Luminosity monitor for the EIC, update on light collection and energy resolution

Jaroslav Adam

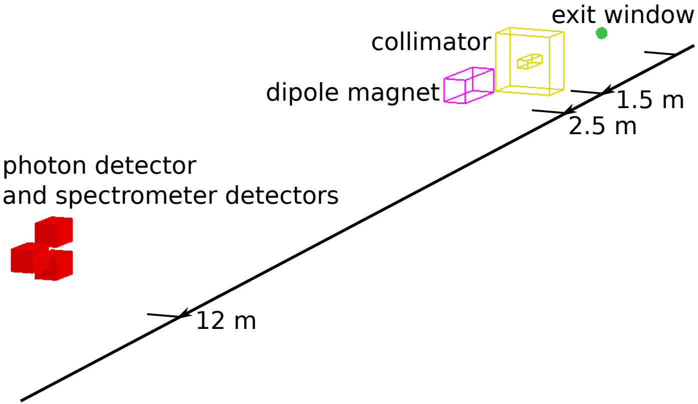
BNL

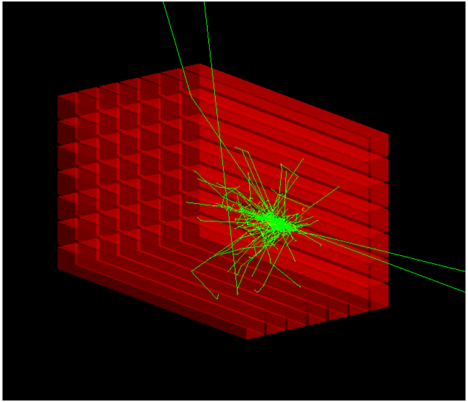
BNL, November 15, 2019

IR Meeting

Scintillation and Cherenkov photons and light collection in model of photon calorimeter

- Adding optical properties and detector for optical photons to Geant model of $PbWO_4$ calorimeter for luminosity detector
- The purpose is to complete the model and address the energy resolution





Optical properties and light detection in model of $PbWO_4$ crystal

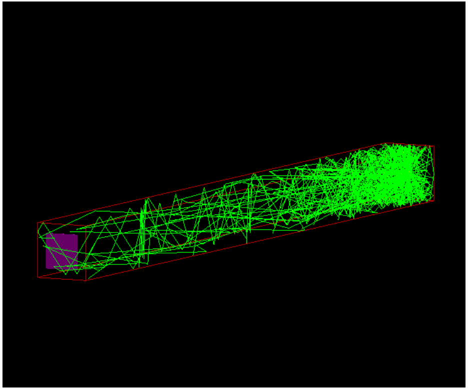
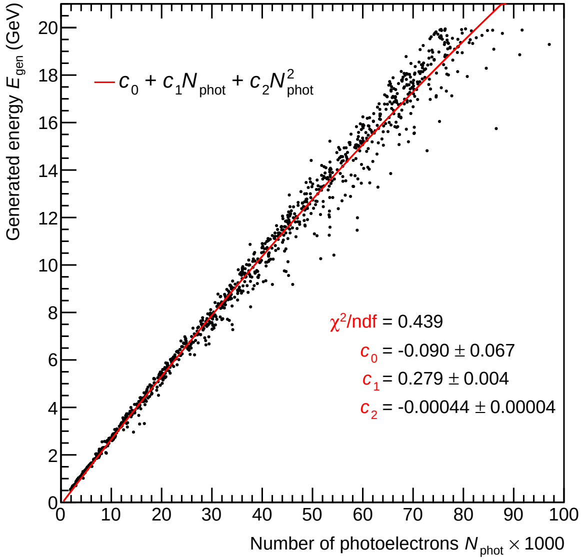


Figure: One calorimeter cell with 2 MeV deposition on the far side (facing the IP) and optical photon detector (magenta) on the opposite side. Optical photons are shown as green lines.

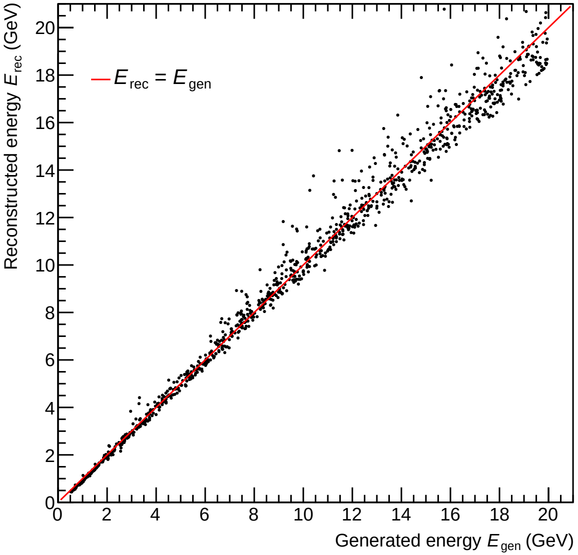
- Scintillation light yield is 200 per MeV with 6 ns decay constant (Knoll textbook)
- Wavelenght 420 nm (peak of emission as measured for ALICE)
- Optical properties approximately according to ALICE TDR
  - Uniform across 350 - 800 nm
  - Refractive index 2.4, absorption length 200 cm
  - Reflectivity 0.8, efficiency 0.9
- Detection by PIN diode, magenta square in the drawing
  - Silicon of 17×17 mm^2 area, 300 μm thickess (following ALICE device)
  - Reflectivity of optical boundary from the crystal is 0.1
  - Quantum efficiency is 0.8
  - Detected photon creates one photoelectron of signal (after applying quantum efficiency)
  - Number of photoelectrons is the output of the detector

Reconstructing the energy from number of photoelectrons



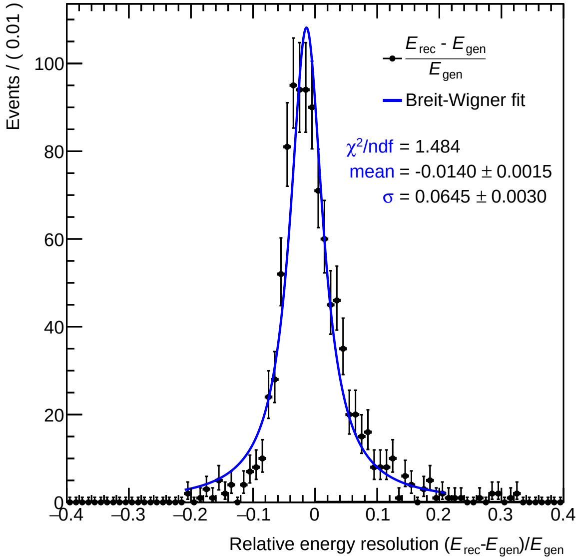
- Plot shows energy of generated photon entering the detector and number of photoelectrons from all cells
- One point is one event (1000 in total)
- Generated photons have uniform energy distribution in 0.5 - 20 GeV
- Fit is made by quadratic polynomial, not ideal but works
- Coefficients c1, c2, c3, known from the fit, allow to calculate reconstructed energy from number of photoelectrons

Reconstructed and generated energy



- Reconstructed energy is calculated from number of photoelectrons using c1, c2 and c3 determined from the fit on previous page
- Reconstructed energy is then compared to generated energy, same simulation of 1000 events
- Spread gets larger at energies beyond 10 GeV
- Caused by fluctuations in number of photoelectrons

Relative energy resolution



- Relative energy resolution is obtained as distribution of difference between reconstructed and generated energy, divided by generated energy
- Fit is made by Breit-Wigner distribution
- Width σ gives the relative resolution of 6.5% for energy in 0.5 - 20 GeV
- ALICE is quoting 3% over 0.2 - 10 GeV
- Difference is likely due to different energy range and conservative approach to light collection
- Light collection will need particular care because of limited light yield

Summary

- The model of luminosity monitor is now complete from event generator (Bethe-Heitler bremsstrahlung photons) to realistic signal of the detector (number of photoelectrons)
- Results are consistent with similar devices at ZEUS and ALICE
- The model is now ready to iterate various shapes of photon exit window, scenarios of pile-up, beam divergence and emittance ...