中国高能核物理网络论坛
HIGH ENERGY NUCLEAR PHYSICS IN CHINA

# *From HIC to* Electron-Ion Collider

## -- next generation nuclear physics facility


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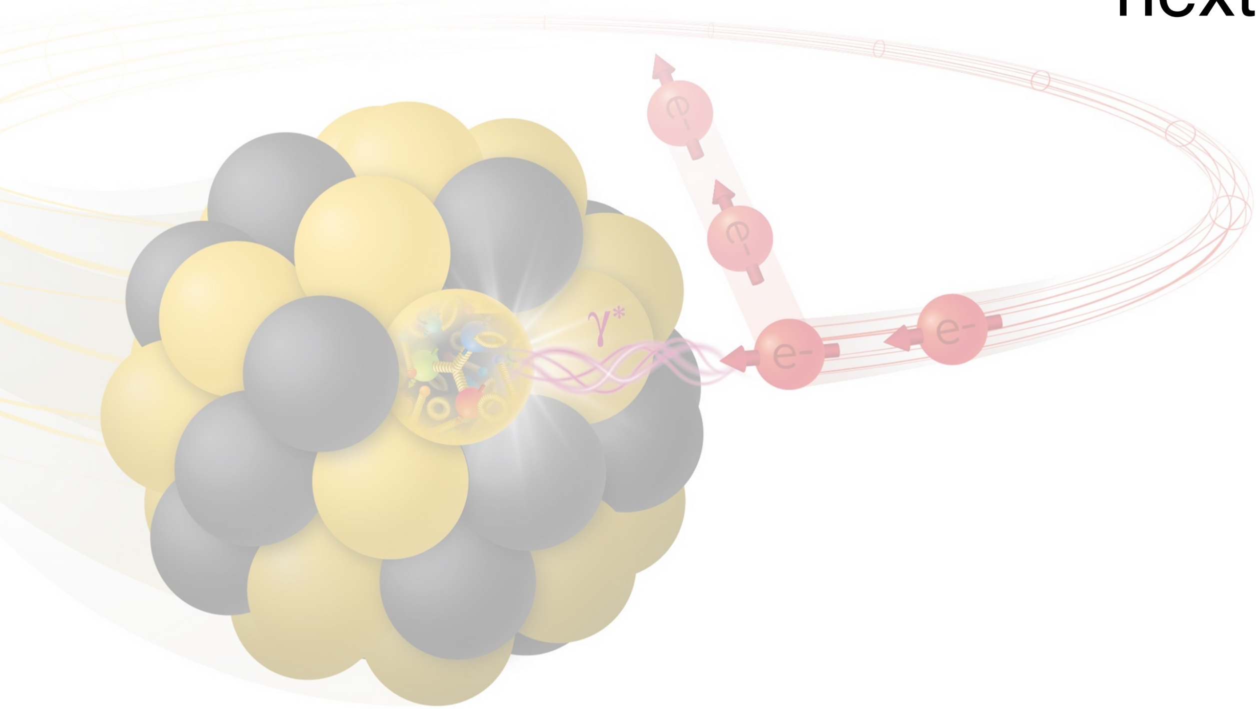
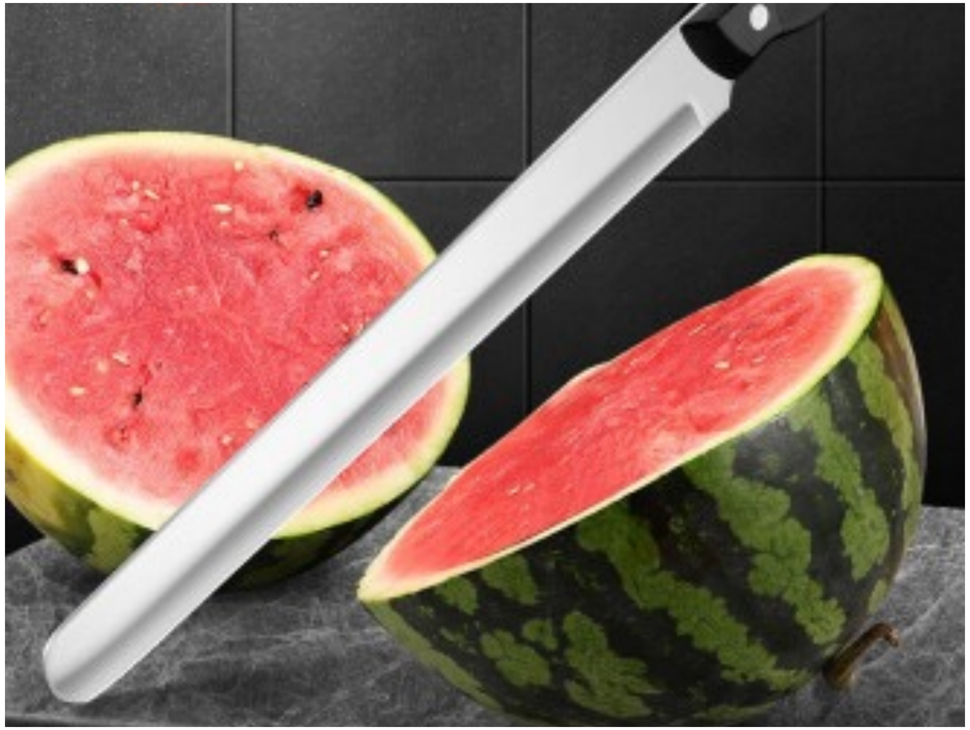


# Study of internal structure of watermelon

*-- analogy from A. Deshpande*

Violent collision of melons

Heavy-ion Collison (RHIC/LHC)

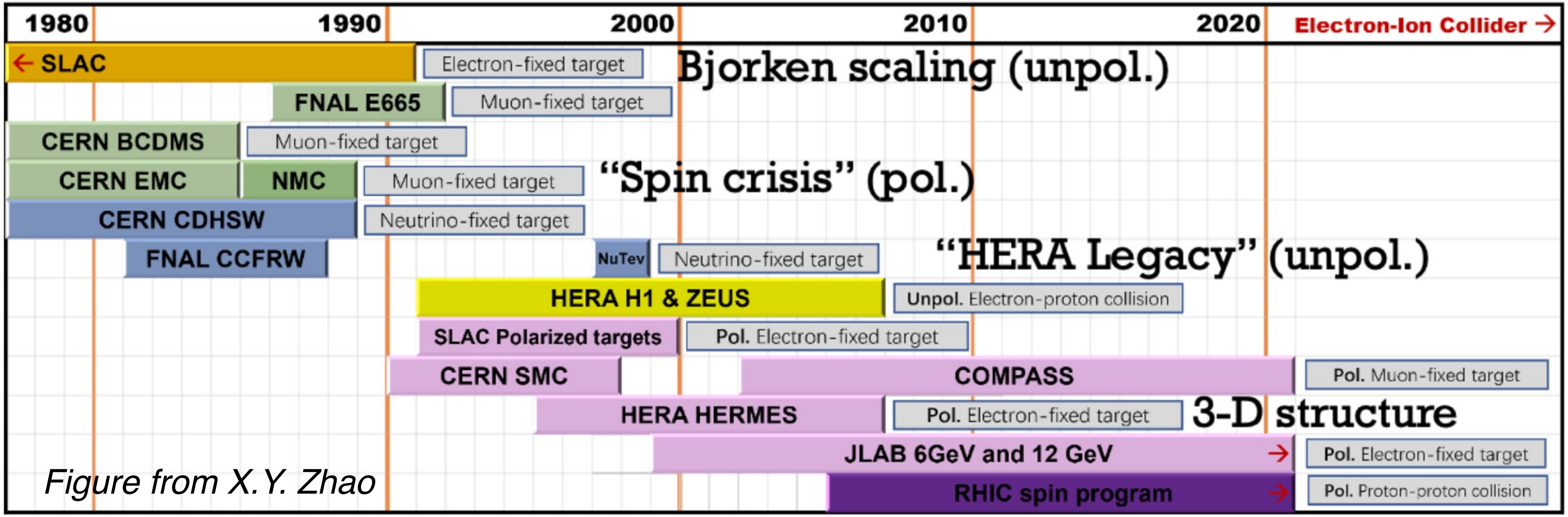


Cutting the watermelon with a knife

Violent DIS e-A (EIC)

# Lepton scattering: an ideal tool

T. B. Liu, SPIN2023



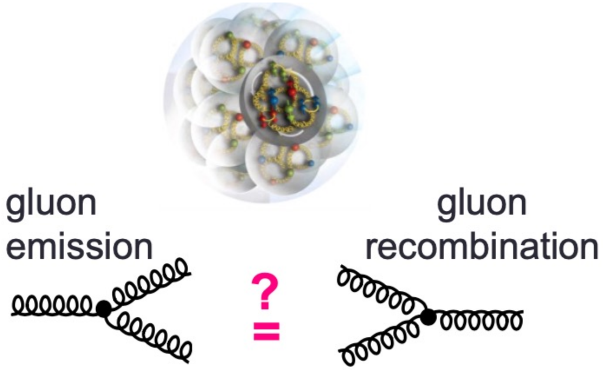

Modern "Rutherford Scattering" Experiment

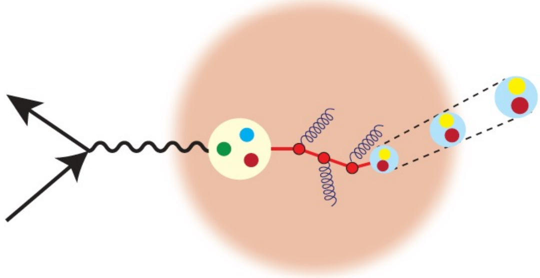
- Start from unpolarized fixed targets
- Extended unpolarized collider experiments
- and polarized fixed-target experiments

Need polarized electron-ion collider

- High luminosity: 100~1000 × HERA lumi.
- High polarization: both electron and ion beams
- Large acceptance: nearly full detector coverage

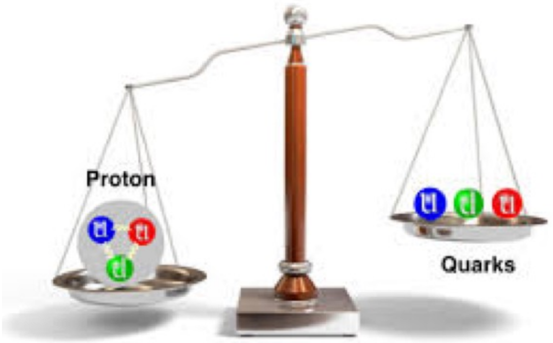
# Questions expecting EIC to answer

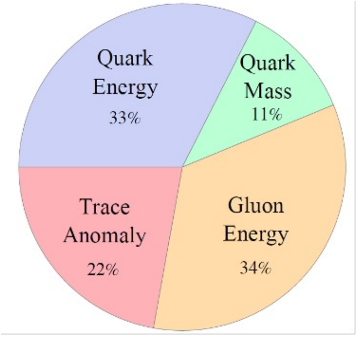


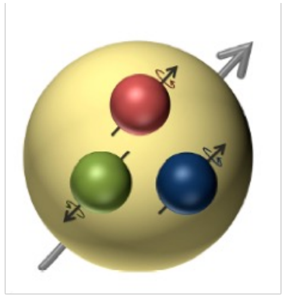



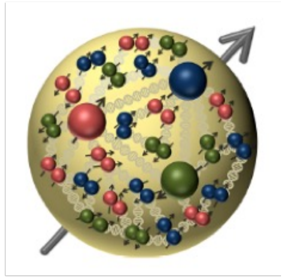
Does gluon saturate at high energy?
How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions?

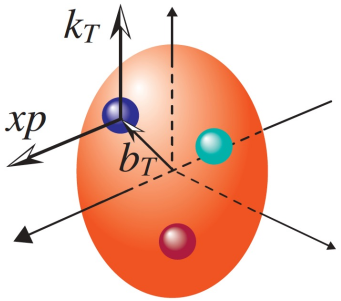
How do the nucleon properties (mass & spin) emerge from their interactions?








How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon?

# Proposed Electron-ion colliders (incomplete list)

FAIR ➔ ENC

LHC ➔ LHeC



RHIC ➔ eRHIC/EIC

HIAF ➔ EicC

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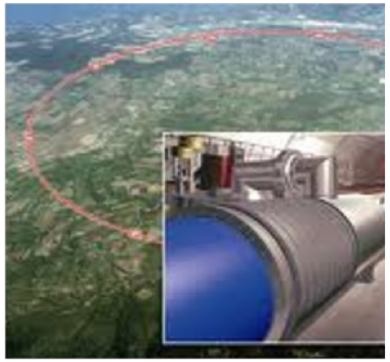
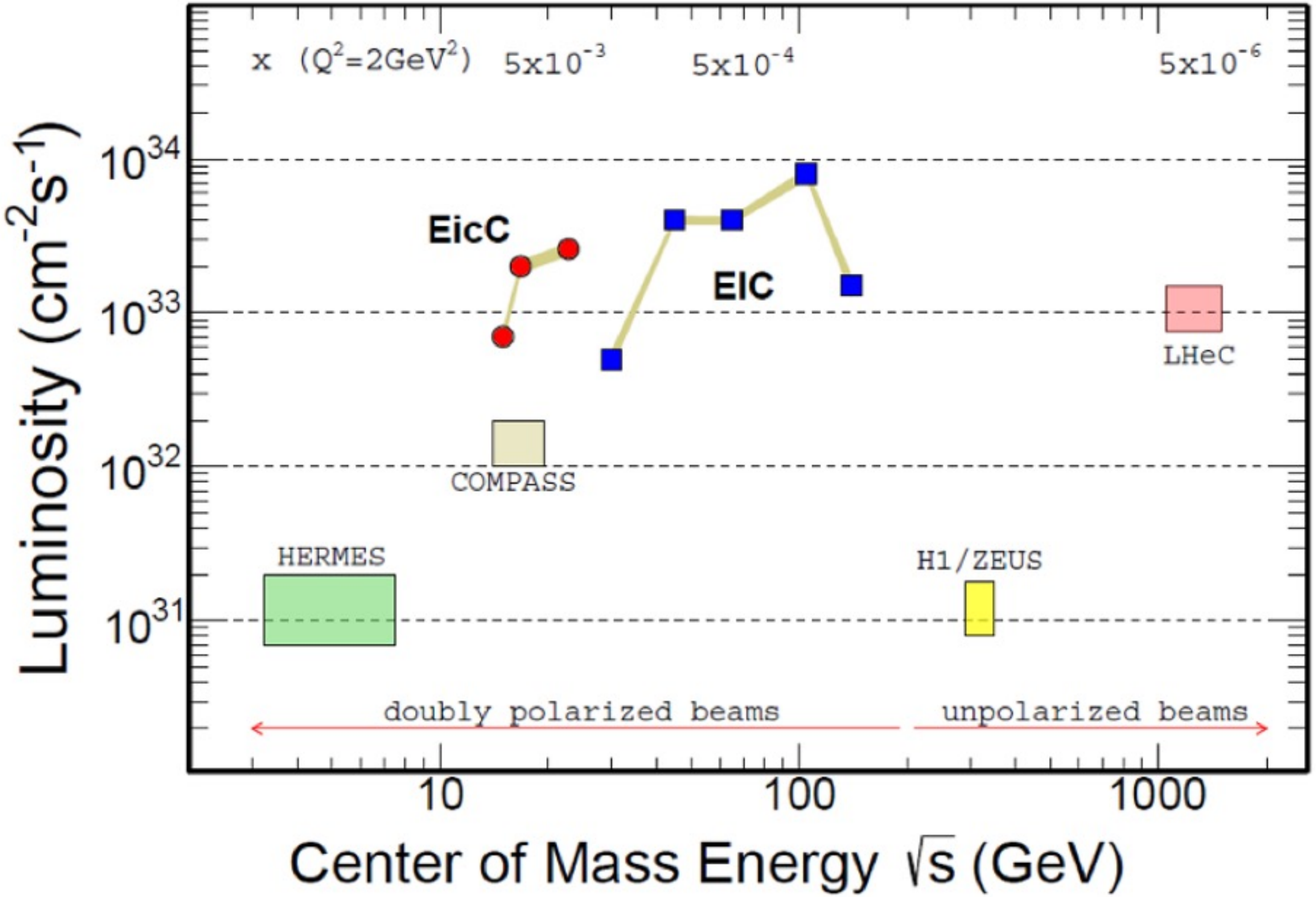
FAIR ➔ EN

LHC ➔ LHe







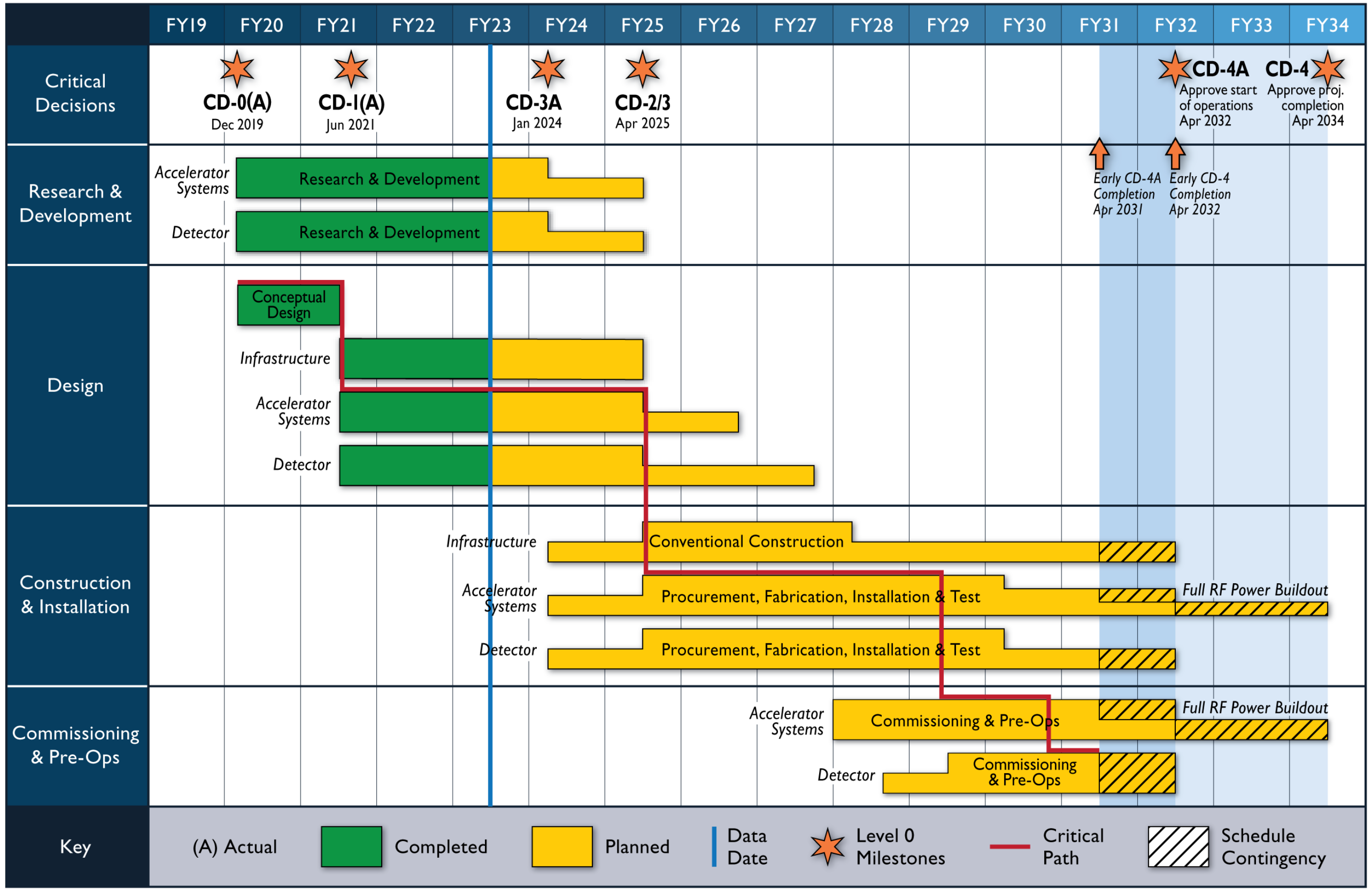
IC ➔ eRHIC/EIC

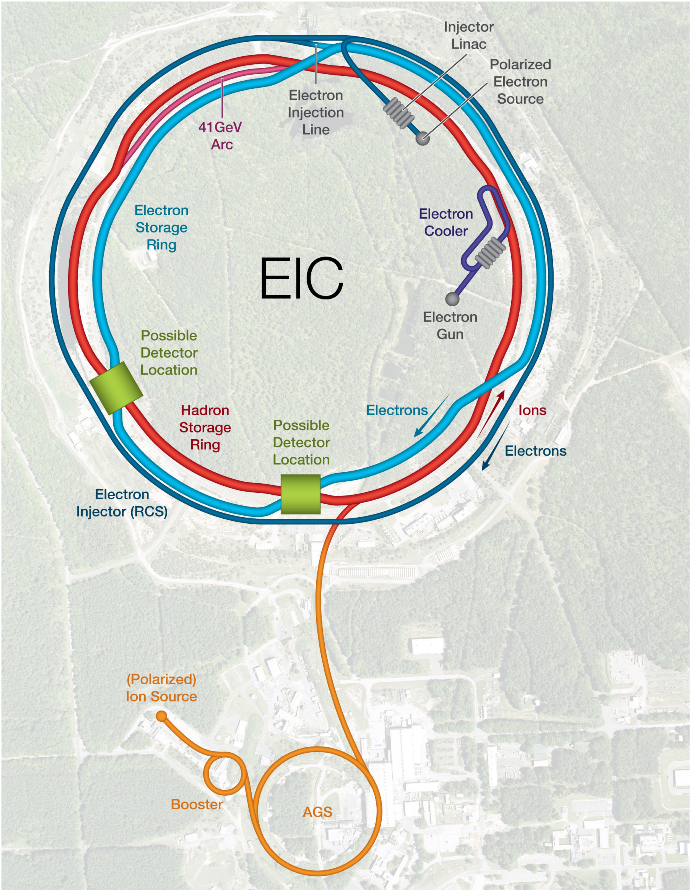
HIAF ➔ EicC

# US-EIC Status

Approved in Dec 2019 (CD0)

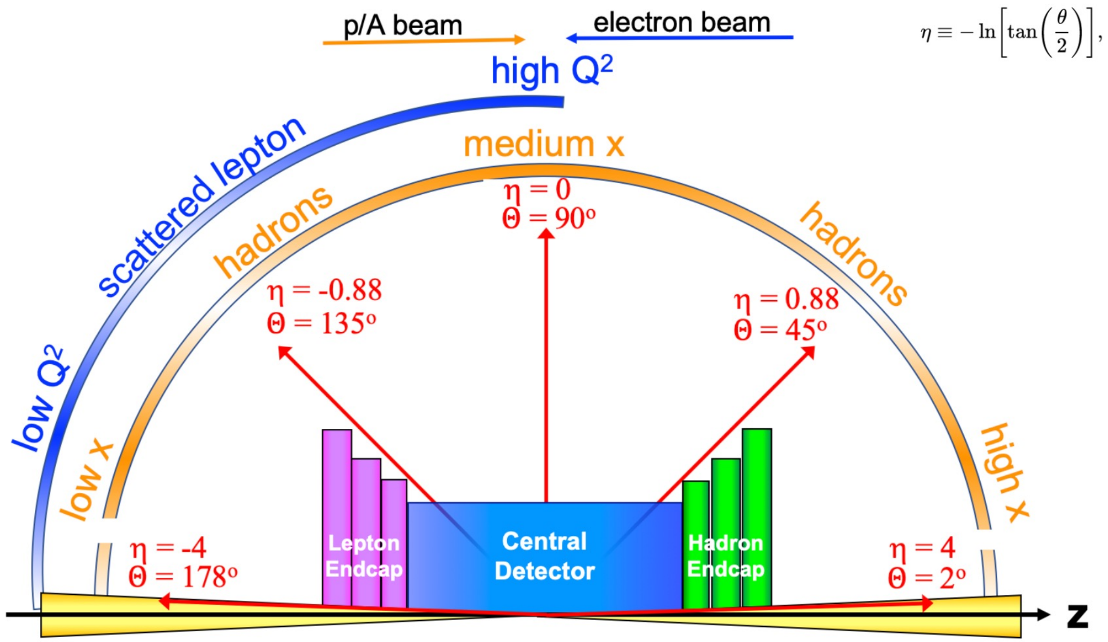
- US EIC is based on the RHIC complex: proton/ion ring, injectors, ion sources, infrastructure
- Add a 5 to18 GeV electron storage ring and its injector complex to the RHIC facility



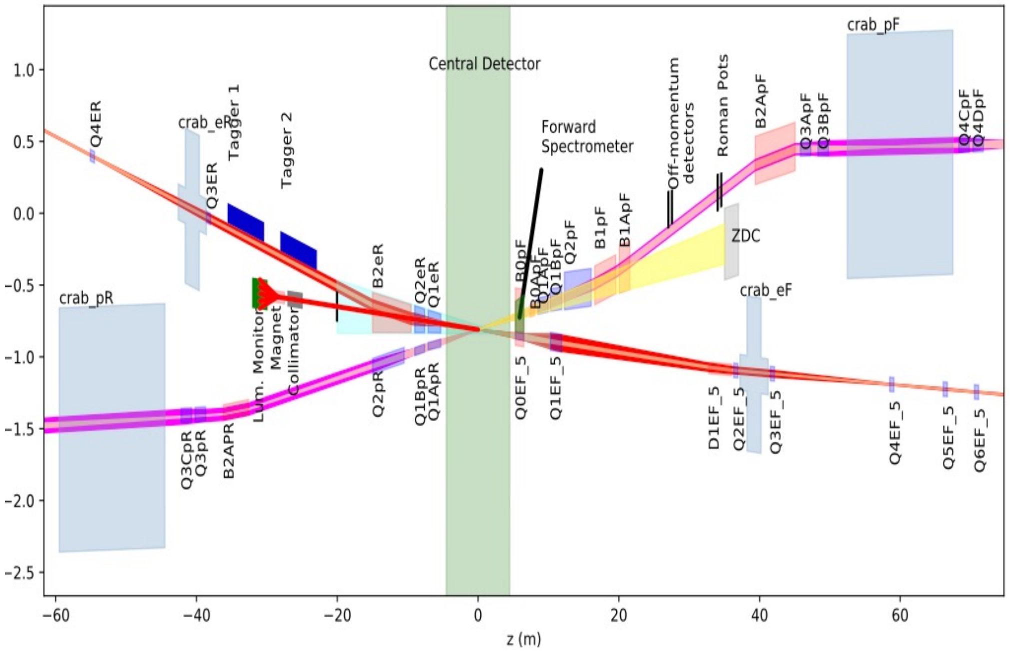




C. Montag, SPIN2023

# General concept of an EIC detector



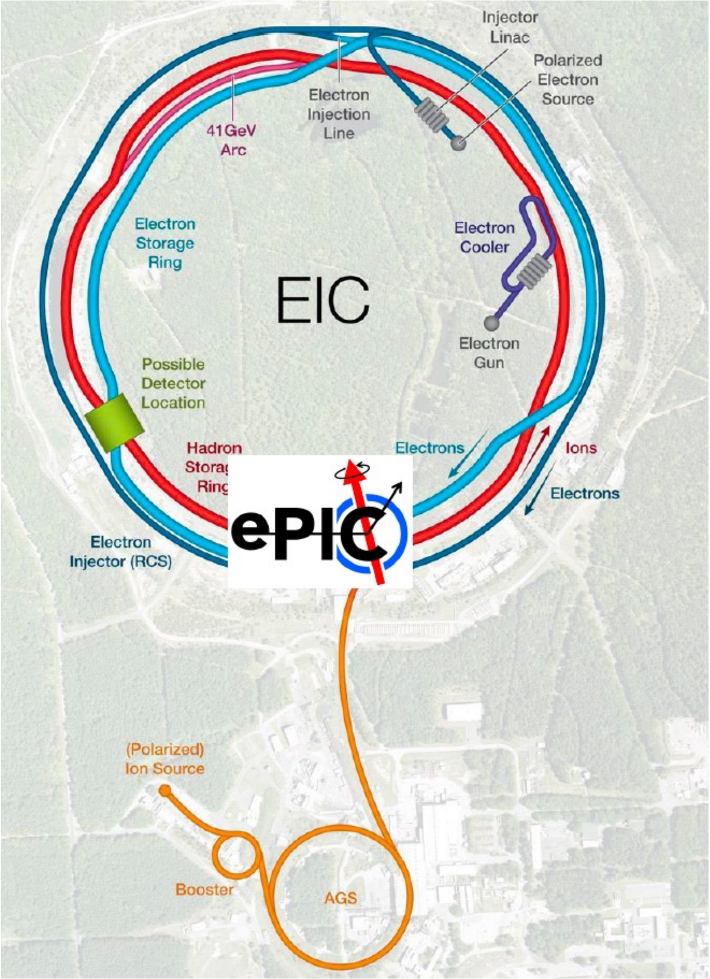

Central detector

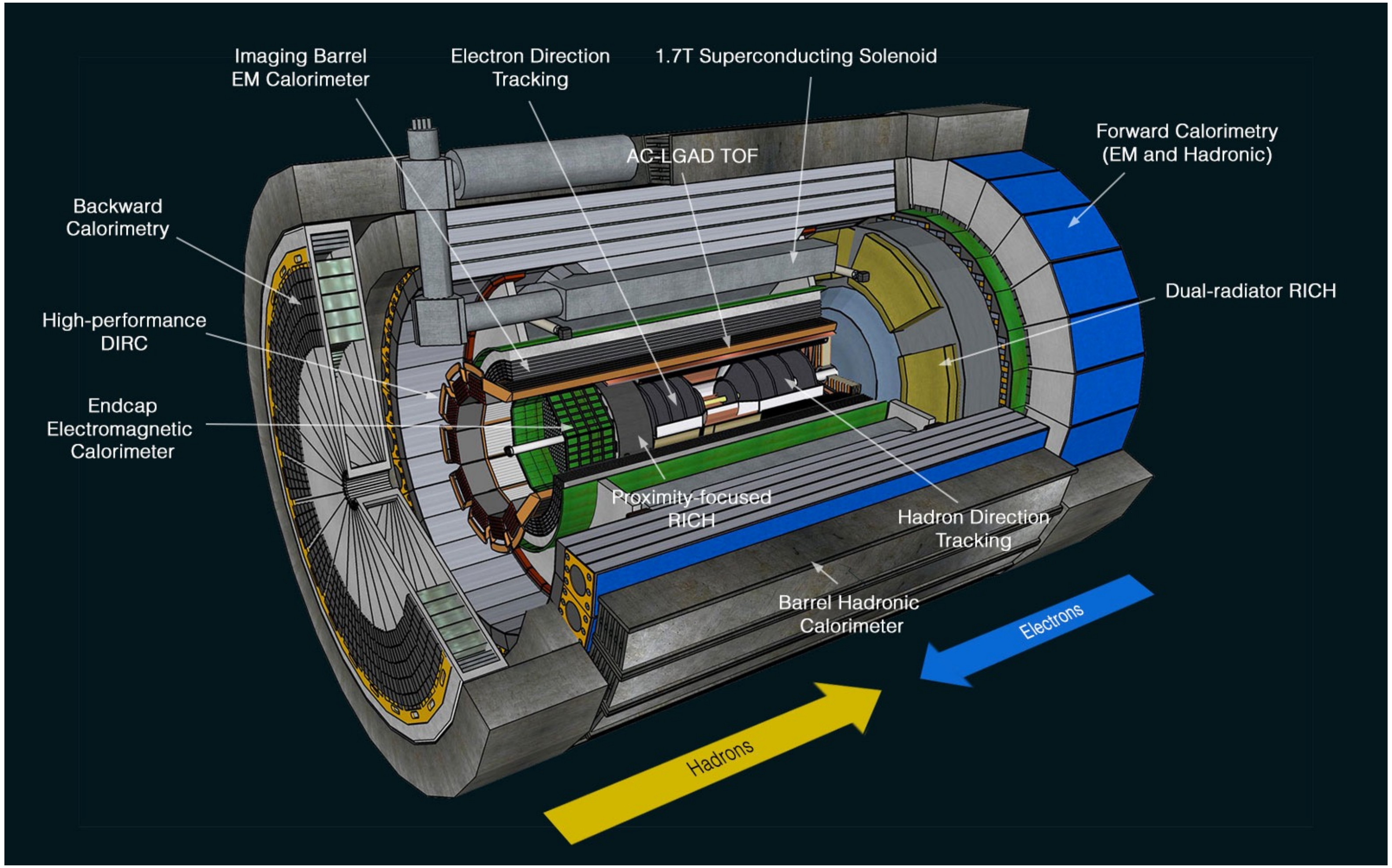



Forward and backward detector

- Hermetic detector, low mass inner tracking, good PID (e and π/K/p) in wide range, calorimetry
- Moderate radiation hardness requirements, low pile-up, low multiplicity.

# US-EIC first detector: ePIC




ePIC: mature design and innovative technologies; Technical Design Report (TDR) is coming.

The 2nd detector at IP8 is also being discussed and pushed forward.

# EIC participation status from China-mainland

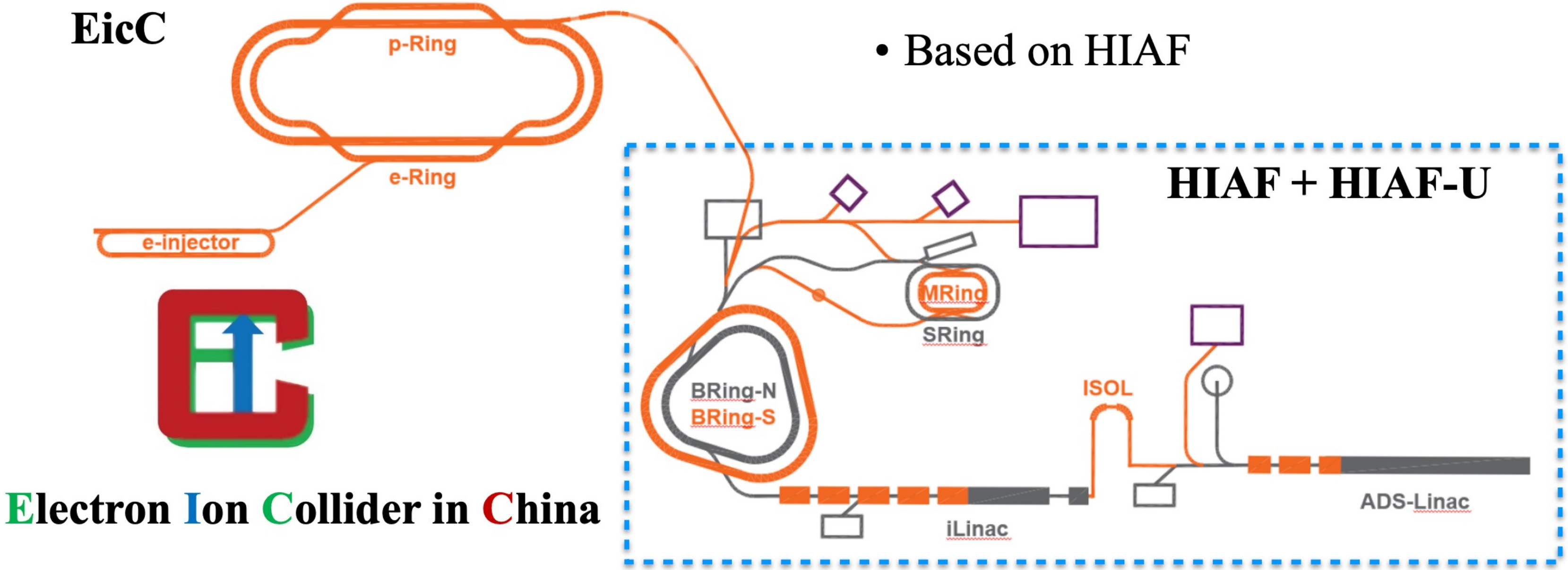
*Materials from Q. H. Xu*

- **Express of Interest (Oct 2020)**
  - ✓ 8 institutions submitted EOI to EIC, with main detector interests on calorimetry and tracking
- **Yellow Report (2020~2021)**
  - ✓ Authors from 14 Chinese institutions involved in YR writing including both theorists and experimentalist, Bowen Xiao served as co-convener of semi-inclusive WG
- **EIC detector proposals (2021)**
  - ✓ 8 institutions joined ATHENA proposal, Qinghua Xu served as co-convener of inclusive WG, with detector interest on EMCal etc.
  - ✓ 6 institutions joined ECCE proposal, Wangmei Zha served as co-convener of jets and heavy flavor WG, with detector interest on silicon tracker, MPGD etc.
- **ePIC collaboration (March 2022)** (24 countries, 171 institutions)
  - ✓ 6 universities from China-mainland are members of ePIC
  - ✓ Subsystems of interest: Forward Emcal (fECal) : W powder/ScFi

# EicC Status

中国极化电子-离子对撞机
Polarized electron ion collider in China

- Based on HIAF




[Figure by EicC Accelerator WG]

High Intensity heavy-ion Accelerator Facility in Huizhou, Guangdong province

- a national facility on nuclear physics, atomic physics, heavy-ion applications …
- beam commissioning is planned in 2025

EicC is based on HIAF

- electron: 3.5 GeV, polarization ~ 80%
- ion: $p$, $d$, $^{3}He^{++}$, $^{7}\mathrm{Li}^{3+}$, $^{12}\mathrm{C}^{6+}$, $^{40}\mathrm{Ca}^{20+}$, $^{197}\mathrm{Au}^{79+}$, $^{208}\mathrm{Pb}^{82+}$, $^{238}\mathrm{U}^{92+}$

# EicC Status

中国极化电子-离子对撞机
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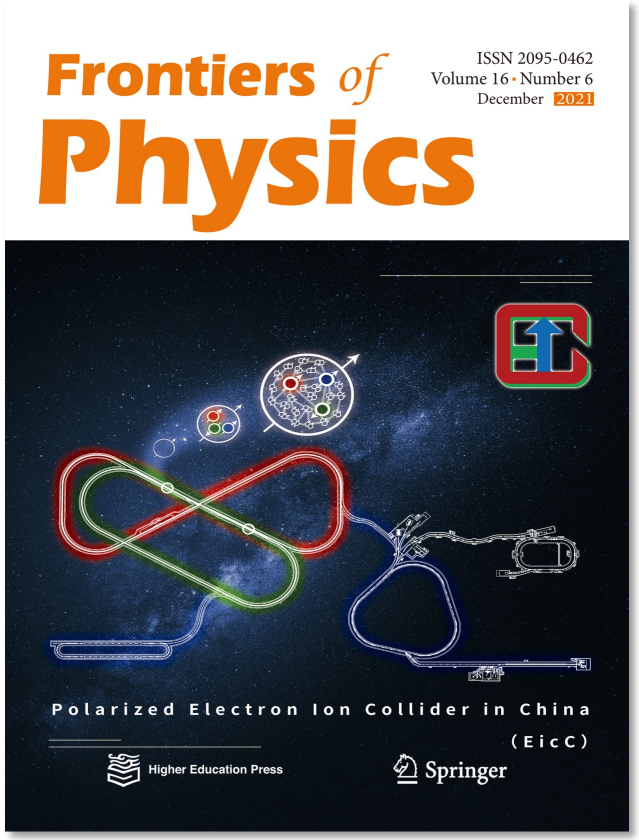
## EicC white paper




Published in 2021
(Chinese version in 2020)

## EicC Conceptual Design Report (CDR)

Volume I: Accelerator

Contents



Volume II: Physics and Detectors

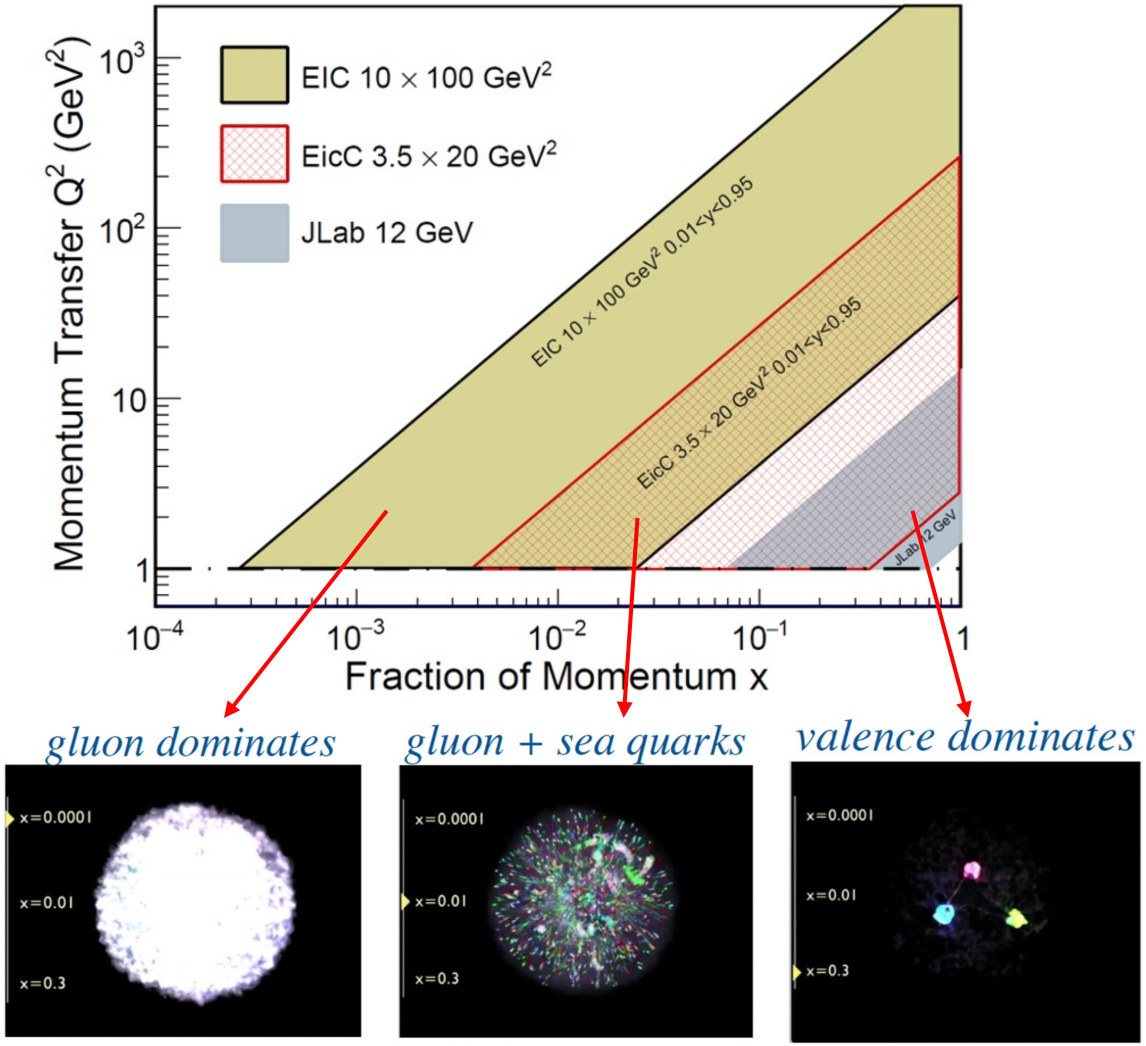
Contents



First draft by the end of 2023
Final version expected by the end of 2024

The 6th CDR workshop in Huizhou after QPT

# Complementarity of US-EIC and EicC




R.G. Milner and R. Ent, *Visualizing the proton* 2022

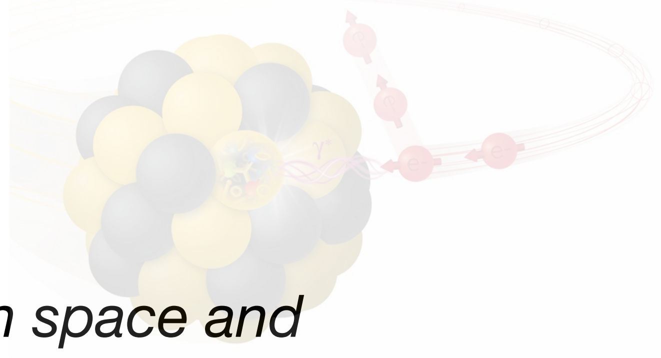
## Common physics goal:

- nucleon 1D, 3D spin structure
- Nucleon mass origin
- Nuclear environment effect

## Complementary QCD phase space:

- US-EIC: small-x gluon dominated region; saturation behavior; etc.
- EicC: moderate x sea quark region; exotic hadron states, especially those with heavy flavor quark contents; etc

# Summary



Electron-ion colliders will address fundamental questions:

*How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleus and nucleons?*

*How does the nuclear environment affect the distribution of quarks and gluons and their interactions in nuclei?*

*Where does the saturation of gluon densities set in?*

. . .

US-EIC (approved) and EicC (proposed) will complement to each other in yet unexplored regions of phase spaces in QCD with their high luminosity/energy, nuclei & beam polarization

The success of Electron-ion colliders will significantly advance our understanding of the many body and multi-dimension structure of nucleons and nucleus in terms of sea quarks & gluons.

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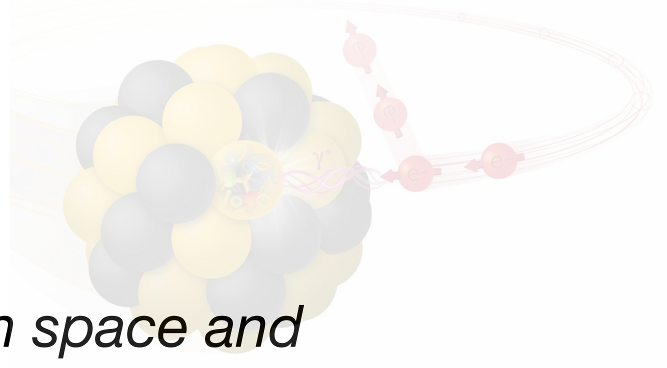

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*Thank you for your attention.*