R & D of the Cherenkov detectors at LAL

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Outline

Two main physical effects which are used:

Cherenkov effect

Total internal reflections

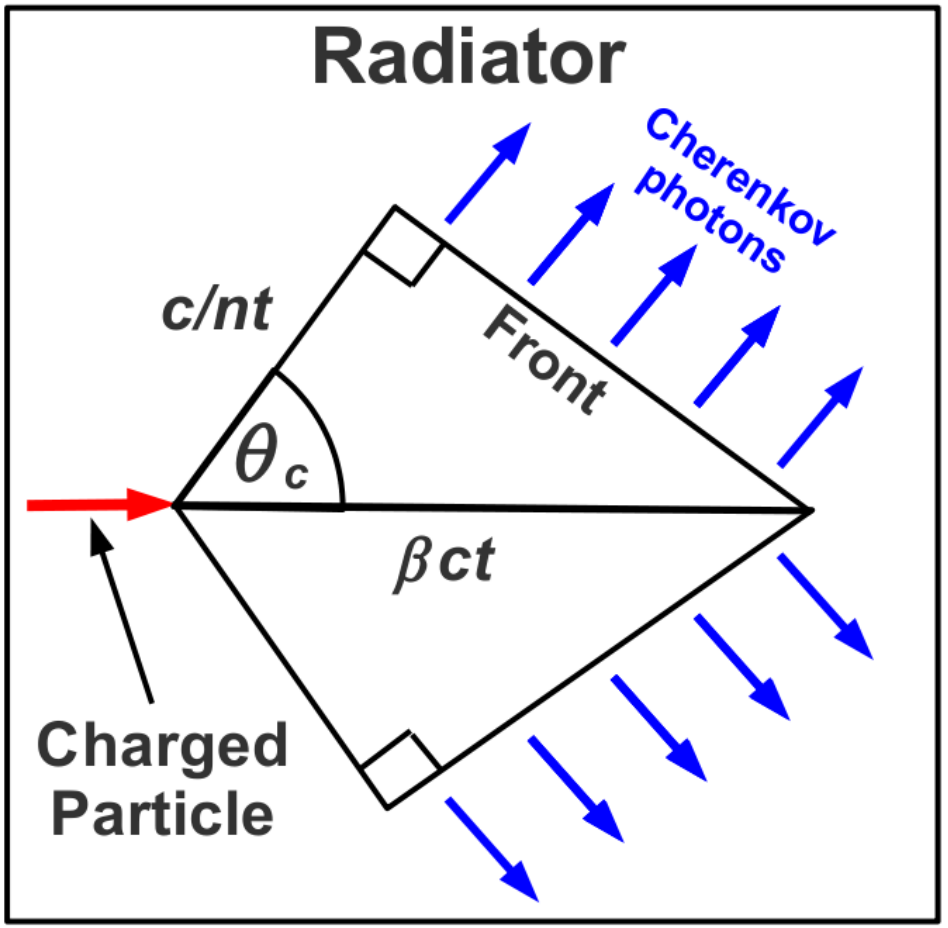
Our activities:

→ FTOF for SuperB project

→ UA9

Conclusions

Cherenkov effect



c – speed of light vacuum

299 792 458 m/s

v_p – speed of the light in the material

$v_p < c$

$n = c/v_p$ – refractive index

$n > 1$

$\beta = v/c$, v – speed of the particles

$\theta_c =$ – Cherenkov angle

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

Produisant de lumière qui a lieu lorsqu'une particule chargée se déplace dans un milieu avec une vitesse supérieure à la vitesse de la lumière dans ce milieu.

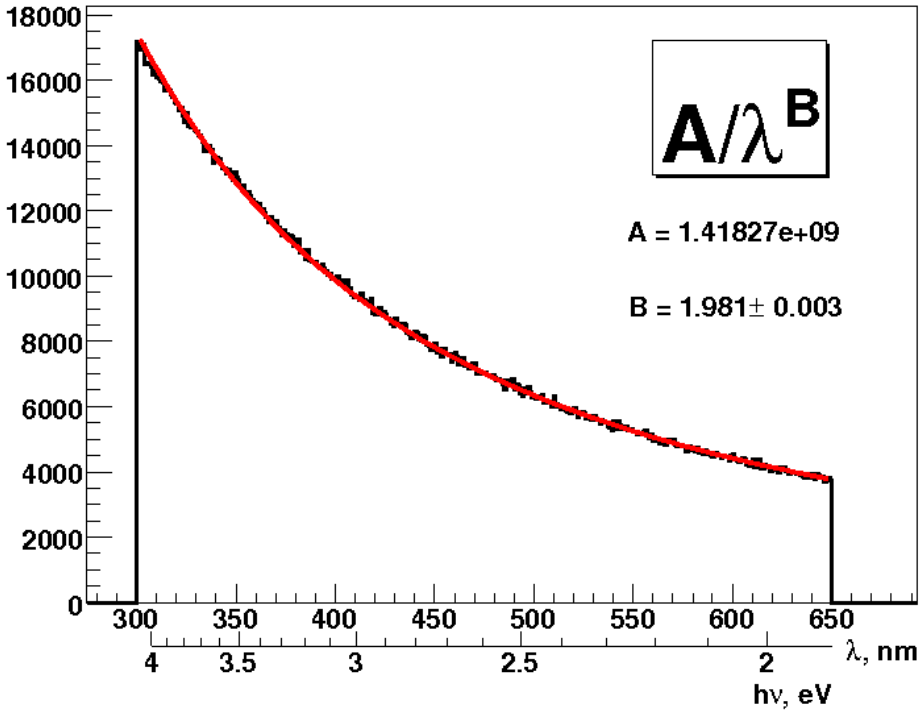
Cherenkov effect (2)

Energy of the photon

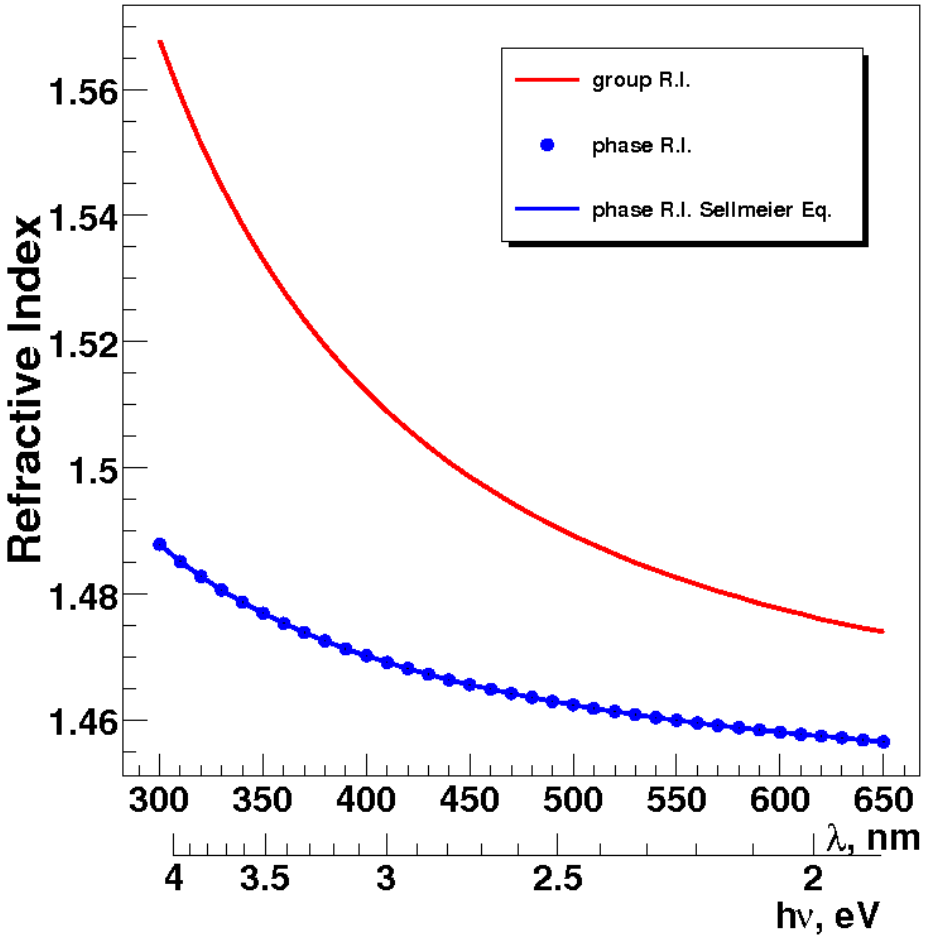
Wavelength

$$E = \hbar\omega = h\nu = \frac{hc}{\lambda}$$

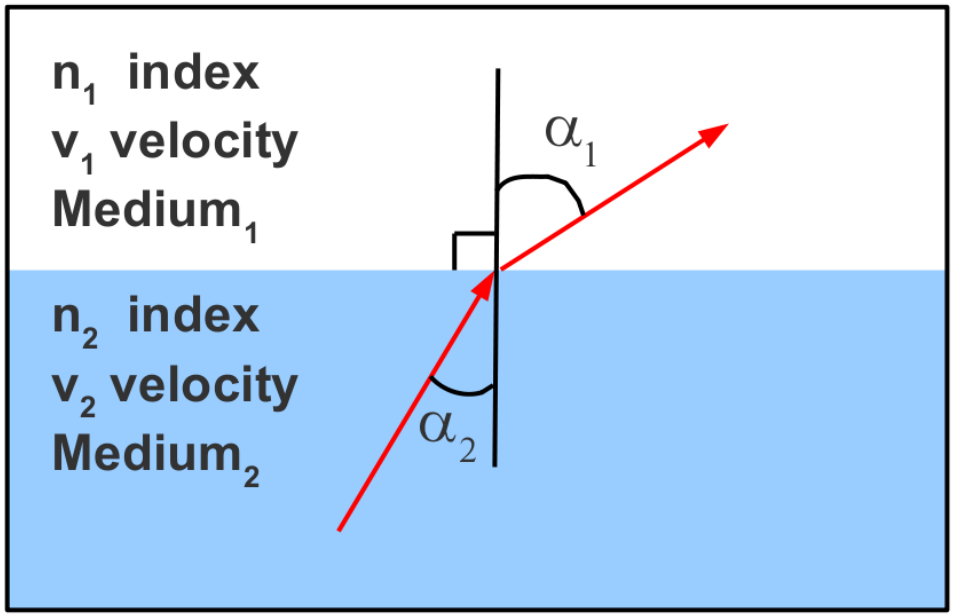
Wavelength distribution of the Cherenkov photons



Refractive index as the function of wavelength

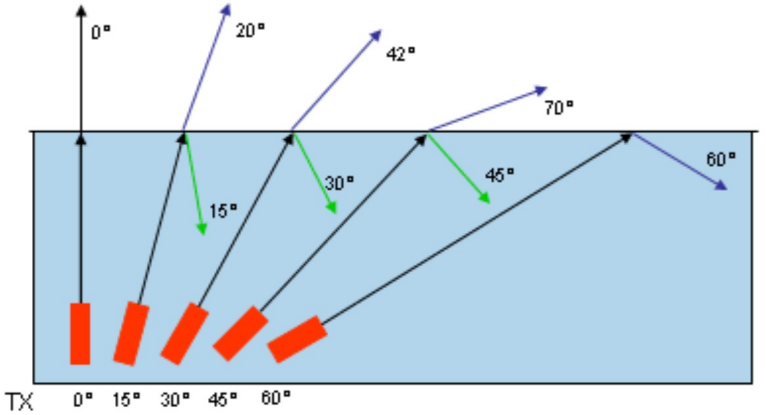


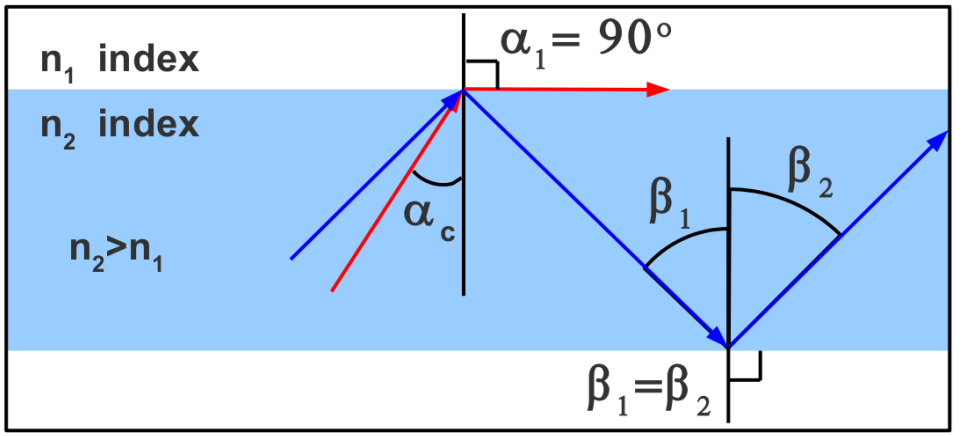
Total internal reflections



Lois de Snell-Descartes

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

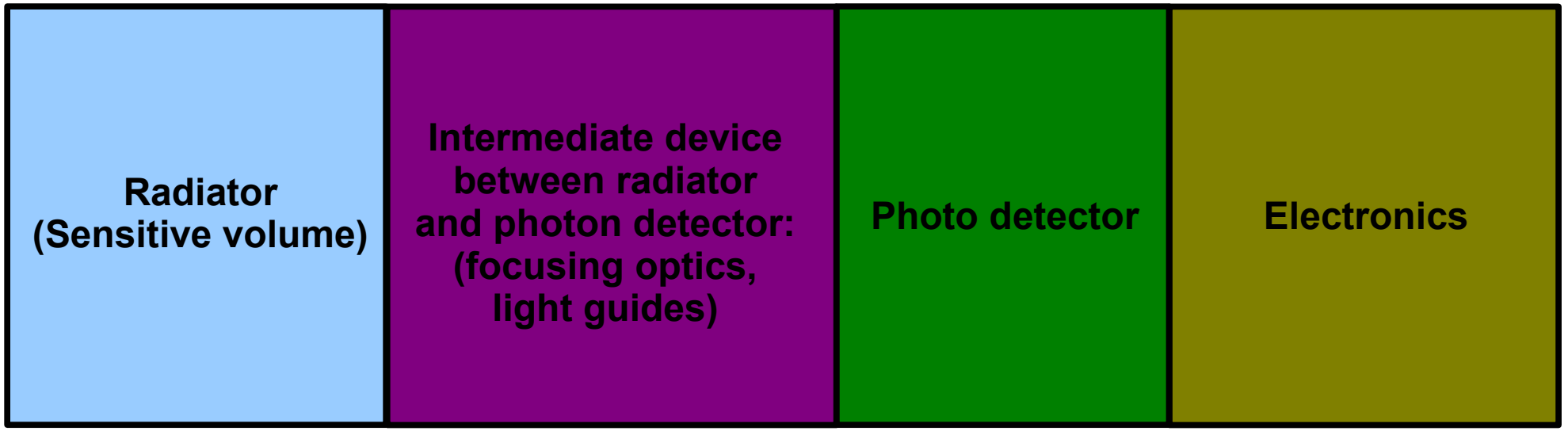




$$\sin(\alpha_1 = 90°) = \frac{n_2}{n_1}\sin(\alpha_2) = 1.$$

R & D of the Cherenkov detectors at LAL

General concept of different Cherenkov detectors



Development and optimization of the detector geometry

Development of very fast readout electronics

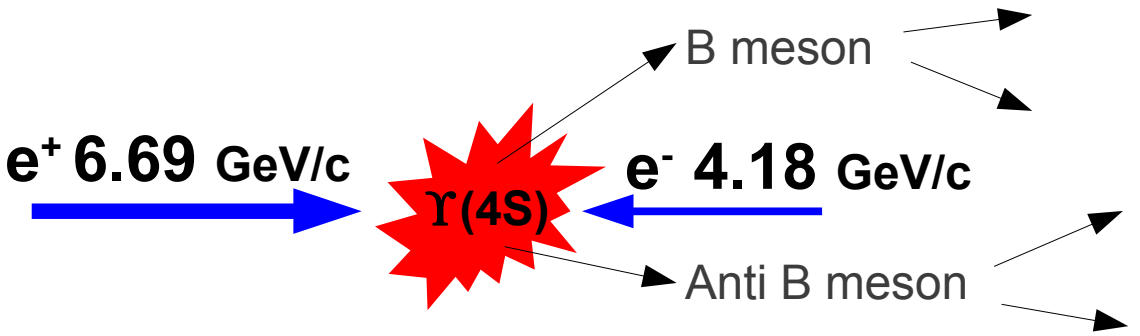
Study and characterization of wide spectrum of PMTs.

All these steps can be done at LAL

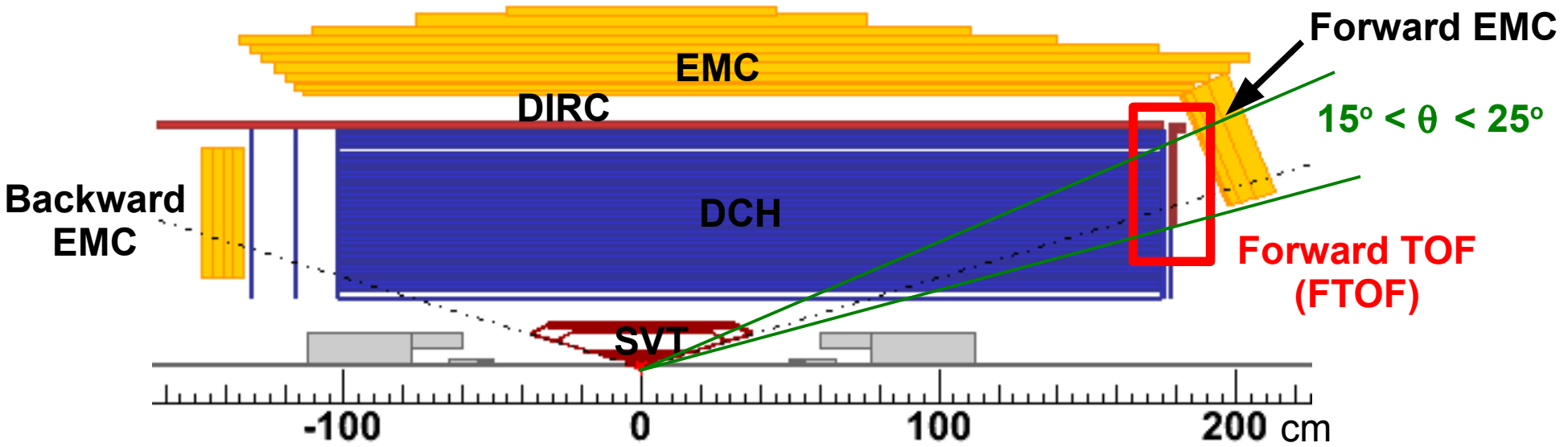
FTOF detector for SuperB project

FTOF detector for SuperB project

SuperB electron positron collider



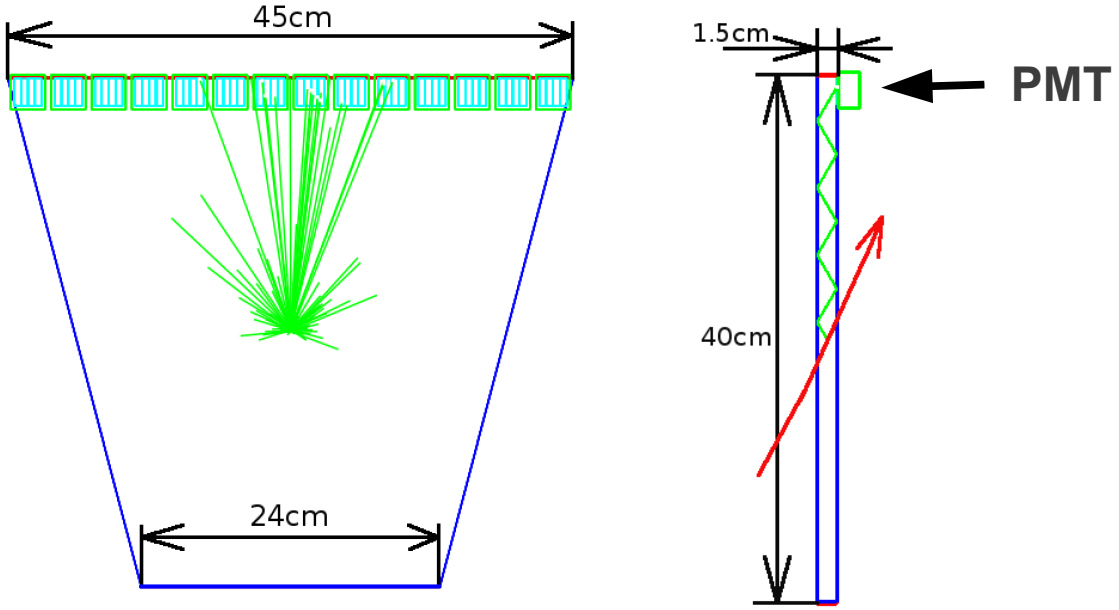
SuperB inner detector



- Good K/π separation in (0.7-3.0) GeV/c momentum range
- Compact device (limited space between DCH and forward EMC)
- Small amount of material in front of the EMC
- Radiation hard (close to IP)

FTOF: a DIRC-like TOF detector

Detection of Internally Reflected Cherenkov light (DIRC)



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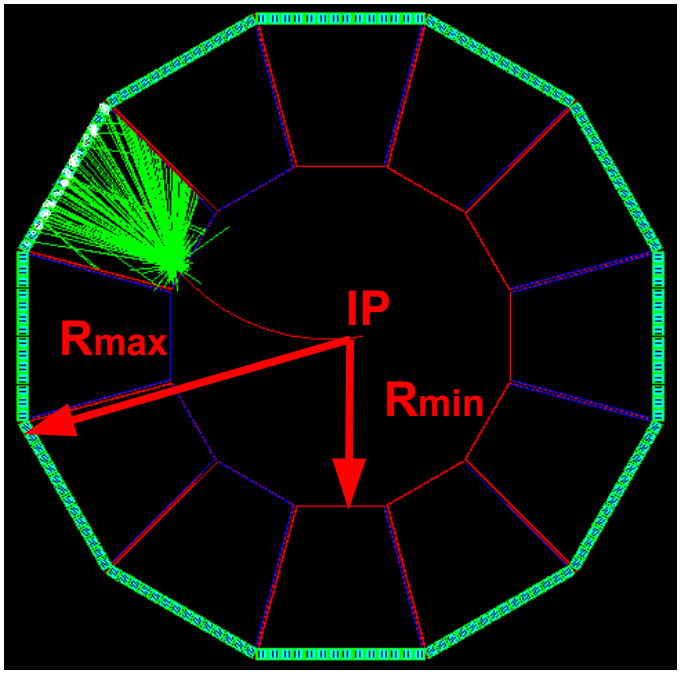
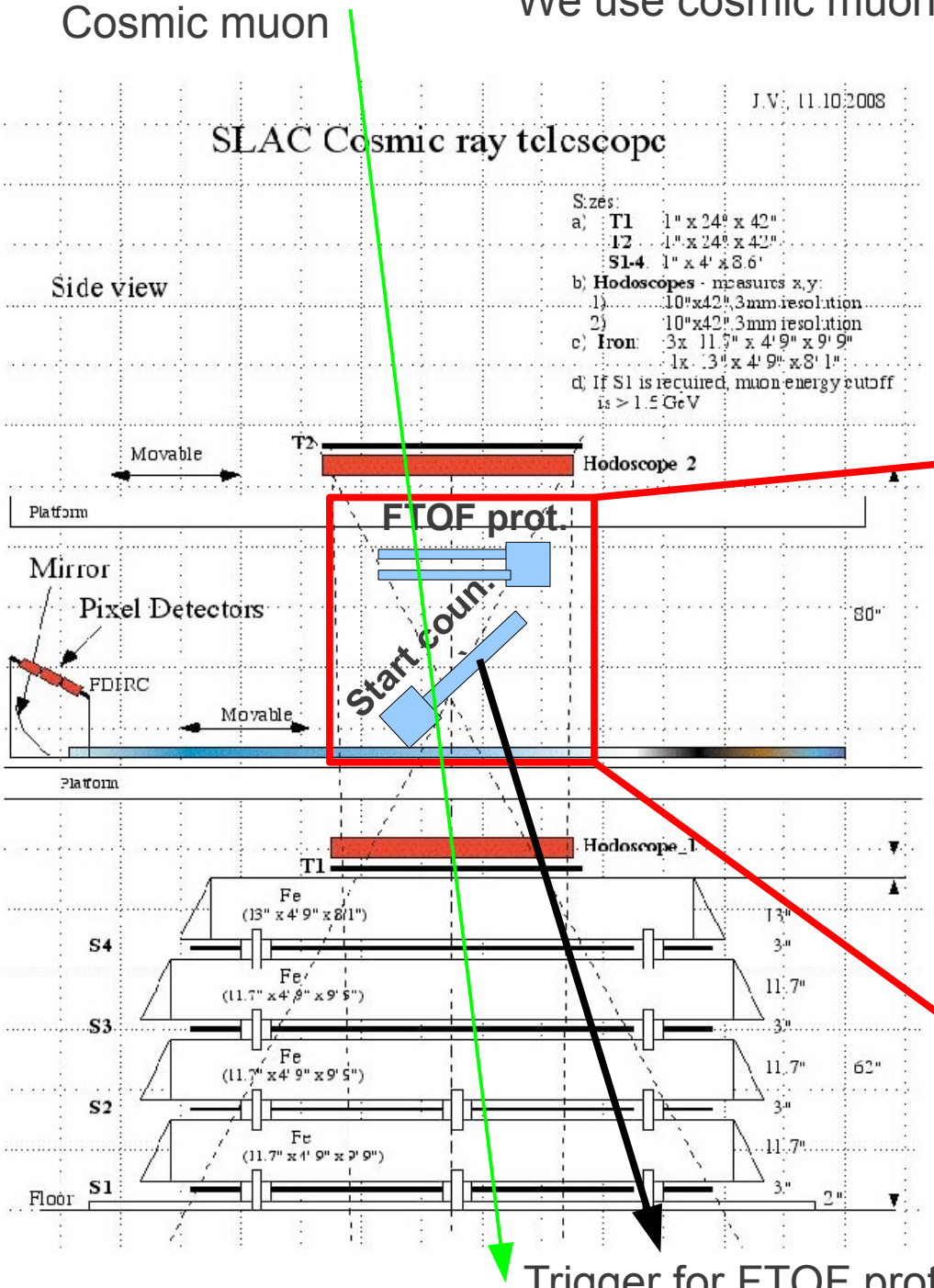


- Detector made of 12 well-polished quartz sectors, covering 2π in azimuth
- The quartz used as radiator of Cherenkov photons and as light guide (DIRC technique)
- Thickness of the detector is 1.5 cm (12 % of X_0)
- R_{min} ~ 50 cm, R_{max} ~ 90 cm

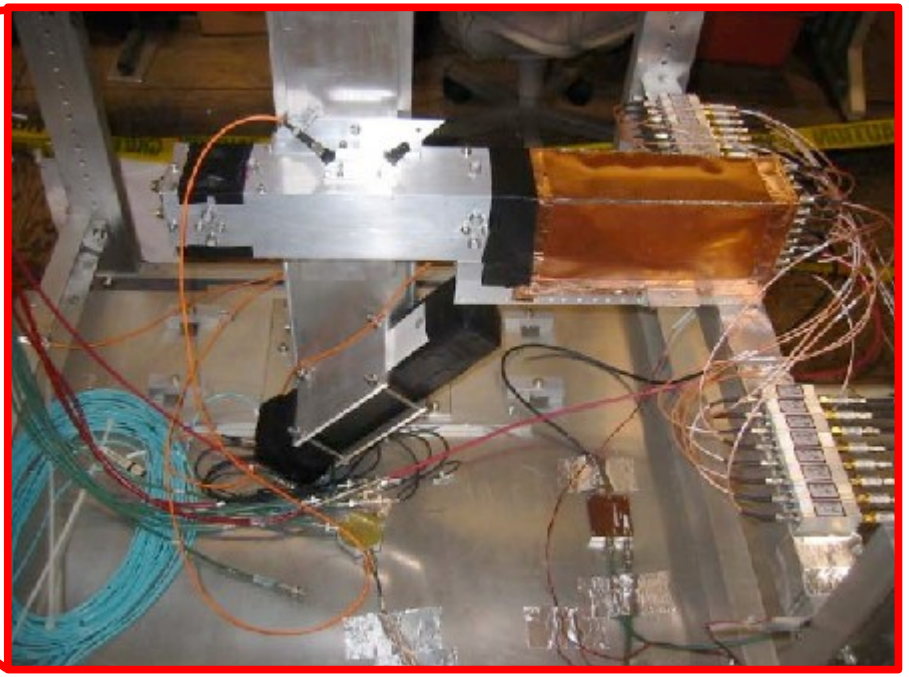
- Each sector is readout by 14 very fast photon detectors – micro channel plate photomultipliers (MCP-PMT).
- **This is a 2D device which measures the time and the position of the photon hits.**

Test of the prototype at SLAC cosmic ray telescope

We use cosmic muons for our measurements



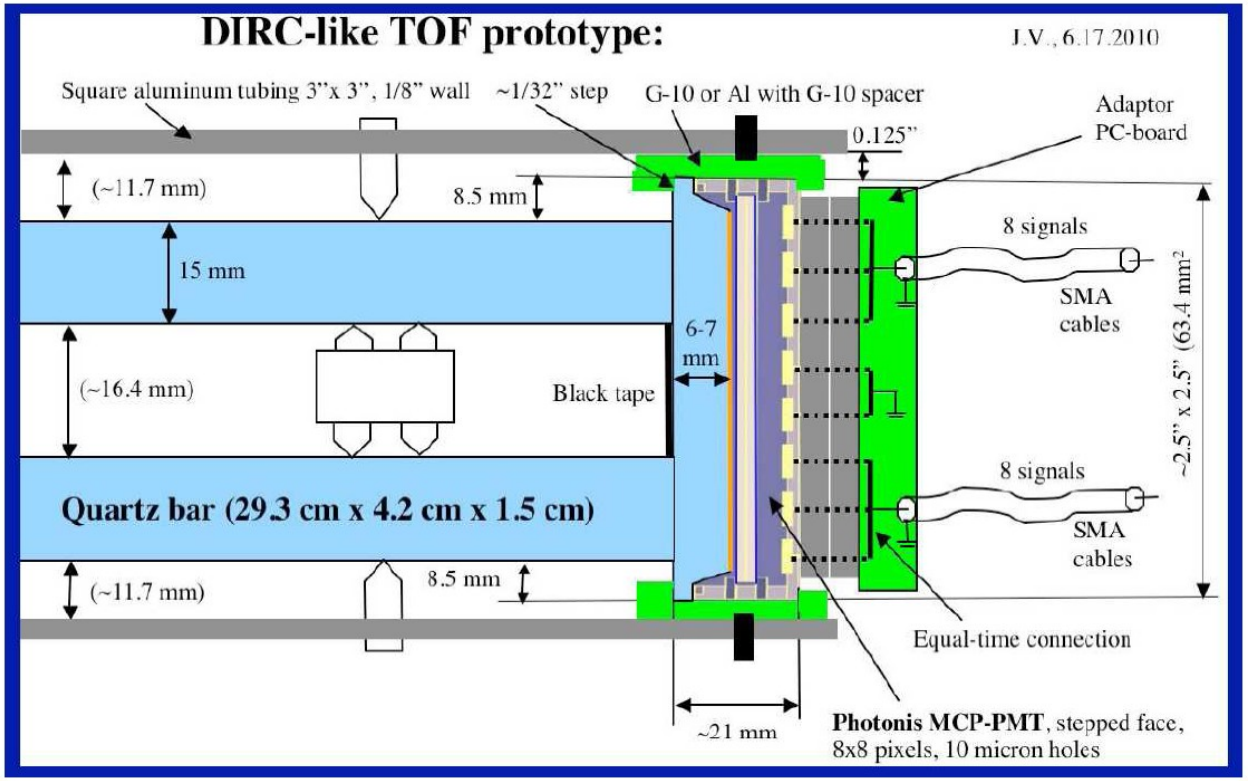
- Two hodoscopes (T1, T2), allow reconstruction of the muon tracks.
- Quartz start counter gives precise timing of the muon arrival.
- Stack counters (S1, S2, S3, S4) define muon energy.

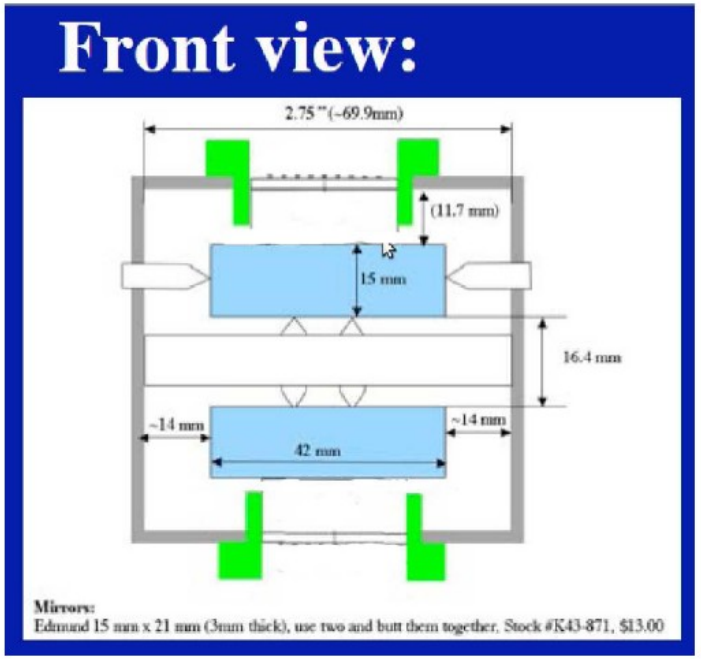


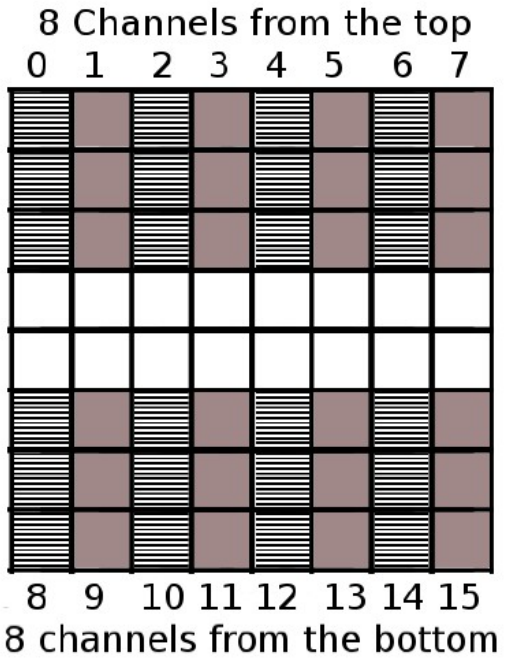
- We use reconstructed muons which cross the FTOF prototype and the start counter

Trigger for FTOF prototype

Test of the prototype at SLAC cosmic ray telescope (2)

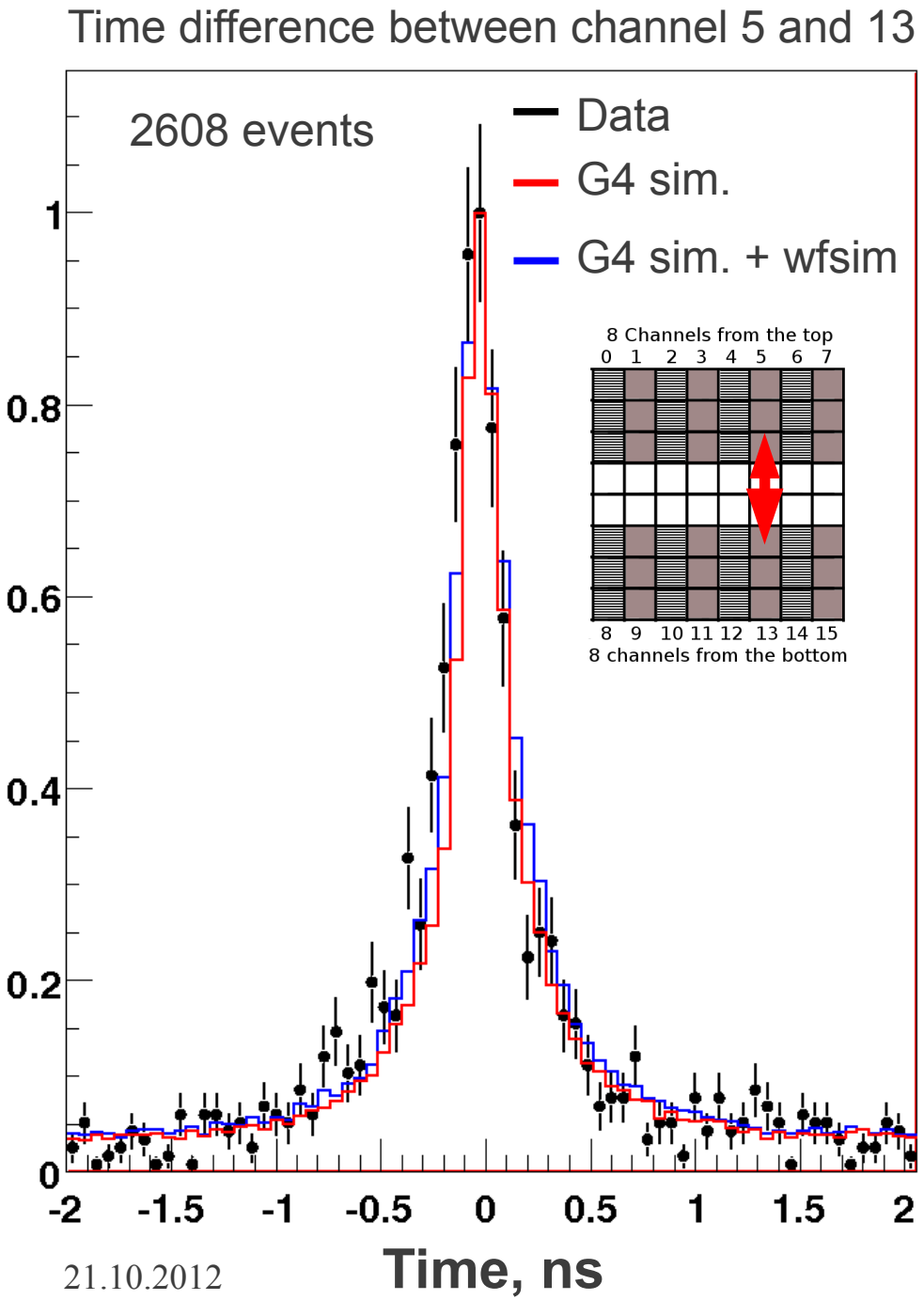






- Two quartz bars connected to one Photonis MCP-PMT (8x8 pixels, 10 micron holes).
- 16 channels connected to the USB-Wave Catcher electronics.
- Constructed at SLAC and installed in a cosmic ray telescope.
- Tube operate at gain ~ 7×10^5.
- Amplifiers (40dB), Filters (600MHz bandwidth).
- All connections done with SMA cables.

FTOF – conclusions



→ Test of the electronics
→ Estimate time resolution per channel

$$\textbf{80 ps} = \frac{\sigma_{\text{narrow}}}{\sqrt{2}}$$

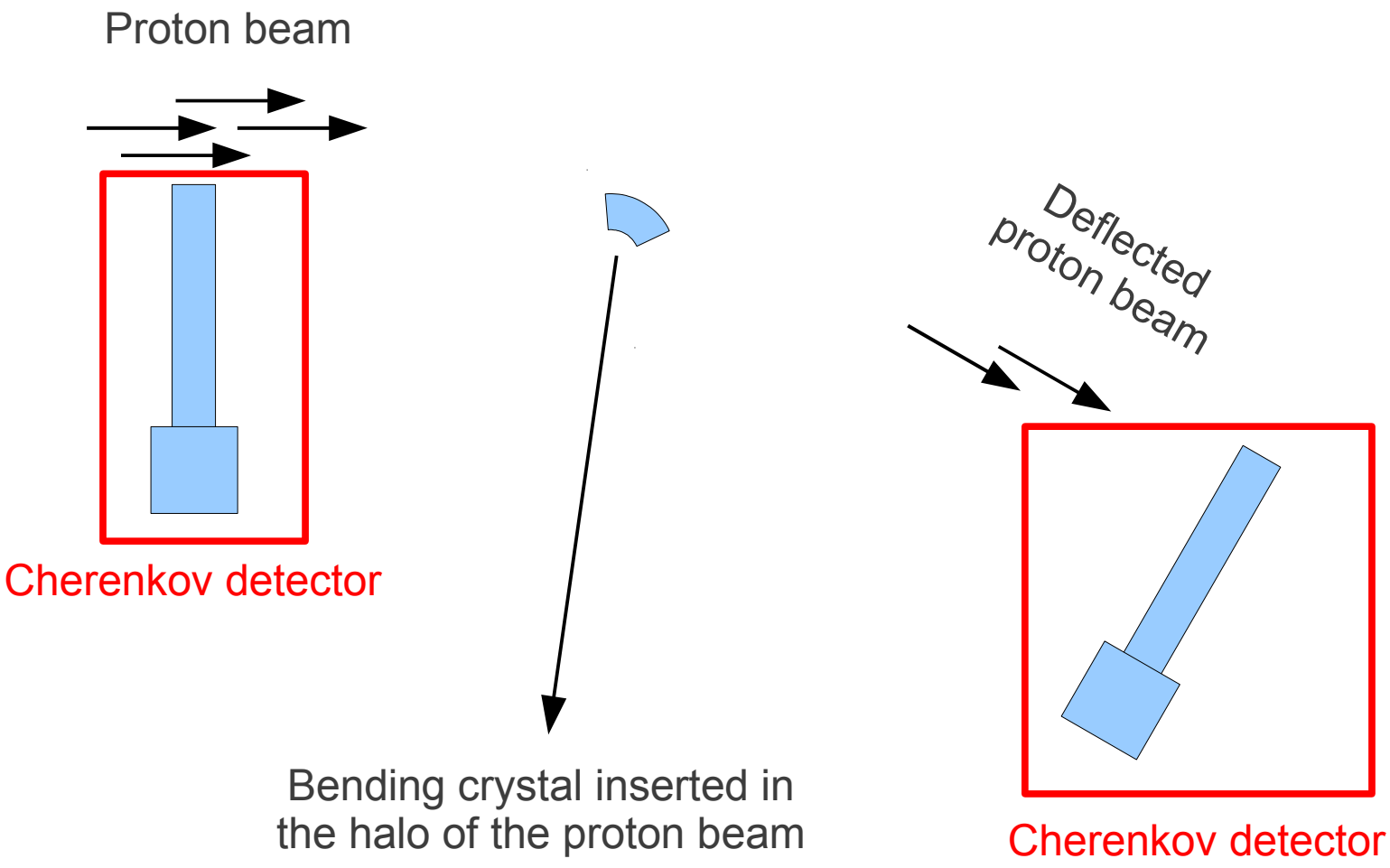
TDR phase is almost finished now. FTOF detector has been included there.

UA9 project

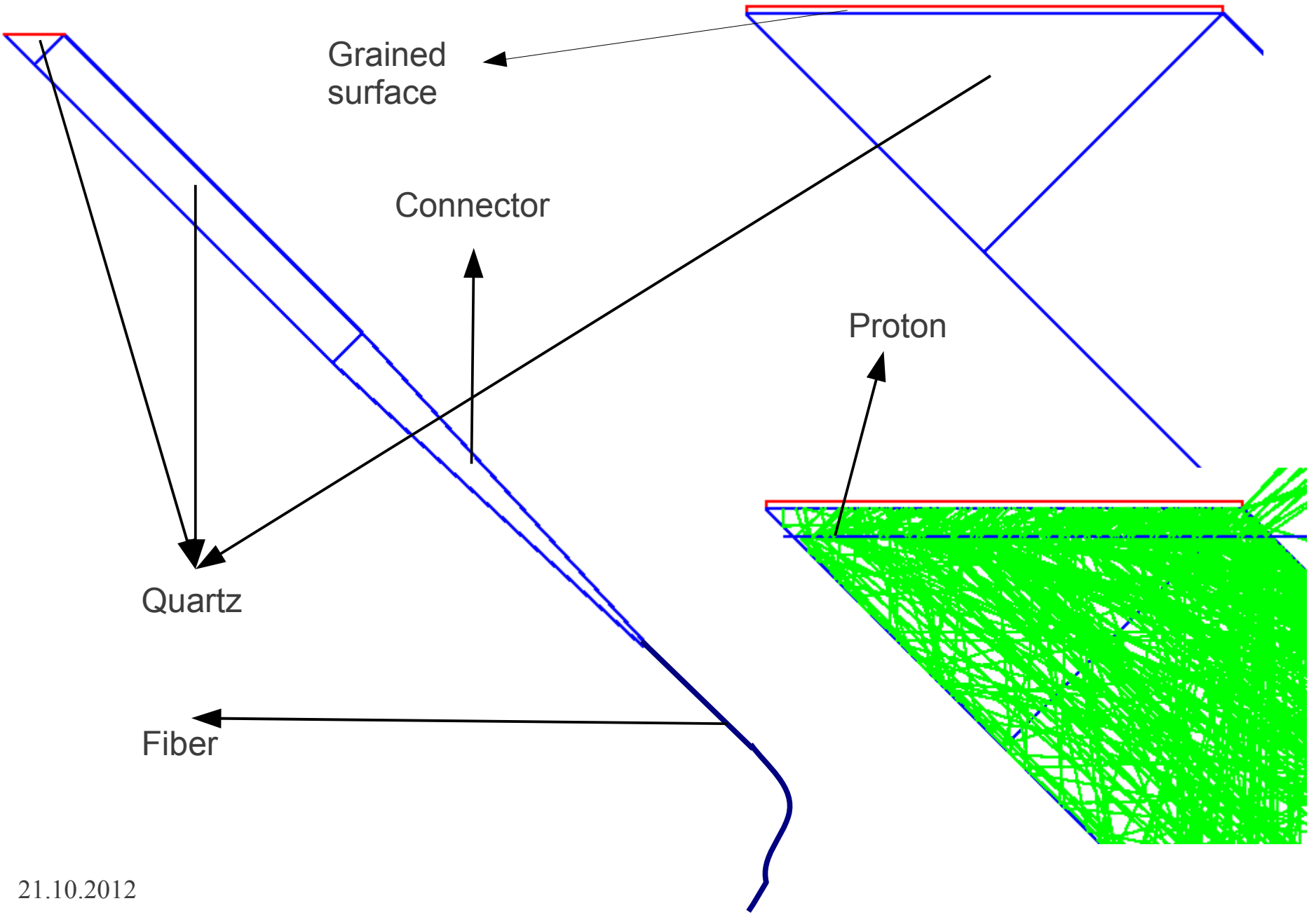
LAL participation:

Measurements of the proton flux in the halo of the LHC beam

Simplified schema of the experiment (Geometry reminder)

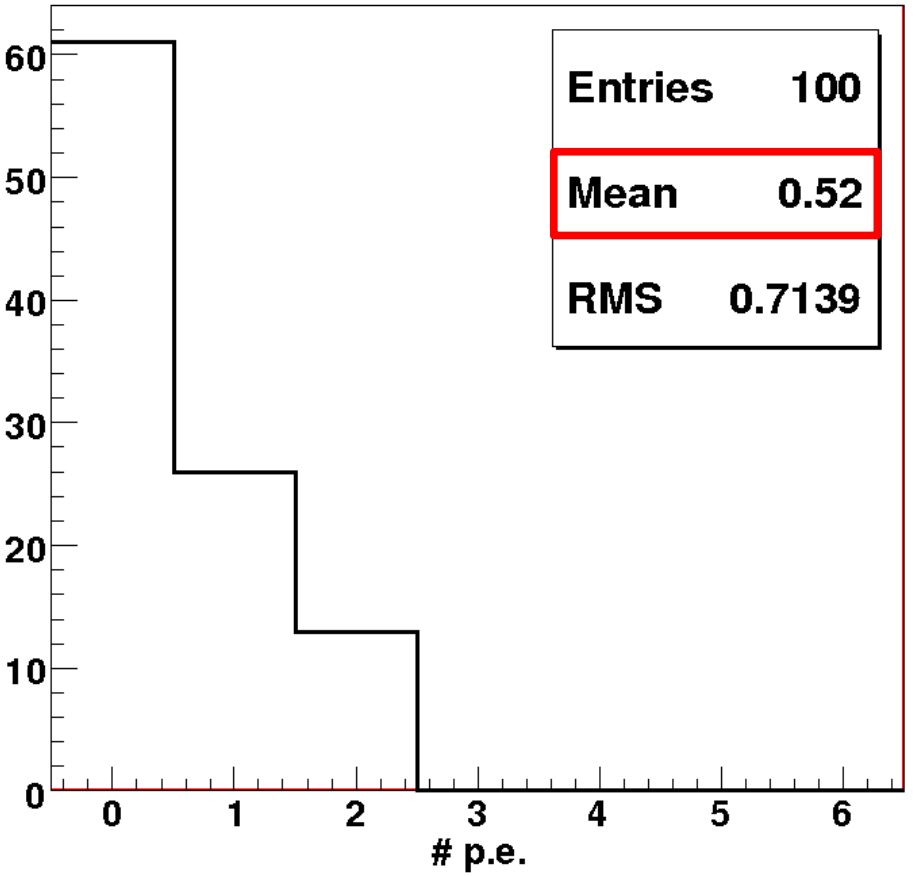


Geant4 simulation (Quartz finger + fiber)

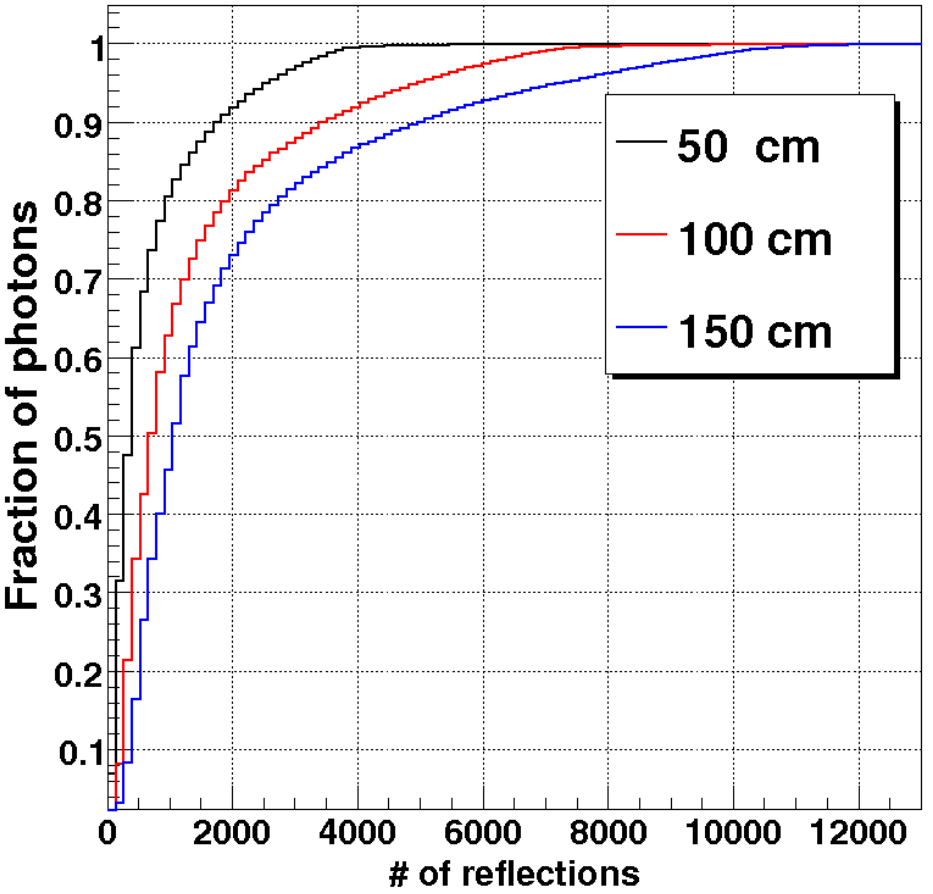


Conclusion from the simulation

Quartz radiator + fiber.



One have to study this geometry more in details to increase number of detected light



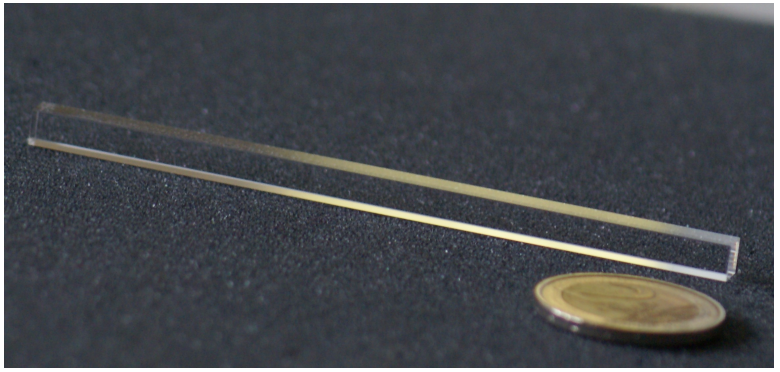
90 % of photons will make less then 2500 reflections in 1 m long fiber.

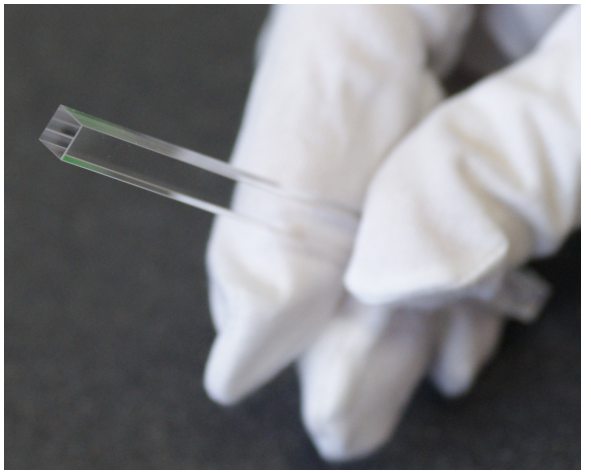
0.9999999

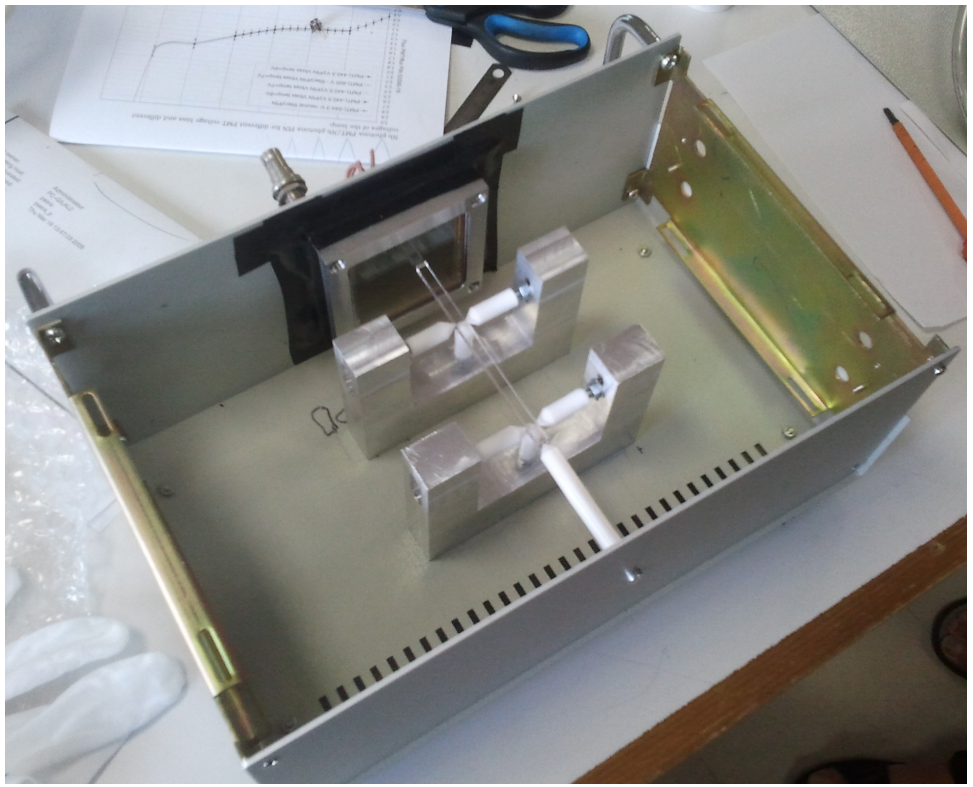
Probability of reflection

Pioneer prototype

100 x 5 x 5 mm^3



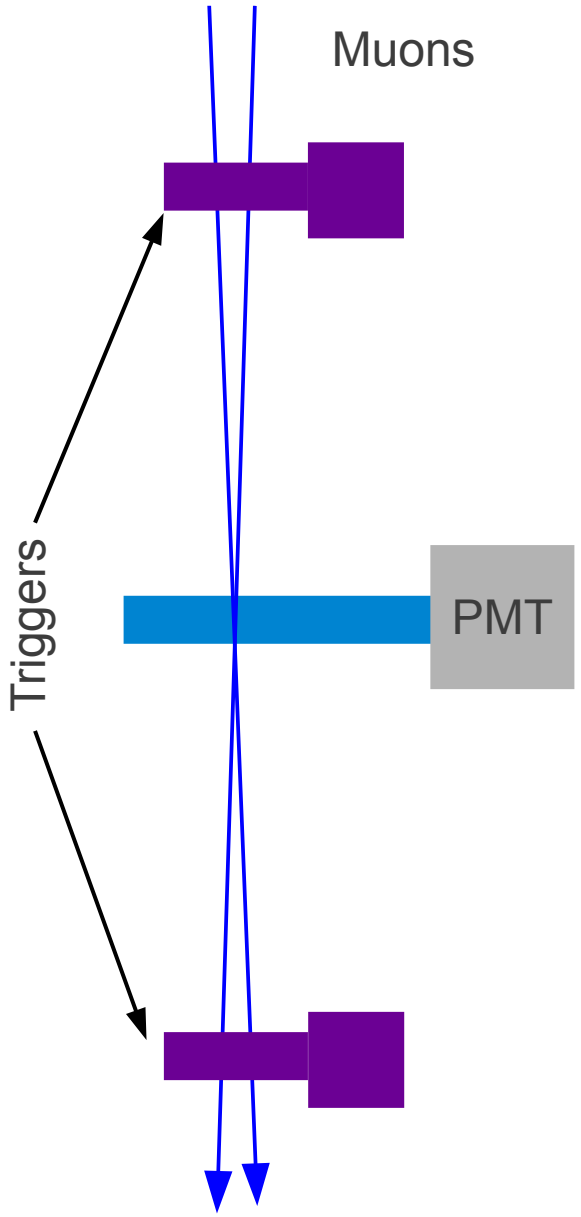




Quartz “finger” connected to the PLANACON MCP-PMT

And “located” in the dark box.

Test with muons



Conclusions

FTOF: a DIRC-like TOF detector

SLAC test

UA9 project