Exercises Physics VI (Nuclei and Particles)

Summer Semester 2009

Exercise sheet Nr. 1

Work out until 30.04.2009

Website for exercises:
http://www-ekp.physik.uni-karlsruhe.de/˜kreps/teaching/Physik6_SS2009/

Exercise 1: Relativistic Kinematics, Accelerators (Points: 3)

a) A linear accelerator for protons operates at constant frequency of $\nu = 200$ MHz. How long the accelerating tubes have to be at places where protons have a kinetic energy of 1 MeV, 100 MeV and 10 GeV?

b) The HV generator frequency and magnetic field in the Synchrotron has to match to the energy of the relativistic particle which is accelerated to keep the particle on the orbit with constant radius R. How do the frequency and magnetic field depend on energy for a particle with mass m and charge e?

c) Calculate centre of mass energy for collisions at following accelerators:

Accelerator	Particles	Energies
LEP 2	e^+e^-	$E_{e^+} = E_{e^-} = 103$ GeV
PEP-II	e^+e^-	$E_{e^+} = 3.1$ GeV, $E_{e^-} = 9$ GeV
HERA	ep	$E_e = 27.5$ GeV, $E_p = 920$ GeV
	ep	$E_e = 27.5$ GeV, p in rest
Tevatron	$p\bar{p}$	$E_p = E_{\bar{p}} = 980$ GeV
LHC	pp	$E_p = 7$ TeV
	${}^{208}_{82}\mathrm{Pb}\ {}^{208}_{82}\mathrm{Pb}$ (Nuclei)	$E = 2.76$ TeV per Nucleon

What approximations can be made in calculations for those energies?

How large has the energy of the Pb to be at a fixed target (Pb in rest) experiment to achieve the same centre of mass energy as for PbPb collisions at LHC?

Exercise 2: Synchrotron radiation (Points: 2)

The energy loss of the relativistic particle with mass m and charge q is:

$$\frac{dE}{dt} = \frac{2}{3}\frac{q^2}{c}\gamma^6\left[\left(\frac{d\vec{\beta}}{dt}\right)^2 - \left(\vec{\beta}\times\frac{d\vec{\beta}}{dt}\right)^2\right].$$

Illustrate how to obtain the formula

$$\Delta E[\text{MeV}] = 6.02 \cdot 10^{-15} \frac{\beta^3}{R[\text{m}]} \cdot \left(\frac{E}{mc^2}\right)^4$$

for energy loss for a particle with charge $q = e$ in an accelerator with radius R, which is radiated during one revolution in the accelerator. Help: $e^2/\hbar c = \alpha = 1/137$, $\hbar c = 197$ MeV fm

Calculate ΔE for a proton with $E = 1$ TeV in an accelerator with radius of 1 km. How large has to be the radius of an electron accelerator with the same energy in order to radiate the same amount of energy per revolution as protons.

Exercise 3: Cerenkov detectors (Points: 2)

a) A RICH-detector has a 1 cm thick radiator filled by liquid Freon with index of refraction $n = 1.22$. The distance between the radiator and photodetector is 9.5 cm.

   How large is the threshold momentum for Pions and Kaons for generation of Cerenkov light? Calculate the radius of the radiation ring from the middle of the radiator as a function of momentum of the pions and kaons and plot those functions from the pion threshold momentum to 2 GeV/c^2.

b) A Cerenkov counter filled by CO_2 is setup for detection of π-mesons. One thing to pay attention is that susceptibility $\chi = \epsilon - 1$ is proportional to the pressure of the filling gas. At normal pressure the refraction index is $n = 1.00041$.

   What pressure is required to detect pions with energies above 5 GeV? From which energy will such Cerenkov counter detected kaons at this pressure?

Exercise 4: Detector concept (Points: 1)

Describe principal concept of the detector used for analysis of high energy particle collisions (for instance ones at the accelerators from the exercise 1).

Which components are needed and from what reasons? How different components are ordered? What effect has the ratio of energies of accelerated particles for geometry of the detector?

In this exercise you can use existing detectors for inspiration.

Exercise 5: Relativistic kinematics (Points: 1 Bonus)

Calculate velocity of the protons in Tevatron and LHC, current and future accelerators with highest energy. Express results as difference from speed of light and use units natural to human beings.