Plans for novel Cherenkov detectors at the Super Charm-Tau Factory at Novosibirsk

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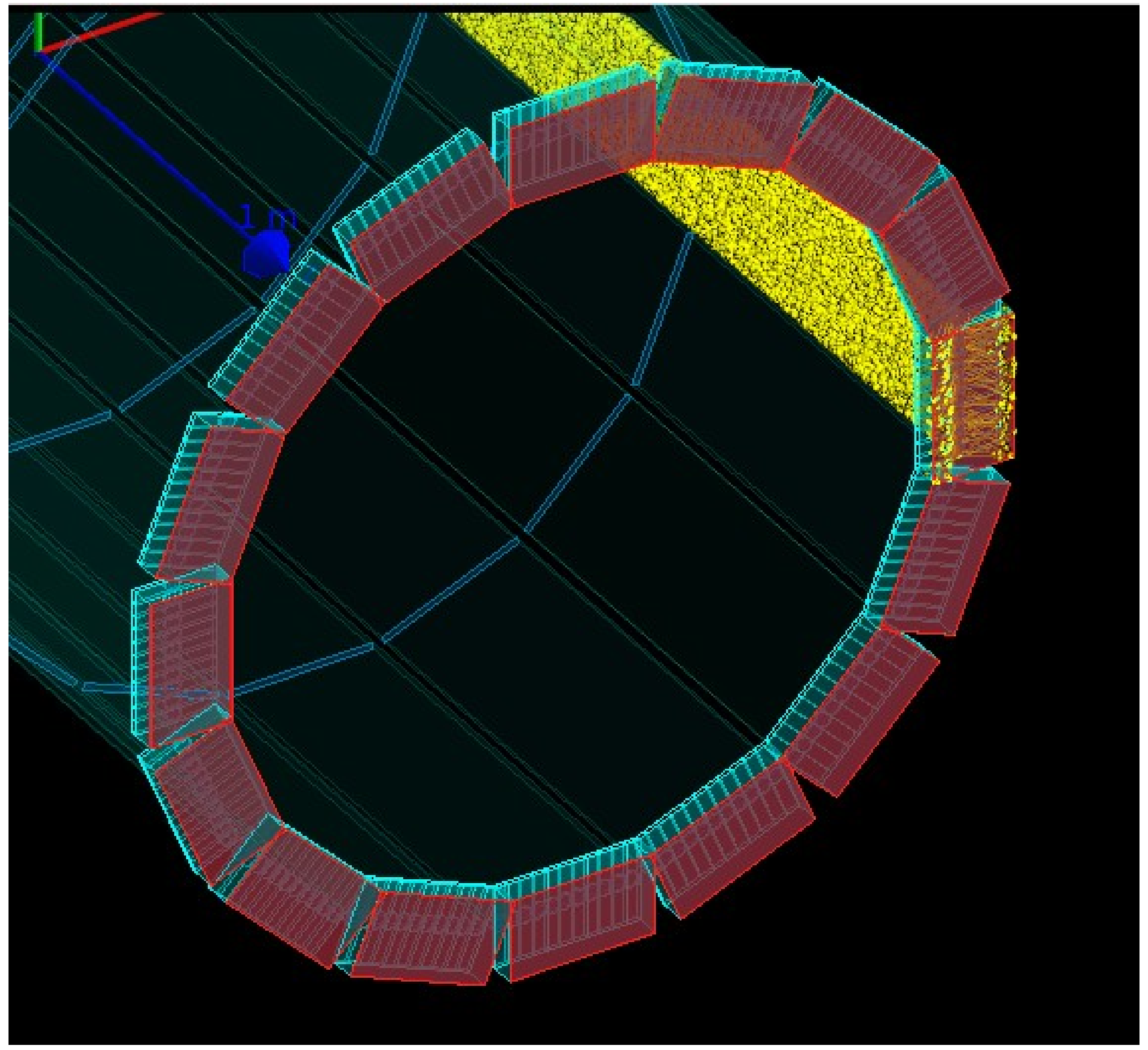
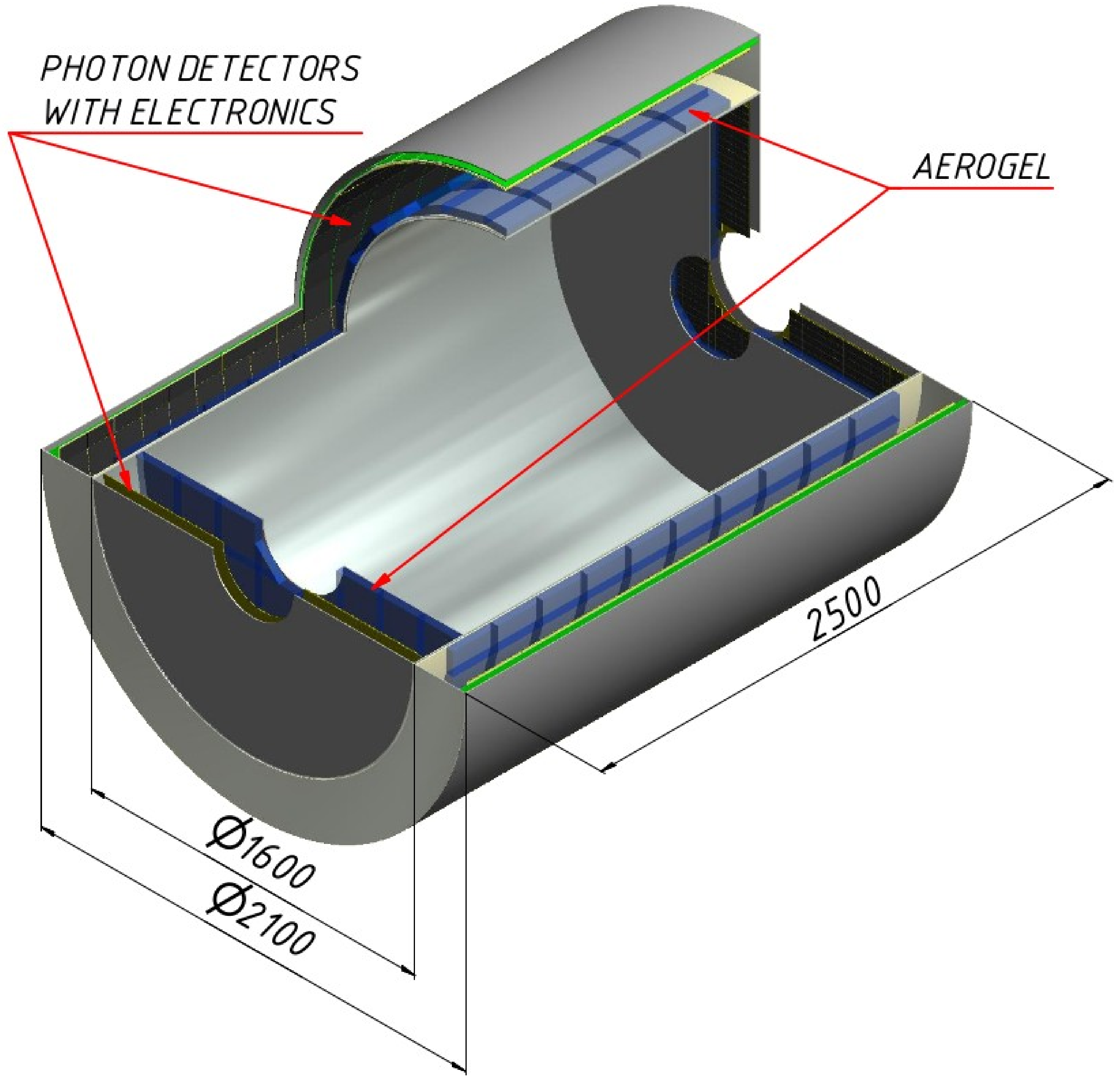
https://ctd.inp.nsk.su/c-tau/



Avetik Hayrapetyan, M. Dueren, S. Kegel, M. Schmidt,

A. Yu. Barnyakov, V.S. Bobrovnikov, S.A. Kononov

Justus-Liebig-University, Giessen, Germany and Budker Institute of Nuclear Physics, Russian Federation



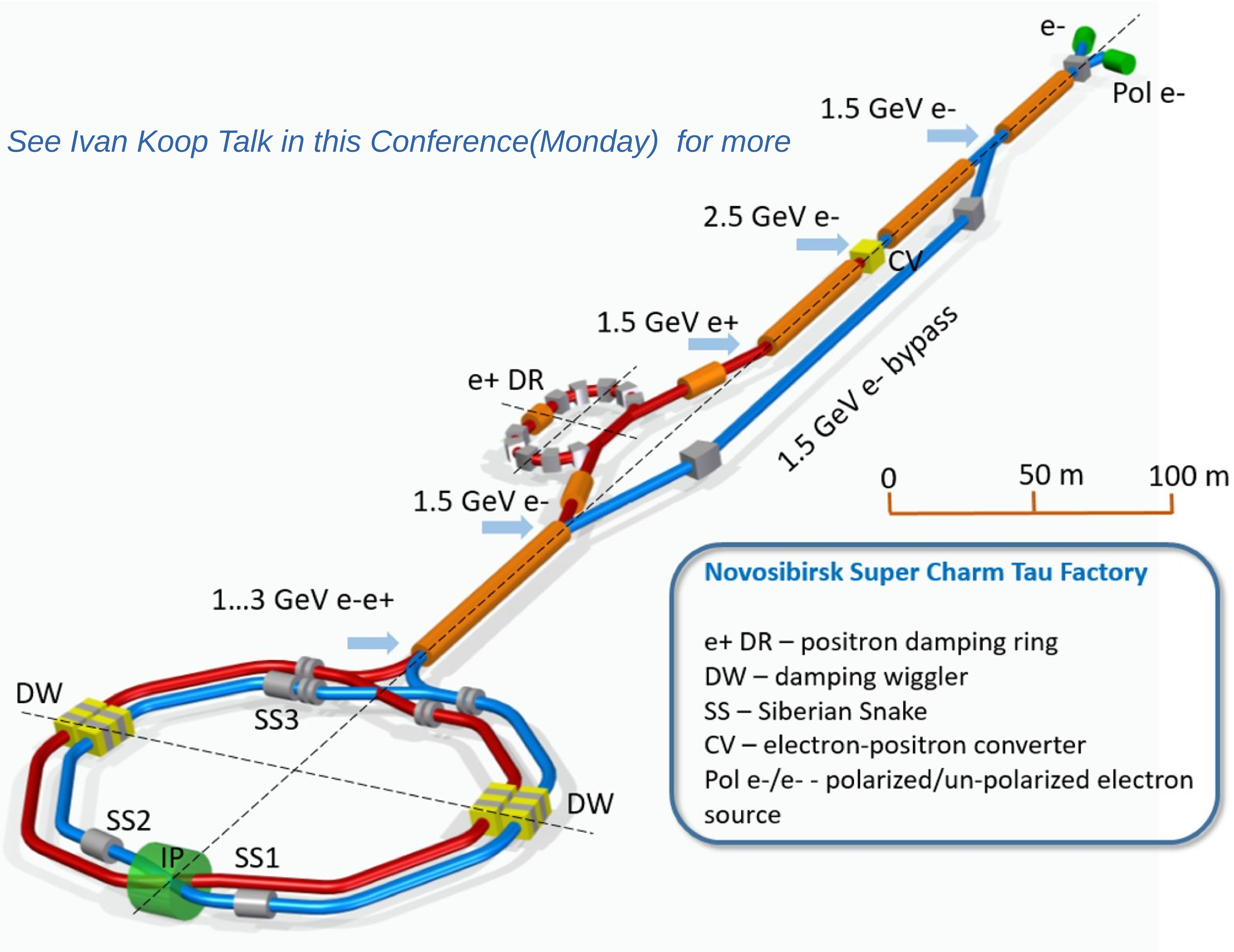
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Budker Institute of Nuclear Physics

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072

The new SCTF Collider

See Ivan Koop Talk in this Conference(Monday) for more



E(MeV)	1500	2000	3000
I(A)	2	2	2
N_(e/bunch)×10^(-10)	8	6	10
N_bunches	323	431	259
Lumi 10^(-35) (cm^(-2) s^(-1))	0.4	0.5	1
τ_Lifetime(s)	2800	3200	1731

It offers also a polarised e- beam, high(90%) at 1500 and moderate(40%) at 3000 MeV

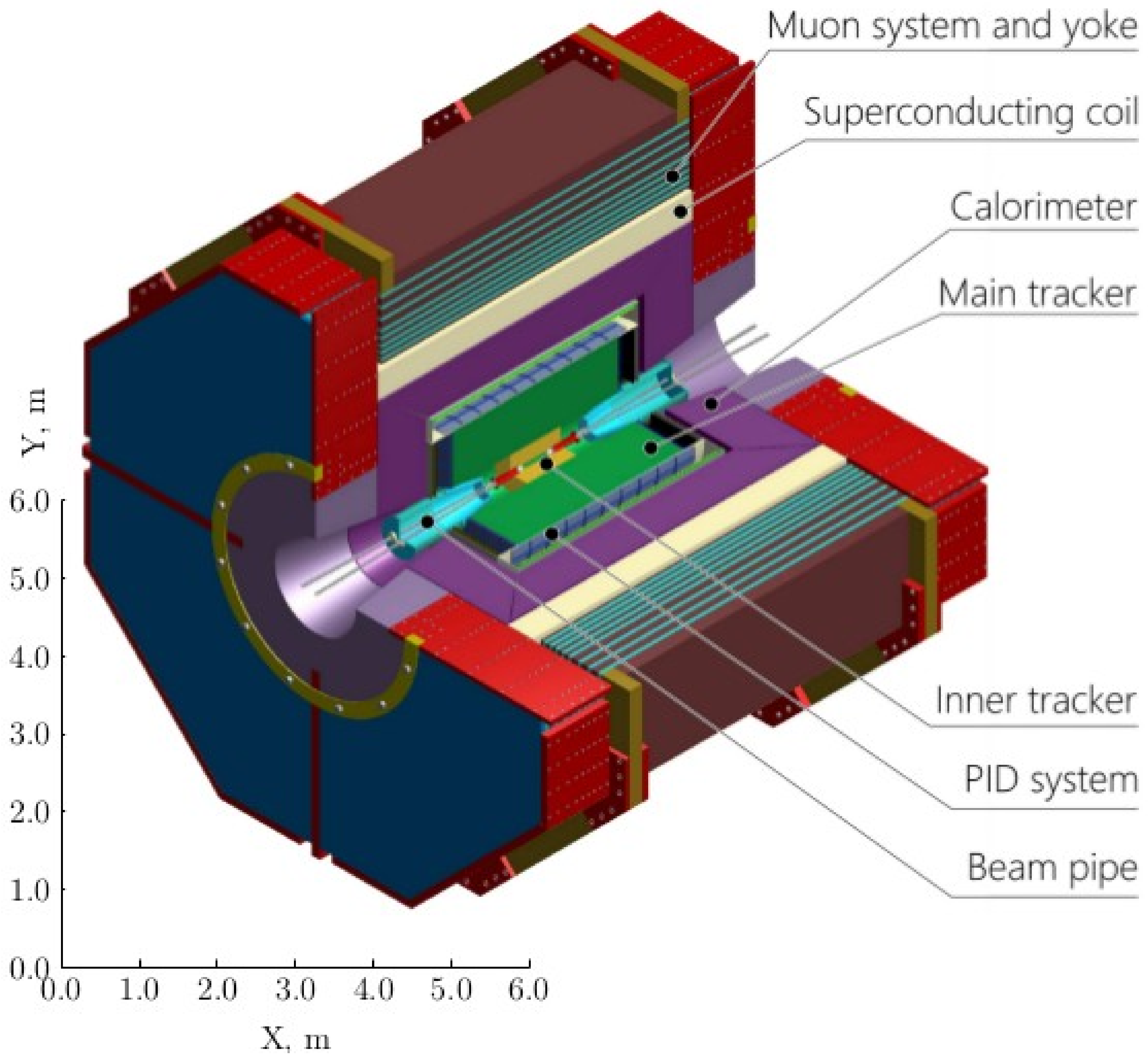
Having such a hightec device one can „attack“ a big goals, like a LFV
Decay of tau leptons into mu gamma

$\tau \rightarrow \mu\, \gamma$

A. Bogomyagkov(BINP)

The 2020 joint international workshop for Super-Charm Tau Facility
16-18 November 2020

The Detector and requirement on it



There are very tight requirements on different detector parts:

Here we stress the part direct touching PID for LFV search, Because it is the strongest one is:

-Very good momentum resolution , below 1%

-Good μ/π/k separation till 1.5GeV/c

-special tight requirement on muon/pion acceptance and separation

-good π^0/γ separation in wide range of energies 10-3000 MeV

For detailed physics program and all requirements on detector see here:

В. Воробьев, ИЯФ СО РАН , "Проект «Супер Чарм-Тау Фабрики"

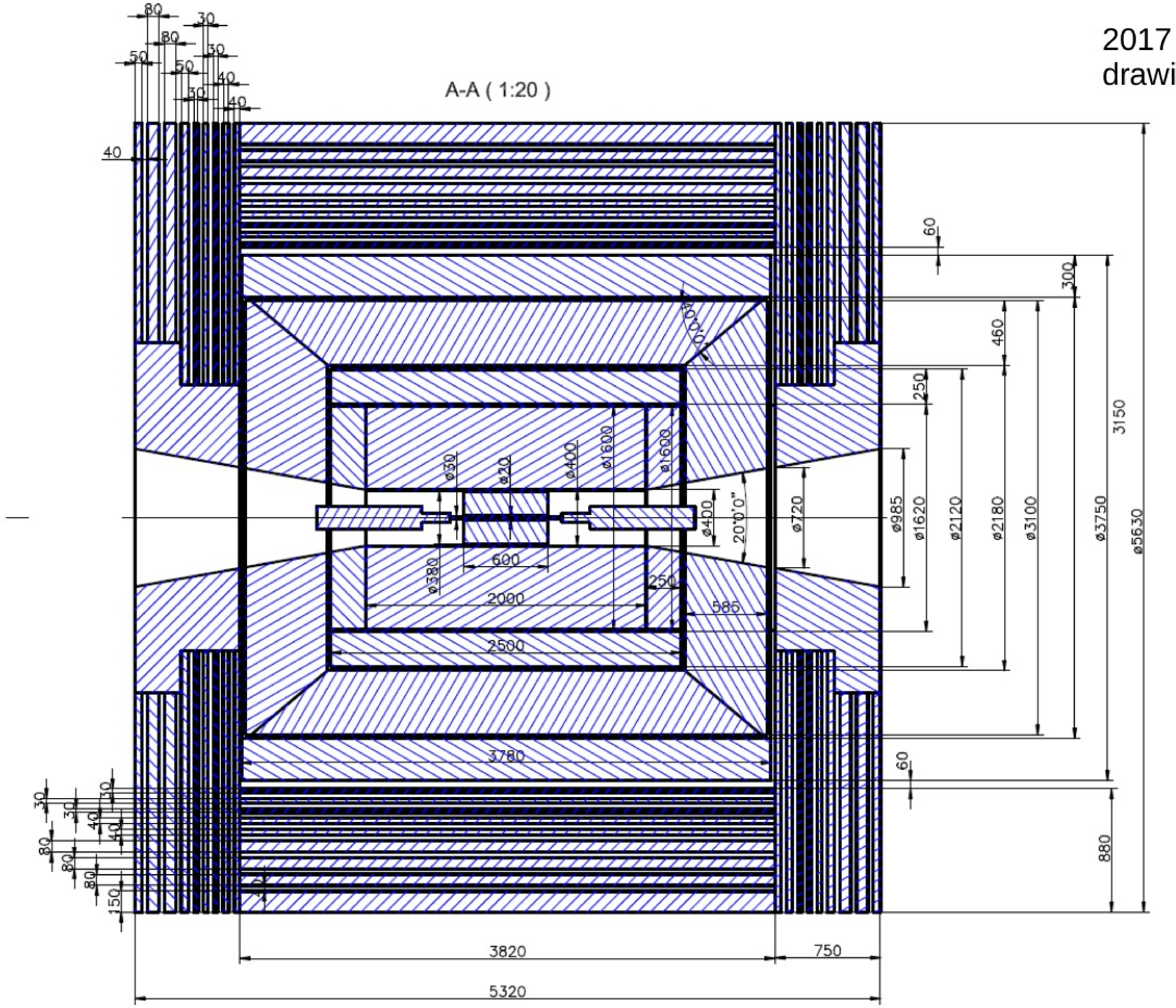
Seminar ,15.04.2021, ФИАН

A. Sokolov "R&D activities on SCT detector"

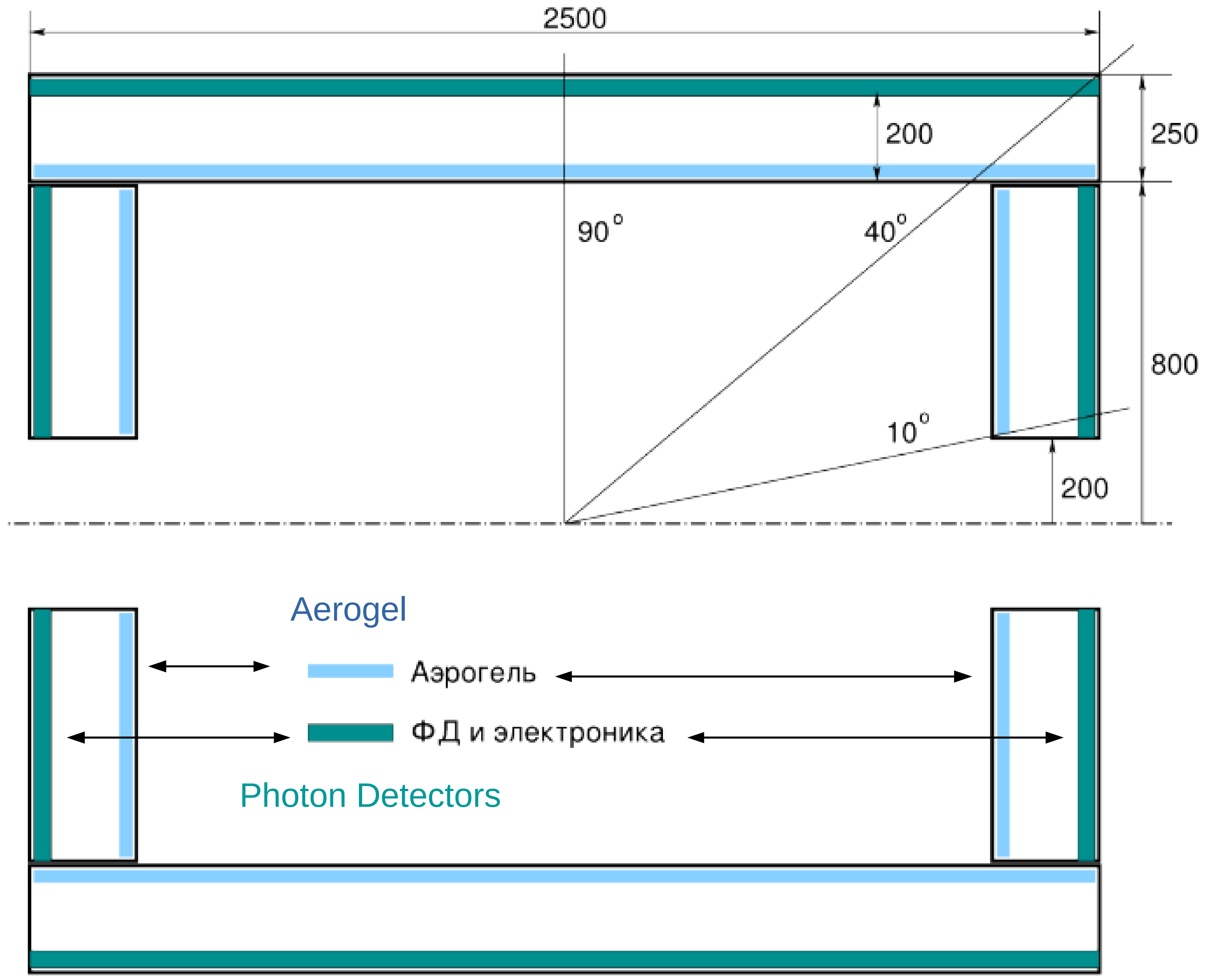
The 2020 joint international workshop for Super-Charm Tau Facility
16-18 November 2020

The SCTF detector volumes and PID part (here the FARICH version)

2017 size drawing



2



The fDIRC models we implement in Geant MC should reside inside this volumes

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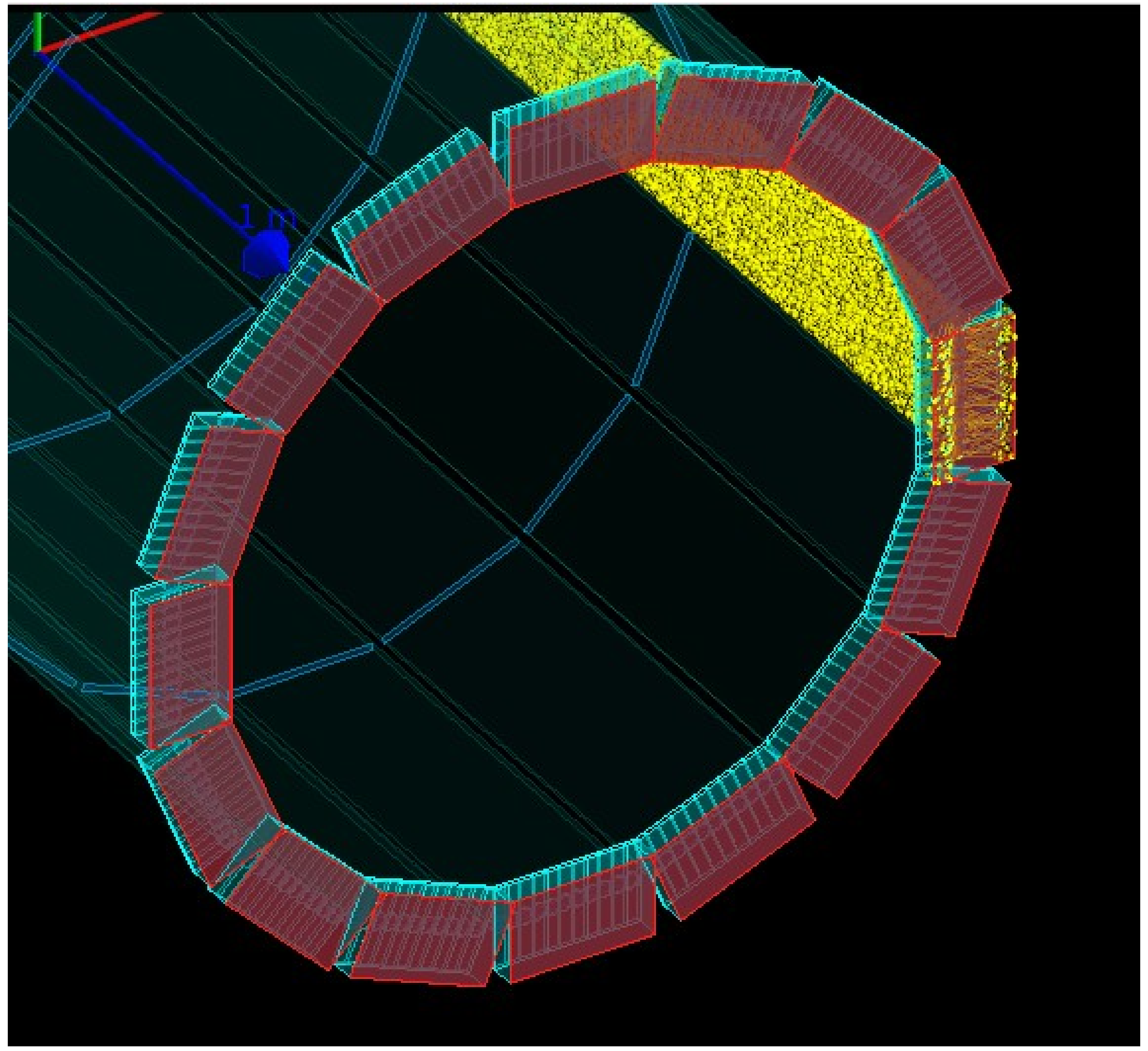
Two PID concepts are in consideration



The Outline of this talk

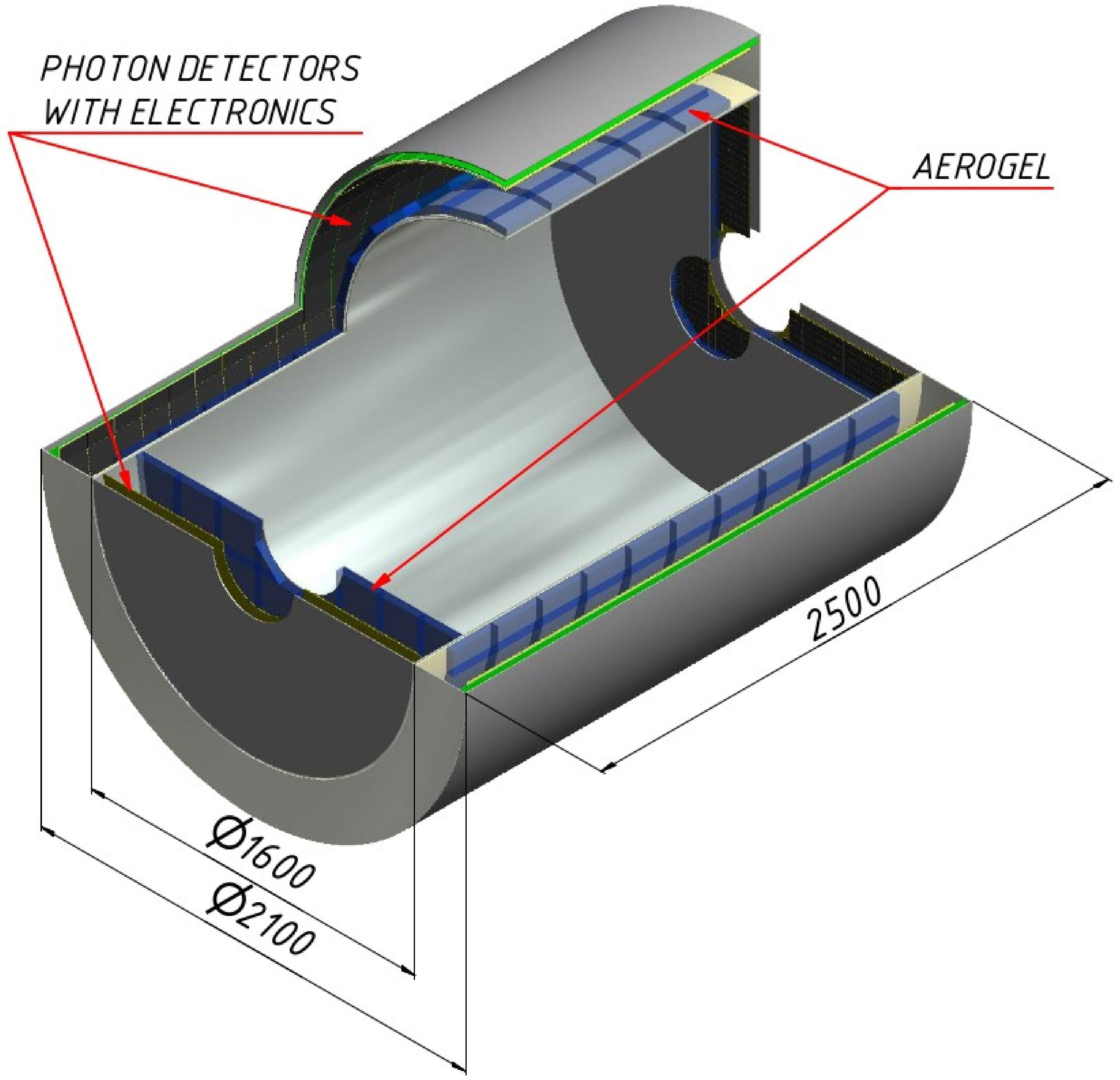
Barrel fDIRC in GEANT MC

Addressing the main “contributor” of the resolution

Candidate Prototype Photon detector tests at GCS

RD activities of FARICH part

Conclusions



FocusingAerogelRICH, FARICH Option,

two BEll-2 ARICH geometry like endcap FARICH and one novel Barrel

Will project Cherenkov Photons on **~16.0 m²** (Barrel) and **~5.0 m²** (Endcaps) Detection Surface with granularity to be optimized

fDIRC Option, two “PANDA like” endcap disc DIRC and one Barrel, both with focusing optics

Will project Cherenkov Photons on **~1.024 m²** (Barrel) and **~0.6912 m²** (Endcaps) Detection Surface with granularity to be optimized

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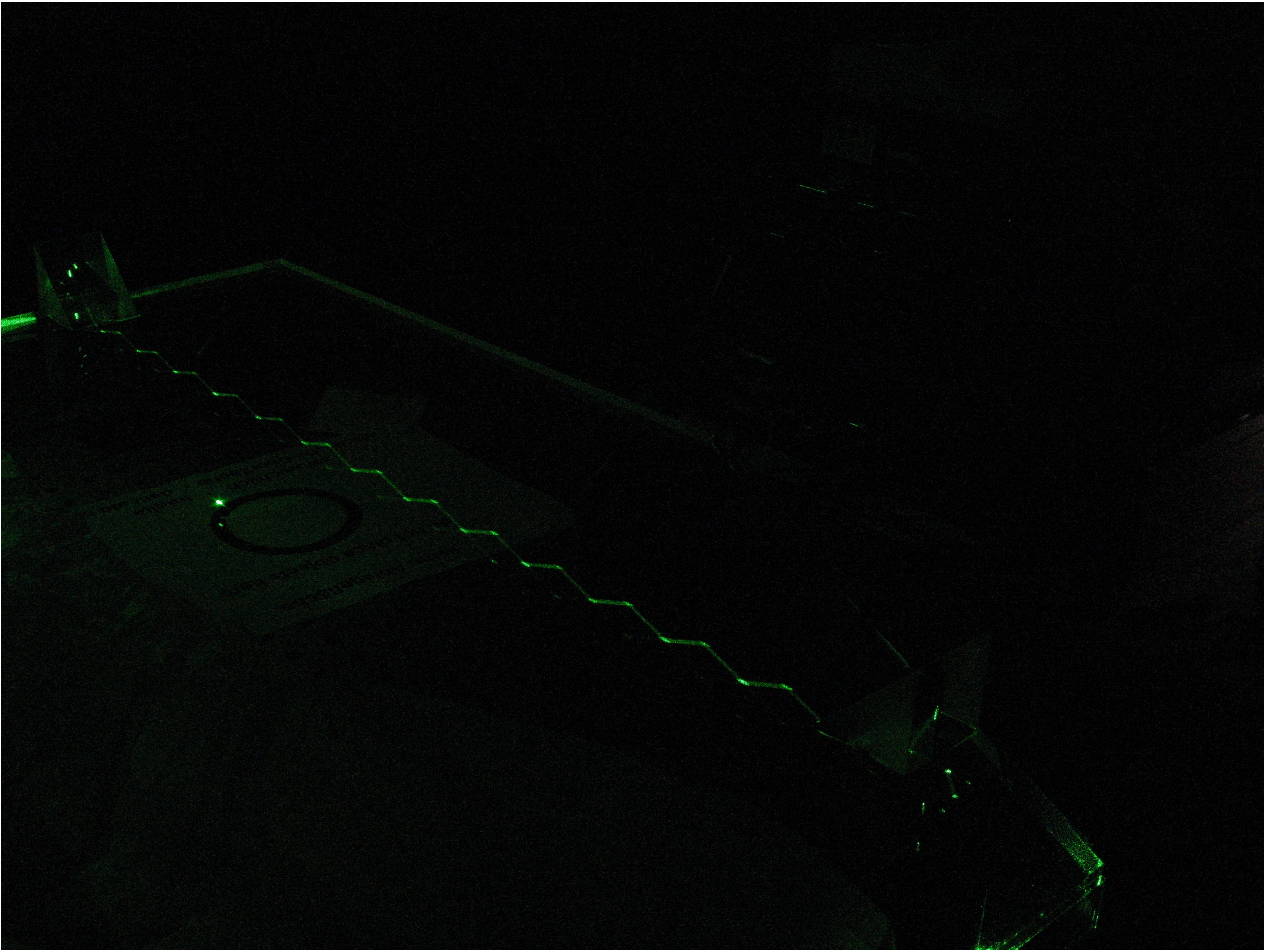
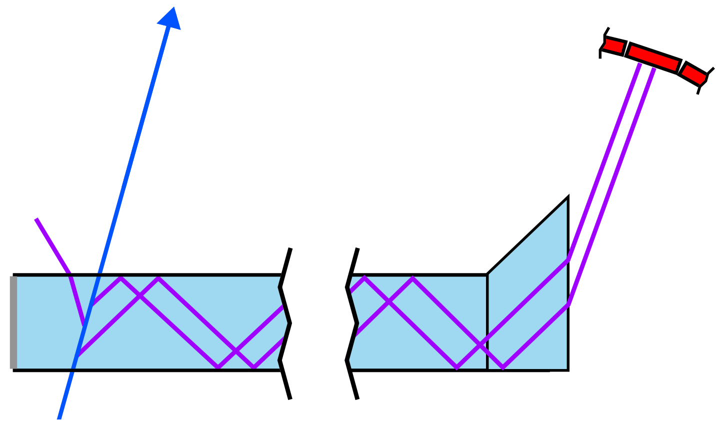
The Cherenkov radiation and the DIRC principle



$n\beta>1$

$\theta_{AOI} > \theta_{TIR}$



$\theta_C=\arccos(1.0/n(\lambda)\beta)$

Such a stationary setup with possibility to measure radiator Quality parameters should be a good test bed for students to learn DIRC optics

For the recent review of past,current,future DIRCs see here:
J. Schwenning "DIRC technology requirements"

https://indico.cern.ch/event/999817/contributions/4253047/attachments/2239796/3797410/20210506-ECFA-TF4-DIRC-schwiening.pdf

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The many opposite requirements to build a good fDIRC

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-more photons at creation, low wavelength ⟷ -bigger color dispersion in quartz

-smaller color dispersion at higher wavelengths ⟷ -smaller or zero QE for MCP-PMTs

-thinner radiator to minimize effect of multiple scattering ⟷

Ivan Krilov Basni(Fables)

⟷ -difficulties to fabricate DIRC required sizes, price

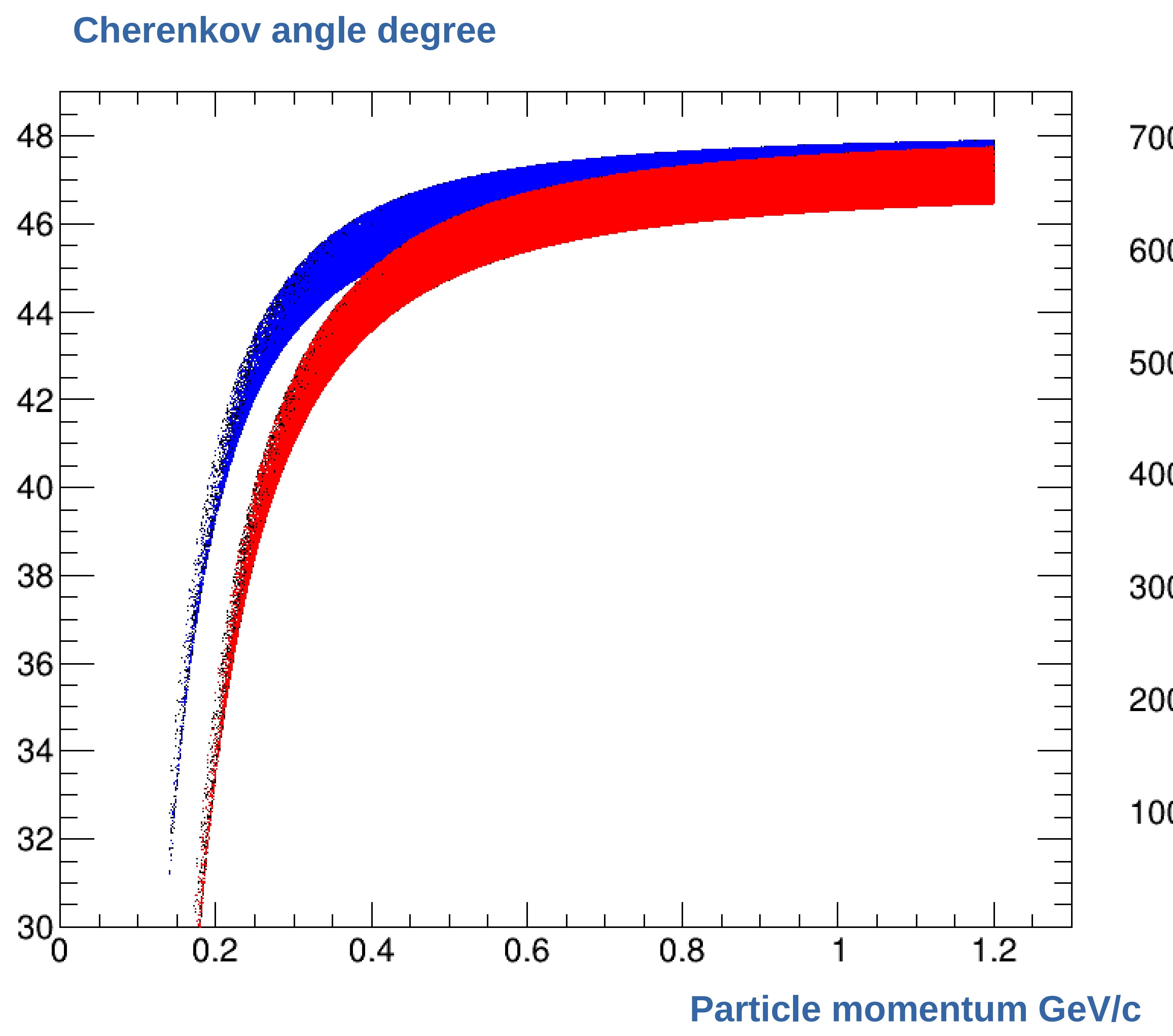
-high quality surface polish and parallel surface to preserve Cherenkov angle ⟷ -higher price for fabrication

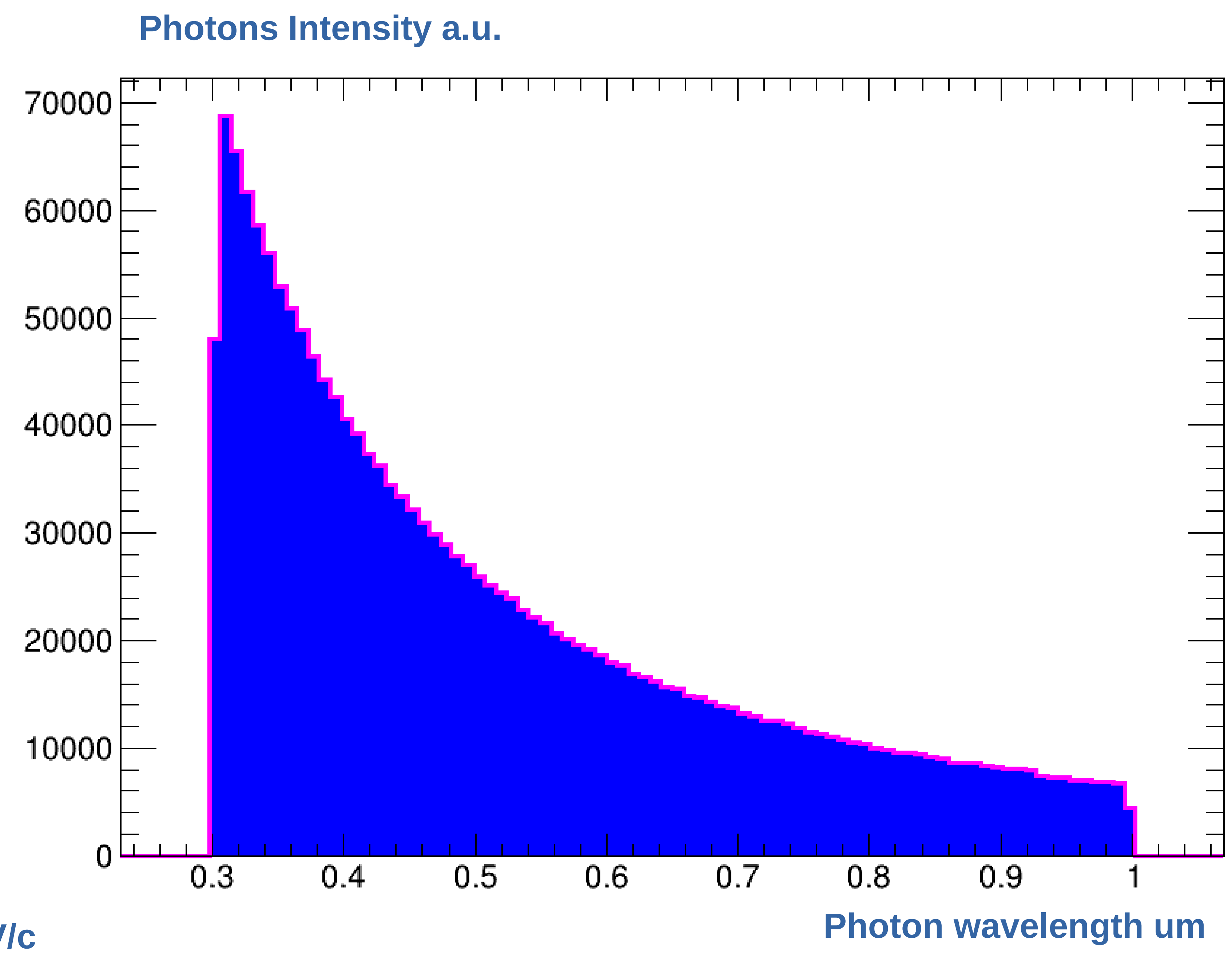
-good focusing to minimize the size of photon detection surface, to be accommodated inside the magnet ⟷ -difficult to find producer,higher price for fabrication

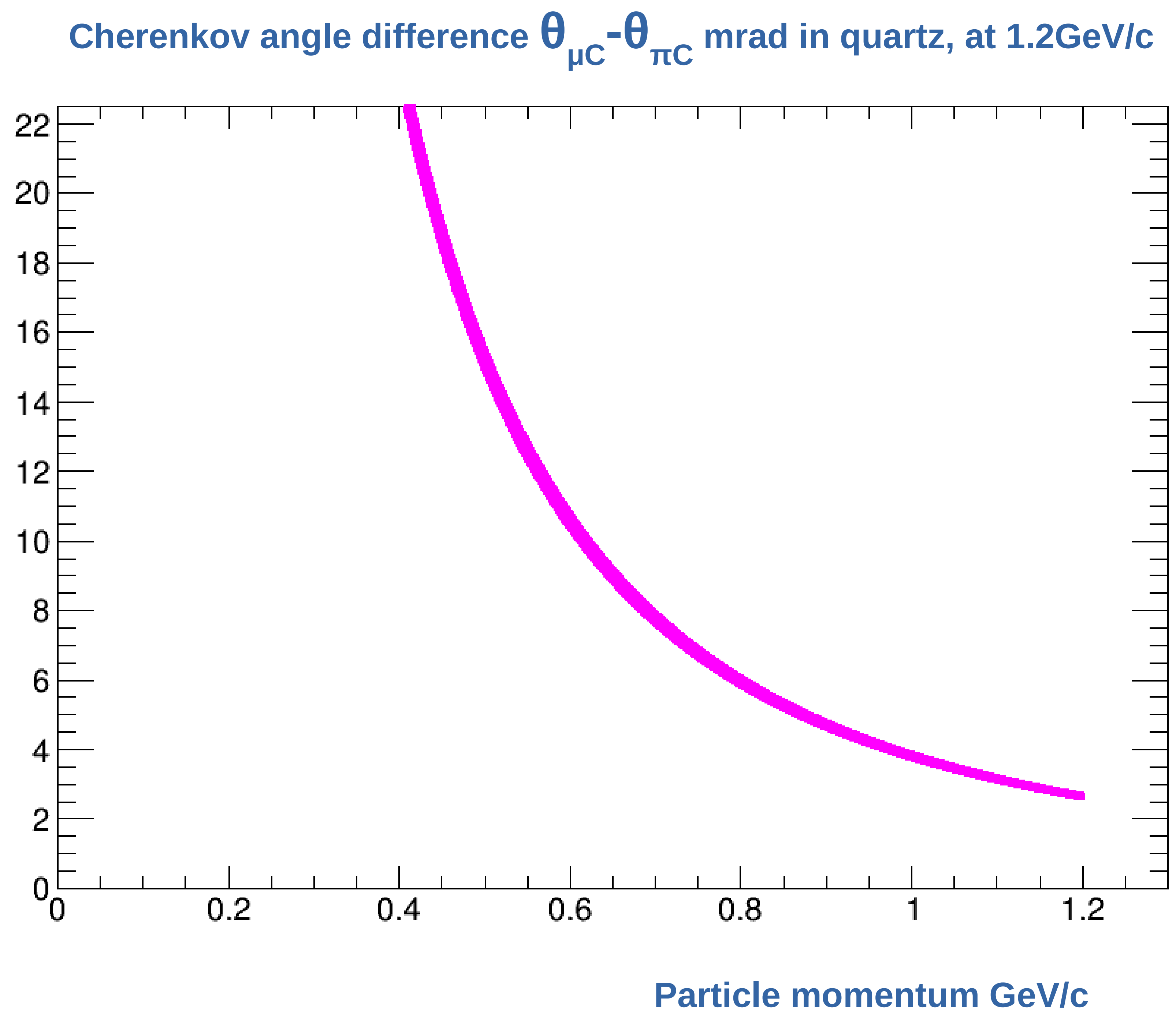
-fine pixelation of photon detectors ⟷ -exponential rise of readout channels , requirement to have fastest DAQ, price

And many more, I was lazy(time!) to list, in this talk
I'll address only color dispersion

The characteristic spectra of Cherenkov Photons in Quartz







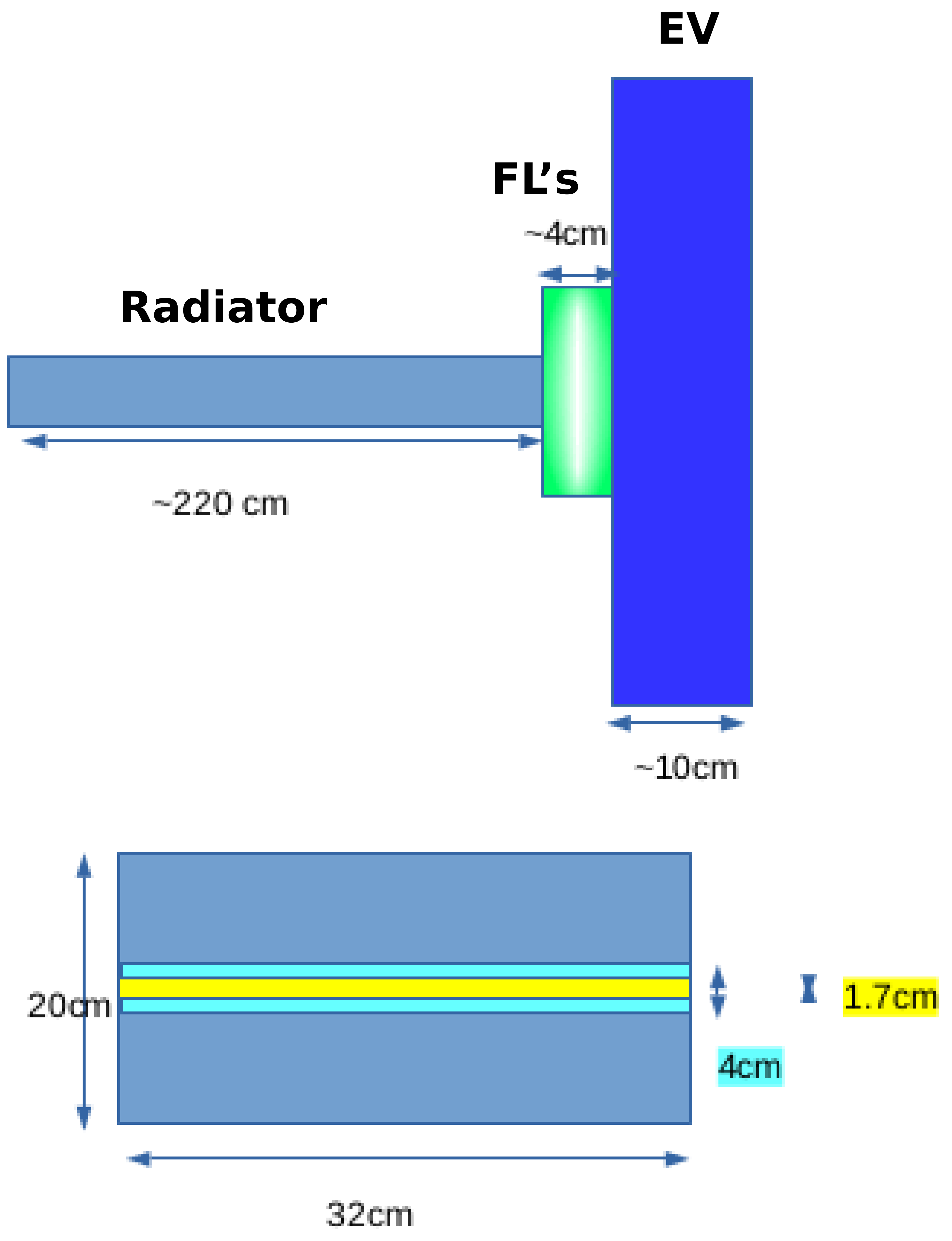
From now we will discuss the case of **π μ** in quartz radiator, because of as one see from plot at the right side

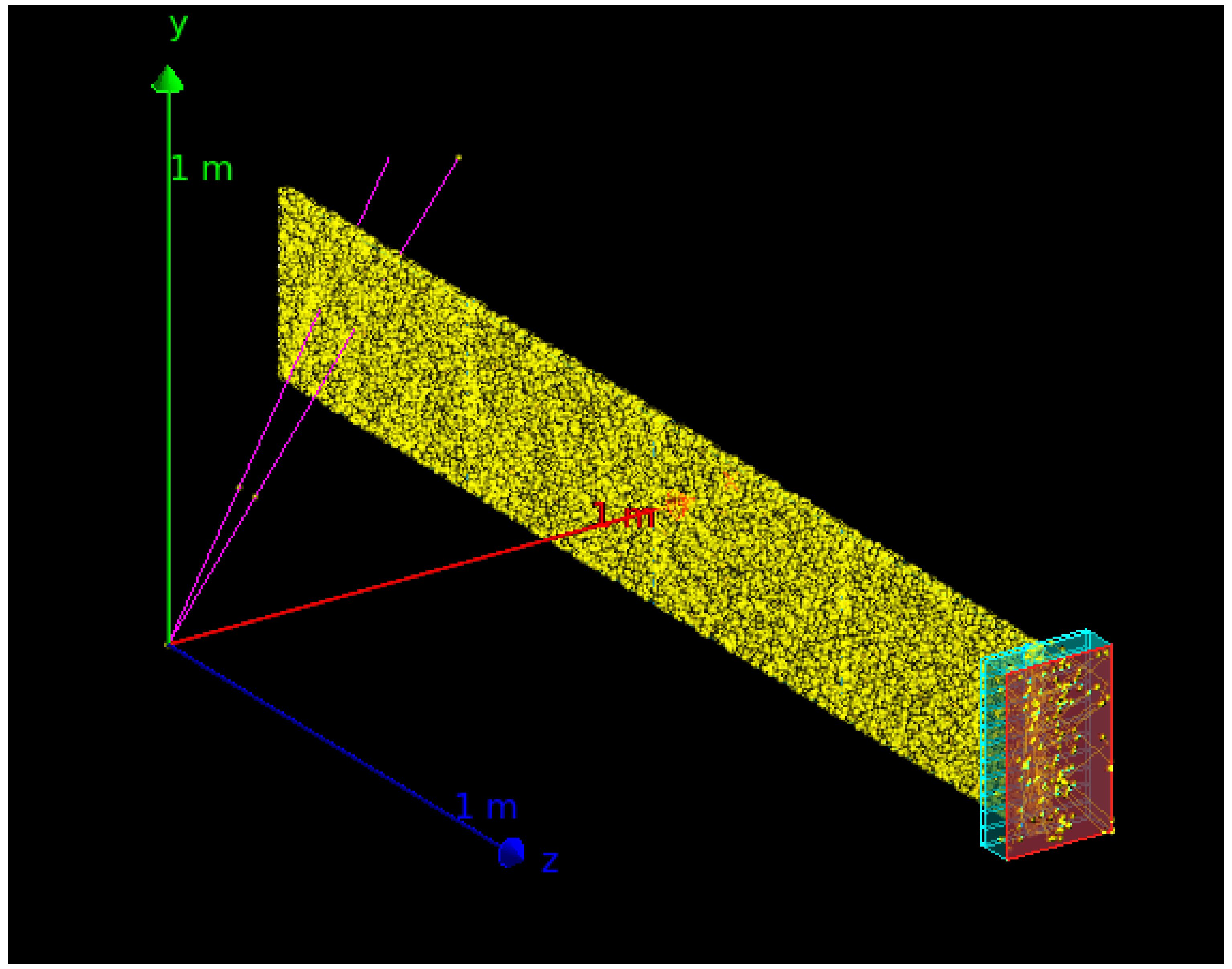
The separation of **π/μ** is most challenging

We start at 300 nm because of usage of only radiation hard glue Epotek-2 to connect optics, is transparent above this limits

The upper limit is defined by quantum efficiency of common photon detectors

Possible Module for barrel fDIRC





The Geant model is based on R. Dzhygadlo(GSI) EIC fDIRC, with modification of focusing lens(FL) and expansion volume (EV)

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The new Expansion Volume and 3 layer focusing Lens

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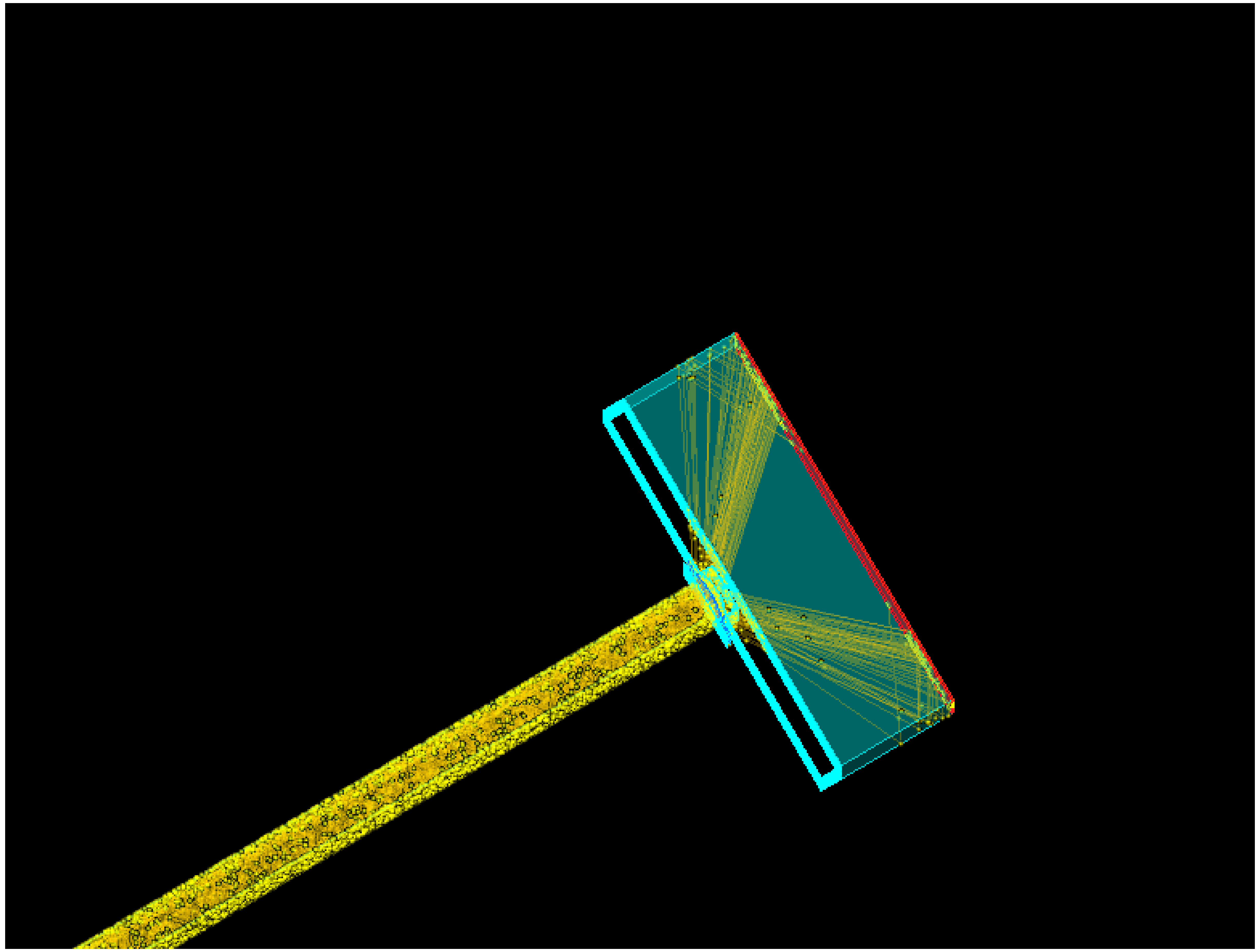
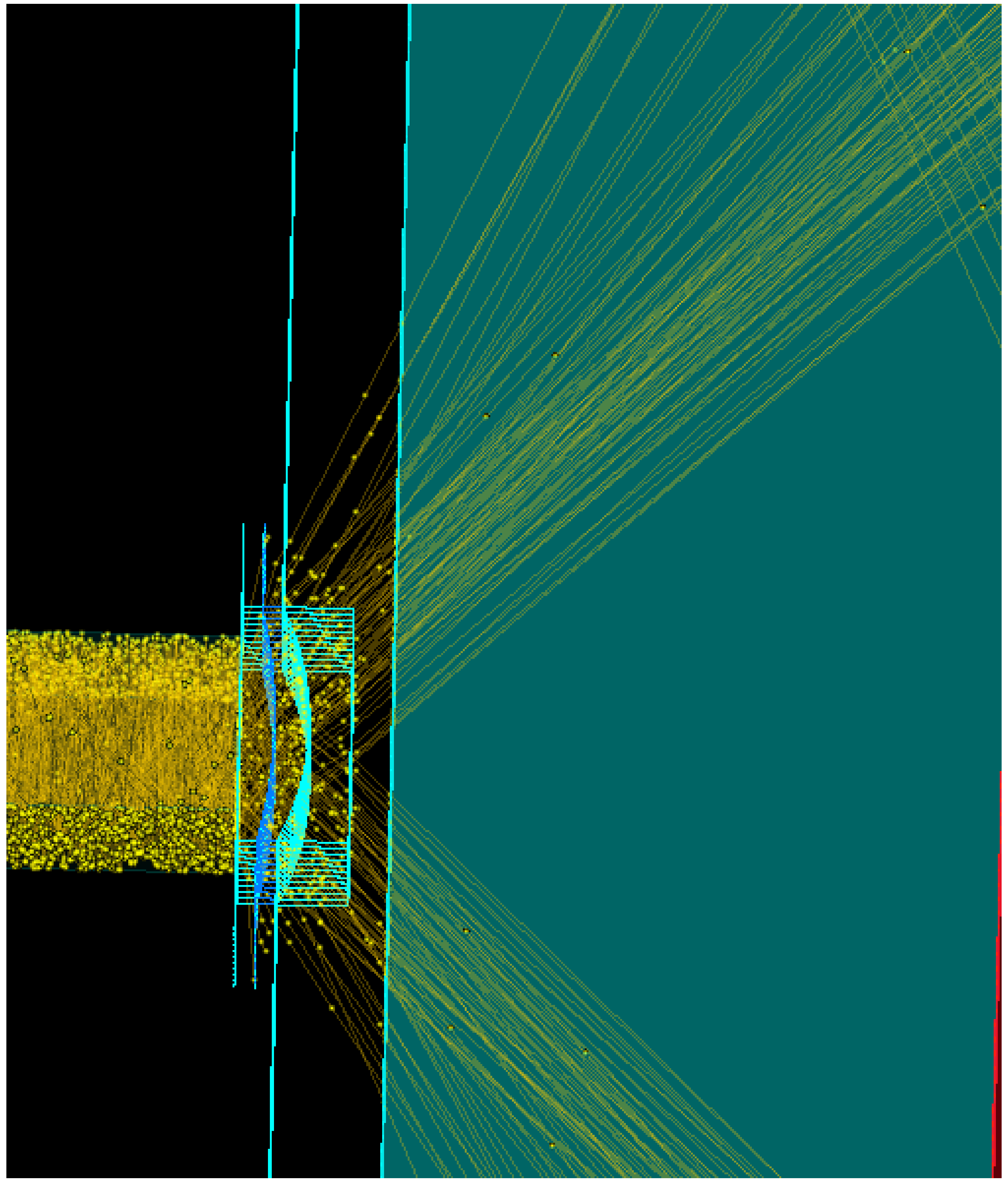


The new
Expansion Volume is 320X200X100mm
Quartz Module in MC, here zoomed with
Cherenkov Photons produced by 1 GeV/C Muons



Here zoomed area shows the
3 Layer focusing Lens with circa 20mm
thickness all together, again with MC photons
There are ongoing MC studies for the Lens, 2 or 3 layer??
Focusing length,materials

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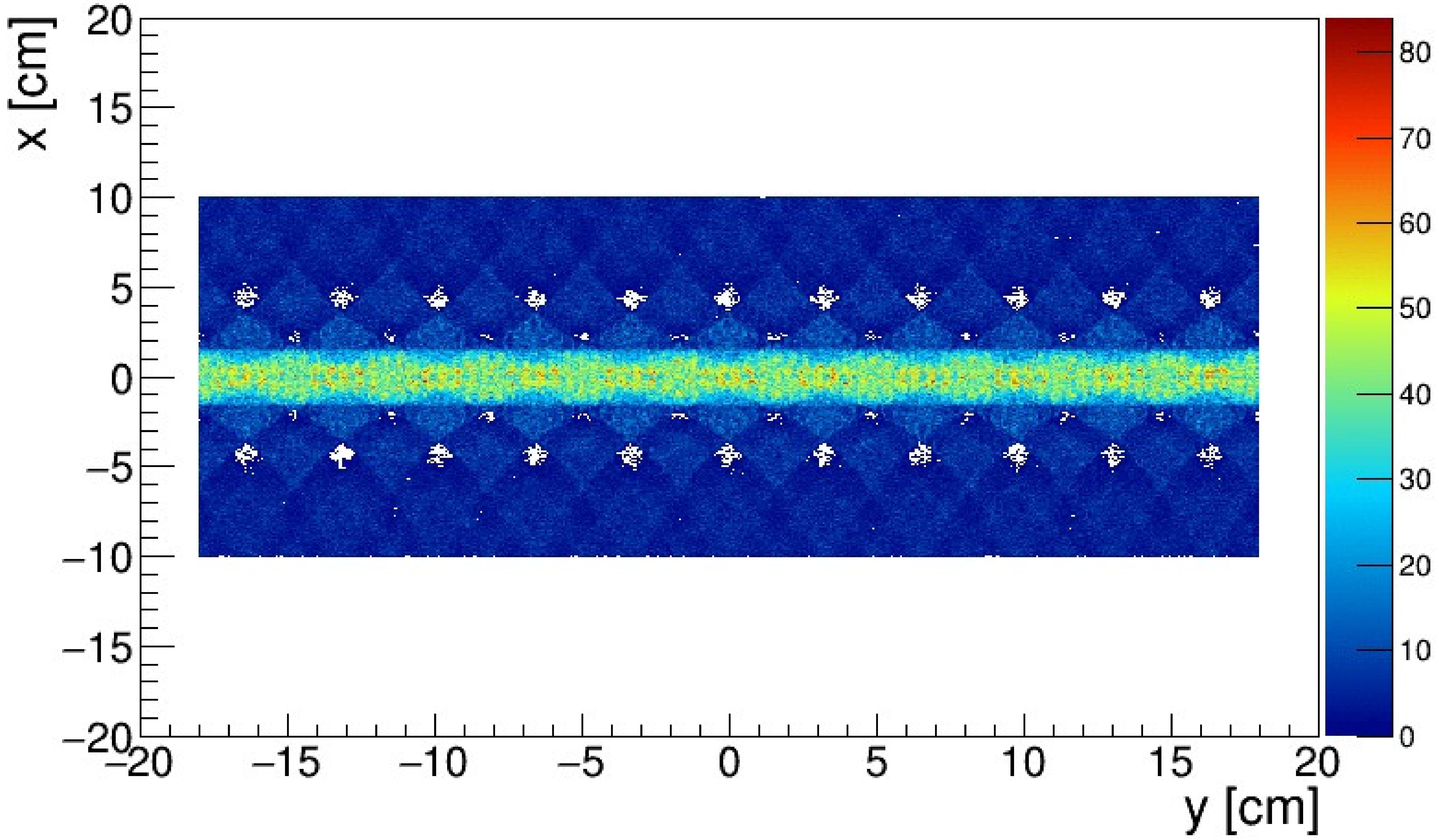
The angle coverage of Barrel DIRC



The hit map of Cherenkov photons on surface of EV where the Photon Detectors supposed to be coupled Starting from 40 till 140 degree polar angle

It is assumed that Barrel PID(DIRC) Should cover from 40 to 140 degree of polar angle and 360 in azimuthal

The magnet/detector geometry allows To install 2500mm length radiator at circa 930mm position in radial direction

The fDIRC option requires space for Expansion Volume(EV), focusing Lens (fL) And for Photon detector+Readout Electronic

Taking all this into account we suggest to have such a configuration at first in MC

Radiator 17*320*2200 mm
EV 30*200*100 mm
fL 8X20*40*40 mm

The remaining circa 160 mm place in Z direction One can use for a place for Photon detector and Readout electronic

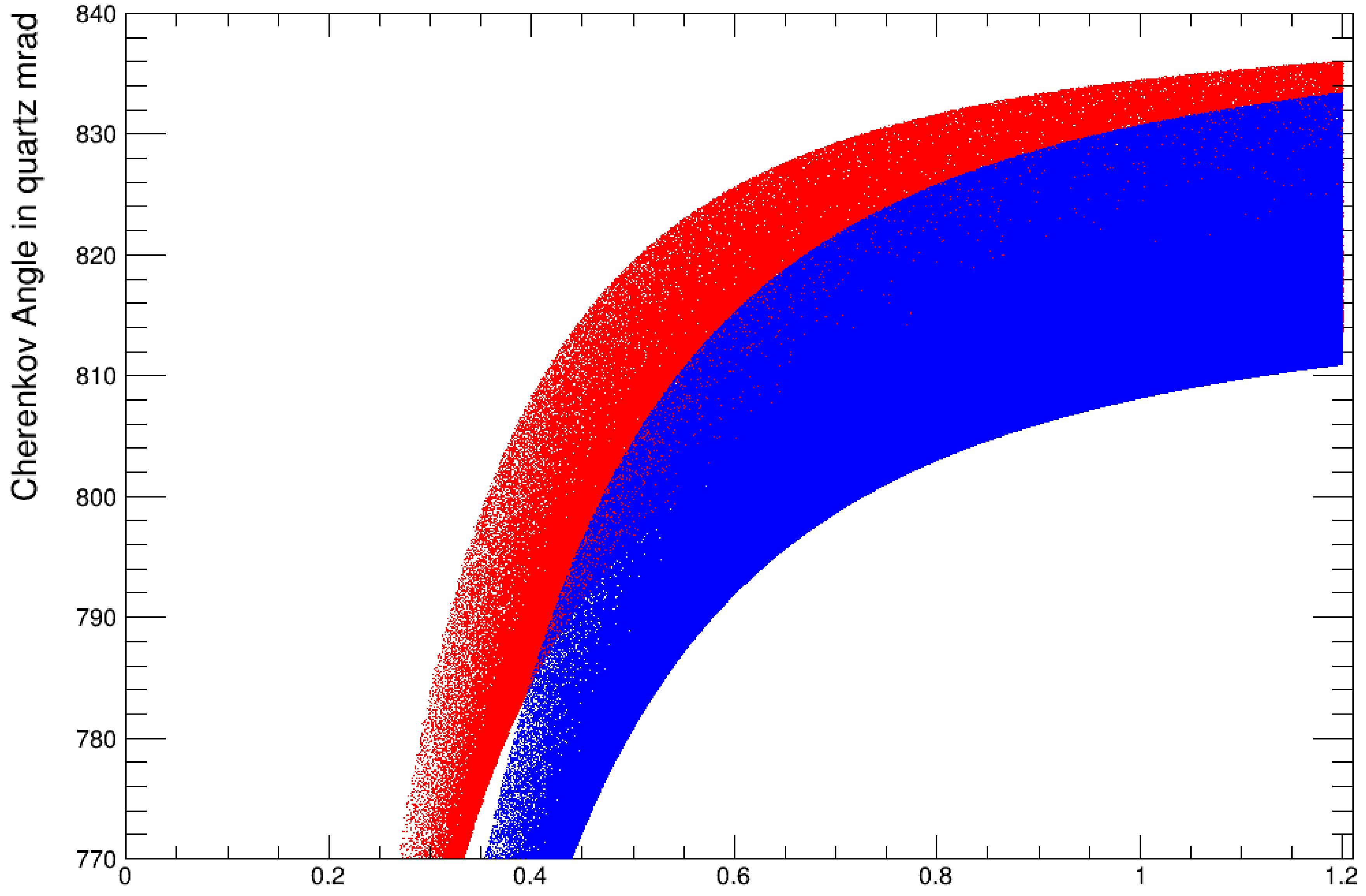
The importance of the wavelength restriction

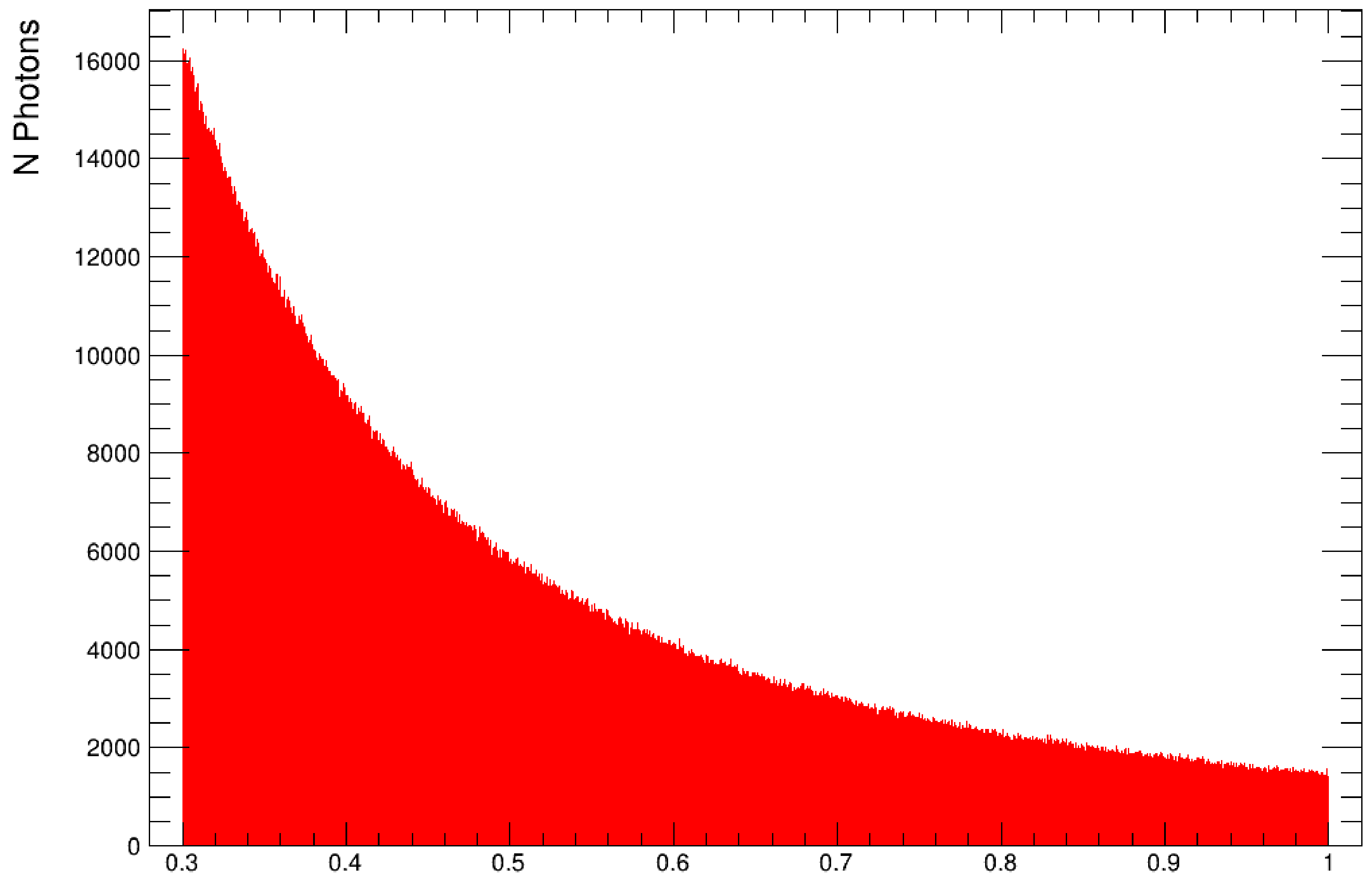
In Silica produced Cherenkov Photons Number Against wavelength –>

Pions

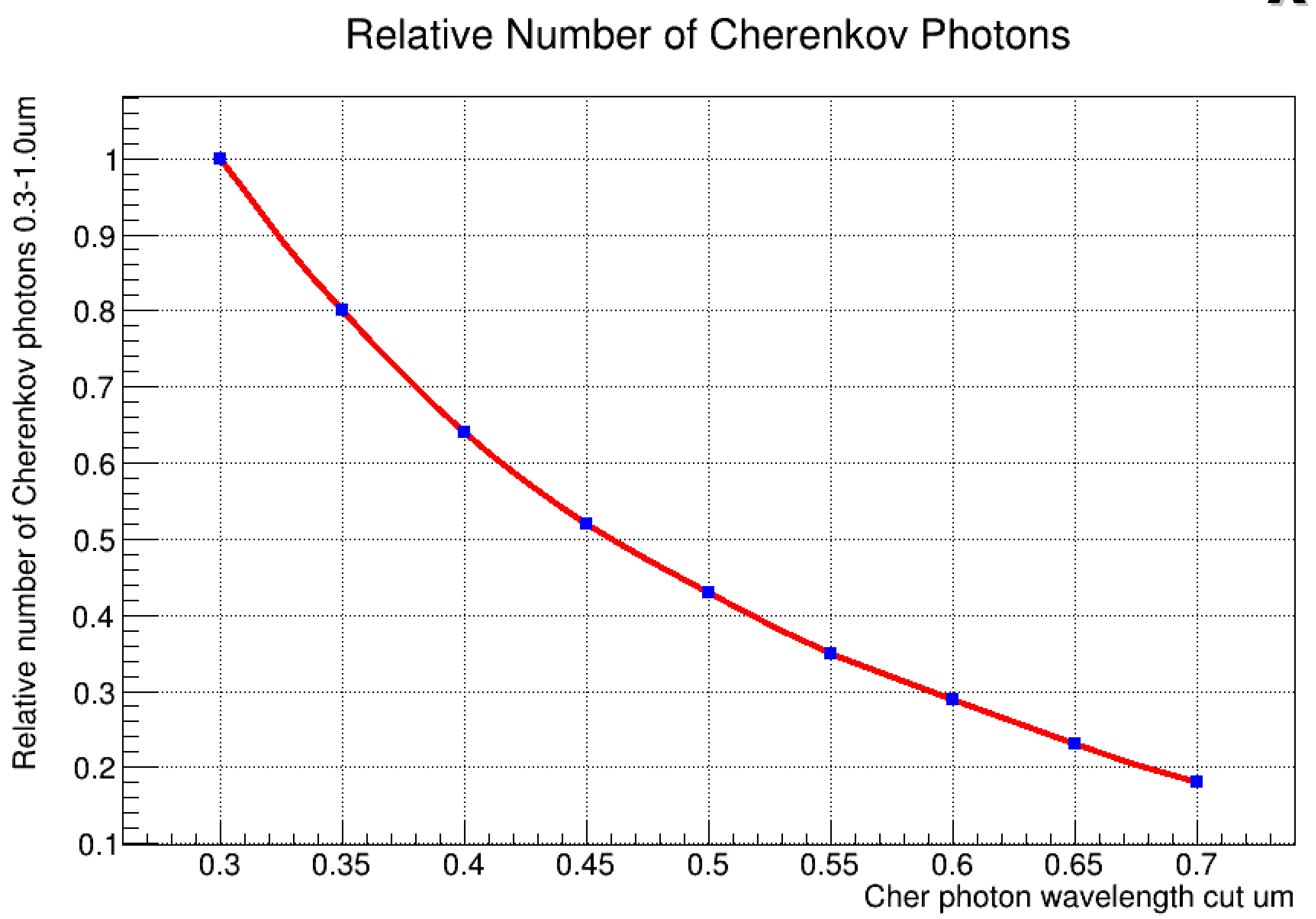
Muons

Cherenkov angle against momentum





λ um



Radiator with less dispersion

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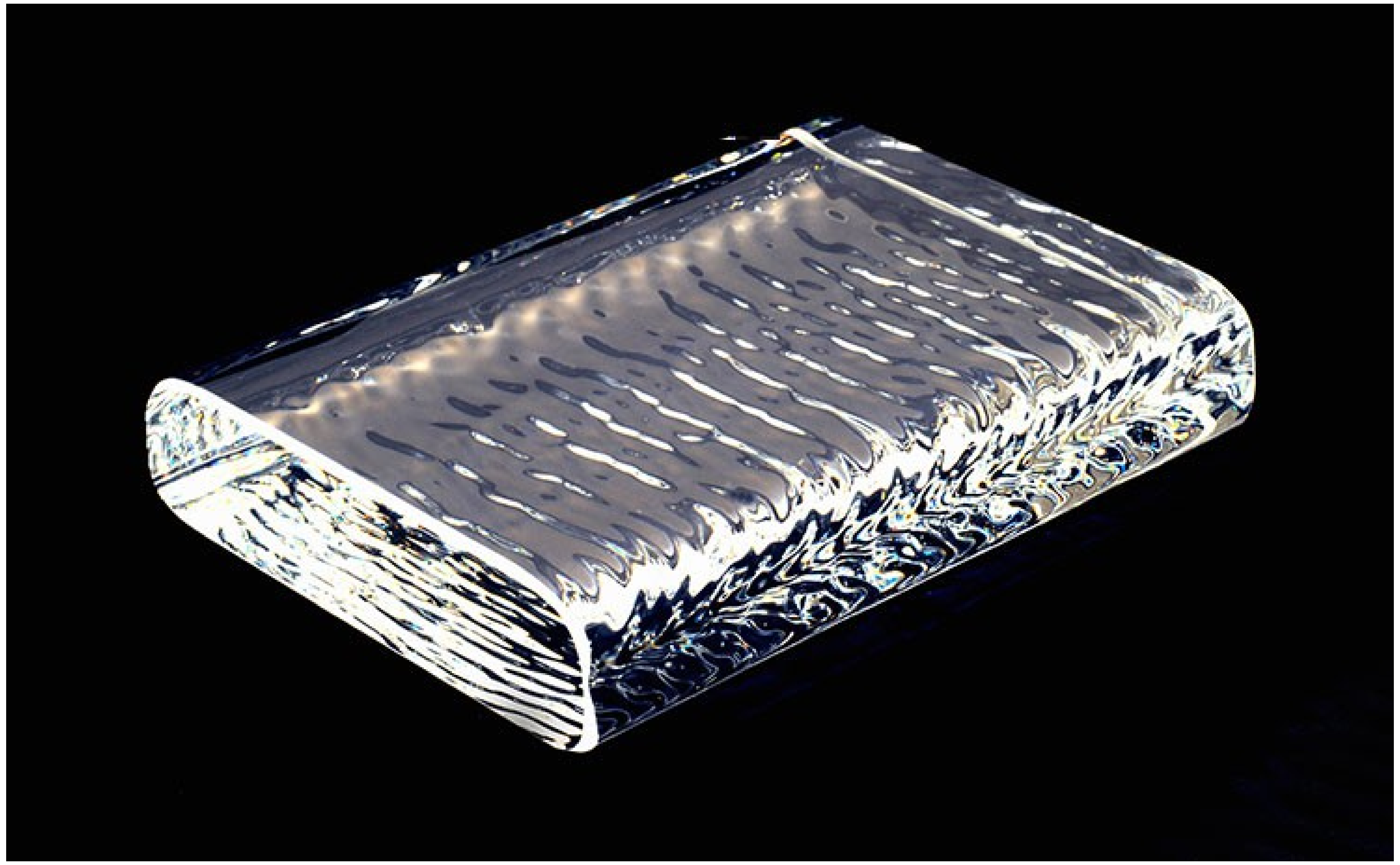
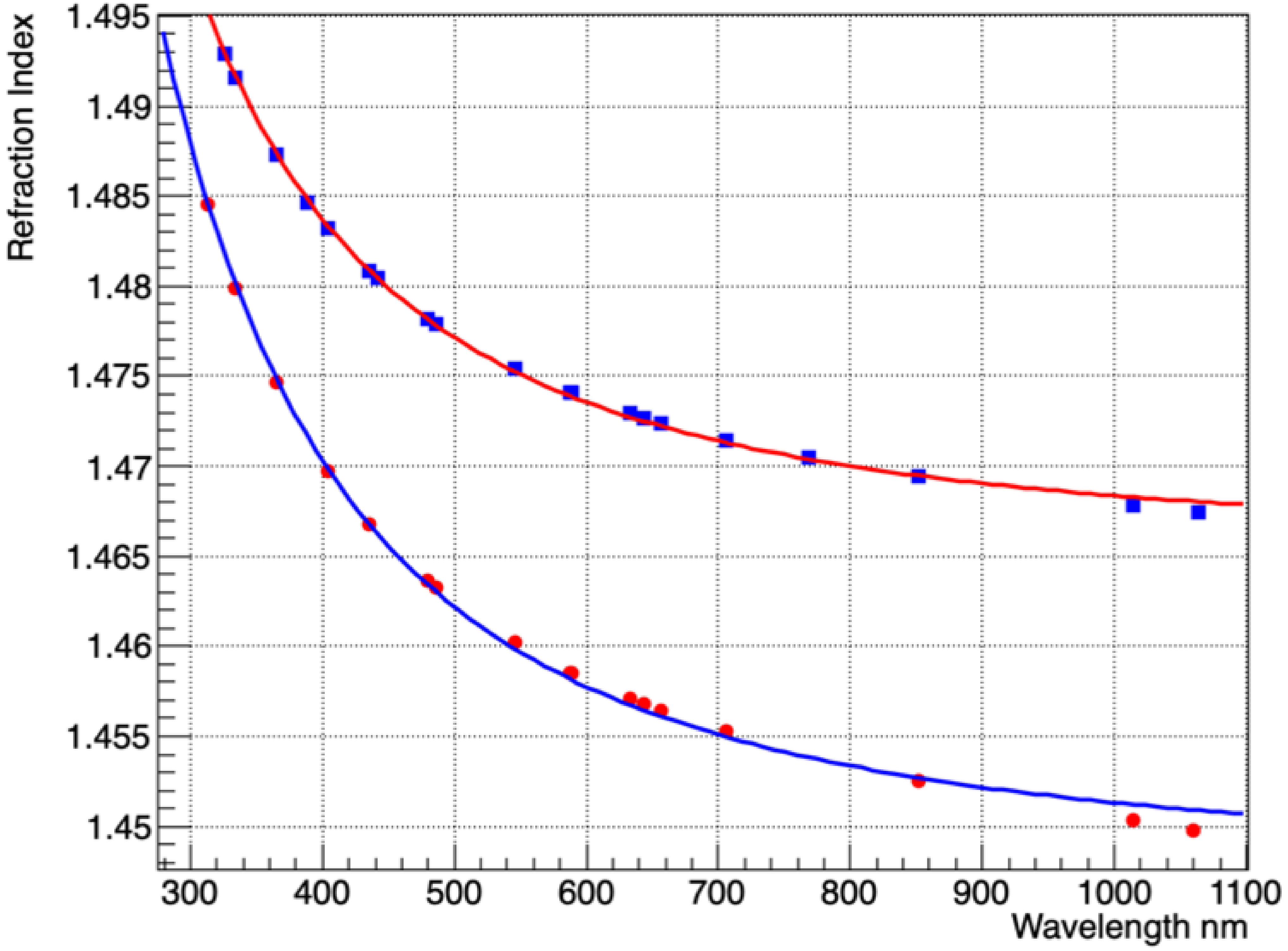
Nikon i-line Glass

https://www.nikon.com/





One of main components that restricts DIRC angular resolution is radiator dispersive medium while in case of disc DIRC one can go into LiF bars to correct the Cherenkov angle, here we might try to use a material with small dispersion

In both cases the radiation hardness could come in game

Nikon iGlass(blue points) and SiO_2(red points) Refractive Index against photon wavelength, such a radiator could already minimize color dispersion 1-2 mrad at creation compared to quartz one

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The color dispersion, ways to overcome

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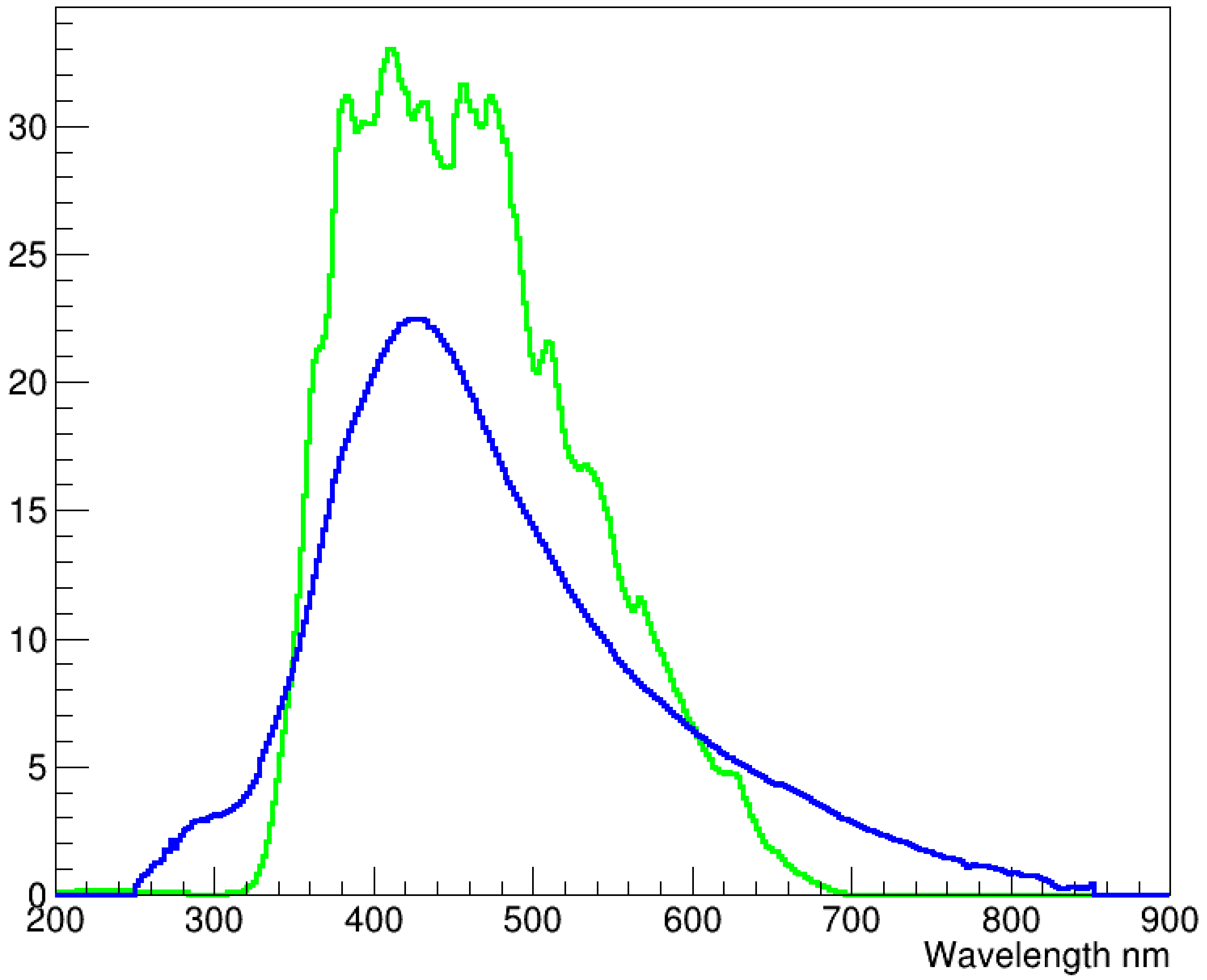
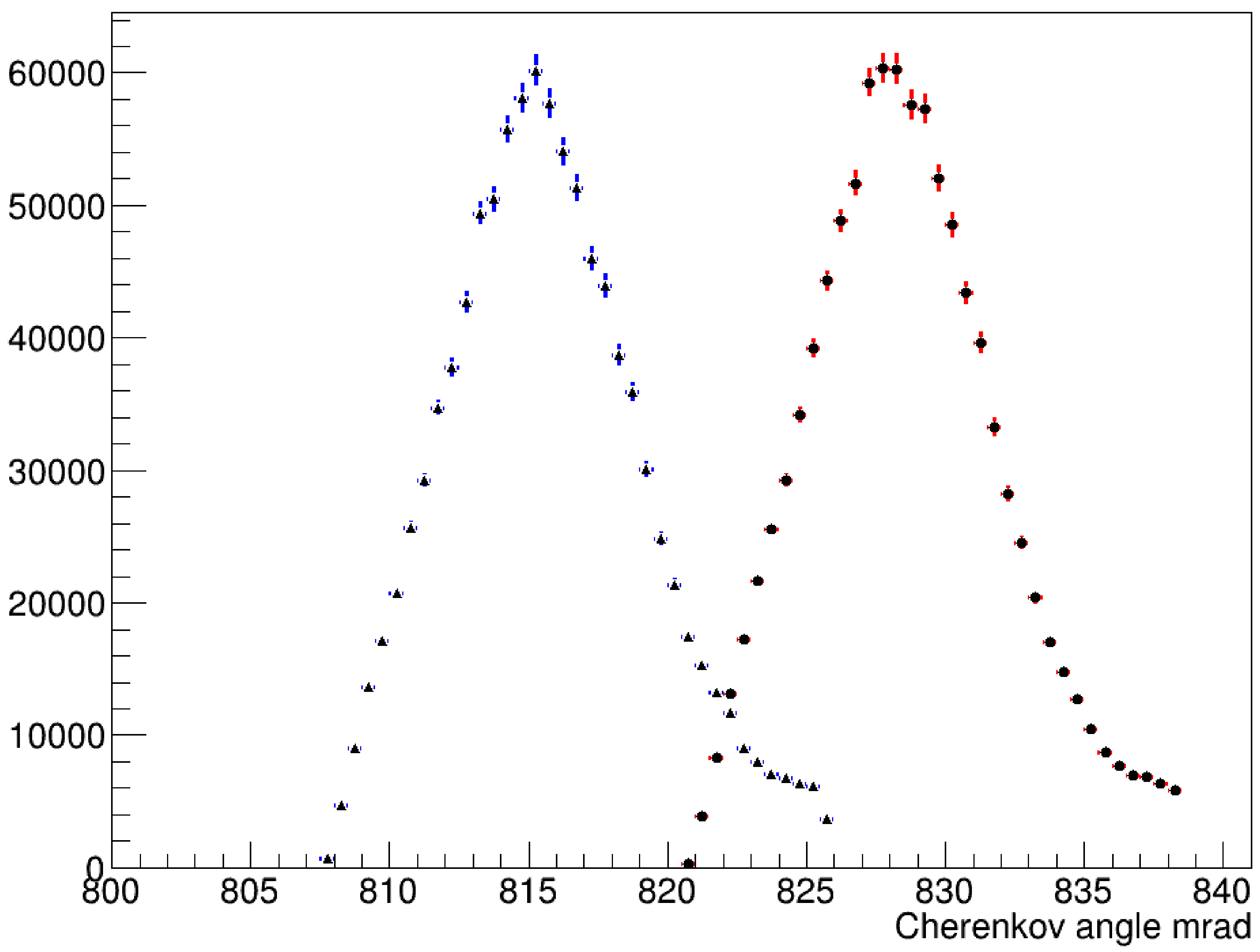
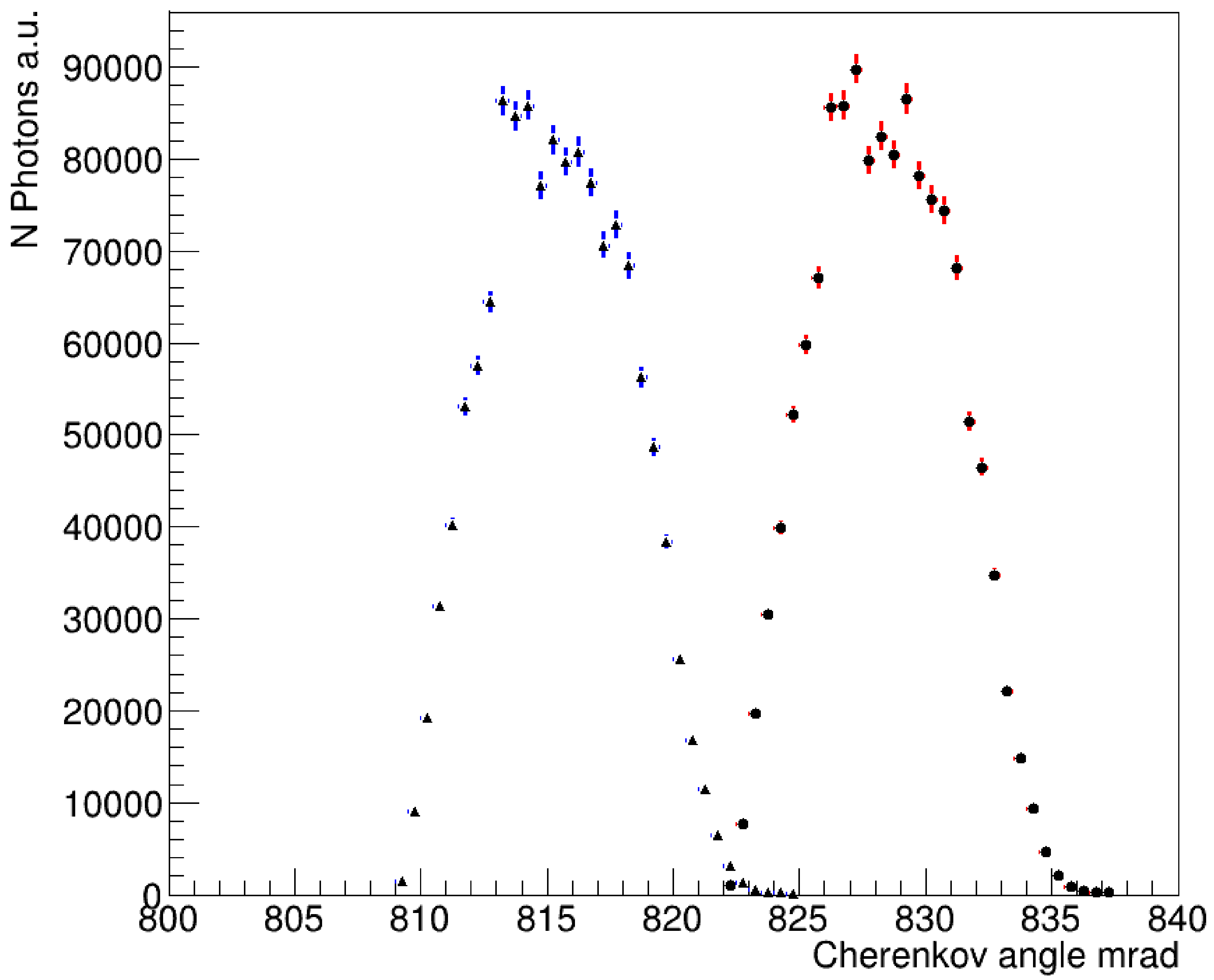






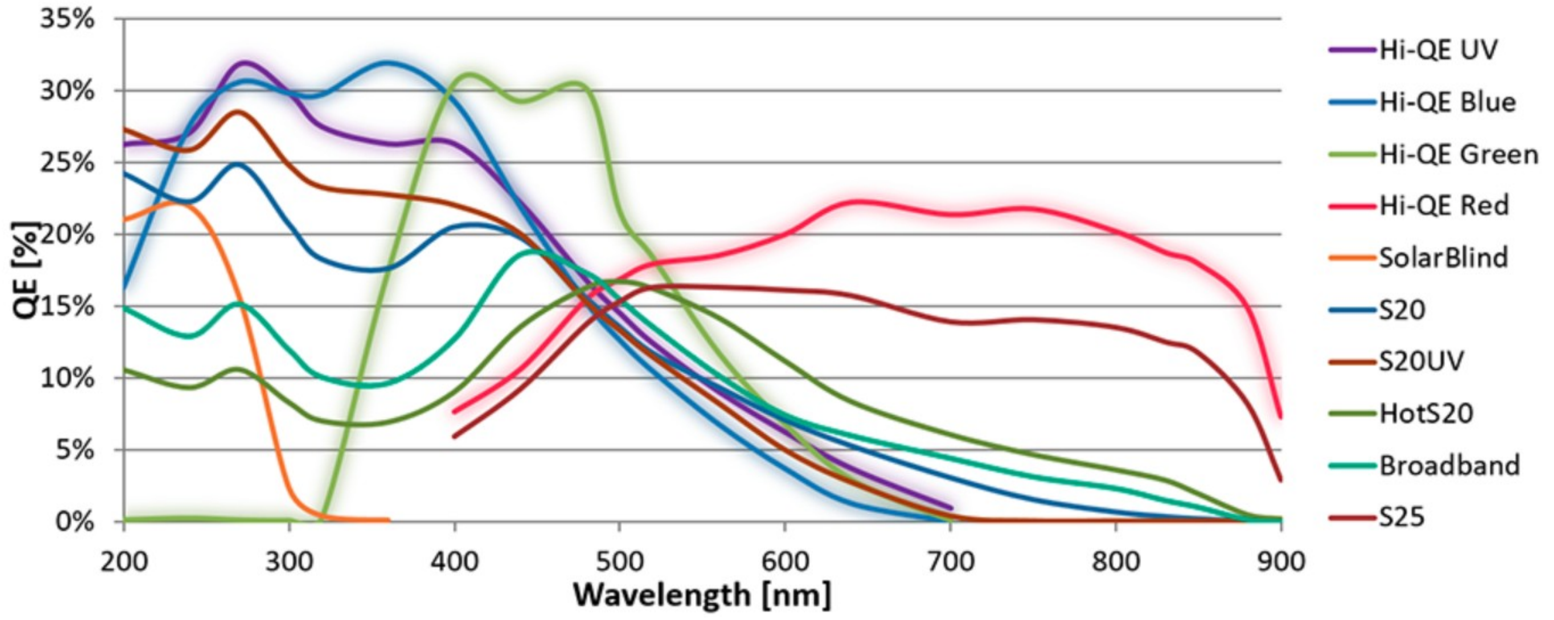
Even small restriction of wavelength interval,
here our both MCP-PMTs QE against wavelength
helps to reach a bit better separation

But if one can get Planacon MCP-PMT or
SiPM like red cathode
MCP's from Photonis this will ease
the job significantly

See here for Photonis new development

https://www.photonis.com/products/hi-qe-photocathodes

Cherenkov Photons emission angle spectra from
4 GeV/C Pions(right)
and Kaons(left) weighted with Photonis
Aqua(blue curve in left) QE



Cherenkov Photons emission angle spectra from
4 GeV/C Pions(right)
and Kaons(left) weighted with Photonis
Green(green curve in far left) QE

For better separation then it will be a must:

-go into red side(High-QE Red is a candidate)

-use less disperse materials

-use fast photon timing to perform a correction

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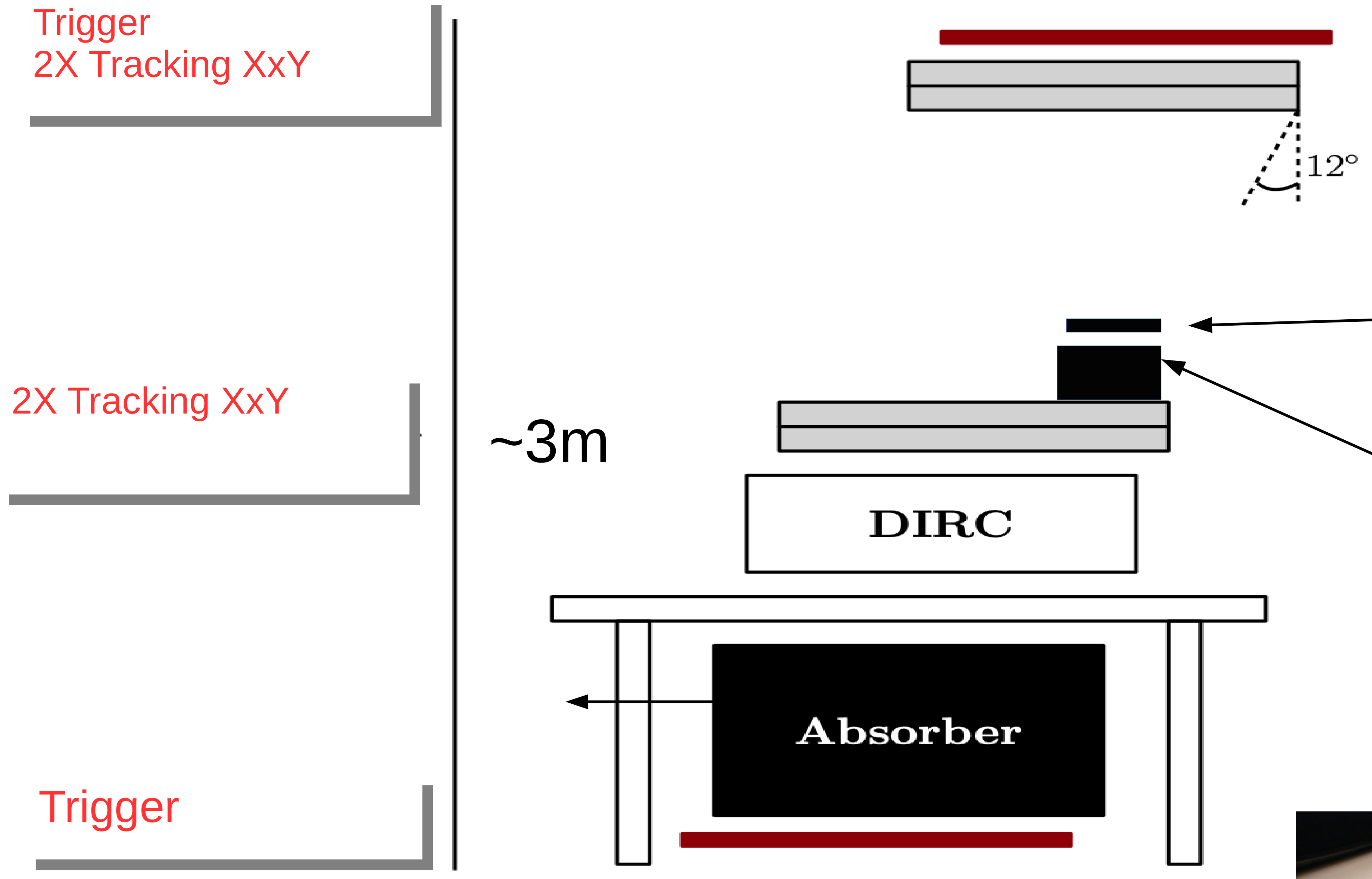
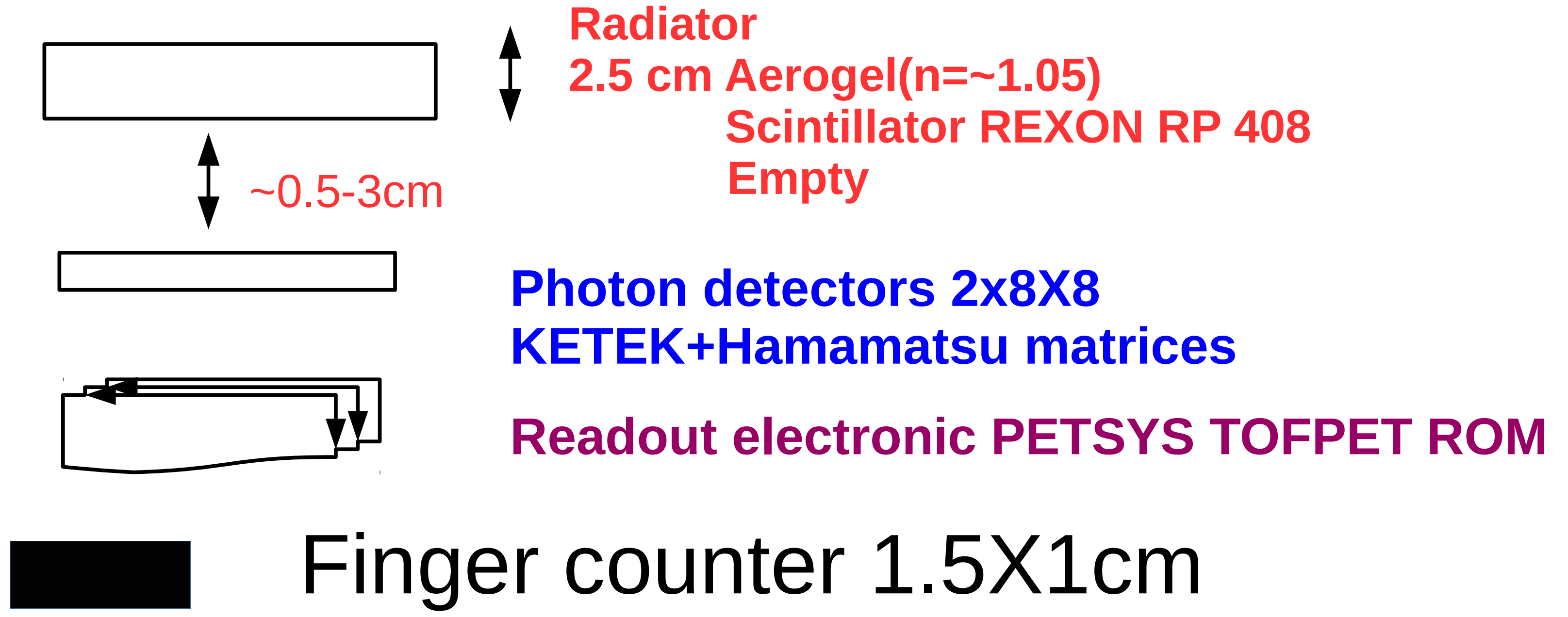
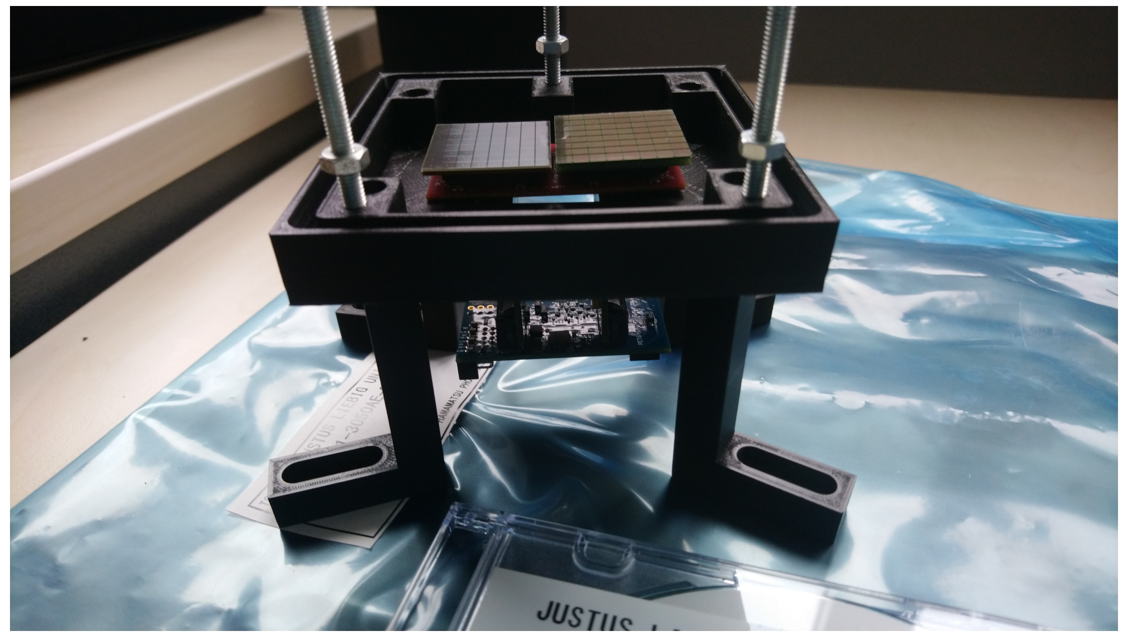
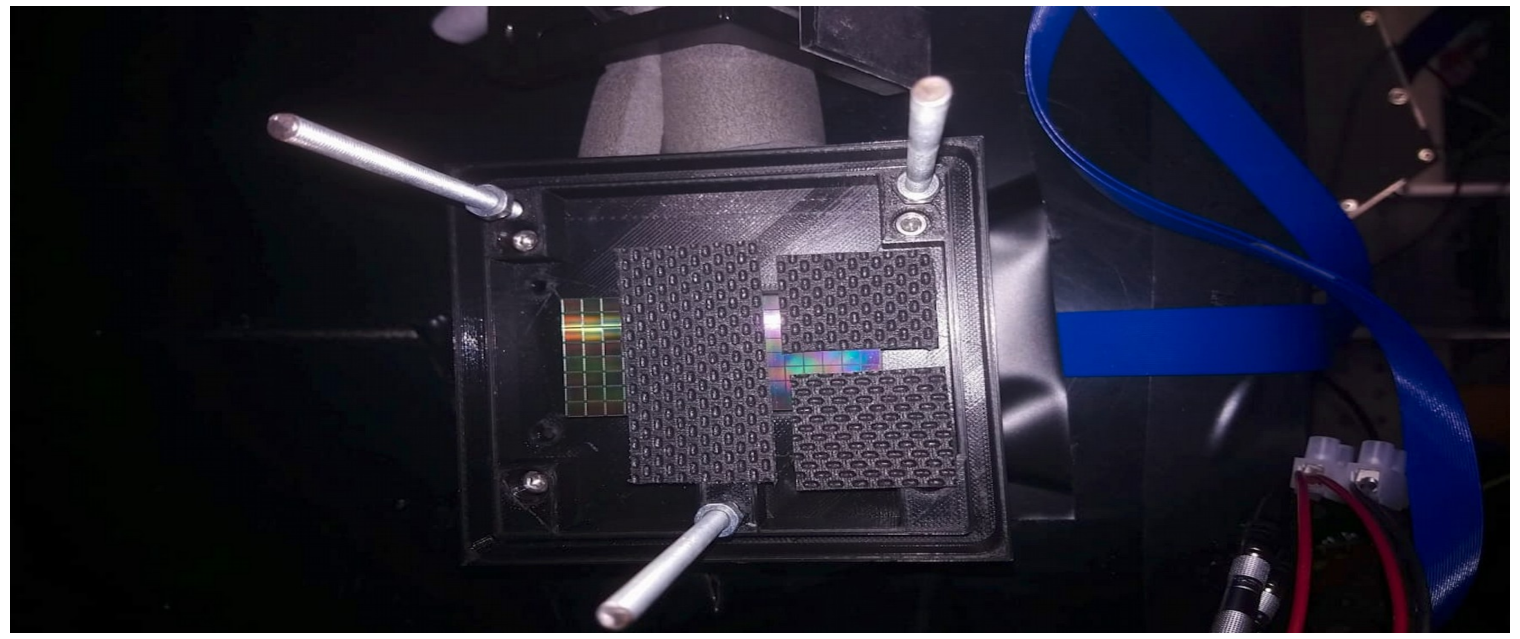
The Giessen Cosmic Station(GCS), miniGCS Configuration for photon detector tests







WO Mask



Mini GCS with Mask on
WO radiator and cover

Details for Giessen Cosmic Station(GCS)
https://iopscience.iop.org/journal/1748-0221/page/extraproc89
for TOFPET
https://www.petsyselectronics.com/web/
for KETEK
https://www.ketek.net/
For Hamamatsu
https://www.hamamatsu.com/eu/en/index.html

Radiator comparison

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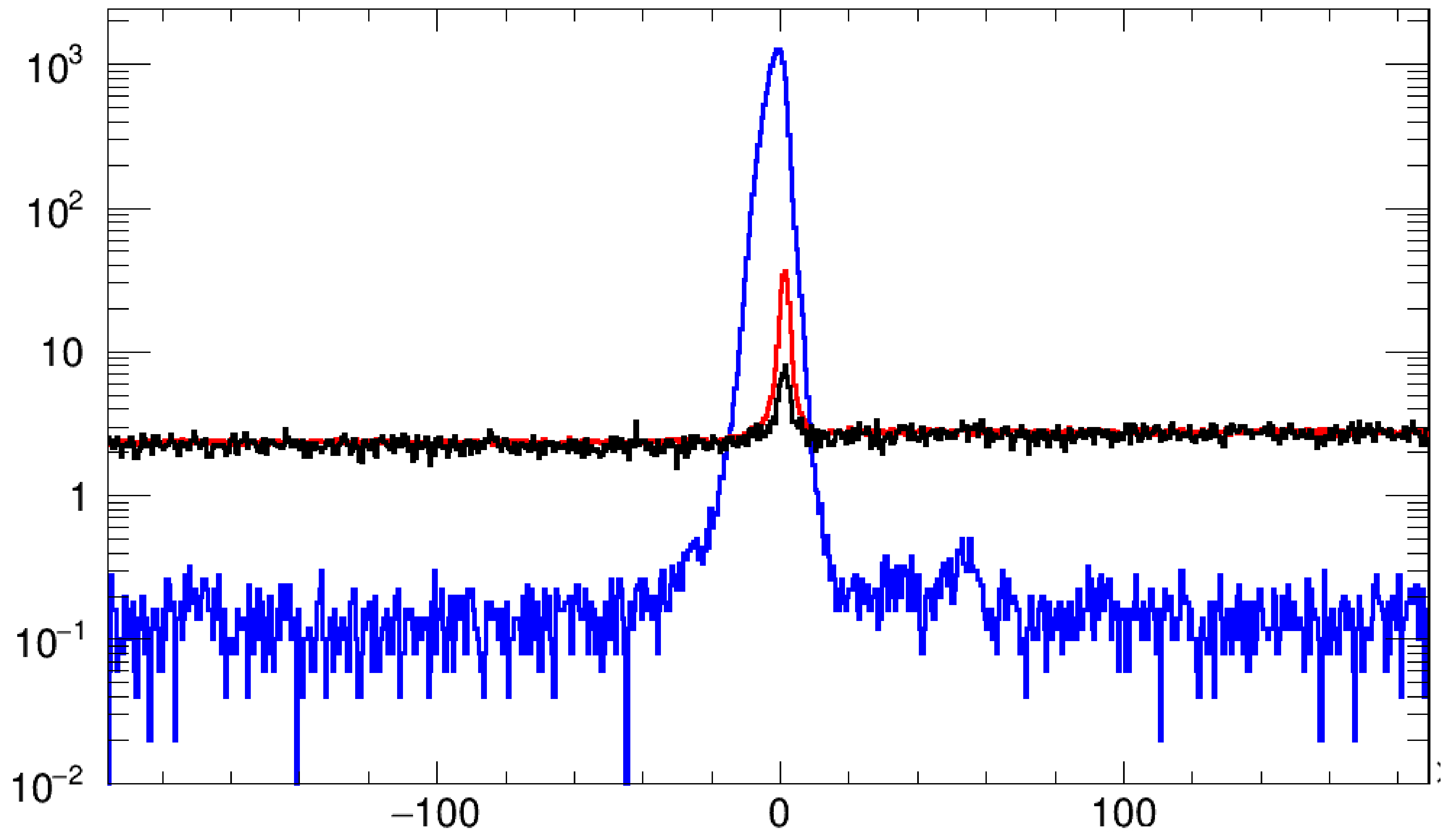

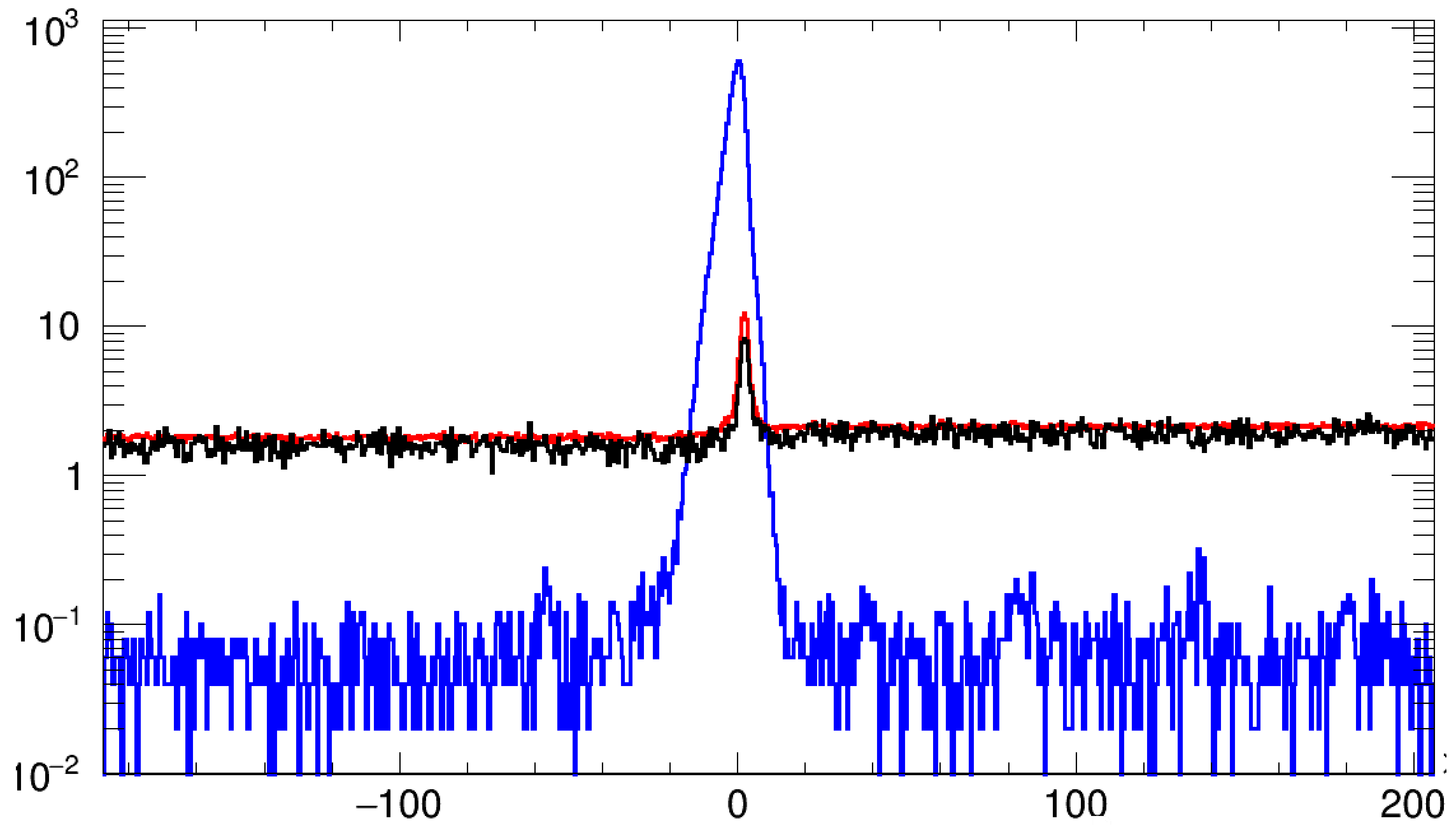

Hodoscope Box time – miniGCS Time ns

Left side is for Hamamatsu , right is for KETEK

Blue is from Scintillator

Red is from Aerogel

Black is for Empty Runs

Normalized for 30 min RUNS

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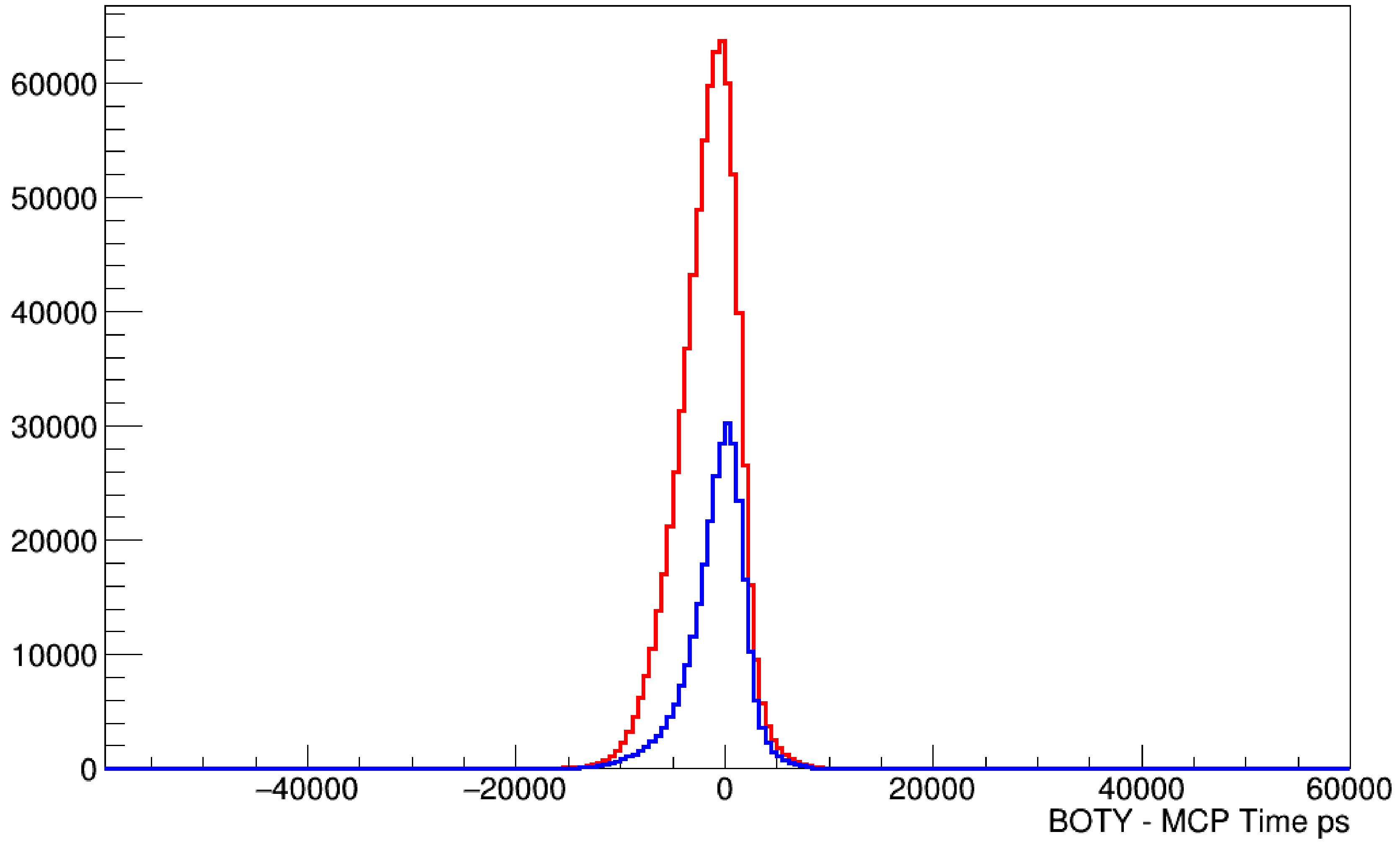
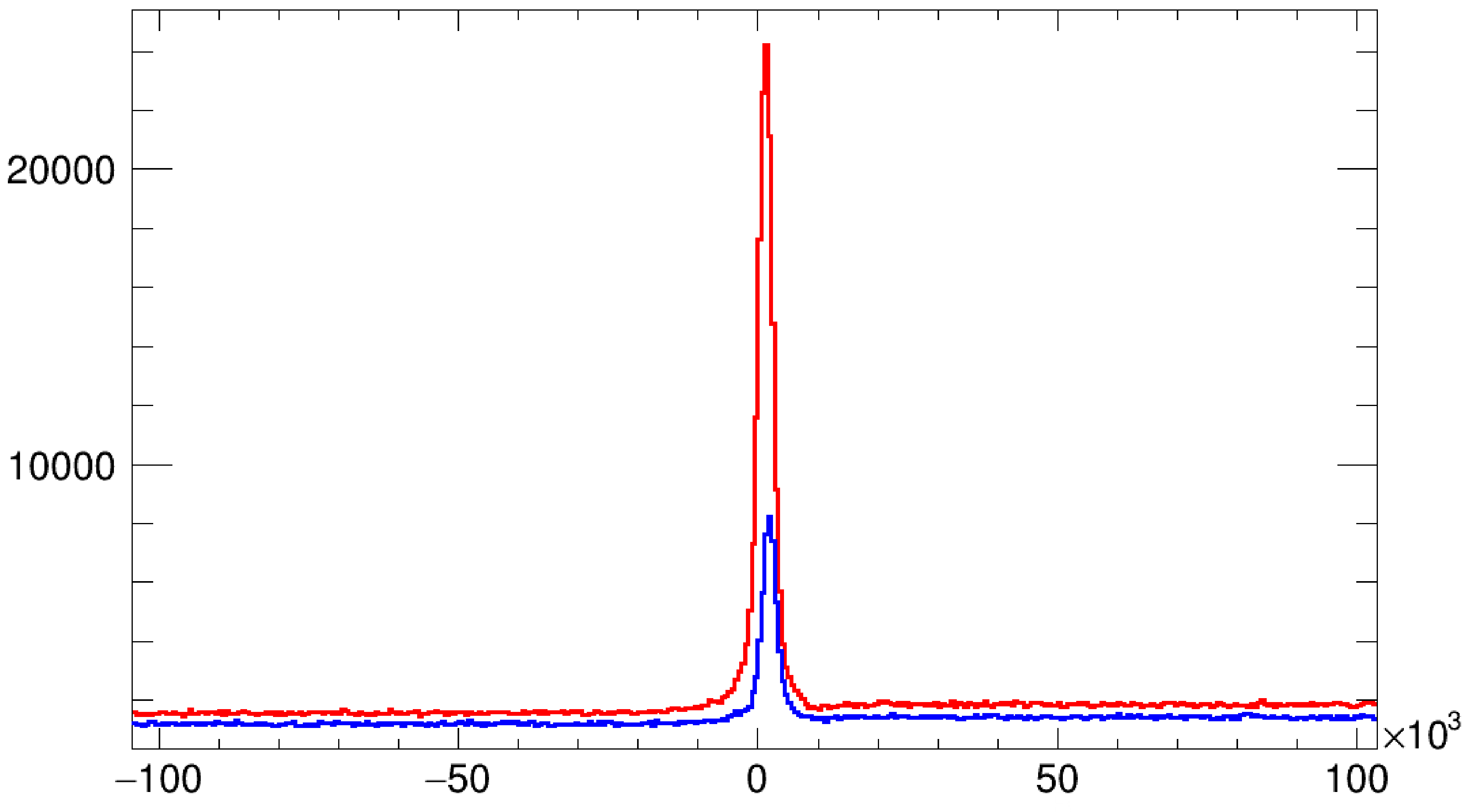
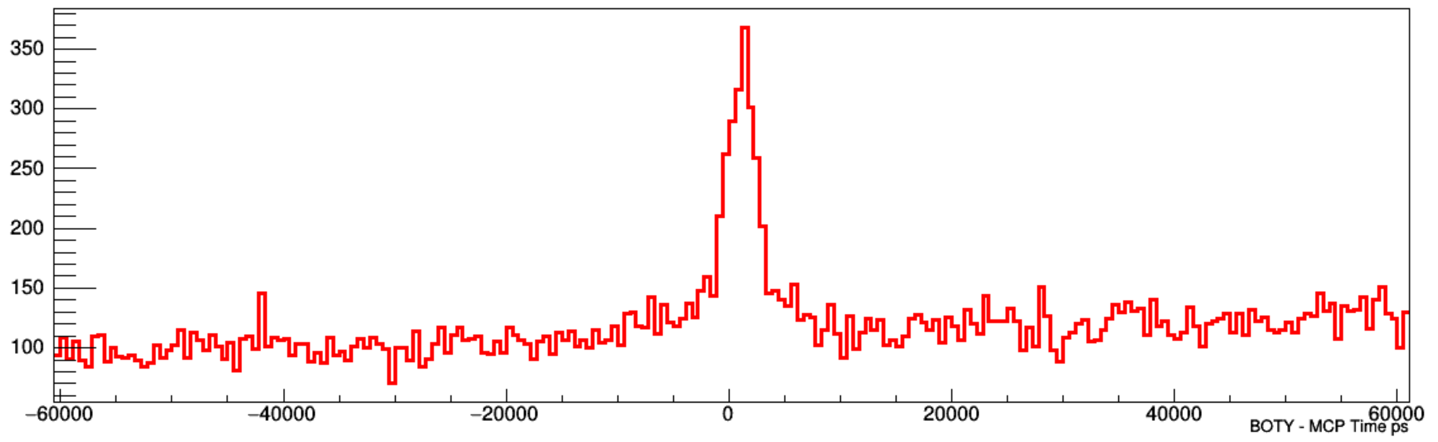
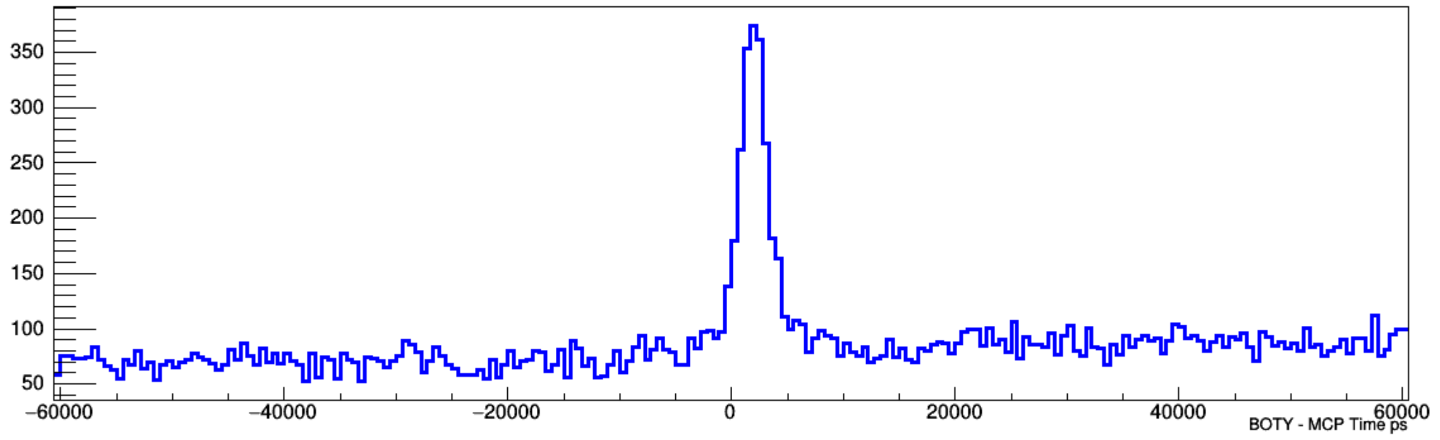
Detector comparison









Red is from Hamamatsu, Blue is from KETEK

Scintillator

Aerogel

Empty

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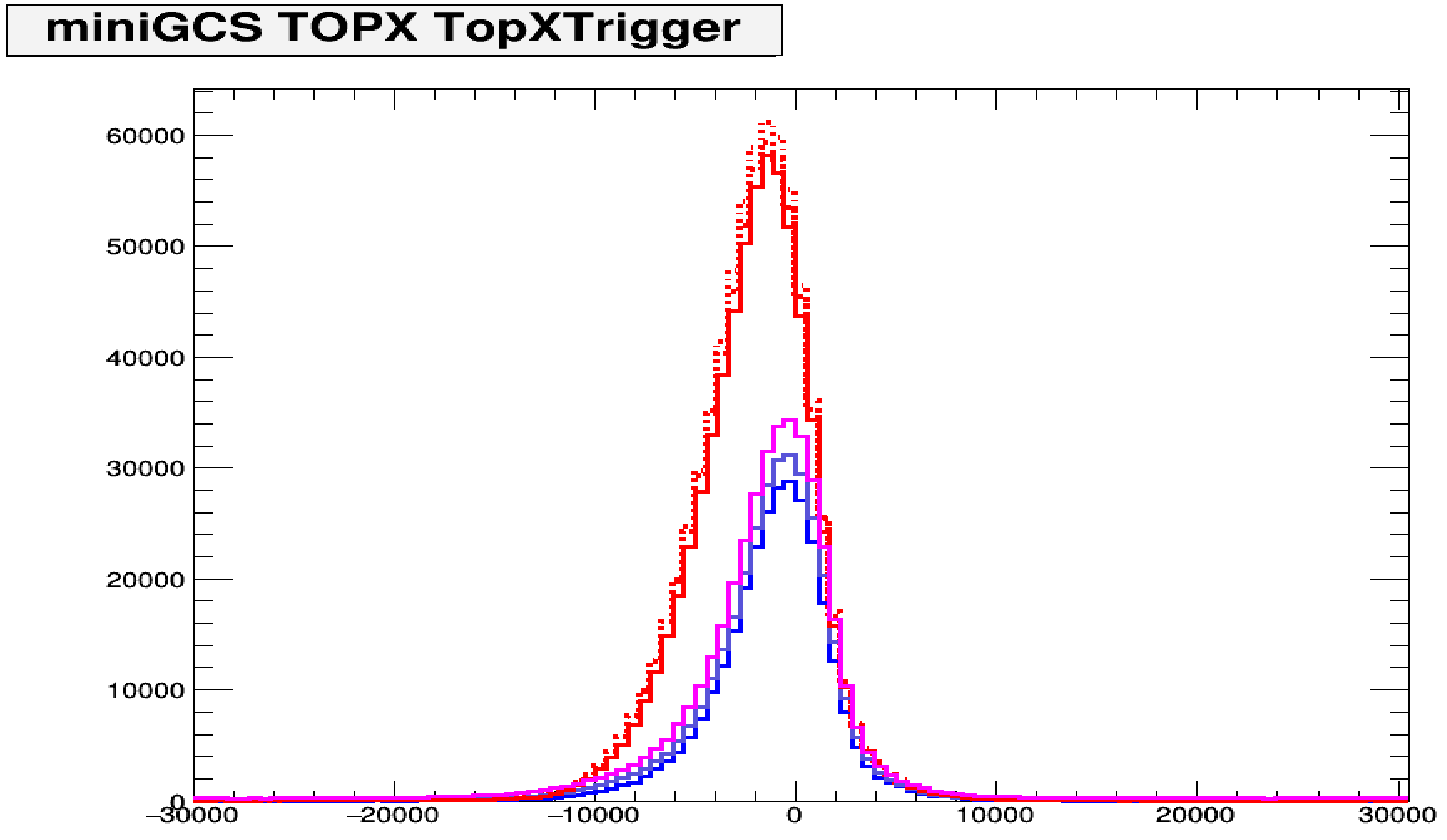
Comparisons



Hamamatsu 57.6 Volt
3 Runs
Overvoltage 3Volt

KETEK
31.5, overvoltage 3Volt
32.0, 3.5
32.5, 4 Volt

The difference between KETEK and Hamamatsu
Cannot be explained by overvoltage

And here are the numbers for Radiator, Signal/Noise, Hamamatsu/KETEK

Aerogel
- Hamamatsu Signal/Noise = 4.58
- KETEK Signal/Noise = 1.83
- HamamatsuSignal/KETEKSignal = 3.25

Scintillator
- Hamamatsu Signal/Noise = 1468.7
- KETEK Signal/Noise = 1440.4
- HamamatsuSignal/KETEKSignal = 2.43

“Empty” Target
- Hamamatsu Signal/Noise = 0.886
- KETEK Signal/Noise = 1.26
- HamamatsuSignal/KETEKSignal = 0.986

***The stat error is very small**

The good conclusion is that both matrices are seeing Cherenkov photons at room temperature (20°C)
Based on this numbers and the prices one can say in football language: after halftime the result is:

Hamamatsu	KETEK
1	1

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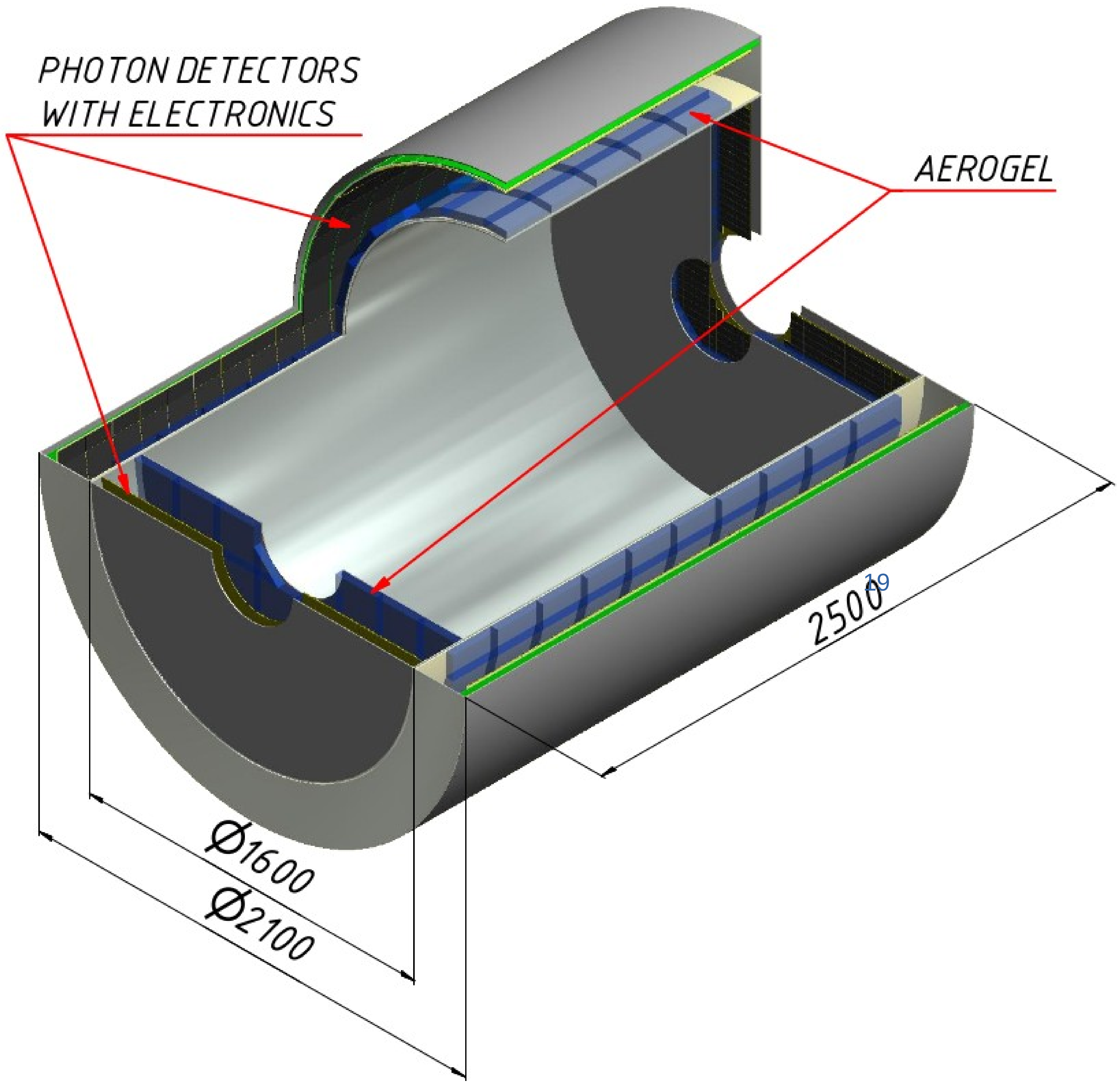
The FARICH option



Compact, hermetic design

Endcaps covering 10-40 and 140-180 polar angles

Barrel should cover 40-140 degree

4 layer of aerogel with different **n** for focusing

Fine pixelation for photon detection

Ability to operate inside magnet

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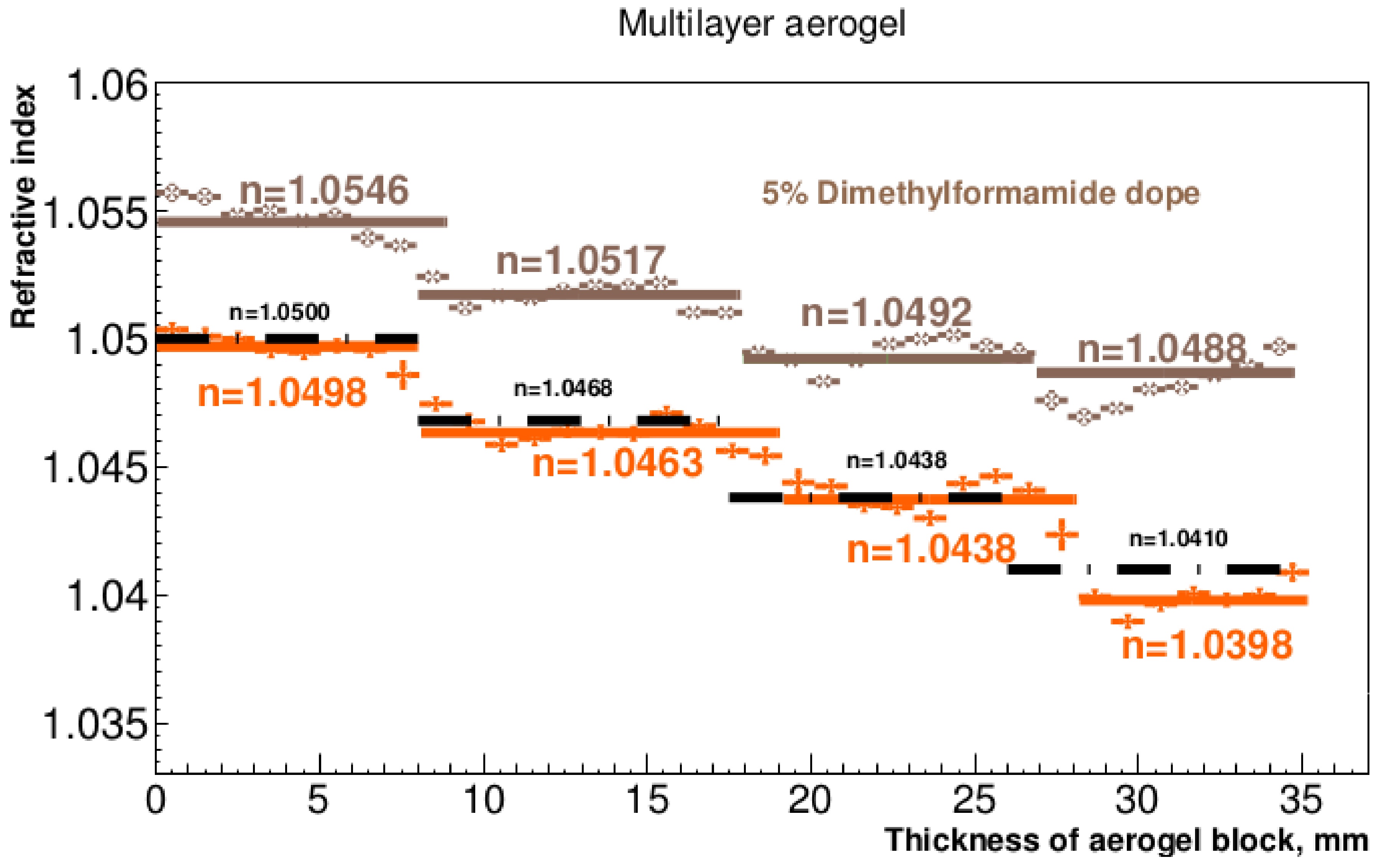
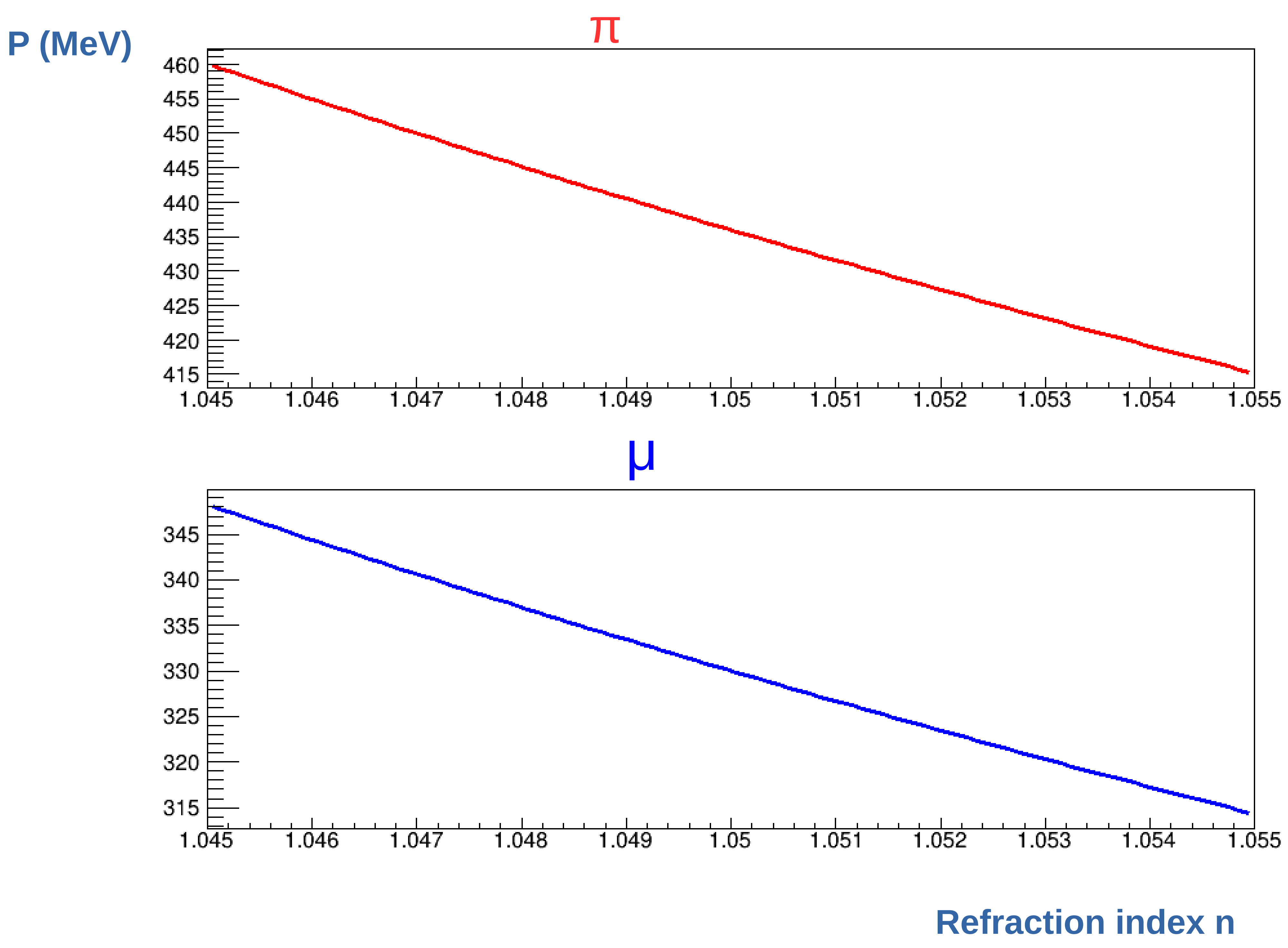
The "entry point" of FARICH, the 4layer aerogel radiator



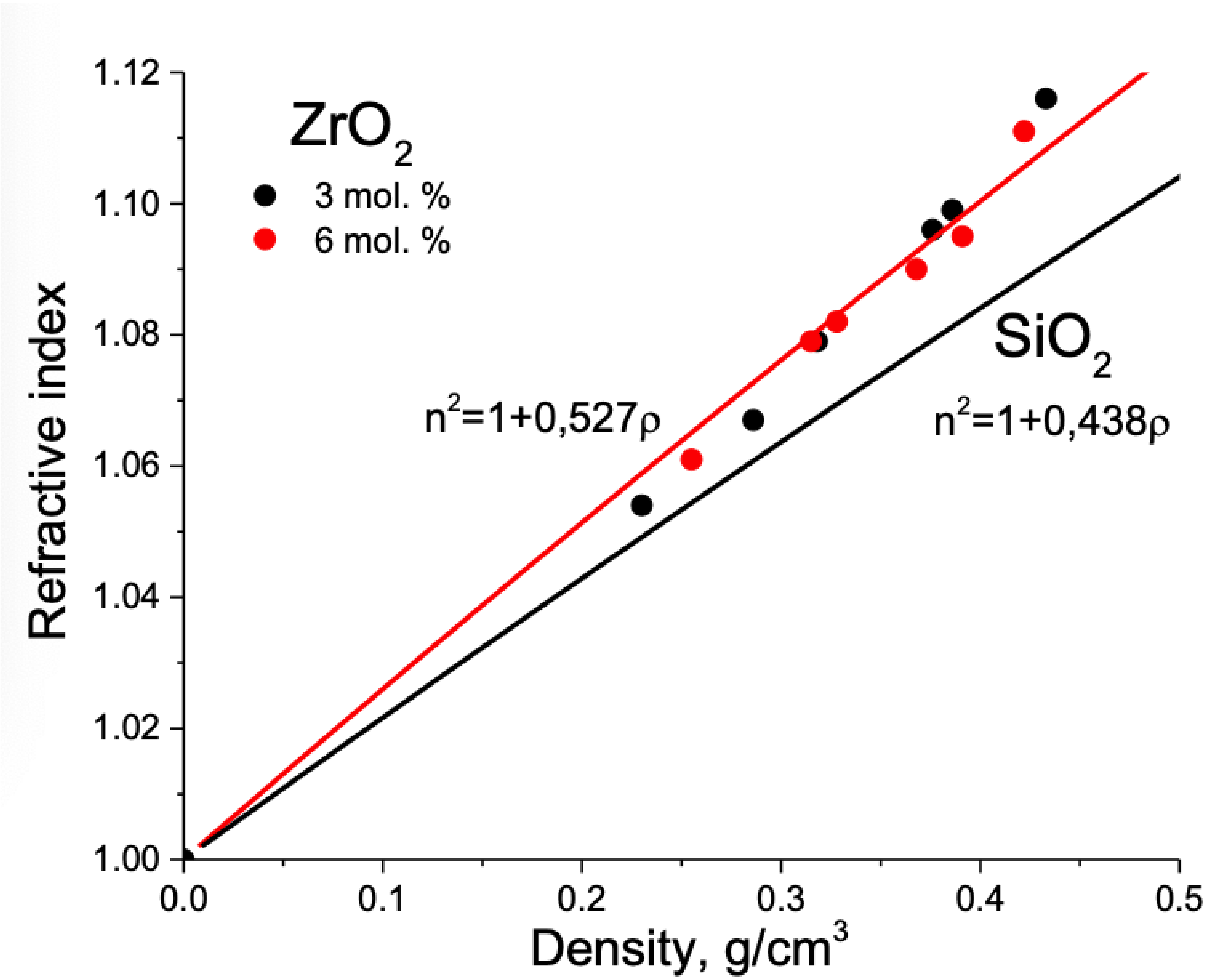
But the aerogel with n=~1.05 makes the threshold for **μ π** higher



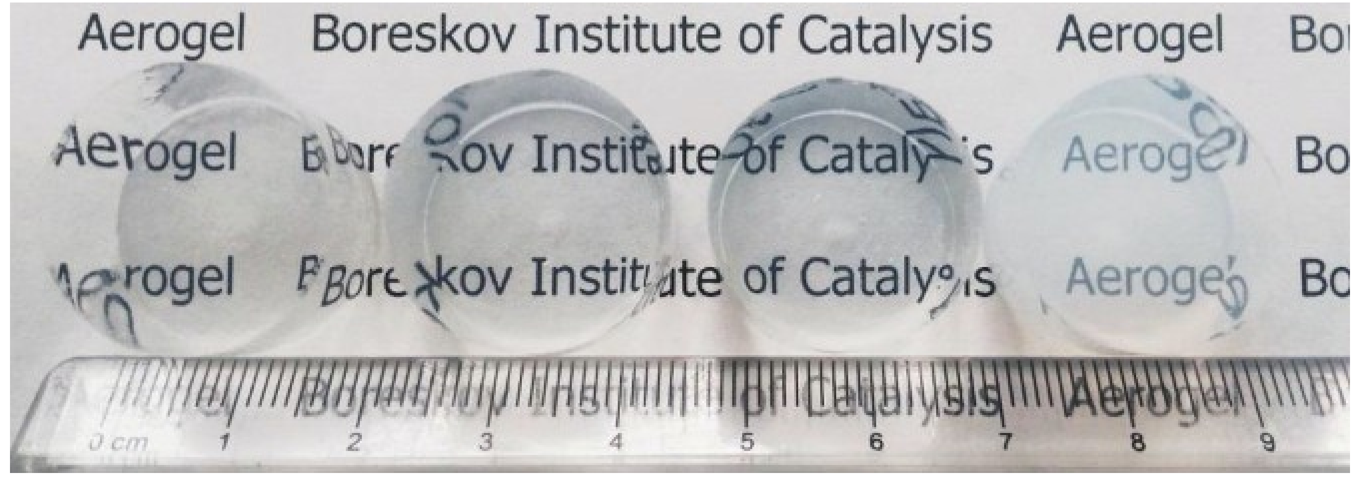
Most likely this configuration will be built in a new prototype

For the final detector RD for aerogel is also underway

The "entry point" of FARICH, the 4layer aerogel radiator



the aerogel with n=~1.12 will make threshold for
μ π significantly lower



Examples of the new aerogel with higher n

The publication

Ceramic International 47 (2021) 9585-959

The FARICH complete prototype under constructtion

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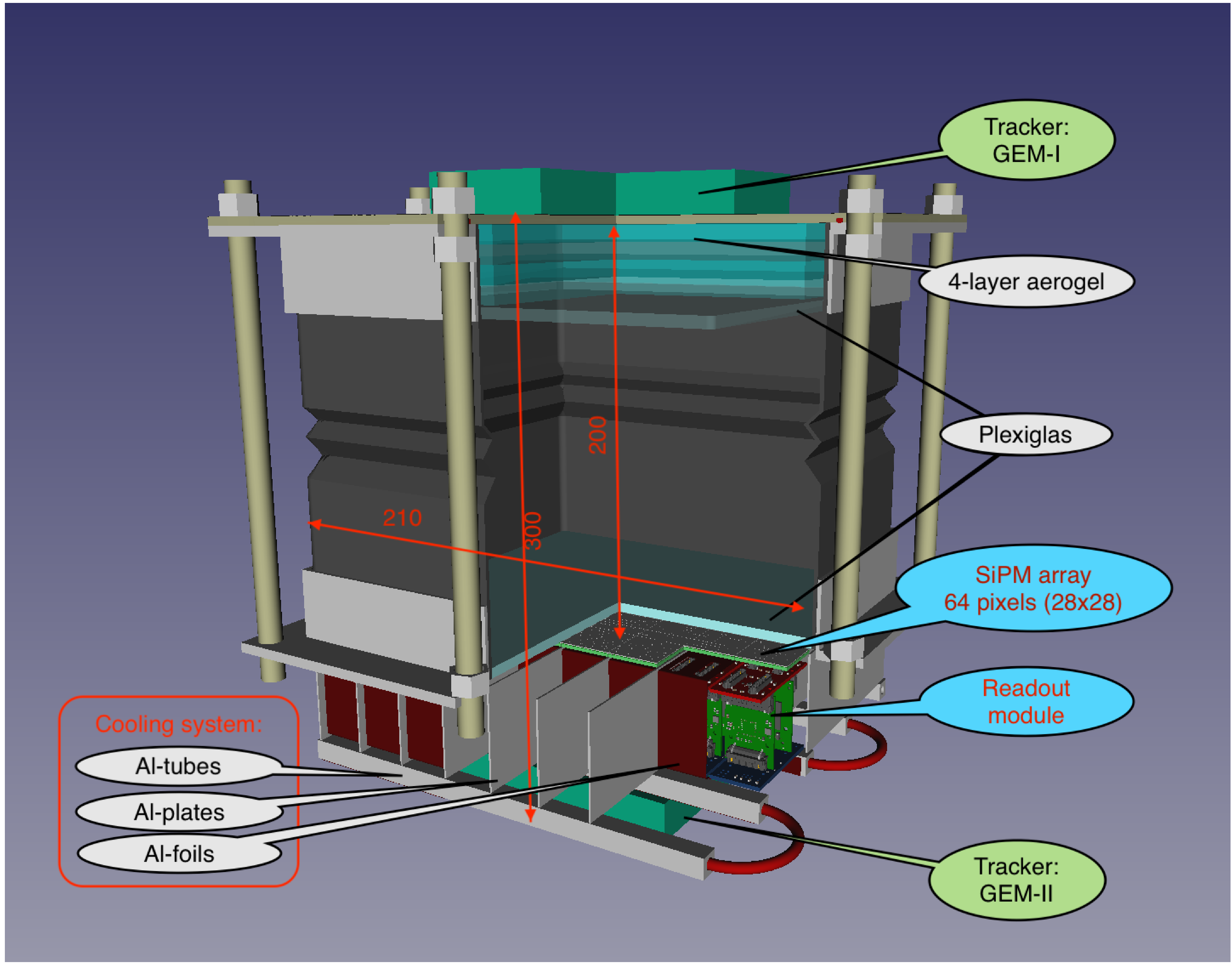
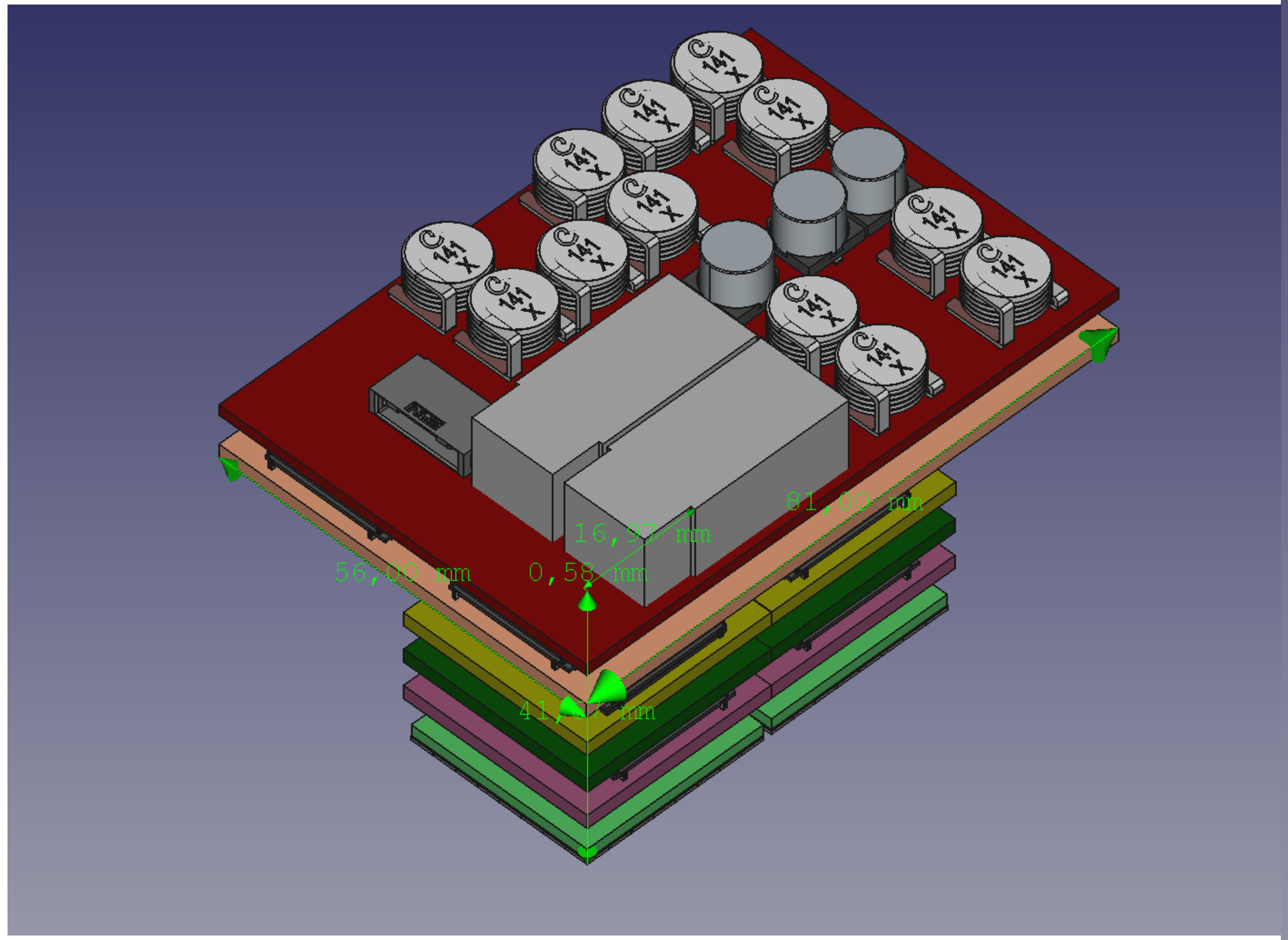
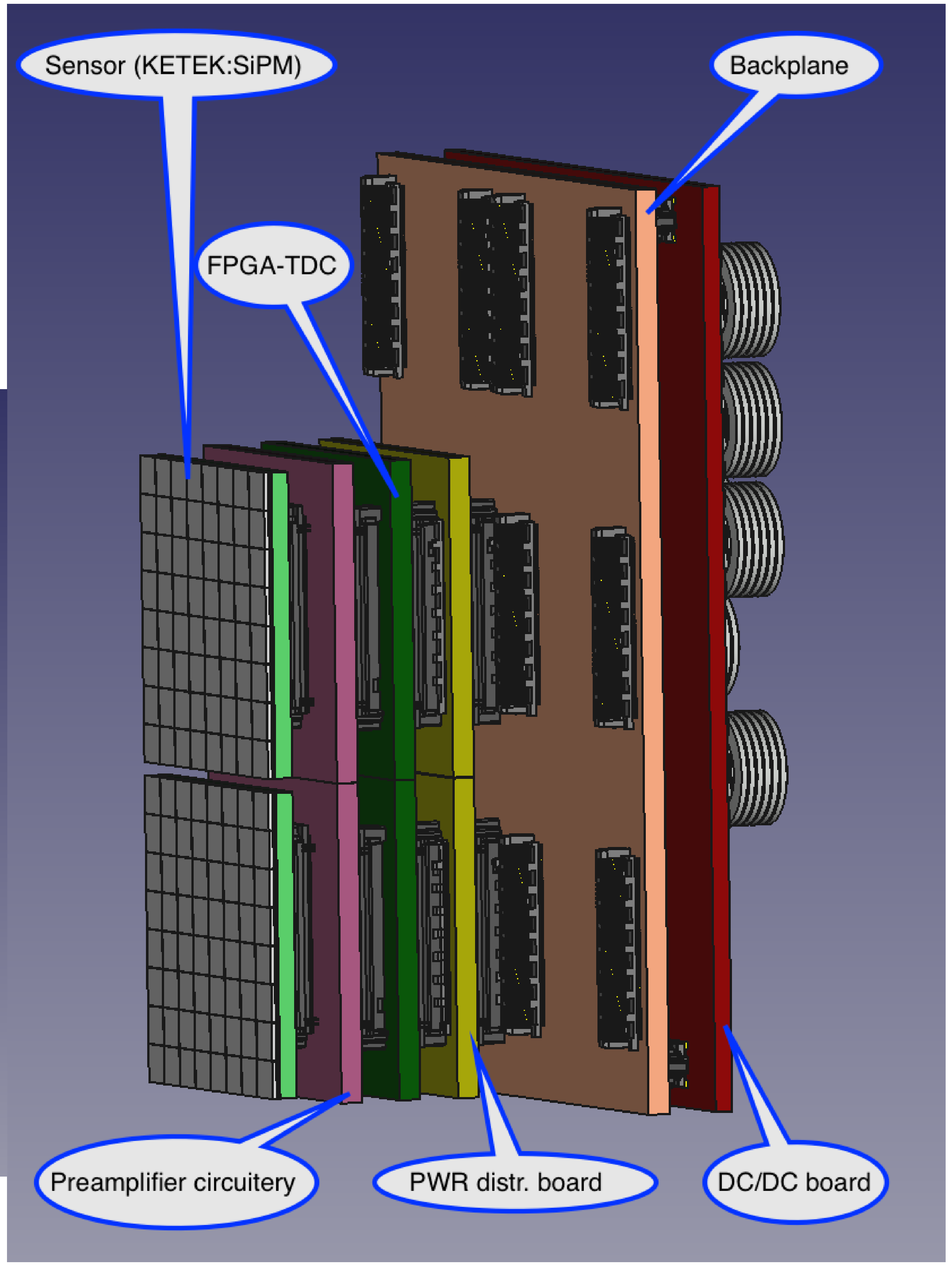
- photon detector area ~21X21cm, almost the same size as in “proof of principle” setup at CERN
- 4 layer of aerogel 10X10cm with focusing
- Simultaneous tests with different photon detectors(KETEK, Hamamatsu,SensL)
- This version assumes PETSYS ToFPET readout
- Compact isolated enviroment allowing cool-down of sensitive elements



The FARICH complete prototype under constructtion

- photon detector area ~21X21cm, almost the same size as in “proof of principle” setup at CERN
- 4 layer of aerogel 10X10cm with focusing
- Simultaneous tests with different photon detectors(KETEK, Hamamatsu,SensL)
- In this version the FEE is GSI development with data transfer via optical link
- Compact isolated enviroment allowing cool-down of sensitive elements



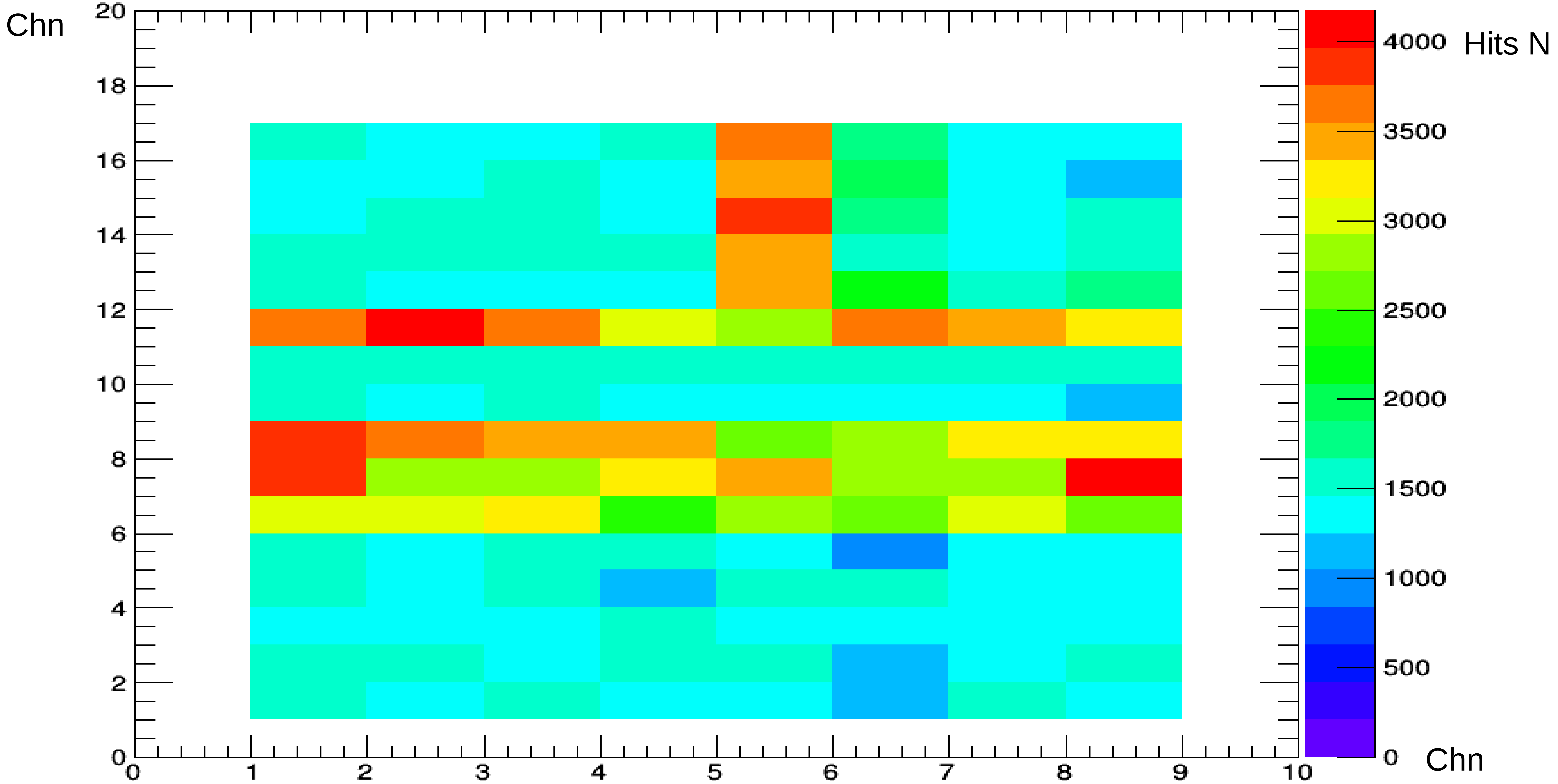


Conclusions

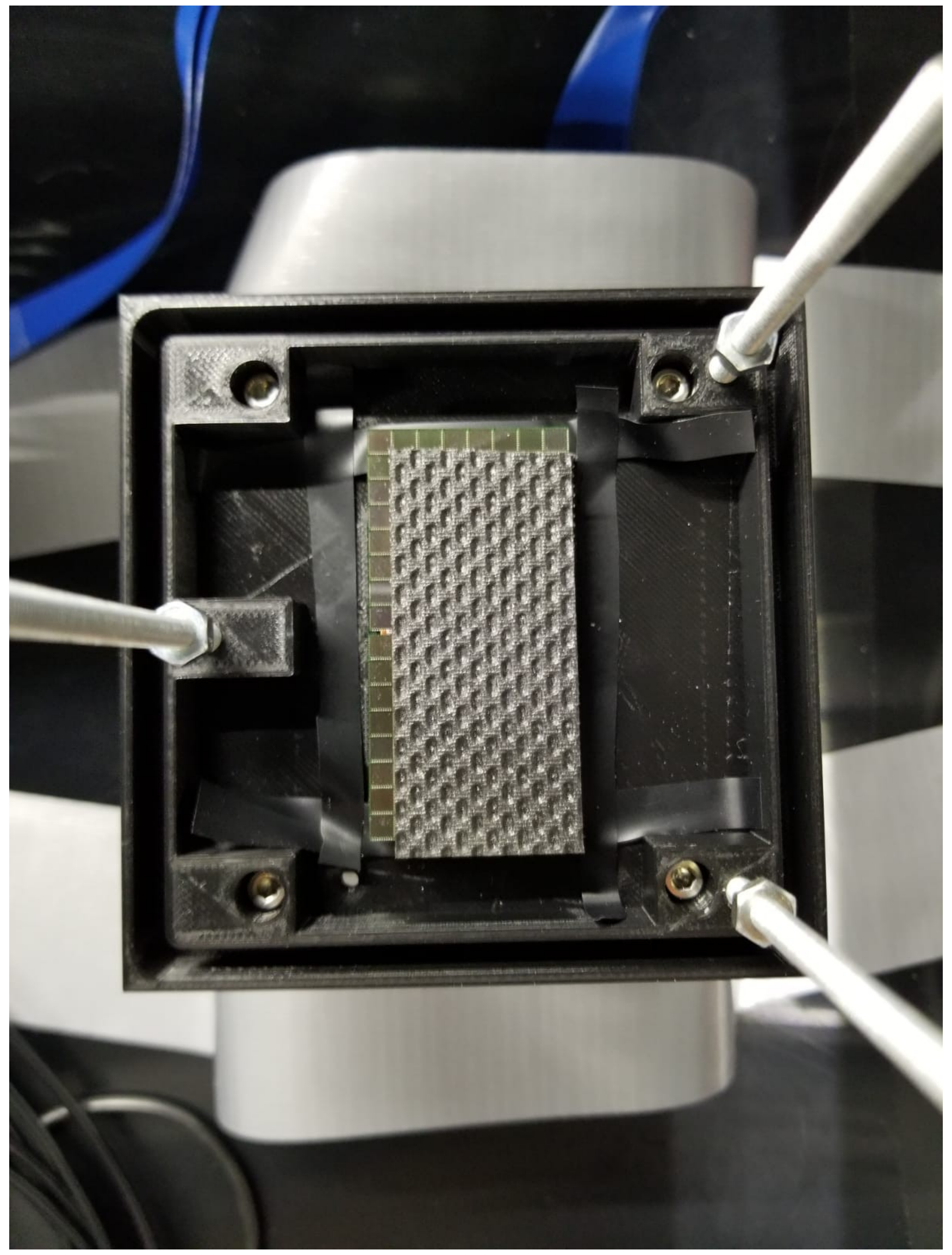
- The models of FARICH and fDIRC with certain novelties are build in GEANT system and optimization are ongoing, focusing optics,photon detector pixelation and many more
- Small prototypes already exist and are under tests in beam-line (FARICH) and using cosmic muons (fDIRC)
- The GCS first runs allowed to get first comparison points for a candidate photon detectors, analysis ongoing to get time resolutions
- There are ongoing efforts on both sides to get a full prototype to be built and test
- Stay healthy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072

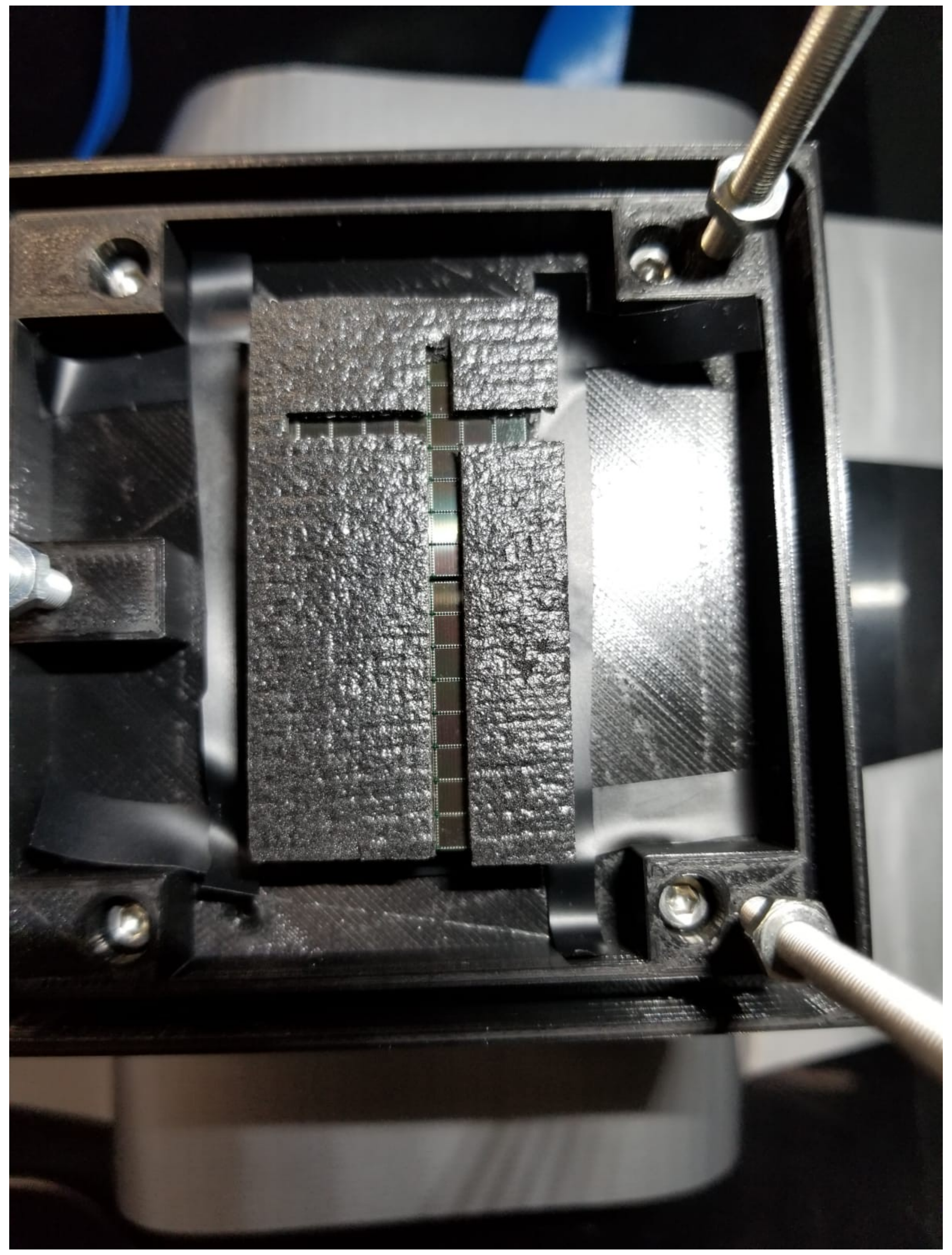
The “Mask” is reproducible
mapping is OK

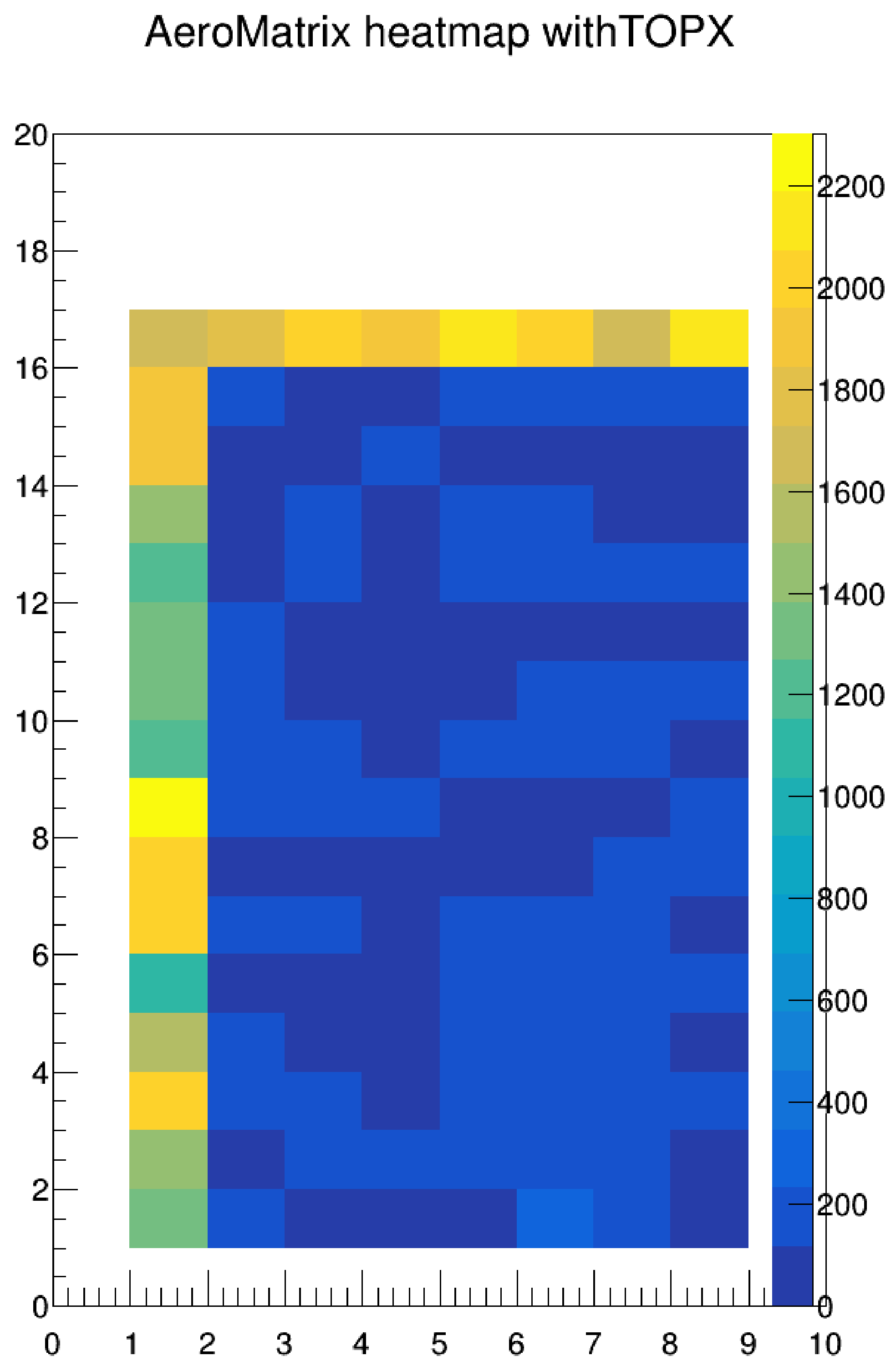


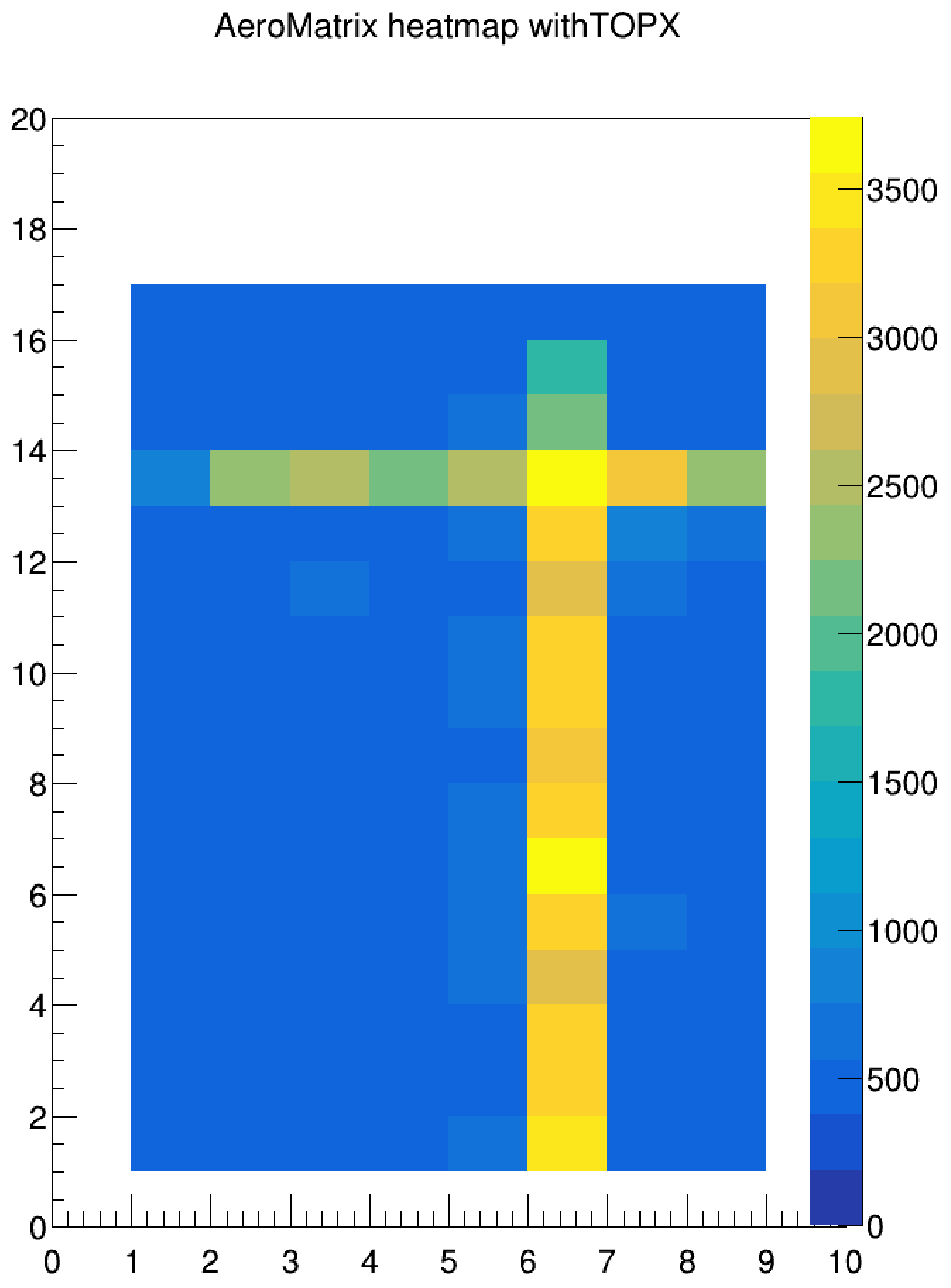
Photon detector candidate



KETEK 3X3 mm 8X8 two SiPM matrices are a good candidate for Photon detector
Already first checks was done to check their mapping







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