Name: **Group:**

Problem Sheet No 3 – Physik V – WS 2006/07

Due: (Thu 9th / Fri 10th) of November 2006 in the "Gruppenunterricht"

Problem 3.1 **(30 Points)** Solar Neutrinos

A historical experiment in a gold mine in South Dakota has been carried out to detect solar neutrinos via the reaction

$$\nu \, + \, ^{37}Cl \, \rightarrow \, ^{37}Ar \, + \, e^{-}.$$

The detector contained $4 \cdot 10^5$ liters of C_2Cl_4 ("tetra-chlorethylene") with a density of 1.5 g cm^{-3}. Estimate how many atoms of ^{37}Ar would be produced per day, making the following assumptions:

a) The solar energy flux is $8.8 \cdot 10^{11}$ MeV s^{-1} cm^{-2}. b) 10 % of the sun's thermonuclear energy appears in neutrinos of mean energy 1 MeV. c) 1 % of all neutrinos are energetic enough to induce the above reaction. d) The cross section per ^{37}Cl nucleus for "active" neutrinos is 10^{-45} cm^2. e) The isotopic abundance of ^{37}Cl is 25 %.

Problem 3.2 **(20 Points)** "3 - Kelvin" Photons

A lonesome photon of the "3 K(elvin) background radiation", a relic of the so called "Big Bang", travels through space. Its energy is $25 \cdot 10^{-5}$ eV. After some million years, it meets another lonesome particle, a cosmic proton. They collide "head on" (i.e. under an angle of $180°$) and produce one more particle, a neutral pion (π^0).

What is the minimal energy the proton needs in order to generate the pion? (The reaction is $\gamma \, + \, p \, \rightarrow \, p \, + \, \pi^0$; assume $E_p \, = \, p_p$)

Problem 3.3 **(25 Points)** Annihilation Cross Section

The (angular) differential cross section for the annihilation reaction $e^+ \, + \, e^- \, \rightarrow \, \mu^+ \, + \, \mu^-$ is, in natural units,

$$\frac{d\,\sigma}{d\,\Omega} = \frac{\alpha^2}{4\,s}(1 \, + \, cos^2\theta).$$

Assume that the reaction takes place in a storage ring where electrons with an energy of 5.5 GeV collide "head on" with positrons of the same energy (neglect the particles' rest masses). In the above formula, s denotes the squared centre-of-mass energy E_{CM}^2, and θ is the polar angle of the μ^- w.r.t. the incoming electron.

a) Calculate the total cross section for the annihilation reaction by integrating over the full solid angle.

b) What is the corresponding cross section expressed in cm^2 or barns? (1b = 100 fm^2)

c) In this annihilation reaction, an intermediate "virtual" photon is created. Write down its four - momentum components and estimate its lifetime.

Problem 3.4 **(25 Points)** Mass Reconstruction

The figure attached shows the reaction

$$\pi^- + p \rightarrow \Lambda + V^0$$

where “V^0” means an “invisible” and (yet) unidentified neutral particle which decays into two charged particles.

The charged daughter particles are identified as a π^+ with a momentum of 400 MeV, and a π^- with a momentum of 1027 MeV. The opening angle between the pions is measured as $40.3°$.

Calculate the rest mass of the mother particle. Which particle has most likely decayed, given a measurement uncertainty on the mass determination of roughly 10 % ?

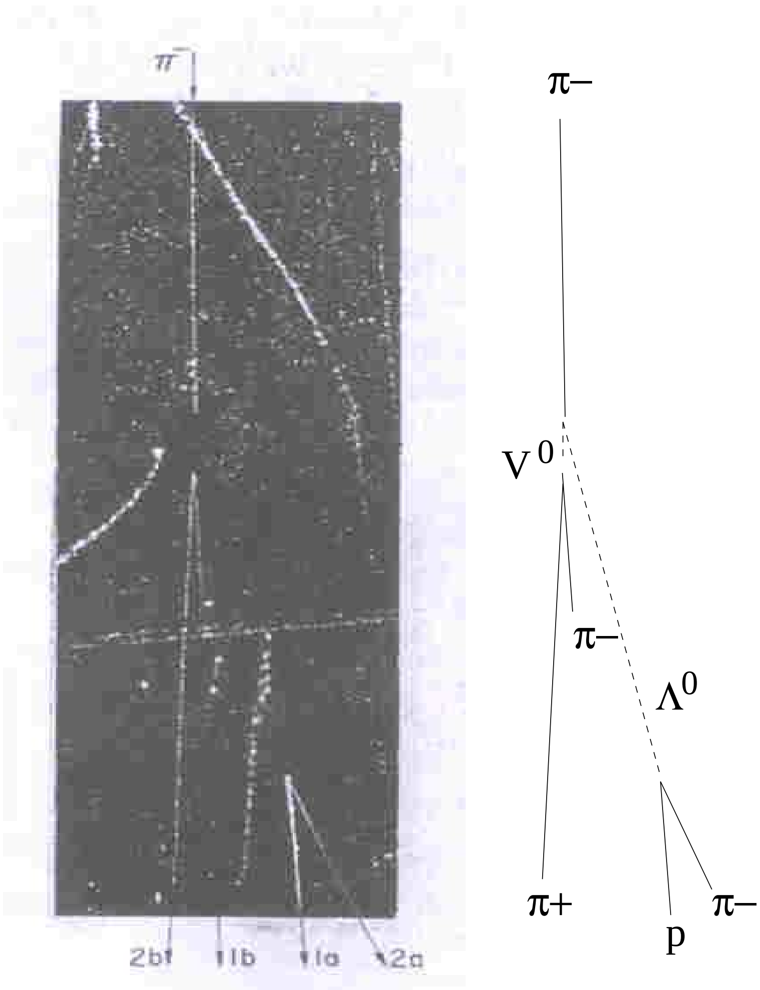

Abbildung 1: V-zero decays