Name: **Group:**

Problem sheet 5 - Physics V - WS 2006/2007

Due: November 23/24, 2006

Problem 5.1 Synchrotron Radiation (30P)

The maximum energy which can be reached in a circular accelerator is limited by the emission of synchrotron radiation. In order to go beyond LEP energies it was no longer possible to use electrons as beam particles. Let us consider LHC, a ring-shaped accelerator of 27 km circumference at CERN. The LHC dipoles have a bending radius of 2.8 km. Protons can be accelerated up to a total energy of 7 TeV. In order to compensate for the energy loss due to the emission of synchrotron radiation, the protons have to be re-accelerated constantly.

(a) How much energy (absolute in keV and relative in % of the initial energy) do the protons lose (without re-acceleration) in one turn?

(b) Assume that 6.5×10^{14} protons are stored in the two rings and that the re-acceleration works 100% efficient. What power is necessary to keep the protons at constant energy?

(c) How large would the bending radius of a 7 TeV electron collider have to be, assuming that their energy loss should not exceed the one calculated under (a)?

Problem 5.2 Particle Identification with a RICH Detector (25P)

The investigation of b-quark decays in the LHCb experiment at LHC requires the identification of charged pions and kaons. For this purpose, a Ring Imaging Cherenkov Counter (RICH) will be built. The RICH measures the angle θ_c of the Cherenkov light produced in CF_4 and Aerogel radiators. The refraction indices are $n(CF_4) = 1.0005$ and $n(\text{Aerogel}) = 1.03$.

(a) Calculate the threshold energies of pions and kaons for Cherenkov light in these materials.

(b) Calculate the Cherenkov angles for pions and kaons at $p = 4$ GeV/c and at $p = 20$ GeV/c for the two radiators.

Problem 5.3 Particle Identification using TOF detectors (25P)

The mass (and therefore the identity) of a particle can be determined using the relation $\vec{p} = m\gamma\vec{\beta}$. This requires the simultaneous measurement of the velocity v and the momentum $\vec{p}$ of the particle using tracking and time-of-flight detectors. In the FOPI experiment at SIS/GSI this is done with a drift chamber surrounded by resistive plate counters (TOF-RPCs) at a distance of 90 cm.

(a) Which time resolution is needed to allow the separation of pions and kaons up to a momentum of 1 GeV/c by three standard deviations, i.e. a time resolution fulfilling the relation

$$\sigma_t < \left| \frac{1}{3} \Delta\ t_{\pi,K} \right|$$

where $\Delta\ t_{\pi,K}$ is the difference of the time-of-flight of pion and kaon.

(b) Plot $\Delta\ t$ as a function of the particle momentum in a momentum range from 100 MeV/c to 4 GeV/c for muons and pions, pions and kaons, kaons and protons, and protons and deuterons for a flight path of 90 cm.

Problem 5.4 Energy Loss of a Muon (20P)

Estimate the energy loss of a 2 GeV muon when passing through either 2 cm of lead or 2 cm of plastic scintillator.