ECCE Forward & Backward detector systems

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for the ECCE Consortium

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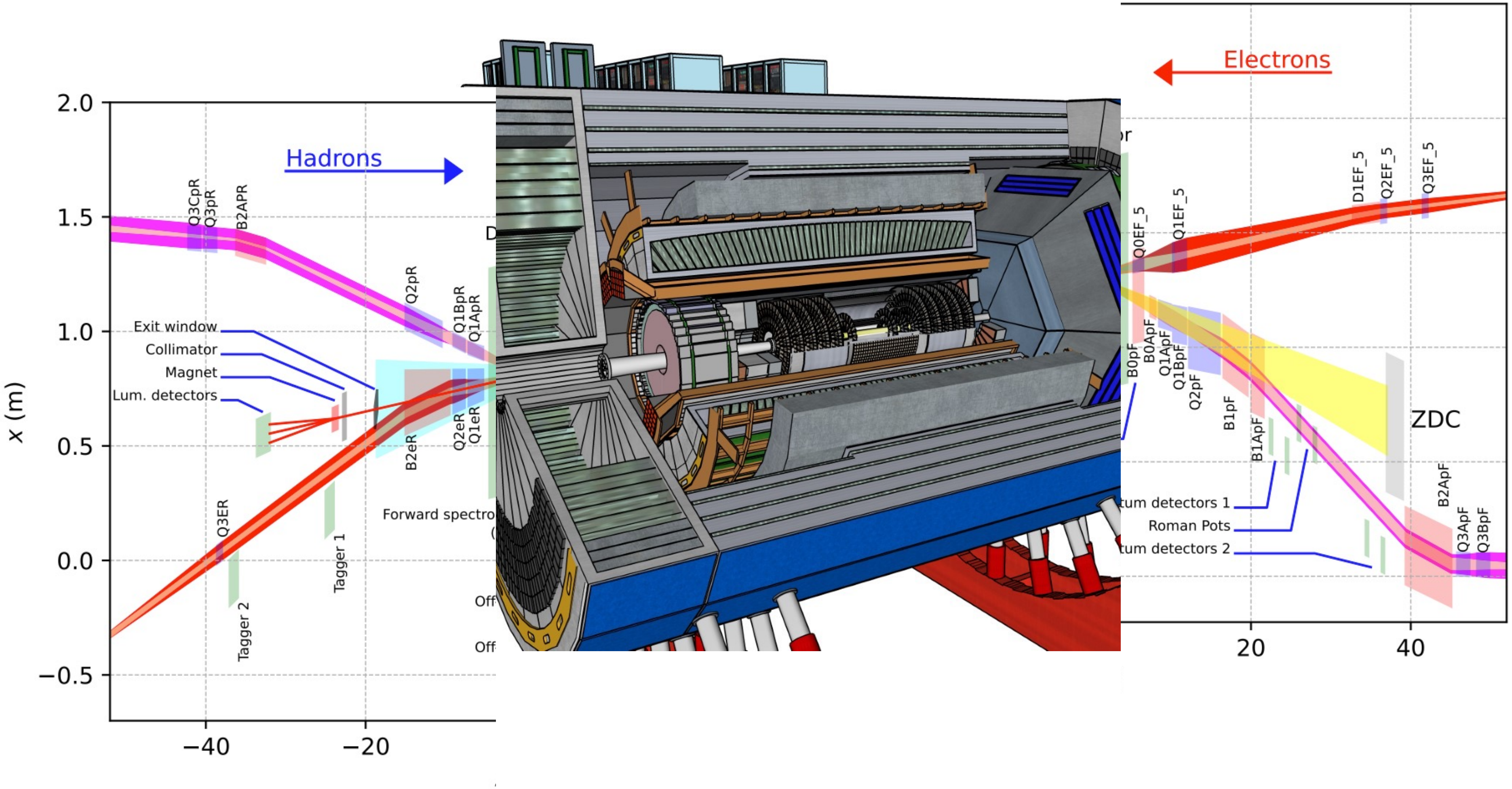
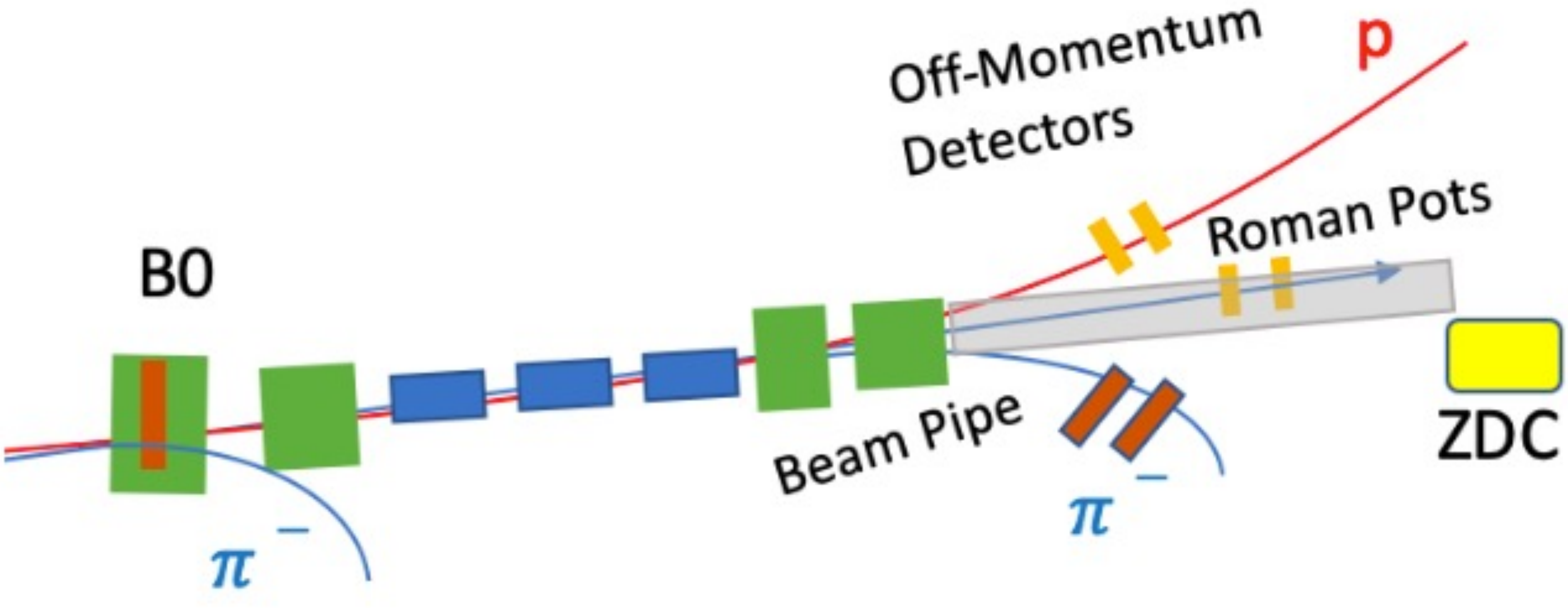
Extension to Far-Forward and Far-Backward



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

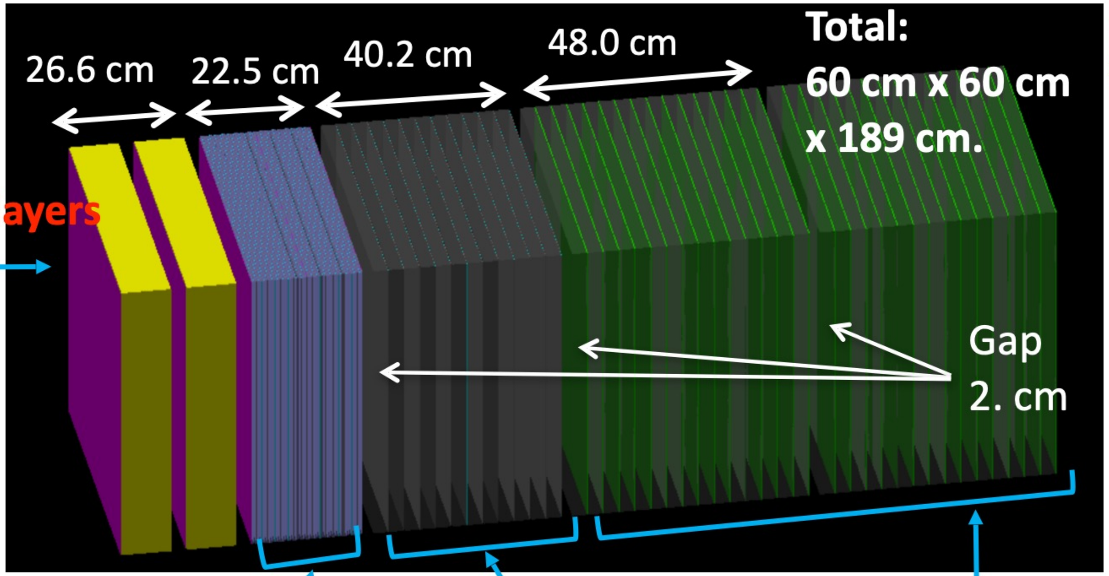
Channel count

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? EMcal: Crystal (PbWO4)

ZDC

Courtesy to
Shima Shimizu
(RIKEN/JSPS)

What I put in Fun4All
-- ongoing



2 layers

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

Si +

20 layers x 2

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

+

1 layer

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

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

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

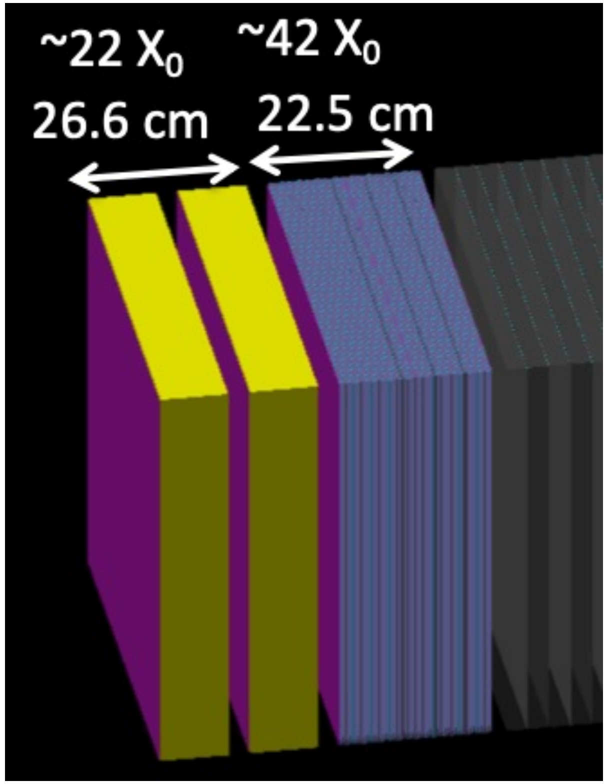
ZDC study and optimization

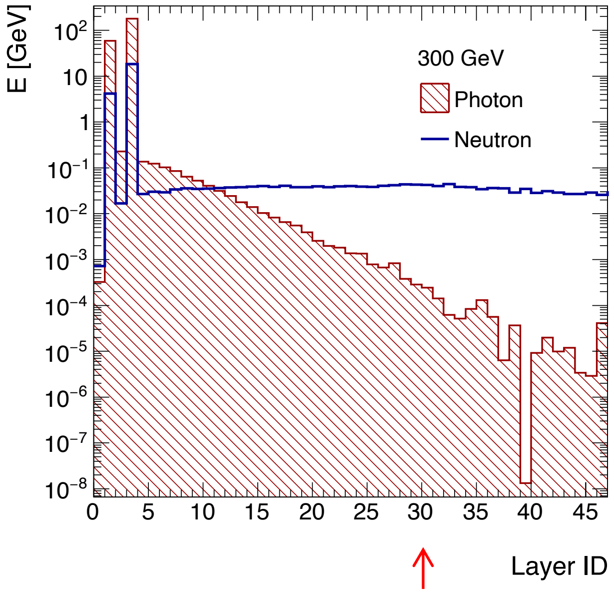
Reduction of Crystal size 10 cm x 2 → 7 cm x 2

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

Adding charge particle veto

Neutron / photon separation
Photon energy reconstruction/resolution
Position resolution



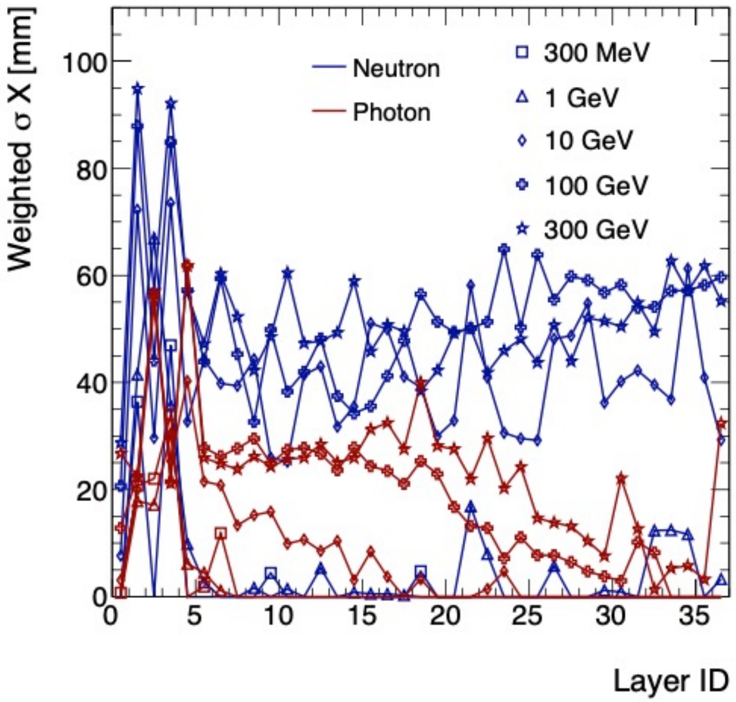


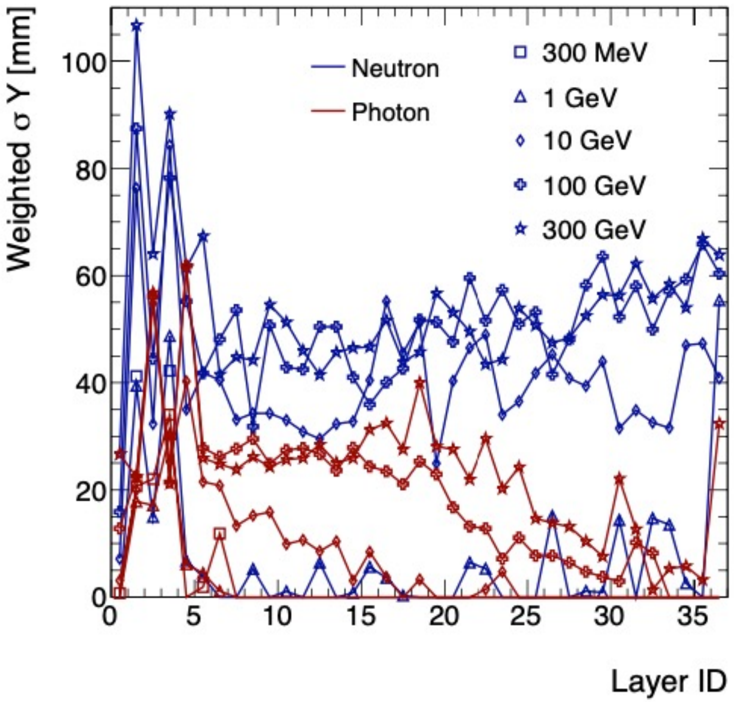
Tiny energy deposits for Layer ID > 30, for photons.

Transverse spread of energy deposits

Energy weighted sigma are checked.

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





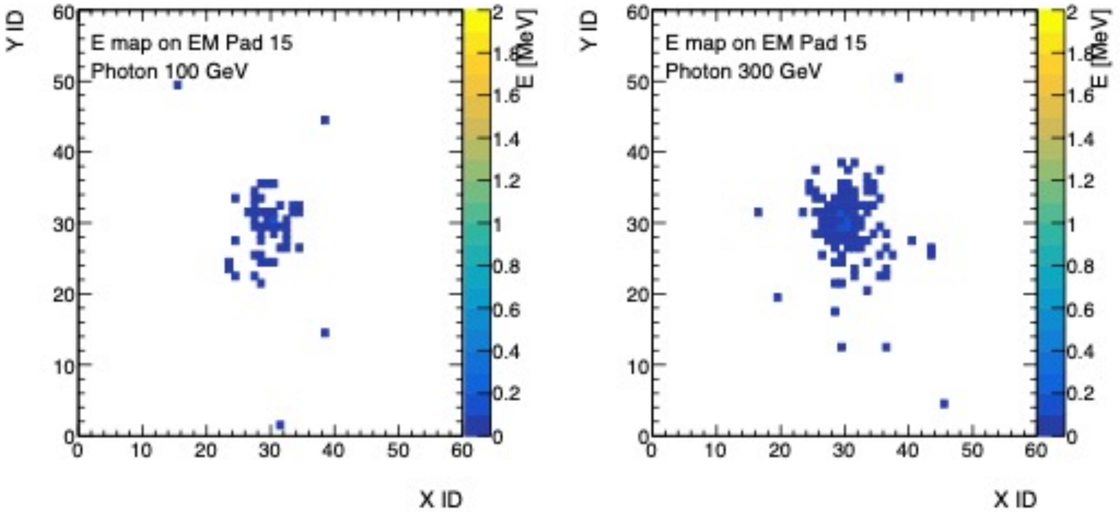
Difference of shower width is visible in Si/W layers (Layer ID>5)

Photon shower is fading around Layer ID 20 - 30

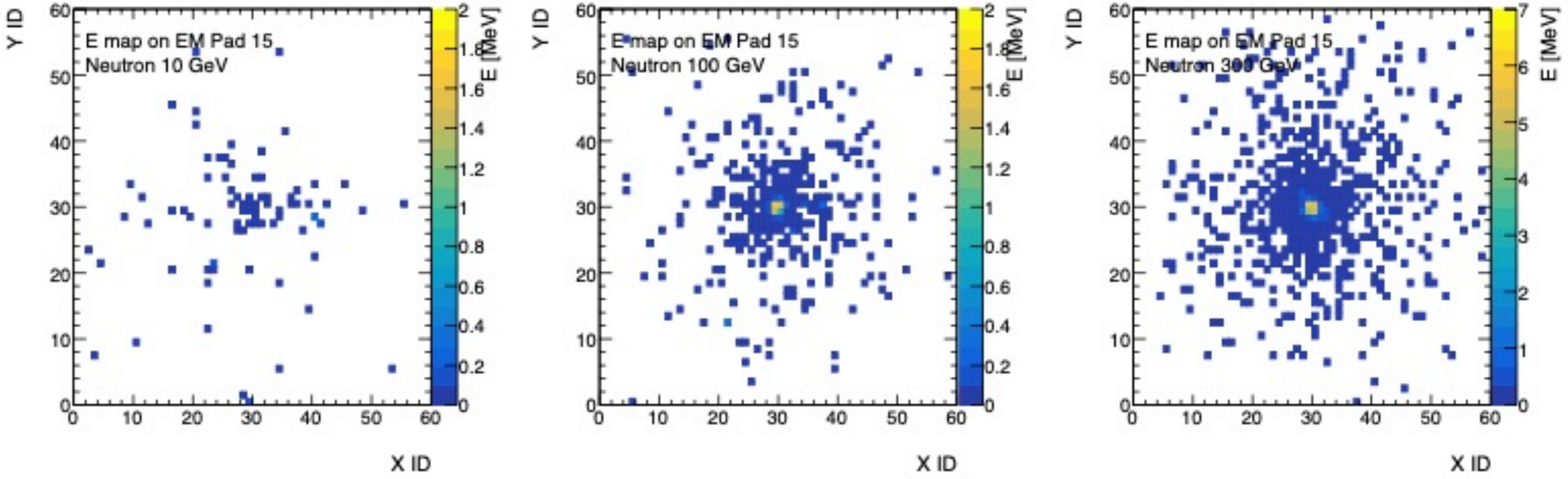
Energy deposits on Layer ID 20

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.

Expected technology: AC-LGADs

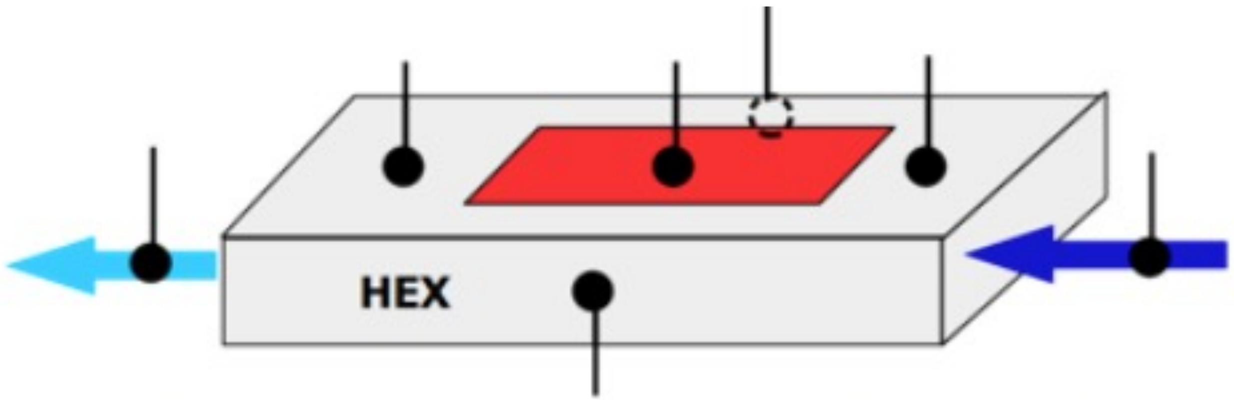
Technology	Spatial Resolution	Integration time	Prototype sensor active area	Prototype status	Power Consumption	Radiation Tolerance
AC-LGAD	20-30 μm	< 300 ps	2.5 mm by 2.5 mm	ready	< 350 mW/cm^2	~5×10^{15} n_{eq}/cm^2
MALTA	~5 μm	~ 5ns	2cm by 2cm	ready	Under R&D	~1×10^{15} n_{eq}/cm^2

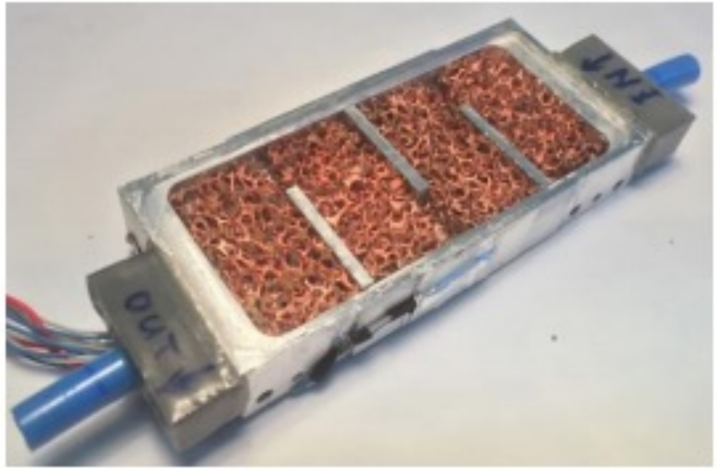
Both prototype sensors are under R&D and ongoing tests at LANL

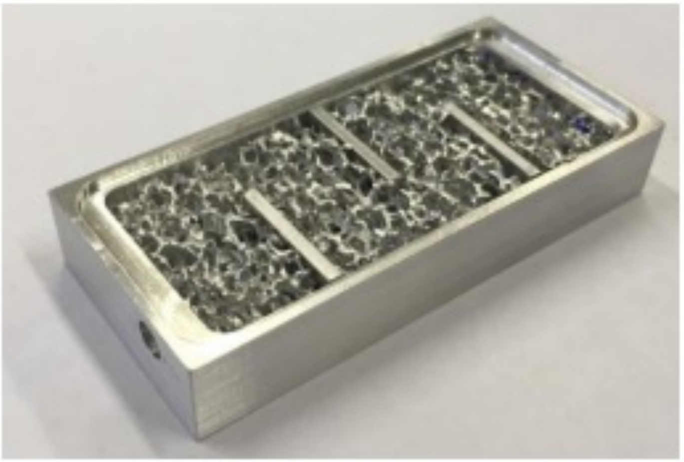
ASIC readout for AC-LGAD, require cooling: need to dissipate approximately 750 W per station of RP

Such a load could be handled by compressed air Vortex cooling but need to think through mechanics

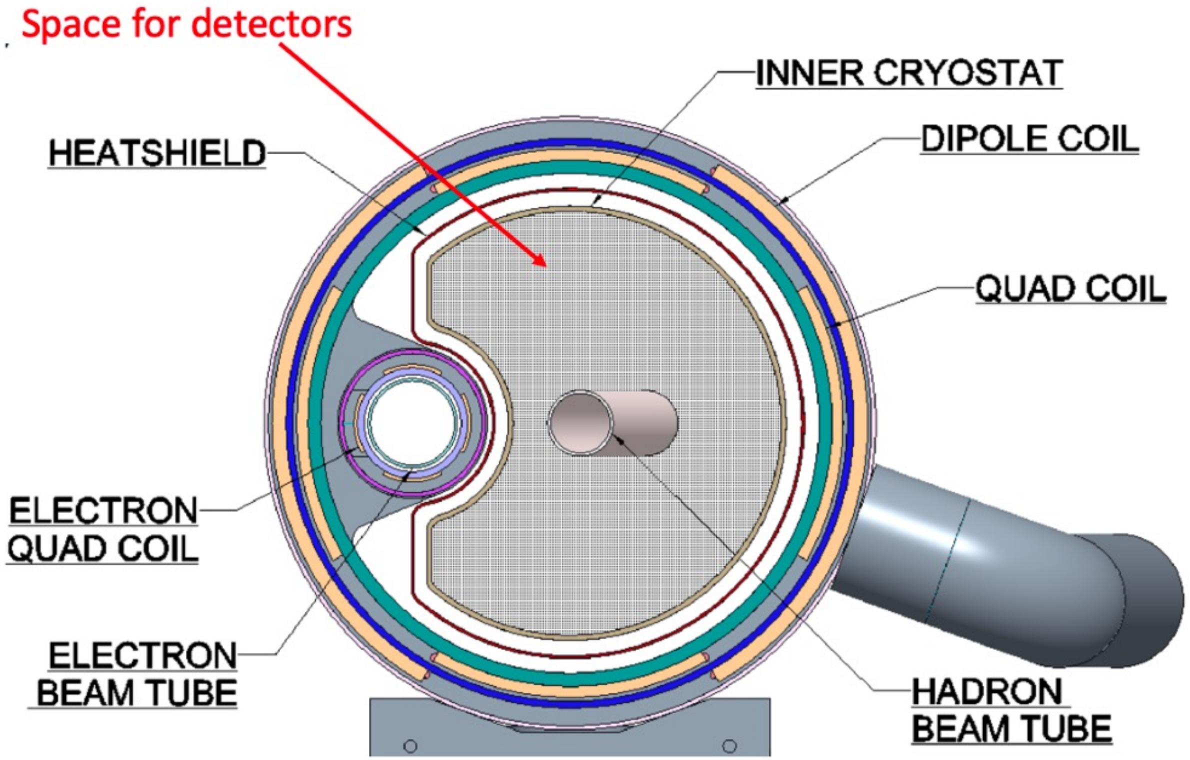
- Air Vortex cooling using compressed air and foam metal heat sink is working well for AFP and PPS at the LHC.
- Compressed air will be available at EIC,
- Can cool up to 900W per pot but could go higher for higher pressure, say 9 bar

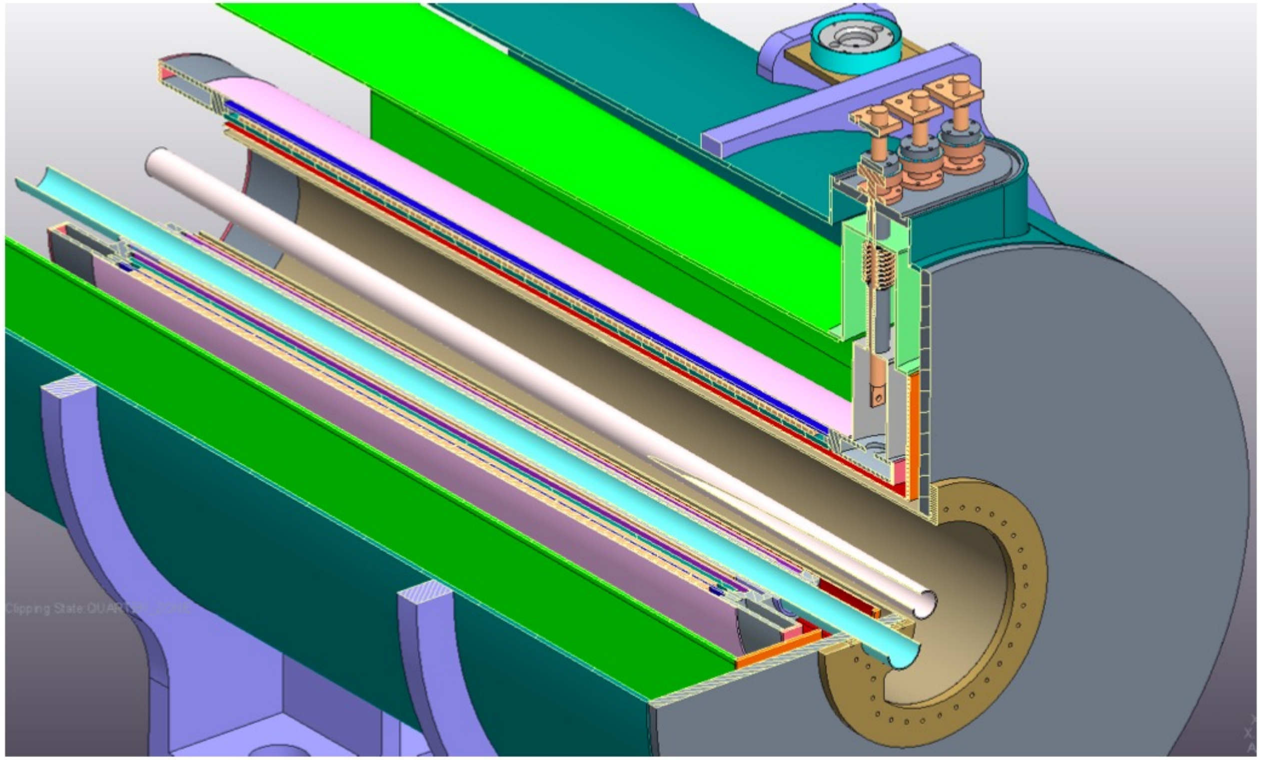






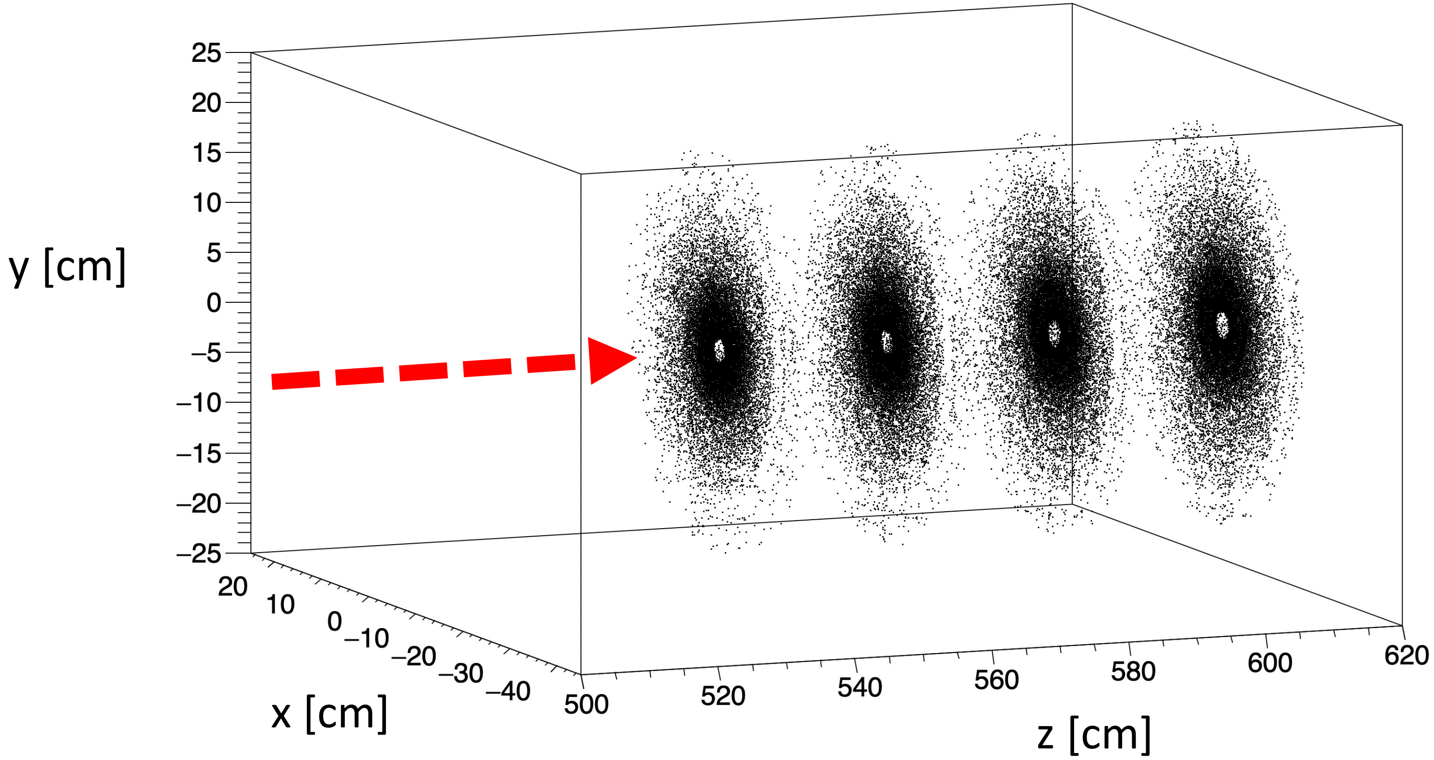
B0 tracker and calorimeter





Considered technology

Technology	Spatial Resolution	Integration time	Prototype sensor active area	Prototype status	Power Consumption	Radiation Tolerance
AC-LGAD	20-30 μm	< 300 ps	2.5 mm by 2.5 mm	ready	< 350 mW/cm^2	~5×10^{15} n$_{eq}$/cm^2
MALTA	~5 μm	~ 5ns	2cm by 2cm	ready	Under R&D	~1×10^{15} n$_{eq}$/cm^2



Current implementation

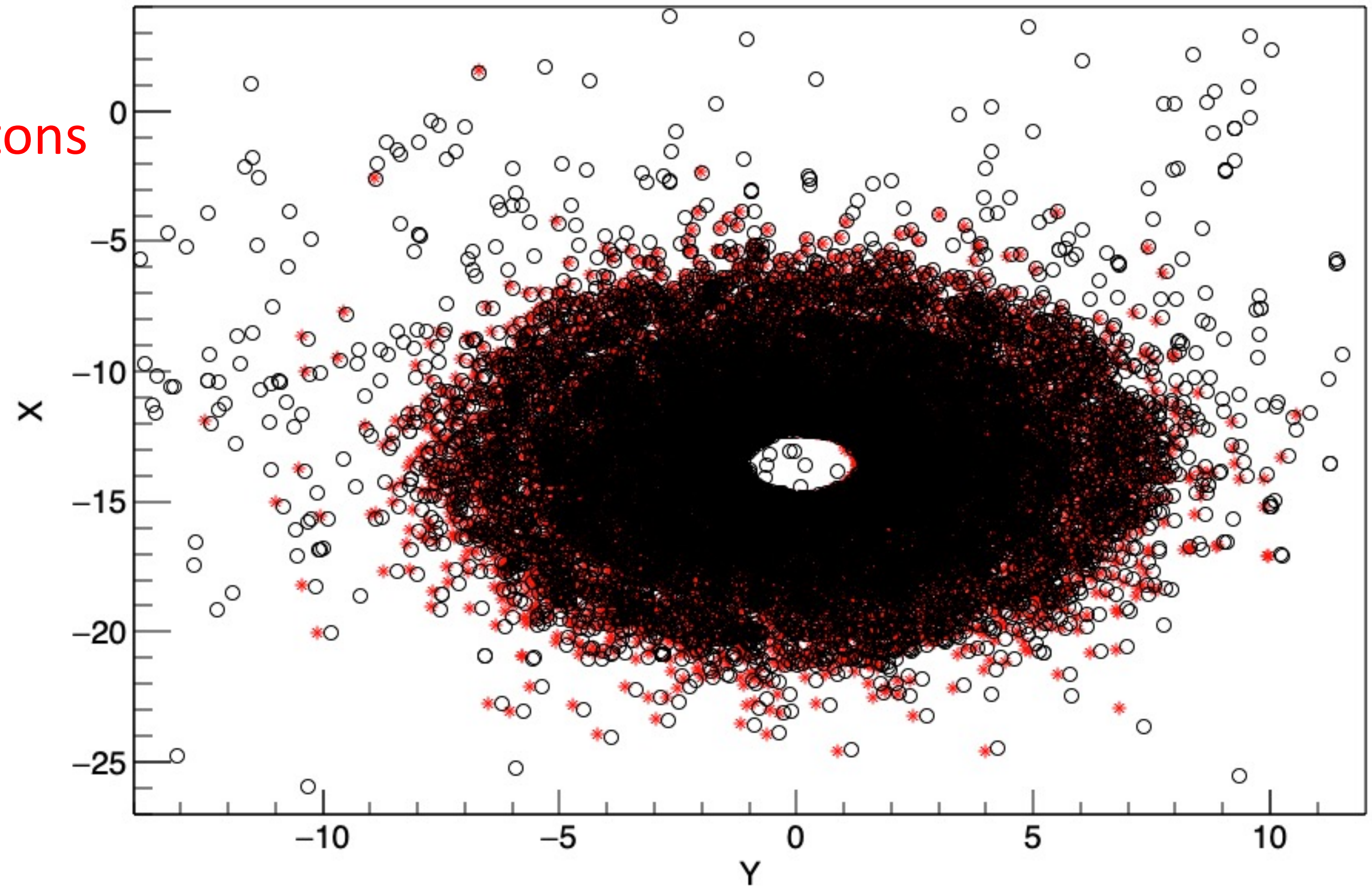
Hits clearly identified in 4 tracking layers

Example: Proton hits in B0

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

Beam Setup: 5x41 GeV

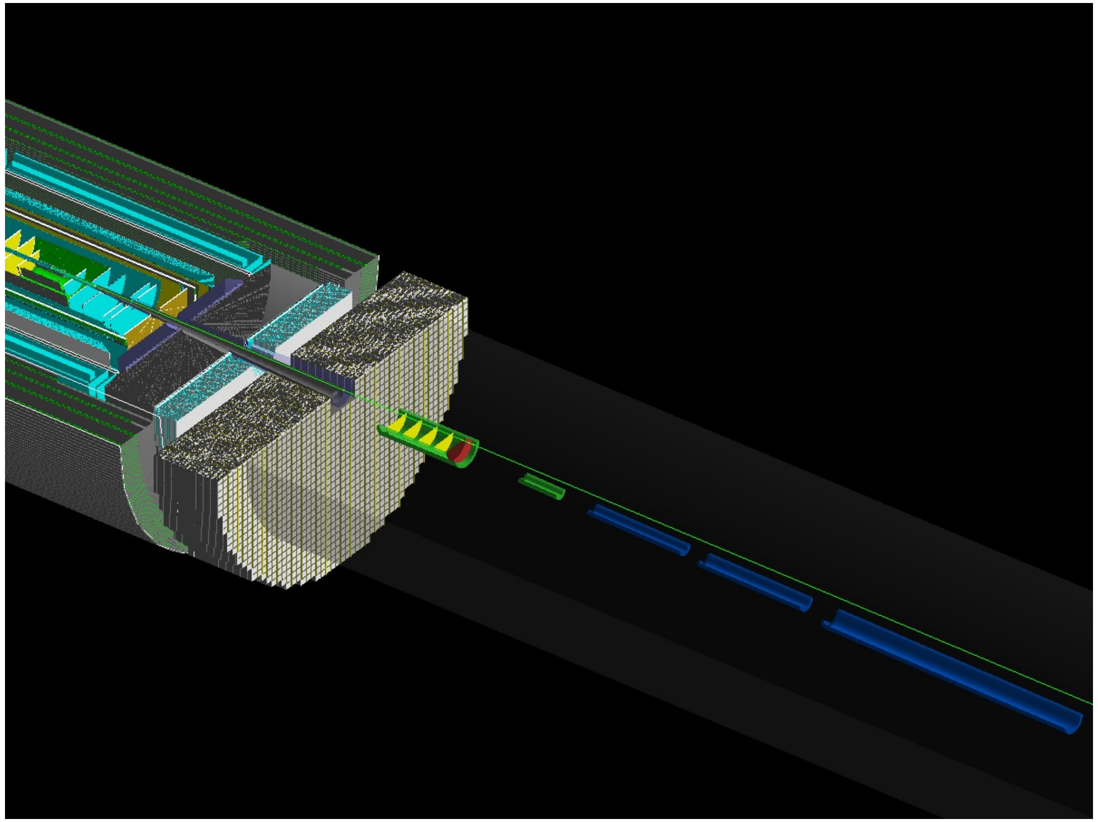
Red: Projection of the protons to the 1st layer of B0 (assuming straight line)



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

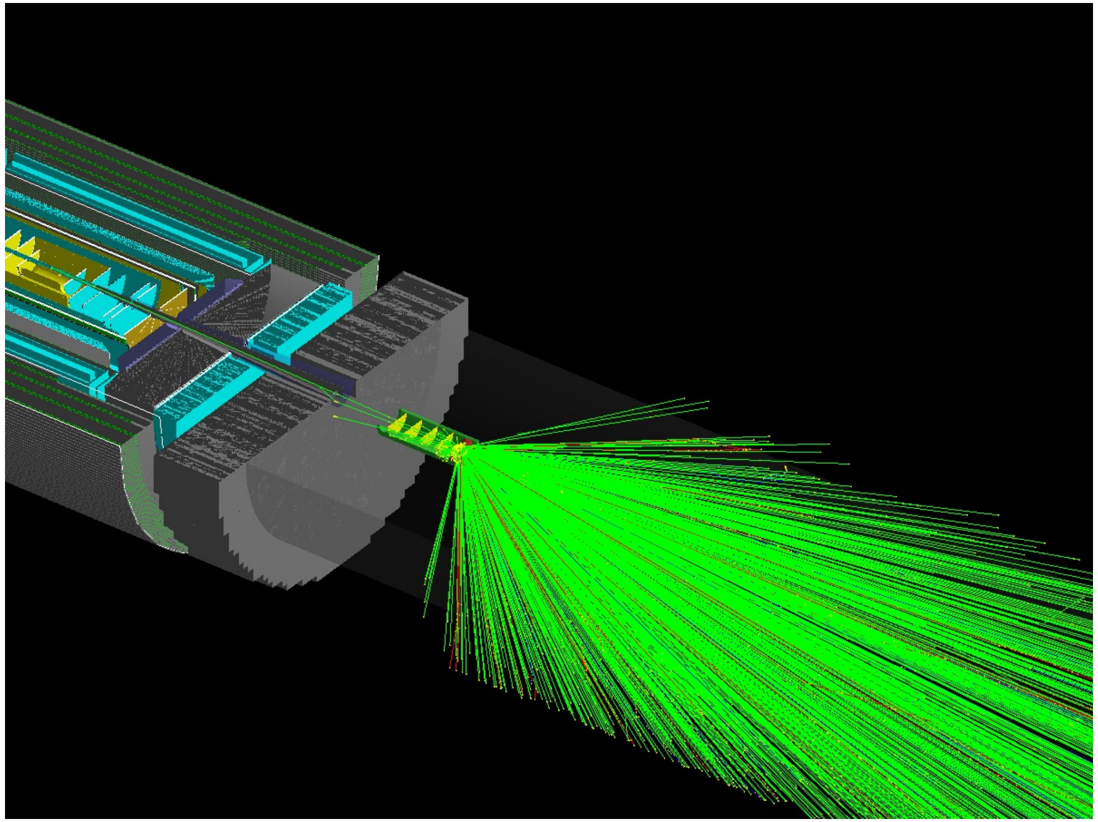
Photon detection study of the B0

Courtesy to Quan Wang
University Kansas.



- After coordination correction
- Beam direction (0,0,+)
- B0 Calorimeter
  - $PbWO_4$
  - R=20cm, thickness = 10cm, 20cm

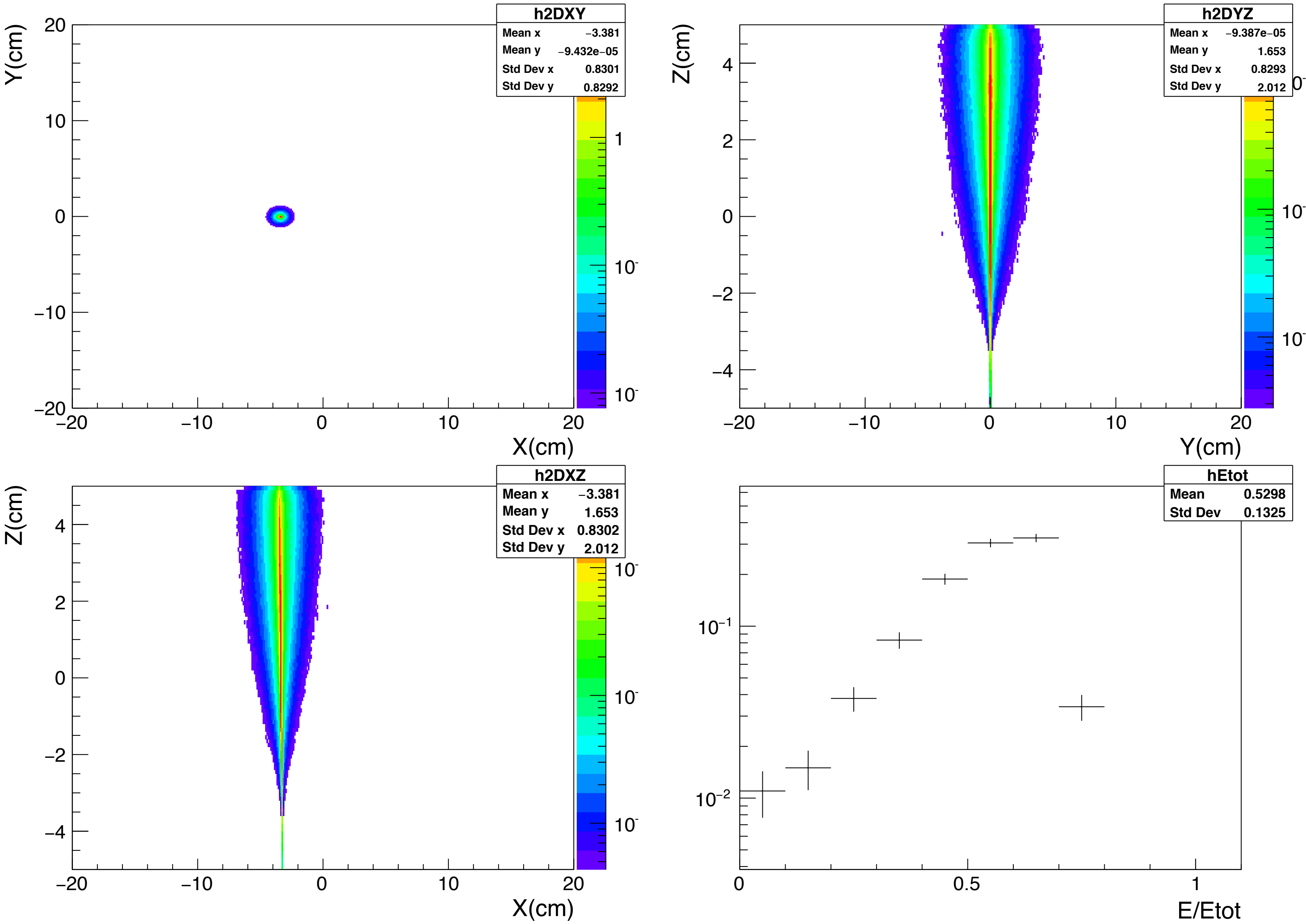
Photon detection study of the B0



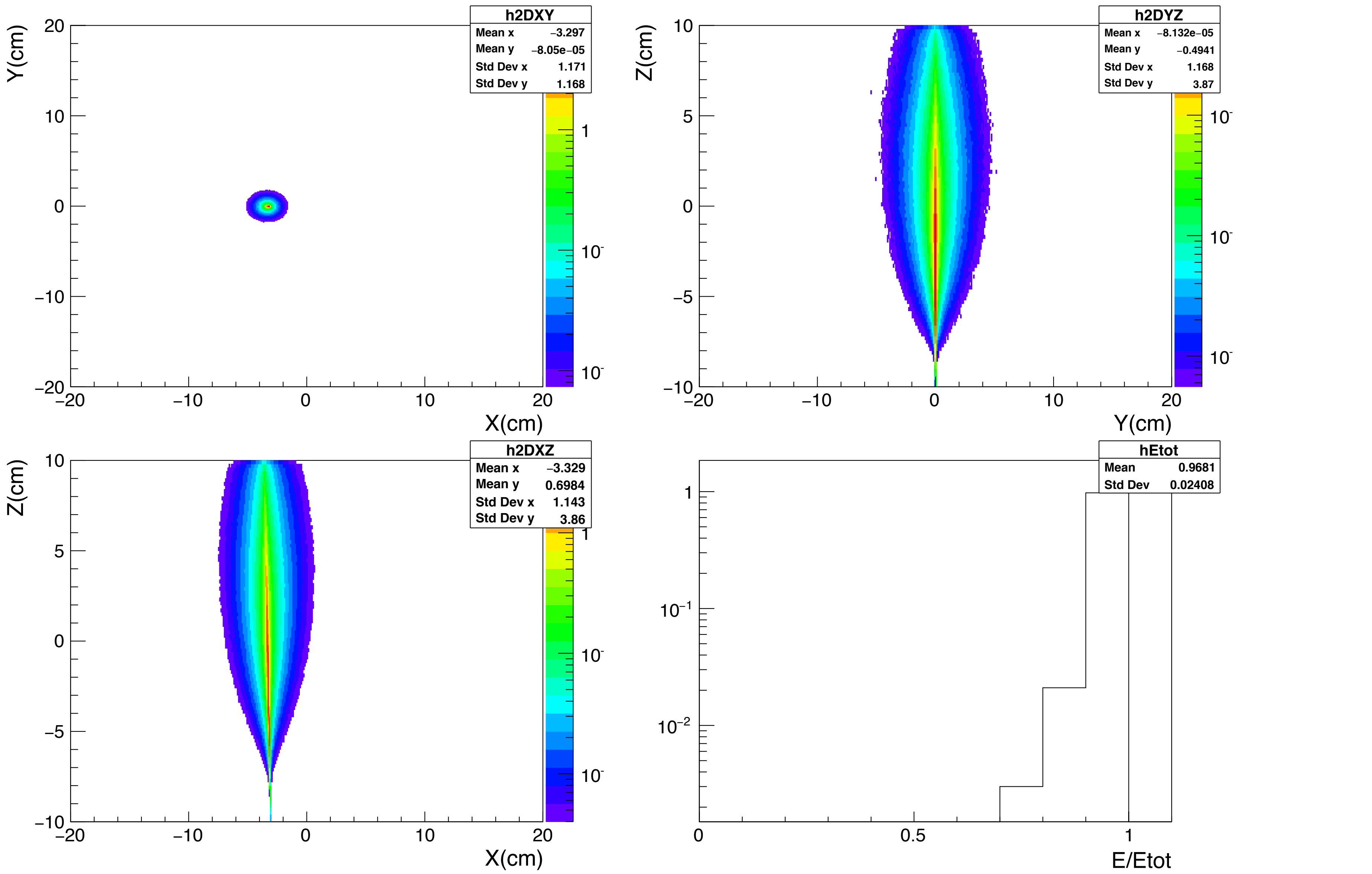
- After coordination correction Beam direction

  (-E*26mrad,0,E)
- B0 Calorimeter
  - $PbWO_4$
  - R = 20cm,
  - Thickness = 10cm, 20cm
- Gamma, E
  - 0.1, 0.3, 0.5, 1, 3, 5, 10 GeV

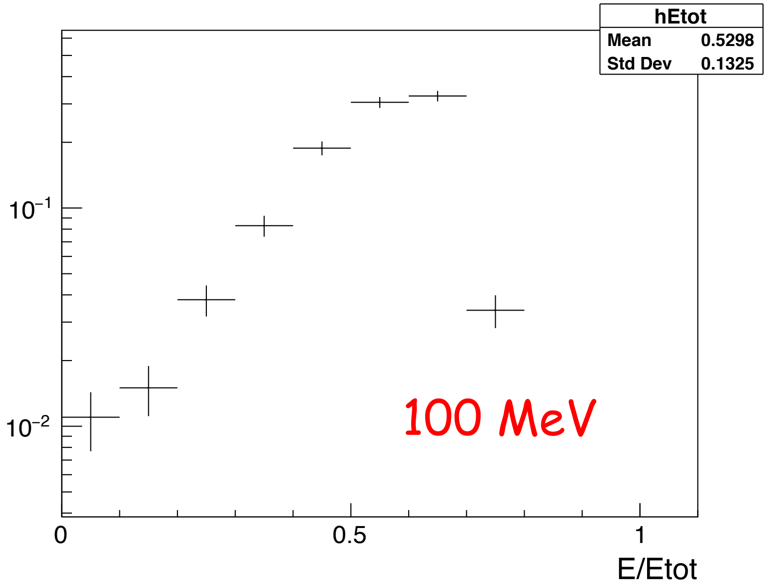
B0 Calorimeter 10 cm Gamma 100 MeV



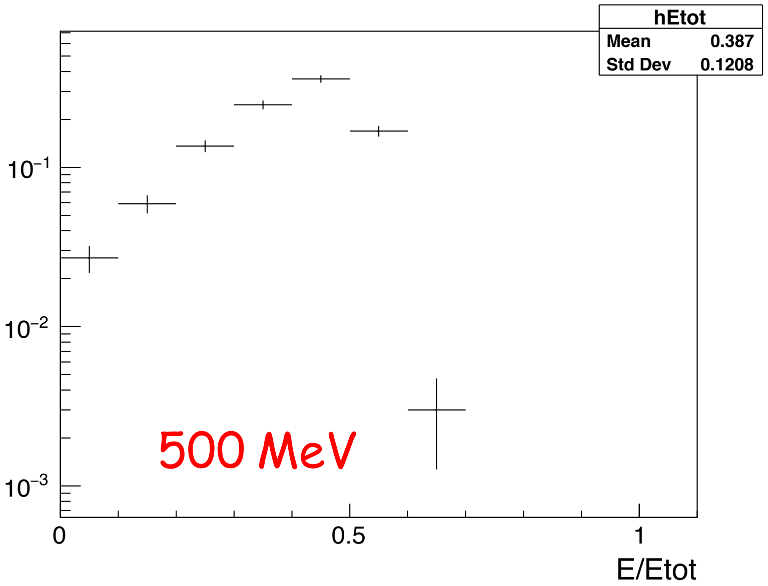
B0 Calorimeter 20 cm Gamma 100 MeV



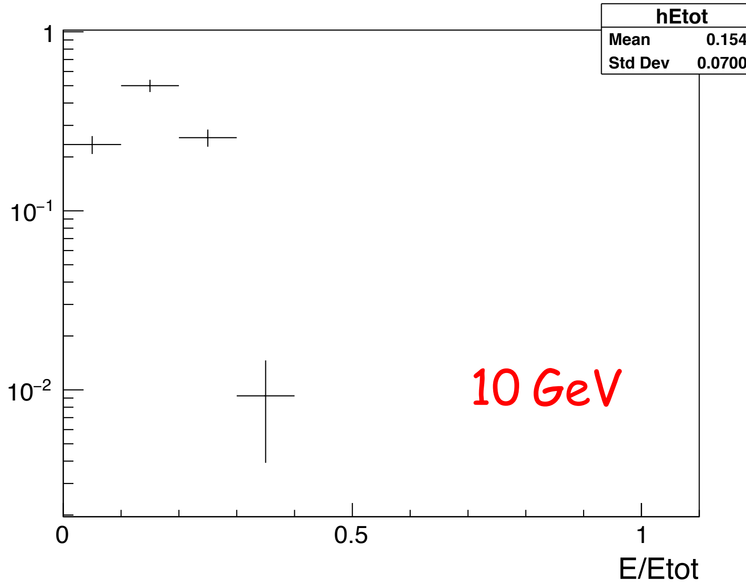
10 cm



hEtot
Mean 0.5298
Std Dev 0.1325
10^{-1}
10^{-2}
0
0.5
1
E/Etot
100 MeV

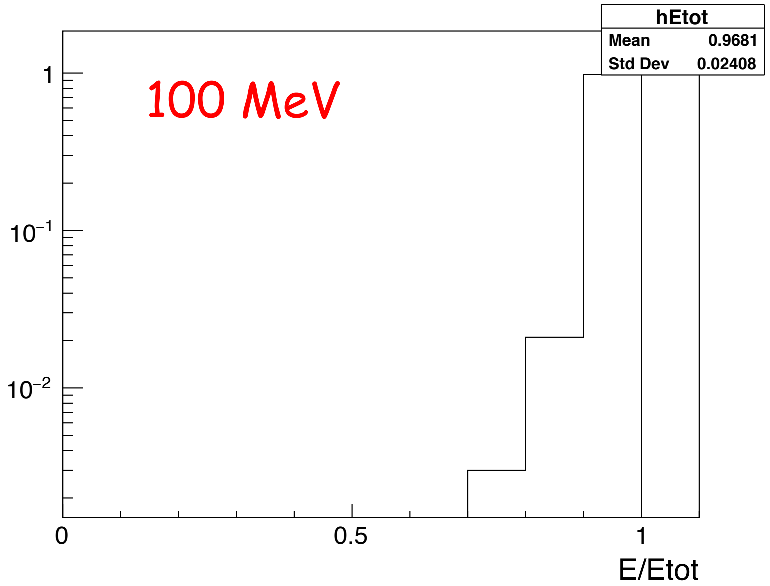


hEtot
Mean 0.387
Std Dev 0.1208
10^{-1}
10^{-2}
10^{-3}
0
0.5
1
E/Etot
500 MeV

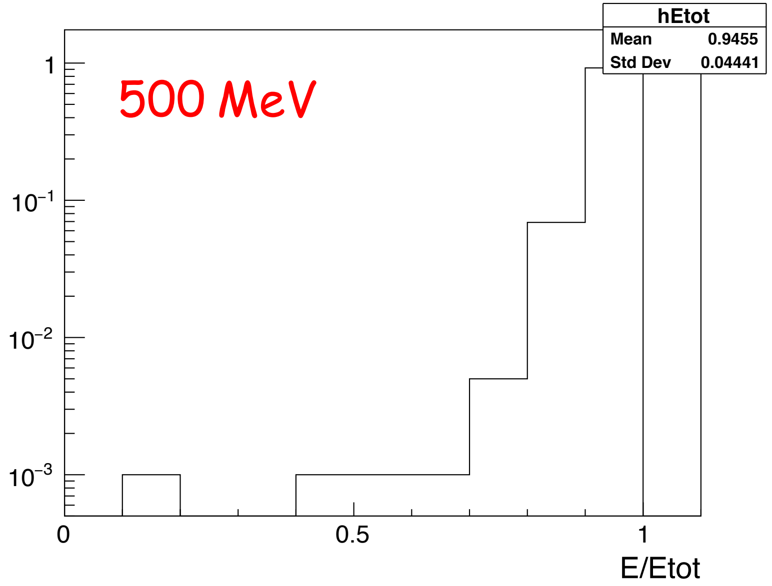


hEtot
Mean 0.154
Std Dev 0.0700
1
10^{-1}
10^{-2}
0
0.5
1
E/Etot
10 GeV

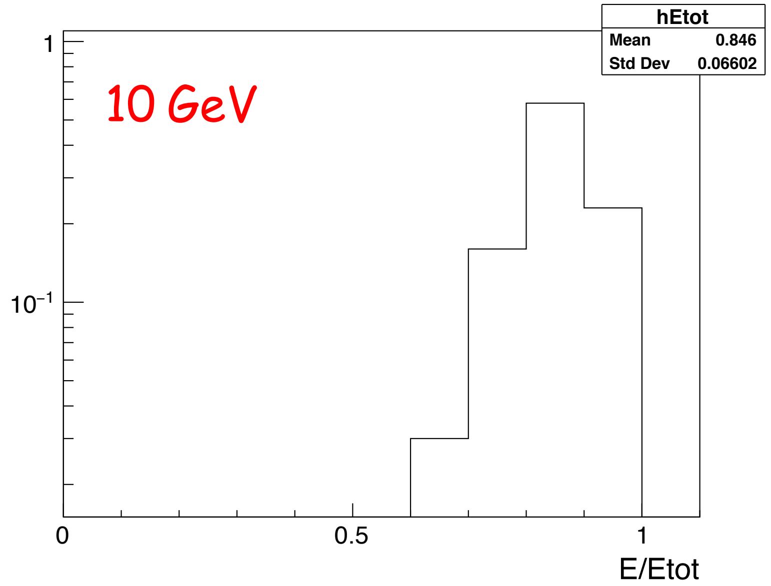
20 cm



hEtot
Mean 0.9681
Std Dev 0.02408
1
10^{-1}
10^{-2}
0
0.5
1
E/Etot
100 MeV



hEtot
Mean 0.9455
Std Dev 0.04441
1
10^{-1}
10^{-2}
10^{-3}
0
0.5
1
E/Etot
500 MeV



hEtot
Mean 0.846
Std Dev 0.06602
1
10^{-1}
0
0.5
1
E/Etot
10 GeV

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:
- 1^{st} step, positioning detector planes in the simulation

Thank you for
your attention.