Measurement of $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ at Low Q^2 and x using the H1 Vertex Detector at HERA

hep-ex/0507081

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DIS 06

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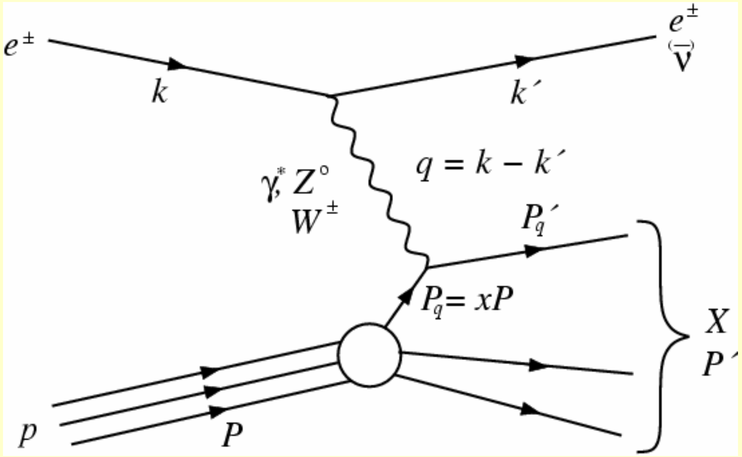
Structure Functions, Heavy Quarks and QCD



DIS cross section and Structure Functions:

$$\frac{d^2\sigma_{NC}^{e^{\pm}p}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}(1+(1-y)^2)\left[F_2 - \frac{y^2}{1+(1-y)^2}F_L\right]$$

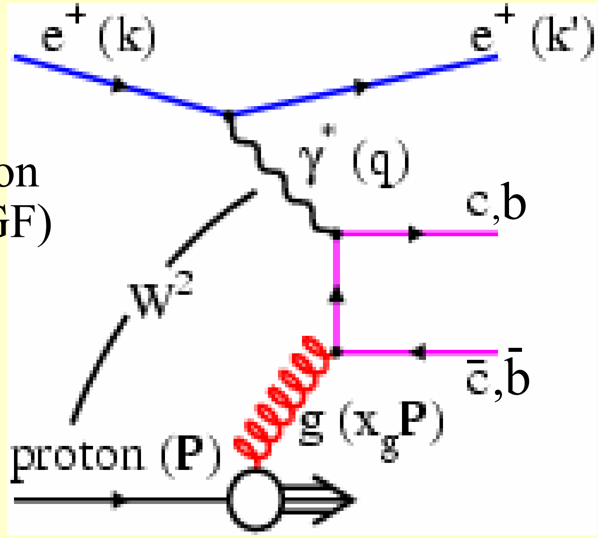
$Q^2 = -q^2$	*virtuality of* $\gamma^*, Z^o, W^{\pm}$
$x = Q^2/2(pq)$	*Bjorken scaling variable*
$y = (Pq)/(pk)$	*inelasticity*

Define heavy quark reduced cross-sections as:

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

NLO QCD Treatment

Boson Gluon Fusion (BGF)



Treatment of HQ in QCD

m_c^2 ; 2.5 GeV^2, m_b^2 ; 25 GeV^2

$Q^2 >> M^2_{HQ}$ massless scheme

$Q^2 \sim M^2_{HQ}$ massive approach (FFNS)

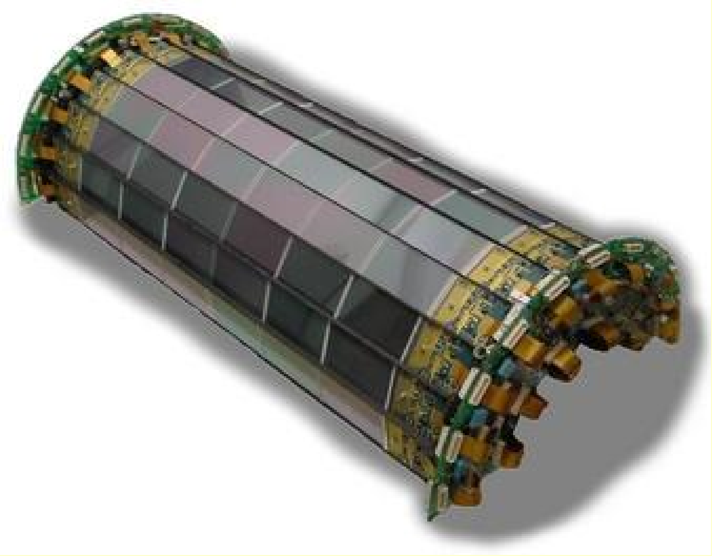
Interpolation over full Q^2 range: VFNS, e.g. ACOT(CTEQ), MRST

Heavy flavour production is driven by the gluon density

Experimental checks of HQ calculations in pQCD

Thus far the measurements have been limited by statistics, e.g. D* mesons; try to be more inclusive…

Precision tracking and heavy flavours



Central **S**ilicon **T**racker of H1 covers

$30^o < \theta < 150^o$

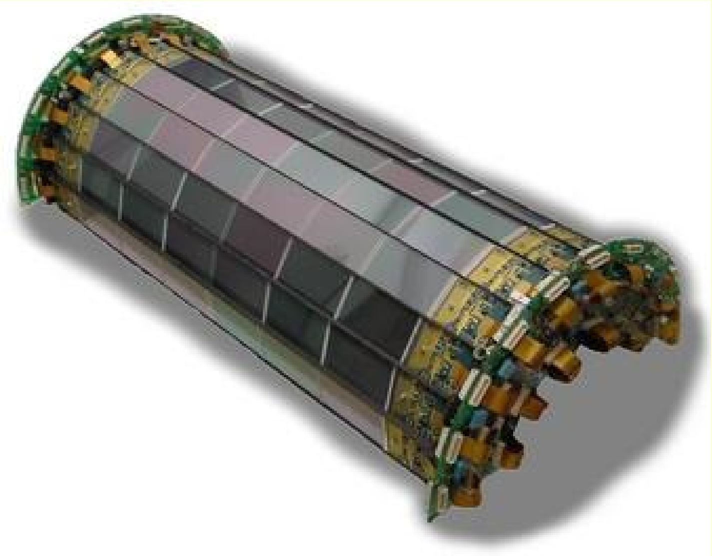
and provides precision tracking information ***5.7*** cm from the vertex:

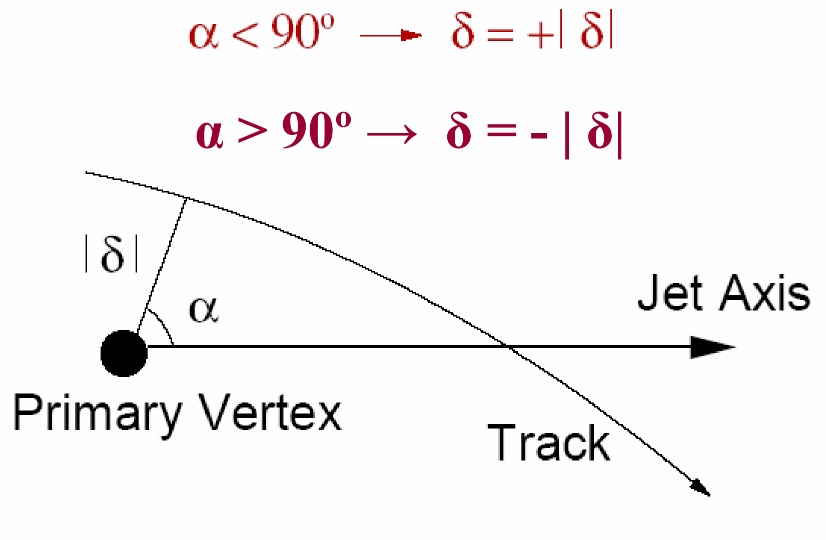
rφ hit resolution of 12 μm (25 μm in ***z***)

Measure the **impact parameter** in **r-φ plane** for
- **all** tracks with pt > 500 MeV and 2 hits in CST

Look for asymmetries arising from the flavour composition of the event via lifetime signature

Precision tracking and heavy flavours

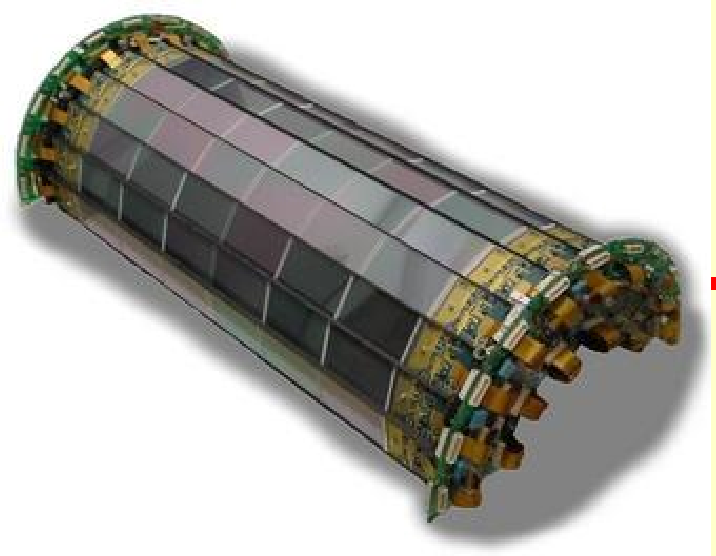


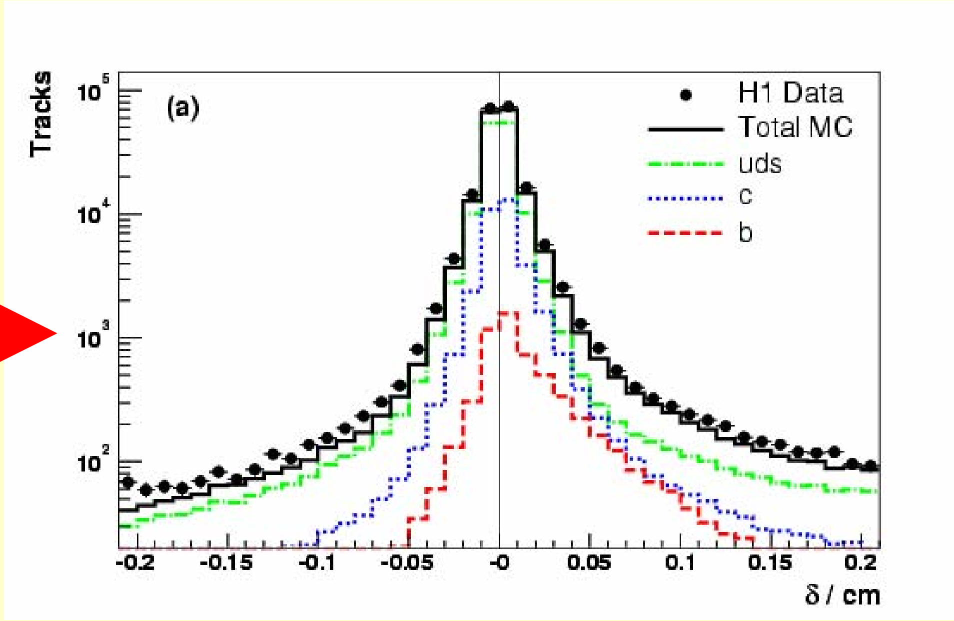


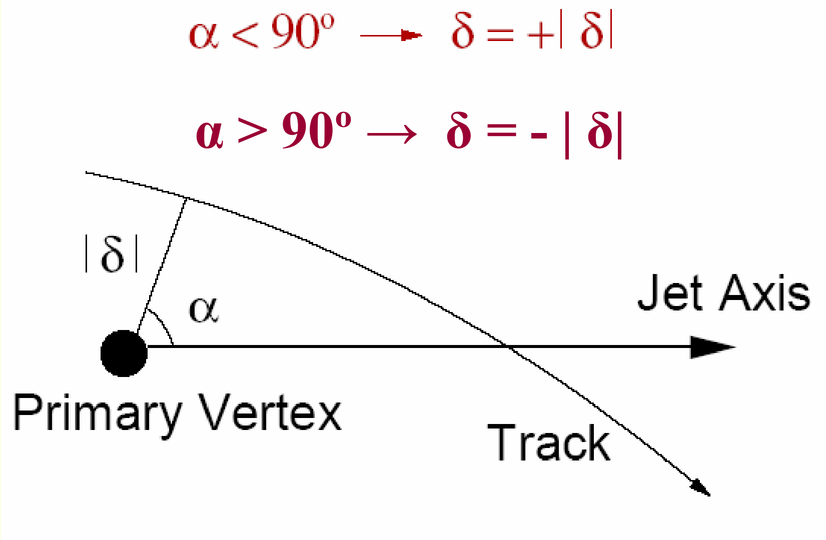
Signed impact parameter δ shows sensitivity to the flavour of the event

Sign of δ given by the angle α

Precision tracking and heavy flavours







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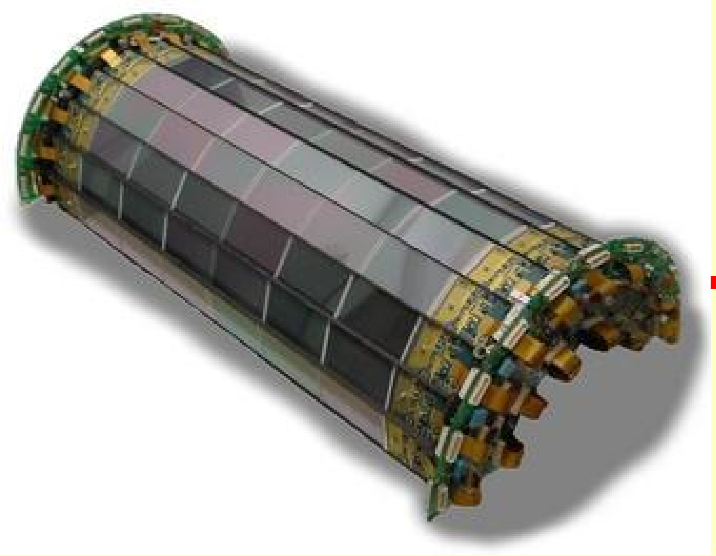
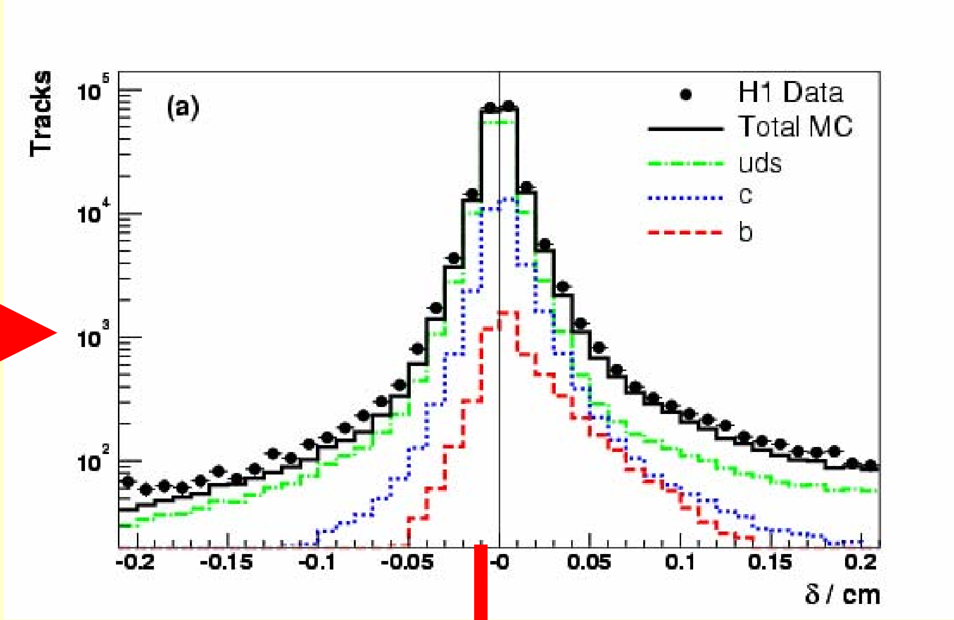
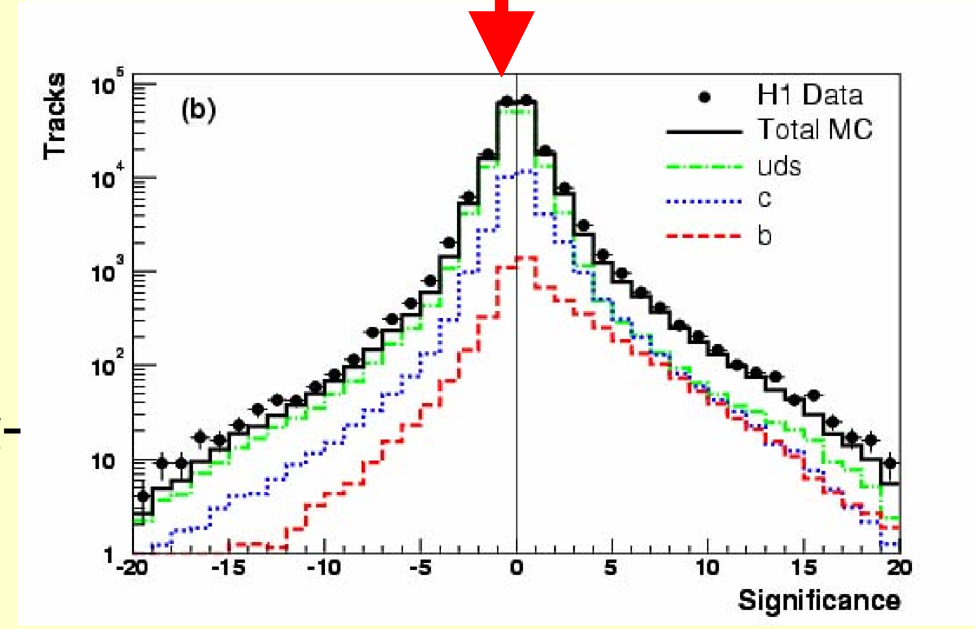




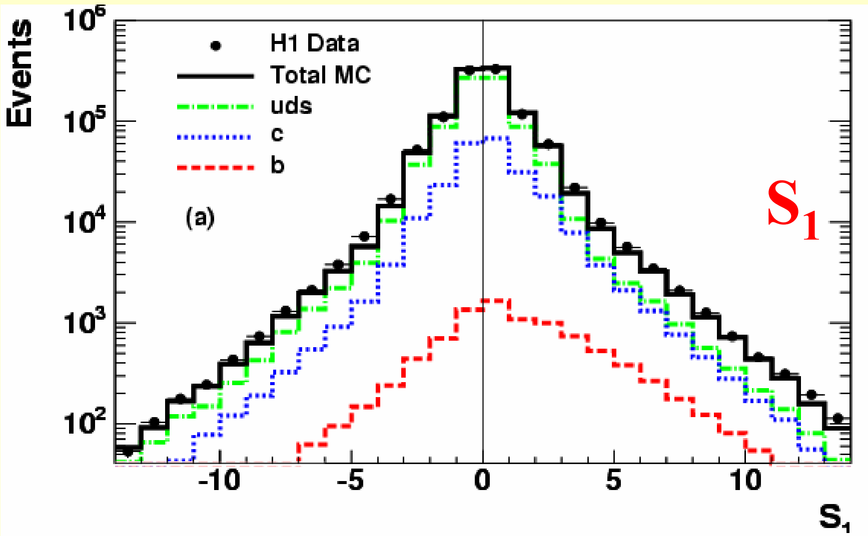
Significance of a track

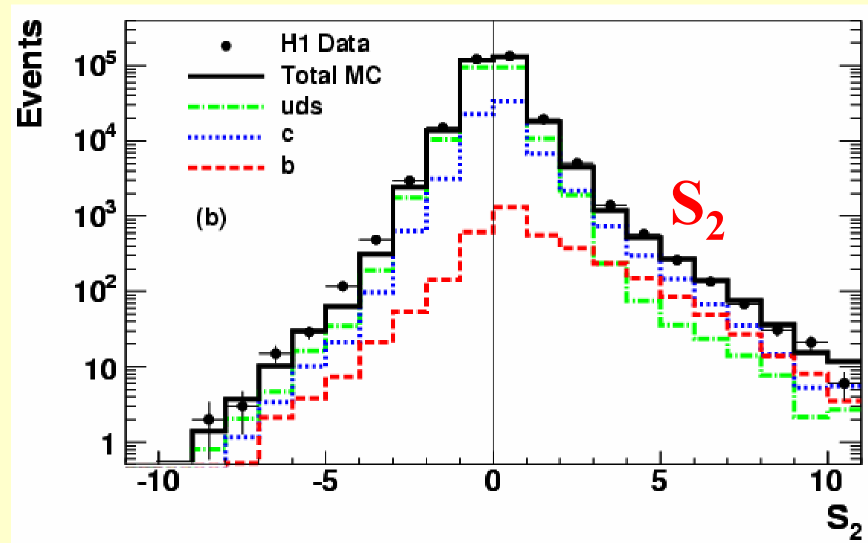
$$S = \frac{\delta}{\sigma(\delta)}$$

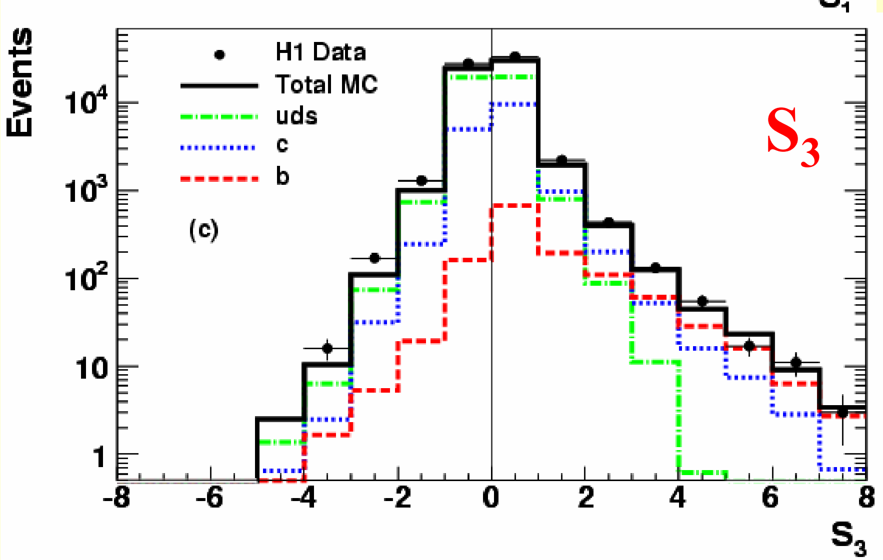


remove $|\boldsymbol{\delta}|$>1mm (to suppress long-lived strange particles, e.g. K_s^0)

Significance distributions







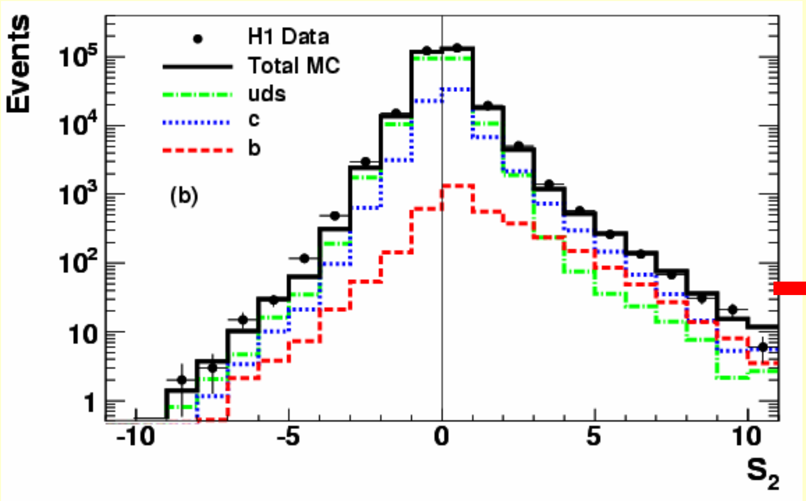
S1 – highest absolute significance track

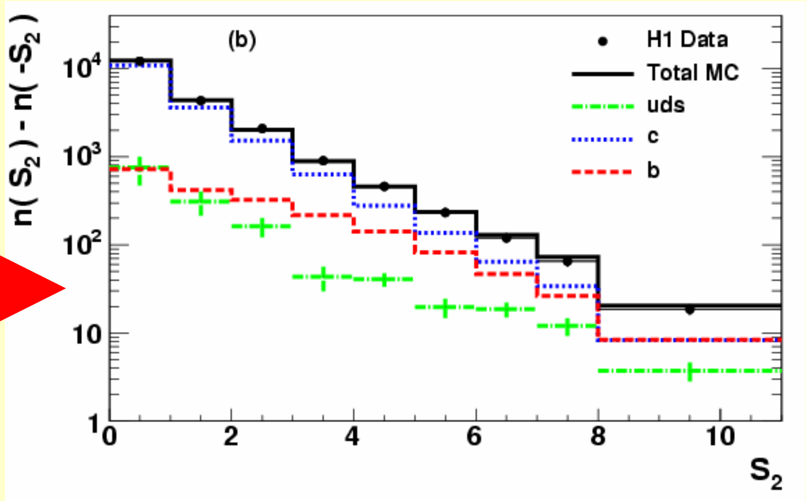
S2 – 2nd highest absolute significance track with the same sign as S1

S3 – 3rd highest absolute significance track with the same sign as S1 and S2

S2 is sensitive to charm, S3 is sensitive to beauty

Negative component subtraction

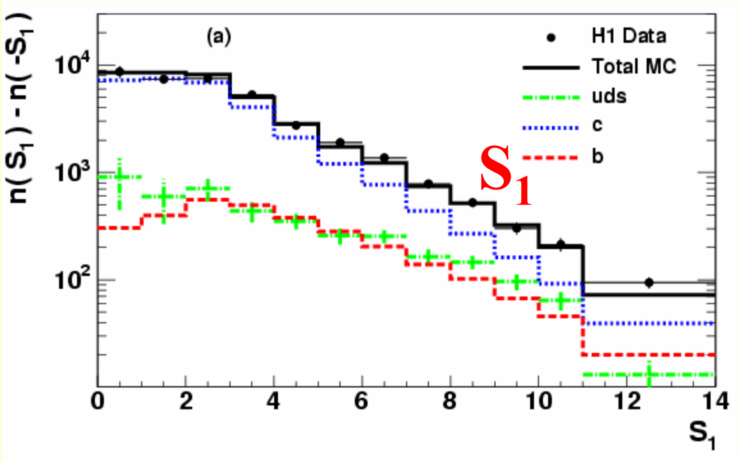


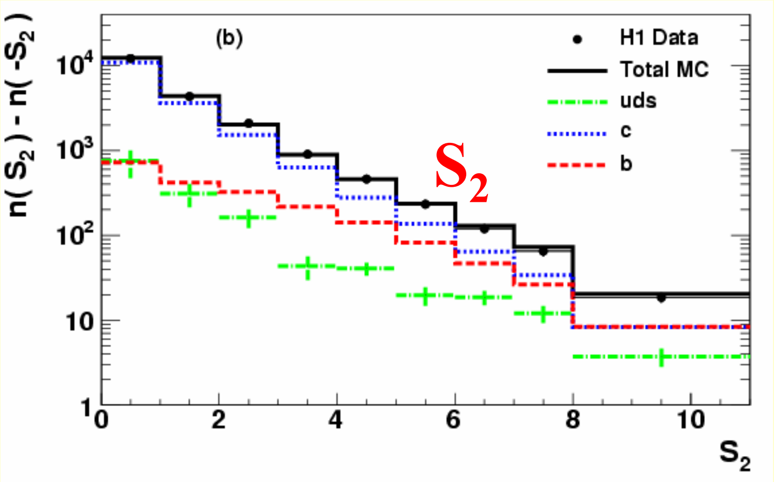


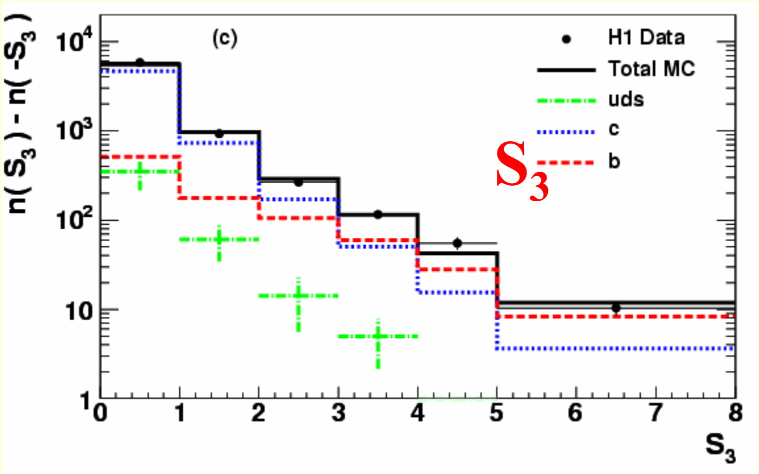
subtract the contents of negative bins from the contents of the corresponding positive bins

→ substantially reduce uncertainty due to resolution of δ and light quark normalisation

Subtracted significance distributions







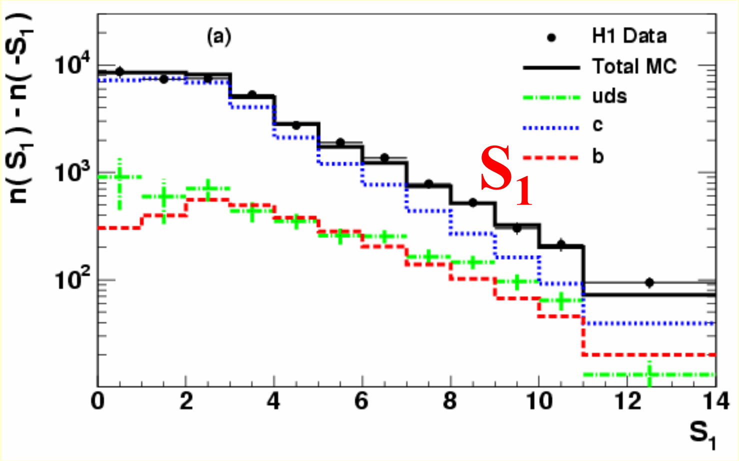
→ dominated by c

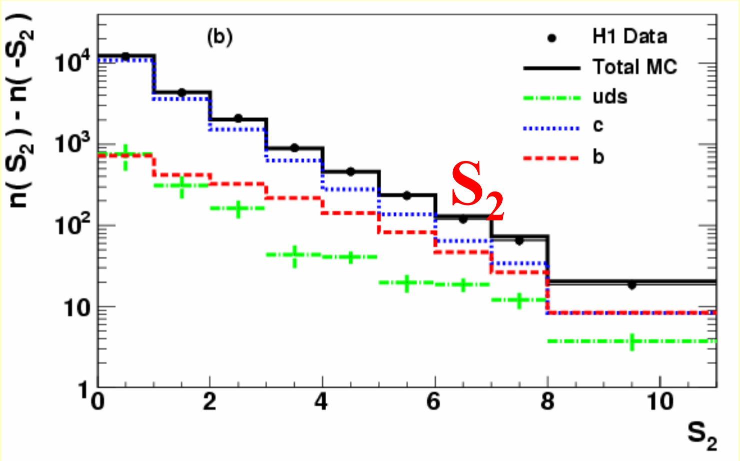
→ increasing b fraction at high S_i

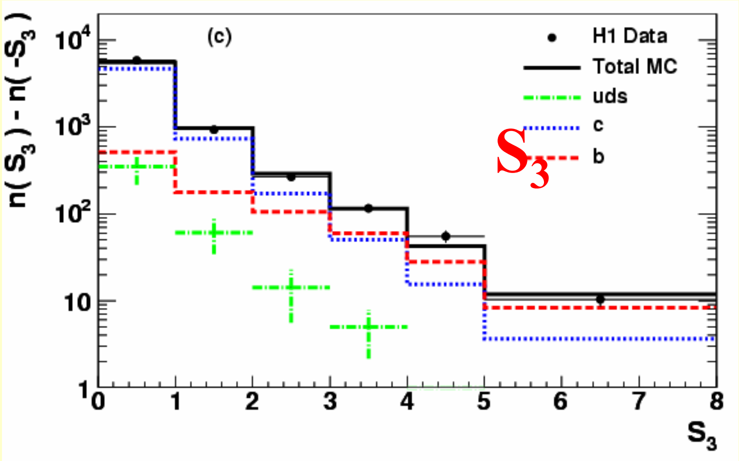
Simultaneous fit to subtracted S_1,S_2,S_3 distributions and total number of inclusive events before track selection using c, b and uds shapes from MC

→ individual fit for each x-Q^2 interval

Subtracted significance distributions







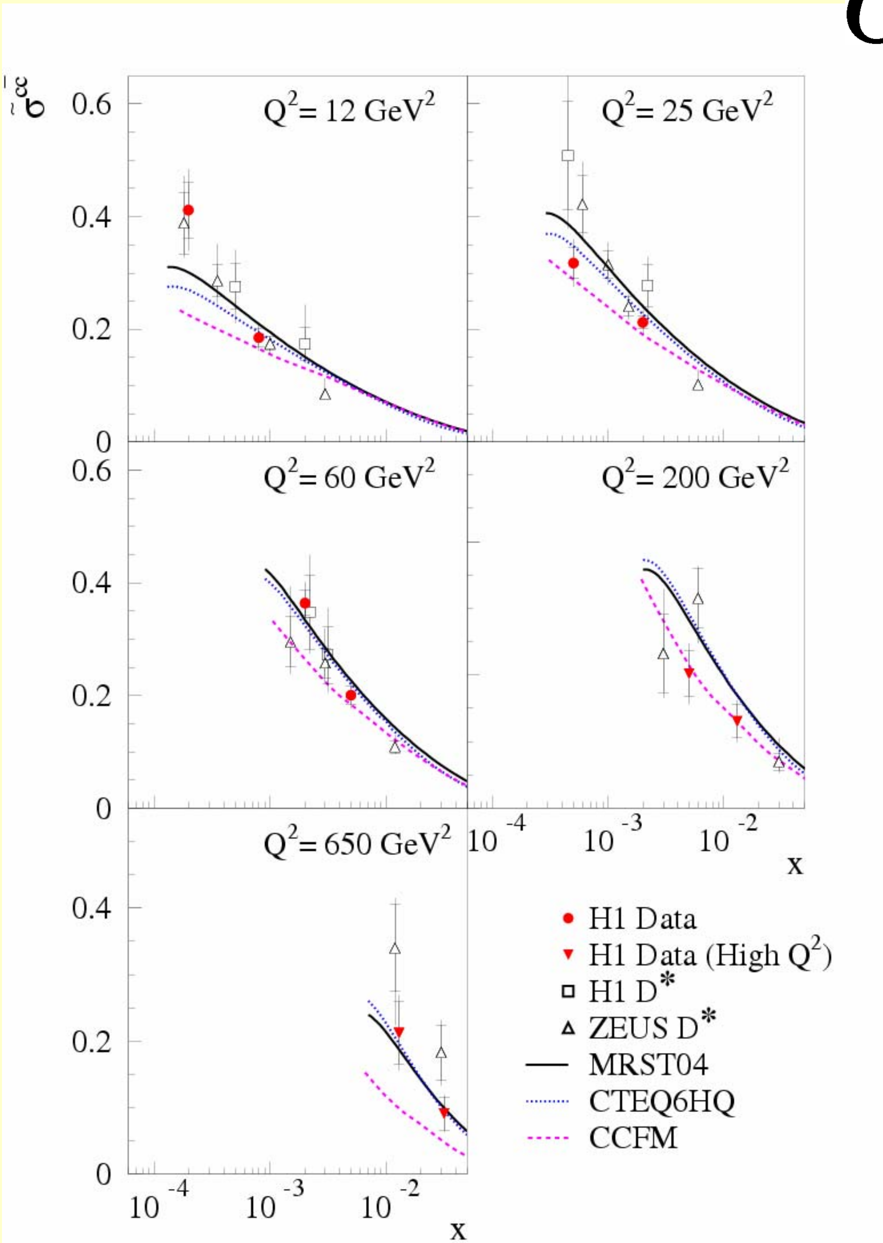
3 parameters:

- P_c scale factor for charm MC (b decays are excluded)
- P_b scale factor for beauty MC
- P_l scale factor for light quark MC

$$P_c = 1.28 \pm 0.04, P_b = 1.55 \pm 0.16, P_l = 0.95 \pm 0.01$$

→ individual fit for each x-Q^2 interval

$\tilde{\sigma}^{c\bar{c}}$



In this and the following plots, higher Q^2 H1 data is also shown

Results are consistent with H1 and Zeus D* measurements

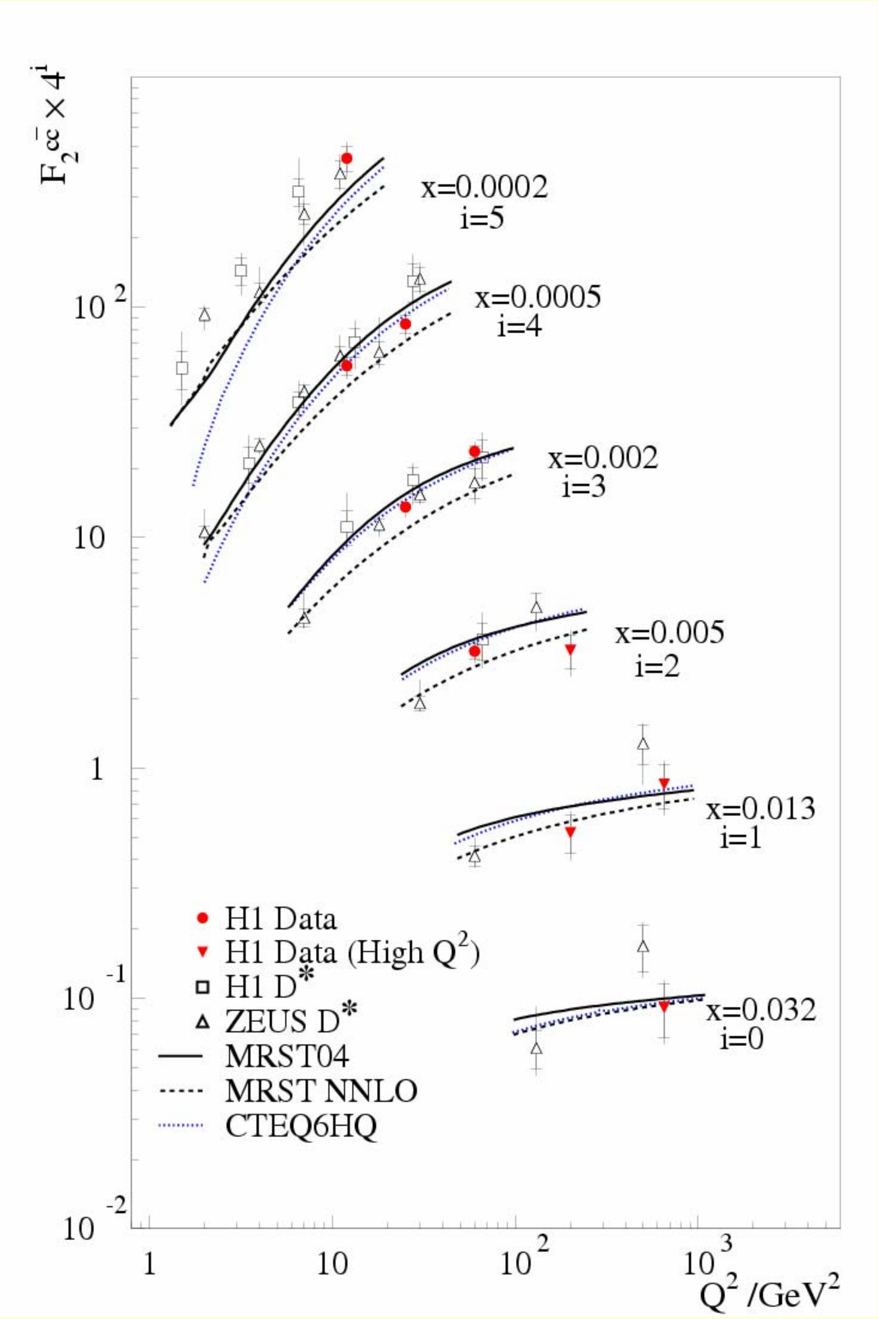
Results also consistent with all QCD predictions:

MRST04 = NLO QCD VFNS

CTEQ6HQ = NLO QCD VFNS

CCFM = CASCADE Monte Carlo

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



Extract structure function from the reduced cross-section:

→ Small (3% at high y) corrections from F_L

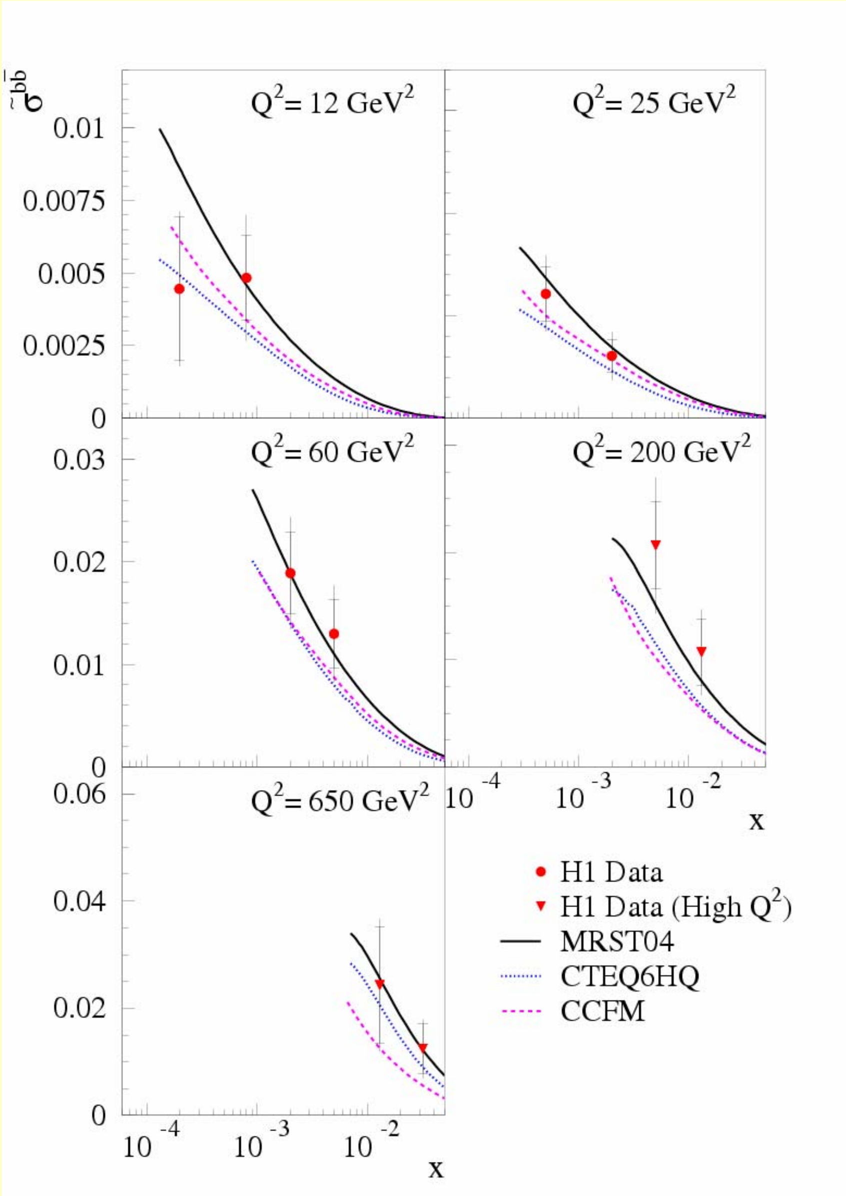
→ Bin centre corrections (2-3%) determined using NLO fit

Strong scaling violations:
→ heavy flavours are driven by the gluon!

Large difference between NNLO and NLO predictions

MRST and CTEQ similarly good description, except for lowest Q^2 and x (CTEQ prediction is low)

$\tilde{\sigma}^{b\bar{b}}$



First measurement of b cross-section

Significant differences in NLO QCD predictions but

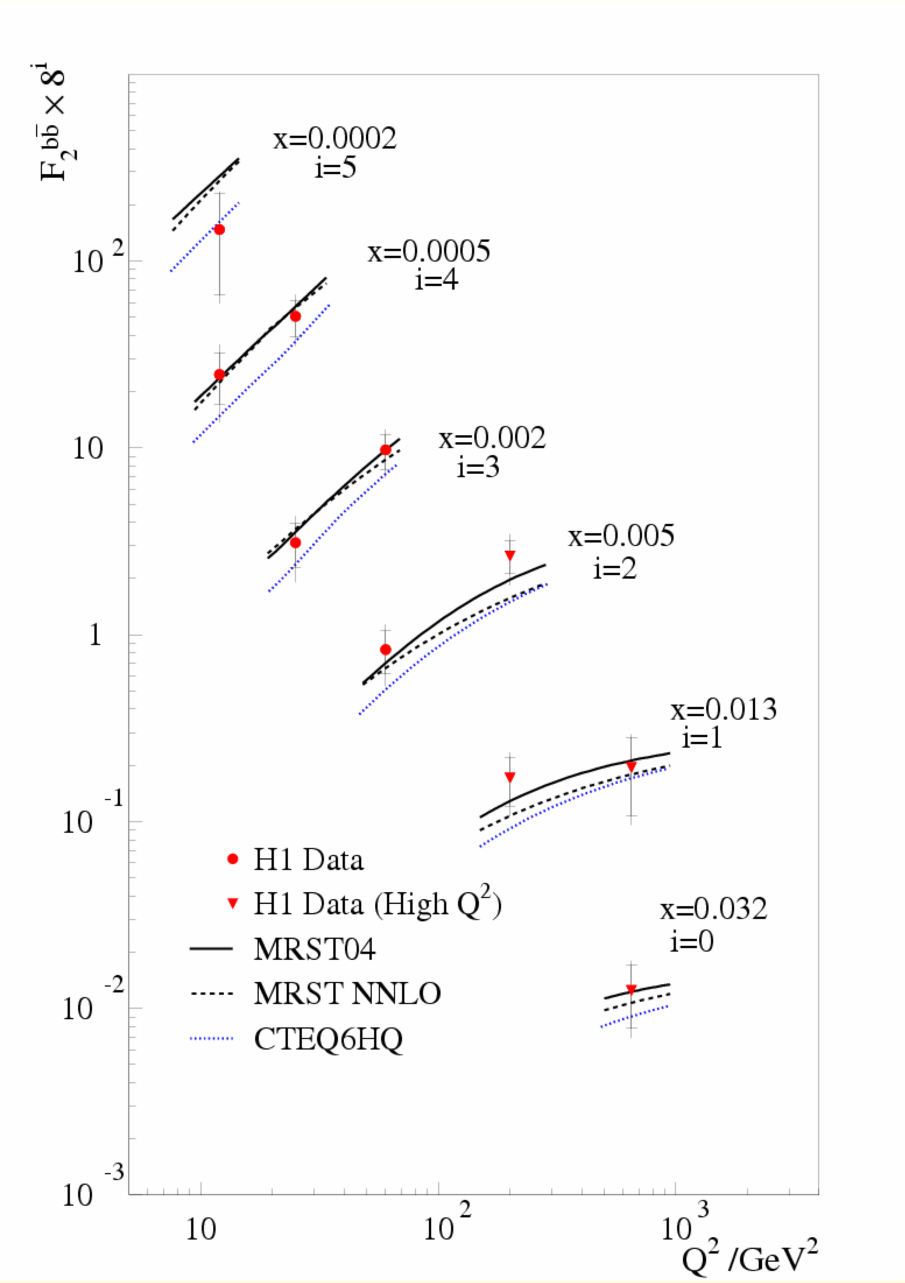
Statistical precision of the data worse due to large beauty mass, threshold effect

→ data consistent with all predictions

MRST04 = NLO QCD VFNS

CTEQ6HQ = NLO QCD VFNS

CCFM = CASCADE Monte Carlo



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

Extract structure function from the reduced cross-section:

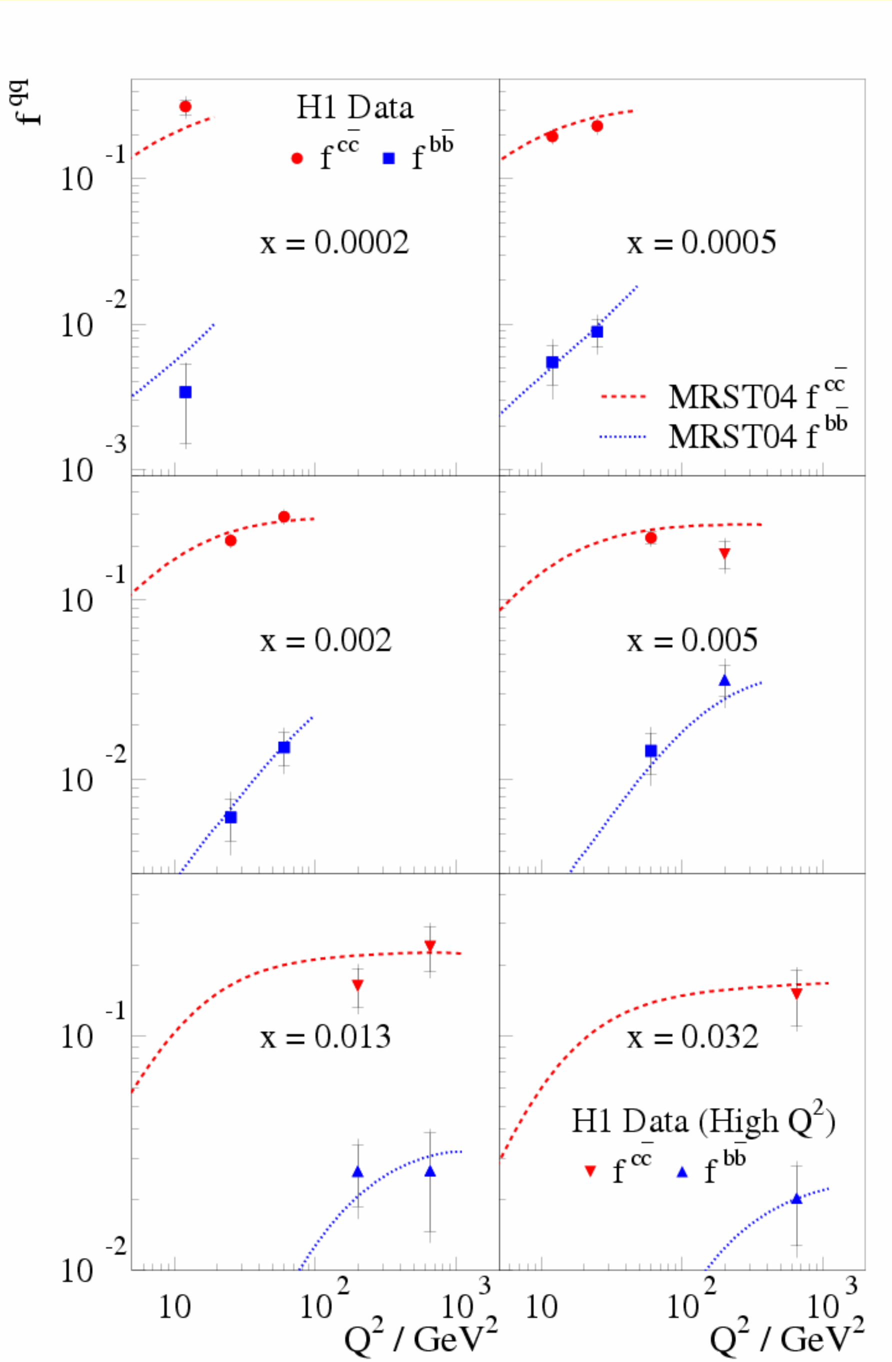
→ Small (5% at high y) corrections from F_L

→ Bin centre corrections (2-3%) determined using NLO fit

NNLO not as different to NLO as was the case for charm (beauty samples higher x)

CTEQ ~factor of 2 lower than MRST

Data are consistent with both MRST and CTEQ predictions



Fractional contributions of charm and beauty to proton structure

Charm contributes 15-30%

Beauty contributes 0.3-3.5%

Good description by NLO QCD (MRST04)

Summary

Charm and beauty structure functions F_2^{cc} and F_2^{bb} have been measured in the Q^2 range from 12 to 60 GeV^2 using lifetime tagging

Charm:

- Charm contribution to F_2 is around 24%, so we'd better understand it!
- Data are consistent with H1 and Zeus D* results

Beauty:

- Beauty contribution to F_2 ranges from 0.3 to 3.5%
- F_2^{bb} measured for the first time; data consistent with predictions

Overall:

- Both F_2^{cc} and F_2^{bb} are reasonably well described by NLO QCD
- Large potential for Hera II to improve on the precision of these measurements thanks to the increased luminosity and the newly installed forward and backward silicon tracking detectors