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Monte Carlo simulation of the particle identification (PID) system of the Muon Ionization Cooling Experiment (MICE)

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GEANT4 based simulation of the beam channel and the upstream PID system of the MICE experiment is presented. Results of the analysis of particle separation capabilities exploiting the time of flight system are discussed. Comparison of the performance for different settings of the magnetic elements of the beam channel and for different intrinsic resolutions of the TOF counters is made.

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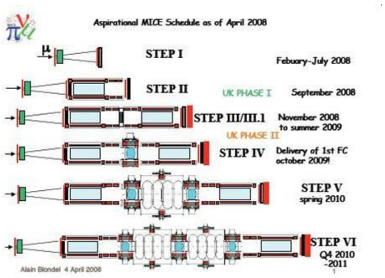

Figure 1: MICE experiment.

1. MICE experiment

MICE is an essential step in accelerator R&D towards the realization of the neutrino factory. For muons, the standard cooling techniques can not be applied. However, there is another technique, called Ionization Cooling.

The goal of MICE [1, 2] is to build a section of a cooling channel that can provide a measurable ionization cooling effect of the order of 10% in transverse emittance and to use particle detectors to measure the cooling effect with precision of 0.1% or better. MICE will be implemented in steps. Each step will validate one part of the setup, starting with the beam line and the detectors for particle identification in spring 2008, and then progressively introducing the spectrometers, the absorbers and the RF units. The final setup will be operational in 2009 (figure 1).

2. Particle identification and time measurement

The muon beam may contain residual pions which are transported through the large momentum acceptance of the beam line, and electrons from the in-flight decay of muons. A three-plane time-of-flight system [3] provides the precise time information for emittance measurement and particle-identification. Additional particle identification is provided before and after the cooling channel by Cherenkov detectors and a calorimeter at the end.

Precise timing measurements are required to relate the time of the incoming muon to the phase of the field in each RF cavity and for particle identification by time-of-flight (TOF) method. Each of the tree TOF stations consists of two planes of vertical and horizontal scintillator slabs. Each slab is optically connected to two fast PMTs. In the tests of the TOF detector prototype in the Frascati Beam Test Facility, intrinsic time resolution of $\sim$ 50-60 ps per counter was obtained.

In order to obtain correct numbers and momentum distributions of muons, pions and electrons at the end of the beam channel, the propagation of the particles trough the beam channel is simulated exploited tools developed in [4]. This is made for different settings of the magnetic field in the two dipole magnets. The coordinates and the momenta of the particles at the end of the beam channel are recorded.

Simulated particles are used to investigate how the settings of the dipole magnets affect particle separation by the time-of-flight between TOF0 and TOF1 (figure 2). The performance is tested also for different intrinsic time resolutions of the TOF counters (figure 3).

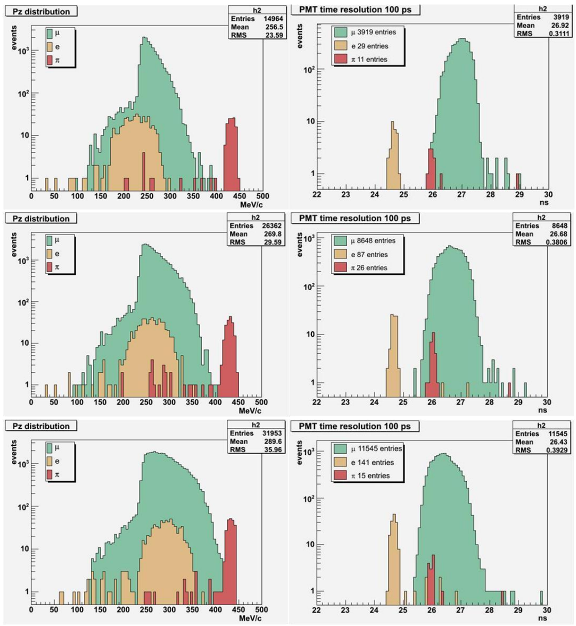

Figure 2: Momentum distributions of muons, pions and electrons (left) for different settings of the dipole magnets, and obtained TOF plots (right).

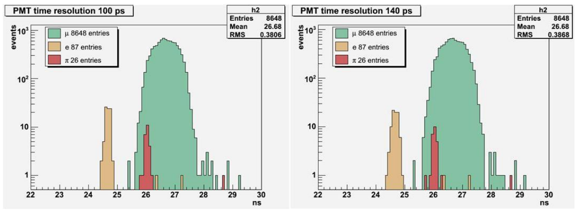

Figure 3: TOF plots with 100 (left) and 140 ps (right) time resolution per PMT which gives 70 and 100 ps counter time resolution.

3. Conclusion

The time-of-flight method gives good separation of electrons and muons, even with very conservative expectation of 100 ps intrinsic time resolution per counter. The separation of muons and pions is not possible using only time-of-flight and also the reconstructed momentum from the tracker has to be used.

References

[1] MICE web site *http://mice.iit.edu* contains thorough information about the experiment.

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[4] C.T. Rogers and R. Sandstrom, Simulation of MICE using G4MICE, EPAC 06, Edinburgh, Conf. proceedings, 2006, p. 2400-2402.