Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

BNL LDRD Detector-II Weekly Meeting

Page Turner – DIS 2025

Scheduled 20-minute talk in "Future Experiments" session

Titled in "Overview on Efforts for a Second Detector at the Electron-Ion Collider (EIC)"

Jihee Kim (jkim11@bnl.gov)

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2025/03/03

Deep Inelastic Scattering 2025

Overview on Efforts for a Second Detector at the Electron-Ion Collider (EIC)

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Brookhaven National Laboratory

2025/03/25

Cape Town, South Africa

@BrookhavenLab

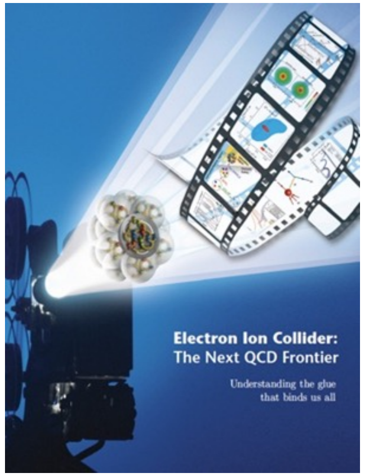
Electron-Ion Collider Physics

Investigate **dynamics of gluons** to understand emergence of properties of quarks and gluons **in nucleons and nuclei** (= **QCD** physics)

Main Questions:

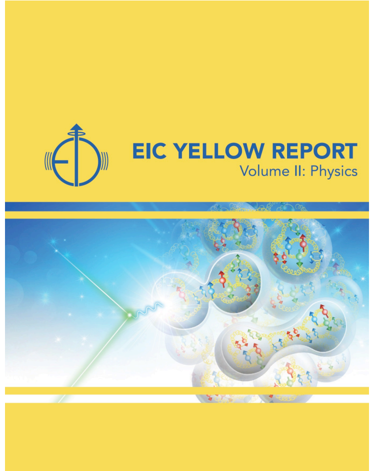
- (**3D Imaging**) How are sea quarks and gluons distributed in space and momentum inside the nucleon?
- (**Origin of Mass and Spin**) How do nucleon properties emerge from sea quarks and gluons and their interaction?
- (**Gluon Saturation**) What happens to gluon density at low-x?

2012



White Paper

2021



Yellow Report

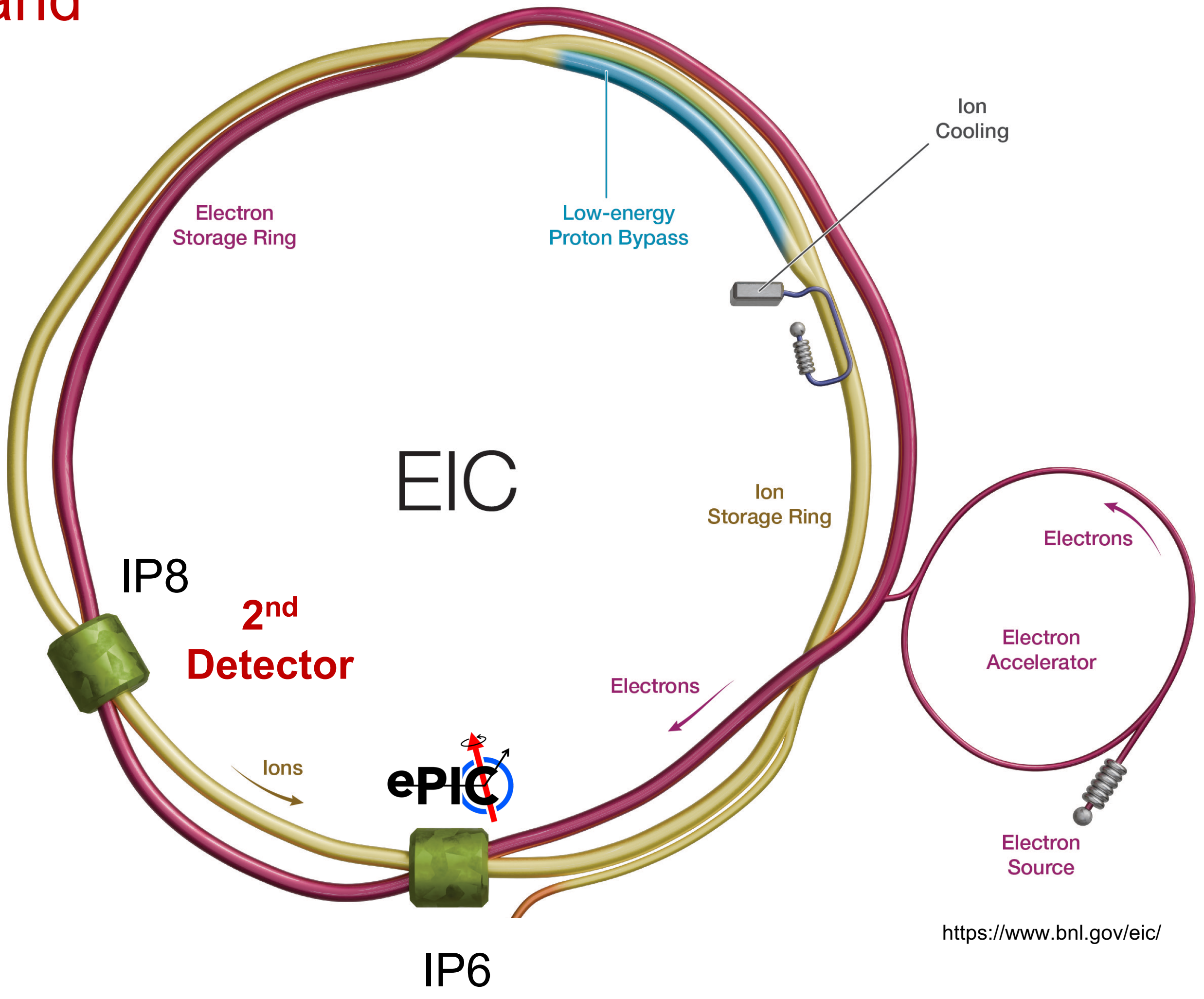
Eur. Phys. J. A (2016) 52: 268, arXiv:1212.1701
Nucl. Phys. A 1026 (2022) 122447, arXiv:2103.05419

Comprehensively discussed in
White paper (**physics cases**) and Yellow report (**detector requirements** + **concepts**)

EIC and EIC Detector(s)

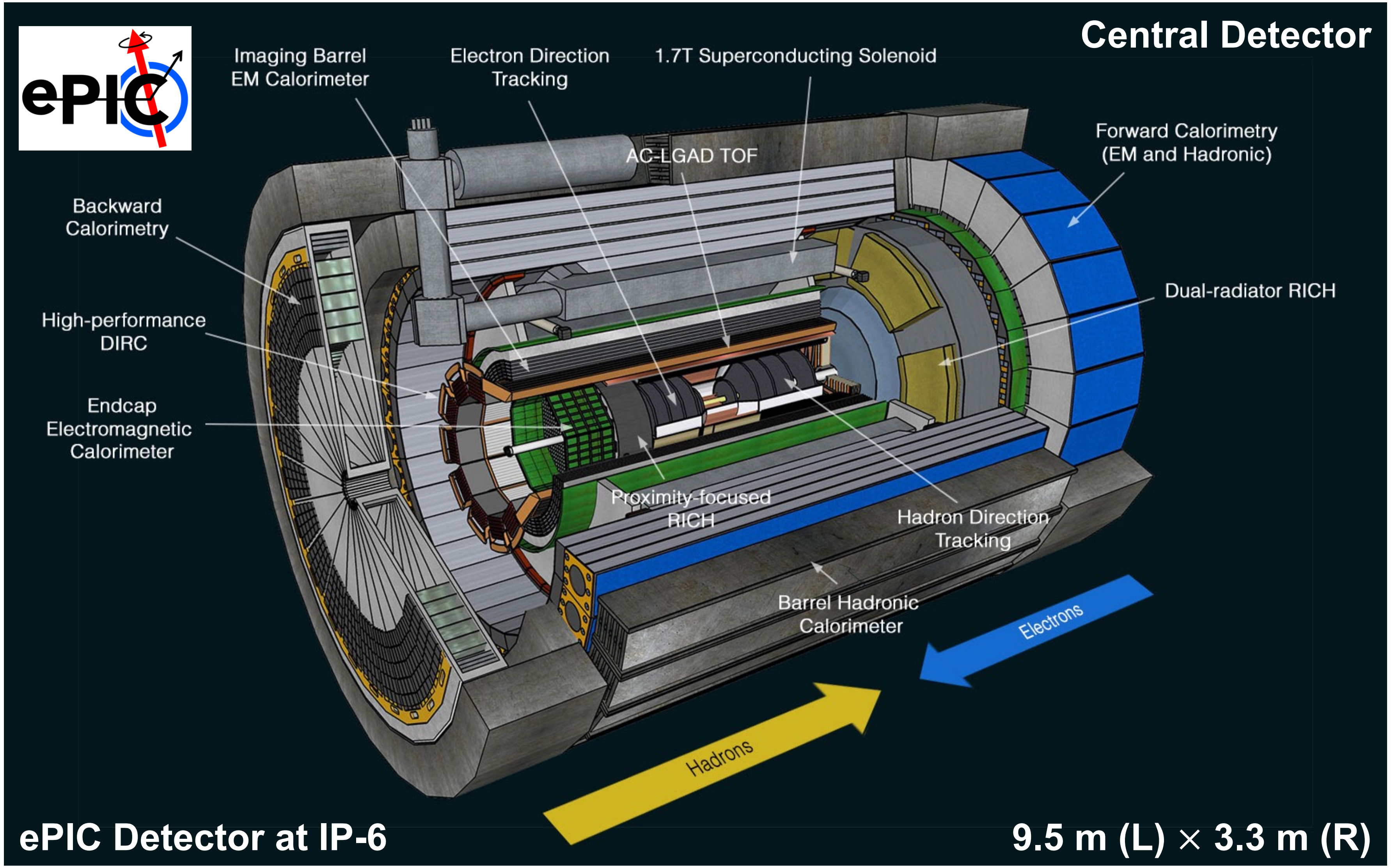
Unique, high-energy, high-luminosity, and polarized beam collider in this decade

- Capable of accommodate **two** detectors and **two** interaction regions (IP6 and IP8)
- **ePIC**: **One** detector and **one** interaction region supported DOE-NP project
- Community is strongly in favor of
  - Two general purpose detectors
  - Dedicated chapter in Yellow Report: Two Complementary Detectors
  - EIC User Group has Detector-II Working Group



https://www.bnl.gov/eic/

ePIC Central Detector



Hermetic detector
Low mass inner tracking

Overall,
Good momentum resolution
Excellent PID $\pi/K/p$

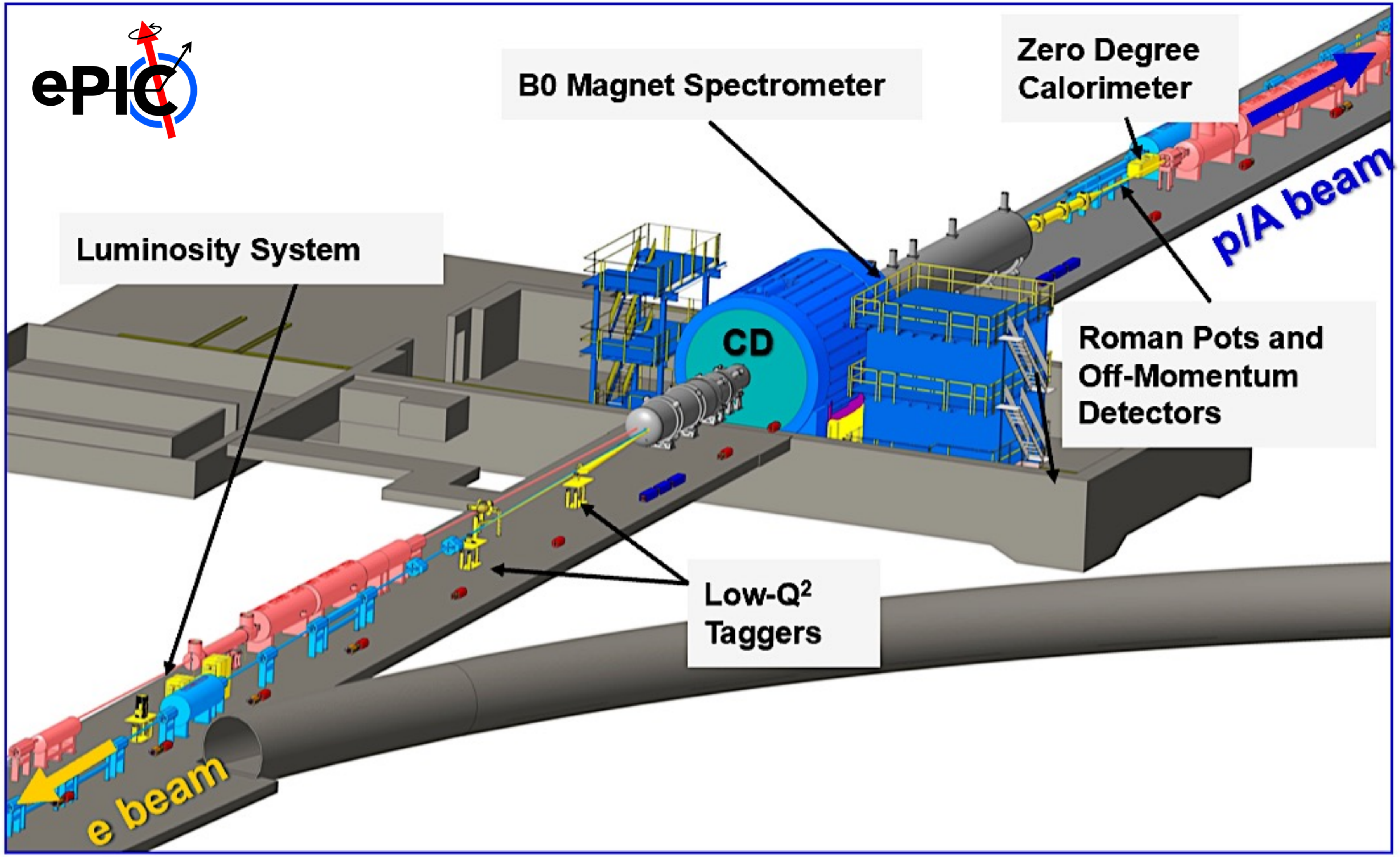
In electron-going direction,
Excellent energy resolution

In hadron-going direction,
Good energy resolution

Subsystems:
Tracker w/ Vertexing
PID
EMCAL and HCAL
Magnet

https://www.epic-eic.org

And Far Detectors in Interaction Region



In electron-going direction,
Low-Q^2 scattered lepton

In hadron-going direction,
Nuclear breakup
Diffractive reactions

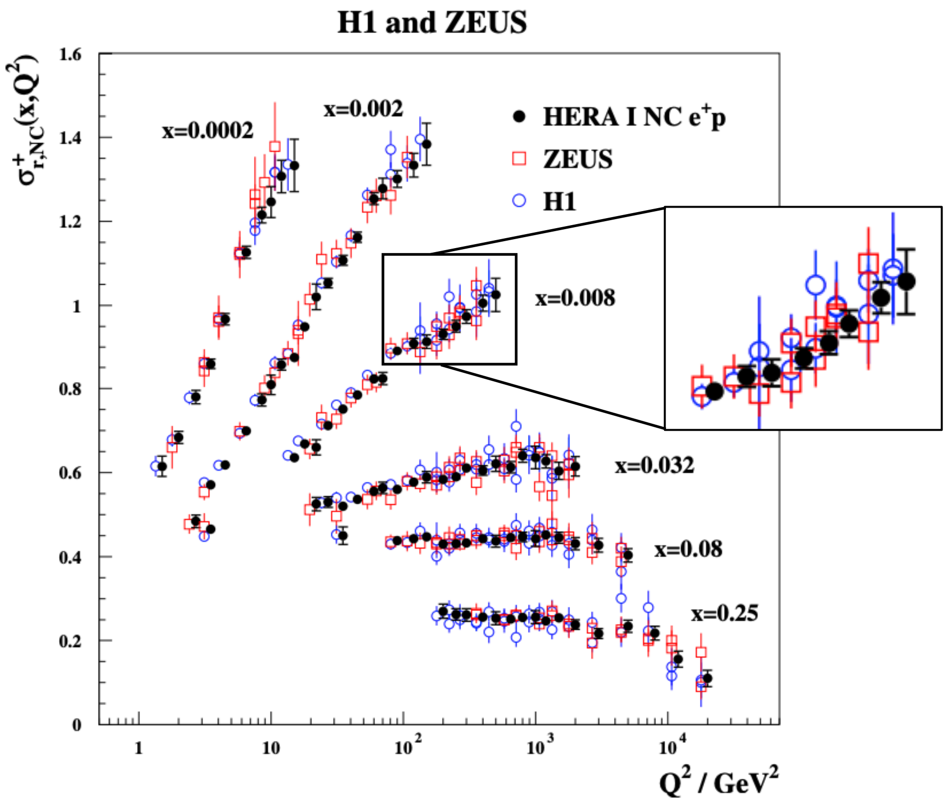
Subsystems:
Tracker
EMCAL and HCAL
Luminosity Monitor

https://www.epic-eic.org

EIC 2nd Detector Motivation

Another general-purpose collider detector to support full EIC program (**complementarity**); 1 + 1 > 2

- **Cross-Checking**
  ex) HERA (H1 & ZEUS), RHIC (PHENIX & STAR)
- **Cross-Calibration**
  Beyond $\sqrt{N}$ statistical improvement
  Reducing uncertainties associated with a single detector configuration
- **Technology Redundance**
  Different technologies to similar physics aims
- **Primary Physics Focus**
  Optimizing overall sensitivity to full physics scope



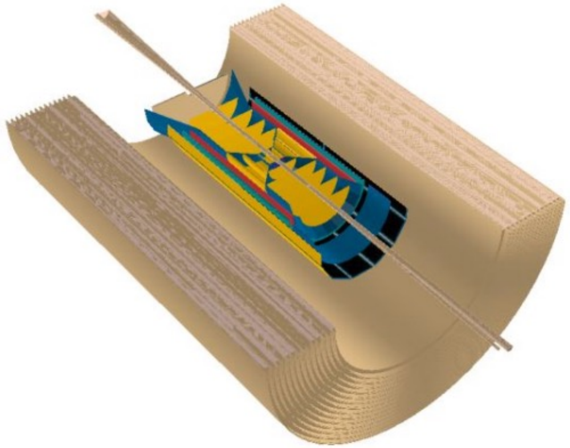
Eur. Phys. J. C 75, 580 (2015), arXiv:1506.06042

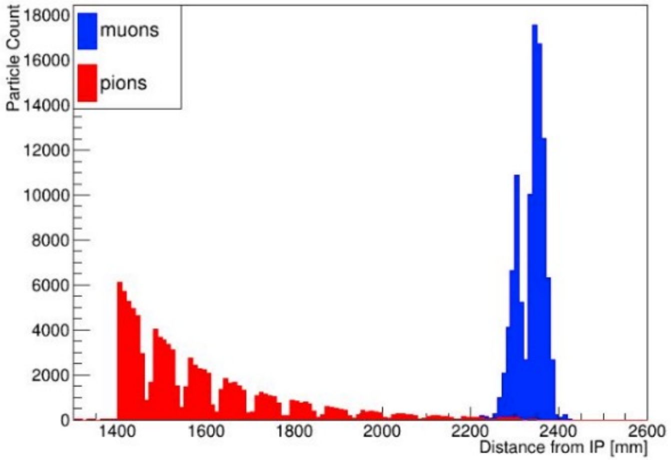
Complementarity of Technologies

System	ePIC	2nd Detector	Comments
Magnet	1.7 T Solenoid	2-3 T Solenoid with large radius	Space for services, deeper detector depth, and improve resolution
Tracker	MAPS + MPGDs	Gaseous detectors + Outer MAPS layers	Improve pattern recognition
PID	dRICH (gas + aerogel) + TOF	Gaseous-RICH + TOF	Up to 50 GeV/c and R&D 10 ps resolution
EMCAL	Imaging calorimeter (AstroPix + Pb/SciFi)	SciGlass	R&D SciGlass
HCAL	Steel/Scintillator plates	Belle-II style KLM	R&D Improved KLM + muon detection

Noted that some were selected and illustrated here

EIC 2nd Detector Muon Detector

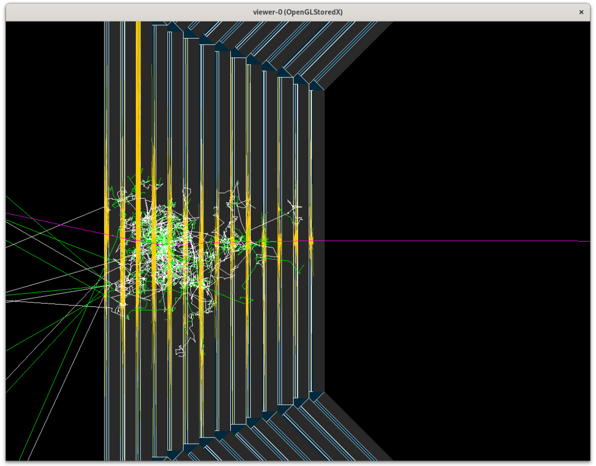


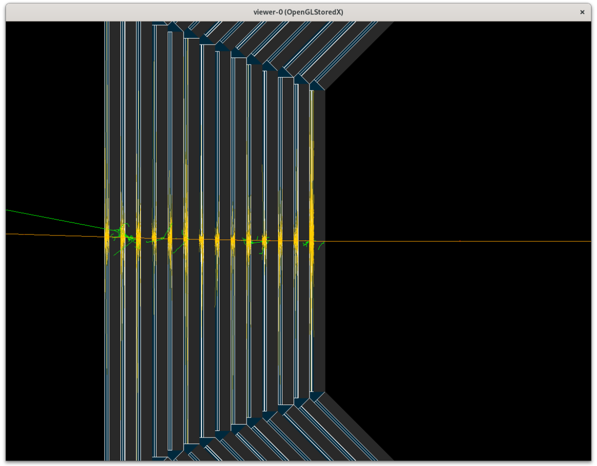


Dedicated muon ID detector

Muon channel (quarkonium)

Served as cost effective HCAL



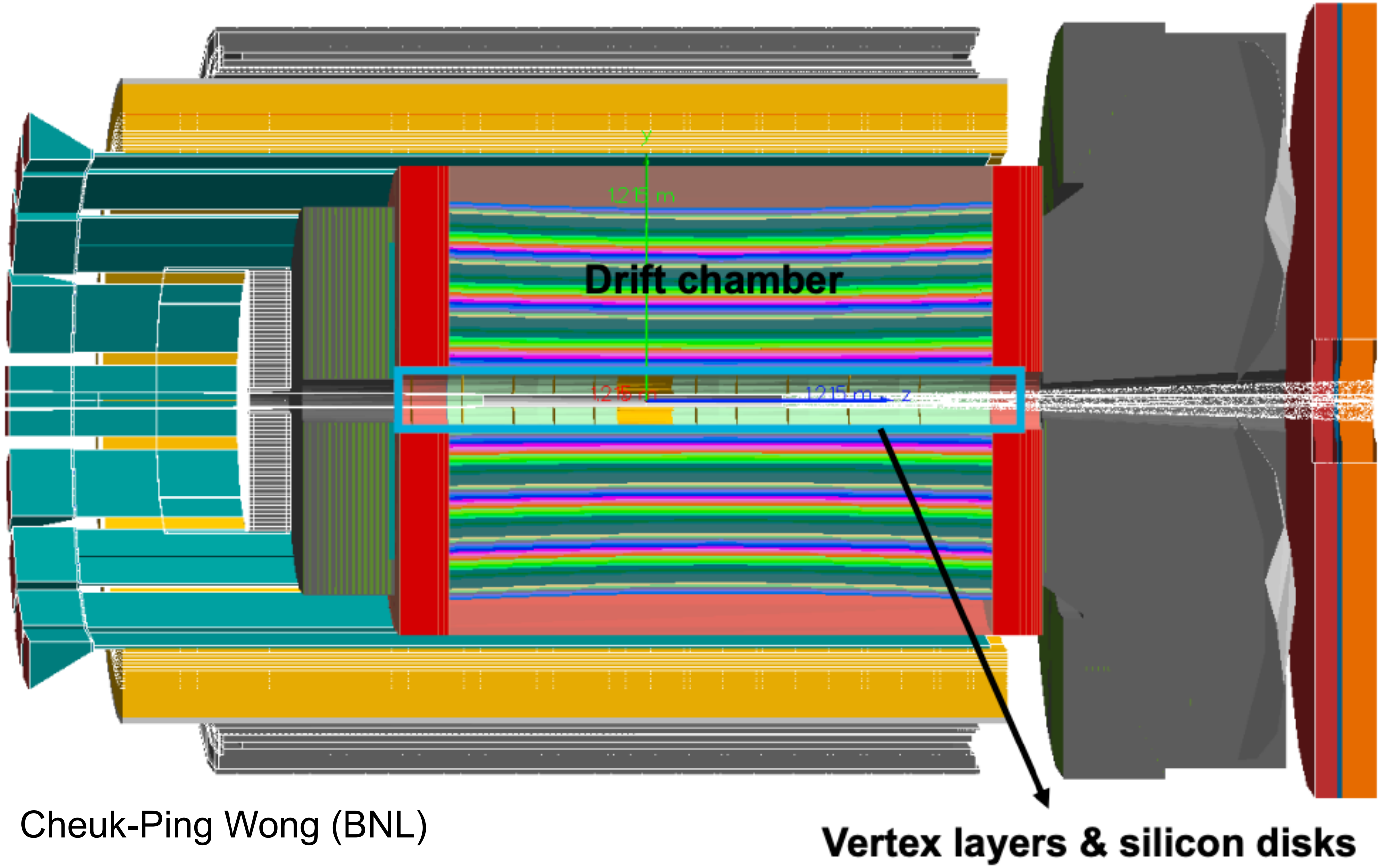


- **Iron/Scintillator** sandwich (like Belle-II)
- Longitudinal segmentation for better h/μ ID and energy reconstruction
- μ ID at low ($\approx$1 GeV) momenta
- **R&D on fast scintillator** (readout)
- Possible solution for endcap HCAL

Rowan Kelleher, Simon Schneider, Anselm Vossen, Nilanga Wickramaarachchi (Duke), Will Jacobs (Indiana) Yordanka Ilieva (USC)

EIC 2nd Detector **Central Tracker**

HCAL/Muon Detector not shown



Cheuk-Ping Wong (BNL)

Mixed-tracking technologies

- Inner silicon vertex tracker
- **Gaseous detector** (TPC or drift chamber)

Cons

- More material budgets
- **Worser spatial resolution** compared to pixelated silicon sensor

Pros

- More hits → **better pattern recognition**
- PID info at low-momentum using dE/dx

Complementarity of Interaction Region

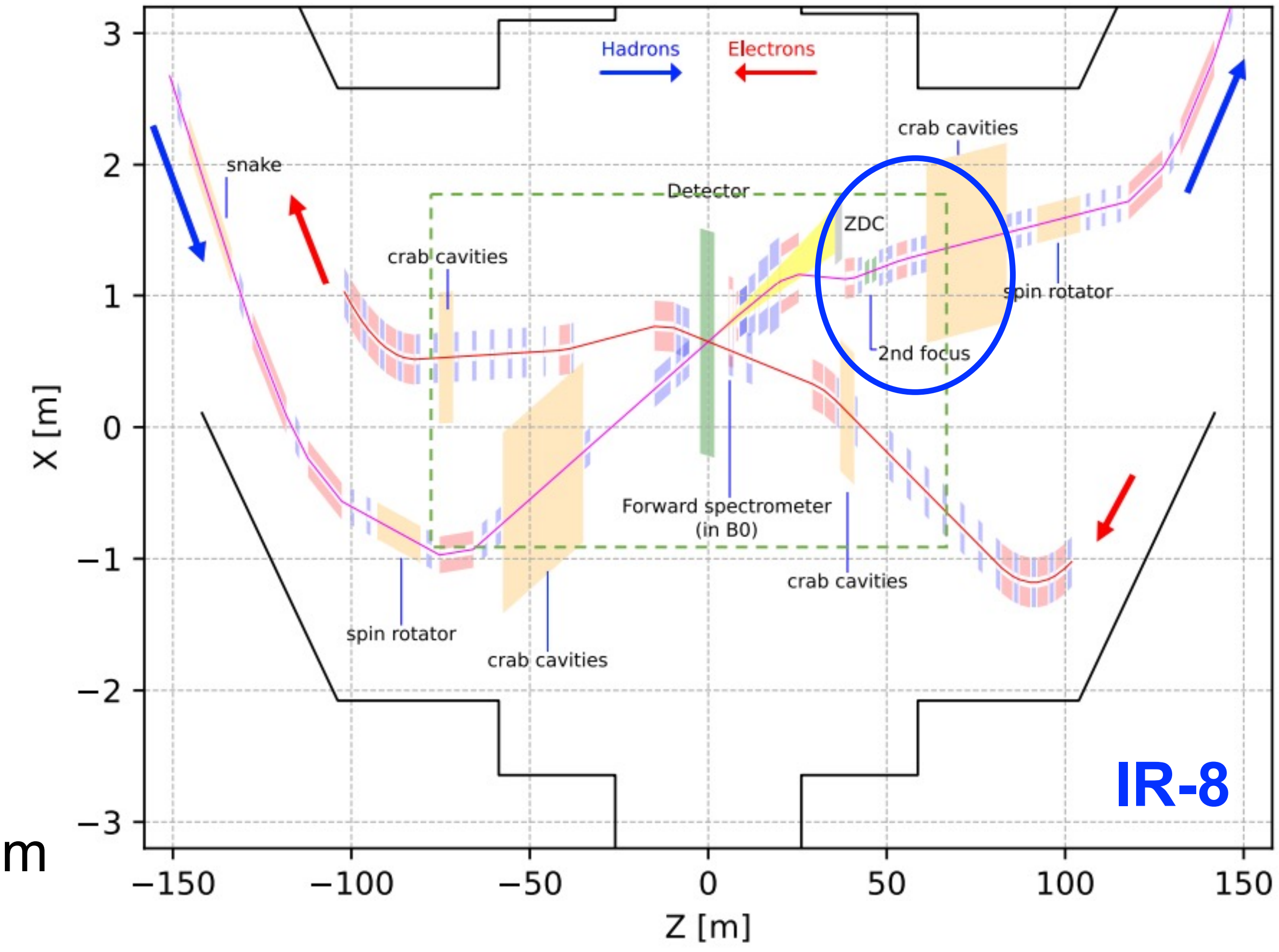
Same

- Accelerator highlights/challenges
- Luminosity at both IRs
- Center-of-mass energy coverages

Different

- **Blind spots** (crossing angle)

  ex) IP-6 25 mrad vs IP-8 35 mrad
- **Larger far-forward detector acceptance**
  - **2nd focus**: Squeeze hadron beam
  - **Larger neutron acceptance**

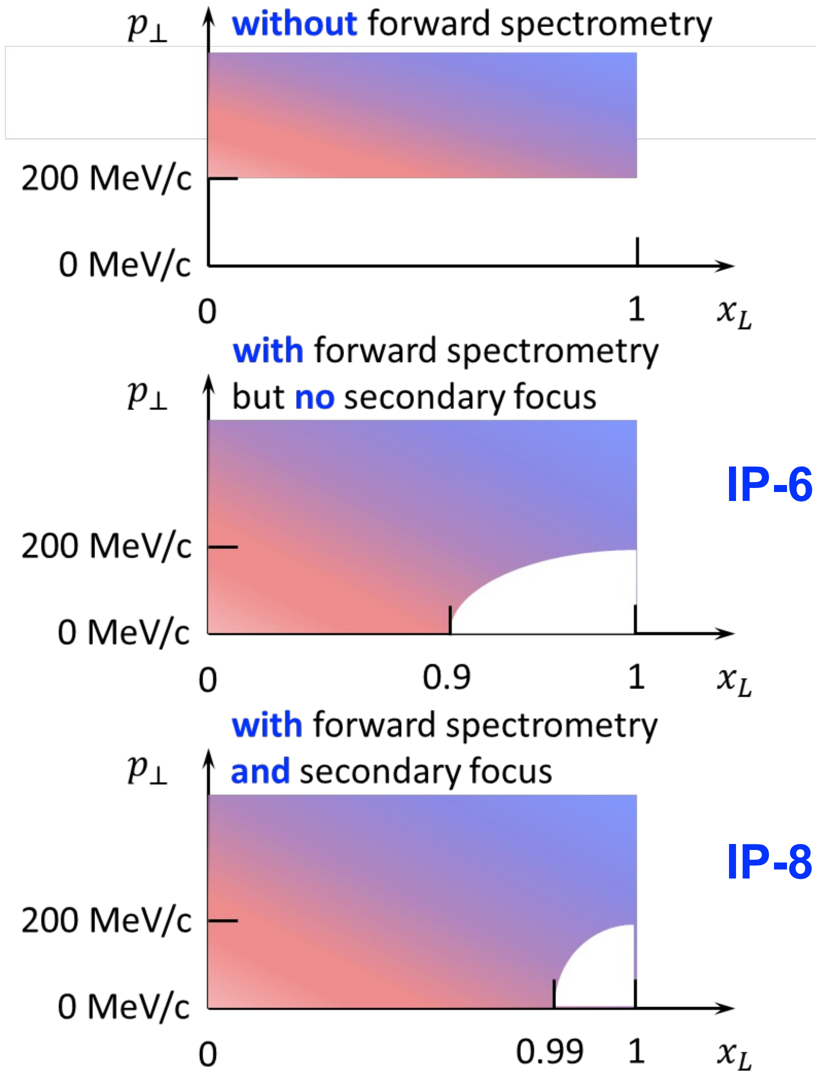


Compelling Opportunity with 2nd Focus

EIC 2nd detector can **benefit from machine design**

- Allows access to **low-p_T particles/fragments**
  - Higher probability to detect low-p_T (< 250 MeV)
- **New physics opportunities**:
  - Exclusive/diffractive measurements at low t
  - Recoiling nuclei and fragments from nuclear breakup
  - Coherent diffraction on heavy nuclei
- **Challenges**:
  - Chromaticity budget
- **Unique capabilities to enhance overall EIC exclusive, tagging and diffractive physics program**

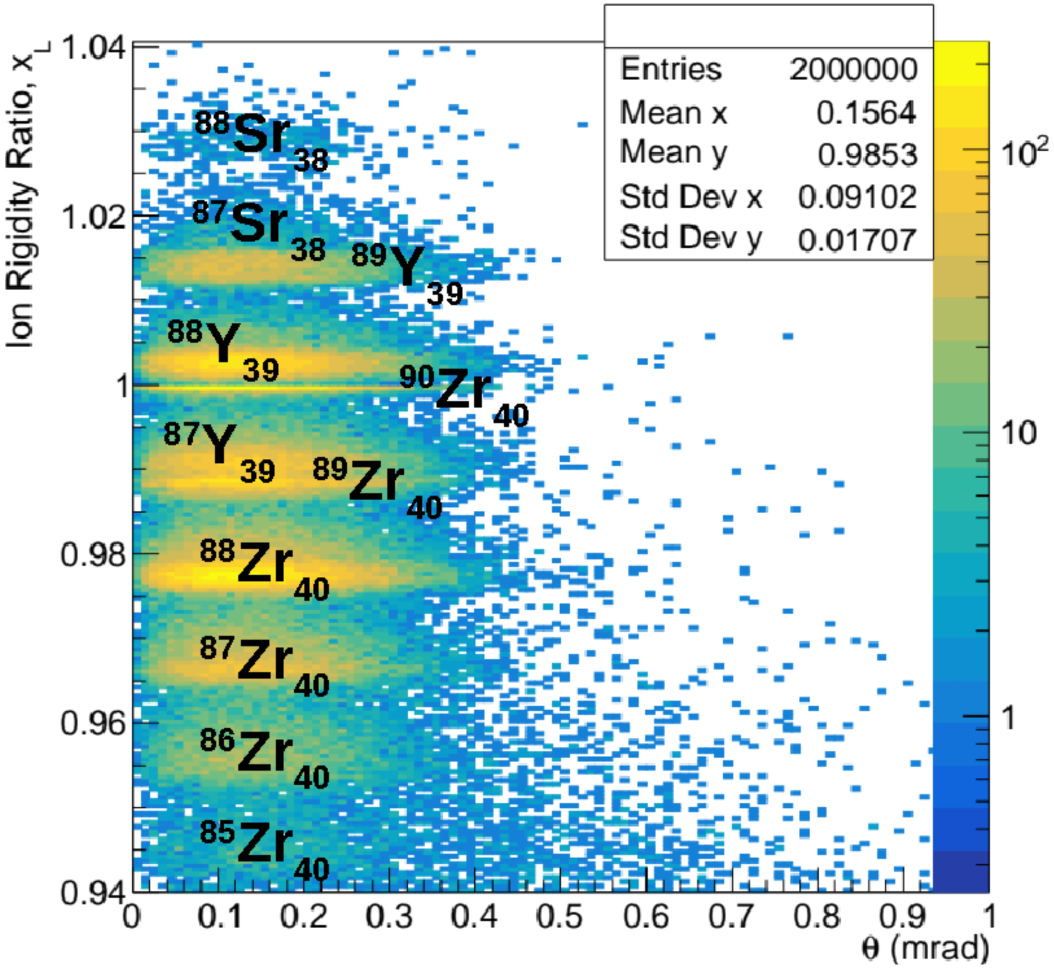
($x_L = p'/p_{\mathrm{beam}} \sim 1 - x$)

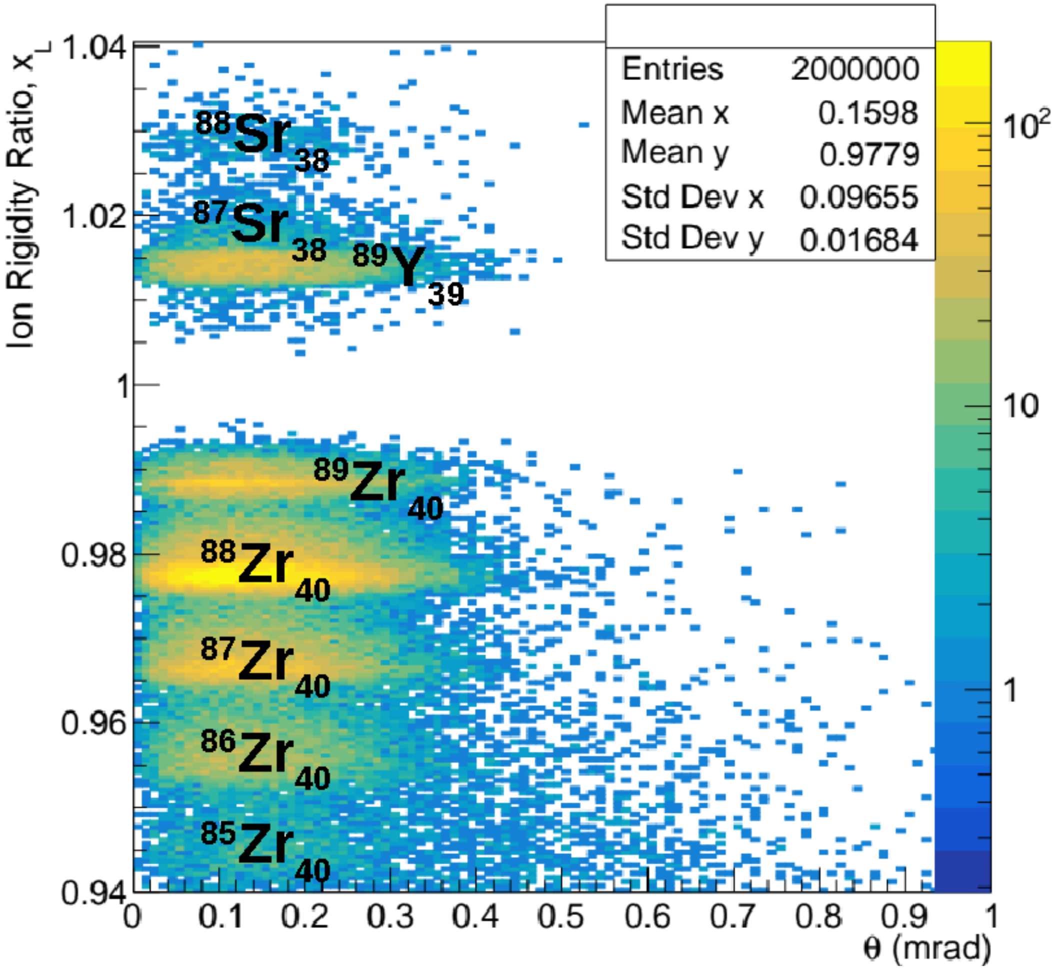


JACoW IPAC2021 (2021), arXiv:2105.13564

Detection of Nuclear Remnants of ^{90}Zr

Nuclear Inst. And Methods in Physics Research, A 1052 (2023) 168238, arXiv:2208.14575





Illustrated ability of 2nd focus to allow detection of nuclear remnants (ex. A-1) using ^{90}Zr beam

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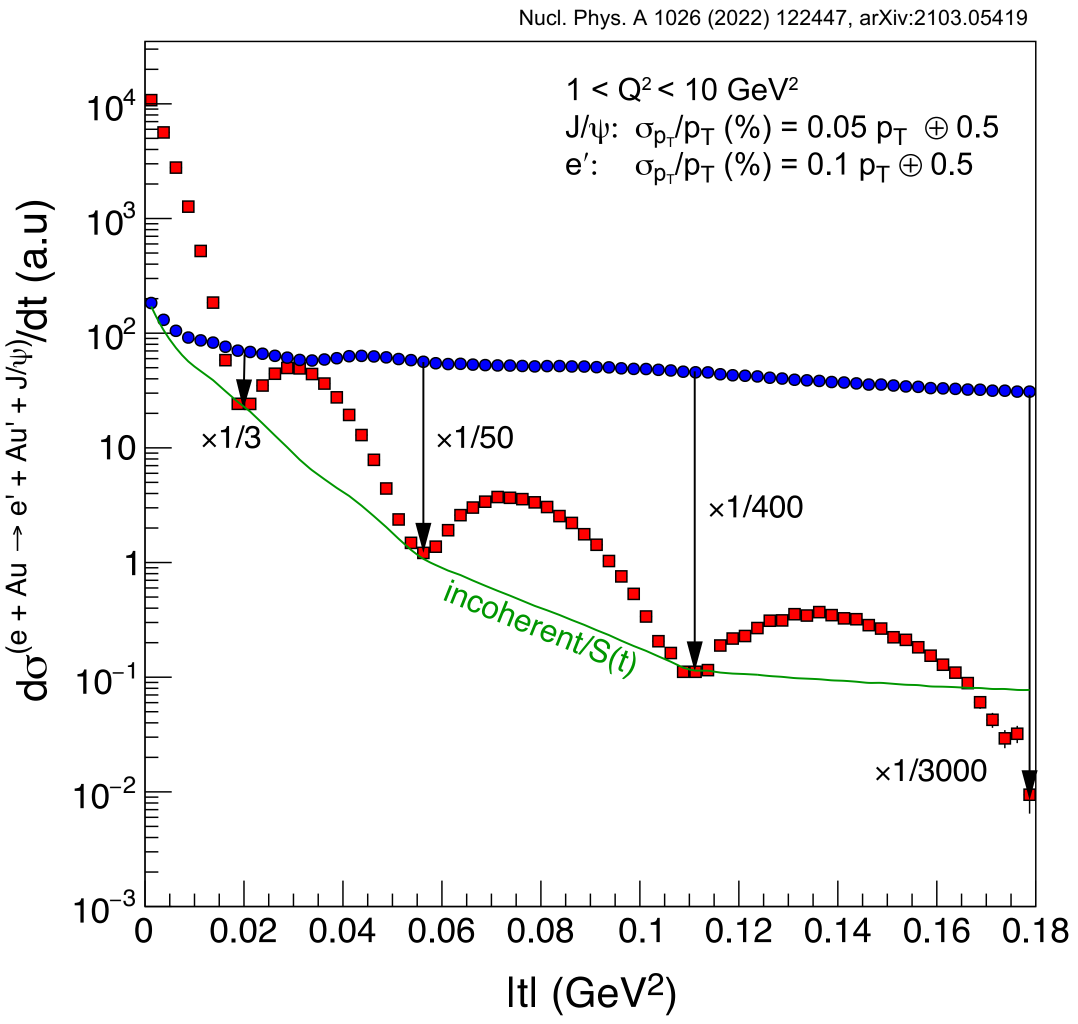
JIHEE KIM

Coherent Diffraction on Heavy Nuclei



For $\boldsymbol{e} + \boldsymbol{A}$ program:

Suppression of incoherent background

Diffractive cross section:

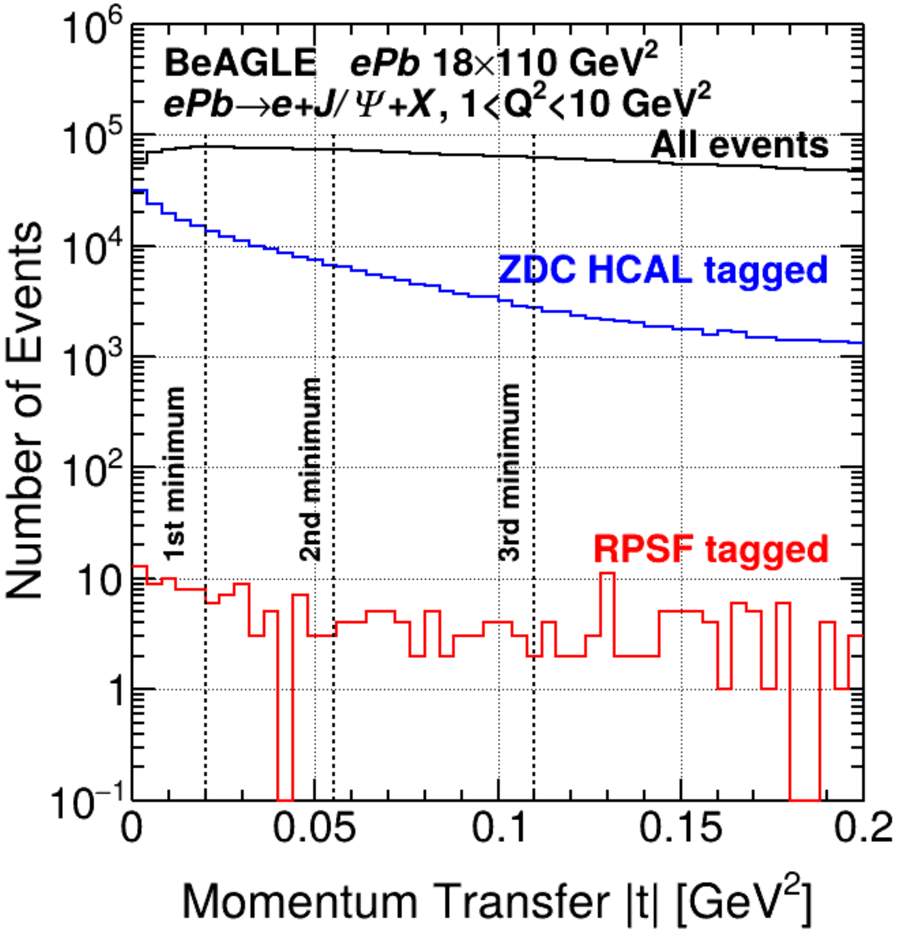
Sum of coherent (nucleus stays intact) and incoherent (nucleus breaks up) processes → **Very challenging!**

How to veto incoherent process:

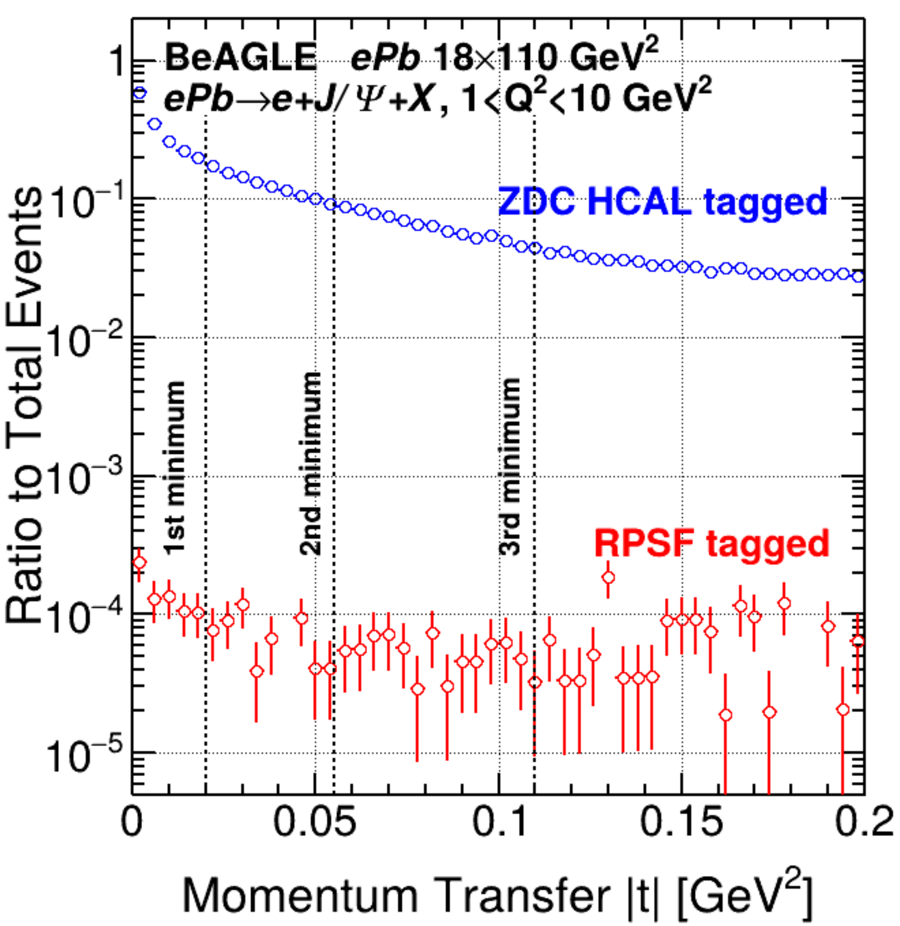
By tagging nucleus breakups using far-forward detectors

Coherent Diffraction on Heavy Nuclei

Number of non-vetoed incoherent events



Vetoing power distribution



ZDC hcal tagged (neutrons)
RPSF tagged (protons, nuclear fragments)

arXiv:2501.12410

Found to be enough to suppress incoherent contribution at three minima (**vetoing eff. > 99.99 %**)

Summary and Outlook

- EIC 2nd Detector
  - Strong support and interest in community
  - Endorsed in early NSAC/NAS documents and DPAP panel

- To support and to enhance full EIC science program
  - Complementarity
  - Compelling physics opportunities by potential new feature "2nd focus"

- Large interests and inputs will drive project forward
  - Your input is extremely valuable
  - If you would like to share your idea, please reach out to EICUG Detector-II WG group conveners (https://eicug.github.io/content/wg.html#detector-iiip8-group)

Backup Slides