Electron-Ion Collider in China

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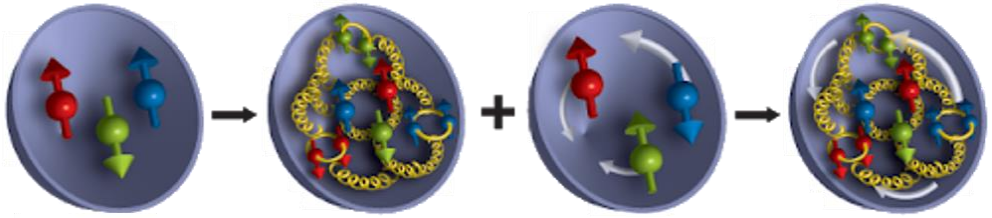
Outline

- Introduction
- Selected physics highlights at EicC
- Detector conceptual design
- Summary

spin

Gell-Mann
quark model



1970s 1980s/2000s Now

Spin decomposition:

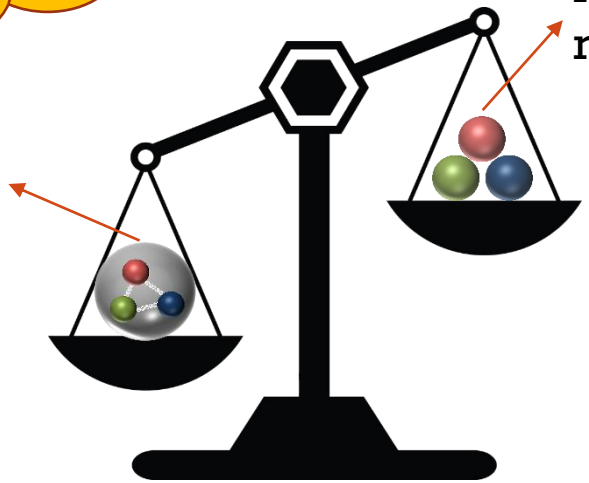
$$S_{tot} = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \mathcal{L}_q + \mathcal{L}_g$$

Quark spin | Gluon Spin | Quark OAM | Gluon OAM

mass

Higgs
mechanism

Proton
mass



Mass decomposition:

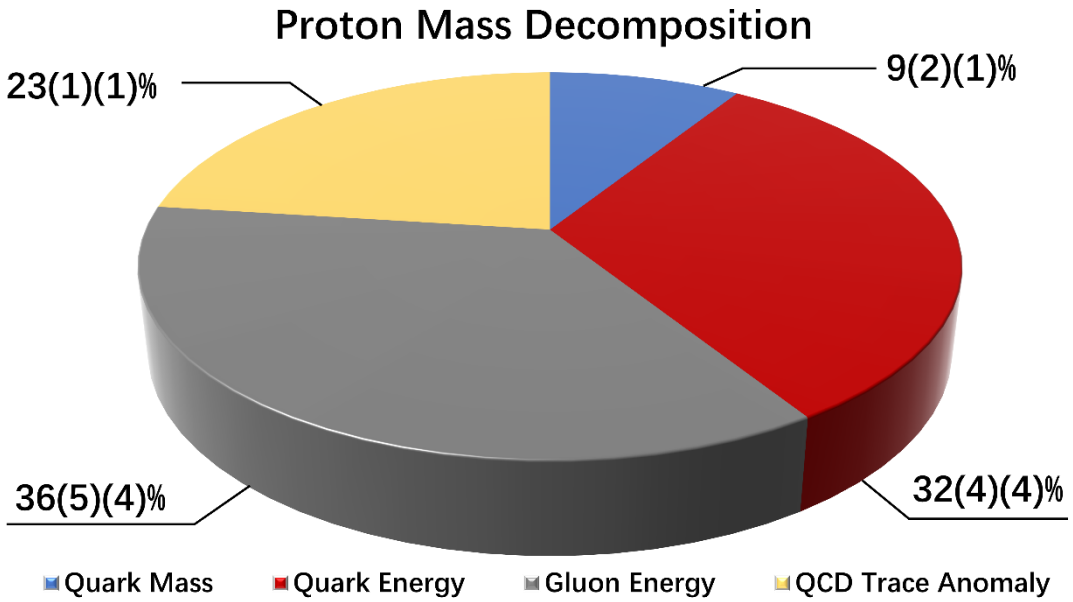
$$M = M_q + M_m + M_g + M_a$$

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

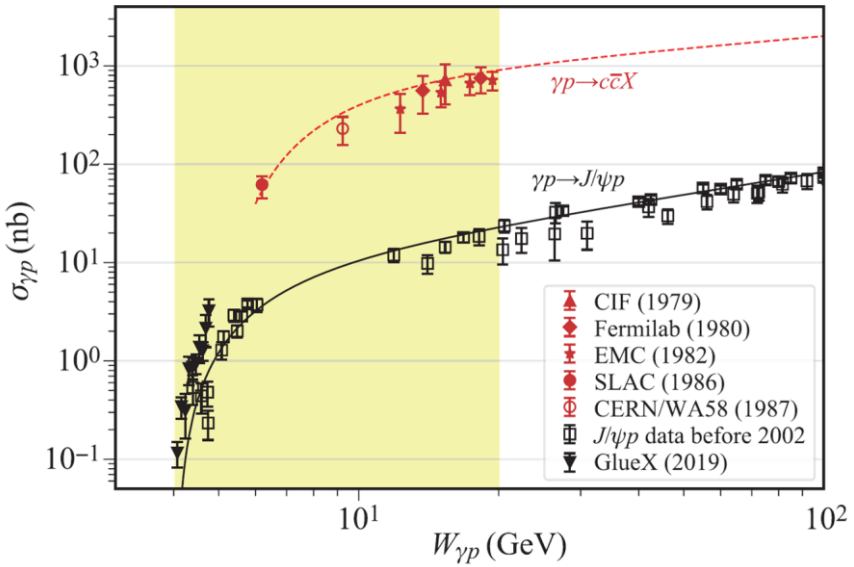


- **Quark energy** and **gluon energy** constrained by PDFs
- **Quark mass** via πN low energy scattering

- **Trace anomaly** via threshold production of J/Psi and Upsilon ? ? ?

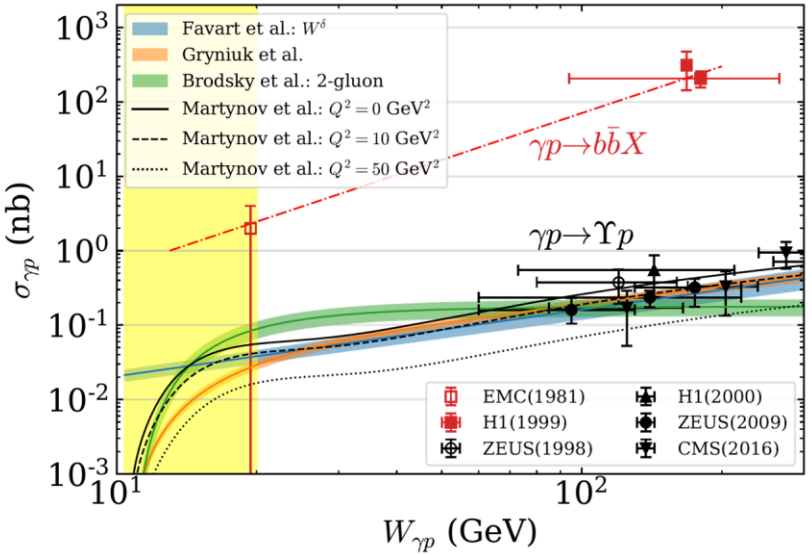
One of the hot topics under discussions

Near threshold J/Psi production



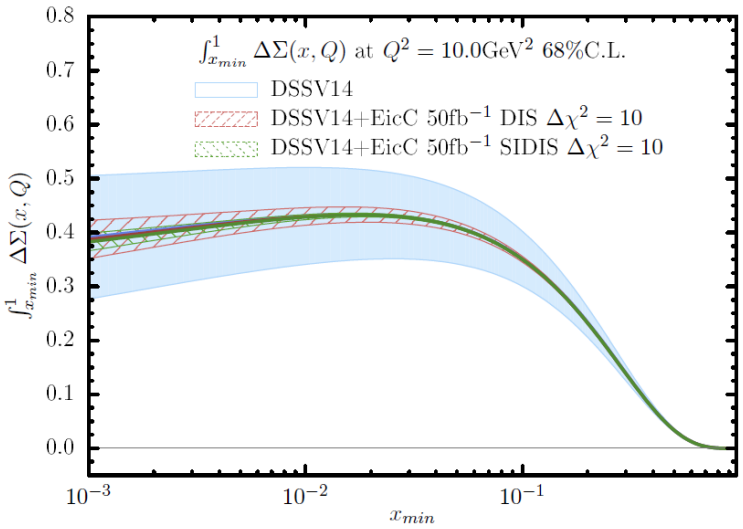
JLab & EicC & EIC

Near threshold Upsilon production

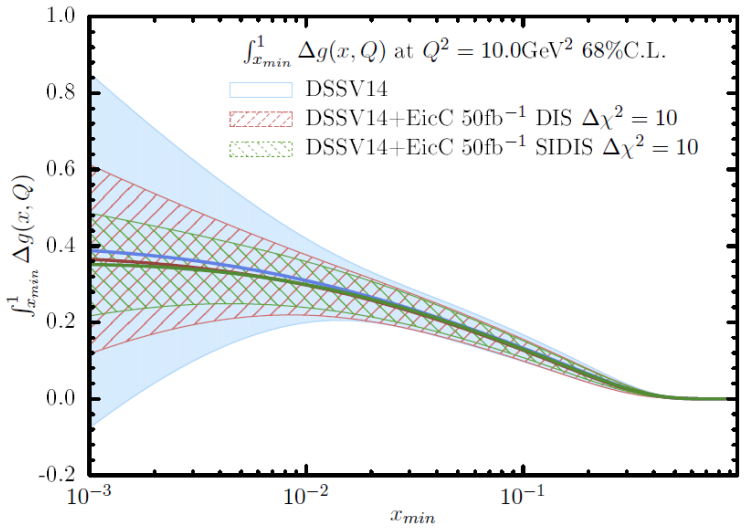


EicC & EIC

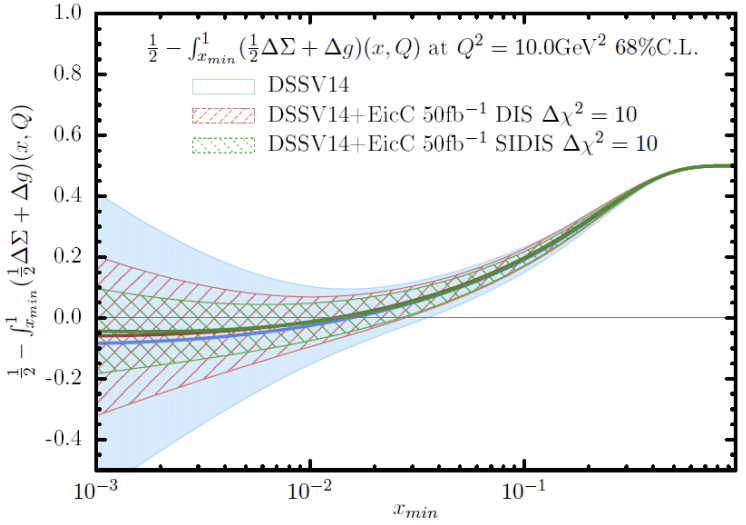
Origin of proton spin



Quark spin contribution



Gluon spin contribution

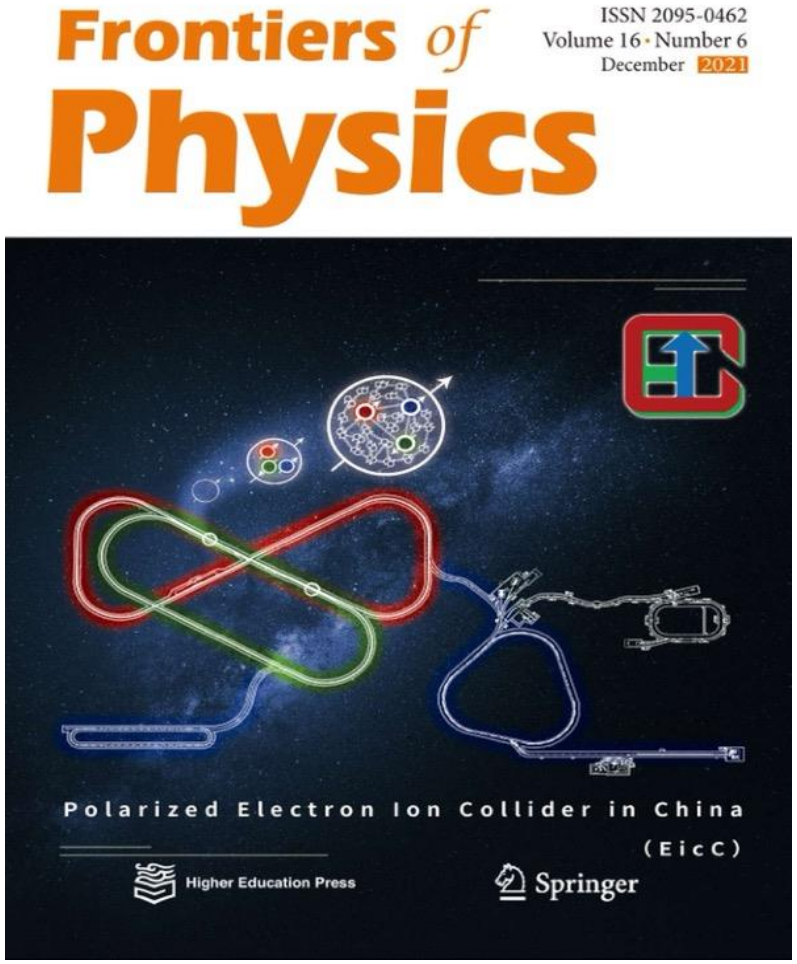


Quark/gluon OAM

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

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/c-bar, b/b-bar
- Origin of the proton mass study

Detector + Accelerator preliminary design

45 institutes and >100 physicists

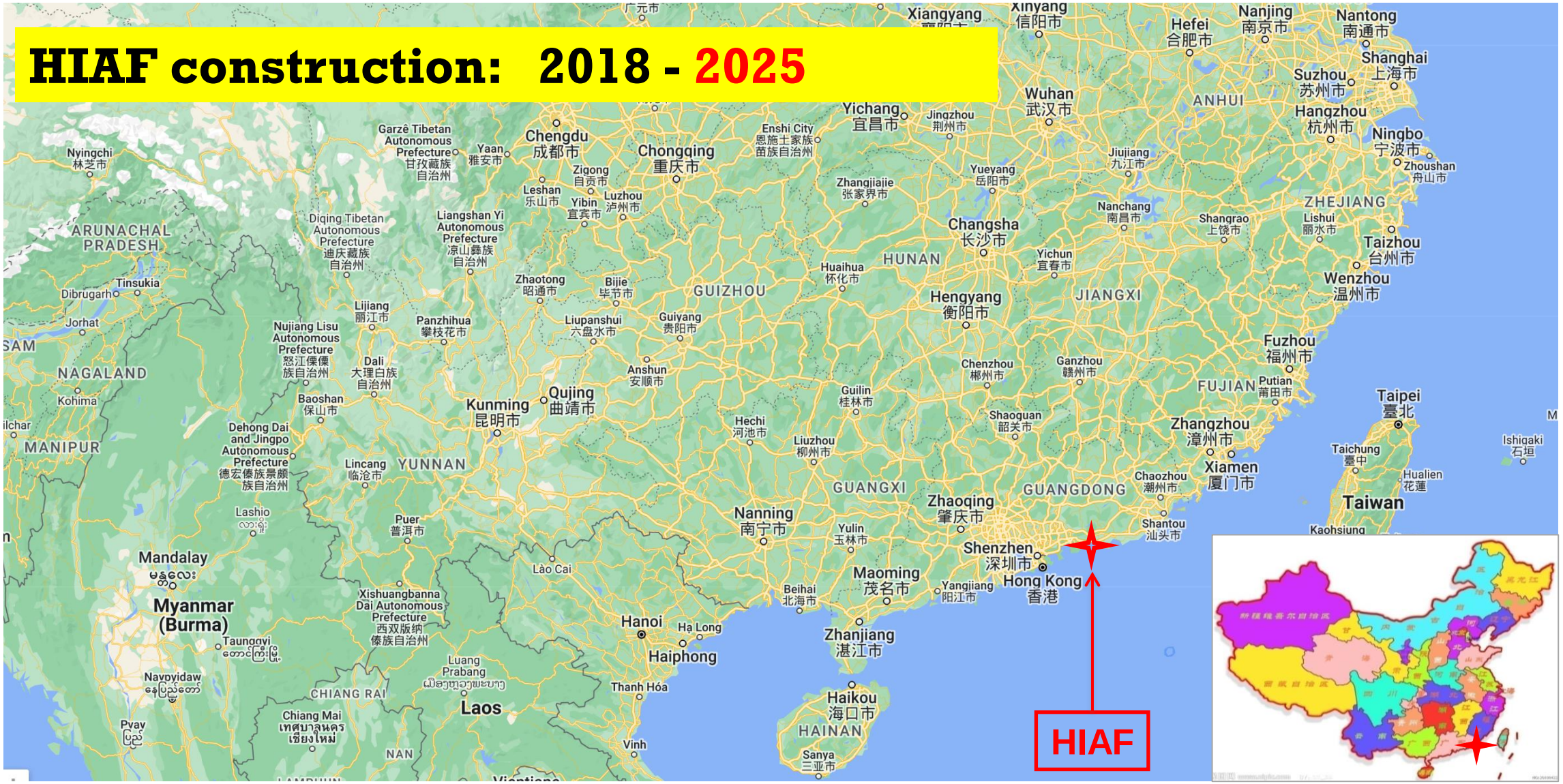
Electron Ion Collider in China…Huizhou(惠州) in Guangdong province

HIAF under construction

EIC in China

Electron Ion Collider in China, EicC

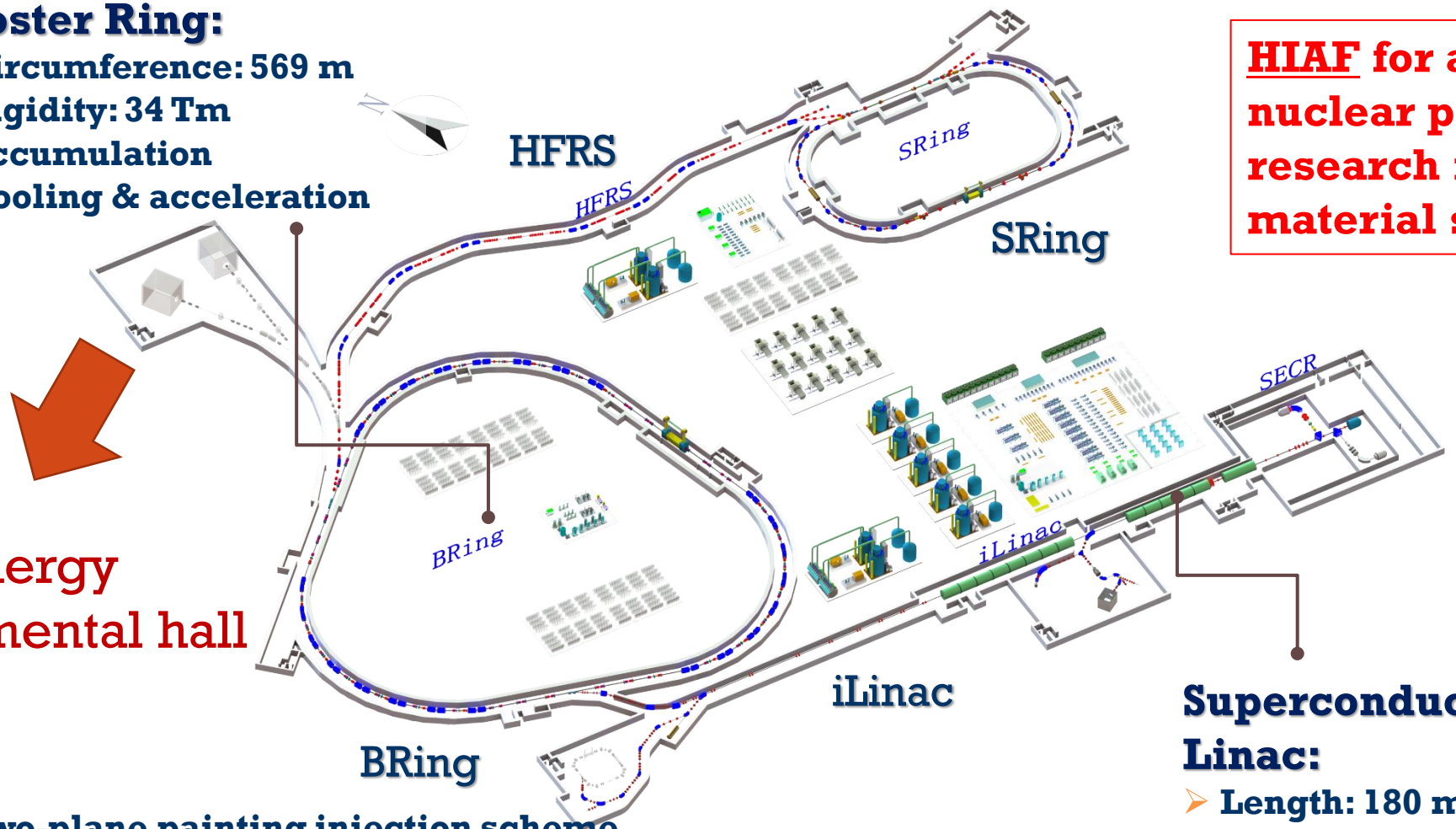
Location: Huizhou, Guangdong



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

High Intensity heavy-ion Accelerator Facility (HIAF)

Booster Ring:

- **Circumference: 569 m**
- **Rigidity: 34 Tm**
- **Accumulation**
- **Cooling & accele**

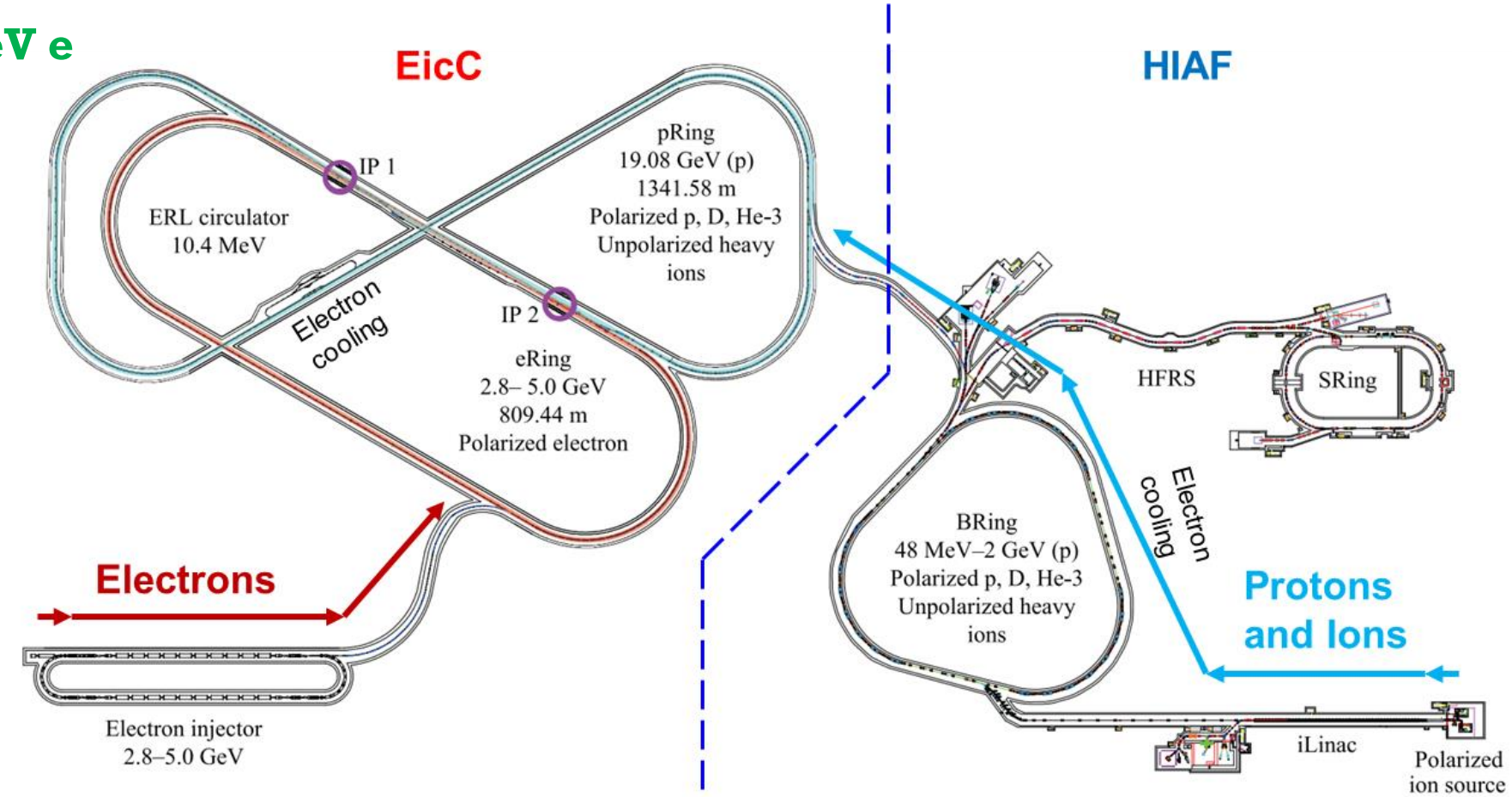
High energy experimental hall

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

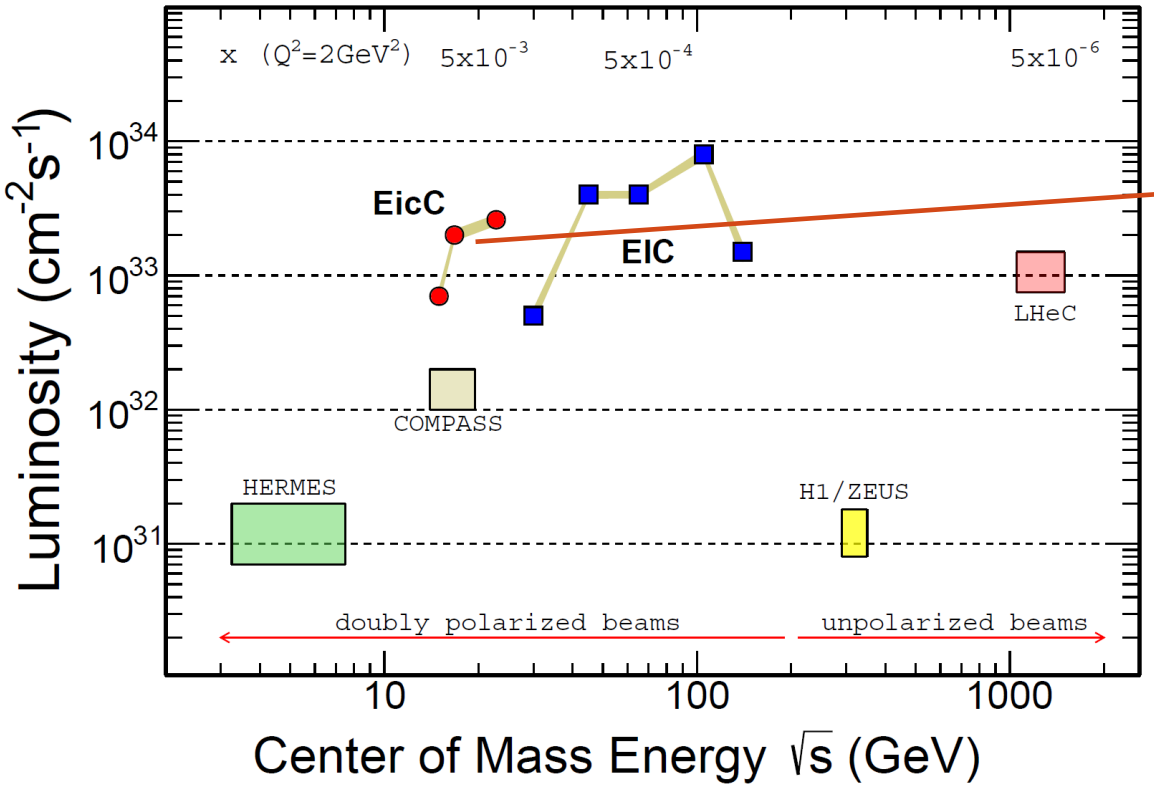
EicC Accelerator complex layout

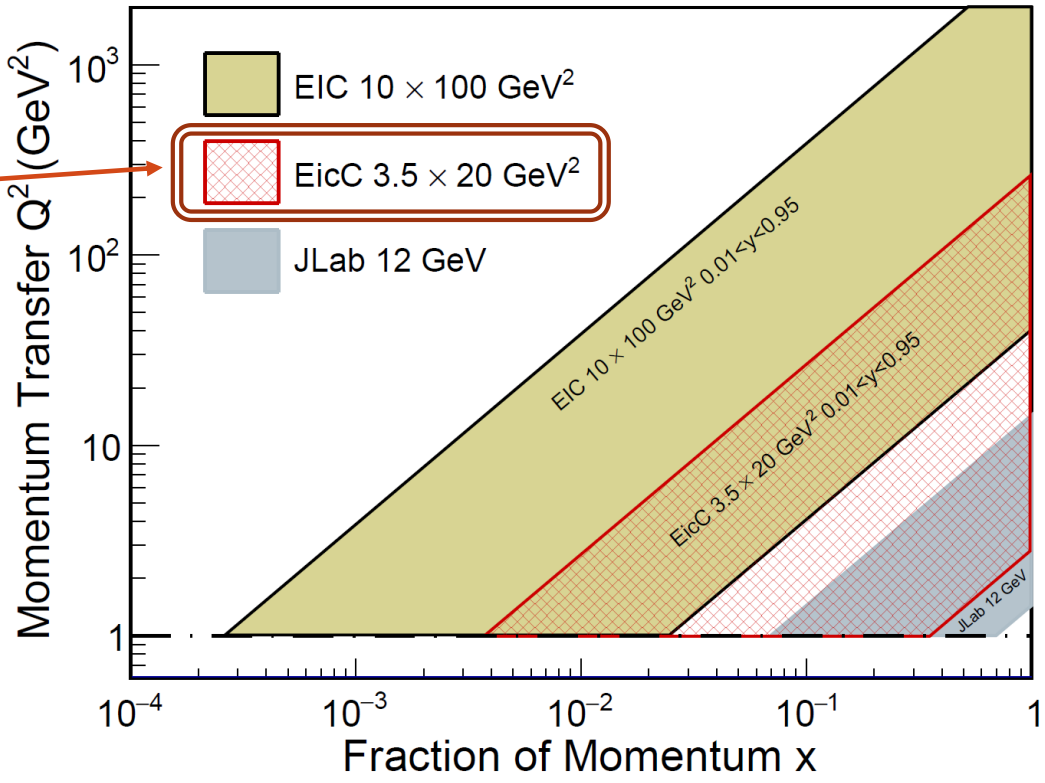
- **20 GeV p + 3.5 GeV e**
- **$\sqrt{S}$: 16.7GeV**
- **High Lumi.:**

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



EicC parameters

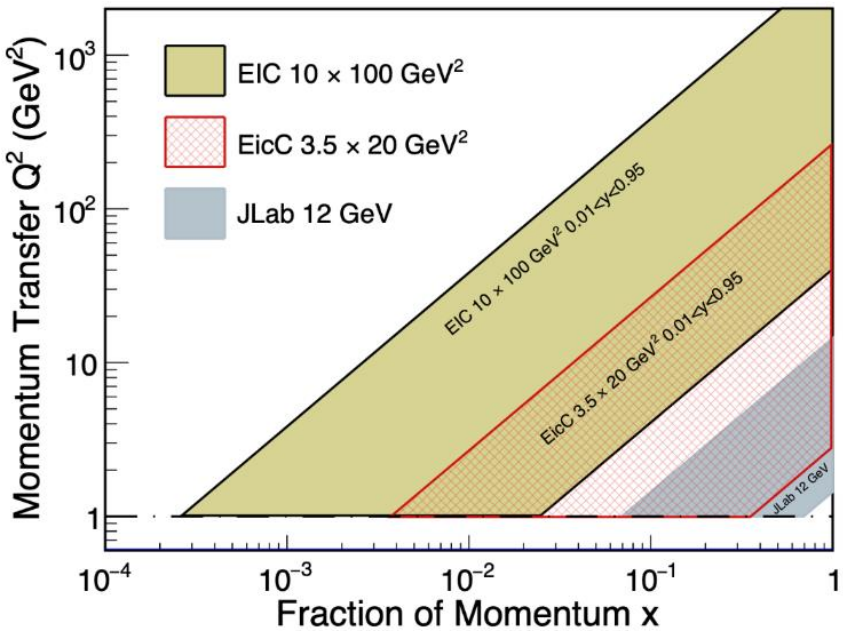


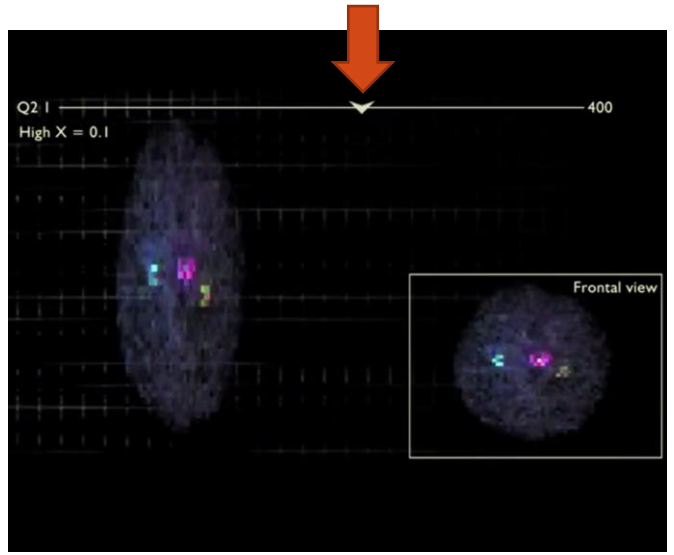


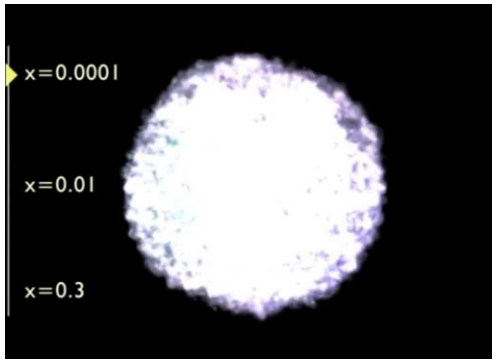
- EicC covers the kinematic region between JLab experiments and EIC@BNL
- EicC complements the ongoing scientific programs at JLab and future EIC project
- EicC focuses on moderate x and sea-quark region

Kinematic region VS physics

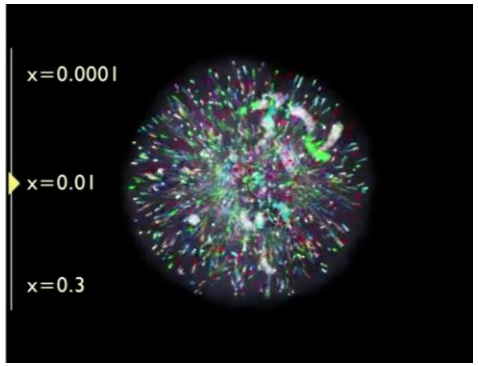
See a video at:
http://eicug.org/



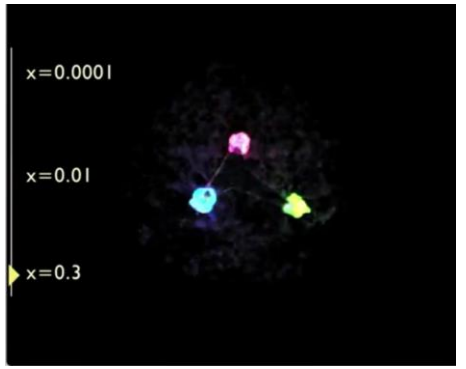




Gluon dominates



Gluon + sea quarks



Valence quarks

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

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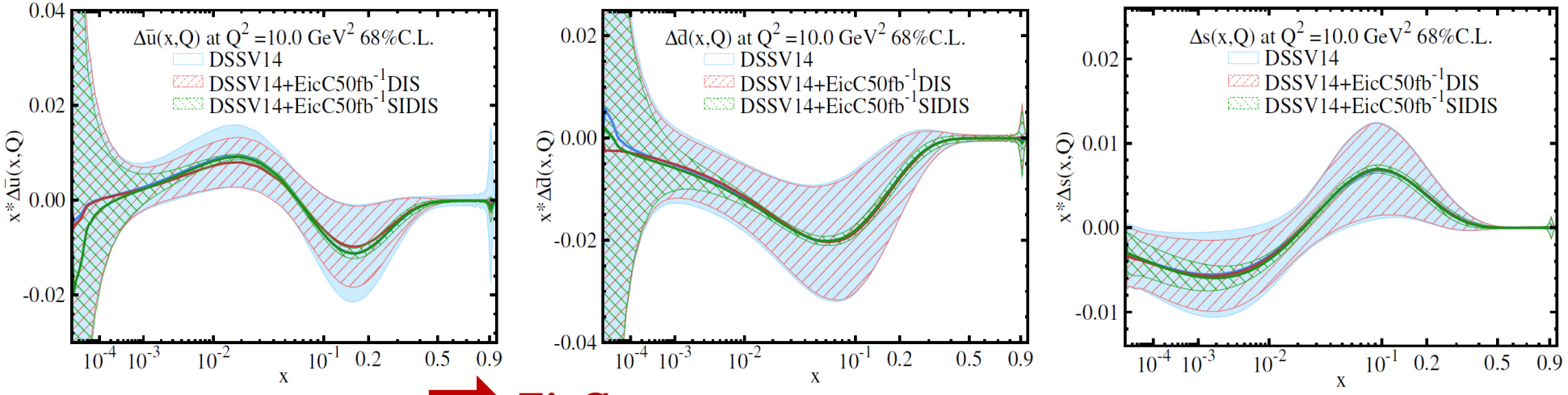
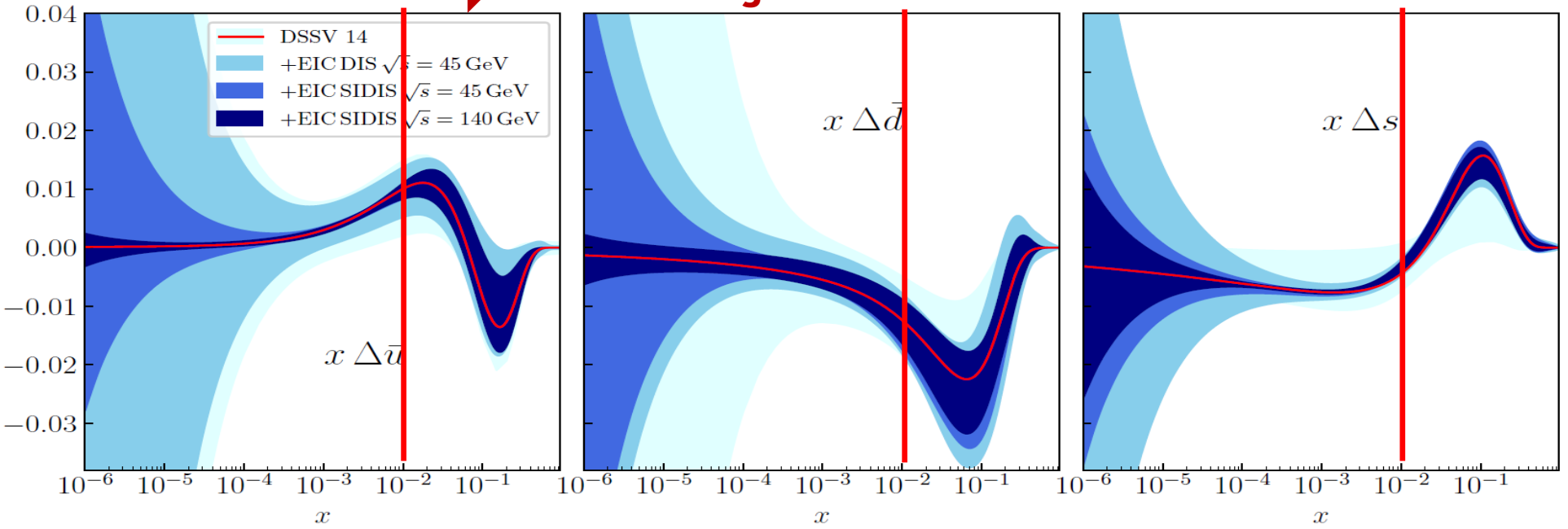
EicC and EIC-helicity distribution via SIDIS (1D spin)

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



EicC coverage



An NLO study

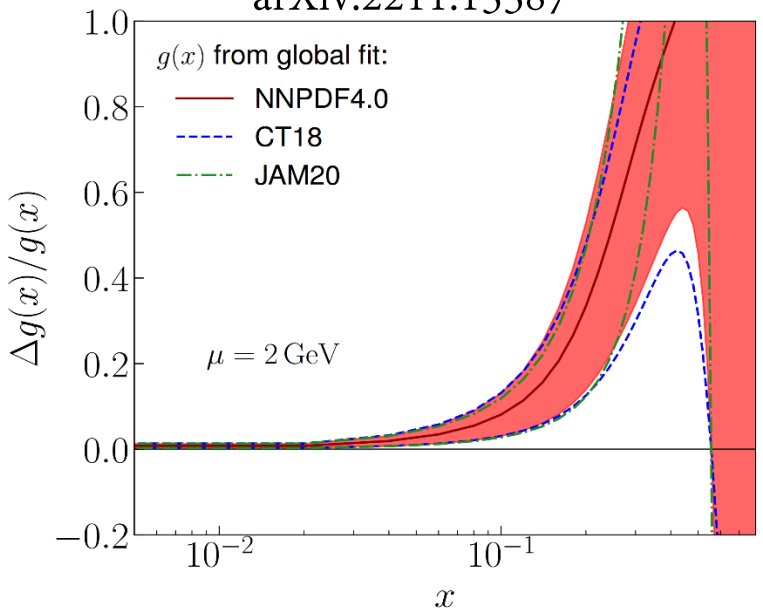
EicC white paper

complementary

EIC Yellow Report

EicC and EIC-gluon polarization (at large x)

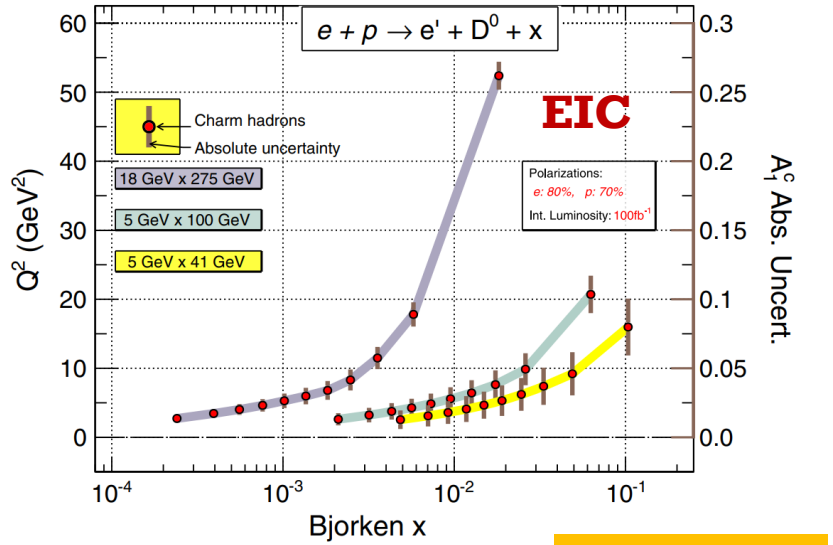
arXiv:2211.15587



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

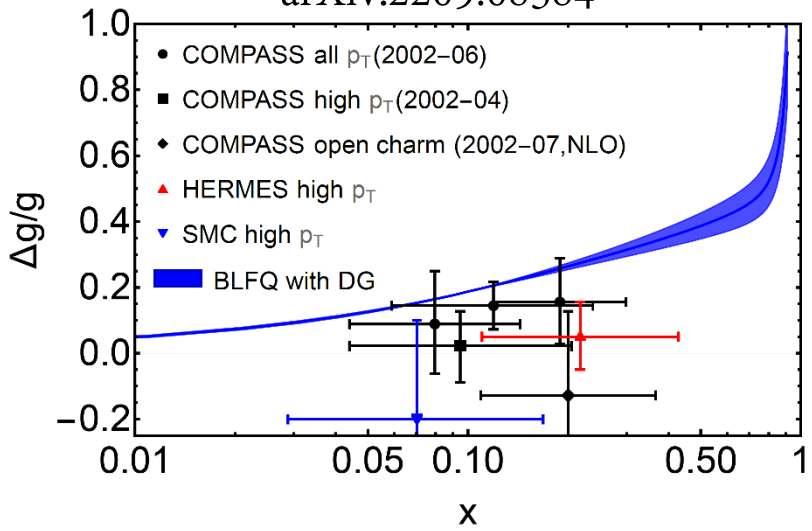
$$A_{LL}^{\vec{e}+\vec{p}\to e'+D^0+X} = \frac{d\sigma^{++} - d\sigma^{+-}}{d\sigma^{++} + d\sigma^{+-}}$$

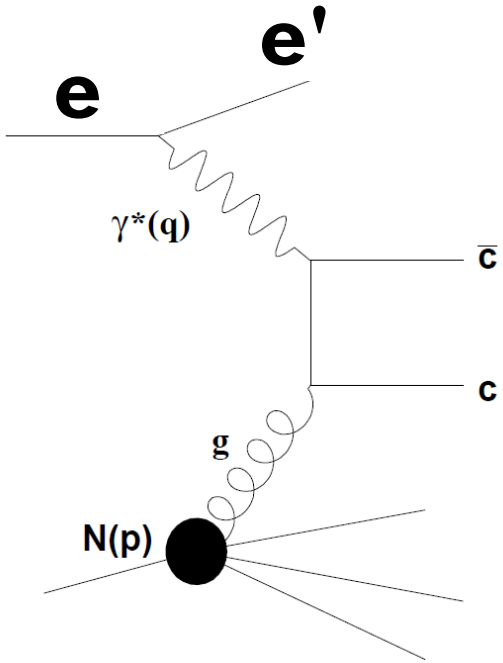
$$= \frac{1}{P_e P_p} \frac{N^{++} - N^{+-}}{N^{++} + N^{+-}}$$

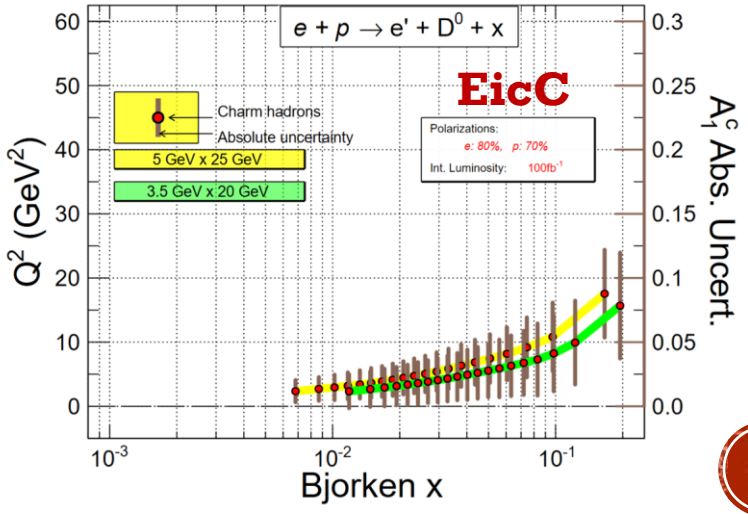


complementary

arXiv:2209.08584

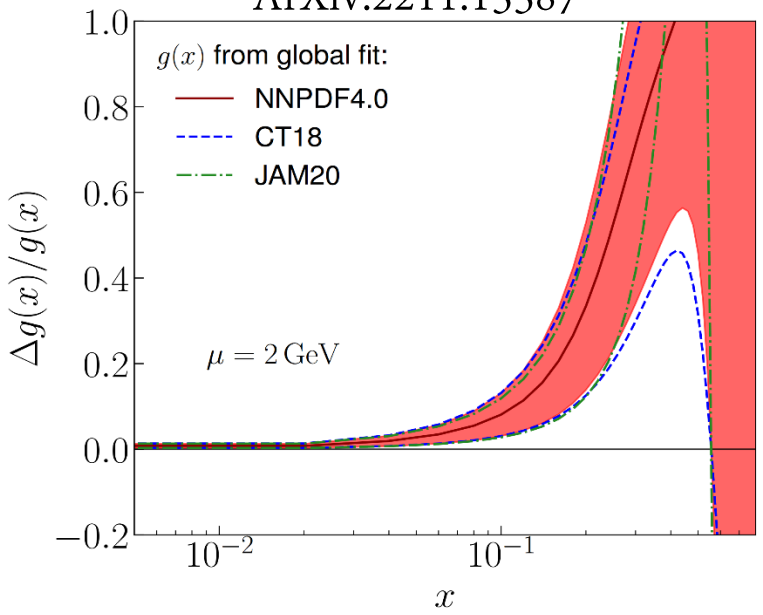






EicC and EIC-gluon polarization (at large x)

ArXiv:2211.15587



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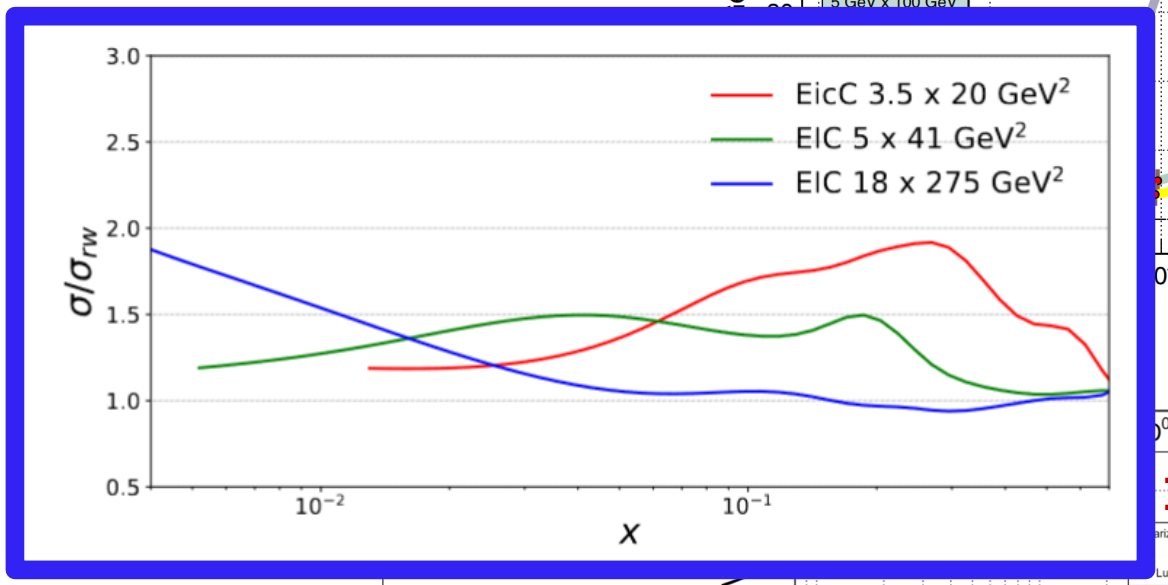
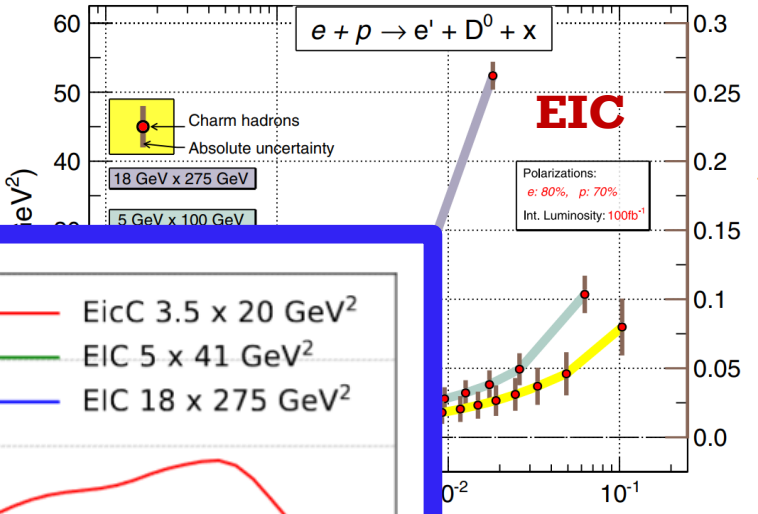
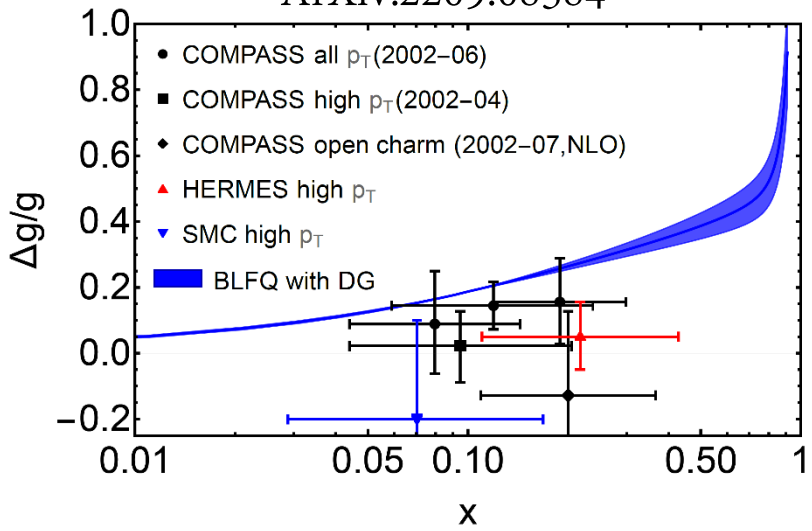
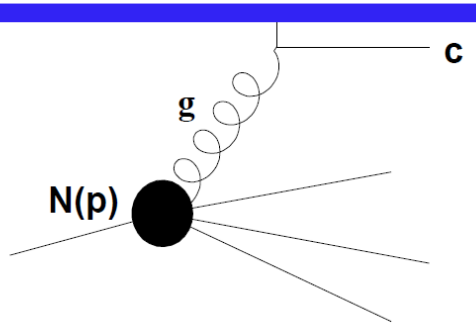


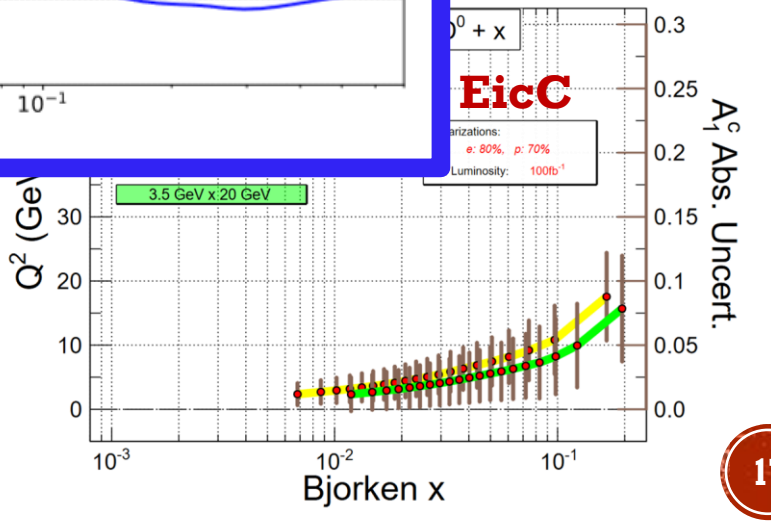


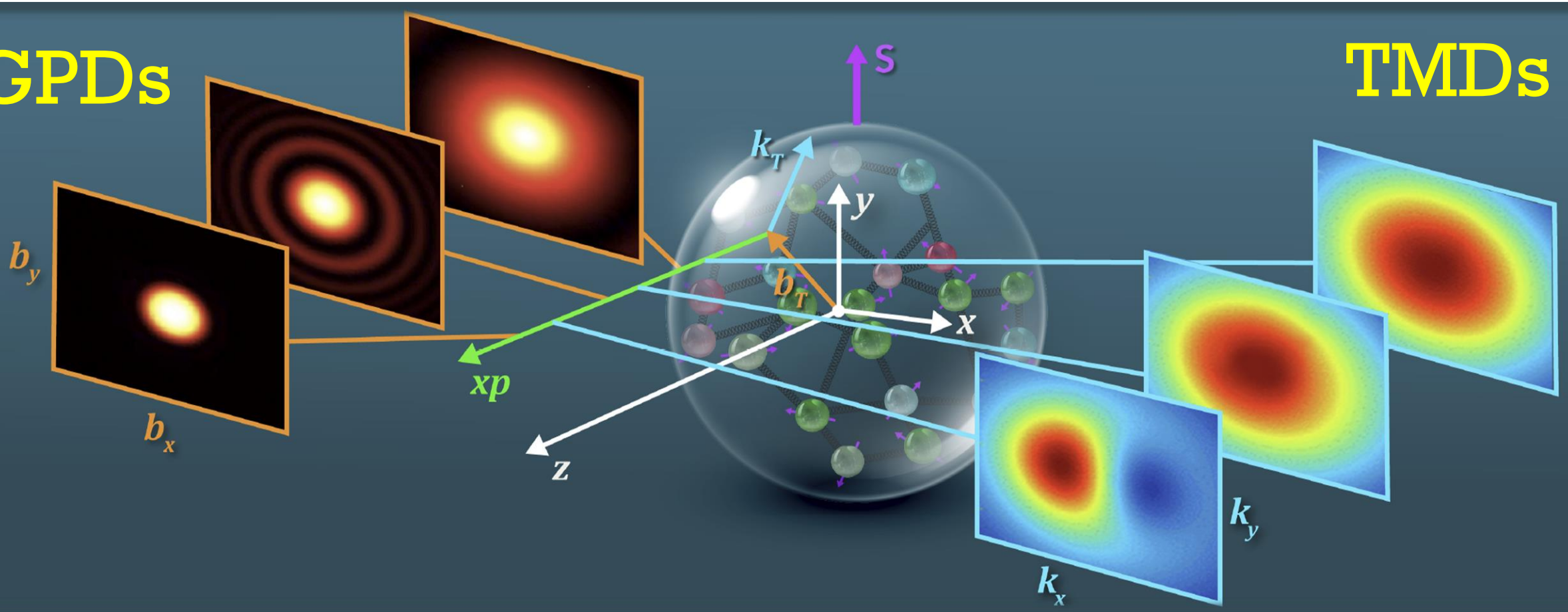
complementary

ArXiv:2209.08584







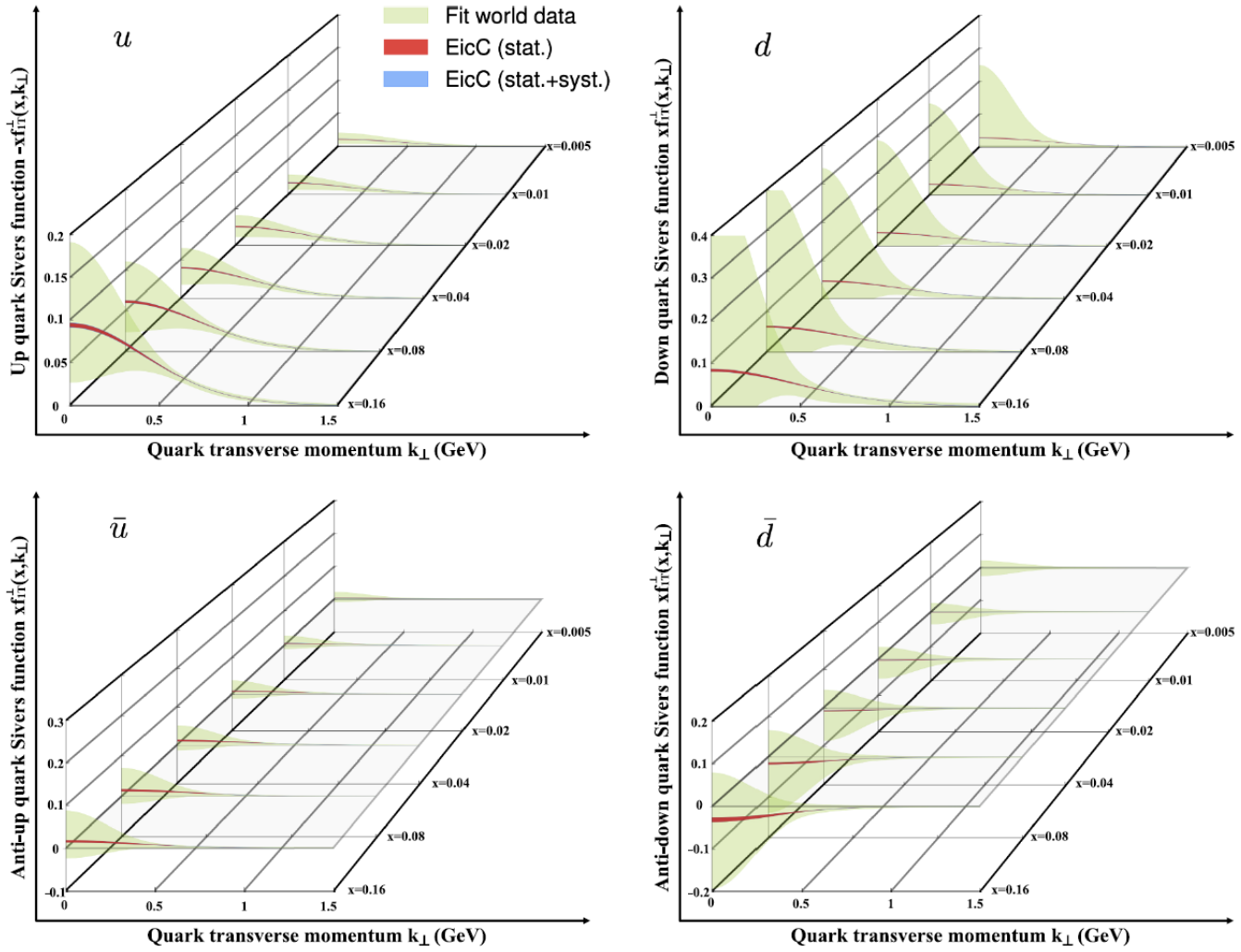


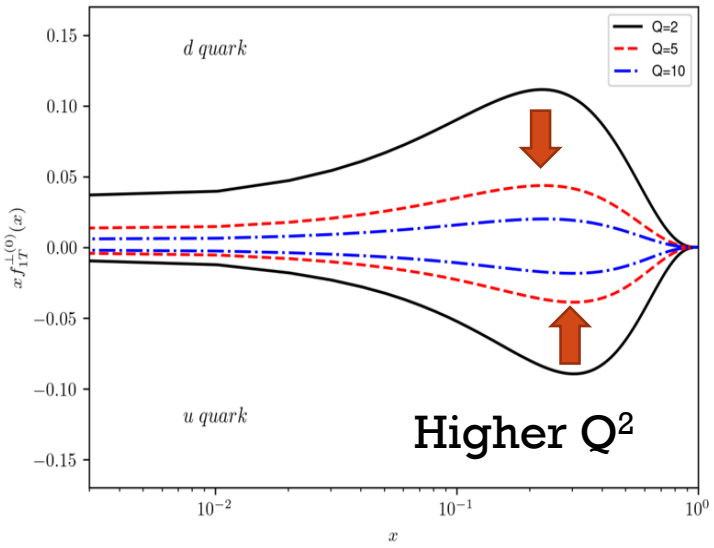
GPDs: deformation of Parton's spatial distribution when hadron is polarized

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

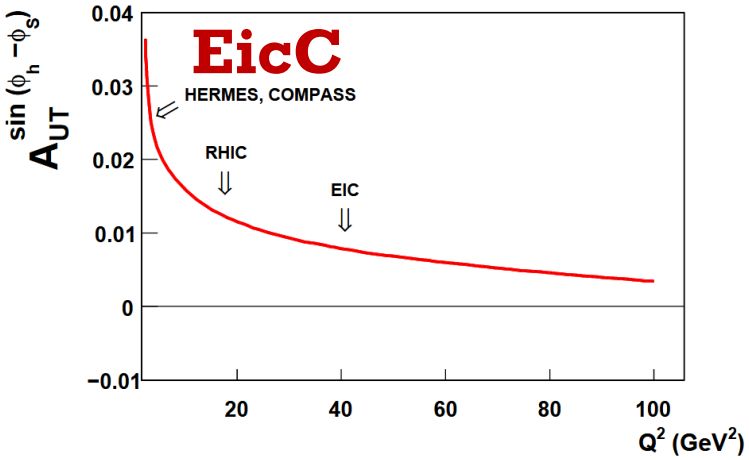
EicC and EIC-Sivers TMDs

C. H. Zeng, T. B. Liu, P. Sun, Y. X. Zhao, PRD106.094039 (2022)





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

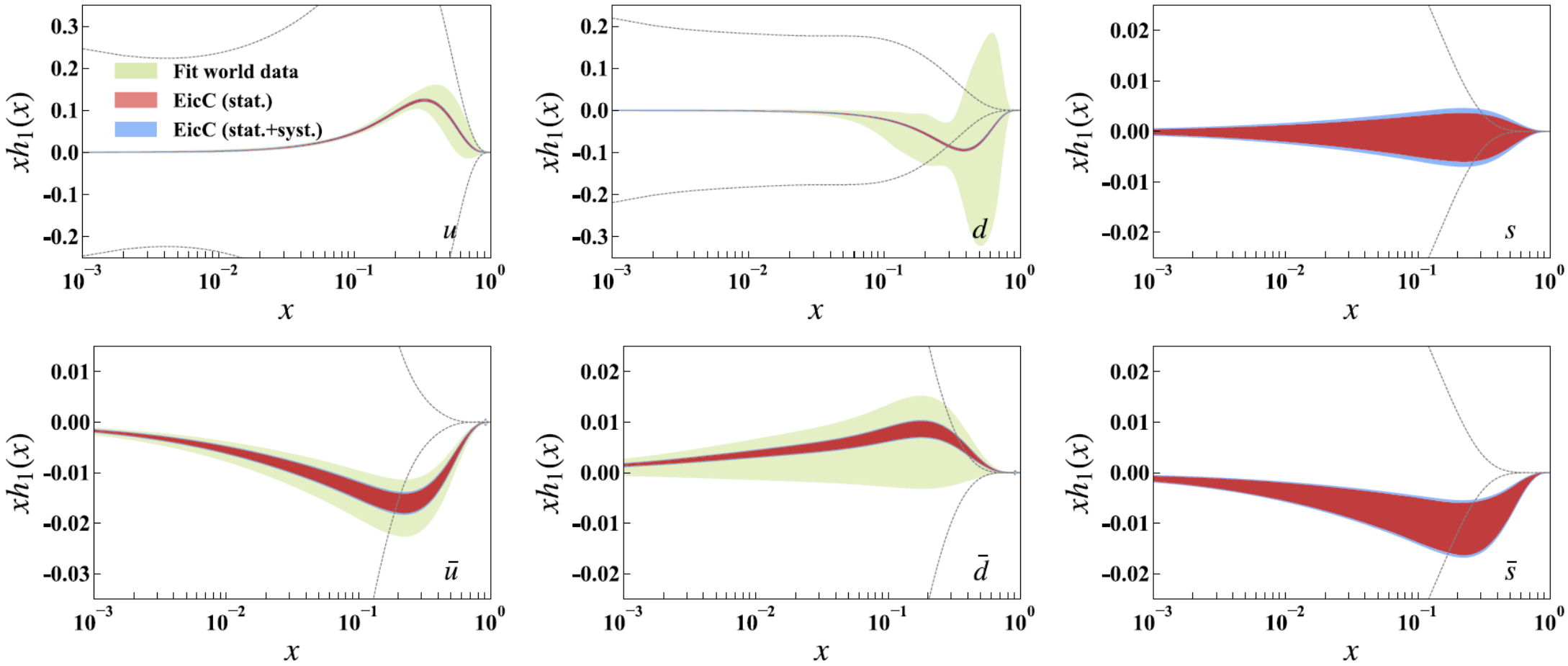


1. Higher Q^2, smaller effect
2. Smaller x, smaller effect

complementary

EicC impact on Transversity

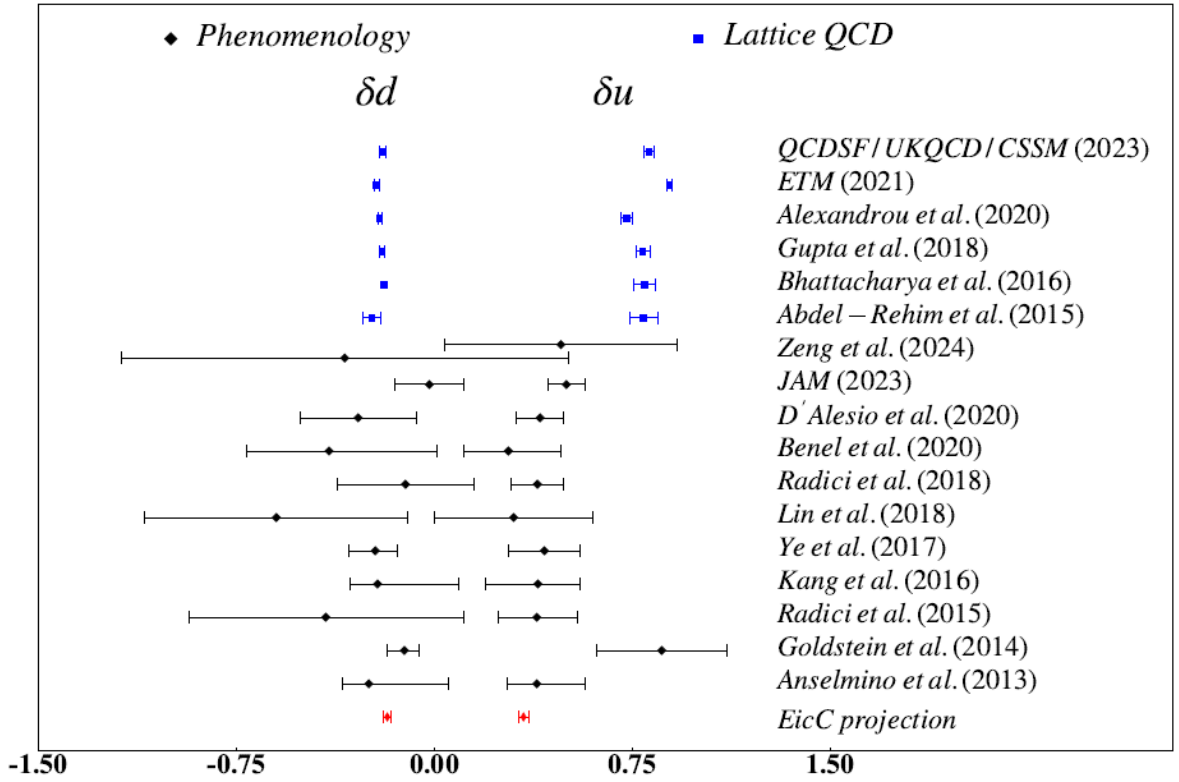
C. Zeng, H. Dong, T. B. Liu, P. Sun, and Y. X. Zhao, Phys. Rev. D 109 (5), 056002 (2024)

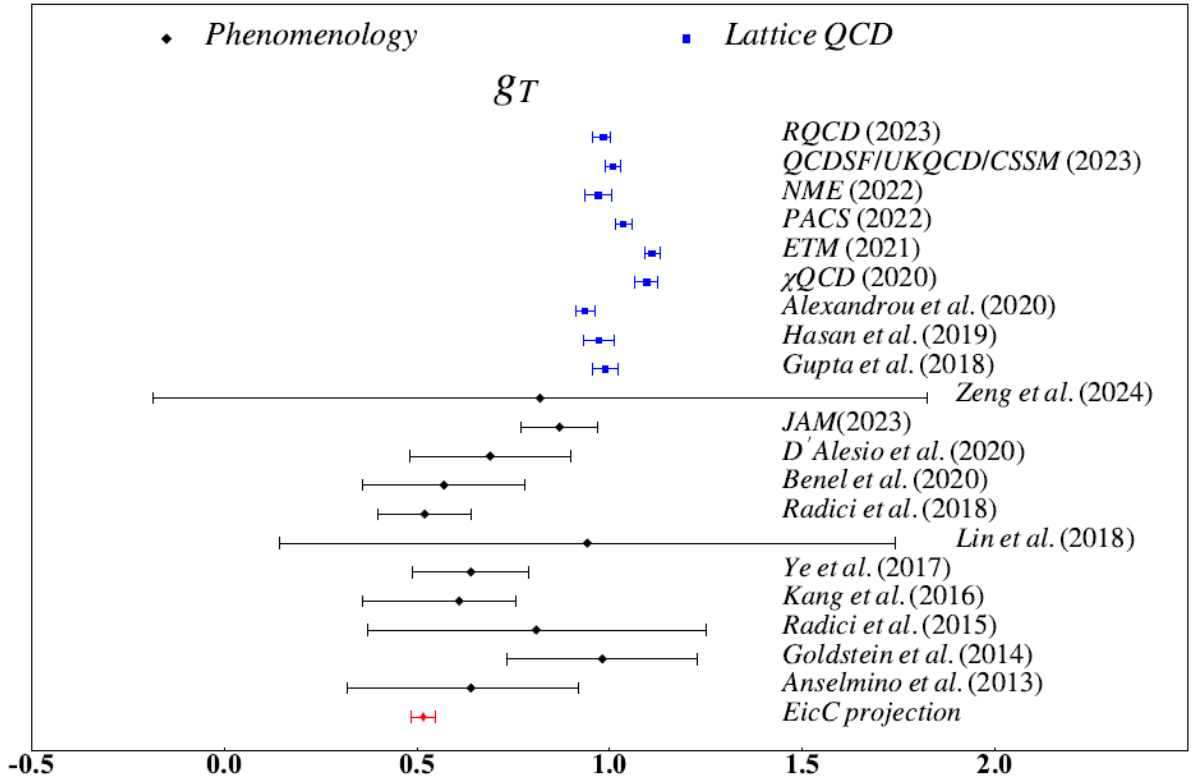


EicC can significantly improve the precision of transversity distributions, especially for sea quarks

Results on Tensor Charge

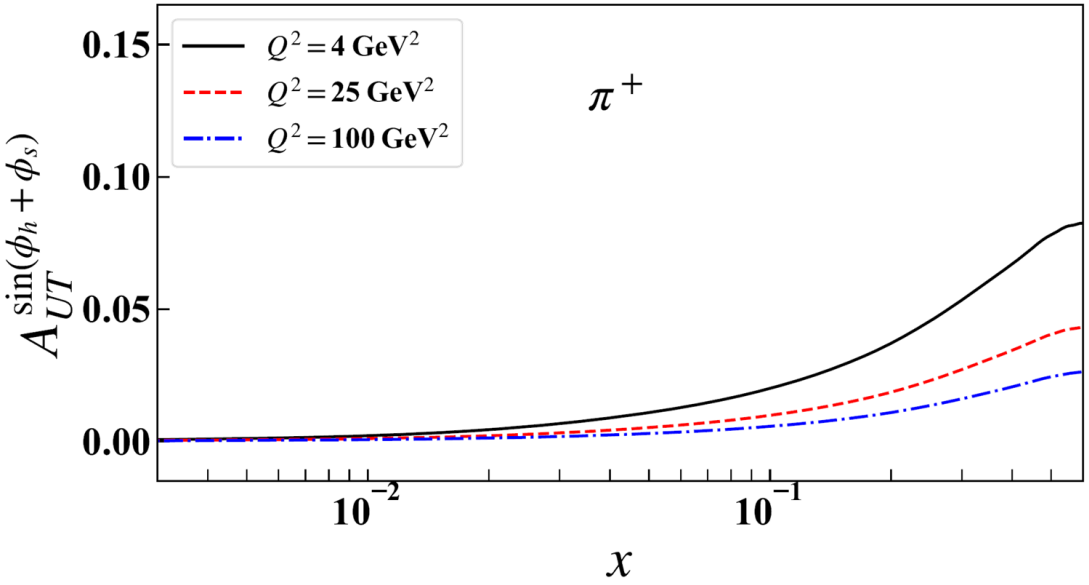
$$g_T = \delta u - \delta d$$



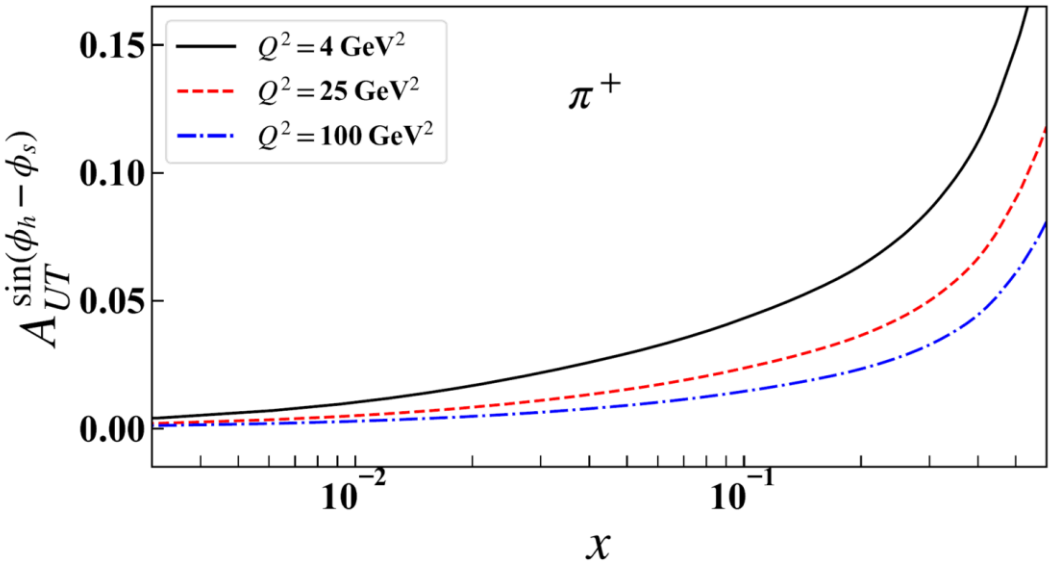


C. Zeng, H. Dong, T. B. Liu, P. Sun, and Y. X. Zhao, Phys. Rev. D 109 (5), 056002 (2024)

More words on TMDs study



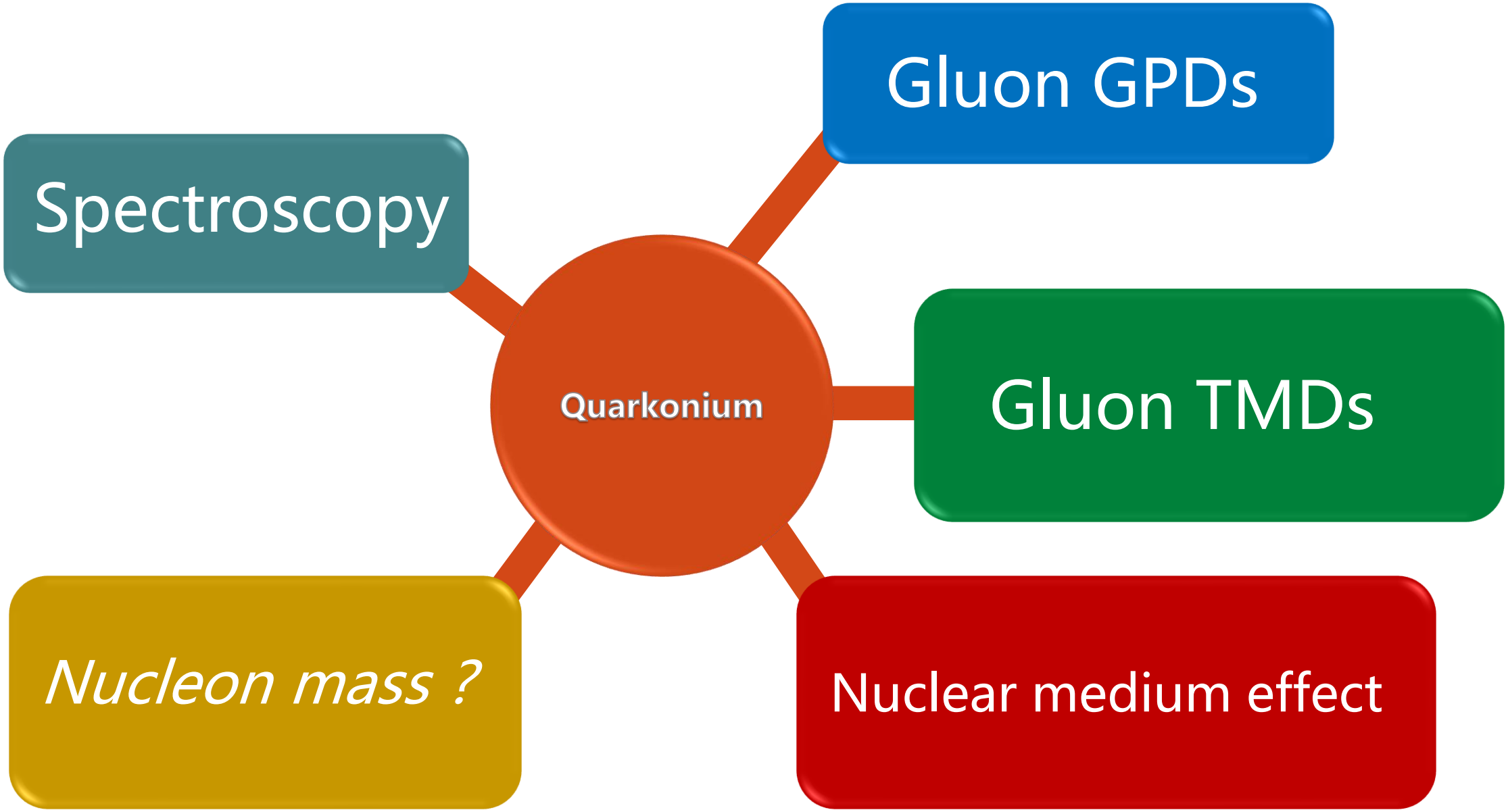
Collins effect observable



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

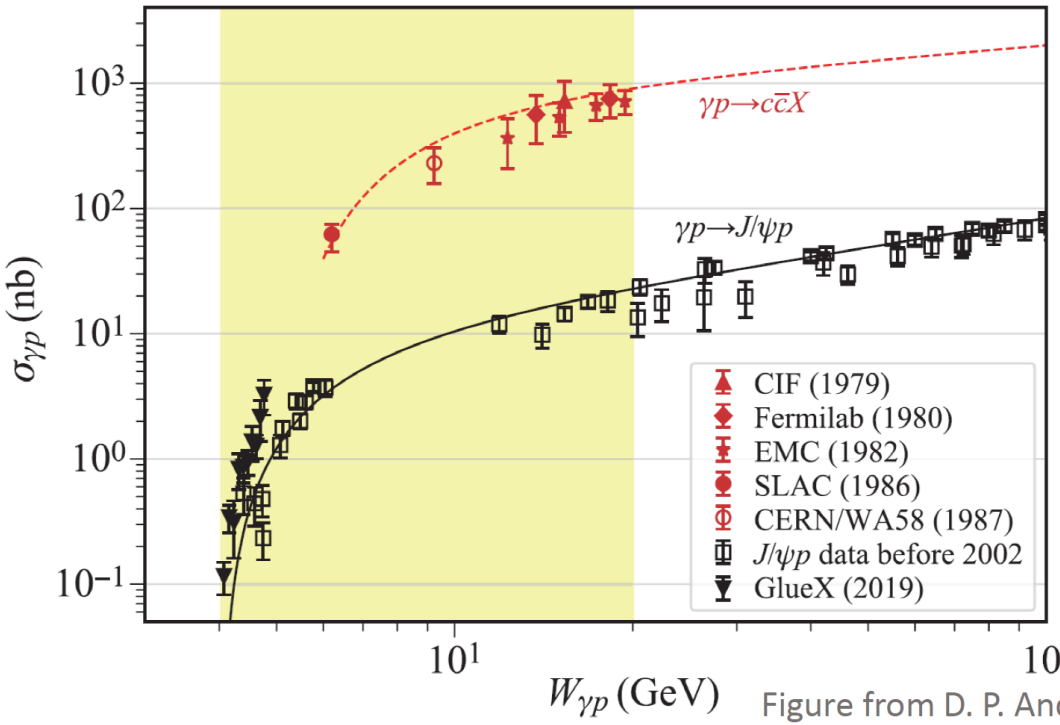


Figure from D. P. Anderle et al. Front.Phys.16(2021)64701

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

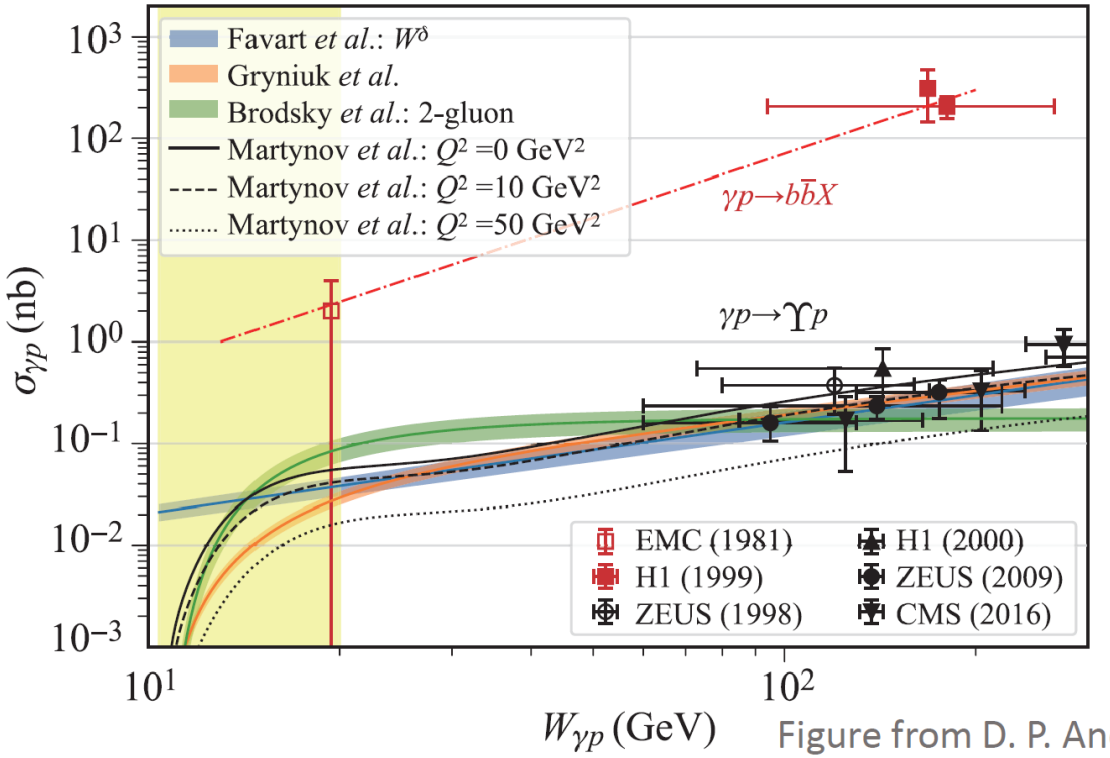


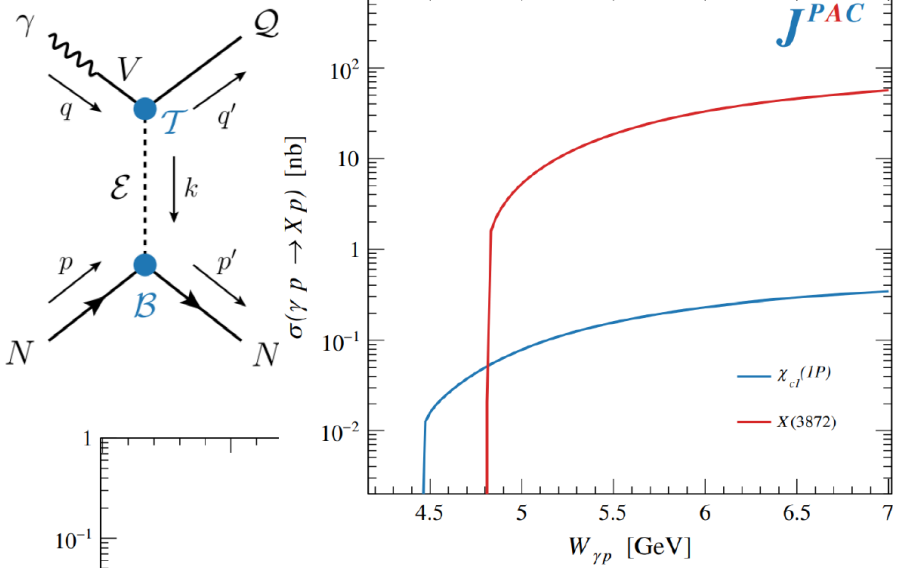
Figure from D. P. Anderle et al. Front.Phys.16(2021)64701

For W=15-20 GeV,

- Photoproduction: $\sigma(\gamma p \to \Upsilon p) \sim O(10\ \mathrm{pb})$ (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, $\sim O(0.1\ p\mathrm{b})$
- 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

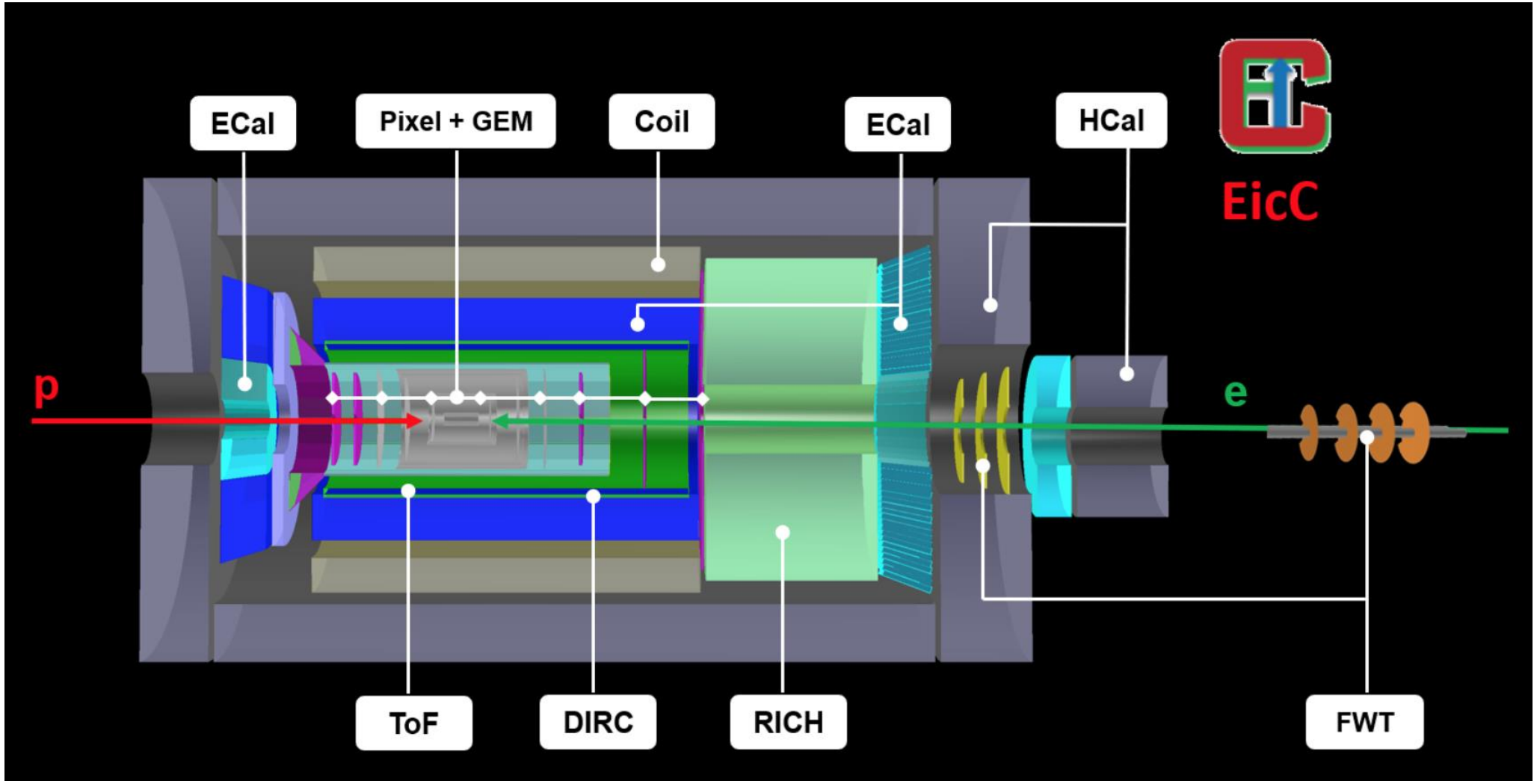
➢ Estimated events for EicC (50 /fb)

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
$P_b(\text{narrow})$	$ep \to eP_b(\text{narrow})$ $P_b(\text{narrow}) \to p\Upsilon$ $\Upsilon \to l^+l^-$	~30%	0−20
$P_b(\text{wide})$	$ep \to eP_b(\text{wide})$ $P_b(\text{wide}) \to p\Upsilon$ $\Upsilon \to l^+l^-$	~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

Outline

- Introduction
- Selected physics highlights at EicC
- Detector conceptual design
- Summary

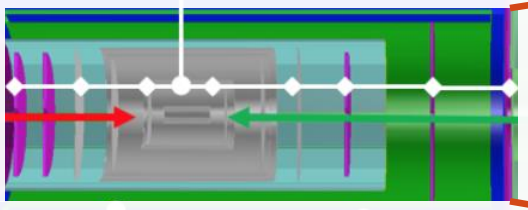
EicC detector design



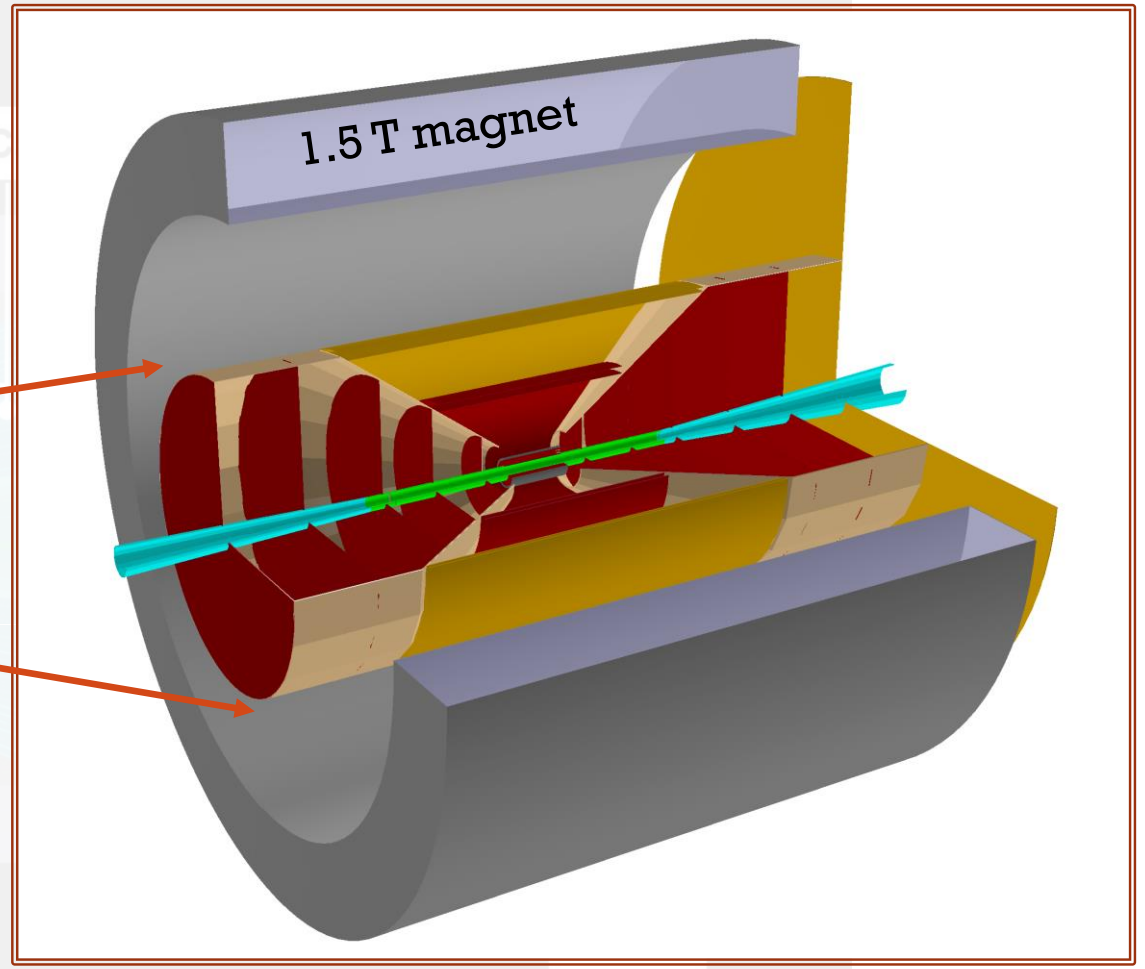
EicC detector design

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(rϕ)x150(z)	0.40	MPGD
67.50	174.88	150(rϕ)x150(z)	0.40	MPGD

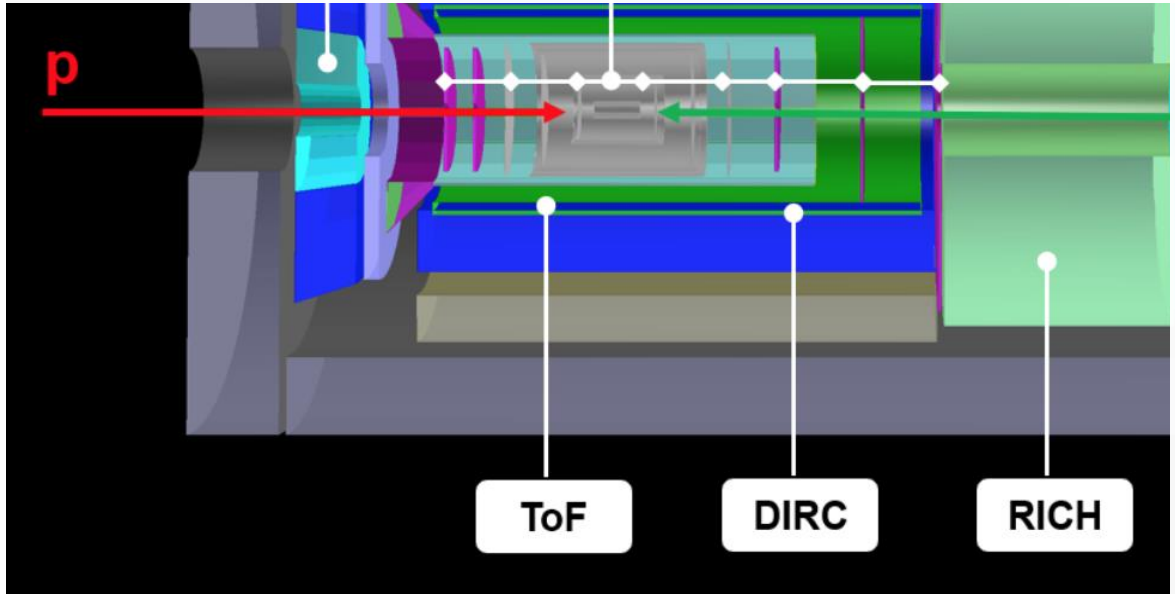


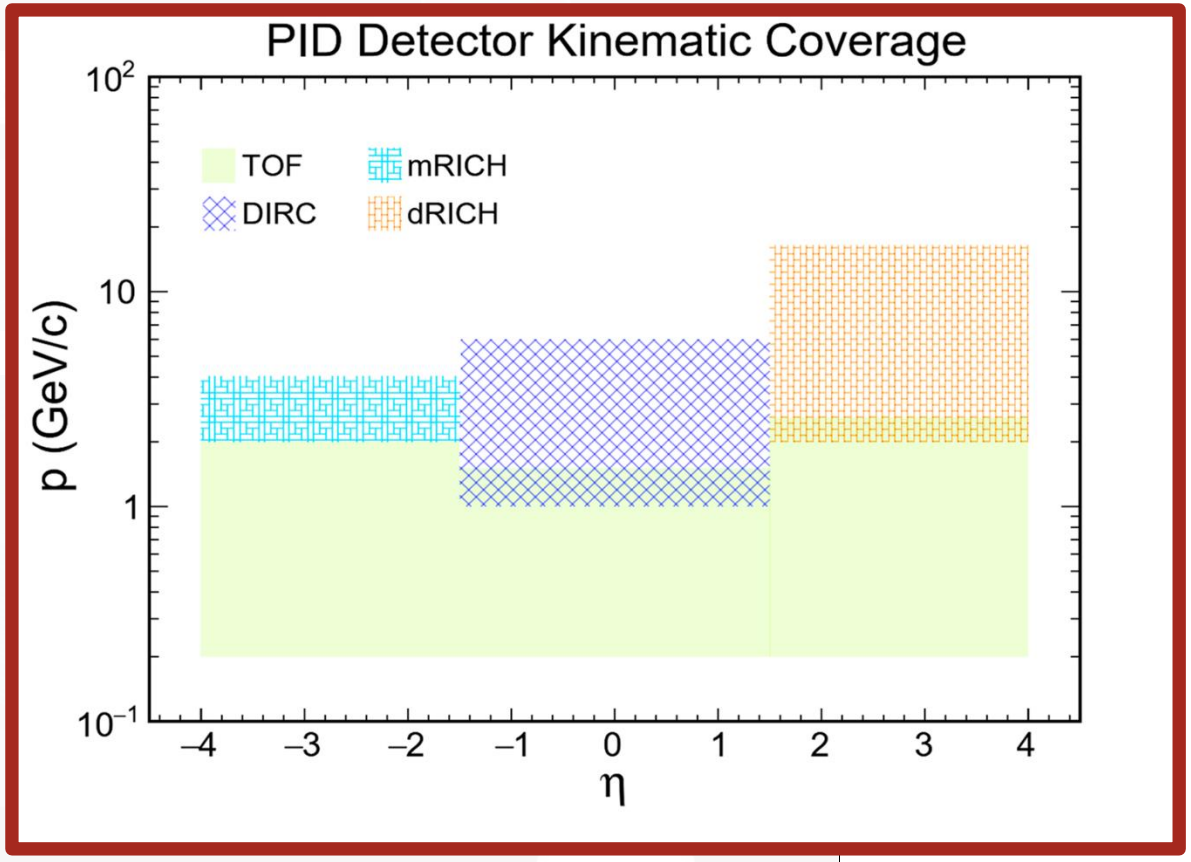
In R(cm)	Out R(cm)	Z(cm)	Pixel Pitch(μm)	Material Budget (X/X0 %)	Tech
3.18	18.62	25	25	0.42	MIC6
3.18	36.50	49	25	0.42	MIC6
3.47	55.00	73	25	0.42	MIC6
5.08	67.50	103.65	25	0.42	MIC6
6.58	67.50	134.33	25	0.42	MIC6
8.16	150.00	165.00	50(rϕ)x250(r)	0.26	MPGD
In R(cm)	**Out R(cm)**	**Z(cm)**	**Pixel Pitch(μm)**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

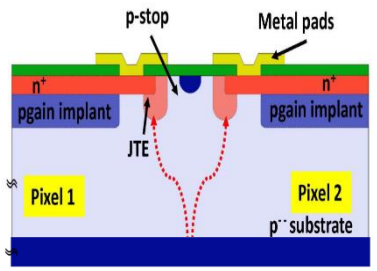
PID: ToF + (DIRC + RICH)



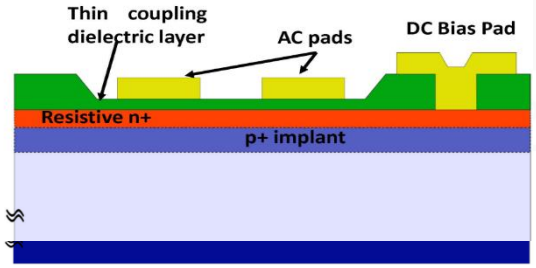


EicC detector design

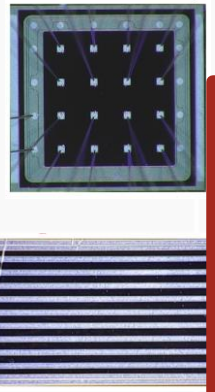
PID: ToF + (DIRC + RICH)

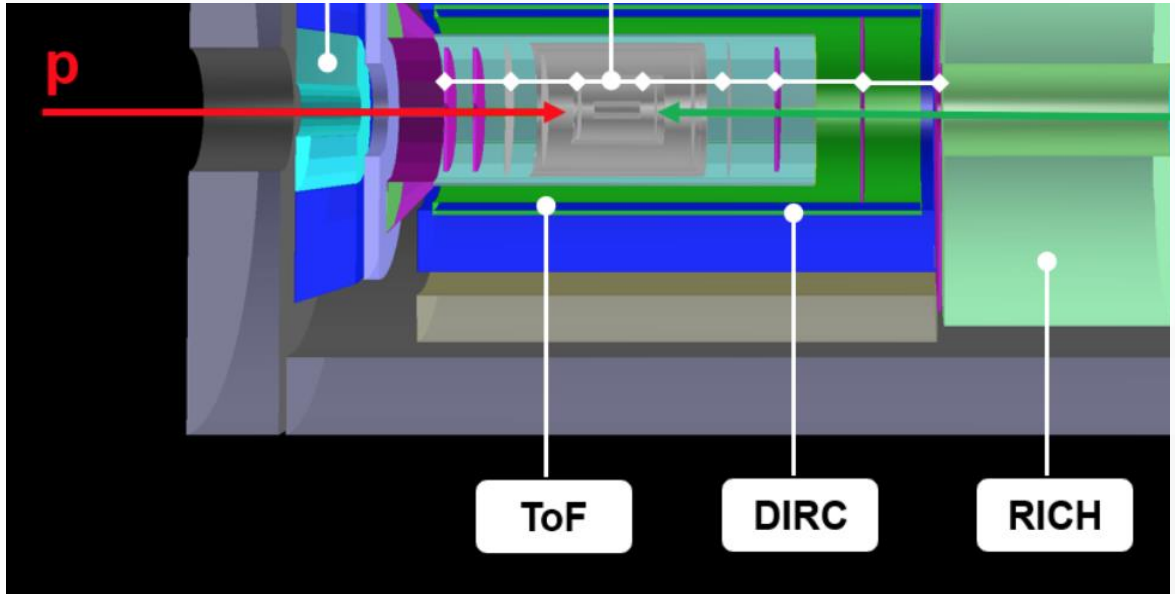


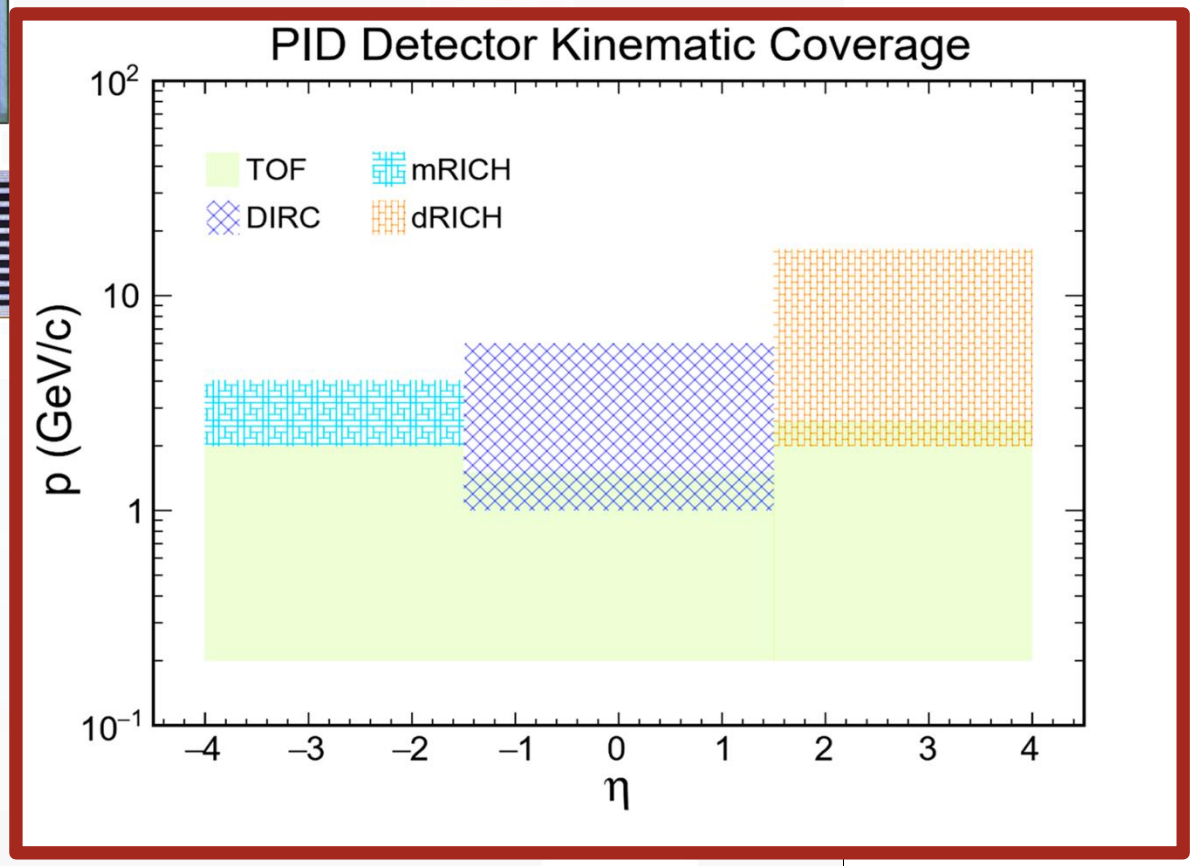
DC-LGAD



AC-LGAD

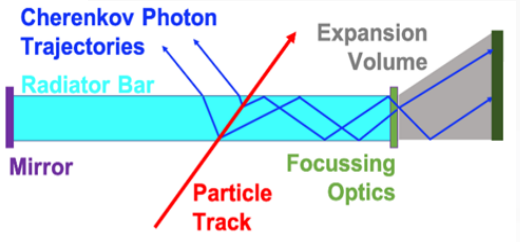


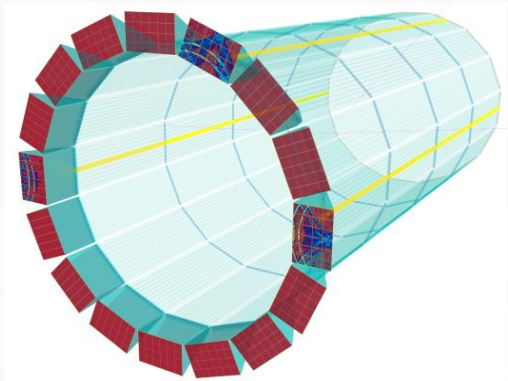


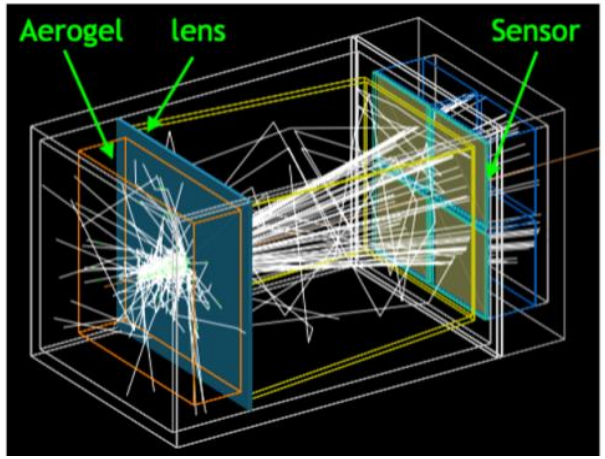


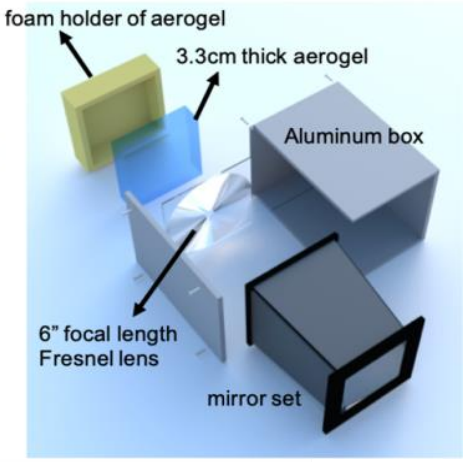
EicC detector design

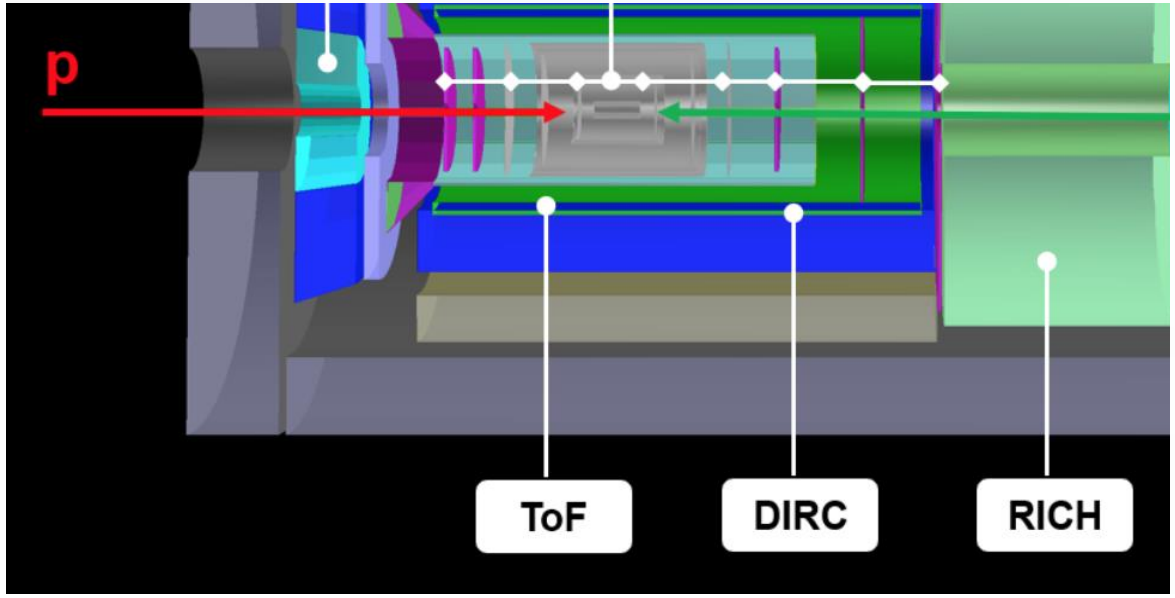
PID: ToF + (DIRC + RICH)

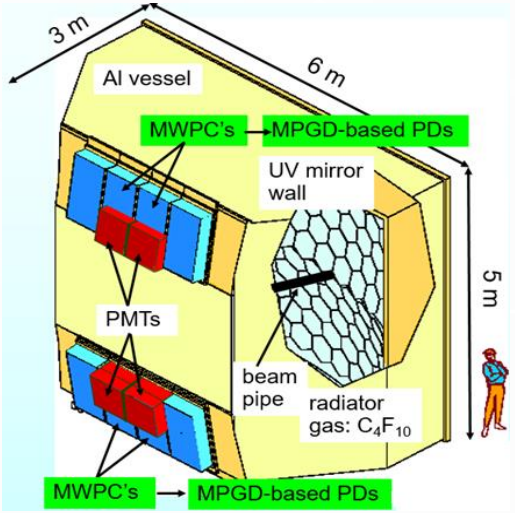


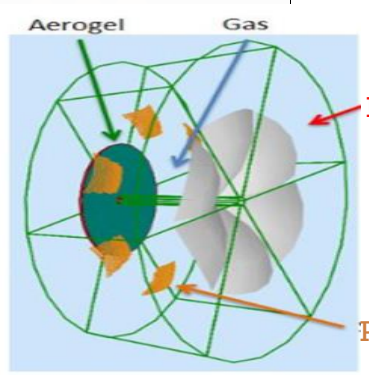






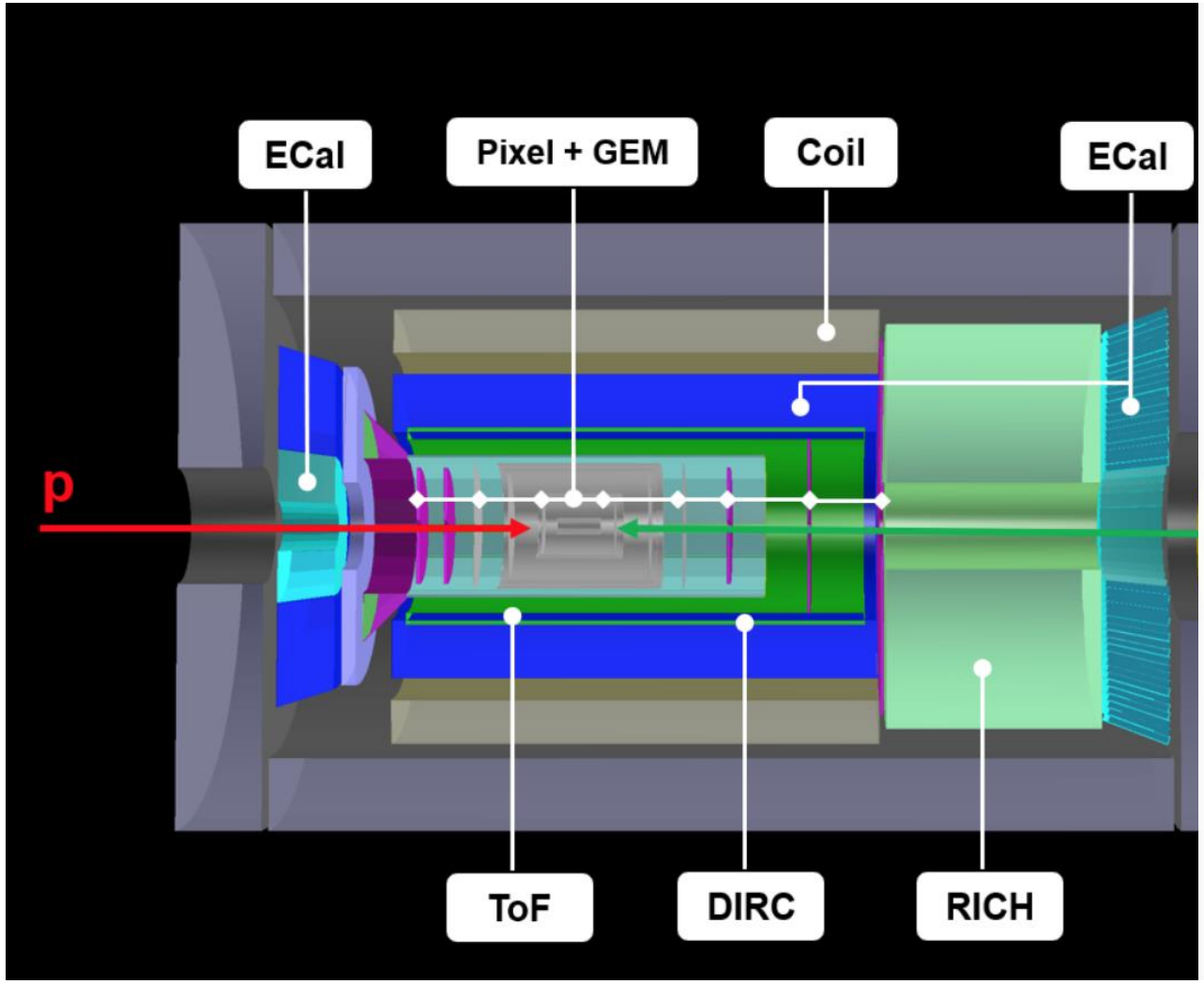


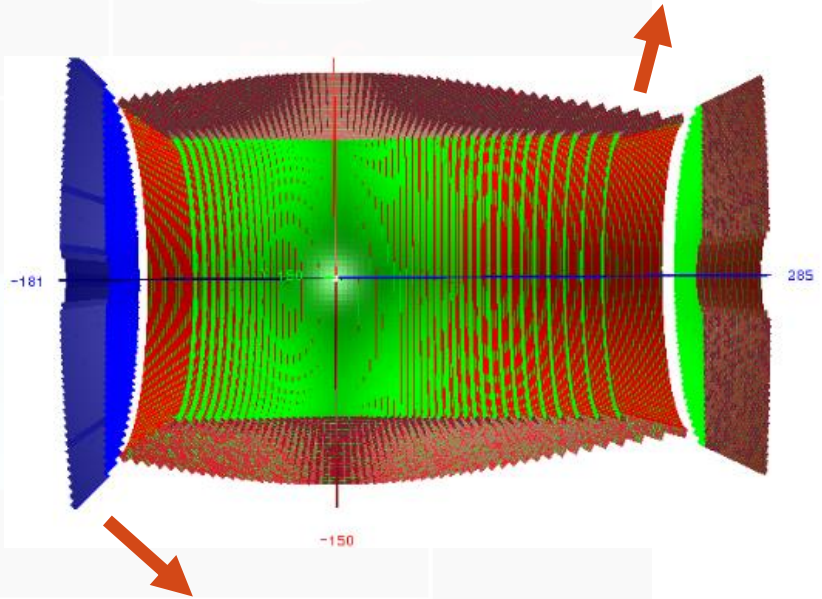


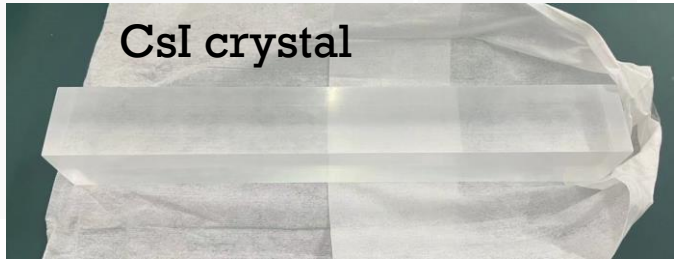


EicC detector design

Ecal: Shashlik + CsI crystal

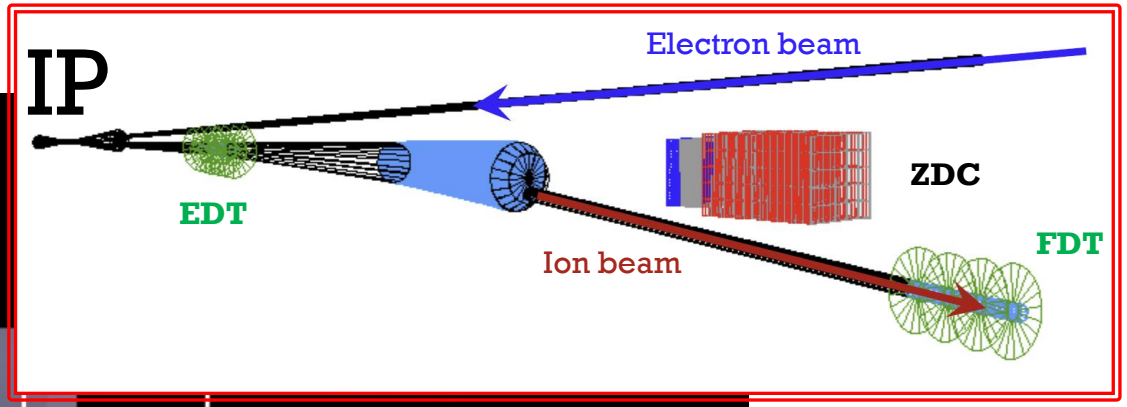




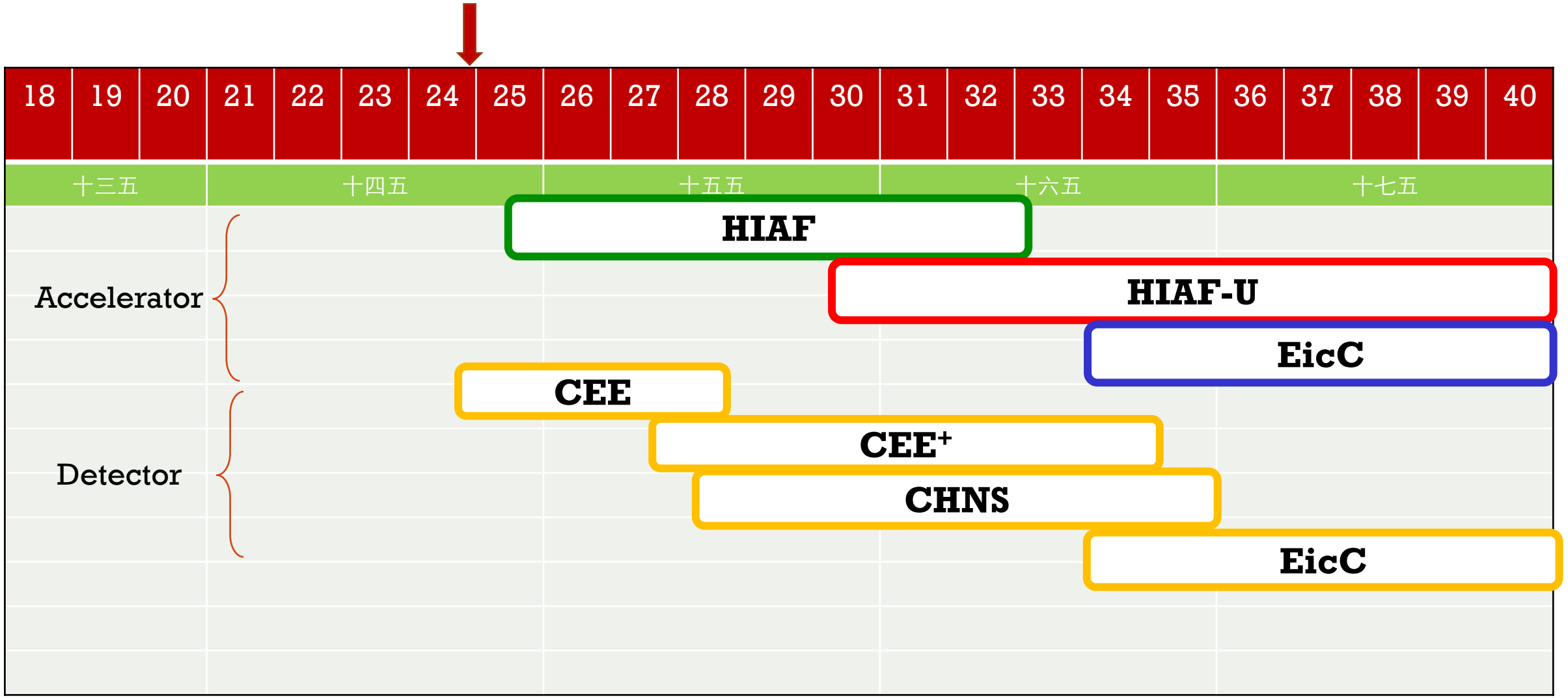


EicC detector design

Far-Forward detector



Timeline


18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
十三五
十四五
十五五
十六五
十七五
Accelerator
Detector
HIAF
HIAF-U
EicC
CEE
CEE+
CHNS
EicC

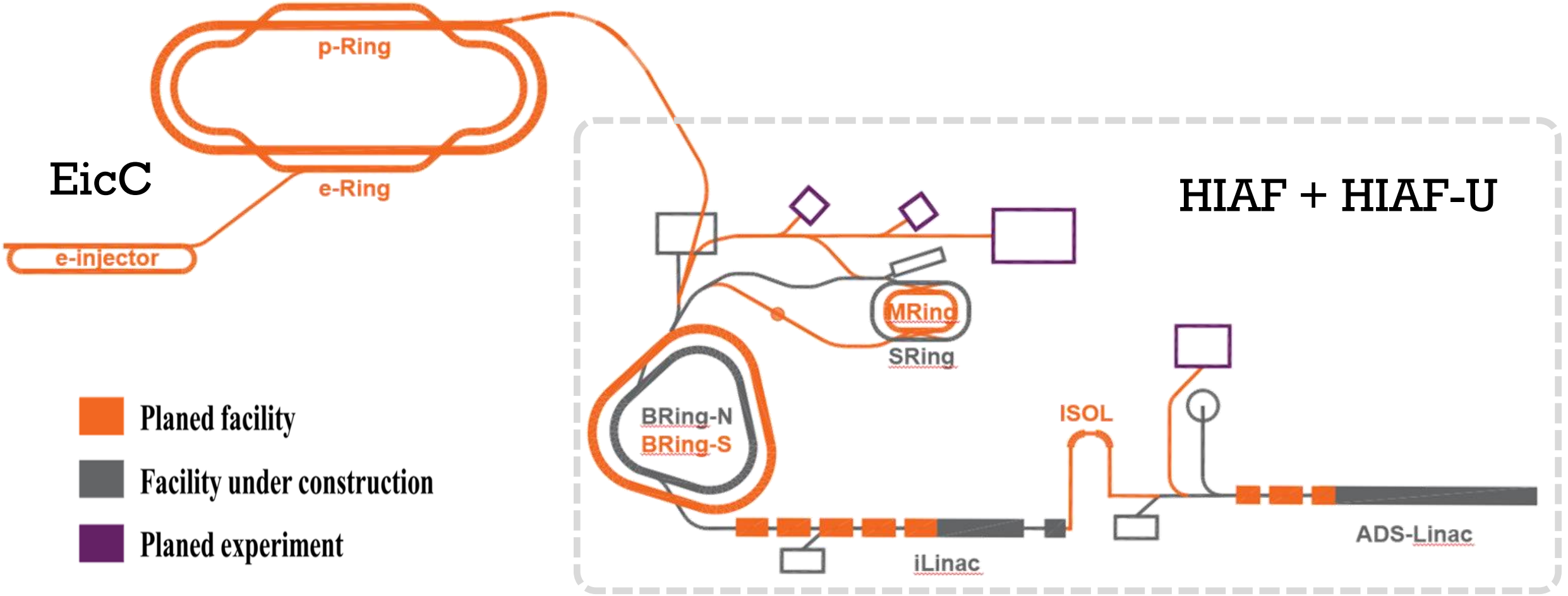
Summary

- 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 → EicC is part of the upgrade plan, likely within 2030-2040
- **International interests/involvements are very welcome!**

Contact me: yxzhao@impcas.ac.cn

Backups

EicC Accelerator complex layout

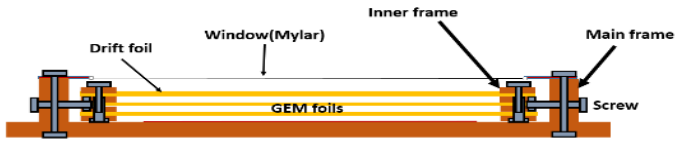


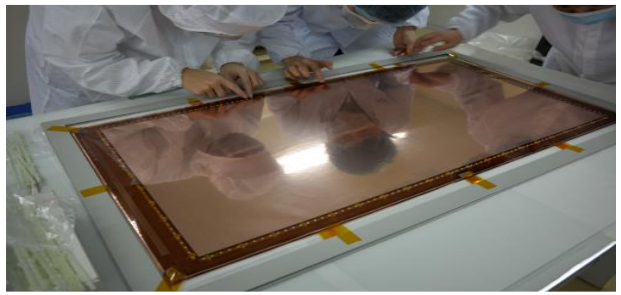
Detector R&Ds

Clean rooms of ISO6 and ISO7 (in total of 200 m^2) for detector assembling

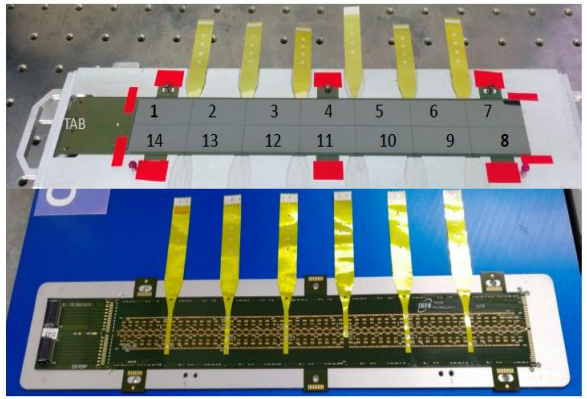
- 25cm x 25 cm Micromegas mass production
- R&D on 0.4m x 0.4m

1m x 0.5 m GEM (self-stretching)

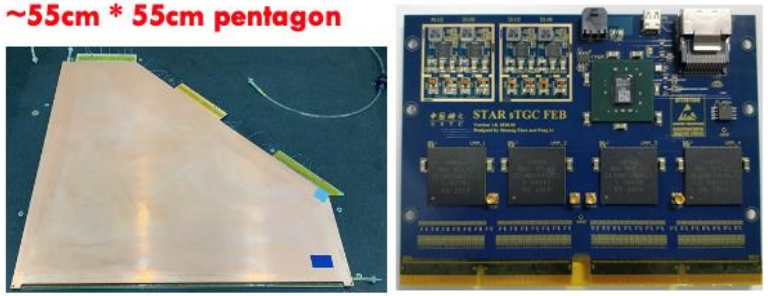




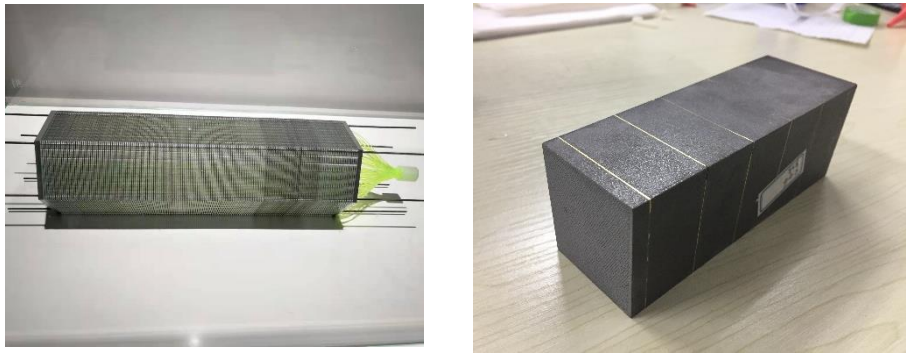
ALICE style ITS2 MAPS pixel detector



sTGC detector



Shashlyk and W-powder+ScFi EMCal



DIRC prototype