Electron-Ion Collider in China

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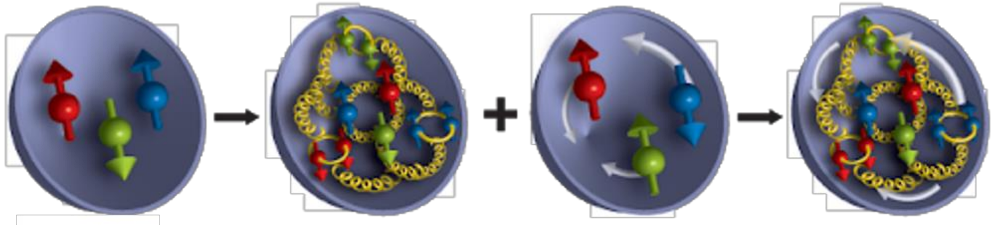
Outline

- Introduction
- Selected physics highlights at EicC
- Detector conceptual design
- China Hyperon-Nuclear Spectrometer (CHNS)
- Summary

spin

Gell-Mann
quark model



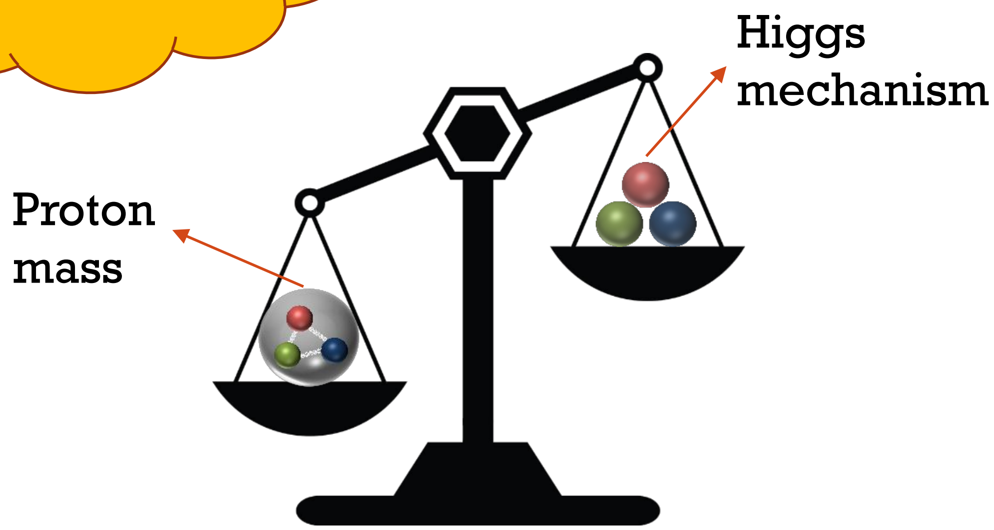
1970s 1980s/2000s Now

Spin decomposition:

$$S_{tot} = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \mathcal{L}_q + \mathcal{L}_g$$

Quark spin	Gluon Spin	Quark OAM	Gluon OAM

mass



Mass decomposition:

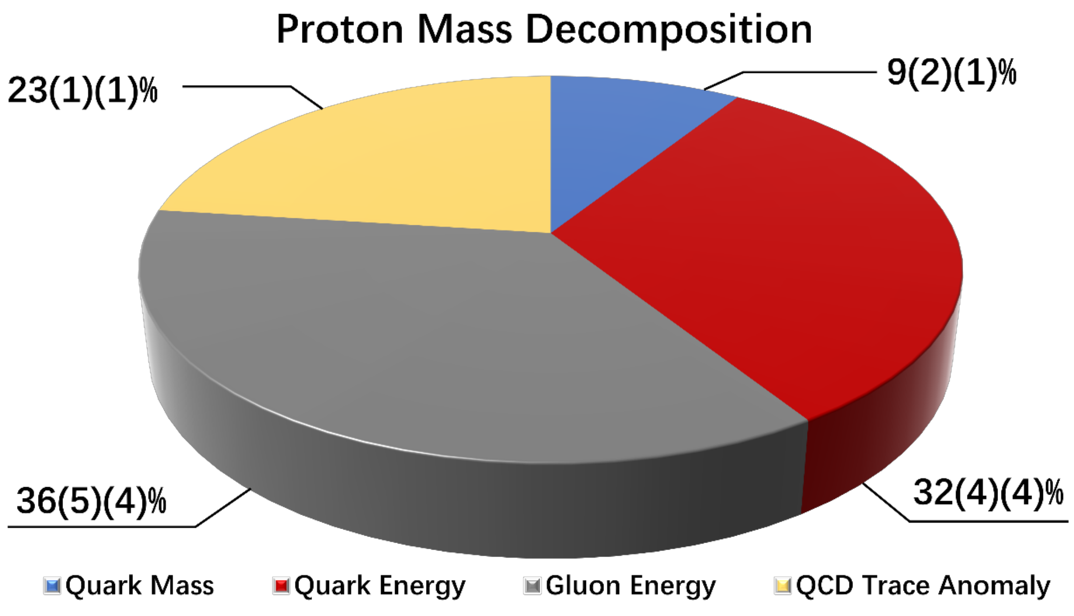
$$M = M_q + M_m + M_g + M_a$$

Quark energy	Quark mass	Gluon energy	Trace anomaly

Experimentally… we need to determine each of the above contributions

Origin of proton mass

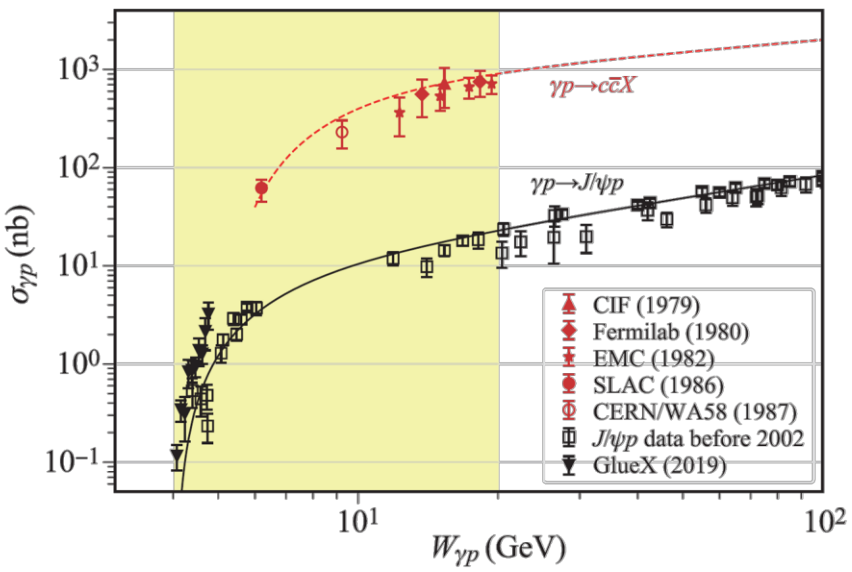
Lattice QCD calculation
Phys. Rev. Lett. 121 (2018) 21, 212001



- **Quark energy** and **gluon energy** constrained by PDFs
- **Quark mass** via πN low energy scattering
- **Trace anomaly** via threshold production of J/Psi and Upsilon ???

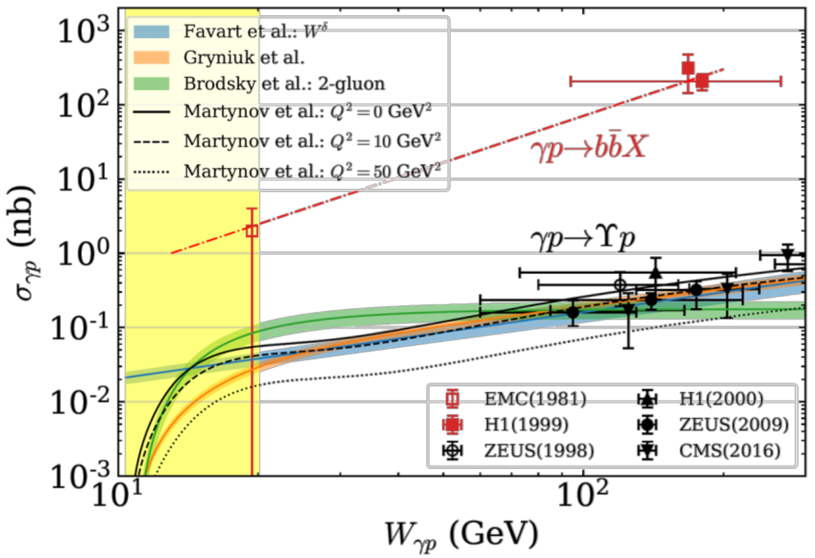
One of the hot topics under discussions

Near threshold J/Psi production



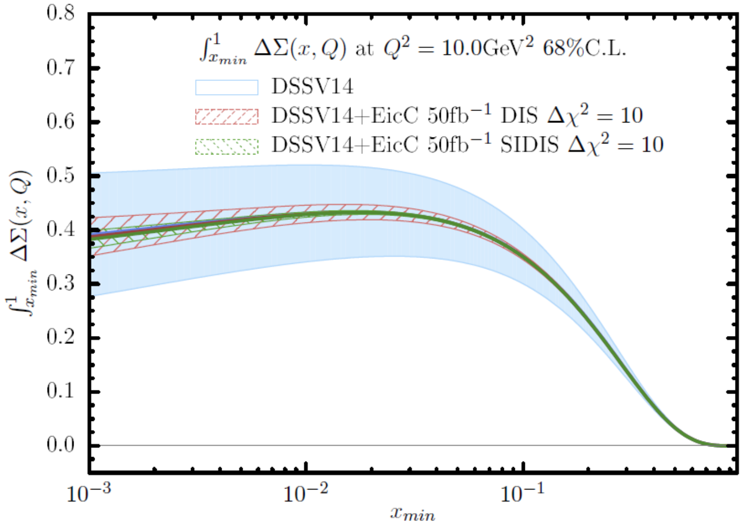
JLab & EicC & EIC

Near threshold Upsilon production

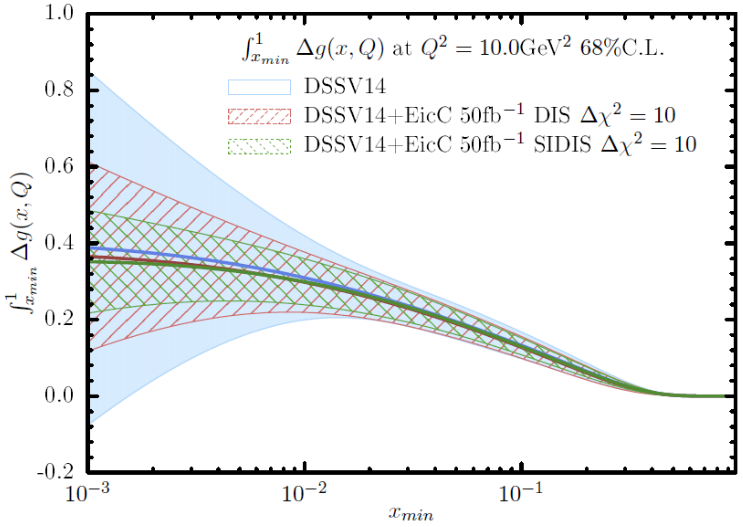


EicC & EIC

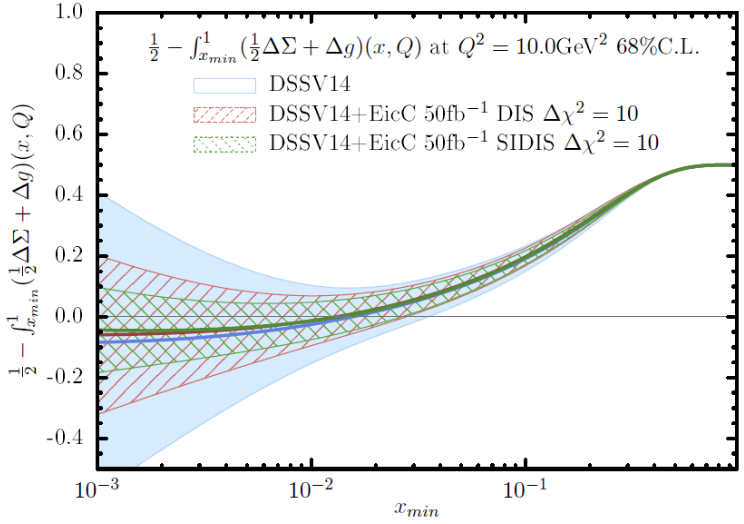
Origin of proton spin



Quark spin contribution



Gluon spin contribution

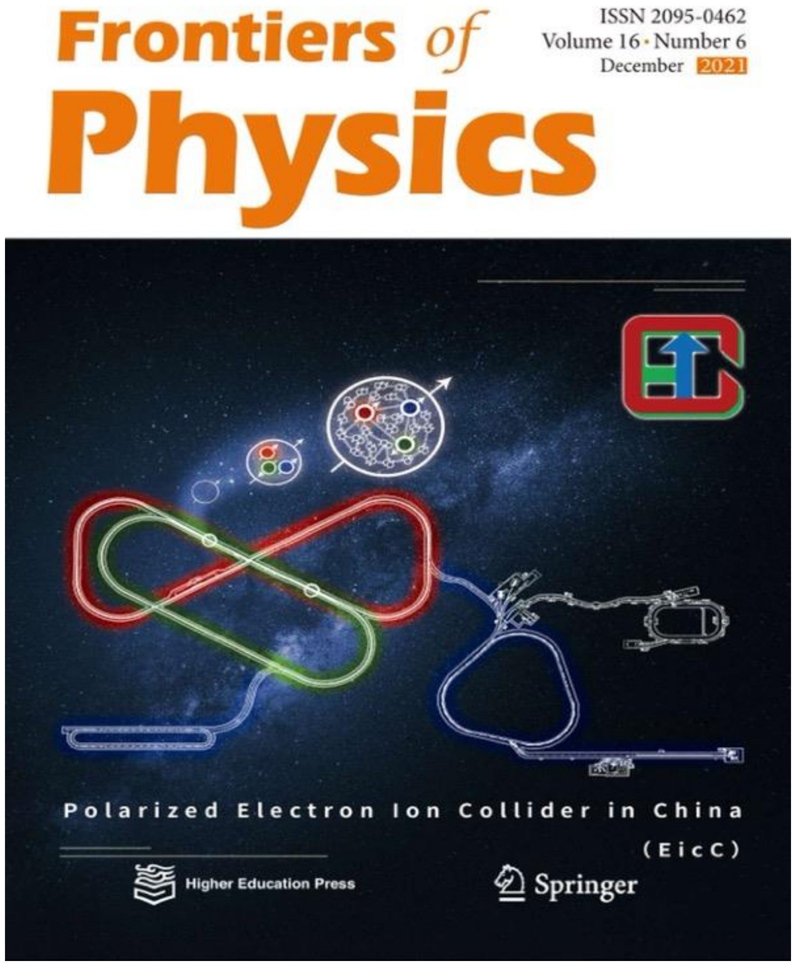


Quark/gluon OAM

$$S_{tot} = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \mathcal{L}_q + \mathcal{L}_g$$

EicC white paper (arXiv: 2102.09222)

Published in the *Frontiers of Physics* (2021)



https://link.springer.com/article/10.1007/s11467-021-1062-0

- Spin structure of the nucleon: 1D, 3D
  - polarized electron + polarized proton/light nuclei
- Partonic structure of nuclei and the Parton interaction with the cold nuclear environment
  - unpolarized electron + unpolarized various nuclei
- Quarkonium with c/cbar, b/bbar
- Origin of the proton mass study

Detector + Accelerator preliminary design

45 institutes and >100 physicists

EicC organization for the CDR preparation

Accelerator:

- EicC Accelerators
- Ion Sources
- Ion Machine
- Electron Machine
- Polarization
- Cooling
- IR
- Common System

Detector:

- Tracking
- PID
- Calorimetry
- IR+Magnet
- Luminosity and polarimetry
- Far-Forward detector
- DAQ
- Simulations

Physics:

- Inclusive
- SIDIS
- Heavy Flavor
- Exclusive

IMP SCNT 南方核科学理论研究中心 Southern Center for Nuclear-Science Theory

Software: EicCRoot

Computing (at SCNU):
Southern Nuclear Science Computing Center

Electron Ion Collider in China…Huizhou(惠州) in Guangdong province

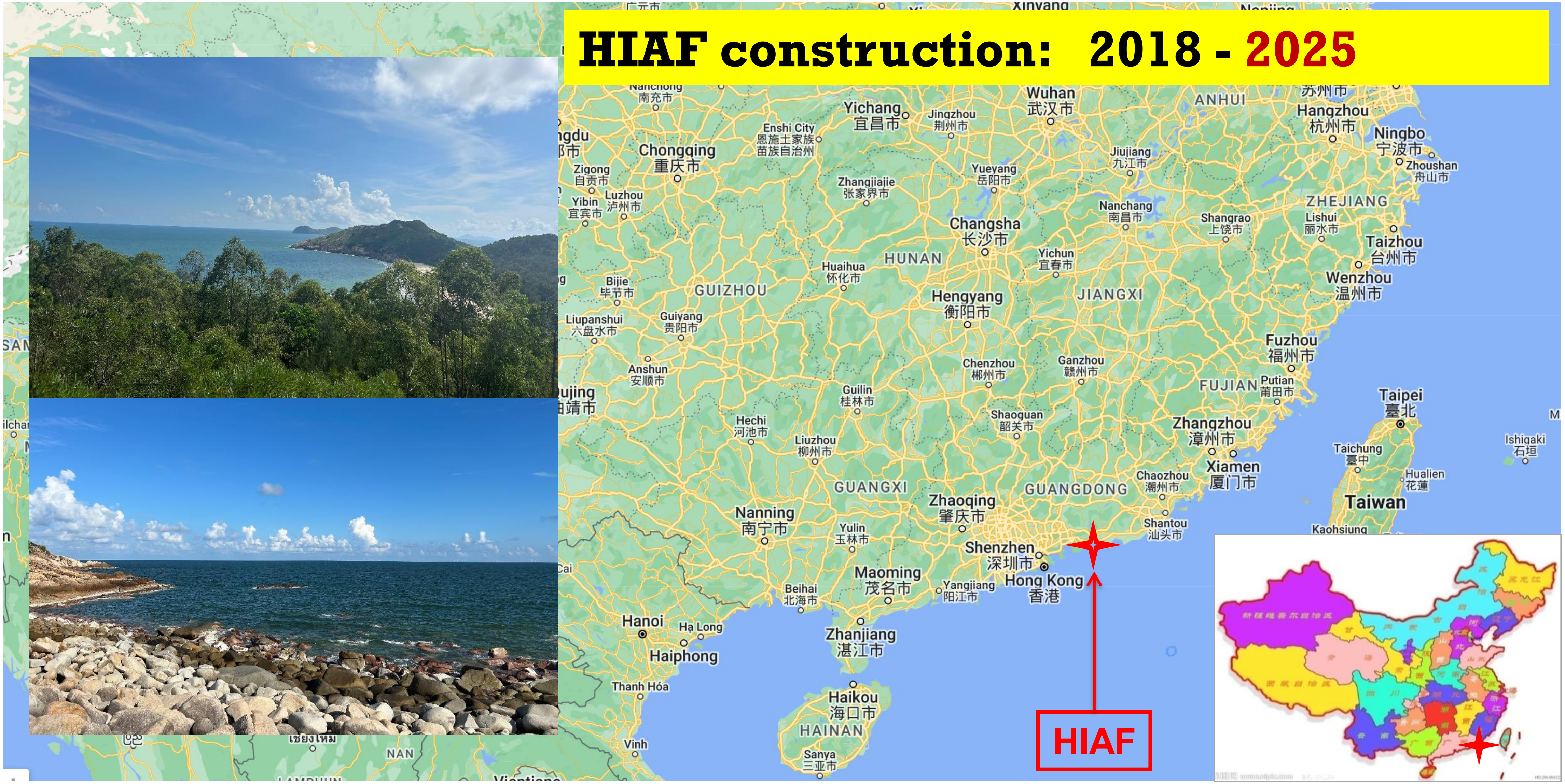
HIAF under construction

EIC in China

Electron Ion Collider in China, EicC

Location: Huizhou, Guangdong

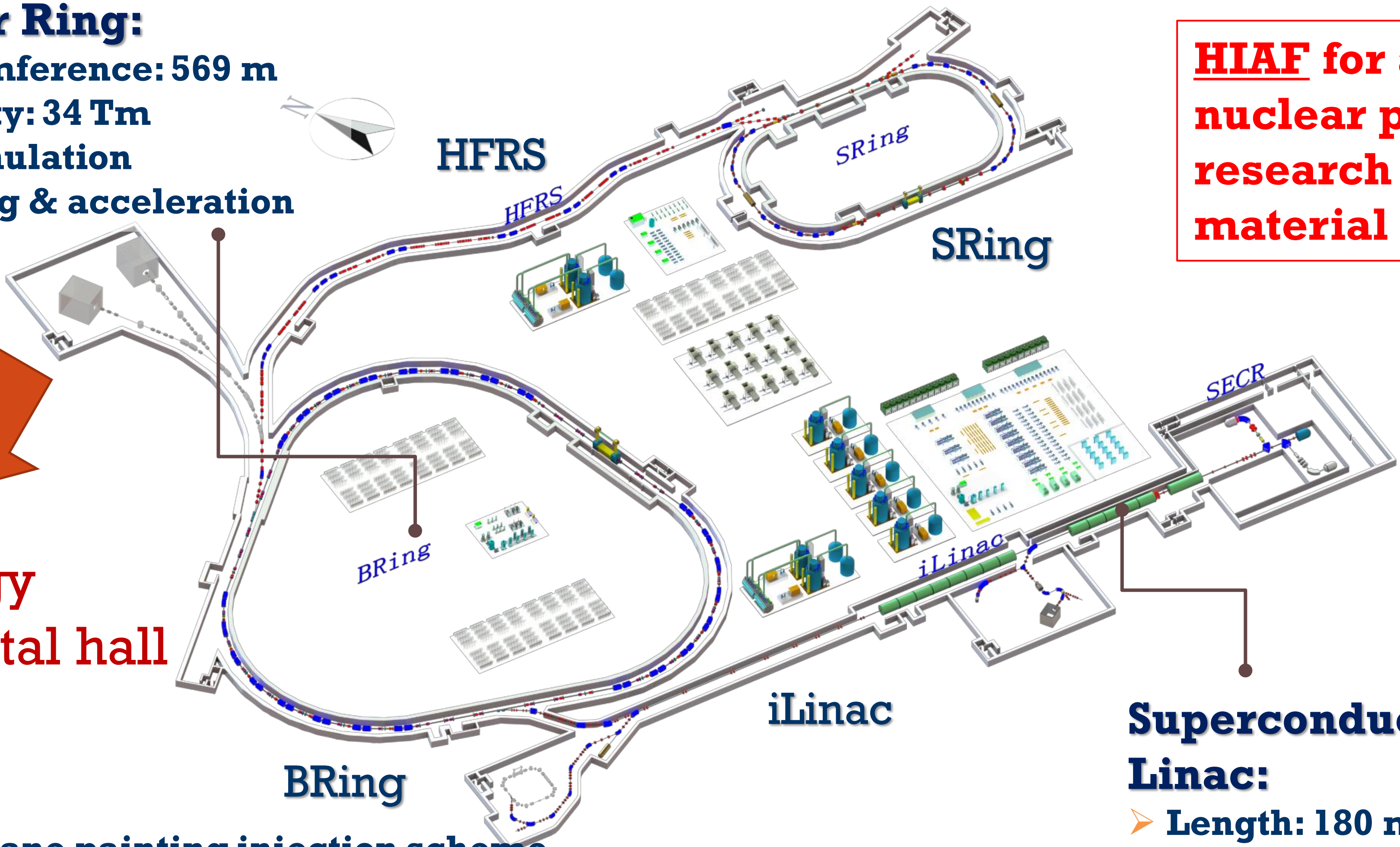
HIAF construction: 2018 - 2025



High Intensity heavy-ion Accelerator Facility (HIAF)

Booster Ring:
- Circumference: 569 m
- Rigidity: 34 Tm
- Accumulation
- Cooling & acceleration

HIAF for atomic physics, nuclear physics, applied research in biology and material science etc.



High energy experimental hall

- Two-plane painting injection scheme
- Fast ramping rate operation

Superconducting Ion Linac:
- Length: 180 m
- Energy: 17 MeV/u (U^{34+})
- CW and pulse modes

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Booster Ring:

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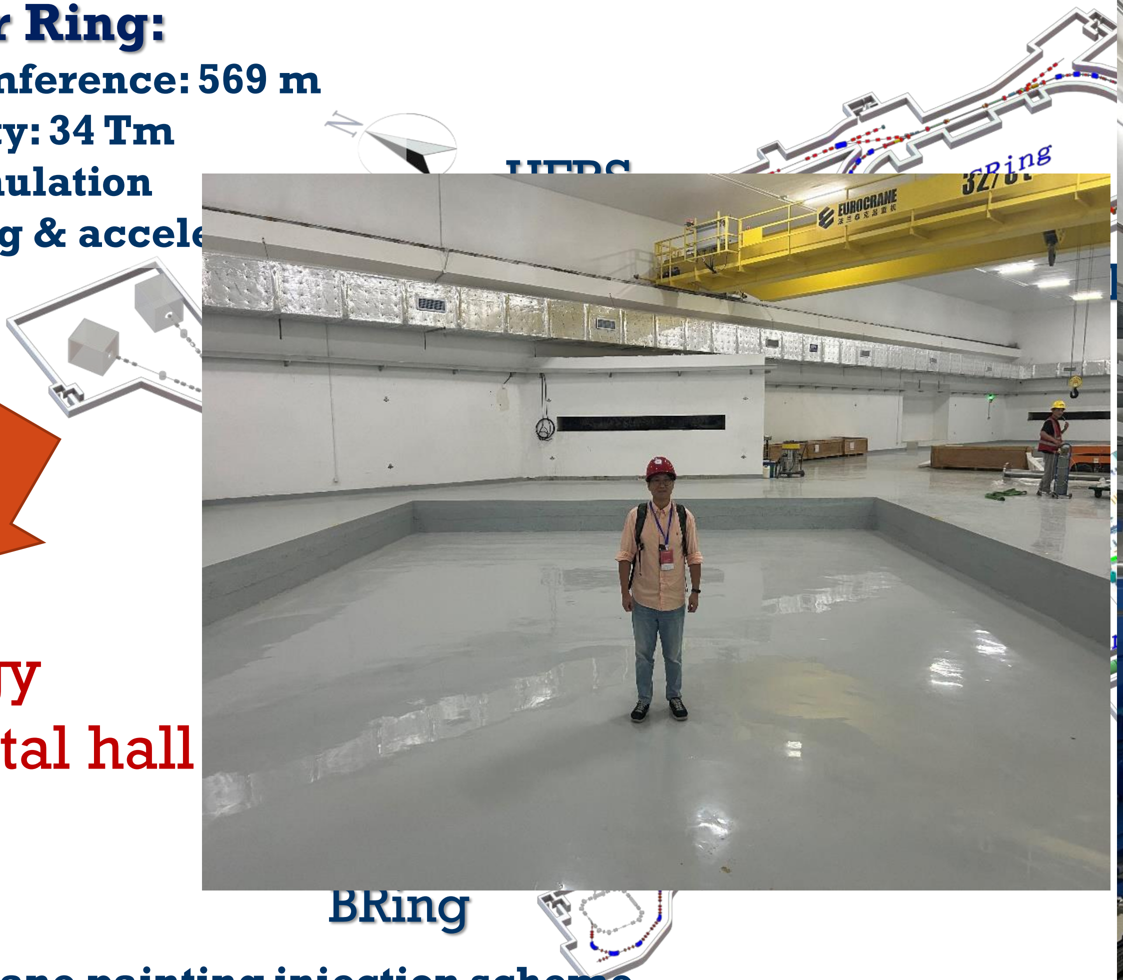


High energy experimental hall

- Two-plane painting injection scheme
- Fast ramping rate operation

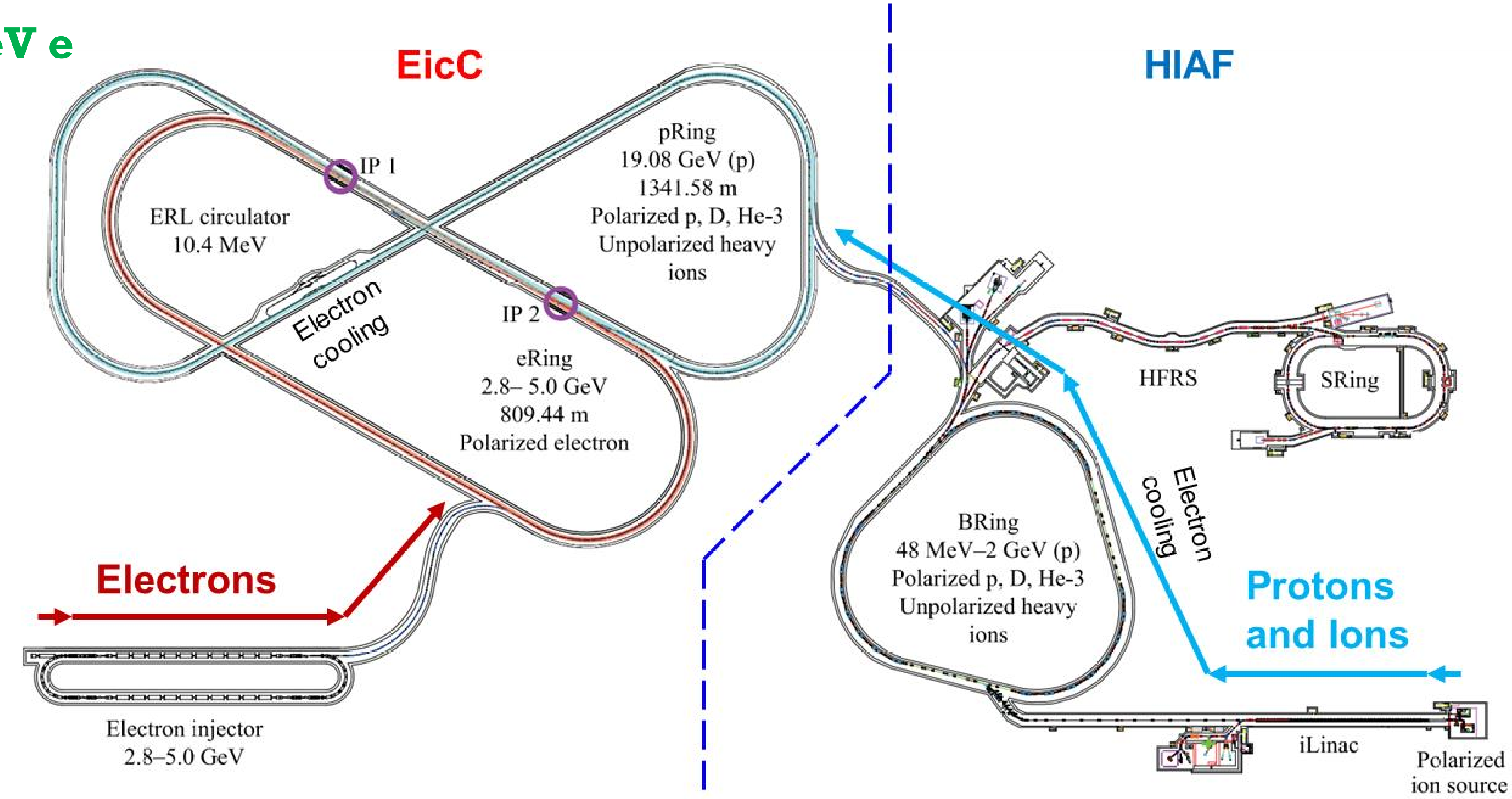
HIAF beam parameters

Ion	Intensity (ppp)	Energy (GeV/u)
$^{238}U^{35+}$	2.0×10^{11}	0.84
$^{238}U^{76+}$	5.0×10^{10}	2.5
$^{129}Xe^{27+}$	3.6×10^{11}	1.4
$^{78}Kr^{19+}$	5.0×10^{11}	1.7
$^{40}Ar^{12+}$	7.0×10^{11}	2.3
$^{18}O^{6+}$	8.0×10^{11}	2.6
p	5.0×10^{13}	9.3

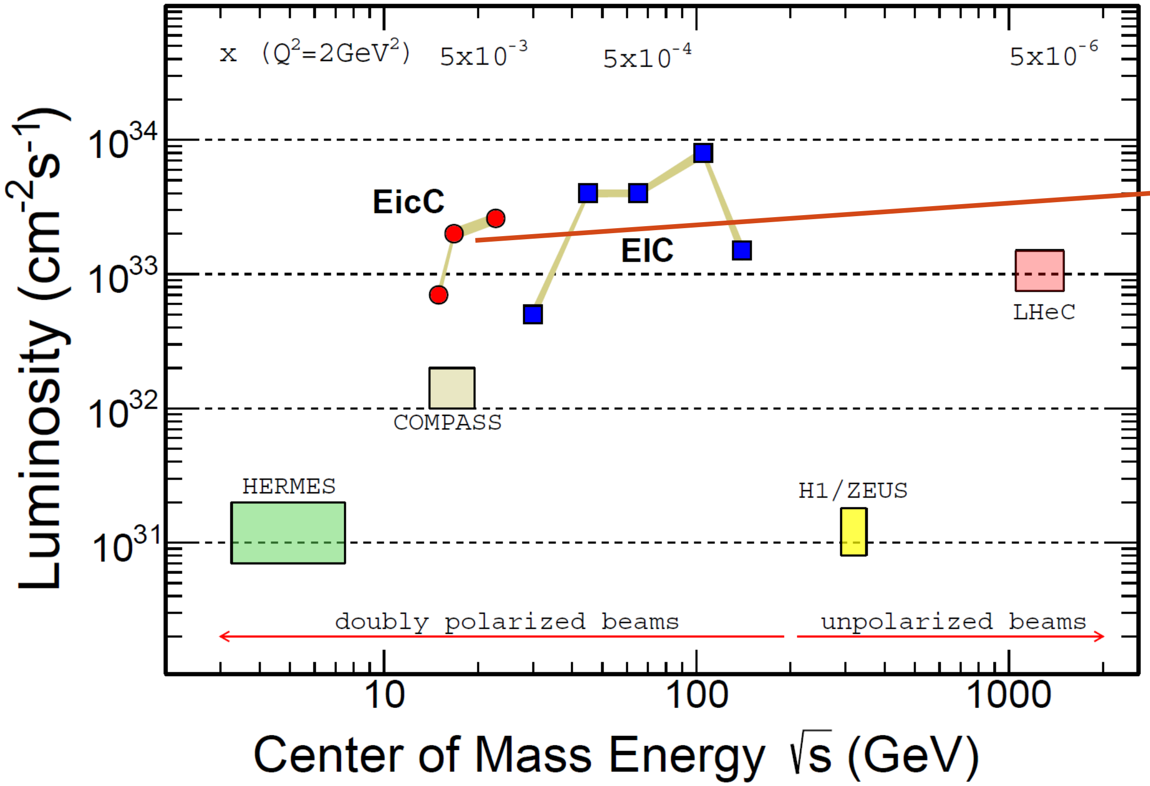
EicC Accelerator complex layout

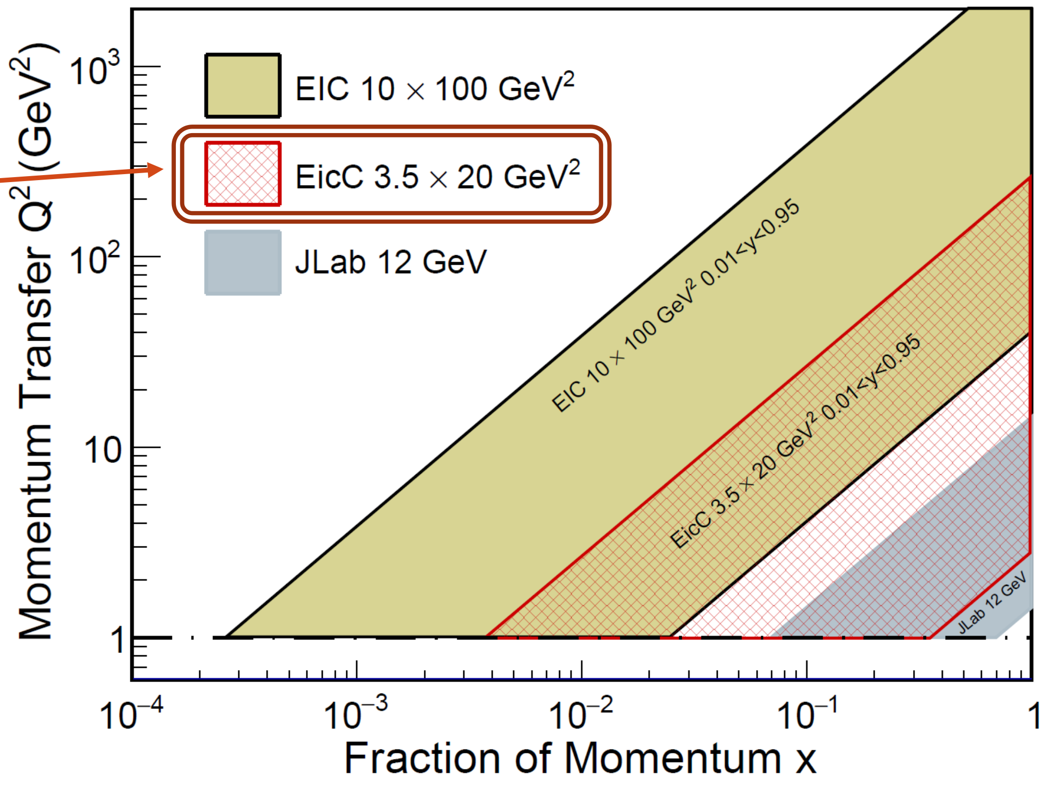
- 20 GeV p + 3.5 GeV e
- $\sqrt{S}$: 16.7GeV
- High Lumi.:

  2-4 x10^{33} $cm^{-2}s^{-1}$
- Polarized beams



EicC parameters

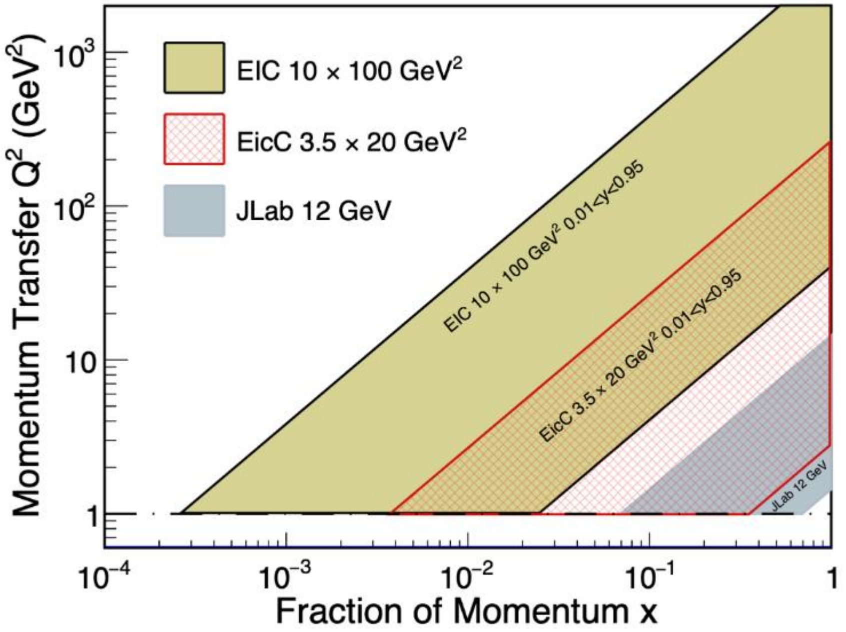


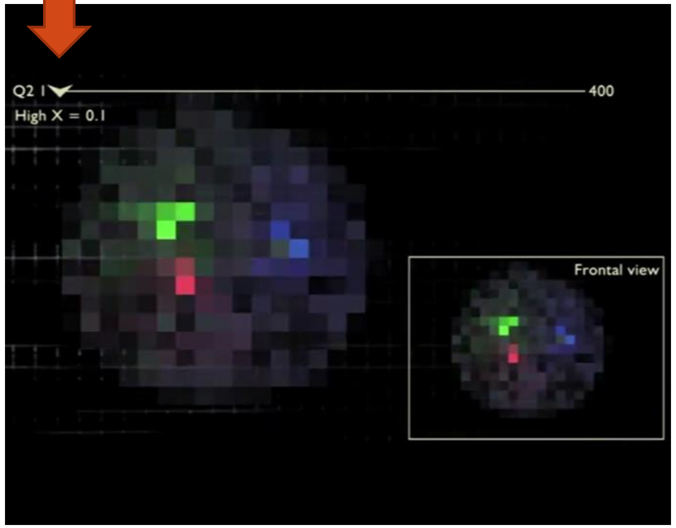


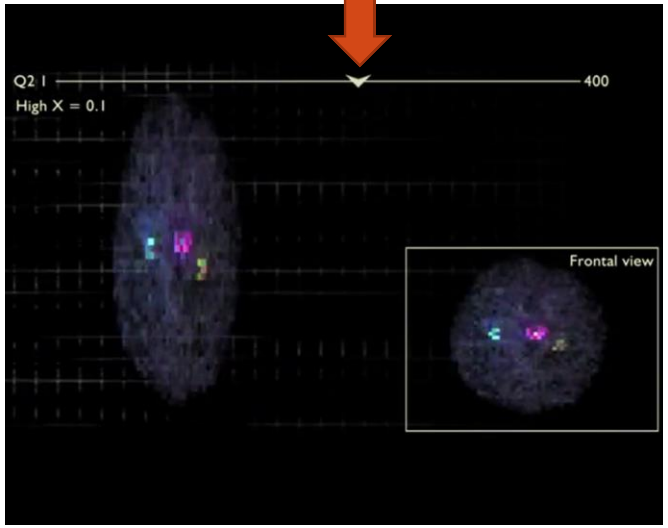
- EicC covers the kinematic region between JLab experiments and EIC@BNL
- EicC complements the ongoing scientific programs at JLab and future EIC project
- EicC focuses on moderate x and sea-quark region

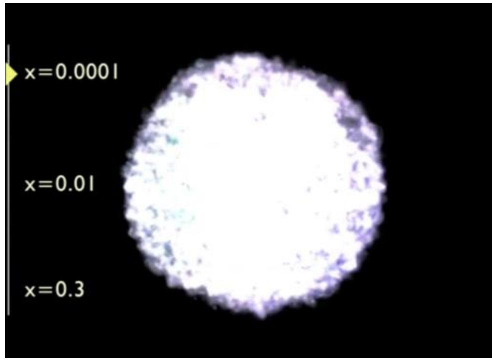
Kinematic region VS physics

See a video at:
http://eicug.org/

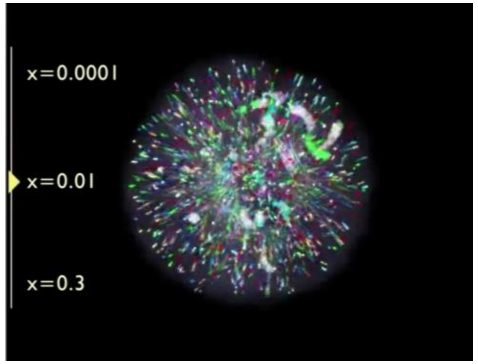




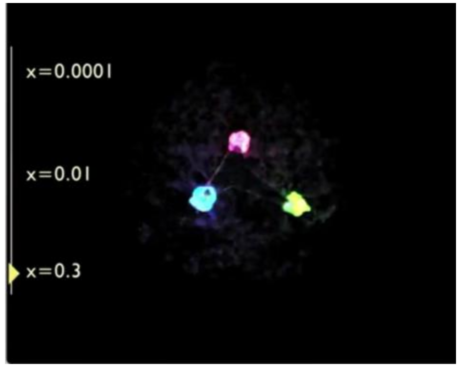




Gluon dominates



Gluon + sea quarks



Valence quarks

- Different x → different picture
- Broad Q^2 coverage:
  - ➢ QCD evolution
  - ➢ Non-perturbative → perturbative

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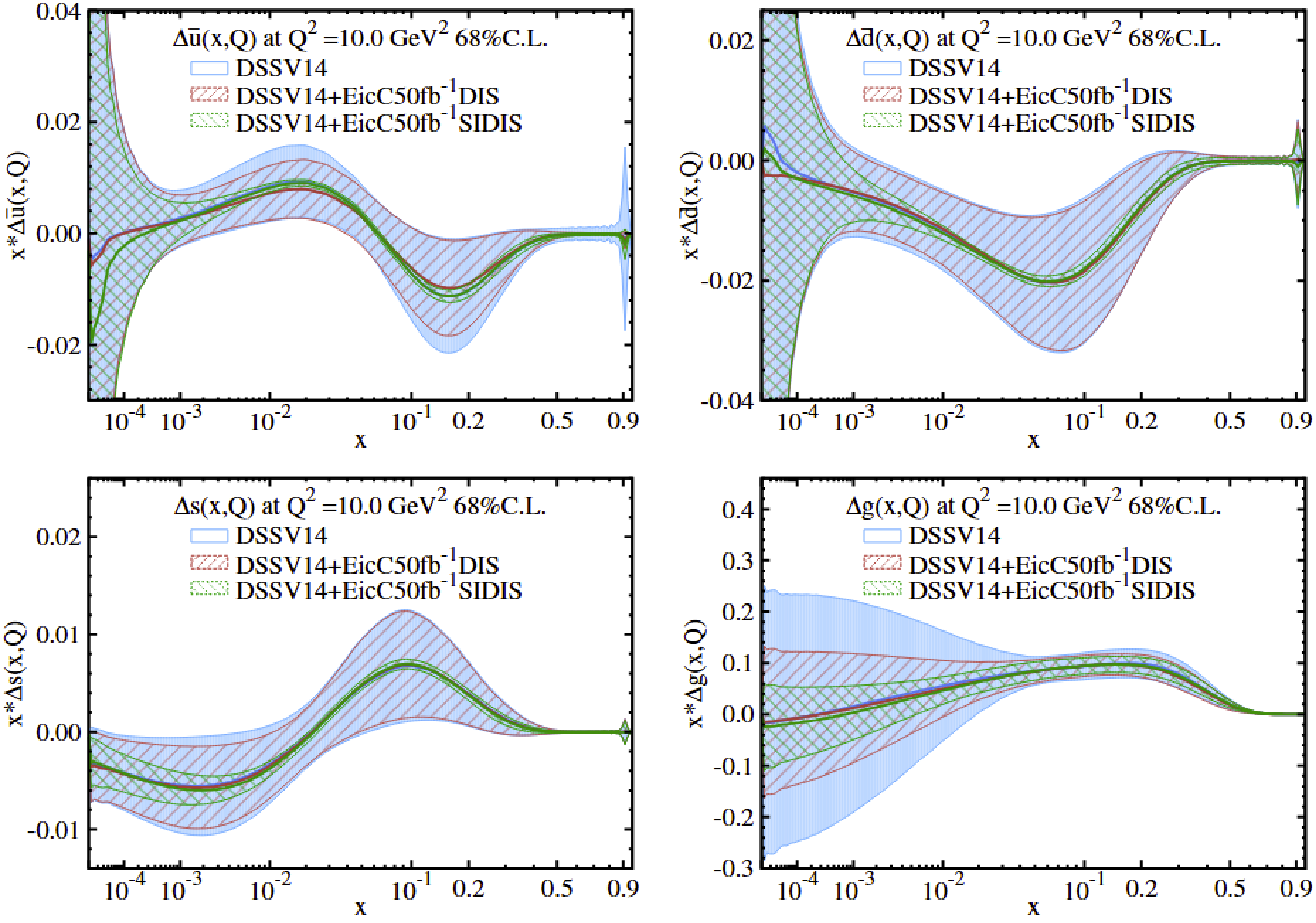
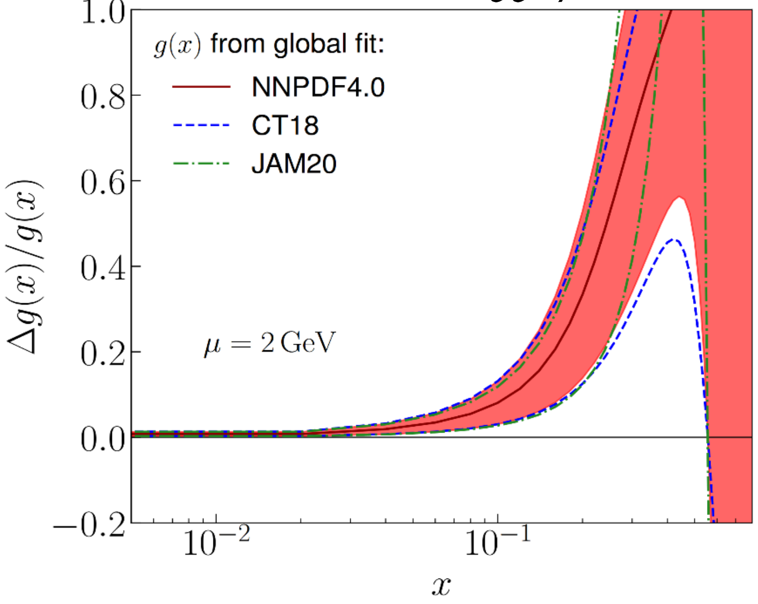
EicC -helicity distribution via SIDIS (1D spin)

D. Anderle, T. Hou, H. Xing, M. Yan, C. -P. Yuan, Y. X. Zhao, JHEP08, 034 (2021)

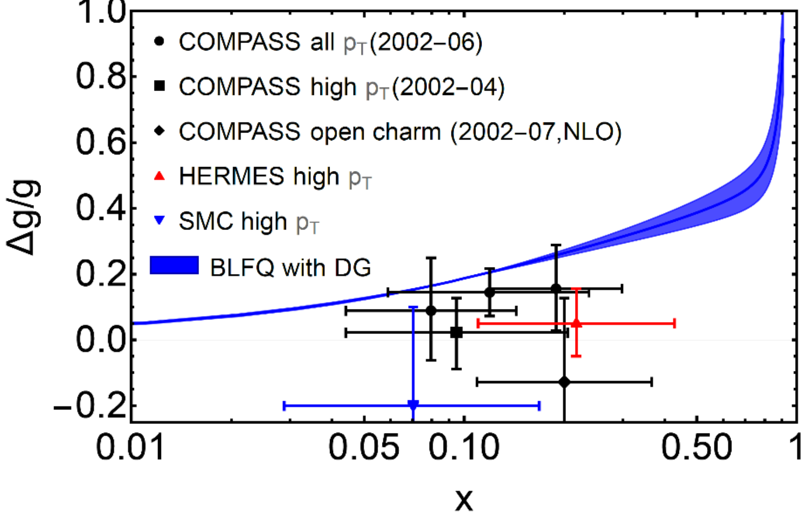


EicC and EIC-gluon polarization (at large x)

ArXiv:2211.15587



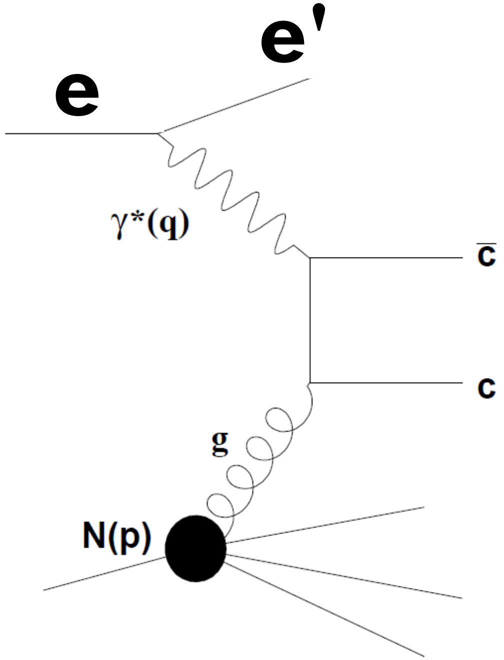
ArXiv:2209.08584

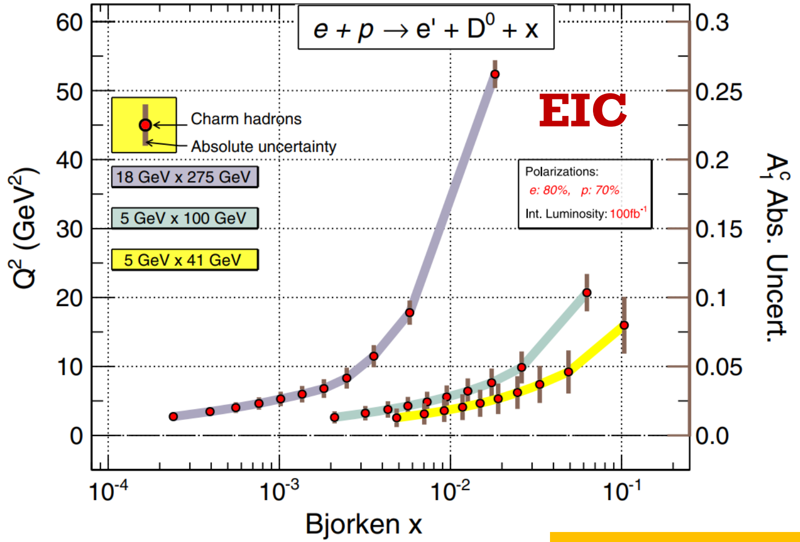


D. Anderle , X. Dong, …, E. Sichtermann, …, F. Yuan, Y. X. Zhao , Phys. Rev. D104, 114039 (2021)

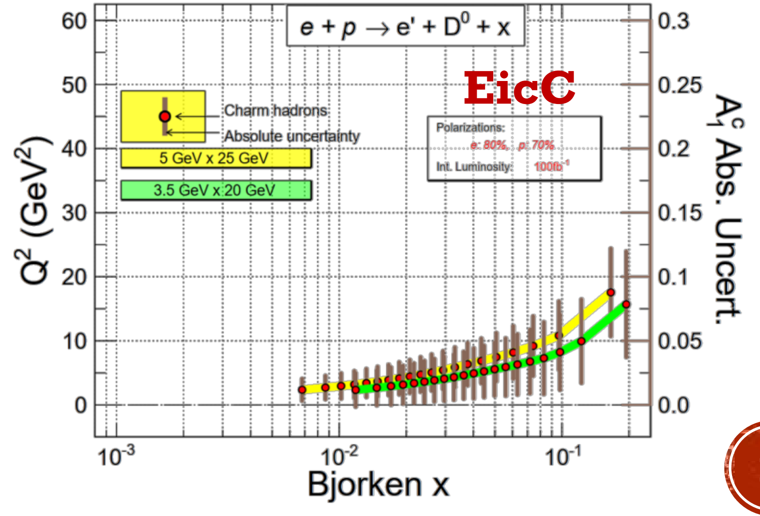
$$A_{LL}^{\vec{e}+\vec{p}\to e'+D^0+X} = \frac{d\sigma^{++} - d\sigma^{+-}}{d\sigma^{++} + d\sigma^{+-}}$$

$$= \frac{1}{P_e P_p} \frac{N^{++} - N^{+-}}{N^{++} + N^{+-}}$$





complementary



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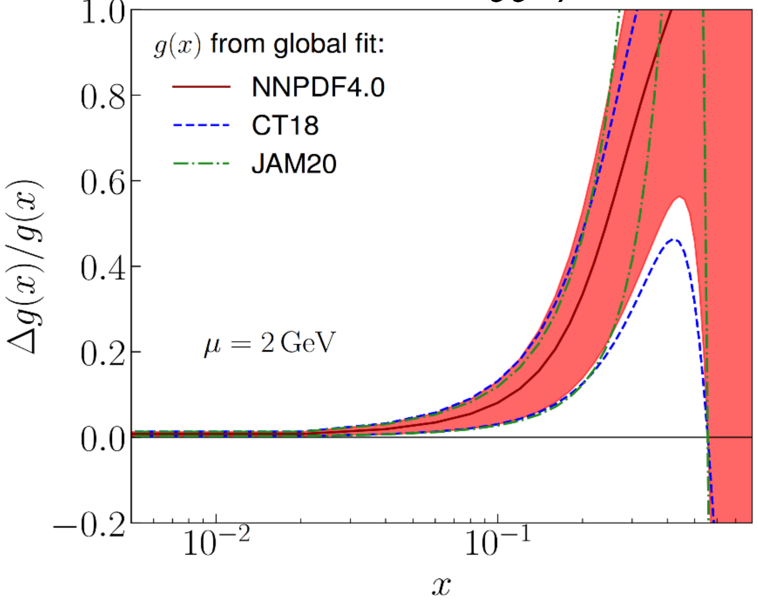

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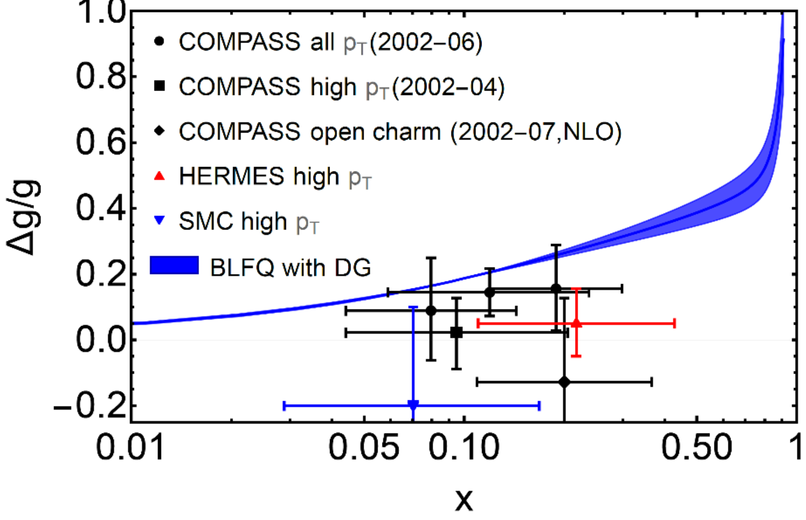

D. Anderle , X. Dong, …, E. Sichtermann, …, F. Yuan, Y. X. Zhao, Phys. Rev. D104, 114039 (2021)

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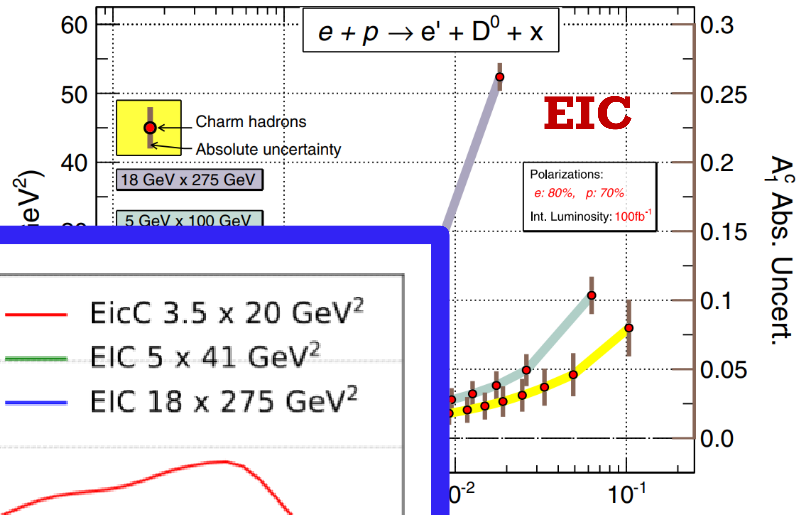
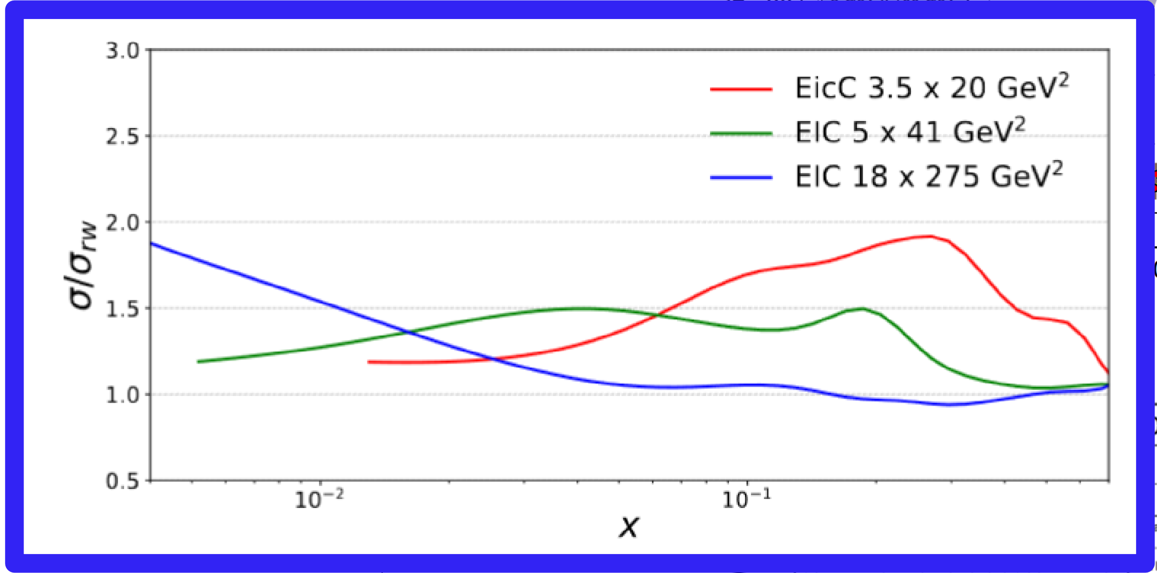
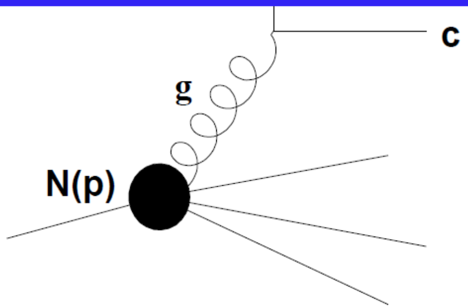
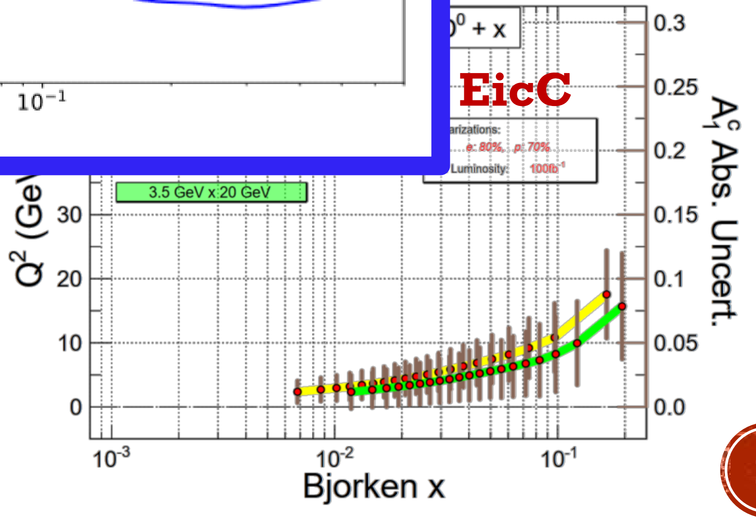
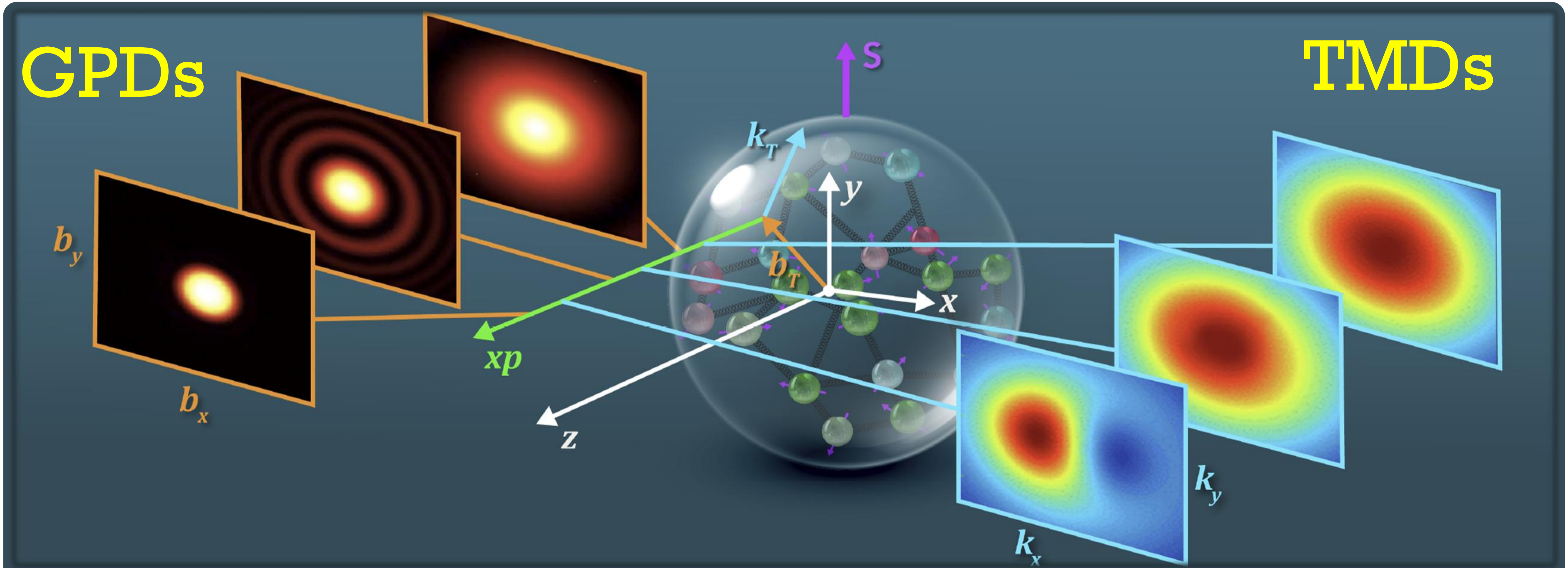




complementary





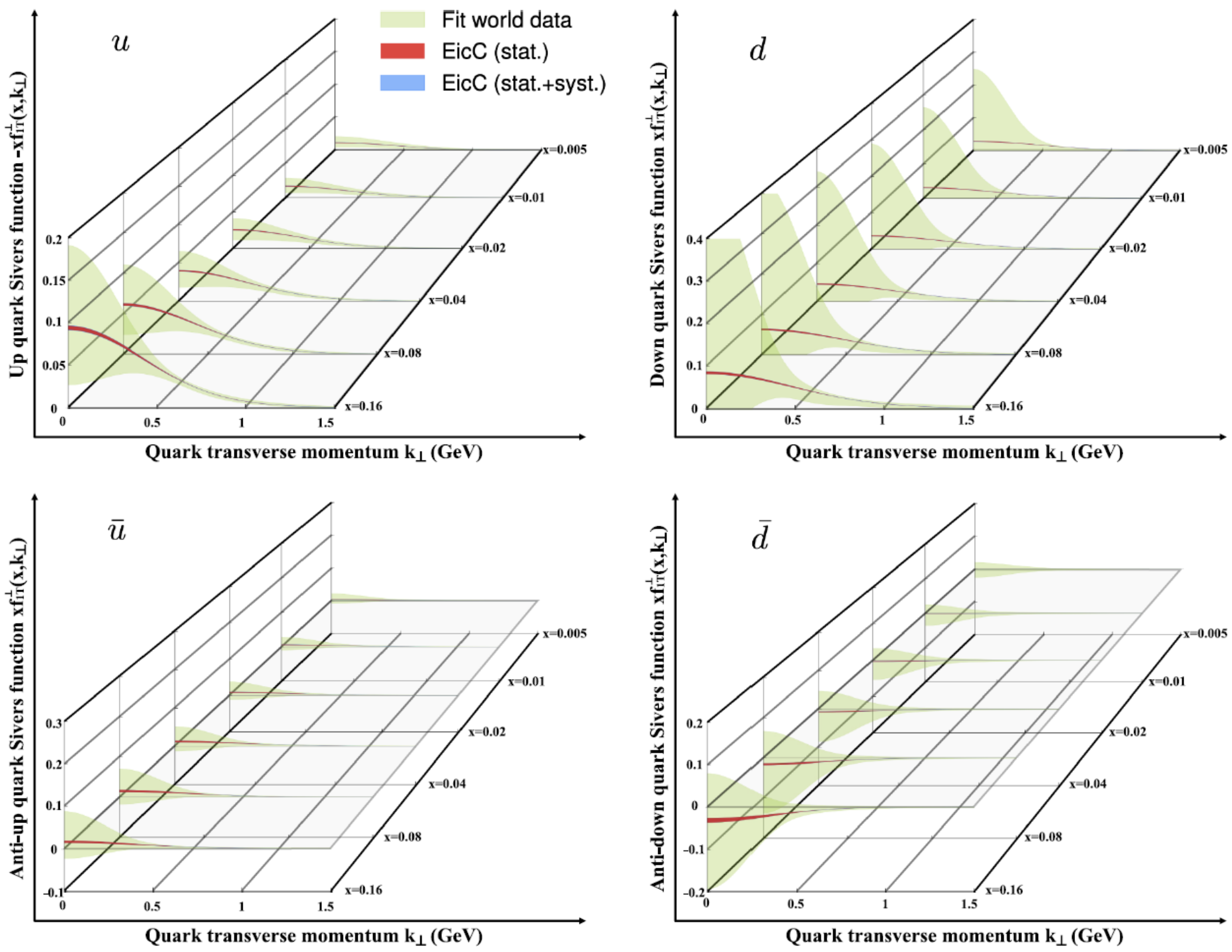


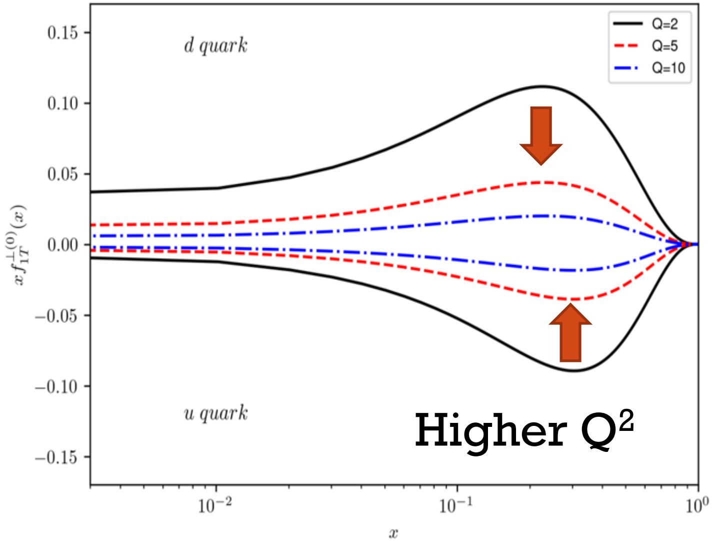
GPDs: deformation of Parton's spatial distribution when hadron is polarized

TMDs: deformation of Parton's confined motion when hadron is polarized

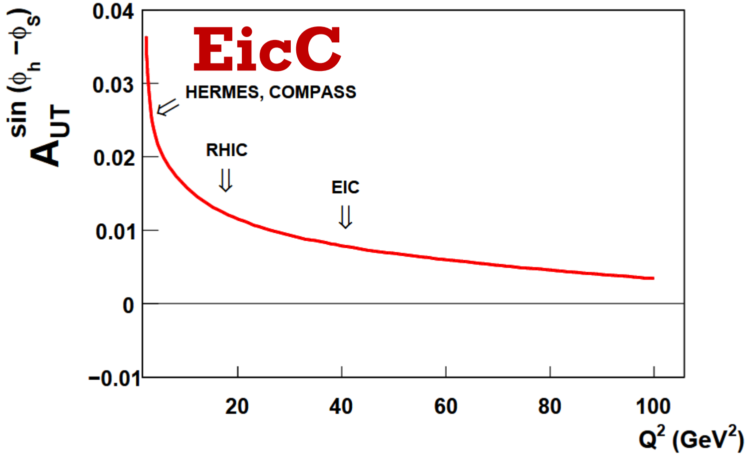
EicC and EIC-Sivers TMDs

C. H. Zeng, T. B. Liu, P. Sun, Y. X. Zhao, Phys. Rev. D106.094039 (2022)





S. Aybat et. al. Phys. Rev. Lett 108, 242003 (2012)

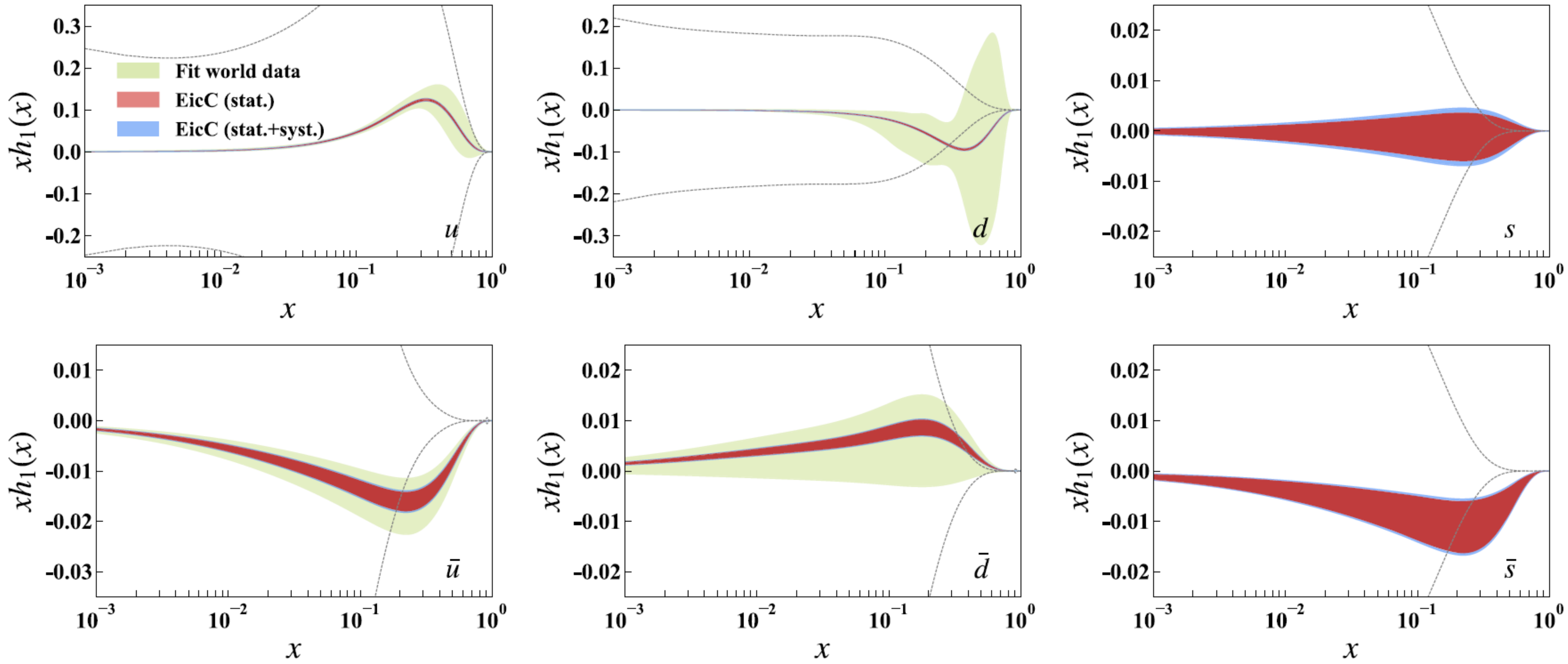


1. Higher Q^2, smaller effect
2. Smaller x, smaller effect

complementary

EicC impact on Transversity

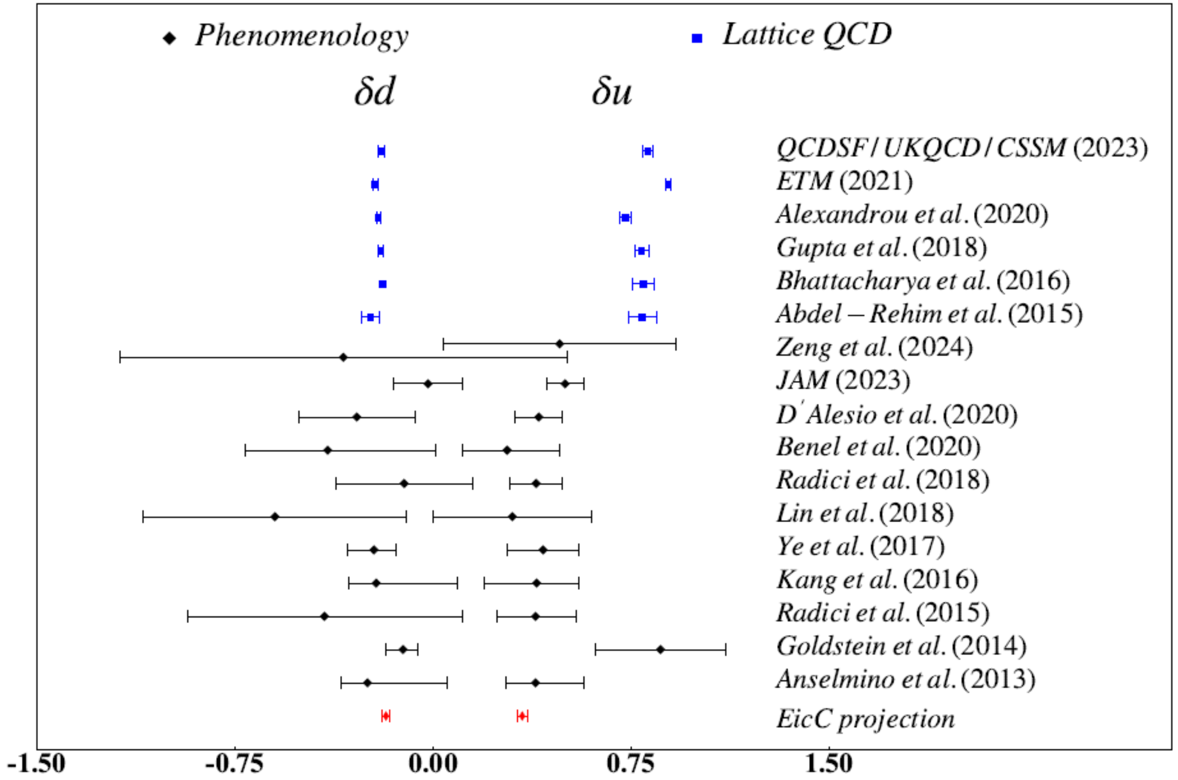
C. Zeng, H. Dong, T. B. Liu, P. Sun, and Y. X. Zhao, Phys. Rev. D 109 (5), 056002 (2024)

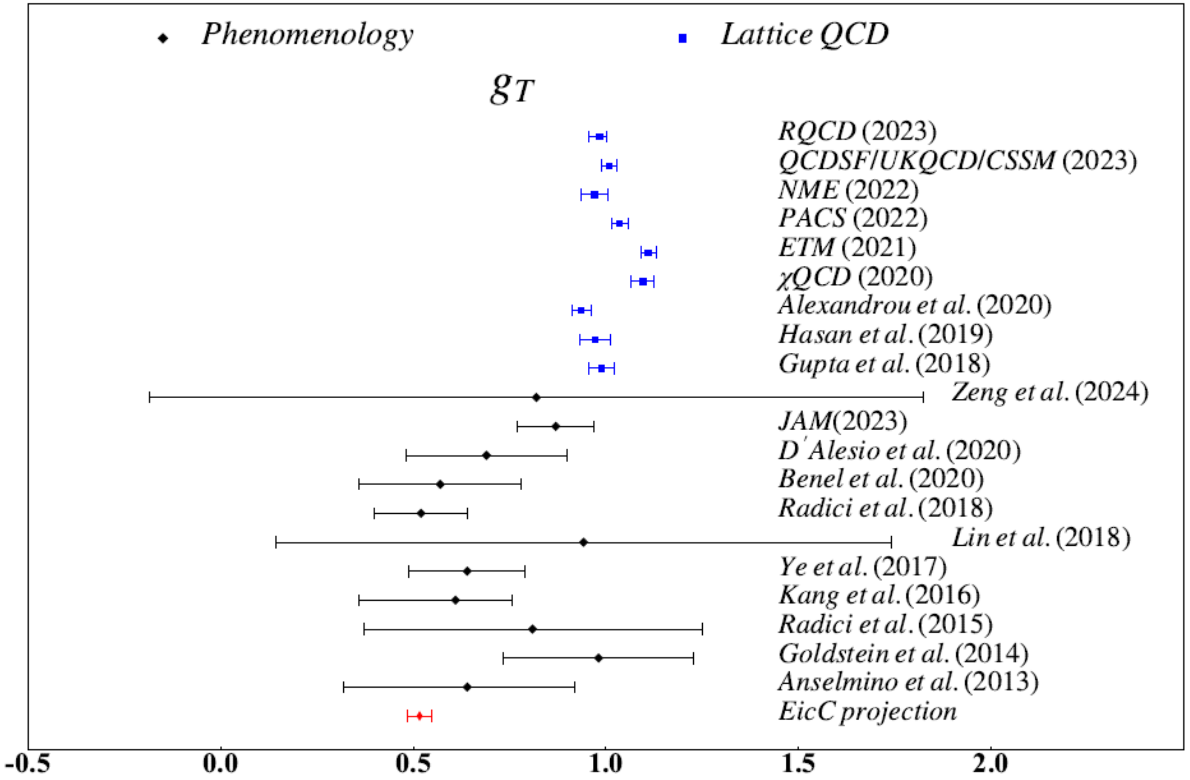


EicC can significantly improve the precision of transversity distributions, especially for sea quarks

Results on Tensor Charge

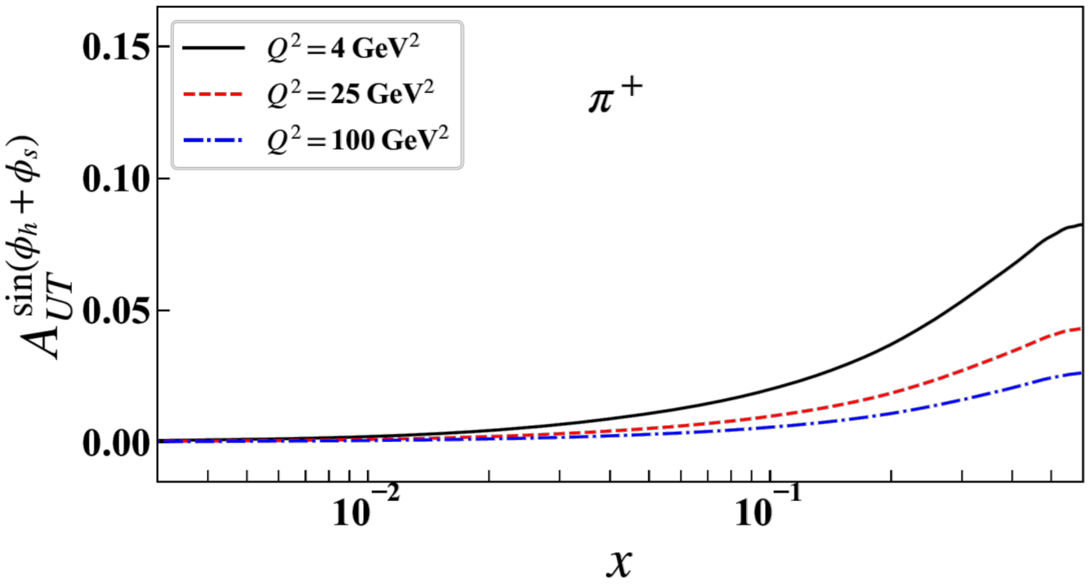
$$g_T = \delta u - \delta d$$



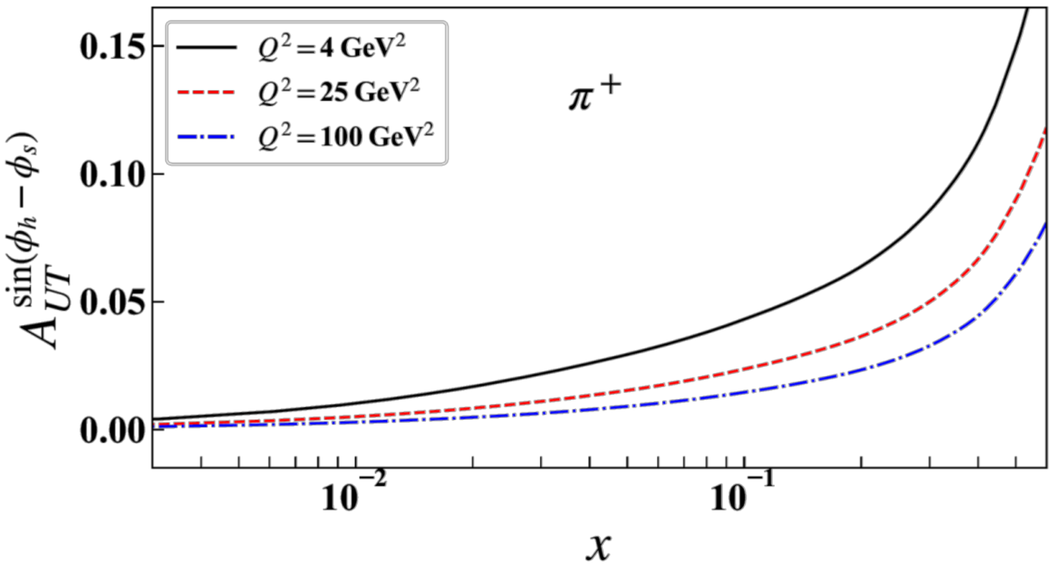


C. Zeng, H. Dong, T. B. Liu, P. Sun, and Y. X. Zhao, Phys. Rev. D 109 (5), 056002 (2024)

More words on TMDs study



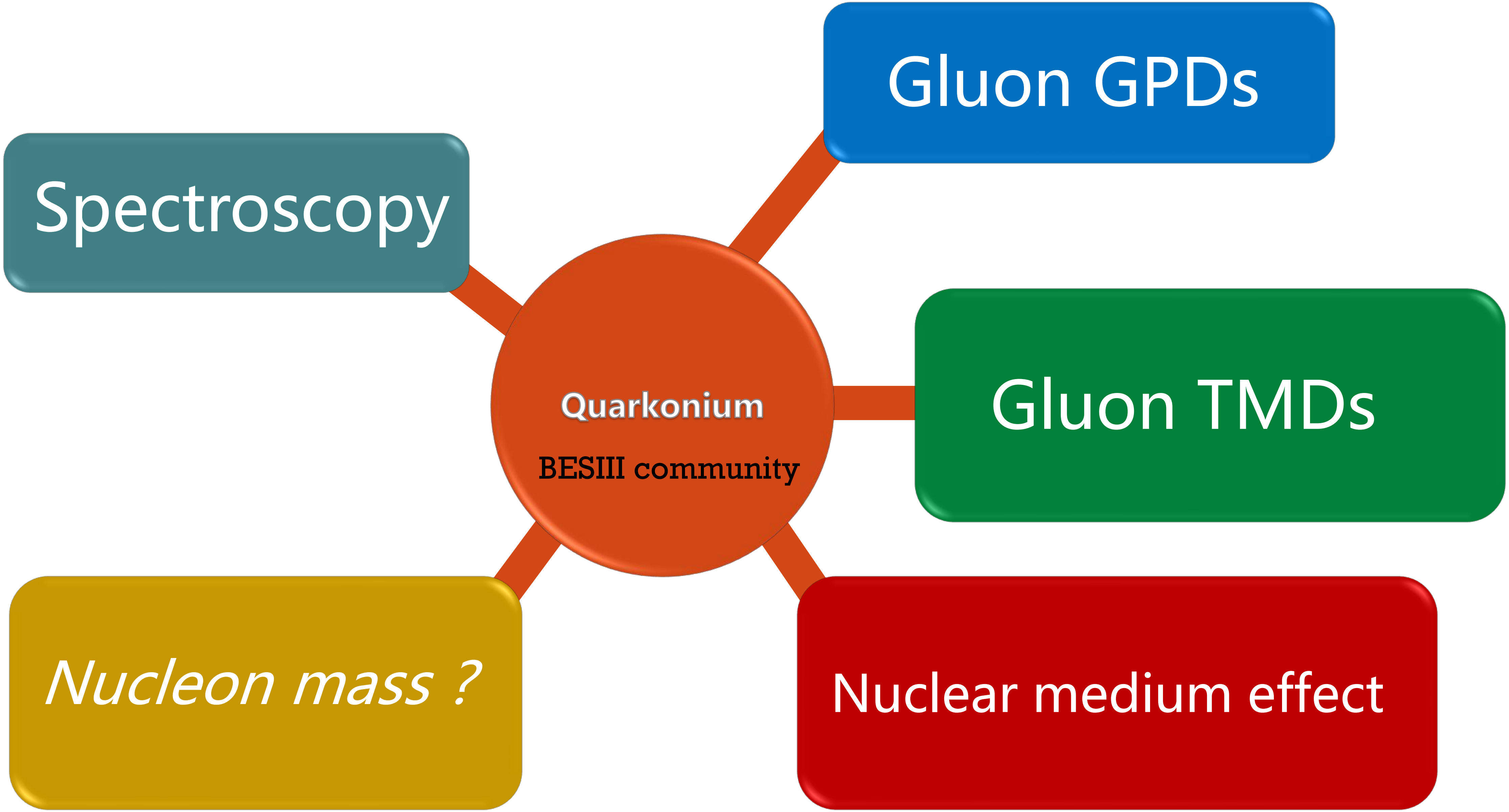
Collins effect observable



Sivers effect observable

For TMDs study: We need a moderate-energy EIC but with high luminosity

Quarkonium as a probe



J/Psi production at EicC

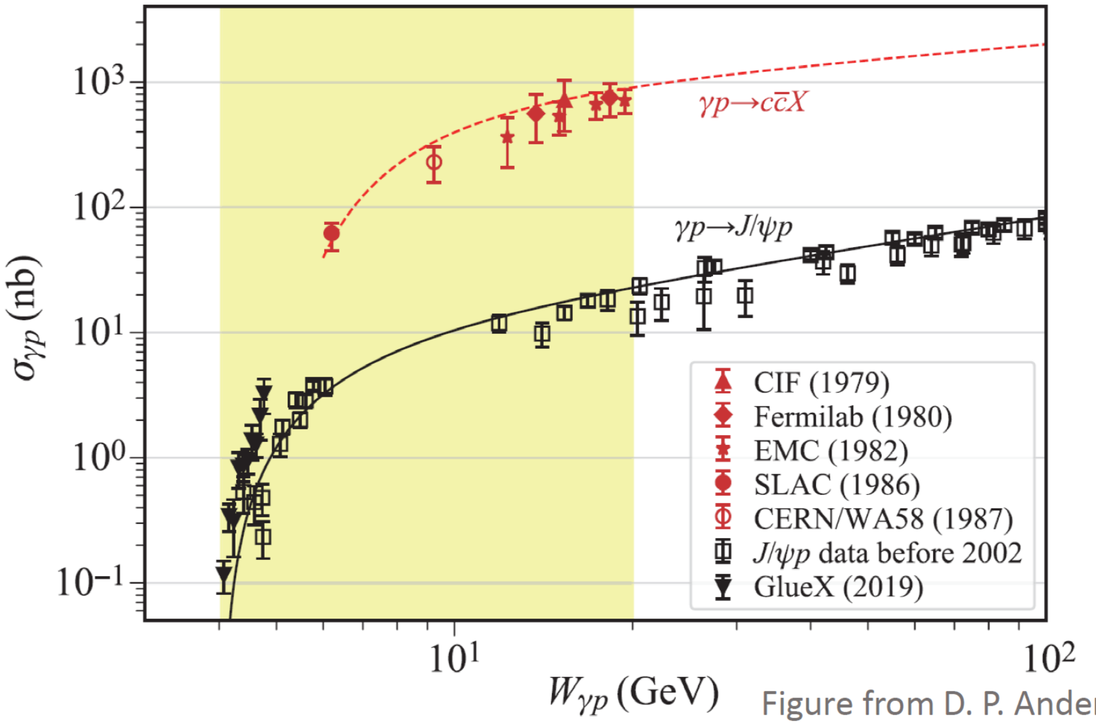


Figure from D. P. Anderle et al. Front.Phys.16(2021)64701

For W=10-20 GeV,

- Photoproduction: $\sigma(\gamma p \to J/\psi p) \sim O(10\text{ nb})$, (no resonant enhancement considered), $\sigma(\gamma p \to c\bar{c}X) \sim 50\sigma(\gamma p \to J/\psi p)$
- Leptoproduction: cross sections are roughly two orders of magnitude (α) smaller
- For an integrated luminosity of 50 fb^{-1}, no. of J/ψ is $\sim O(10^7 - 10^8)$; many more open-charm hadrons D and Λ_c

Upsilon production at EicC

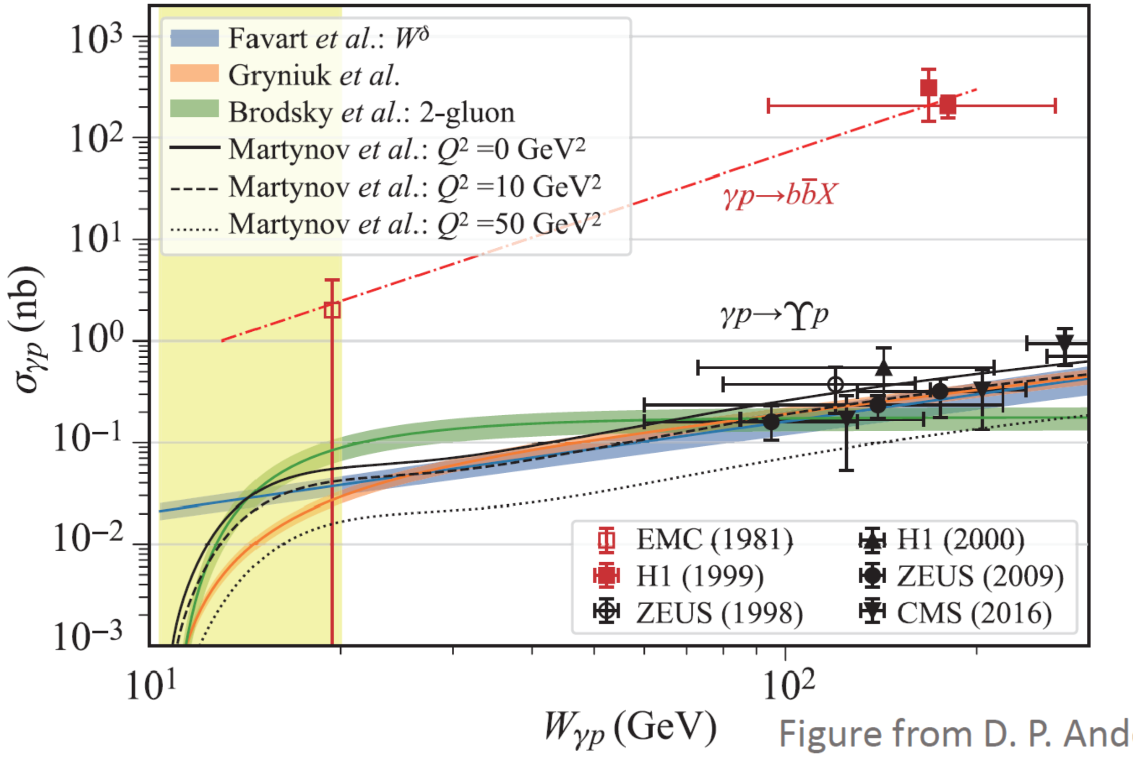


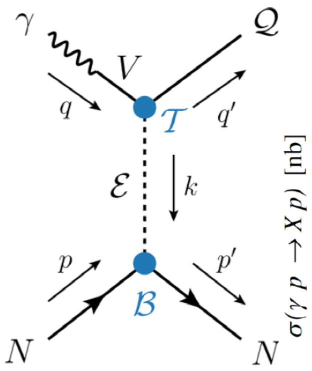
Figure from D. P. Anderle et al. Front.Phys.16(2021)64701

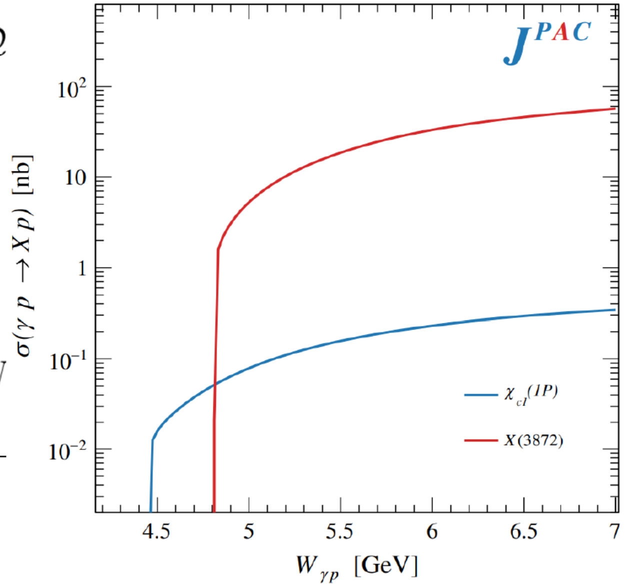
For W=15-20 GeV,

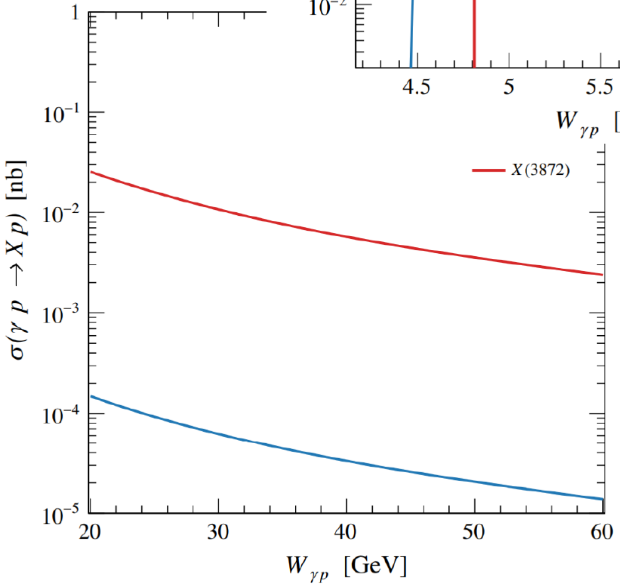
- Photoproduction: $\sigma(\gamma p \to \Upsilon p) \sim O(10\text{ pb})$ (no resonant enhancement considered), $\sigma(\gamma p \to b\bar{b}X)$ is about two orders higher
- Electroproduction: roughly two orders of magnitude (α) smaller, $\sim O(0.1\ pb)$
- For an integrated luminosity of 50 fb^{-1}, no. of Υ is $\sim O(10^4)$;

Search for exotic states at EicC

- Cross section estimates for exclusive reactions assuming VMD (highly model-dependent)







JPAC, PRD102(2020)114010

- Estimated events for EicC (50 /fb)

Exotic states	Production/decay processes	Detection efficiency	Expected events
$P_c(4312)$	$ep \to eP_c(4312)$ $P_c(4312) \to pJ/\psi$ $J/\psi \to l^+l^-$	~30%	15−1450
$P_c(4440)$	$ep \to eP_c(4440)$ $P_c(4440) \to pJ/\psi$ $J/\psi \to l^+l^-$	~30%	20−2200
$P_c(4457)$	$ep \to eP_c(4457)$ $P_c(4457) \to pJ/\psi$ $J/\psi \to l^+l^-$	~30%	10−650
P_b(narrow)	$ep \to eP_b$(narrow) P_b(narrow) $\to p\Upsilon$ $\Upsilon \to l^+l^-$	~30%	0−20
P_b(wide)	$ep \to eP_b$(wide) P_b(wide) $\to p\Upsilon$ $\Upsilon \to l^+l^-$	~30%	0−200
$\chi_{c1}(3872)$	$ep \to e\chi_{c1}(3872)p$ $\chi_{c1}(3872) \to \pi^+\pi^- J/\psi$ $J/\psi \to l^+l^-$	~50%	0−90
$Z_c(3900)^+$	$ep \to eZ_c(3900)^+ n$ $Z_c^+(3900) \to \pi^+ J/\psi$ $J/\psi \to l^+l^-$	~60%	90−9300

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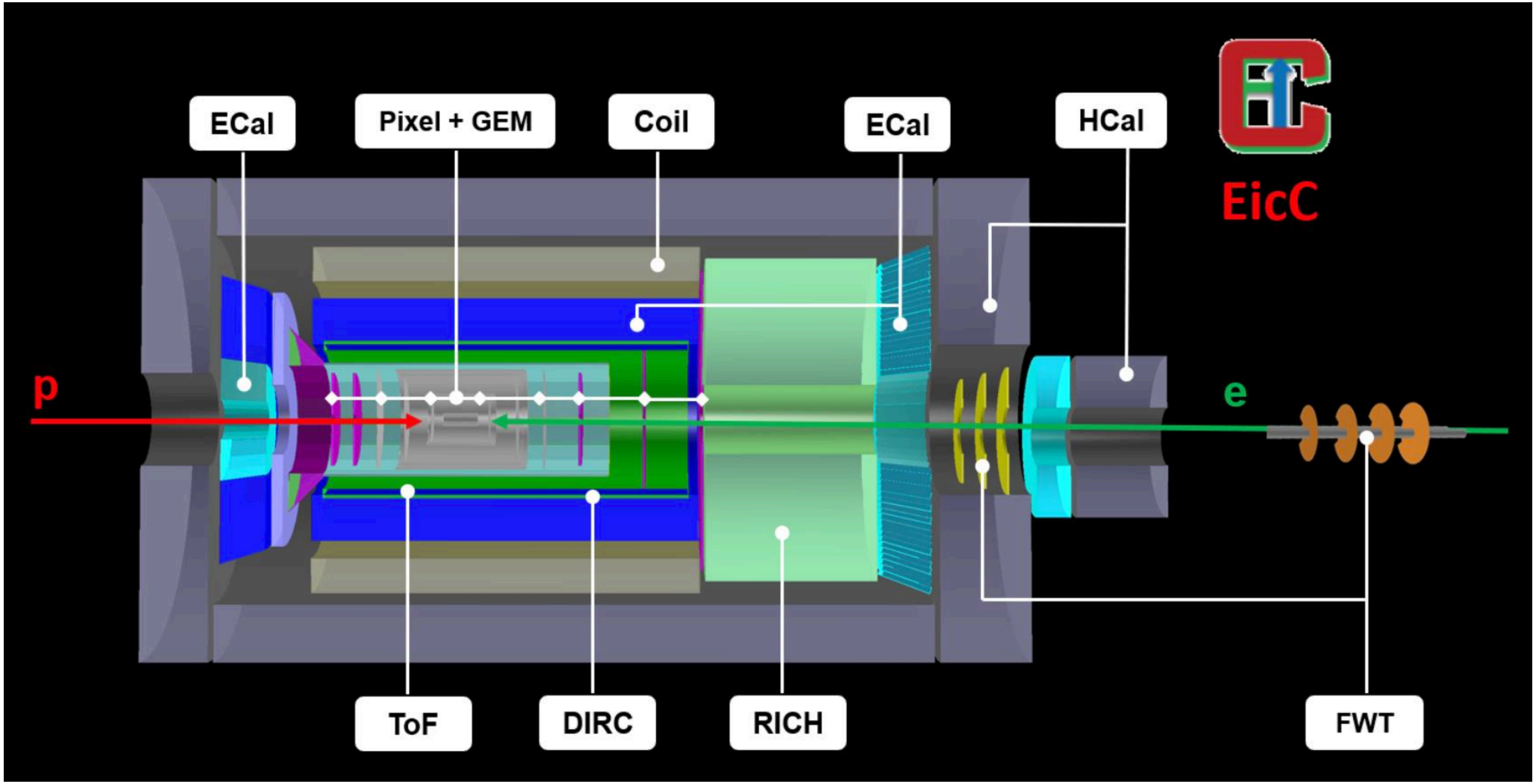
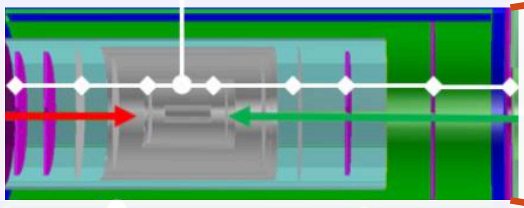
EicC detector design

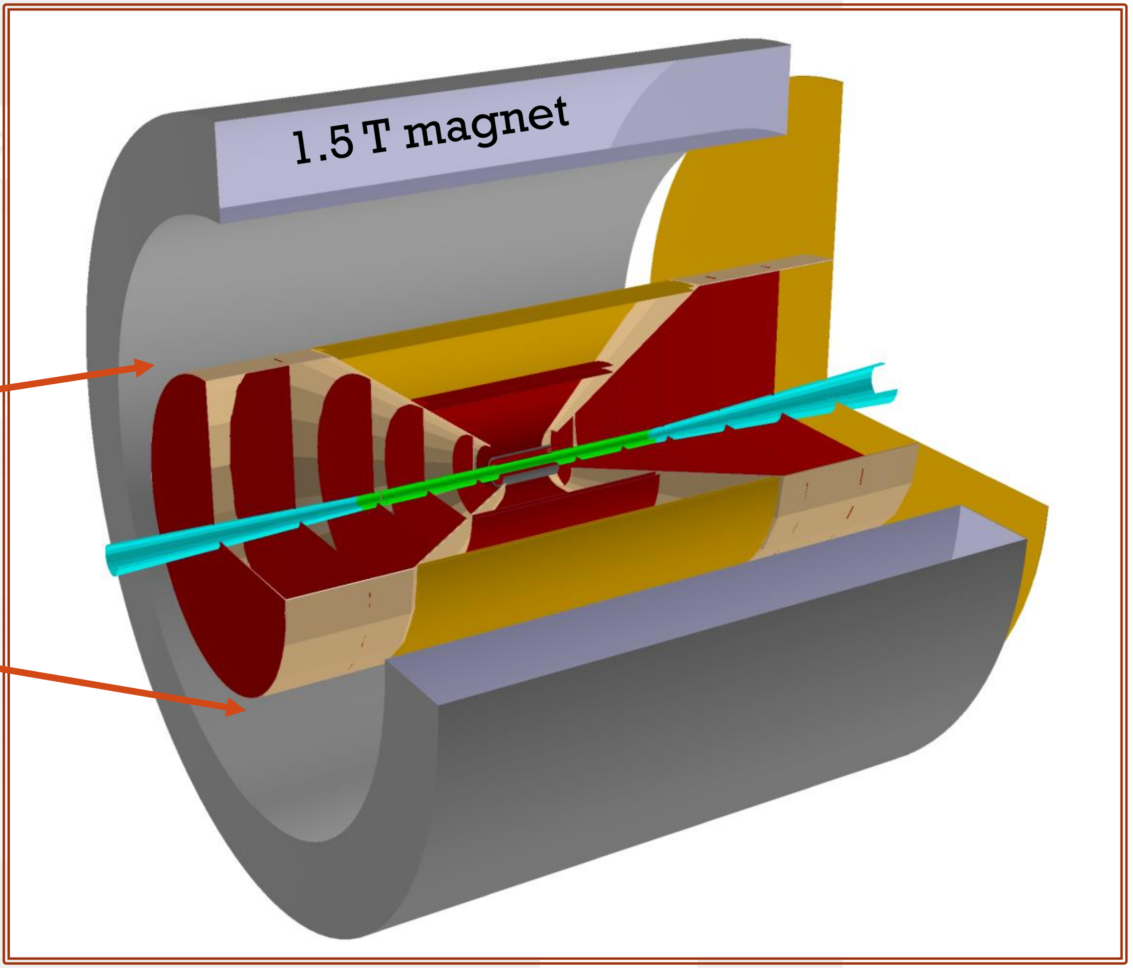


EicC detector design

Tracking: Silicon + MPGD

R(cm)	Length(cm)	Pixel Pitch(μm)	Material Budget (X/X0 %)	Tech
3.30	28.0	20	0.05	MIC7
4.35	28.0	20	0.05	MIC7
5.40	28.0	20	0.05	MIC7
34.85	90.61	25	0.85	MIC6
38.15	90.61	25	0.85	MIC6
65.50	174.88	150($r\phi$)x150(z)	0.40	MPGD
67.50	174.88	150($r\phi$)x150(z)	0.40	MPGD



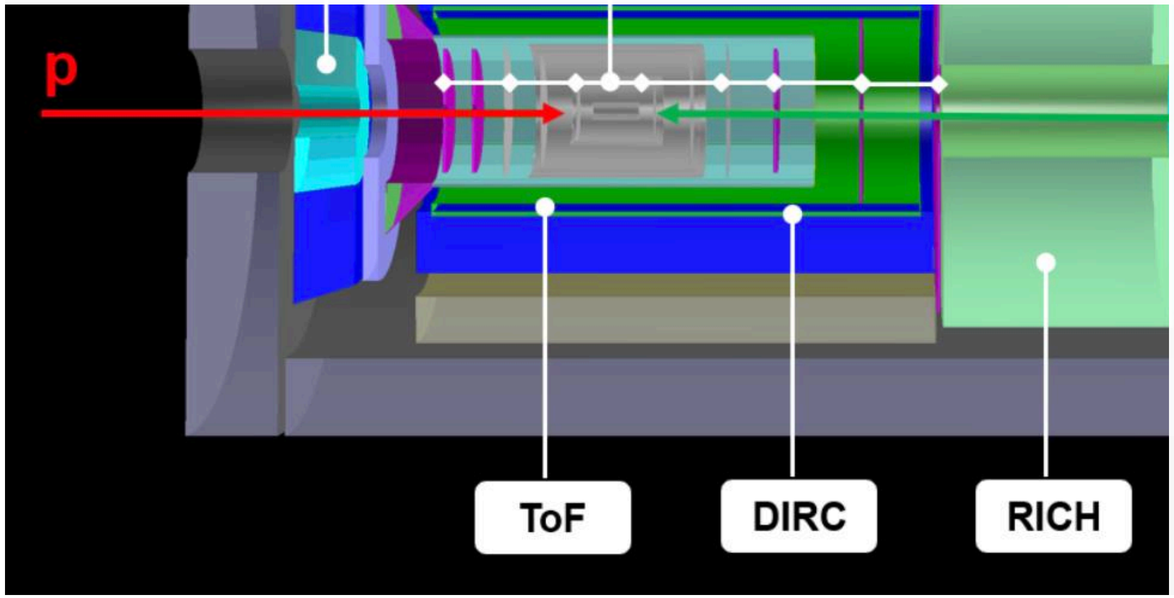


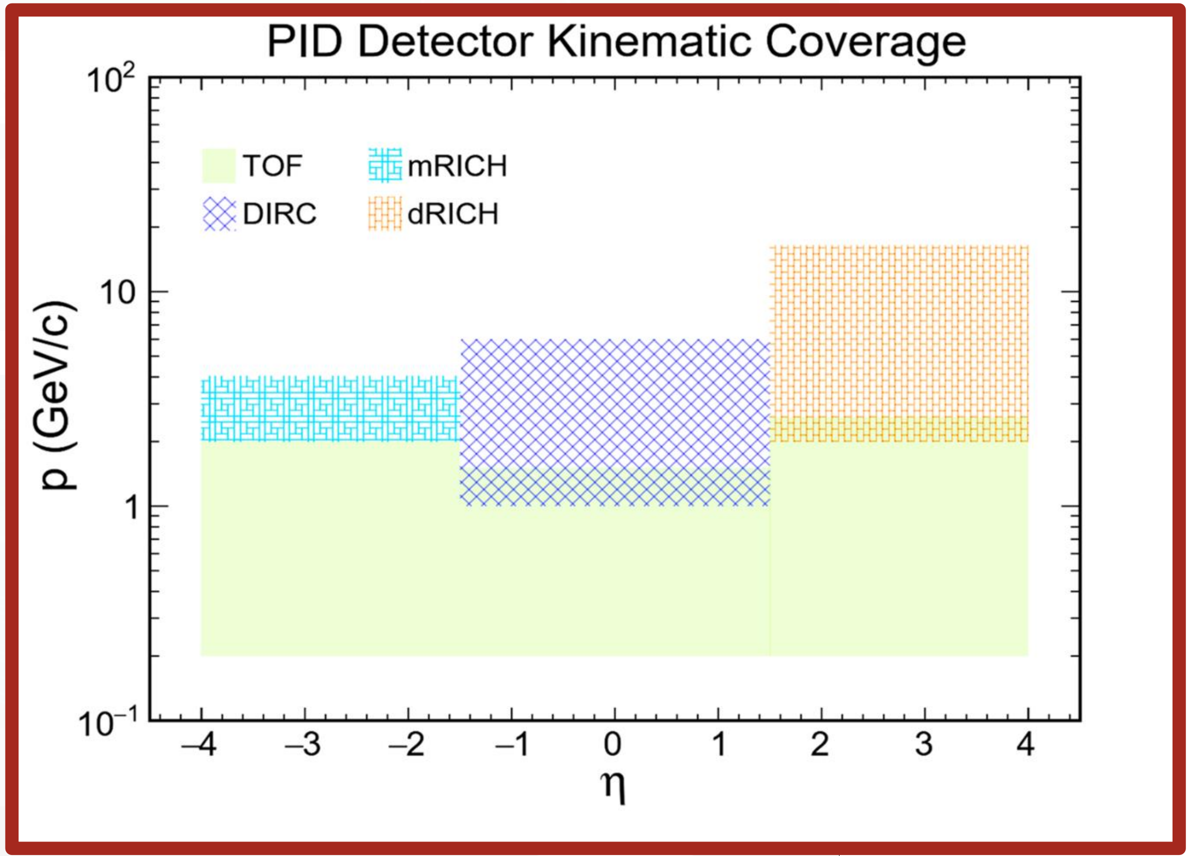
In R(cm)	Out R(cm)	Z(cm)	Pixel Pitch(μm)	Material Budget (X/X0 %)	Tech
3.18	18.62	25	25	0.42	MIC6
3.18	36.50	49	25	0.42	MIC6
3.47	55.00	73	25	0.42	MIC6
5.08	67.50	103.65	25	0.42	MIC6
6.58	67.50	134.33	25	0.42	MIC6
8.16	150.00	165.00	50($r\phi$)x250(r)	0.26	MPGD

In R(cm)	Out R(cm)	Z(cm)	Pixel Pitch(μm)	Material Budget (X/X0 %)	Tech
3.18	18.62	-25	25	0.42	MIC6
3.18	36.50	-49	25	0.42	MIC6
3.18	55.00	-73	25	0.42	MIC6
3.95	67.50	-109.0	25	0.42	MIC6
5.26	67.50	-145.0	25	0.42	MIC6

EicC detector design

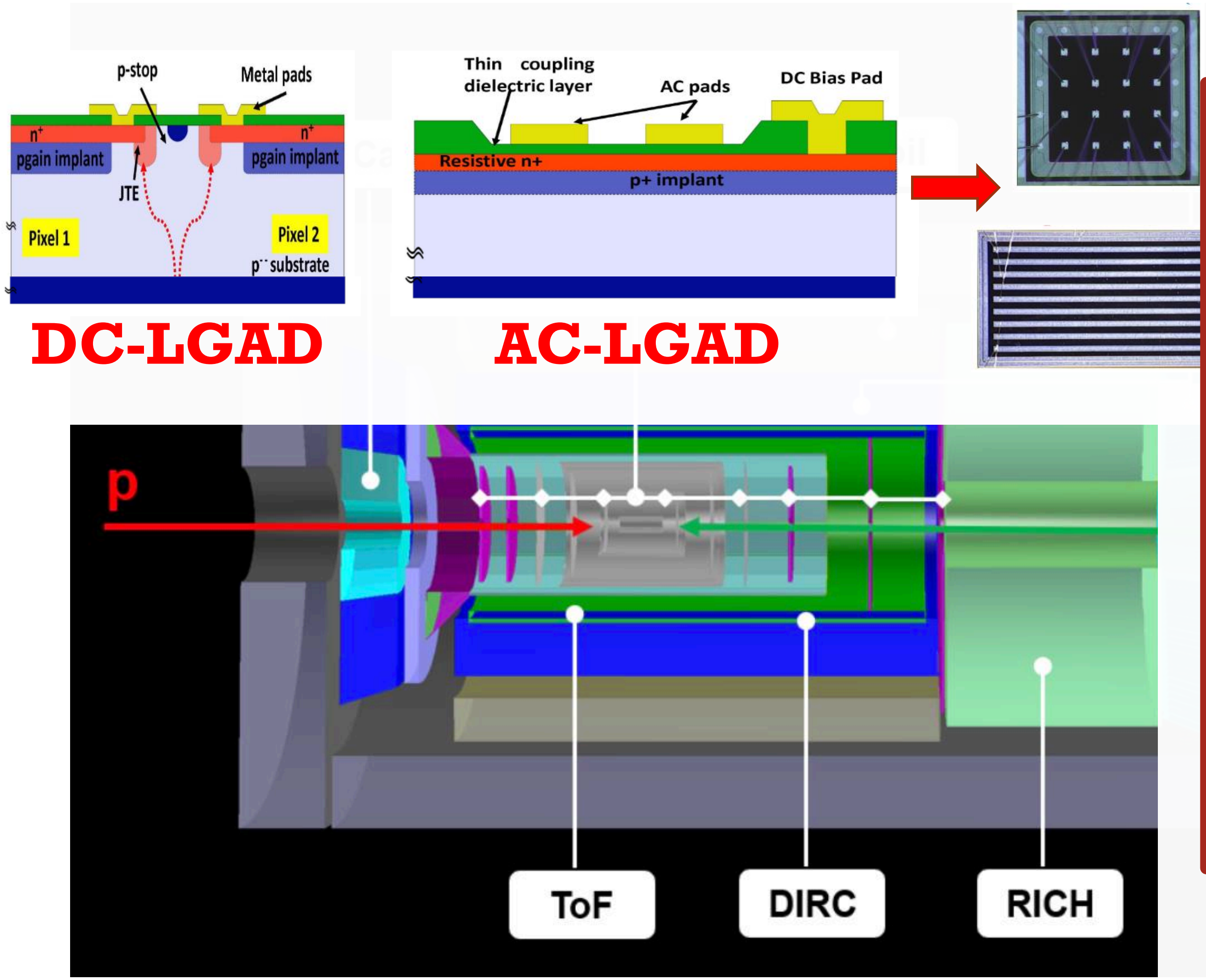
PID: ToF + (DIRC + RICH)

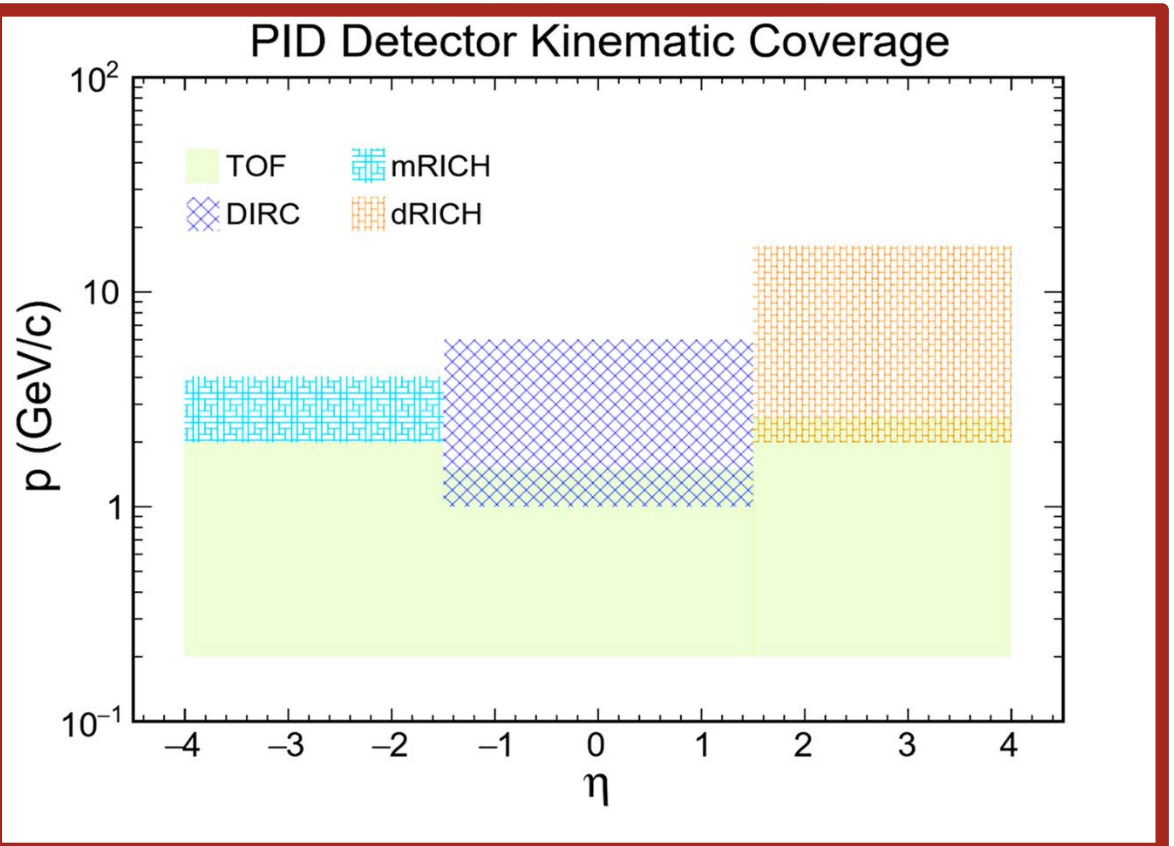




EicC detector design

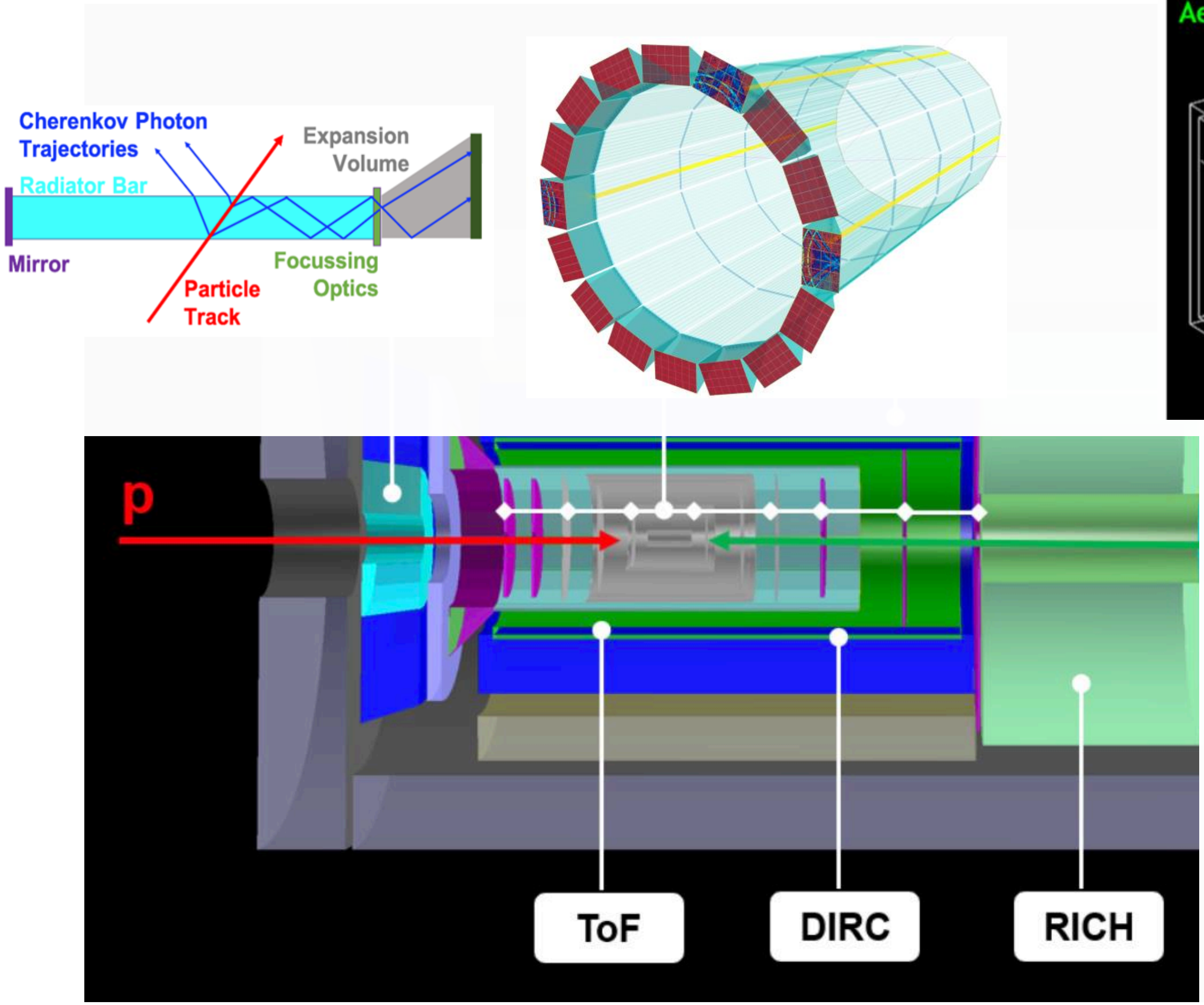
PID: ToF + (DIRC + RICH)

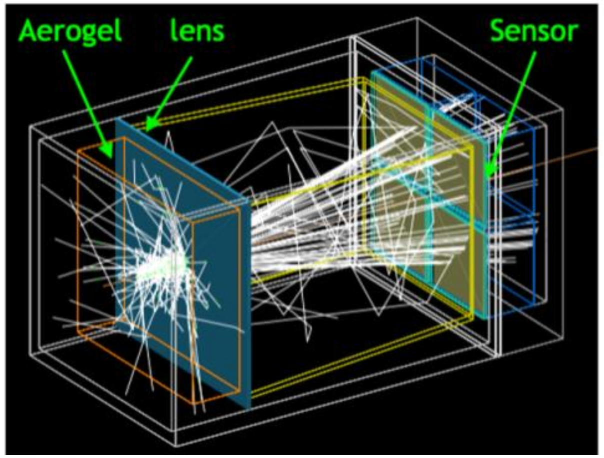


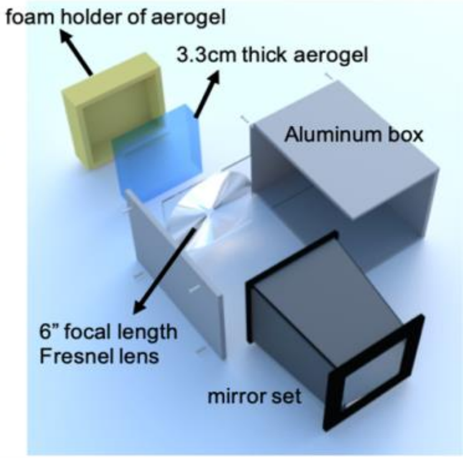


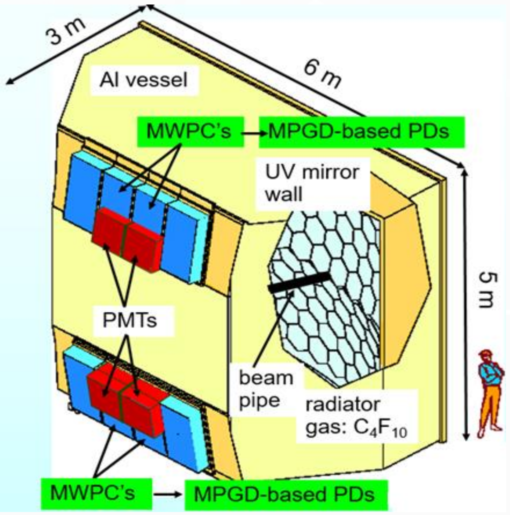
EicC detector design

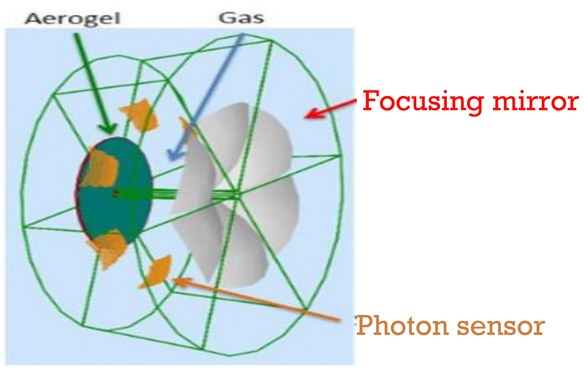
PID: ToF + (DIRC + RICH)





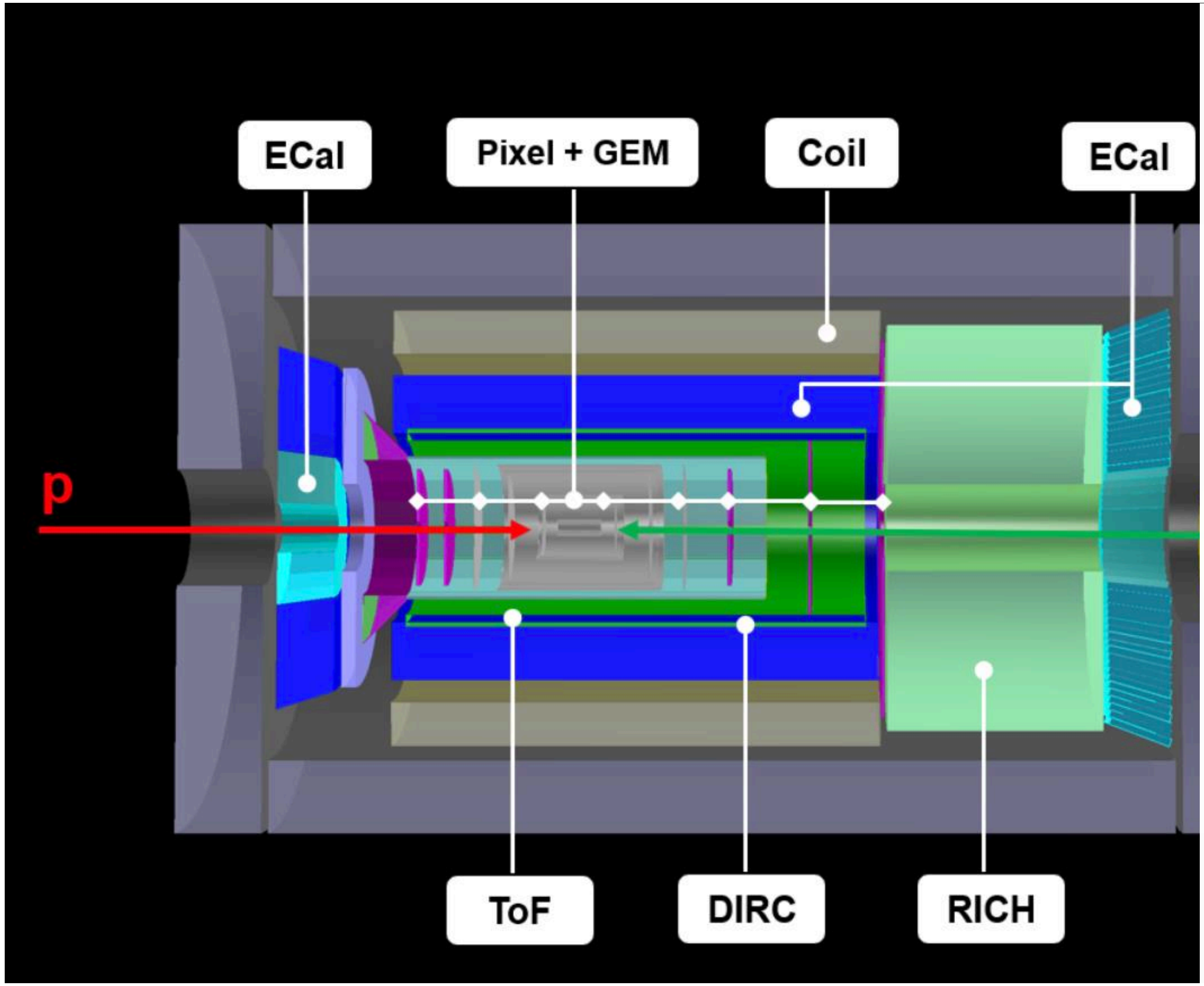


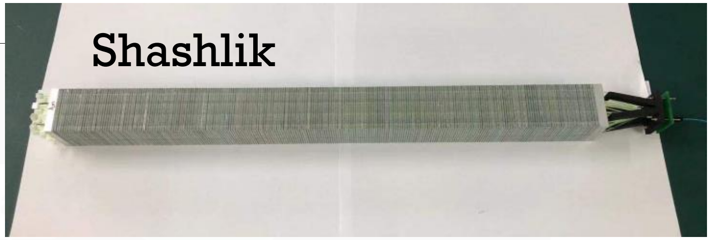


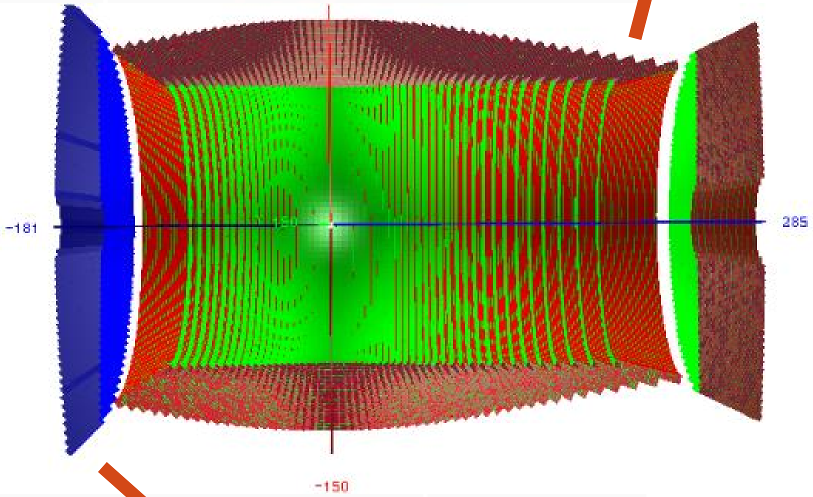


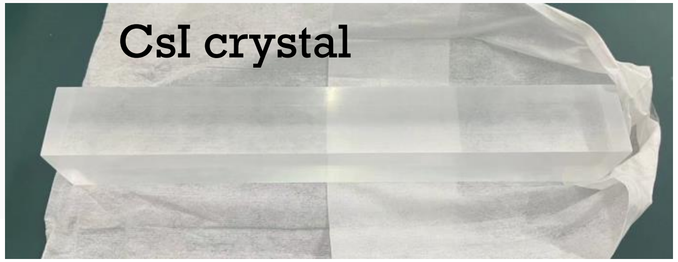
EicC detector design

Ecal: Shashlik + CsI crystal

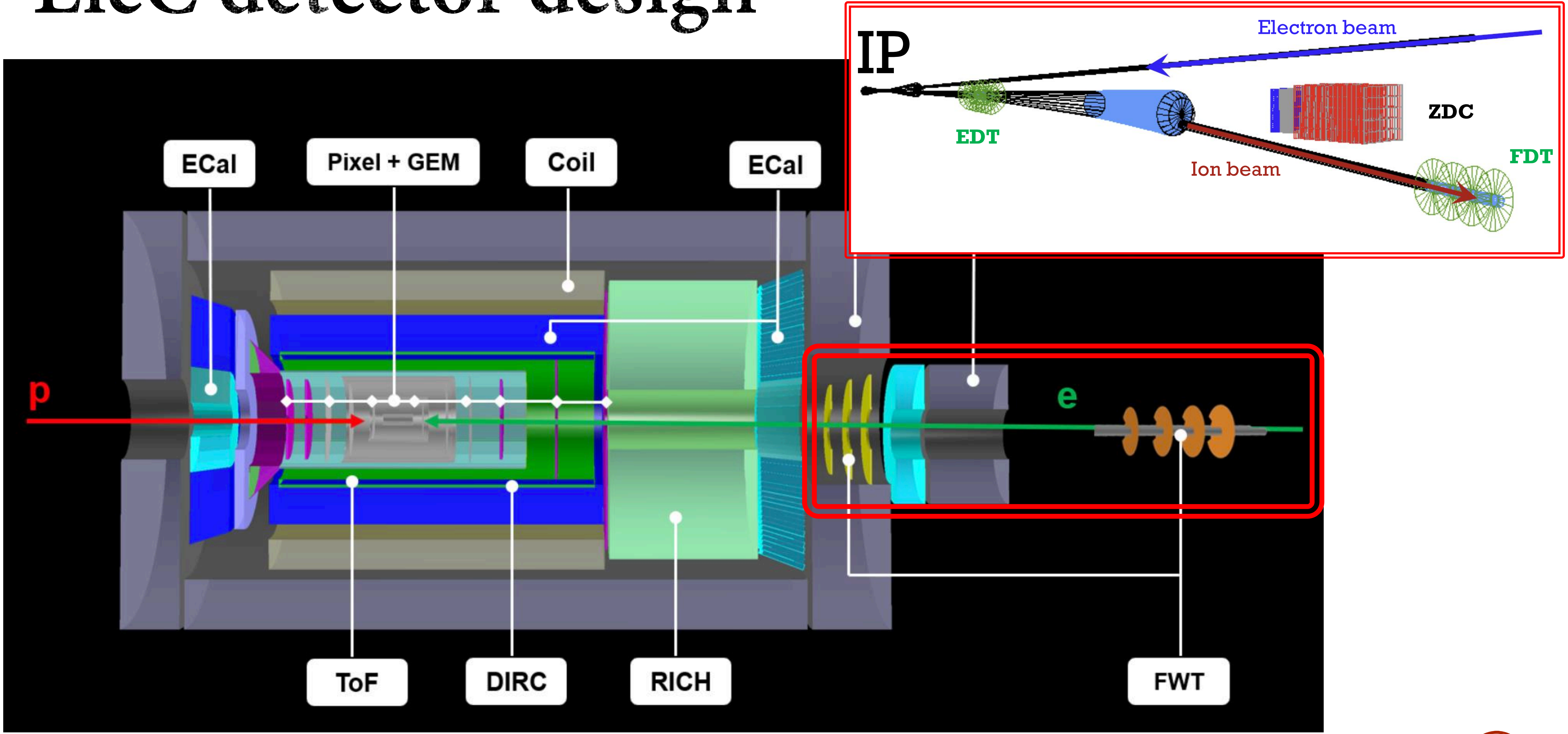








EicC detector design



Outline

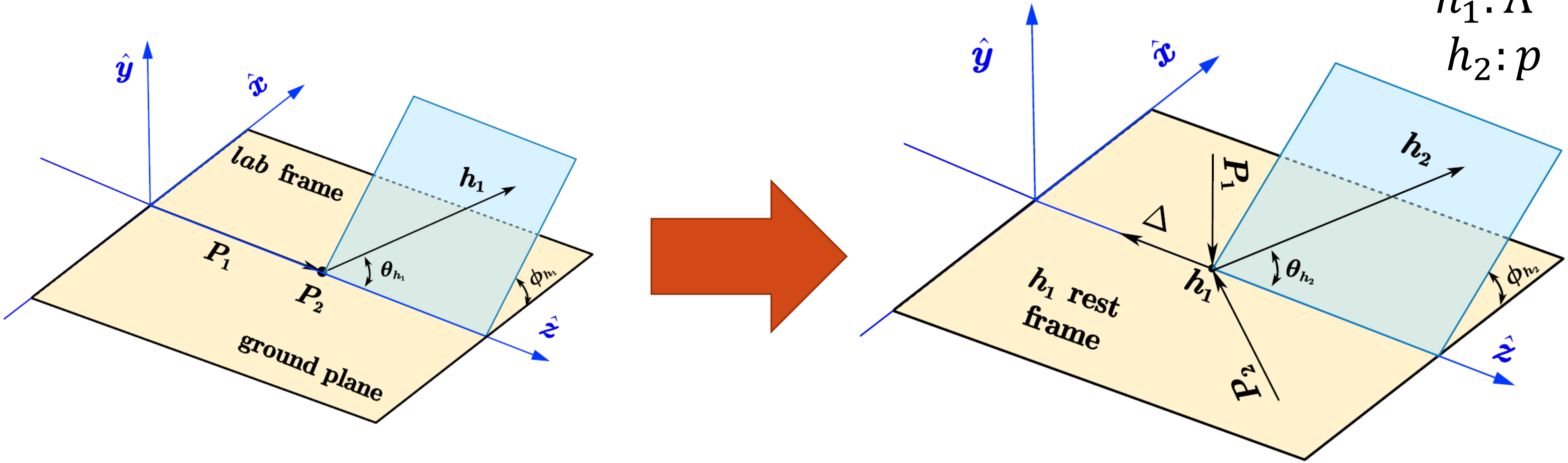
- Introduction
- Selected physics highlights at EicC
- Detector conceptual design
- China Hyperon-Nuclear Spectrometer (CHNS)
- Summary

A new domain: from nucleon to hyperon

Λ^0 serves as its own spin analyzer through the decay $\Lambda^0 \rightarrow p + \pi^-$

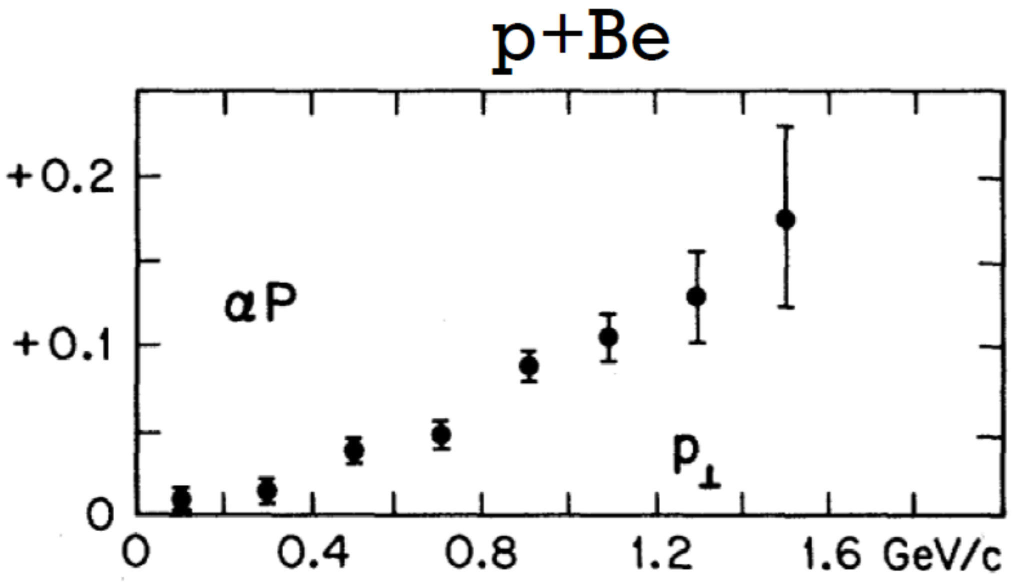
$h_1 : \Lambda^0$

$h_2 : p$



yield $\sim (1 + \alpha P cos\theta_{h_2})/4\pi$

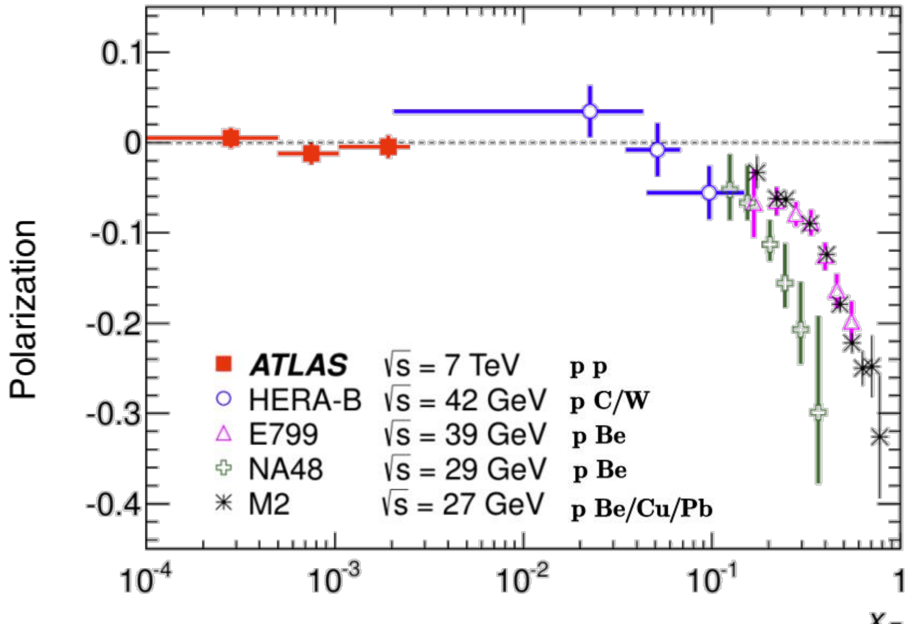
First observation of Λ^0 polarization in the 1970's



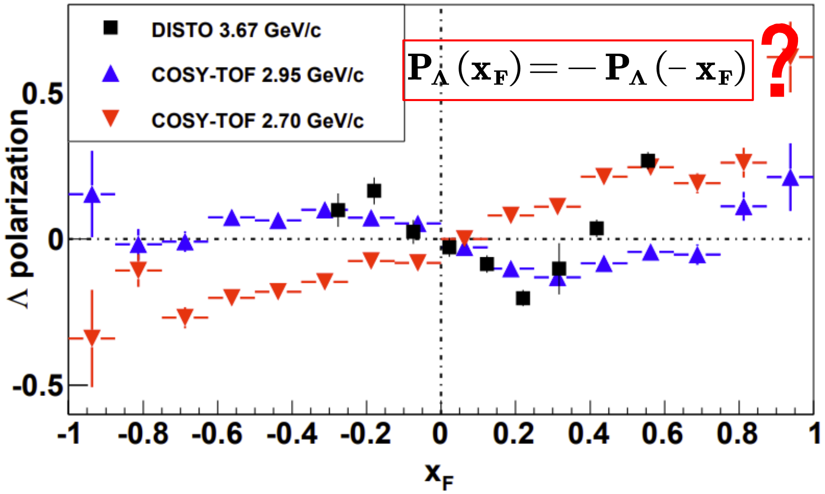
G.Bunce, *et al*.: Phys.Rev.Lett. 36, 1113-1116 (1976)

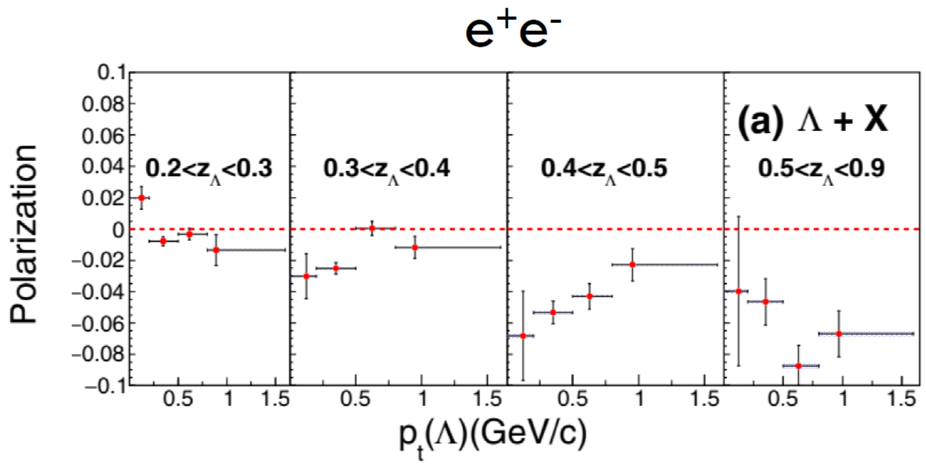
- Hyperons can be produced polarized in collisions of elementary particles
- Discovered at Fermilab in the 1970's in p + Be collisions: 300 GeV protons on Beryllium

Λ^0 polarization observed in both high and low energy collisions

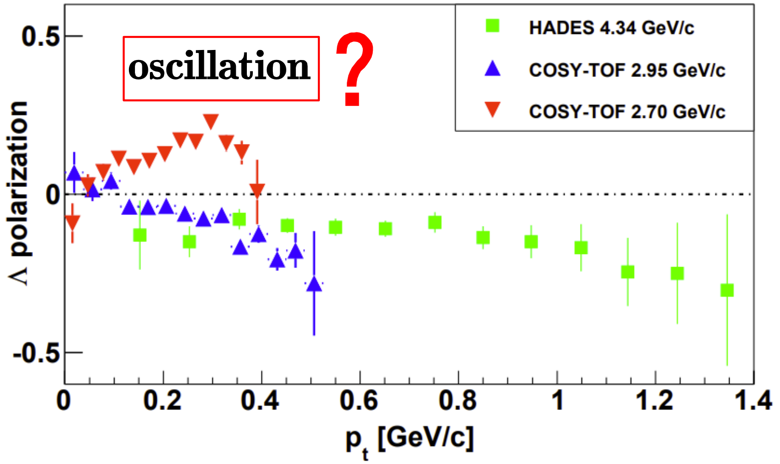


ATLAS Collaboration, Phys. Rev. D 91, 032004 (2015)



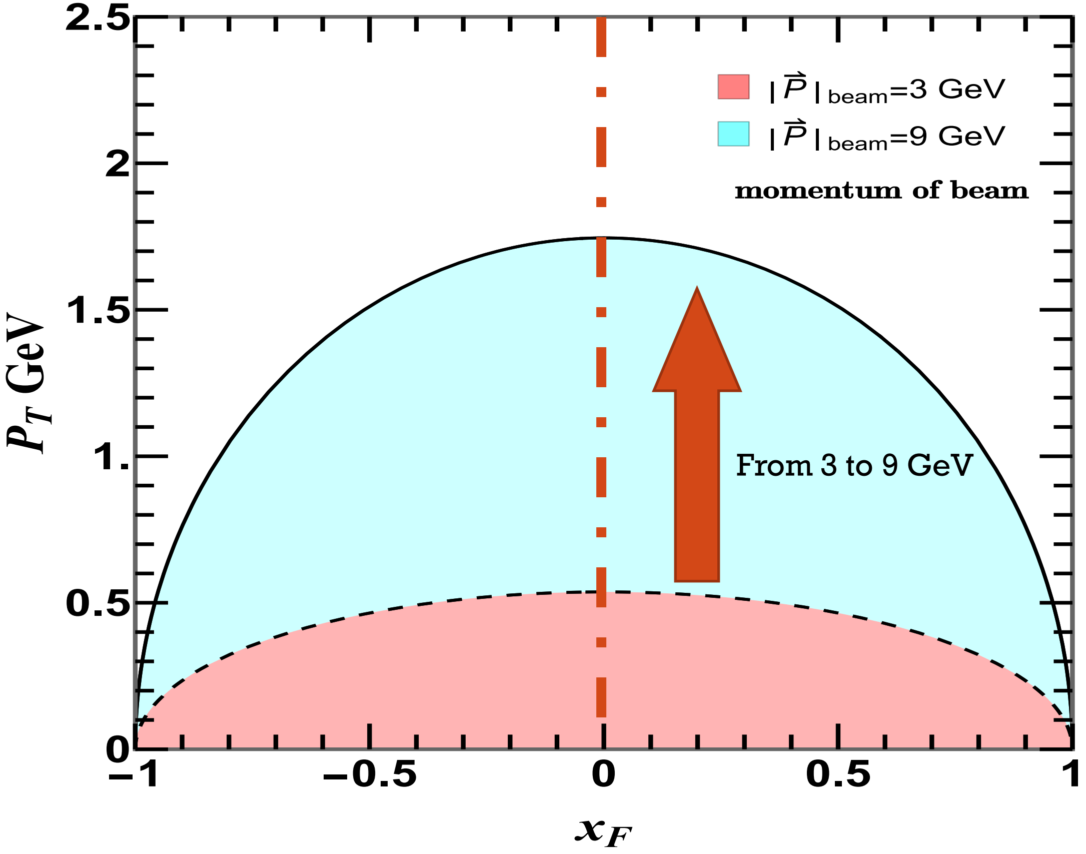


BELLE: Phys.Rev.Lett. 122, 042001 (2019)



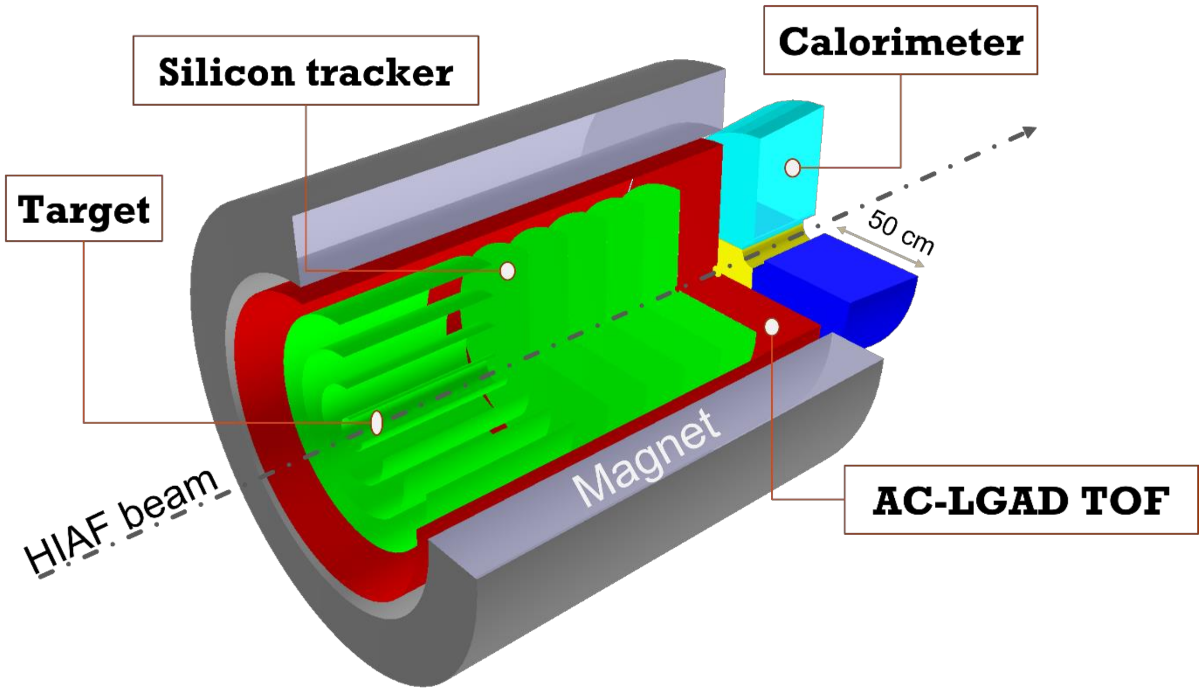
COSY-TOF Collaboration, Eur. Phys. J. A 52, 337 (2016)

HIAF kinematics coverage



Allow for a multi-dimensional mapping of the Λ^0 polarization and production

China Hyperon-Nuclear Spectrometer (CHNS)



I. Physics:

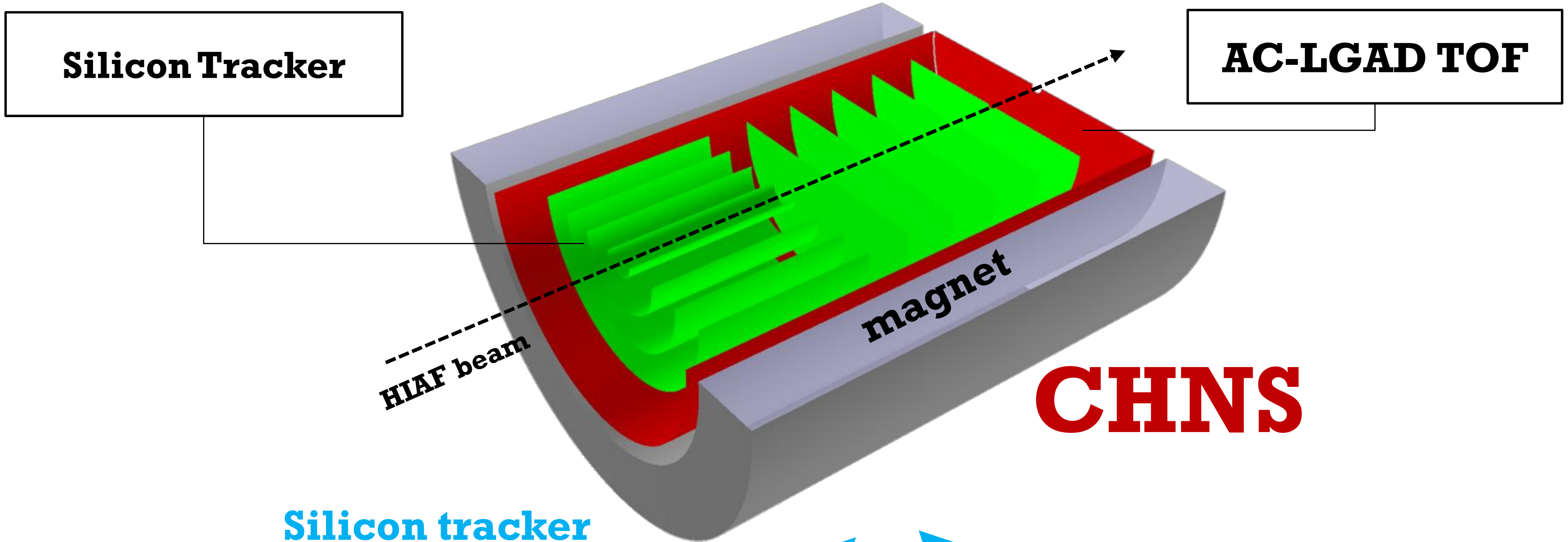
- Λ production and polarization (*p*+*p*)
    - Medium effect (*p*+*A*)
    - Global polarization of Λ hyperon (*A*+*A*)
- Hadron physics via *p*+*p*

II. Community:

- Supports both communities of hadron structure and heavy-ion physics
- Your involvements are very welcome!

III. Detector R&D

- Many parts are similar for CHNS, EicC, STCF and CEPC. Save resources.
- CHNS: a detector R&D platform for EicC, ½ EicC

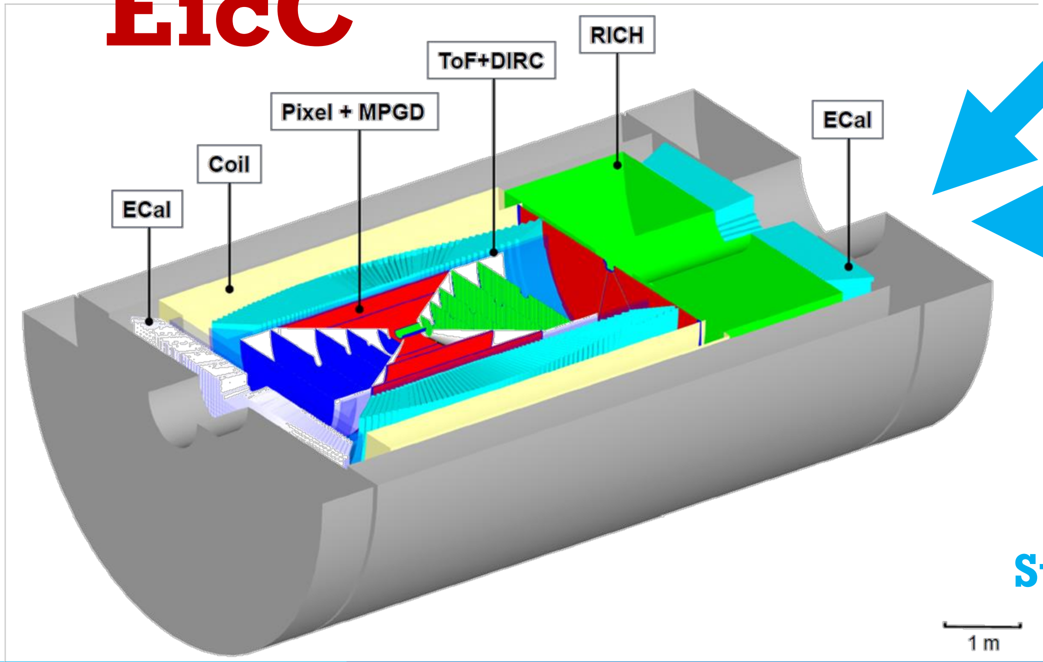


CHNS

Silicon tracker
AC-LGAD (PID)
Super-conducting Solenoid

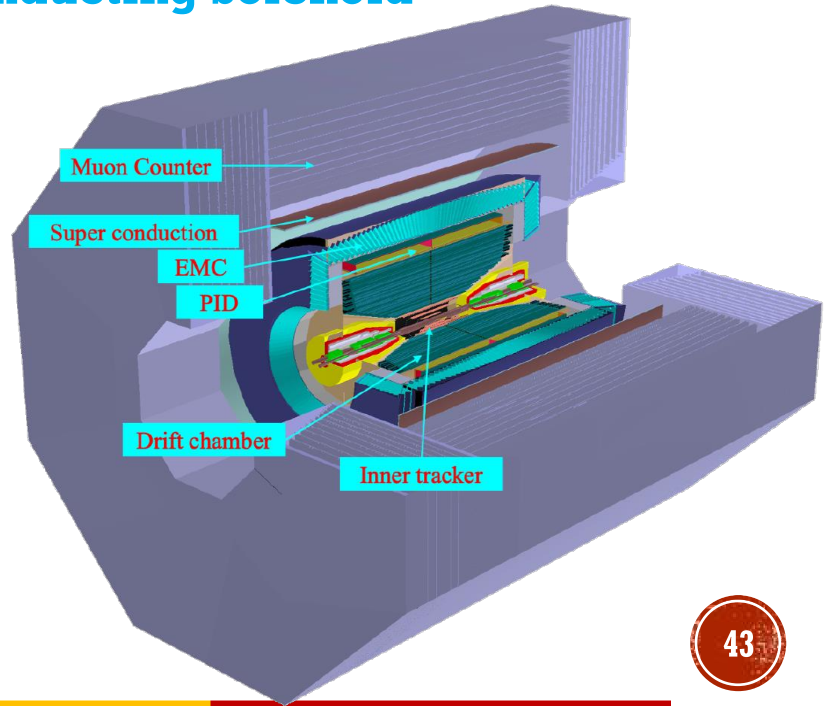
Silicon tracker
Super-conducting Solenoid

EicC

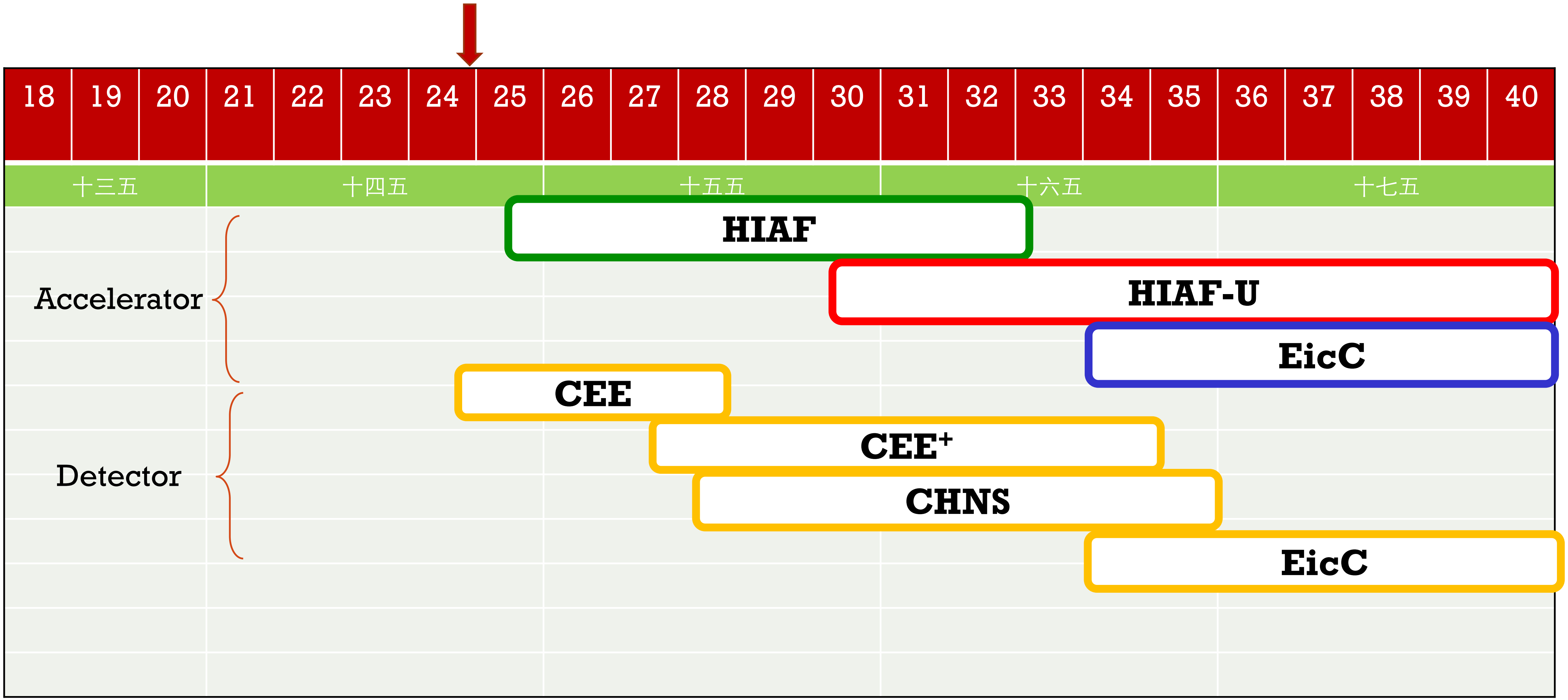


Silicon tracker
MPGD tracker
DIRC (PID)
RICH (PID)
Ecal
Super-conducting Solenoid

STCF



Timeline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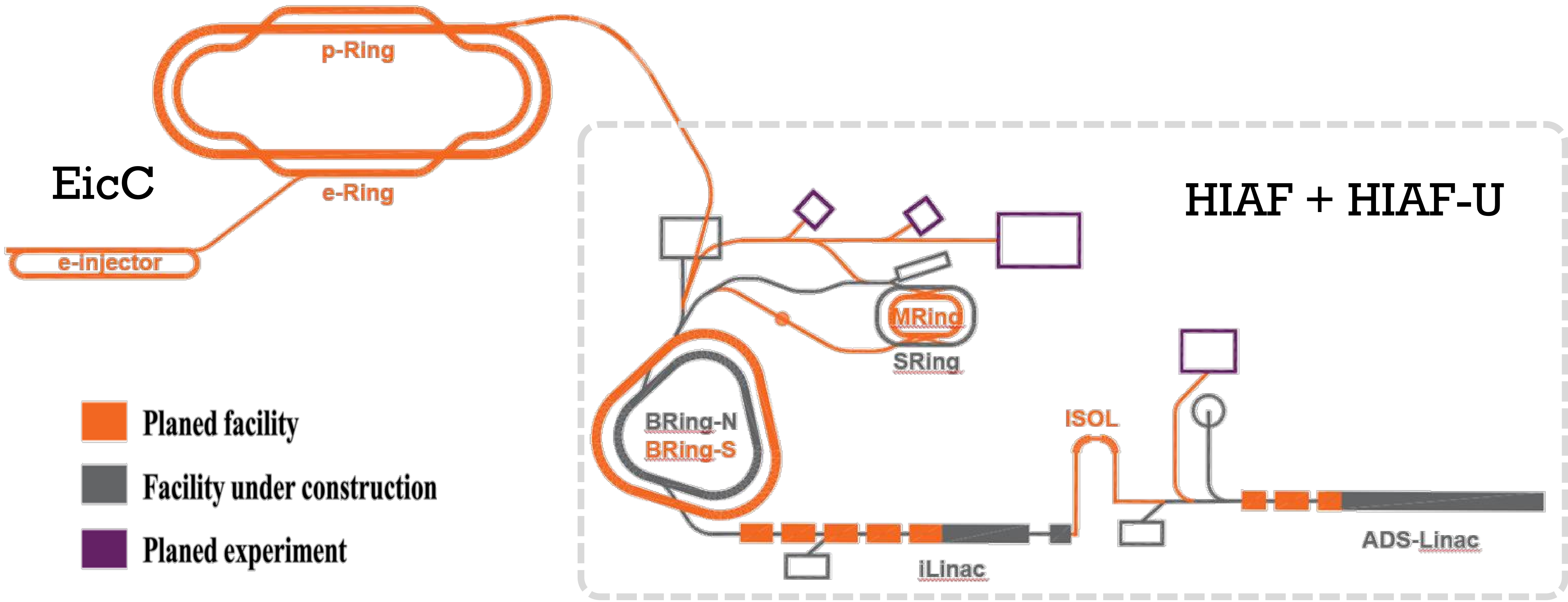
十三五
十四五
十五五
十六五
十七五
Accelerator
HIAF
HIAF-U
EicC
Detector
CEE
CEE+
CHNS
EicC

Summary

- EicC is briefly introduced
  - EicC focuses on sea-quark/gluon related study at moderate/large-x region
  - EicC complements EIC physics program at higher energy
  - EicC CDR will be released soon
- HIAF will deliver the first ion beam in 2025
  - CHNS: Exploring the potential of HIAF for fundamental physics and pave the way for EicC in terms of physics and detector
  - EicC is part of the upgrade plan in HIAF-U, likely within 2030-2040
- **Your interests/involvements are very welcome！** Contact me: yxzhao@impcas.ac.cn

Backups

EicC Accelerator complex layout

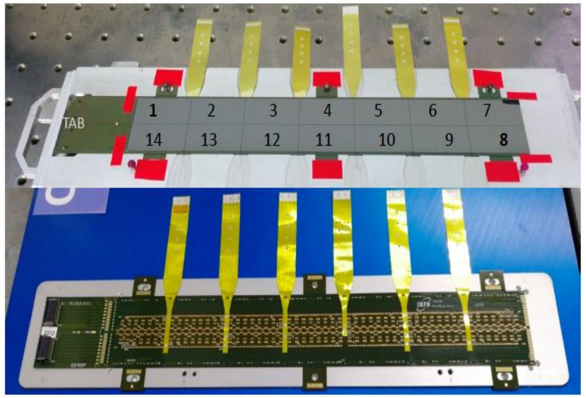


Detector R&Ds

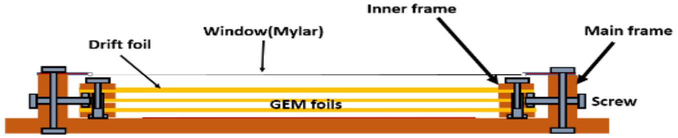
Clean rooms of ISO6 and ISO7 (in total of 200 m²) for detector assembling

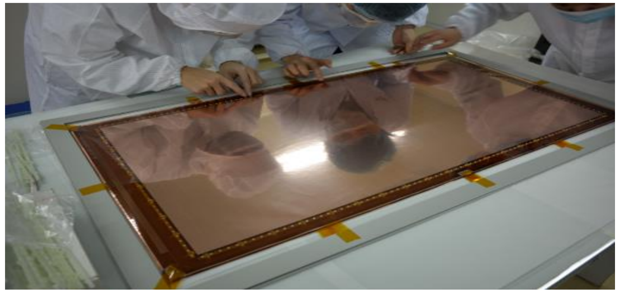
- 25cm x 25 cm Micromegas mass production
- R&D on 0.4m x 0.4m

ALICE style ITS2 MAPS pixel detector

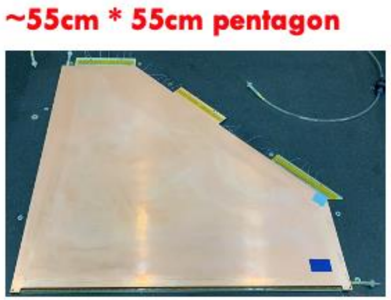


1m x 0.5 m GEM (self-stretching)

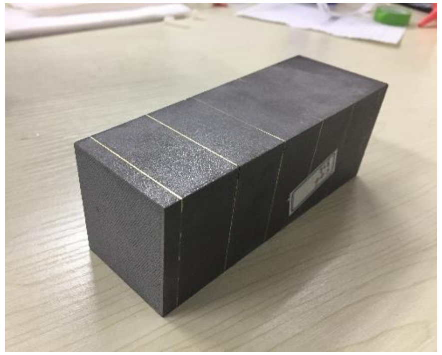




sTGC detector



Shashlyk and W-powder+ScFi EMCal



DIRC prototype