Übungen zu Physik an Hadron-Collider SS 2011
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Übungsblatt Nr. 1

Die Lösungen müssen bis 11 Uhr am Donnerstag den 12.5.2011 in die Briefkästen im Erdgeschoss des Gustav-Mie-Hauses eingeworfen werden!

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1. **Stopping particles**

   A muon behaves in matter with a good approximation as a minimum ionizing particle (MIP), that is, as a particle that is in the minimum of the $\frac{dE}{dx}$ distribution of the Bethe-Bloch formula. A typical MIP energy loss is 1.5 MeV/(g cm^{-2}).

   - Compute the thickness of a lead layer needed to stop a 1 GeV muon (typical cosmic ray energy) assuming that the muon behaves like a MIP over all its path [**2 points**].
   - Given your knowledge of the Bethe-Bloch formula, do you think that the estimate just done is an overestimation or an underestimation of the actual thickness of lead needed? Why? [HINT: as the muon slowes down, it's energy loss per unit length.....] [**2 points**]

2. **Particles in a Uniform Magnetic field**

   The inner detector of a high energy physics experiment at a collider has a cylindrical layout around the beam line and it has a radius of 1 m. It is immersed in a uniform magnetic field of 2 T parallel to the beam axis. The inner detector is embedded in a cylindrical calorimeter (also with the beam line as axis)

   - Compute the minimum transverse momentum that a charged particle must have to reach the calorimeter. [**2 points**]
   - Estimate the energy loss in the inner detector for a charged track with charge 1, assuming the particle always behave as a MIP and that the inner detector has a uniform density equal to 1/10 of that of the water. Will the particle reach the calorimeter or stop before? [**2 points**]

   Let's say that the inner detector is a silicon detector measuring 10 tracking points.

   - With reasonable assumptions on the spatial resolution on the single track hit, estimate the resolution of the inner detector for transverse momentum (p_T) measurement. Does it increase or decrease with p_T? [**2 points**]
   - The calorimeter resolution decreases with the particle energy (see exercise 1). For a pion (rather than a photon), the first coefficient on the right side of the formula is more like 80% and the second is something like 5%. Would you use the inner detector or the calorimeter to measure a 3 GeV pion? And a 300 GeV pion? [**3 points**]

3. **Relativistic kinematics (bonus exercise)**

   A hypothetic scalar neutral particle of mass $M_H = 120$ GeV can decay into two photons.

   - Write down the angular distribution of the decay $\frac{dN}{d\Omega^*}$ in the reference frame of the particle center of mass. [**1 point**]
   - Write down the same angular distribution in the lab reference frame, in which the particle is moving with a momentum $p = 40$ GeV [**1 point**]
   - What is the minimum angle between the two photons in the lab frame? What is their energy? [**2 points**]

The two photons are measured with an electromagnetic calorimeter that has a resolution

$$\frac{\sigma(E)}{E} = \frac{10\%}{\sqrt{E\ (\text{GeV})}} + 0.3\% \tag{1}$$

and that can measure the angle θ between the two photon with a precision

$$\frac{\sigma(\theta)}{\theta} = 1\% \tag{2}$$

- Assuming that the angle between the two photons is always minimum (see above), what is the resolution on the measurement of the particle invariant mass? **[2 points]**