Los Alamos
NATIONAL LABORATORY
EST.1943

Updates on heavy flavor reconstructed with latest FST design

Xuan Li and Cheuk-Ping Wong on behalf of
the Los Alamos National Laboratory

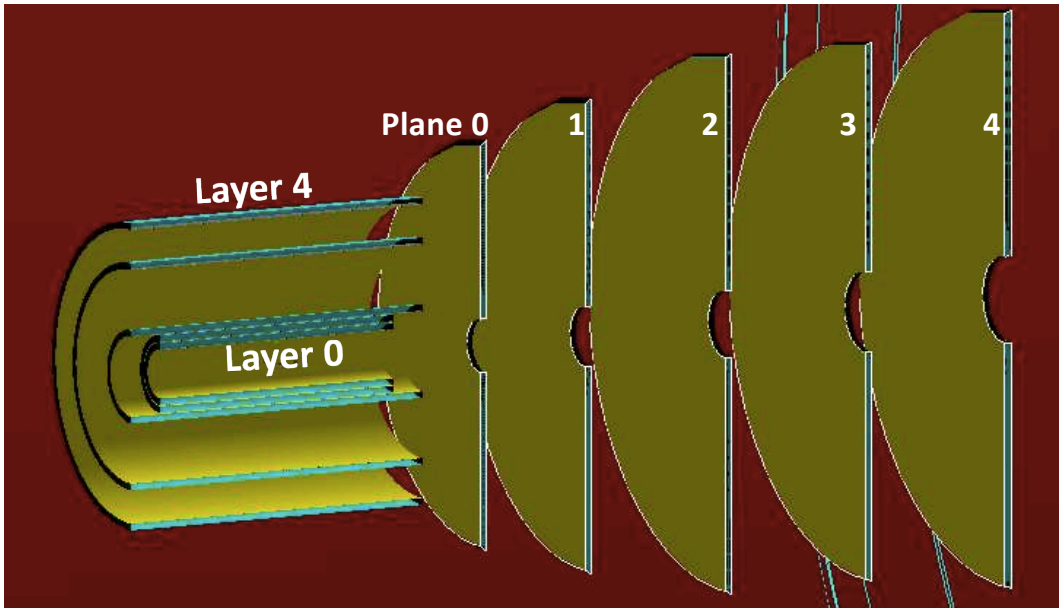
Outline

- The updated design of the proposed forward silicon tracking detector in the Fun4All framework.
  - Detector geometry
  - Tracking performance.
- Updated open heavy flavor physics simulation results with the updated detector geometry.
  - Reconstructed heavy flavor mesons.
  - Updated projection on the nuclear modification factor R_{eA}
- Summary and Outlook.

Detector Initial Design in Fun4all

- The proposed Forward Silicon Tracker (FST) geometry in the Fun4All framework.

Babar magnet with a peak at 1.4 T magnetic field



Barrel layer

Layer	Half length (cm)	r (cm)
0	20	3.64
1	20	4.81
2	25	5.98
3	25	16
4	25	22

Plane detector

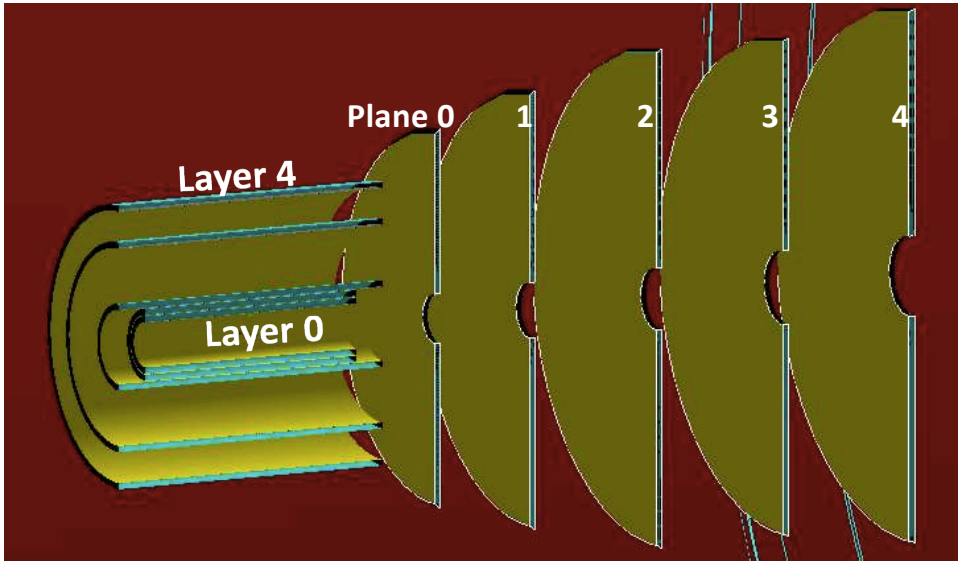
Plane	z (cm)	r_{in} (cm)	r_{out} (cm)
0	35	4	30
1	53	4.5	35
2	77	5	40
3	101	6	40
4	125	6.5	43

- The barrel layers are a place holder for central silicon vertex detector, which provide the primary vertex determination.

Updated FST geometries

Babar magnet with a peak at 1.4 T magnetic field

Version 0



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2	77	5	40
3	101	6	40
4	125	6.5	43

100um thick silicon wafer in both barrel and FST

Version 1: modify the outer radius of the plane 0 and 1

Plane detector

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)
0	35	4	**25**
1	53	4.5	**36**
2	77	5	40
3	101	6	40
4	125	6.5	43

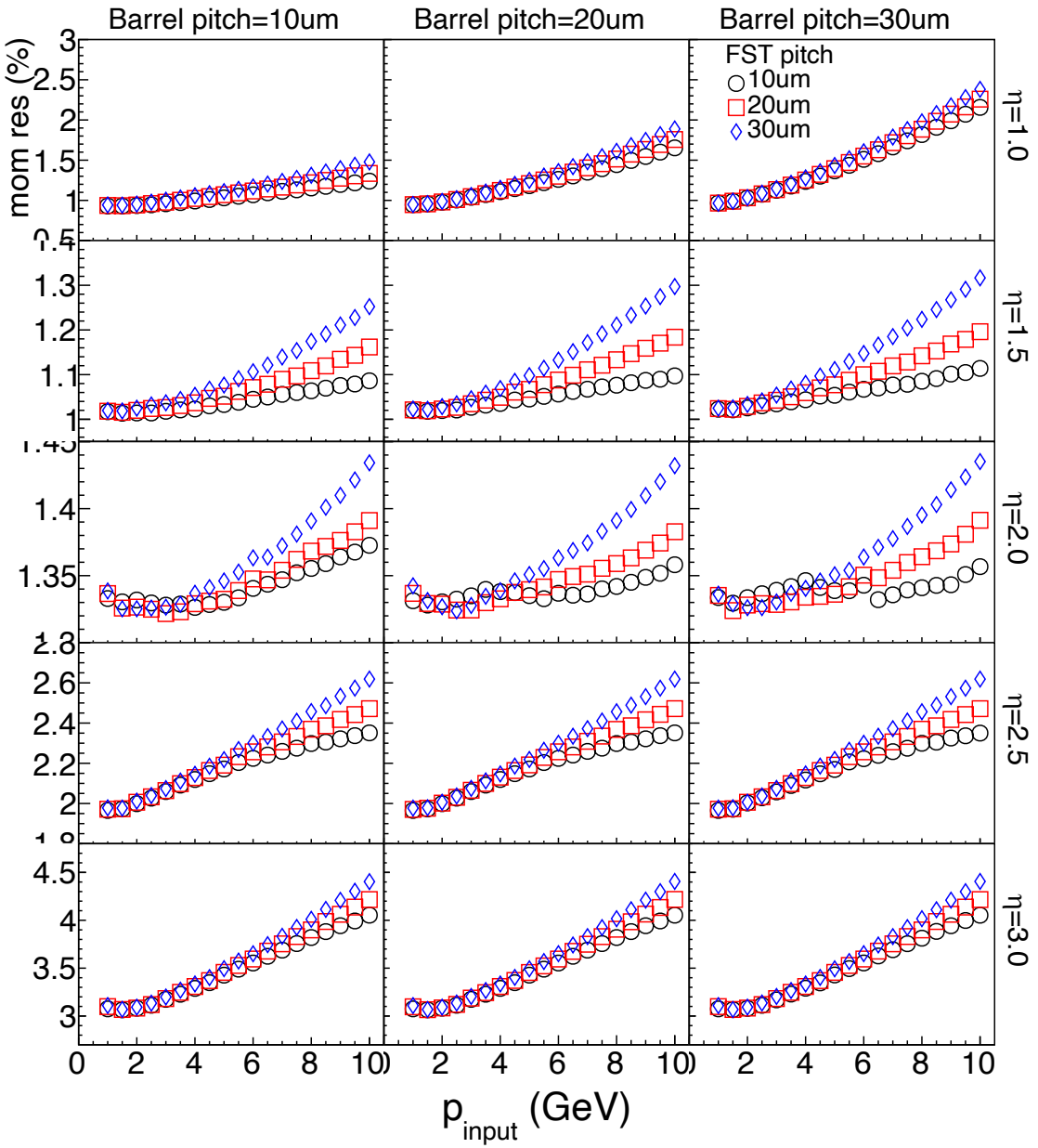
100um thick silicon wafer in the layer 3 & 4 of the barrel, 50um thick silicon wafer in the rest of barrel and FST

Version 2: move the last plane (plane 4) from Version 0 far back to z=2.7m to improve detector performance at large pseudorapidity

Plane	z (cm)	r_{in} (cm)	r_{out} (cm)
0	35	4	30
1	53	4.5	35
2	77	5	40
3	101	6	40
4	**270**	6.5	43

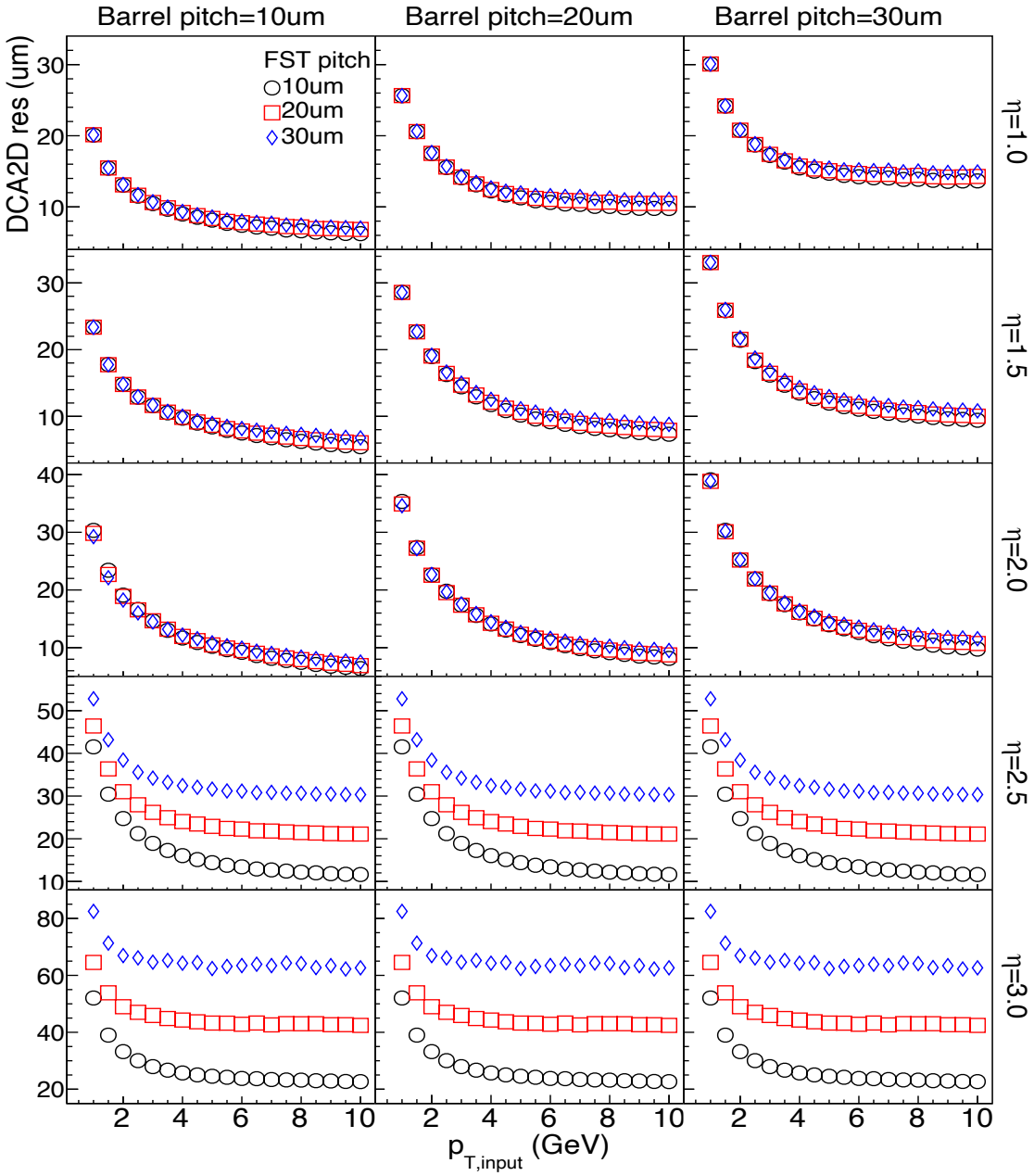
100um thick silicon wafer in the layer 3 & 4 of the barrel, 50um thick silicon wafer in the rest of barrel and FST

FST tracking performance (I)



- Track momentum resolution for FST geometry version 0 with different pixel pitch options.
- The silicon sensor thickness is $100\mu m$.
- The track momentum resolution is below 3% at $\eta \leq 2.5$
- Barrel (FST) pixel pitch dominates the momentum resolution at central (forward) pseudorapidity.

FST tracking performance (I)

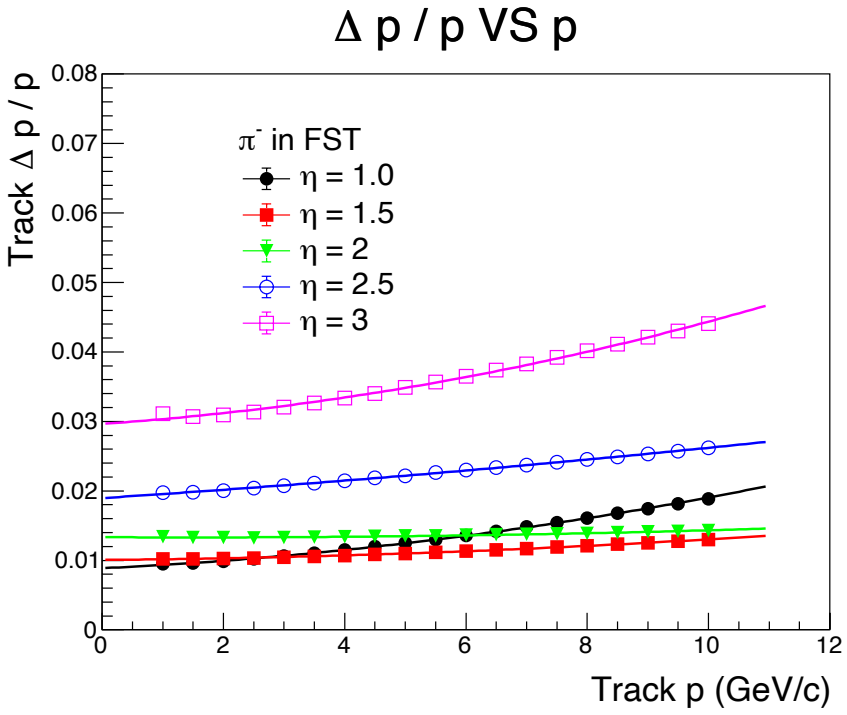


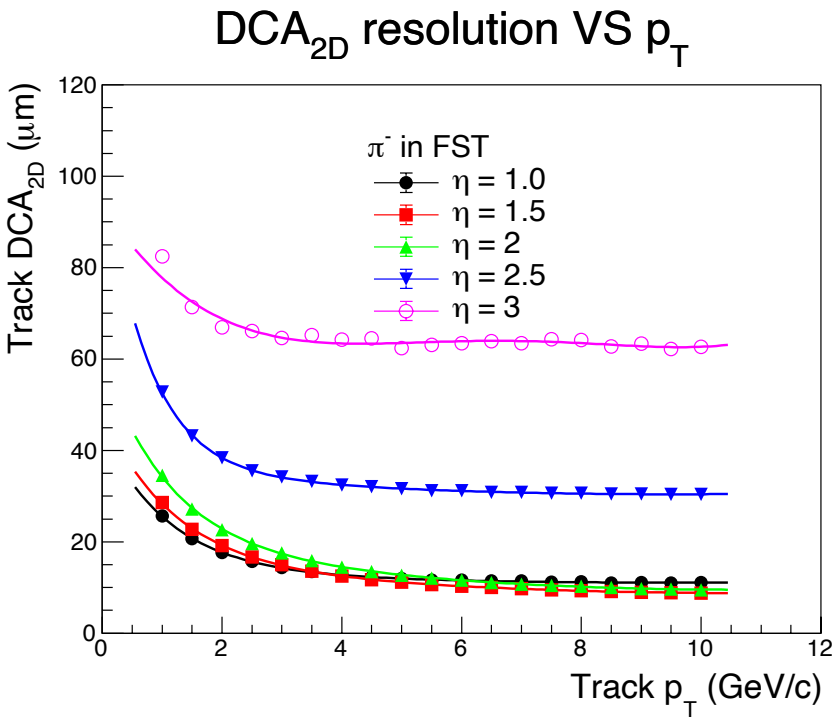
- Track DCA_{2D} resolution for FST geometry version 0 with different pixel pitch options.
- The silicon sensor thickness is $100\mu m$.
- The track DCA_{2D} resolution is better than $40\mu m$ ($85\mu m$) for $\eta \leq 2.0$ (3.0).
- Barrel (FST) pixel pitch dominates the momentum resolution at central (forward) pseudorapidity.

See more details in Ping's presentation in the 7/30/20 EIC YR tracking meeting.

Tracking performance from updated FST design in Fun4All (I)

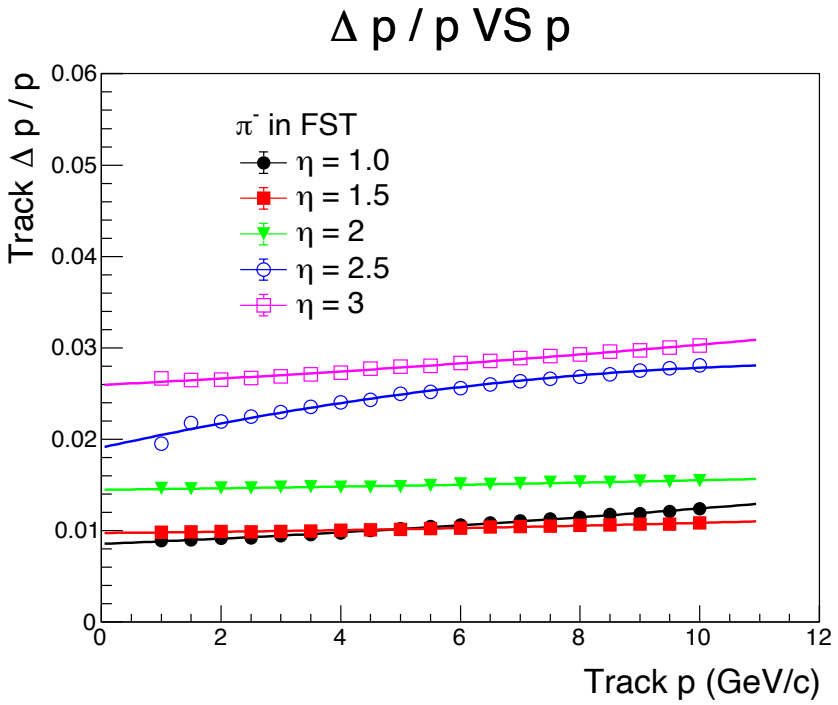
- FST version 0 configuration:
  - Babar magnetic field peaked at 1.4T.
  - Silicon sensor thickness: 100 μm
  - Barrel layer pixel pitch: 20 μm and forward plane pixel pitch: 30 μm

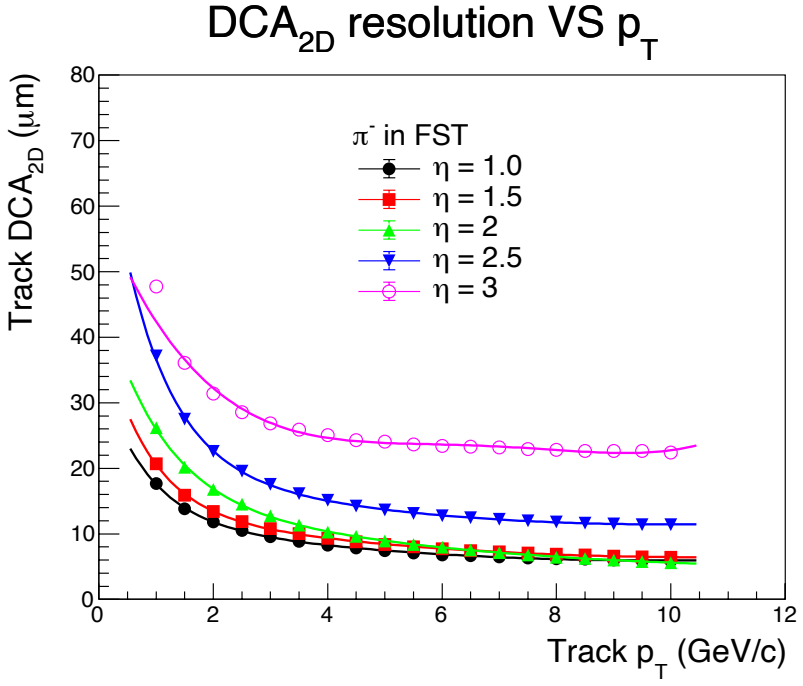




Tracking performance from updated FST design in Fun4All (I)

- FST version 1 configuration:
  - Babar magnetic field peaked at 1.4T.
  - Barrel layer 0-2 silicon sensor thickness: 50 μm, layer 3-4 silicon sensor thickness: 100 μm.
  - Forward plane silicon sensor thickness: 50 μm.
  - Barrel layer pixel pitch: 10 μm and forward plane pixel pitch: 10 μm

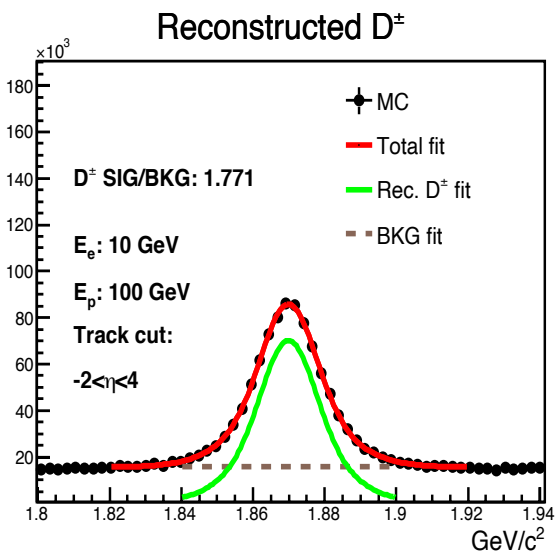


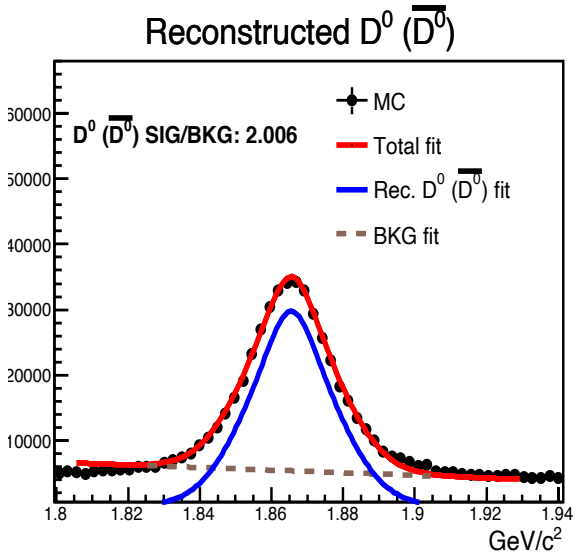


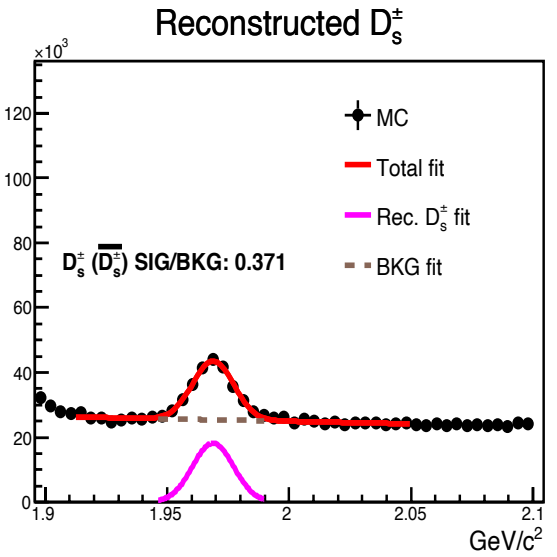
Heavy Flavor reconstruction with FST configuration version 0

Reconstructed heavy flavor hadrons – D mesons with FST configuration version 0

- Additional detector performance:
  - Primary vertex resolution: 20 μm.
  - 95% K/π/p separation over all the acceptance.
  - Charged track clusters with a decay length (DCA) cut.







- Overall broader peaks in these reconstructed D-meson mass spectrum than the distribution with 3T magnetic field setup.
- Will study the detector parameter dependent signal/background ratio.

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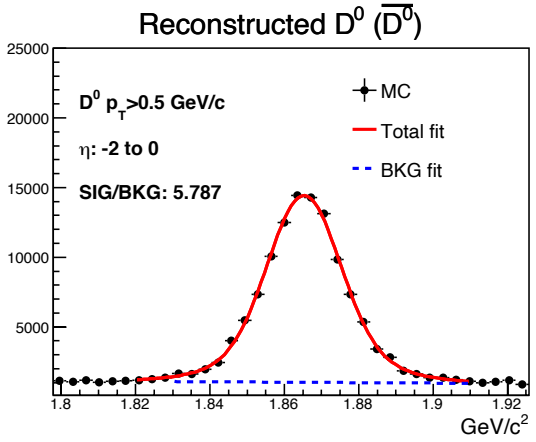

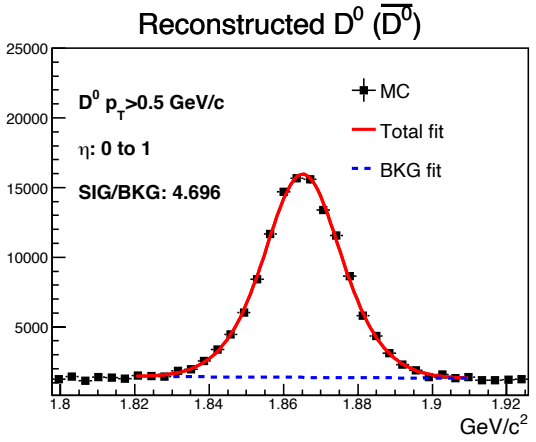

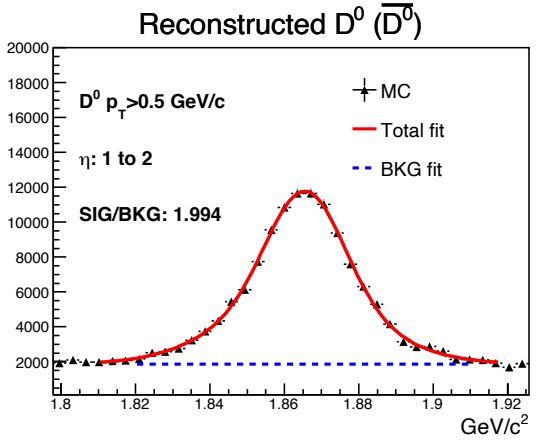

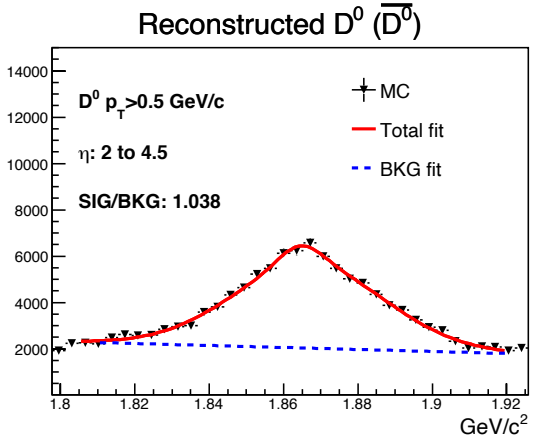

Pseudorapidity dependence has been updated.

Reconstructed heavy flavor hadrons – B mesons with FST configuration version 0

- Additional detector performance:
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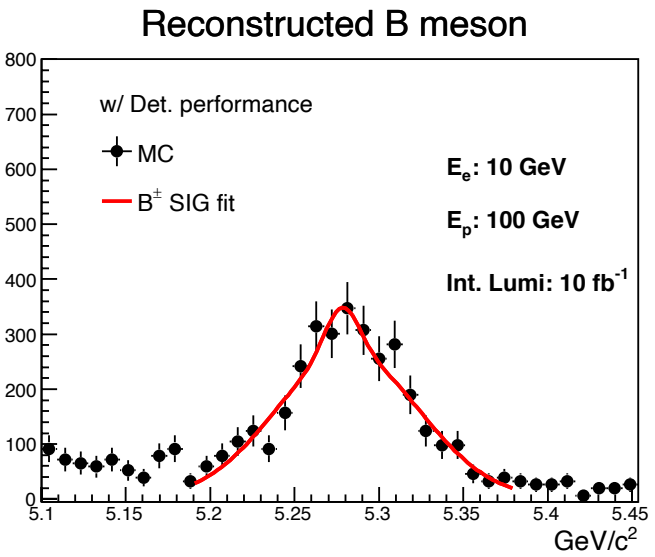
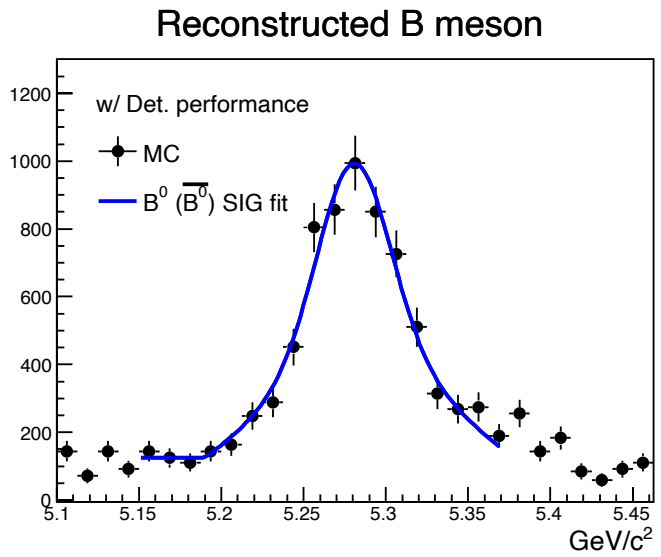
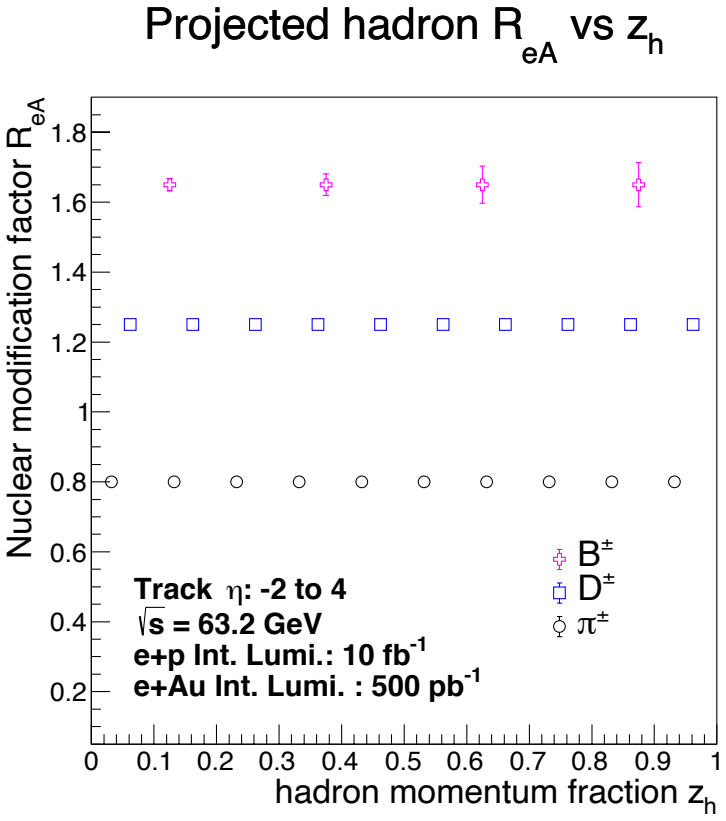


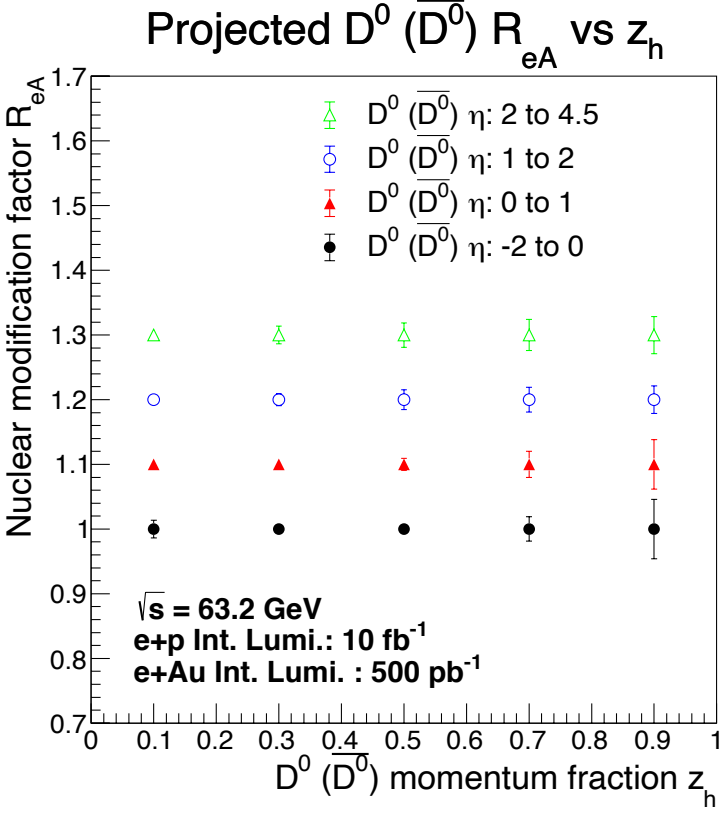


- Overall broader peaks in these reconstructed B-meson mass spectrum than the distribution with 3T magnetic field setup.
- Lost the B_s signal in this detector configuration. Different detector geometry and tocology options are under study.

Reconstructed heavy flavor hadrons R_{eA} projection with FST configuration version 0

- 10 GeV electron and 100 GeV proton/gold collisions.





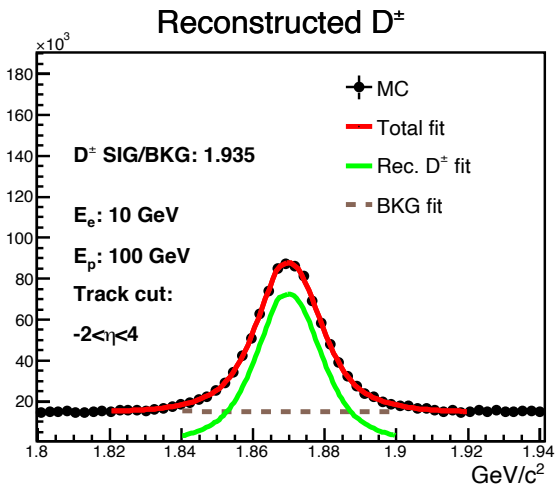
- Good statistical precision has been achieved for reconstructed heavy flavor mesons, which can provide good discriminating power for theoretical calculations.

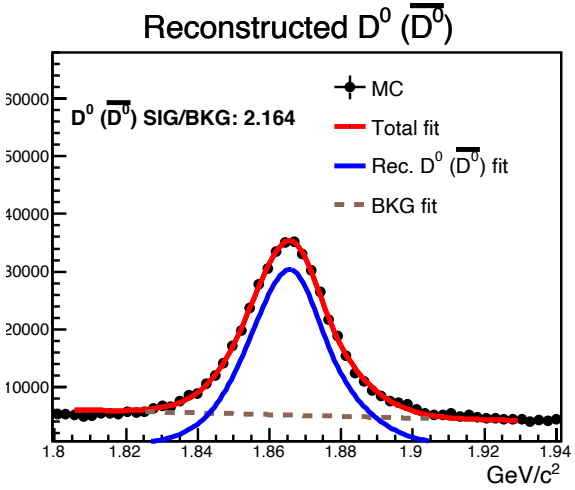
HF tomography in EIC
arXiv: 2007.10994

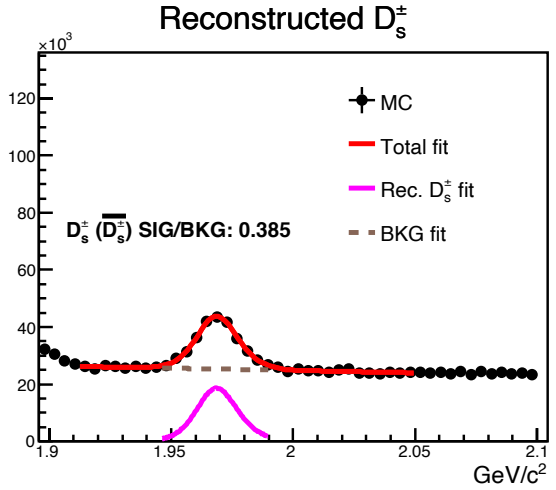
Heavy Flavor reconstruction with FST configuration version 1

Reconstructed heavy flavor hadrons – D mesons with FST configuration version 1

- Additional detector performance:
  - Primary vertex resolution: 20 μm.
  - 95% K/π/p separation over all the acceptance.
  - Charged track clusters with a decay length (DCA) cut.







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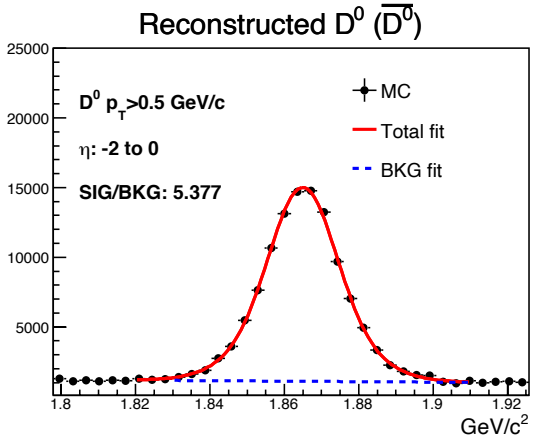

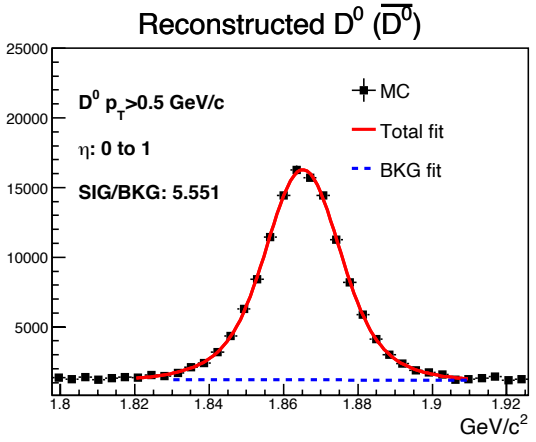

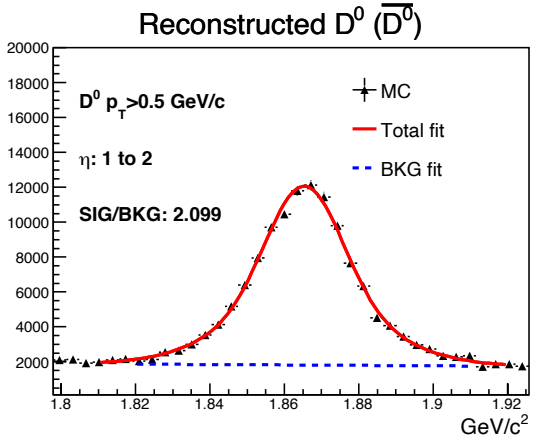

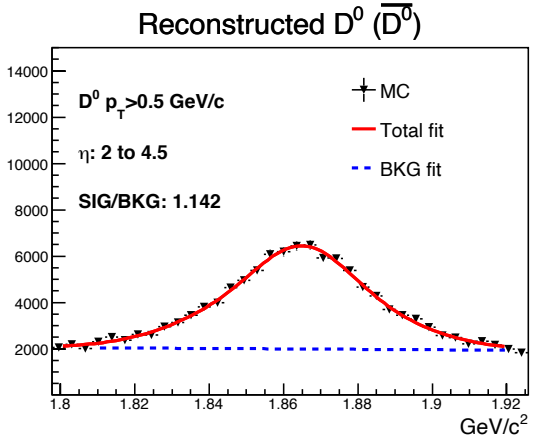

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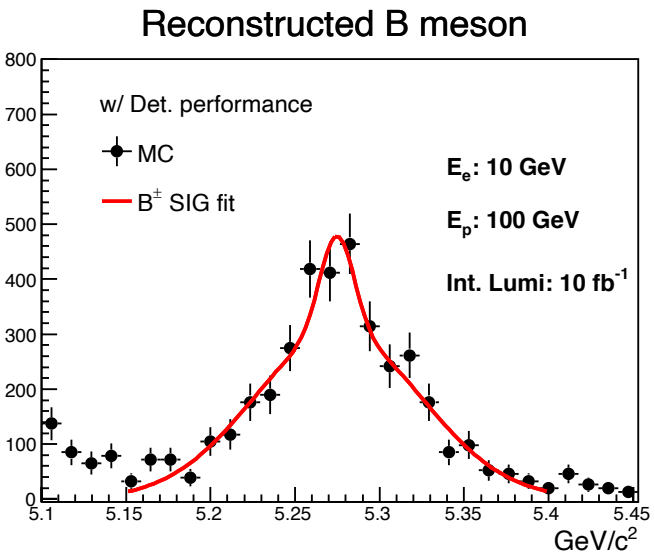

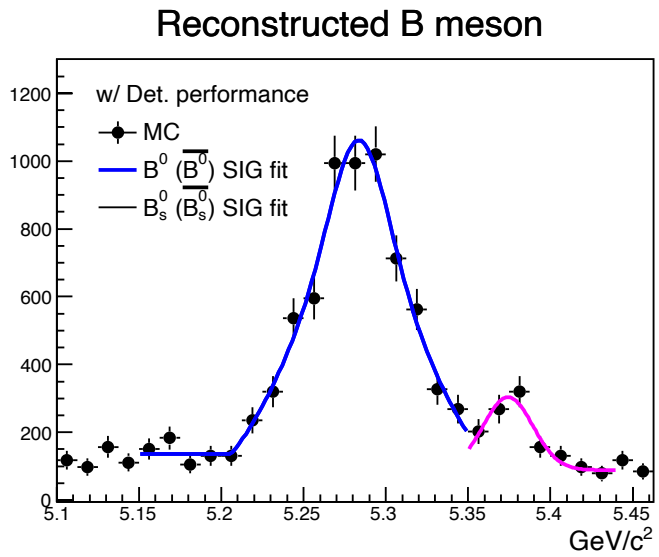

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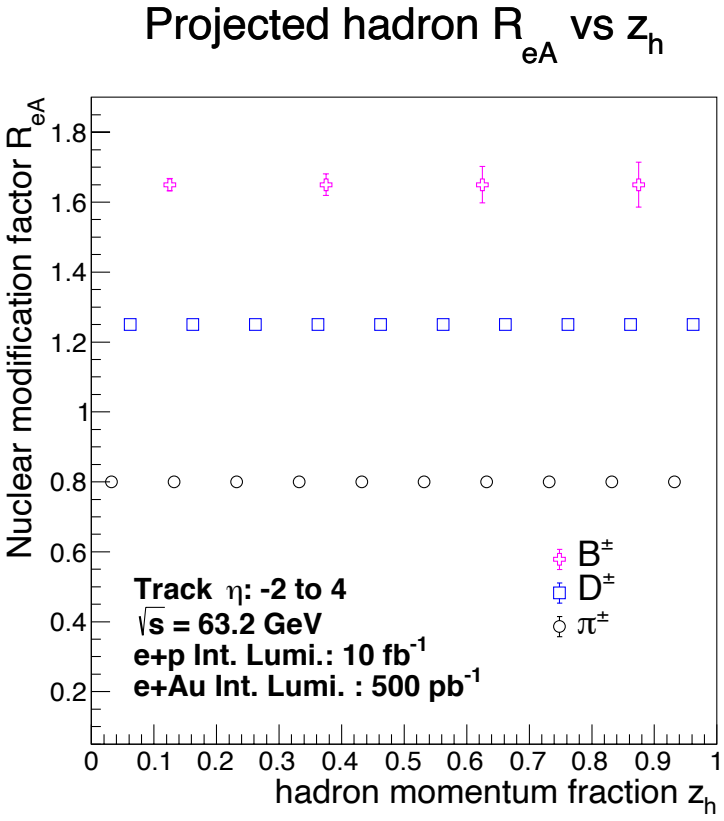

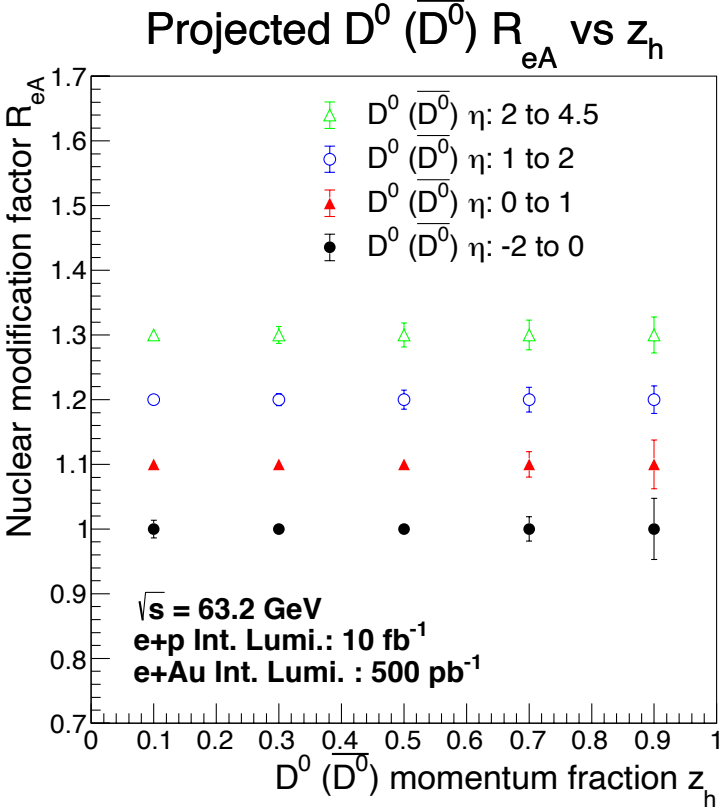

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HF tomography in EIC
arXiv: 2007.10994

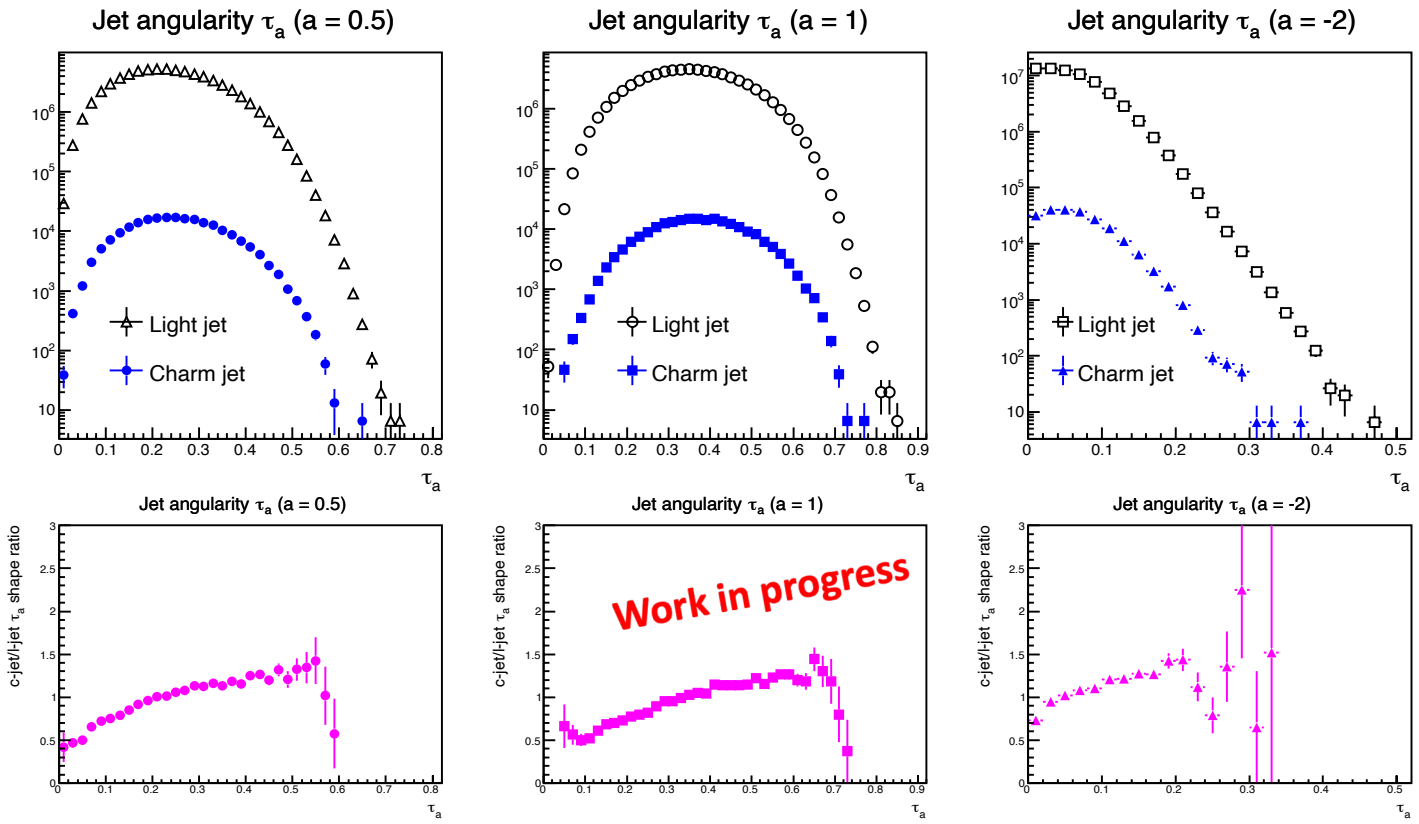
New heavy flavor observables under study

- Heavy flavor jet tagging and sub-structure under study.

Jet angularity definition: $\tau_a \equiv \tau_a^{pp} \equiv \frac{1}{p_T} \sum_{i \in J} p_T^i \left(\Delta \mathcal{R}_{iJ}\right)^{2-a}$ JHEP 1804 (2018) 110

- Light-jet and charm-jet jet angularity comparison:

arXiv: 2007.14417



- Charm-jets and light-jets have different jet angularity distributions.
- Detector requirements are under study.

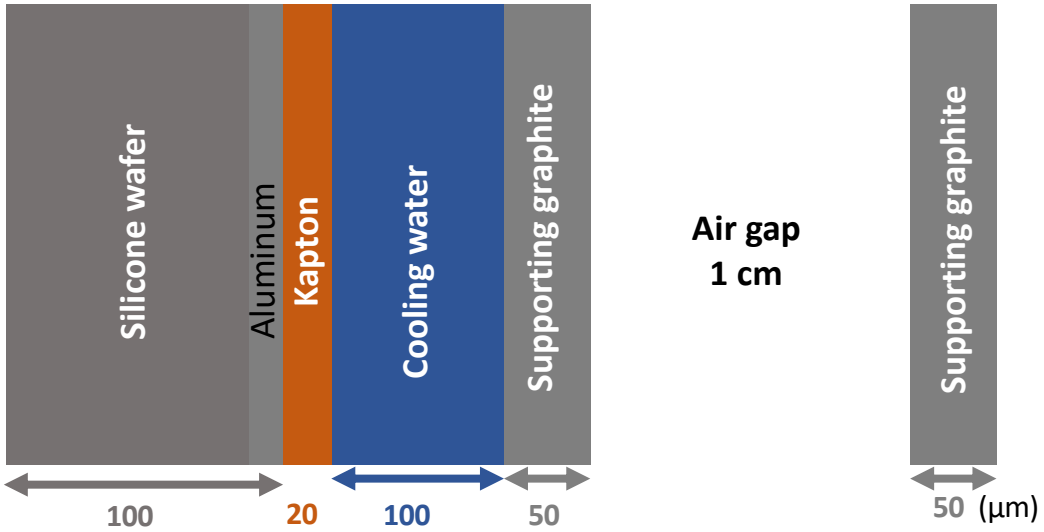
Summary and Outlook

- The proposed Forward Silicon Tracker (FST) design has been implemented in the Fun4All framework.
- Tracking performance with different FST geometries and detector options has been evaluated. Optimization is underway.
- Good statistical precision has been achieved for heavy flavor meson reconstruction with the updated FST tracking performance.
- New observables such as the flavor tagger jet angularity have been explored and will implement with relevant detector performance in full simulation.

Backup

Detector Initial Design in Fun4all

Material sublayers of the plane detectors (arbitrary scale)



Pixel Pitch

Barrel \ FST	10um	20um	30um
10um	✓ Same	✓	✓
20um	✓	✓ Same	✓
30um	✓	✓	✓ Same