Charm Production in ep collisions

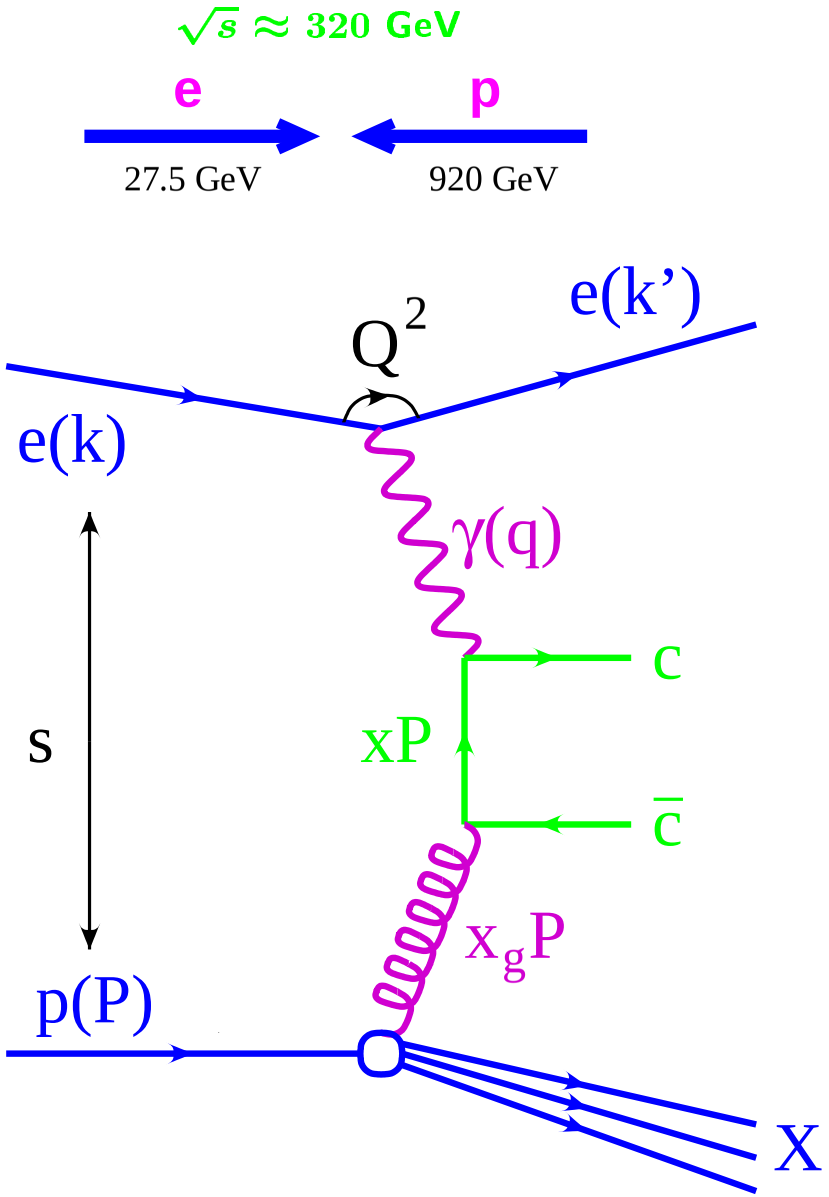
XXXXth Recontres de Moriond

Jeannine Wagner

DESY / EKP Karlsruhe

- Introduction, theoretical Framework
- D mesons - Fragmentation
- Proton structure function: F_2^c
- D^* (+jets)
- D^* + muon: Double tag

HERA - Kinematics



Center of mass energy ($\sqrt{s}$) :

$$s = (k + P)^2$$

Virtuality of γ:

$$Q^2 = -q^2 = -(k - k')^2$$

x (x_g) : Fraction of the parton (gluon) of the total p-momentum in the QPM

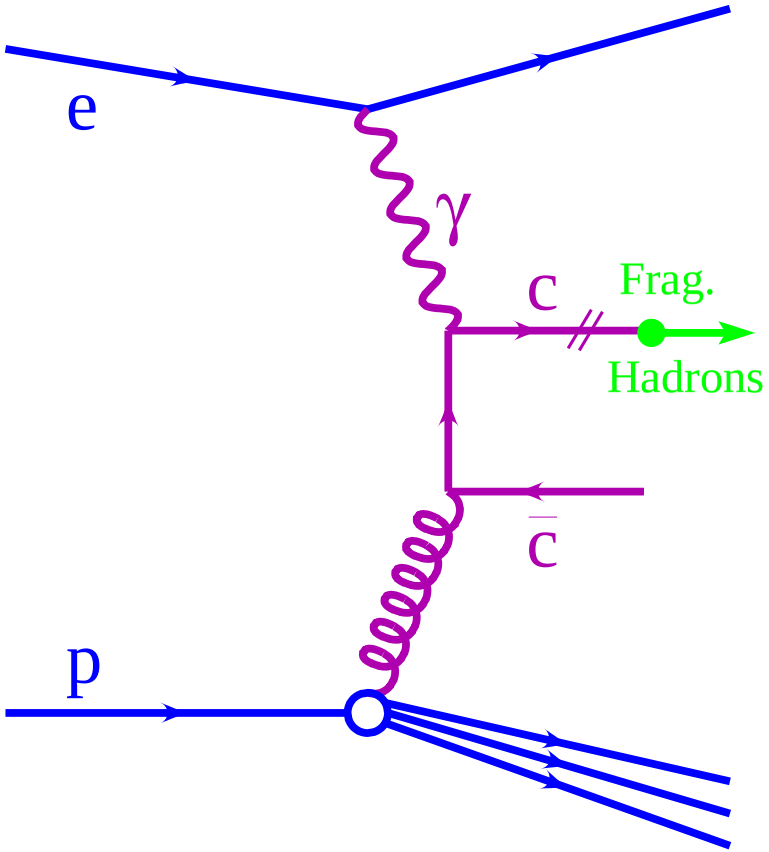
$$x = Q^2 / (2 \cdot P \cdot q)$$

Two kinematic regimes:

- $Q^2 \to 0$ GeV^2: Photoproduction (γp)
- $Q^2 \gtrsim 2$ GeV^2: Electroproduction (DIS)

Production of Heavy Quarks at HERA

Dominant process (PhotonGluonFusion):



Fragmentation:

◇ Universality

p structure:

◇ Proton structure function: F_2^c

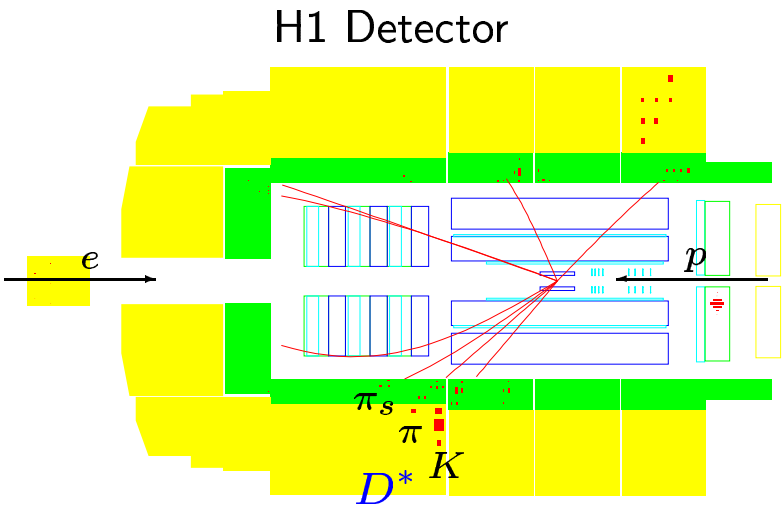
Production mechanism:

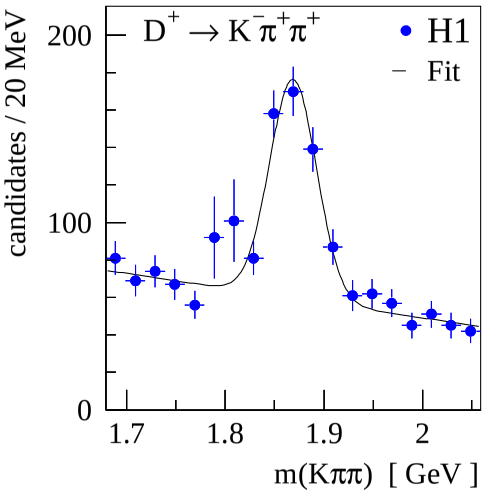
◇ Contributing processes

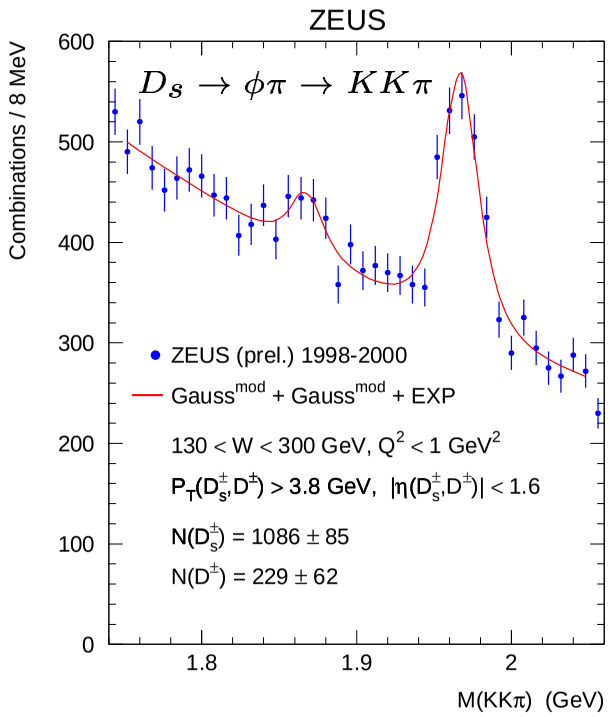
Factorisation:

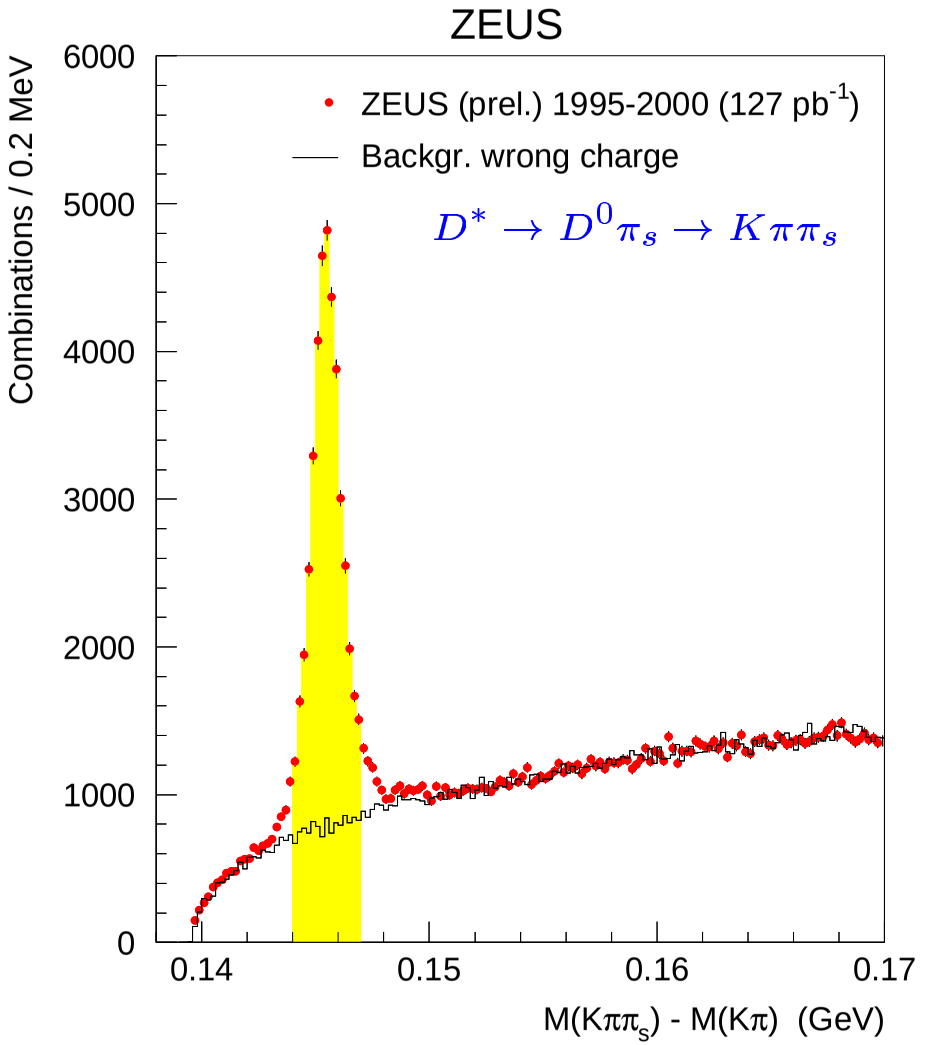
p structure ⊗ **hard process** ⊗ **fragmentation**

Charm Tagging



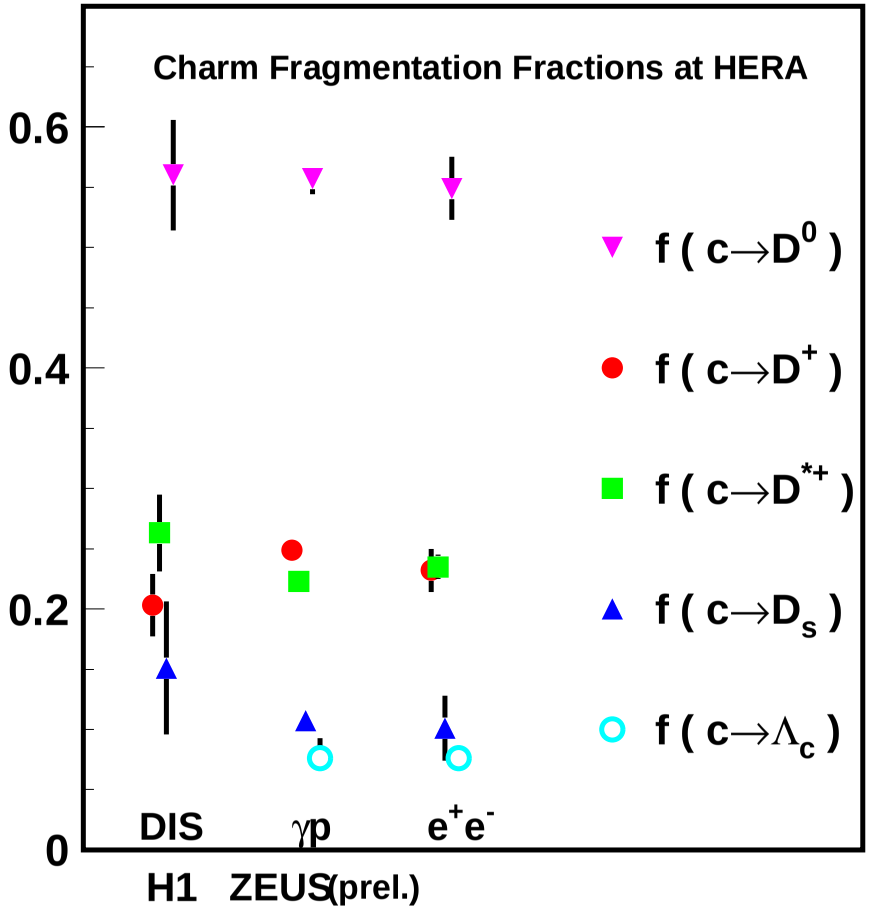


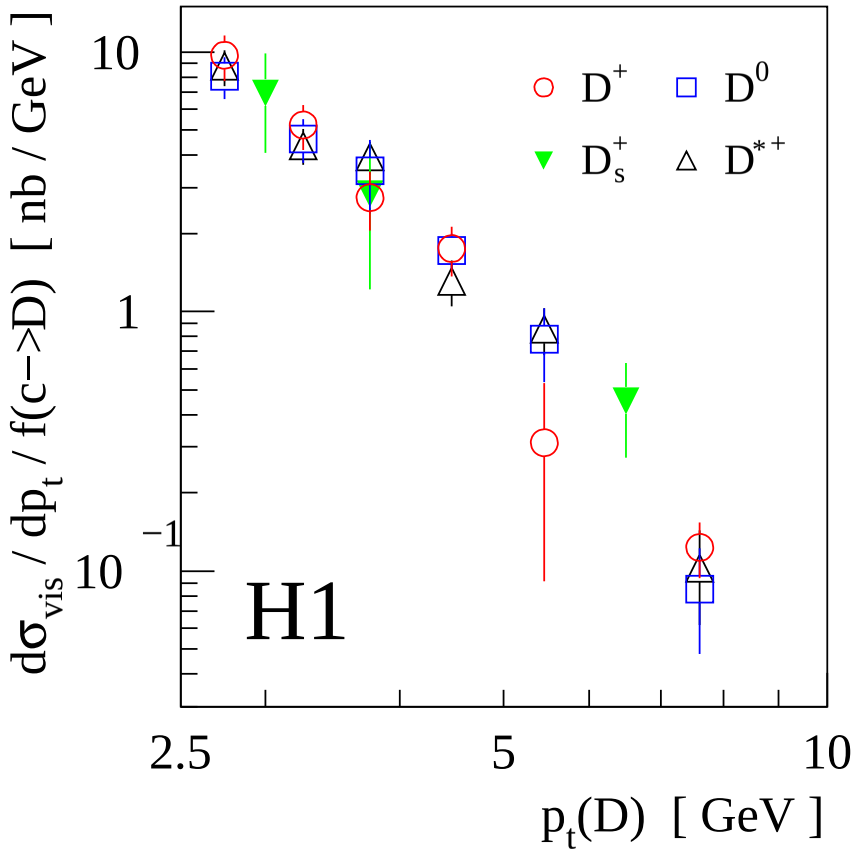




Charm Fragmentation

Reconstruction of charmed mesons: $D^{\pm}$, D^0, $D_s^{\pm}$, $D^{*\pm}$, ($\Lambda_c^{\pm}$, ZEUS only)



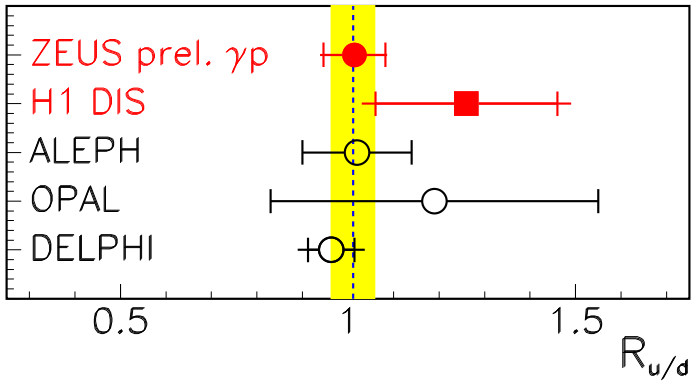


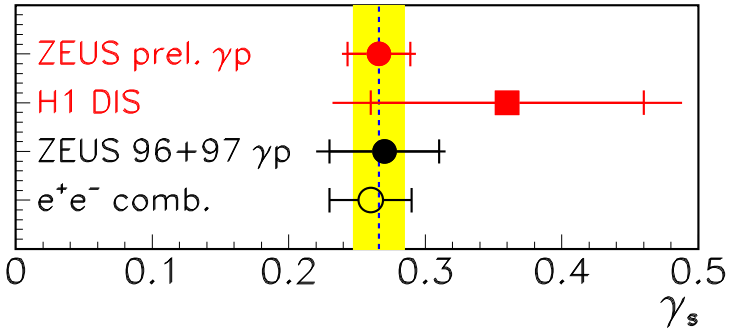
Similar shapes for different D mesons

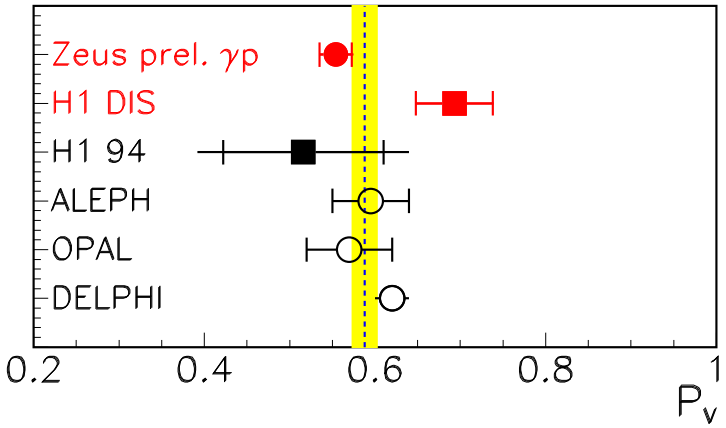
Universal fragmentation ansatz reasonable

(independent of hard scat. process and of c prod. scale)

Fragmentation Ratios







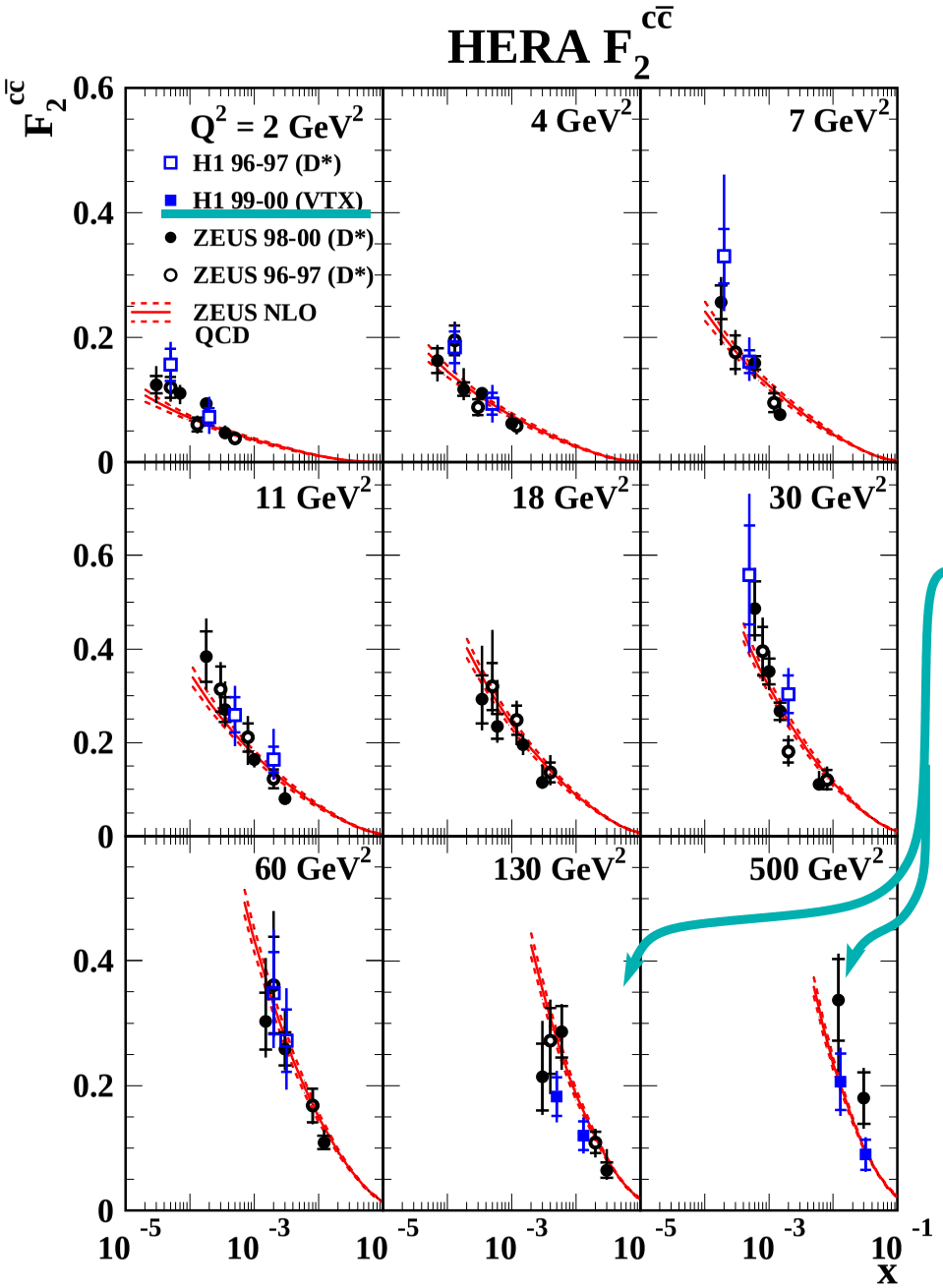
- $R_{u/d} = c\bar{u}/c\bar{d}$
  Ratio of u to d
- ▷ $R_{u/d} \sim 1 \rightarrow$ Confirmation of isospin invariance

- $\gamma_s = 2c\bar{s}/(c\bar{u} + c\bar{d})$
  Strangeness suppression factor (u:d:s=1:1:γ_s)
- ▷ s suppressed by a factor 3-4

- $P_v = VM/(VM + PS)$
  Fraction of D mesons produced as VM
- ▷ Naive spin counting ($P_v = 3/4$) does not work

Good agreement between data and world average
Precision comparable with LEP (DELPHI)

Charm contribution to F_2: $F_2^{c\bar{c}}$



F_2: Proton structure function

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

D^* cross section in visible range
$\rightarrow$ Large extrapolation

Inclusive c tagging (vertex detector, VTX)
$\rightarrow$ Almost no extrapolation

- Agreement between data and ZEUS NLO QCD fit over a wide rang in Q^2 and x
- Prediction of charm contribution to F_2 from scaling violations is consistent with $F_2^{c\bar{c}}$ measurement

Modelling Heavy Quark Production

pQCD calculations in NLO: (DGLAP evolution used for PDF's)

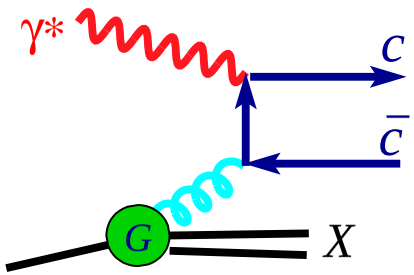
◇ Fixed order *massive* scheme (scale $\mu^2 \approx m_Q^2$)

γp: FMNR (Frixione et al.)
DIS: HVQDIS (Harris et al.)

μ^2

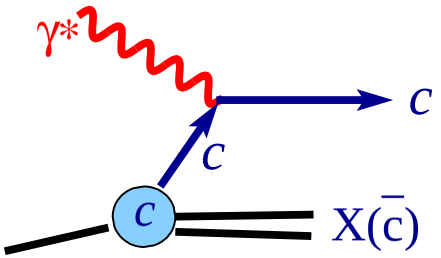
◇ *Massless* scheme ($\mu^2 >> m_Q^2$)

γp: Cacciari et al., Kniehl et al.



◇ *Matched* scheme (FONLL)

Cacciari et al.



MC generators: (LO matrix element + parton showers)

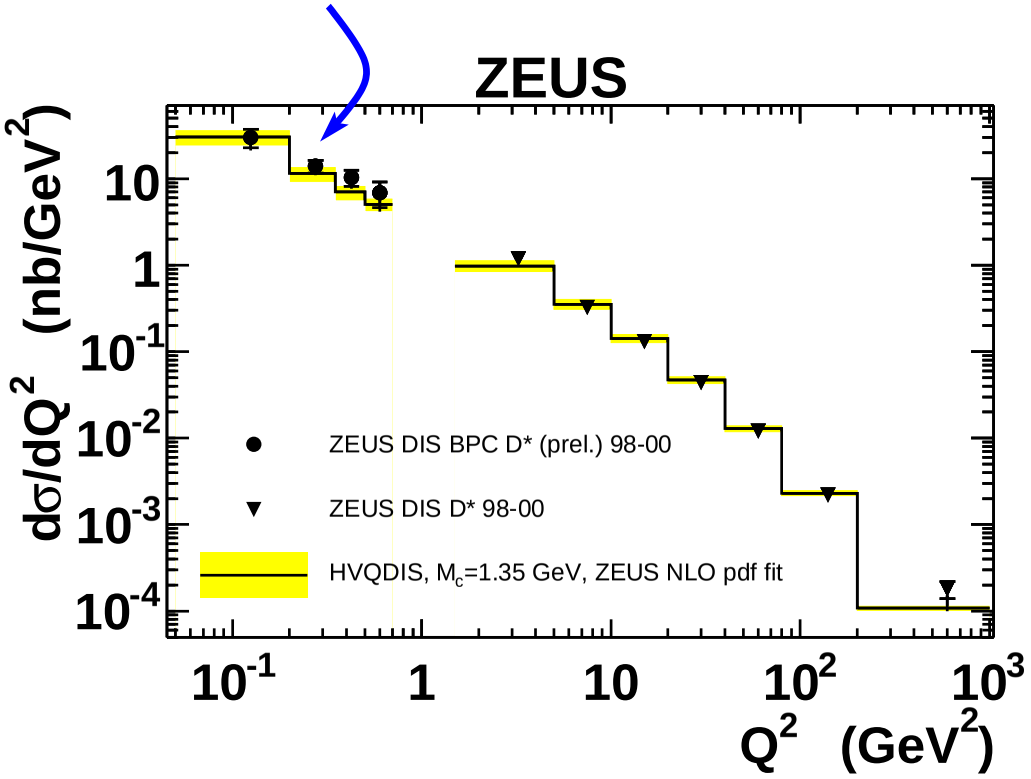
◇ PYTHIA (DGLAP evol.), CASCADE (CCFM evol.)

Evolution models for PDF: (PDF known at $\mu_0^2 \rightarrow$ PDF at μ^2)

Inclusive D^* Events

DIS and Photoproduction

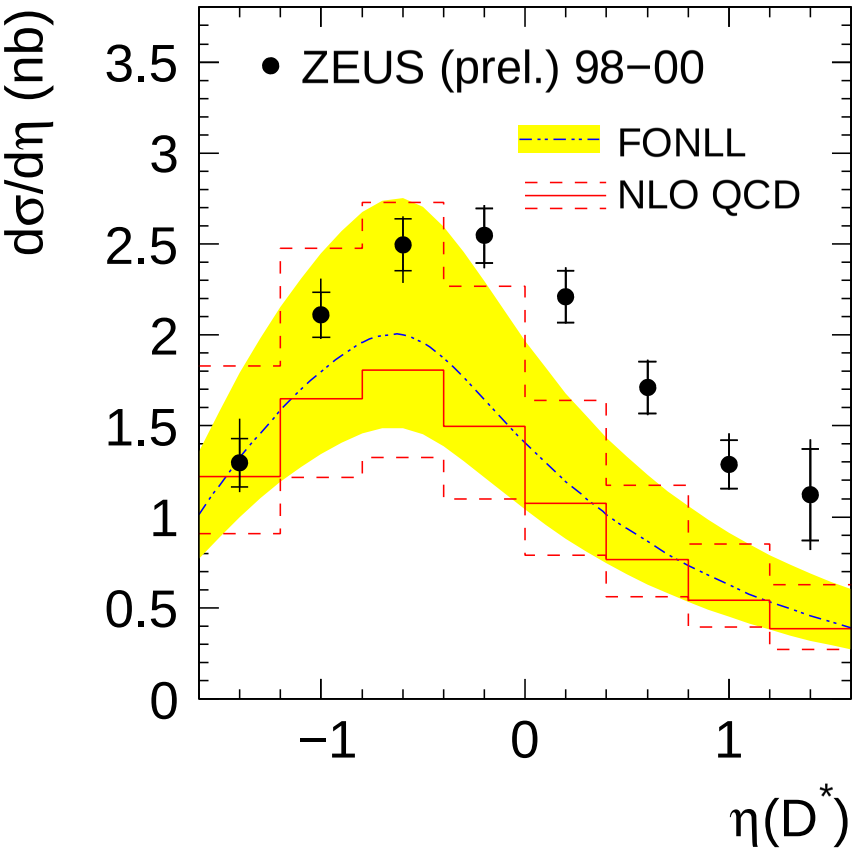
Extension of Q^2 distribution towards low values using the beam pipe calorimeter (BPC)



◇ Massive NLO calculation consistent with data

Photoproduction

$3.25 < p_T(D^*) < 5$ GeV



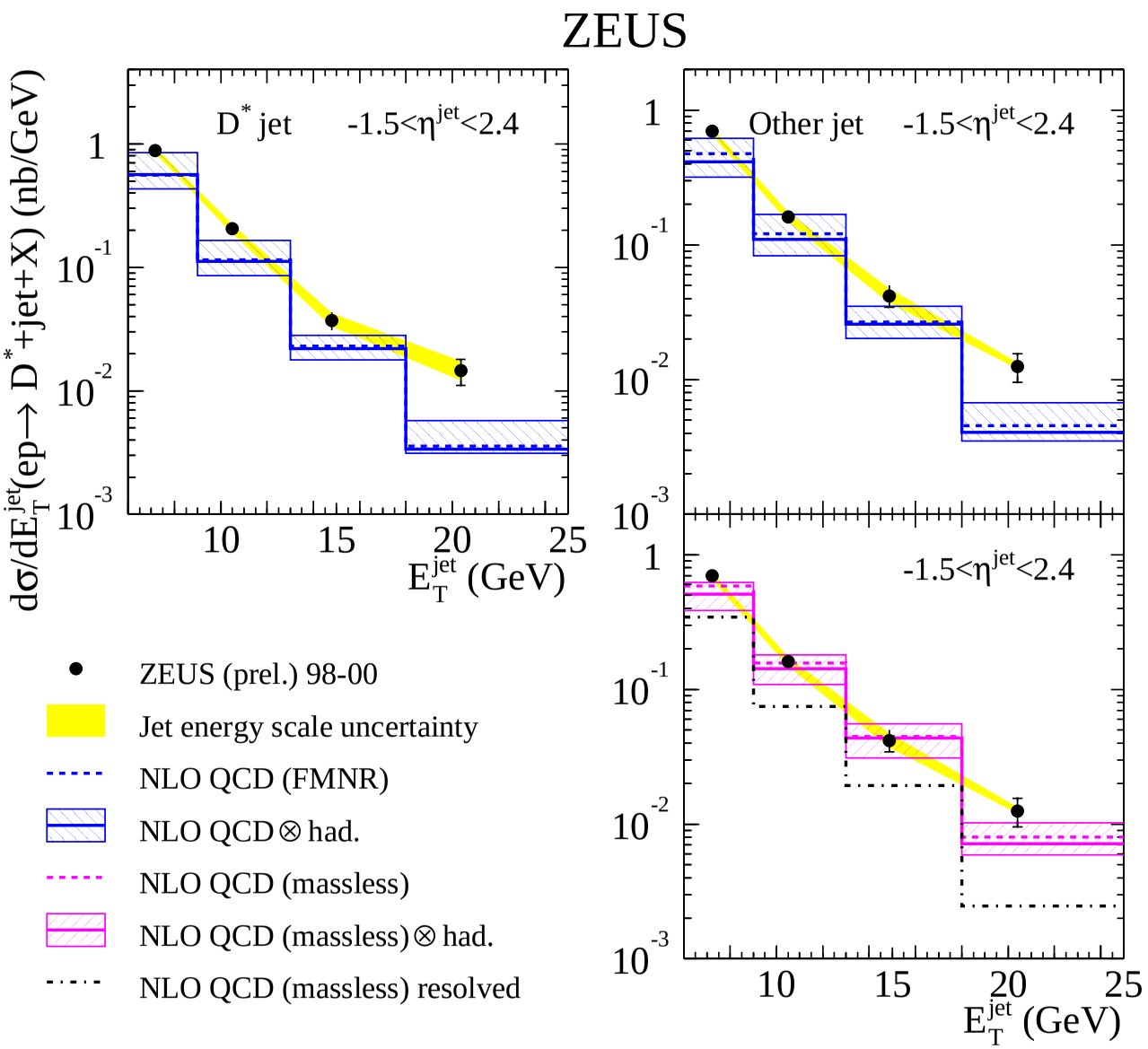
◇ Massive and matched (FONLL) NLO calculations do not describe all details of the data

D^*+ Jet in Photoproduction

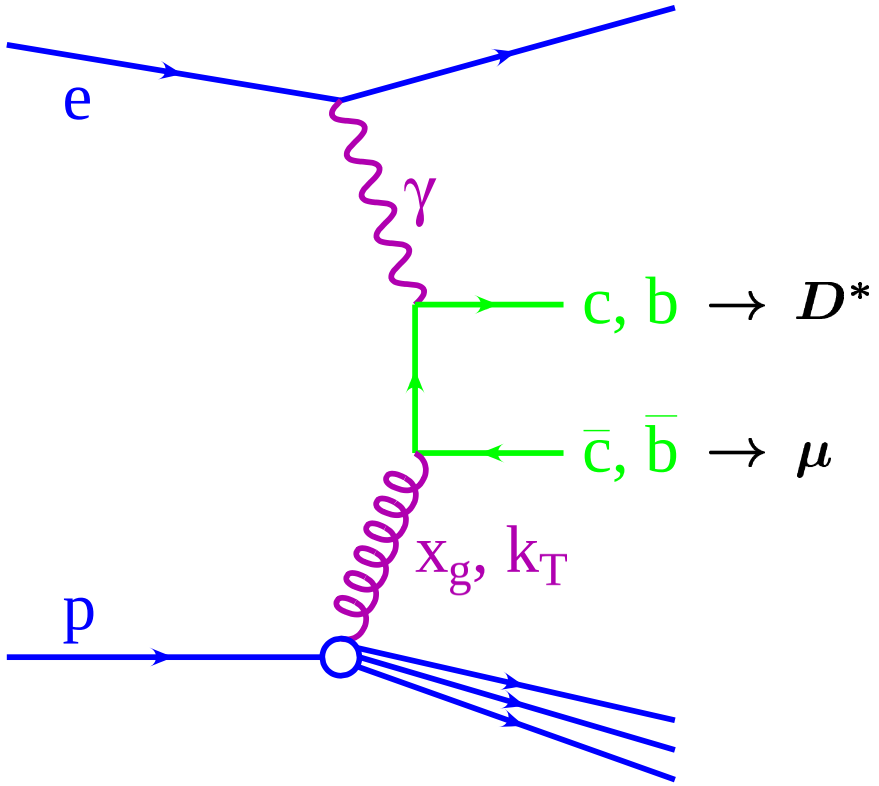
- Jet requirement $\rightarrow$ Additional scale E_T^{jet}
- **At high E_T^{jet}:**

  'Massive' NLO calculation below data

  'Massless' NLO calculation better here
- Theories have large uncertainties



Double Tag - D^* + muon



◇ Require muon in addition to D^*

◇ **Charge and angle correlation:**

▷ Separation of charm and beauty
(not shown)

▷ Selection of double tagged events
(90% charm, 10% beauty)

◇ **Double tag:**

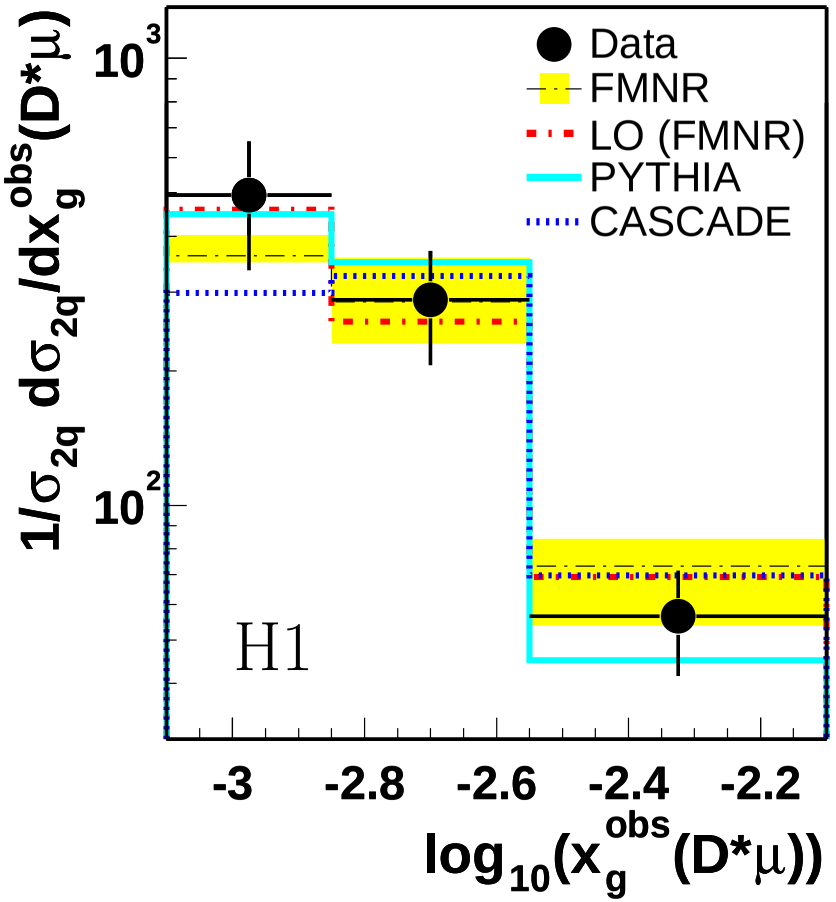
▷ Sensitiv to details of production mechanism
(e.g. NLO effects - LO: $p_T(Q\bar{Q}) = 0$)

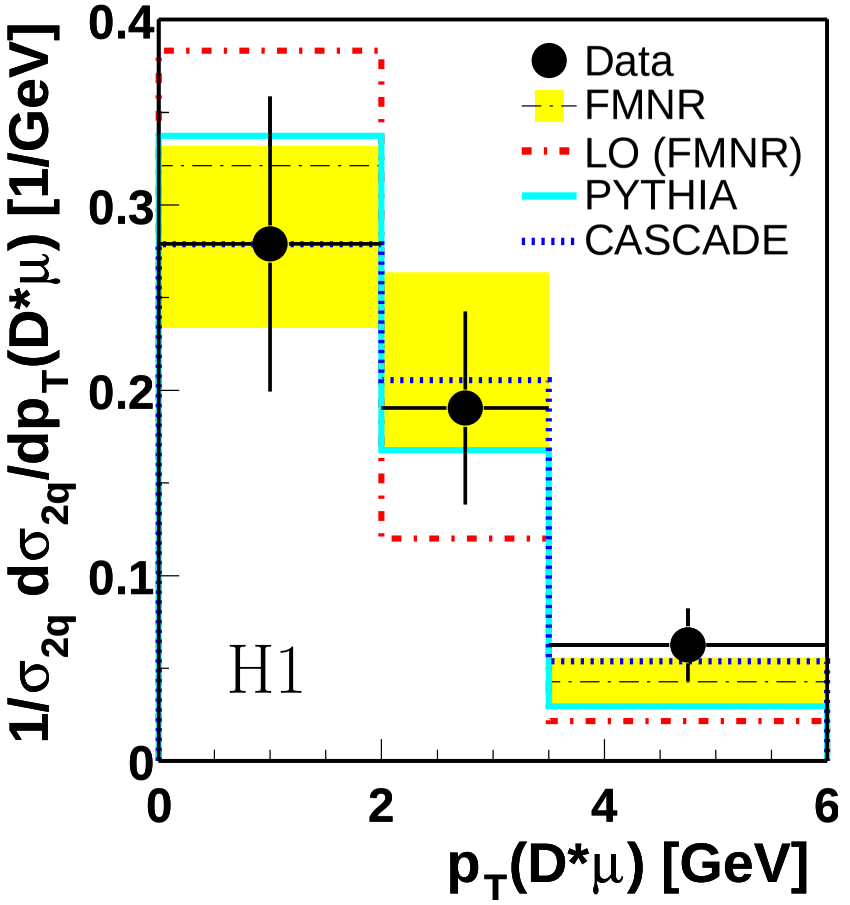
▷ Correlation between $D^*\mu$ and $Q\bar{Q}$

$x_g^{obs}(D^*\mu) = M^2(D^*\mu) \cdot x/Q^2$ approximates x_g well

Correlation between $p_T(D^*\mu)$ and k_T worse

D^* + muon in Photoproduction





- All calculations give a reasonable description of the data
- LO FMNR is too soft, while NLO FMNR fits the data well
- Differences between PYTHIA (DGLAP evol.) and CASCADE (CCFM evol.) small

Summary

- **Fragmentation - fractions and ratios:**
  - Fragmentation of charm is independent of the hard physics

- **Proton structure - $F_2^{c\bar{c}}$:**
  - c contribution to F_2 predicted from scaling violations consistent with $F_2^{c\bar{c}}$ measurement $\rightarrow$ QCD does a good job

- **Production mechanism:**
  - D^* ($+$ Jets) in photoproduction:
    NLO QCD calculations have some problems to describe data
  - D^* $+$ muon - double tag:
    NLO effects clearly seen