FARICH

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SPD Collaboration Meeting
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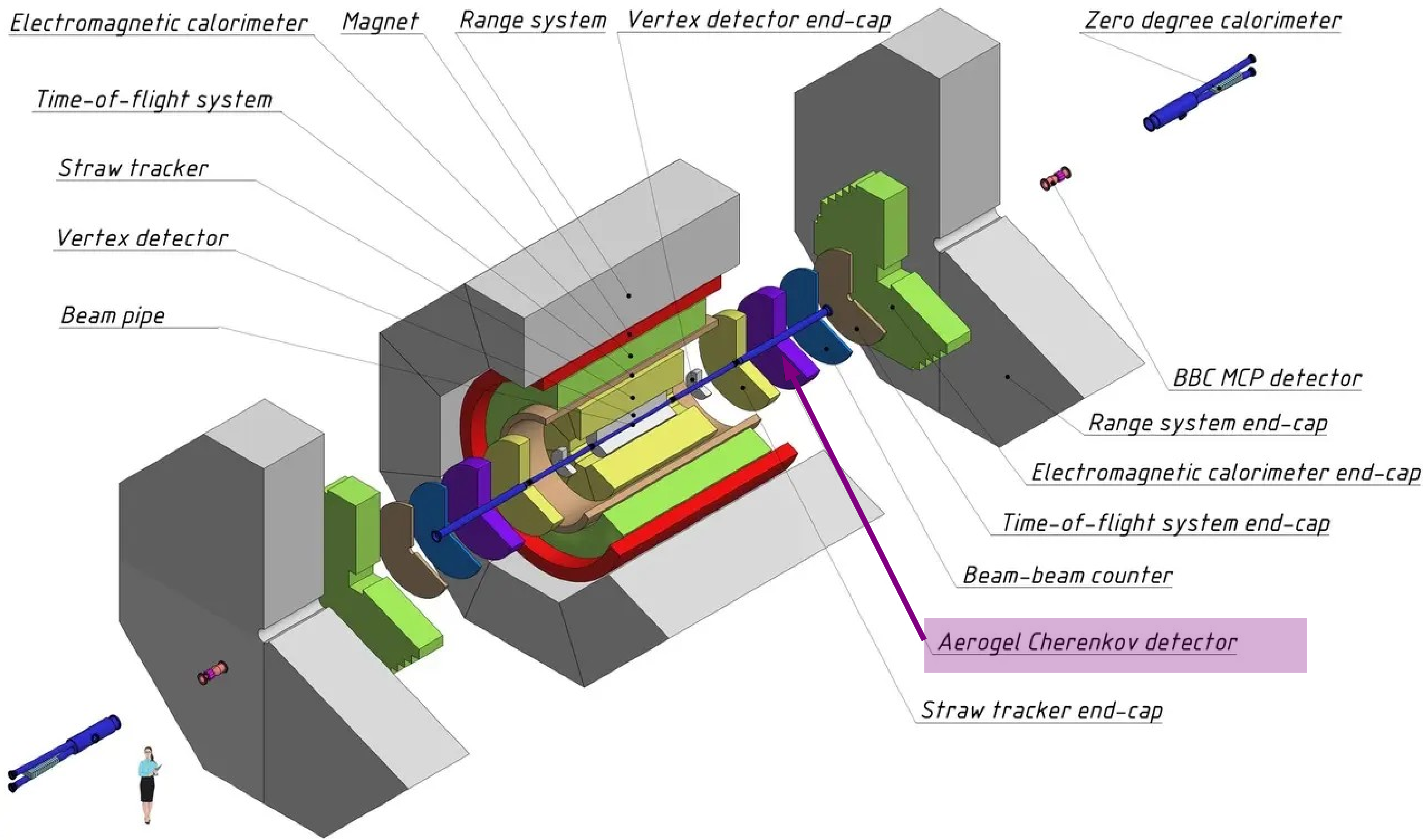
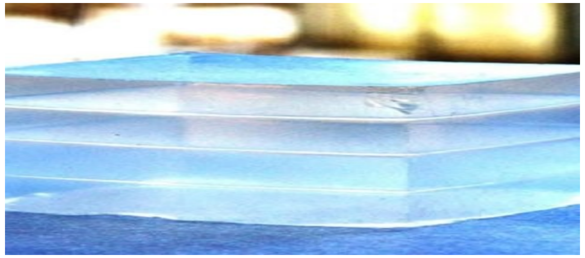
Focusing Aerogel RICH detector in SPD

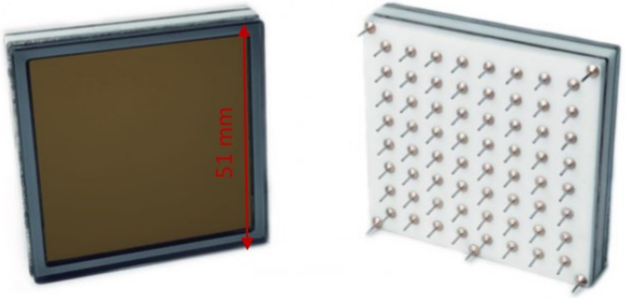


FARICH detector: basic principles

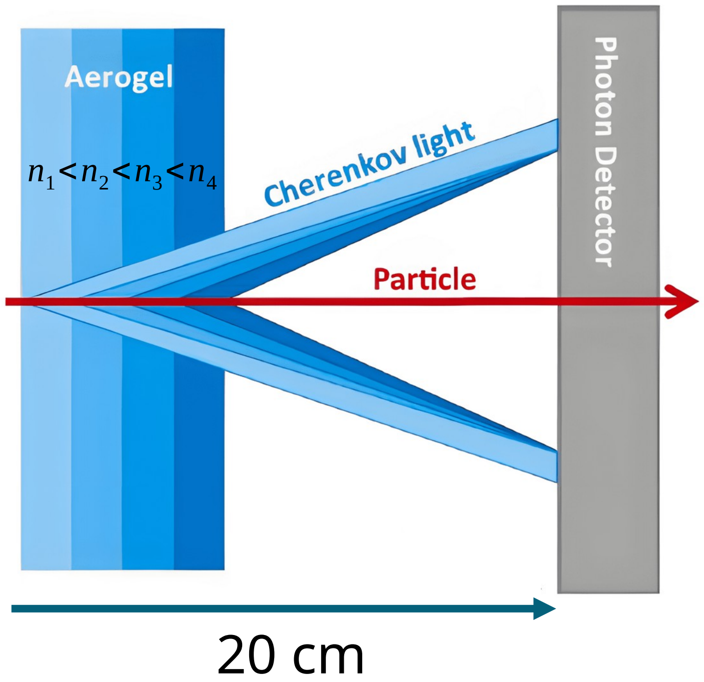
aerogel



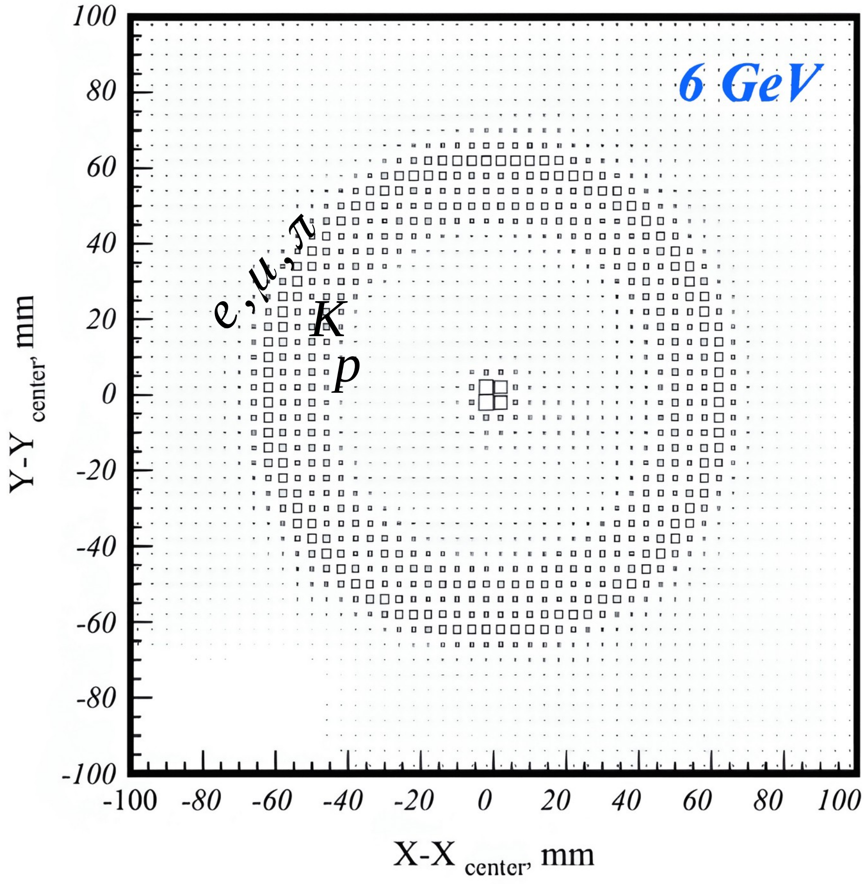
MCP PMTs N6021 from NNVT



Principle of detector operation

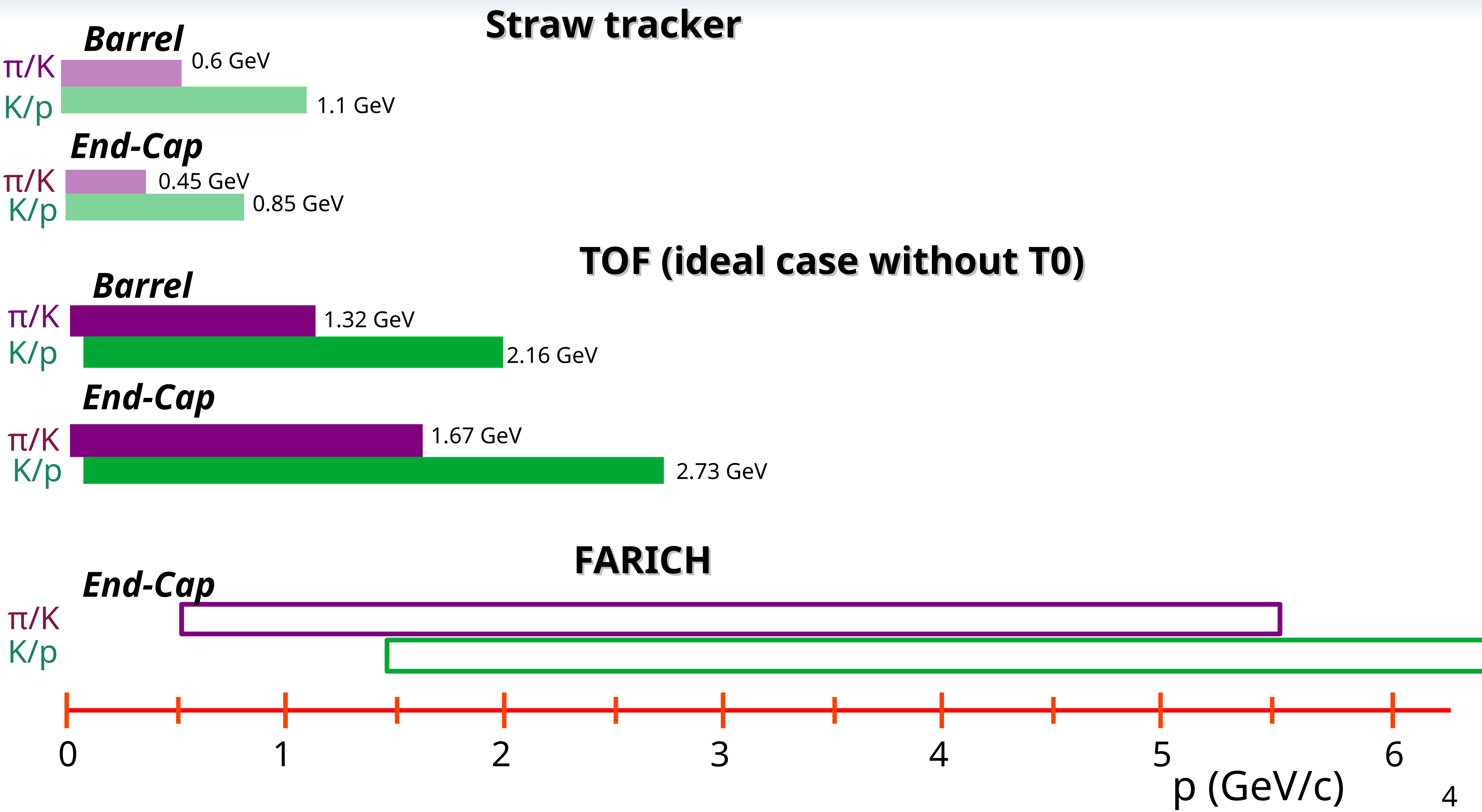


Accumulated *xy* distribution of hits

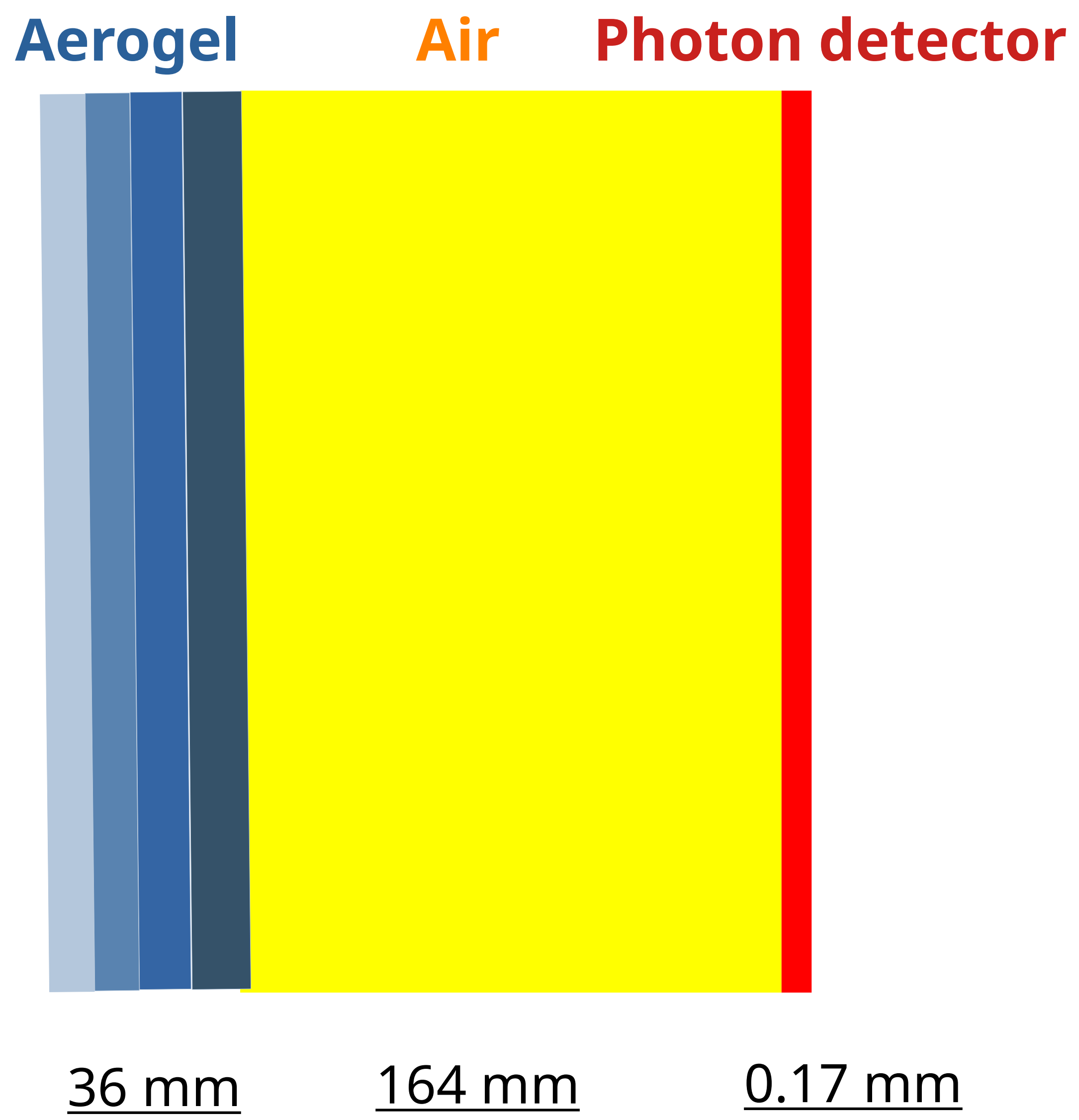


This work was carried out under the supervision of A.Yu. Barnyakov from the Budker Institute of Nuclear Physics, Novosibirsk.

Particle ID in SPD

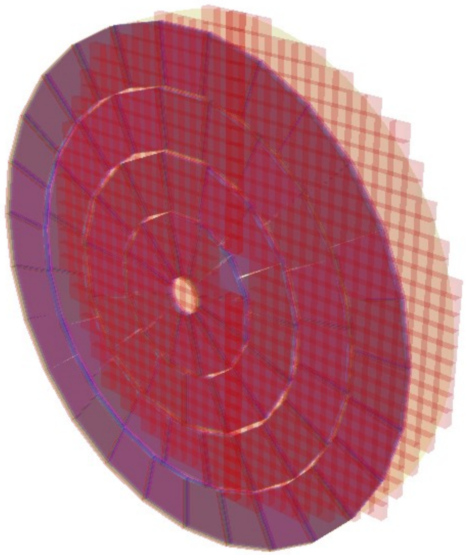


FARICH in SpdRoot: geometry

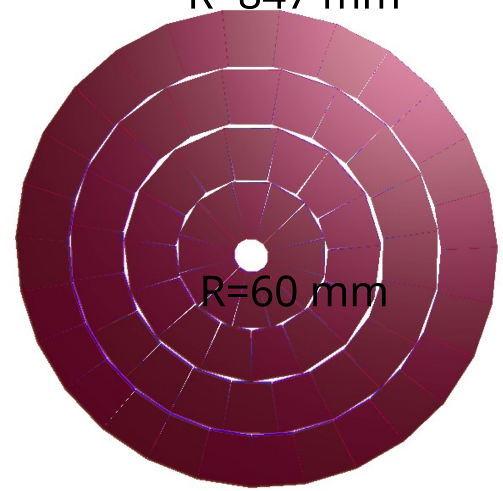


FARICH in SpdRoot: geometry

FARICH detector



Aerogel



Material:

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

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

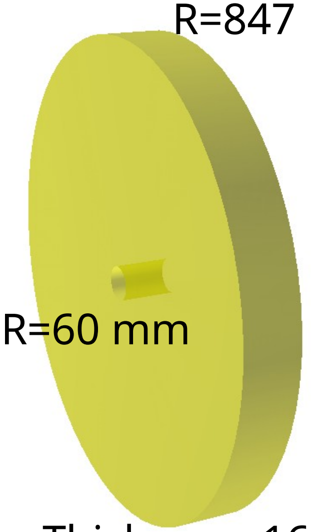
$$density = \frac{(n^2-1)}{0.438}, [cm^3/g]$$

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

R=36 mm

Air

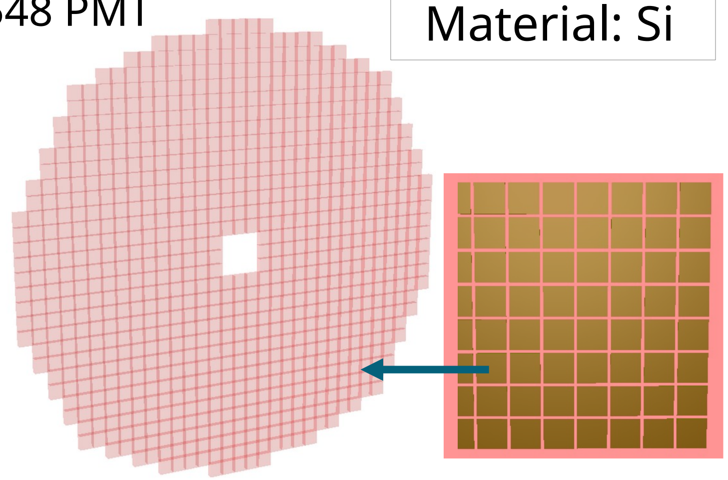
Material: Air



Photon detector

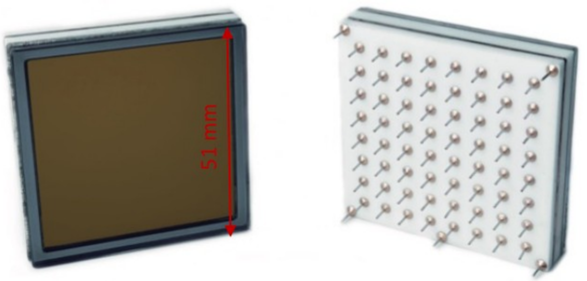
548 PMT

Material: Si



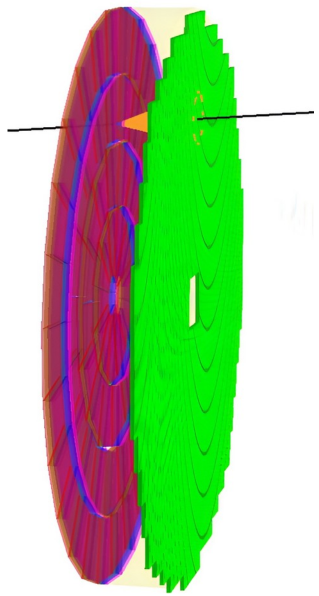
MCP PMTs N6021 from NNVT

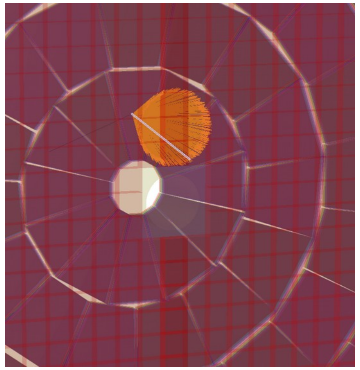
- 8×8 pixels with size 5.8×5.8 mm^2
- Lateral size 51×51 mm^2
- Thickness = 1.7 mm



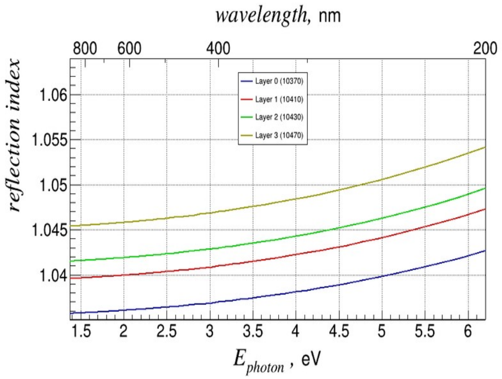
FARICH in SpdRoot: optical properties

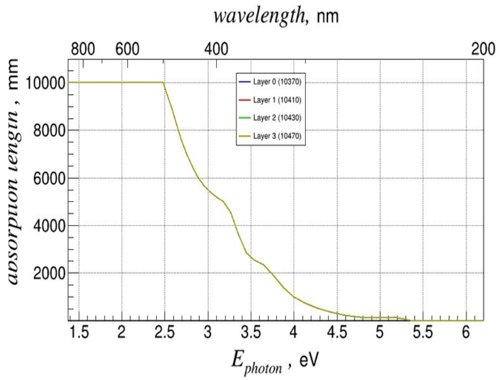
FARICH detector

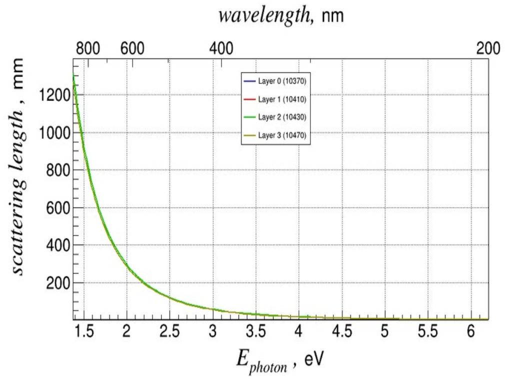




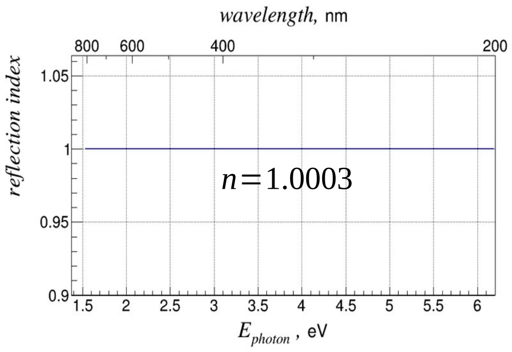
Aerogel

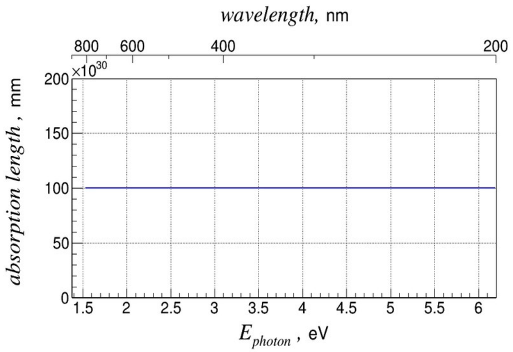




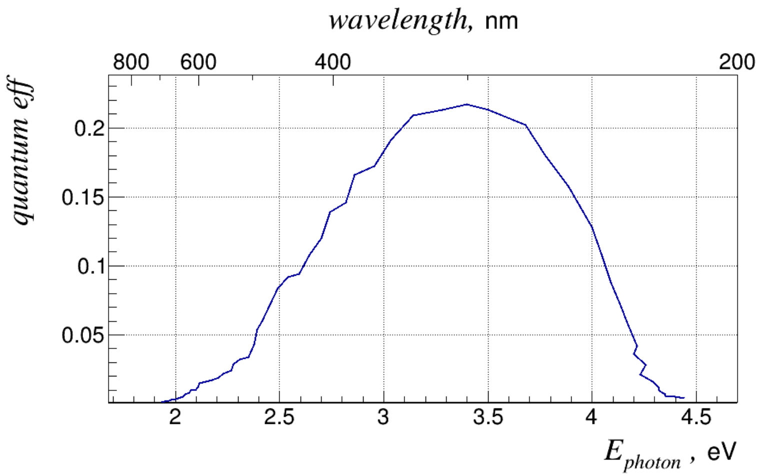


Air





Photon detector



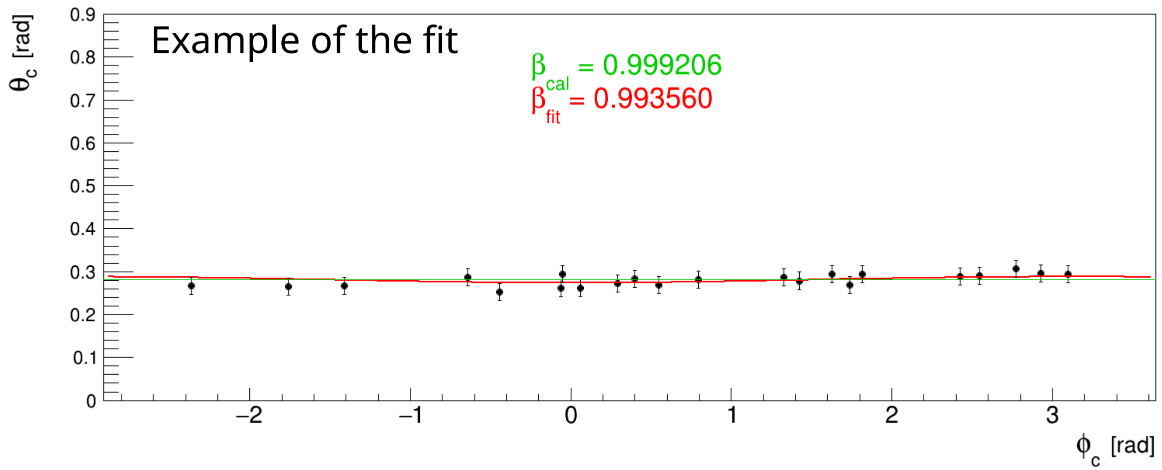
FARICH reconstruction: by dependence θ_c vs φ_c

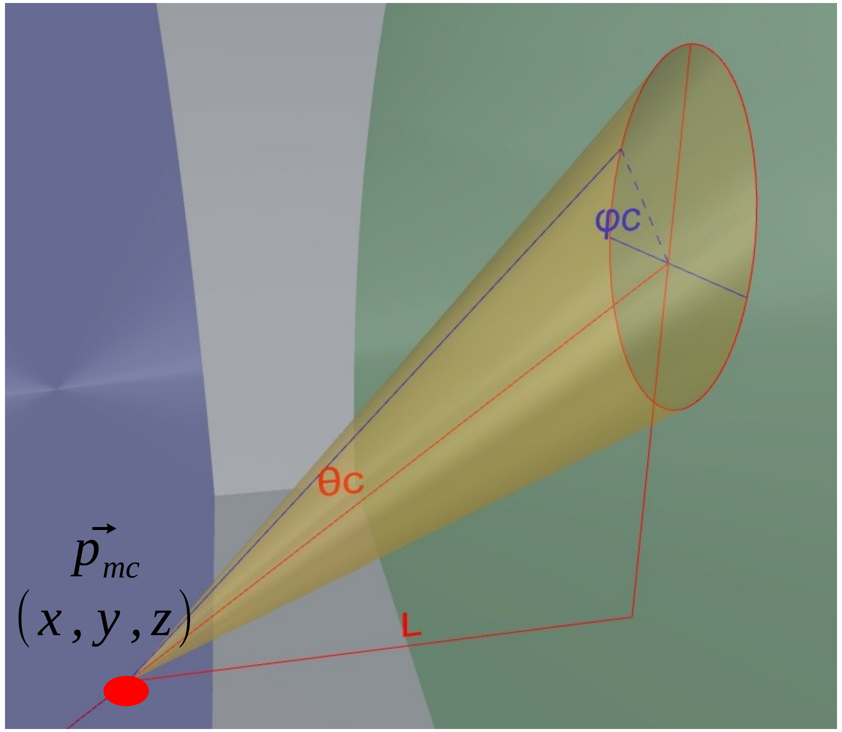
The simulation of FARICH was done at the SpdRoot framework for sets of particles: electrons, muons, pions, kaons, and protons. Momentum range is from p_{th} to 8 GeV. Currently, only Cherenkov photons from the ring are being studied.

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

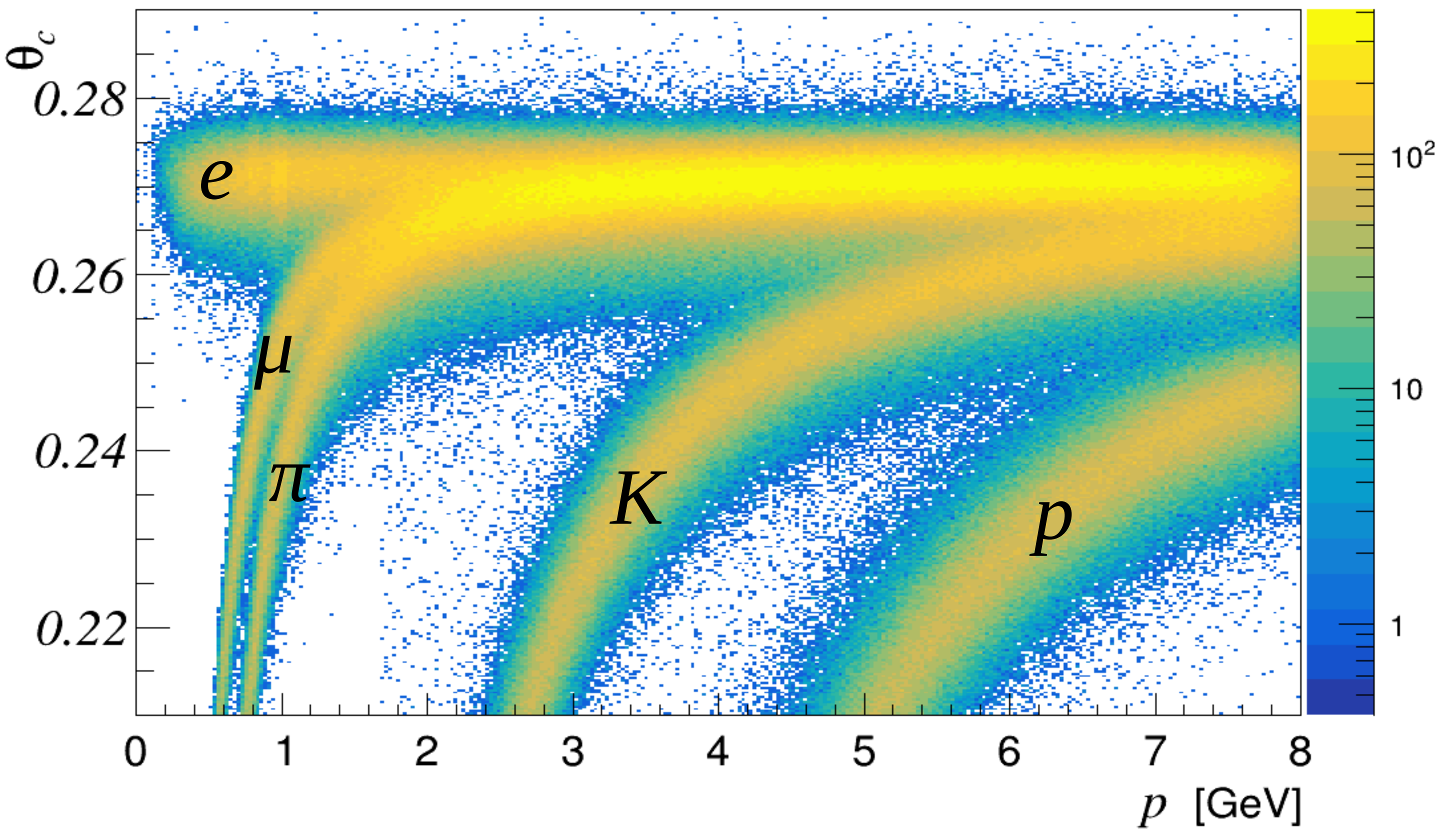
$$\theta_c(\varphi_c|\beta,n,\theta_t) = \arccos\left(\frac{1}{n\beta}\right)+\arccos\left(n\left(1-(\vec{n}_0\vec{n}_\gamma)^2\right)+(\vec{n}_0\vec{n}_\gamma)\sqrt{1-n^2\left(1-(\vec{n}_0\vec{n}_\gamma)^2\right)}\right)$$

- 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

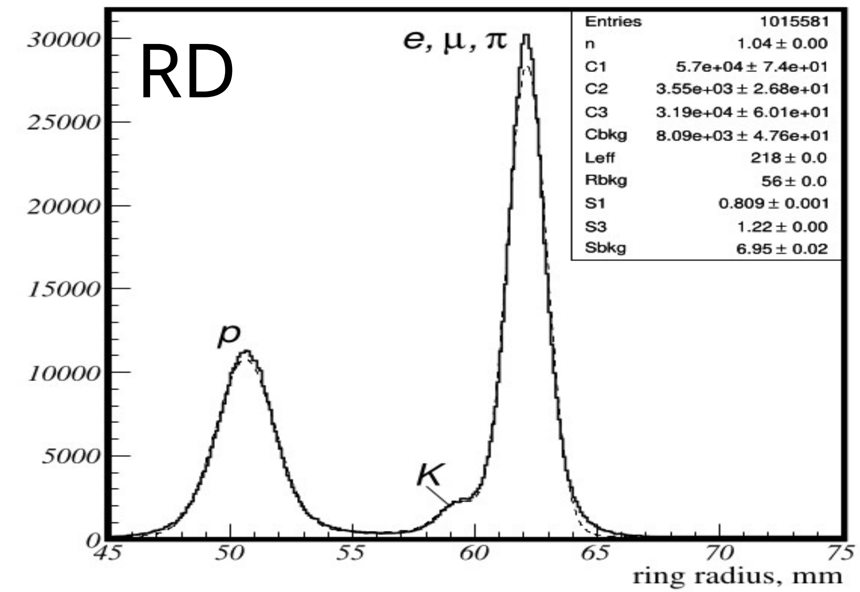




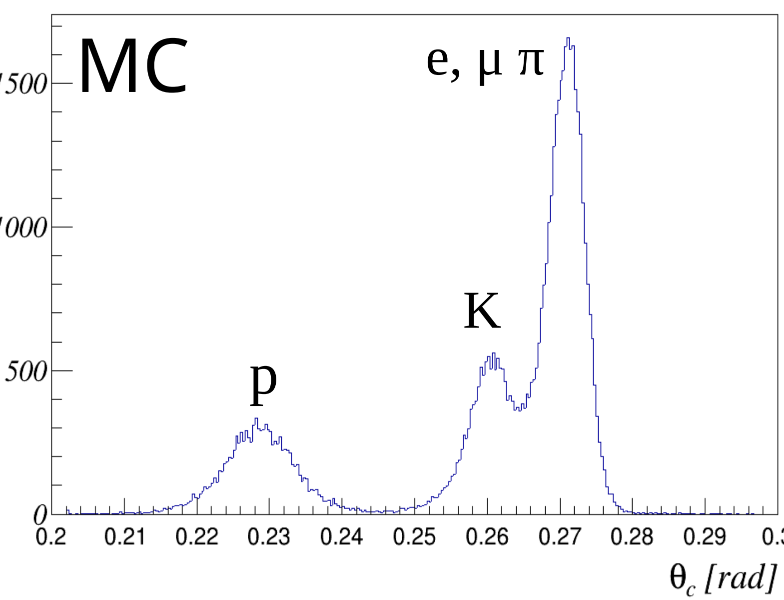
FARICH reconstruction: θ_c vs p_{rc}



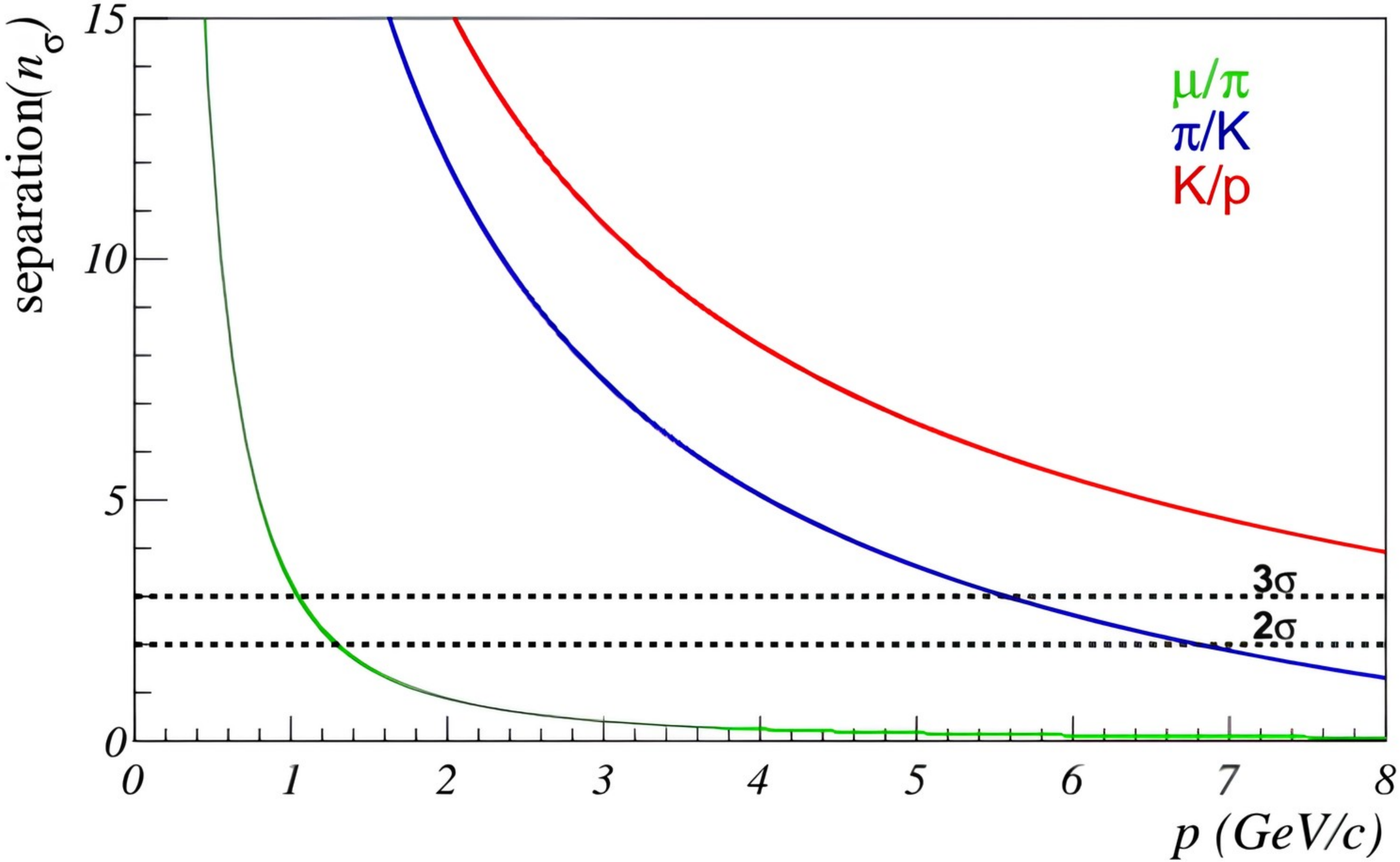
Nucl. Instrum. Meth. A, 732:352–356, 2013



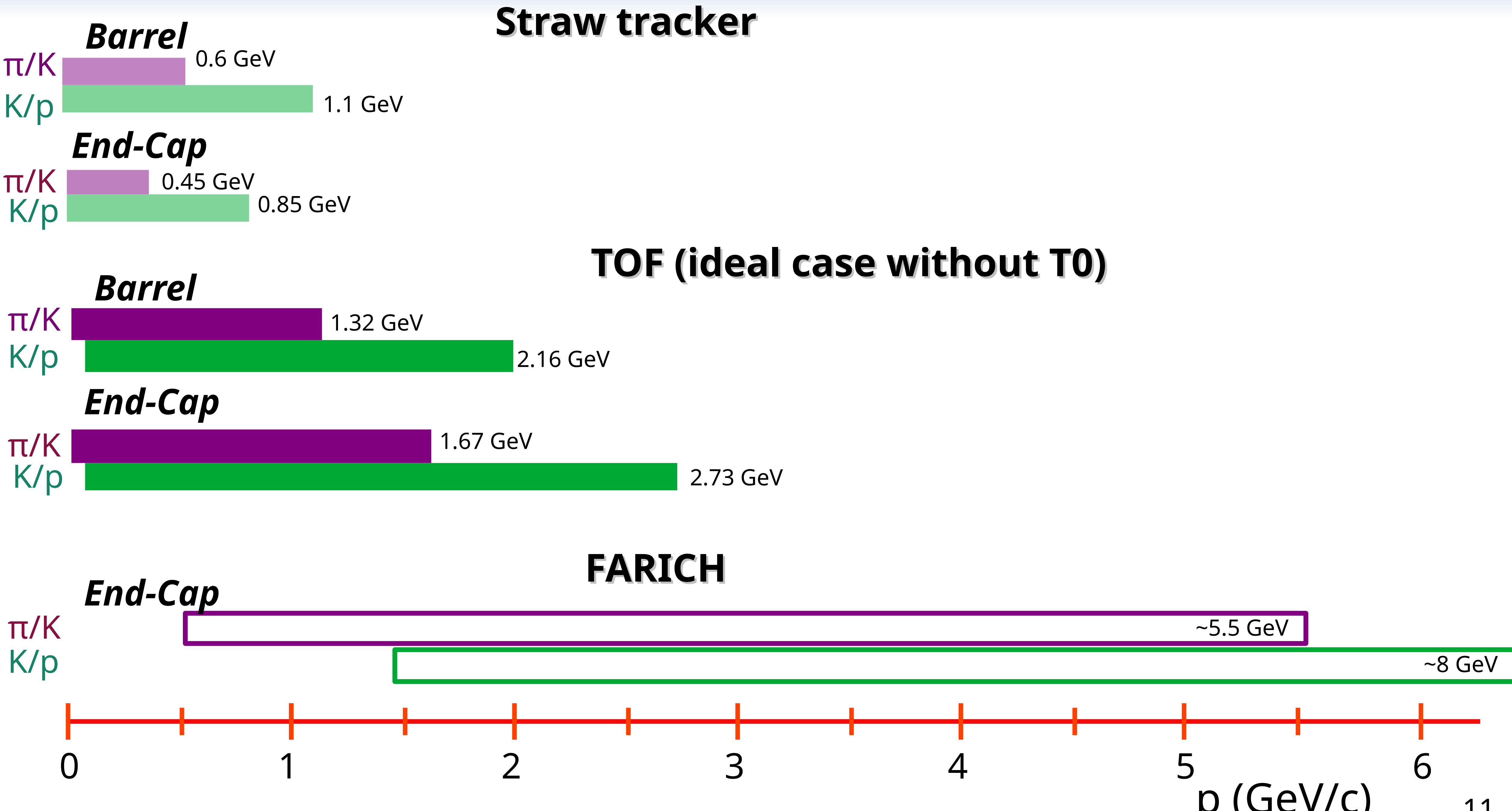
particles momentum 6 GeV/c



Separation power



Particle ID in SPD



Status of FARICH in SpdRoot

Simulation

- geometry description
- Optical processes

Recostuction

- Fit by dependence θ_c vs φ_c

PID

- Probabilities calculation

Likelihood PID

Global likelihood PID

uses all particle data in event for a construct likelihoods

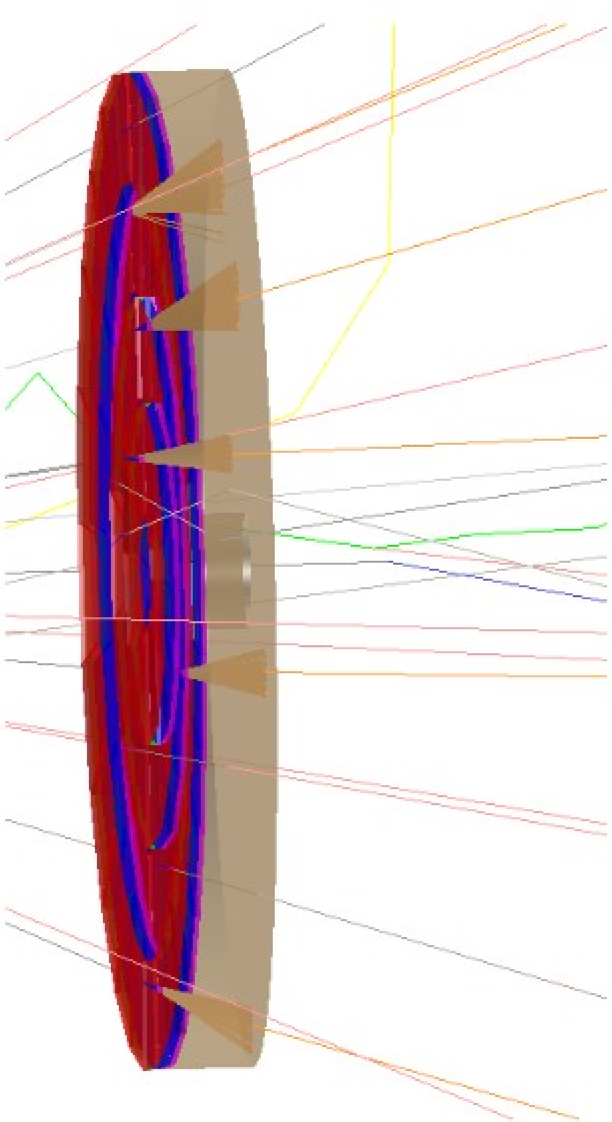
Local likelihood PID

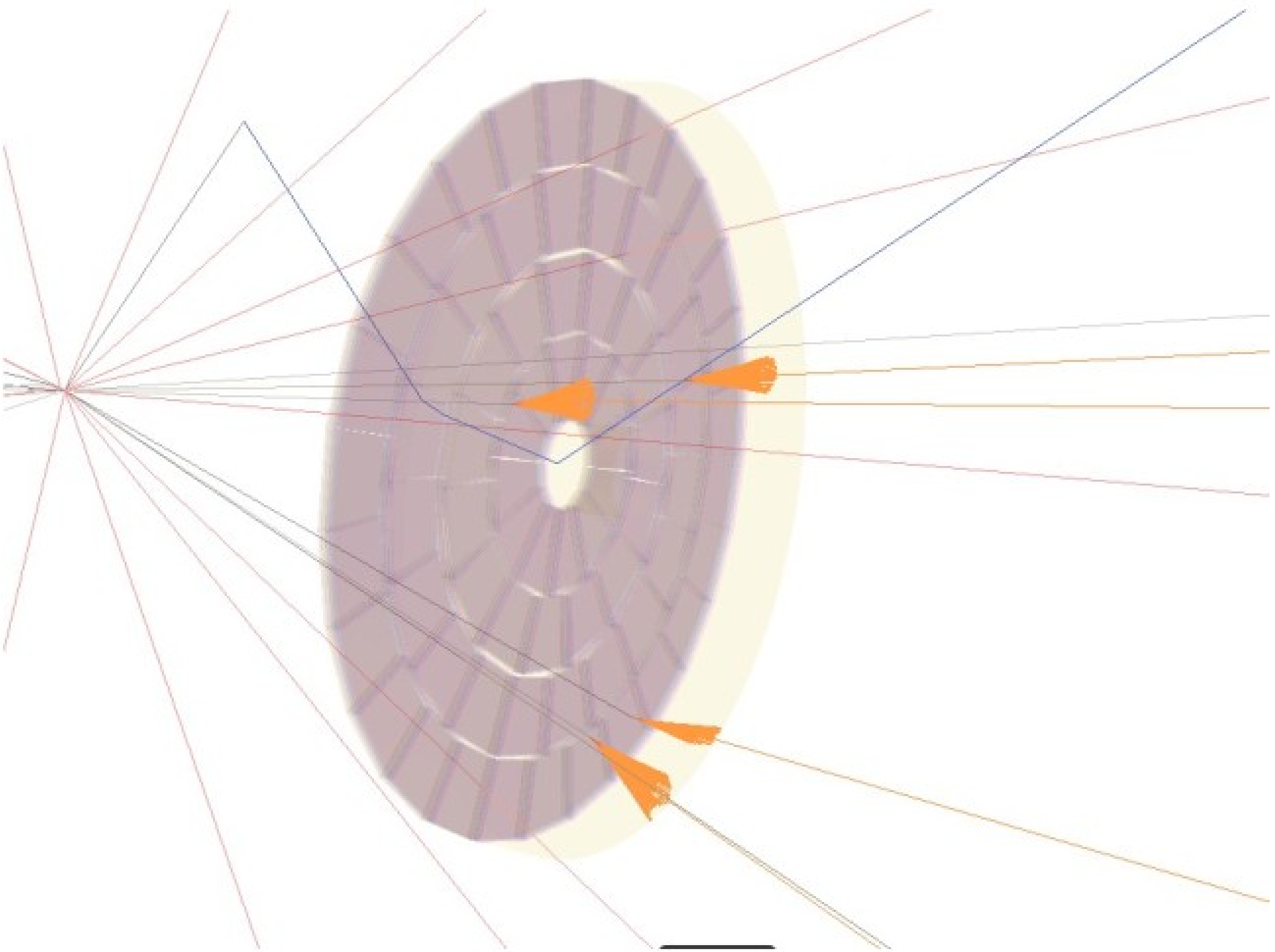
uses likelihood for each Cherenkov ring separately

used in case where lower track densities, no overlap of rings

FARICH simulation

1 event $\sqrt{27}$, $SoftQCD = all$





Likelihood PID

Global likelihood PID

uses all particle data in event for a construct likelihoods

Local likelihood PID

uses likelihood for each Cherenkov ring separately

used in case where lower track densities, no overlap of rings

Local likelihood PID algorithm

- reconstructed track is extrapolated to FARICH
- Cherenkov Ring (hits) is associated to track
- construct likelihood function for 5 particle type hypotheses

Likelihood PID

$L(h) = L(h; p, n)$ n is measured

$L(h) = L(h; p, n) \times L(h; p, \theta)$ n and θ are measured

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

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

Likelihood PID

In case $n_e^b=0$

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

calculate

n_e - expected number of photoelectrons

θ_{hyp} - expected Cherenkov angle

measure

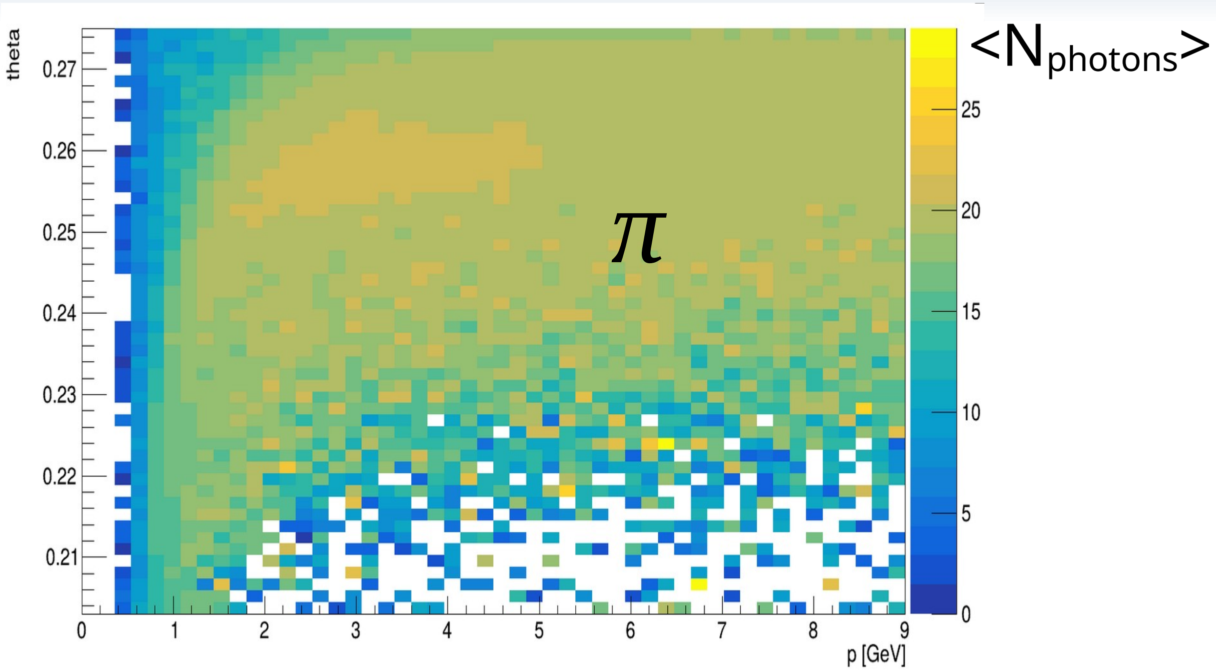
n - measure number of photoelectrons

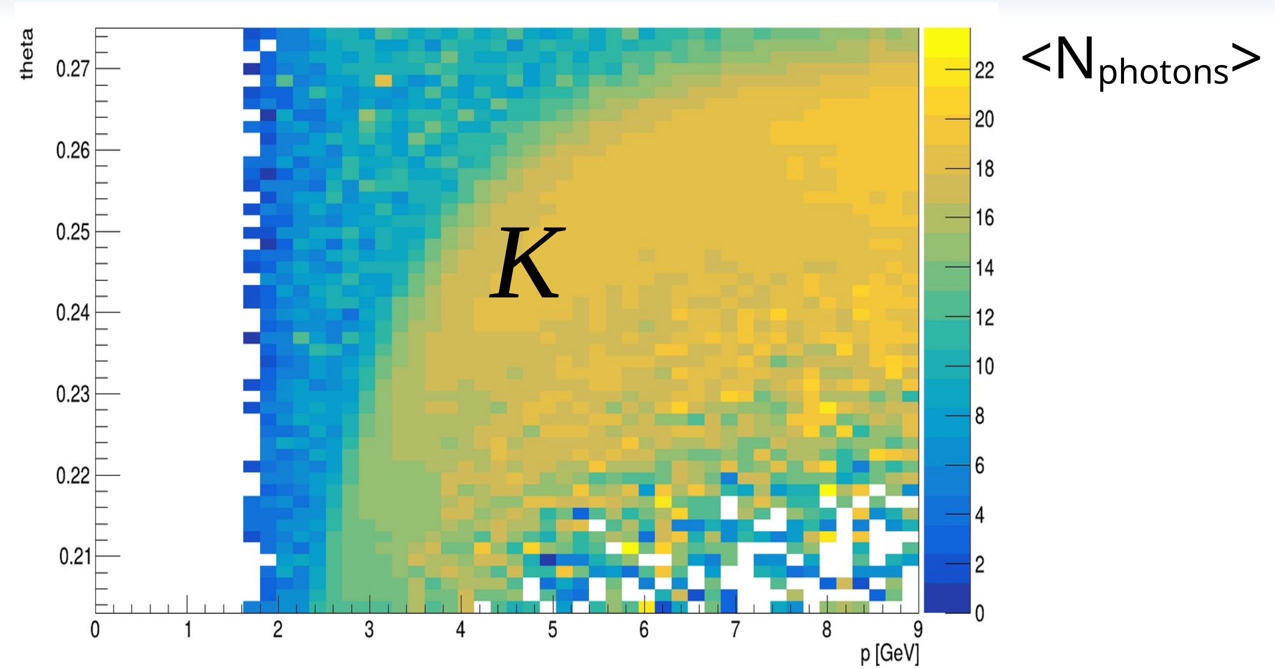
θ_i - measure Cherenkov angle

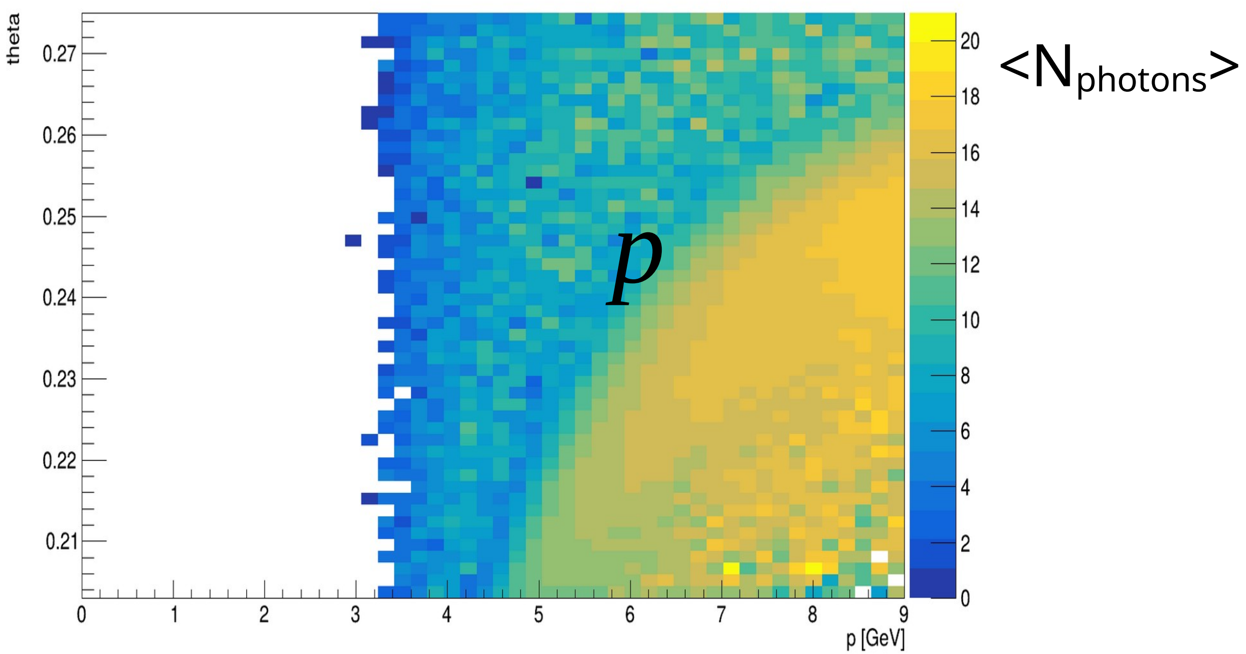
σ_i - single angular resolution

$$\sigma_i=\sqrt{\delta_{pix}^2/(\sqrt{12}Ln)^2+\sigma_{aer}^2+\sigma_{trk}^2}$$ ~0.06

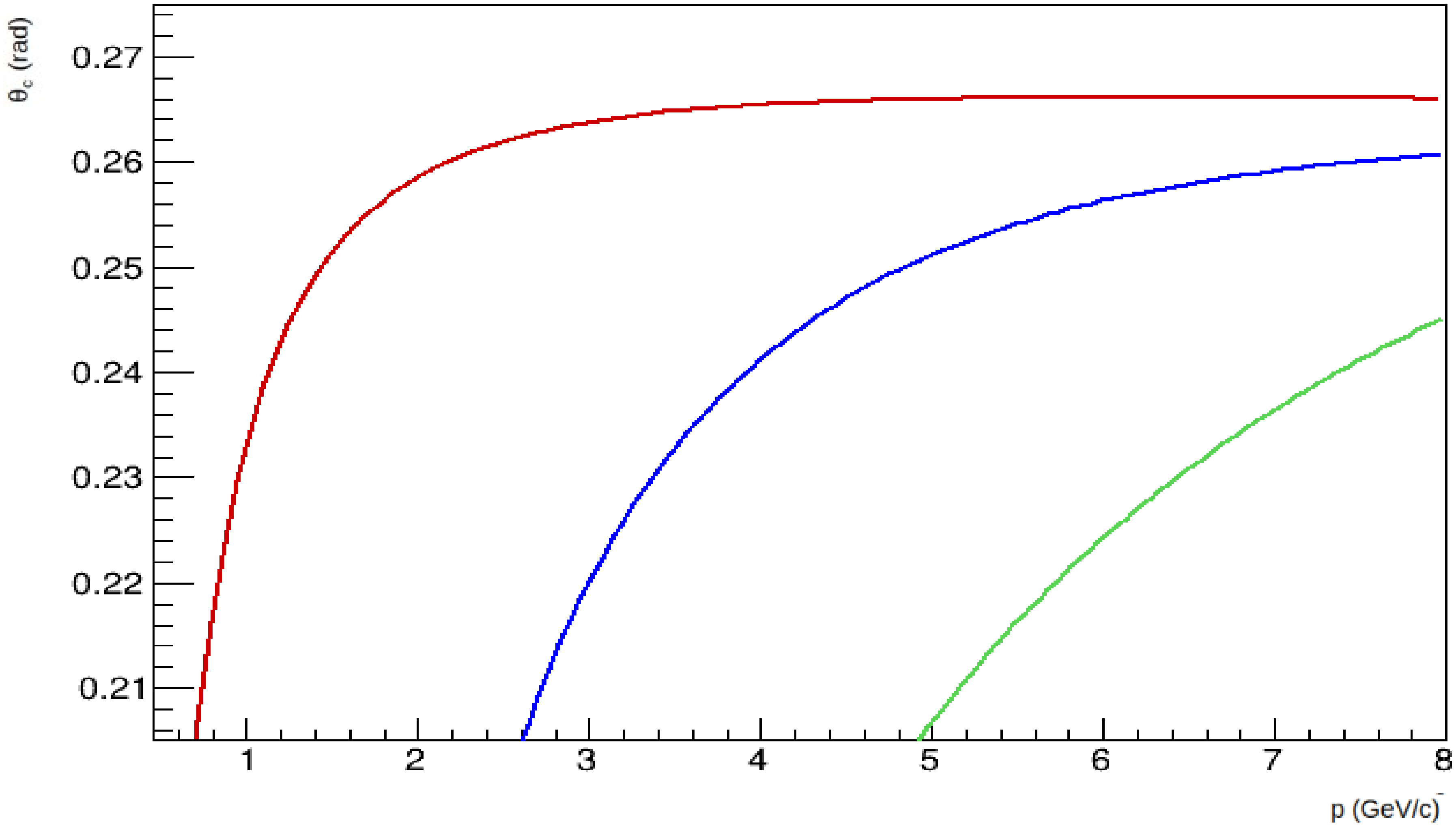
Mean of photons as (θ_c, p)



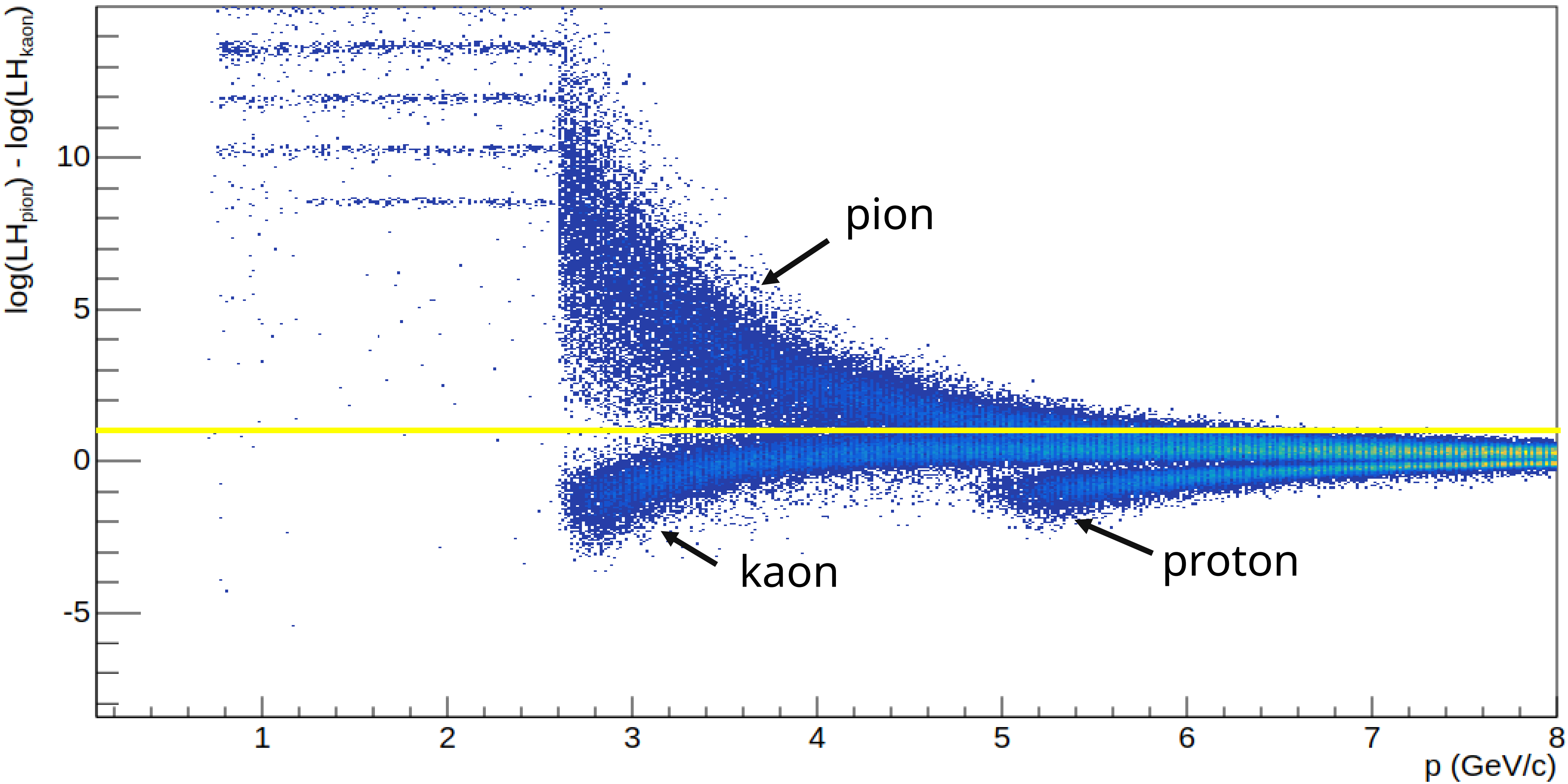




Mean of θ_c as p

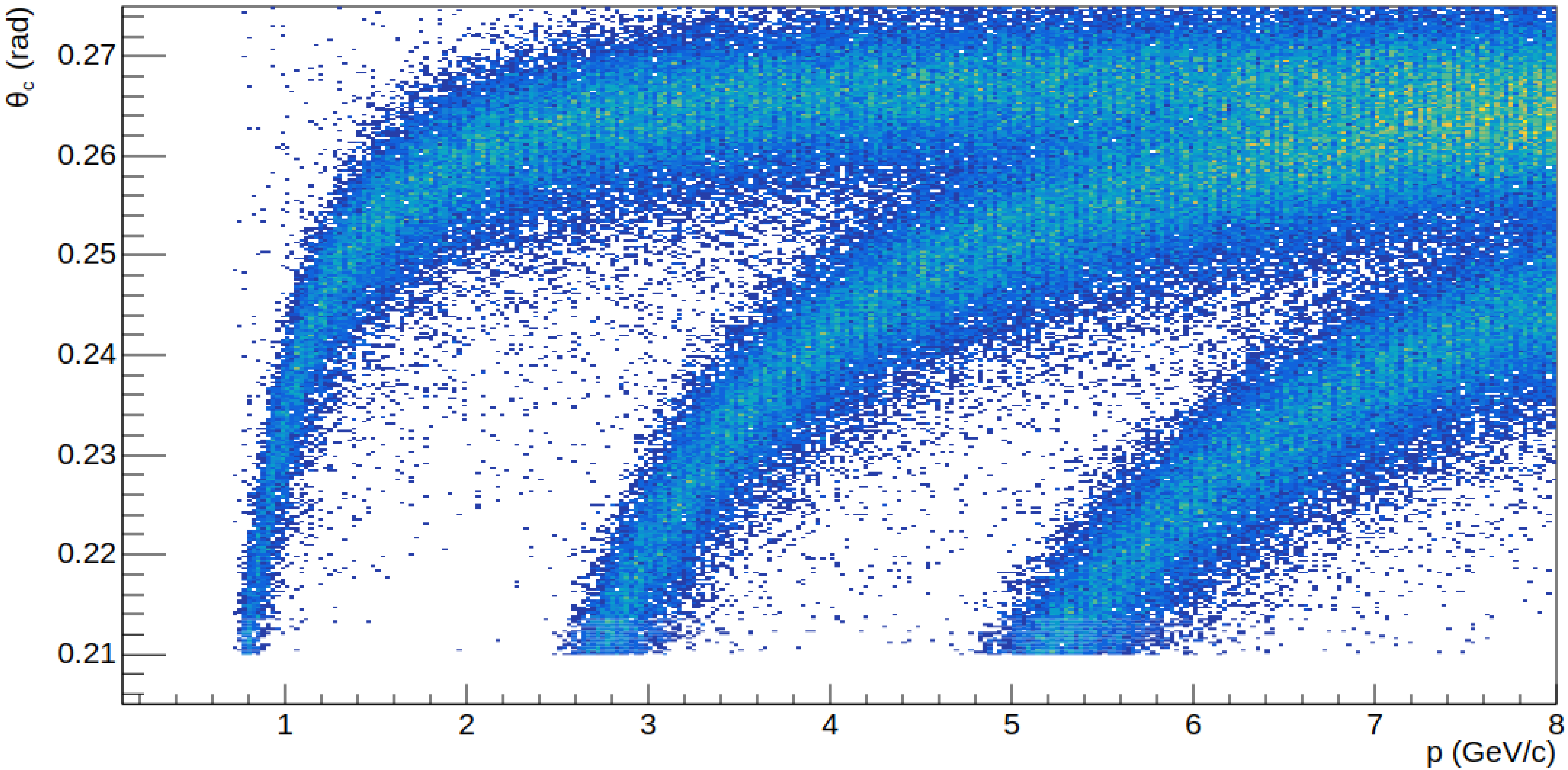


$\log(LH_{pion}) - \log(LH_{kaon})$

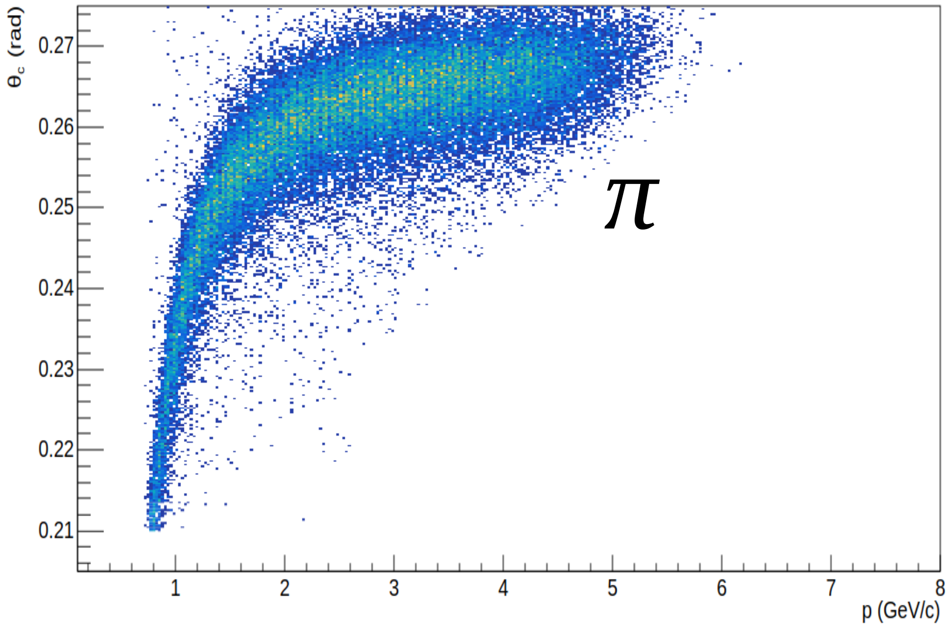


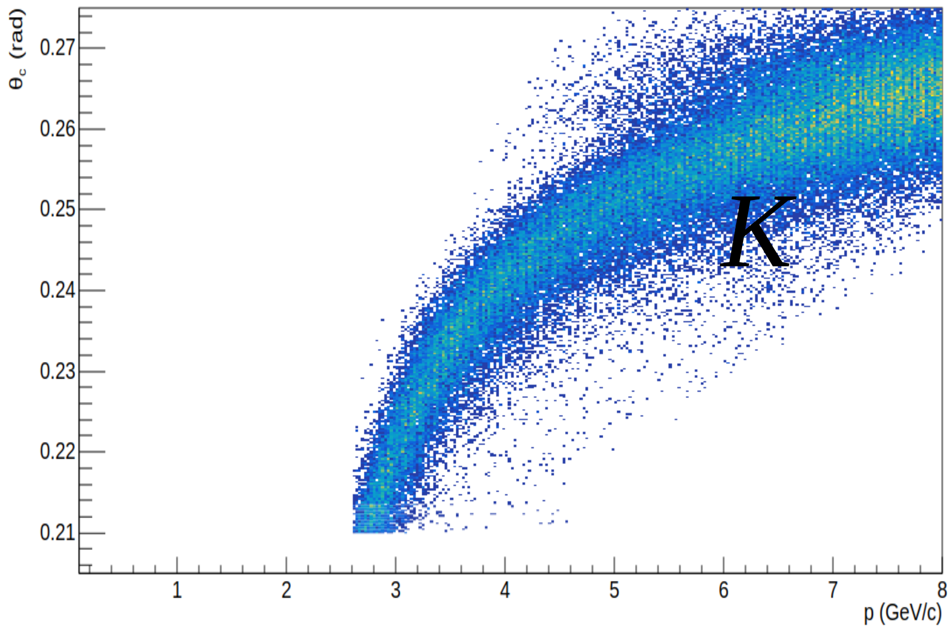
$PID_{pion} = (\log(LH_{pion}) - \log(LH_{kaon})) > 1.1$

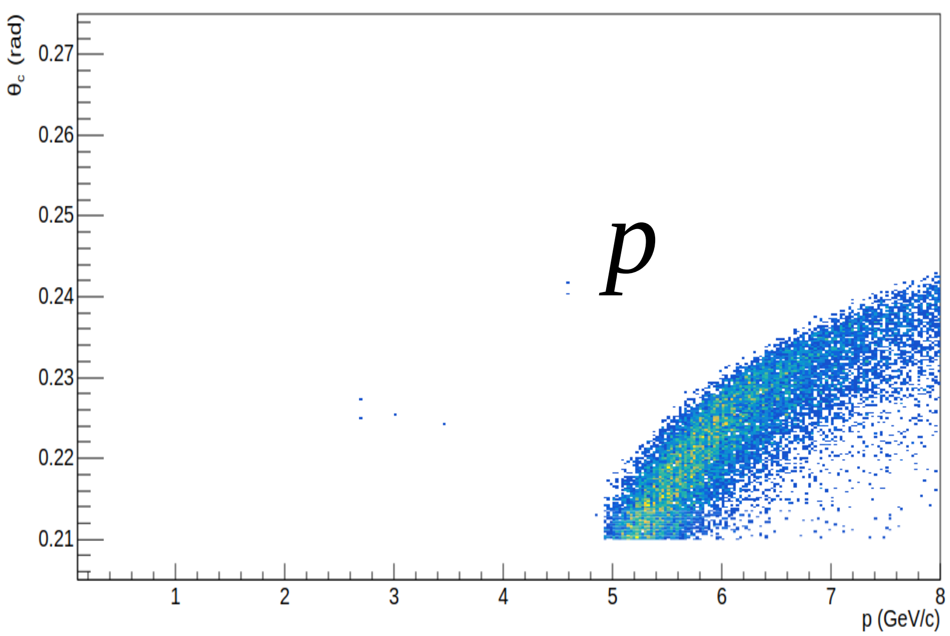
FARICH reconstruction: θ_c vs p_{rc}



PID with strict criteria



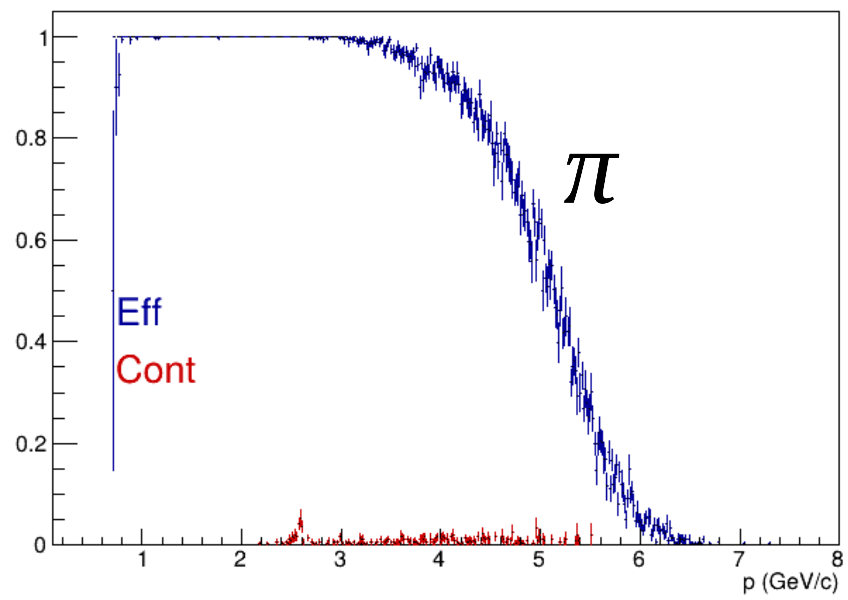


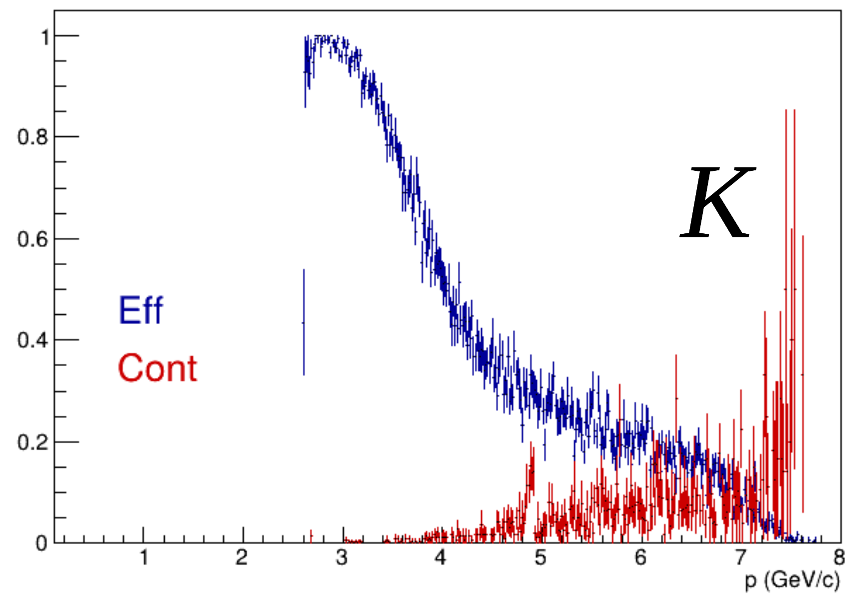


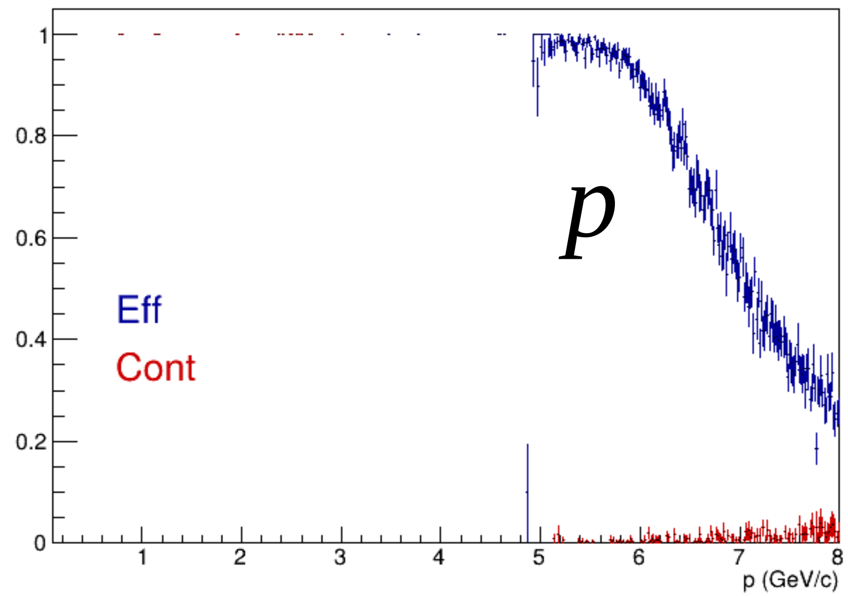
Strict criteria

PID_{pion} =	$(\log(LH_{pion}) - \log(LH_{kaon})) > 1.1$
PID_{kaon} =	$(\log(LH_{kaon}) - \log(LH_{pion})) > -0.2$ $(\log(LH_{kaon}) - \log(LH_{proton})) > 1.0$
PID_{kaon} =	$(\log(LH_{proton}) - \log(LH_{kaon})) > -0.5$ $(\log(LH_{proton}) - \log(LH_{pion})) > -0.5$

Eff and Cont with strict criteria







$$efficiency = \frac{N_{corr}}{N_{true}}$$

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

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 .

FARICH in SpdRoot

Simulation

```
SpdFarich *farich = new SpdFarich();
farich->setopticalphysics(true);
```

build FARICH detector

set optical physics (true/false)

```
run->AddModule(farich);
```

Reconstruction

```
SpdFarichMCHitProducer *farich_hits_producer = new SpdFarichMCHitProducer();
farich_hits_producer->SetVerboseLevel(1);
Run->AddTask(farich_hits_producer);
```

create FARICH hit

```
SpdMCFarichParticleProducer *mcfarich_part = new SpdMCFarichParticleProducer();
mcfarich_part->SetVerboseLevel(1);
Run->AddTask(mcfarich_part);
```

calculate θ_c and LH

FARICH in SpdRoot

Analysis

```
const TClonesArray *particles_farich = 0;
const TClonesArray *mc_farich_hits = 0;
```

```
IT->ActivateBranch("FarichParticles");
IT->ActivateBranch("FarichMCHits");
```

```
mc_farich_hits = IT->GetFarichHits();
particles_farich = IT->GetFarichParticles();
```

Read FARICH from file

```
SpdFarichParticle *ffarichparticle = (SpdFarichParticle *)particles_farich->At(IdhitFarich);

Int_t hitid = ffarichparticle->GetHitId();
SpdFarichMCHit *mc_farich_hit = (SpdFarichMCHit *)mc_farich_hits->At(hitid);
```

```
vHitPhoton = mc_farich_hit->GetvHitPhotonCenterPixel();
ThetaC = ffarichparticle->GetThetaC();
Chi2ndf = ffarichparticle->GetChi2ndf();
```

X, Y, Z positions of photons

Cherenkov angel from fit

Conclusion

- FARICH is upload to Development branch of SpdRoot
- Some modification still need to do in code
- LH criteria for PID selection will be optimized and LH code will added to Development branch SpdRoot

~two weeks