Update on HF studies in standalone simulation

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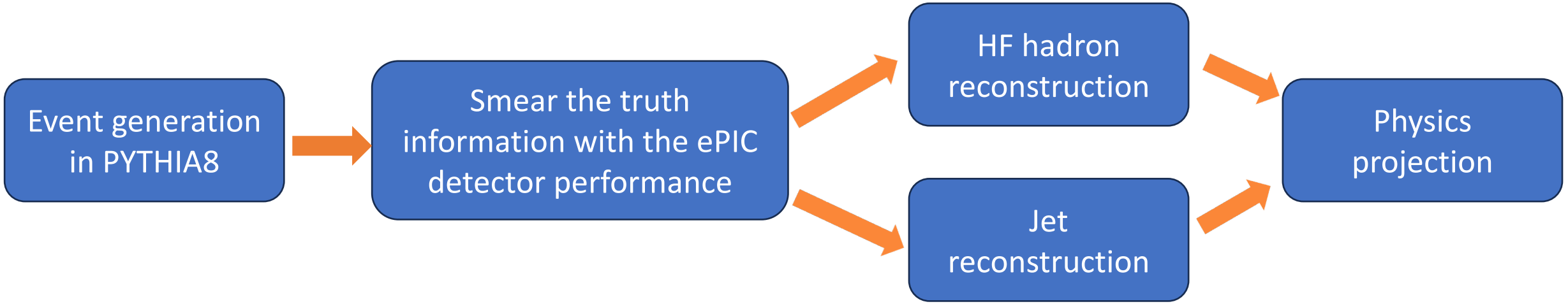
Outline

- Workflow of HF reconstruction
- Heavy flavor hadron and jet update in standalone simulation with the 2023 ePIC detector performance.
- Summary and Outlook.

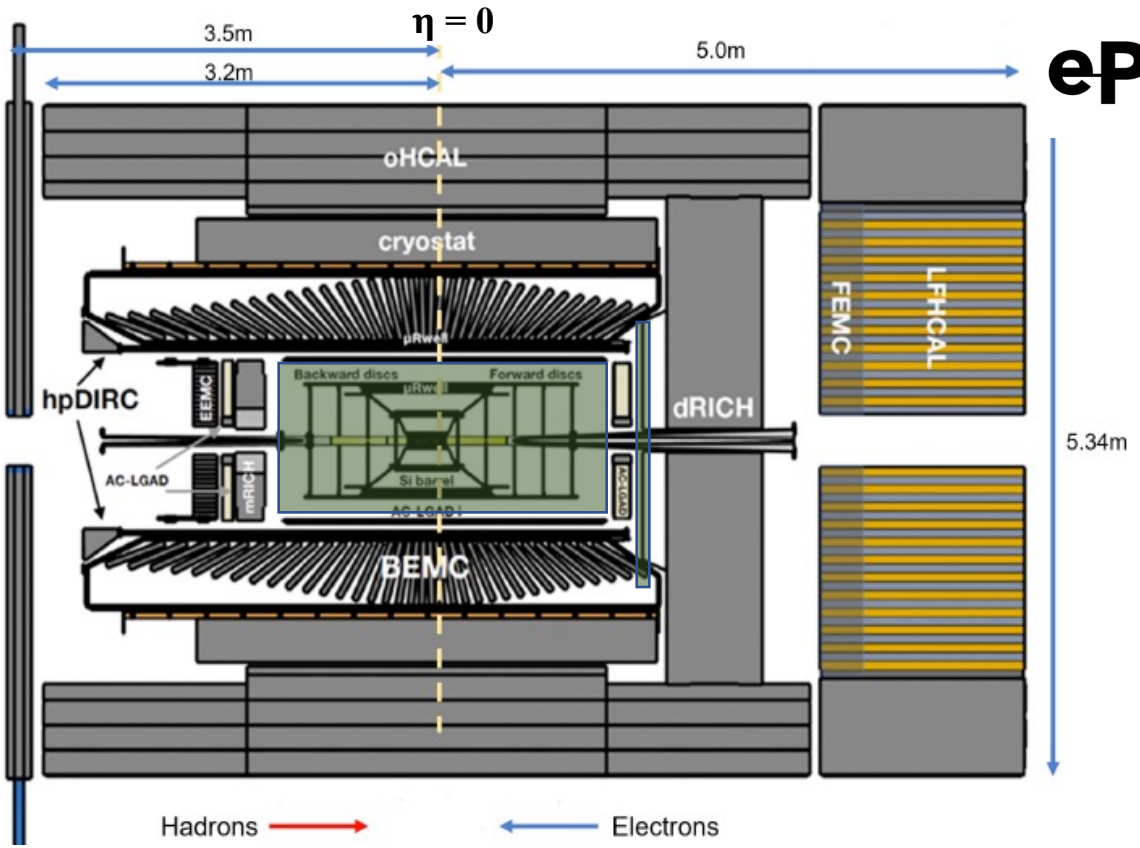
Workflow used in the standalone simulation

- Event generation in PYTHIA8.2.
- Parameterized ePIC tracking performance (momentum, DCA_{2D}) to smear the truth particle information. Apply a 95% tracking efficiency for all charged particles.
- Apply the EMCal and Hcal energy resolution smearing for neutral particles.
- Reconstruct heavy flavor hadrons via their hadronic channel and match the track related secondary vertex. Reconstruct jets with all neutral and charged particles with the fastjet anti-k_T algorithm.



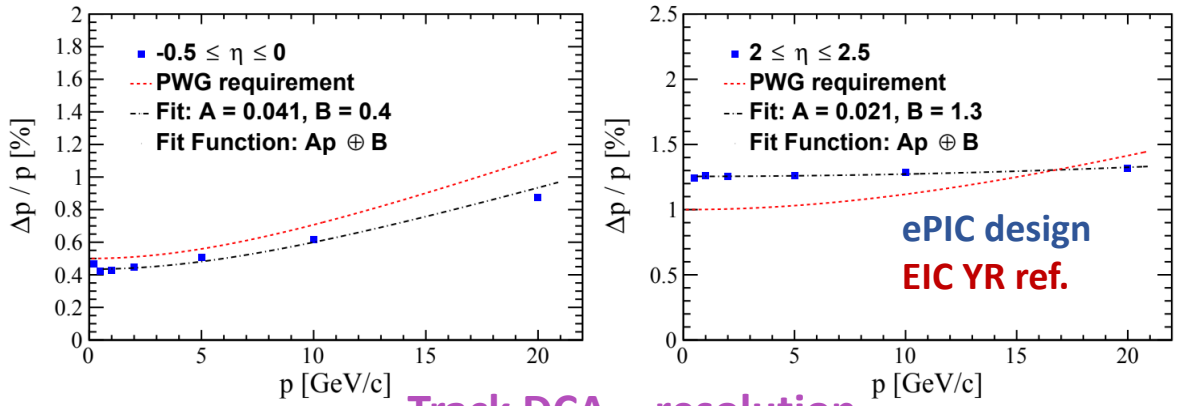
ePIC tracking performance used for HF reconstruction

- Use the 2023 ePIC tracking performance (no additional 2 MPGD disks in the hadron/electron endcap region, no addition 2 MPGD layers in the barrel region).

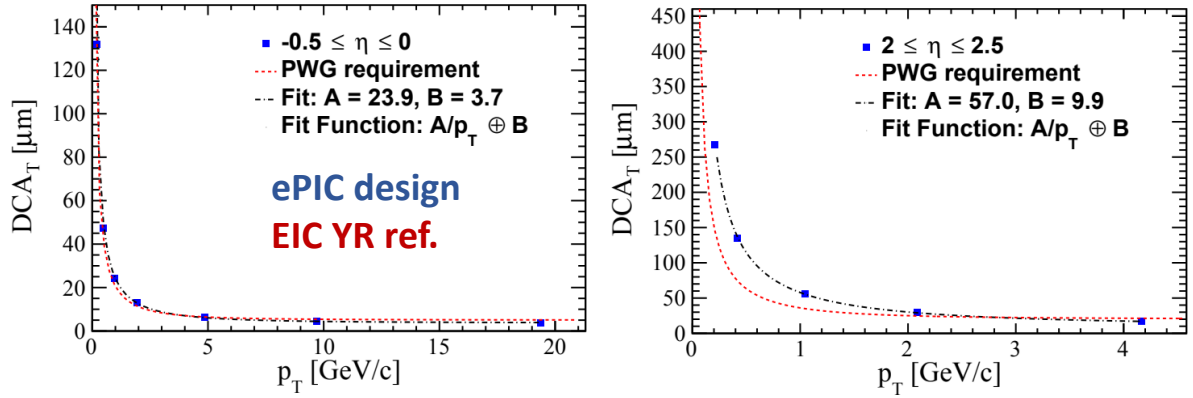


ePIC

Track momentum resolution



Track DCA_{2D} resolution

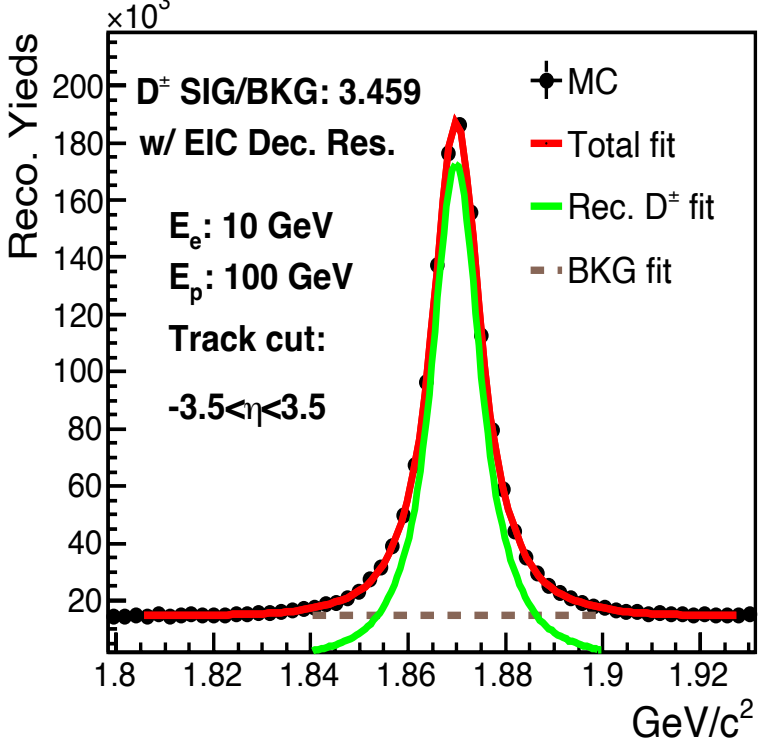


Reconstruction of open heavy flavor hadron in e+p simulation

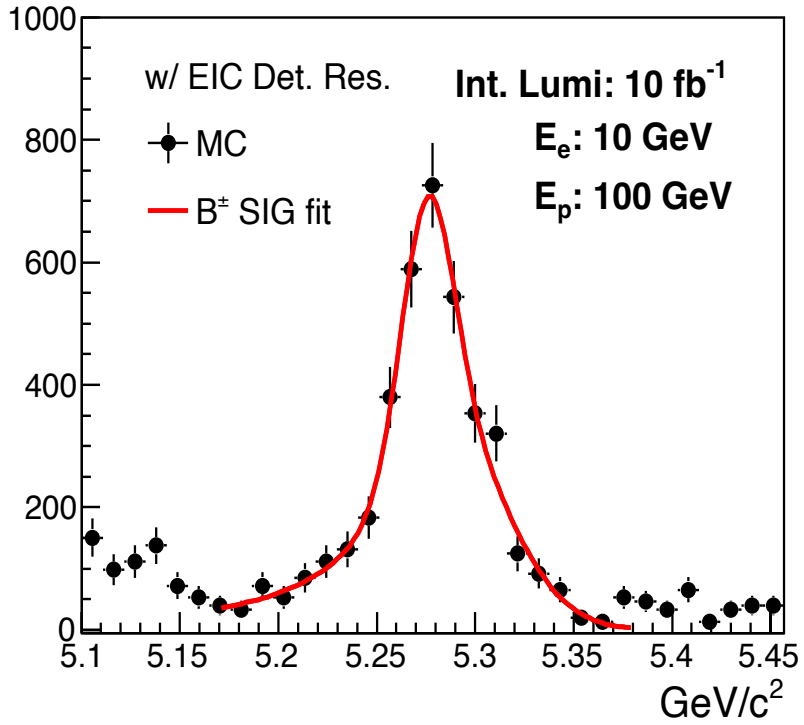
- A variety of heavy flavor hadrons have been successfully reconstructed in simulation, which includes the event generation (PYTHIA), EIC ePIC detector performance evaluated in GEANT4 simulation, beam remnant & QCD background, and developed heavy flavor reconstruction algorithm.

arXiv: 2311.10875

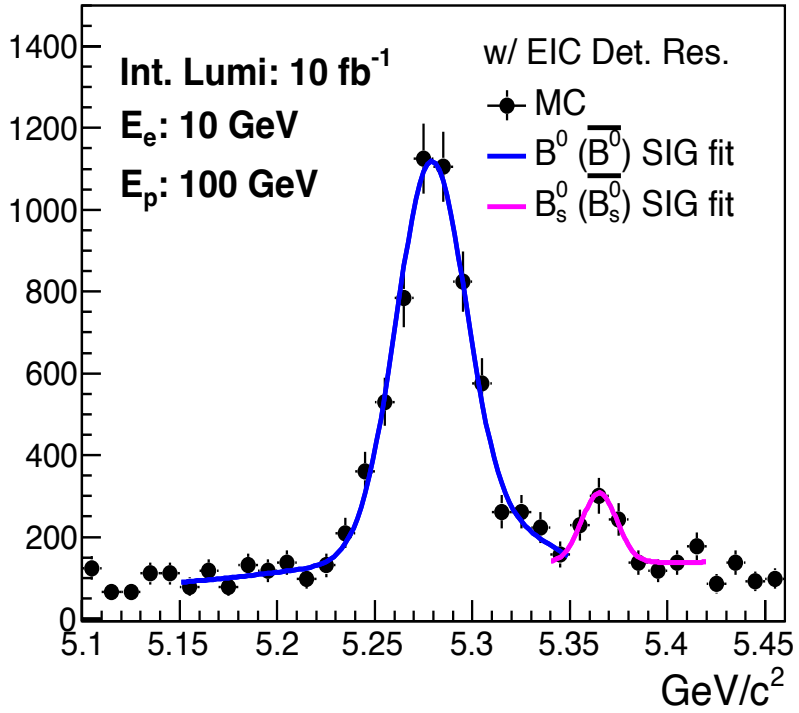
Reconstructed $D^{\pm}$ meson



Reconstructed $B^{\pm}$ meson



Reconstructed B^0 (B_s^0) meson

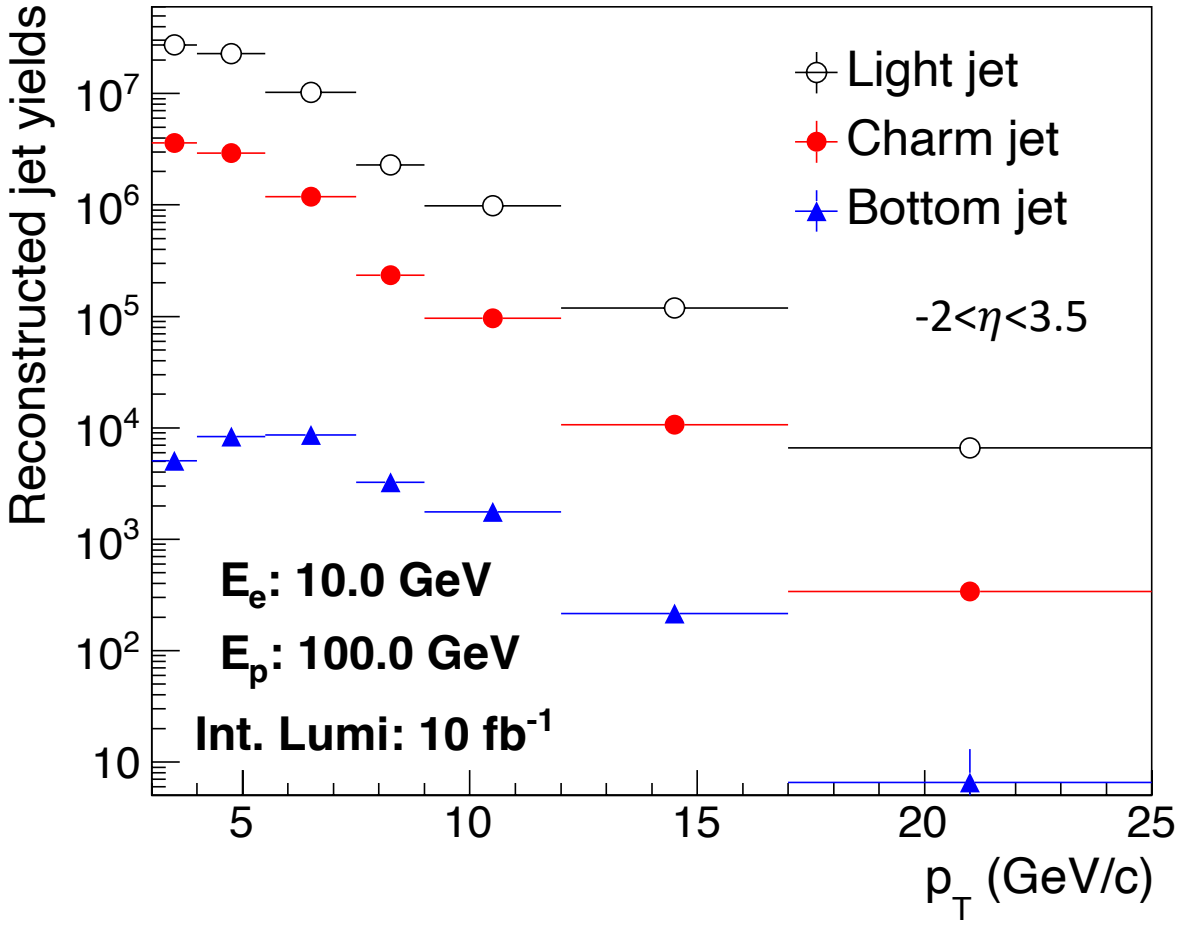


Reconstructed heavy flavor jets in e+p simulation

- Jets are reconstructed with the anti-k_T algorithm and cone radius R is 1.0.
- Reconstructed jet yields with different flavors in simulation using the EIC detector performance in 10 GeV electron and 100 GeV proton collisions with 10 fb^{-1} integrated luminosity.
- Charm-jets (bottom-jets), which are surrogates of the created heavy quarks, are tagged with the associated displaced vertex.
- Reconstructed jet yields are not corrected with the corresponding efficiency and purity yet.

Jet p_T spectrum

arXiv: 2311.10875

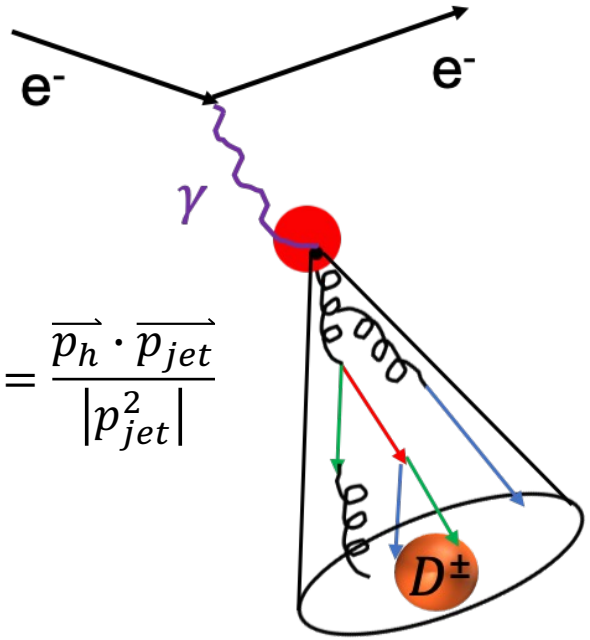


Most jets with p_T < 15 GeV/c

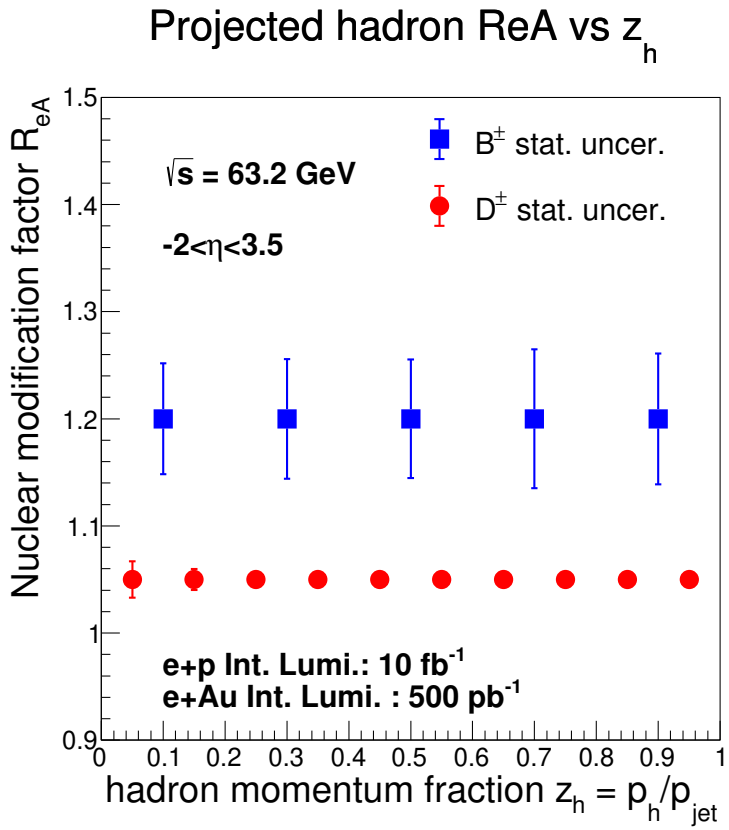
Hadron inside jet nuclear modification factor R_{eAu} projection

- Hadron inside jet studies at the EIC can provide good sensitivity to directly extract the flavor dependent fragmentation functions.

$$e^- + p \rightarrow e^- + jet(D^{\pm}) + X$$



$$z_{proj} = \frac{\overrightarrow{p_h} \cdot \overrightarrow{p_{jet}}}{|p_{jet}^2|}$$



$$R_{eA} = \frac{1}{A}\frac{\sigma_{eA}}{\sigma_{ep}}$$

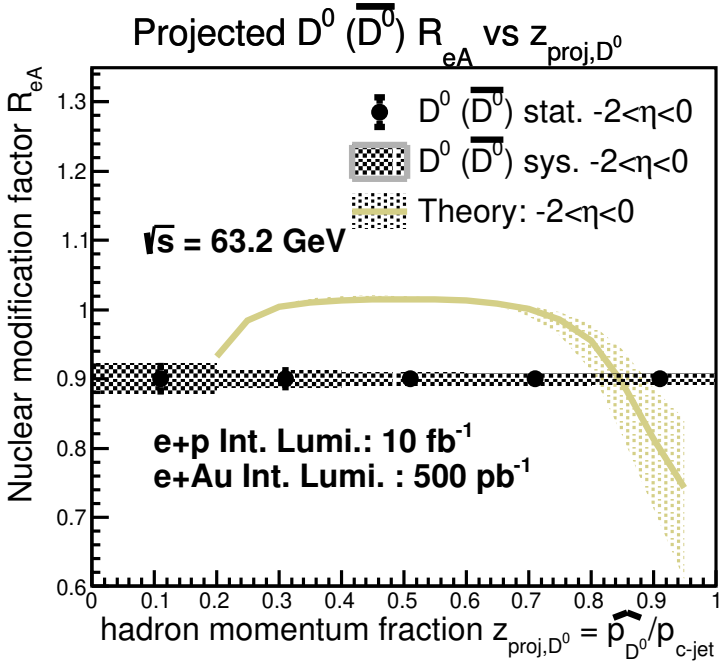
Best precision to be achieved by the EIC measurements in the accessed kinematic phase space.

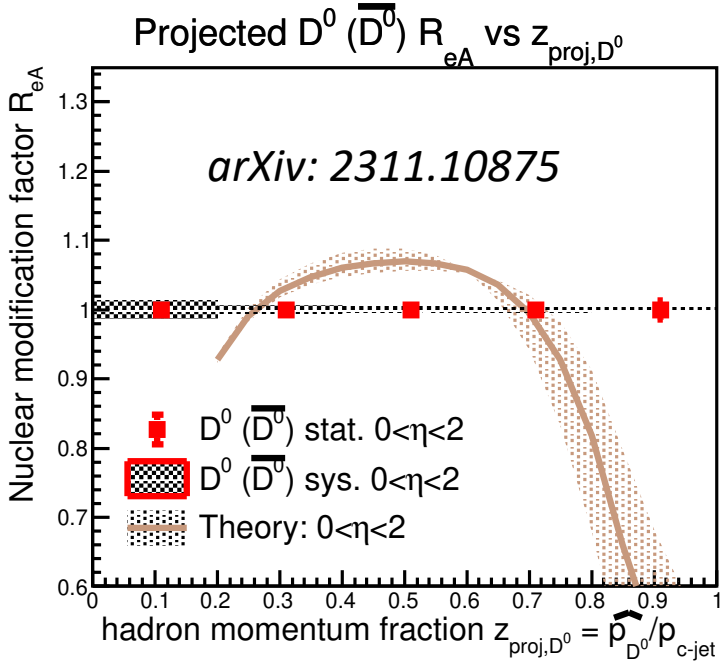
- Projected R_{eAu} statistical uncertainties of $D^{\pm}$ inside charm jets (red) and $B^{\pm}$ inside bottom jets (green) in 10 GeV electron and 100 GeV gold collisions.

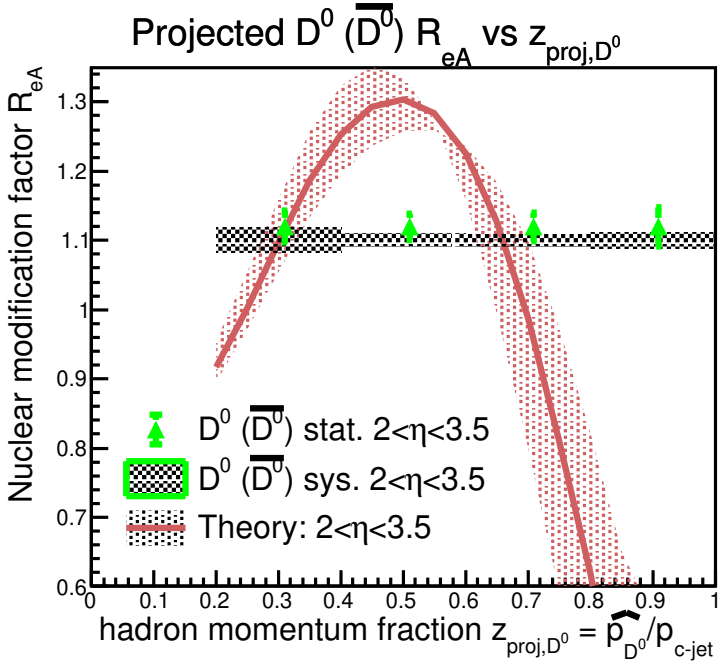
Pseudorapidity dependent D^0 ($\overline{D^0}$) inside charm jet R_{eAu} projection

- Projected accuracy of D^0 ($\overline{D^0}$) inside charm jet R_{eAu} within $-2<\eta<0$ (left), $0<\eta<2$ (middle) and $2<\eta<3.5$ (right) regions in 10+100 GeV e+Au collisions with around one-year EIC operation.

Theoretical calculations: Phys. Lett. B 816 (2021) 136261.







- Good discriminating power in separating different model calculations on the heavy flavor production in a nuclear medium can be provided by future EIC heavy flavor measurements over a wide pseudorapidity region. *arXiv: 2311.10875*

Summary and Outlook

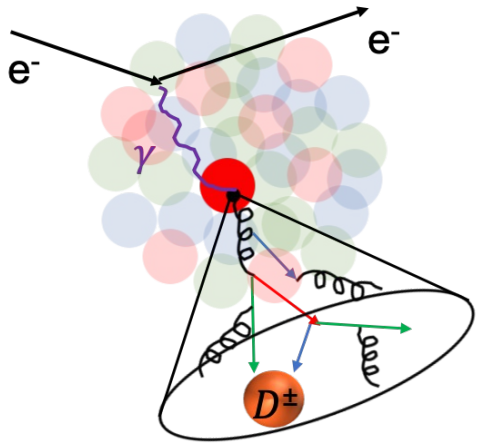
- Heavy flavor hadron and jet studies at the EIC will provide unique opportunities to explore both initial and final state effects with great precision especially in the not well constrained kinematic region.
- Reconstructed primary vertex and secondary vertex and PID information play an essential role in the HF reconstruction.
- Look forward to work with other colleagues to update the proposed heavy flavor physics performance and projection.

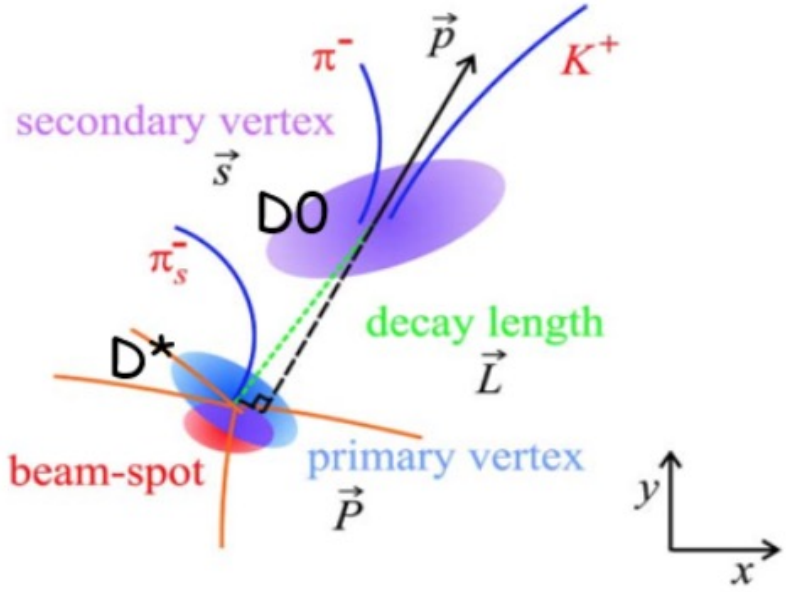
Backup

High precision vertex/tracking detector is required to measure HF products

- Heavy flavor hadrons usually have a short lifetime compared to light flavor hadrons. They can be identified by detectors using their unique lifetime and masses.

$e^- + \mathrm{Au} \rightarrow e^- + jet(D^{\pm}) + X$



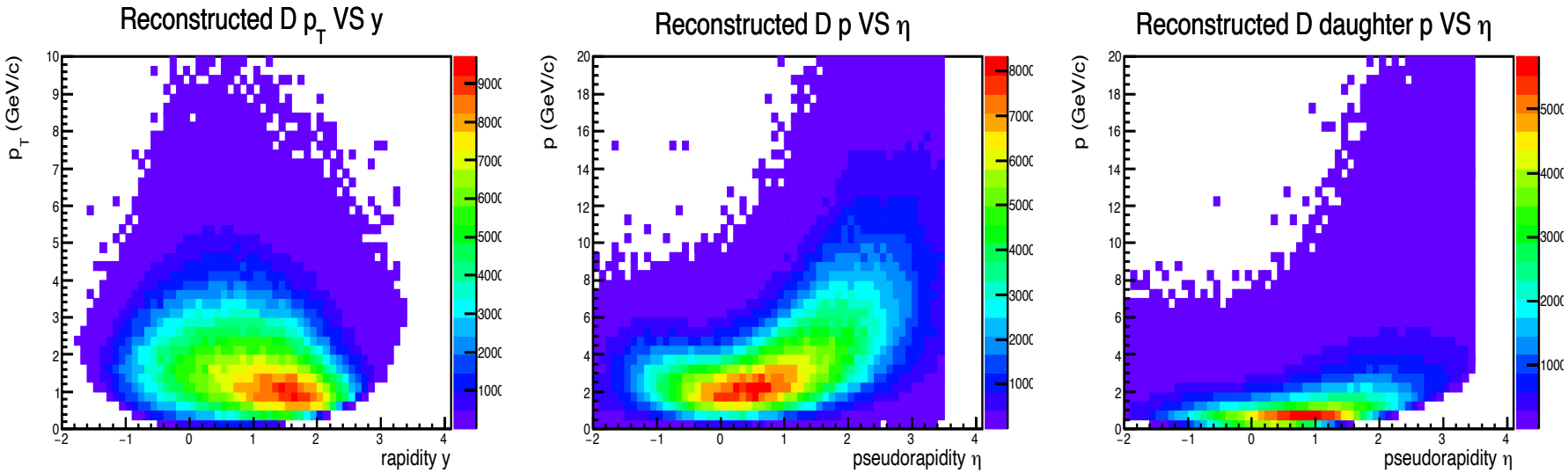


Particle	Mass (GeV/c²)	Average decay length
$D^{\pm}$	1.869	312 micron
D^0	1.864	123 micron
$B^{\pm}$	5.279	491 micron
B^0	5.280	456 micron

- Heavy flavor physics-driven detector performance requirements:
  - Fine spatial resolution (<80 μm) for displaced vertex reconstruction.
  - Fast timing resolution (<2μs) to suppress backgrounds from neighboring collisions.
  - Low material budgets to maintain fine hit resolution for track reconstruction.

EIC detector requirements for a silicon vertex/tracking detector

- To meet the heavy flavor physics measurements, a silicon vertex/tracking detector with low material budgets and fine spatial resolution is needed.
- Particles produced in the asymmetric electron+proton and electron+nucleus collisions have a higher production rate in the forward pseudorapidity. The EIC detector is required to have large granularity especially in the forward region.



- Fast timing (1-10ns readout) capability allows the separation of different collisions and suppress the beam backgrounds.