中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

Electron Ion Collider in China

Xurong Chen

Email: xchen@impcas.ac.cn

Institute of Modern Physics, CAS, China

(Collaboration with X. Cao, Q. Fu, J. Xie, N. Xu, Z. Yang)

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Outline

I. Introduction

II. EicC Designs and Its Physics Goals

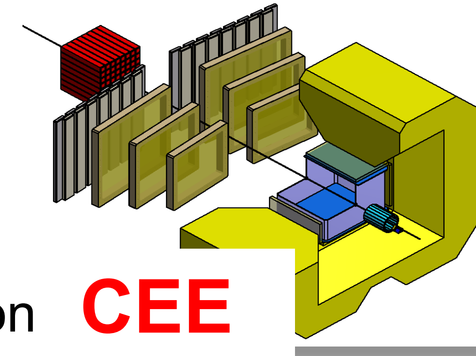
- Nucleon Structure(sea quark): 1D PDF, GPD, TMD
- Hadron spectroscopy
- The mass of proton

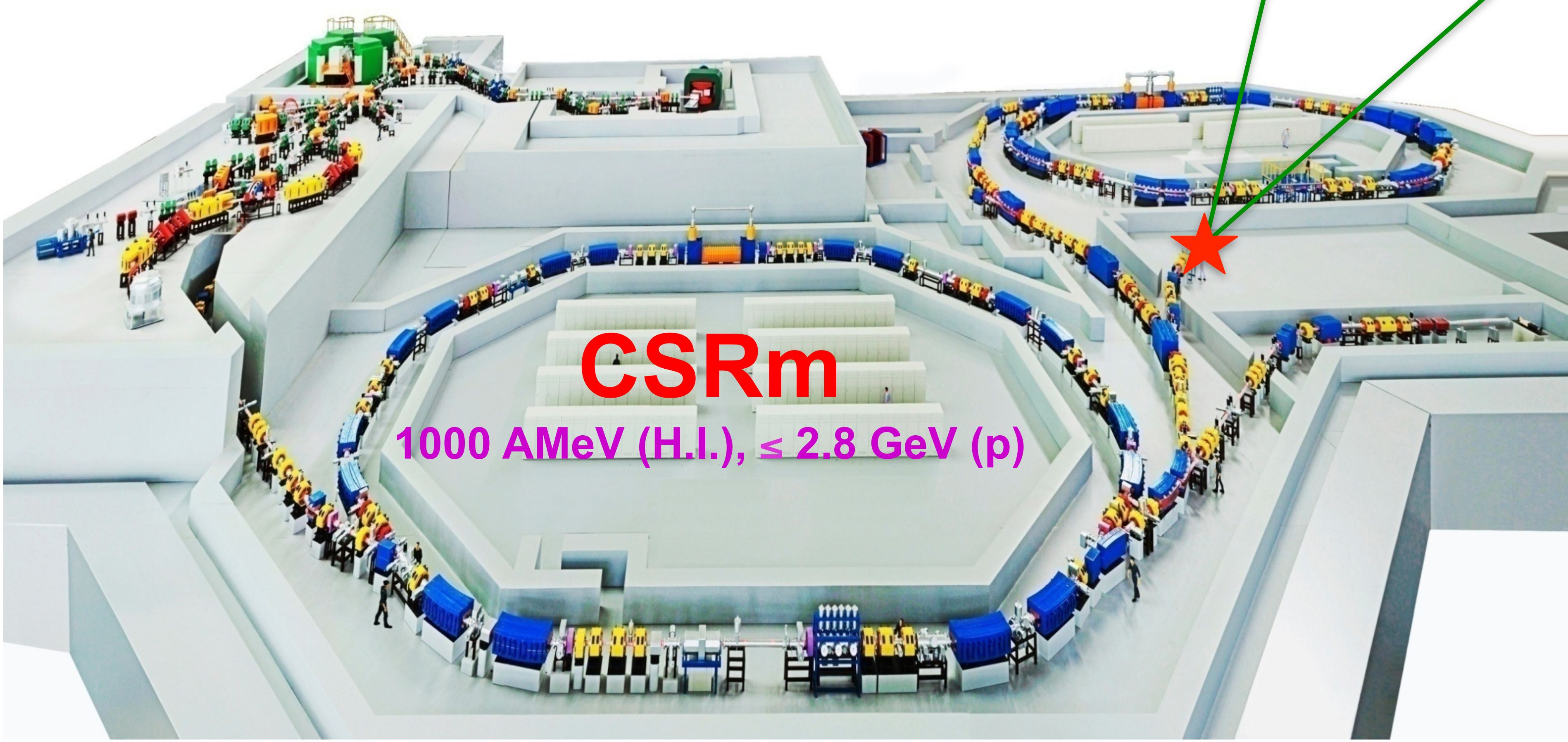
III. Summary

Lanzhou (HIRFL-CSR）

CEE: CSR External-target Experiment

1) Extreme high baryon density and low temperature region
2) Strong nucleonic interactions



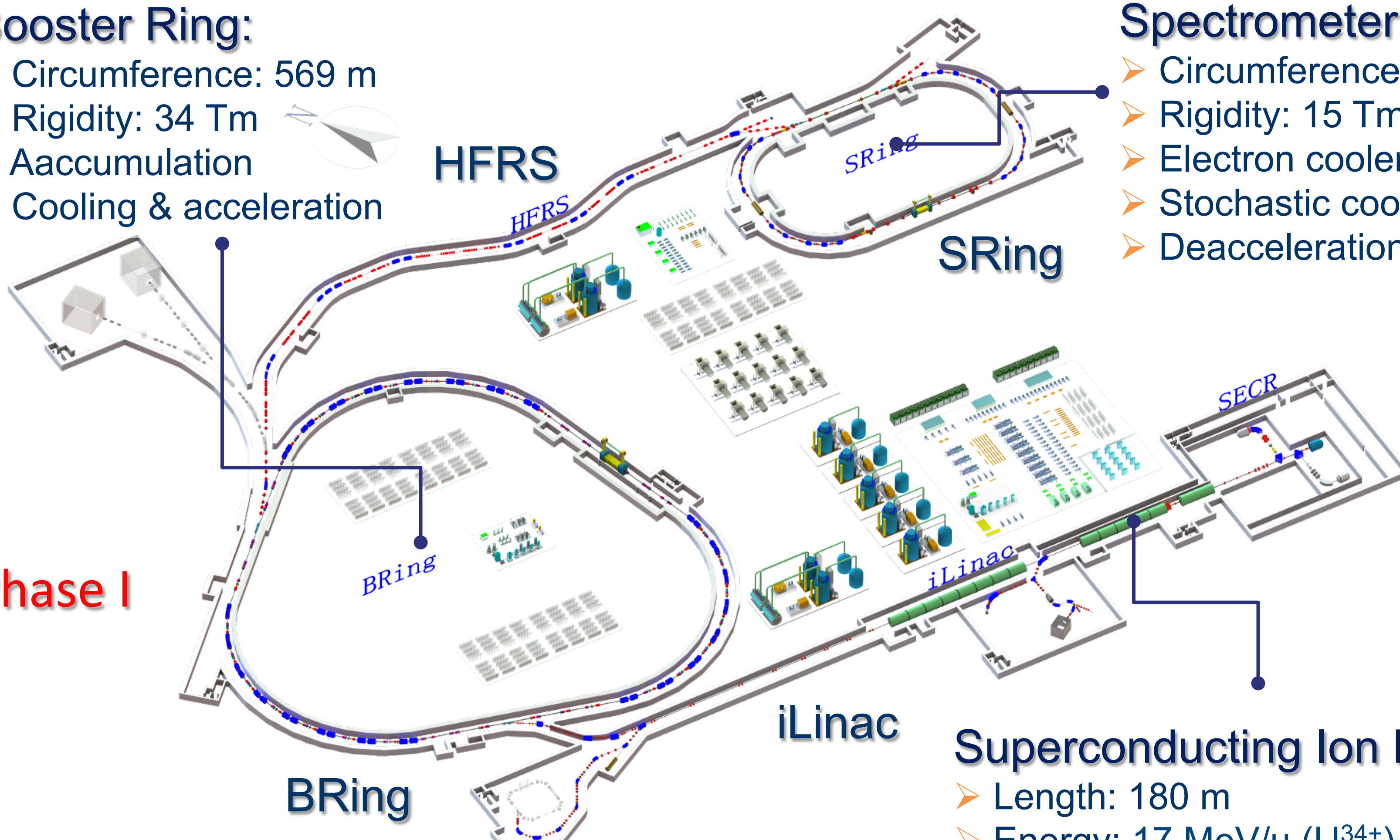


High Intensity Heavy-ion Accelerator Facility

HIAF

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

Spectrometer Ring:
- Circumference: 270.5 m
- Rigidity: 15 Tm
- Electron cooler
- Stochastic cooler
- Deacceleration

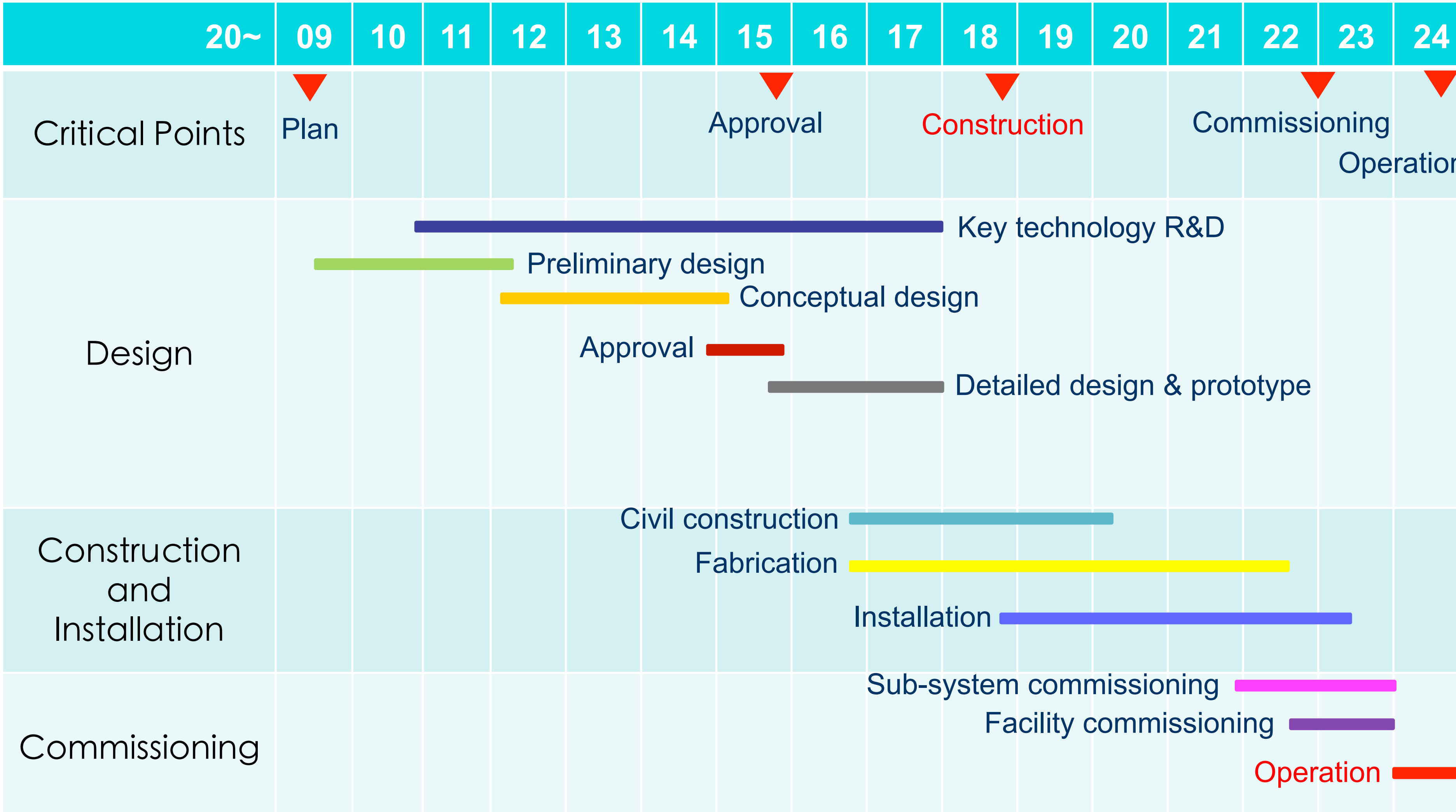


Phase I

- 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

HIAF Timetable



II. EicC Designs and Its Physics Goals

EicC-I New construction

- polarization ion source
- Siberia snake for FRing
- e injector

SRF Linac-ring

4~5 passes

- eRing

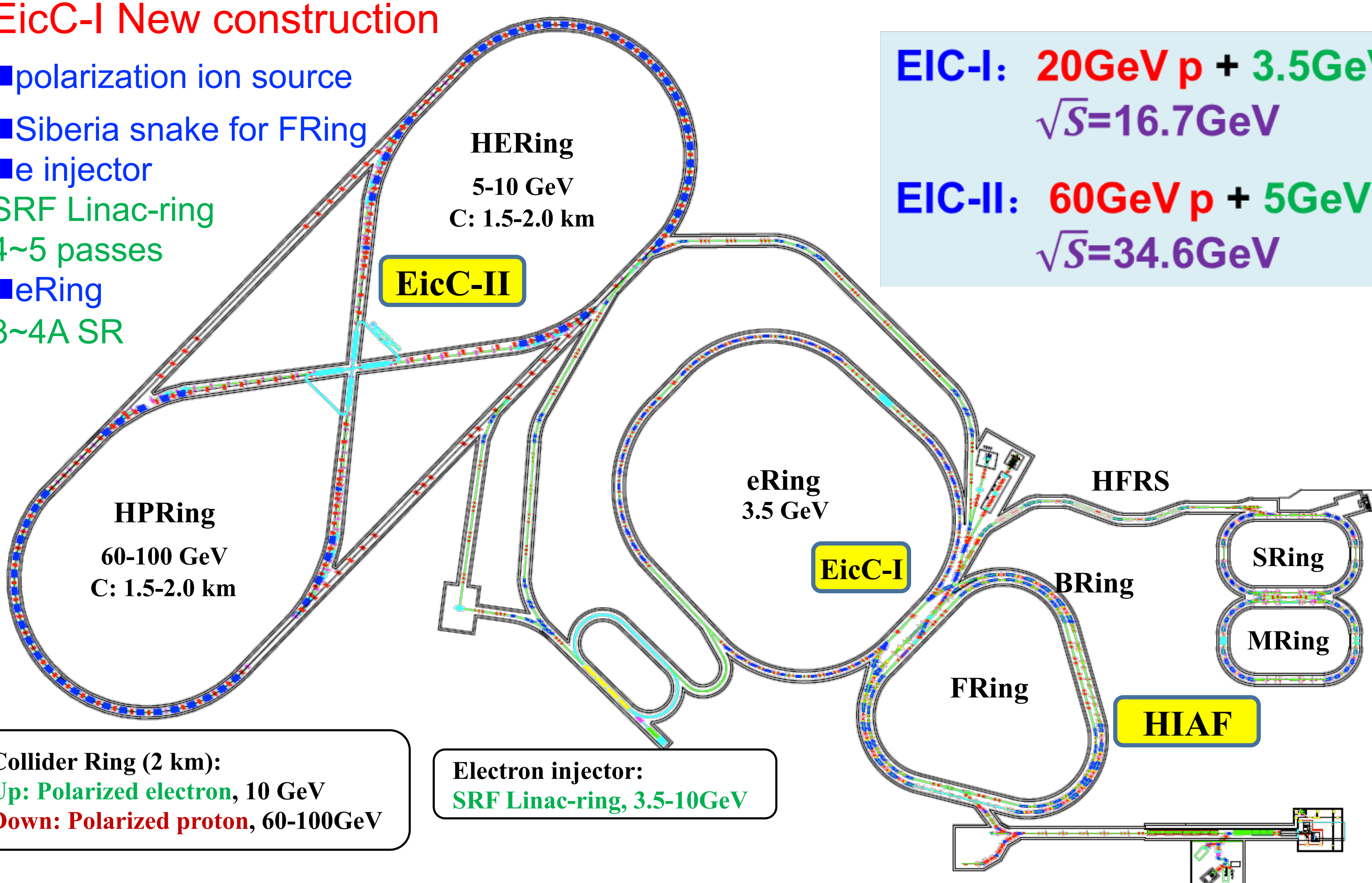
3~4A SR

EIC-I: 20GeV p + 3.5GeV e

$\sqrt{S}$=16.7GeV

EIC-II: 60GeV p + 5GeV e

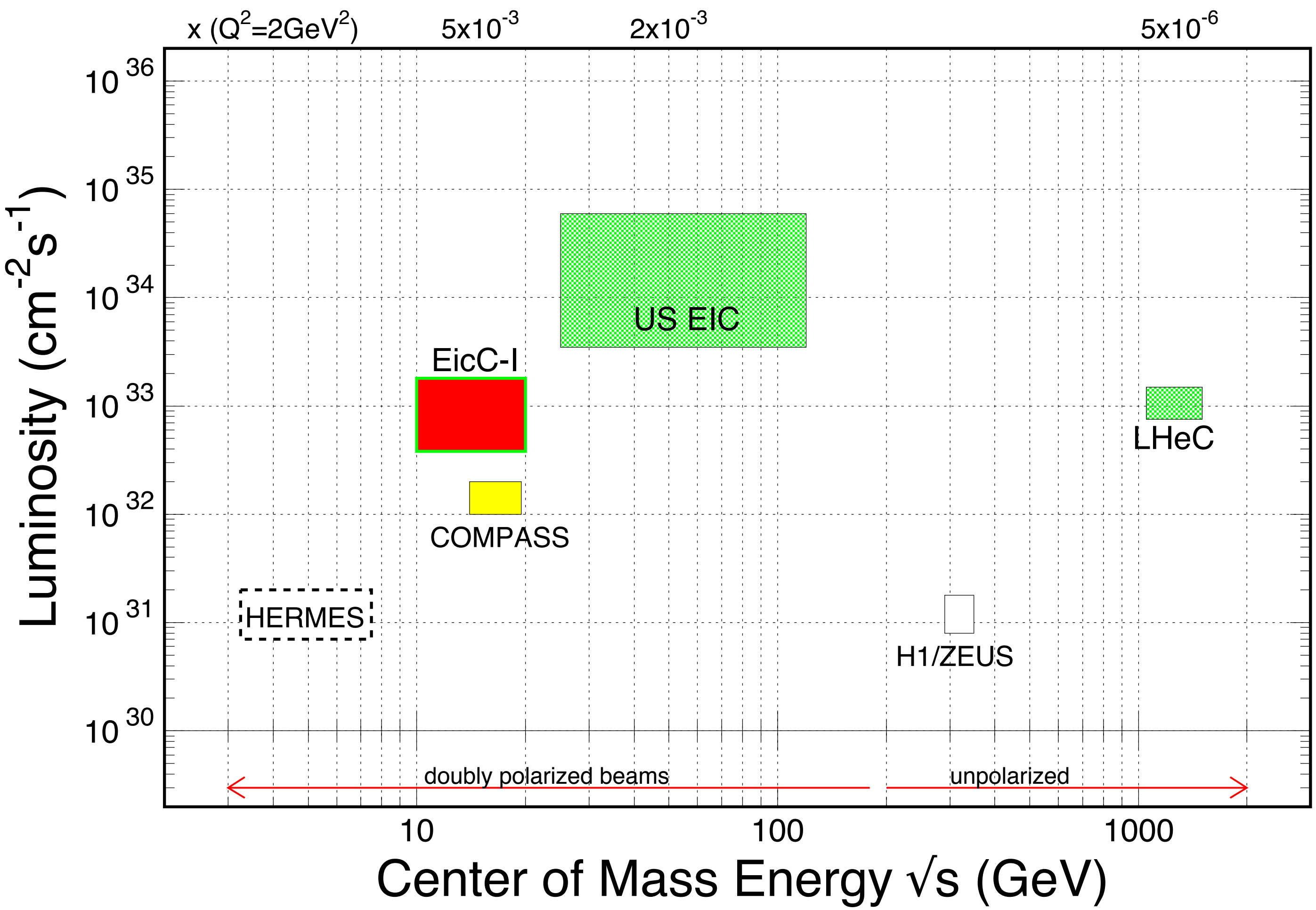
$\sqrt{S}$=34.6GeV



Collider Ring (2 km):
Up: Polarized electron, 10 GeV
Down: Polarized proton, 60-100GeV

Electron injector:
SRF Linac-ring, 3.5-10GeV

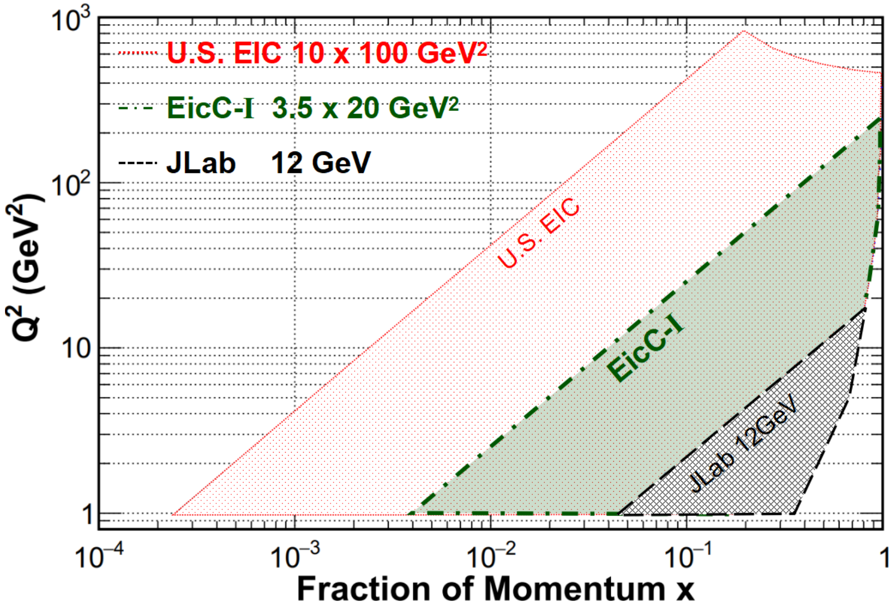
Designed Energy and Luminosity

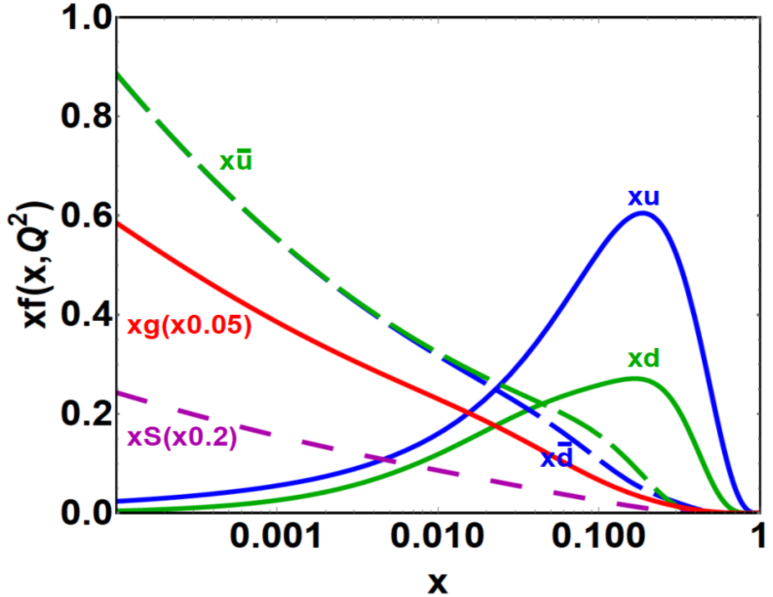


EicC-I: will be constructed at $\sqrt{s}$ ~ 15 ~ 20 GeV region

1) Focus on nuclear physics
2) B-quark hadron production

EicC vs. JLab: Machine Kinematics





Compare the kinematic ranges of EicC with JLab 12 GeV and US EIC

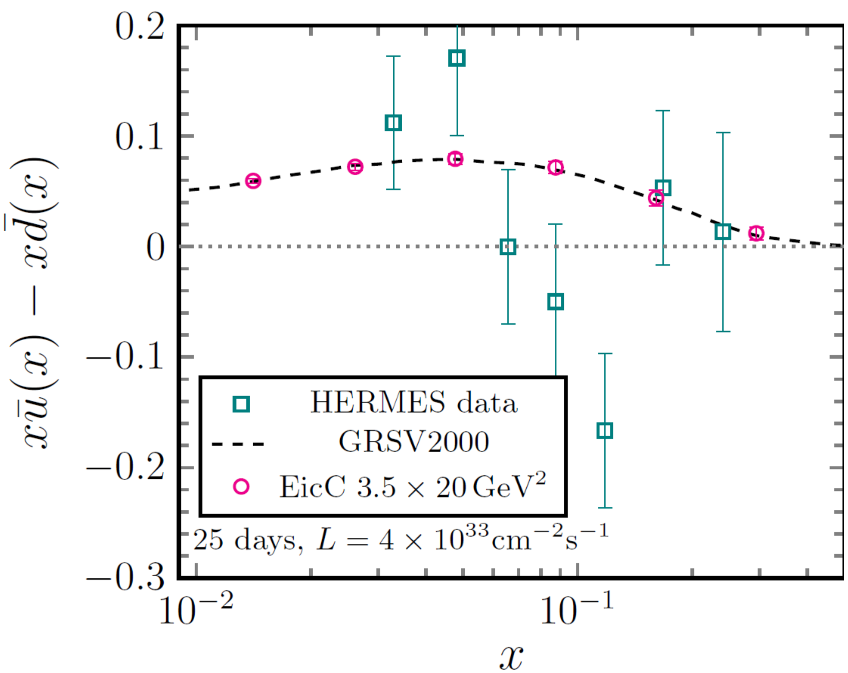
Facilities	Main goals
JLab 12 GeV	Valence quark
EicC-I	Valence and Sea quark
US and Europe EIC	gluon

EicC-I Main Physics Goals

- **Nucleon Structure (sea quark): 1D PDF, GPD, TMD**
- **Hadron spectroscopy**
- **proton mass**

Physics I: Nucleon Structure (sea quark) 1D PDF, GPD, TMD

- Sea Quarks 1D Structure: quarks are poorly known!
  - Current data: large uncertainties in nuclear sea quarks and gluons
  - EicC: significantly reduces sea quark uncertainties



Unique opportunity for Δs

Significant improvement for Δubar, Δdbar from SIDIS

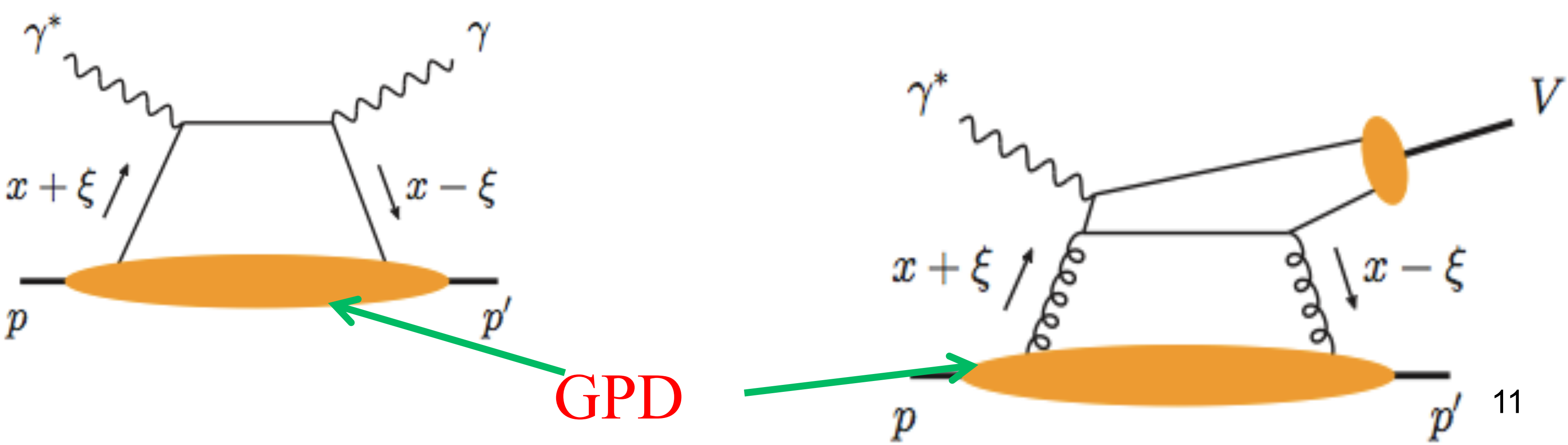
4 weeks running at EicC-I

Plot Courtesy of B. Xiao

GPD Study at EicC

- **Two ways to study GPD: DVCS vs. DVMP**
  - DVCS: Low energy
  - DVMP: needed by flavor decomposition: energy reaches $Q^2 > 5\sim10\ \mathrm{GeV}^2$, scaling region for exclusive light meson production
- **EicC:**
- significantly increase the range for DVCS
- Unique opportunity for DVMP (pion/Kaon)

DVCS **DVMP**



DVCS simulations

- **polarized (3.5 GeV) e + (20 GeV) p collisions**
- **Simulated asymmetries is a function of azimuthal angle between hadron and electron planes**
- **cuts: $1 < Q^2 < 1.5$, $0.01 < x_B < 0.03$ and $-0.05 < t < 0$**
- **80% of polarization for both electron and proton is assumed**
- **Results:**

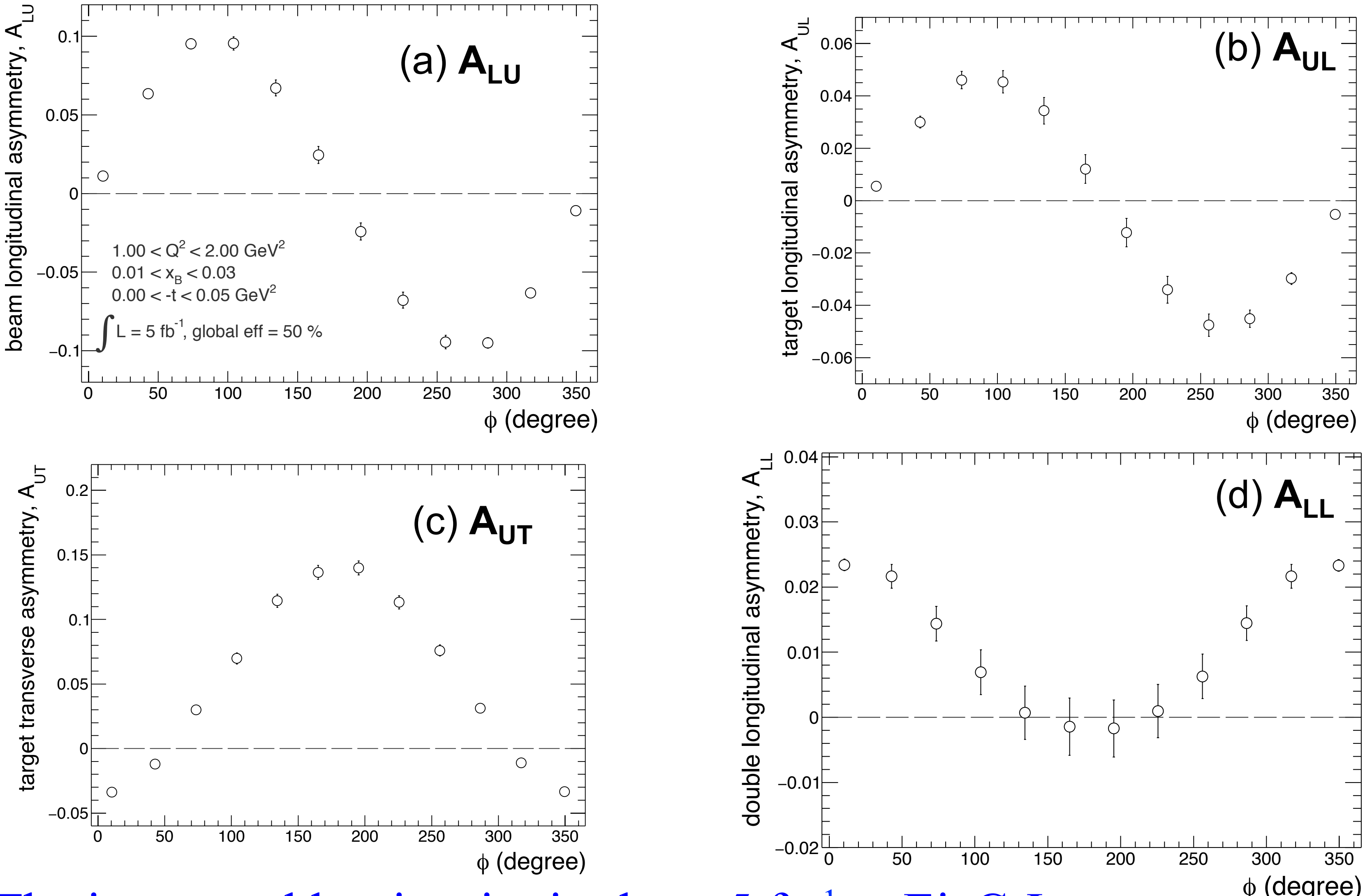
a) polarized electrons (fig. a)

b) polarized protons (fig. b)

c) transversely polarized protons (fig. c)

d) polarized electrons and protons (fig. d)

DVCS Simulation



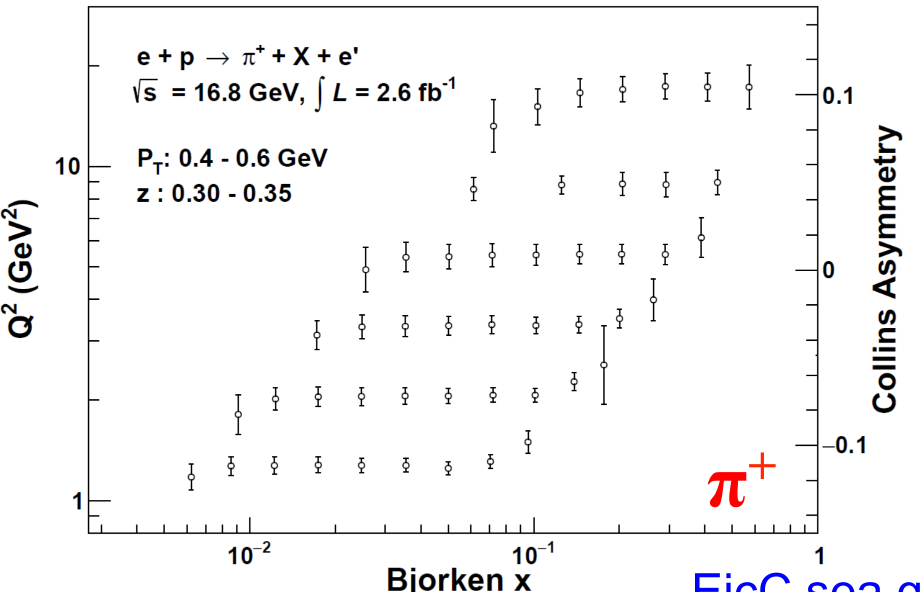
The integrated luminosity is about 5 fp^{-1} at EicC-I

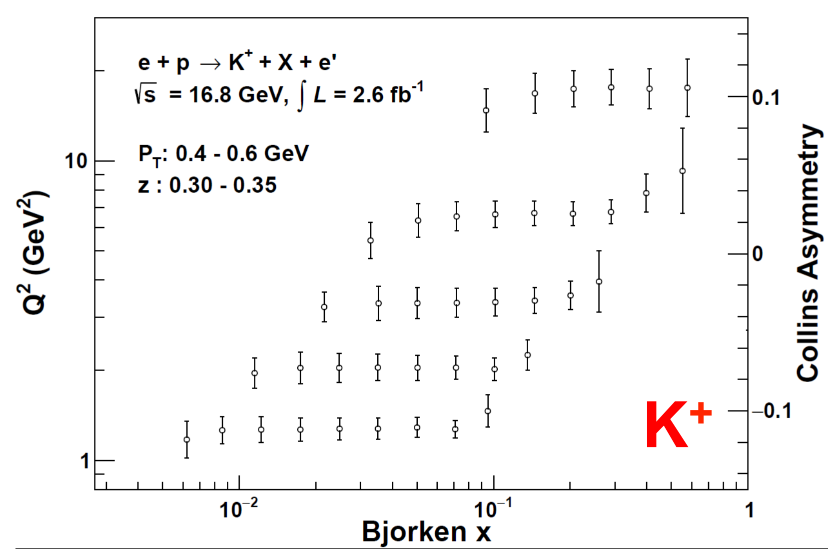
EicC will offer high precision measurements

TMD Study at EicC

EicC: Wide kinematic range for SIDIS

1. Significant increase in Q^2 range for valence region: energy reach Q^2 ~40 GeV^2 at x ~ 0.4
2. Unique opportunity for TMD in "sea quark" region: reach x ~ 0.01





EicC sea quark Collins TMD

Collins asymmetry projection of π^+ and K^+ on electron proton colliding bins ($0.30 < z < 0.35$, 0.4 GeV $< P_T <$ 0.6 GeV); W < 2.3 GeV and W' < 1.6 GeV

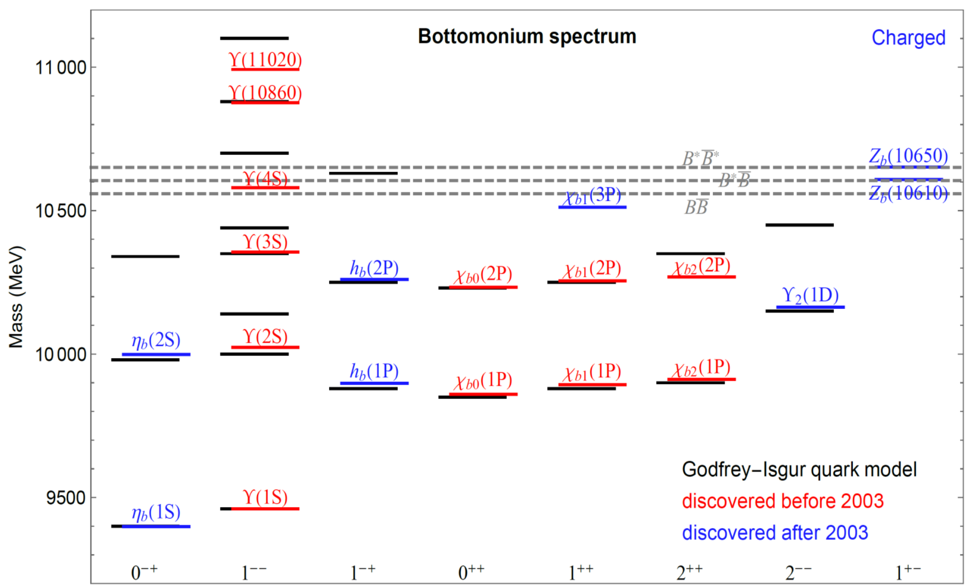
The position of the dots is according to the x - axis and the Q^2 - axis on the left the error bar of each dot: on the right

Physics II: Baryon States with Heavy Flavor

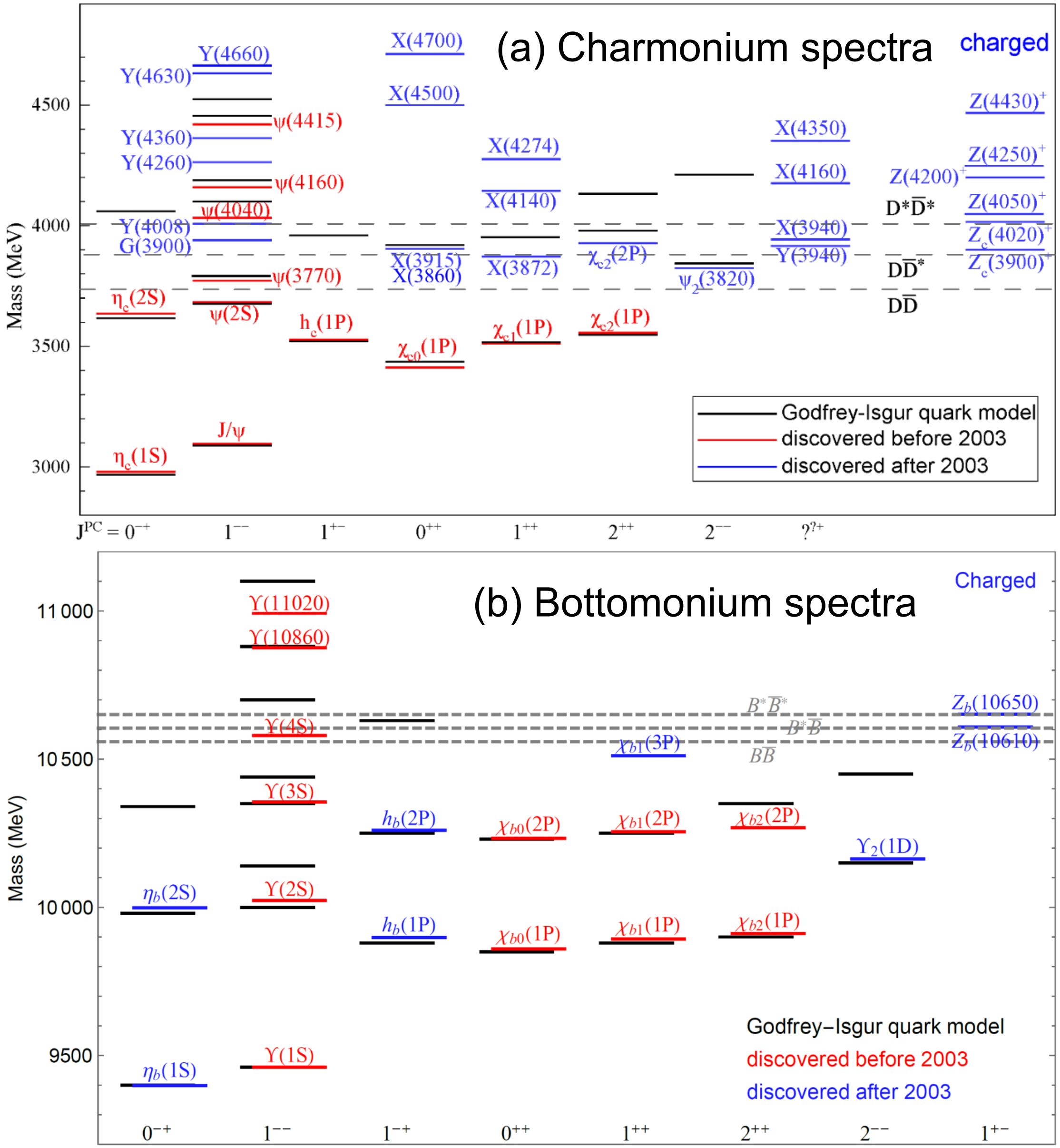
For Baryon States with bottom quark , EicC's advantages:

1. larger cross section comparing to e+e- collision
2. smaller background comparing to pp and ppbar collision
3. Especially, the polarized EicC can well pin down the quantum numbers of the observed particles

Bottomonium Spectrum



Charm and beauty plots

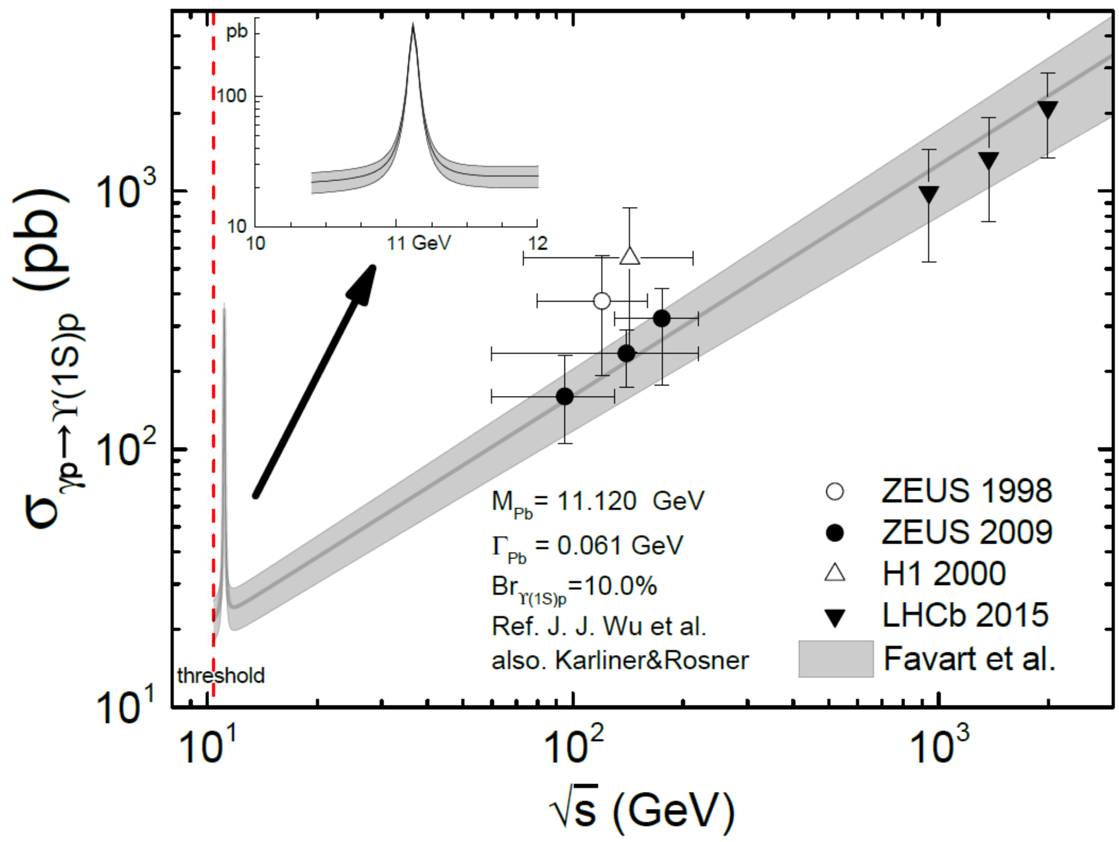


- **EicC can:**
  1. Search for **Hidden "bottom pentaquarks"**
  2. Search **for Open Bottom Baryons**
  3. Search for other exotic particles

- Predicted by Godfrey-Isgur quark model (black)
- Experimental data (red (before 2003) and blue (after 2003)
- black dashed line denotes the threshold to produce meson pairs with heavy flavor)

Penta-quark P_b search

EicC has unique advantage to search for Penta-quark P_b



J. J. Wu and B. S. Zou, Phys. Lett. B 709, 70 (2012)

Phyiscs III: Explore Proton Mass

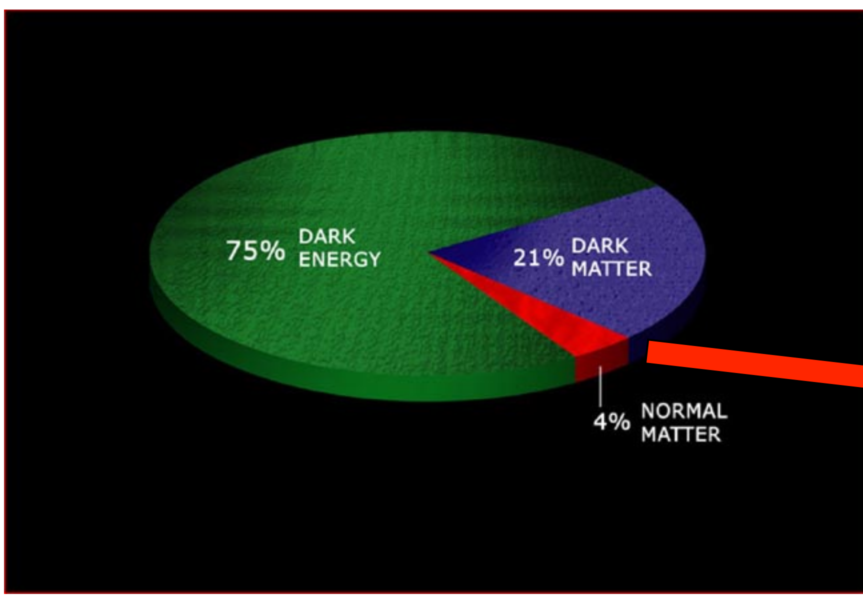
- **Proton Mass Ji's decomposition:** parameters a and b

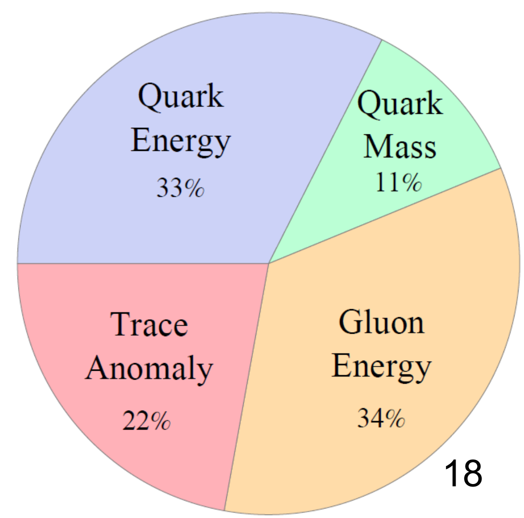
- Parameter a: related to PDFs, well constrained
- parameter b: related to quarkonium-proton scattering amplitude $M_{\psi p}$ near-threshold

X. Ji, PRL 74, 1071 (1995) & PRD 52, 271 (1995)

$$M_q = \frac{3}{4}\left(a - \frac{b}{1+\gamma_m}\right)M,$$
$$M_g = \frac{3}{4}(1-a)M,$$
$$M_m = \frac{4+\gamma_m}{4(1+\gamma_m)}bM,$$
$$M_a = \frac{1}{4}(1-b)M,$$

- Proton mass budget: about 22% comes from trace anomaly
- We know very little about it

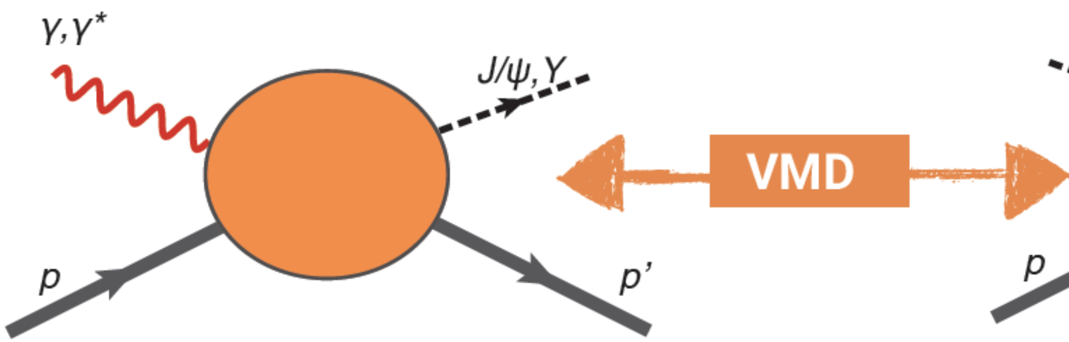




VMD Model Calculates parameter b

- **VMD relates photo-production cross section to quarkonium-nucleon scattering amplitude**

D. Kharzeev, nucl-th/9601029; D. Kharzeev, H. Satz, A. Syamtomov, and G. Zinovjev, Eur.Phys. J., C9,1999



$$\frac{d\sigma_{\gamma N\to\psi N}}{dt}(s,t=0)=\frac{3\Gamma(\psi\to e^+e^-)}{\alpha m_\psi}\left(\frac{k_{\psi N}}{k_{\gamma N}}\right)^2\frac{d\sigma_{\psi N\to\psi N}}{dt}(s,t=0)$$

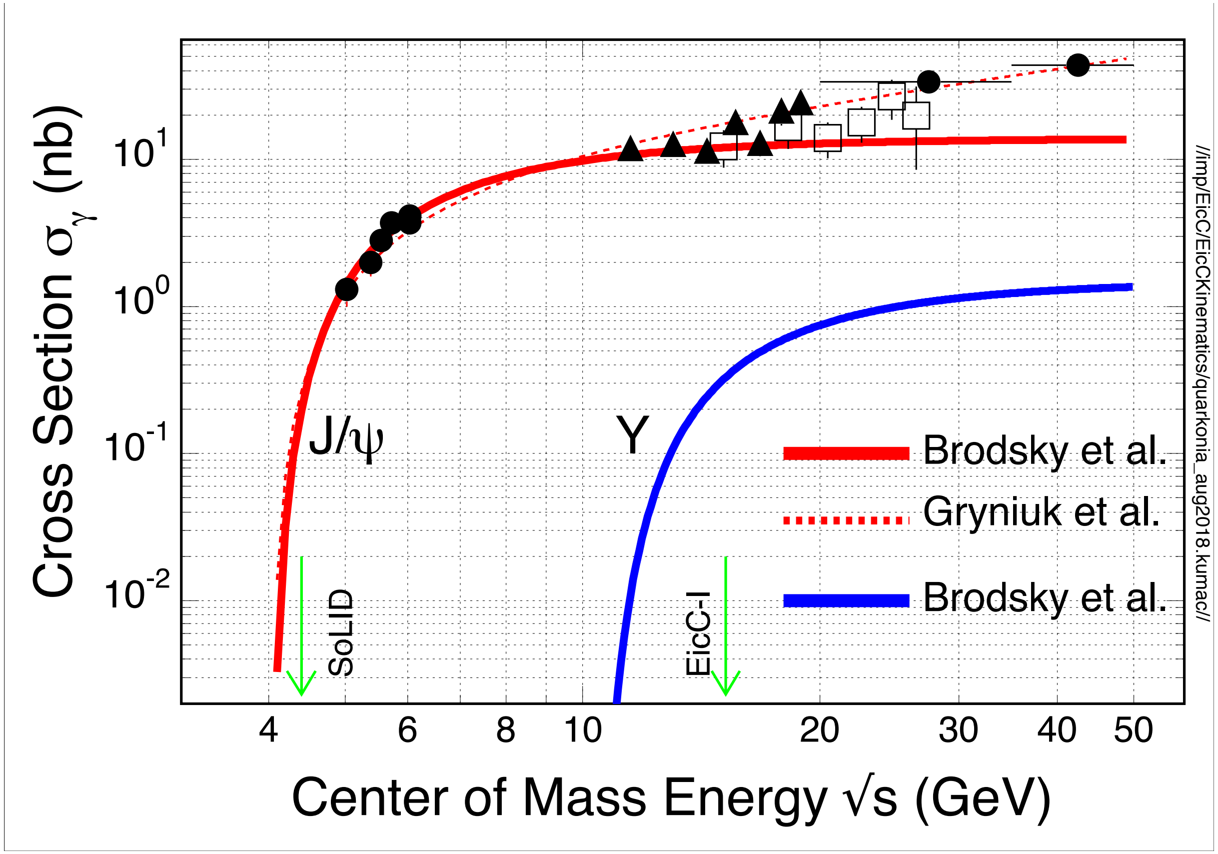
$$\frac{d\sigma_{\psi N\to\psi N}}{dt}(s,t=0)=\frac{1}{64\pi}\frac{1}{m_\psi^2(\lambda^2-m_N^2)}|\mathcal{M}_{\psi N}(s,t=0)|^2$$

$$M_{\psi p} = 4M^2 r_0^3 d_2 \pi^2 (1 - b)/27$$

- $M_{\psi p}$ Imaginary part, is related to the total cross section
- $M_{\psi p}$ Real part, contains the conformal (trace) anomaly **(=>b)**
  - Dominate the near threshold region

Measure J/psi or Upsilon cross-section near threshold, then obtain b, hence get proton mass !

J/psi and Upsilon production cross-sections



O. Gryniuk and M. Vanderhaeghen, Phys. Rev. D 94, 074001 (2016)

●**EicC will offer unique opportunity for** precision measurement **Upsilon** near threshold

the heavier mass of the bottom could suppress the theoretical systematic uncertainties

Physics Summary: neucleon strucutre

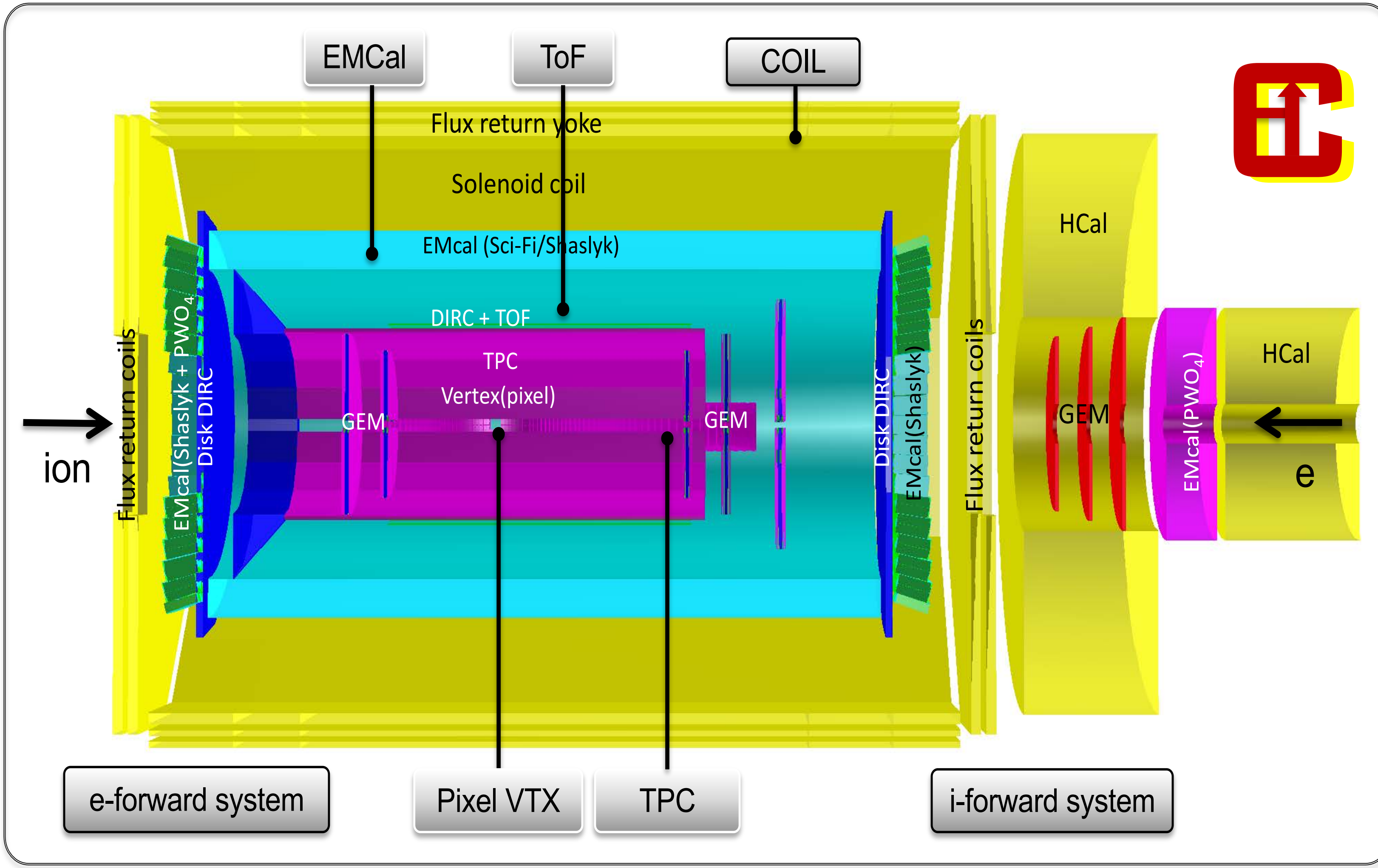
- **Nucleon Structure (sea quark): 1D PDF, GPD, TMD**

  The EicC-I has unique advantages comparing to the existing and planning fixed target experiments, especially in the polarized cases
- **Baryon States with Heavy Flavor**
- **proton mass study**

◆ **EicC-I also has the potential to make important contributions to other topics, such as:**

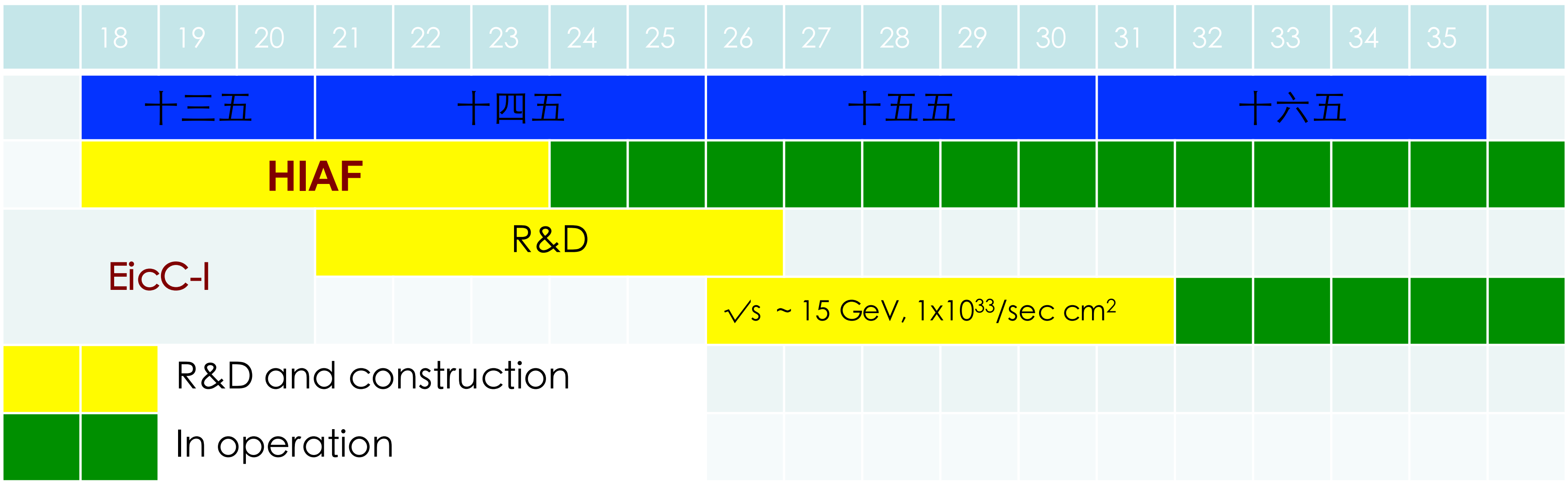
- medium effects (hadronization, EMC, SRC, color transparency)
- pion and kaon structure functions
- …..etc.

EicC Conceptual Detector



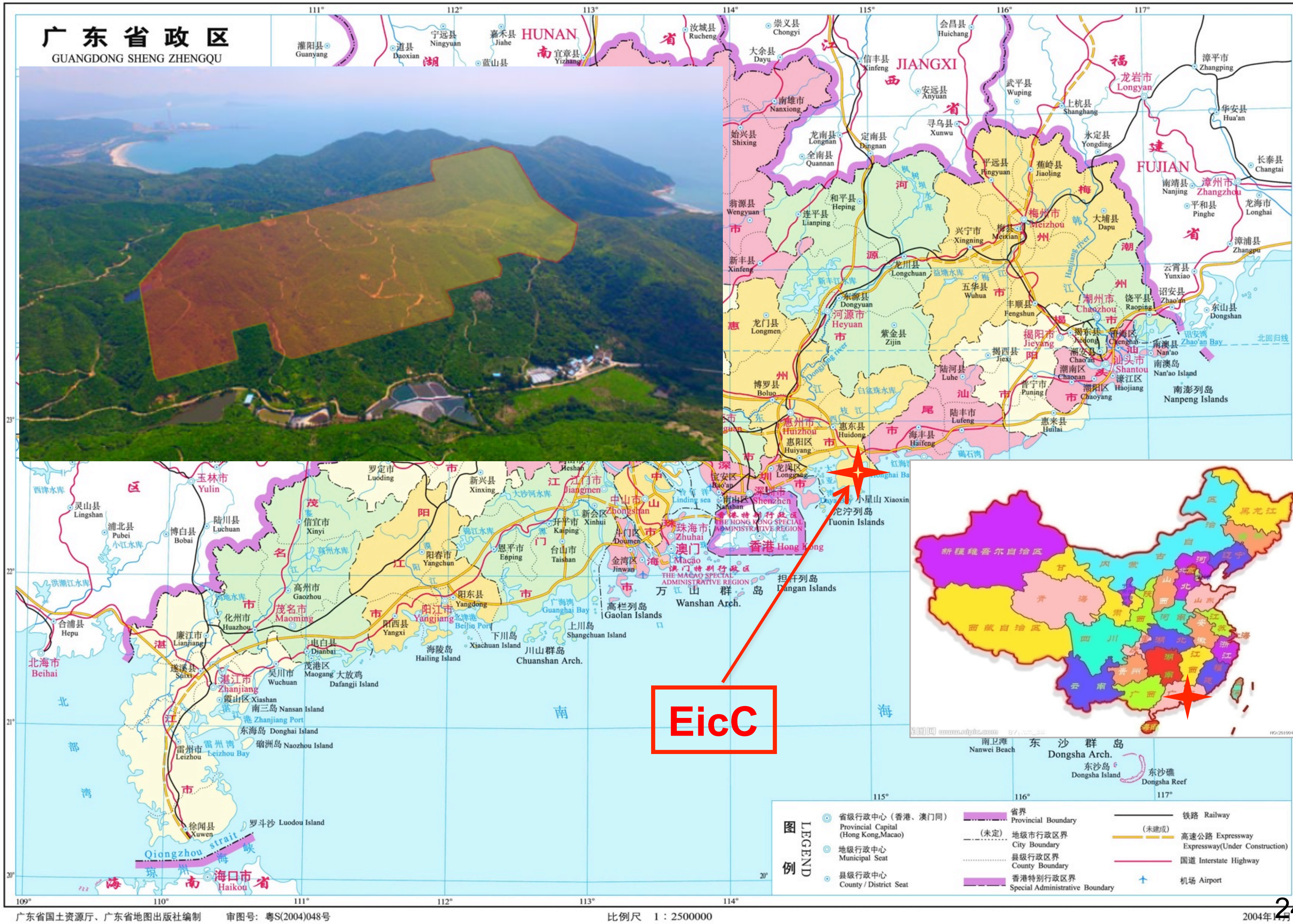
EicC detector systems design and simulation in early stage

EicC Timetable



EicC-I whitepaper draft: End of 2019

EicC Location



Location

Huizhou city and Guangdong province will cover the expenses for buying land, preparing land, building roads, building electricity and water supply stations, …

Location

About 5 km to downtown of Huizhou City.
Construction will start soon.

Summary

- **EicC-I focuses on valence- and sea-quark region, addresses nuclear physics：**

1. **nucleon structure: 1D and** 3D imaging of quarks
2. **Exotic hadrons**
3. **proton mass**
4. **Medium effects, pion and kaon structure function, etc.**

- **Complements to the world EIC physics programs:**

➢ **JLab12: Valence quark region**

➢ **U.S. and Europe's EIC: Higher energy for gluon saturation**

Worldwide efforts, theoretical and experimental, are needed

You are ALL invited to join the scientific endeavor: EicC

Thank You !