

ePIC Experimental Overview

Rongrong Ma (BNL)

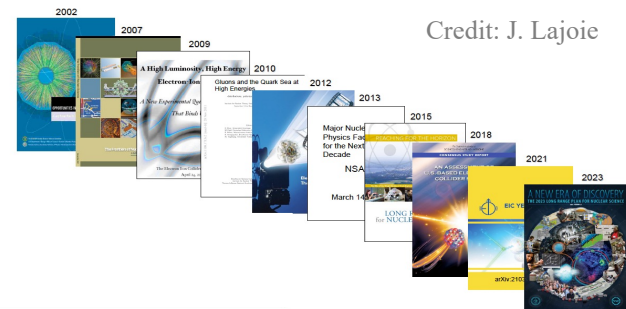
On behalf of ePIC Collaboration

10/19/2026



Electron-Ion Collider

- Decades long community efforts to build the science case
 - 2018 NAS: “The science questions that an EIC will answer are central to *completing an understanding of atoms* as well as being integral to the agenda of nuclear physics today.”
 - 2023 NSAC LRP: “We recommend the *expeditious completion of the EIC* as the highest priority for facility construction.”



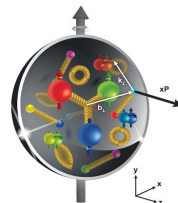
EIC science pillars



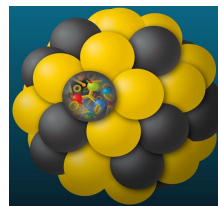
MASS



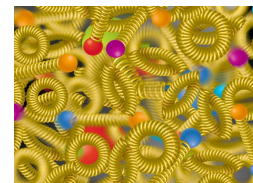
SPIN



IMAGING



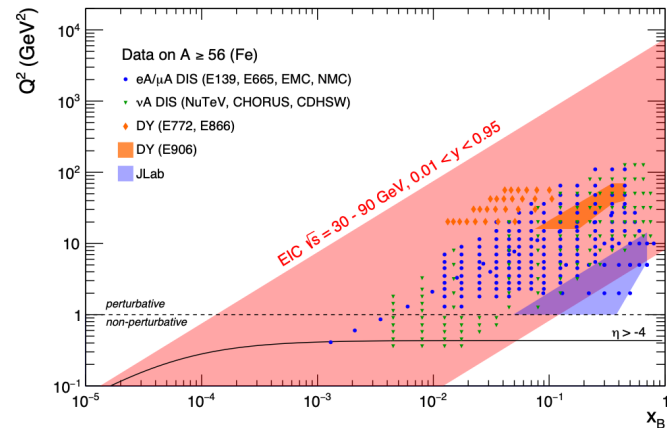
NUCLEI



GLUONS

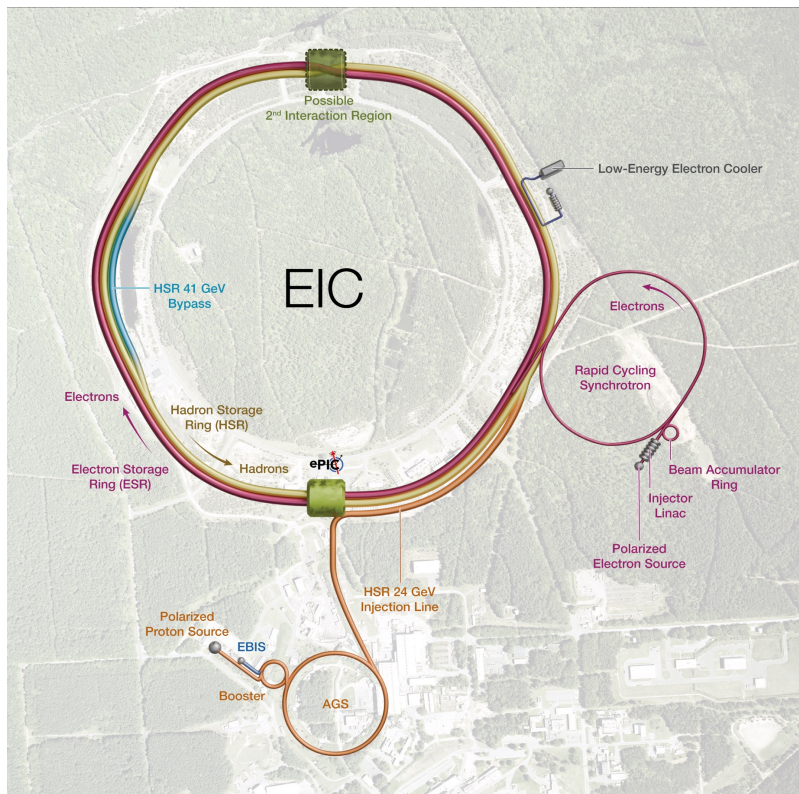
How To Achieve The Goal?

- Precision multi-differential electron-scattering measurements across x , Q^2 , flavor, polarization and nuclear size
- Design performance
 - High luminosity: $L = 10^{33-34} \text{ cm}^{-2}\text{sec}^{-1}$
 - High polarization: $P \sim 70\%$
 - Wide range of energy: $\sqrt{s} = 29 - 140 \text{ GeV}$
 - Variety of ion species: proton – Uranium



S. Diehl, et al., arXiv:2504.01236

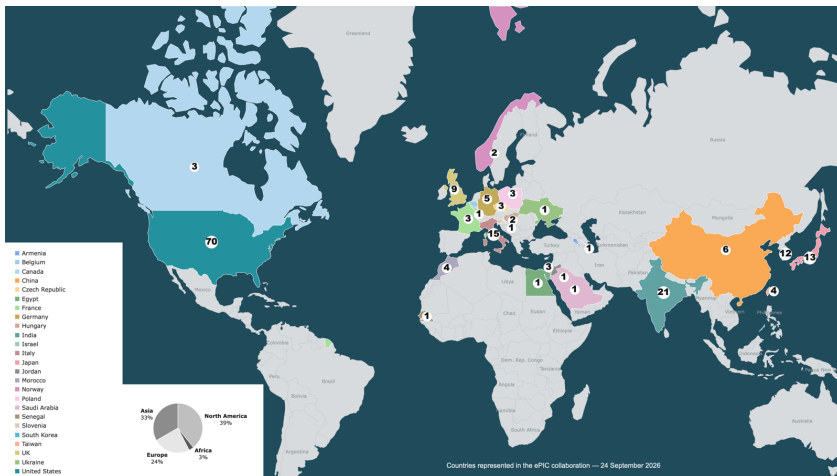
The EIC Machine



- A single integrated line-item construction project
 - Infrastructure
 - Project detector – ePIC
 - Accelerator
- **Reuse:**
 - Ion injection and acceleration systems (Linac, Booster, AGS)
 - Polarized ion/proton sources
- **New build:**
 - Electron injector
 - Electron storage ring

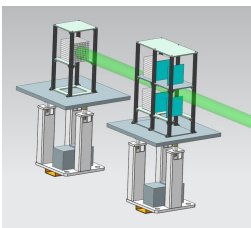
ePIC Collaboration

- Founded in July 2022
- **International**: 1100+ collaborators, 180+ institutions, 26 countries
- Priorities: detector design; pTDR; *early science report ...*



ePIC Detector

Bunch-by-bunch
luminosity through
Bethe-Heitler
process



Luminosity
System

p/A beam

electron beam

Forward neutrons
and γ

Zero Degree Calorimeter

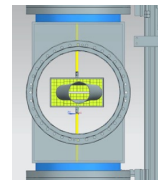
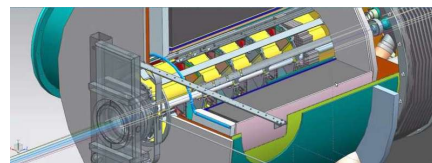
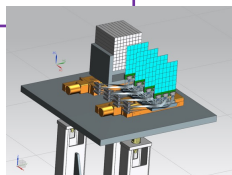
Roman Pots (RPs) and
Off-Momentum Detectors (OMDs)

B0 Magnet
Spectrometer

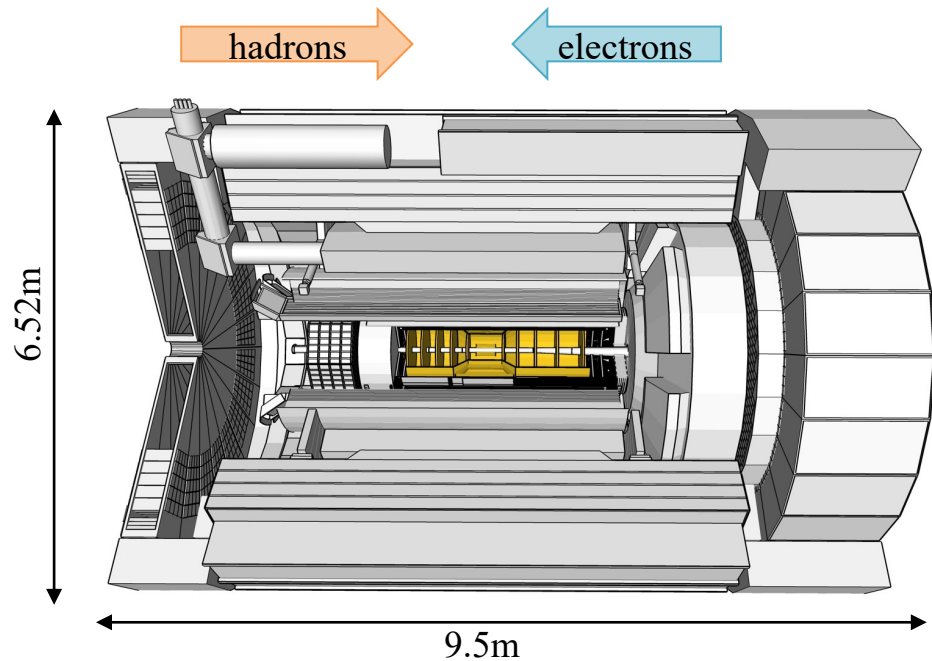
Forward scattered
proton and γ

Forward scattered
proton and nuclei

Low-Q2 Taggers
Backward scattered
electrons



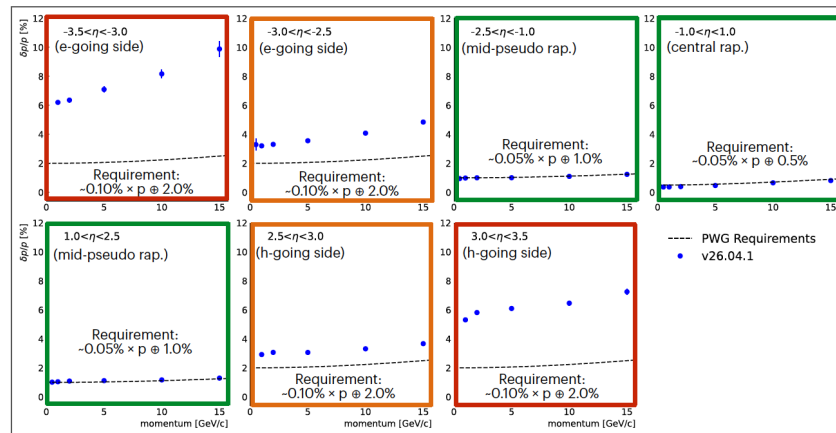
ePIC Detector



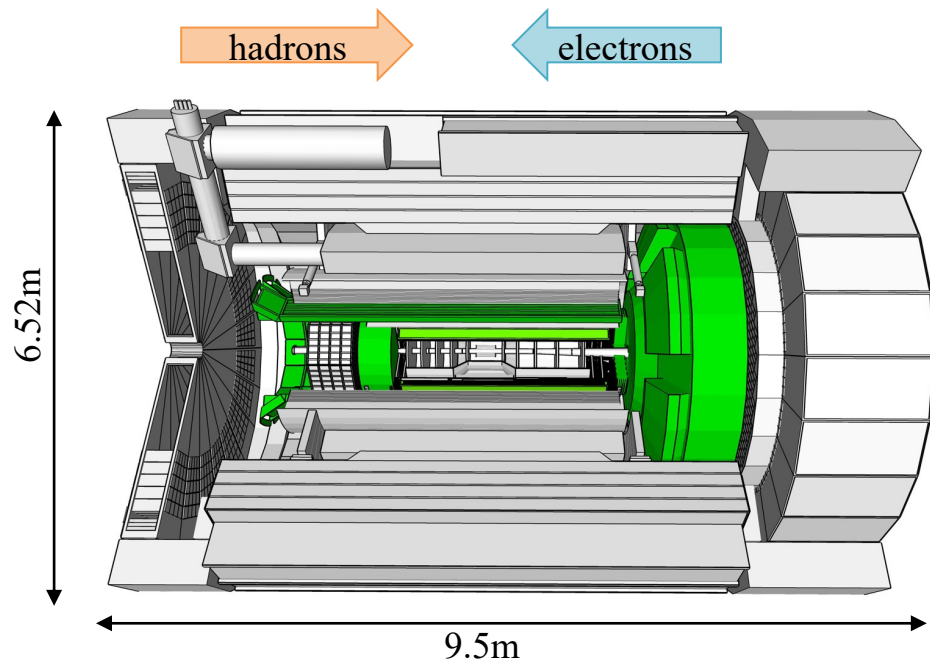
Tracking:

- New 1.7T solenoid magnet
- Si MAPS Tracker
- MPGDs

Relative momentum resolution

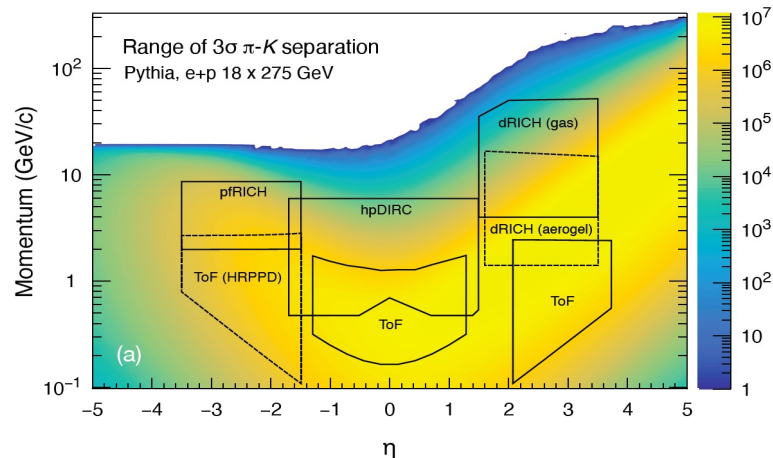


ePIC Detector

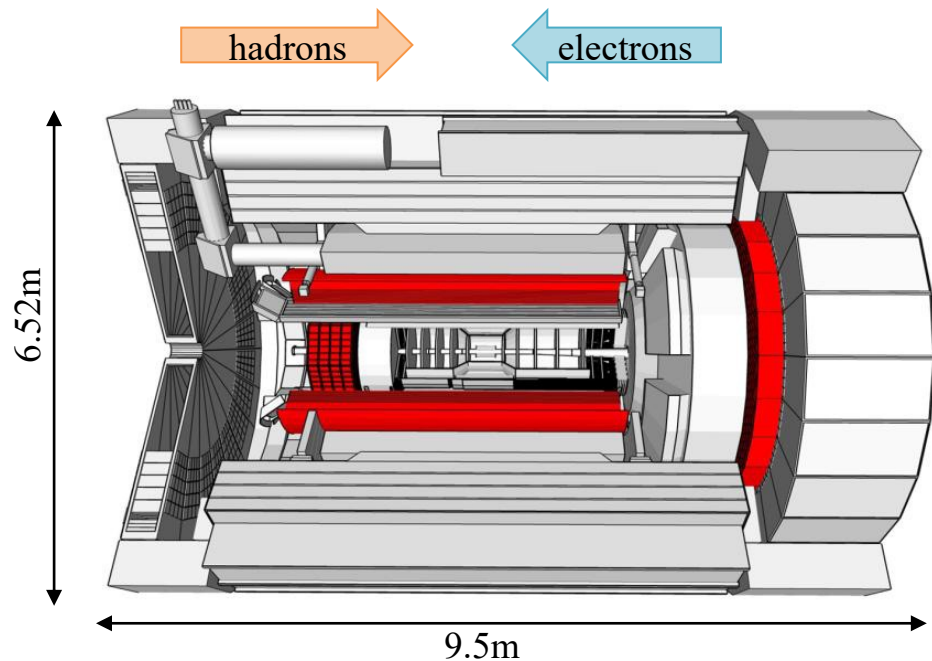


Particle identification

- high-performance DIRC (central)
- proximity-focused RICH (bwd)
- dual-radiator RICH (fwd)
- AC-LGAD ToF (barrel & fwd)

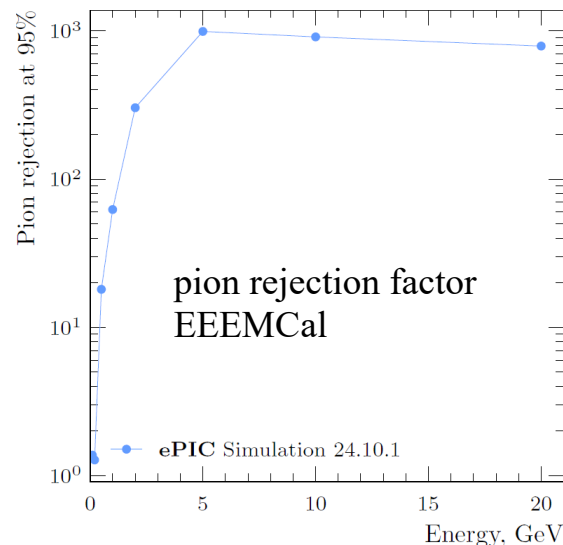


ePIC Detector

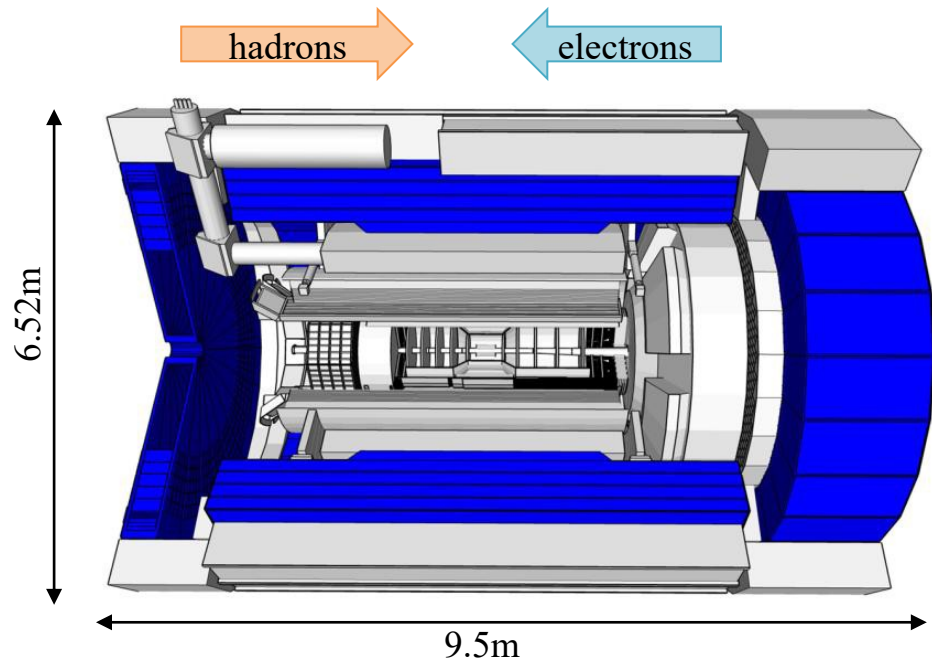


EM Calorimetry: e , DVCS γ , jets ...

- Barrel Imaging EMCal
- EEEMCal (PbWO4)
- fEMCal (W powder/SciFi)

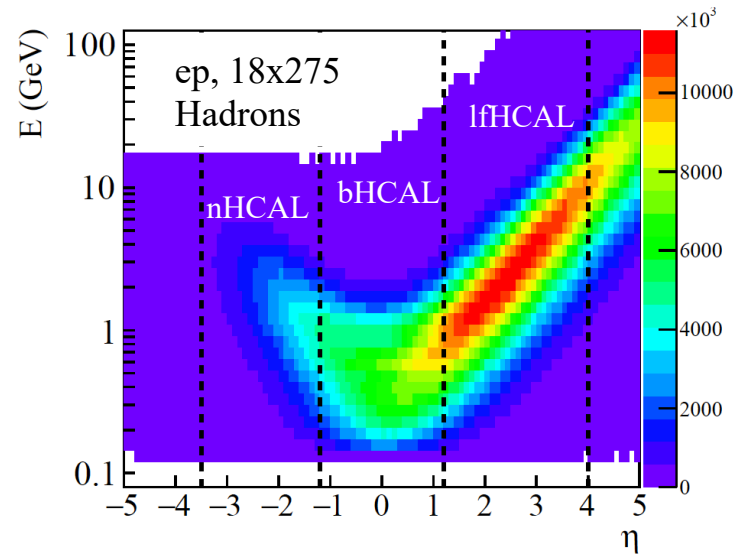


ePIC Detector



Hadron Calorimetry: muon, jets ...

- Barrel (sPHENIX re-use)
- Endcap (Steel/Fe – Scintillator)



Start-up Plan

Species	Beam energy (GeV)	Integrated luminosity (fb^{-1})	Electron-beam polarization	Hadron-beam polarization
$e+\text{Ag}$	9×115	1.0	NO	N/A
$e+\text{D}$	9×130	1.5	LONG	NO
$e + p$	9×130	1.0	LONG	TRANS and/or LONG
$e + p$	9×275	2.5	LONG	TRANS and/or LONG
$e+\text{Au}$	9×100	1.0	LONG	N/A
$e + {}^3\text{He}$	9×166	1.5	LONG	TRANS and/or LONG

- Electron energy at 9 GeV; upgradable to 18 GeV
 - **NOTE: many projection plots use 10 GeV electrons**
- Start with ion running to establish technical stability
- Electron/hadron polarization comes later; first access to Au
- **Yearly projected luminosity exceeds HERA's lifetime $L_{\text{int}} \sim 0.5 \text{ fb}^{-1}$**

ePIC Early Science Report

ePIC: arXiv:2608.05377

Charge from BNL and JLab ALDs

...

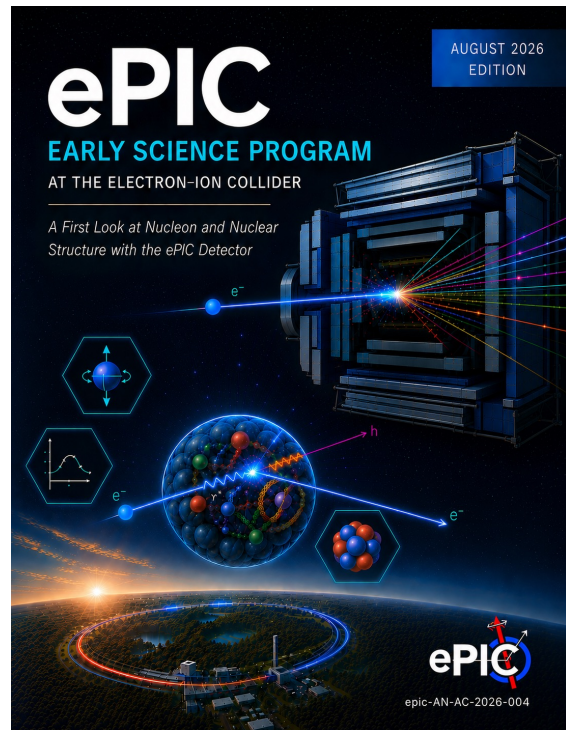
We are writing to you – the ePIC collaboration – to develop a short document *summarizing the science that would be possible from those early data.*

...

The results in the document should be based on the *most recent understanding of the ePIC detector* including the acceptances, efficiencies of each detector subsystem,

...

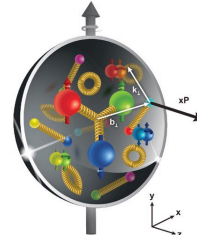
prepares this report by August 30, 2026.



ORIGIN OF NUCLEON MASS

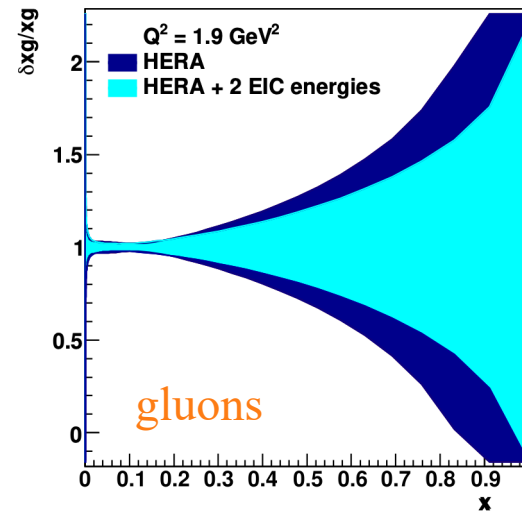
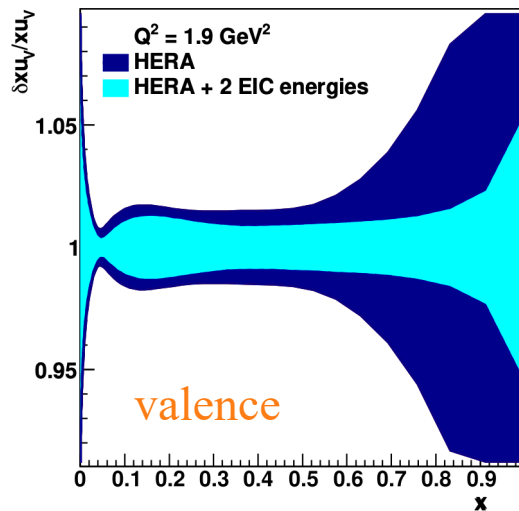
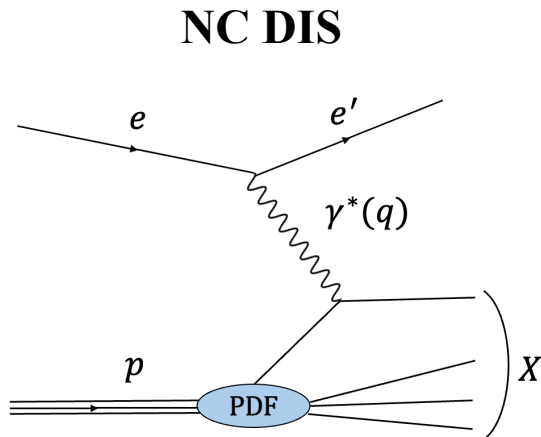


MASS



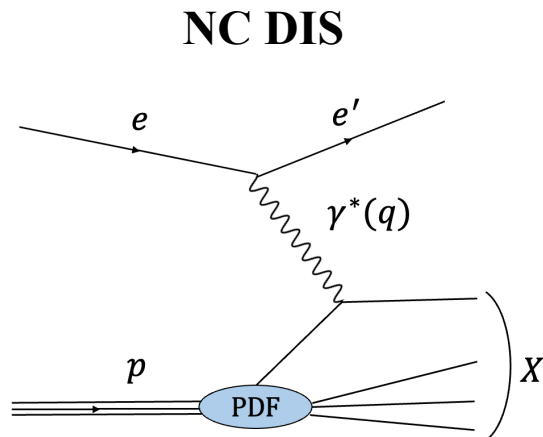
IMAGING

Constrain proton PDFs

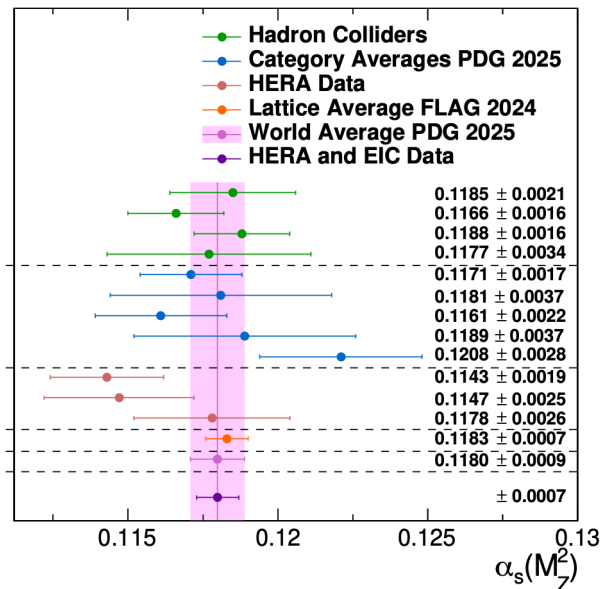


- Day-1 measurements that improve PDFs at intermediate and large- x
 - Heavy-flavor provides additional constraints for gluons at large- x

Competitive in measuring α_s



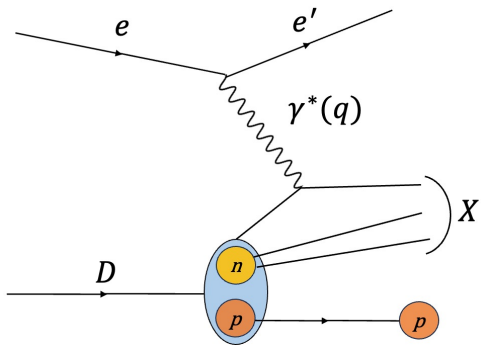
ATLAS ATEEC
CMS Jets
W, Z Inclusive
tt Inclusive
 τ Decays
QQ Bound States
PDF Fits
 e^+e^- Jets and Shapes
Electroweak Fit
ZEUS Inclusive + Jet Data
H1 Inclusive + Jet Data
H1 and ZEUS Jet Data
Lattice Average
World Average
HERA and EIC Early Science
Inclusive Data (exp)



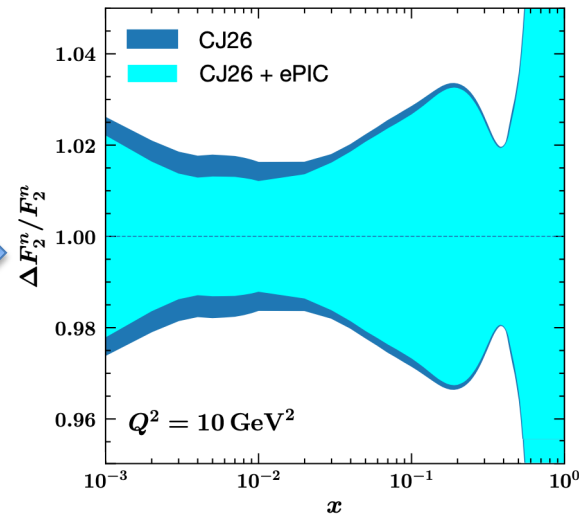
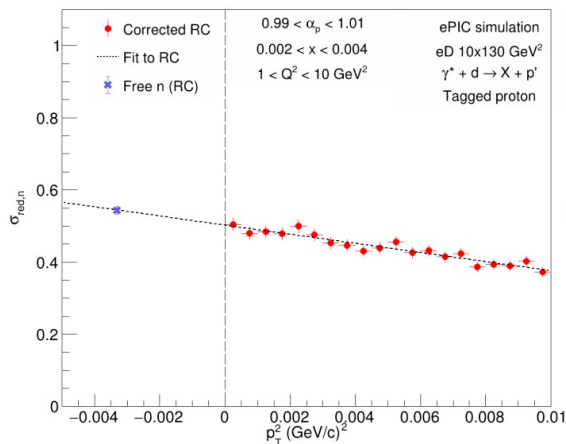
- Byproduct of PDF fits
- Comparable uncertainty to world average and lQCD calculation

Constrain neutron PDF

p-tagged *eD* DIS

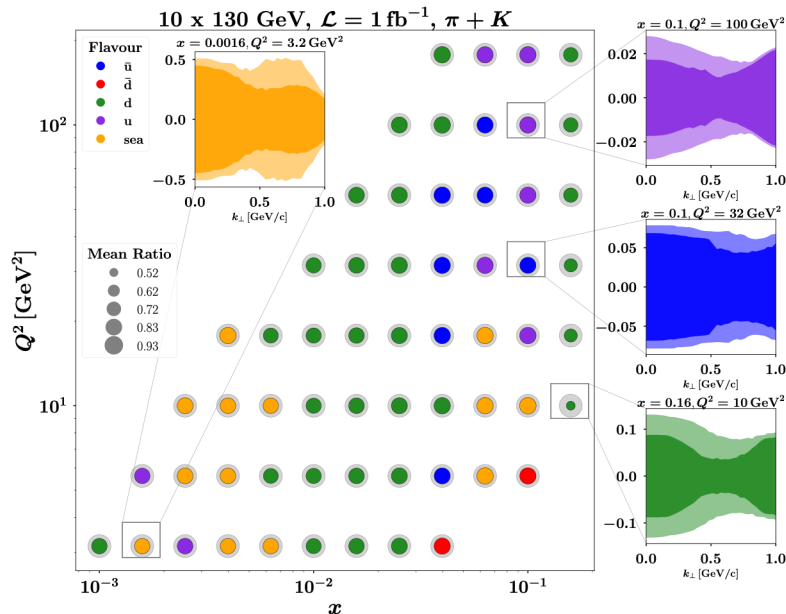
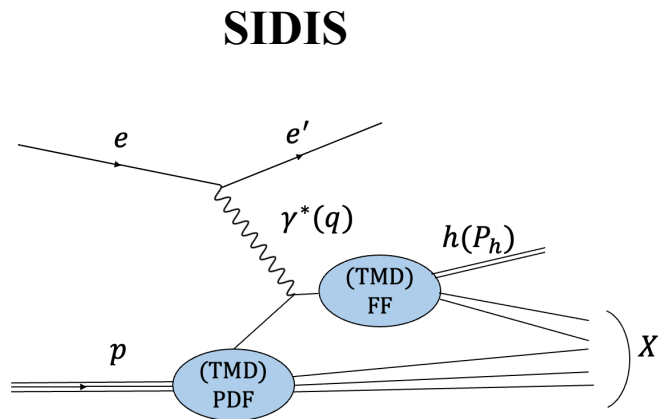


Pole extrapolation



- Isolate *e*+*n* interaction by tagging forward protons
- Pole extrapolation → “measurement” of free neutron structure function
- Up to 25% reduction in neutron F_2 uncertainty
 - Potentially change the central values

Unpolarized TMDs

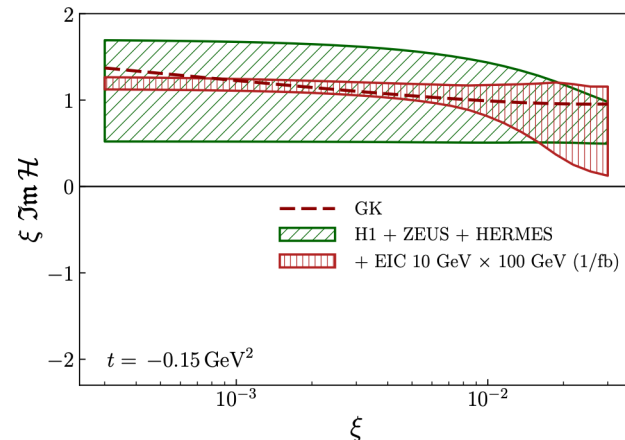
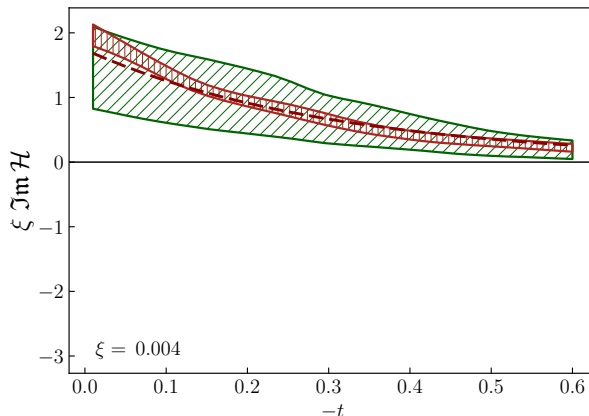
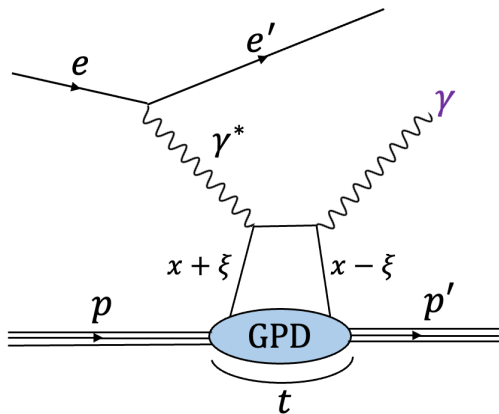


- Additional sensitivity to quark flavor, transverse momentum ...
- Early data significantly reduce TMD PDF uncertainties **for both valence and sea quarks**

Chiral-even GPDs: $\text{Im}(\mathcal{H})$

O. Jevons, Thu 09:25

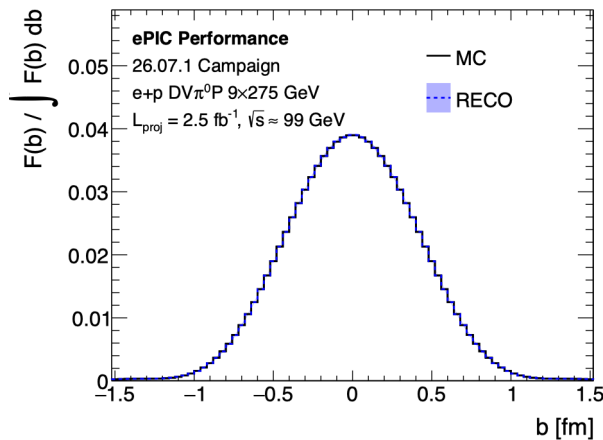
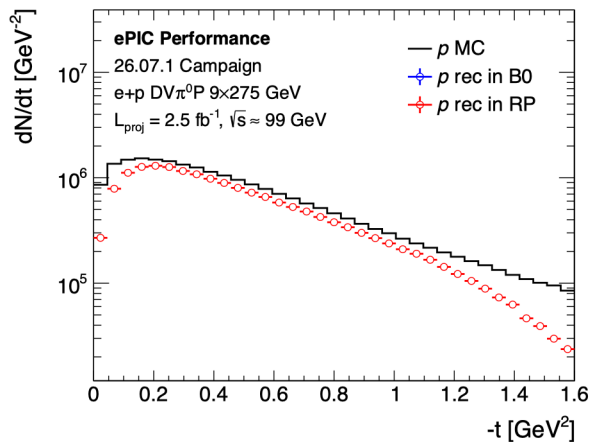
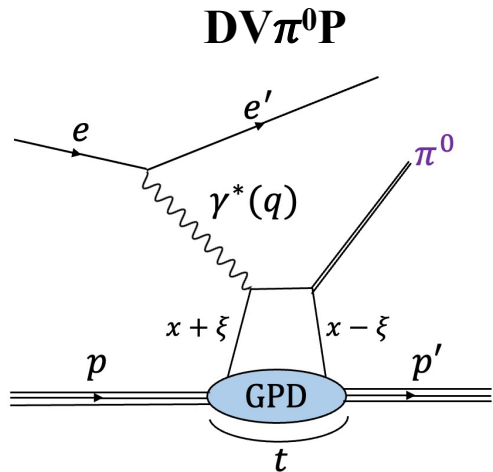
DVCS



- Connect momentum transfer t with transverse spatial distribution
- Significantly narrowing uncertainties on Compton Form Factors

Chiral-odd GPDs

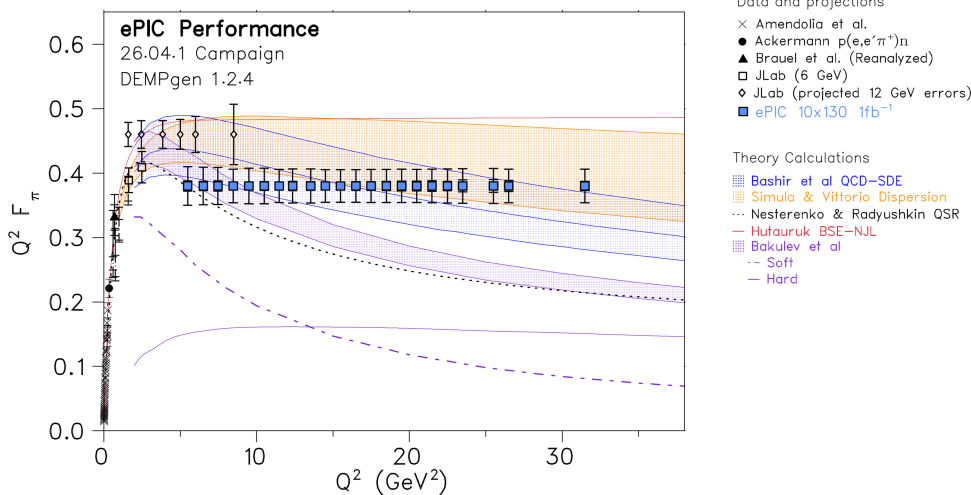
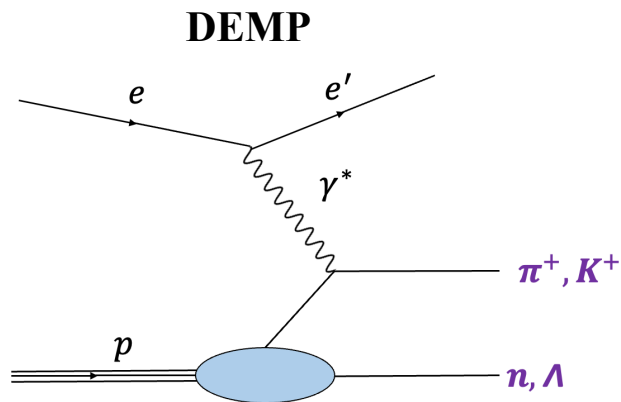
L. Xu, Tue 11:30



- t can be reconstructed in RP alone spanning 0 – 1.6 GeV ^{2}
- Detector effects correction + Fourier transformation $\rightarrow$ spatial distribution

Pion structure function

- Different mixture of mass generating mechanisms compared to proton
 - Probe Dynamical Chiral Symmetry Breaking (DCSB)

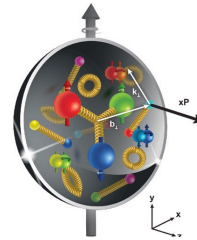


- Studies for kaons are underway: role of strange quarks

ORIGIN OF NUCLEON SPIN



SPIN

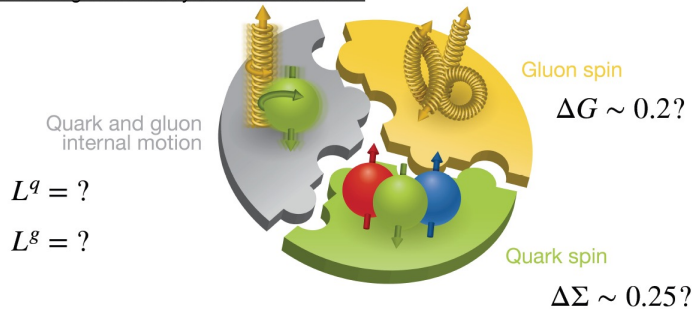


IMAGING

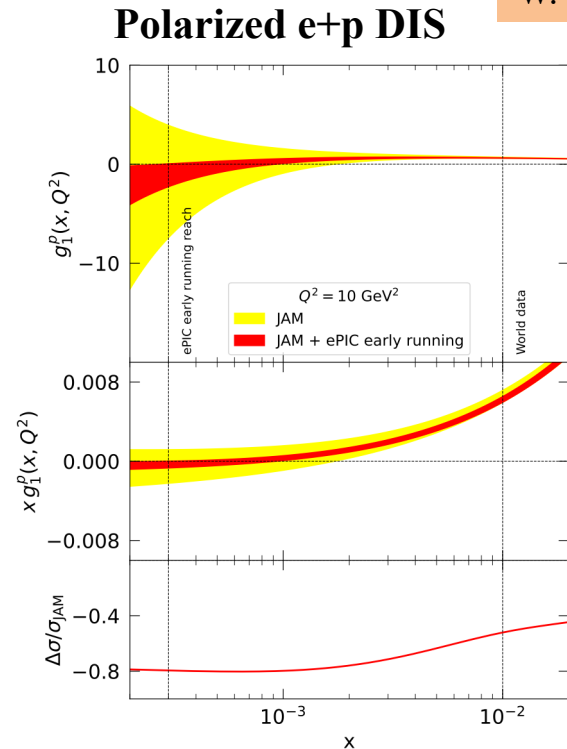
Proton longitudinal spin structure

W. Lin, Thu 11:55

<https://doi.org/10.1103/PhysRevLett.113.012001>



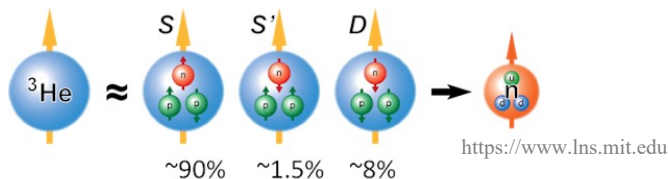
$$g_1(x, t) = \frac{1}{2} \sum_{k=1}^{n_f} \frac{e_k^2}{n_f} \int_x^1 \frac{dy}{y} \left[C_q^s \left(\frac{x}{y}, \alpha_s(t) \right) \Delta\Sigma + 2n_f C_g \left(\frac{x}{y}, \alpha_s(t) \right) \Delta G(y, t) + C_q^{\text{NS}} \left(\frac{x}{y}, \alpha_s(t) \right) \Delta q_{\text{NS}}(y, t) \right]$$



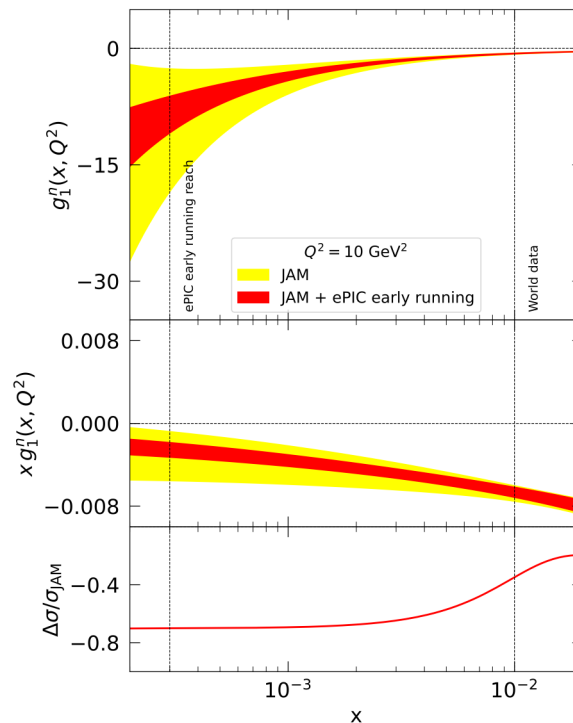
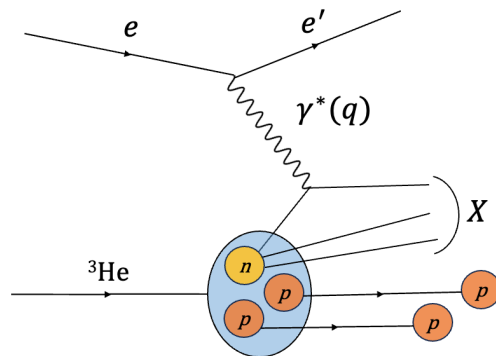
Neutron longitudinal spin structure

W. Lin, Thu 11:55

■ Polarized ^3He ~ polarized neutron target

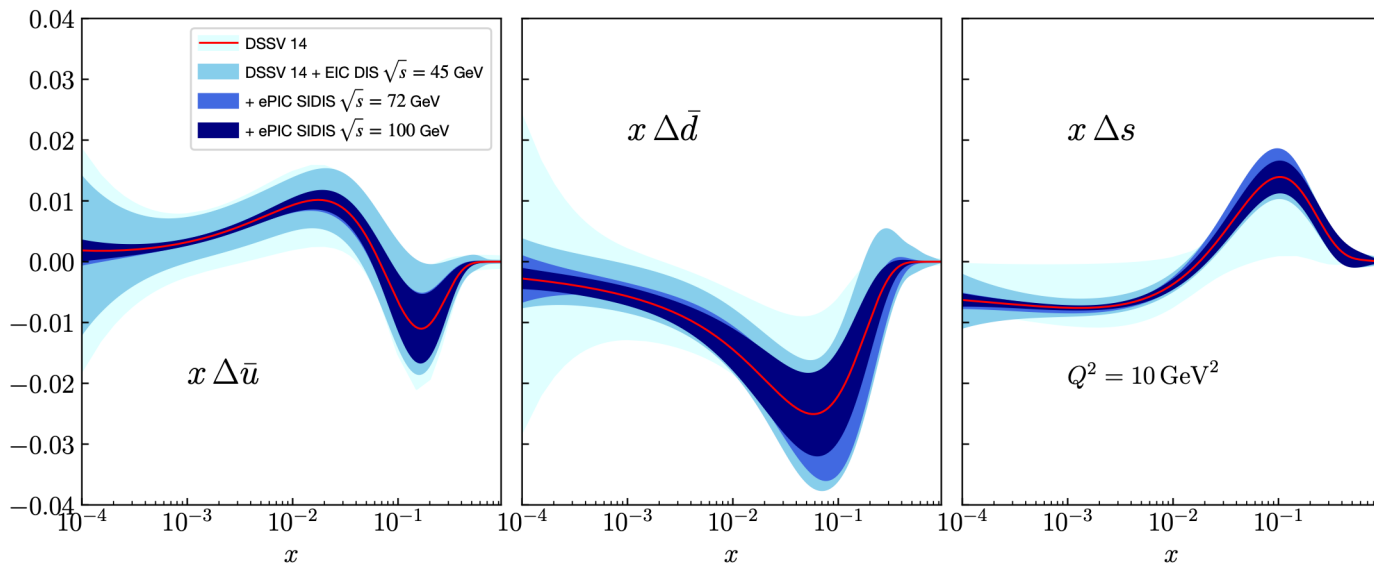


■ Double-tagging: tag $e+^3\text{He}$ events with two forward protons



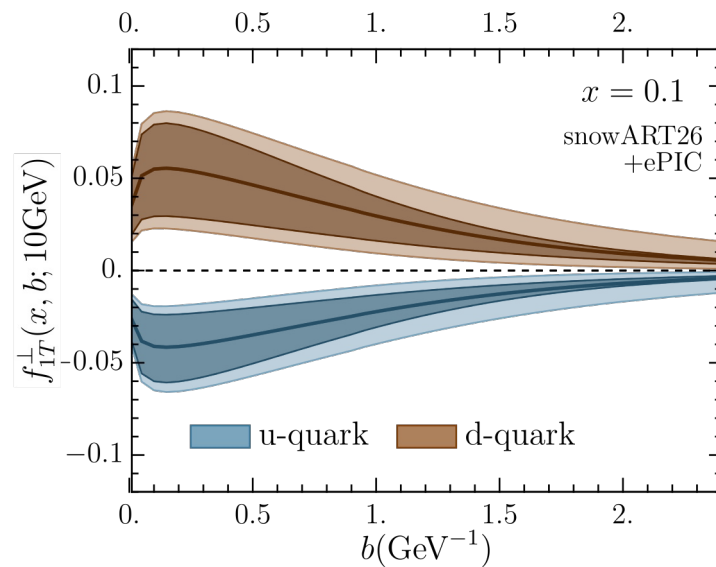
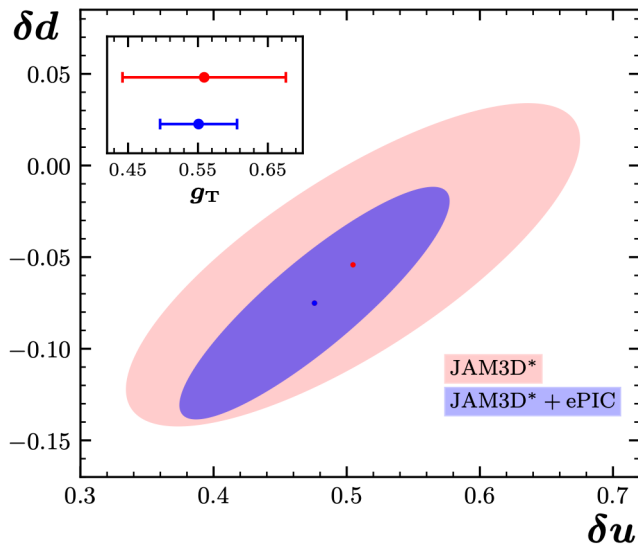
Flavor dependent helicity

- **SIDIS: extra sensitivity to sea and strange quarks**
- Greatly improve uncertainties of these helicities over an extended kinematic range

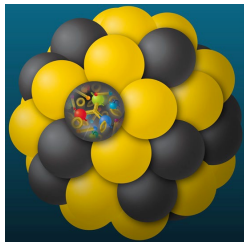


Nucleon transverse spin structure

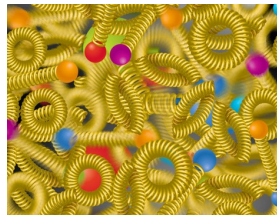
- Tensor charge: first moment of transversity
- Through SIDIS Collins asymmetry
- Sivers function: spin-orbit correlation
- Non-zero Sivers $\rightarrow$ non-zero OAM



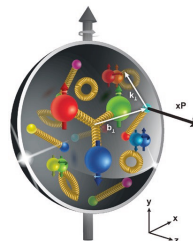
NUCLEAR MATTER & GLUONS



NUCLEI

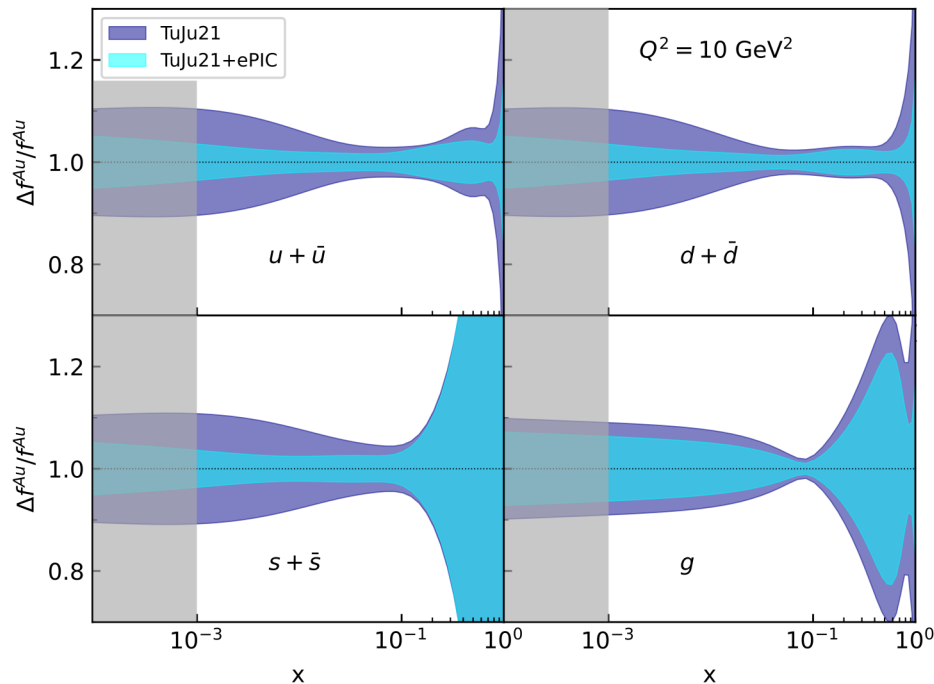


GLUONS



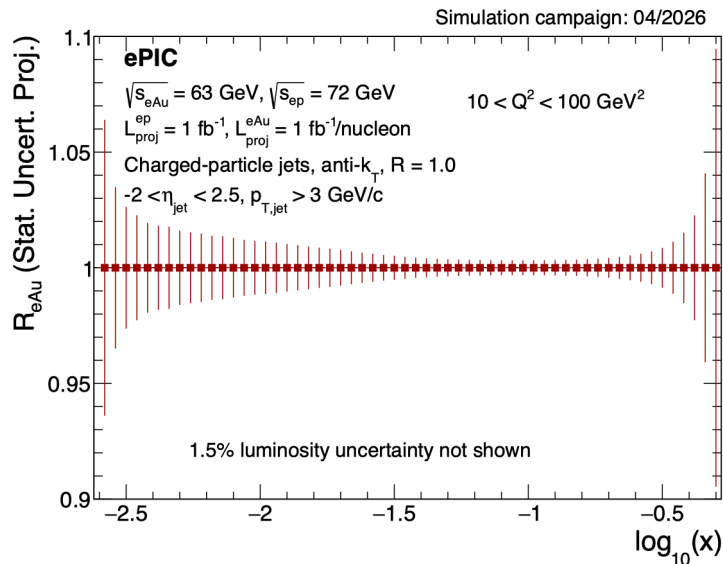
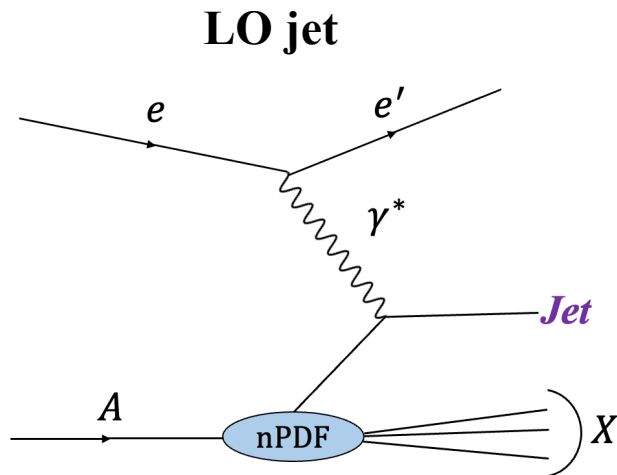
IMAGING

nPDF from eA DIS



- First eA DIS measurements in a collider
 - Access nPDF down to $x \sim 10^{-3}$
- Early running reduces uncertainties on various nPDF flavors
 - Based on reweighting of TUJU21 parameterizations
- *Heavy flavor measurements will provide complementary constraints on gluons*

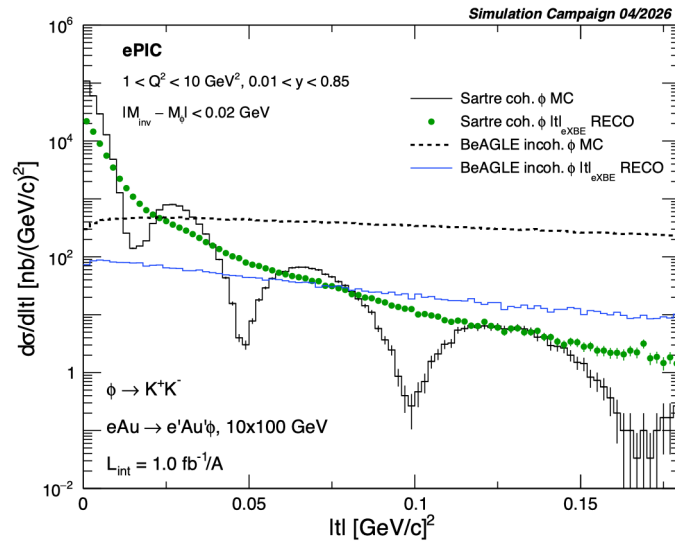
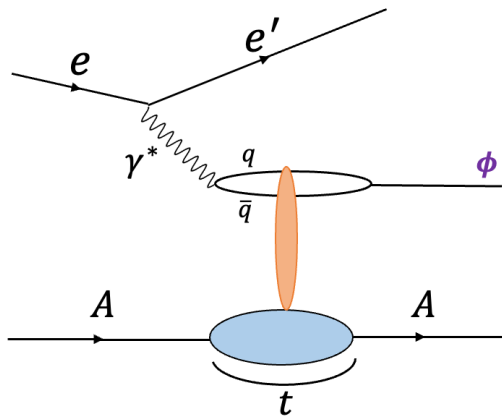
Inclusive jet: initial-state



- Clean access to initial-state effects (nPDF); avoid complication with hadronization
- Percent level statistical precision with early data
- Charged jets only; full jet reconstruction coming soon

Gluon imaging & Saturation

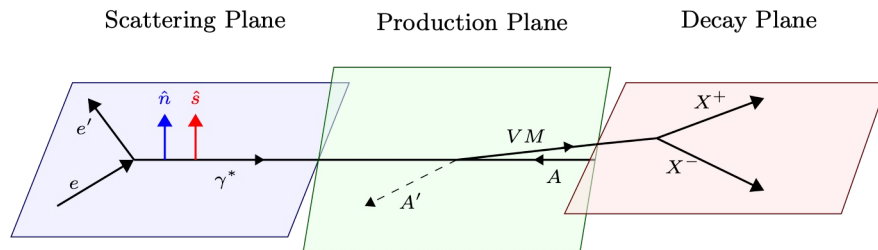
Coherent VM



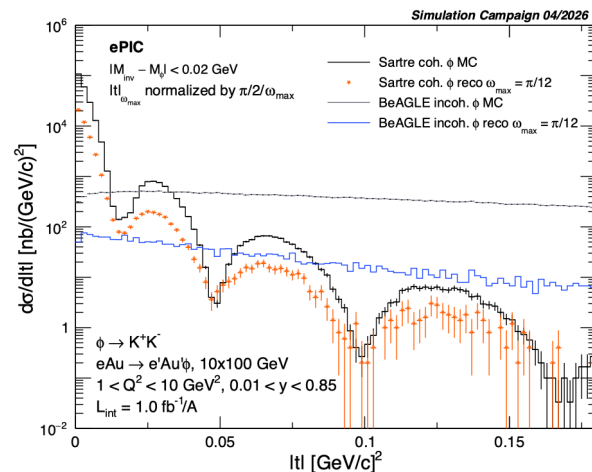
- Considered a golden channel for imaging gluons
- *Limited resolution in measuring $|t|$ largely washes out diffractive pattern*

Projective imaging

- Solution: restrict to the **normal direction of the scattering plane** to minimize the effect of momentum resolution



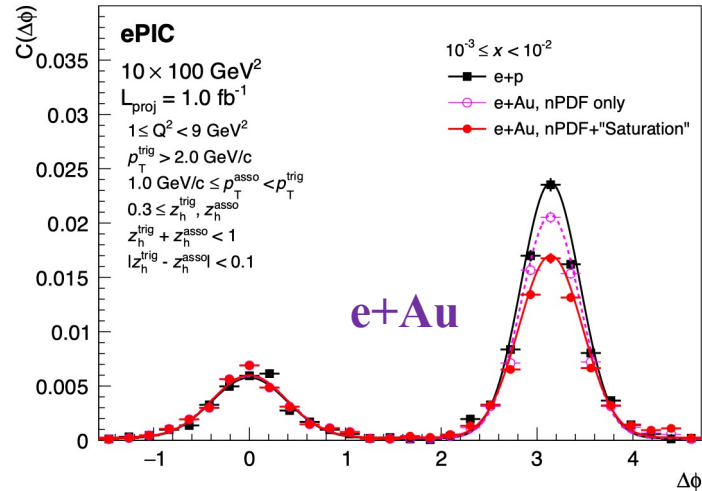
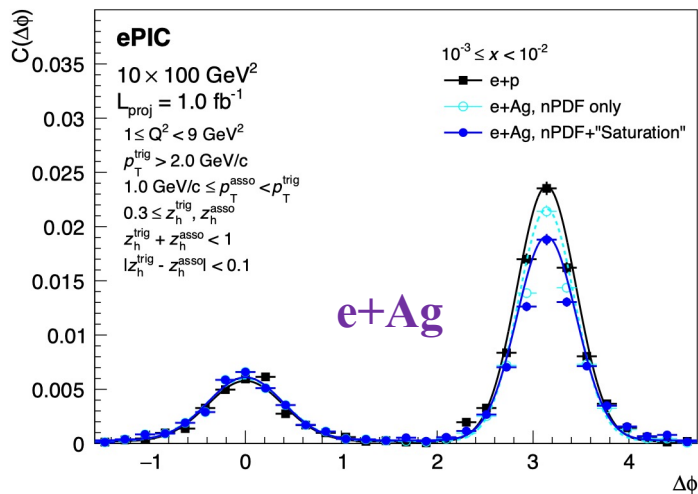
M. Kesler, et al., PLB 879 (2026) 140585



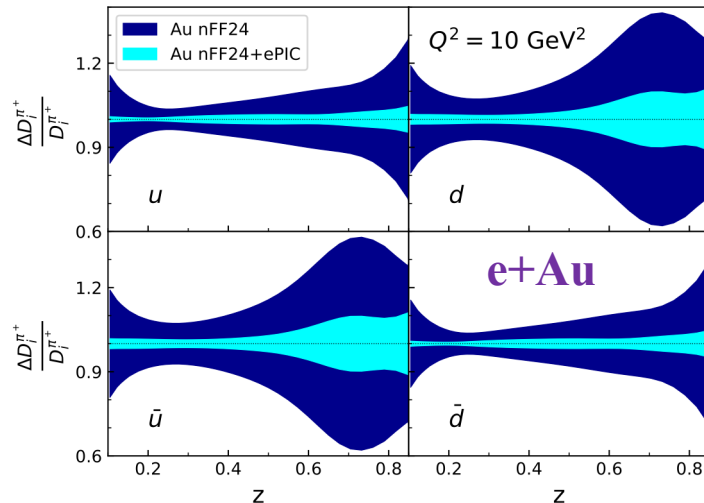
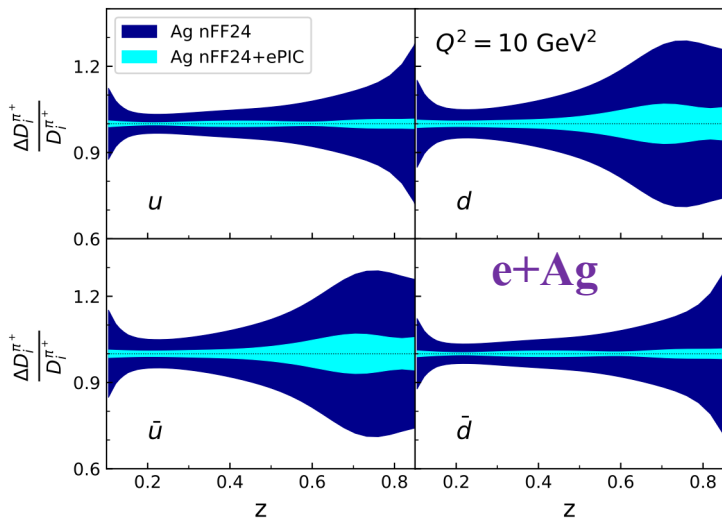
- Ongoing: separate coherent vs. incoherent via spin transfer

Another handle on saturation

- Di-hadron **decorrelation enhanced by saturation** in addition to nPDF
 - Larger effects for Au than Ag
- Early measurements benchmark the approach

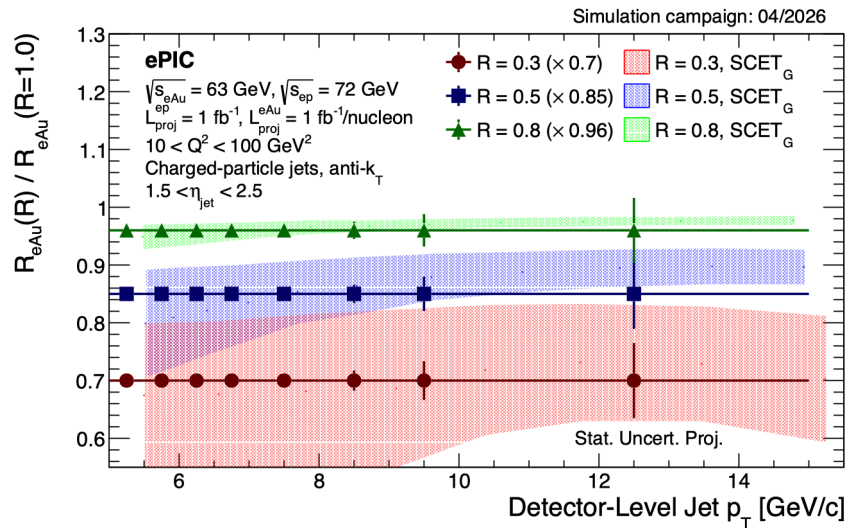
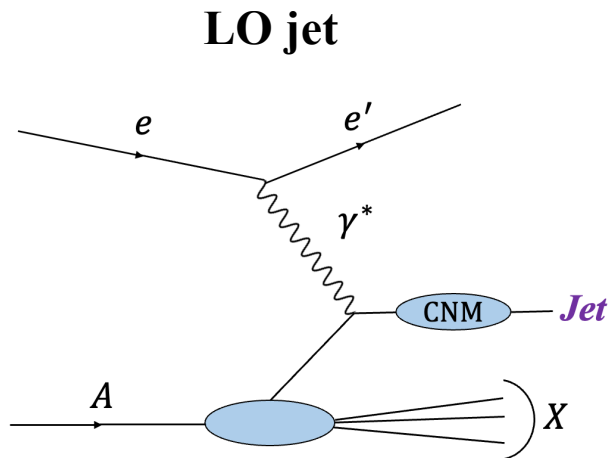


nFF from eA SIDIS



- Measuring hadron multiplicities reduces nPDF effects
- Early e+Ag and e+Au data already **provide significant constraints on nFF**
 - Reweighting based on nFF24 sets
 - Only 5% of bins from π^+ simulation data used

Jet: color propagation in CNM



- Ratio of different R largely cancels initial-state effects $\rightarrow$ sensitive to final-state effects
 - Inputs for interpreting jet quenching results in heavy-ion collisions
- Better precision than current e-loss calculations

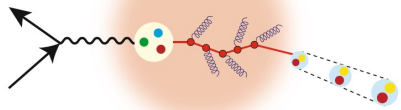
HF: color propagation in CNM

- Probe propagation and hadronization in nuclei

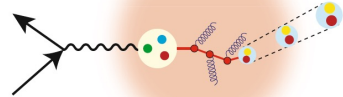
$$R_{eA}(p_T, z, \nu) = \frac{N^{D0}(p_T, z, \nu)|_{eAu}}{N^{D0}(p_T, z, \nu)|_{ep}} \times \frac{N^{inc}(\nu)|_{ep}}{N^{inc}(\nu)|_{eAu}} \rightarrow \text{Reduce initial-state effects}$$

virtual photon energy

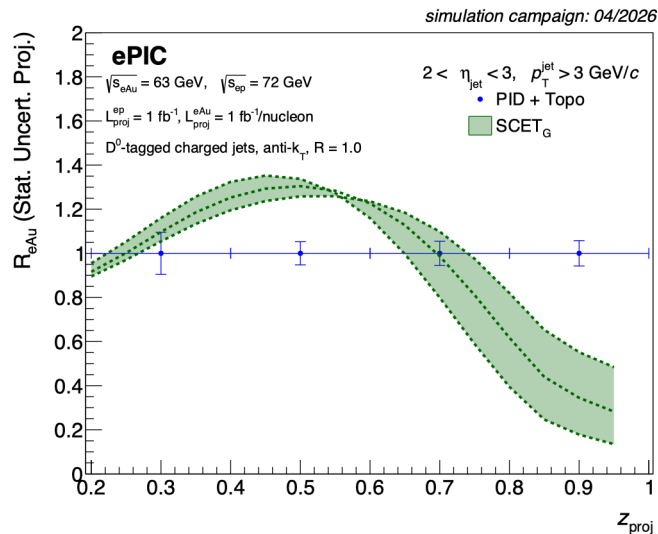
large ν



small ν



EIC white paper: arXiv:1212.1701



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

Summary

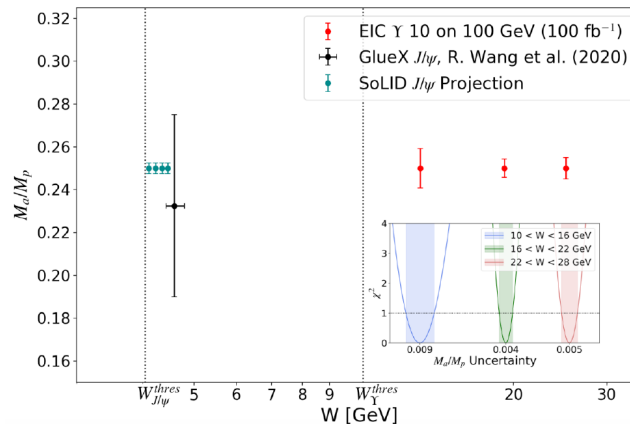
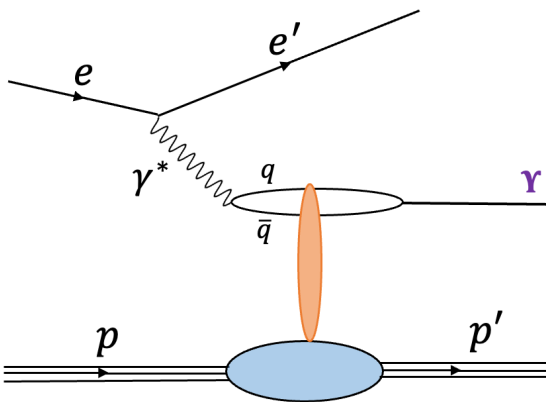
- **EIC is the next flagship facility** and highest construction priority for US nuclear physics community
 - Baselineing well underway
- **ePIC is the project detector**: general purpose with state-of-the-art technologies
 - Mature software stack for simulating detector performance
- **Early science: profound impacts** on understanding nucleon mass, spin and nuclear matter
- Ultimate performance will unlock EIC's **full potential in revealing the internal landscape of nucleons and nuclei**

Backup

Constrain trace anomaly

- Trace anomaly: a key contribution to nucleon mass
 - Arises from **gluon dynamics**
 - Not well understood

Near-threshold quarkonium production

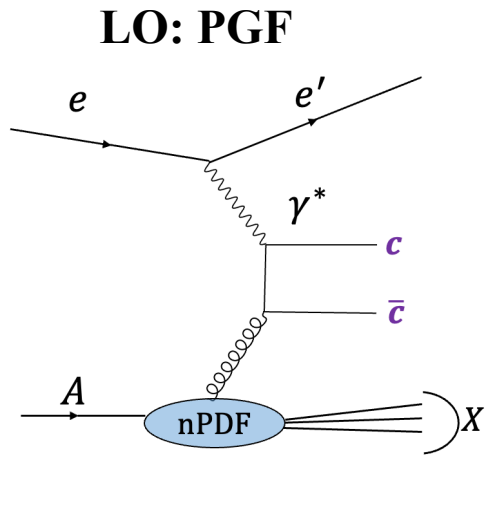


Near-threshold Υ
at EIC

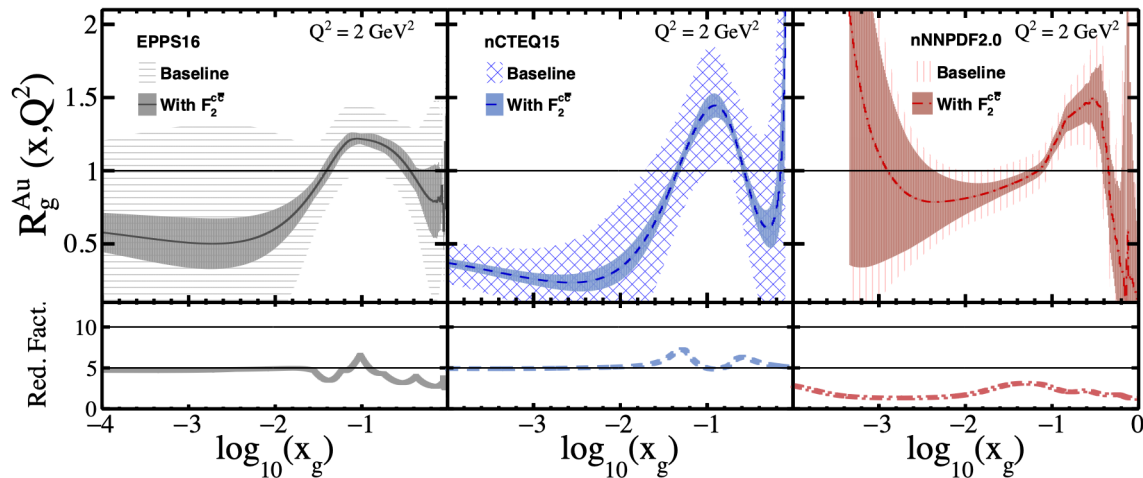
EIC yellow report: arXiv:2103.05419

Heavy flavor: initial-state

- Sensitive probe of gluons, especially at large x



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



ep, eAu @ 5x41, 10x100
1 fb⁻¹/nucleon per energy and system

- Ongoing: incorporate full ePIC detector effects