Exercises: Particle Detectors WS 2016/17
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Problem Set No. 7

Solutions have to be handed in by Wednesday 3pm, 7.12.2016 in letter box no. 3, in the ground floor of Gustav-Mie building!

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1. **Precision of tracking detectors**
   Scintillators, gaseous and silicon detectors can be used to measure the energy lost by a particle. The key parameter is the energy required to create a photon (or e/ion pair, or e/hole pair). Consider:

   - a scintillator, where one photon is emitted every 100 eV of deposited energy. Only 10% of the photons reach the photomultiplier, which has 25% quantum efficiency.
   - a silicon detector, where 3.6 eV are required to create one e/hole pair.
   - a gaseous detector, with one e/ion pair created every 26 eV of deposited energy.

   What are the relative precisions with which energy losses of 100 keV and 20 MeV can be measured in the three detectors? **[6 points]**

2. **Photomultipliers**
   Photomultipliers are used for collection of signals. Typical models have 14 dynodes and are operated at a total operation voltage of 2000 V. A typical amplification factor is 4. Calculate the signal height in Volts for one, three and five input electrons.
   The time of travel is assumed as 5 ns and the resistance is 50 Ω. Calculate the differences in arrival of the electrons. **[2 points]**

3. **Scintillator and Photomultiplier Efficiencies**
   The quantum efficiency of a photomultiplier tube is 18%.

   - For eight photons hitting the photocathode, what is the probability of emitting a) no electrons, b) at least one electron and c) exactly one electron
   - The photomultiplier is used to detect light from an organic scintillator with a density of 1.15 g cm^{-3} and 4x10^3 photons being emitted per MeV of particle energy loss. The probability of scintillation photons reaching the photomultiplier is only 5%, due to losses in the scintillator and light guide. How thick a scintillator slab is required to detect minimum ionizing particles with an efficiency of at least 99%?

   [4 points]