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Performance of Clear Fiber TOP Detector

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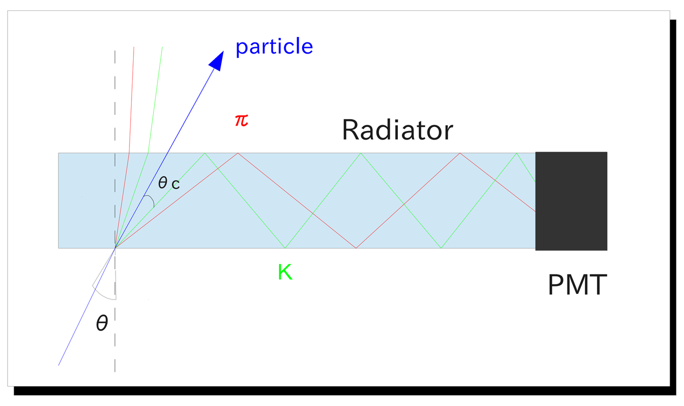
1.Introduction



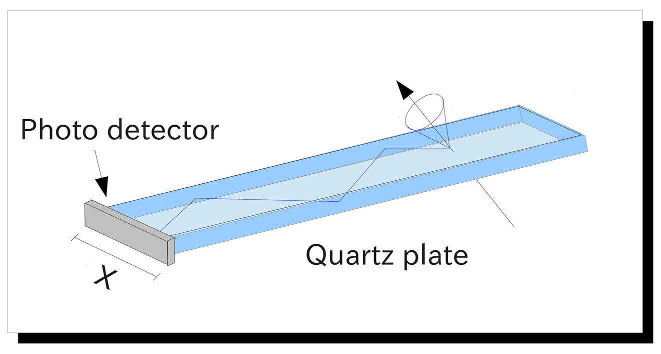
Charged particle passes through the material of refractive index n,

$$\cos\theta c = 1/n\beta$$

Cherenkov light is emitted at an angle in accordance with the formula.

If the momentum of the particle are equal, the Cherenkov angle is different because of various β of each particle. As a result, the difference of propagation time is appeared from the difference of propagation length of each particle's photons. Time of Propagation detector (TOP detector) identifies particles by using this method.

2.Current TOP Detector



TOP detector which is made already today is like a above figure. This identifies particles (π/K) by reconstructing a ring image with arrival time and arrival X coordinate.

Merit

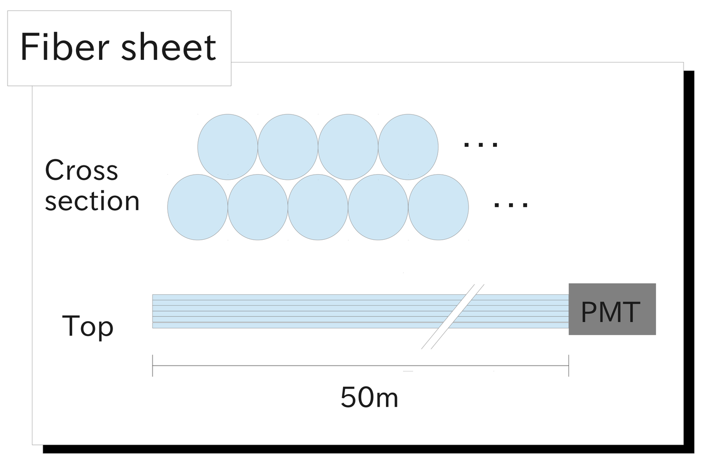
- This can identify particles if particles incident at any angle.

Demerit

- Production costs are high because it uses a quartz plate and polishes its surface.
- Because propagation length is short, the difference of the time is small.
- This need to use many PMTs which has high time resolution and can be used in a magnetic field.

3.TOP Detector in Development

Fiber sheet



Candidate fiber

- Mitsubishi Rayon Co. LTD ESKA CK-40
  n_{core} = 1.49, n_{clad} = 1.42
  price: $330 per 1km (Φ = 1mm)
- Kuraray Co. LTD multi-clad-fiber
  n_{core} = 1.59, $n_{inner\ clad}$ = 1.49, $n_{outer\ clad}$ = 1.42
  price: $5,400 per 1km (Φ = 1mm)

The detector uses the optical fibers as a radiator. This is constructed from several fiber sheets. The fiber sheet is composed of 2 layers of the optical fibers. Thickness of detector is modifiable by a condition. Cherenkov light generated propagates in fibers. its attenuation length is 50m. We have 2 candidate fibers.

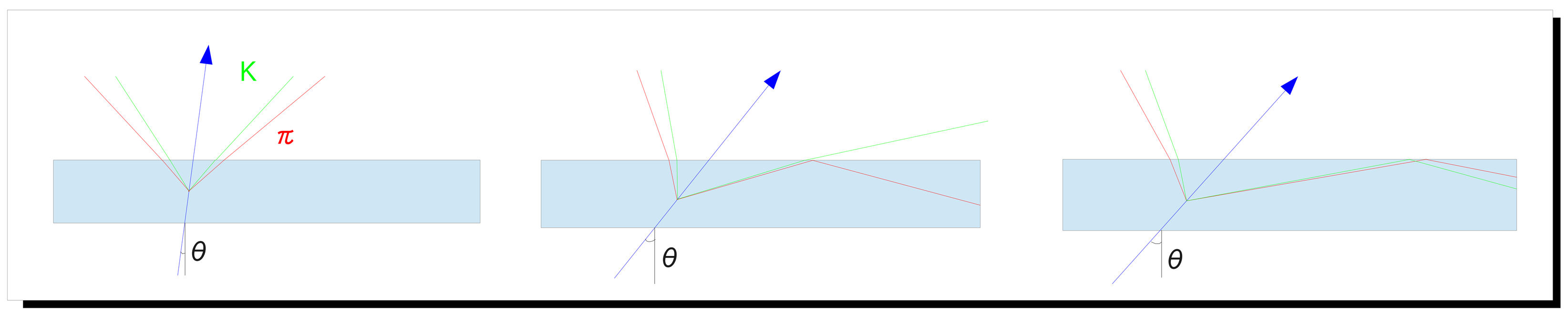
Merit

- Because the time difference gets longer, this detector can identify by the only it.
- It is available out of a magnetic field because of the long fiber.

Demerit

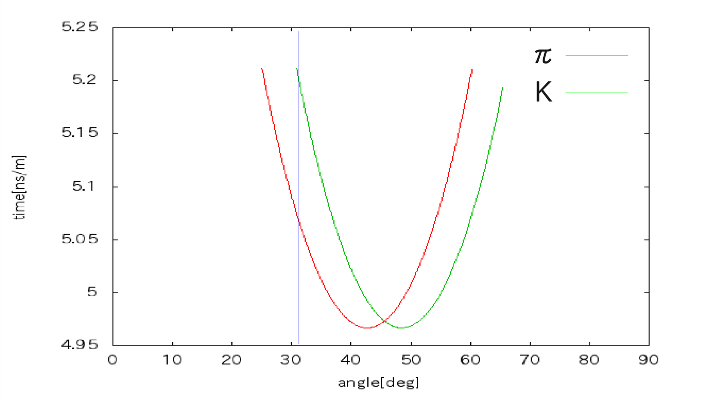
- Usable range of angle is limited(Chapter 4).

4.Calculation



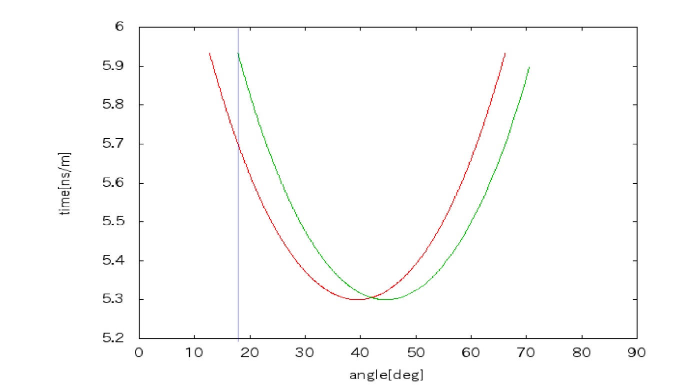
Because the difference between refractive index of core and clad of an optical fiber is small, range of angles satisfying the total reflection condition is limited. it is conceivable that both Cherenkov light of π and K is not reflected or the light generated either π or K is reflected as the above figure. So we calculated range of incident angles of particles that cherenkov light generated in the optical fiber is totally reflected. we also calculated the angle that the difference of time is the biggest. The momentum of particles is 1 GeV/c.

Results



Fiber: Mitsubishi Rayon

Maximum time difference
0.13ns/m(θ = 31°)



Fiber: Kuraray

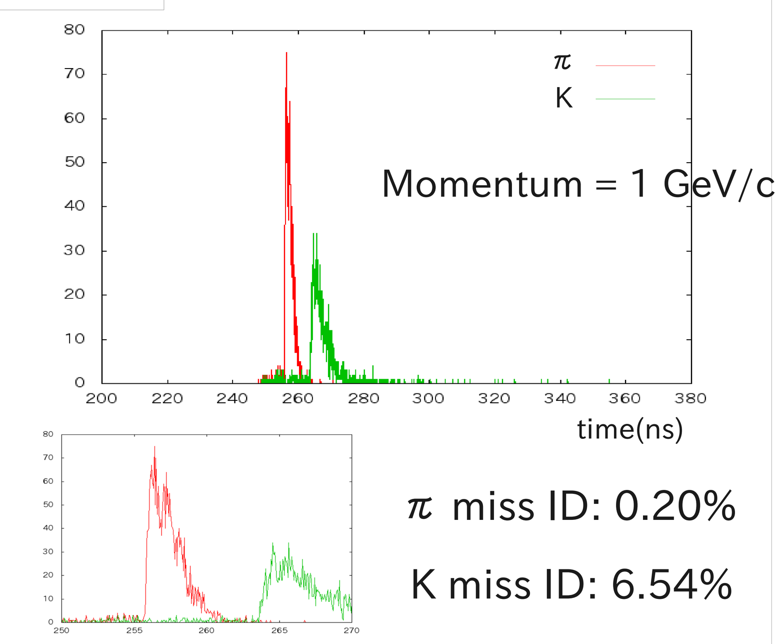
Maximum time difference
0.23ns/m(θ = 18°)

The vertical axis of the figure on the left expresses the arrival time per meter, the horizontal axis represents the incident angle of particles.

5.Simulation

We did a Monte Carlo simulation with Geant4. In this simulation, π/K separation and e^+/μ separation is a purpose. e^+/μ separation is required from E-36 experiment(see chapter 7). These figures show the propagation time distribution in case that the propagation length of 50 m. Particles passed into a target that is five layers of the fiber sheet at the angle of the maximum difference of propagation time. A fiber made by Mitsubishi Rayon Co. LTD.

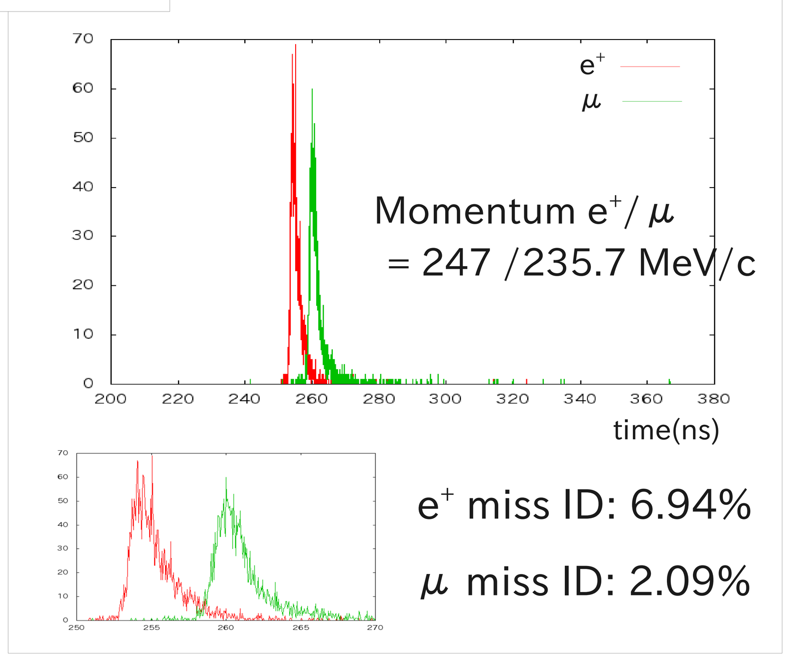
π/K



π miss ID: 0.20%

K miss ID: 6.54%

e^+/μ



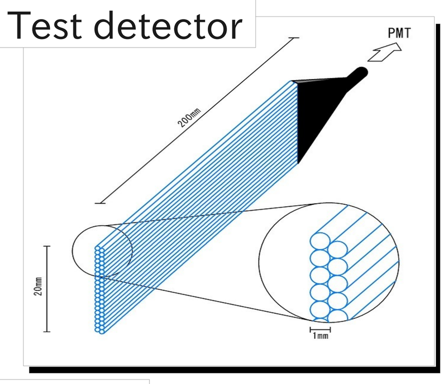
e^+ miss ID: 6.94%

μ miss ID: 2.09%

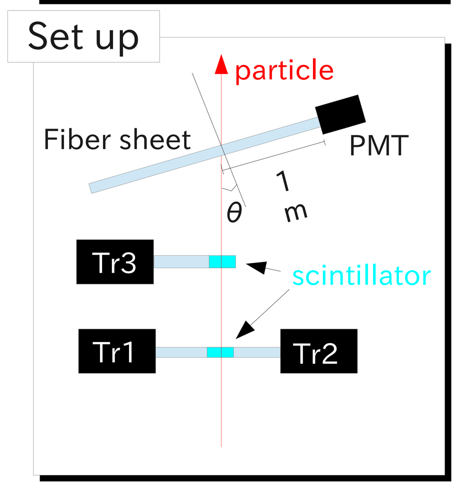
In the left figure, a detector read cherenkov light from all fiber sheets. It outputs the shortest propagation time when the light is detected. The light emitted by knock on electrons also were detected. Because of that, miss-identification of K increased but miss-identification of π decreased. In the simulation of right figure, we prepared a detector for each sheet. We collected the shortest propagation time of each detector and calculated average of propagation time without the shortest and longest propagation time of five propagation times.

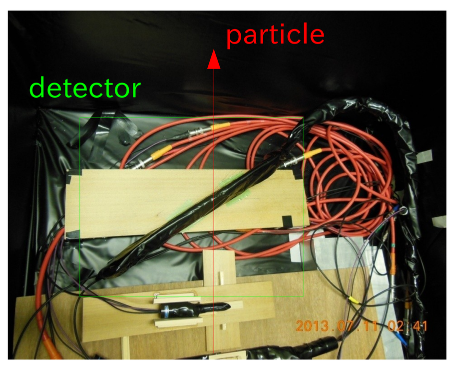
6.Test experiment

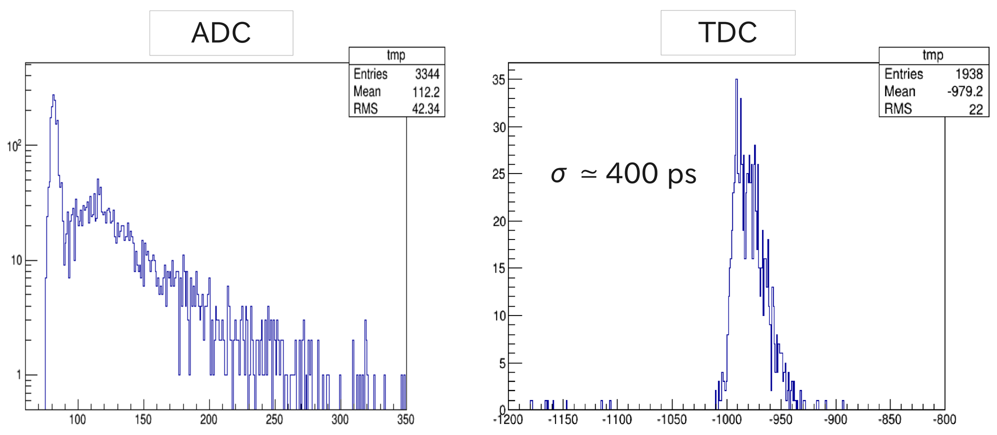
Test detector



Set up

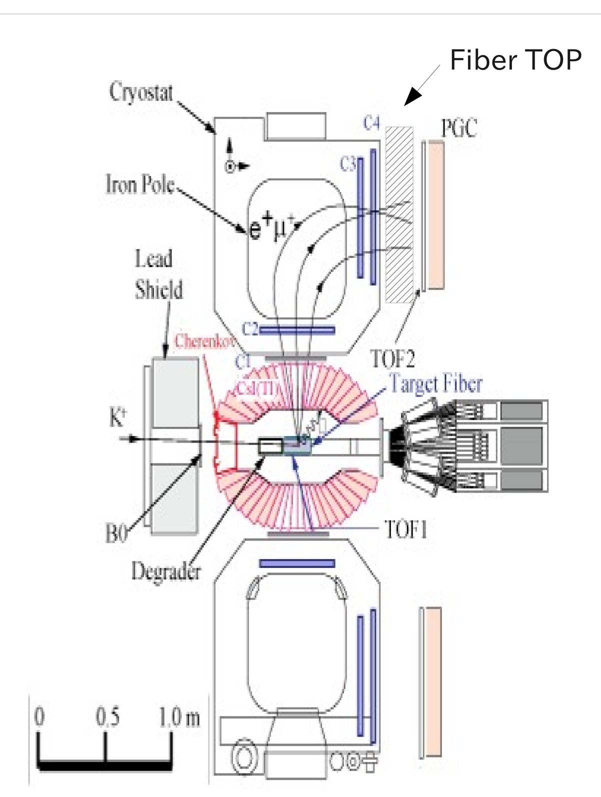






We tested Clear Fiber TOP detector whether cherenkov light arrived to a PMT. This test use e+ of 0.7-1GeV at Spring-8 BR33LEP beam line. As a result, The fiber transmitted cherenkov light without a critical problem. In this experience, $N_{p.e.}$ is approximately 0.80 because efficiency is 55.2%. if a detector is made with ten fiber sheets and fiber length is 50m, efficiency is 94.7%. Time resolution of this detector is 400 ps. This value is consist of Time resolution of PMT. (Rise time of PMT used in this experiment is 570 ps.)

7.Plans for the future



Left figure shows the rough design of E-36 detectors at J-PARC. This experience's purpose is to measure a ratio of 2 body leptonic decay width of K. Now,

$$\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu) = 2.493 \pm 0.025.$$

This experiment want to measure this ratio with ± 0.01. Therefore, more accurate e^+/μ separation is necessary. Particle identification system is not decided. We propose the Clear Fiber TOP detector. This is put between C4 and PGC, but doesn't affect PGC.