Strange and Heavy Flavor Physics at EIC and ePIC status

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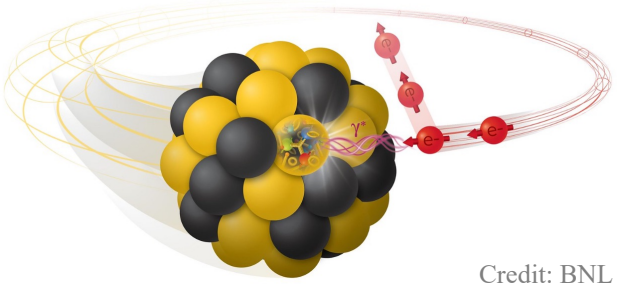
Electron-Ion Collider

- **Internal landscape of nucleons and nuclei, and underlying dynamics**
  - *How does the mass of the nucleon arise?*
  - *How does the spin of the nucleon arise?*
  - *What are the emergent properties of dense system of gluons?*

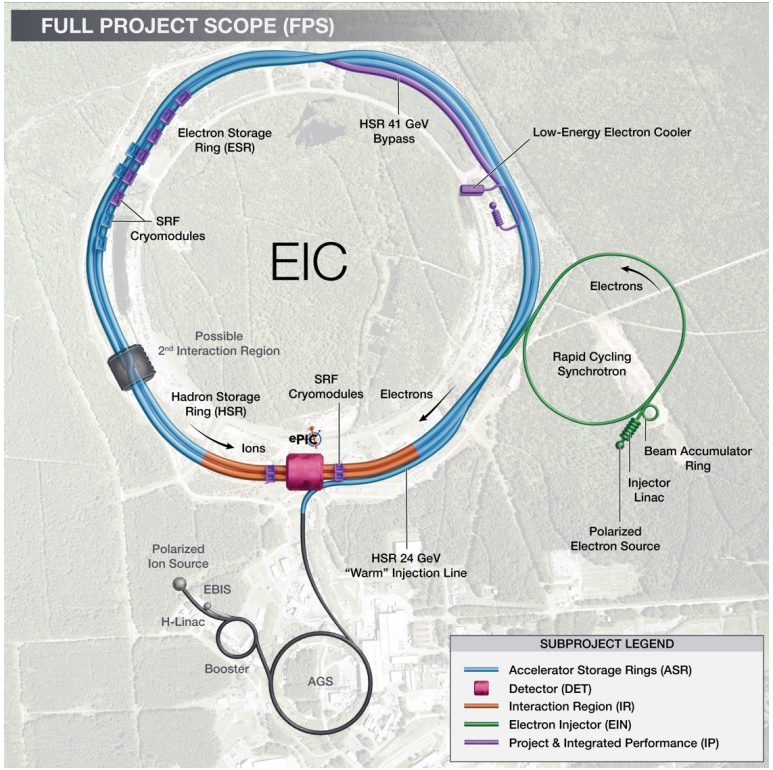
- **How to achieve that?**
  - High luminosity: $L = 10^{33\text{-}34}$ cm^{-2}sec^{-1}
  - High polarization: $P \sim 70\%$
  - Wide range of energy: $\sqrt{s} = 29 - 141$ GeV
    - With upgrade to 18 GeV electron beam
  - Variety of ion species: proton – Uranium



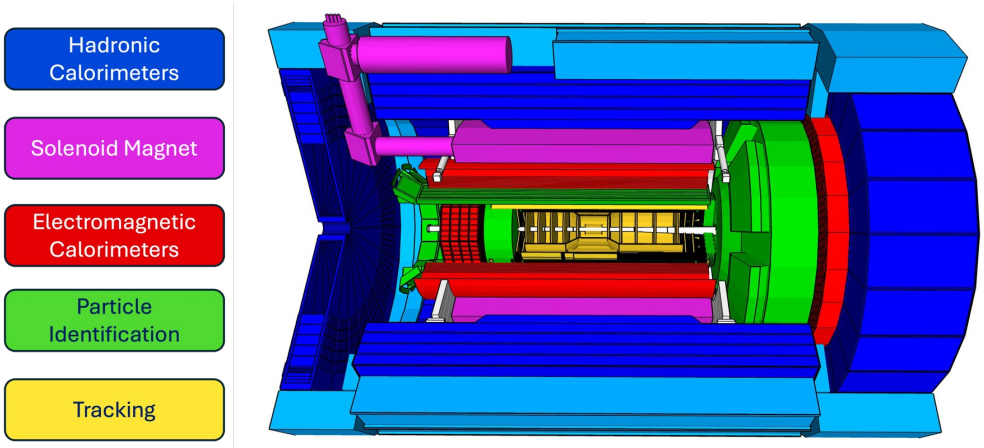
Credit: BNL

Electron-Ion Collider

- A single integrated line-item construction project
- Divided into **five sub-projects**
  - Accelerator Storage Rings (ASR)
  - Detector (DET) – ePIC
  - Interaction Region (IR)
  - Electron Injector (EIN)
  - Integrated Performance (IP)
- **Re-use**:
  - Ion injection and acceleration systems (Linac, Booster, AGS)
  - Polarized ion/proton sources



Electron-Proton/Ion Collider (ePIC)

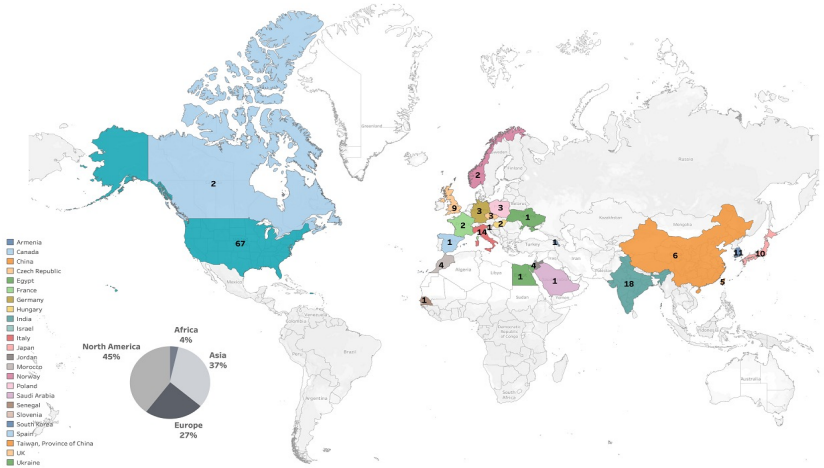


- 1.7 T superconducting solenoid
- Large acceptance
- Excellent tracking, calorimetry and PID
- Great pointing resolution

$\|\eta\|$	$\sigma(DCA_{xy})$ [μm]
0 – 1.0	$20/p_T \oplus 5$
1.0 – 2.5	$30/p_T \oplus 20$
2.5 – 3.5	$30/p_T \oplus 40$

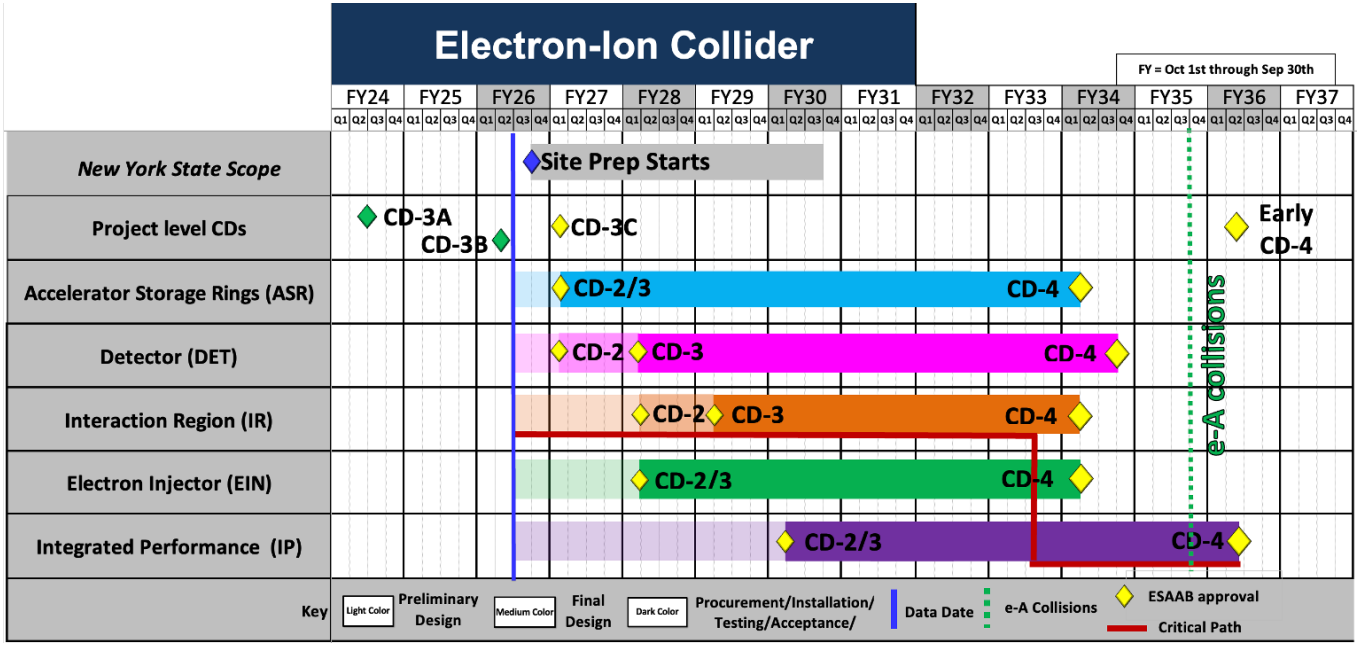
ePIC Collaboration

- Founded in July 2022
- **International**: 1100+ collaborators, 180+ institutions, 25 countries
- ePIC is a *CERN recognized experiment*

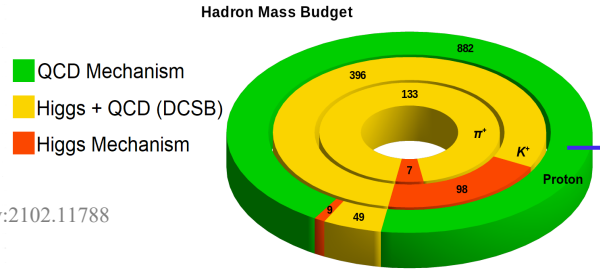


Timeline

- RHIC operation ended on 02/06; removal starts on 04/01
- Aim to start construction in FY27



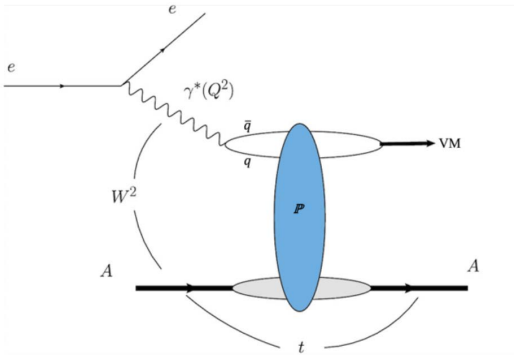
Origin of Mass: Gluon

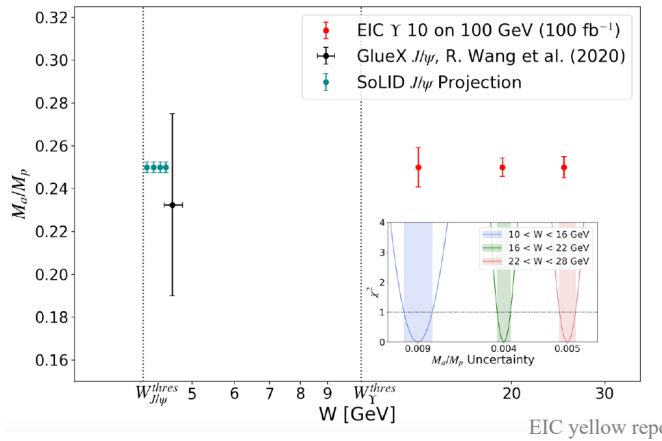


Credit: S. Kay
Adapted from arXiv:2102.11788

Trace anomaly $T^{\mu}_{\mu} = \frac{\beta(g)}{2g} G^{\mu\nu} G_{\mu\nu} + \sum m_q \bar{q} q$

Near-threshold quarkonium production

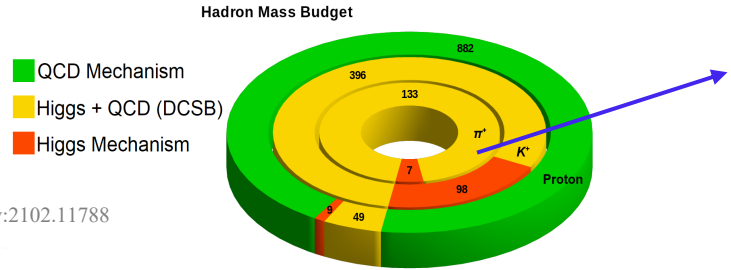




Near-threshold ϒ at EIC

EIC yellow report: arXiv:2103.05419

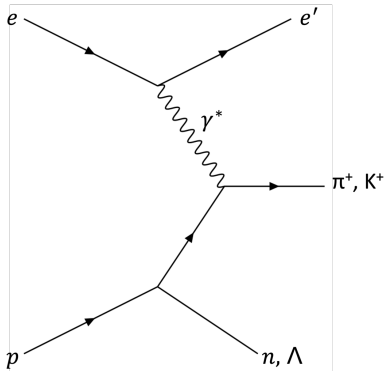
Origin of Mass: Quark



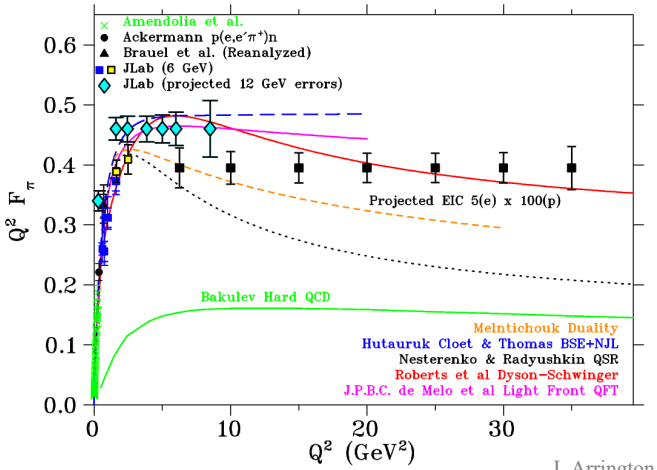
Credit: S. Kay
Adapted from arXiv:2102.11788

- Influence of quarks
- Kaon: contain *s* quark with large Higgs mass

Deep Exclusive Meson Production



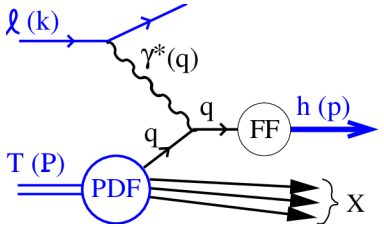
π^+ form factor



J. Arrington, et.al., arXiv:2102.11788

K^+ studies underway

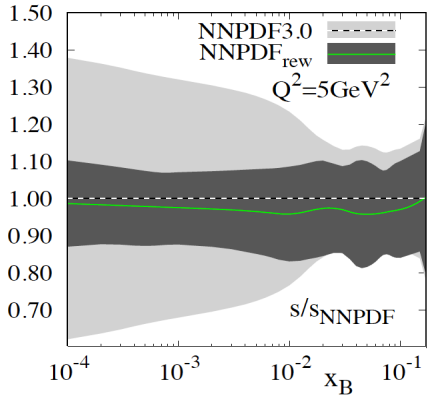
Access Sea Quark with Kaon



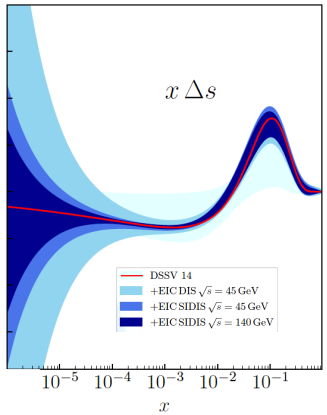
- Extra sensitivity to parton flavor
- Kaon → strange quark

H. Pirner, arXiv:hep-ph/0311279

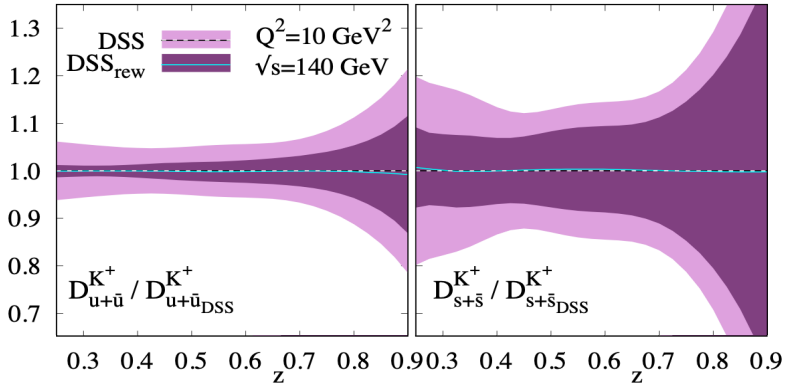
PDF



Helicity



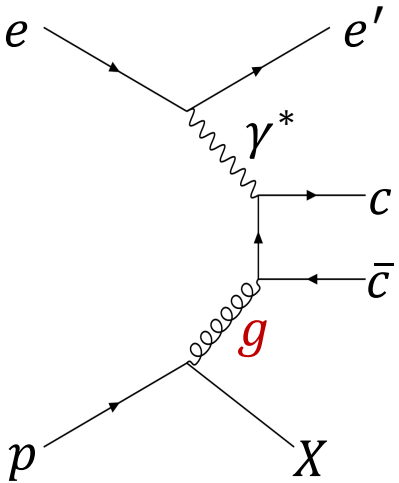
FF



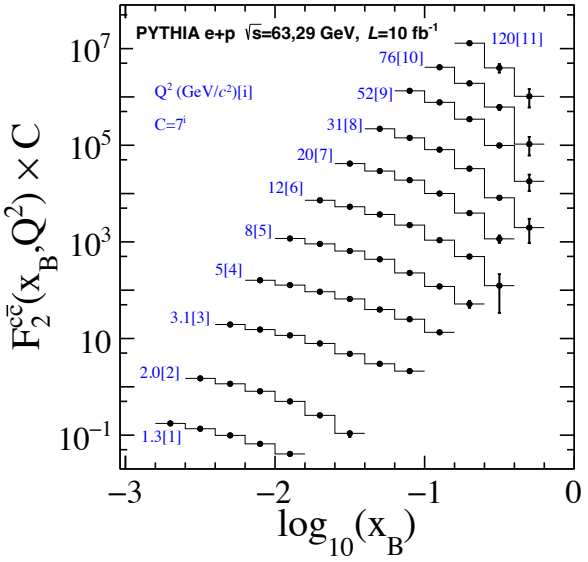
EIC yellow report: arXiv:2103.05419

Charm Quark Production

- Leading-order: photon-gluon fusion → clean probe of gluon distribution



Charm structure function

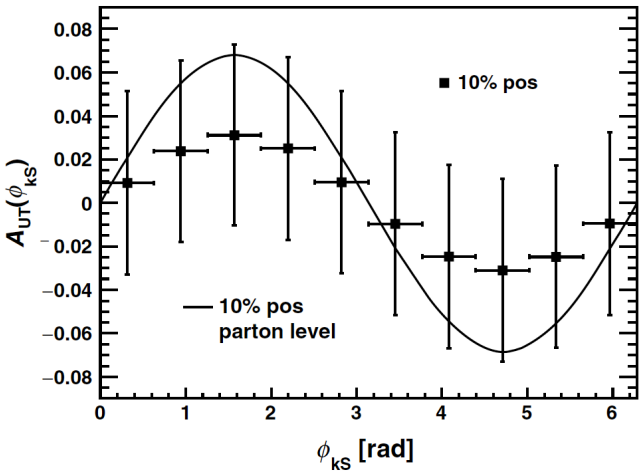


M. Kelsey, et. al., PRD 104 (2021) 054002

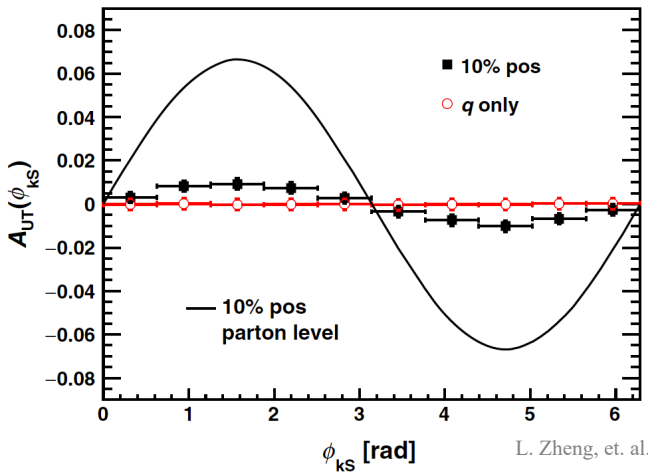
Access Gluon Sivers Function

- Correlation between gluon's transverse momentum with the proton spin

$D\bar{D}$ pair



Single D



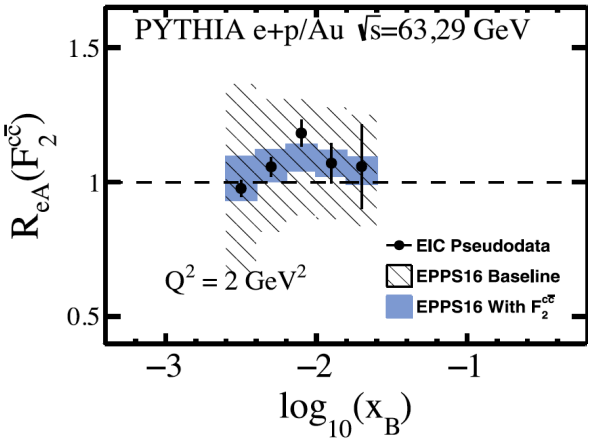
L. Zheng, et. al., PRD 98 (2018) 034011

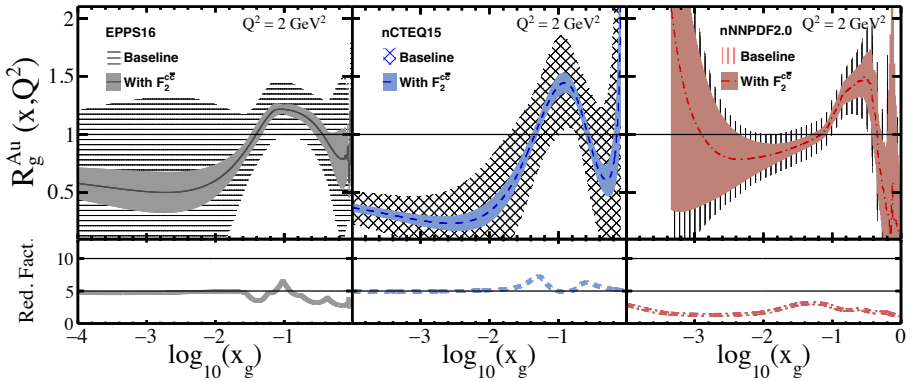
- Complementary to other channels: di-jet, di-hadron …

Constrain Gluon nPDF

- Leading-order: photon-gluon fusion → clean probe of gluon distribution

M. Kelsey, et. al., PRD 104 (2021) 054002



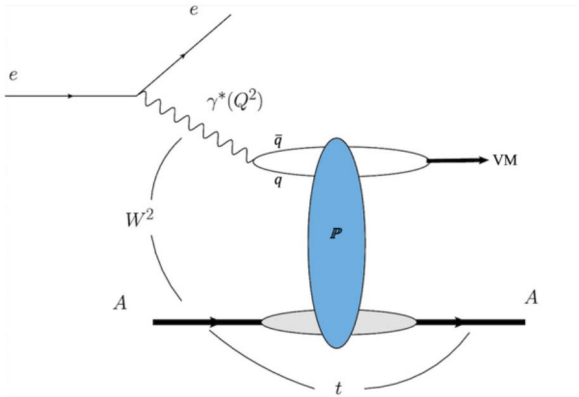


- Complimentary to inclusive measurements, especially ***at high x***

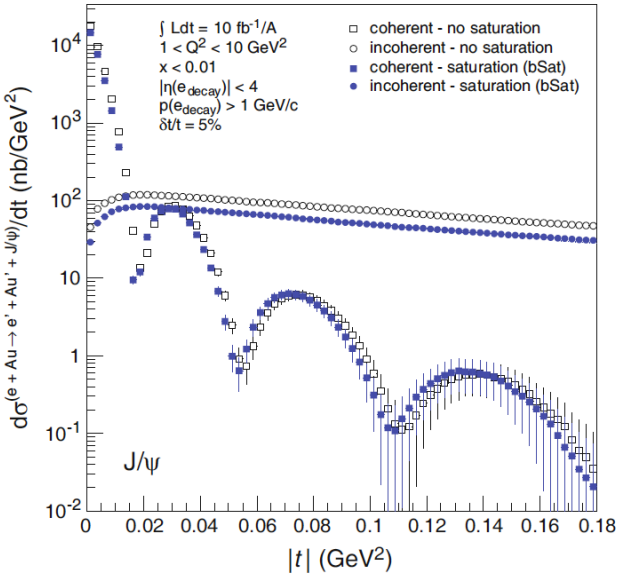
Constrain Gluon Spatial Distribution

- Exclusive VM production

M. Kesler, et. al., arXiv:2502.15596



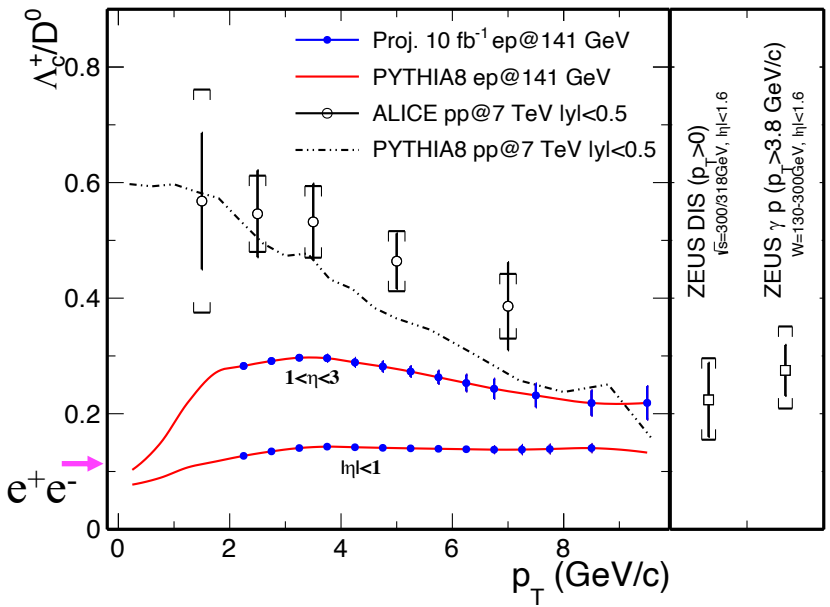
EIC white paper: arXiv:1212.1701



- Coherent: diffractive pattern → *b*-dependent gluon distribution
- Incoherent: fluctuations

Charm Quark Fragmentation

- A clear difference in Λ_c/D^0 ratio has been observed in p+p and e^+e^- collisions
  - Breakdown of FF universality?
- *How about e+p?*
  - Previous measurements have large errors and p_T-integrated



J. Arrington, et. al., arXiv:2102.08337

Propagation in Nuclei

- Probe hadronization and energy loss in nuclei

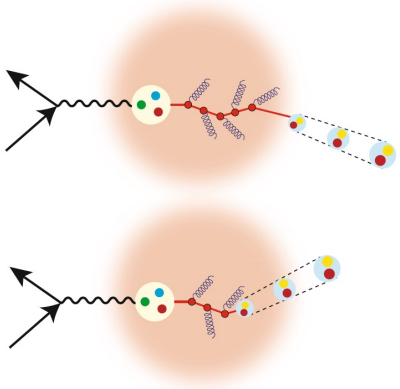
$$R_{eA}(p_T, z, \nu) = \frac{N^{D0}(p_T, z, \nu)|_{eAu}}{N^{D0}(p_T, z, \nu)|_{ep}} \times \frac{N^{inc}(\nu)|_{ep}}{N^{inc}(\nu)|_{eAu}}$$

Reduce initial-state effects

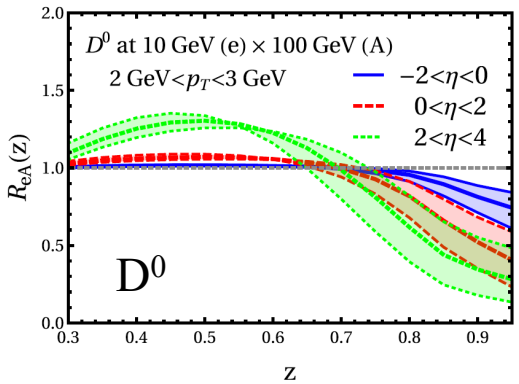
ν: *virtual photon energy*

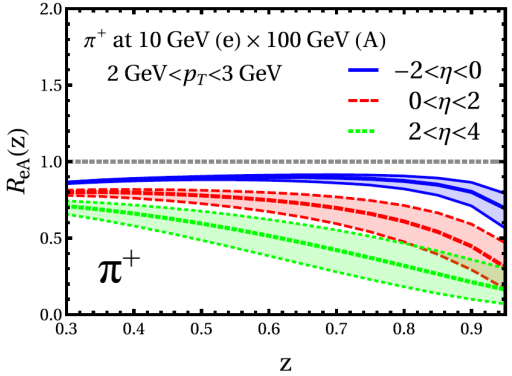
large ν

small ν



Energy loss model





EIC white paper: arXiv:1212.1701

H. Li, et. al., PLB 816 (2021) 136261

Summary

- EIC will be the ONLY collider in the US, and ONLY of its kind in the world
  - Next milestone: CD2/3 → start of construction
  - Aim to start operation in FY35

- ePIC detector is designed to fully realize EIC science mission
  - ONLY detector currently planned

- Strange/heavy-flavor play an important role in answering essential scientific questions EIC is built for

Backup