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

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H1 Collaboration, DESY

Content:

- Theory and Motivation
- DCA (Impact Parameter) Method
- Results for $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$
- Conclusion

DIS Theory

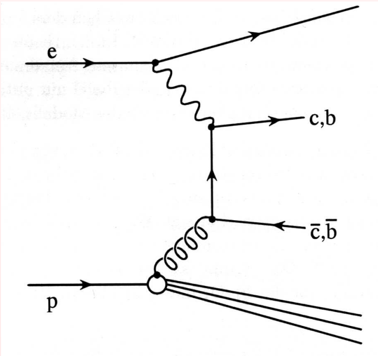
$$Q^2 \sim M^2_{HQ}$$

"Massive scheme"

Fixed Flavour Number Scheme (FFNS)

Main LO Process: Photon Gluon Fusion

$$\gamma g \longrightarrow q\bar{q}$$



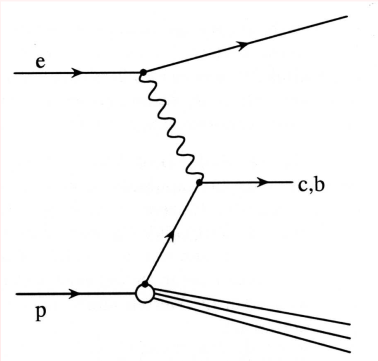
$$Q^2 \gg M^2_{HQ}$$

"Massless scheme"

Zero Mass Variable Flavour Number Scheme (ZM-VFNS)

Main LO Process: Quark Parton Model

$$\gamma q \longrightarrow q$$



Variable FNS: Interpolate between massive and massless avoiding double counting

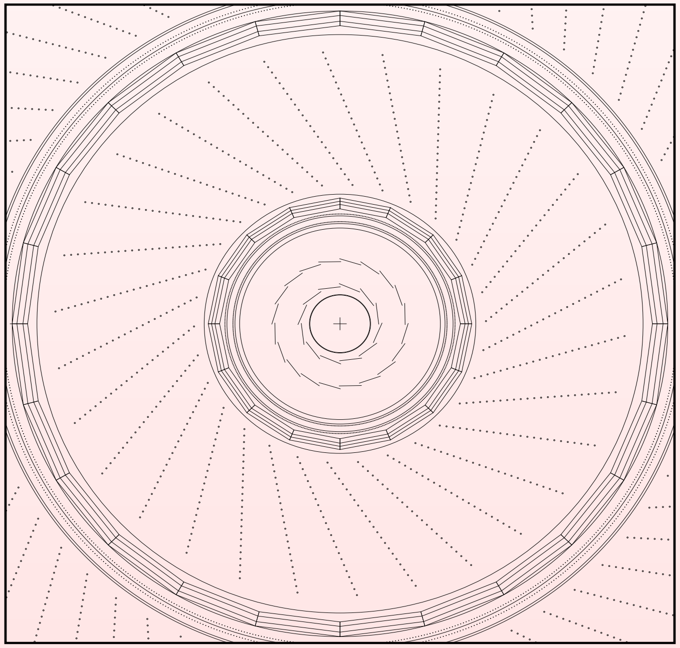
etc. ACOT(CTEQ), MRST

Motivation

- Aim: to make a measurement of charm and beauty in transition region: $3.75 < Q^2 < 60$ GeV^2
- Existing Methods:
  - D^* } exclusive methods
  - μ }
  - explicit reconstruction of secondary vertex

  } Statistically limited!
- Model dependent extrapolations for D^* method
- $\Longrightarrow$ Inclusive method: use CST-improved impact parameter for all tracks
  method comes from high Q^2 measurements: recenty published analysis for $Q^2 > 110$ GeV^2 (hep-ex/0411046 accepted Eur. Phys. J)
- Aim to be as inclusive as possible and keep size of extrapolations in p_T, η to minimum
- Method is based on lifetime information of heavy quarks
- Fraction of b falls at low Q^2 $\Longrightarrow$ experimentally challenging
- We work with e^+p neutral current events, 99/00 HERA-I Data, $\mathcal{L} \simeq 57.4\,\mathrm{pb}^{-1}$

H1 Central Silicon Tracker

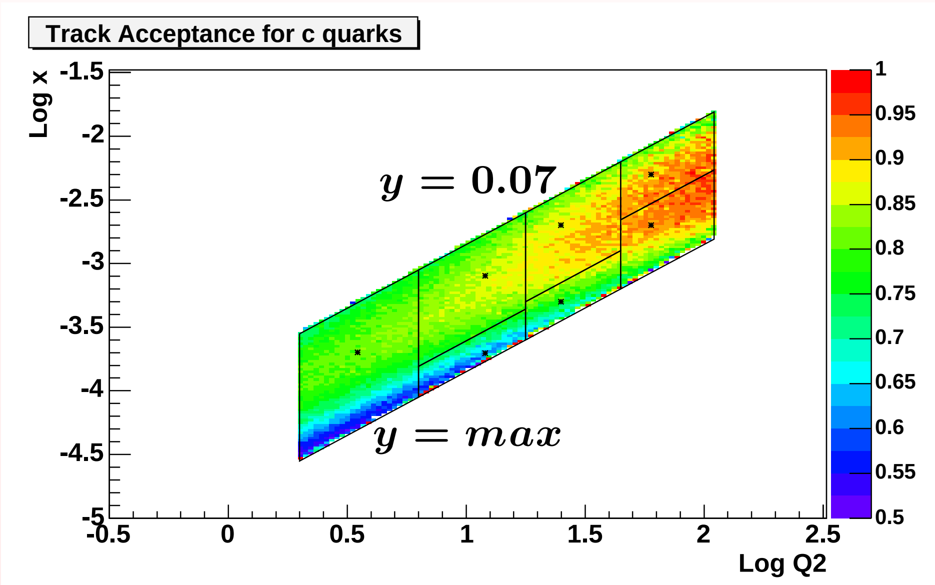


- **Consists of two cylindrical layers of double-sided silicon strip detectors surrounding the beam pipe at radii of 5.7 cm and 9.7 cm**
- **Covers angular range** $30^\circ < \theta < 150^\circ$
- **Hit resolution: 12** μm **in** $r\phi$
  25 μm **in** z
- **For CTD tracks with CST hist in both layers DCA resolution in** xy **plane:** $33\mu m \oplus \frac{90\mu m}{p_T}$ **[GeV]**
- **The efficiency to link 2 CST hits to a CTD track: 76%**

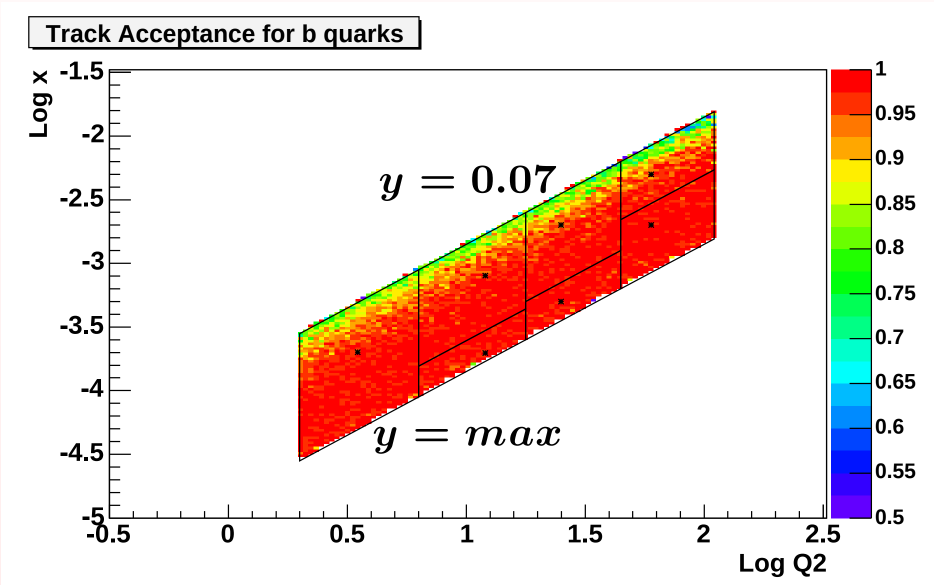
Acceptance

Acceptance for a charged track from c, b hadrons to be in CST acceptance ($30^\circ < \theta < 150^\circ$, $p_T > 0.5$ GeV) and generated z-vertex within ± 20 cm

c quarks



b quarks

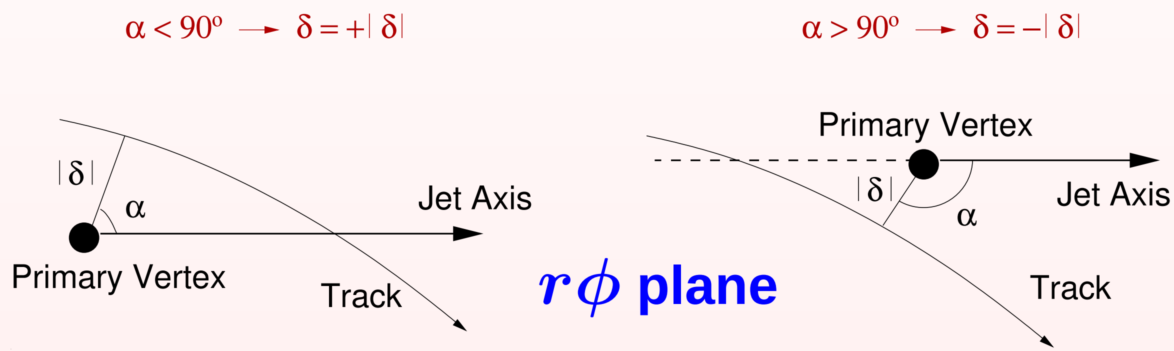


- **Acceptance for c is $68\% - 89\%$**
- **Bin centres from measured F_2**

- **Acceptance for b is $93\% - 99\%$**
- $y_{max} = 0.625$ **for** $Q^2 < 17.78$ GeV^2
  $y_{max} = 0.7$ **for** $Q^2 > 17.78$ GeV^2

Technique

Look at signed DCA (Distance of Closest Approach $\equiv$ Impact Parameter δ) for all tracks with precise measurement from Central Silicon Tracker (CST)



$r\phi$ **plane**

- **The sign is infered from a reference axis approximating the flight direction of the decaying hadron**
- **Events with secondary vertex decays from heavy flavour particles will have large positive impact parameter w.r.t. primary vertex**
- **Light flavour primary decays will have small negative and positive impact parameter due to resolution effects**

Jets vs HFS

Reference axis is given by:

- **Highest p_T jet axis**
  - inclusive k_T algorithm in the lab. frame
  - $p_T >$ 4 GeV
  - 25$^\circ < \theta <$ 155°

  33% of matched track-jet events for c

  55% of matched track-jet events for b

  ($>$ 97% at high Q^2)

- **If we don't have jets: use Hadronic Final States (HFS)**

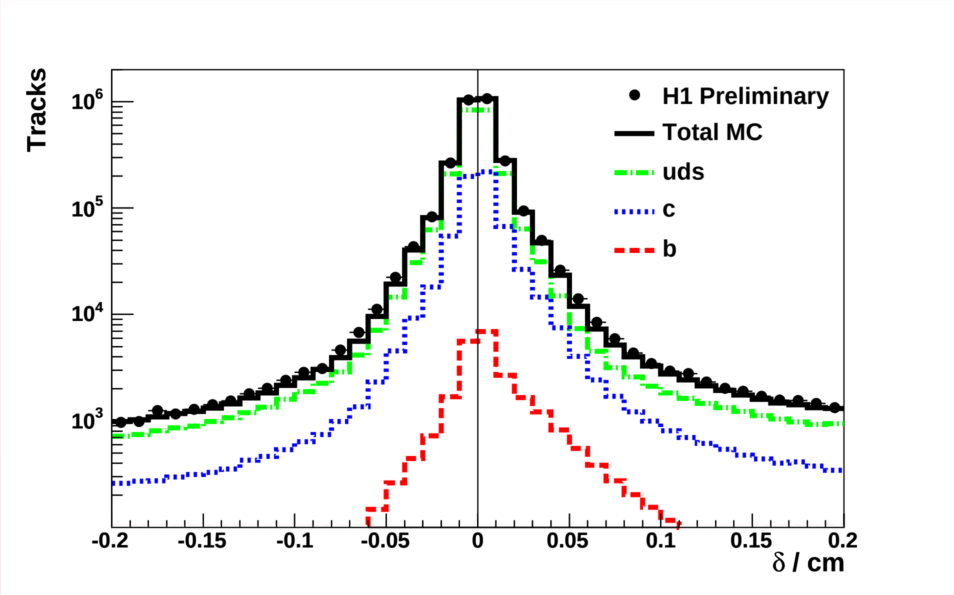
  Reference axis is approximated by $\phi_{\mathrm{ref.axis}}$ measured from the electron

DCA and Significance at Low Q^2

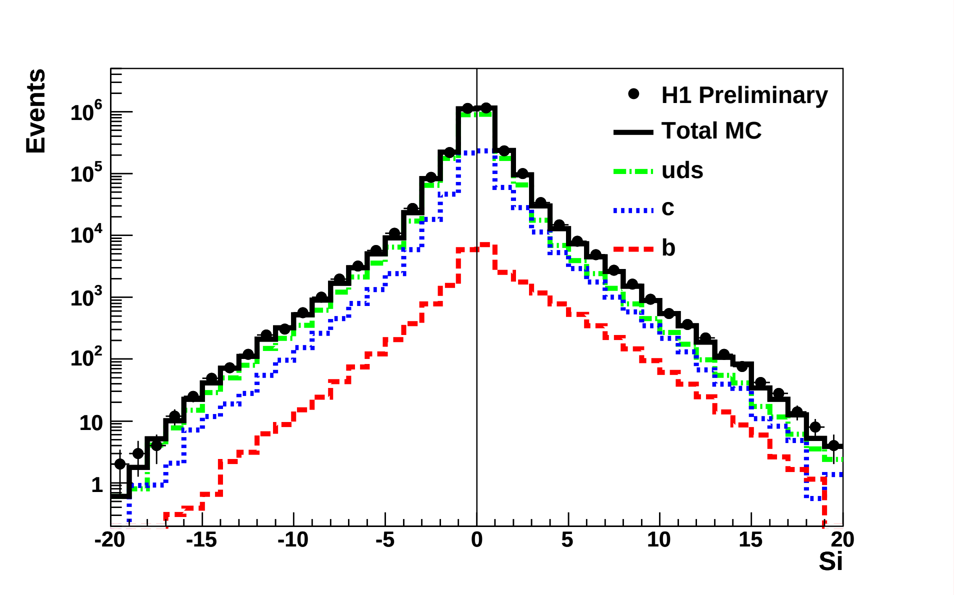
- Tracks matched to reference axis within $\Delta\phi_{\mathrm{ref.axis}} < \pi/2$
- For matched tracks, plot DCA to primary vertex in $r\phi$ plane (δ)

  Tracks required to have $|\delta| < 1\ \mathrm{mm}$ (remove e.g. K0s).
- Significance of each track given by $S_i = \frac{\delta}{\sigma(\delta)}$

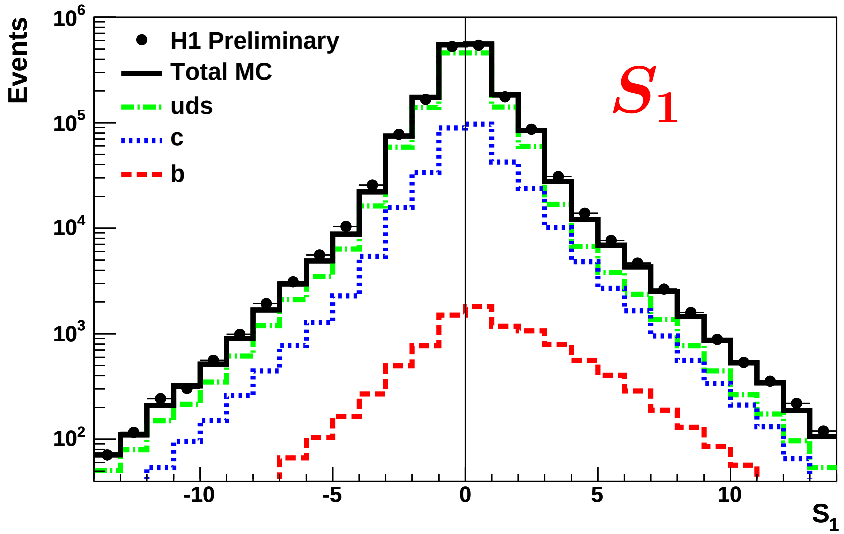
DCA

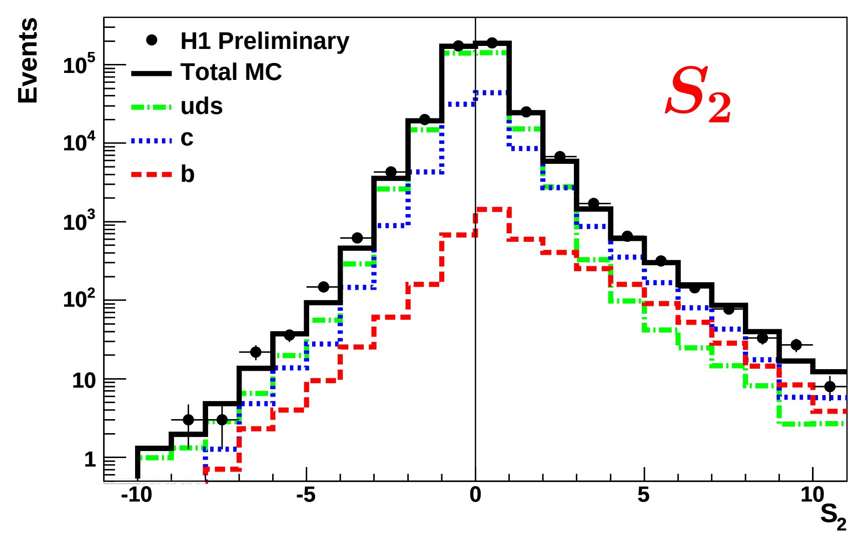


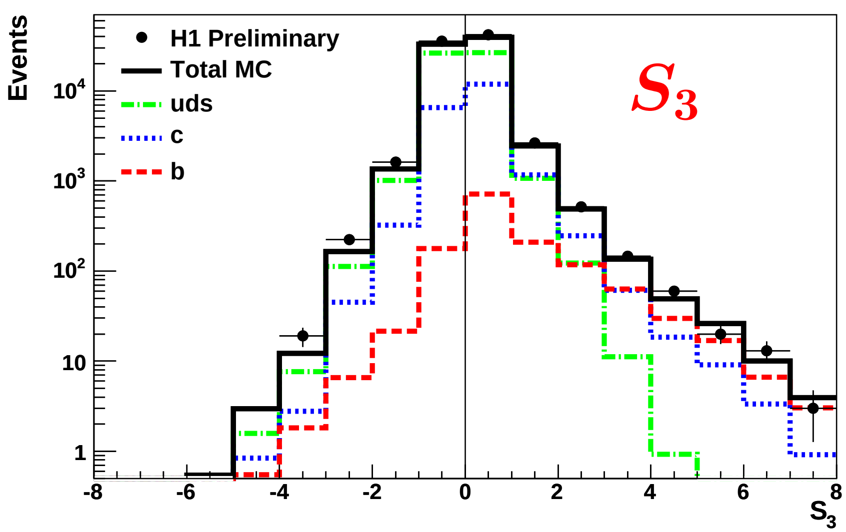
Significance



Significance (S_i) at Low Q^2







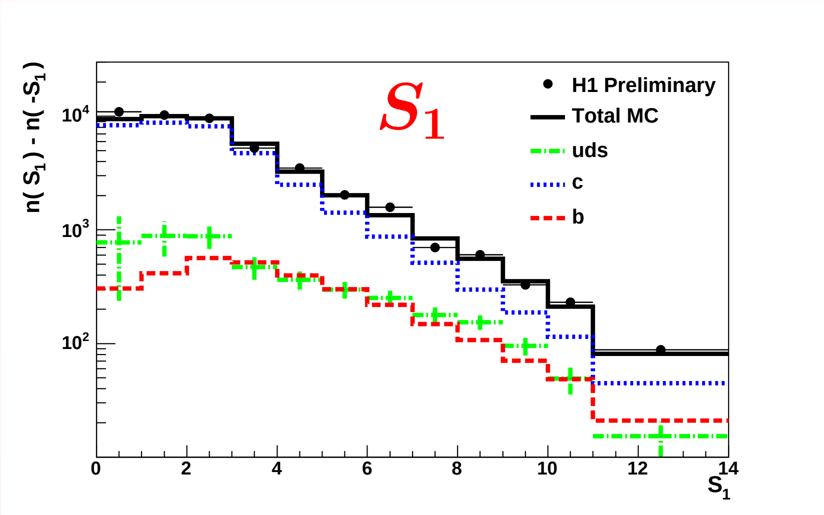
At low Q^2, beauty fraction is smaller. Need to do more to separate b and c

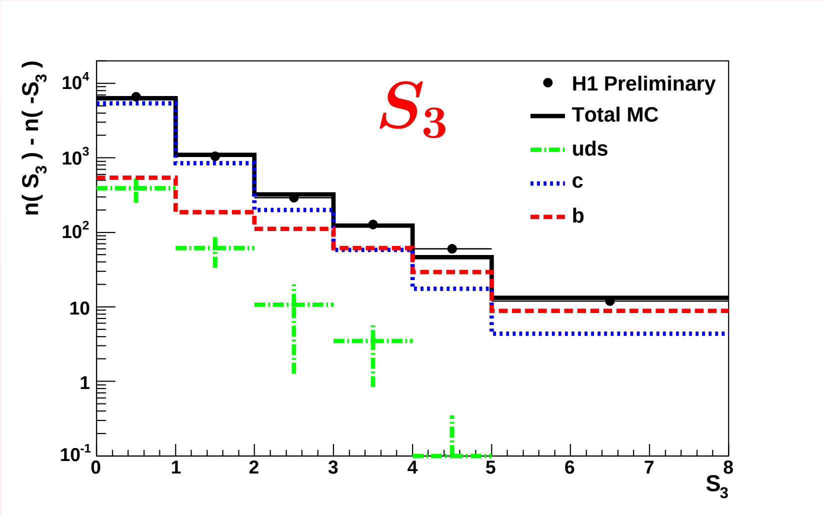
Define three distributions:

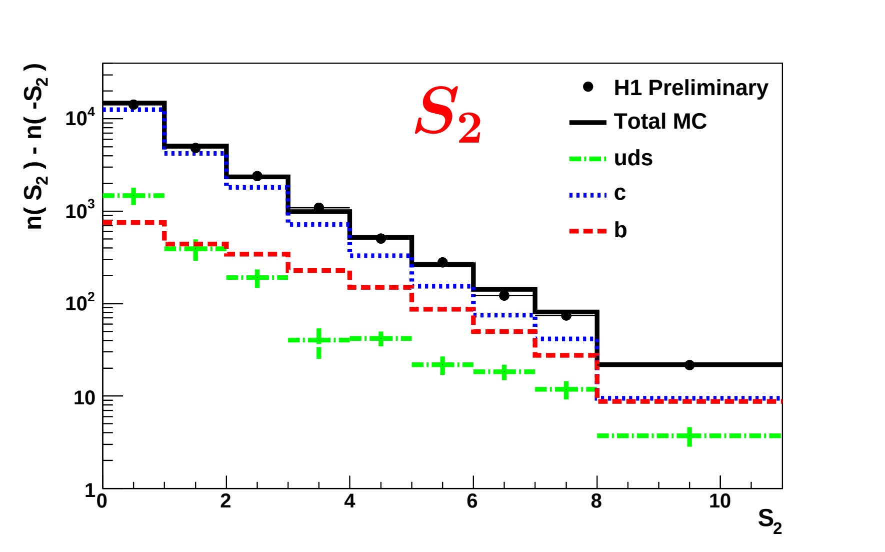
- S_1 highest significance track
- S_2 2nd highest significance track with same sign as S_1
- S_3 3rd highest significance track with same sign as S_1 and S_2

Subtracted Significance (S_i) at Low Q^2

Subtract the negative S_i bins from the positive for both data and MC to reduce sensitivity to resolution of light quarks







For each $x - Q^2$ bin make a simultaneous fit to S_i and total number of inclusive events before CST track selection with 3 parameters:

- **MC scale factor c - P_c**
- **MC scale factor b - P_b**
- **MC scale factor uds - P_l**

Structure Function Extraction

Fit results: P_c = **1.34 $\pm$ 0.06,**

P_b = **1.43 $\pm$ 0.17,**

P_l = **1.16 $\pm$ 0.01**

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

The differential c cross section is calculated from $\tilde{\sigma}^{c\bar{c}}(x, Q^2)$ as

$$\frac{\mathrm{d}^2\sigma^{c\bar{c}}}{\mathrm{d}x\,\mathrm{d}Q^2} = \tilde{\sigma}^{c\bar{c}}(x, Q^2) \frac{2\pi\alpha^2(1 + (1-y)^2)}{xQ^4} \Longrightarrow f^{c\bar{c}} = \frac{\mathrm{d}\sigma^{c\bar{c}}/\mathrm{d}x\mathrm{d}Q}{\mathrm{d}\sigma/\mathrm{d}x\mathrm{d}Q}$$

The structure function $F_2^{c\bar{c}}$ is then evaluated from the expression

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

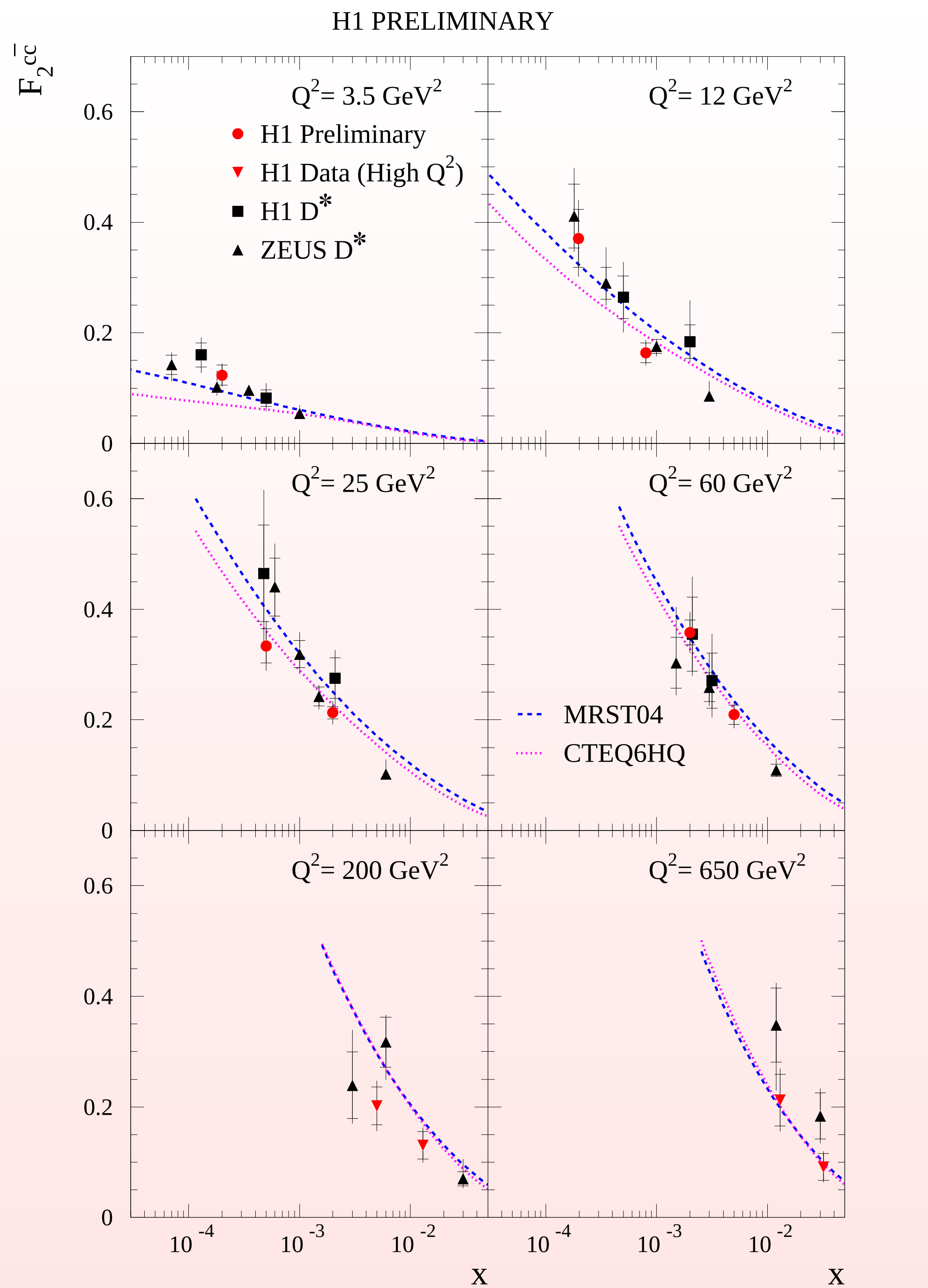
$F_L^{c\bar{c}}$ **is estimated from the NLO QCD expectation**

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

- Consistent results with H1 and ZEUS D^* measurements
- Consistent with pQCD predictions
- Highest Q^2 $F_2^{c\bar{c}}$ measurement for H1 (hep-ex/0411046 accepted Eur. Phys. J)

MRST04 - Variable FNS

CTEQ6HQ - Variable FNS



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

- First measurement of $F_2^{b\bar{b}}$
- Consistent with pQCD predictions
- MRST04 describes the data best
- Limit on the lowest Q^2 point comes from the fact that the fit to S_i is consistent with zero

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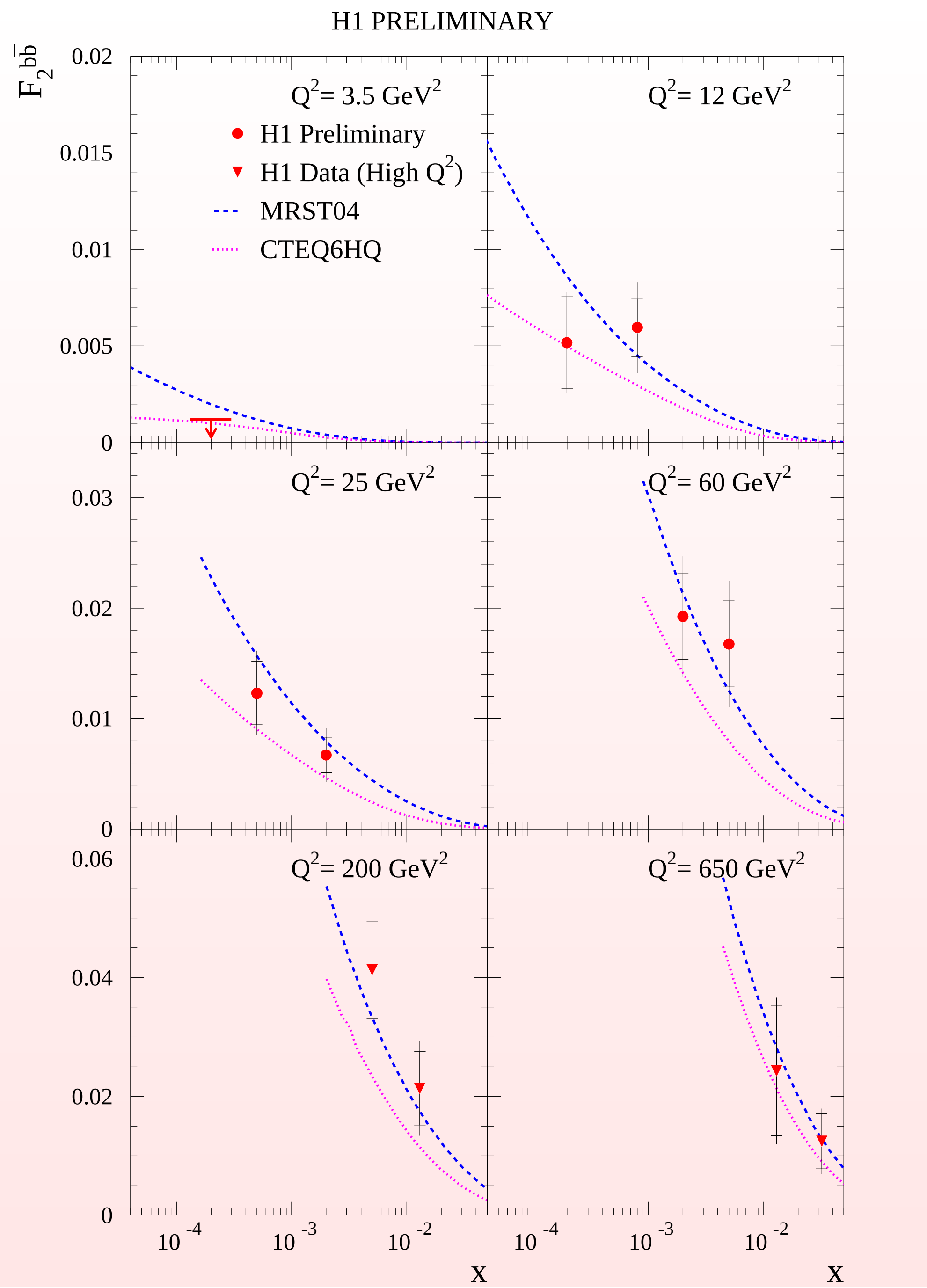
MRST04 - Variable FNS

CTEQ6HQ - Variable FNS



Contribution to σ

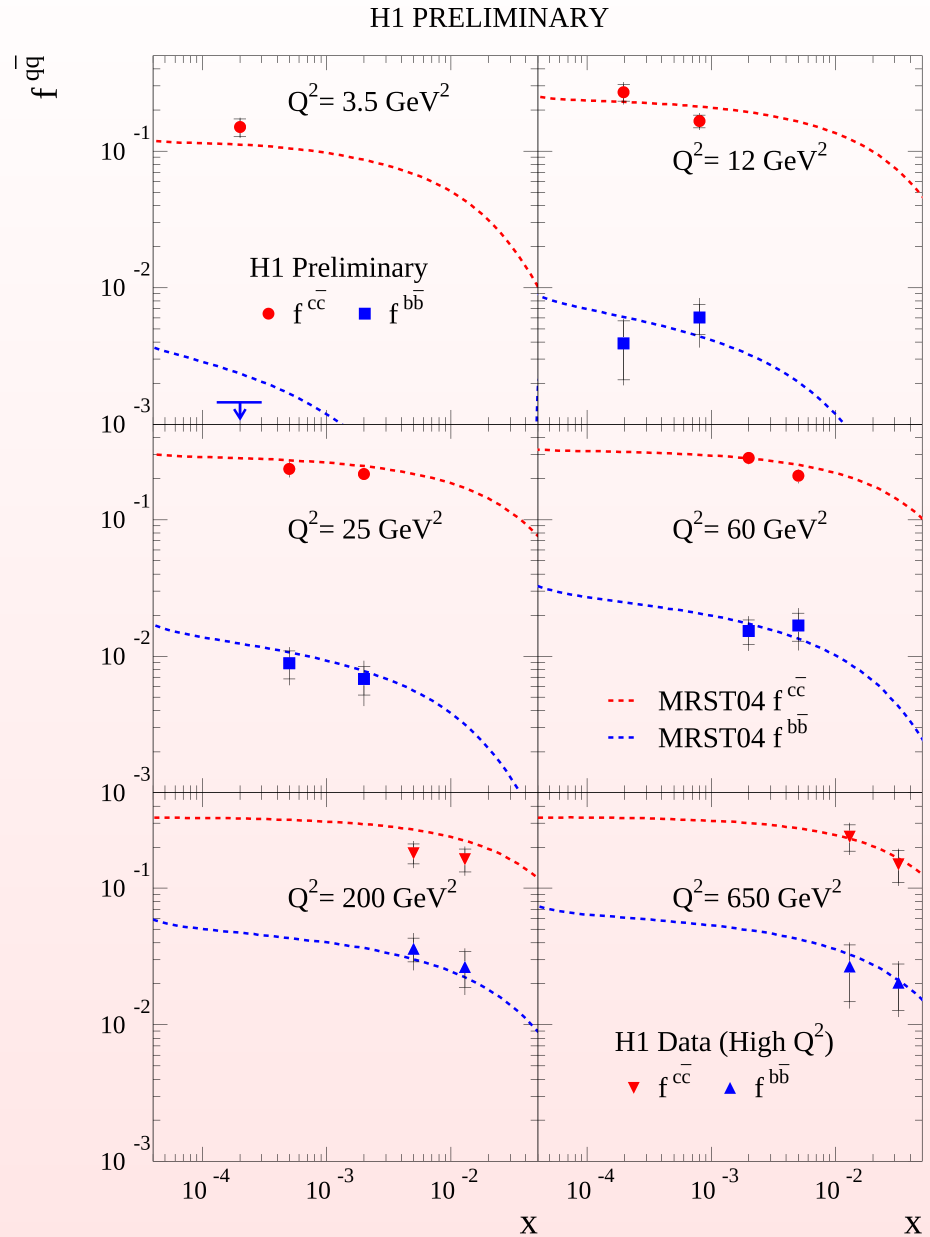
$$f^{q\bar{q}} = \frac{d\sigma^{q\bar{q}}/dx dQ^2}{d\sigma/dx dQ^2}$$

c **and** b **fractions fall towards low** Q^2

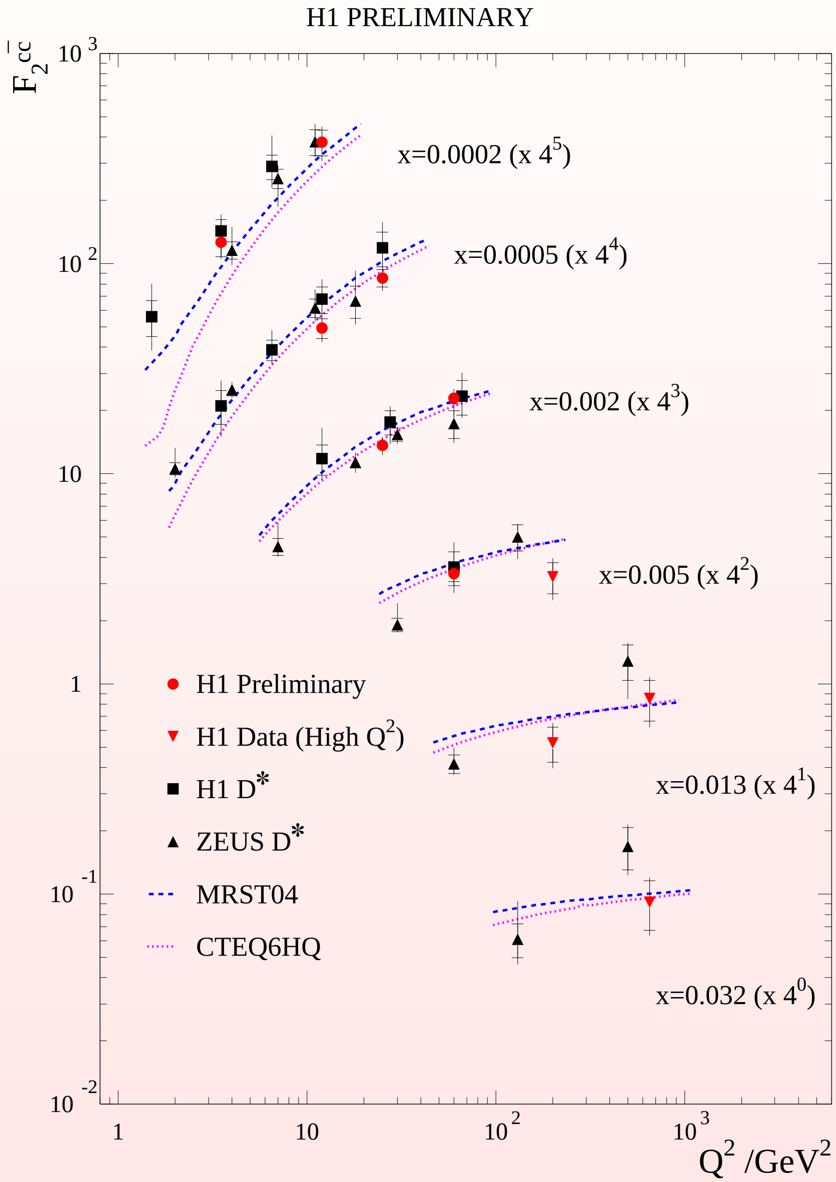
b **fraction falls by a larger amount**

MRST04 - Variable FNS

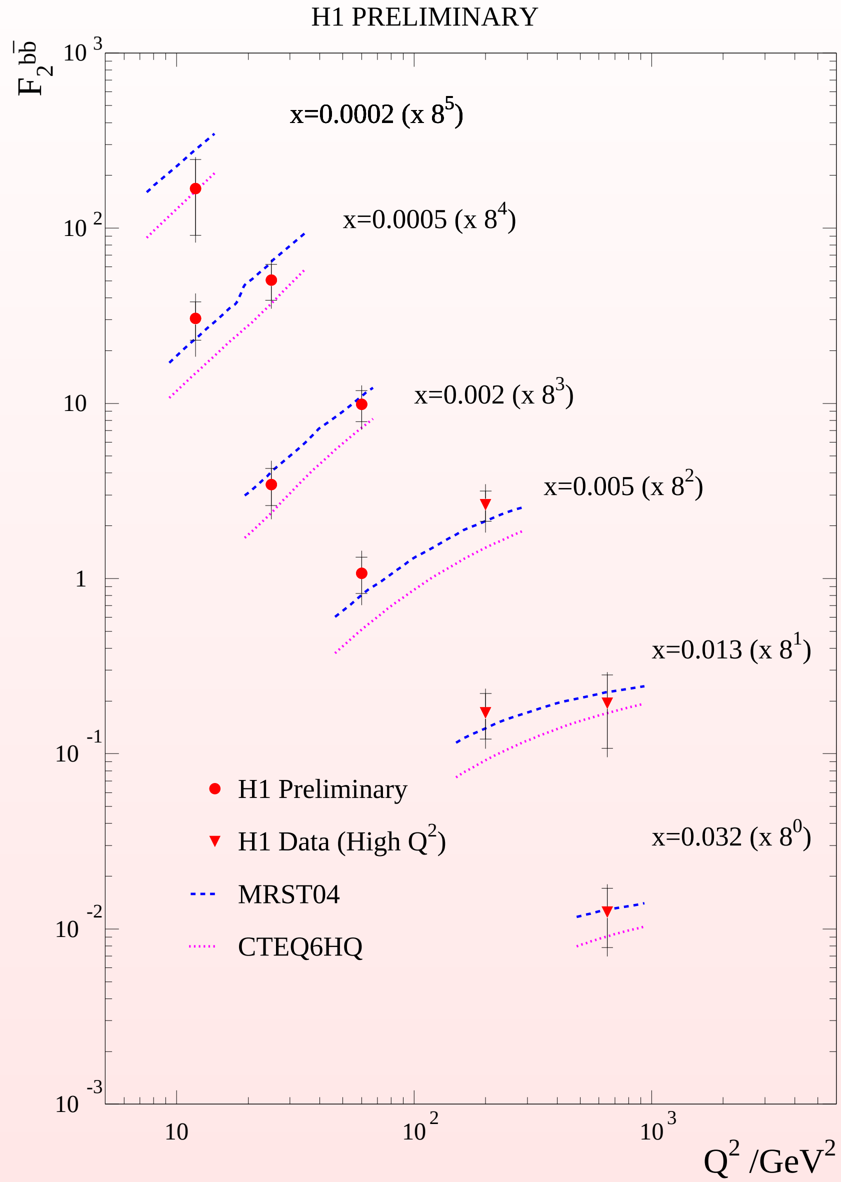
CTEQ6HQ - Variable FNS



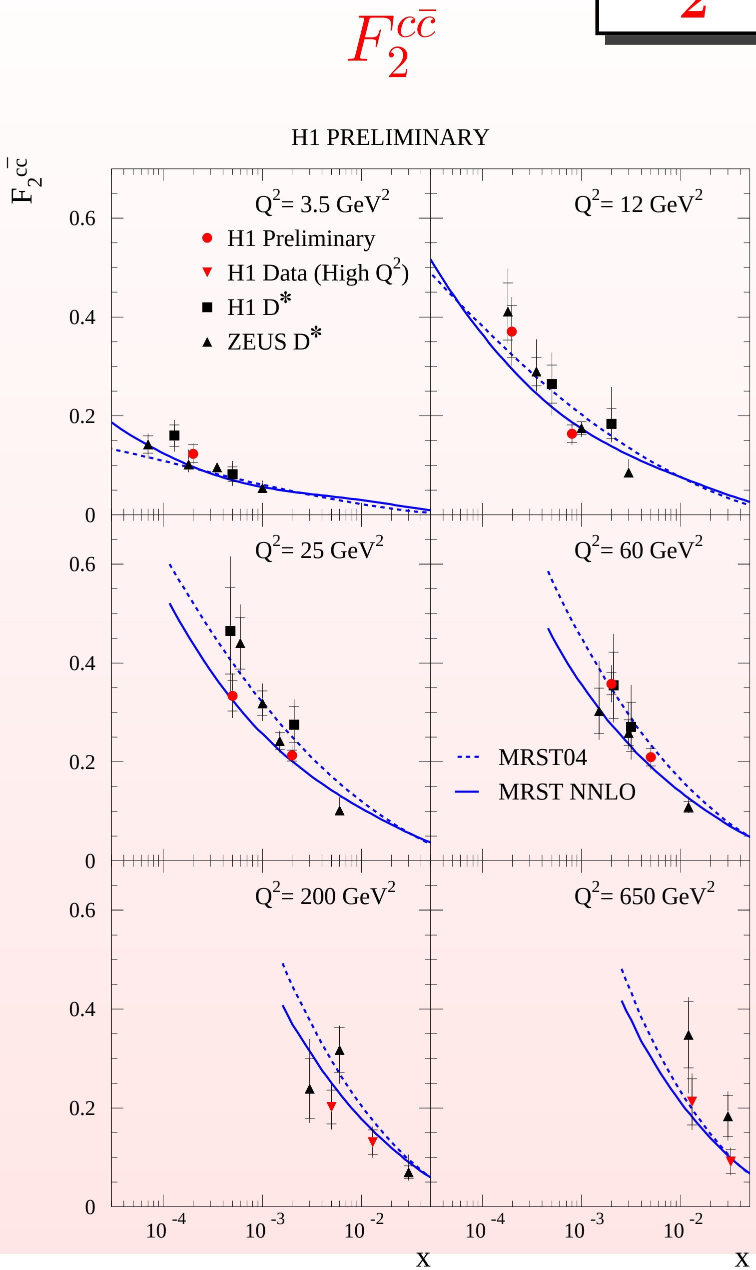
$F_2^{c\bar{c}}$ vs Q^2

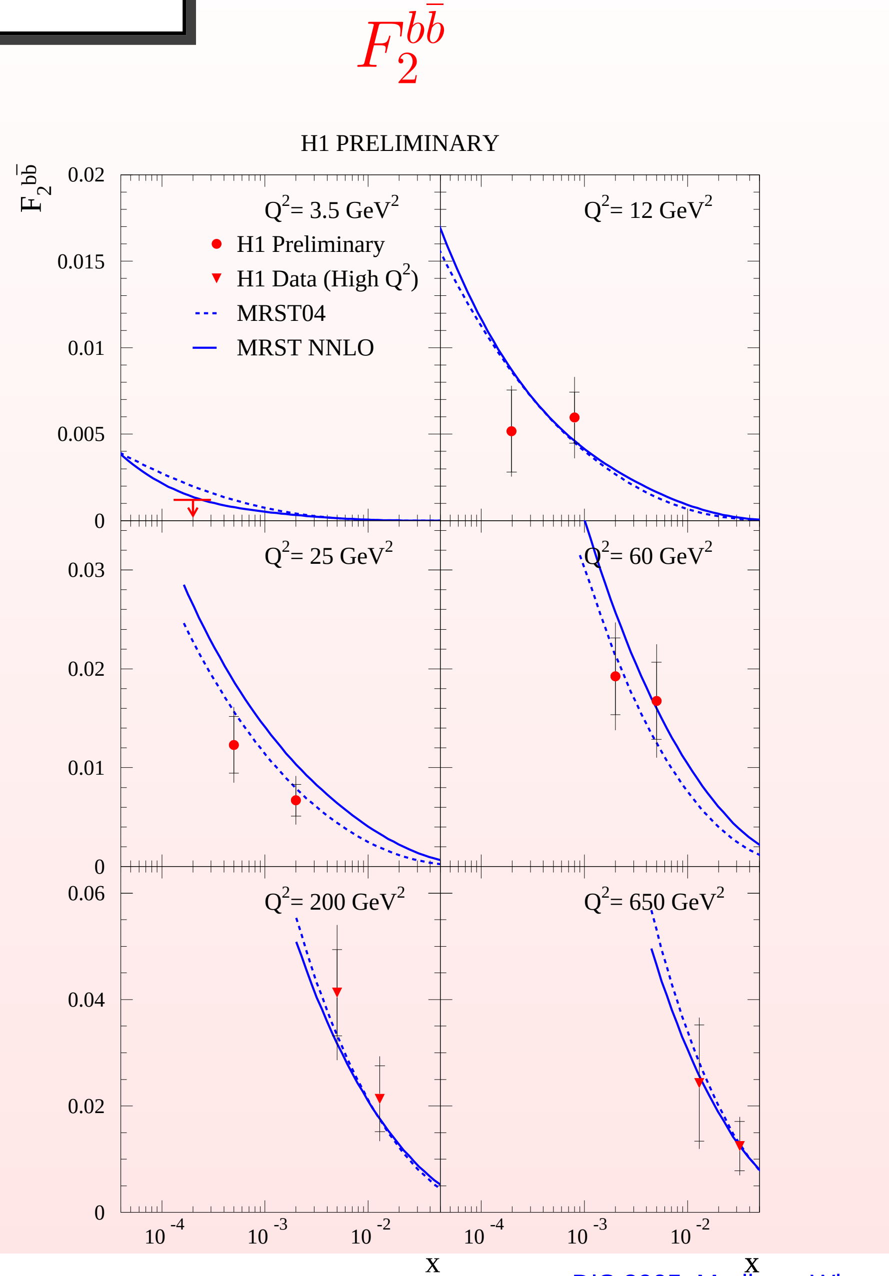


$F_2^{b\bar{b}}$ vs Q^2



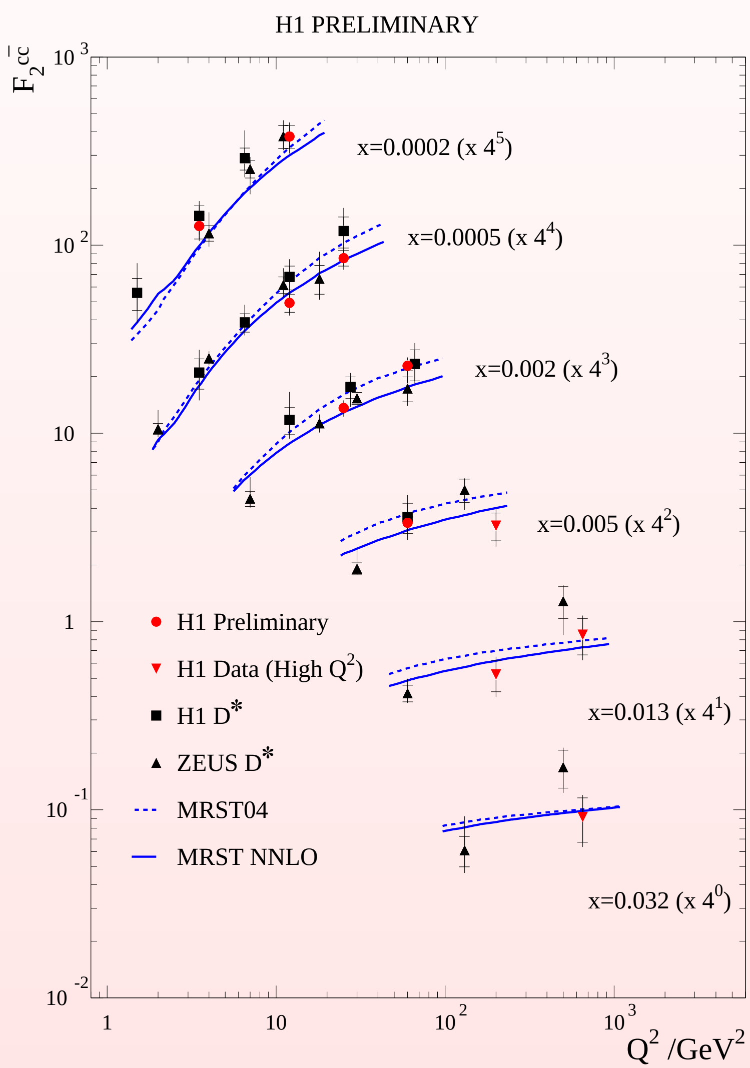
$F_2^{q\bar{q}}$ MRST NNLO



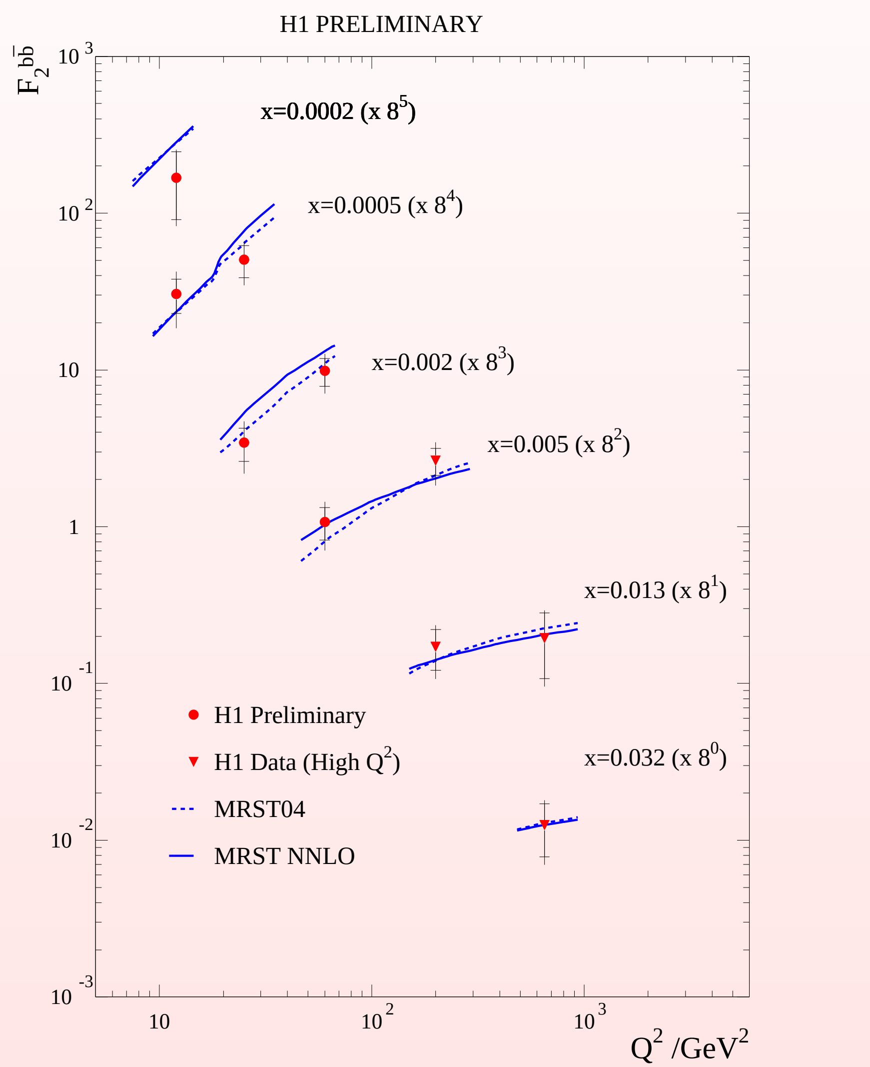


$F_2^{q\bar{q}}$ vs Q^2 MRST NNLO

$F_2^{c\bar{c}}$ vs Q^2

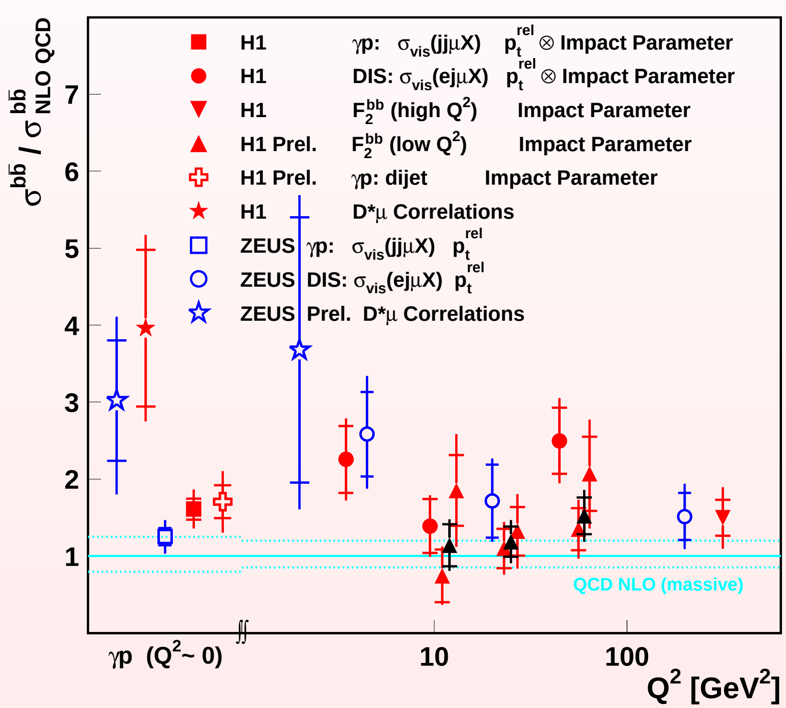


$F_2^{b\bar{b}}$ vs Q^2

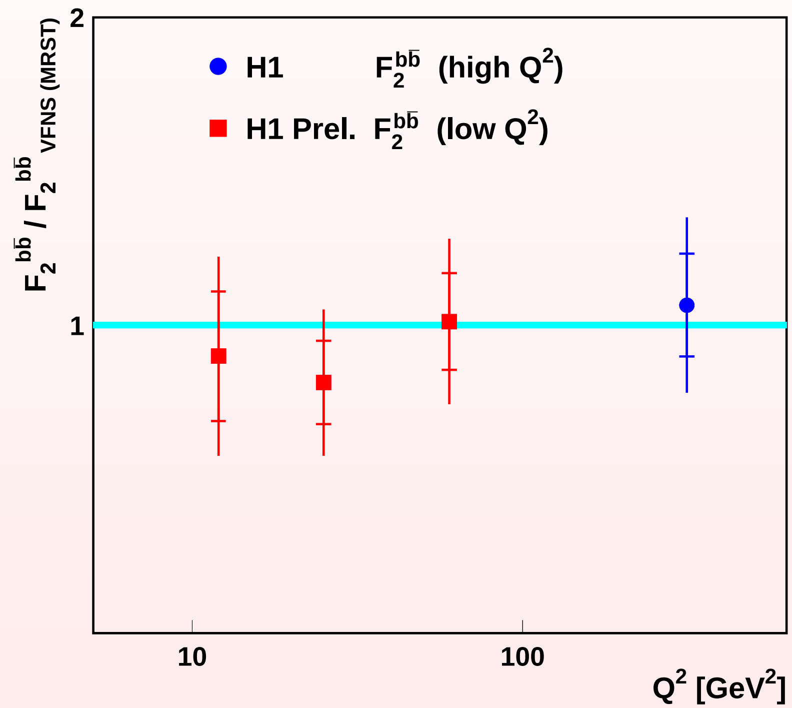


Data vs Theory for $F_2^{b\bar{b}}$

HVQDIS (NLO)



MRST (NLO)

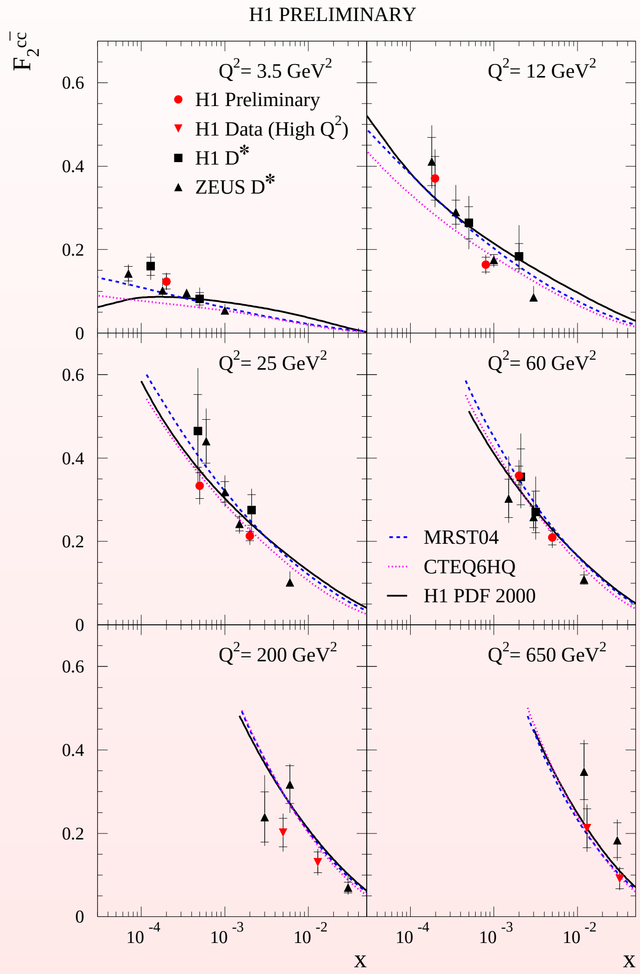


Conclusion

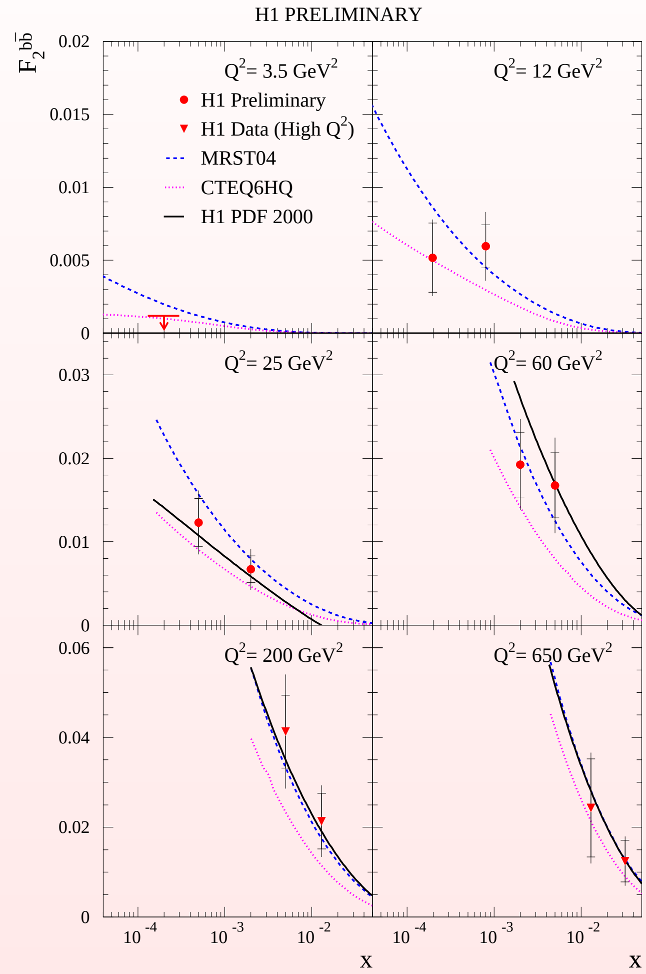
- Inclusive measurements of $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ at Low and High Q^2 region using impact parameter method
- The cross sections and structure functions are found to be well described by predictions of perturbative QCD
- The first measurement of $F_2^{b\bar{b}}$ in the low Q^2 kinematic regime
- $F_2^{c\bar{c}}$: Model dependent extrapolations to the full cross section are small
- 22% of charm and 0.8% of beauty contribution to the total ep cross section at low Q^2

Backup

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



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



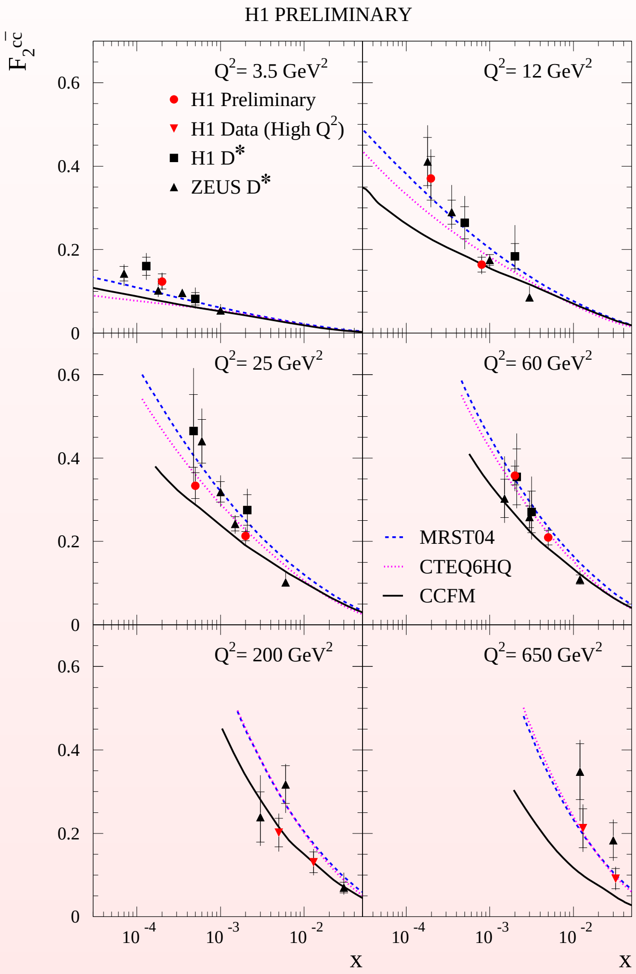
MRST04 - Variable FNS

H1 PDF 2000 - Massless scheme

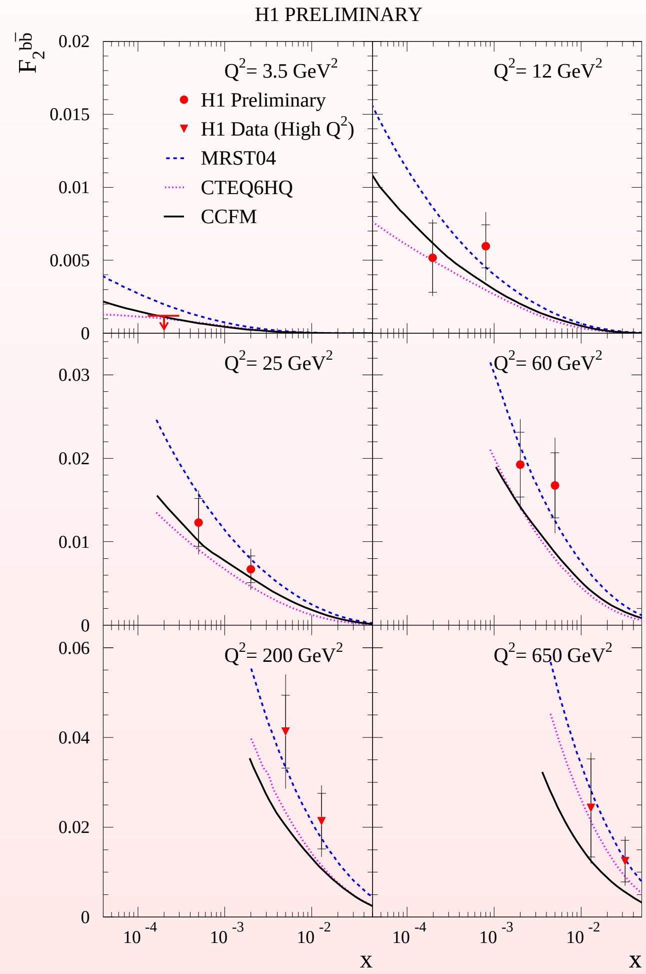
CTEQ6HQ - Variable FNS

Backup

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



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



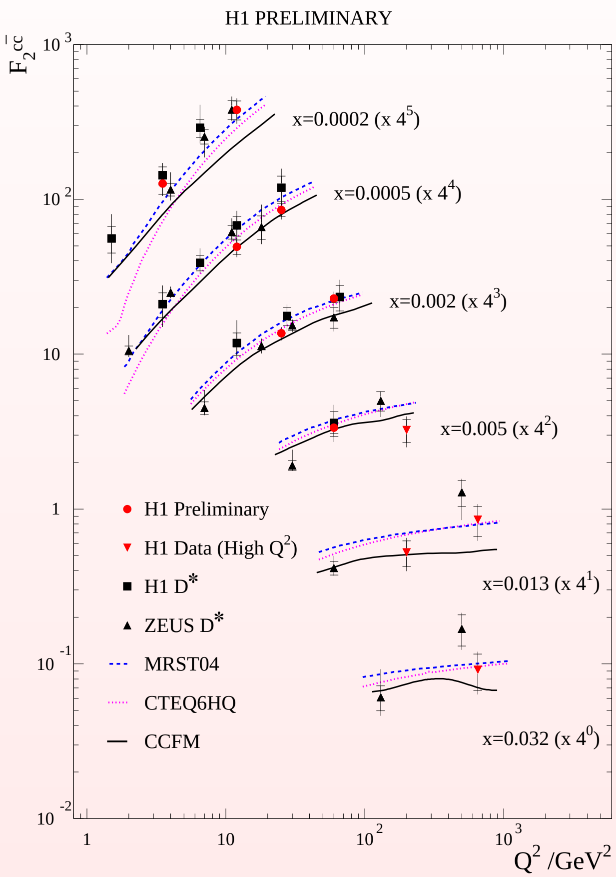
MRST04 - Variable FNS

CCFM - Massive BGF

CTEQ6HQ - Variable FNS

Backup

$F_2^{c\bar{c}}$ vs Q^2



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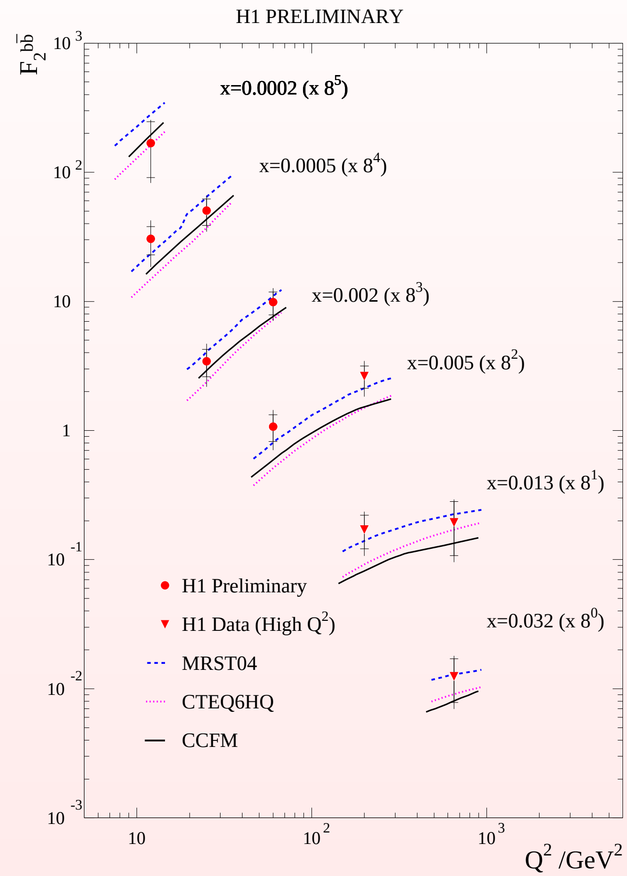

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