Electron-Ion Collider in China

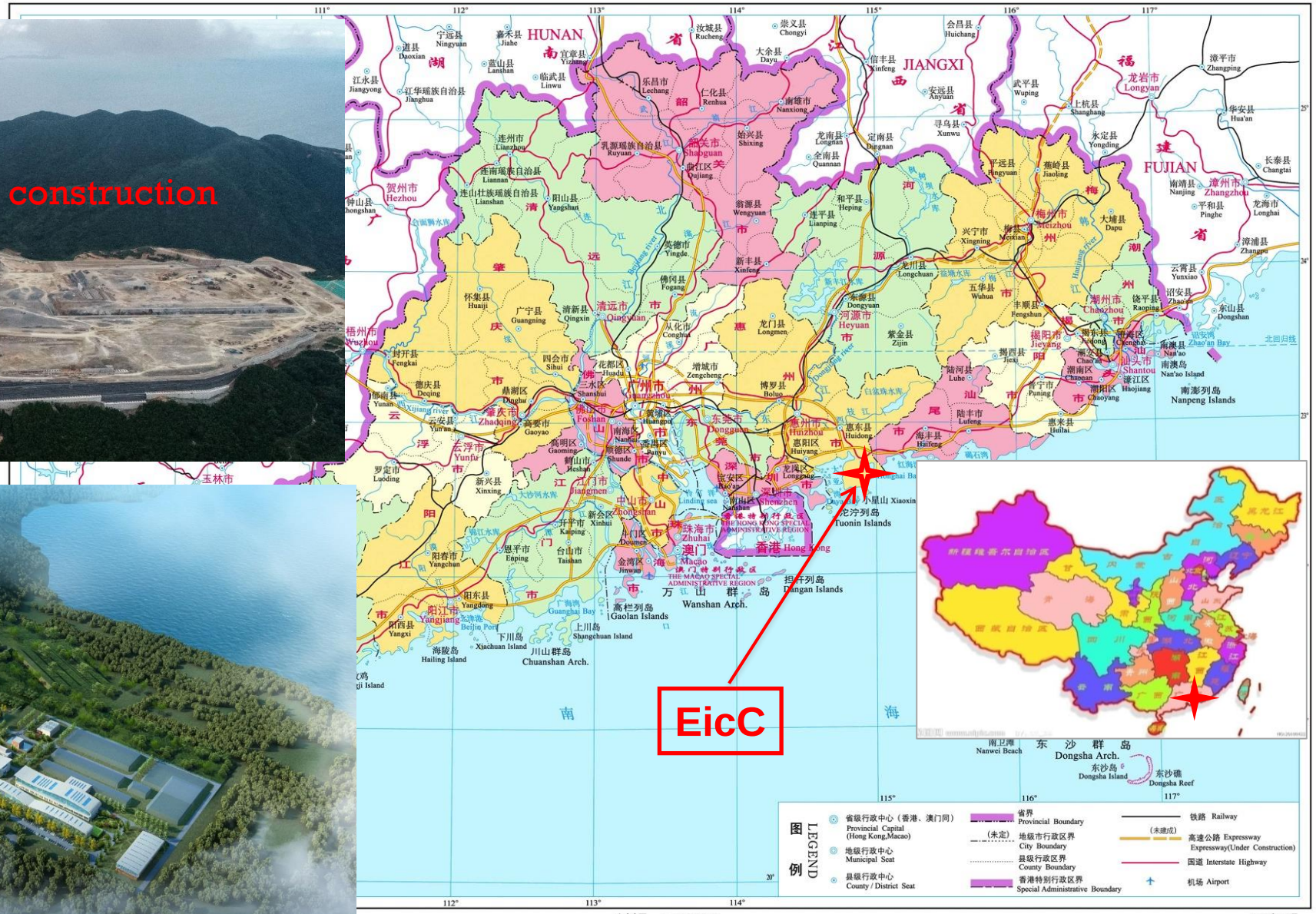
Yuxiang Zhao (IMP)

On behalf of the EicC working group

Outline

- General introduction of the Electron-Ion Collider in China
- Physics highlights
- Project status
- Summary

Where we are talking about…Huizhou(惠州) in Guangdong province

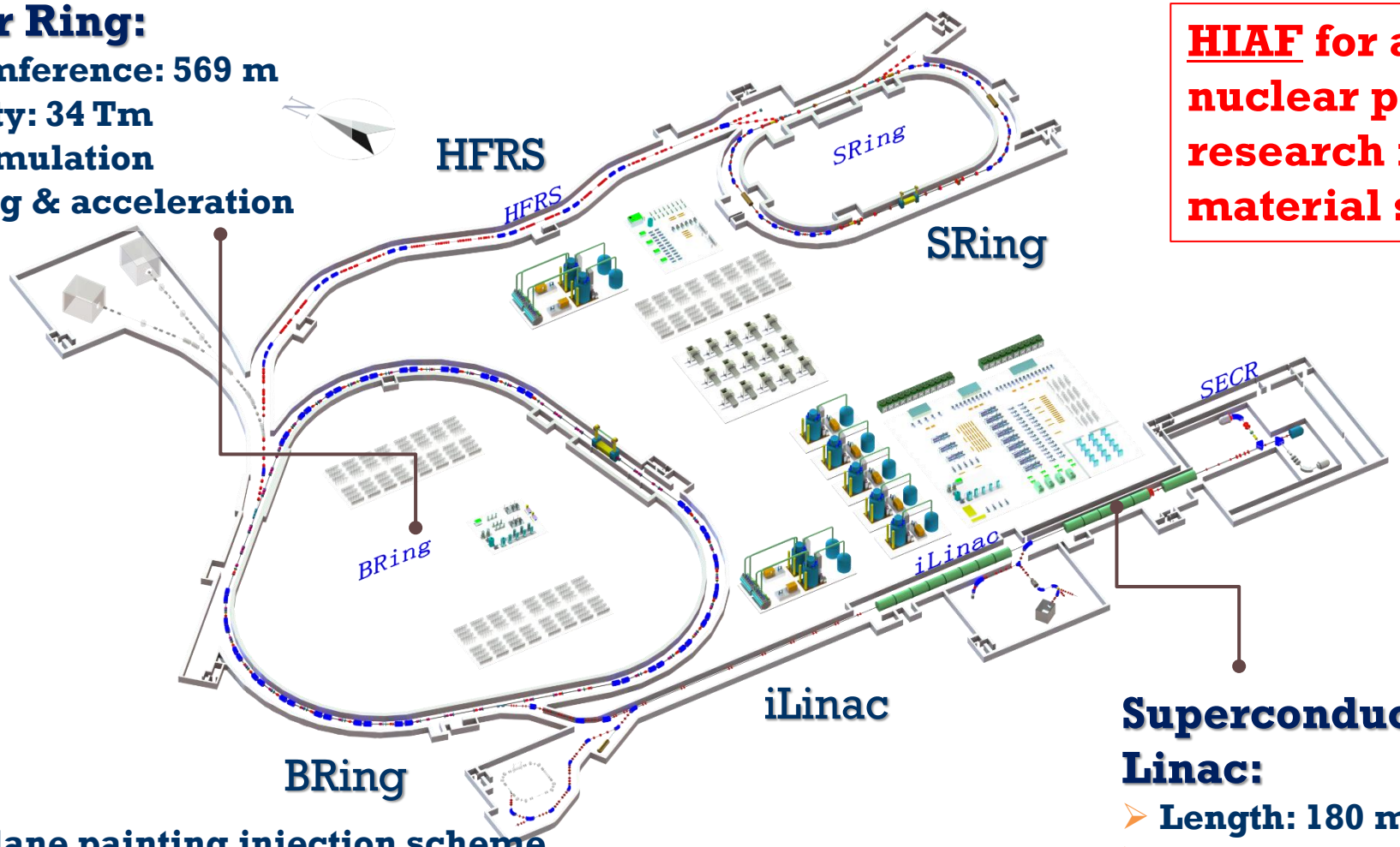


High Intensity heavy-ion Accelerator Facility (HIAF)

HIAF total investment: 2.5 billion RMB

Booster Ring:

- Circumference: 569 m
- Rigidity: 34 Tm
- Aaccumulation
- Cooling & acceleration

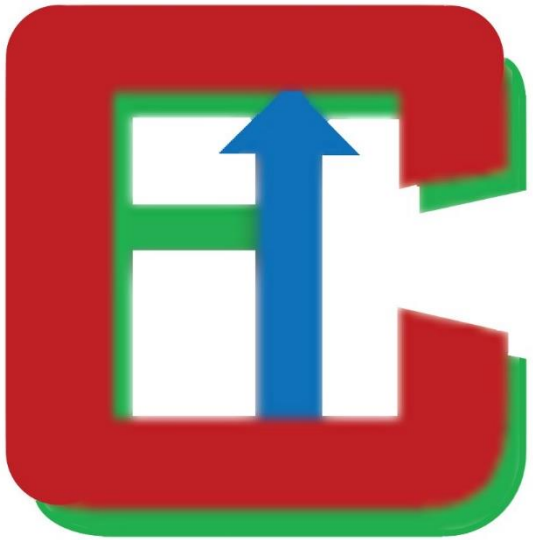


HIAF for atomic physics, nuclear physics, applied research in biology and material science etc.

- 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



Electron Ion Collider in China, EicC

EicC white paper (arXiv: 2102.09222)

Also in production in the *Frontiers of Physics* Journal

Nuclear Experiment

[Submitted on 18 Feb 2021]

Electron-Ion Collider in China

Daniele P. Anderle, Valerio Bertone, Xu Cao, Lei Chang, Ningbo Chang, Gu Chen, Xurong Chen, Zhuojun Chen, Zhufang Cui, Lingyun Dai, Weitian Deng, Minghui Ding, Xu Feng, Chang Gong, Longcheng Gui, Feng-Kun Guo, Chengdong Han, Jun He, Tie-Jiun Hou, Hongxia Huang, Yin Huang, Krešimir Kumerički, L. P. Kaptari, Demin Li, Hengne Li, Minxiang Li, Xueqian Li, Yutie Liang, Zuotang Liang, Chen Liu, Chuan Liu, Guoming Liu, Jie Liu, Liuming Liu, Xiang Liu, Tianbo Liu, Xiaofeng Luo, Zhun Lyu, Boqiang Ma, Fu Ma, Jianping Ma, Yugang Ma, Lijun Mao, Cédric Mezrag, Hervé Moutarde, Jialun Ping, Sixue Qin, Hang Ren, Craig D. Roberts, Juan Rojo, Guodong Shen, Chao Shi, Qintao Song, Hao Sun, Paweł Sznajder, Enke Wang, Fan Wang, Qian Wang, Rong Wang, Ruiru Wang, Taofeng Wang, Wei Wang, Xiaoyu Wang, Xiaoyun Wang, Jiajun Wu, Xinggang Wu, Lei Xia, Bowen Xiao, Guoqing Xiao, Ju-Jun Xie, Yaping Xie, Hongxi Xing, Hushan Xu, Nu Xu, Shusheng Xu, Mengshi Yan, Wenbiao Yan, Wencheng Yan, Xinhu Yan, Jiancheng Yang, Yi-Bo Yang, Zhi Yang, Deliang Yao, Peilin Yin, C.-P. Yuan, Wenlong Zhan, Jianhui Zhang, Jinlong Zhang, Pengming Zhang, Chao-Hsi Chang, Zhenyu Zhang, Hongwei Zhao, Kuang-Ta Chao, Qiang Zhao, Yuxiang Zhao, Zhengguo Zhao, Liang Zheng, Jian Zhou, Xiang Zhou, Xiaorong Zhou et al. (2 additional authors not shown)

Lepton scattering is an established ideal tool for studying inner structure of small particles such as nucleons as well as nuclei. As a future high energy nuclear physics project, an Electron-ion collider in China (EicC) has been proposed. It will be constructed based on an upgraded heavy-ion accelerator, High Intensity heavy-ion Accelerator Facility (HIAF) which is currently under construction, together with a new electron ring. The proposed collider will provide highly polarized electrons (with a polarization of \sim80%) and protons (with a polarization of \sim70%) with variable center of mass energies from 15 to 20 GeV and the luminosity of (2-3) \times 10^{33} cm^{-2} s^{-1}. Polarized deuterons and Helium-3, as well as unpolarized ion beams from Carbon to Uranium, will be also available at the EicC.

The main foci of the EicC will be precision measurements of the structure of the nucleon in the sea quark region, including 3D tomography of nucleon; the partonic structure of nuclei and the parton interaction with the nuclear environment; the exotic states, especially those with heavy flavor quark contents. In addition, issues fundamental to understanding the origin of mass could be addressed by measurements of heavy quarkonia near-threshold production at the EicC. In order to achieve the above-mentioned physics goals, a hermetical detector system will be constructed with cutting-edge technologies.

This document is the result of collective contributions and valuable inputs from experts across the globe. The EicC physics program complements the ongoing scientific programs at the Jefferson Laboratory and the future EIC project in the United States. The success of this project will also advance both nuclear and particle physics as well as accelerator and detector technology in China.

Comments: EicC white paper, written by the whole EicC working group

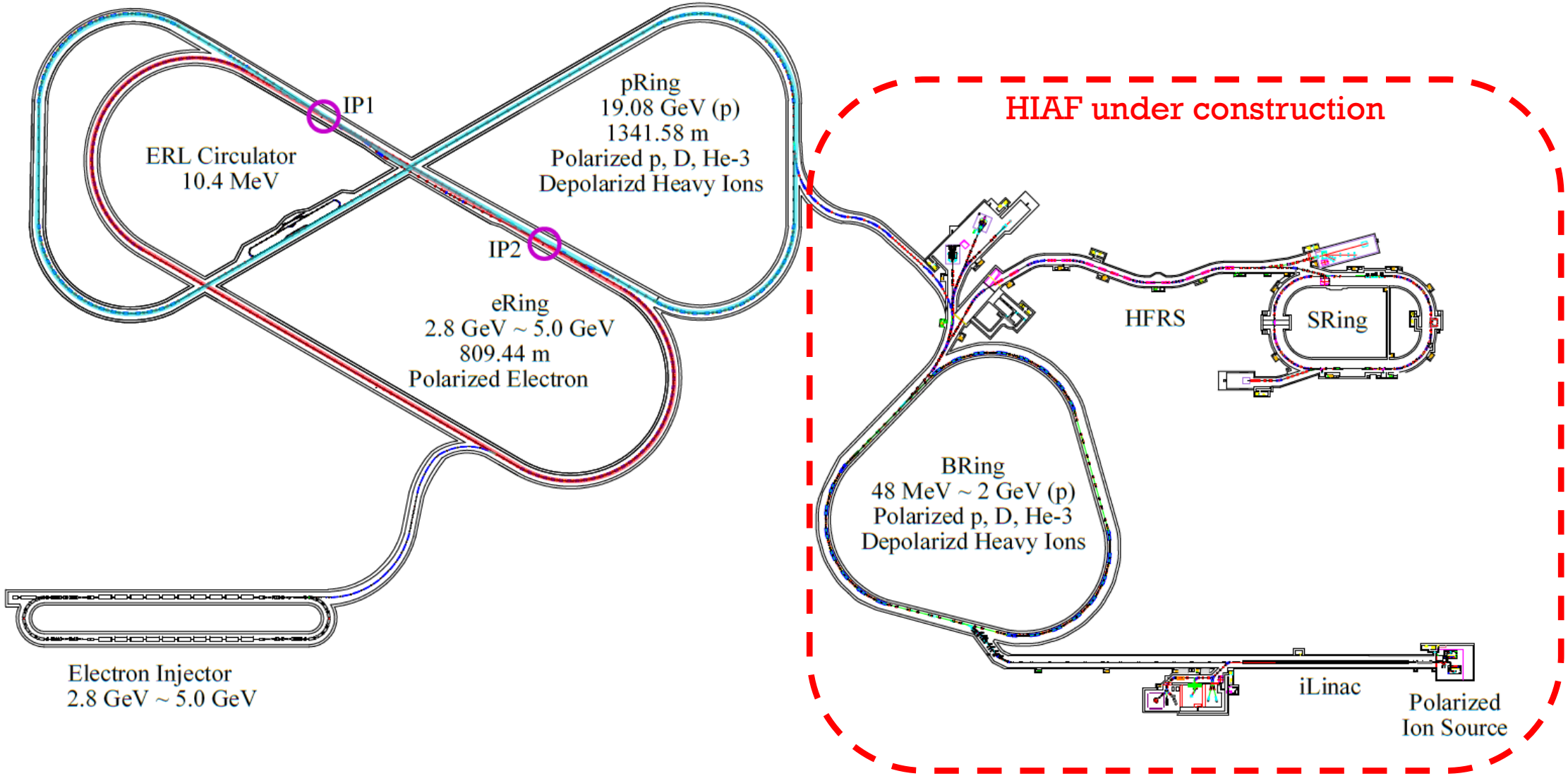
Subjects: **Nuclear Experiment (nucl-ex)**; High Energy Physics - Experiment (hep-ex); High Energy Physics - Phenomenology (hep-ph); Nuclear Theory (nucl-th)

Cite as: arXiv:2102.09222 **[nucl-ex]**

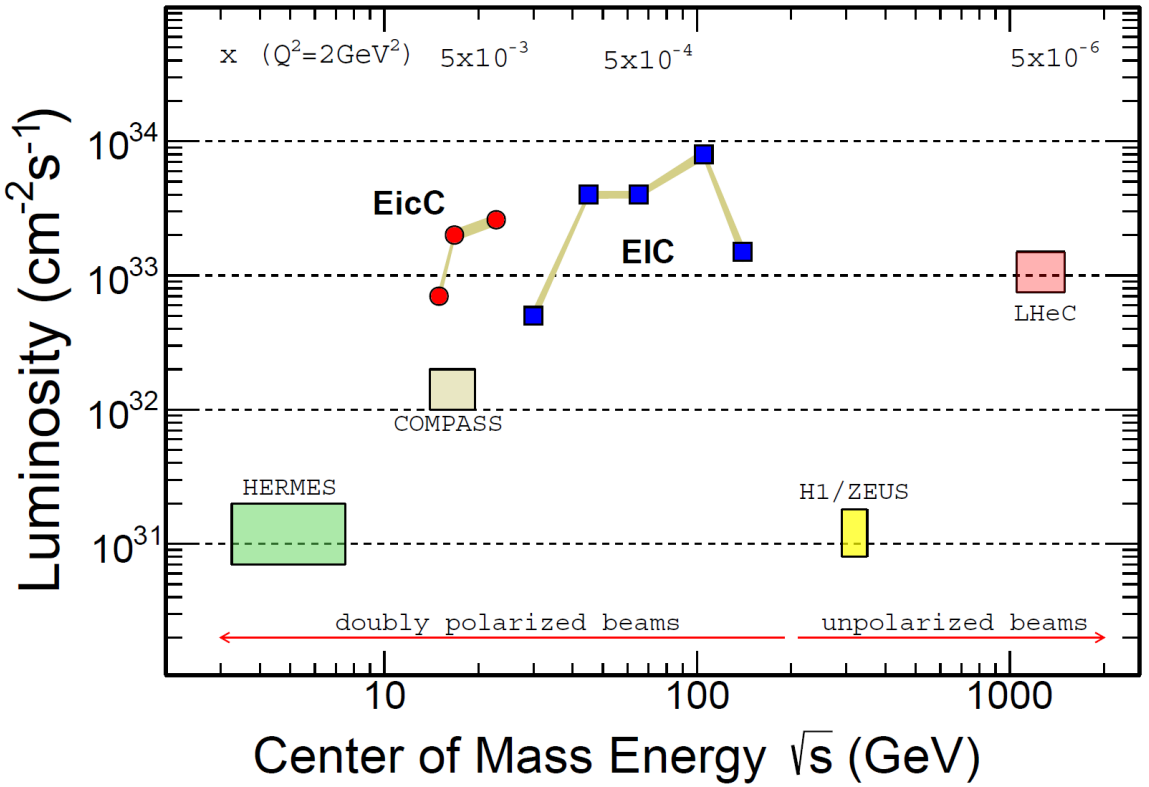
(or arXiv:2102.09222v1 **[nucl-ex]** for this version)

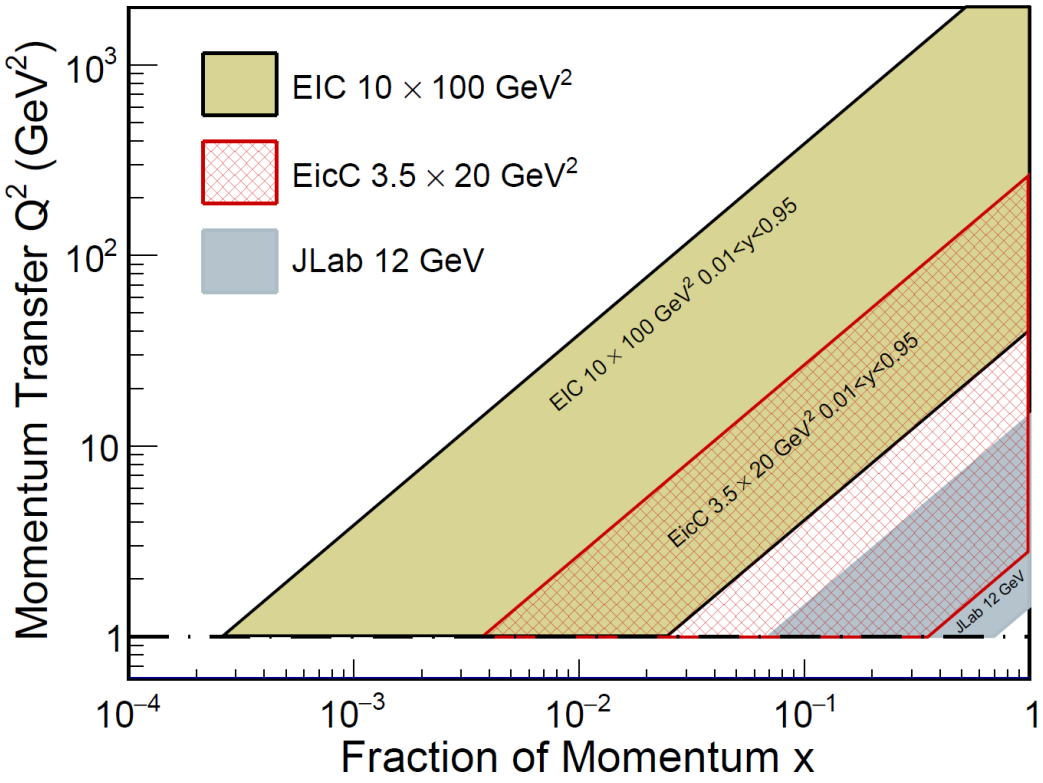
Now we have 46 institutes and >100 physicists

EicC Accelerator complex layout



EicC Specs





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

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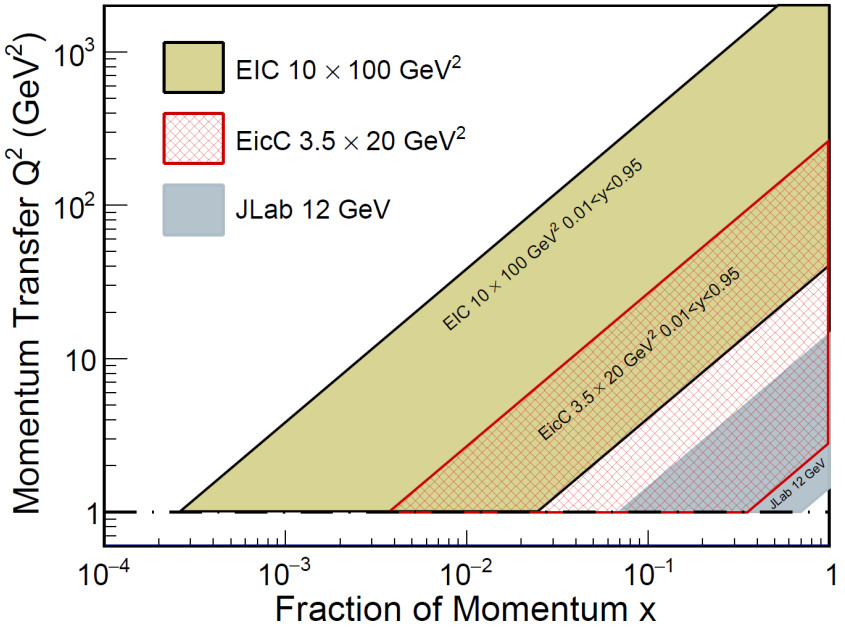
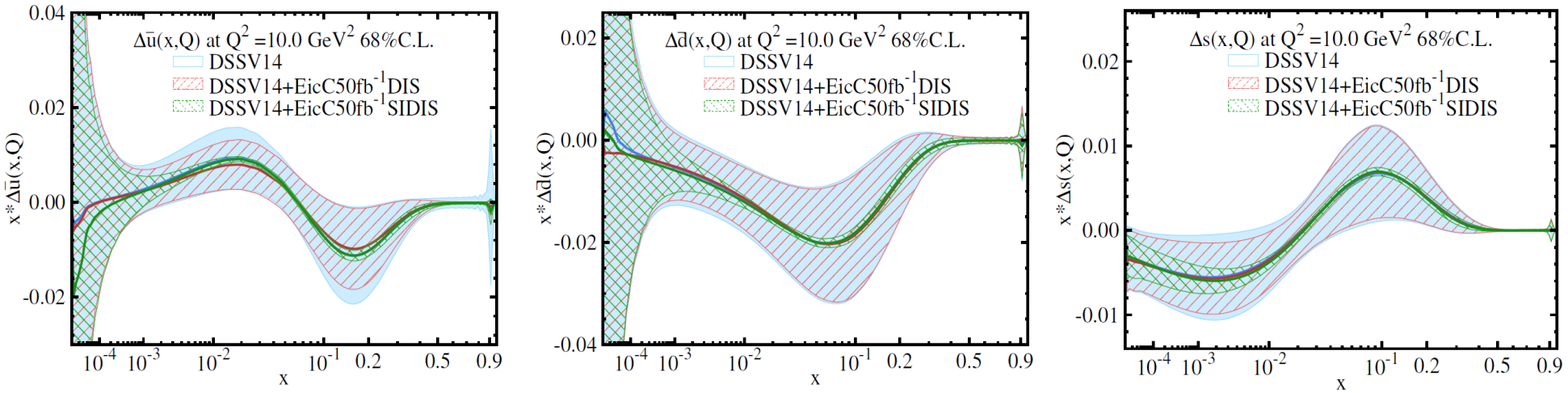
Highlighted physics topics



- Spin structure of the nucleon: 1D, 3D
  - polarized electron + polarized proton/light nuclei
- Partonic structure of nuclei and the parton interaction with the nuclear environment
  - unpolarized electron + unpolarized various nuclei
- Exotic states with c/cbar, b/bbar
- Origin of the proton mass study via heavy quarkonium near-threshold production

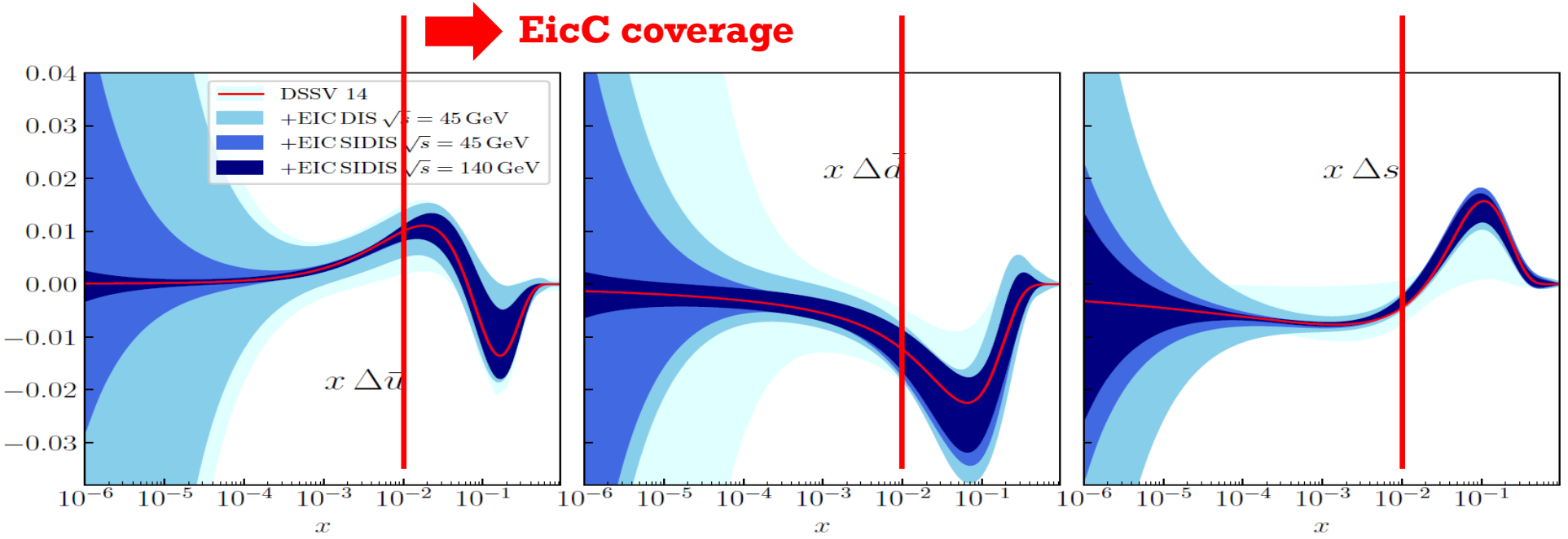
Spin structure of the nucleon-helicity distribution



A NLO impact study
See arXiv:2103.10276

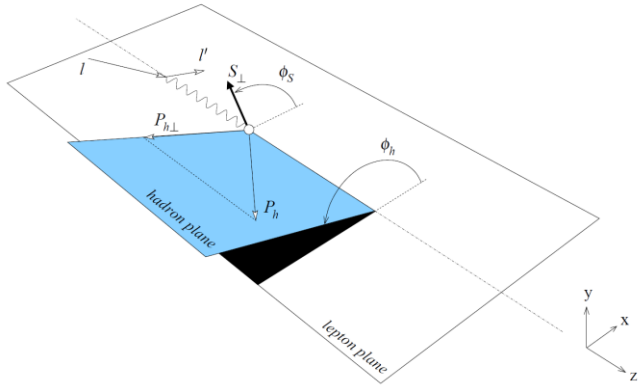
EicC white paper

EicC coverage



EIC Yellow Report

Spin structure of the nucleon-TMDs



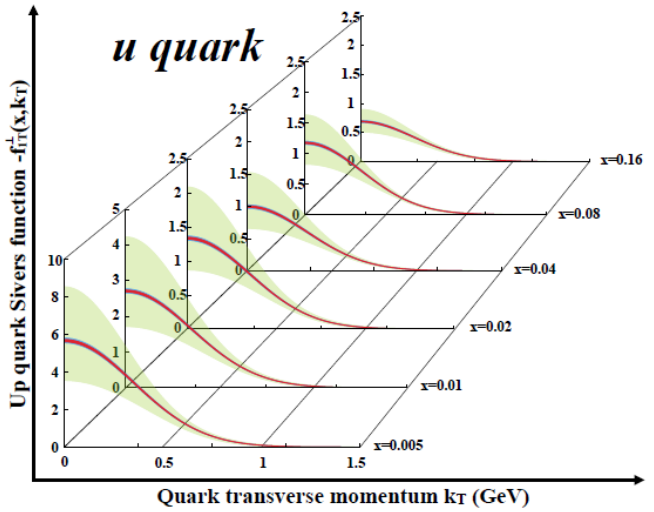
u/d Sivers EicC vs world data

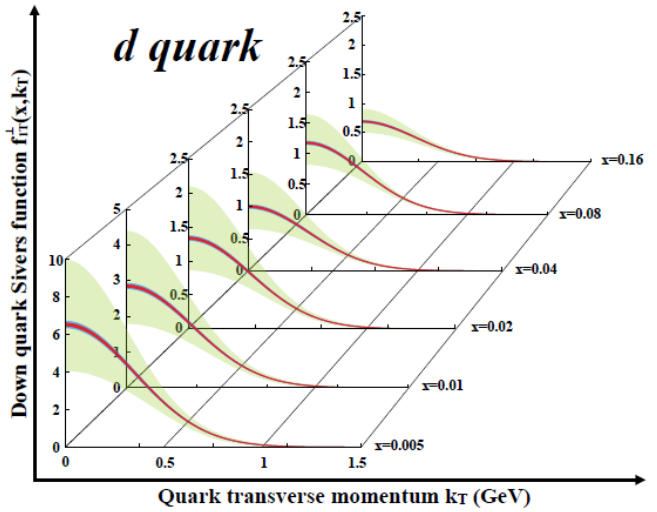
LO analysis

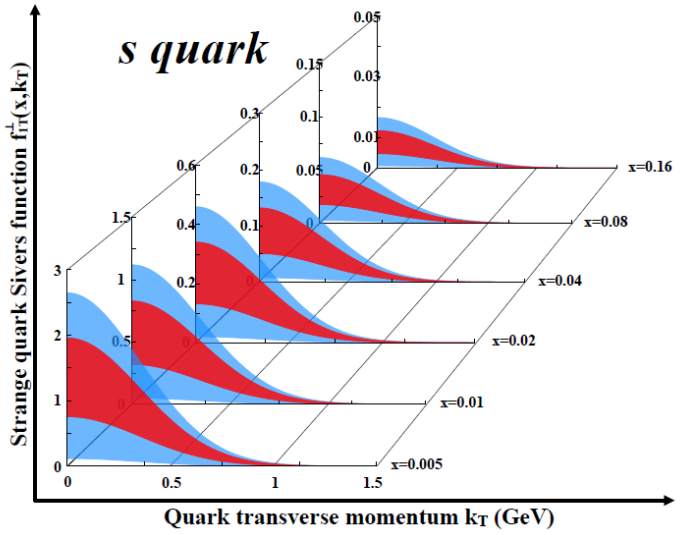
EicC SIDS data:

- 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}

EicC, precise measurements.



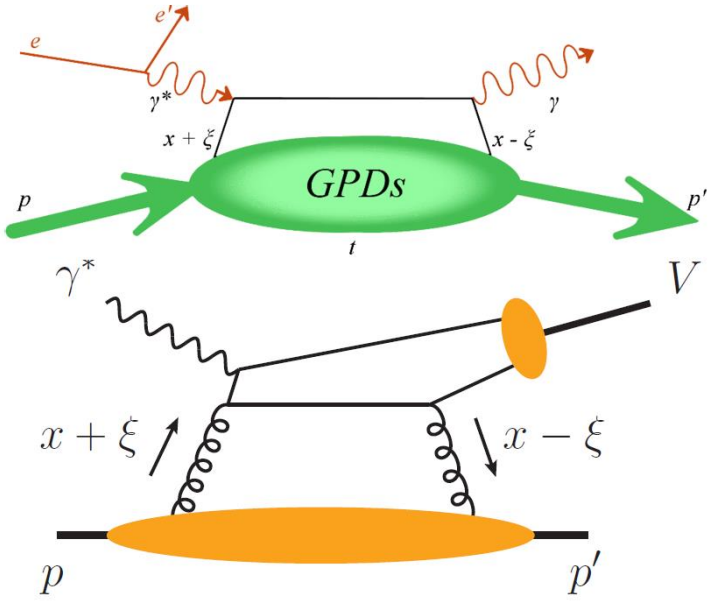




Green: Current accuracy
Red: stat. error only
Blue: sys. Error included

Spin structure of the nucleon-GPDs

The extraction of CFF with neural network methods [Kumeriki, 19]



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)

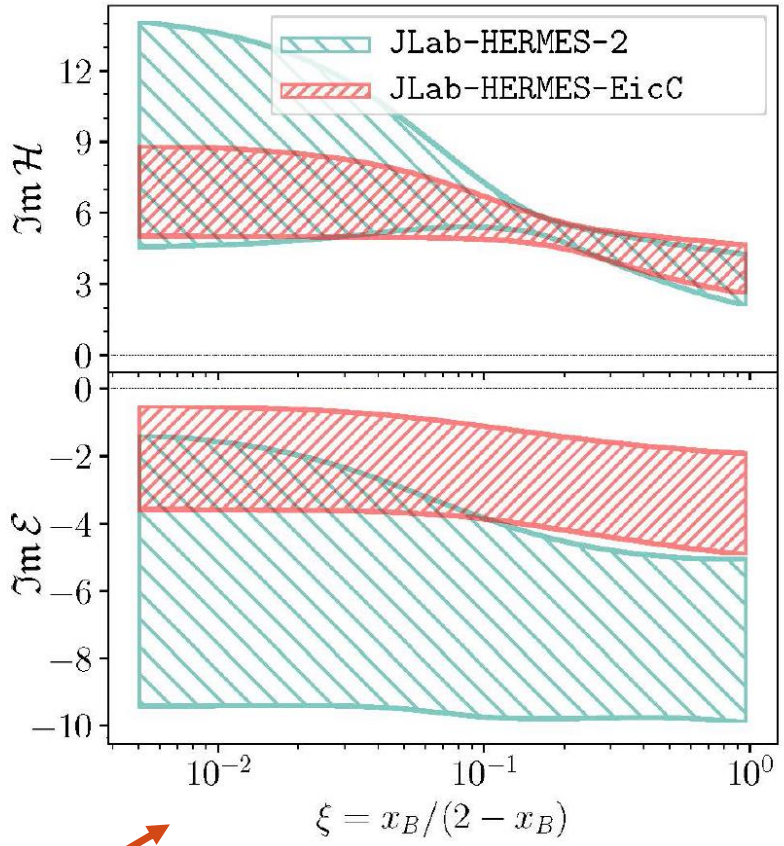
$$A_{UL}^{\sin\phi} \propto \frac{\sqrt{1-y}}{2-y}\sqrt{\frac{-t}{y^2Q^2}} \times x_B Im\left[F_1\widetilde{\mathcal{H}} + x_B(F_1+F_2)(\widetilde{\mathcal{H}} + \frac{x_B}{2\mathcal{E}}) - x_B kF_2\widetilde{\mathcal{E}} + ...\right](x_B, t, Q^2),$$

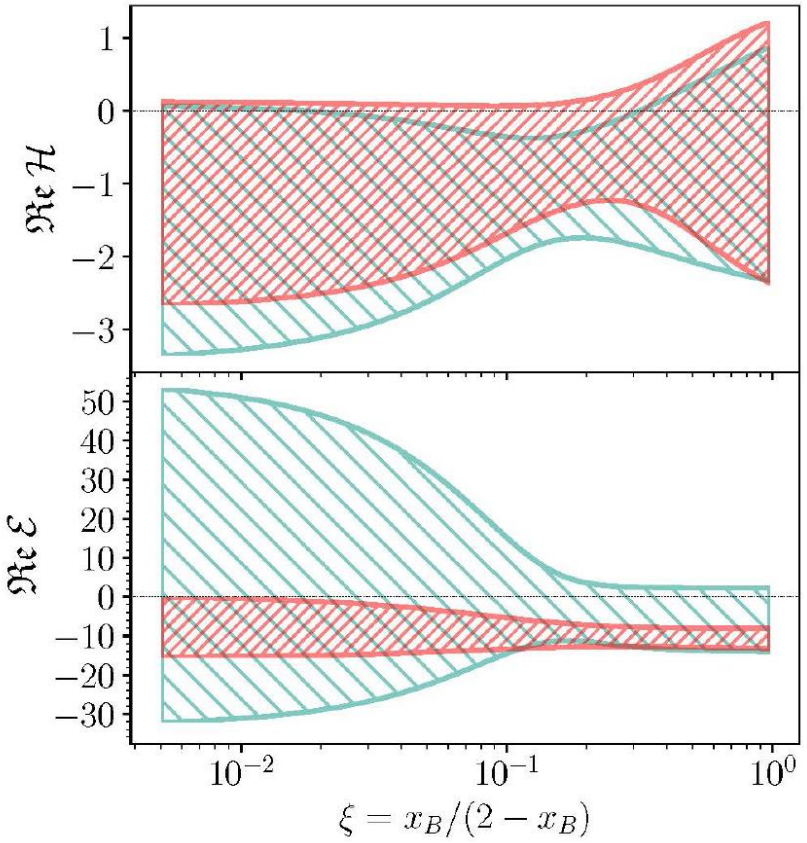
Unpolarized beam, transverse target (tTSA)

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

Polarized beam, longitudinal target (DSA)

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

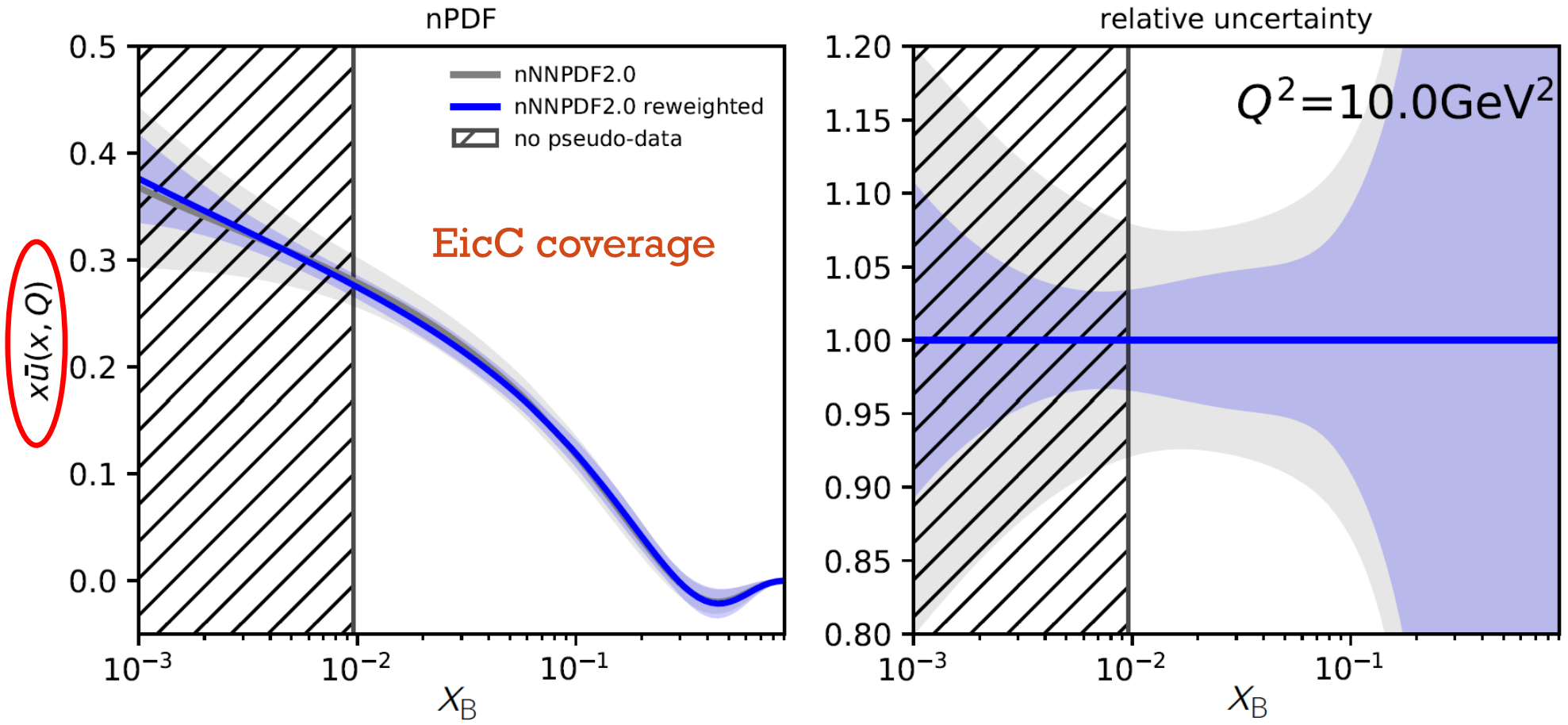




Only with this azimuthal angular modulation

Another CFF impact study with PARTONS group is ongoing

Nuclear PDFs study with ion beam



With only a few hours of running

Proton mass study

Mass decomposition [Ji, 95]

$$M = \underbrace{M_q + M_m}_{\text{Quark}} + \underbrace{M_g + M_a}_{\text{Gluon}}$$

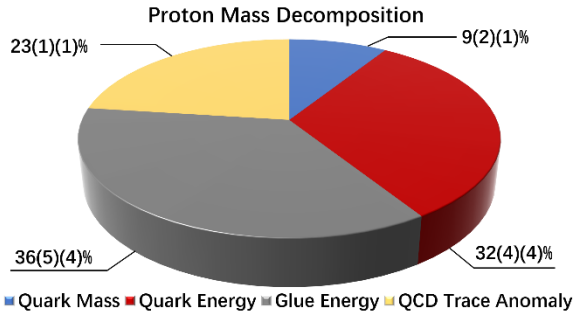
M_q : quark energy

M_m : quark mass (condensate)

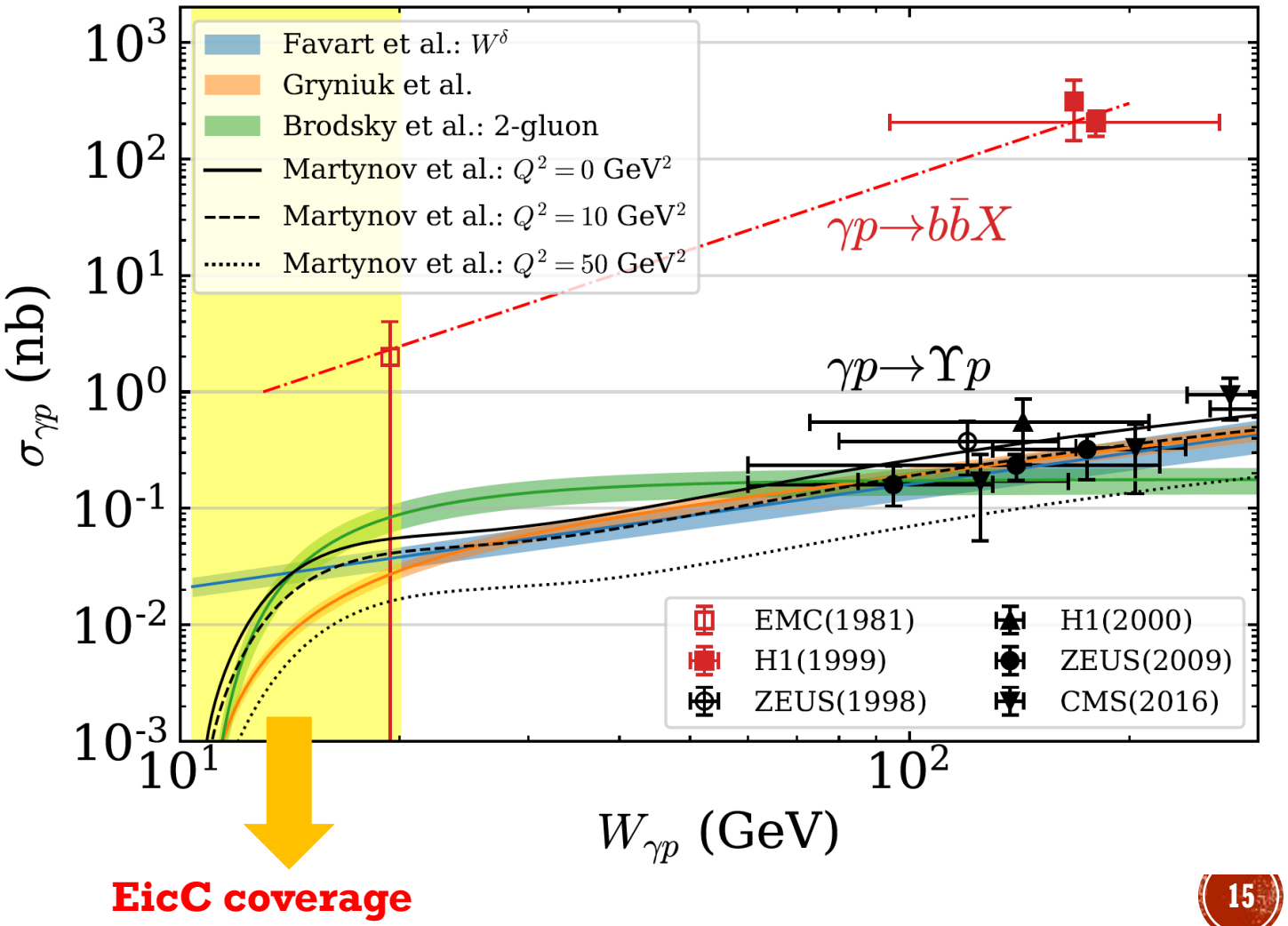
M_g : gluon energy

M_a : trace anomaly

- M_q and M_g constrained by PDFs.
- M_m via πN low energy scattering.
- M_a via threshold production of J/Ψ (8.2 GeV; JLab) and Υ (12 GeV);
- Threshold requires low CoM energy. (Low y at EIC).
- Complementarity between EicC (and EIC) and lattice. Guideline



Lattice calculation by Yang et al, 2018



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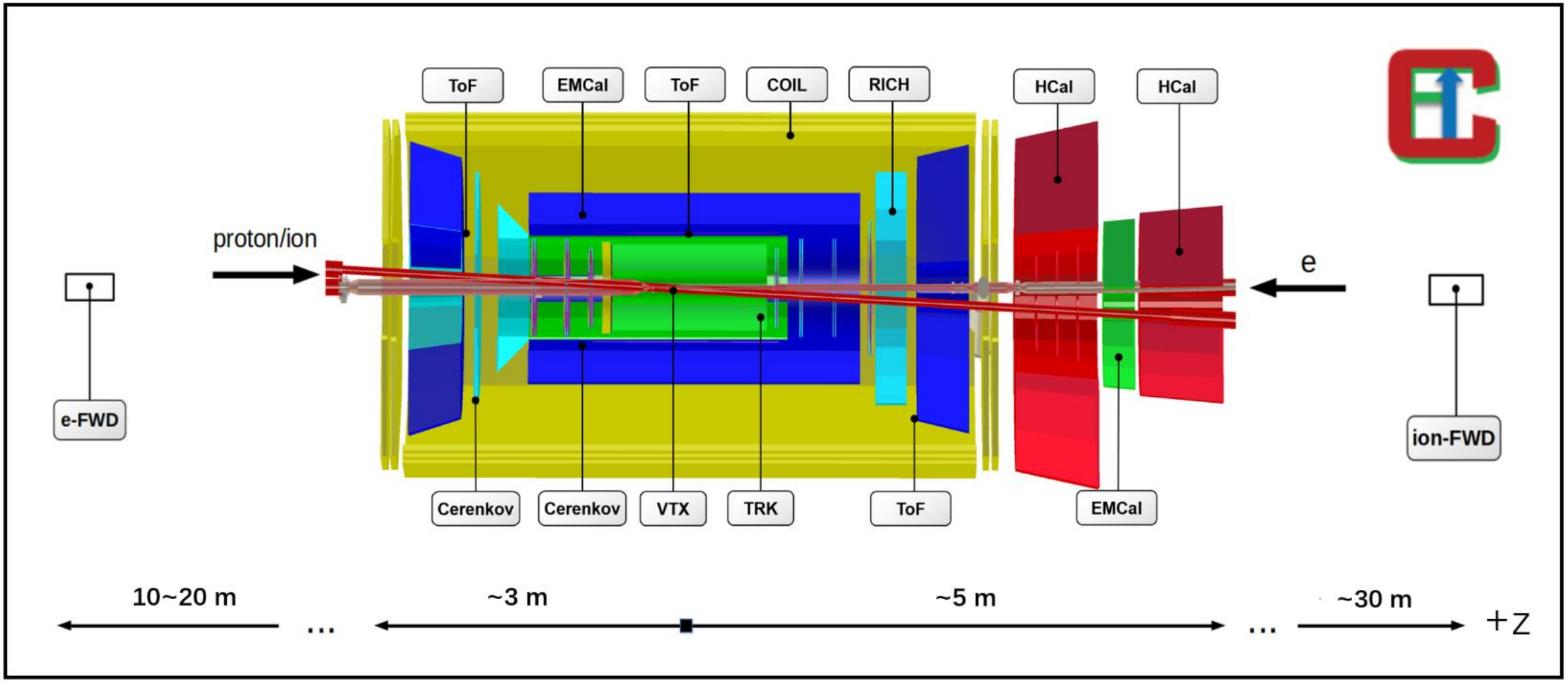
EicC detector considerations



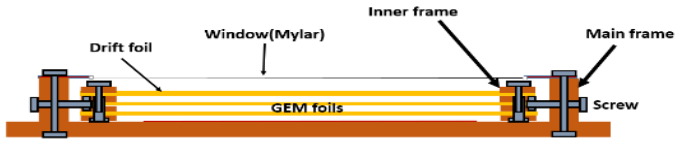
Geant4 simulation is ongoing

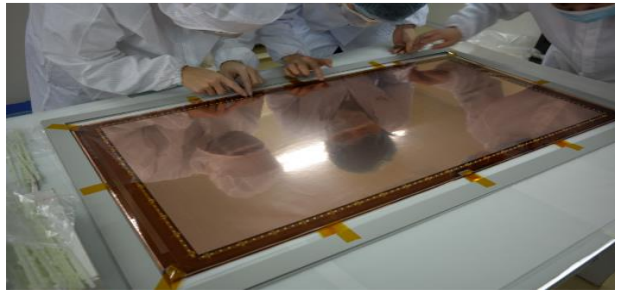
Detector R&Ds

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

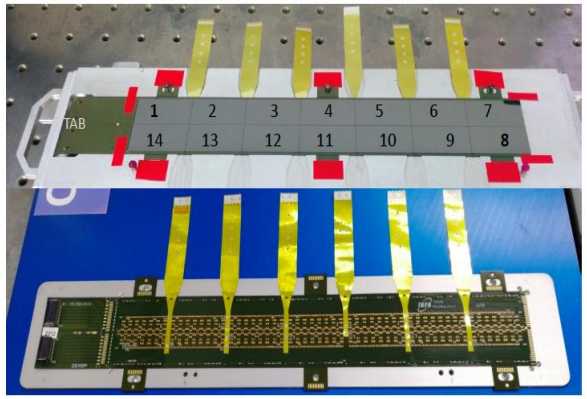
- 25cm x 25 cm Micromegas mass production
- R&D on 0.4m x 0.4m

1m x 0.5 m **GEM (self-stretching)**

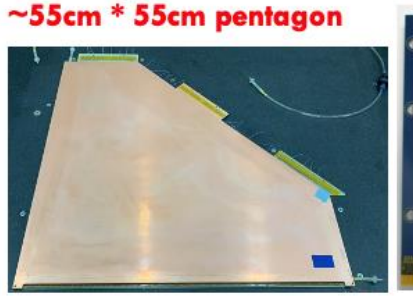




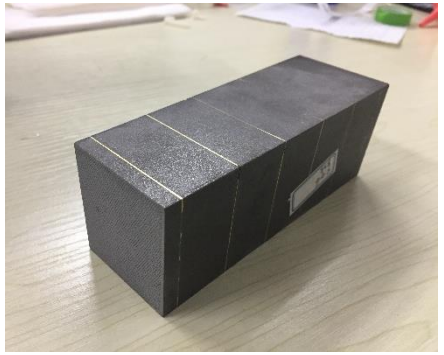
ALICE style ITS2 MAPS pixel detector



sTGC detector



Shashlyk and W-powder+ScFi EMCal



Others such as DIRC and RICH R&Ds will be followed …

Timeline

We are here

CY	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
	5-year-plan			5-year-plan					5-year-plan					5-year-plan					
	HIAF																		
EicC				R&D															
									√s ~ 17GeV, $2x10^{33}/s/cm^2$										

R&D and construction

In operation

Summary

- EicC is briefly introduced
  - EicC focuses on sea-quark/gluon related study at moderate/large-x region
  - EicC can help to tackle the issue of the trace anomaly contribution to the proton mass at the Upsilon threshold
- More physics topics are under study and development
- Geant4 simulation and detector R&Ds are ongoing

- **EicC complements EIC physics program at higher energy**

Thanks and you are more than welcome to join us