Detector development and wishlist: FTOF

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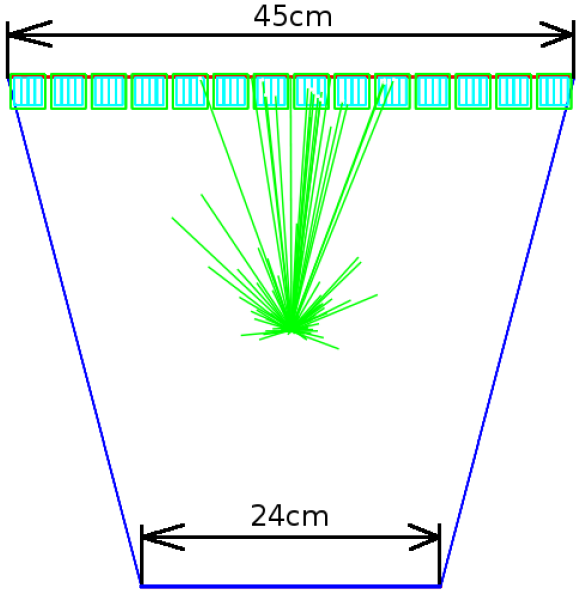
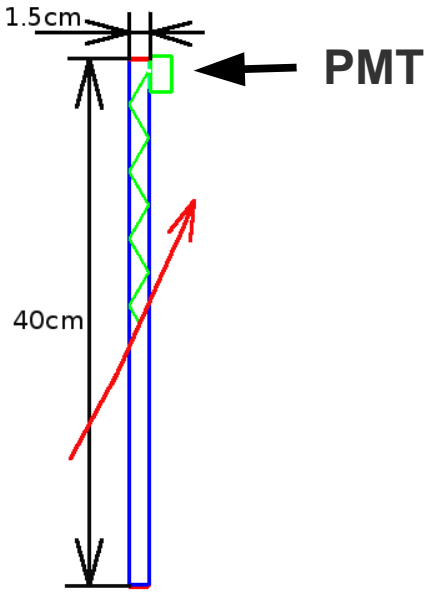
1st SuperB Collaboration Meeting - QMUL (UK)

Outlook

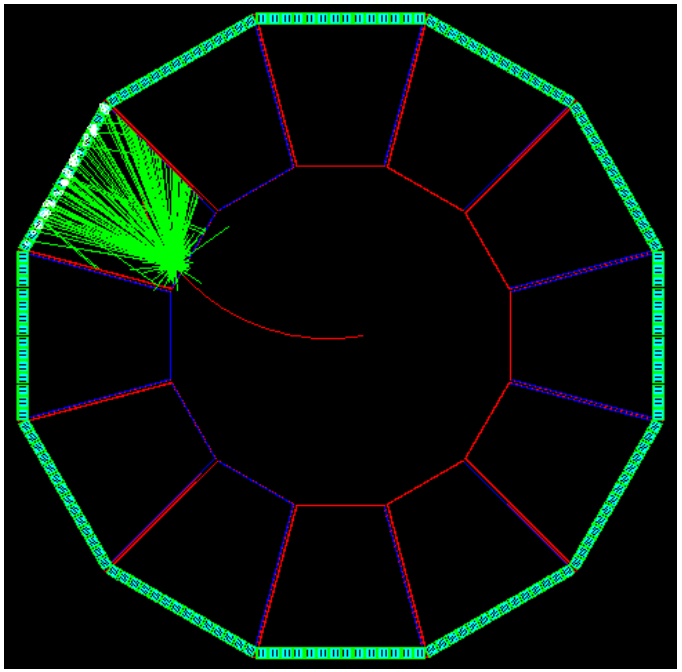
- The DIRC-like TOF detector for SuperB project (FTOF)
- Historical overview
- Full simulation of the FTOF detector
- Wishlist

The DIRC-like TOF detector for SuperB project (FTOF)





0.7 GeV/c kaon hit the FTOF detector



- Detector made of 12 identical quartz sectors
- The quartz used as radiator of Cherenkov photons and as a light guide (DIRC technique)
- Each sector is readout by PMTs located from the top
- Time-of-flight (TOF) measured between time of bunch crossing (time start) and signals in the PMT channels (time stop).

Time resolution of the FTOF detector

$$\sigma_{\mathrm{tot}}^2 \sim \left(\frac{\sigma_{\mathrm{electronicsSTOP}}}{\sqrt{N_{\mathrm{p.e.}}}}\right)^2 + \left(\frac{\sigma_{\mathrm{detector}}}{\sqrt{N_{\mathrm{p.e.}}}}\right)^2 + \left(\frac{\sigma_{\mathrm{TTS}}}{\sqrt{N_{\mathrm{p.e.}}}}\right)^2 + \sigma_{\mathrm{trk}}^2 + \sigma_{t0}^2 + \sigma_{\mathrm{electronicsSTART}}^2$$

Number of the detected photoelectrons (N_{pe}) is at least 10 (Estimated with Geant4 sim.)

Contribution	Resolution (ps)	Comment
Electronics (start, stop)	<10	Measured
Detector	**70**	**Estimated with Geant4 sim.**
TTS for SL10	40*	arXiv:1010.1057v1
trk	10	Estimated with fast sim.
t_0	20	$\sigma_t = \sigma_z / c$ σ_z – longitudinal size of the bunch

Total time resolution per track will be between 30 – 40 ps

Historical overview of the FTOF simulation, and background estimation

We start from the standalone Geant4 simulation of the focusing DIRC (provided by Douglas Roberts)

XI SuperB General Meeting – LNF (1 of December 2009)

First presentation about simulation of the DIRC-like TOF detector.

http://agenda.infn.it/getFile.py/access?contribId=88&sessionId=23&resId=0&materialId=slides&confId=1165

XII SuperB General Meeting - LAPP – Annecy (15 of March 2010)

Study of the different geometries of the FTOF detector.

http://agenda.infn.it/getFile.py/access?contribId=86&sessionId=67&resId=0&materialId=slides&confId=2026

Same time we started to look at background rates estimated with help of Bruno

http://agenda.infn.it/getFile.py/access?contribId=124&sessionId=19&resId=0&materialId=slides&confId=2026

XIII SuperB General Meeting - Isola d'Elba (30 of May 2010)

Demonstration that we can get acceptable amount of light.

http://agenda.infn.it/getFile.py/access?contribId=31&sessionId=4&resId=0&materialId=slides&confId=2262

Update on background estimation (using Bruno)

http://agenda.infn.it/getFile.py/access?contribId=34&sessionId=4&resId=0&materialId=slides&confId=2262

Historical overview of the FTOF simulation, and background estimation

XIII SuperB General Meeting - Isola d'Elba (30 of May 2010) was the last meeting when we present results about FTOF full simulation.

XVI SuperB Workshop (LNF) (4 of April 2011)

Update of the FTOF geometry in Bruno

http://agenda.infn.it/getFile.py/access?contribId=73&sessionId=20&resId=0&materialId=slides&confId=3410

XVII SuperB Workshop and Kick Off Meeting - La Biodola (Isola d'Elba) Italy (28 of May 2011)

Analise of the most precise and 'bug free' output from Bruno

http://agenda.infn.it/getFile.py/access?contribId=76&sessionId=14&resId=0&materialId=slides&confId=3352

1st SuperB Collaboration Meeting - QMUL (UK) (13 of September 2011)

Comparison between BRN and (Elba 2011 Bruno production)

http://agenda.infn.it/getFile.py/access?contribId=58&sessionId=21&resId=0&materialId=slides&confId=3827

Full simulation of the FTOF detector

- So fare we were using geant4.9.2.p02 version of Geant4
- We have running version in geant4.9.3, but it never been used.

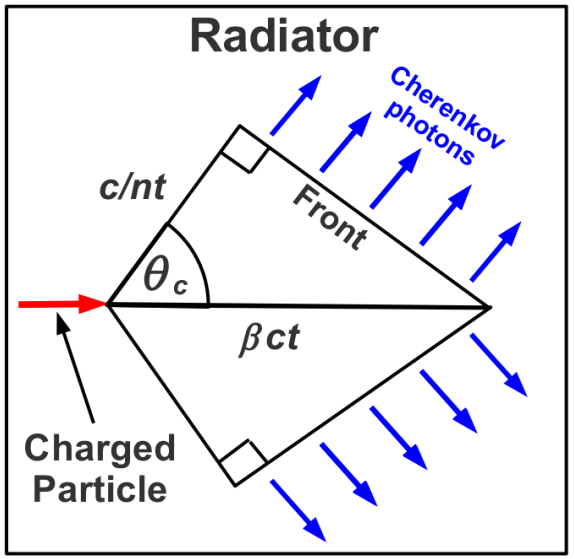
<u>What needed to be simulated:</u>

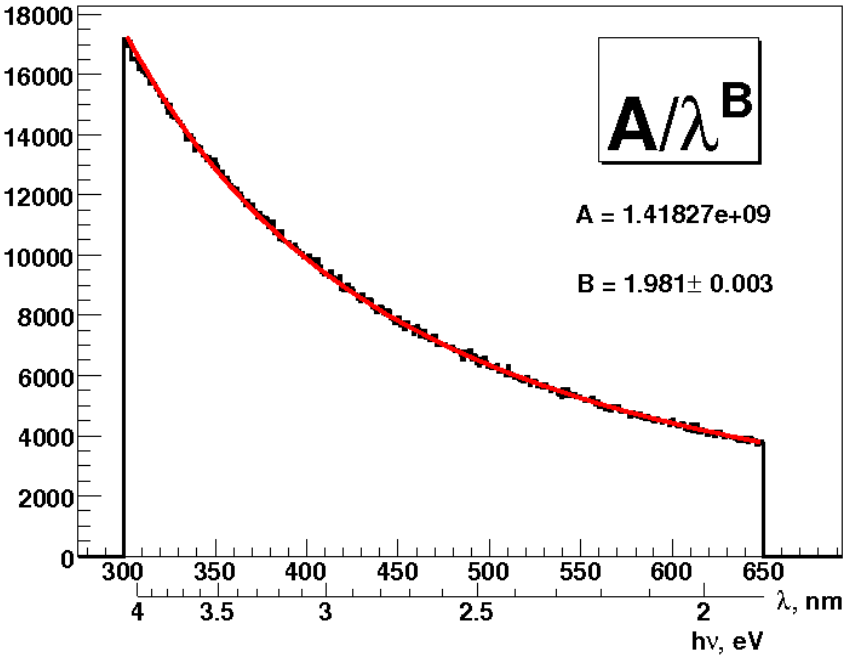
- Cherenkov effect (quartz does not have any scintillation light)
- Snells low and total internal reflection
- Optical properties of the quartz (Refractive index, absorption length and properties of the surface)
- Properties of the mirror (Absorption)

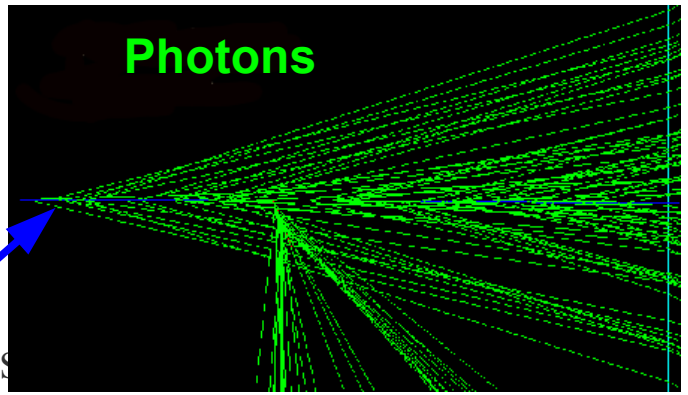
Cherenkov effect

$$\cos\theta_c = \frac{1}{n\beta}$$

$$\frac{\partial^2 N}{\partial x \partial \lambda} = \frac{2\pi\alpha z^2}{\lambda^2}\left(1 - \frac{1}{(n(\lambda))^2\beta^2}\right)$$



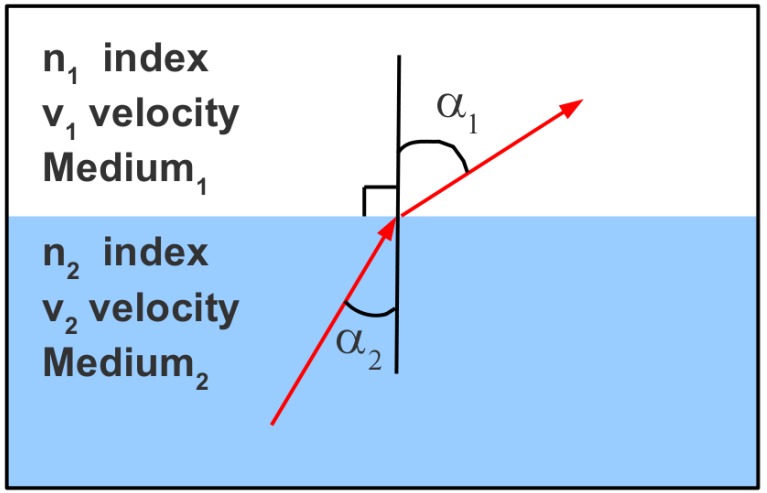




Photons emitted during all the way particle penetrate the radiator

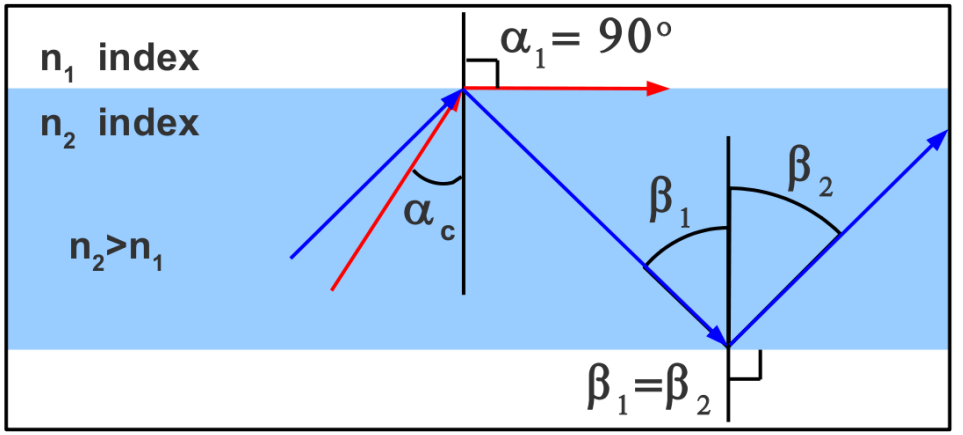
Snells low and total internal reflection

Snells low



$$\frac{\sin(\alpha_1)}{\sin(\alpha_2)} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

Total internal reflection



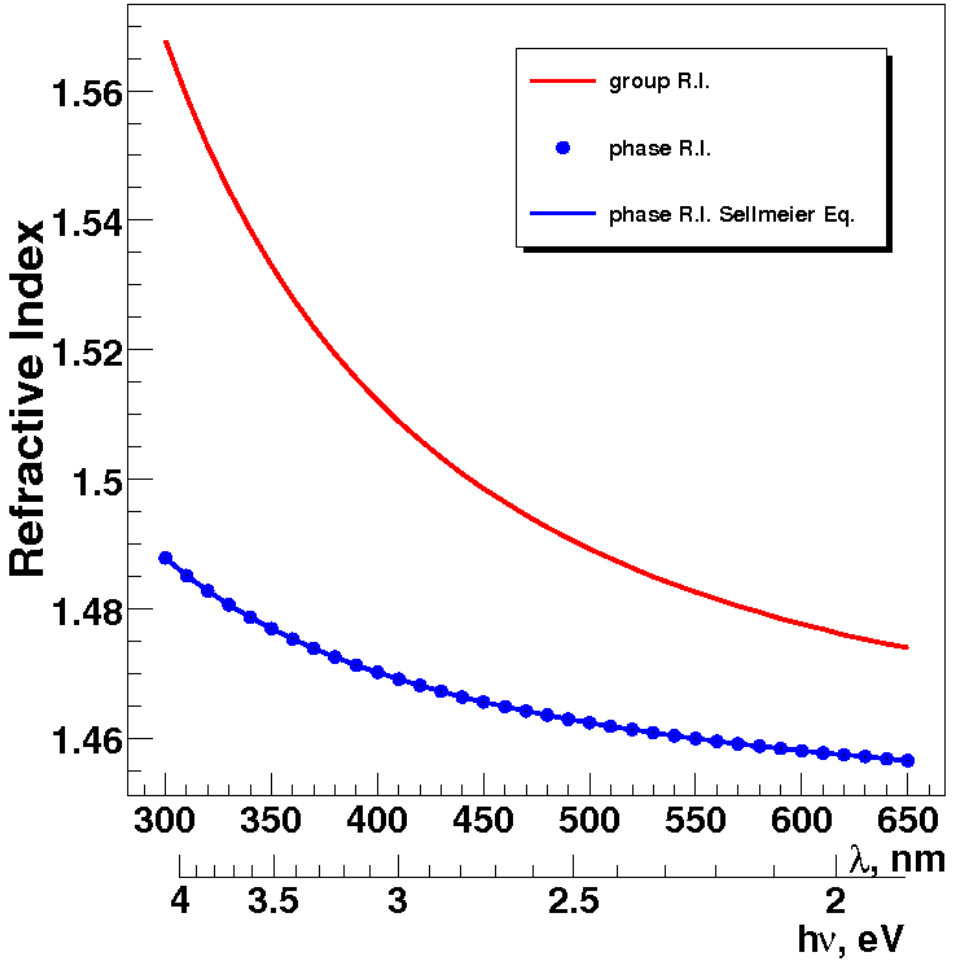
$$\sin(\alpha_1 = 90°) = \frac{n_2}{n_1}\sin(\alpha_2) = 1$$

If the photon propagates from more optically dense medium to less optical dense medium with incidence angle $\beta_1 > \alpha_{critical}$ total internal reflection occurs

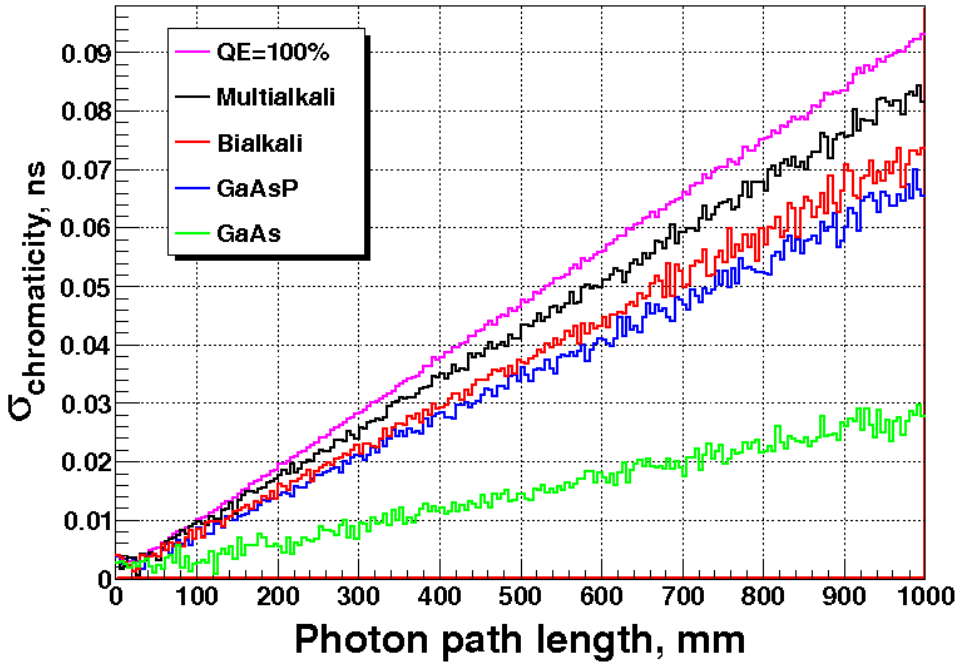
Refractive index

$$t_{\mathrm{TOP}} = \frac{L}{v_g(\lambda)} \longleftarrow v_g = v_p\left(1 + \frac{\lambda}{n}\frac{\partial n}{\partial \lambda}\right) \longleftarrow n(\lambda) = \frac{c}{v_p(\lambda)}$$

The time-of-propagation (TOP) of the photon



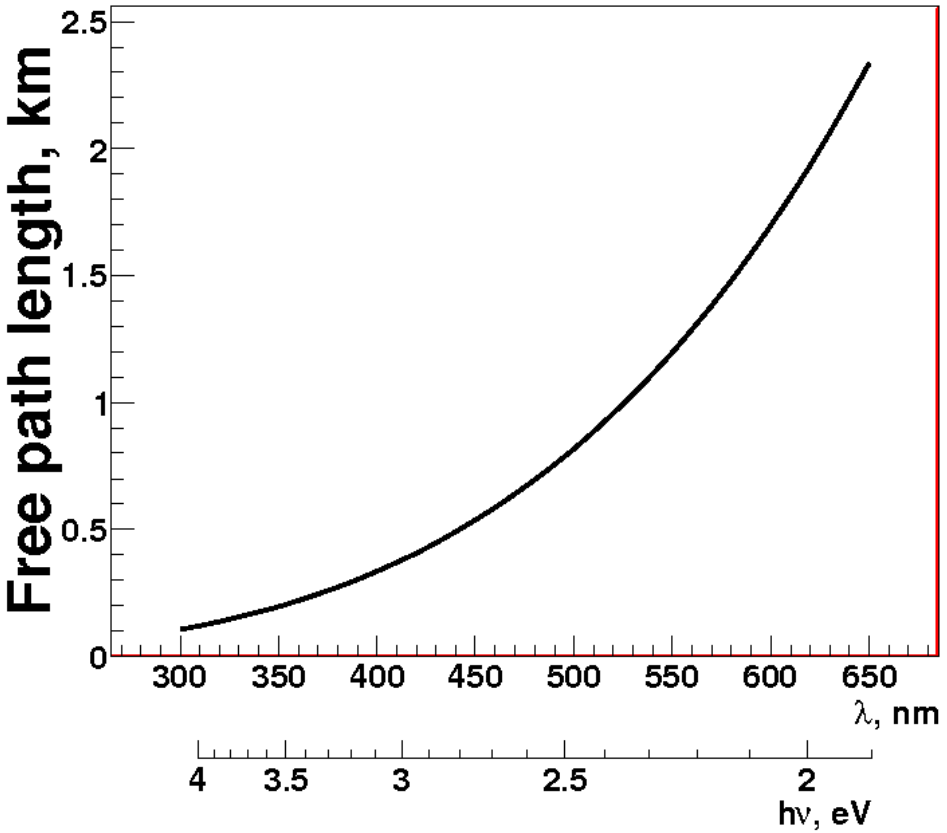
Important to take into account → reason of chromatic effect which contributes to the time resolution.

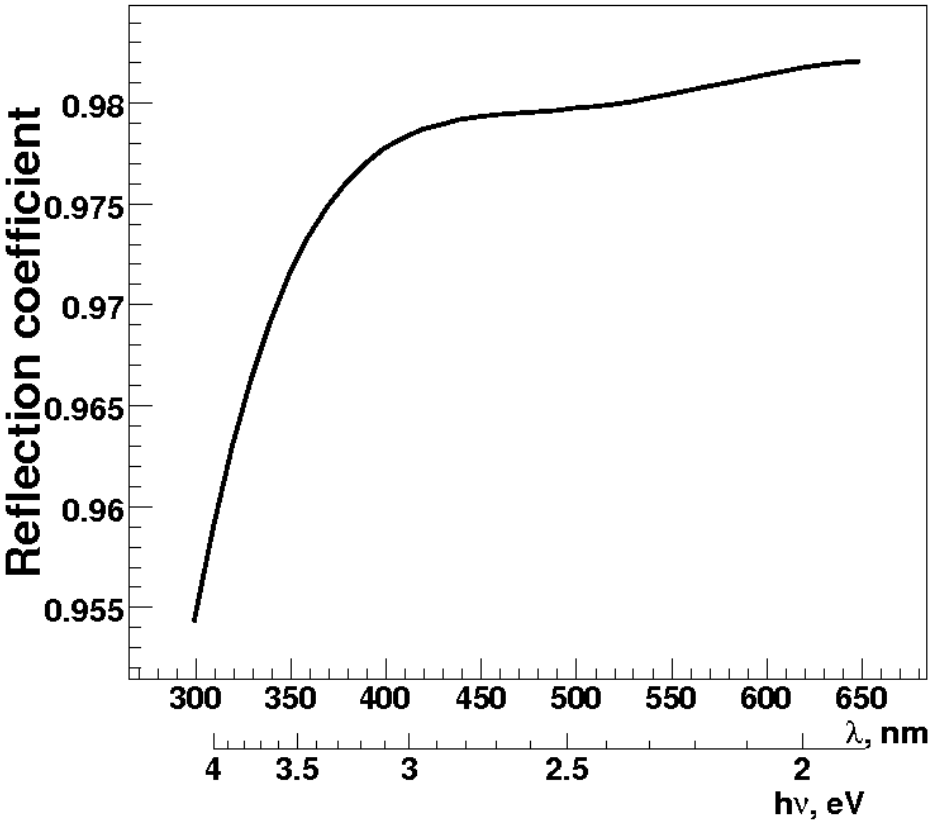


Absorption length and properties of the surface

Absorption in quartz bar

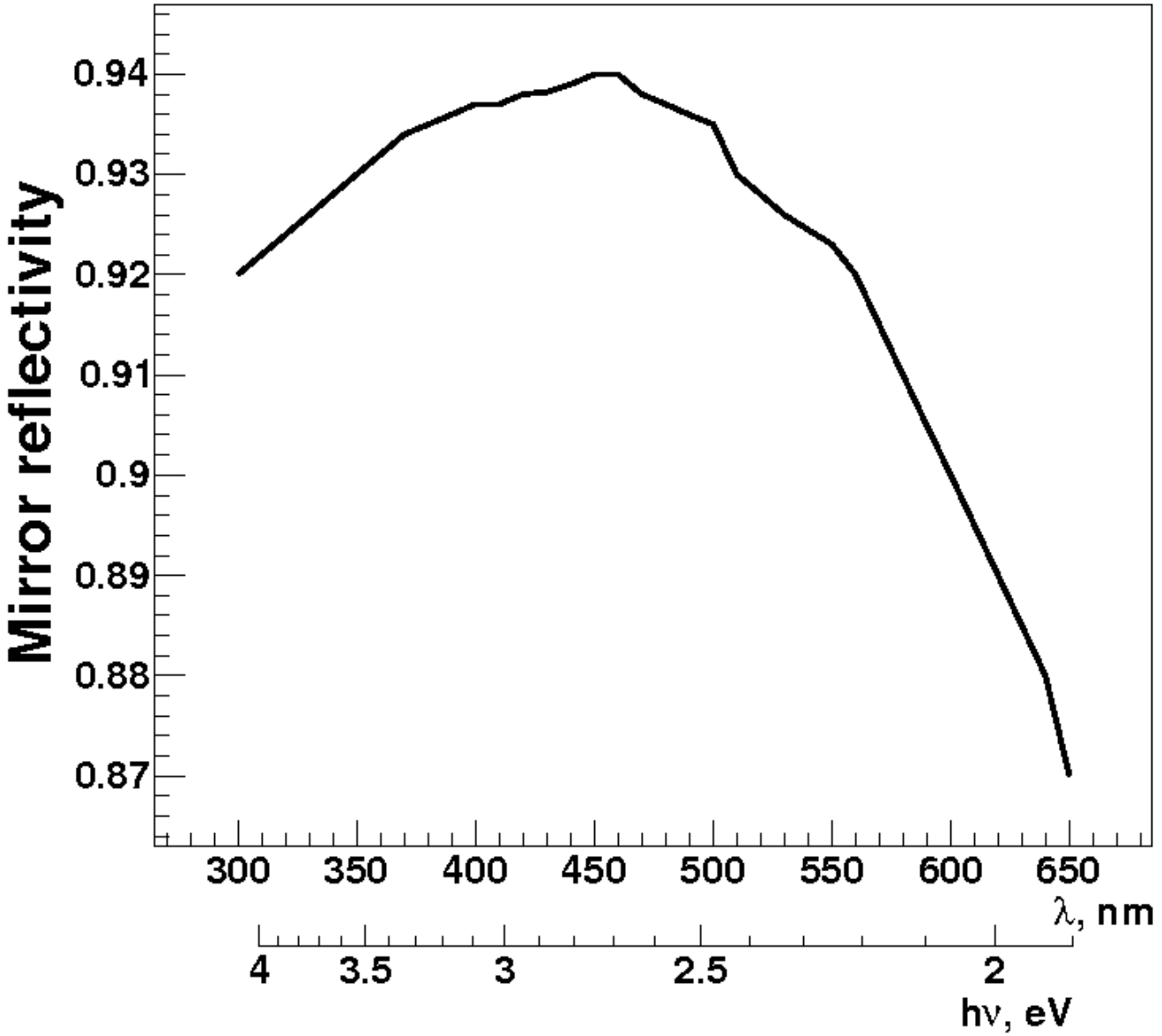
Each time photon deflect from boundary non zero probability to hit dust exist (depends from level of surface polishing).





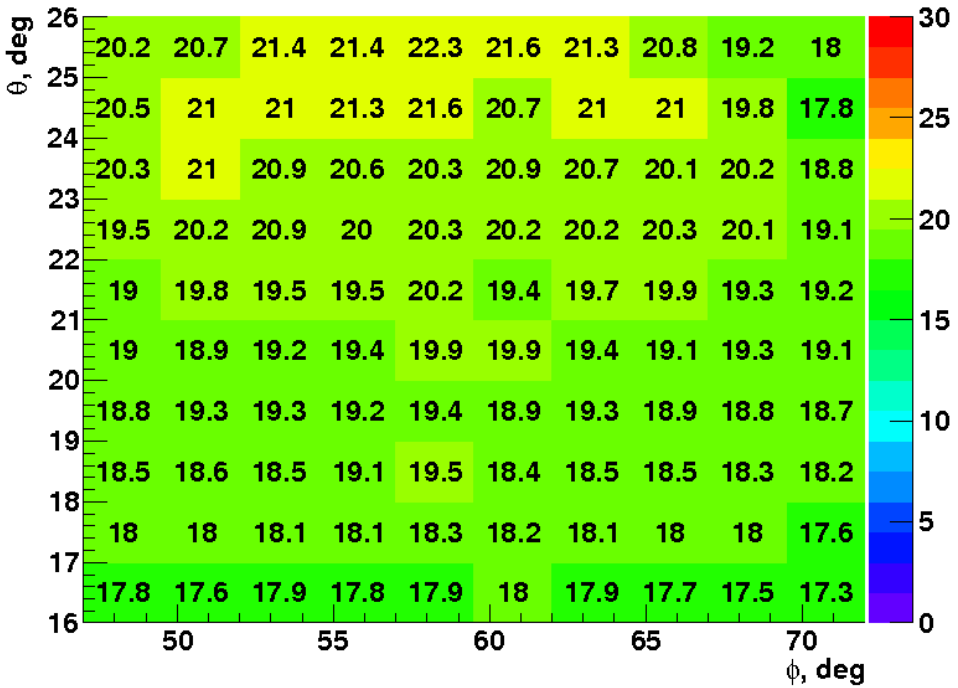
These effects are small for FTOF detector

Properties of the mirror (Absorption)

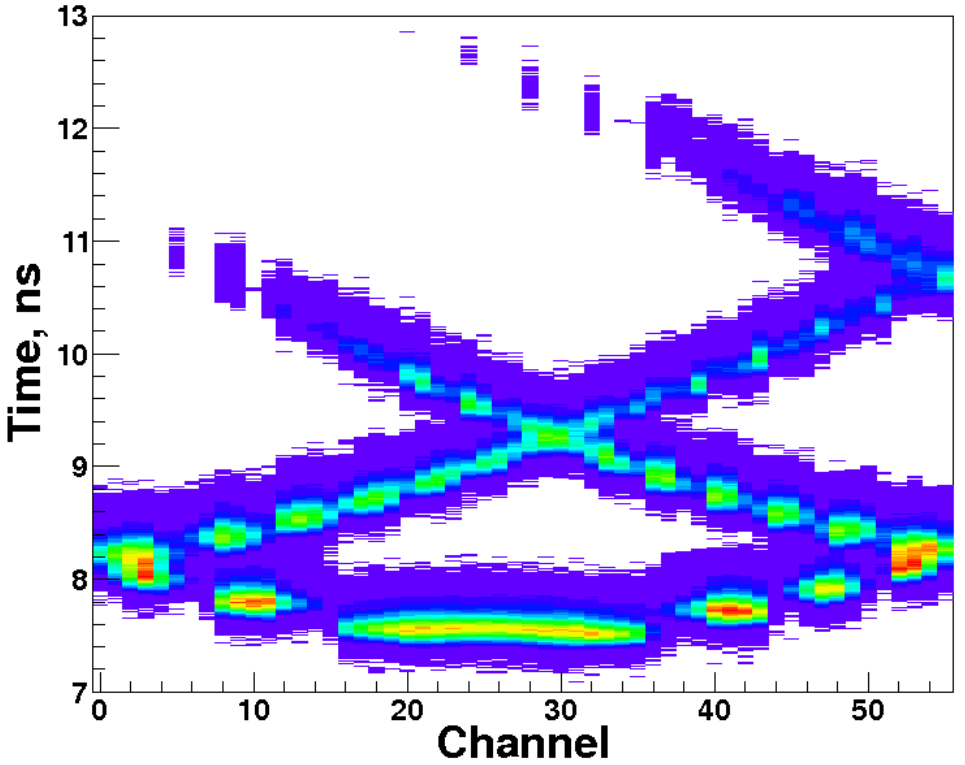


Two main parameters where studied: number of photo electrons and time distribution vs. channel

Number of photo electrons in θ, ϕ plane.



Time distribution vs. channel



θ, ϕ - Angles of the tracks at the interaction point (I.P.)

0.8 GeV/c kaon

Wishlist

So fare we did our studies with standalone Geant4 simulation.

We are going to 'jump' to a version based on BRN for FTOF simulation.

We know that part of quartz properties are already can be taken into account by BRN. Unfortunately we did not test it so fare.

Comparison between this two simulation have to be done in order to validate BRN simulation.

Backup