21st International Conference on Computing in High Energy and Nuclear Physics (CHEP2015)

Development of tracker alignment software for the J-PARC E16 experiment

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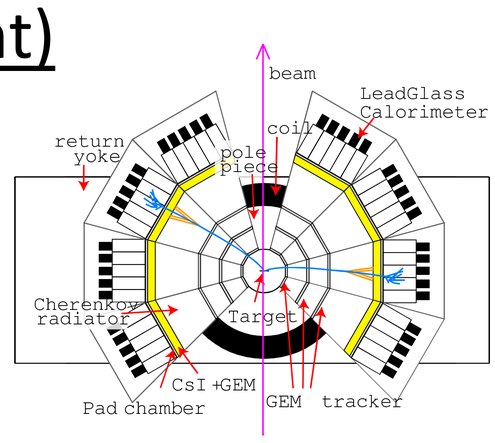
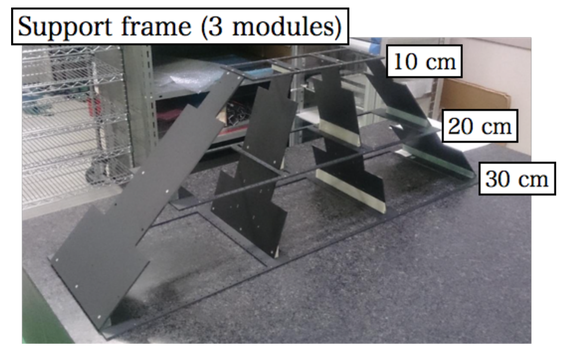
Introduction (J-PARC E16 experiment)

The J-PARC E16 experiment will measure the mass modification of phi meson in nuclear matter at J-PARC in order to study an origin of hadron mass.

The E16 experiment aims for the mass resolution of 5 MeV/c^2 around ϕ meson peak. In order to achieve this, the position resolution of 100 μm is required. Detector R&D has been well performed and by several beam tests, the requirement is shown to be satisfied.

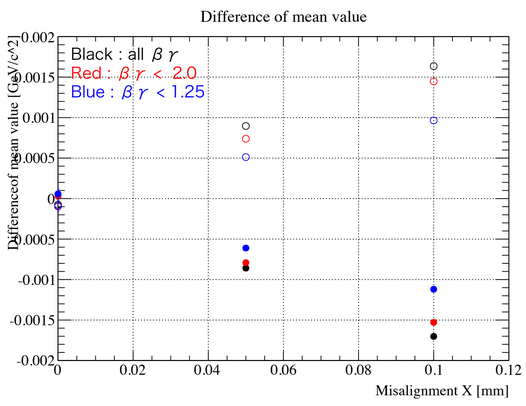


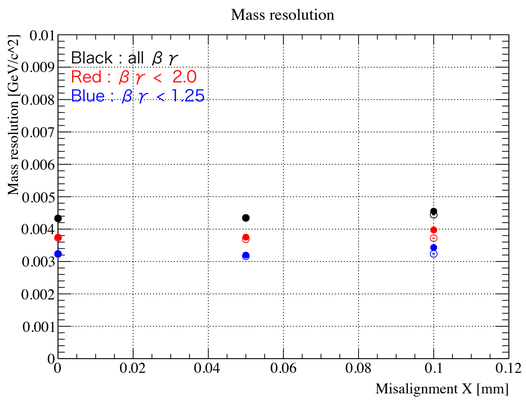
The J-PARC E16 spectrometer consists of GEM trackers, Cherenkov counters, and LG-calorimeters.

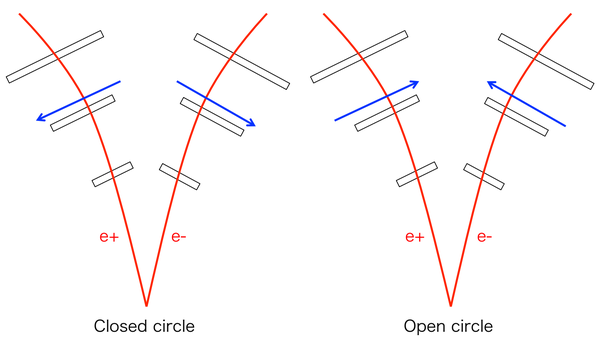


One module has 3-layers of GEM trackers (GTRs). The sizes of GTRs are 100 mm, 200 mm, and 300 mm, respectively.

Requirement



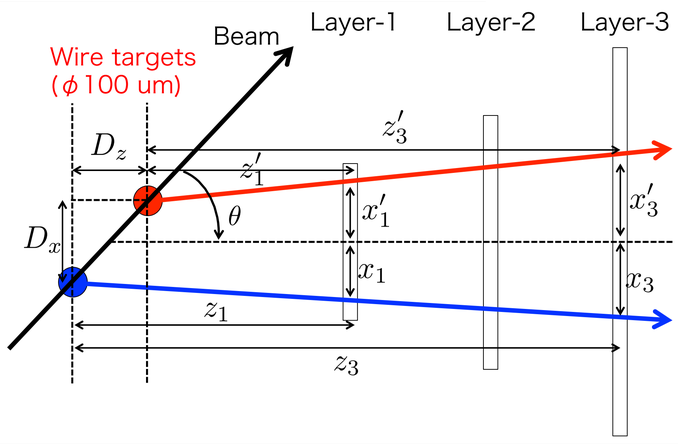




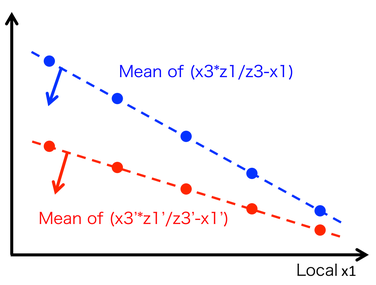
The required accuracy of alignment is evaluated by using Geant4-based simulation. Difference between the generated and reconstructed phi-meson mass as a function of local-x direction misalignment are obtained.

The required accuracy is 25 um so that the mean of reconstructed mass spectrum is consistent with PDG value within 1 MeV/c^2.

Alignment algorithm



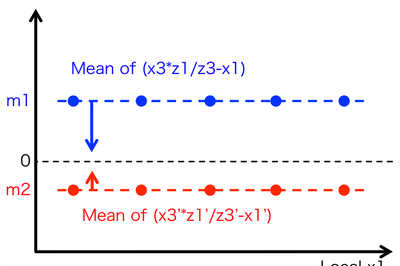
z alignment



If non zero misalignment of z exists, these values depend on local x.

Corrected z1/z3 (z1'/z3') ratios are determined in order that these slopes become zeros.

x alignment



If non zero misalignment of x exists, means of these values will become zeros.

Misalignment parameter can be calculated this equation.

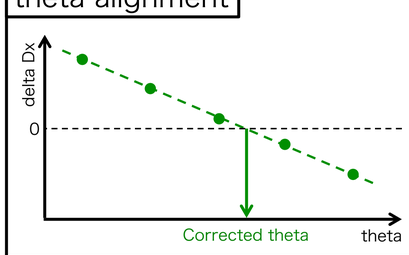
$$\Delta x_3 = -\frac{m_1 - m_2}{z_1/z_3 - z_1'/z_3'}$$

Dx reconstruction

$$\Delta D_x = \frac{x_1 z_3 - x_3 z_1}{z_3 - z_1} - \frac{x_1' z_3' - x_3' z_1'}{z_3' - z_1'} - D_x$$

change theta

theta alignment

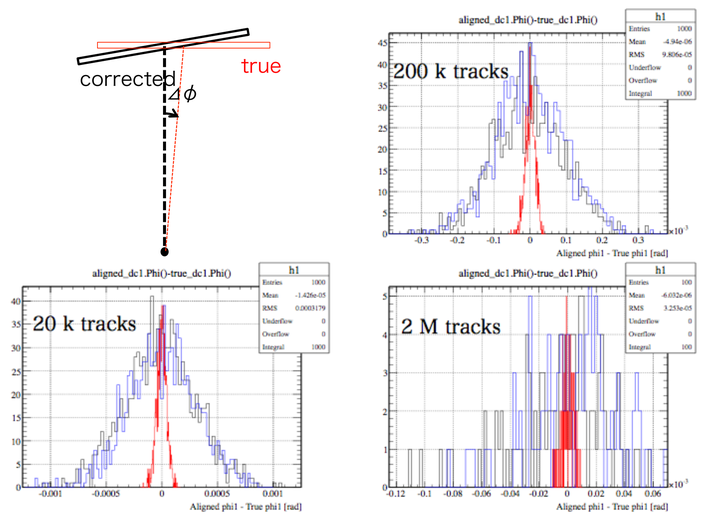


Corrected theta is determined by scanning theta value until ⊿Dx becomes zero.

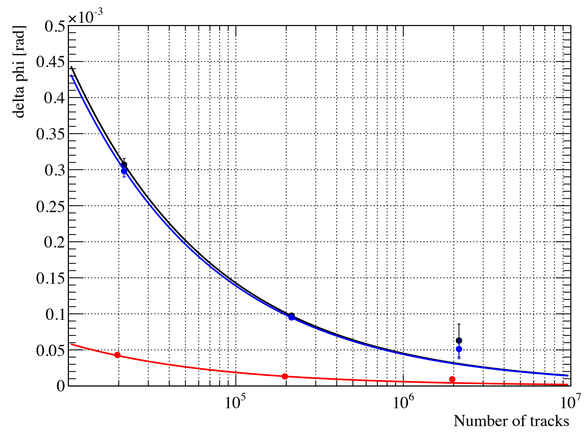
Results of MC simulation

We evaluate this algorithm using a Monte Carlo simulation. In the simulation, many data sets are generated after misaligning detectors in random directions from designed places.

The results are shown in below. In conclusion, we need more than 200 k tracks, in order to achieve the accuracy of 0.1 mrad (20 um at 1st layer).



These histograms are distributions of difference between simulation true and corrected phi coordinate of detector centers. Red is that of the most forward module, black and blue are transverse modules (opposite side). 1000 data sets of 20 k tracks, 1000 data sets of 200 k tracks, and 100 data sets of 2 M tracks are generated.



Summary and Outlook

- ✓ For the J-PARC E16 experiment, we have been developing the alignment algorithm.
- ✓ The requirement of alignment is evaluated the accuracy of 25 um by using Geant4-based simulation.
- ✓ We achieved the requirement with the current algorithm.
- ✓ This result does not include multiple scattering effect. This study is on going.
- ✓ We should develop alignment algorithm of local y and local z rotation.