Study on ZDC Crystal calorimeter

Shima Shimizu (RIKEN)

EIC-Japan meeting on 4/Jul/2022

Material for crystal calorimeter

- Current choice in Geant4 simulation : $PbWO_4$
- Other candidates for Crystal:

	light yield	cost	note
$PbWO_4$	low	less expensive	
LYSO	high (>100 x $PbWO_4$)	high (~ 4 x $PbWO_4$)*	good timing resolution
SciGlass	better than $PbWO_4$	not high	still in development

* Ce doped. EIC calorimetry workshop 2021

- Today:
  - Introduce the simulation of LYSO
  - Introduce the effect of photon counting
  - Compared to $PbWO_4$ using single photon events.

LYSO calorimeter

LYSO = $Lu_{2(1-x)}Y_{2x}(SiO_4)O$

In my simulation:

- Lu : Y : Si : O = 1.8 : 0.2 : 1 : 5
- Density = 7.4 g/cm^3
- No Ce is doped.

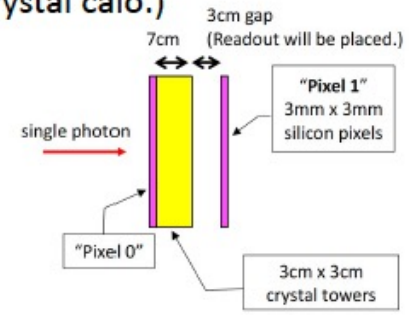
→ Radiation length: 11.7 mm (cf. $PbWO_4$ 8.9 mm)

➔ Check energy response using the energy deposits

The thickness of crystal calorimeter is set as 7 cm.

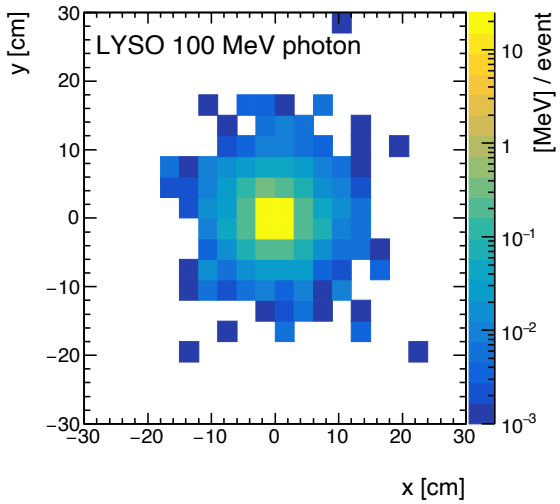
(3cm x 3cm x 7cm towers are filled in 60cm x 60 cm x 7 cm crystal calo.)

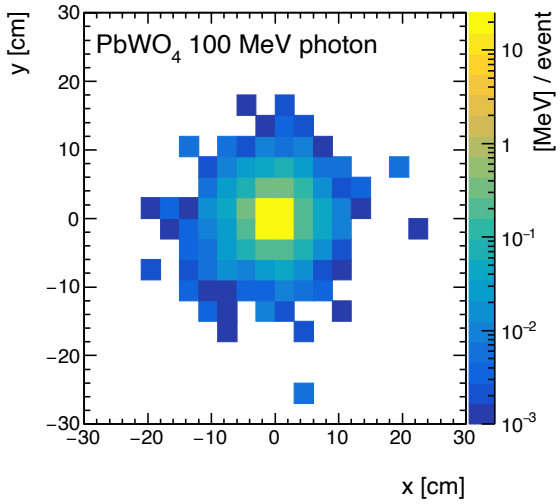
100 MeV / 20 GeV photons are shot on the center of the calorimeter.



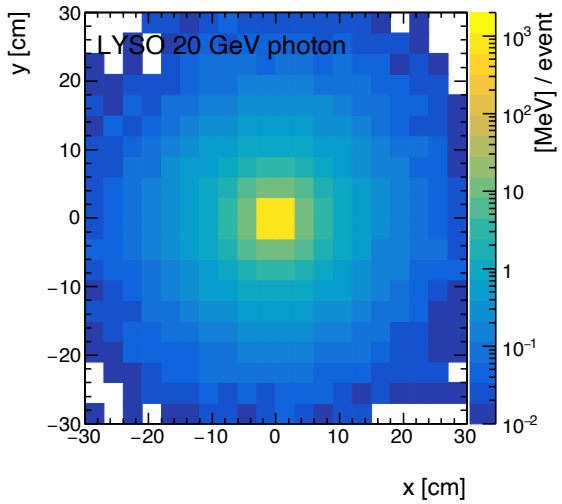
Photon energy map on Crystal

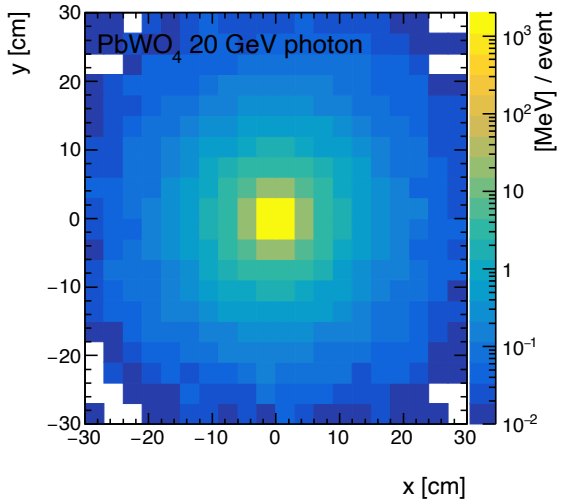
100 MeV photons





20 GeV photons





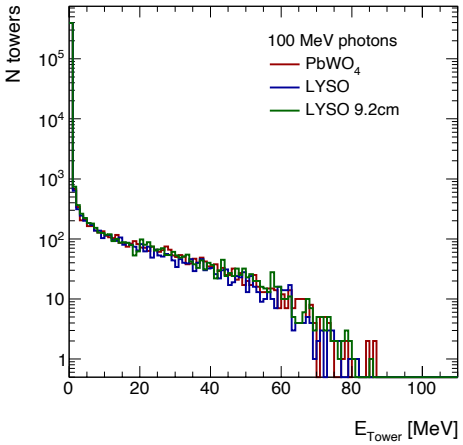
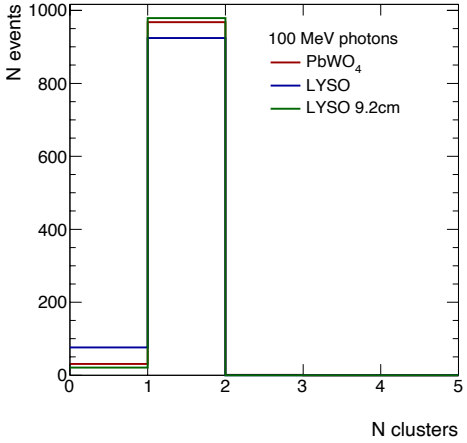
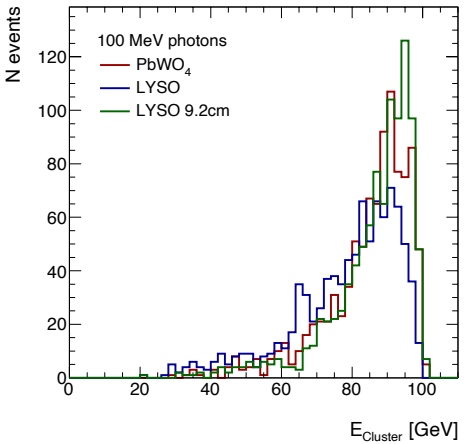
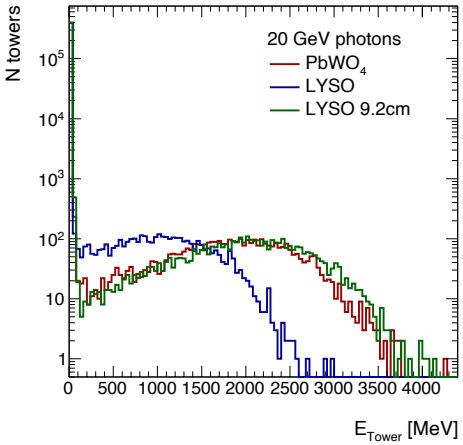
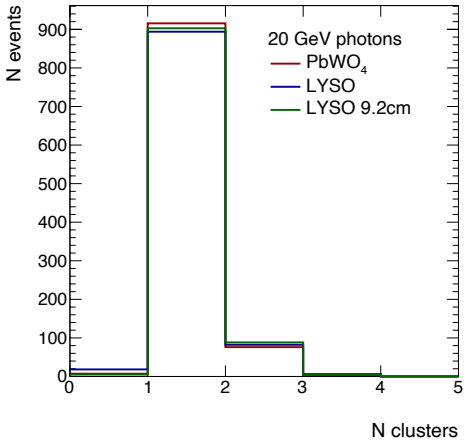
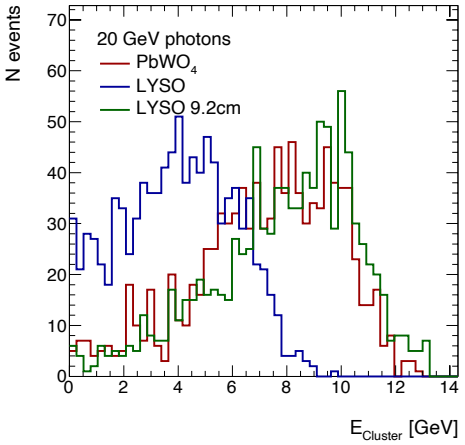
Shown energy is "**amount of energy that can make scintillation light**".

- No clear tendency in the energy spread on x-y plane.

Energy distribution on Crystal (energy deposits)

Comparison of 7cm $PbWO_4$ (=7.9 X_0), 7 cm and 9.2 cm (=7.9 X_0) LYSO

A cluster is created from a tower w/ E> 15 MeV. 3x3 towers form a cluster.

	Tower energy	Cluster finding	Cluster energy
100 MeV photons			
20 GeV photons			

As far as the crystal has the same radiation length, the performance looks similar.

Photon counting effect

Recipe:

For each G4 step,

E_deposited [GeV] = GetVisibleEnergyDeposition(aStep)

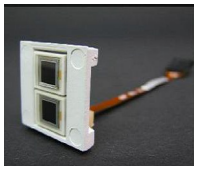
Function to get amount of energy that can make scintillation light, in Unit of GeV

mu = E_deposited * 1000* Nphoton_per_MeV

Nphoton = Random_Poisson(mu)

Nphoton_detected = Nphoton * (1/18) * 0.7

Considering 2 APDs (each has 5mm x 5mm window) per tower (3cm x 3cm) as in CMS ECAL.
Quantum efficiency = 70%.



E_reconstructed = Random_Poisson (Nphoton_detected) /Nphoton_per_MeV / 1000 / (1/18) / 0.7

Nphoton_per_MeV

PbWO4: 130

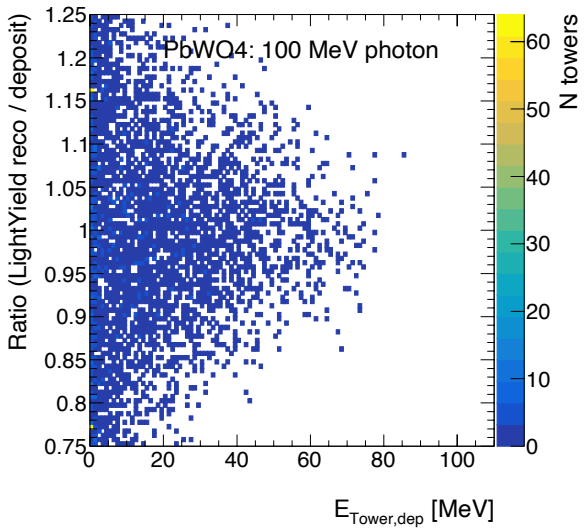
LYSO: 30000 (27000~39000?)

Deposited vs Reconstructed energy on Crystal

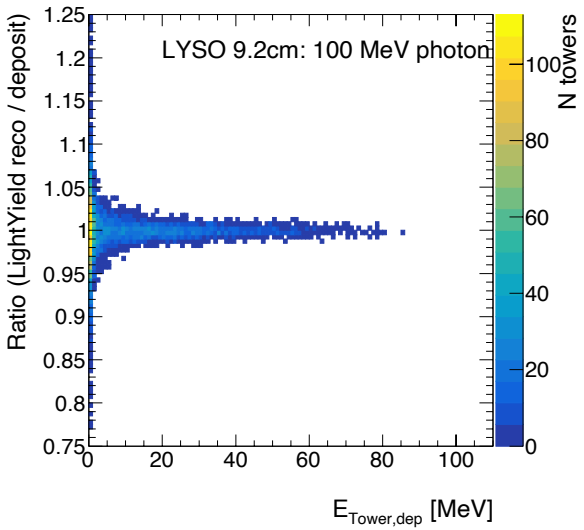
- Comparison using **100 MeV photons**

Crystal tower energy (Reco./Dep. vs Dep.)

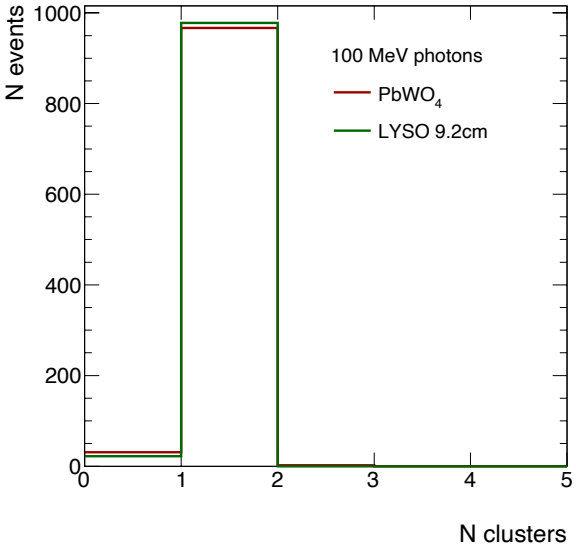
$PbWO_4$



LYSO 9.2cm



Cluster finding



Worse resolution for $PbWO_4$ tower energy, but the clustering efficiency is not largely affected with a threshold value of 15 MeV

Energy reconstruction

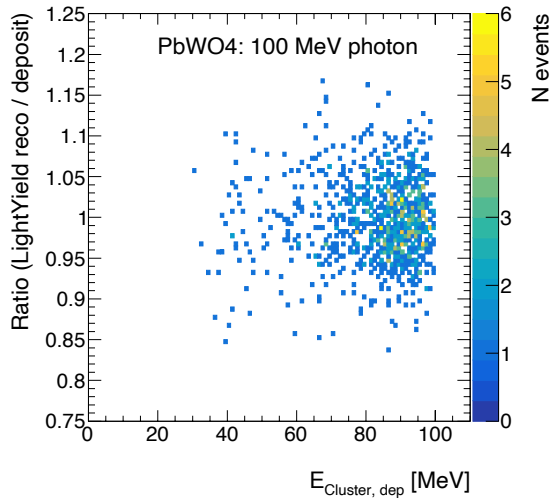
Cluster energy (Reco./Dep. vs Dep.)

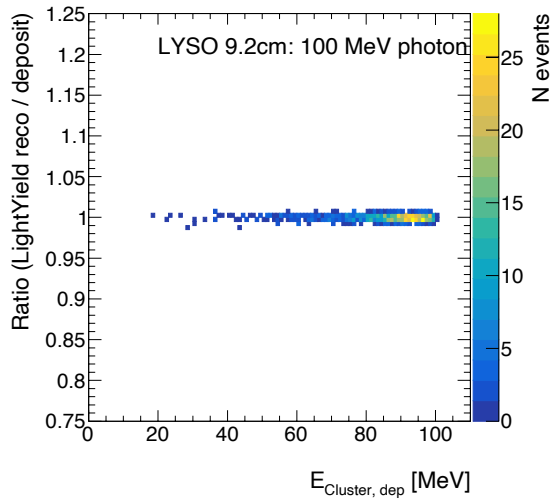
Reconstructed EM cal Energy (Crystal + W/Si)

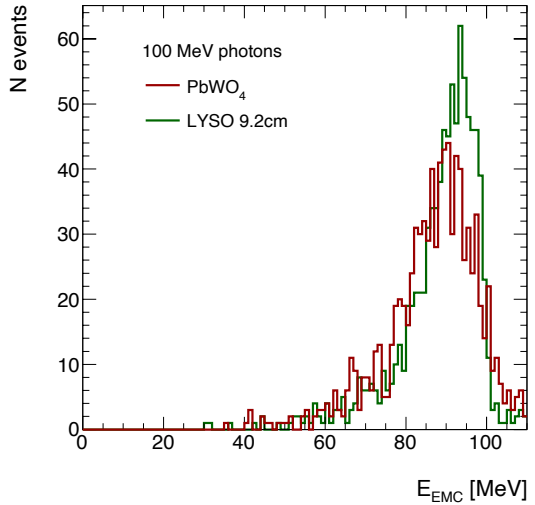
$PbWO_4$

LYSO 9.2cm

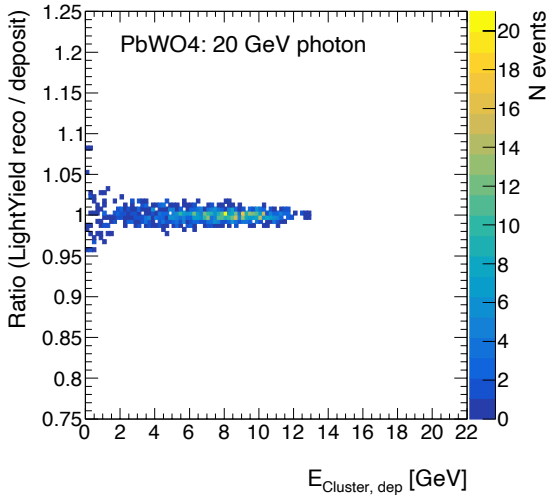
100 MeV photon

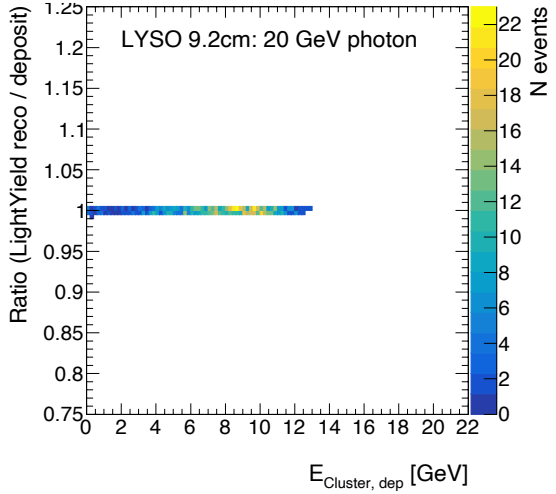


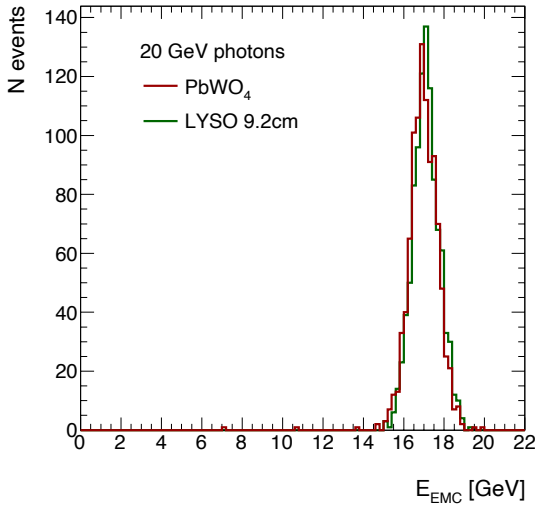




20 GeV photon







$PbWO_4$ has worse resolution for O(100) MeV photons, but still seems to be fine with a requirement of 20~30% resolution.

Summary and note

- Comparison of $PbWO_4$ and LYSO, with including photon counting effect.
  - Assuming 2 APDs for each crystal tower.
  - No large difference in cluster finding efficiency.
  - Worse energy resolution for $PbWO_4$, but still acceptable wrt the requirement of 20%?

- However:
  - Our RANS test indicates APDs are not radiation hard enough.
    → Need another photon detector.

- Also:
  - As discussed in the previous EIC-J meeting, we may need to consider Pre-shower detector instead of Crystal calorimeter.