Imaging probability of coherent light nuclei with a Second Interaction Region at the EIC

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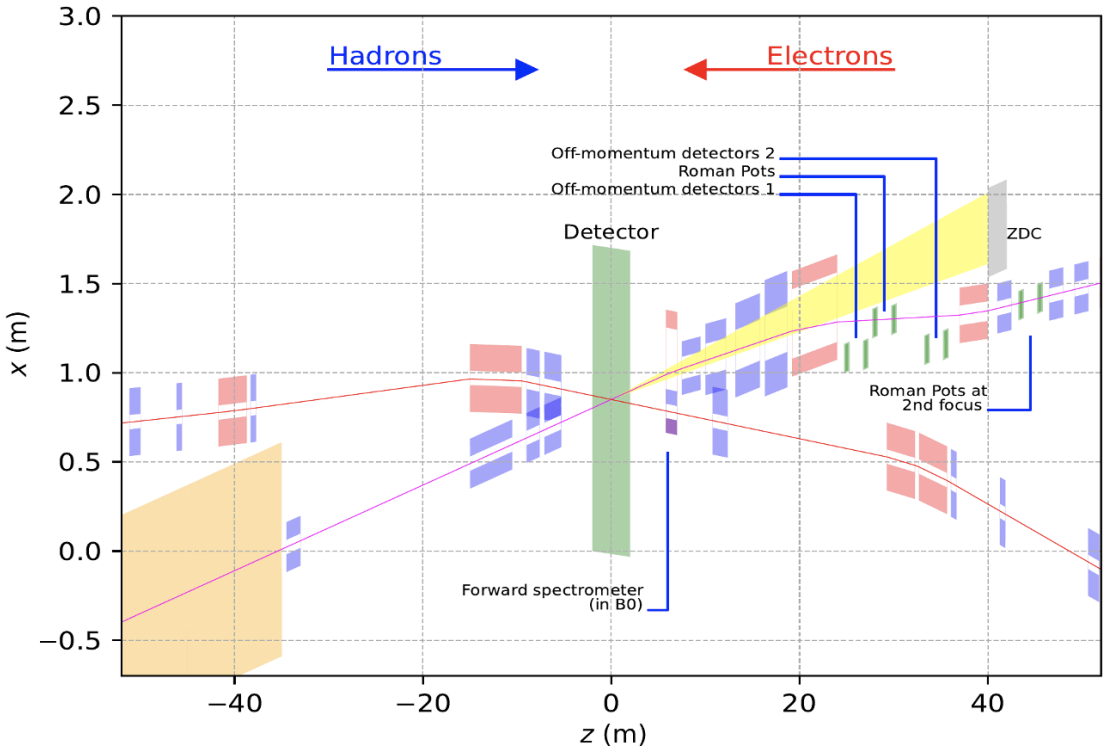
Proposed IR-8 Layout

The wider EIC community is strongly supporting a second interaction region and associated second detector to enhance the full science program. This machine configuration would significantly benefit exclusive, tagging, and diffractive physics programs, complementing those of the ePIC experiment. In particular, **accessing coherent diffractive processes on light nuclei by tagging of the full, intact nucleus is essential for mapping their spatial parton distributions.**



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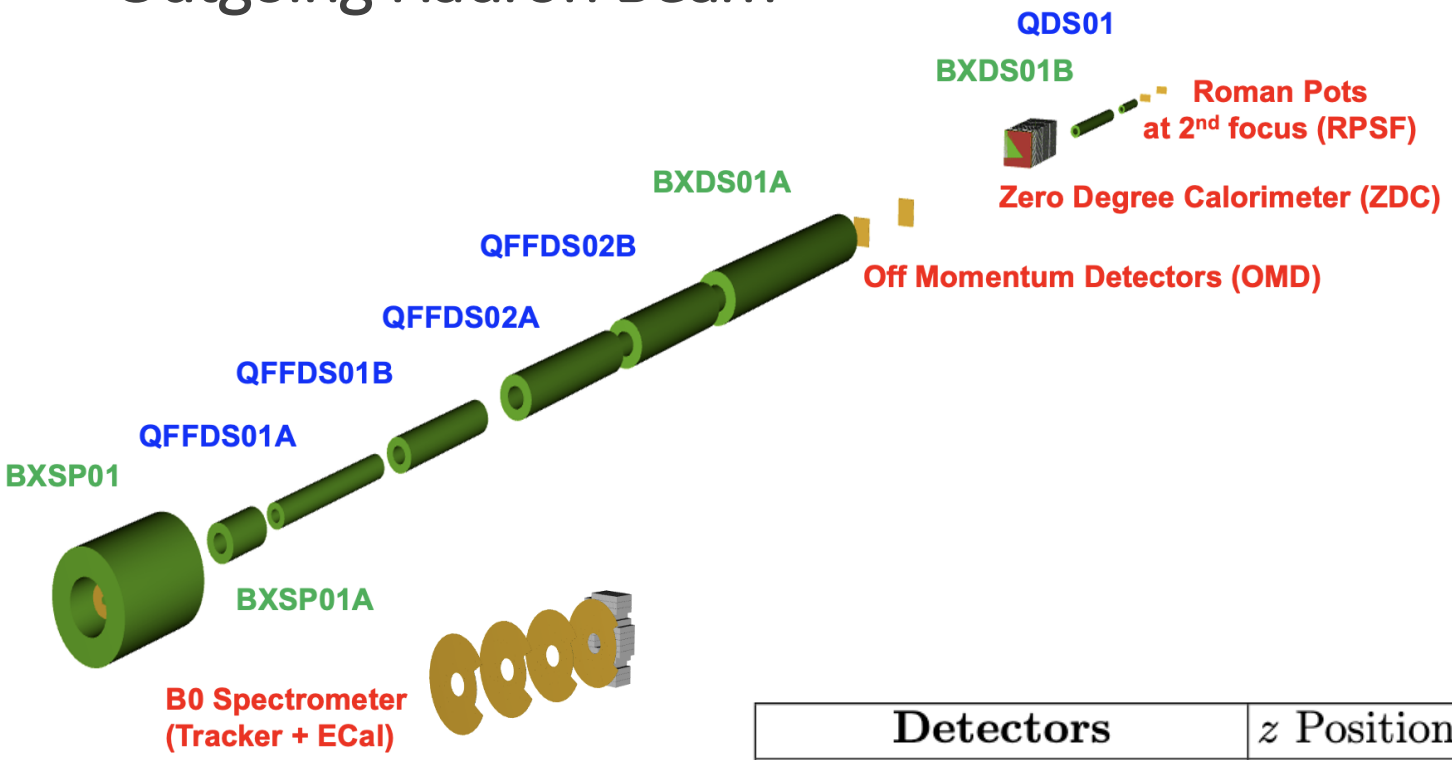
- ❑ crossing angle 35 mrad
- ❑ potential new feature 2nd beam focus
- ➢ explore its capability to identify coherent eA scattering events by tagging the intact nucleus

eSTARLight generator:

Coherent diffractive processes with vector mesons (VM) production: $e + A \rightarrow e' + VM + A'$

Far-Forward Detectors

Outgoing Hadron Beam



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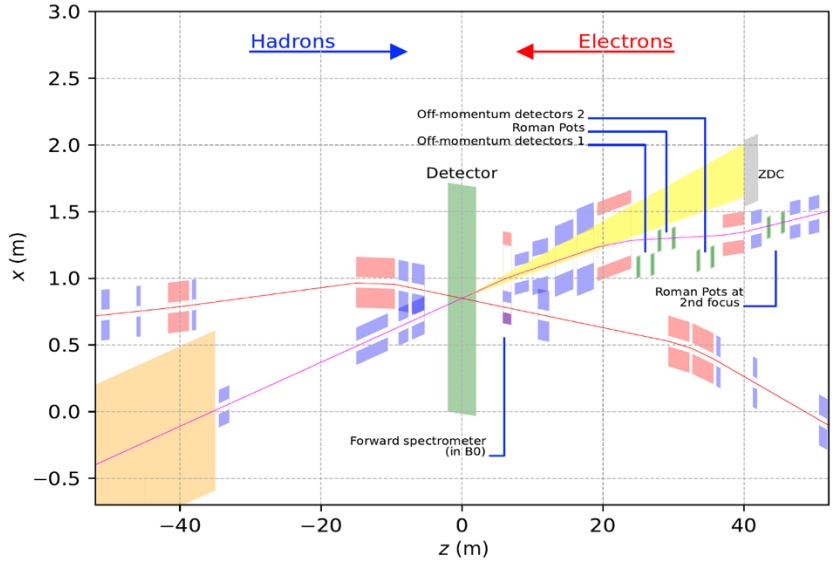
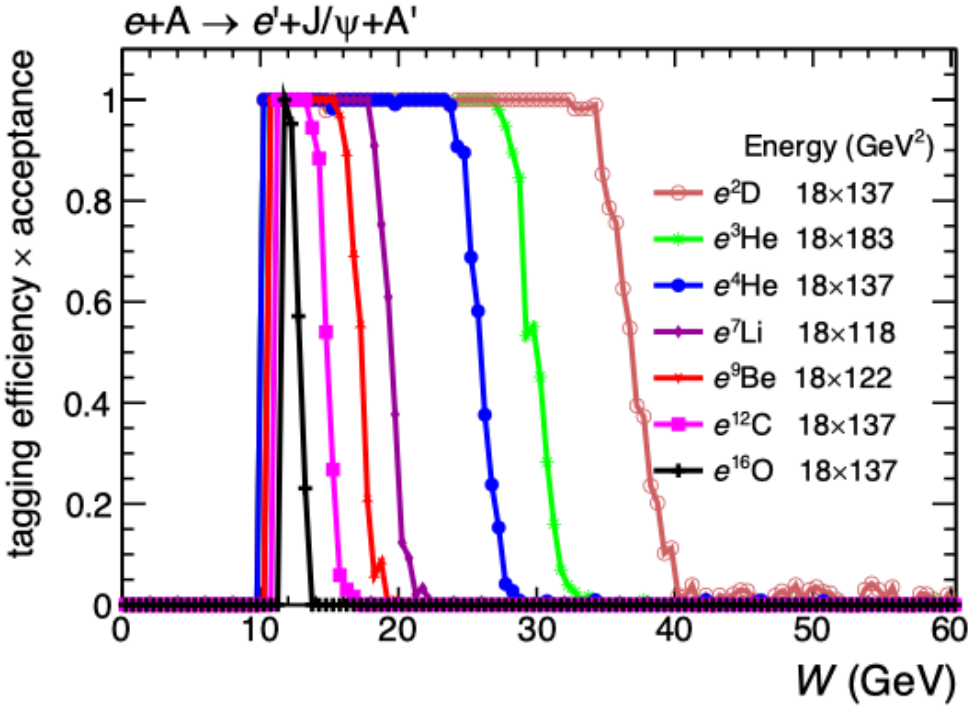


Detectors	z Positions [m]	θ [mrad]	Note
B0 spectrometer	(5.8, 6.4)	$5.0 < \theta < 20$	tracker and calorimeter
Off-momentum detector	(25.9, 28.0)	$0 < \theta < 5.0$	40% to 60% rigidity
Zero-degree calorimeter	40	$\theta < 5.5$	full acceptance at $\theta < 5$ mrad
Roman Pots	(44.0, 45.5)	$0 < \theta < 5.0$	10σ cut

The detection efficiency of various nuclear species



- $W = \sqrt{(P+q)^2}$ is the invariant mass of the produced hadronic system.
- The lighter nucleus allows for the detection of events with larger W.
- The global tagging efficiency x acceptance as the increasing nucleon number, from deuterium(D) to oxygen(O), is 47.12%, 32.23%, 29.42%, 17.75%, 12.37%, 6.36%, 1.59%, respectively.

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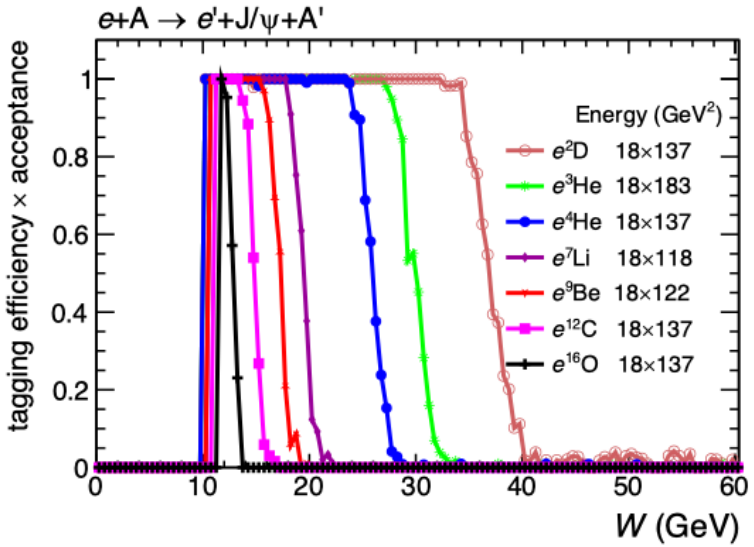
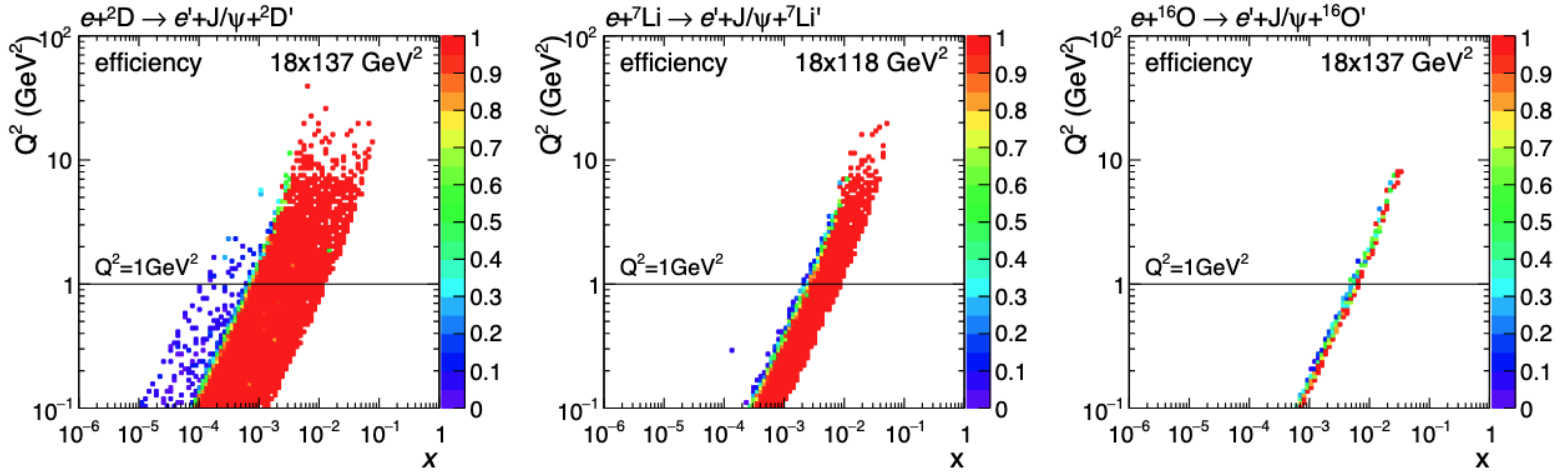
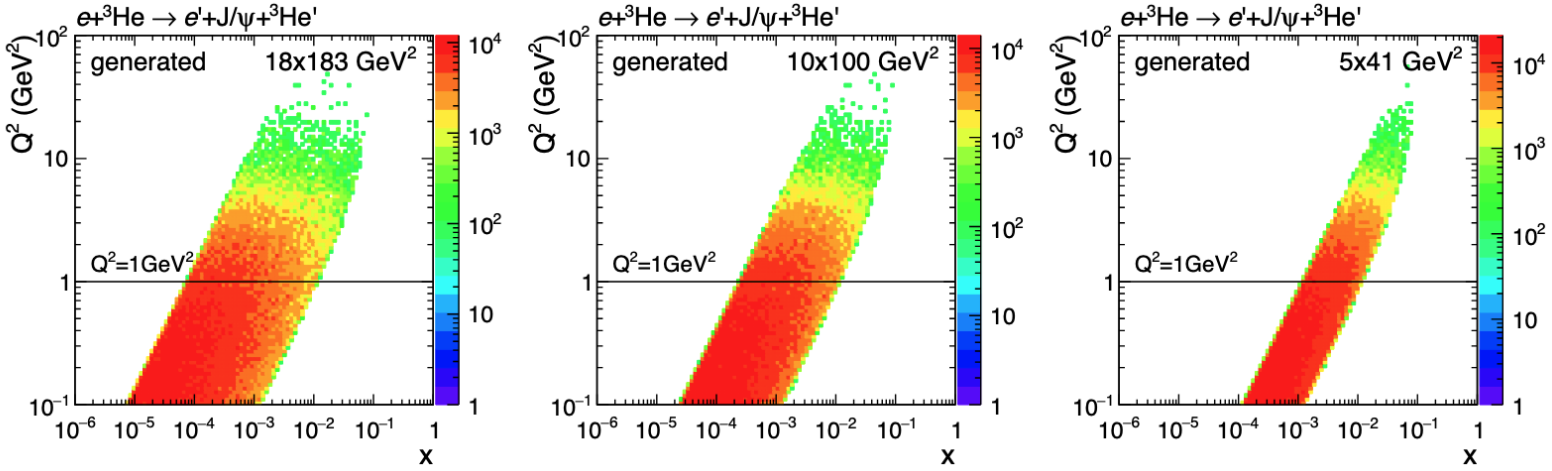
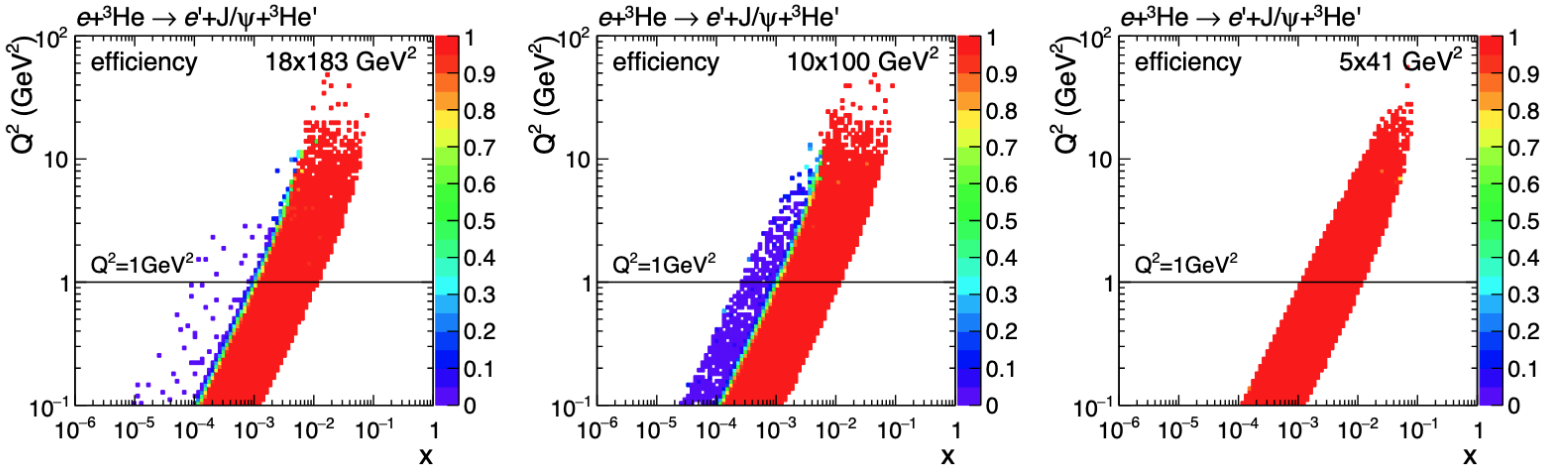




- The lighter nucleus allows for the detection of events with smaller x.
- For $Q^2 > 1\ GeV^2$, the x range for accepting events is $x > 10^{-4}$ for e^2D collision events, $x > 2 \times 10^{-3}$ for e^7Li collision events, and $x > 4 \times 10^{-3}$ for $e^{16}O$ collision events.

The detection efficiency of different collision energies

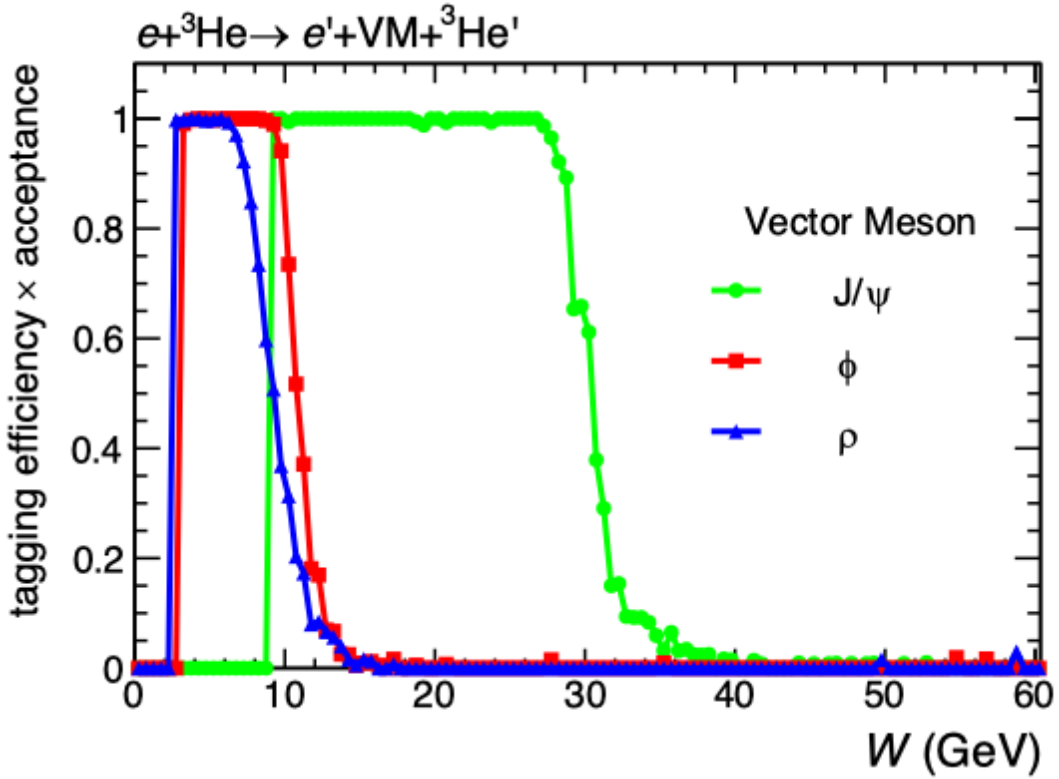




- The higher the collision energy, the lower the value of x can be.
- The maximum x is remaining constant.

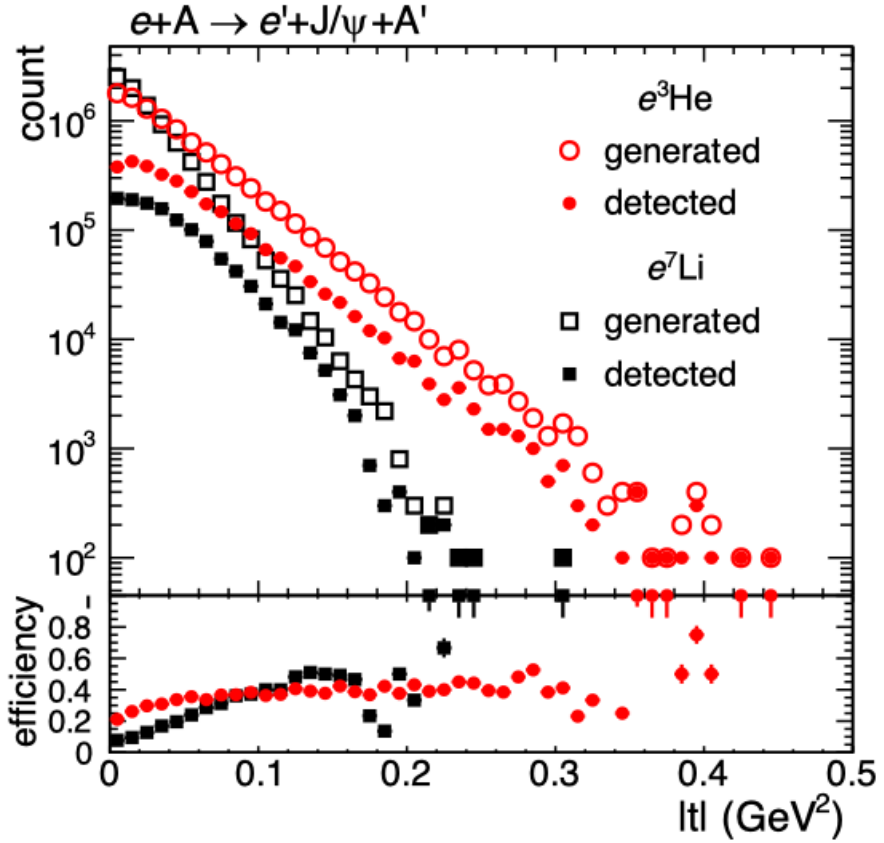
- With a fixed collision energy, the detection efficiency in the high x range is much greater than that in the low x range.
- The detection efficiency does not show a significant dependence on Q^2.
- The detection efficiency is 32.23%, 54.38%,99.41%, respectively.

The detection efficiency for events with different VMs



- Coherent ρ production goes to the smallest *W* value, which is 2 GeV.
- In the case of coherent ϕ production, the detection efficiency remains nearly 1 for the W range of 3 GeV to 9 GeV, and then it rapidly decreases to nearly 0.
- For coherent J/ψ production, the detectable range of W is relatively broad.

Momentum transfer t distributions



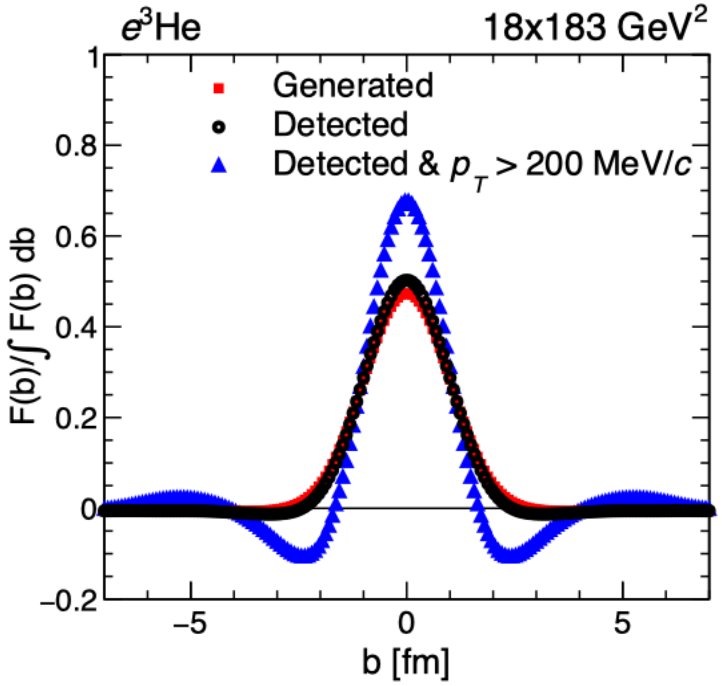
- The Fourier transformation of the momentum transfer |t| distribution of the coherent diffraction reveals the spatial distribution of transverse gluons.
- The ratio of observable events shows an increase as |t| increases.

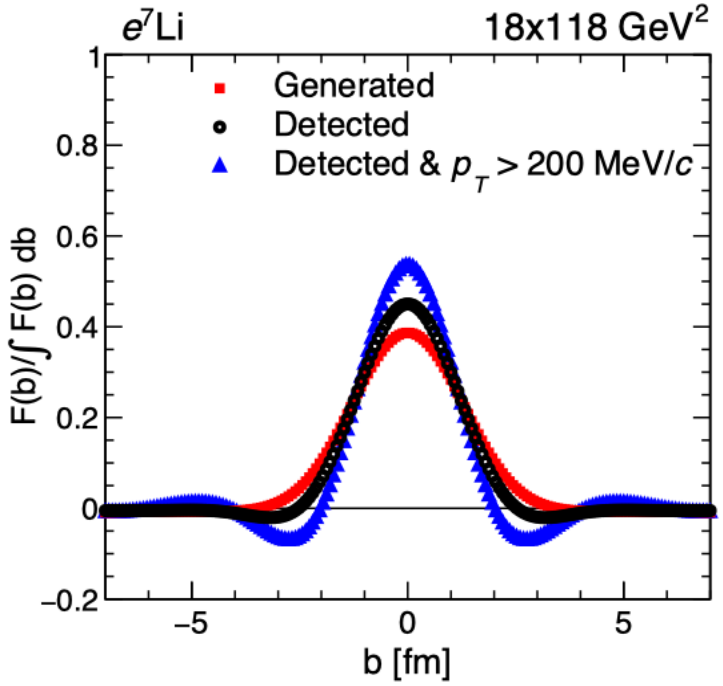
The resulting Fourier transforms from t distributions

The coherent $|t|$ distributions can be used to obtain information about the gluon distribution in impact parameter space F (b) through a two-dimensional Fourier transform:

$$F(b) = \frac{1}{2\pi}\int_0^\infty \mathrm{d}\Delta \cdot \Delta J_0(\Delta b)\sqrt{\frac{\mathrm{d}\sigma_{\mathrm{coherent}}}{\mathrm{d}|t|}(\Delta)}$$

$\Delta = \sqrt{-t}$,
J_0 is the Bessel function





- $|t| < 0.4\ \mathrm{GeV}^2$
- normalized to unity

The significant difference (p_T >200 MeV/c) with respect to the full capability ($p_T \approx 0$ MeV/c) is to highlight the importance of low pT acceptance in the imaging program of light ions.

Summary

- eSTARlight is used to simulate the coherent vector meson production samples

- A study of the coherent light nuclei detection at the second interaction region at EIC is presented
  - Detection efficiency of various coherent light nuclei, ranging from deuterium to oxygen at their top energies
  - Compare the detection efficiency of coherent 3He nucleus across different collision energies
  - Coherent 3He nucleus with different VMs production
  - The momentum transfer |t| distributions in the MC-generated level and detected by far-forward detectors at IR-8 for $e^{3}He$ and $e^{7}Li$ collisions with top energies

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- In the pre-conceptual design of the second interaction region, the incorporation of the secondary focus enhances the ability to tag particles with low transverse momentum and/or high longitudinal scattered ion momentum.

- The current results show an opportunity to enhance the exclusive, tagging, and diffractive physics program with improved far-forward acceptance for such an IR-8 design.