

Electron-Ion Collider Science and Status

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EIC Science Pillars



SPIN is one of the fundamental properties of matter.

All elementary particles, but the Higgs carry spin.

Spin cannot be explained by a static picture of the proton

It is the interplay between the intrinsic properties and interactions of quarks and gluons

The EIC will unravel the different contribution from the quarks, gluons and orbital angular momentum.



Does the mass of visible matter emerge from quark-gluon interactions?

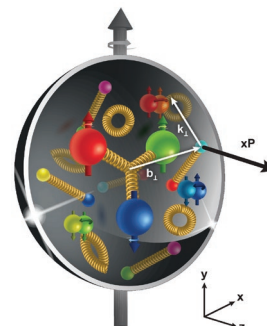
Atom: Binding/Mass = 0.00000001

Nucleus: Binding/Mass = 0.01

Proton: Binding/Mass = 100

Hadrons will determine important contributions to the proton, pion, kaon mass,

- "QCD trace anomaly"
- Meson momentum terms

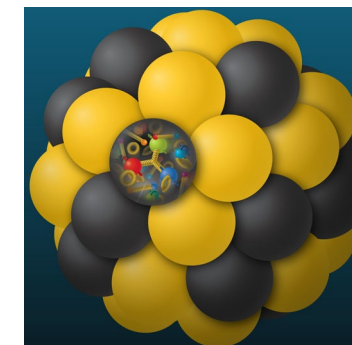


How are the quarks gluon distributed in space and momentum inside the nucleon & nuclei?

nucleon properties emerge from them and their interactions?

How can we understand their dynamical origin in QCD?

What is the relation to Confinement

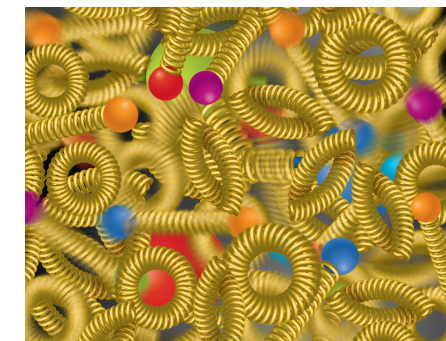


Is the structure of a free and bound nucleon the same?

How do quarks and gluons, interact with a nuclear medium?

How do the confined hadronic states emerge from these quarks and gluons?

How do the quark-gluon interactions create nuclear binding?



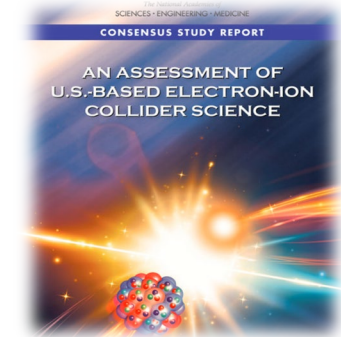
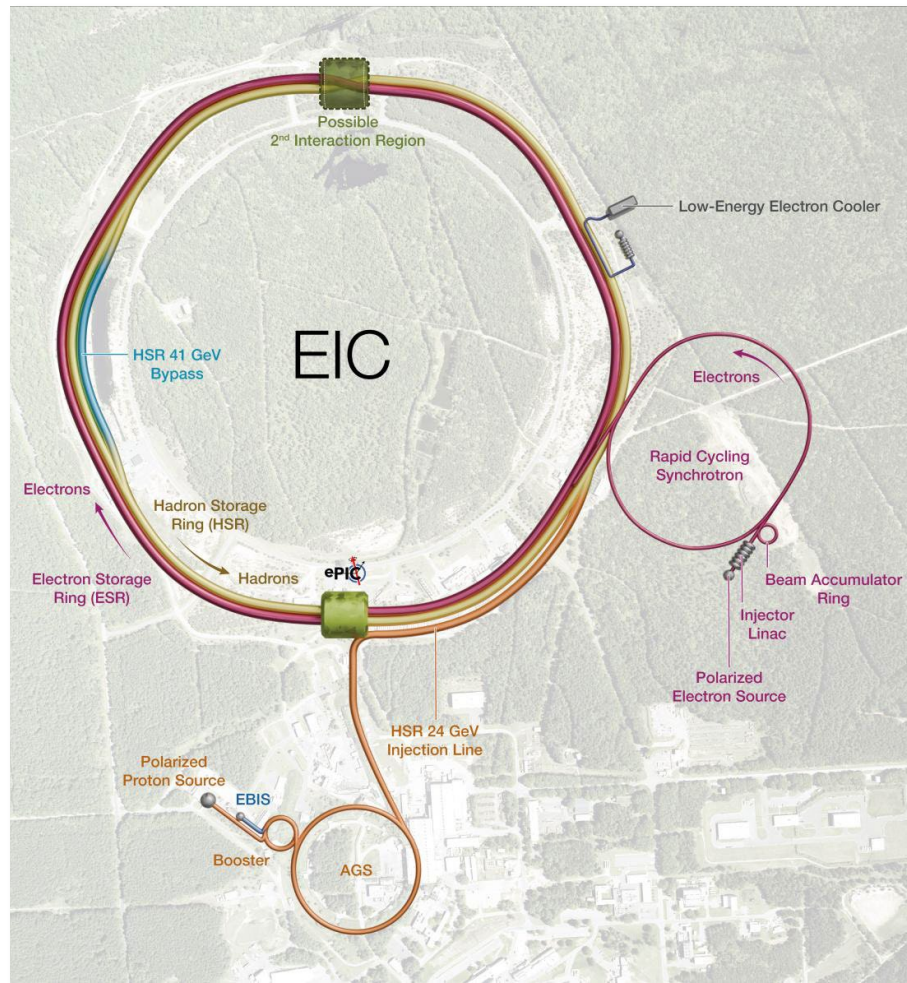
How many gluons can fit in a proton?

How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions?

What happens to the gluon density in nuclei? Does it saturate at high energy?

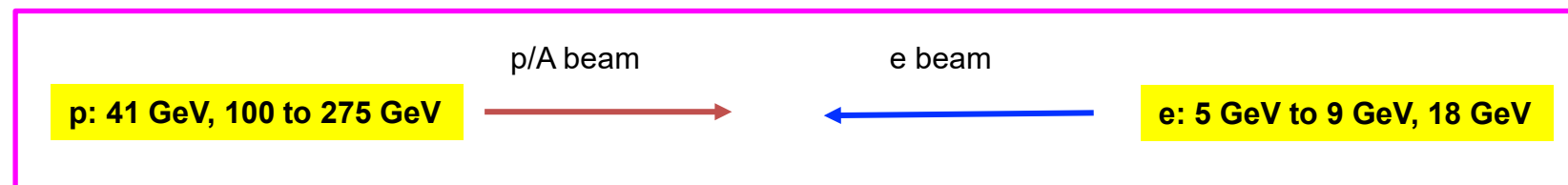
gluon splitting = ? = gluon recombination

EIC Scope



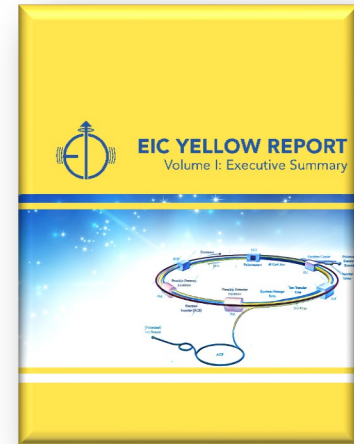
Project Design Goals

- ❑ High Luminosity: $L = 10^{33} - 10^{34} \text{cm}^{-2}\text{s}^{-1}$, $10 - 100 \text{fb}^{-1}/\text{year}$
- ❑ Highly Polarized Beams: 70%
- ❑ Large Center of Mass Energy Range: $E_{\text{cm}} = 29 - 100 \text{ GeV}$, upgradeable to 140 GeV
- ❑ Large Ion Species Range: protons – Uranium
- ❑ Large Detector Acceptance and Good Background Conditions
- ❑ Accommodate a Second Interaction Region (IR)



Experimental Program Progress Since CD-1 (2021)

BNL and TJNAF Jointly Leading Efforts Towards Experimental Program		
2021	Yellow Report Completed (https://arxiv.org/abs/2103.05419)	March 2021
	<u>Call for Collaboration Proposals for Detectors</u>	March 2021
	Collaboration Proposals for Detectors Submitted	December 2021
2022	Decision on Project Detector – baseline “ECCE”	March 2022
	Process to consolidate ECCE & ATHENA to the EIC Project Detector	Spring 2022
	ePIC Collaboration Formed – 160 institutions	July 2022
2023	ePIC Charter ratified & elected Leadership Team	February 2023
	1st Resource Review Board Meeting	April 2023
	ePIC (Central) Detector remaining technology choices made	April 2023
2024	ePIC Detector technical baselined	February 2024
	Introduction of early physics planning to ePIC Collaboration	July 2024
	Started drafting Preliminary Technical Design Report	July 2024
2025	Passed 60% Cost-Weighted Design Maturity	January 2025
	Detector R&D Completed	September 2025
2026	Preliminary Technical Design Report full draft completed	January 2026
	Early Science Report complete (https://arxiv.org/abs/2608.05377)	August 2026

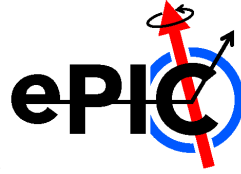


EIC / ePIC Science Community

The EIC Users Group: <https://eicug.org>

Formed 2016: 400 Users → Now

1563 collaborators, 41 countries, 310 institutions

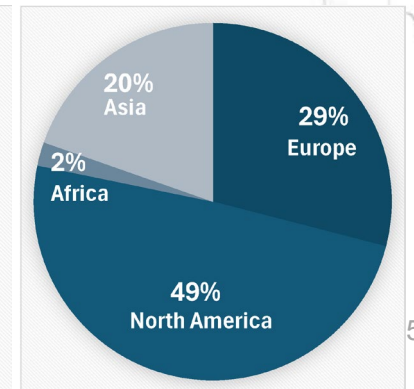
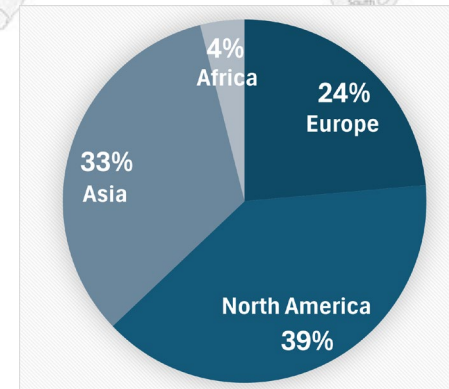
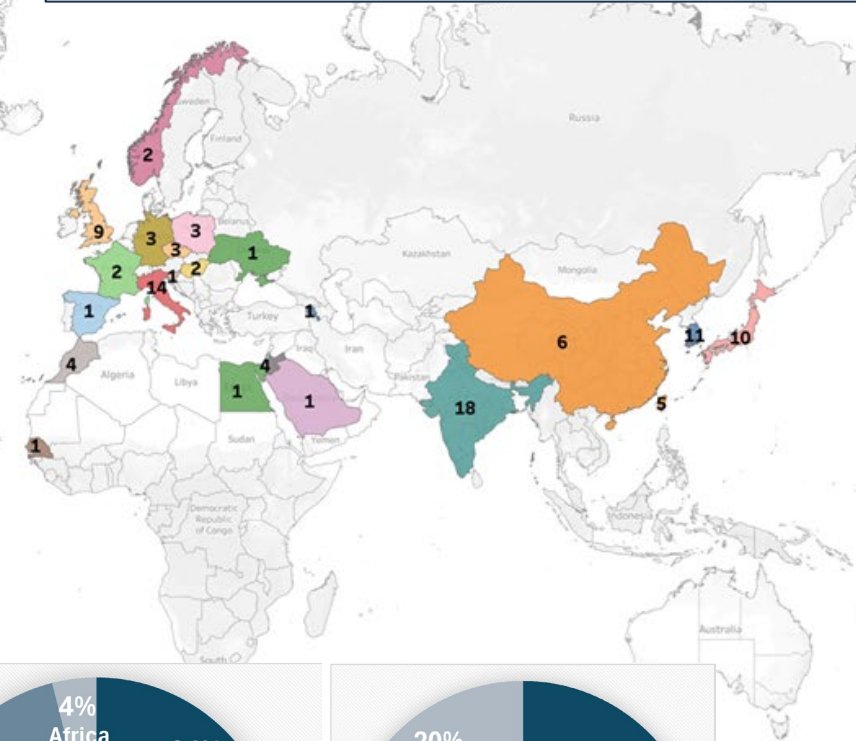
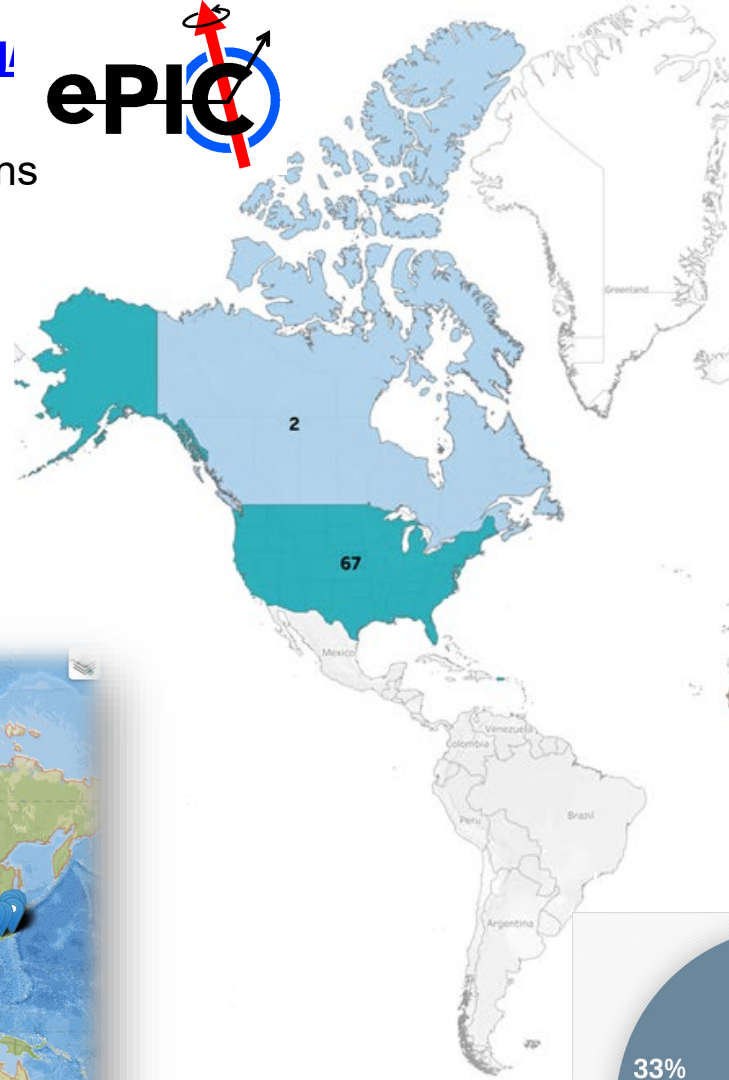
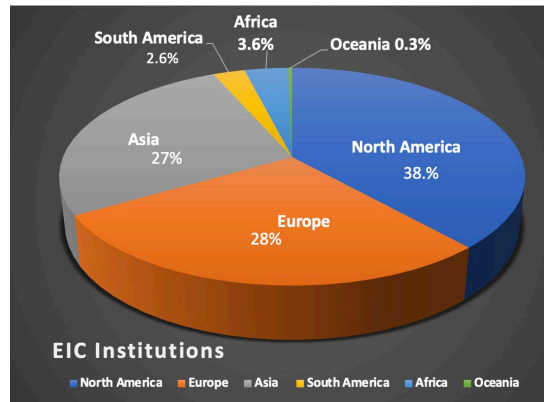


>1100 collaborators

181 institutions, 25 countries

US: 8 National Labs + 59 Universities

ePIC is a CERN recognized experiment



EIC Planning Dates

Milestone		Milestone	
DOE Independent Project Review (IPR)	Jan 7-9, 2025	EIC Project Advisory Committee	Dec. 2, 2025
Start Developing Scope of Subprojects	January 10, 2025	EIC Project Strategy Workshop - Stakeholders	Dec. 4, 2025
IR SC Magnet Steering Group Meetings - Monthly	January 17, 2025	<i>(ASR) Assessment of Baseline Readiness</i>	<i>Jan. 14-16, 2026</i>
Project Advisory Committee Meeting	February 11, 2025	<i>(DET) Assessment of Baseline Readiness</i>	<i>Feb. 3-5, 2026</i>
Resource Review Board Meeting	Project Advisory Committee Review		Aug. 18-19, 2026
Detector Advisory Committee Meeting	DOE IPR Comprehensive Review incl. CD-3C, INF CD-2/3		Sept. 15-18, 2026
EIC Advisory Board Meeting	DOE CD-3C and NYS Infrastructure CD-2/3 Approvals		~ Q1 FY27
DOE CD-3B ESAAB Approval			May 28, 2026
DOE IPR Focused Status Meeting			<i>June 3-5, 2026</i>
DOE RHIC R&R/Injector Meeting			June 9-10, 2026
Machine Advisory Committee Meeting	Sept. 16-18, 2025	Infrastructure Construction Advisory Committee	June 10-11, 2026
Infrastructure Construction Advisory Committee	October 1-2, 2025	Project Advisory Committee Review	Aug. 18-19, 2026
EIC Advisory Board Meeting	October 10, 2025	DOE IPR Comprehensive Review incl. CD-3C, INF CD-2/3	Sept. 15-18, 2026
Resource Review Board Meeting (BNL)	Nov 4-5, 2025	DOE CD-3C and NYS Infrastructure CD-2/3 Approvals	~ Q1 FY27
<i>(IR) Assessment of Baseline Readiness</i>	Nov. 18-20, 2025		

What is required of an EIC Detector

Asymmetric beam energies

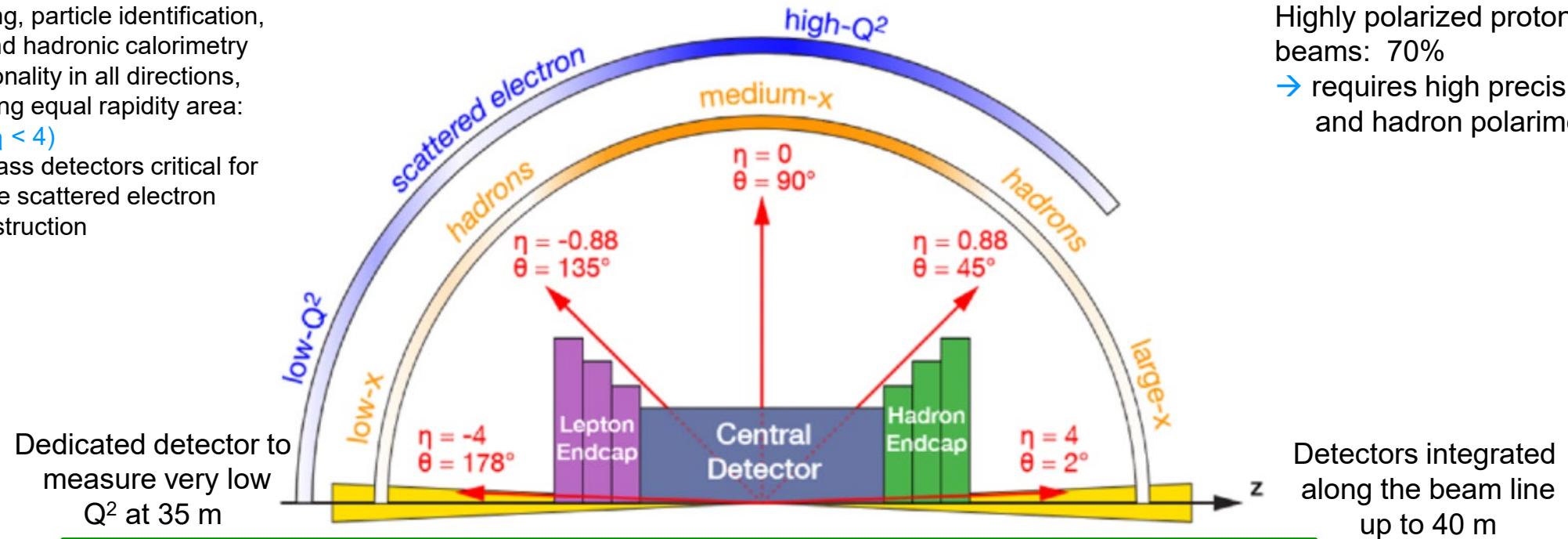
41 GeV, 100 to 275 GeV **polarized p/A**  **polarized electrons** 5 GeV, 10 GeV, 18 GeV

requires an asymmetric detector with an electron and a hadron endcap

- tracking, particle identification, EM and hadronic calorimetry functionality in all directions, covering equal rapidity area: $(-4 < \eta < 4)$
- low mass detectors critical for precise scattered electron reconstruction

Highly polarized proton and electron beams: 70%

- requires high precision electron and hadron polarimetry



SPIN

QCD in Nuclei

Dense Gluon Systems

MASS

3D-Imaging

require detection of scattered electron and produced hadrons

require detection of all produced particles,
especially the ones scattered under very small
angles into the detectors along the beam line

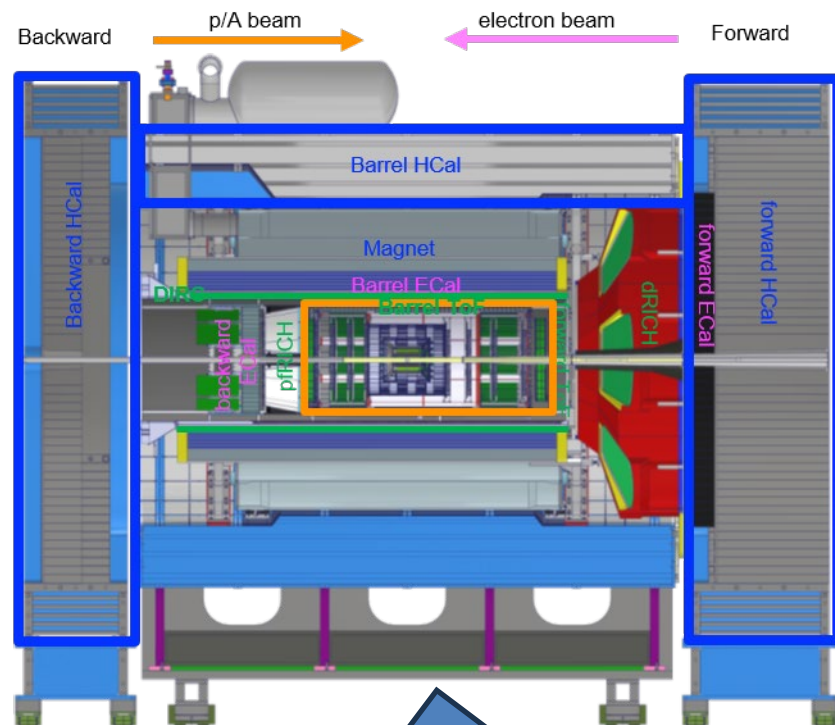
ePIC – The EIC State-of-the-Art General-Purpose Detector

26 subsystems over ± 40 m to measure particle momenta, energy and type

- 2T Solenoid ($\varnothing$ 2.84 m)
- 3 hadronic calorimeters (also serve as flux return)
- 3 electromagnetic calorimeters
- 1 DIRC + 2 RICH detectors + barrel and forward time-of-flight detectors
- Various Silicon and Micro-pattern gas tracking detectors

8 world first technologies

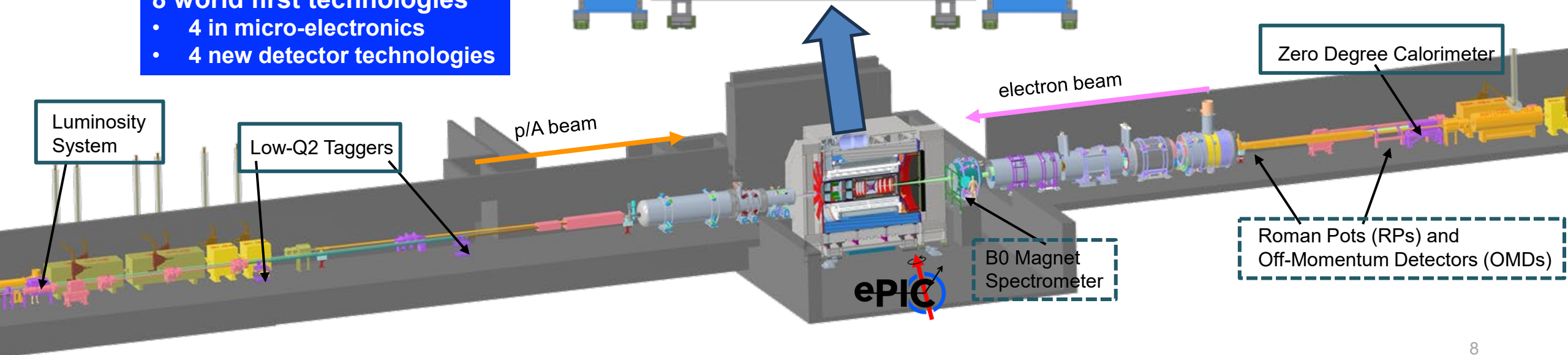
- 4 in micro-electronics
- 4 new detector technologies



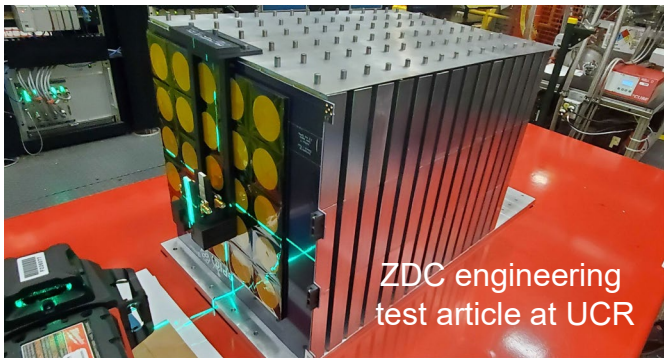
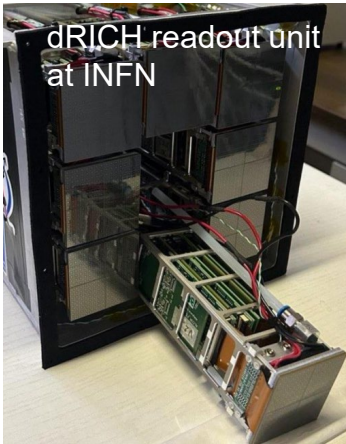
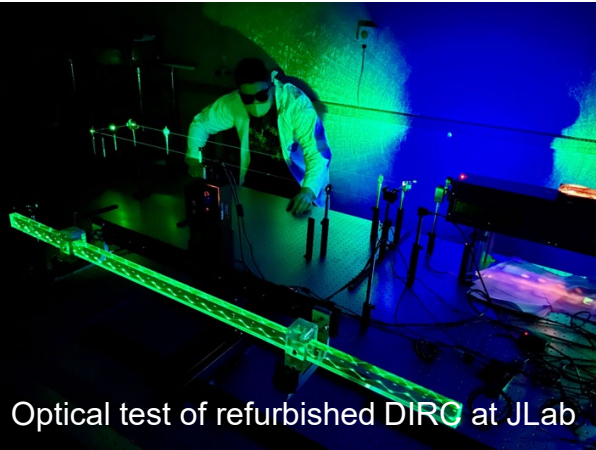
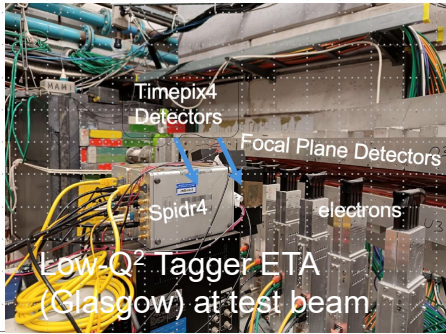
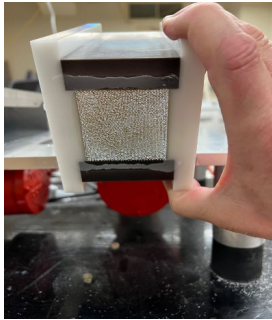
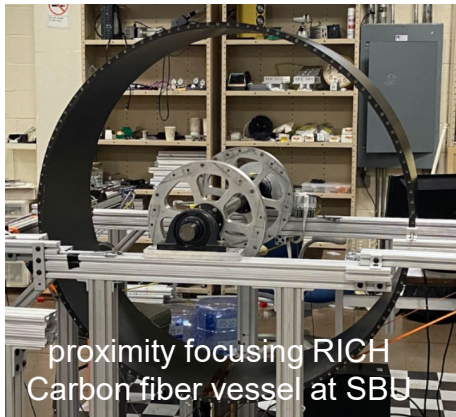
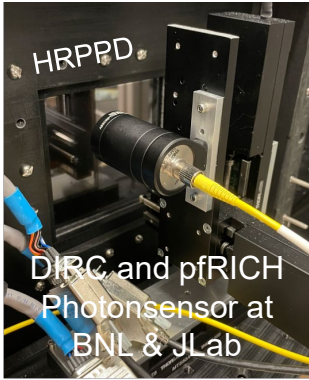
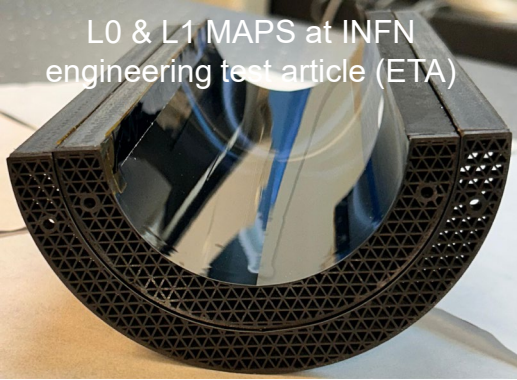
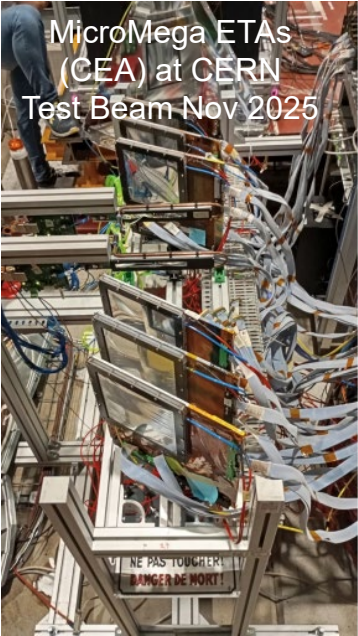
- 7 Auxiliary detectors (Si + HCal + ECals)
- fully streaming readout electronics and DAQ (integrate AI/ML capabilities from the start)
- electron (IR-6 and RCS) and hadron (IR-4 & IR-6) polarimetry

Integration, Installation and Infrastructure

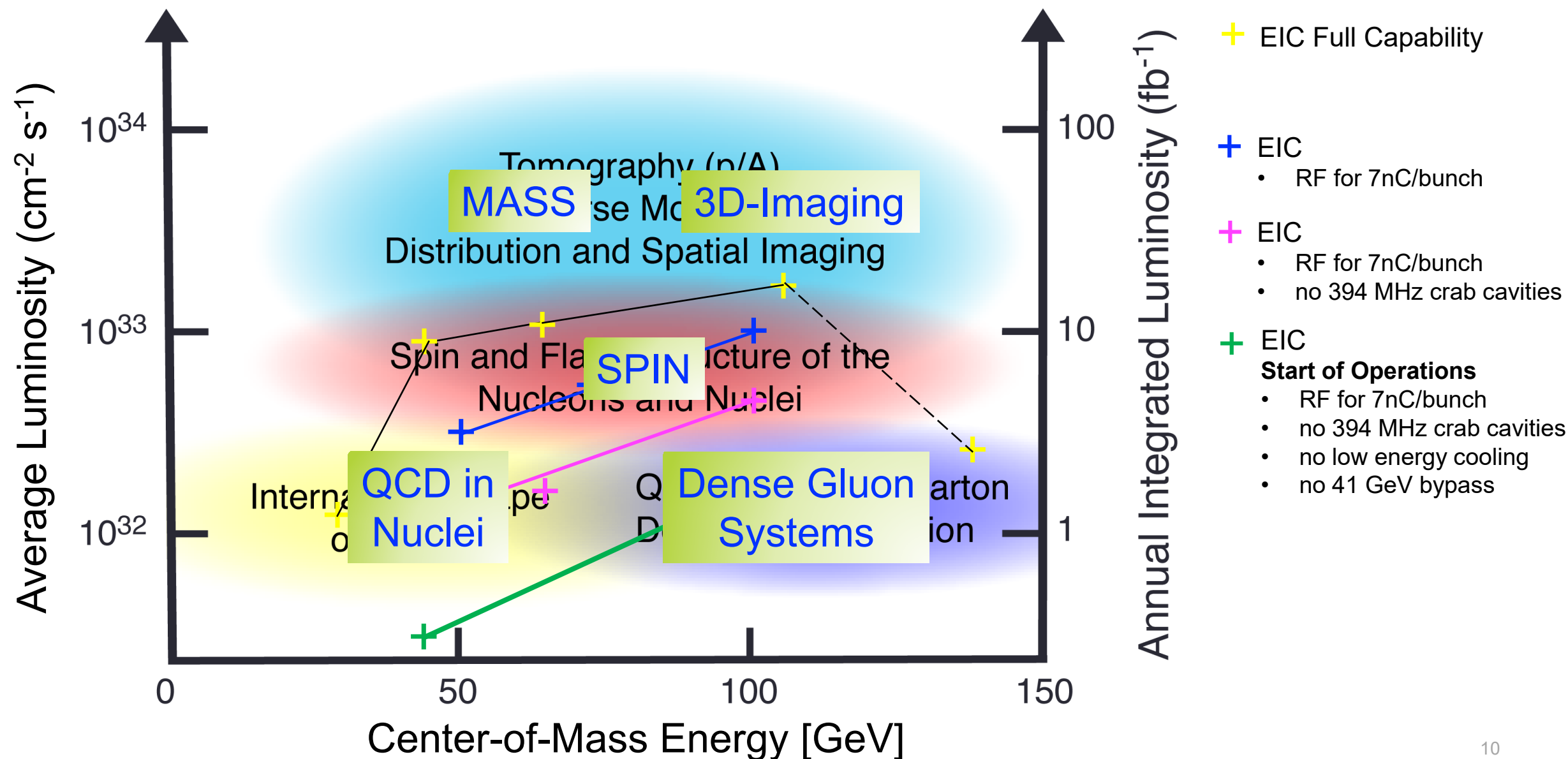
Non-Beam Commissioning



EIC Detector – Around the World Progress



EIC Science Reach for ep



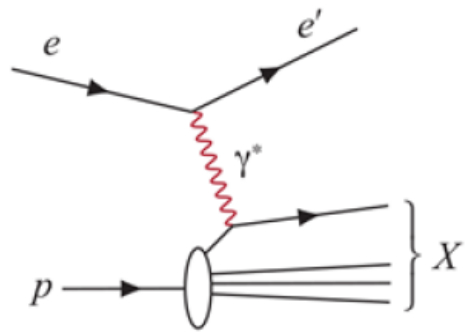
EIC Science Program in First Years of Operations

Year - 1	Year - 2	Year - 3	Year - 4	Year - 5
Start with Phase 1 EIC	Phase 1 EIC + long. electron polarization	Phase 1 EIC + long. electron polarization + proton polarization	Phase 1 EIC + long. electron polarization + proton polarization + spin rotators	Phase 1 EIC + long. electron polarization + proton polarization + operation of hadron spin rotators
New Capability: Commission electron polarization in parallel	New Capability: Commission proton polarization in parallel	New Capability: Commission running with hadron spin rotators	New Capability: Commission hadron accelerator to operate with not centered orbits	
Run: 9 GeV electrons on 115 GeV/u heavy ion beams (Ag, Nb, Cu, Ru)	Run: 9 GeV long. polarized electrons on 130 GeV/u Deuterium	Run: 9 GeV long. polarized electrons on 130 GeV transverse polarized protons	Run: 9 GeV long. polarized electrons on 110 GeV Au	Run: 9 GeV long. polarized electrons on 110 GeV Au
Physics: Dense Gluon Systems QCD in Nuclei	Physics: QCD in Nuclei Flavor structure of nucleons and nuclei Run: Last weeks: 9 GeV long. polarized electrons and 130 GeV polarized protons Physics: Flavor structure of nucleons and nuclei	Physics: Flavor structure of nucleons and nuclei Run: Last weeks switch to longitudinal proton polarization Physics: Spin	Physics: Dense Gluon Systems QCD in Nuclei Run: 9 GeV long. polarized electrons on 275 GeV transverse and longitudinal polarized protons Physics: Spin	Physics: Dense Gluon Systems QCD in Nuclei Run: 9 GeV long. polarized electrons on 166 GeV transverse and longitudinal polarized He-3 Physics: Spin

Unique science questions addressed as EIC performance ramps up to ultimate performance

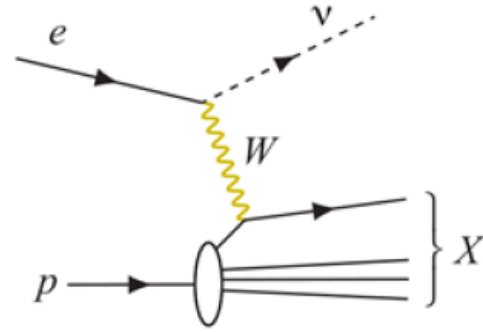
Physics Processes at The Electron-Ion Collider

DIS event kinematics - **scattered electron** or **final state particles** (CC DIS, low y)



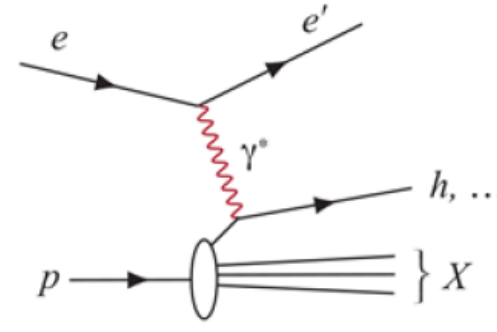
Neutral Current DIS

Detection of **scattered electron** with high precision - event kinematics



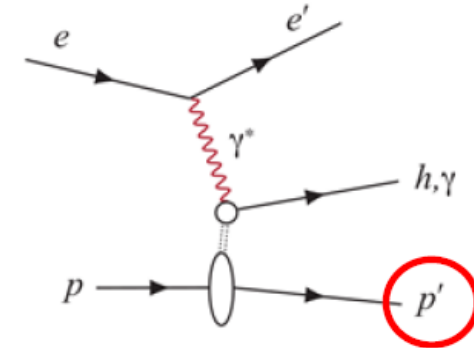
Charged Current DIS

Event kinematics from the **final state particles** (Jacquet-Blondel method)



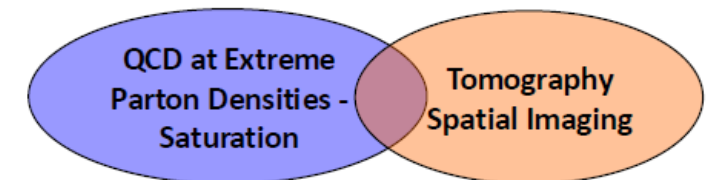
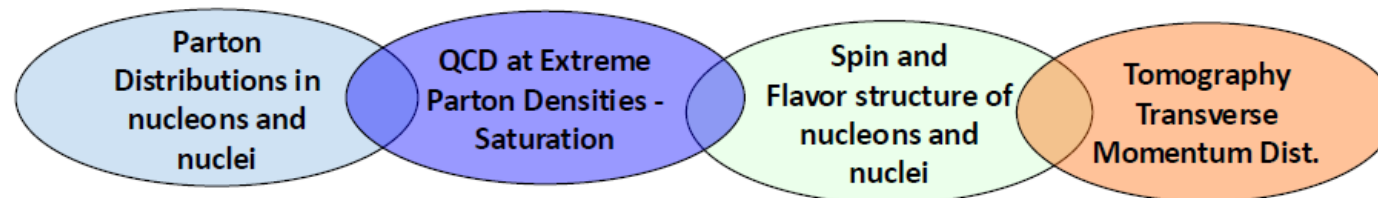
Semi-Inclusive DIS

Precise detection of **scattered electron** in coincidence with at least 1 **hadron**



Exclusive Processes

Detection of **all particles** in event



Scientific Goals: Proton PDFs

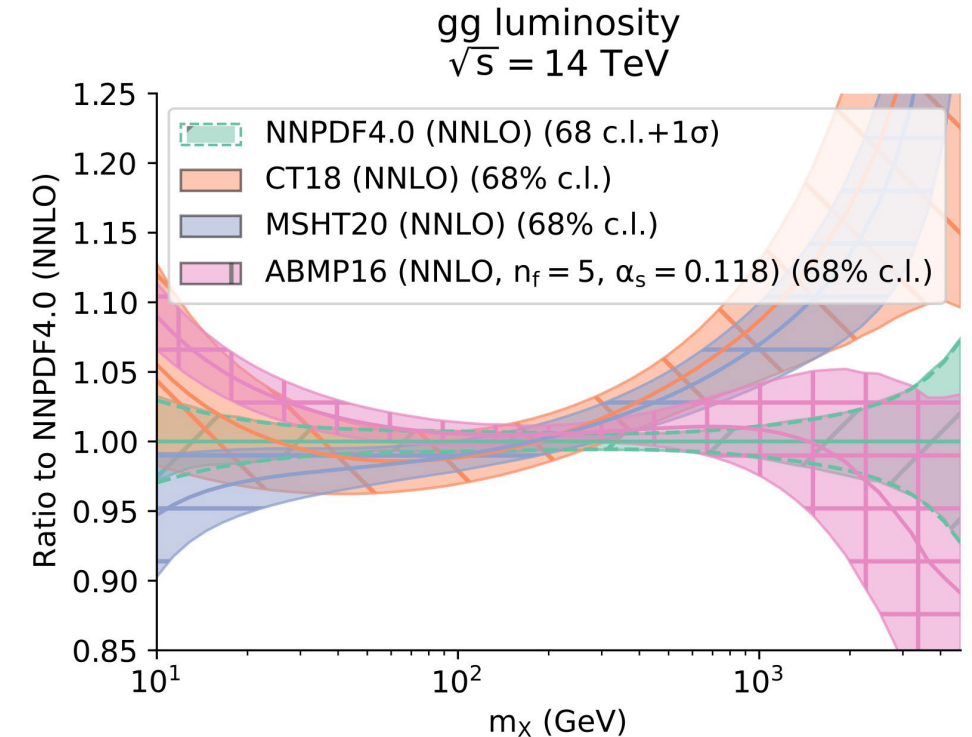
❑ $F_2(x, Q^2)$ largely studied at HERA

❑ Nevertheless, a better precision often needed for precise calculations!

- LHC impacts/needs PDF's mainly at large x
- Not fully convergent between different global fitting groups
- Large x BSM effects can hide

❑ Observable: **Neutral Current cross sections**

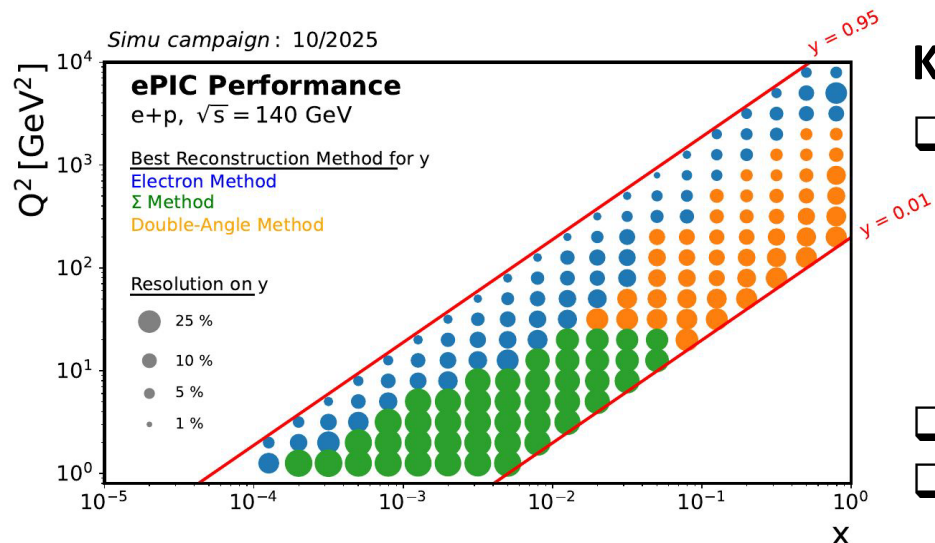
- Novel impact studies [[Phys.Rev.D 114 \(2026\) 3, 033002](#)] based on ePIC pseudo-data and the conditions of the EIC early running (1 fb^{-1}) combined with HERA data



Key detector performance:

- Electron ID
- Fine y resolution over large phase space

ePIC Performance: Proton PDFs



Kinematic Resolutions

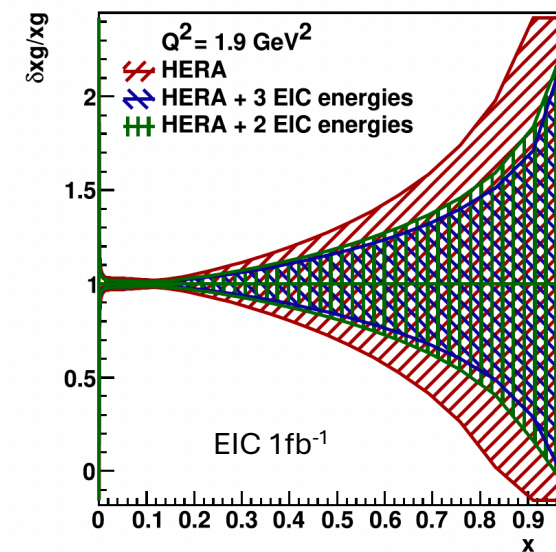
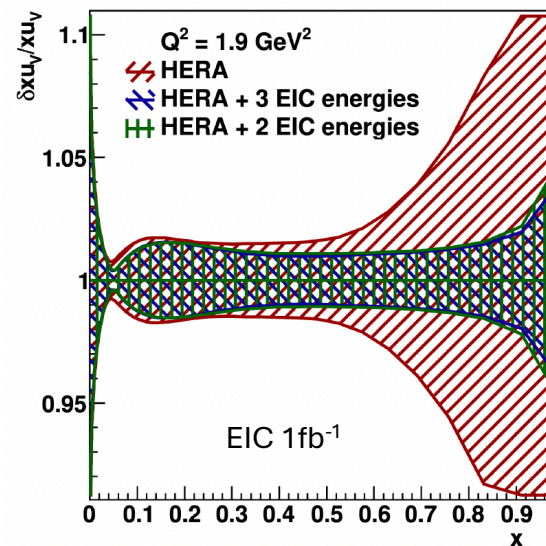
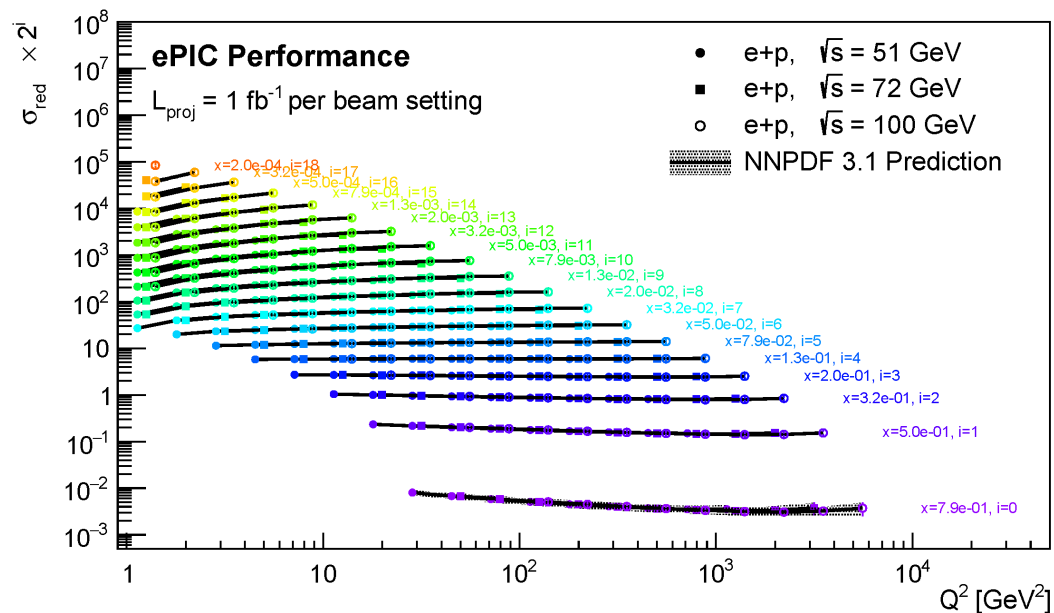
- ❑ Reconstruct inclusive kinematics using various methods
 - Color of point indicates best method for y (inelasticity)
 - Size of point indicates y resolution
- ❑ < 30% y resolution across $x - Q^2$ plane
- ❑ Improvements from kinematic fitting and AI/ML

$$y_e = 1 - \frac{E_e(1 - \cos \theta_e)}{2E_0},$$

$$y_{DA} = \frac{\alpha_h}{\alpha_e + \alpha_h},$$

$$y_{\Sigma} = \frac{\delta_h}{\delta_h + E_e(1 - \cos \theta_e)},$$

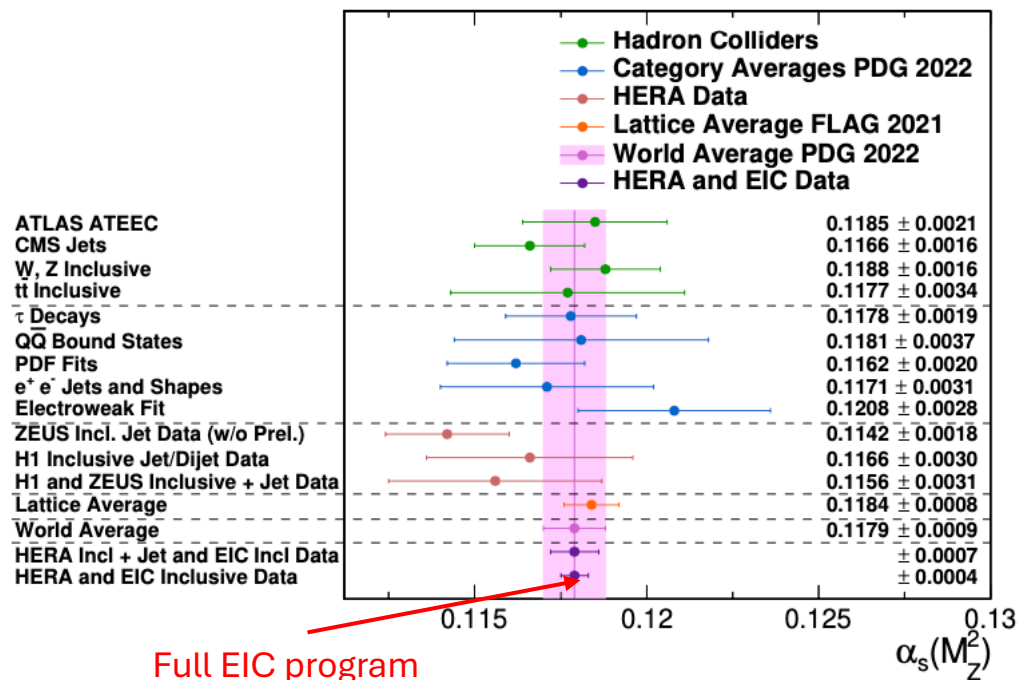
Neutral Current Cross Sections → Parton Distributions



ePIC Performance: α_s

- HERA data alone (HERAPDF2.0) shows only limited sensitivity when fitting inclusive data only.
- Adding EIC (precision high x) data to HERA can lead to a precision a factor ~ 2 better than current world experimental average, and than lattice QCD average
 - Scale uncertainties remain to be understood (ongoing work)

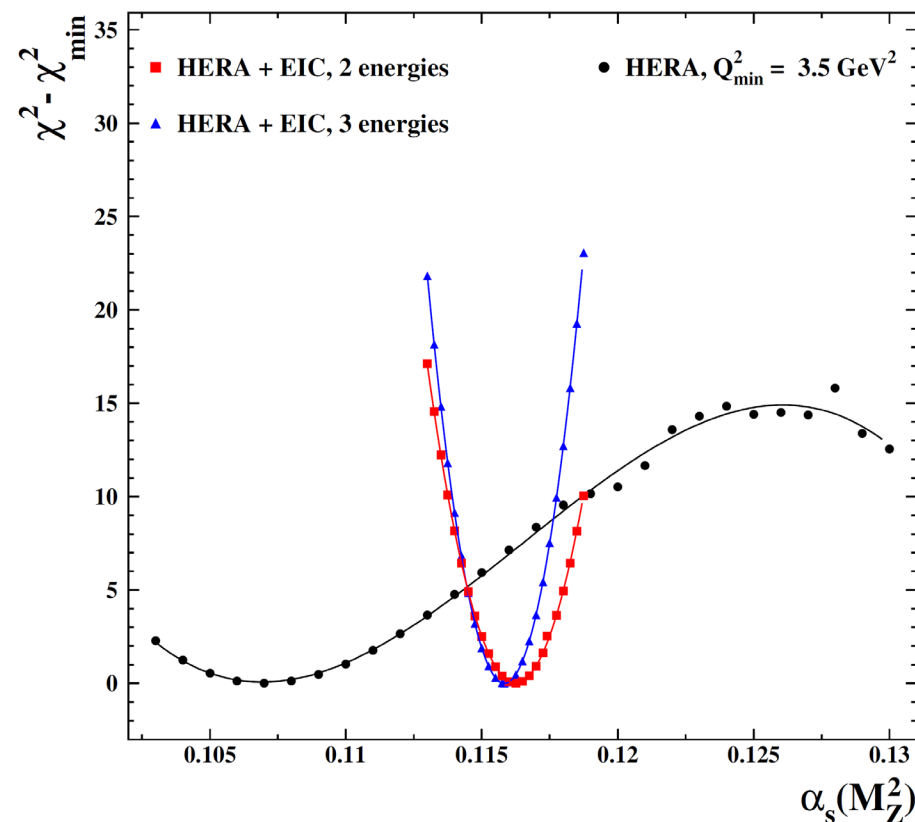
EPJC (2023) 83: 1011



2 EIC Energies (1fb^{-1} ea.): $\alpha_s(M_Z^2) = 0.1162 \pm 0.0008$

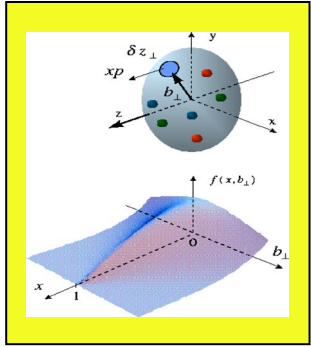
3 EIC Energies (1fb^{-1} ea.): $\alpha_s(M_Z^2) = 0.1158 \pm 0.0006$

HERA and EIC



Scientific Goals: Generalized Parton Distribution Functions

NAS Science Pillar: Origin of Nucleon Mass:
Gluon Dynamics and the Hadron Structure



$H(x, \xi, t)$
GPDs

N / q	U	L	T
U	H		E_T
L		$\tilde{H}$	$\tilde{E}_T$
T	E	$\tilde{E}$	$H_T \quad \tilde{H}_T$

Spin-1/2 hadron: **4 chiral-even** (H, E and their polarized-hadron versions $\tilde{H}, \tilde{E}$) and **4 chiral-odd** ($H_T, E_T, \tilde{H}_T, \tilde{E}_T$) quark and gluon **GPDs at leading twist**

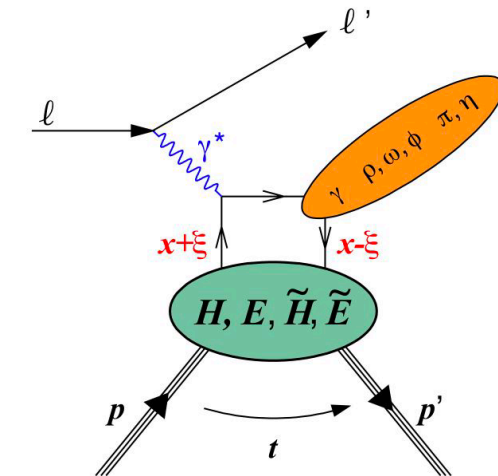
Like usual PDFs, GPDs are non-perturbative functions **defined via the matrix elements of parton operators**:

$$\begin{aligned}
 F^q &= \frac{1}{2} \int \frac{dz^-}{2\pi} e^{ix\bar{P}^+z^-} \langle p' | \bar{q}(-\frac{1}{2}z) \gamma^+ q(\frac{1}{2}z) | p \rangle |_{z^+=0, \mathbf{z}=0} \\
 &= \frac{1}{2P^+} \left[H^q(x, \xi, t, \mu^2) \bar{u}(p') \gamma^+ u(p) + E^q(x, \xi, t, \mu^2) \bar{u}(p') \frac{i\sigma^{+\alpha} \Delta_\alpha}{2m_N} u(p) \right]
 \end{aligned}$$

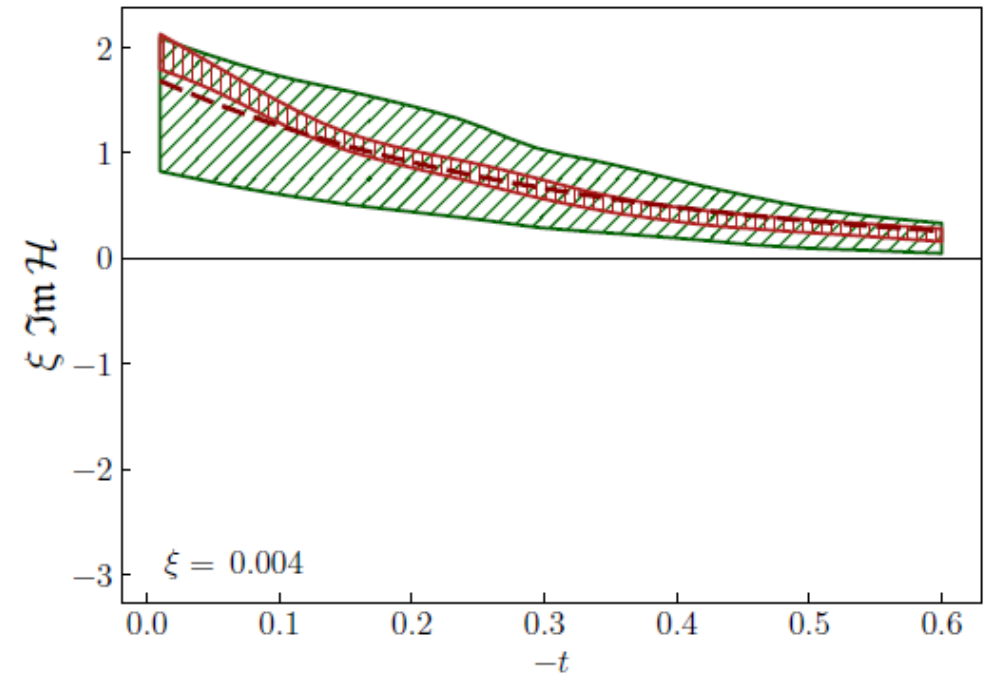
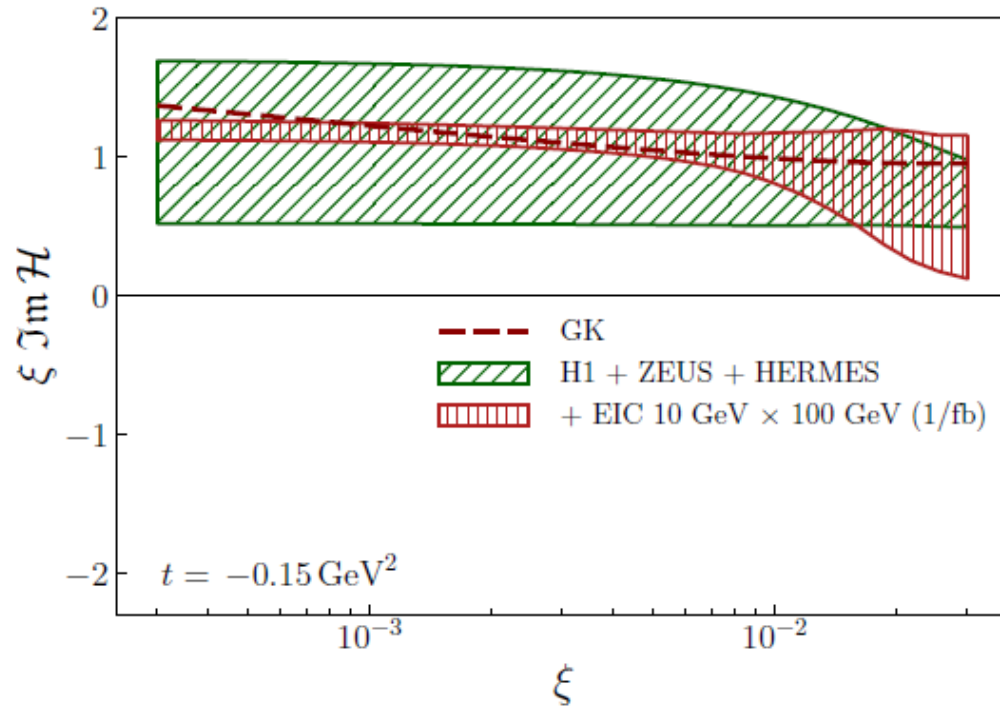
- Experimental access to GPDs via Compton Form Factors (CFFs)

$$\mathcal{H}(\xi, t) = \sum_q e_q^2 \int_{-1}^1 dx H^q(x, \xi, t) \left(\frac{1}{\xi - x - i\varepsilon} - \frac{1}{\xi + x - i\varepsilon} \right)$$

- Measure t -differential cross sections and asymmetries in **exclusive processes** [DVCS + VMs needed to constrain the whole set and separate flavors]



Mandelstam variable:
 $t = (p' - p)^2$



Projected Deeply Virtual Compton Measurements at EIC

Expected impact

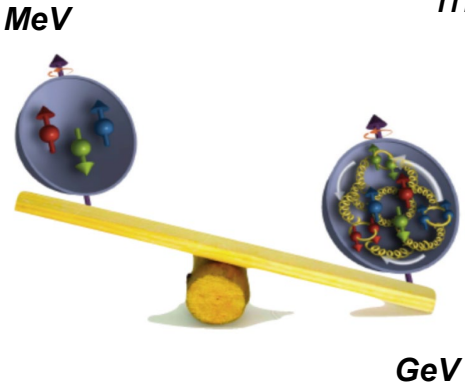
Compton Form Factors (CFFs)

- Green: Constraints on $\mathcal{H}$ with HERA and HERMES data along
- Red: Constraints on $\mathcal{H}$ including ePIC beam spin asymmetry pseudo-data

Scientific Goals: Structure of Light Mesons

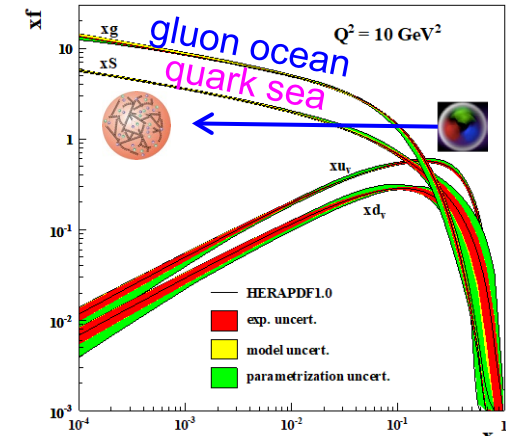
NAS Science Pillar: Origin of Nucleon Mass:
Gluon Dynamics and the Hadron Structure

Visible world: mainly made of light quarks – its mass emerges from quark-gluon interactions.



Proton

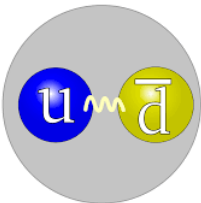
Quark structure: uud
Mass ~ 940 MeV (~1 GeV)
Most of mass generated by dynamics.
Gluon rise discovered by HERA e-p



Fraction of overall proton momentum carried by quark or gluons

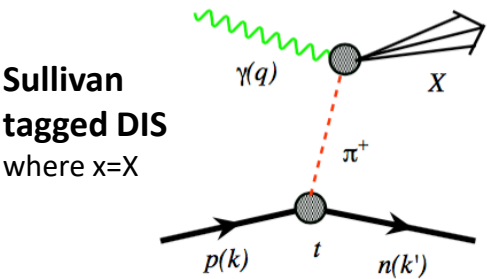
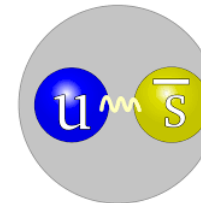
Pion

Quark structure: ud
Mass ~ 140 MeV
Exists only if mass is dynamically generated.
Empty or full of gluons?



Kaon

Quark structure: us
Mass ~ 490 MeV
Boundary between emergent- and Higgs-mass mechanisms.
More or less gluons than in pion?



Sullivan tagged DIS
where $x=X$

Mandelstam variable:

$$t = (p' - p)^2$$

proton the EIC will allow determination of an important term contributing to the proton mass, the so-called “QCD trace anomaly”

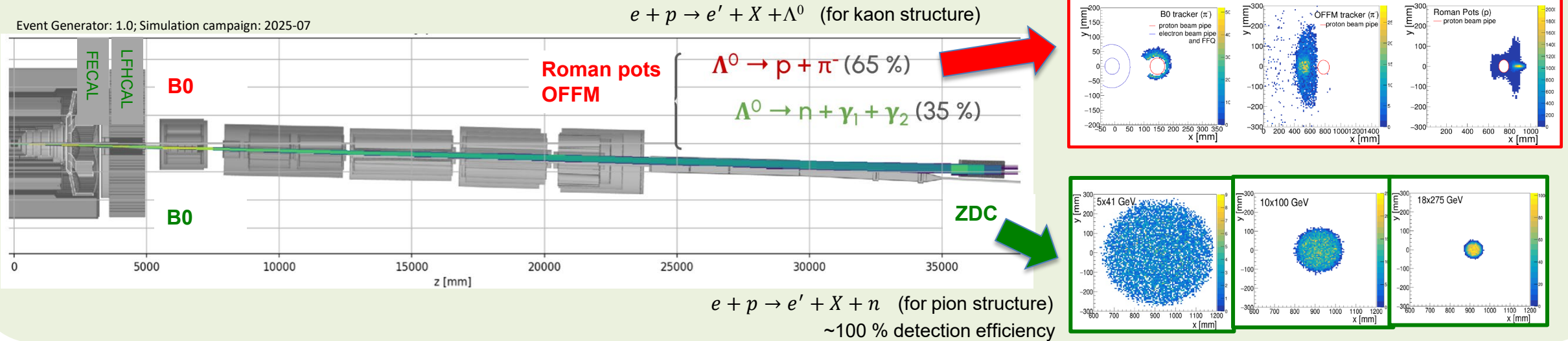
pion and the kaon the EIC will allow determination of the quark and gluon momentum contributions with the Sullivan process.
Observable: Tagged DIS cross sections

C. Aguilar et al., EPJA 55 (2019) 190.
Arrington et al., J. Phys. G 48 (2021) 7, 075106.



ePIC performance: Far Forward Region

NAS Science Pillar: Origin of Nucleon Mass:
Gluon Dynamics and the Hadron Structure



Meson SF measurement requirements drive the design of the Far-Forward region

$$p \rightarrow \pi + n$$

- ❑ ZDC helps to constrain both the scattering kinematics and the π 4-momentum
 - ❑ spatial resolution plays an important role for the highest energy setting, since it is directly related to the measurements of p_T or t
 - ❑ total acceptance coverage is important at lowest energy – requirement of 60cm x60cm for ~100% detection efficiency

$$p \rightarrow K + \Lambda$$

- ❑ Track the decay products of the Λ at small forward angles through the very forward spectrometer – challenging: long decay lengths!
 - ❑ Tracking the decay products requires a more complex reconstruction strategy combining multiple detectors
 - ❑ $\Lambda \rightarrow n + \gamma_1 + \gamma_2$: Combination of ZDC and calorimeters in the B0 area
 - ❑ $\Lambda \rightarrow p + \pi^-$: B0 tracker, Off-Momentum tracker, Roman Pots for detection and reconstruction

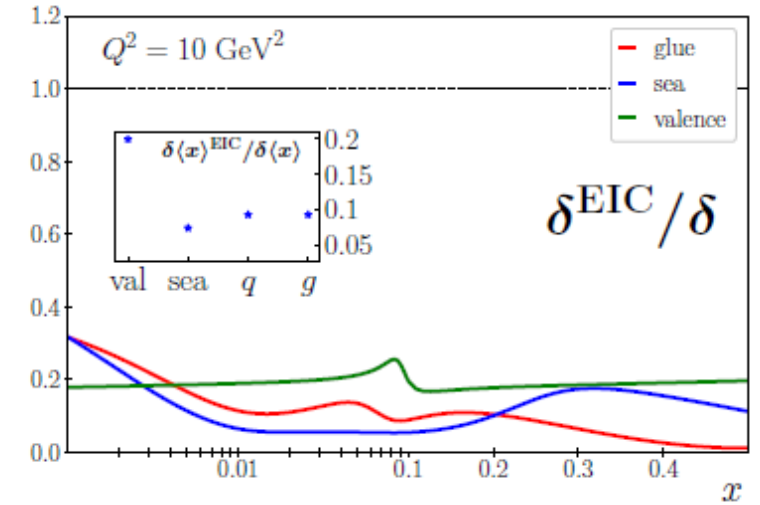
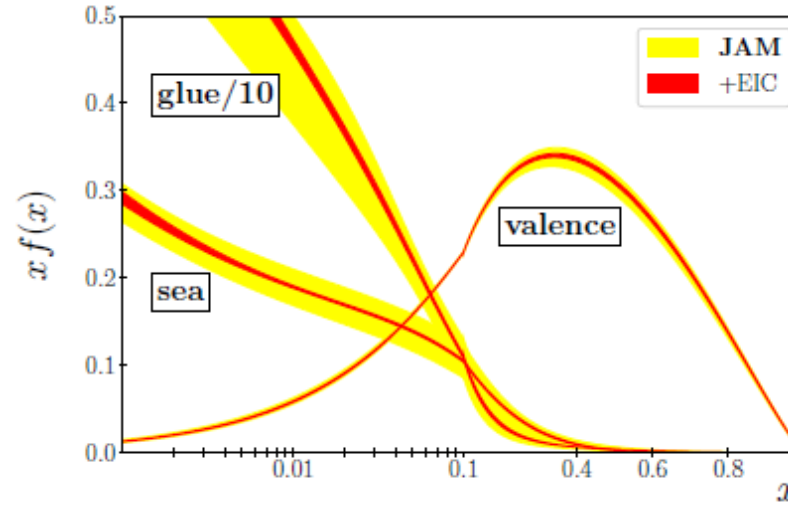
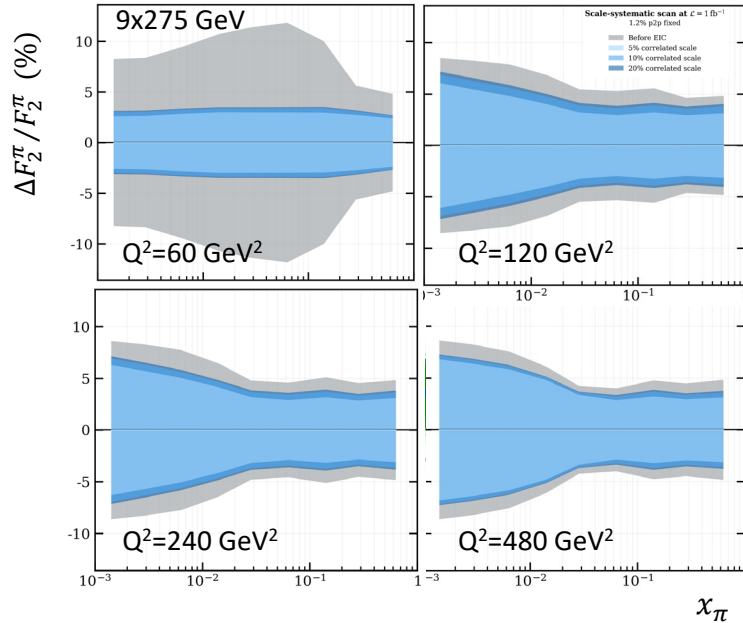
Key detector performance:
➤ Far Forward Region

ePIC performance: Meson Structure

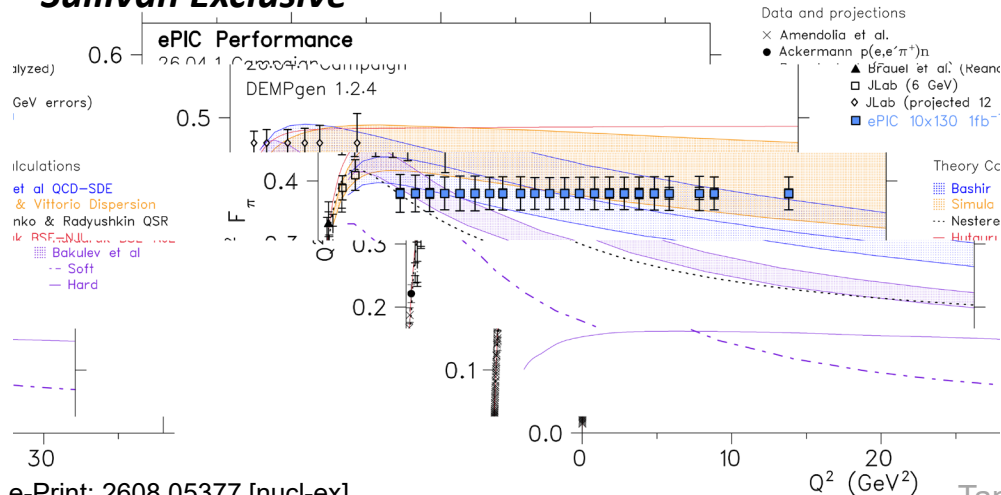
NAS Science Pillar: Origin of Nucleon Mass:
Gluon Dynamics and the Hadron Structure

Sullivan Tagged DIS

26.08.0 Campaign
SURGE 1.0



Sullivan Exclusive



Impact of EIC: reduction in PDF uncertainty – meson momentum terms

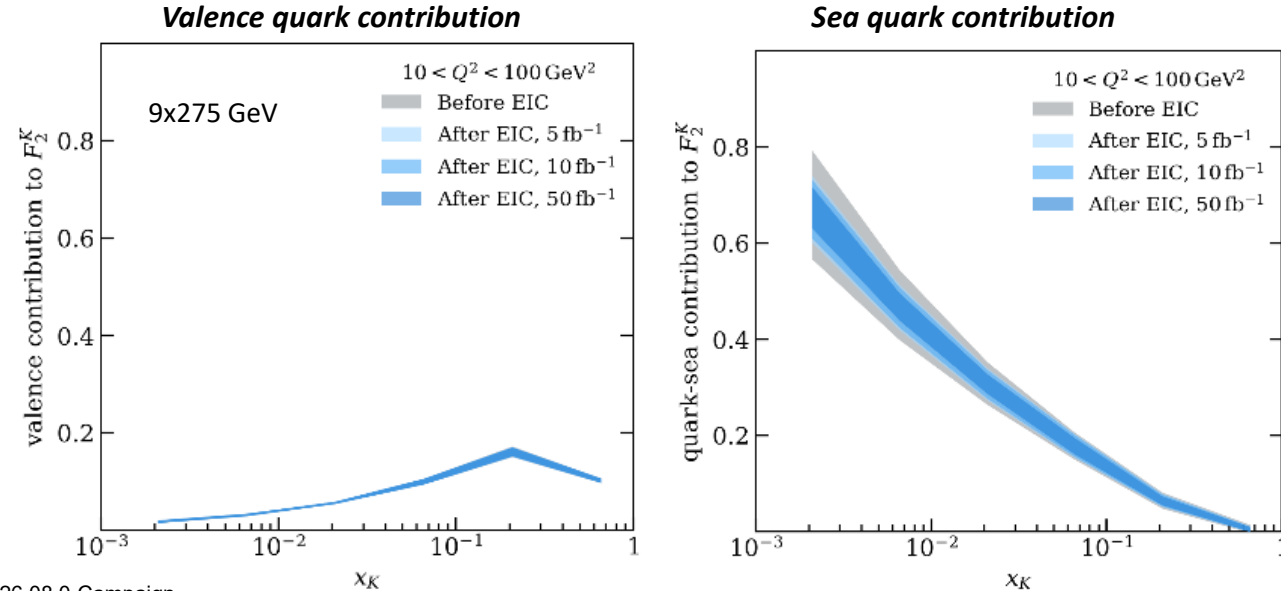
- Left: Unprecedented mid-large x_π -coverage (down to 10^{-3}), wide x/Q^2 complementing HERA and JLab
- Middle Uncertainties on pion's valence, sea quark, and gluon PDFs before (yellow) and after including EIC design data (red)
- Right: Ratio of uncertainties with EIC design data and without; inset: corresponding ratios of momentum fraction uncertainties

Sullivan Exclusive opens up the high Q^2 regime for F_π measurements – overlap with data points from Jefferson Lab

ePIC performance: Meson Structure

NAS Science Pillar: Origin of Nucleon Mass:
Gluon Dynamics and the Hadron Structure

Sullivan Tagged DIS (Kaon)

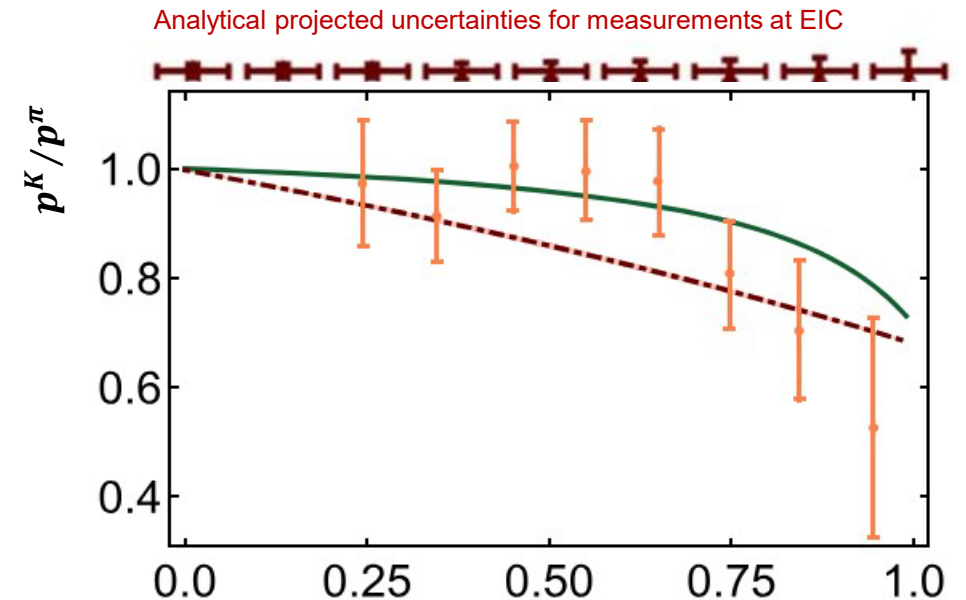


26.08.0 Campaign
SURGE 1.0

- ❑ Difference exists between pion and kaon glue and sea on the valence quark domain, where the current quark mass plays a role
- ❑ EIC data could provide data to shed light on this – projected uncertainties for the ration are shown

Essentially no kaon data currently – EIC could have a large impact

- Uncertainties on kaon's valence and sea quark before and after including EIC data are shown



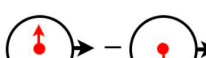
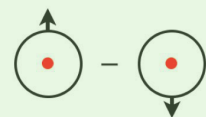
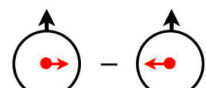
Scientific Goal: TMDs

TMDs surviving integration over k_T

Time-reversal odd TMDs describing **strength of spin-orbit correlations**

Chiral odd TMDs

Note: off-diagonal part vanishes without parton's transverse motion

		Quark Polarization		
		U	L	T
Nucleon Polarization	U	f_1  unpolarized		$h_1^\perp$  Boer-Mulders
	L		g_{1L}  helicity	$h_{1L}^\perp$  longi-transversity (worm-gear)
	T	$f_{1T}^\perp$  Sivers	g_{1T}  trans-helicity (worm-gear)	h_1  transversity

Non-zero strength of spin-orbit correlations → indication of parton OAM

- **Sivers**: correl. of transverse-spin direction and the parton transverse momentum
- **Boer-Mulders**: correl. of parton transverse spin and parton transverse momentum
- **Collins**: fragmentation of a transversely polarized parton into a final-state hadron

What we want to measure:

$$\frac{d\sigma}{dx dQ^2 dz d\phi_s d\phi_h dp_T^h}$$

- 6-fold differential cross sections in SIDIS
- Azimuthal asymmetries and their modulations

Key detector performance:

- Acceptance
- PID
- Vertexing (heavy flavor)
- Quality of tracking
- HCal (for jets)

ePIC Performance: Unpolarized TMDs

NAS Science Pillar: Origin of Nucleon Mass:
Gluon Dynamics and the Hadron Structure

Expected statistical/total uncertainty of unpolarized

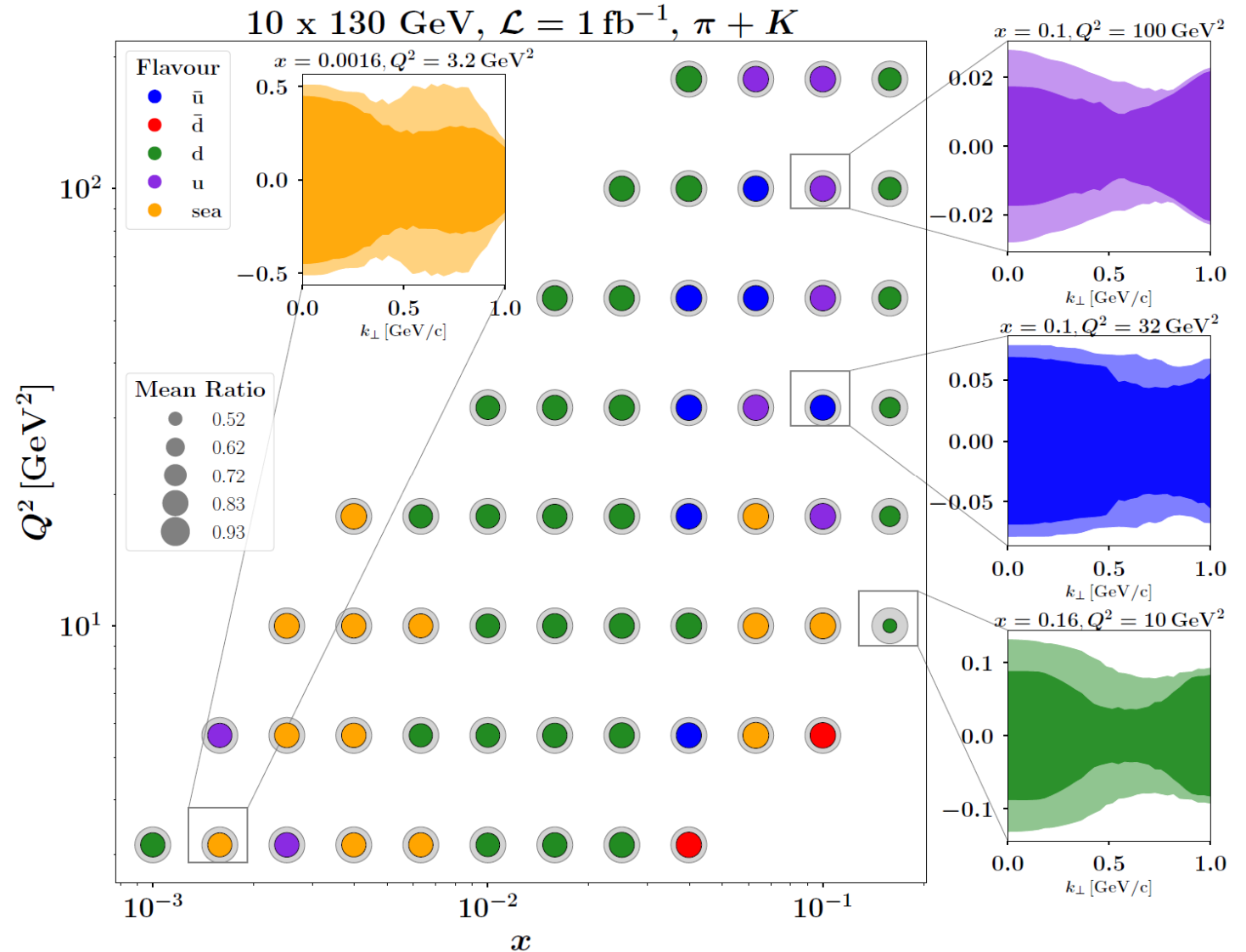
TMD PDFs

- Inner (outer) circles: max uncertainty with (without) EIC data
- Colors indicate the most impacted quark flavors

Uncertainties based on the MAP24 global TMD fit

- Lighter shades: based on existing data
- Darker shades: after including ePIC pseudo-data

Not shown – possible to test universality of TMD evolution kernel with EIC data

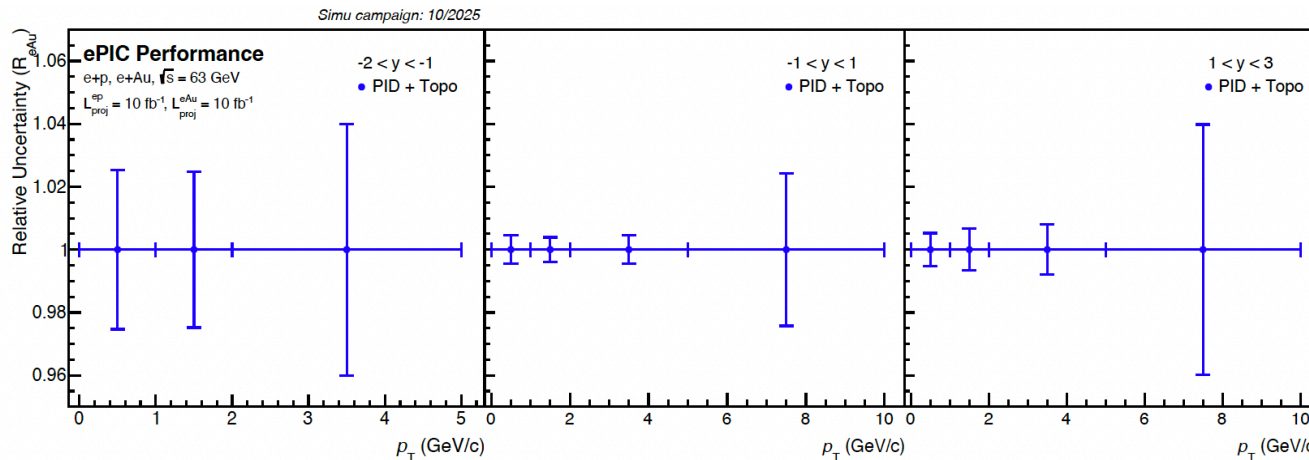
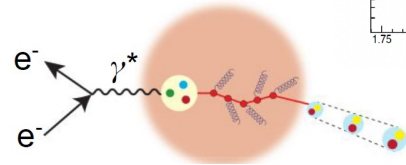


ePIC Performance: Open D^0 Reconstruction

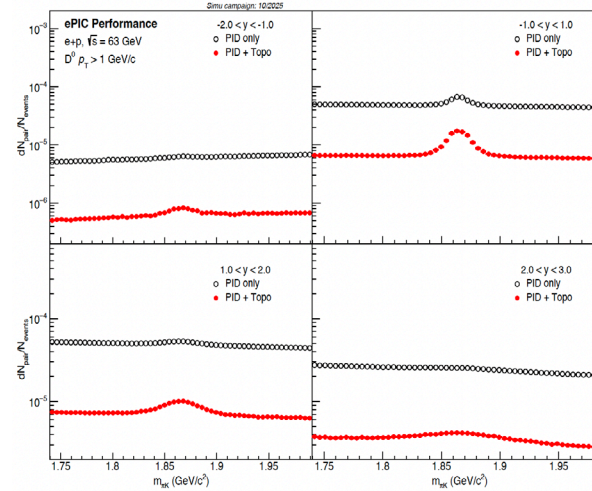
- Open D^0 reconstruction
 - Invariant mass distributions of $\pi + K$ pairs vs different D^0 rapidity ranges
 - Projected statistical uncertainty for $D^0 R_{eAu}$

Projection for $D^0 R_{eAu}$

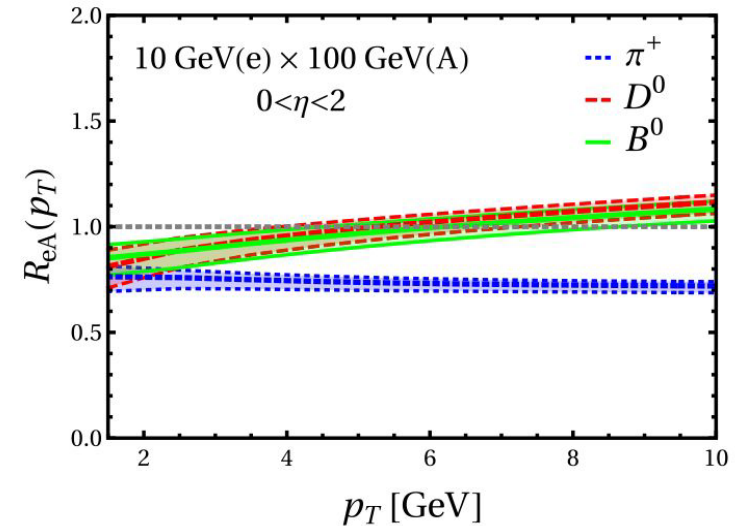
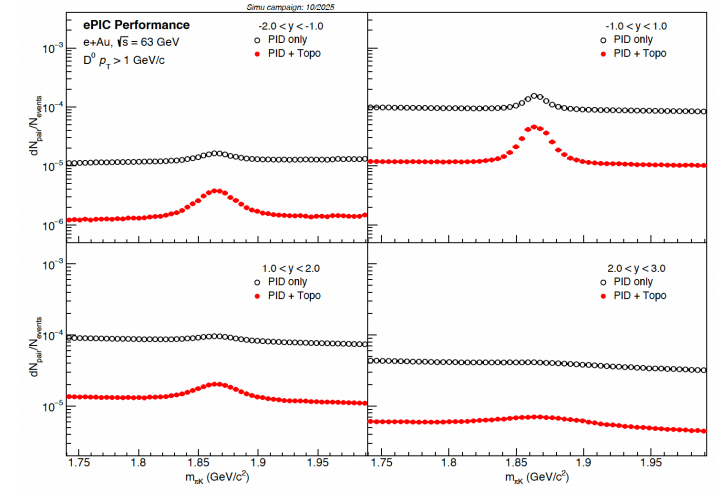
$$R_{eA}(p_T, z, v) = \frac{N^{D^0}(p_T, z, v)_{eAu}}{N^{D^0}(p_T, z, v)_{ep}} \times \frac{N^{inc}(v)_{ep}}{N^{inc}(v)_{eAu}}$$



e+p, $Q^2 > 1 \text{ GeV}^2$



e+Au, $Q^2 > 1 \text{ GeV}^2$

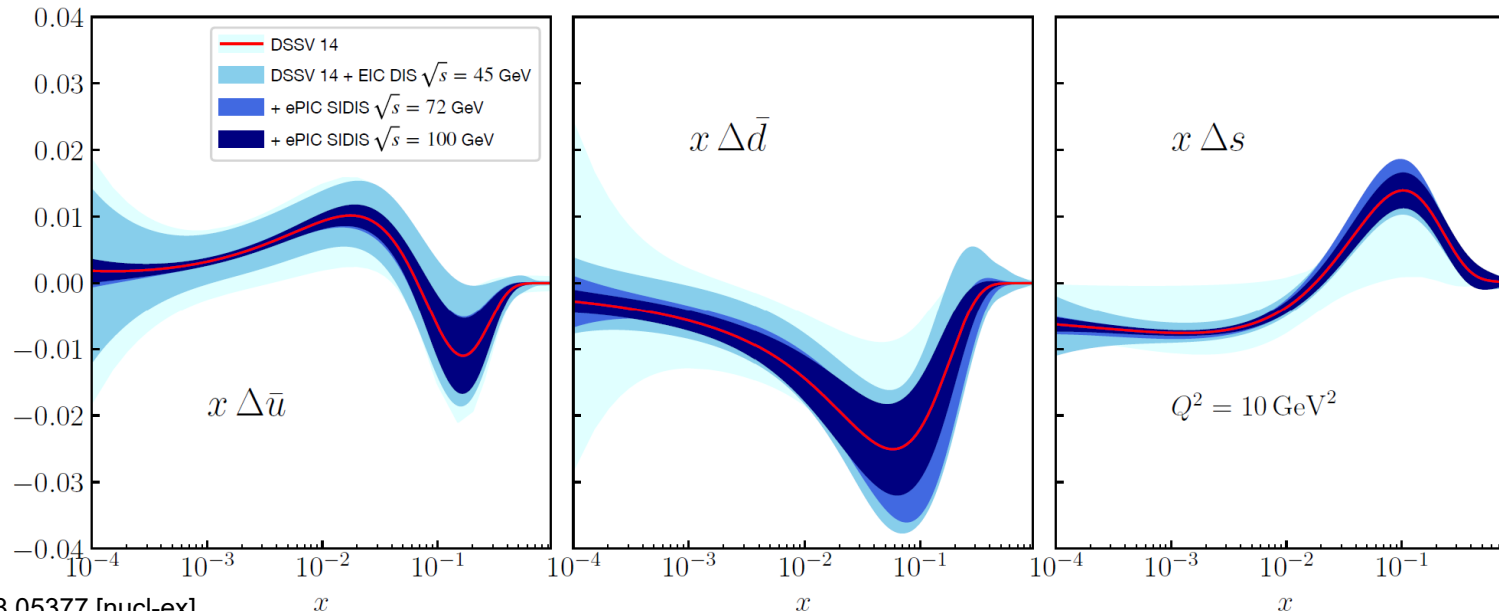


Scientific Goal: Origin of the Proton's Spin

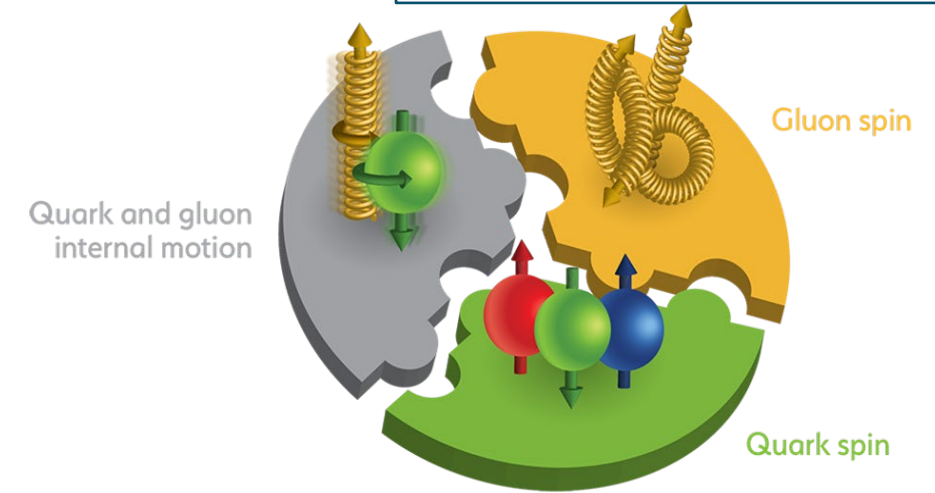
Jaffe and Manohar “sum rule” [Nucl. Phys. B337, 509 (1990)]

$$\frac{1}{2}\hbar = \left\langle P, \frac{1}{2} \left| J_{QCD}^Z \right| P, \frac{1}{2} \right\rangle = \underbrace{\sum_q \frac{1}{2} S_q^Z}_{\text{total u+d+s quark spin}} + \underbrace{\overbrace{S_g^Z}^{\text{gluon spin}}}_{\text{gluon spin}} + \underbrace{\sum_q L_q^Z + L_g^Z}_{\text{angular momentum}}$$

- **Observable:** double spin asymmetries
- **DIS** scaling violations determine **gluons** at small x
- **SIDIS** extracting the helicities of sea quark flavors



NAS Science Pillar: Origin of Nucleon Spin: Helicity, Orbital Motion, and Spin–Orbit Correlations



orbital angular momentum



ePIC Performance: Double Spin Asymmetries - $A_1^{p,n}$

NAS Science Pillar: Origin of Nucleon Spin: Helicity, Orbital Motion, and Spin–Orbit Correlations

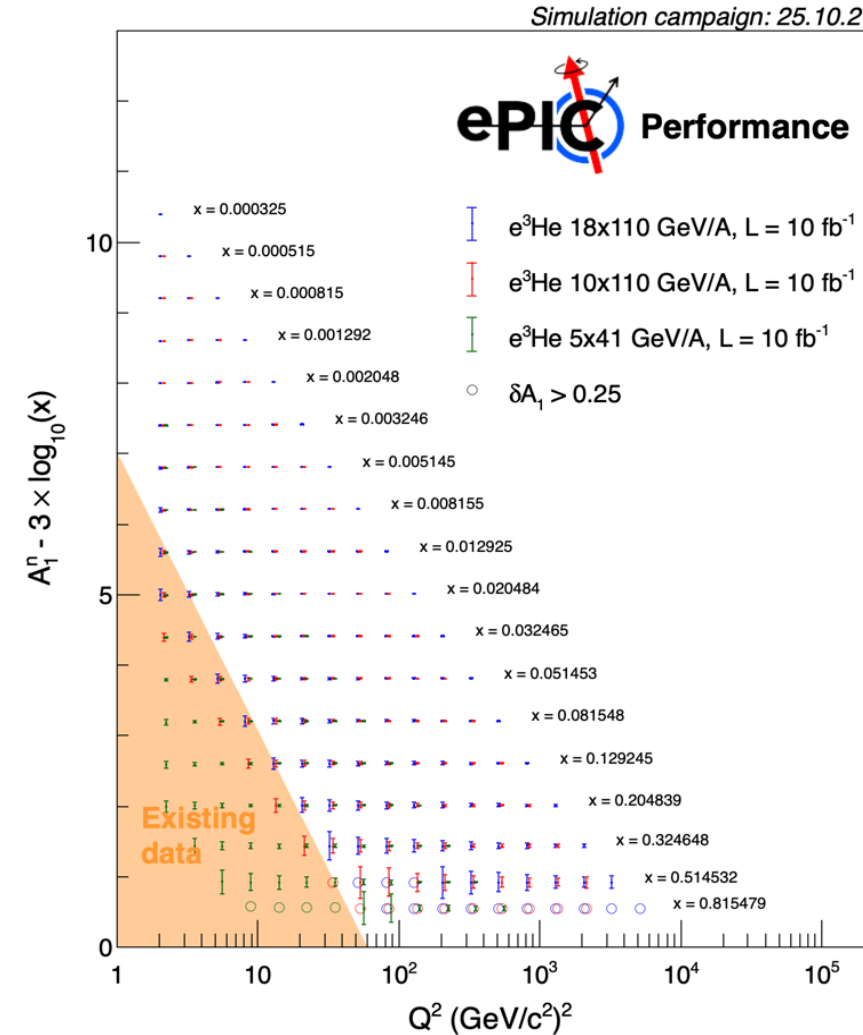
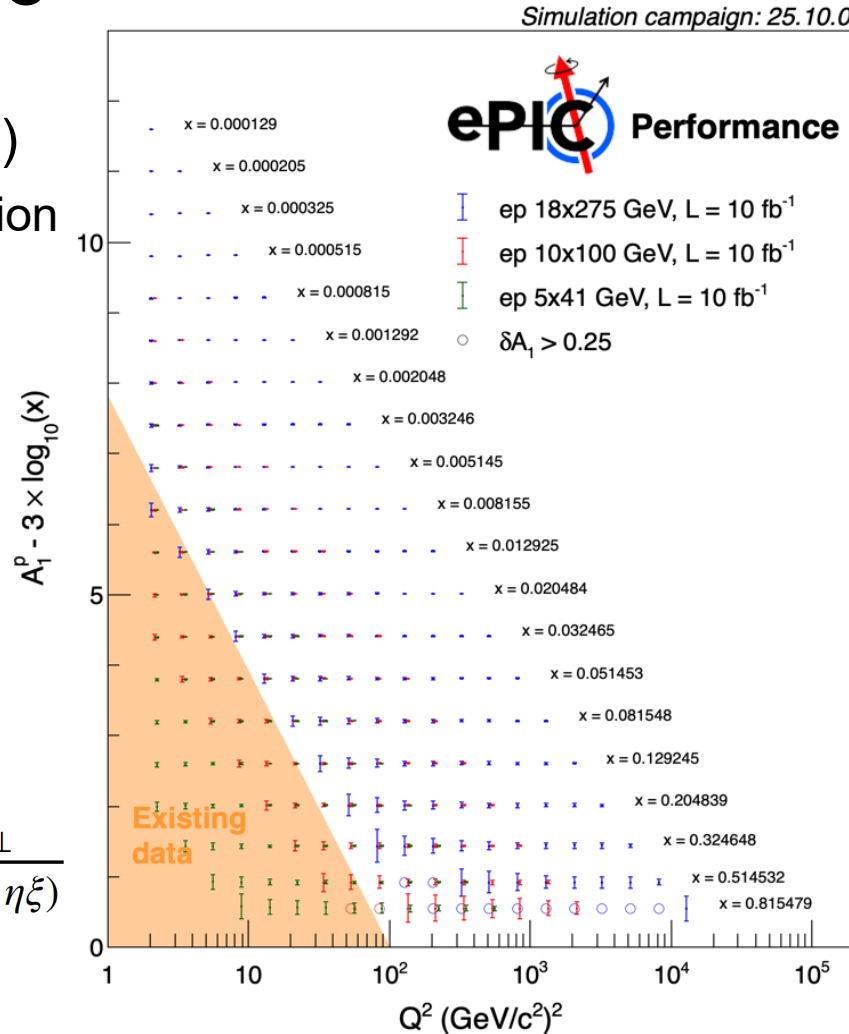
$A_1^{p,n}$ determination in ePIC

- Realistic electron ID (Tracking + Electron method)
 - Acceptance and bin migration from simulation
- A_1^p calculated according to parametrization
- A_1^n using He^3
 - Inclusive or double tagging

$$A_{||} = \frac{\sigma_{\downarrow\uparrow} - \sigma_{\uparrow\uparrow}}{\sigma_{\downarrow\uparrow} + \sigma_{\uparrow\uparrow}}, \quad A_{\perp} = \frac{\sigma_{\downarrow\Rightarrow} - \sigma_{\uparrow\Rightarrow}}{\sigma_{\downarrow\Rightarrow} + \sigma_{\uparrow\Rightarrow}}$$

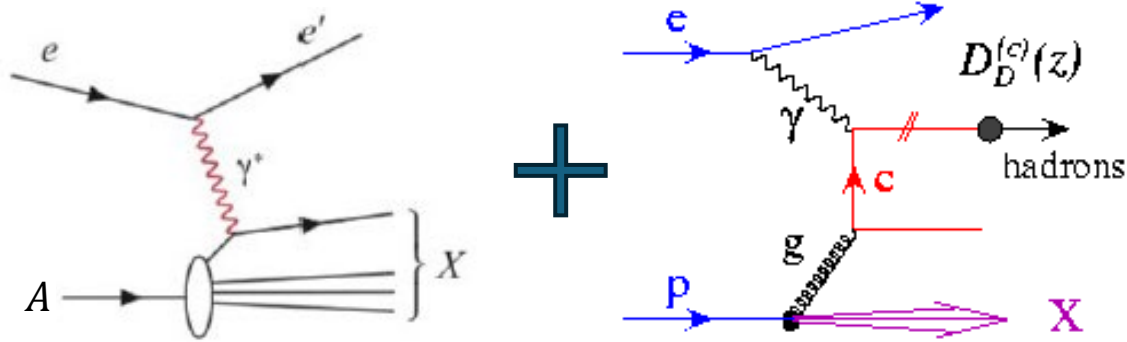
$$A_1(x, Q^2) \equiv \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{A_{||}}{D(1 + \eta\xi)} - \frac{\eta A_{\perp}}{d(1 + \eta\xi)}$$

$$\rightarrow A_1 \approx g_1/F_1$$

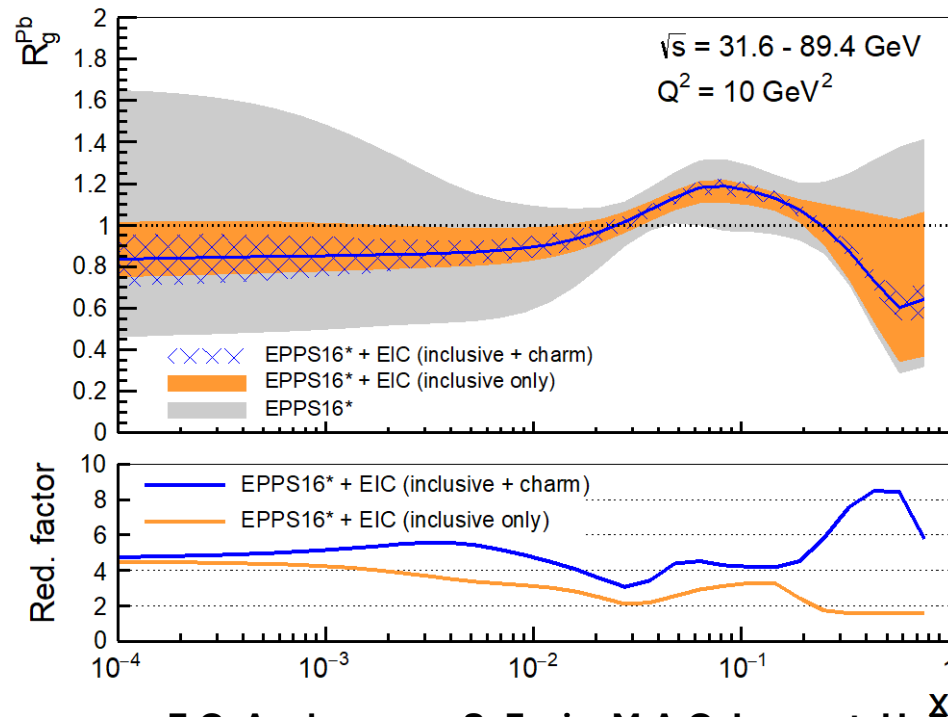


Scientific Goal: Nuclear PDFs

NAS Science Pillar: Emergent Properties of Dense Gluonic Matter



- **Inclusive DIS in e+A**
 - Tag the scattered electron
- **Charm production**
 - Direct access to gluons at medium to high x by tagging **photon-gluon fusion**



The EIC provides a factor ~ 10 larger reach in Q^2 and at low- x compared to available data

- Higher $\sqrt{s}$ energy constrains gluons at mid- and low- x
- Charm has a dramatic effect at high- x

Key detector performance:

- Vertexing (for charm tagging)
- Electron ID
- Fine resolution in y over a large phase space

E.C. Aschenauer, S. Fazio, M.A.C. Lamont, H. Paukkunen, P. Zurita

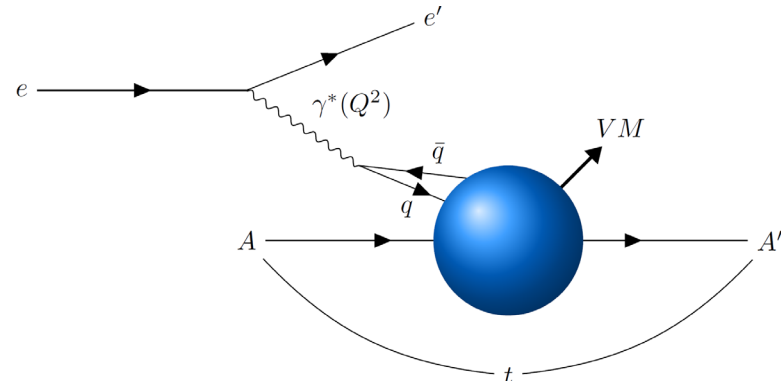
[[Phys. Rev. D 96, 114005 \(2017\)](#)]

Tanja Horn, NSTAR 2026

ePDFs studies in progress in ePIC

ePIC Performance: Coherent VMP

NAS Science Pillar: Emergent Properties of Dense Gluonic Matter



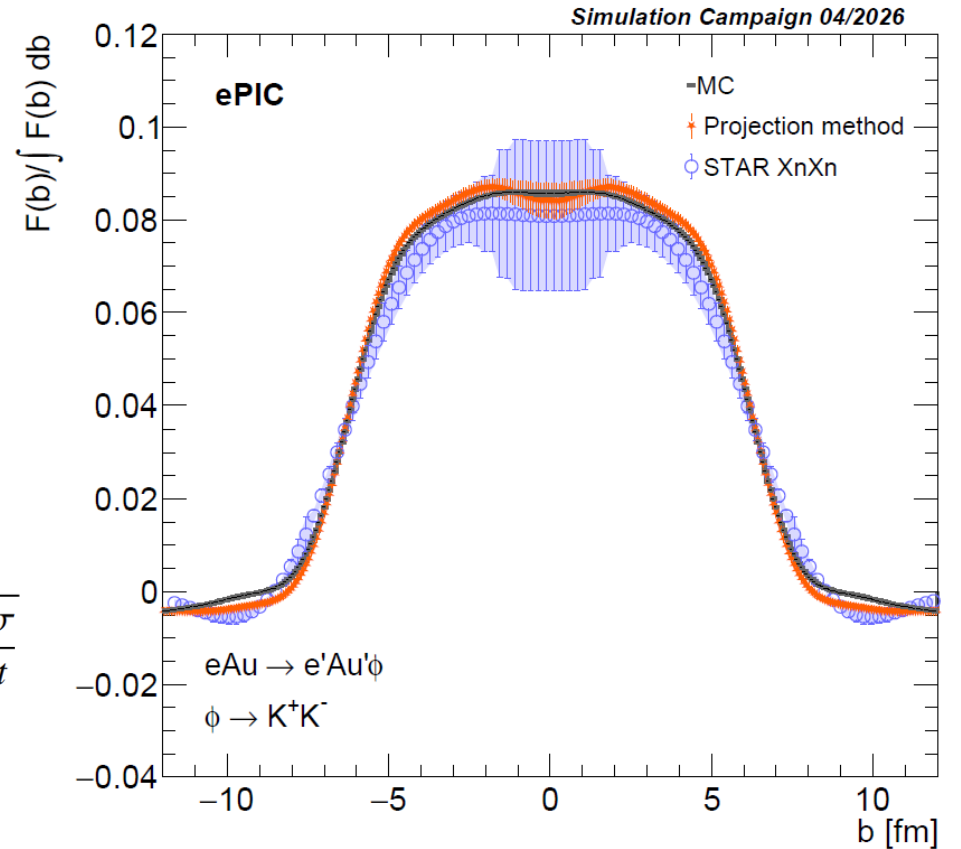
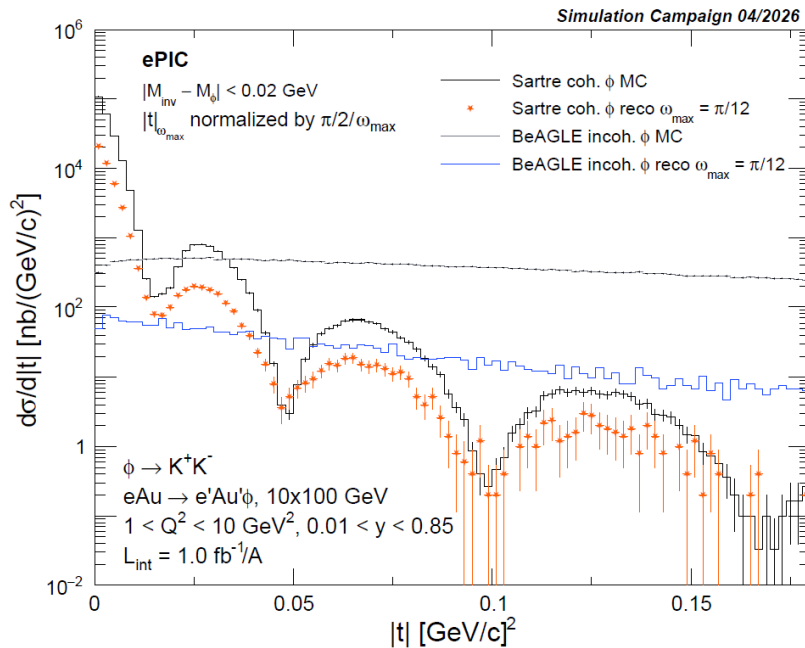
Diffraction

High sensitivity to gluon density in linear regime
 $\sigma \sim [g(x, Q^2)]^2$

Fourier Transform

$$F(b) \propto \frac{1}{2\pi} \int_0^\infty dp_T p_T J_0(bp_T) \sqrt{\frac{d\sigma}{dt}}$$

Work ongoing to use electron spin flip to further separate coherent and incoherent components statistically.



2-dimensional Fourier-Bessel transformation of the $|t|$ distribution can be interpreted as the **spatial distribution of gluons**

Summary

- ❑ The EIC will address fundamental questions on the structure and dynamics of nucleons and nuclei in terms of quark and gluons
- ❑ The ePIC detector design is mature, with engineering test articles under evaluation and subsystems moving towards final design in the coming year.
- ❑ The EIC Project is making good progress toward construction
 - Two detector related CD-3A long-lead procurements have completed
 - Preparing for a DOE comprehensive Independent Project Review and civil construction start
- ❑ An Early Science has been developed to start the science of the EIC while the collider commissions and the full capabilities of the EIC are realized.
- ❑ The ePIC Collaboration is developing the detector, computing, and analysis tools and techniques to fully enable the potential of EIC science.

Detector Technical Readiness for Baselining

- Detector has been technically baselined since Spring 2024; Project Detector R&D was completed in 2025
- June 11-13, 2025: Comprehensive Design Review by DAC, follow-up planned for October 28-30, 2026
- Detector Baseline Readiness Review Feb 3 – 5, 2026
- One Preliminary (60%) Design Review remains, first full sub-system Final Design Review completed
- **DOE OPA Status Review September 15-18, 2026**

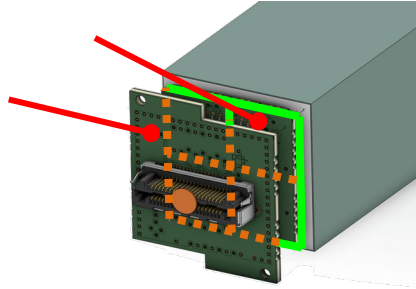
Subsystem	PDR Completed	PDR Scheduled	CD-3A,B FDR Completed	Subsystem FDR Completed
Tracking	40% & 60% Si, 40% & 60% MPGD			
PID	40% & 60% hpDIRC, pfRICH, dRICH ToF 40%, Peer Review, 60%		DIRC Bar refurbishment HRPPDs	
ECals	60% bECal, BECal, fECal		SiPM & SciFi fECal, BEcal SiPM & PbW04 bECal	Backward Ecal (bECal/EEEMCal)
HCals	40% & 60% BHCal & fHCal 40% & 50% bHCal		SiPM bHcal & fHcal Lead blocks fHCal	
Solenoid	60% PDR Cryogenics		Magnet, Conductor and Power Supply	
Electronics	40%, 50% & 60%		VTRX+ & IpGBT	
DAQ	40%, 50% & 60%			
Integration- Installation - infrastructure	60% Inner and outer Barrel support- structures		electron and hadron endcap support structures	
Auxiliary Detectors	40% & 50% RP, B0, ZDC, Low Q2- Tagger, Lumi, 60% ZDC, Low Q2- Tagger, Lumi	60% B0, RP/OMD: December 2026		
Polarimetry	40% & 60% RCS & ESR Compton Polarimeter & HSR Polarimeters			

EEEMCAL FDR, May 26, 2026

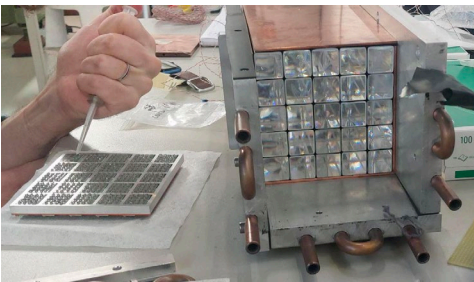
PWO crystal FDR: July 21, 2023
Photosensor FDR: Sep 14, 2023
Mech. Structure FDR: This Review

Review Committee:
Liping Gan (UNC Wilmington)
Lars Schmitt (GSI Darmstadt)
Timothy Whitlatch (Jefferson)

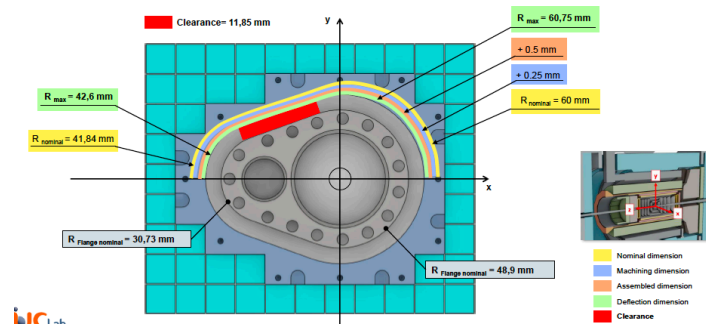
Electronics Integration



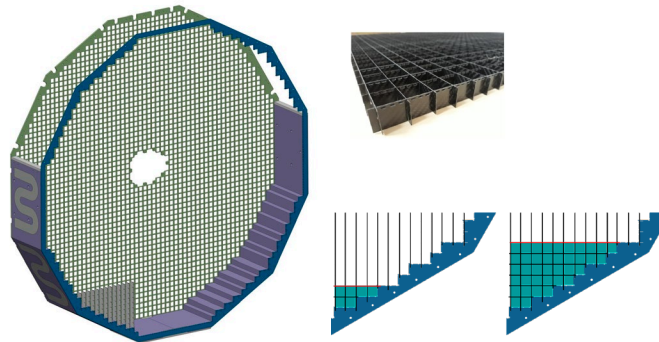
Cooling Prototyping



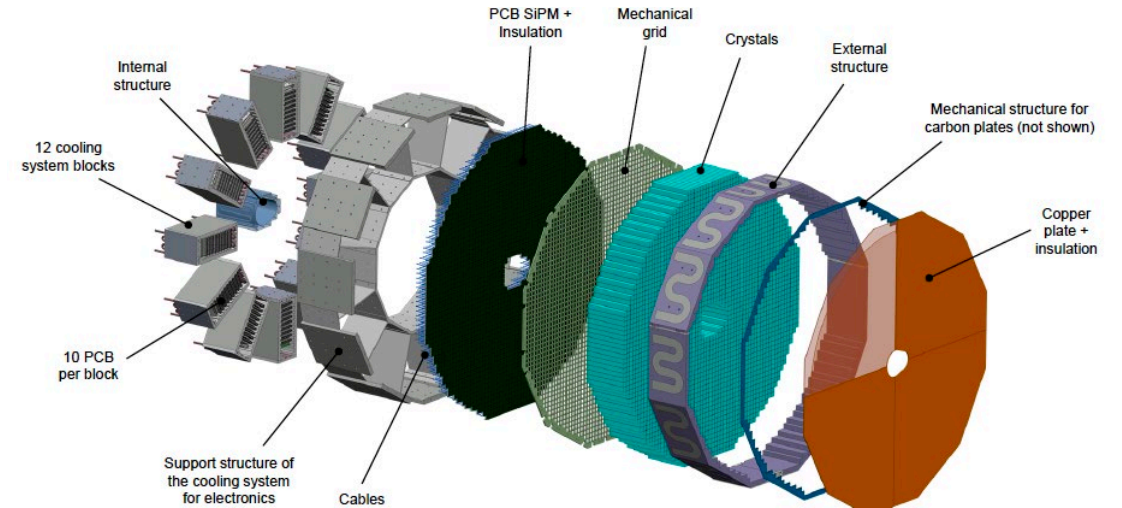
Integration with beam pipe



Assembly



Overall mechanical Design



Conclusion:

- We congratulate the Backward EEEMCal team for the remarkable achievements.
- We thank the team for the excellent quality of the presentations and the constructive discussions in the Q&A.
- We are looking forward to further progress towards CD2 and the realization of the project.

Quality Assurance: PbWO₄ crystals for EEEMCAL

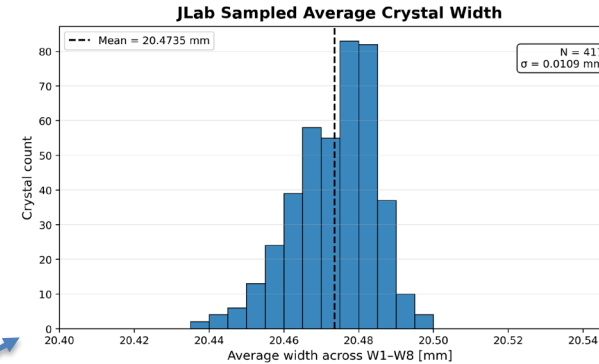
Inspection QA Plan for PbWO₄ Crystal Tests in the EEEMCal

Joshua Crafts, Baptiste Fraise, Tanja Horn, Chi Kin Tam

The Catholic University of America
and the EEEMCAL Consortium

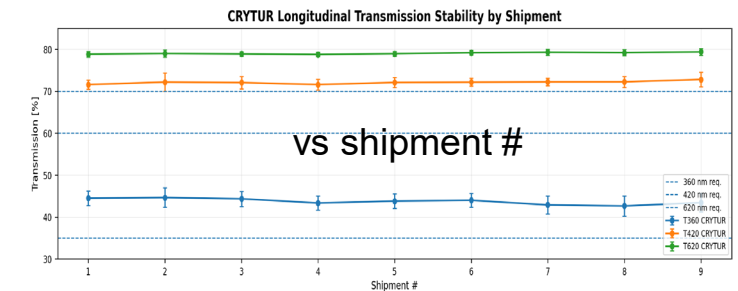
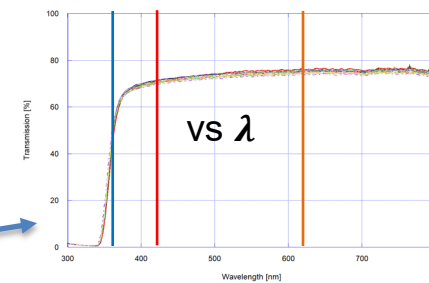
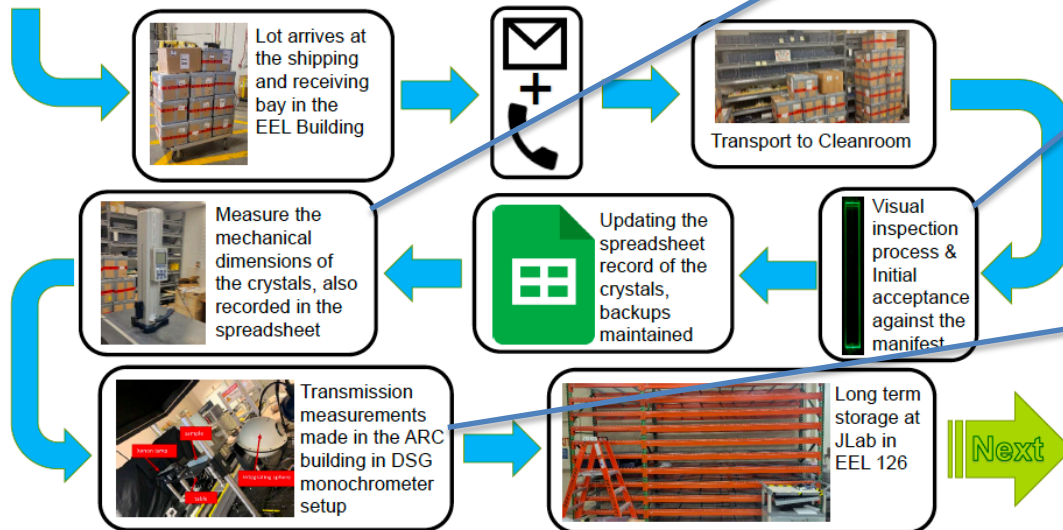
Abstract

This ITP document will provide an overview on the PbWO₄ (PWO) crystal properties that need to be verified as part of the overall EEEMCal QA plan. The procedures and hardware used to determine these properties will be outlined as well as the recording and reporting methods used.



Mech. dimension:
Spec: $20.5^{+0.0}_{-0.1}$ mm width
Passed

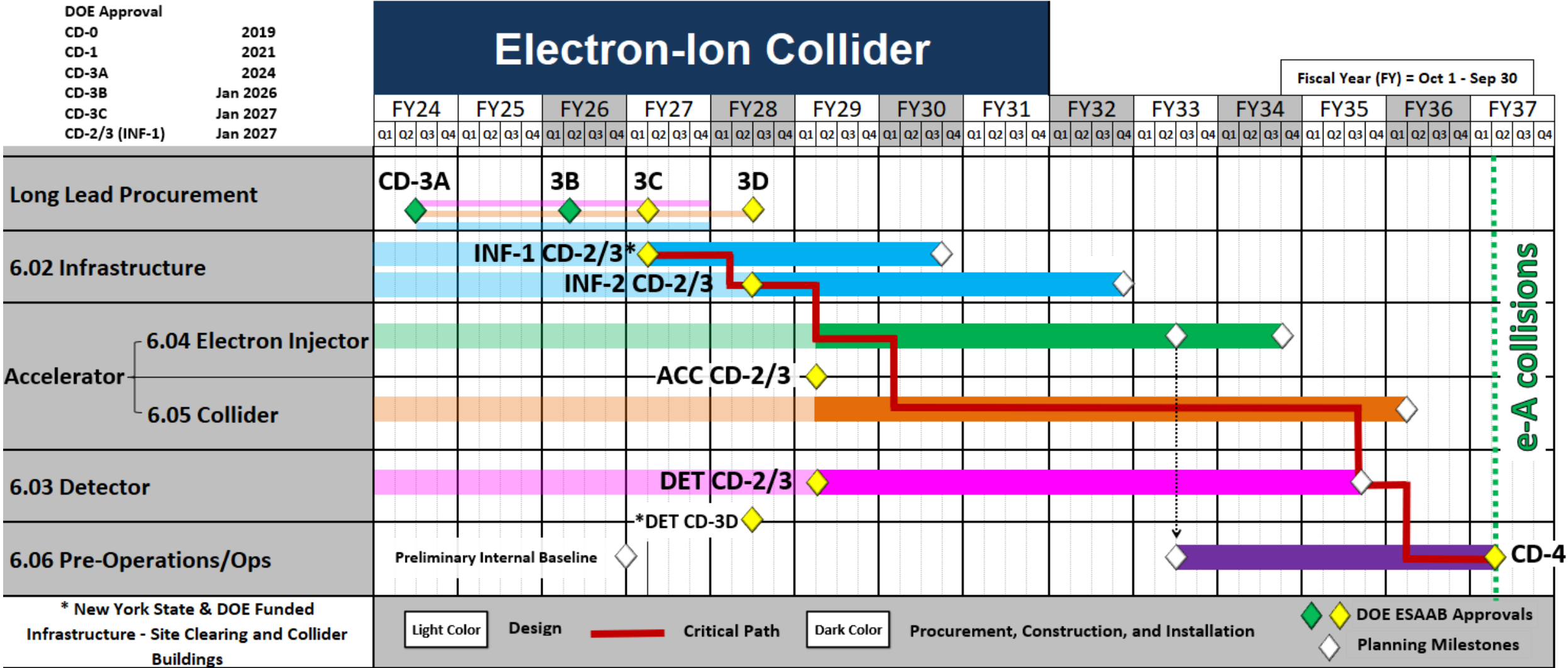
Visual test (also with laser):
No Scratches, no surface pitting, no internal bubbles
Passed



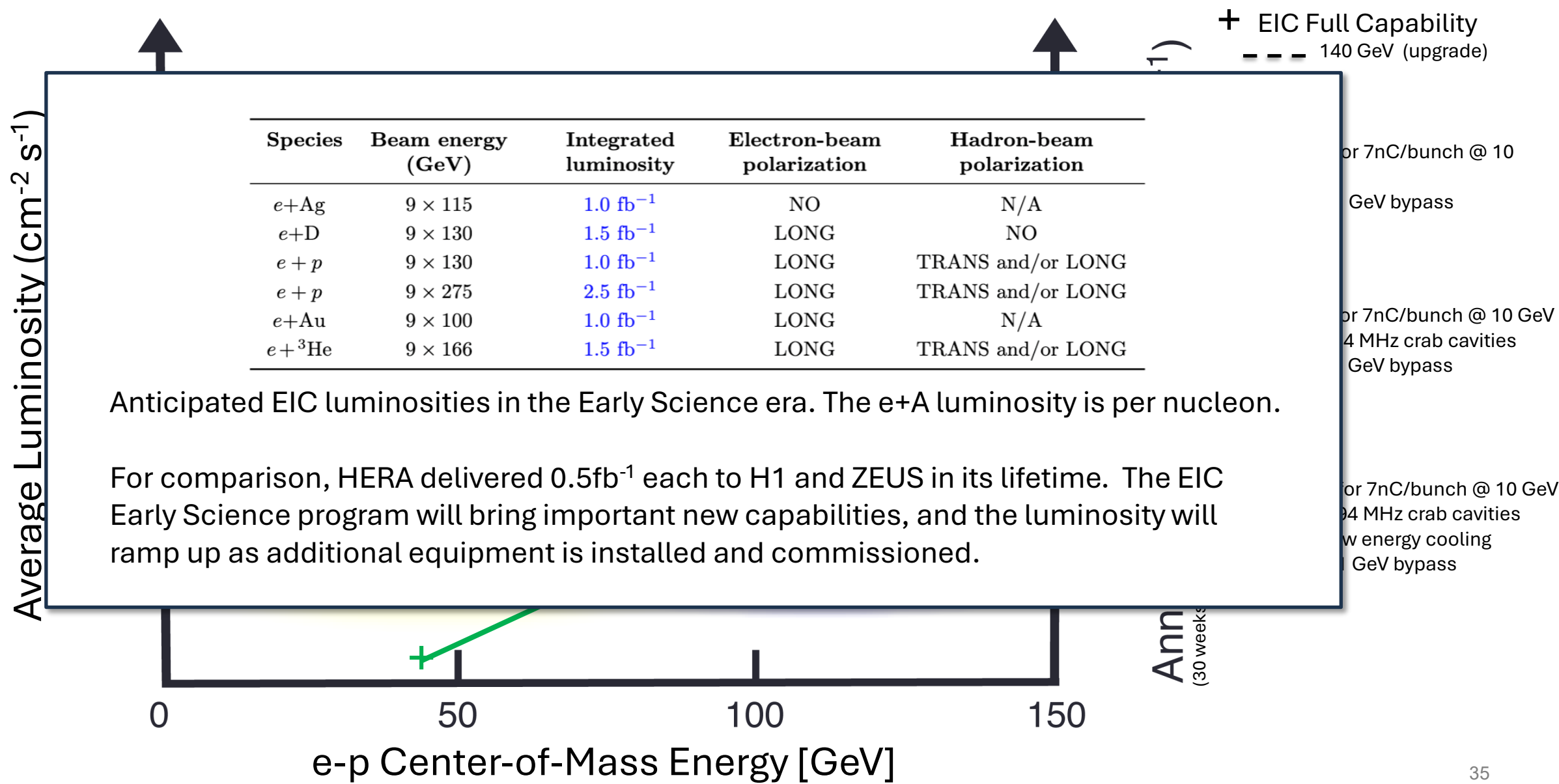
Optical transmission:
Spec: >35% at 360nm, >60% at 420nm and >70% at 620nm
Passed

High-Level Master Schedule - Notional

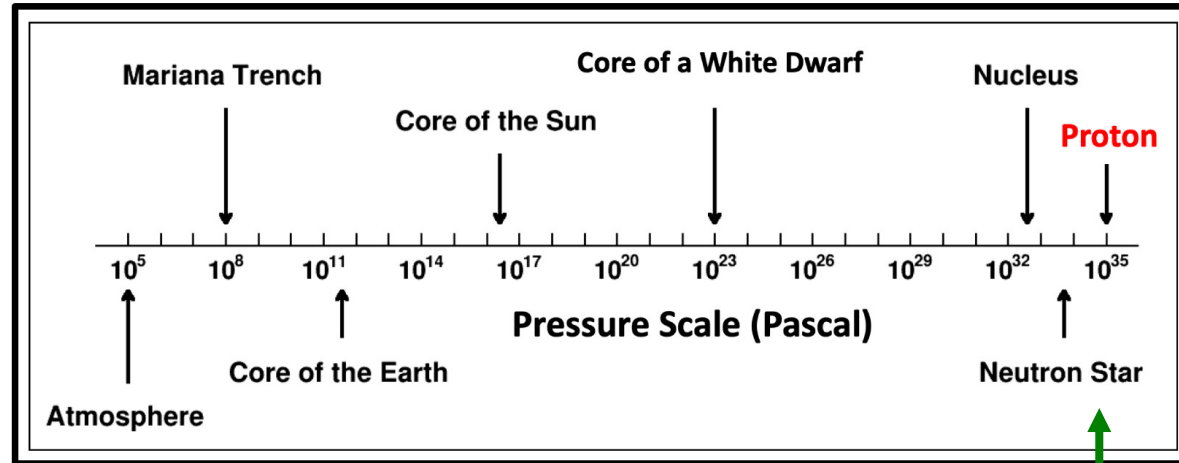
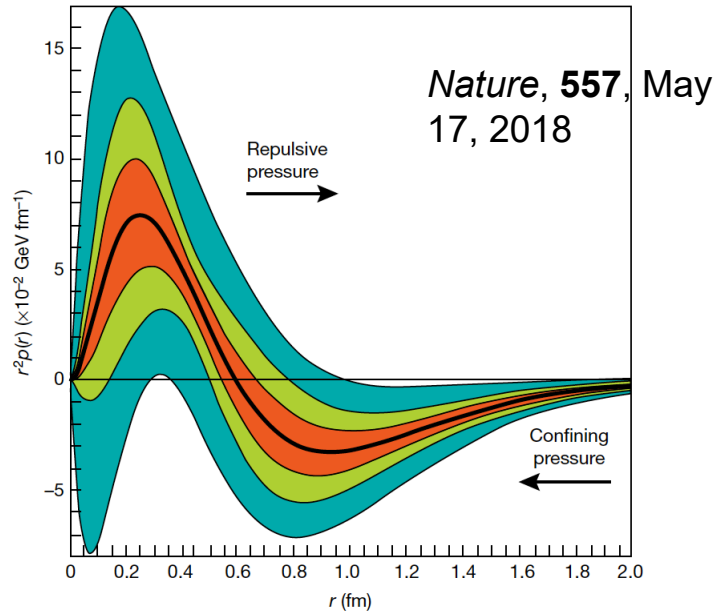
Note: CD-2/3 for DET delayed to align with accelerator and given risk in large in-kind contributions for DET without signed agreements as of yet. To keep momentum, we envision a DET CD-3D.



EIC Science Reach

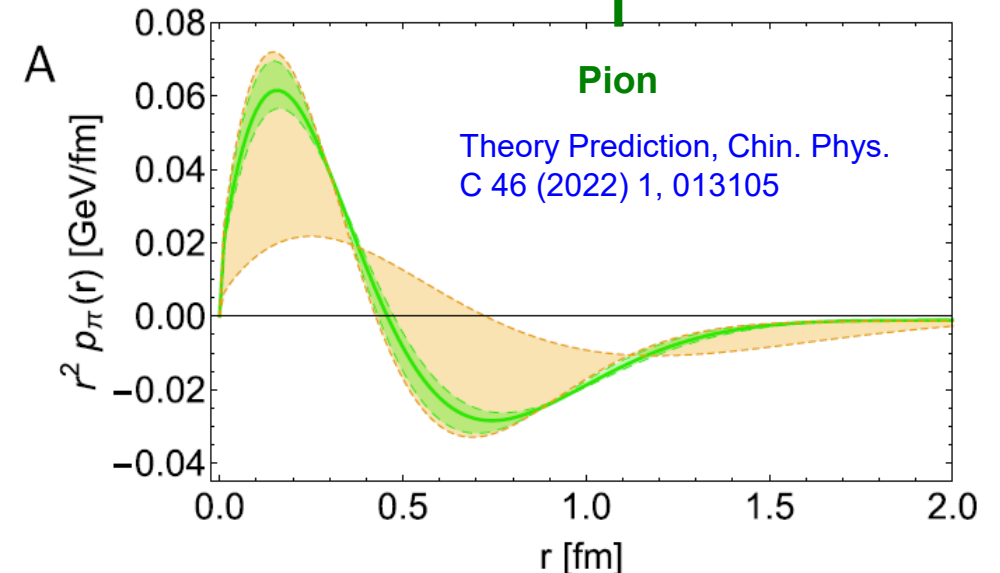


Steps towards pressure distribution



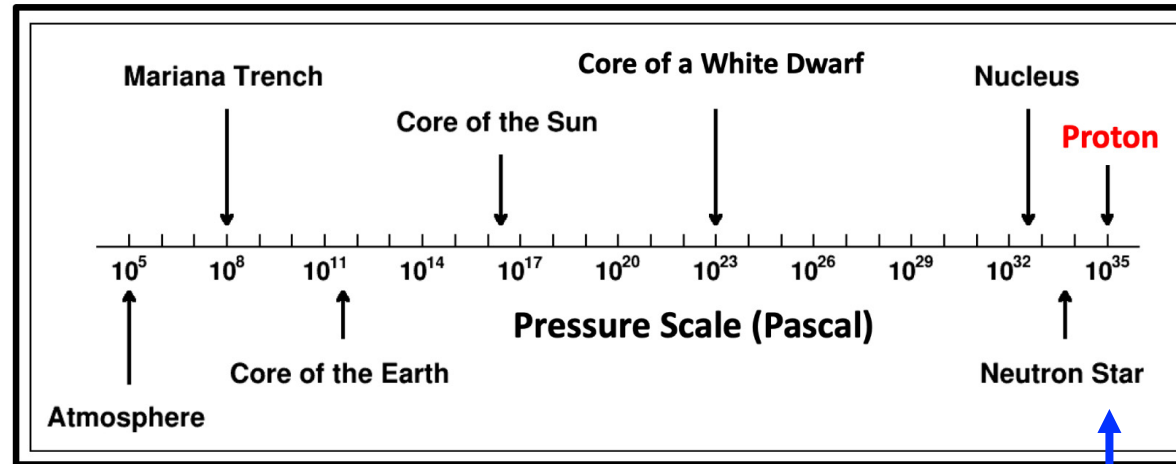
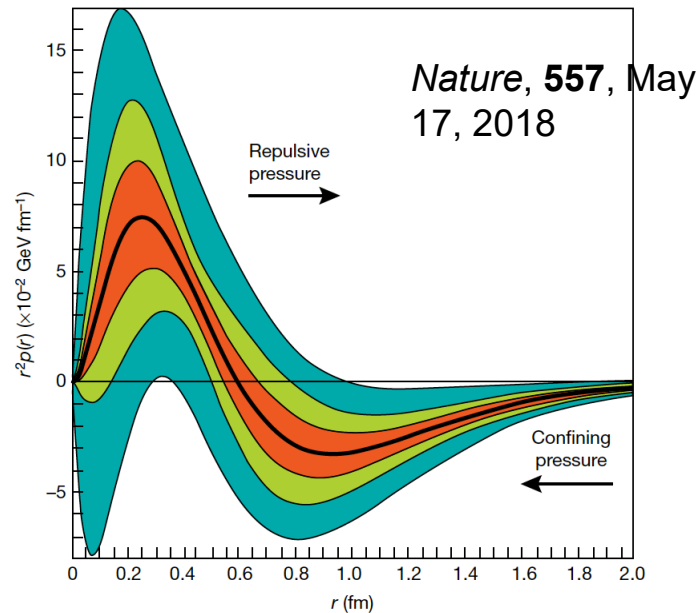
- **Pressure in the Proton**

- First determination using DVCS (Deeply Virtual Compton Scattering) data
- Interior pressure in proton is > pressure inside a neutron star! **Who knew that!**
- Lattice calculation motivates determination of gluon GPDs at EIC



Experimental prospects at EIC first discussed in J. Phys. G 48 (2021) 7, 075106 – further work ongoing

Steps towards pressure distribution



• Pressure in the Proton

- First determination using DVCS (Deeply Virtual Compton Scattering) data
- Interior pressure in proton is > pressure inside a neutron star! *Who knew that!*
- Lattice calculation motivates determination of gluon GPDs at EIC

