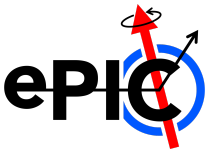
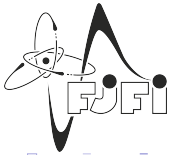
Updates on the Simulation of Direct Photon Calorimeter

Ayanabha Das
Advisor: Ing. Jaroslav Adam, Ph.D.

Department of Physics
Faculty of Nuclear Sciences and Physical Engineering
Czech Technical University in Prague

May 28, 2026





Introduction

- Geometry reconstruction of a direct photon calorimeter from longitudinal fibers to inclined fibers with respect to the beam axis.
- Simulation was conducted to compare the performance of optical photon yield
- Energy resolution was measured for various energies relative to the title angle of fibers.

Motivation: For better matching the Cherenkov emission angle to improve optical photon capture efficiency

Version 2 - Inclined fibers

- Cherenkov quartz fibers in Cu absorber, and optical photons detected by SiPMs, groups of 3×3 act as single sensor as in previous case of longitudinal placement
- Angle of tilt (θ) relative to incoming γ-photons was checked within the range of (35° - 55°), expectation for better optical photon yields
- Almost same outer size as longitudinal version $\sim 165 \times 170 \times 405$ mm

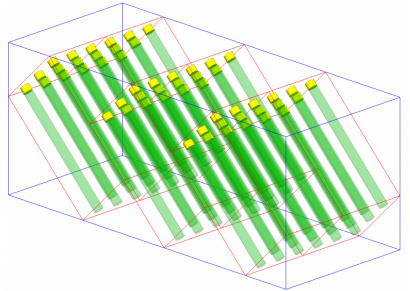


Figure: Schematic diagram of tilted fibers at an angle θ to the z-axis

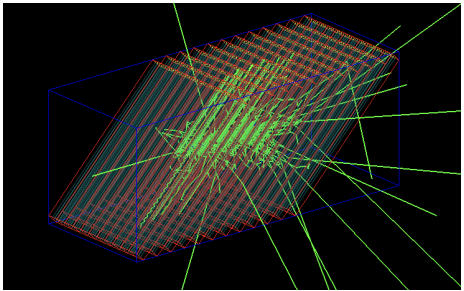
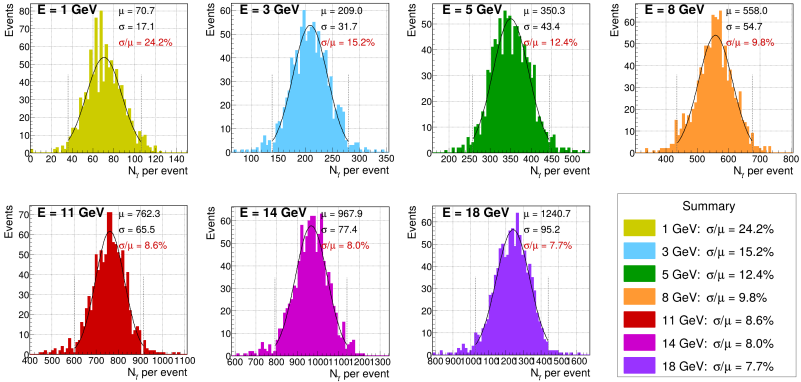


Figure: Geant4 visualisation with 1 GeV photon incident energy

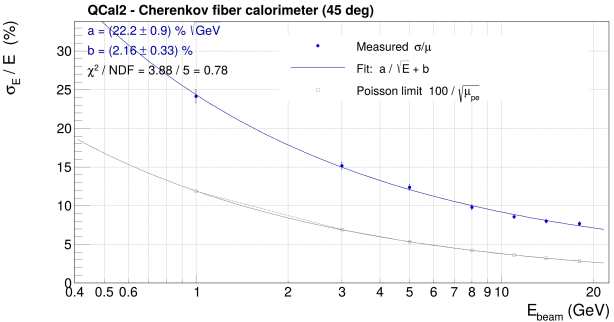
Optical photons yield

- Same sets of incident γ energies for different angle of fibers' inclination
- 1000 events are simulated for each energies
- Plot shows optical photons count per event for the tilt of 45° as a representative of the optimal angle



Energy resolution

- Resolution as σ/μ in detected optical photon counts (same procedure as before)
- Gaussian fit: mean $\pm\ 2\sigma$ (core only), to avoid non-Gaussian leakage tails pulling the fit.
- Energy resolution was fitted with $\frac{a}{\sqrt{E}} \oplus b$
- Poisson floor was calculated with $100/\sqrt{\mu}$ for each energies



Summary of results

Angles	Resolution (%)							a-value (%)	b-value (%)
	1 GeV	3 GeV	5 GeV	8 GeV	11 GeV	14 GeV	18 GeV		
35°	27.7	17.1	15.2	11.8	10.9	10.2	8.8	24.8 ± 1.1	3.24 ± 0.38
40°	25.5	16.0	13.2	10.8	9.8	8.5	8.1	23.1 ± 0.9	2.61 ± 0.35
45°	24.2	15.2	12.4	9.8	8.6	8.0	7.7	22.2 ± 0.9	2.16 ± 0.33
50°	26.7	16.2	12.1	10.6	9.1	8.2	8.0	24.1 ± 1.0	1.95 ± 0.35
55°	29.5	17.0	13.4	11.9	10.4	8.7	8.0	27.4 ± 1.1	1.63 ± 0.40

- The stochastic term is lowest for 45° ($22\%/\sqrt{E}$ with 0.02 constant term) which was $33\%/\sqrt{E}$ for the longitudinal case of version 1
- Next steps include implementing a light-guide section using bent optical fibers to direct photons towards the SiPM sensors, with the aim of increasing photon yield

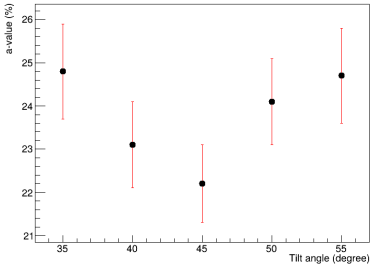


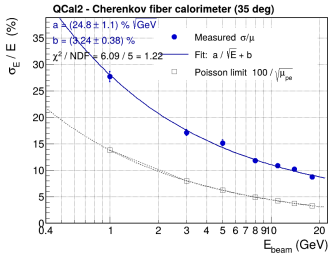
Figure: Dependence of stochastic term with respect to fibers' angle

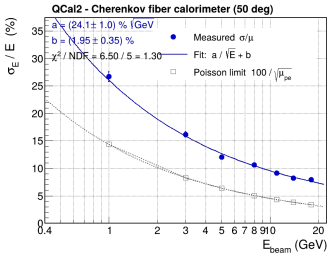
References

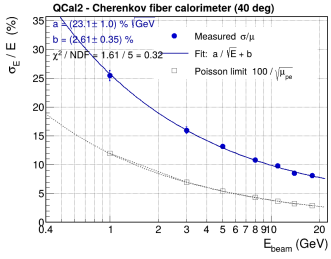
1. Performances of zero degree calorimeters for the ALICE experiment, R. Arnaldi et al, Nuclear Instruments and Methods in Physics Research A 456 (2001) 248 - 258
2. Quartz Fiber Calorimetry, P. Gorodetzky et al, Nuclear Instruments and Methods in Physics Research A 361 (1995) 161-179
3. R. Abdul Khalek et al.: Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report, BNL-220990-2021-FORE, arXiv:2103.05419

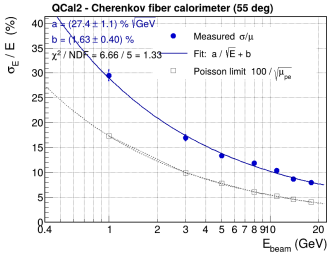
Thank You

Backup


QCal2 - Cherenkov fiber calorimeter (35 deg)
a = (24.8 ± 1.1) % √GeV
b = (3.24 ± 0.38) %
χ² / NDF = 6.09 / 5 = 1.22
Measured σ/μ
Fit: a / √E + b
Poisson limit 100 / √μ_pe
σ_E / E (%)
E_beam (GeV)


QCal2 - Cherenkov fiber calorimeter (50 deg)
a = (24.1 ± 1.0) % √GeV
b = (1.95 ± 0.35) %
χ² / NDF = 6.50 / 5 = 1.30
Measured σ/μ
Fit: a / √E + b
Poisson limit 100 / √μ_pe
σ_E / E (%)
E_beam (GeV)


QCal2 - Cherenkov fiber calorimeter (40 deg)
a = (23.1 ± 1.0) % √GeV
b = (2.61 ± 0.35) %
χ² / NDF = 1.61 / 5 = 0.32
Measured σ/μ
Fit: a / √E + b
Poisson limit 100 / √μ_pe
σ_E / E (%)
E_beam (GeV)


QCal2 - Cherenkov fiber calorimeter (55 deg)
a = (27.4 ± 1.1) % √GeV
b = (1.63 ± 0.40) %
χ² / NDF = 6.66 / 5 = 1.33
Measured σ/μ
Fit: a / √E + b
Poisson limit 100 / √μ_pe
σ_E / E (%)
E_beam (GeV)