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# An Electron Ion Collider Plan in China

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CAS, Lanzhou, China

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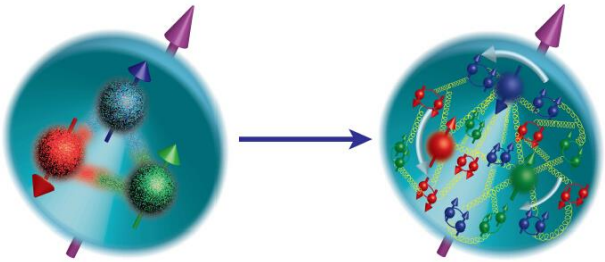
# EIC@China Project

- IMP and HIAF Project
- EIC@HIAF Project

  3 GeV (pol. e) X 12 GeV (pol. p), L= $4 \times 10^{32}$
- Unique Opportunities for EIC@HIAF
  - Spin-Flavor Structure (sea quark polarization)
  - 3-d Structure of the Nucleon (GPDs/TMDs)
  - $\pi$/K Structure Functions
  - Hadronization/EMC/SRC
- Summary



# Part 1

# IMP and HIAF

# Institute of Modern Physics (IMP)

- 1957: The institute of Modern Physics(IMP) was founded. It is affiliated with the Chinese Academy of Sciences (CAS)
- 1991: Heavy Ion Research Facility in Lanzhou (HIRFL).
- 2007: Cooler Storage Ring (HIRFL-CSR) : ~1 GeV/u for heavy ion up to U
- Main focus: basic research in heavy ion physics and related interdisciplinary science
- Research center for low-to-intermediate energy physics in China.
- 800 scientists and engineers
- 2011New Proposal: High Intensity Heavy Ion Accelerator Facility (HIAF)


**(Physics Today, May 2013)**

# China prepares to spend billions (US Dollars) on science & technology

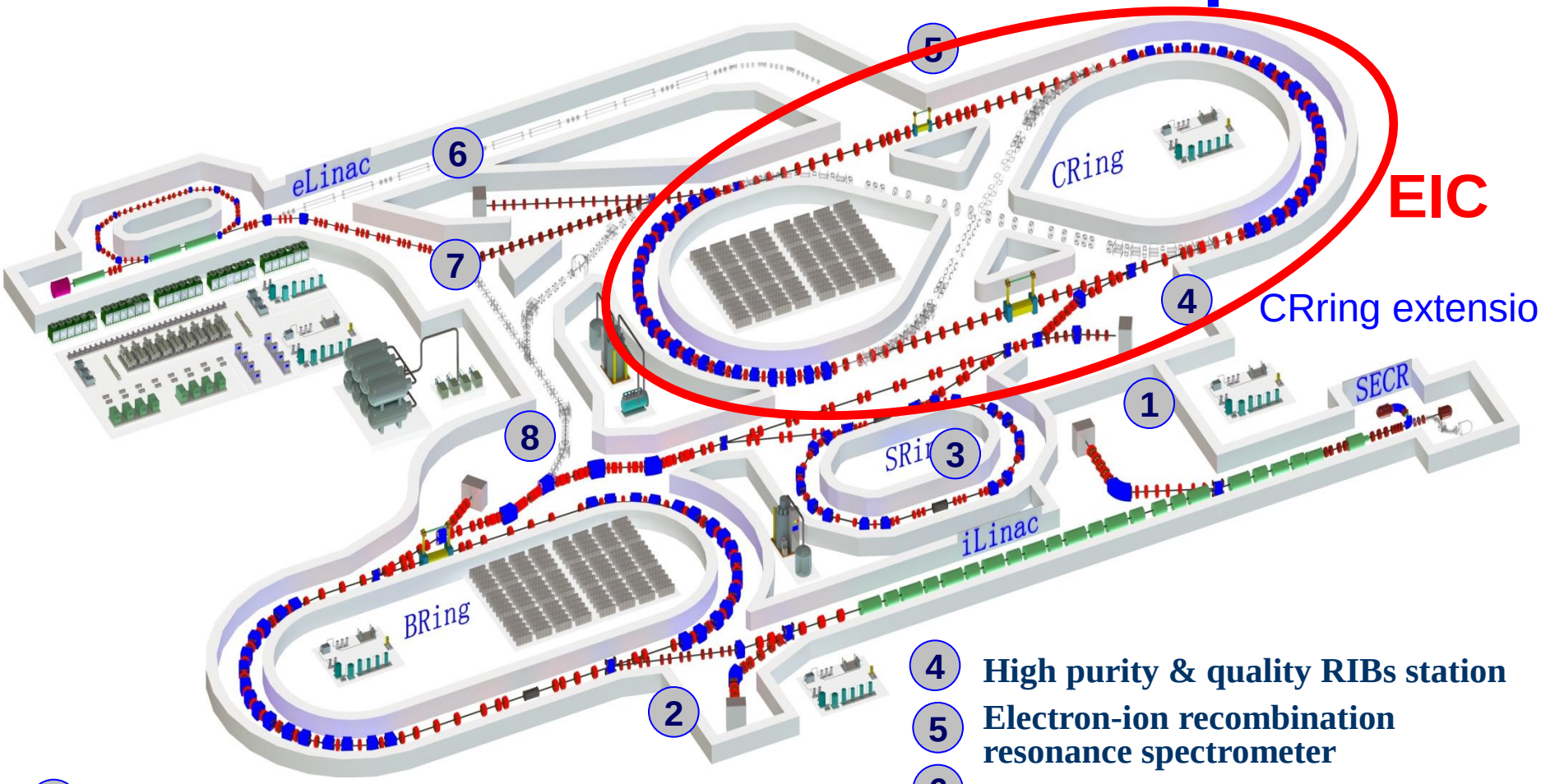
## 12th five-year plan: Mid- to long-term projects ranked by priority

**China National Mid- to long-term projects:**

- 12th five-year plan: 2011~2015
- 13th five-year plan: 2016~2020

1. Ocean-floor scientific survey network
2. High-energy synchrotron test facility
3. Accelerator-driven subcritical reactor research facility
4. Synergetic Extreme Condition User Facility
5. High-flux heavy ion accelerator ---> HIAF
6. High-efficiency, low-carbon gas turbine testing facility
7. Large High Altitude Air Shower Observatory
8. Future network experimental facility
9. Outer-space environment simulating facility
10. Translational medicine research facility
11. China Antarctic Observatory
12. Precision gravity measurement research facility
13. Large-scale low-speed wind tunnel
14. Shanghai Synchrotron Radiation Facility Phase-II Beamline Project
15. Model animal phenotype and heredity research facility
16. Earth system digital simulator

# Overview of the HIAF Complex




1. Low energy nuclear structure spectrometer
2. Low energy RIBs beam station
3. High precision spectrometer
4. High purity & quality RIBs station
5. Electron-ion recombination resonance spectrometer
6. High energy irradiation terminal
7. High-Energy-Density Matter terminal
8. External target station

# Part 2

# EIC@HIAF Project

# EIC@ HIAF Propose

- **Initial goals for HIAF:**
  1) Nuclear Physics (rare isotope)
  2) high-energy-density matter
  3) applications …
- **New:** add collision physics –EIC

  Discussions, 2012- 2014: inputs from Chinese and international communities

  Phase one: 3 GeV (pol. e) x 12 ~16 GeV (pol. p), L >= $4x10^{32}$

  Time: significantly before US EIC (5 ~10 years)
- **Many discussions on China EIC plan:**
  - $2^{nd}$ Int. Conf. on "QCD and Hadron Physics", March, 2013, Lanzhou
  - Symposium on EIC @ China, July, 2013, Weihai, China

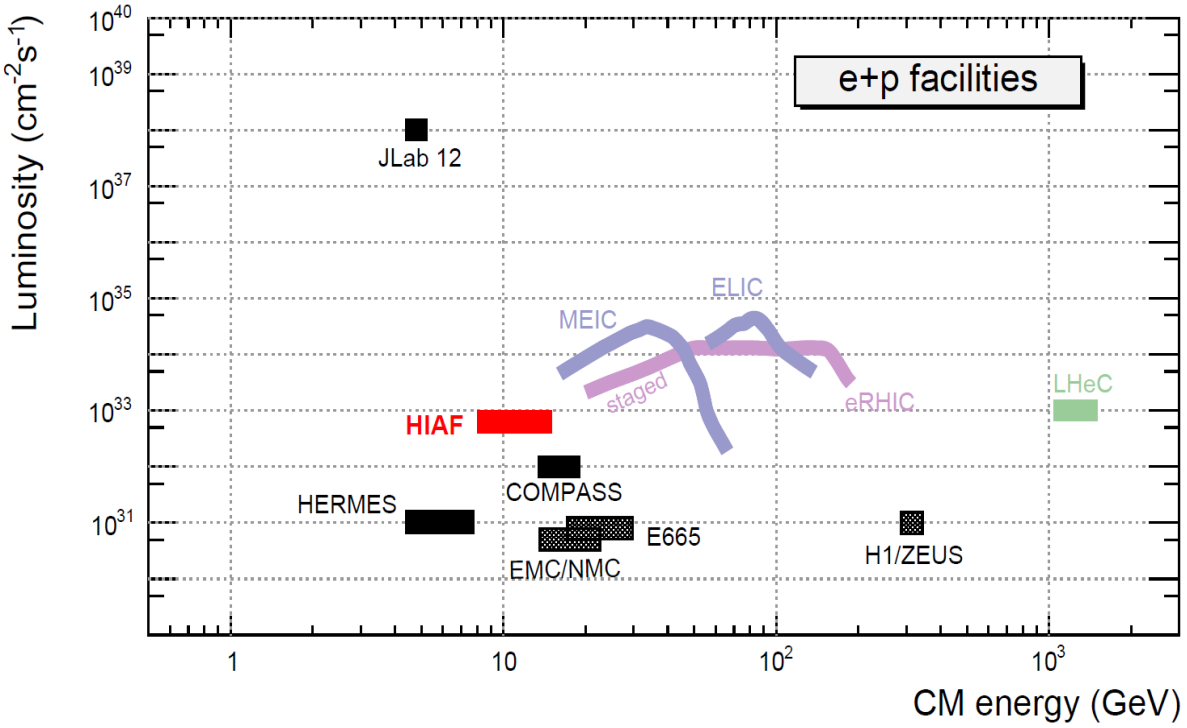
    strong support for EIC@HIAF

# Part 3

## Unique Opportunities for EIC@HIAF

# Lepton-Nucleon Facilities

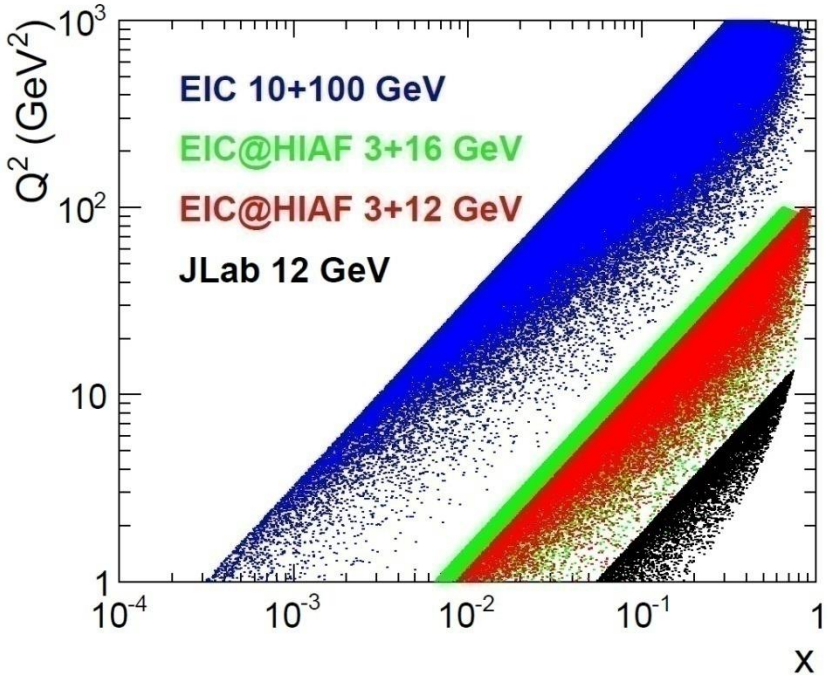
HIAF: e(3GeV) +p(12~16 GeV), both polarized, L>= 4*10$^{32}$cm$^2$/s

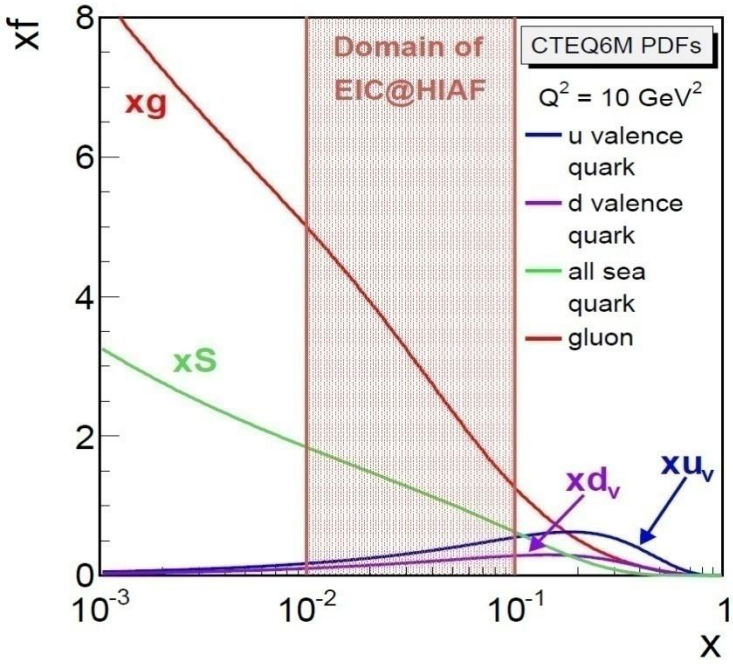



- The energy reach of the EIC@HIAF is significantly higher than JLab12 but lower than the full EIC being considered in US
- COMPASS has similar (slightly higher) energy, but significantly lower polarized luminosity (about a factor of 200 lower, even though the unpolarized luminosity is only a factor of 4 lower)
- HERA only has electron and proton beams collision, but no electron and light or heavy ion beams collision, no polarized beams and its luminosity is low (10^31).

# EIC@HIAF Kinematic Coverage

# Comparison with JLab 12 GeV




**EIC@HIAF :**

Explore the spin and spatial structure of valence & sea quarks in nucleons

The best region for studying sea quarks (x > 0.01)
higher $Q^2$ in valance regime
Allows some study gluons

# EIC@HIAF's Advantages

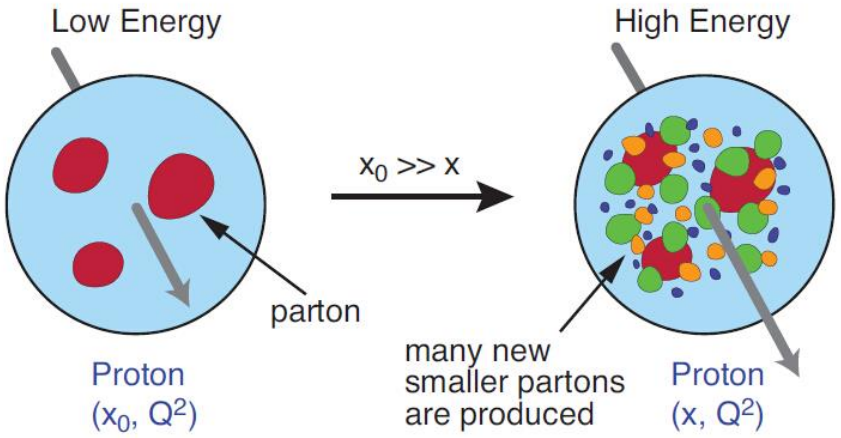
- Many aspects of parton structure can be uniquely addressed by an EIC, especially an EIC with polarization, such as EIC@HIAF
- The main theme for the future full EIC machines (eRHIC, MEIC, LHeC) is to understand the gluons
- The Phase-I of EIC@HIAF will fill the gap between the existing facilities (HERA, JLab…) and future high energy facilities
- EIC@HIAF will provide a broad range of opportunities to explore new frontier research of QCD dynamics which is key to the visible matter
- EIC@HIAF will also be very good in study the fragmentation process, complementary to the e+e-machines

# Physics Programs at EIC@HIAF

## Six golden experiments

1. Nucleon spin-flavor structure (polarized sea, $\Delta s$)
2. GPDs (Deep-Virtual Meson Production, pion/Kaon)
3. TMD in "sea quark" region and significant increase in $Q^2$ / $P_T$ range for valence region
4. Pion/Kaon structure functions in the high-x (valence) region
5. e-A to study hadronization
6. EMC-SRC in e-A

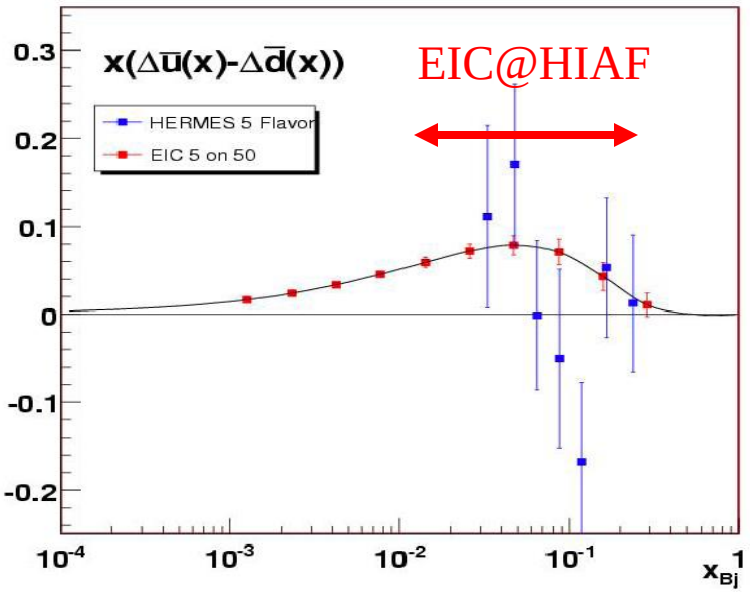
You may propose your experiments!




# 1. Spin-Flavor Study at EIC@HIAF

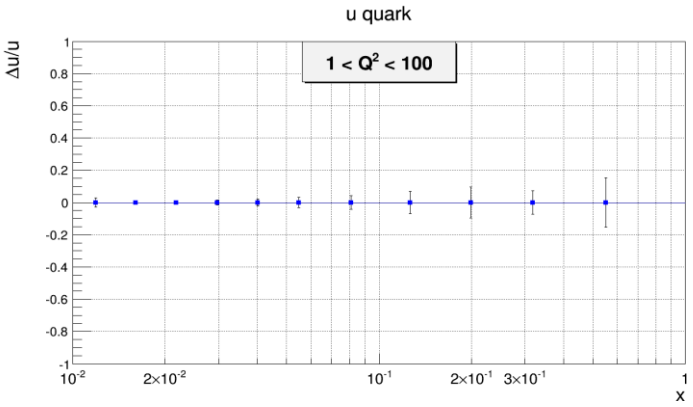
- Flavor asymmetries poorly determined from present data HERMES
- EIC@HIAF, combination of energy and luminosity：offer precise measurements in the region 0.01 < x < 1

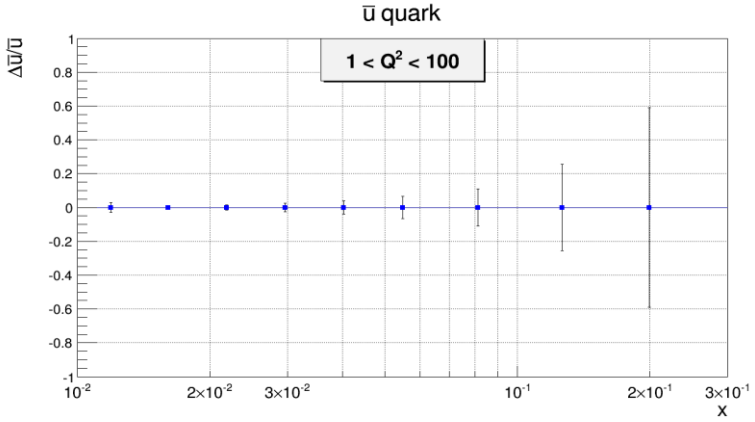
Sea Quark Polarization

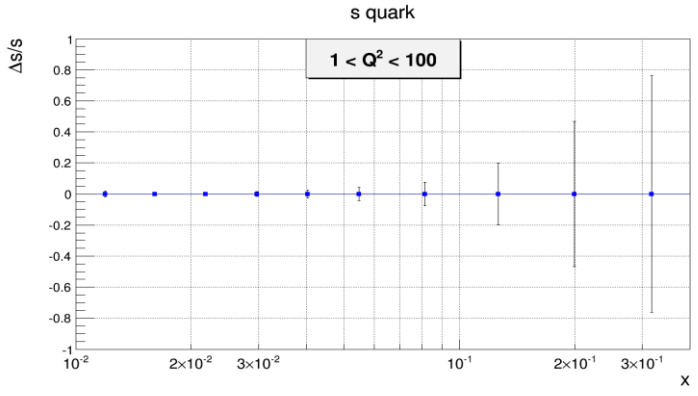


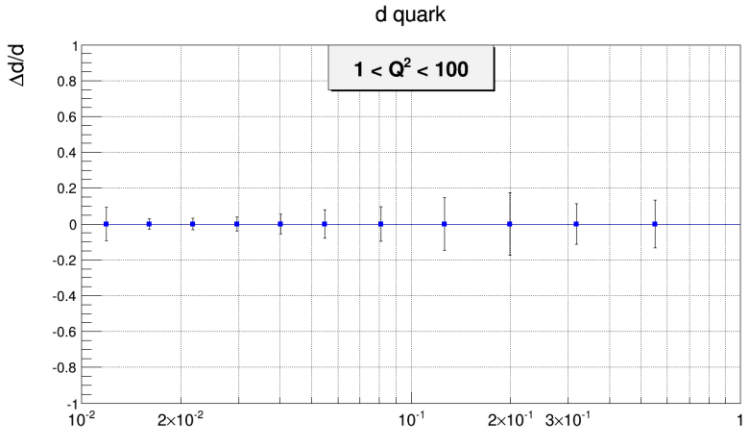
- Significant improvement for $\Delta$ubar, $\Delta$dbar from SIDIS
- By SIDIS, in particular, for Kaons , EIC@HIAF energy reaches the current fragmentation region for Kaon tagging in SIDIS, will help to identify strange quark helicity (For $\Delta$s , one needs to tagging Kaon in the current fragmentation region. To separate current fragmentation from target fragmentation, it requires high energy. But JLab 12 GeV is not high enough to satisfy simple criteria (such as Bergen‘s criteria) to be in the current fragmentation region)
- Increase in $Q^2$ range/precision for $g_1$ (and $g_2$): constraint on $\Delta$g.

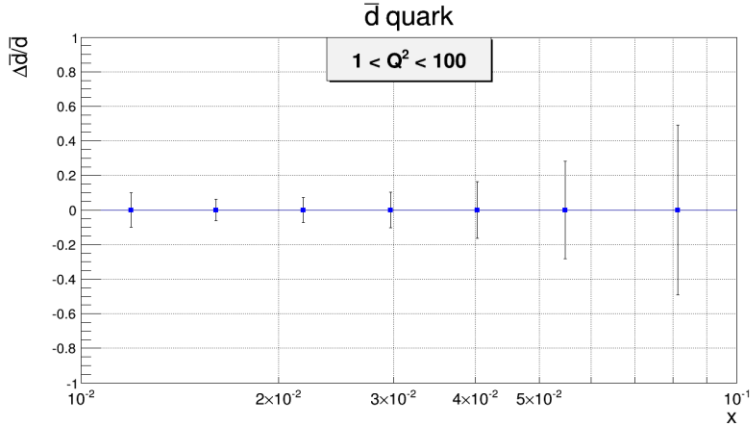
# sea-quark polarization simulation



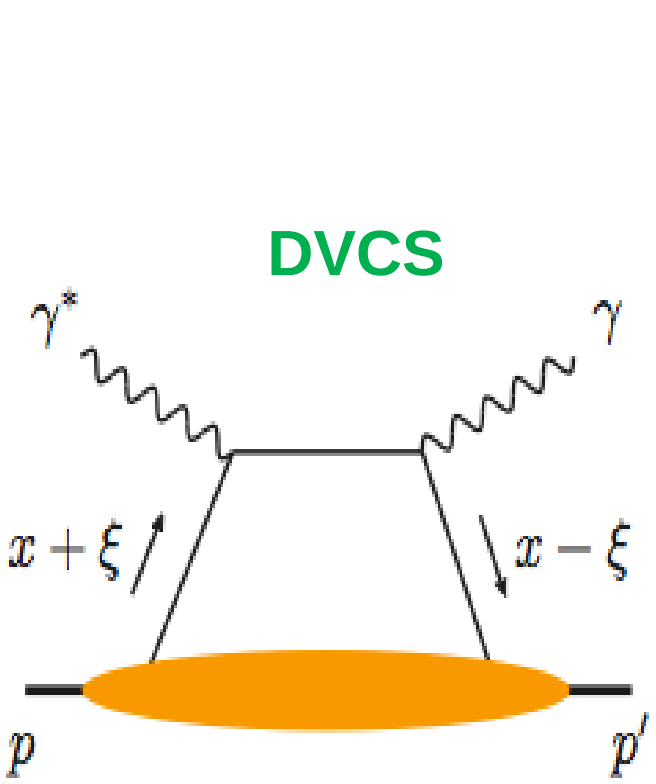



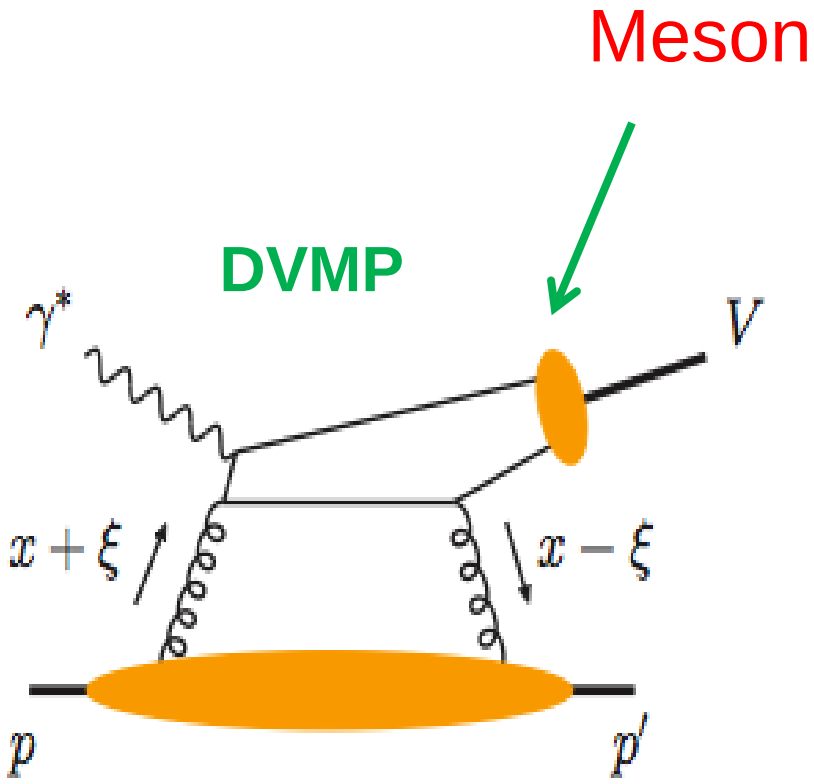

- EIC@HIAF, 200 days
- The accuracy is higher in 0.01 < x < 0.5 region
- U and d quark is more accurate than ubar and dbar

(For details pls see Baiyang Zhang's poster)

# 2. GPD Study at EIC@HIAF

**GPD Study:** by Deeply virtual Compton Scattering (DVCS) and deeply virtual exclusive meson production (DVMP)

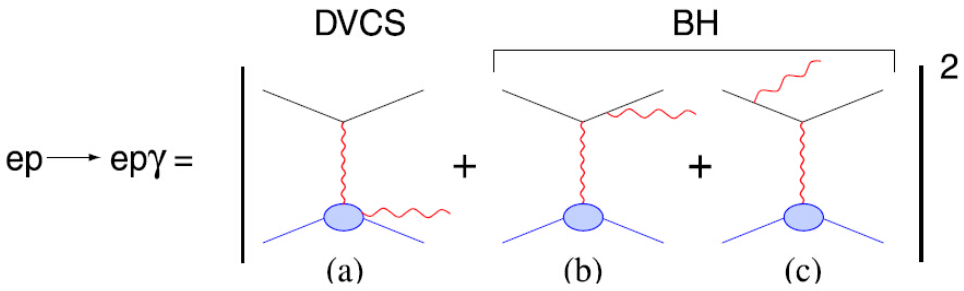


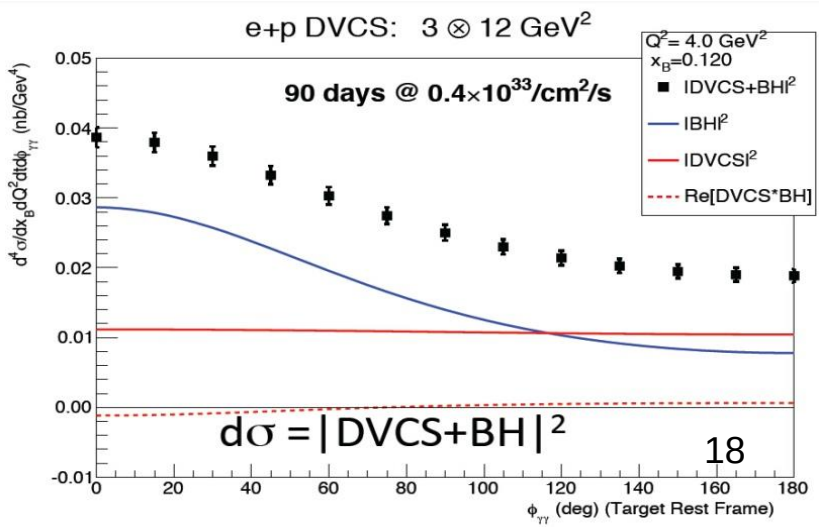



# GPD Study at EIC@HIAF

- flavor decomposition needs DVMP
- JLab12 energy is not high enough to have clean meson deep exclusive process
- EIC@HIAF: significant increase in range for DVCS
- Unique opportunity for DVMP (pion/Kaon)
- energy reaches $Q^2 > 5\sim10\ GeV^2$, scaling region for exclusive light meson production

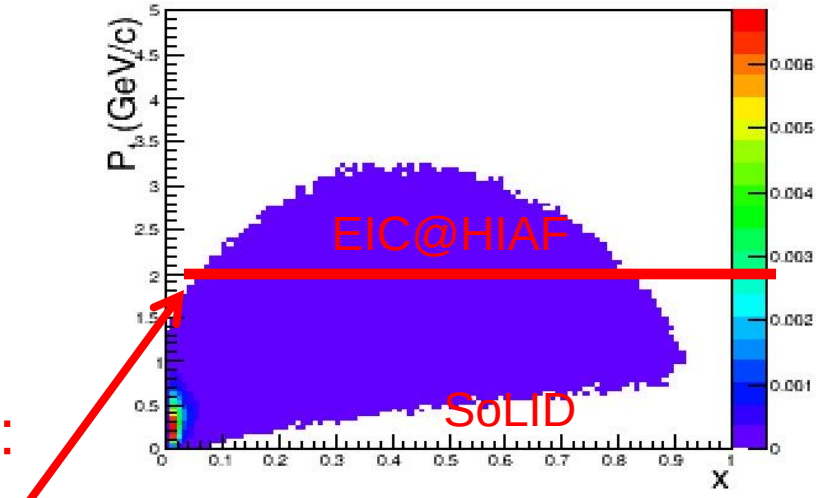
DVCS Simulation by Charles Hyde (ODU)



# 3.TMD Study at EIC@HIAF

- Measure TMD in DIS process
- Unique opportunity for TMD in “sea quark” region:
  reach x ~ 0.01
- Significant increase in $Q^2$ range for valence region:
  energy reach $Q^2$ ~40 $GeV^2$ at x ~ 0.4
- Significant increase in $P_T$ range:



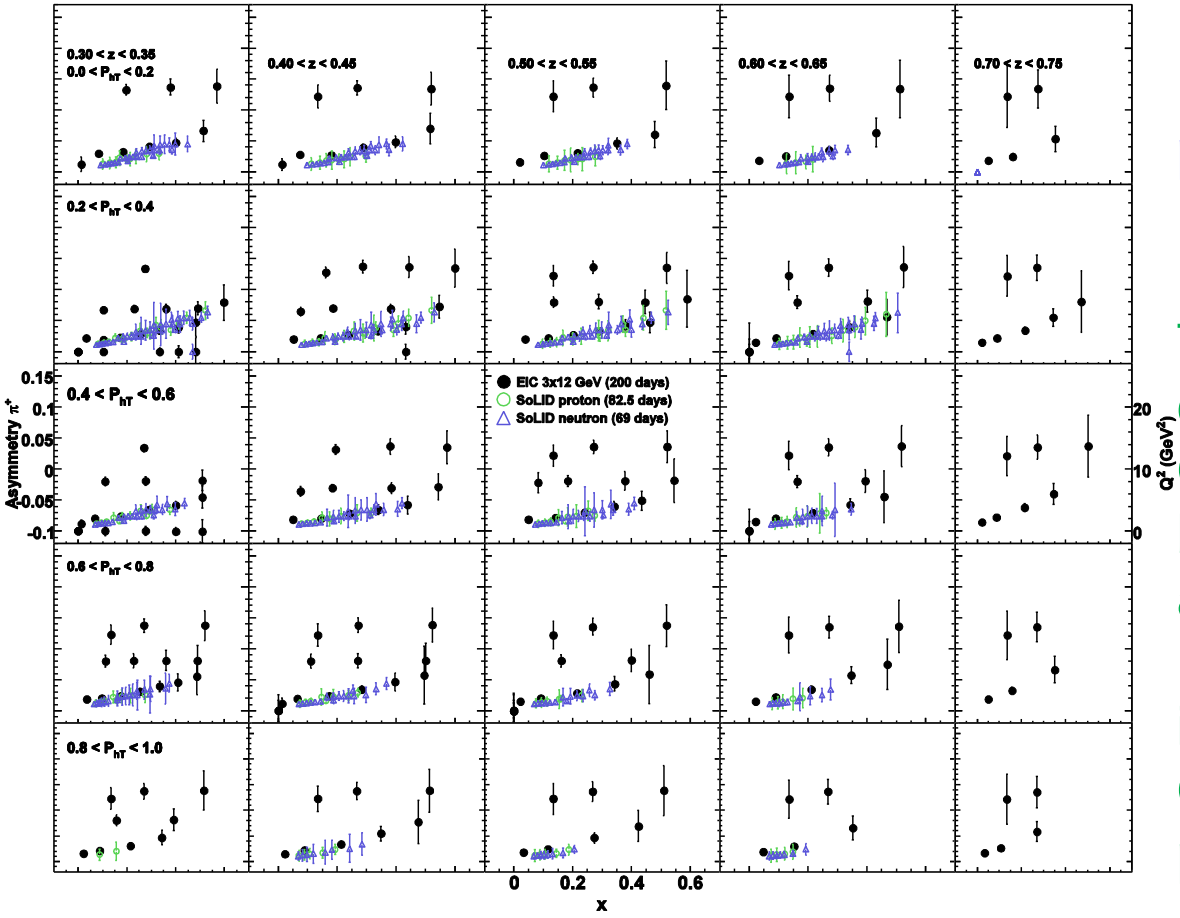

➢ The region around 2 GeV is the overlap region for TMD factorization and collinear factorization (X. Ji, etc., Phys. Rev. D73 (2006) 094017 )

➢ SoLID has $P_T$ coverage slightly higher than 1 GeV/c (up to 1.2~1.4)

➢ For EIC@HIAF, it reaches up to 2~3 GeV/c

➢ So observation in this region will help to check/test the QCD factorization theory predictions.

# The TMD simulation: Projections for SIDIS Asymmetry $\pi^+$




EIC@HIAF reaches high precision similar to SoLID at lower x, higher Q2 region

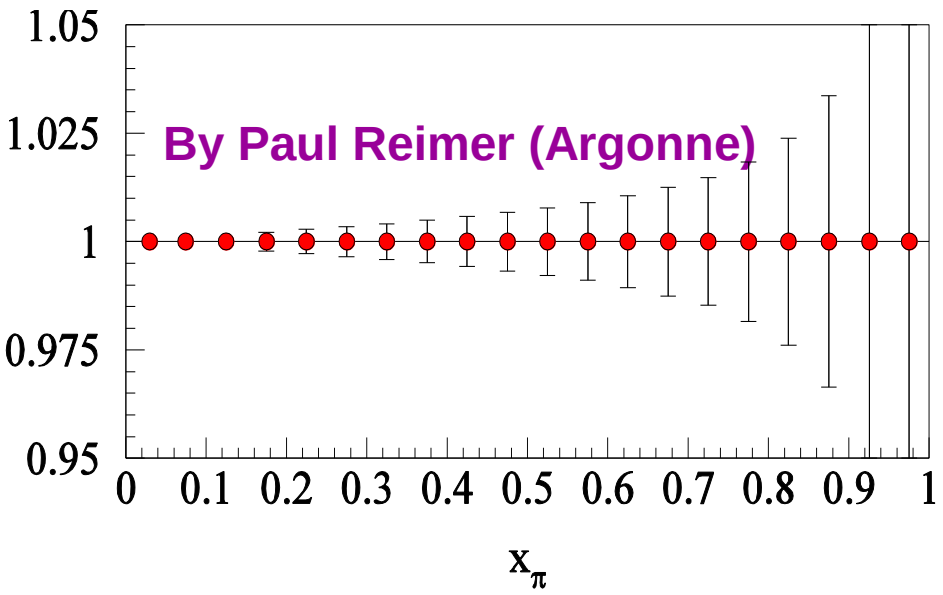
This precision is not only crucial for the fundamental QCD test of the sign change between the Sivers asymmetries in the DIS and Drell-Yan processes, but also important to investigate the QCD dynamics in the hard processes in SIDIS

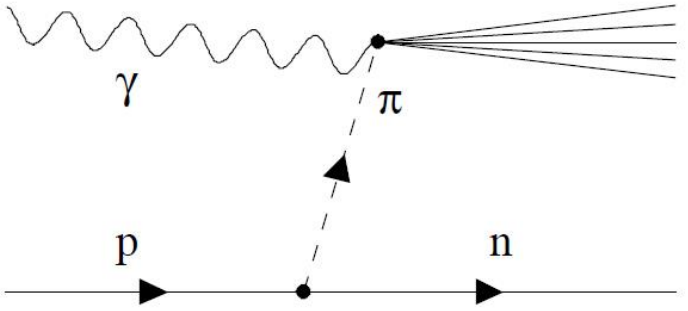
Green (Blue) Points: SoLID projections for polarized $NH_3$ ($^3$He/n) target
Luminosity: $10^{35}$ ($10^{36}$) (1/cm$^2$/s); Time: 120 (90) days

**By Haiyan Gao (Duke)**

Black points: EIC@HIAF projections for 3 GeV e and 12 GeV p
Luminosity: 4 x $10^{32}$ /cm$^2$/s; Time: 200 days

# 4. π/K Parton Distribution Function in Valence Quark Region




π structure simulation for EIC@HIAF

- 3 GeV e and 12 GeV p
- Luminosity: 5 x $10^{32}$ /$cm^2$/s; Time:$10^6$ seconds

EIC@HIAF will be able to extract pion PDFs with a high precision. These, together with the Kaon PDFs, will provide benchmark tests of theoretical calculations, such as Lattice QCD and the Schwinger-Dyson equations approach.

# Other Physics Programs for EIC@HIAF?

- **Form Factor Measurements at EIC@HIAF?**
  - Fast Falling of Form Factors and Elastic Cross Sections

    Needs very high luminosity
  - Luminosity comparison:

    JLab: $>10^{38}$ unpolarized, $>10^{36}$ polarized, EIC@HIAF: $10^{33}$
  - Limited role for EIC@HIAF in nucleon form factor study
- **Hadron Spectroscopy Measurements with an EIC?**
  - e+e- (Bella, BaBar, BES): charmonium states: x-y-z

    search for new states.
  - JLab12: GlueX search for gluon excitation

    **Search for new hadron states**

# Part 4

## Status and Summary

# Symposium on EIC @ HIAF
# May 6, 2014, Beijing

- A special and key important symposium on the EIC@HIAF was held in Beijing between the Chinese government and high energy physics communities in May 6, 2014

- Both the Chinese government and experts strongly support the EIC@HIAF plan and think the EIC program should be started up in the earliest time of the Chinese 13th five-year (2016-2020)

- The possibility of combination of Super Tau and Charm machine was also being proposed

# Current EIC@HIAF Status

- HIAF proposal (~US$ 400M, with ENC) has been submitted to the National Development and Reform Commission (NDRC), with space for EIC upgrade. Preliminary defense on Oct.21, 2014
- EIC@ HIAF short proposal (~US$ 300M) has been submitted, as 13$^{th}$ five year plan, to the NDRC
- HIAF Location: Huizhou, Guangdong province
- J.P. Chen from JLab is organizing the six golden experiments simulations and detector simulations
- J.W. Qiu and F. Yuan (BNL), etc., are organizing the China EIC whitepaper writing (in English)

# Summary

- EIC@HIAF plan is underway
- It will open up a new window to study/understand nucleon structure, especially the sea quark. Examples of Possible "Golden Experiments":
  - Nucleon spin-flavor structure (polarized sea, $\Delta s$)
  - 3-d structure: GPDs (DVMP) and DVCS
  - 3-d structure: TMDs (sea, range in $Q^2$, $P_T$)
  - Meson (pion/Kaon) structure function at high-x
  - Hadronization/EMC/SRC
- There are wonderful Physics and Time windows for EIC@HIAF machine
- The Chinese high energy and nuclear physics communities strongly support this EIC project
- Opportunity to bring Chinese hadron physics to the forefront in the world

**Thanks for your attention!**

**Any comments are welcome!**