EIC Detector-1 pECal performance study

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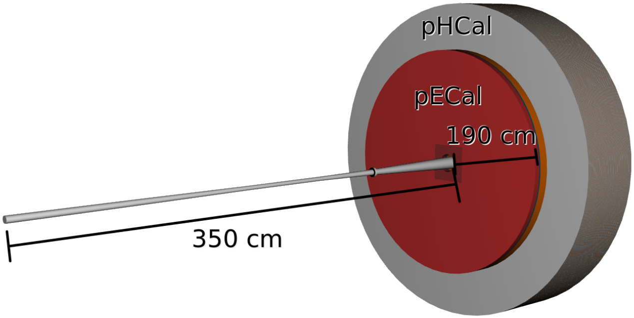
Outline

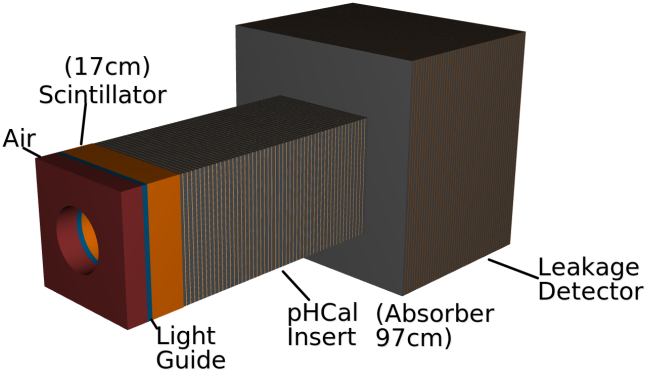
1. pECal geometry
2. Mixture tower structure
3. pECal insert energy resolution
4. $\pi^0 \rightarrow \gamma\gamma$ separation
5. Fiber implementations
6. Future plan

pCal geometry



pECal tower size 2.5×2.5 cm

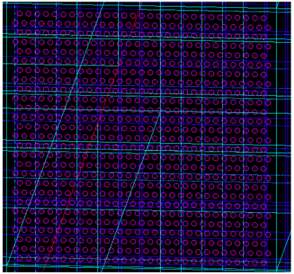
pCal insert geometry



pECal insert tower size 2×2 cm

Mixture tower configurations

Slides from Zhiwan



Fibers distributed inside one tower

	geometry fraction	material mass fraction
Absorber	78%	97% Tungsten+ 3% polystyrene
Fiber	22%	100% polystyrene

- **W/ScFi structure: 24 x 24 towers of 2.5 cm*2.5cm**
  - **796 Fibers placed in each tower, r = 0.235 mm.**
- **Mixture structure: 24 x 24 towers of 2.5 cm*2.5cm**
  - **Mixture material at same composition as W/ScFi**
- **Total material density to be 10.15 g/cm^3 (from experiment)**

```
// Get materials
G4Material* defaultMaterial = G4Material::GetMaterial("Galactic");
G4Material* gapMaterial2 =G4Material::GetMaterial("G4_POLYSTYRENE");
G4Material* absorberMaterial2= G4Material::GetMaterial("G4_Fe");

G4double a=183.85*g/mole;
G4Element* elW=new G4Element("Tungsten","W",74.,a);

  G4Material* EMCal_abs_mat=new G4Material("EMCal_fiber_mat", 10.15*g/cm3,2);
  EMCal_abs_mat->AddElement(elW, 94.8*perCent);
  EMCal_abs_mat->AddMaterial(gapMaterial2, 5.2*perCent);
```

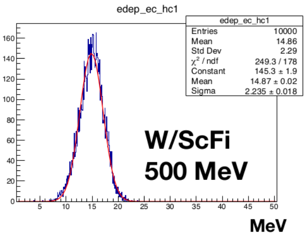
	mass fraction
Tungsten	94.8%
Polystyrene	5.2%

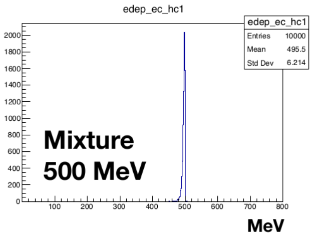
- **Next step: reconstructed the energy from this mixture tower configuration**

Sampling fraction for fibers

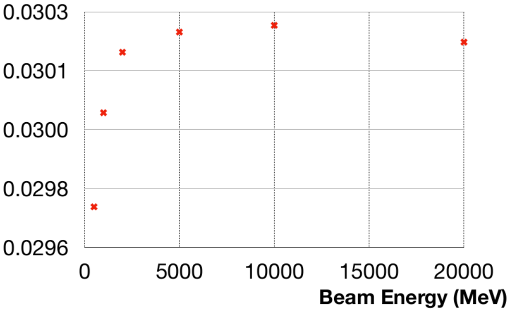
Slides from Zhiwan

- **Get the mean value of energy deposition for W/ScFi, and plot it out with respect to 6 beam energies.**
- **We have roughly 0.03 (at a 1% difference)**



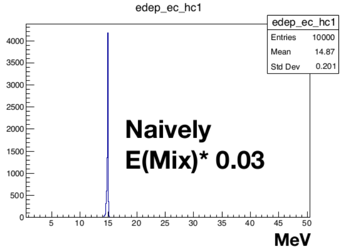


Beam Energy (MeV)	Energy in fibers(mean)	fraction
500	14.86	0.02972
1000	30.0	0.03000
2000	60.36	0.03018
5000	151.2	0.03024
10000	302.6	0.03026
20000	604.1	0.03021



Smearing procedure

Slides from Zhiwan



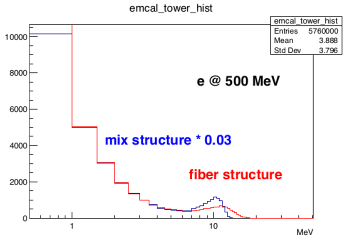
- **Smearing process is required to help get the correct energy resolution**

$$Gaus(E) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(E-\mu)^2}{2\sigma^2}}$$

  - **Mean** $\mu = 0.03E$
  - **Sigma** $\sigma = E\sqrt{a^2/E + b^2}$
  - **a = 0.1, b = 0.0015**

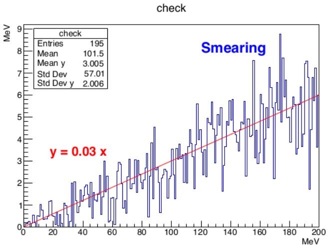
```
double threshold = 6.1;

double reco(double E0)
{
double E = E0;
if(E0 < threshold) return 0;
else{
double a = 0.1;
double b = 0.;
double sigma =  E* TMath::Sqrt(a*a/E +b*b) ;
double random = gRandom->Gaus(E*0.03,sigma);
E = random;
return E;
}
}
```

- **Code on the right**
  - **The parameter a and b is determined by fiber structure study**



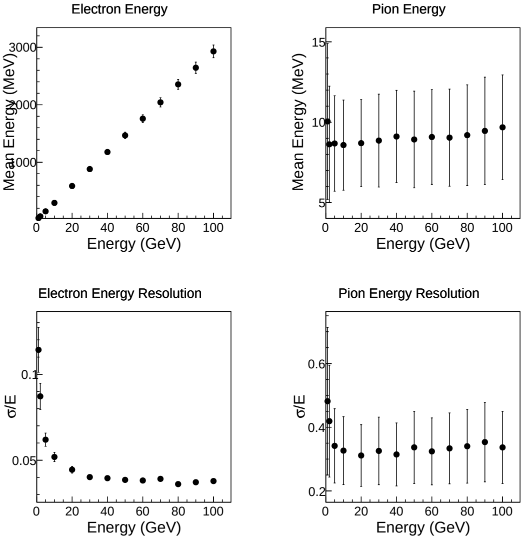
Purpose:

- **Reproduce the fluctuation from Gaussian random**
- **keeps the mean ~ 0.03 E_0**



pEcal insert energy resolution

- Using mixture tower structure.
- Linear for e^-.
- MIP-like for π^-.



$\pi^0 \to \gamma\gamma$ separation

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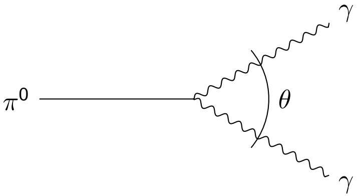
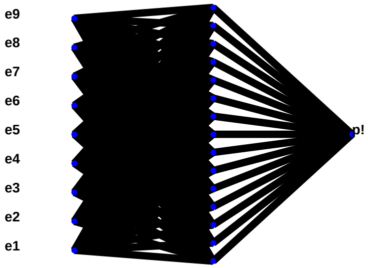
- "Usual" criteria: $\pi^0 \to \gamma\gamma$ distinguished if photons are separated by one tower size.
- pECal: 2.5×2.5 cm at z = 350 cm.
- $\theta_{min} = \frac{2.5\ cm}{350\ cm} = 0.007 \Rightarrow E_{\pi^0} = 38\ GeV$.

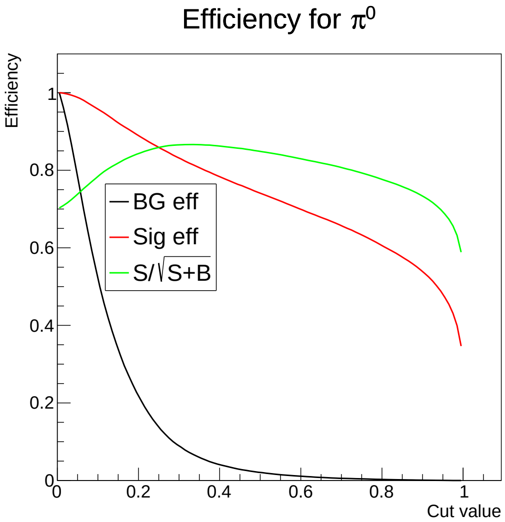


$$\theta_{min} = \frac{2m_{\pi^0}}{E_{\pi^0}}$$

Toy model study for $\pi^0 \to \gamma\gamma$ separation

- Two Gaussian clusters as signal π^0 with 1σ separation equals one tower.
- Single Gaussian clusters as background photons.
- Input: normalized 3×3 tower energy.
- Output: softmax function as cut value.





Fiber implementations

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- Problem: pECal with fibers uses $\sim$6 GB memory in NPSim and $\sim$8.8 GB memory in Juggler. It will use more memory when other detectors were included.
- Reason: storing *PlacementPath–VolumeID* mapping in *m_geo.g4Paths* uses large memory.
- Method I (hacking DD4hep): Change DD4hep to let it only store the *VolumeID* for each module instead of each fiber.
- Method II (covering non-fiber): Set the whole module as a sensitive detector and cover the insensitive areas by daughter radiators.

Consistency check in fiber implementations

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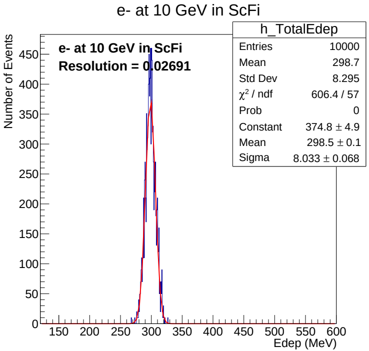
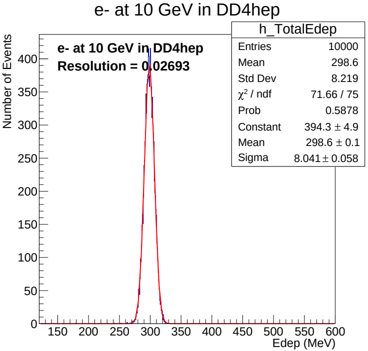
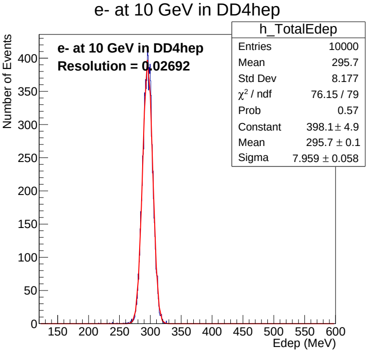


Geant4



Method I (hacking DD4hep)



Method II (covering non-fiber)

Consistent with Geant4, though Method II is slightly different possibly due to the voxelization of Geant4.

Future plan

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- Study pECal performance in standalone Geant4 simulations with fiber structure.
- Study $\pi^0 \to \gamma\gamma$ separation *vs* pECal energy resolution.
- Implement fiber structure in DD4hep for updated geometry.