Simulation of Quartz Fiber Calorimeter for Photon Detector

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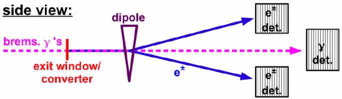
Outline

Luminosity monitor for EIC

Two methods for detecting bremsstrahlung photons from $ep \to e\gamma p$ and $eAu \to e\gamma Au$:

1. $e^{\pm}$ pair conversion
2. **Direct γ**



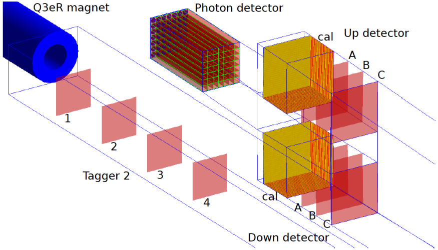
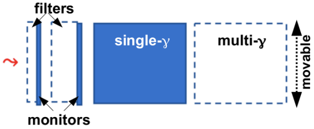


Figure: Detector section in Geant4

Direct photon detector

- Direct counts of bremsstrahlung photons
- detector provides fast machine performance
- Implementation as homogeneous or fused silica spaghetti calorimeter



Geometry model

Previous plan:

- Implementation of homogeneous calorimeter
  1. $PbWO_4$ crystal: $22 \times 22 \times 350$ mm^3 [7×7 module] (Red with green wrapping)
  2. 2 mm thick BK7 glass (Blue)
  3. Photocathode (Red circles)

Result: simulated for light collection time measurement → Observation of expected pulse shape for our calorimeter at different energies

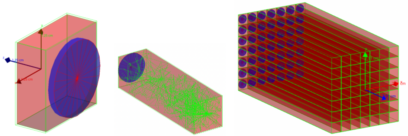


Figure: Single cell light collection and 7×7 towers of PWO crystals

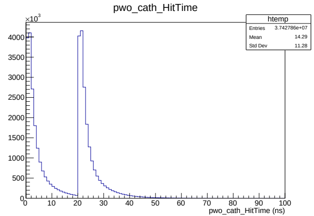


Figure: Statistics for 100 events at 18 GeV

Conclusion: Efficiency of the scintillation light yield fluctuates with the temperature variation inside beam-pipe

Current plan:

Detector construction in Geant4

- Implementation of amorphous silica (SiO_2) infused calorimeter

1. Quartz fiber with optical Cherenkov photons
   - size-xy = 16 cm, z-length = 160 cm, fiber-length = 150 cm
   - r_{clad} = 0.54 mm, r_{core} = 0.5 mm, fiber spacing = 4 mm
2. Absorber material: Cu

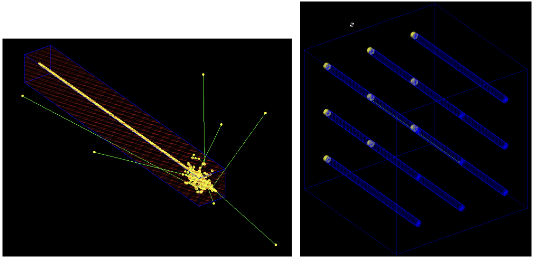


Figure: Quartz fiber calorimeter with the production of optical photon inside

Simulation

General particle source

- Particle type: Positron (e^+)
- Distance: 1 mm
- Energy: 50, 75, 100, 120 GeV
- Cherenkov photon collection through the fiber

```

#detector
#/lmon/construct/geometry geom_A456.xml
/lmon/construct/geometry geom_optics.xml

#input
/lmon/input/type gun
#/gun/energy 50 GeV
#/gun/particle e+
#/gun/position 0 0 1 mm
#/gun/direction 0.000913 0.052328 -0.99863
/gun/particle opticalphoton
/gun/polarization 0 1 0
/gun/energy 7.07 eV
#/gun/position 0 0 -0.1 mm
/gun/position -0.3 0 -0.1 mm
/gun/direction 0 0 -1

#output
#/lmon/output/name pwo.root

#initialize and run
/run/initialize

#/process/optical/boundary/setInvokeSD true

#/process/optical/cerenkov/verbose 2
#/process/optical/scintillation/verbose 2
/process/optical/verbose 2

/run/beamOn 1
```

Energy distribution

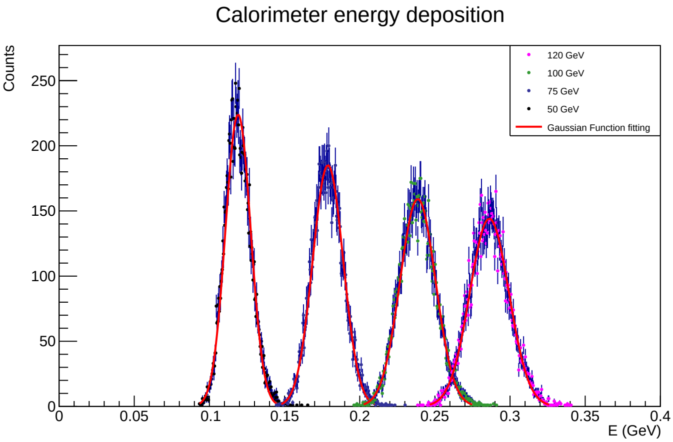


Figure: Statistics for 120000 events for different energies

Optical Photon measurement

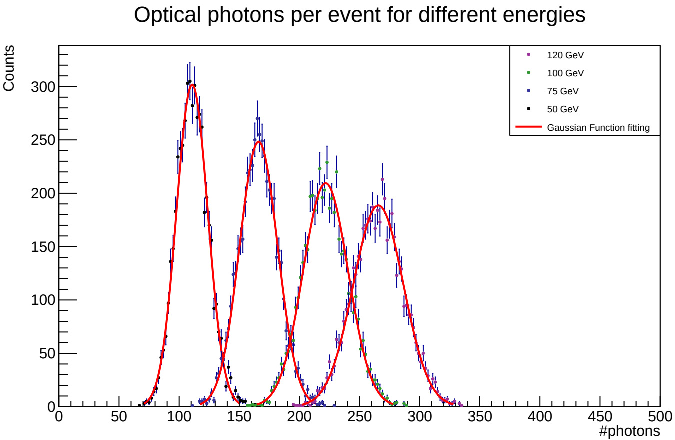


Figure: Statistics for 5000 events for different energies

Energy resolution

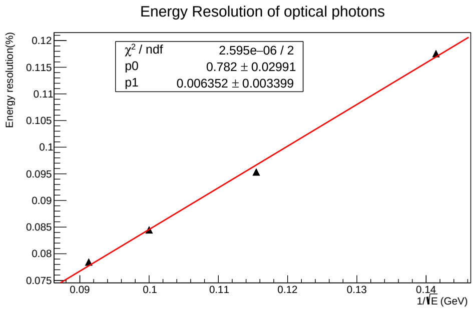


Figure: Resolution $\sigma(E)/E$ as a function of $1/\sqrt{E}$

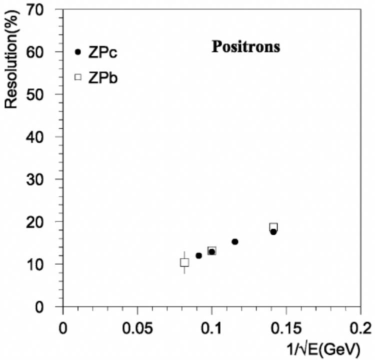


Figure: ALICE ZDC - R. Arnaldi et al. Nuclear Instruments and Methods in Physics Research A 456 (2001)

Conclusion

- For the calorimeter, $\sim$1.2 optical photons are produced per GeV for positron beams
- Optical photons produced in the quartz fiber is obtained from the simulation
- Distribution of energy fit the gaussian very well
- Observation of expected energy resolution values for our calorimeter at different energies
- **Next step:** test for linearity and fiber specification for optimum results
- **Reference:** Performances of zero degree calorimeters for the ALICE experiment, NIMR A 456 (2001)

Thank You