PARTICLE PHYSICS · OPTICAL DETECTION · GEANT4

Simulation of Aerogel light yield for prototype detector.

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Physical detector — laboratory bench test

Motivation and Aim

Aerogel material studies, prototype measurements, and parallel Monte Carlo simulation

1. Following a collaboration proposal from SPD, our group at AANL is working on studies of the Aerogel Cherenkov detector.
2. In a real detector, the aerogel radiator can be quite large and can be made of several separate tiles. Therefore, it is important to check that different aerogel parts have similar optical properties.
3. Work includes detector component studies, prototype detectors construction, and preliminary tests of various Aerogel batches from Novosibirsk and Japan, in prototype detector.
4. Diffusion light collector prototype (not real SPD detector model) was built for testing different materials for light yield, different reflector efficiencies and PMTs gain.
5. One of our main tasks is to study the aerogel material used in the detector. For this, we need to measure the aerogel transparency, refractive index, uniformity, and light yield.
6. Monte Carlo calculations are performed in parallel for crosscheck with the laboratory prototype measurements.

AANL prototype setup



Prototype experiments

aerogel light-yield measurements

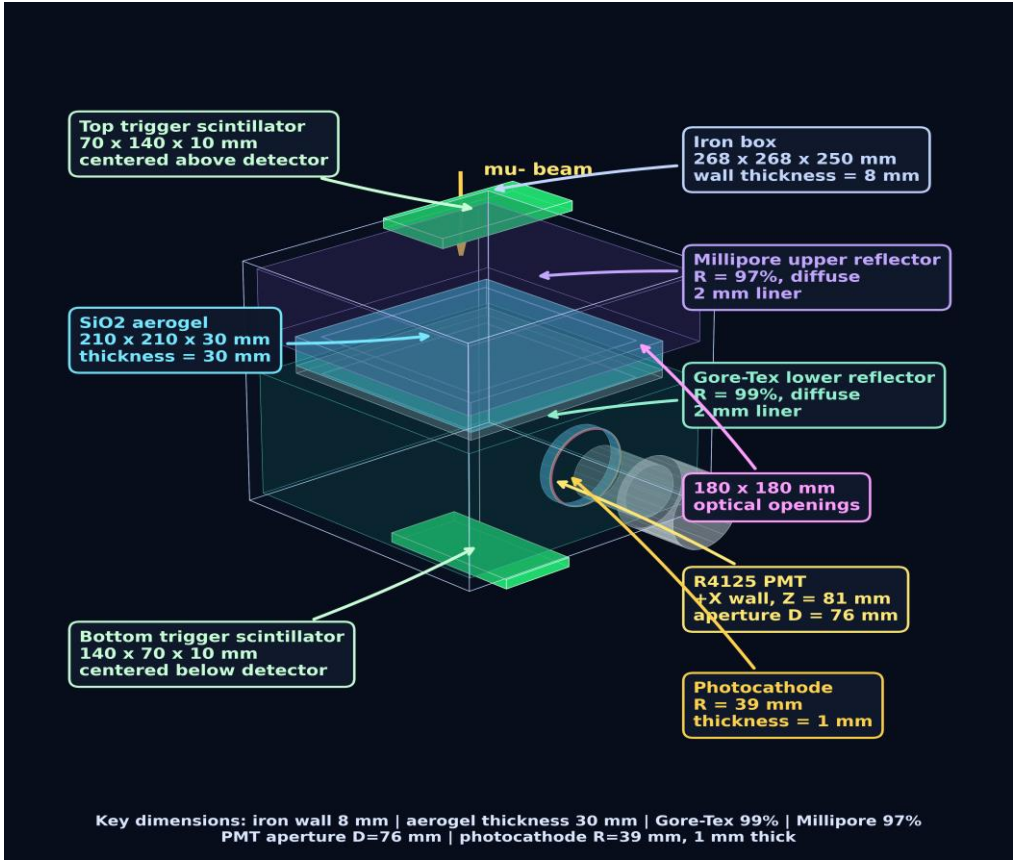
Crosscheck with MC calculation

prototype response and PE yield

The simulation supports the prototype experiments aimed at studying the aerogel materials.

Prototype measurements in the lab and Monte Carlo calculations are carried out in parallel.

Prototype Detector — 3D Model



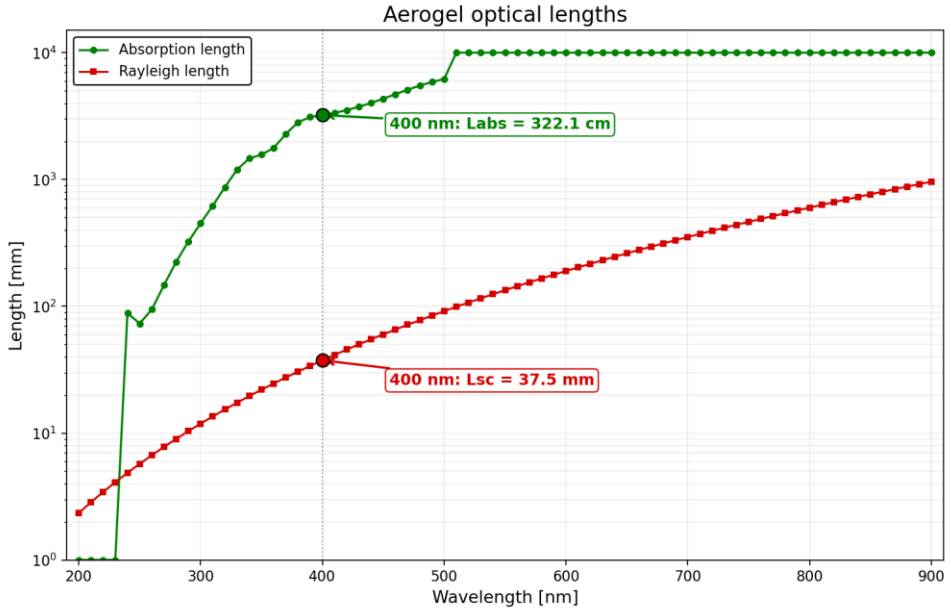
Novosibirsk aerogel
210 x 210 x 30 mm (3 cm)

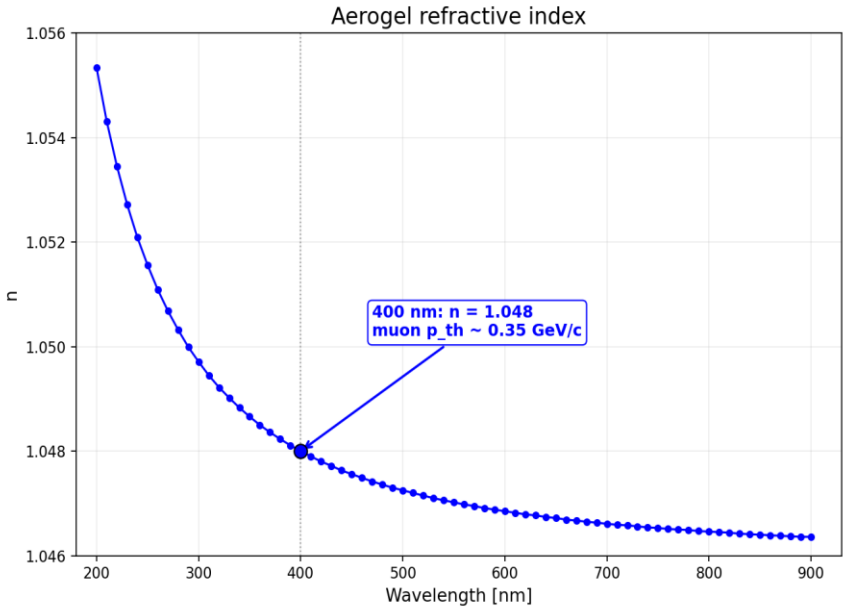
Triggered event = coincidence
Top scintillator AND Bottom scintillator
Only these events enter the PE histogram.

PMT · Hamamatsu R4125
Bialkali photocathode
Peak QE: 27% @ 360 nm
Borosilicate window
Reflector: Gore-Tex
Diffuse, high-reflectance

Geant4 v11.2.2 · Physics: FTFP_BERT · EM: G4EmStandardPhysics_option4 · Optical: G4OpticalPhysics

Aerogel Optical Lengths & Refractive Index





Aerogel optical parameters n(λ), Labs(λ), and Lsc(λ) were taken from Barnyakov-calculated tables for aerogel and implemented in Geant4.

PMT Quantum Efficiency & Reflector Response

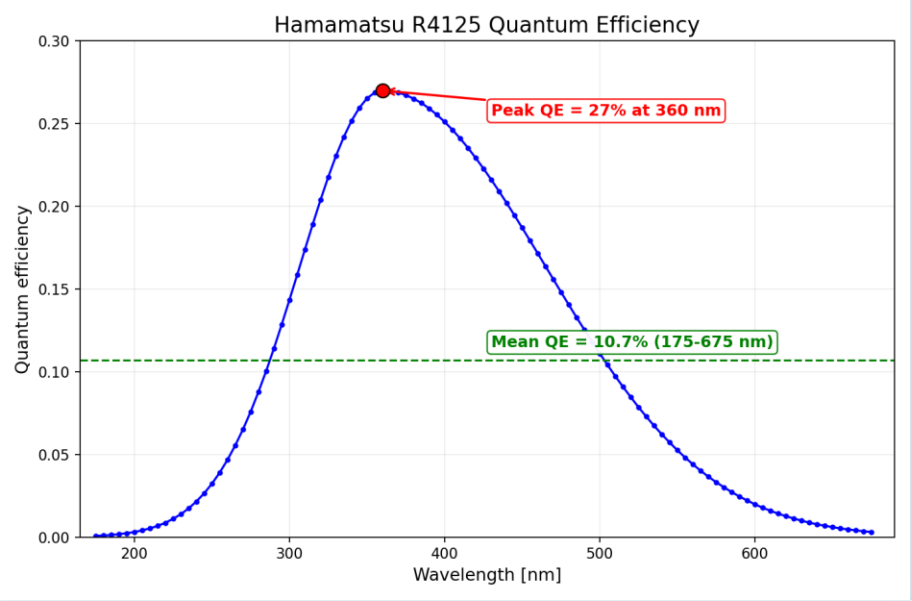


Fig 3. Hamamatsu R4125 quantum efficiency — peak 27% at ~360 nm

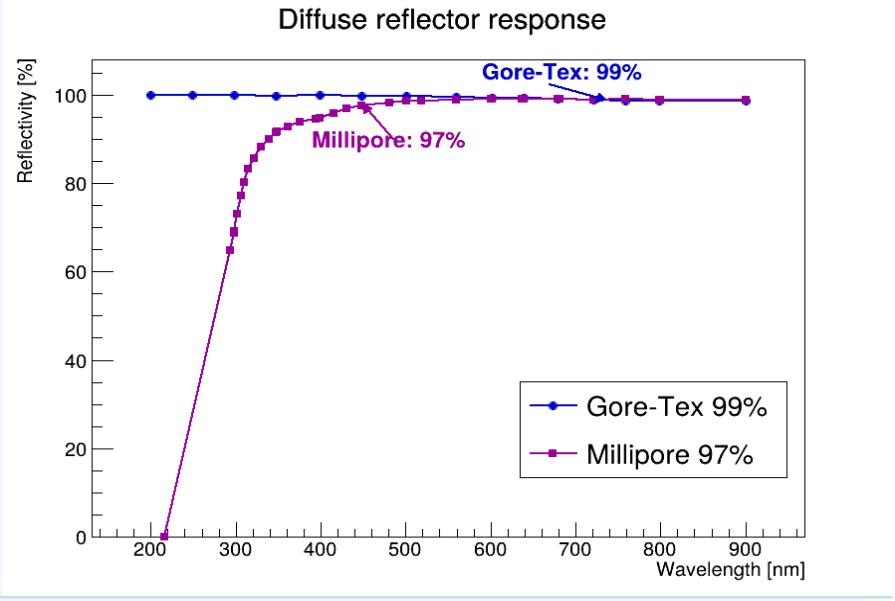


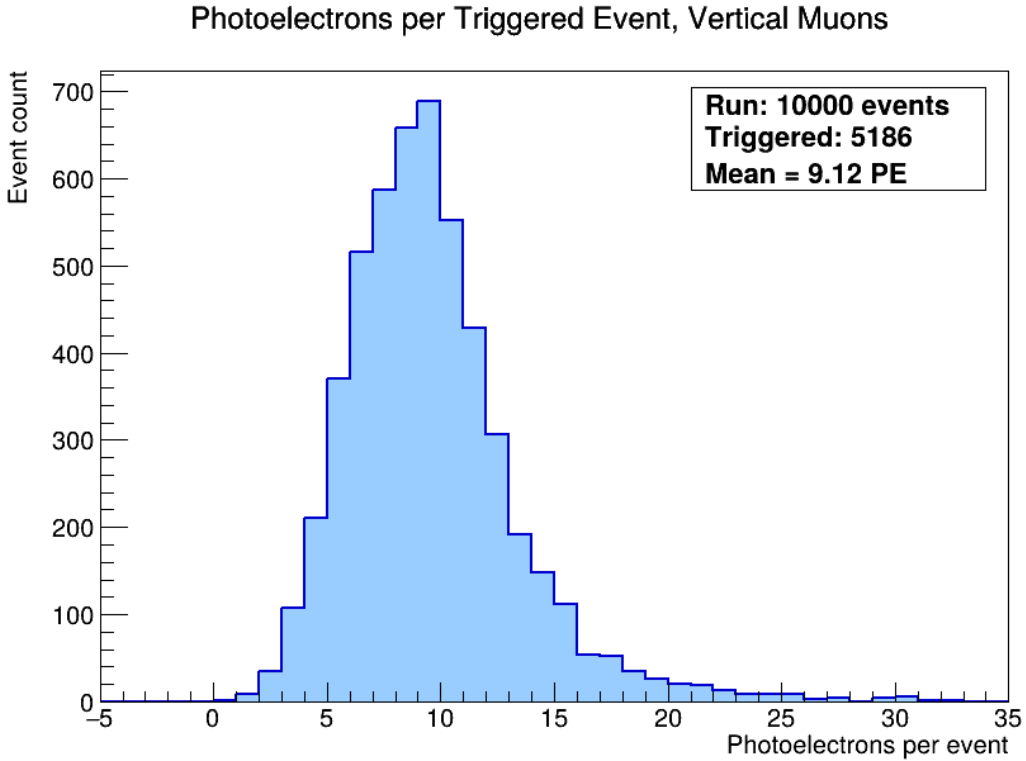
Fig 4. Diffuse reflector response — Gore-Tex (blue) vs Millipore (purple)

Hamamatsu R4125
(bialkali photocathode, borosilicate window)
Hamamatsu booklet, p.65

Data for Gor and Millipore were based on Catholic University data from 2017.

Photoelectron Yield: Vertical

Vertical muons



Vertical run
Generated: 10 000 Triggered: 5186
Mean: 9.12 PE / triggered event

Geant4 Configuration & Photon Transport Chain

PHYSICS LIST

Geant4 version: 11.2.2 FTFP_BERT + G4EmStandardPhysics_option4 + G4OpticalPhysics

PRIMARY BEAM

μ · 3.0 GeV ·

TRIGGER

Coincidence: top ∩ bottom scintillator paddles

PHOTON TRANSPORT CHAIN

1. μ crosses aerogel
Cherenkov photons emitted

↓

2. Scattering & absorption
Rayleigh + absorption (Barnyakov tables)

↓

3. Gore-Tex reflection
Lambertian diffuse reflector

↓

4. PMT detection
QE-weighted photoelectron count

↓

PE Histogram → Mean yield
Triggered events only

QE: Hamamatsu R4125 datasheet. Aerogel: Barnyakov parameterisation..

Summary & outlook

SIMULATION RESULTS

9.12 **PE / event (vertical muons)**
3 GeV/c, triggered 5186 / 10 000

Simulation fully validated
Geant4 + Barnyakov aerogel + Hamamatsu QE pipeline reproduces expected detector response

FUTURE WORK

Comparison with lab bench data
Validate simulation against measured PE yield

Aerogel n scan
Simulate n = 1.03 – 1.10, optimise PE yield

Reflector optimisation
Compare Gore-Tex vs Millipore reflectance impact

We plan to simulate muons at an angle in future work.

Thank You

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