Spin-flavor study with EIC@HIAF

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EIC@China

- High Intensity Heavy Ion Accelerator Facility (HIAF)
  - Rare isotopes
  - High energy density matter
  - Collision experiments
    - EIC
    - Ion-Ion Collider

1st Stage: 3 Gev polarized electron × 12 GeV polarized proton, L= 4 × 10^{32}

Unique Opportunities for EIC@HIAF:

- Flavor dependent polarized PDFs
- 3D structure of nucleon
  - GPDs
  - TMDs
- π/K Structure

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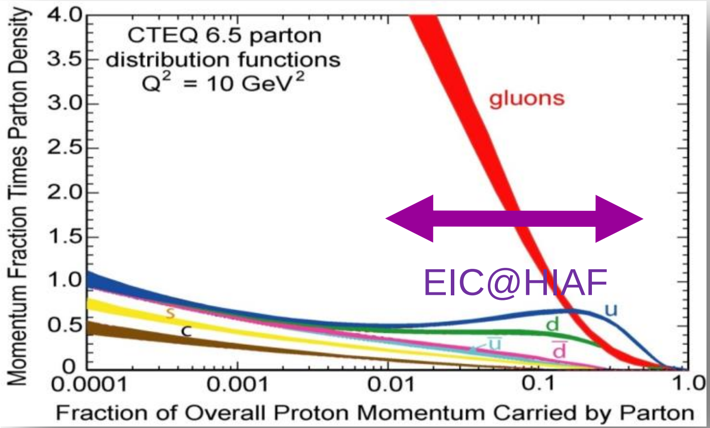
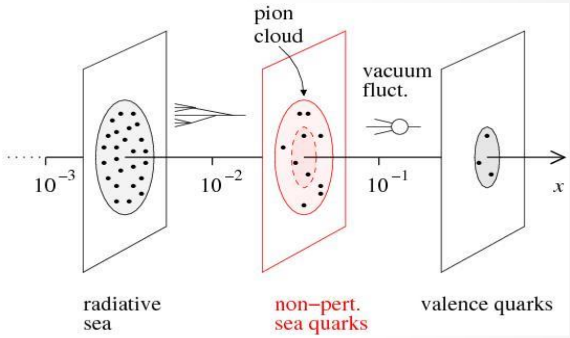


Advantages of EIC@China

- Unique opportunity for Δs

  Energy reach current fragmentation region for Kaon tagging in SIDIS

  The measurement of Kaon production SIDIS allows us to extract polarized PDFs of s quark



- Significant improvement for $\bar{u}, \bar{d}$ from SIDIS

- Increase in Q^2 range/precision

  In EIC Q^2 can reach 100 GeV, have access to non-perturbative sea quarks.

Polarized PDF

From longitudinally polarized inclusive DIS asymmetry, structure functions can be obtained.

$$g_1(x) = \frac{1}{2} \sum_j e_j^2 \left[\triangle q_j(x) + \triangle \bar{q}_j(x)\right]$$

where

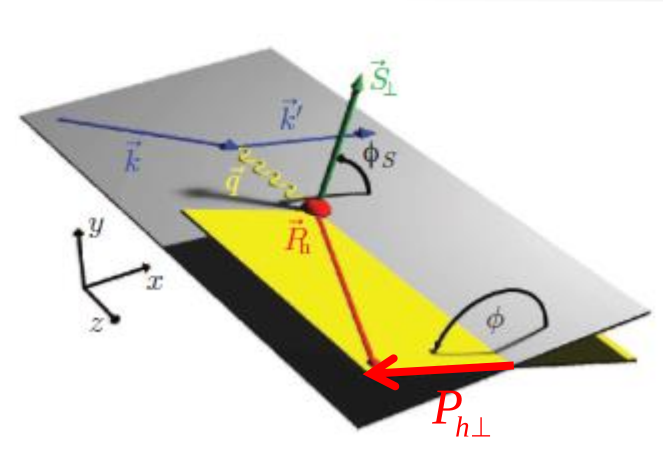
$$\triangle q(x) = q_+(x) - q_-(x)$$

Inclusive data alone, cannot distinguish the contributions from different flavors.

To extract flavor decomposed polarized PDFs, we need semi-inclusive DIS, together with the knowledge of Fragmentation Functions.

On EIC various asymmetries can be measured:

$$A_1^{p,\pi^+}, A_1^{p,\pi^-}, A_1^{p,K^+}, A_1^{p,K^-}$$
$$A_1^{n,\pi^+}, A_1^{n,\pi^-}, A_1^{n,K^+}, A_1^{n,K^-}$$



$$e + N \to e' + h + X,$$

Allow us to fit pPDFs of $u, \bar{u}, \mathrm{d}, \bar{\mathrm{d}}, \mathrm{s}, \bar{\mathrm{s}}$

Flavor Decomposition

At leading order

$$\sigma^h(x,Q^2,z) \propto \sum_f e_f^2 q_f(x,Q^2) D_f^h(z,Q^2)$$

$D_f^h(z,Q^2)$ is the probability for a quark of flavor f to hadronize into a hadron h

Double spin asymmetries to be measured:

$$A_1^h(x,Q^2) = \frac{\sum_f e_f^2 \Delta q_f(x,Q^2) \int_{z_{min}}^{z_{max}} D_f^h(z,Q^2)dz}{\sum_f e_f^2 q_f(x,Q2) \int_{z_{min}}^{z_{max}} D_f^h(z,Q^2)dz} \times \frac{(1+R(x,Q^2))}{(1+\gamma^2)}$$

Introduce Purity matrix, whose components are defined as

$$P_f^h(\mathrm{x}) = \frac{e_f^2 q_f(\mathrm{x}) \int D_f^h(\mathrm{z})\,\mathrm{dz}}{\sum_{f'} e_{f'}^2 q_{f'}(\mathrm{x}) \int D_{f'}^h(\mathrm{z'})\,\mathrm{dz'}} \frac{1+R}{1+\gamma^2}$$

$\rightarrow$

$$A_1^h(x) = \sum_f P_f^h(x) \frac{\Delta q_f(x)}{q_f(x)}$$

Flavor Decomposition

Generally eight kinds of asymmetries can be measured in SIDIS at EIC:

$$\boldsymbol{A} \equiv (A_1^{p,\pi^+}, A_1^{p,\pi^-}, A_1^{p,K^+}, A_1^{p,K^-}, A_1^{n,\pi^+}, A_1^{n,\pi^-}, A_1^{n,K^+}, A_1^{n,K^-})^T$$

Depend directly on pPDFs

$$A = P(\mathrm{x}) \cdot Q(\mathrm{x})$$

Where Q(x) is the pPDF vector

$$Q(\mathrm{x}) \equiv (\frac{\Delta \mathrm{u}}{u}, \frac{\Delta \bar{\mathrm{u}}}{\bar{u}}, \frac{\Delta d}{d}, \frac{\Delta \bar{d}}{\bar{d}}, \frac{\Delta s}{s}, \frac{\Delta \bar{s}}{\bar{s}})^{\mathrm{T}}$$

χ^2 is defined as

$$\chi^2 \equiv (\boldsymbol{A} - P \cdot Q)^T V_A^{-1} (\boldsymbol{A} - P \cdot Q)$$

Where V_A^{-1} is the covariance matrix of asymmetries

Error Simulation of Flavor Decomposition

3 Gev polarized electron $\times$ 12 GeV polarized proton
Electron pol = 0.7 Proton pol = 0.7
200 Days, 0.5 overall acceptance, L= 4 $\times$ 10^{32}

Event generator is the same used by Jefferson-Lab to simulate TMD measurement by SIDIS

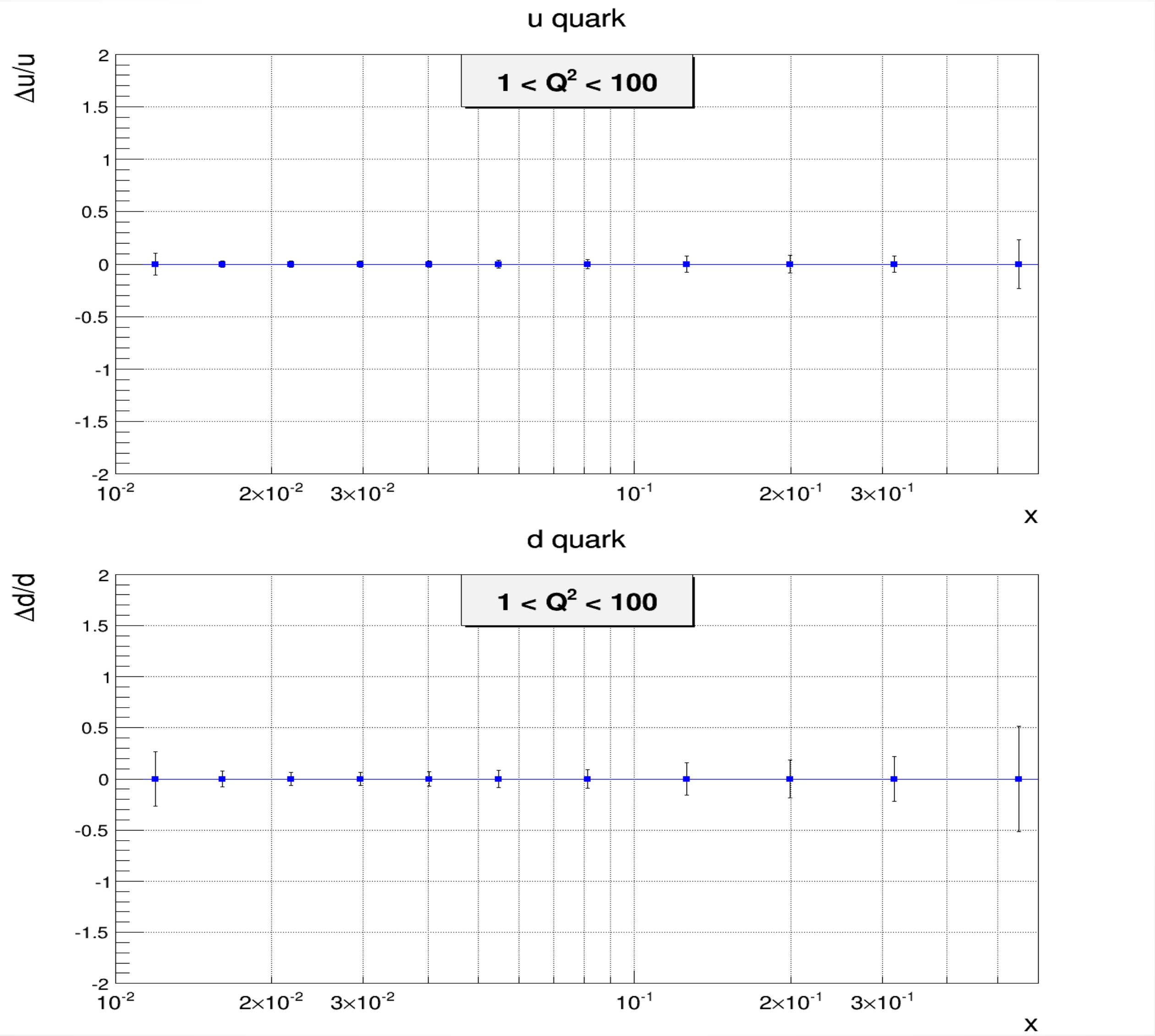
For PDF Sets, CTEQ6 is used to calculate Purity.

In the leading order simulation, the uncertainty in the purity is assumed to be zero, only statistical uncertainty of measured asymmetries are considered when simulating the uncertainty of polarized PDFs.

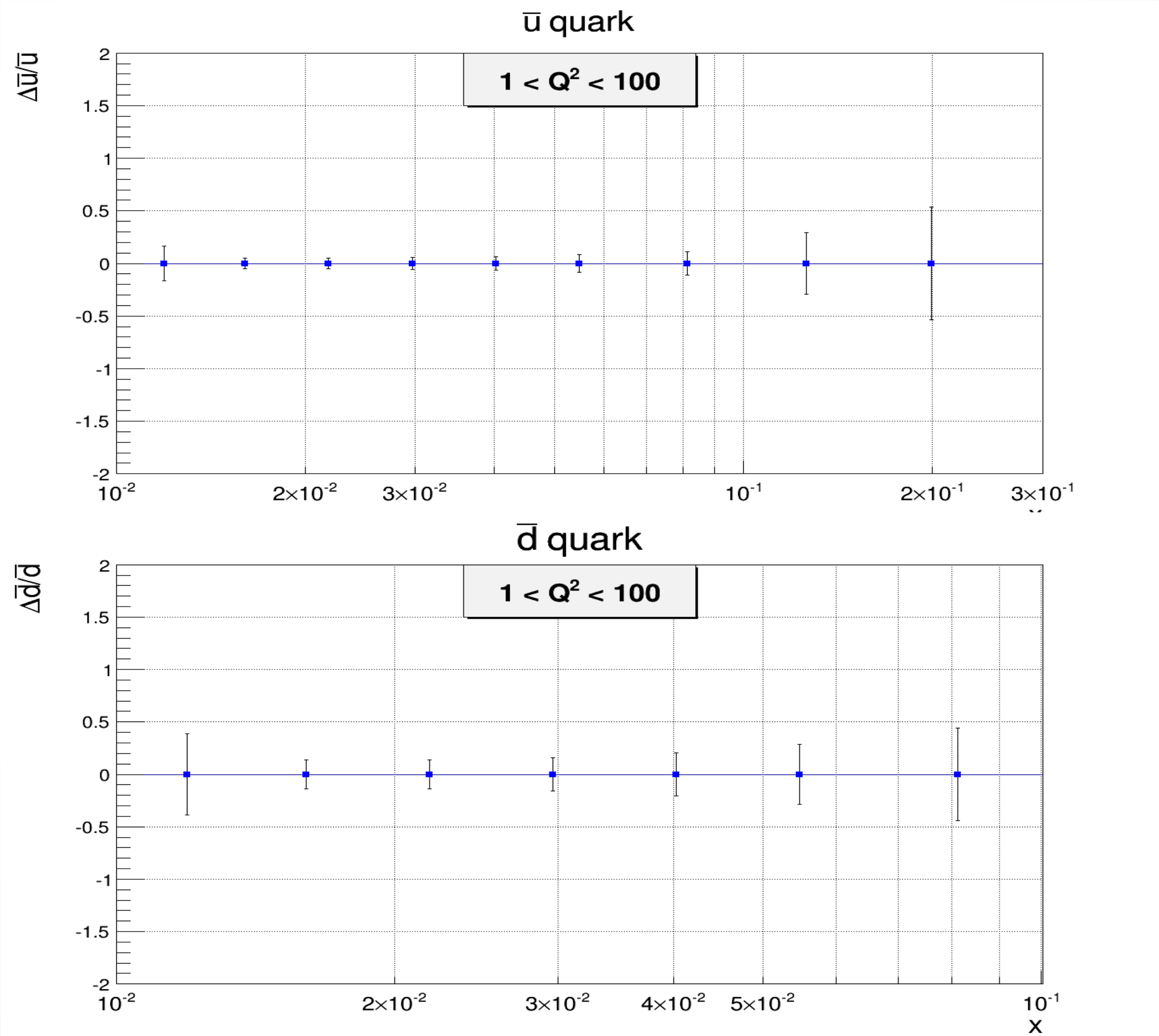
In the simulation procedure, one constraint was imposed:

$$\frac{\Delta s}{s} = \frac{\Delta \bar{s}}{\bar{s}}$$

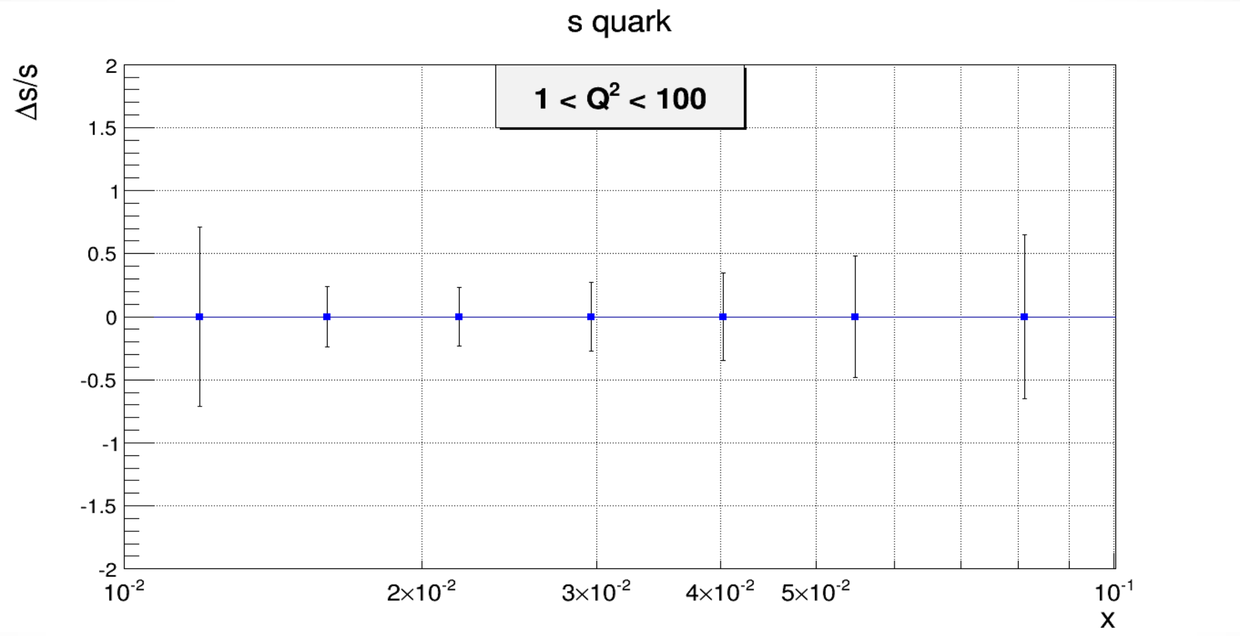
Simulation of Errors



Simulation of Errors



Simulation of Errors



Very sensitive to $u, \bar{u}, d$ quarks, less sensitive to $\bar{d}$ and s quarks

Uncertainties are smaller for $x < 0.1$; When $x > 0.1$, errors grow rapidly.

Discussion

- The simulated errors depend strongly on what assumptions were made. Instead of using two frequently used constraints:

$$\frac{\Delta \mathrm{u}_s(\mathrm{x})}{u_s(\mathrm{x})} = \frac{\Delta \bar{\mathrm{u}}(\mathrm{x})}{\bar{u}(\mathrm{x})} = \frac{\Delta d_s(\mathrm{x})}{d_s(\mathrm{x})} = \frac{\Delta \bar{d}(\mathrm{x})}{\bar{d}(\mathrm{x})} = \frac{\Delta s(\mathrm{x})}{s(\mathrm{x})} = \frac{\Delta \bar{s}(\mathrm{x})}{\bar{s}(\mathrm{x})}$$

$$\Delta \mathrm{u}_s(\mathrm{x}) = \Delta \bar{\mathrm{u}}(\mathrm{x}) = \Delta d_s(\mathrm{x}) = \Delta \bar{d}(\mathrm{x}) = \Delta s(\mathrm{x}) = \Delta \bar{s}(\mathrm{x})$$

  here only $\frac{\Delta s}{s} = \frac{\Delta \bar{s}}{\bar{s}}$ is assumed. Adopting more constraints will reduce the errors.

- Uncertainties in Purity and other kinematic variables will be taken into consideration in the NLO simulation.

Thank you