Parity-Violating spin structure functions in CC DIS at EIC

Churamani Paudel, David Ruth

New Mexico State University

DIS Processes and Kinematics

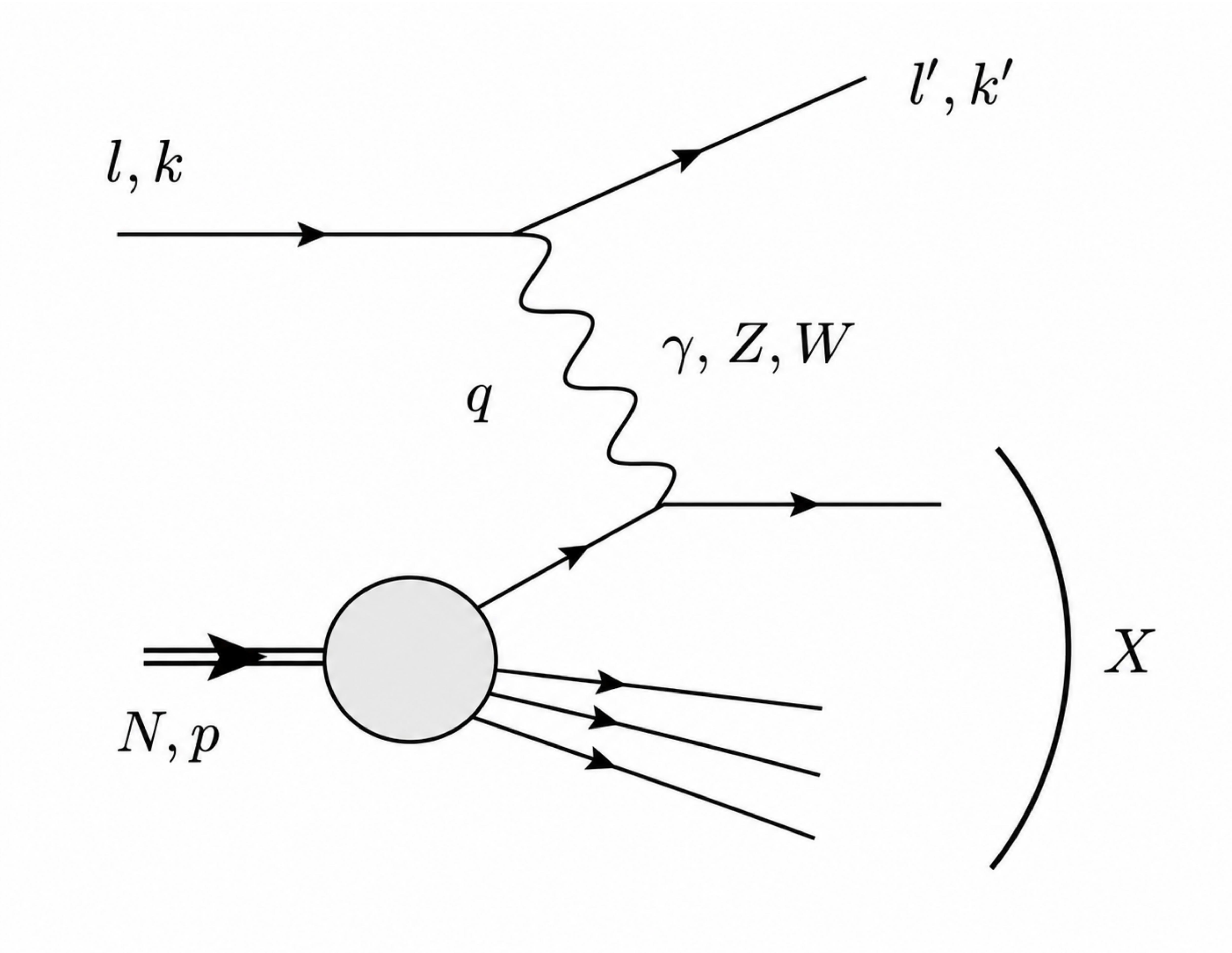
$$\ell(k) + N(p, S) \to \ell'(k') + X$$

$$e^- + \vec{p} \to \nu_e + X \qquad \text{[for Charged Current]}$$

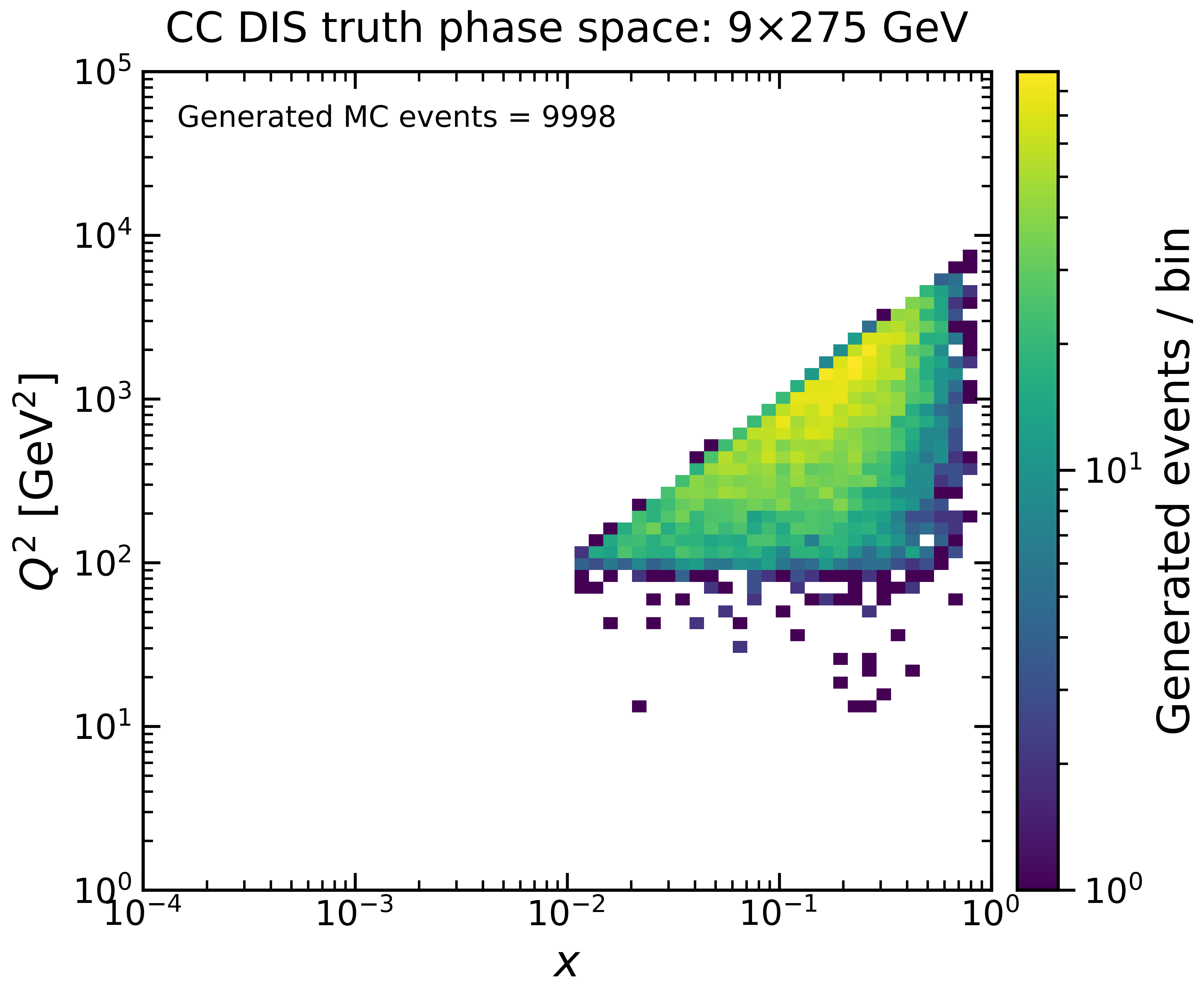
$$q = k - k'$$

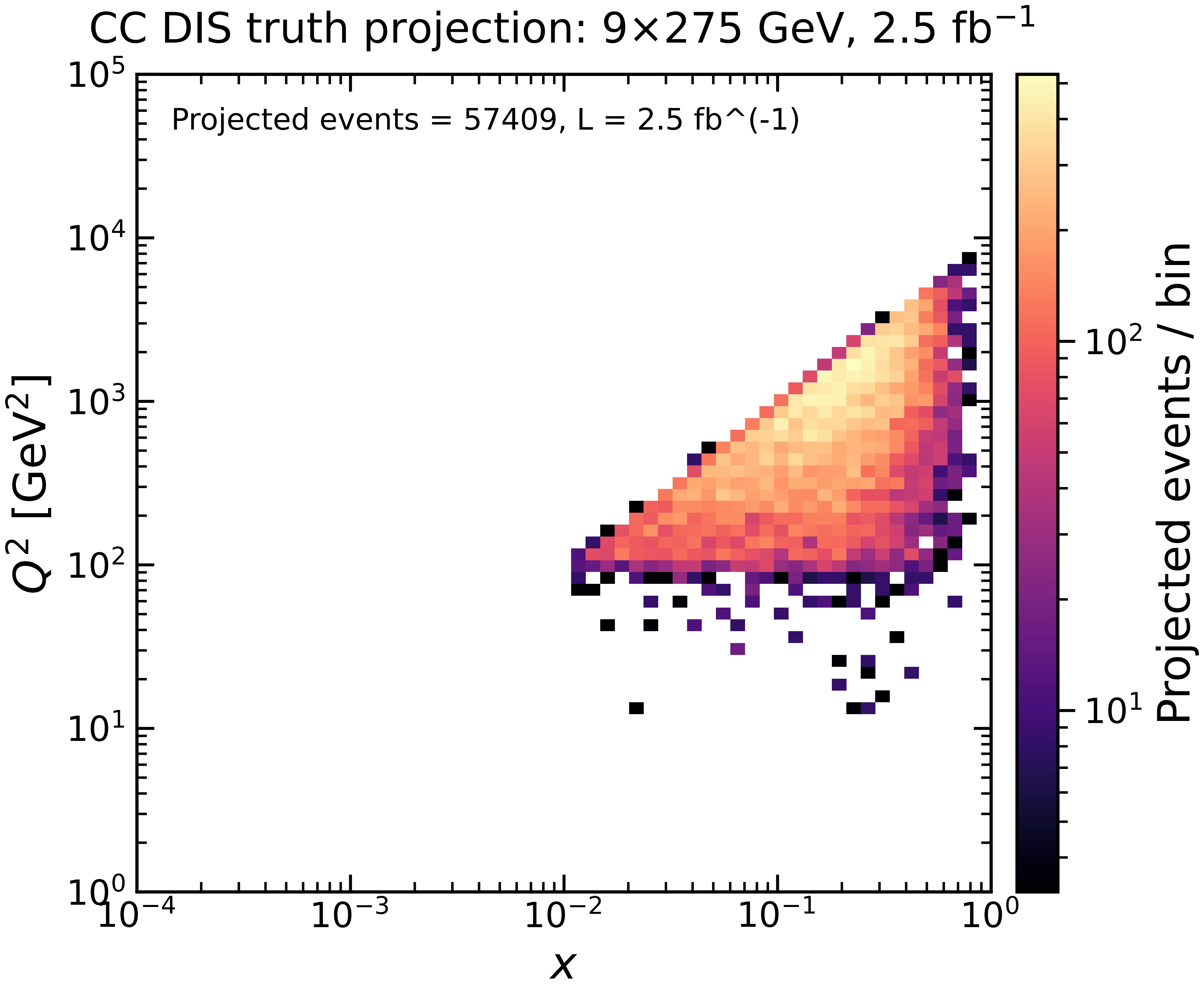
$$Q^2 = -q^2, \; W^2 = (p+q)^2 = m_N^2 + Q^2\left(\frac{1}{x} - 1\right)$$

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

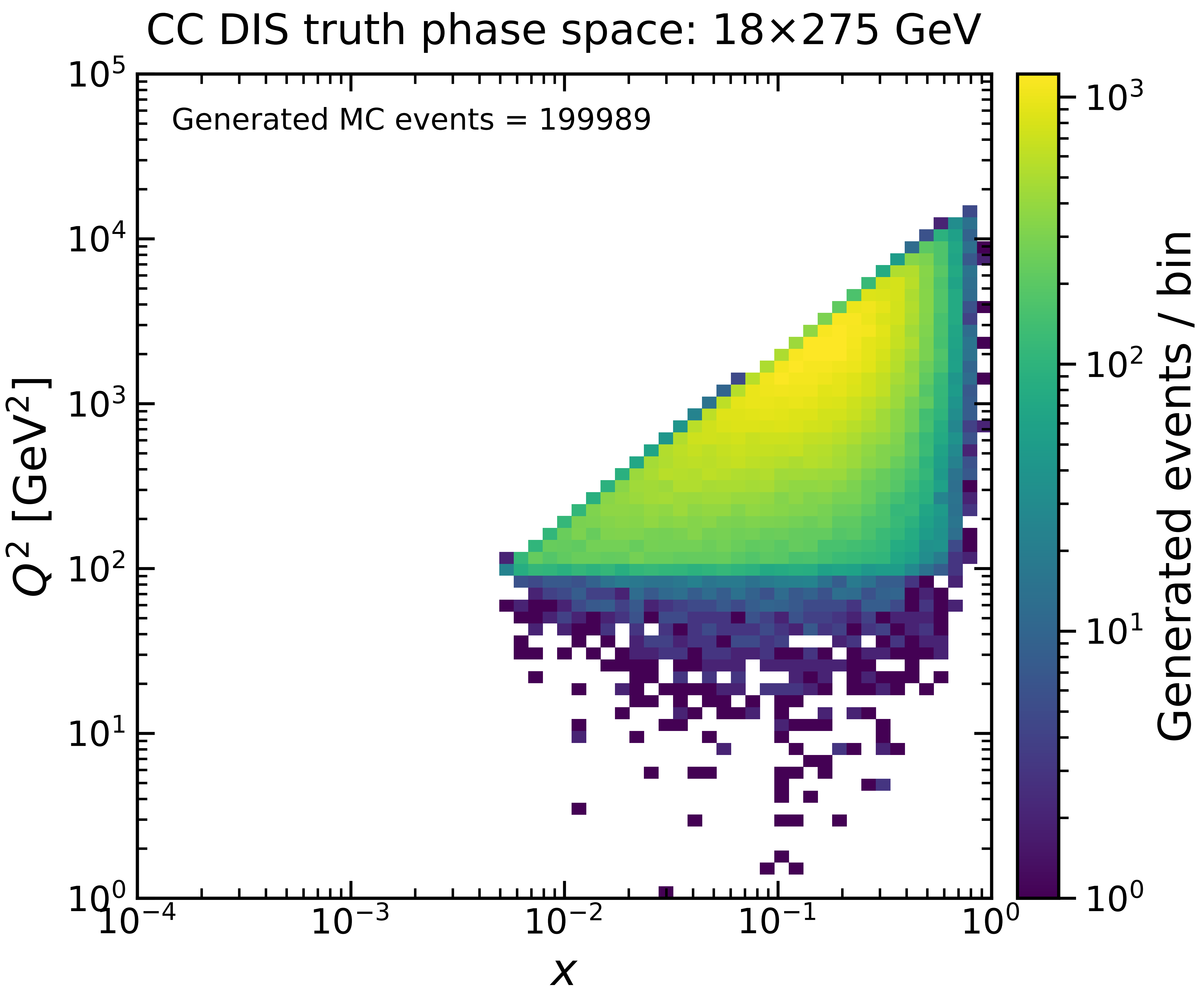


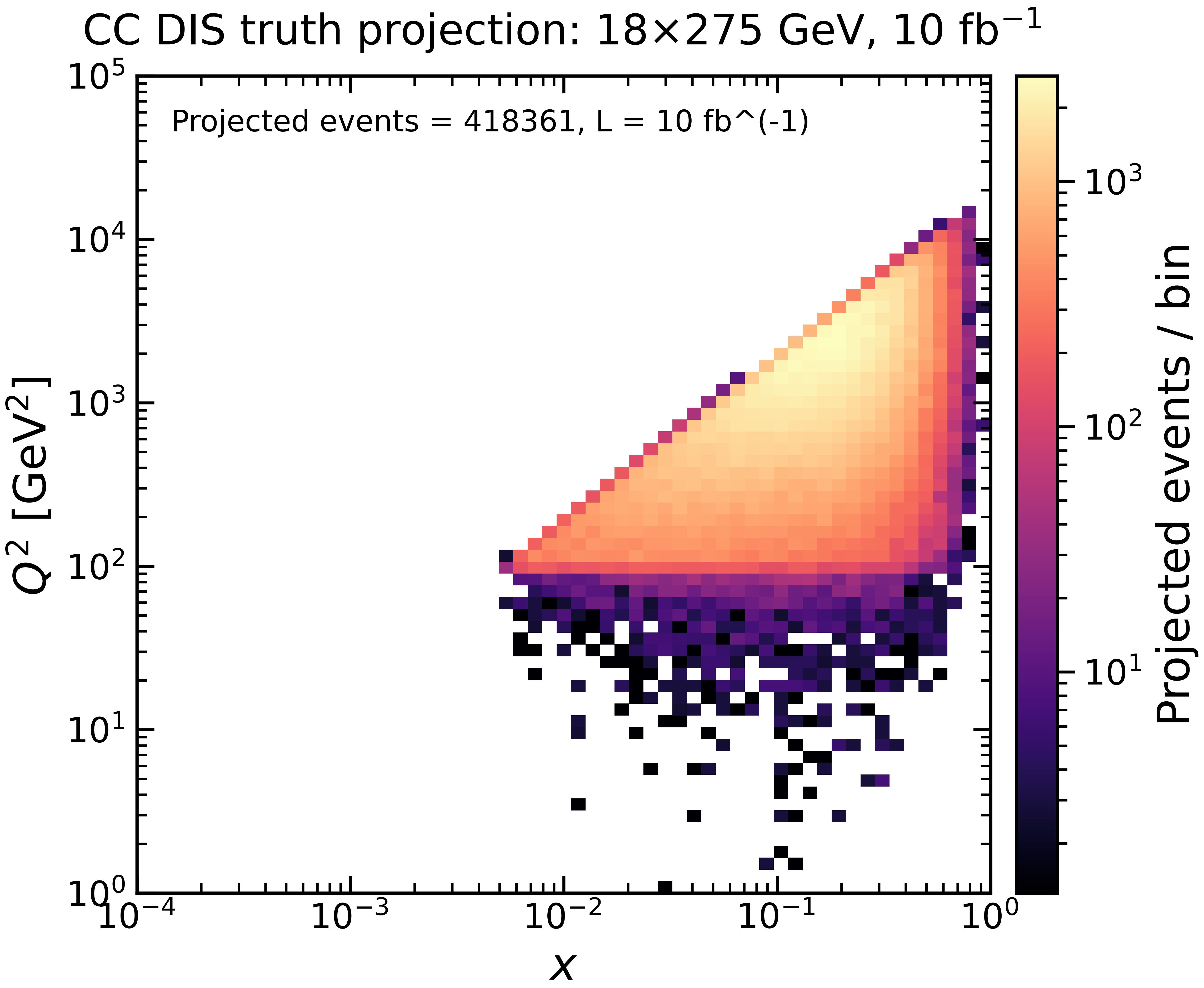
Kinematic reach and projected charged current yields: 9x275





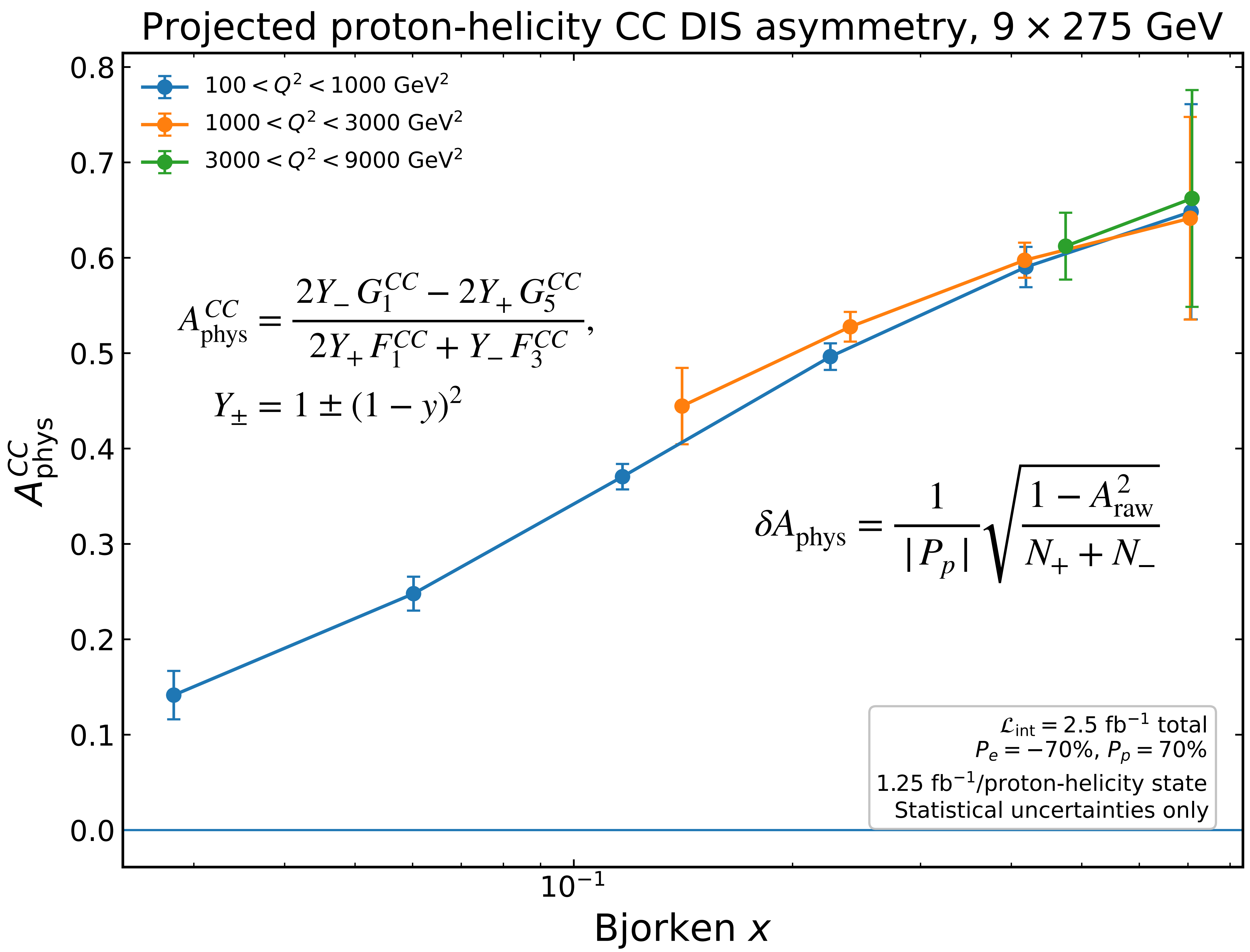
Kinematic reach and projected charged current yields: 18x275





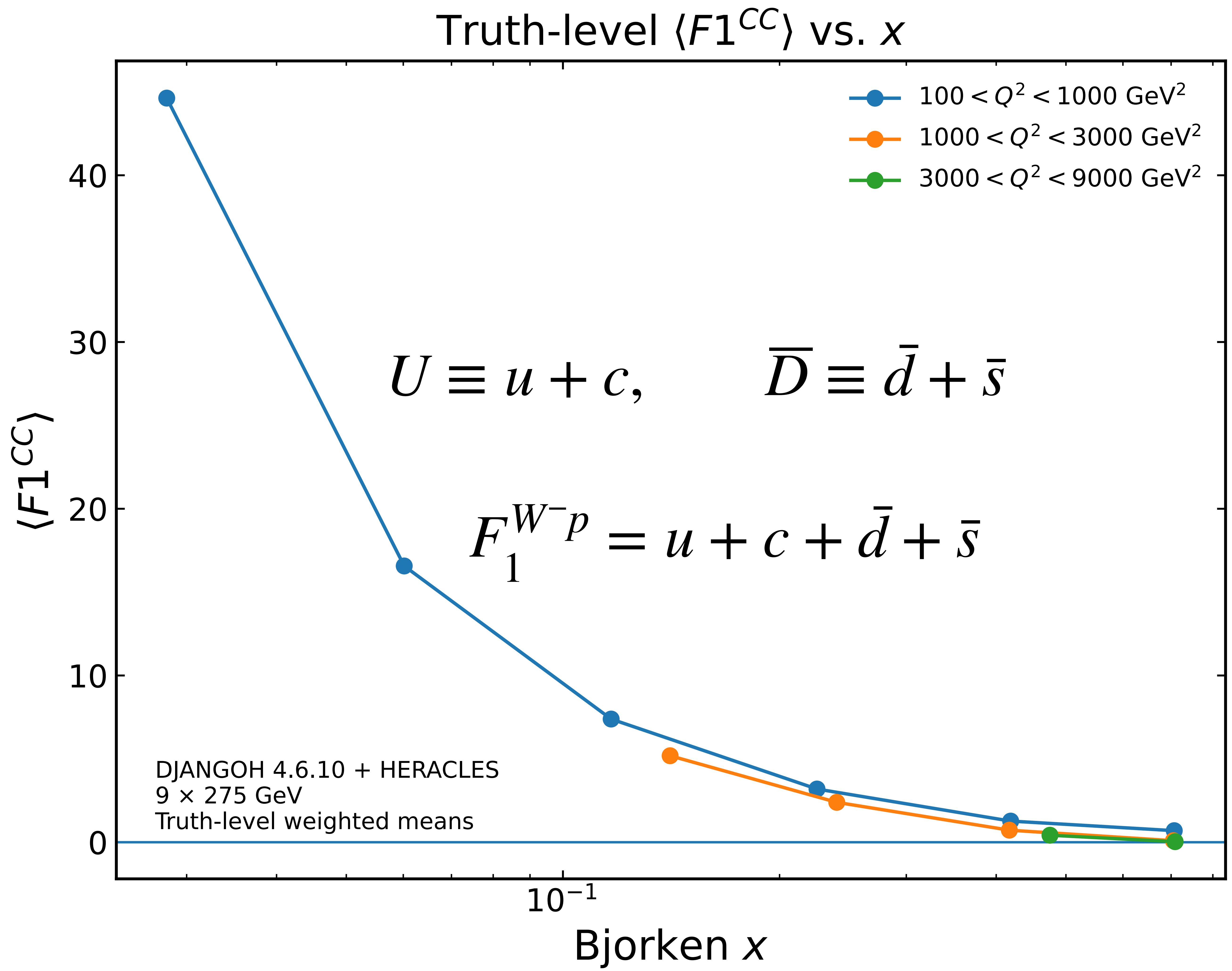
Projected proton-helicity CC DIS Asymmetry

- The projected asymmetry is sizable and statistically precise over most of the accessible intermediate-x region.
- Best statistical precision occurs approximately in 0.08< x< 0.65



Truth-level F_1^{CC} (Unpolarized structure function)

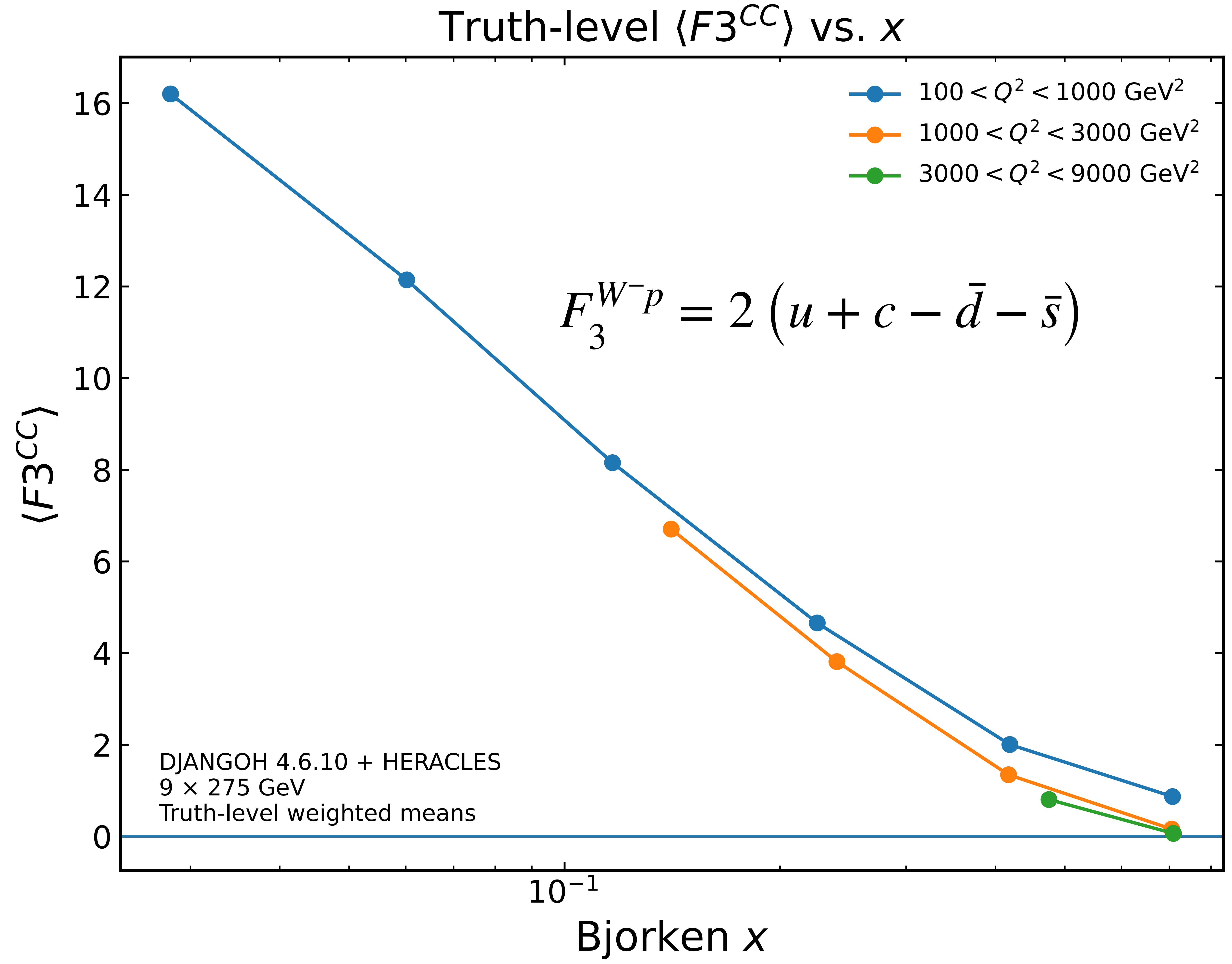
- F_1^{CC} measures a sum-like unpolarized flavor combination and provides the dominant unpolarized normalization in the asymmetry denominator.



F_3^{CC} at truth level

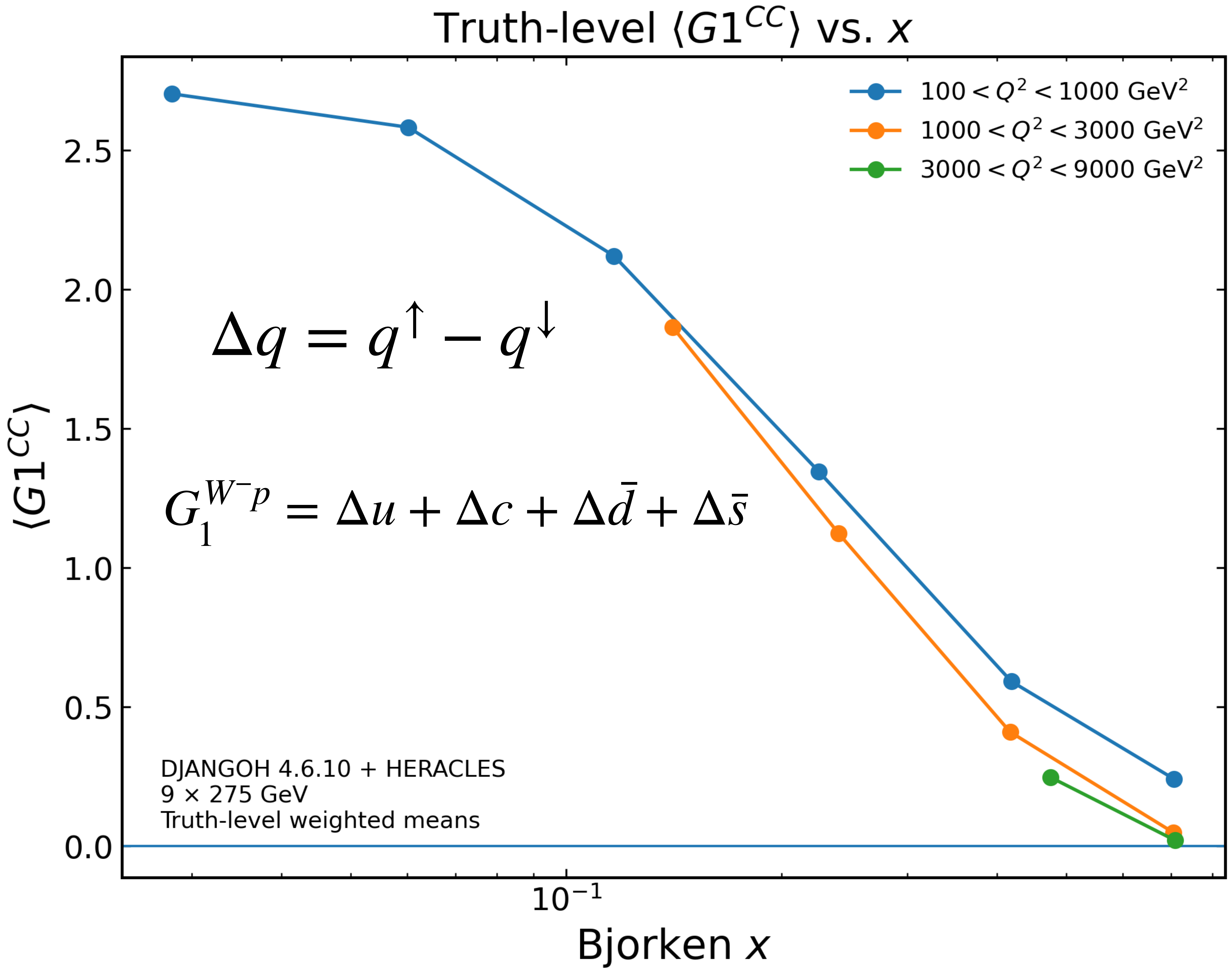
- F_3^{CC} is a parity violating but does not require a polarized proton
- Antiquarks enter from opposite sign from quarks
- It is therefore more sensitive to valence-like flavor combination than F_1^{CC}
- Comparing F_1^{CC} and F_3^{CC} separate quark and antiquark contributions.

$$U = \frac{1}{2}\left(F_1 + \frac{F_3}{2}\right), \qquad \overline{D} = \frac{1}{2}\left(F_1 - \frac{F_3}{2}\right)$$



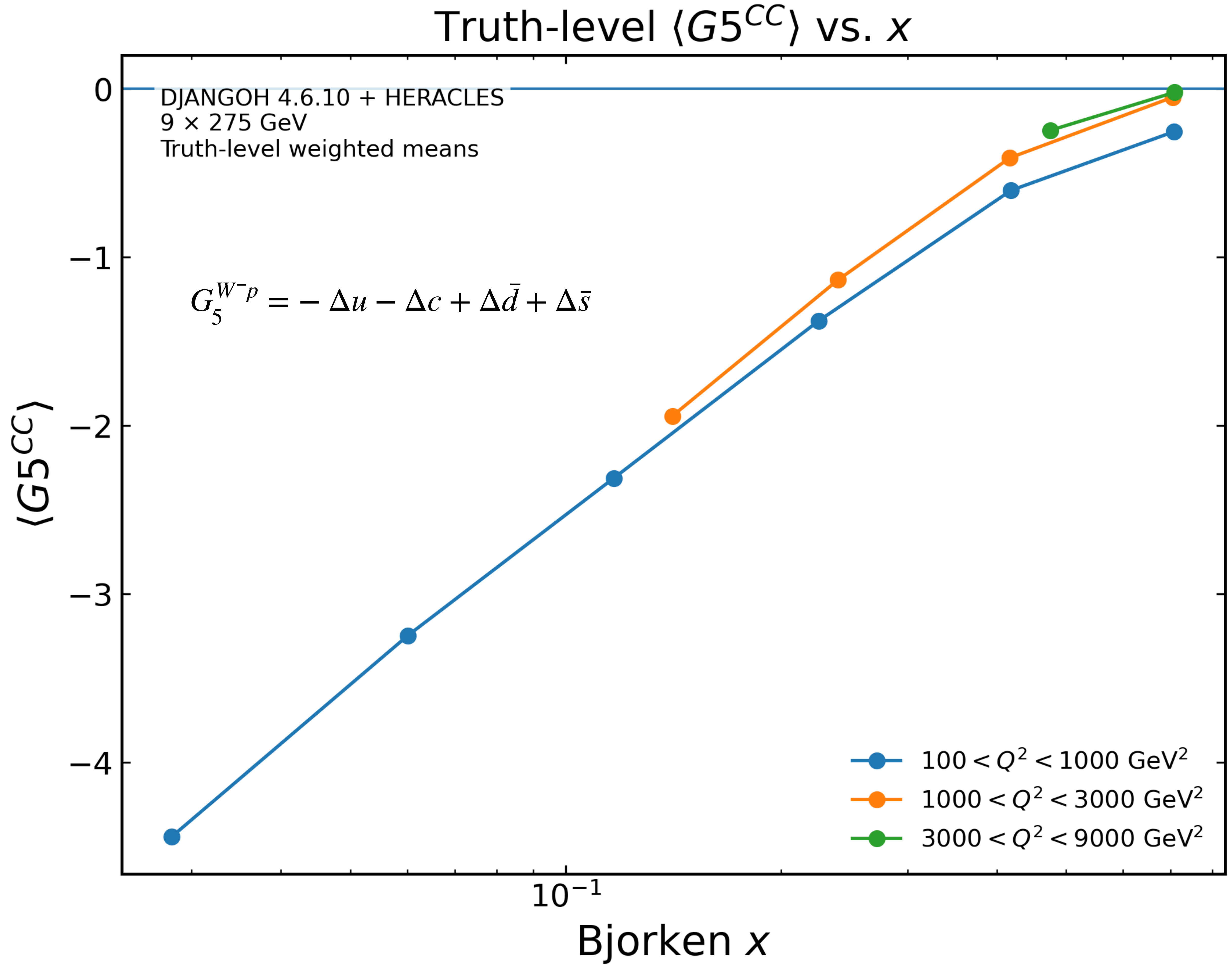
G_1^{CC} at truth level

- G_1^{CC} is a helicity-weighted quark-plus-antiquark combination
- The positive result in this sample reflects the selected polarized-PDF input and convention.
- Its contribution to the measured asymmetry is weighted by $Y_- = y(2-y)$
- G_1^{CC} describes the helicity sum



G_5^{CC} at truth level

- DJANGOH truth-level cross-section-weighted bin means. Curves do not include luminosity-based experimental uncertainties.
- G_5^{CC} is sensitive to a C-odd helicity combination
- It is negative in this truth sample because -ΔU contribution dominates
- It vanishes towards x=1, where polarized PDFs also vanish
- The combination of G_1^{CC} and G_5^{CC} enables inclusive quark-antiquark helicity separation.

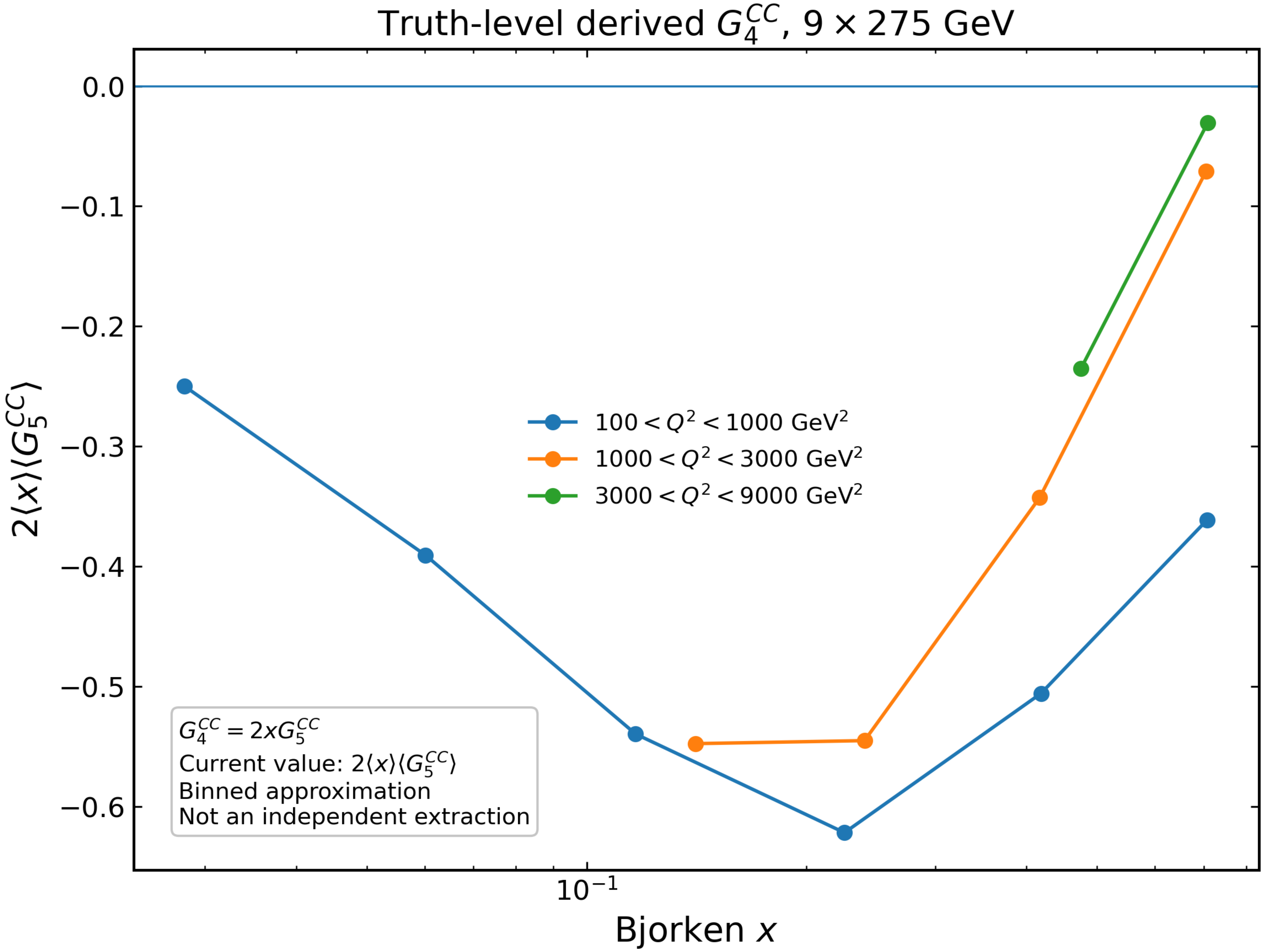


G4 from G5 using Dicus relation

- Derived from the LO Dicus relation; current values use a binned approximation.

$$\left\langle G_4^{CC} \right\rangle_{\text{bin}} = \frac{\sum_i w_i \, 2x_i G_{5,i}^{CC}}{\sum_i w_i}$$

$$\left\langle G_4^{CC} \right\rangle_{\text{bin}} \approx 2 \left\langle x \right\rangle_{\text{bin}} \left\langle G_5^{CC} \right\rangle_{\text{bin}}$$

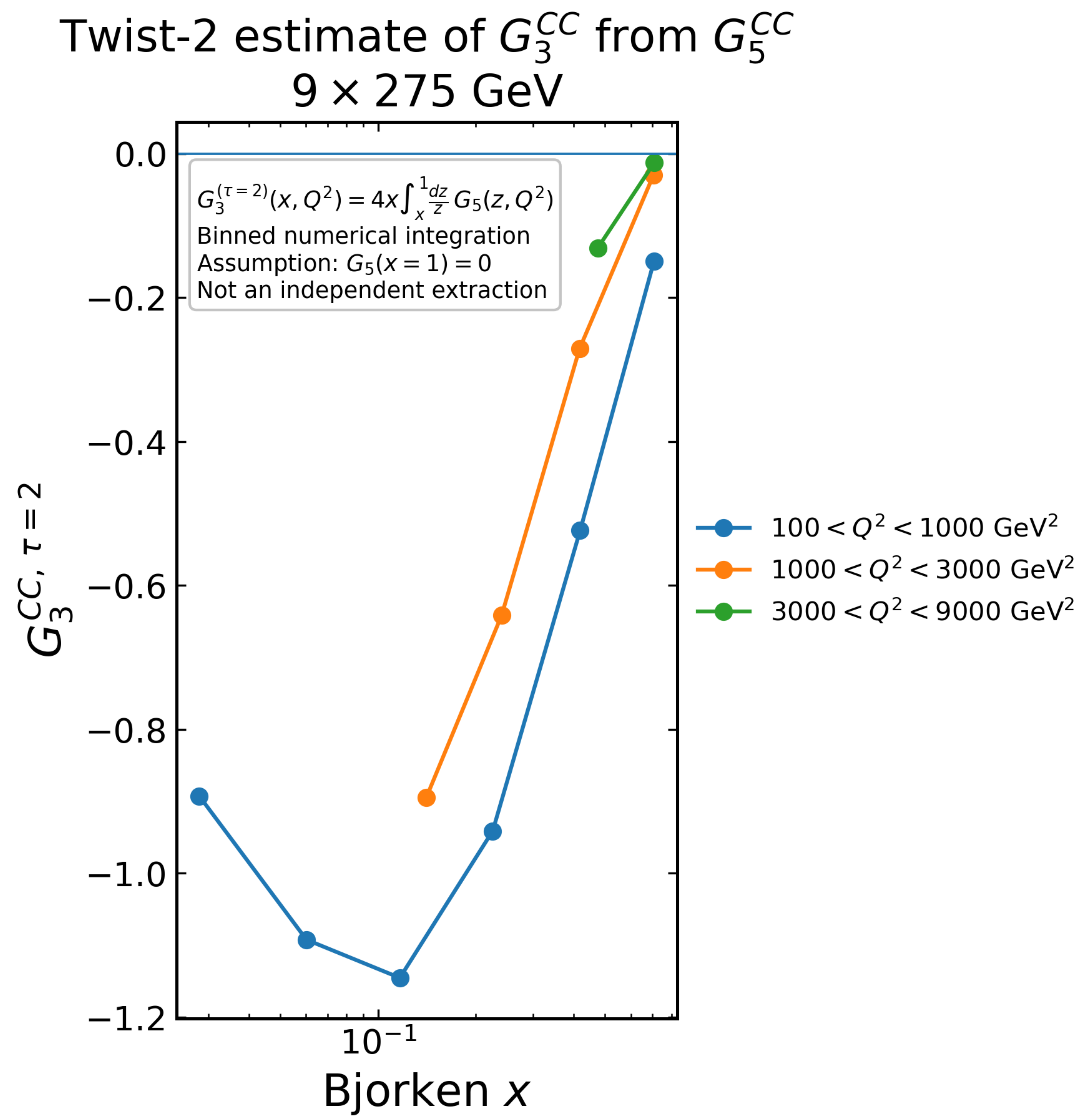


Twist-2 estimate of G3 from G5 at 9x275

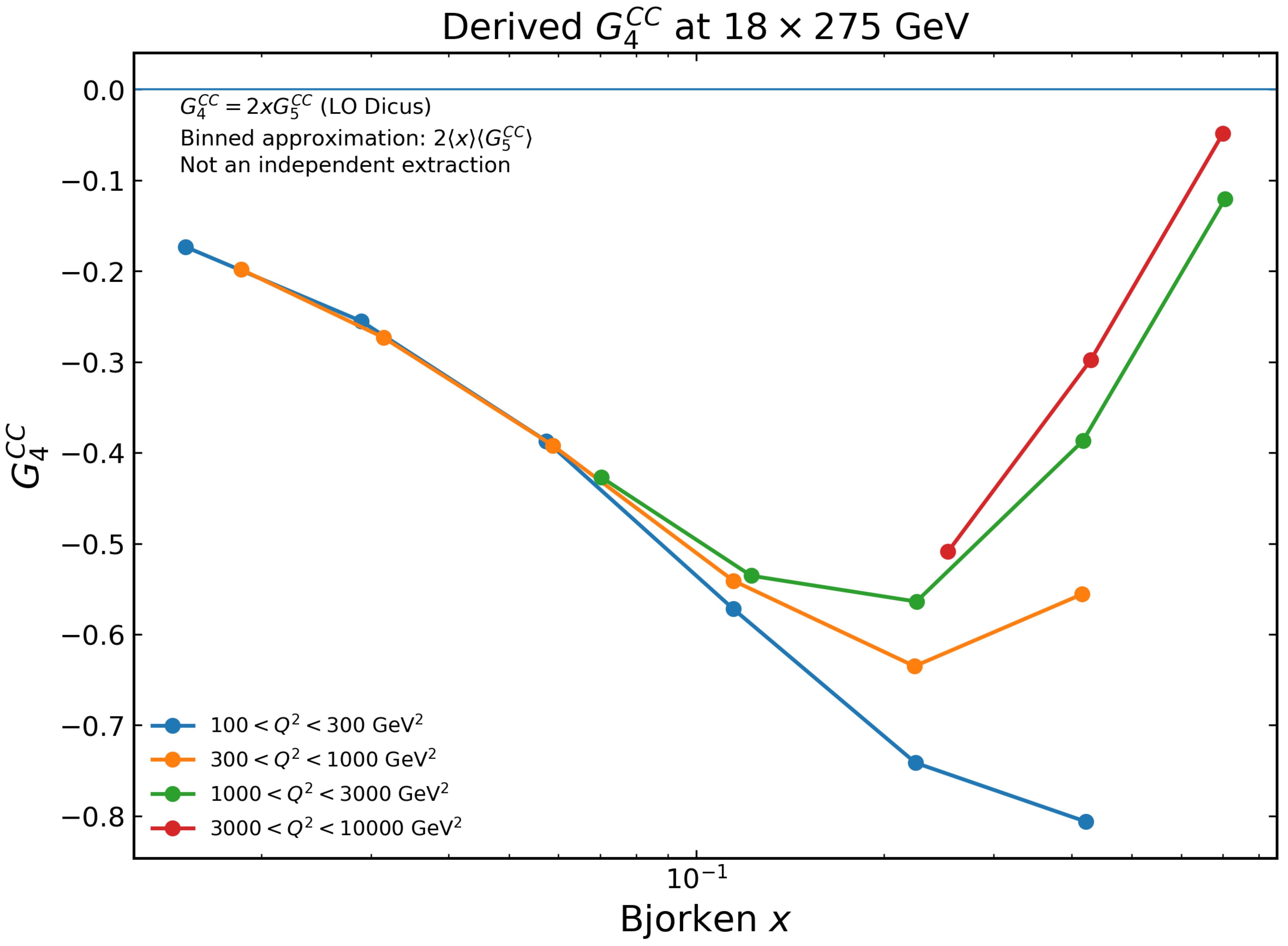
- Preliminary twist-2 integral estimate; endpoint extrapolation and integration-model uncertainties are not shown.
- The present result predicts only the twist-2 component; an independent full G3CC measurement requires sensitivity to transverse-spin and twist-3 contributions.

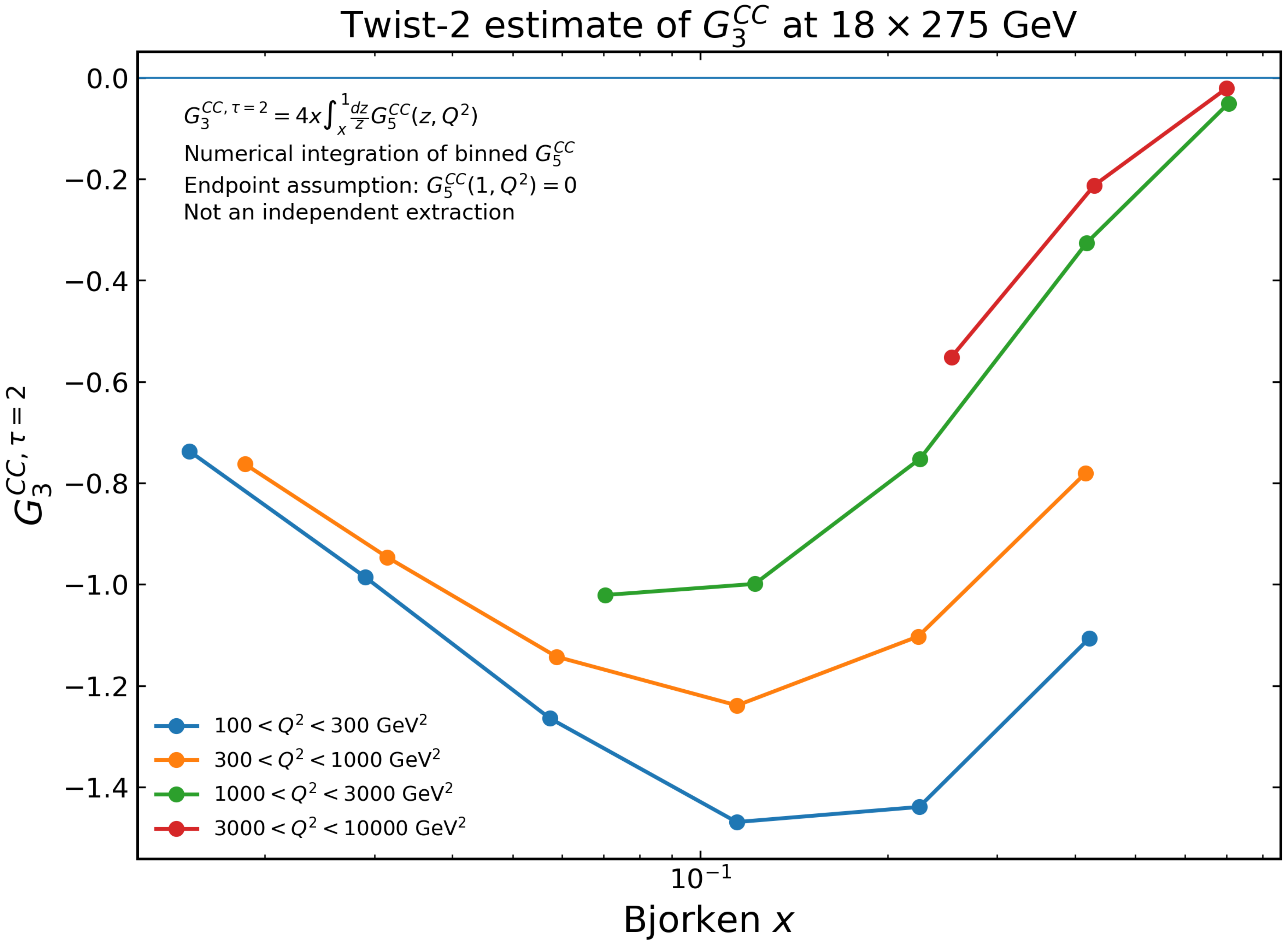
$$G_3^{CC} = G_3^{CC,\tau=2} + G_3^{CC,\tau=3}$$

$$G_3^{CC,\tau=2}(x,Q^2) = 2x\int_x^1 \frac{dz}{z^2}\,G_4^{CC}(z,Q^2)$$

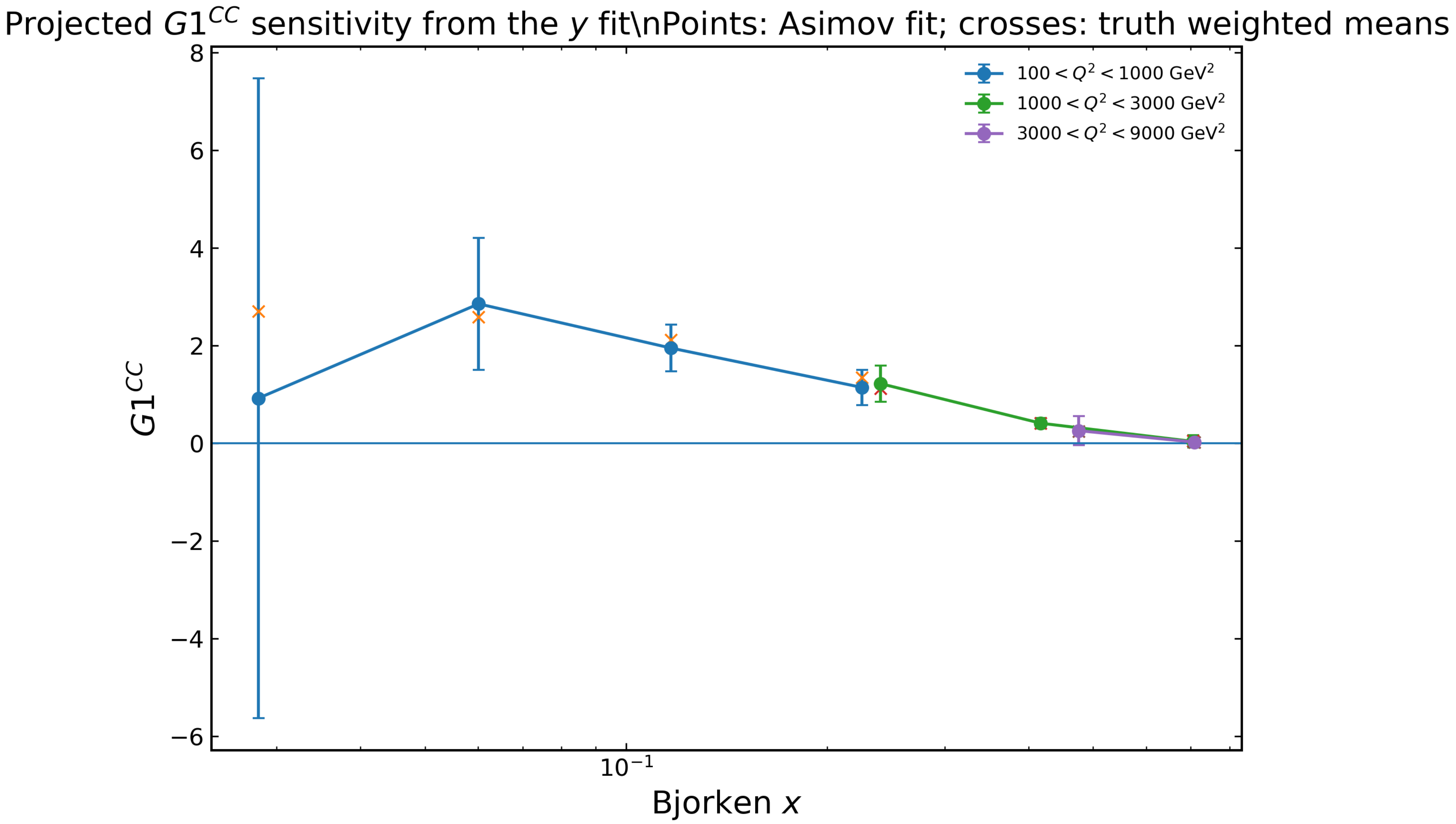


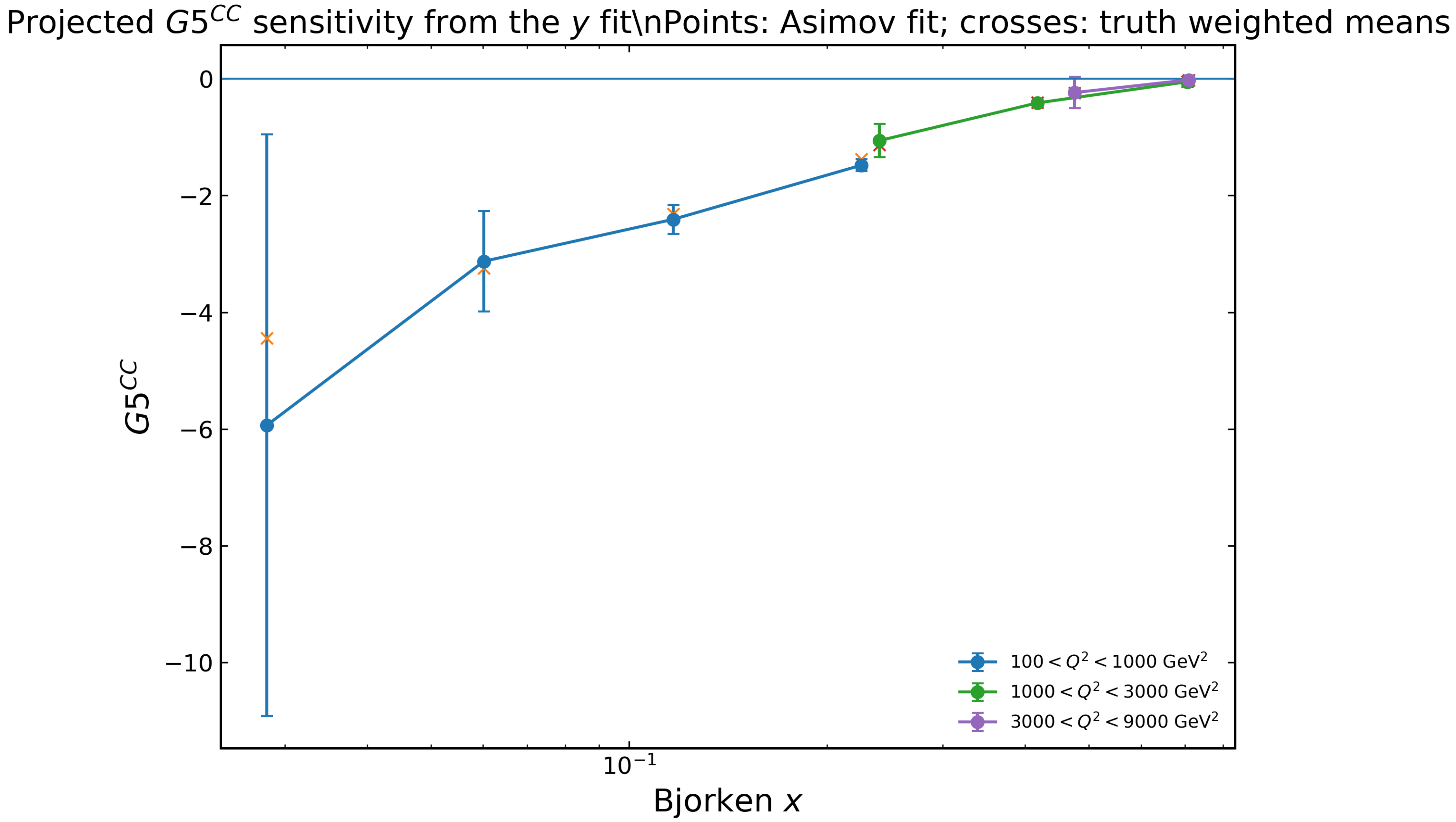
Derived G_4^{CC} and twist-2 G_3^{CC} estimate at 18x275





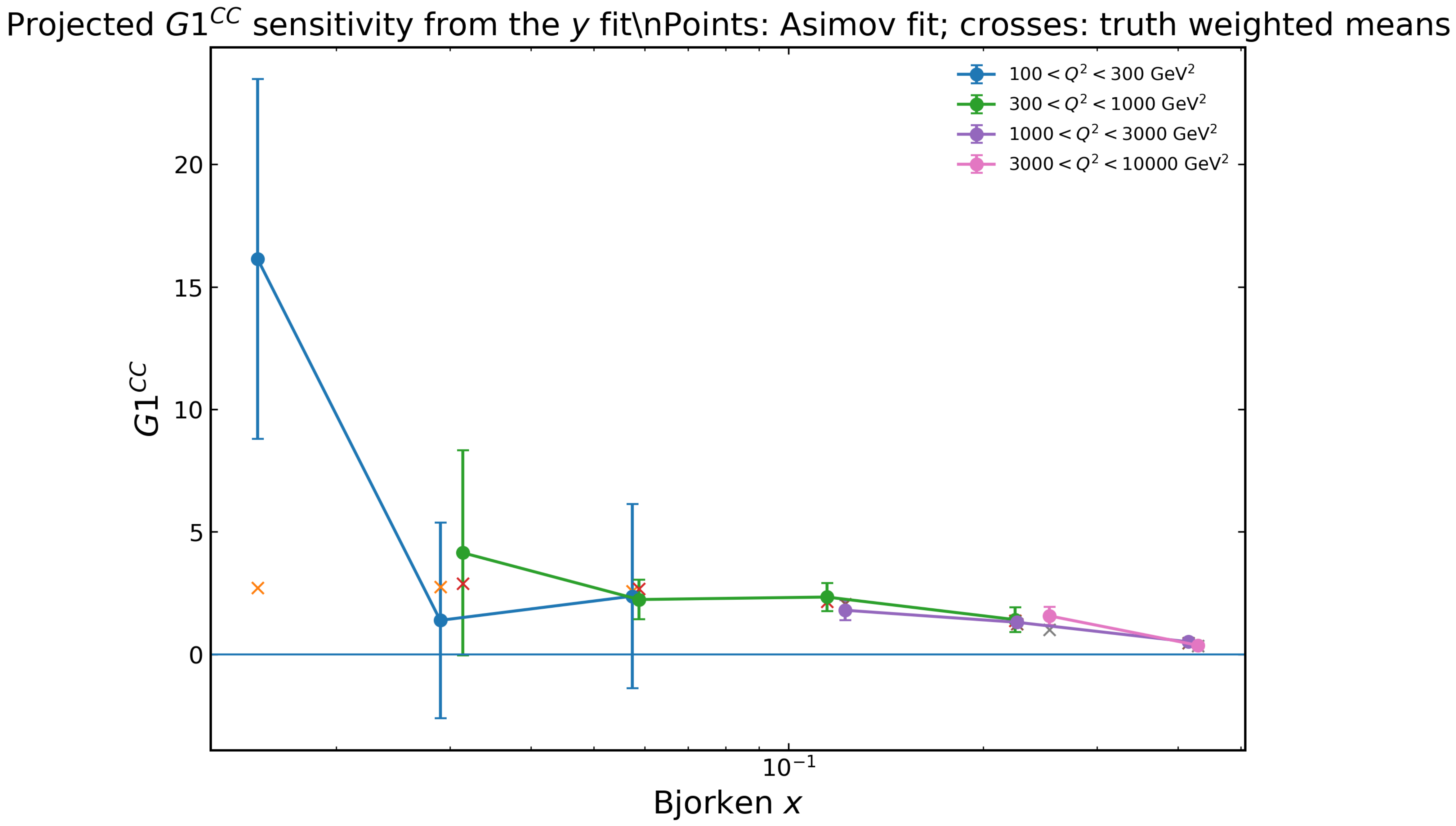
Projected G_1^{CC} and G_5^{CC} sensitivity At 9x275

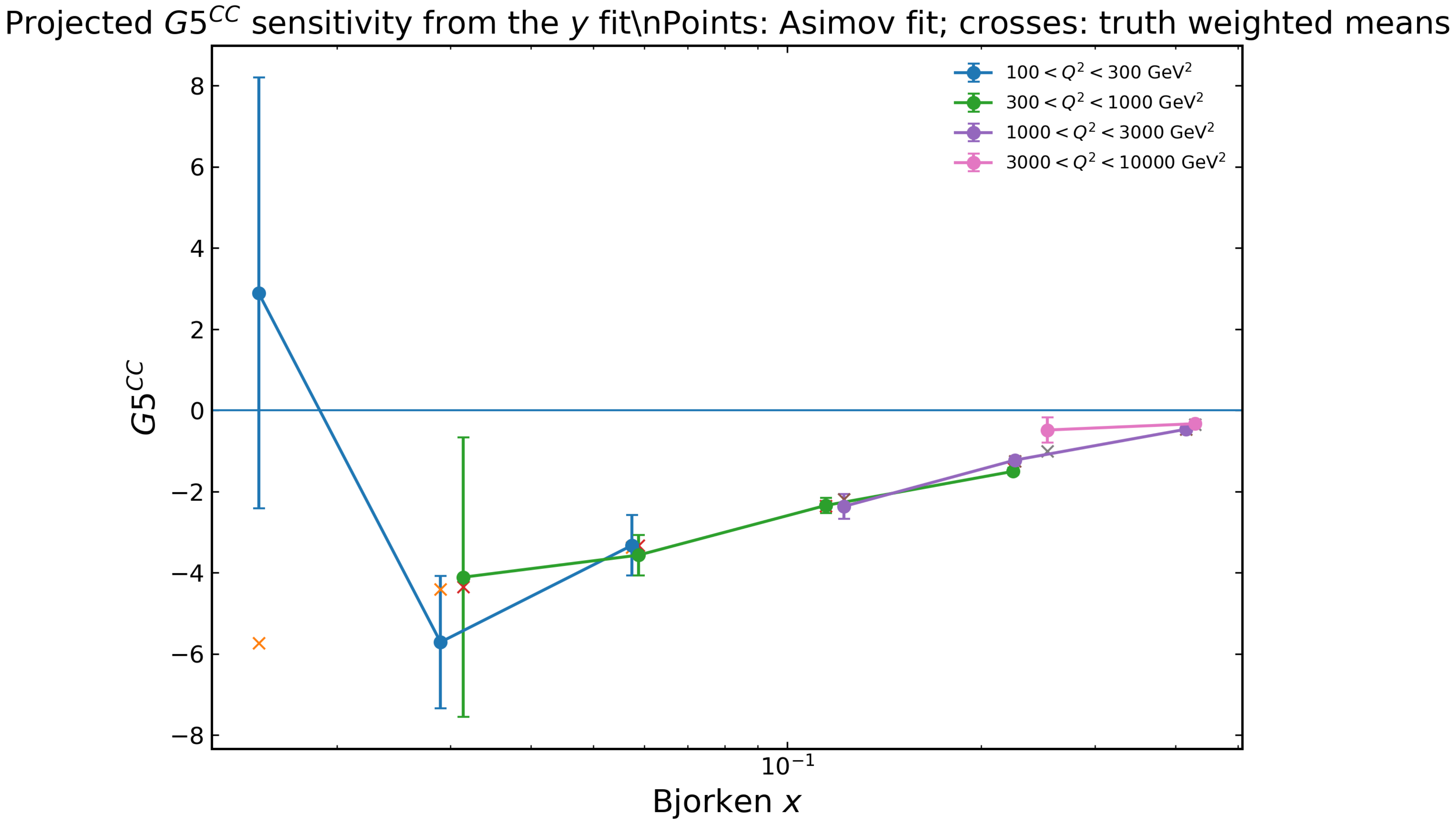




Beam Energy(GeV)	G1CC(Precision)	G5CC Precision
9x275	48%	28%

Projected G_1^{CC} and G_5^{CC} sensitivity At 18x275





Beam Energy(GeV)	G1CC	G5CC
18x275	30%	14%

Current status and next analysis step

What was looked at?

- Built luminosity-scaled asymmetry pseudodata at 9x275 and 18x275 GeV.
- Performed truth-level y-dependent fits for G_1^{CC} and G_5^{CC}.
- Verified luminosity assumptions: 2.5 fb^{-1} at 9x275 and 10 fb^{-1} at 18x275, with Pp = 70%.
- Produced projected statistical error bars for G_1^{CC} and G_5^{CC}.

What should be looked at?

- Include detector response and bin migration in x, Q^2, and y.
- Reconstructed-level forward folding.
- Propagate G_5^{CC} fit covariance into derived G_4^{CC} and twist-2 G_3^{CC} uncertainties.
- Add systematic uncertainty studies: polarization, relative luminosity, and reconstruction model dependence.

Note: this is a truth-level statistical sensitivity projection, not yet a detector-level measurement.

Summary

- The projected proton-helicity CC DIS asymmetry is sizable and statistically useful in the intermediate-x region.
- The y-dependent fit turns asymmetry pseudodata into projected G_1^{CC} and G_5^{CC} statistical sensitivities.
- At 9x275 GeV, the median projected precision is about 48% for G_1^{CC} and 28% for G_5^{CC} At 18x275 GeV, the median projected precision improves to about 30% for G_1^{CC} and 14% for G_5^{CC}.
- The clearest physics impact is projected sensitivity to G_5^{CC}, which enables quark–antiquark helicity separation in charged-current DIS.
- The current truth-level study supports a promising EIC impact case, with detector-level forward folding as the next step.

Thank you for your attention!!