P1  The curvature $1/R$ of a particle trajectory in a tracking device can be determined with precision

$$
\Delta \left( \frac{1}{R} \right) = \frac{\sigma}{L^2} \sqrt{\frac{720}{N + 4}},
$$

where $L$ is the measured track length (the distance between the first and the last hit), $N$ is the number of hits, and $\sigma$ is the measurement error of an individual hit (hit position resolution).

The CMS silicon tracker consists of 10 layers providing on average 10 hits per track (in the central region), with the average hit position resolution of 20 $\mu$m. The inner layer is positioned at a radius of 25 cm, and the outer layer is positioned at a radius of 105 cm. The tracker is embedded in a 4 T magnetic field.

(a) Find the relative transverse momentum resolution $\Delta p_T/p_T$ for a $p_T = 10$ GeV pion. Assume that the multiple scattering is negligible.

(b) At what transverse momentum it is no longer possible to reliably determine the particle charge? (This would be the transverse momentum at which the relative resolution approaches 1.)

(c) At what transverse momentum the resolution begins to deteriorate due to multiple scattering? Assume that each layer has $x/X_0 \sim 0.1$.

P2  A minimum ionizing particle crossing a 300 $\mu$m silicon strip detector produces 24000 electron-hole pairs which generate a signal of $S = 24000$ $e$ (measured in units of elementary charge $e$). The noise is dominated by the detector capacity at the input of the charge sensitive amplifier, and can be parameterized as a function of the strip length $L$ as follows:

$$
N = a + bL,
$$

where $a = 400$ $e$, $b = 40$ $e$/cm. The detector pitch is 50 $\mu$m. What is the maximum strip length $L$ if we want to achieve the hit position resolution better than 2 $\mu$m ?

P3  A beam of $p = 2$ GeV particles travels between two scintillating detectors which measure their time of passage. Find the minimum distance $L$ between the detectors required to separate kaons from pions, if the time-of-flight can be measured with an accuracy of 80 ps.