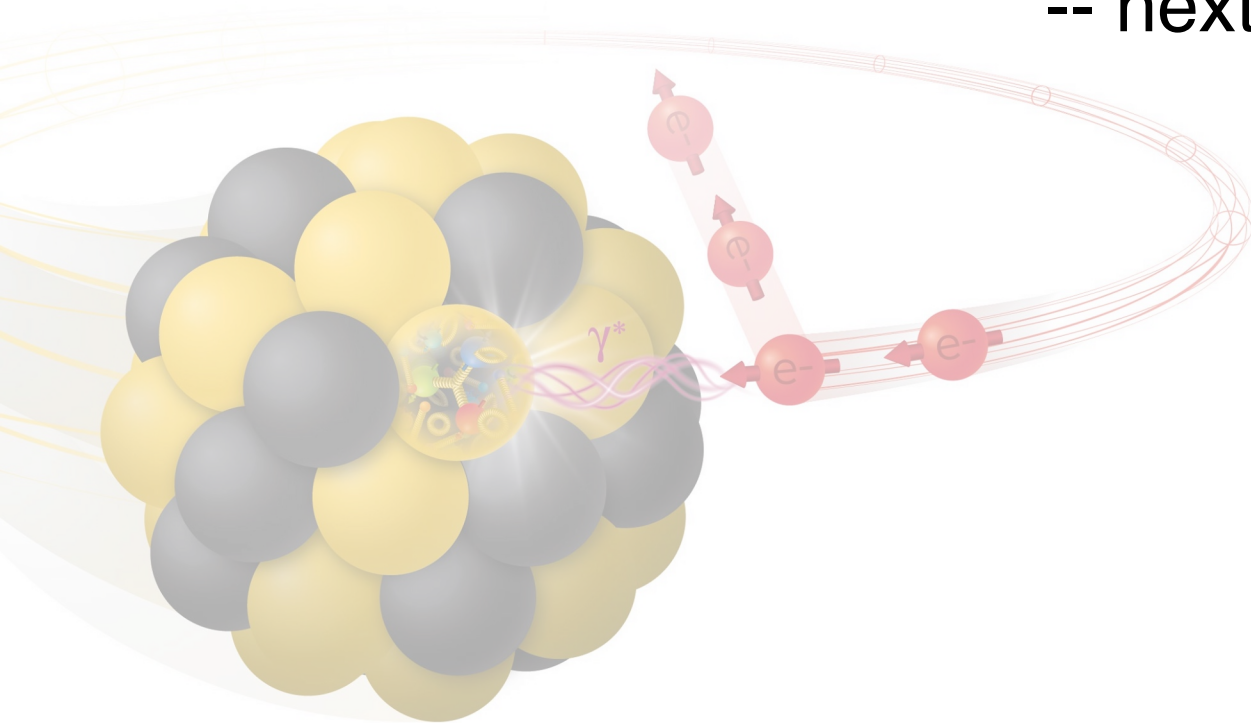


From HIC to

Electron-Ion Collider

-- next generation nuclear physics facility



Jinlong Zhang (张金龙)



山东大学
SHANDONG UNIVERSITY

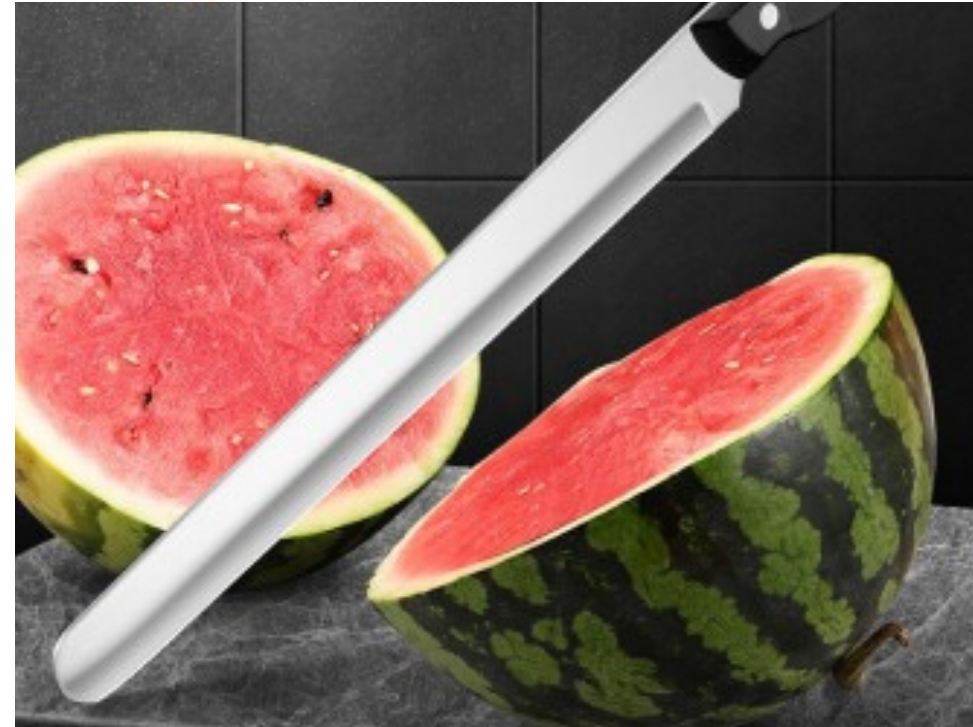
Study of internal structure of watermelon

-- analogy from A. Deshpande



Violent collision of melons

Heavy-ion Collision (RHIC/LHC)

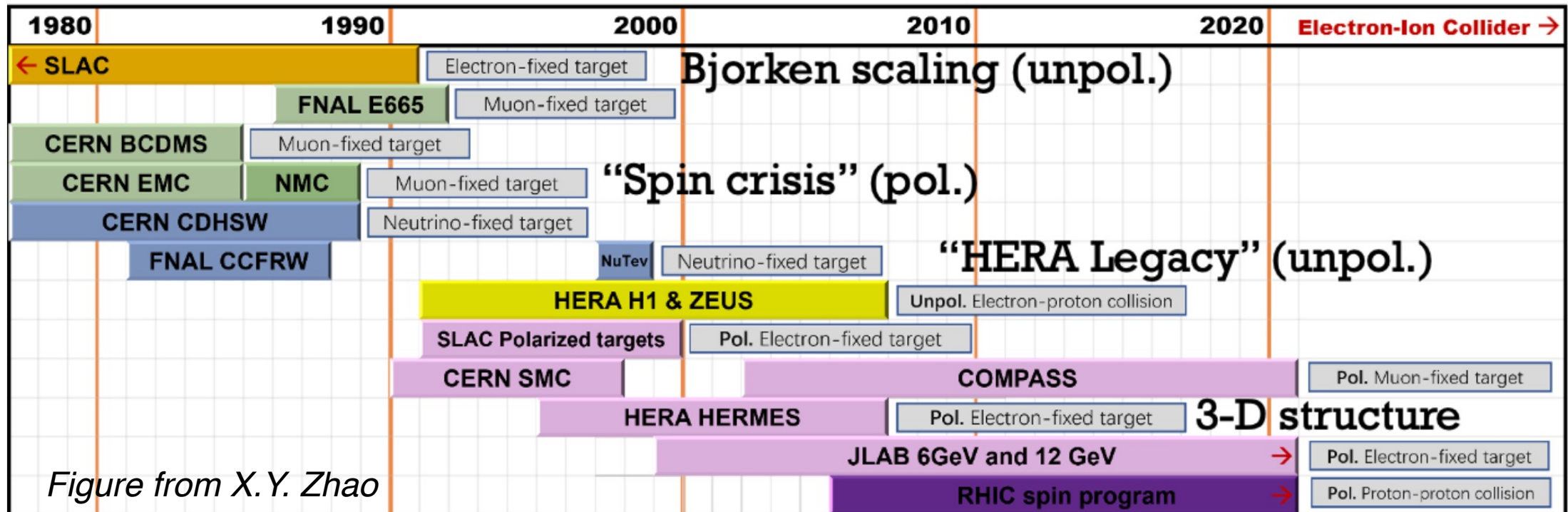


Cutting the watermelon with a knife

Violent DIS e-A (EIC)

Lepton scattering: an ideal tool

T. B. Liu, SPIN2023



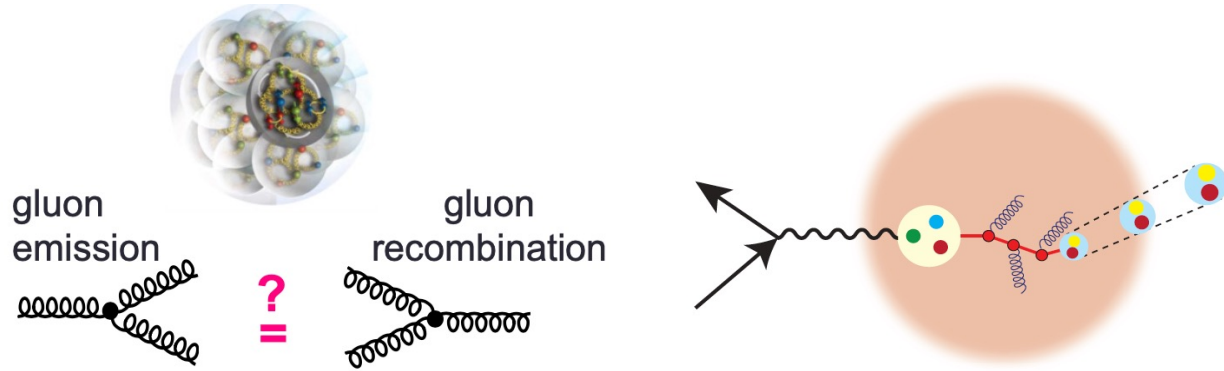
Modern "Rutherford Scattering" Experiment

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

Need polarized electron-ion collider

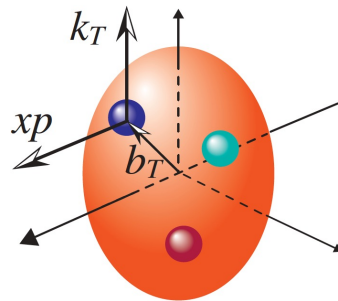
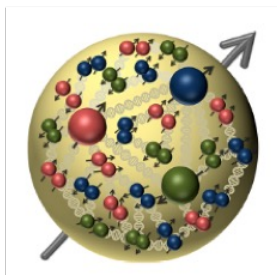
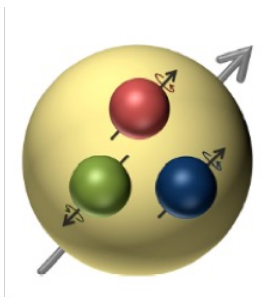
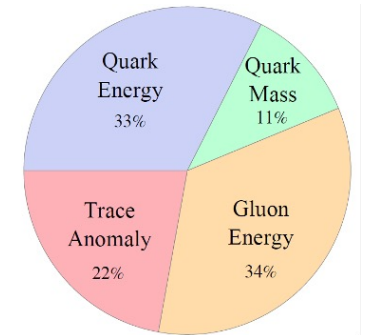
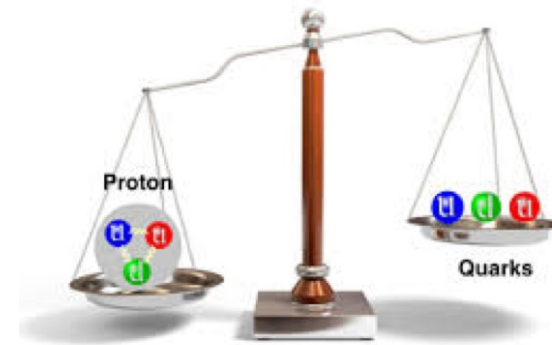
- High luminosity: $100 \sim 1000 \times$ HERA lumi.
- High polarization: both electron and ion beams
- Large acceptance: nearly full detector coverage

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?



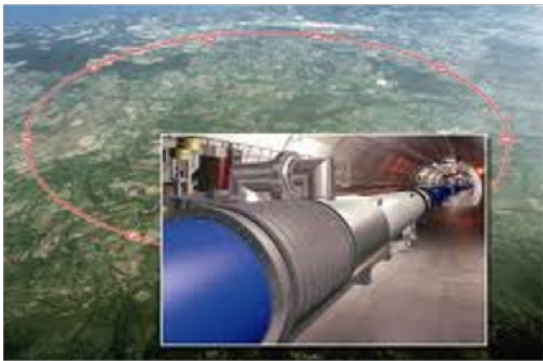
How are the sea quarks and gluons, and their spins, **distributed in space and momentum** inside the nucleon?

Proposed Electron-ion colliders (incomplete list)



FAIR → ENC

LHC → LHeC



RHIC → eRHIC/EIC



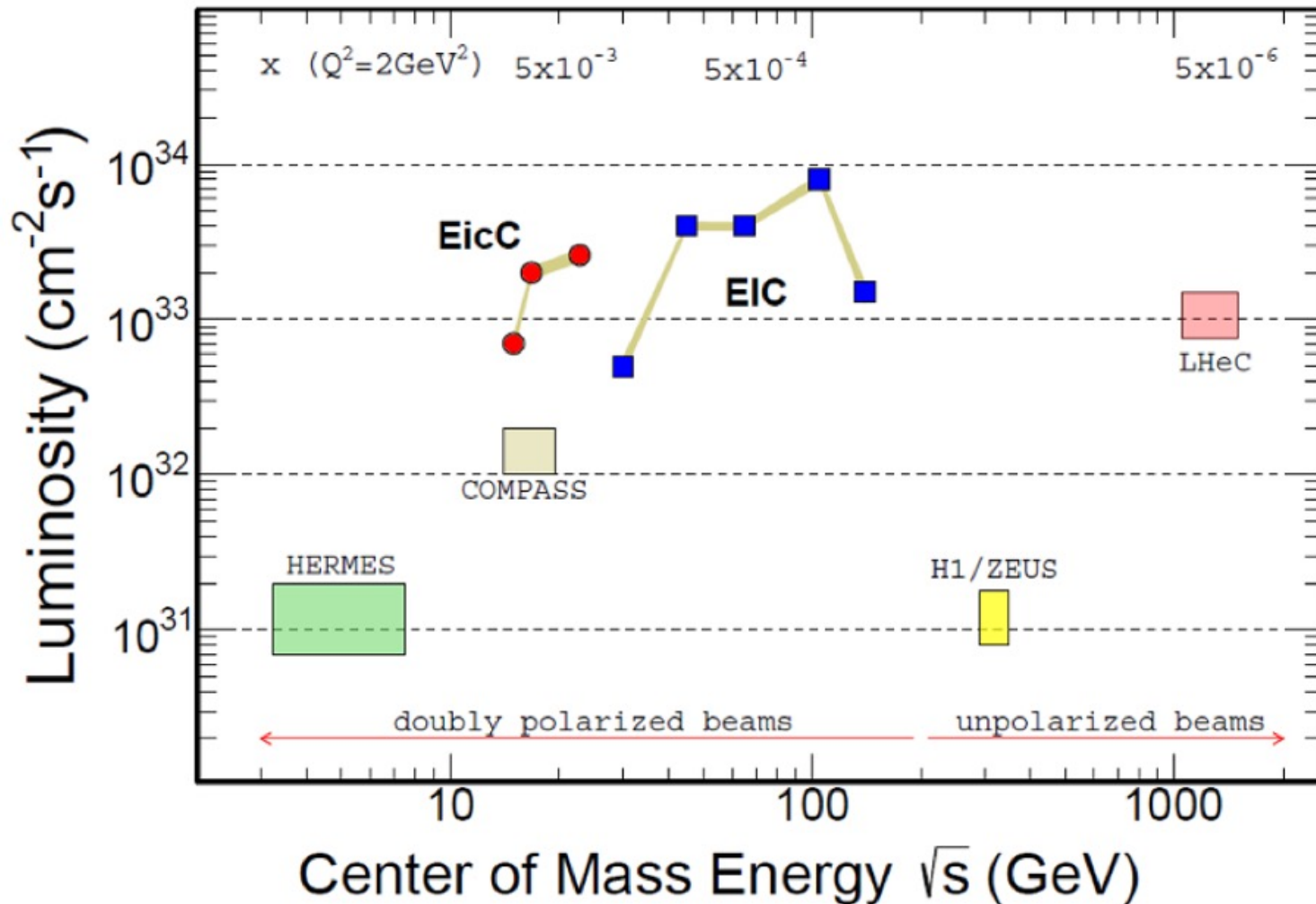
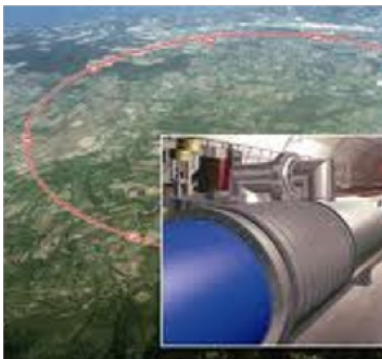
HIAF → EicC

Proposed Electron-ion colliders (incomplete list)



FAIR → EN

LHC → LHeC



IC → eRHIC/EIC

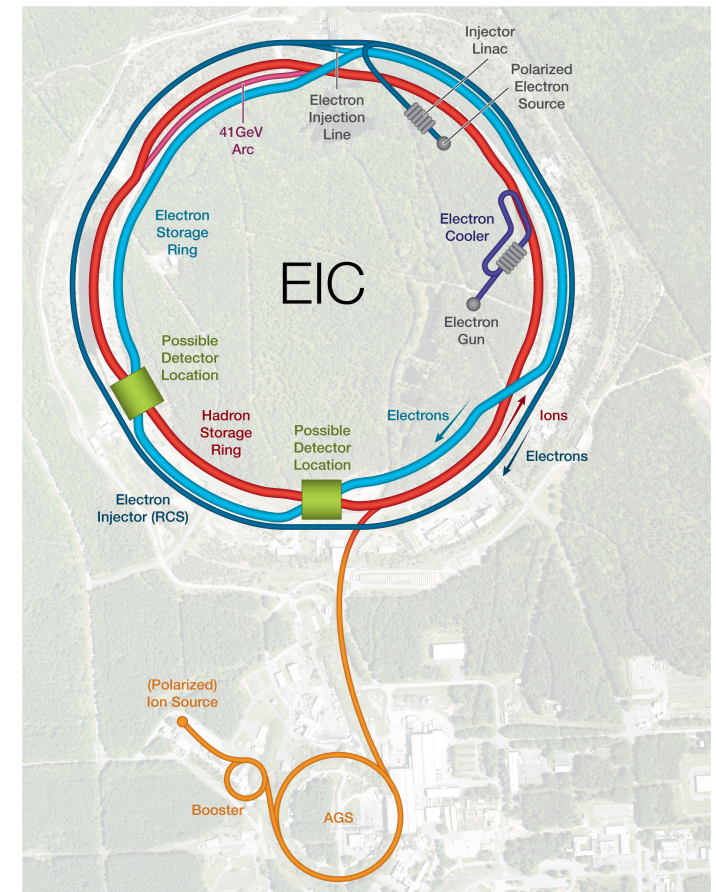
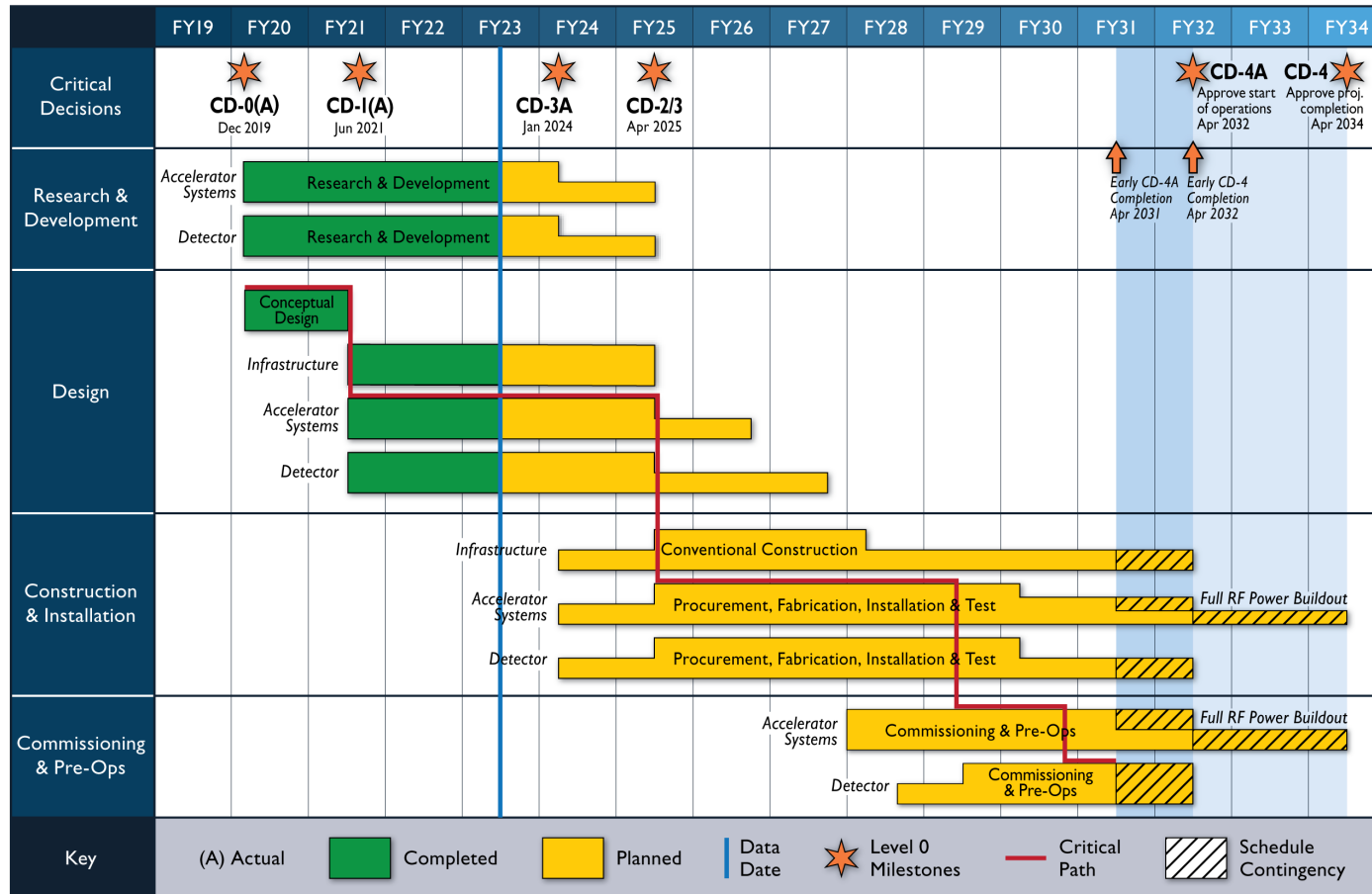
HIAF → EicC



US-EIC Status

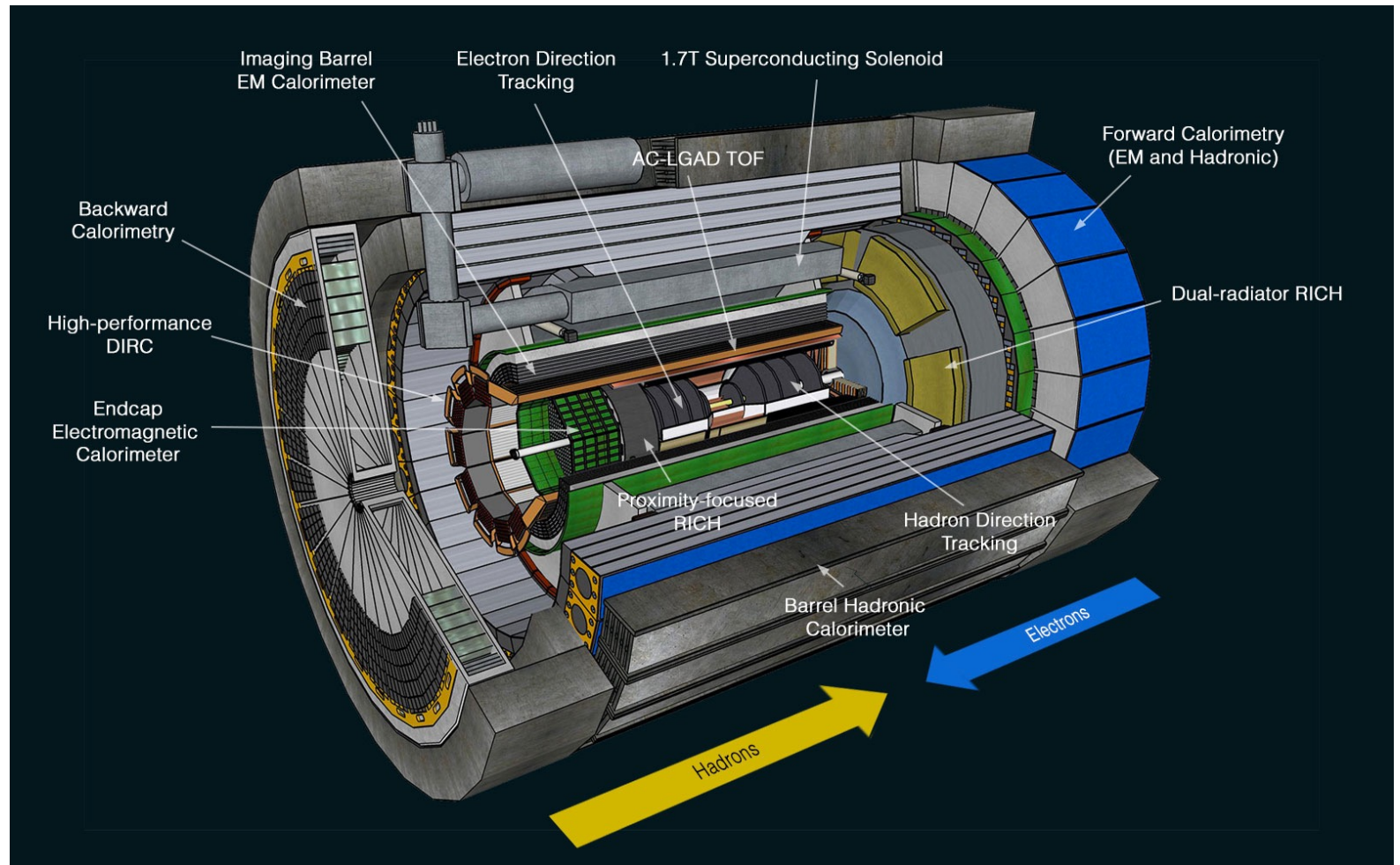
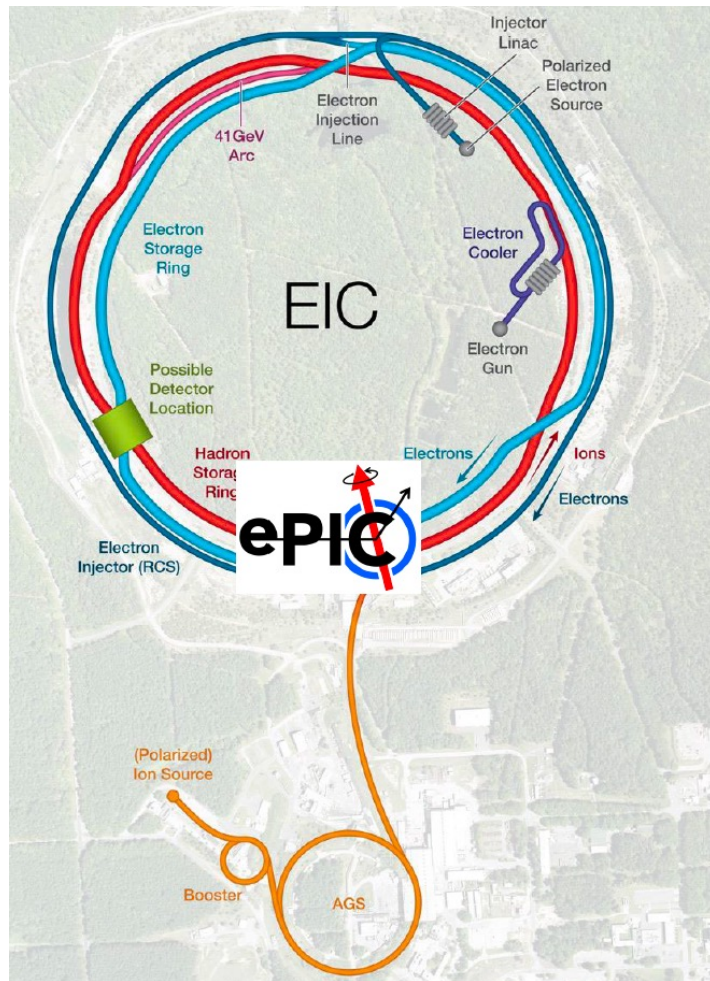
Approved in Dec 2019 (CD0)

- US EIC is based on the RHIC complex: proton/ion ring, injectors, ion sources, infrastructure
- Add a 5 to 18 GeV electron storage ring and its injector complex to the RHIC facility



C. Montag, SPIN2023

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.

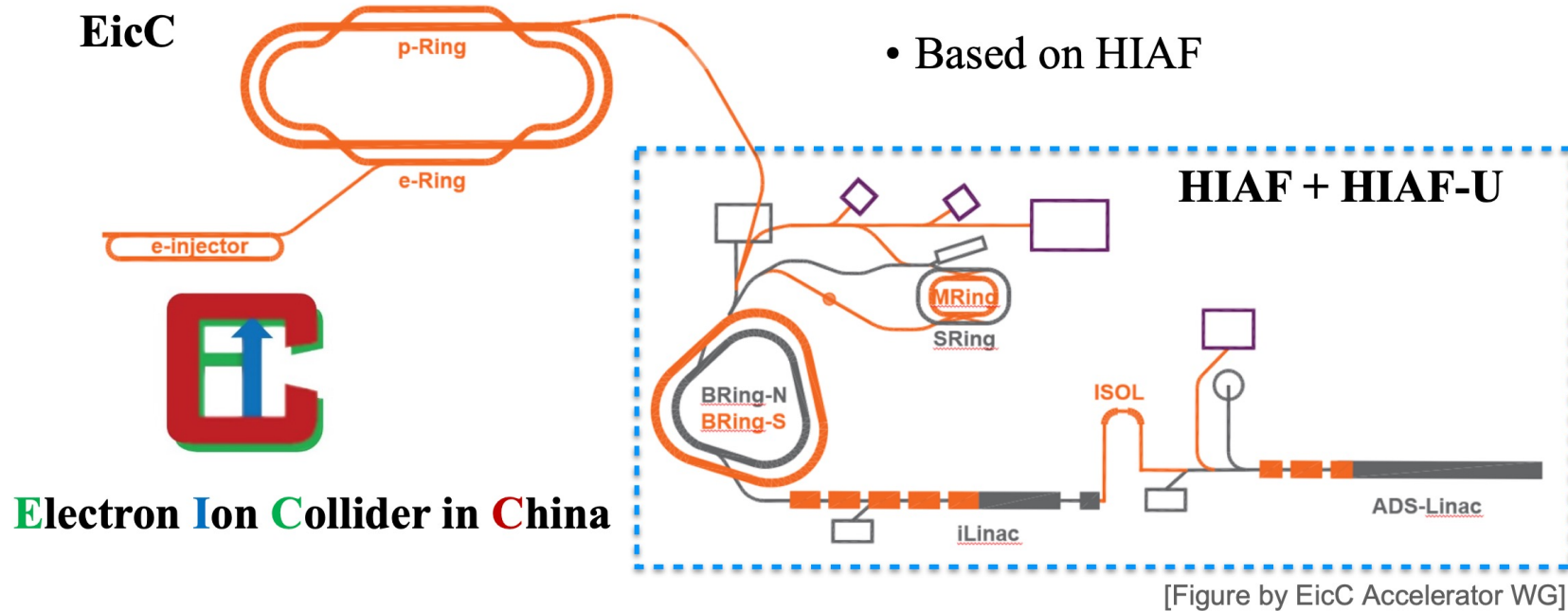
EIC participation status from China-mainland

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



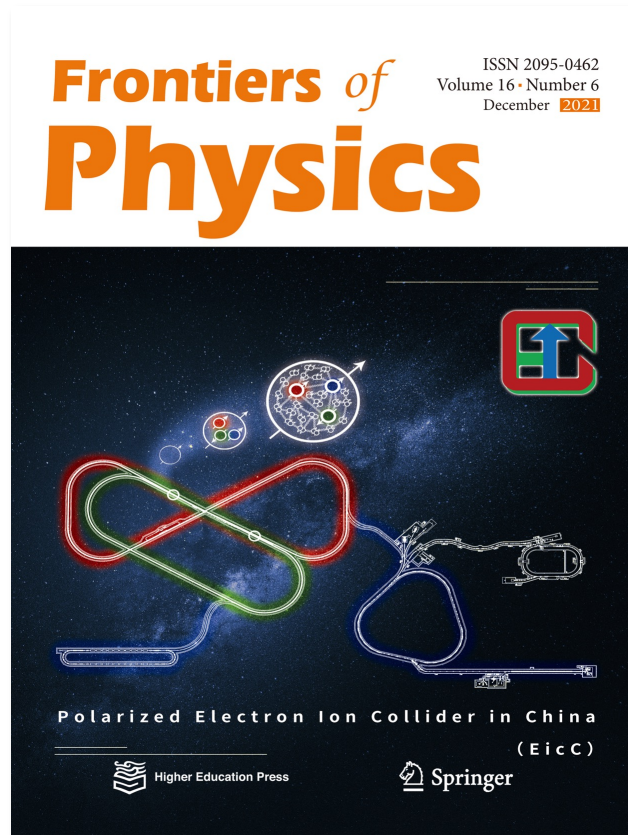
- High Intensity heavy-ion Accelerator Facility in Huizhou, Guangdong province
- a national facility on nuclear physics, atomic physics, heavy-ion applications ...
 - beam commissioning is planned in 2025

EicC is based on HIAF

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

EicC Status

EicC white paper



Published in 2021
(Chinese version in 2020)

EicC Conceptual Design Report (CDR)

Volume I: Accelerator

Volume II: Physics and Detectors

Contents

1 Overview of EicC	
1.1 The Science Goals and the Requirements for EicC	
1.2 EicC Design Concept	
1.3 Beam Parameters and Luminosity	
1.4 Ion Accelerator Complex Design	
1.5 Electron Accelerator Complex Design	
1.6 Staged Electron Cooling for Ions	
1.7 The Interaction Region Design	
1.8 Overview Summary	
2 Beam Dynamics Design	
2.1 EicC Collision Scheme	
2.2 Luminosity Lifetime	
2.3 Collective Effects and Beam Stabilities	
2.4 Space Charge Effects	
2.5 Beam-Beam Effects	
2.6 Intra-beam Scattering	
3 Ion Accelerator Complex	
3.1 Introduction	
3.2 Formation of EicC Ion Beams	
3.3 Polarized Ion Source	
3.4 iLinac	
3.5 Booster Ring	
3.6 pRing	
3.7 Beam Synchronization	
3.8 Polarization and Polarimetry	
4 Electron Accelerator Complex	
4.1 Introduction	
4.2 Polarized Electron Source	
4.3 Electron Injector	
4.4 eRing	
4.5 Synchrotron Radiation and Beam Parameters	
4.6 Polarization and Polarimetry	
5 Electron Cooling	
5.1 Introduction	
5.2 Medium Energy Electron Cooler	
5.3 ERL Based High Energy Electron Cooler	
5.4 Novel cooling scheme development	

Contents

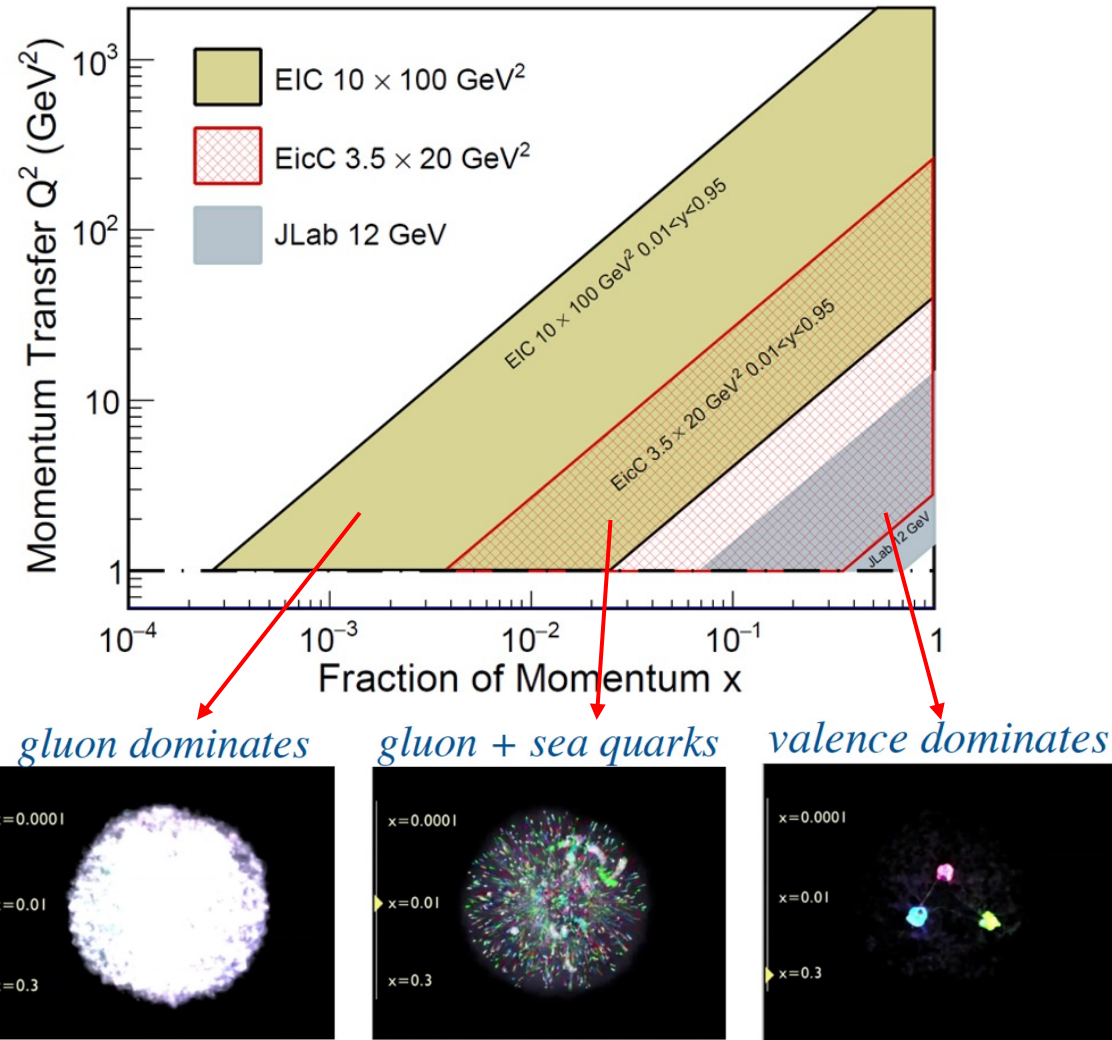
1 EicC Physics	
1.1 One-dimensional spin structure of nucleons	
1.2 Three-dimensional tomography of nucleons	
1.2.1 TMDs	
1.2.2 GPDs	
1.3 Nucleon mass	
1.4 Partonic structure of nucleus	
1.5 Exotic hadronic states	
1.6 Structure of light pseudoscalar mesons	
2 Physics requirements and detector concept	
2.1 Physics requirements	
2.1.1 Particle multiplicity and event rate	
2.1.2 Scattered electron	
2.1.3 Charged hadron identification	
2.1.4 Small angle detection	
2.2 Detector concept	
3 Tracking system	
3.1 Vertex detector	
3.2 Time projection chamber	
3.3 All silicon tracker	
3.3.1 All silicon tracker layout	
3.3.2 Detector simulation and reconstruction	
3.3.3 Tracking and vertexing performance	
3.4 Endcap disk	
4 PID system	
4.1 Detector consideration	
4.2 Time of flight detector	
4.2.1 MRPC	
4.2.2 DIRC-based TOP	
4.3 Cherenkov detector	
4.3.1 DIRC	
4.3.2 Module RICH	
5 Calorimetry	
5.1 Design consideration	
5.2 Shashlik-type EMCal	
5.2.1 Module design and simulation	
5.2.2 Energy and spatial resolution	
5.2.3 Detector layout	
5.3 Crystall EMCal	
5.4 HCal	

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



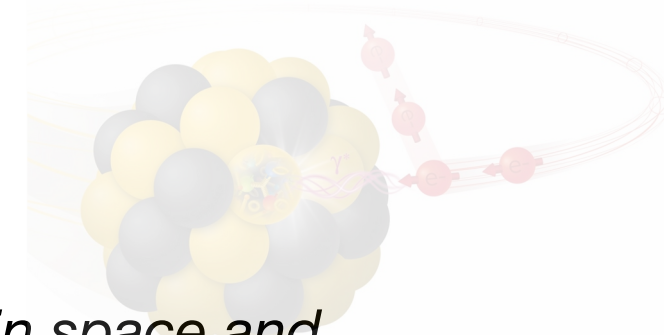
Common physics goal:

- 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?

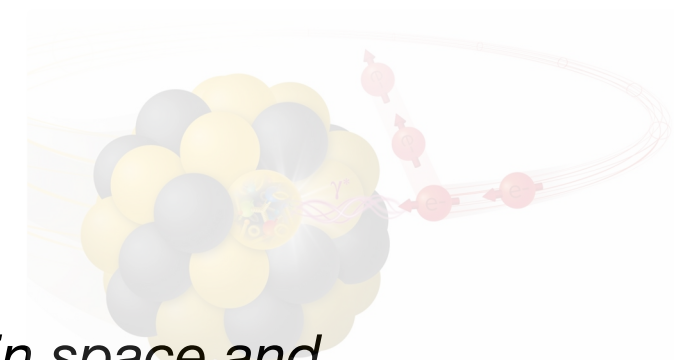
Where does the saturation of gluon densities set in?

...

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.

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.

Thank you for your attention.