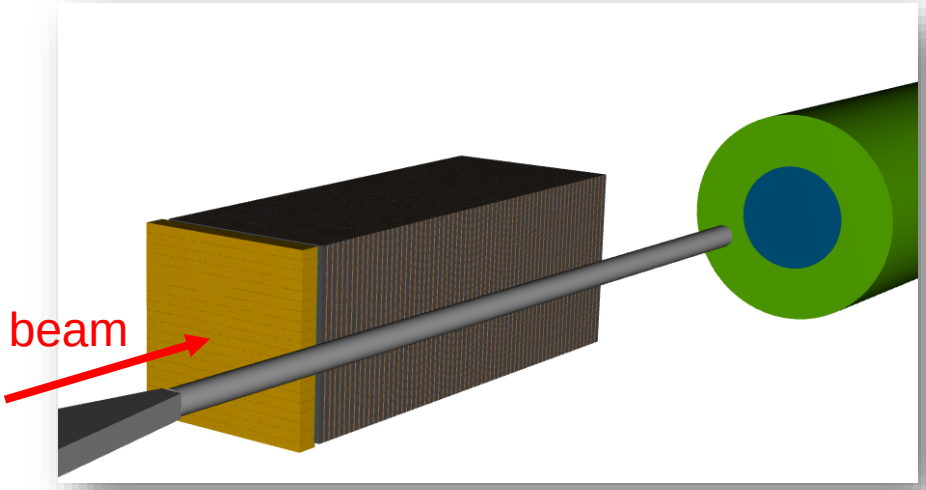
ZDC MC Status 20241109

General Information



Steering.py

```
import math

from DDSim.DD4hepSimulation import DD4hepSimulation
from g4units import cm, mm, GeV, MeV, degree, radian
SIM = DD4hepSimulation()

energyMin = "1*GeV"
energyMax = "20*GeV"
particle = "gamma"

ionCrossingAngle = -0.025 * radian
ZDC_r_pos = 3550 * cm
ZDC_x_pos = ZDC_r_pos * math.sin(-0.025)
ZDC_y_pos = 0 * cm
ZDC_z_pos = ZDC_r_pos * math.cos(-0.025)

SIM.numberOfEvents = 1000

SIM.enableGun = True
SIM.gun.position = (ZDC_x_pos, ZDC_y_pos, ZDC_z_pos)
SIM.gun.particle = particle
SIM.gun.momentumMin = eval(energyMin)
SIM.gun.momentumMax = eval(energyMax)
#SIM.gun.direction = (math.sin(-0.025), 0, math.cos(-0.025))
SIM.gun.thetaMin = ionCrossingAngle
SIM.gun.thetaMax = ionCrossingAngle
SIM.gun.phiMin = 0*degree
SIM.gun.phiMax = 0*degree
SIM.gun.distribution = "uniform"
SIM.gun.multiplicity = 1
```

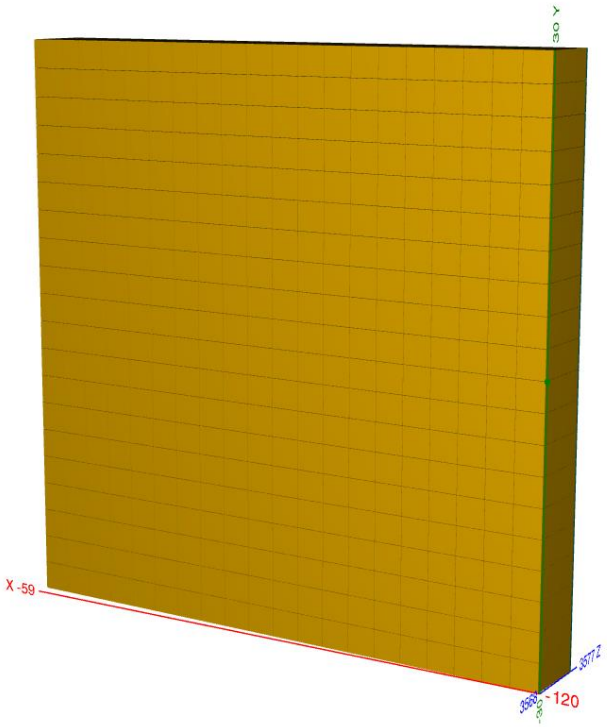
beam type and energy

beam angle

beam position

Ecal, Hcal, and MCtruth information are saved now.

Geometry of ECal and HCal



60cm in X, 60cm in Y, 7cm~6X0 in Z
400 cells, 3cm*3cm*7cm / cell

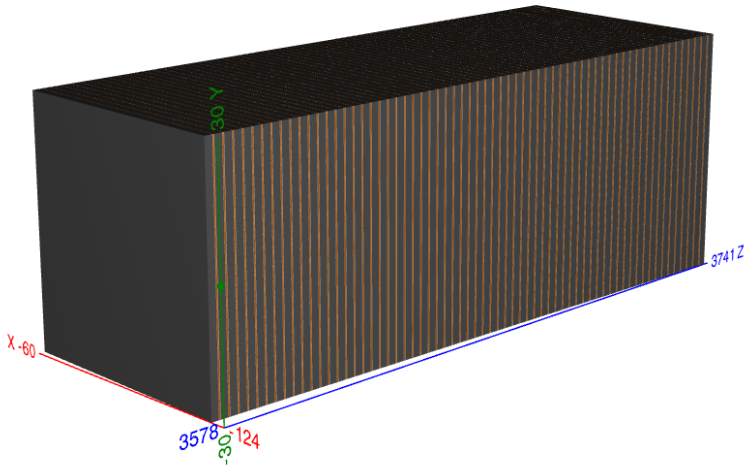
```
<define>
  <constant name="ZDC_width"          value="60.0 * cm"/>
  <constant name="ZDC_r_pos"          value="3550.0 * cm"/>
  <constant name="ZDC_y_pos"          value="0.0 * cm"/>
  <constant name="ZDC_Crystal_r_pos"           value="ZDC_r_pos + 5.9 *cm +19.2*cm"/>
  <constant name="ZDC_Crystal_z_pos"           value="ZDC_Crystal_r_pos * cos(ionCrossingAngle)"/>
  <constant name="ZDC_Crystal_x_pos"           value="ZDC_Crystal_r_pos * sin(ionCrossingAngle)"/>
  <constant name="ZDC_Crystal_y_pos"           value="ZDC_y_pos"/>
  <constant name="ZDC_Crystal_rotateX_angle"   value="0"/>
  <constant name="ZDC_Crystal_rotateY_angle"   value="ionCrossingAngle"/>
  <constant name="ZDC_Crystal_rotateZ_angle"   value="0"/>
  <constant name="ZDC_Crystal_width"           value="ZDC_width"/>


  <constant name="ZDC_Crystal_cell_width"     value="3.*cm"/>
  <constant name="ZDC_Crystal_cell_length"    value="7.*cm"/>
  <constant name="ZDC_Crystal_frame_thickness"  value="0.3*mm"/>
  <constant name="ZDC_Crystal_active_x"       value="ZDC_width"/>
  <constant name="ZDC_Crystal_active_y"       value="ZDC_width"/>
  <constant name="ZDC_Crystal_nx"             value="ZDC_Crystal_active_x/ZDC_Crystal_cell_width"/>
  <constant name="ZDC_Crystal_ny"             value="ZDC_Crystal_active_y/ZDC_Crystal_cell_width"/>
  <constant name="ZDC_Crystal_APD_socket_z"   value="2.5*mm"/>
  <constant name="ZDC_Crystal_space"          value="2.8*cm"/>
</define>
```

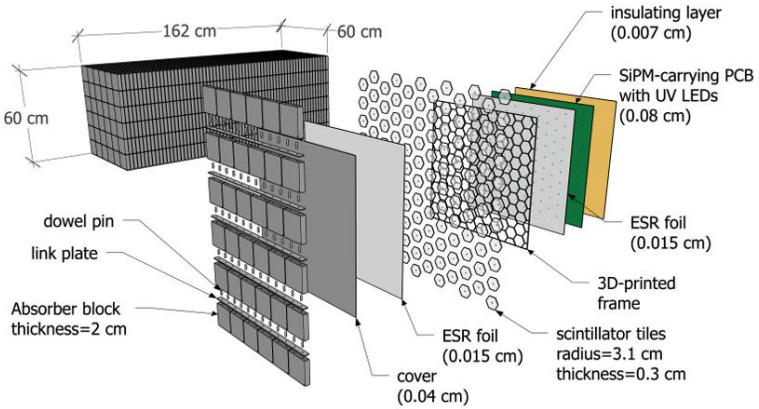
~6X0 (1X0 = 1.1 cm)

/usrX/cyhsieh/2024ZDC/eic/epic/install/share/epic/epic.xml
/usrX/cyhsieh/2024ZDC/eic/epic/install/share/epic/compact/far_forward/default.xml
/usrX/cyhsieh/2024ZDC/eic/epic/install/share/epic/compact/far_forward/ZDC_Crystal_LYSO.xml
/usrX/cyhsieh/2024ZDC/eic/epic/install/share/epic/compact/far_forward/ZDC_SiPMonTile.xml

Geometry of HCal



65cm in X, 60cm in Y, 163cm in Z
64 layers, 8 slice/layer



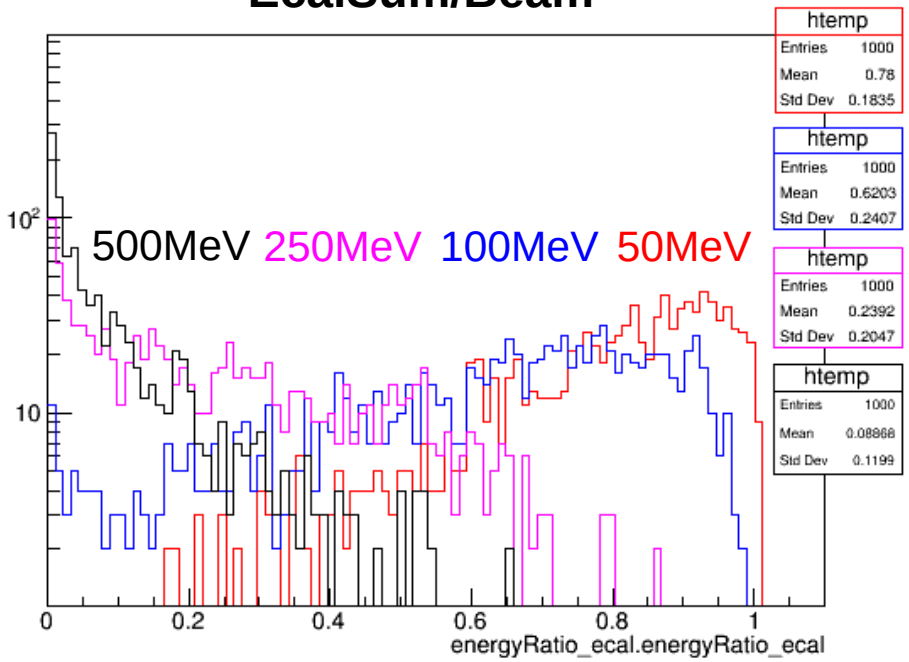

```
<comment> Slices will be ordered according to the slice order listed h
<comment> Steel/Sc layers </comment>
<layer repeat="HcalFarForwardZDC_SiPMonTile_Layer_NSteelRepeat" thickn
  <slice name="Absorber_slice" material="Steel235" thickness="HcalFarF
  <slice name="Air_slice" material="Air" thickness="HcalFarForwardZDC_
  <slice name="ScintCover_slice" material="Aluminum" thickness="HcalFa
  <slice name="ESRFoil_slice" material="Polystyrene" thickness="HcalFa
  <slice name="Scintillator_slice" material="Polystyrene" thickness="H
  <slice name="ESRFoil_slice" material="Polystyrene" thickness="HcalFa
  <slice name="PCB_slice" material="Fr4" thickness="HcalFarForwardZDC_
  <slice name="Air_slice" material="Air" thickness="HcalFarForwardZDC_
</layer>
<comment> Final layer of steel </comment>
```

```
<documentation>
  #### Material Thicknesses
</documentation>
<constant name="HcalFarForwardZDC_SiPMonTile_AirThickness"                value="0.02*cm"/>
<constant name="HcalFarForwardZDC_SiPMonTile_AbsorberThickness"           value="2*cm"/>
<constant name="HcalFarForwardZDC_SiPMonTile_ScintillatorCoverThickness"  value="0.04*cm"/>
<constant name="HcalFarForwardZDC_SiPMonTile_PolystyreneThickness"        value="0.30*cm"/>
<constant name="HcalFarForwardZDC_SiPMonTile_PCBThickness"                value="0.08*cm"/>
<constant name="HcalFarForwardZDC_SiPMonTile_ESRFoilThickness"            value="0.015*cm"/>
```

Not clear how to define FEE channel

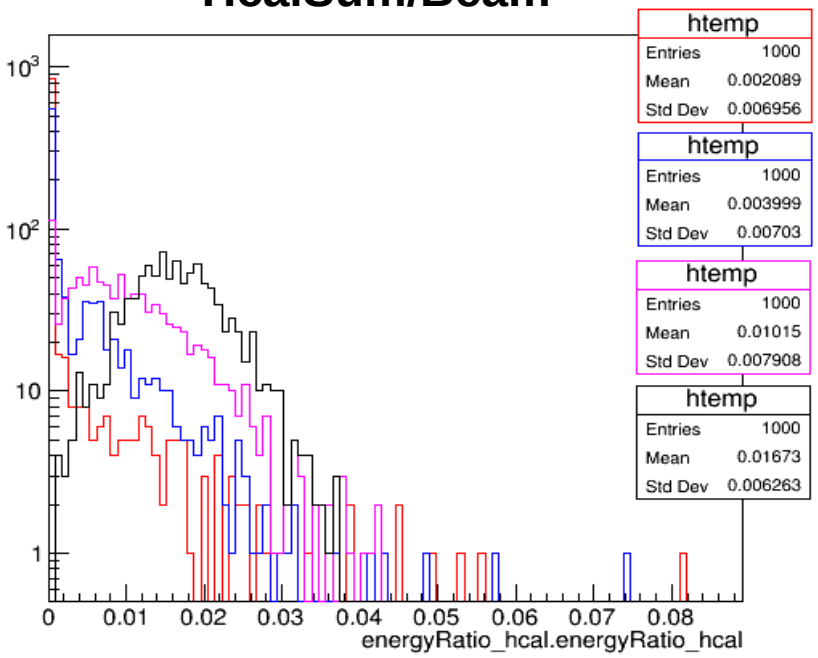
Positron Beam (1)

EcalSum/Beam



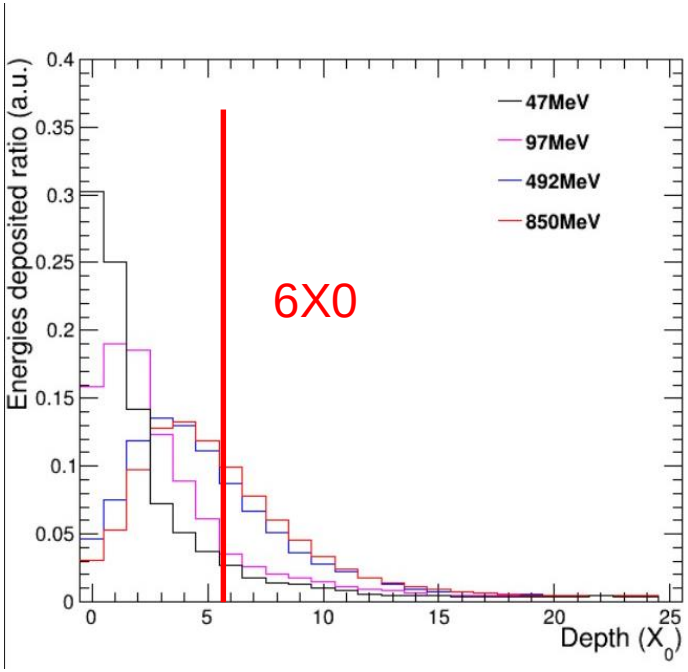
Energy dump in ECal
50MeV : 77%
100MeV : 61%
250MeV : 24%
500MeV : 9%
=> check student's results

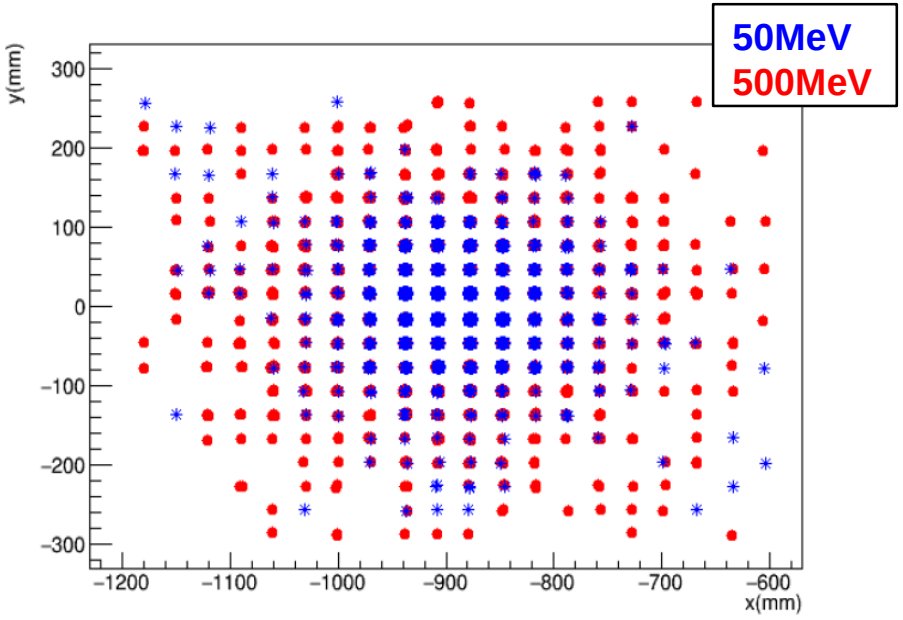
HcalSum/Beam



Energy dump in Hcal
⇒ Less than 2%
⇒ **Leakage from the side?**

Positron Beam (2)





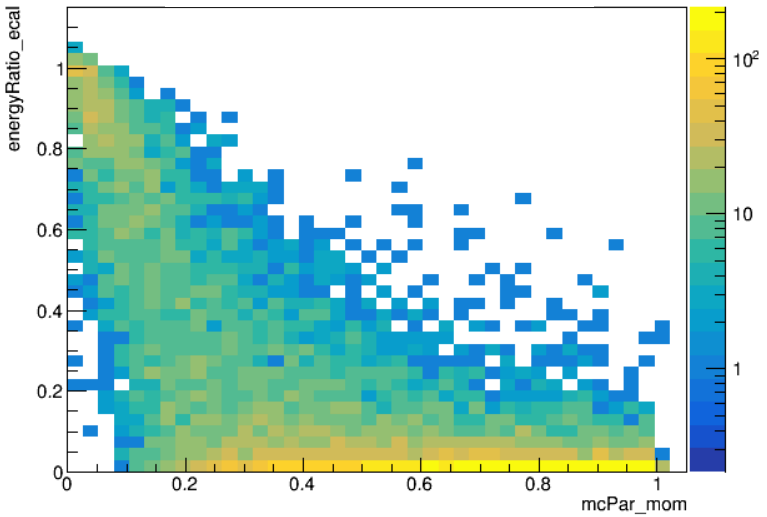
- Student's MC
- Toy MC
- Only ECal
- **Even for 850MeV, more than 50% energy left in ECal. Defiantly something wrong with my sample.**

- **Leakage from the sides?**

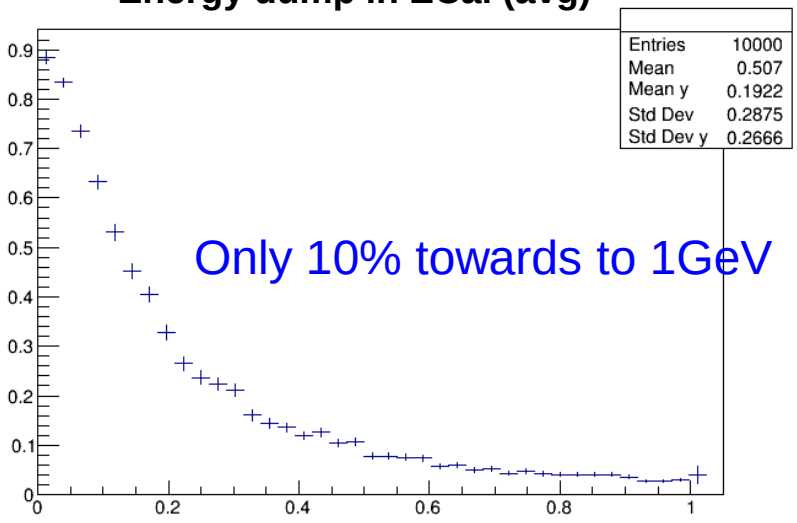
Shower shape for both 50MeV and 500MeV are centered. **Should not be the case.**

Positron (0.01GeV ~ 1GeV)

Energy dump in ECal

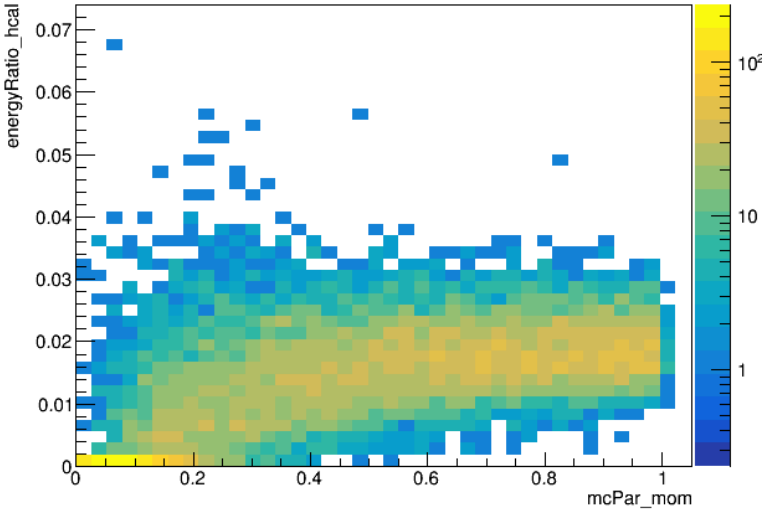


Energy dump in ECal (avg)

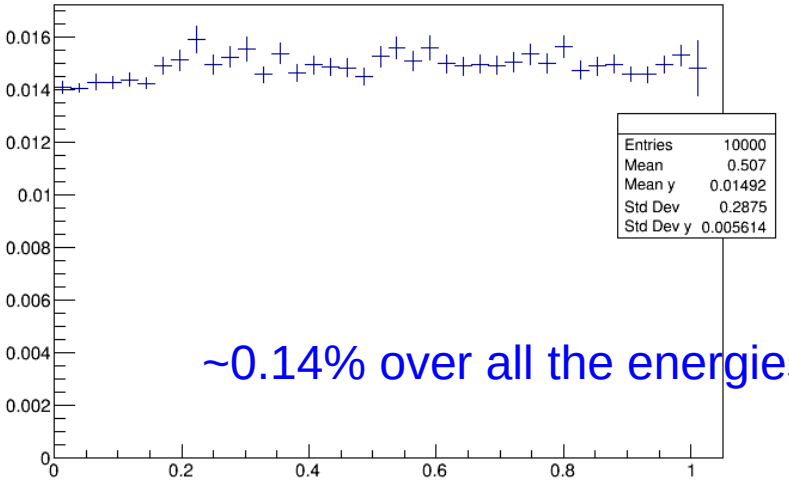


Only 10% towards to 1GeV

Energy dump in HCal

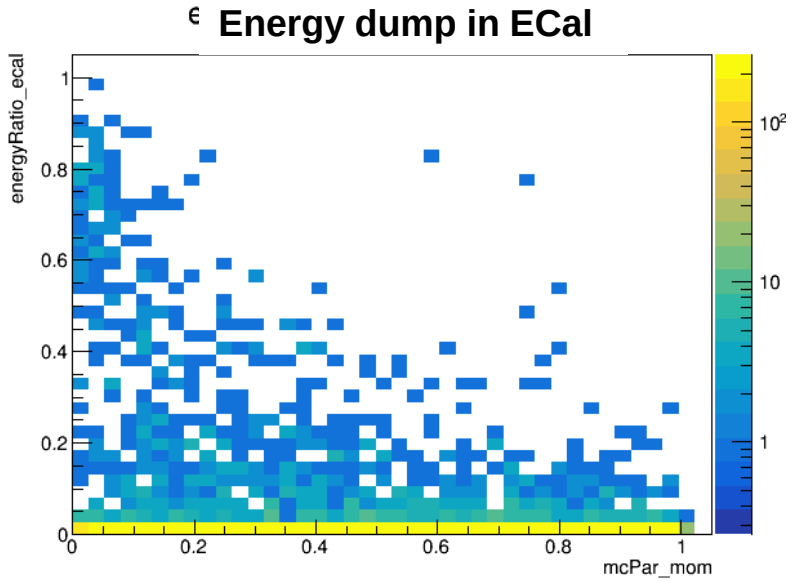


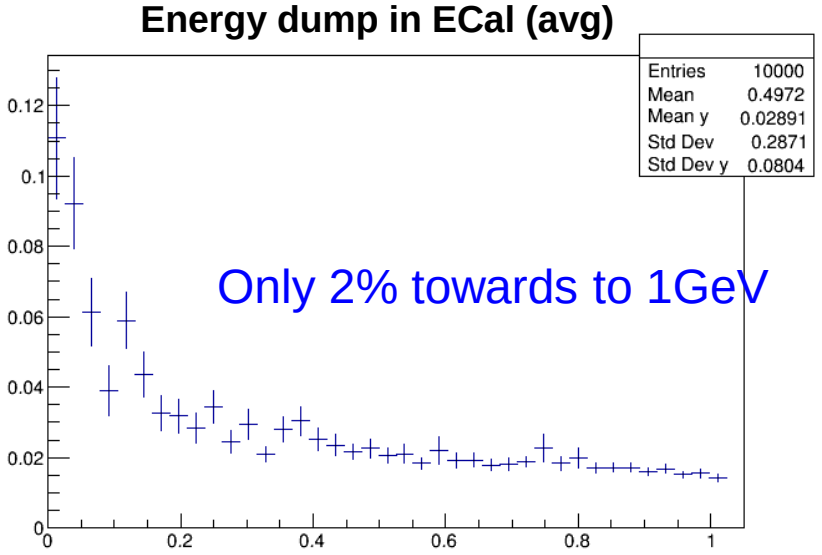
Energy dump in Hcal (avg)

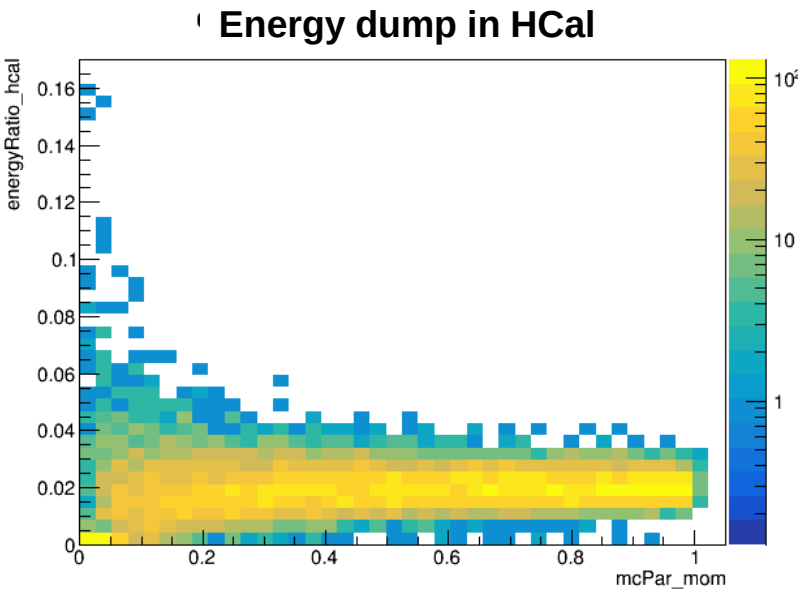


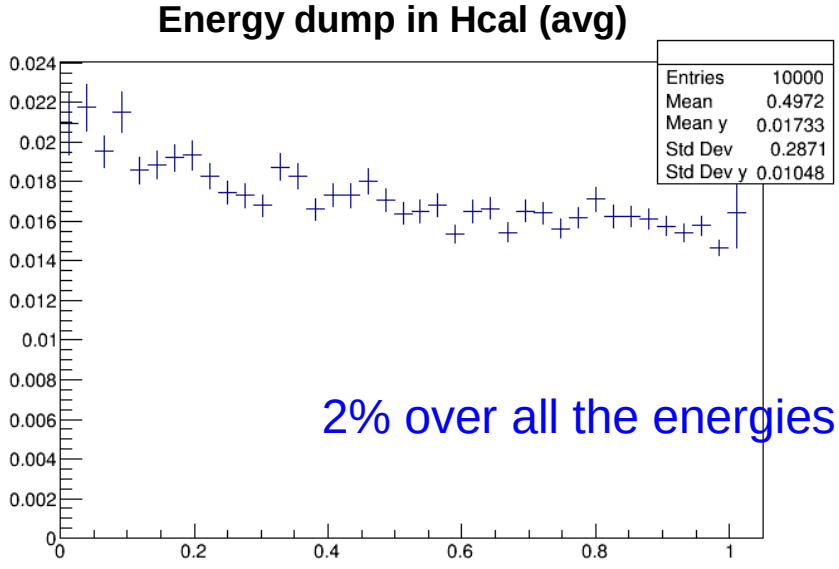
~0.14% over all the energies

Gamma (0.01GeV ~ 1GeV)

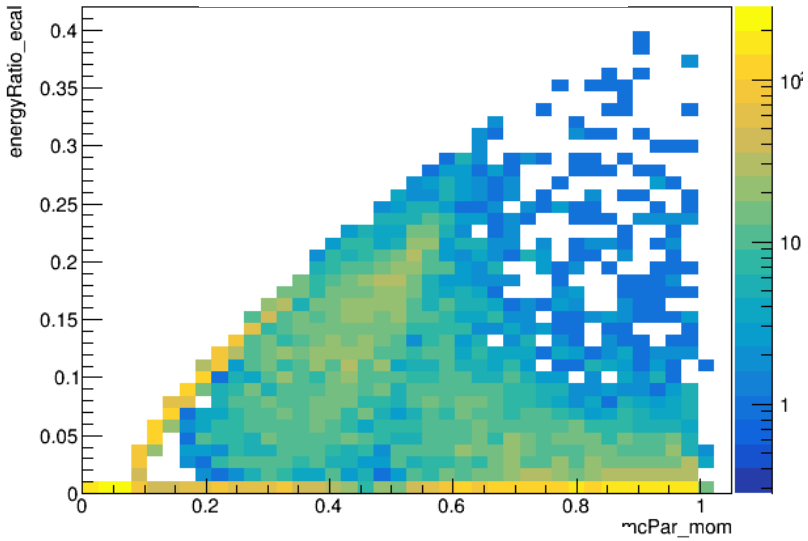


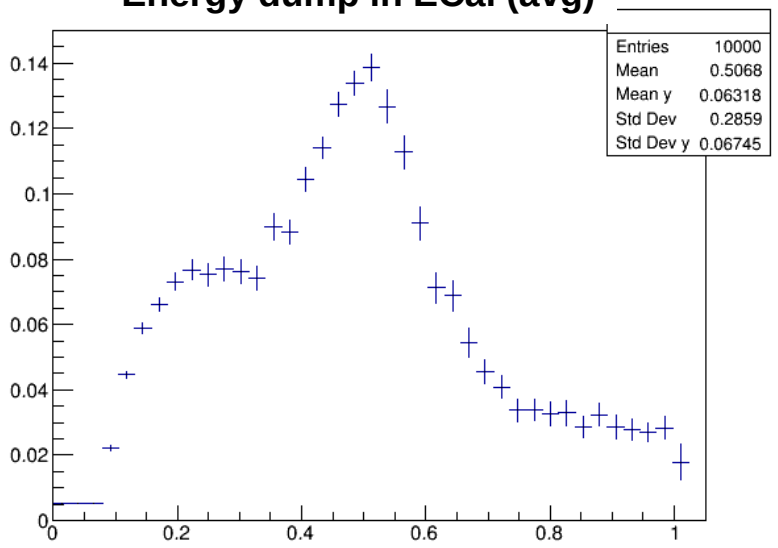


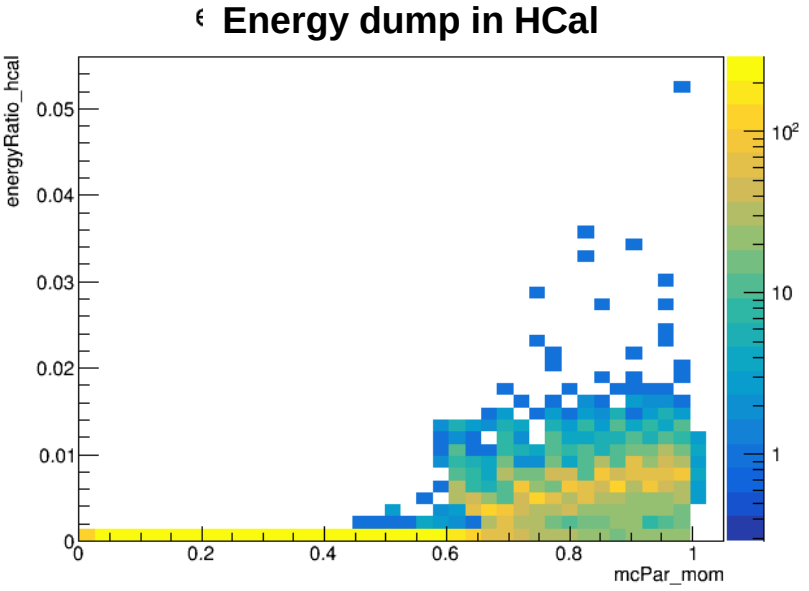


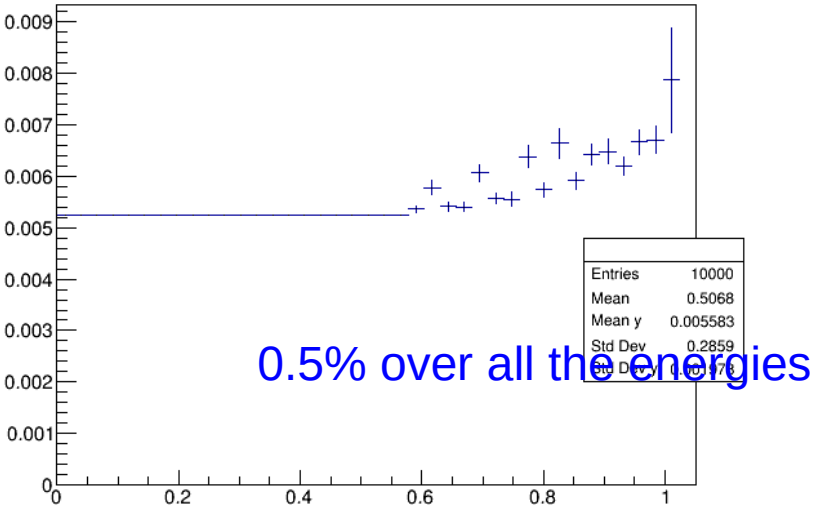


Proton (0.01GeV ~ 1GeV)





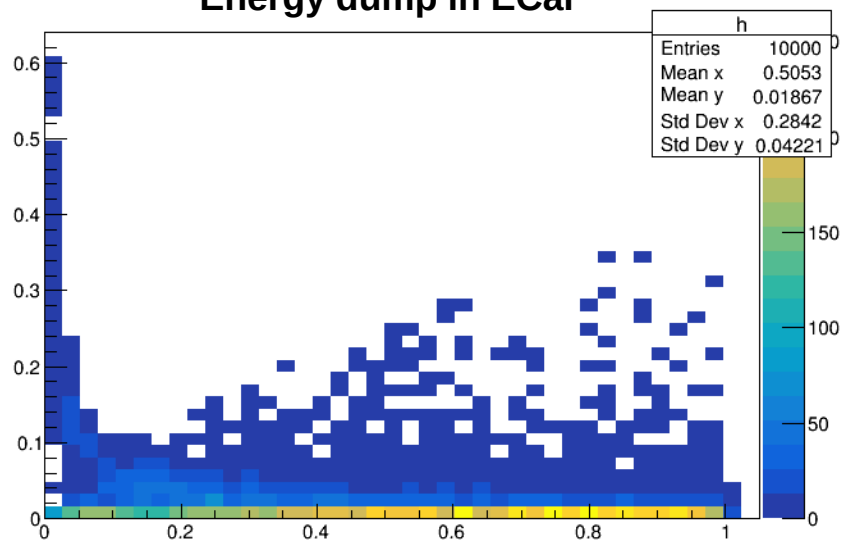




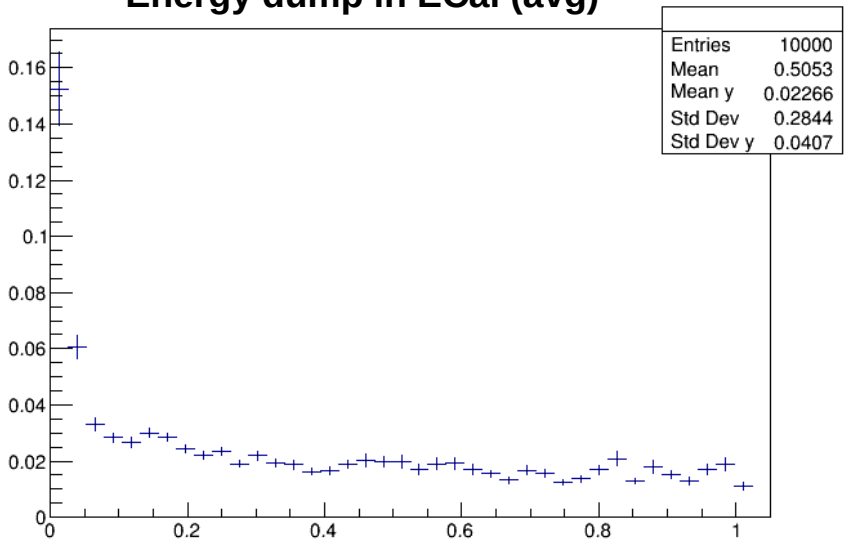
0.5% over all the energies

Neutron (0.01GeV ~ 1GeV)

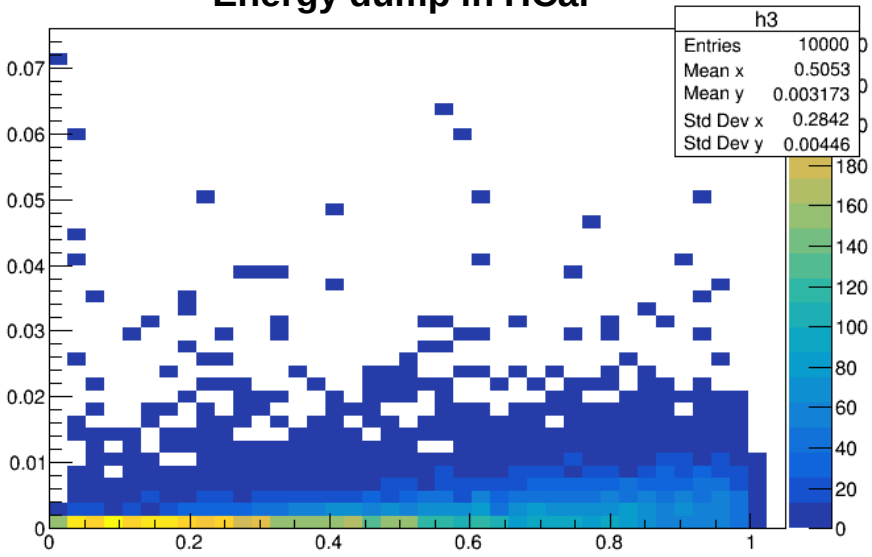
Energy dump in ECal



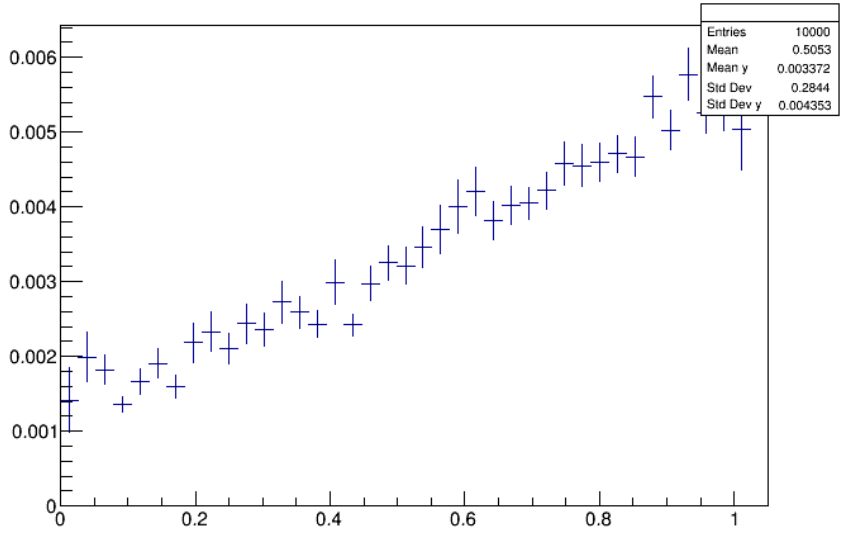
Energy dump in ECal (avg)



Energy dump in HCal

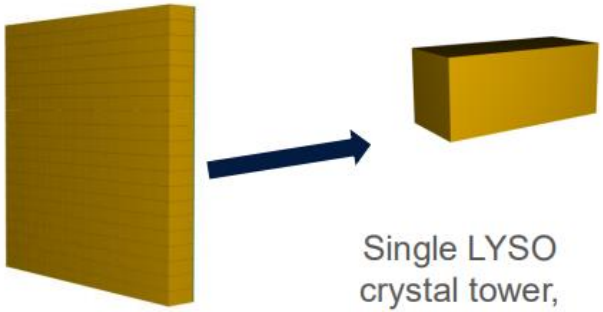


Energy dump in Hcal (avg)



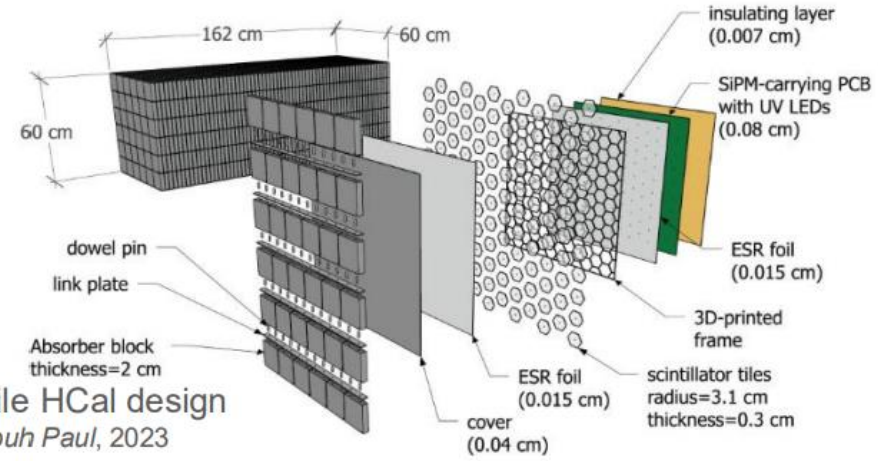
Latest Update form ZDC Meeting (Alessio I. University of Connecticut October 10, 2024)

reconstruction



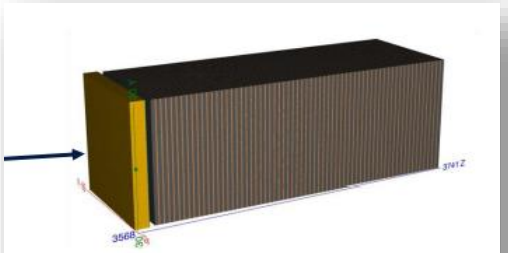
Single LYSO crystal tower, 3x3x7 cm^3

LYSO crystal and readout
Design source: EIC ePIC Geometry Team



SiPM on tile HCal design
source: *Sebouh Paul*, 2023

- **MC Simulations**: Conducted with DD4sim, compiled with Geant4
- **Particle Gun Data**: Generated with variable angles to uniformly cover the ZDC face
- **No Background**: Simulations do not include background
- **Integrated Hits**: The hit data reflects the **integrated energy** deposited in the scintillating pads of the calorimeters, summed over the respective pad and reported at its center
- **ZDC with HCal-Only**: Separate MC data generated for ZDC HCal to study neutron and photon interactions specifically in the hadronic calorimeter
- **ZDC with ECal and HCal**: ZDC geometry in simulations has ECal and HCal
- **Lambda MC**: Energy range 0–270 GeV, with 200k events, decay table restricted to $\Lambda \rightarrow n\pi^0 \rightarrow n\gamma\gamma$
- **Photon MC**: Energy range 0–50 GeV, with 100k events
- **Neutron MC**: Energy range 50–250 GeV, with 60k events

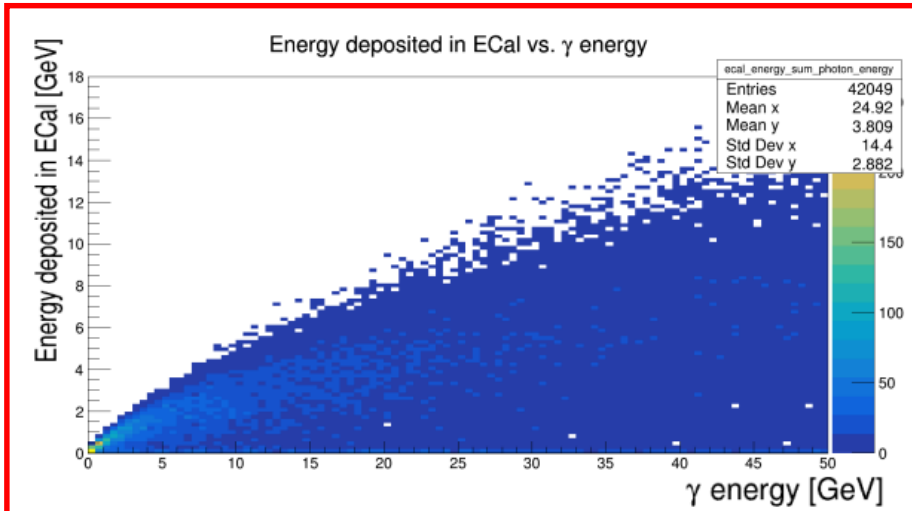


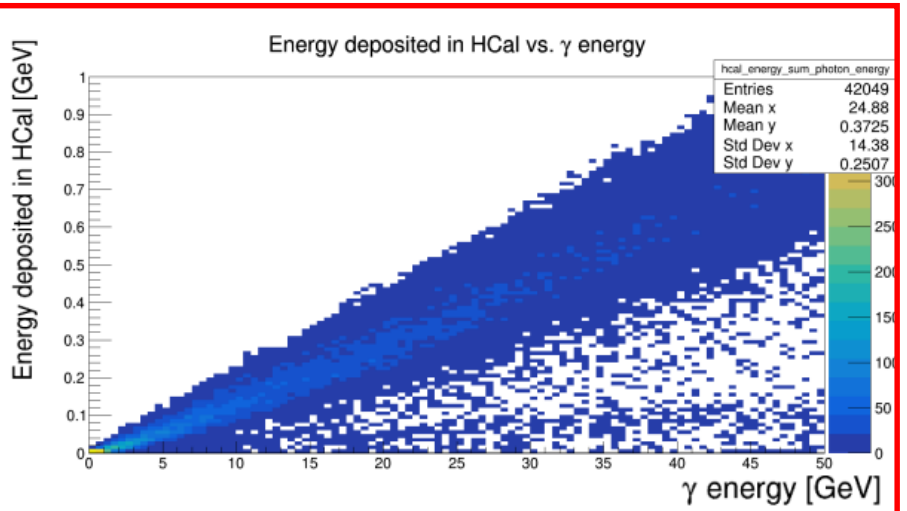
Zero Degree Calorimeter (ZDC)
design source: EIC ePIC Geometry team

Latest Update form ZDC Meeting (Alessio I. University of Connecticut October 10, 2024)

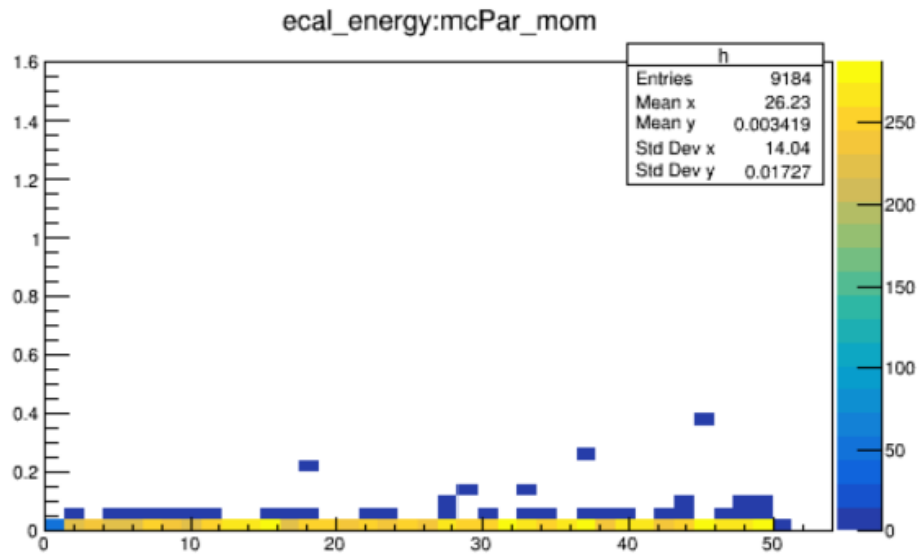
Single Photon ECal and HCal energy ratio

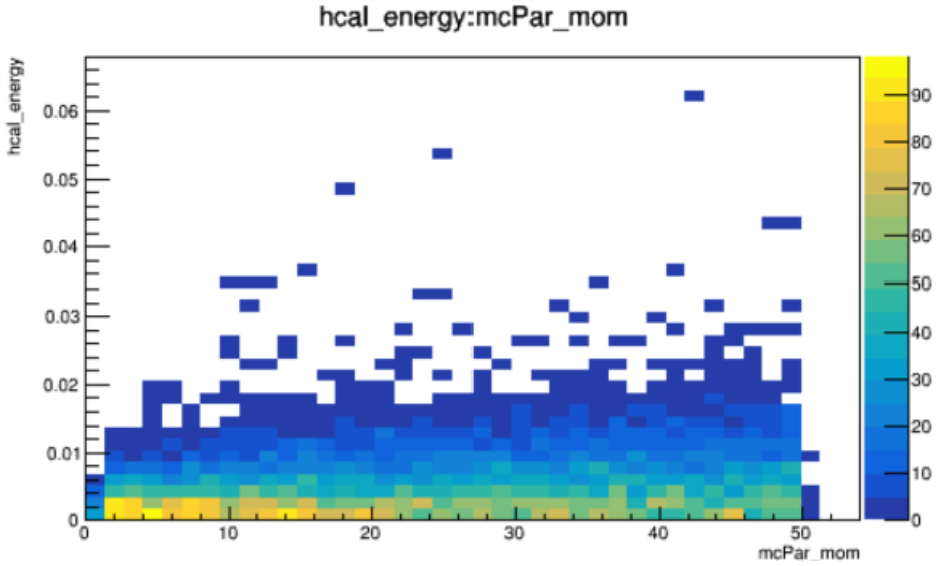
- ECal tiles are short, designed for low energy photons from nuclear breakup
- Most of the photon energy is deposited in ECal, but higher energy showers continue to propagate into the HCal
- Necessary to understand energy resolution for single photon for both calorimeters





Gamma 1GeV-50GeV



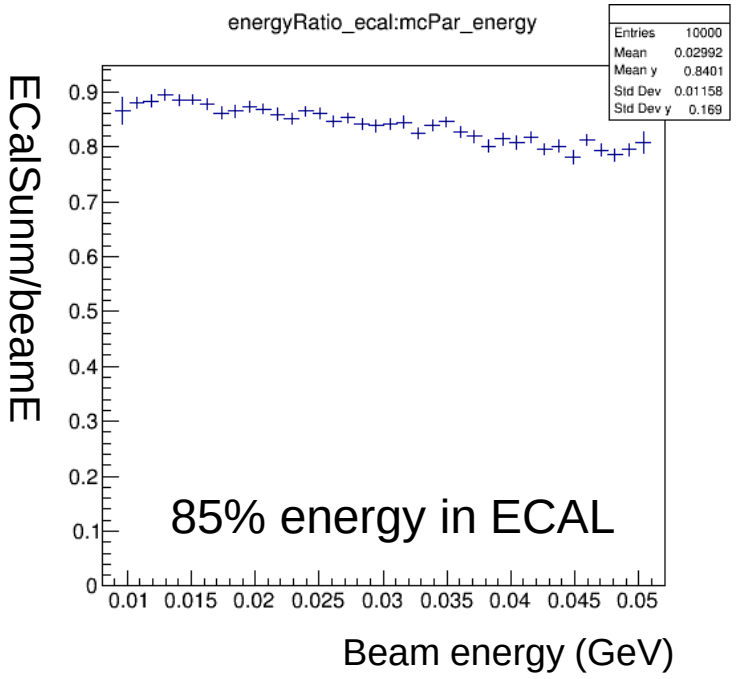


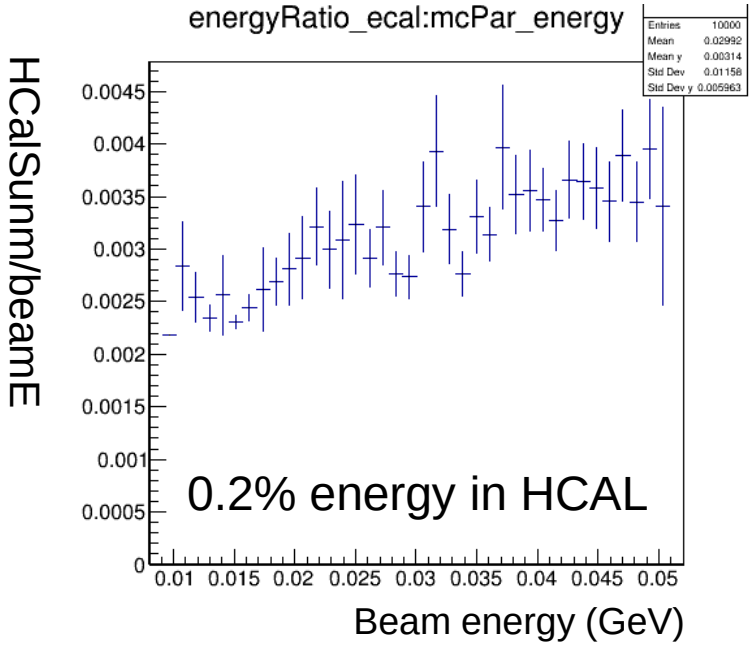
Summary

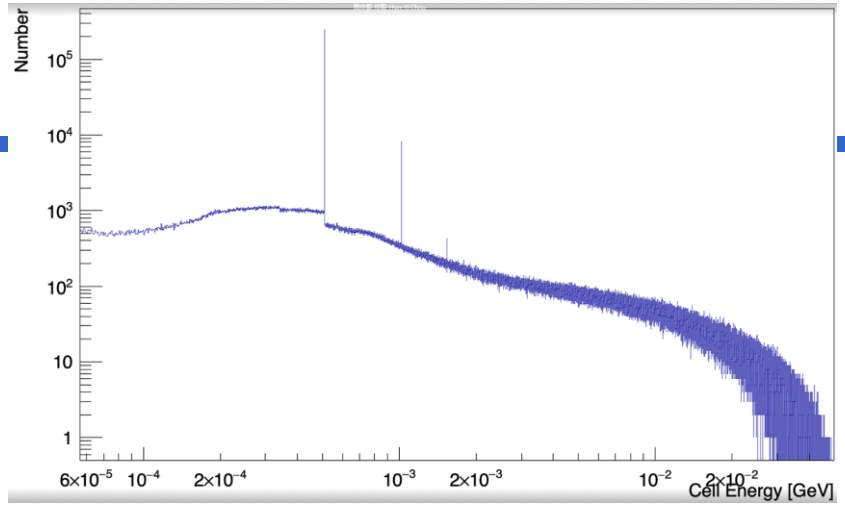
- MC outputs are not reasonable. The energy dump in both ECal and HCal is not increased with the injected beam energy. I will also contact “Alessio I.” to ask questions.
- In the meantime, some MC samples with beam energy less than 50MeV are generated and given to Hsin-Yi to have the preliminary test.

Positron Sample for ML Framwork

- Quick sample for ML framework
  - 10MeV to 50MeV
  - 10, 000 evets / sample
  - 100 samples







三個 peak 剛好對應 electron mass 1x, 2x, 3x

```
*****************************************************************************************************
* G4Track Information:   Particle = e+,   Track ID = 1,   Parent ID = 0
*****************************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
   24    -1.26    -1.47    -44.1     0.104        0        0      56.7    physLYSO initStep
   25    -1.25    -1.46    -44.1       0.1  0.00376  0.00318      56.7    physLYSO Cerenkov
   26    -1.25    -1.46    -44.1    0.0987  0.00147  0.00119      56.7    physLYSO Cerenkov
   27    -1.25    -1.46    -44.1    0.0981 0.000591 0.000424      56.7    physLYSO Cerenkov
   28    -1.25    -1.46    -44.1    0.0981 3.17e-05 0.000119      56.7    physLYSO Cerenkov
   29    -1.25    -1.46    -44.1    0.0981 5.61e-05 0.000102      56.7    physLYSO Cerenkov
   30    -1.25    -1.46    -44.1     0.098 8.28e-05 7.36e-05      56.7    physLYSO Cerenkov
   31    -1.25    -1.46    -44.1     0.098        0 3.09e-05      56.7    physLYSO Cerenkov
   32    -1.25    -1.46    -44.1     0.098 2.26e-05 3.09e-05      56.7    physLYSO Cerenkov
   33    -1.25    -1.46    -44.1    0.0976 0.000399 1.92e-05      56.7    physLYSO Cerenkov
   34    -1.25    -1.46    -44.1         0   0.0976   0.0297      56.7    physLYSO eIoni
    :----- List of 2ndaries - #SpawnInStep=  8(Rest= 0,Along= 0,Post= 8), #SpawnTotal=  8 --------------
    :     -1.25     -1.46     -44.1   3.1e-06      opticalphoton
    :     -1.25     -1.46     -44.1  3.12e-06      opticalphoton
    :     -1.25     -1.46     -44.1  3.26e-06      opticalphoton
    :     -1.25     -1.46     -44.1  2.88e-06      opticalphoton
    :     -1.25     -1.46     -44.1  2.68e-06      opticalphoton
    :     -1.25     -1.46     -44.1  2.99e-06      opticalphoton
    :     -1.25     -1.46     -44.1  2.79e-06      opticalphoton
    :     -1.25     -1.46     -44.1   2.7e-06      opticalphoton
    :-------------------------------------------------------------- EndOf2ndaries Info ---------------
   35    -1.25    -1.46    -44.1         0 E      0 dE    0      56.7    physLYSO Scintillation
    :----- List of 2ndaries - #SpawnInStep=  2(Rest= 2,Along= 0,Post= 0), #SpawnTotal= 10 --------------
    :     -1.25     -1.46     -44.1    0.511 ??          gamma
    :     -1.25     -1.46     -44.1    0.511             gamma
    :-------------------------------------------------------------- EndOf2ndaries Info ---------------
```

e+e- annliation, 0.511<MeV = mass of electron

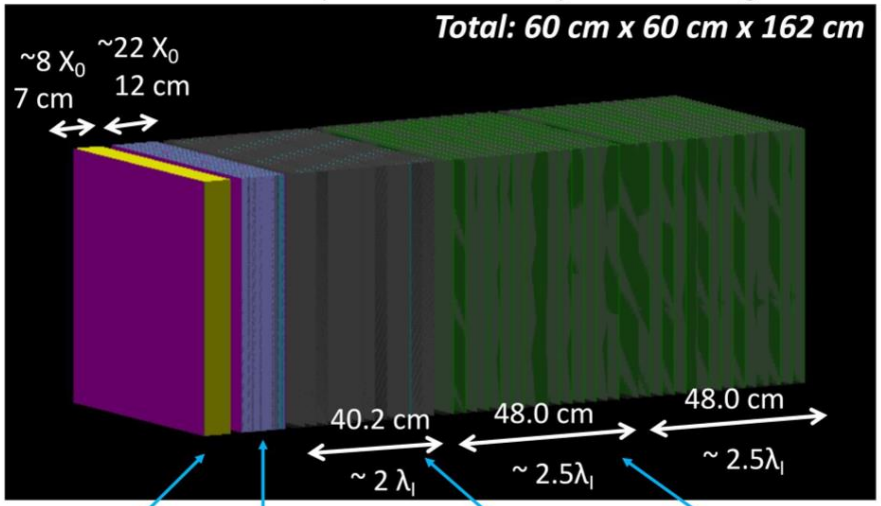
Backup

ZDC slides

- https://indico.bnl.gov/event/21546/contributions/84522/attachments/51613/88272/ZDC_EICCALO_121323.pdf
- https://indico.phys.sinica.edu.tw/event/85/contributions/404/attachments/439/1054/TIDC_Annual_PoJuLin_20231125.pdf
- Manuscript : https://arxiv.org/pdf/2412.12346

Po-Ju's Results

*note: space for readout may extend the longitudinal length.



Crystal ($PbWO_4$) + Silicon Pixel layer | W/Si calo. 3 Pixel layers are inserted. | Pb/Si calo. | Pb/Sci. calo.