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Gluons at high x in Nuclei at EIC

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Jefferson Lab

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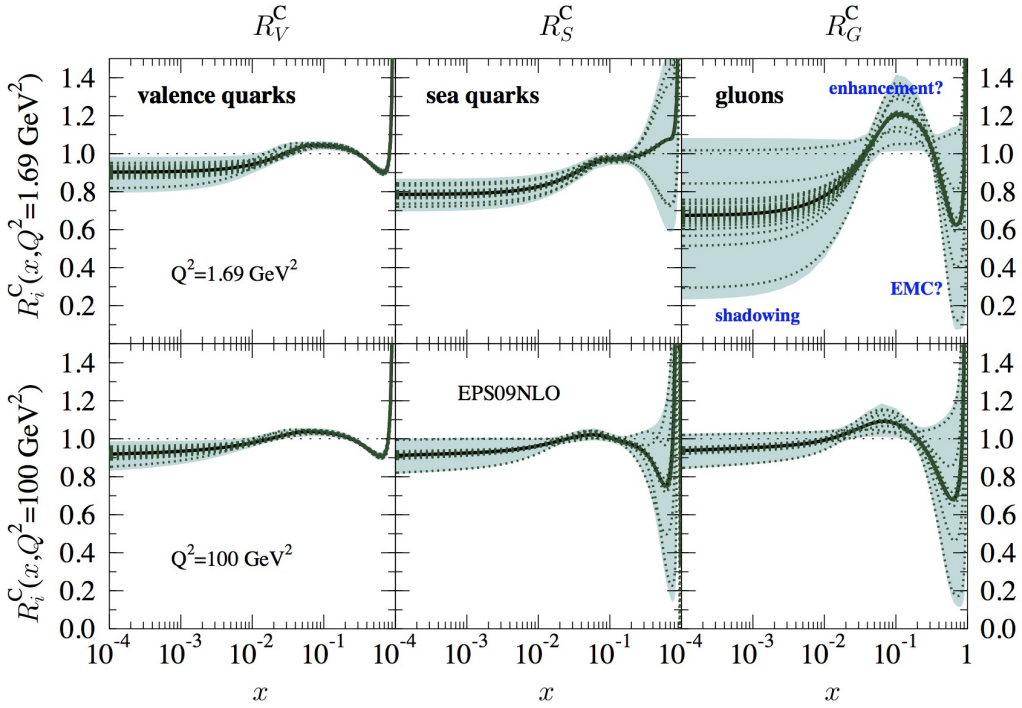
Outline

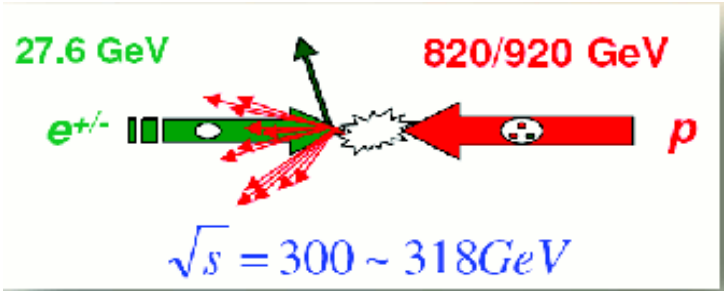
- *Motivation*
- *HERA and ZEUS experience*
- *EIC charm simulation*
- *Detector requirements*
- *Conclusion*

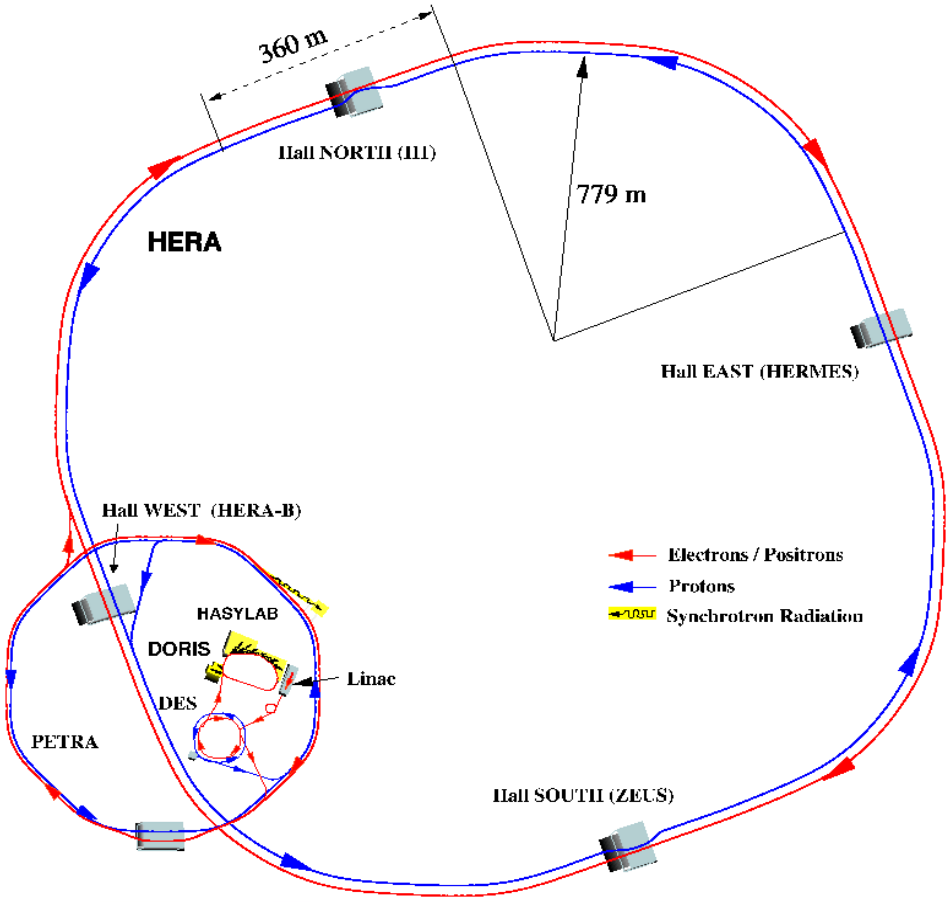
Introduction

- *A medium-energy Electron-Ion Collider (EIC) would enable the first direct measurements of the gluon density in nuclei at x >~ 0.1 using heavy quark production (charm, beauty).*
- *Such measurements could answer two outstanding questions regarding nuclear modifications of the nucleon's gluonic structure:*
  - Is the nuclear gluon density suppressed at x > 0.3 ?
  - What is the quark/gluon structure of the nuclear enhancement at x ~ 0.1?
- *This work is started to demonstrate the feasibility of direct measurements of nuclear gluons with heavy quark production at EIC.*



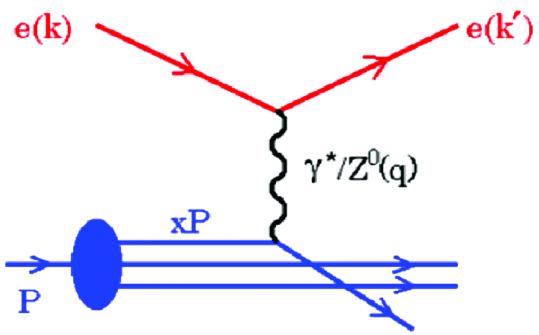
HERA and ZEUS



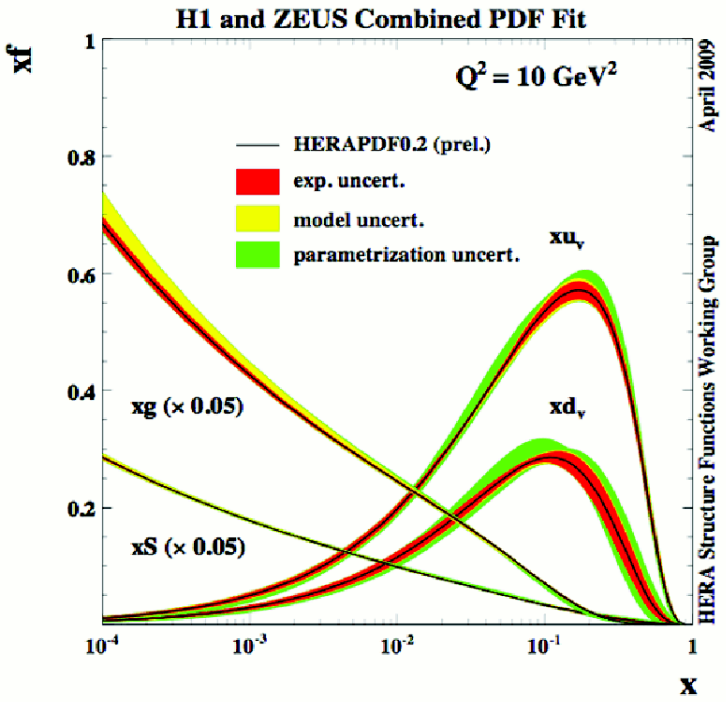


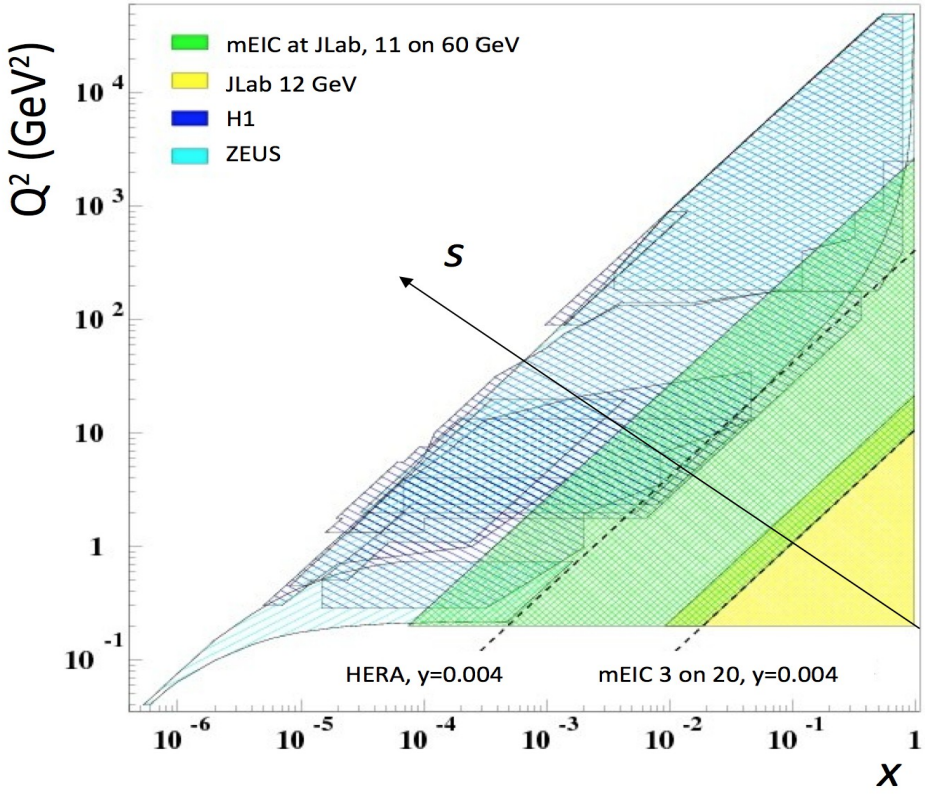
- *The HERA (Hadron-Electron Ring Anlage) machine is the world's first lepton-nucleon collider (Hamburg, Germany)*
  - ~6.3 km circumference
  - 27.5 GeV electrons
  - 920 GeV protons
  - CM energy=318 GeV
  - 180 bunches,
  - Bunch crossing = 96 ns
  - Collected 0.5 fb^{-1} of data
  - Luminosity ~$3*10^{31}$ cm^{-2} s^{-1}

HERA and EIC kinematics



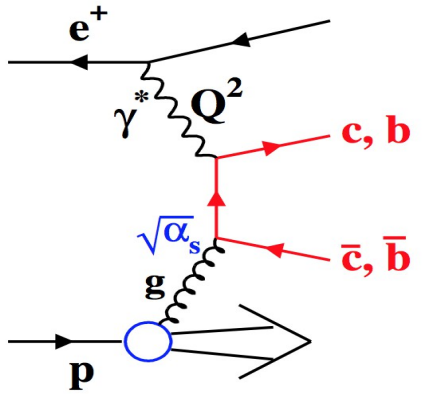
- *HERA, with its center-of-mass energy of 320 GeV, was built to search for quark substructure.*
- *HERA data provide the most insight into the behavior of unpolarized parton distribution functions.*
- *An EIC, with its scientific focus on studying QCD in the regime where the sea quarks and gluons dominate, would have a lower CM energy.*
- *EIC kinematic range overlaps both JLAB and HERA experiments .*





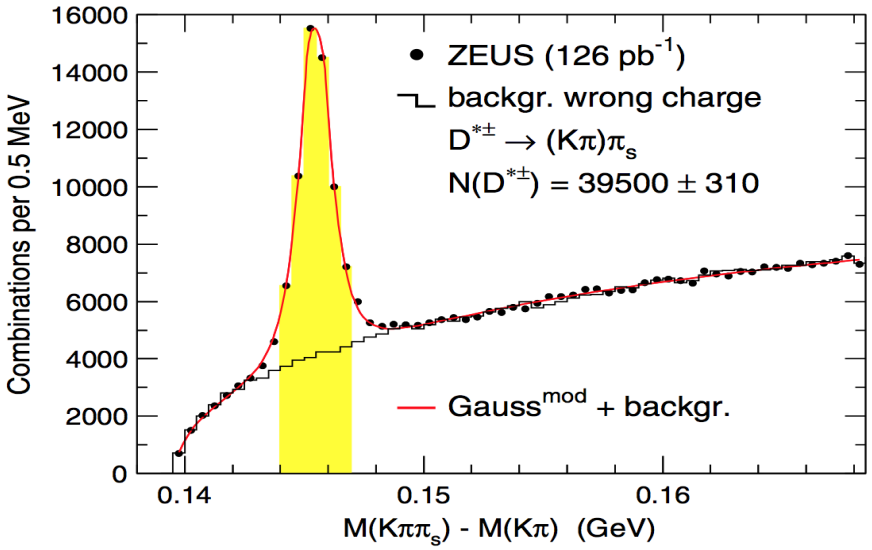
Charm production in DIS at HERA

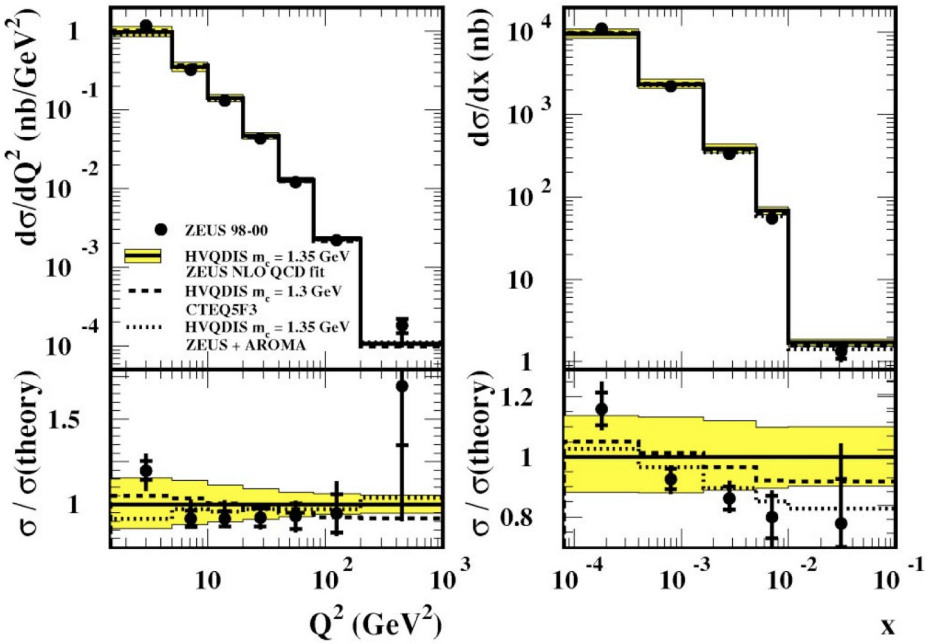
- *In leading order, heavy quarks are produced in ep collisions via the Boson Gluon Fusion (BGF) process.*
- *This process provides direct access to the gluon density in the proton.*
- *Due to the large gluon density in the proton, the BGF processes gives large contributions to DIS :*
  - The cross section obtained is: 8.44 nb.
  - The prediction from the HVQDIS program is 8.41 nb
- *The 'golden' decay channel :*



$$D^{*+} \rightarrow D^{o}\pi_{s}^{+} \ , \ D^{o} \rightarrow K^{-}\pi^{+}$$

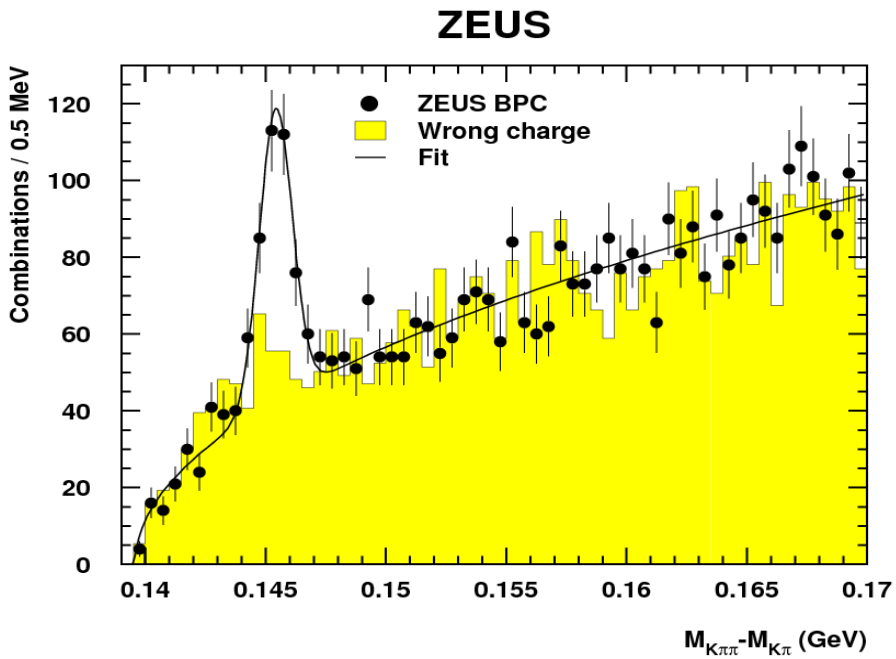
Chekanov, S., et al. (ZEUS Collaboration), 2009i, Eur. Phys. J. C 60, 25.



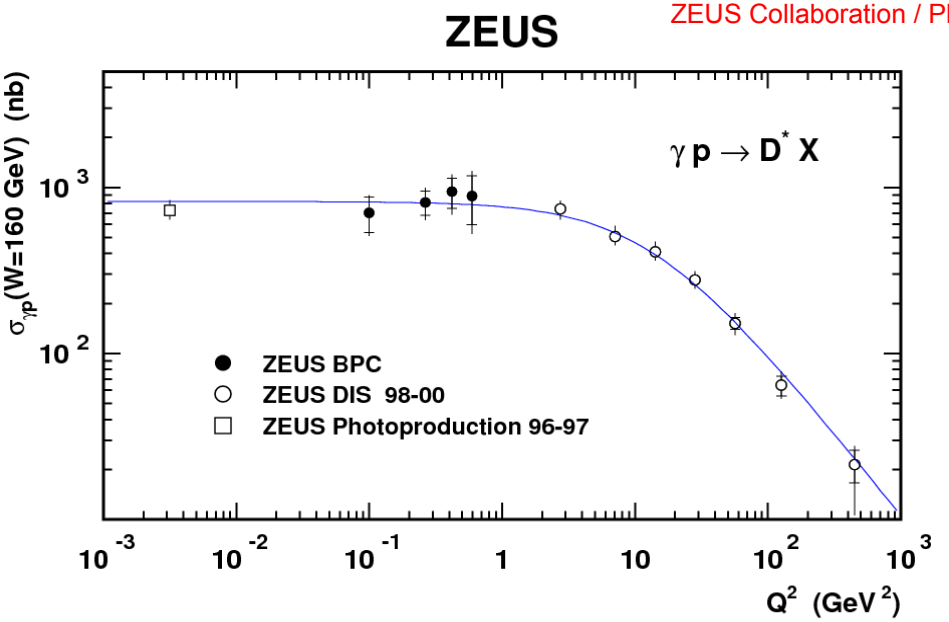


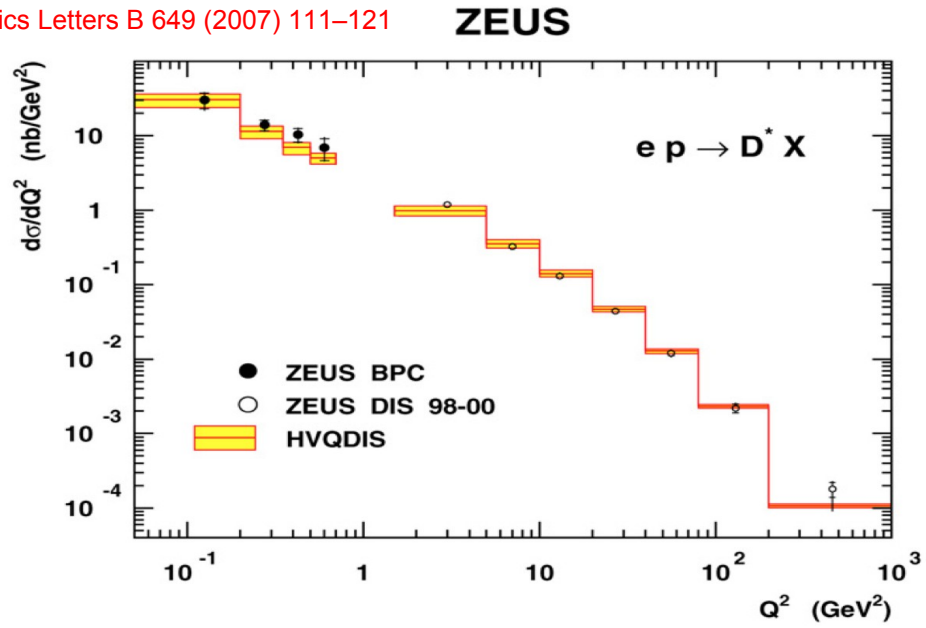
Charm production at low Q^2

- *Inclusive photoproduction ($Q^2 \sim 0$) of D mesons and charm production in the transition region between DIS and photoproduction has been measured with the ZEUS detector at HERA.*
- *The HVQDIS calculation produces a good description of the measured data.*
- *In particular, NLO QCD describes the dependence on Q^2 of the data over 4 orders of magnitude in Q^2 .*
- *The measurements, converted to γp cross sections, also agree well with the D* photoproduction data.*



ZEUS Collaboration / Physics Letters B 649 (2007) 111–121





HVQDIS for EIC

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HVQDIS program calculates the differential D–meson production cross section using the NLO QCD approximation, implemented heavy quark fragmentation functions, and nucleon parton densities and permits MC integration over phase space.

B. W. Harris and J. Smith, Phys. Rev. D 57, 2806 (1998) [hep-ph/9706334].

- *Renormalization Factorization scale :* $\mu_R = \mu_F = \sqrt{Q^2 + 4m_c^2}$
- *ZEUS PDF has the following parameter settings: 3 quark flavours,*
  - $M_c = 1.35\ GeV,\ M_b = 4.3\ GeV,\ \Lambda_{QCD} = 0.363\ GeV$
  - $\mu_R^2 = \mu_F^2 = Q^2$
- *Energy of proton :* *50 GeV (250 GeV)*
- *Energy of electron :* *10 GeV (20 GeV)*
- *Kinematic region :*
  - $0.05\ GeV^2 < Q^2 < 1000\ GeV^2$
  - $0.01 < y < 0.95$
  - $0.5\ GeV < P_t < 10\ GeV$
  - $|\eta| < 4$
- *Peterson fragmentation :* $\epsilon = 0.035$
- *Hadronization fraction :* *0.235*

HVQDIS for *ep* at EIC

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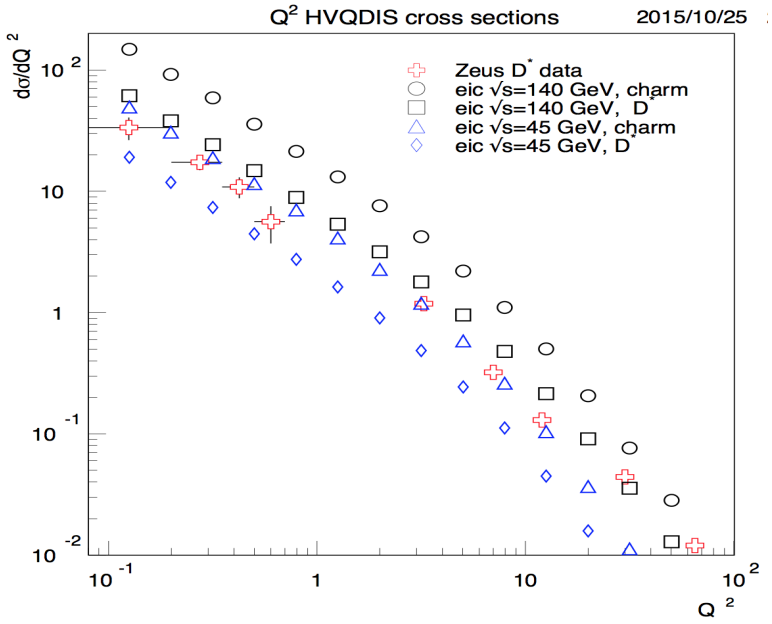
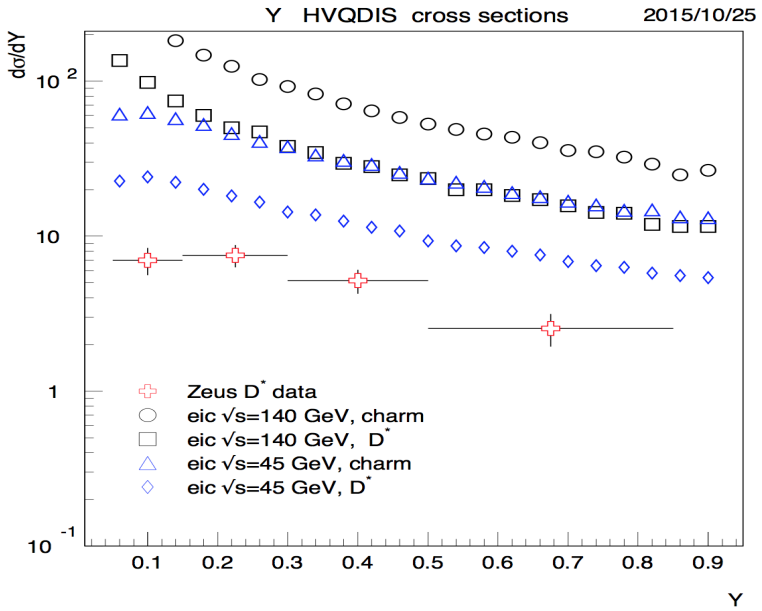
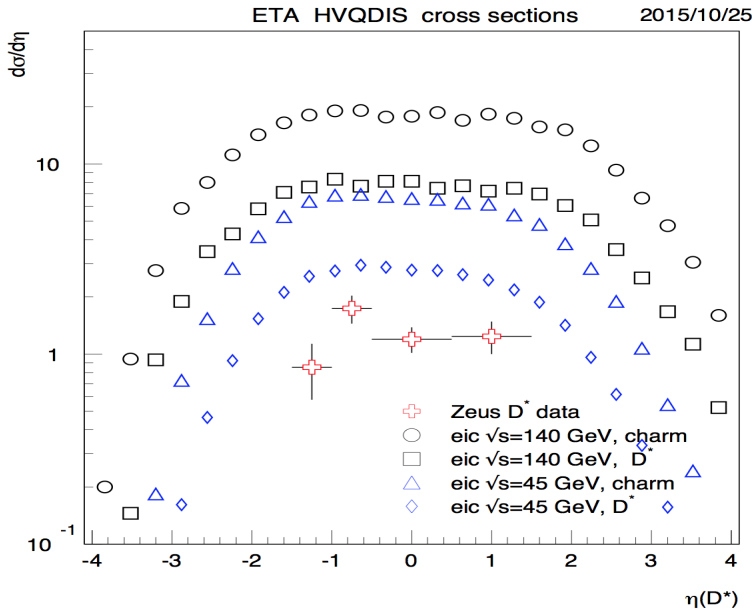
Calculation is done for 2 ep energies of EIC:

- *Ee=10 GeV , Ep=50 GeV :*
  - Total charm cross section : 28 nb
  - Total D* cross section : 11 nb
- *Ee=20 GeV , Ep=250 GeV :*
  - Total charm cross section : ~93 nb
  - Total D* cross section : ~38 nb
- *Zeus data are shown for different kinematic region :*
  - for estimation only







HVQDIS for *ep* at EIC

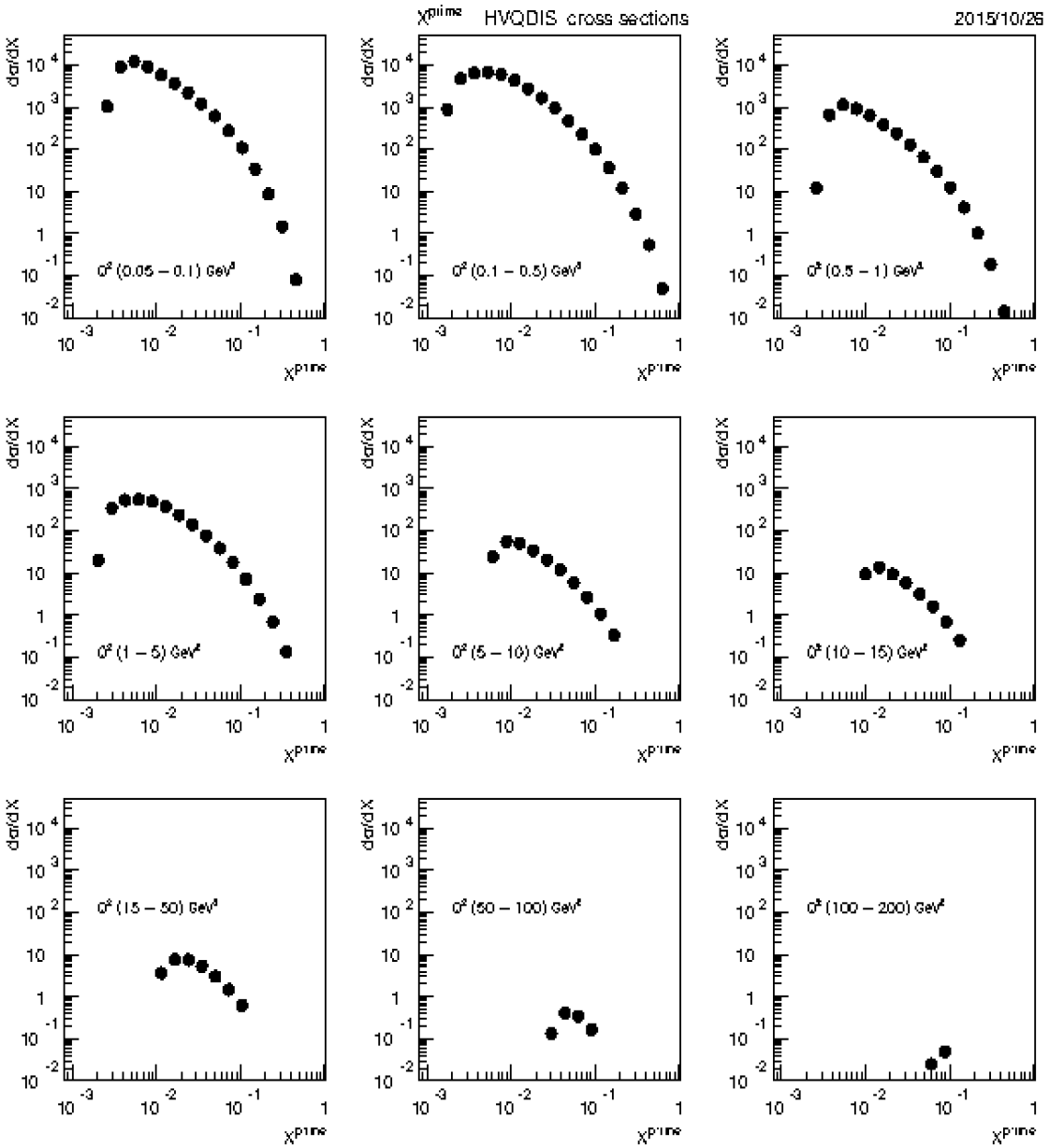
- *BGF process probes the gluon density in the target at light-cone momentum fractions :*

  $x' > x\,(1 + 4\,Mc^2/Q^2)$

  where x is the Bjorken variable and Mc^2 *the heavy quark mass.*

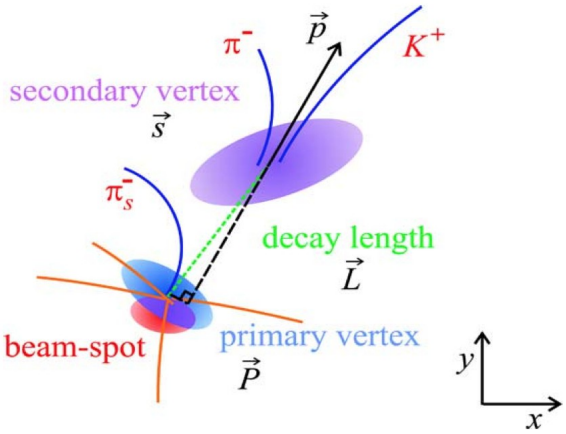
- *Calculation for dσ/dx is done for x'*

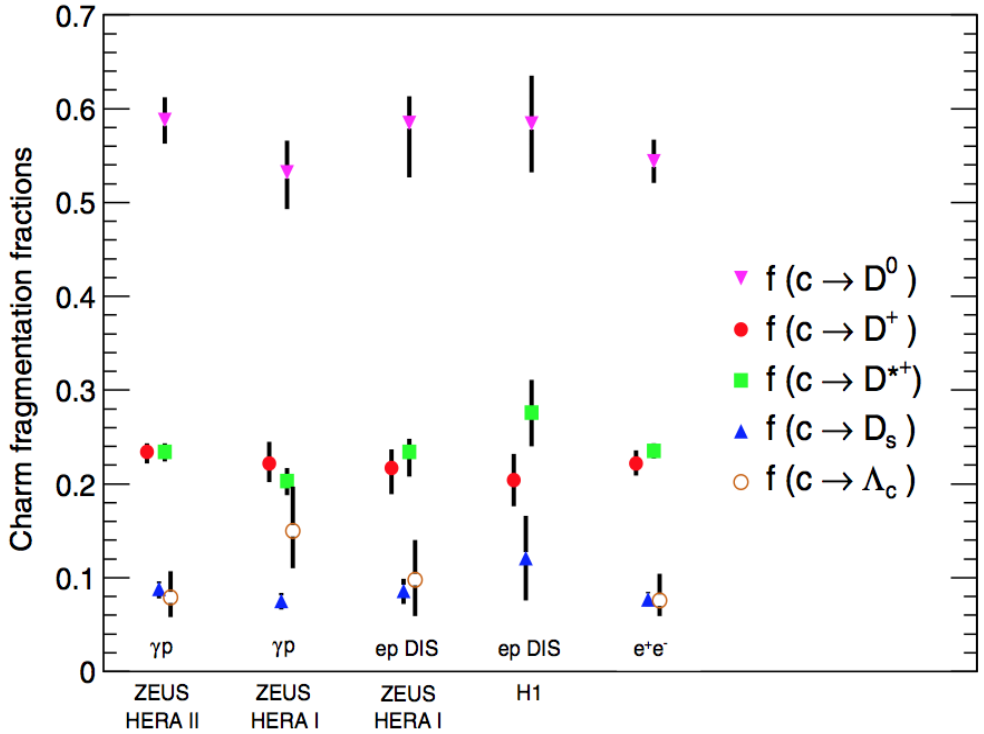
- *The results show good sensitivity to the gluon density even at x' > 0.1.*



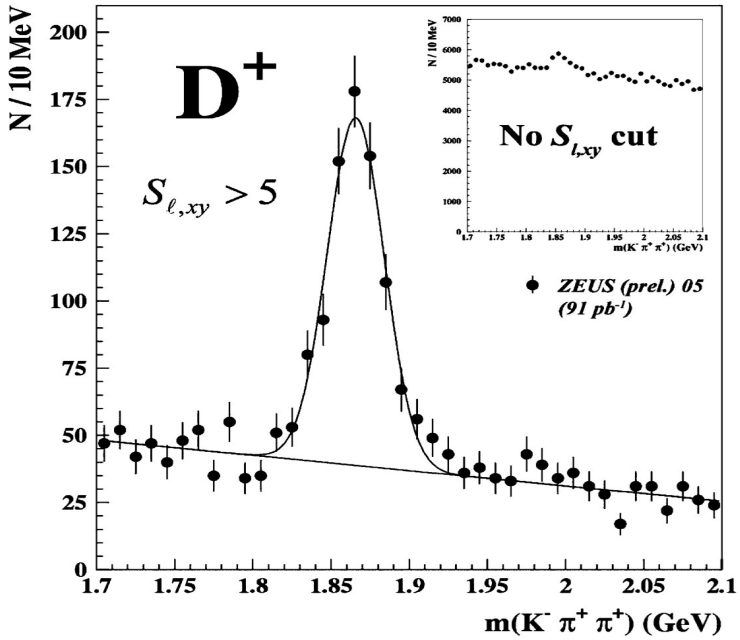
Other charmed mesons

- *Charm fragmentation to other mesons is measured.*
- *However reconstruction most of them require microvertex to resolve primary and secondary vertices.*
- *Right-bottom plot shows reconstruction of D+ with microvertex and without.*





Abramowicz, H., et al. (ZEUS Collaboration), 2013b, J. High Energy Phys. 09, 058.



N. Coppola, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 54, NO. 5, OCTOBER 2007

Conclusion

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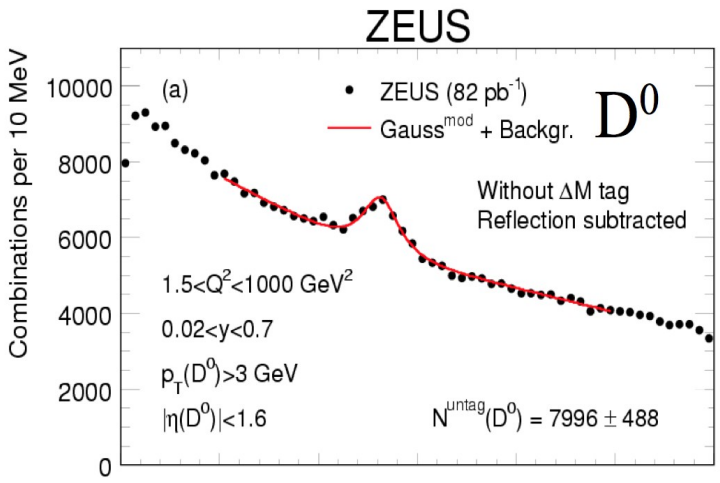
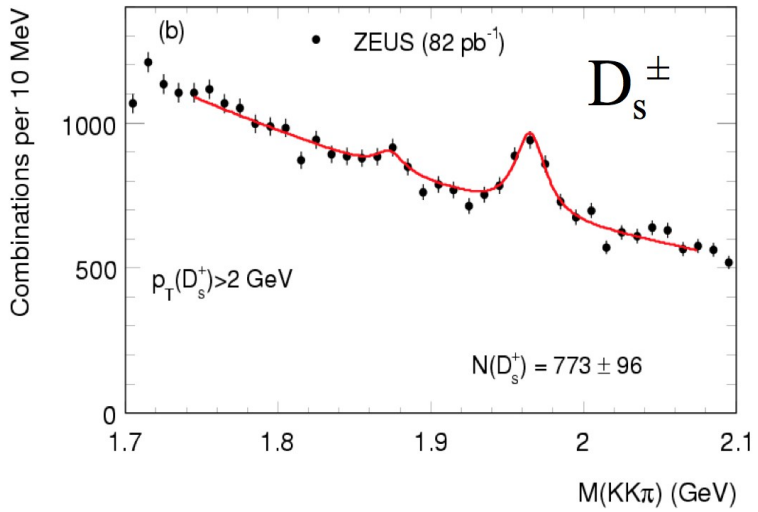
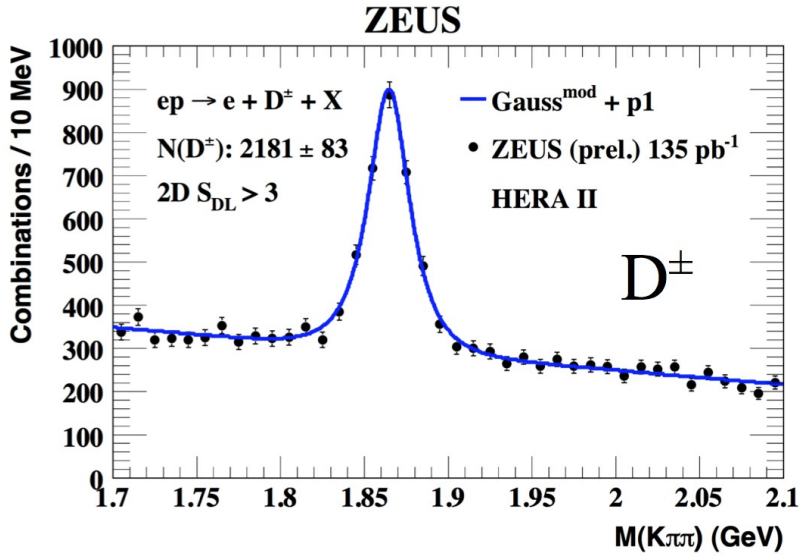
- *Direct measurements of the gluon density in nuclei at x >~ 0.1 using heavy quark production (charm, beauty) could answer several outstanding questions regarding the nuclear modifications of the nucleon's quark / gluon structure.*
- *BGF framework yields a very good description of all available HERA data within the present uncertainties and is expected to be relevant also in the entire kinematic regime of an EIC.*
- *HVQDIS program has a good performance for HERA data and can be adjusted for EIC calculation :*
  - to demonstrate the feasibility of direct measurements of nuclear gluons with heavy quark production at EIC
  - delineate the detector and accelerator requirements specific to this channel, and quantify the physics impact.
  - the first results for e/p at EIC confirms good prospects for charm measurements.
- *The next step is to adjust the program for heavy ions at EIC.*
- *Charmed mesons can be identified via a displaced vertex. This can be achieved by integrating a high-resolution vertex detector into the detector design.*

Backup Slides

Other charmed mesons







H1 and ZEUS combined data

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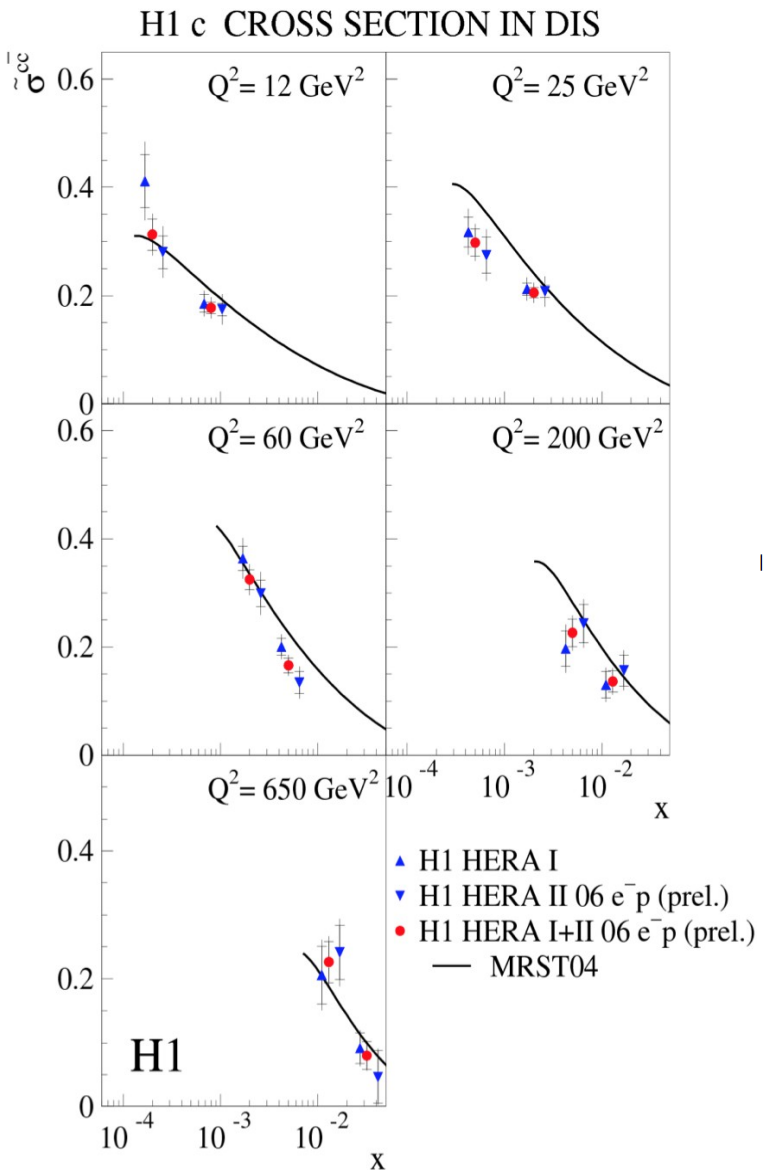
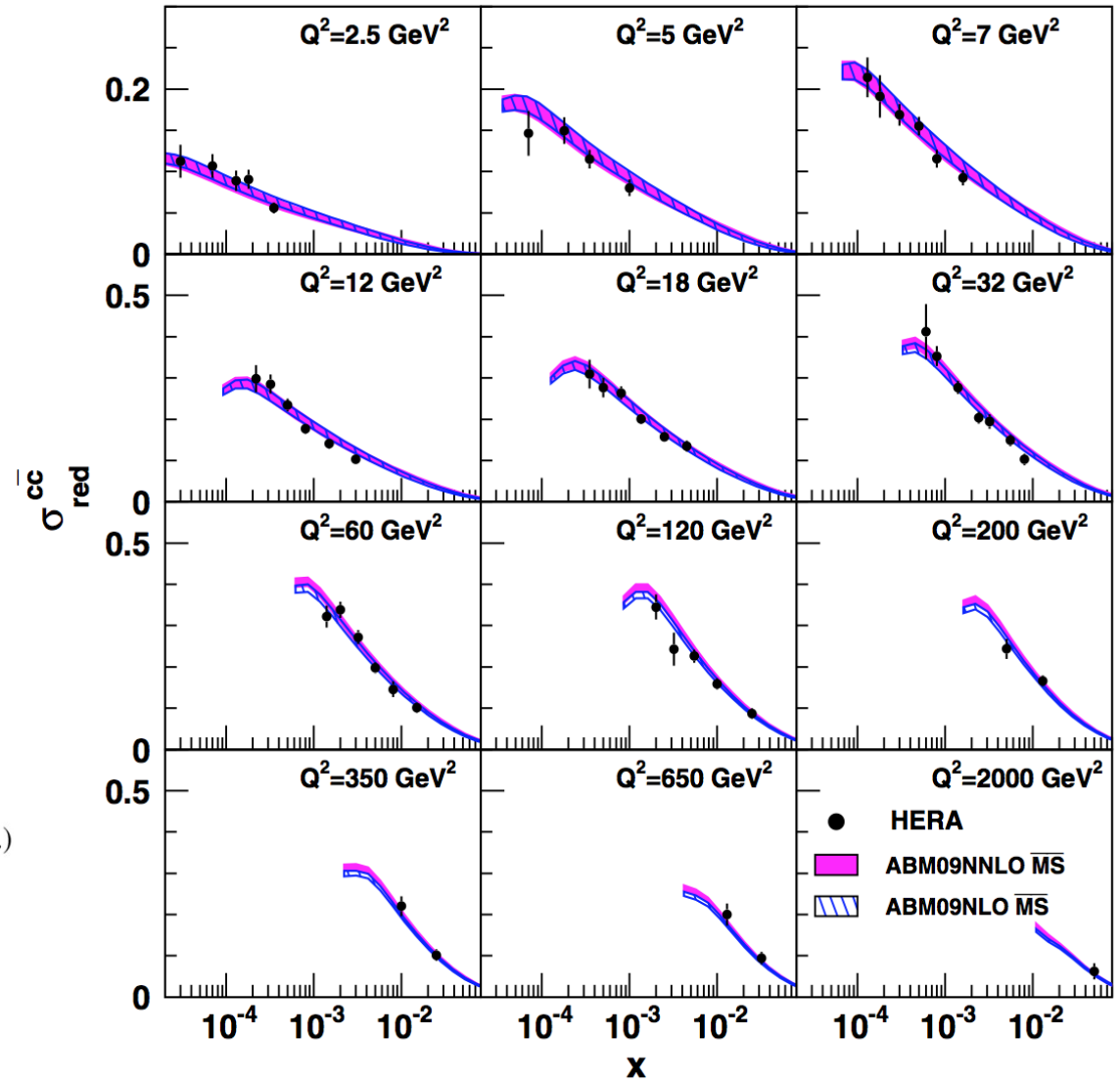
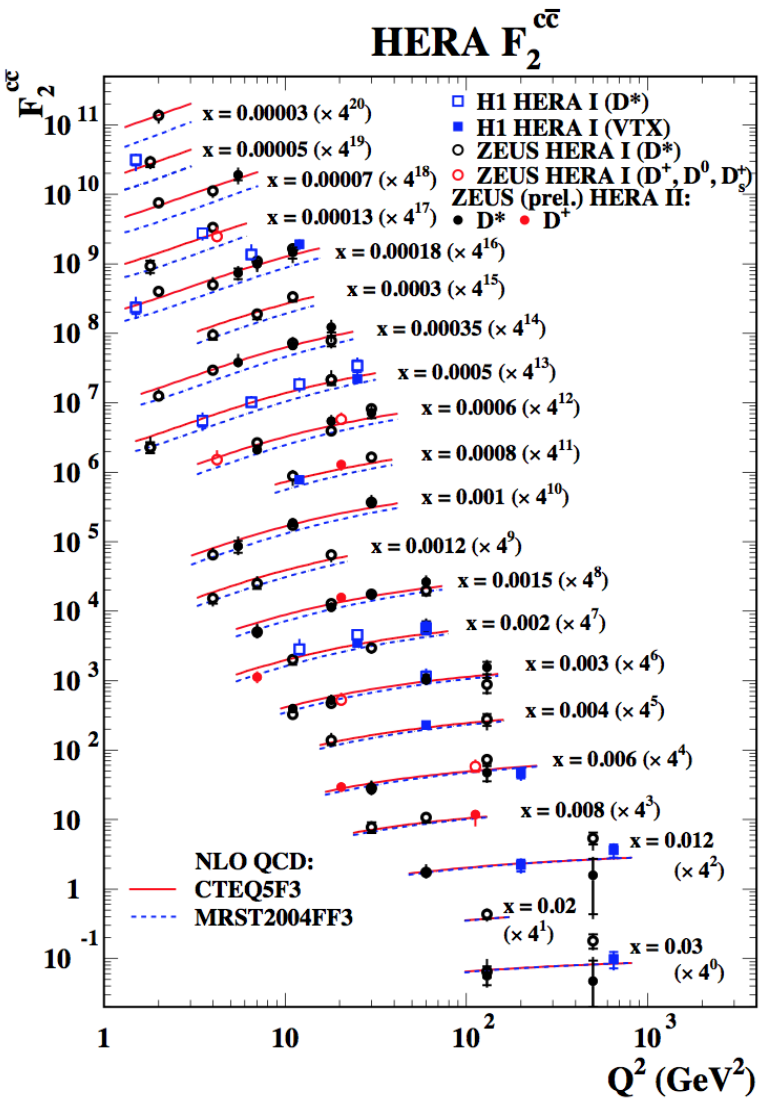
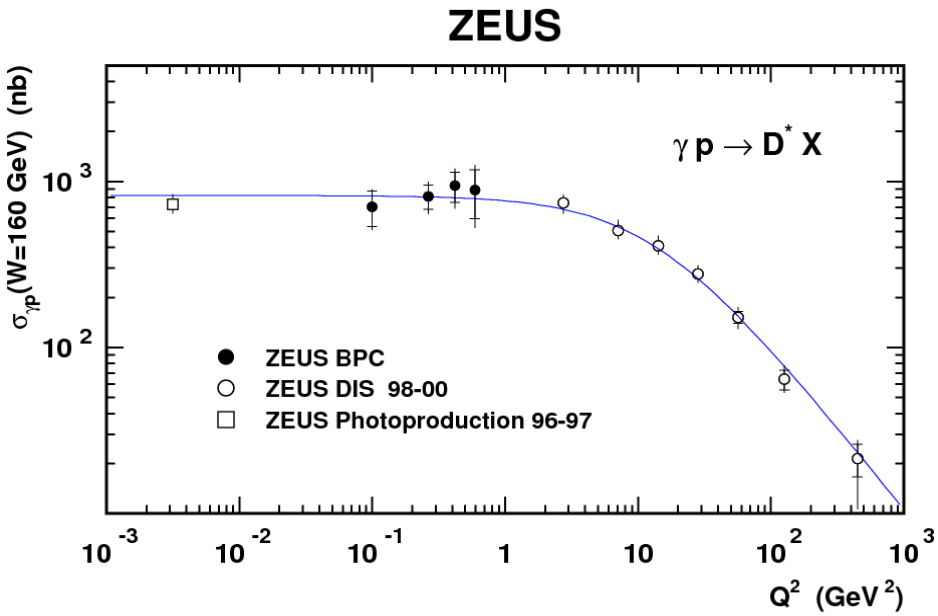
Rev. Mod. Phys., Vol. 86, No. 3, July–September 2014



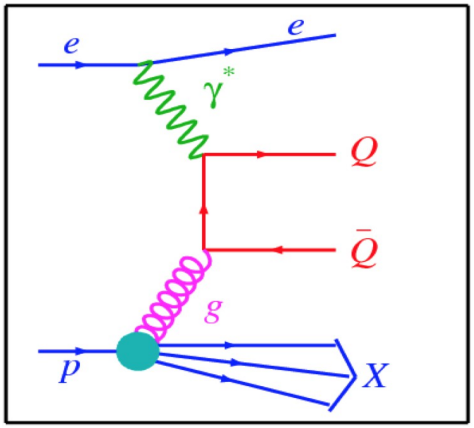


Charm production in ep scattering at HERA

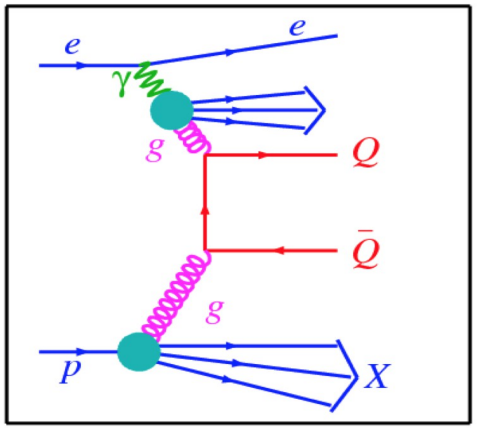




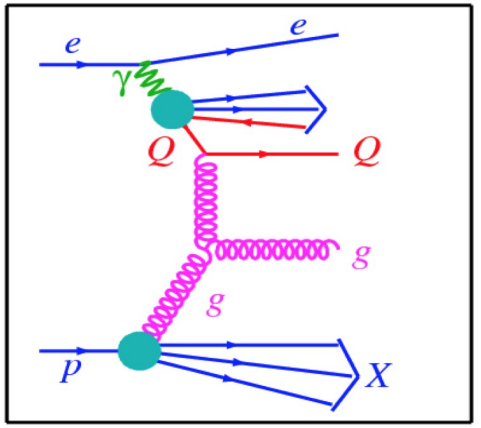
Charm production at HERA



Direct



Resolved



Excitation

ZEUS detector

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