Exercise 1

Short questions to help learning and reviewing lectures

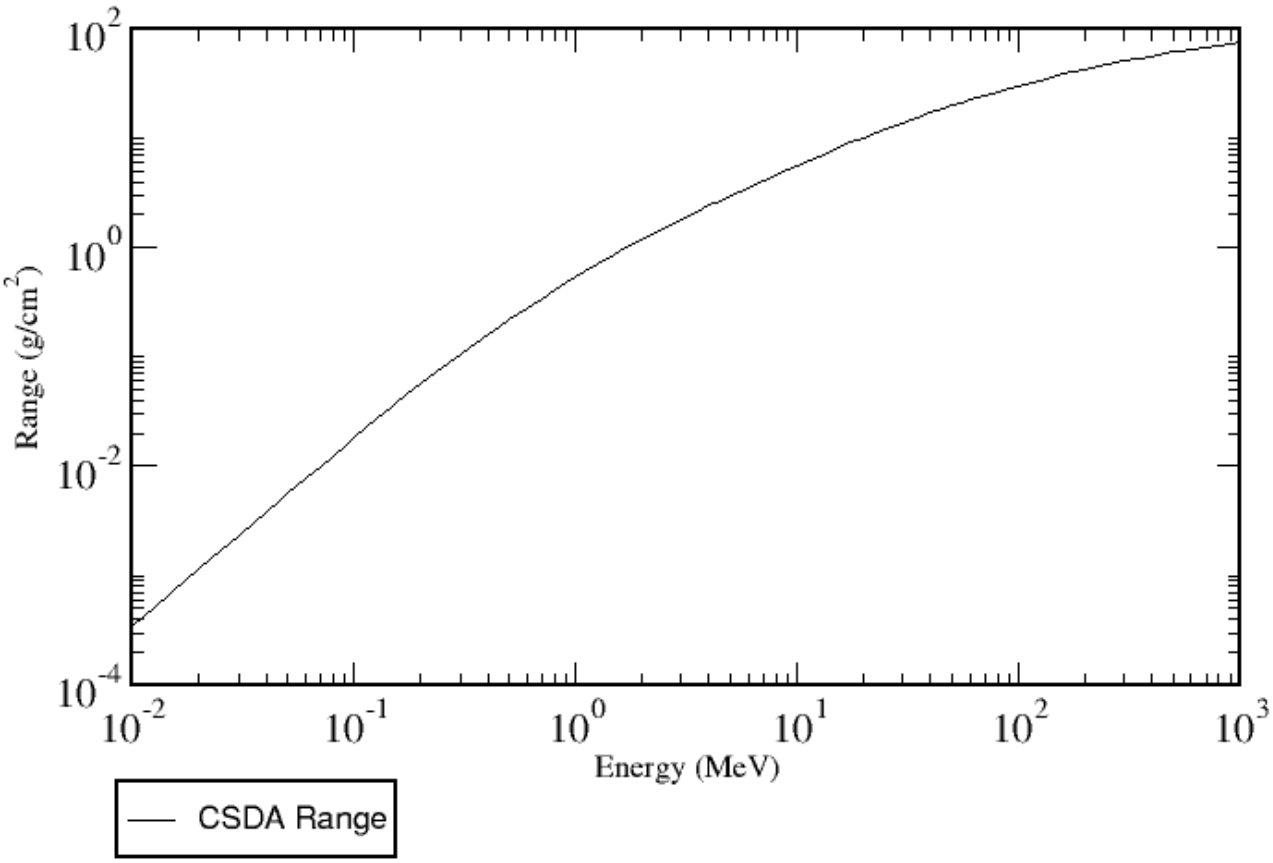
1) What is the typical energy deposit needed to create an electron-ion pair in most gases ?
2) Is a Geigen-Müller counter a proportional detector ?
3) Is a pure noble gas a good choice as detection medium in proportional gaseous detectors ? If not , in which type of gaseous chambers could it be used ?
4) List the most common types of gaseous detectors.
5) What are the typical space resolution and time response of a multi-wire proportional chamber (MWPC) ?
6) Can a MWPC read two perpendicular coordinates ?
7) Explain with the help of a drawing how a drift chamber works.
8) Same question for a time projection chamber (TPC).
9) What reduces the radial electron diffusion in a gaseous TPC ?
10) Can a TPC be operated with a liquid detection medium ?
11) What is the main usage of resistive-plate chambers (RPC) ?
12) Do RPCs detect both x and y ?
13) Using a drawing, explain how a micro-strip gaseous chamber (MSGC) works.
14) What is the main advantage of micro-pattern gaseous chambers (MPGC) ?
15) Using a drawing, explain how a gas electron multiplier (GEM) chamber works.
16) Same question for a micro-mesh gaseous structure (micromegas) chamber.
17) What are the signal carriers in semiconductor detectors ?
18) Why is germanium difficult to use as detection medium at room temperature ?
19) Explain how a np junction can be used for detection purpose ?
20) What should be the polarity of the bias voltage with respect to the n and p sides ?
21) Produce a simple drawing of a DC- and an AC-coupled strip silicon detector
22) Produce a cross-section of an AC-coupled strip silicon detector that shows the read-out and the biasing circuits.
23) What is the Fano factor ?
24) What is the role of the guard rings ?
25) What is the impact of radiation on the signal/noise ratio ?
26) What are the pros and cons of double-sided strip detectors ?
27) What is the alternative to double-sided strip detectors ?
28) How can the space resolution of a strip detector be made lower than the strip pitch value ?
29) What are the pros and cons of pixel silicon detectors ?
30) How can the pixel-to-read-out connection be made on a pixel detector ?
31) When was the first silicon detector built ?
32) What is the typical space resolution of a strip and pixel detector ?
33) What are the pros and cons of CMOS pixel detectors ?
34) What is a 3D silicon detector ?
35) What are the typical time constants of fluorescence and phosphorescence ?
36) What are the main components of a scintillation detector ?
37) What are the pros and cons of organic and inorganic scintillators ?
38) What is the role of the wave shifter in an organic scintillator ?
39) Write Birk's law and explain its meaning.
40) The light yield of BC-412 is 60% of that of anthracene. What does it mean ?
41) What is the typical decay time of common plastic organic scintillators ?
42) Briefly explain how an inorganic crystal scintillator works.
43) The light yield of BGO is 10% of that of NAI(Tl). What does this mean ?
44) What is the typical decay time of common crystal scintillators ?

45) What is the role of a light guide ? Show a typical example.
46) What type of crystal is used by CMS in their electromagnetic calorimeter ?
47) What could be the usage of optical and scintillating fibers ?
48) Draw a simple scheme of a photomultiplier.
49) What is the typical gain of a photomultiplier and what does this mean ?
50) How does a SiPM work ?
51) What are the pros and cons of SiPMs ?
52) Explain what a RICH detector is ?
53) Explain briefly how ATLAS TRT works.
54) What are the Nobel liquids that were used as detector medium till now ?
55) How does a Kinetic Inductance Detector work ?
56) What is a bolometer ?
57) Explain briefly how gravitational waves are detected.

Exercise 2

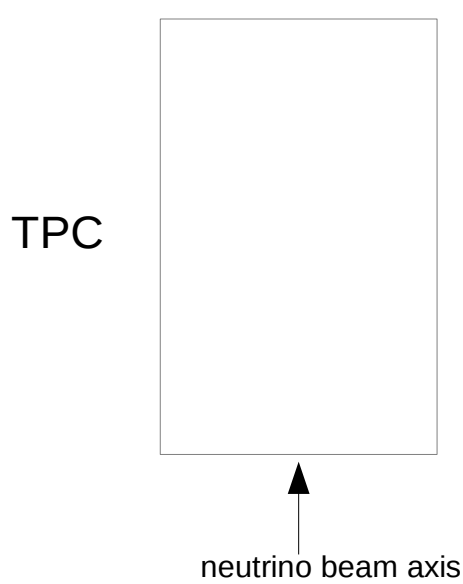
A 300 μm-thick silicon detector is perpendicularly traversed by 30 GeV electrons. The induced charge signal is read by a charge preamplifier that is affected by an electronic noise of 750 electrons (standard deviation). For silicon, A(g) = 28 g , Z = 14 , ρ= 2.33 g cm^{-3} , I = 173 eV, X_0 = 21.8 g cm^{-2}

1) Show that the radiation loss does not contribute significantly to the signal.
2) Compute the maximal kinetic energy that can be transferred to an electron.
3) Is this maximal transfer possible ?
4) Find an estimate of the maximal electron energy that can be deposited in this detector. (see graph below)
5) What is the right stopping power formula to be used then ?
6) Compute the average energy deposited in this detector.
7) Compute the most probable signal.
8) Compute the S/N ratio
9) Conclusion



Exercise 3

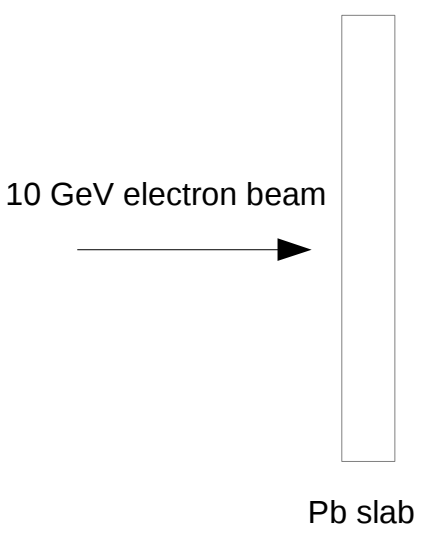
A huge liquid argon (LAr) TPC is being designed to detect and identify electrons and muons resulting from the interaction of a neutrino beam in liquid argon. For the sake of simplification, we will consider here that the kinetic energy of both the electrons and the muons is 10 GeV. The properties of LAr are ρ=1.4 g cm^{-3}, Z=18, A(g)=39.9 g, I=188 eV and a radiation length X_0 = 14 cm.



1) Draw on one side of the TPC the typical track of a 10 GeV muon, and on the other side the typical signal pattern of a 10 GeV electron.
2) Compute the stopping power (dE/dx) of a 10 GeV muon in liquid argon ? Density and low-energy corrections will be neglected .
3) Use this value to roughly estimate the range of a 10 GeV muon that would stop in the TPC. We will consider that muons and electrons are mainly emitted along the neutrino beam axis.
4) Estimate the rough depth in centimeters of an electron shower in the TPC ?
5) What would then be the minimal depth of the TPC ?
6) How could the drift electric field be oriented with respect to the beam axis ?
7) How would you position the electric field wires : anodes and cathodes ? Draw the wire planes on the drawing.
8) What would be the adequate electronic readout mode knowing that the detection rate will be low ?
9) Which physical signal can be used to trigger the detector, and how can it be technically detected ?

Exercise 4

A thin slab of lead is used to radiate high-energy photons from a 10 GeV electron beam. The physical data of lead are : Z=82, A(g)=207.2 g , ρ=11.3 g cm^{-3}, X_0 = 5.6 mm.



1) Compute the thickness of this slab to produce a photon beam of 1 GeV mean energy.

2) Check that within this slab only a small fraction of these photons get converted into e^+e^- pairs.

3) What magnetic device could be used to sweep the remaining electron beam out of the photon beam downstream of the slab ? Represent the magnetic field on the sketch.

   This 1 GeV photon line can be used to test photon detectors.

4) Give the typical thickness in X_0 units of a total energy absorption detector (calorimeter) in this photon energy regime.

   A liquid xenon prototype is studied. The radiation length of xenon is 2.7 cm. Its specific mass is 3.1 g cm^{-3}. Its Molière radius is 3.9 cm. Reminder : a cylinder of 3 Molière radii in radius is needed to contain 99% of a shower energy.

5) Give the shape and the dimensions of the detector. We will assume that the transverse size of the photon beam is of the order of a few millimeters.

6) Evaluate the needed mass of Xe.

7) What would be the simplest and most appropriate detection mode to use if only the energy is measured and if a detection response faster than 0.1 µs is sought.

8) What type of photo-sensors could be used then ?

9) Position these photo-sensors on a sketch of the detector. Think of the light reflectors.

10) What could be the value of the typical energy resolution obtained with this detector ?