

# An EIC proposed in China (EicC)

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On behalf of the EicC collaboration

# Outline

- Introduction of an EIC facility proposed in China
- Introduction of several selected physics topics
- Project status and future plan



# Where we are talking about...Huizhou in Guangdong province



Coast city

Nice weather and food 😊

Strong support from local government

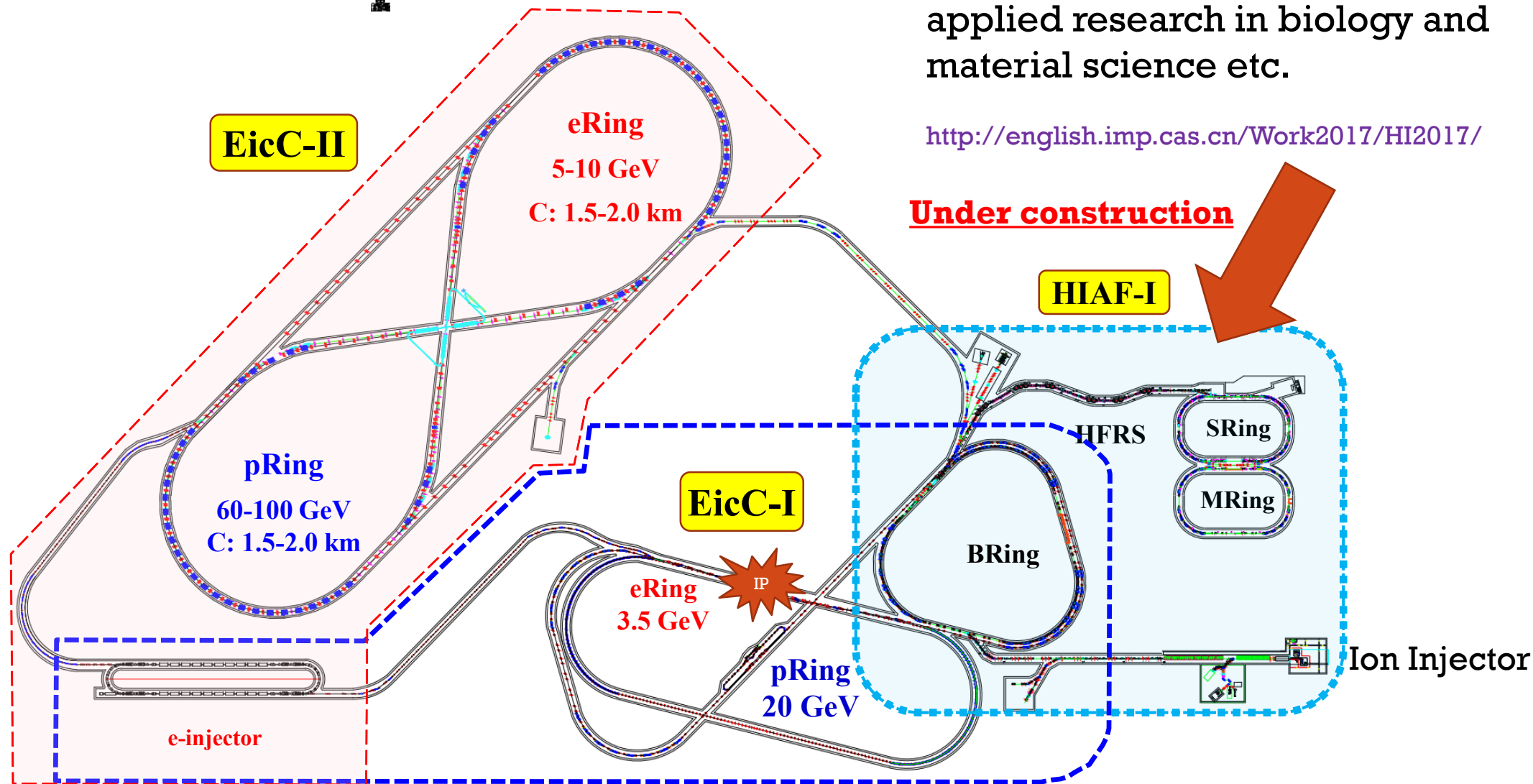




# Accelerator complex overview

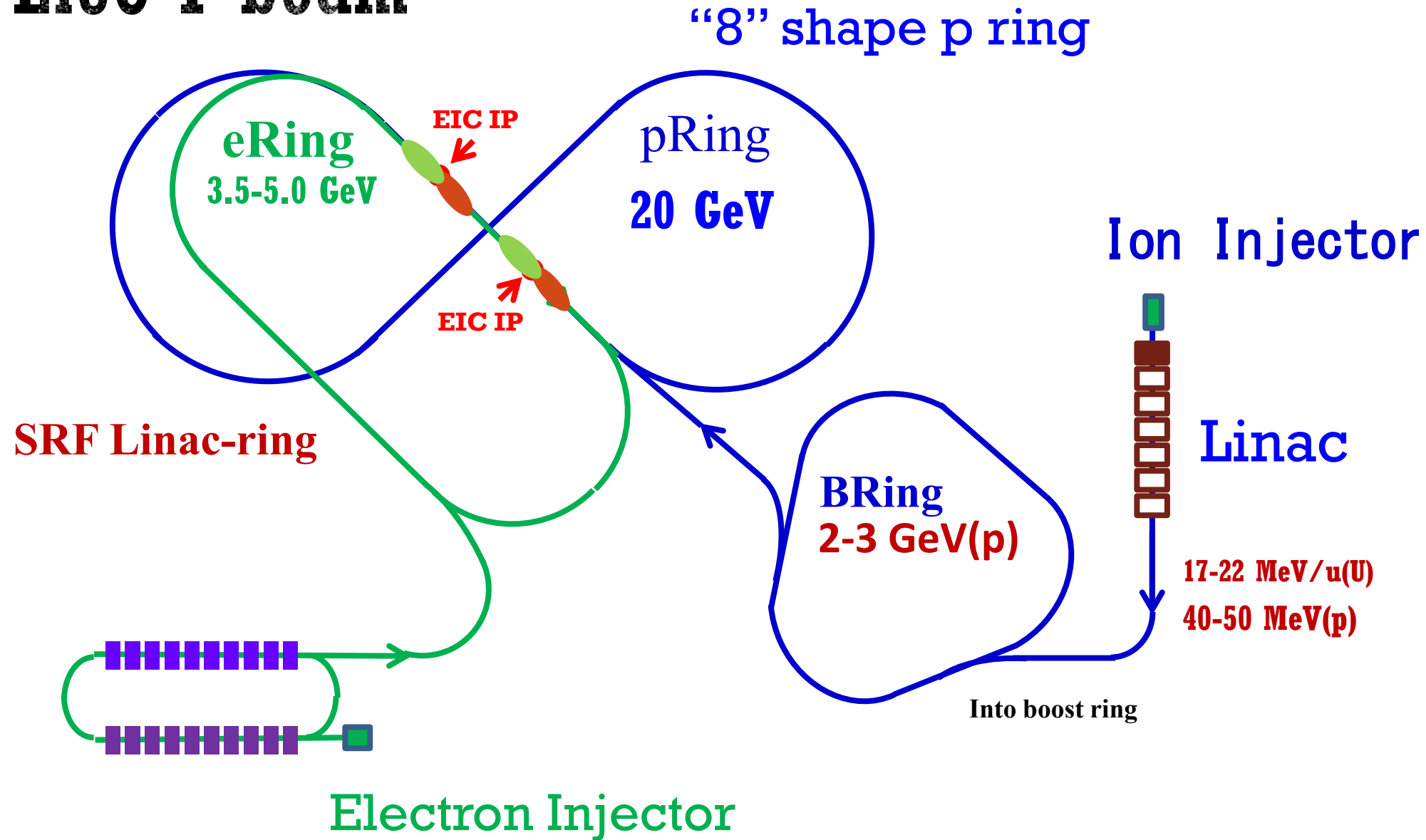
High intensity ion beams for atomic physics, nuclear physics, applied research in biology and material science etc.

<http://english.imp.cas.cn/Work2017/HI2017/>

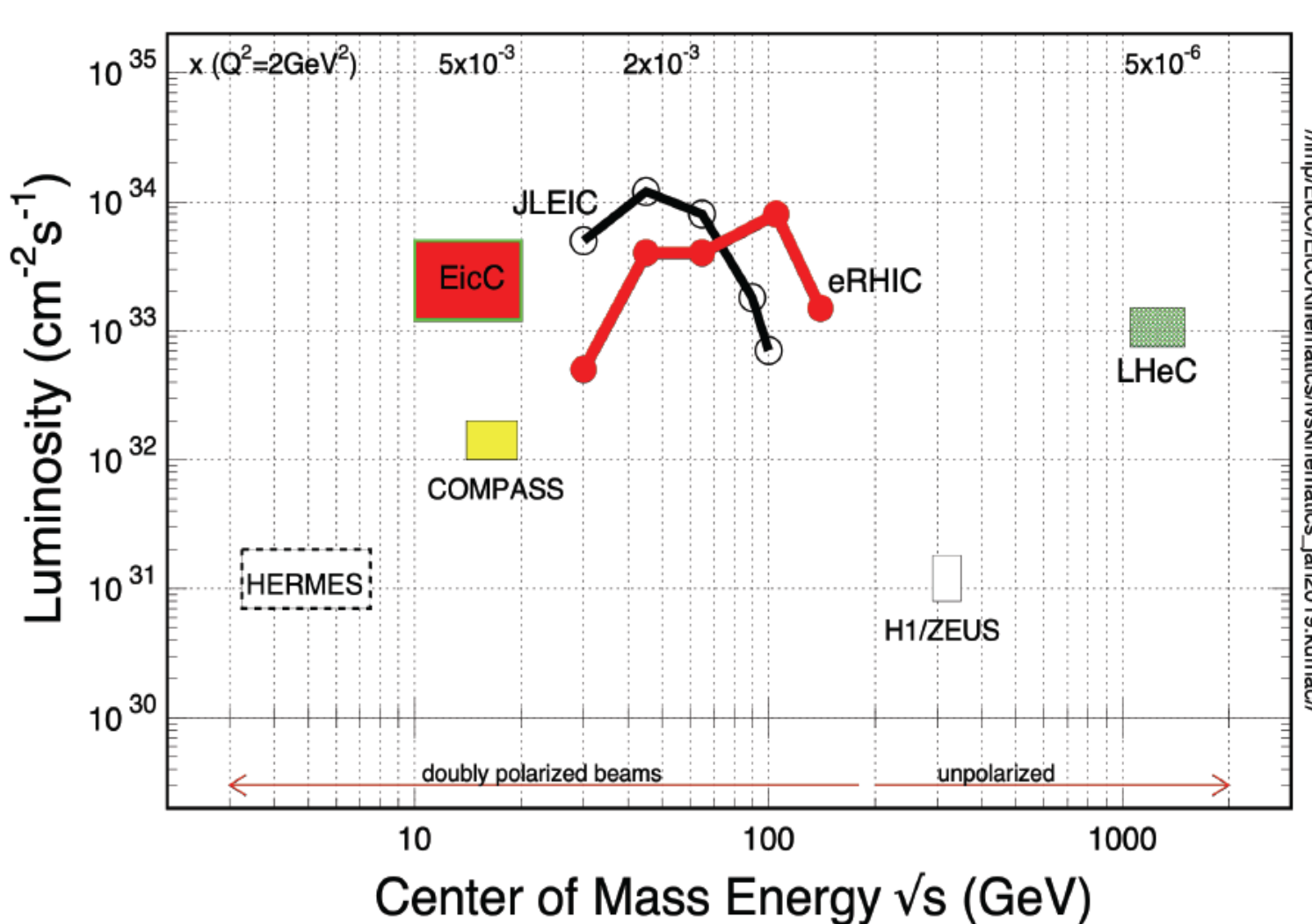


High-Intensity Heavy Ion Accelerator Facility (HIAF)

# EicC-I beam



# EicC beam energy and luminosity



## EicC-I:

**Beam energy: 3.5 GeV e + 20 GeV P**

**Polarization: e 80%, P 70%**

**Inst. Lumi.:  $(1-5) \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$**

**Also D, He-3, heavy nuclear beam**

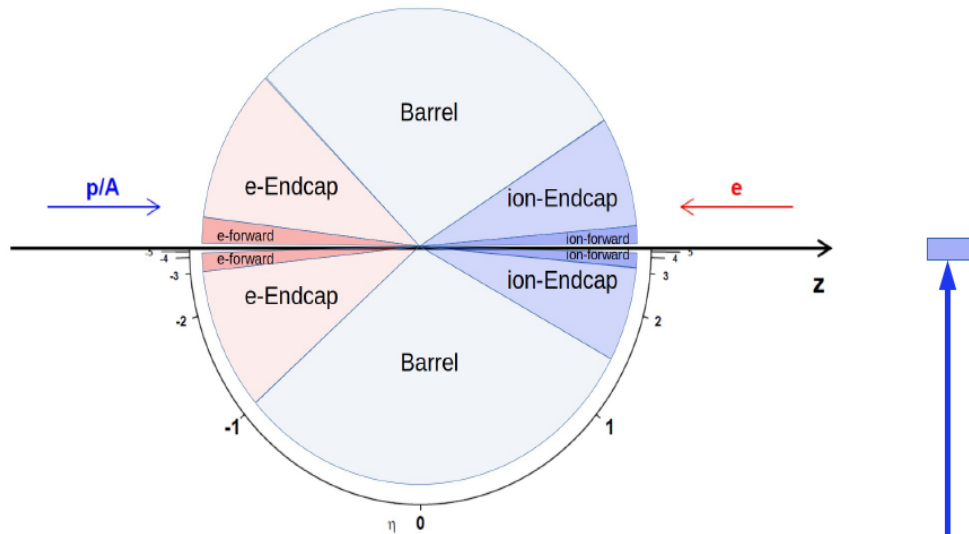
## EicC-II:

**Beam energy: 10 GeV e + (60-200) GeV P**

**Polarization: e 80%, P 70%**

**Inst. Lumi.: up to  $5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$**

# EicC detector conceptual design



For electron:

For  $Q^2 > 1\text{GeV}^2$ ,  $-3 < \eta < 2$  is sufficient.

For lower  $Q^2$ , a dedicated detector

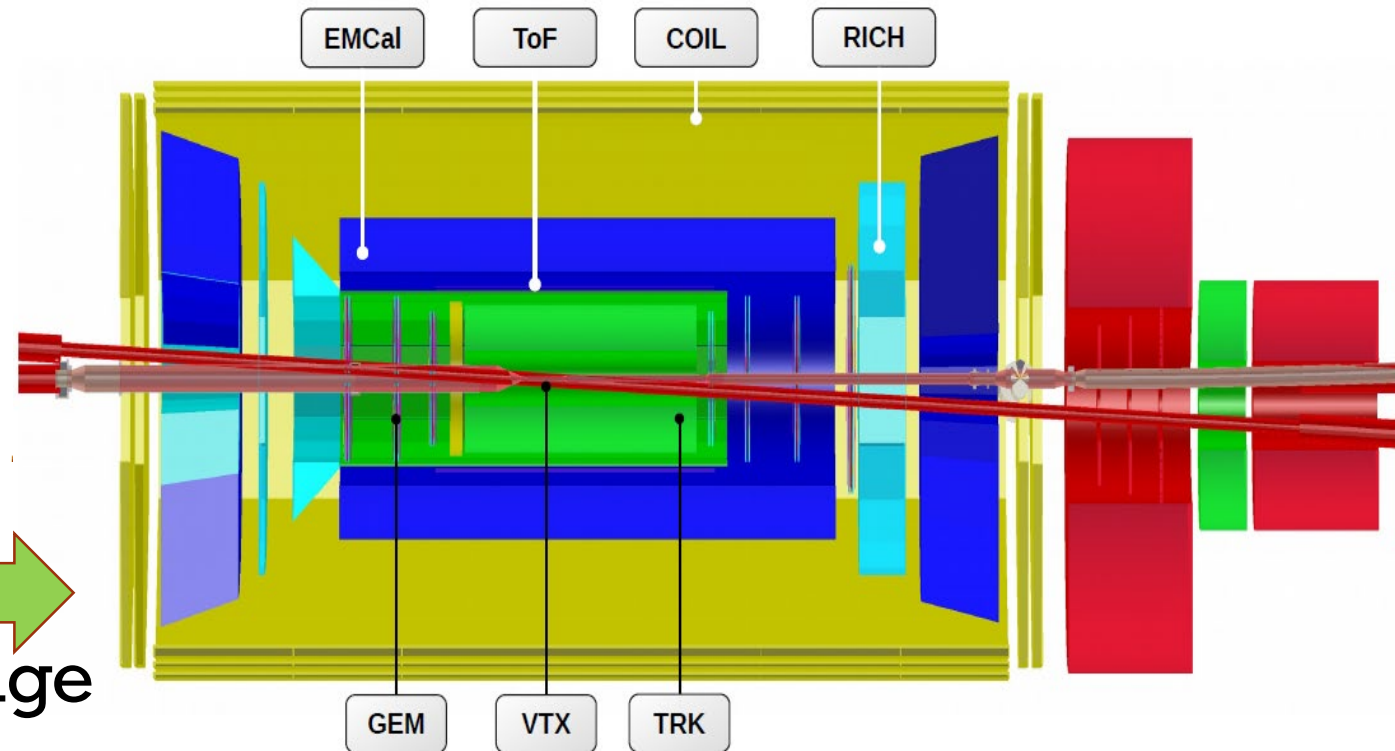
For hadrons:

central detector:  $-3 < \eta < 3.5$

- $-3 < \eta < 1$ :  $\pi/K/p$  separation  $< 5\text{ GeV}/c$
- $1 < \eta < 3\sim 4$ :  $\pi/K/p$  separation  $< 10\sim 15\text{ GeV}/c$

$\eta > 4$ : detectors in the far-forward region.

General requirements



Very first design,  
Still in the very...very... early stage  
Detector options are open

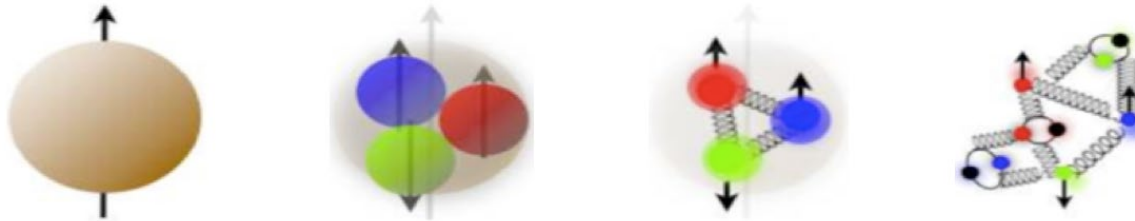
# Outline

- Introduction of an EIC facility proposed in China
- Introduction of several selected physics topics
  - ✓ Longitudinal spin structure of the nucleon
  - ✓ TMDs via SIDIS
  - ✓ GPDs via DVCS
  - ✓ Other physics topics



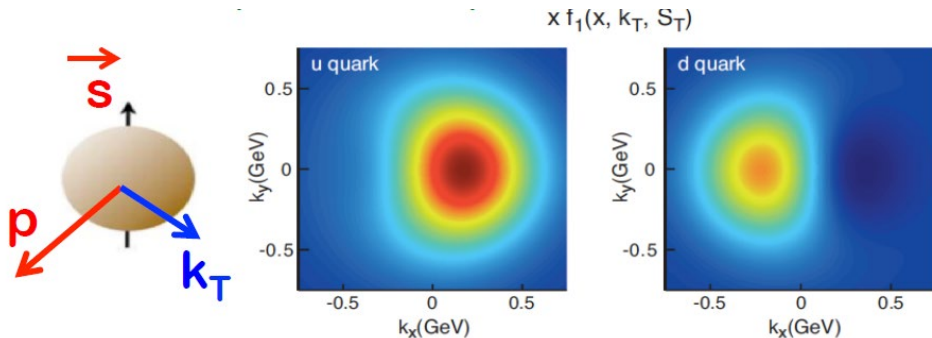
# Questions driving the spin physics

- How do quarks/gluons + their dynamics make up the proton spin?



Helicity distributions + orbital contribution

- How is proton's spin correlated with the motion of the quarks/gluons?



Deformation of parton's  
**confined motion**  
When hadron is polarized?



TMDs!

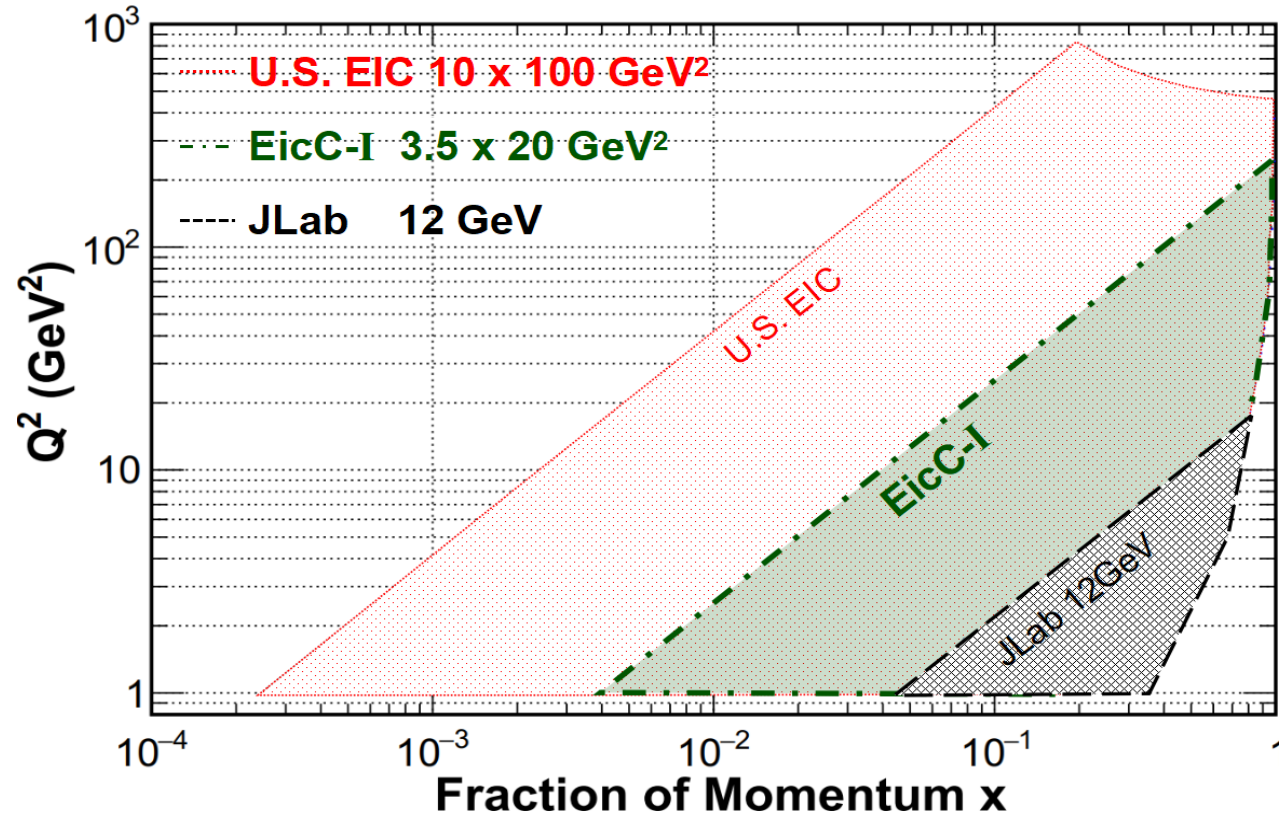
- How does proton's spin influence the spatial distribution of partons?

Deformation of parton's  
**spatial distribution**  
When hadron is polarized?



GPDs!

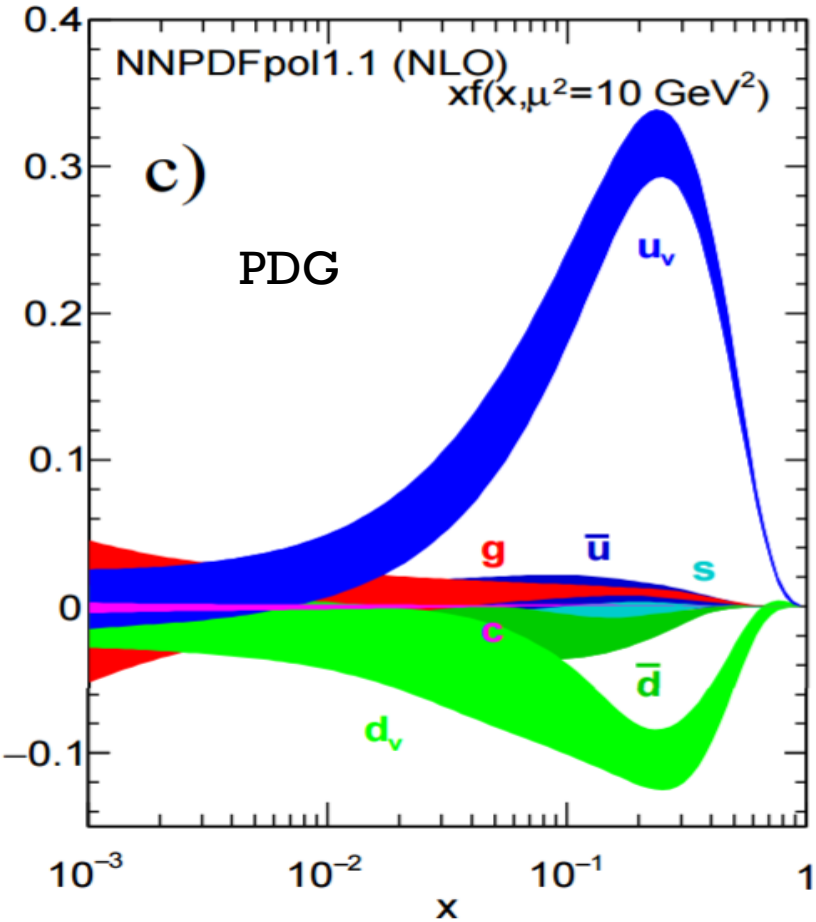
# Phase space coverage of EicC-I



What we can have at EicC-I with **polarized electron and polarized ion beam**:  
**Precise measurements for 1D (helicity), 3D (TMDs, GPDs) nucleon spin structure with flavor separations ... in the valence/sea quark region ...**

# World data of helicity study

ArXiv: 1801.04842 (2018)



$\Delta\Sigma$

$\Delta f$	$\langle\Delta f\rangle^{[0,1]}$	$\langle\Delta f\rangle^{[10^{-3},1]}$	
	NNPDFpol1.1	NNPDFpol1.1	DSSV08
$\Delta u^+$	$+0.79 \pm 0.07$	$+0.76 \pm 0.04$	$+0.793^{+0.028}_{-0.034} (+0.020)$
$\Delta d^+$	$-0.47 \pm 0.07$	$-0.41 \pm 0.04$	$-0.416^{+0.035}_{-0.025} (-0.042)$
$\Delta \bar{u}$	$+0.06 \pm 0.06$	$+0.04 \pm 0.05$	$+0.028^{+0.059}_{-0.059} (+0.008)$
$\Delta \bar{d}$	$-0.11 \pm 0.06$	$-0.09 \pm 0.05$	$-0.089^{+0.090}_{-0.080} (-0.026)$
$\Delta s$	$-0.07 \pm 0.05$	$-0.05 \pm 0.04$	$-0.006^{+0.028}_{-0.031} (-0.051)$
$a_0$	$+0.18 \pm 0.21$	$+0.25 \pm 0.10$	$+0.366^{+0.042}_{-0.062} (+0.124)$

	$\langle\Delta g\rangle^{[0,1]}$	$\langle\Delta g\rangle^{[10^{-3},1]}$	$\langle\Delta g\rangle^{[0.05,0.2]}$
NNPDFpol1.1	$+0.03 \pm 3.24$	$+0.49 \pm 0.75$	$+0.17 \pm 0.06$
DSSV08	—	$0.01^{+0.70}_{-0.31} (+0.10)$	$0.01^{+0.13}_{-0.16}$
DSSV++	—	—	$0.10^{+0.06}_{-0.07}$

$\Delta G$

RHIC spin data put strong constraint on  $\Delta G$

# A few discussions of helicity study

- Light sea, still large uncertainties
  - ✓ Unpol.  $\bar{u}-\bar{d} < 0$ , larger than expected  $\rightarrow$  polarized ?
- Strange quark helicity?
  - ✓ think about unpolarized  $s, \bar{s}$ , with  $s=\bar{s}$  in most case
  - ✓ May change sign along  $x$
  - ✓ SU(3) flavor symmetry  $\rightarrow \Delta S + \Delta \bar{S} \sim -0.1$ , not observed in SIDIS, because of fragmentation functions?
- SIDIS data is very powerful for flavor separation, however fragmentation functions are involved
- Further  $\Delta g$  constraint, precise data needed

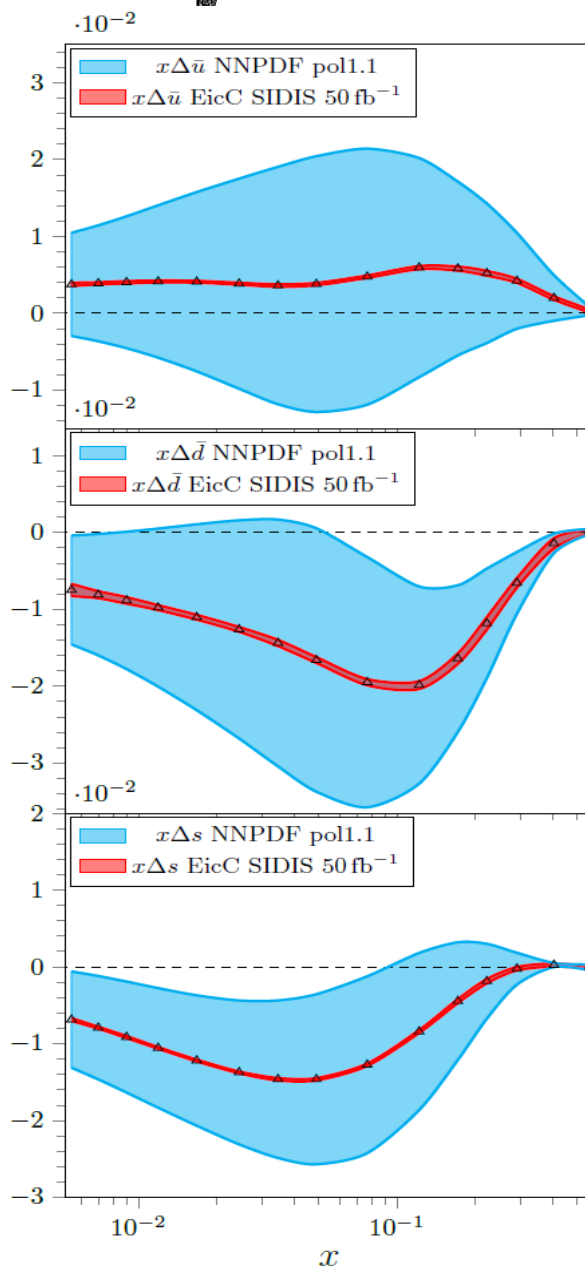
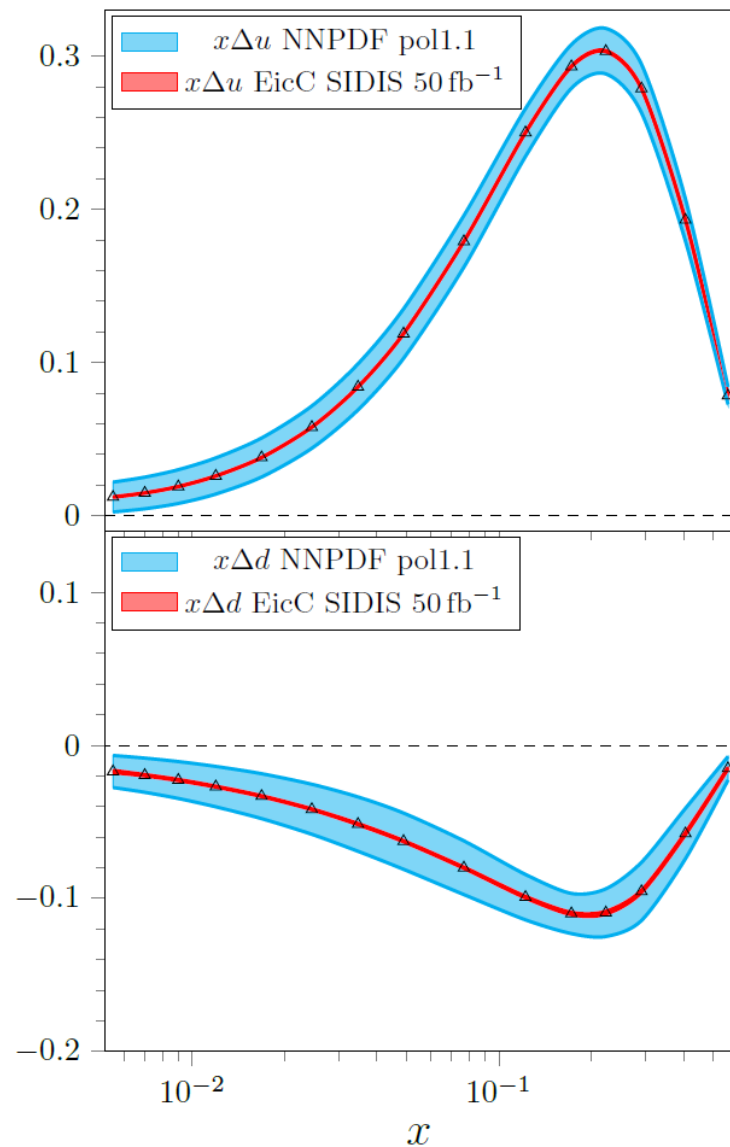




# Projections on helicity distributions (EicC)

Preliminary

**LO analysis**



EicC SIDIS data:

- Pion(+/-), Kaon(+/-)
- **ep**: 3.5 GeV X 20 GeV
- **eHe-3**: 3.5 GeV X 40 GeV
- Pol.: e(80%), p(70%), He3(70%)
- Lumi:
  - ep 50 fb-1
  - eHe3 50 fb-1

Fragmentation functions used: DSS

# Leading-Twist TMDs

		Quark polarization		
		Unpolarized (U)	Longitudinally Polarized (L)	Transversely Polarized (T)
Nucleon Polarization	U	$f_1 = \text{[red dot in circle]}$		$h_1^\perp = \text{[red dot in circle with up arrow]} - \text{[red dot in circle with down arrow]}$ Boer-Mulders
	L		$g_1 = \text{[red dot in circle with right arrow]} - \text{[red dot in circle with left arrow]}$ Helicity	$h_{1L}^\perp = \text{[red dot in circle with up-right arrow]} - \text{[red dot in circle with up-left arrow]}$ Worm Gear
	T	$f_{1T}^\perp = \text{[red dot in circle with up arrow]} - \text{[red dot in circle with down arrow]}$ Sivers	$g_{1T} = \text{[red dot in circle with up arrow and right arrow]} - \text{[red dot in circle with up arrow and left arrow]}$ Worm Gear	$h_1 = \text{[red dot in circle with up arrow]} - \text{[red dot in circle with down arrow]}$ Transversity $h_{1T}^\perp = \text{[red dot in circle with up arrow and right arrow]} - \text{[red dot in circle with up arrow and left arrow]}$ Pretzelosity

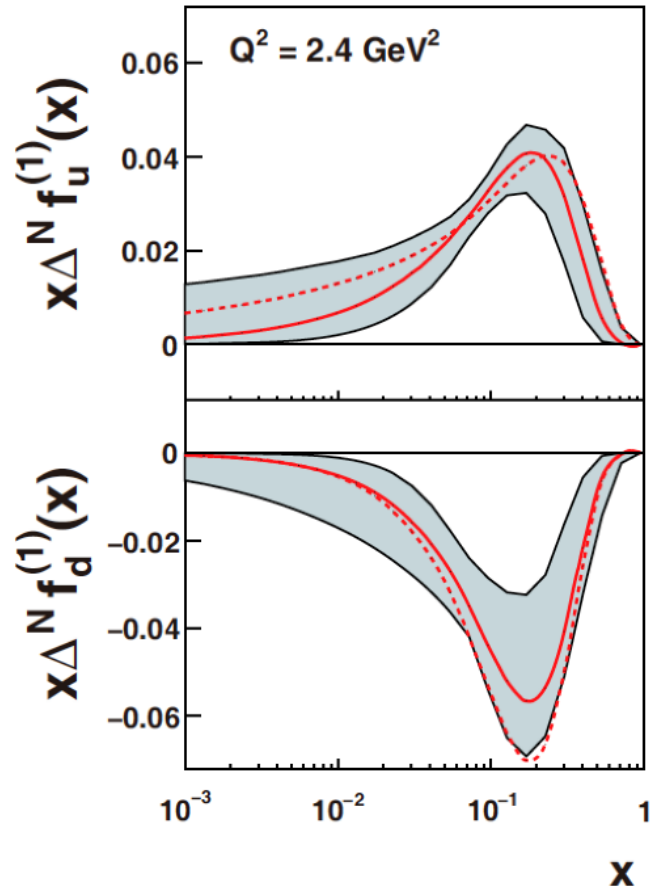

Nucleon Spin


Quark Spin


Survive the  $k_T$  integration, yield 1D pdfs

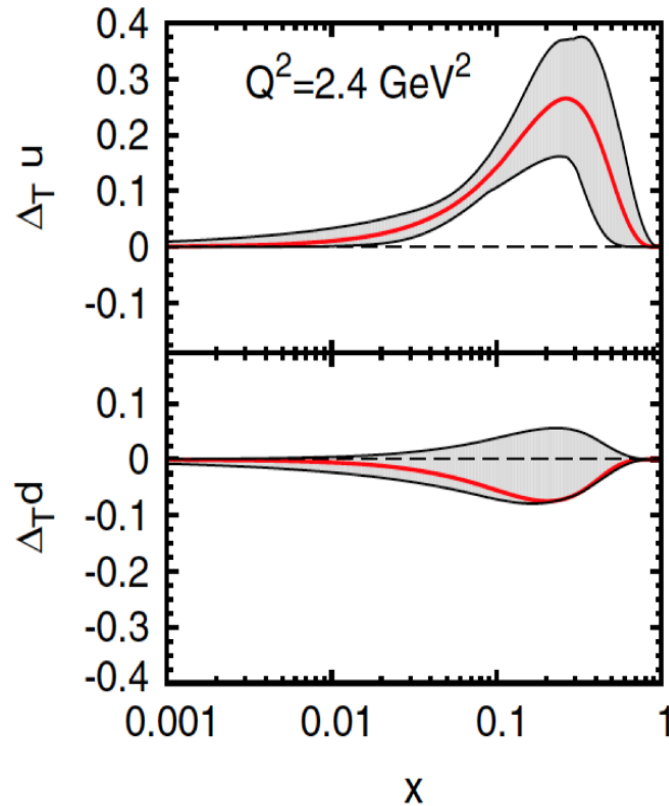
# Present status of TMDs extraction

Sivers



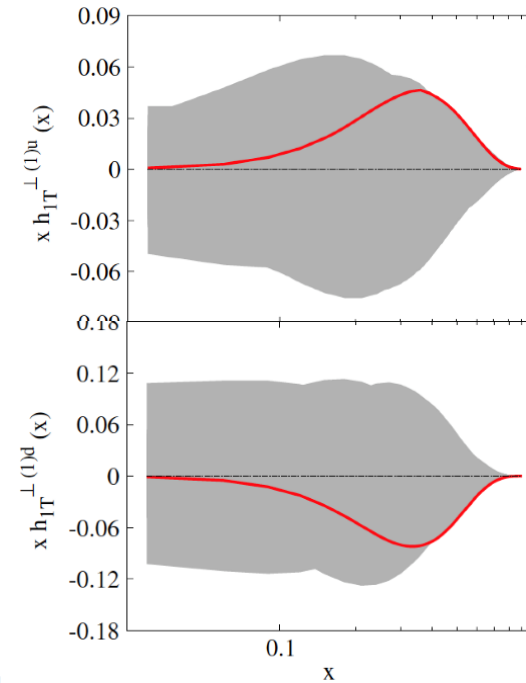
Anselmino et al, EPJA39, 89 (2009)

Transversity

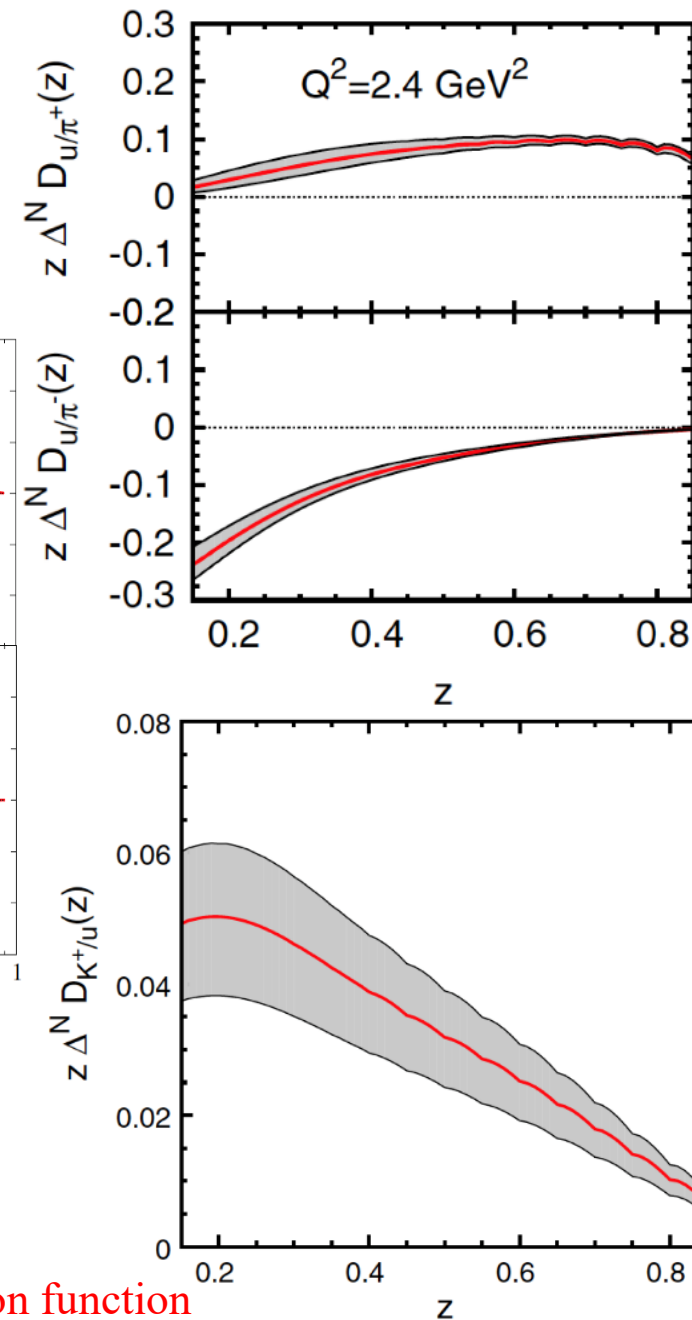


Anselmino et al, PRD92, 114023 (2015)

Pretzelosity



Lefky et al, PRD91, 034010 (2015)



Collins fragmentation function

Anselmino et al, PRD92, 114023 (2015)

PRD93, 034025 (2016)



# EicC-I projections on Sivers

U quark sivers EicC VS world data

d quark

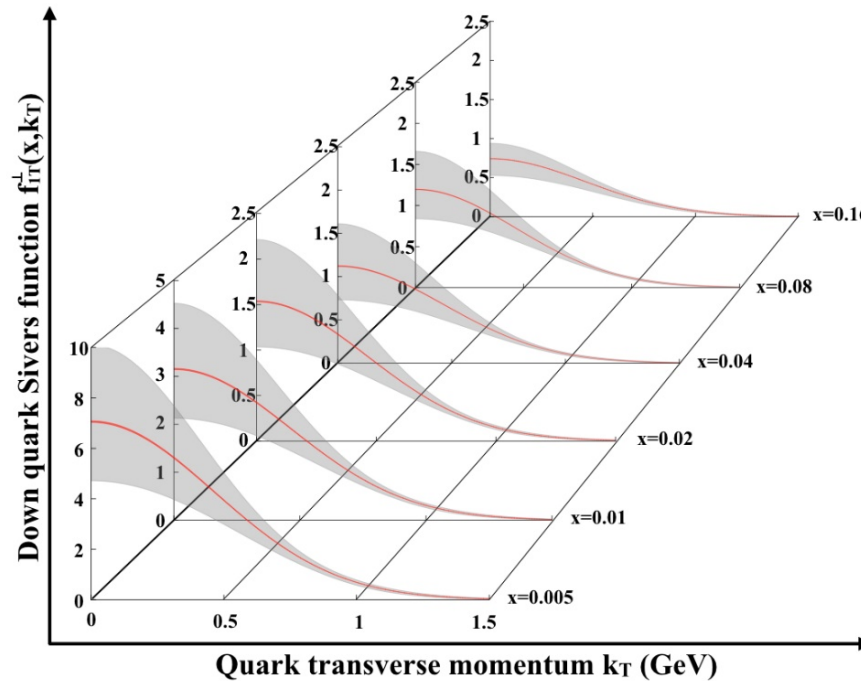
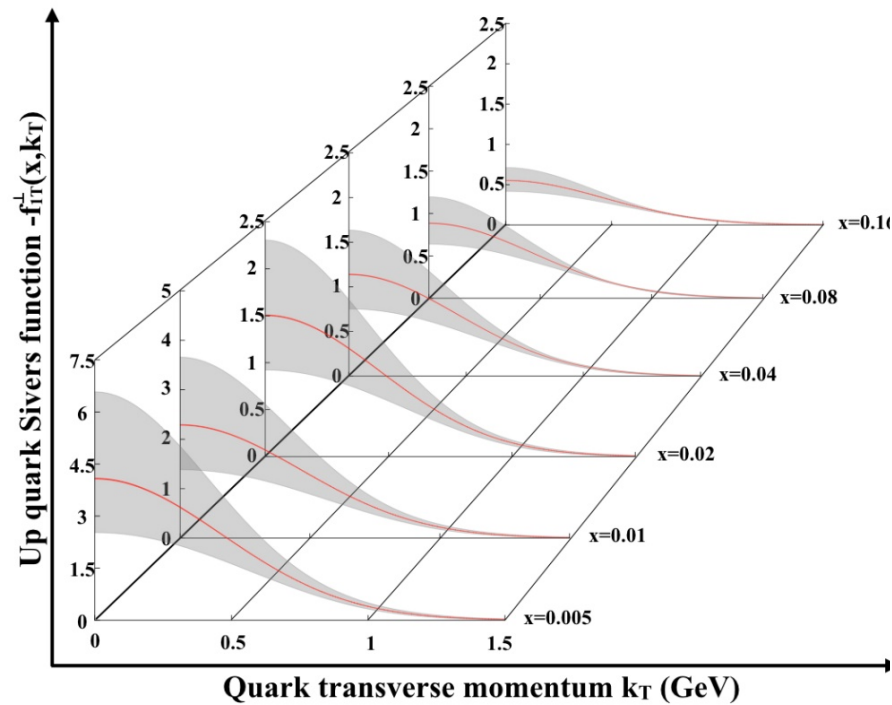
EicC SIDIS data:

- ✓ e x p 3.5 GeV x 20 GeV
- ✓ e x he3 3.5 GeV x 40 GeV (He3)

Lumi:

- ✓ Ep 50 fb<sup>-1</sup>
- ✓ eHe3 50 fb<sup>-1</sup> (per nucleus)

Pion, Kaon SIDIS measurements



Preliminary

LO study

Only u,ubar,d,dbar included

Current & target fragmentation  
un-distinguished clearly yet:

$W > 2.3 \text{ GeV}$

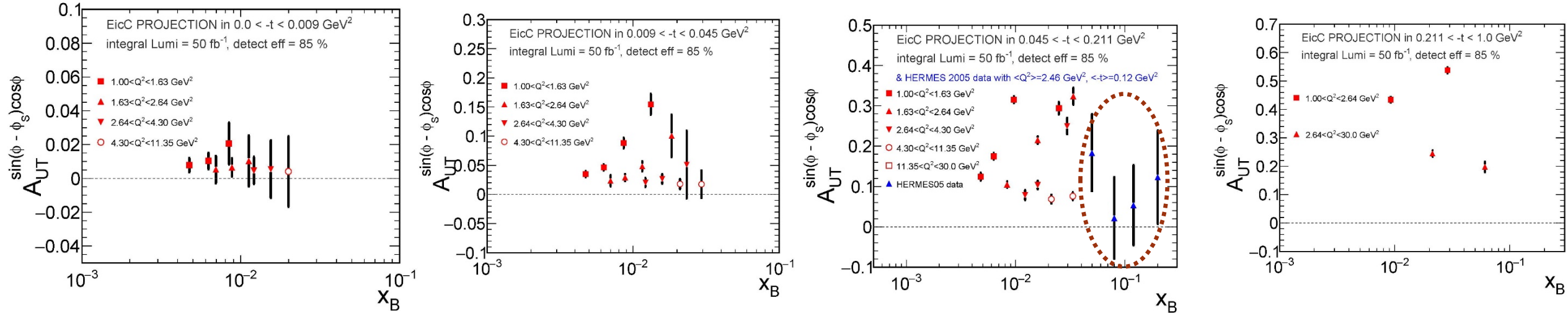
$W' > 1.6 \text{ GeV}$

$0.3 < z < 0.7$

$Q^2 > 1 \text{ GeV}^2$

# GPDs study via DVCS

Projection with multi-dimensional binning:  $t$ ,  $Q^2$ ,  $x_B$  (an example)



Polarized beam, unpolarized target (SSA)

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

Unpolarized beam, longitudinal target (LTSA)

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

Unpolarized beam, transverse target (tTSA)

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

Polarized beam, longitudinal target (DSA)

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

**All these asymmetries can be measured at EicC-I in high precision in multi-dimensional bins**

**On P and n for flavor separations**

# Other interesting physics topics

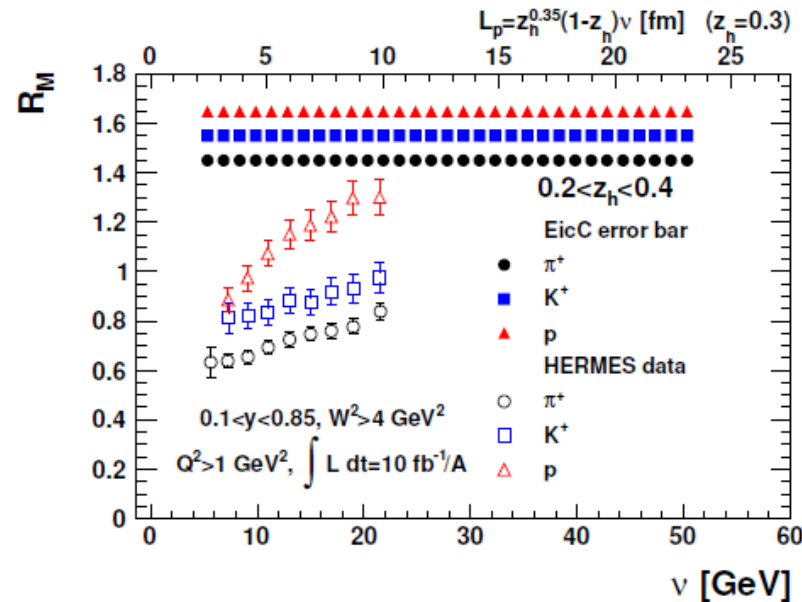
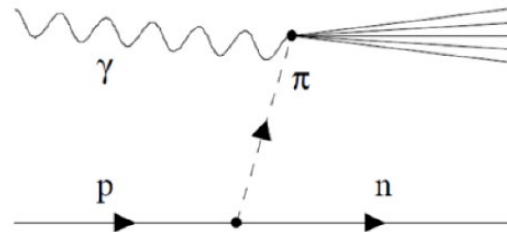
- Proton mass structure study

✓ **EicC with Upsilon near threshold production**

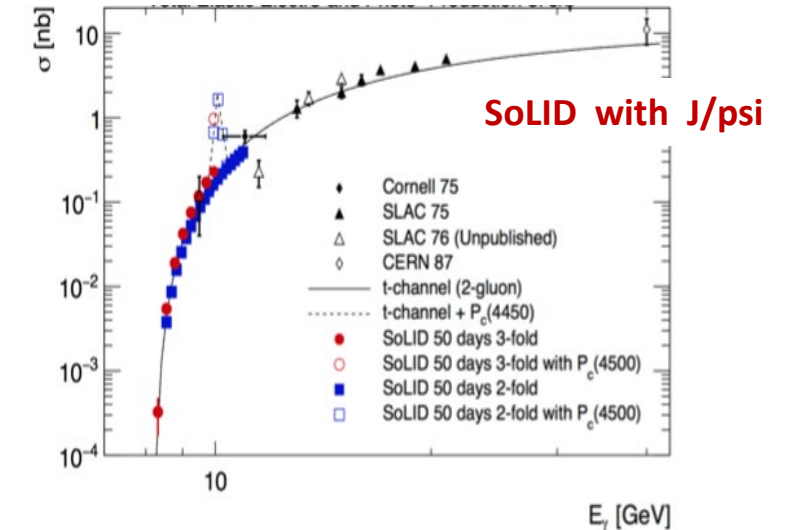
- Pion/Kaon structure

- Hadronization

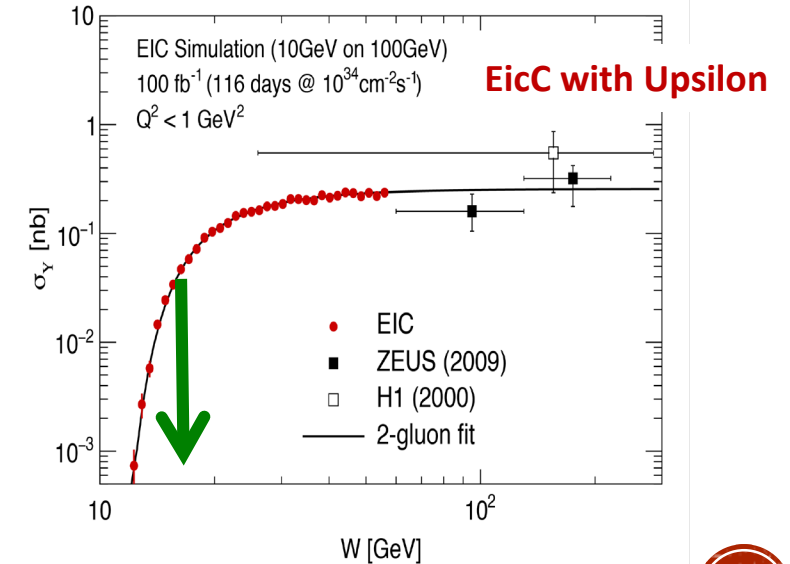
- And more...

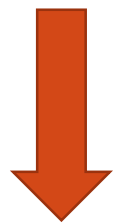


Total elastic Electro and photo-Production of J/psi

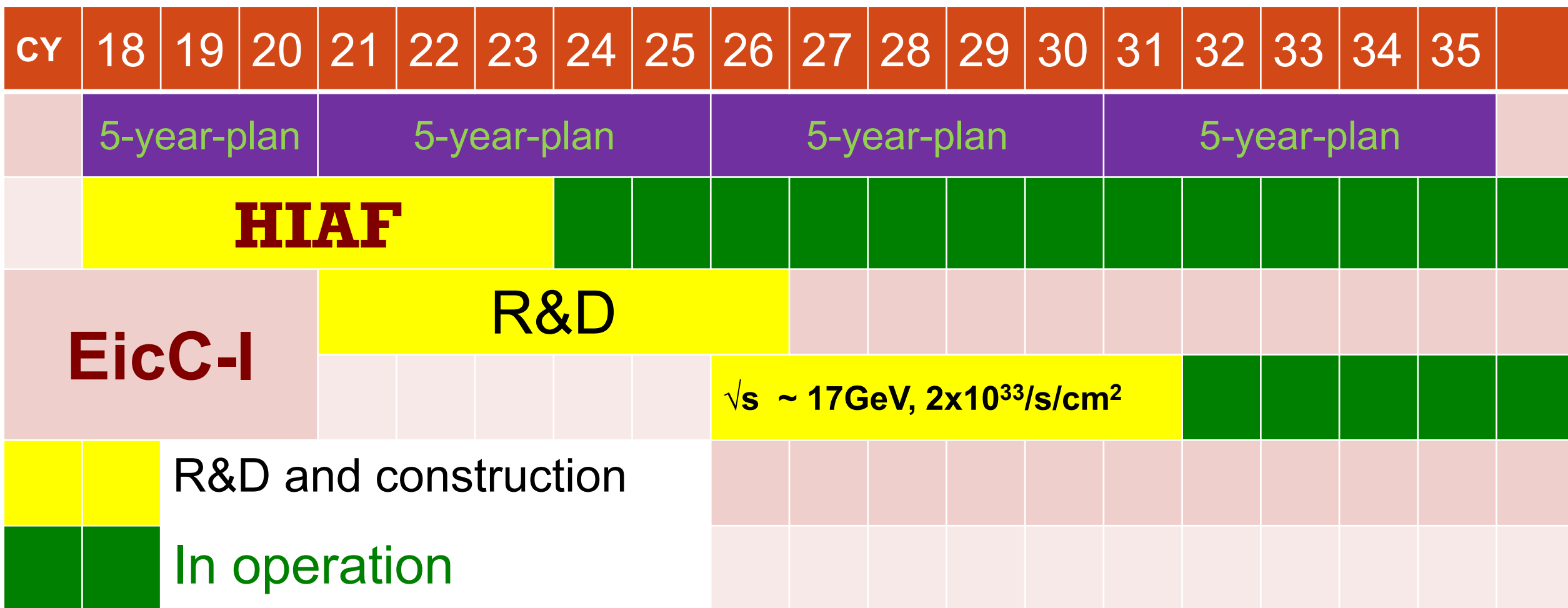


Total elastic Electro and photo-Production of Upsilon





# Timeline for the project



EicC white paper will be submitted to the government by the end of 2019 → put project in line in the next 5-year-plan



# Summary

- EicC-I has been proposed based on the HIAF facility (under construction)
  - ✓ polarized electron beam (3.5 GeV) and polarized proton beam (20 GeV)/ion beam (20 GeV/u)
  - ✓ Both beams are polarized
- High precision measurements for 1D (helicity), 3D (TMDs/GPDs) nucleon spin structure study with flavor separation in the valence and sea quark dominated region
- Other interesting physics topics will be delivered as well, not mentioned here in details
- Complimentary to the US EIC with higher center-of-mass
- Plan: To put EicC-I project in the next 5-year-plan starting from 2021

**Please join us if you are interested in the EicC-I project, from physics to detectors, to anything you are interested in!**