B0 EMCAL Update

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B0 design

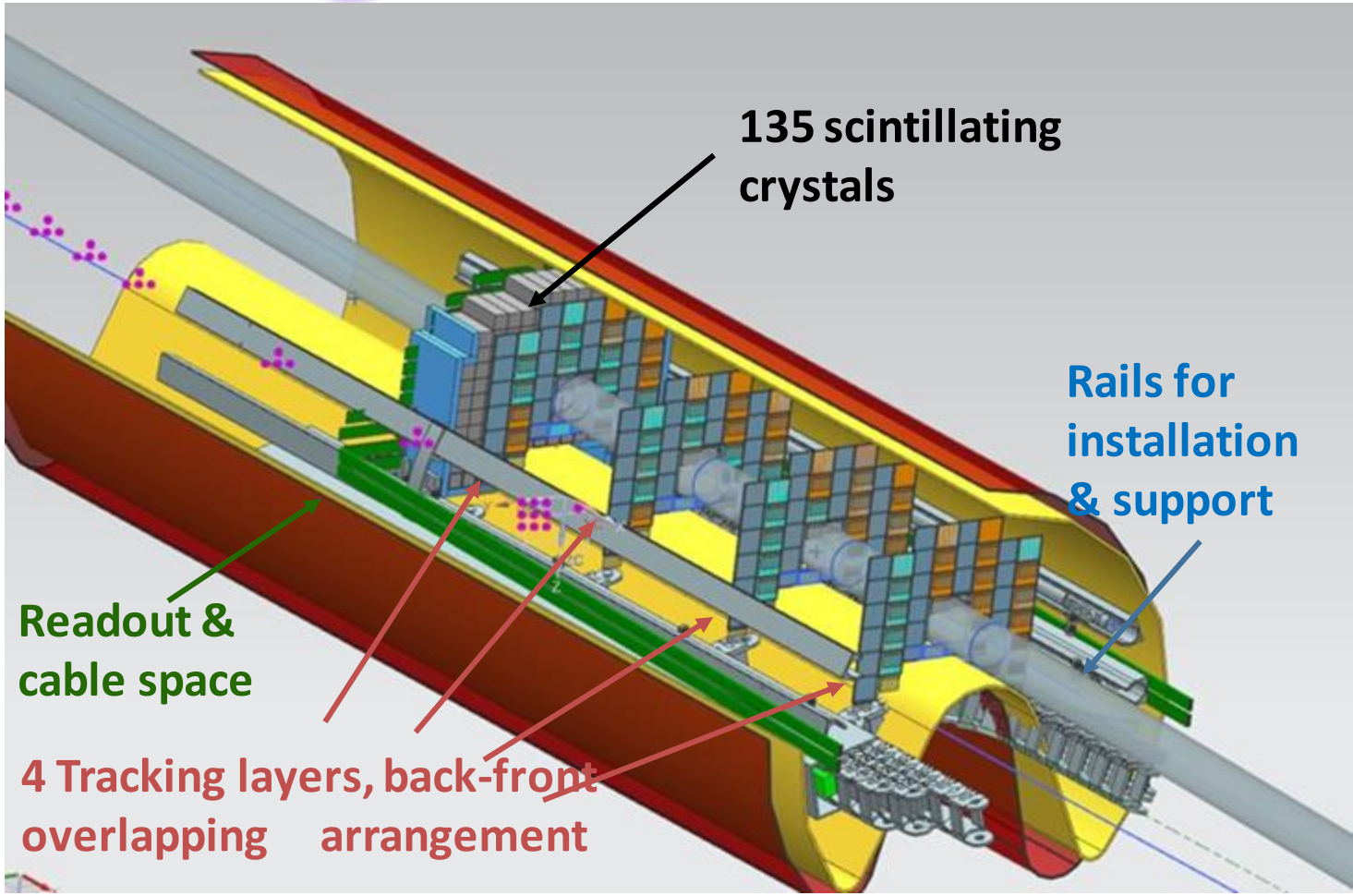
*since last ePIC collaboration meeting

Si Tracker:

- 4 Layers of **AC-LGAD**
- dZ=8.1cm → 27cm between planes
- Great timing capabilities
- Sufficient position resolution by utilizing charge sharing
- Technology overlap w/ Roman pots

EM Calorimeter:

- 135 2x2x10 cm^3 LYSO crystals
- Sensitivity for sub-GeV photons
- Can work at room temperature, stable against temperature gradients
- Good timing and position resolution



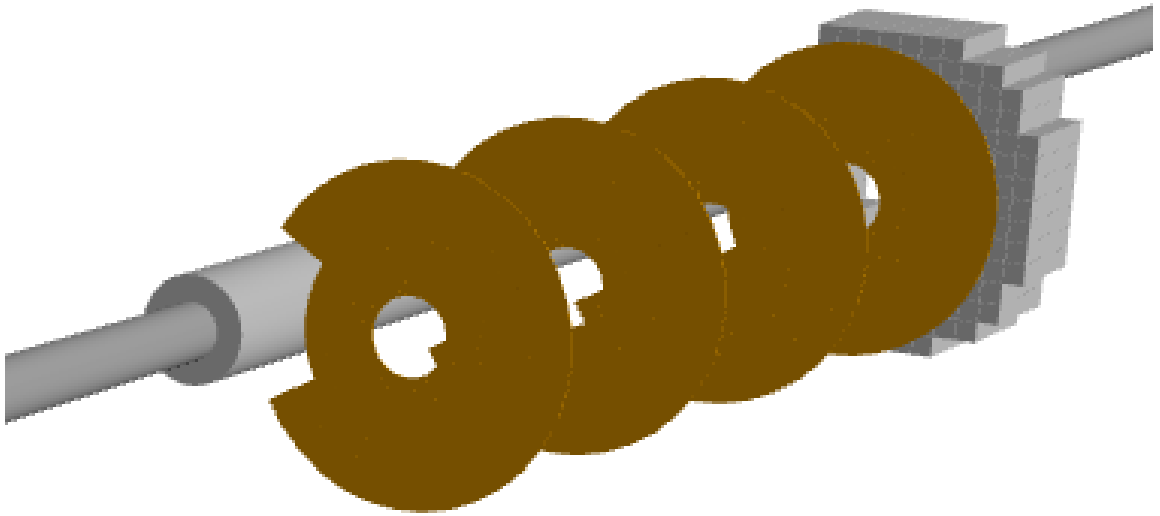
BOECAL Simulation status

Geometry

B0 Tracker: 4 AC-LGAD layers separated by 27 cm

~~10cm~~ 20cm* long ~~PbWO4~~ LYSO crystals to form a B0 ECAL

* Actively working on figuring out which crystals need to be shortened due to mechanical constraints



B0ECAL update

ECAL crystals

https://github.com/eic/epic/blob/main/compact/far_forward/B0_ECal.xml

- Crystal length form 10 cm to 20 cm:

```
<constant name="B0ECal_IP_distance" value="683*cm"/>
<constant name="B0ECal_length" value="10*cm"/>
```

```
<constant name="B0ECal_IP_distance" value="688*cm"/>
<constant name="B0ECal_length" value="20*cm"/>
```

https://github.com/eic/epic/blob/main/compact/materials.xml

```
<material name="LYSO"><!-- given by the Taiwan Applied Crystals -->
   <D type="density" unit="g/cm3" value="7.125"/>
   <fraction n="0.71813" ref="Lu"/>
   <fraction n="0.03613" ref="Y"/>
   <fraction n="0.06338" ref="Si"/>
   <fraction n="0.18046" ref="O"/>
   <fraction n="0.00190" ref="Ce"/>
 </material>
```

- Crystal material PbWO4 -> LYSO

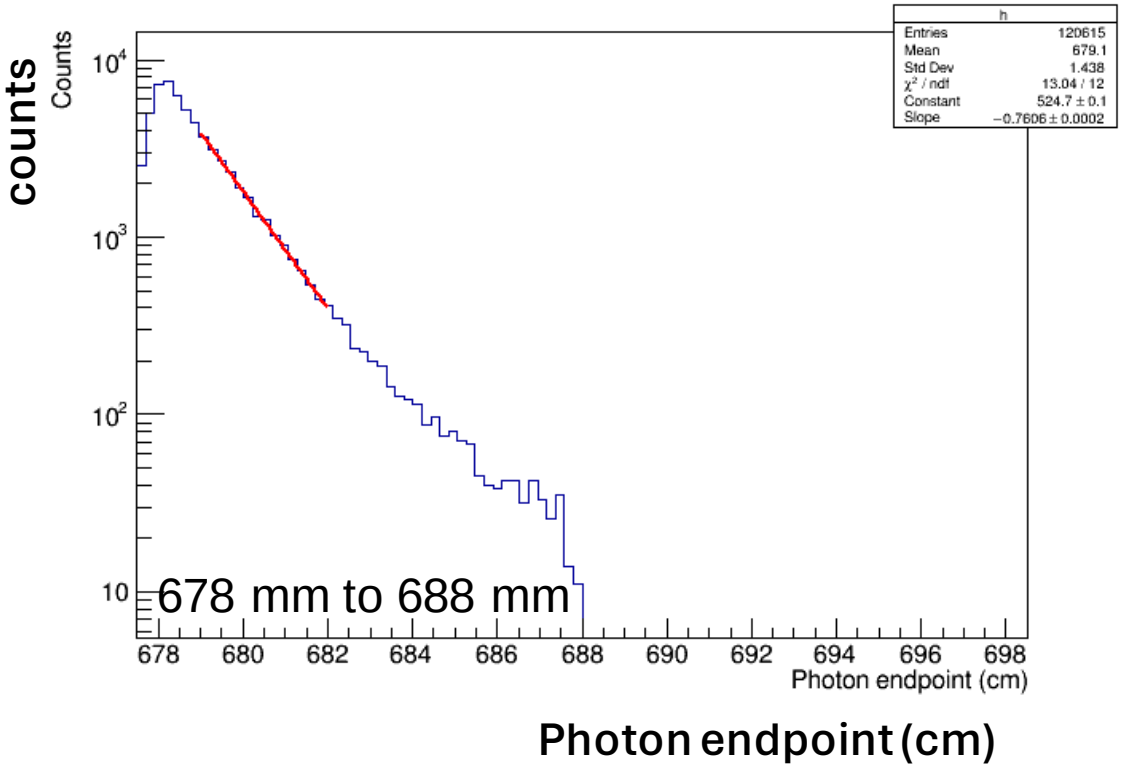
```
...
      <module
        sizex="B0ECal_CrystalModule_width"
        sizey="B0ECal_CrystalModule_width"
        sizez="B0ECal_CrystalModule_length"
        vis="GreenVis"
        material="PbWO4"/>
...
```

```
...
      <module
        sizex="B0ECal_CrystalModule_width"
        sizey="B0ECal_CrystalModule_width"
        sizez="B0ECal_CrystalModule_length"
        vis="GreenVis"
        material="LYSO"/>
...
```

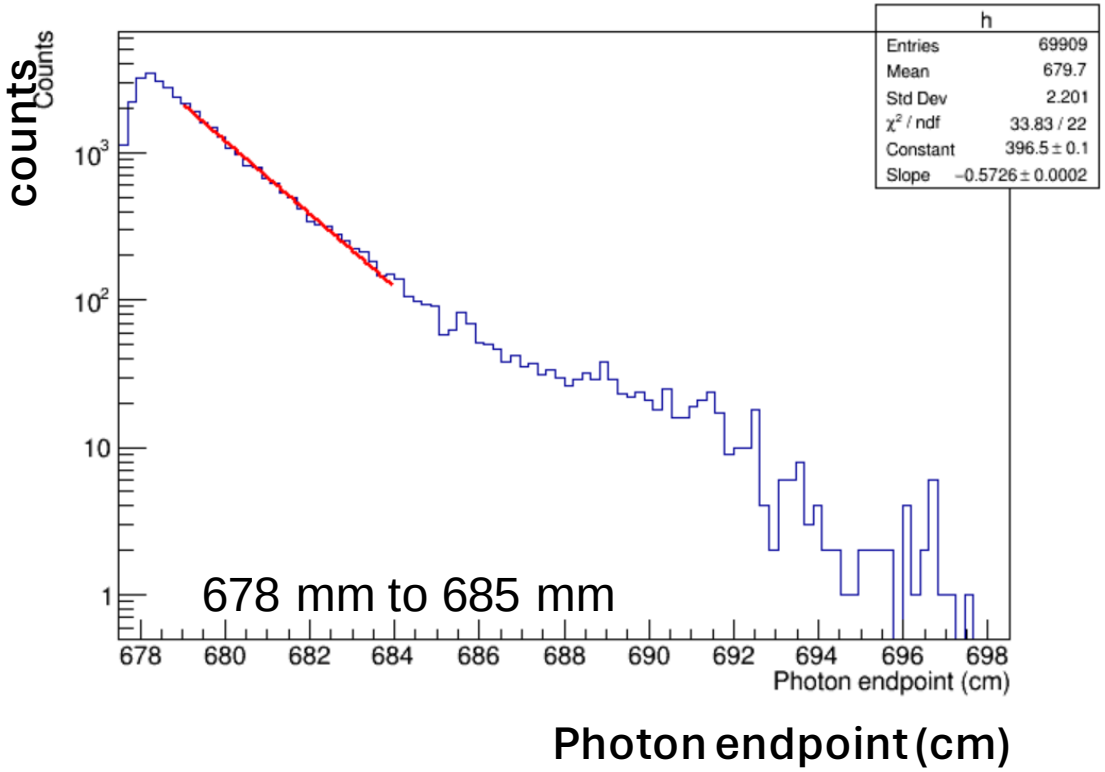
BOECAL update

ECAL crystals

- X0 of PbWO4 is 0.92cm, of LYSO is 1.12.cm (20%)
- Density of PbWO4 is 8.3 g/cm3, LYSO is 7.125 g/cm3 (16%)
- Inspect the photon mean free path(end point along the Z axis), λ=1.3cm -> λ=1.75cm (35%)



Photon endpoint (cm)

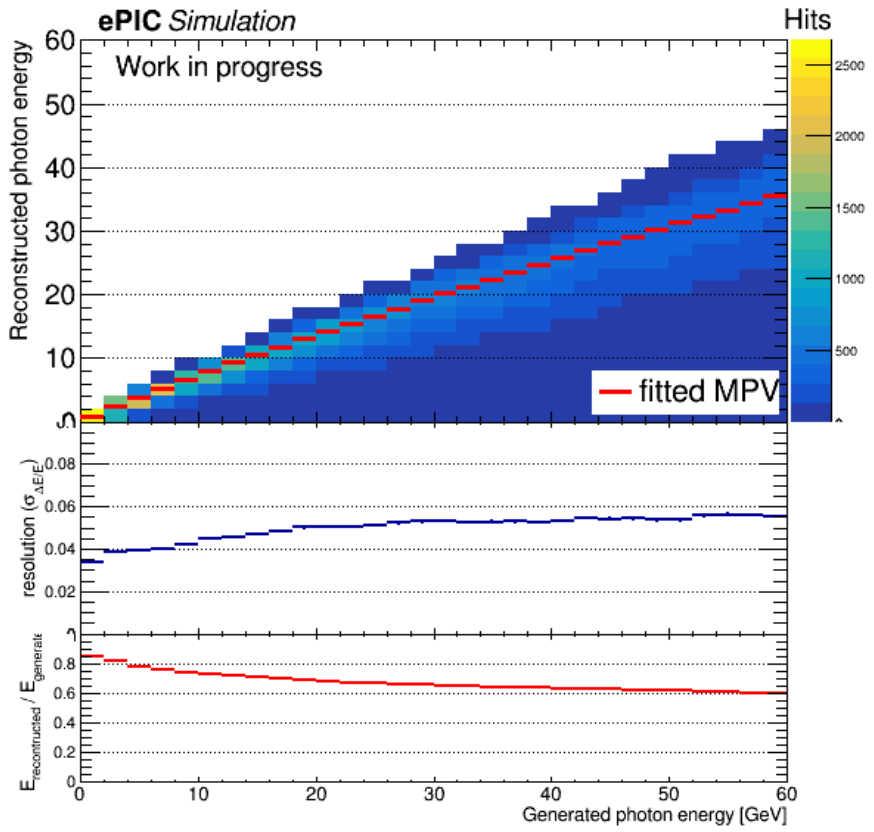


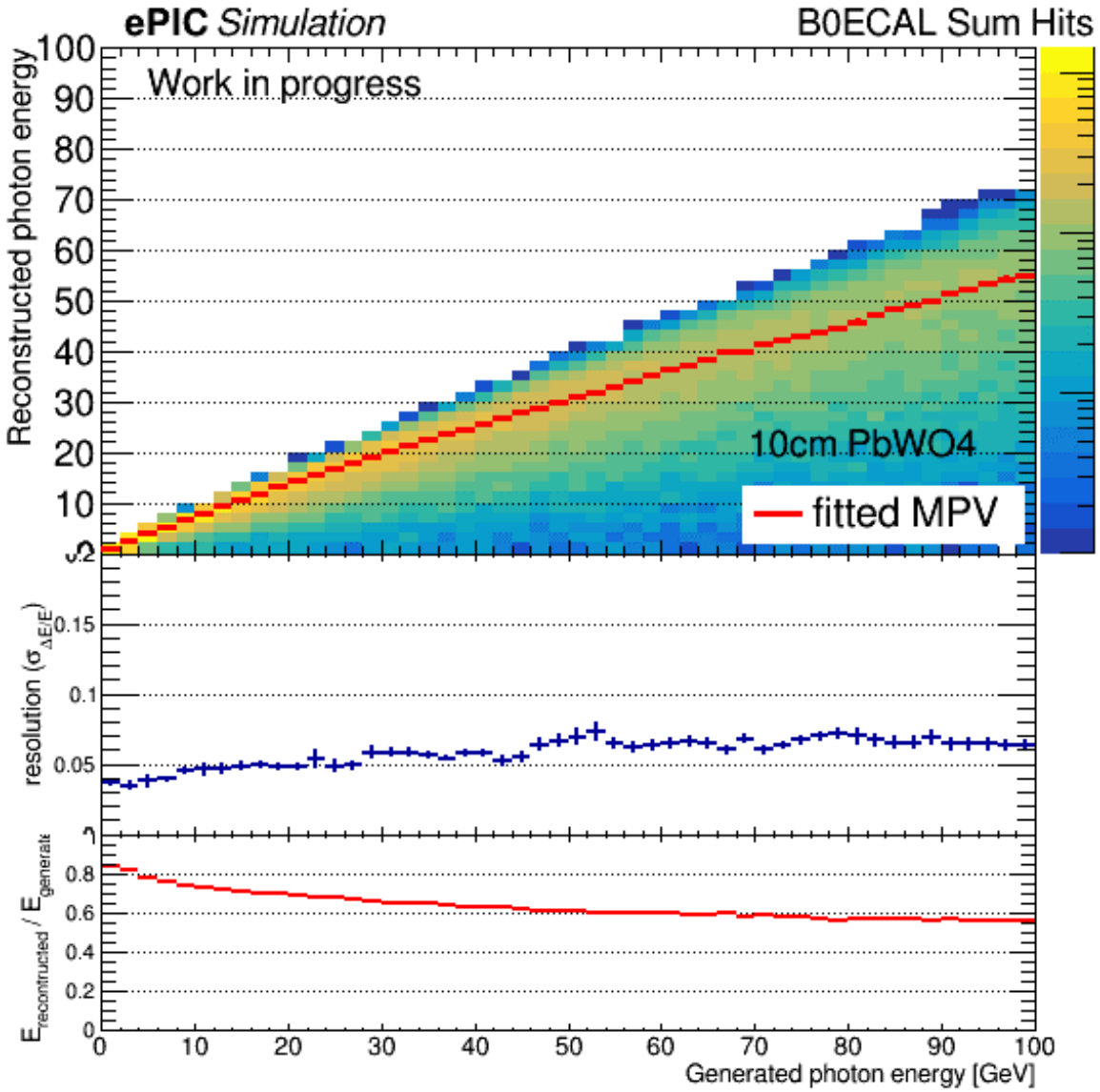
Photon endpoint (cm)

BOECAL update

ECAL crystals

- Reproduce old results (ePIC Cal. Jan 10 2023)

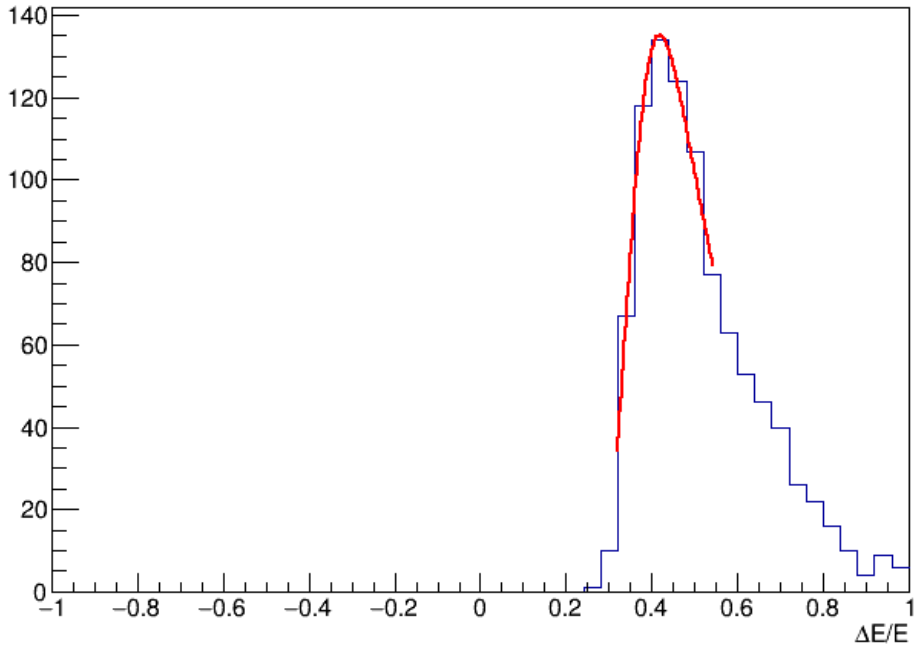


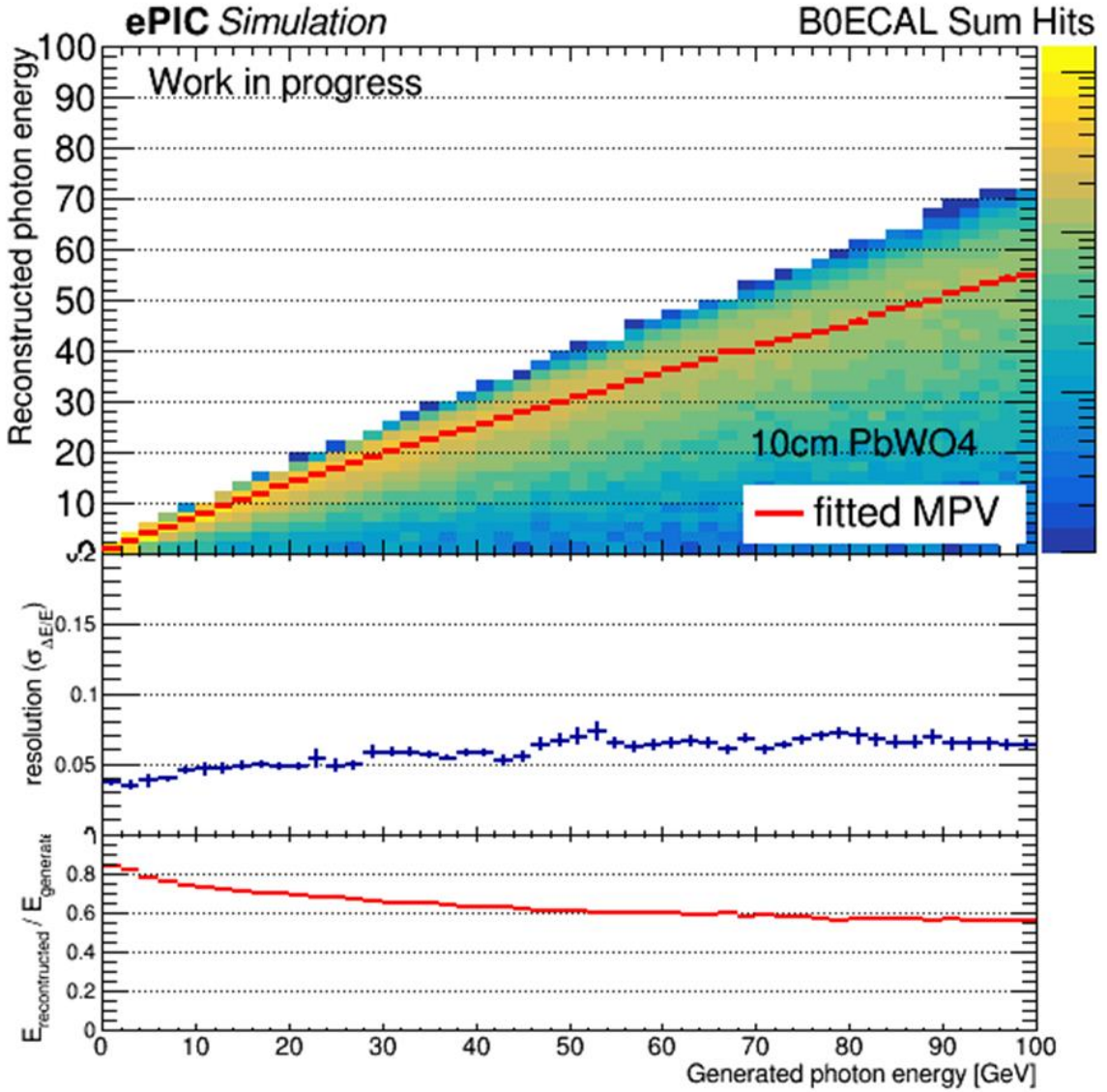


BOECAL update

ECAL crystals

- Reproduce old results (ePIC Cal. Jan 10 2023)
- Fit Landau (to obtain mean/~~resolution~~) – Large leakage prevent of using normal distribution.

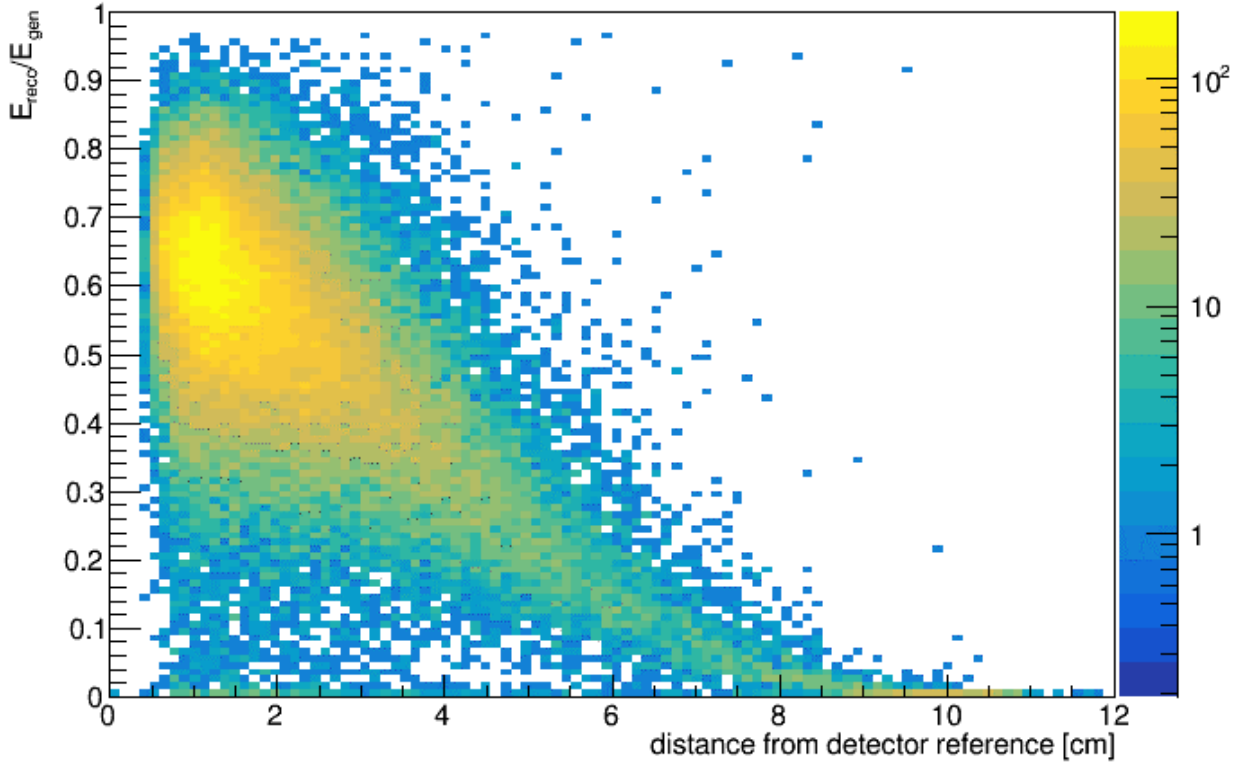


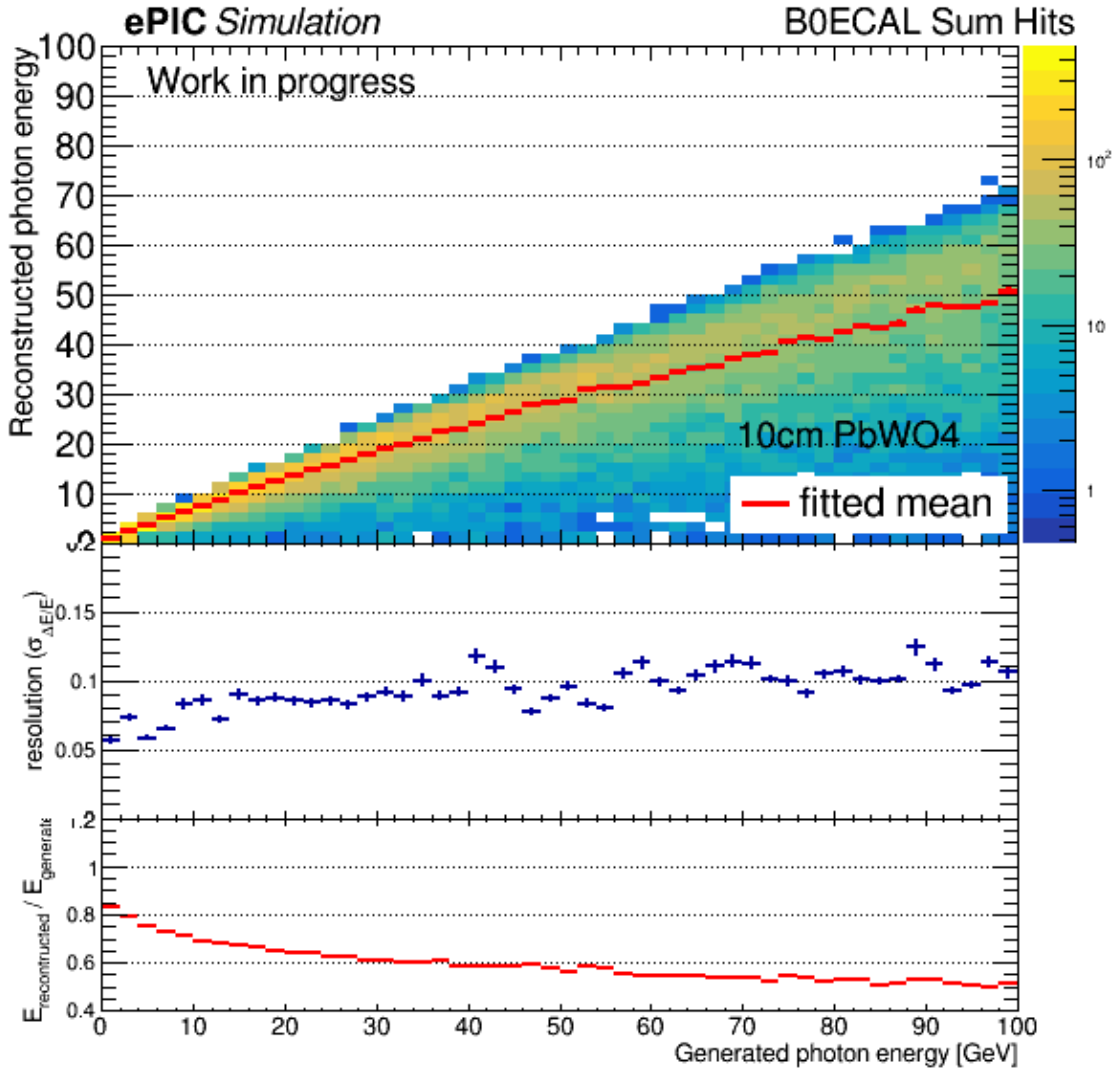


B0ECAL update

ECAL crystals

- Fit Gauss for comparison with other configurations



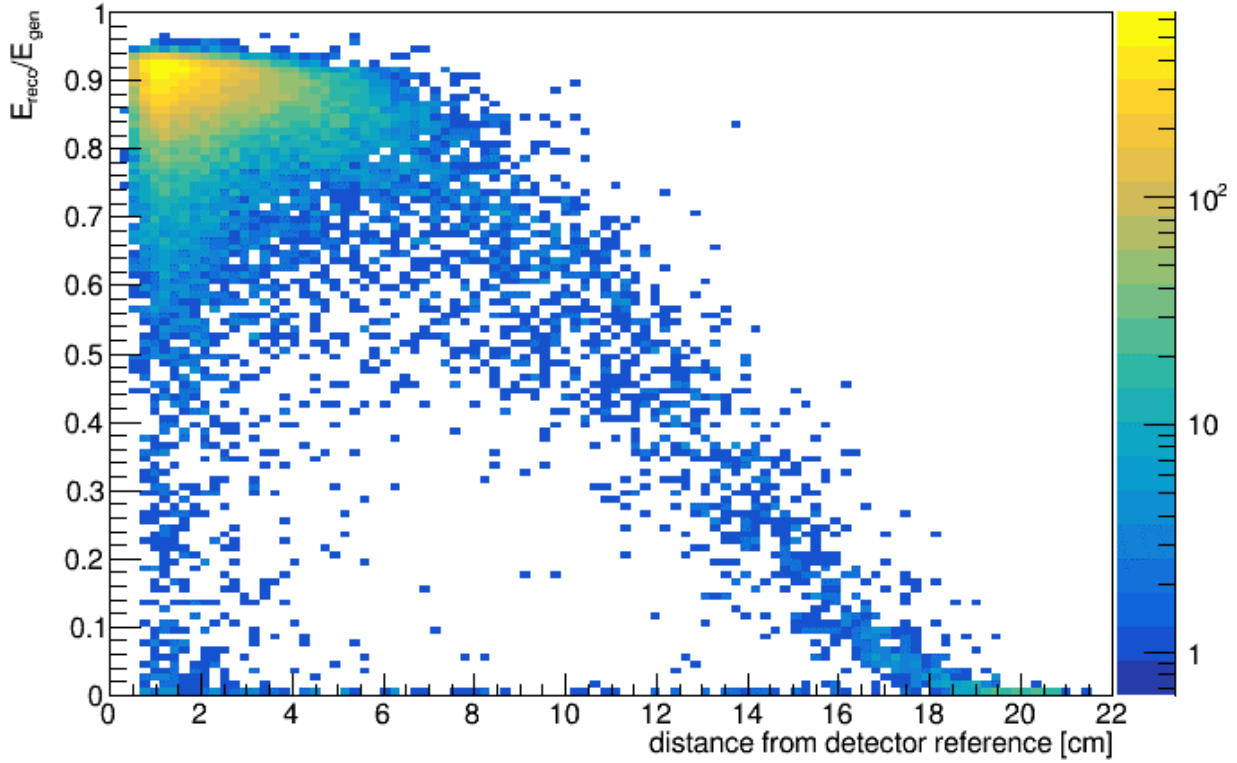


Z coordinate of the shower from B0ECAL edge

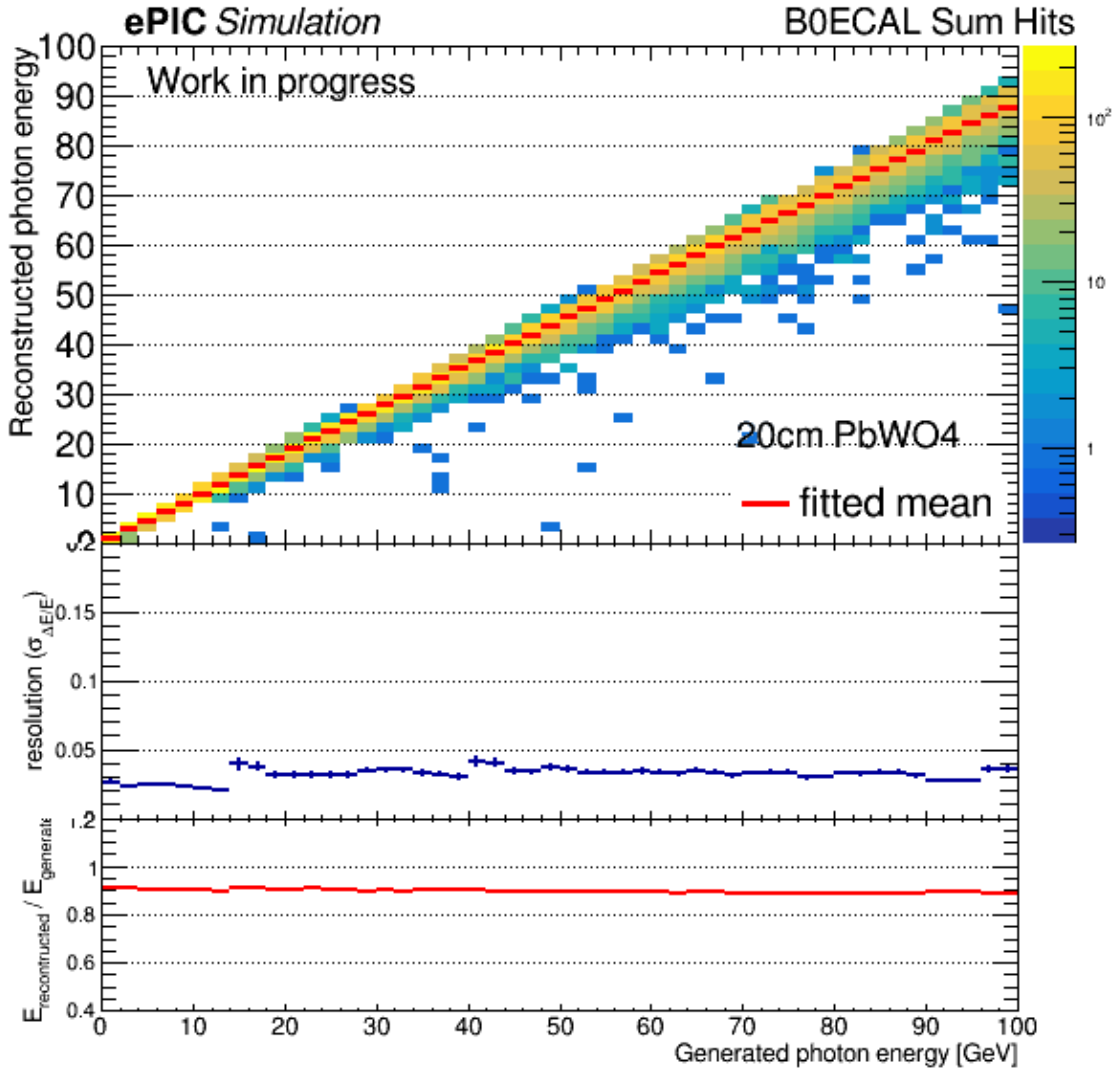
B0ECAL update

ECAL crystals

- Fit Gauss for comparison with other configurations
- Double the crystal length (10cm → 20 cm)



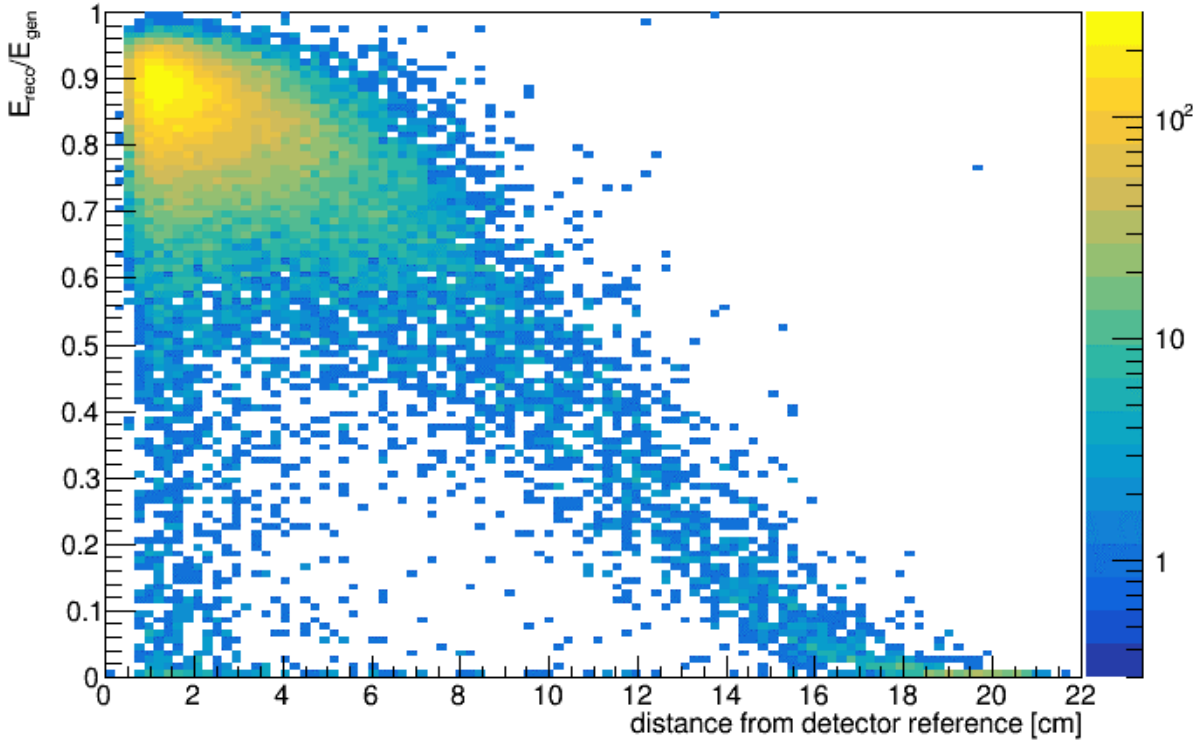
Z coordinate of the shower from B0ECAL edge



B0ECAL update

ECAL crystals

- Fit Gauss for comparison with other configurations
- Double the crystal length (10cm → 20 cm)
- Change to LYSO (more Gaussian distributions)



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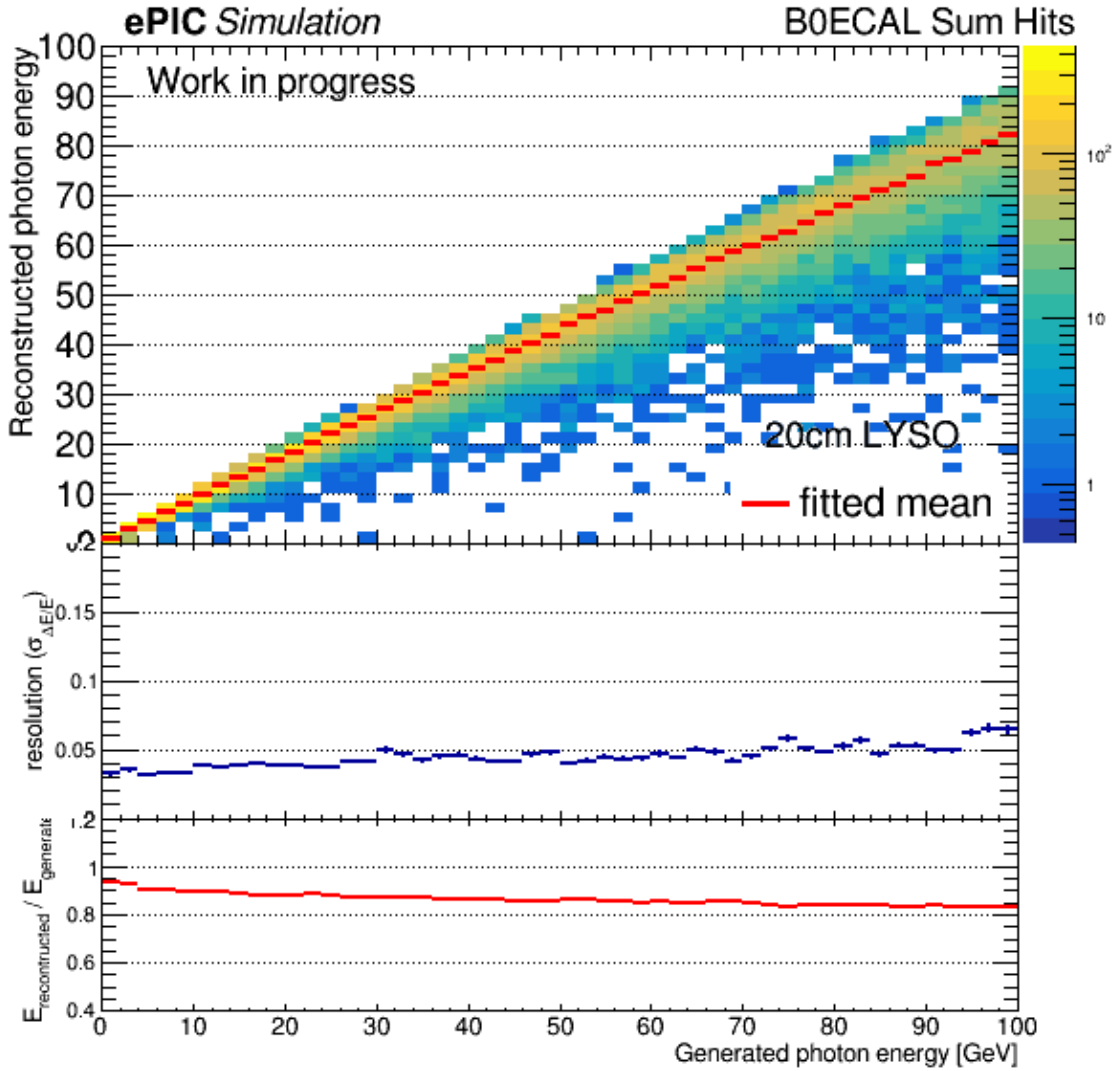
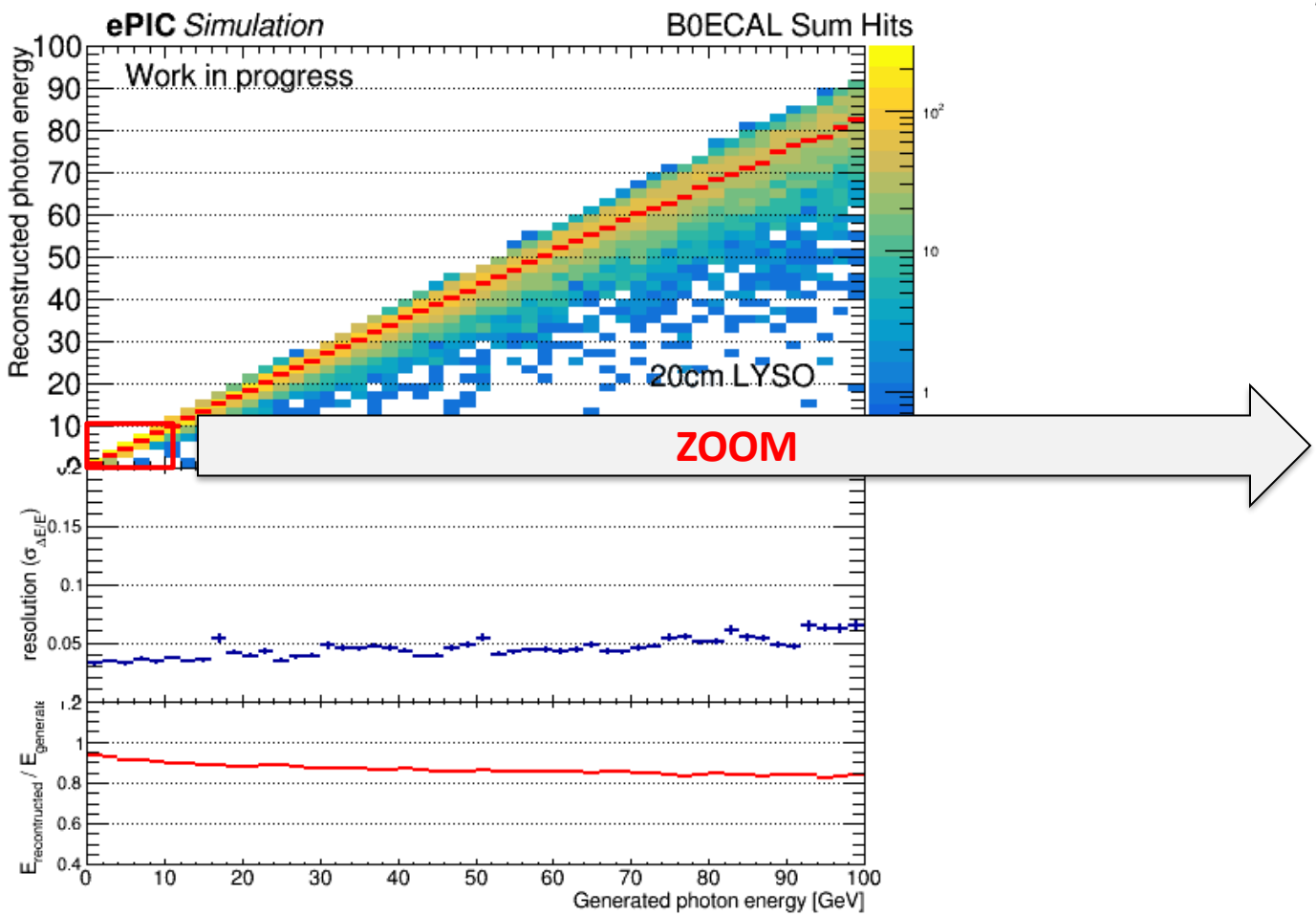
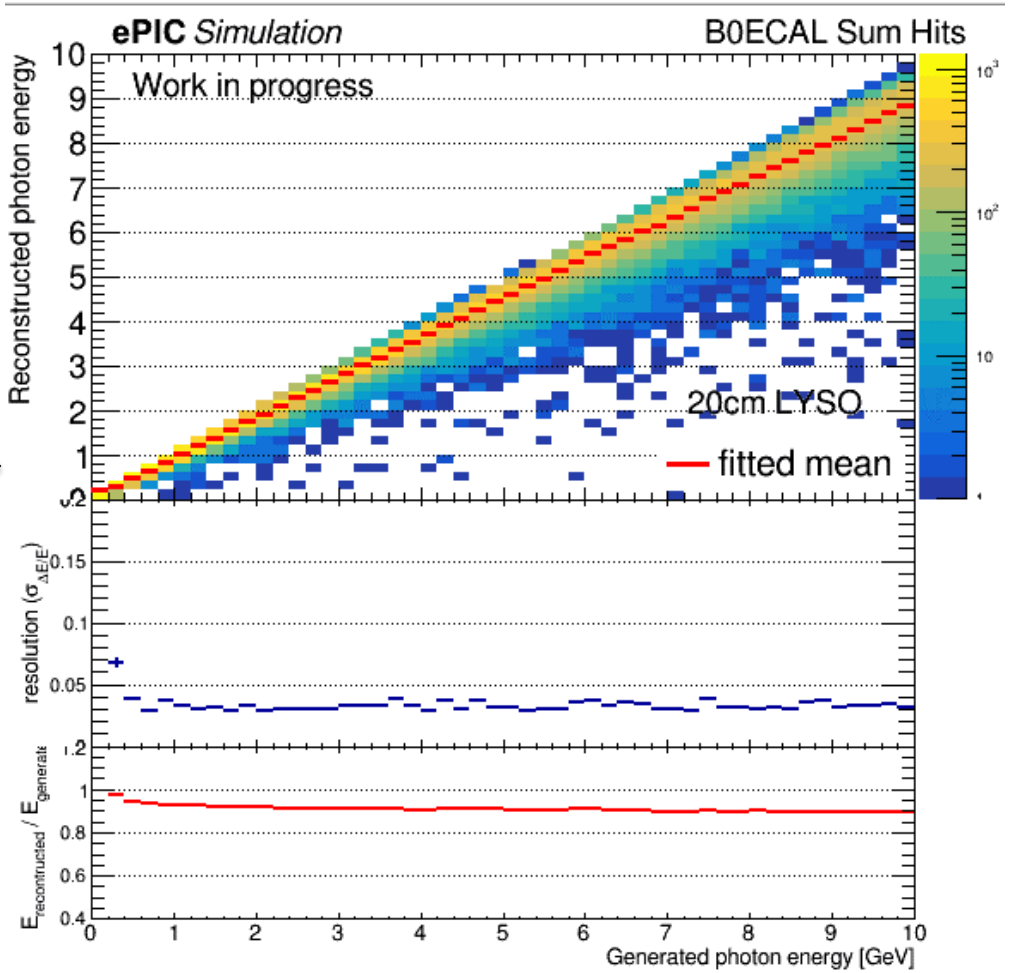


Soft photons

- Zoom in to E< 10 GeV range, all photons interacted in B0ECAL

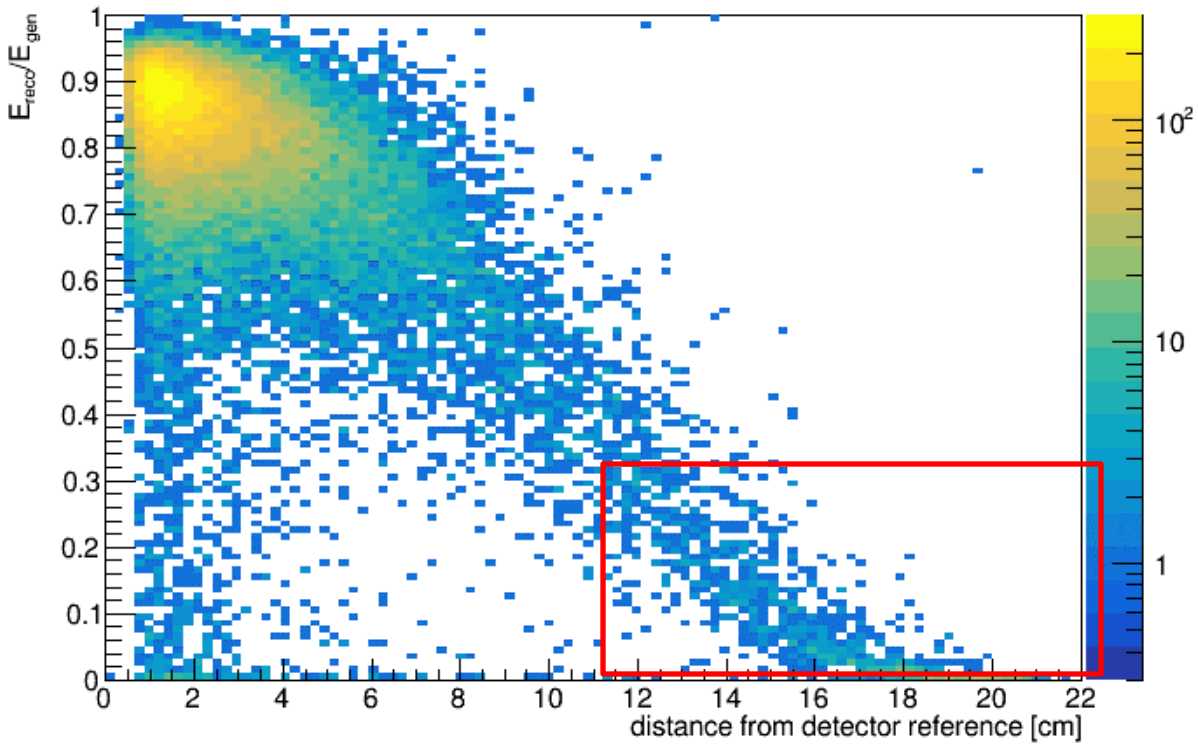


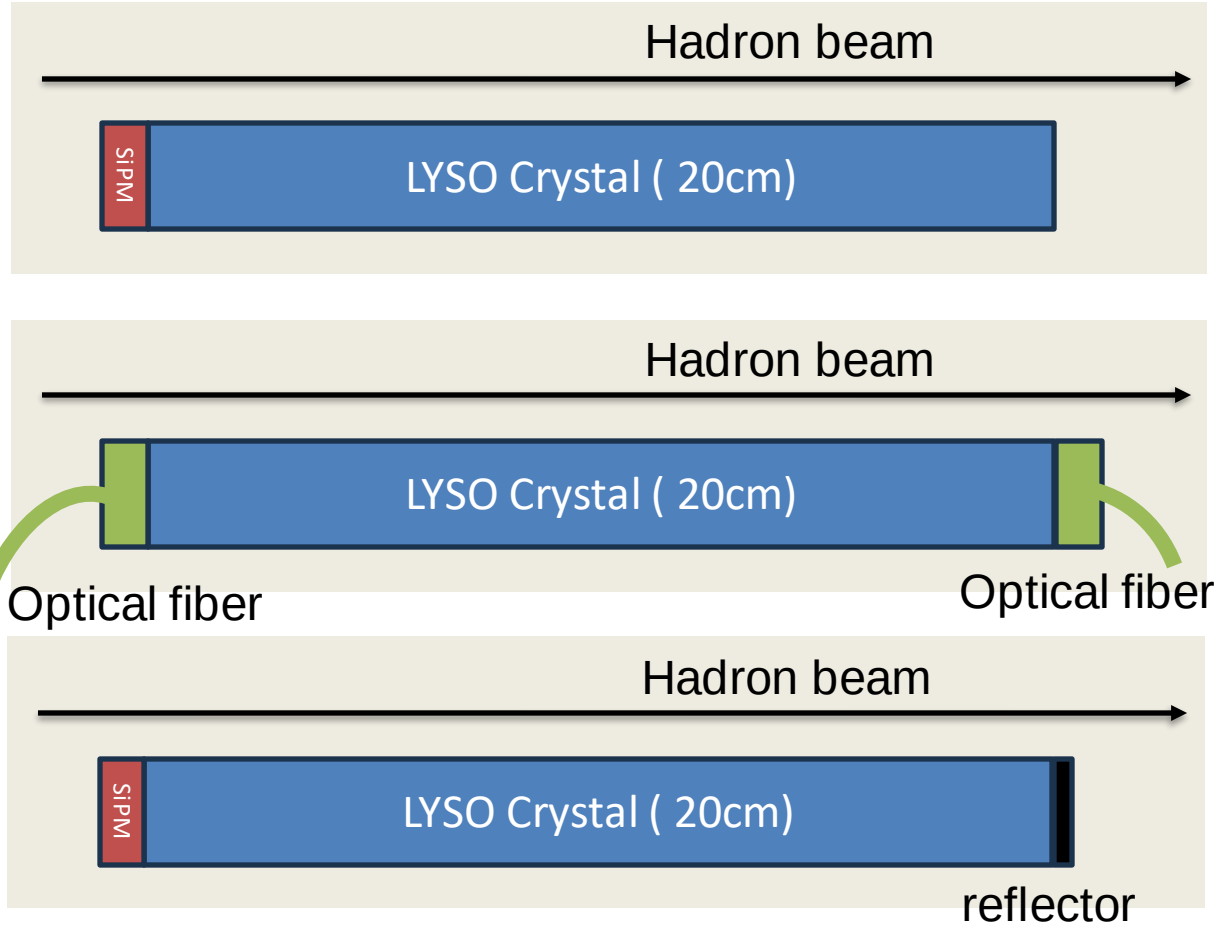
ZOOM



Soft photons - backgrounds

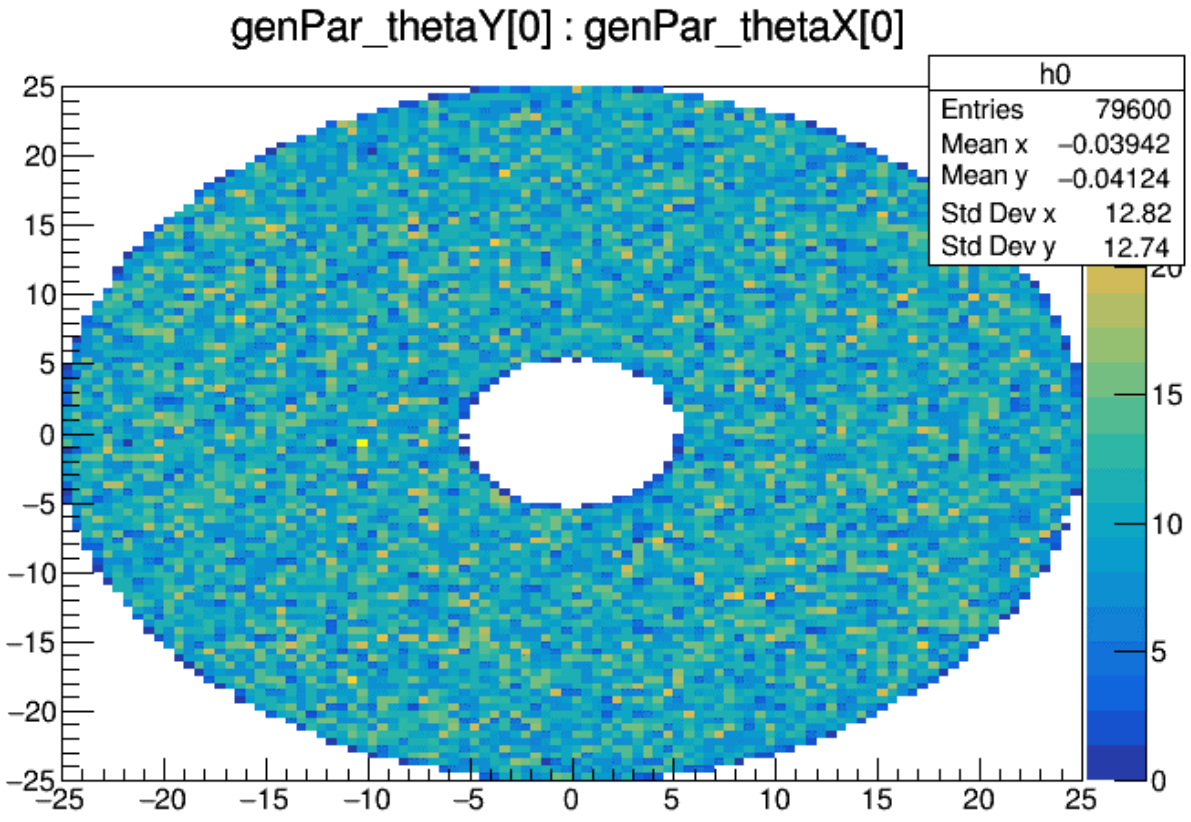
- Hard photons with late shower can be a background to soft photons
- 20 cm requires positioning the readout in front of the crystal
- A few options investigated: measuring waveforms to determine shower profile

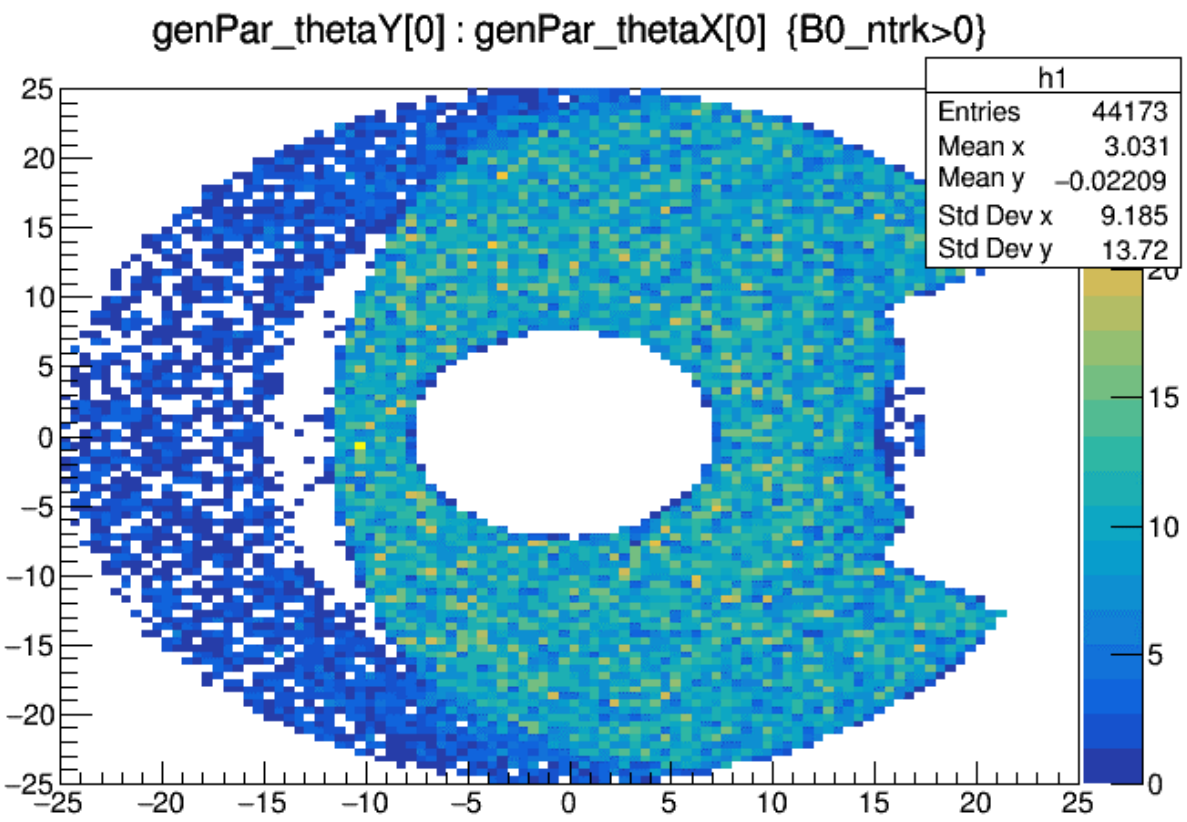




Protons in B0 detectors

- Protons with E=110 GeV were generated within the B0 acceptance
- Protons interacting the beampipe(?) are scattered away





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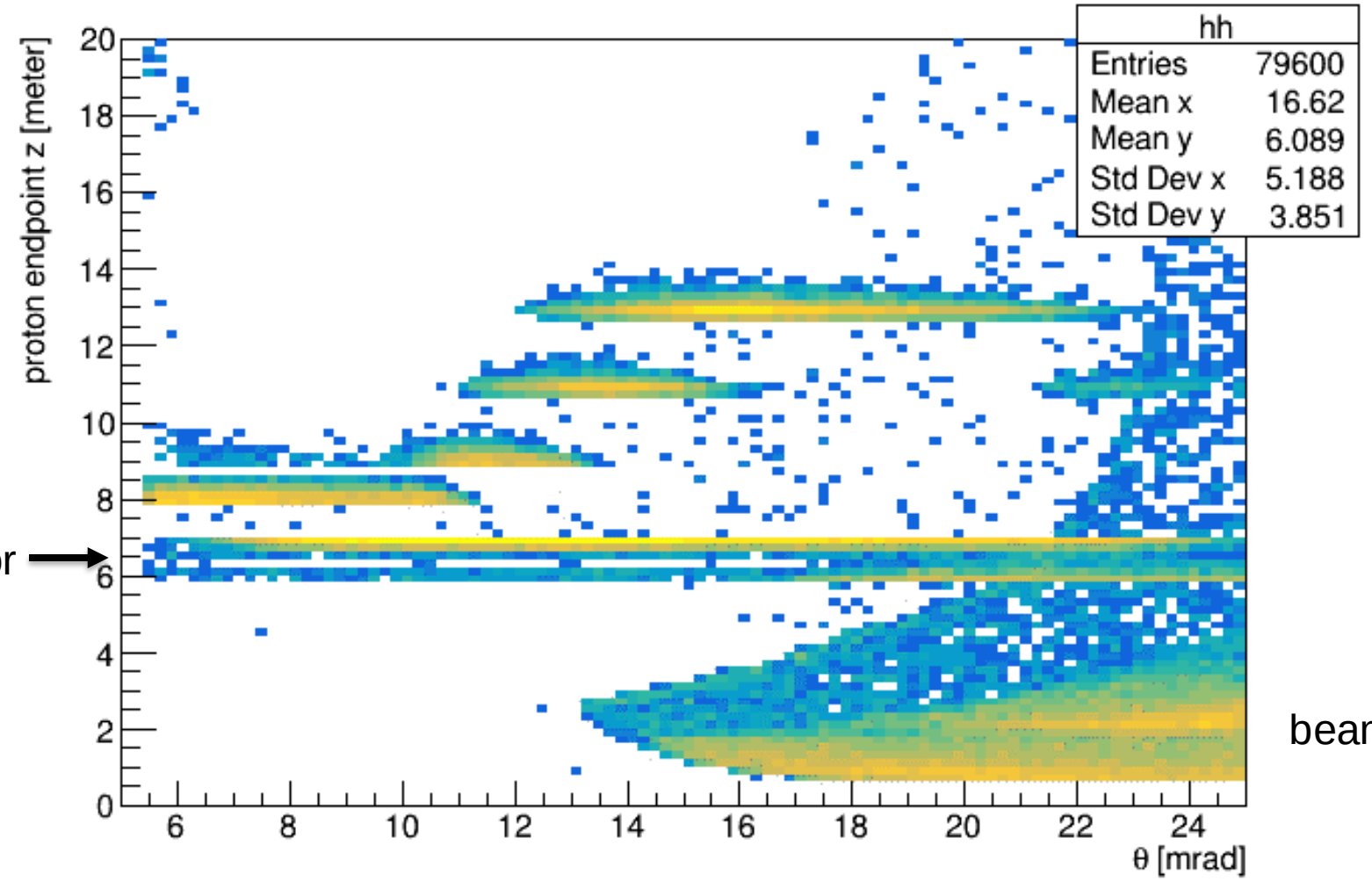
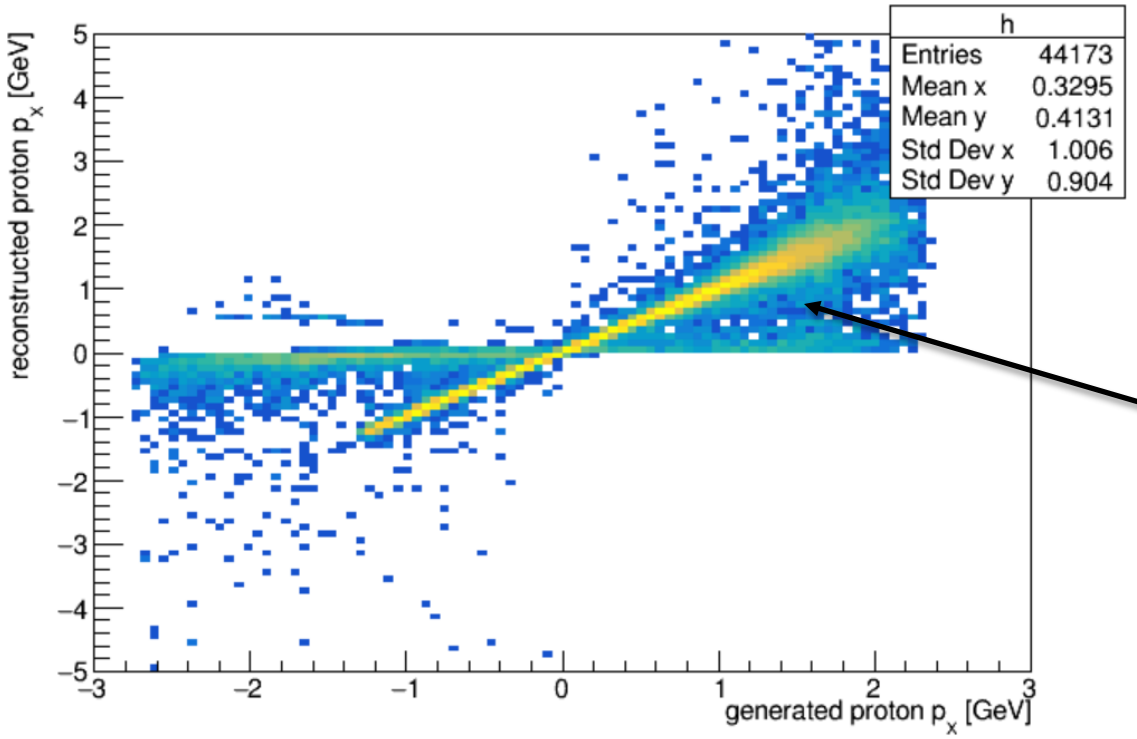
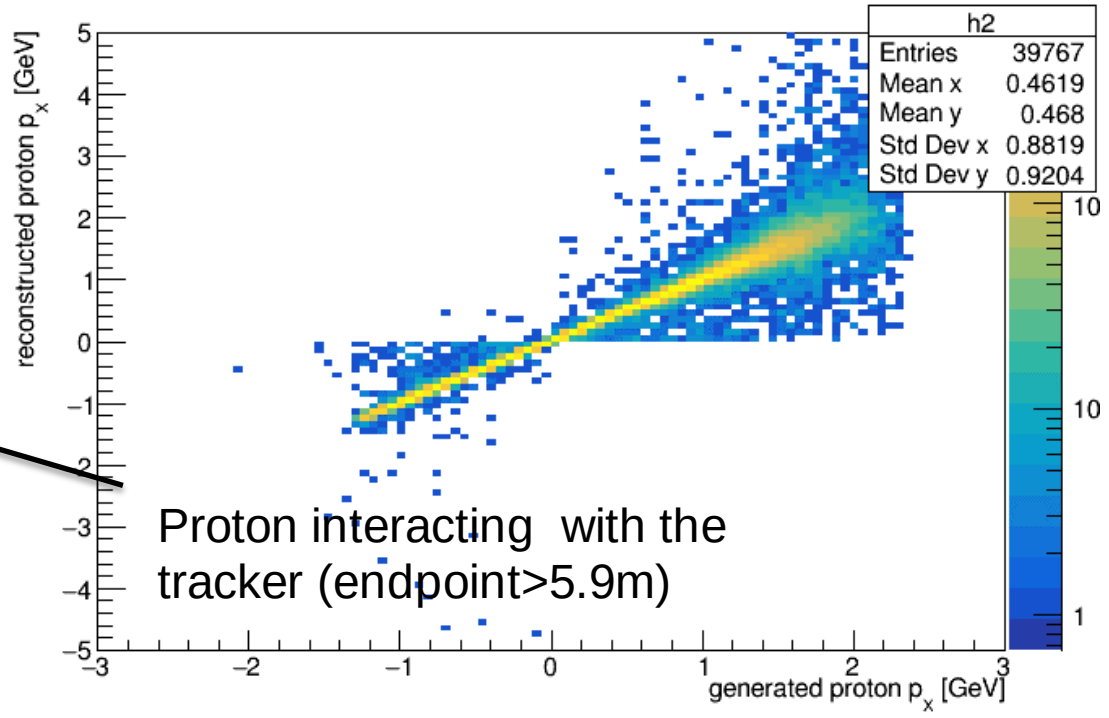


Protons in B0 detectors

- Protons with E=110 GeV were generated within the B0 acceptance
- Protons in early stage scattered away by interacting the beampipe (similar to photons)
- Resolution for protons is extracted and can be studied with different configurations (realistic B0 field, spacing between the detectors, etc..)

*** PX is defined along the hadron beam**





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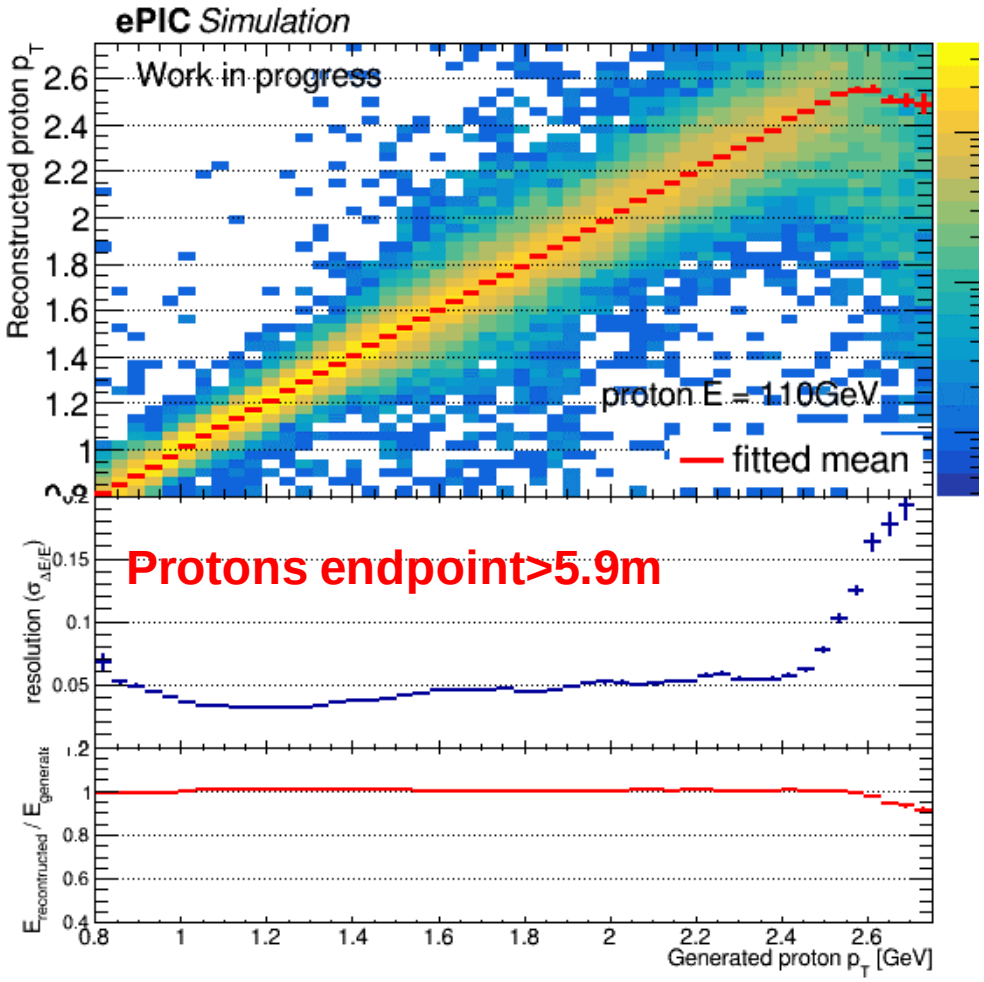
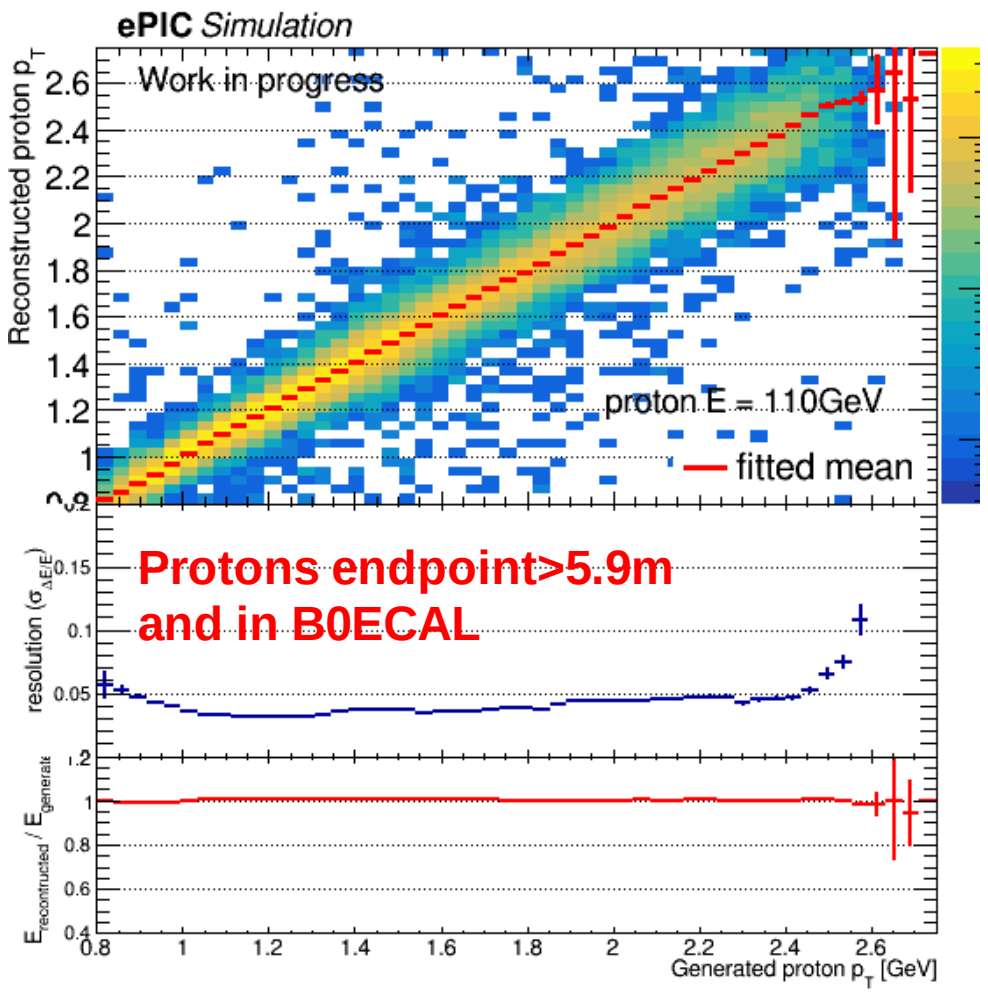
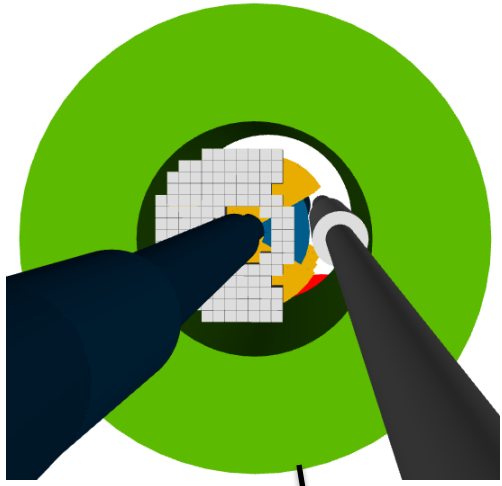
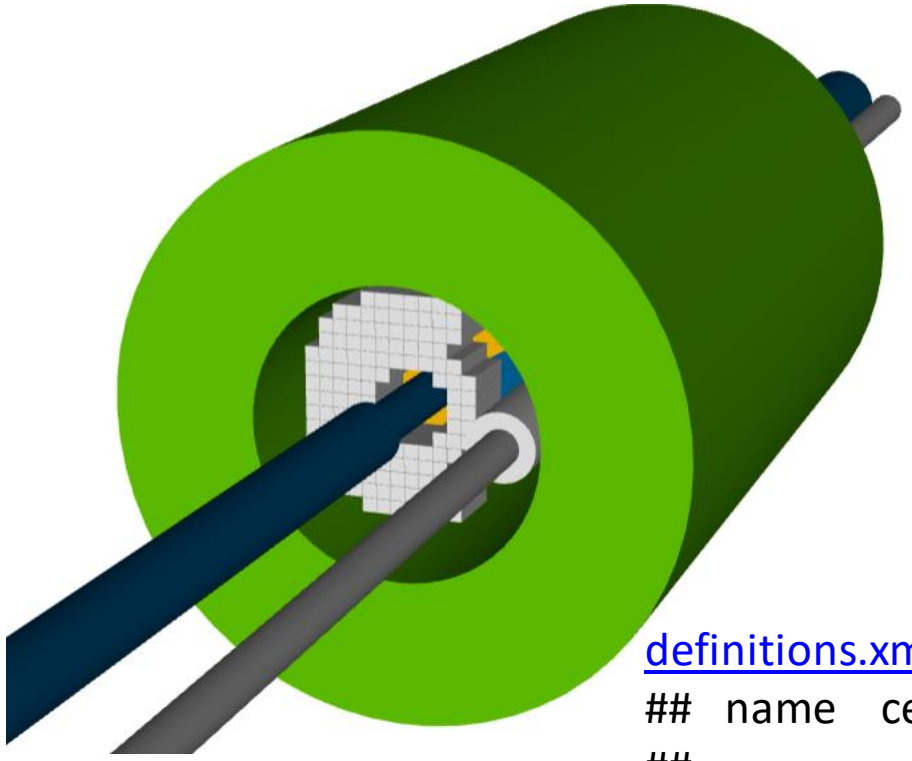


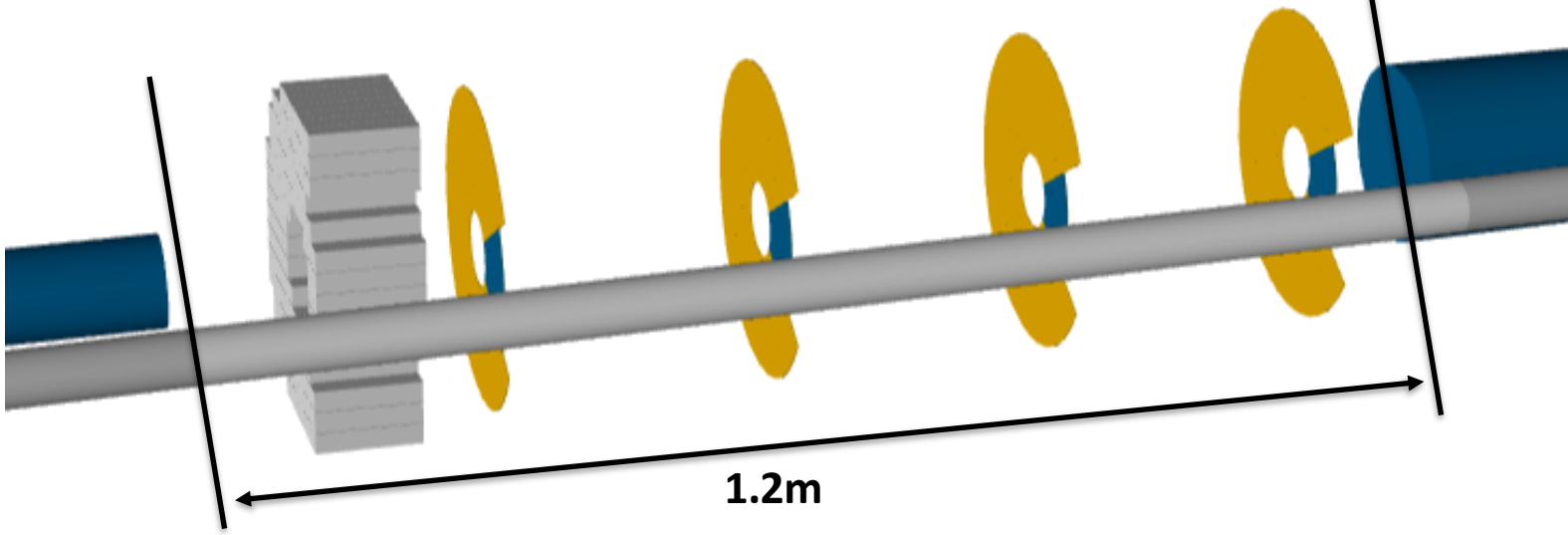


B0 detector layout

- In DD4HEP, B0 detector have 10 cm between the end of the 10cm crystal to the end of B0 Magnet (B0 magnet back)



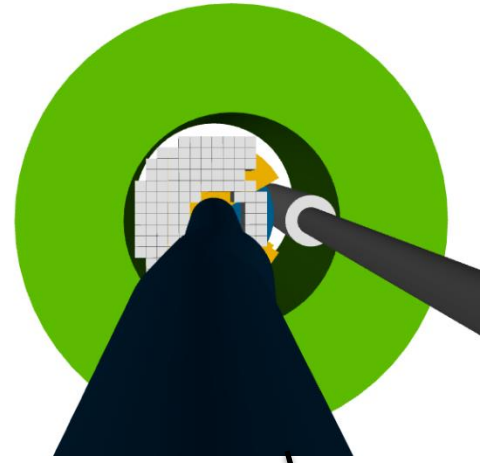




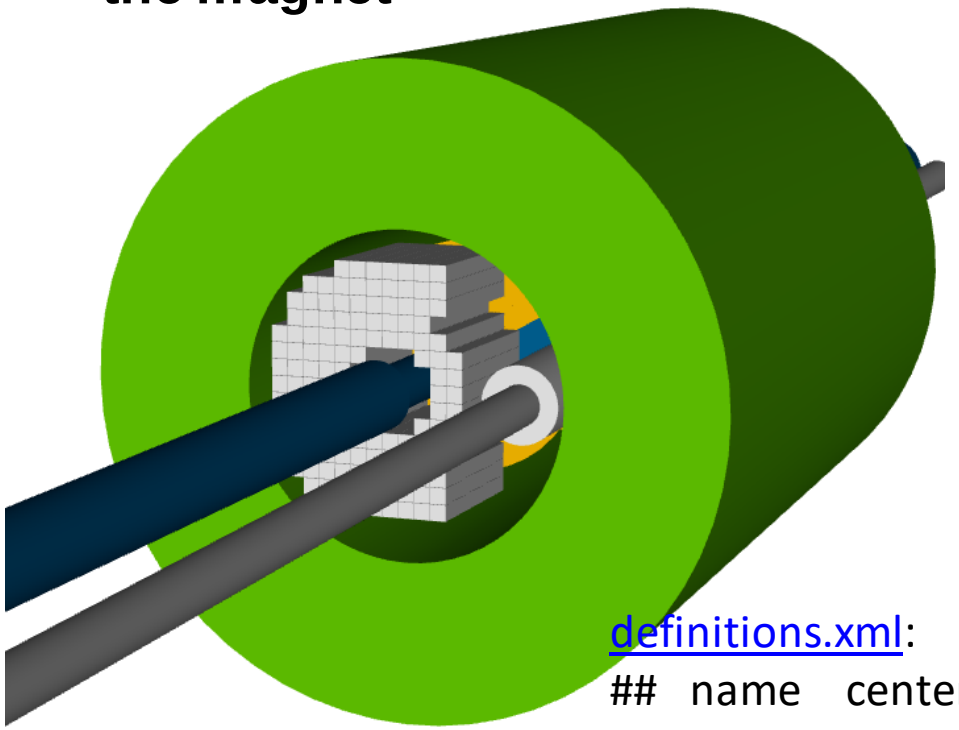
definitions.xml:

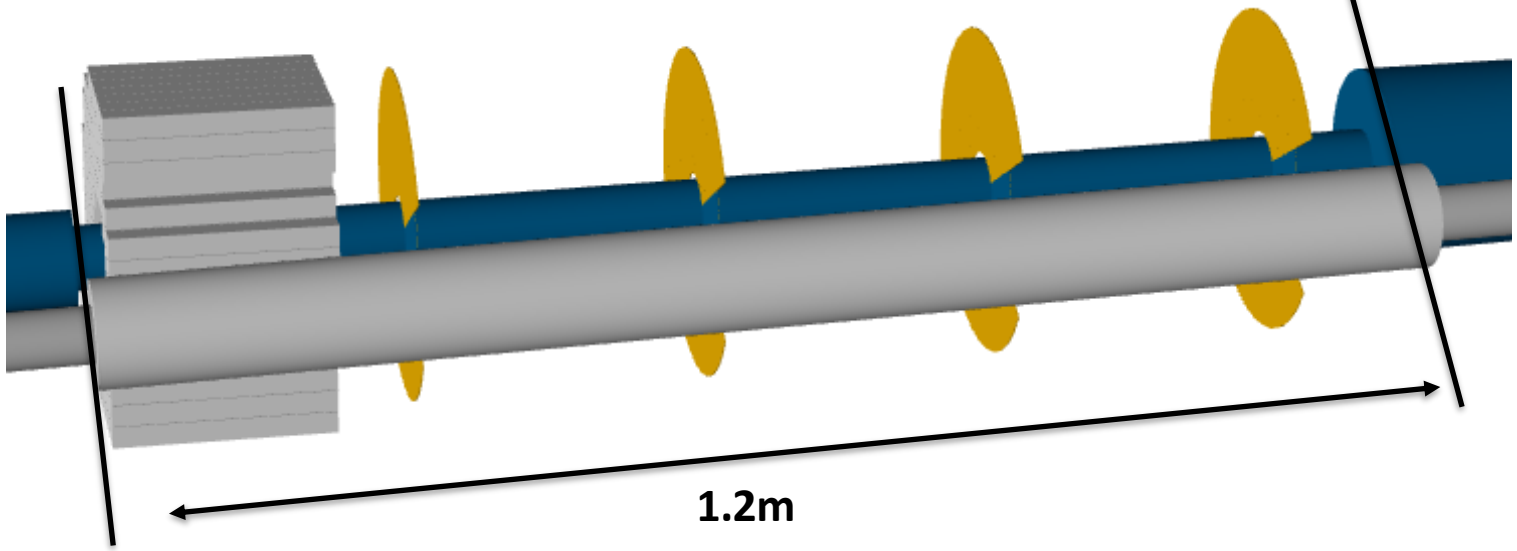
## name	center_x	center_y	center_z	rin(z-in)	rin(z-out)	dout	length	angle	B	gradient
##	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[mrad]	[T]	[T/m]
B0PF	0.132497	0.0	5.89913	0.2000	0.2000	0.5000	1.200	0.00	-1.300	0.000

B0 detector layout



- In DD4HEP, B0 detector have 10 cm between the end of the 10cm crystal to the end of B0 Magnet (B0 magnet back)
- **Adding 10 cm to the crystal layer extends the detector to the end of the magnet**

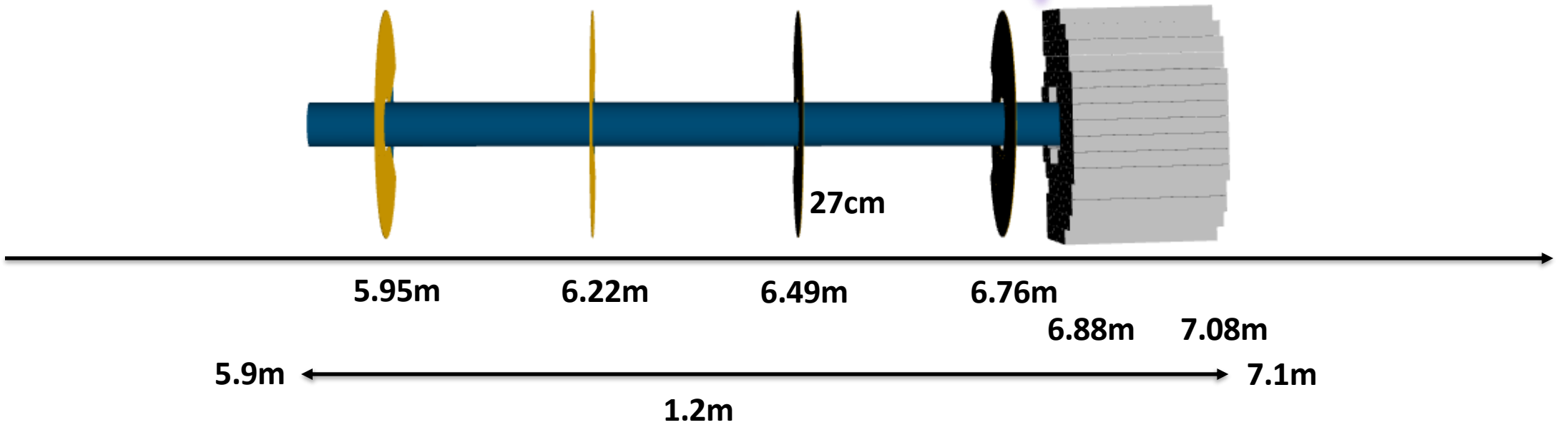




definitions.xml:

## name	center_x	center_y	center_z	rin(z-in)	rin(z-out)	dout	length	angle	B	gradient
##	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[mrad]	[T]	[T/m]
B0PF	0.132497	0.0	5.89913	0.2000	0.2000	0.5000	1.200	0.00	-1.300	0.000

B0 detector layout



- First B0tracking layer placed ~ 10cm from the magnet edge
- Increasing the crystal's length to 20cm extend the detector until the edge
- **This is not what we show in CAD drawings (longer B0 magnet)**
- Can we push the crystals backwards?

Summary and discussion

Summary:

- B0ECAL geometry change: 20 cm of LYSO
- Better in resolution (x2) and shower is almost contained in the crystals (~95%)
- Pending issues
  - Energy saturation observed in the reconstruction algorithm
  - Photons with $15<\theta<23$ intersect central beampipe (not clear if it is expected), a similar trend observed for charged particles

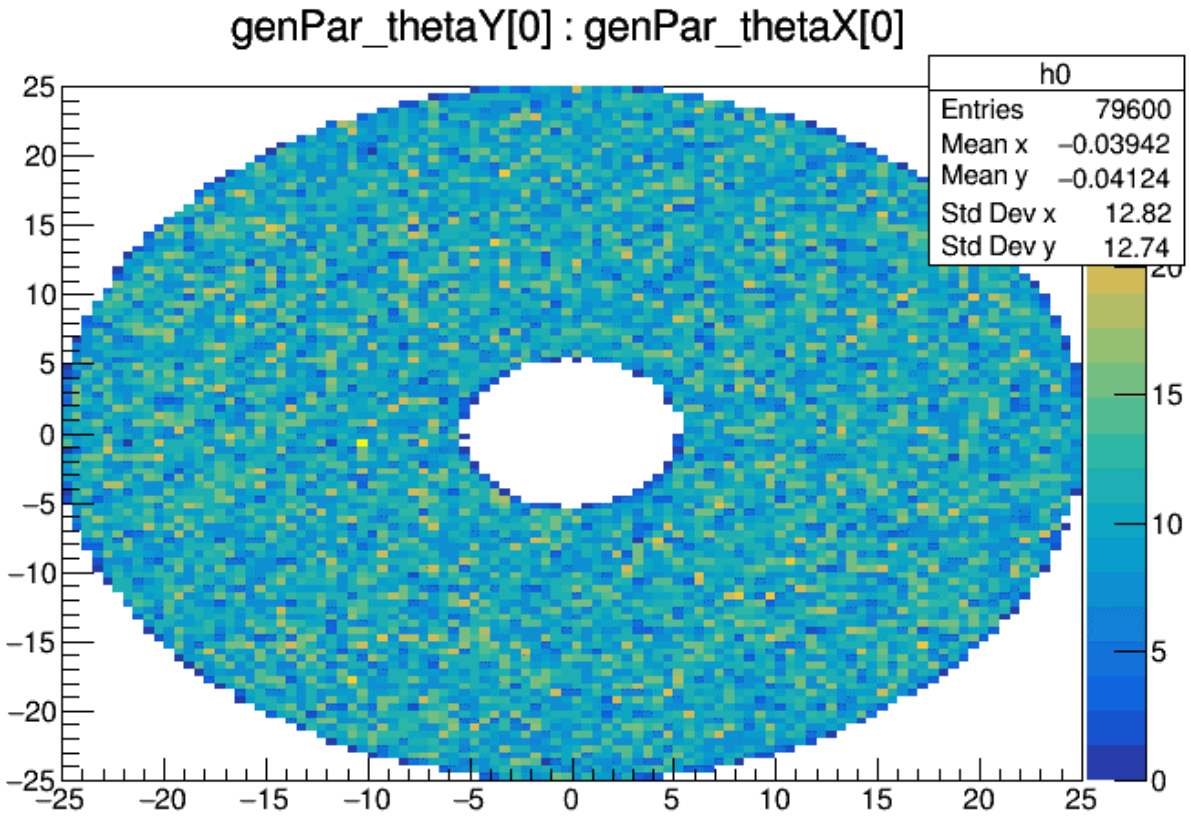
Discussion:

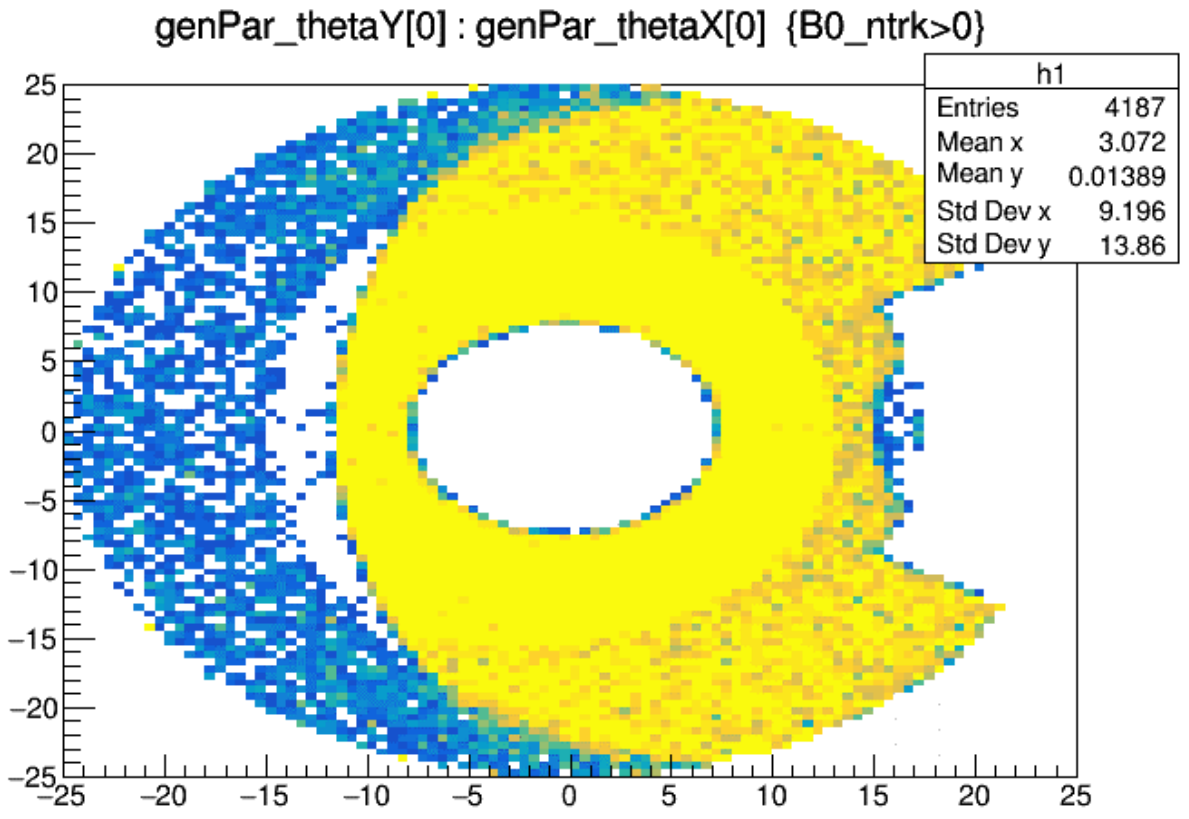
- Extracting shower development using the waveforms
- Pushing ECAL back to improve tracking performance
- Dynamic range – if we aim for 0 – 100 GeV photons in ECAL, do we need >1 gains

Backup

Protons in B0 detectors

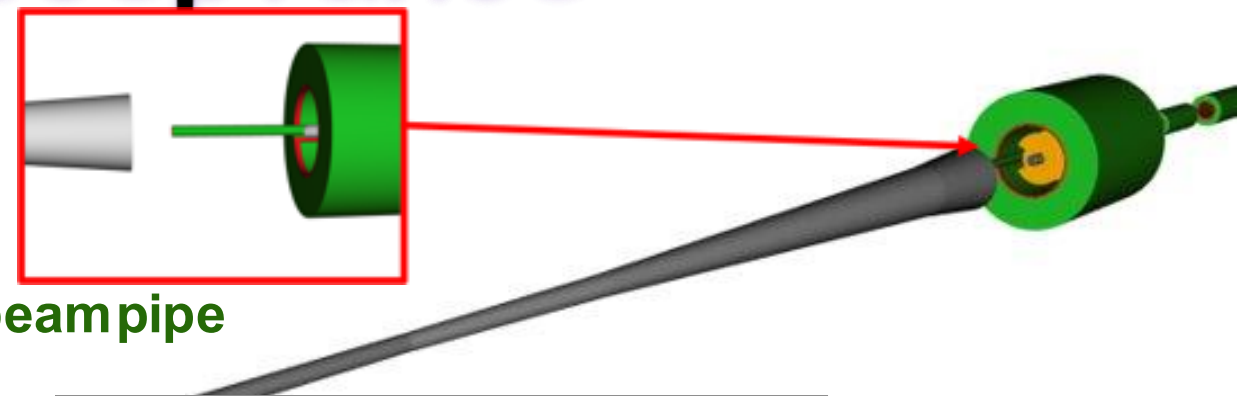
- Protons with E=110 GeV were generated within the B0 acceptance
- Protons in early stage scattered away by interacting the beampipe



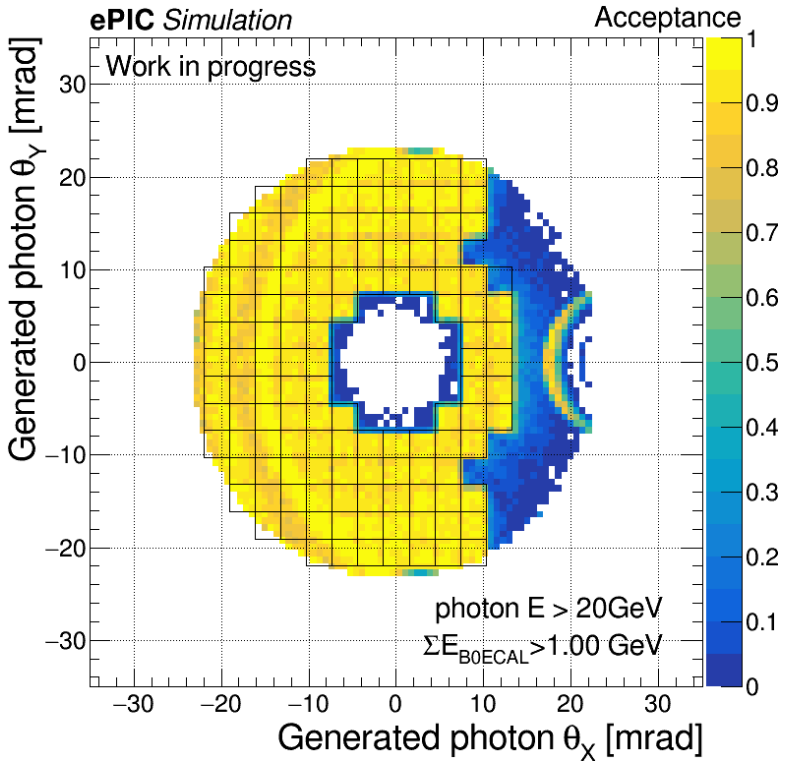


BOECAL acceptance

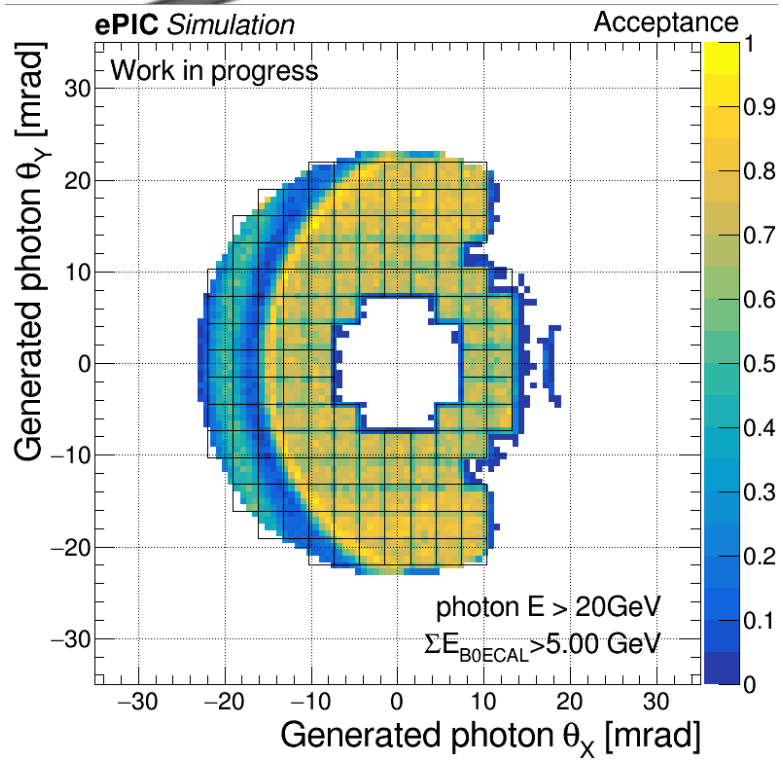
- Acceptance if E> E_{th}
- Very low material budget in 5 < η < 5.5



Particles within 5.5 < θ < 15 mrad don't cross the beampipe

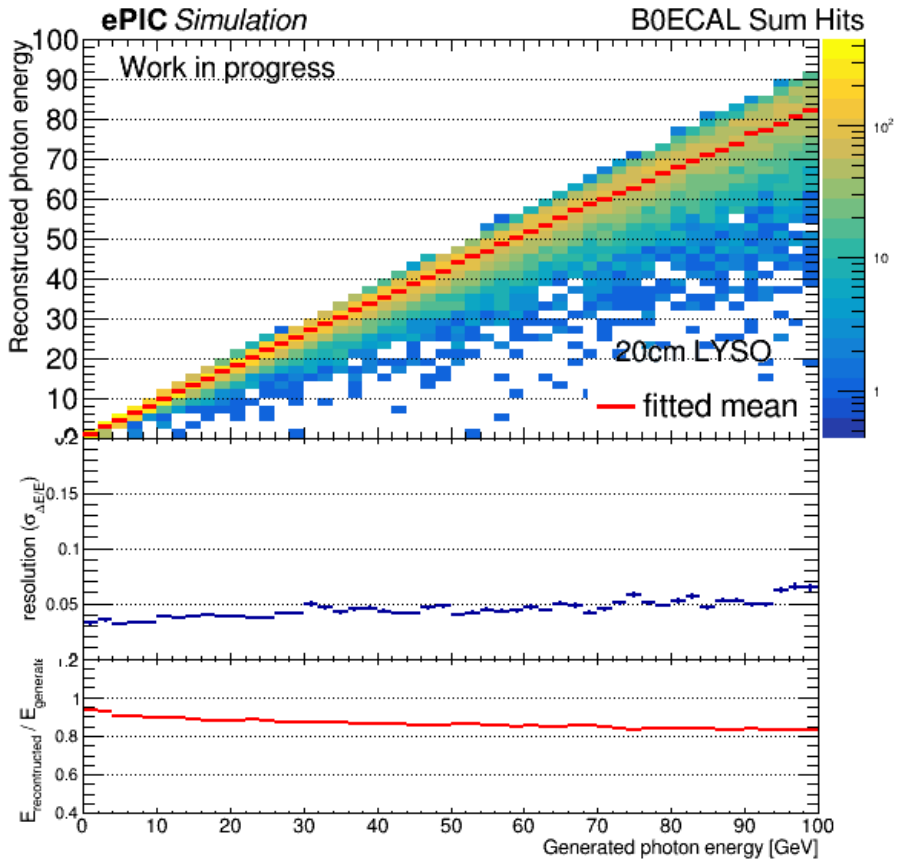


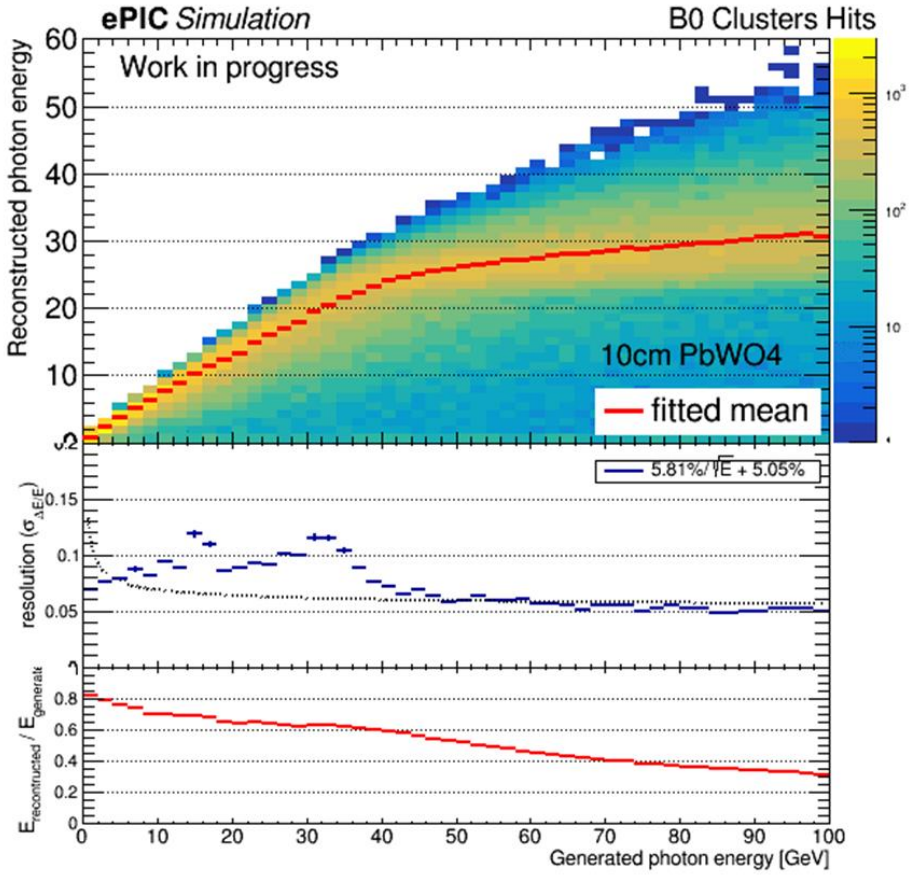
threshold



B0ECAL reconstruction

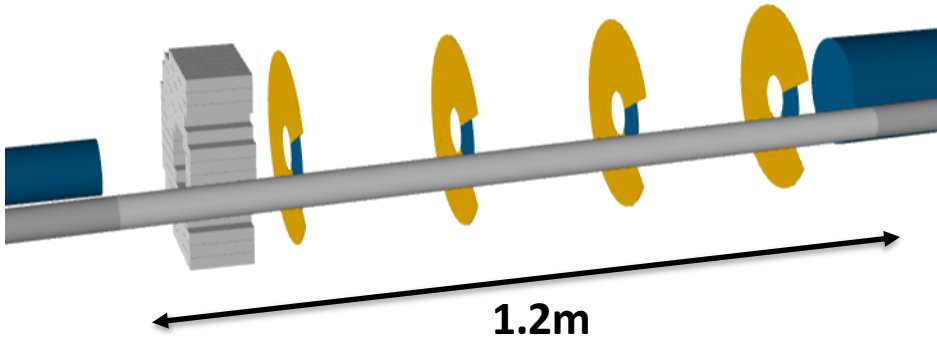
- Cluster energy is used instead of Sum of hits – beas at high values





B0 detector tracker

```
<comment>
  - The detector length based on the 0.2*m step size and 4 layers.
  - I start from the downstream side of the B0 magnet and an arbitrary offset
    which puts the downstream of the detector 10cm from the end of the magnet.
</comment>
<constant name="B0Tracker_length"      value="81.0*cm"/>
<constant name="B0Tracker_zoffset"     value="5.0*cm"/>
<constant name="B0TrackerCenter_zpos"  value="6.3*m"/>
<constant name="B0TrackerCenter_xpos"  value="-0.16000052*m" />
<constant name="B0Tracker_zmin"        value="B0TrackerCenter_zpos - B0Tracker_length/2.0 "/>
<constant name="B0Tracker_rotation"    value="ionCrossingAngle"/>
<comment>
```

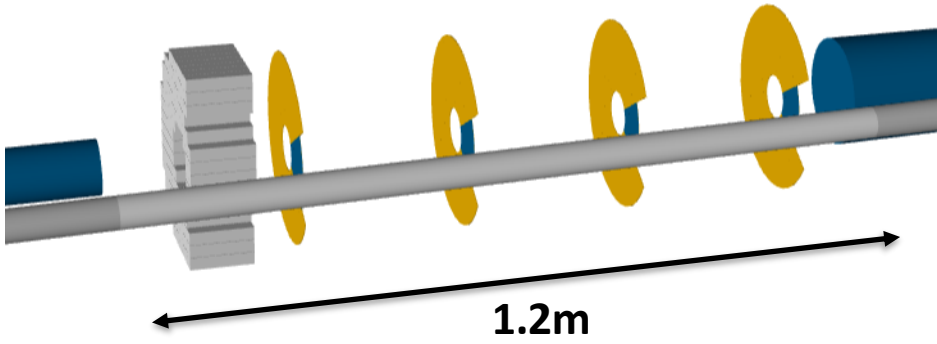


definitions.xml:

## name	center_x [m]	center_y [m]	center_z [m]	rin(z-in) [m]	rin(z-out) [m]	dout [m]	length [m]	angle [mrad]	B [T]	gradient [T/m]
B0PF	0.132497	0.0	5.89913	0.2000	0.2000	0.5000	1.200	0.00	-1.300	0.000

B0 detector calorimeter

```
<define>
  <constant name="B0ECal_rotation" value="ionCrossingAngle"/>
  <constant name="B0ECal_IP_distance" value="683*cm"/>
  <constant name="B0ECal_xcenter" value="B0ECal_IP_distance*sin(ionCrossingAngle)"/>
  <constant name="B0ECal_zcenter" value="B0ECal_IP_distance*cos(ionCrossingAngle)"/>
  <constant name="B0ECal_length" value="10*cm"/>
  <constant name="B0ECal_CrystalModule_width" value="2*cm"/>
  <constant name="B0ECal_CrystalModule_length" value="B0ECal_length"/>
  <constant name="B0ECal_CrystalModule_wrap" value="0.50*mm"/>
```



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B0PF	0.132497	0.0	5.89913	0.2000	0.2000	0.5000	1.200	0.00	-1.300	0.000