清華大學物理系
TSINGHUA UNIVERSITY DEPARTMENT OF PHYSICS

电子核子碰撞实验

第三节:未来展望

叶志鸿，清华大学物理系
yez@tsinghua.edu.cn

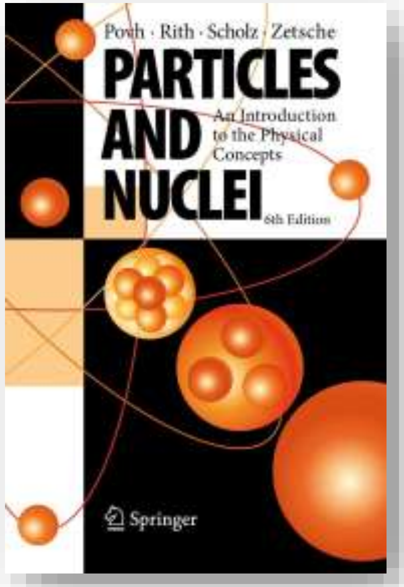
复旦大学2022年“优秀学生培养计划”粒子物理与核物理暑期学校
08/20/2022

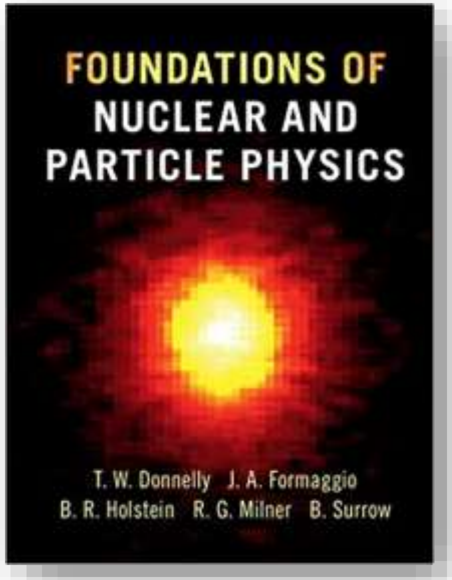
清華大學
Tsinghua University

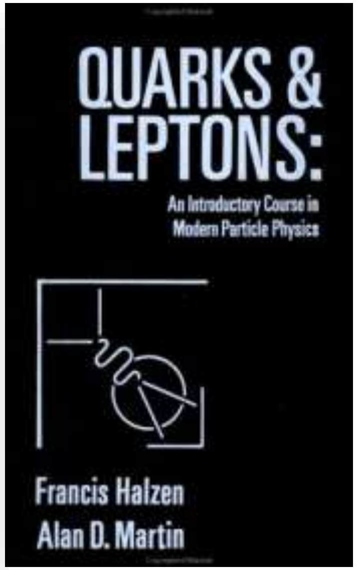
课堂内容

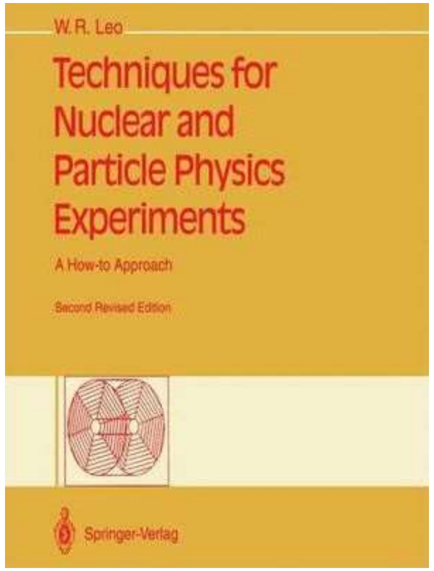
- 第一节：物质结构概要
- 第二节：实验方法详解和实验分析实例
- 第三节：未来展望

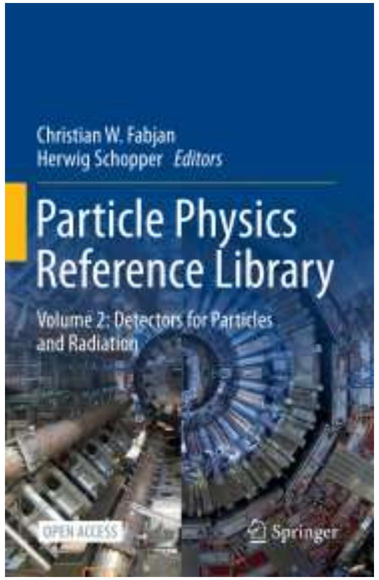
推荐读物（请联系本人索取英文版PDF）：









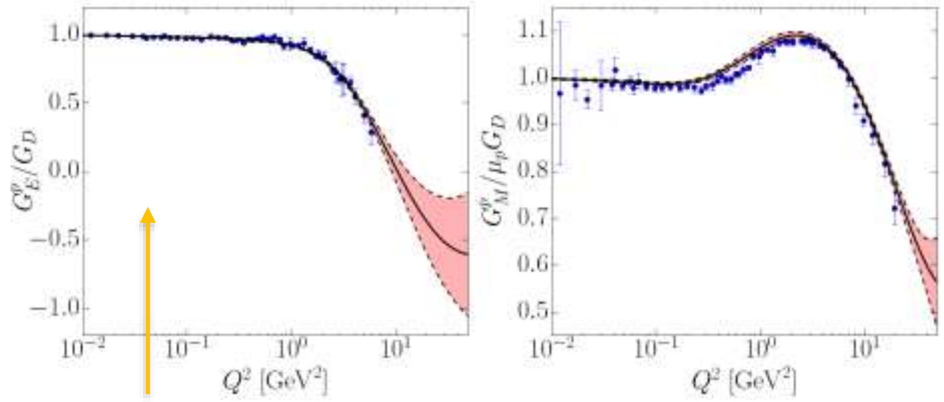


未来展望

➢电子-核子碰撞的未来目标→核子三维结构

❑ 核子的一维结构已经精确测量（Form-Factors，PDFs）

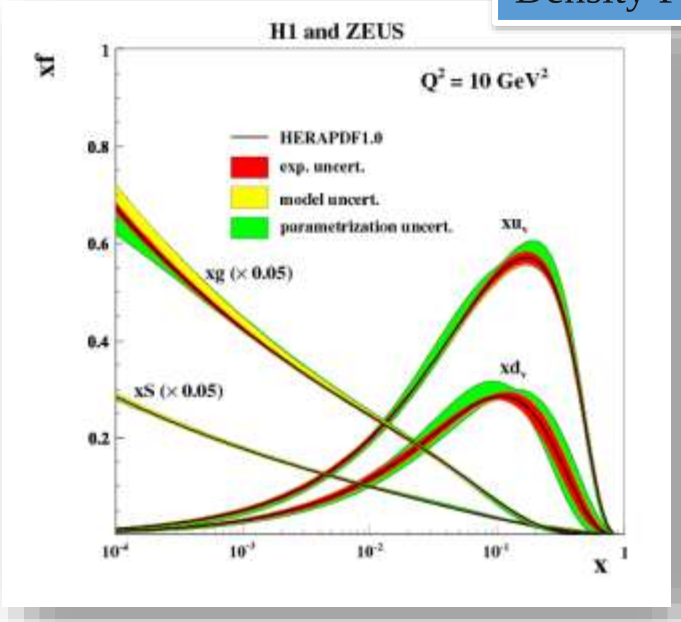
✓ Form Factors



✓ Most Recent Global Fit (Phys. Lett. B 777 8-15 (2018))
✓ New Radius extraction (Phys. Rev. C 99, 044303 (2019))
✓ New data: PRAD Experiment and E12-11-112 (Tritium)

✓ Three types of Parton Distribution Functions (PDFs):
- ✓ Density (well measured)
- ✓ New data from MARATHON (Tritium)
- ✓ Helicity (Spin puzzle)
- ✓ Transversity (need 3D info)

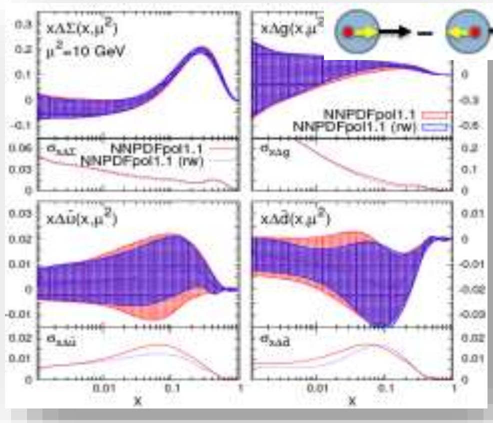
Density Functions



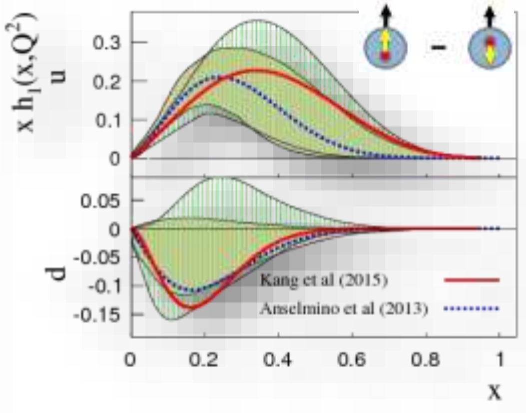
Saturation at low-x

d/u at high-x

Helicity Functions



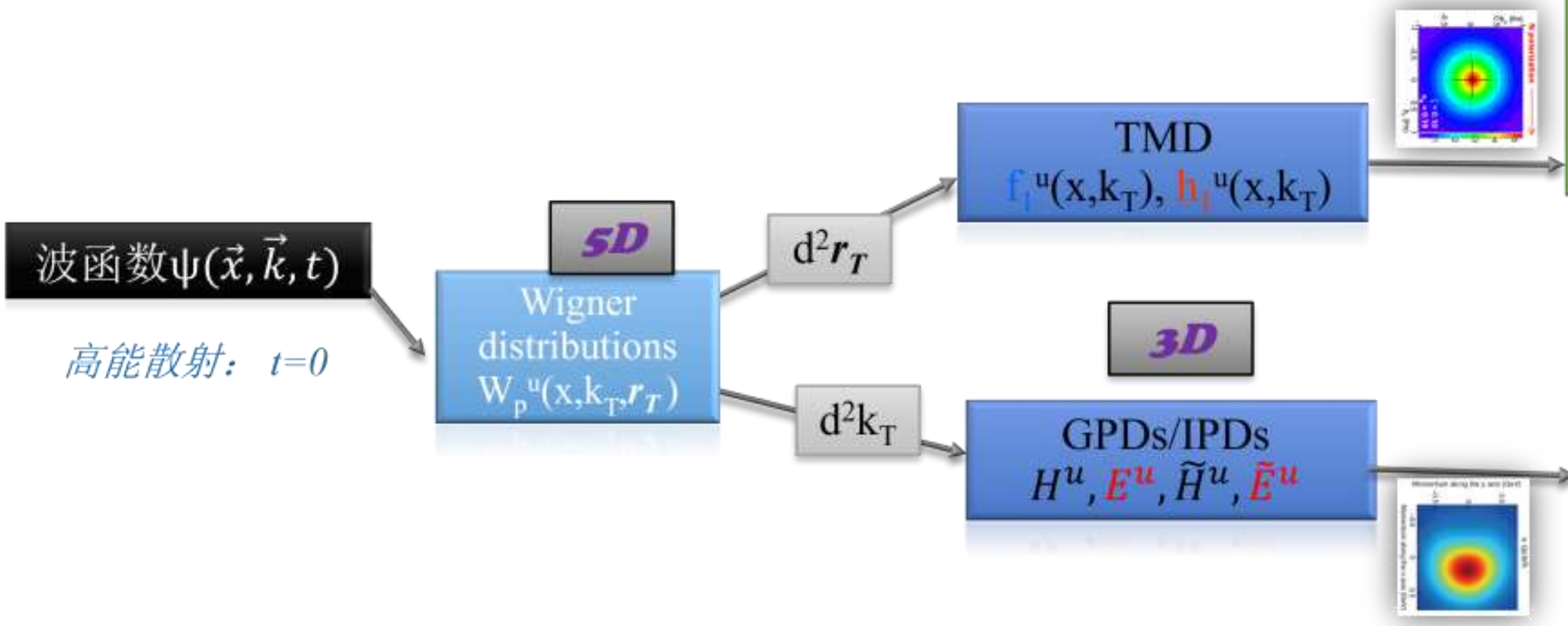
Transversity Functions



未来展望

➢电子-核子碰撞的未来目标→核子三维结构

- 核子的3维结构测量（TMD,GPD）需要高能极化电子加速器，极化靶技术和全新的探测器系统（高流量，全方位角，多粒子）

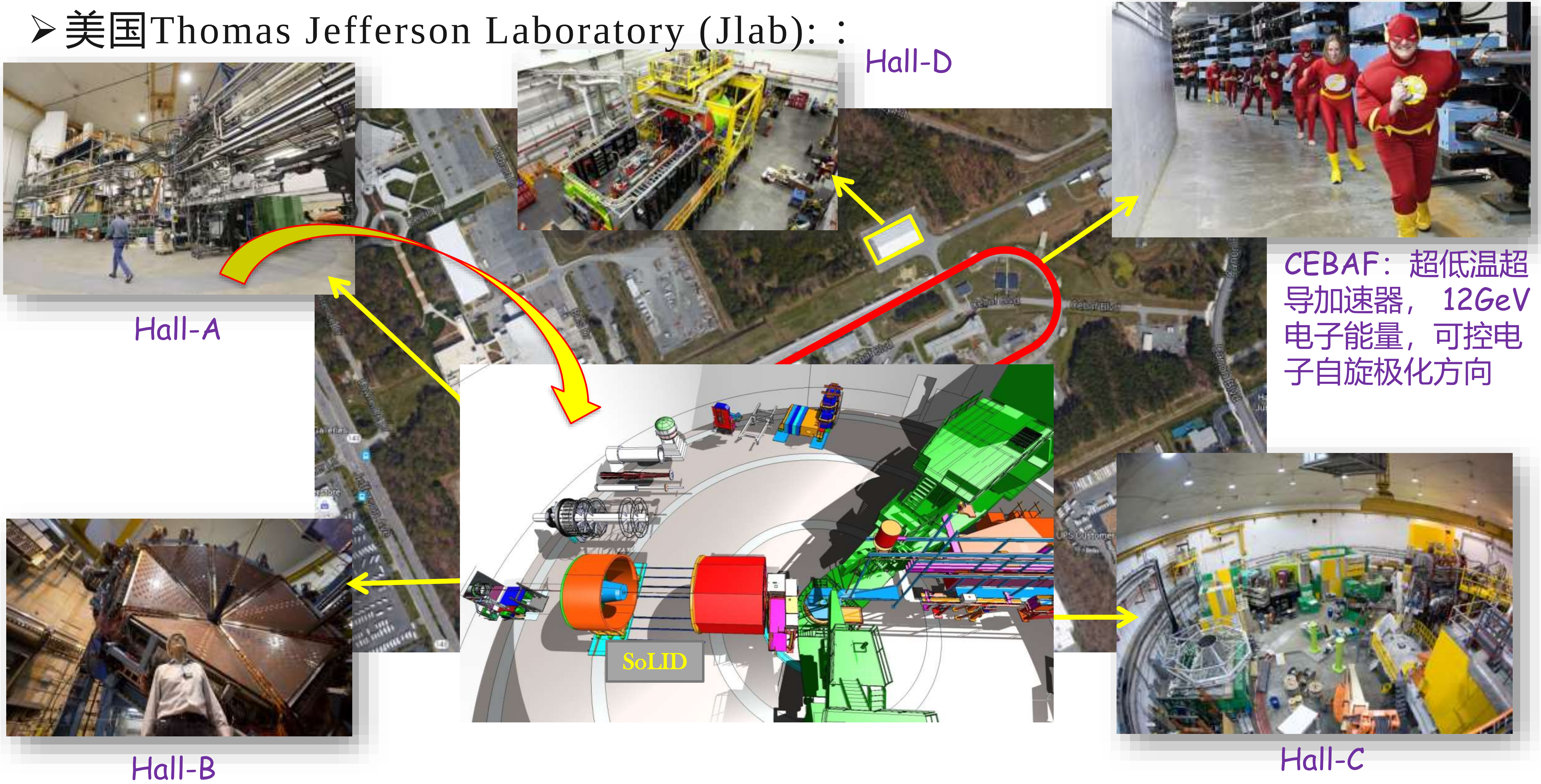


Leading Twist TMDs	Nucleon Polarization	Quark Polarization: Unpolarized (U)	Quark Polarization: Longitudinally Polarized (L)	Quark Polarization: Transversely Polarized (T)
	U	$f_1(x,k_T^2)$ Unpolarized		$h_1^{\perp}(x,k_T^2)$ Boer-Mulders
	L		$g_1(x,k_T^2)$ Helicity	$h_{1L}^{\perp}(x,k_T^2)$ Long-Transversity
	T	$f_{1T}^{\perp}(x,k_T^2)$ Sivers	$g_{1T}(x,k_T^2)$ Trans-Helicity	$h_1(x,k_T^2)$ Transversity; $h_{1T}^{\perp}(x,k_T^2)$ Pretzelosity

Nucleon Polarization	Quark Polarization: Unpolarized (U)	Quark Polarization: Longitudinally Polarized (L)	Quark Polarization: Transversely Polarized (T)
U	H		$2\tilde{H}_T + E_T$
L		$\tilde{H}$	$\tilde{E}_T$
T	E	$\tilde{E}$	$H_T, \tilde{H}_T$

Thomas Jefferson Lab

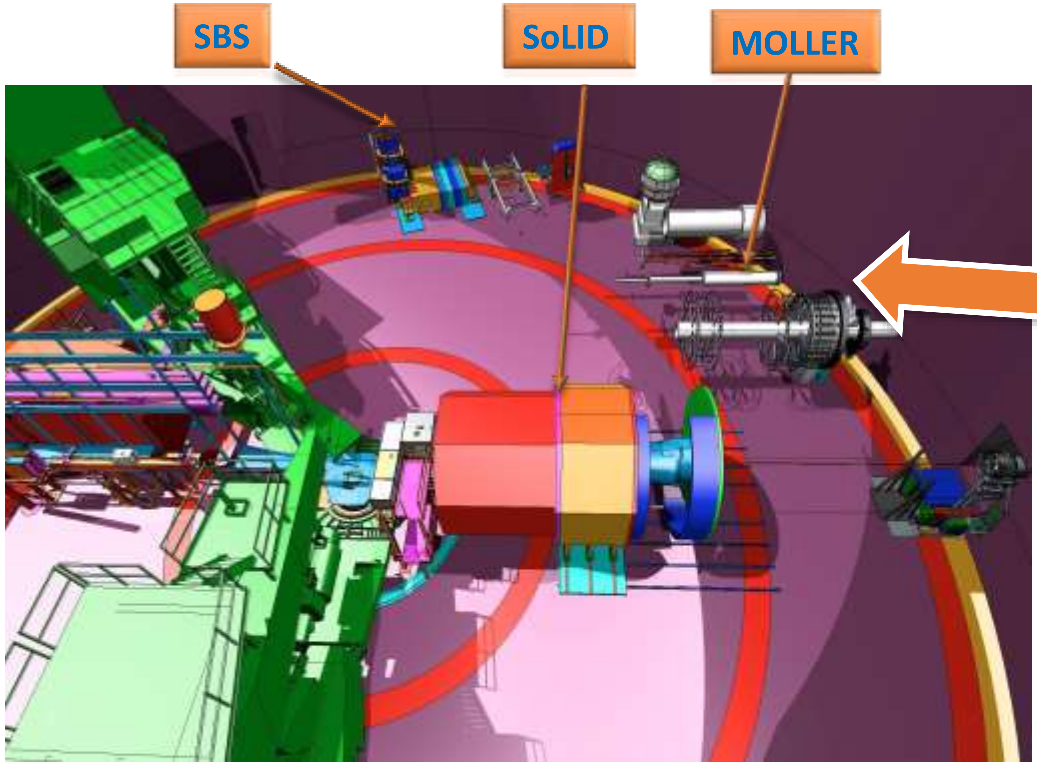
- 美国Thomas Jefferson Laboratory (Jlab):：

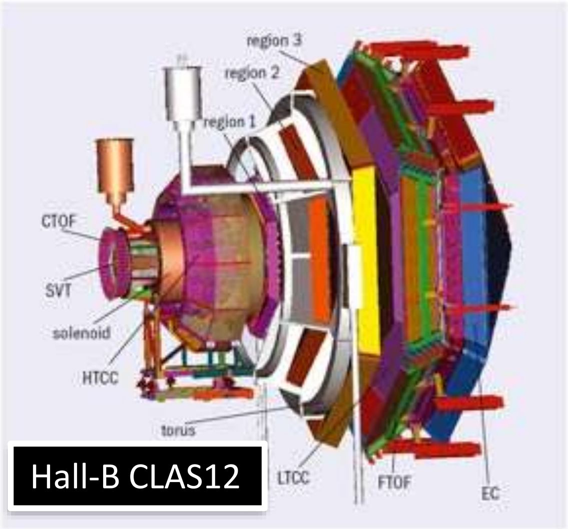


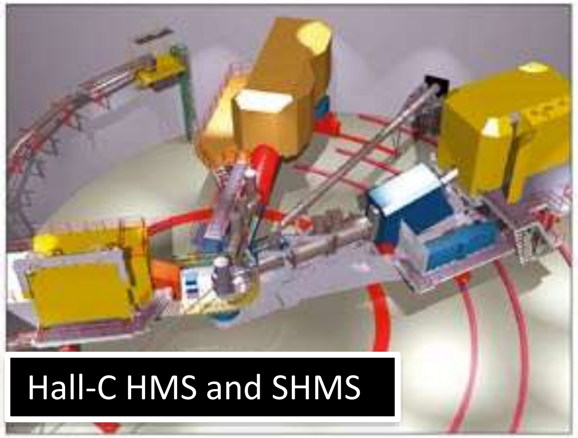
CEBAF：超低温超导加速器， 12GeV电子能量，可控电子自旋极化方向

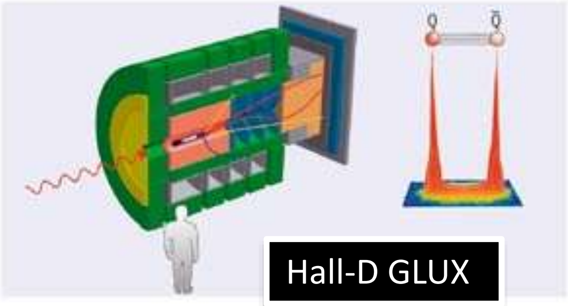
➢四个实验大厅→四种探测器系统

- ❑ Hall-A: HRS, then Super-BigBite Spectrometer (SBS), then MOLLER are for dedicated purpose experiments
- ❑ Hall-B: CLAS12 is a multiple purpose 4 π detector (low luminosity, large acceptance, limited resolution)
- ❑ Hall-C: HMS and Super-HMS are high-luminosity, limited acceptance, for precision measurement at limited region.
- ❑ Hall-D: GLUX detector system is for real-photon production experiment to search exotic gluon states





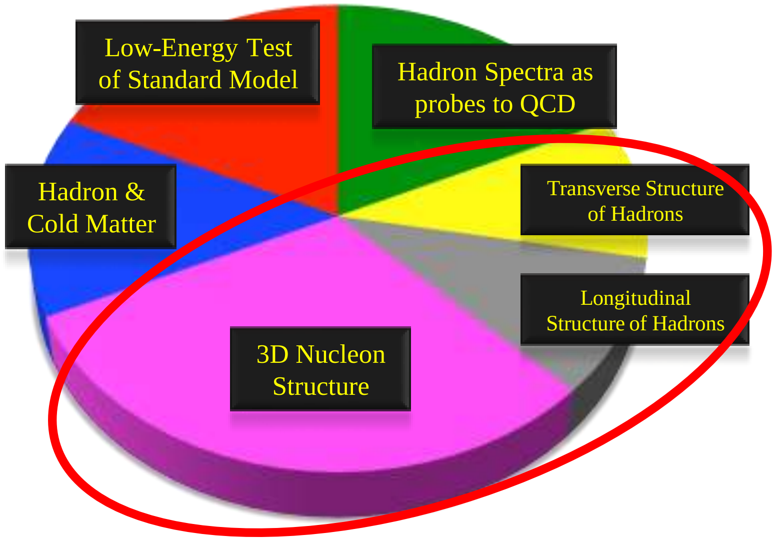




- **3D Nucleon Tomography is the major Program at Jlab 12GeV Eva:**
  - Many approved experiments in SBS & SoLID (Hall-A), CLAS12 (Hall-B), HMS+SHMS (Hall-C)

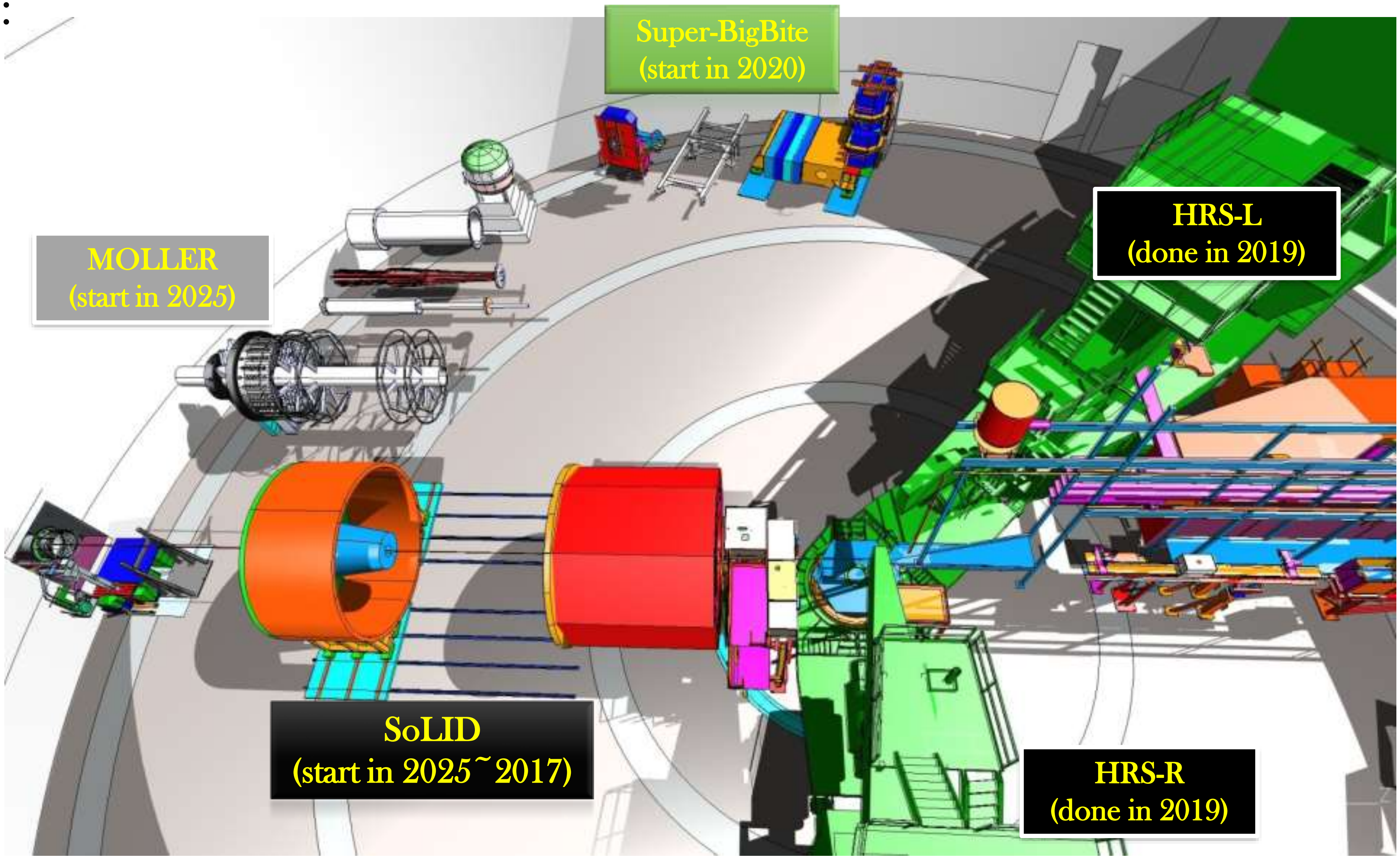
12 GeV Approved Experiments by Physics Topics

Topic	Hall A	Hall B	Hall C	Hall D	Other	Total
The Hadron spectra as probes of QCD	0	3	1	3	0	7
The transverse structure of the hadrons	6	4	3	1	0	14
The longitudinal structure of the hadrons	2	3	6	0	0	11
The 3D structure of the hadrons	5	9	6	0	0	20
Hadrons and cold nuclear matter	8	4	7	0	1	20
Low-energy tests of the Standard Model and Fundamental Symmetries	3	1	0	1	1	6
Total	**24**	**24**	**23**	**5**	**2**	**78**
Total Experiments Completed	**2.5**	**1.1**	**0**	**0.4**	**0**	**4.0**
Total Experiments Remaining	**21.5**	**22.9**	**23.0**	**4.6**	**2.0**	**74.0**



Thomas Jefferson Lab

- Hall-A:



➢Solenoidal Large Intensity Detector

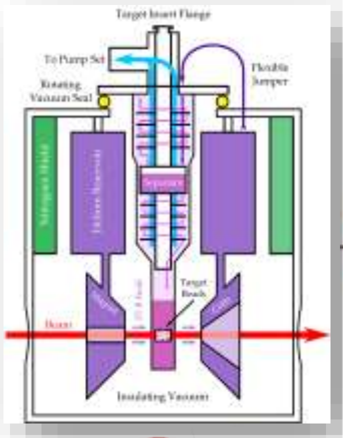
- ❑ **SoLID** will ***maximize*** the science return of the 12-GeV CEBAF upgrade by **combining...**

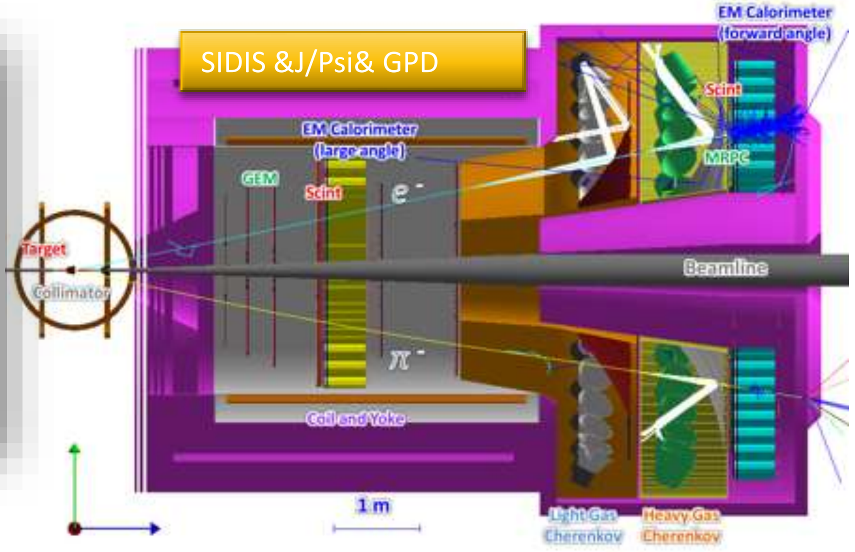
- ❑ Unique advantages:
  - ✓ High Intensity ($10^{37} \sim 10^{39}$ $cm^{-2}s^{-1}$),
  - ✓ Large Acceptance, 4Pi Coverage
  - ✓ Both polarized proton and "neutron" targets

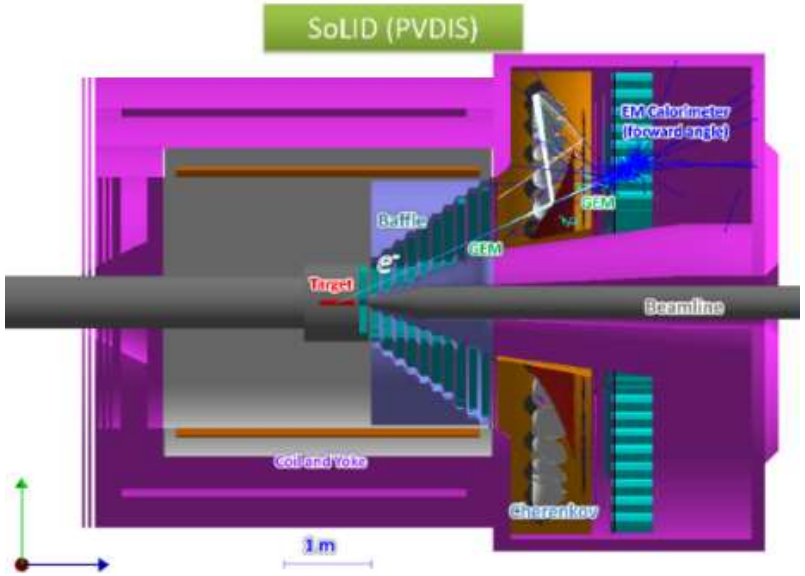
- ❑ Three initial topics:
  - ✓ SIDIS w/ long.- & tans.-pol. proton & He3
  - ✓ PVDIS w/ unpol. protons
  - ✓ J/ψ w/ unpol. protons

- ❑ Approved GPD experiments:
  - ✓ TCS with J/Psi
  - ✓ DVMP with polarized He3 target & SIDIS

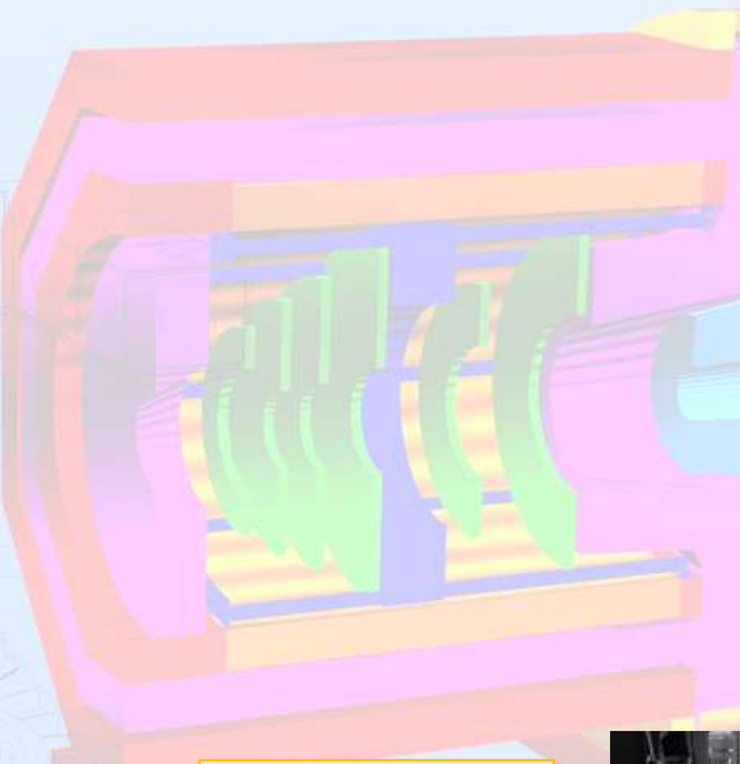
- ❑ DVCS & DVMP with polarized p& He3, Doubly DVCS, etc.



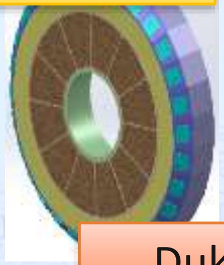




➢Solenoidal Large Intensity Detector



重气奇伦科夫



Duke+Regina

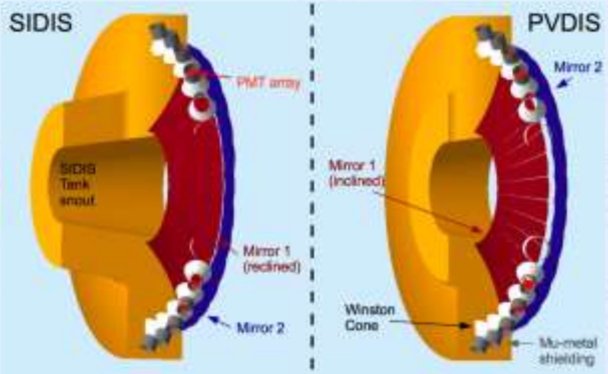
GEM径迹测量仪

USTC+Lanzhou+CIAE+UVA

MRPC时间飞行仪

Tsinghua+USTC+UIC

轻气奇伦科夫



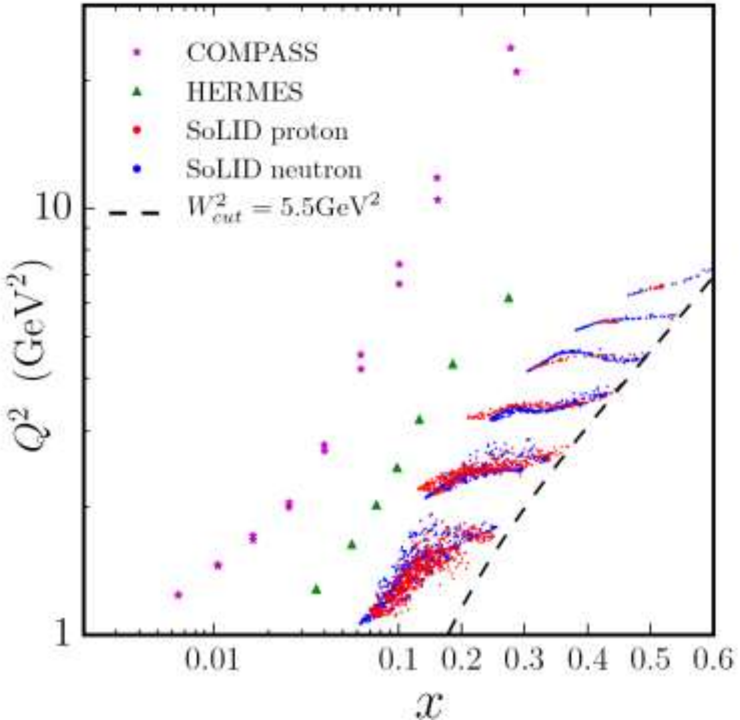
Argonne+Temple

Shashlyk量能器

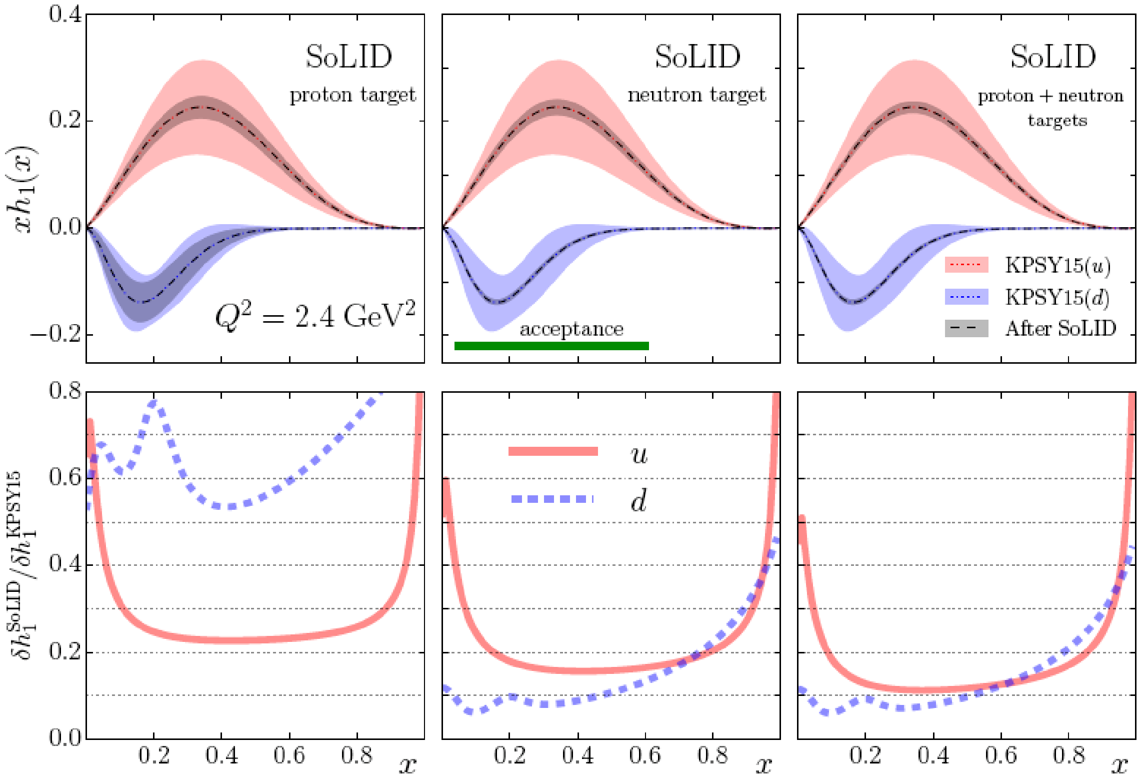
Tsinghua+Shandong+UVA

➢SoLID TMD

- ❑ Much wider phase-space to cover the valance quark region
- ❑ Full 2π azimuthal acceptance:
- ❑ Polarized beam & targets:
- ❑ Detect $\pi^{\pm}$, and adding Kaon detections (sea quark contribution)
- ❑ High statistics for 4D binning in (x, p_T, Q^2, z)
- ❑ Overall >1000 bins for neutron and >600 bins for proton

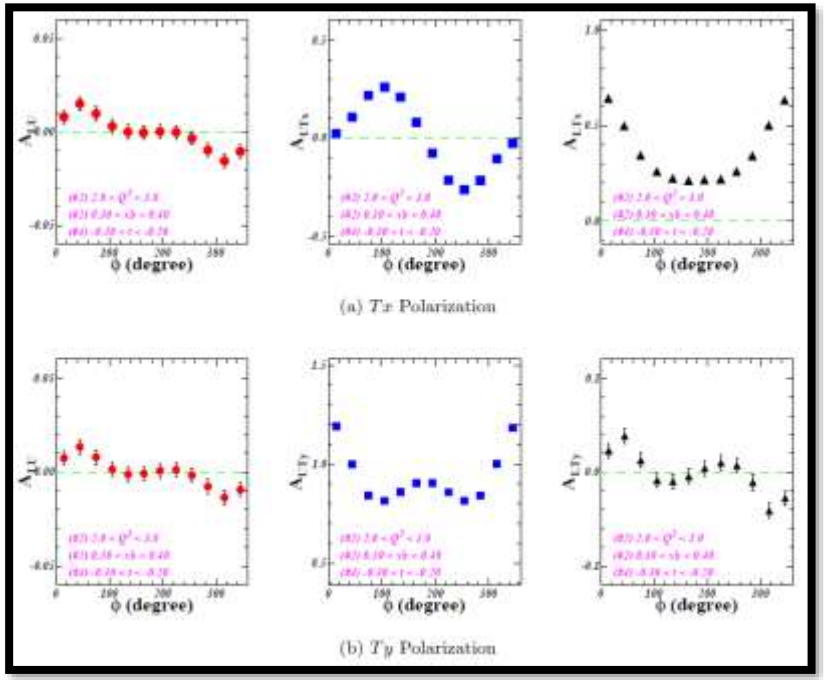


Z. Ye, et. al., Phys. Letter B767, 91-98 (2017)



➢SoLID GPD

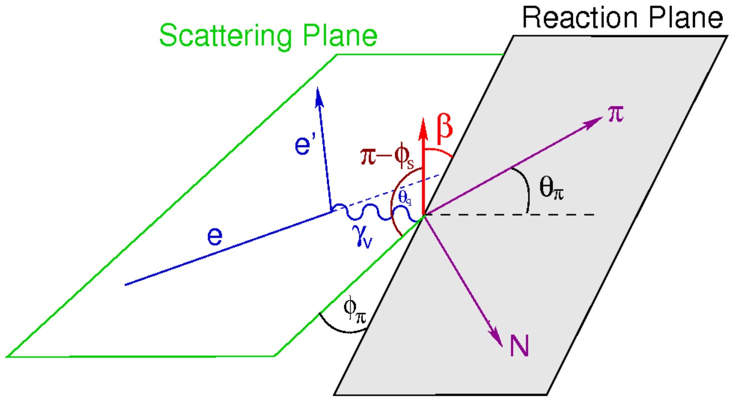
- **Deep Exclusive π^- Production using Transversely Polarized ^{3}He Target**
  - *G.M. Huber, Z. Ahmed, Z. Ye*
  - *Approved as run group with Transverse Pol. ^{3}He SIDIS (E12-10-006B)*
- **Timelike Compton Scattering (TCS)** with circularly polarized beam and unpolarized LH_2 target
  - *Z.W. Zhao, P. Nadel-Turonski, J. Zhang, M. Boer*
  - *Approved as run group with J/ψ (E12-12-006A)*
- **Double Deeply Virtual Compton Scattering (DDVCS)** in di–lepton channel on unpolarized LH_2 target
  - *E. Voutier, M. Boer, A. Camsonne, K. Gnanvo, N. Sparveri, Z. Zhao*
  - *LOI12-12-005 reviewed by PAC43*
- **DVCS on polarized proton and 3He targets**
  - *Z.Y. Ye, N. Liyanage, W. Xiong, A. Cansomme and Z.H. Ye (under study)*



SoLID DVCS with Polarized He3 Projection: one (Q2, x, t) bin out of 1000+ bins

➢SoLID GPD

- **Azimuthal modulations of Transverse Single Spin Asymmetry allow access to different GPDs:**
  - $\sin(\beta=\varphi-\varphi_s)$ moment sensitive to helicity-flip GPD $\tilde{E}$
  - $\sin(\varphi_s)$ moment sensitive to transversity GPDs

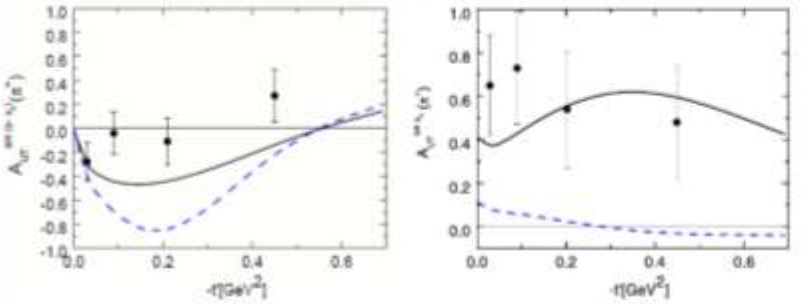


$\vec{n}(e,e'\pi^-)p$ with transversely polarized ^{3}He

$$\langle A_{UT}\rangle = \frac{1}{P\cdot\eta_n\cdot d}\left(\frac{N^\uparrow - N^\downarrow}{N^\uparrow + N^\downarrow}\right)$$

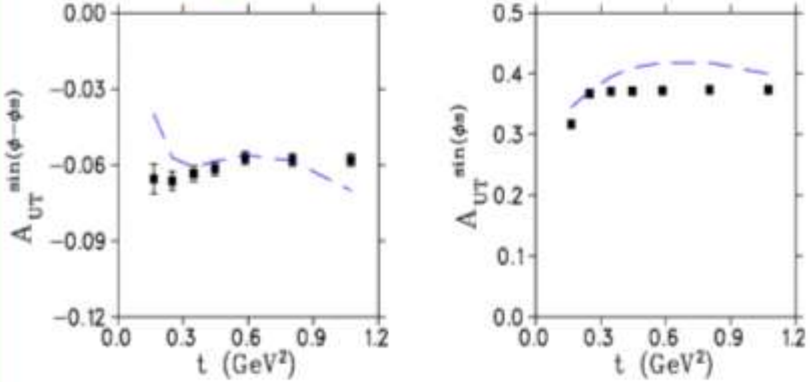
World Data: HERMES

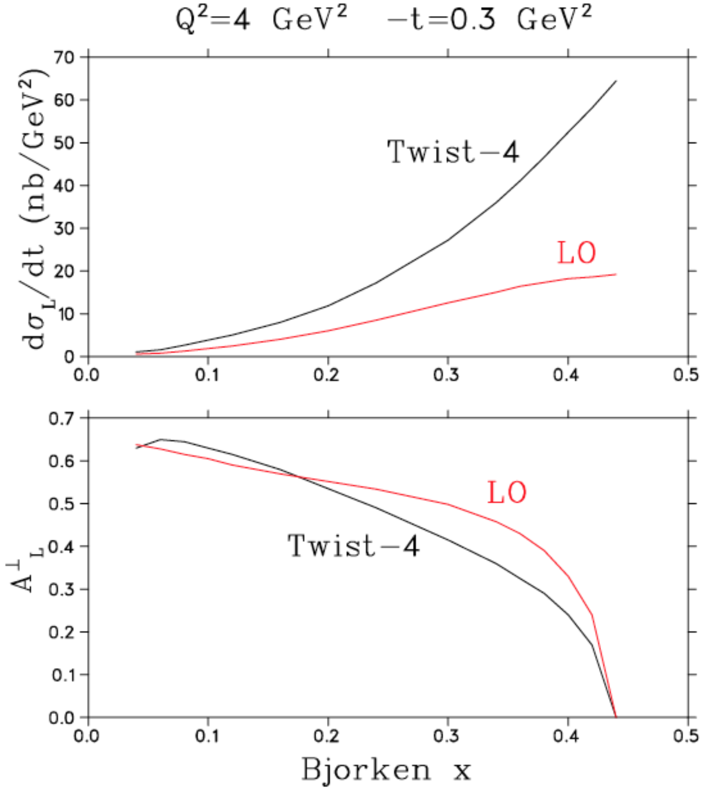
Pioneering measurement [PLB **682**(2010)345]



SoLID Projected Uncertainties

Proton is tagged to isolate exclusive π^- events



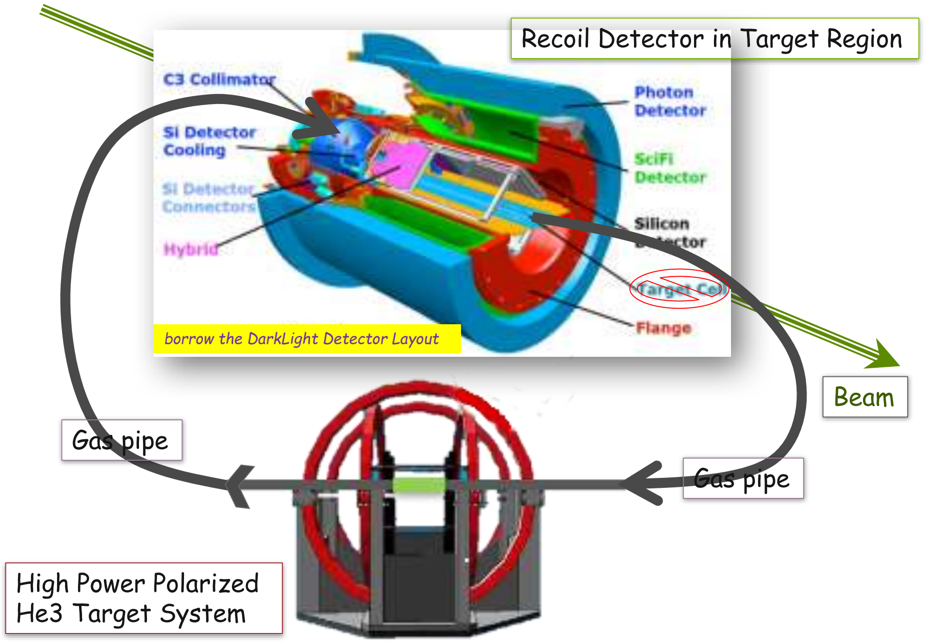


SoLID's large acceptance and high luminosity well-suited to this measurement

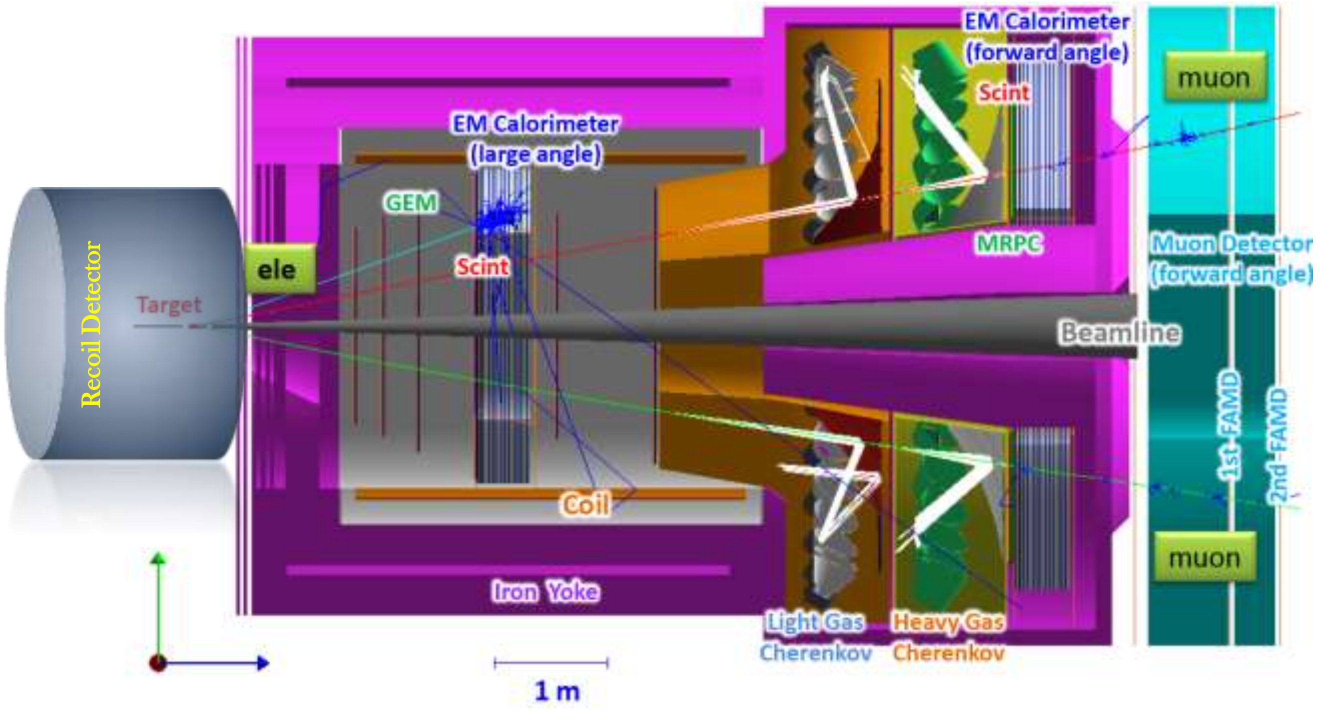
- **World unique, cannot be done anywhere else!**

➢SoLID Dedicated Upgrade for GPD

A Recoil Detector with a Polarized He3 Target



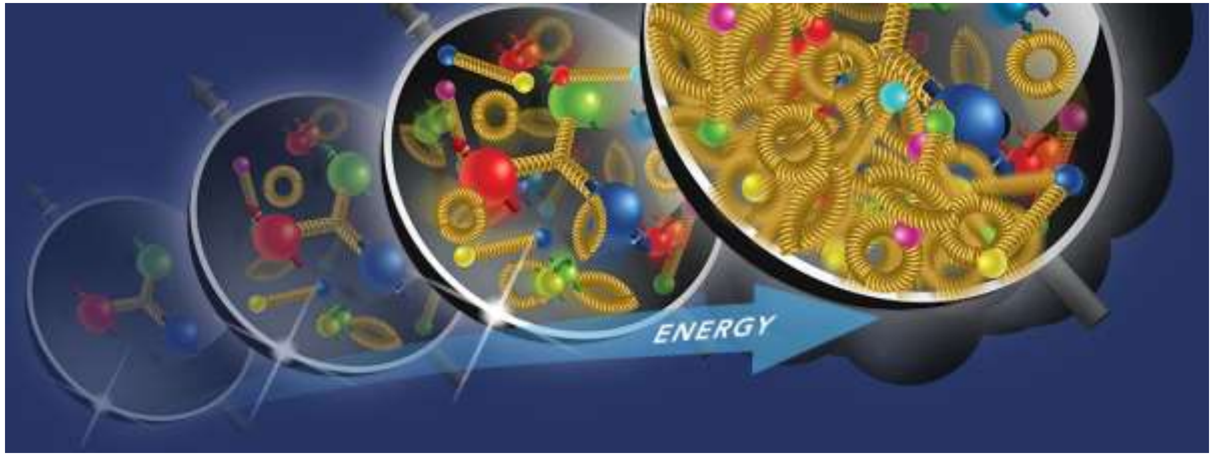
- Add a recoil detector near the target region to detect outgoing protons and neutrons
- Improve performance of Electromagnetic Calorimeters for photon detection
- Add a muon detector for DDVCS



Electron-Ion Collider, EIC

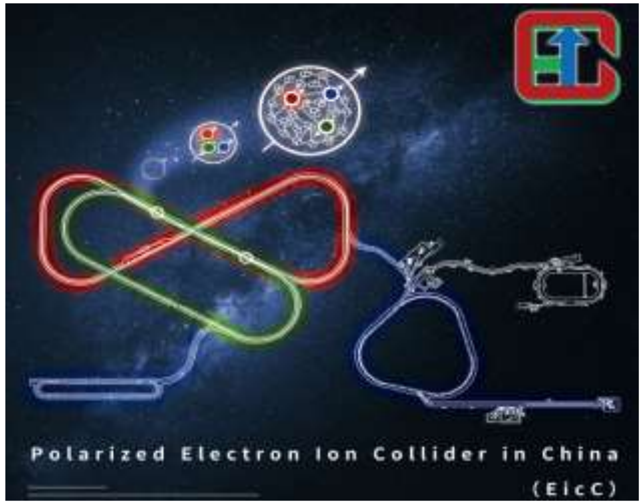
➢From Quarks to Gluons

- ❑ Jlab实验→研究物质的价夸克结构(u,d)
- ❑ 更高能量→研究物质的海夸克+胶子结构
  - ✓ 加速极化电子+极化质子或离子



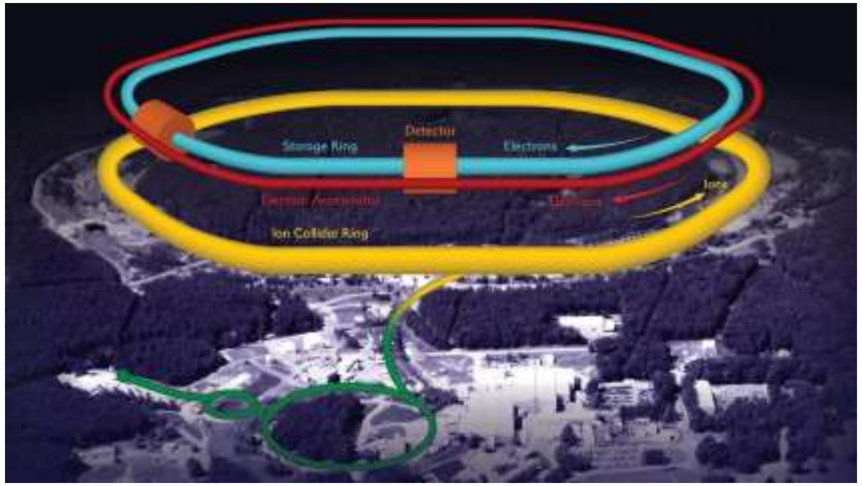
❑ 中国电子离子对撞机（EicC）

- ✓ 3.5GeV 电子 + 20GeV质子
- ✓ 探测物质的海夸克结构
- ✓ 地点：广东惠州
- ✓ 质子加速器在建中
- ✓ 项目申请中



❑ 美国电子离子对撞机（eRIHC）

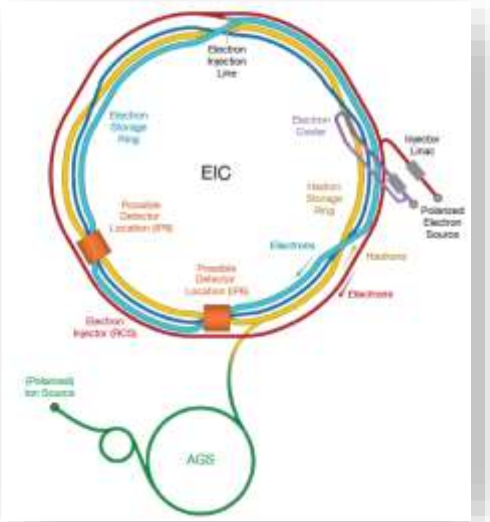
- ✓ 20GeV 电子 + 100GeV质子
- ✓ 探测物质的胶子结构
- ✓ 地点：布鲁克海文国家实验室
- ✓ 项目以批准，设计中

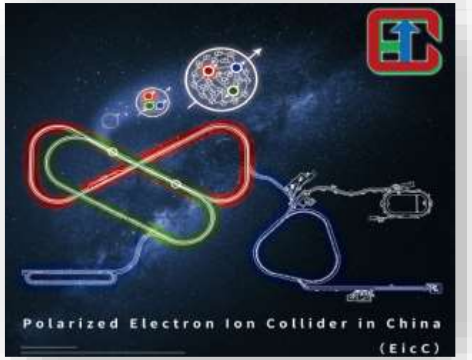


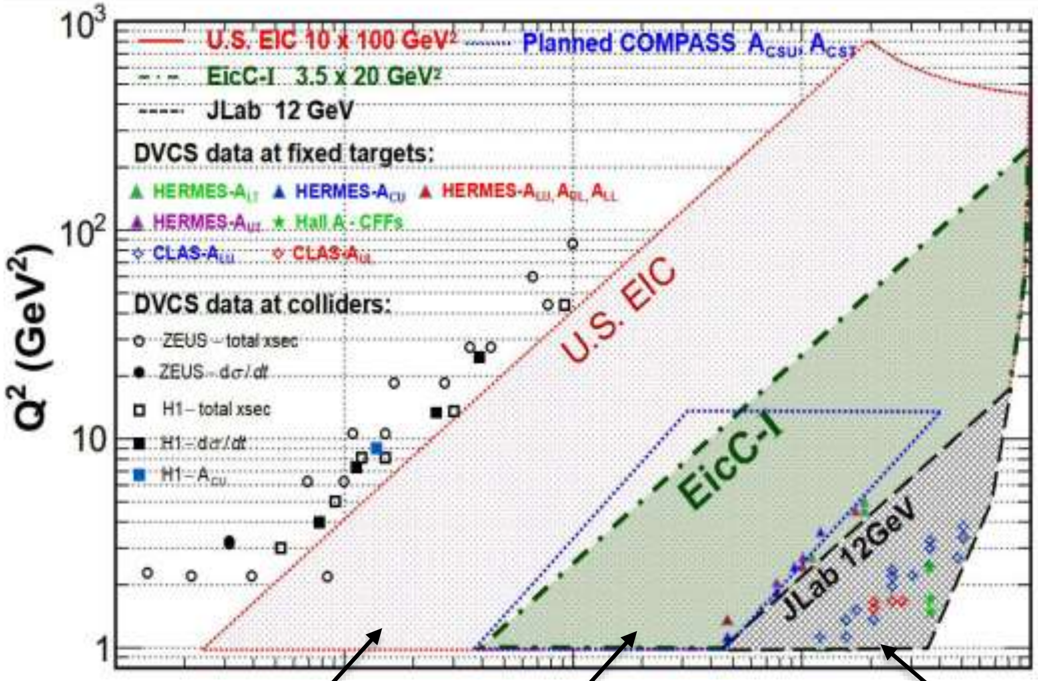
Electron-Ion Collider, EIC

➢From Quarks to Gluons

- ❑ Unlock the full power of DVMP
- ❑ Large Q^2 to go beyond the $x=\xi$ limit
- ❑ From valance to sea+gluons
- ❑ Solve spin- puzzle : JLab12 + EicC + EIC+COMPASS + Theories

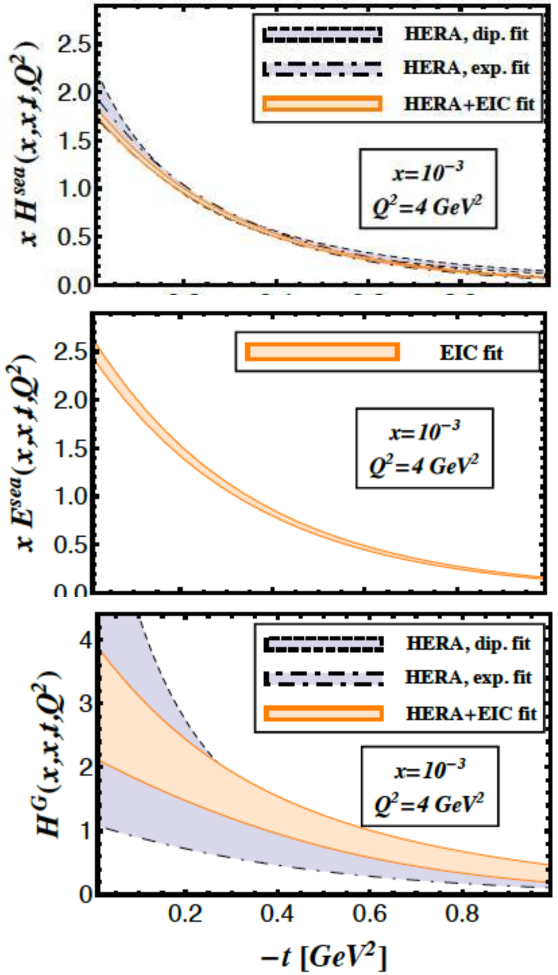






Gluons | Sea-Quarks | Valance-Quarks

U.S. EIC Yellow-Report



US EIC Roadmap

2007, NPAC Long-Range Plan recommended

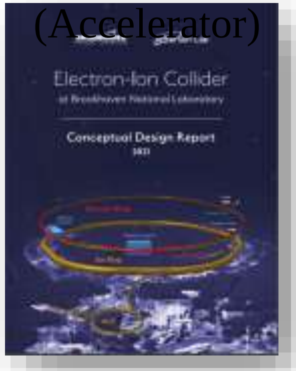
2015, NPAC Long-Range Plan highly recommended

2010, White Paper

2018, NAS Review

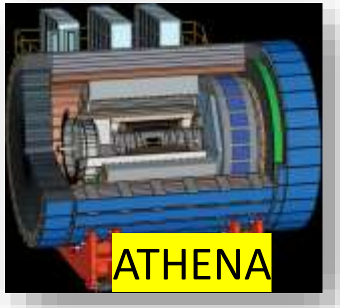
~2000

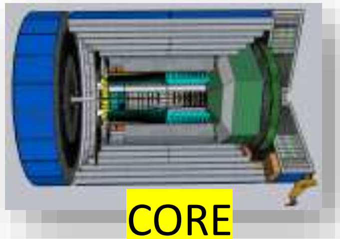
Feb. 2021, CDR (Accelerator)

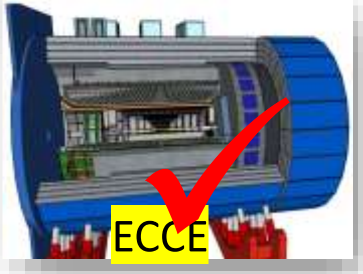


Mar. 2021, Yellow Report (Physics & Detector)

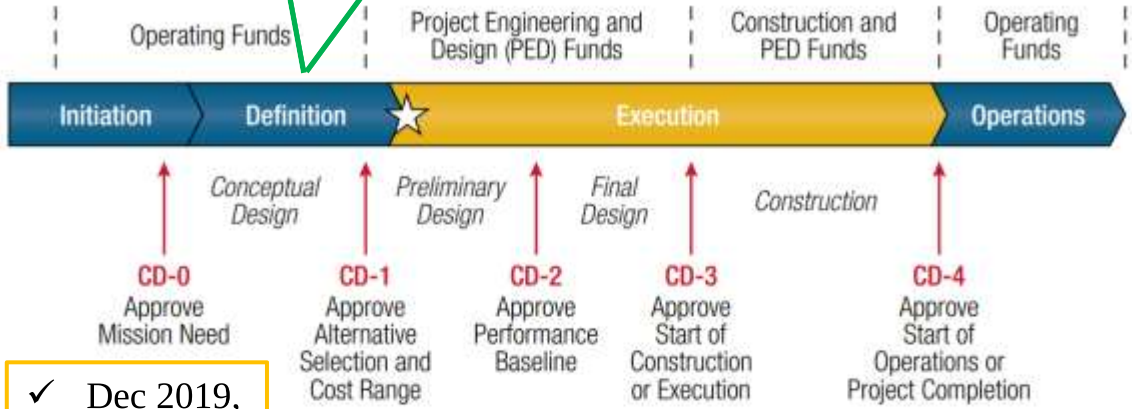
Reference

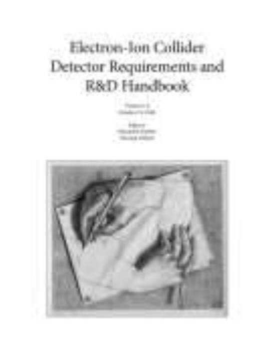


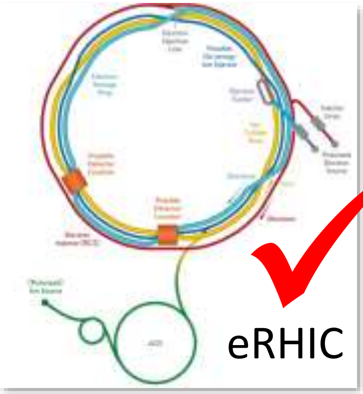




Dec 2021, Accept Detector Proposals







✓ Dec 2019, CD-0

✓ Jan 2020, Select BNL

✓ Dec 2021, CD-1

TDR

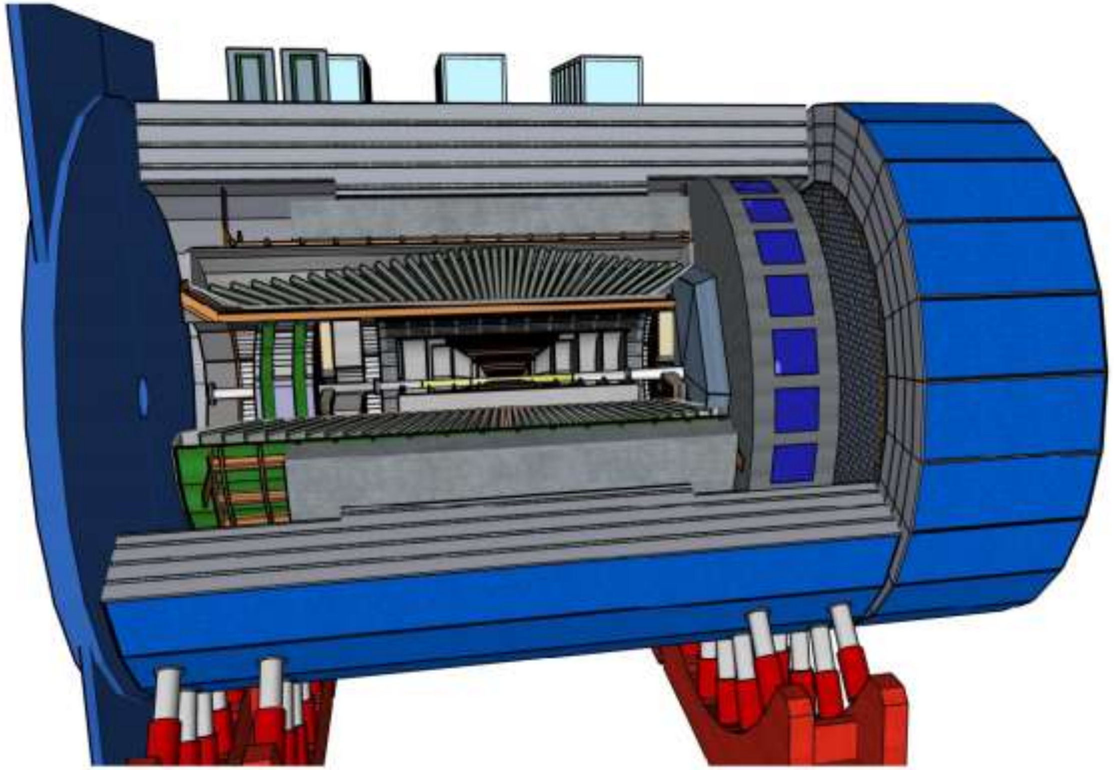
✓ 2023, CD-2?

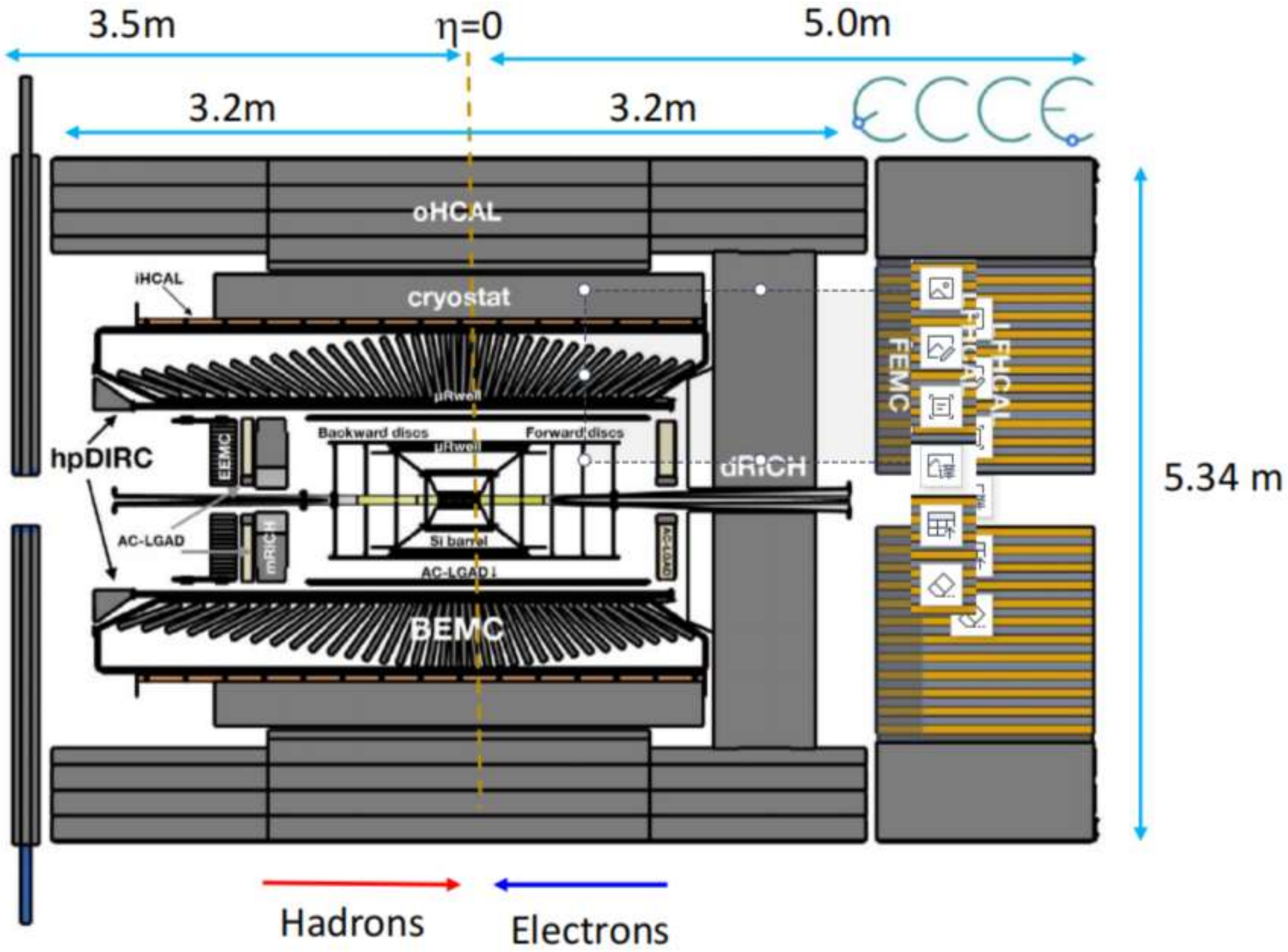
✓ 2010, EIC Detector R&D started

2016, EIC Users Group formed (1300+ from 260+ institutes)

EPIC Detector

➢Detector Layout:





- BaBar Manget:

Currently refurbished and to be used by sPHENIX (an option to build a brand new one, to be decided in 2023)

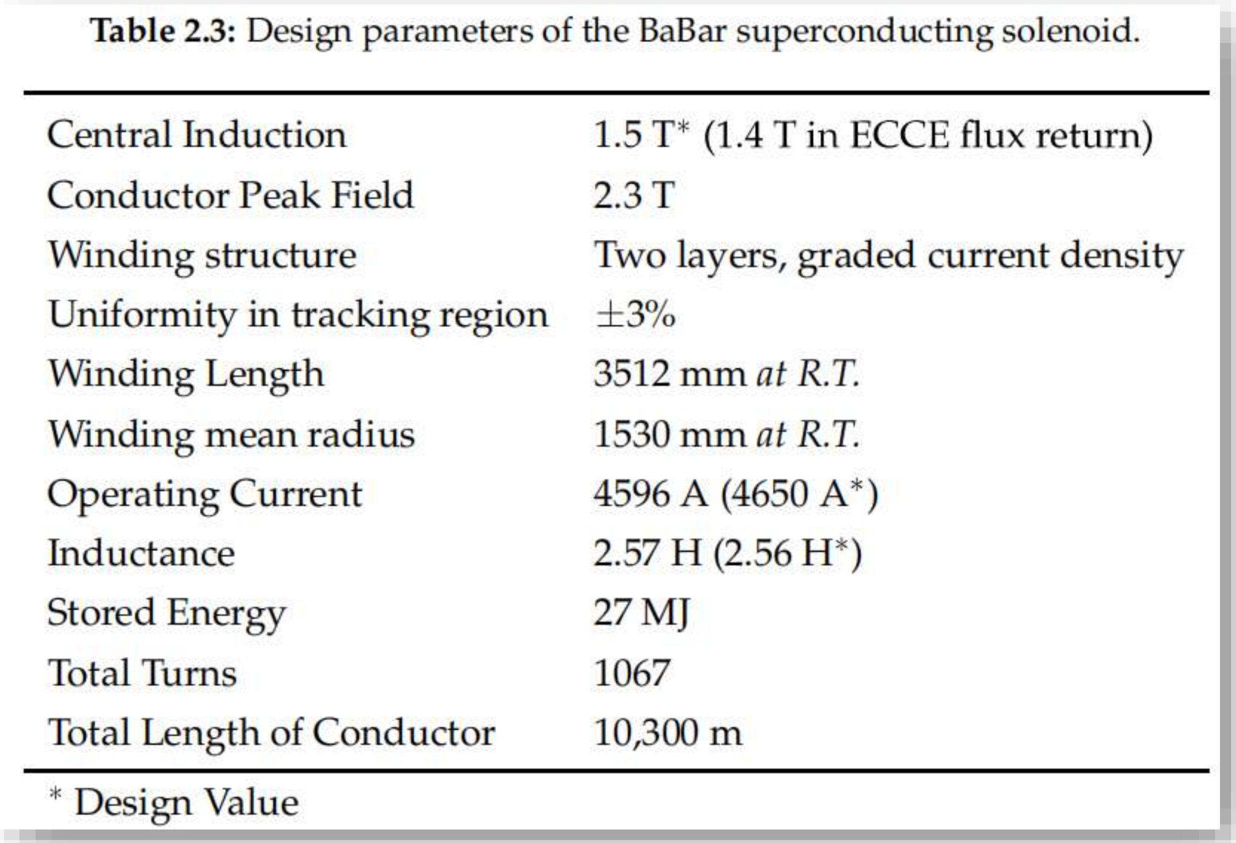


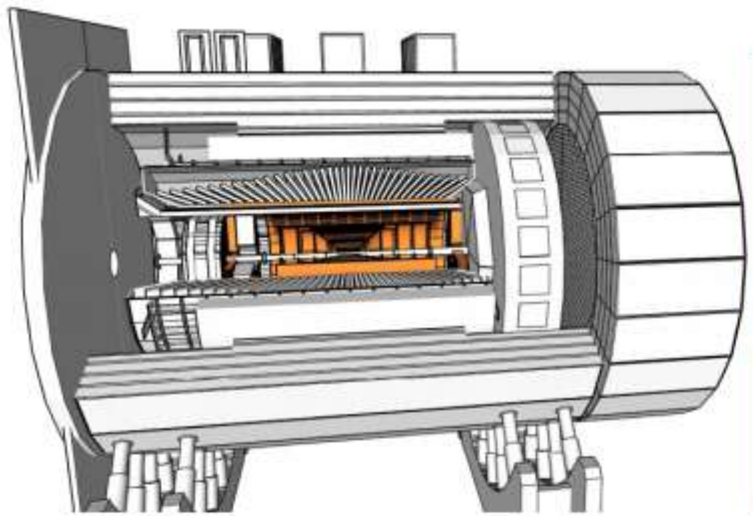
Table 2.3: Design parameters of the BaBar superconducting solenoid.

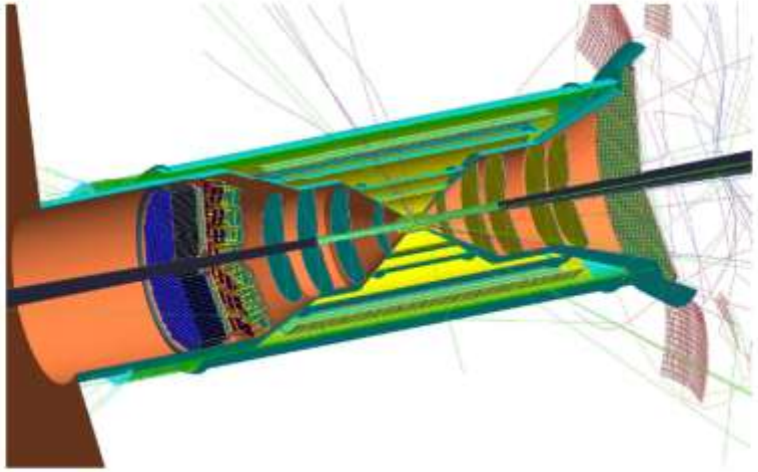
Central Induction	1.5 T* (1.4 T in ECCE flux return)
Conductor Peak Field	2.3 T
Winding structure	Two layers, graded current density
Uniformity in tracking region	±3%
Winding Length	3512 mm *at R.T.*
Winding mean radius	1530 mm *at R.T.*
Operating Current	4596 A (4650 A*)
Inductance	2.57 H (2.56 H*)
Stored Energy	27 MJ
Total Turns	1067
Total Length of Conductor	10,300 m

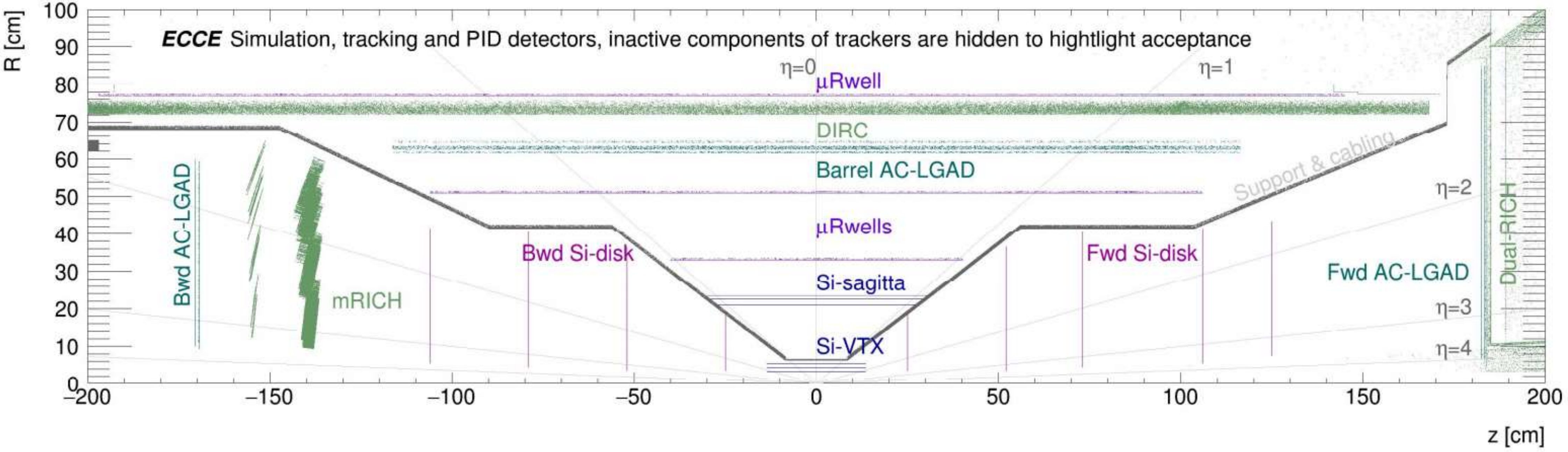
* Design Value

EPIC Detector

- Tracking System:
  - Si Tracker (MAPS)
  - uRwell (only gas detector)
  - AC-LGAD

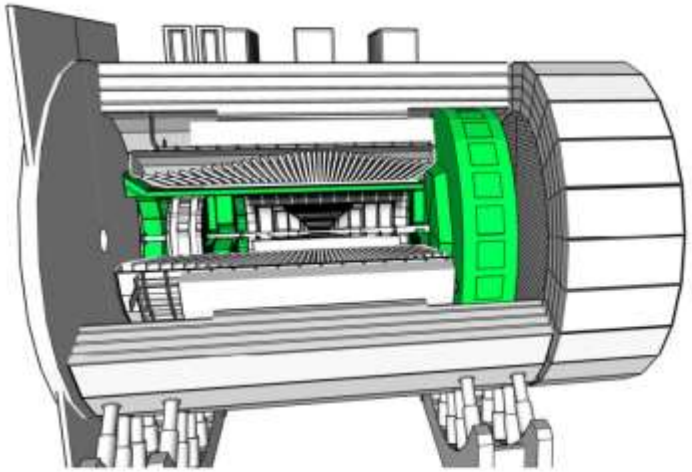


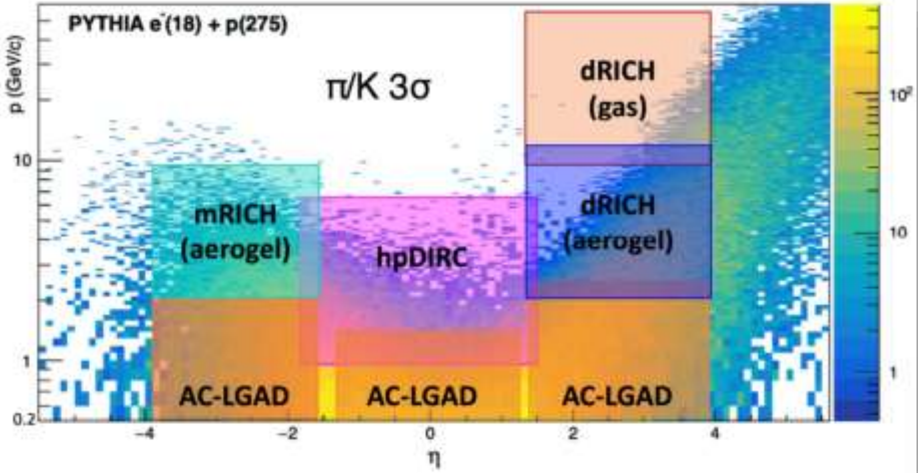




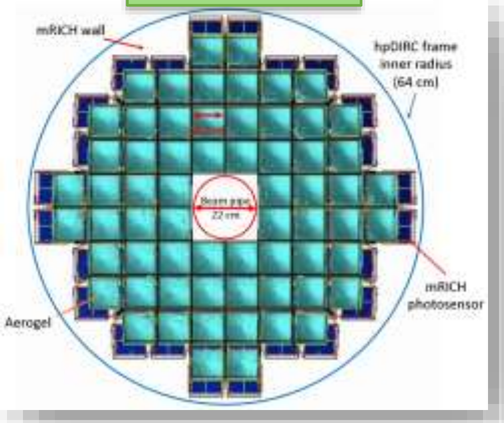
EPIC Detector

➢Particle-Identification:

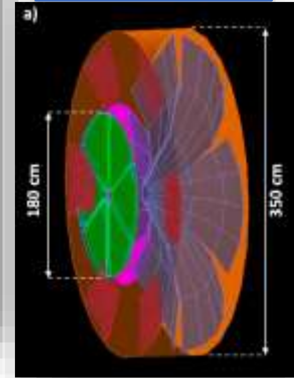


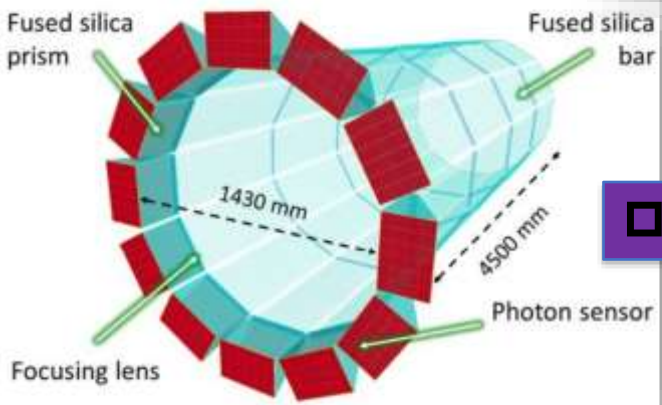


☐ mRICH



☐ dRICH

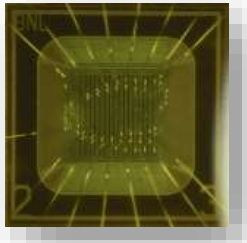


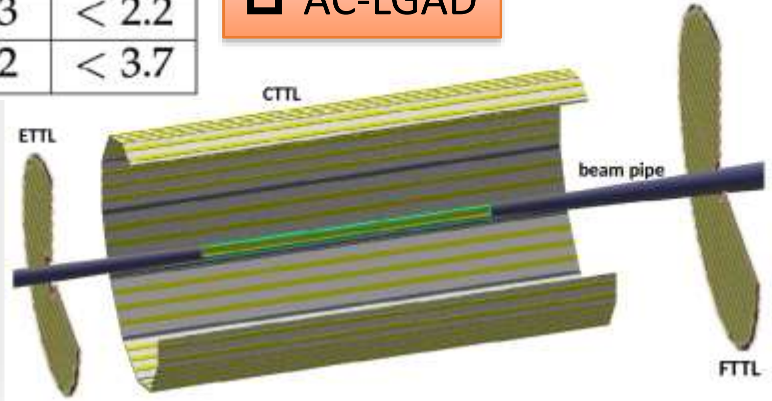


☐ DIRC

PID	ETTL	CTTL	FTTL
e/π	< 0.5	< 0.45	< 0.6
π/K	< 2.1	< 1.3	< 2.2
K/p	< 3.3	< 2.2	< 3.7

☐ AC-LGAD

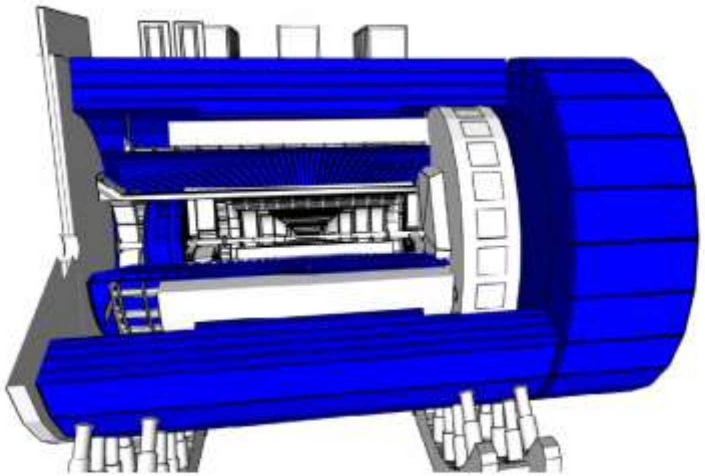




PID	Mode	mRICH	hpDIRC	dRICH aerogel	dRICH gas
π/K	Ring Imaging Threshold	$2-9$ $0.6-2$	$1-7$ $0.3-1$	$2-13$ $0.7-2$	$12-50$ $3.5-12$
e/π	Ring Imaging Threshold	$0.6-2.5$ < 0.6	< 1.2 –	$0.6-13$ < 0.6	$3.5-15$ < 3.5

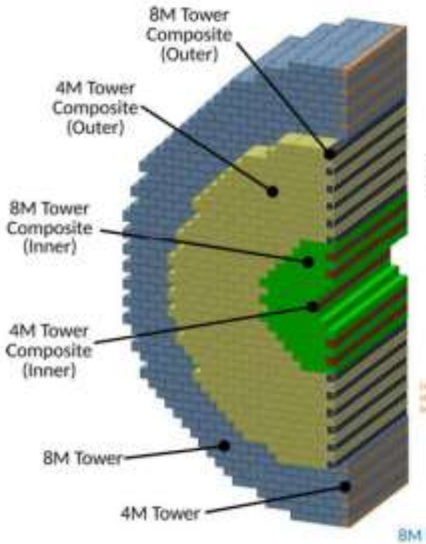
EPIC Detector

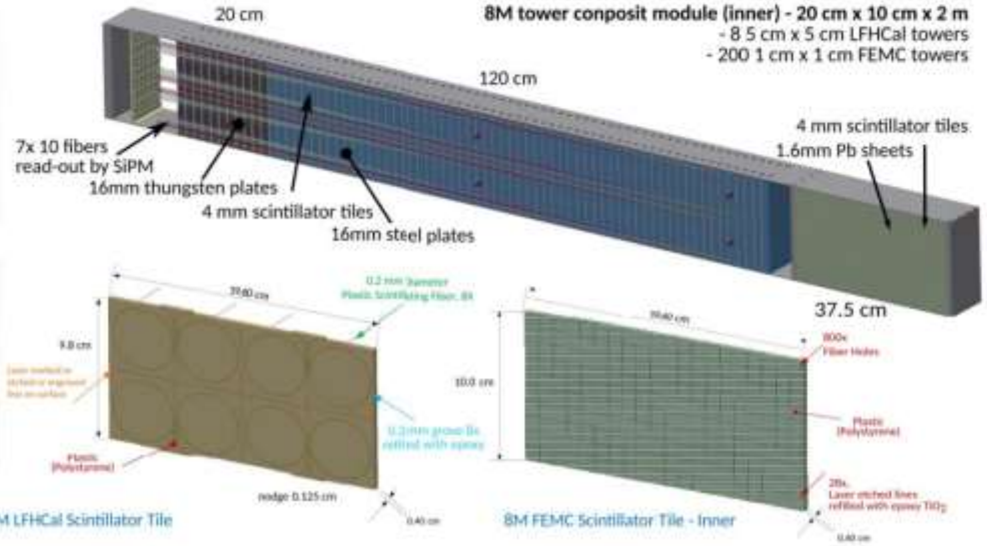
➢Calorimeters:

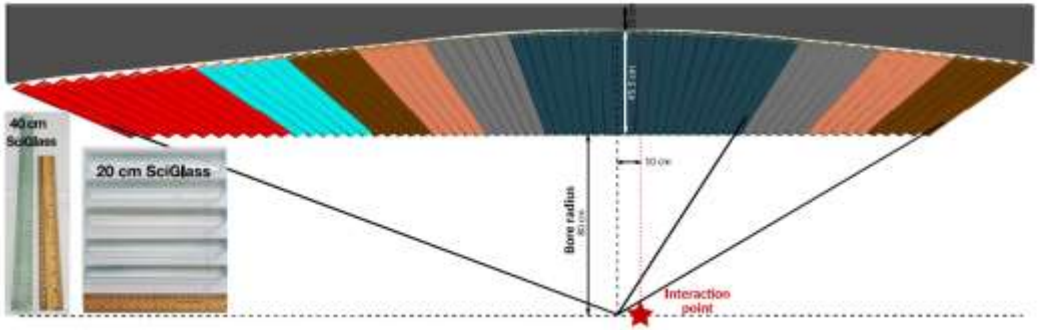


	EEMC	BEMC	FEMC	IHCAL	OHCAL	LFHCAL
tower size	2x2x20 cm^3	4x4x45.5 cm^3 projective	in: 1x1x37.5 cm^3 out: 1.6x1.6x37.5 cm^3	$\Delta\eta \sim 0.1$ $\Delta\varphi \sim 0.1$ $l \sim 4.5$ cm	$\Delta\eta \sim 0.1$ $\Delta\varphi \sim 0.1$ $l \sim 88$ cm	5x5x140 cm^3
material	$PbWO_4$	SciGlass	Pb/Scintillator	Steel/Scintillator	Steel/Scintillator	Steel/W/Scintillator
d_{abs}	-	-	1.6 mm	13 mm	in: 10.2 mm out: 14.7 mm	16 mm
d_{act}	20 cm	45.5 cm	4 mm	7 mm	7 mm	4 mm
N_{layers}	1	1	66	4	5	70
$N_{towers(channel)}$	2876	8960	19200/34416	1728	1536	9040(63280)
X/X_0	~ 22	~ 17	~ 19	~ 2	$36-48$	$65-72$
R_M	2.73 cm	3.58 cm	5.18 cm	2.48 cm	14.40 cm	21.11cm
f_{sampl}	0.914	0.970	0.220	0.059	0.035	0.040
λ/λ_0	~ 0.9	~ 1.6	~ 0.9	~ 0.2	$\sim 4-5$	$7.6-8.2$
η acceptance	$-3.7<\eta<-1.8$	$-1.7<\eta<1.3$	$1.3<\eta<4$	$1.1<\eta<1.1$	$1.1<\eta<1.1$	$1.1<\eta<4$
resolution						
- energy	$2/\sqrt{E}\oplus 1$	$2.5/\sqrt{E}\oplus 1.6$	$7.1/\sqrt{E}\oplus 0.3$		$75/\sqrt{E}\oplus 14.5$	$33.2/\sqrt{E}\oplus 1.4$
- φ	~ 0.03	~ 0.05	~ 0.04		~ 0.1	~ 0.25
- η	~ 0.015	~ 0.018	~ 0.02		~ 0.06	~ 0.08

sPHENIX reused





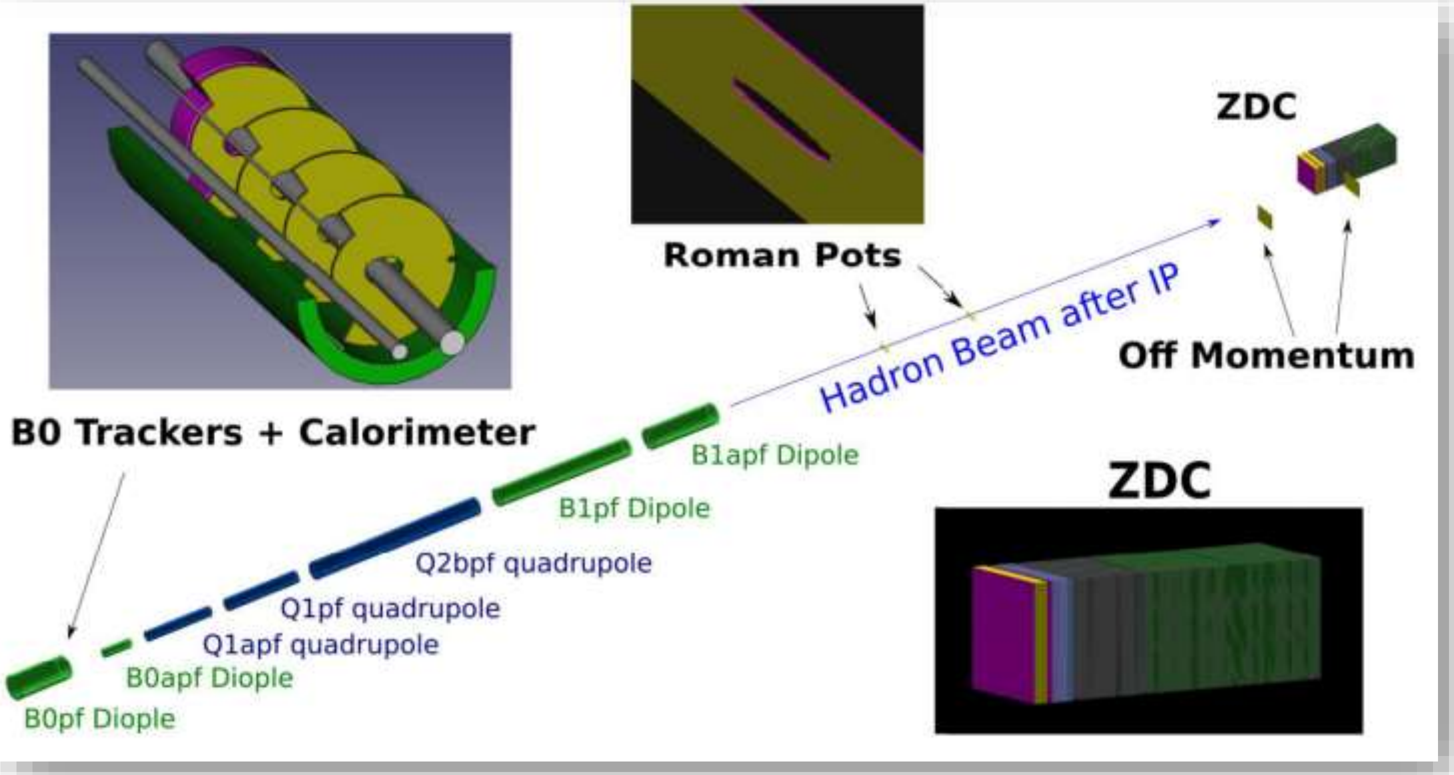


EPIC Detector

➢Forward/Backward Detectors:

- **B0 system** measures charged particles in the forward direction and tags neutral particles.
- **Off-momentum** detectors measure charged particles with different rigidity than the beam, e.g., those following decay and fission.
- **Roman pot** detectors measure charged particles close to the beam envelope.
- **Zero-Degree Calorimeter** measures neutral particles at small angles

Detector	(x,z) Position [m]	Dimensions	θ [mrad]	Notes
ZDC	(-0.96, 37.5)	(60cm, 60cm, 1.62m)	$\theta < 5.5$	~4.0 mrad at $\phi = \pi$
Roman Pots (2 stations)	(-0.83, 26.0) (-0.92, 28.0)	(30cm, 10cm)	$0.0 < \theta < 5.5$	10σ cut.
Off-Momentum Detector	(-1.62, 34.5), (-1.71, 36.5)	(50cm, 35cm)	$0.0 < \theta < 5.0$	$0.4 < x_L < 0.6$
B0 Trackers and Calorimeter	(x = -0.15, 5.8 < z < 7.0)	(32cm, 38m)	$6.0 < \theta < 22.5$	~20 mrad at ϕ=0



EPIC Detector

➢DAQ:

- Trigger-less streaming readouts

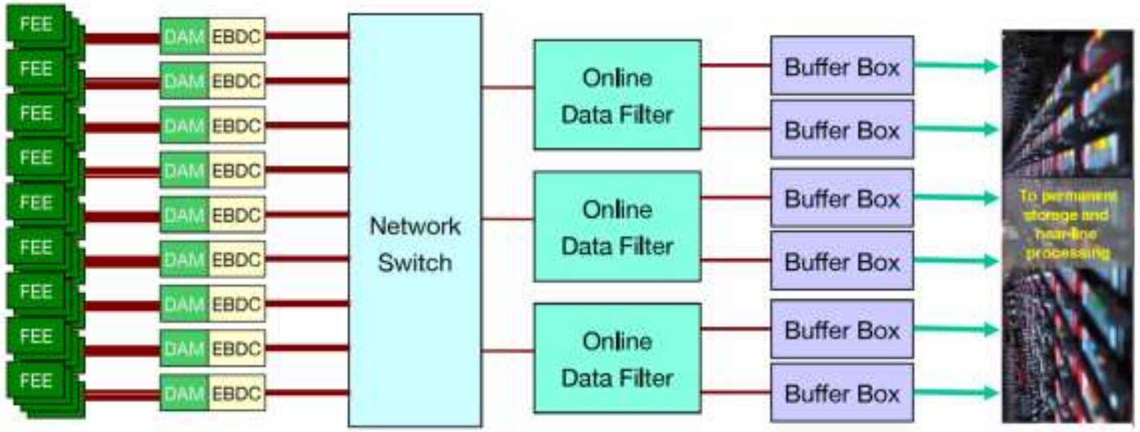
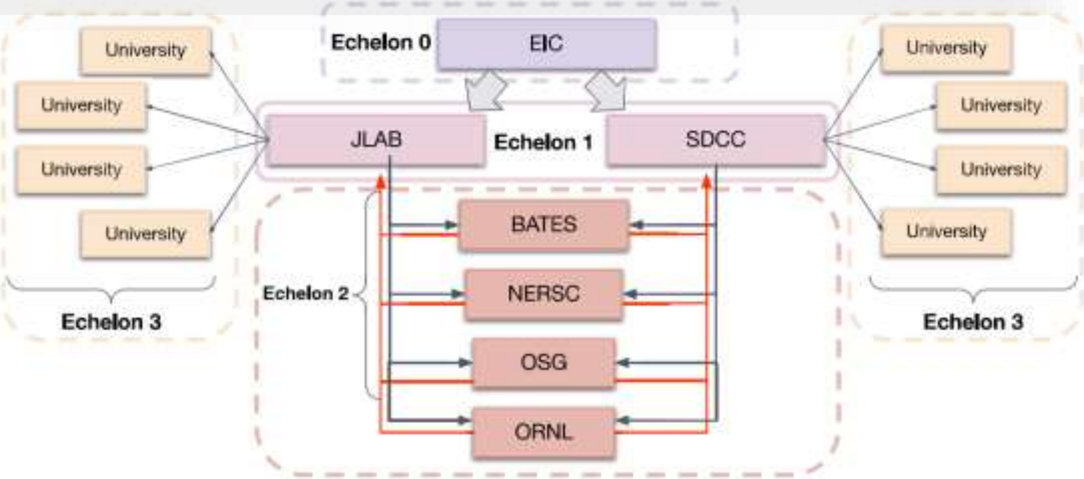


Table 2.8: Estimate of raw data storage and compute needs for first three years of ECCE, assuming ramp up to full luminosity by year 3 [32]

	ECCE Runs		
	year-1	year-2	year-3
Luminosity	$10^{33}cm^{-2}s^{-1}$	$2\times10^{33}cm^{-2}s^{-1}$	$10^{34}cm^{-2}s^{-1}$
Weeks of Running	10	20	30
Operational efficiency	40%	50%	60%
Disk (temporary)	1.2 PB	3.0 PB	18.1 PB
Disk (permanent)	0.4 PB	2.4 PB	20.6 PB
Data Rate to Storage	6.7 Gbps	16.7 Gbps	100 Gbps
Raw Data Storage (no duplicates)	4 PB	20 PB	181 PB
Recon process time/core	5.4 s/ev	5.4 s/ev	5.4 s/ev
Streaming-unpacked event size	33kB	33kB	33kB
Number of events produced	121 billion	605 billion	5,443 billion
Recon Storage	0.4 PB	2 PB	18 PB
CPU-core hours (recon+calib)	191M core-hours	953M core-hours	8,573M core-hours
2020-cores needed to process in 30 weeks	38k	189k	1,701k

Table 2.7: PID Detector ASICs and channel counts.

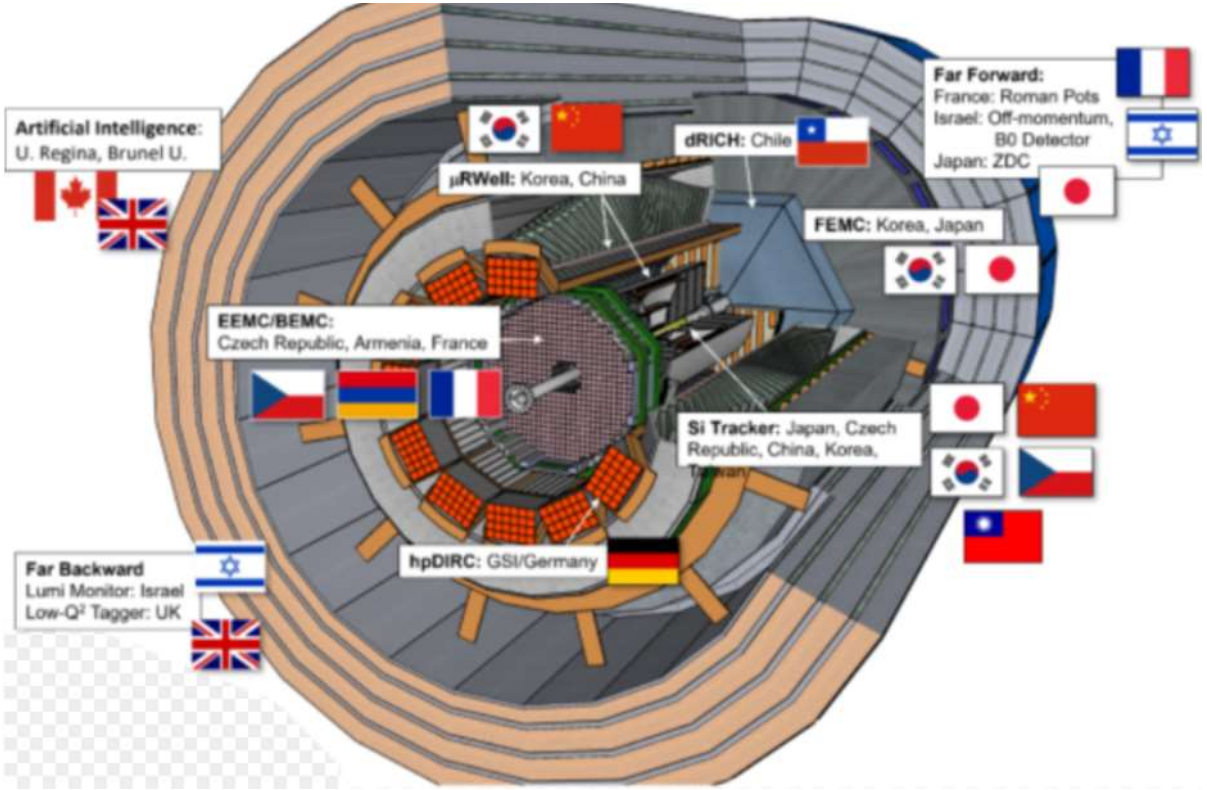
PID WBS Name	Detector	ASIC	Channels
Barrel PID	hpDIRC	High Density SoC	69,632
	TOF	eRD112 development	8,600,000
Electron Endcap	mRICH	High Density SoC	65,536
	TOF	eRD112 development	920,000
Hadron Endcap	dRICH	MAROC3	5,376
	TOF	eRD112 development	1,840,000
Far-Forward Detectors	Roman Pots	eRD112 development	524,288
	B0 Detector	eRD112 development	2.6M
	Off-Momentum Detectors	eRD112 development	1.8M
Far-Backward Detectors	Low-Q^2 Tagger	eRD112 development	4.6M
	Luminosity Monitor	eRD112 development	268,441

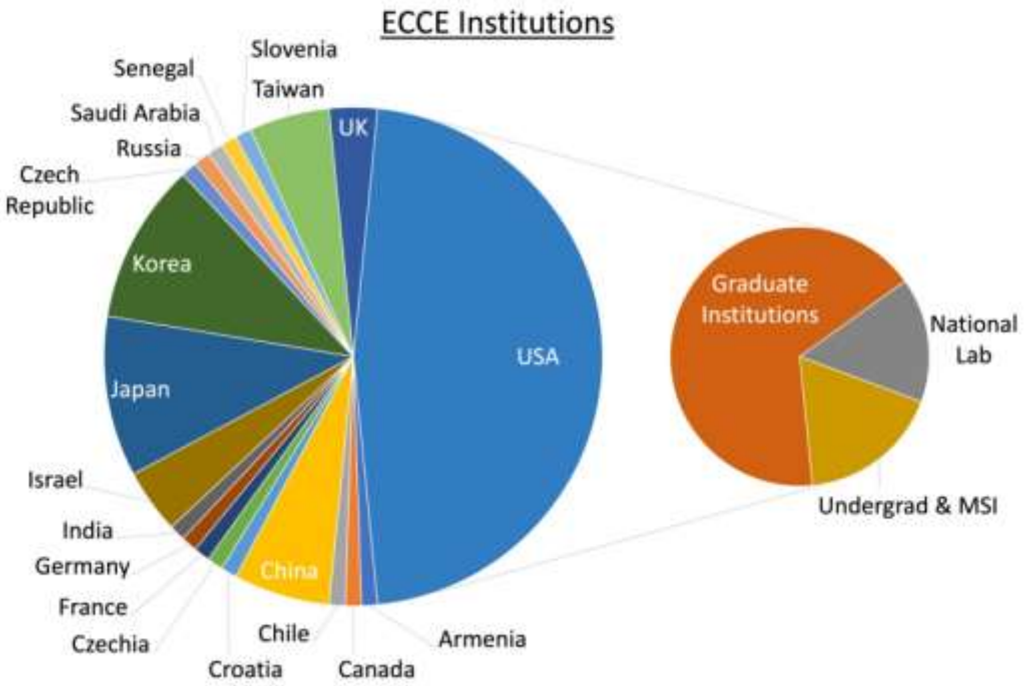


EPIC Detector

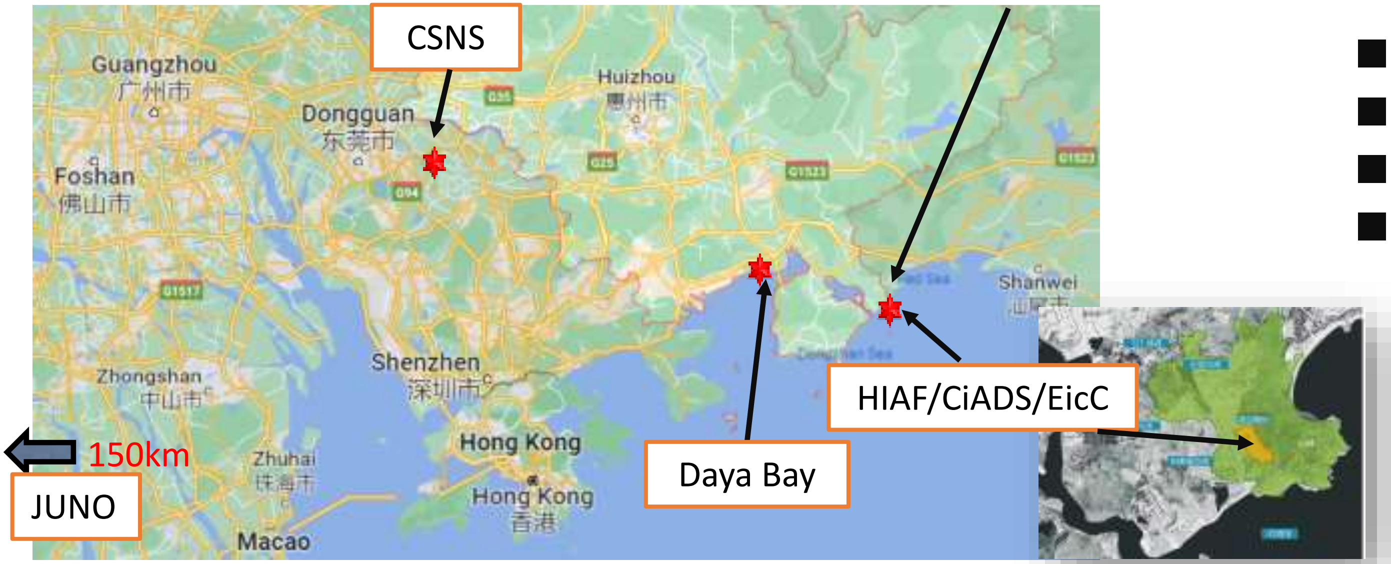
➢China-EIC Consortium Involvement:

- Si Tracker: CCNU, CIAE, IMP
- uRwell: USTC, IMP
- EM Calo: Fudan, SDU, Tsinghua
- RICH: Tsinghua
- DAQ: CCNU
- Forward EM Cal: SCNU





➢High Intensity heavy-ion Accelerator Facility (HIAF):

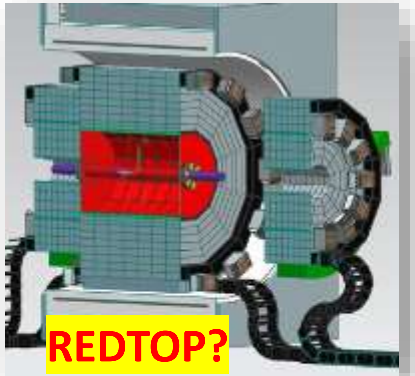


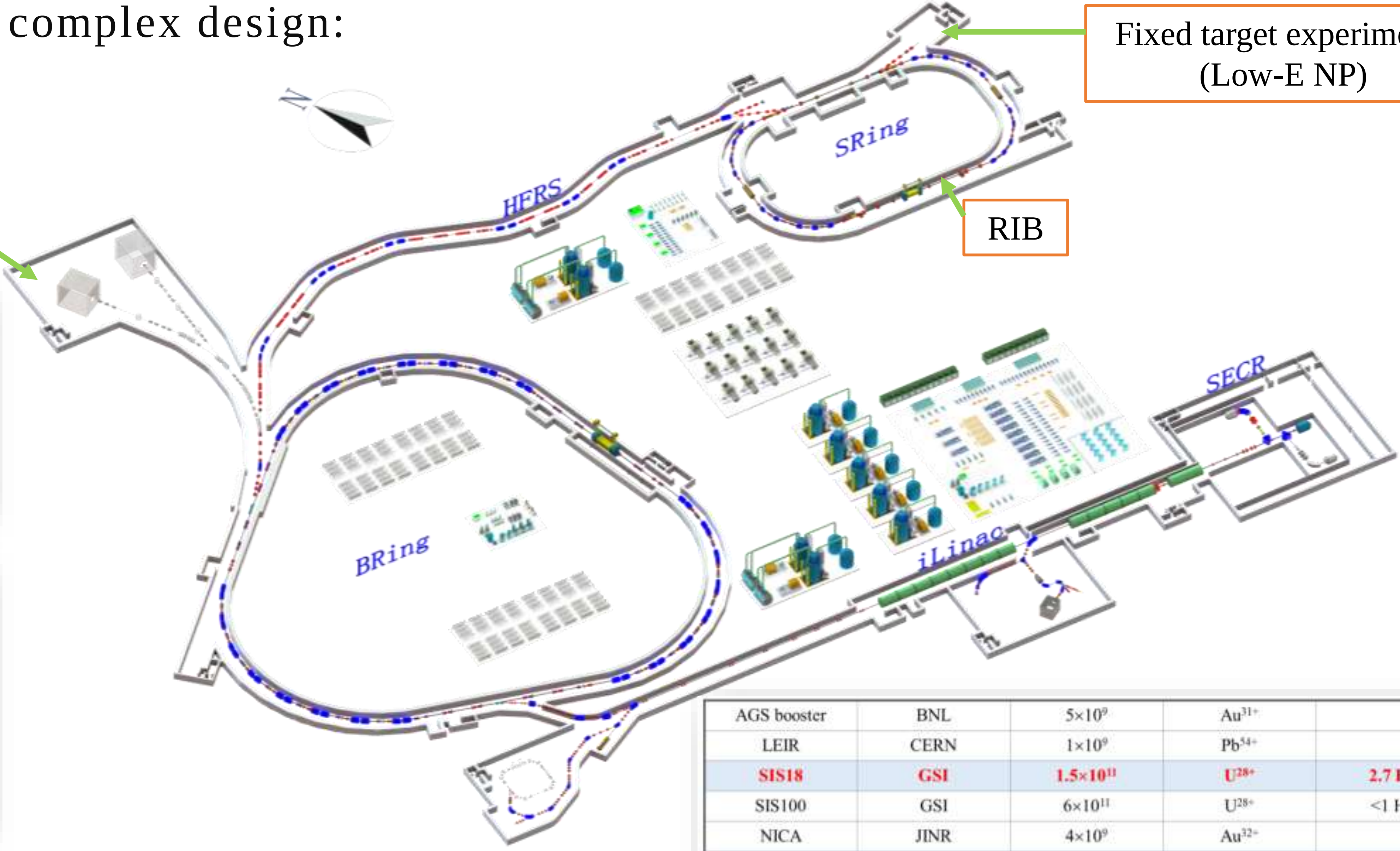
- Run by Institute of Modern Physics (IMP)
- First phase ~0.6 km^2 ; Construction area ~ 0.12 km^2
- +2 km^2 is reserved for future development
- Total budget:~ 6.8 billion CNY (~1billion US Dollars)
  - ✓ 3.5 billion comes from the central government.
  - ✓ 2.35 billion from local government for infrastructure
  - ✓ 1.0 billion from The China National Nuclear Corporation (CNNC) for CiADS

HIAF

➢Accelerator complex design:

Fixed target experiments (Mid/High-E NP)





Fixed target experiments (Low-E NP)

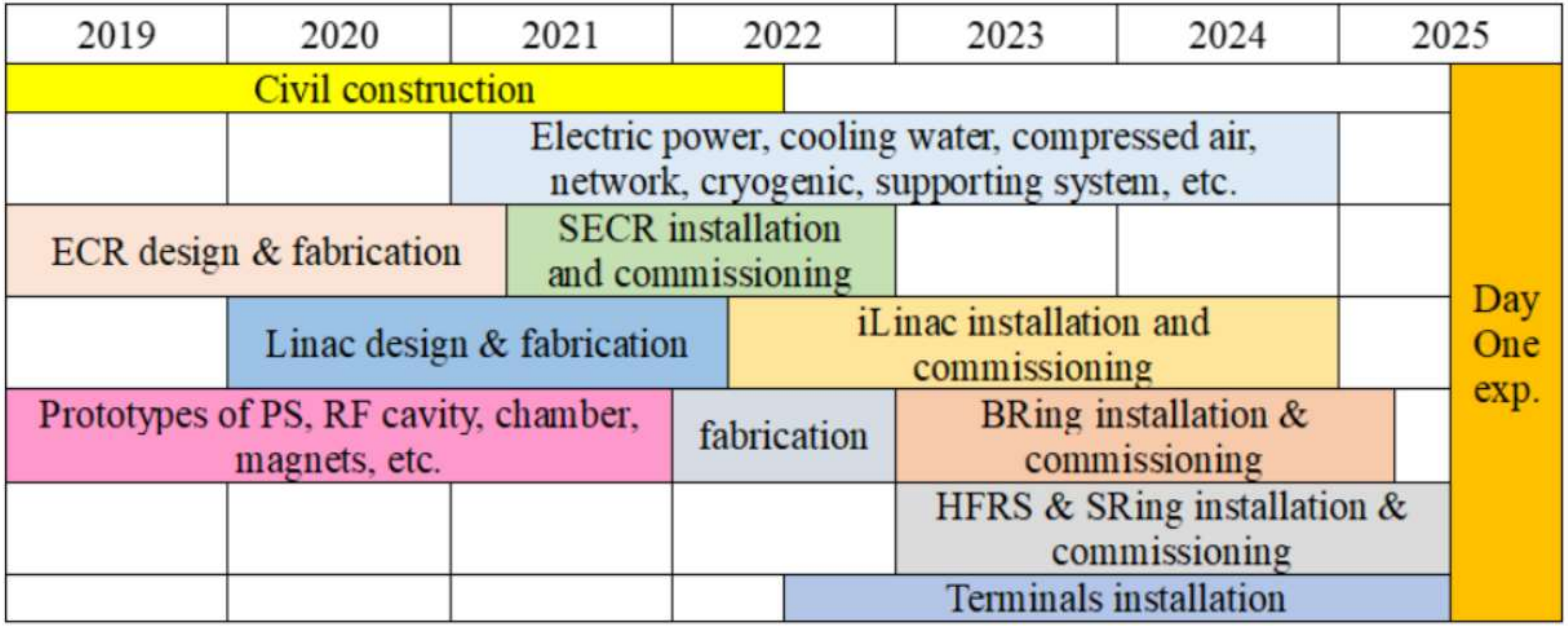
RIB

AGS booster	BNL	5×10^9	Au^{31+}	
LEIR	CERN	1×10^9	Pb^{54+}	
SIS18	**GSI**	**1.5×10^{11}**	**U^{28+}**	**2.7 Hz**
SIS100	GSI	6×10^{11}	U^{28+}	<1 Hz
NICA	JINR	4×10^9	Au^{32+}	
HIAF	**IMP**	**2×10^{11}**	**U^{35+}**	**3-10 Hz**

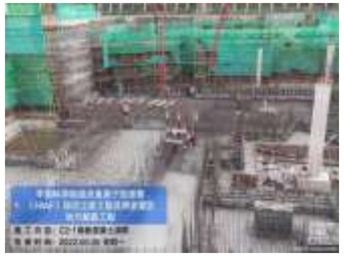
➢Timeline:

- Road Map:

- Construction Plan:

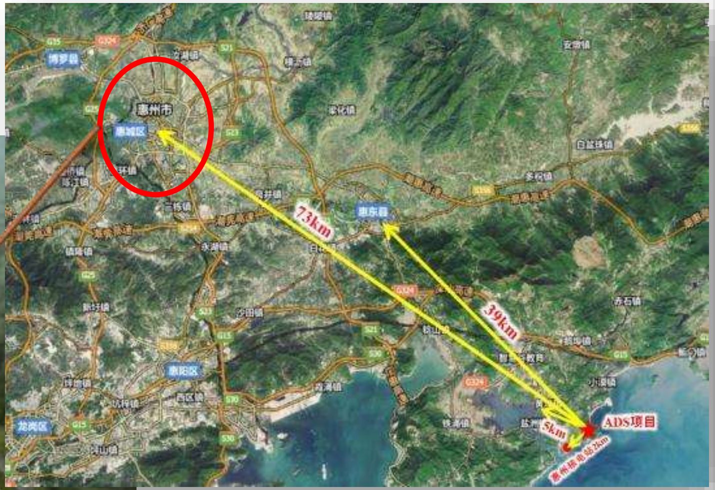


➢Accelerator Site Construction:



➢IMP Office Site Construction:

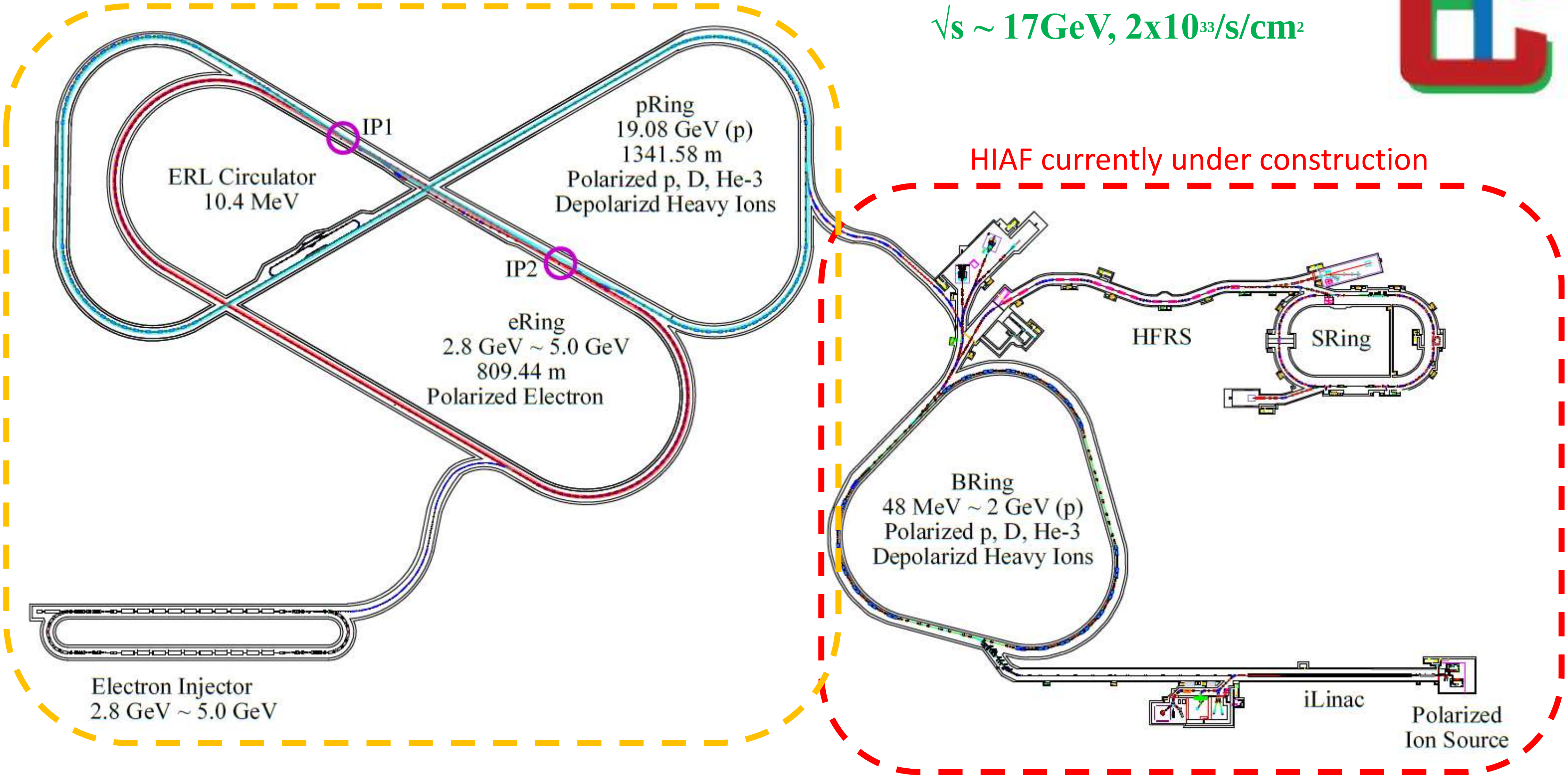
New IMP branch in Huizhou downtown (73km from HIAF)



➢Upgraded Accelerator complex layout:

NEW: Electron injector and collider rings

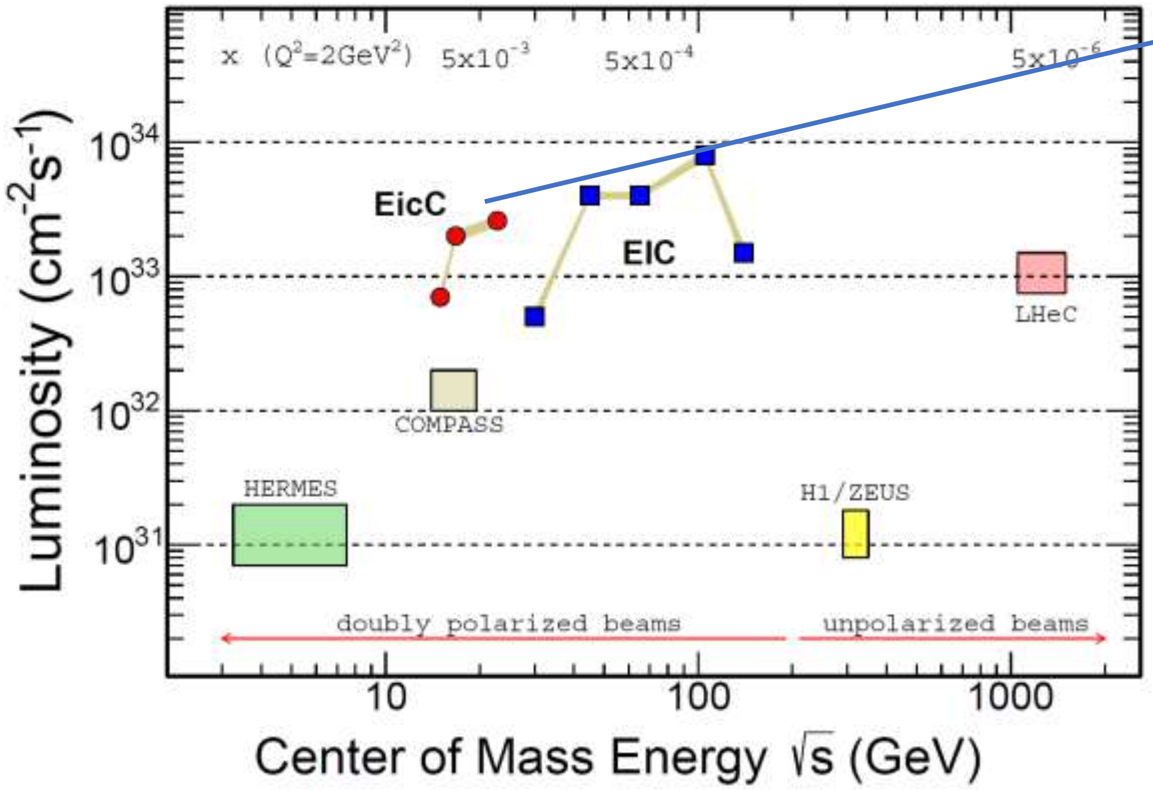
$\sqrt{s} \sim 17GeV, 2x10^{33}/s/cm^2$

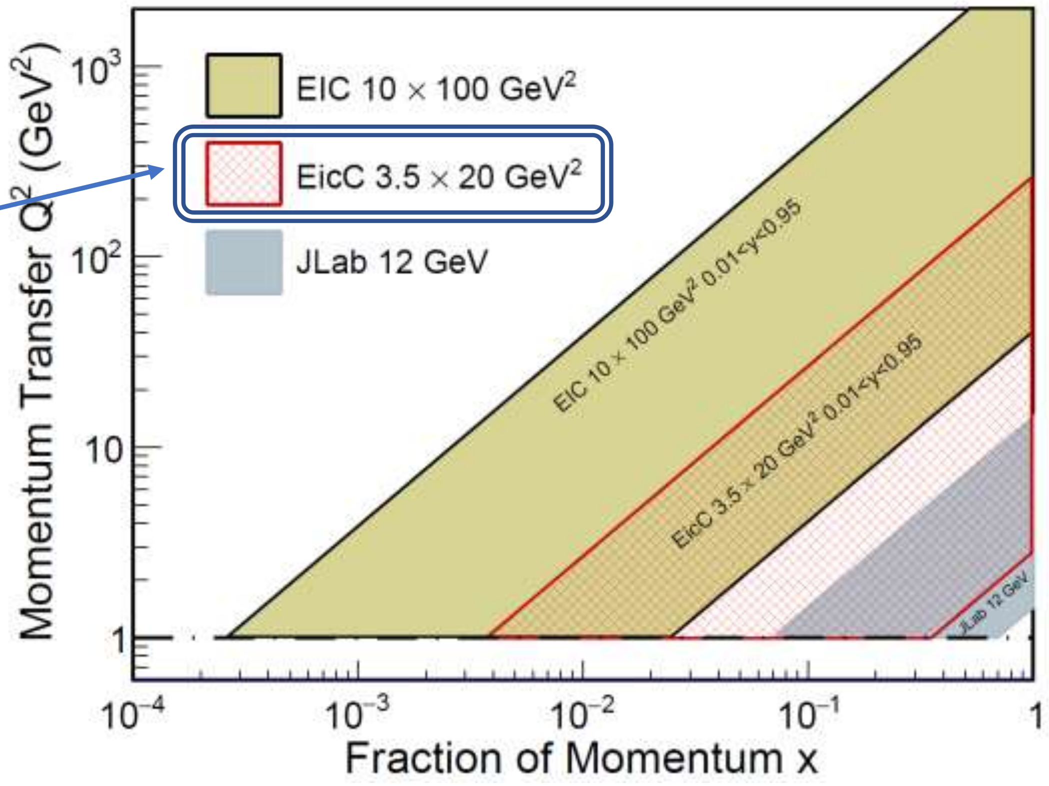


EicC

EicC

- ➢Complementary to JLab@12GeV and US-EIC:
  - ✓ Luminosity: $2x10^{33}cm^{-2}s^{-1}$;
  - ✓ Polarization: electrons →70%, ^{2}D & ^{3}He

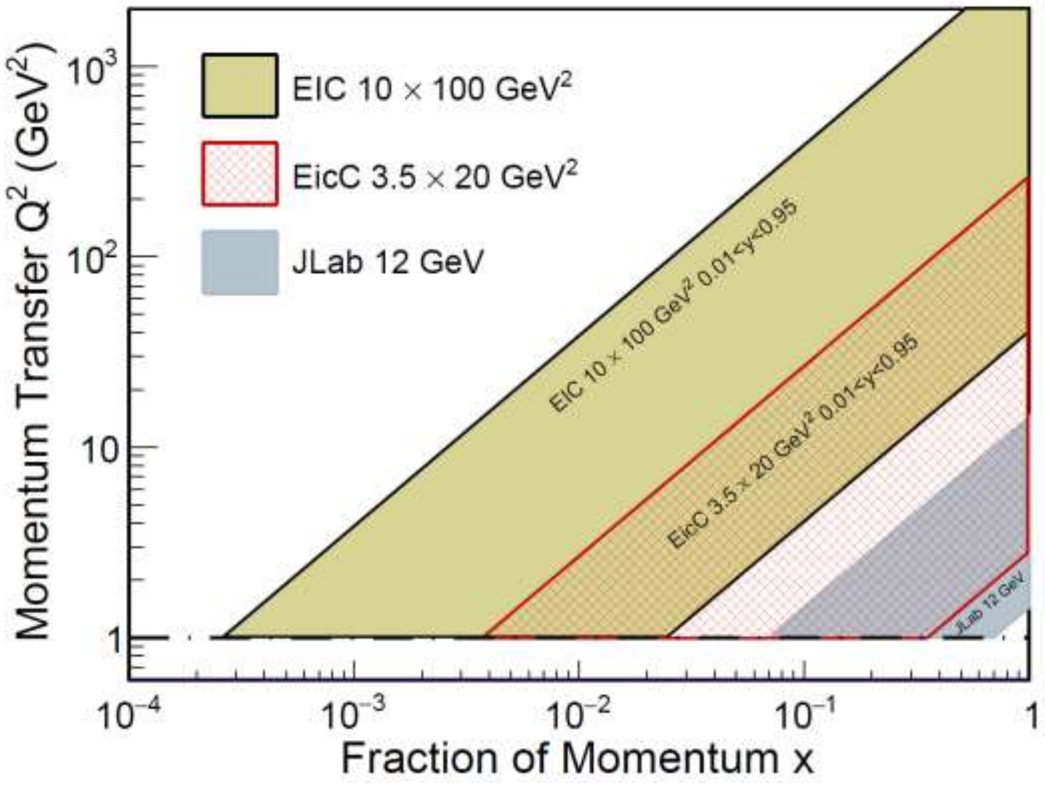




◆ Some overlap with JLab@24GeV

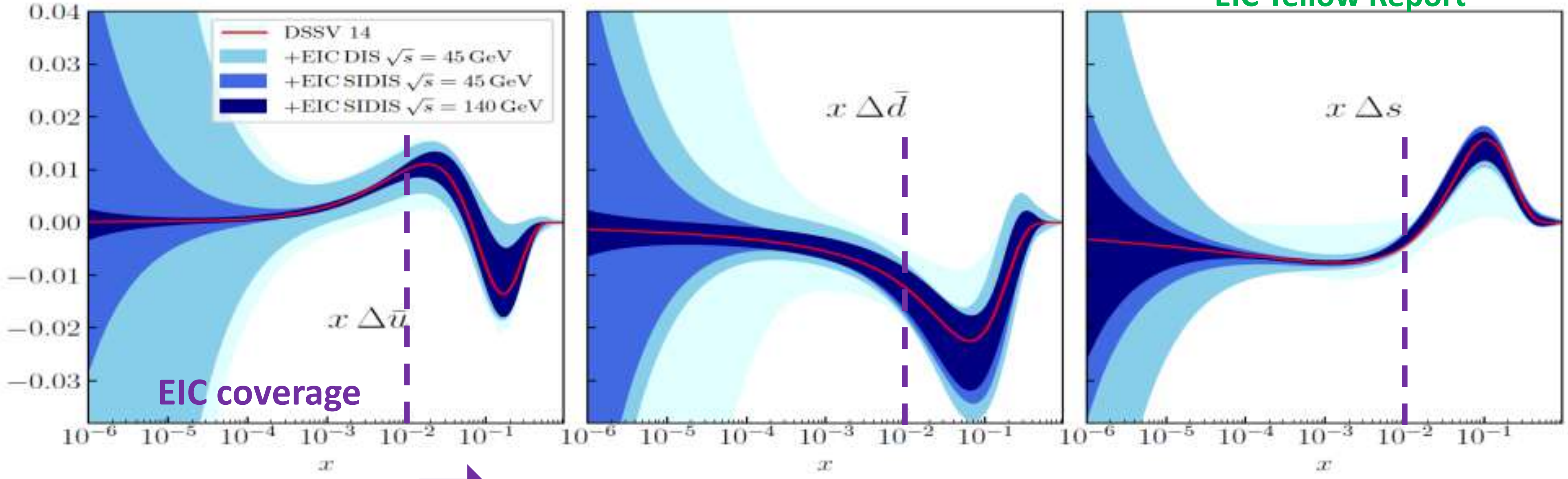
➢Complementary to JLab@12GeV and US-EIC:

- Spin of the nucleon: 1D, 3D
  - Polarized electron + Polarized proton/light nuclei
  - Valance and see quarks TMDs and GPDs
- Partonic structure of nuclei and the parton interaction with the nuclear environment
  - Unpolarized electron + unpolarized various nuclei
  - Well developed heavy-ion community
- Pion/Kaon Structure
- Mass of the nucleon
  - J/Psi and Upsilon Production
- Exotic states with c/cbar, b/bbar
  - Strong BESIII community in China



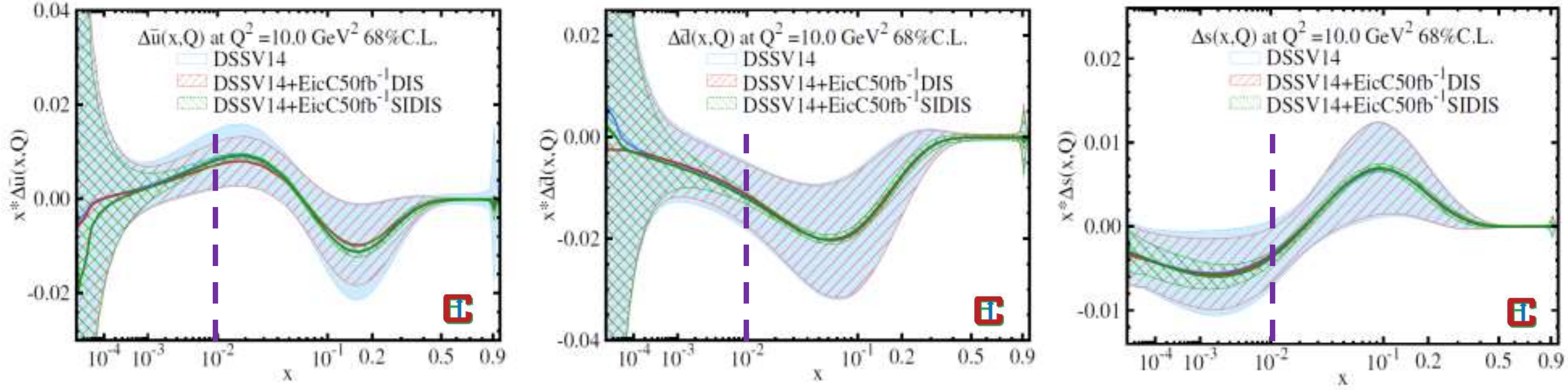
- Spin of the nucleon-helicity distribution

EIC Yellow Report



EicC coverage

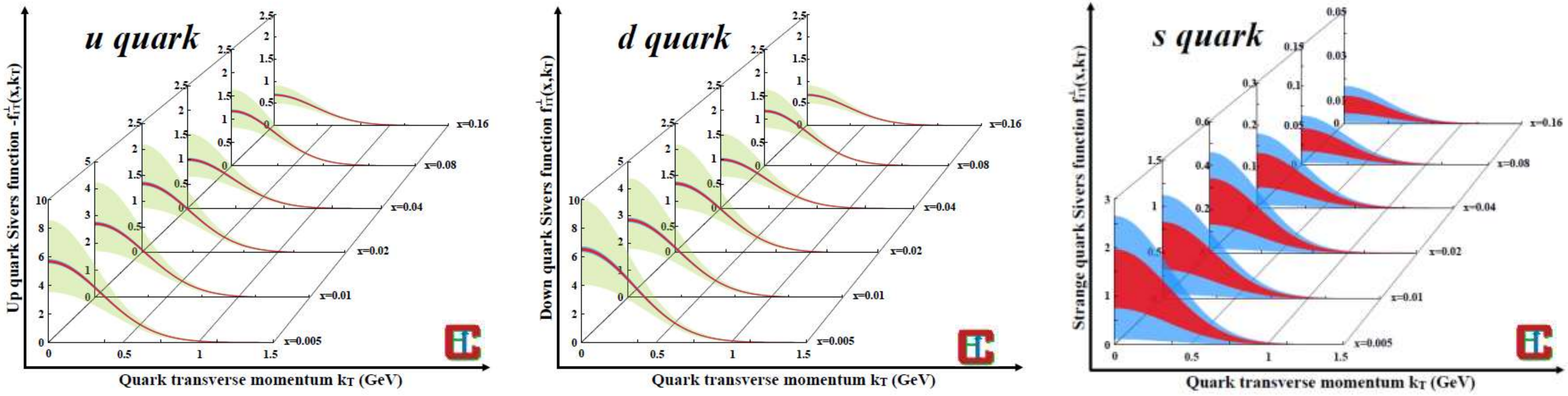
EicC white paper



arXiv:2103.10276
JHEP08(2021)034

Physics Highlight

➢Spin structure of the nucleon-TMDs



Green: Current accuracy

Red: stat. error only

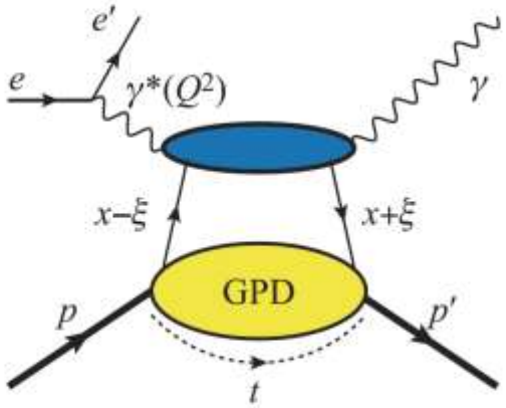
Blue: sys. Error included

H. Dong, D. X. Zheng, J. Zhou, 2018

EicC SIDIS MC Data:

- ➢ Pion(+/-), Kaon(+/-)
- ➢ ep: 3.5 GeV X 20 GeV
- ➢ eHe-3: 3.5 GeV X 40 GeV
- ➢ Pol.: e(80%), p(70%), He-3(70%)
- ➢ Lumi: ep 50 fb^{-1}, eHe-3 50 fb^{-1}

➢Spin structure of the nucleon-GPDs



Polarized beam, unpolarized target (SSA)

$$A_{LU}^{\sin\phi} \propto \frac{y\sqrt{1-y}}{2-2y-y^2}\sqrt{\frac{-t}{y^2Q^2}} \times x_B Im\left[F_1\mathcal{H} + \xi(F_1+F_2)\widetilde{\mathcal{H}} - kF_2\mathcal{E} + ...\right](x_B, t, Q^2),$$

Unpolarized beam, longitudinal target (lTSA)

$$A_{UL}^{\sin\phi} \propto \frac{\sqrt{1-y}}{2-y}\sqrt{\frac{-t}{y^2Q^2}} \times x_B Im\left[F_1\widetilde{\mathcal{H}} + x_B(F_1+F_2)(\mathcal{H} + \frac{x_B}{2\mathcal{E}}) - x_B kF_2\widetilde{\mathcal{E}} + ...\right](x_B, t, Q^2),$$

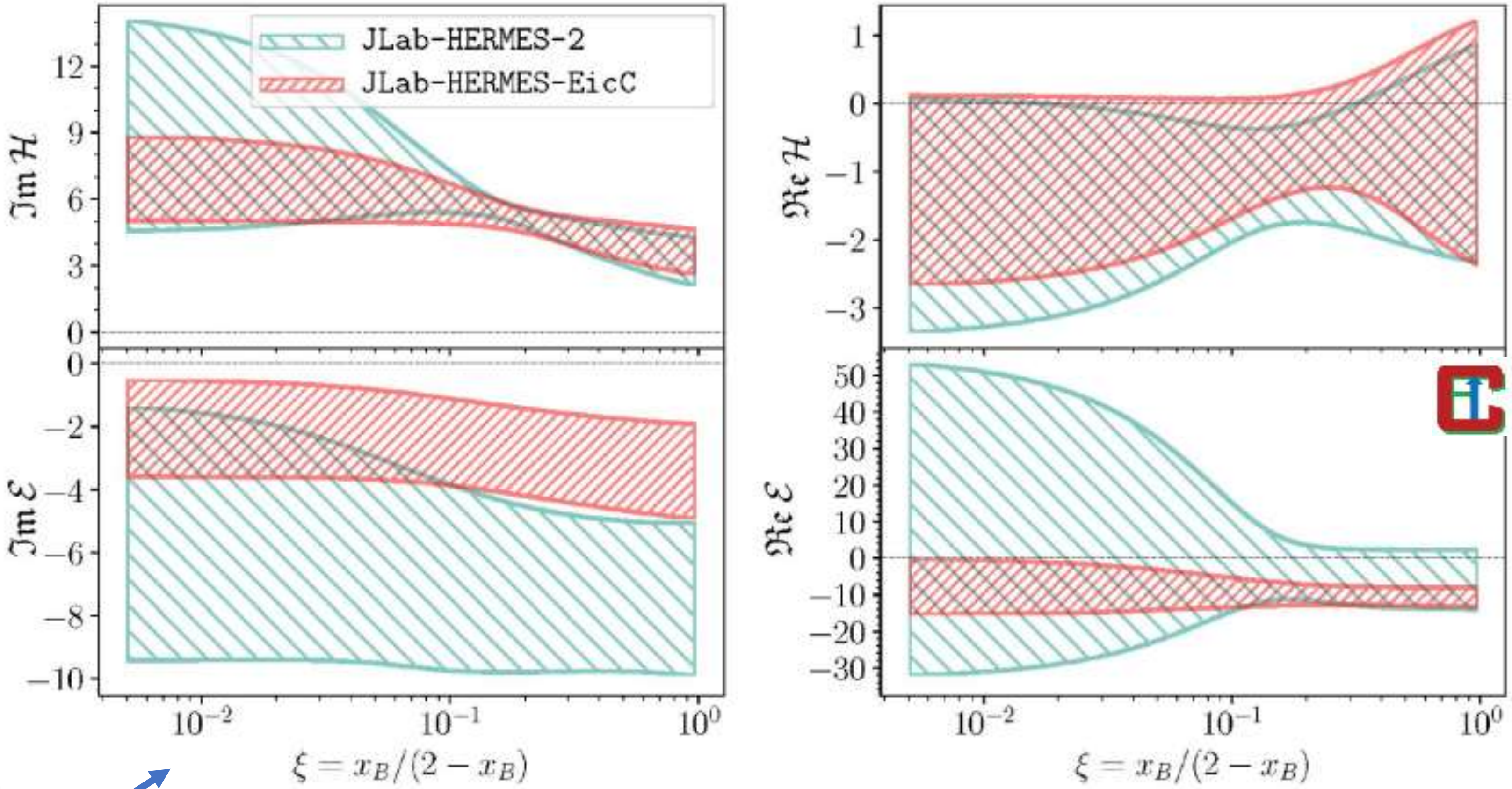
Unpolarized beam, transverse target (tTSA)

$$A_{UT}^{\sin(\phi-\phi_S)\cos\phi} \propto \frac{\sqrt{1-y}}{2-y}\frac{-t}{2yM_NQ} \times x_B Im\left[F_1\mathcal{H} + \xi(F_1+F_2)(\widetilde{\mathcal{H}} + \frac{x_B}{2}\mathcal{E}) - \xi kF_2\widetilde{\mathcal{E}} + ...\right](x_B, t, Q^2),$$

Polarized beam, longitudinal target (DSA)

$$A_{LL} \propto (A + B\cos\phi) Re\left[F_1\mathcal{H} + \xi(F_1+F_2)(\mathcal{H} + \frac{x_B}{2}\mathcal{E}) + ...\right],$$

The extraction of CFF with neural network methods



Only with this azimuthal angular modulation

Strong support from PARTONS collaboration

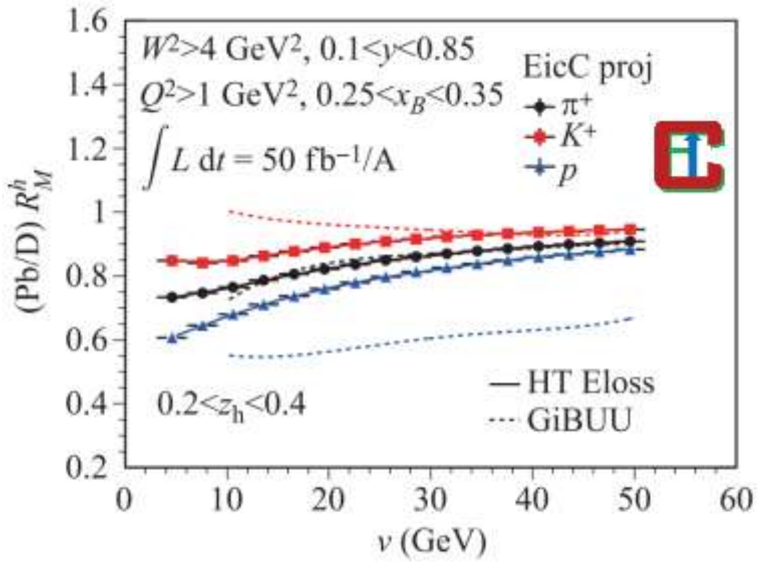
[Kumericki, 19]

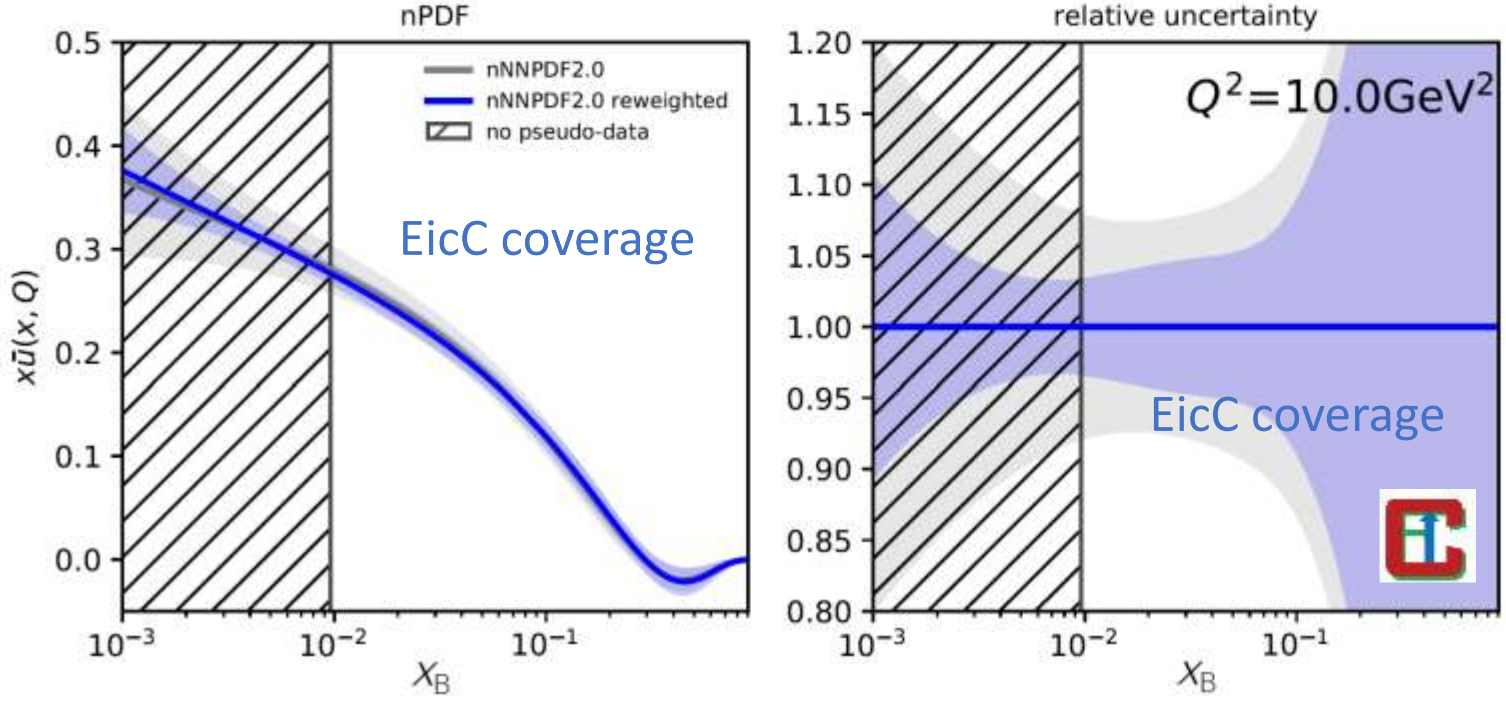
Physics Highlight

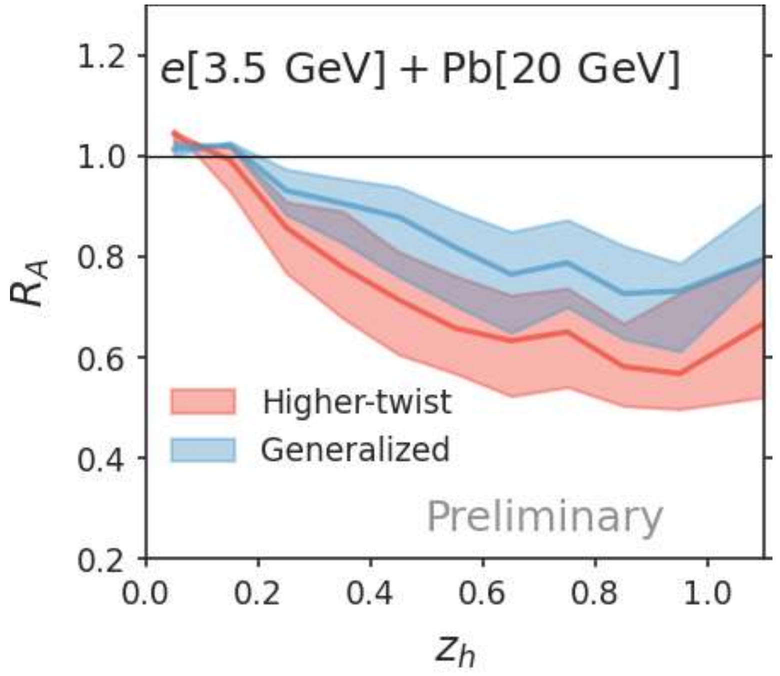
➢Nuclear medium effect

eA Physics:

- EMC / Anti-shadowing
- Nuclear-PDF
- Hadronization
- Nuclear-TMD, Nuclear-FF, Nuclear-GPD

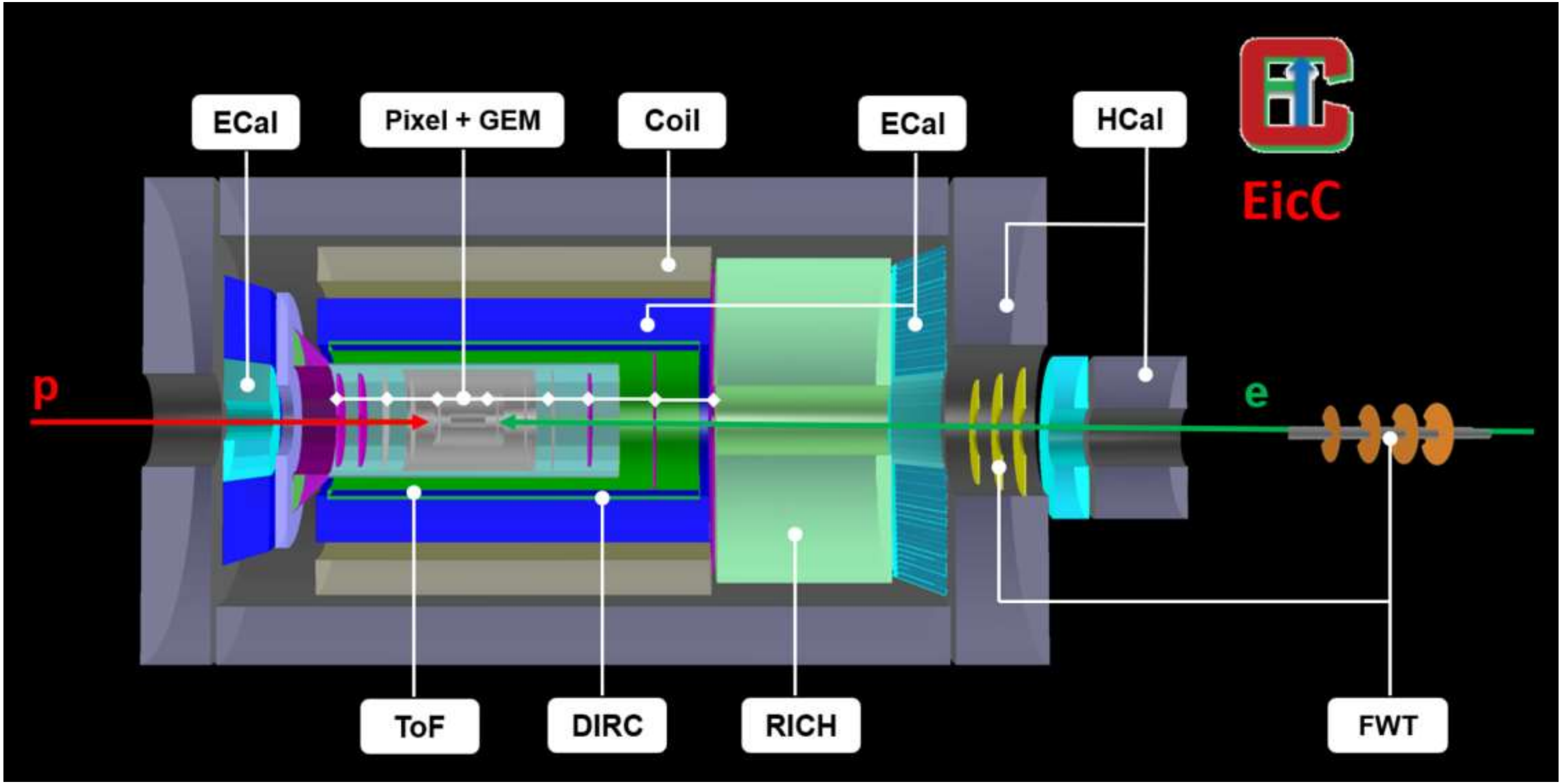






IP Detector Layout

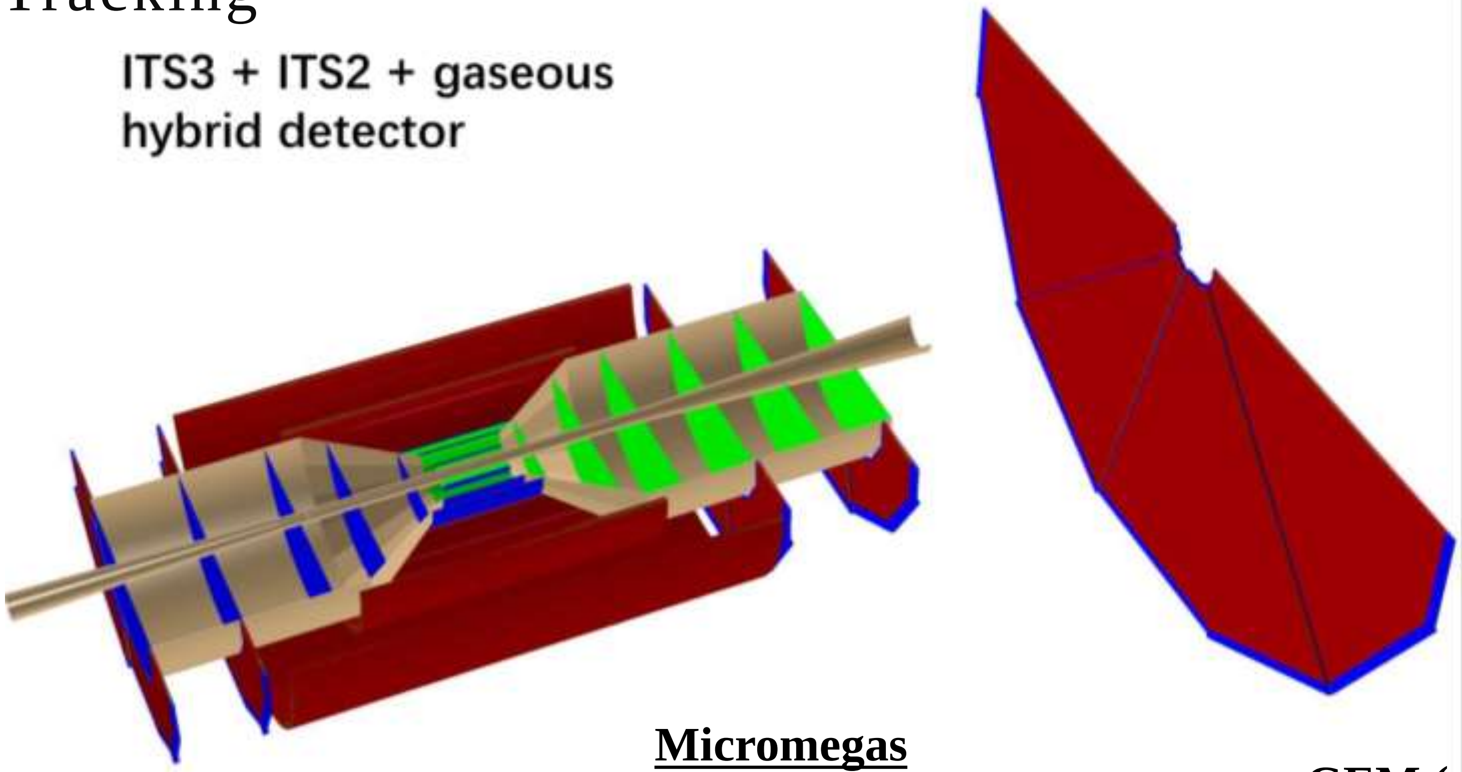
- Very Preliminary Design: Ongoing full Geant4 simulation



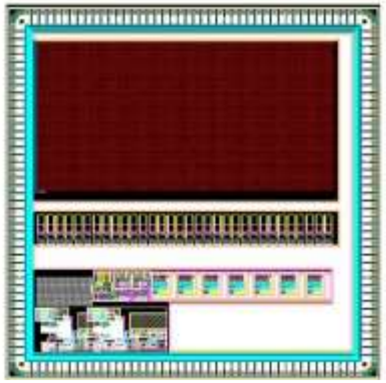
Detector Designs and R&D

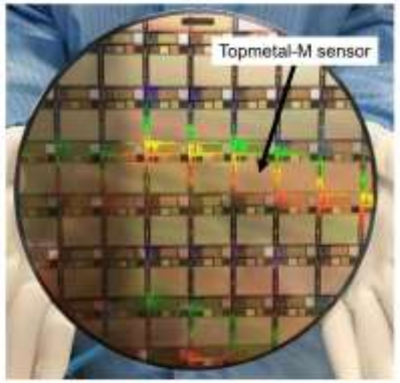
➢Tracking

ITS3 + ITS2 + gaseous
hybrid detector

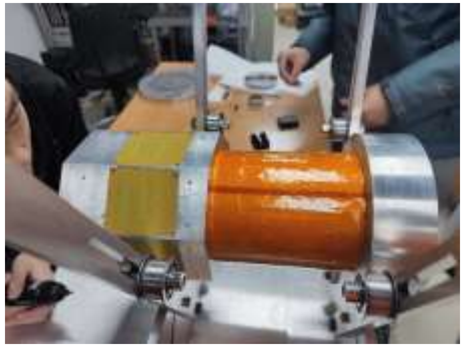


Nupix-A1: First Protype MAPS in China



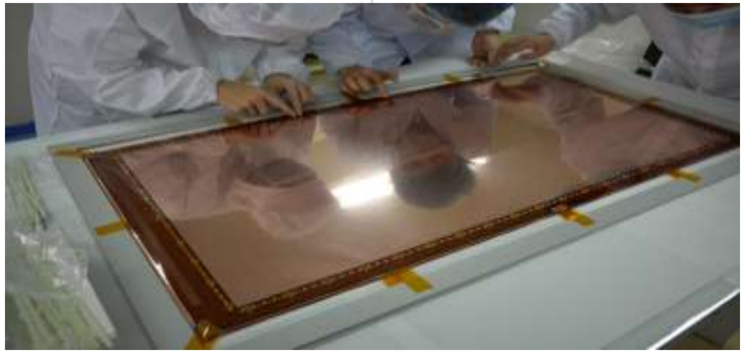


uRWELL



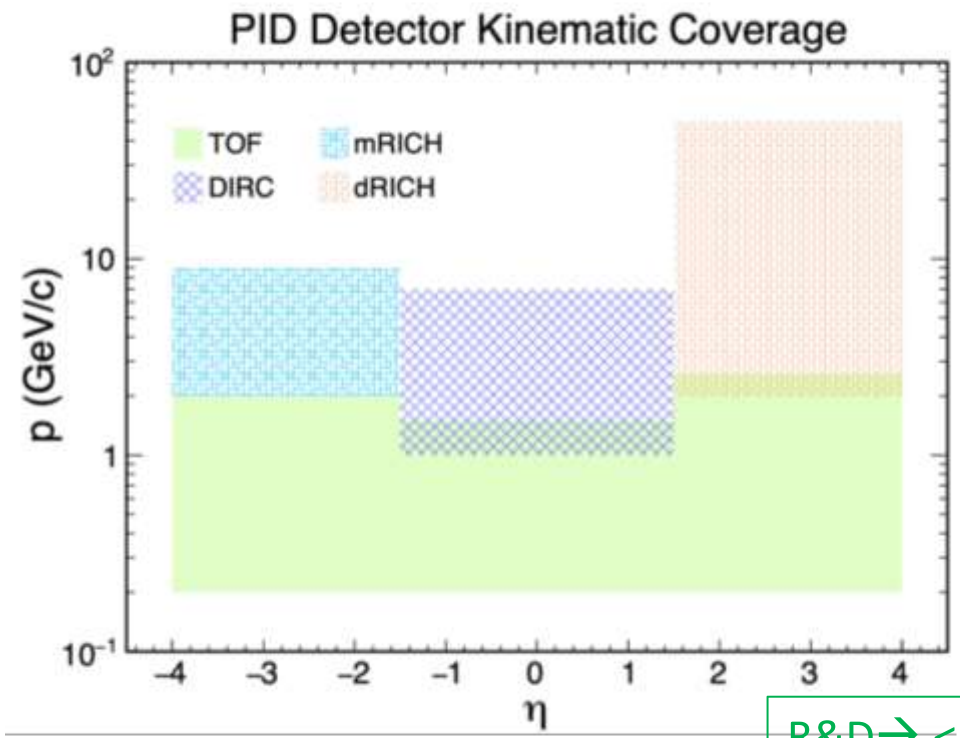
Micromegas

GEM (self-stretching)



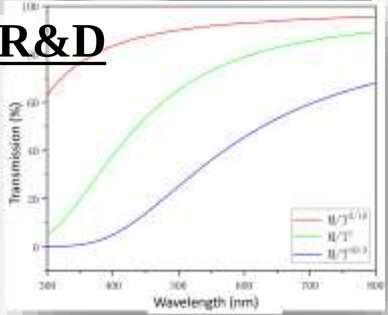
Detector Designs and R&D

➢PID



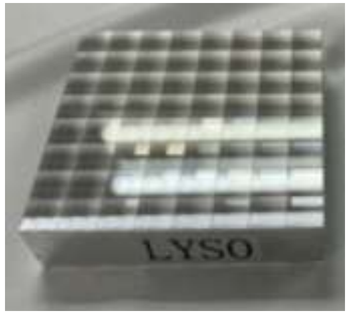
R&D→ < 20ps

	AC-LGAD	MRPC	MCP
Timing resolution	30-50 ps	~50 ps	~50 ps
Spatial resolution	A few to hundreds μm	a few mm to 1 cm	1 mm
Overall thickness	2 cm	10 cm	2 cm
High B field tolerant	Yes	Yes	Yes?
Cost	High	No	High

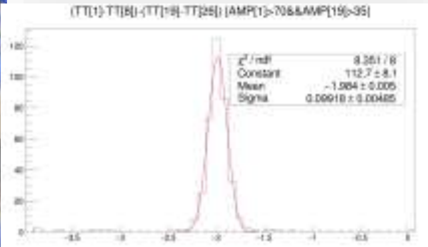


Aerogel R&D

MCP+LYSO

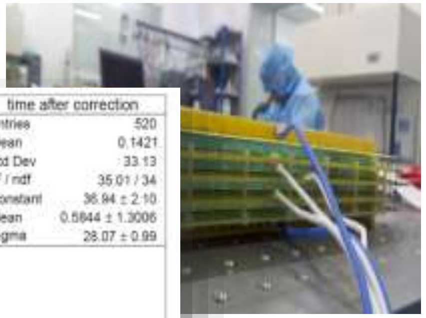


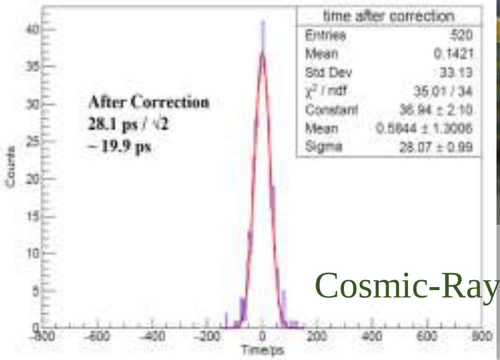
MCP+LYSO Beam Test at FermiLab



Prelim:<100ps

MRPC

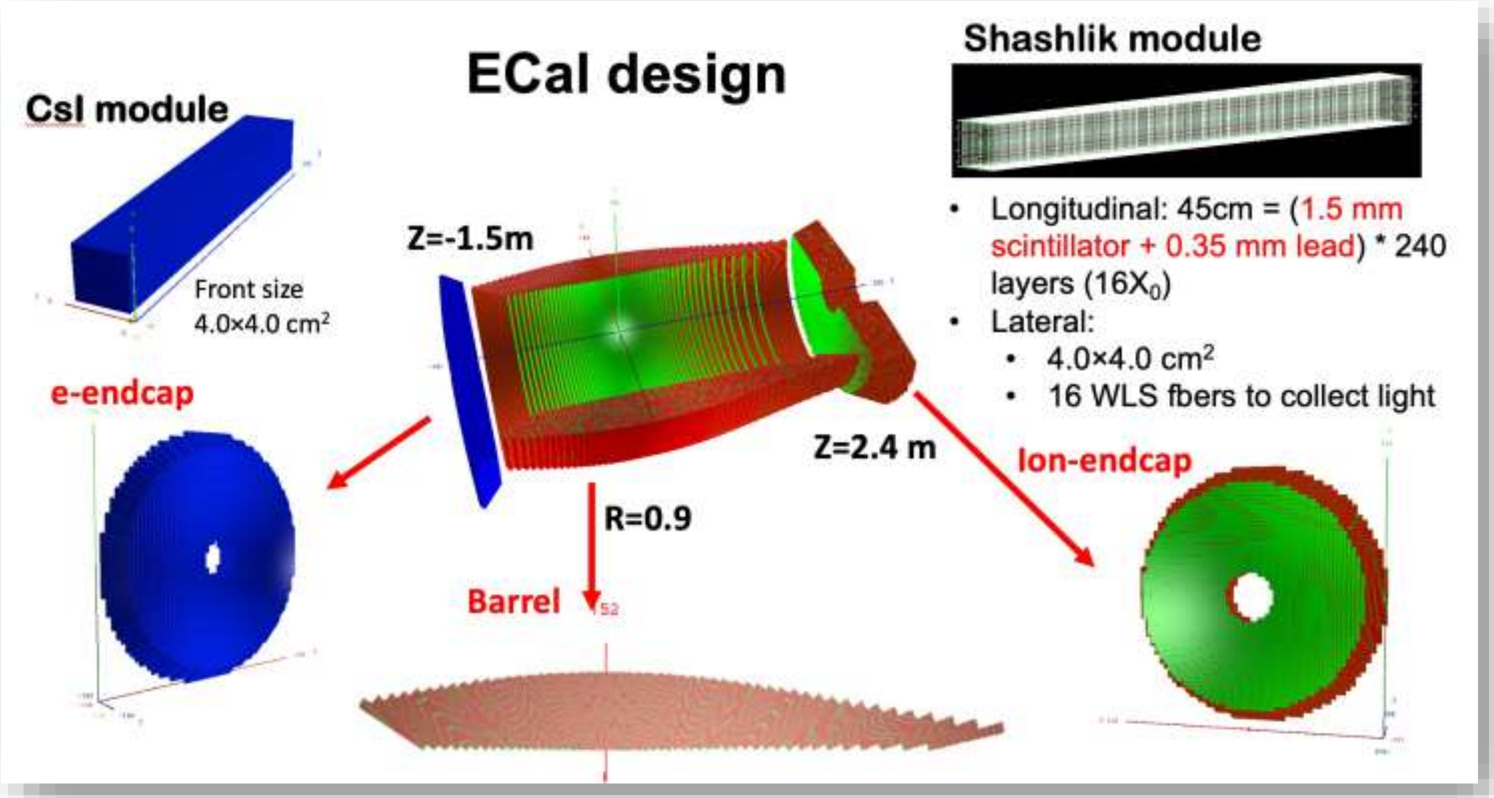




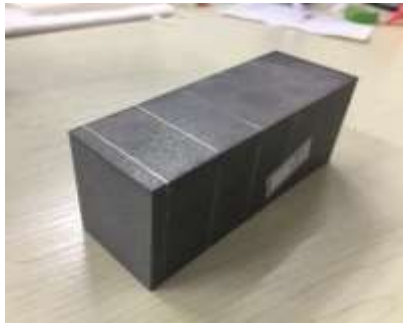
Cosmic-Ray~20ps

Sealed MRPC Beam Test at FermiLab

➢Calorimeters

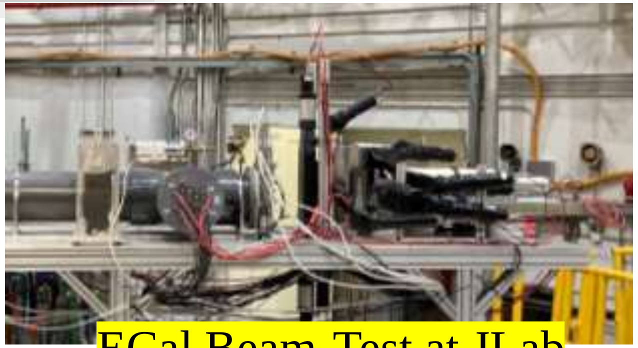


W-Powder+ScFi



Shashlyk ECal

Strong mass production capability

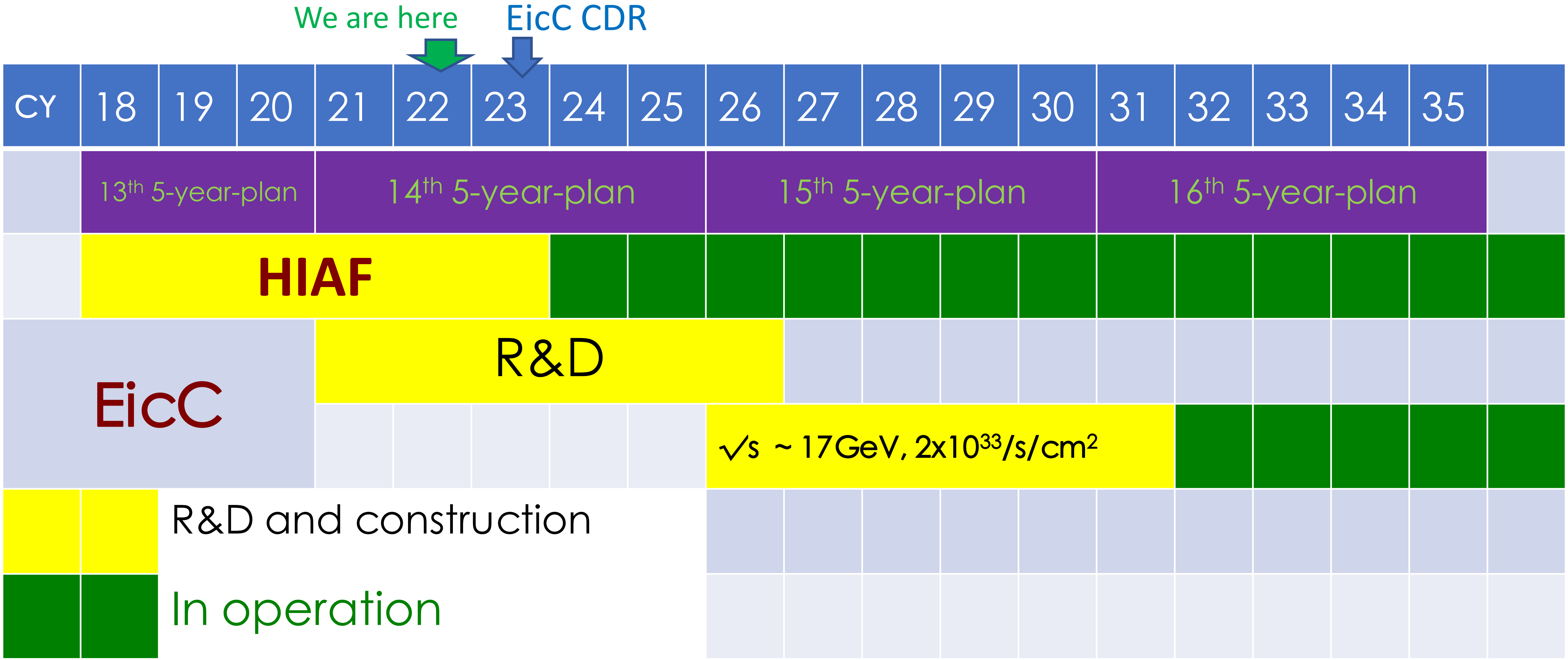


ECal Beam-Test at JLab

Front End Board for SiPM-based Ecal

Projected Timeline

- Discussion started in 2012:



➢An International Effort:

EicC Current Collaborators:

- ➢ 102 scientists
- ➢ 47 institutes
- ➢ 8 countries

EIC User Group:

- 1330 members
- 266 institutions
- 36 countries (7 world regions)

➢ Need strong supports from international collaborators!

EicC White Paper (arXiv: 2102.09222)

Frontiers Journals | Home | Journals | Subscription | Open access | Editorial policy | About us | Sign in

Frontiers of Physics

Title / Author / Abstract / Keywords / DOI / Affiliation | Adv search

Atomic, molecular, optical physics, condensed matter, materials physics, particle, nuclear physics...

About the journal | Browse | Collections | Video collections | Authors & reviewers

Front. Phys. » 2021, Vol. 16 » Issue (6) : 64701. DOI: 10.1007/s11467-021-1062-0

REPORT

Electron-ion collider in China

Daniele P. Anderle[1], Valerio Bertone[2], Xu Cao[3,4], Lei Chang[5], Ningbo Chang[6], Gu Chen[7], Xurong Chen[3,4], Zhuojun Chen[8], Zhufang Cui[9], Lingyun Dai[8], Weitian Deng[10], Minghui Ding[11], Xu Feng[12], Chang Gong[12], Longcheng Gui[13], Feng-Kun Guo[4,14], Chengdong Han[3,4], Jun He[15], Tie-Jiun Hou[16], Hongxia Huang[15], Yin Huang[17], Krešimir Kumerički[18], L. P. Kaptari[3,19], Demin Li[20], Hengne Li[1], Minxiang Li[3,21], Xueqian Li[5], Yutie Liang[3,4], Zuotang Liang[22], Chen Liu[22], Chuan Liu[12], Guoming Liu[1], Jie Liu[3,4], Liuming Liu[3,4], Xiang Liu[21], Tianbo Liu[22], Xiaofeng Luo[23], Zhun Lyu[24], Boqiang Ma[12], Fu Ma[3,4], Jianping Ma[4,14], Yugang Ma[4,25,26], Lijun Mao[3,4], Cédric Mezrag[2], Hervé Moutarde[2], Jialun Ping[15], Sixue Qin[27], Hang Ren[3,4], Craig D. Roberts[9], Juan Rojo[28,29], Guodong Shen[3,4], Chao Shi[30], Qintao Song[20], Hao Sun[31], Paweł Sznajder[32], Enke Wang[1], Fan Wang[9], Qian Wang[1], Rong Wang[3,4], Ruiru Wang[3,4], Taofeng Wang[33], Wei Wang[34], Xiaoyu Wang[20], Xiaoyun Wang[35], Jiajun Wu[4], Xinggang Wu[27], Lei Xia[36], Bowen Xiao[23,37], Guoqing Xiao[3,4], Ju-Jun Xie[3,4], Yaping Xie[3,4], Hongxi Xing[1], Hushan Xu[3,4], Nu Xu[3,4,23], Shusheng Xu[38], Mengshi Yan[12], Wenbiao Yan[36], Wencheng Yan[20], Xinhu Yan[39], Jiancheng Yang[3,4], Yi-Bo Yang[4,14], Zhi Yang[40], Deliang Yao[8], Zhihong Ye[41], Peilin Yin[38], C.-P. Yuan[42], Wenlong Zhan[3,4], Jianhui Zhang[43], Jinlong Zhang[22], Pengming Zhang[44], Yifei Zhang[36], Chao-Hsi Chang[4,14], Zhenyu Zhang[45], Hongwei Zhao[3,4], Kuang-Ta Chao[12], Qiang Zhao[4,46], Yuxiang Zhao[3,4], Zhengguo Zhao[36], Liang Zheng[47], Jian Zhou[22], Xiang Zhou[45], Xiaorong Zhou[36], Bingsong Zou[4,14], Liping Zou[3,4]

总结

- 展望未来电子-核子碰撞的实验计
  - ✓ SoLID
  - ✓ US-EIC
  - ✓ China-EIC

- 本课堂没有涉及的其他重要电子散射物理课题：
  - 质子质量
  - 奇异强子态
  - 原子核结构
  - 强子化（Hadronization）
  - 核子的介质效应（Nuclear Medium Effect)
  - 介子的部分子结构
  - Jets
  - 小x物理
  - 等等…

结语

- 历经5000年探索的物质终极结构