SPD Aerogel Detector

Geant4 simulations at AANL,
A.I.Alikhanyan National Science Laboratory

V. Tadevosyan

Outline

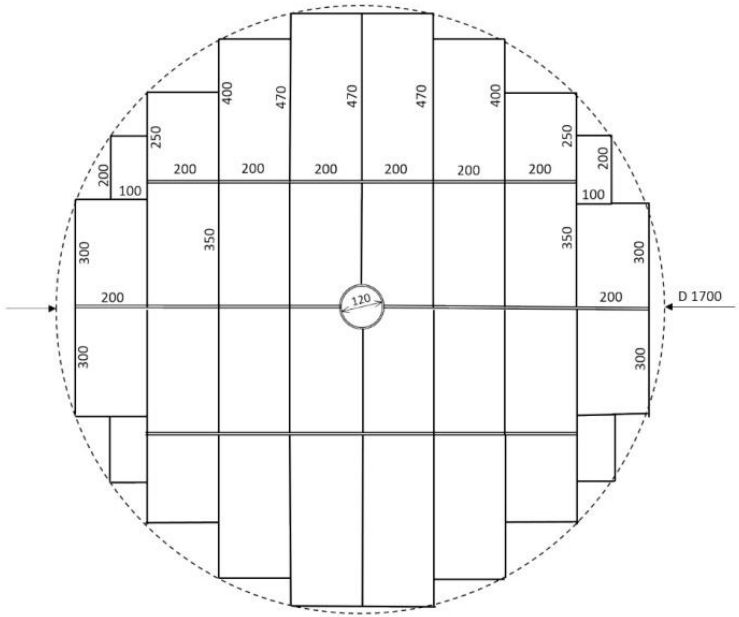
Aerogel detector from TDR

- Parameters in simulation
- Results from simulation
- Summary

BINP ASHIPH prototype simulation

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

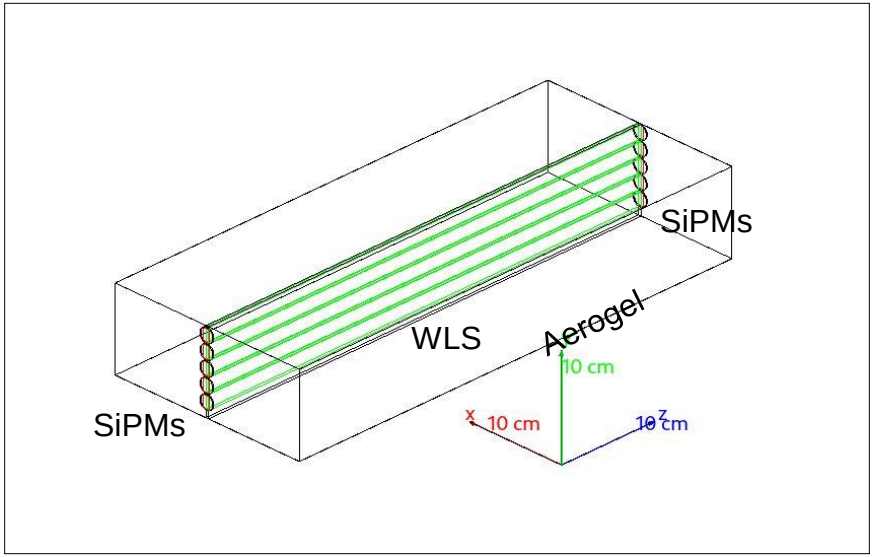
Aerogel Detector, outline of construction

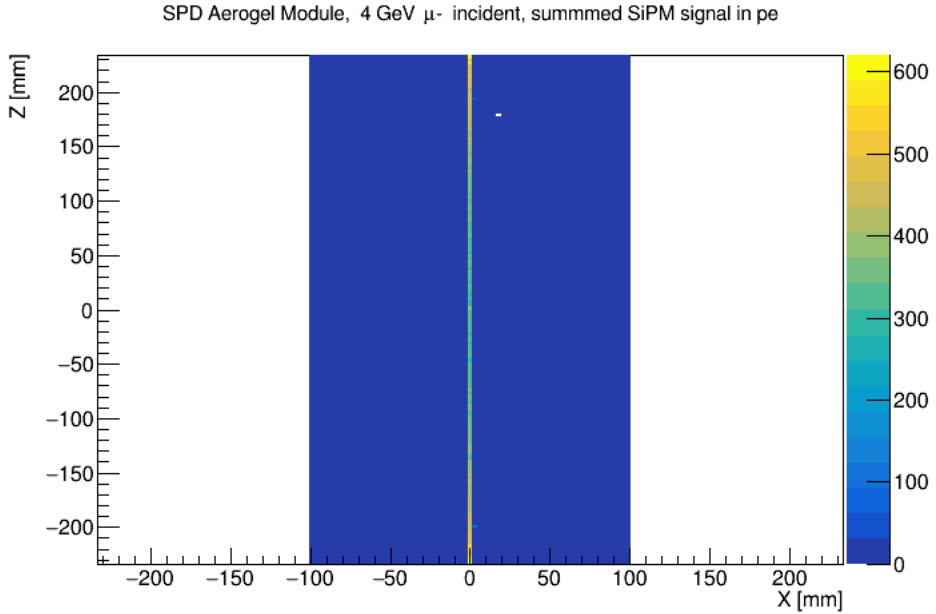


A sketch of the SPD aerogel detector from TDR’23.

- The Aerogel Detector is needed for reliable π/K separation in momentum range from 1 to 2.5 GeV/c.
- SPD end-cap acceptance covered by isolated modules, with rectangular tiles of aerogel of various cross sections.
- 2 layers of modules, 8 cm thick aerogel of refractive index 1.02 in each.
- Cherenkov light collected by WLS shifters imbedded in aerogel.
- Light detected by SiPM-s, on both ends of WLS bars.

Aerogel Detector, the simulated module



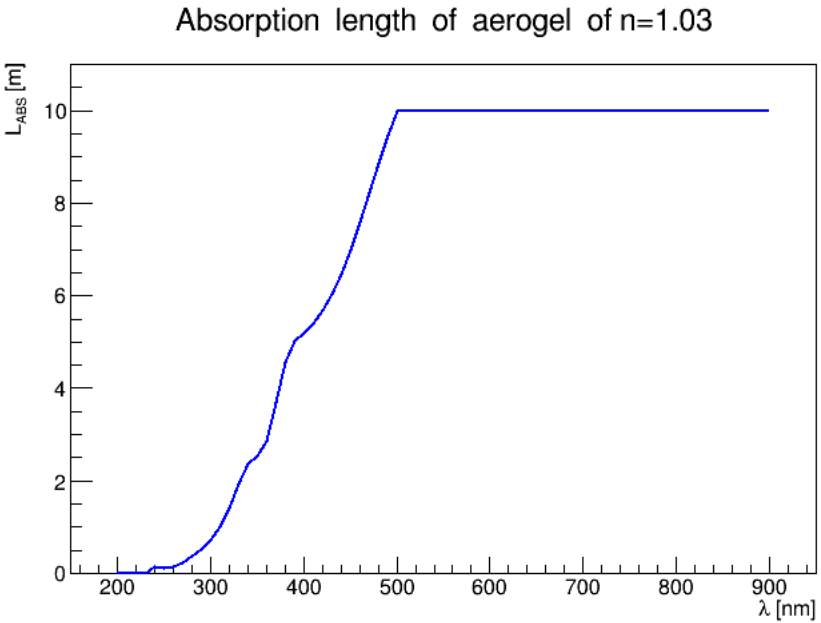


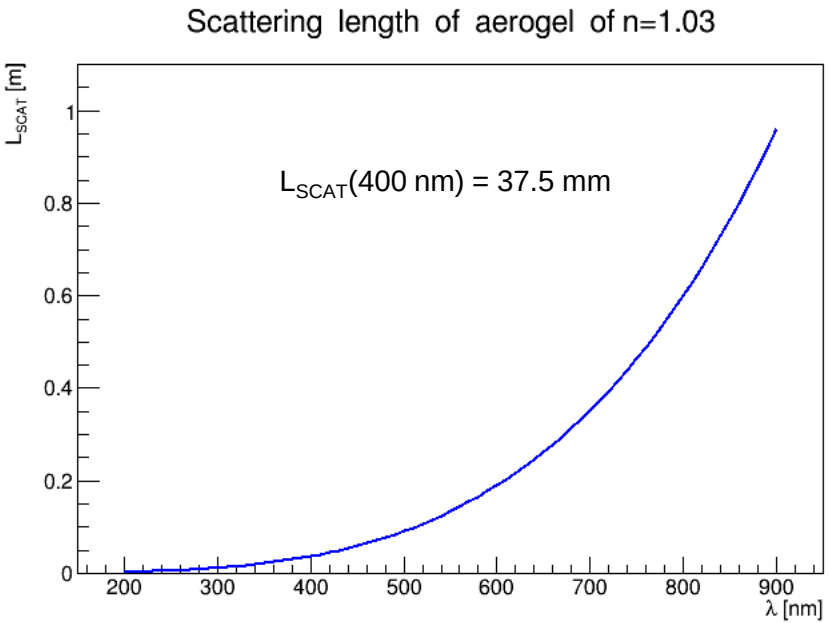
The simulated module:

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

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.

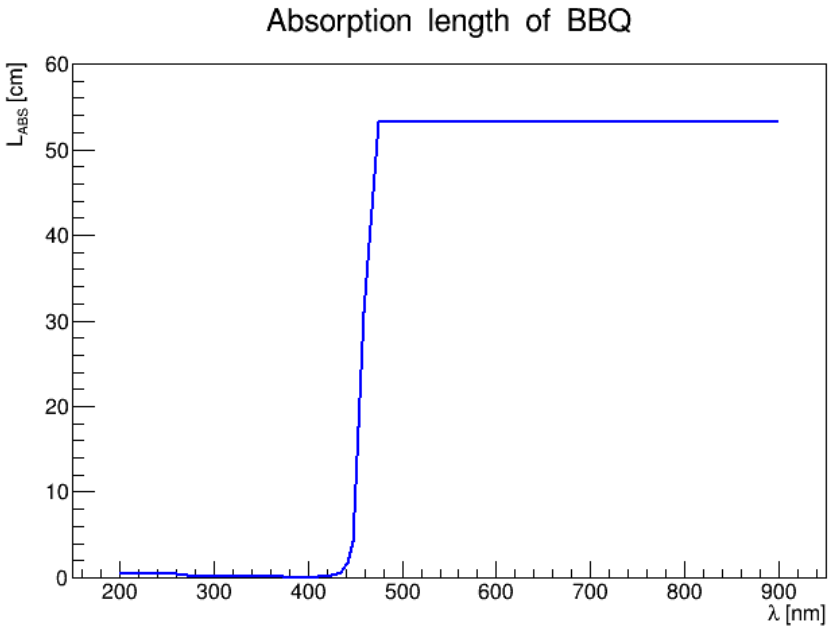
Aerogel Detector, aerogel properties



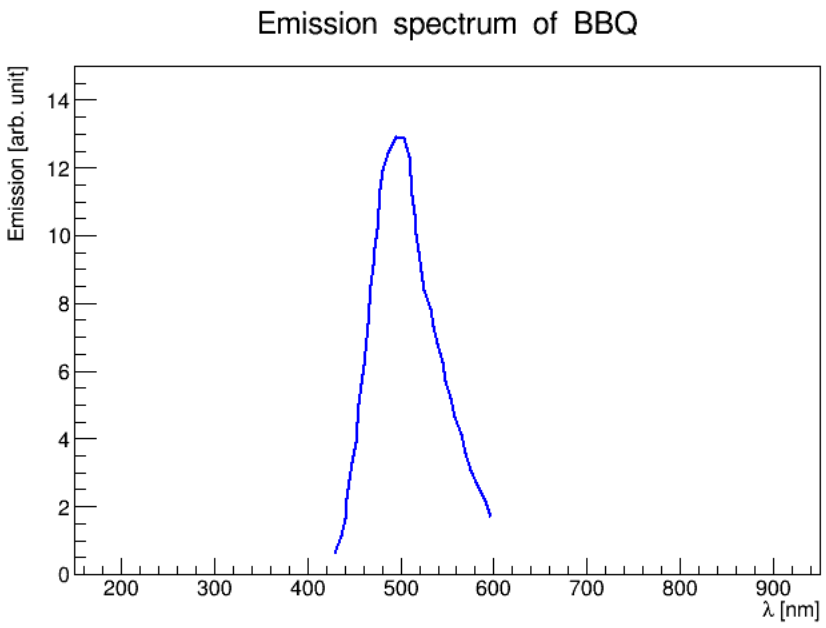


Courtesy of A.Barnyakov

Aerogel Detector, BBQ dye properties

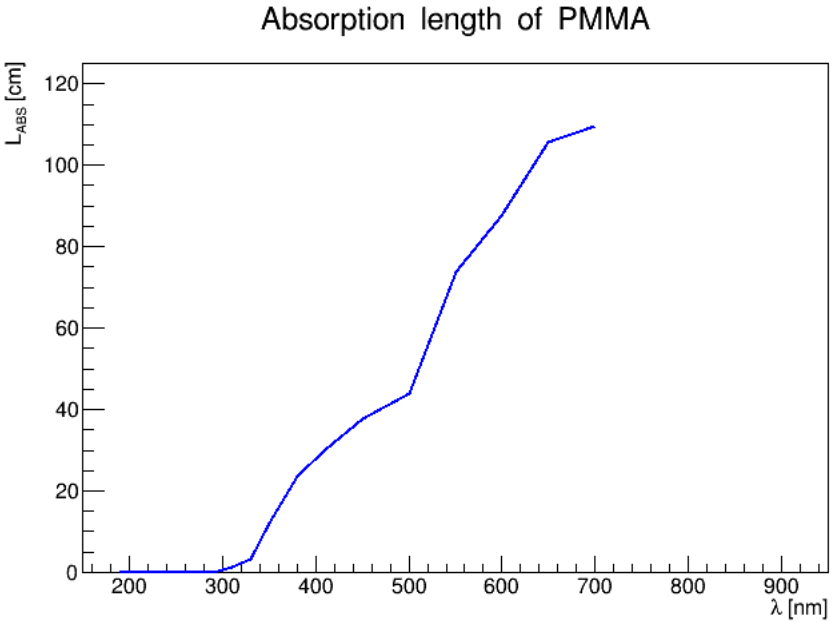


Absorption length of BBQ derived from “photon to photon” measurements (A.Buzykaev, thesis) of 3 mm thick slab.

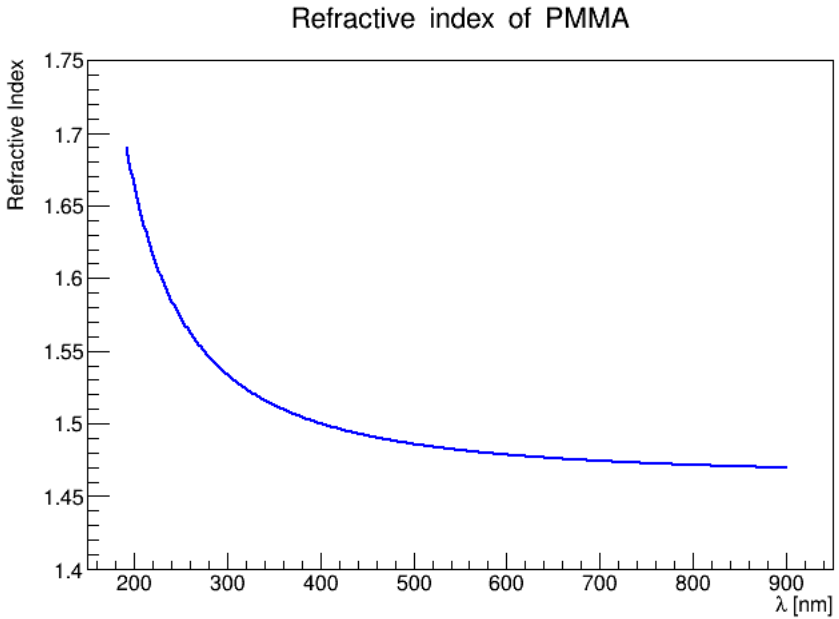


Emission spectrum of BBQ peaking at ~500 nm, above absorption range.

Aerogel Detector, Plexiglass (PMMA) properties

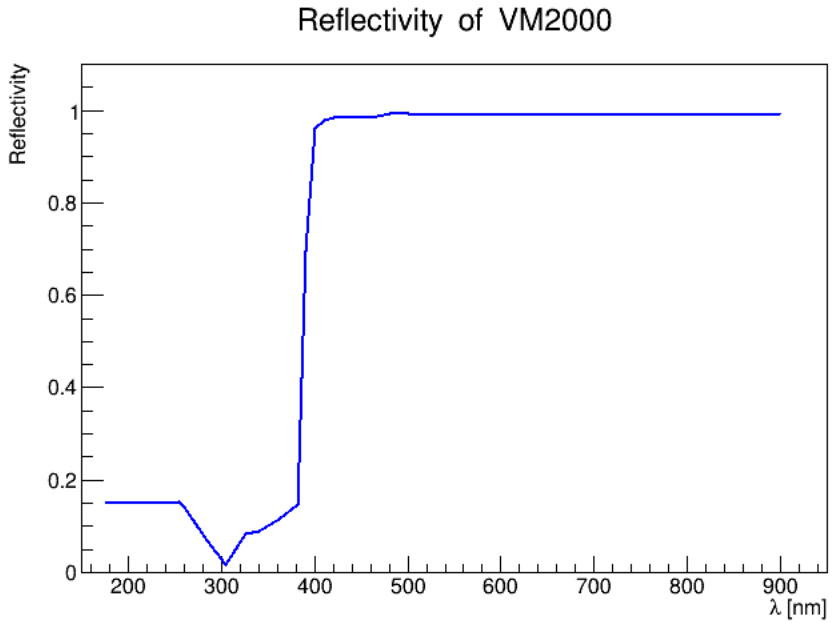


Absorption length of PMMA derived from external transmittance measurement of 5 mm thick slab (courtesy of A.Barnyakov), and dispersion of refractive index of PMMA.

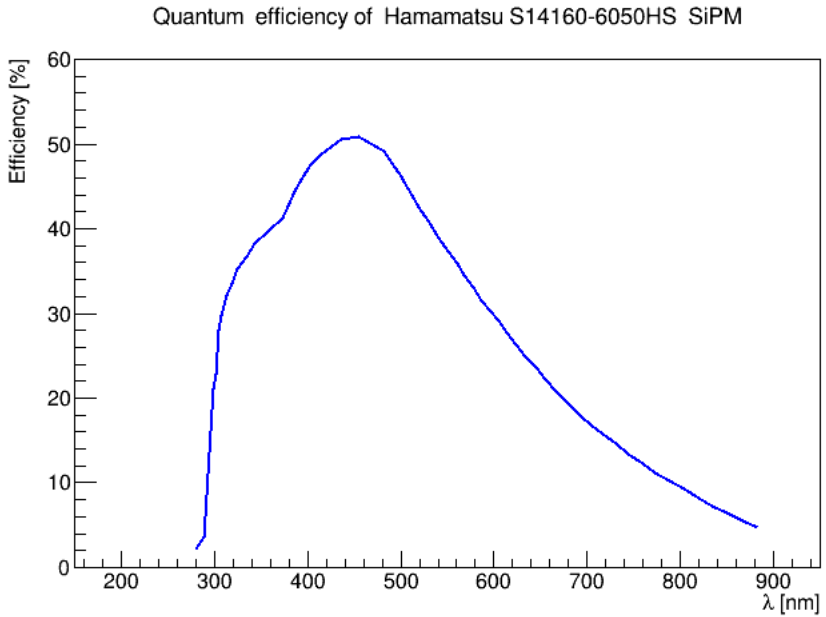


Refractive index of PMMA from spectroscopic ellipsometry measurements (T. Roychowdhury et al, *Surf. Sci. Spectra* 27, 016002 (2020)).

Aerogel Detector, Reflector properties

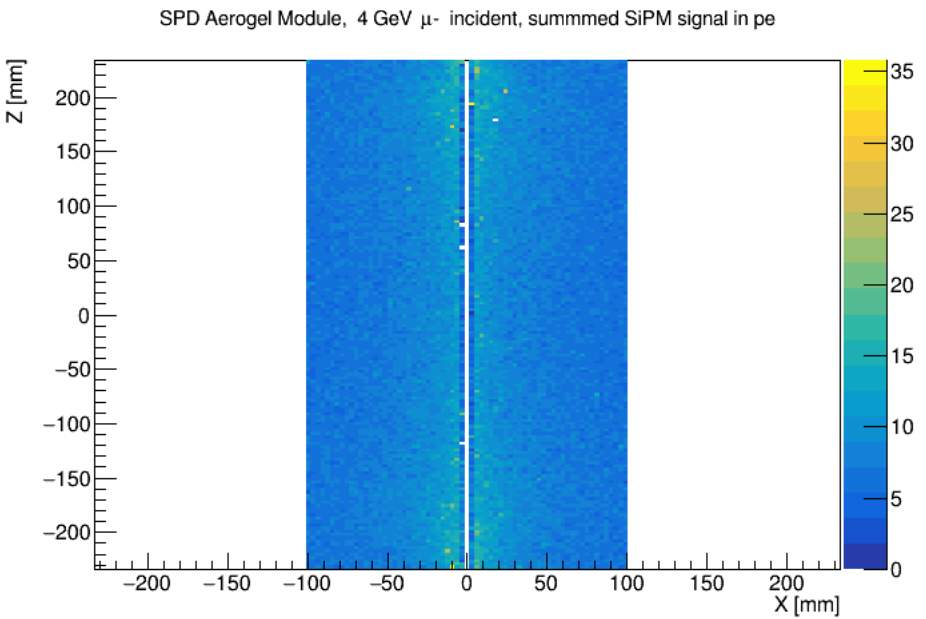


VM2000 dielectric specular reflector of 65 μm thickness (M.Janecek, IEEE Transactions on Nuclear Science 59(3):490-49).

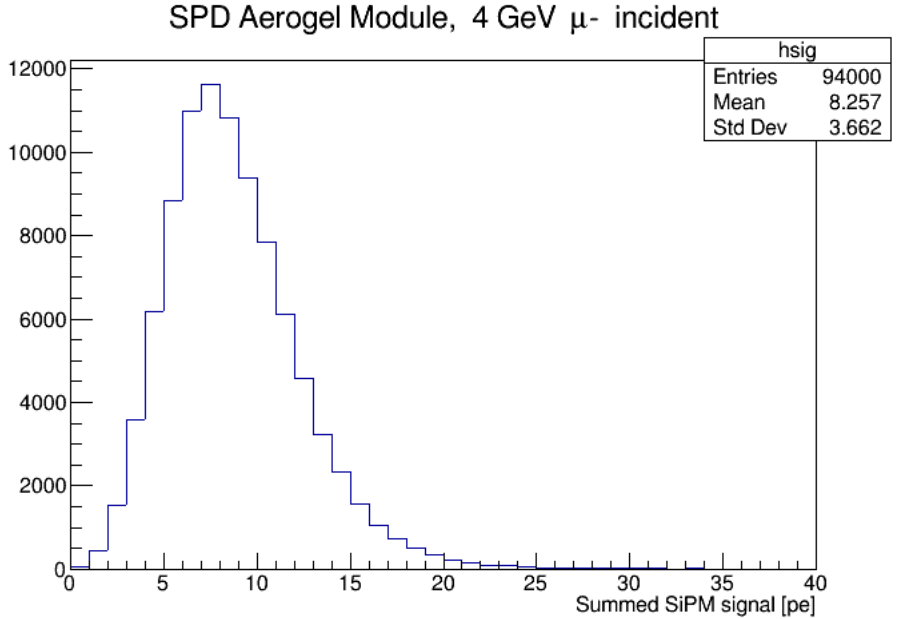


QE peaks at ~420 nm. Dow Corning 3145 RTV-CLEAR MIL-A-44146 adhesive sealant, n = 1.4, couples SiPM with aerogel.

Aerogel Detector, MC results

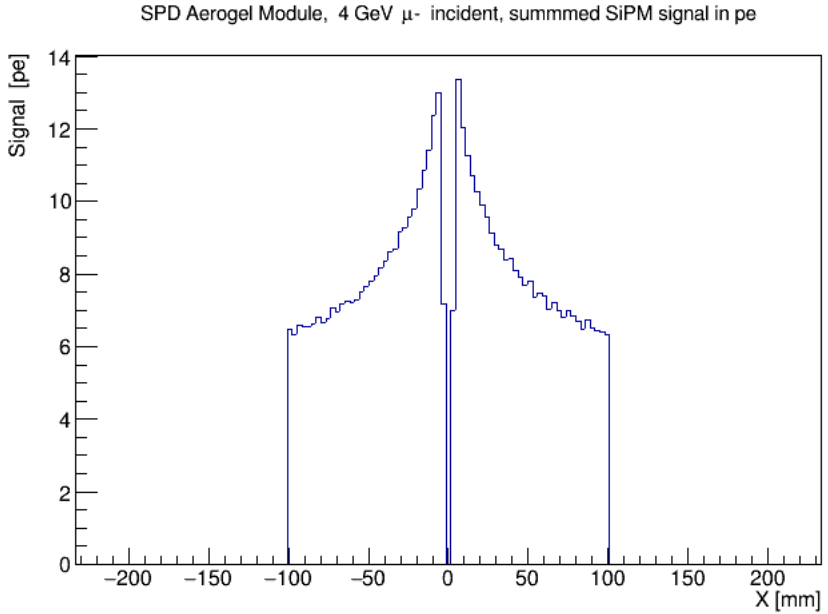


Signal distribution from tracks passing through aerogel (WLS bars masked).

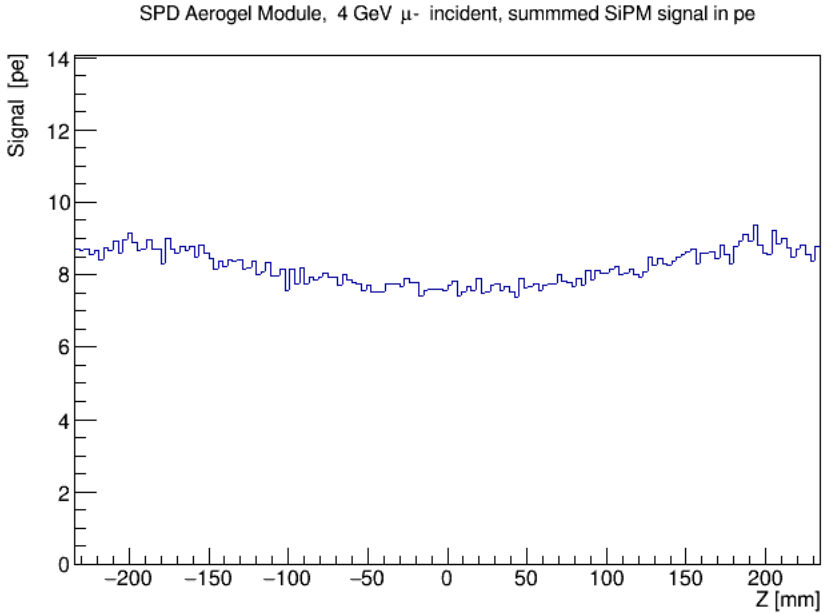


Expected typical signal from detector ~8 pe (from 5 WLS bars, 2 6x6 mm^2 SiPM-s on each end).

Aerogel Detector, MC results



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



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

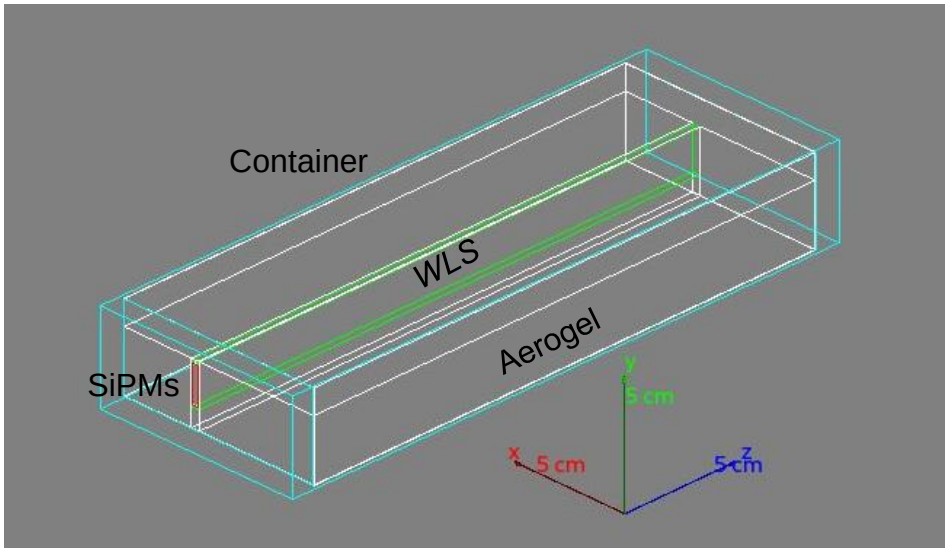
Summary

- Geant4 code is developed to simulate single module of aerogel detector from SPD TDR 2023.
- The code closely 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 detected.
- The coordinate dependence in direction along WLS bars is mild.

ASHIPH Prototype, layout

The real prototype:

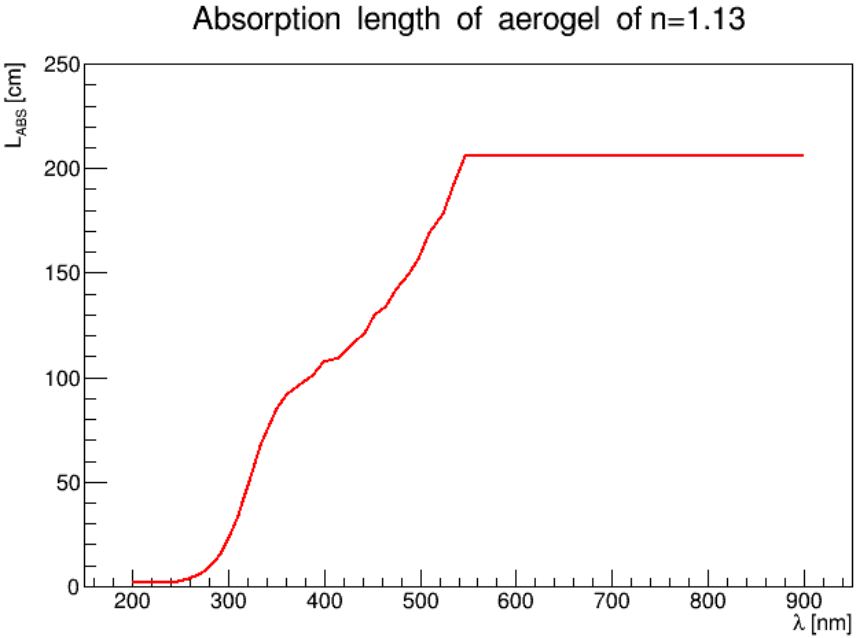
- Al container box, 3.5 cm high, cyl. ($R = 10.5\ cm$, $\theta = 40°$)
- 4 trapezoidal aerogel blocks (BIC, n=1.12)
- WLS bar, 3x17 mm^2 cross section, shifted by $\Delta\theta = 5°$
- 5 3x3 mm^2 Hamamatsu SiPM-s on end of WLS bar
- PTFE (Teflon) reflector

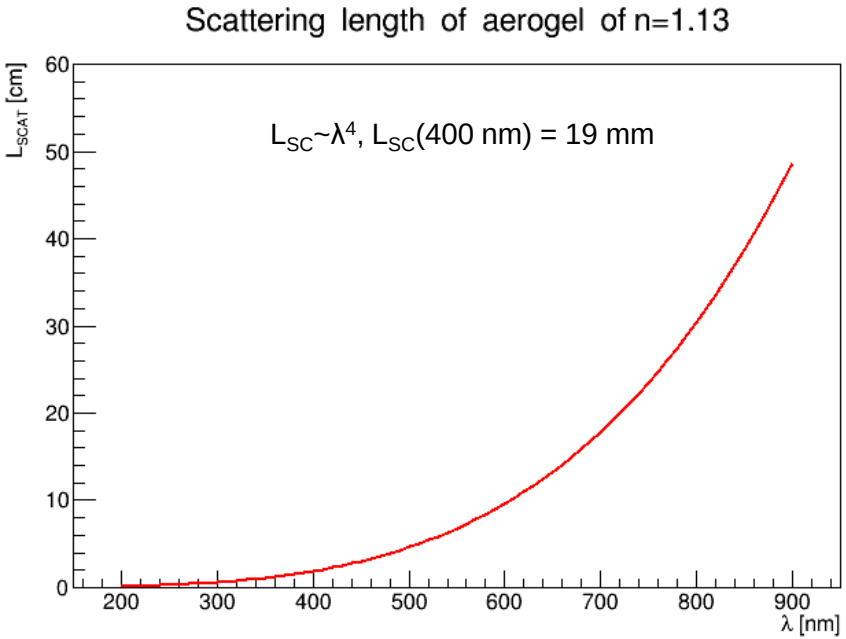


The simulated prototype:

- Al container box, 3.5 cm high
- 8.6x2.5x22.6 cm^3 aerogel block (BIC, n=1.12) inside
- Imbedded WLS bar, 3x17 mm^2 cross section
- 5 3x3 mm^2 Hamamatsu SiPM-s on end of WLS bar
- Container box covered by PTFE reflector from inside

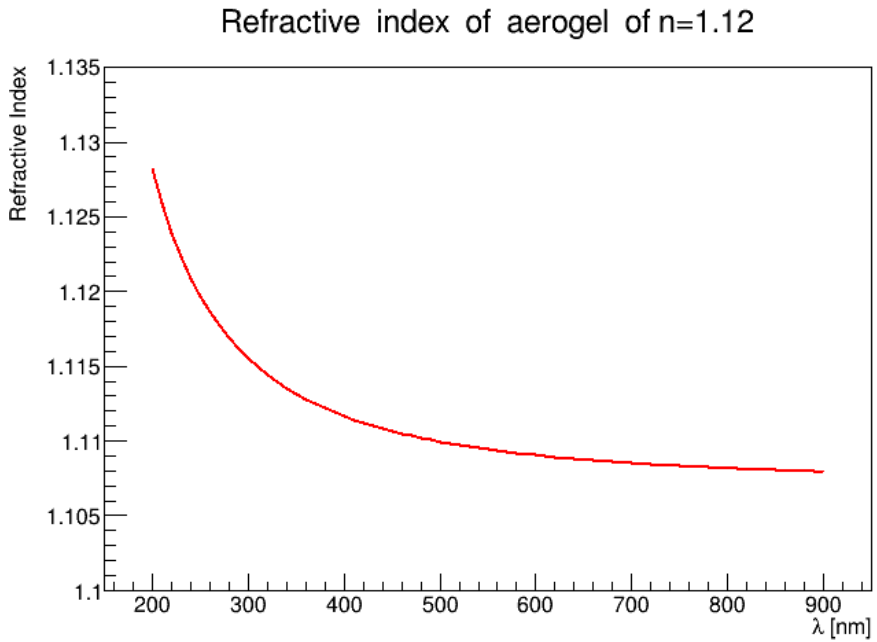
ASHIPH Prototype, aerogel properties





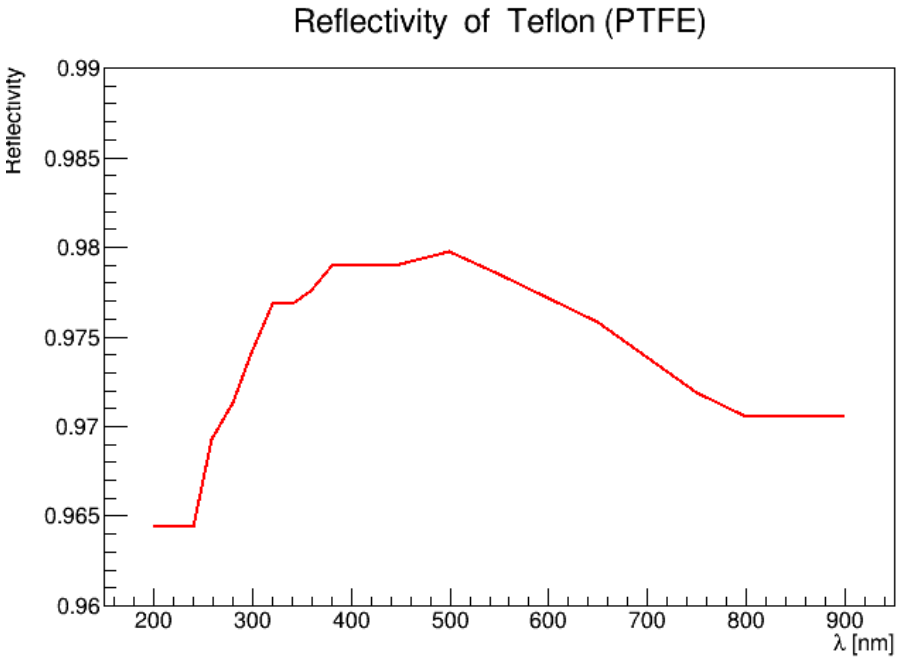
Absorption and scattering lengths from A.F.Danilyuk et al., NIMA 494 (2002) 491– 494.

ASHIPH Prototype, aerogel properties

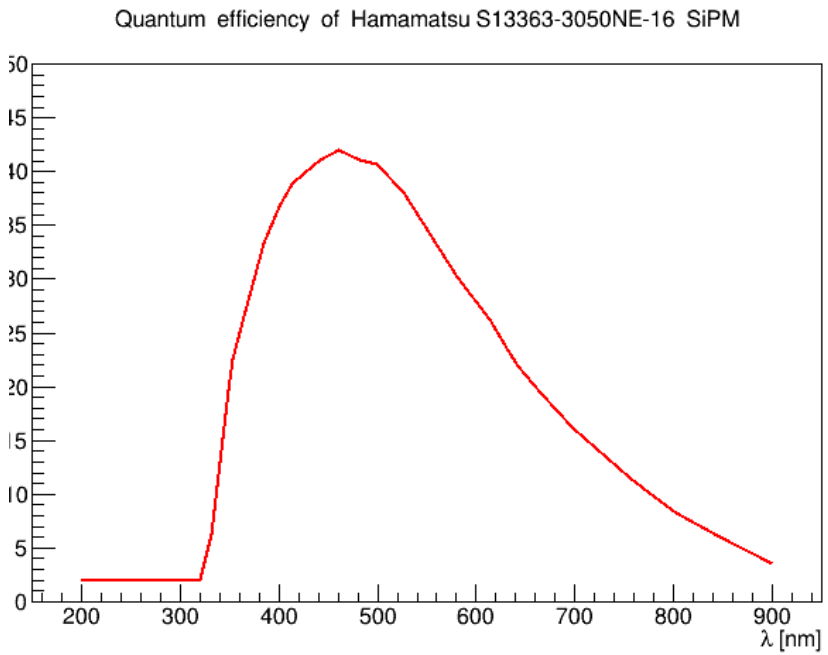


Aerogel refractive index according to diffractive formula (T.Bellunato et al, Eur. Phys. J. C52, 759-764 (2007)).

ASHIPH Prototype, SiPM



Reflectivity of Teflon (PTFE) from A.Buzykaev's thesis.

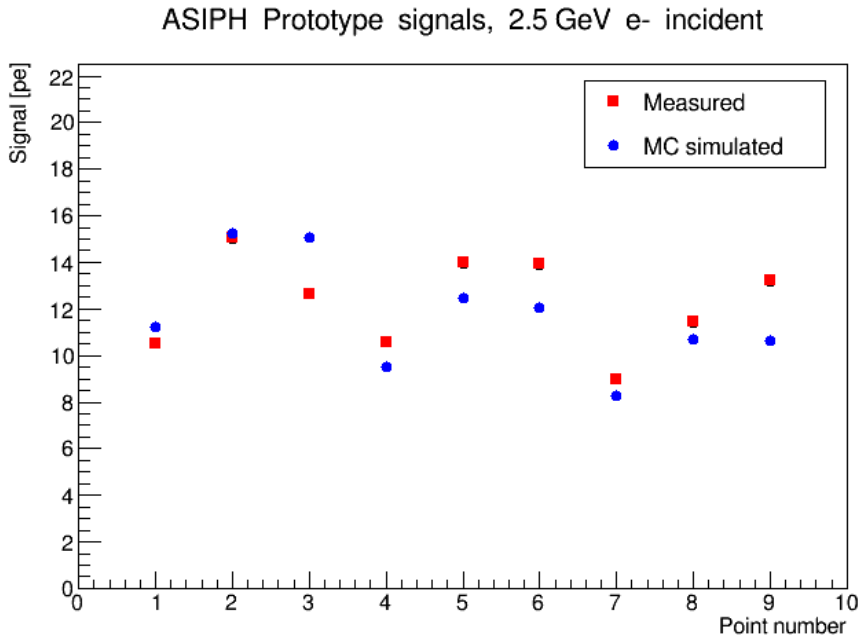


Hamamtsu 3x3 mm^2 SiPM QE taken from booklet. Refractive index of epoxy window 1.55.

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.

Comparison of real and simulated data

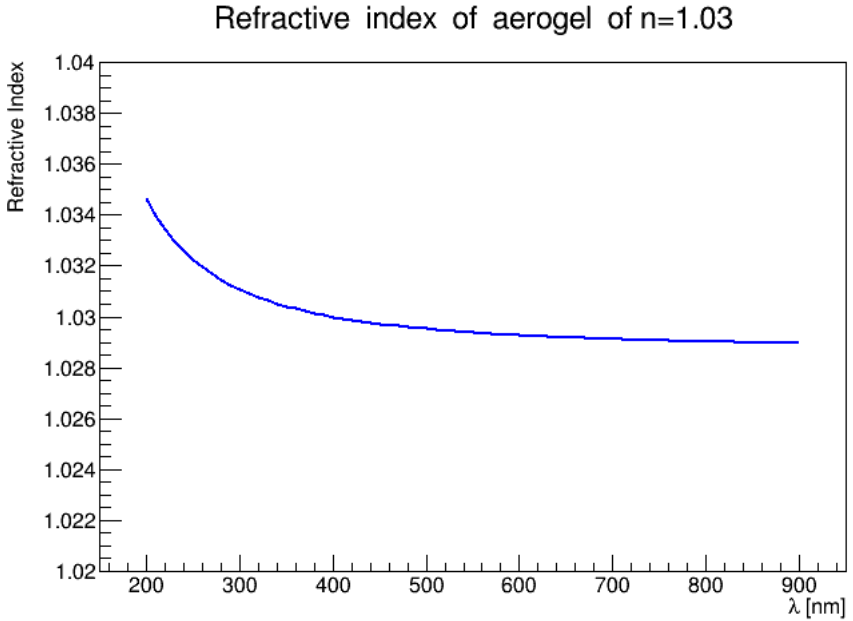
Summary & Outlook

- Geant4 code is developed to simulate ASHIPH prototype developed in Novosibirsk.
- Outputs from MC simulation are in reasonable agreement with data from beam tests conducted at BINP.
- The model is being modified to bring it closer to real prototype (aerogel properties, beam spread, detector's shape etc.). Work is in progress.

Thank you for your attention!

Back-up slides

Aerogel Detector, aerogel properties



Refractive index of n=1.03 aerogel (T.Bellunato et al, Eur. Phys. J. C52, 759-764 (2007)).

Note: in this calculations the aerogel refractive index was taken constant, n=1.02.

Aerogel Detector, BBQ dye properties

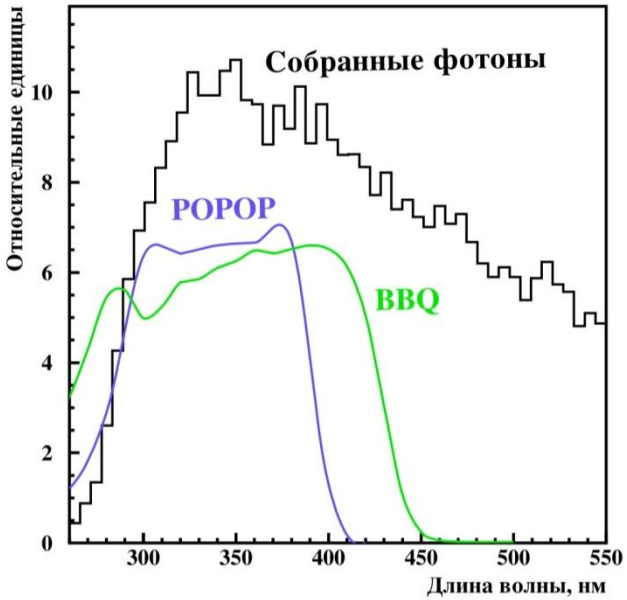
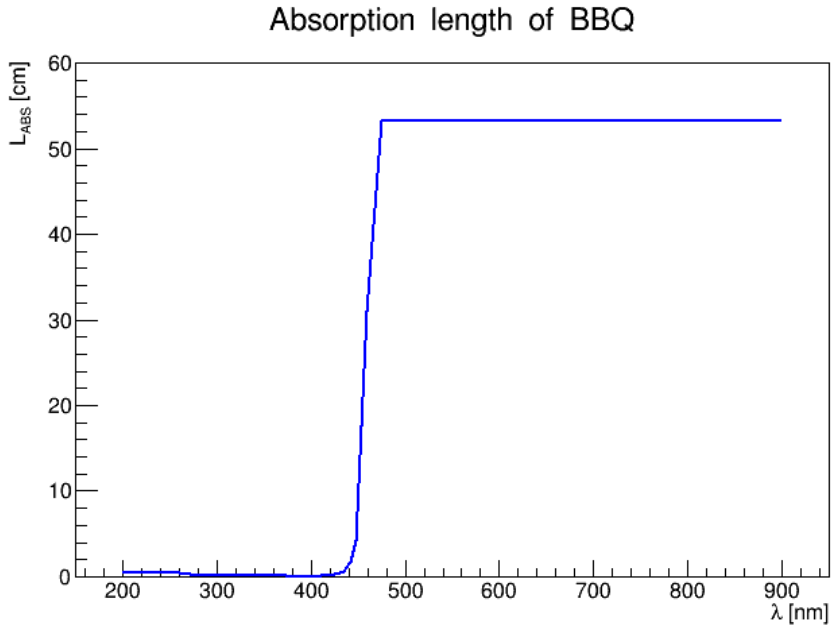


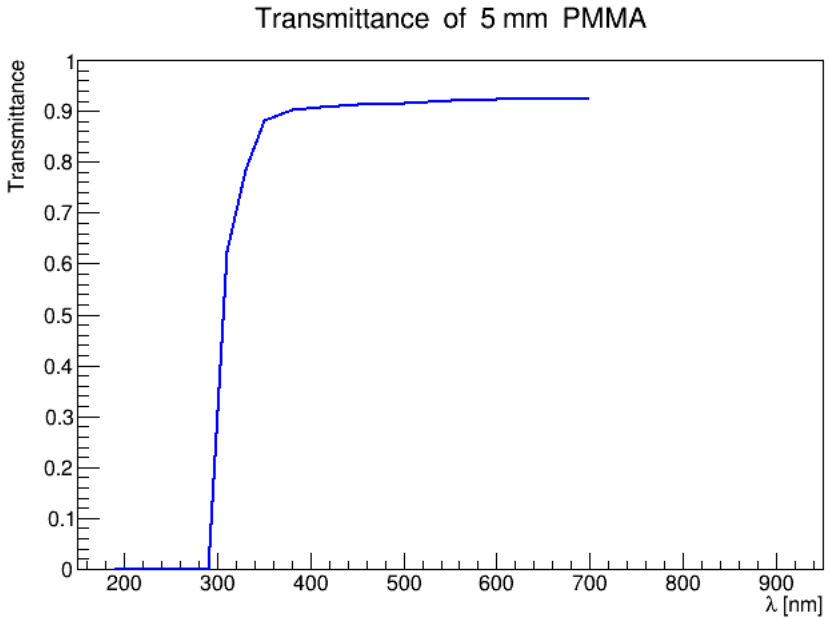
Рис. 3.17. Вероятности фотон в фотон для шифтеров на основе POPOP и BBQ, спектр фотонов, собранных на шифтер, полученный из Монте-Карло моделирования черенковского счётчика.

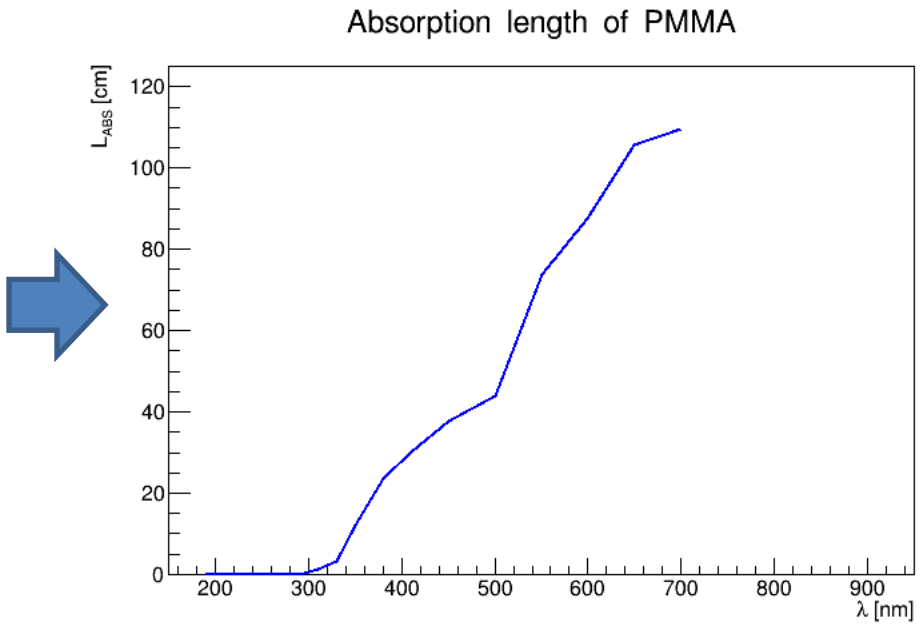


Absorption length of BBQ obtained from “photon to photon” curve in Fig.3.17 of Buzykaev’s thesis, in assumption:

- BBQ slab thickness 3 mm;
- Absorption ~100% at 420 nm.

Aerogel Detector, Plexiglass (PMMA) properties





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

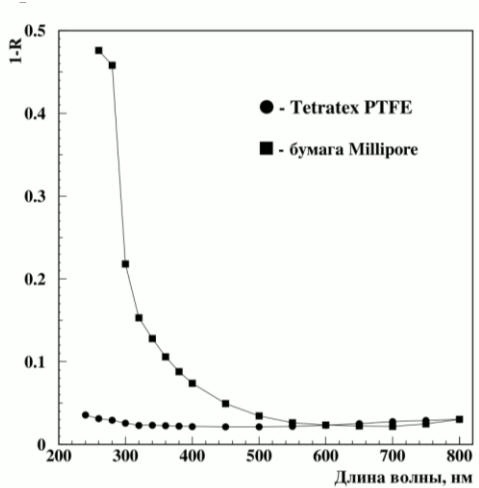
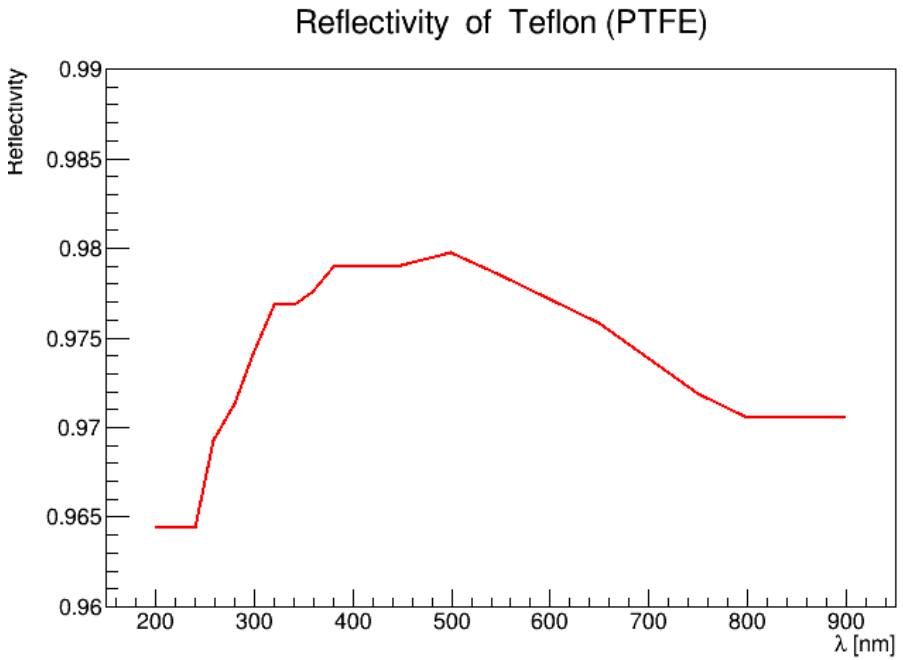


Рис. 3.22. Сравнение коэффициента поглощения для тефлона PTFE и бумаги Millipore



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