Spin interference effects at the Electron Ion Collider in the Diffractive J/ψ Process

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Introduction:

- Entanglement-enabled spin interference effects were first discovered in diffractive $\rho^0 \rightarrow \pi^+\pi^-$ in ultra-peripheral A+A collisions at STAR.
- Linear polarization of photons and two-source interference leads to a $cos2\phi$ azimuthal modulation.
- In e+A, a virtual photon from the electron beam may interact with the nucleus and form a vector meson.
- Despite lacking two-source interference, azimuthal asymmetry from linear polarization is expected in e+A collisions.
- This effect are very sensitive to the gluon distribution within the nucleus.

Theory:

- J/ψ is a particularly interesting vector meson that can form in this way. It is massive enough to be treated perturbatively.
- J/ψ rapidly decays to an e^+e^- pair.
- In the final state, a **soft photon** is emitted from the outgoing e^+ or e^-.
- ϕ is defined as the angle between the direction of the J/ψ P_T, and the momentum of the emitted soft photon.
- The recoil from the soft photon induces a positive $cos2\phi$ and $cos4\phi$ azimuthal asymmetry.

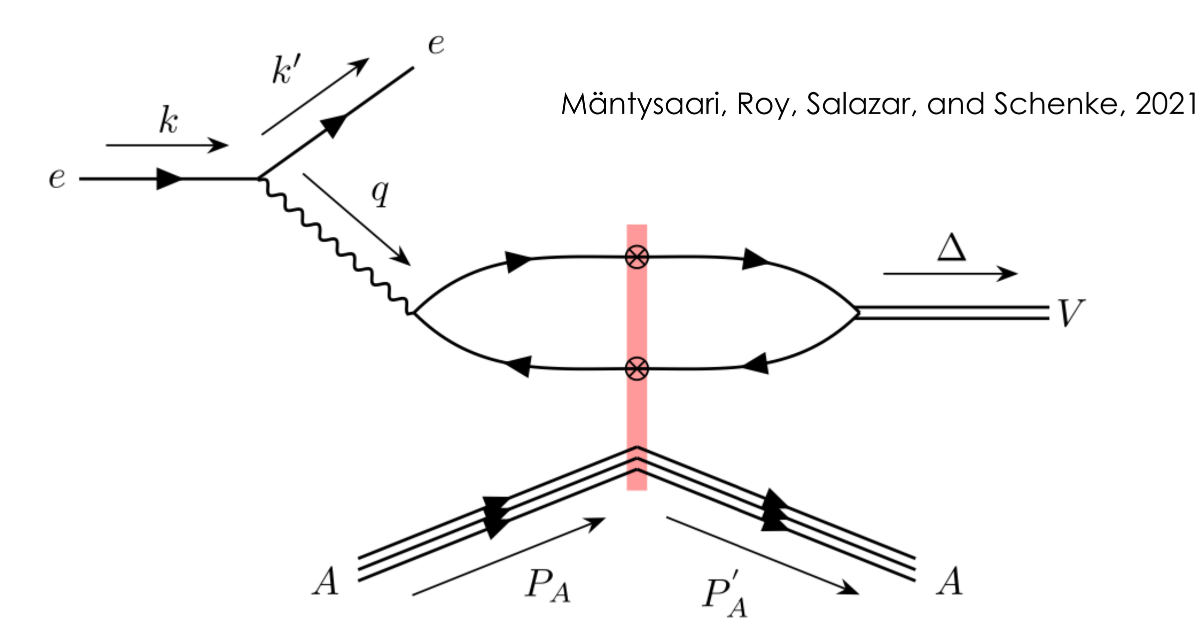

Figure 1: Illustration of diffractive vector meson production in e+A collisions.

Process: Generate e^+e^- pair 4-vectors with toy model → detector geometry simulation (npsim) → EIC reconstruction (EICrecon).

Simulation and Analysis:

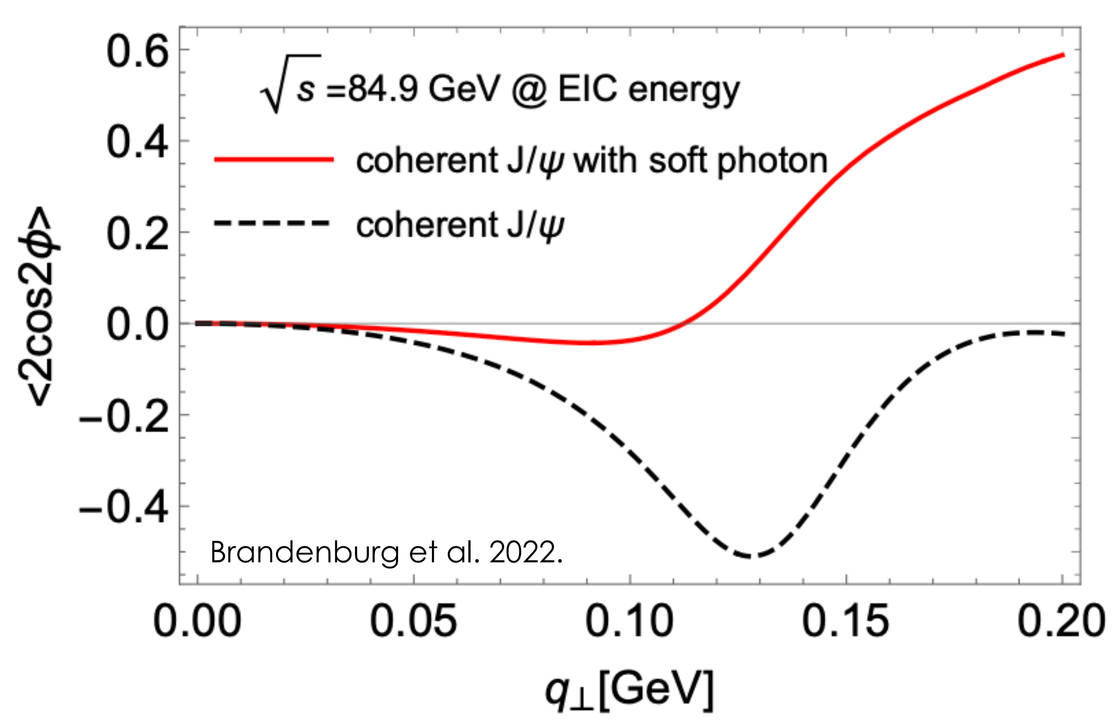

Figure 2: $A_{2\phi}$ as a function of e^+e^- pair transverse momentum.

Toy model

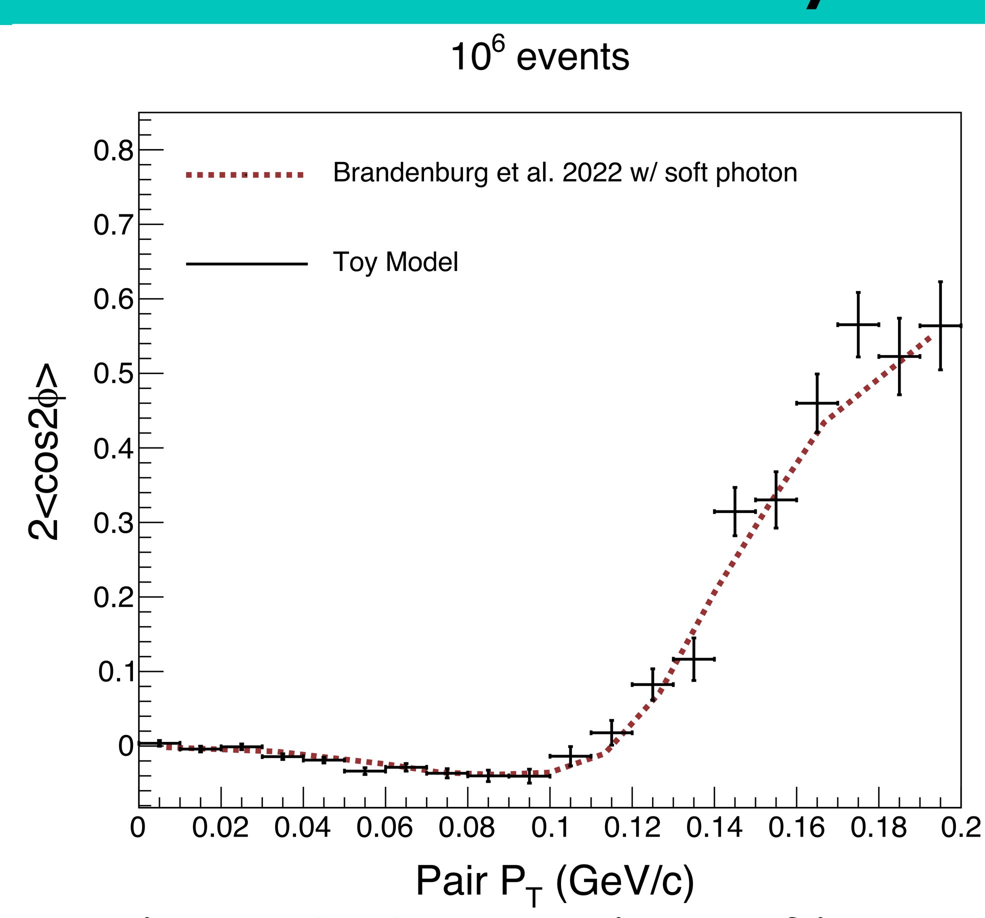

Figure 3: Comparison of input distribution and model output with $\mathrm{N} = 10^6\ J/\psi$.

npsim
+
EICrecon

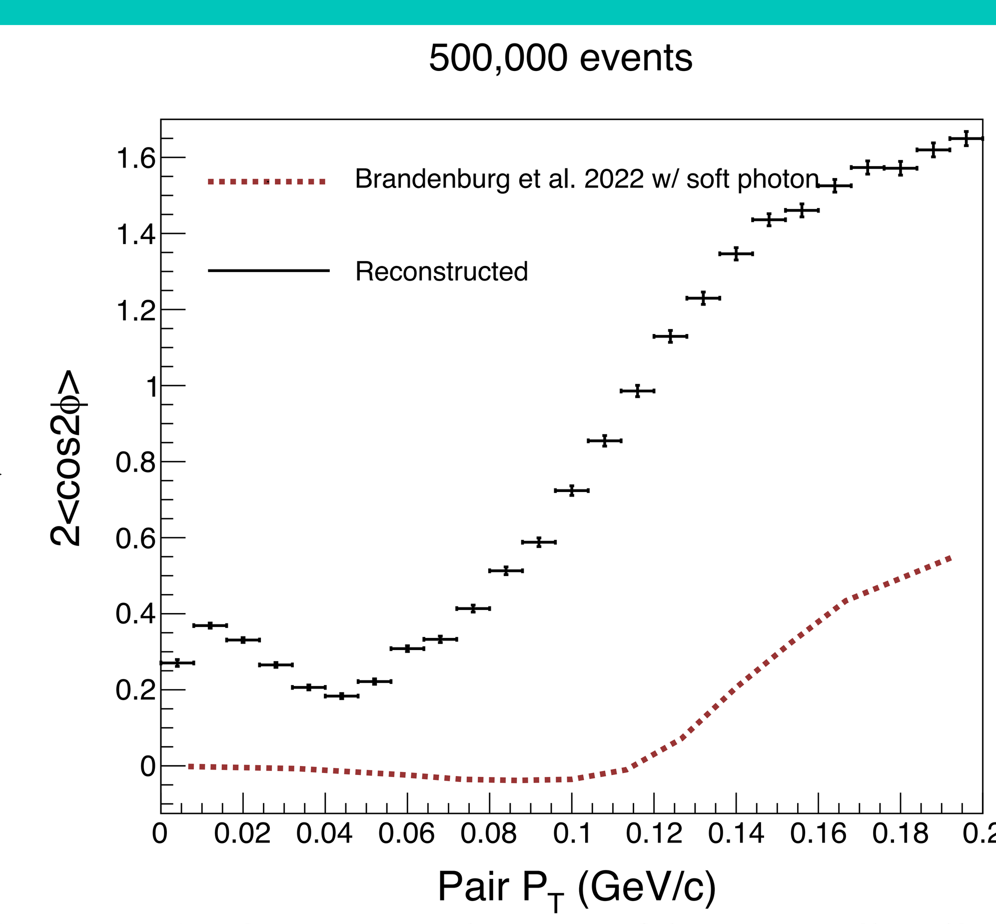

Figure 4: Comparison of input distribution and reconstructed output with $\mathrm{N} = 500{,}000\ J/\psi$.

Results:

- A baseline azimuthal modulation exists in the absence of physics correlations.
- To extract physics correlations, one must estimate and correct for this baseline.
- In this case, the baseline is estimated by applying geometry simulation and reconstruction to a data set with a uniform ϕ distribution.
- Correction of Fourier components such as $2 < cos2\phi >$ is not a simple subtraction. Assuming no background of any kind, the correction function is as follows: $$2 < cos2\phi >_{corr} = 2\frac{< cos2\phi >_{uniform} - < cos2\phi >_{reco}}{< cos2\phi >_{uniform} < cos2\phi >_{reco} - 2}$$

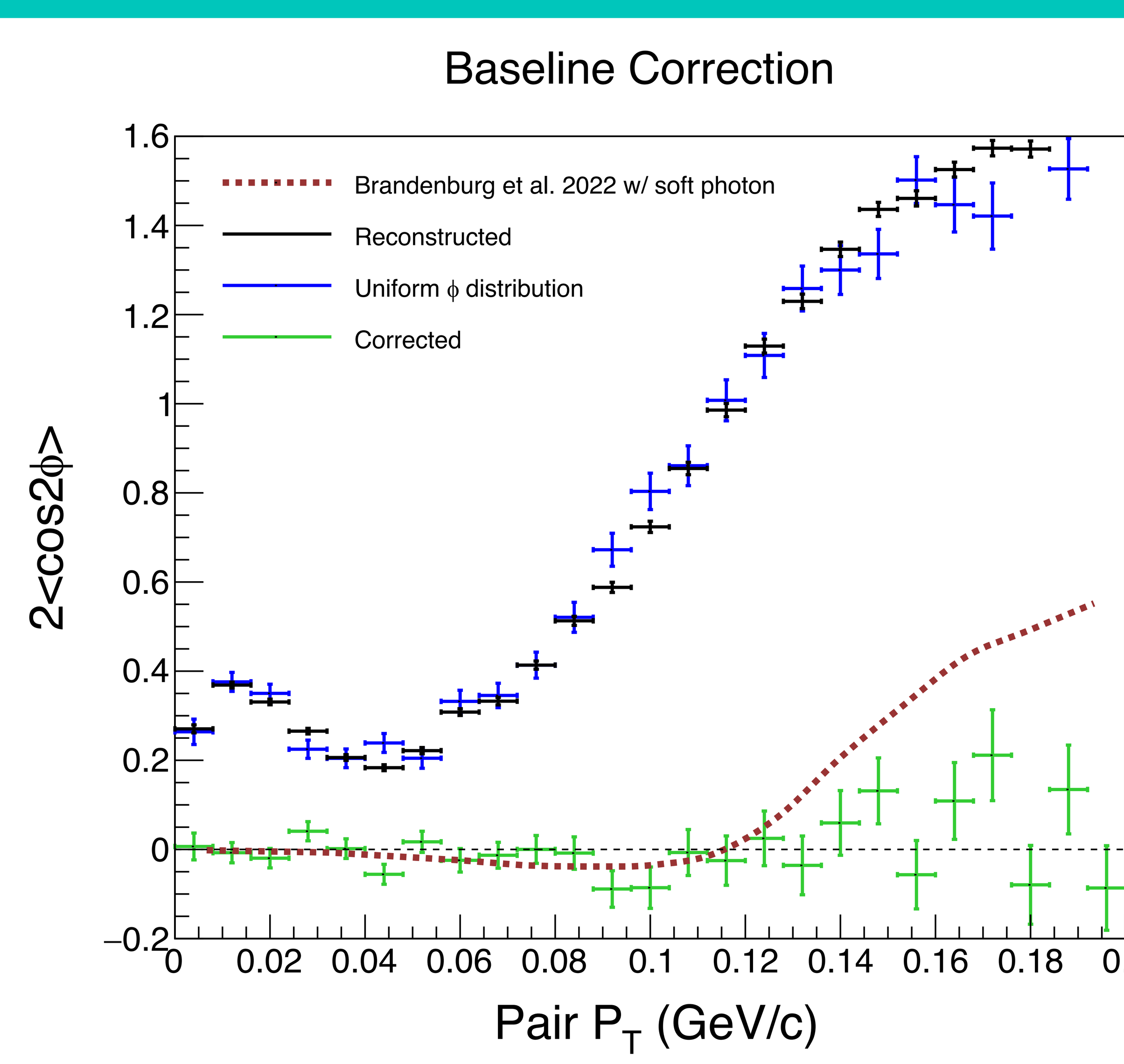

Figure 5: Reconstructed data corrected using an input with uniform ϕ distribution.

Summary:

We studied the feasibility of spin polarization interference measurements in eA collisions. The expected modulation was simulated through npsim and reconstructed with EICrecon. Detector acceptance and momentum resolution result in a significant modulation which obfuscates the physical signal.

- Unfolding may be useful for removing or reducing migration due to momentum resolution effects.

Plan for additional studies:

- Incorporate backgrounds from continuum e^+e^- production and incoherent J/ψ production.
- Study techniques for suppressing the incoherent process.
- Study backgrounds from imperfect particle identification for electrons.
- Investigate methods that are being studied within the ePIC collaboration to improve detector resolution.

References:

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