Klausur Experimentalphysik V
Wintersemester 2012/13
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Klausur

This sheet is not going to be corrected and evaluated. It is just to evaluate how prepared one is for the Klausur. The tutors will discuss these exercises in the week of February 13^{th} - 20^{th}. The actual Klausur is going to be very similar to this test.

General questions (1 point per question)

1. What quantity would you measure to estimate the lifetime of the following particles:
   (a) ^{238}U (lifetime $\tau = 4.5 \times 10^9$ years)
   (b) Λ^0 (lifetime $\tau = 2.5 \times 10^{-10}$ s)
   (c) ρ^0 (lifetime $\tau = 10^{-22}$ s)

2. To penetrate the Coulomb barrier of a light nucleus, a proton must have a minimum energy of the order of:
   (a) 1 GeV
   (b) 1 MeV
   (c) 1 keV

   Motivate your answer

3. A nucleus of mass M is initially in an excited state whose energy is ΔE above that of the ground state. The nucleus then decays to the ground state emitting a photon with energy $h\nu$. Explain why $h\nu \neq \Delta E$ and estimate $\frac{h\nu - \Delta E}{\Delta E}$ if $\Delta E \ll Mc^2$.

4. In the β decay, the spectrum of the electron shows evidence that it is a three-body decay. Why? Sketch the spectrum

5. In the nuclear shell model, orbitals are filled in the order:

$$1s_{1/2}, 1p_{3/2}, 1p_{1/2}, 1d_{5/2} \tag{1}$$

^{16}O is a good closed shell nucleus and has a spin parity of $J^p = 0^+$. What are the predicted J^p values for ^{15}O and ^{17}O?

6. List what of the following quantities are conserved respectively by strong, weak and electromagnetic interaction:

    (a) electric charge
    (b) baryon number
    (c) quark flavour
    (d) angular momentum
    (e) parity

7. What is the lifetime of the muon? $10^9, 10^2, 10^{-2}, 10^{-6}$ s? What type of interaction is responsible for the decay?

8. Give a decay mode with BR $> 5\%$ for each of the following particles: $n, \pi^+, K^0, \mu^-, J/\Psi$.

9. An experiment is colliding protons and antiprotons at $\sqrt{s} = 100$ GeV. However, no production of Z bosons (mass of about 90 GeV) is observed. Why?

Exercises

1. **Übung 1 (3 points)**

   In a neutron-activation experiment, a flux of 10^8 neutrons/cm$^2 \cdot$ s is incident normally on a foil of area 1 cm^2, density 10^{22} atoms/cm^2, and thickness 10^{-2} cm. The target nuclei have a cross section for neutron capture of 1 barn, and the capture leads uniquely to a nuclear state which β-decays with a lifetime of 10^4 s. At the end of 100 s neutron irradiation, at what rate will the foil be emitting β-rays?

2. **Übung 2 (3 points)** Proton from an accelerator collide with a stationary proton target. What is the threshold energy for antiproton production?

3. **Übung 3 (3 points)** For each of the following reactions, indicate if it is allowed or forbidden. If allowed, say which is the interaction (strong, weak, electromagnetic) responsible for it and draw the Feynman diagram. If forbidden, say why.

   (a) $\pi^- + p \to \pi^0 + n$

   (b) $\pi^0 \to \gamma\gamma$

   (c) $\pi^+ \to \mu^+ \bar{\nu}_\mu$

   (d) $p + \bar{p} \to \Lambda^0 \Lambda^0$

   (e) $p + \bar{p} \to \gamma$

4. **Übung 4 (5 points)**

(a) Through which reaction can a pure K^0 beam be prepared?

(b) A pure neutral kaon beam is prepared. At time $t = 0$, what is the value of the charge asymmetry factor δ giving the number of $e^+\pi^-\nu$ decays relative to the number of $e^-\pi^+\bar{\nu}$ as

$$\delta = \frac{N(e^+\pi^-\nu) - N(e^-\pi^+\bar{nu})}{N(e^+\pi^-\nu) - N(e^-\pi^+\bar{nu})} \tag{2}$$

(c) In the approximation that CP is conserved, calculate the behaviour of the charge asymmetry factor δ as a function of proper time. Explain how the observation of the time dependence of δ can be used to extract the mass difference Δm between the short-lived neutral kaon K_S^0 and the long-lived K_L^0