Homework 2 *Due on Wednesday Sept 17, 3:00 pm*

13 + 2 (bonus) = 15 points

Problem 1 (2+2=4 points)

Find how thick a target of liquid Hydrogen should be to give 50-50 chances for scattering

- 10 GeV protons (energy typical for cosmic rays)—2 points
- 10 MeV neutrinos (~ the highest energy solar neutrino)—2 points (express the answer in light years)

The total cross-section of the proton-proton scattering is about σ_{pp}~40 mb in a very wide range of energies. The total cross-section of neutrino-proton interaction is about $\sigma_{\nu p}$~$10^{-38}E_\nu$ (where σ is in cm^2 and E_ν is neutrino's energy in GeV units and in lab frame).

Problem 2 (1 point)

Typical lifetime of excited states of proton and neutron is 10^{-23} s. What is their width in MeV? (1 point)

Problem 3 (2 points)

What were the two main problems with the Klein-Gordon relativistic equations for Ψ-function? (1 point)
Did the Dirac equation resolve them? (1 point)

Problem 4 (6 points)

If protons were positive point-like charges, the matrix element and cross section for elastic scattering of electrons on protons would be (see Lecture 7):

$$M_0(q) = \frac{e^2}{q^2} \qquad \text{and} \qquad \frac{ds_0}{d\Omega} = \frac{1}{4p^2}\frac{e^4}{q^4}\frac{p^2}{v^2}$$

Find how these expressions should be modified (3 points) to account for spatial distribution of charge in proton in the form

$$r = Ae^{-r/r_0}\ .$$

The normalization constant A is such that the proton charge integrated over volume remains e. Find this constant—2 points.

Looking at the modifying factors, argue how large electron energy must be to allow one seeing the proton structure if r_0~1 fm (1 point).

Bonus Problem (2 points)

How did Anderson know that the track he detected in his Cloud Chamber was a positively charged particle and why it could not be a proton?