ECCE Forward & Backward detector systems

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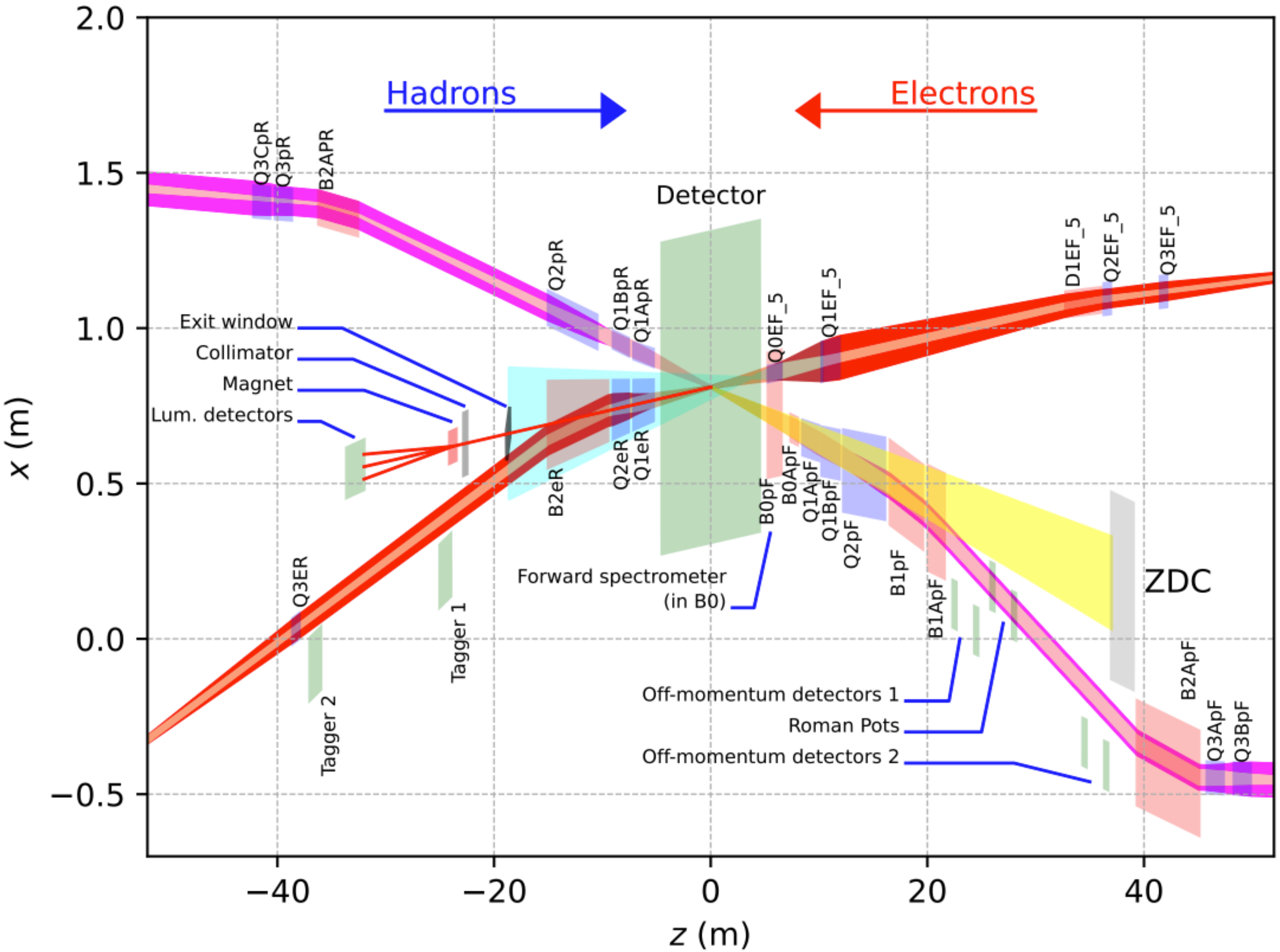
for the ECCE Consortium

Detector Integration Meeting

Far-Forward and Far-Backward regions



ZDC

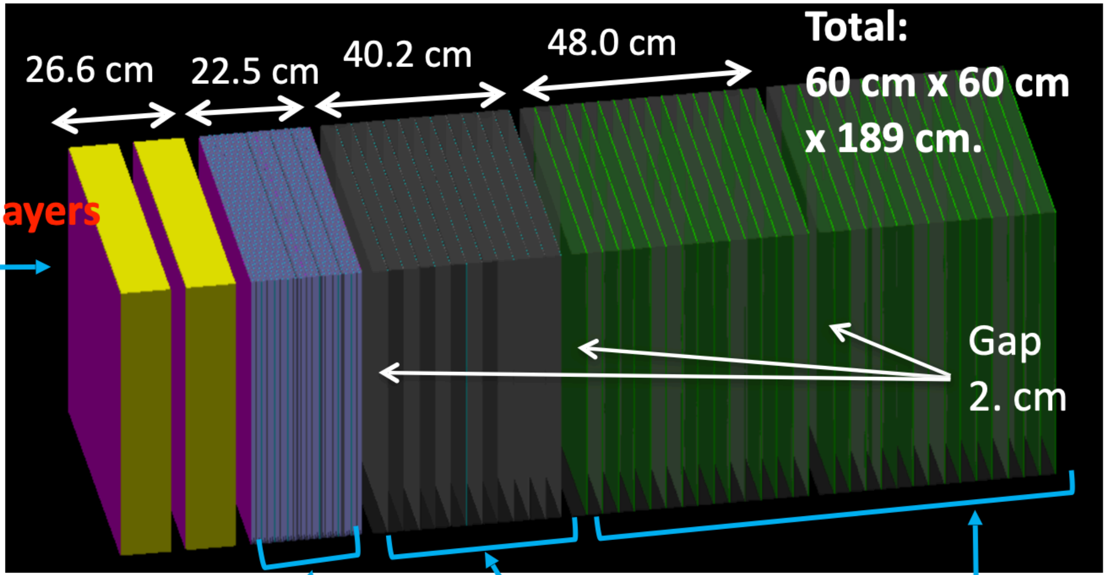
Courtesy to
Shima Shimizu (RIKEN/JSPS)

Shima
Shimizu

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 ($PbWO_4$)
3cm x 3cm x 10 cm
Gap 3 cm

2 layers



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 +

x 2

20 layers

+

1 layer

12 layers

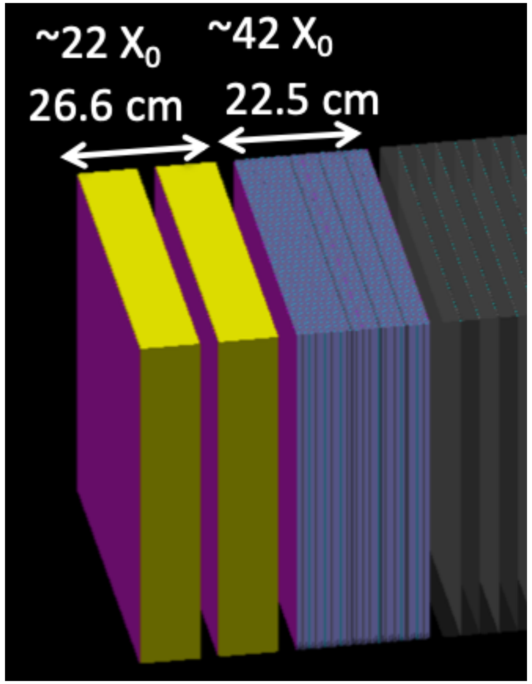
Pb 3cm Thickness
PET (Glue) 0.11 mm
Silicon 1 cm x 1 cm x 320 µm
PET (Glue) 0.13 mm
PET(FPC) 0.28 mm
Gap 1. mm

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

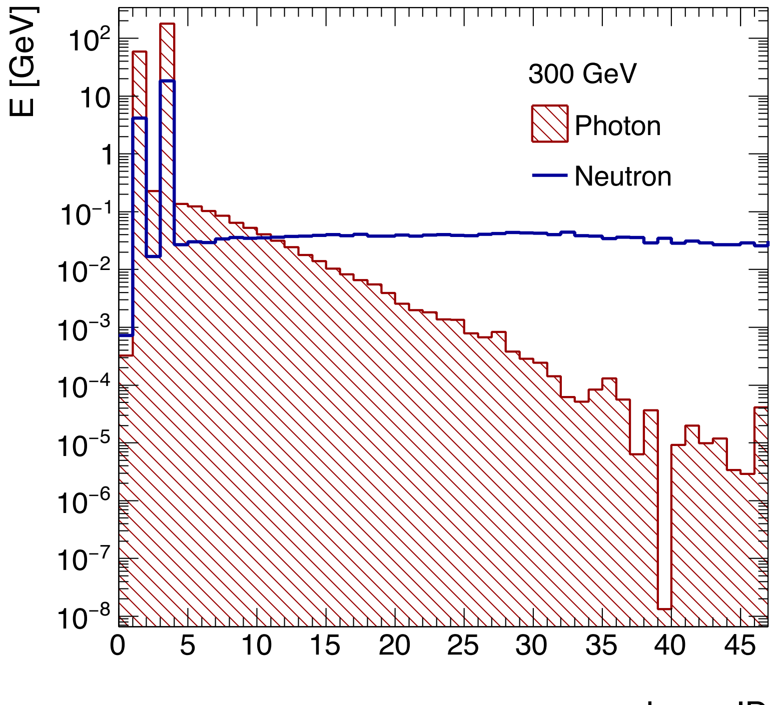
ZDC study and optimization



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

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

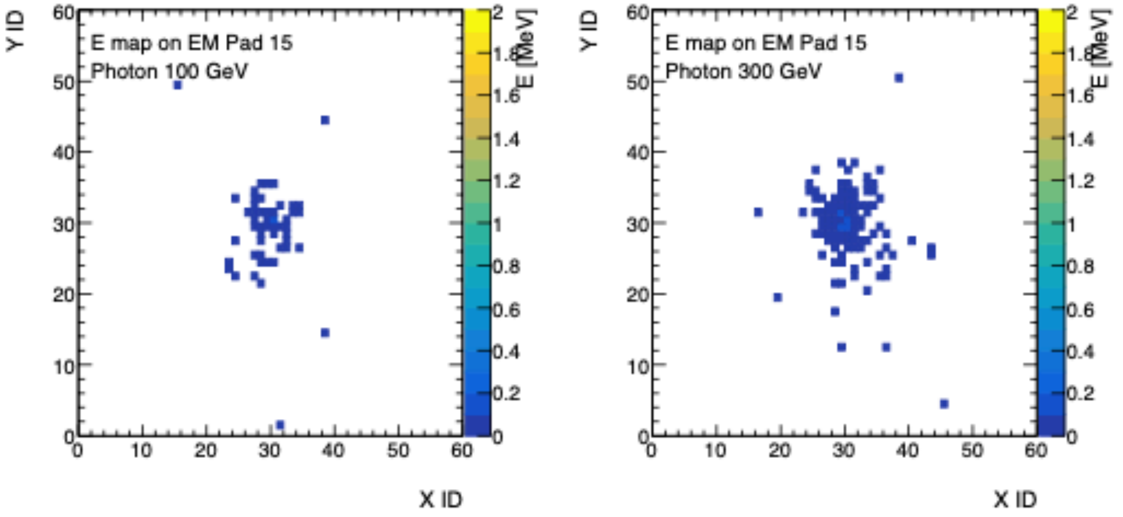
Neutron / photon separation
Photon energy reconstruction/resolution
Position resolution



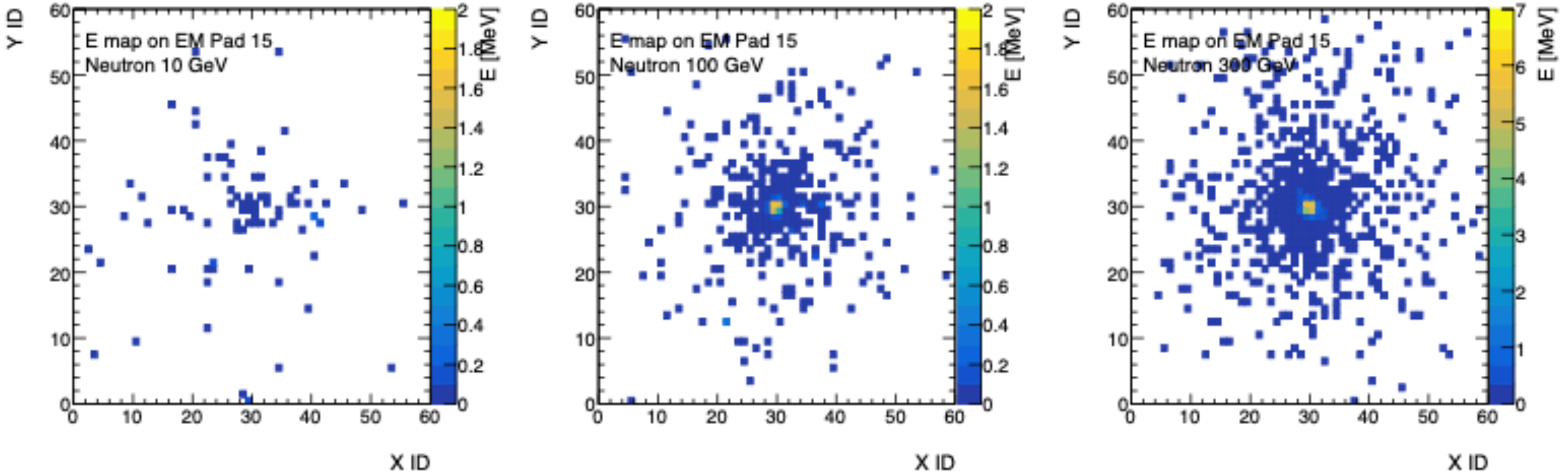
Energy deposits on Layer ID 20

Photon

Difference of shower shape is seen at Layer 20.



Neutron



Roman Pots

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

Expected technology: AC-LGADs

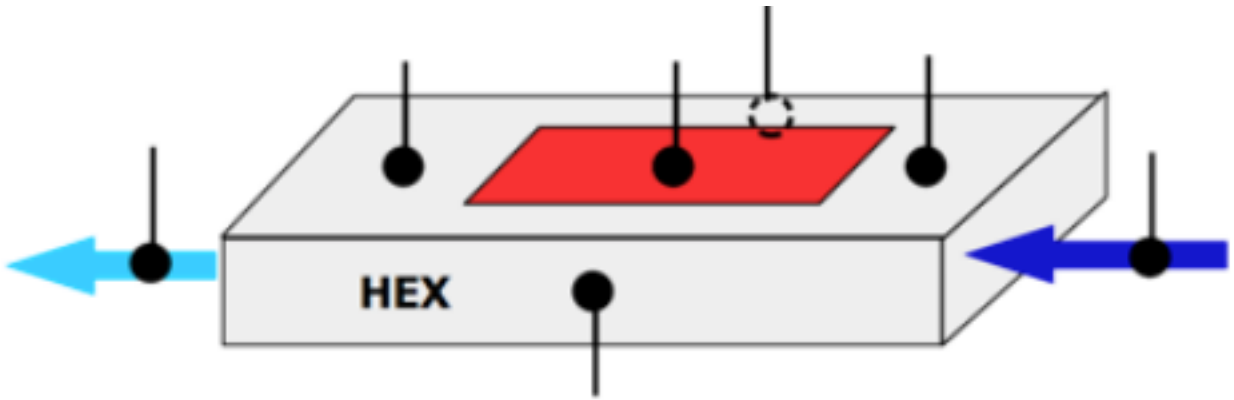
Technology	Spatial Resolution	Integration time	Prototype sensor active area	Prototype status	Power Consumption	Radiation Tolerance
AC-LGAD	20-30 μm	< 300 ps	2.5 mm by 2.5 mm	ready	< 350 mW/cm^2	~5×10^{15} n_{eq}/cm^2
MALTA	~5 μm	~ 5ns	2cm by 2cm	ready	Under R&D	~1×10^{15} n_{eq}/cm^2

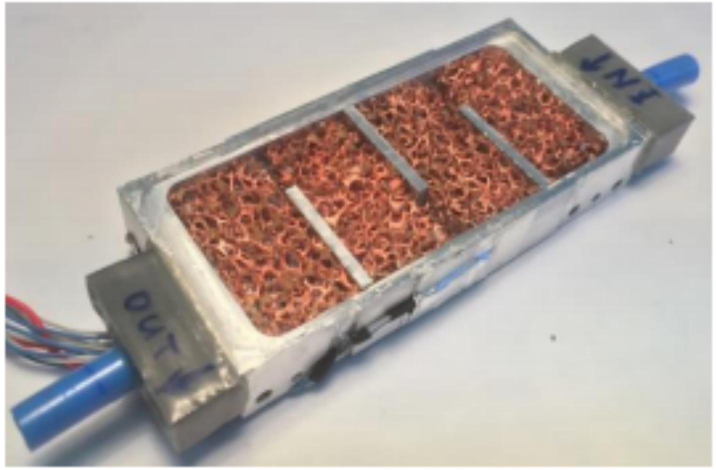
Both prototype sensors are under R&D and ongoing tests at LANL

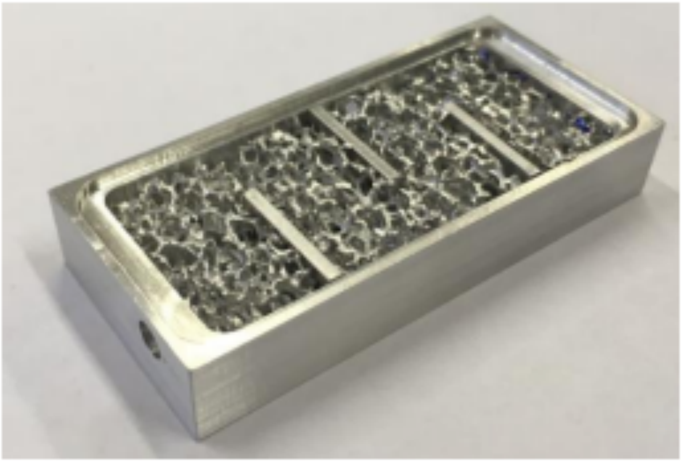
ASIC readout for AC-LGAD, require cooling: need to dissipate approximately 750 W per station of RP

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

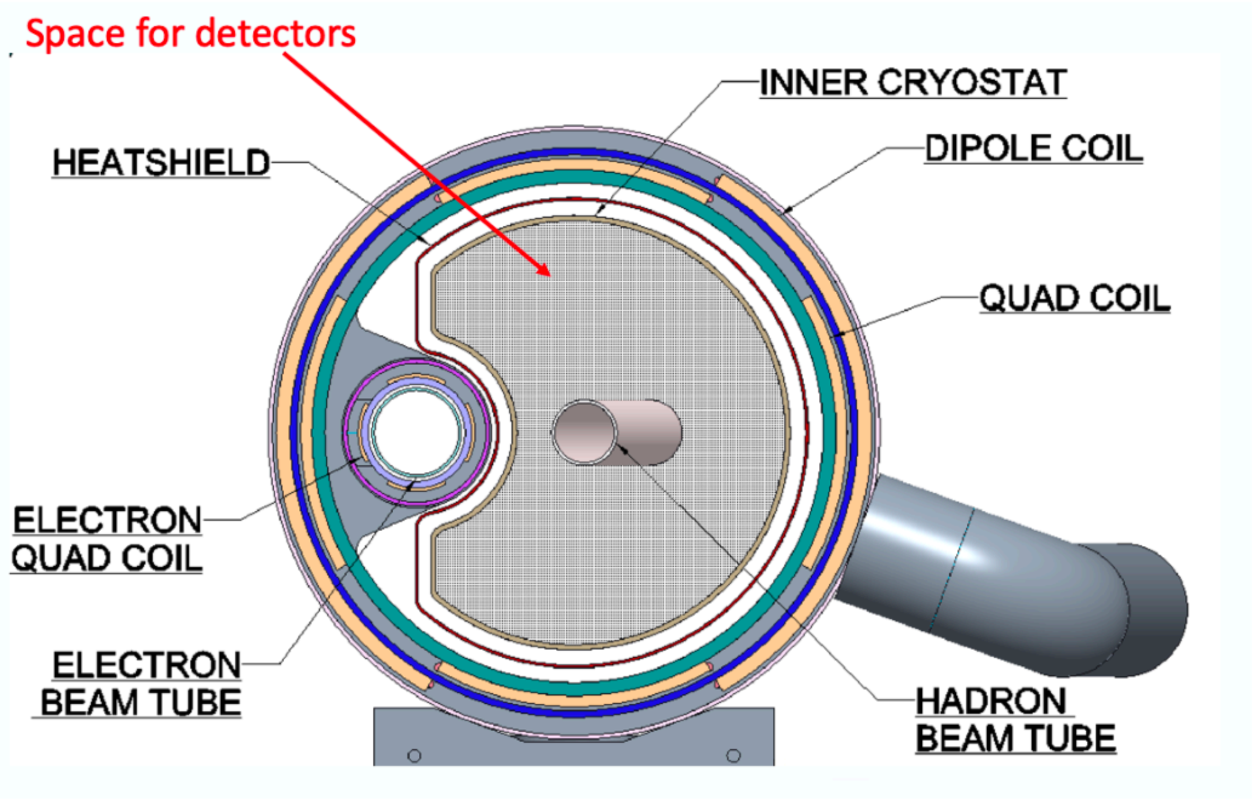
- Air Vortex cooling using compressed air and foam metal heat sink is working well for AFP and PPS at the LHC.
- Compressed air will be available at EIC,
- Can cool up to 900W per pot but could go higher for higher pressure, say 9 bar

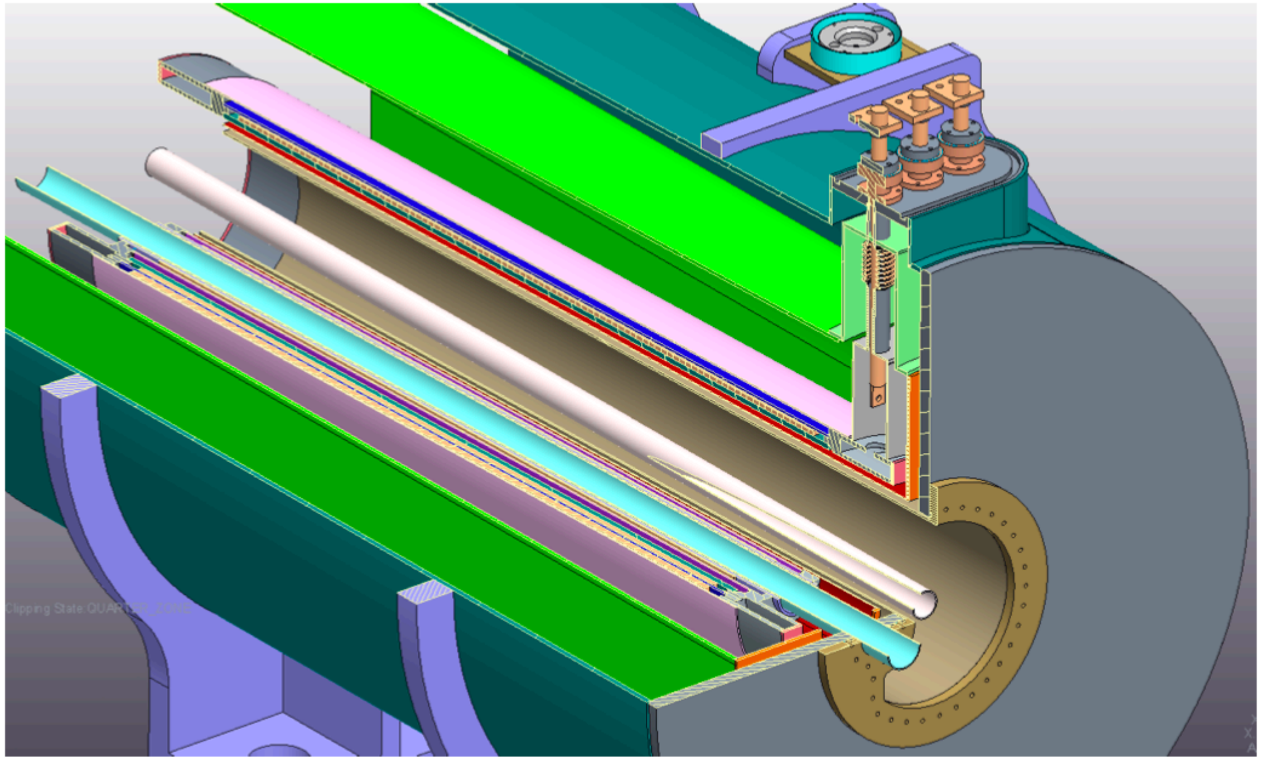






B0 tracker and calorimeter





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
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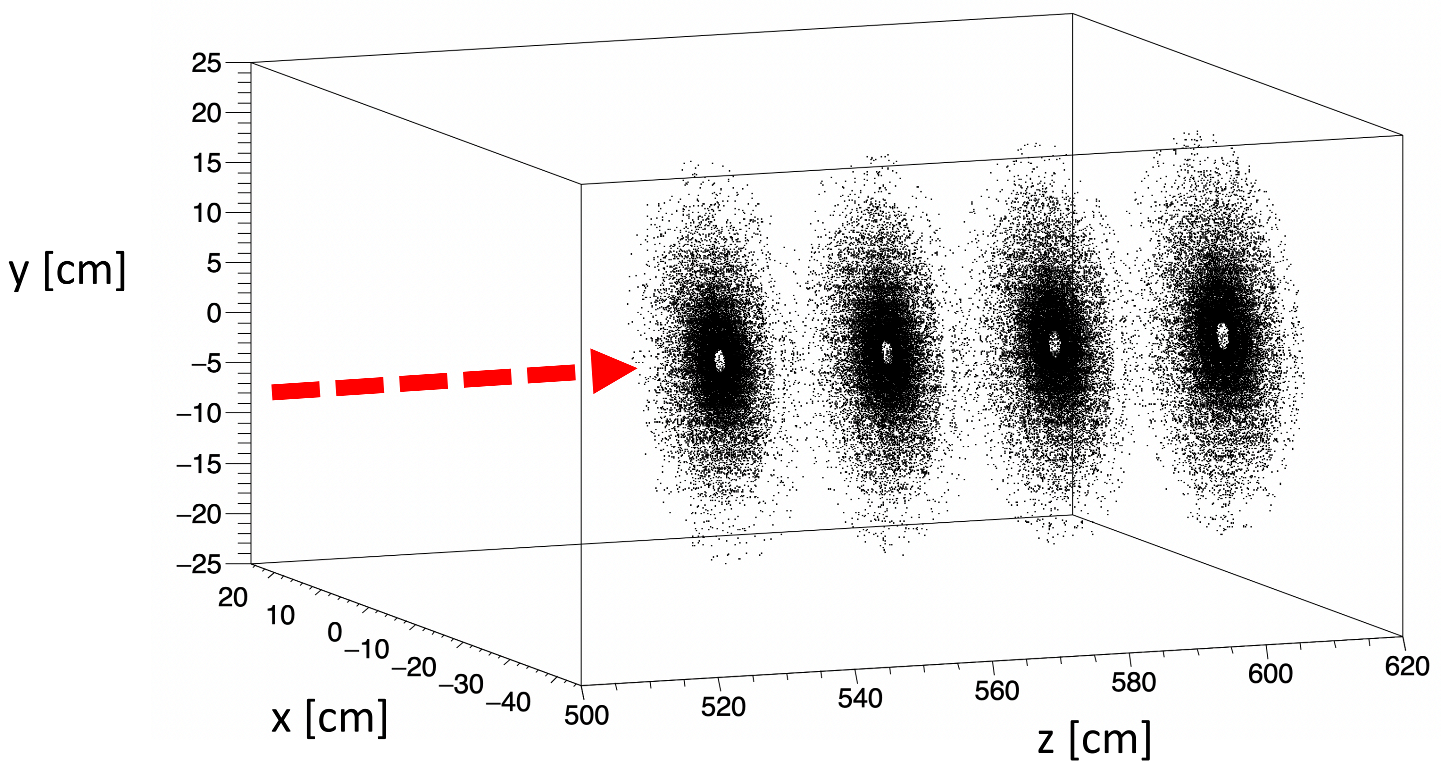
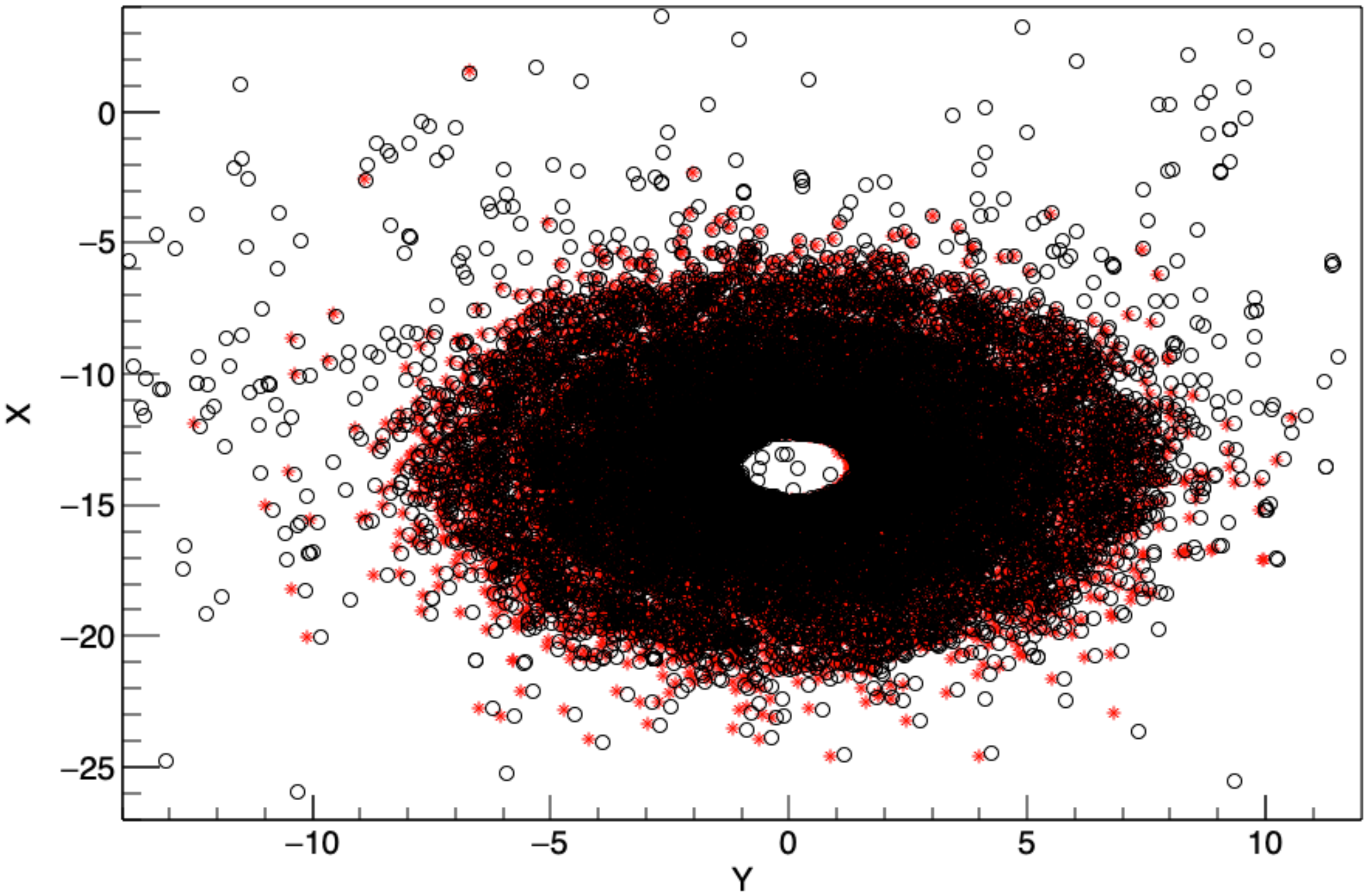


Current implementation

Hits clearly identified in 4 tracking layers

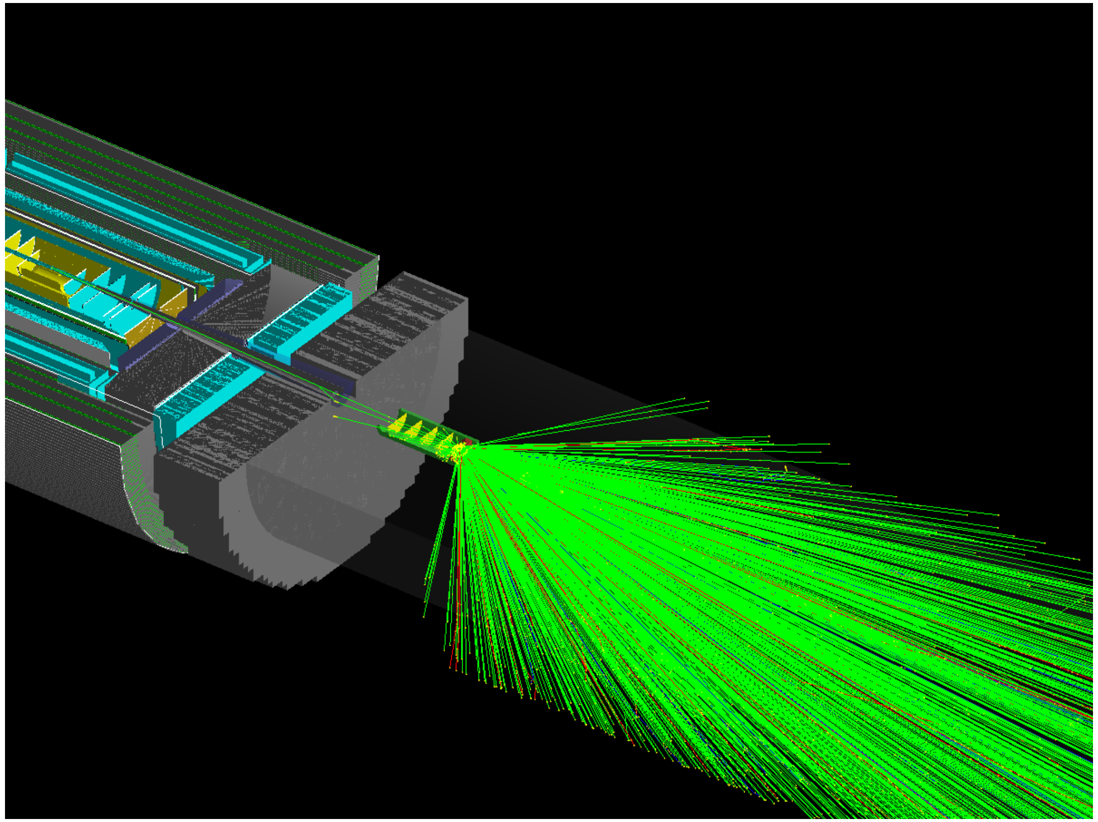
Red: Projection of the protons to the 1st layer of B0 (assuming straight line)

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



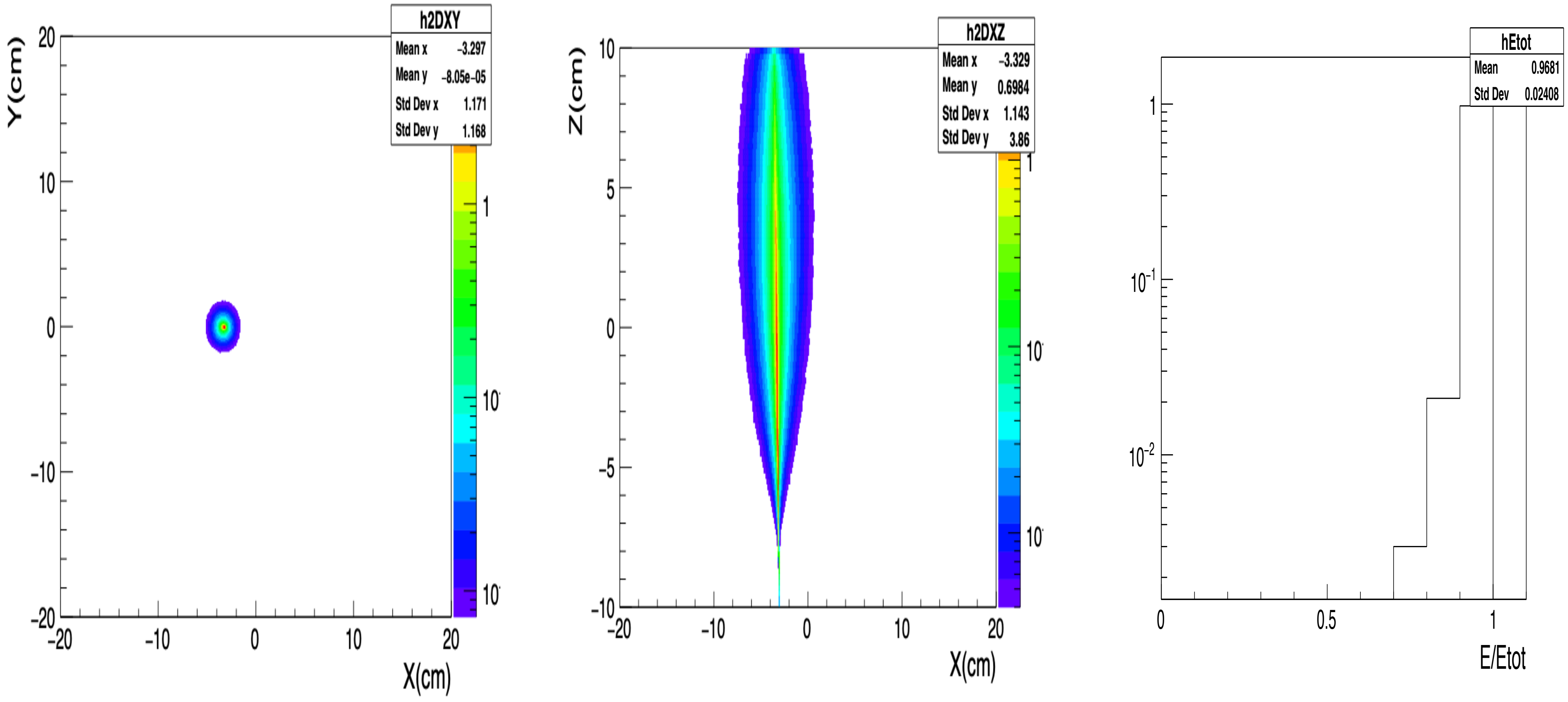
Shift between black and red symbols is due to the magnetic field.

Photon detection study of the B0



- After coordination correction
- Beam direction (-E*26mrad,0,E)
- B0 Calorimeter
  - PbWO4
  - R=20cm, thickness = 10cm, 20cm
- Gamma, E
  - 0.1, 0.3, 0.5, 1, 3, 5, 10 GeV

B0 Calorimeter 20 cm Gamma 100 MeV



Outlook

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

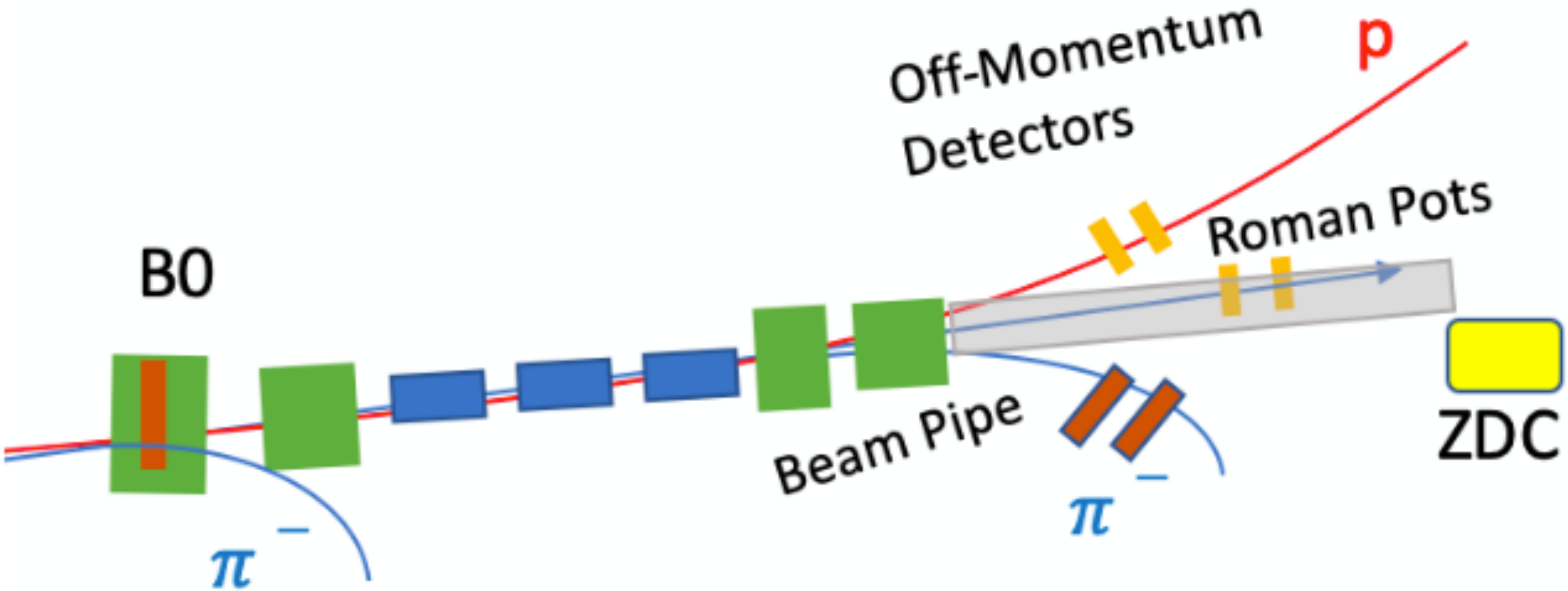
Roman pots:
Final selection of a detection technology
Channel count
Finalize the readout and estimate the heat load
Discussing cooling and mechanics with Prague group

B0 tracker:
Study of $PbWO_4$ for photon detection
Need 20cm $PbW0_4$ to measure high energy photons
Add realistic beam pipes to the simulation

Far-Backward, Low Q2 tag.
1st step, positioning detector planes in the simulation
Magnet components information needed

Backup

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

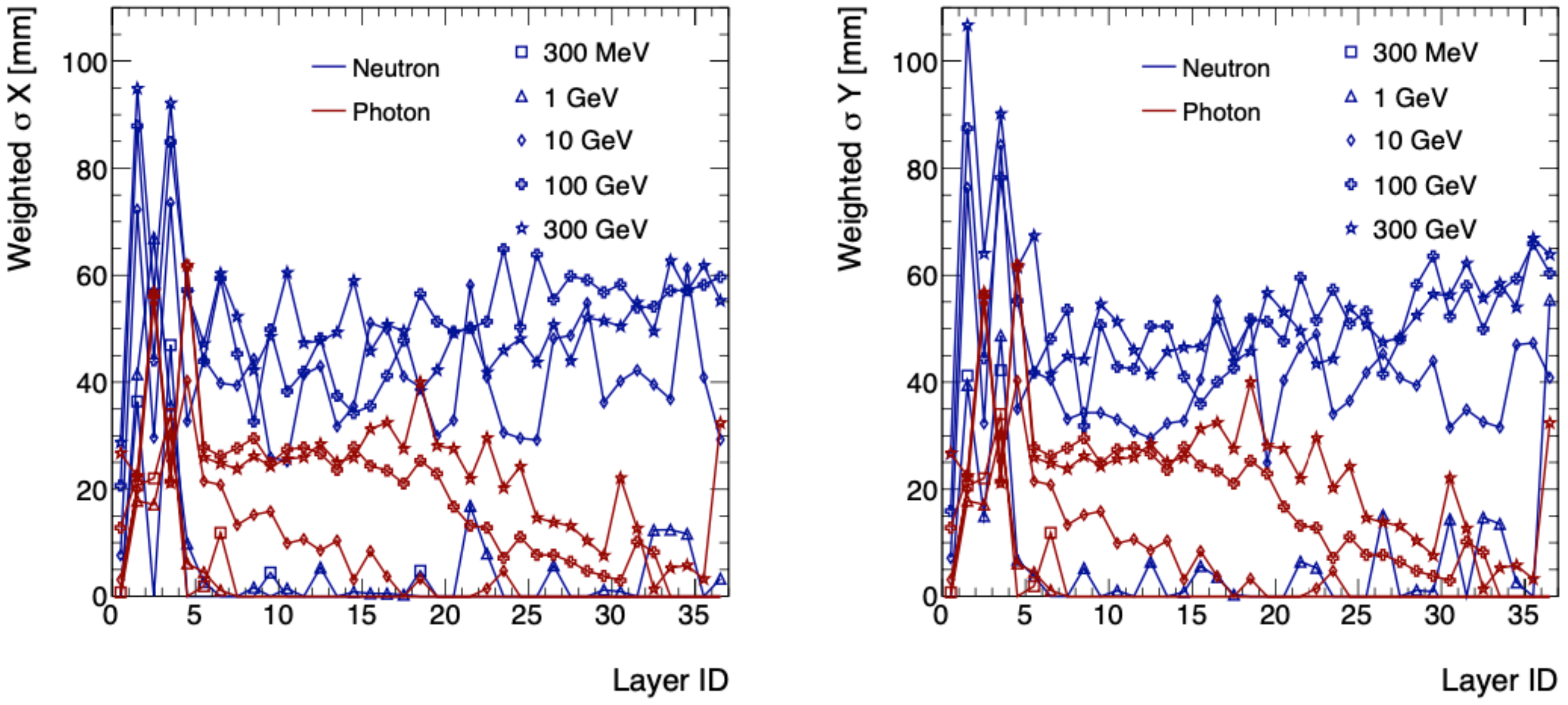
Channel count

Detector	Proposed technology
Zero-Degree Calorimeter (ZDC)	EMcal: Crystal (PWO?) + 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 (PWO?) or preshower?
Low-Q^2 tagger	Tracker? EMcal: Crystal (PWO?)

Transverse spread of energy deposits

Energy weighted sigma are checked.

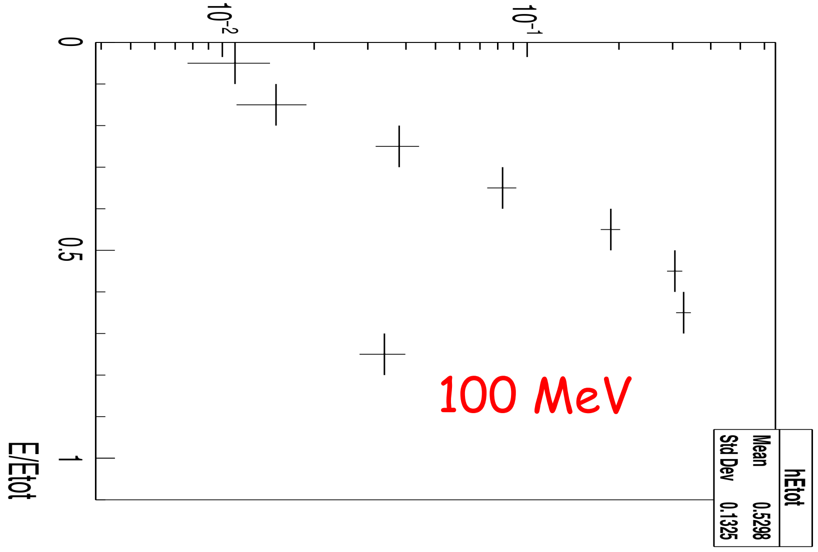
$$\sigma = \sqrt{\frac{\sum E_i (x_i - \bar{x})^2}{\sum E_i}} = \sqrt{\left|\frac{\sum E_i x_i^2}{\sum E_i} - \bar{x}^2\right|}, \text{ where } \bar{x} = \frac{\sum E_i x_i}{\sum E_i}$$

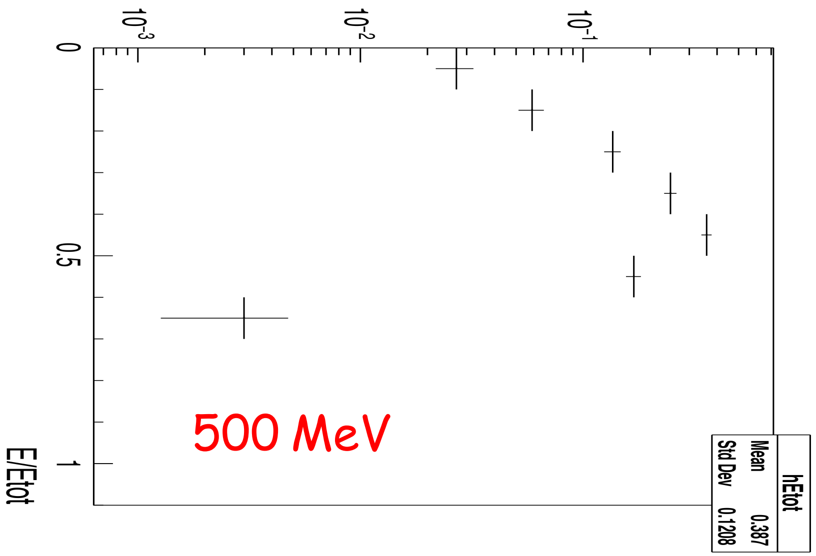


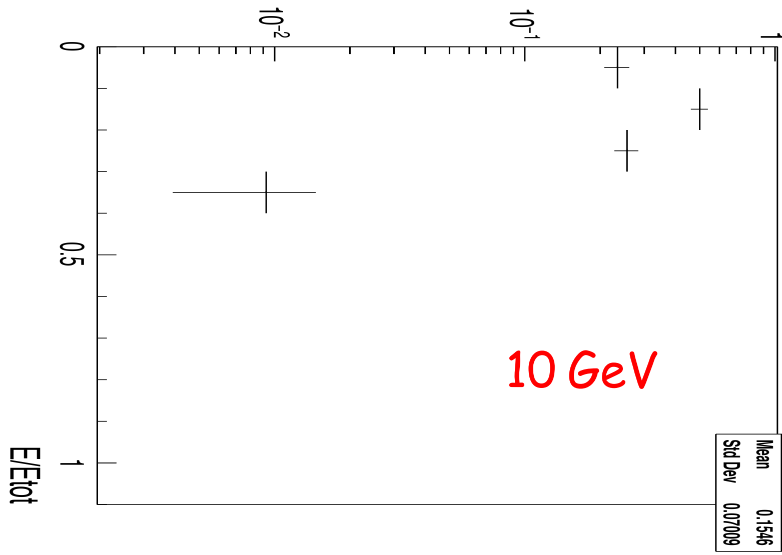
Difference of shower width is visible in Si/W layers (Layer ID>5)

Photon shower is fading around Layer ID 20 - 30

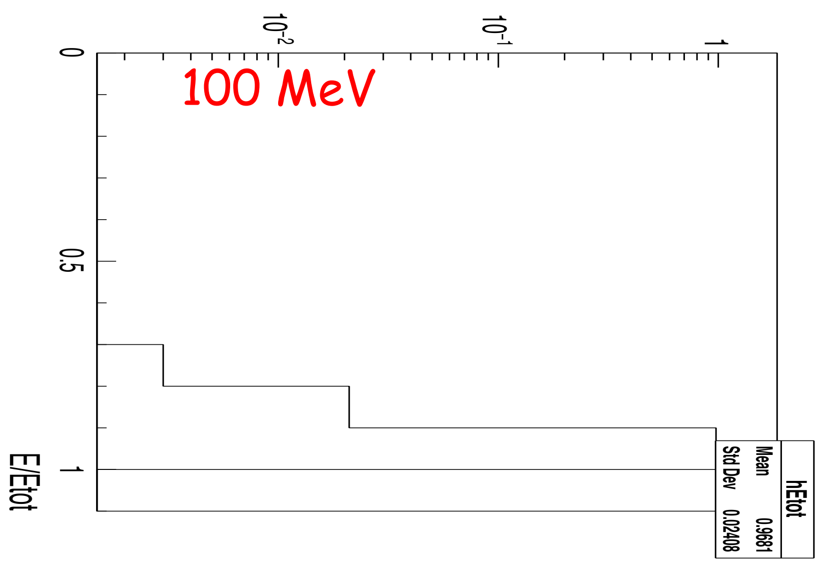
10 cm

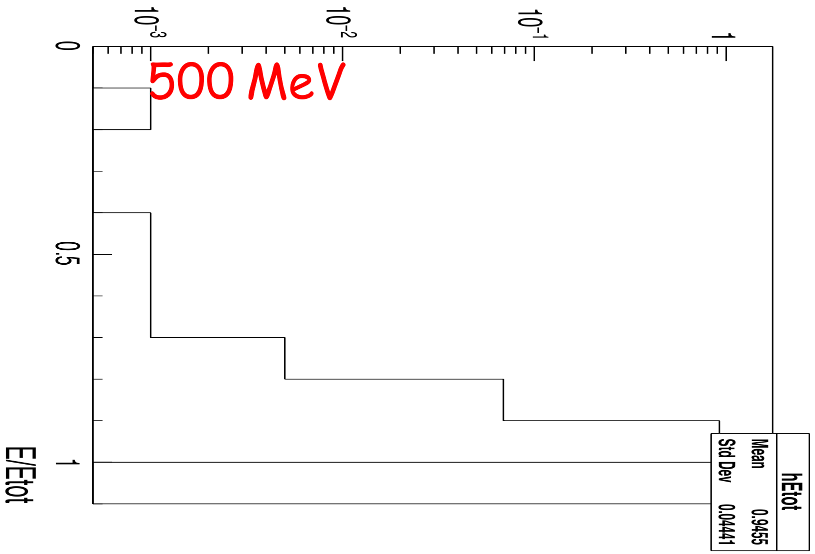

100 MeV
E/Etot
hEtot
Mean 0.5298
Std Dev 0.1325

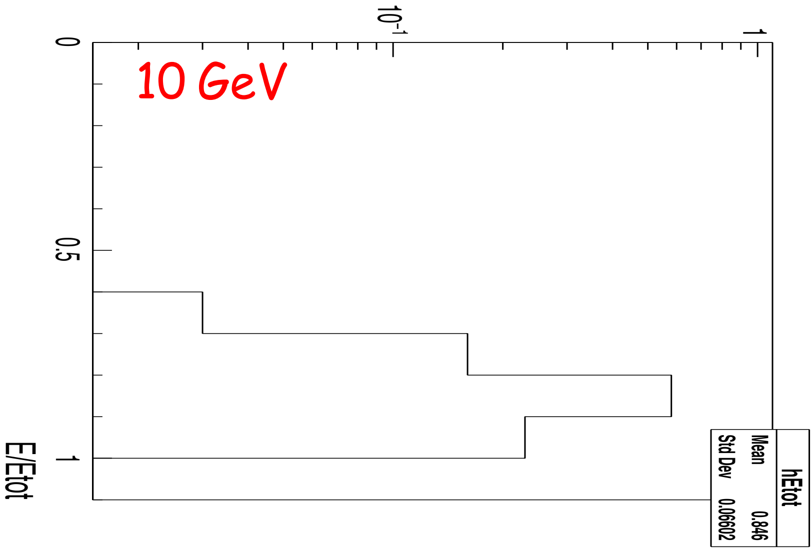

500 MeV
E/Etot
hEtot
Mean 0.387
Std Dev 0.1208


10 GeV
E/Etot
Mean 0.1546
Std Dev 0.07009

20 cm

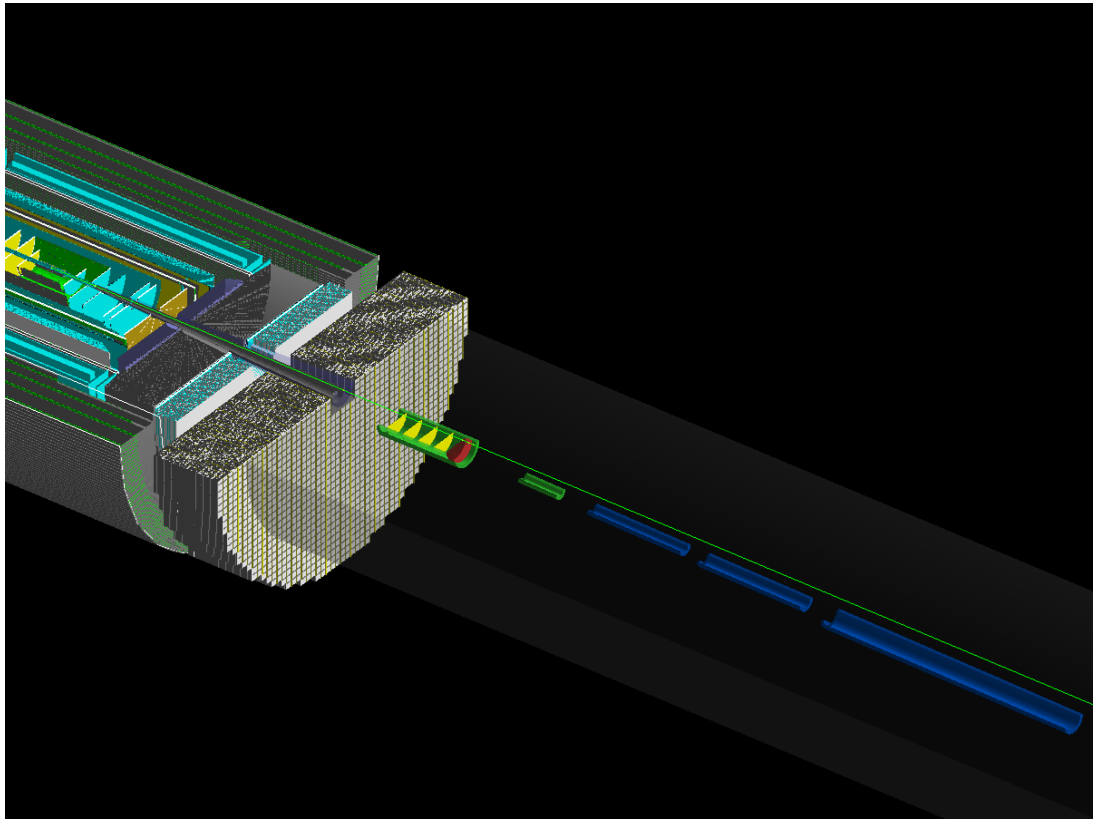

100 MeV
E/Etot
hEtot
Mean 0.9681
Std Dev 0.02408


500 MeV
E/Etot
hEtot
Mean 0.9455
Std Dev 0.04441


10 GeV
hEtot
Mean 0.846
Std Dev 0.06602

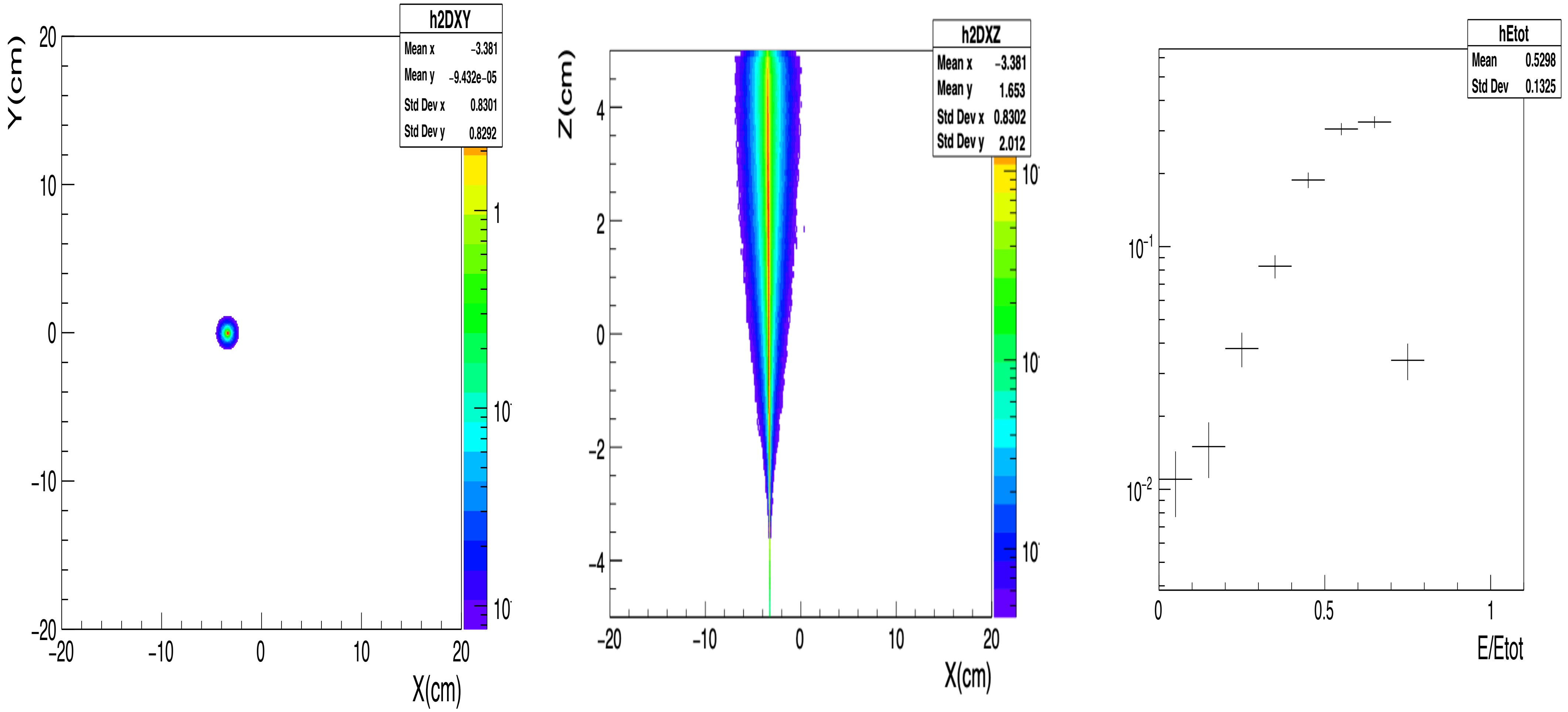
Photon detection study of the B0

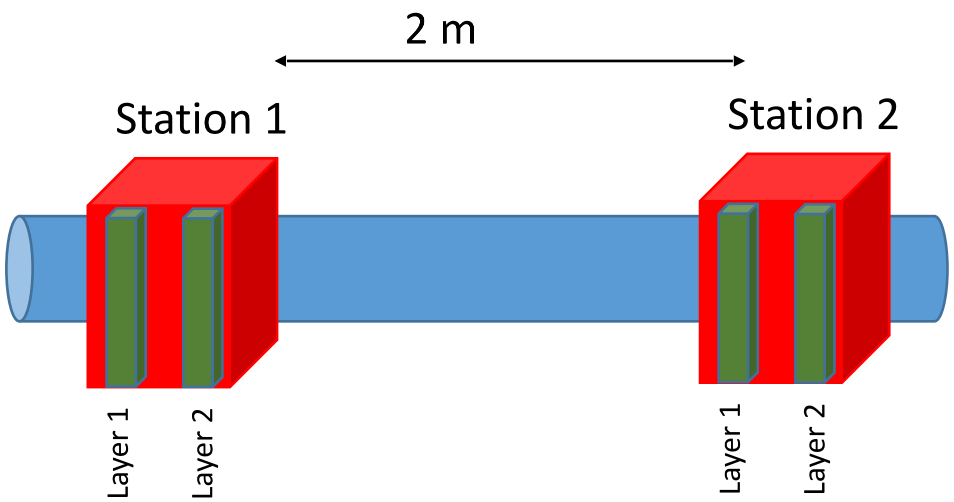
Courtesy to Quan Wang

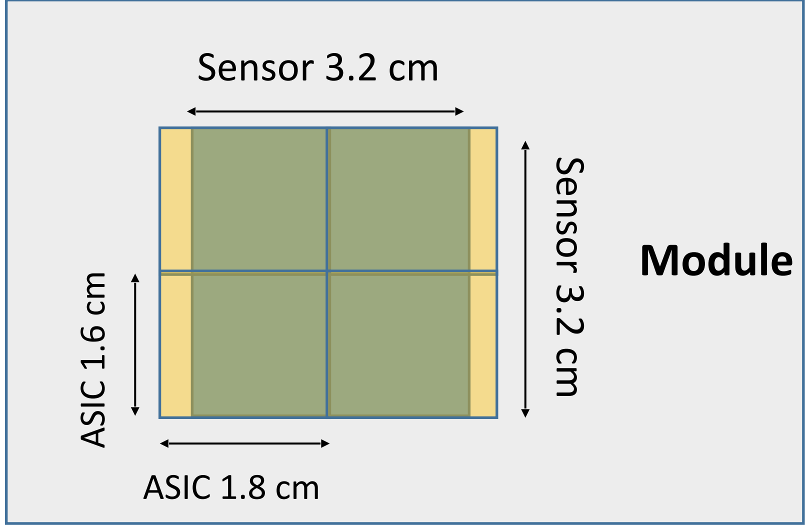


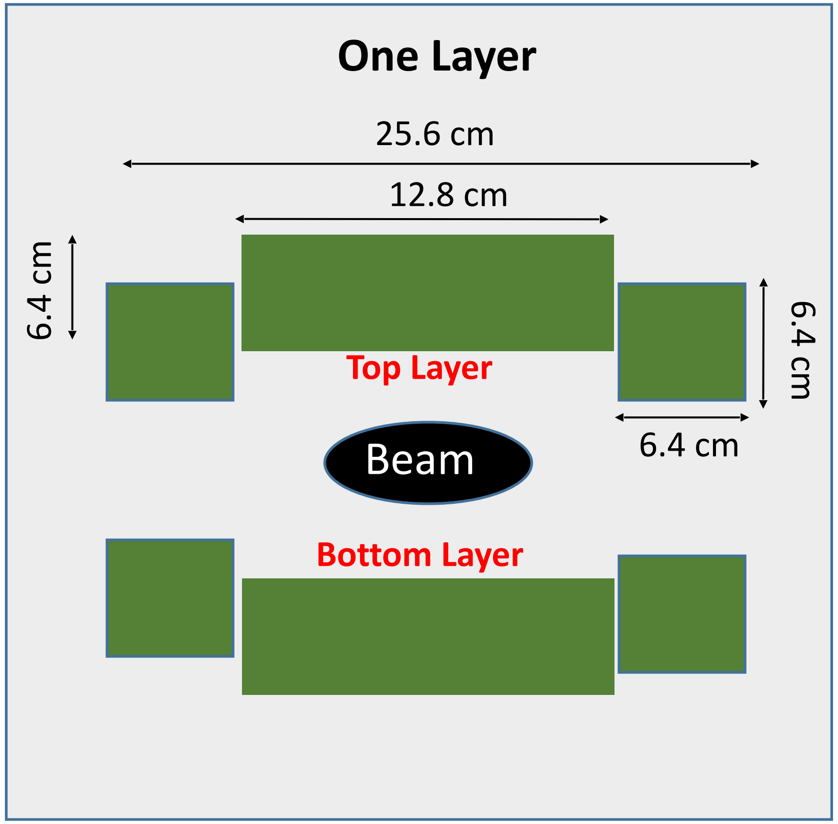
- After coordination correction
- Beam direction (0,0,+)
- B0 Calorimeter
    - PbWO4
    - R=20cm, thickness = 10cm, 20cm

B0 Calorimeter 10 cm Gamma 100 MeV









No. Modules/layer: 2x(2x(2x2) + (2x4)) =32
No. Modules: 32*2*2 = 128
Silicon Area: 128*(3.2*3.2) = 1310.7 cm2