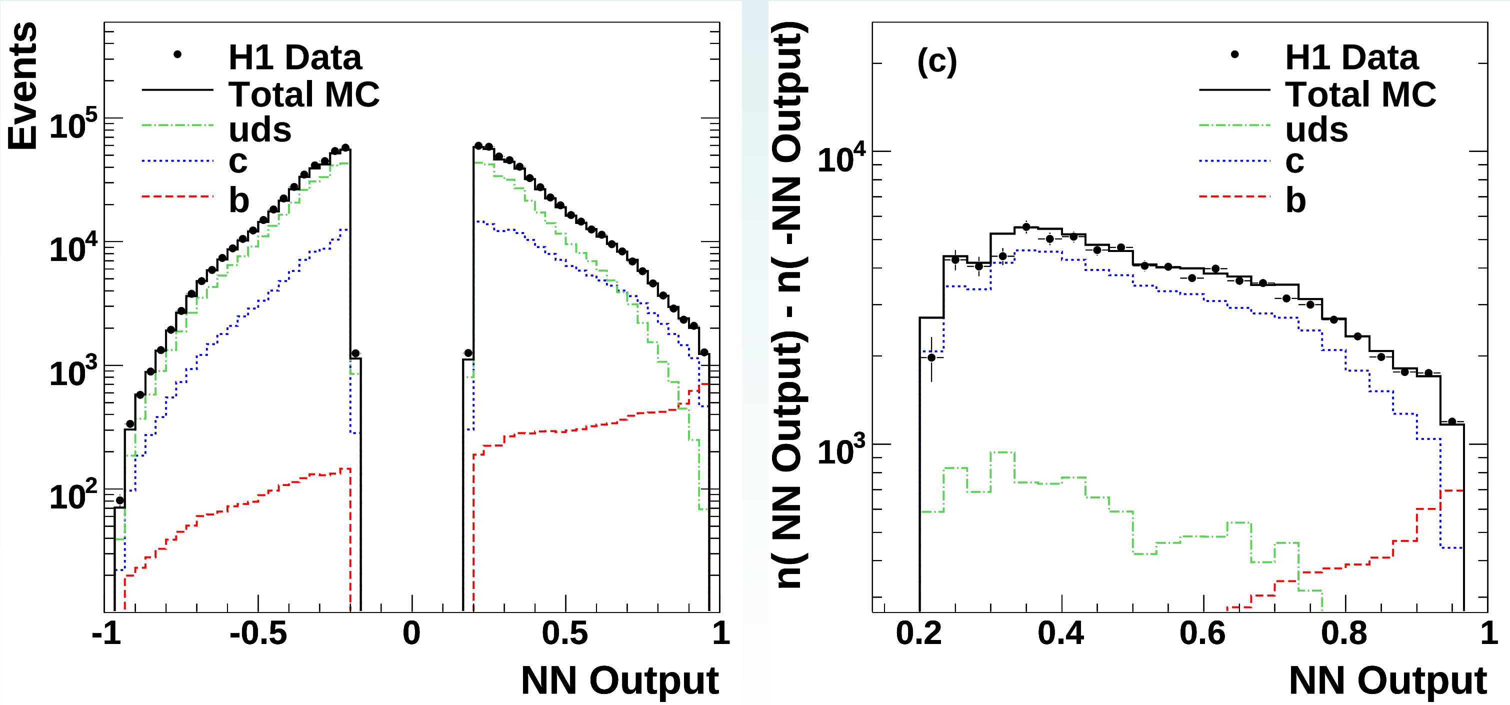


Flavor separation

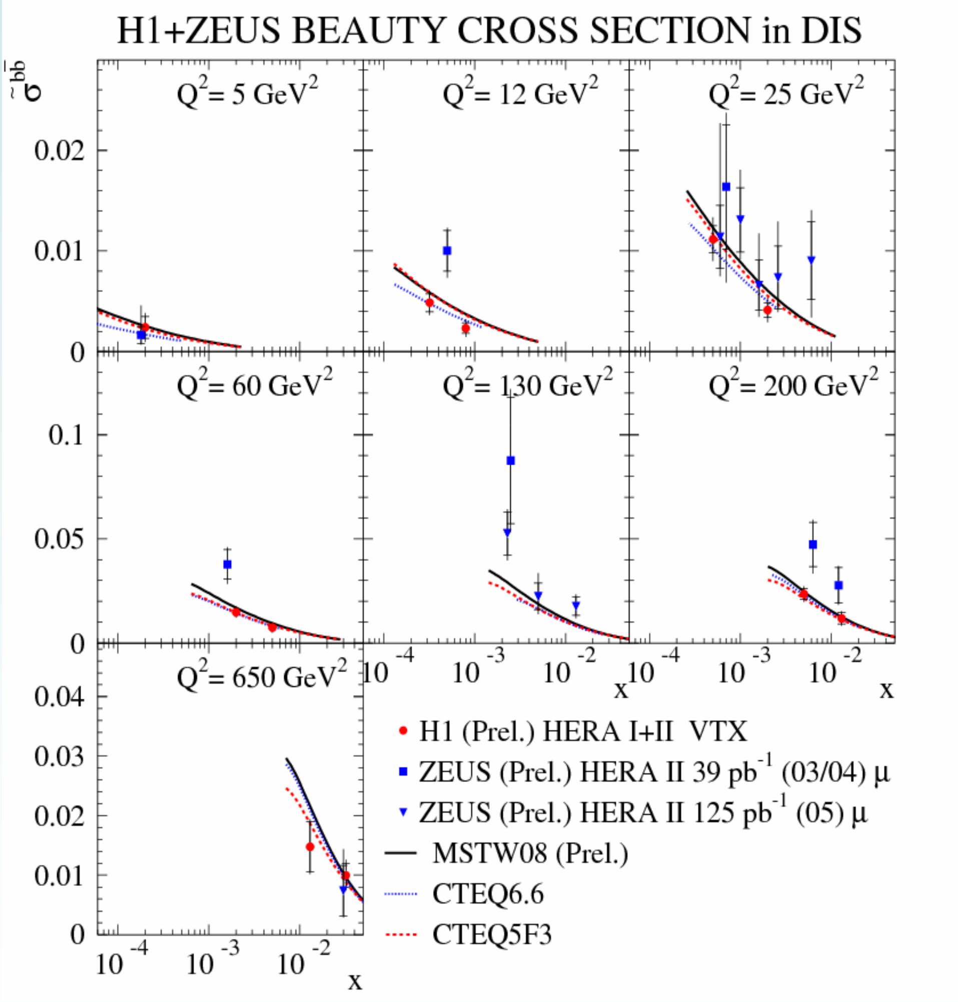
NN output: clear separation of charm and beauty

Sign given by S_1. Subtract –'ve from +'ve to reduce systematic error

Fit subtracted S_1, S_2 and NN output to obtain c-, b- fractions



HERA beauty cross section



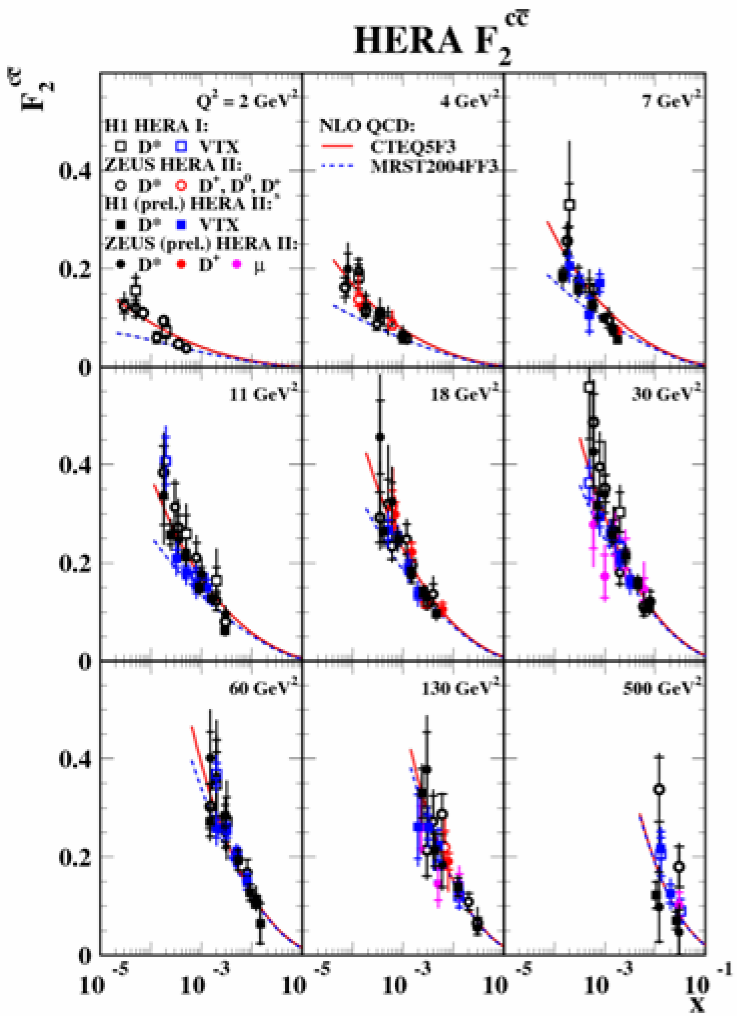
different methods [acceptance]

- Inclusive (H1VTX) [>90%]
- μ p_t^{rel} (ZEUS) [20-35%]
- μ p_t^{rel} + δ (ZEUS) [25-50%]

ZEUS tend to be higher than H1

described by NLO QCD

HERA charm cross section



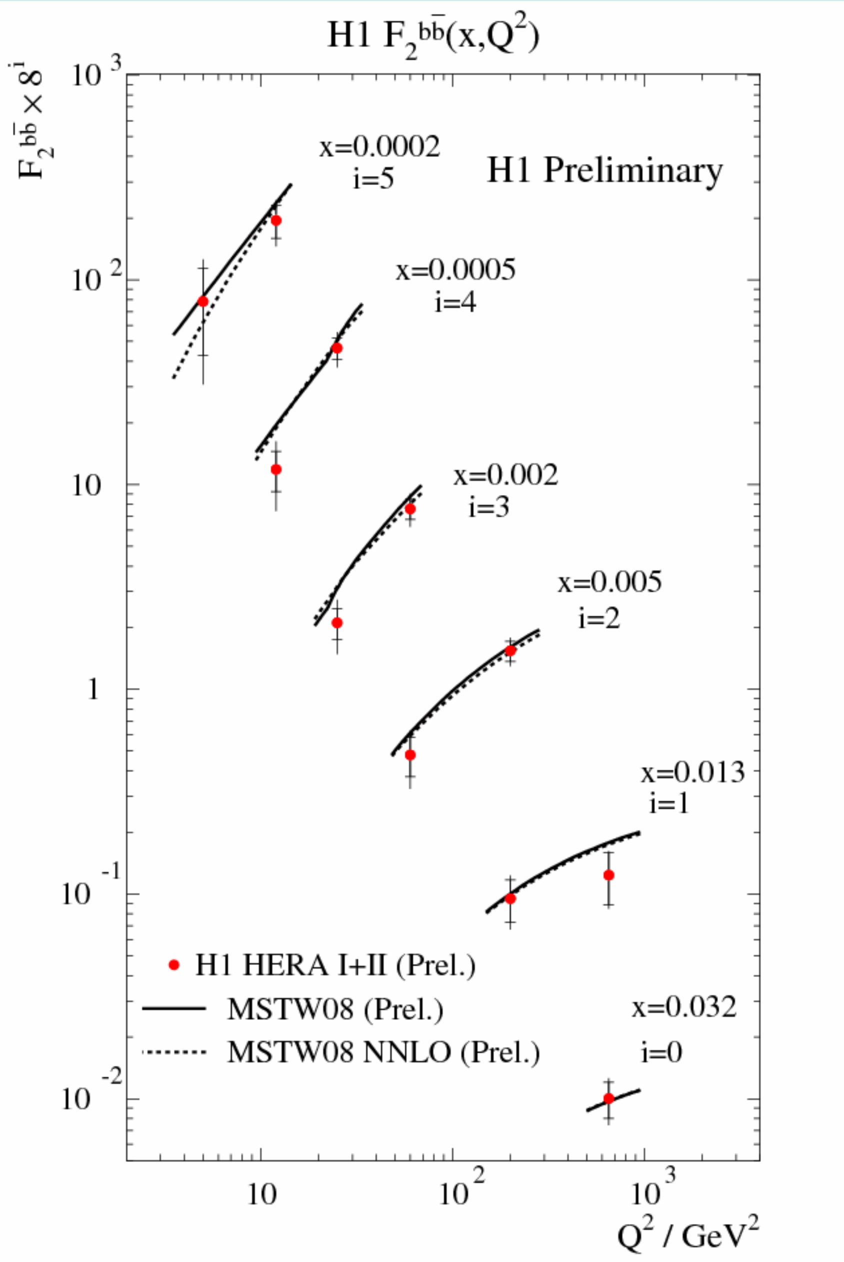
different methods [acceptance]

- inclusive (H1 VTX) [>70%]

– μ p_t^{rel}+δ (ZEUS) [25-50%]

-D* cross sections [20-70%]

different methods agree well



Scaling violations visible

NNLO predictions available

Differences between NLO and NNLO small except for $Q^2<(m_b)^2$

Data well described