EicC detector and physics

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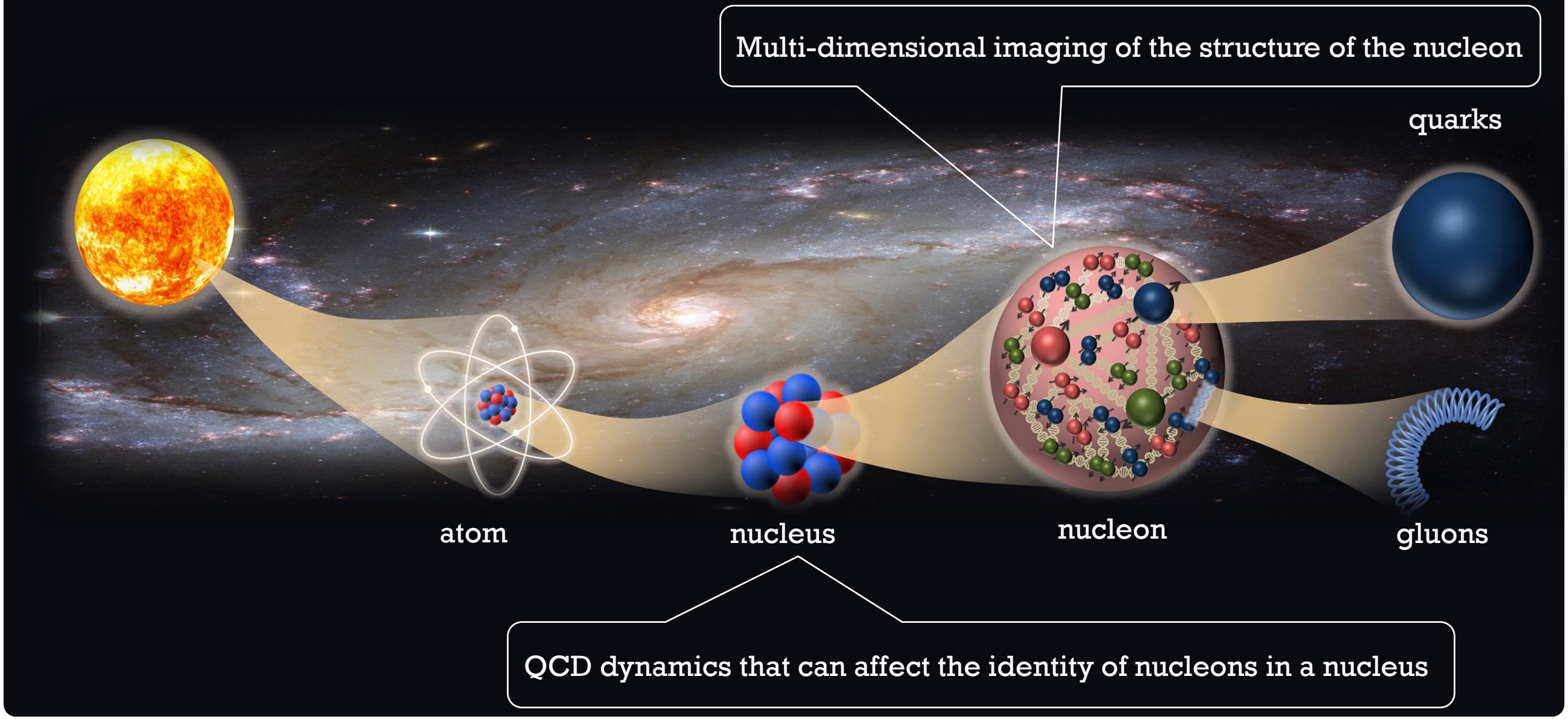
Outline

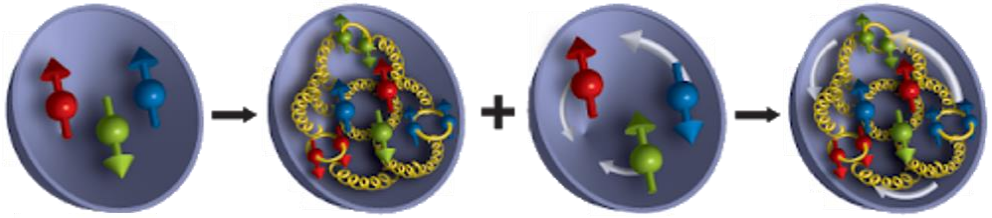
1. Introduction of **Electron-Ion Collider in China** (**EicC**)
2. EicC detector conceptual design
3. **Hyperon-Nucleon Spectrometer** (**HNS**) at HIAF
4. Summary

Building blocks of our visible universe



spin

Gell-Mann
quark model



1970s 1980s/2000s Now

Spin decomposition:

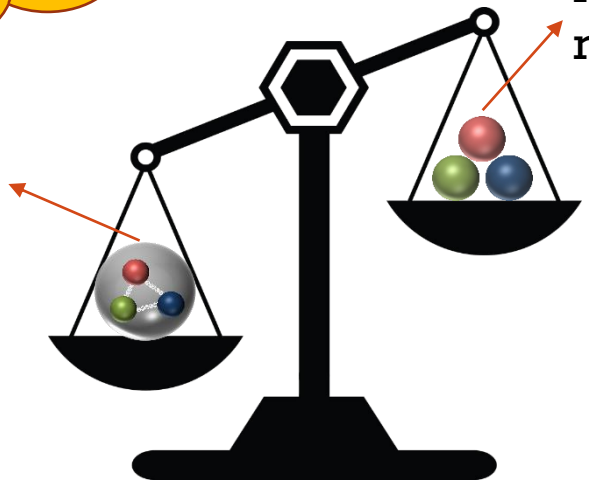
$$S_{tot} = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \mathcal{L}_q + \mathcal{L}_g$$

Quark spin | Gluon Spin | Quark OAM | Gluon OAM

mass

Higgs
mechanism

Proton
mass



Mass decomposition:

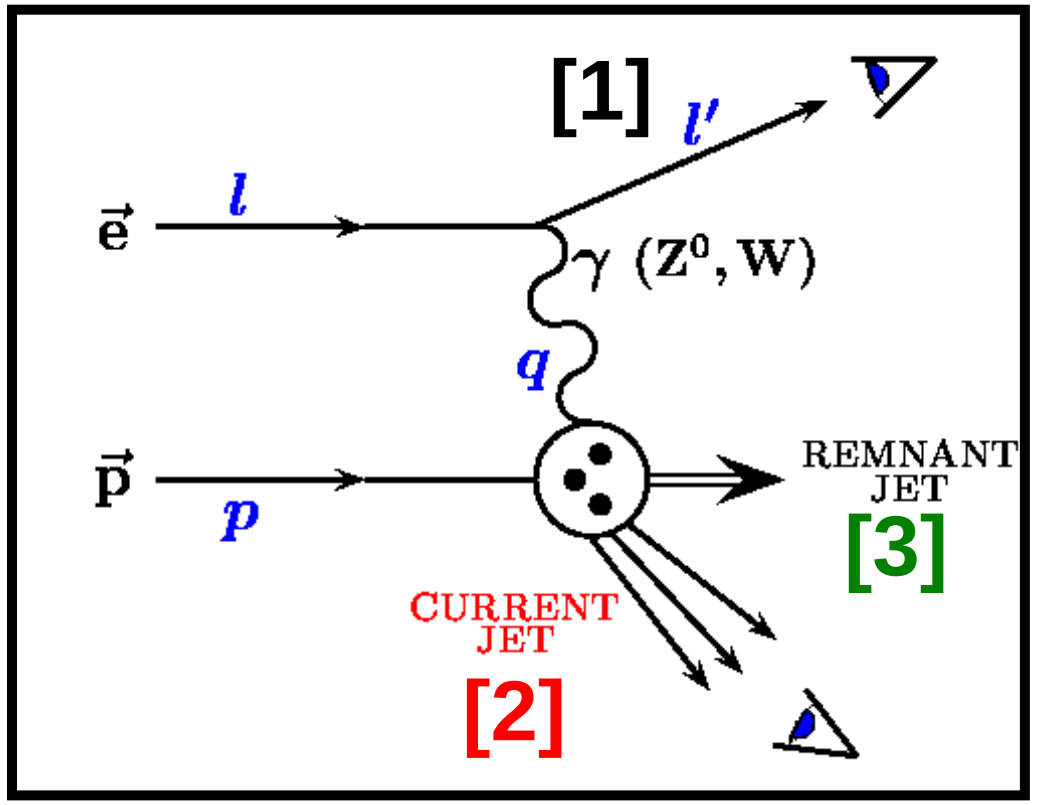
$$M = M_q + M_m + M_g + M_a$$

Quark energy | Quark mass | Gluon energy | Trace anomaly

Experimentally… we need to determine each of the above contributions

Lepton-Nucleon Scatterings

QED tool to study QCD nature of the nucleon



$$Q^2 = -q^2 = sxy$$

$$x = \frac{Q^2}{2p \cdot q}$$

$$y = \frac{p \cdot q}{p \cdot l}$$

$$s = 4E_e E_p$$

$$W = (q + p)^2$$

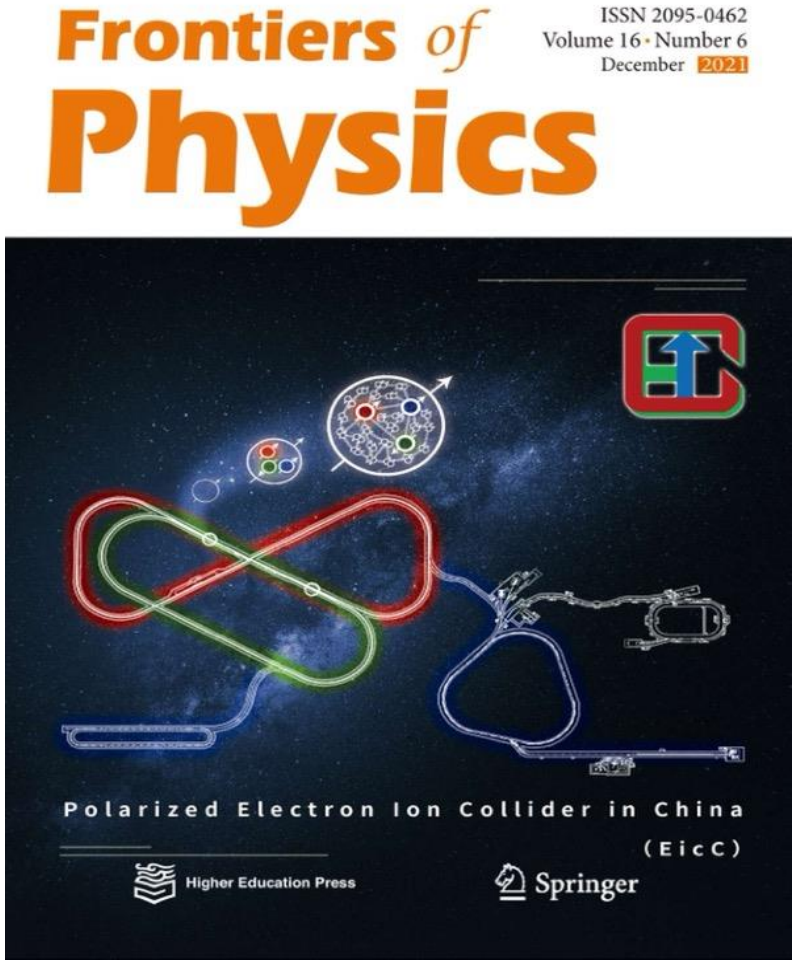
- QED probe is clean
- α_{EM} ~1/137 with broad Q coverage
- One-photon exchange approximation: ~1% accuracy
- Detection scale is determined by Q: 200MeV ~ nucleon size

Observe scattered electron/muon	[1]	→ **inclusive**
Observe current jet/hadron	[1]+[2]	→ **semi-inclusive**
Observe remnant jet/hadron as well	[1]+[2]+[3]	→ **exclusive**

HIAF → EicC

EicC white paper (arXiv: 2102.09222)

Published in the *Frontiers of Physics* (2021)



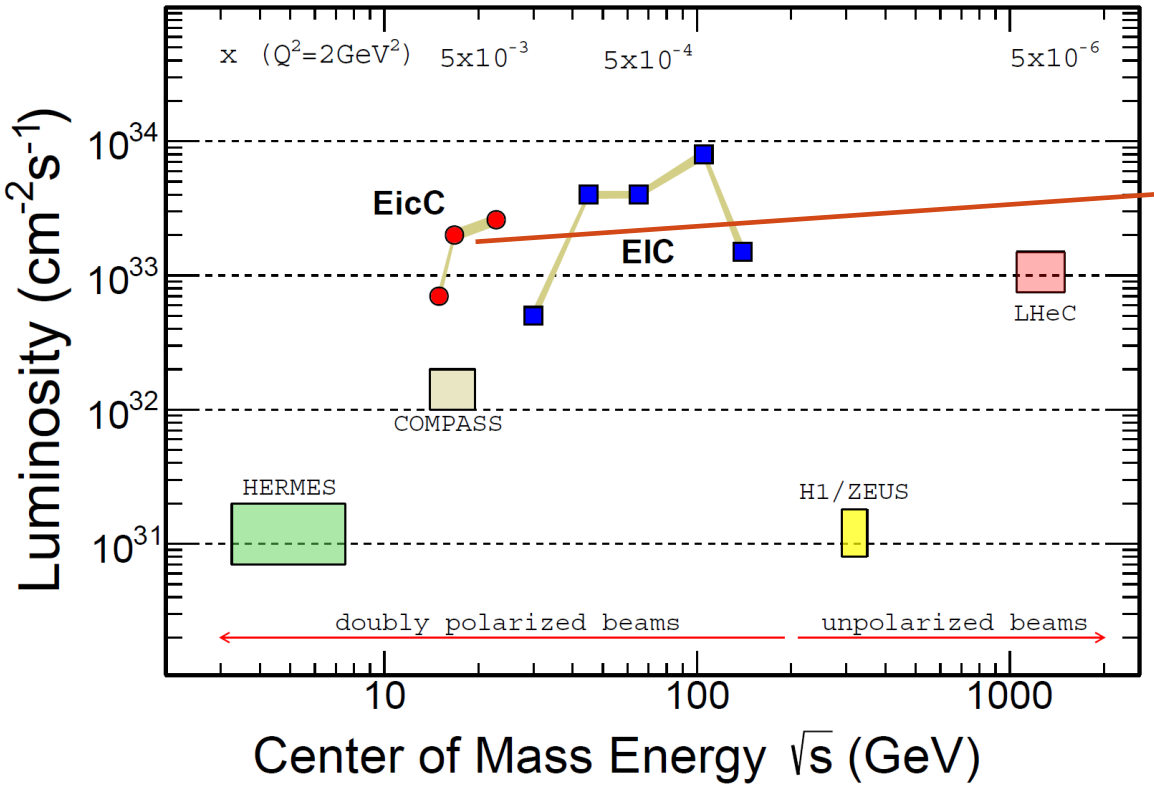
https://link.springer.com/article/10.1007/s11467-021-1062-0

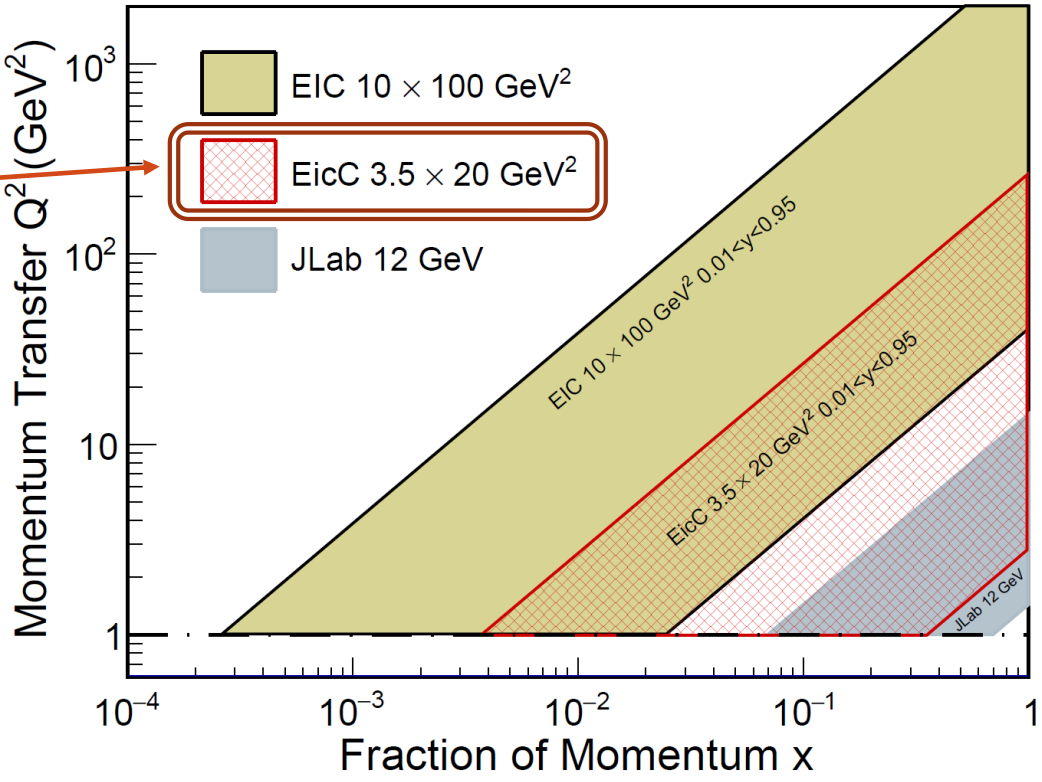
- Spin structure of the nucleon: 1D, 3D
  - polarized electron + polarized proton/light nuclei
- Partonic structure of nuclei and the Parton interaction with the cold nuclear environment
  - unpolarized electron + unpolarized various nuclei
- Quarkonium with c/cbar, b/bbar
- Origin of the proton mass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

Detector + Accelerator preliminary design

45 institutes and >100 physicists

EicC parameters

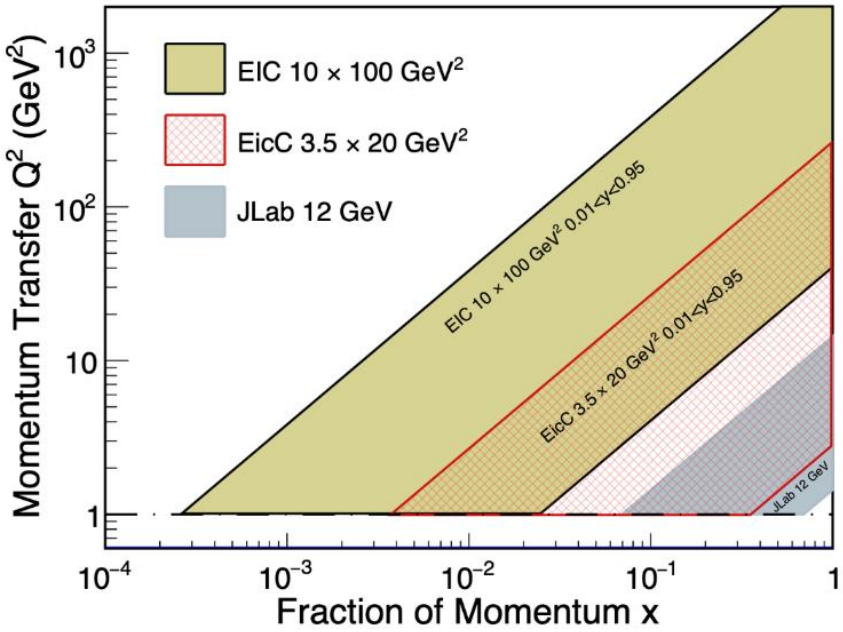


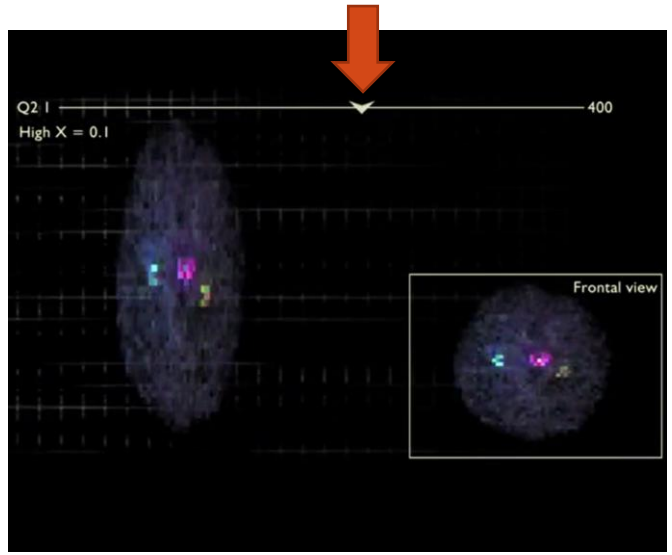


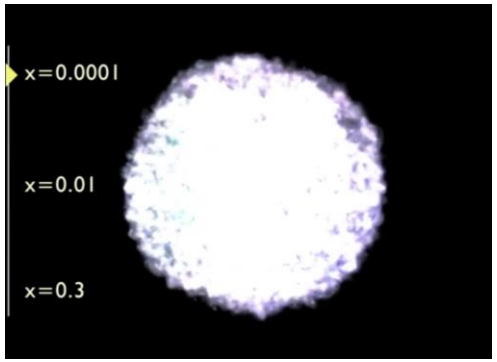
- EicC covers the kinematic region between JLab experiments and EIC@BNL
- EicC complements the ongoing scientific programs at JLab and future EIC project
- EicC focuses on moderate x and sea-quark region

Kinematic region VS physics

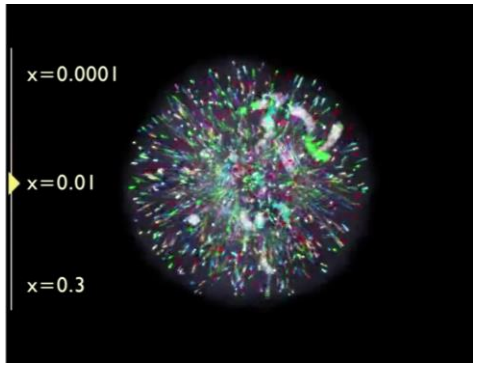
See a video at:
http://eicug.org/



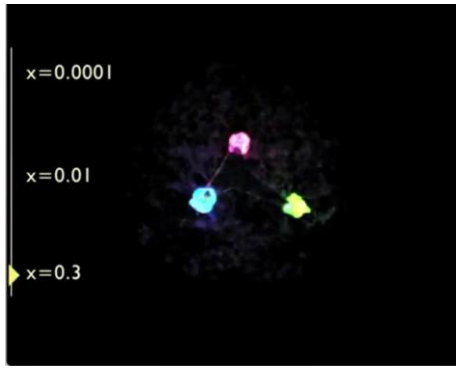




Gluon dominates



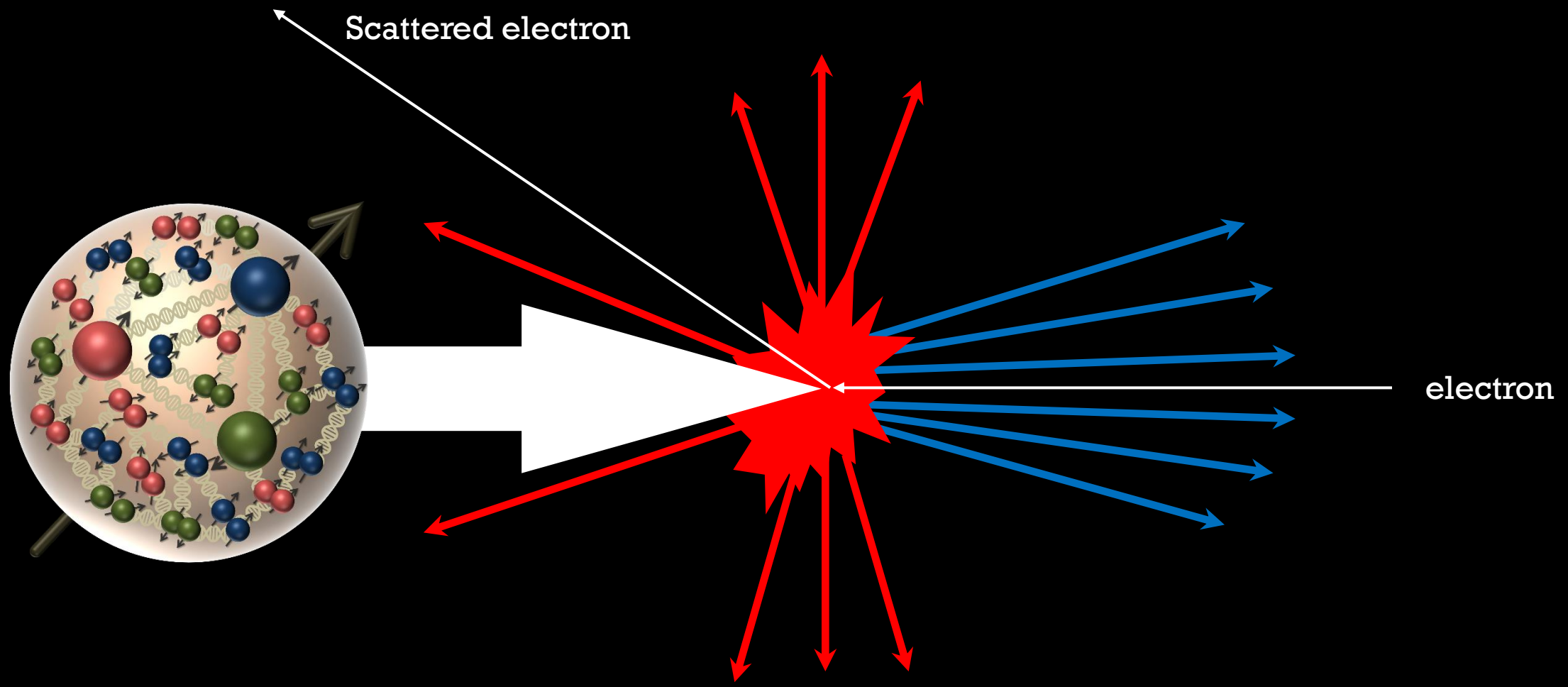
Gluon + sea quarks



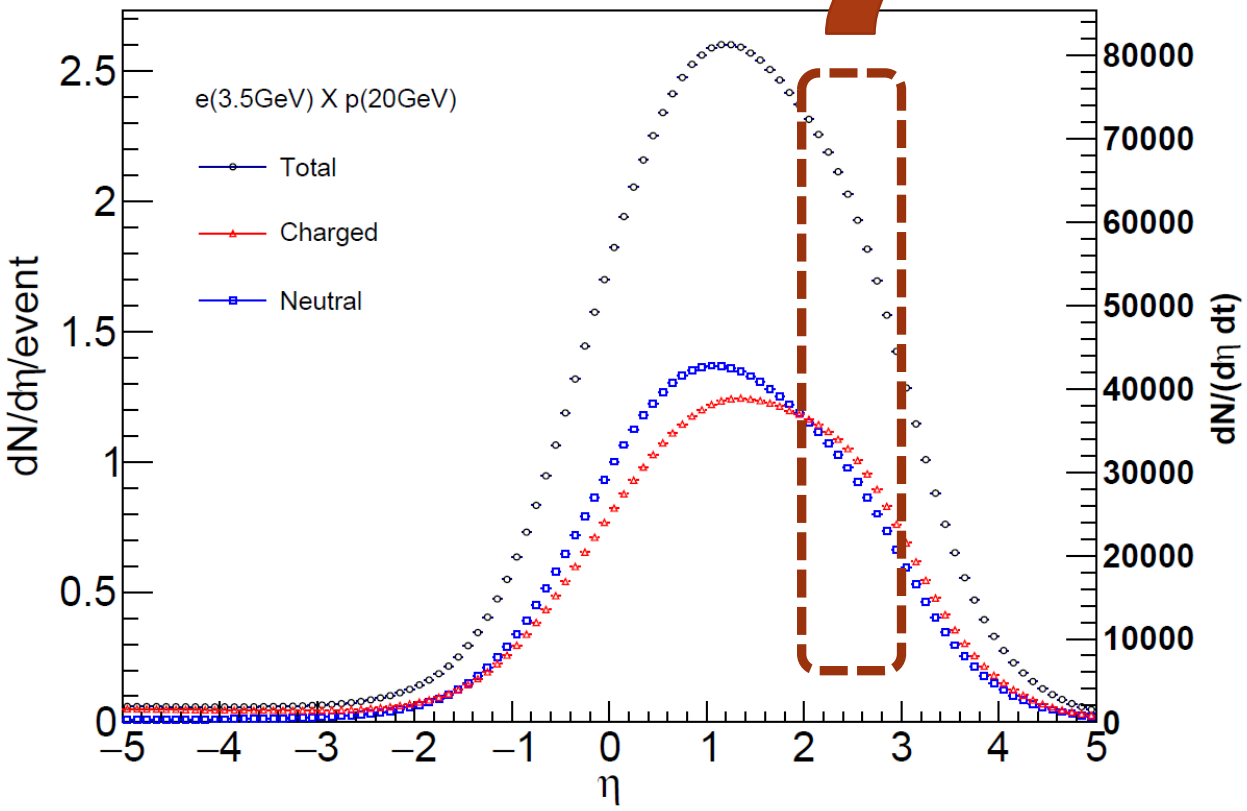
Valence quarks

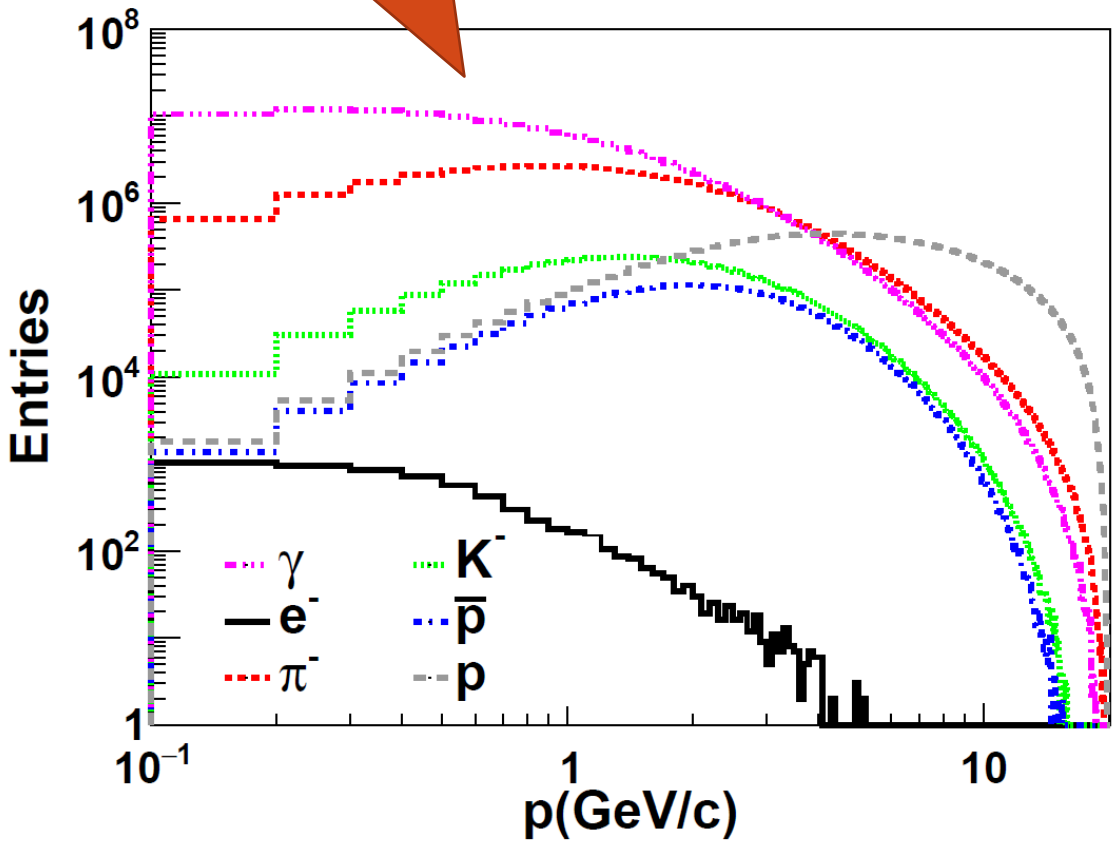
- Different x → different picture
- Broad Q^2 coverage:
  - QCD evolution
  - Non-perturbative → perturbative

Detection of Electron-Ion Collision



Distributions

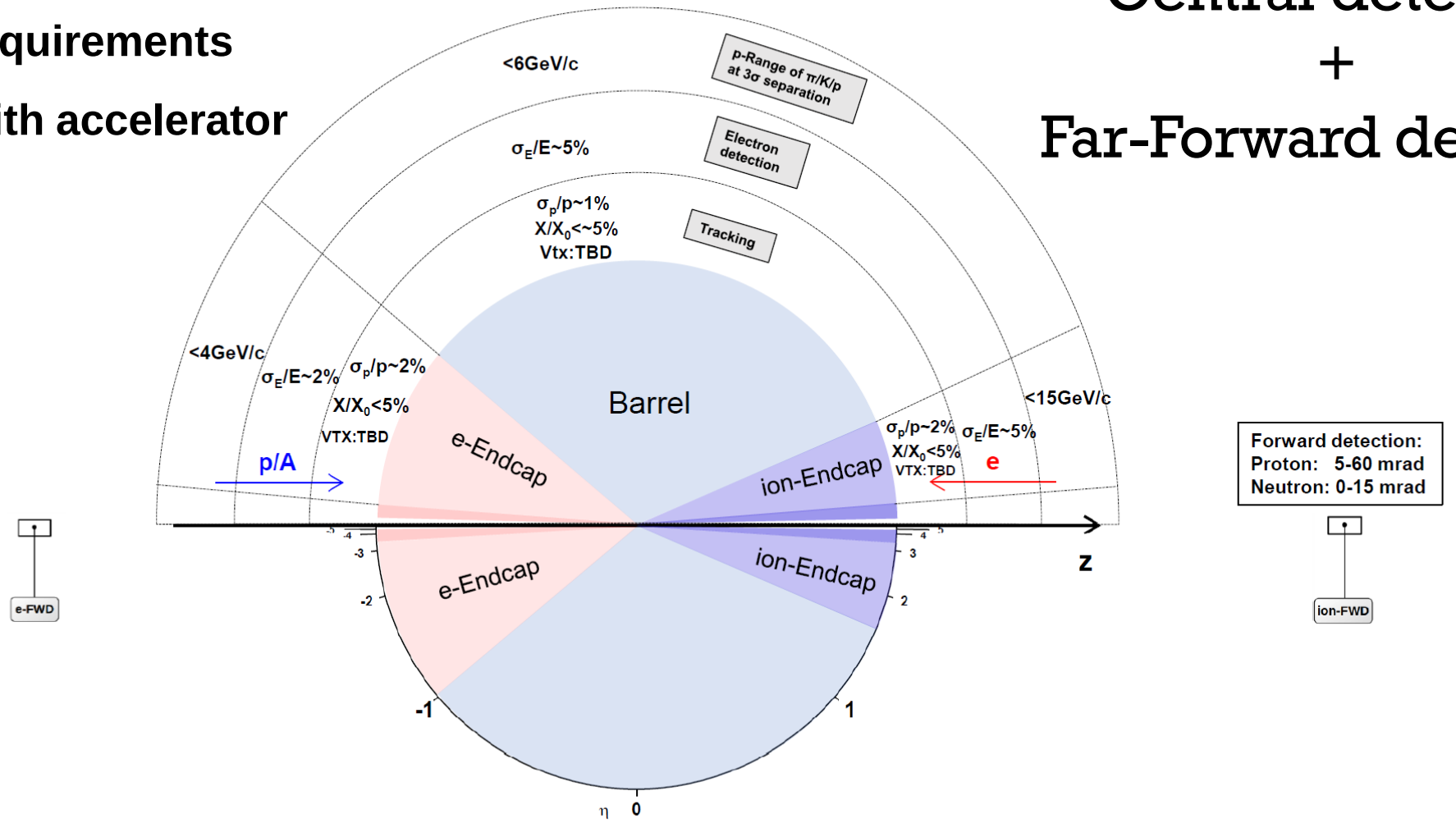




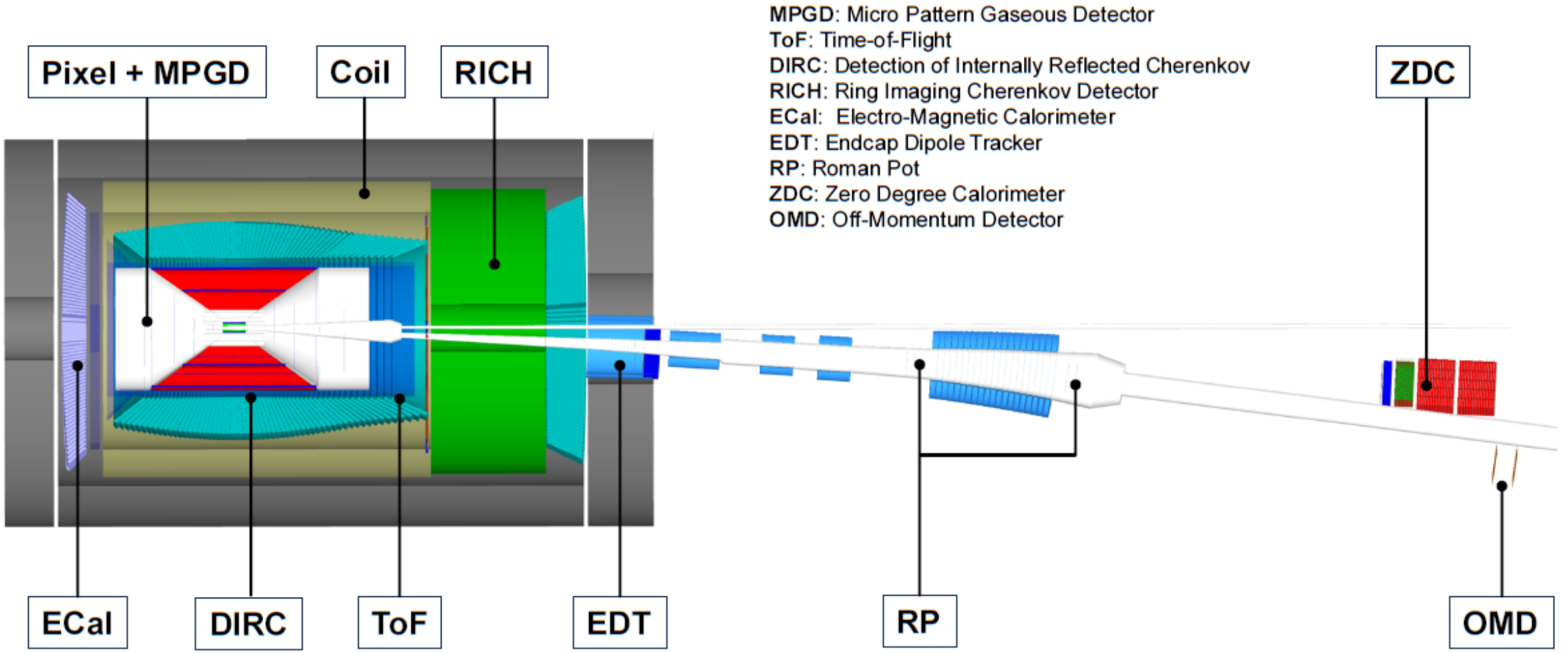
Detection requirements

- **4π coverage**
- **Strong PID requirements**
- **Integration with accelerator**

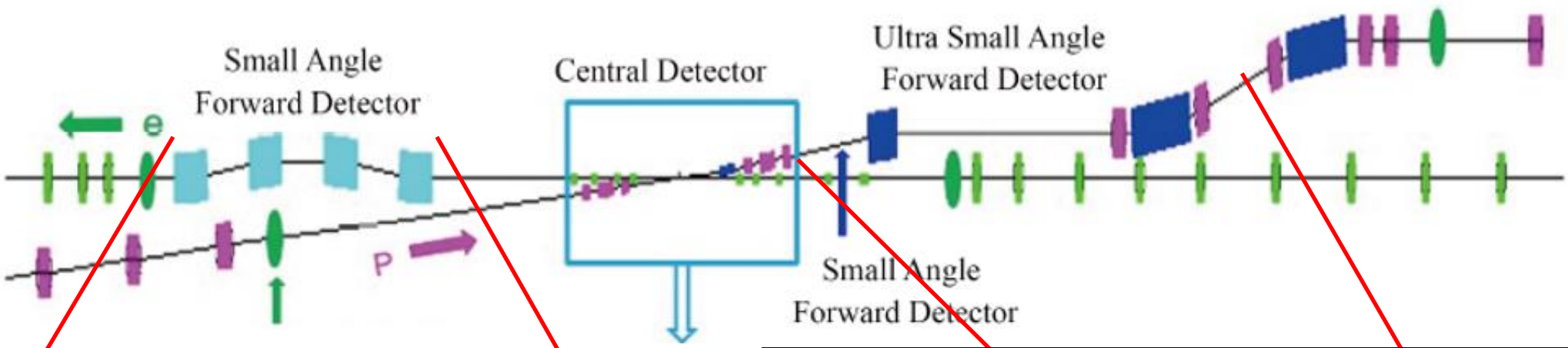
Central detector
+
Far-Forward detector

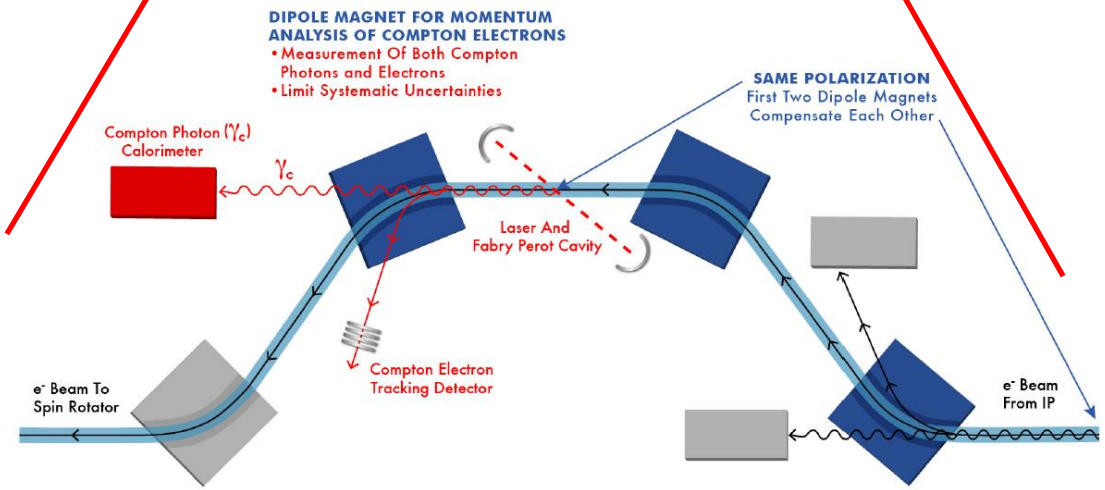


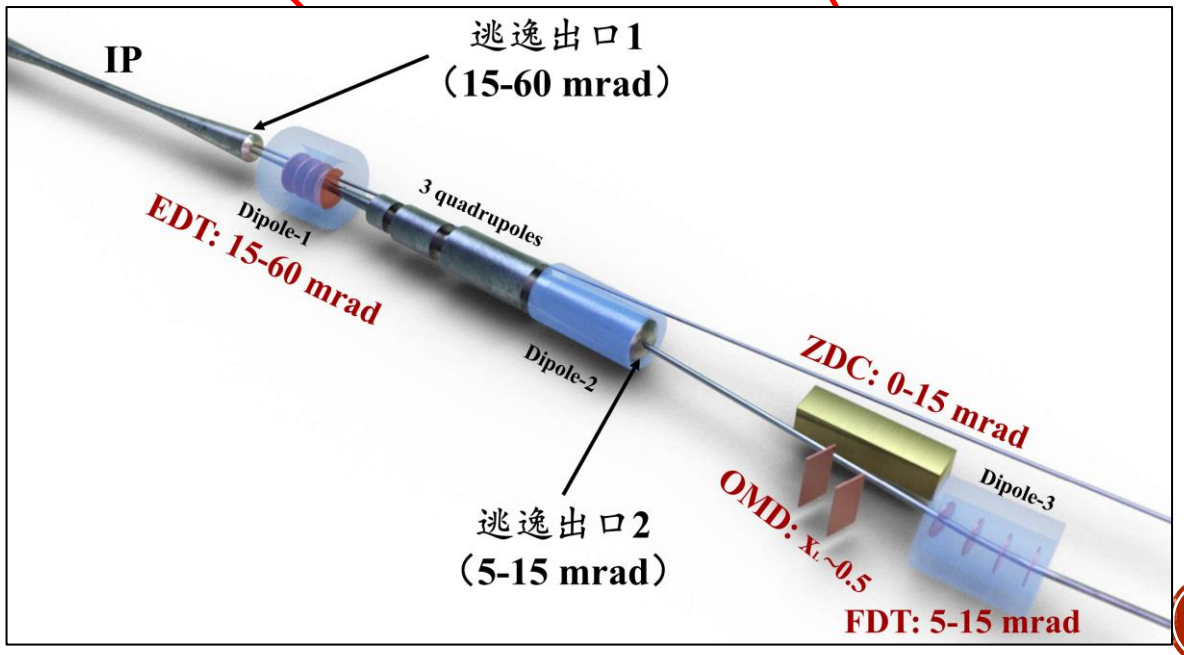
Detector conceptual design



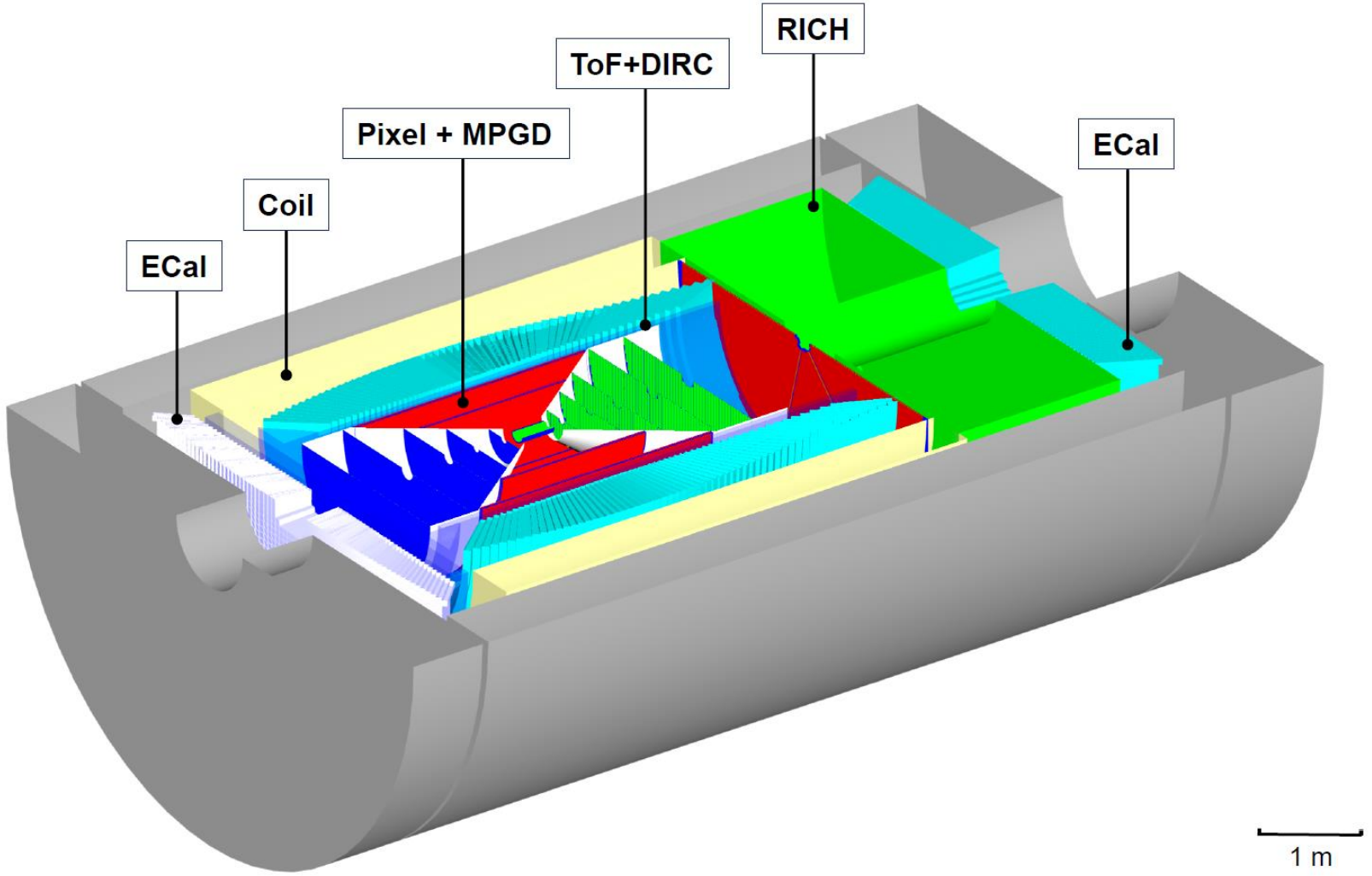
EicC interaction region



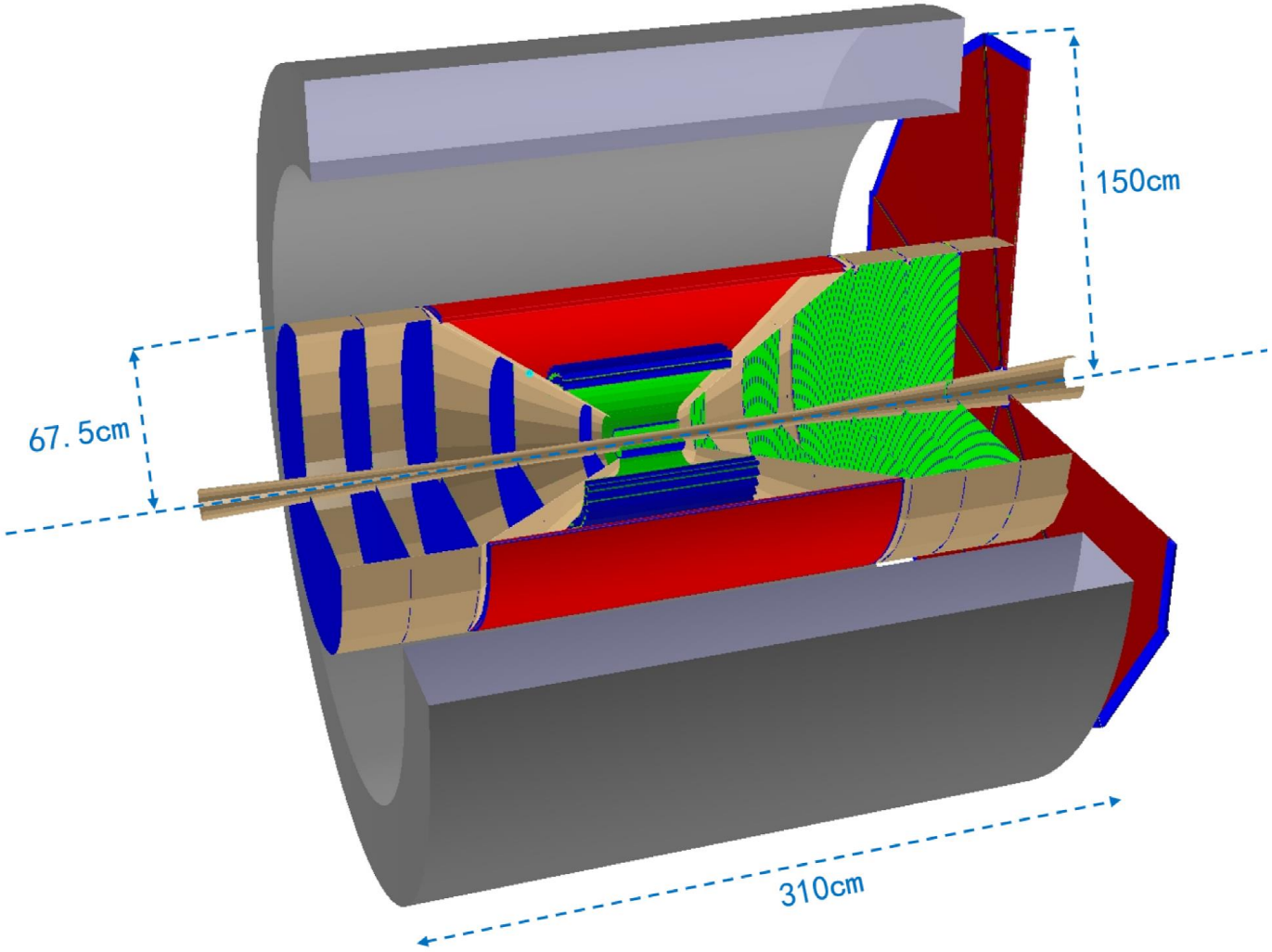




EicC Central detector design



EicC Tracking system



R(cm)	Length(cm)	Pitch Size(μm)	$X/X_0\%$	Tech.
3.3	28.0	20	0.09	MIC7
4.4	28.0	20	0.09	MIC7
5.5	28.0	20	0.09	MIC7
27.5	73.42	30	0.85	MIC6
30.0	80.01	30	0.85	MIC6
65.5	174.88	150($r-\phi$)x150(z)	1.50	MPGD
67.5	174.88	150($r-\phi$)x150(z)	1.50	MPGD

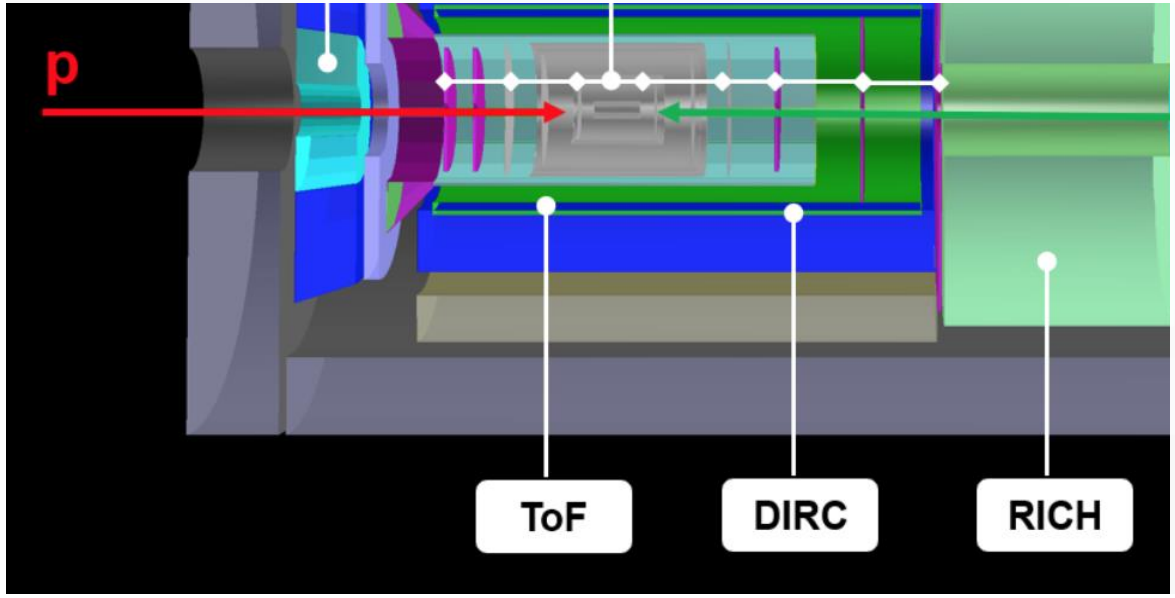
R_{in}(cm)	R_{out} (cm)	Z(cm)	Pitch Size(μm)	$X/X_0\%$	Tech.
3.18	18.62	25.0	30	0.45	MIC6
3.18	43.20	58.0	30	0.45	MIC6
3.47	67.50	91.0	30	0.45	MIC6
6.58	67.50	115.0	30	0.45	MIC6
6.58	67.50	140.0	30	0.45	MIC6
8.16	150.00	165.0	50($r-\phi$)x250(r)	1.50	MPGD

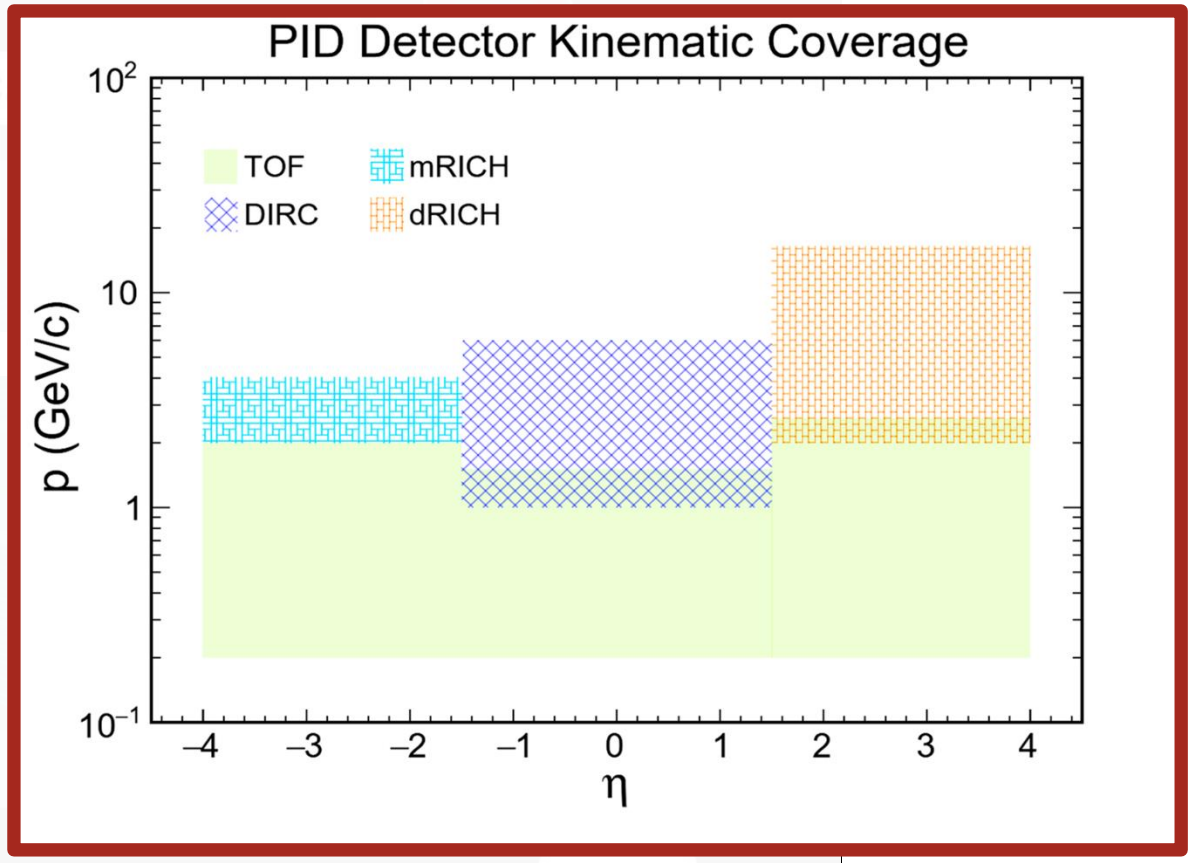
R_{in}(cm)	R_{out} (cm)	Z(cm)	Pitch Size(μm)	$X/X_0\%$	Tech.
3.18	18.62	-25.0	30	0.45	MIC6
3.18	43.20	-58.0	30	0.45	MIC6
3.95	67.50	-91.0	30	0.45	MIC6
5.26	67.50	-118.0	30	0.45	MIC6
5.26	67.50	-145.0	30	0.45	MIC6

EicC PID system

PID: ToF + (DIRC + RICH)

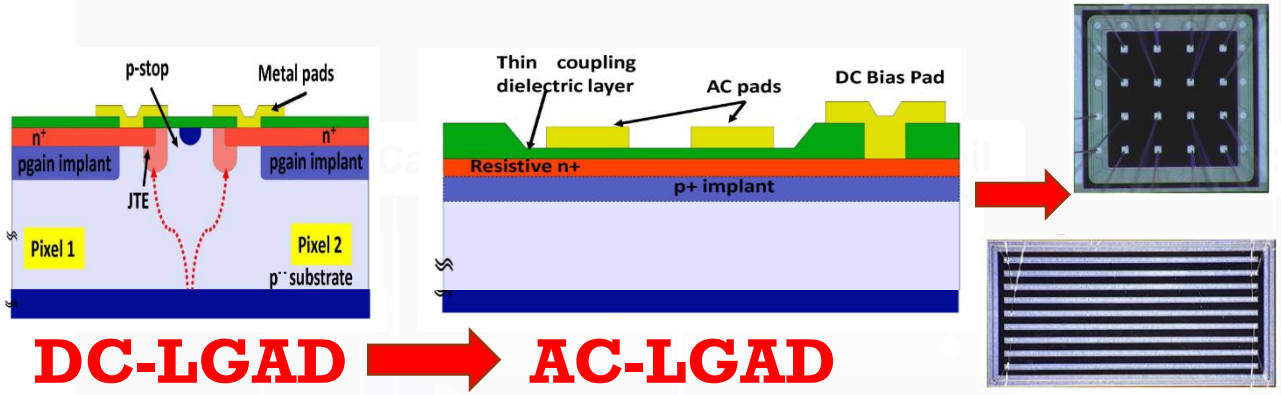
Forward Detector (Ion-Endcap)	e/π (GeV/c)	π/K (GeV/c)
dRICH(aerogel n=1.03)+(C_2F_6)	(0.6-4)+(3.5-15)	(2.0-13)+(12-50)
ToF(30 ps)	≤0.6	≤2.1
Barrel Detector	e/π (GeV/c)	π/K (GeV/c)
hpDIRC(quartz)	<1.2	1-6
ToF(30 ps, r=0.6 m, 1.5 T)	≤ 0.3	≤ 1.6
Backward Detector (e-Endcap)	e/π (GeV/c)	π/K (GeV/c)
mRICH(aerogel, n=1.03)	0.6-2	2-9
ToF(30 ps)	≤ 0.6	≤ 2.1



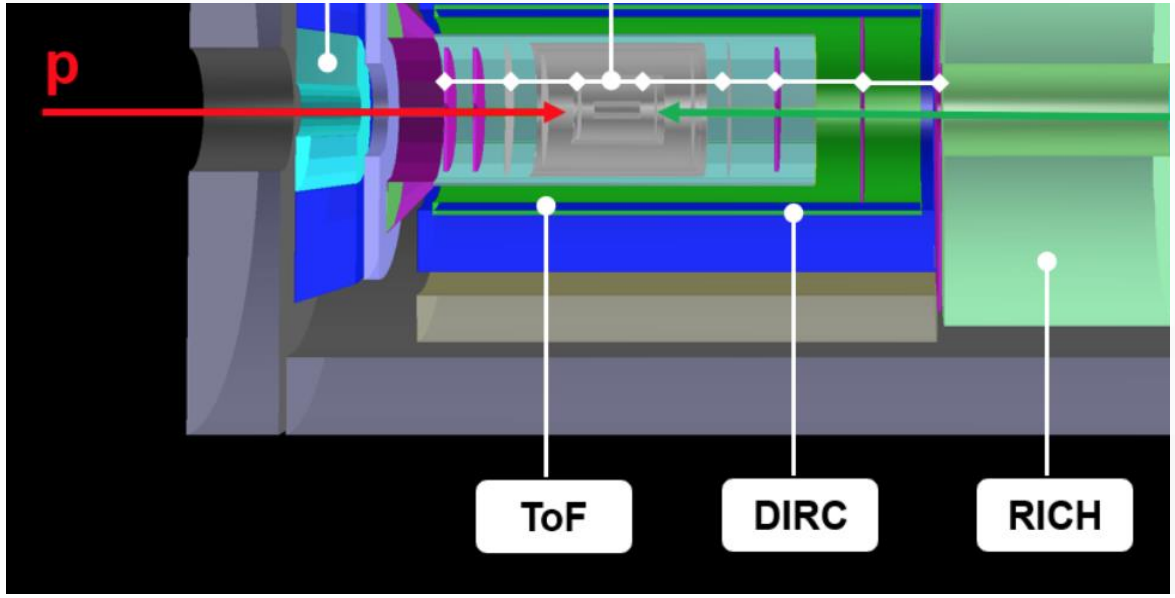


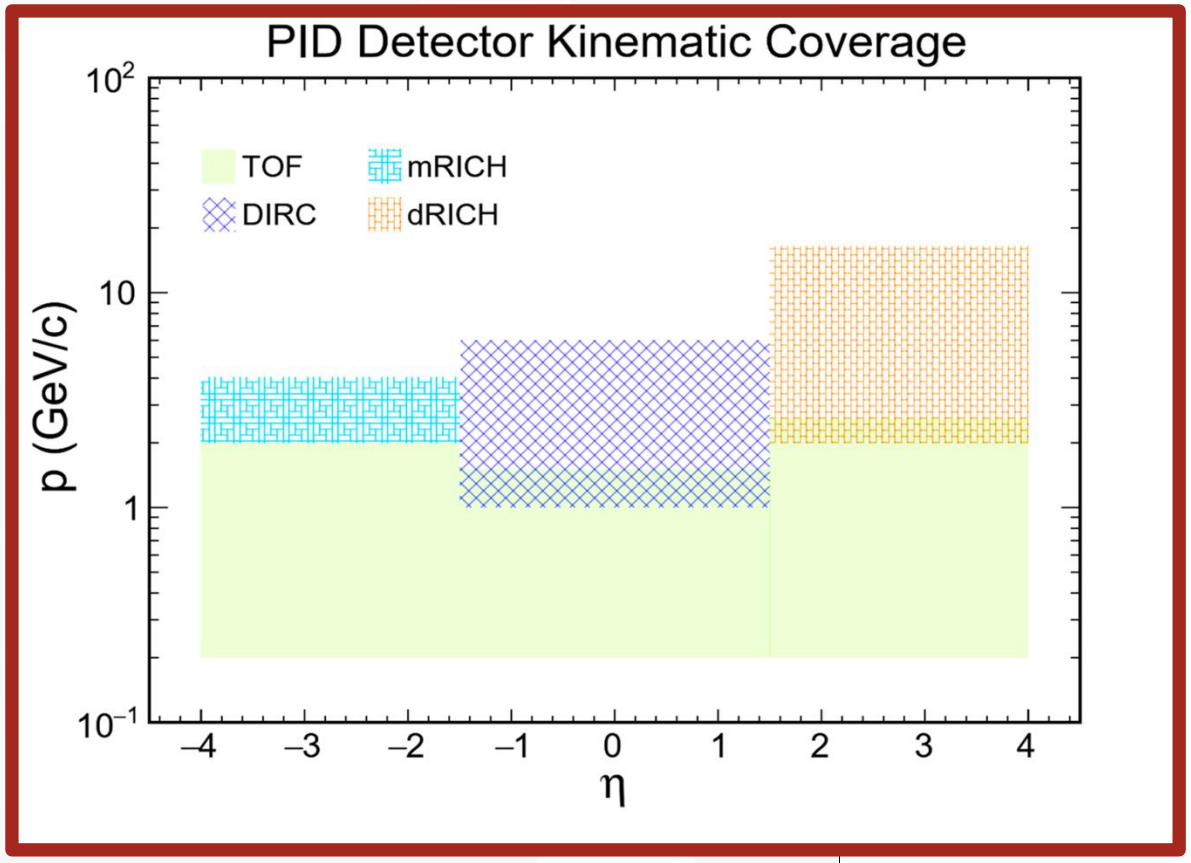
EicC PID system

PID: ToF + (DIRC + RICH)



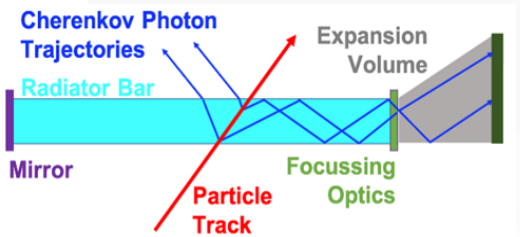
DC-LGAD → AC-LGAD

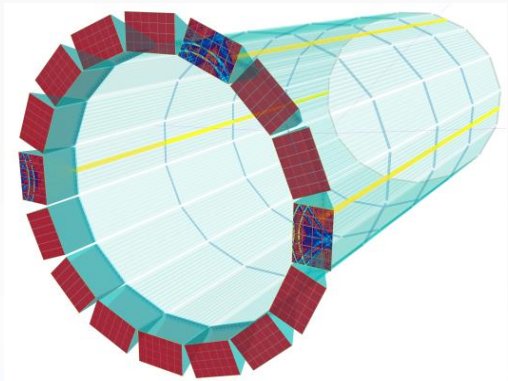


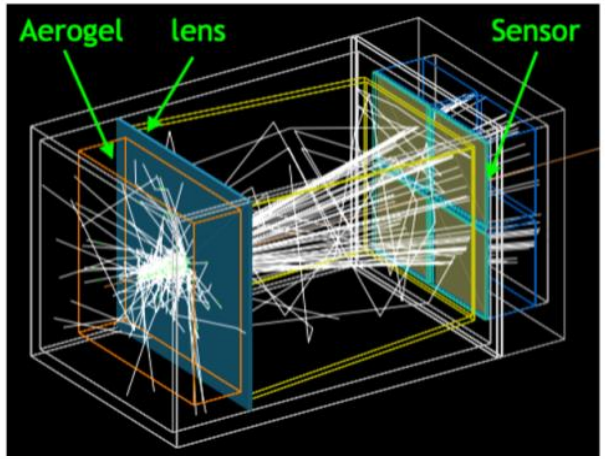


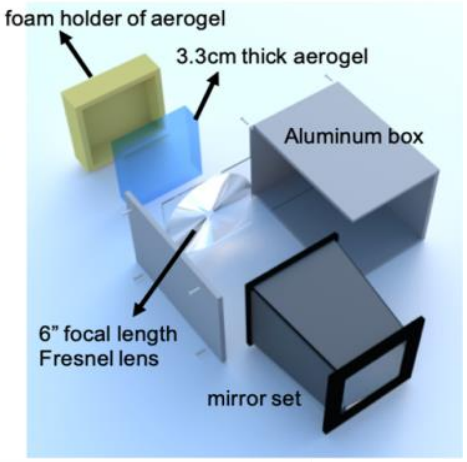
EicC PID system

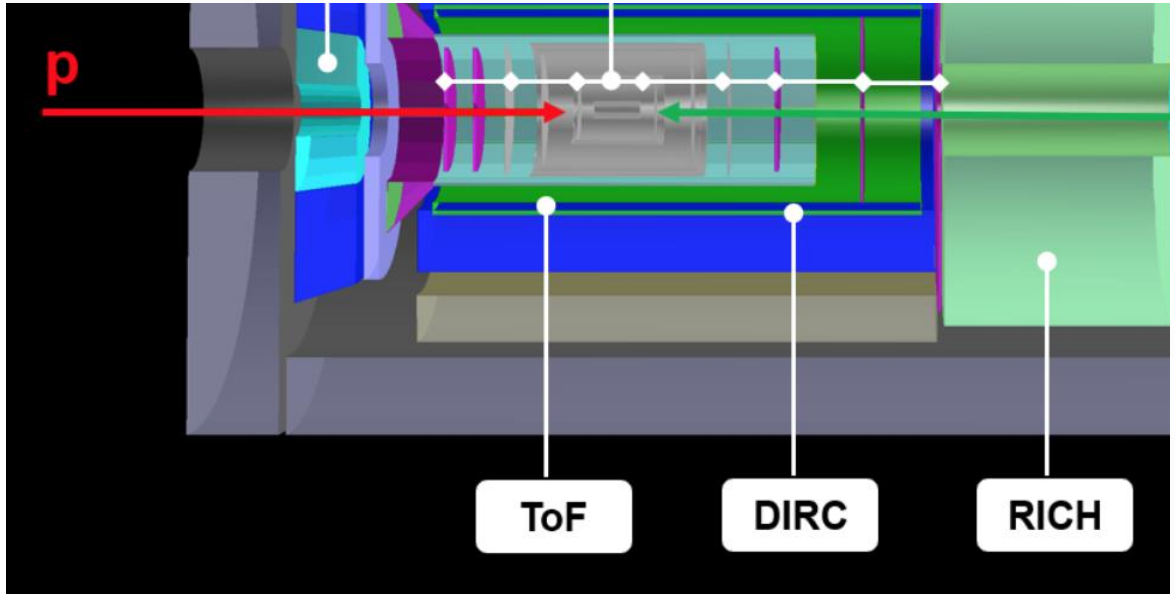
PID: ToF + (DIRC + RICH)

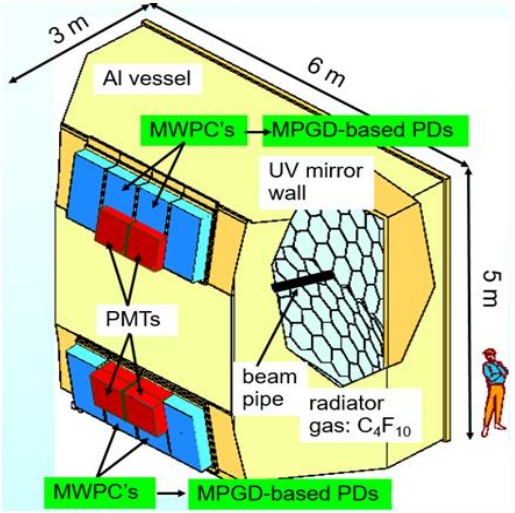


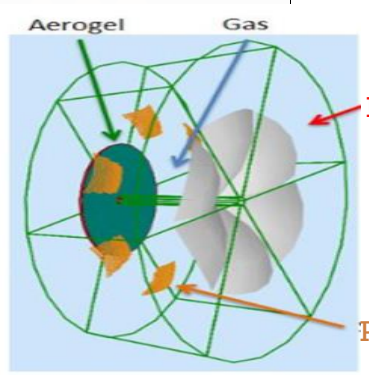




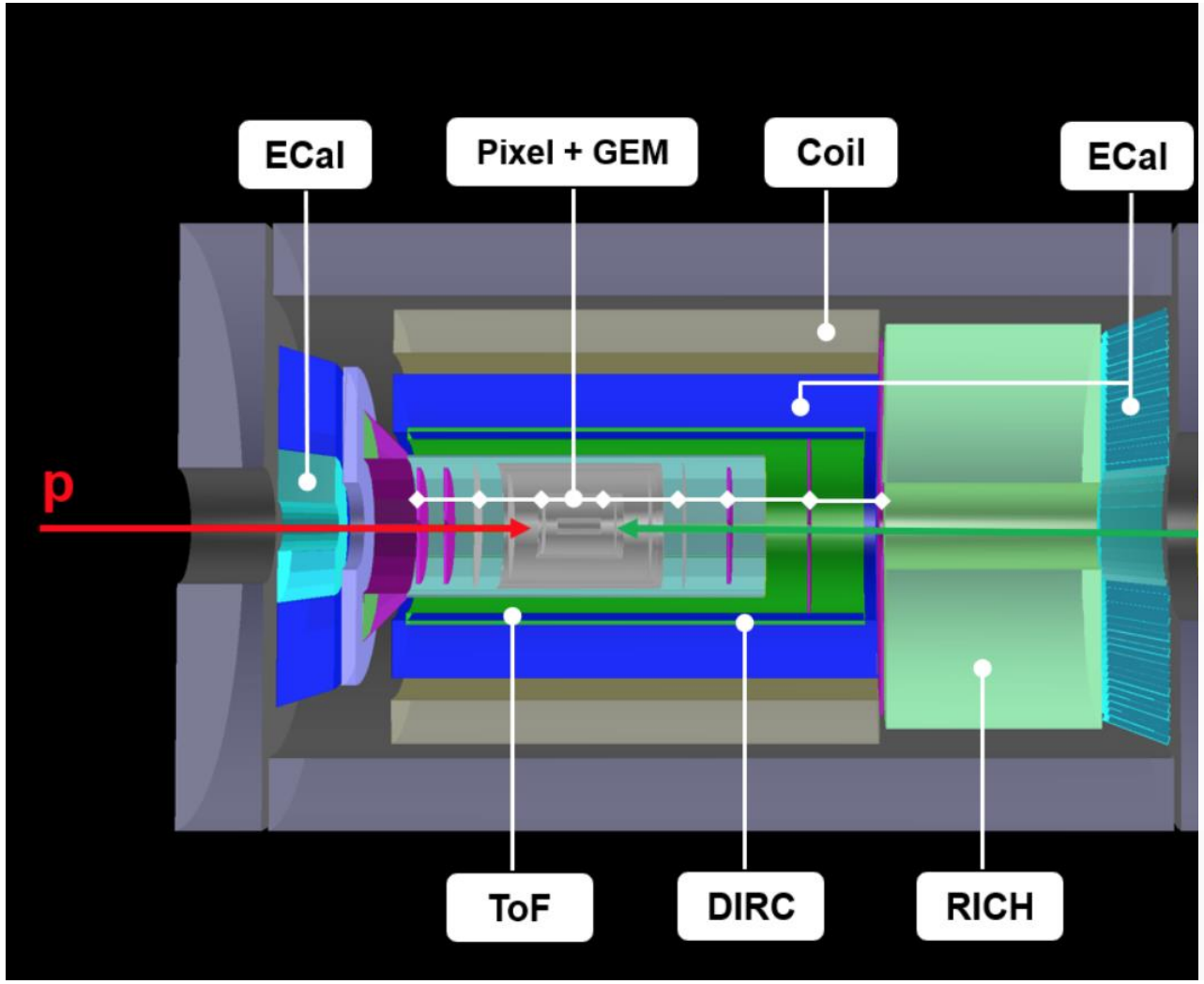




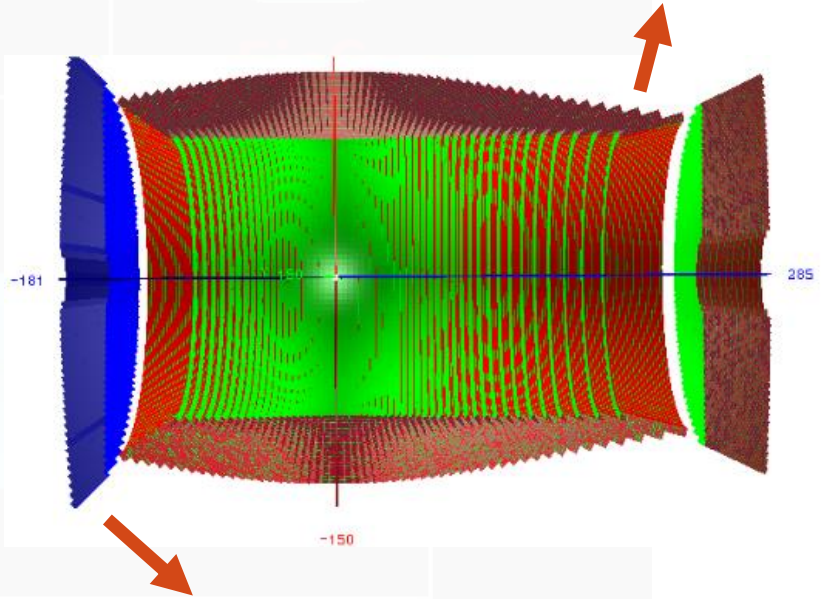


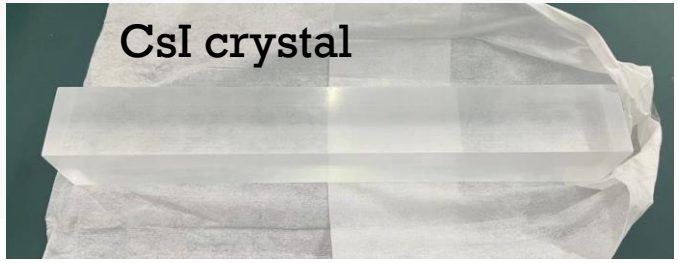


EicC Ecal system

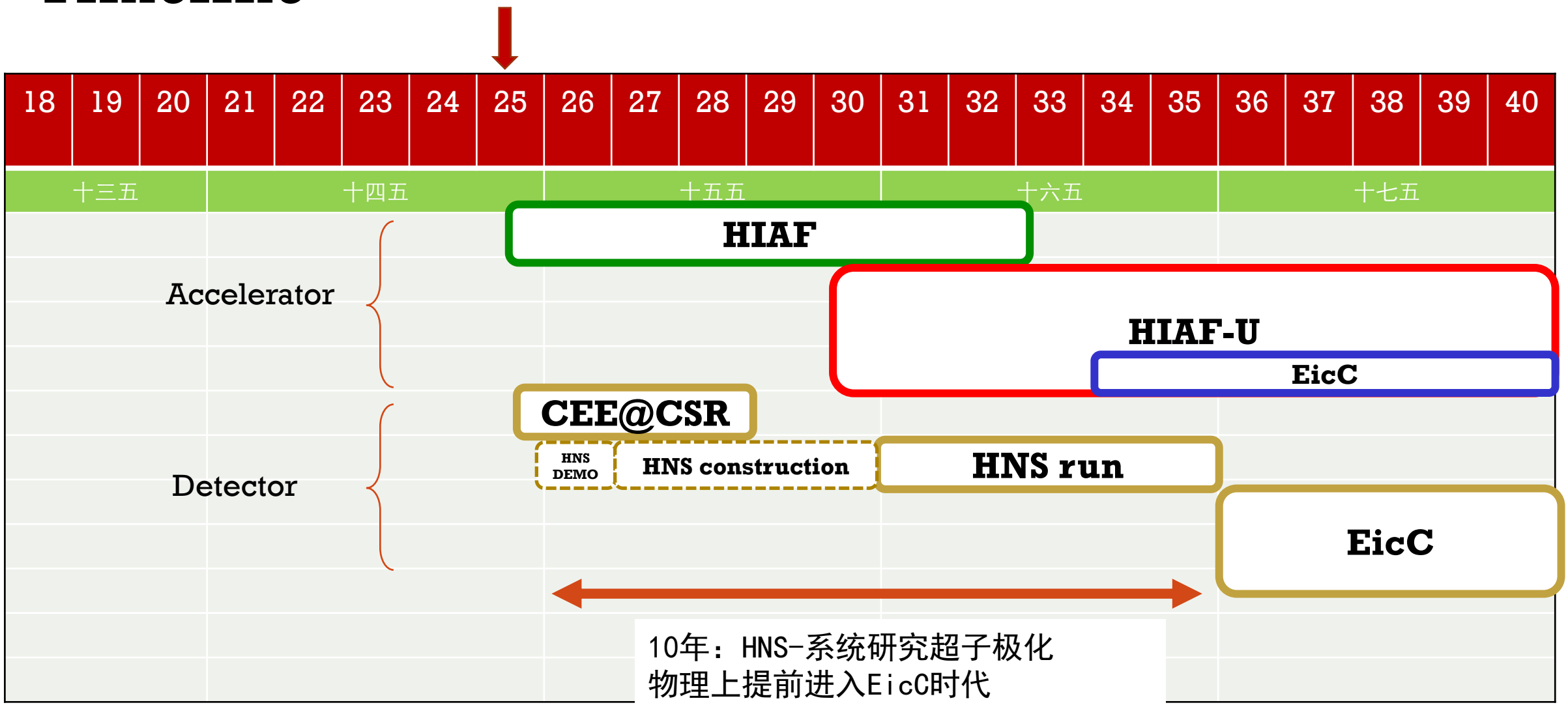


Ecal: Shashlik + CsI crystal





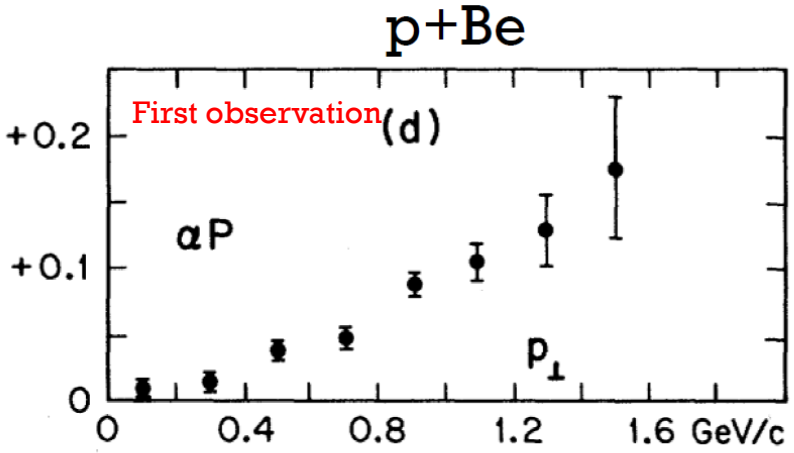
Timeline



10年：HNS-系统研究超子极化
物理上提前进入EicC时代
探测器上=1/2 EicC探测器，R&D平台

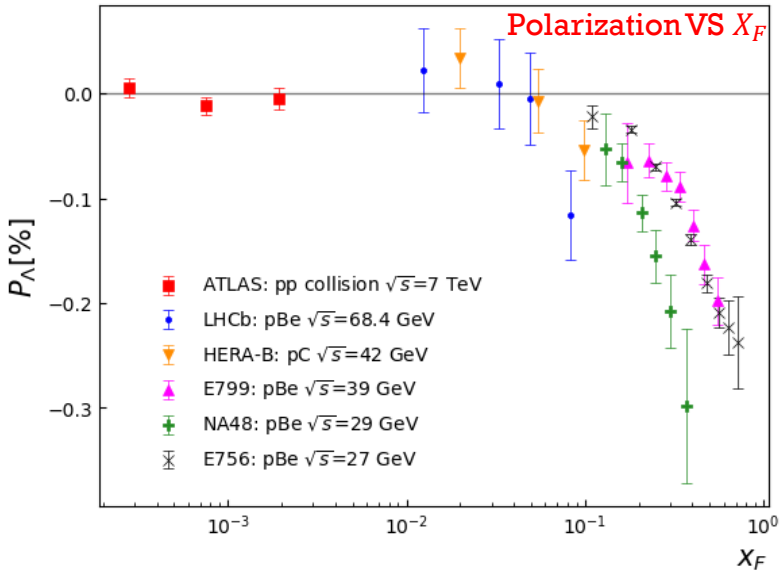
Puzzle of Λ polarization since 1976

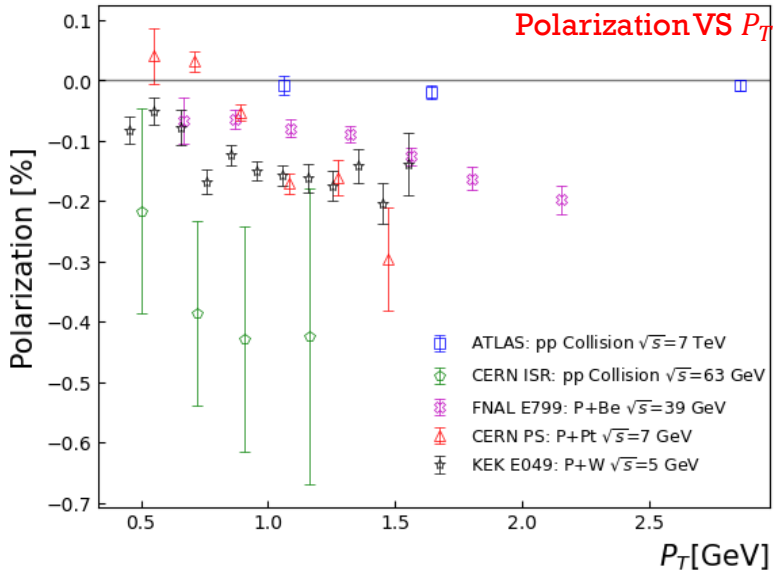
-12 years before "Proton Spin Crisis"

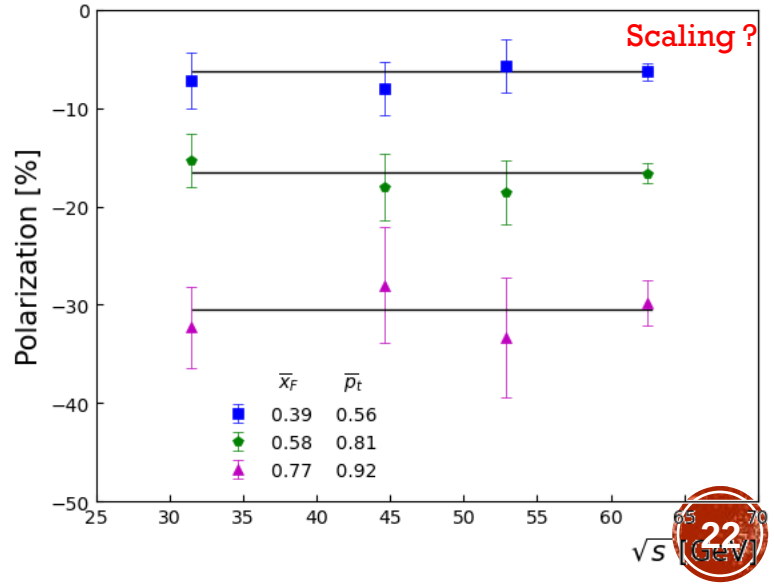


G.Bunce, *et al.*: Phys.Rev.Lett. 36, 1113-1116 (1976)

- In 1976 at Fermi–Lab, Hyperons were produced polarized in p + Be collisions: 300 GeV protons on Beryllium target
- Λ is observed to be polarized in e–e, e–p, p–p, p–A, A–A processes
- Unlike the case of "Proton spin crisis", it is lack of systematic studies both theoretically and experimentally

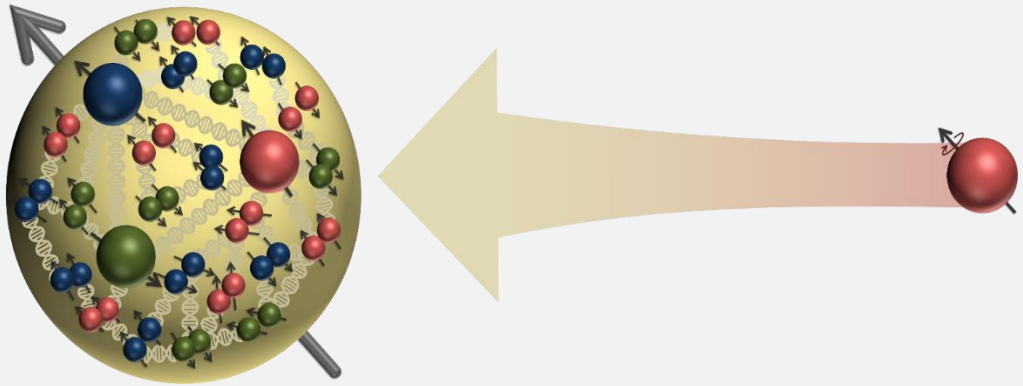






-What is the origin of Λ polarization?
-What is the link between Λ spin structure and polarization?

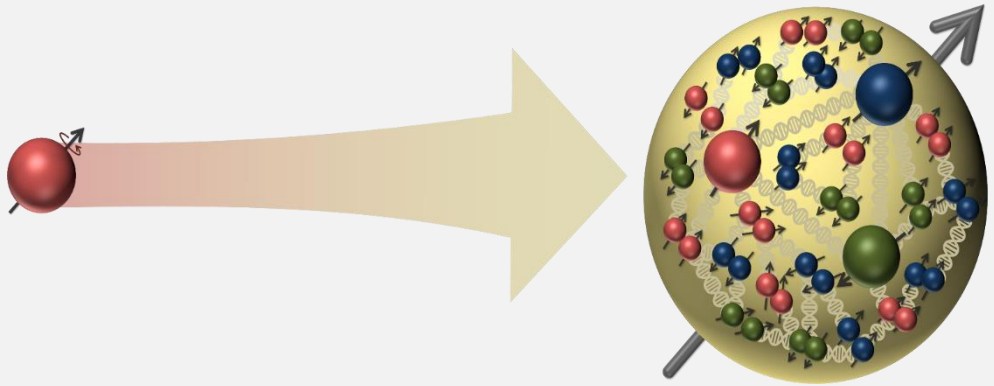
EIC: **Initial state** is polarized
-How do partons form up a polarized nucleon?



Initial state

Polarized by device

Λ polarization: **Final state** is polarized
-How do partons form up a polarized Λ?

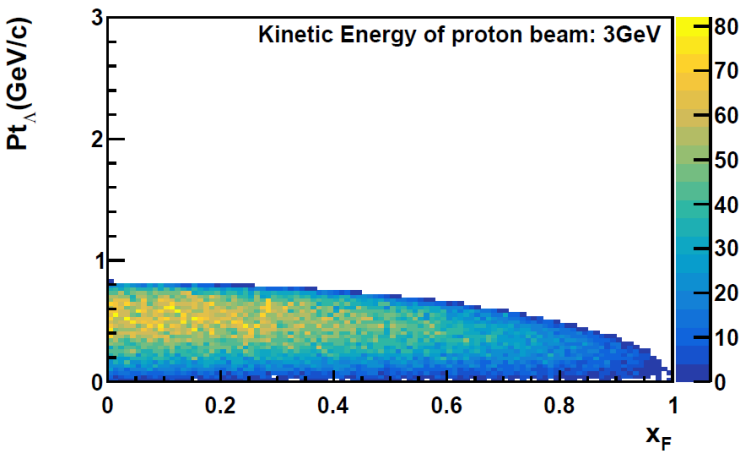


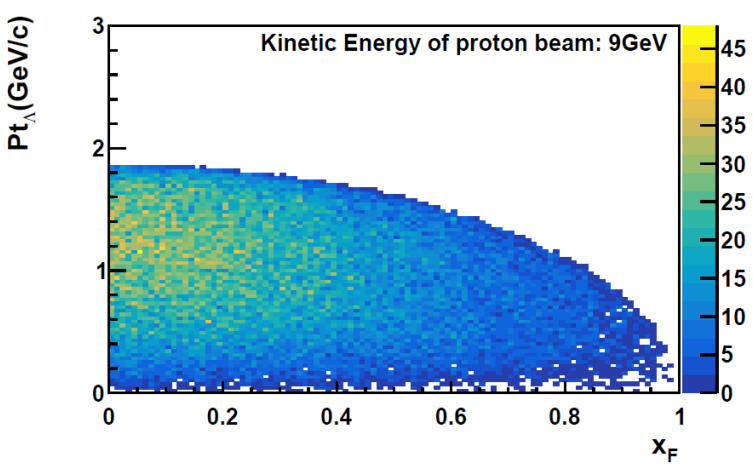
Final state

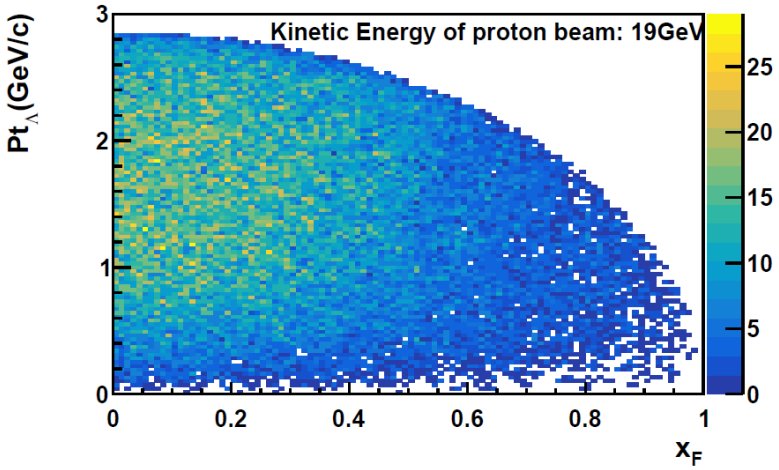
Λ serves as its own spin analyzer through the decay $\Lambda^0 \rightarrow p + \pi^-$

Baryon spin structure: origin of nucleon spin VS origin of Λ polarization

HIAF: Allows for a multi-dimensional mapping of Λ polarization



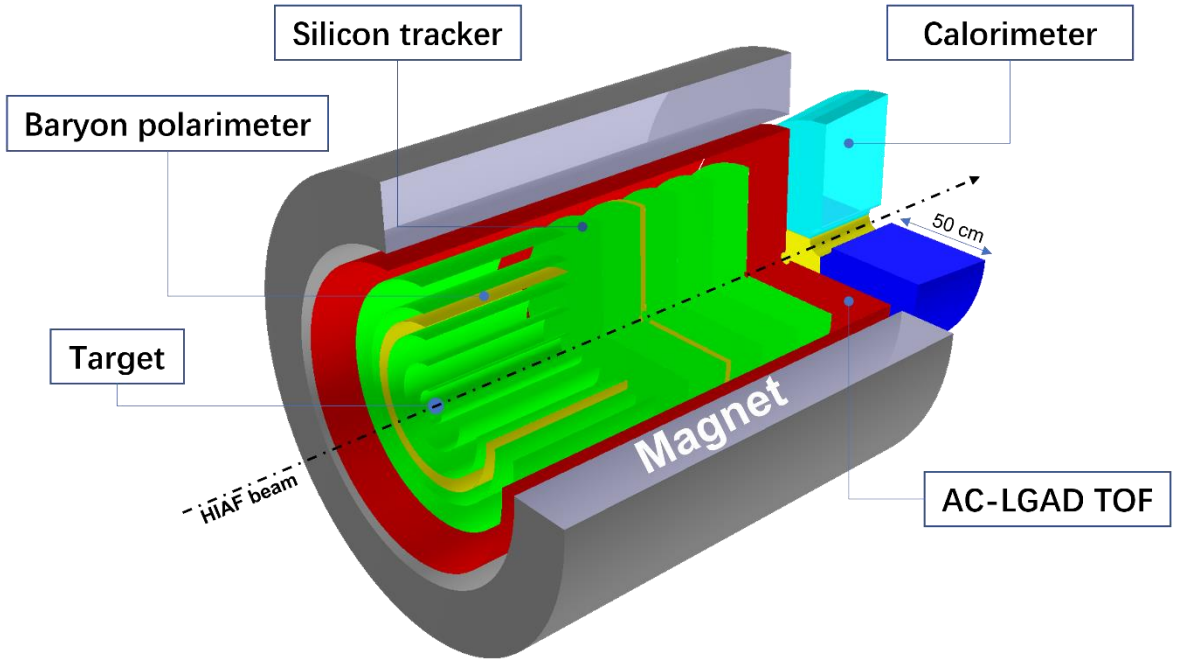




3 GeV → 9 GeV → 20 GeV

With proton beam and ion beam: **p-p, p-A, A-A** reactions → study Λ polarization systematically

Hyperon-Nucleon Spectrometer (HNS)



目前参加单位：北京航空航天大学、复旦大学、国科大、华中师范大学、华南师范大学、近代物理研究所、清华大学、山东大学、香港中文大学（深圳）、中科大

子系统研发：Silicon tracker, AC-LGAD, Target, Baryon polarimeter, Calorimeter, Electronics, DAQ, Magnet, slow control, Beamline, Mechanics + Engineering

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:

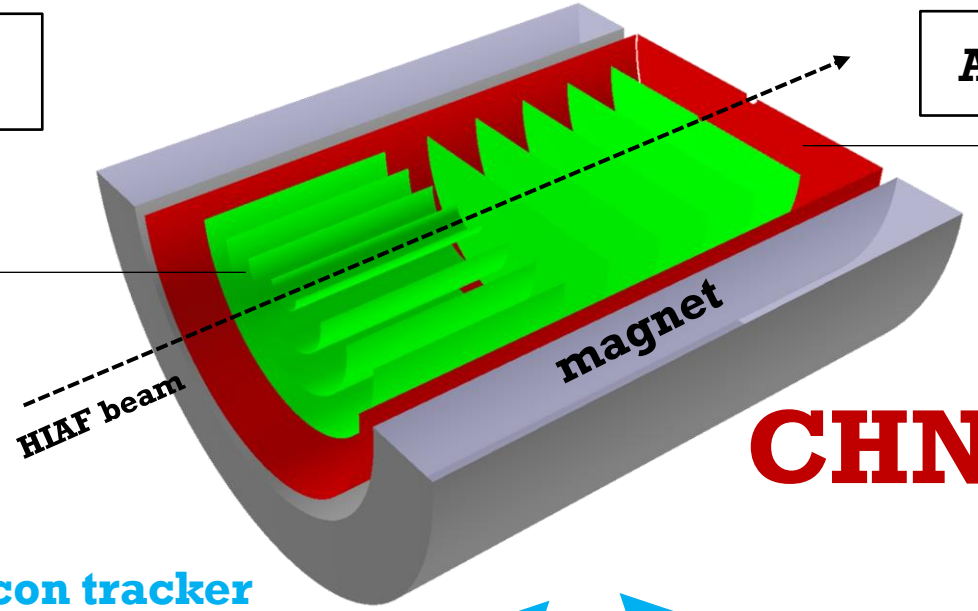
- Supports both communities of hadron structure and heavy-ion physics
- International interests are expected: Japan

III. Detector R&D

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

Silicon Tracker

AC-LGAD TOF



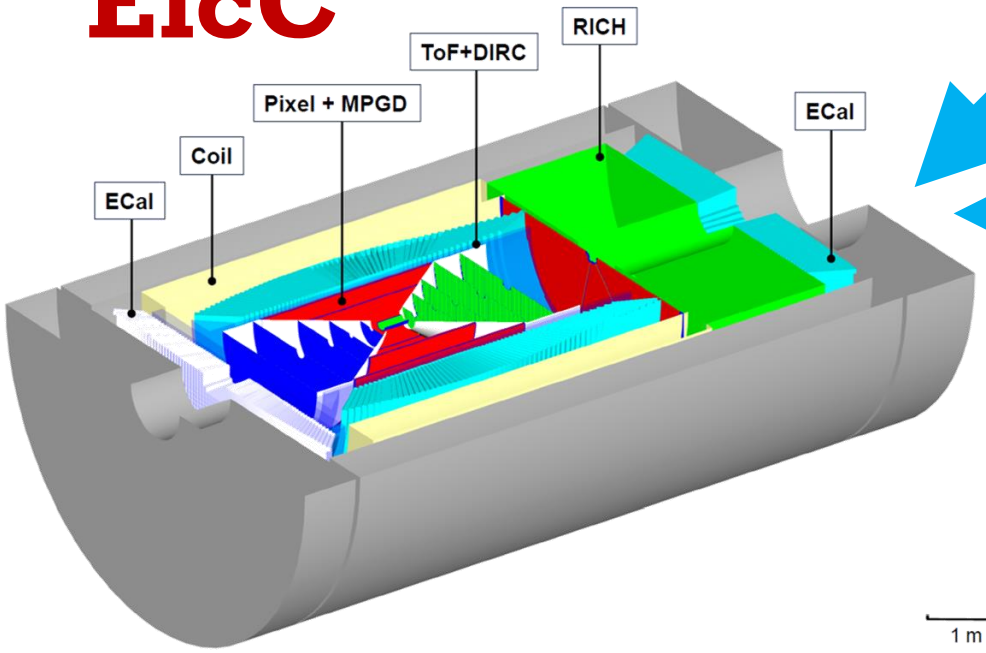
CHNS

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

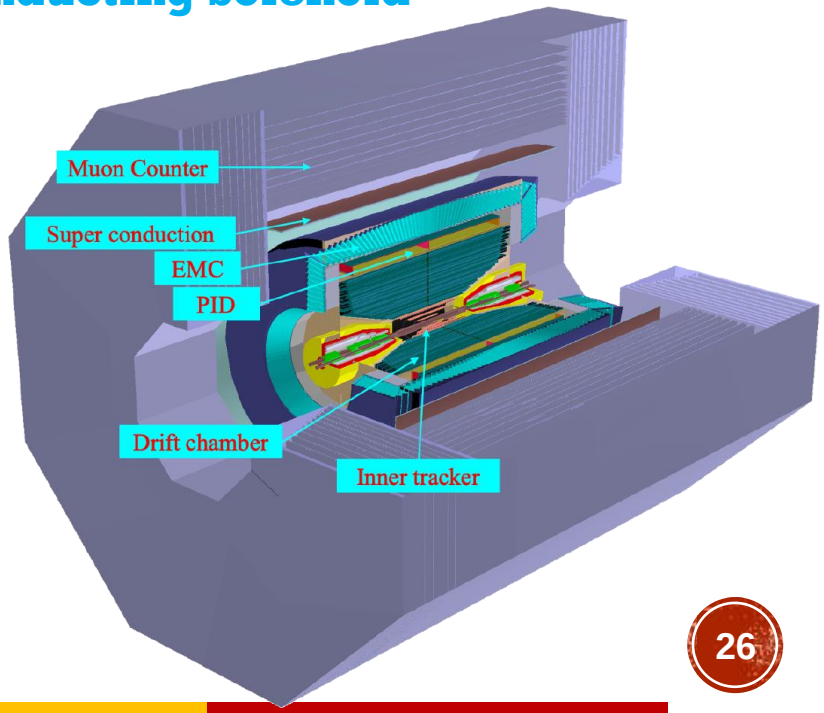
Silicon tracker
Super-conducting Solenoid

STCF

EicC



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



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Summary

- 电子-离子对撞机：高能核物理的下一个前沿研究领域-质子自旋结构及质量起源
- 强子物理与重离子物理领域自然的交叉点
- 未来10年：依托HIAF，HNS将系统研究超子极化机制，同时提供了新一代探测器预研及应用的平台