Measurement of F_2^{cc} at HERA

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for

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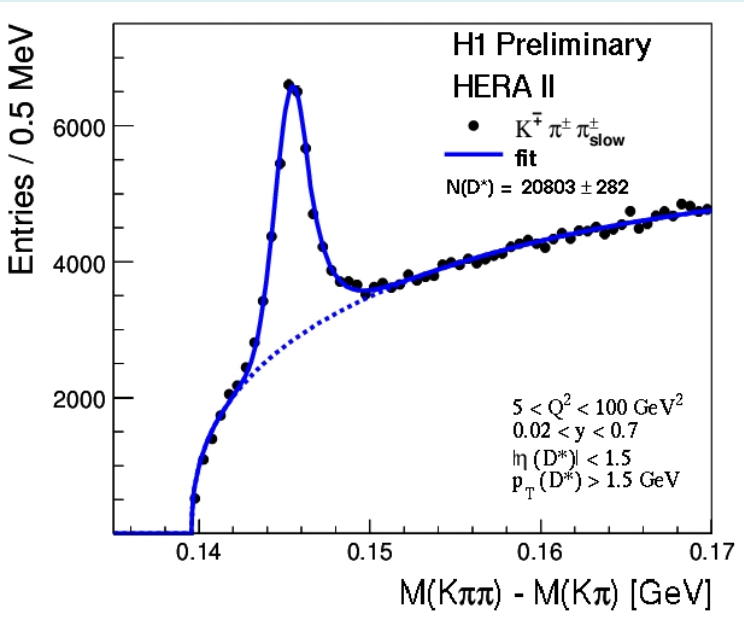
PDF4LHC October 2009 DESY

Heavy quark tagging methods at HERA

Full reconstruction of charmed mesons: $D^*, D^{\pm}, D^0$ from decay particles in detector

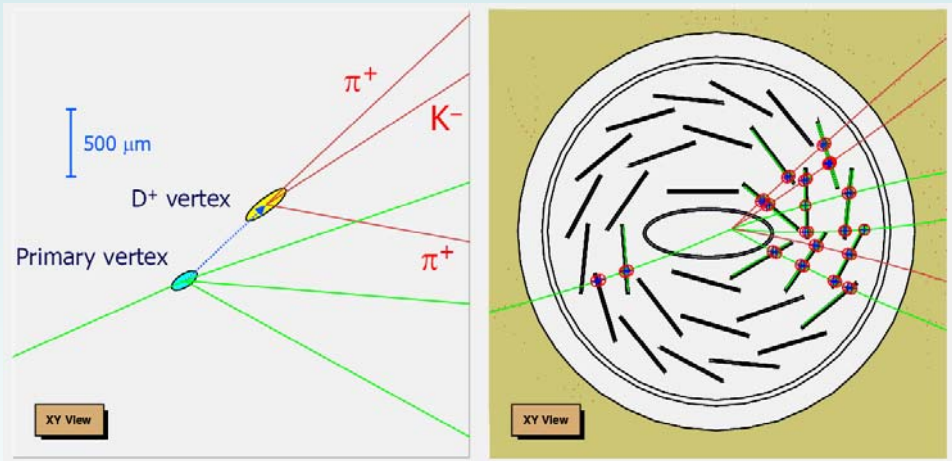
Via reconstructed $D^* \to D^0\pi \to K\pi\pi$

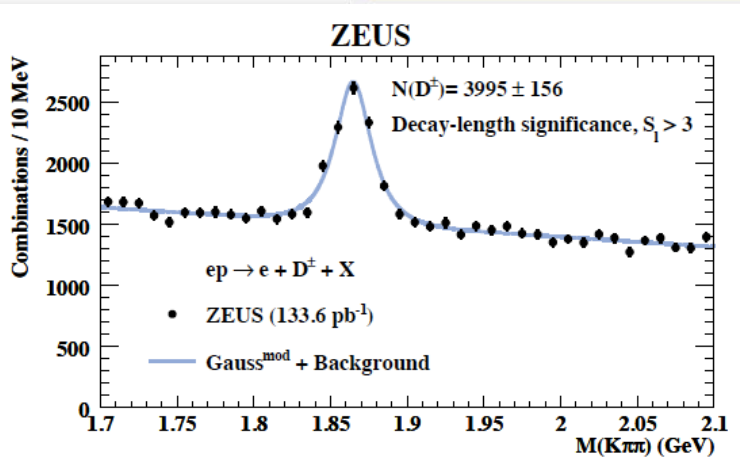
$\Delta m\,(D^*) = M_{inv}(K\pi\pi) - M_{inv}(K\pi)$



Signal obtained from the fit

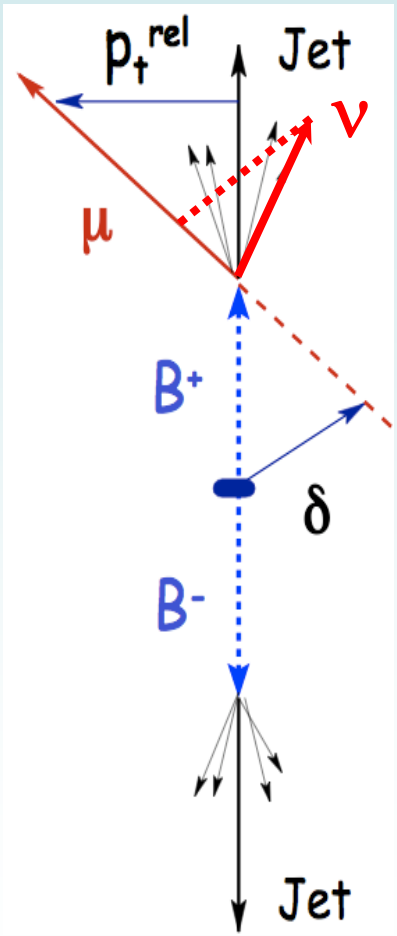
Via vertex reconstruction in silicon detector:



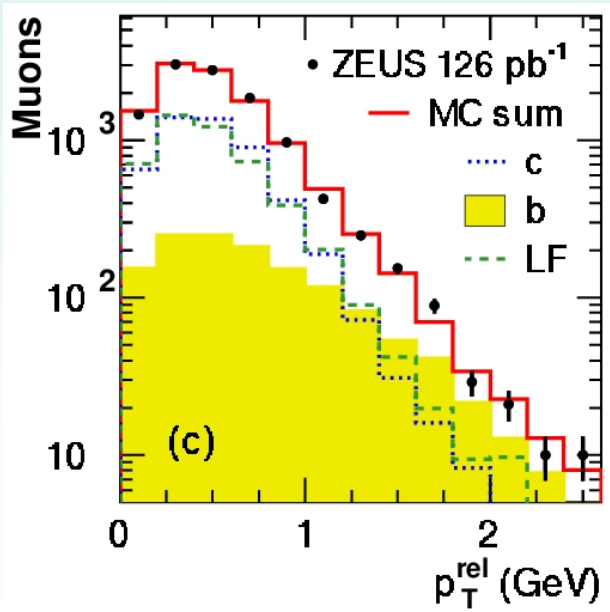


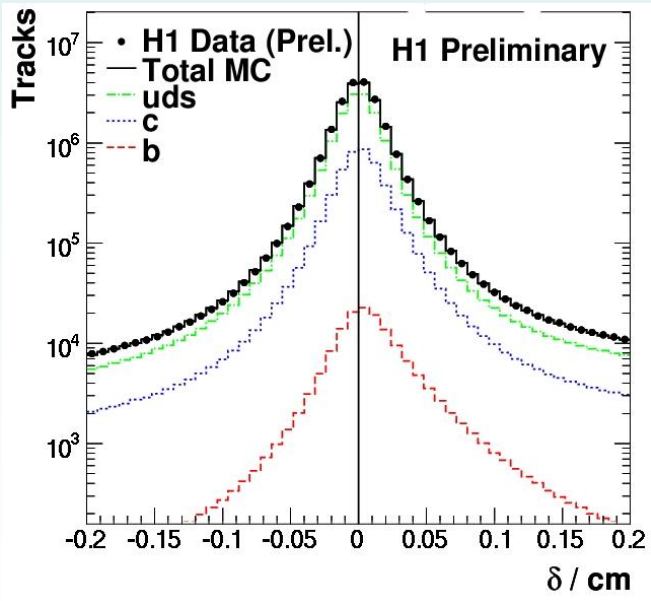
Heavy quark tagging methods at HERA

Large mass, long lifetime of heavy hadrons: charm comes alone with beauty



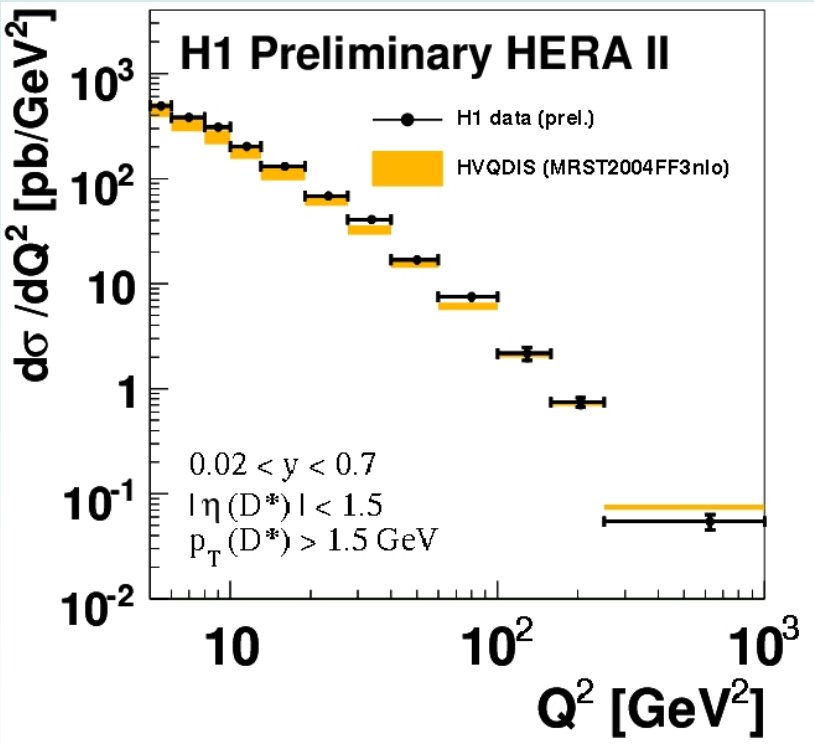
- Semi-leptonic decays (e,μ)
- Large mass: transverse momentum to Jet axis: muon p_t^{rel}
- Large lifetime: impact parameter δ



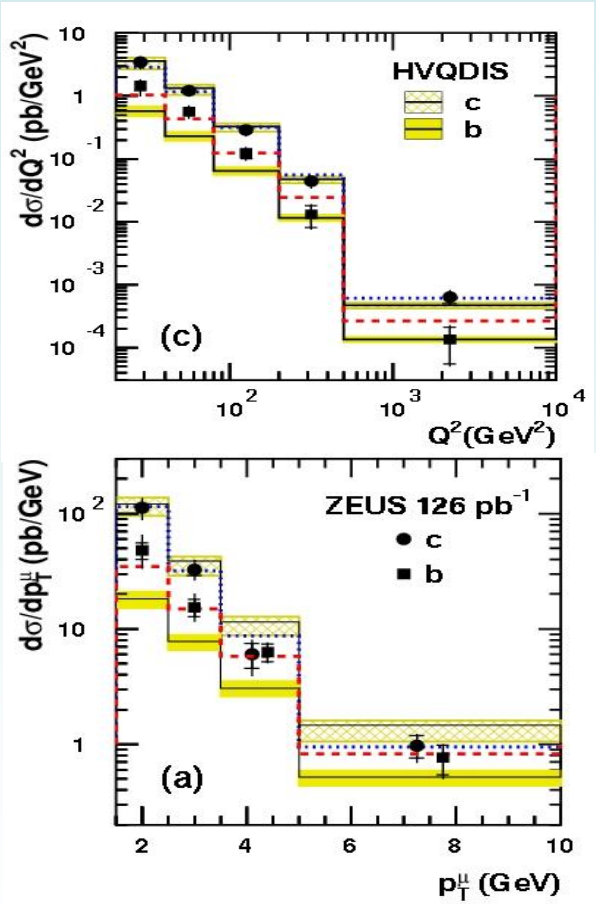


Heavy Quarks in Deep Inelastic Scattering

Charm from D*



HQ from semi-leptonic decays



Charm: NLO QCD agrees with data

Beauty: NLO lower in normalization

Theory uncertainties: HQ mass, scales, fragmentation model

Charm contribution to F_2 (charm via D)

$$F_2^{c\bar{c}}(\exp) = \frac{\sigma_{vis}(\exp)}{\sigma_{vis}(theory)} F_2^{c\bar{c}}(theory)$$

Visible meson cross section: $p_T(D^*)>1.5$ GeV, $|\eta(D^*)|<1.5$

Problem: detector sees only ~30% of the phase space for c→D

→ strong model dependence due to large extrapolation factors

Extrapolation models: HVQDIS / CASCADE

Extrapolation uncertainties: mass of charm quark, scales,

fragmentation model (experimentally measurable)

Charm contribution to F_2 (μ, lifetime)

Quark fractions ρ_c, ρ_b, ρ_{uds}: from fit to observables sensitive to lifetime or heavy mass of charmed (beauty) hadrons using Monte Carlo templates

Normalization: inclusive reduced cross section $\sigma_{red}(x,Q^2)$

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

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

Connection to F^c_2:

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

Averaged F_2^{cc}: H1-ZEUS Combination

- H1 data:
  - D* HERA I (1999-2000) 47 pb^{-1}
  - HERA II (2004-2007) 340 pb^{-1} (Preliminary)
  - Lifetime tag: HERA I + HERA II (2004-2007)
- ZEUS data:
  - semi-leptonic events (muons) (2005)
  - D^0, $D^{\pm}$ (2005)
  - D* HERA I (1996-2000)
- Correlations of systematic uncertainties taken into account

Extrapolation uncertainties cross-correlated between H1 and ZEUS:

Variations of m_c, $\mu_r=\mu_f$, fragmentation parameters in HVQDIS (D-mesons)

Averaging

Similar procedure as used for combining inclusive cross sections

$$\chi^2(\vec{m},\vec{b}) = \sum_i \frac{\left(m^i - \sum_j \gamma^i_j m^i b_j - \mu^i\right)^2}{(\delta_{i,stat}\,\mu^i)^2 + (\delta_{i,unc}\,m^i)^2} + \sum_j b_j^2$$

μ^i measured value at point i

δ_i statistical, uncorrelated systematic error

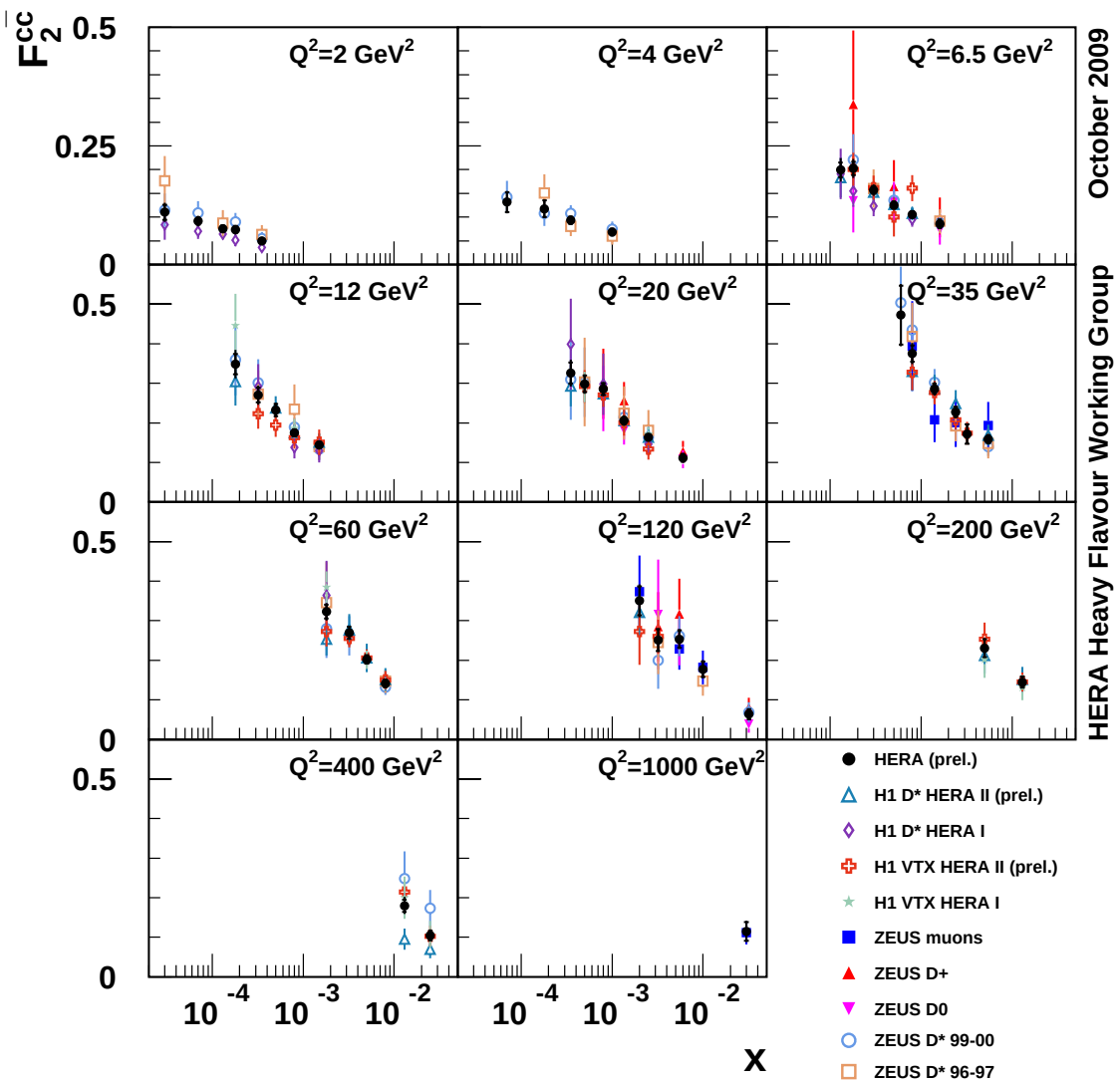
γ_j^j – correlated systematic error

b_j – shift of correlated systematic error sources

m^i – true value (corresponds to min χ^2)

swimming to the common (x,Q^2) grid via FFNS NLO (Riemersma *et al*)

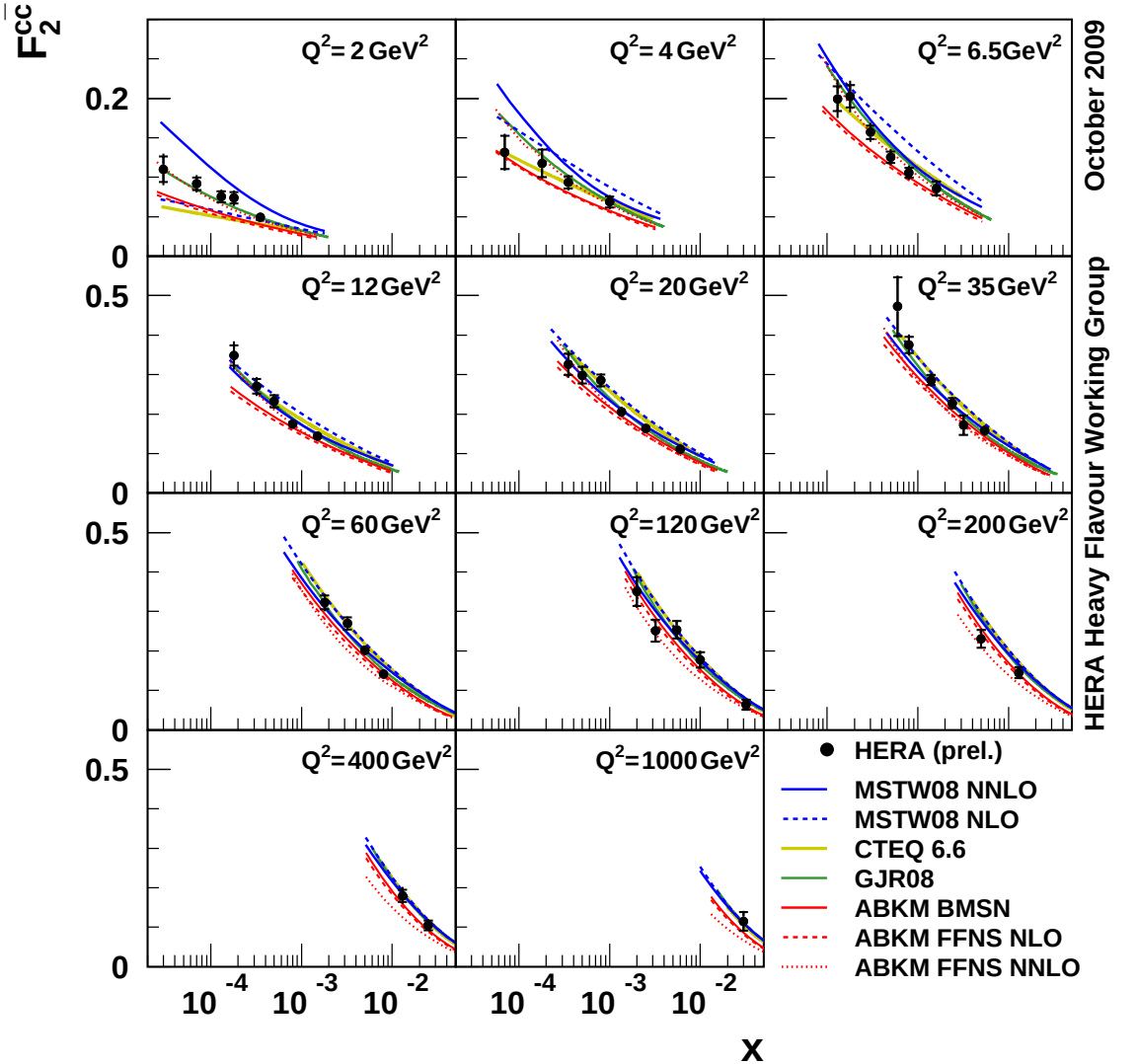
Averaging Result



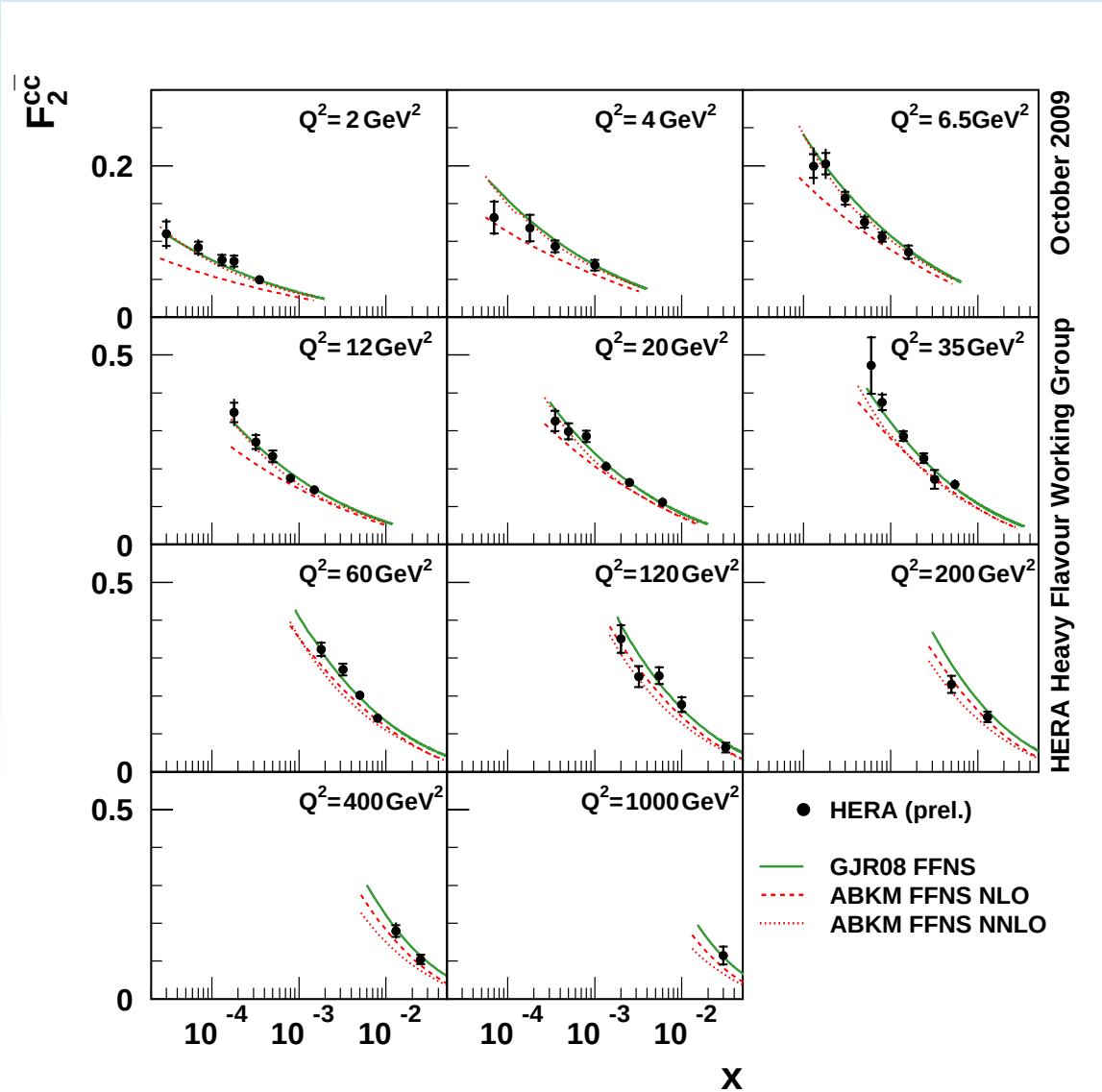
Combined result precision:

5-10%

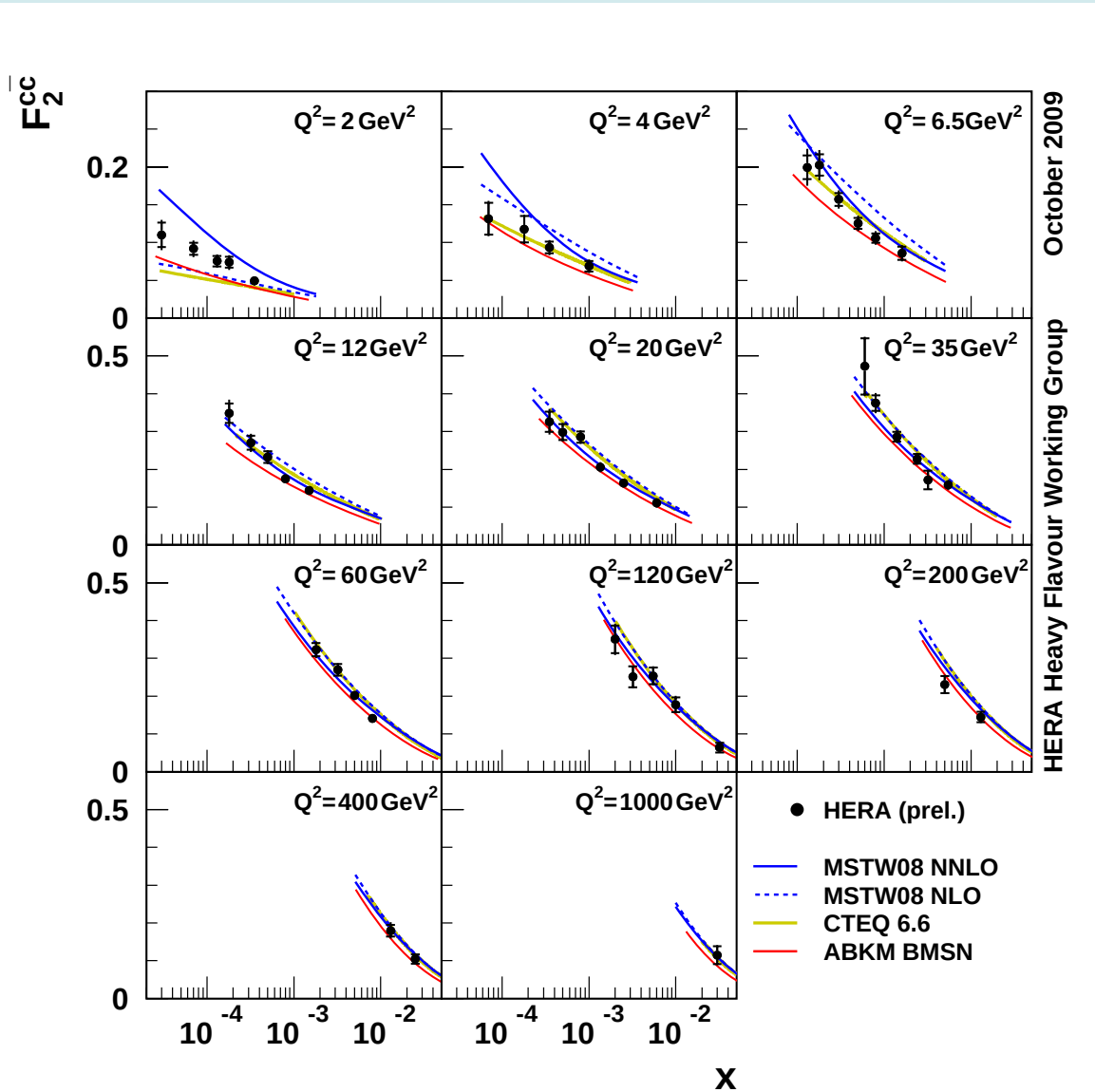
F2cc vs theory



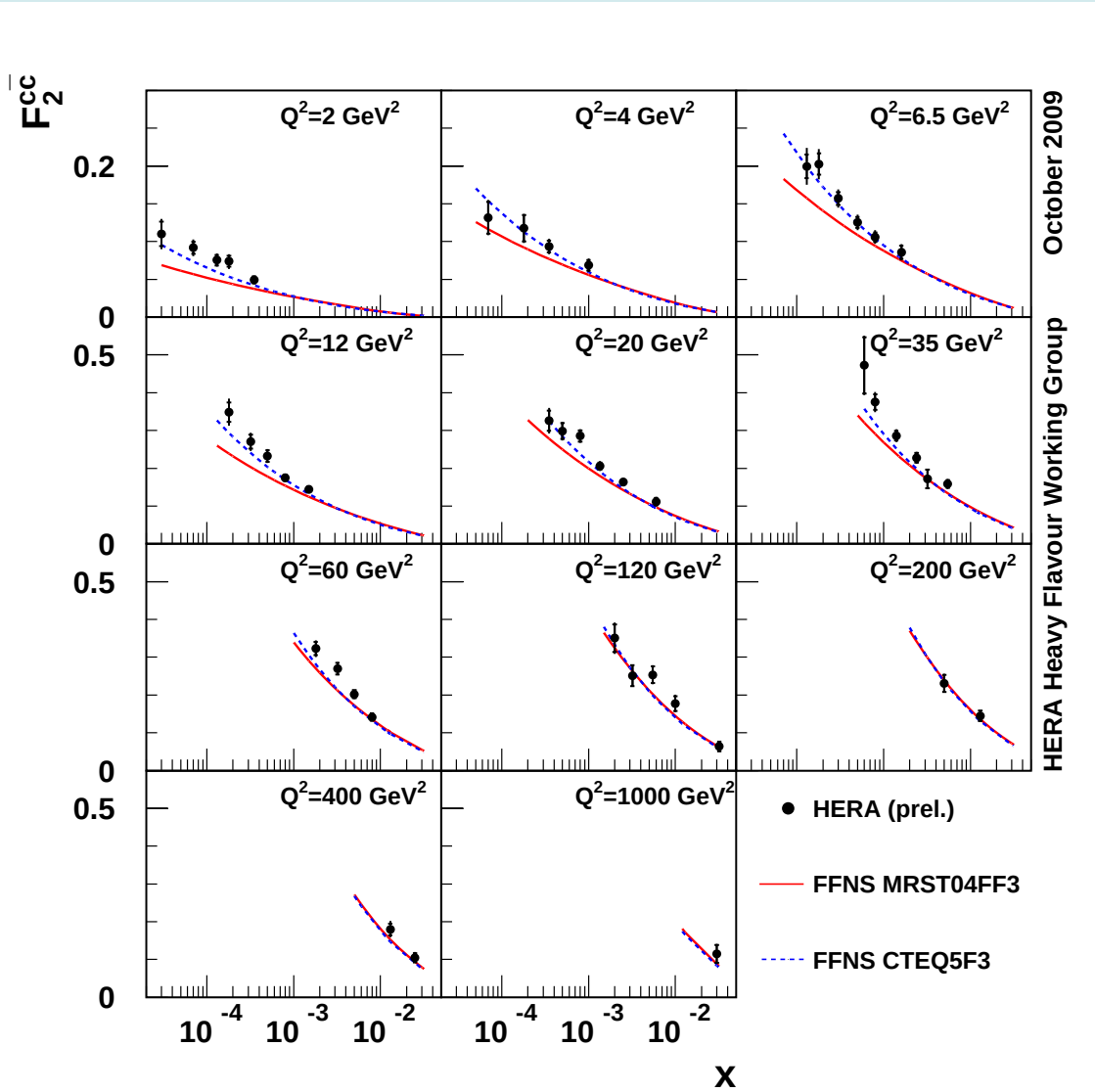
F2cc vs FFNS


$\bar{F}_2^{cc}$
Q^2= 2 GeV^2
Q^2= 4 GeV^2
Q^2= 6.5GeV^2
Q^2= 12GeV^2
Q^2= 20GeV^2
Q^2= 35GeV^2
Q^2= 60GeV^2
Q^2=120GeV^2
Q^2=200GeV^2
Q^2=400GeV^2
Q^2=1000GeV^2
0.2
0
0.5
0
0.5
0
0.5
0
10^{-4}
10^{-3}
10^{-2}
x
HERA (prel.)
GJR08 FFNS
ABKM FFNS NLO
ABKM FFNS NNLO
October 2009
HERA Heavy Flavour Working Group

F2cc vs GMVFNS



F2cc vs FFNS NLO



Summary / Discussion

HERA Prelim. averaged result on F_2^{cc} for $2<Q^2<1000$ GeV^2 , $10^{-5}<x<10^{-1}$

Average uncertainty 10%, in some bins 5%

Outlook: experimental precision will further improve

F2cc can be included in the PDF fits

Discussion:

extrapolation from the visible range of the measurements to full phase space via FFNS, need consistent model to include in PDF fits

FFNS in general does much better job, is it a feature of extrapolation?

GMVFNS NLO does not fit the data at low Q^2, should it? Is Q^2 right scale?

Need help from theory for the consistent treatment of charm in PDF fits!