Ασκήσεις Ανιχνευτές αερίου γεμίσματος – από κεφ. 4, από το βιβλίο του Tavernier

1. Consider an MWPC with wire spacing Δ. Assume that for perpendicular tracks the biggest signal is always on the nearest wire. Show that the r.m.s. position resolution obtainable with such a detector is given by $\sigma = \dfrac{\Delta}{\sqrt{12}}$

Solution: The r.m.s. measurement error σ is given by

$$\sigma^2 = \int (x_{\text{measured}} - x)^2 f(x)\, dx$$

In this expression x represents the true position of the track, $f(x)$ the probability density function for the true position x and x_{measured} represents the measured value of the position. In this case, the measured position is the position of the wire nearest to the true position. Let us first consider the particular case where the true position is within a distance $\Delta/2$ of a particular wire at position P. In this case the integral becomes

$$\sigma^2 = \int (P - x)^2 f(x)\, dx$$
$$\begin{cases} f(x) = \dfrac{1}{\Delta} & P - \Delta/2 < x < P + \Delta/2 \\ f(x) = 0 & \text{all other values of x} \end{cases} \cdot$$

The r.m.s. position error is hence given by

$$\sigma^2 = \int_{P-\Delta/2}^{P+\Delta/2} (P - x)^2\, f(x)\, dx = \frac{\Delta^2}{12}$$

Since the true position is always within a distance $\Delta/2$ of one of the wires this result holds for any value of the true position of the track.

2. You suspect that the gas in a cave is heavily contaminated by radon [$^{222}{}_{86}$Rn] gas. To determine the radon contamination, you measure the current caused by the radon in an ionisation chamber containing one litre of air from the cave. You measure 0.1 pA. How much radiation expressed in pico Curie (pCi) per litre is there in the air of the cave? How many radon atoms per litre are there in the air of the cave?

   Radon has a half-life of 3.8 days and decays into alpha particles of 5.6 MeV nearly 100% of the time. To simplify the calculation, ignore the fact that radon decay products will also be present and will significantly contribute to the current. Also ignore the fact that often the alpha particle will hit the wall of the ionisation chamber and therefore will not use all its energy to ionise the air.

   Solution: The average energy needed to produce one electron–ion pair in air is 33.8 eV. (see Table 4.1). The current produced if there is one alpha particle per second therefore is 2.65×10^{-14} A. The number of alpha particles per second corresponding to 0.1 pA therefore is 3.77 This corresponds to an activity of ≈100 pCi. The decay time constant for alpha emission by radon is $\tau = T_{1/2}/\ln 2 = 5.48$ days.

   The number on radon atoms in one litre is $3.77 \times \tau$ [s] $= 1.88 \times 10^6$.

3. A GEM detector has a conversion gap of 2 mm. The gas filling is 90% Ar and 10% CH4. Cosmic ray muons are falling perpendicularly on this detector. What is the probability that a muon will be go undetected because there is no primary ionisation event in the conversion gap?

   Solution: The number of primary ionisation events in this gas mixture is the weighted average of the number of primary ionisations of the two components. In this case the number of primary ionisations per cm is therefore 26.2/cm. The average number of primary ionisation events in two mm is hence 5.2. The number of primary ionisation events has a Poisson statistics. The probability to have nothing is $e^{-5.2} = 0.005$.

4. Calculate the mobility of nitrogen ions in nitrogen gas assuming that the cross section for the collision is 3.7×10^{-15} cm^2.

   Solution: The mean free path is $\lambda = 1/N\sigma$. The number of nitrogen molecules/cm^2 is found from the fact that one mole of gas has a volume of 22.4 l. The mean fee path therefore is ≈100 nm. The mobility is obtained from Eq. (4.1). Remember to express all quantities in MKSA units. The result is 3.4 cm^{2}V^{-1}s^{-1}.