High-granularity insert for the EIC

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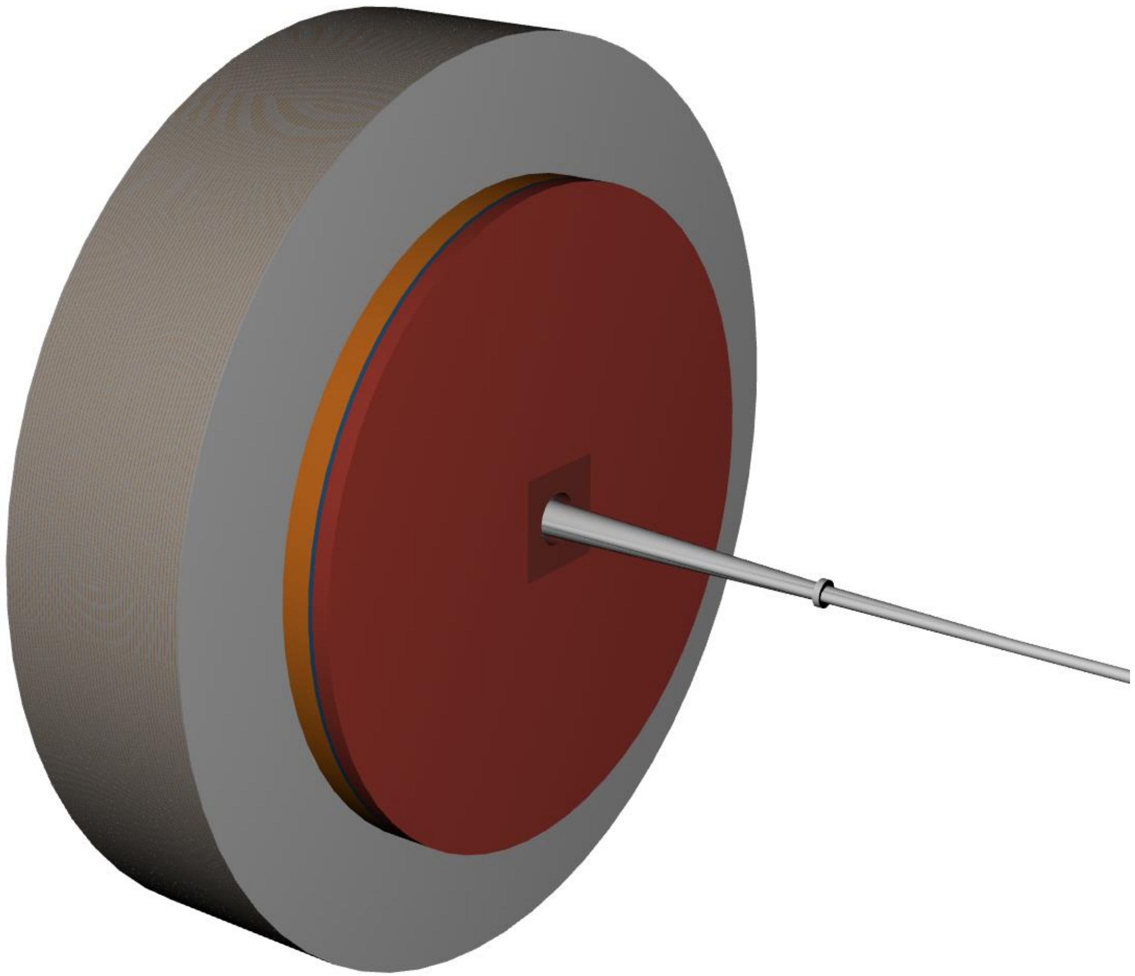
EICUG Early Career Workshop 2022



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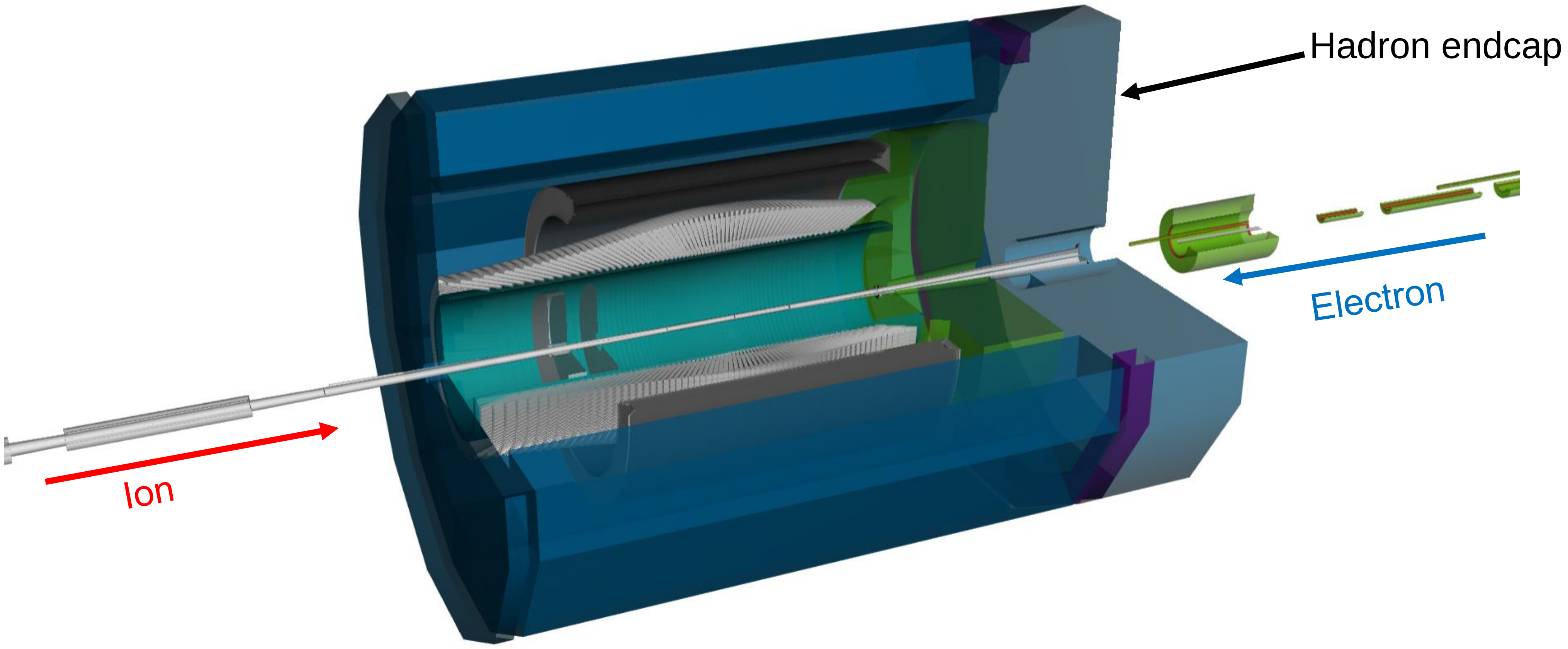
CALIFORNIA EIC CONSORTIUM

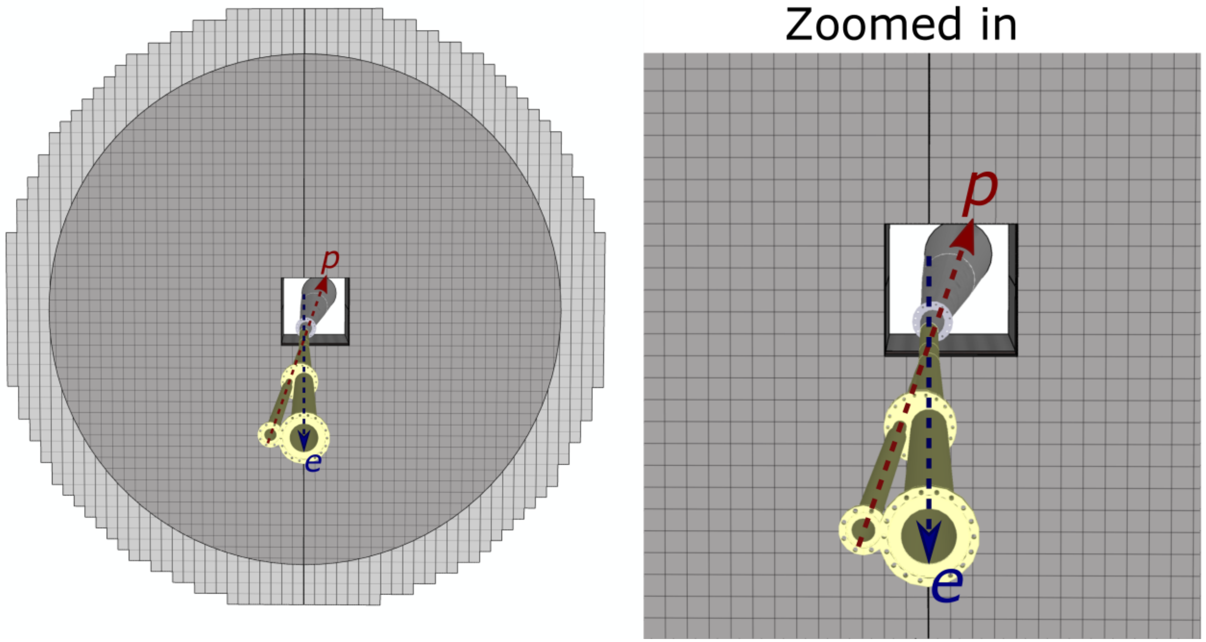
Focus: Hadron endcap

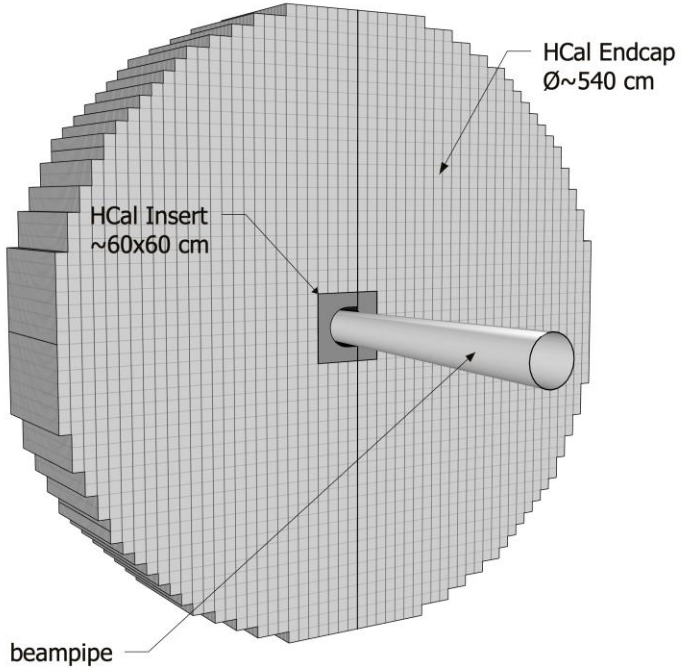


Detector image from ECCE DD4hep model

Insert motivation and constraints

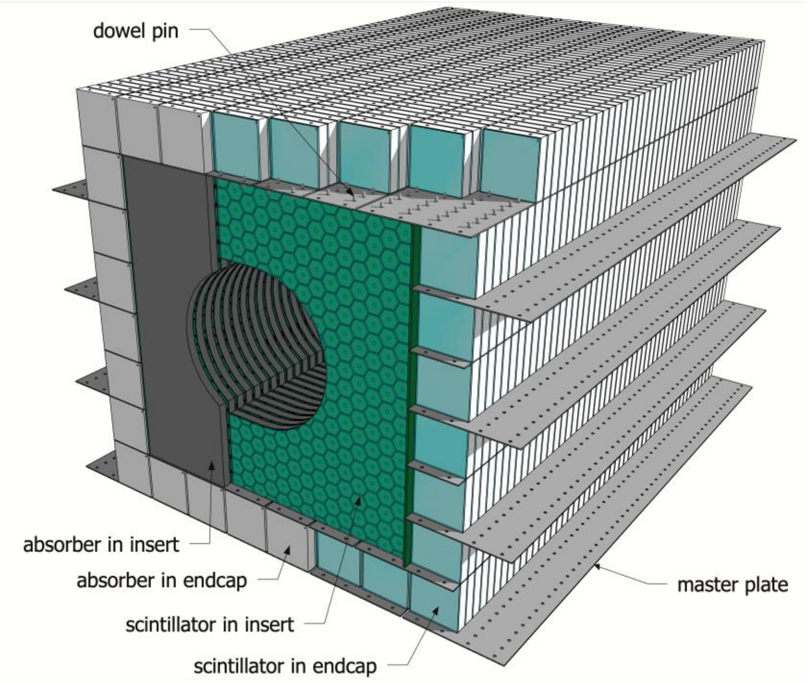
- Want coverage near the beampipe in forward region, $3 < \eta < 4$ or $2.1^{\circ} < \theta < 5.7^{\circ}$
  - About 70 cm x 70 cm area
- Want high-granularity to yield a good angular resolution
  - Allows measurements of jets and hadronic final states in DIS reactions
- Should be integrated into forward endcap without additional support structures
- Needs to account for cone-shaped, angled beampipe

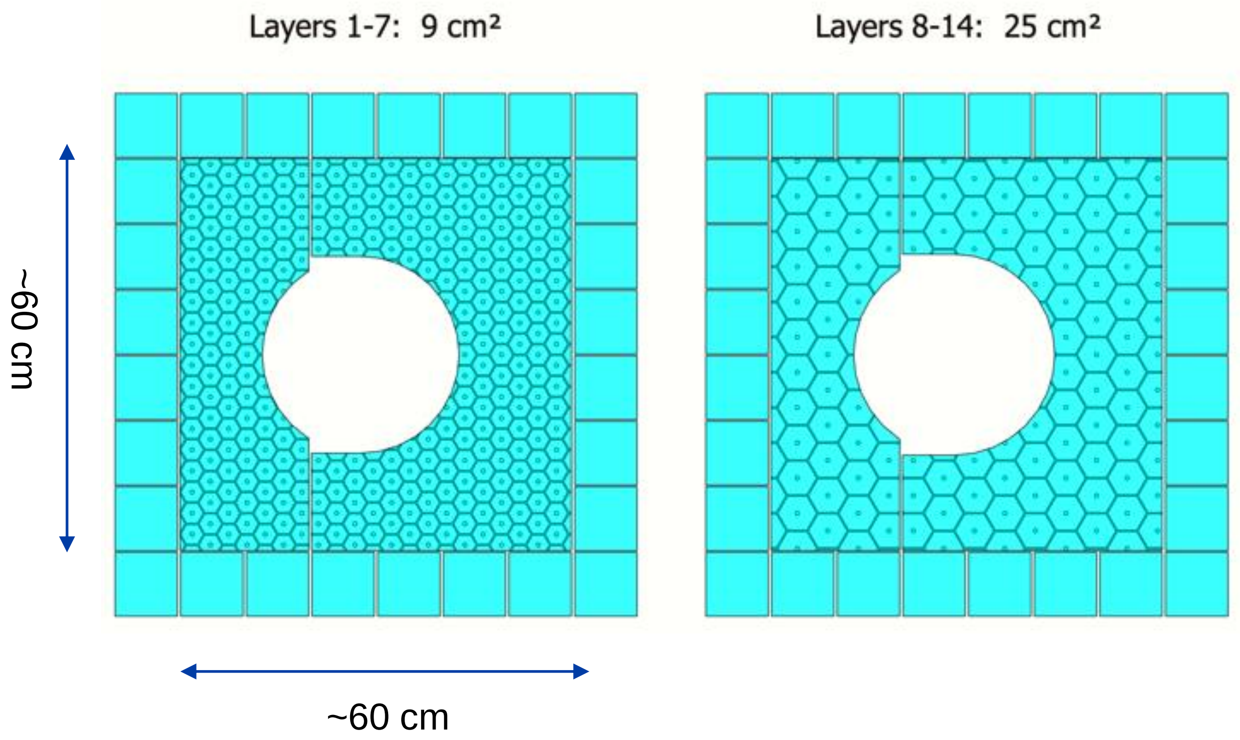




Insert design

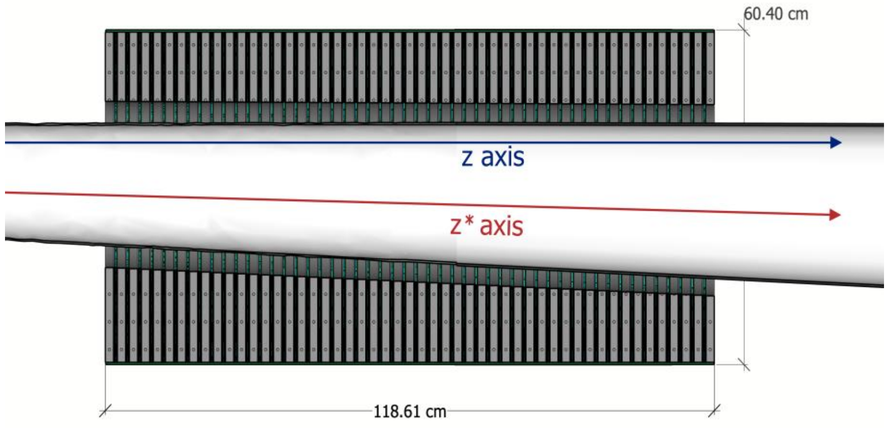
- 60 cm x 60 cm layers with a hole for the beampipe
  - Hole radius and position change in each layer
- 30 W/Sc layers and 21 Steel/Sc layers
- Half-layer “megatile” with hexagonal scintillating cells and SiPM-on-tile technology
  - Hexagon size varies along z-direction

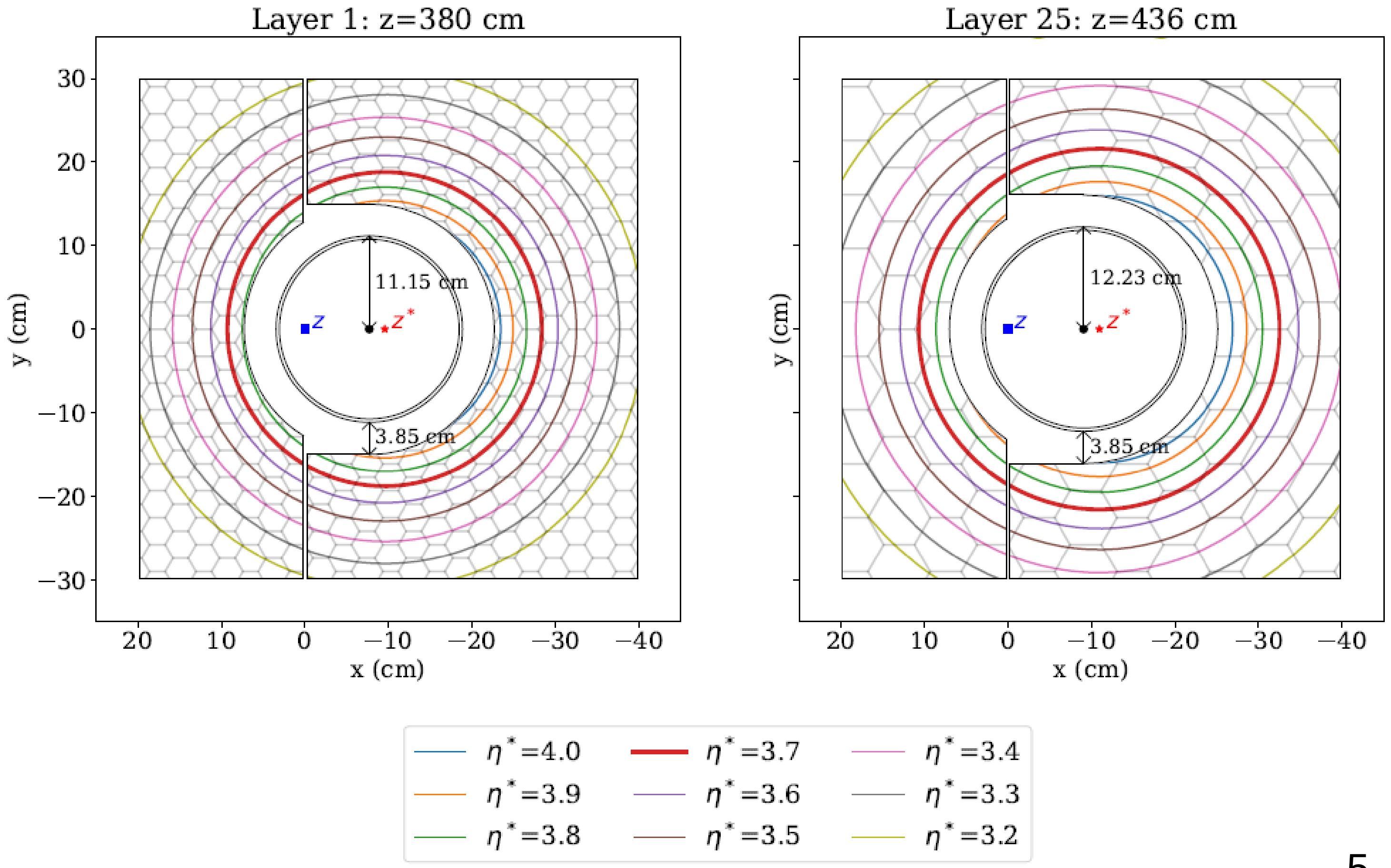




Geometric acceptance

- Use the proton-beam axis – variables labelled with *
- Smallest full-acceptance is $\eta^* = 3.7$, with some acceptance for larger η^* up to 4.0
- Acceptance down to $\eta^* = 3.2$ at front of insert





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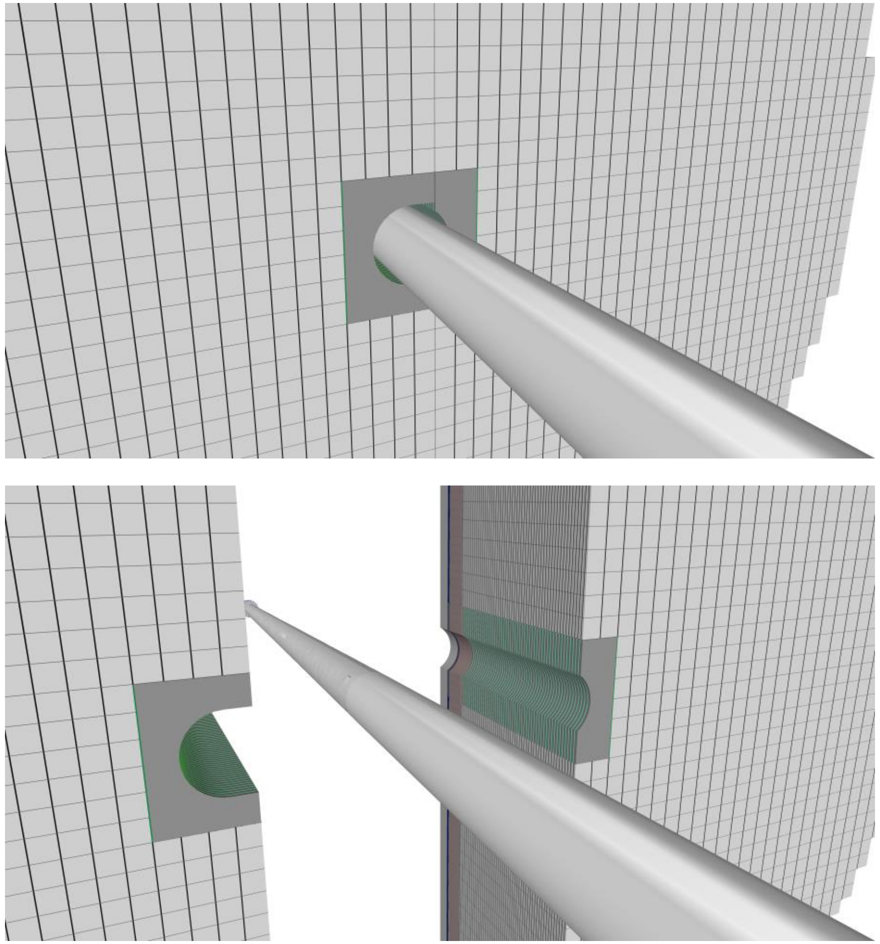
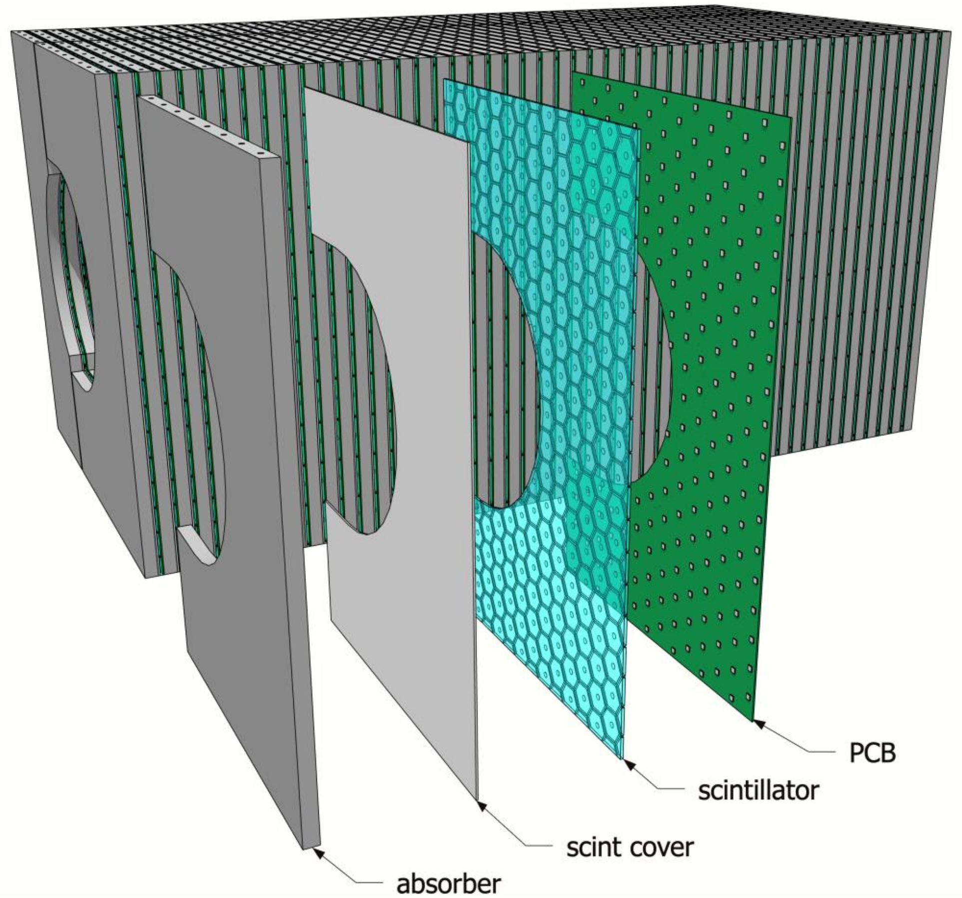
Opening the endcap

- Insert opens with endcap via rails
- Can access individual layers for installation and maintenance





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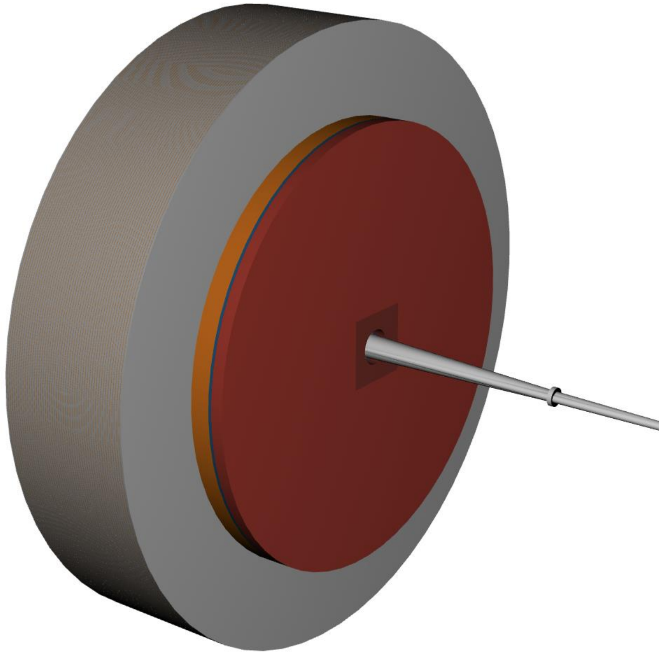
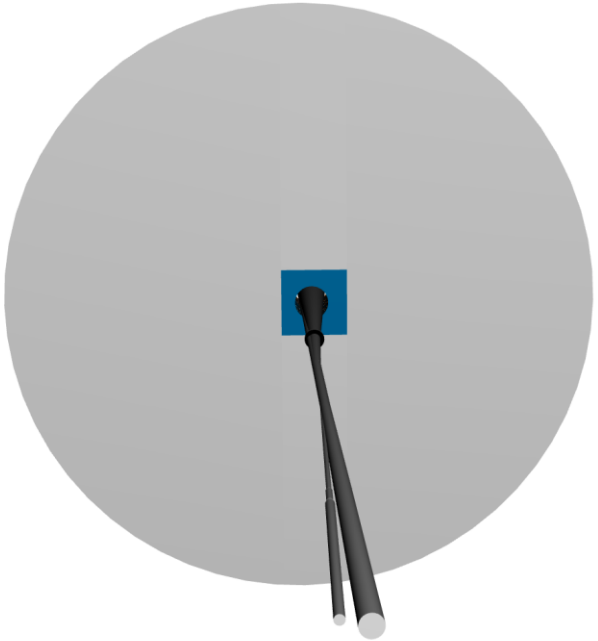
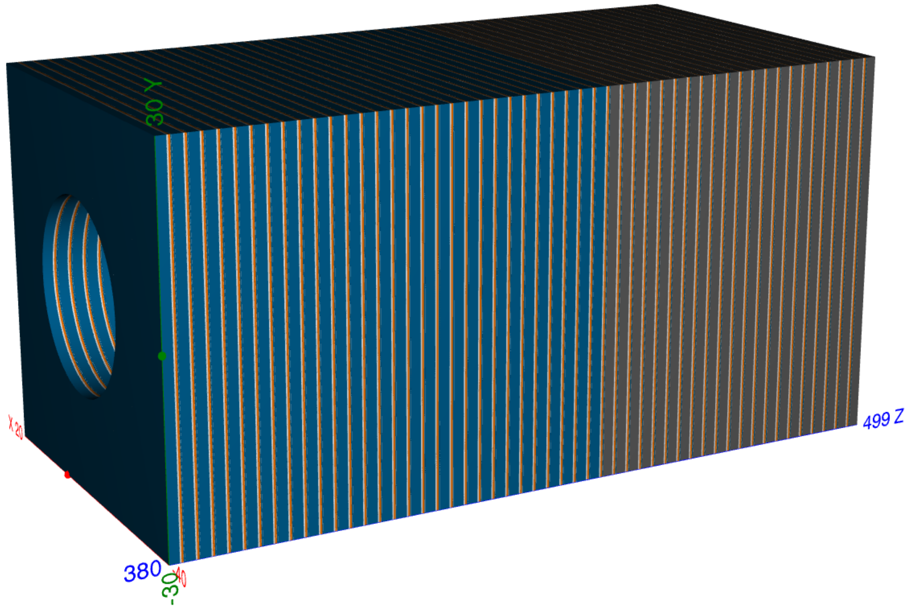
Implementation in DD4hep

- Created model of the forward endcap with HCal insert
- Have models for both ATHENA and ECCE HCals
  - Using ATHENA HCal for following results
- Using simplified read-outs of 3 cm x 3 cm squares instead of hexagons
- Using DD4hep with G4.10.7.p3 and FTFP_BERT_HP





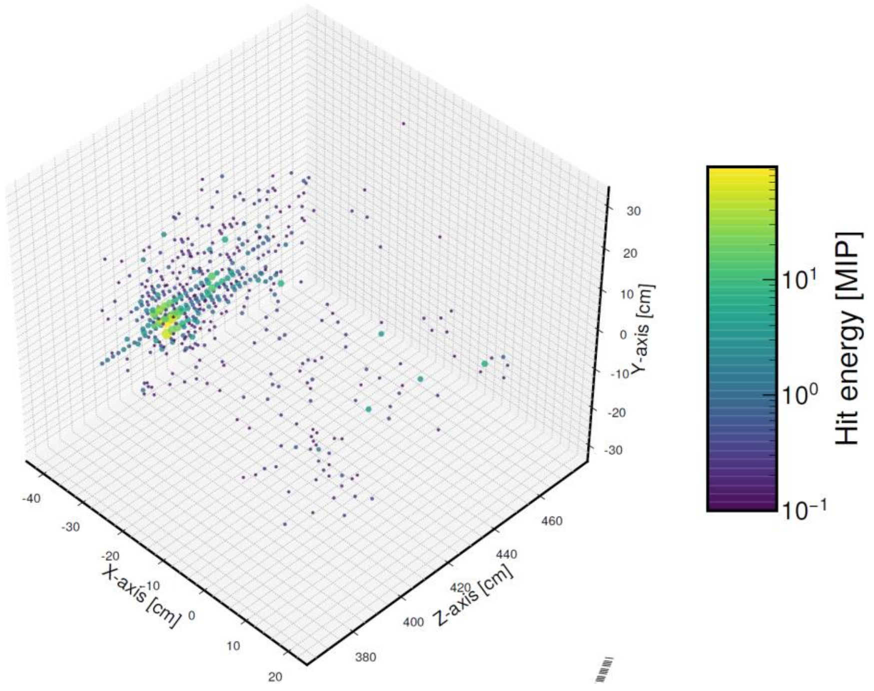
HCal and HCal Insert

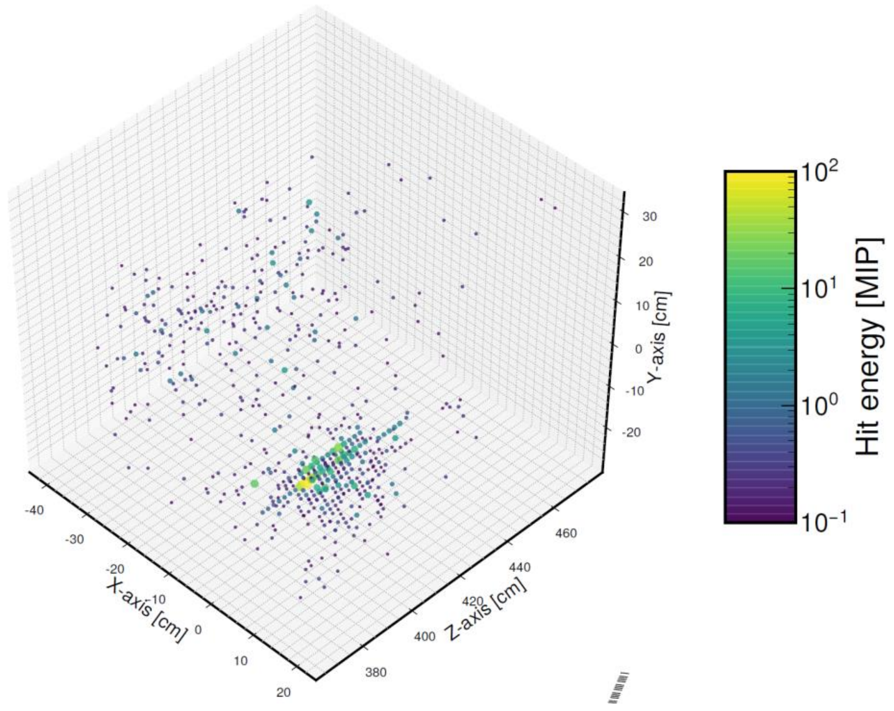


Insert
Blue: Tungsten, Gray: Steel

Simulation and analysis parameters

- Single particle π^- and e^- from origin along proton-beam axis
- Digitization (200 MeV ADC max dynamic range) and reconstruction via Juggler
- Timing cut: $t_{hit} < 200\ \text{ns}$
- Energy cut: $E_{hit} > 0.1\ E_{MIP} = 0.1\ (0.8\ \text{MeV})$





Insert shower shapes for 50 GeV π^- at $\eta^* = 3.7$

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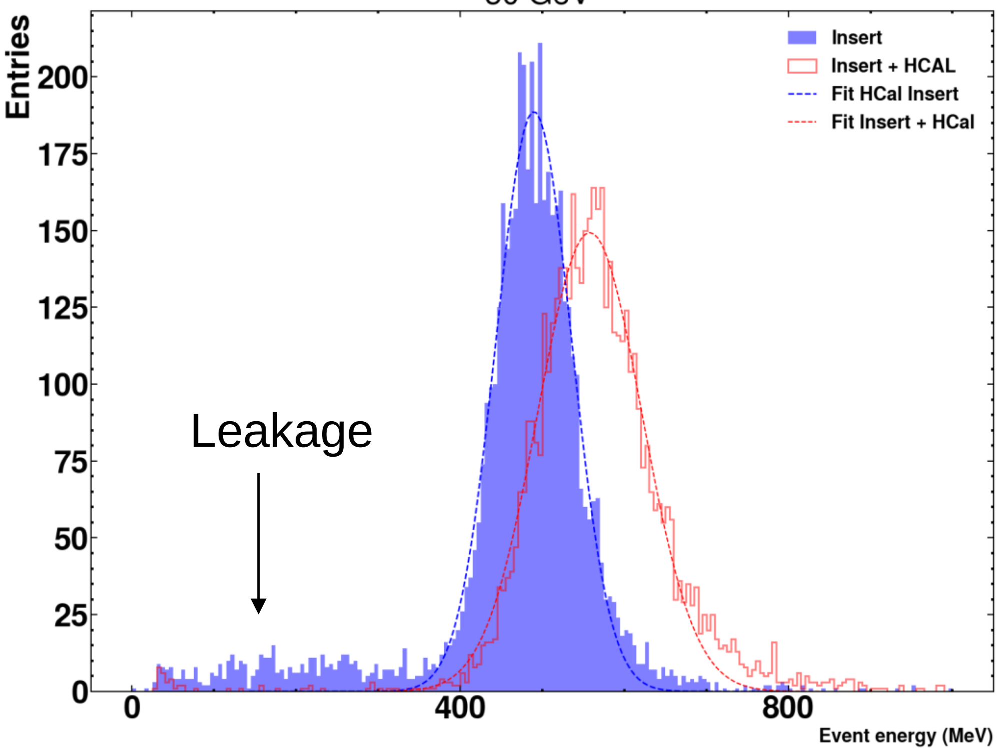
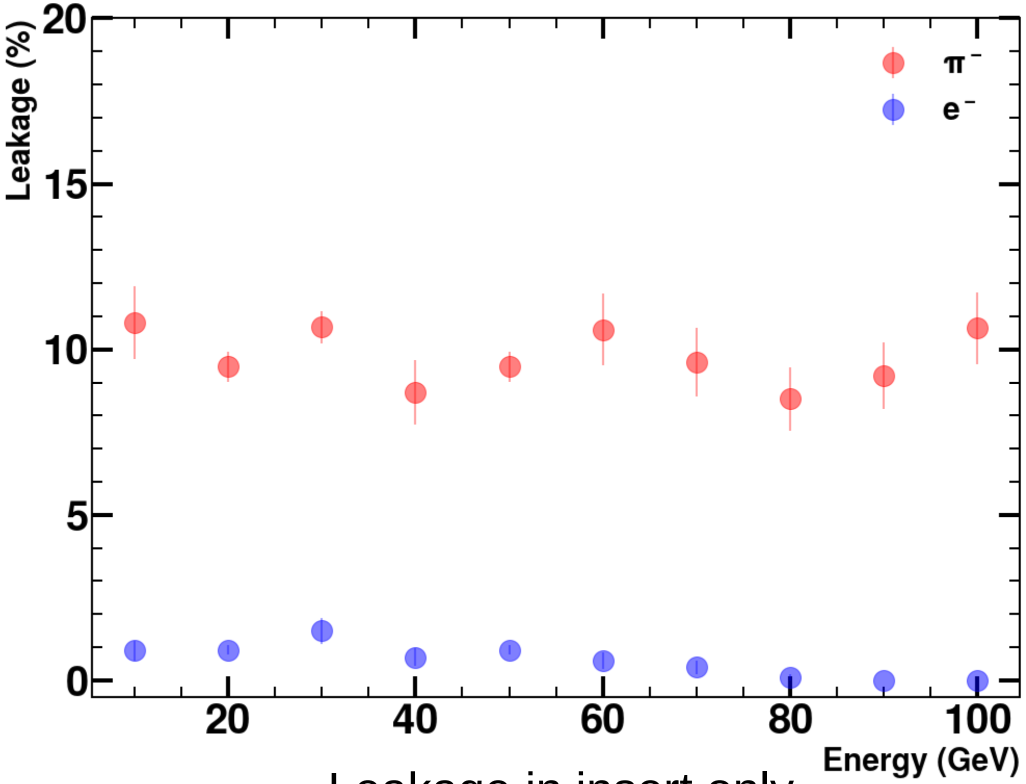
Quantifying leakage

- Leakage – energy that escapes from the detector
    - Will result in events with lower energy deposition
- To quantify leakage: $\text{Leakage} = (\#\text{ events} < \mu - 3\sigma)/\#\text{ events}$
- Some transverse leakage from HCal insert to HCal



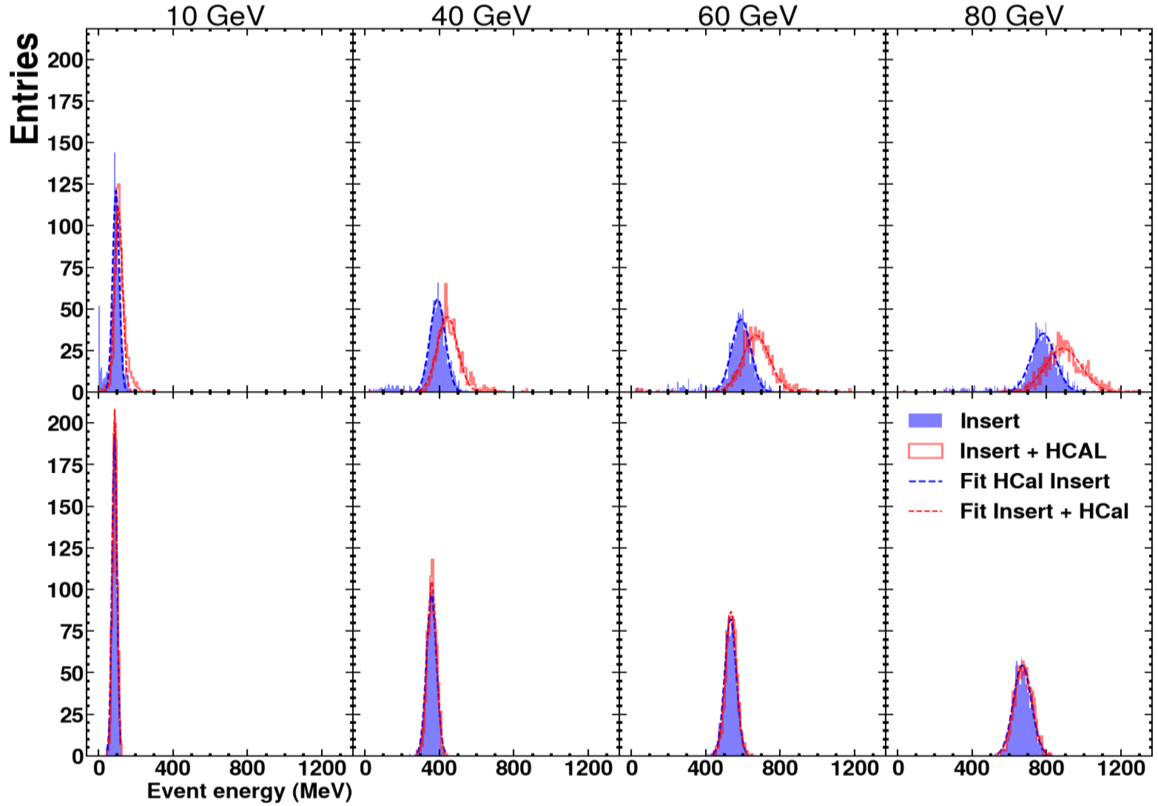
50 GeV π^- at $\eta^* = 3.7$



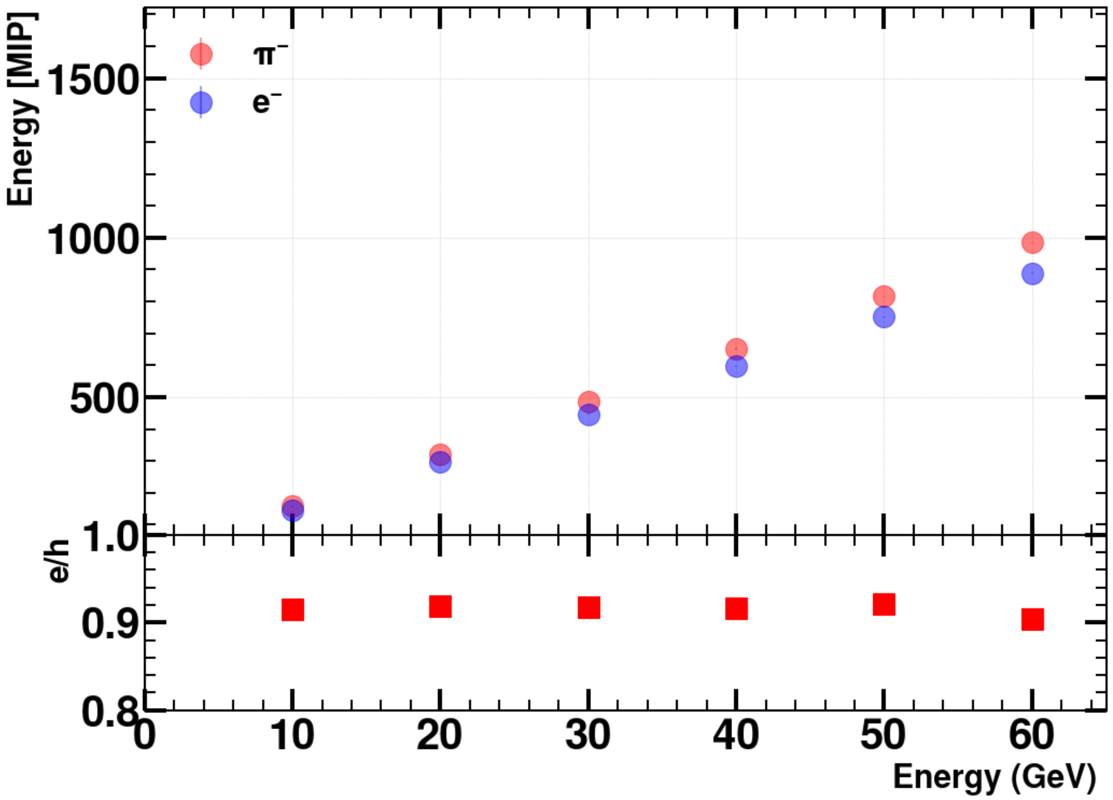
Leakage in insert only

Energy depositions

- Can compare how electrons and hadrons perform
- Compare quantitatively with $\frac{e}{h} = \frac{e^{-}\text{energy}}{\pi^{-}\text{energy}}$
  - Tungsten absorbers make ratio close to 1



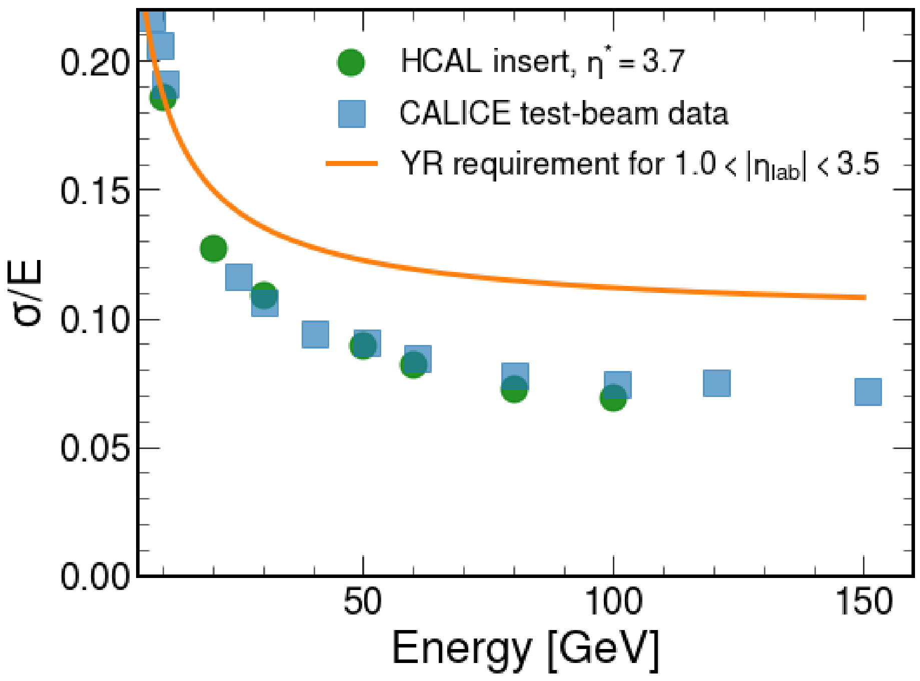
Top: π^{-} at $\eta^{*} = 3.7$
Bottom: e^{-} at $\eta^{*} = 3.7$



HCal insert only at $\eta^{*} = 3.7$

Energy Resolution

- Resolution = σ/μ from Gaussian fit of energy spectrum
- Good comparison with CALICE's pion test beam data
  - 10/5 mm W/Sc HCal
- Promising since hadron endcap validation was a trouble point for ATHENA/ECCE



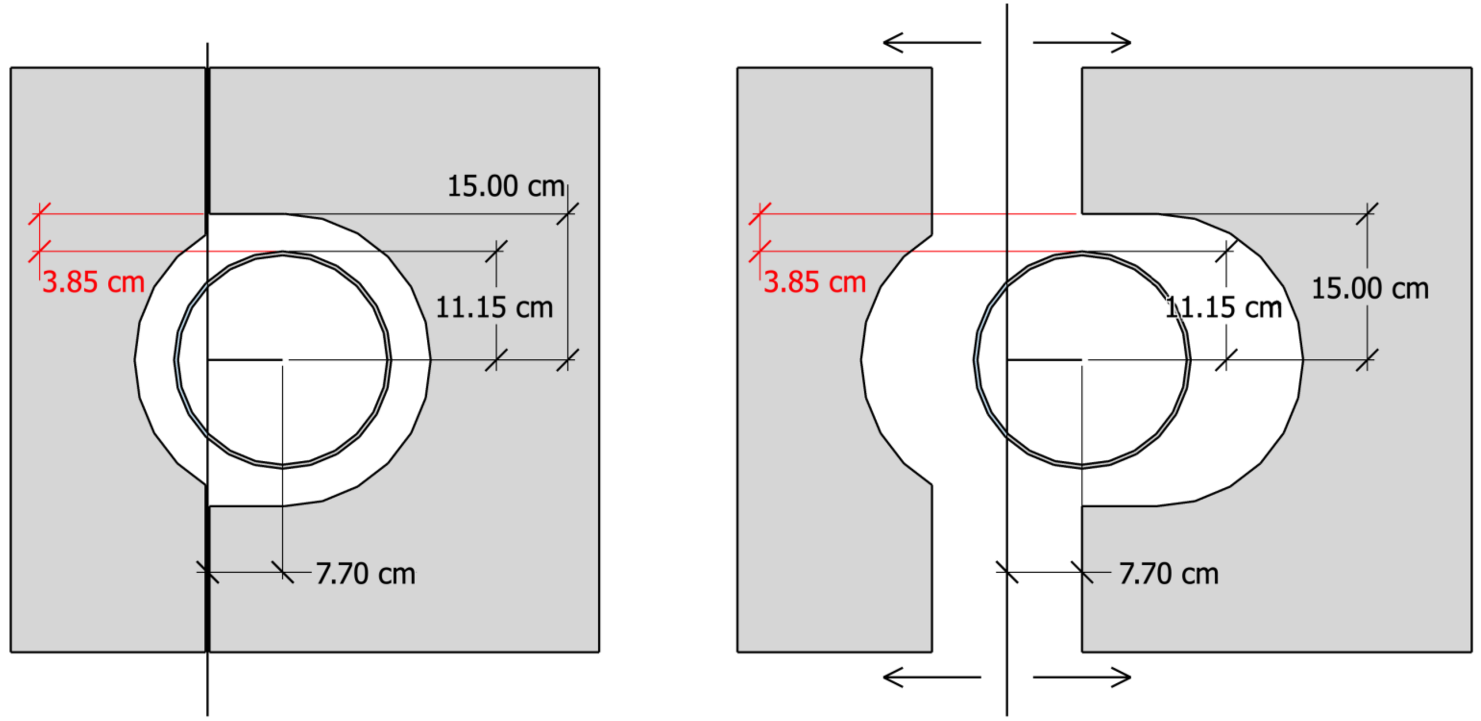
Summary and plans

- HCal insert enables detection near beampipe in forward region
- Promising performance: Good e/h, manageable leakage, and validated resolution in insert
- Next steps:
  - Implementing insert and endcap model into full detector simulation
  - Publish paper on insert design and performance in NIM
  - High-granularity leads to potential optimization with machine learning
    - In collaboration with LBNL & LLNL

Some contributing members from UCR & UCLA!

Backup: Insert clearance

- Maintain a constant clearance of 3.85 cm for insert around beampipe
- Introduce a D-shape of insert hole to maintain this when opening endcap



Backup: STAR HCal validation

- Used 20/3 mm Fe/Sc HCal in DD4hep to compare against STAR HCal test beam data