Exercises: Particle Detectors WS 2016/17
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Problem Set No. 9

Solutions have to be handed in by Wednesday 3pm, 18.1.2017 in letter box no. 3, in the ground floor of Gustav-Mie building!

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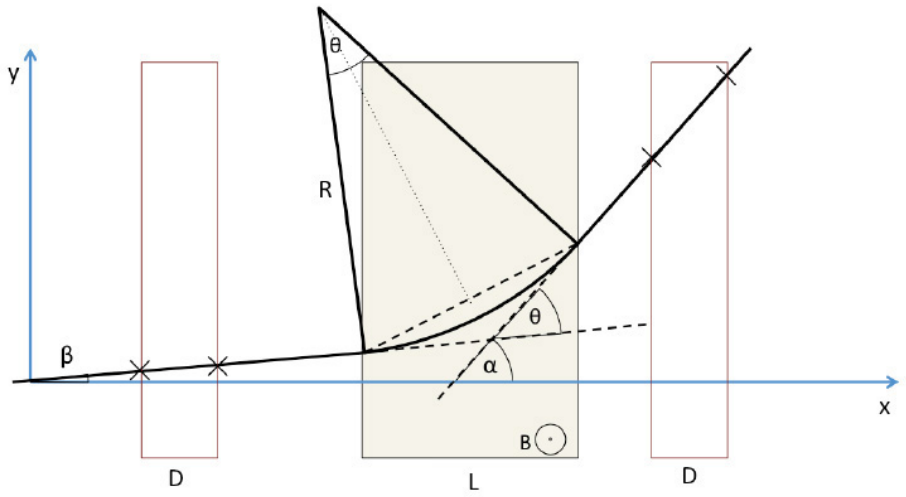
1. **Dipole spectrometer**
   The momentum of relativistic particles is measured using a setup consisting of two



tracking detectors of length D each, with a dipole magnet in between. The magnetic field is assumed to be uniform and constrained to a volume with length L. The momentum is calculated from the deflection angle θ between the two straight tracks measured before (having an angle β) and after (α) the magnetic field. Due to a very high p_x of incident particles, all three angles are assumed to be small and linear approximation of angles can be used.

(a) The tracking detectors consist of two tracking layers each, with a distance D between the two layers providing a 'lever arm' to measure the path of the particle. The uncertainty on the measurement of the slope of the path σ_{slope} is given as

$$\sigma_{slope} = \frac{\sigma_x}{D}\sqrt{\frac{12(N-1)}{N(N+1)}}, \tag{1}$$

where N is the number of tracking layers. Determine the uncertainty on α, β and using error propagation θ.

(b) The momentum p can be calculated from $p/(GeV/c) = 0.3 * (B/T) * (R/m)$, where R is the radius of the curved path inside the magnetic field. First determine $dp/d\theta$ and then, given the result of (a), calculate the relative uncertainty σ_p/p on the momentum measurement.

(c) Calculate the relative uncertainty using $\sigma_x = 100\mu m, D = 1m, B = 1.5T$ and $L = 2m$ for muons with a momentum of either 10 GeV/c and 100 GeV/c?

[5 points]

2. **Charged particle in B-field**
The path of a particle is measured at N equidistant tracking layers inside a solenoid field.

   (a) Derive the maximum transverse momentum p_T for which the sign of the charge of an electron can be determined with an uncertainty of two standard daviations, given

$$\sigma_\kappa \approx \frac{\sigma_x}{L^2}\sqrt{\frac{720}{N+4}}, \kappa = 1/R. \tag{2}$$

   (b) Calculate the maximum transverse momentum for which (a) holds using $N = 12, L = 1.15m, B = 2T, \sigma_x = 20\,\mu m$.

[2 points]

3. **Momentum measurement**
A cylindrical detector is built around the point of interaction of a storage ring experiment, with a solenoid field along the z-axis of the cylinder. All particles originate from the point of interaction.

   (a) What is, using classical mechanics, the transverse momentum of a charged particle, in GeV/c, depending on a measured radius of curvature ρ in meters and the field strength B in Tesla?

   (b) The detector has a radius $R = 3.5\,m$ and the strength of the magnetic field is 1 T. What is the minimum transverse momentum for a particle to be able to leave the detector?

[3 points]