Status and Prospects of Electron-ion collider in China (EicC)

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On behalf of the EicC working groups

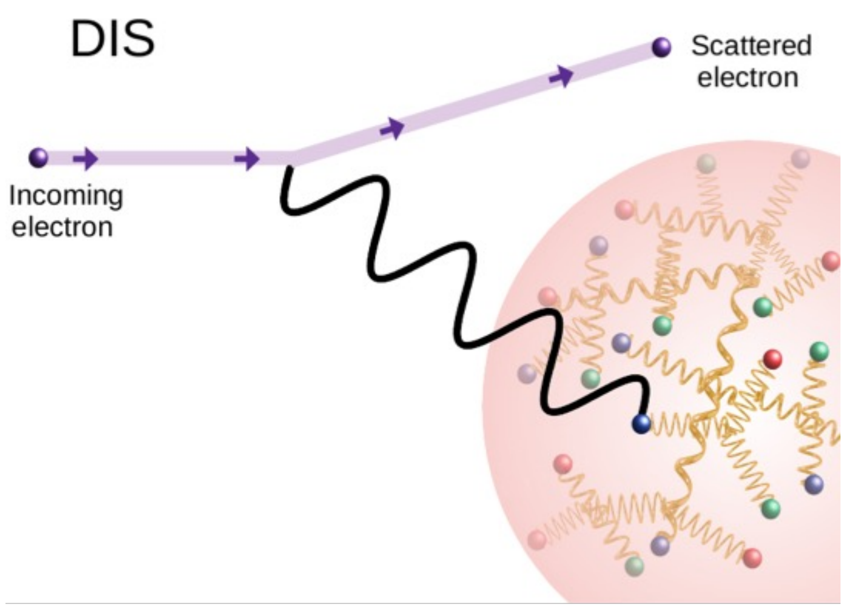
The XXXI International Workshop on Deep Inelastic Scattering and Related Subjects (DIS2024)

Grenoble, France, April 8-12, 2024

National Natural Science Foundation of China

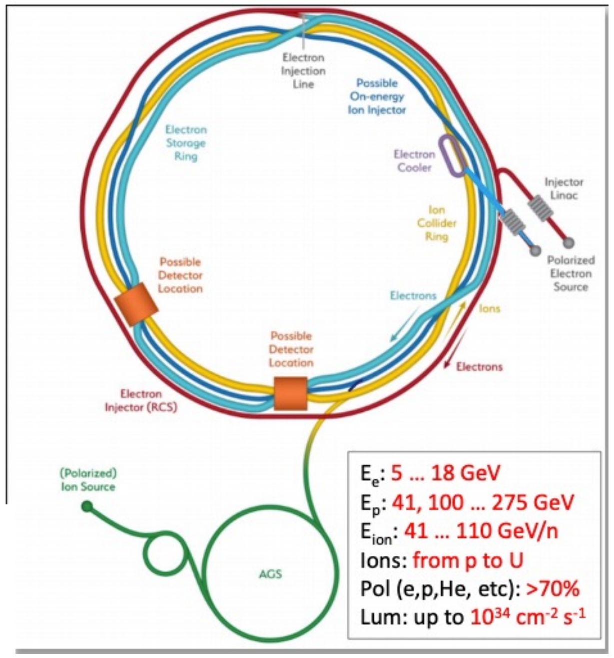
Lepton Scattering: An Ideal Tool

- Modern "Rutherford Scattering" experiment in understanding internal structure of nucleon
  - ➢ Start from unpolarized fixed targets
  - ➢ Extended unpolarized collider experiments
  - ➢ Polarized fixed-target experiments for spin structure of nucleon



[Figure from DESY-21-099]

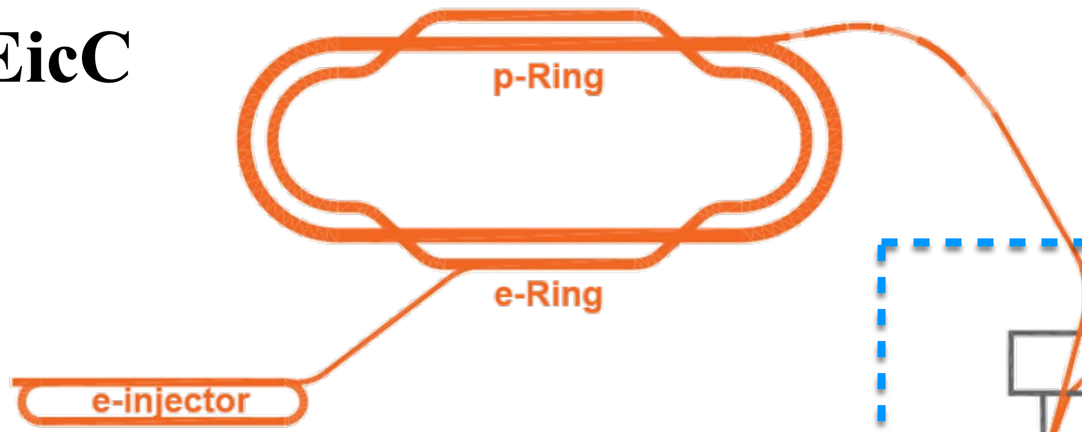
- Need polarized electron-ion collider for deeper understanding of nucleon spin structure & nuclear structure
  - ➢ High luminosity: $10^2 \sim 10^3 \times$ HERA lumi.
  - ➢ High polarization: both electron and ion beams
  - ➢ Large acceptance: nearly full detector coverage



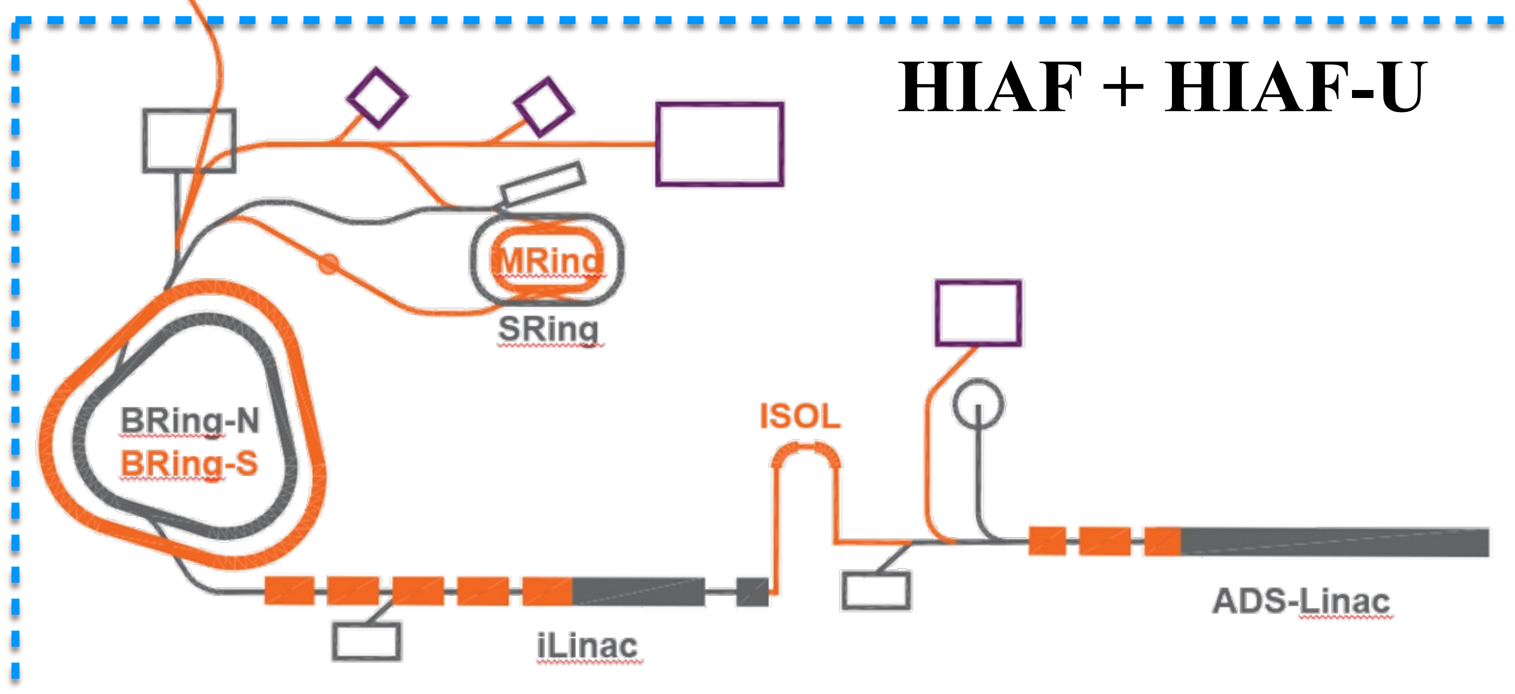
- EIC will be built at Brookhaven National Lab. in ~2032 at Ecm ~ 29 – 141 GeV

Electron-ion collider in China (EicC)

EicC



- Based on High Intensity heavy-ion Accelerator Facility (HIAF), at HuiZhou



Electron Ion Collider in China

[Figure by EicC Accelerator WG]

- Energy in c.m.: 15 ~ 20 GeV
- Electron beam: 3.5 GeV, polarization ~ 80%
- Proton beam: 20 GeV, polarization ~ 70%
- Luminosity: $\gtrsim 2 \times 10^{33}\ cm^{-2} \cdot s^{-1}$
- Other available polarized ion beams: d, $^{3}He^{++}$
- Available unpolarized ion beams: $^{7}Li^{3+}$, $^{12}C^{6+}$, $^{40}Ca^{20+}$, $^{197}Au^{79+}$, $^{208}Pb^{82+}$, $^{238}U^{92+}$

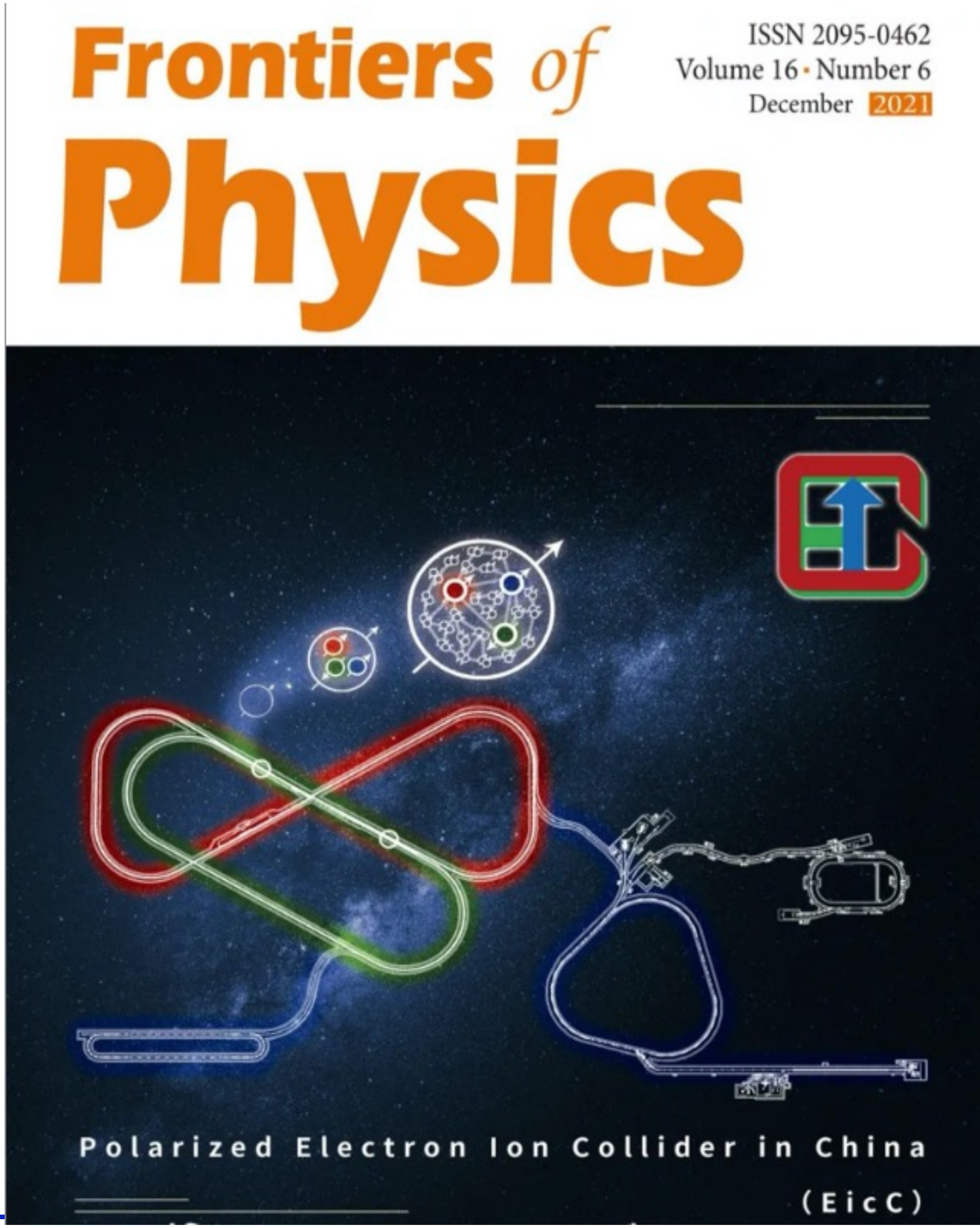
HIAF in Huizhou (惠州)

High Intensity heavy-ion Accelerator Facility

- A national facility on nuclear physics, atomic physics, heavy-ion applications …
- Open to scientists all over the world
- Provide intense beams of primary and radioactive ions
- Beam commissioning is planned in 2025

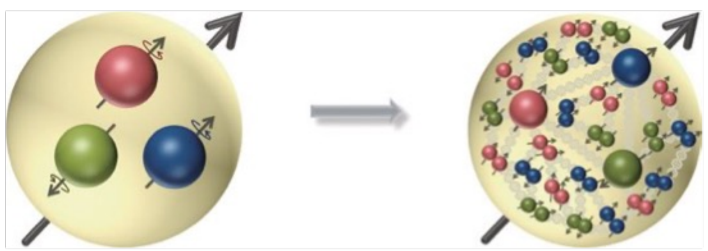
Electron-ion collider China(EicC)

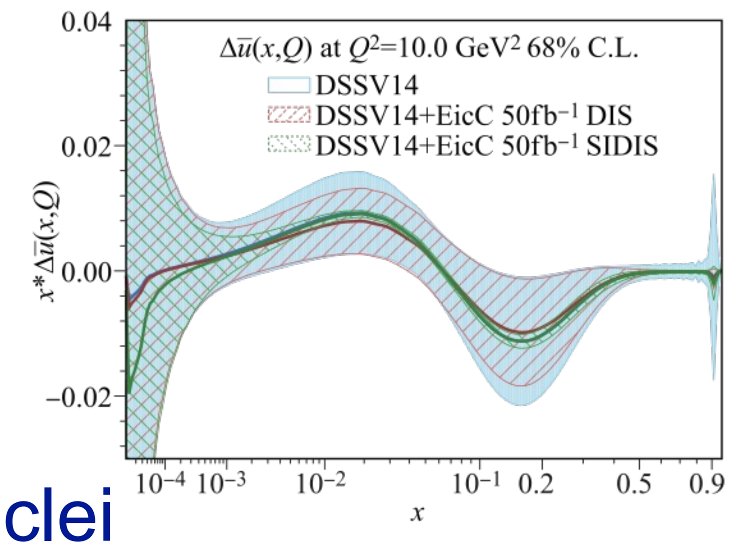
- EicC White paper: arXiv: 2102.09222, Front. Phys.16(6), 64701 (2021)

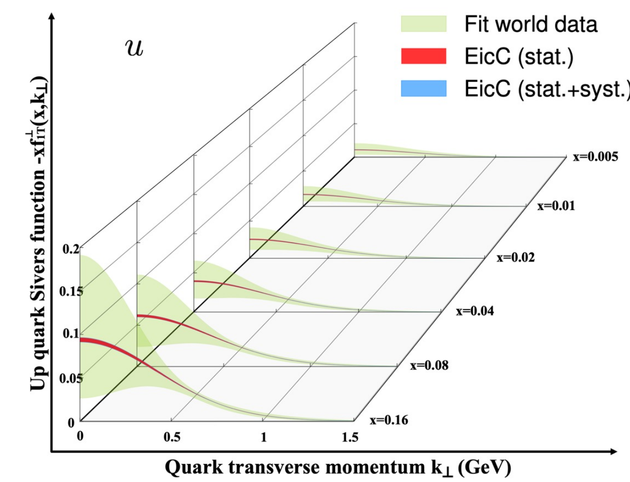


Physics Highlights

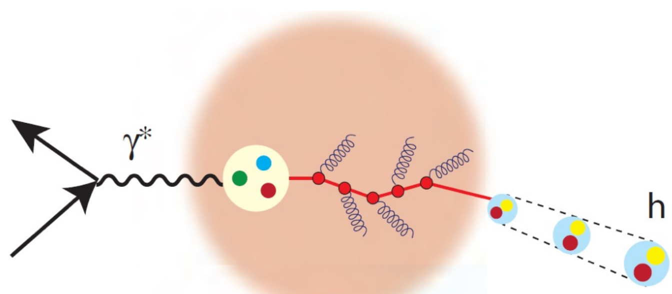
- Partonic structure and three-dimensional landscape of the nucleon

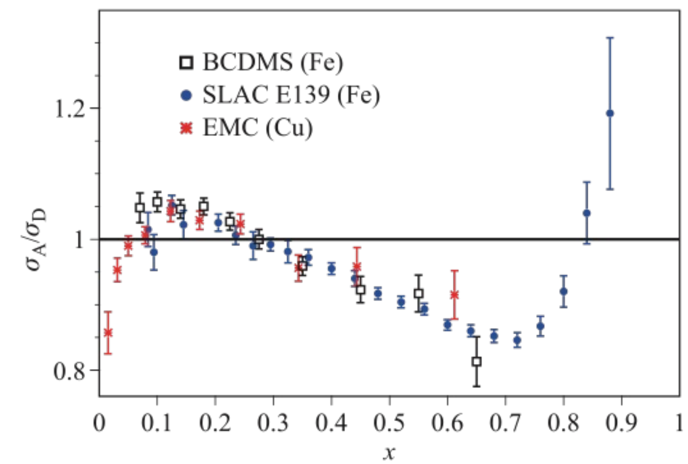


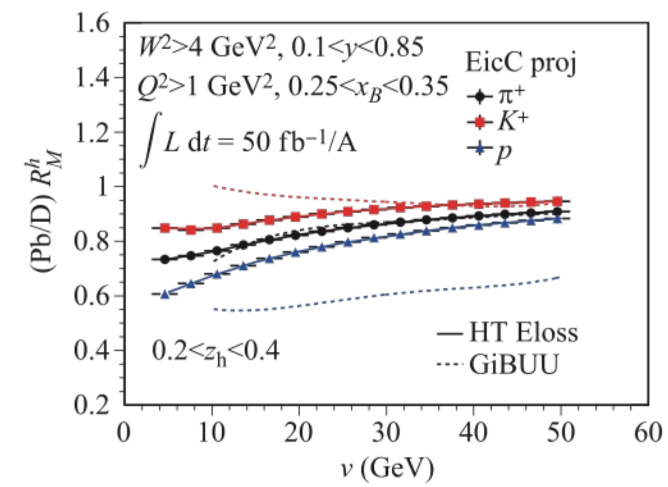




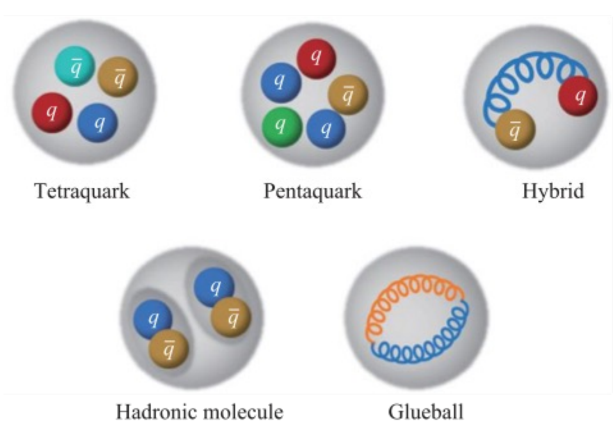
- Partonic structure of nuclei

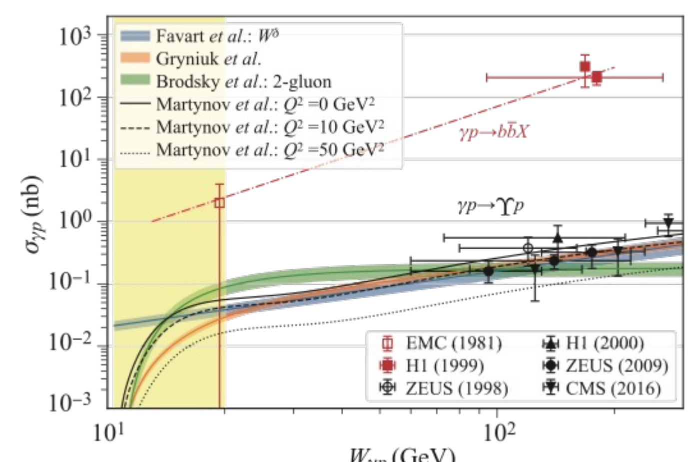


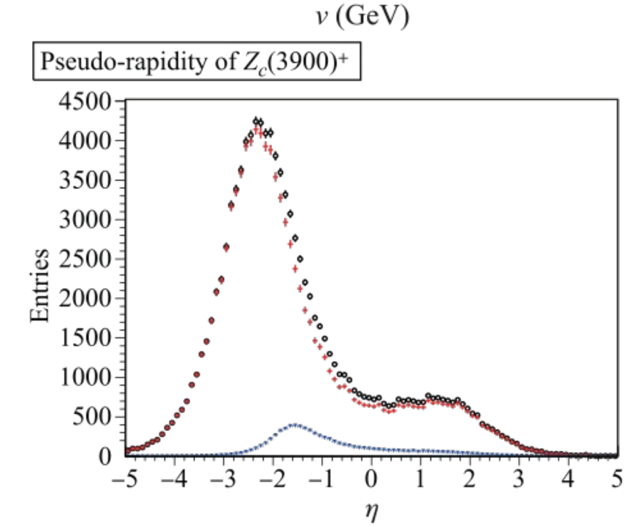




- Exotic hadronic states

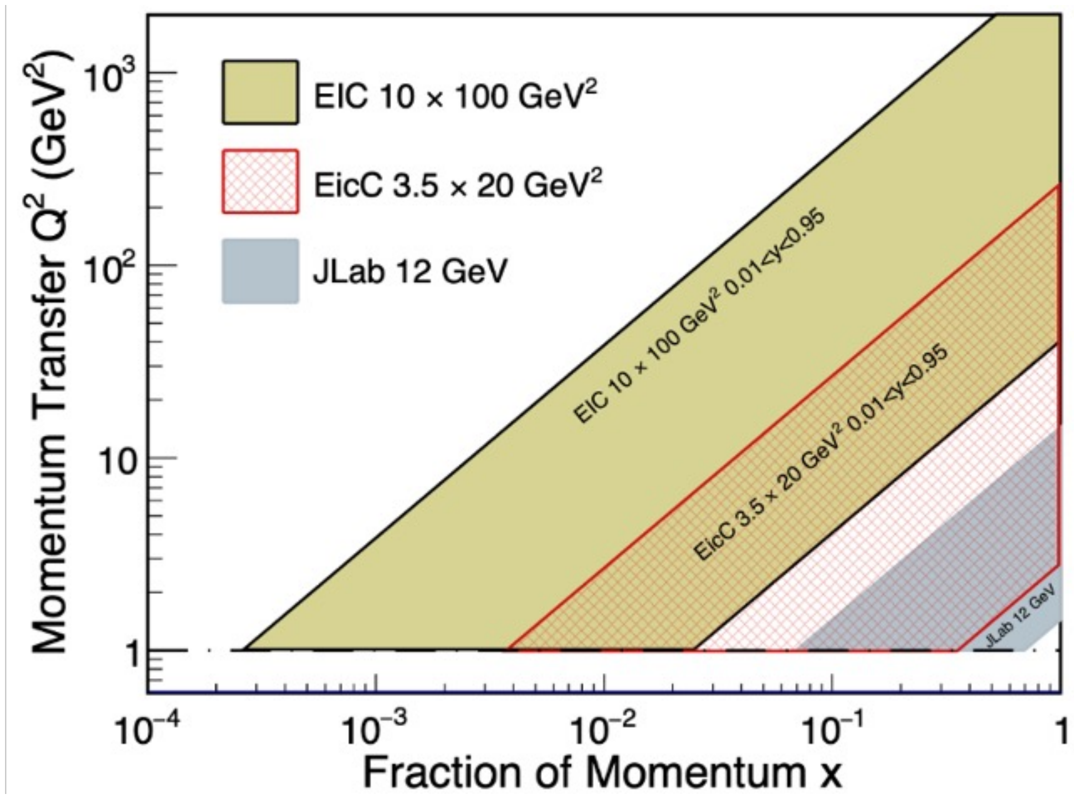


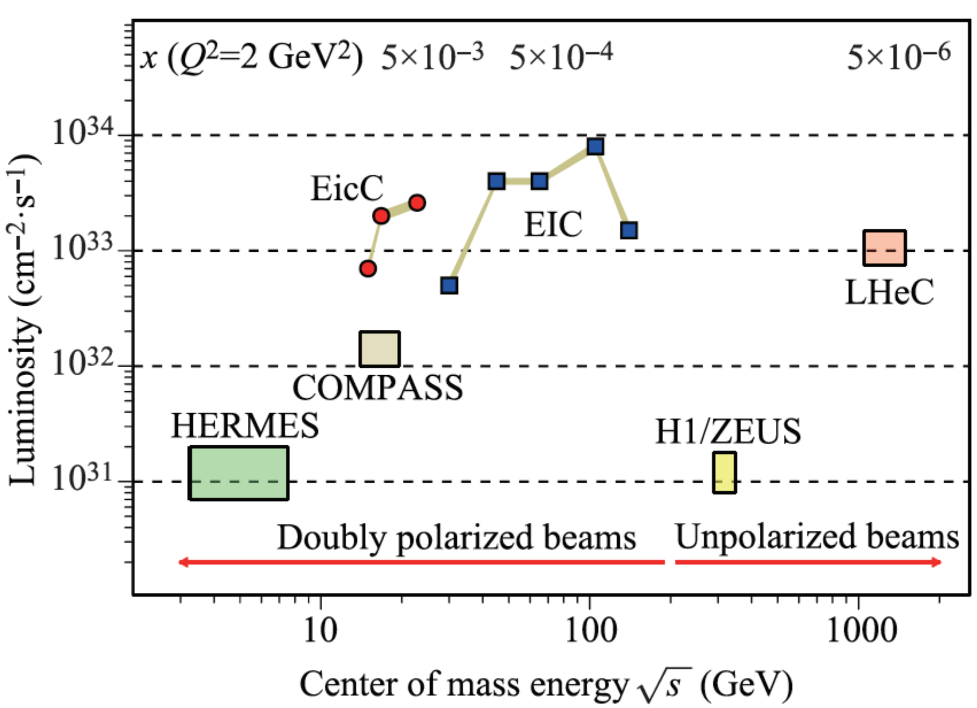




- Proton mass / quarkonium production

Complementarity of EicC and EIC-US





[Figures from EicC White paper]

Nucleon spin structure:

EicC is optimized to systematically explore the gluon and sea quarks in moderate *x* regime

At a crucial place between JLab and EIC-US

Partonic structure in nuclear environment:

Parton distribution in nuclei at moderate *x*

Fast parton/hadron interaction with cold nuclear matter

Exotic hadron states:

Independent confirmation of hidden-charm pentaquarks and search for hidden-bottom analogues

Exotic hadron production: final particles in mid-rapidity

Proton mass / quarkonium production:

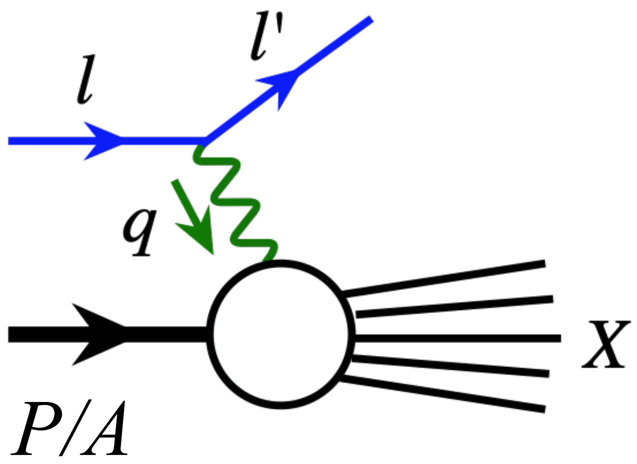
Systematic investigation of Υ near threshold production

Complementary kinematic coverage to EIC-US

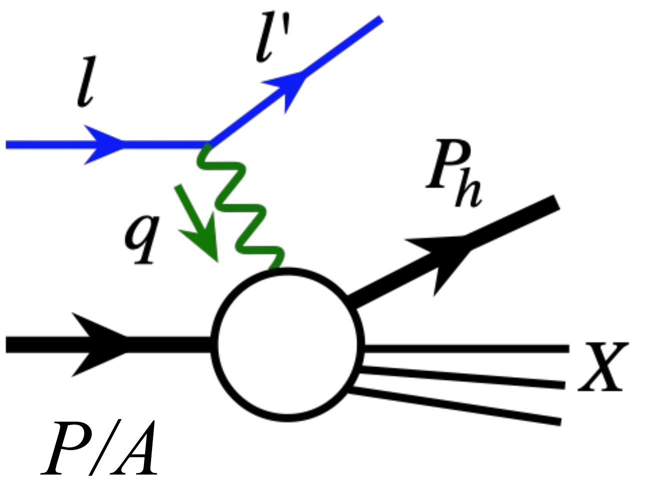
Combine with J/ψ production at JLab

Physics Processes

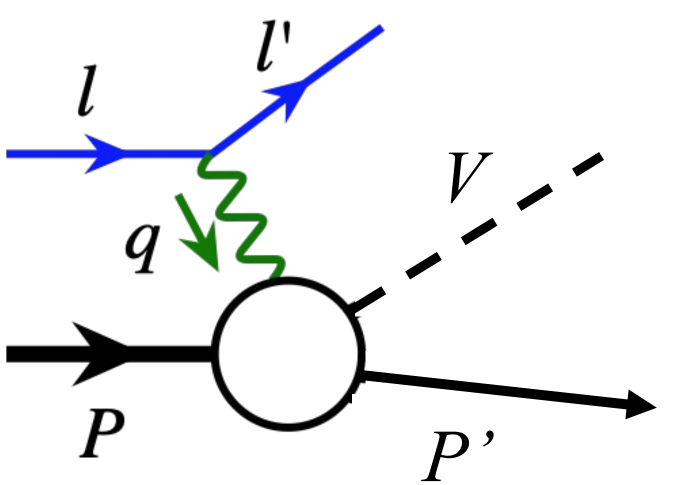
- Inclusive DIS at a large momentum transfer
  - dominated by the scattering of the lepton off an active quark/parton
  - collinear factorization
  - indirectly "see" quarks, gluons and their dynamics



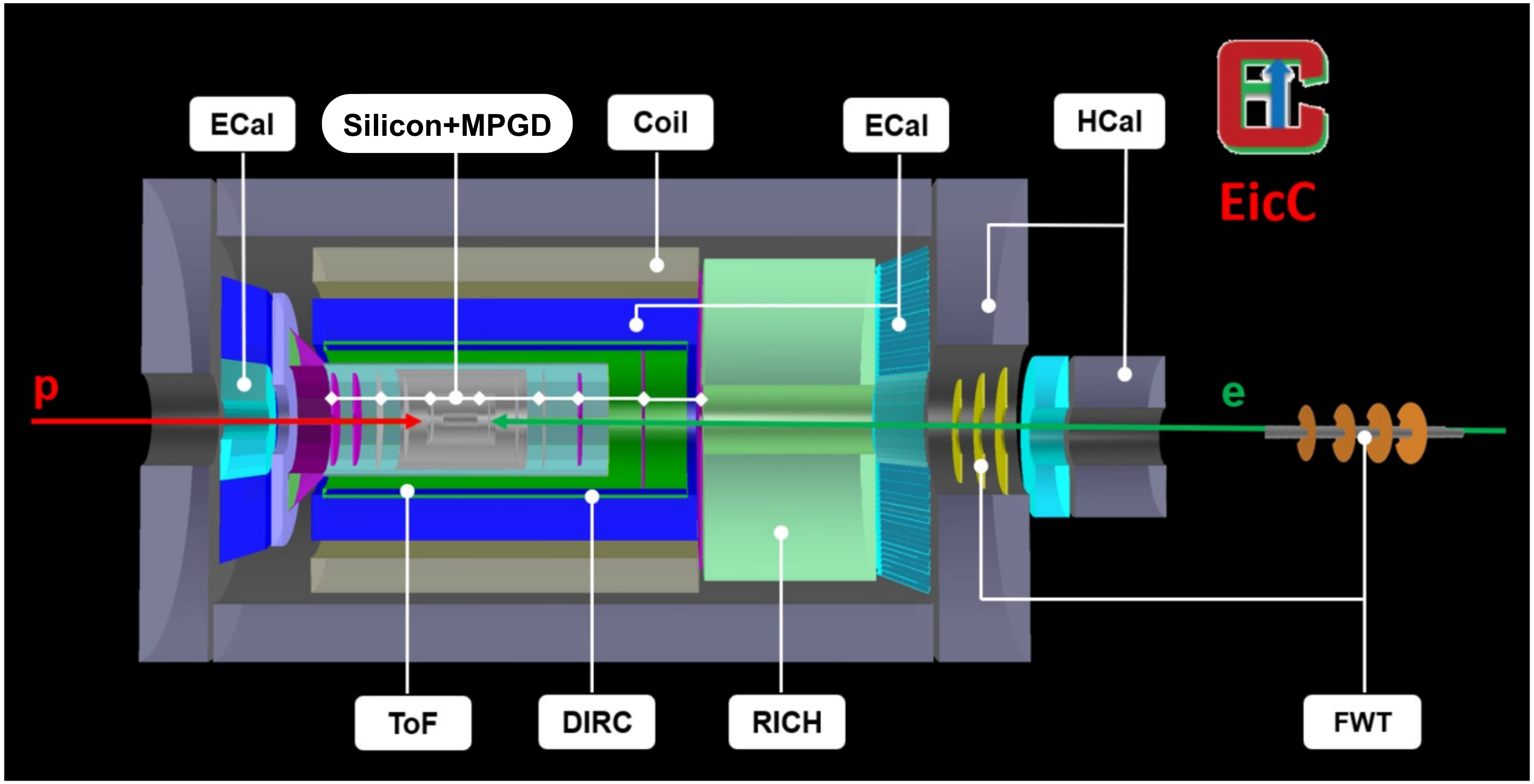
- Semi-inclusive DIS
  - identify a final state hadron
  - explore the emergence of hadrons from colored quarks/gluons
  - flavor dependence by selecting different observed hadrons

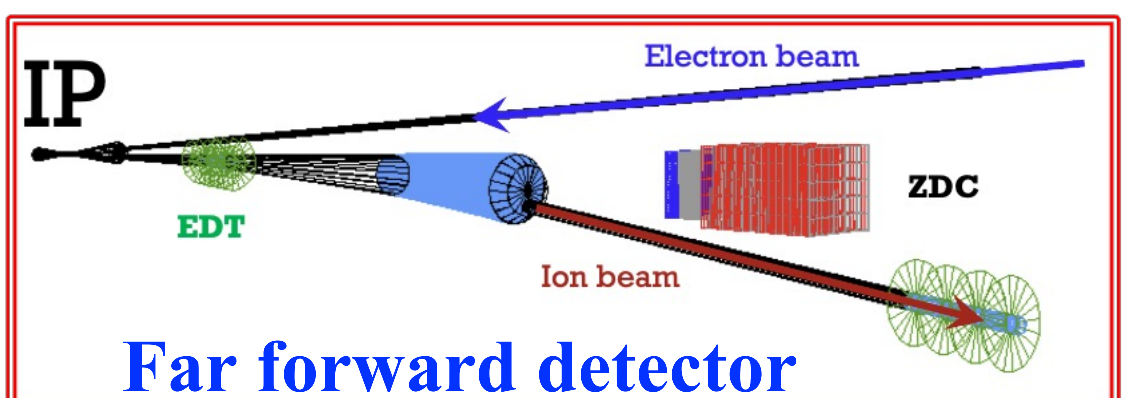


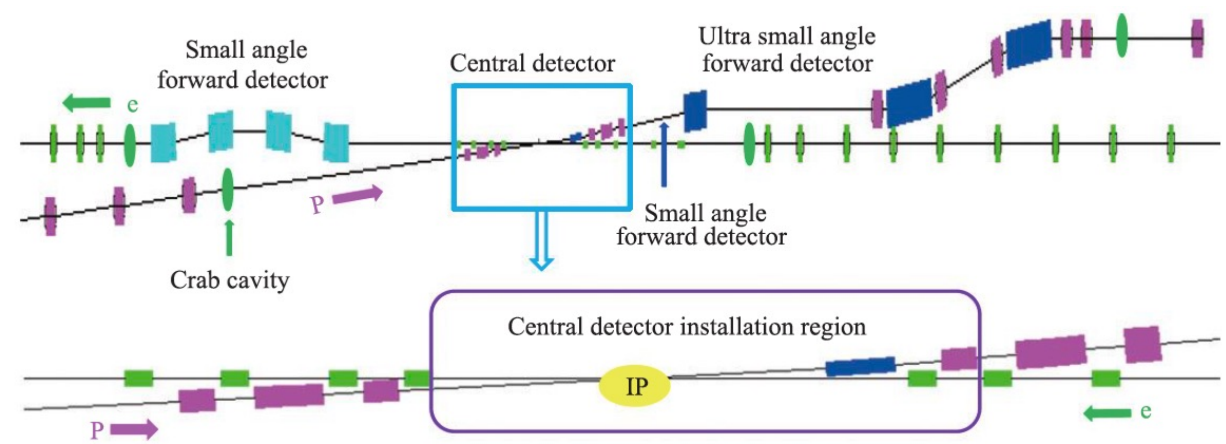
- Exclusive process
  - identify all the final state particles
  - explore the exotic hadron states, proton mass



Conceptual Design of the EicC Detector

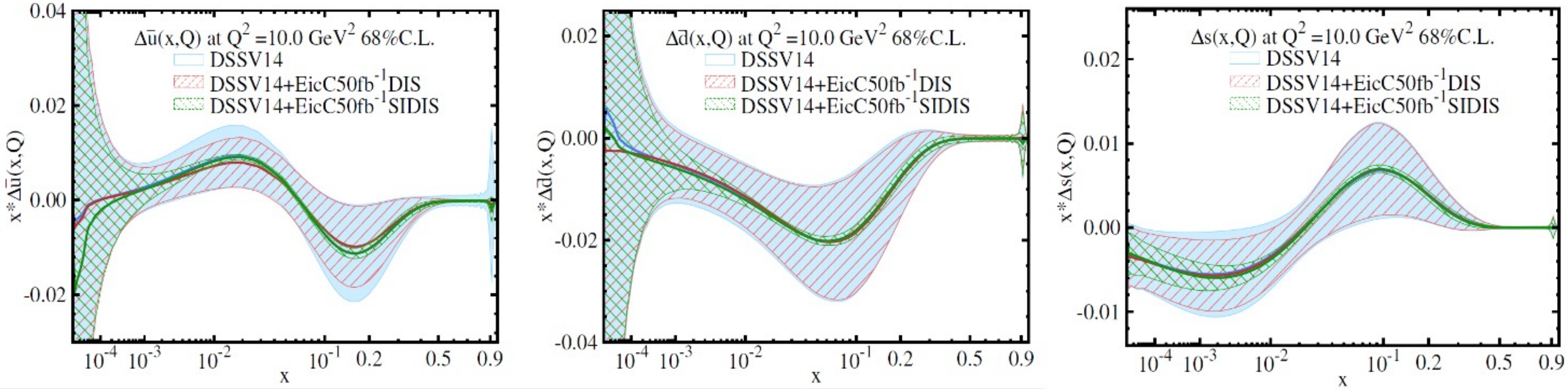






EicC Impact: Helicity distribution

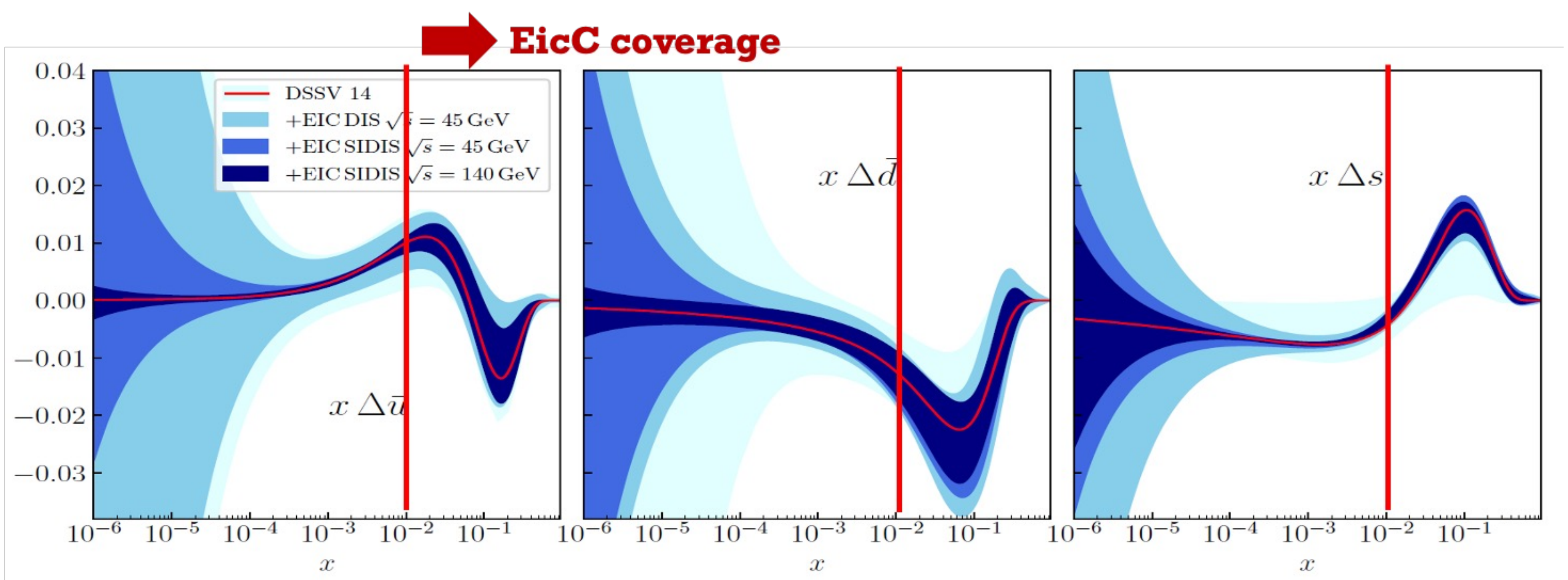
EicC:



D.P. Anderle, T.J. Hou, H. Xing, M. Yan, C.-P. Yuan and Y. Zhao, JHEP 08 (2021) 034.
Also included in the EicC White paper.

complementary

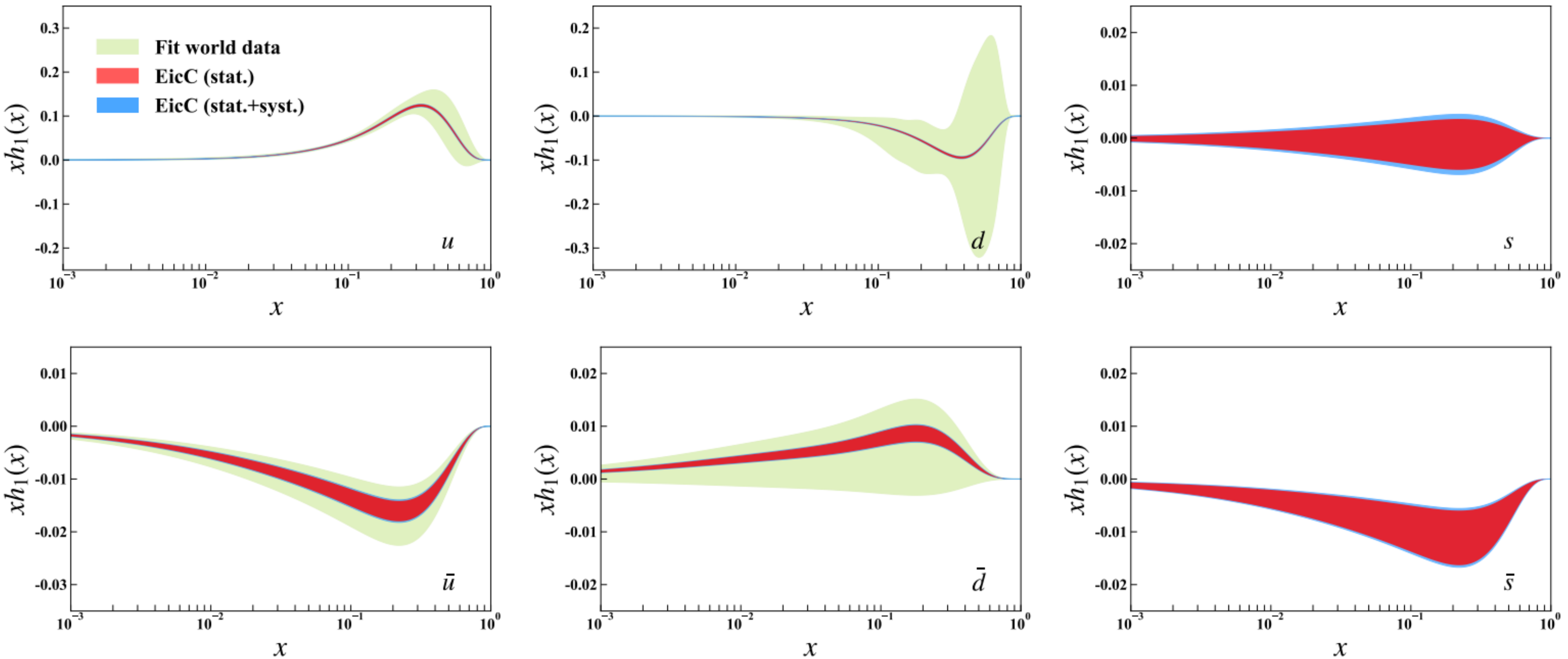
EIC-US:



[Figure from EIC Yellow Report]

EicC Impact: Transversity and Collins

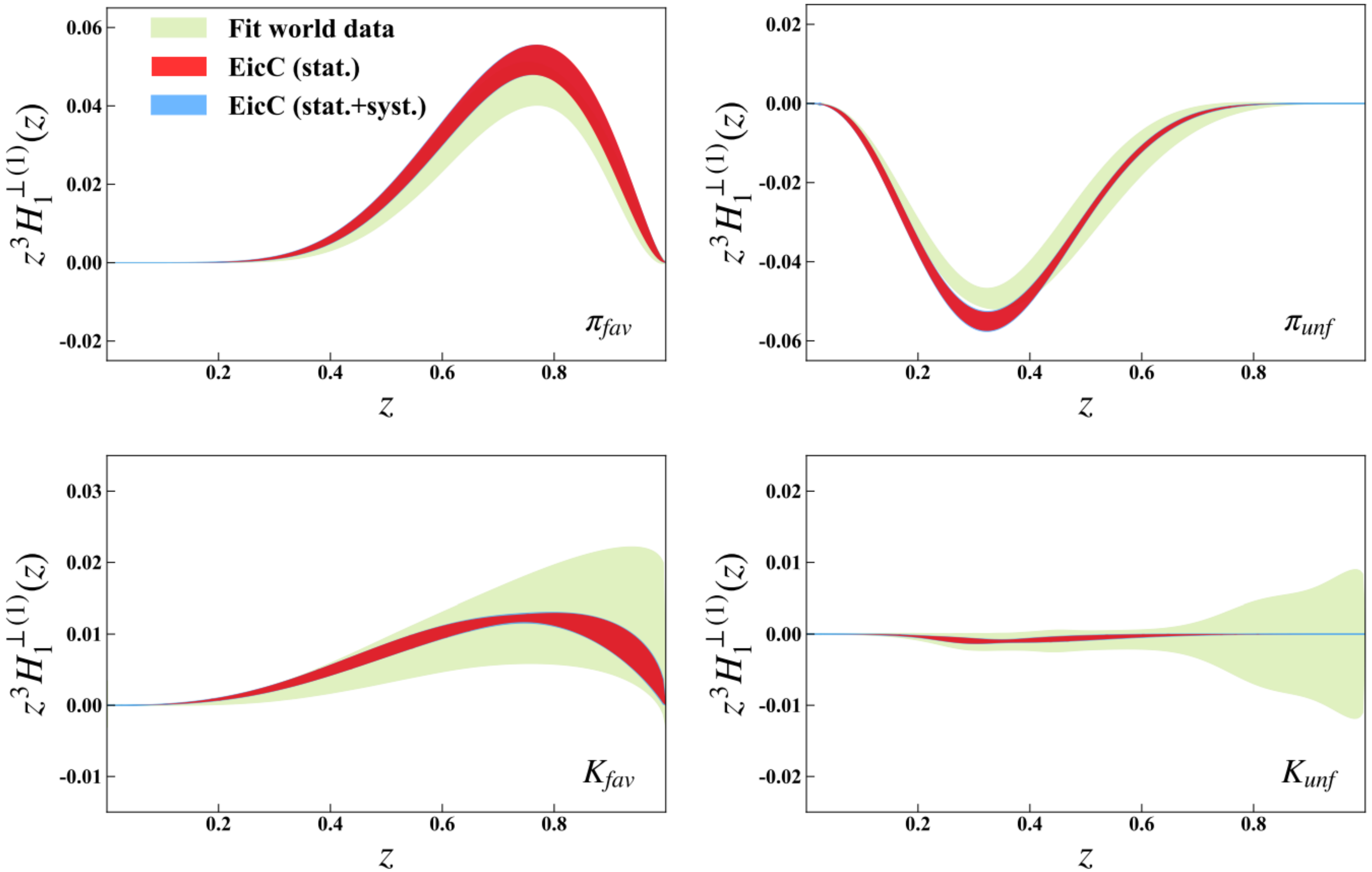
- Fit results and EicC impact: transversity distributions



C. Zeng, H. Dong, T. Liu, P. Sun, Y. Zhao, Phys. Rev. D 109 (2024) 056002

EicC Impact: Transversity and Collins

- Fit results and EicC impact: Collins fragmentation functions

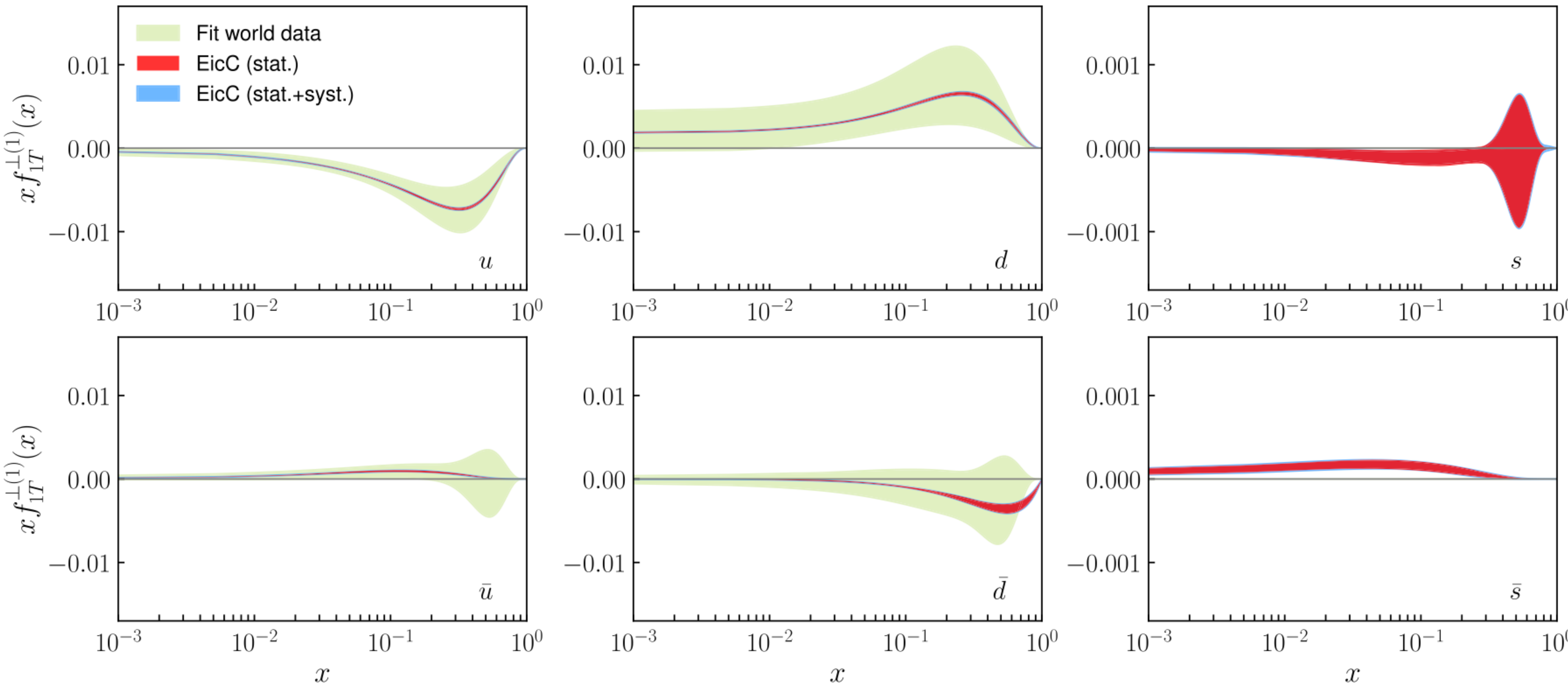


C. Zeng, H. Dong, T. Liu, P. Sun, Y. Zhao, Phys. Rev. D 109 (2024) 056002

EicC Impact: Sivers function

- EicC impact: Sivers functions

$$f_{1T}^{\perp(1)}(x) = \pi \int d\mathbf{k}_\perp^2 \frac{\mathbf{k}_\perp^2}{2M^2} f_{1T}^\perp(x, \mathbf{k}_\perp^2)$$



C. Zeng, T. Liu, P. Sun, Y. Zhao, Phys. Rev. D 106 (2022) 094039

EicC CDR in preparation

Volume I: Accelerator

Contents

Volume II: Physics and Detectors

Contents

- *Final version expected by the end of 2024*

CDR Working Groups

Accelerator	Physics	Detector
1) EicC Accelerators	1) 1D spin	1) Vertexing + tracking
2) Ion Sources	2) 3D spin (TMDs + GPDs)	2) PID
3) Ion Machine	3) Exotic states	3) Calorimetry
5) Electron Machine	4) EHM and proton mass	4) IR + Magnet
5) Polarization	5) Nuclei	5) Luminosity and polarimetry
6) Electron cooling	6) LQCD	6) Forward detector
7) IR	7) DSE	7) DAQ
8) Common System	8) New ideas	8) Simulations
		Software: EicCRoot
EicC CDR Volume I	**EicC CDR** Volume II	

EicC Detector: Physics Requirement

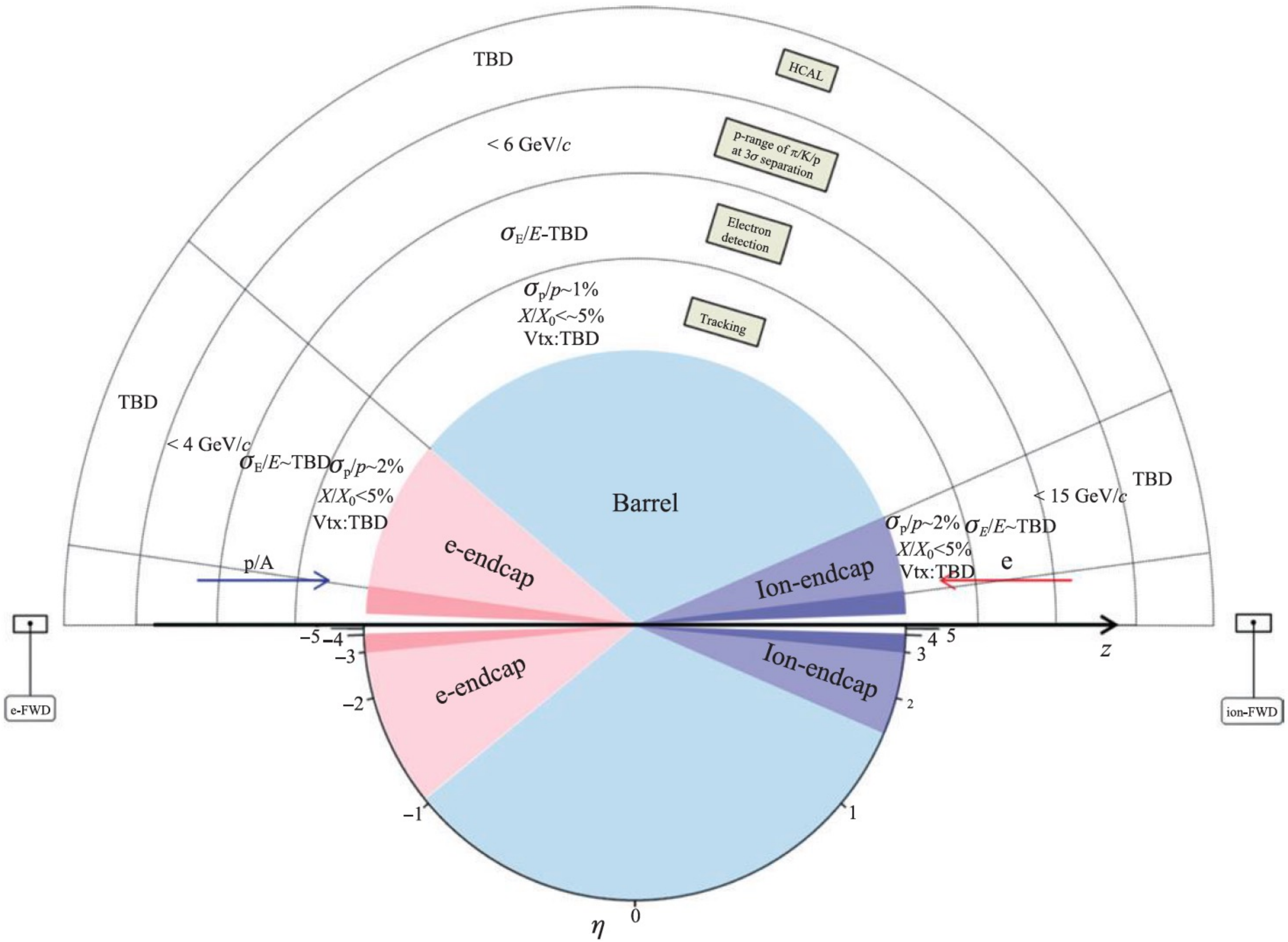


Fig. 4.7 Physics requirements for EicC.

[Figure from EicC White paper]

EicC Detector design- evolving to CDR

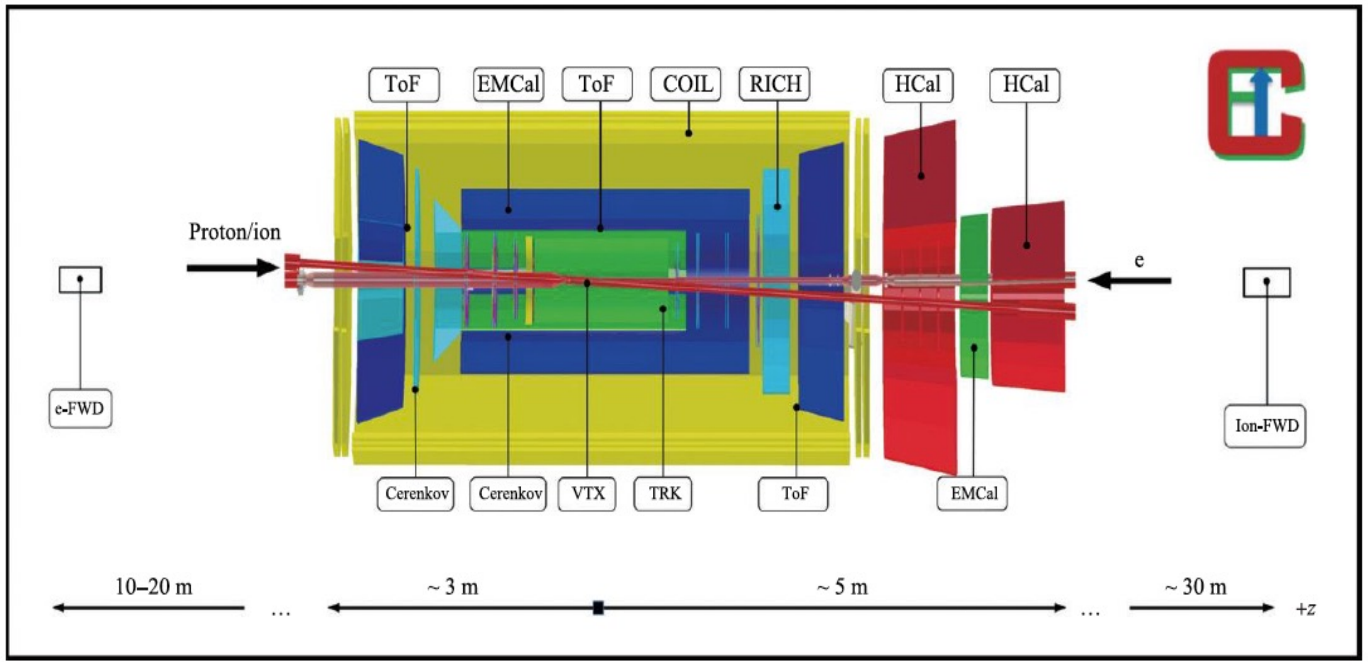
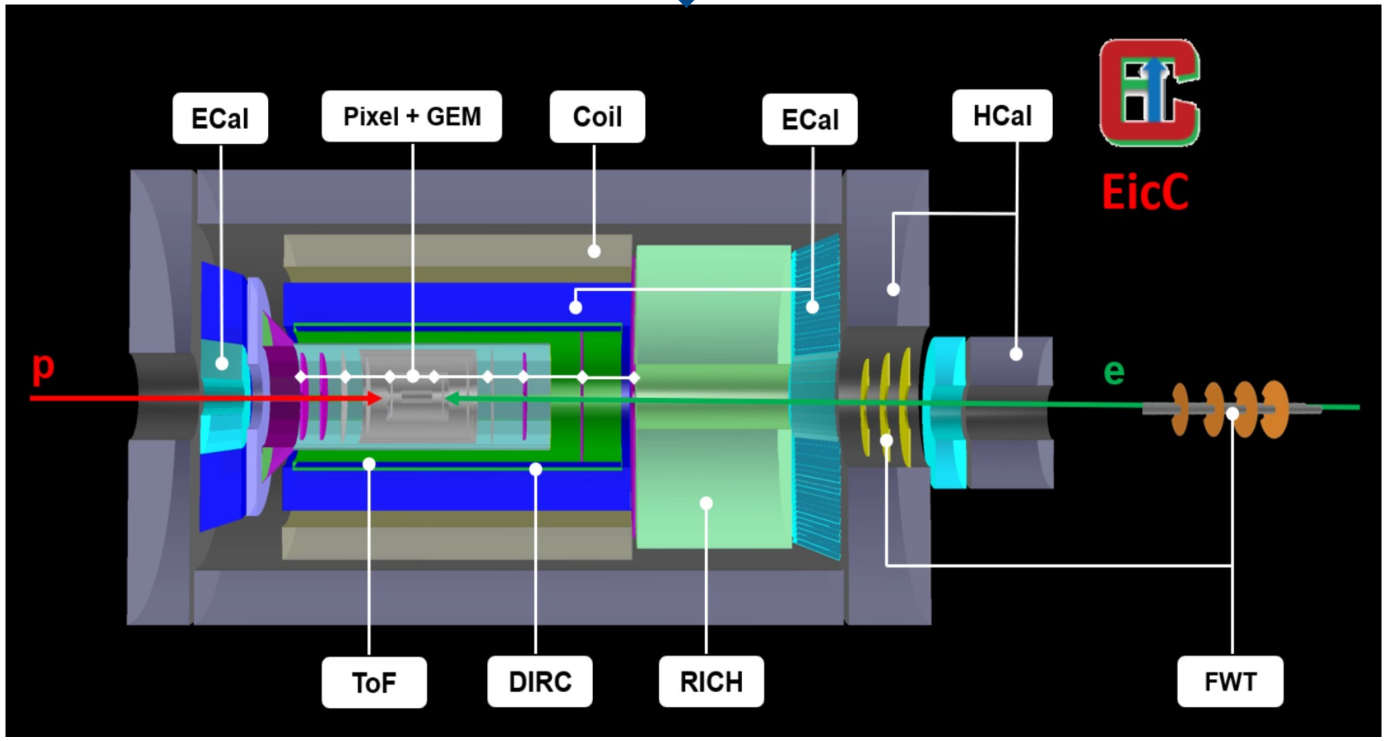


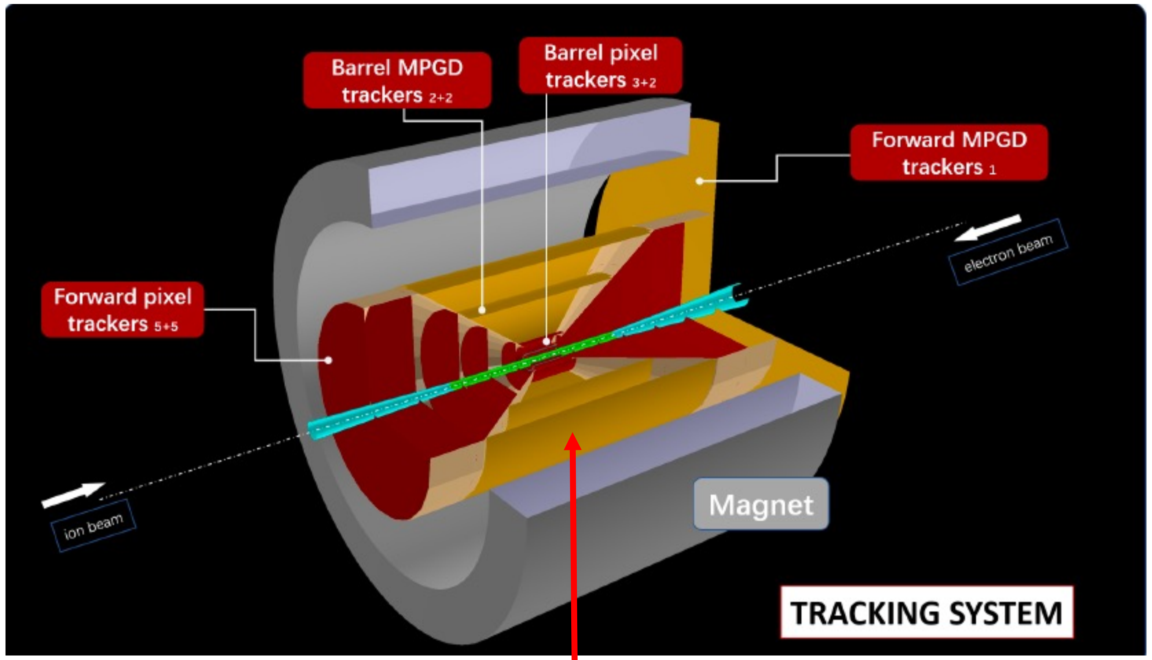
Fig. 4.10 Conceptual design of the EicC detector.



[Figure by EicC Detector WG]

I. Vertex and tracking detectors

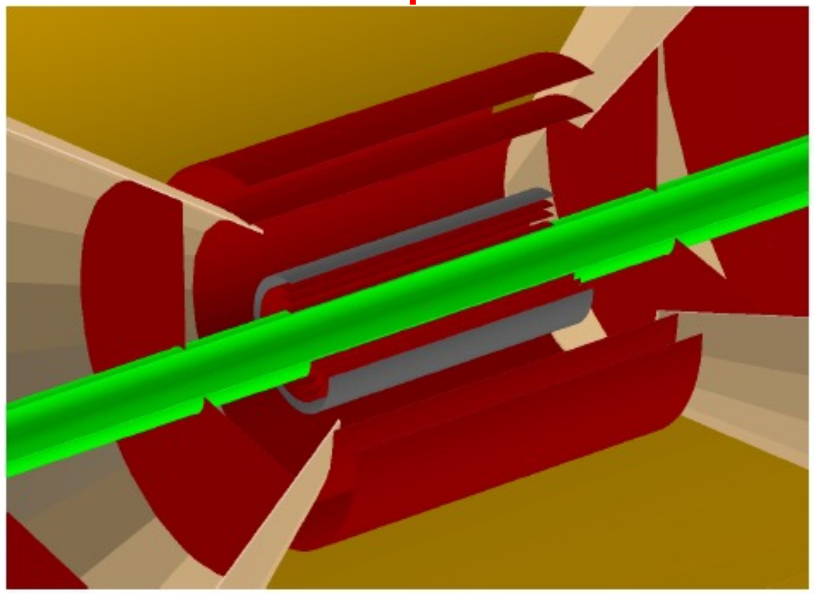
- Physics requirements for EicC tracking:
  - ➢ Assume B ~ 1.5 T
    - ◆ Barrel ($-1 < \eta < 1.6$):
      - $\sigma(p)/p \sim 1\%$ @ 1GeV;
    - ◆ E-endcap ($-3 < \eta < -1$):
      - $\sigma(p)/p \sim 2\%$ @ 1GeV;
    - ◆ P-endcap ($1.6 < \eta < 3$):
      - $\sigma(p)/p \sim 2\%$ @ 1GeV;



[Figure by EicC Detector WG]

- Silicon+MPGD hybrid design

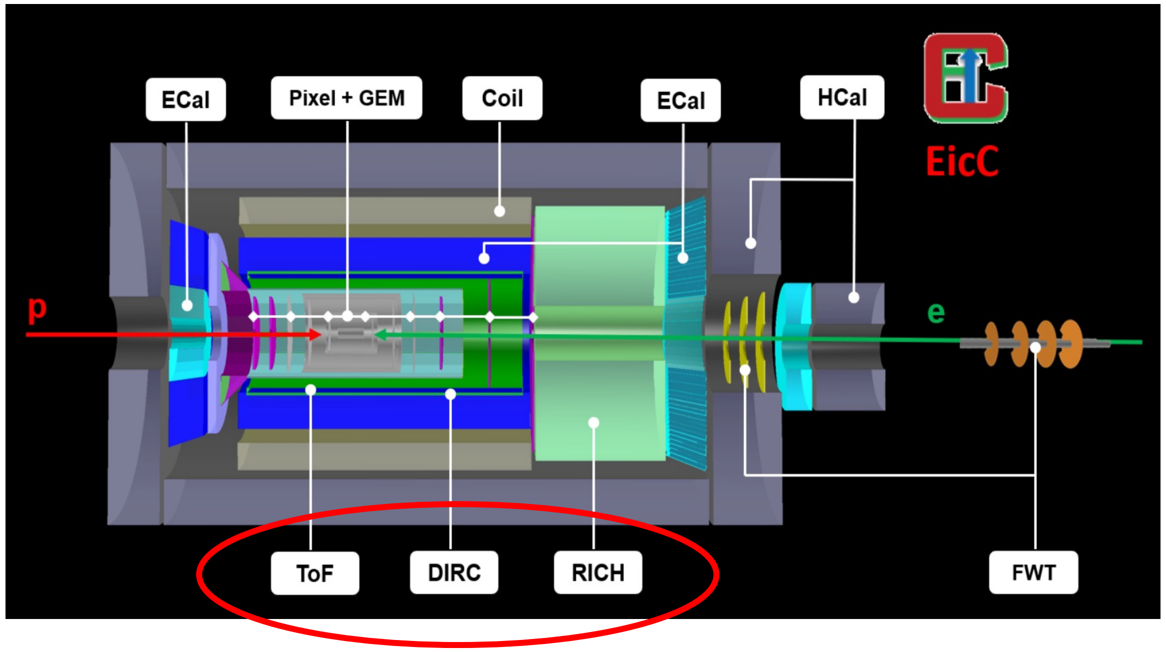
- Silicon tracking detector concept
  - ➢ Reduced Material budget **is ~0.26%**
  - ➢ Optimal Pixel size: **10 to 20 mircon**
  - ➢ Thickness: **50 micron**



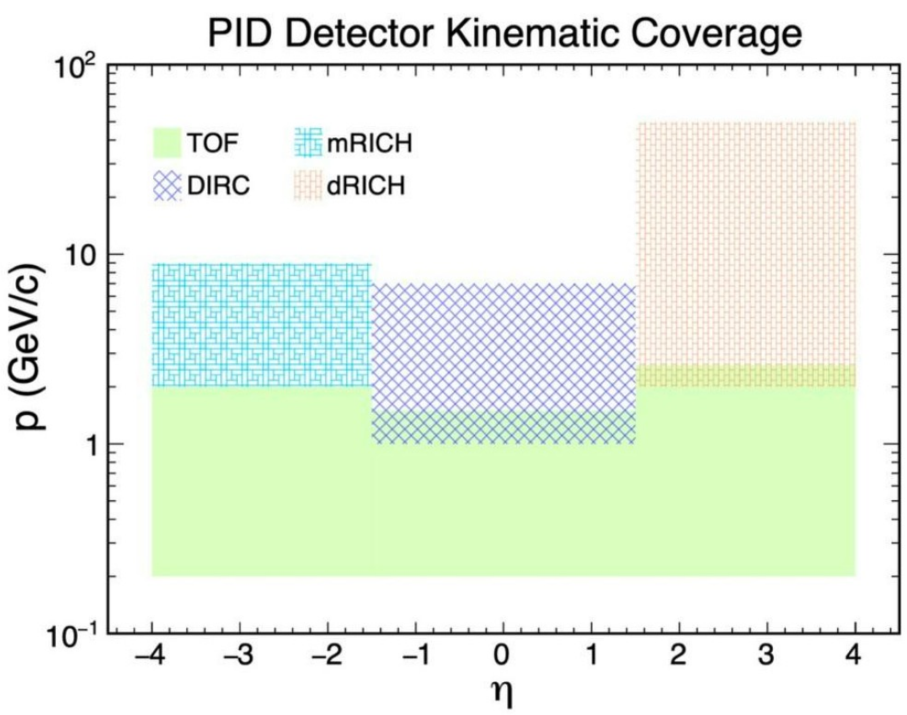
the vertex and inner tracker

2. PID detectors

- PID design concept:
  - ➢ Barrel region: DIRC+TOF
  - ➢ Backward e-Endcap: mRICH
  - ➢ Forward ion-Endcap: dRICH



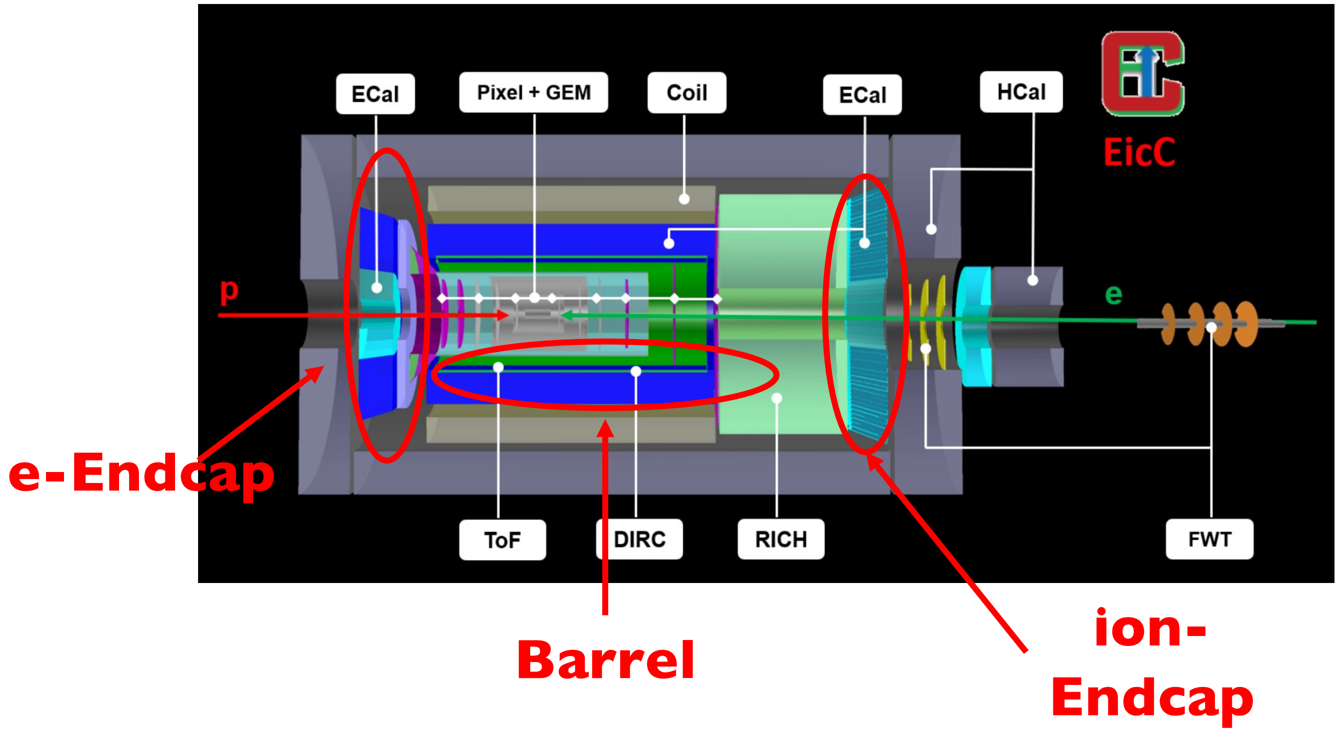
- PID momentum coverage:
  - ➢ <6 GeV/c at Barrel
  - ➢ <4 GeV/c at e-Endcap;
  - ➢ <15 GeV/c at ion-Endcap ;



[Figure by EicC Detector WG]

3. Calorimeter system

- General EMCal requirement:
  - E-endcap: energy resolution, 2.5%/√E
  - Barrel: good angle resolution, 5.0%/√E
  - Ion-endcap: angle resolution, 5.0%/√E

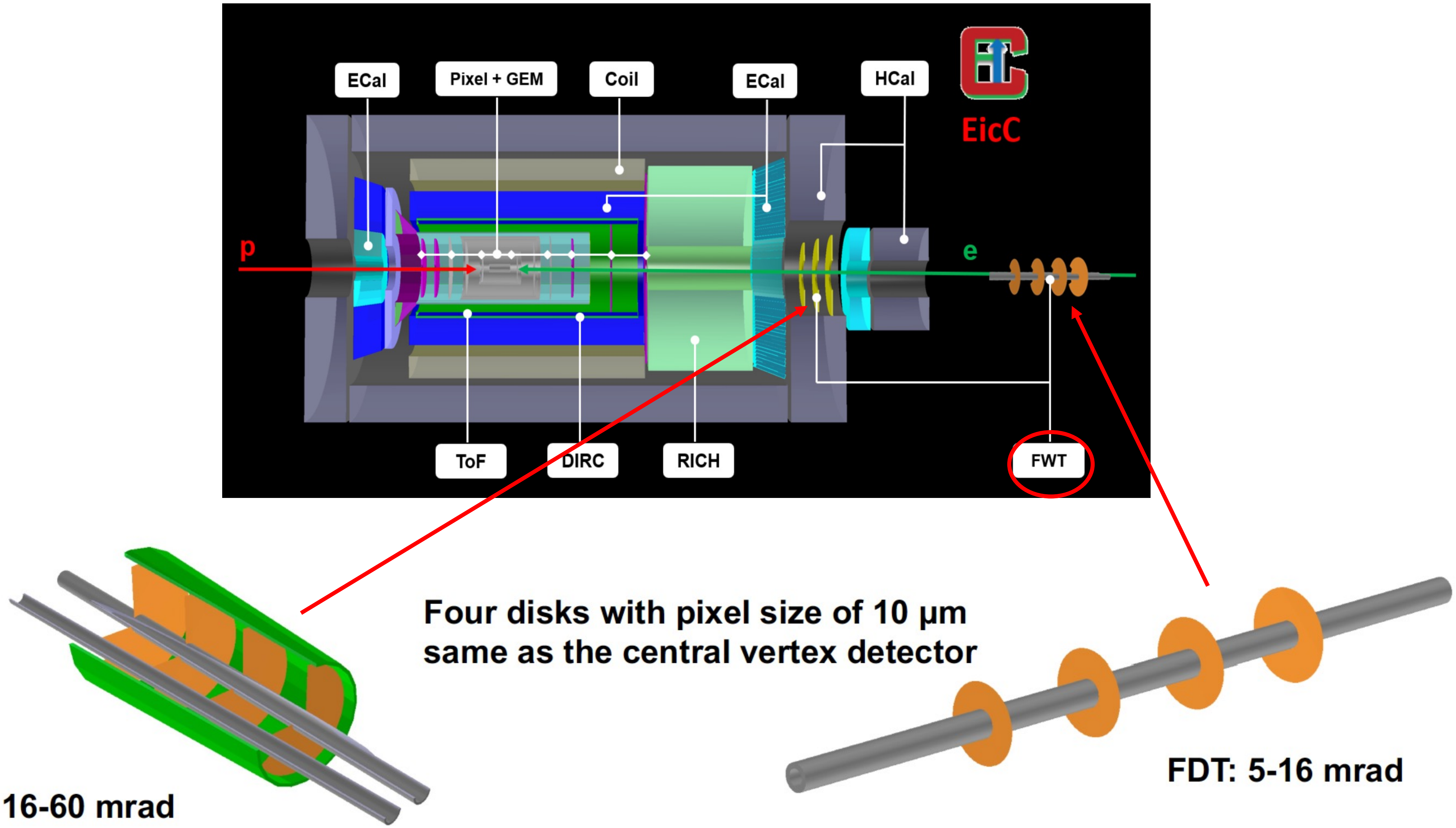


- General design of EMCal:

	EMC	type	z/r[m]	Length[cm], X_0	Coverage[cm]	pseudorapidity	Tower size
EicC	e-endcap	**CsI/crystal**	**Z=-1.5**	30, $16X_0$	15.0<r<128	(-3.0, -1.0)	4.0*4.0(front)
	barrel	**Shashlik**	**R=0.9**	45, $16X_0$	-105.8<z<187.5	(-1.0, 1.5)	4.0*4.0 (front)
	Ion-endcap	**Shashlik**	**Z=2.4**	45, $16X_0$	24.0<r<113	(1.5, 3.0)	

4. Far Forward Detectors

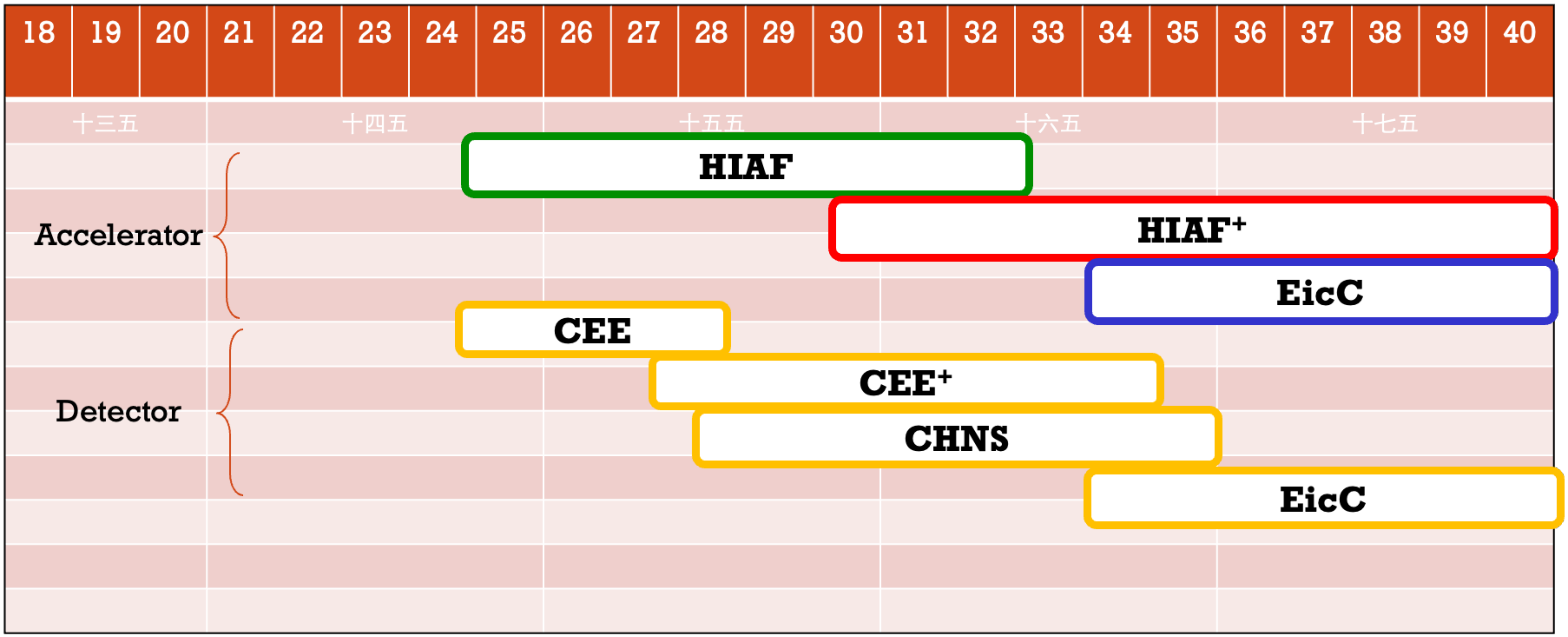
- General design concept for far forward detectors EDT+FDT:



EDT (Endcap Dipole Tracking)

FDT (Forward Dipole Tracking)

EicC @HIAF Timeline



Summary

- EicC, has been proposed to be constructed based on HIAF in Huizhou, Guangdong, China, to advance the nuclear and particle physics.
- Physics highlights of EicC with a large acceptance detector:
  - Precision measurements of nucleon spin structures in the sea quark region, including 3D tomography of nucleon;
  - The partonic structure of nuclei and the parton interaction with the nuclear environment;
  - The exotic states, proton mass etc.
- The EicC physics program complements the scientific programs at JLab and the future EIC project in the US.
- The EicC CDR preparation is underway, expected to be released by the end of 2024.

Summary

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Thank you!

Many thanks to Tianbo Liu, Yuxiang Zhao and all EicC working group members!