Status of ZDC

Shima Shimizu

18/June/2021 Forward/Backward WG meeting

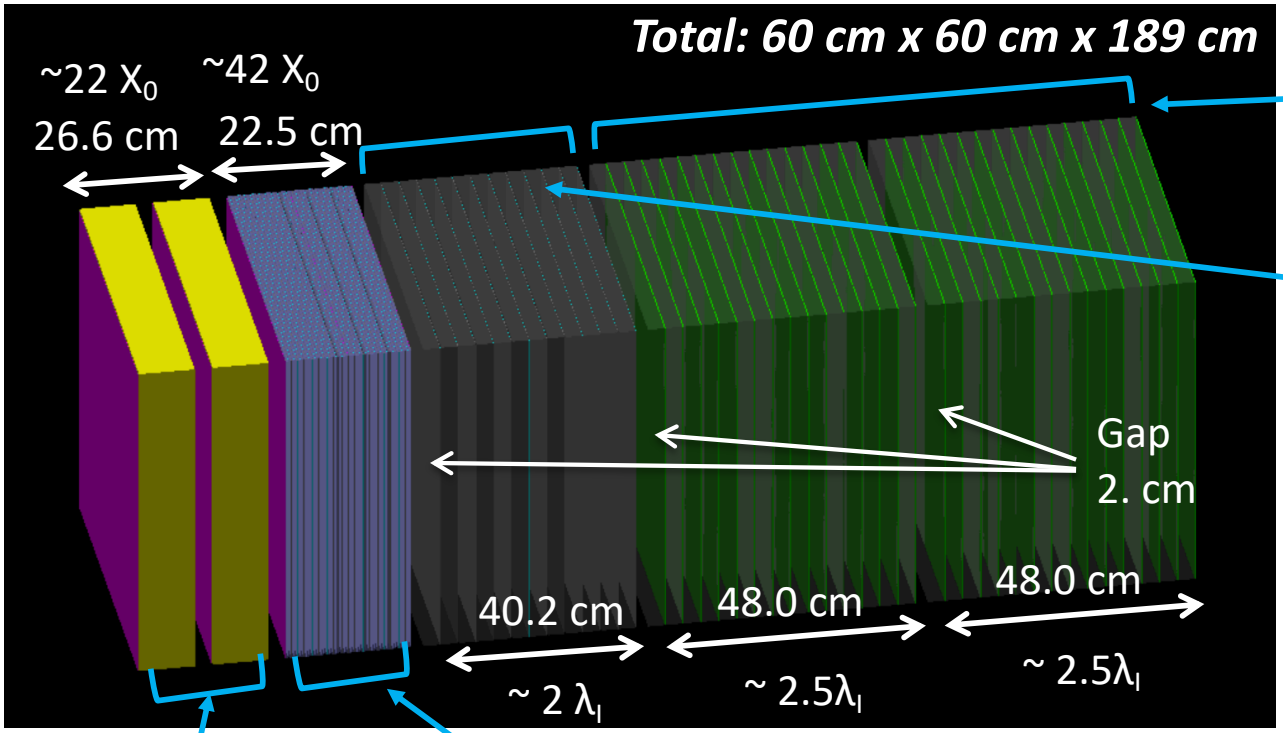
Current status of ZDC

- The first version of the ZDC design is in Fun4All.
  - Crystal + ALICE FoCal style EM and hadron calorimeter.
  - G4Hits to which ZDC layer/pixel information attached are available.
  - eic/fun4all_eicdetectors/simulation/g4simulation/g4zdc

- ZDC will not be in the standard simulation, but it will have dedicated photon or neutron samples for study.
  - Coordinated by Diffraction and Tagging group.

First ZDC design

Plots of energy deposition are in backup slides.



30 layers (15 layers x 2)

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

12 layers

Pb 3cm Thickness
PET (Glue) 0.11 mm
Silicon
1 cm x 1 cm x 320 µm
PET (Glue, FPC) 0.41 mm
Gap 1. mm

2 layers

Silicon
3 mm x 3mm x 300 µm
PET (Glue, FPC) 0.39 mm
Gap 1.2mm
Crystal (PbWO4)
3cm x 3cm x 10 cm
Gap 3 cm

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

= Si + 2 x

20 layers

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 1 cm x 1 cm x 320 µm
PET (Glue, FPC) 0.41 mm, Gap 1.mm

+

1 layer

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 3 mm x 3mm x 300 µm
PET (Glue, FPC) 0.39 mm, Gap 1.2mm

To do items

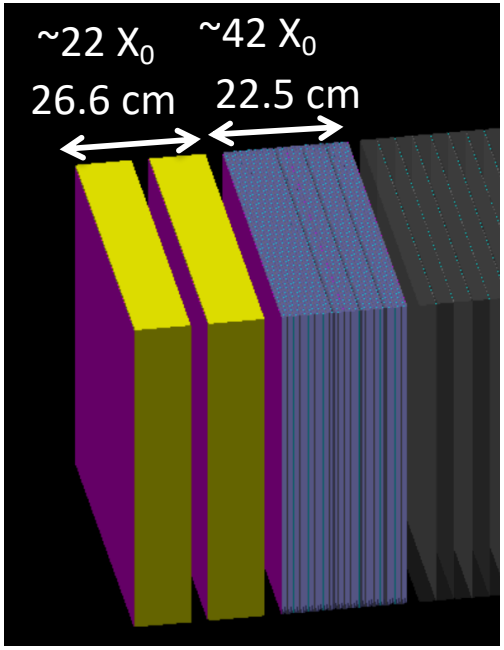
- Preparation of Reconstruction Codes.
  - Not G4Hits, but energy and timing information of tower/channel.
  - Estimation of sampling fraction.

- First optimization of the ZDC design.
  - Reduction of EM Calorimeter thickness. ← Today, ongoing.

- Consideration of readout system.
  - Check of the space.
  - Add materials to G4 ZDC design.

    (e.g. readout for the crystals will affect energy reconstruction.)

Reduction of EMC thickness



Possible reductions:

- Crystal 10 cm x2 → 7 cm (7.9 X_0) x2
  - Can we keep the position and energy resolution?

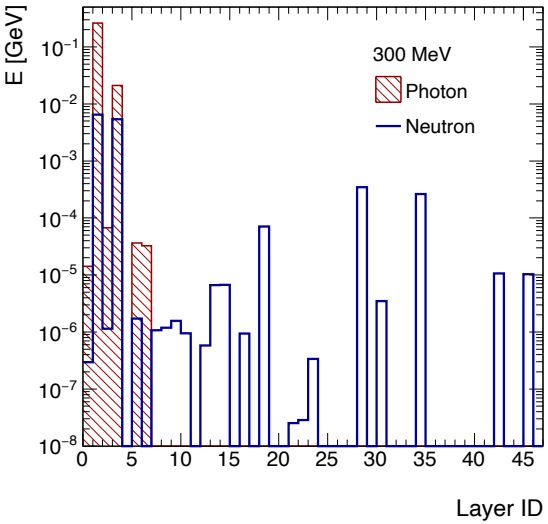
- W/Si 42 layers → ~ 30 layers
  - Does it affect photon energy reconstruction?
  - How many layers we need, to distinguish neutrons and photons?

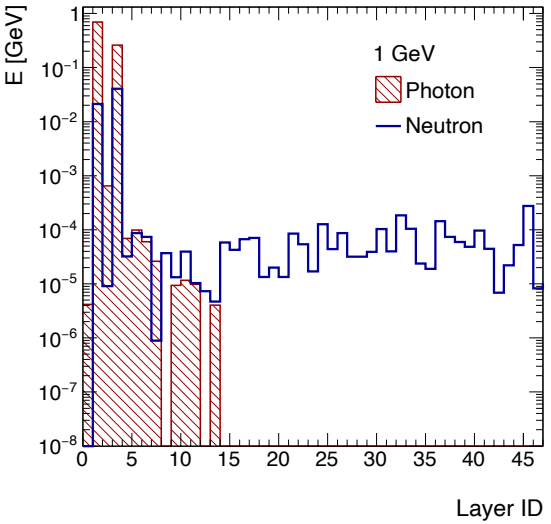
Start looking at Si/W layers first, with reduced Crystal size of 7 cm.

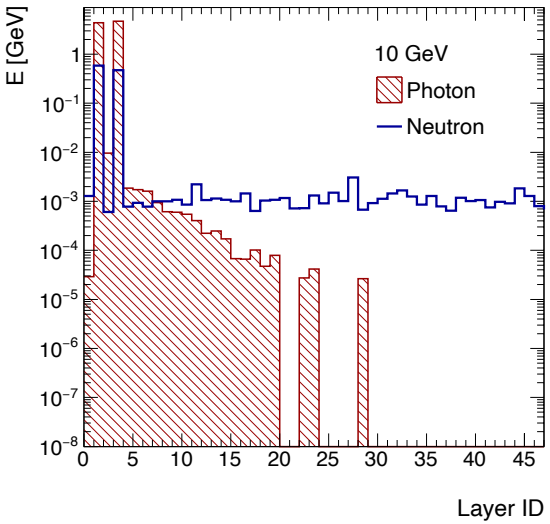
- Particle gun: neutron and photon
- Energy: 300 MeV, 1 GeV, 10 GeV, 300 GeV
- 20 events for each sample.

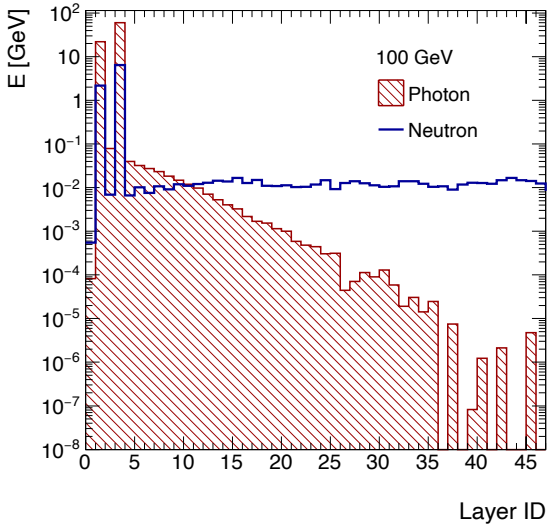
Energy per layer

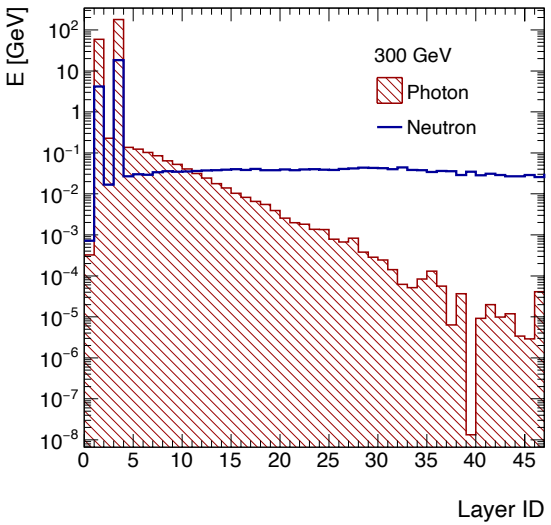
- W/Si 42 layers
  = Layer ID up to 46 →
  - 32 layers = up to layer ID =36
  - 26 layers = up to layer ID=30





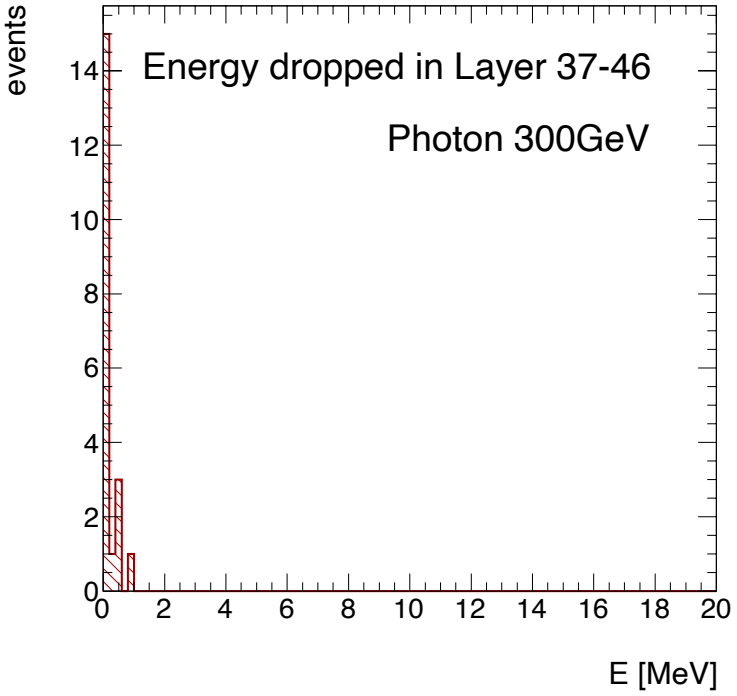


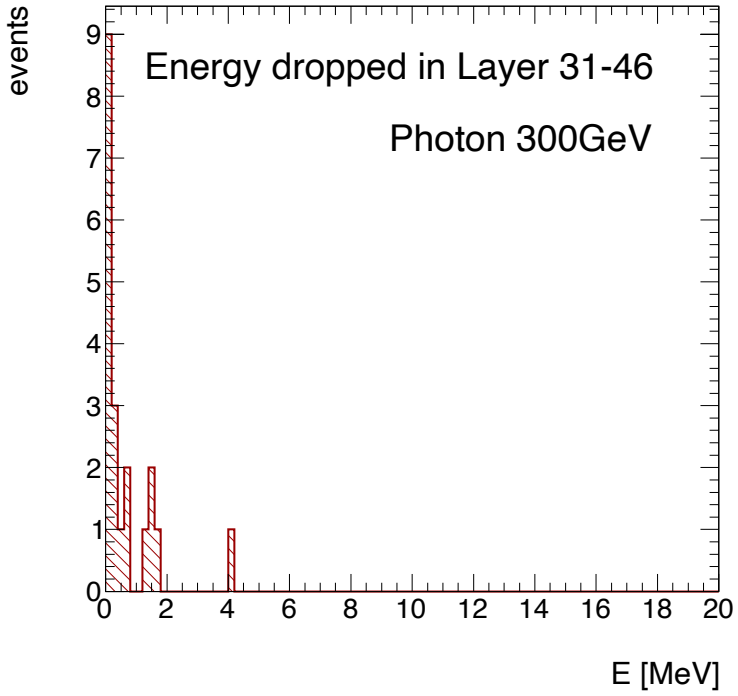




Sum of energy deposits in Layer ID > 30

- A master thesis on FoCal-E says the sampling fraction ~89.
- If sampling fraction=100, 10 MeV in W/Si layers → 1 GeV = 1% of O(100) GeV



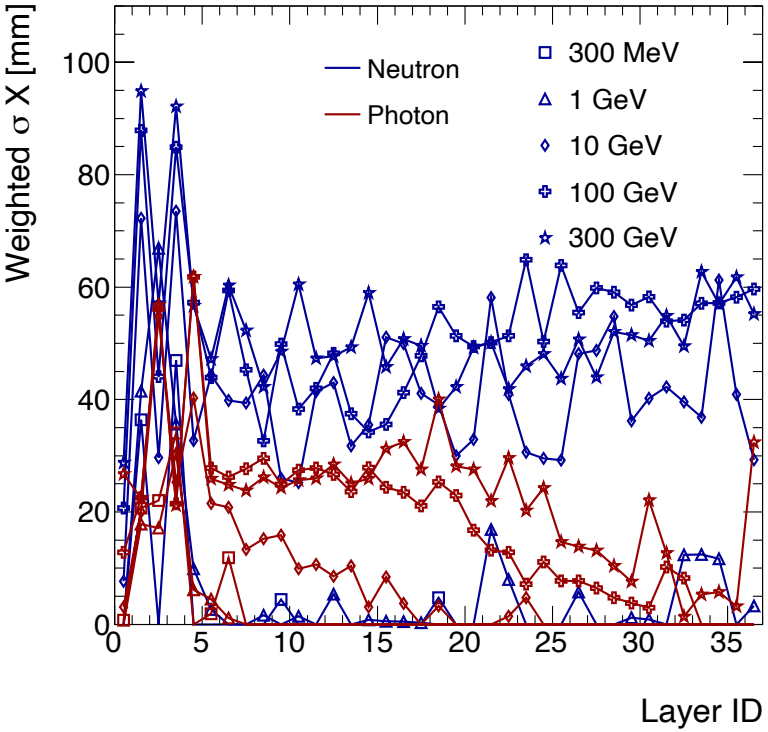


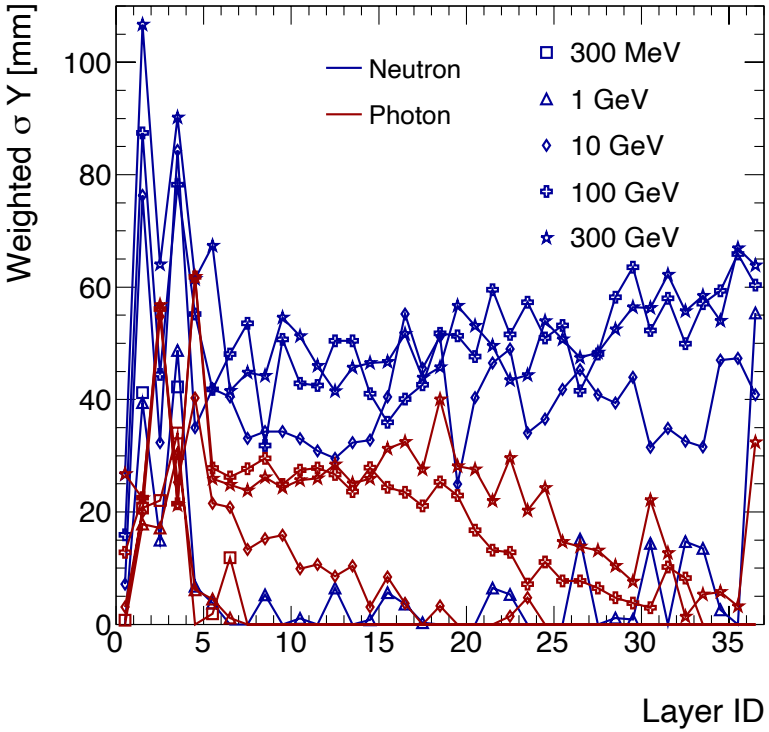
Dropped energy < 5 MeV → O(0.1) % of the photon energy will be affected. i.e. measured in Pb/Si.

Transverse spread of energy deposits

- Energy weighted sigma are checked.

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



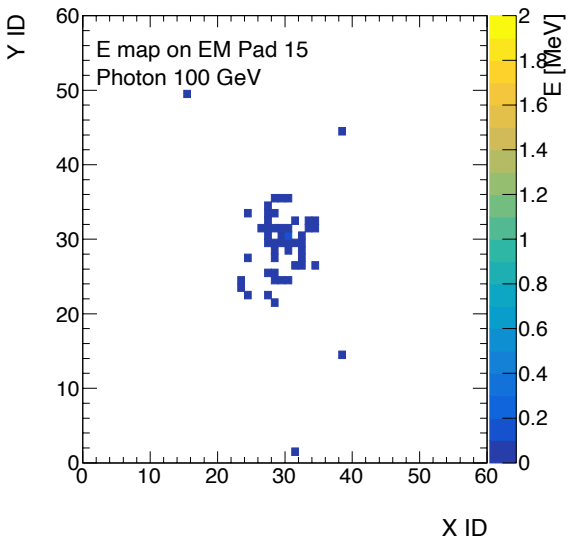


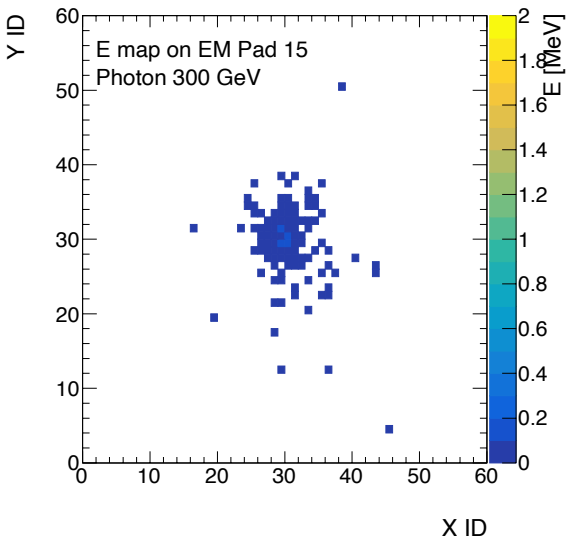
- First 5 layers will be looked in details later.
- Difference of shower width is visible in Si/W layers (Layer ID > 5).
- Photon shower is fading around Layer ID 20-30.

Energy deposits on Layer ID 20

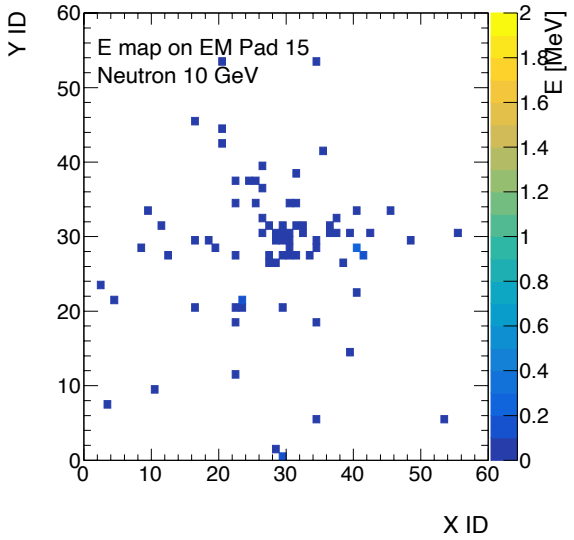
Photon

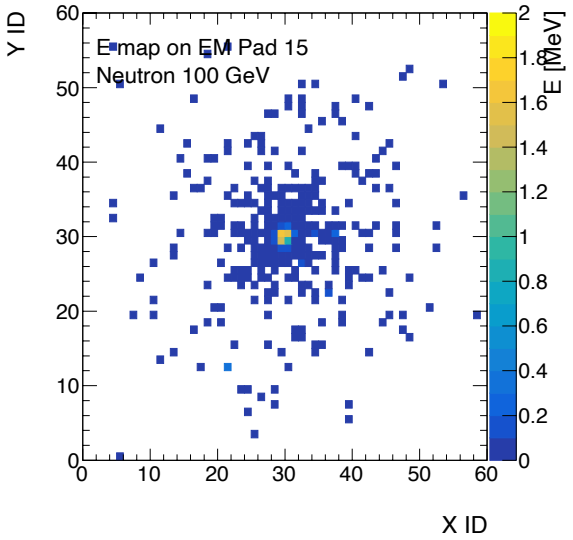
Difference of shower shape is seen at Layer 20.

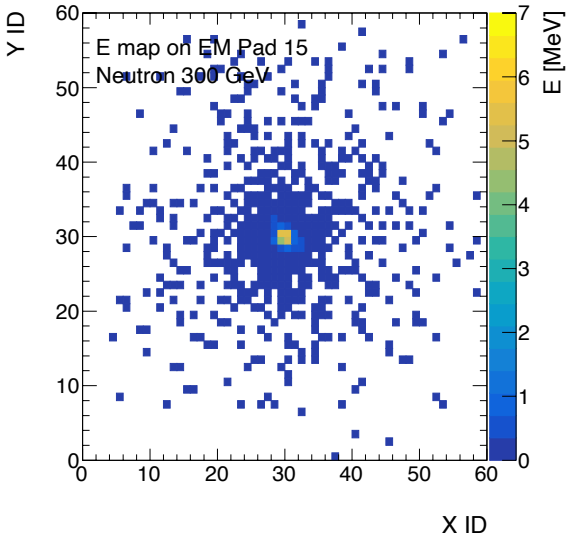




Neutron





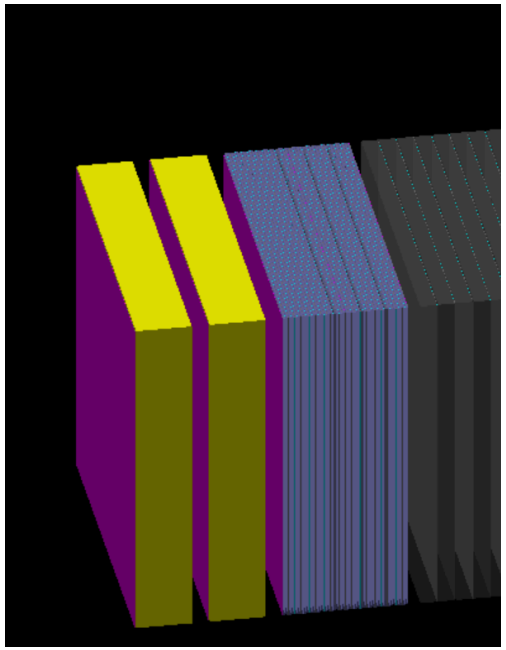


Conclusion

- With 16 X_0 of crystal (tentative), reduction of W/Si layers to 26 layers seems to be quite safe.
  - (12 Pad layers + 1 Pix layer) x 2

    → 26 X_0 W/Si layers
- Probably we can reduce more, but keep 26 layers for future discussion.

- Next: Optimization of Crystal part.
  (Preliminary look in the backup.)
  - How much of energy resolution and position resolution are required for low energy photons?
  - Any PIDs in addition to photons? (Background particles?)



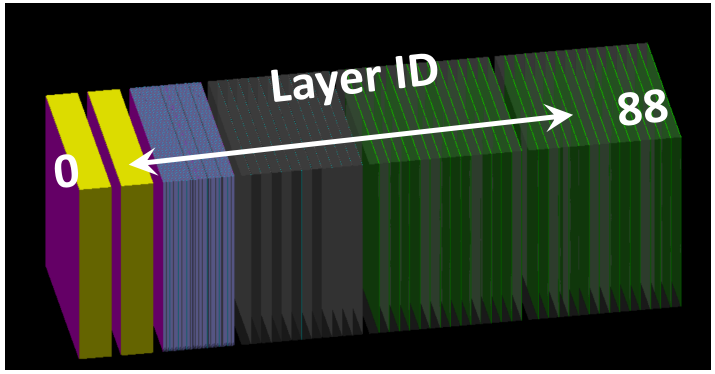
List of questions…

- What are the required energy and position resolutions for soft photons?
- Which kind of particles would hit ZDC in addition to photons and neutrons?
  (i.e. what would be the background?)
- Is there any restriction in the space around ZDC?
  （Do we need to reduce the size of ZDC from 60cm x 60cm x 2m, in order to place readout systems?)
- Does ZDC need to tag real photon from Pb ISR? Any study?

Backup

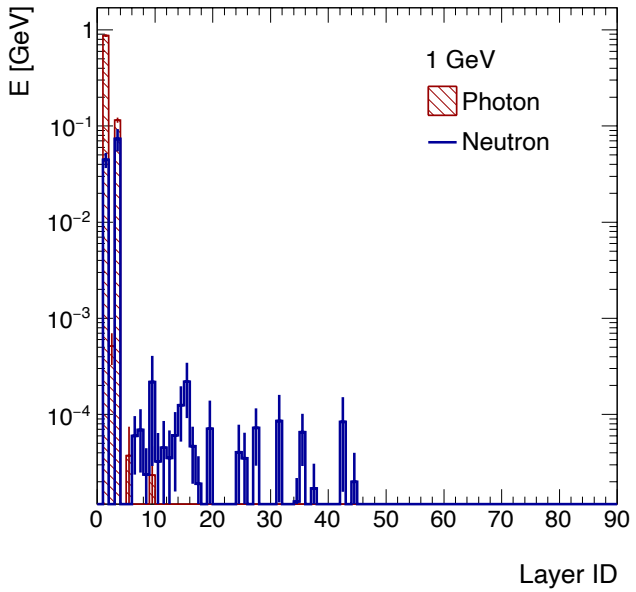
w/ current design in Fun4All

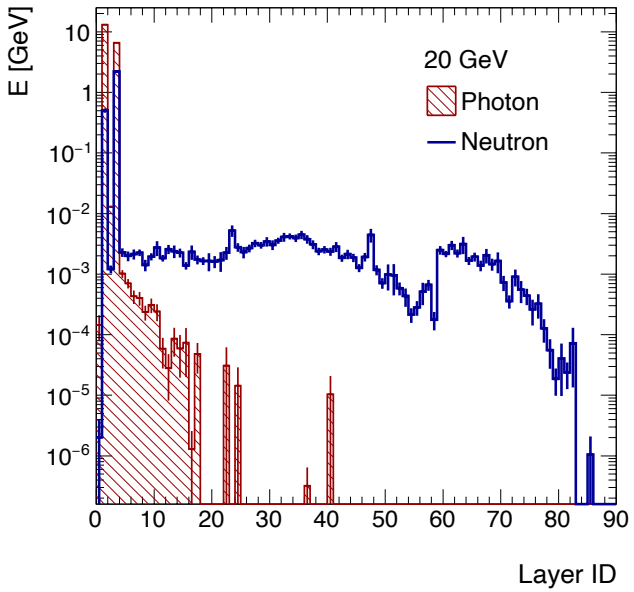
Energy deposition per layer

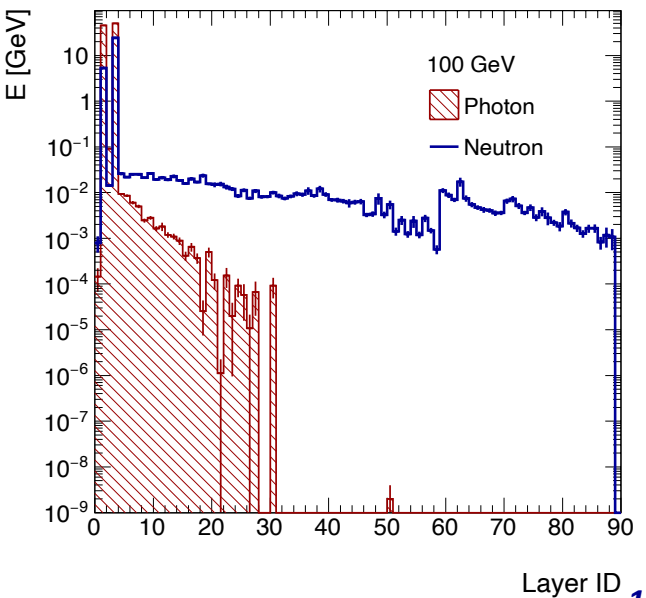


- Using particle gun of photon and neutron.
  - 1, 20, 100 GeV

- Layer 1, 3: Crystal 3cm x 3cm 10cm thick
- Layer 0, 2, 4, 25, 46: Silicon 3mm x 3mm 300µm thick
- Layer 5-24, 25-45: Silicon 1cm x 1cm (w/ Tungsten) 320µm thick
- Layer 47-58: Silicon 1cm x 1cm (w/ Pb) 320µm thick
- Layer 59-88: Scintillator 10cm x 10cm (w/ Pb) 2mm thick







w/ current design in Fun4All

Energy map w/ 100 GeV photon or neutron

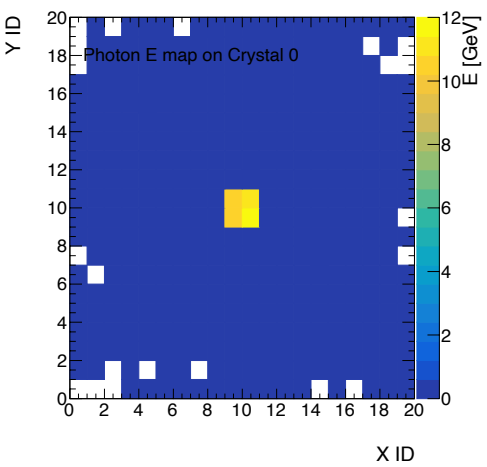
Layer 1 (Crystal 0)

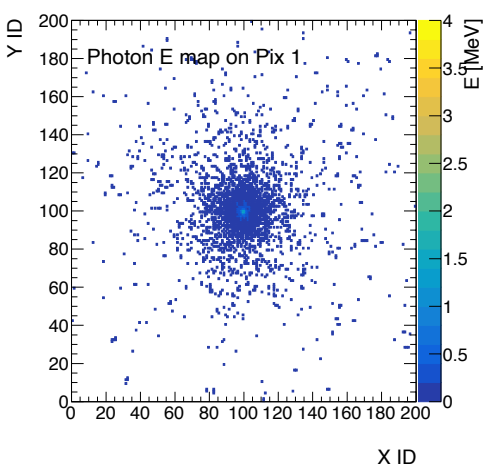
Layer 2 (3mm x 3mm Silicon)

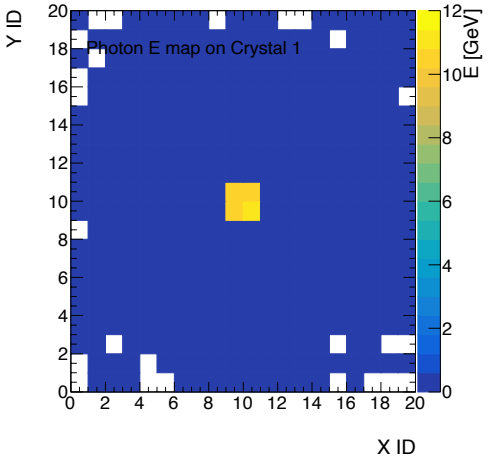
Layer 3 (Crystal 1)

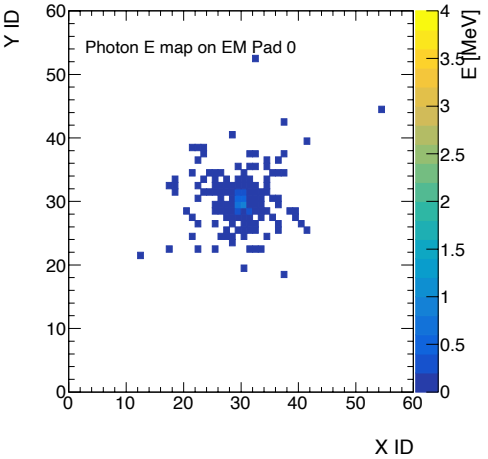
Layer 5 (1cm x 1cm Silicon)

Photon

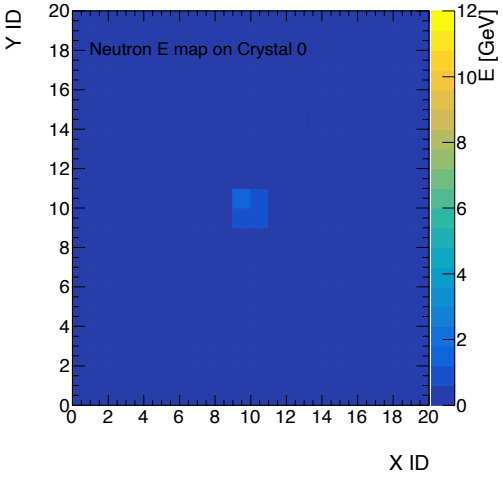


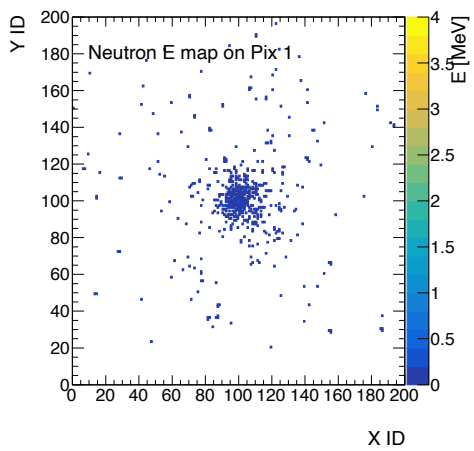


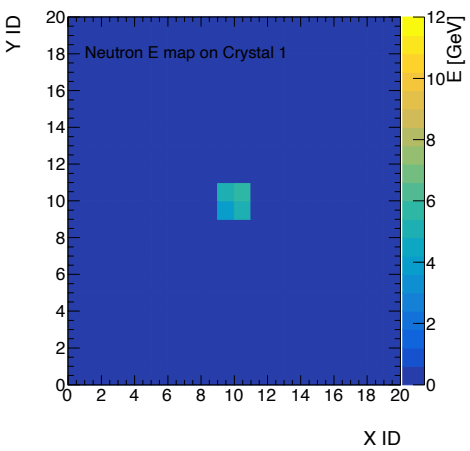


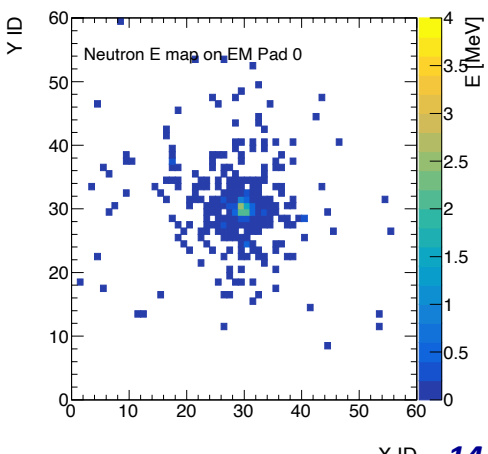


Neutron





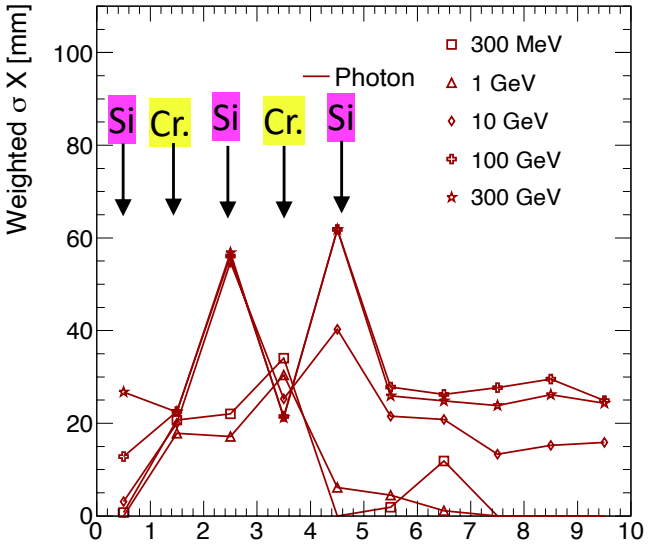




Reduced crystal 10cm -> 7cm

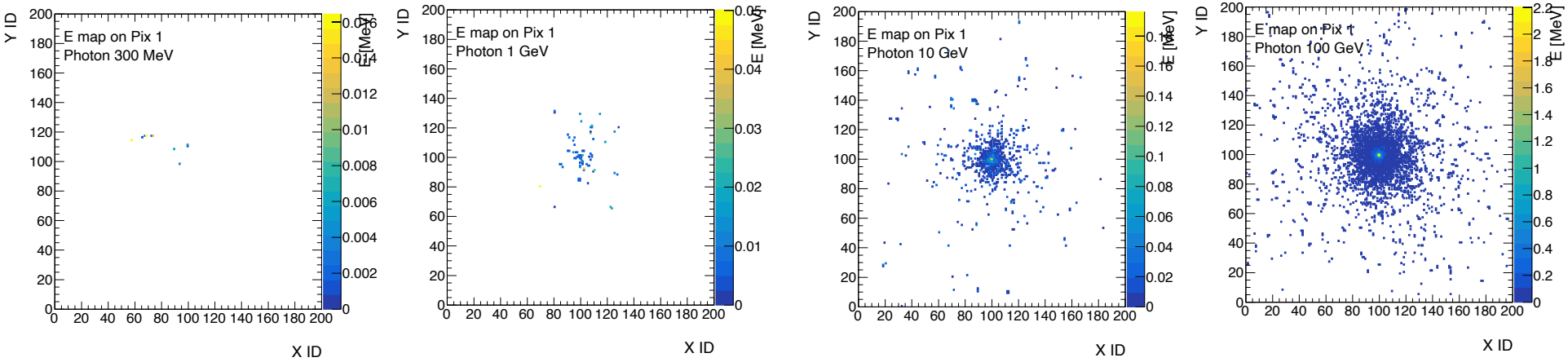
Crystal part

- Looking at sigma again, for photons only.



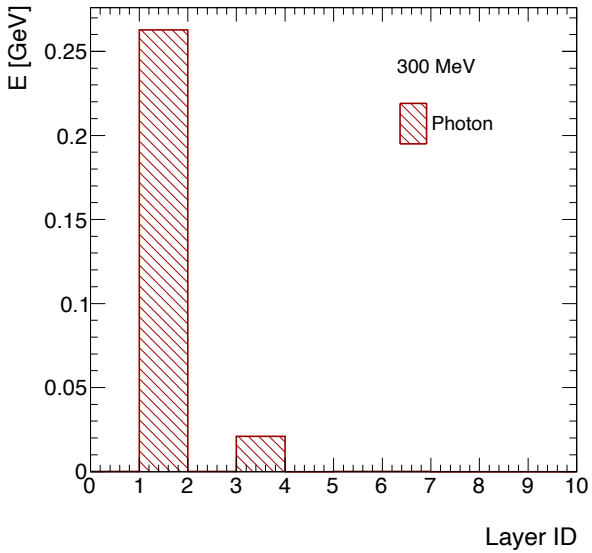
Silicon
3 mm x 3mm x 300 µm
PET (Glue, FPC) 0.39 mm
Gap 1.2mm
Crystal (PbWO4)
3cm x 3cm x 7 cm
Gap 3 cm

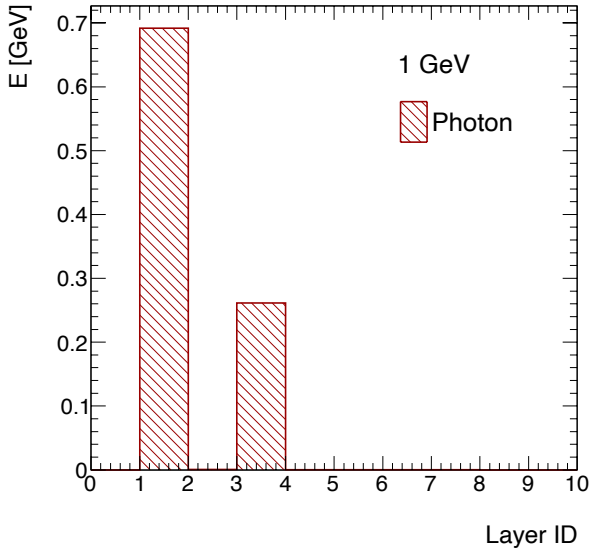
- On crystal 3cmx3cm, shower width is not really seen.
- On Silicon, shower width can be seen for E > 10 GeV.

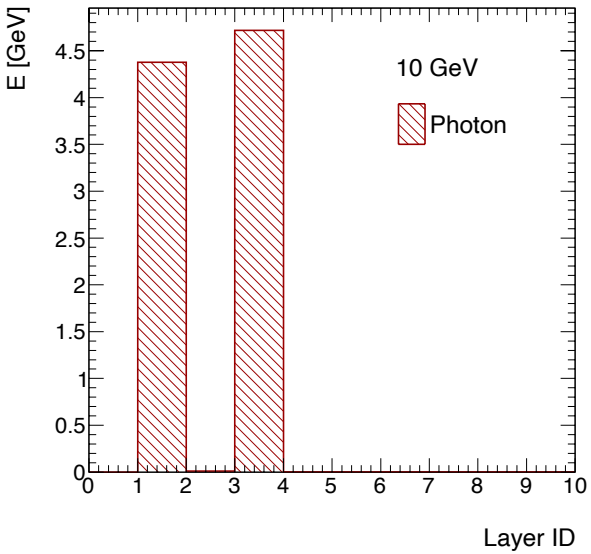


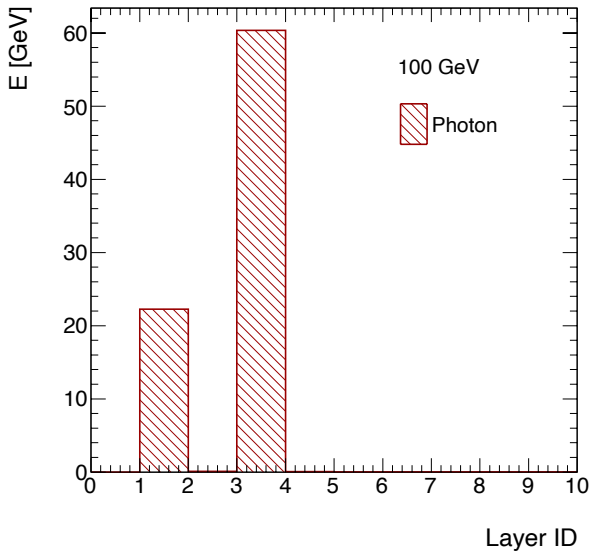
Reduced crystal 10cm -> 7cm

Energy deposit in Crystal part









- Should learn how much resolution are needed for low energy photons