



Electron **I**on **C**ollider in **C**hina, EicC

Physics Highlights at EicC and the project status

1

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中国极化电子离子对撞机计划

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Outline

- EicC highlighted physics
- Why do we need both EIC in China (**EicC**) and EIC in the US (**BNL EIC**)
- EicC project status

Celebration of Higgs boson discovery

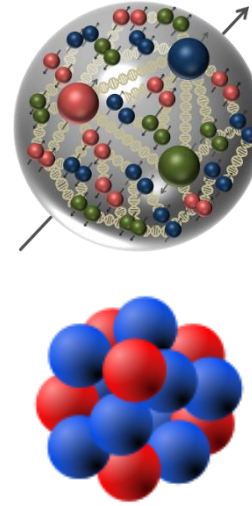
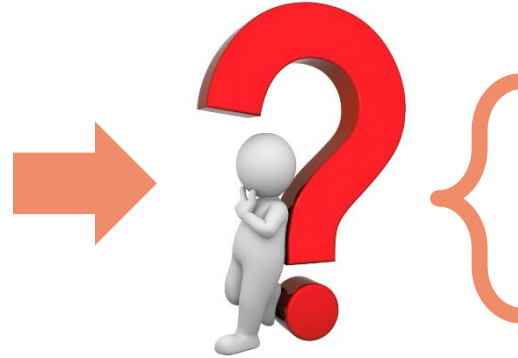
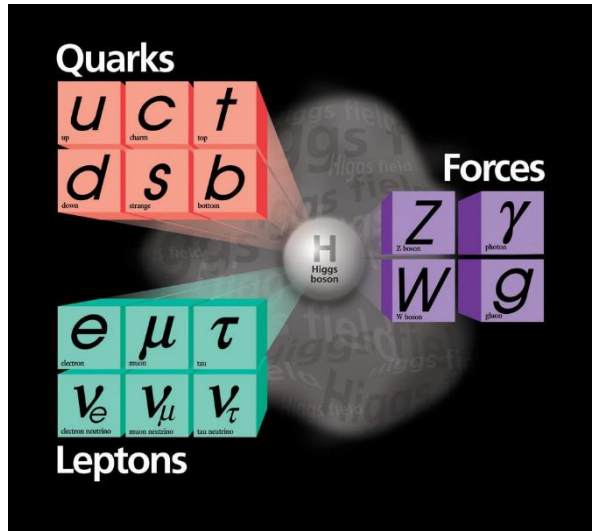


2013 Nobel prize in physics

... for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles ...

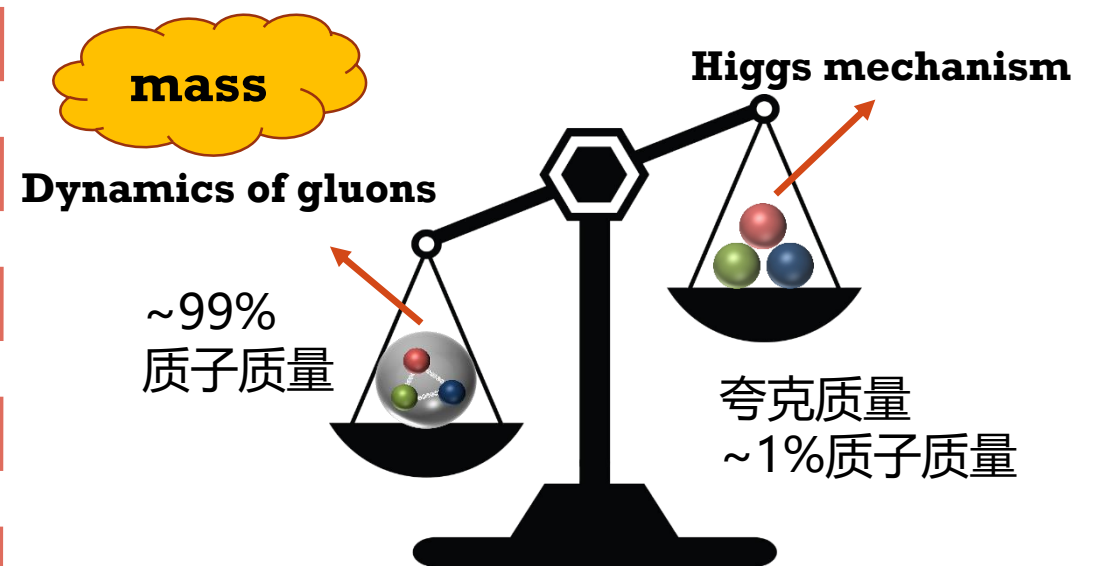
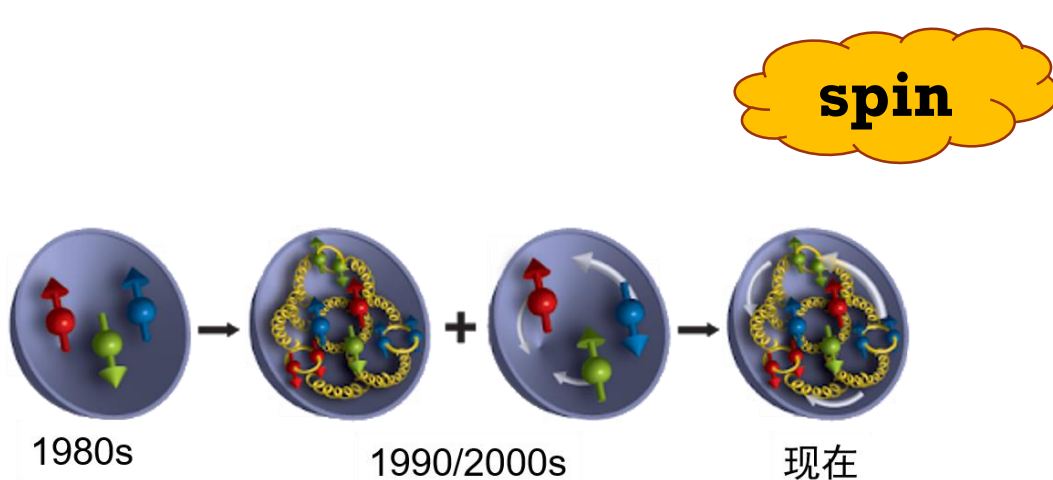
However... do we really understand the building blocks of our visible world?

We know very little...



Spin structure

Mass structure



EicC highlighted physics

- Spin structure of the nucleon: 1D, 3D

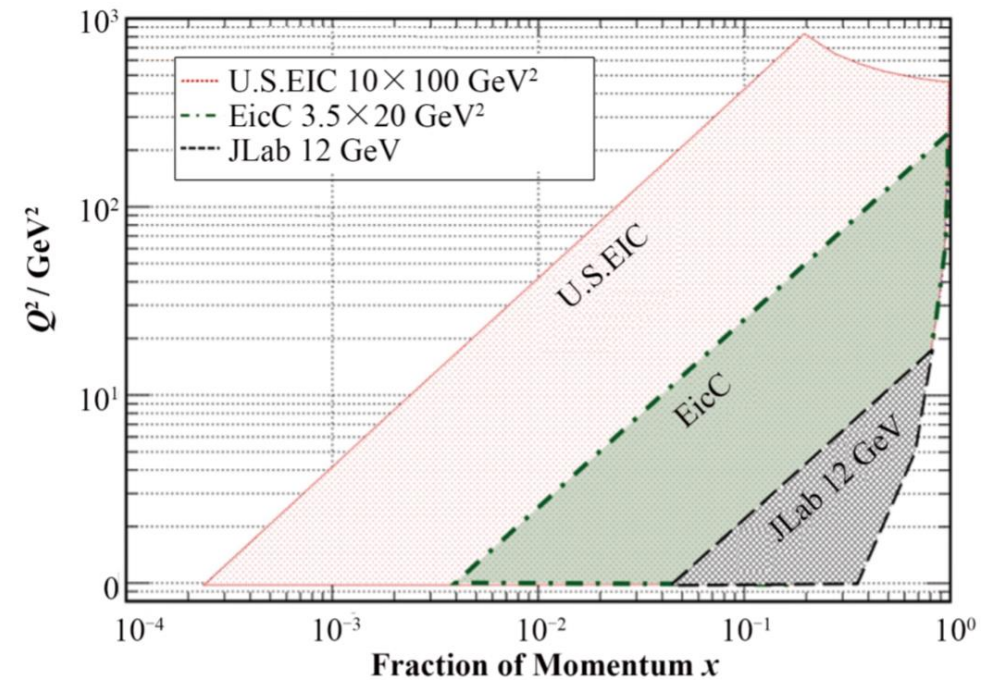
- polarized electron + polarized proton/light nuclei

- Partonic structure of nuclei and the parton interaction with the nuclear environment

- unpolarized electron + unpolarized various nuclei

- Exotic states with $c/\bar{c}$, $b/\bar{b}$

- Origin of the proton mass study via heavy quarkonia near-threshold production

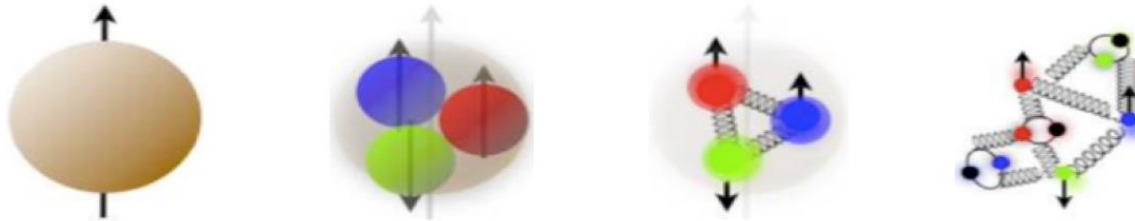


EicC highlighted physics

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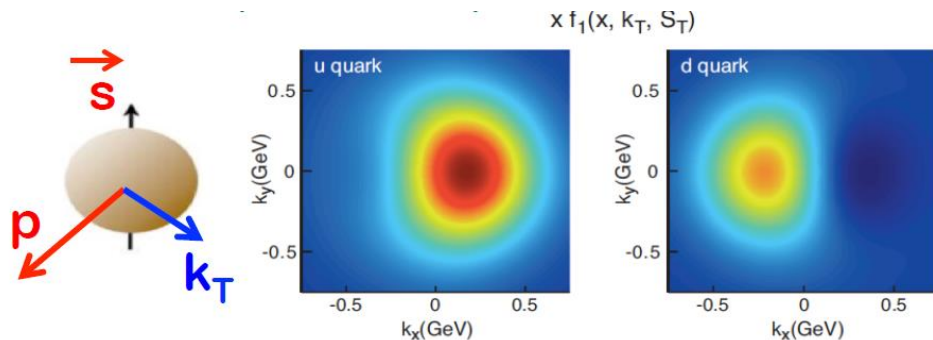
Questions driving the spin physics

- 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!

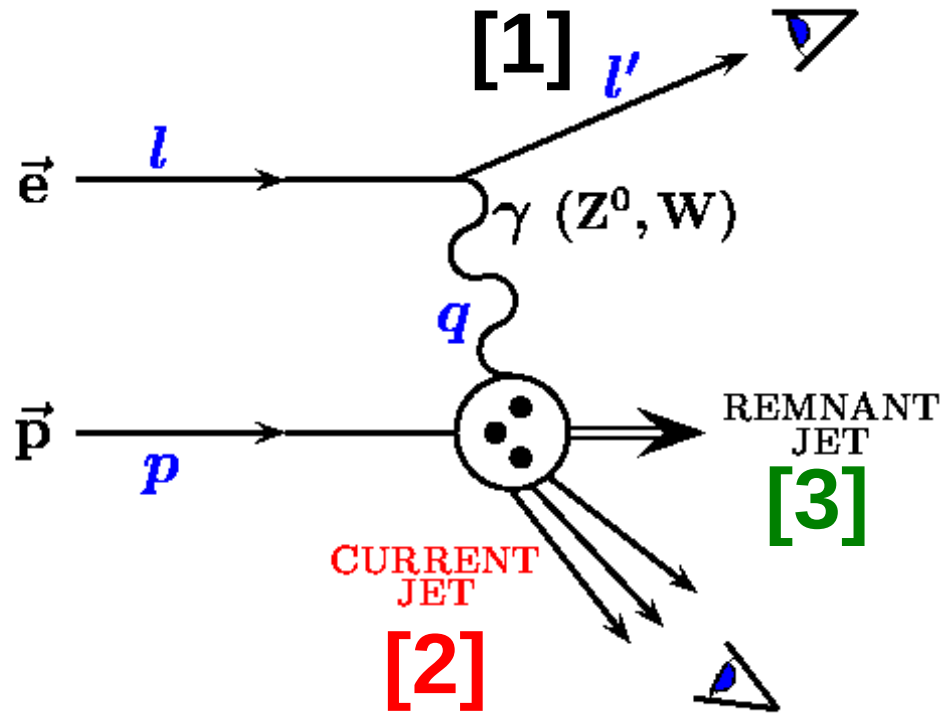
- How does proton's spin influence the spatial distribution of partons?

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



GPDs!

Lepton-Nucleon Scatterings



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

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

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

$$s = 4E_e E_p$$

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

- QED probe is clean
- $\alpha_{\text{EM}} \sim 1/137$ with broad Q coverage
- One-photon exchange approximation: $\sim 1\%$ accuracy
- Detection scale is determined by Q^2 : $1\text{GeV}^2 \sim \text{nucleon size}$

Observe scattered electron/muon

Observe current jet/hadron

Observe remnant jet/hadron as well

[1] $\rightarrow$ inclusive

[1]+[2] $\rightarrow$ semi-inclusive

[1]+[2]+[3] $\rightarrow$ exclusive

Spin structure of the nucleon

An effort of more than 30 years

	Quark Spin	Gluon Spin
SLAC -> 2000	E80 – E155	
CERN ongoing	EMC, SMC, COMPASS	
DESY ->2007	HERMES	
JLab ongoing	Hall A,B,C	
RHIC ongoing	(BRAHMS), (PHENIX), STAR	

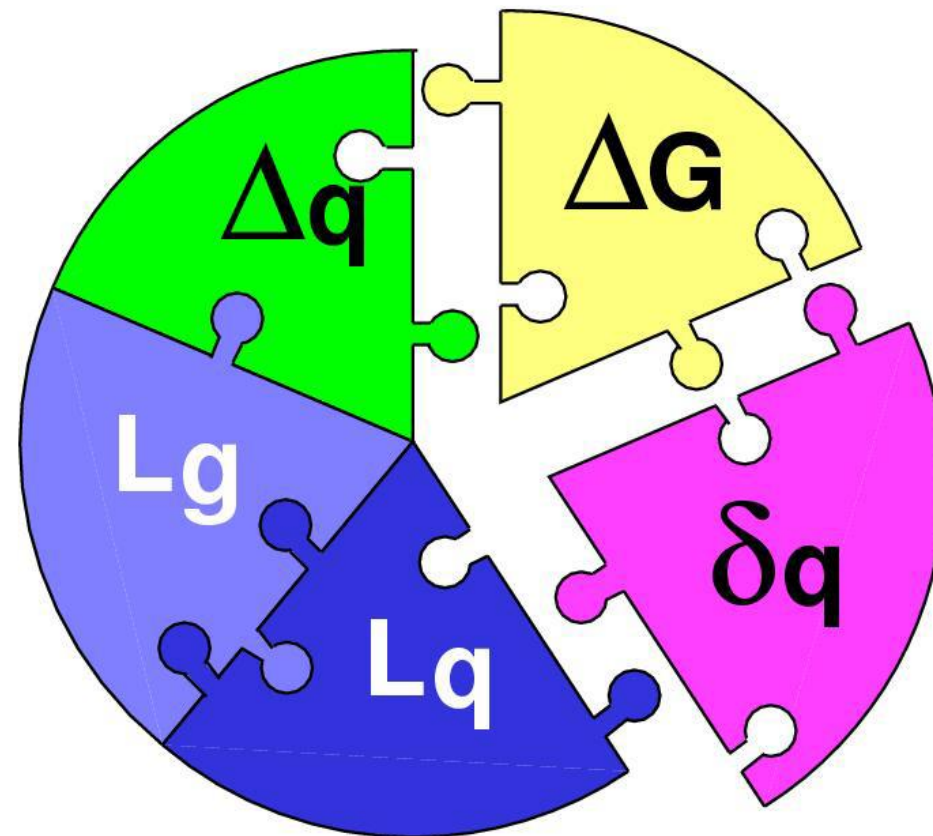


SIDIS/DIS



Polarized p+p

Fundamental question:

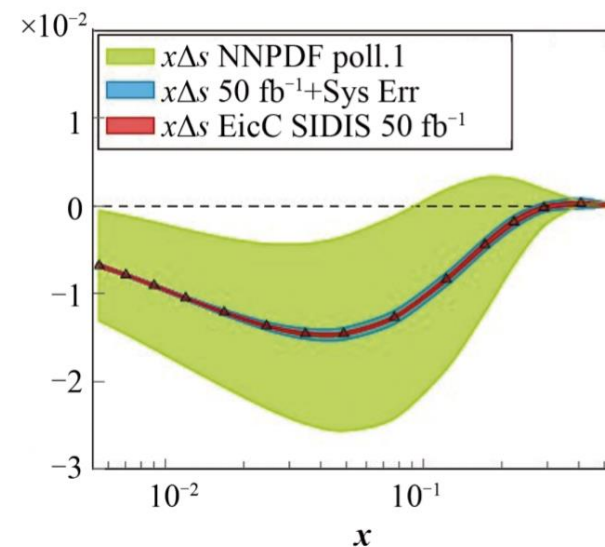
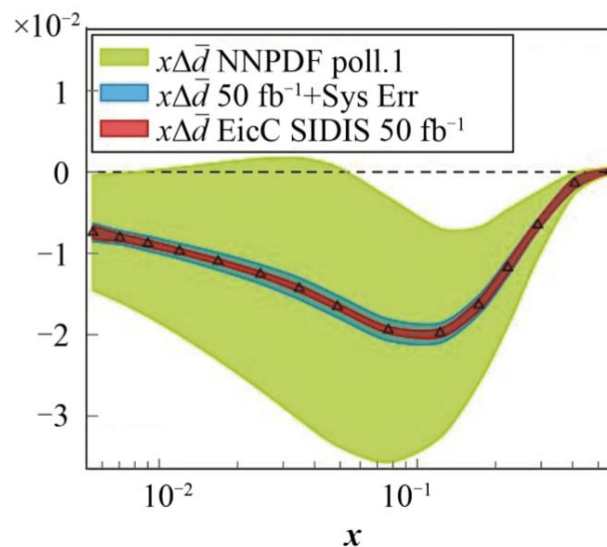
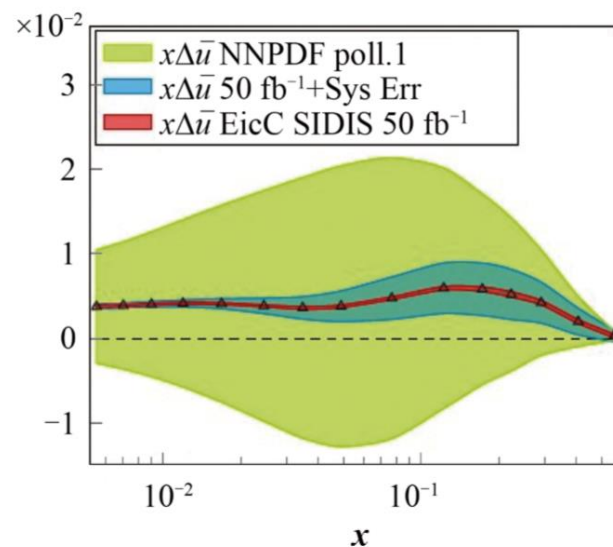


Finally, EIC is approaching...

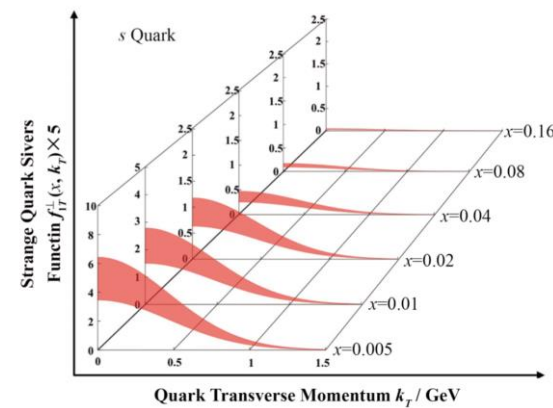
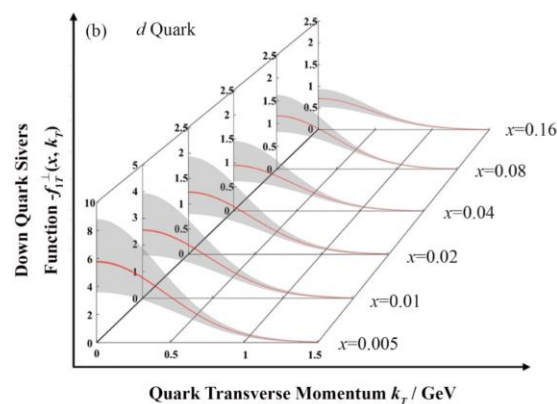
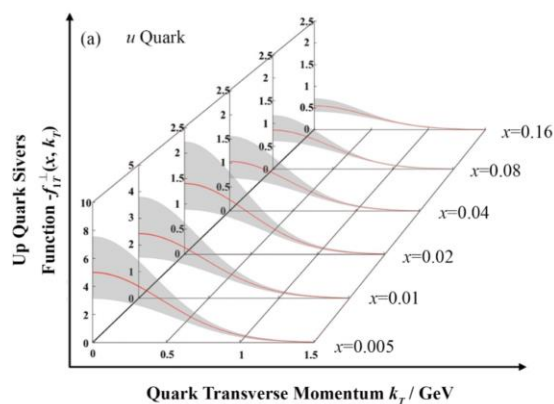
Impact of EicC

50 fb⁻¹: around 2 years of running

1D polarized helicity PDFs

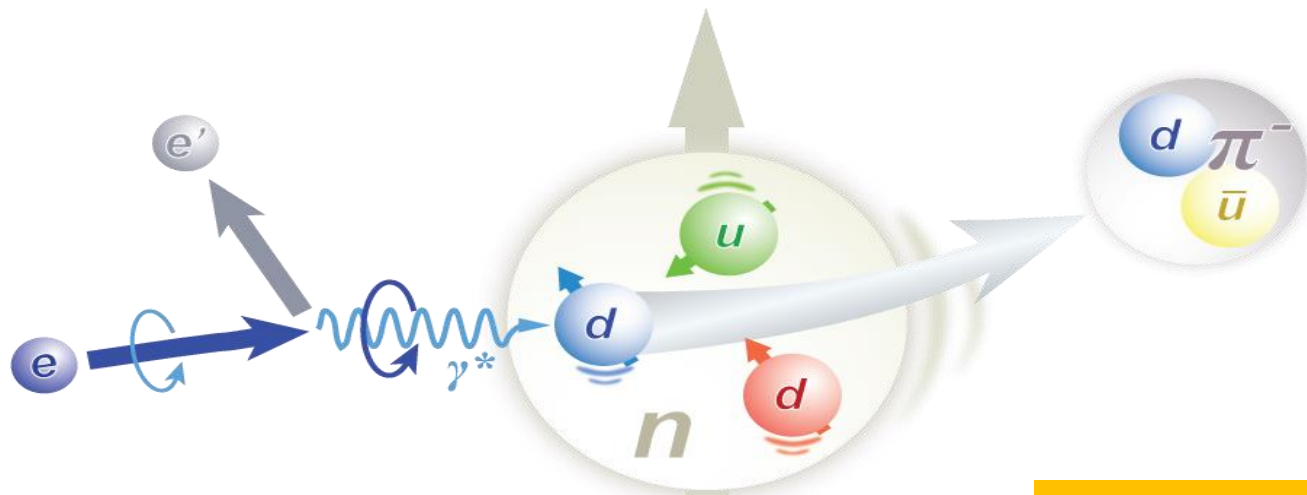


3D-Tomography, Sivers TMDs



Electron-positron collider can contribute significantly

SIDIS



A golden channel
for spin structure study

1D polarized helicity PDFs

$$g_1^h(x, Q^2, z) = \frac{1}{2} \sum_q e_q^2 \left[\Delta q(x, Q^2) D_q^h(z, Q^2) + \Delta \bar{q}(x, Q^2) D_{\bar{q}}^h(z, Q^2) \right]$$

3D-Tomography, TMDs

$$A_{UT}^{Collins} \propto \langle \sin(\phi_h + \phi_S) \rangle_{UT} \propto h_1 \otimes H_1^\perp$$

$$A_{UT}^{Sivers} \propto \langle \sin(\phi_h - \phi_S) \rangle_{UT} \propto f_{1T}^\perp \otimes D_1$$

$$A_{UT}^{Pretzelosity} \propto \langle \sin(3\phi_h - \phi_S) \rangle_{UT} \propto h_{1T}^\perp \otimes H_1^\perp$$

非极化碎裂函数

e+ / e- 对撞机上直接高精度测量

非极化碎裂函数 + Collins 碎裂函数

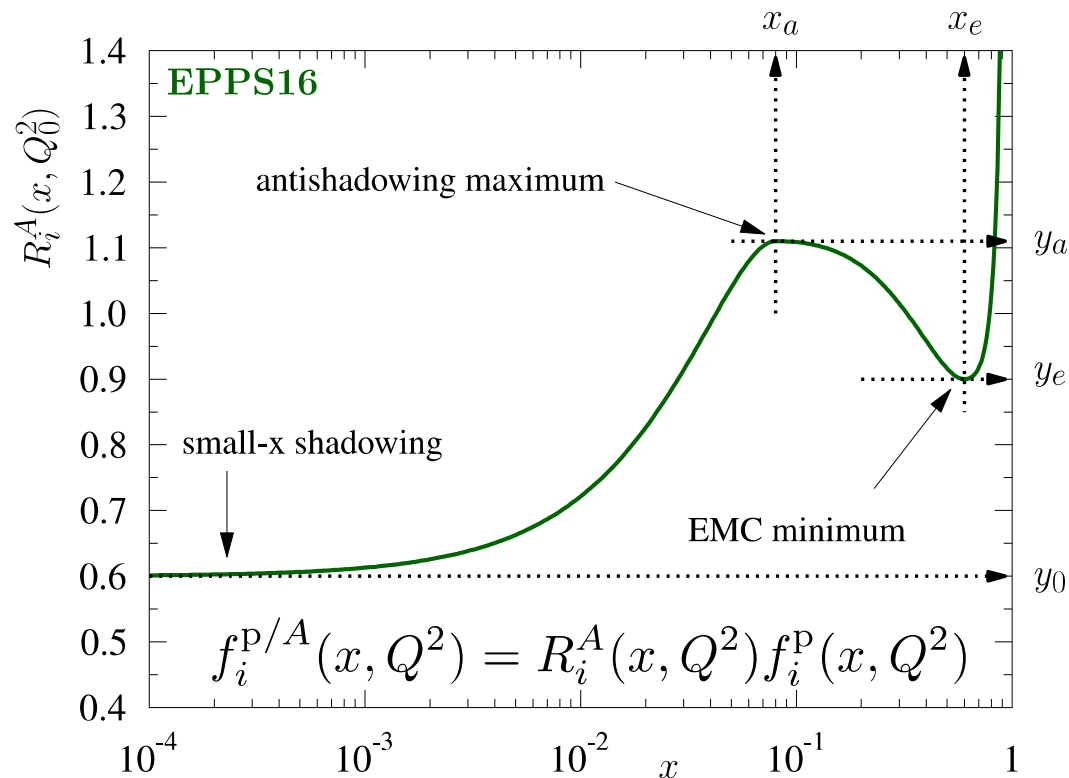
EicC highlighted physics

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PDFs study in nuclei

- Nuclear parton distribution functions

- Data far away from precise
- Especially for different quark flavors and gluon

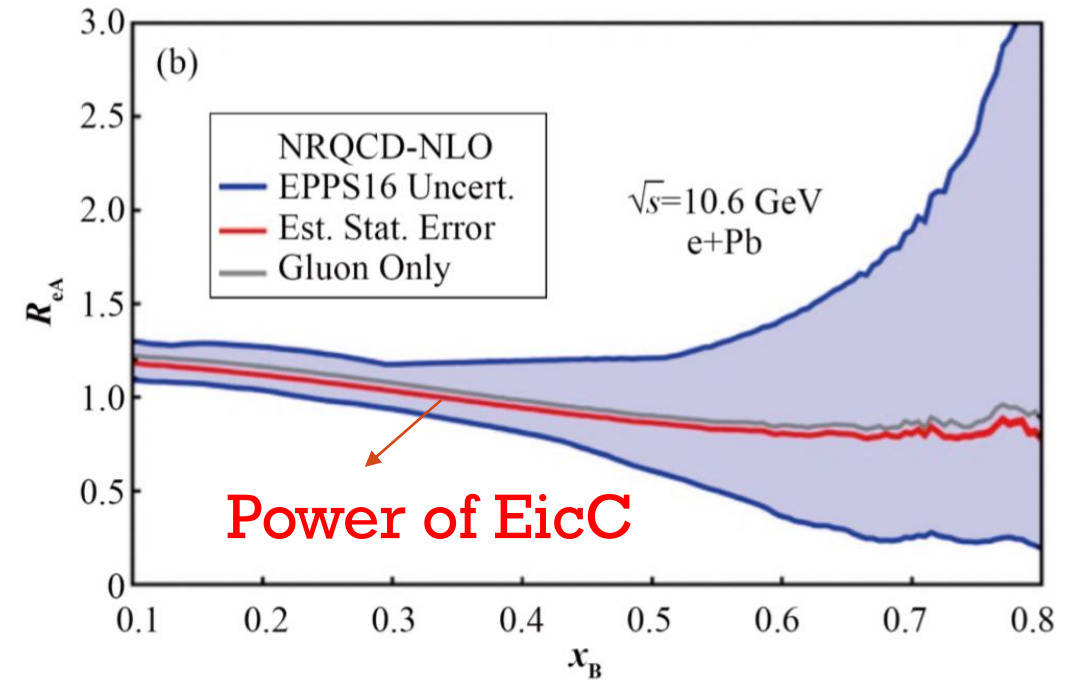


- Probe nuclear gluon distribution in large- x region

- Nuclear modification factor:

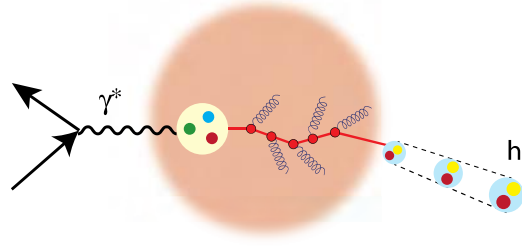
$$R_{eA} = \frac{d\sigma^{eA} / dx dQ^2}{d\sigma^{ep} / dx dQ^2}$$

- J/psi tagged DIS at EicC could provide precise probe of nuclear gluon distribution in the region $0.4 < x_B < 0.8$.

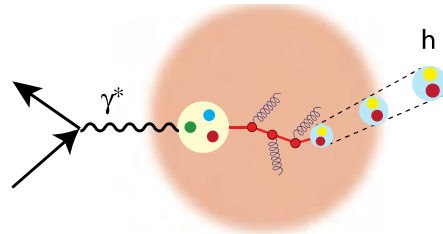


Propagation of a color charge in cold nuclear matter

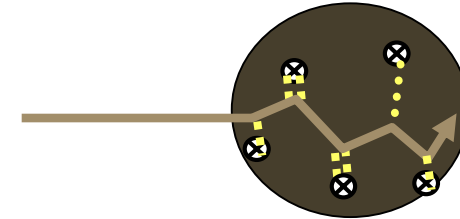
Two mechanisms of parton propagating in nucleus



Parton energy loss
(solid lines)



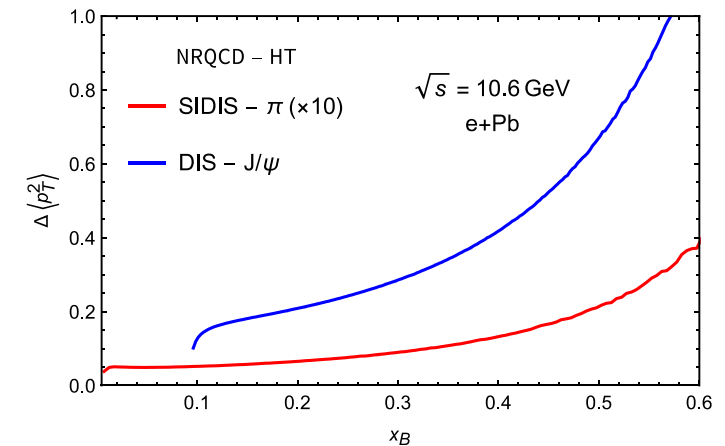
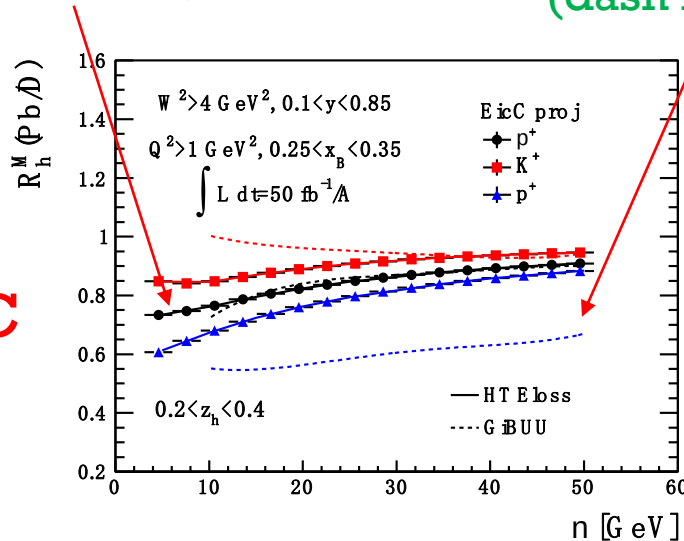
Hadronization in medium
(dash lines)



Transverse momentum
broadening

$$\Delta \langle p_T^2 \rangle = \langle p_T^2 \rangle_{eA} - \langle p_T^2 \rangle_{ep}$$

Power of EicC



- ❖ Pin down the mechanisms of a color charge propagating in nuclear medium.
- ❖ Measure transverse momentum broadening in SIDIS and DIS-J/psi, extract medium property as characterized by jet transport coefficient → related to heavy ion physics

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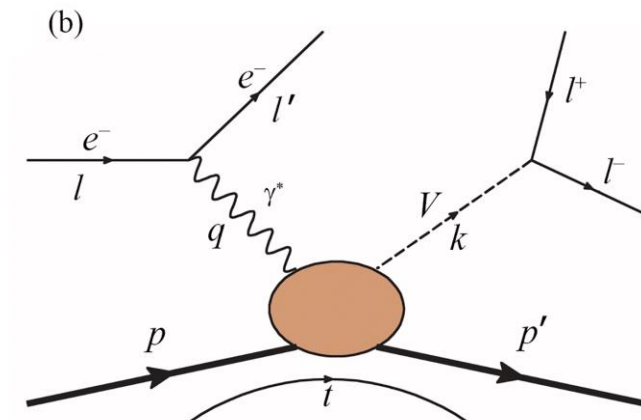
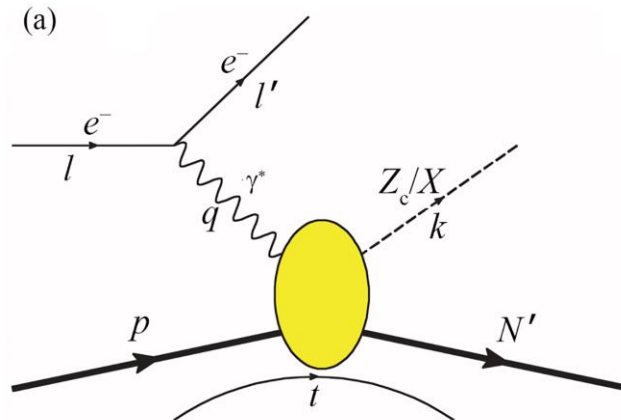
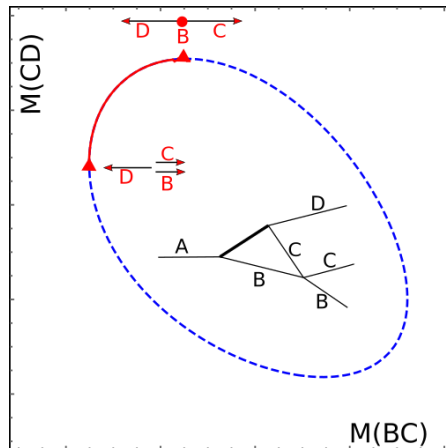
Potential advantages at EicC

- Larger cross-section compared to e^+e^- collision
- Smaller background compared to pp and $p\bar{p}$ collision
- Polarized beam $\rightarrow$ pin down the quantum numbers
- Gamma-P invariant mass, i.e. W , is a window in ep collision

$$B \rightarrow K \text{ } X \quad M_B - M_K \approx 4.8 \text{ GeV}$$

$$\Lambda_b \rightarrow K \text{ } P_c \quad M_{\Lambda_b} - M_K \approx 5.1 \text{ GeV}$$

- No triangle singularity for kinematics



You are the expert
We want you !!!

Preliminary study for the yield at EicC

---exclusive reconstruction

奇特强子态	产生、探测过程	探测效率	预期探测数量
$P_c(4312)$	$ep \rightarrow eP_c(4312)$ $P_c(4312) \rightarrow pJ/\psi$ $J/\psi \rightarrow l^+l^-$	$\sim 30\%$	15 ~ 1450
$P_c(4440)$	$ep \rightarrow eP_c(4440)$ $P_c(4440) \rightarrow pJ/\psi$ $J/\psi \rightarrow l^+l^-$	$\sim 30\%$	20 ~ 2200
$P_c(4457)$	$ep \rightarrow eP_c(4457)$ $P_c(4457) \rightarrow pJ/\psi$ $J/\psi \rightarrow l^+l^-$	$\sim 30\%$	10 ~ 650
$P_b(\text{narrow})$	$ep \rightarrow eP_b(\text{narrow})$ $P_b(\text{narrow}) \rightarrow p\Upsilon$ $\Upsilon \rightarrow l^+l^-$	$\sim 30\%$	0 ~ 20
$P_b(\text{wide})$	$ep \rightarrow eP_b(\text{wide})$ $P_b(\text{wide}) \rightarrow p\Upsilon$ $\Upsilon \rightarrow l^+l^-$	$\sim 30\%$	0 ~ 200
$X(3872)$	$ep \rightarrow eX(3872)p$ $X(3872) \rightarrow \pi^+\pi^-J/\psi$ $J/\psi \rightarrow l^+l^-$	$\sim 50\%$	0 ~ 90
$Z_c^+(3900)$	$ep \rightarrow eZ_c^+(3900)n$ $Z_c^+(4430) \rightarrow \pi^+J/\psi$ $J/\psi \rightarrow l^+l^-$	$\sim 60\%$	90 ~ 9300

- EicC: production and decay of heavy flavor hadron
- We know little about hidden charm&bottom photo-/electro-production

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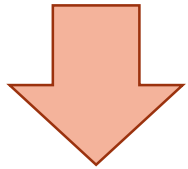
Proton mass decomposition

Covariant Decomposition of the Energy Momentum Tensor (EMT)

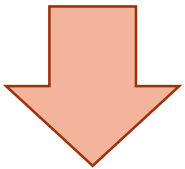
Proton Mass:

$$\langle P | T_{\alpha}^{\alpha} | P \rangle = 2P^{\alpha} P_{\alpha} = 2M_p^2$$

$$T_{\alpha}^{\alpha} = \underbrace{\frac{\tilde{\beta}(g)}{2g} F^{\mu\nu,a} F_{\mu\nu}^a}_{\text{QCD trace anomaly}} + \underbrace{\sum_{q=u,d,s} m_q (1 + \gamma_m) \bar{\psi}_q \psi_q}_{\text{Light quark mass}}$$



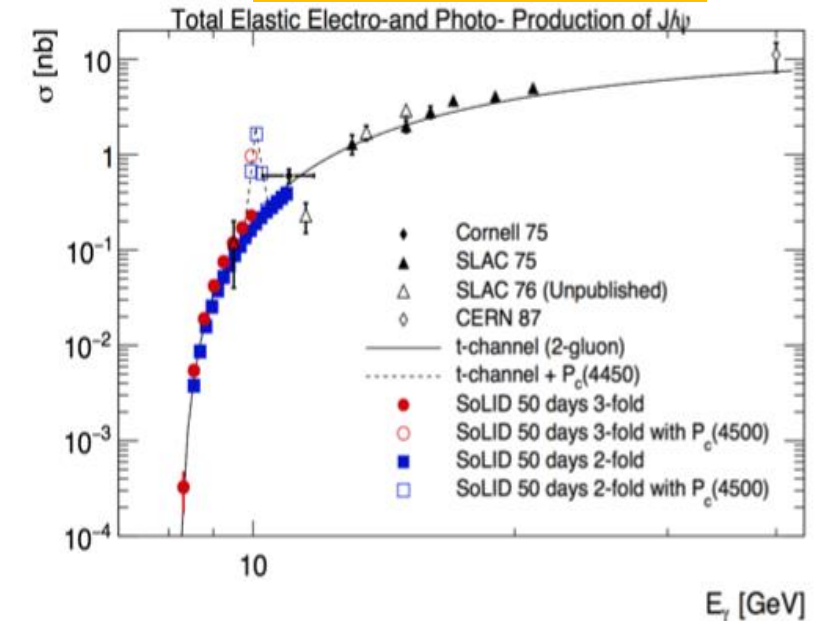
Could be studied via heavy quarkonia near threshold production



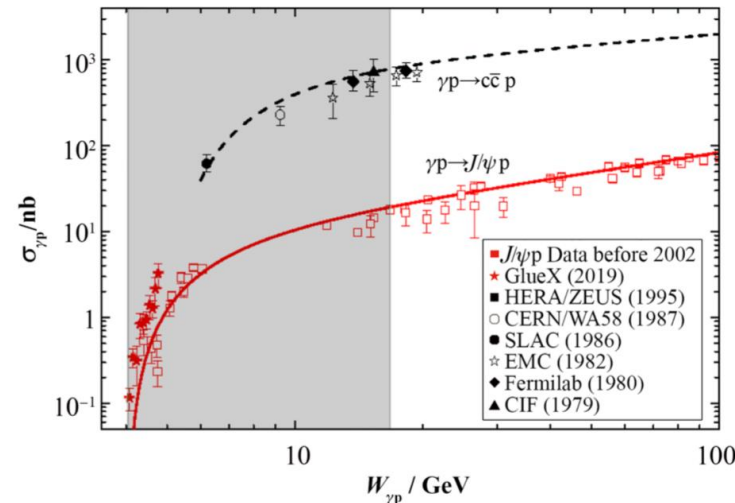
JLab-12 GeV: J/Psi
EicC: Upsilon

Potential breakthrough ...

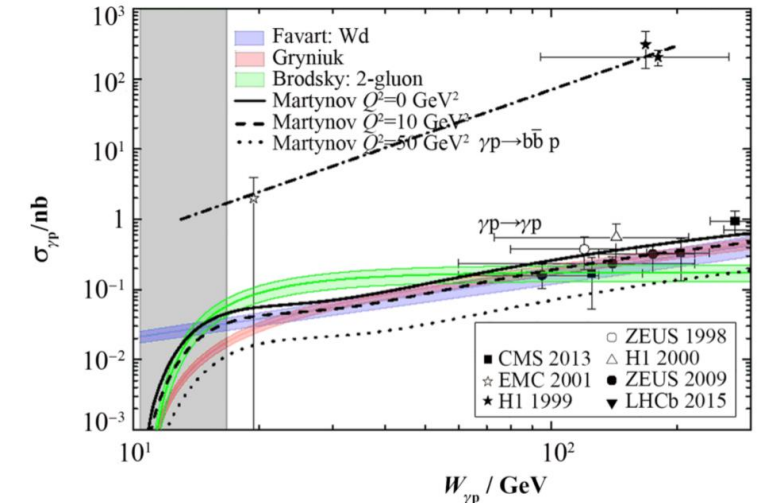
SoLID at Jlab: J/Psi



EicC: J/Psi



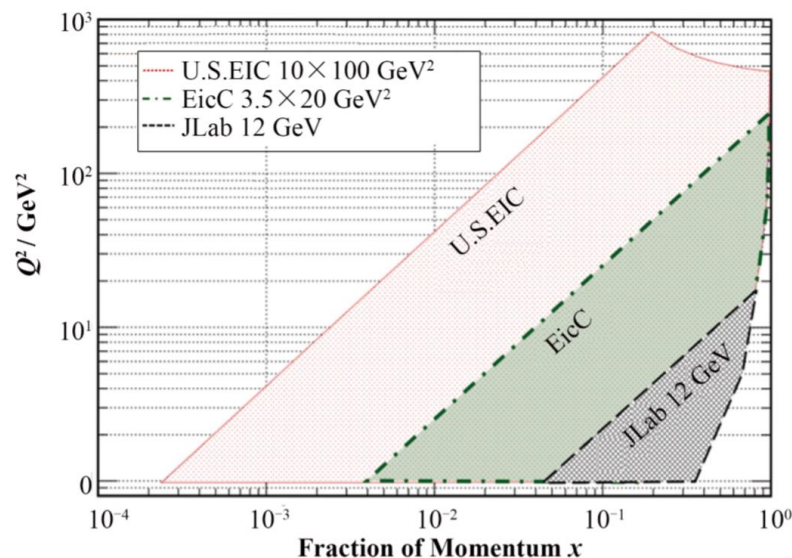
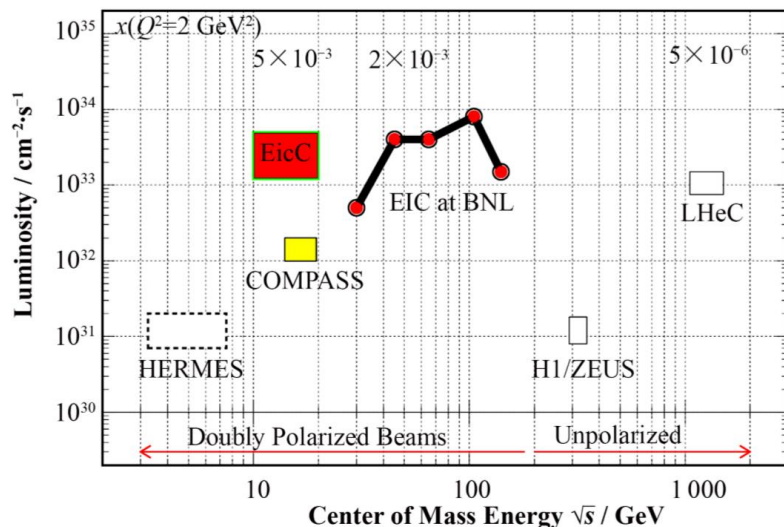
EicC: Upsilon



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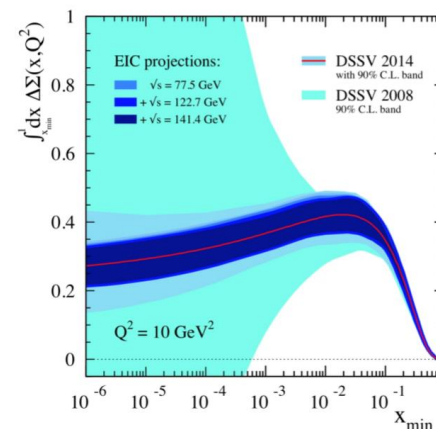
EicC VS EIC-US



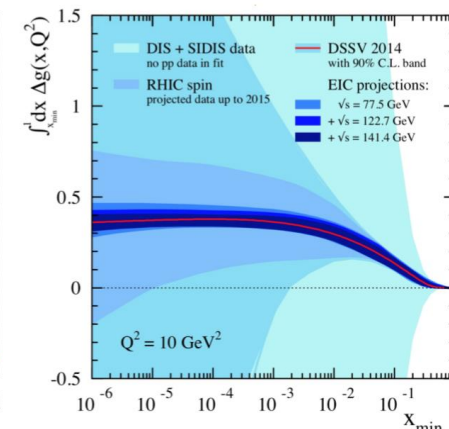
US-EIC: Optimized for gluon related physics

Spin physics

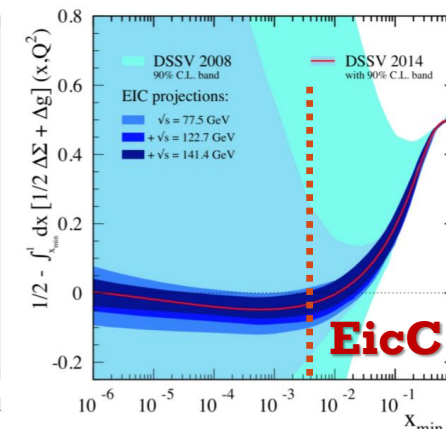
Optimized for sea quarks, orbital angular momentum



Quark spin



Gluon spin



Orbital angular momentum

US-EIC: Saturation at small x → QCD Phase

Nuclear PDFs

Systematic & precise studies at moderator x → LHC physics

Proton mass

EicC: near threshold $b/\bar{b}$ production
Complementary with JLab measurements

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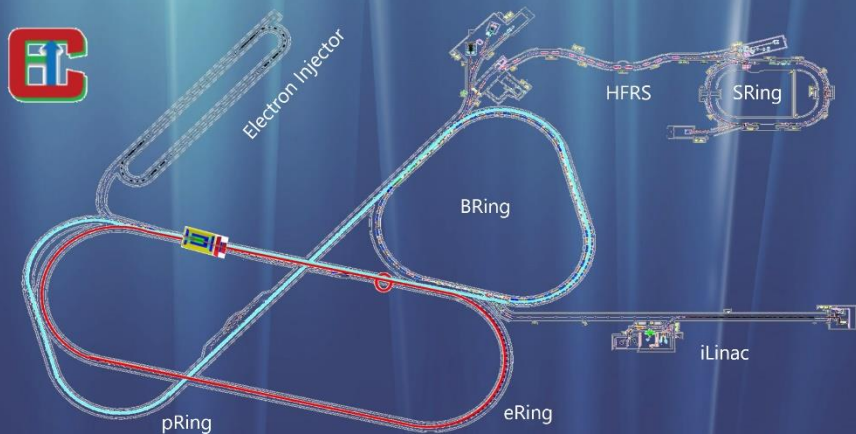
ISSN 0253-3219
CN 31-1342 / TL
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核技术

NUCLEAR TECHNIQUES

Vol.43 No.2 2020.2



中国极化电子离子对撞机计划专辑(P.020001)

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上海应用物理研究所
主办
中国核学会

科学出版社

Next steps:

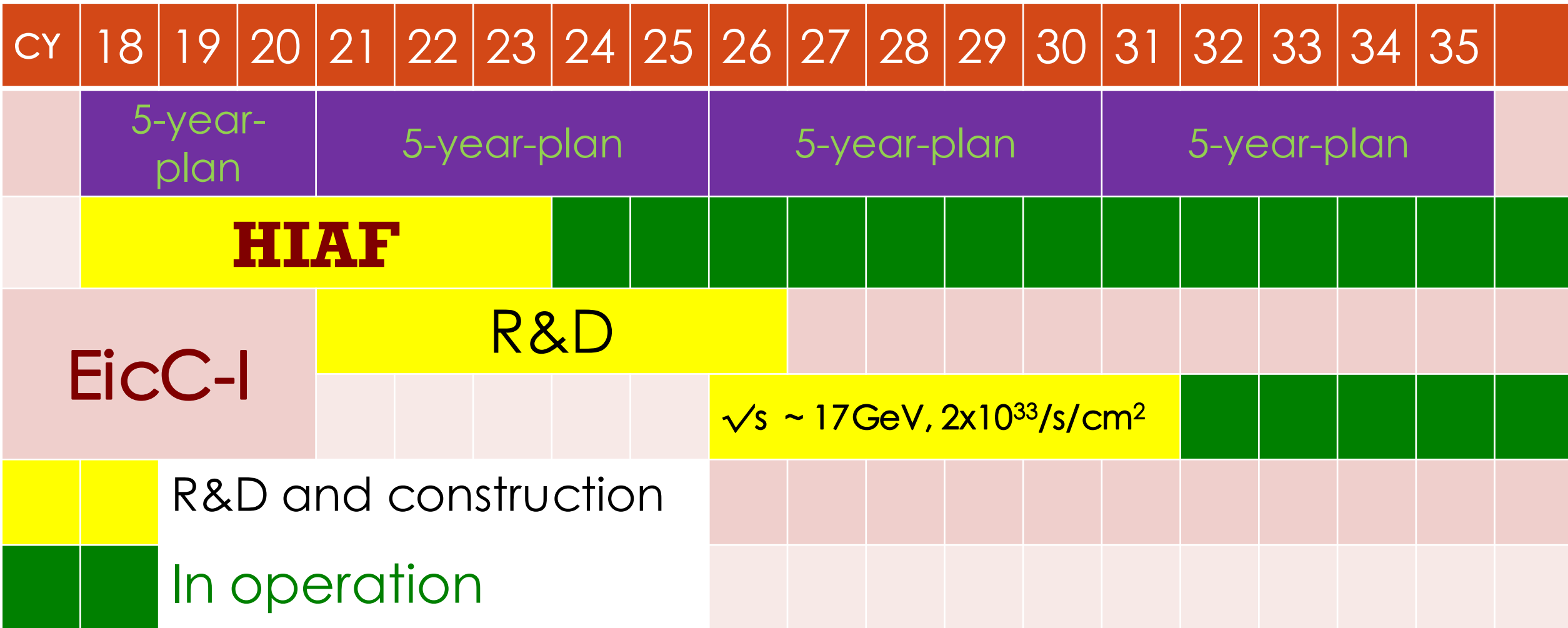
- English version of EicC white paper (**summer 2020**)
- Detailed simulations involving detector design and optimization
- Detector Hardware R&D, **such as EMcal, tracker R&D**
- Accelerator design optimization and R&D
- ...

Looking for collaboration...

Accelerator Conceptual design → Jiancheng's presentation

Detector Conceptual design → Yutie's presentation

Possible Timeline for the project





Electron **I**on **C**ollider in **C**hina, EicC

Understand the vacuum excitation

Backups