Joint Institute for Nuclear Research

Simulation of Electromagnetic Calorimeter for the Soft Photons study

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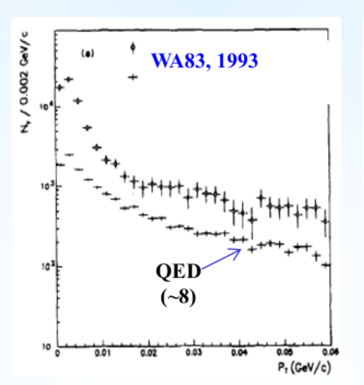
Contents

What are Soft Photons?

- Photons Sources:
  1- Indirect (decay) Photons
  2- Direct Photons
  Soft photons (SPh) are photons that are the direct products of high energy interactions (not decay products of secondary particles)
- Their energy is less than 50 MeV.

Why are we interested in Soft Photons?

In contradiction with QED, experimental data shows excess yield of Soft Photons when E<50 MeV.



Models of Soft Photons

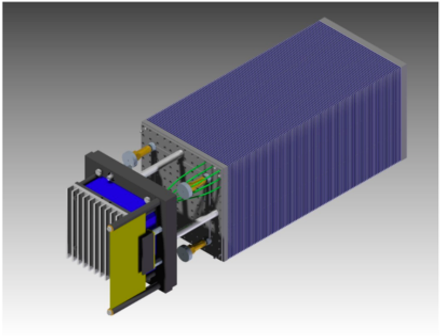
Soft Photons are formed in the region of non perturbative Quantum Chromodynamics (non pQCD). So physicists build phenomenological models to explain them.

- Model of P. Lichard and L. Van Hove
- Gluon Dominance Model (GDM)

Calorimetry

- Calorimetric methods imply total absorption of the particle energy in a bulk of material followed by the measurement of the deposited energy.
- In order to search for new phenomena, good electromagnetic calorimetry will be essential.
- Physicists use homogeneous, pure crystal ECals (expensive $ 50/cm3). They started designing a heterogeneous ECals “spaghetti” or “shashlik” (“sandwich").

Shashlik Calorimeter



Absorber

We can choose for the absorber, a composite of 2 metals. eg: W and Cu and check different ratios between them to get better energy resolution.
Tungsten(W) - 5 % Copper(Cu) - 95 %

$$m_W = d_W V_W$$

$$m_{Cu} = d_{Cu} V_{Cu}$$

$$\frac{m_{Cu}}{m_W} = \frac{95\,\%}{5\,\%} = 19$$

$$m_{Cu} = 19 m_W$$

$$d_{Cu} V_{Cu} = 19 d_W V_W$$

$$V_{Cu} = 19 \frac{d_W V_W}{d_{Cu}}$$

Absorber

The Specific densities for pure metal W and Cu is:

$$d_{sp} = \frac{m_w + m_{Cu}}{V_W + V_{Cu}} = \frac{d_W V_W + d_{Cu} V_{Cu}}{V_W + V_{Cu}} = \frac{d_W V_W + d_{Cu} \frac{19 d_W V_W}{d_W}}{V_W + \frac{19 d_W V_W}{d_W}}$$

$$d_{sp} = \frac{d_w + 19 d_w}{1 + \frac{19 d_w}{d_{Cu}}} = \frac{20 d_w d_{Cu}}{d_{Cu} + 19 d_W}$$

If $d_{Cu} = 8.94 g/cm^3$, $d_W = 19.25 g/cm^3$

$$d_{sp} = 9.16 g/cm^3$$

This is the density of the composite.

Scintillation Crystals

Selecting scintillation materials for the registration of low-energy photons, we focused on the following characteristics:

- high density ($\geq 5\ g/cm^3$)
- high light yield ($\geq$ 30 ph/KeV)
- short decay time

We used $Gd_3Al_2Ga_3O_{12}(Ce)$

Monte Carlo Simulation

- We need to know how our detector will see the productions from collisions.
- Detector simulation tracks the particles through detector material. (simulating their interactions with material)

Toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science.

Geant4

- EmCalActionInitialization.cc
- EmCalDetectorConstruction.cc
- EmCalEventAction.cc
- EmCalPrimaryGeneratorAction.cc
- EmCalRunAction.cc
- EmCalSteppingAction.cc

Geant4

```
// making absorber 95% Cu
  G4Material* W = new G4Material(name="W", z=74., a=183.84*g/mole, density= 15.0*g/cm3);
  G4Material* Cu = new G4Material(name="Cu", z=29., a=63.546*g/mole, density= 8.92*g/cm3);

  density = 9.16*g/cm3; //95 Cu 5 W
  G4Material* WCu = new G4Material(name="WCu",density,ncomponents=2);
  WCu->AddMaterial(W,fractionmass=5.0*perCent);
  WCu->AddMaterial(Cu,fractionmass=95.*perCent);
```

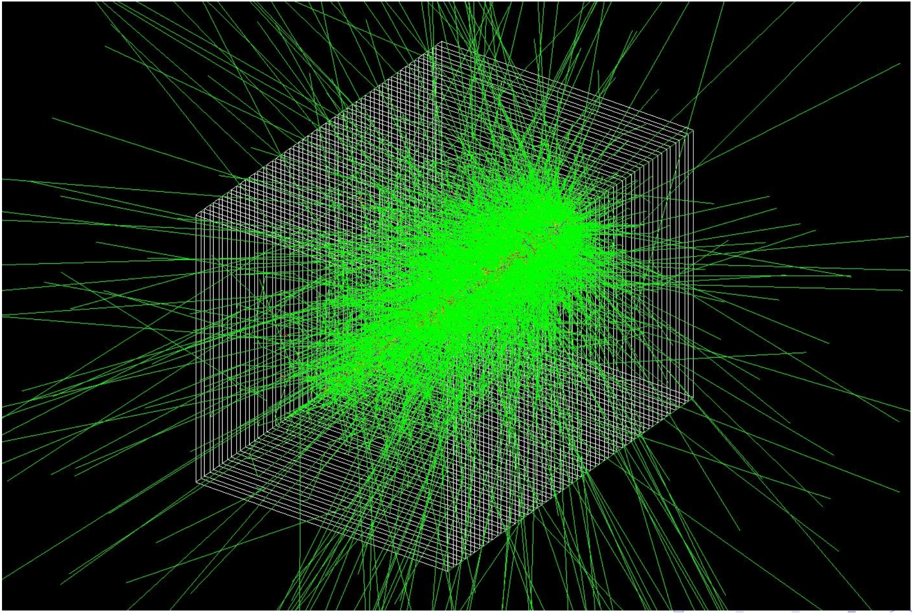
```
// making Gd3Al2Ga3012Ce
  G4Element* O = new G4Element(name="Oxygen" , symbol="O" , z= 8., a= 16.00*g/mole);
  G4Element* Ga = new G4Element(name="Gallium" , symbol="Ga" , z= 31., a= 69.723*g/mole);
  G4Element* Gd = new G4Element(name="Gadolinium" , symbol="Gd" , z= 64., a= 157.25*g/mole);
  G4Element* Al = new G4Element(name="Aluminium" , symbol="Al" , z= 13., a= 26.9816*g/mole);

  G4Material* Gd3Al2Ga3012Ce = new G4Material(name="Gd3Al2Ga3012Ce", density= 6.67*g/cm3, ncomponents=4);
  Gd3Al2Ga3012Ce->AddElement(Gd, 3);
  Gd3Al2Ga3012Ce->AddElement(Al, 2);
  Gd3Al2Ga3012Ce->AddElement(Ga, 5);
  Gd3Al2Ga3012Ce->AddElement(O, 12);
```

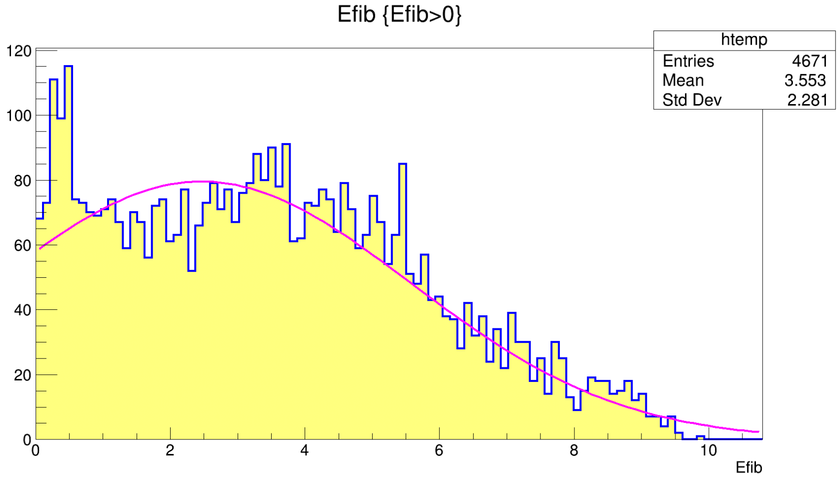
ROOT

An open-source data analysis framework used by high energy physics and others.

At 10 MeV

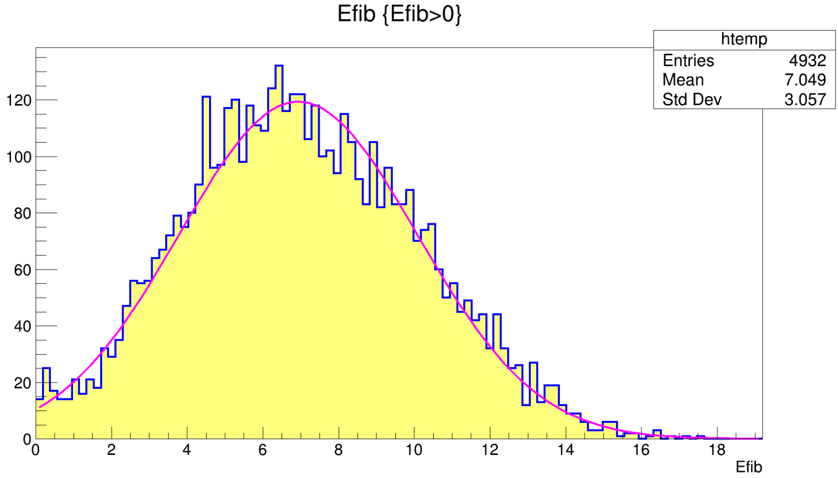


At 10 MeV



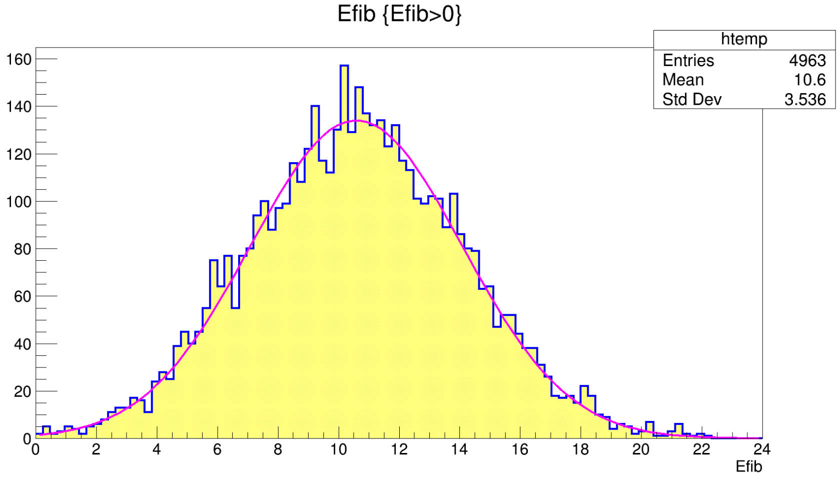
$$\text{Energy Resolution} = \frac{\sigma}{E}\,\% = \frac{2.281}{10}\,\% = 22.81\,\%$$

At 20 MeV



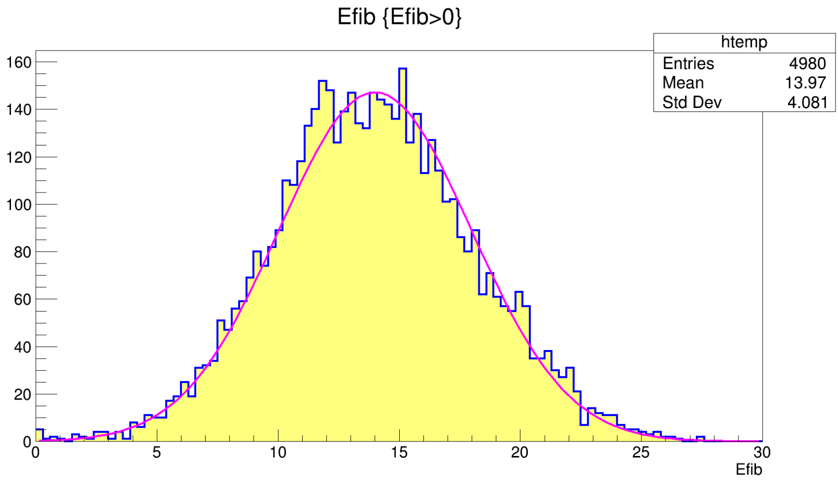
$$\text{Energy Resolution} = \frac{\sigma}{E}\,\% = \frac{15.285}{20}\,\% = 15.285\,\%$$

At 30 MeV



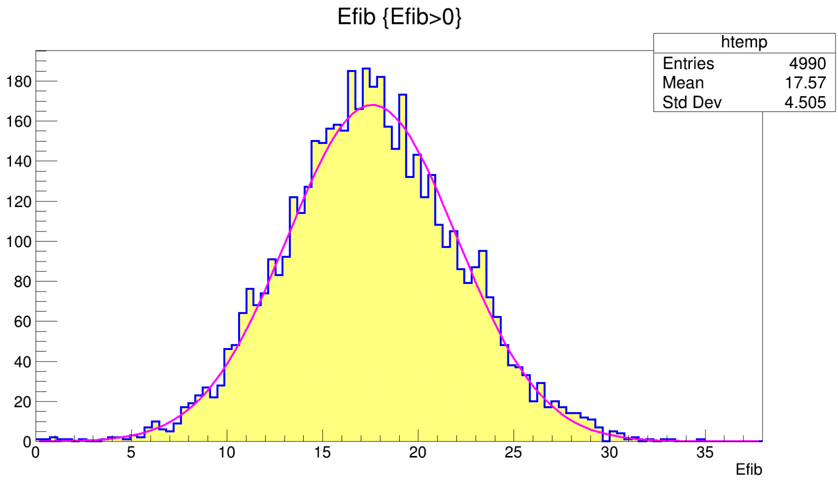
$$\text{Energy Resolution} = \frac{\sigma}{E}\,\% = \frac{3.536}{30}\,\% = 11.79\,\%$$

At 40 MeV



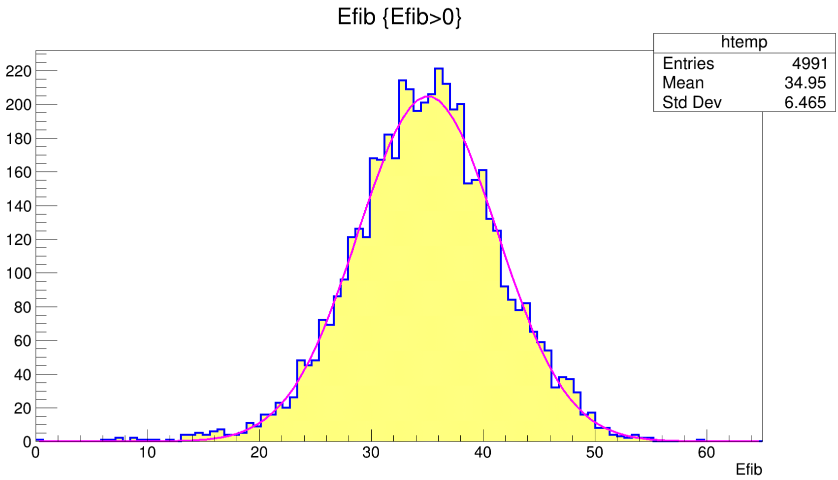
$$\text{Energy Resolution} = \frac{\sigma}{E}\,\% = \frac{4.081}{40}\,\% = 10.20\,\%$$

At 50 MeV



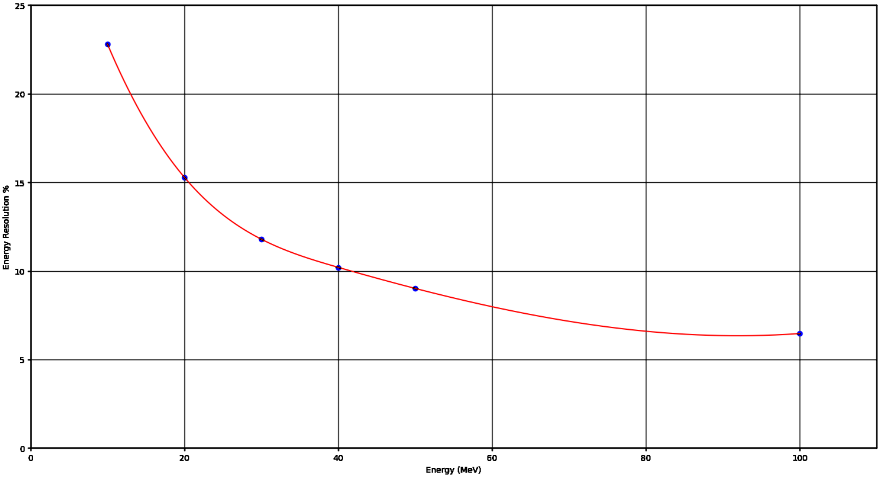
$$\text{Energy Resolution} = \frac{\sigma}{E}\,\% = \frac{4.505}{50}\,\% = 9.01\,\%$$

At 100 MeV



$$\text{Energy Resolution} = \frac{\sigma}{E}\,\% = \frac{6.465}{100}\,\% = 6.465\,\%$$

Energy Resolution



References

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May 2014.

Questions?