ECCE Far Forward & Far Backward detector systems

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for the ECCE Consortium

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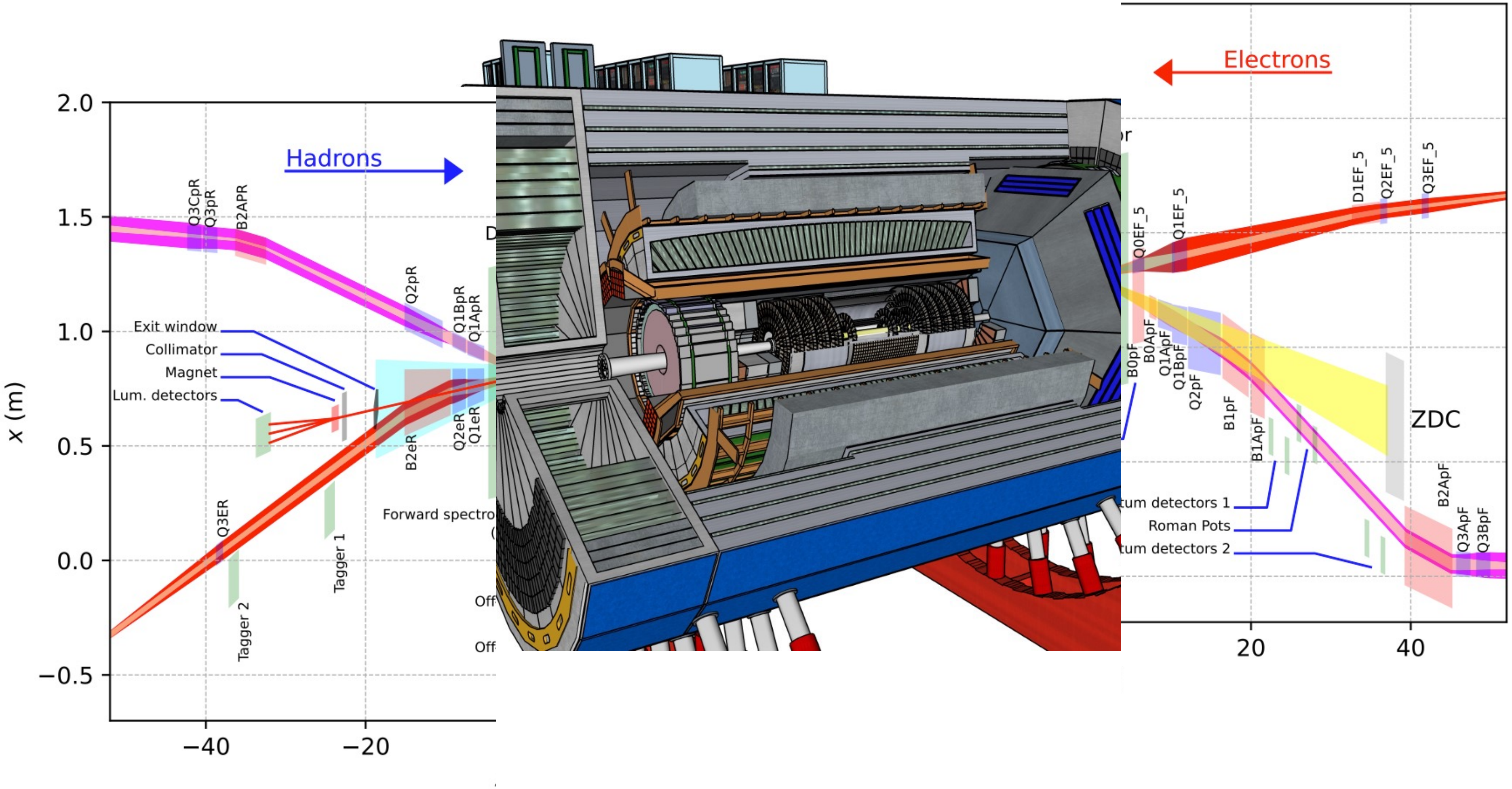
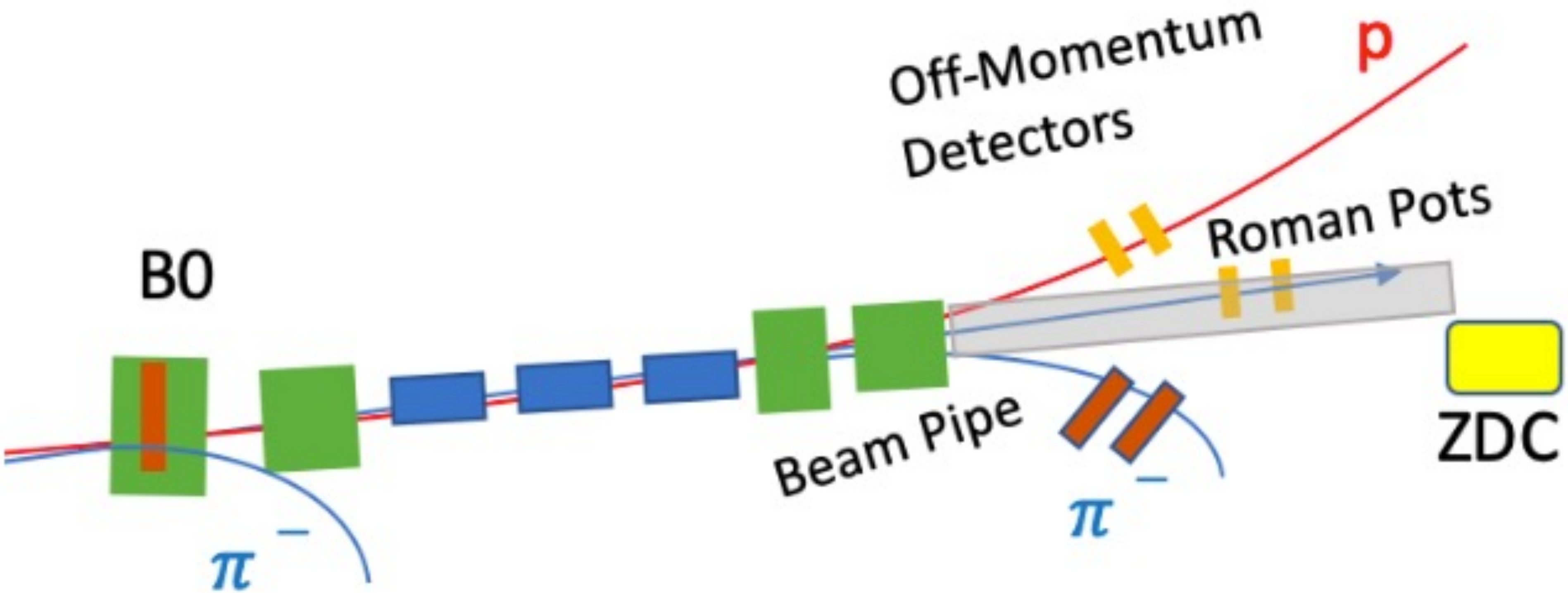
Extension to Far-Forward and Far-Backward



General overview of the detectors – far - forward region



Detector	(x,z) Position [m]	Dimensions	θ [mrad]
ZDC	(0.96, 37.5)	(60cm, 60cm, 2m)	$\theta < 5.5$
Roman Pots (2 stations)	(0.85, 26.0) (0.94, 28.0)	(25cm, 10cm, n/a)	$0.0 < \theta < 5.5$
Off-Momentum Detector	(0.8, 22.5), (0.85, 24.5)	(30cm, 30cm, n/a)	$0.0 < \theta < 5.0$
B0 Spectrometer	$(x = 0.19, 5.4 < z < 6.4)$	(26cm, 27cm, n/a)	$5.5 < \theta < 13.0$

Our goal is to workout a feasible technologies that could be costed for proposal

Implement Forward/Backward regions in Fun4All

Map both the performance and acceptance of the individual subsystems and for both IP6 and IP8

Develop risk estimates

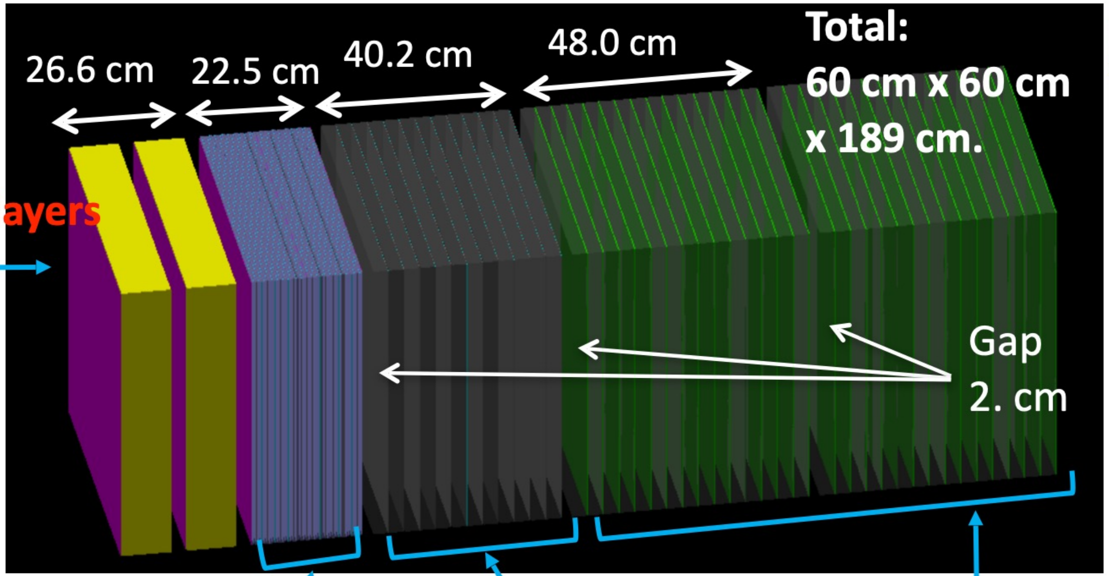
Channel count

Detector	Proposed technology
Zero-Degree Calorimeter (ZDC)	EMcal: Crystal (PbWO4) + W/Si (based on ALICE-FoCal-E) Hcal: Pb/Si + Pb/Sci (Shashlik or Spaghetti) (+ AC-LGAD?)
Roman Pot (RP)	AC-LGADs
Off-Momentum Detectors (OMD)	AC-LGADs
B0 spectrometer	Tracker: MAPS or AC-LGADs EMcal (PbWO4) or preshower?
Low-Q^2 tagger	Tracker: AC-LGADS EMcal: Crystal (PbWO4)

ZDC

Courtesy to Shima Shimizu (RIKEN/JSPS)

What I put in Fun4All -- ongoing



Silicon
3 mm x 3mm x 300 µm
PET (Glue) 0.11 mm
PET (FPC) 0.28 mm
Gap 1.2mm
Crystal (PbWO4)
3cm x 3cm x 10 cm
Gap 3 cm

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 1 cm x 1 cm x 320 µm
PET (Glue) 0.13 mm
PET (FPC) 0.28 mm
Gap 1. mm

5.34 mm

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 3 mm x 3mm x 300 µm
PET (Glue) 0.11 mm
PET(FPC) 0.28 mm
Gap 1.2mm

5.5 mm

Si + 20 layers + 1 layer x 2

Total:
W: 42 layers,
Si: 3 layers,
Si: 40 layers

12 layers

Pb 3cm Thickness
PET (Glue) 0.11 mm
Silicon 1 cm x 1 cm x 320 µm
PET (Glue) 0.13 mm
PET(FPC) 0.28 mm
Gap 1. mm

30 layers (15 layers x 2)

Pb 3cm Thickness
Scintilator 10 cm x 10 cm x 2 mm
Gap 0.0013 mm

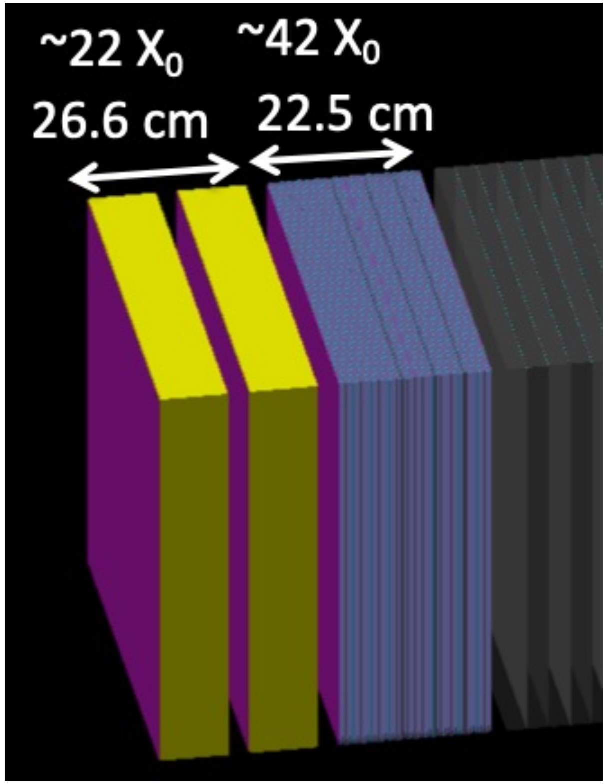
ZDC optimization

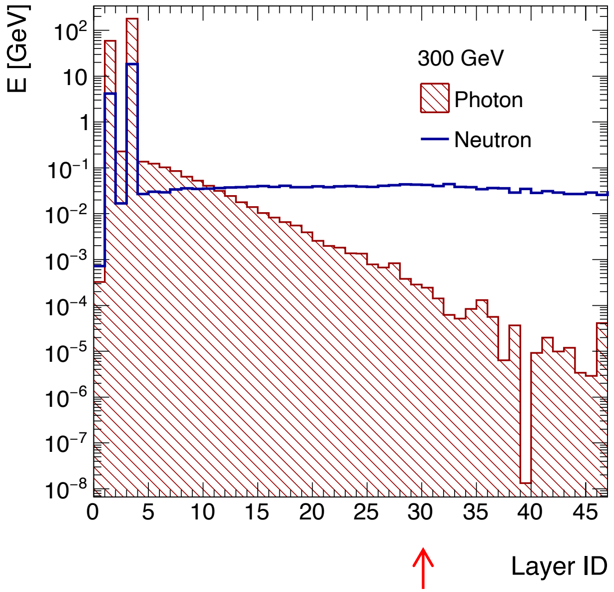
Reduction of Crystal size 10 cm x 2 → 7 cm x 2

Reduction of number of layers, W/Si 42 layers → ~ 30 layers

Adding charge particle veto

Neutron / photon separation
Photon energy reconstruction/resolution
Position resolution



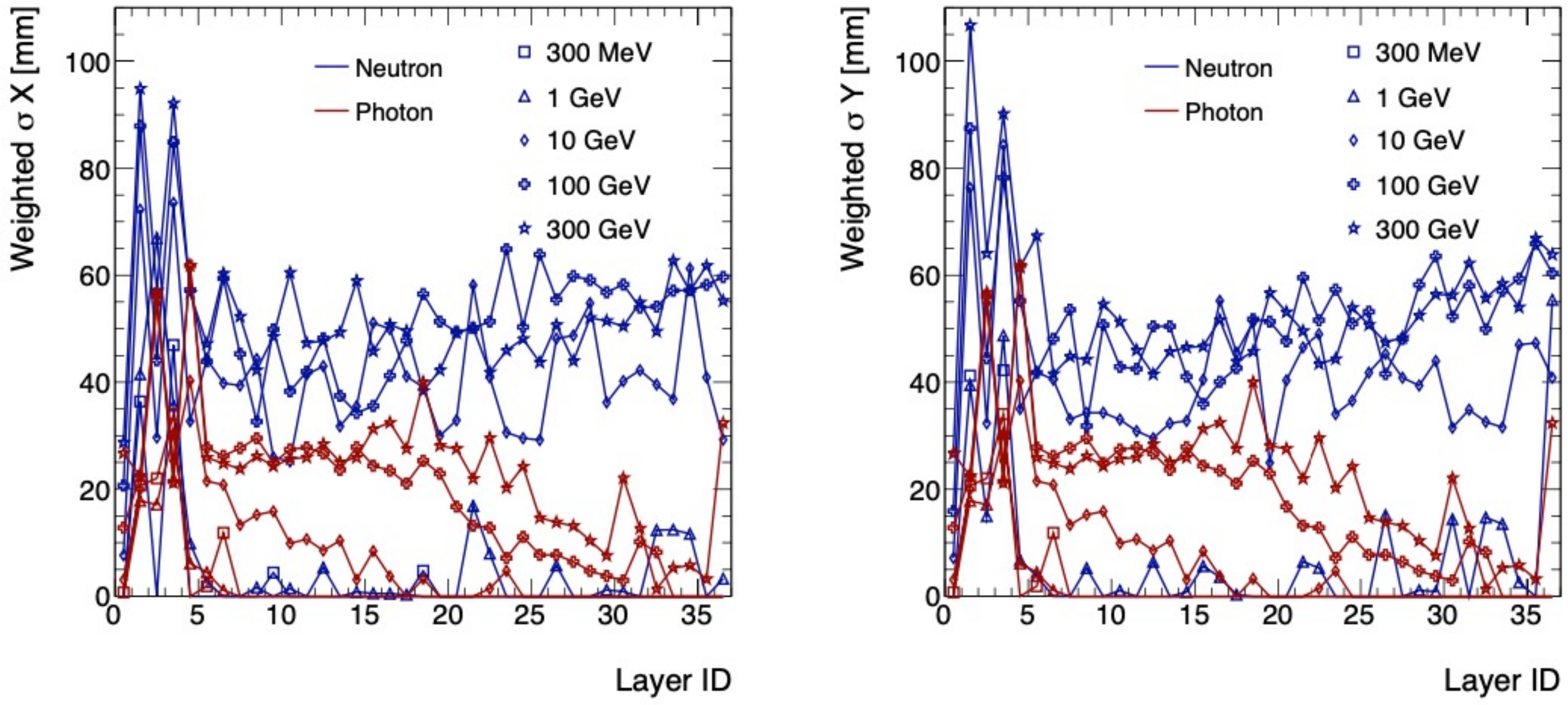


Tiny energy deposits for Layer ID > 30, for photons.

Transverse spread of energy deposits

Energy weighted sigma are checked.

$$\sigma = \sqrt{\frac{\sum E_i (x_i - \bar{x})^2}{\sum E_i}} = \sqrt{\left|\frac{\sum E_i x_i^2}{\sum E_i} - \bar{x}^2\right|}, \text{ where } \bar{x} = \frac{\sum E_i x_i}{\sum E_i}$$



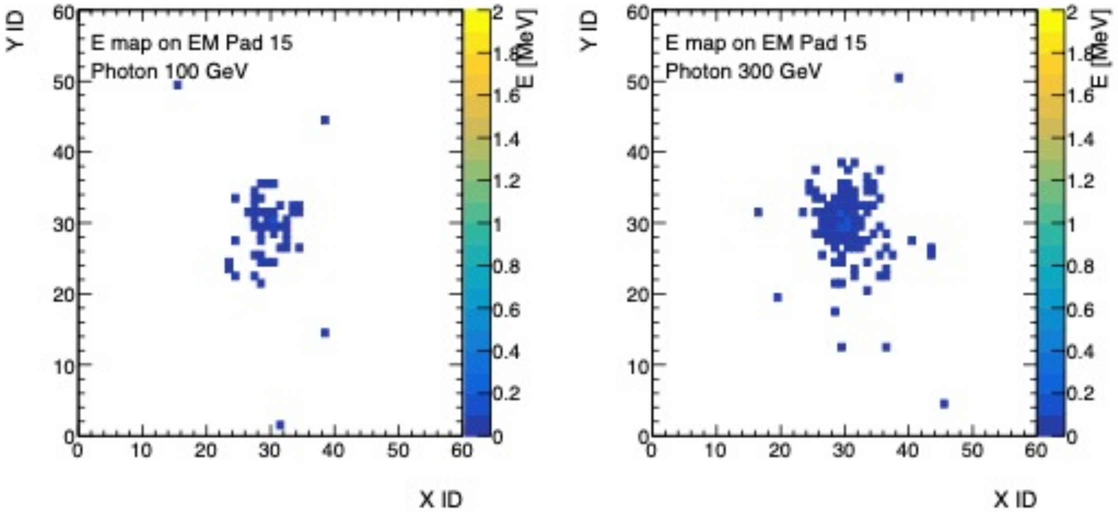
Difference of shower width is visible in Si/W layers (Layer ID>5)

Photon shower is fading around Layer ID 20 - 30

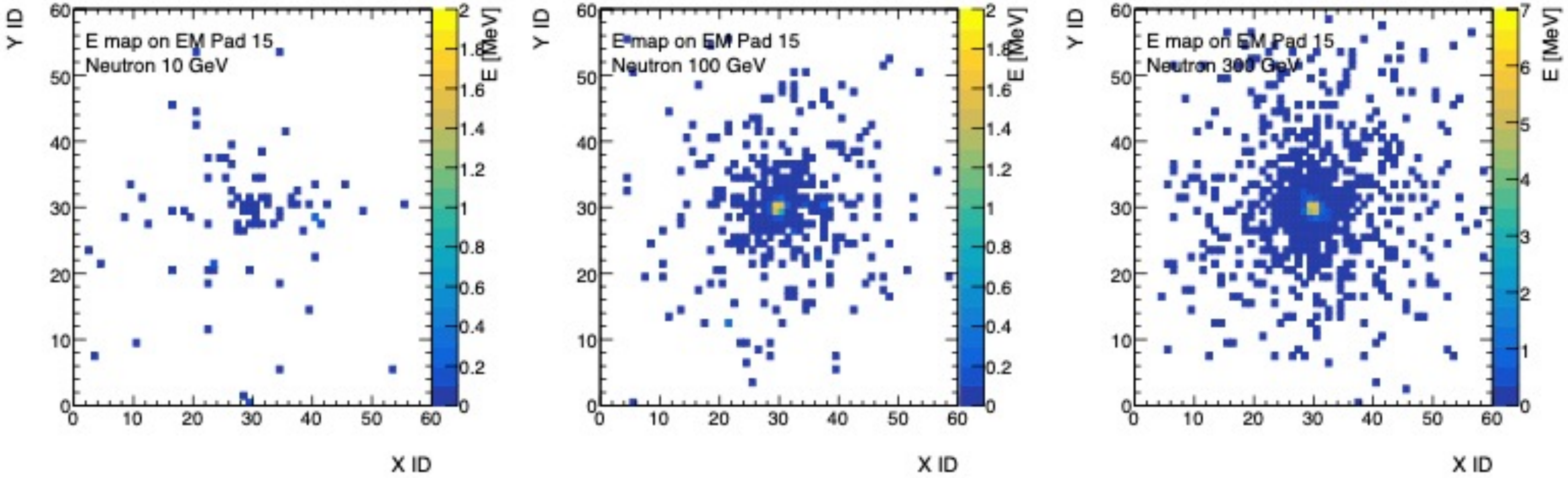
Energy deposits on Layer ID 20

Difference of shower shape is seen at Layer 20.

Photon



Neutron



Roman Pots

Settings in the simulation (Fun4All): two 50 cm discs at nominal position 26 and 28 m.

Preferred Technology: AC-LGADs

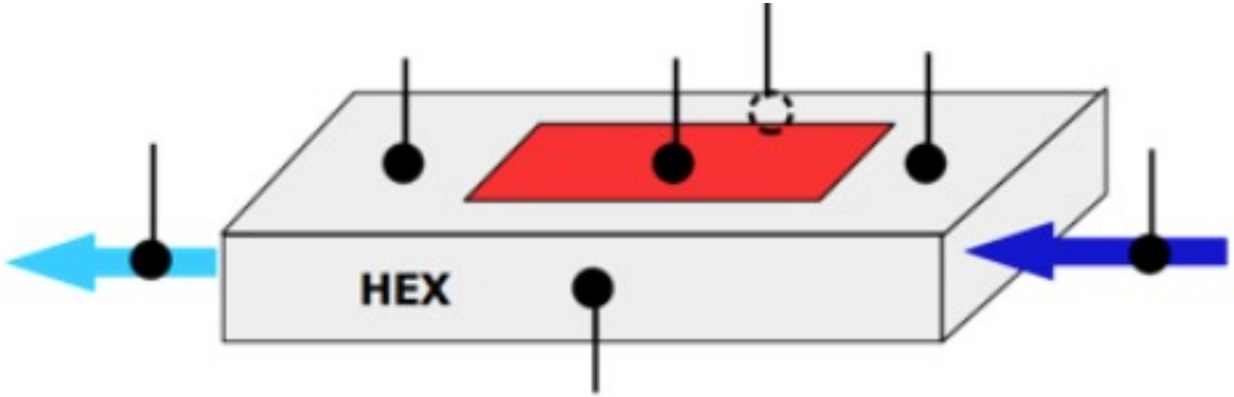
Technology	Spatial Resolution	Integration time	Power Consumption	Radiation Tolerance
AC-LGAD	20 – 30 μm	< 300 ps	< 350 mW/cm^2	~ 5 x10^{15} n$_{eq}$/cm^2
MALTA	~5 μm	~ 5 ns	Under R&D	~ 1 x10^{15} n$_{eq}$/cm^2

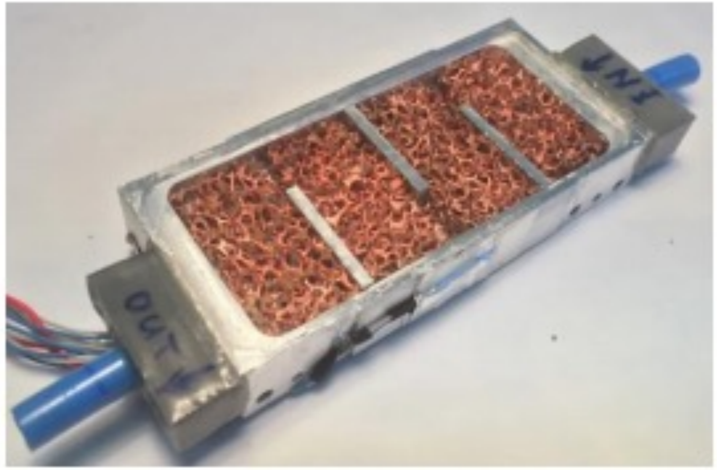
Both prototype sensors are under R&D and ongoing tests at LANL

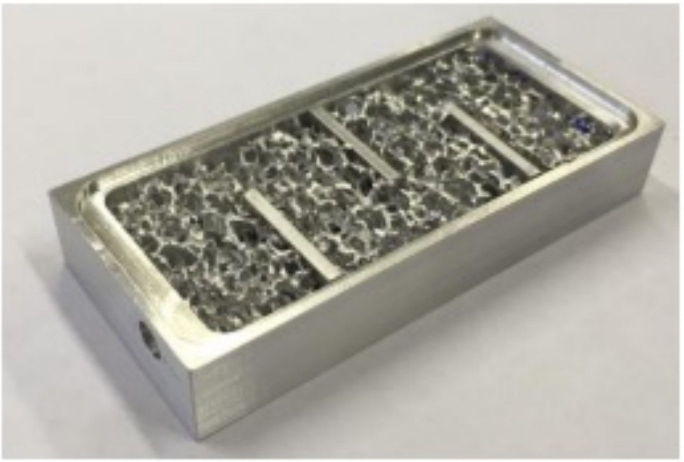
ASIC readout for AC-LGAD, require cooling: need to dissipate approximately 750 W per station of RP

Such a load could be handled by compressed air Vortex cooling

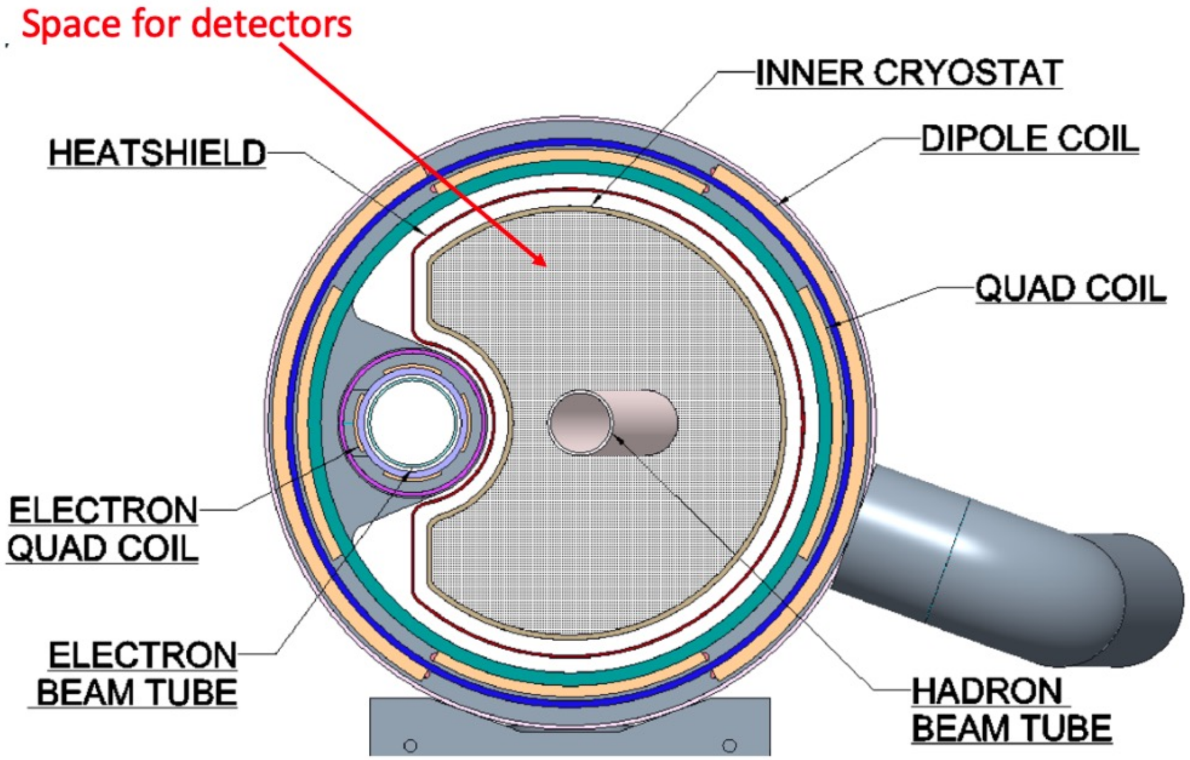
- Air Vortex cooling using compressed air and foam metal heat sink is working well for AFP and PPS at the LHC.
- Compressed air will be available at EIC,
- Can cool up to 900W per pot but could go higher for higher pressure, say 9 bar

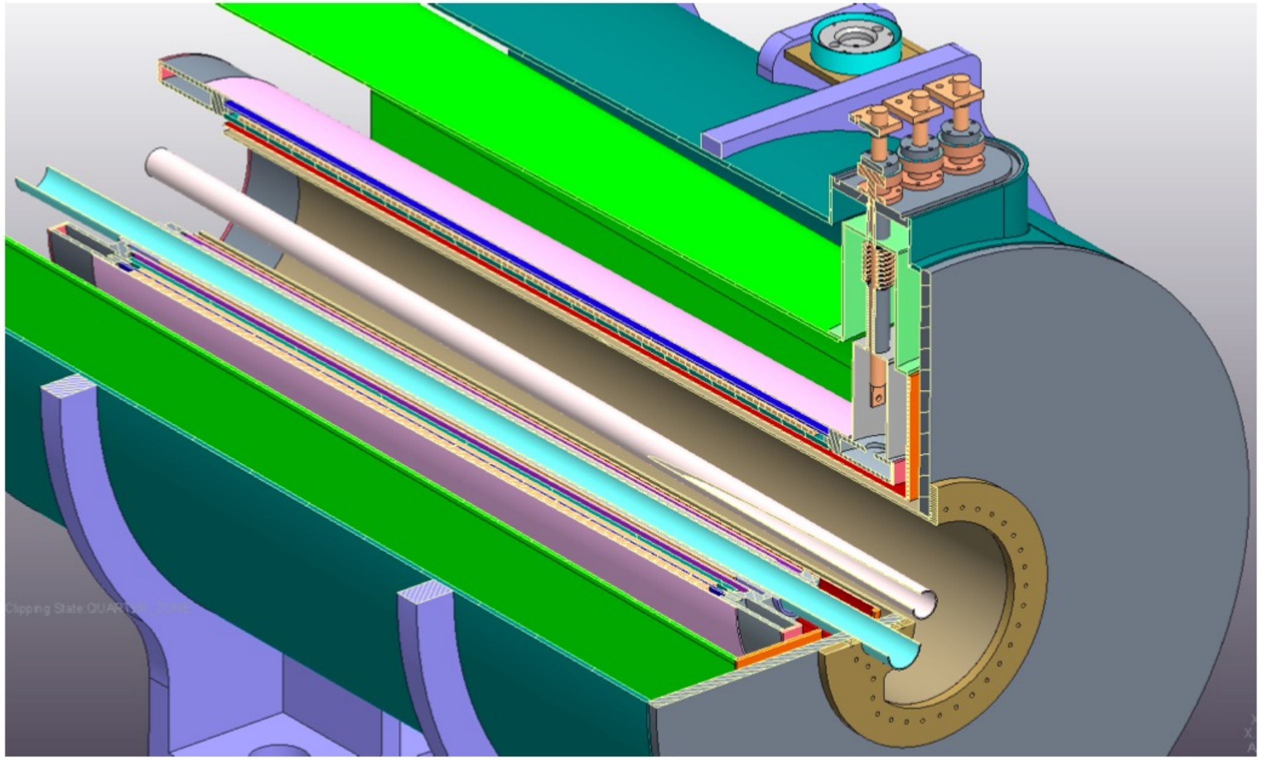






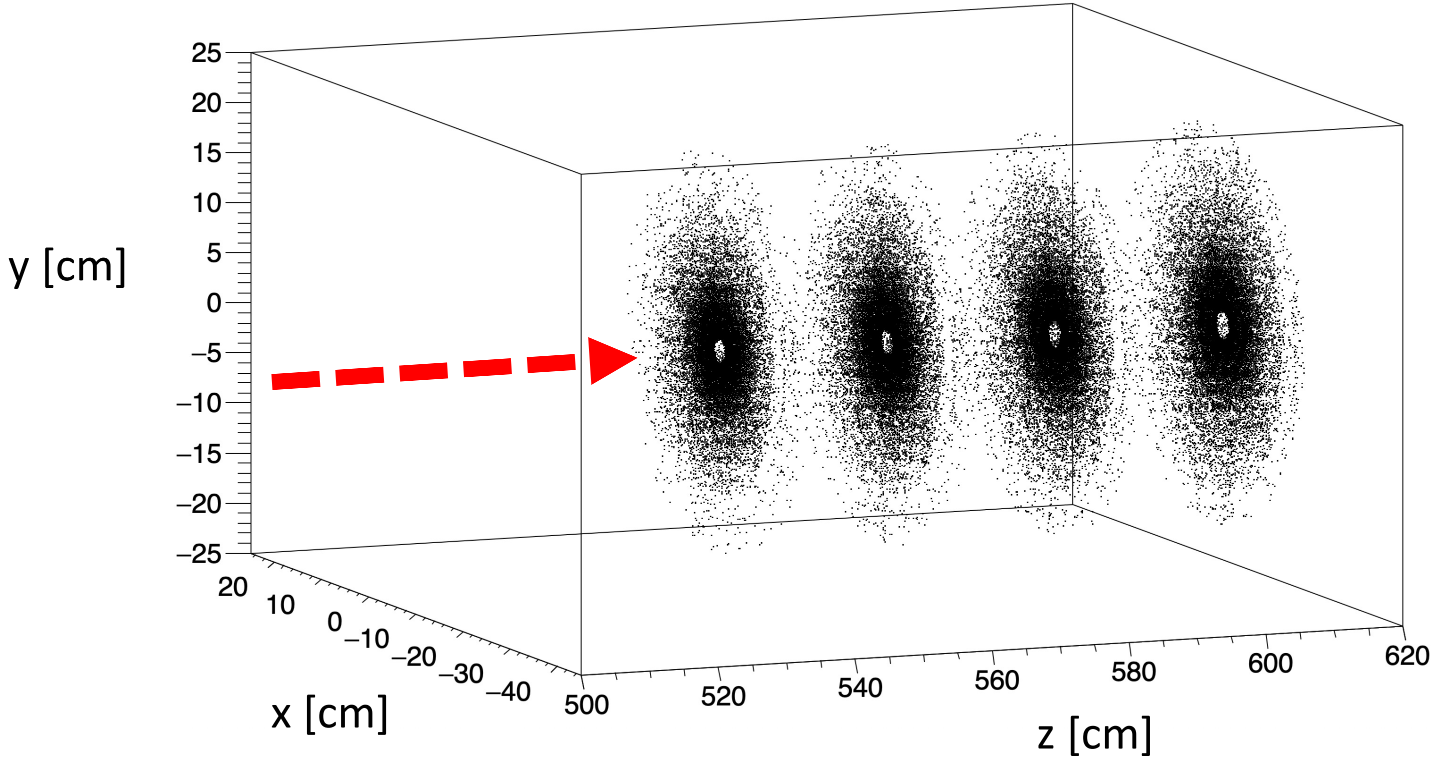
B0 tracker and calorimeter





Considered technology

MAPS + AC-LGADs



Current implementation

Hits clearly identified in 4 tracking layers

Next step: more realistic material budget

Example: Proton hits in B0

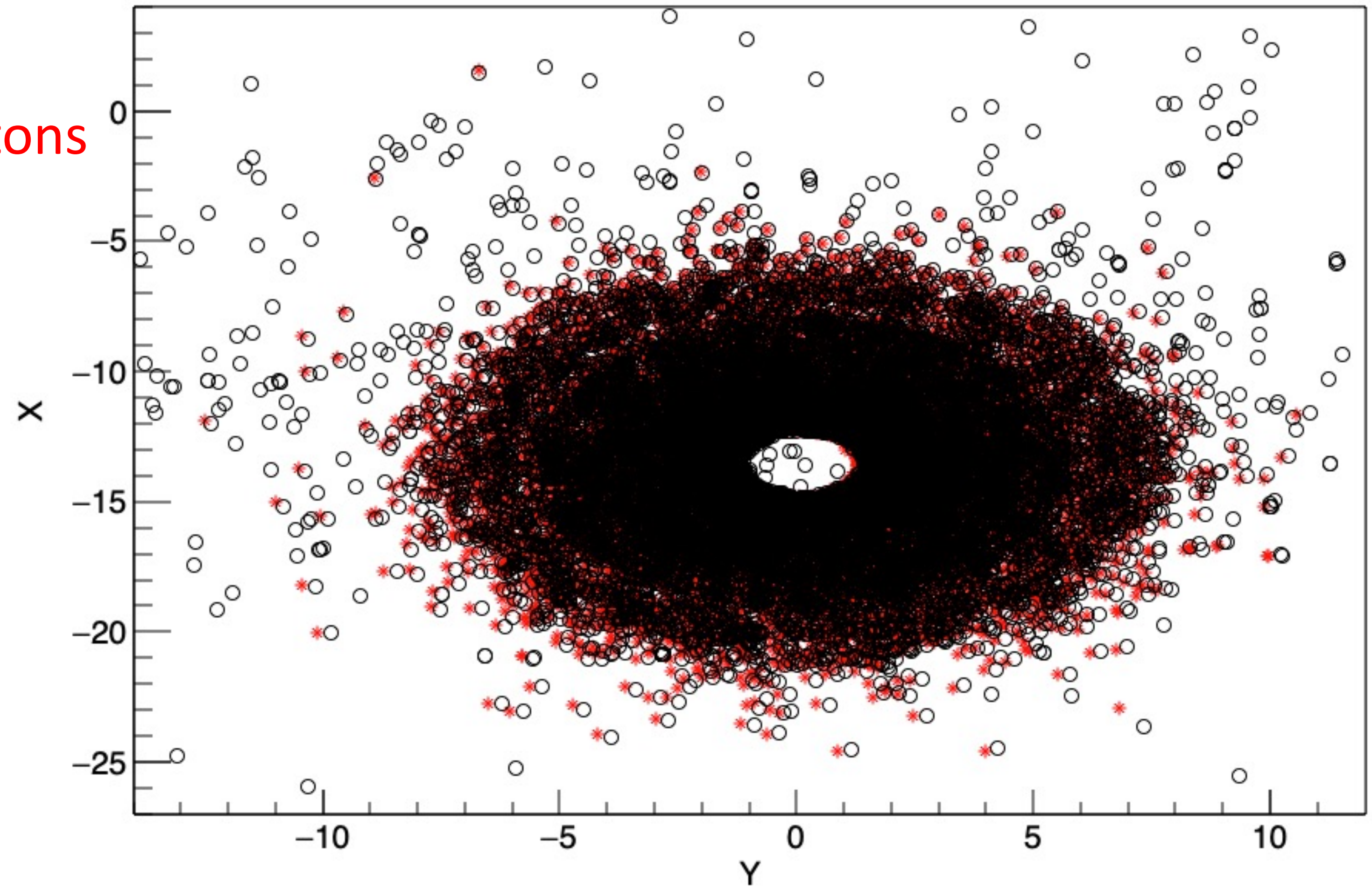
Black circles: hits detected in the B0 1st plane.

Beam Setup: 5x41 GeV

Red: Projection of the protons to the 1st layer of B0 (assuming straight line)

Red-black shift: need to implement optics matrix

Black with no red: upstream detector background (secondaries)



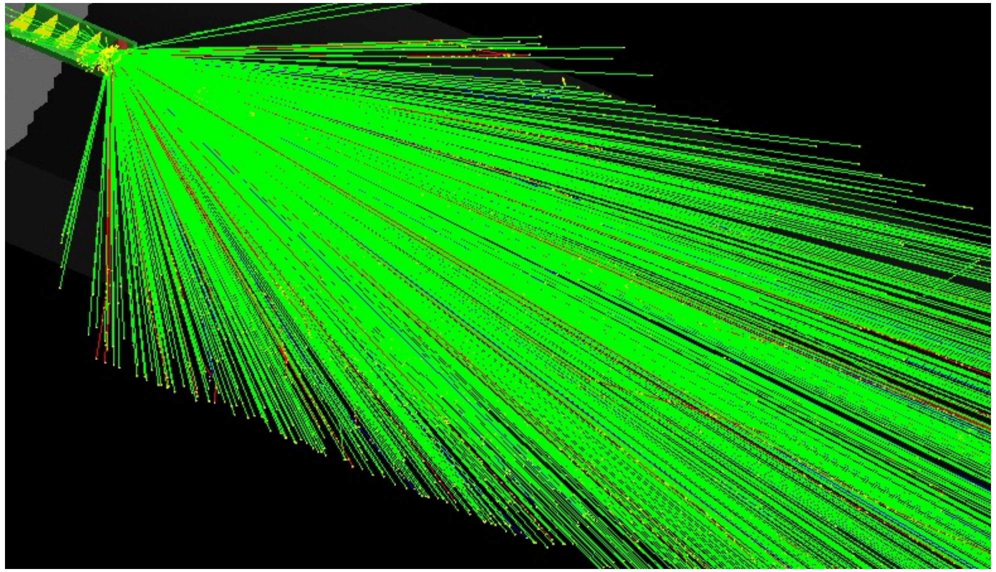
Shift between black and red symbols is due to the magnetic field.

Stand-Alone B0 Photon detection study

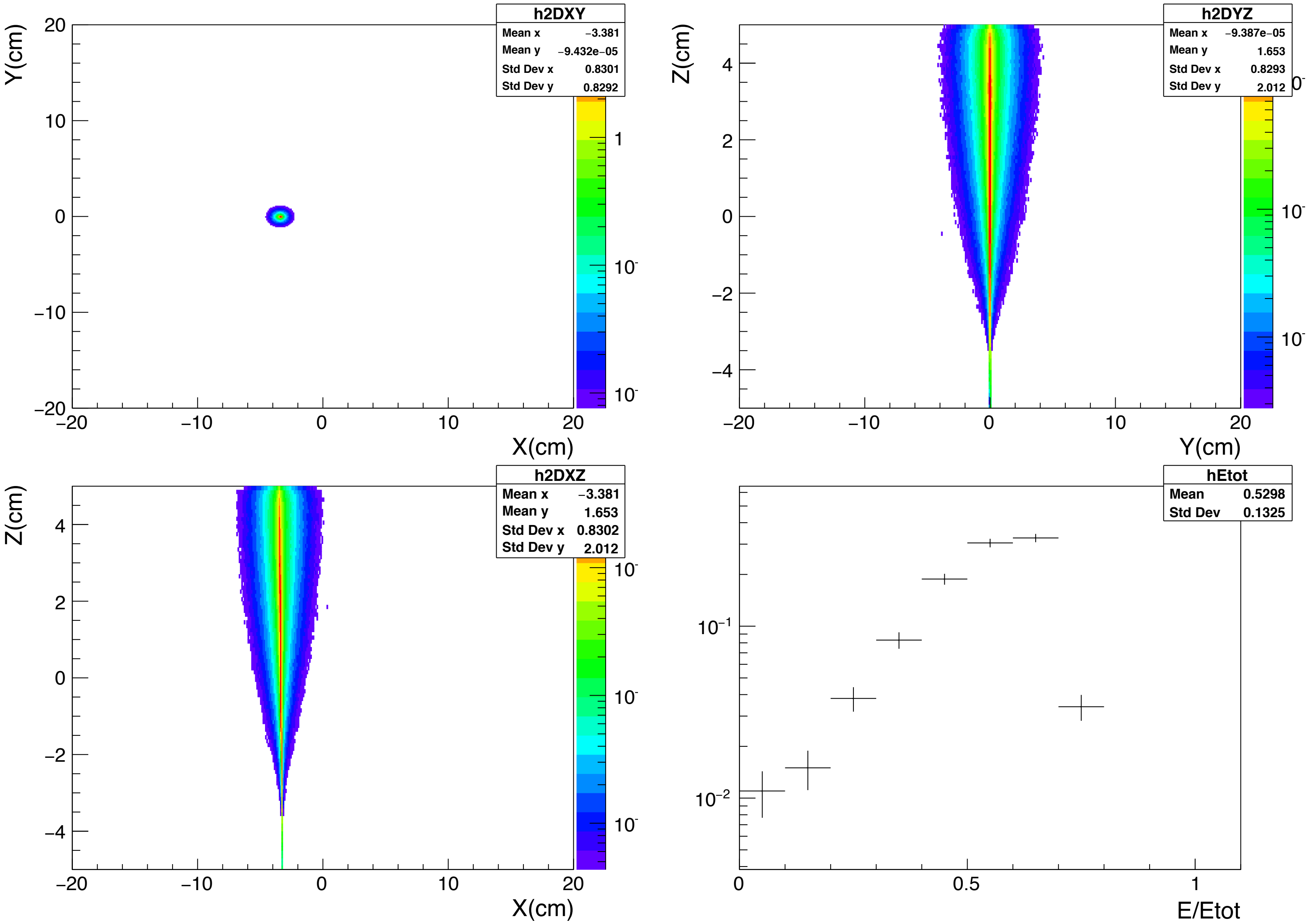
Courtesy to Quan Wang
University of Kansas.

- B0 Calorimeter
  - $PbWO_4$
  - R = 20cm,
  - Thickness = 10cm, 20cm

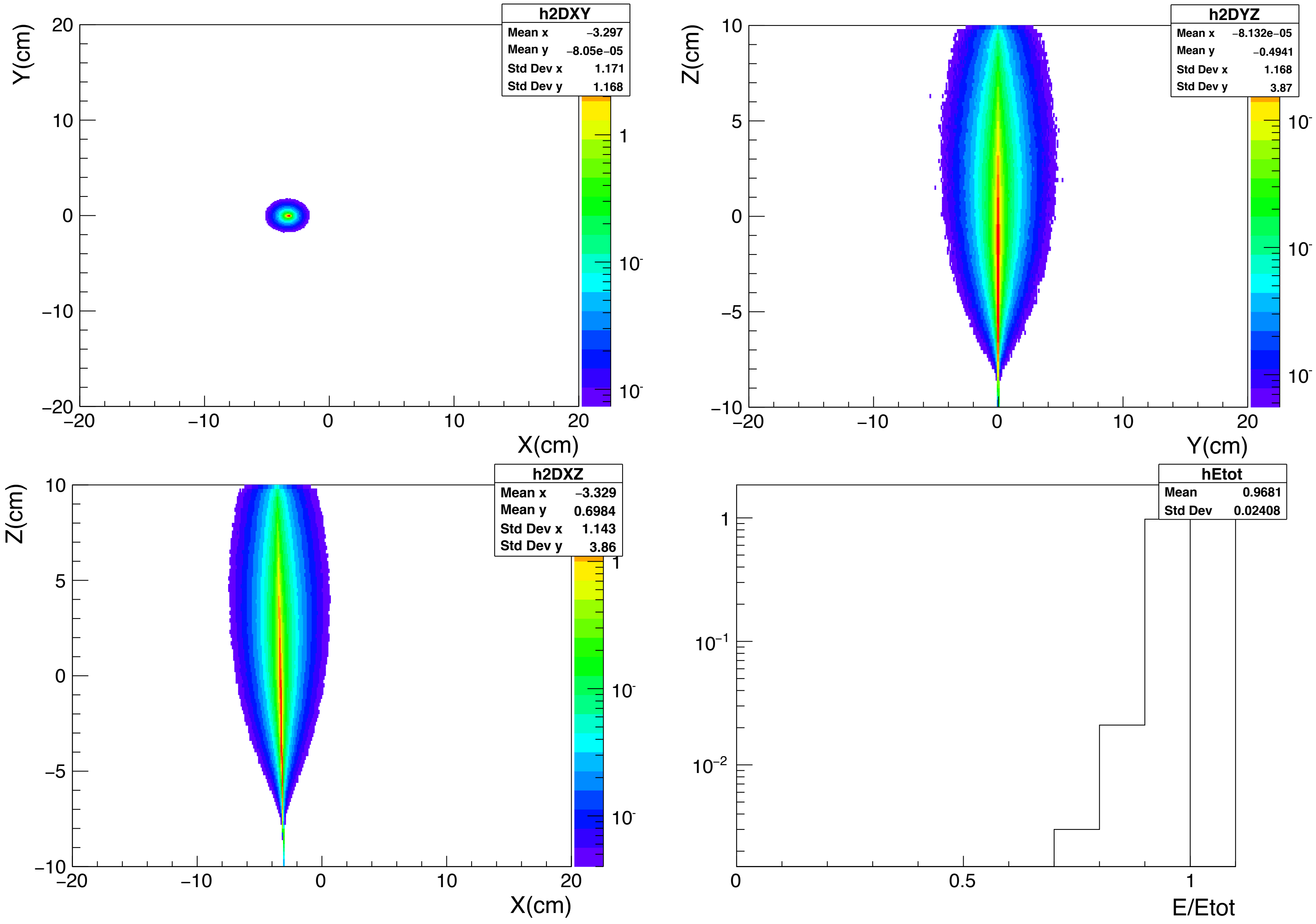
- Gamma, E
  - 0.1, 0.3, 0.5, 1, 3, 5, 10 GeV



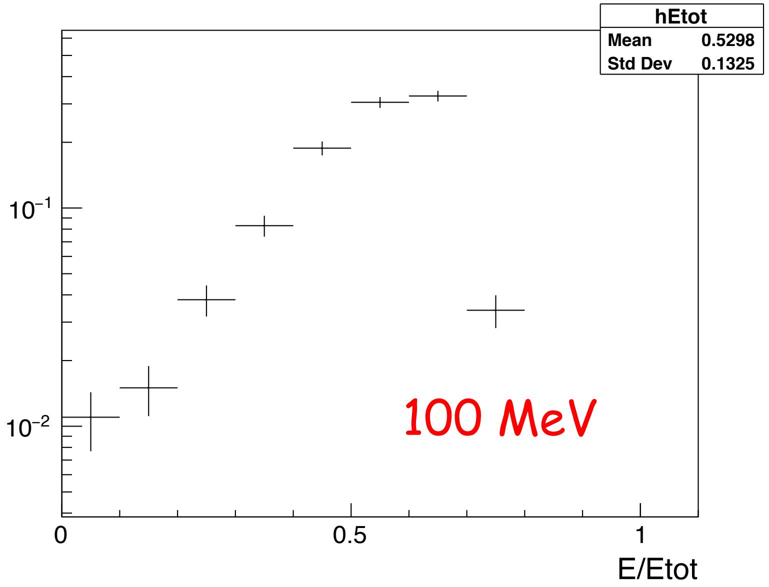
10 cm Calorimeter, 100 MeV Gamma

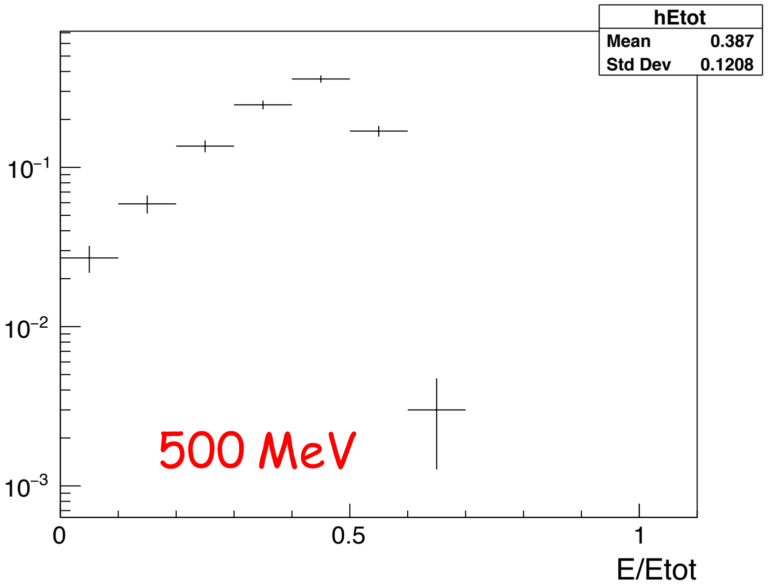


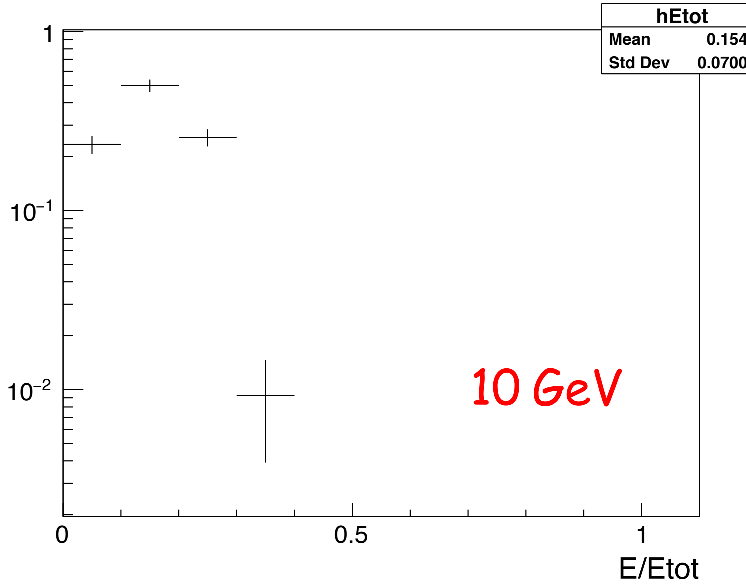
20 cm Calorimeter, 100 MeV Gamma



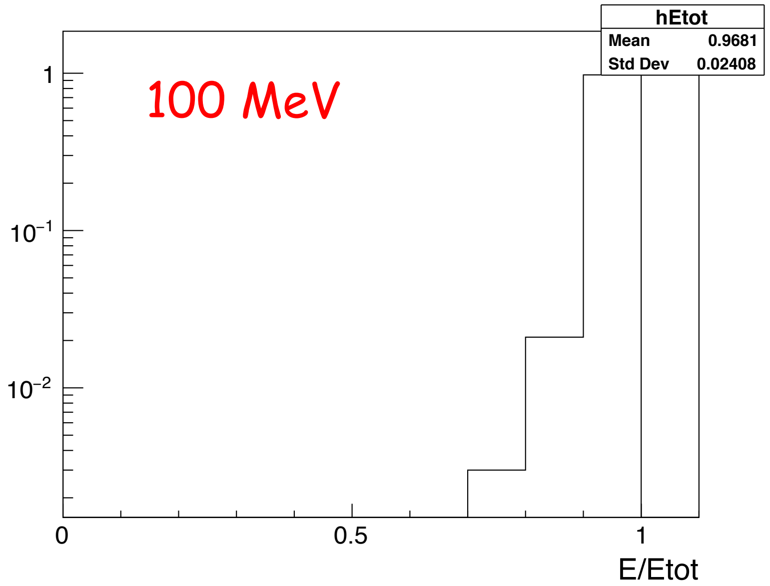
10 cm

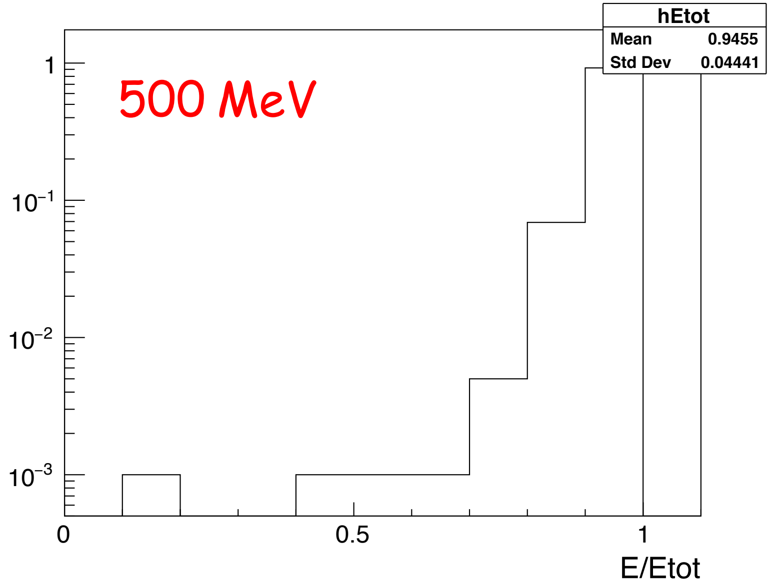

hEtot
Mean 0.5298
Std Dev 0.1325
100 MeV
E/Etot

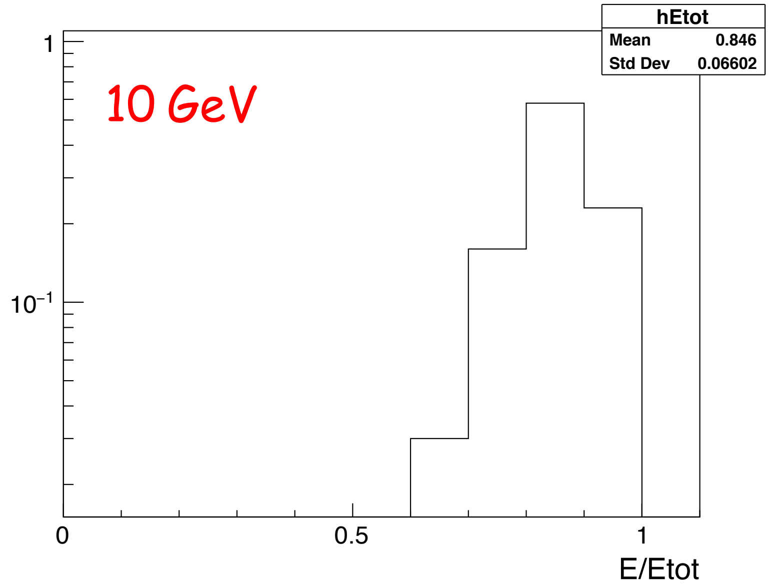

hEtot
Mean 0.387
Std Dev 0.1208
500 MeV
E/Etot


hEtot
Mean 0.154
Std Dev 0.0700
10 GeV
E/Etot

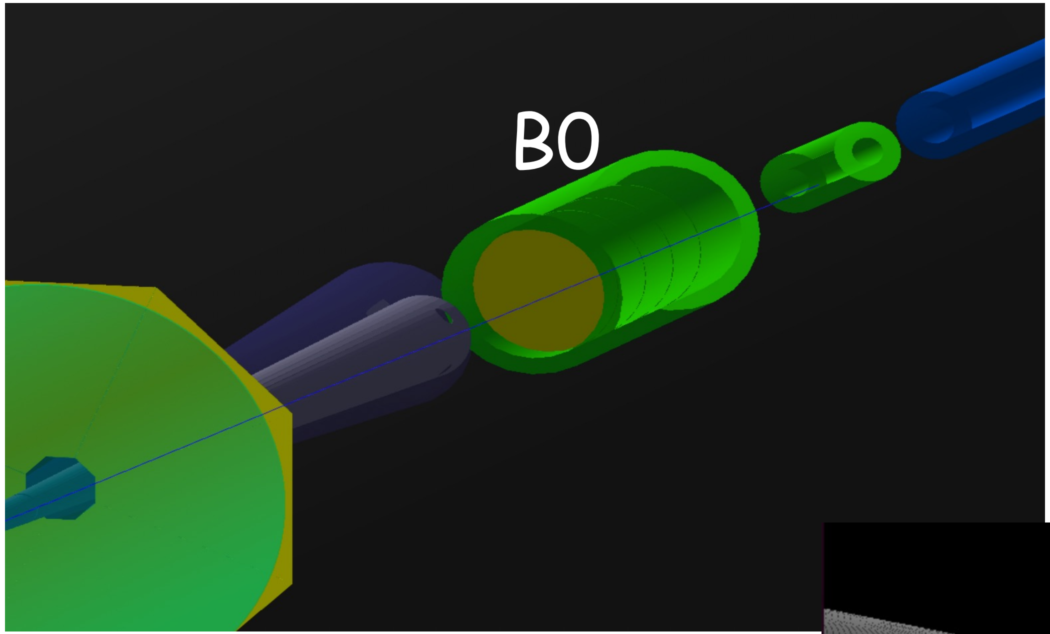
20 cm


hEtot
Mean 0.9681
Std Dev 0.02408
100 MeV
E/Etot


hEtot
Mean 0.9455
Std Dev 0.04441
500 MeV
E/Etot

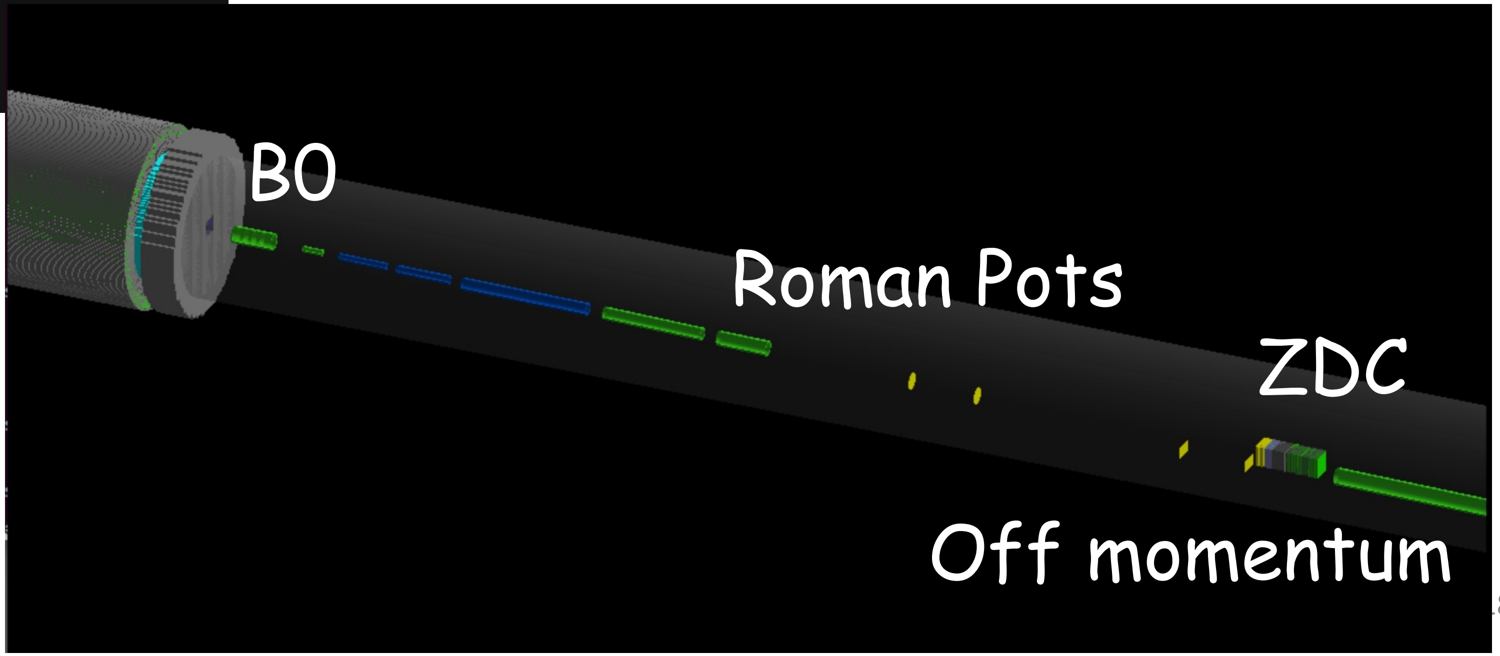

hEtot
Mean 0.846
Std Dev 0.06602
10 GeV
E/Etot

Far-Forward simulation



1st campaign: Full ZDC;
B0 & AC-LGADs as sensitive detectors
(acceptance & background estimations)

2nd campaign: Full (optimized) ZDC;
B0 from stand-alone study
AC-LGADs as sensitive detectors \w realistic
material budget & geometry



Outlook

ZDC:

Study of the low energy photons and reconstruction of neutrons
Energy and position resolution
Simulation of radiation dose
Readout system

Roman pots:

Final selection of a detection technology
Channel count
Finalize the readout and estimate the heat load
Cooling and mechanics

Off momentum:

Detection technology selection

B0 tracker:

Study of PbWO4 for photon detection
Need 20 cm PbWO4 to measure high energy photons
Add realistic beam pipes to the simulation

Far-Backward, Low Q2 tagger:

1st step, positioning detector planes in the simulation

Thank you for your attention.