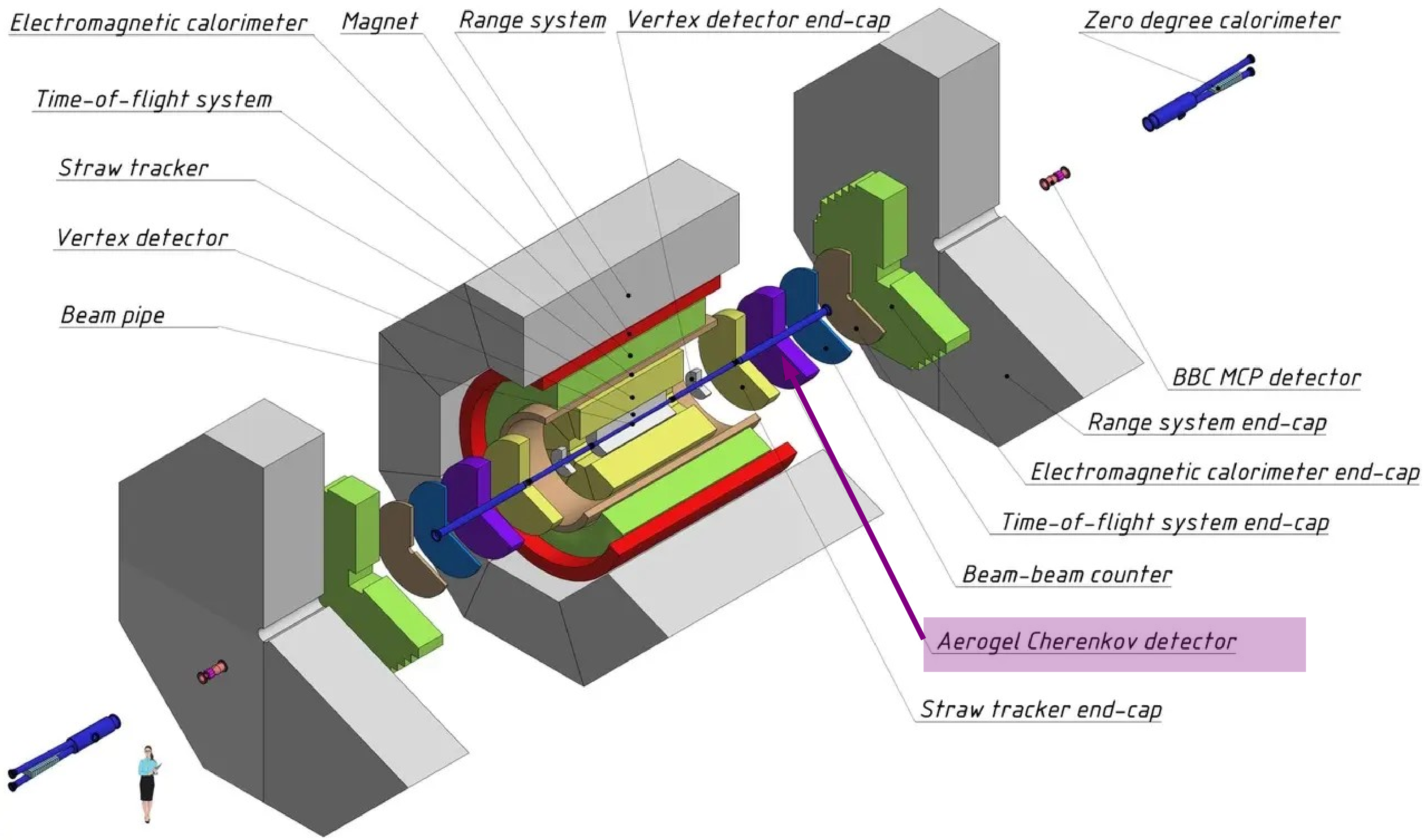
IX SPD collaboration meeting

FARICH simulation and PID

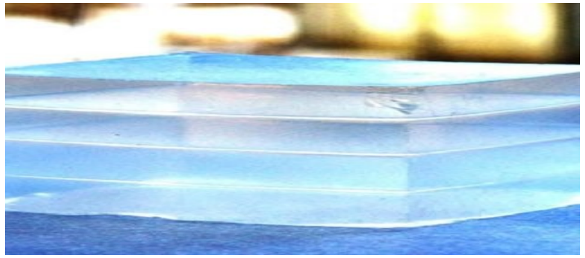
Artem Ivanov
JINR, Dubna

Focusing Aerogel RICH detector in SPD

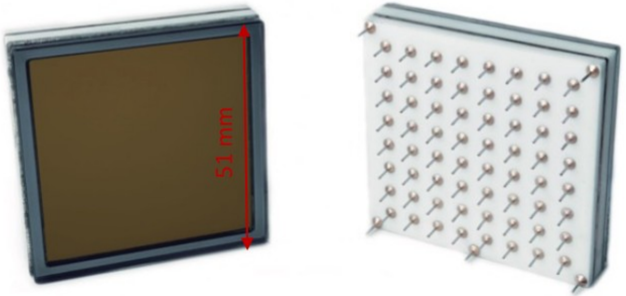


FARICH detector: basic principles

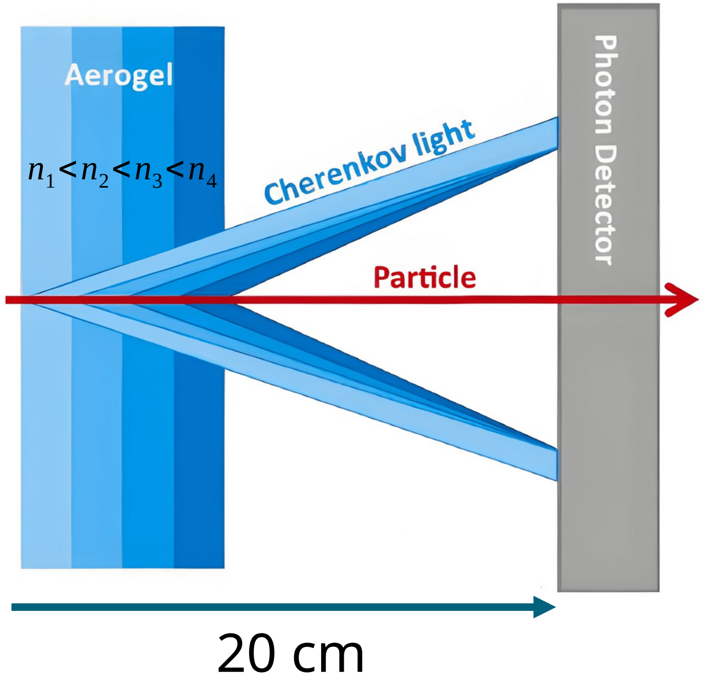
aerogel

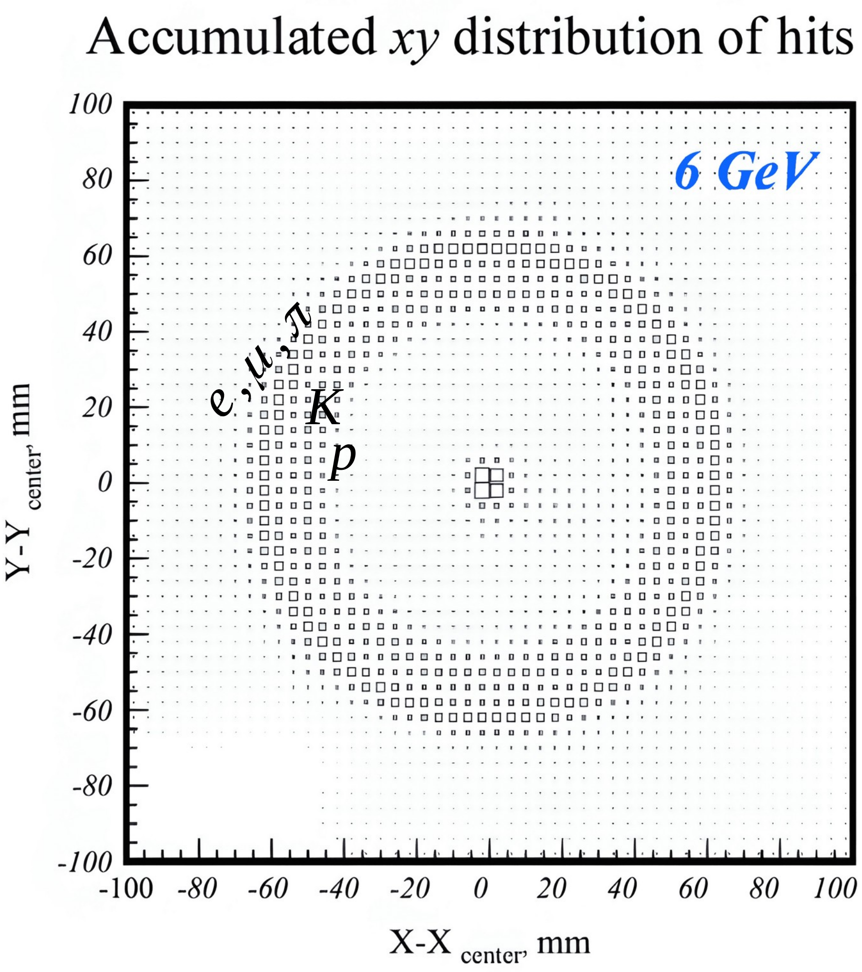


MCP PMTs N6021 from NNVT



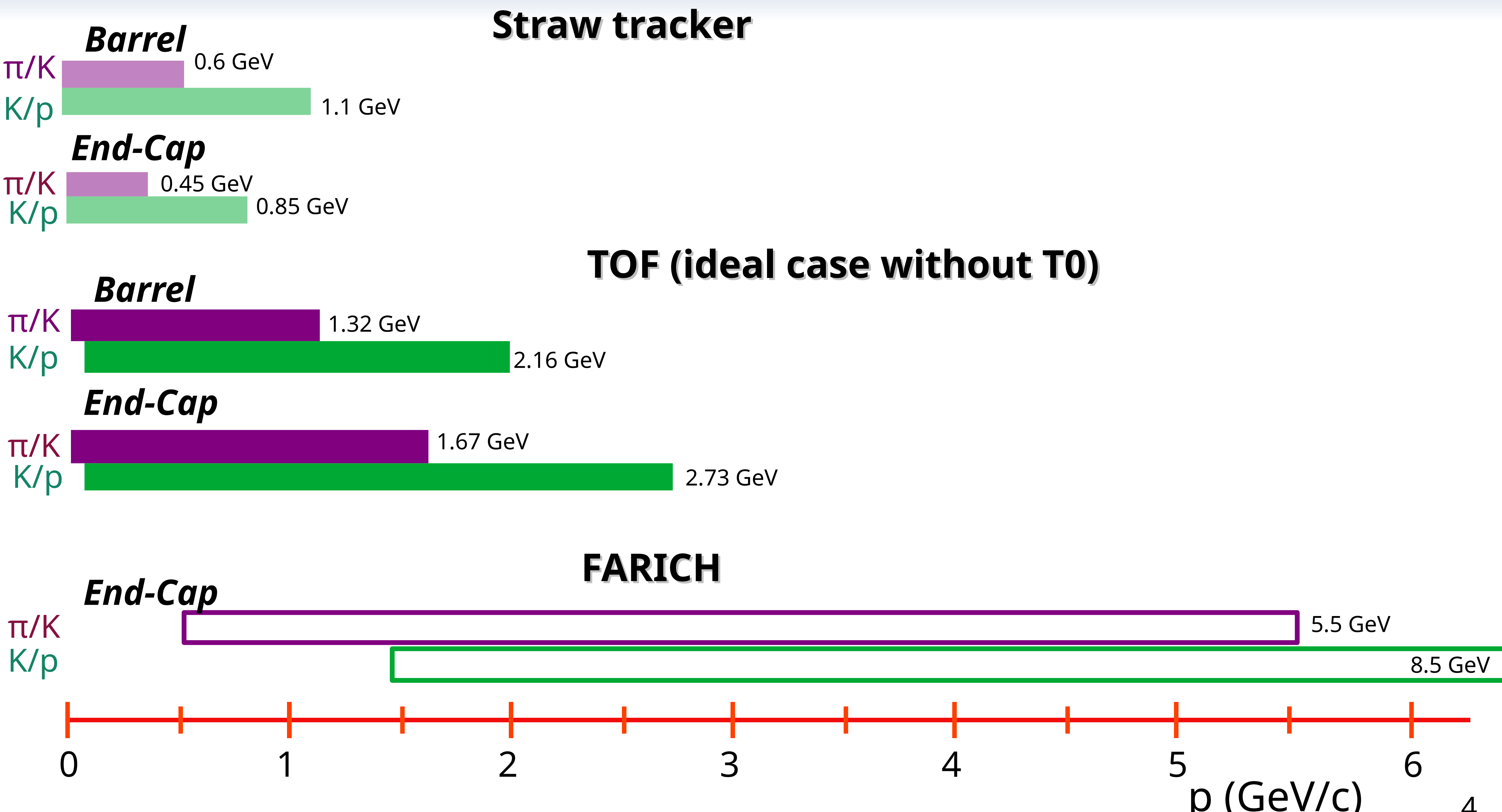
Principle of detector operation



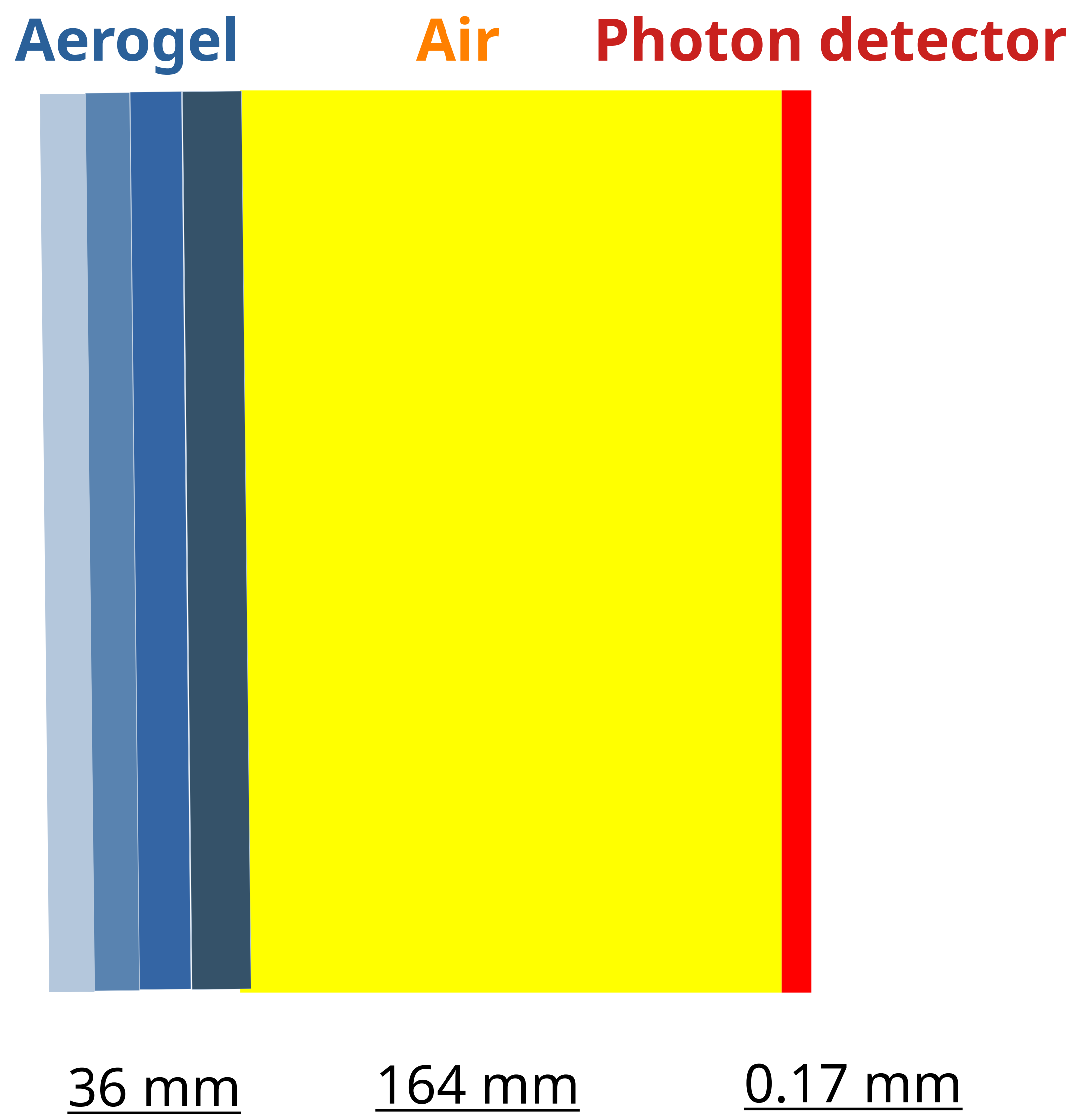


This work was carried out under the supervision of A.Yu. Barnyakov from the Budker Institute of Nuclear Physics, Novosibirsk.

Particle ID in SPD

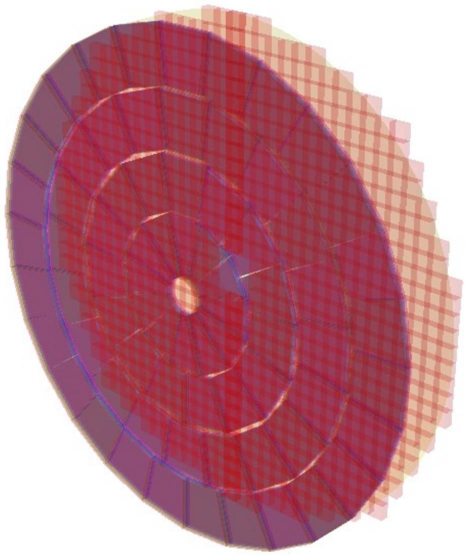


FARICH in SpdRoot: geometry

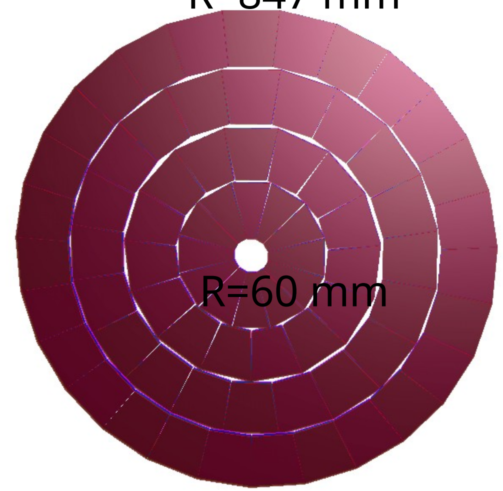


FARICH in SpdRoot: geometry

FARICH detector



Aerogel

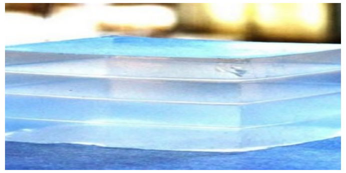


Material:

$$SiO_2 \; - \; 97\%$$

$$H_2O \; - \; 0.03\%$$

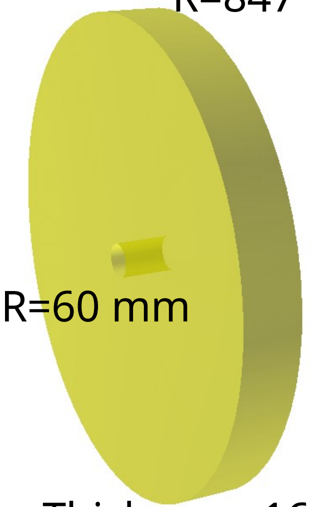
$$density = \frac{(n^2-1)}{0.438}, [cm^3/g]$$



n(400)=1.0370, L=7.00 mm	R=36 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

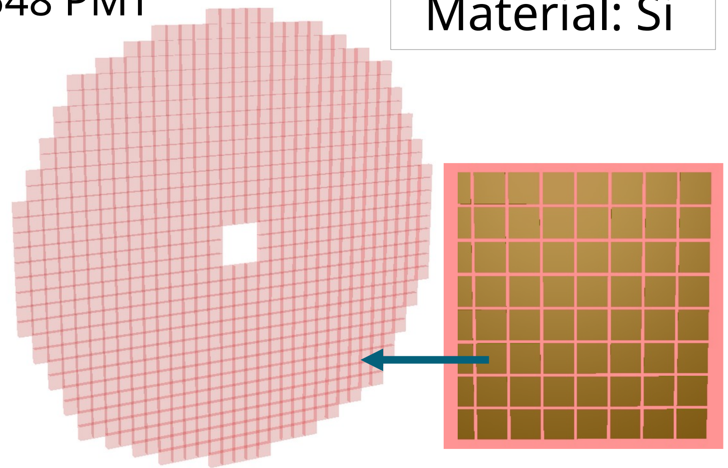
Material: Air



Photon detector

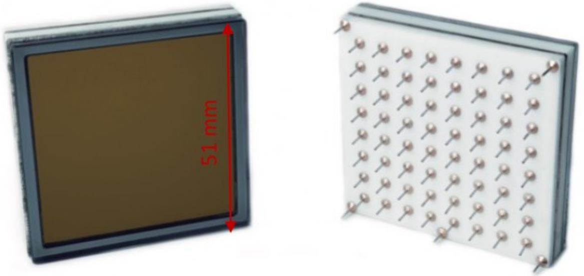
548 PMT

Material: Si



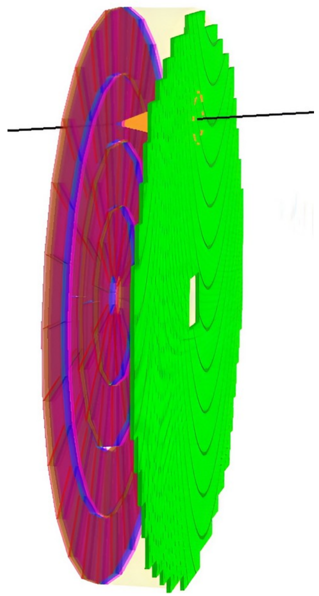
MCP PMTs N6021 from NNVT

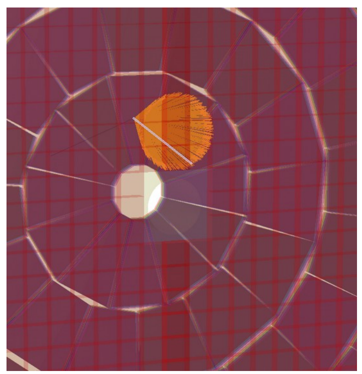
- 8×8 pixels with size 5.8×5.8 mm^2
- Lateral size 51×51 mm^2
- Thickness = 1.7 mm



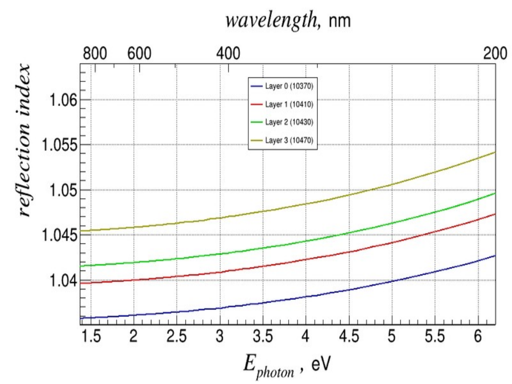
FARICH in SpdRoot: optical properties

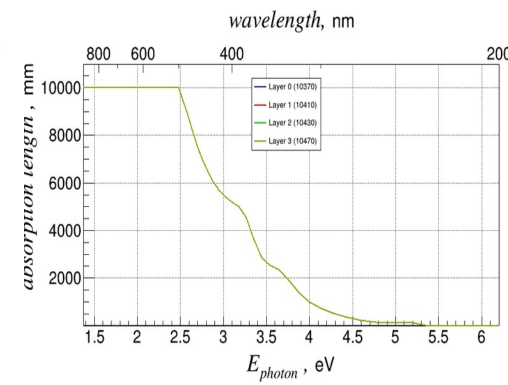
FARICH detector

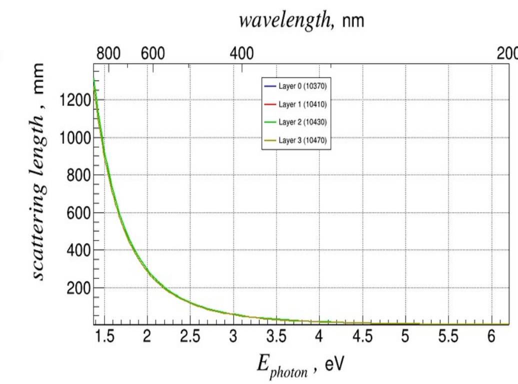




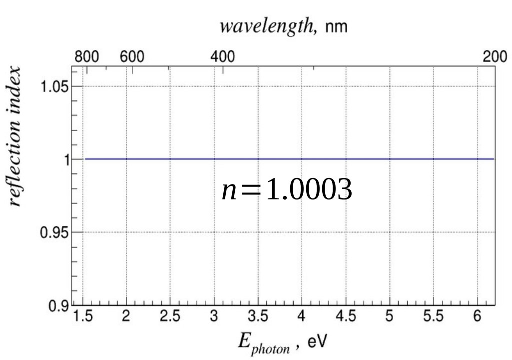
Aerogel

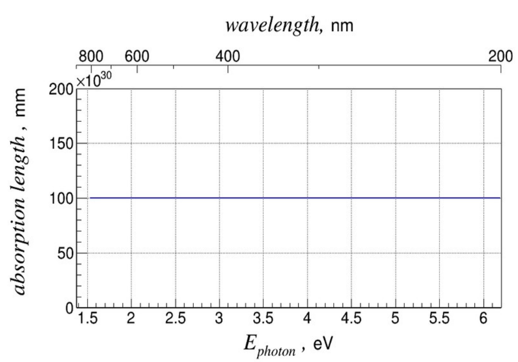




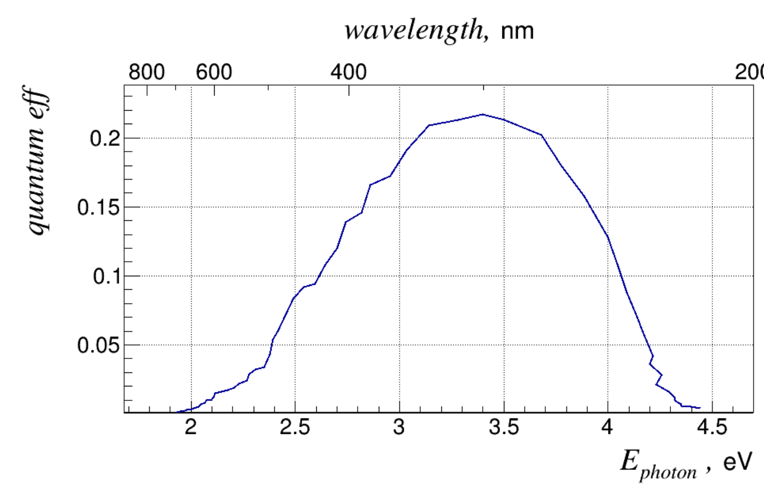


Air





Photon detector

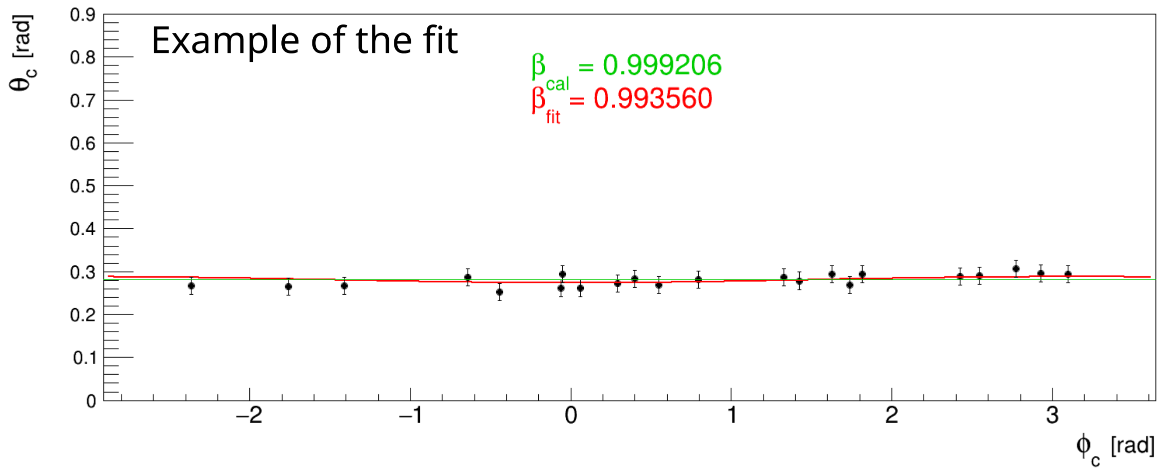


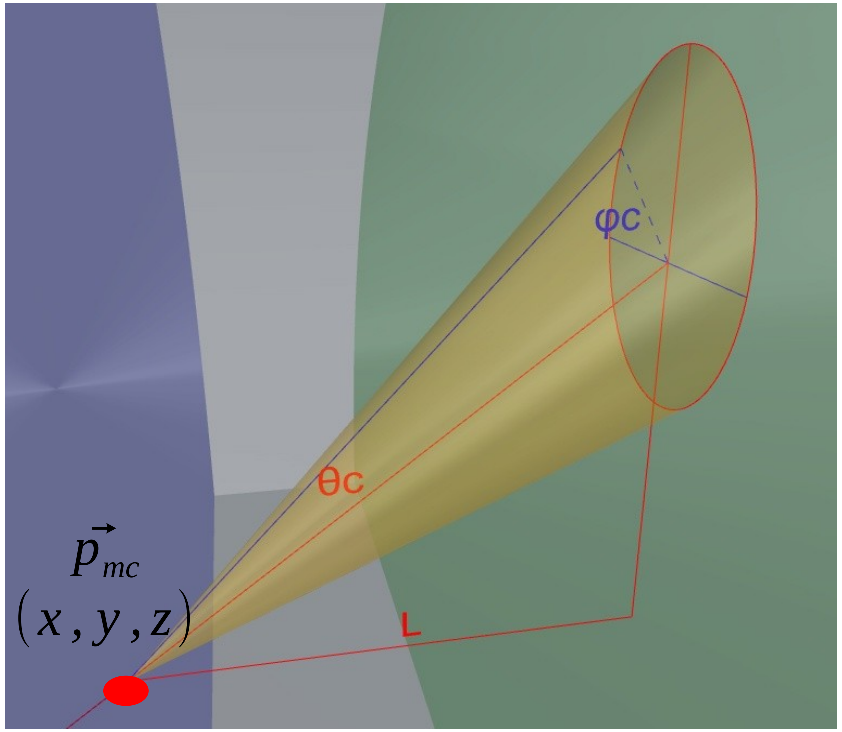
FARICH reconstruction: by dependence θ_c vs φ_c

The dependence of polar angle of Cherenkov photons θ_C on azimuth angle φ_c are used for reconstruction

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

- 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 in SpdRoot

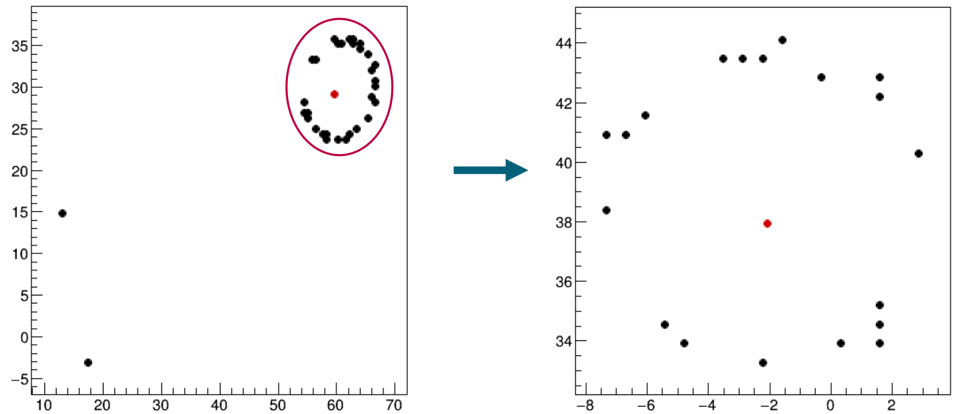
Development branch:

From previous collaboration meeting to now:

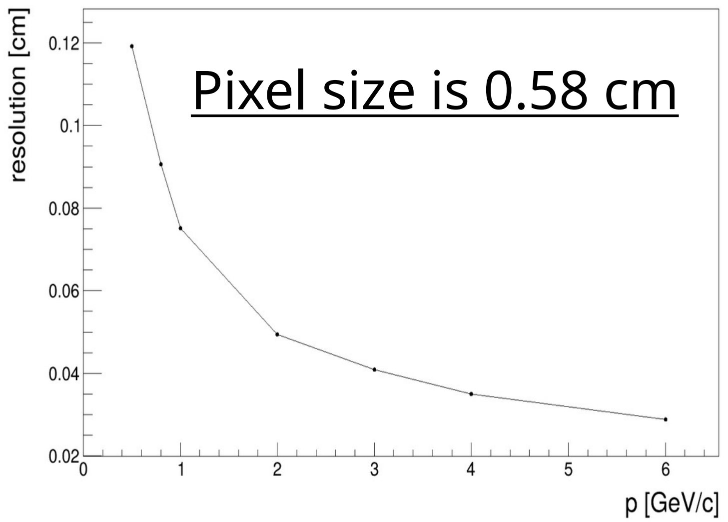
1) PID based on Likelihoods was added
2) Fixed stupid and others bugs
3) Ready for physics analysis

My private FARICH branch:

1) reconstructed track is extrapolated to FARICH (entrance and photon detector)
2) simple selection of photons belonging to the ellipse



Track in position of photon detector

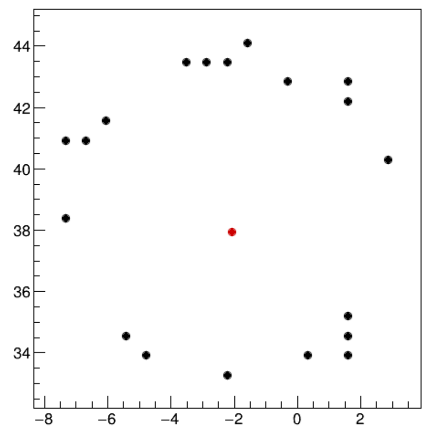


Likelihoods, method №1

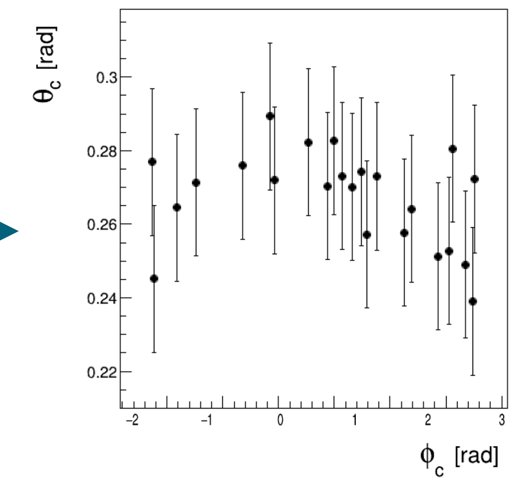
The probability density for a particular hit i;

$$S(\theta_i,\theta_{hyp})=\frac{1}{\sqrt{2\pi*\sigma_i}}e^{\frac{(\theta_i-\theta_{hyp})^2}{2\sigma_i^2}}$$

$$G(n,n_{\exp})=\frac{(n_{\exp})^n}{n!}e^{-n_{\exp}}$$



θi(ϕi)



$$\log L=\sum_{i=i}^{n}\log S(\theta_i,\theta_{hyp})+\log G(n,n_{\exp})$$

$\theta_i(\phi_i)$ - measure Cherenkov angle for hit i

$\theta_{i'hyp}$ - expected Cherenkov angle for hit i

σ_i - single angular resolution for hit i

n - number of registered photoelectrons

n_e - expected number of photoelectrons

Likelihoods, method №1

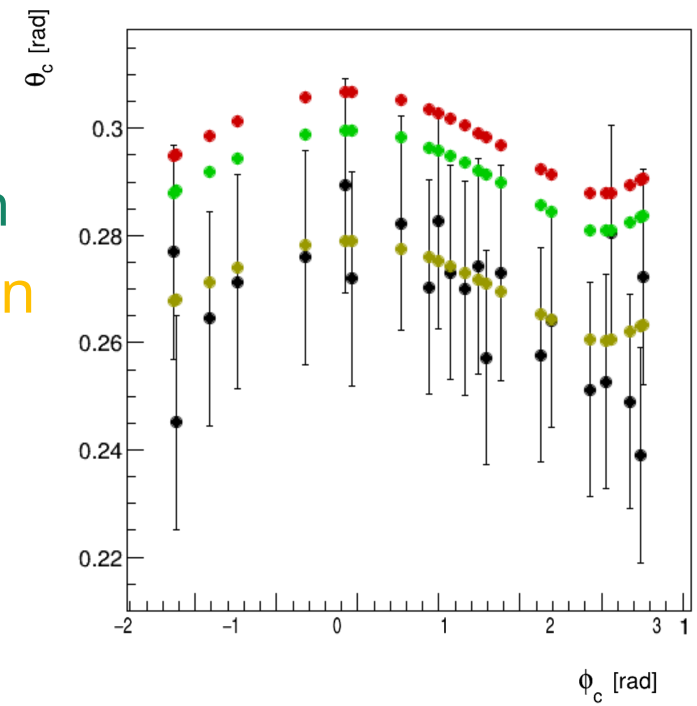
data

$$S(\theta_i, \theta_{hyp}) = \frac{1}{\sqrt{2\pi * \sigma_i}} e^{\frac{(\theta_i - \theta_{hyp})^2}{2\sigma_i^2}}$$

Pion

kaon

proton



Proton data

Know momentum → can calculate β for different mass

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

- 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

Likelihoods, method №1

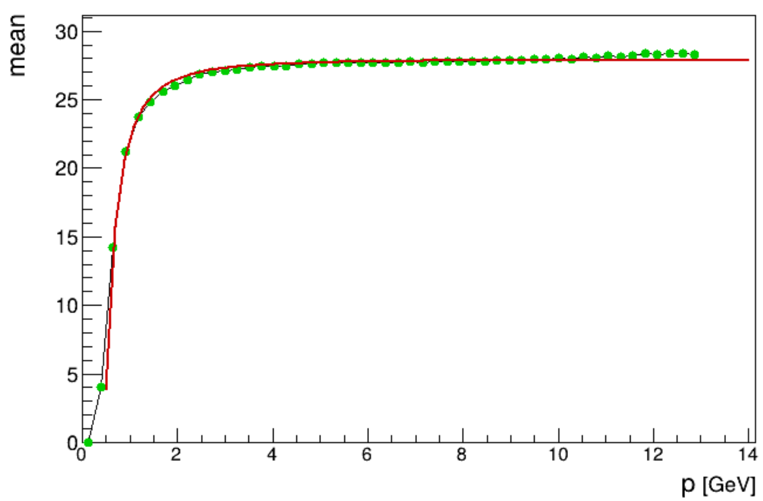
data

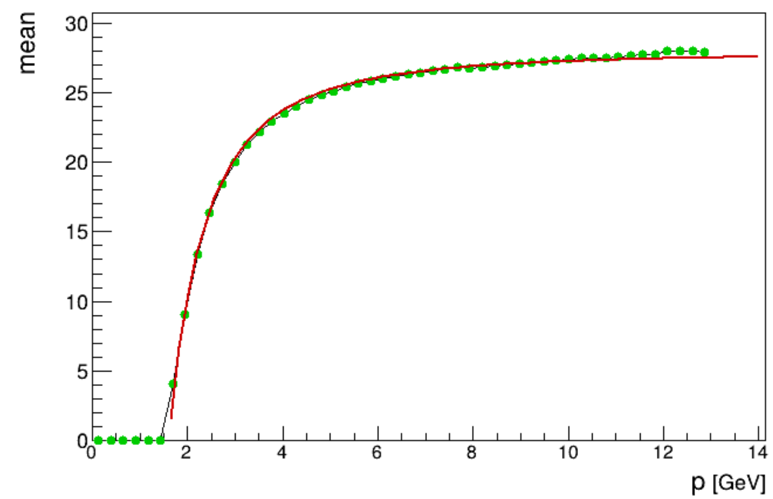
$$G(n, n_{\exp}) = \frac{(n_{\exp})^n}{n!} e^{-n_{\exp}}$$

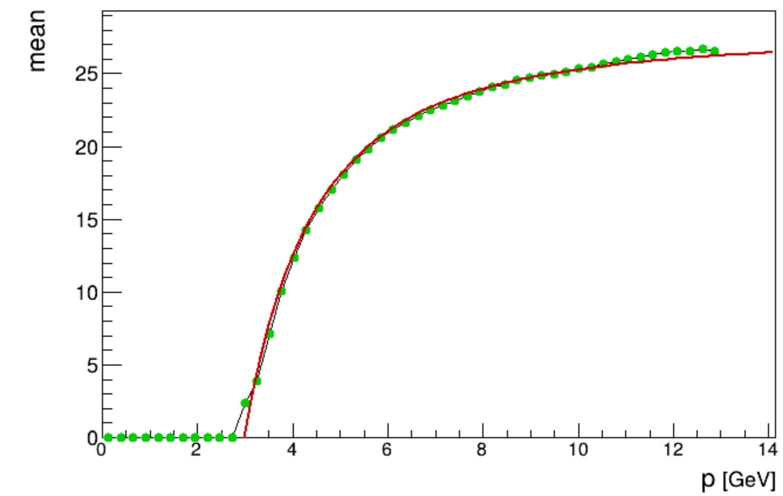
pion

kaon

proton

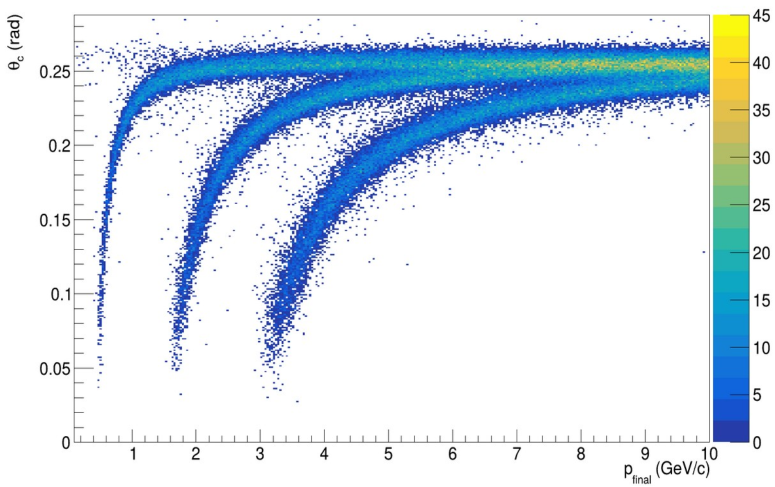






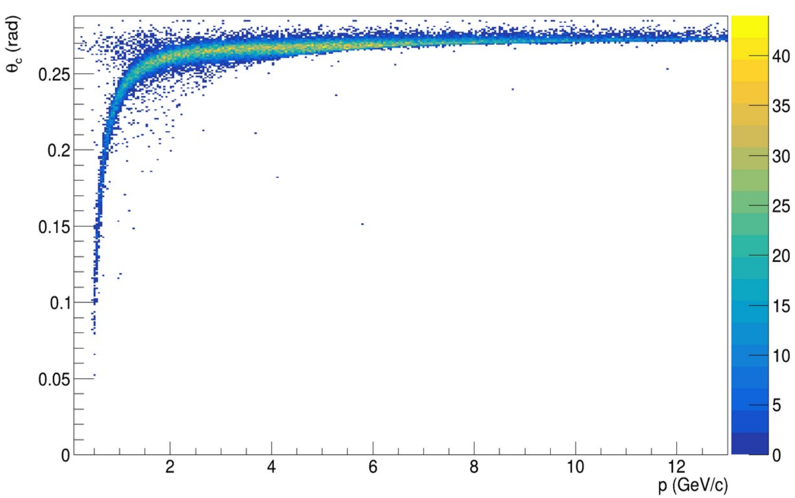
Likelihoods, method №1

Artificial sample

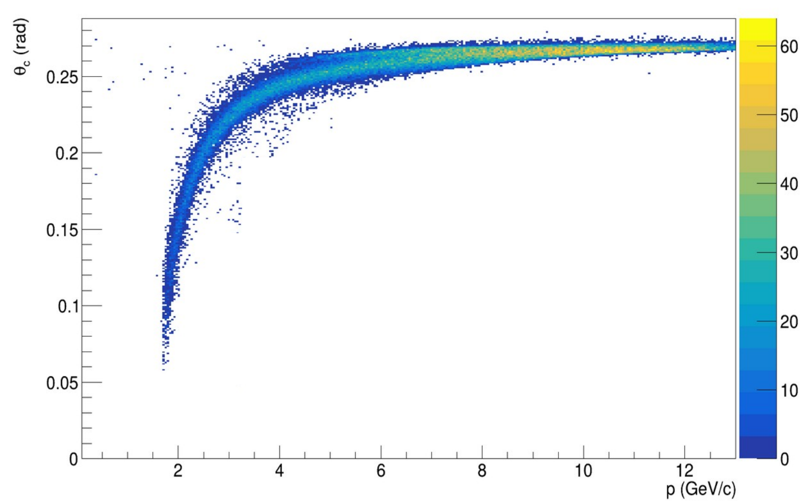


$$\log L=\sum_{i=i}^{n}\log\frac{1}{\sqrt{2\pi*\sigma_i}}e^{\frac{(\theta_i-\theta_{hyp})^2}{2\sigma_i^2}}+\log\frac{(n_e)^n}{n!}e^{-n_e}$$

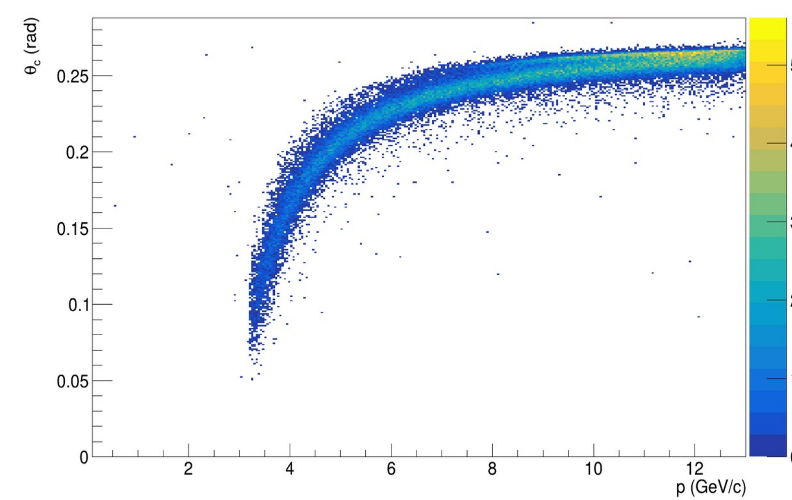
LH_{pion} $>LH_{kaon}>LH_{proton}$



LH_{kaon} $>LH_{pion}>LH_{proton}$

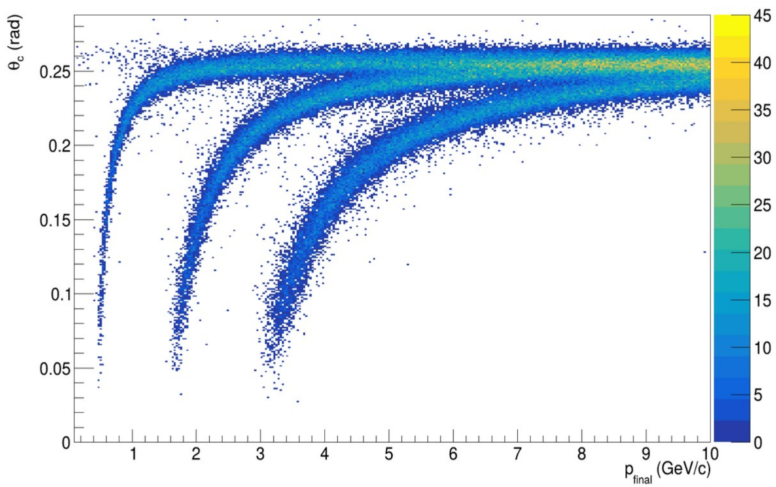


LH_{proton} $>LH_{pion}>LH_{kaon}$



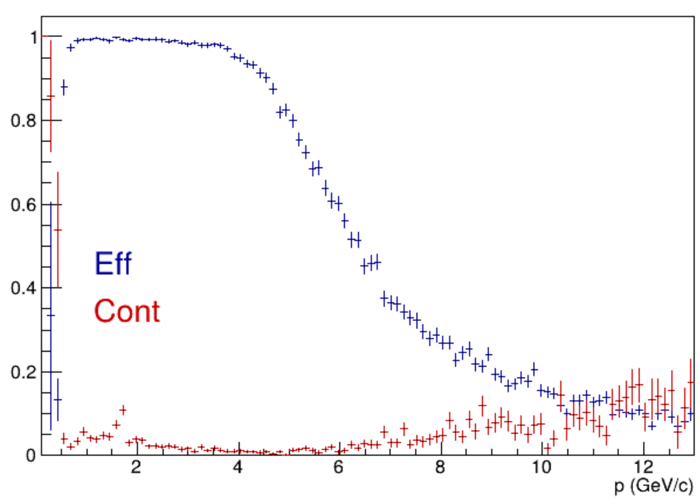
Likelihoods, method №1

Artificial sample

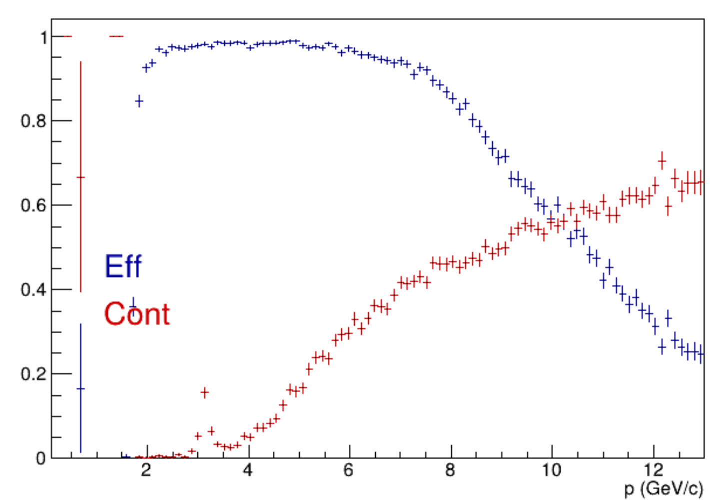


$$\log L = \sum_{i=i}^{n} \log \frac{1}{\sqrt{2\pi * \sigma_i}} e^{\frac{(\theta_i - \theta_{hyp})^2}{2\sigma_i^2}} + \log \frac{(n_e)^n}{n!} e^{-n_e}$$

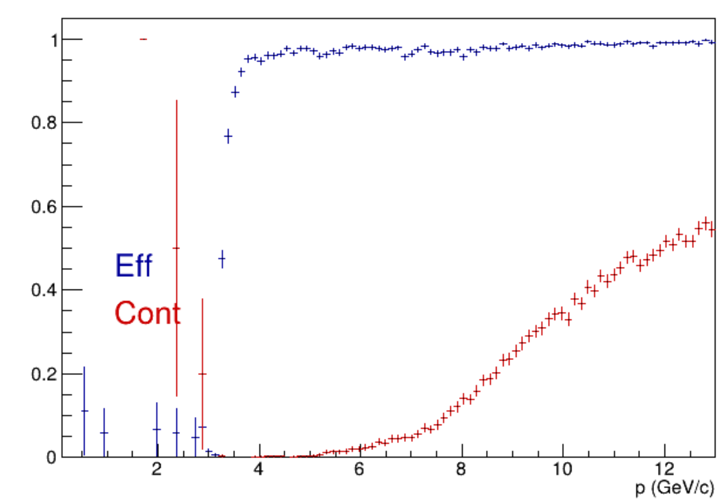
LH_{pion} $> LH_{kaon} > LH_{proton}$



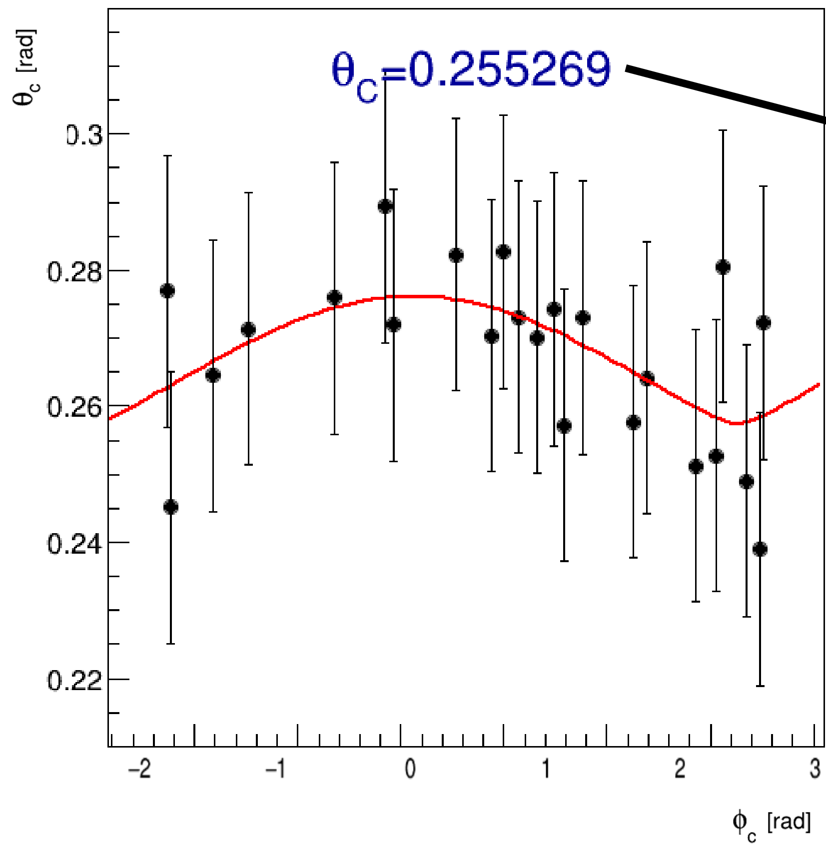
LH_{kaon} $> LH_{pion} > LH_{proton}$



LH_{proton} $> LH_{pion} > LH_{kaon}$



Likelihoods , method №2



data

$$L = \frac{1}{\sqrt{2\pi * \sigma}} e^{\frac{(\theta_{fit} - \theta_{hyp})^2}{2\sigma^2}}$$

Get from parametrization

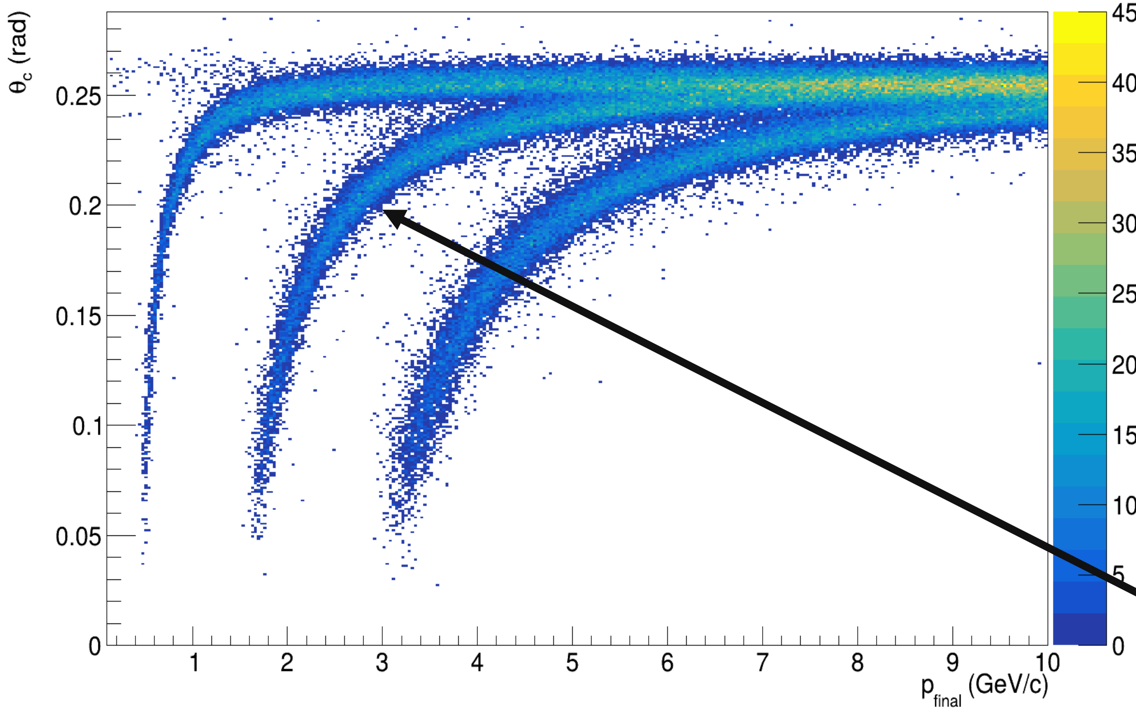
θ_{fit} - Cherenkov angle from fit

$\sigma_{hyp,fit}$ - angular resolution

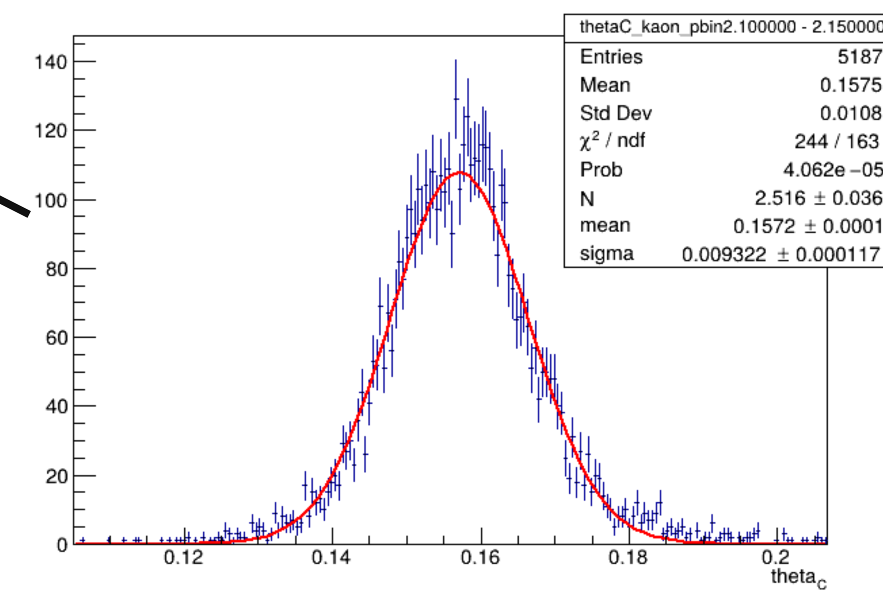
θ_{hyp} - expected Cherenkov angle

Likelihoods, method №2: calculation parametrization

Artificial sample

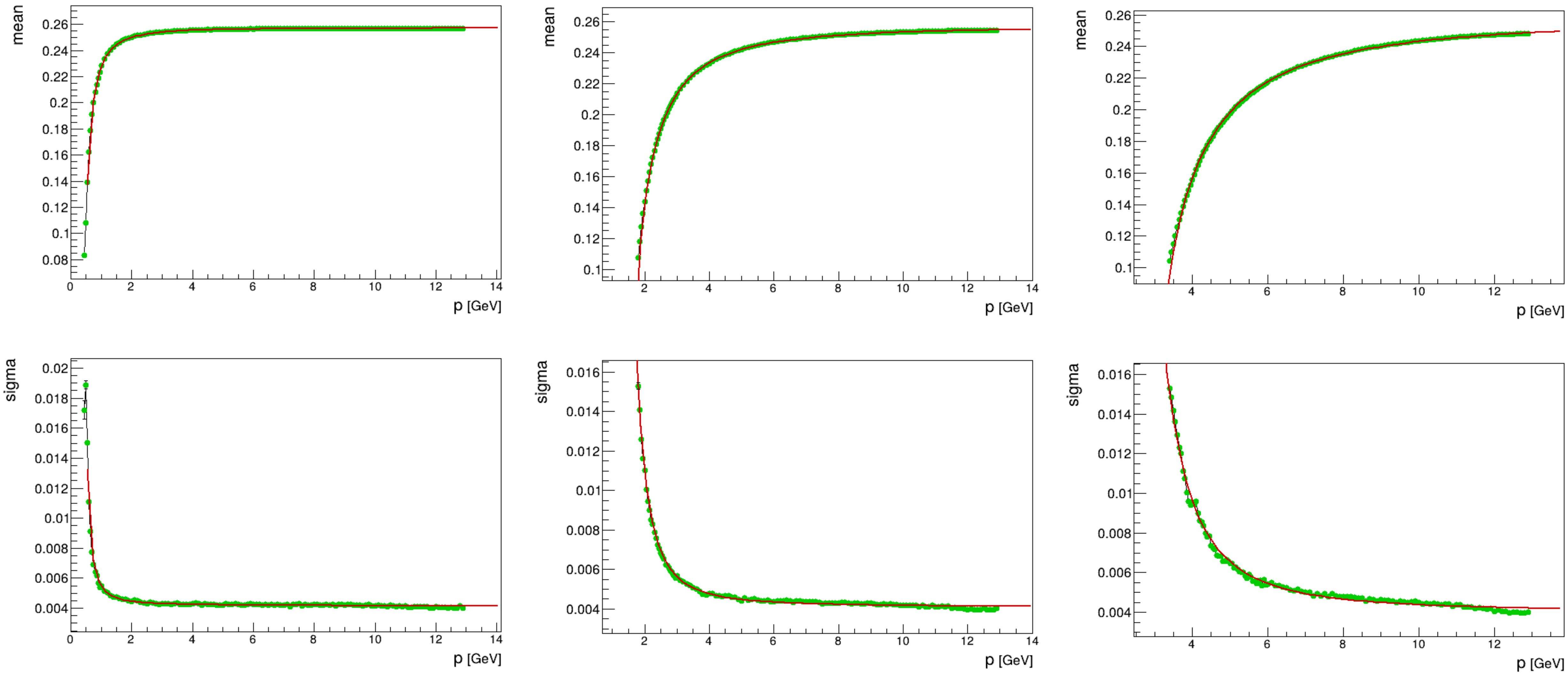


Divide distribution of θ_c in bins of momentum and then fit by gauss function



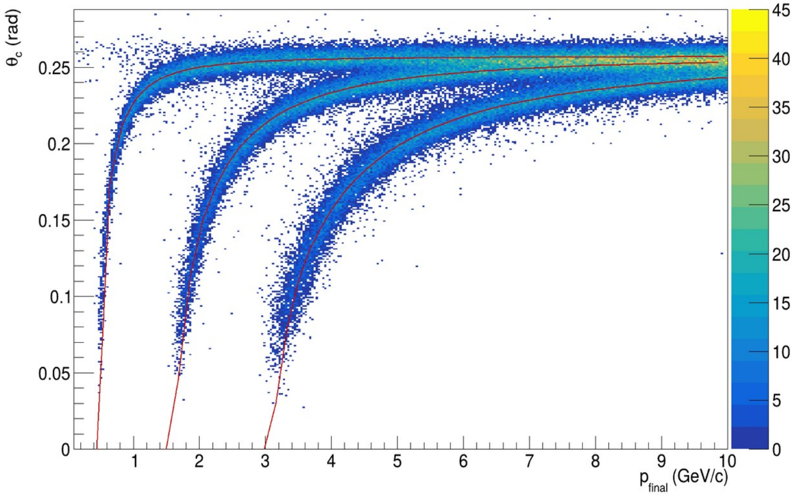
Likelihoods, method №2: mean and sigma from fit

pion kaon proton



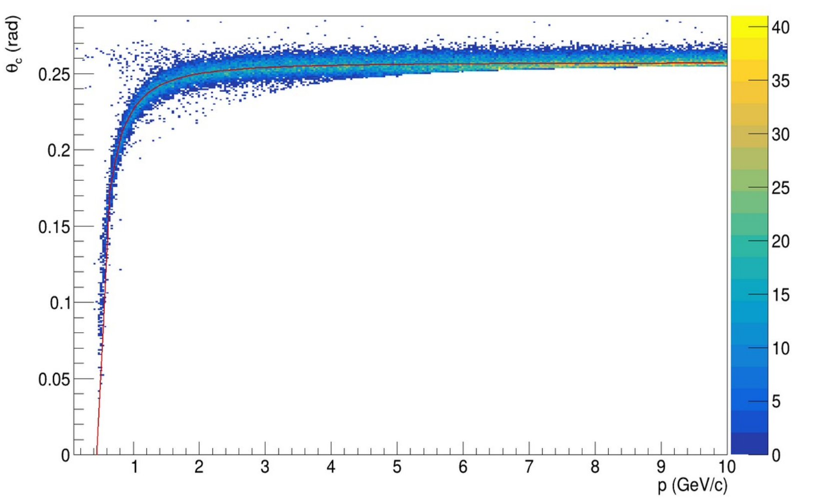
Likelihoods, method №2

Artificial sample

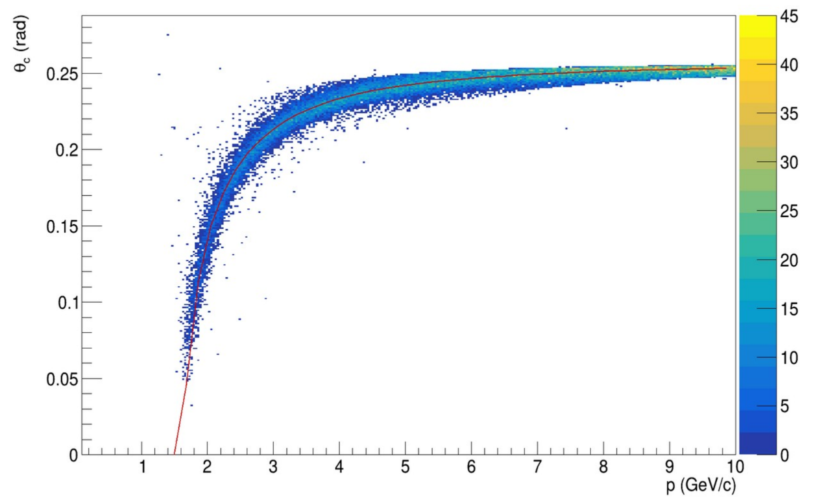


$$L = \frac{1}{\sqrt{2\pi * \sigma}} e^{\frac{(\theta - \theta_{hyp})^2}{2\sigma^2}}$$

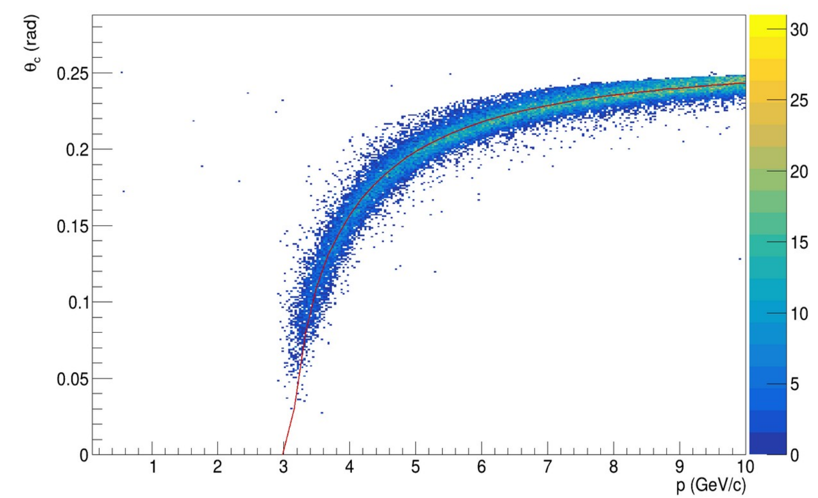
LH_{pion} $>LH_{kaon}>LH_{proton}$



LH_{kaon} $>LH_{pion}>LH_{proton}$

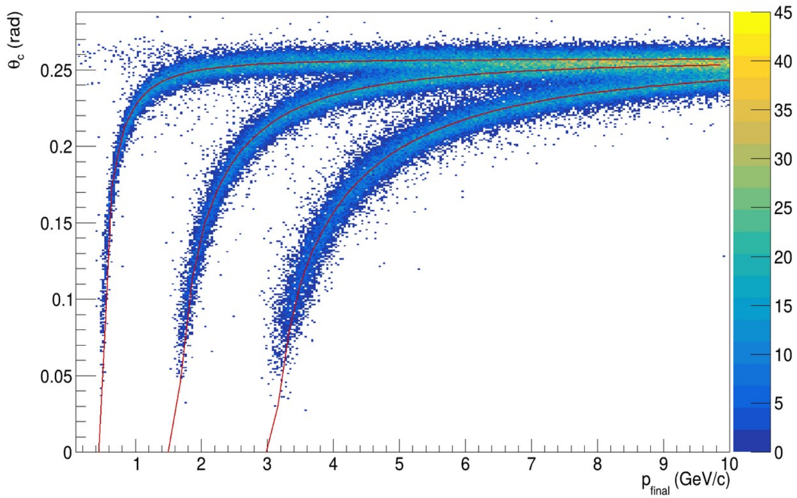


LH_{proton} $>LH_{pion}>LH_{kaon}$



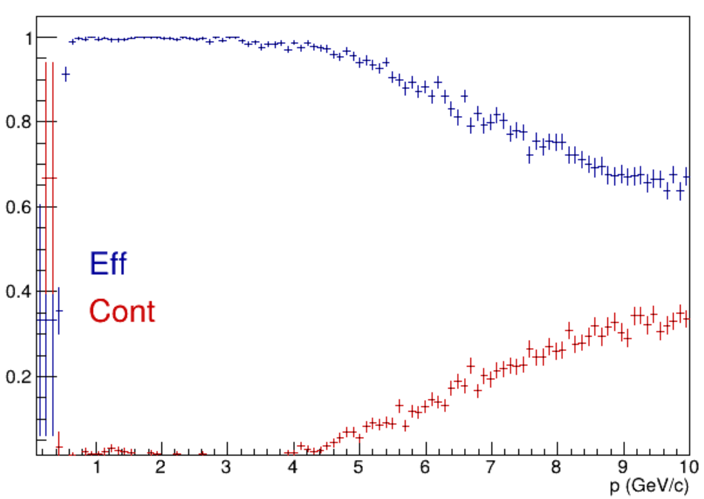
Likelihoods, method №2

Artificial sample

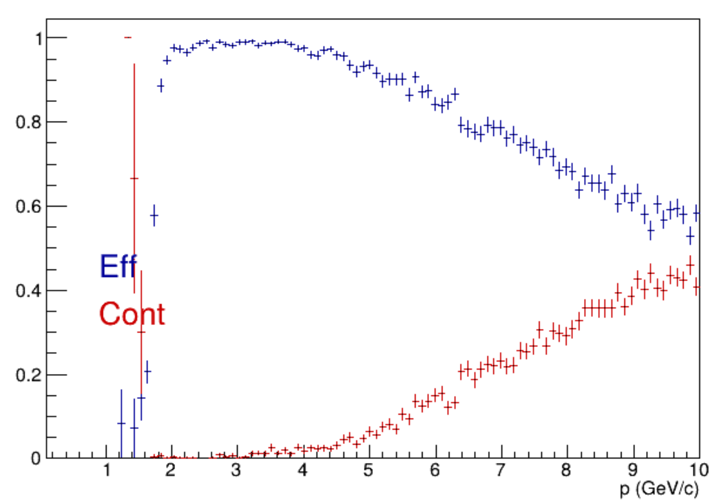


$$L = \frac{1}{\sqrt{2\pi * \sigma}} e^{\frac{(\theta - \theta_{hyp})^2}{2\sigma^2}}$$

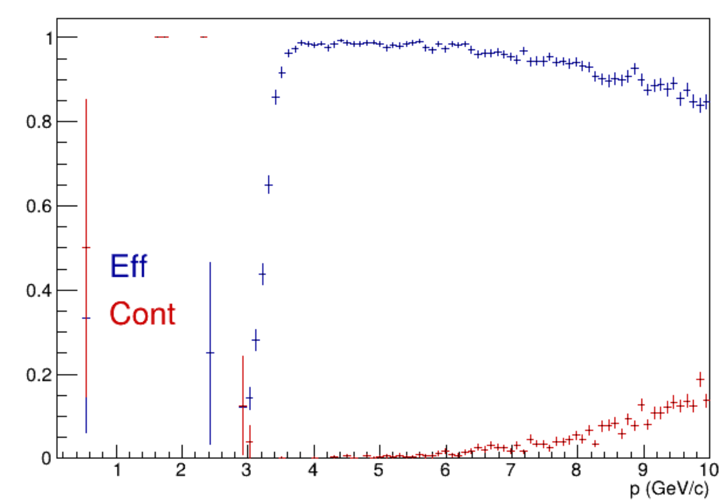
LH_{pion} $>LH_{kaon}>LH_{proton}$



LH_{kaon} $>LH_{pion}>LH_{proton}$

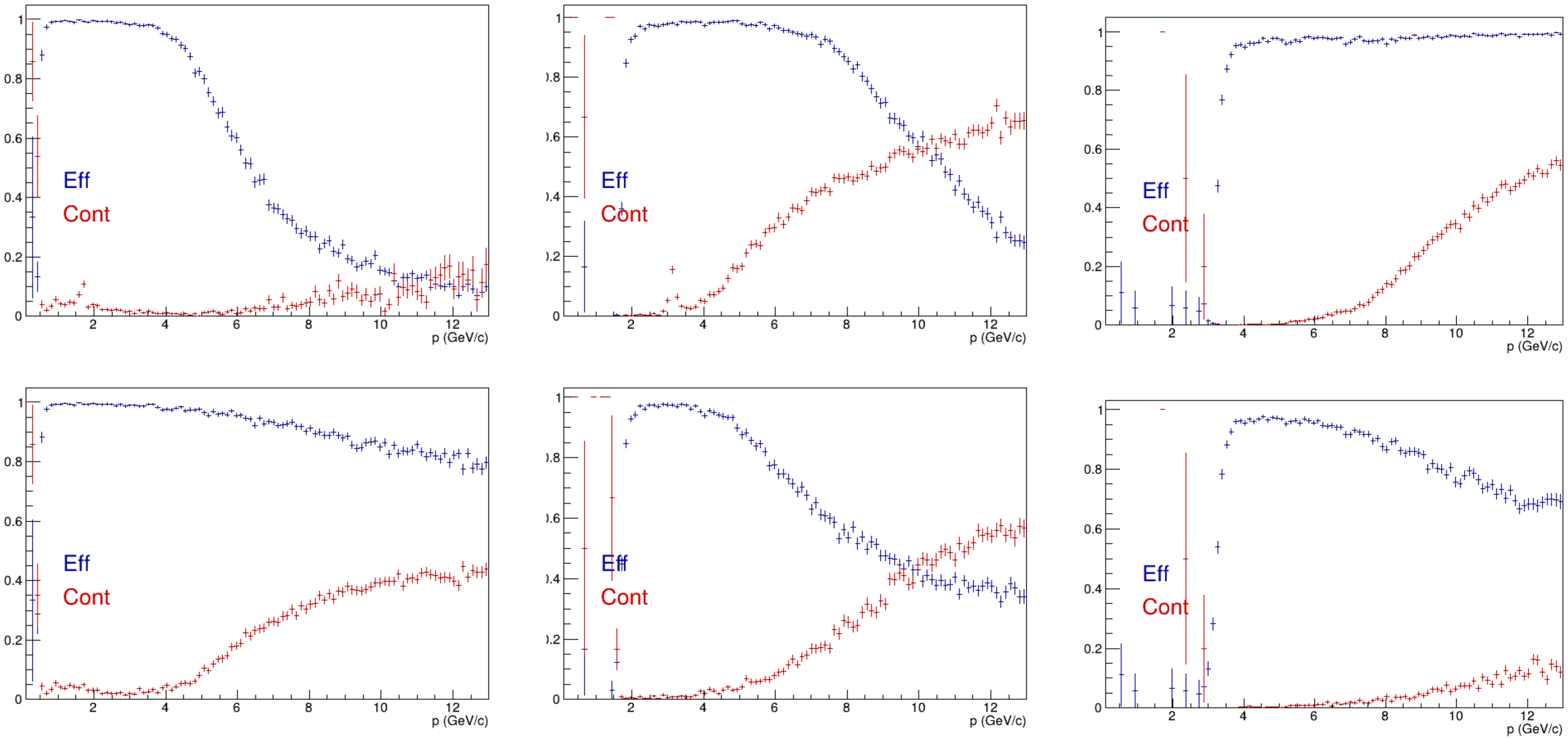


LH_{proton} $>LH_{pion}>LH_{kaon}$



Likelihoods, method №1 and №2

$\mathbf{LH_{pion}} > LH_{kaon} > LH_{proton}$ $\mathbf{LH_{kaon}} > LH_{pion} > LH_{proton}$ $\mathbf{LH_{proton}} > LH_{pion} > LH_{kaon}$



$$efficiency = \frac{N_{corr}}{N_{true}} \qquad contamination = \frac{N_{incorr}}{(N_{incorr} + N_{corr})}$$

N_{corr} – the number of correctly identified particles of a certain type

N_{incorr} – number of misidentified particles a certain type

N_{true} – the true number of particles of a certain type.

Conclusion

- FARICH PID likelihood fixed and ready for physics analysis
- Two methods for PID selection was implemented

Backup slides

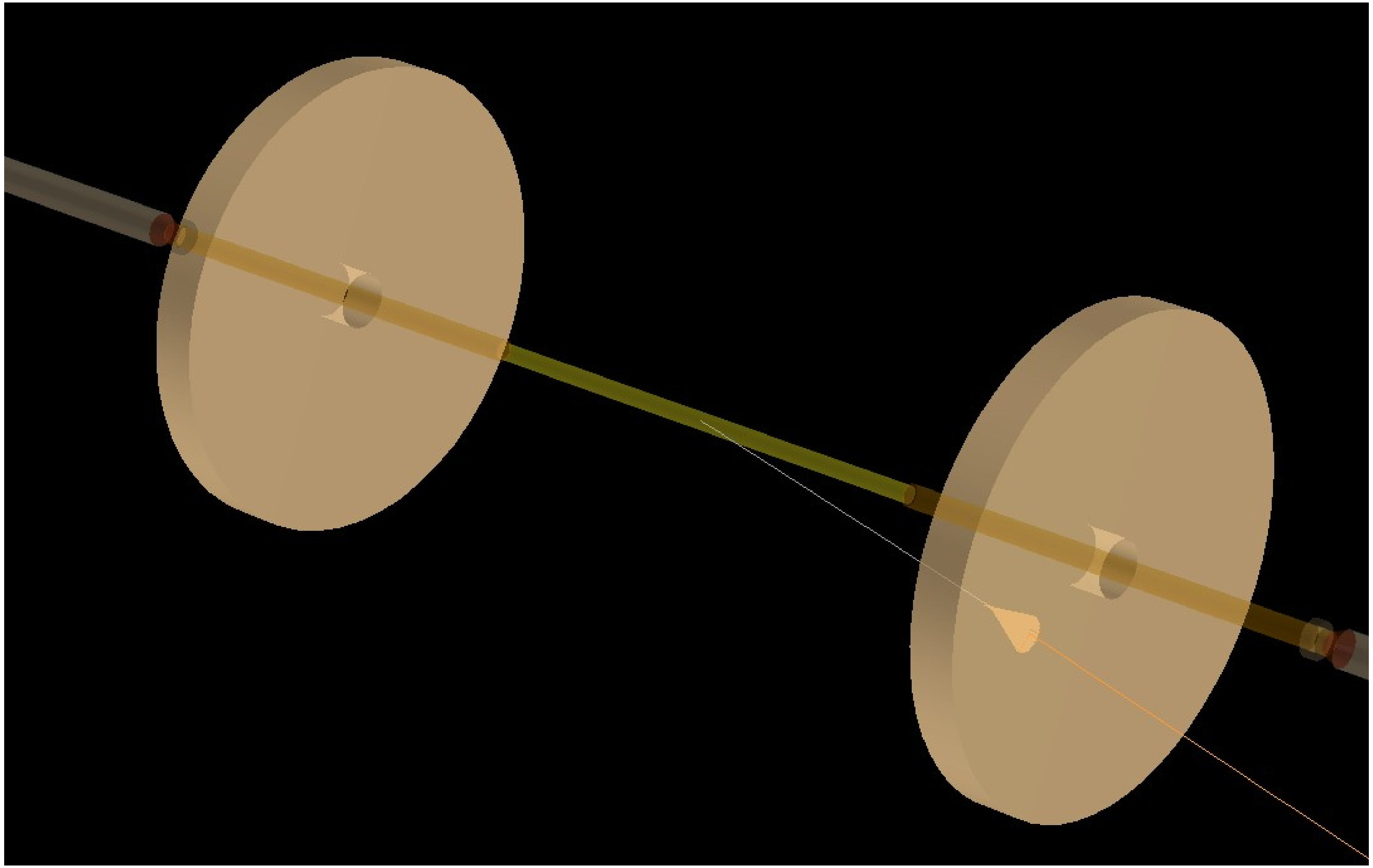
Input for study resolution

Pion+

0.5 0.8 1 2 3 4 6 GeV

Phi = 180

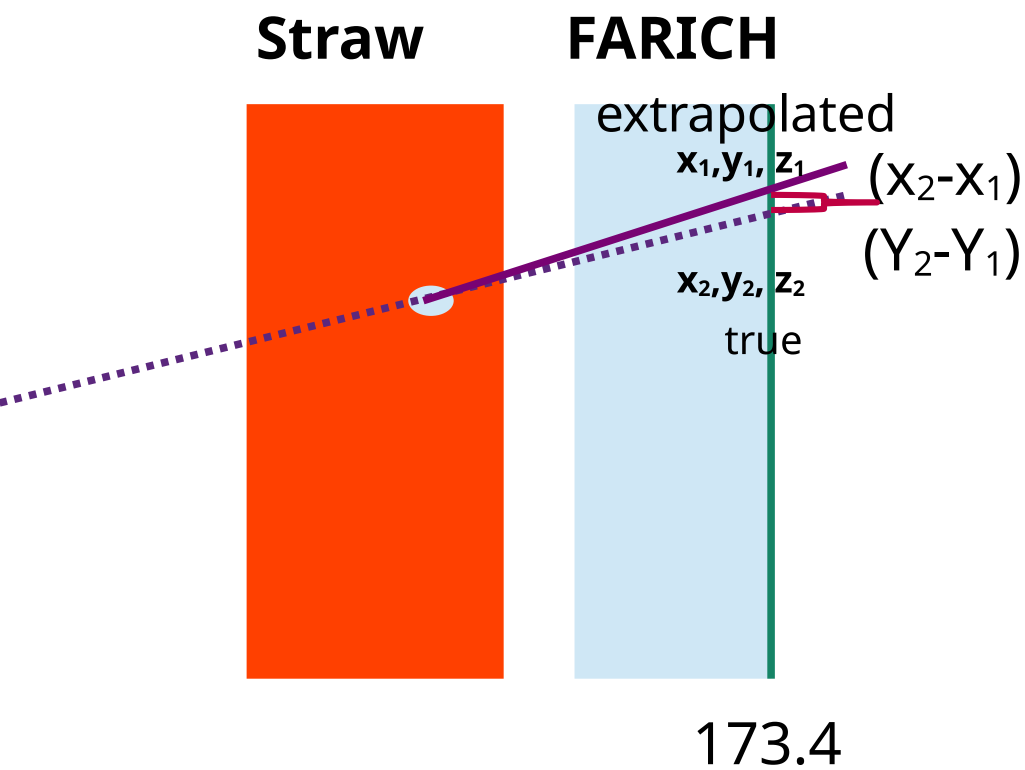
Theta = 15



Set-up
DSSD + STRAW+FARICH

Analysis

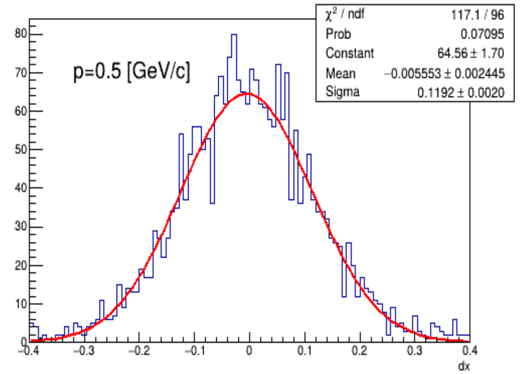
state last point (Straw) → extrapolate in plane (0,0,173.4)

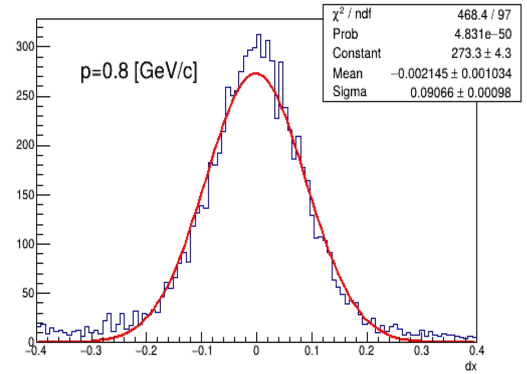


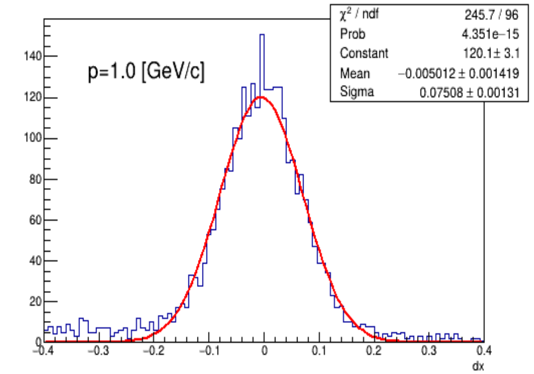
MCP PMT N6021

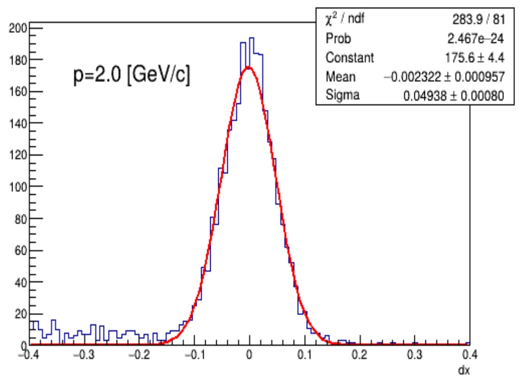
- 8×8 pixels with size 5.8×5.8 mm^2
- Lateral size 51×51 mm^2
- Width = 1.7 mm

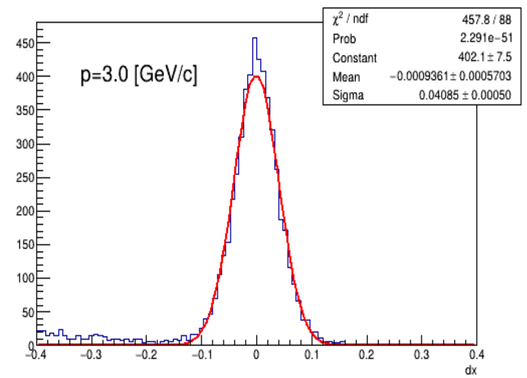
$x_{true} - x_{extrapolated}$ for different momentum

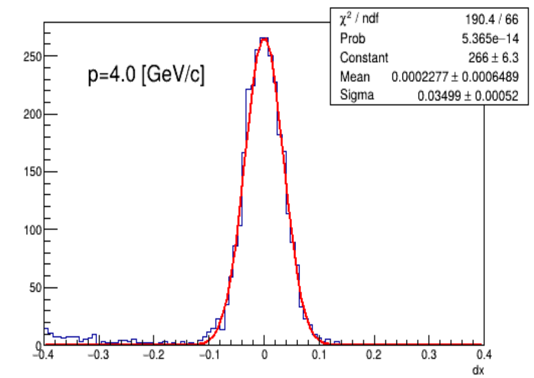


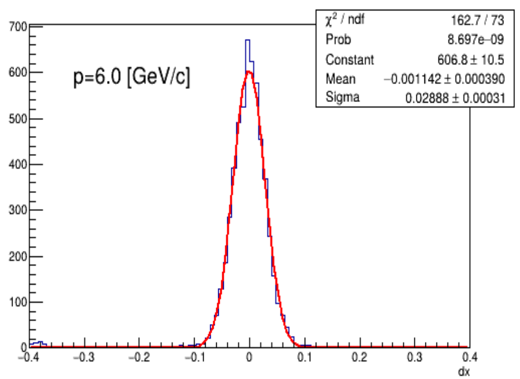




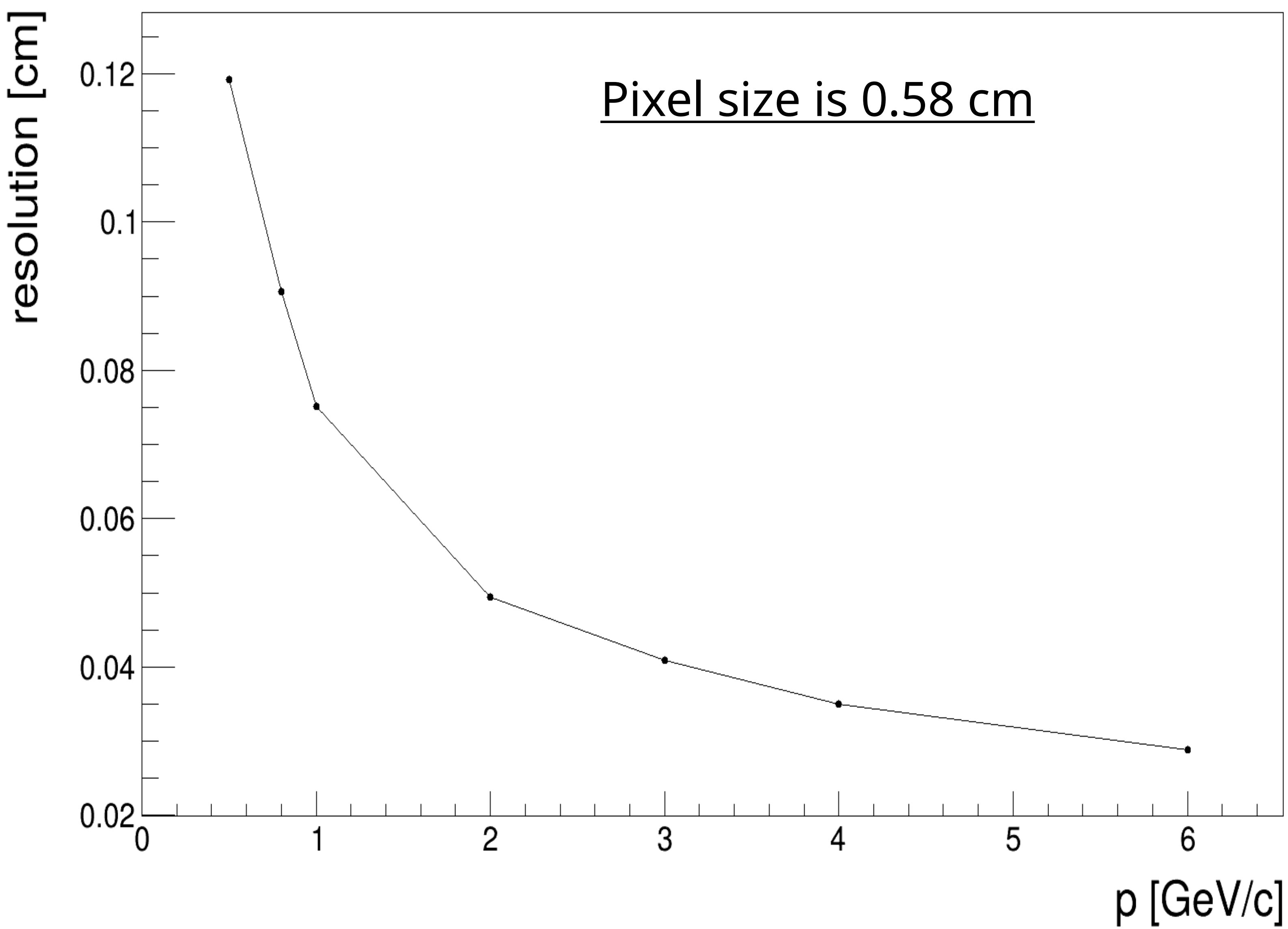








Resolution


Pixel size is 0.58 cm
resolution [cm]
0.12
0.1
0.08
0.06
0.04
0.02
0
1
2
3
4
5
6
p [GeV/c]

Likelihood PID

The probability density for a particular hit i;

$$F(\theta_i, \theta_{hyp}) = pS(\theta_i, \theta_{hyp}) + (1-p)B(\theta_i)$$

- signal $S(\theta_i, \theta^{hyp}) = \frac{1}{\sqrt{2\pi * \sigma_i}} e^{\frac{(\theta_i - \theta_{hyp})^2}{2\sigma_i^2}}$
- background $B(\theta_i) = B_0 \theta_i$
- signal fraction $p = \frac{N_{exp,\ signal}}{N_{\exp}}$

$$G(n, n_{\exp}) = \frac{(n_{\exp})^n}{n!} e^{-n_{\exp}}$$

n - number of registered photoelectrons

n_{exp} = ($n_{exp,\ signal}$ + $n_{exp,\ bgr}$) - expected number of photoelectrons

$$\log L(h) = \sum_{i=i}^{n} \log F(\theta_i, \theta_{hyp}) + \log G(n, n_{\exp})$$