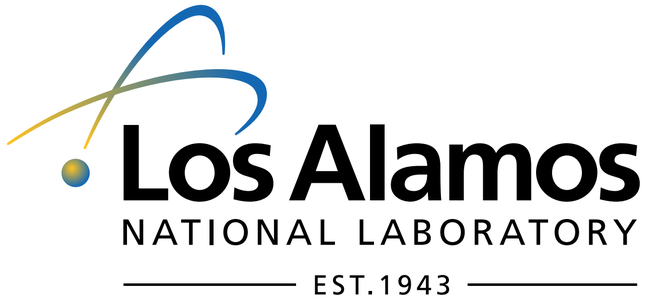
LANL Overview



Kei Nagai
on behalf of LANL EIC team

July 18th, 2022

LANL members for EIC

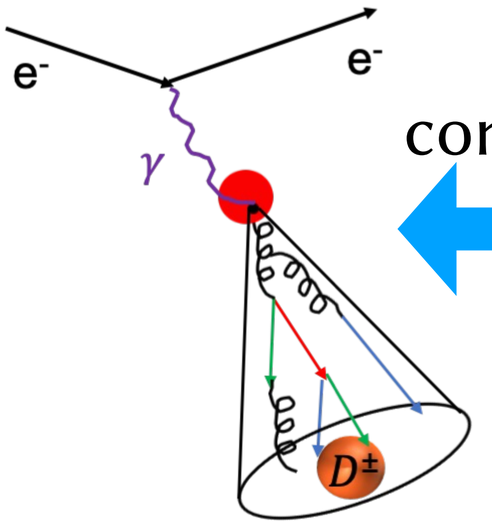
- LANL members
  - Staff members: Xuan Li, Matthew Durham, Cesar Luis Da Silva, Ming Liu, Yasser Corrales Morales,
  - Postdoc: Kei Nagai

- Working on
  - Silicon tracker
  - Beam-gas background

Heavy Flavor Measurement

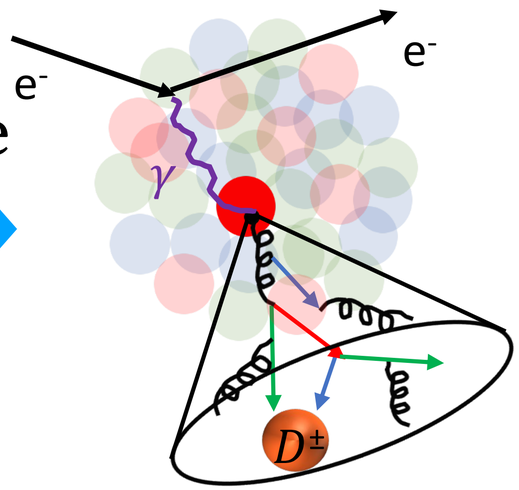
- Heavy flavor hadron and jet measurements at EIC can help solve the following science problems and play a significant role in exploring:
  - **Nuclear modification** on the initial nuclear Parton Distribution Functions (PDFs) especially in the high and low Bjorken-x (x_{Bj}) region.
  - **Parton energy loss**:
    Final state parton propagation inside the nuclear medium and hadronization processes in vacuum and nuclear medium

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

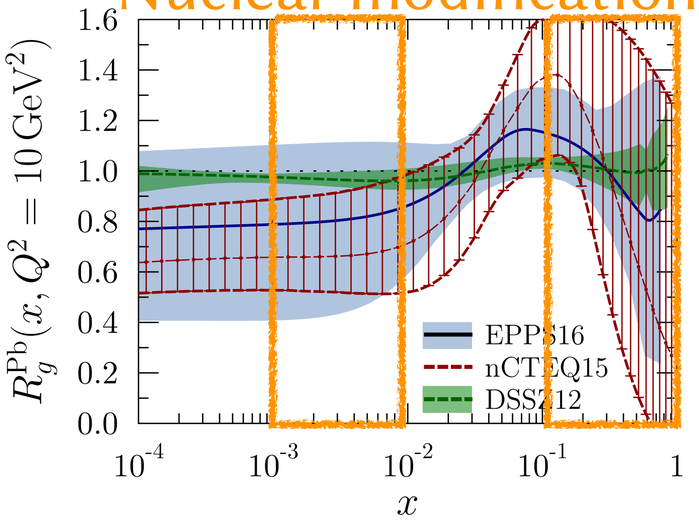


compare

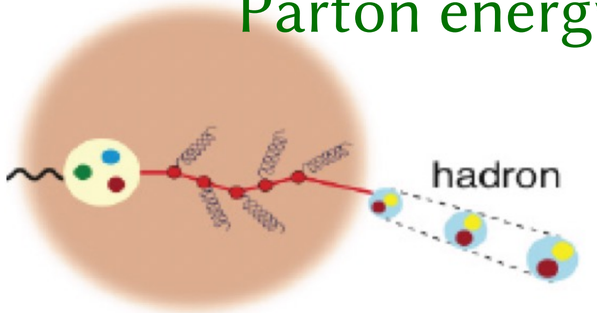
$e^- + \mathrm{Au} \rightarrow e^- + jet(D^\pm) + X$



Nuclear modification



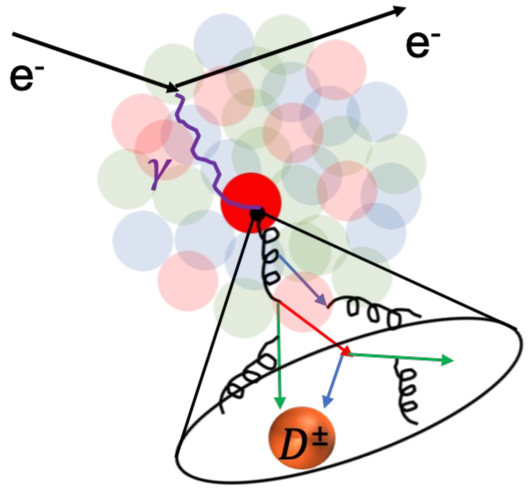
Parton energy loss

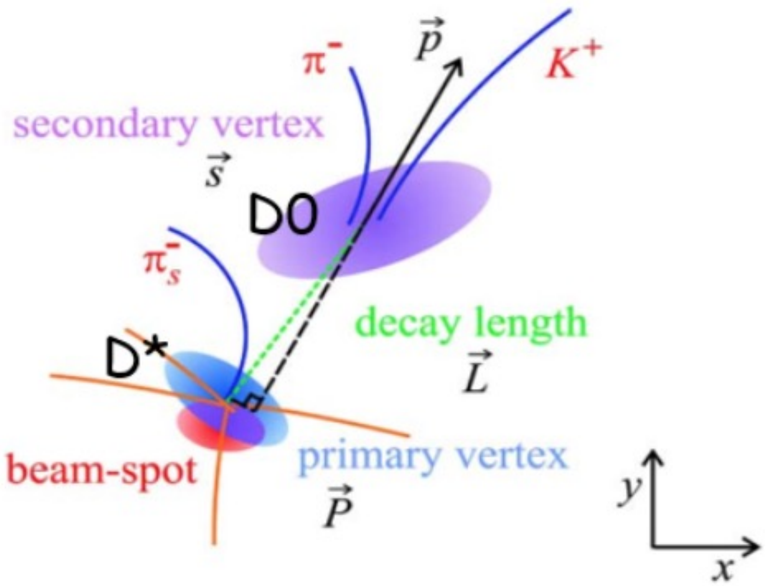


Detector Requirements for HF physics

- 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.

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



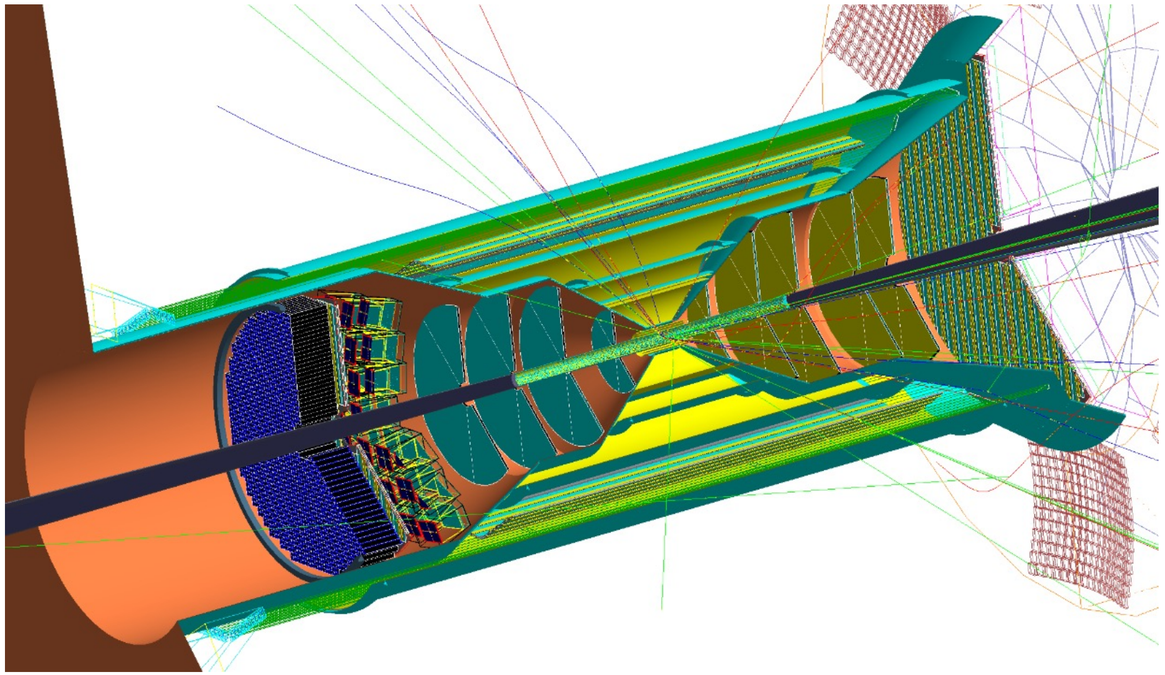


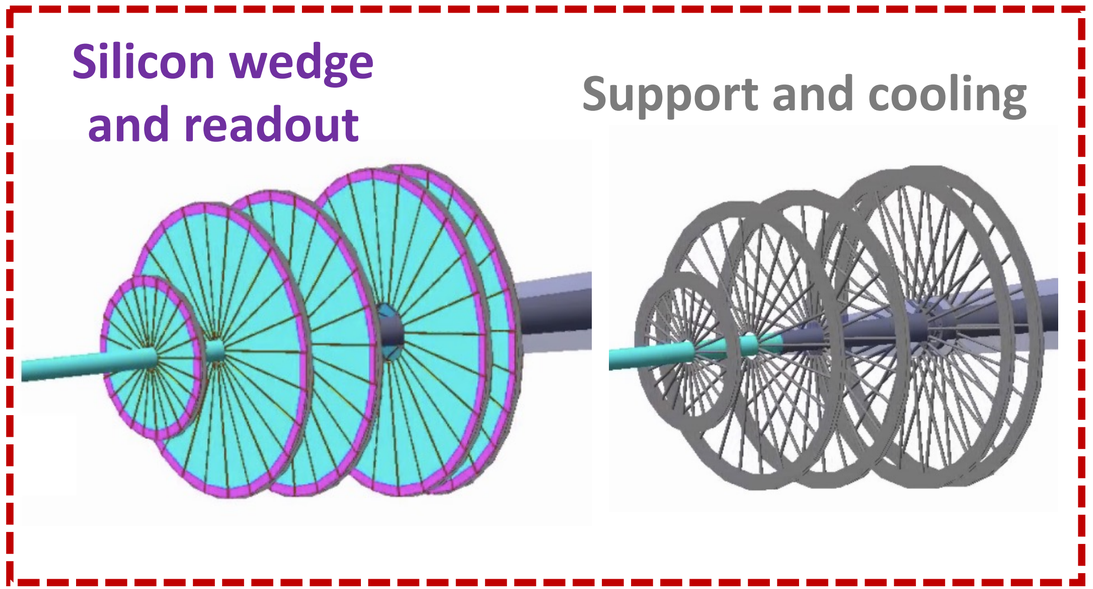
	Mass (GeV/c^2)	Average Decay Length (μm)
$D^{\pm}$	1.869	312
D^0	1.864	123
$B^{\pm}$	5.279	491
B^0	5.280	456

- Performance requirements:
  - Fine spatial resolution for displaced vertex reconstruction (< 100 μm)
  - Fast timing resolution to suppress backgrounds from neighboring collisions
  - Low material budgets to maintain fine hit resolution

Forward Silicon Tracker design implemented in the ECCE detector

- The Monolithic Active Pixel Sensor based Forward Silicon Tracker (FST) design consists of 5 disks with the pseudorapidity coverage from 1.2 to 3.5, ~10 B pixels and ~2.2 m^2 active area.

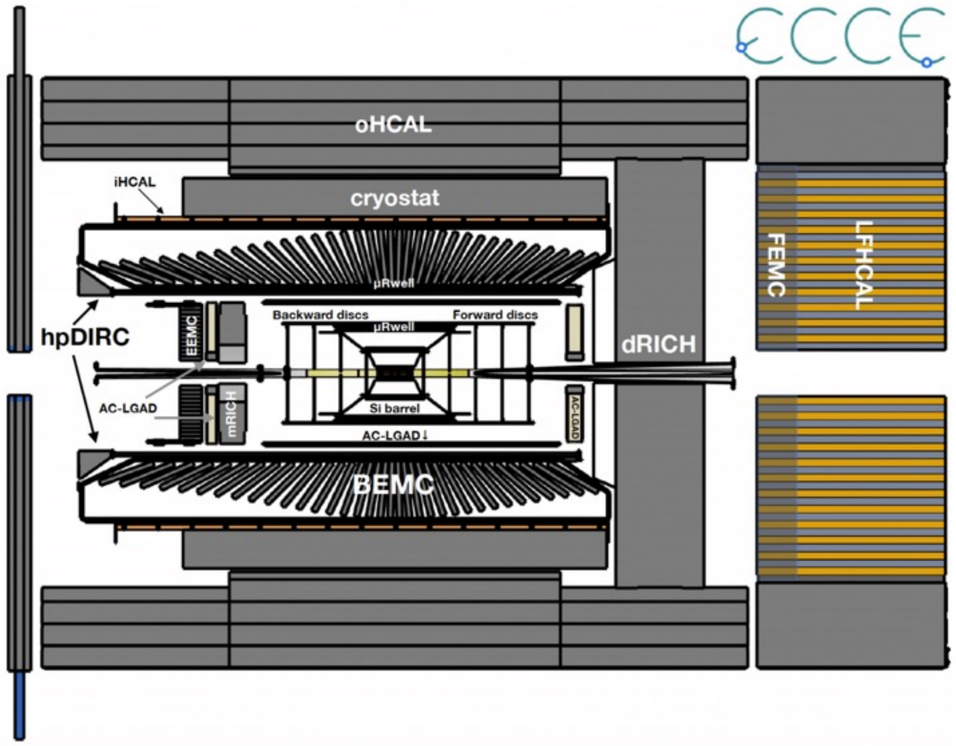


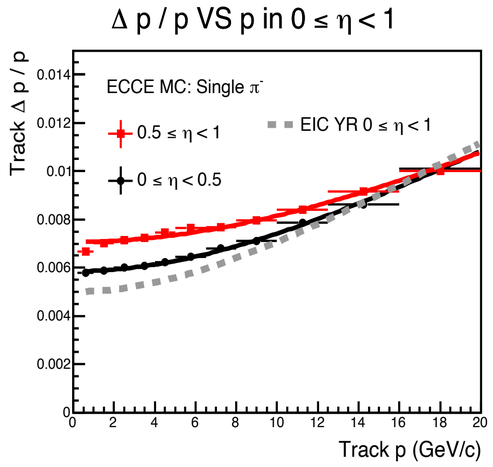


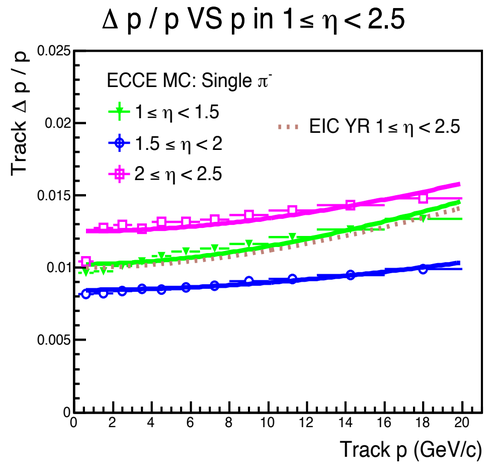
Detailed detector layout (segmentations, readout units, cooling and support structures) have been implemented in GEANT4 simulation.

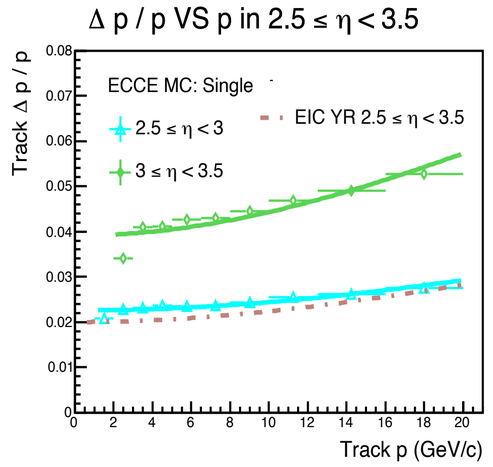
Tracking performance in GEANT4 simulation

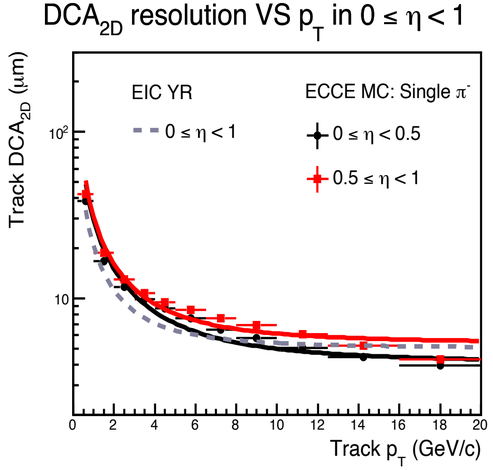
- Integrated MAPS, MPGD (e.g., µRwell) and AC-LGAD tracking detectors of the EIC reference design (ECCE) provide precise momentum and transverse DCA_{2D} resolutions.

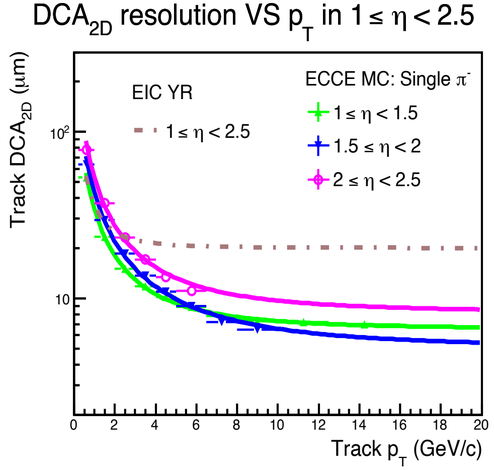


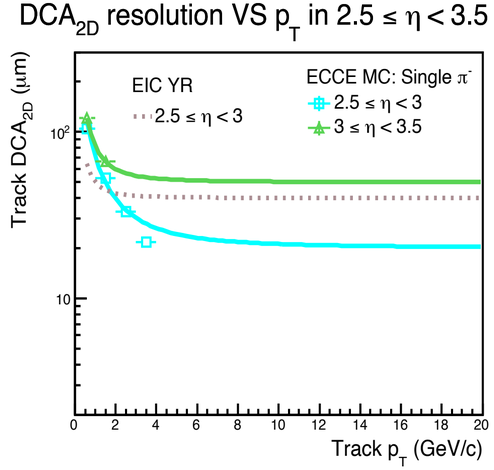




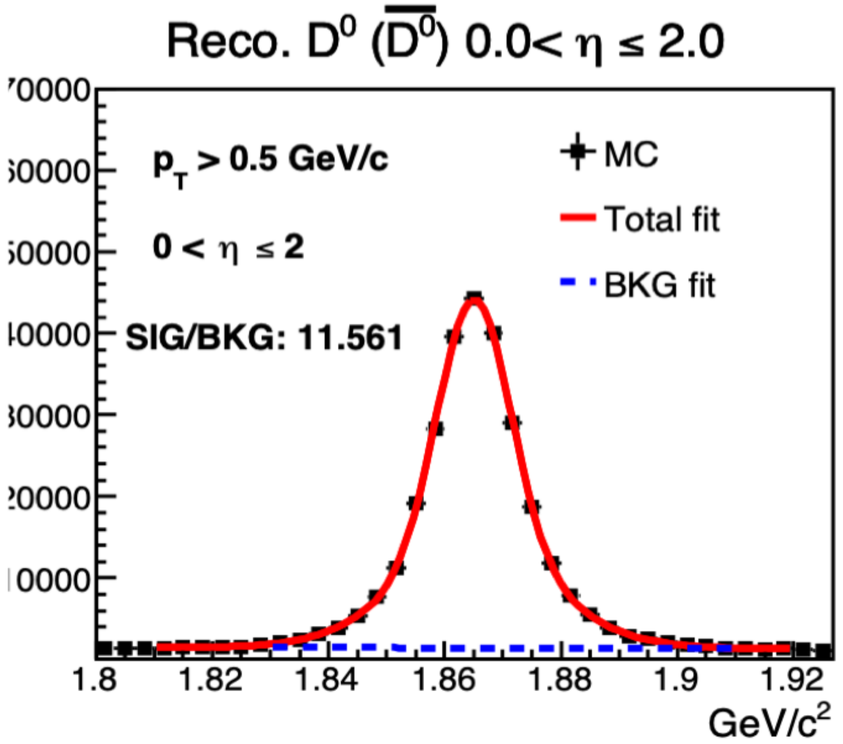


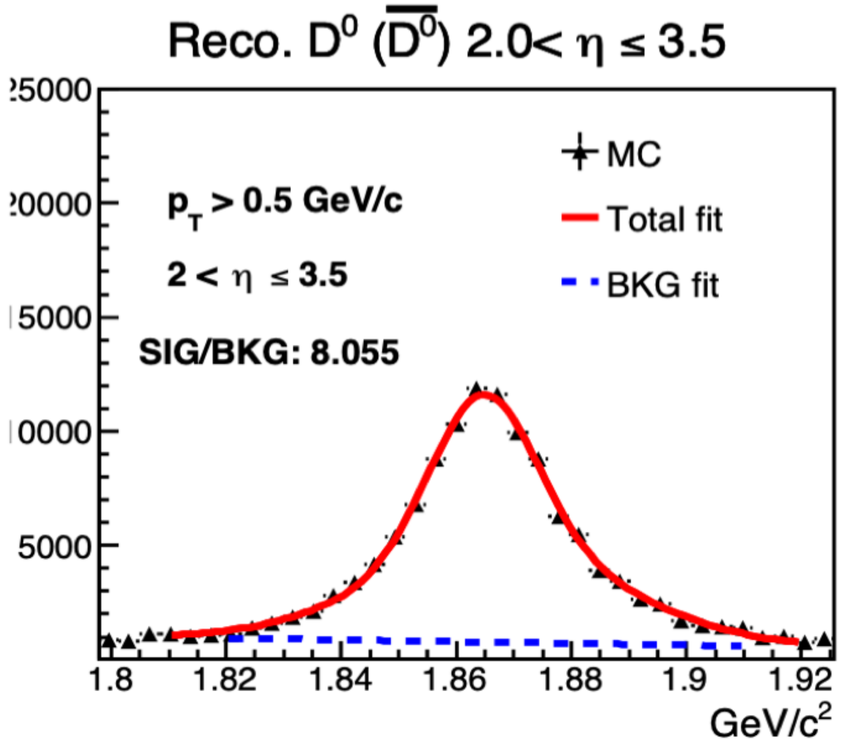






D^0 meson reconstruction with FST



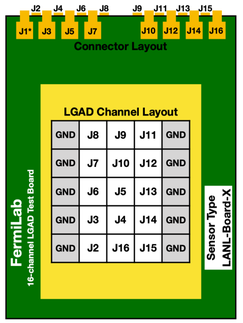


- Clear D^0 signals have been found in 10+100 GeV e+p simulation
- It will provide us the precise measurement of nuclear modification in different pseudorapidity regions

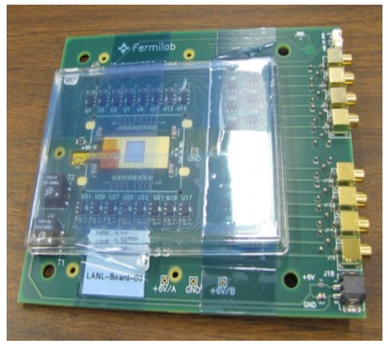
Advanced silicon technology candidates for the EIC silicon tracker

Several advanced silicon technologies are under characterization at LANL.

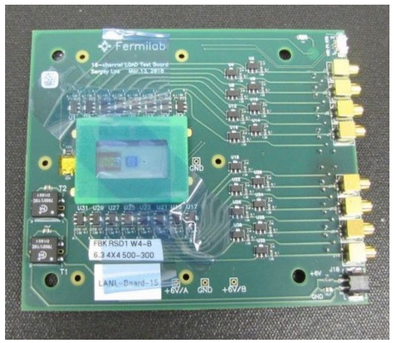
LGAD pixel map 3X5 Matrix



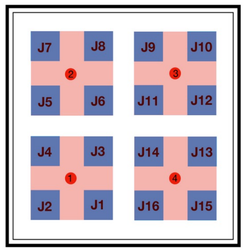
LGAD Carrier Board



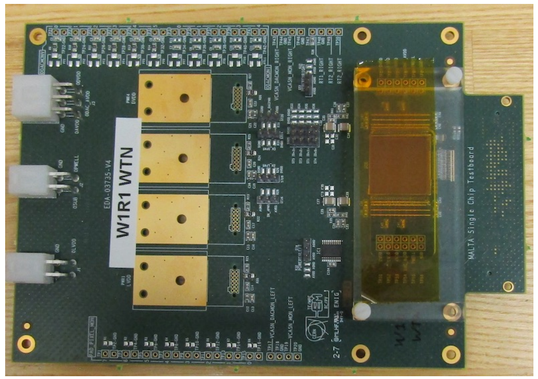
AC-LGAD Carrier Board



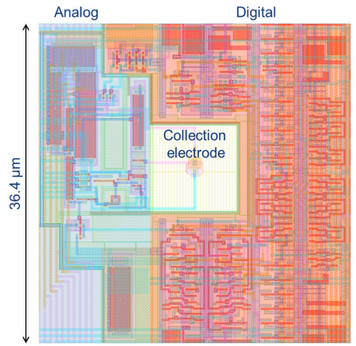
AC-LGAD pixel map 4X4 Matrix



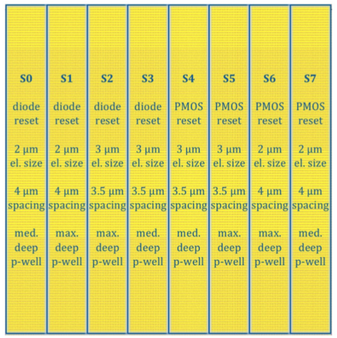
MALTA Carrier Board



MALTA Pixel diagram



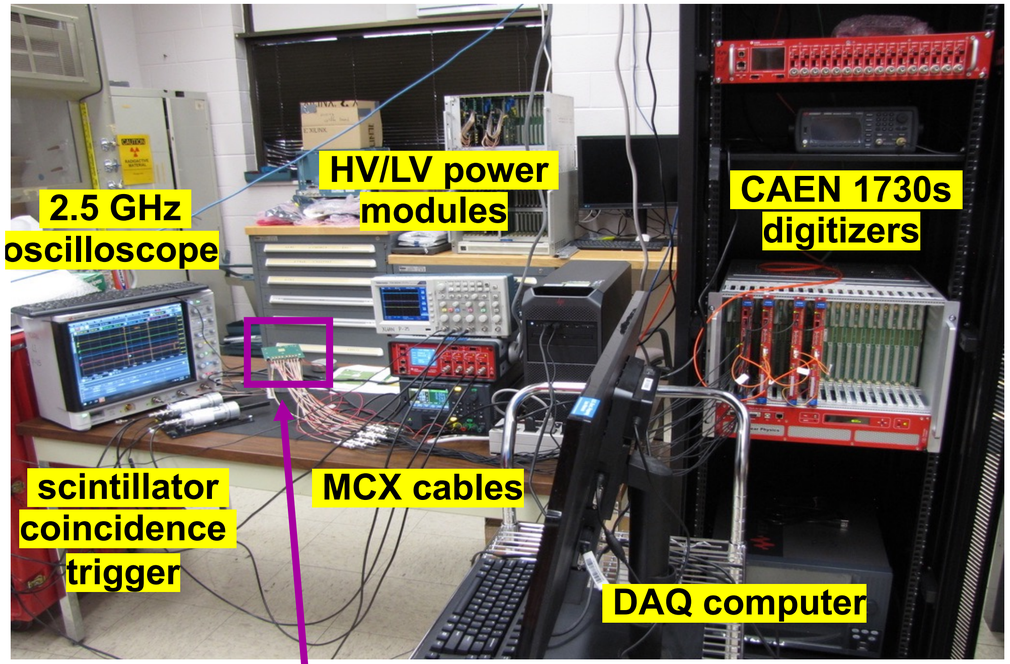
MALTA sensor diagram 512X512 Matrix

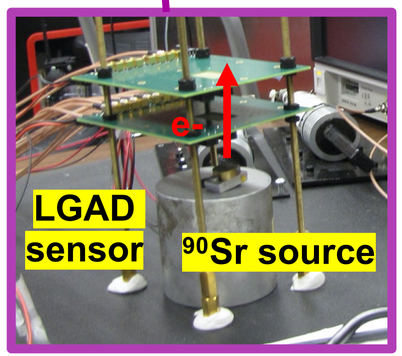


- in collaboration with BNL, JLab, UCSC, CERN, FNAL, Rice Univ., UM, UNM, ANL, KIT, LGAD Consortium, UC Consortium
- Low Gain Avalanche Detector (LGAD) and AC-Coupled LGAD (AC-LGAD)
  - Pixel size: 0.5 to 1.3 mm
  - Spatial resolution: ~30 μm
  - Time resolution: < 30 ps
- Depleted Monolithic Active Pixel Sensor (e.g., MALTA)
  - Pixel size: 36.4 μm
  - Spatial resolution: ~7 μm
  - Time resolution: ~2 ns

Advanced silicon technology R&D setup

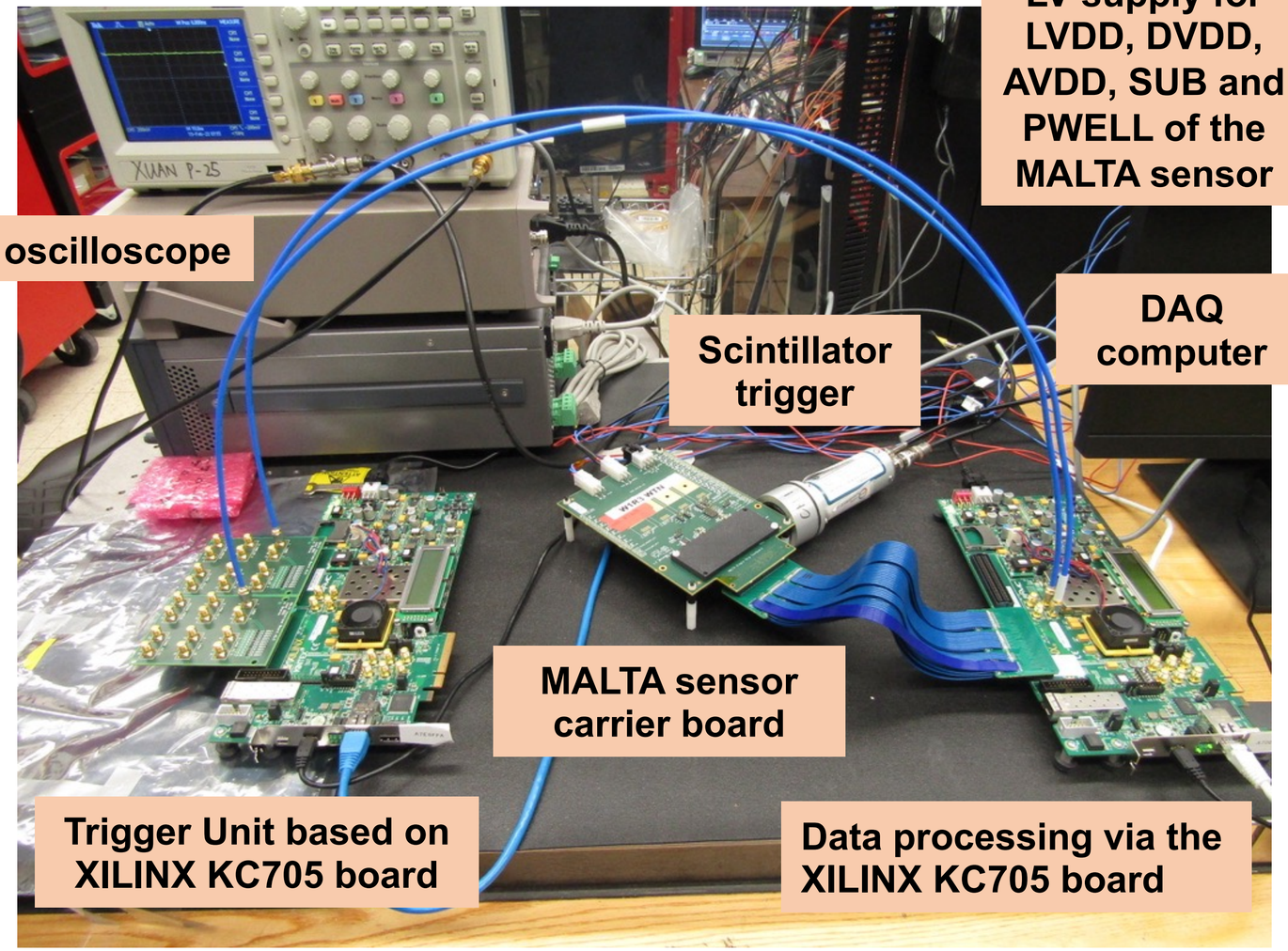
LGAD (AC-LGAD) characterization with the ^{90}Sr source test





2-layer LGAD telescope

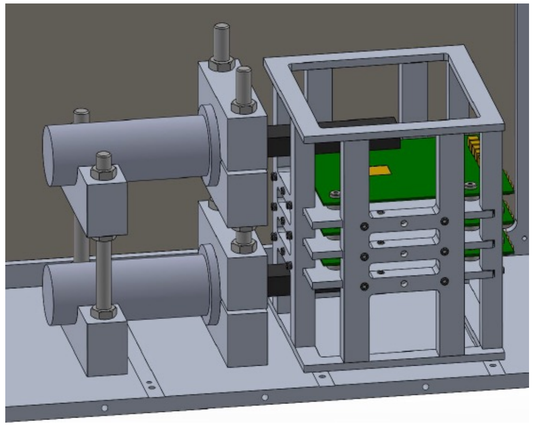
MALTA sensor characterization test bench



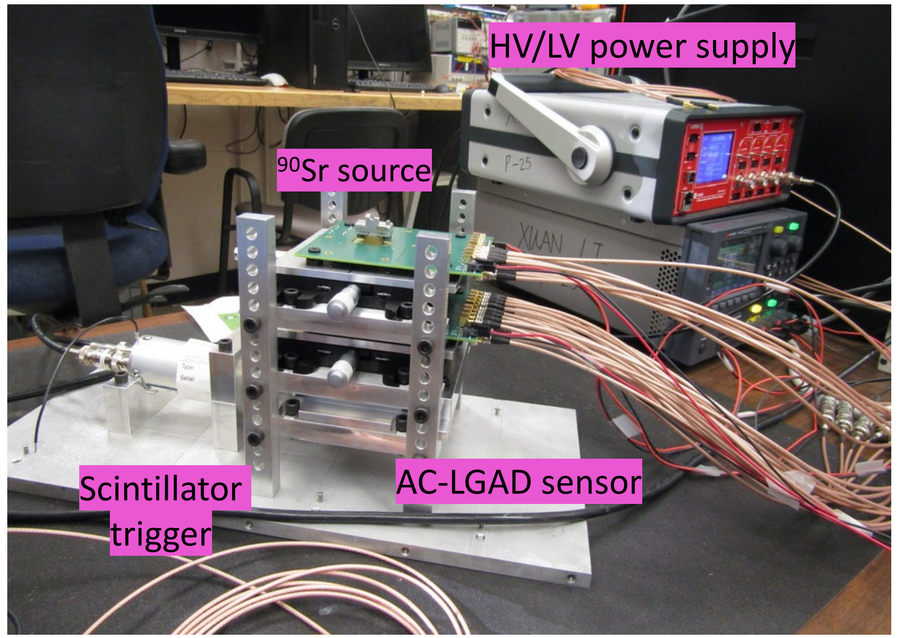
LGAD and AC-LGAD R&D test results

Feasibility tests of a two-layer AC-LGAD telescope using a ^{90}Sr source.

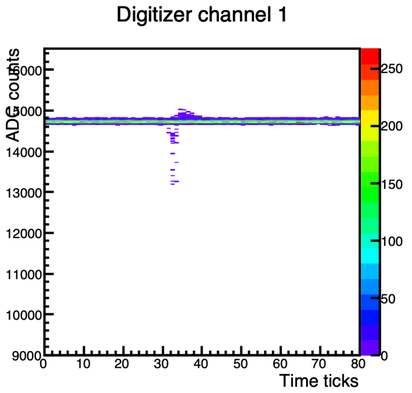
Mechanical design of 3-layer LGAD (AC-LGAD) telescope



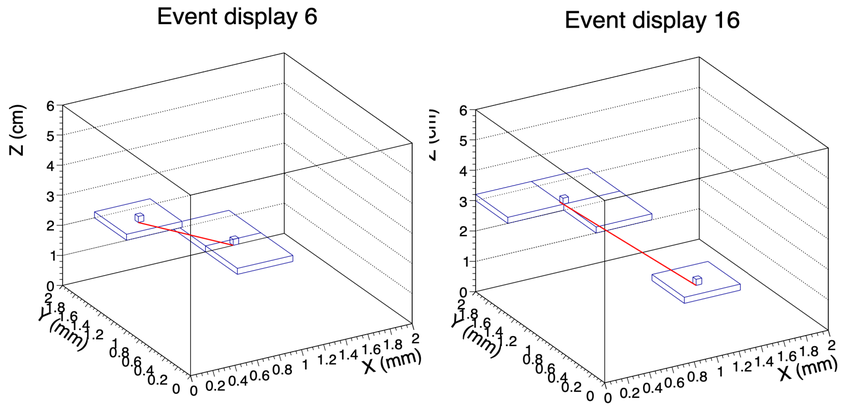
3-layer AC-LGAD telescope ^{90}Sr test setup with 2 sensors connected to the readout



Digitized pulse shape VS time tick (2ns) for individual pixel from the ^{90}Sr source tests.



Event display of reconstructed electron tracks

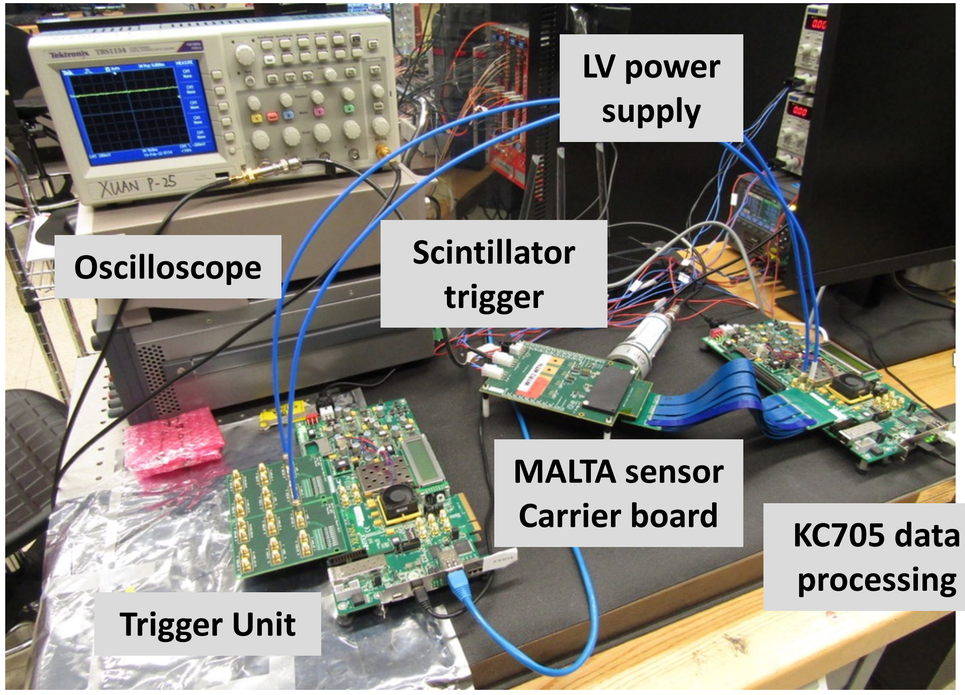


- Tracking performances such as efficiency, spatial and temporal resolutions are under study with the 3-layer telescope configuration.

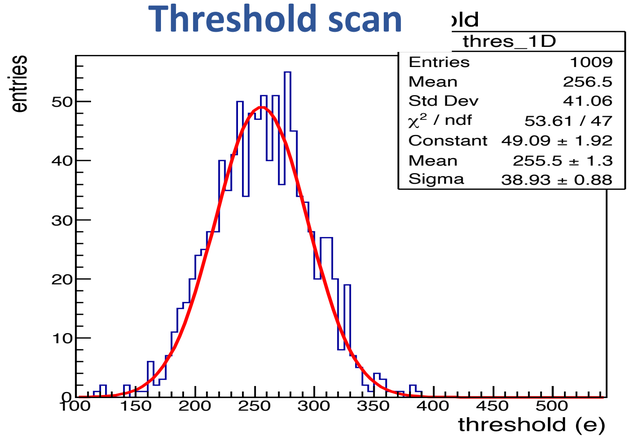
MALTA R&D test results

- Threshold and noise scan has been performed.
- Successfully suppressed the noise hits and the hit occupancy has been studied with the ^{90}Sr source tests.

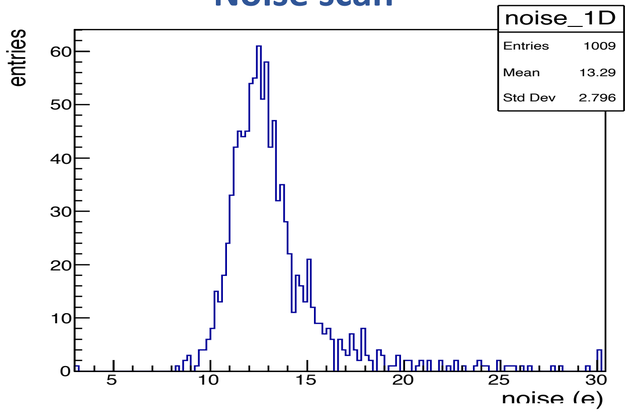
MALTA prototype sensor test setup



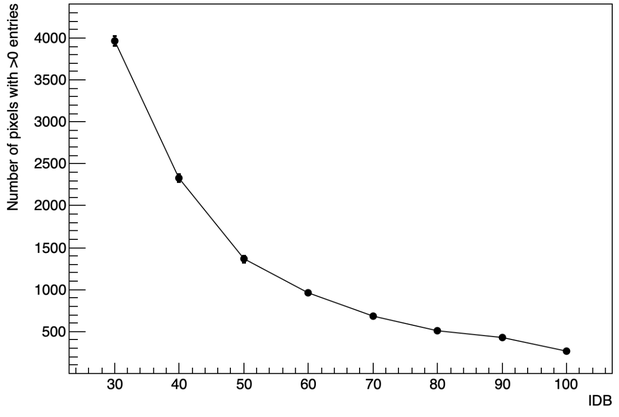
Threshold scan



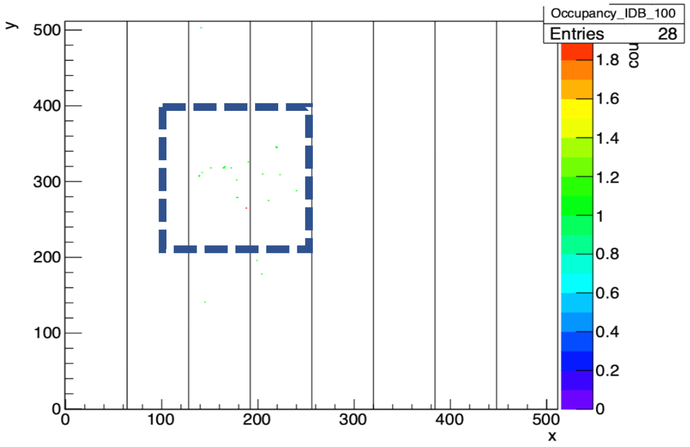
Noise scan



Noisy pixel rate VS IDB value

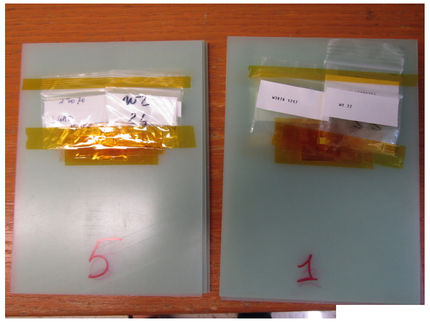


^{90}Sr source hit occupancy



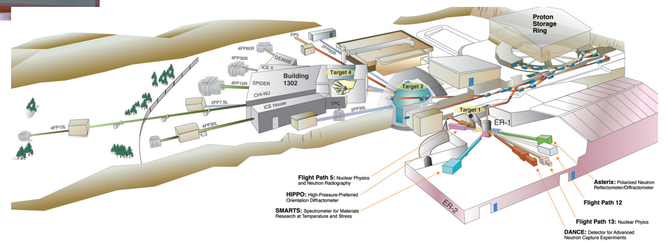
EIC Silicon detector design and R&D path forward

- Irradiation tests has been done in the beginning of this month with the LANL LANSCE facility to test the radiation hardness for LGAD and AC-LGAD prototype sensors with 10^{13}-10^{16} $n_{eq}cm^{-2}$ doses.
  - Analysis is in progress.
- Telescope bench tests ongoing at LANL and planed beam tests in collaboration with other institutions.
- Work towards the EIC detector 1 technical design.
  - The EIC detector 1 proto-collaboration formed in April 2022, is working on the detector technology down selection and the detector design optimization and updates for the CD2 approval scheduled in 2023.

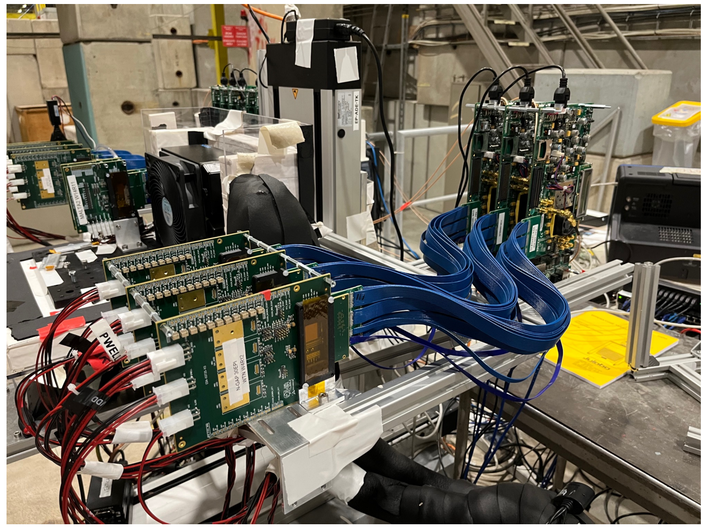


LGAD and AC-LGAD test samples under irradiation tests at LANL.

LANL LANSCE



MALTA telescope beam tests at CERN SPS



ATLAS EXPERIMENT

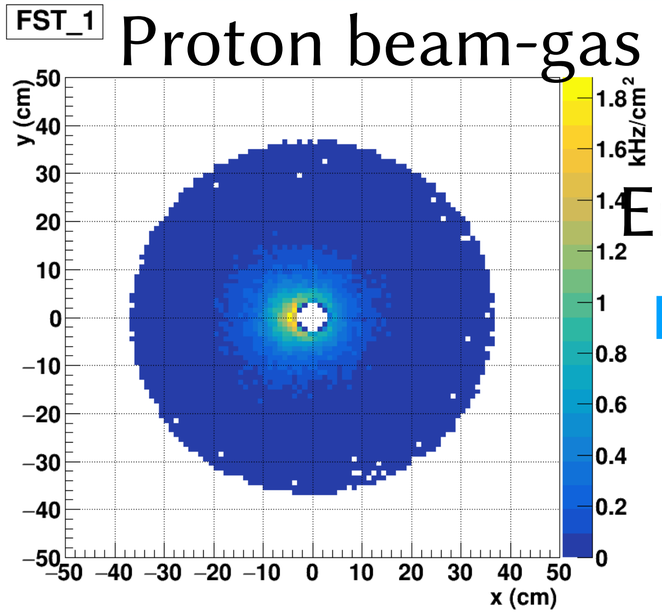
Beam-Gas Background

- See the detector response of the electron/proton beam-gas background

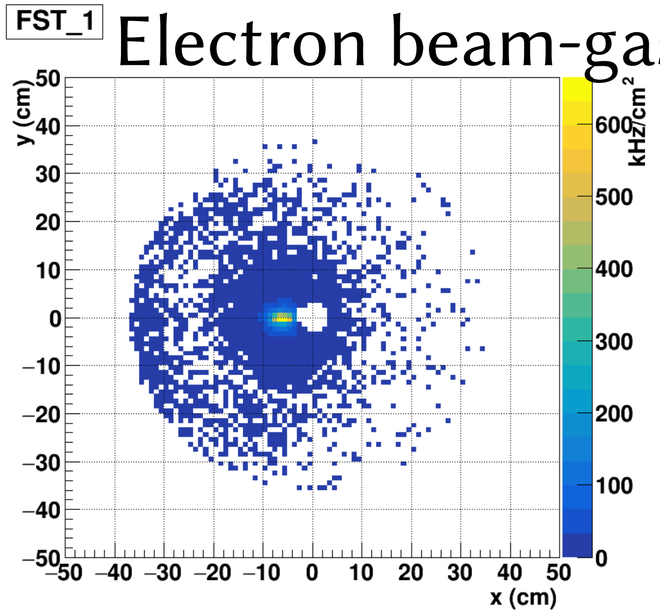
- Input files from Zhengqiao and Jaroslav
  - Hadron & electron
    - ★275 GeV proton beam
    - ★ 10 GeV electron beam
  - Electron beam-gas background file format is not compatible for fun4all. Thanks to Kolja and Cameron, we were able to use the available files using eicsmear.

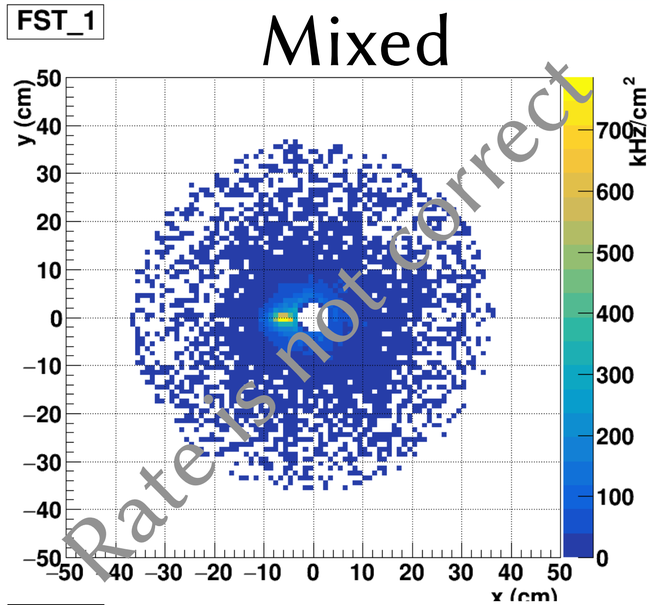
- Use Fun4All (ECCE) with some modification
  - Magnetic field: 1.5 T
  - Enabled tracking
    - ★Tracking on the silicon detectors only

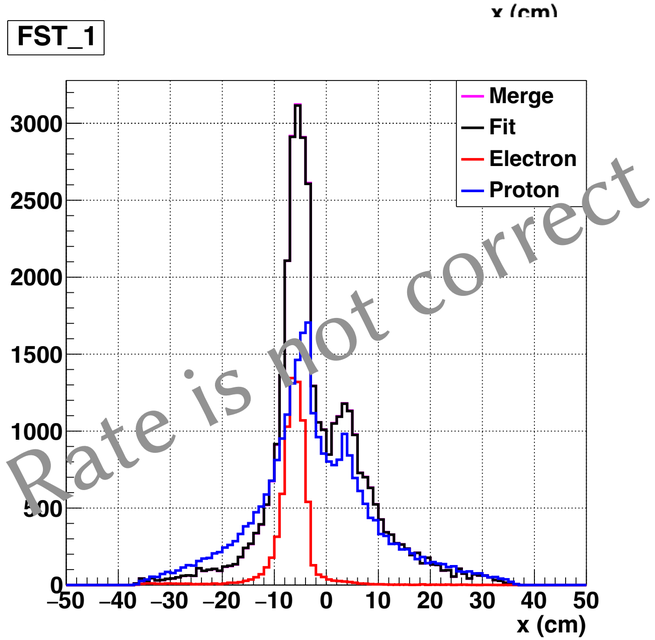
Embedding test for beam-gas background



Embed







- Simulation level embedding works
  - Rate is not correct
    - ★ Embedded to high rate background, so the pileup effect is not taken into account on one of the backgrounds
    - ★ Expect no problem if using physics events – work in progress

- Will investigate the effect of beam-gas background on the physics events

Summary

- Silicon sensor R&D is in progress
  - Continue characterization and R&D work
    - ★ Efficiency, resolution etc..
    - ★ Analysis of the irradiation test
- Silicon tracking system mechanical design
- Beam-gas background study is in progress
  - Embedding/effect on e-p events