

ASHIPH Simulations

Geant4 modeling at AANL,
the A.I.Alikhanyan National Science Laboratory

V. Tadevosyan

Outline

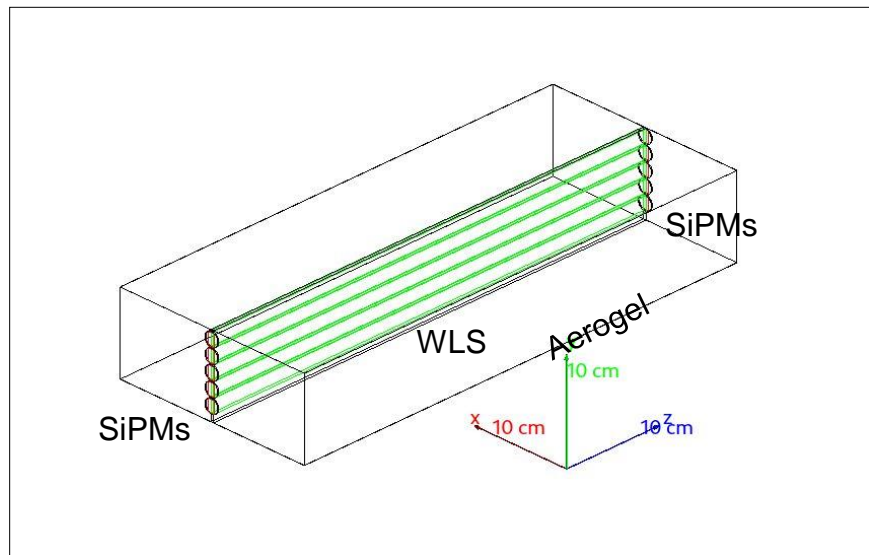
Aerogel detector from TDR

- Parameters in simulation
- Results from simulation
- Summary

BINP ASHIPH prototype simulation

- Parameters in simulation
- Results, comparison with beam tests
- Summary

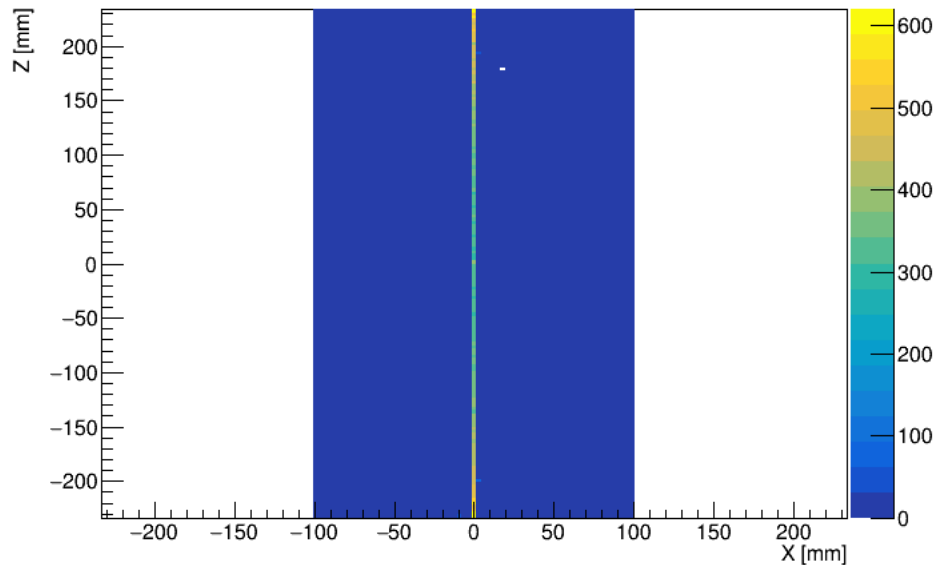
SPD Aerogel Detector: The simulated module



The simulated module:

- 20x47x8 cm³ rectangular aerogel block (BIC, n=1.02)
- 5 imbedded WLS bars, 3x14 mm² cross section
- 2 6x6 mm² Hamamatsu SiPM-s on ends of WLS bar
- DOWSIL 3145 adhesive to couple WLS with SiPM-s
- Container box covered by VM2000 reflector inside

SPD Aerogel Module, 4 GeV μ^- incident, summed SiPM signal in pe

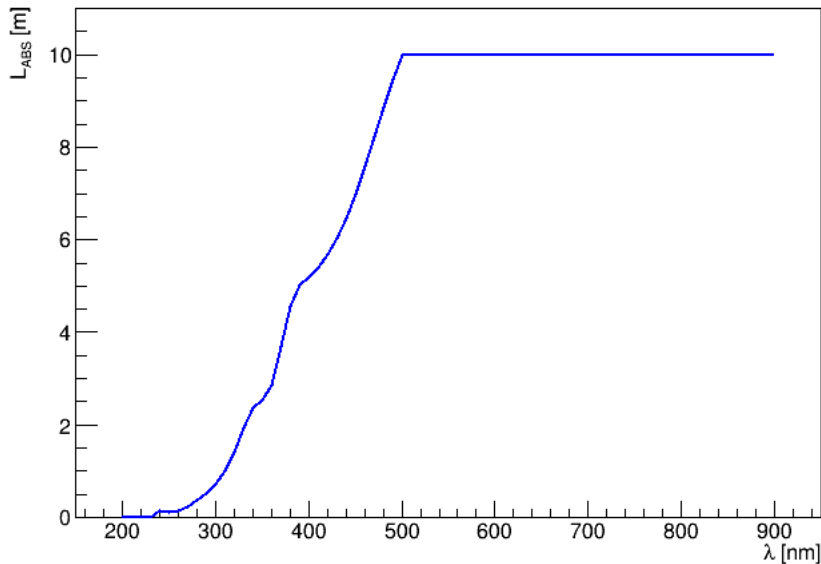


Cosmic rays mimicked by 4 GeV charged muons falling uniformly on the surface of module.

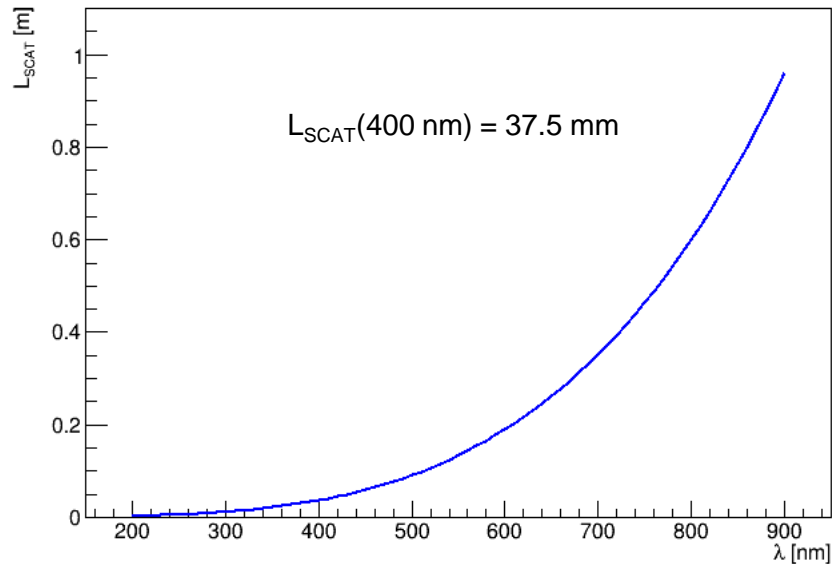
Big signal when track hits WLS bar at the middle.

SPD Aerogel Detector: Aerogel properties

Absorption length of aerogel of $n=1.03$



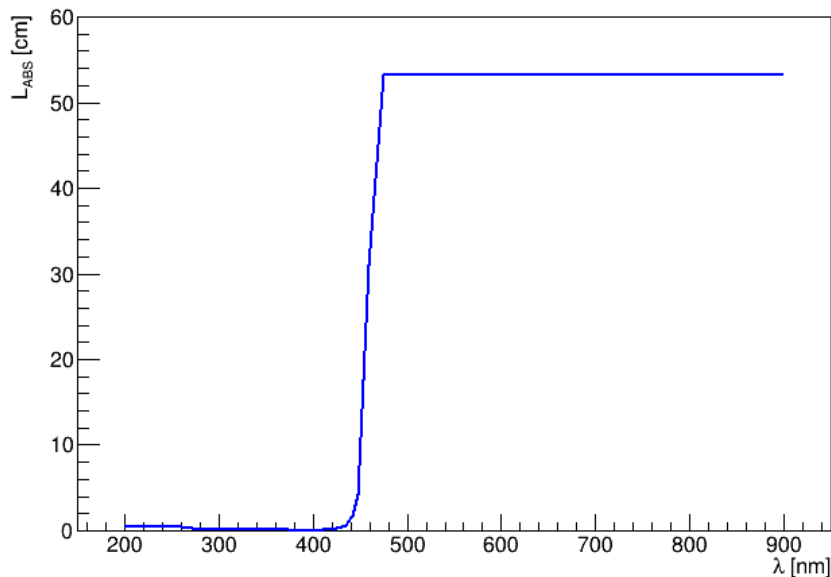
Scattering length of aerogel of $n=1.03$



Courtesy of A. Barnyakov

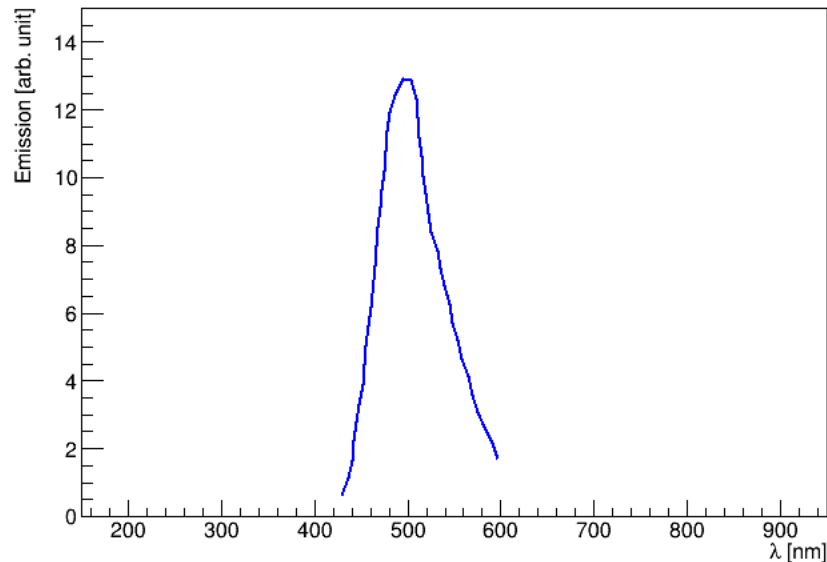
SPD Aerogel Detector: BBQ dye properties

Absorption length of BBQ



Absorption length of BBQ derived from “photon to photon” measurements (A.Buzykaev, thesis) of 3 mm thick slab.

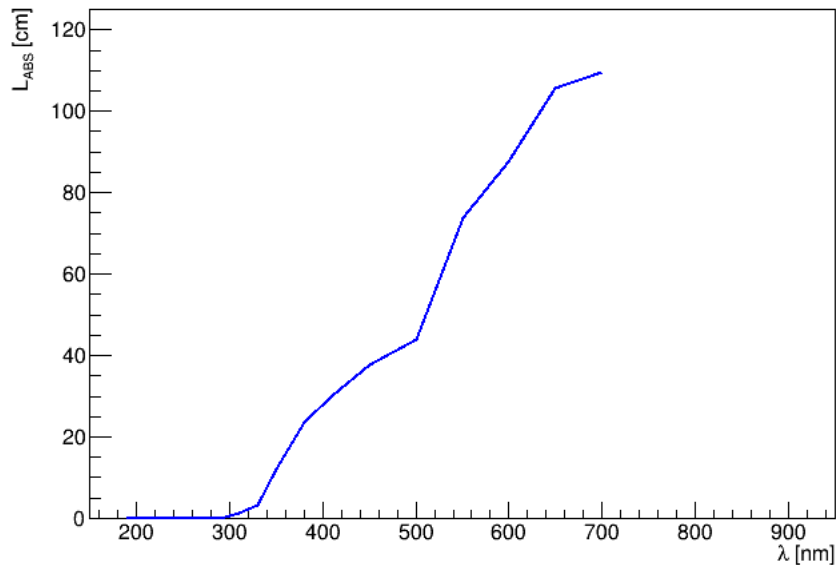
Emission spectrum of BBQ



Emission spectrum of BBQ peaking at ~500 nm, above absorption range.

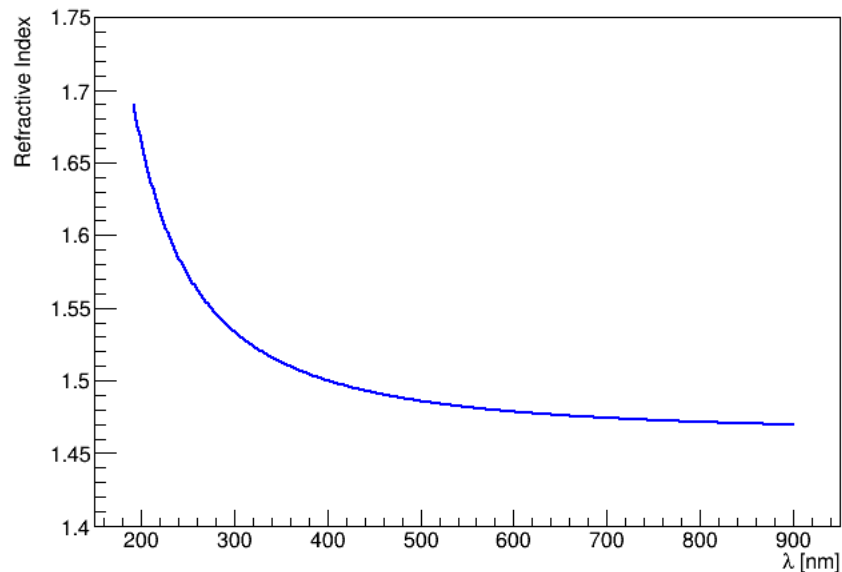
SPD Aerogel Detector: Plexiglass (PMMA) properties

Absorption length of PMMA



Absorption length of PMMA derived from external transmittance measurement of 5 mm thick slab (courtesy of A. Barnyakov), and dispersion of refractive index of PMMA.

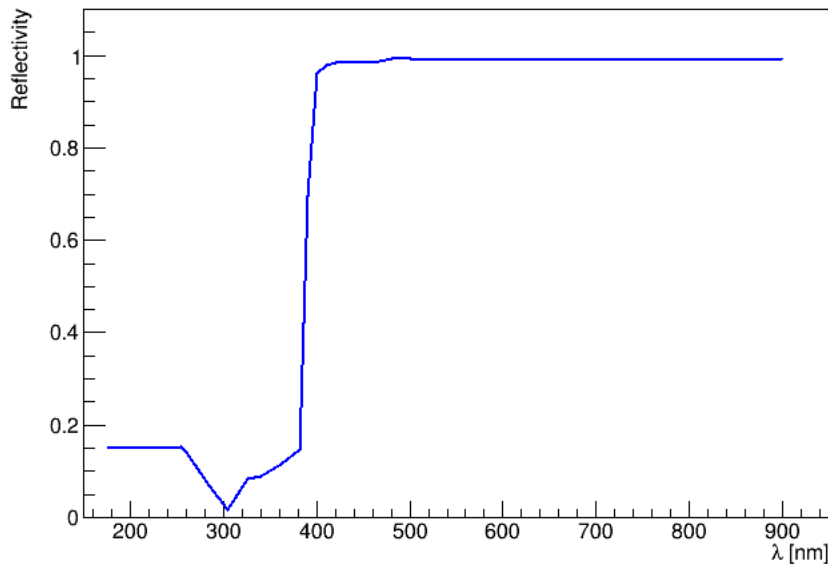
Refractive index of PMMA



Refractive index of PMMA from spectroscopic ellipsometry measurements (T. Roychowdhury et al, *Surf. Sci. Spectra* 27, 016002 (2020)).

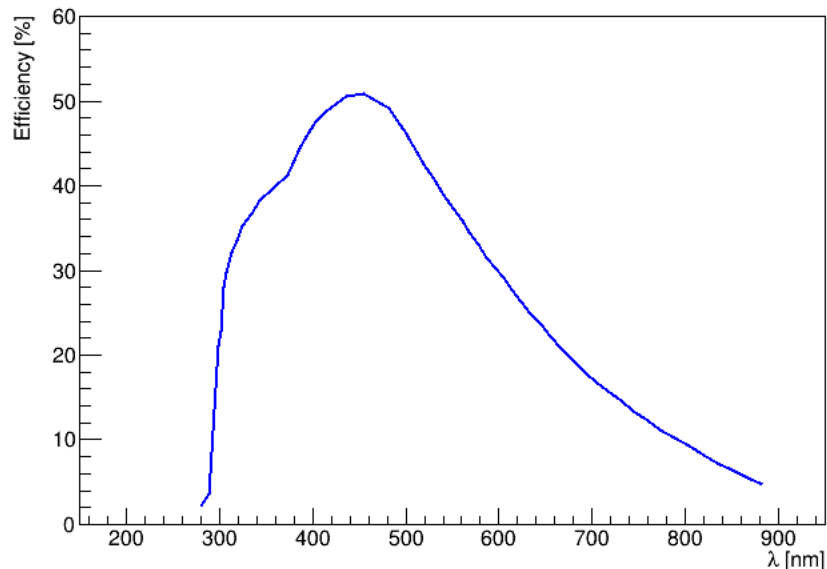
SPD Aerogel Detector: Reflector and SiPM properties

Reflectivity of VM2000



VM2000 dielectric specular reflector of 65 μm thickness (M.Janecek, [IEEE Transactions on Nuclear Science](#) 59(3):490-49).

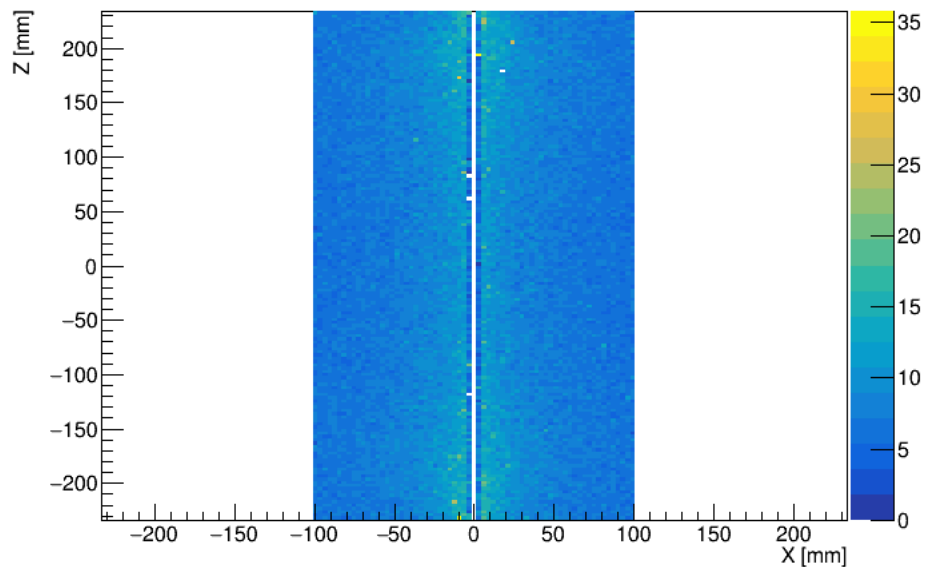
Quantum efficiency of Hamamatsu S14160-6050HS SiPM



QE peaks at ~ 420 nm. Dow Corning 3145 RTV-CLEAR MIL-A-44146 adhesive sealant, $n = 1.4$, couples SiPM with aerogel.

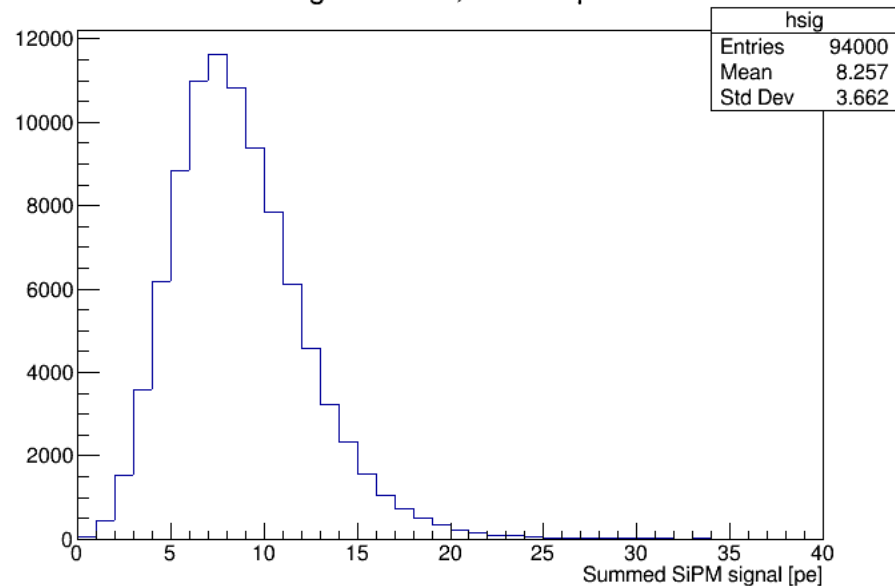
SPD Aerogel Detector: MC results

SPD Aerogel Module, 4 GeV μ^- incident, summed SiPM signal in pe



Signal distribution from tracks passing through aerogel (*WLS bars masked*).

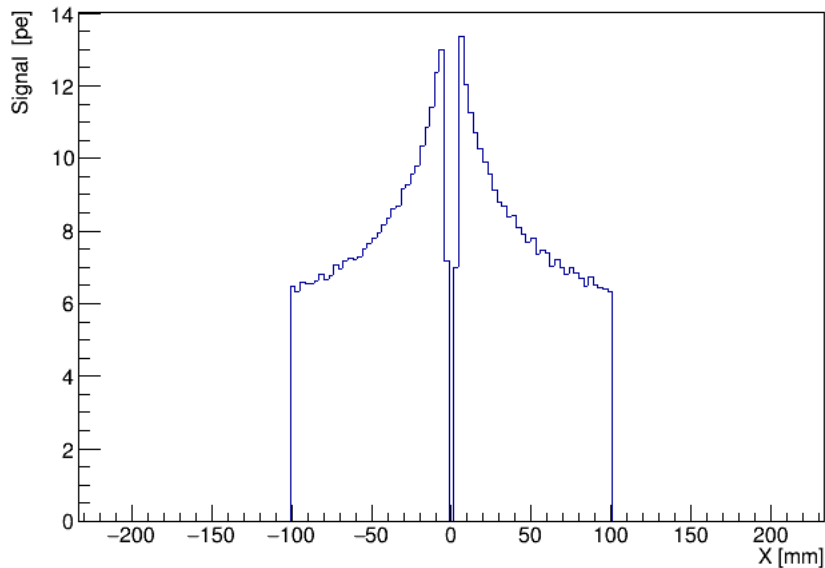
SPD Aerogel Module, 4 GeV μ^- incident



Expected typical signal from detector ~ 8 pe (from 5 WLS bars, 2 6×6 mm² SiPM-s on each end).

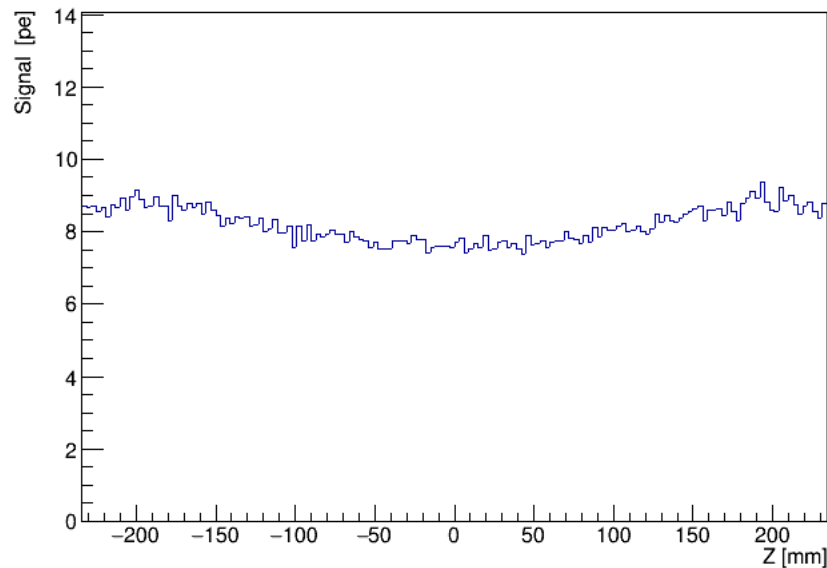
SPD Aerogel Detector: MC results

SPD Aerogel Module, 4 GeV μ^- incident, summed SiPM signal in pe



Significant coordinate dependence in X direction, perpendicular to WLS bars.

SPD Aerogel Module, 4 GeV μ^- incident, summed SiPM signal in pe



Moderate coordinate dependence in Z direction, along the WLS bars.

Summary

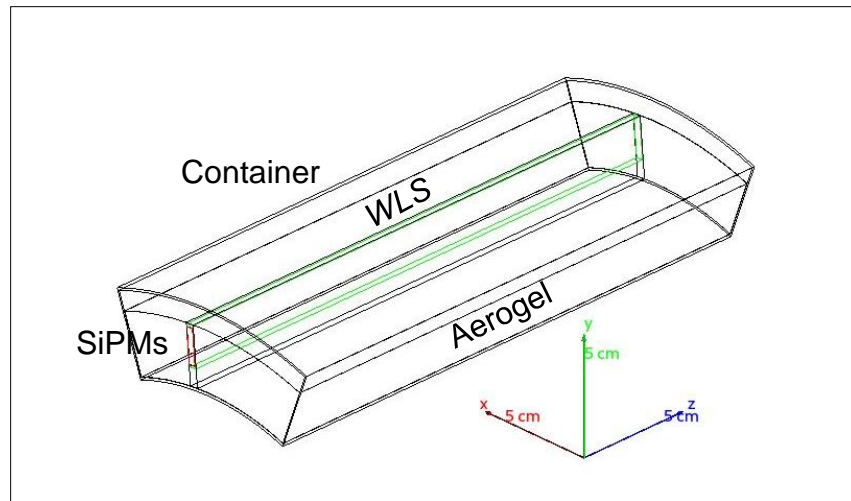
- Geant4 code is developed to simulate single module of aerogel detector from SPD TDR 2023.
- The code follows descriptions of constituents found in various sources.
- Response to cosmic rays was simulated, 8 p.e. typical signal from the module with 5 WLS bars was obtained.
- Significant coordinate dependence in direction perpendicular to the WLS bars was revealed.
- The coordinate dependence in direction along WLS bars is moderate.

ASHIPH Prototype: Layout



The real prototype:

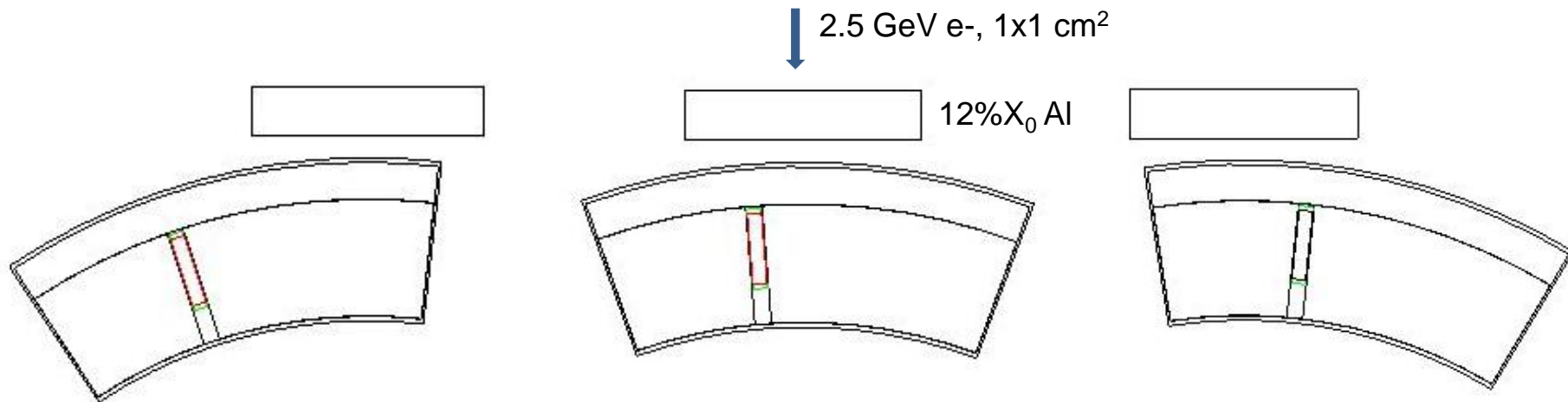
- Al container box, 3.5 cm high, cyl. ($R = 10.5 \text{ cm}$, $\theta = 40^\circ$)
- 4 trapezoidal aerogel blocks (BIC, $n=1.12$)
- WLS bar, $3 \times 17 \text{ mm}^2$ cross section, shifted by $\Delta\theta = 5^\circ$
- 5 $3 \times 3 \text{ mm}^2$ Hamamatsu SiPM-s on end of WLS bar
- PTFE (Teflon) reflector



The simulated prototype:

- Al container box, 3.5 cm high, cyl. ($R = 10.5 \text{ cm}$, $\theta = 40^\circ$)
- Cylindrical sector of aerogel block ($n=1.12$, 2.5 cm thick), covered by PTFE reflector
- Imbedded WLS bar, $3 \times 17 \text{ mm}^2$, shifted by $\Delta\theta = 5^\circ$
- 5 $3 \times 3 \text{ mm}^2$ Hamamatsu SiPM-s on end of WLS bar

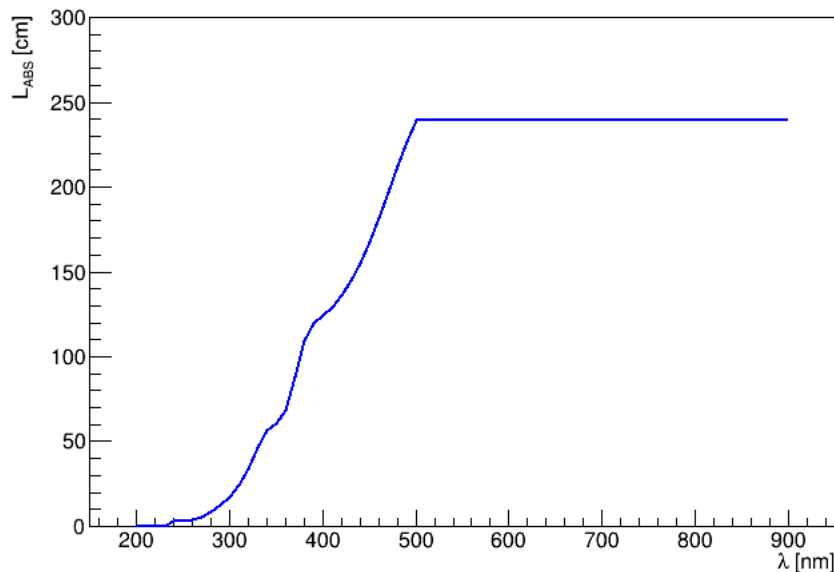
ASHIPH Prototype: Positioning under beam



- The counter was rotated and shifted along its axis for different positioning under beam.
- The beam tract material was modeled by 12% X_0 Al slab before detector.

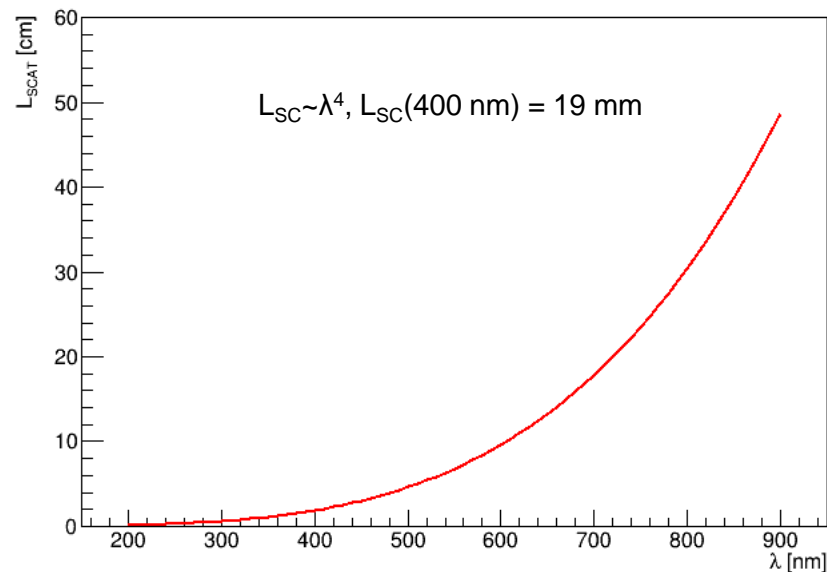
ASHIPH Prototype: Aerogel optical properties

Absorption length of aerogel of $n=1.12$



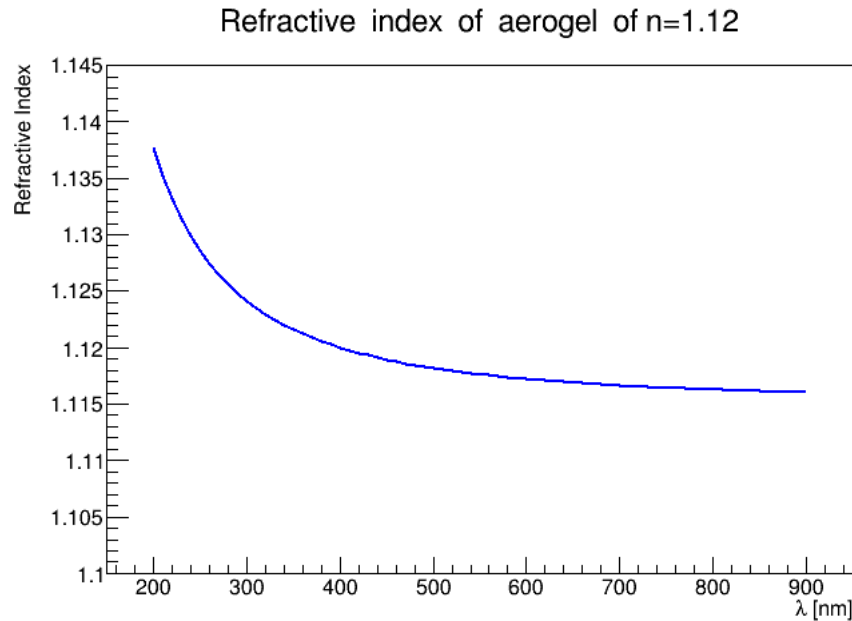
L_{ABS} is density corrected extrapolation of measurement of $n=1.03$ aerogel (T.Bellunato et al., Eur. Phys. J. C 52, 759–764 (2007)) (A.Barnyakov).

Scattering length of aerogel of $n=1.13$



L_{SC} at 400 nm from A.F.Danilyuk et al., NIMA 494 (2002) 491– 494.

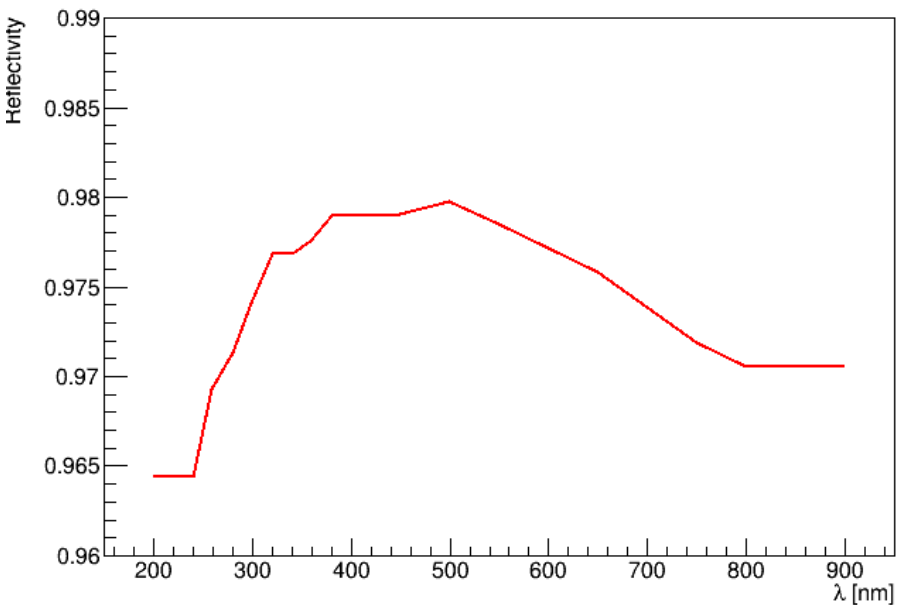
ASHIPH Prototype: Aerogel optical properties



Assume $n = 1.12$ at 400 nm, dispersion from T.Bellunato et al.,
Eur. Phys. J. C 52, 759–764 (2007) (A.Barnyakov).

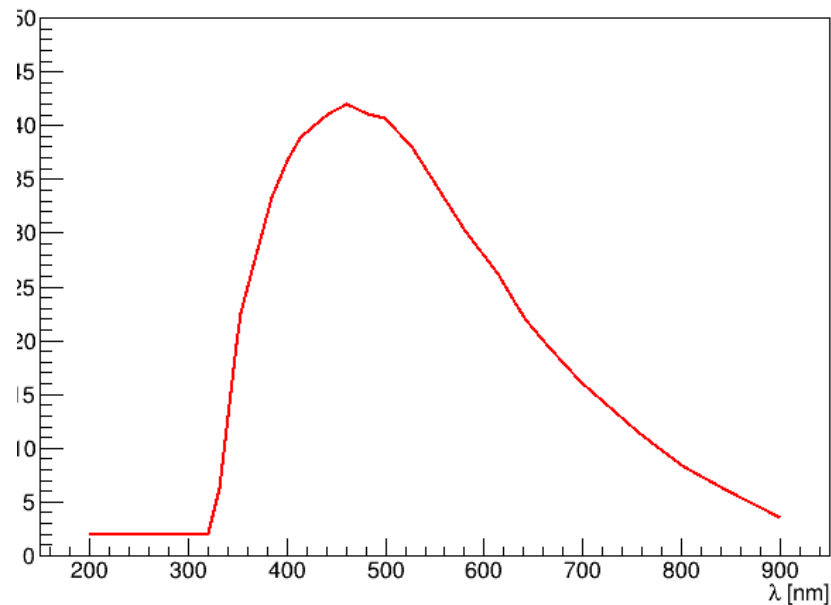
ASHIPH Prototype: Reflector and SiPM

Reflectivity of Teflon (PTFE)



Reflectivity of Teflon (PTFE), derived from A.Buzykaev, thesis.

Quantum efficiency of Hamamatsu S13363-3050NE-16 SiPM



Hamamtsu 3x3 mm² SiPM QE taken from booklet. Refractive index of epoxy window 1.55.

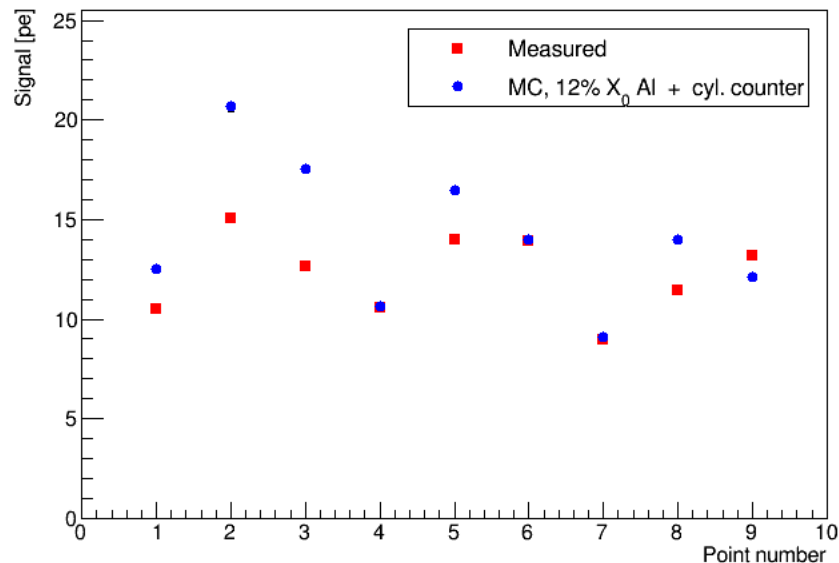
ASHIPH Prototype: MC Results

U=54 V

p1 10.53±0.16	p2 15.05±0.22	p3 12.62±0.17
p4 10.55±0.16	p5 14.00±0.22	p6 13.91±0.21
p7 8.96±0.14	p8 11.43±0.18	p9 13.20±0.20

Data from 2.5 GeV e- beam measurements,
courtesy of I.Ovtin.

ASHIPH Prototype signals, 2.5 GeV e- incident



Comparison of real data and MC.

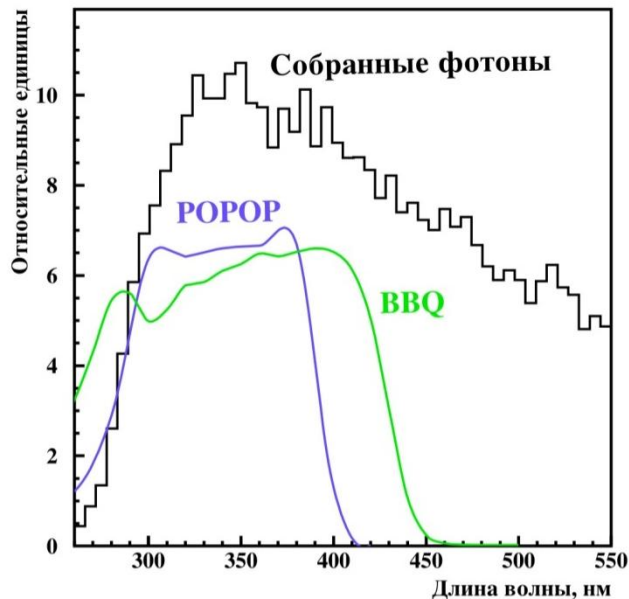
Summary

- Geant4 code is developed to simulate ASHIPH prototype developed in Novosibirsk.
- Outputs from MC simulation are in reasonable agreement with, albeit overestimate experimental data from beam tests conducted at BINP.
- Measured optical properties of aerogel would enhance accuracy of MC predictions.

Thank you for your attention!

Back-up slides

Aerogel Detector, BBQ dye properties



Absorption length of BBQ

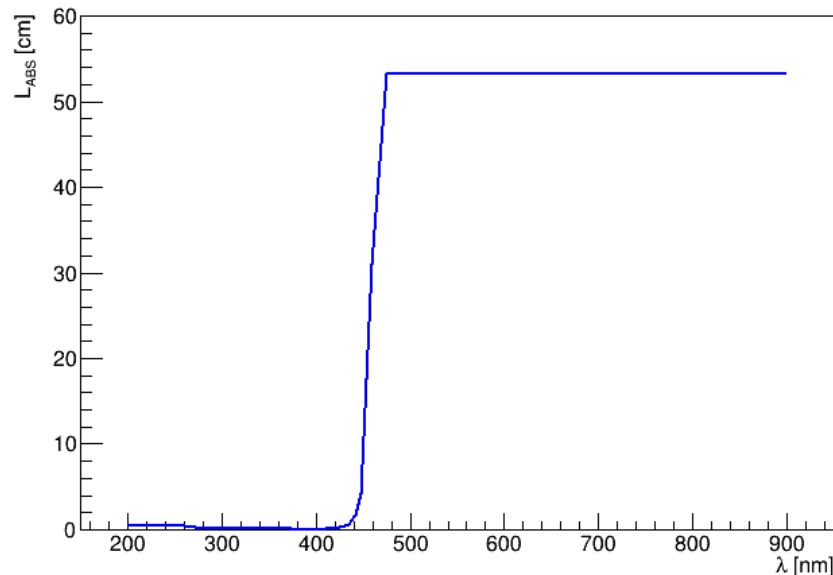


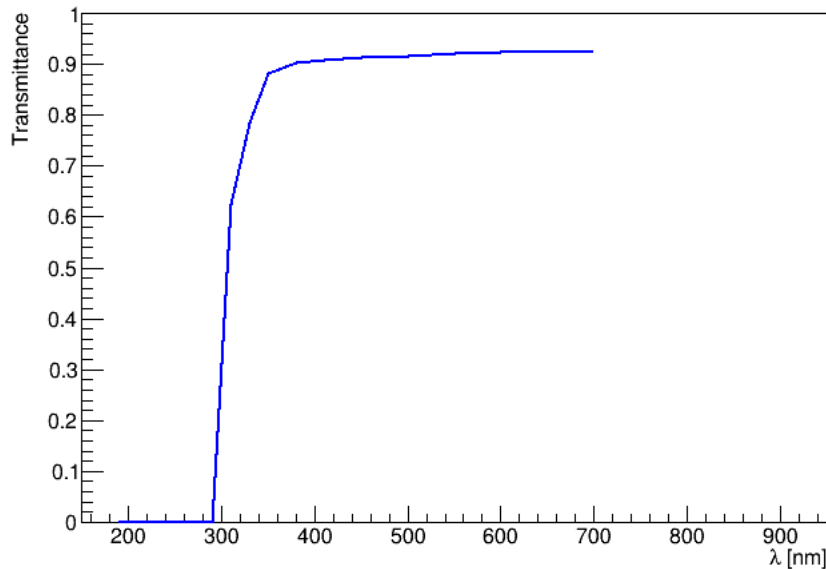
Рис. 3.17. Вероятности фотон в фотон для шифтеров на основе ROROR и BBQ, спектр фотонов, собранных на шифтер, полученный из Монте-Карло моделирования черенковского счётчика.

Absorption length of BBQ obtained from “photon to photon” curve in Fig.3.17 of Buzykaev’s thesis, in assumption:

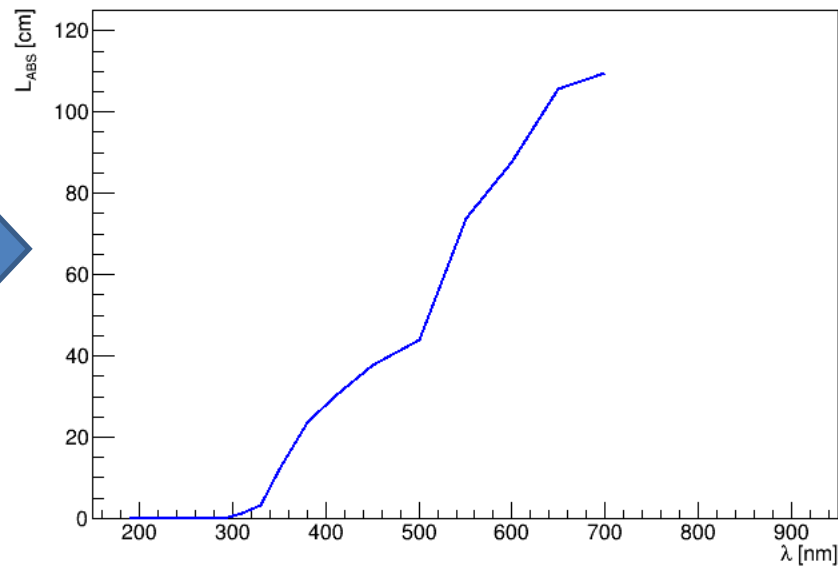
- BBQ slab thickness 3 mm;
- Absorption $\sim 100\%$ at 420 nm.

Aerogel Detector, Plexiglass (PMMA) properties

Transmittance of 5 mm PMMA



Absorption length of PMMA



Absorption length of PMMA derived from external transmittance measurement of 5 mm thick slab (courtesy of A.Barnyakov), and dispersion of refractive index of PMMA.

ASHIPH Prototype, reflector

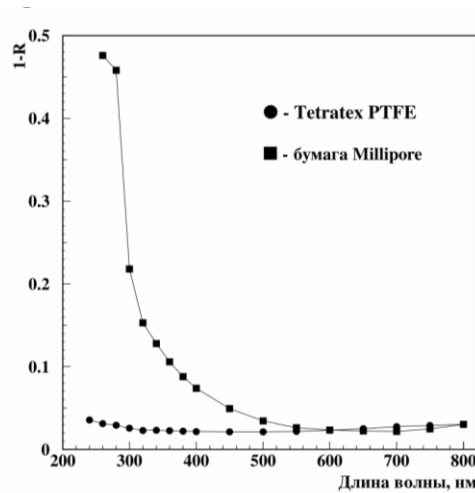
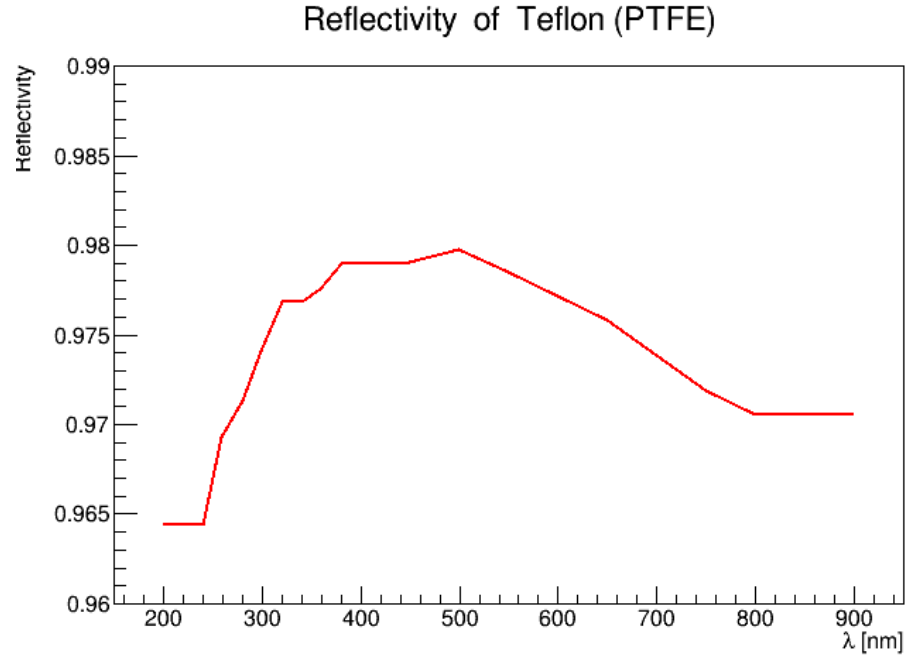


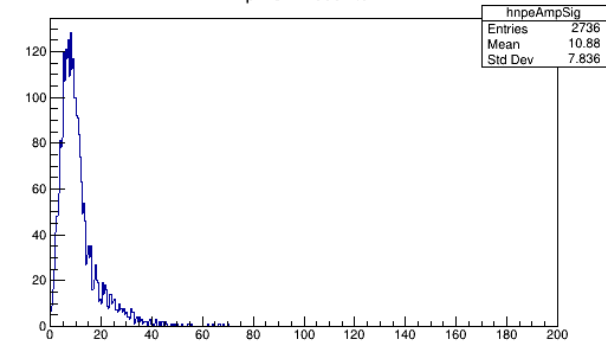
Рис. 3.22. Сравнение коэффициента поглощения для тефлона PTFE и бумаги Millipore



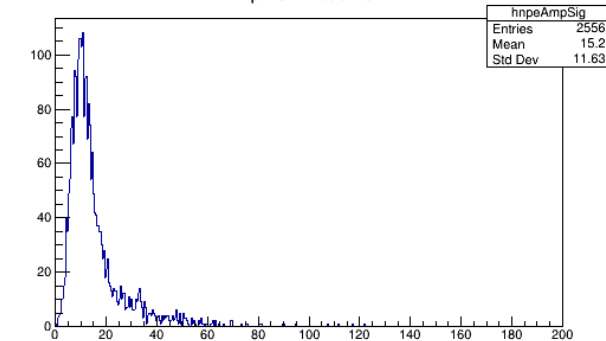
PTFE (Teflon) reflectivity taken from A.Buzykaev's thesis.

Signal spectra, row 1, real (top) vs MC (bottom)

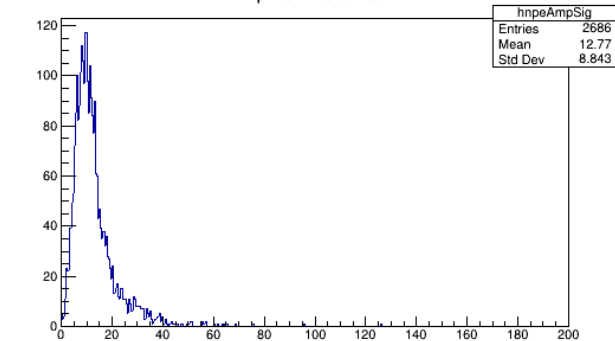
Nph.e. in counter



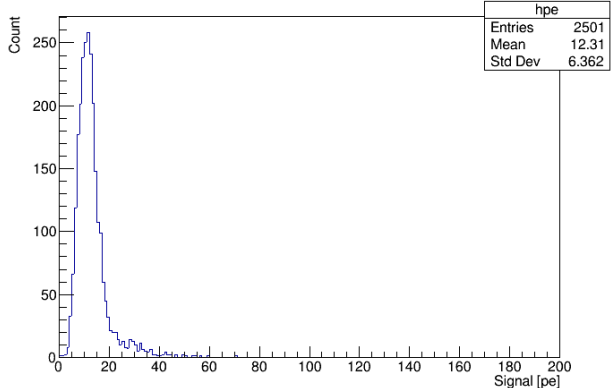
Nph.e. in counter



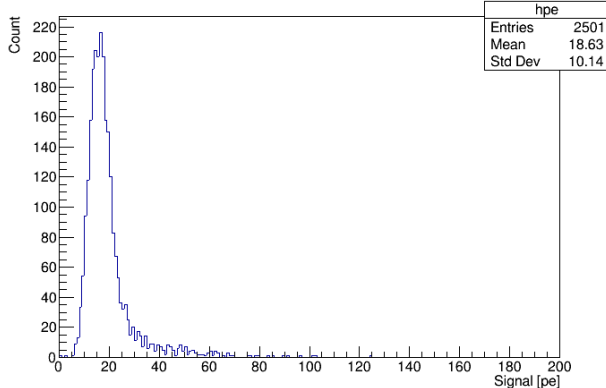
Nph.e. in counter



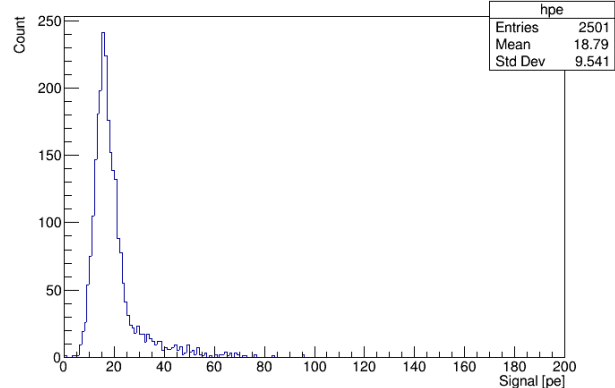
signal at p = 1



signal at p = 2



signal at p = 3



Note: the model detector is of box shape!