Forward RICH simulation

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FRRC - SSC RF ITEP of NRC "Kurchatov Institute"

PANDA LVII. Collaboration Meeting
6-10 June 2016
GSI, Darmstadt, Germany

Work is funded by

HELMHOLTZ GEMEINSCHAFT

NRC Kurchatov Institute

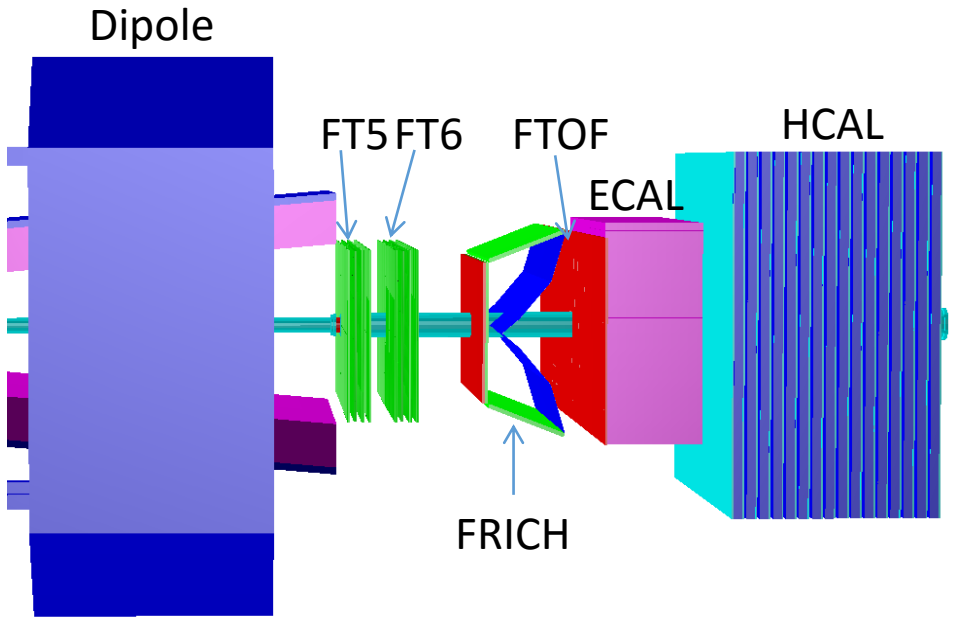
MINISTRY OF EDUCATION AND SCIENCE OF THE RUSSIAN FEDERATION

Introduction

Outline

- What's done
- How to
- Some results

RICH	
Main goal	➢PID ➢Information for higher level triggers
π/K-separation	up to ~10 GeV/c
Radiator	Focusing aerogel
Refractive index	~1.05
Radiator thickness	4 cm
Vertical angle	±5°
Horizontal angle	±10°



Full and fast simulation

FULL*

Full simulation of
- passage of particles through matter
- optical photons
- photodetector noise

Reconstruction of events
- Tracking
- Forward RICH: digitization, hit reconstruction, event fit

PID
- probability in different mass hypothesis

FAST*

Full simulation of
- passage of particles through matter

Reconstruction of events
- Tracking
- Forward RICH: simulate response using previously calibrated parameters

PID
- probability in different mass hypothesis

* Here and after FULL and FAST definitions are concerning Forward RICH only

How to use FULL and FAST simulation of Forward RICH

FULL

FAST

sim_complete()

```
// Create the Simulation run manager------------
 FairRunSim *fRun = new FairRunSim();
 fRun->SetUserConfig("g4Config_opt.C");
 ...
 //------------------------  RICH       ----------------
 PndRich *Rich= new PndRich("RICH",kTRUE);
 Rich->SetGeometryFileName("rich_v313.root");
 Rich->SetRunCherenkov(kTRUE);
 fRun->AddModule(Rich);
```

```
// Create the Simulation run manager------------
 FairRunSim *fRun = new FairRunSim();
 //fRun->SetUserConfig("g4Config_opt.C");
 ...
 //------------------------  RICH       ----------------
 PndRich *Rich= new PndRich("RICH",kTRUE);
 Rich->SetGeometryFileName("rich_v313.root");
 //Rich->SetRunCherenkov(kFALSE);
 fRun->AddModule(Rich);
```

digi_complete()

```
// -----   RICH hit producers   --------------------------------
 PndRichHitProducer* richhit = new PndRichHitProducer();
 richhit->SetVerbose(iVerbose);
 richhit->SetPhDetNoiseON(kTRUE);
 fRun->AddTask(richhit);
```

```
// -----   RICH hit producers   --------------------------------
 PndRichHitProducer* richhit = new PndRichHitProducer();
 richhit->SetVerbose(iVerbose);
 //richhit->SetPhDetNoiseON(kFALSE);
 fRun->AddTask(richhit);
```

pid_complete()

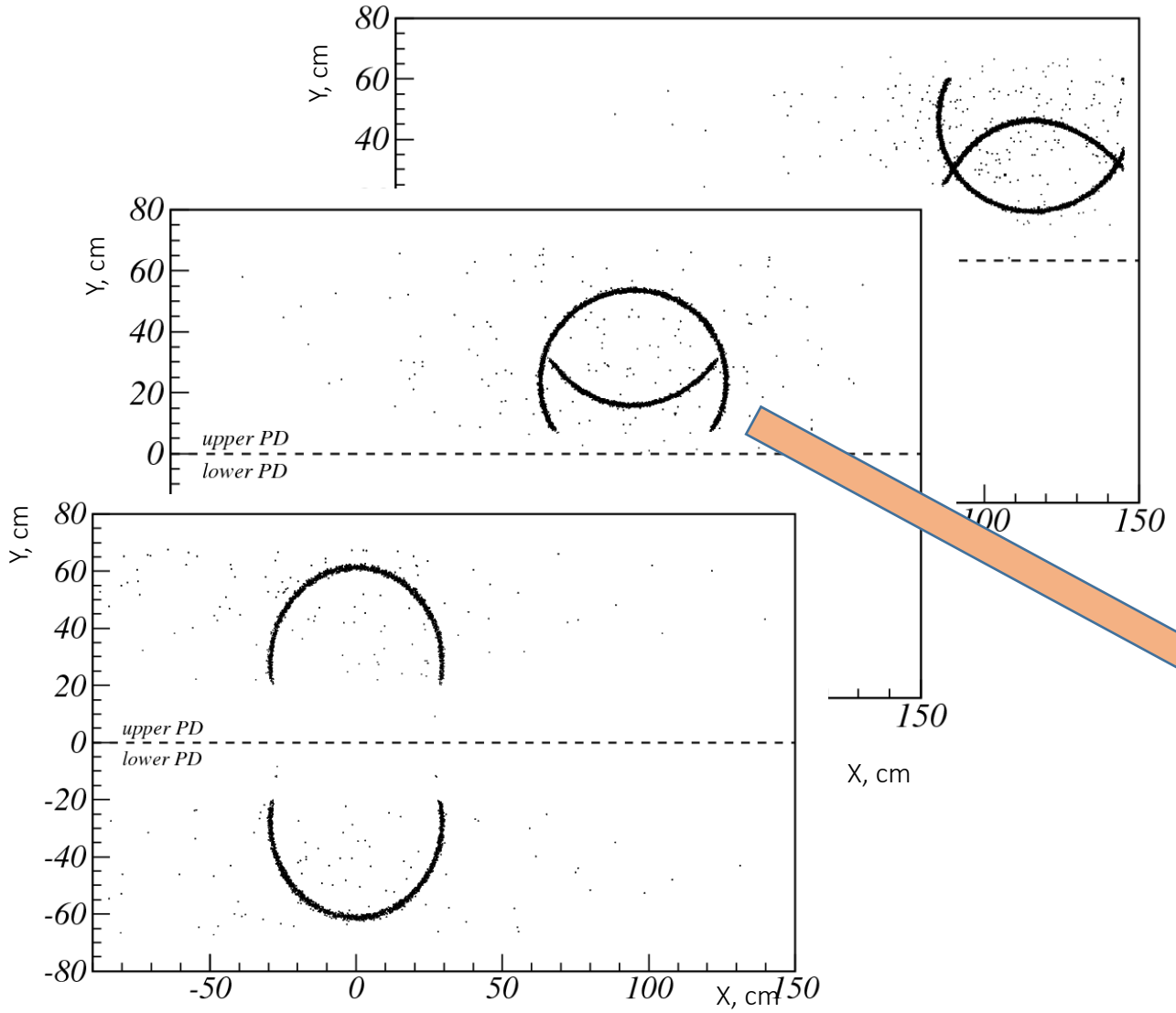
```
PndPidRichAssociatorTask *asRich= new PndPidRichAssociatorTask();
 fRun->AddTask(asRich);
```

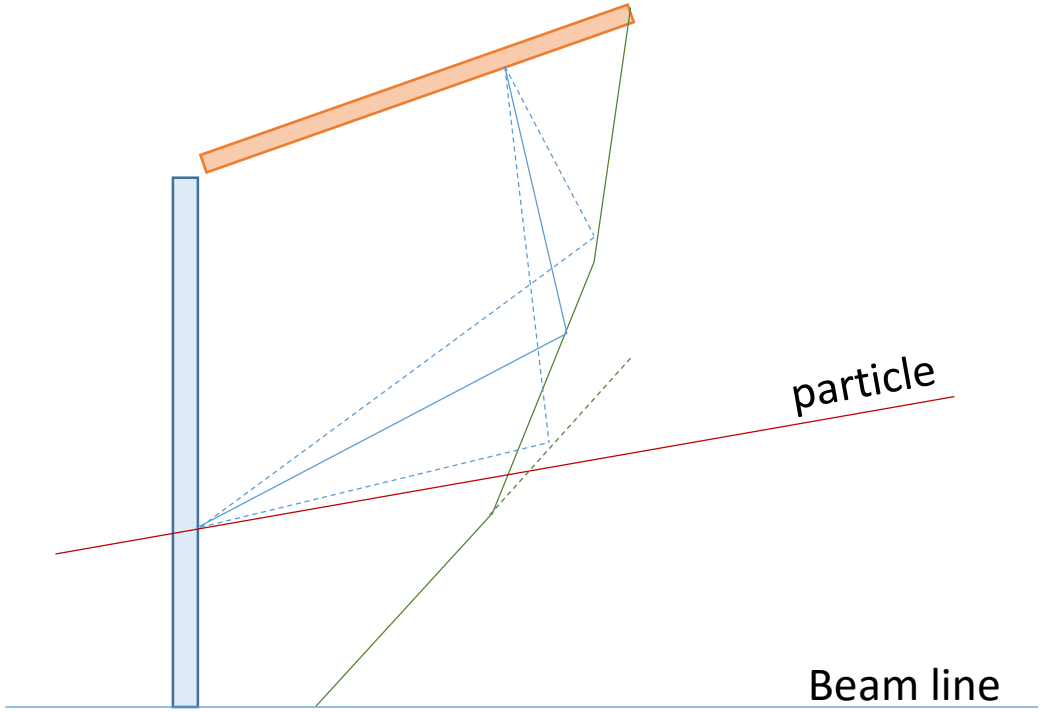
Example: $VMCWORKDIR/macro/rich/   (trunk)

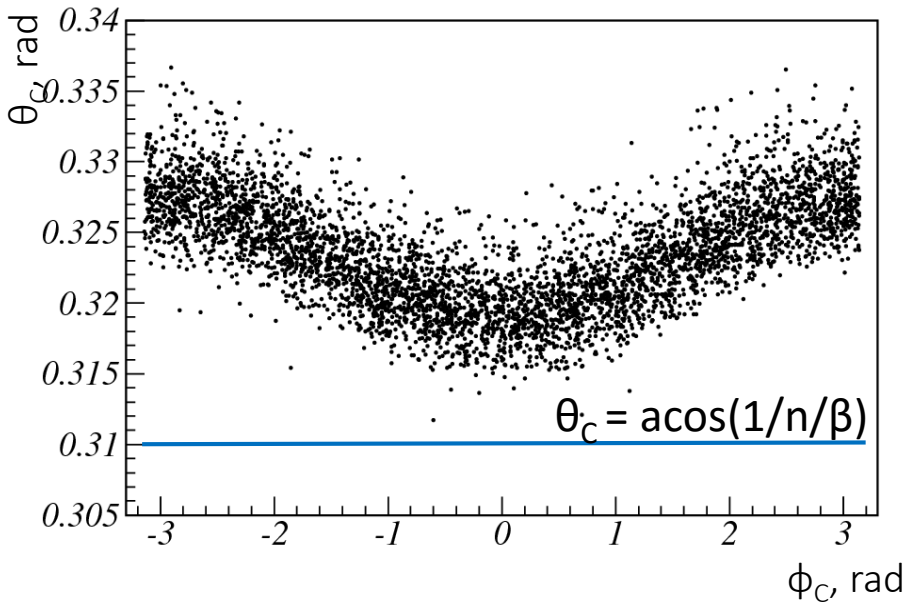
Simulated effects

1. Simulation
   - ✓ Geometry description
     - RICH position
     - Aerogel (size, number of layers, refraction index)
     - Mirror geometry (round, flat)
   - ✓ Properties of materials for optical photons
2. Digitization
   - ✓ Pixelation
   - ✓ Quantum efficiency of photodetector
   - ✓ Photodetector noise
   - ✓ Dead time of photodetector
   - ✓ Photodetector time resolution
   - ✓ Crosstalks (to do)
3. Reconstruction (simple mode)
   - ✓ Hit preselection
   - ✓ Fit $\theta(\phi)$ dependence
4. Calibration of beta resolution for FAST simulation
5. PID
   - ✓ Probability calculation

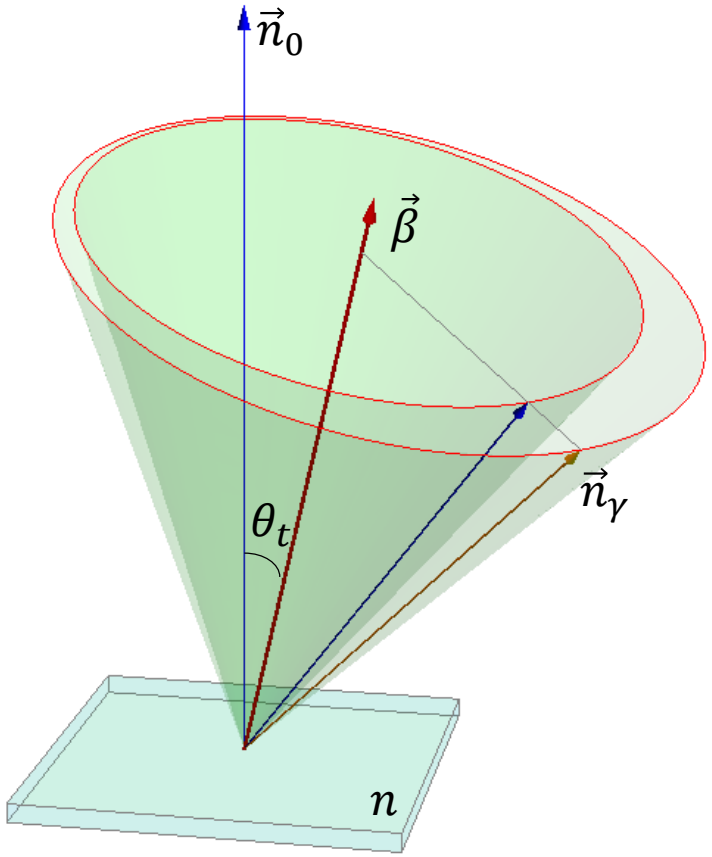
Full reconstruction: geometrical part

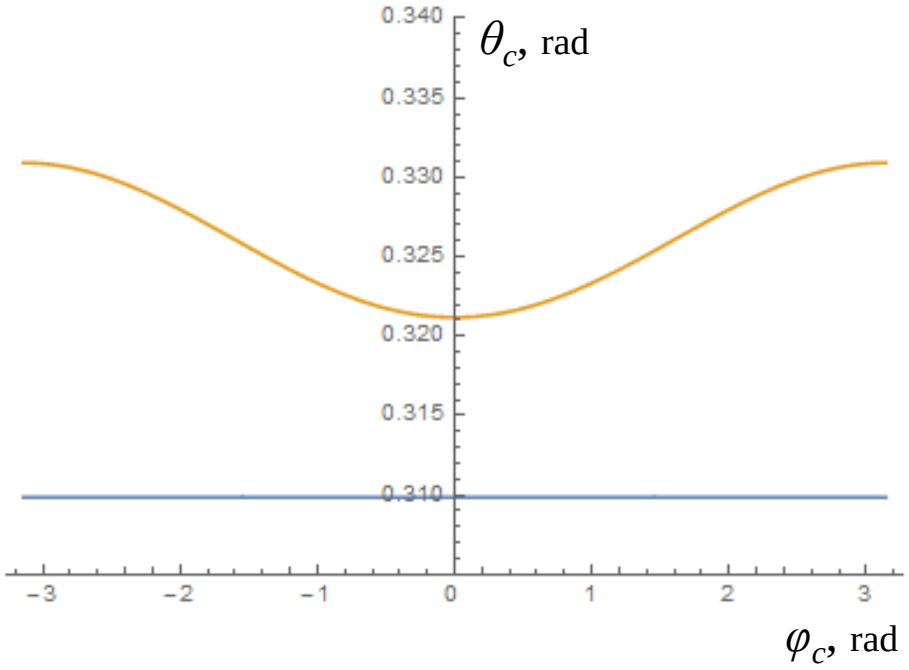






Full reconstruction: refraction on the surface of the aerogel



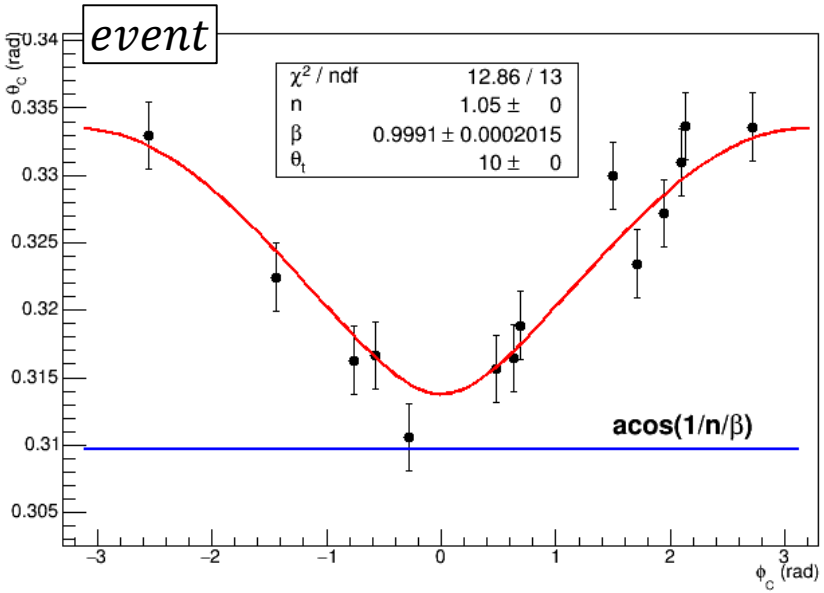


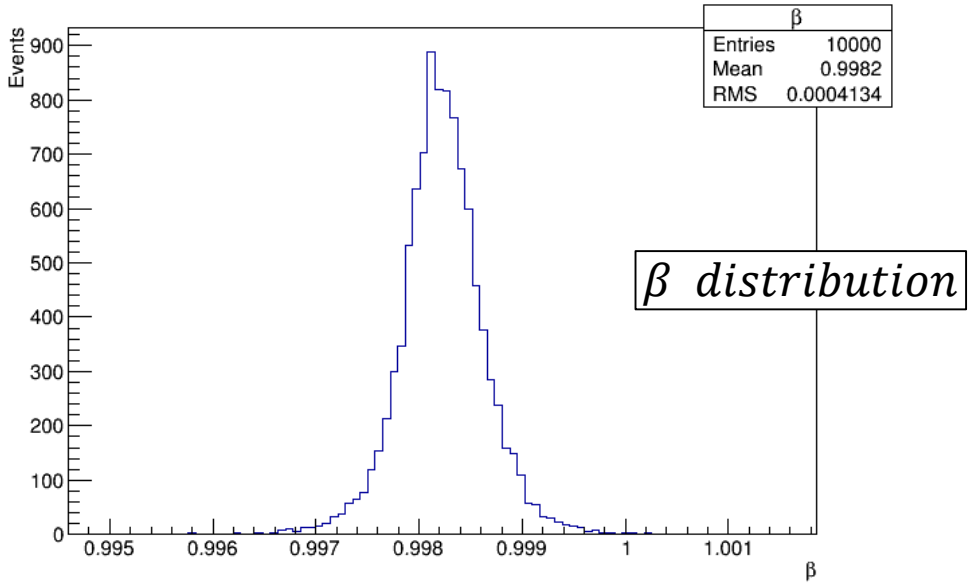
$$\theta_c(\varphi_c;\beta,n,\theta_t) = \operatorname{acos}\left(\frac{1}{n\beta}\right) + \operatorname{acos}\left(n\left(1-\left(\vec{n}_0\vec{n}_\gamma\right)^2\right) + \left(\vec{n}_0\vec{n}_\gamma\right)\sqrt{1-n^2\left(1-\left(\vec{n}_0\vec{n}_\gamma\right)^2\right)}\right)$$

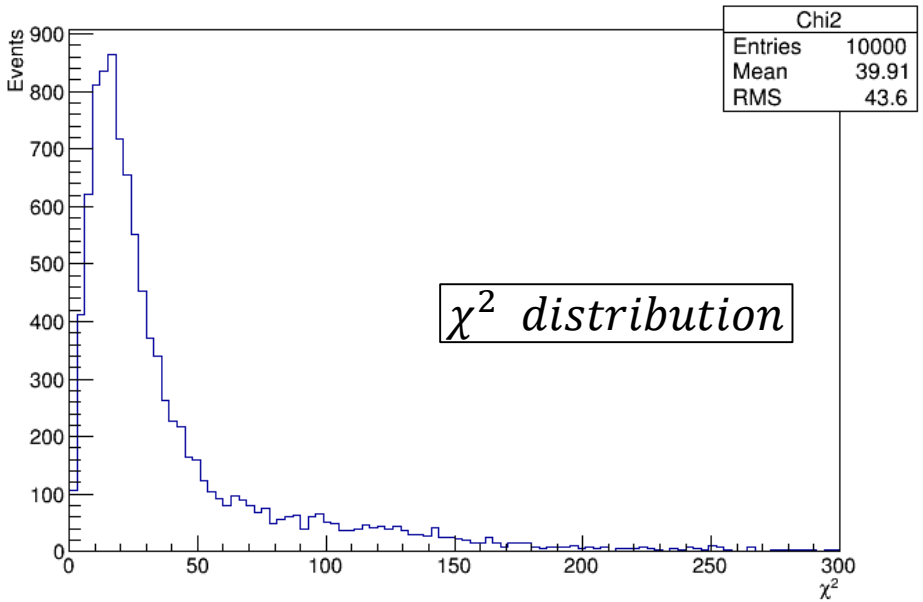
$$\left(\vec{n}_0\vec{n}_\gamma\right) = \frac{\cos\theta_t}{n\beta} + \cos\varphi_c \sin\theta_t \sqrt{1-\frac{1}{(n\beta)^2}}$$

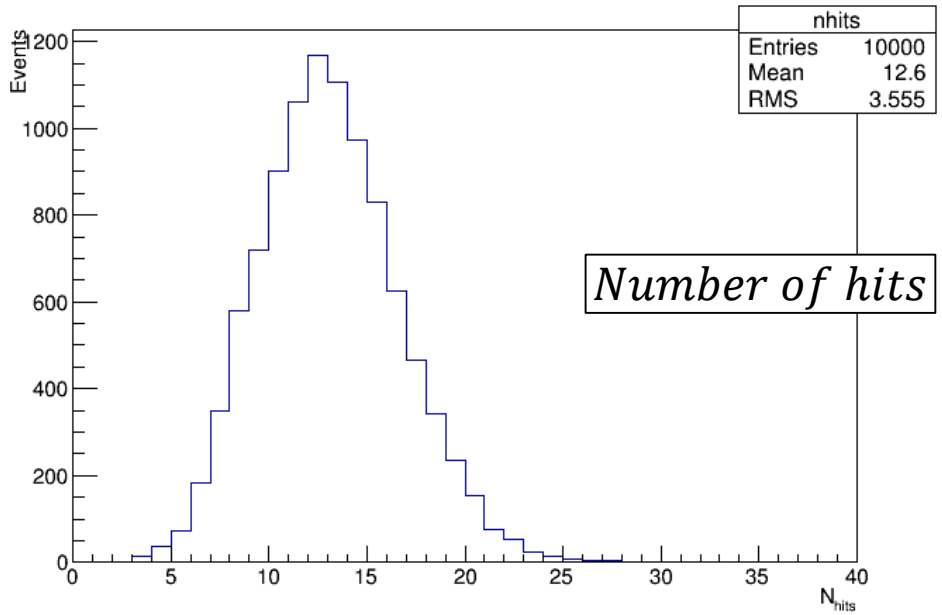
θ_c – polar angle of Cherenkov photon
φ_c – azimuthal angle of Cherenkov photon
β – velocity of the charged particle
n – refraction index of the aerogel
θ_t – polar angle of the charged particle

Full reconstruction: event fit

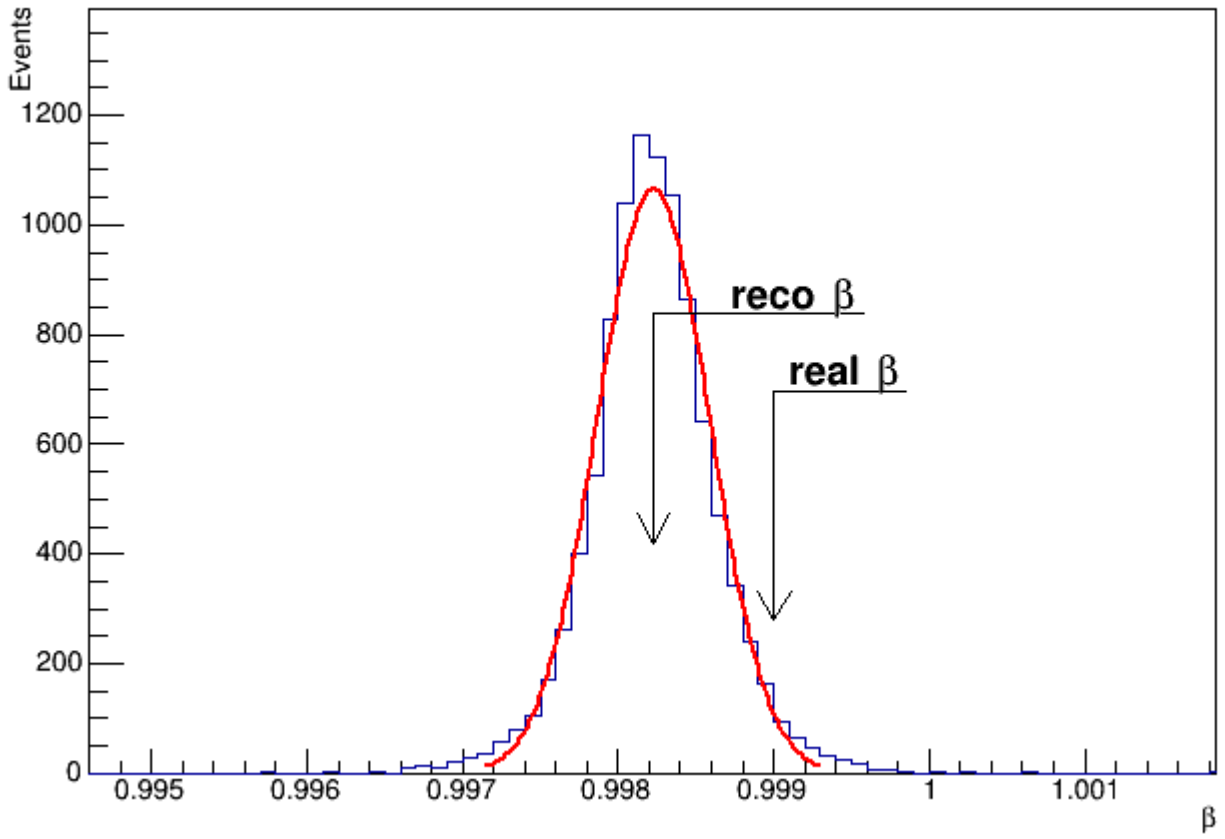








Fit results for fast simulation



Parameters used as calibration data:

- σ_β – β resolution
- $\Delta\beta$ – shift of mean β w.r.t. MC truth
- ε – efficiency of reconstruction

	FULL	FAST
σ_β	not used	used
$\Delta\beta$	used	not used
ε	not used	used

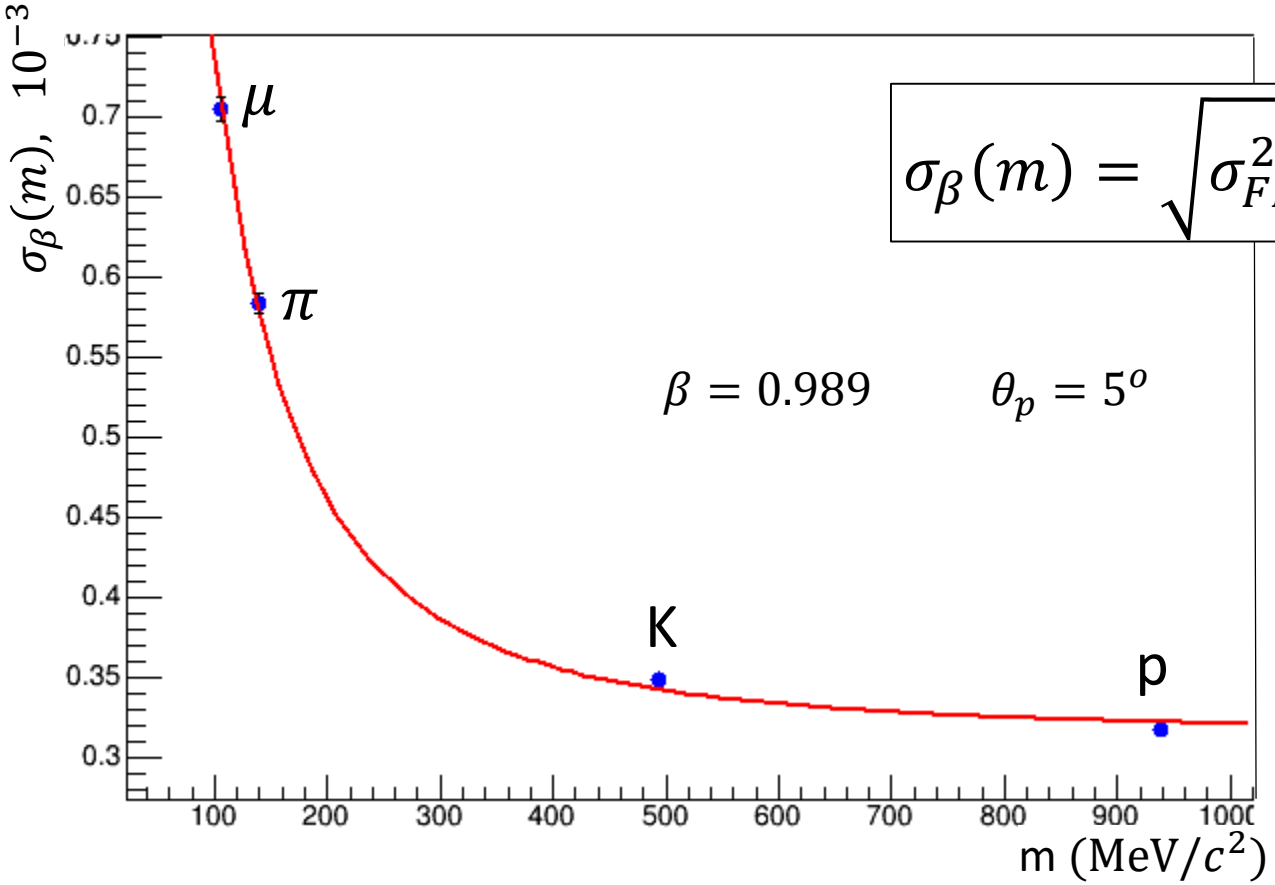
Calibration map

Calibration map should cover working part of particle phase space:

1. Particle type (e, μ, π, K, p)
2. Velocity (β)
3. Coordinates (x_t, y_t)
4. Angles (θ_t, ϕ_t)

- At that moment calibration was done for muons only. For other particles map is in the calibration process.
- Muon part of map can be used for other particle types with correction on difference in multiple scattering.

Multiple scattering correction

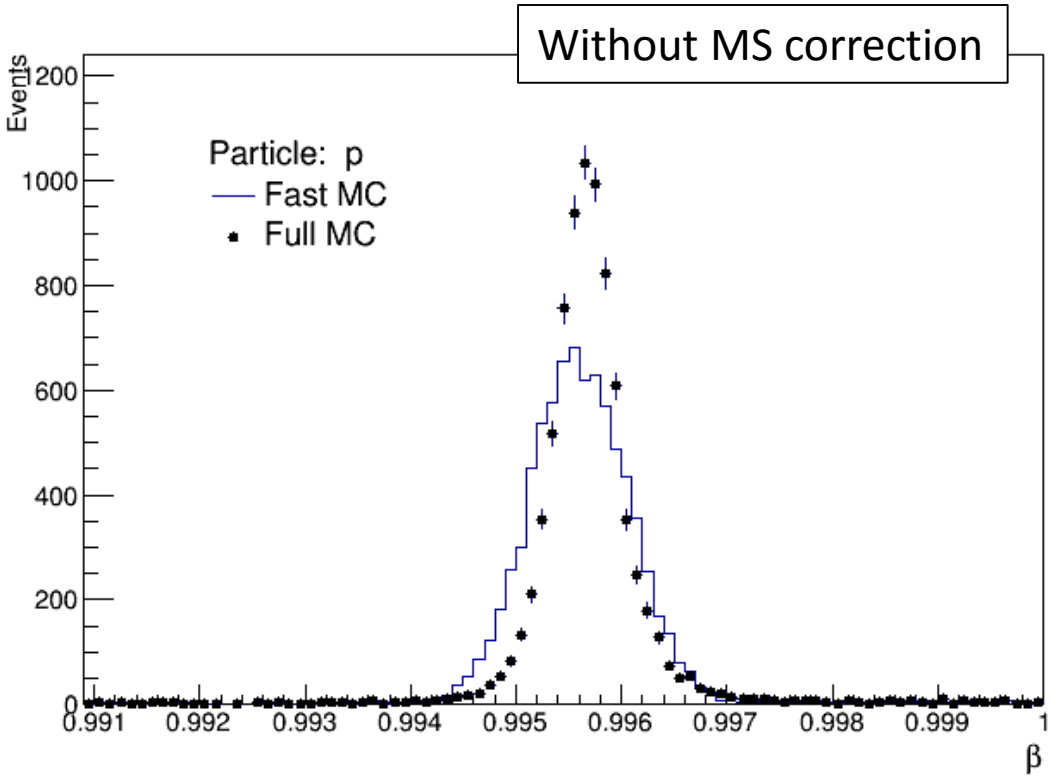


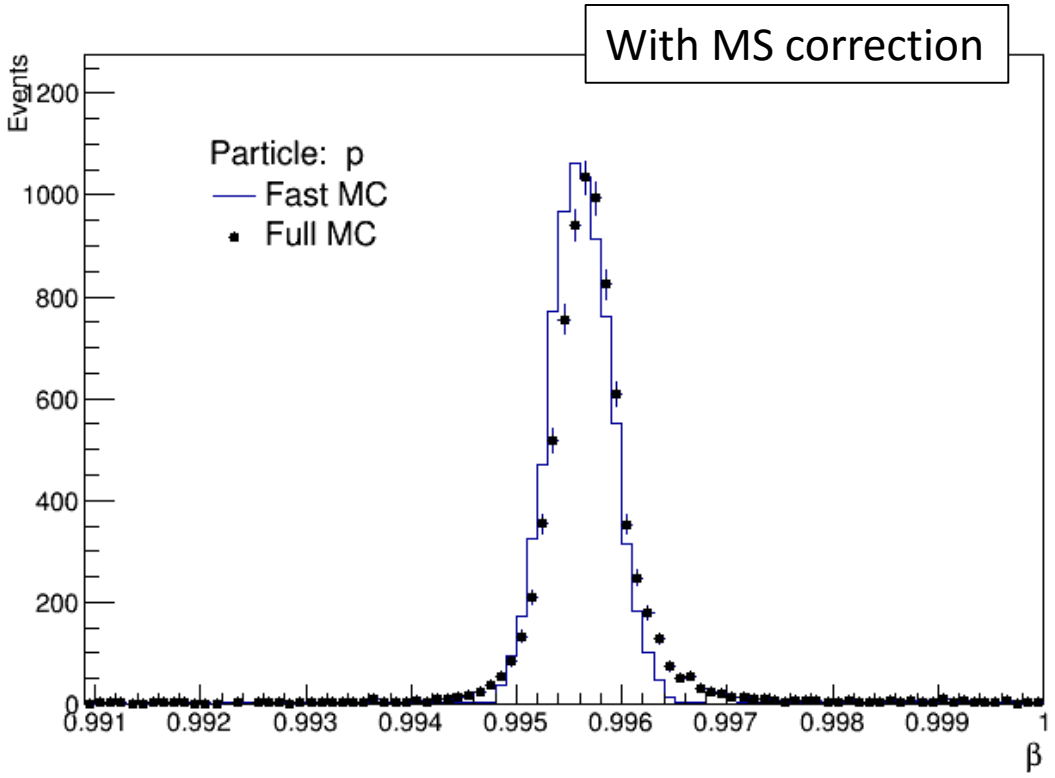
$$\sigma_\beta(m) = \sqrt{\sigma^2_{FRICH} + \sigma^2_{ms}(m, \beta, \theta_p; k)}$$

$$\Longrightarrow \quad k = 0.41\ \mathrm{MeV}/c^2$$

$$\theta_0 = \frac{13.6\ \mathrm{MeV}}{\beta c p} z \sqrt{x/X_0}\left[1 + 0.038 \ln\left(x/X_0\right)\right] \ \sim \ \frac{k}{m\,\beta^2\gamma\sqrt{\cos\theta_p}} \cong \sigma_{ms}(m, \beta, \theta_p; k)$$

Multiple scattering correction in case of proton (p=10 GeV/c)

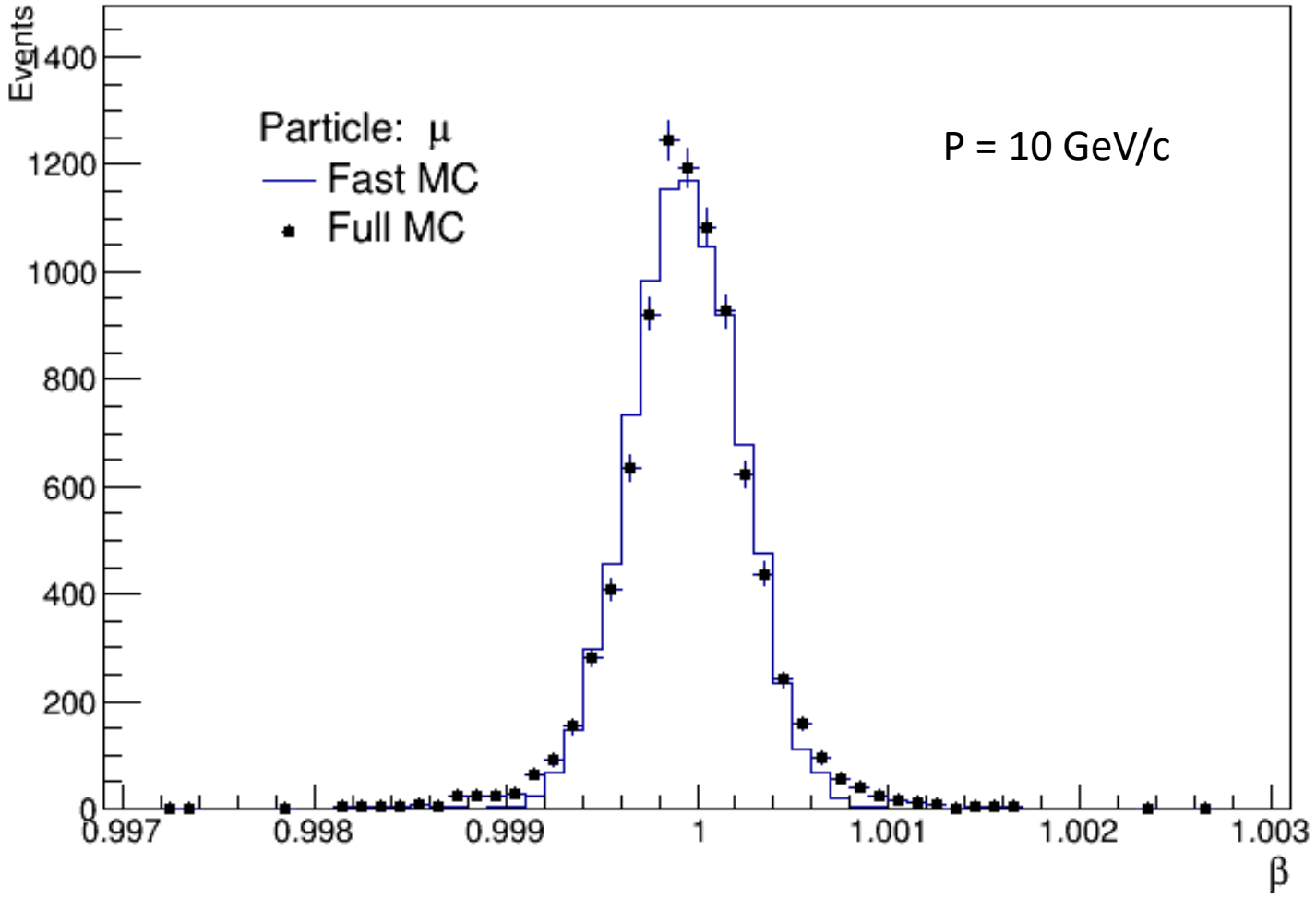




$$\sigma_p = \sigma_\mu$$

$$\sigma_p = \sqrt{\sigma_\mu^2 - \sigma_{ms}^2(m_\mu) + \sigma_{ms}^2(m_p)}$$

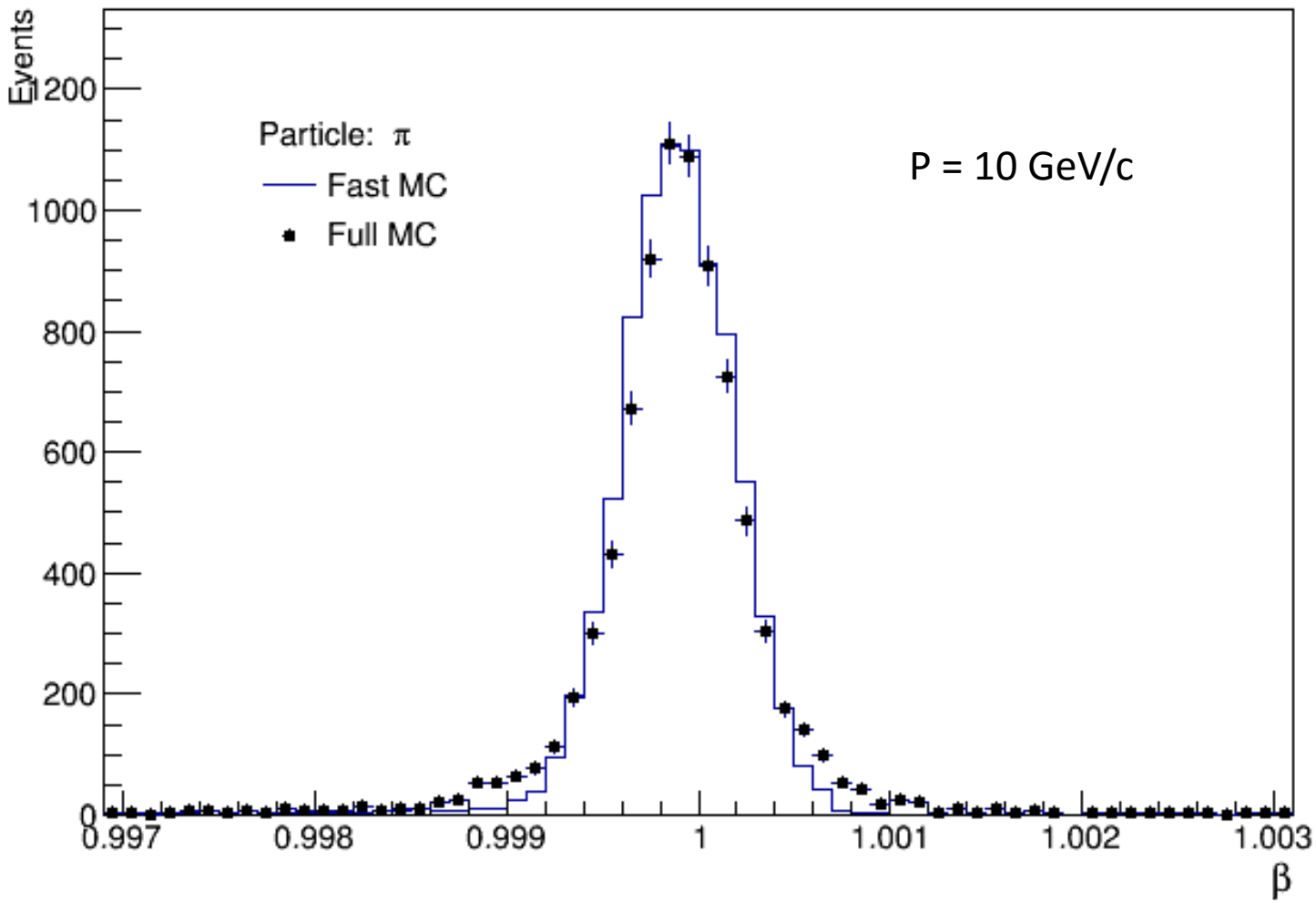
Result of simulation: muons



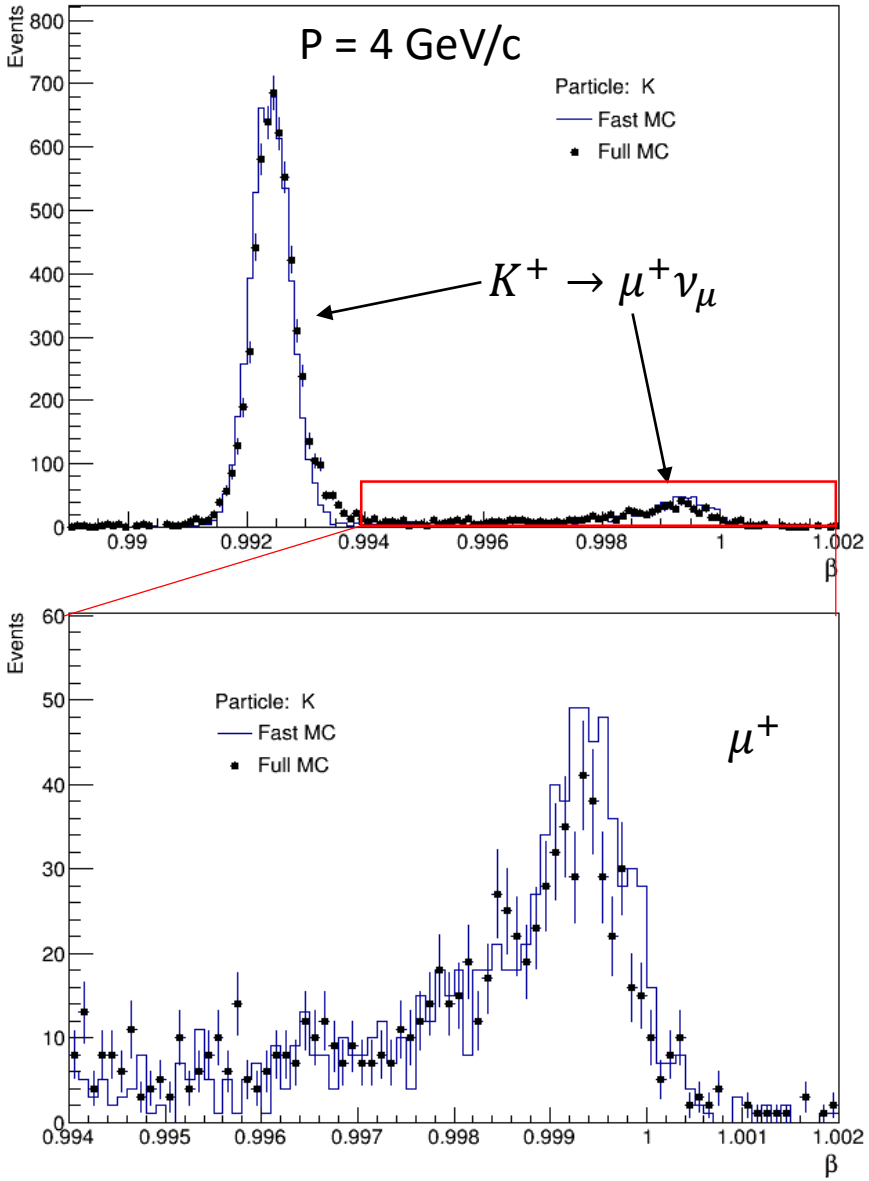
Conditions:

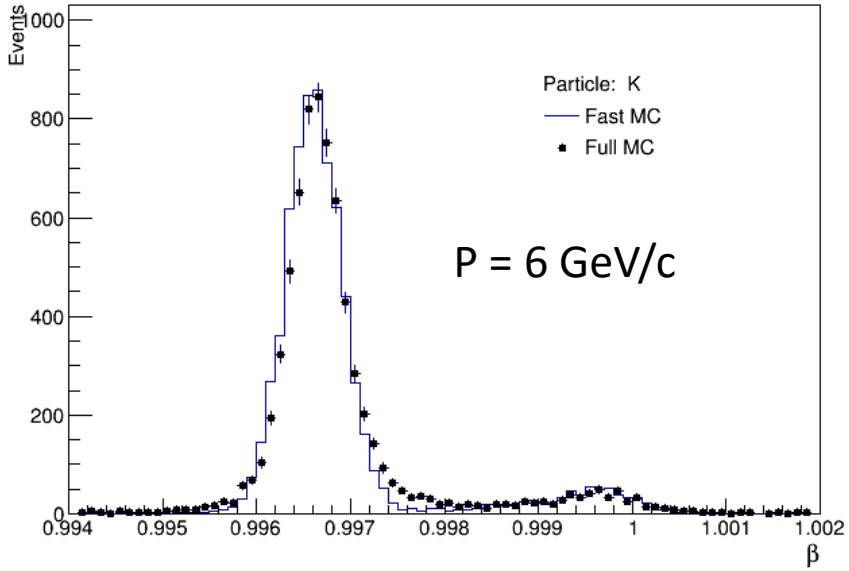
- Full PANDA Root simulation
- FairBoxGenerator
- Particle type: μ
- $\theta = 3^{o}$
- $\phi = 0 - 360^{o}$
- Momentum: 10 GeV/c

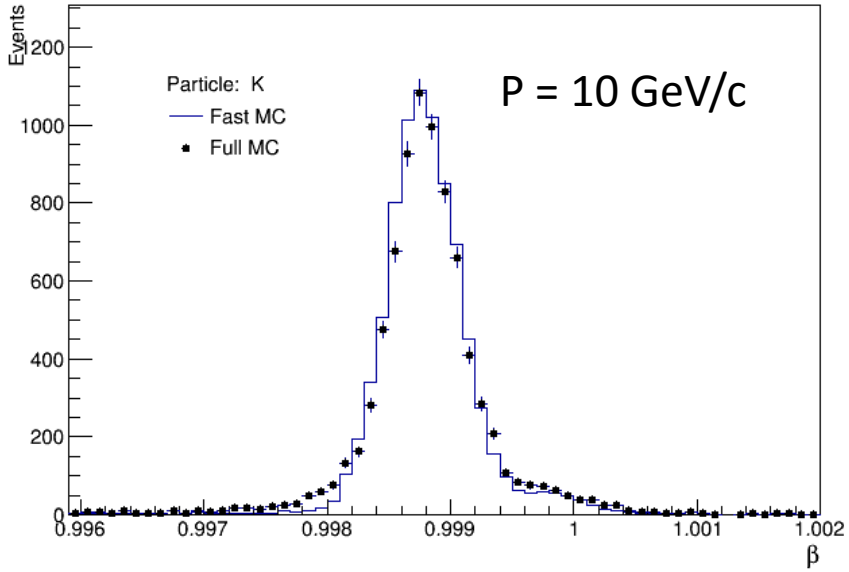
Result of simulation: pions



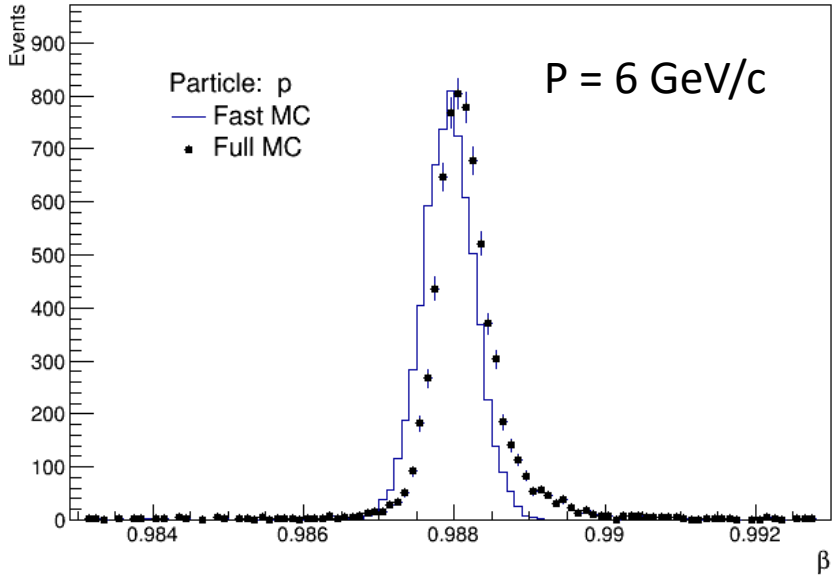
Result of simulation: kaons

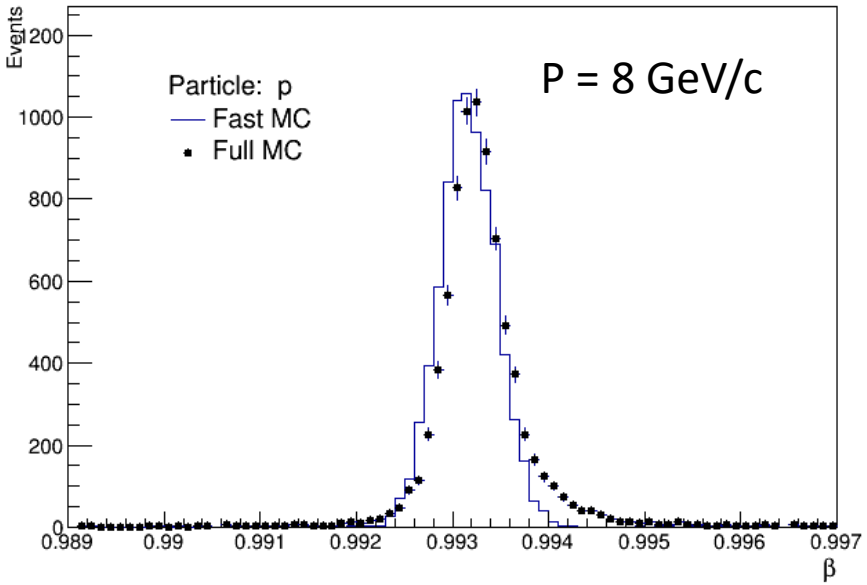


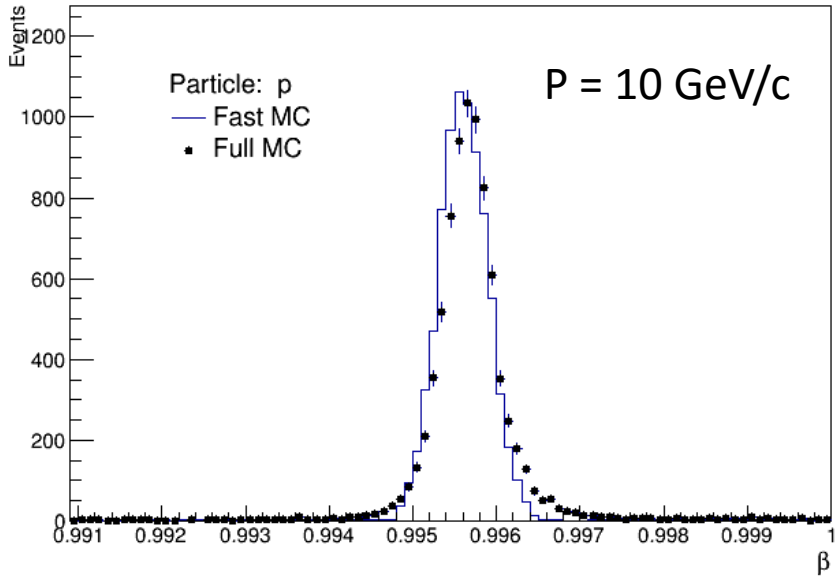




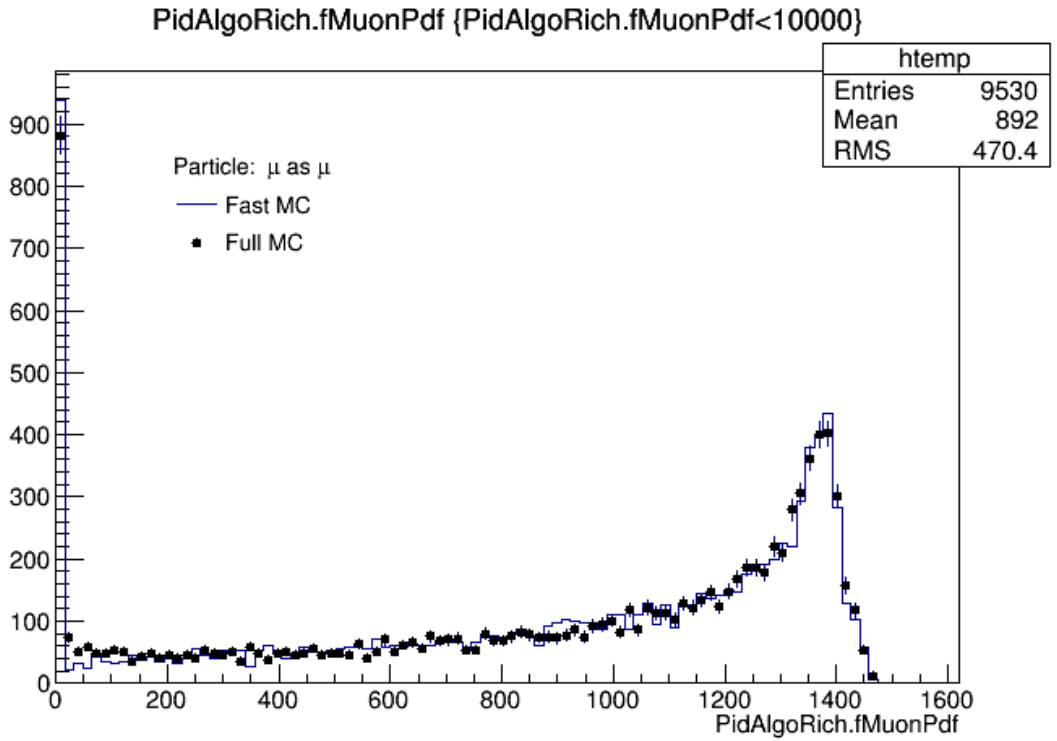
Result of simulation: protons

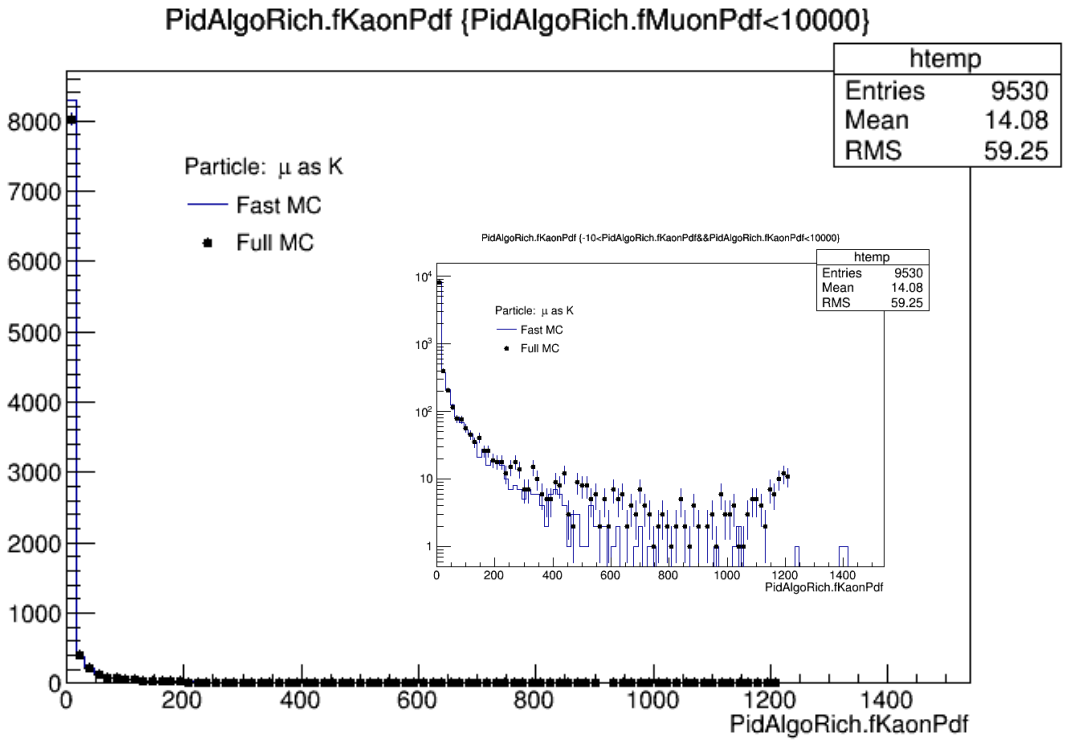




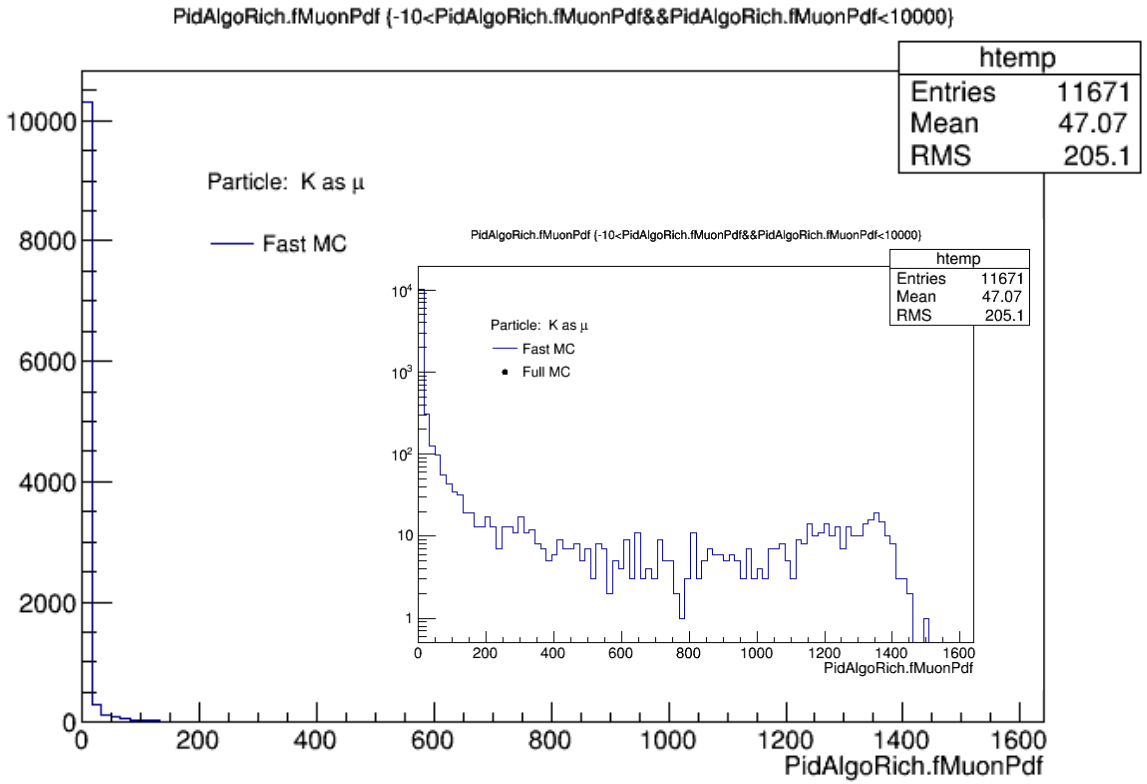


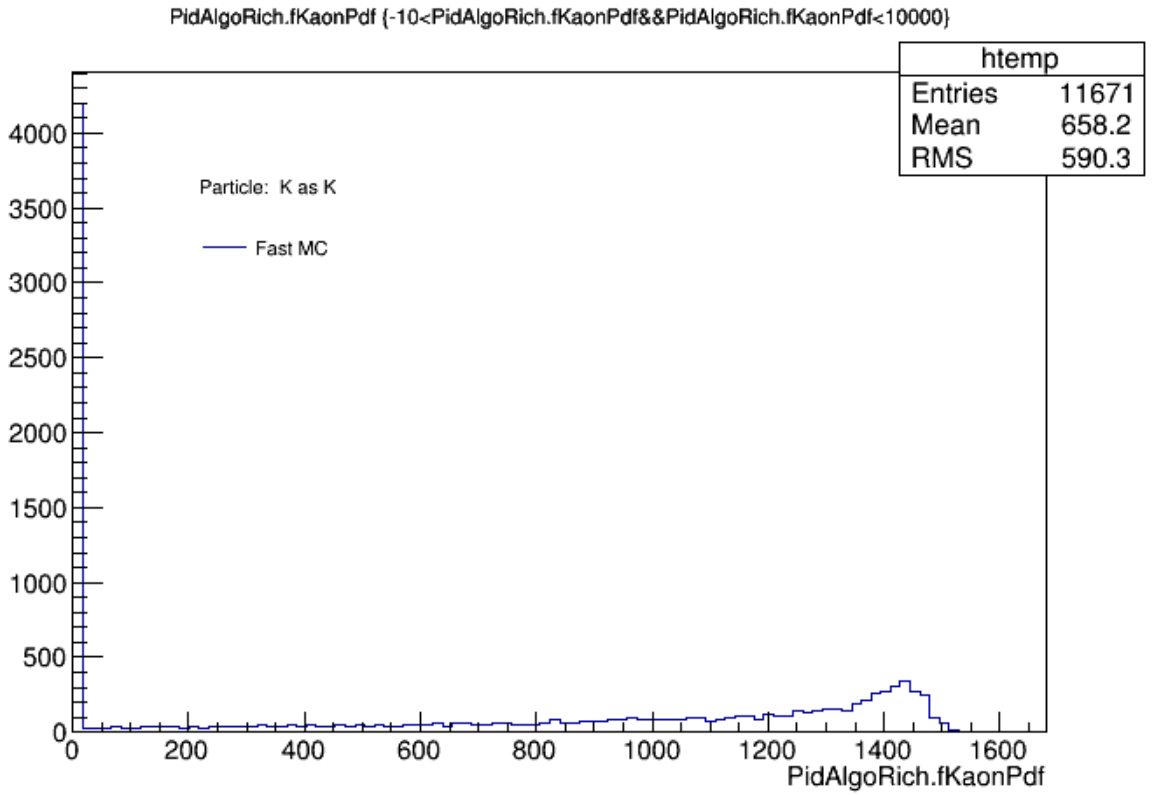
PID for muons (p=10 GeV/c)





PID for kaons (p=10 GeV/c)





Conclusions

- Full simulation and reconstruction were implemented (first working variant)
- Fast simulation using calibrated response was implemented
- FRICH calibration by muons for fast simulation is ready
  - Multiple scattering correction for other types of particles
- Calibration for all particle types will be done soon
- Now it is possible to use fast and full simulation and reconstruction in data analysis
- Simple tests with box generator were performed to compare fast and full reconstruction