Collected ideas from Los Alamos National Laboratory for the EIC forward silicon tracking detector

Xuan Li (LANL)

Outline

- Silicon sensor candidates for the EIC forward silicon tracking detector.
- Initial design of the forward silicon tracking detector and tracking performance.
- Physics driven detector requirements.
- LANL plan

Silicon sensor candidates

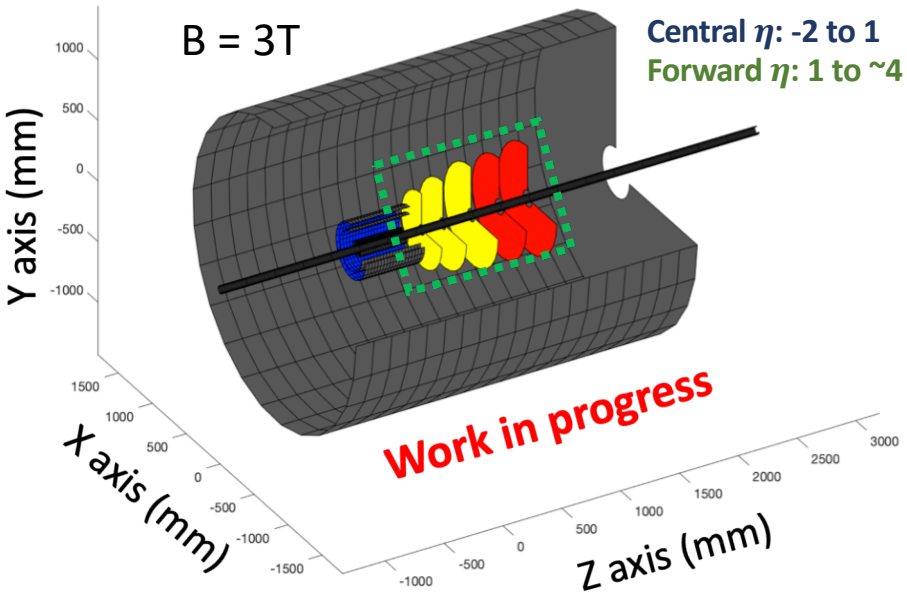
- Ongoing R&D to reduce the pixel size and material budgets, enhance the radiation hardness and improve the timing is underway.
- Current version of silicon sensors to be studied in lab at LANL.

Name	Technique	Pixel Size	Integration Time	Thickness per layer	Proposed location
LGAD or AC-LGAD	Low Gain Avalanche Diode	Current: 1.3mm X 1.3mm Towards 100 X 100 μm^2	< 100 ps	< 1%X_0 per layer	Far-forward silicon planes for time stamping
Radiation hard MAPS (MALTA)	180 nm Tower Jazz HV-MAPS	36.4 X 36.4 μm^2	< 5 ns	< 0.5%X_0 per layer	Far-forward silicon planes for time stamping

- We will demonstrate the performance of the relevant silicon sensors through bench tests etc.
- We are open to work on other new silicon techniques and collaborate with other institutions on the detector integration.

Detector requirements for heavy flavor measurements at the future EIC

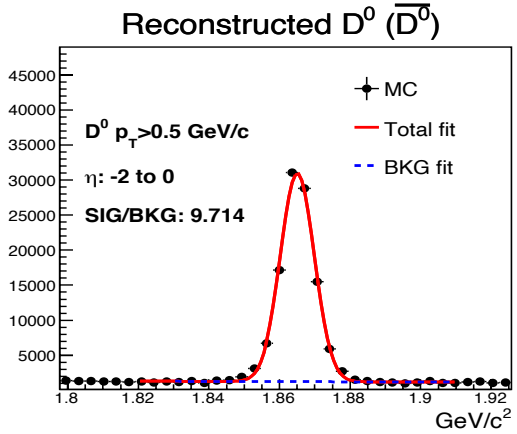
- For fully reconstructed heavy flavor hadrons such as D^0:
  - Precise primary vertex and decay vertex measurements (vertex resolution <50μm).
  - Better than 3 sigma separation of the PID identification.
  - Good tracking momentum resolution in the central and forward pseudorapidity region.
  - Good time resolution (<10ns) to reduce background.

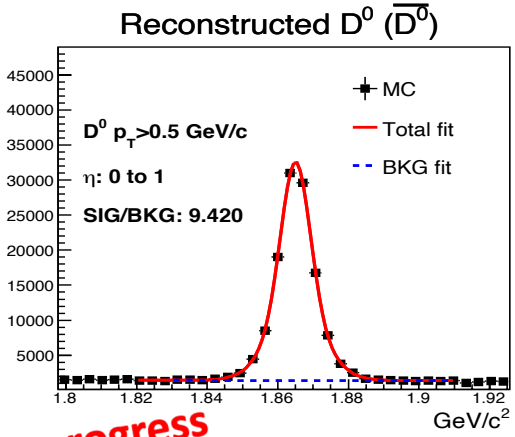


- A hybrid design of central and forward silicon tracker with MAPS and HV-MAPS.
- In the forward region:
  - MAPS: pixel pitch 30 μm, material budgets per detector layer: 0.4%X_0
  - HV-MAPS: pixel pitch 36.4 μm, material budgets per detector layer: 0.8%X_0

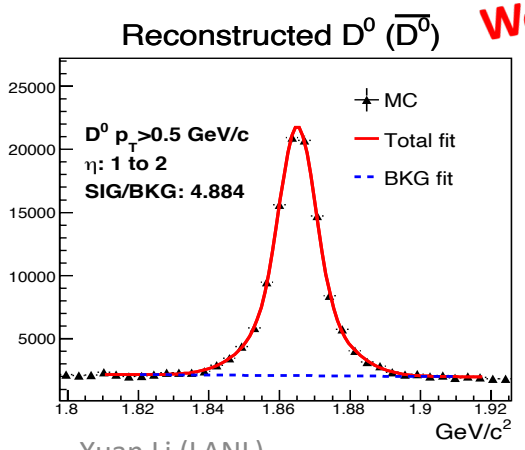
Heavy Flavor reconstruction at the EIC

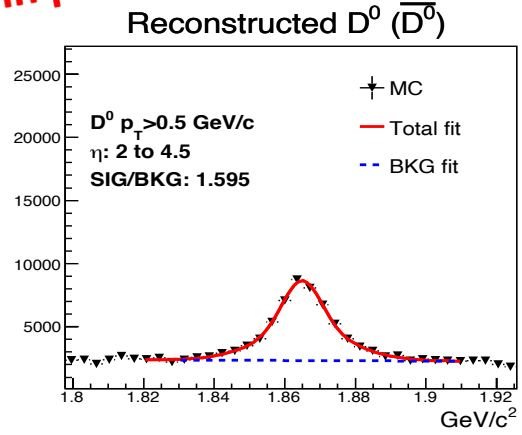
- Reconstructed D^0 ($\overline{D^0}$) meson mass distributions in different pseudorapidity η regions in 10 GeV electron and 100 GeV proton collisions with integrated luminosity: 10 fb^{-1}.
  - Primary vertex resolution: 20 μm.
  - Tracking η cut: -2 to 4 and track efficiency set at 95%.
  - Tracking performance implemented in the simulation.
  - 80% K/π/p separation is implemented.
  - Charged track clusters that contain $K^{\pm}$ with a decay length (DCA) cut.





Work in progress

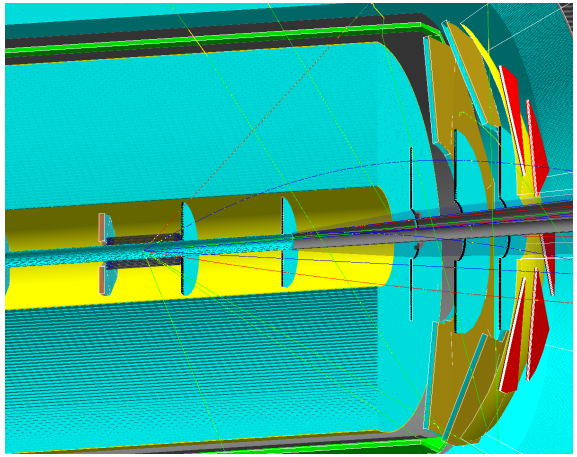


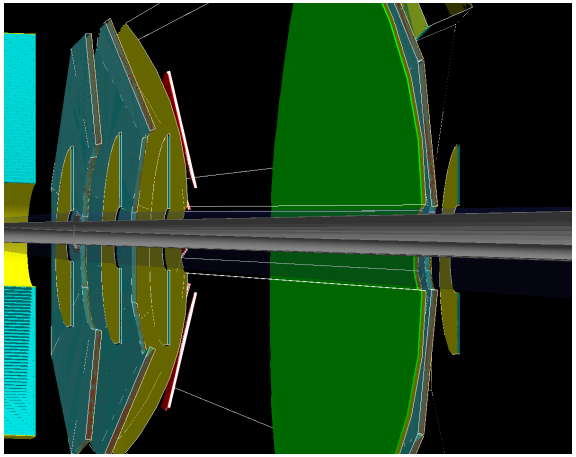


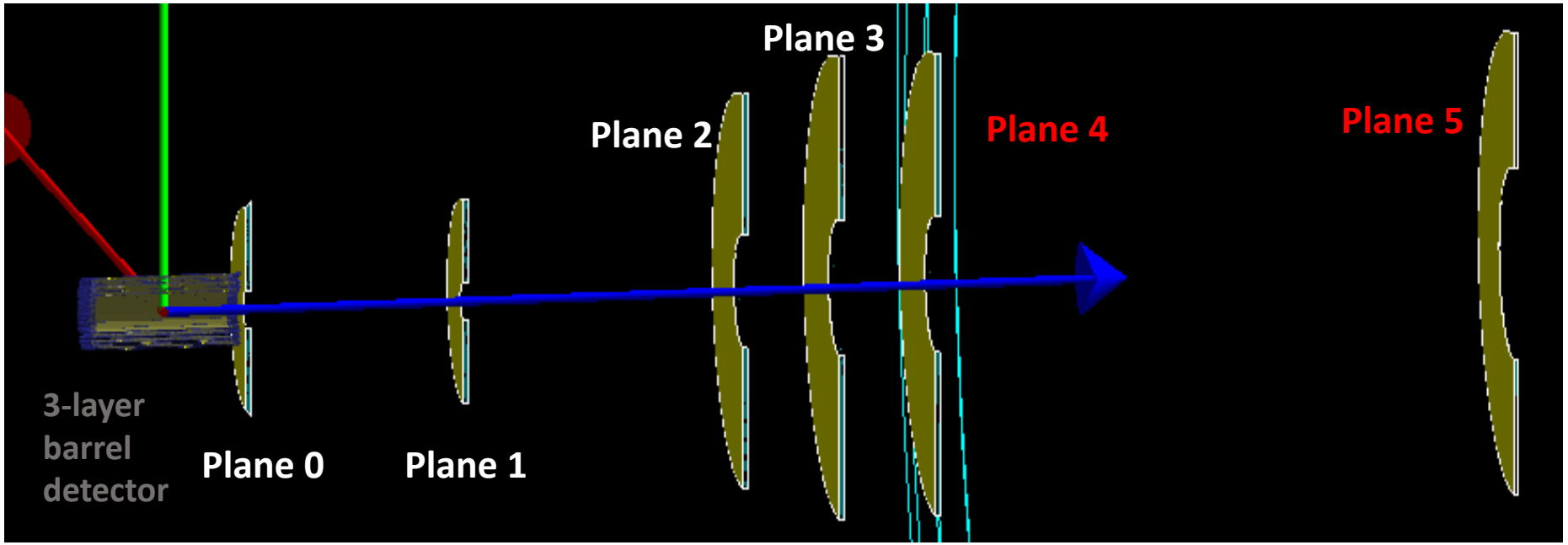
- Smaller signal over background ratio for more forward D^0 ($\overline{D^0}$) reconstruction mainly due to the pseudorapidity dependent tracking momentum resolutions.
- Optimization of the forward silicon tracker is underway to improve the reconstruction purity.

Initial configuration of the proposed Forward Silicon Tracker (FST) in Fun4All simulation

- 3D view of the LANL FST ($1<\eta<4$) integrated with other detector sub-systems w/ the Barbar magnet.
- Time stamping planes: Plane 4 and Plane 5.

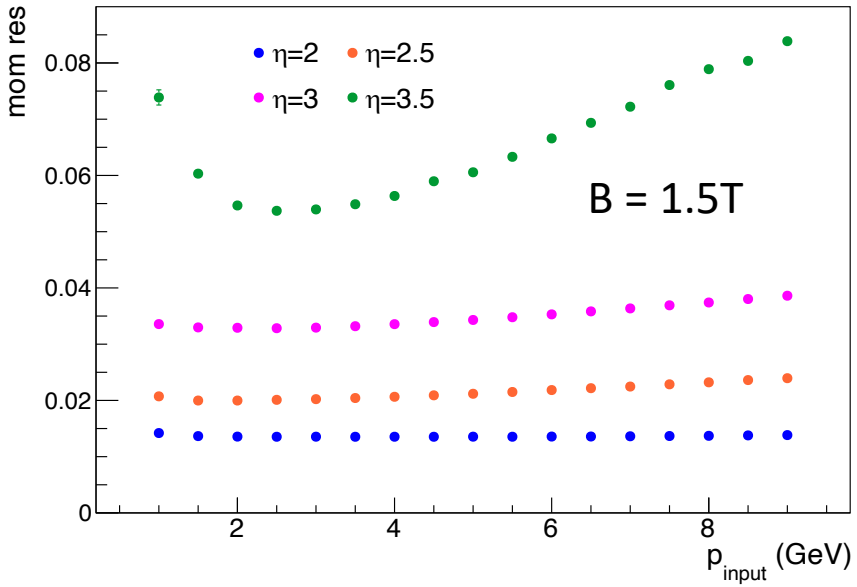




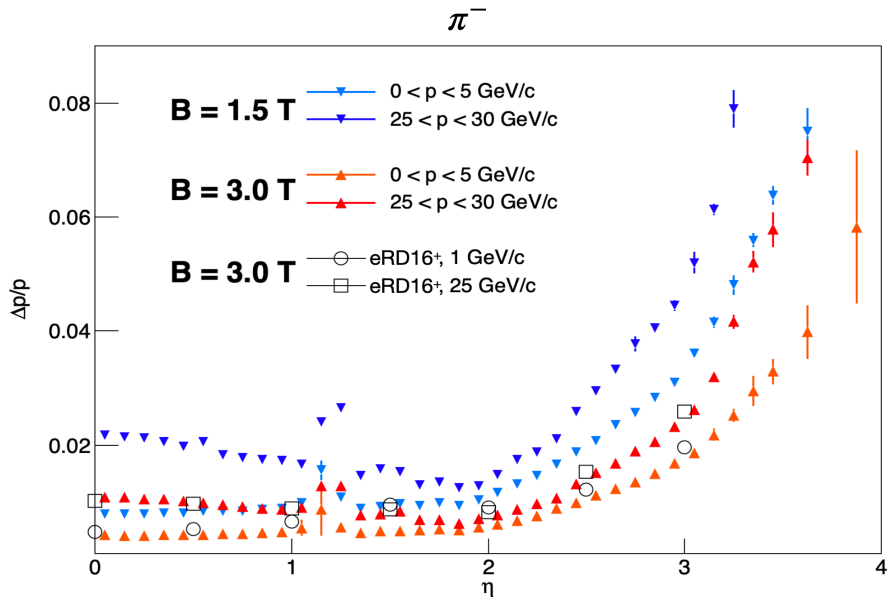


Tracking performance in comparison to eRD16 simulation results

Ping's ongoing MC studies in Fun4All



- Tracking momentum resolution (Δp/p) VS p for forward planes only with vertex constrain.
- Initial parameter:
  - Pixel pitch at 20-micron, 50-micron thick sensors.
- Geometry and detector configuration optimization is underway.



May 14th,
Rey's presentation
https://indico.bnl.gov/event/7894/contributions/37609/attachments/28098/43125/200514_AllSi_in_Fun4All_2.

LANL plan

- Detector R&D:
  - We will continue the silicon sensor characterization at LANL and summarize the performance.
  - The LANSCE facility at LANL will help verify the radiation tolerance of the proposed EIC detector technique options. We welcome you to submit user proposals for relevant tests.
- Detector design:
  - Starts with existing silicon techniques and will implement with new options.
  - Need to integrate with central silicon vertex detector, central gas tracker if any, forward PID detector, forward gas tracker. Any inputs are very welcome!
- Detector simulation:
  - The FST geometry and configuration is under updating.
  - Tracking performance evaluation in the Fun4All framework is ongoing.
  - Will compare our results with the other groups.

Backup

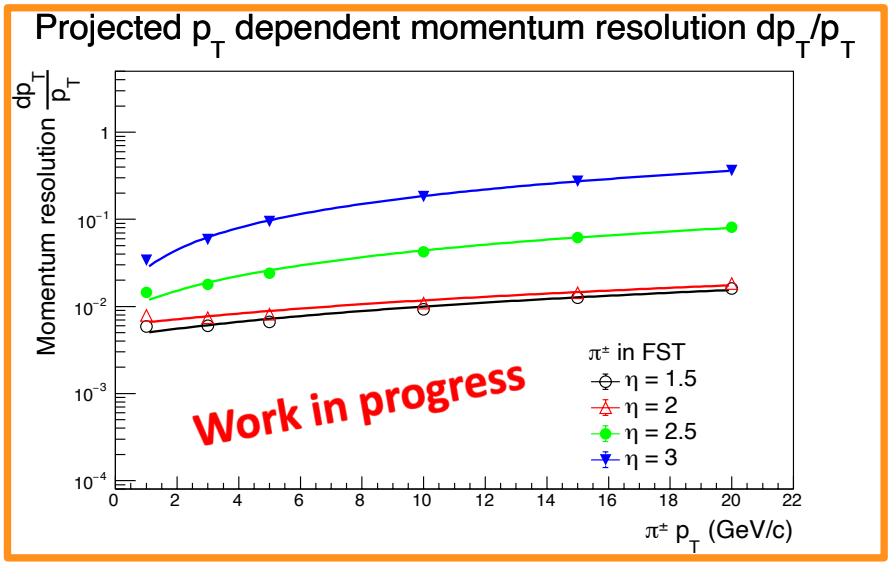
EIC collider design parameters

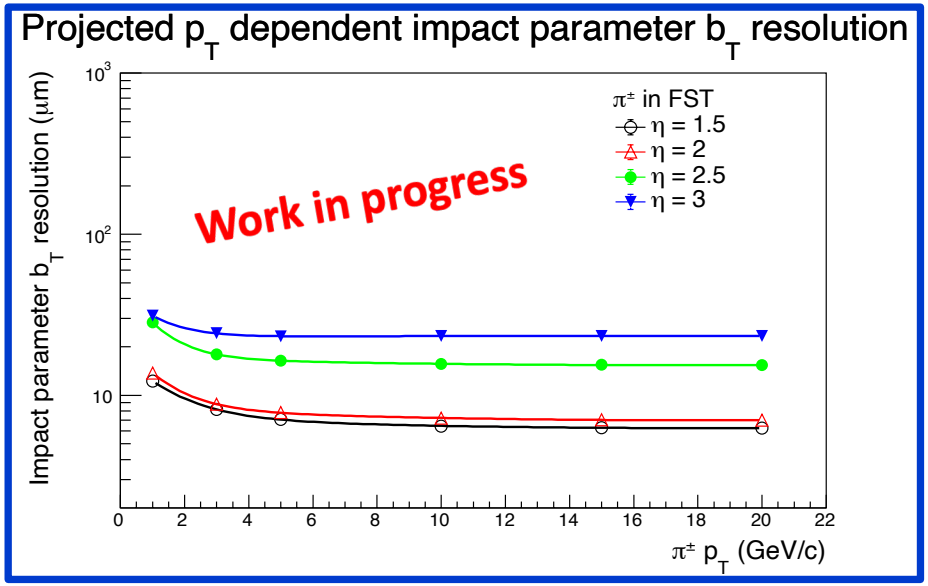
- Repetition rate: ~ 1ns - 9ns.
- Beam crossing angle: 25mrad.
- Collision rate: ~500kHZ.
- Beam induced background especially synchrotron radiation is under evaluation.
- Radiation dose: from primary interaction is estimated at ~250 rad per year. Instant beam luminosity close to beam line at ~10^{34} $cm^{-2}s^{-1}$. The total radiation dose over ~10 years would exceed ~10^{11} n/cm^2.
- Total material budgets for silicon vertex/tracking <3%X_0.

design	eRHIC		JLEIC		eRHIC-opt.		JLEIC-upgrade	
parameter	proton	electron	proton	electron	proton	electron	proton	electron
center-of-mass energy [GeV]	104.9		44.7		63.3		105.8	
energy [GeV]	275	10	100	5	100	10	400	7
number of bunches	1160		3456		2320		864	
particles per bunch [10^{10}]	6.9	17.2	1.06	4.72	3.4	8.6	4.2	19.3
beam current [A]	1.0	2.5	0.75	3.35	1.0	2.5	0.75	3.4
beam polarization [%]	80	80	85	85	80	80	85	85
total crossing angle [mrad]	25		50		50		50	
ion forward acceptances [mrad]	±20/±4.5		±50/±10		±35/±8		±50/±5.6	
h./v. norm. emittance [μm]	2.8/0.45	391/24	0.65/0.13	83/16.6	1.5/0.15	391/24	3/0.5	228/45.6
bunch length [cm]	6	2	2.5	1	4	2	3.5	1
β_x^* / β_y^* [cm]	90 / 4.0	43 / 5.0	8 / 1.3	5.72 / 0.93	18 / 2	13 / 2.4	40 / 2.25	16.9 / 0.8
hor./vert. beam-beam param.	.014/.007	.073/.1	.015/.0135	.049/.044	.012/.013	.036/.062	.014/.008	.076/.037
peak lumi. [$10^{34}cm^{-2}s^{-1}$]	1.01		1.46		1.24		1.78	
average lumi. [$10^{34}cm^{-2}s^{-1}$]	0.93*		1.4		0.95*		1.47*	

Single track performance in fast simulation

- Track performance from the FST with average pixel pitch at 30 μm, materials per detector layer: MAPS 0.4%X_0 and HV-MAPS 0.8%X_0 and the readout rate is at 500 kHZ, same for the central barrel layers:





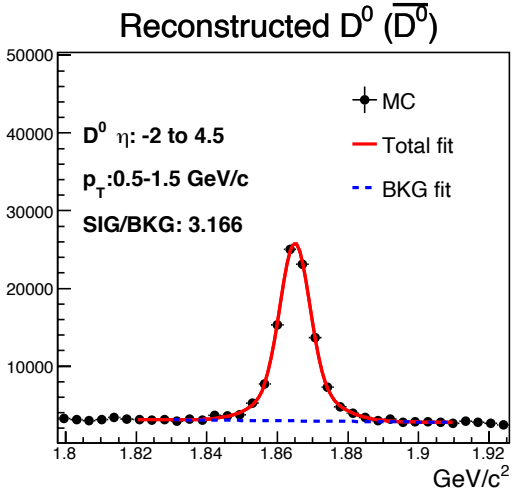
- Better than 40 μm resolution can be achieved by the initial FST design for the transverse decay length b_T measurements for tracks with p_T > 1 GeV/c over the 1.5<η<3.0 region.
- The momentum resolution dp_T/p_T are better than or consistent with the forward tracking requirements from the EIC detector handbook.

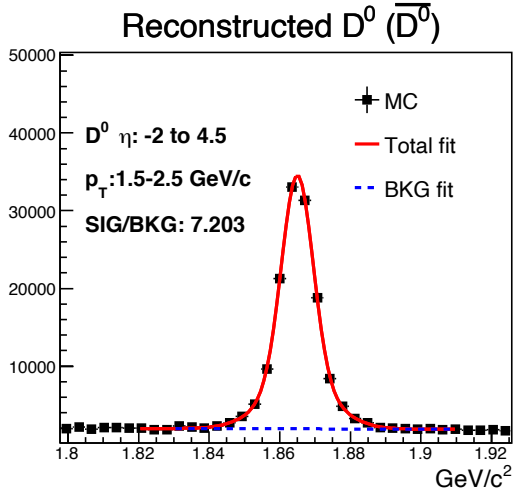
Detector requirements for heavy flavor measurements at the future EIC

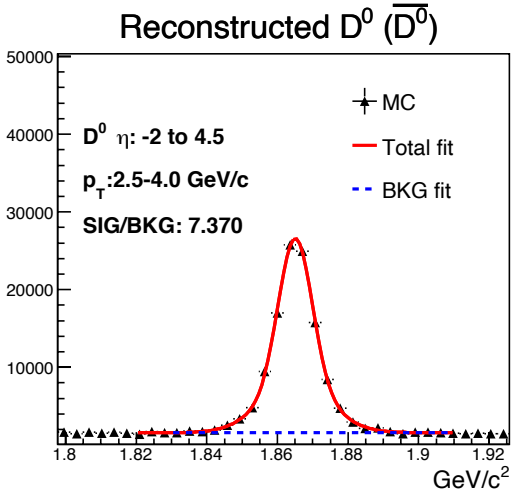
- For fully reconstructed heavy flavor hadrons such as D^0:
  - Precise primary vertex and decay vertex measurements (vertex resolution <50μm).
  - Better than 3 sigma separation of the PID identification.
  - Good tracking momentum resolution in the central and forward pseudorapidity region.
  - Good time resolution (<10ns) to reduce background.
- For jet reconstruction:
  - Fast tracker which can provide synchronized readout with the calorimetry system.
  - Wide pseudorapidity and full azimuthal coverage.
  - Tracker that can provide good spatial resolution for jet sub-structure studies.
  - Better than 3 sigma separation of the PID identification for jet sub-structure studies.

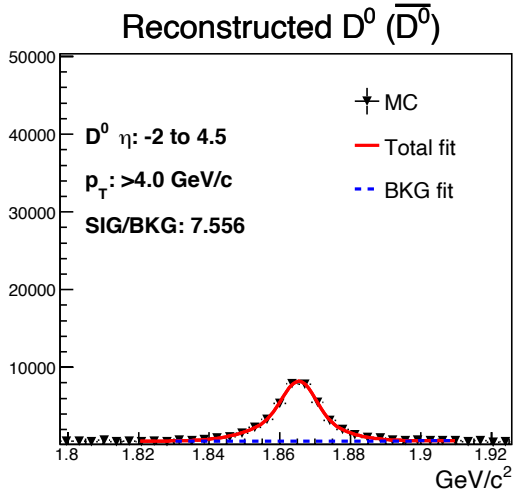
Heavy Flavor reconstruction at the EIC

- Reconstructed D^0 ($\overline{D^0}$) meson mass distributions in different p_T regions.









- Smaller signal over background ratio for lower transverse momentum D^0 ($\overline{D^0}$) reconstruction.