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Tracking parameter simulation for the Turkish accelerator center particle factory tracker system

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ABSTRACT

The silicon tracker part of the Turkish Accelerator Center super charm particle factory detector was designed for effectively tracking charged particles with momentum values up to 2.0 GeV/c. In this work, the FLUKA simulation code has been used to estimate the track parameters and their resolutions in the designed tracker system. These results have been compared with those obtained by the tkLayout software package. The simulated track parameter resolutions are compatible with the physics goals of the tracking detector.

1. Introduction

The Turkish Accelerator Center (TAC) is planned as a regional facility for accelerator-based fundamental and applied research in Turkey. One of the main parts of this project is a super charm particle factory which is designed to collide electrons and positrons in a LINAC-ring type collider at the center of mass energy of 3.8 GeV [1]. The initial design of the particle factory tracking detector consists of five individual cylindrical barrel modules with 4 cm radial distances between them. Each module has two parallel single-sided silicon strip detector planes assembled into carbon-fiber layers, with a radial distance of 2 cm between them. The cylindrical barrel part of the tracker consists of about nine thousand silicon sensors in total as shown in Fig. 1 [2].

The silicon tracker is the innermost detector of the particle factory detector covering mean radius values from 8 cm to 34 cm from the beam pipe. The full tracker provides pseudo-rapidity coverage up to $\eta < 2.1$ while giving 10 hits corresponding to 5 space-points per track. The designed tracker system was extensively described and its energy deposition and transverse momentum resolution variations with pseudo-rapidity were presented in our previous work [2].

In this work, the track parameters in the designed tracker system are calculated by the FLUKA [3,4] and the tkLayout [5] software packages, and the resolutions of the track parameters as a function of η are presented. A precise reconstruction of tracks has a direct impact of certain measurements, for example charm production (J/ψ) measurements. A high reconstruction efficiency is essential for a full reconstruction of rare charm quark decays and for the identification of signal and background events.

2. Track parameterization

When a charged particle moves at an angle to the solenoidal field B in the tracker, it travels in a helical path. Therefore, helix or track parameters p can describe a track in the tracker and can be given as

$$p = (a_0, z_0, \phi_0, \cot\theta, Q/p_t) \quad (1)$$

where the transverse impact parameter a_0 is the distance from the origin to the point of closest approach to the beam line in the xy plane and the longitudinal impact parameter z_0 is the point of intercept between the straight line formed by the track and the z-axis in the rz plane. The sign of a_0 is negative if the track has positive angular momentum around the beam line. Here x, y, z are spatial coordinates and r is the radial distance from origin. ϕ_0 and θ are angular coordinates and indicate azimuthal angle and polar angle, respectively. The pseudo-rapidity η is clearly related to $\cot\theta$ as $\eta = a\sinh(\cot\theta)$. A schematic representation of the parameters a_0, z_0, ϕ_0 and $\cot\theta$ can be seen in Fig. 2. The "true vertex" shows the location where the track is created.

3. Simulation and results

In order to calculate track parameters, the FLUKA software is used to simulate individual negative muons, produced at the

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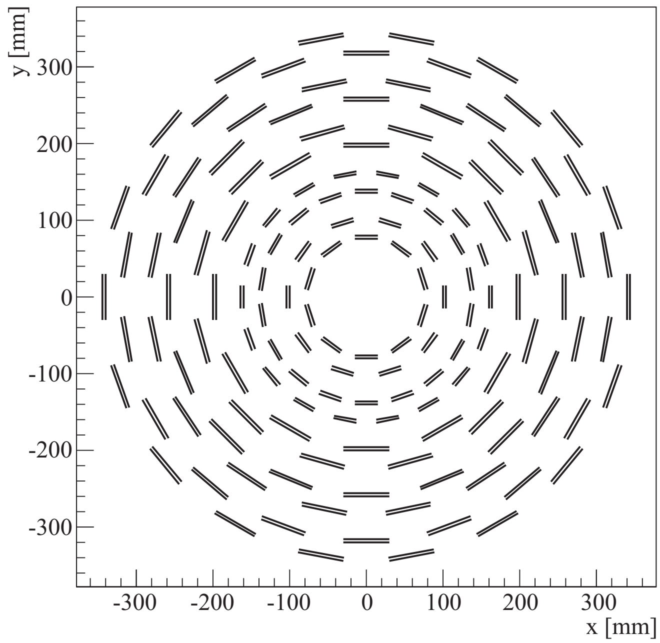

Fig. 1. XY view of the silicon tracker detector [2].

center of the detector with an angle of $\pi/2$ radian azimuth and with polar angles between $\pi/12$ and $\pi/2$ radians, going through the tracker in a 1 T magnetic field. Space-points measured by the tracker are recorded for muons generated in the momentum range from 0.5 to 2.0 GeV/c and pseudo-rapidity values $\eta < 2.1$. The results are analyzed with the ROOT data analysis framework [6].

The radius of curvature of tracks are obtained by applying least square fits in the *xy* plane, for particles passing through the tracker modules. This curvature is extrapolated to the interaction point, then the transverse impact parameter a_0 and the azimuthal angle ϕ_0 are calculated from the tangent. The longitudinal impact parameter z_0 and polar angle θ are also calculated by applying a first order polynomial fit in *rz* plane.

As an example, Fig. 3 shows the fits to the entire track in the *xy* and *rz* planes for a single muon passing through the tracker modules with 1 GeV/c momentum and pseudo-rapidity of $\eta = 1.0$. So, the track parameters a_0, ϕ_0, z_0 and $\cot\theta$ are calculated for this event as -1.76×10^{-4} cm, 1.57 rad, -1.81×10^{-2} cm and 1.29 respectively.

For 10^6 muon tracks, the track parameters are calculated as described above and the distributions of these parameters are plotted in Fig. 4. Then the resolutions of the track parameters are estimated by applying a Gaussian fit to each distribution. As the distributions are drawn for pseudo-rapidity value $\eta = 1$ rather than 0, the fitted z_0 parameter is pulled to negative values, see Fig. 2.

In this work, the track parameters and their resolutions are analysed for all generated muons in given momentum and pseudo-rapidity values. In Fig. 5, the resolutions of the track parameters $\sigma(a_0)$, $\sigma(\phi_0)$, $\sigma(z_0)$ and $\sigma(\cot\theta)$ are given as function of η for p_T = 0.5 GeV/c, 1.0 GeV/c, 1.5 GeV/c and 2.0 GeV/c respectively.

According to the simulations, the track parameter resolutions are better for higher track momenta as expected, as the charged particles are less deflected by multiple scattering. The resolutions of the track parameters get worse for the particles passing through the tracker at larger pseudo-rapidity values.

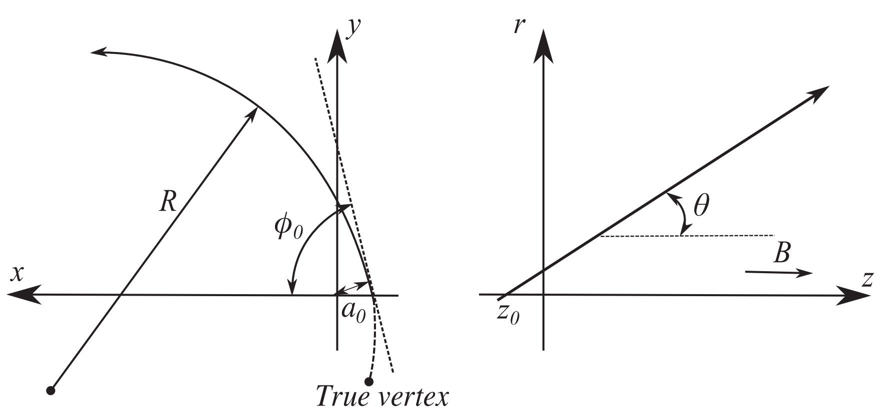

Fig. 2. Schematic representation of the track parameters.