Next Generation Nuclear Physics with JLab12 and EIC
10–13 February 2016
Florida International University

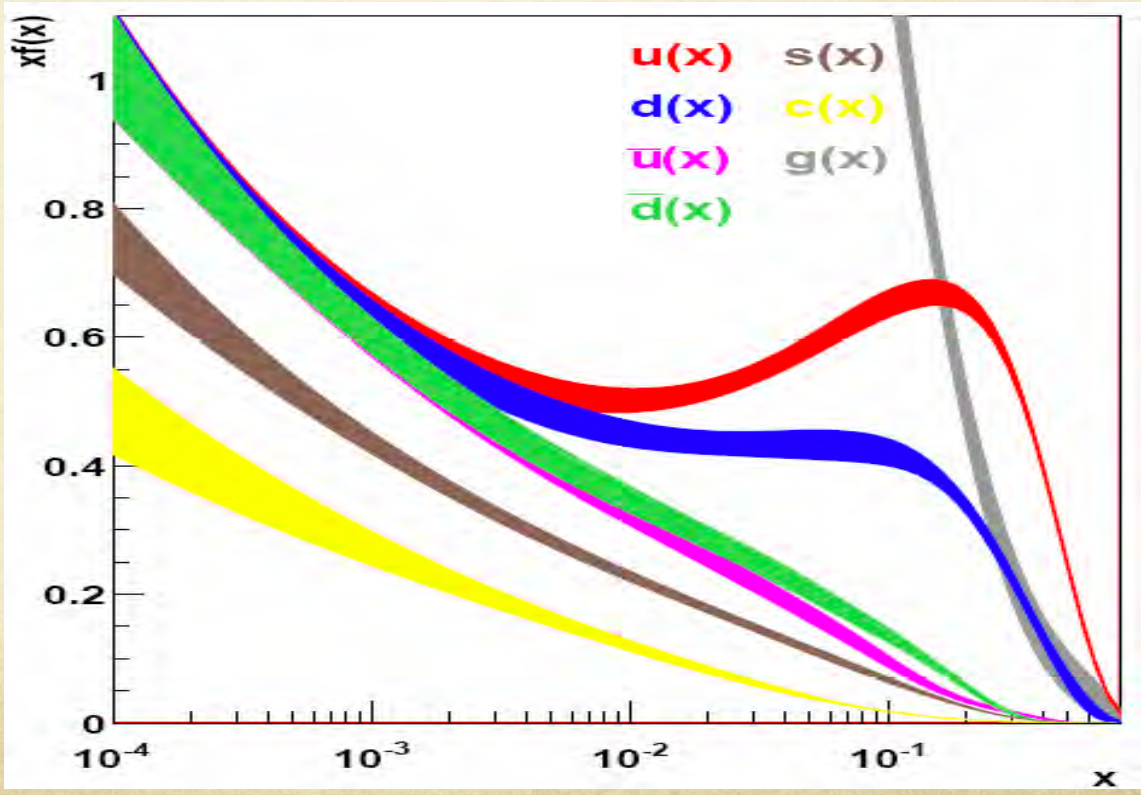
Nuclear Gluons with Charm at EIC*

*Probing High-x Gluons in Nuclei via Open Charm Production

Charles Hyde
Old Dominion University

Gluons at Large-x in (e,e')?

- ~~Gluons are a low x phenomenon~~
  - ~50% of gluon momentum sum rule is at x > 0.1
  - $g(x) \approx d(x)$ quarks at $x \geq 0.3$ (within errors)



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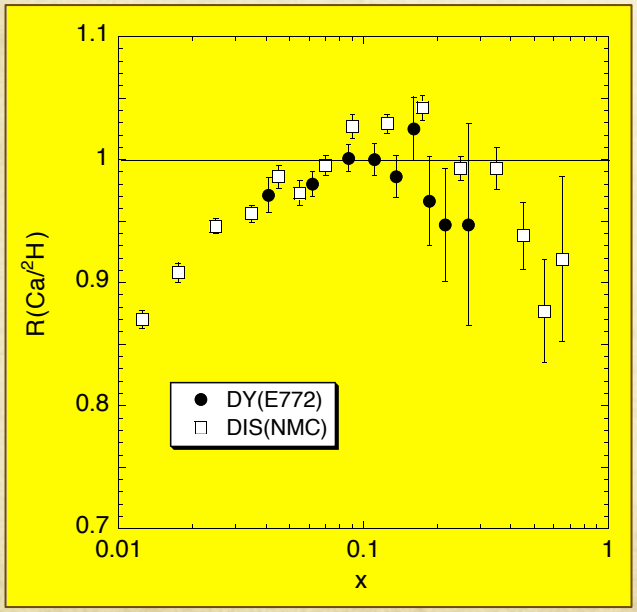
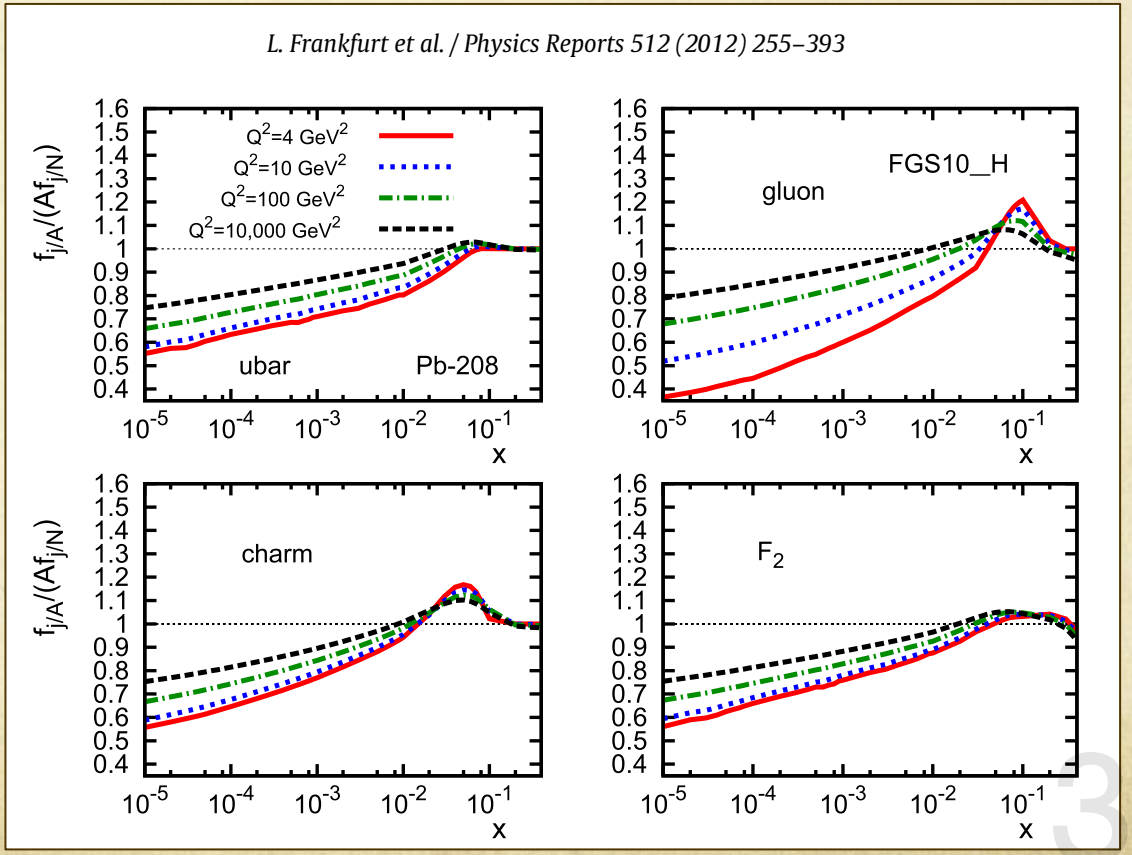
EMC Effect': Anti-Shadowing

- Anti-shadowing is not anti-quarks!
  FermiLab Drell-Yan E722



- Anti-shadowing is glue



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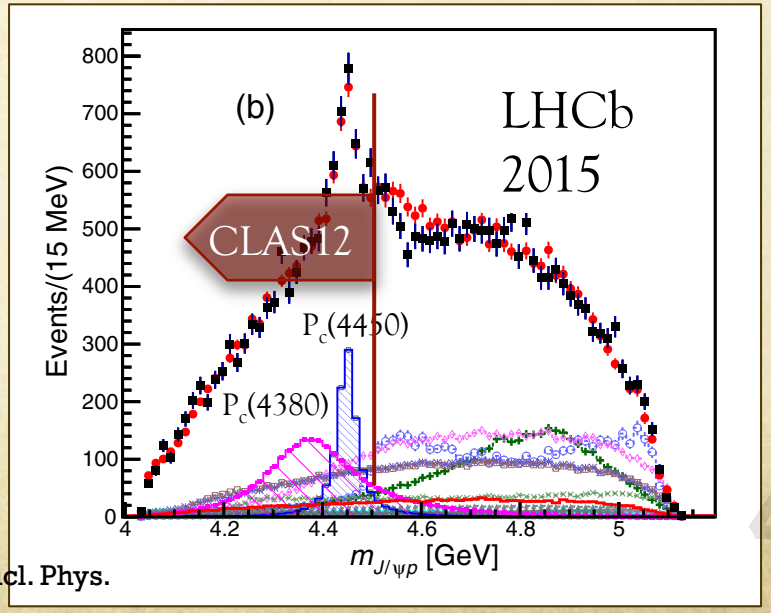
Gluons and Charm @ JLab 12 GeV

- First CLAS12 experiment, *circa* FY17+
  - $e + p \rightarrow e' + X, \qquad E_e = 11\ GeV$
  - $e + p \rightarrow e' + p + (J/\Psi \rightarrow e^+e^-)$
    - Gluon GPD at $x_g = (M_{J/\Psi})^2/(W^2-M^2) > 0.5$ for $Q^2 \geq 1$ GeV^2
    - LHCb resonance in $p \times J/\Psi$ channel: PRL 115, 072001 (2015)
      - *CLAS12* forward tagger $W \leq 4.5\ GeV$ for $Q^2 << 1\ GeV^2$

- Time-like Compton scattering (TCS) up to $M(J/\Psi)$ approved for CLAS12, SoLID (Hall A)

- TCS discussions for Halls C & D



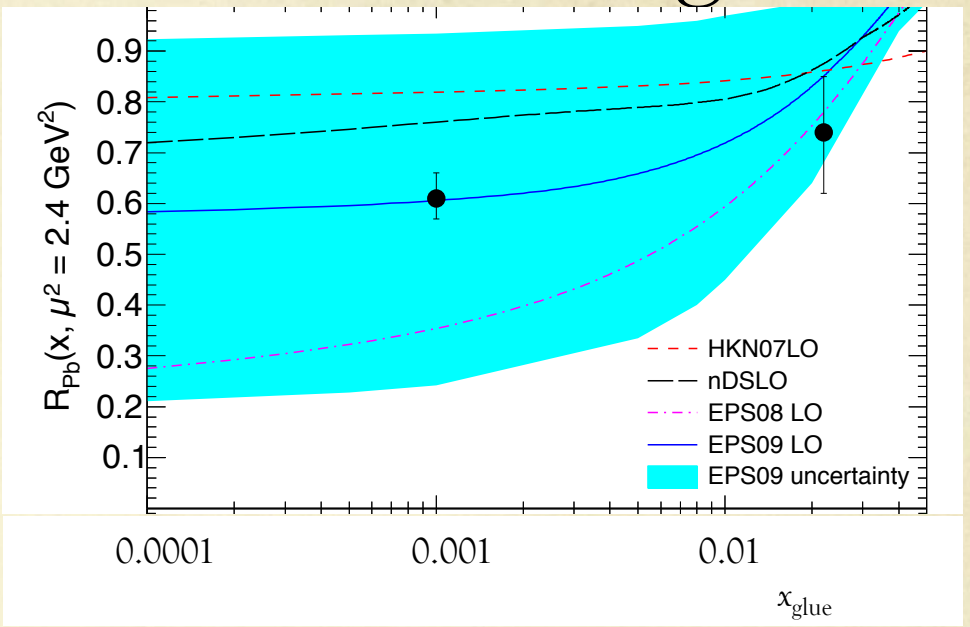
Nuclear gluons with charm at EIC
JLab FY16 LDRD Project LD1601

- E. Chudakov, D. Higinbotham, C. H., S. Furletov, Yu. Furletova, D. Nguyen, M. Stratmann, M. Strikman, C. Weiss.
- https://wiki.jlab.org/nuclear_gluons/index.php/Main_Page
- Investigate feasibility of direct measurements (with EIC@JLab) of nuclear gluons at $x_{glue} \geq 0.1$, via open-charm (open-beauty) production.
- Simulation codes under development
  - Analytic codes,
  - MC + fragmentation via HVQDIS, PYTHIA...
    - Detector Simulations in GEMC/GEANT4
  - Initial results

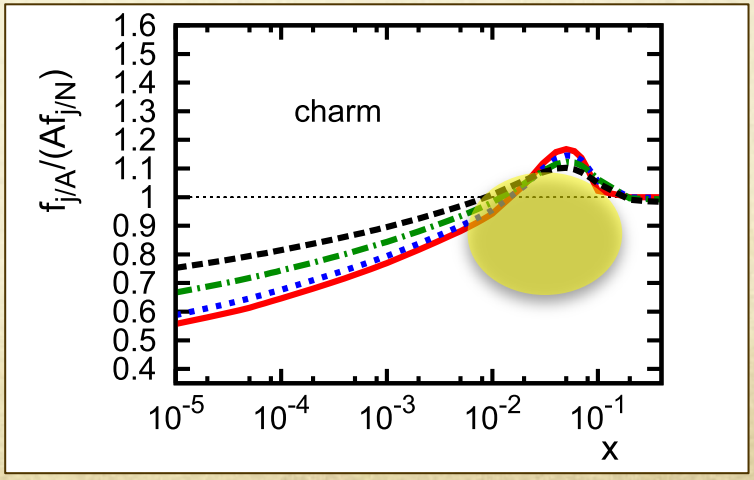
Gluons & Nuclear Binding

- Shadowing (coherent gluons from NN, NNN ...)
  - ALICE data: ultra-peripheral AA→ AA J/Ψ
  - x = 0.001 – 0.01

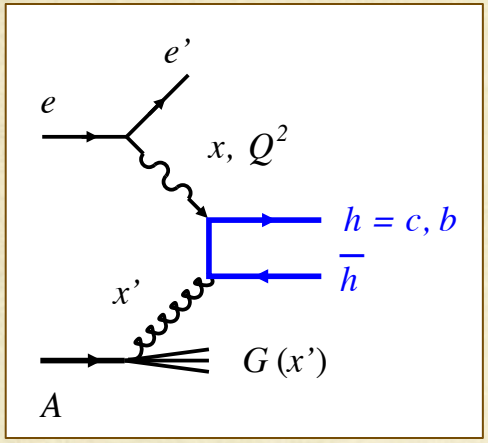
$$R = \frac{G_A(x)}{AG_N(x)}$$



- Expectation of gluonic anti-shadowing at $x \approx 0.1$



Tagging Photon-Gluon Fusion *via* Open Charm Production

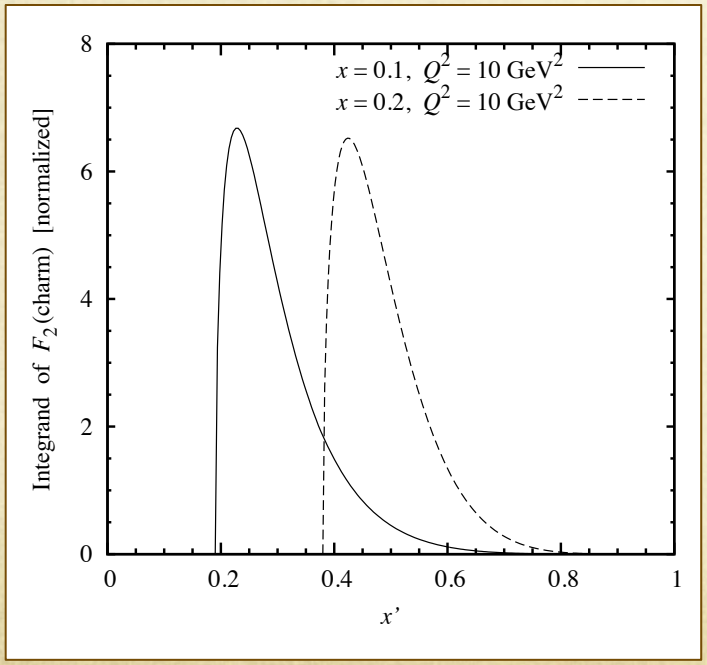


$$F_2^h(x,Q^2) \;=\; \int_{ax}^{1} \frac{dx'}{x'}\, x'G(x')\; \hat{F}_g^h(x/x',\, Q^2,\, m_h^2,\, \mu^2)$$

coefficient function

$$a \;=\; 1+\frac{4m_h^2}{Q^2}$$

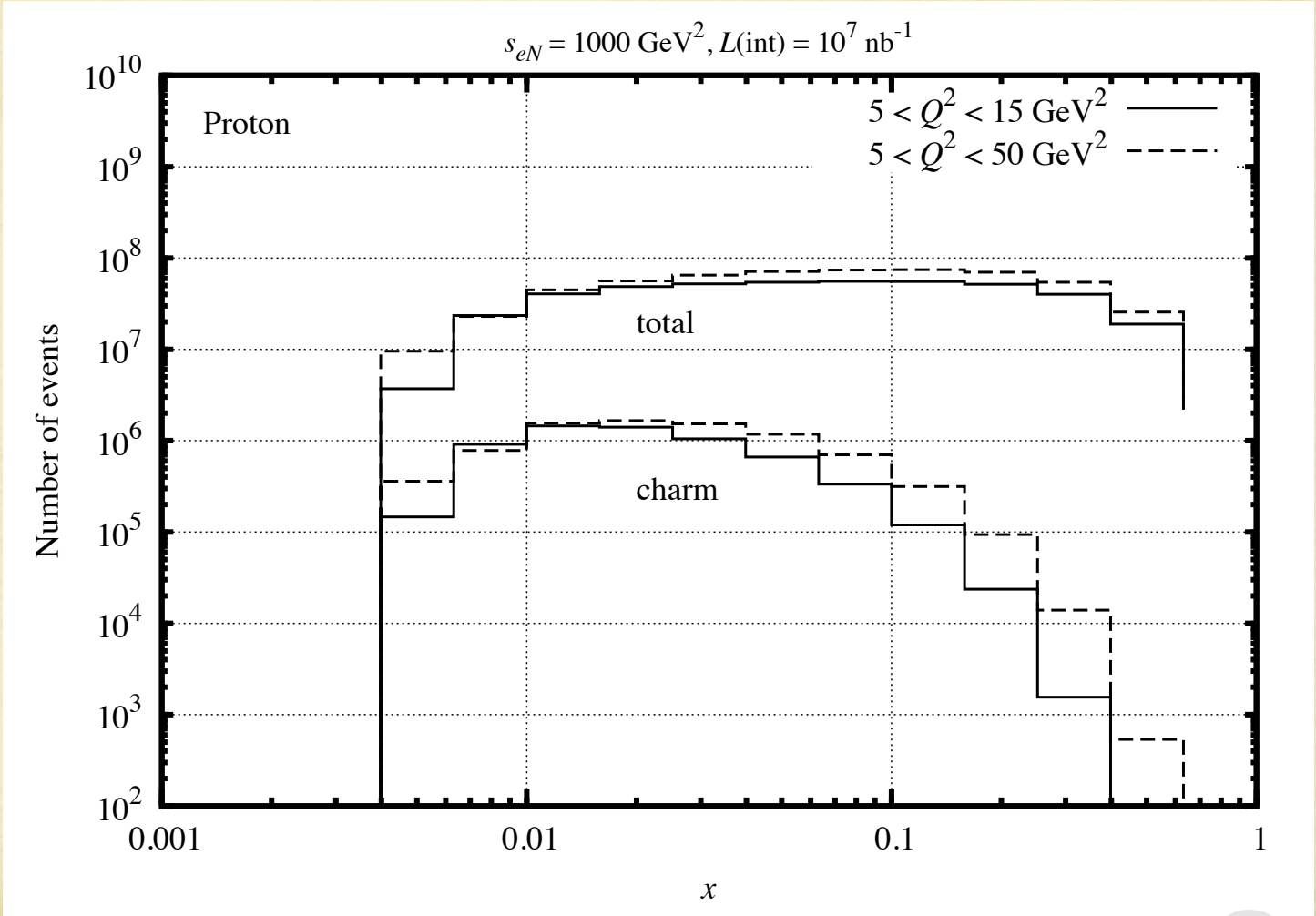
sets limit of x' integral



$x_{glue}G(x_{glue})$ support localized near $x_{glue} \geq x_{Bj}[1+4m_h^2/Q^2]$.

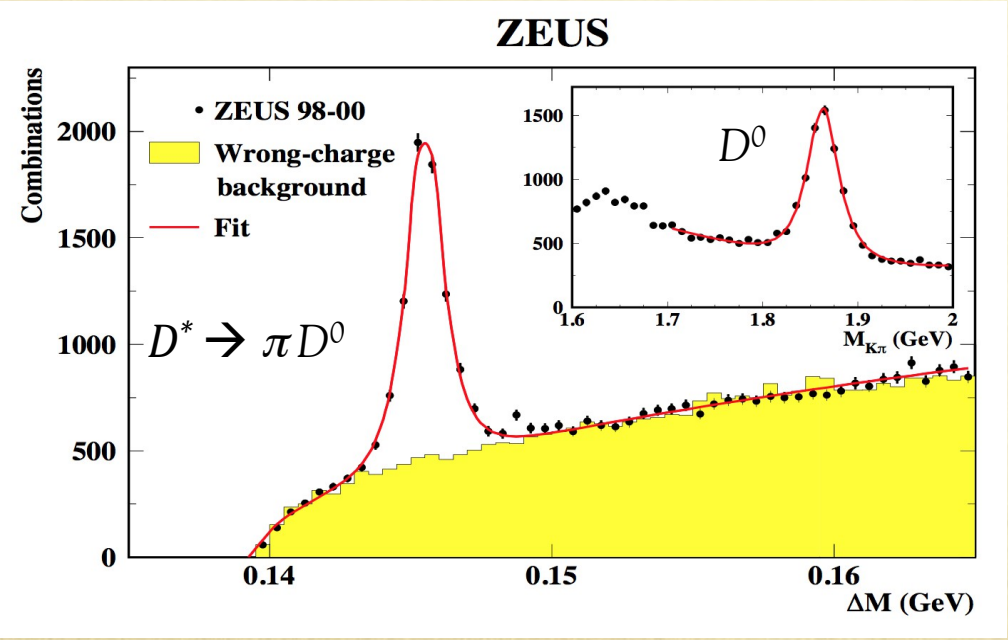
Total Open-Charm Rates @ EIC

- Tagging efficiency study in-process
- Expected ≥ 10%



Open Charm Reconstruction

- $c \rightarrow D^0 \rightarrow \pi^+ K^-$
- $c \rightarrow D^{*+} \rightarrow \pi^+_{slow} + D^0 \rightarrow \pi^+ K^-$



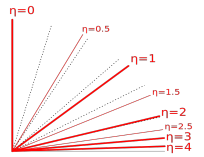
- *ZEUS*, $Q^2 \geq 1.5$ GeV^2
  - Luminosity 80 /pb
- EIC Luminosity
  10-100 /fb/yr
  (10^{33} - 10^{34} /cm^2/s)

EIC Kinematic Distributions

- Yu. Furletova
- Charm and Beauty events are different from inclusive DIS!

p e

Minimum bias (e/p 10/100)



$N \sim \sigma L \sim 20 \cdot 10^{-30} \cdot 10^{34} \sim 200{,}000/\text{sec}$

Scattered e

PhP
0.001<Q2<1

σ~20μb

π±/K±

~5/event

e±

~0.02/event

μ±

~0.001 /event

gammas from π0

~4/event

Ptot,GeV

η

DIS
1<Q2<100

σ~600nb

σ~2nb

DIS
Q2>100

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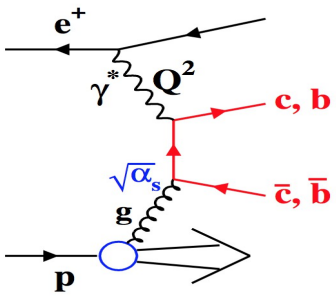
Charm BGF gγ->Q$\overline{Q}$

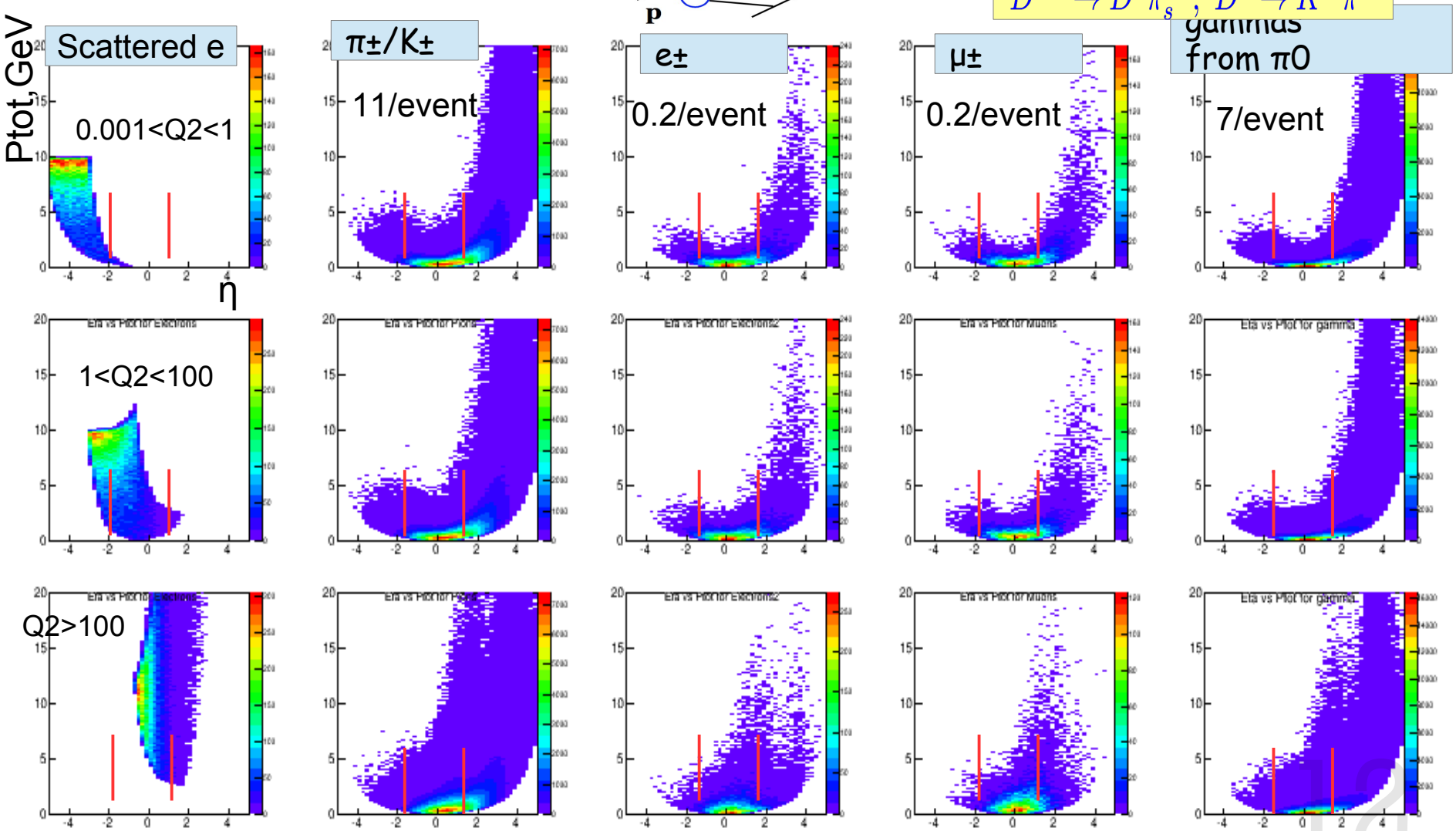
Boson Gluon Fusion (BGF)



σ ~60 nb (e/p 10/100)

N~60·10^{-33}·10^{34} ~600/sec

$D^{*+} \to D^0\pi_s^+$, $D^0 \to K^-\pi^+$



Beauty BGF gγ->$Q\bar{Q}$

$B^- \rightarrow D^0 \mu \nu$, $D^0 \rightarrow K^-\pi^+$

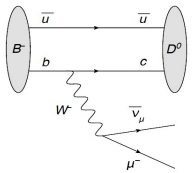
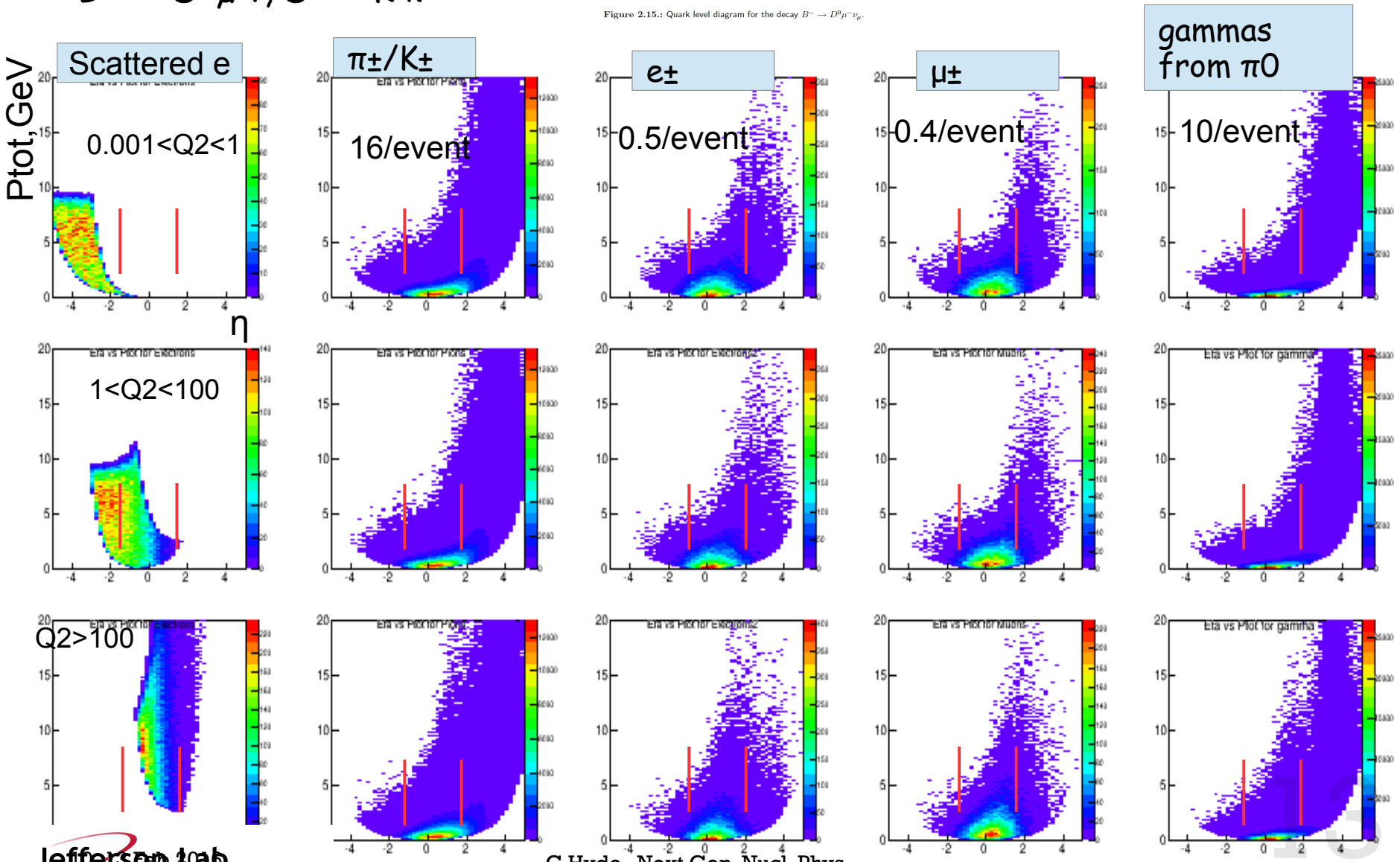


Figure 2.15.: Quark level diagram for the decay $B^- \rightarrow D^0 \mu^- \nu_\mu$.

σ ~0.3 nb(e/p 10/100)

N~$0.3 \cdot 10^{-33} \cdot 10^{34}$~3/sec



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Yulia Furletova

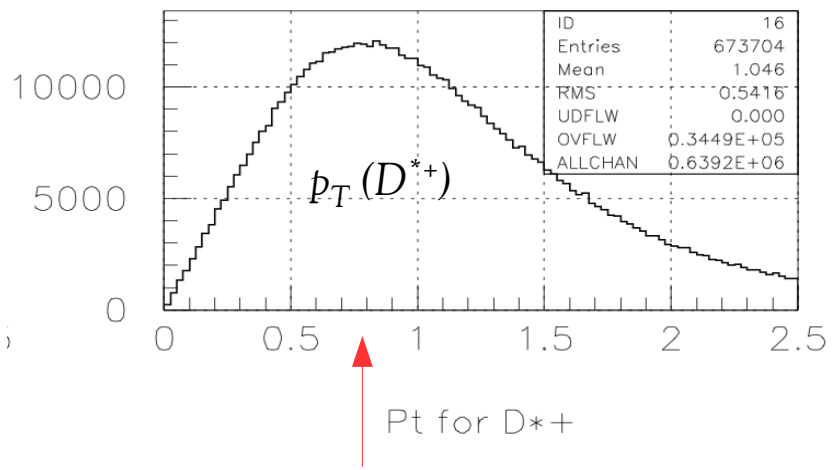
EIC Charm Reconstruction

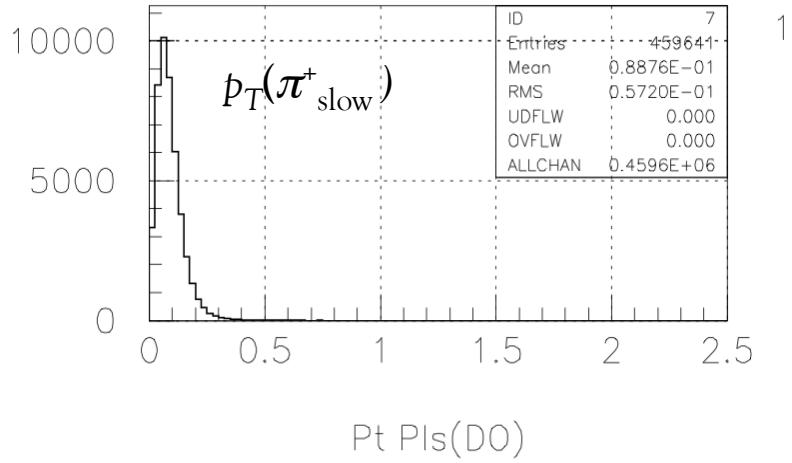
- S. Furletov
  - HVQDIS + PYTHIA

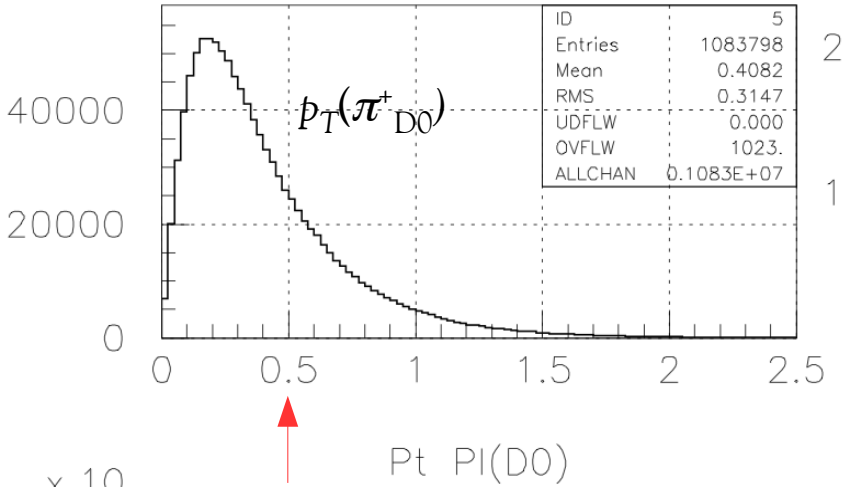
Pt distribution & cuts

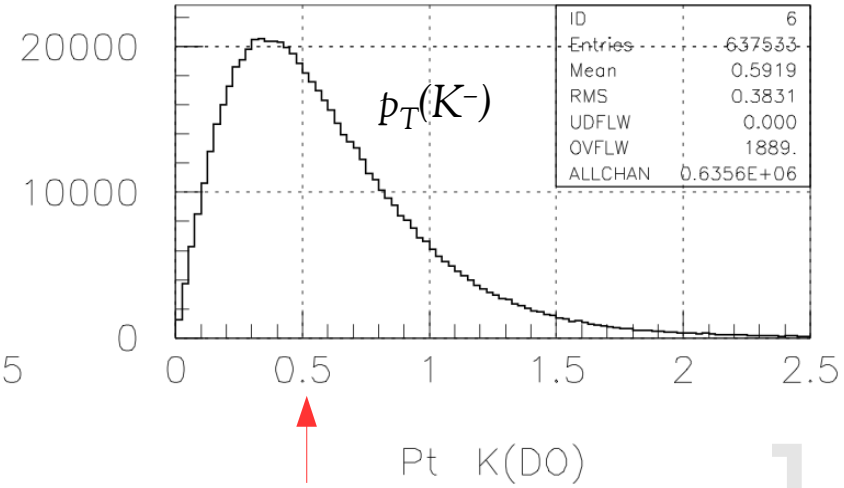
Jefferson Lab
Thomas Jefferson National Accelerator Facility

$c \rightarrow D^{*+} \rightarrow \pi^{+}_{slow} + D^{0} \rightarrow \pi^{+} K^{-}$





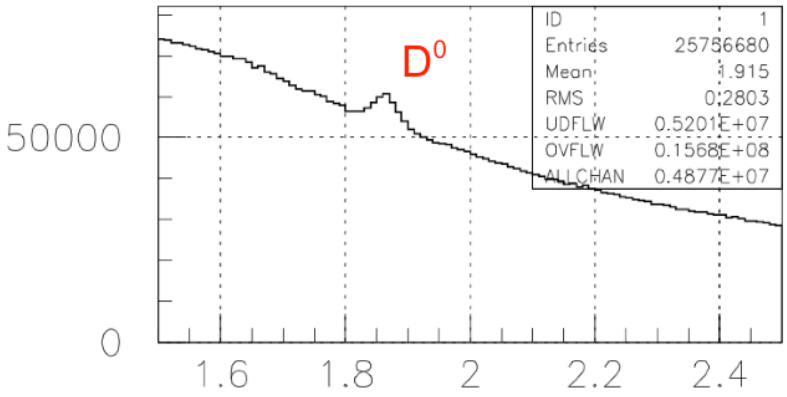


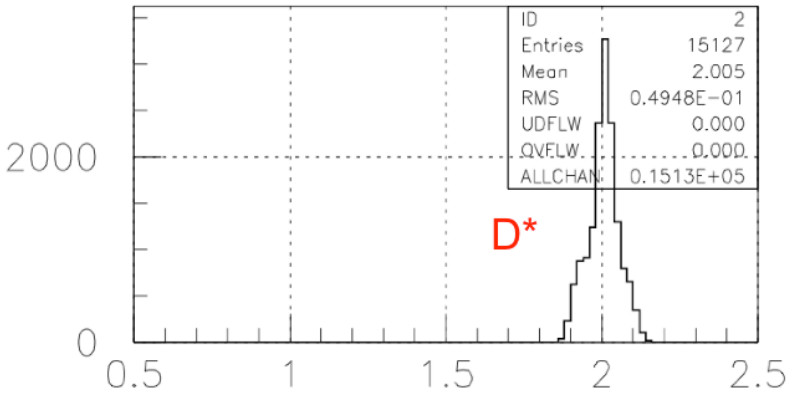


D* reconstruction

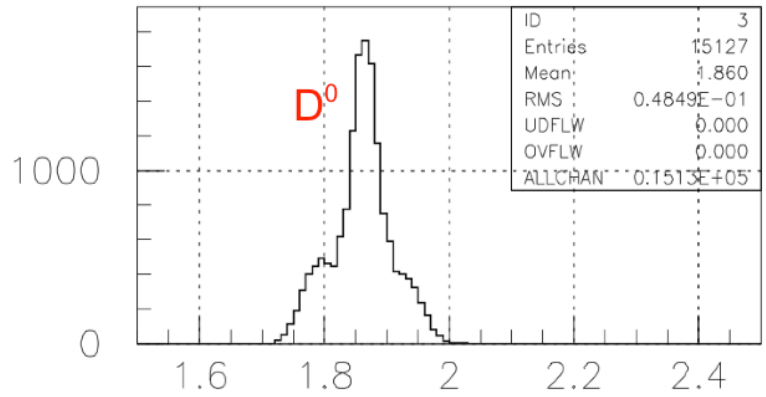
Jefferson Lab
Thomas Jefferson National Accelerator Facility

PtDS=0.8 EtaDS=2.5 D0=1.79 1.93 dM=0.140 0.150 Job=0000



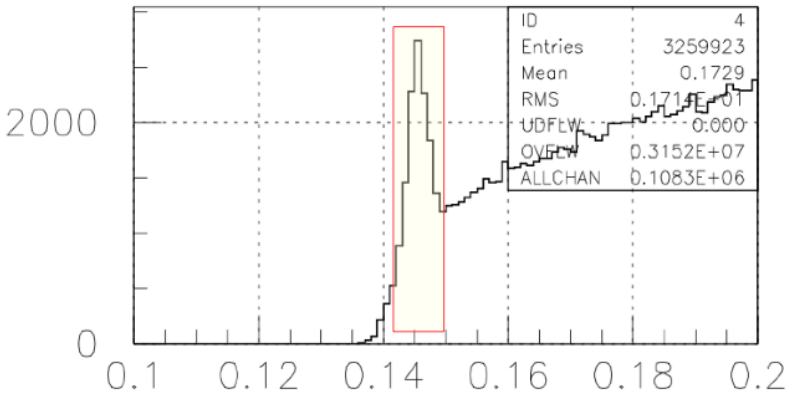


pi/K inv mass Pt cut=0.50 Ptot cut=0.13



D0 mass, dM cut

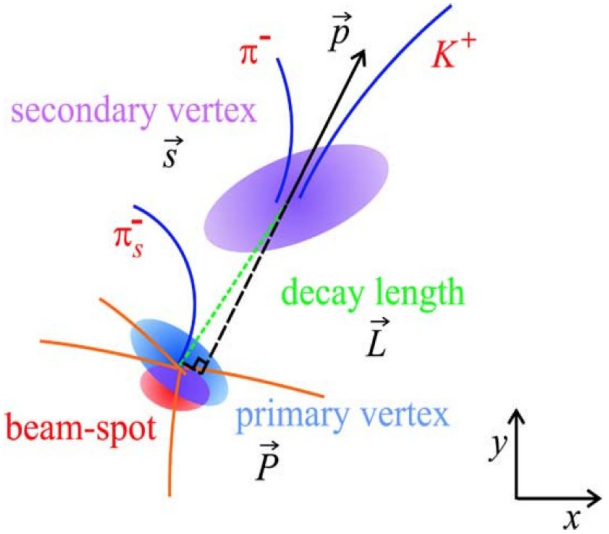
D*+ mass, dM cut

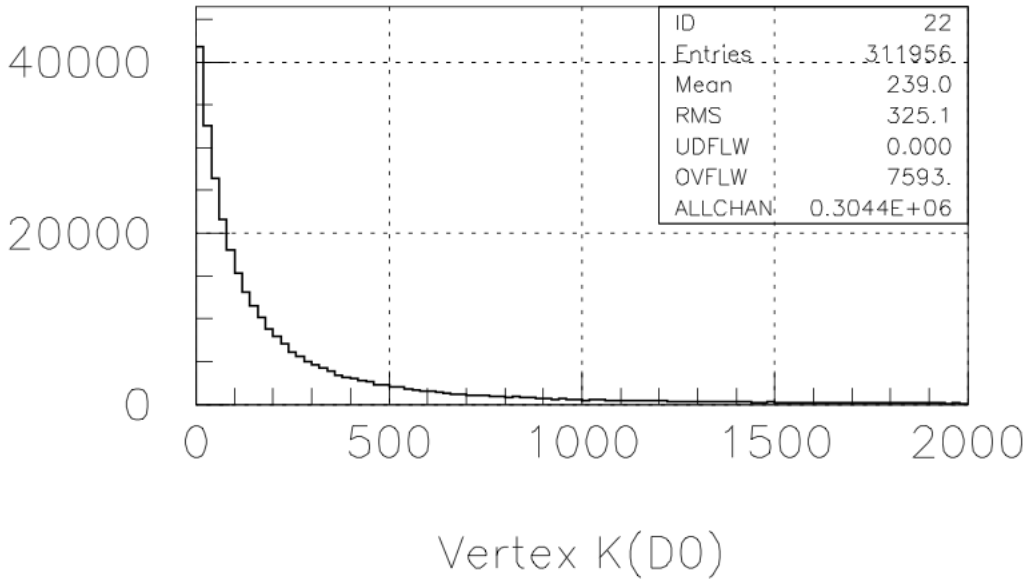


D*−D0 mass

16

Secondary Vertex ($D^0 \rightarrow \pi K$)

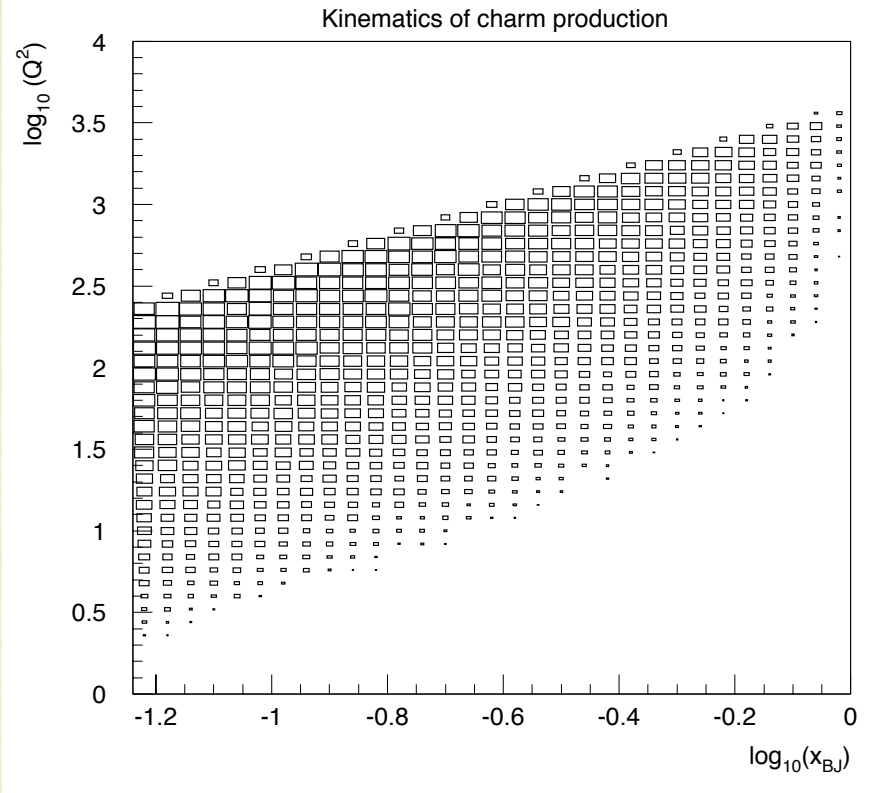




- S. Furletov
  - Pythia simulation
  - EIC Kinematics 10 x 100 GeV^2

LDRD Next Steps

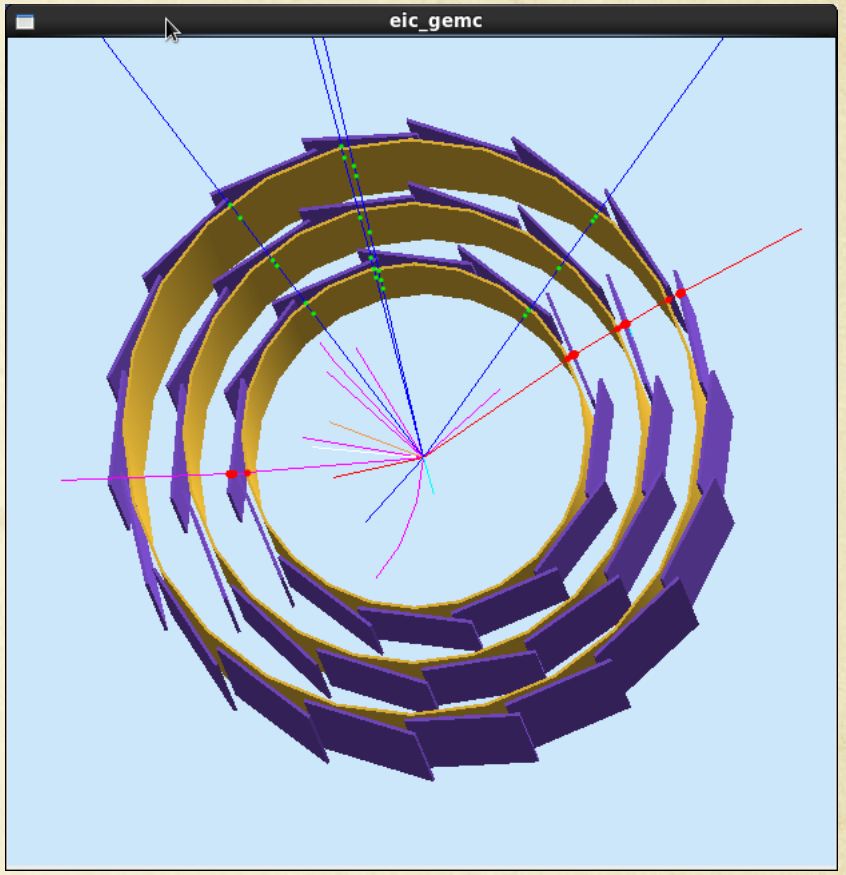
- Kinematic Distributions & Reconstruction Efficiencies differential in x_{glue}
  - Which performance characteristics (and which portions of detector) are crucial to charm and beauty reconstruction
- Vertex Tracker
  - Design and performance (Yu. Furletova)

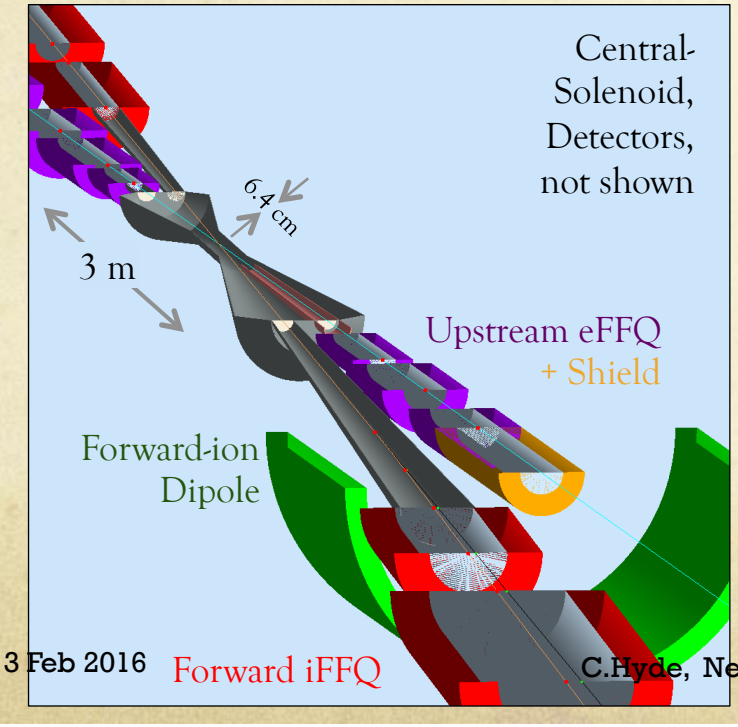


S. Furletov 12 Feb 2016
10x100 GeV^2

EIC @ JLab Vertex Tracker

- Initial concept, implementation in GEMC and event simulation
  - Yu. Furletova, 10 Feb 2016
- Central beam pipe concept
  - C.H., Z. Zhao→GEMC 12 Feb 2016





Conclusions

- Exciting program to probe gluon structure on nuclei
  - Important driver for EIC Detector design
  - 80 m long detector:
    - From 0° electron tagger & Compton Polarimeter to ion far-forward spectrometer & neutron ZDC