Homework 4 *Due on Wednesday October 29, 3:00 pm*

19 + 6 (bonus) = 25 points

Problem 1 (2 point)

What particle detection technique has the best spatial resolution? (1 point)
Why is it hardly ever used nowadays? (1 point)

Problem 2 (2 points)

The flux of cosmic ray muons at the Earth surface is about 10^{-2} $cm^{-2}s^{-1}$ and their typical energy is a few GeV. Estimate the power (in Watts) that these muons transfer to your body via their ionization energy losses. Make reasonable assumptions as needed.

Problem 3 (2 points)

Up to what particle momentum can one distinguish between charged kaons and pions using two scintillator counters with a distance between counters 3 m and the time resolution for each of the two counters σ=100 ps?

Problem 4 (3 points)

You searched for magnetic monopoles in cosmic rays. Assume that the detector had 1 m^2 cross section area and that the experiment continued for 1 year (no dead time). If you did not detect any monopole-like events, what is the limit on the flux that you could claim at 95% CL.

Problem 5 (2+2=4 points)

You searched for free quarks in collisions at Tevatron I. Assume that the amount of data taken corresponded to an integrated luminosity 100 pb^{-1}. If you expected about 1 background track that might pass your selection cuts for that amount of data and you actually observed 3 such tracks, what would your judgment be on whether you discovered free quarks? (2 points).

How would you quantify the results of your search in a scientific paper? (2 points)

Problem 6 (3+3=6 points)

An experiment searching for proton decay in the mode $p \rightarrow \pi^0 + e^+$ is carried out using a cubical tank of water as the proton source. The signal is to be detected via the Cherenkov light emitted when the electromagnetic showers from the decay products transverse water.

A) Estimate the total number of Cherenkov light photons emitted in the visible region of wavelength (3 points). Hint: first, calculate the total track length integral in an electromagnetic shower.

B) If the light is detected by an array of photomultipliers at the water tank surfaces, what fraction of the surface must be covered by photocathode to give an energy resolution of 5%. Assume 20% photocathode efficiency and about 50% light losses due to the imperfect optical transmission of water. (3 points)

Problem 7 (6 bonus points)

Consider a search for the Z^0 boson at the proton-antiproton collider at CERN in the early 1980s. Assume that you are a member of an Experiment that has a central TRACKER that provides 70 measurements of about 200 μm accuracy each, with all measurements being uniformly distributed over the radius R=1 m of a superconducting solenoid with magnetic field of 1 T. The energy resolution of the electromagnetic calorimeter ECAL is 25% $/\sqrt{E(GeV)}$. The Z^0 boson mass was expected to be around 90 GeV and it would be born practically at rest.

A) Describe your strategy for discovering the Z-boson via its Z^0 ® $e^+ e^-$ decay mode. How would you identify electrons/positrons? How would you reconstruct Z-boson mass? Which backgrounds would you be concerned with the most (2 points).

B) Which of the two detectors described above (TRACKER or ECAL) would give you the best resolution for the Z-boson mass reconstruction? (2 points)

C) What would the statistical error on the Z-resonance mass δM be after collecting the first 100 events? Express the answer in GeV. (2 point)