Homework 3 (due Mon Mar.13, 2006)  
Prof. Andrei Gritsan, March 2006

This homework assignment covers selected topics in Chapter 11 (Detectors) and Chapter 3 (Symmetries).

Problem 1

Among the following position detector technologies: (1) emulsion, (2) bubble chamber, (3) streamer chamber, (4) drift chamber, (5) silicon detector, argue briefly which satisfy the following (more than one entry is possible, when in doubt do not hesitate to explain your doubts):

(a). has the best space accuracy;
(b). has the best time resolution;
(c). provides good ionization dE/dx measurements;
(d). can be triggered on an interesting event;
(e). requires pictures to be developed for off-line analysis.

Problem 2

For a crystal calorimeter discussed below, determine resolution of the photon energy ($\sigma_E/E$). Assume the following properties of the scintillator: 10% efficiency for the conversion of the energy into light quanta, the visible light wavelength of 400nm (violet) for the light quanta. The efficiency to collect light on the photocathode is 10% and the cathode has the probability of ejecting an electron of 15%. The photons originate from the $^{137}$Cs radioactive source. Draw the distribution (qualitatively) of the energy measured for a large number of photons from this radioactive source and indicate $\sigma_E$ and the mean $E$ (again qualitatively). Draw dependence of the photon energy resolution ($\sigma_E/E$) on the photon energy ($E$), assuming perfect detector.

Problem 3

For the detector discussed below, determine which particle identification technology provides the best separation between the charged pions and kaons with the momentum of 1 GeV/c. Assume that particles originate in the origin at precisely known time and travel at 90° with respect to the beam axis. The detector includes the following components covering the origin and has cylindrical geometry around the beam axis.

(a). Ionization loss dE/dx in the drift chamber with the outer radius of 1 m. The precision of ionization loss dE/dx measurement is about 6%.
(b). Time-of-flight counters at the radius of 1 m. The time resolution of the counters is 150ps.
(c). Cherenkov detectors next to the time-of-flight counters. The index of refraction of the material is n=1.33 and the angular resolution of the ring-imaging device is 10 mrad.

The momentum of the particles is measured in the magnetic field in the drift chamber. Calculate the separation in units of Gaussian $\sigma$ at least in two of the above cases.

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Problem 4 How do the following quantities (constructed from the position $\vec{r}$, momentum $\vec{p}$, and spin $\vec{\sigma}$) transform under P (parity conjugation) and under T (time reversal)? Identify pseudoscalar, scalar, pseudovector (axial vector), and vector quantities.

(a) $(\vec{r}_1 \times \vec{p}_1) \cdot (\vec{r}_2 \times \vec{p}_2)$
(b) $\vec{\sigma} \times \vec{p}$
(c) $\vec{\sigma} \cdot \vec{r}$
(d) $\vec{r} \times \vec{p}$
(e) $\vec{\sigma} \cdot (\vec{r} \times \vec{p})$

Problem 5 How do the following states transform under C (charge conjugation). Identify eigenstates of the operator C and their eigenvalues.

(a) $|\eta'\rangle$
(b) $|\gamma\rangle$
(c) $|K^+\rangle$
(d) $|K^+\rangle - |K^-\rangle$
(e) $|\Lambda\rangle$

Problem 6 Which of the following decays proceeding through strong or electromagnetic interactions are allowed or forbidden by either P (parity) or C (charge conjugation) symmetry? Identify which symmetry is violated when decay is forbidden.

(a) $\rho^0 \to \pi^0 \pi^0 \pi^0$
(b) $\eta \to \pi^+ \pi^-$
(c) $\omega \to \pi^+ \pi^-$
(d) $\omega \to \eta \pi^0$
(b) $\eta' \to \gamma \gamma \gamma$