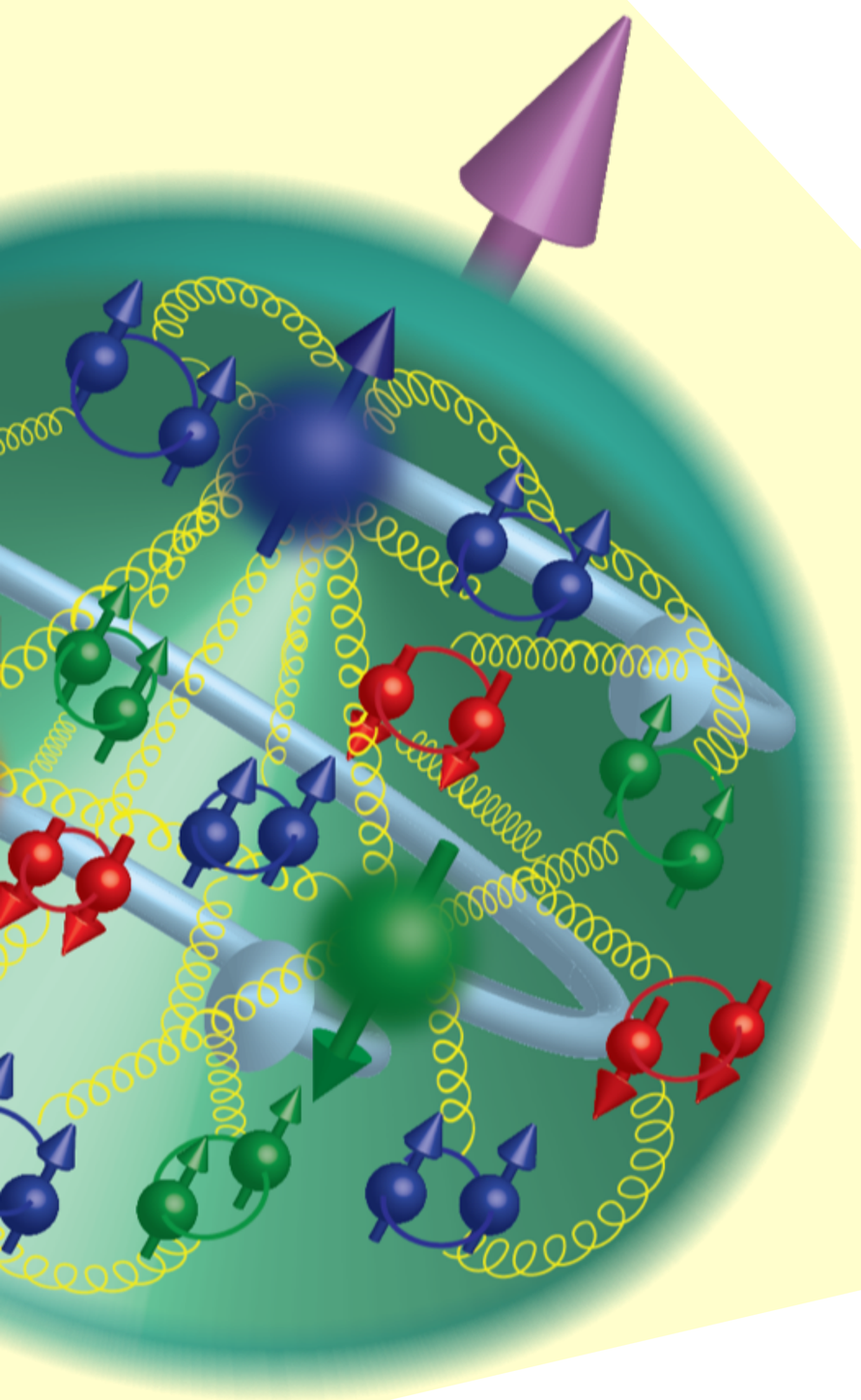
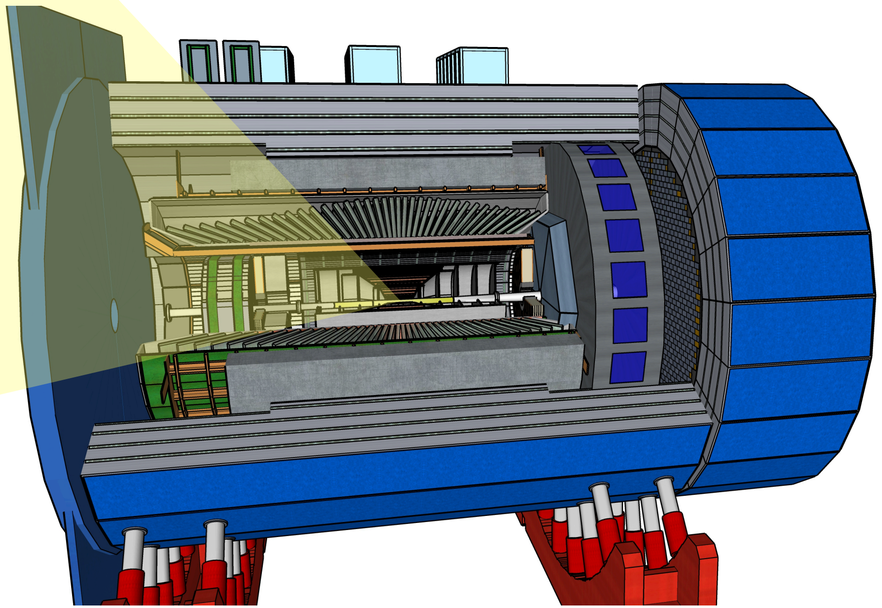


Probing the origin of nucleon spin with ECCE at the EIC

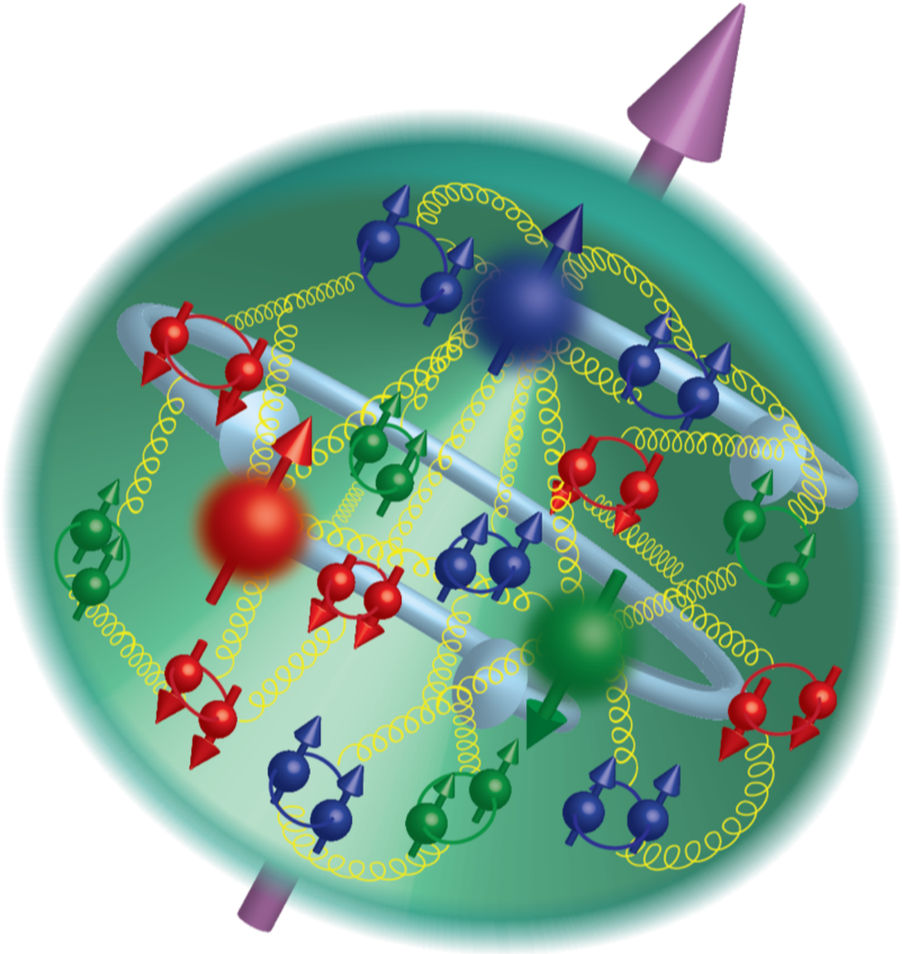
Tyler Kutz
(on behalf of ECCE)

DIS2022: XXIX International Workshop on Deep-Inelastic Scattering and Related Subjects

May 5, 2022



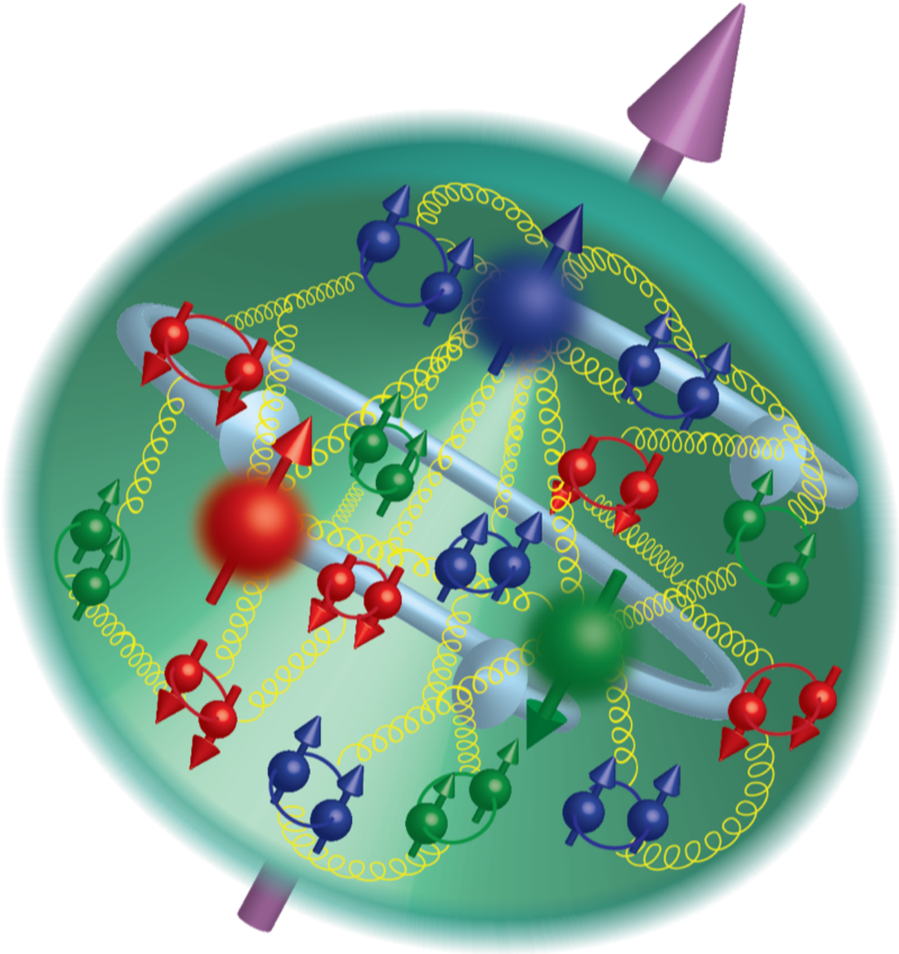
The origin of nucleon spin is complex!



The origin of nucleon spin is complex!

Quark spin

$$\Delta\Sigma = \int_x \sum_q \left(\Delta q - \Delta\bar{q}\right)$$



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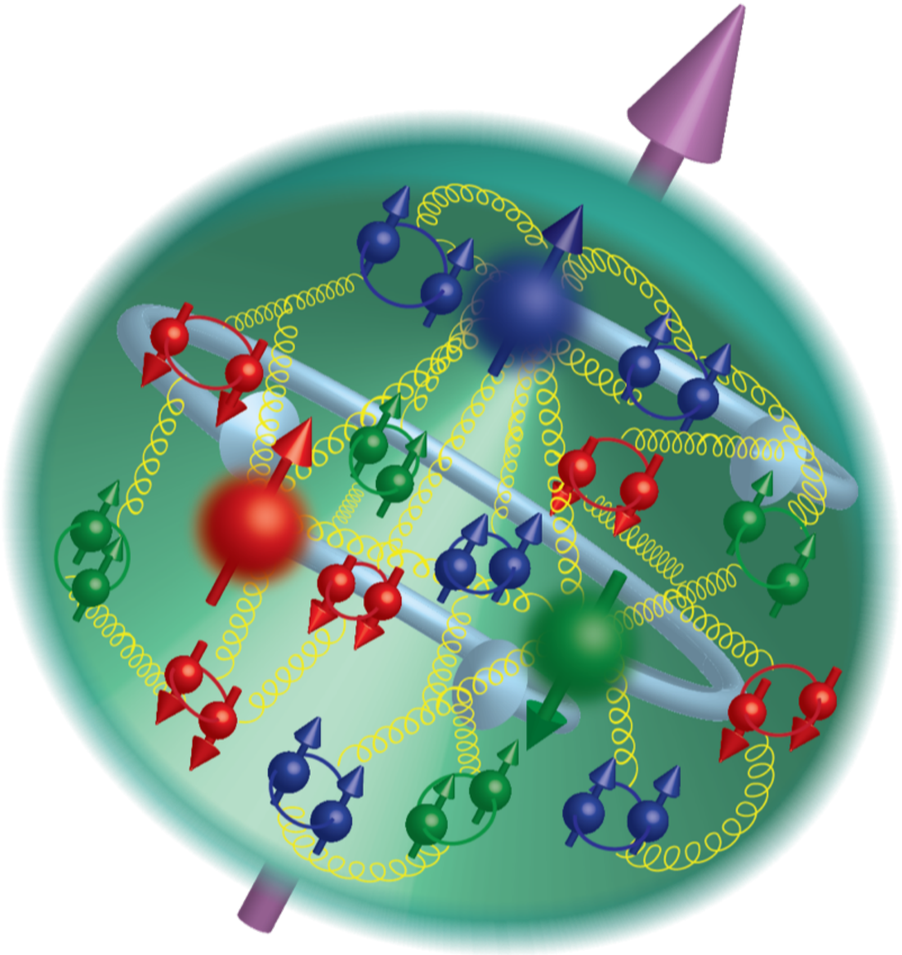
$$\Delta\Sigma = \int_x \sum_q (\Delta q - \Delta\bar{q})$$

Quark orbital angular momentum

L_q



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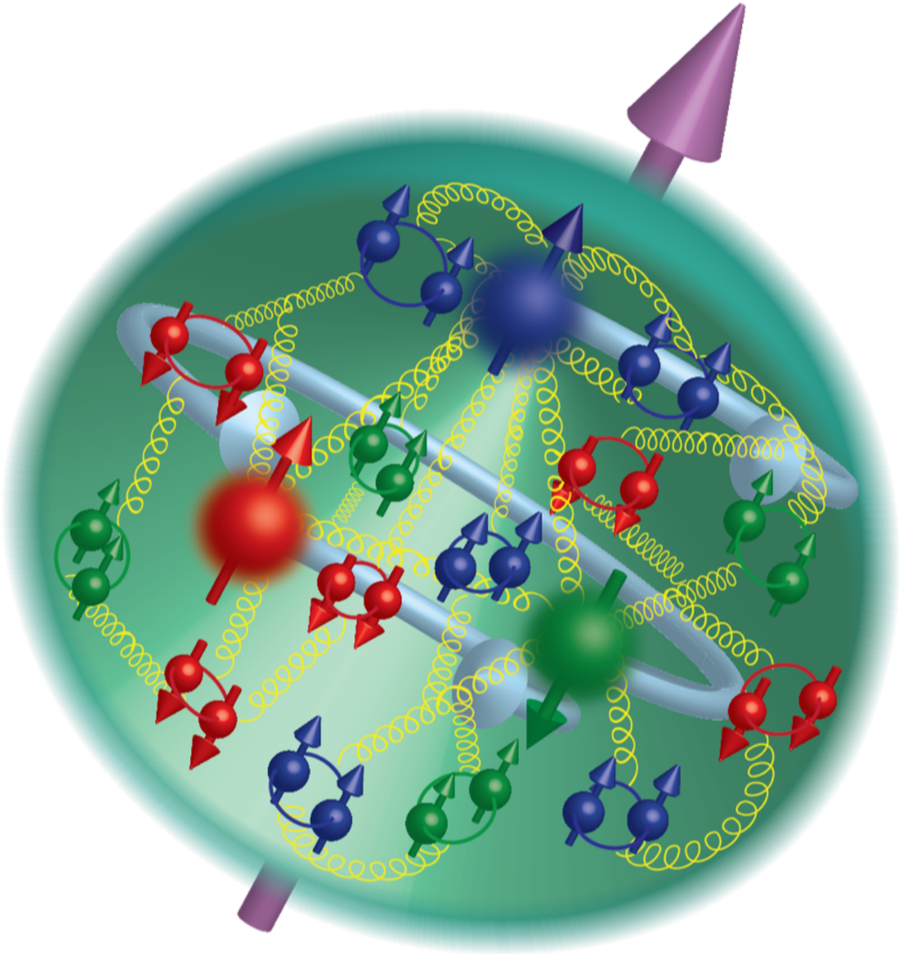

Gluon spin

$$\Delta G = \int_x \Delta g$$

Quark orbital angular momentum

L_g

The origin of nucleon spin is complex!

Quark spin

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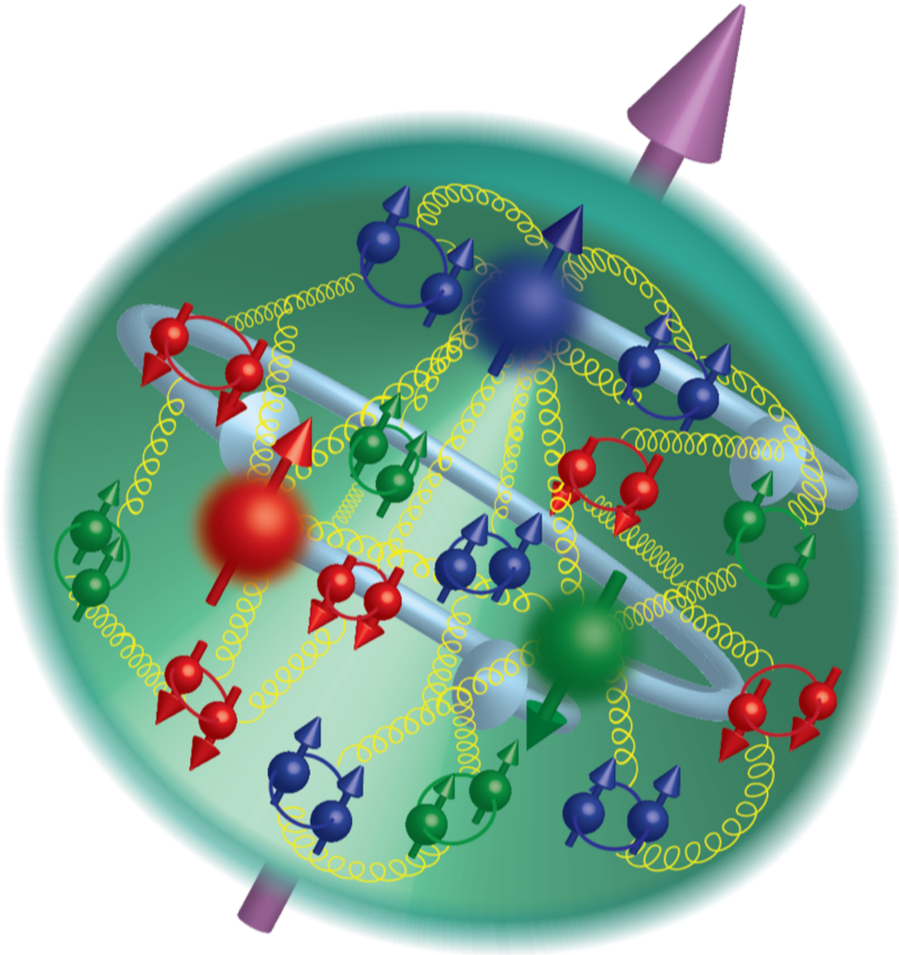


Gluon spin

$$\Delta G = \int_x \Delta g$$

Quark orbital angular momentum

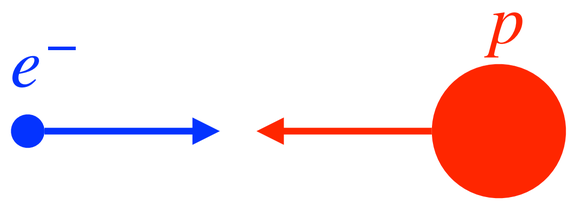
L_q

Quark orbital angular momentum

L_g

$$\Delta\Sigma/2 + \Delta G + L_q + L_g = \frac{1}{2}$$

Complementary measurements required to disentangle



$J_z = \rightarrow \qquad J_z = \leftarrow \qquad = \sigma^{\leftrightarrows}$

$J_z = \rightarrow \qquad J_z = \uparrow \qquad = \sigma^{\rightarrow\uparrow}$

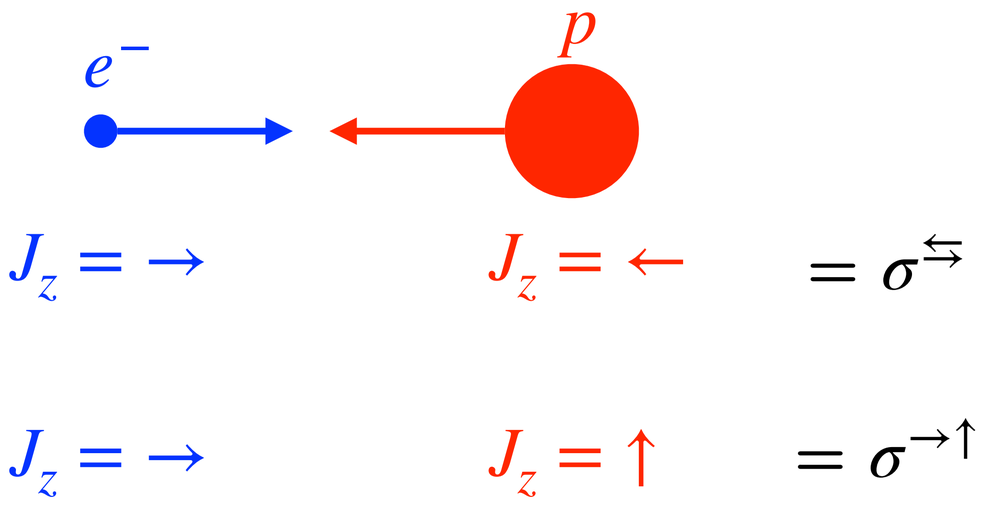
<u>Quark & gluon spin</u>

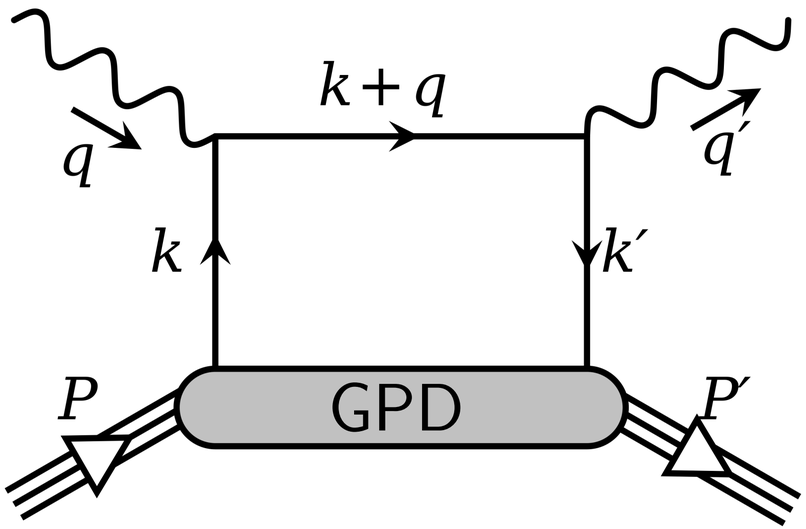
- Polarized DIS
- Sensitive to spin structure function

$$g_1(x) = \sum_q \left(\Delta q(x) + \Delta\overline{q}(x)\right)$$

- Gluon sensitivity from Q^2 dependence

Complementary measurements required to disentangle





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<u>Orbital angular momentum</u>

- GPDs from DVCS

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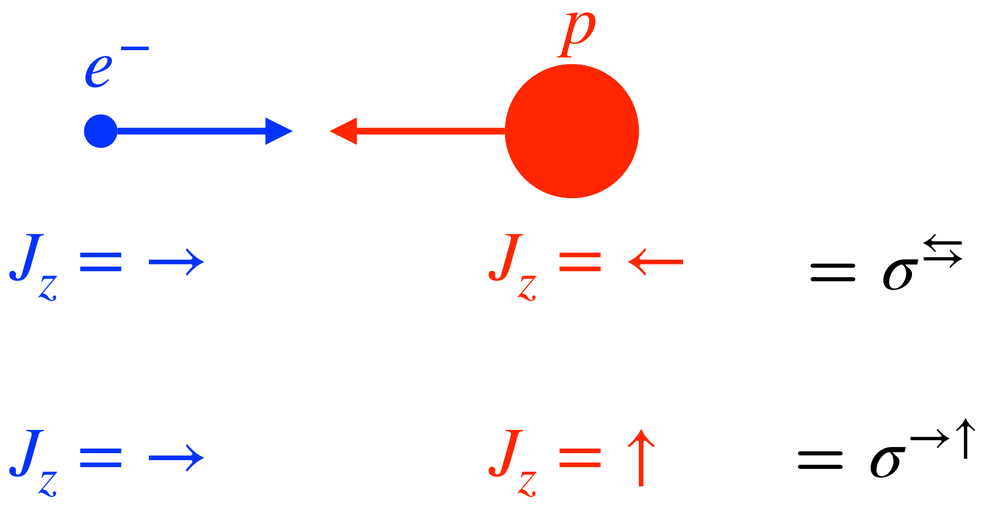

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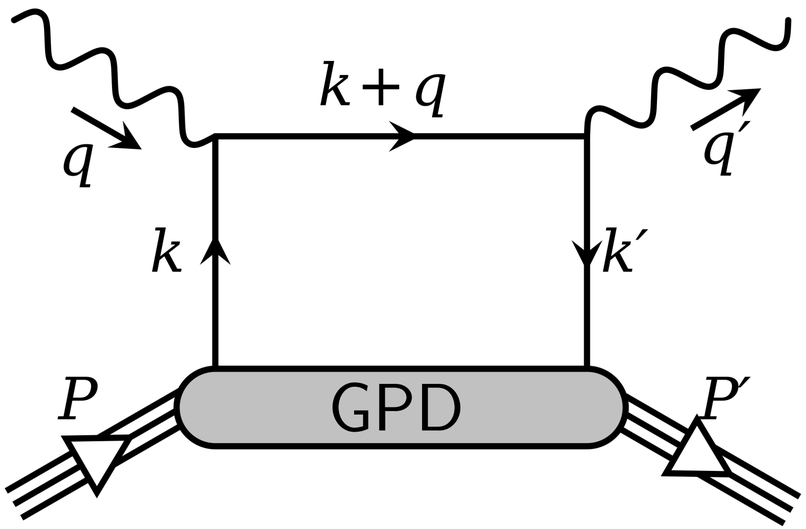


Focus of this talk

Orbital angular momentum

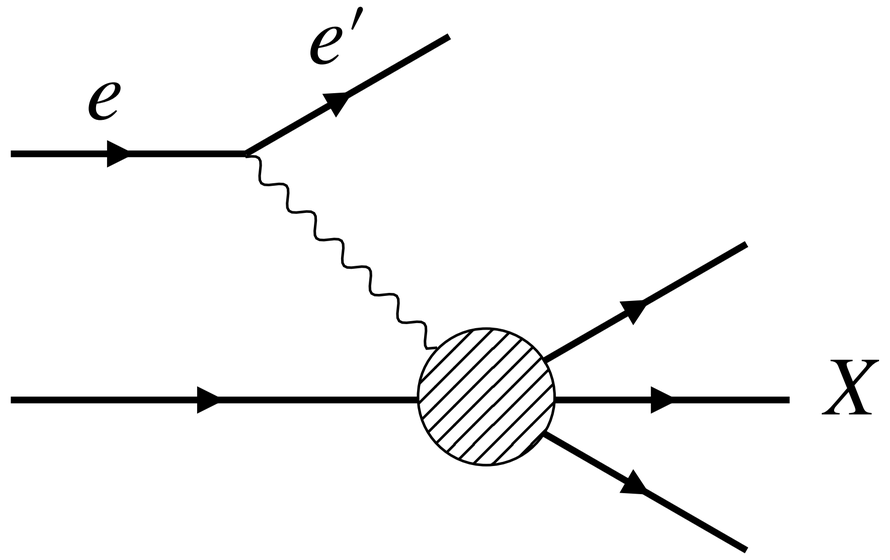
- GPDs from DVCS

Spin structure extracted from double-spin asymmetries

$$A_{\parallel} = \frac{\sigma^{\leftrightarrows} - \sigma^{\rightrightarrows}}{\sigma^{\leftrightarrows} + \sigma^{\rightrightarrows}} \quad \text{and} \quad A_{\perp} = \frac{\sigma^{\rightarrow\uparrow} - \sigma^{\rightarrow\downarrow}}{\sigma^{\rightarrow\uparrow} + \sigma^{\rightarrow\downarrow}} \qquad \rightarrow A_1(x) \approx g_1(x) \big/ F_1(x)$$

Inclusive: sum of quark spins

$$g_1(x) = \sum_q \left(\Delta q(x) + \Delta \overline{q}(x) \right)$$



Spin structure extracted from double-spin asymmetries

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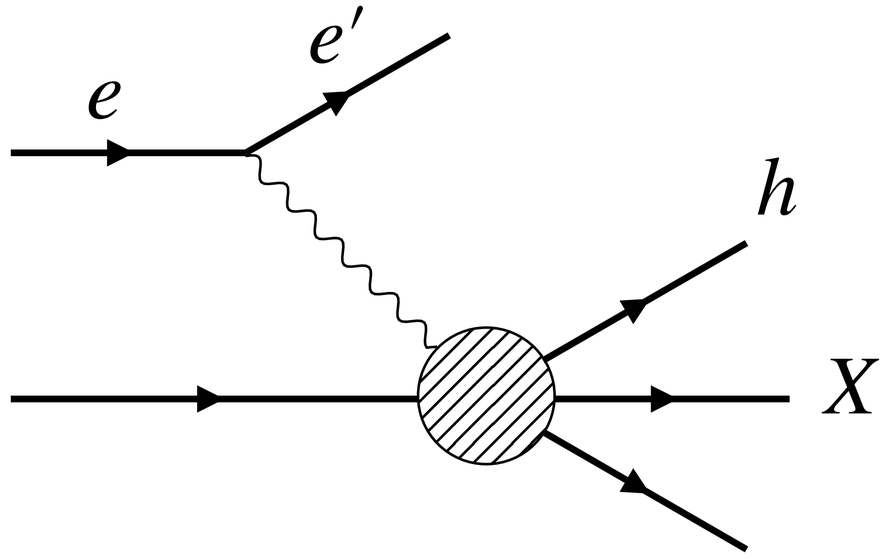
Inclusive: sum of quark spins

$$g_1(x) = \sum_q \left(\Delta q(x) + \Delta \overline{q}(x)\right)$$

Semi-inclusive: combine with fragmentation functions to disentangle flavor information



Existing constraints on $\Delta\Sigma, \Delta G$ limited by kinematic coverage

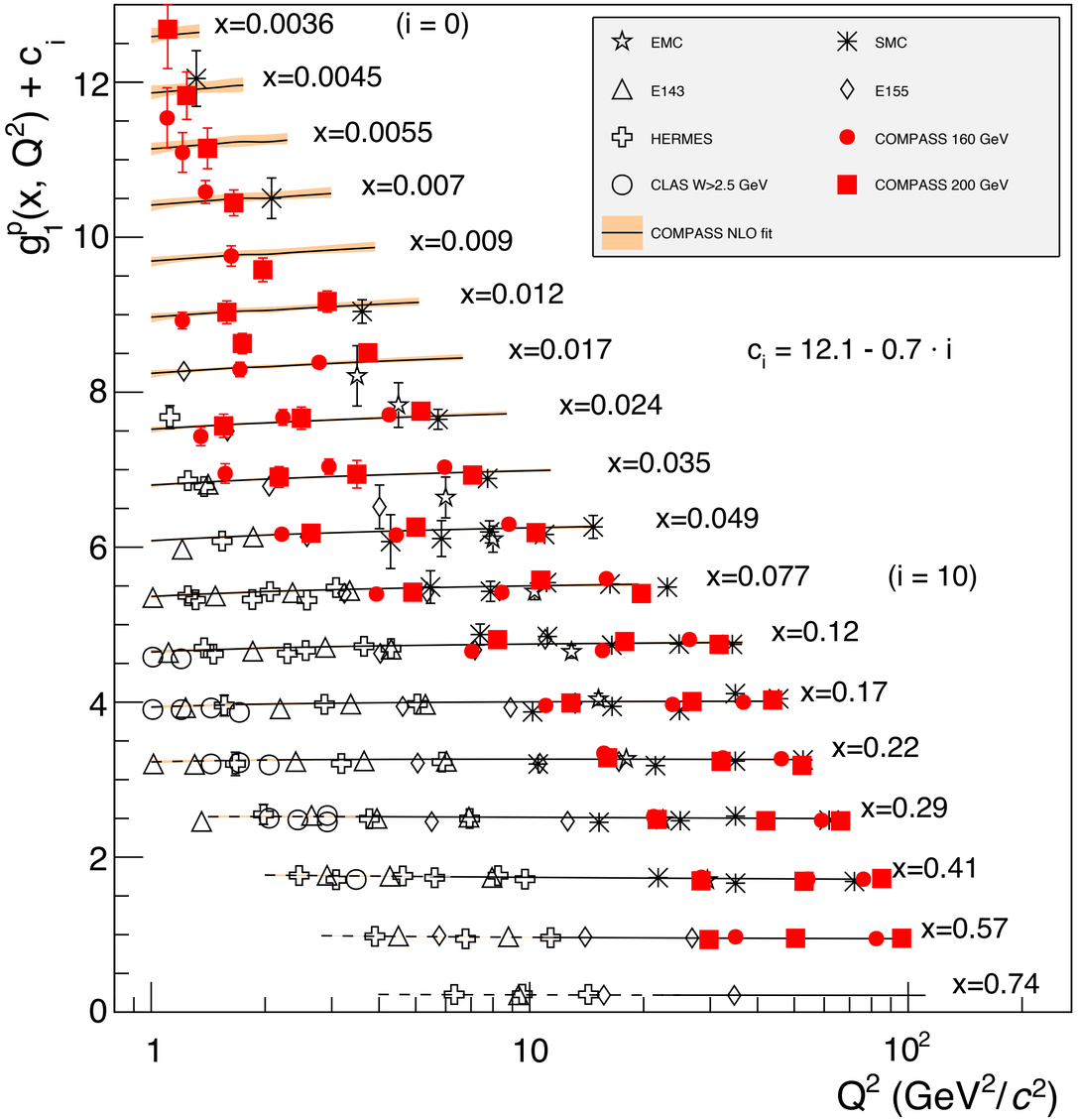
$$\frac{\Delta\Sigma}{2} + \Delta G + L_q + L_g = \frac{1}{2}$$

$\approx 30\%$?%

$\approx 40\%$

Large uncertainty!

COMPASS PLB 753, 18 (2016)



ECCE at the EIC

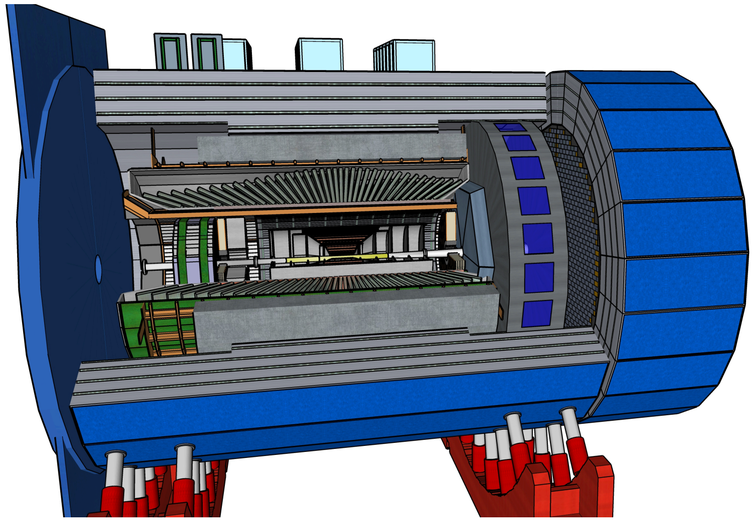
Selected from three proposals
as EIC project detector

Based on re-use of BaBaR
1.4 T solenoid

Full detector simulations of
physics events

ECCE

EIC **C**omprehensive **C**hromodynamics **E**xperiment
Collaboration Detector Proposal



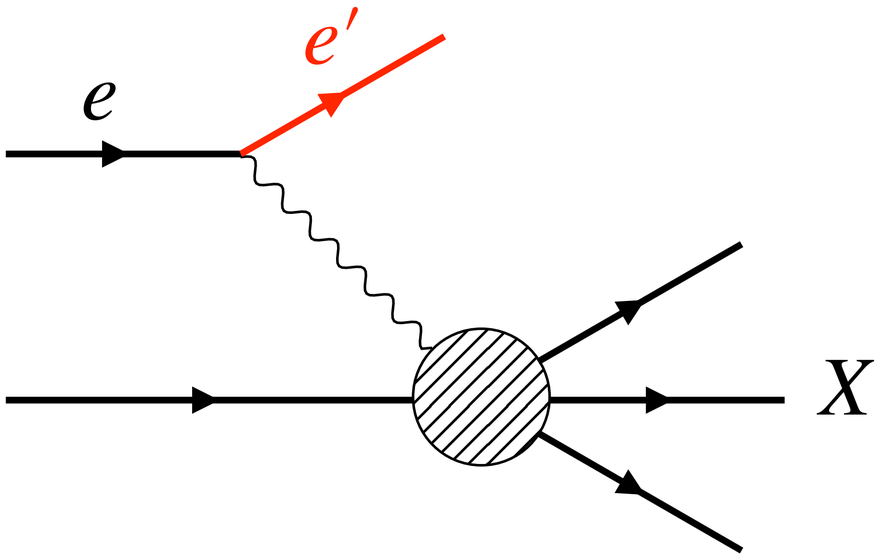
A state of the art detector capable of fully exploiting the science potential of the EIC, realized through the reuse of select instrumentation and infrastructure, to be ready by project CD-4A

December 1, 2021

Proton spin measurement studies from ECCE simulation

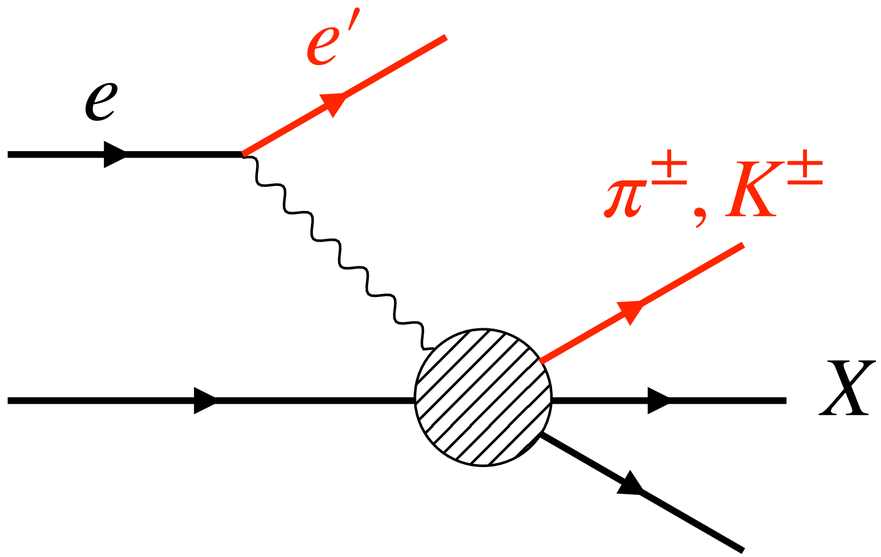
Inclusive double-spin asymmetry

$$A_1^p\left(x, Q^2\right)$$



Semi-inclusive double-spin asymmetry

$$A_1^{p,h}\left(x, Q^2\right),\ h = \pi^{\pm}, K^{\pm}$$



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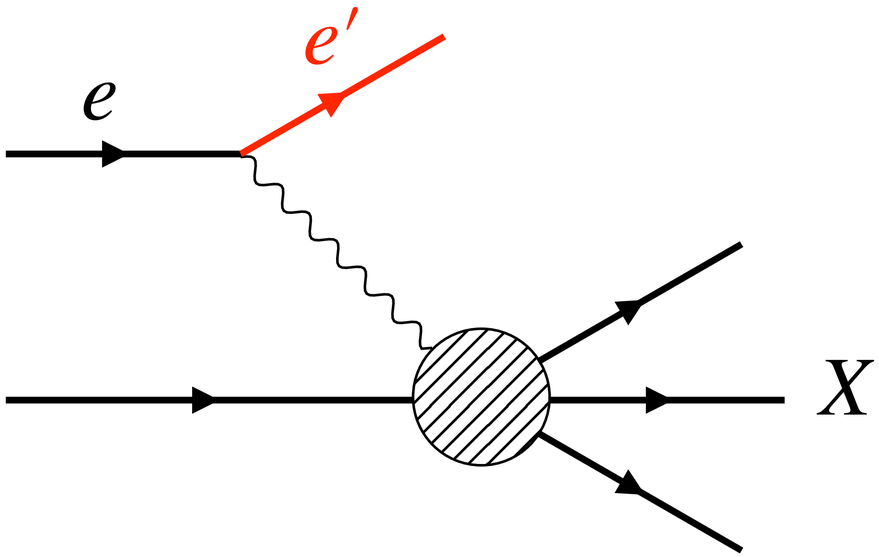

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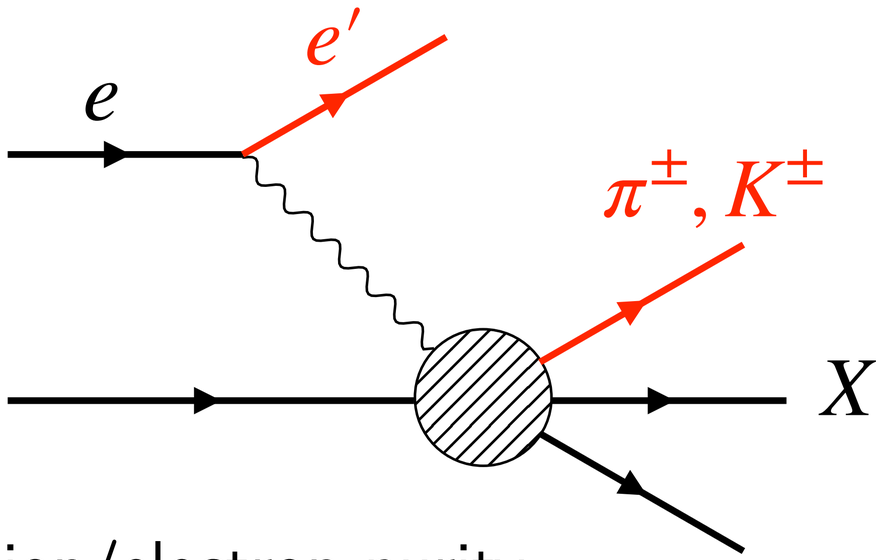
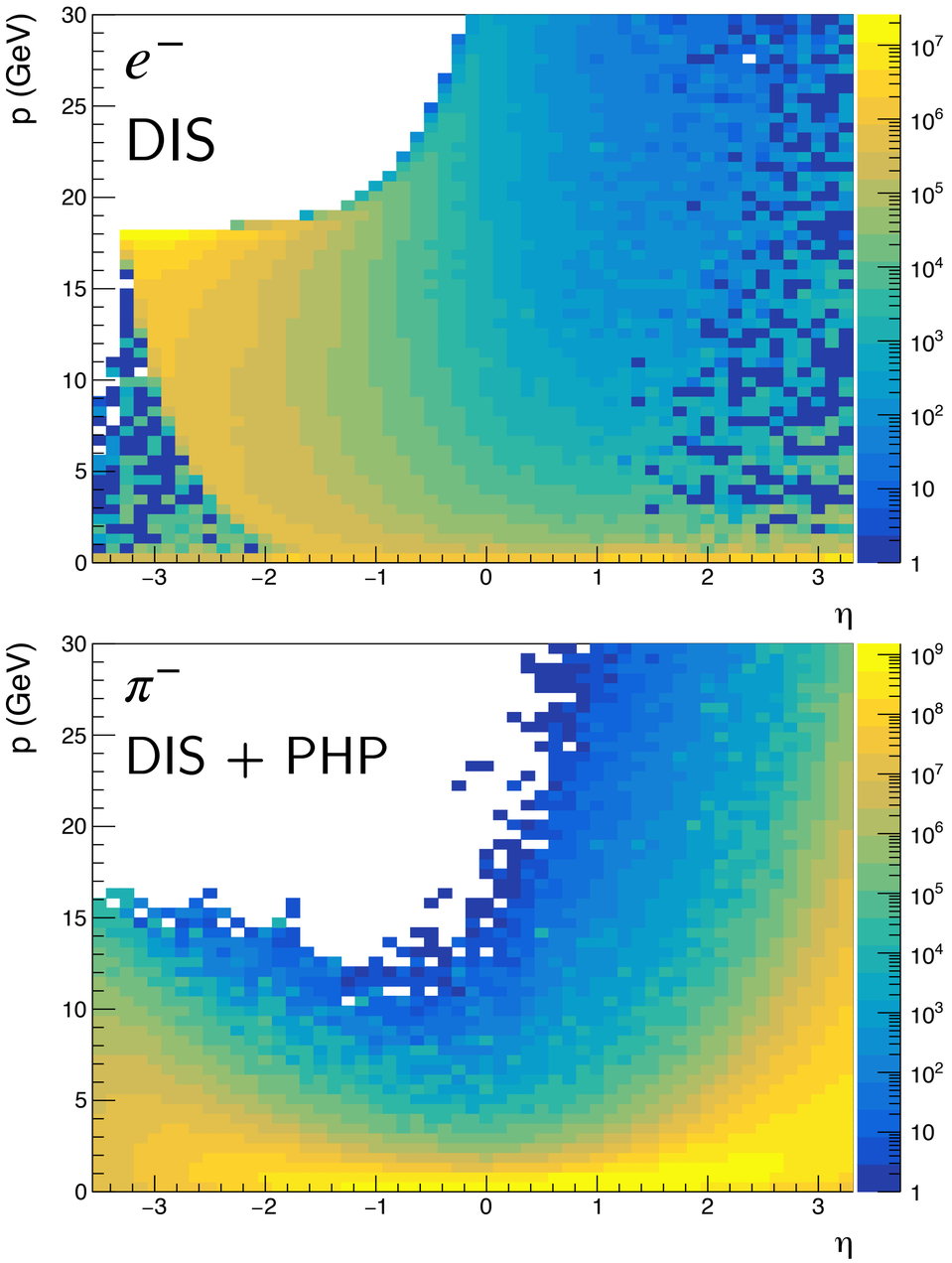


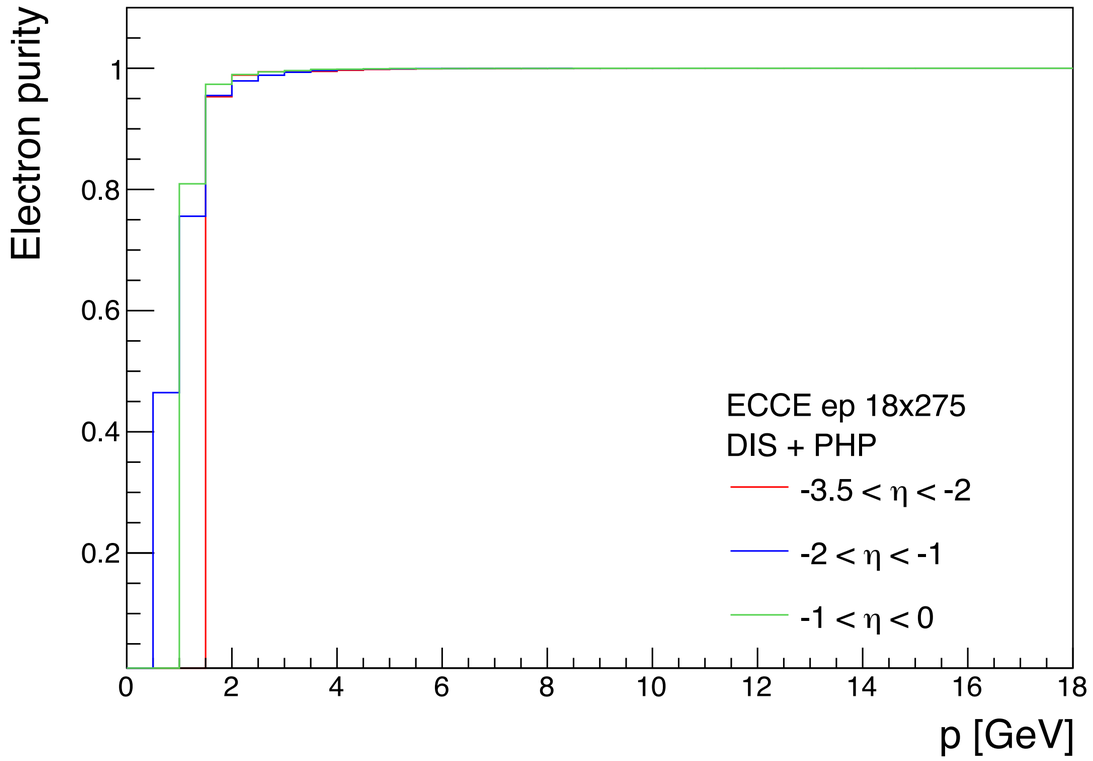
Key detector performance:

- Pion rejection/electron purity
- x, Q^2 reconstruction
- z reconstruction (SIDIS only)

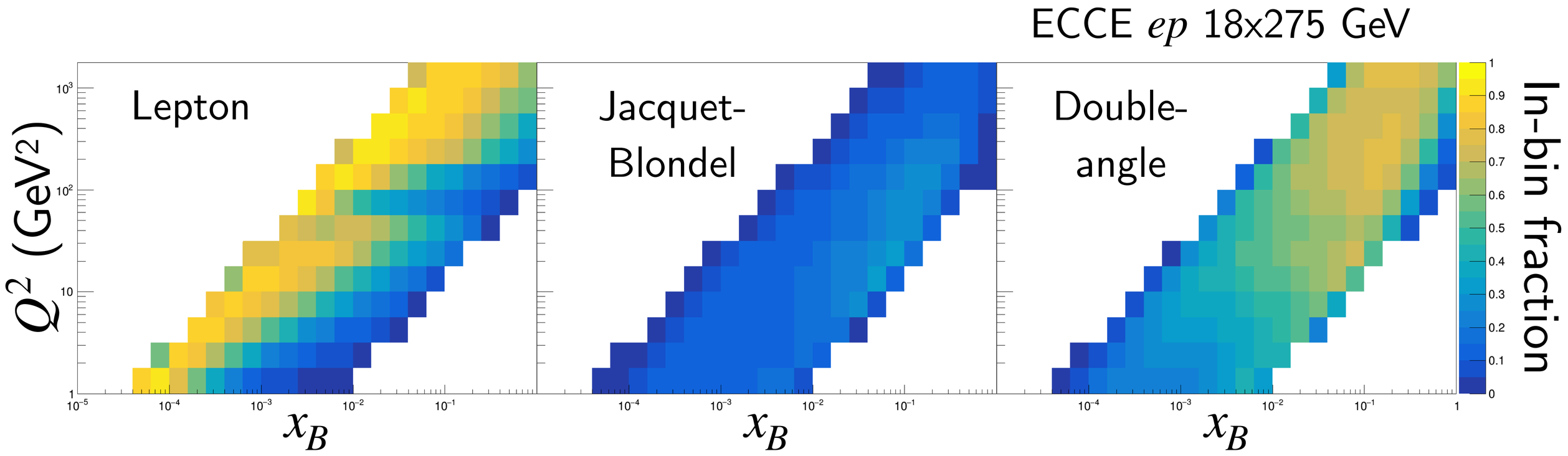
Electron purity



- Estimate π^-/e^- ratio from simulation (includes DIS and photoproduction)
- Apply pion rejection from relevant detectors (E/p, RICH, DIRC, TOF)
- Resulting contamination <2% for $p_e > 2$ GeV

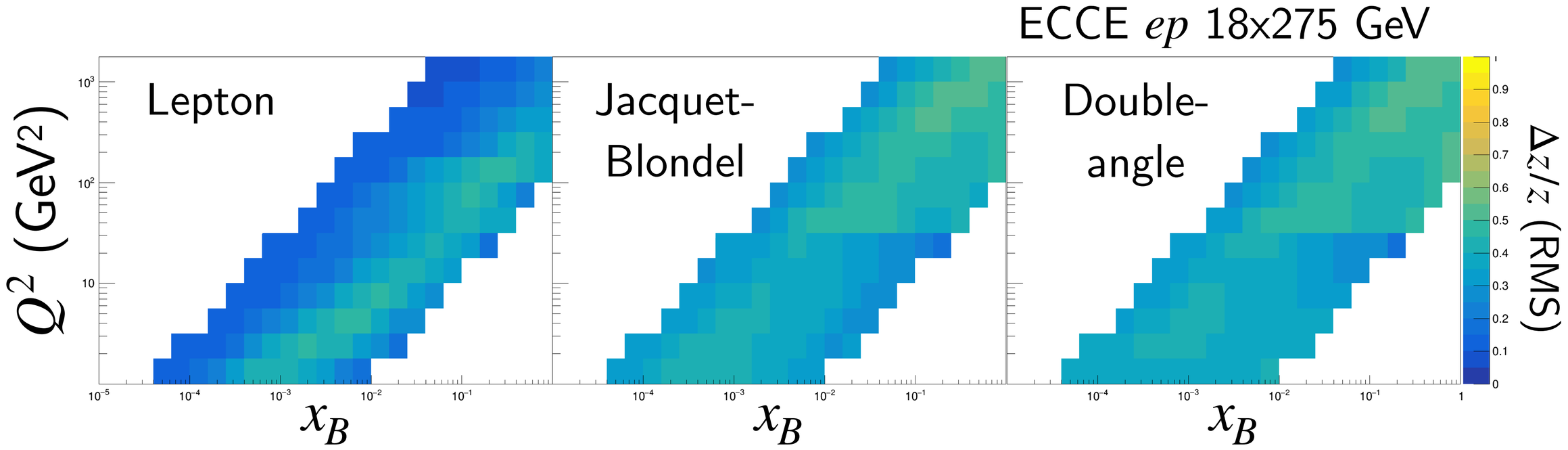


DIS reconstruction (inclusive and semi-inclusive)



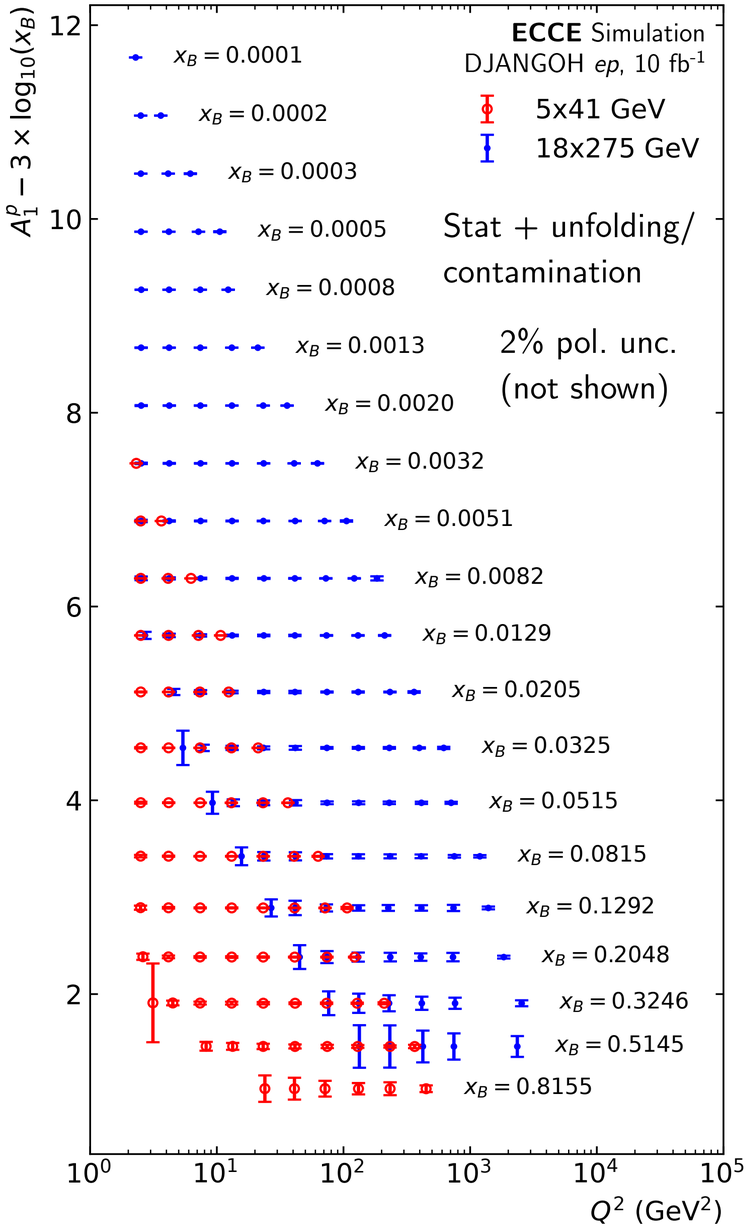
- Leverage multiple reconstruction methods to achieve maximum resolution
- Not shown: Σ methods, which can improve resolution at low y, Q^2

z reconstruction (semi-inclusive)



$$z = \frac{p \cdot p_h}{p \cdot q}$$

Projected results for inclusive A_1^p



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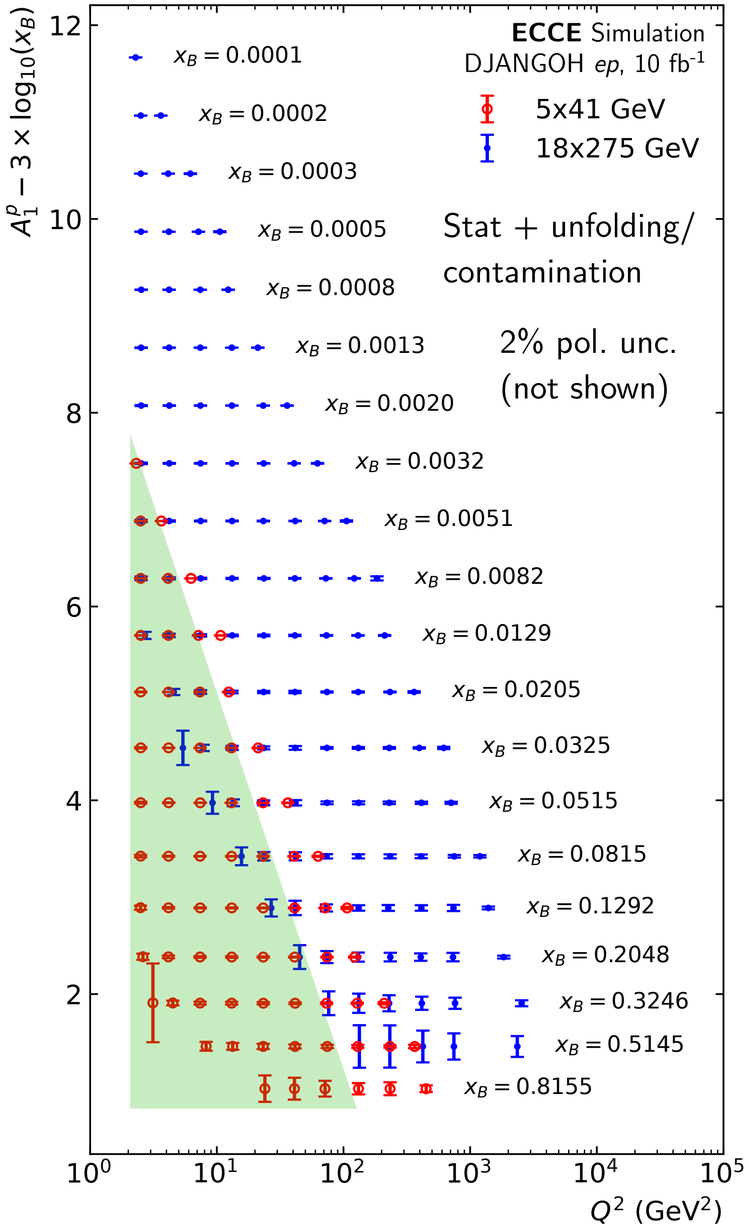
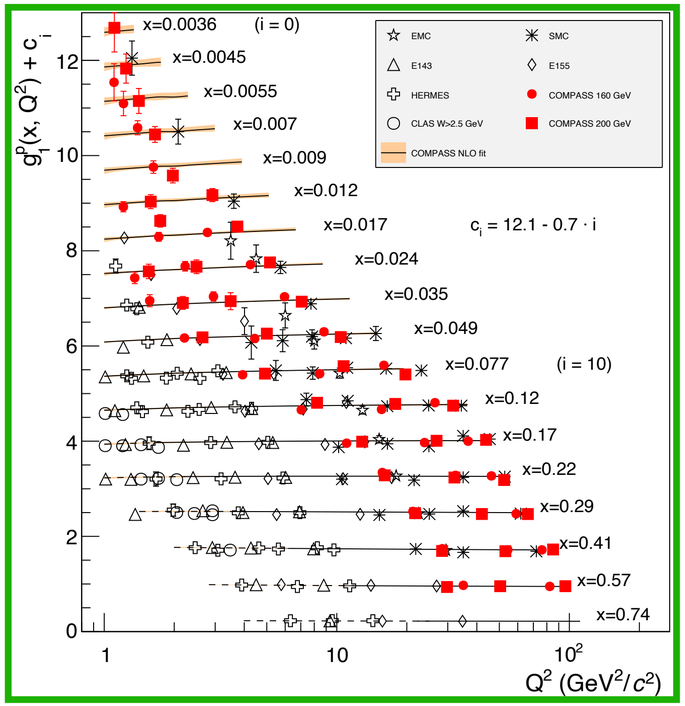


Current:

Down to $x \approx 0.005$,

$Q^2 \approx$ 1-100 GeV^2.



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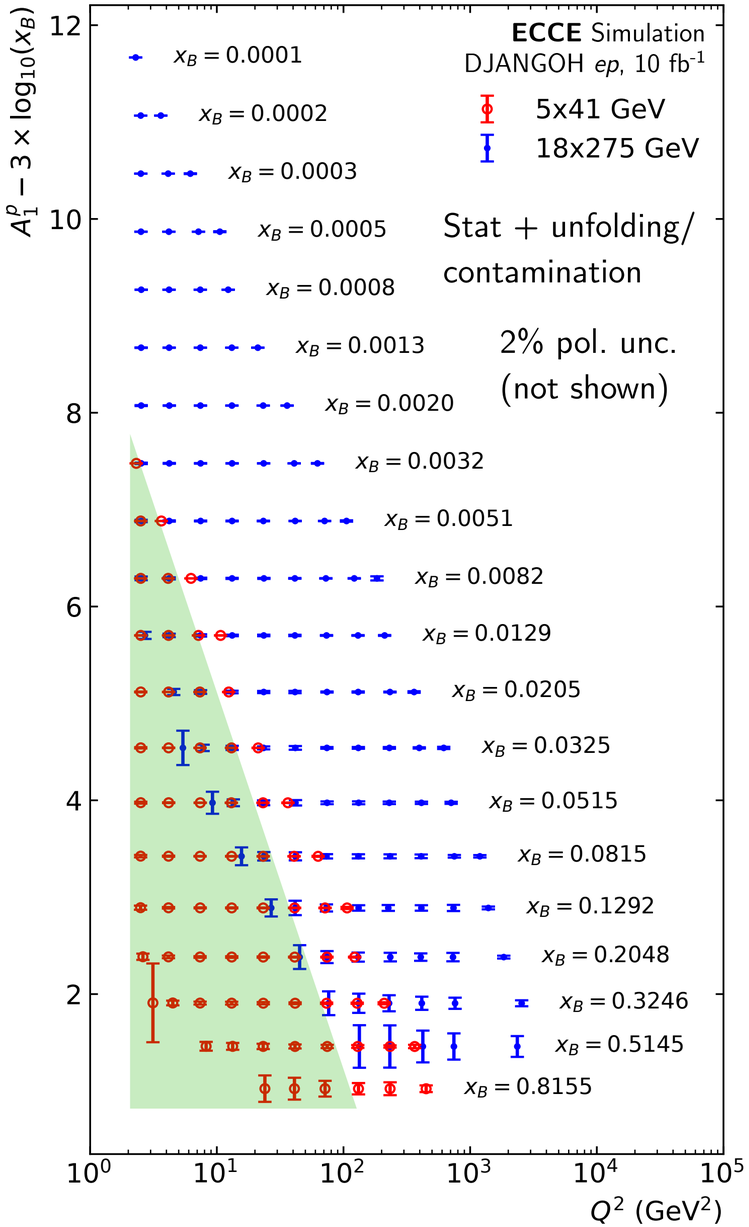
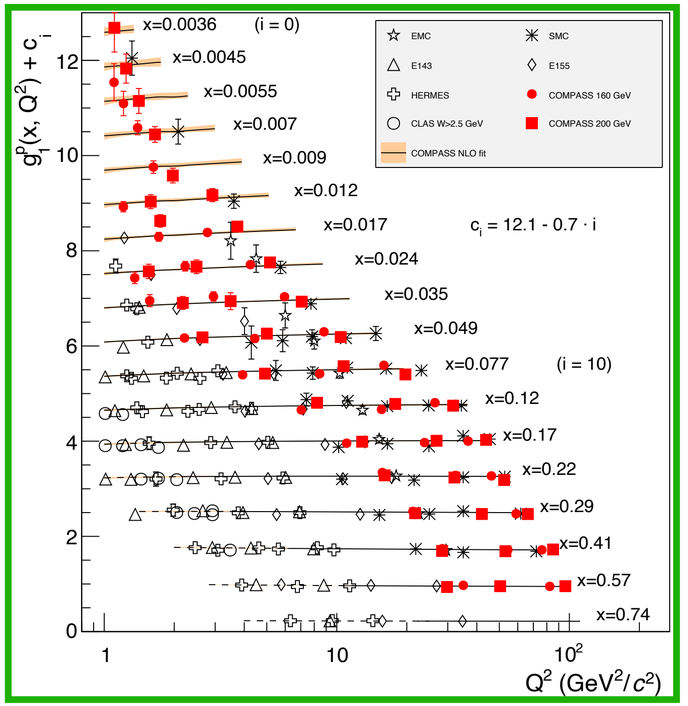


EIC: Down to $x \approx 10^{-4}$, $Q^2 \approx 1\text{-}10^3$ GeV^2!

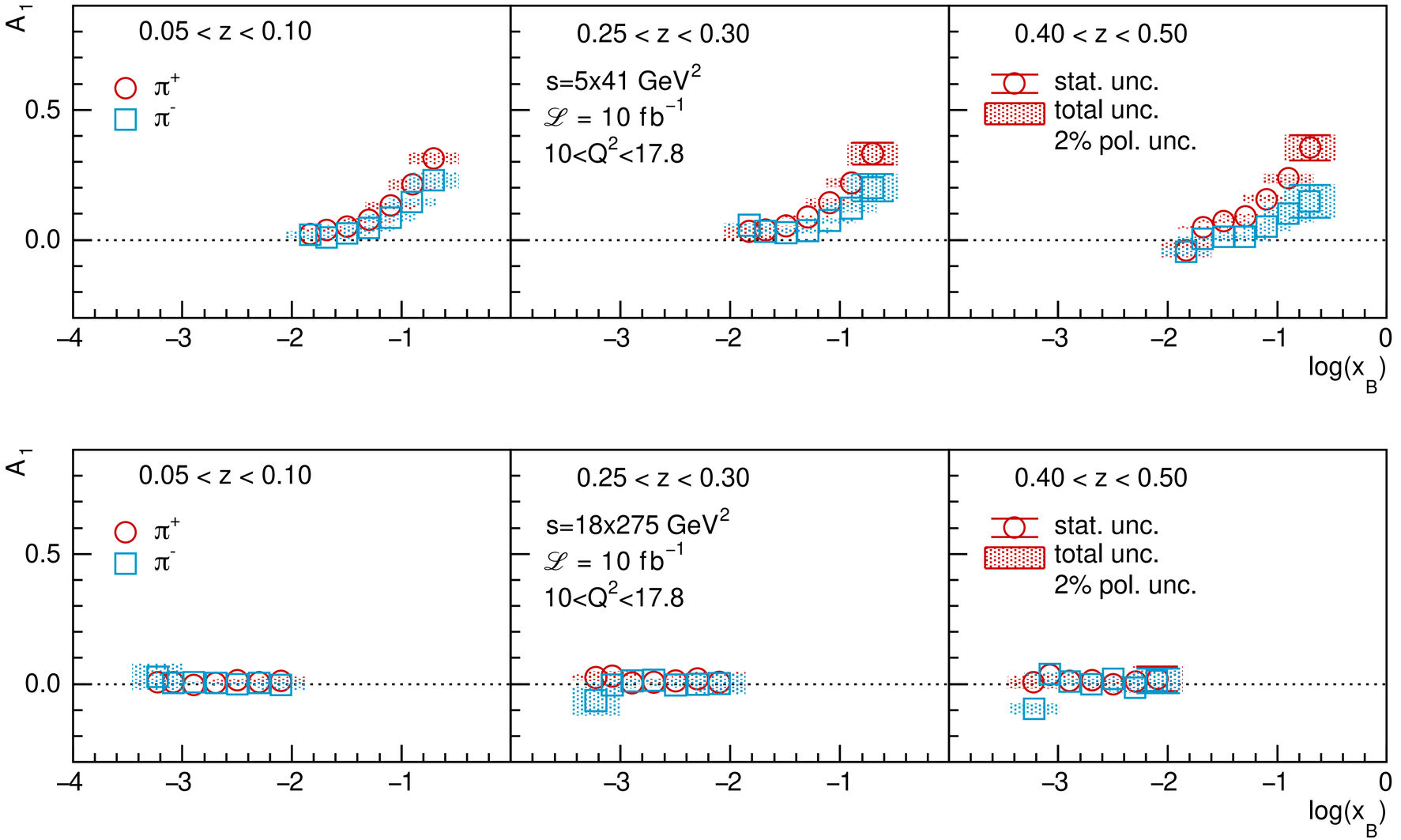
Maximize constraints on gluon spin with multiple $\sqrt{s}$ settings

Current:
Down to $x \approx 0.005$,
$Q^2 \approx 1\text{-}100$ GeV^2.



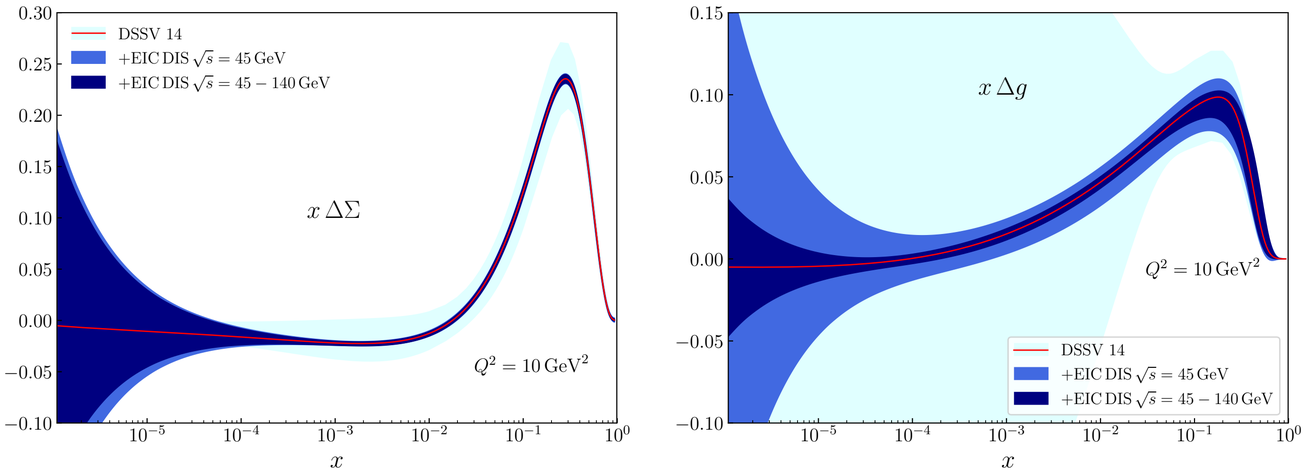
Projected results for semi-inclusive A_1^p

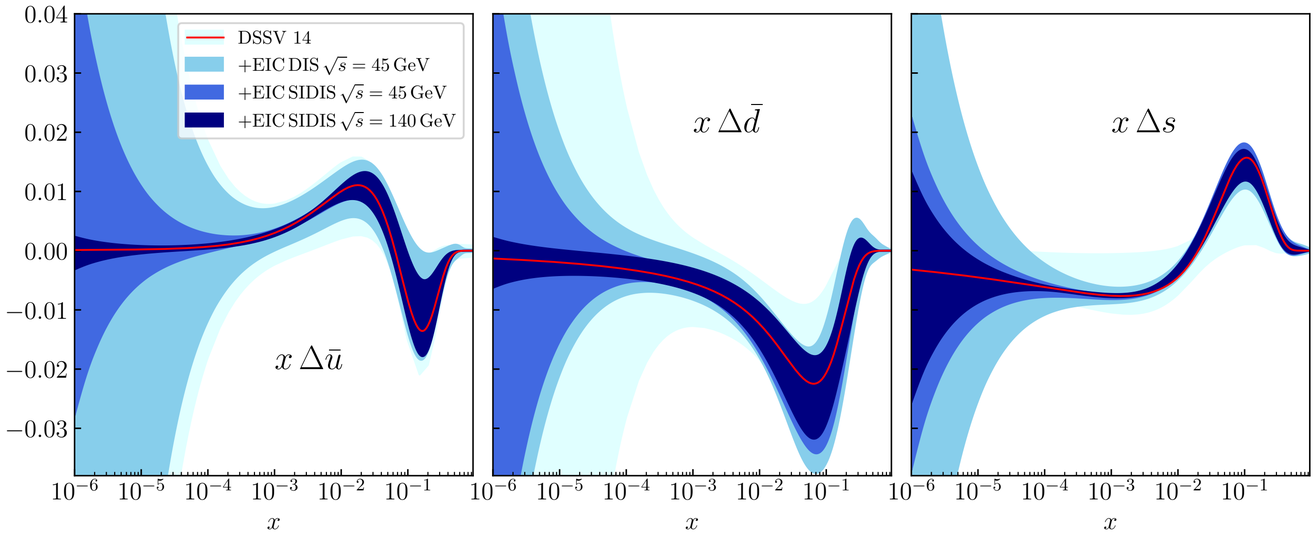
- As with inclusive, complementarity between multiple $\sqrt{s}$ settings
- Similar measurements with $K^{\pm}$



Impact of EIC measurements

- Dedicated impact plots for ECCE pseudodata in-progress
- ECCE meets detector requirements from Yellow Report
- Use YR plots to illustrate impact





What about the neutron?

- Standard (inclusive) approach: A_1^n from A_1^p, $A_1^{^3He}$
- Nuclear corrections introduce model dependence/uncertainties!
- Possible at EIC with ep and e^3He collisions

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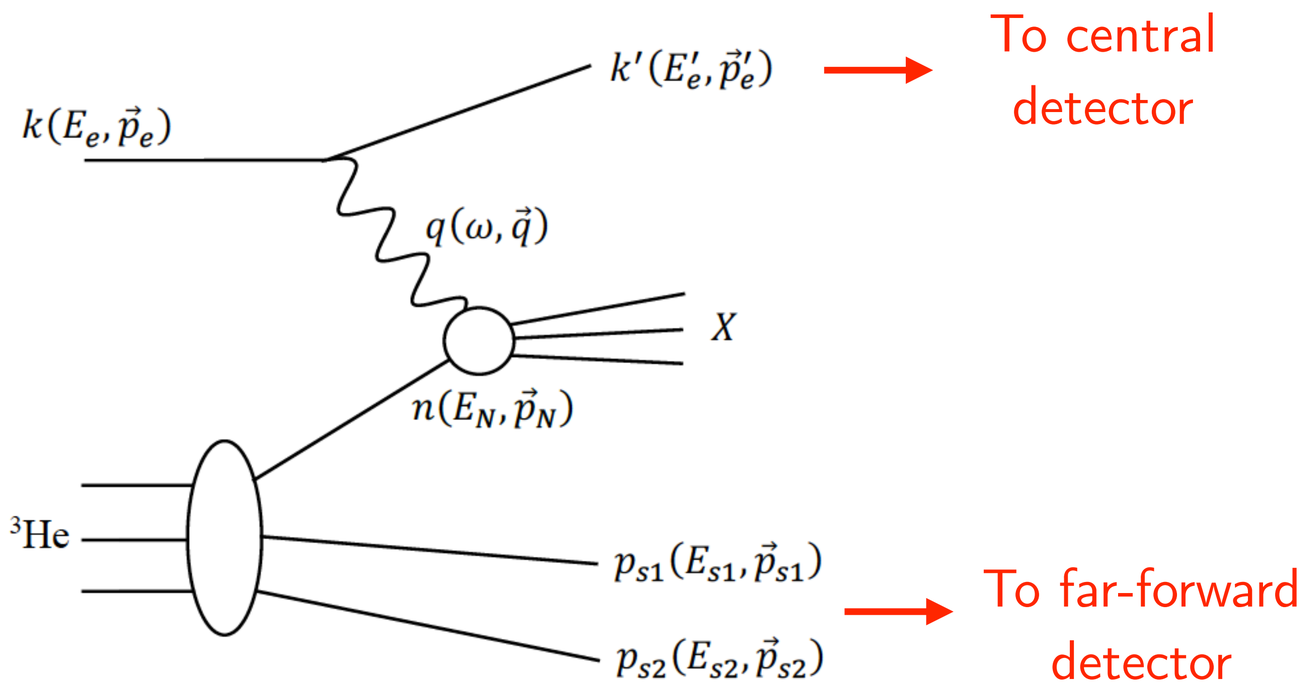

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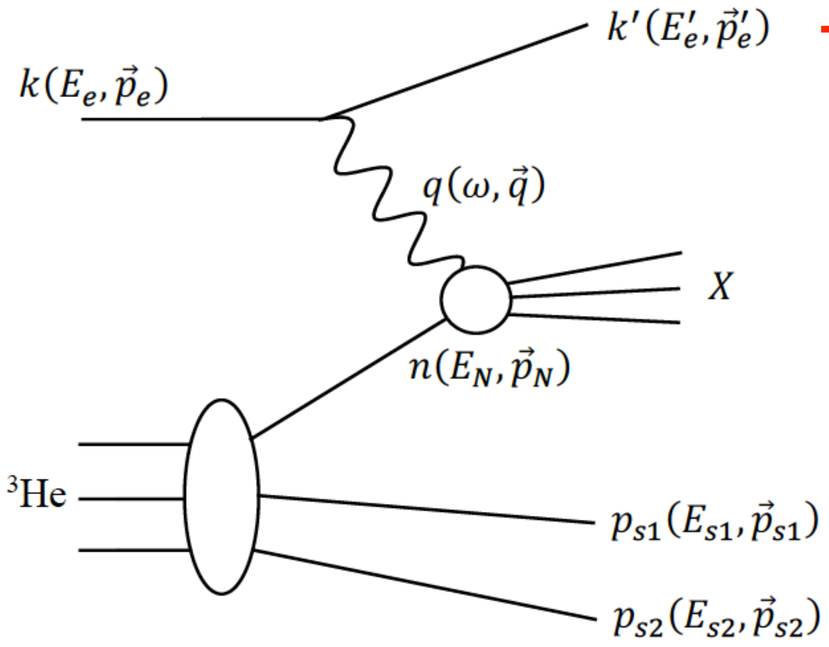
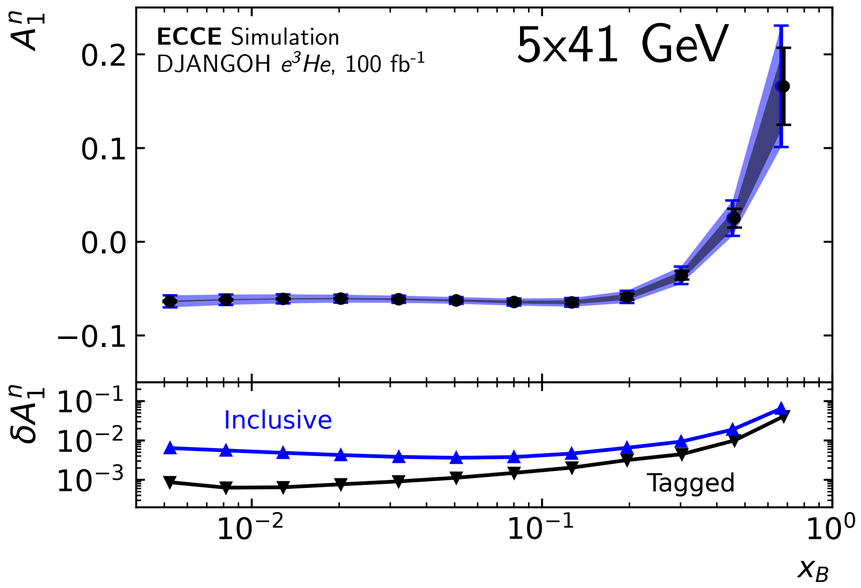
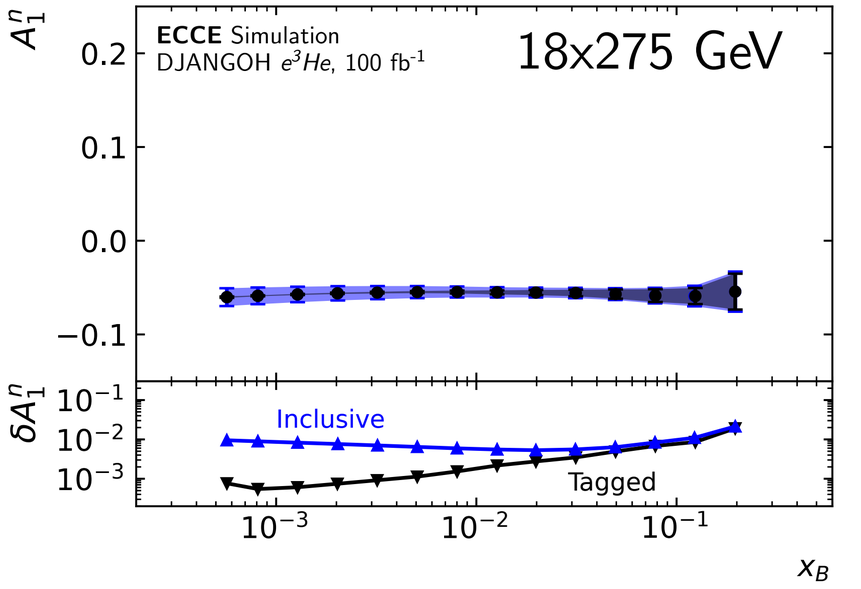


To central detector

To far-forward detector

Friscic, Nguyen, et al. PLB 823, 136726 (2021)
Updated for ECCE proposal





Summary and outlook

- Full detector simulations of ECCE detector benchmarked detector performance and physics observables
- ECCE demonstrated capability to perform variety of inclusive and semi-inclusive measurements critical to constraining quark and gluon spin in the nucleon
- In March 2022, EIC Detector Proposal Advisory Panel recommended ECCE as reference design for EIC Detector 1
- Consolidation of effort underway to form EIC Detector 1 collaboration