TÉCNICO LISBOA

1° test

November 24^{th} 2015: 10h00

Duration of the test: 1h30

Mestrado em Eng. Física Tecnológica (MEFT)
Particle Physics
1° semester of 2015-16

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- The allowed elements for consult during the test are:
  - the PDG (Particle Data Book)
  - one single A4 page with formulas.
- Clearly identify all pages of the test.
- The test has 2 questions (2 pages).

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1. **[10 val]** In 1951 the group lead by Enrico Fermi in Chicago measured charged pion-nucleon cross sections using pion beams originated in the interaction of primary protons in a fixed target, $p\ A \to \pi^+ X$, where A is the nucleus in the target and X the remaining sub-products of the interaction.

a) Compute the mean distance travelled by a beam of π^+ with a momentum of 145 MeV.

b) Discuss a procedure to select the π^+ emitted forward with a momentum of 145 MeV in order to create a pure π^+ beam. Give some quantitative estimation of the main parameters of the proposed selection set-up.

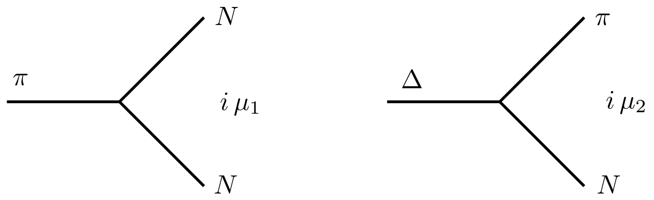
c) Consider that the 145 MeV π^+ beam crossed a target container, filled with liquid hydrogen, and that a set of scintillators were placed before and after the container. Whenever the container is full the projected number of the hydrogen protons in the surface of the target was $8.5 \times 10^{23}\,\text{cm}^{-2}$.

   i. Compute the $\pi^+\ p$ cross-section at this energy knowing that the ratio between the number of beam particles registered in the scintillators placed after the target container with the container respectively empty and full was 1.116. The error in this ratio was around 0.2%.

   ii. Make an estimation of the mean energy loss and of the angular dispersion suffered by the π^+ beam when crossing the liquid hydrogen target.

d) A fraction of the π^+ decay along the beam line into $\pi^+ \to \mu^+ \nu_\mu$. Compute the maximum angle that the μ^+ can have with the beam line. Draw the energy spectrum distribution of the μ^+, measured in the Laboratory framework, indicating its minimum and maximum energy.

2. [10 val] In the beginning of the studies of NN and πN scattering (N=nucleon=neutron or proton), a very simple model was used where the spin of the particles was neglected. The model had the interactions,



where the constants μ_1 e μ_2 have dimension of a mass in our natural system of units ($\hbar = c = 1$). The charges of the particles are such that the charge is conserved at each vertex.

a) Consider the elastic scattering $\pi^- + p \to \pi^- + p$. Draw the Feynman Diagram(s) for the process.

b) Consider now the process $n(p_1) + p\,(p_2) \to p\,(p_3) + \Delta^0(p_4)$ in the Lab frame where the proton is at rest. What is the minimum energy of the neutron beam for the process to take place.

c) For process b) draw the Feynman diagram(s) and obtain the correspondent amplitude.

d) For process b) evaluate the differential cross section $d\sigma/d\Omega$ in the CM frame as a function of the masses of the particles and the Mandelstam variables, $s = (p_1 + p_2)^2$, $t = (p_1 - p_3)^2$ and $u = (p_1 - p_4)^2$.

e) In the limit that $\sqrt{s} \gg m_\pi, m_N, m_\Delta$ neglect the masses and evaluate the total cross section, σ_T, in the CM frame. Neglect the contribution of the *t-channel* to perform the σ_T calculation. Show that it has the correct dimensions for a cross section.