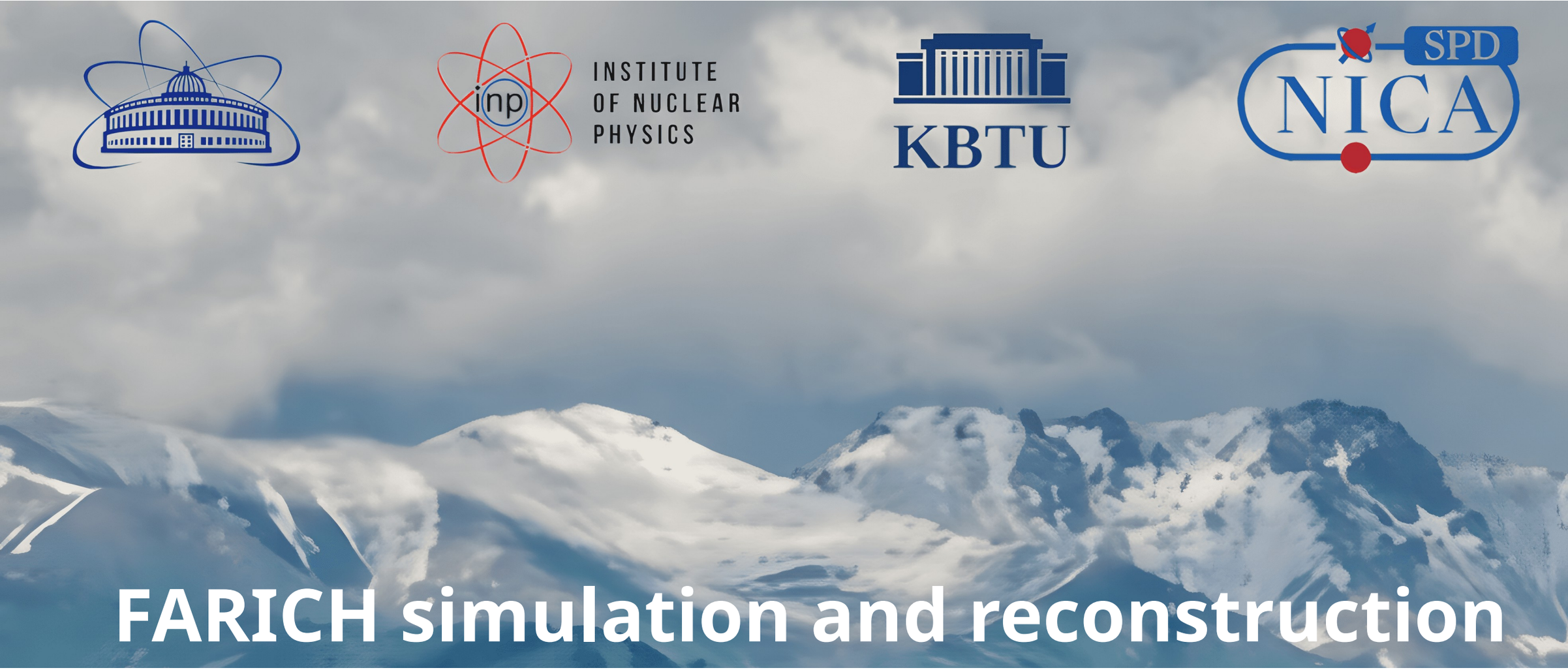
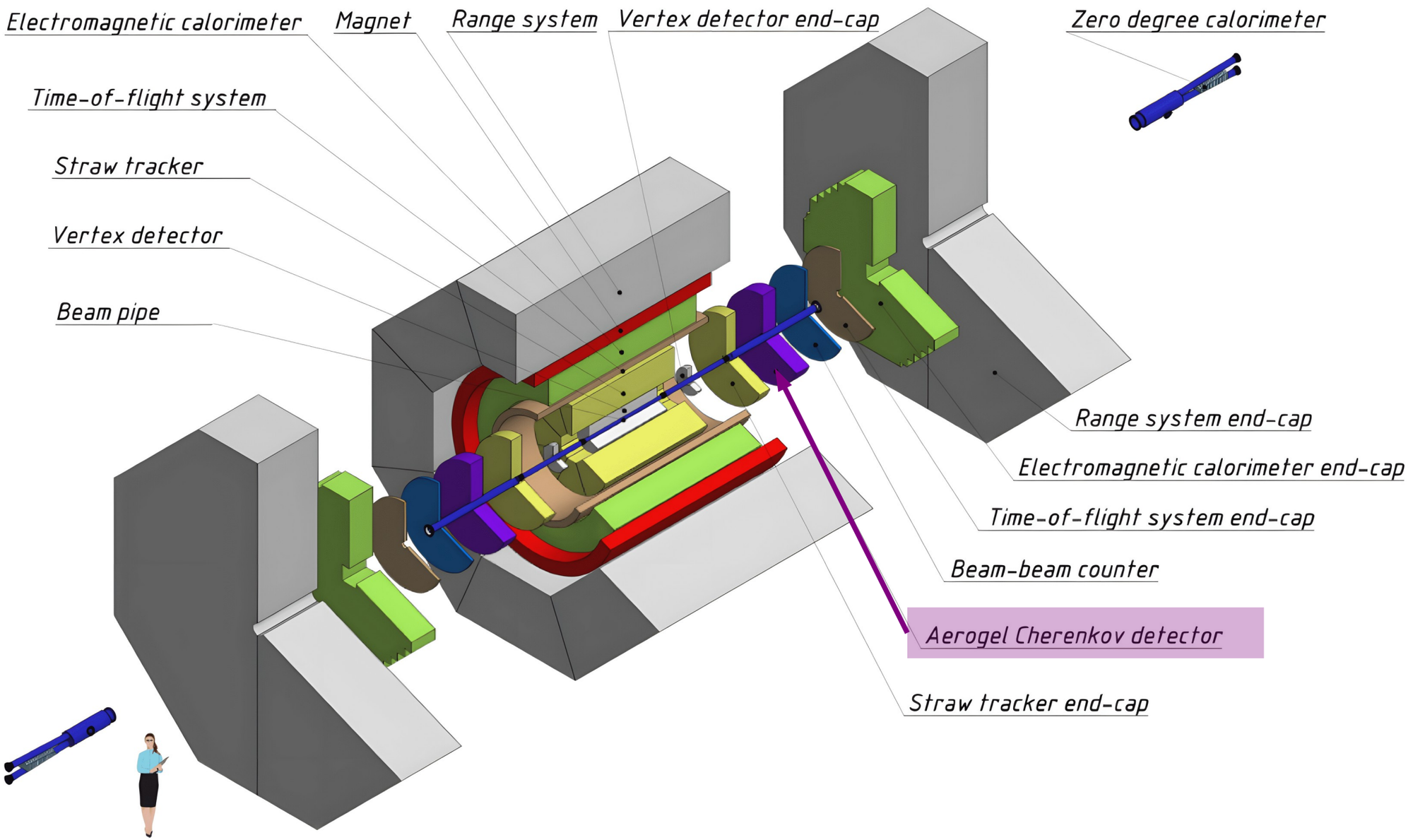


FARICH simulation and reconstruction

Artem Ivanov
JINR, Dubna

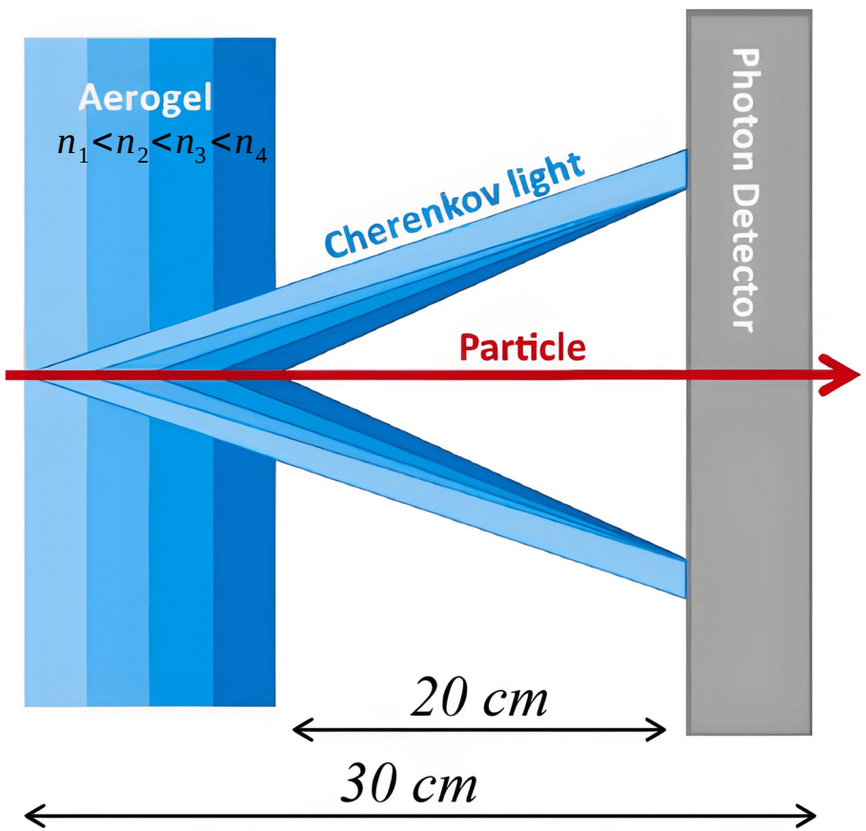
SPD Collaboration Meeting
24.05.2024

Focusing Aerogel RICH detector in SPD

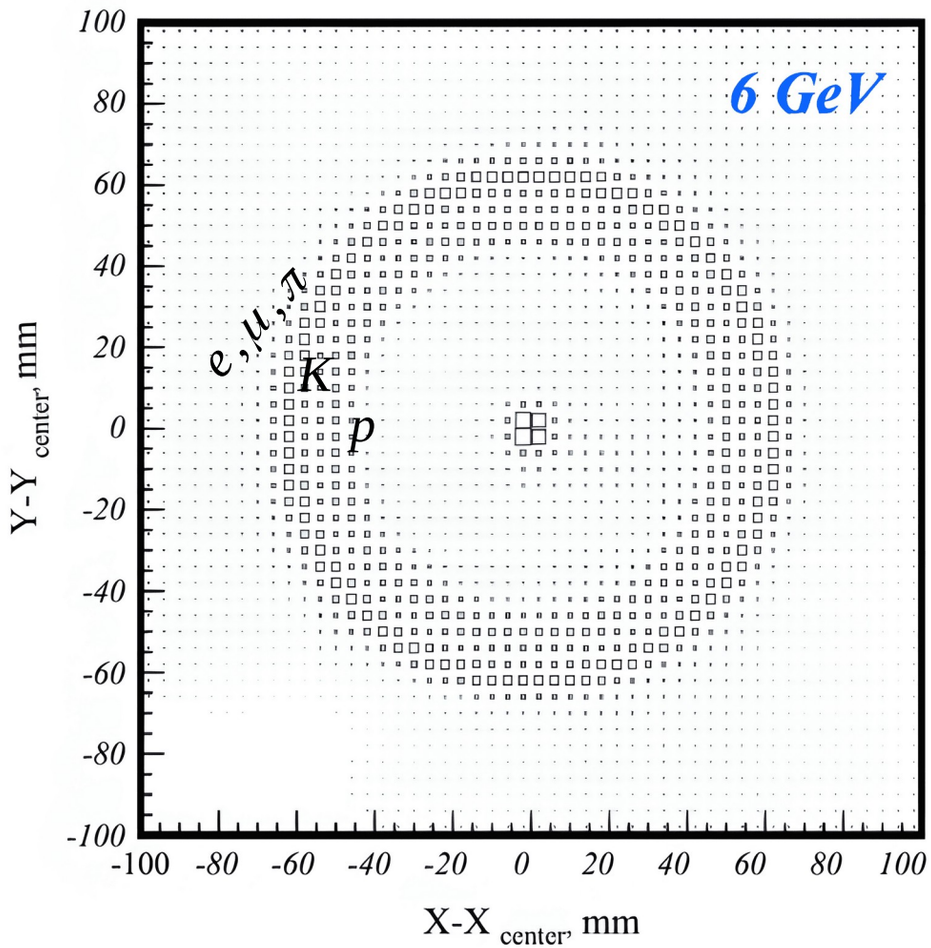


FARICH detector: basic principles

Principle of detector operation

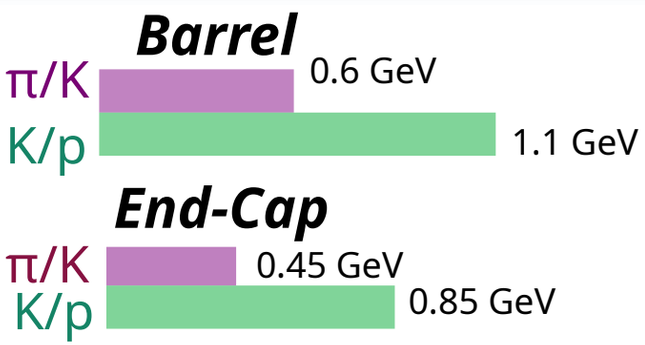


Accumulated xy distribution of hits

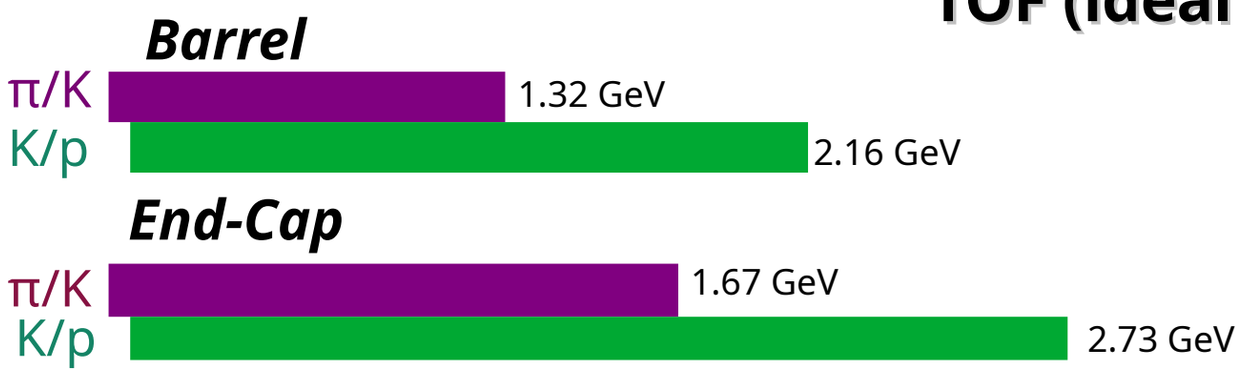


Particle ID in SPD

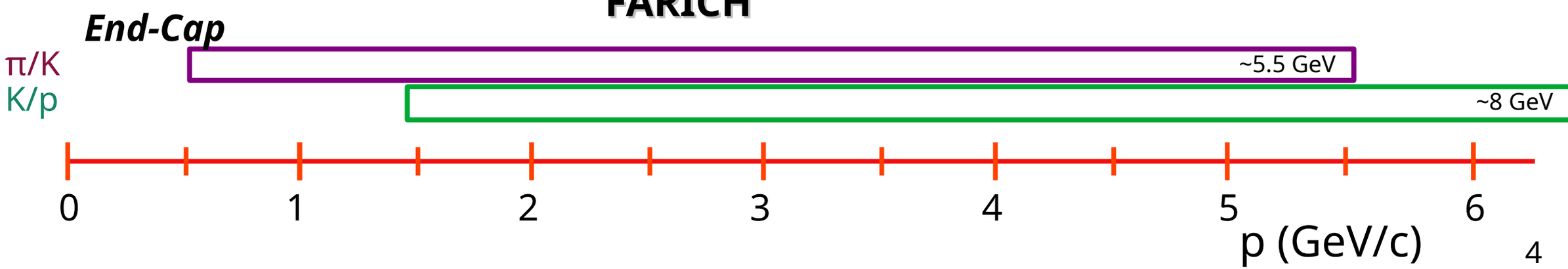
Straw tracker



TOF (ideal case without T0)

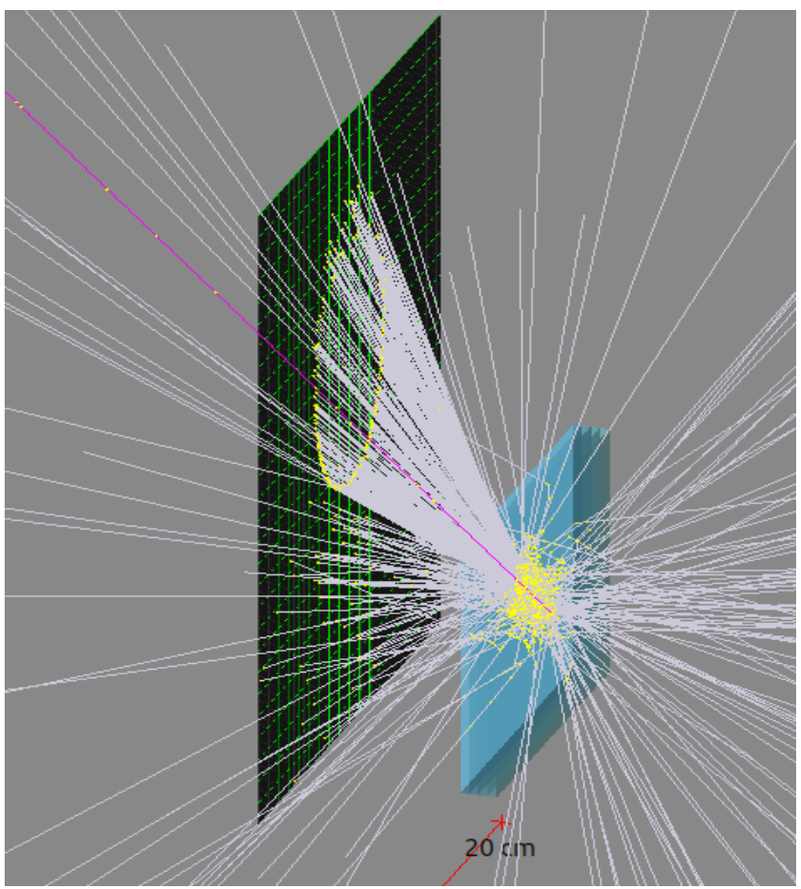


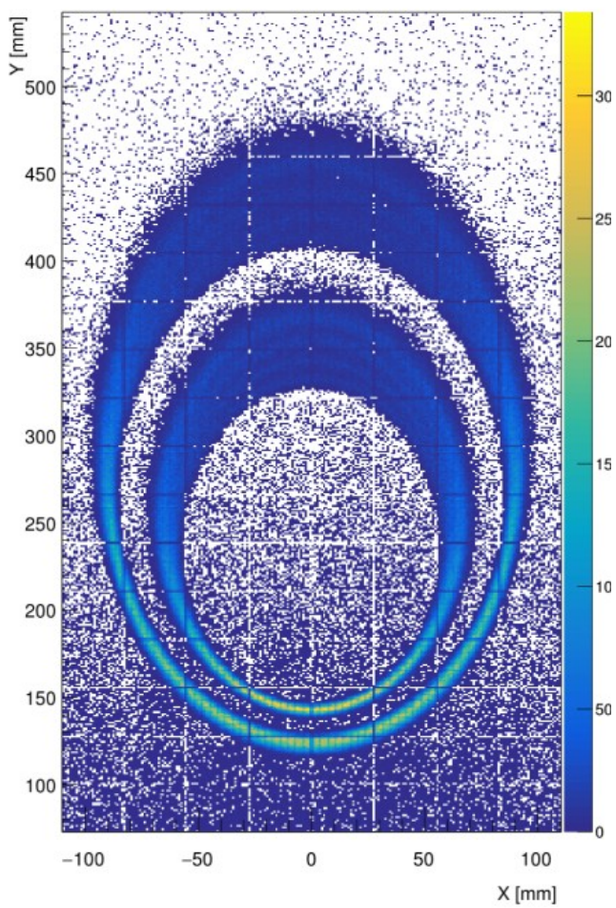
FARICH



FARICH in GEANT4

Based on stand-alone GEANT4 based simulation program from team Budker Institute of Nuclear Physics, Novosibirsk (*Thanks to A.Yu. Barnyakov, V.S. Bobrovnikov)*





FARICH in SpdRoot

1) Description of geometry/material based on TDR

2) Setting of optical properties in Geant4

3) FARICH reconstruction

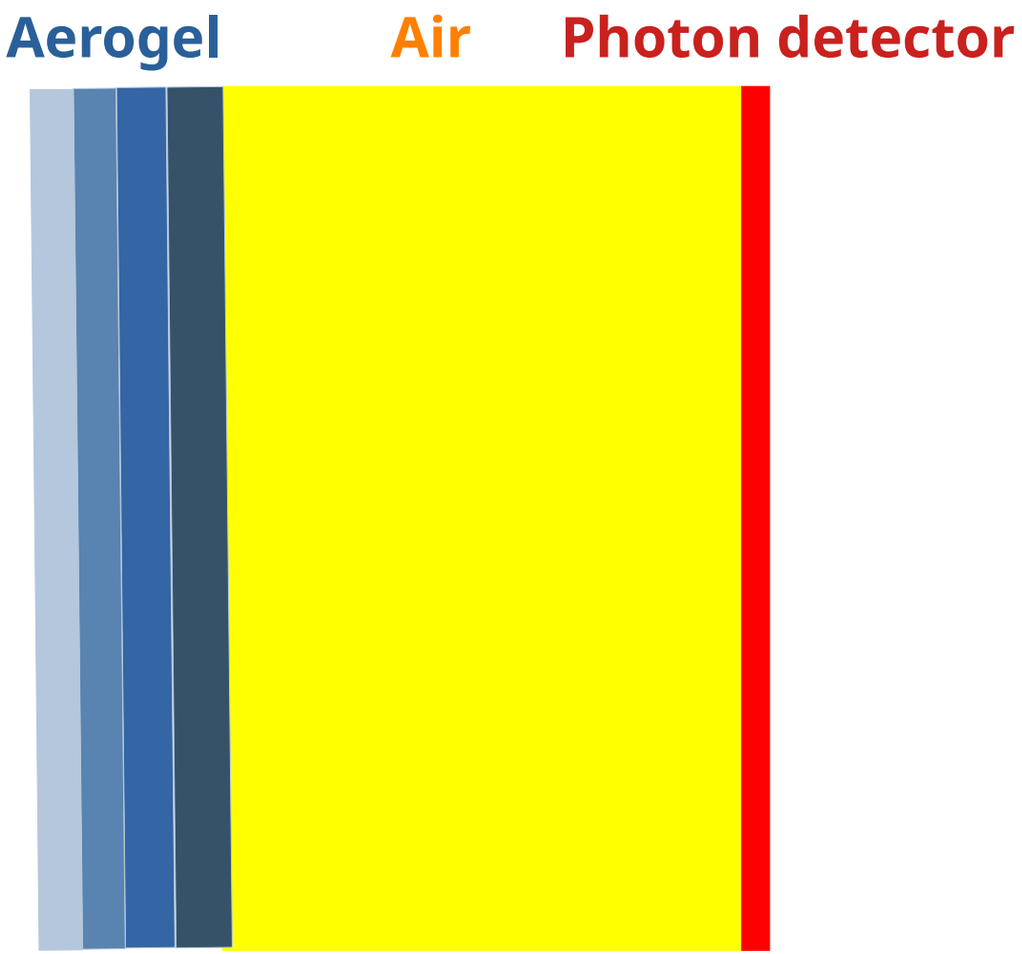
FARICH in SpdRoot

1) Description of geometry/material based on TDR

2) Setting of optical properties in Geant4

3) FARICH reconstruction

FARICH in SpdRoot: geometry



Aerogel geometry/material

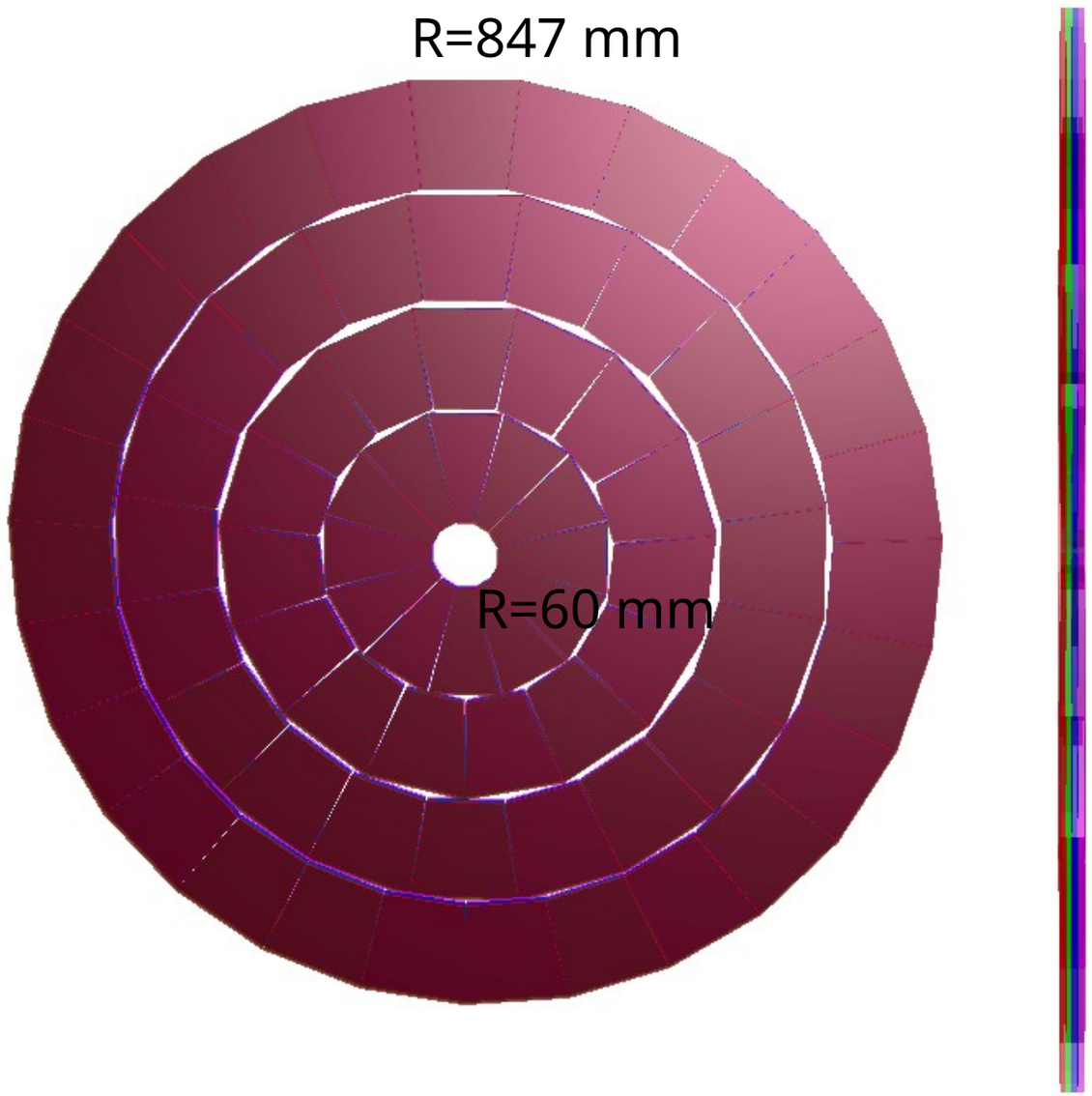
Material:

$$Si\,0_2 \;-\; 97\,\%$$

$$H_2 0 \;-\; 0.03\,\%$$

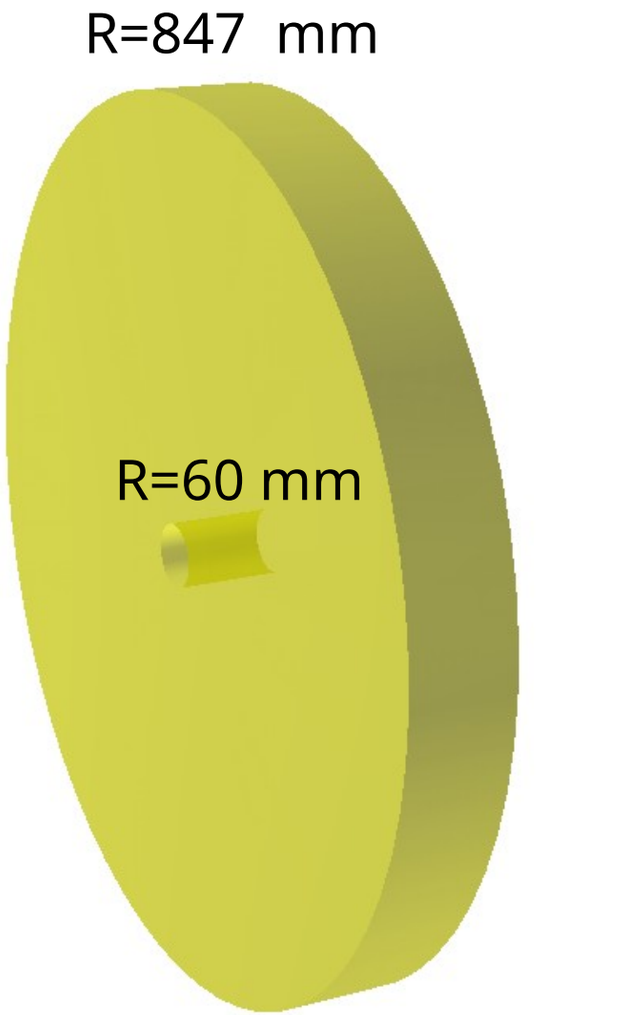
$$density = \frac{(n^2-1)}{0.438}, [cm^3/g]$$

n(400)=1.0370, L=7.00 mm
n(400)=1.0410, L=10.00 mm
n(400)=1.0430, L=9.00 mm
n(400)=1.0470, L=10.00 mm



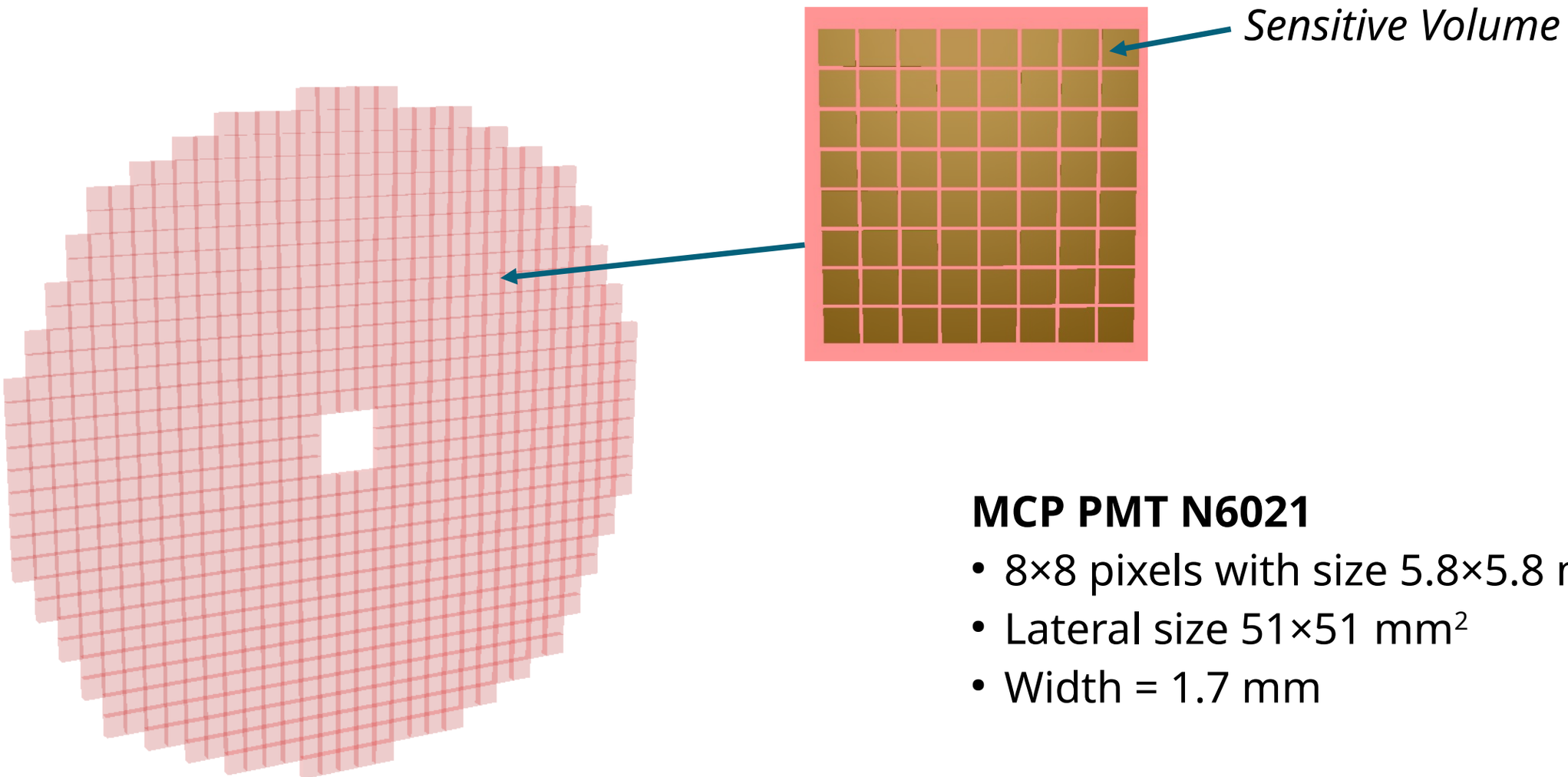
Air geometry/material

Material: *air*



Photon detector geometry/material

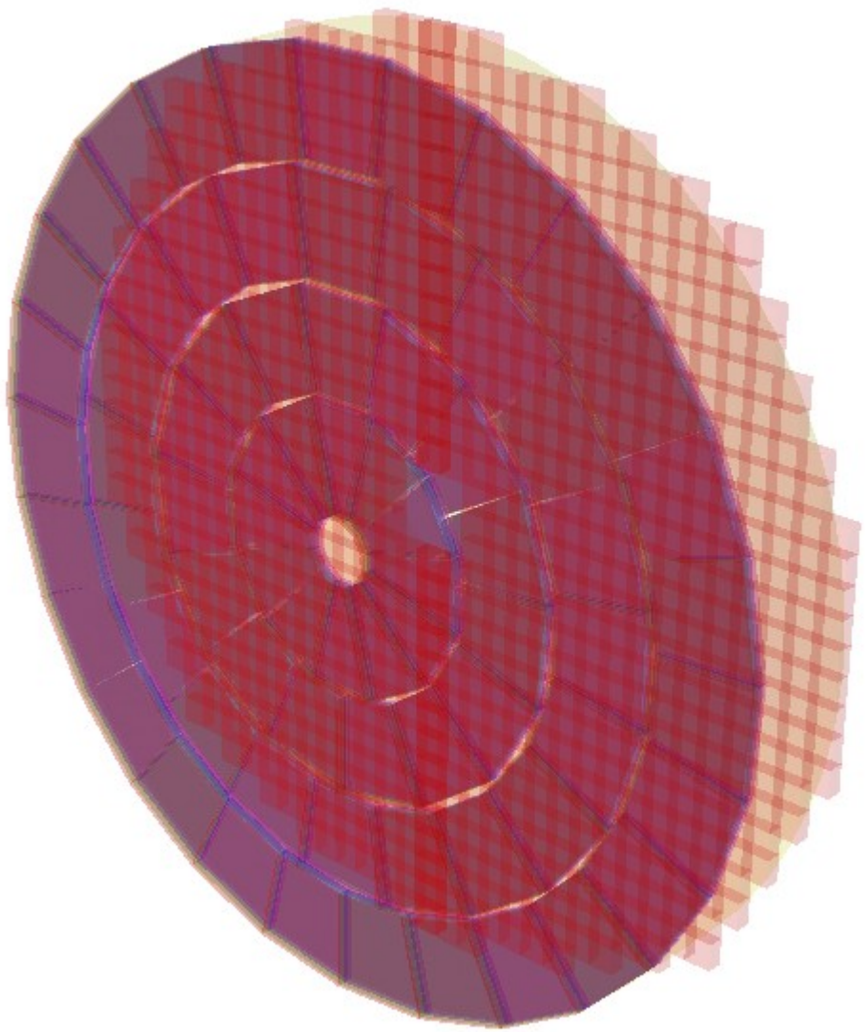
Material: Si

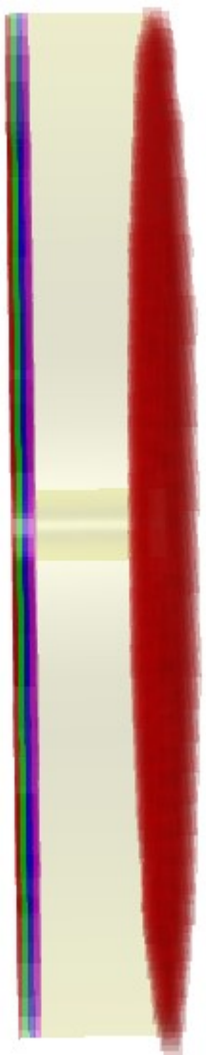


MCP PMT N6021

- 8×8 pixels with size 5.8×5.8 mm^2
- Lateral size 51×51 mm^2
- Width = 1.7 mm

FARICH geometry





FARICH in SpdRoot

1) Description of geometry/material based on TDR

2) Setting of optical properties in Geant4

3) FARICH reconstruction

Settings Geant

SpdRoot (Geant v10.5.1)

spdroot/gconfig/g4config.C

```
TG4RunConfiguration *runConfiguration =
    new TG4RunConfiguration("geomRoot",
                            "QGSP_FTFP_BERT+optical",
                            "stepLimiter+specialCuts+specialControls+stackPopper",
                            false);
```

spdroot/gconfig/g4config.in

```
/process/optical/cerenkov/setMaxPhotons 300
/process/optical/cerenkov/setMaxBetaChange 10.0
/process/optical/cerenkov/setTrackSecondariesFirst  true
```

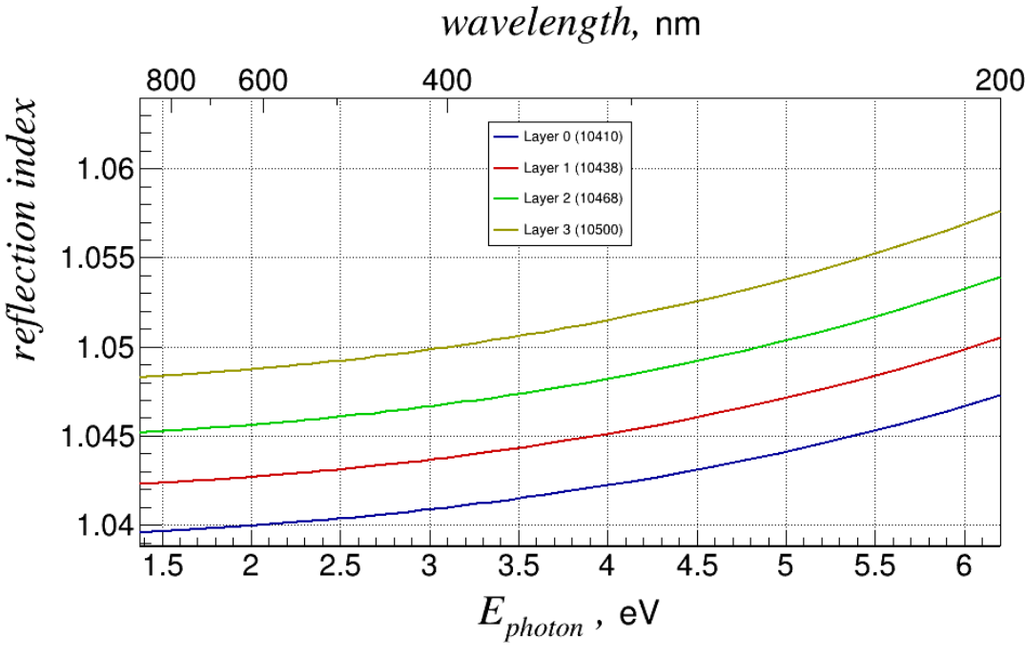
```
/process/optical/processActivation Cerenkov true
/process/optical/processActivation Scintillation false
/process/optical/processActivation OpAbsorption false
/process/optical/processActivation OpRayleigh false
/process/optical/processActivation OpMieHG false
/process/optical/processActivation OpBoundary true
```

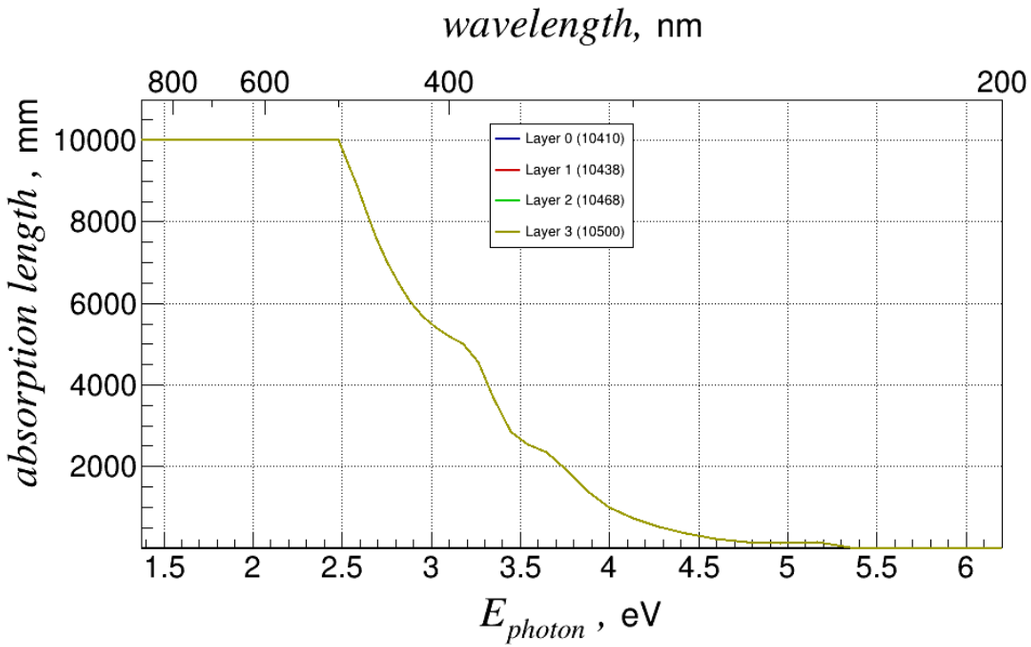
Skin surface

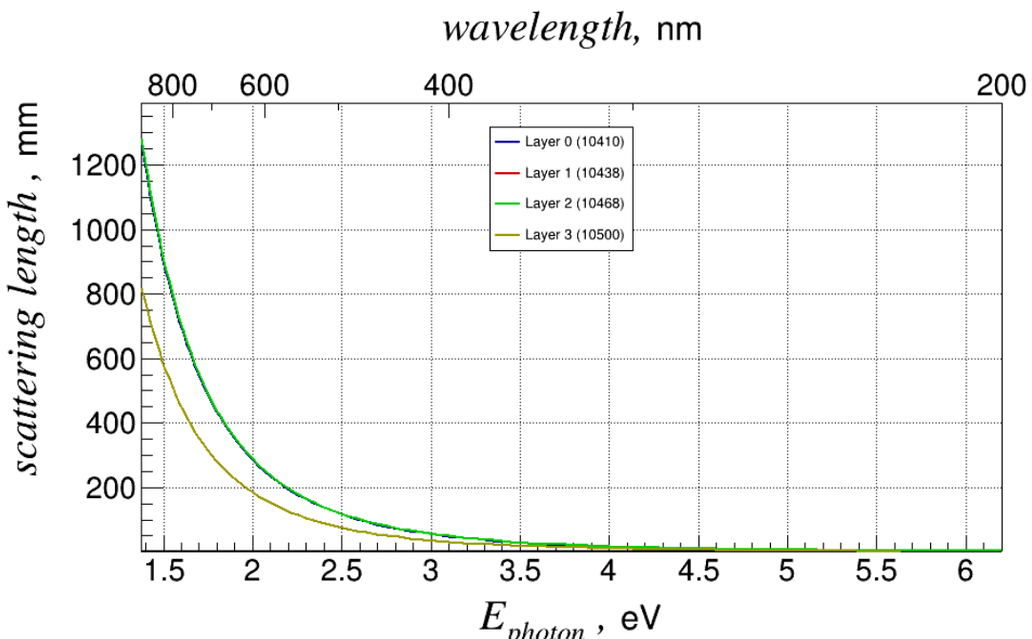
```
gMC->DefineOpSurface("surface_pmt", kUnified, kDielectric_metal, kPolished, 1.3);
```

Currently, only Cherenkov photons from the ring are being studied.

Optical properties of aerogel

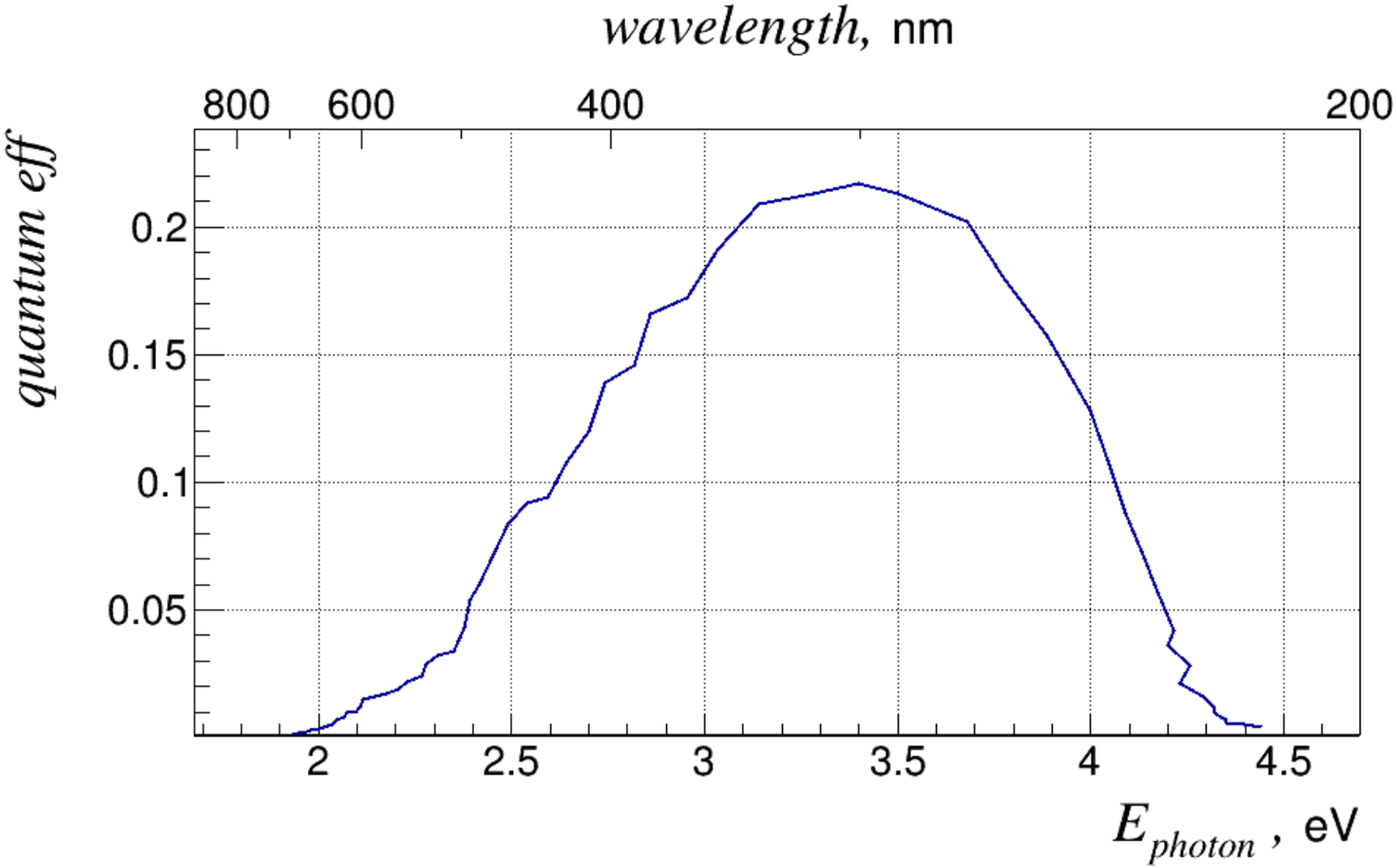




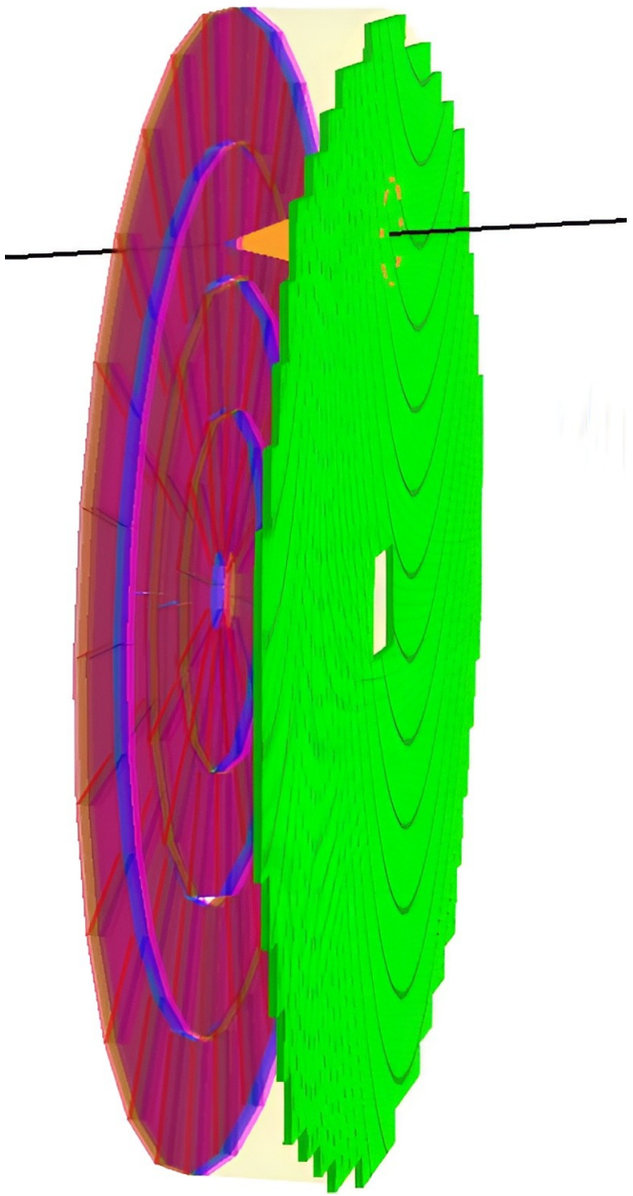


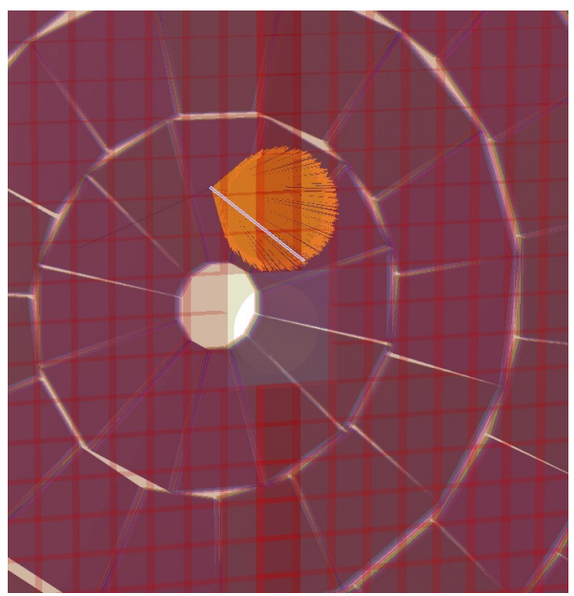
Optical properties of photon detector

MCP PMT N6021



Cherenkov cone in FARICH





FARICH in SpdRoot

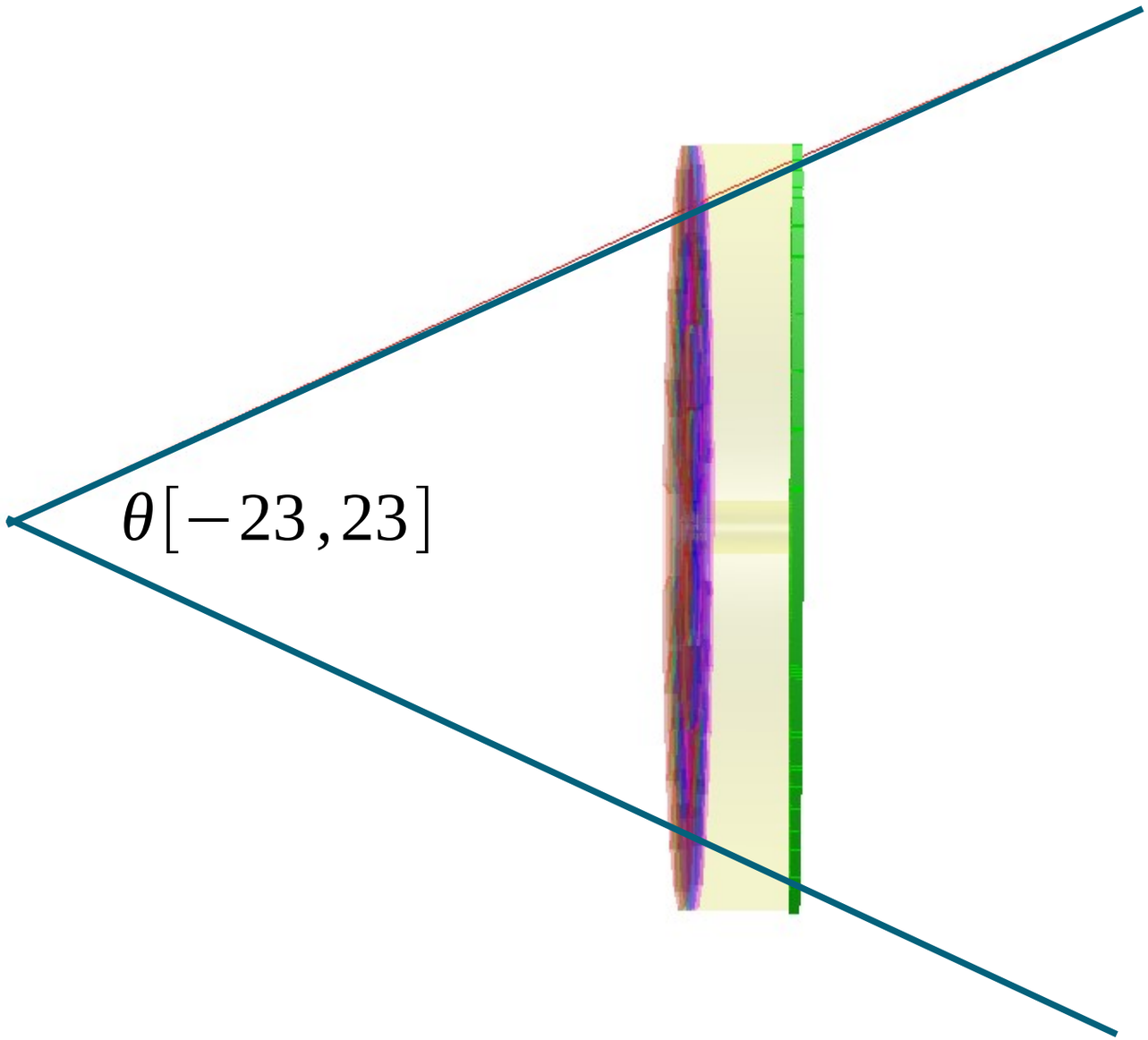
1) Description of geometry/material based on TDR

2) Setting of optical properties in Geant4

3) FARICH reconstruction

FARICH simulation

$e \quad [0.1-8]GeV$
$\mu \quad [0.2-8]GeV$
$\pi \quad [0.5-8]GeV$
$K \quad [1.5-8]GeV$
$p \quad [3.0-8]GeV$



Selection criteria

- *track fit is converged*
- $chi^2/NDF<3$
- $N_{hits,photons}>4$

FARICH reconstruction

1) Reconstruction by ellipse

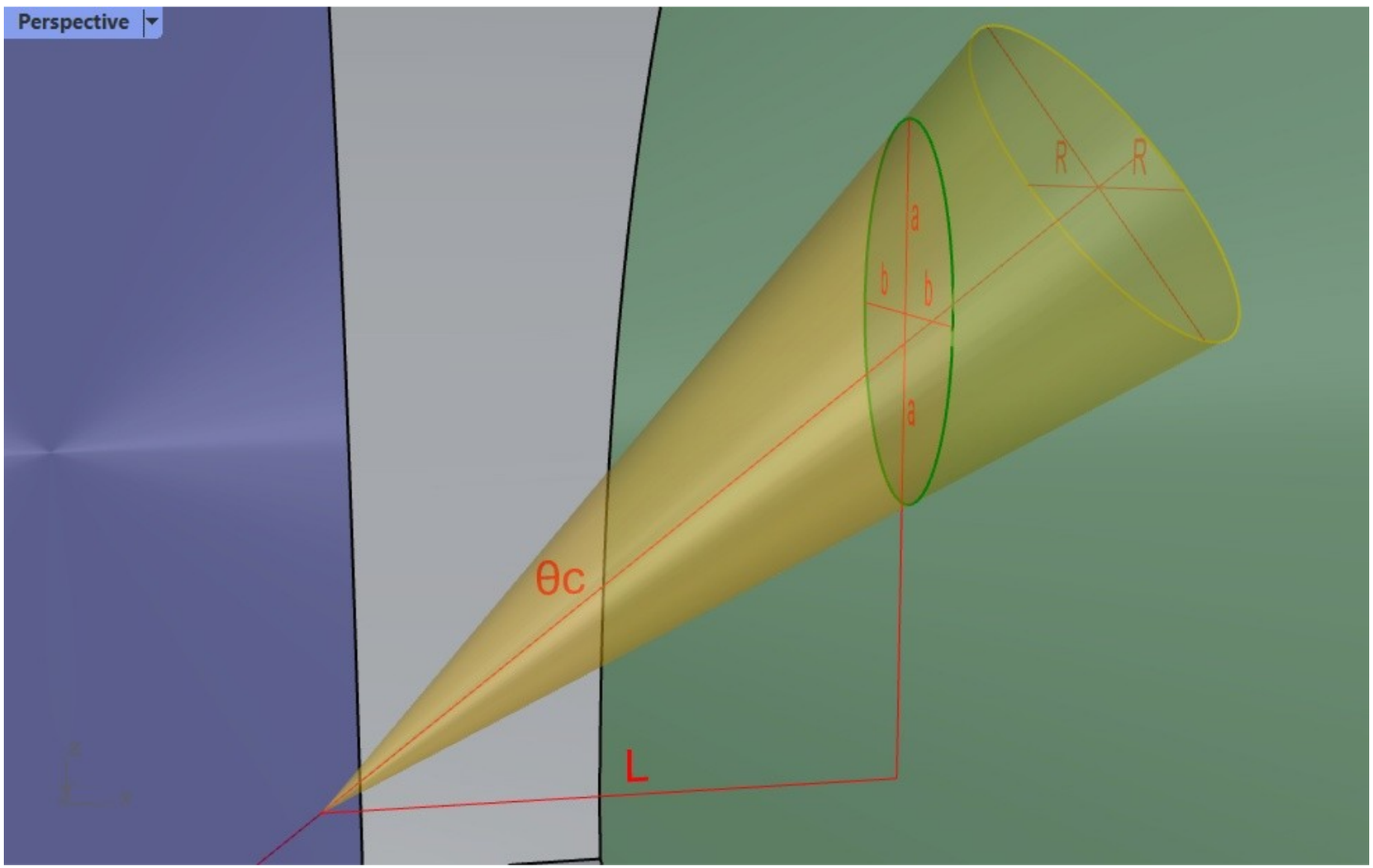
2) Reconstruction by dependence θ_c vs φ_c

3) Reconstruction using Likelihoods

4) Reconstruction using ML

(Fedor Ratnikov, Higher School of Economics)

FARICH reconstruction: by ellipse



$$\tan(\theta_c) = \frac{b^2}{a * L}$$

FARICH reconstruction: by ellipse

“Методы оценки параметров колец черенковского излучения в детекторе RICH для эксперимента CBM”
А. С. Айриян , В. В. Иванов , С. А. Лебедев , Г. А. Ососков , Н. И. Чернов

Equation of ellipse

$$d_1 + d_2 = 2a$$

$$d_1 = \sqrt{(x - x_{F1})^2 + (y - y_{F1})^2}$$

$$d_2 = \sqrt{(x - x_{F2})^2 + (y - y_{F2})^2}$$

Fitting by MINUIT

Fitting parameters

$$x_{F1}, x_{F2}, y_{F1}, y_{F2}, a$$

$$x_c = (x_{F1} + x_{F2})/2$$

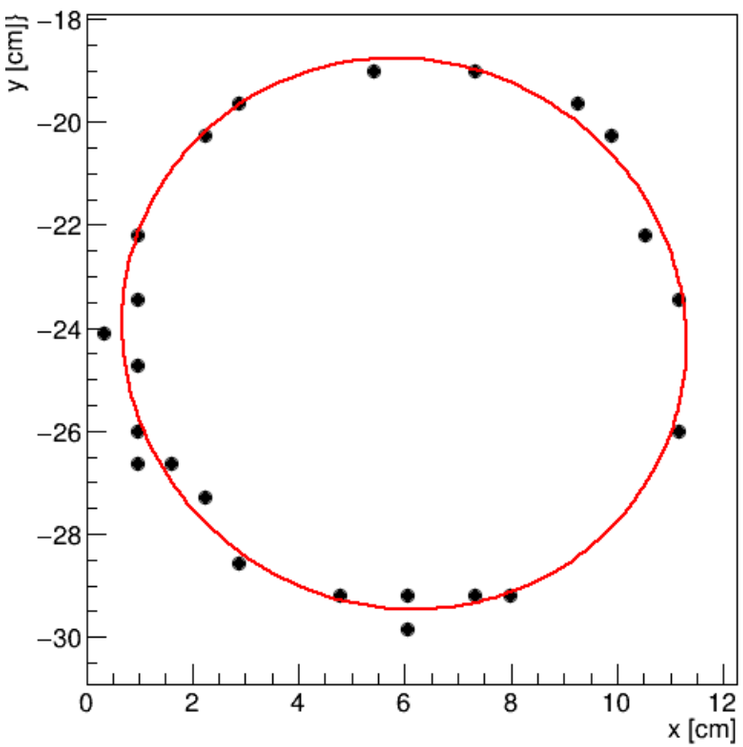
$$y_c = (y_{F1} + y_{F2})/2$$

$$b = \sqrt{a^2 - \sqrt{(x_{F1} - x_{F2})^2 + (y_{F1} - y_{F2})^2}}$$

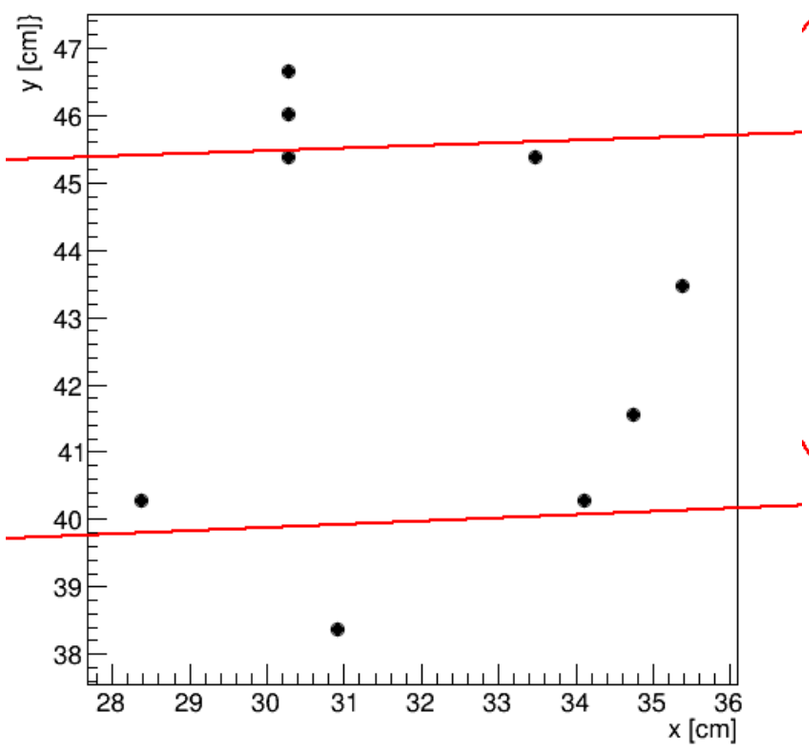
$$\phi = \arctan\left(\frac{y_{F1} - y_{F2}}{x_{F1} - x_{F2}}\right)$$

Results of fit by ellipse

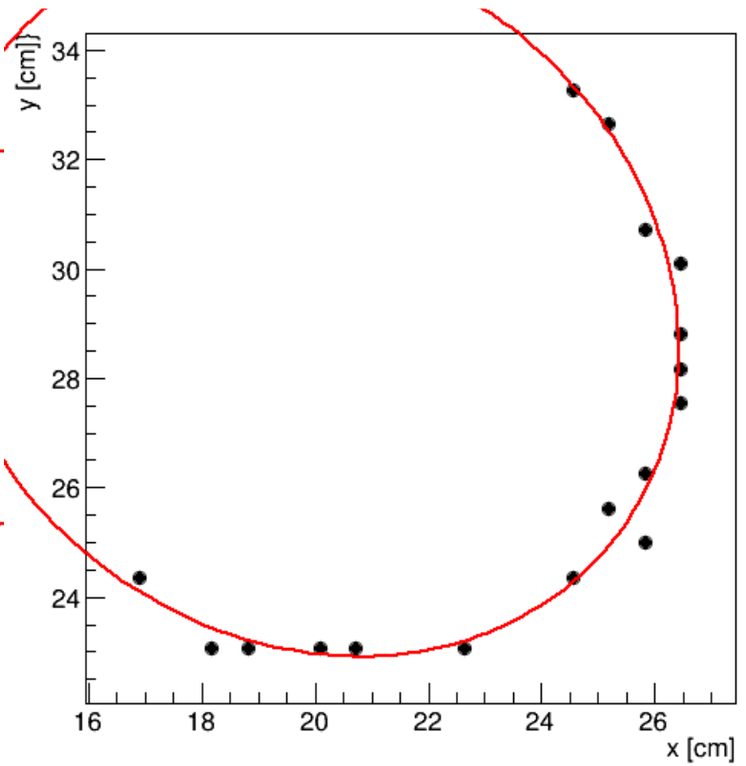
Fit is converged



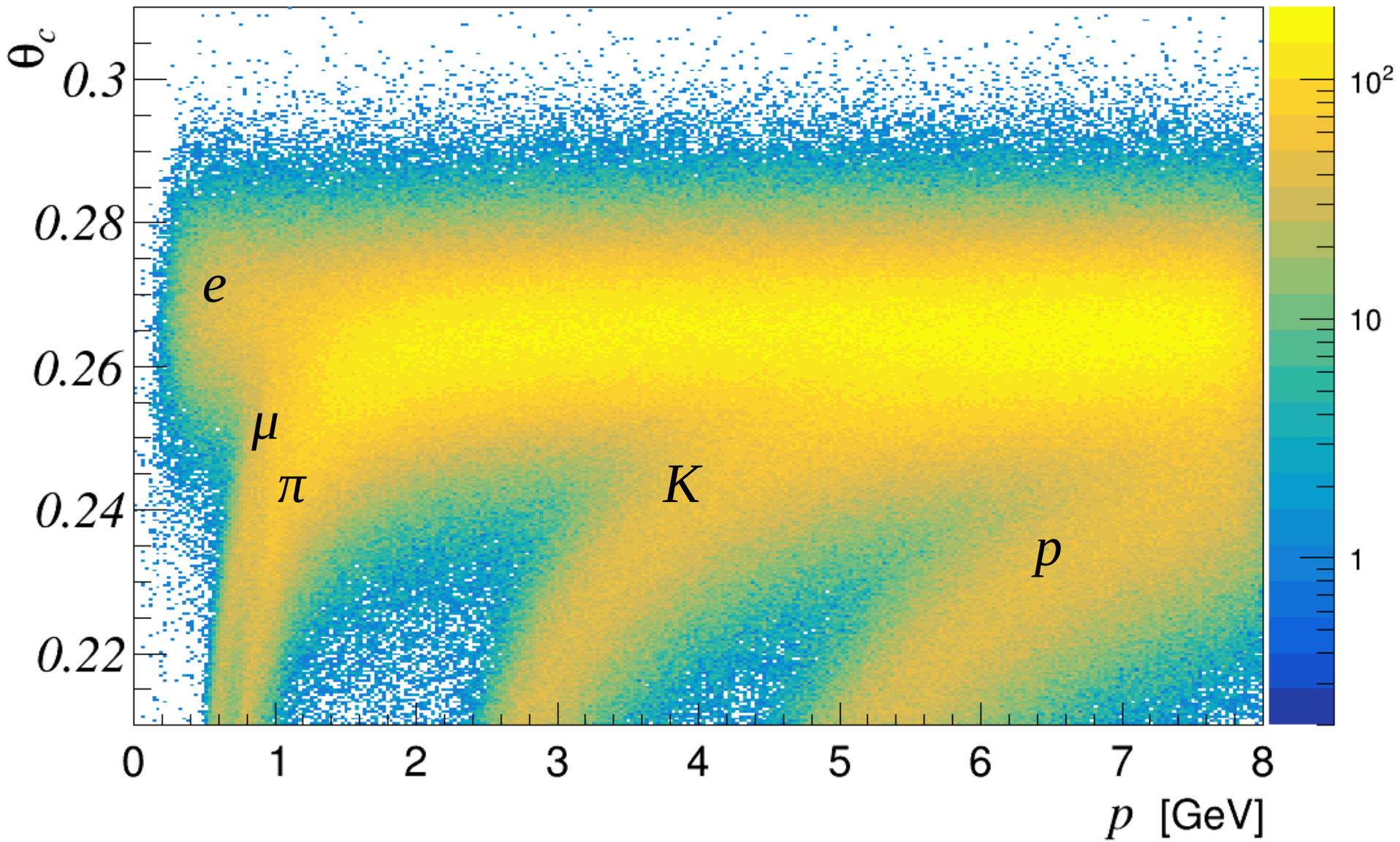
Fit is not converged



Fit is partially converged



θ_c vs p_{rc}



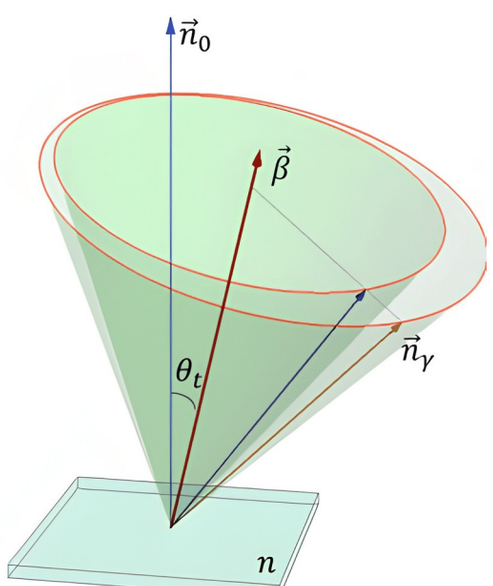
FARICH reconstruction: by dependence θ_c vs φ_c

"FARICH simulation", Viktor Bobrovnikov, 29 September 2020

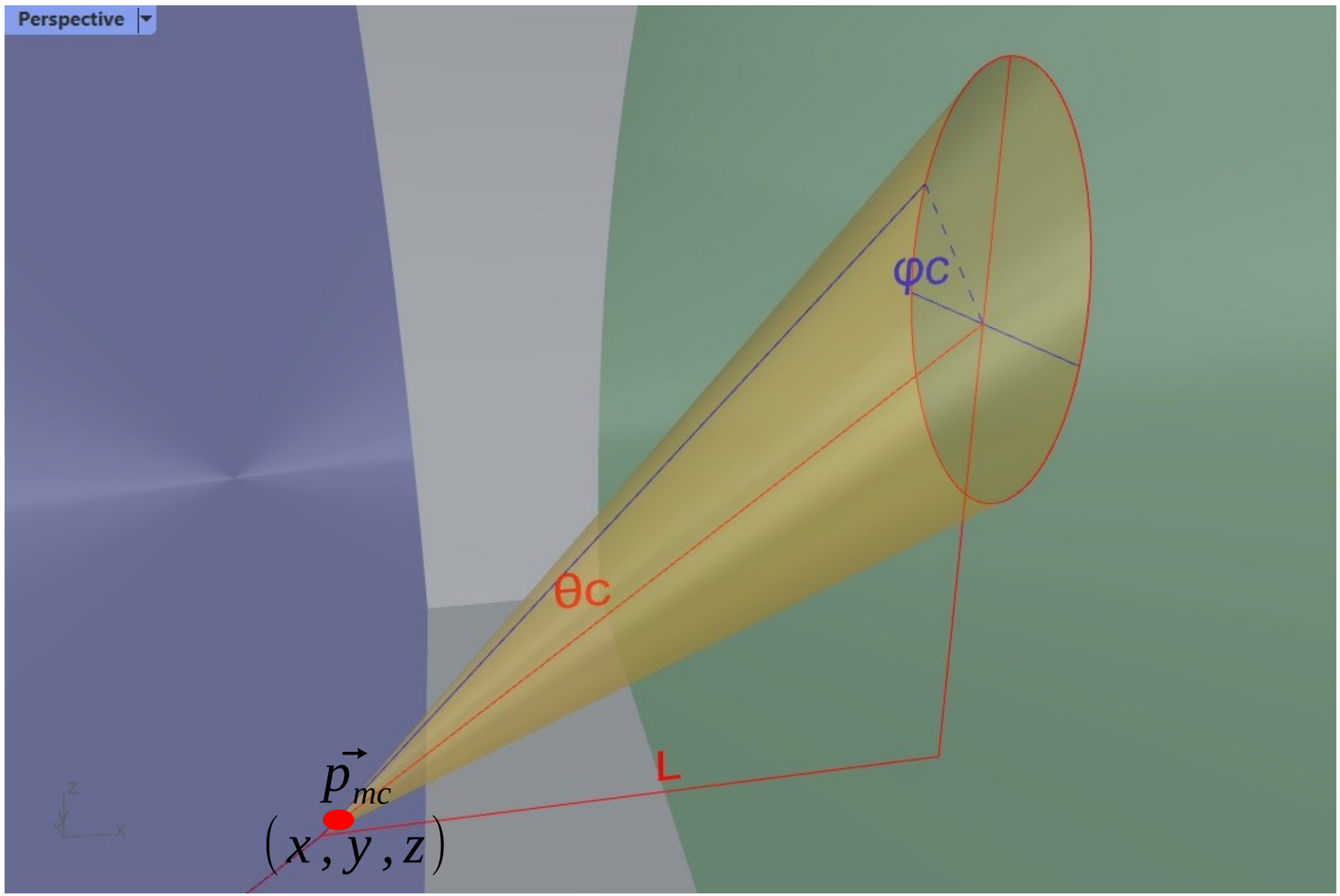
- The dependence of polar angle of cherenkov photons θ_c from azimuth angle φ_c are used in this reconstruction
- The values θ_c and φ_c are defined in primary particle coordinate system and, therefore, to define them, it is necessary to translate them into laboratory coordinate system in which the primary particle moves (position of primary particle in laboratory coordinate system is determined by its initial position and angles θ_t and φ_t)
- The dependence of θ_c on φ_c can be expressed as

$$\theta_c(\varphi_c|\beta, n, \theta_t) = \arccos\left(\frac{1}{n\beta}\right) + \arccos\left(n\left(1-(\vec{n}_0\vec{n}_\gamma)^2\right) + (\vec{n}_0\vec{n}_\gamma)\sqrt{1-n^2\left(1-(\vec{n}_0\vec{n}_\gamma)^2\right)}\right)$$

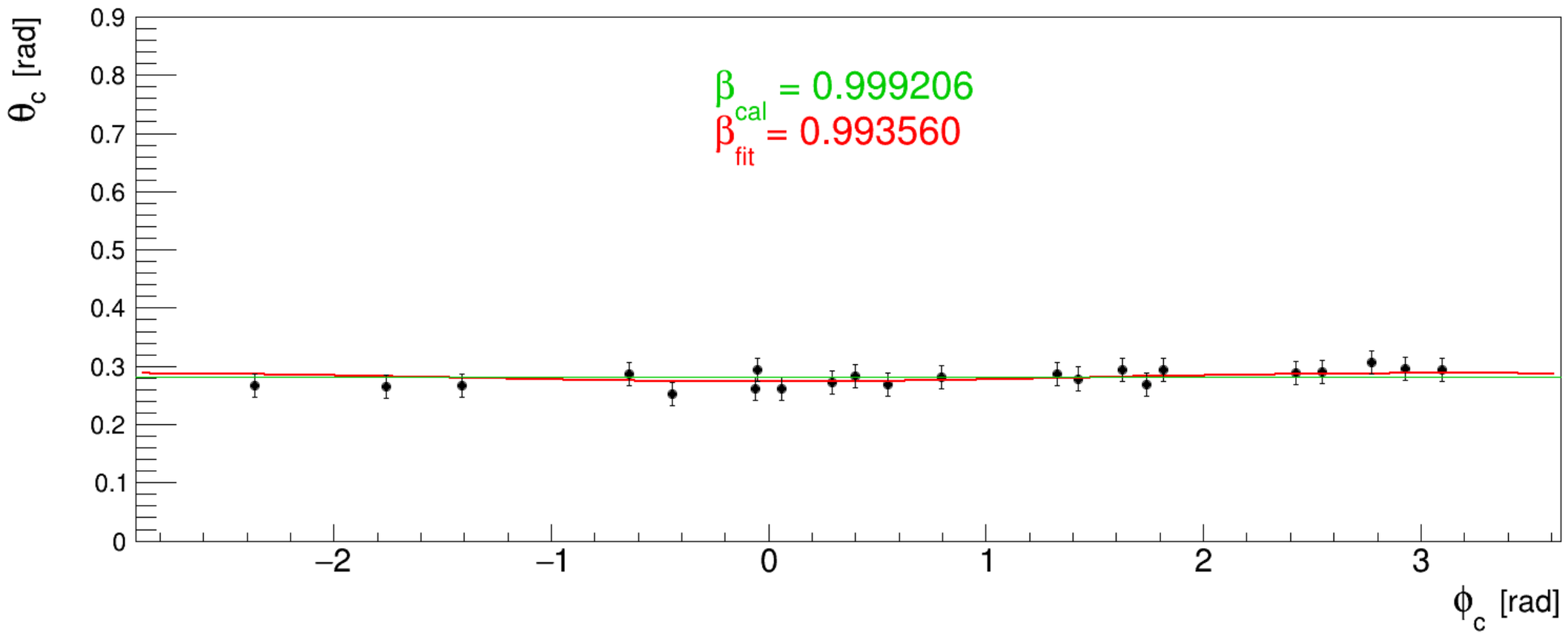
- n average value refraction index of radiator
- $(\vec{n}_0\vec{n}_\gamma) = \cos\theta_t/(n\beta) + \cos\varphi_c \sin\theta_t \sqrt{1-1/(n\beta)^2}$
- $\vec{n}_0$ and $\vec{n}_\gamma$ vectors of the radiator and Cherenkov cone normal, respectively



FARICH reconstruction: by dependence θ_c vs φ_c

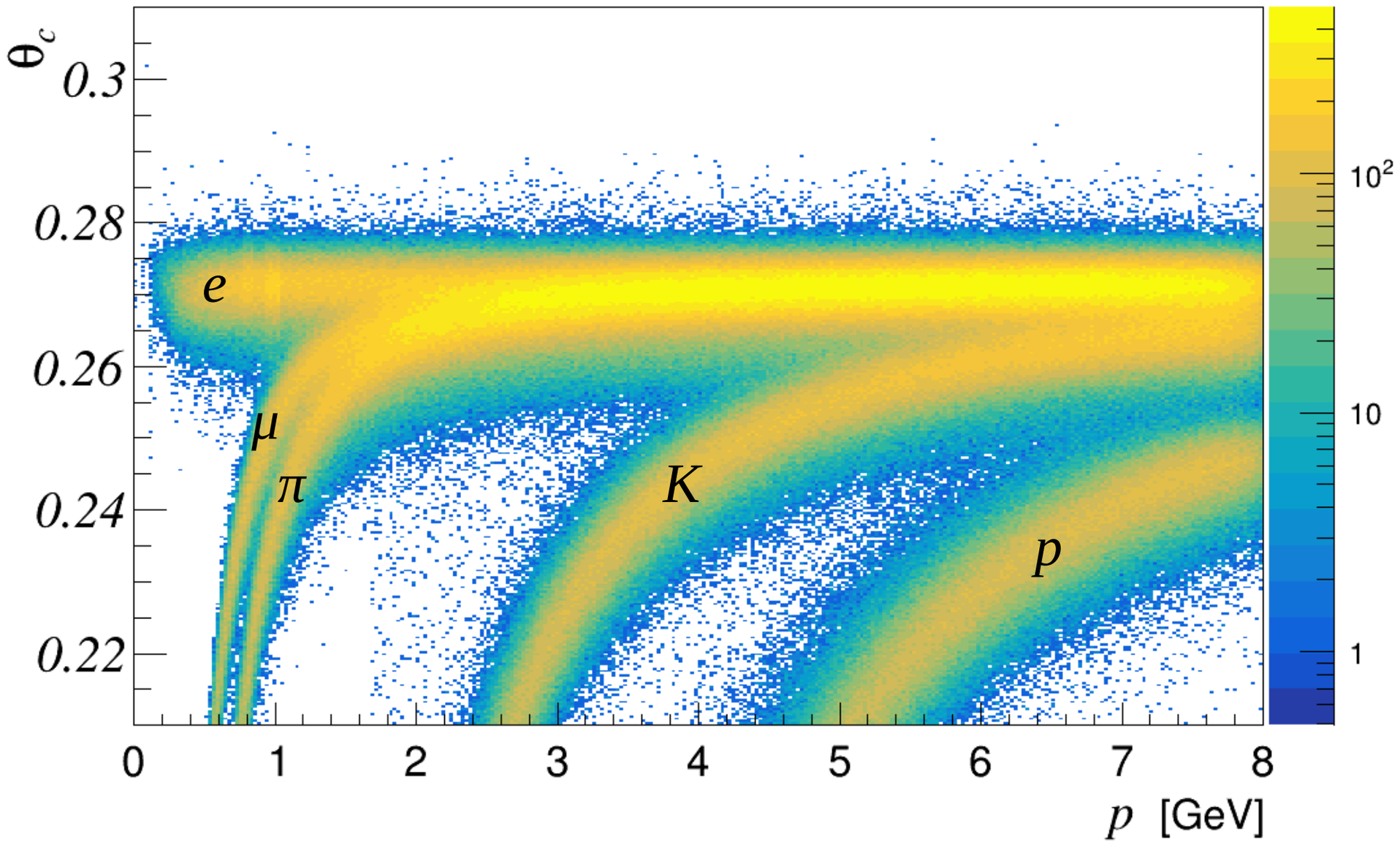


Examples of using function $\theta_c(\varphi_c | \beta, n, \theta_t)$ to fit data

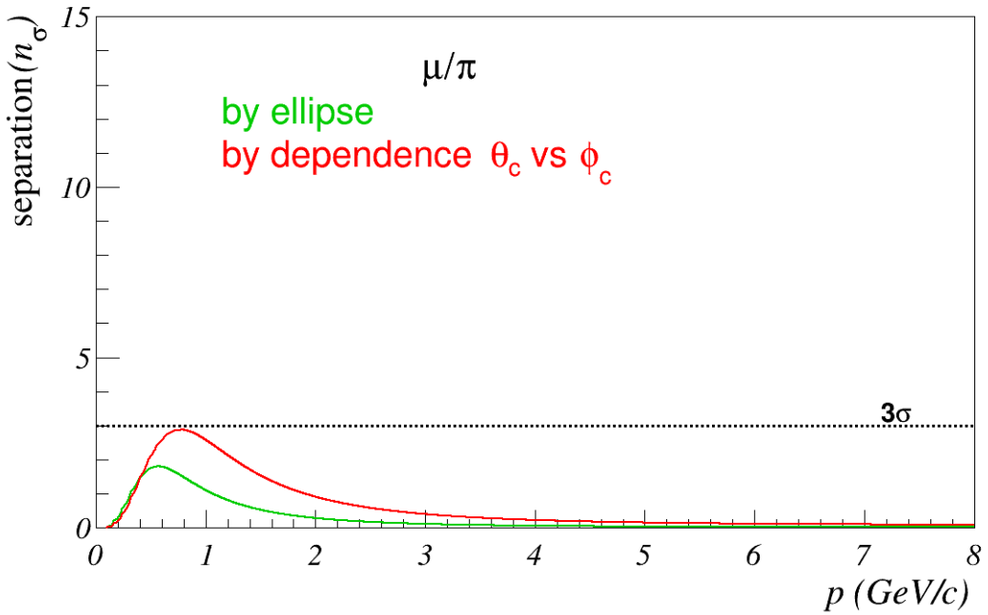


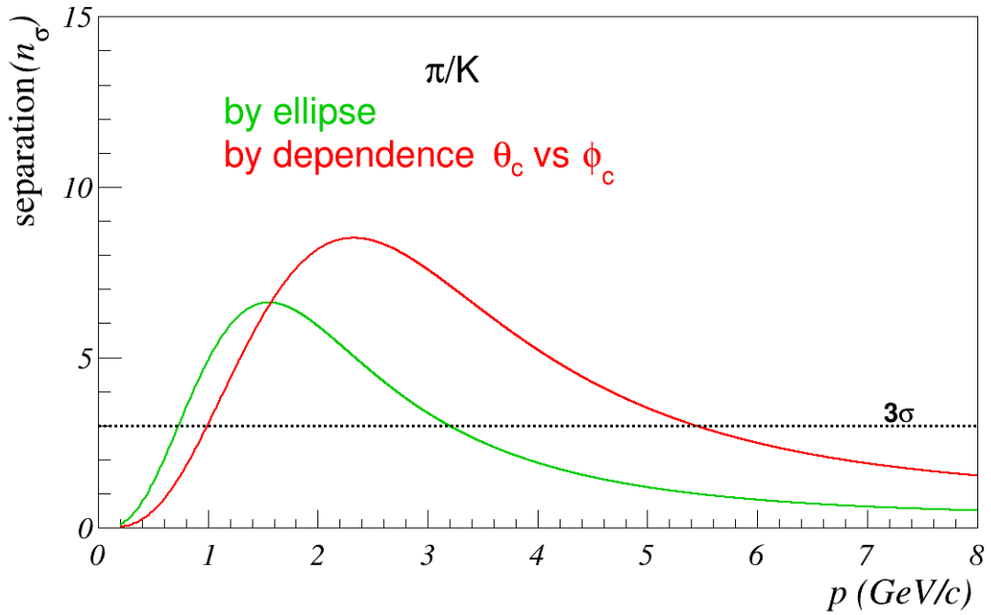
$n = 1.042$

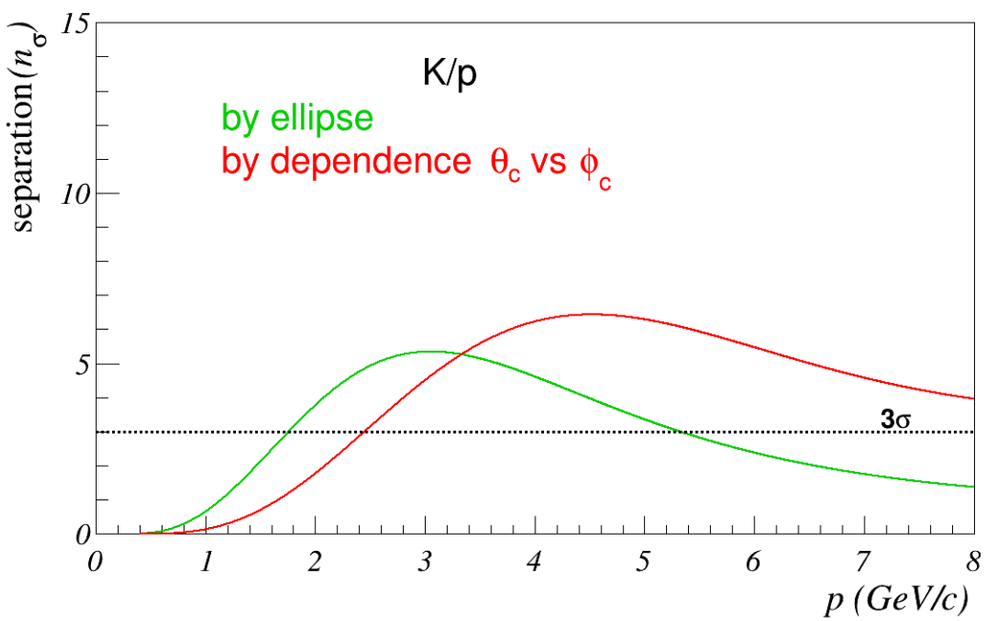
θ_c vs p_{rc}



Separation power







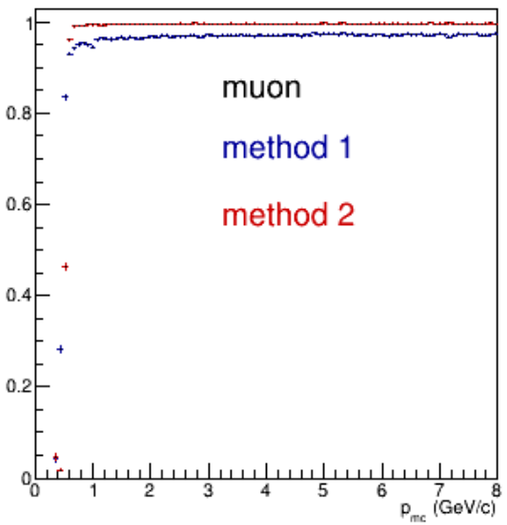
$$n_{sigma} = \frac{x_i - x_j}{\sqrt{\sigma_i^2 + \sigma_j^2}}$$

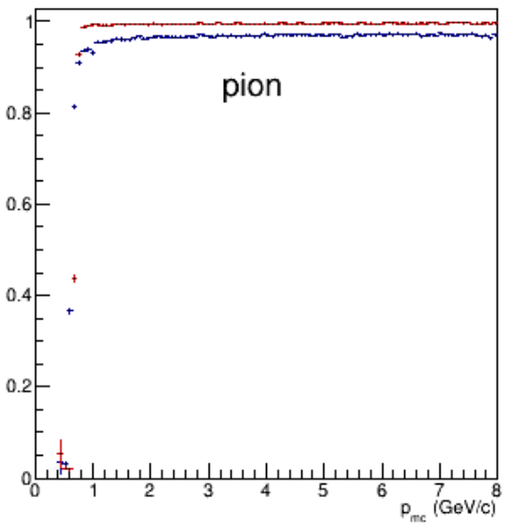
Conclusion

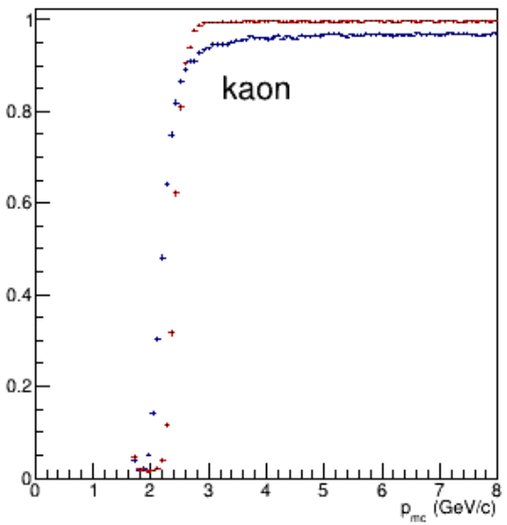
- FARICH is implemented to SpdRoot. Stand-alone GEANT4 based simulation program from Novosibirsk team is taken as the starting point.
- Two methods of reconstruction are added
- Work is ongoing

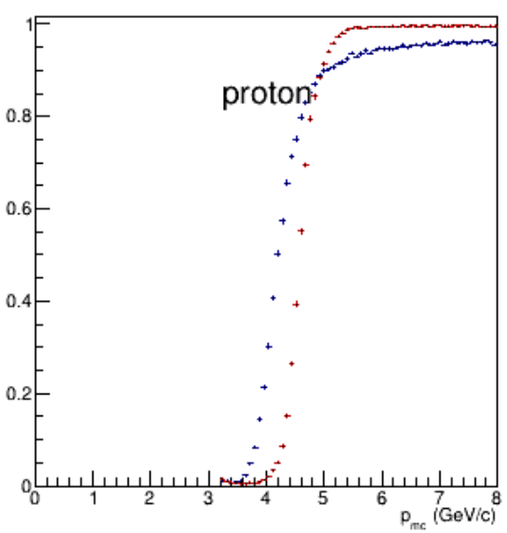
Backup slides

Efficiency


muon
method 1
method 2
p_mc (GeV/c)


pion
p_mc (GeV/c)


kaon
p_mc (GeV/c)


proton
p_mc (GeV/c)