Introduction to Nuclear and Particle Physics 1 – Tutorial
O. Zimmer
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Problem 10 : Bethe-Bloch formula

The classical Bethe-Bloch formula

$$-\frac{\mathrm{d}E}{\mathrm{d}x} = \frac{z^2 e^4 n_e}{4\pi\varepsilon_0^2 v^2 m_e} \ln \frac{2m_e v^2}{I(1-\beta^2)}$$

describes the energy loss of heavy (i.e. $m \gg m_e$) particles in matter by inelastic collisions of the particle with the electron shell of the absorber atoms.
In the formula, n_e denotes the electron density of the absorber ($= n_{atom} \cdot Z$), z is the charge number of the incoming particle and I is an effective ionising potential of the absorber atoms. Show that this formula can be derived from classical considerations, under the assumption that the energy loss per collision is small ($v \approx$ const.).
Hint: Consider the number of electrons "seen" by the particle in a ring-shaped volume around its path. The inner radius b_{min} and outer radius b_{max} of this ring are determined by the maximum and minimum energies transferred to the electron, respectively.

Problem 11 : Energy loss in particle detectors

Moderately relativistic charged particles (other than electrons) lose energy in matter primarily by ionization. In an organic scintillator an energy deposit of typically 100 eV is required to produce one photon in the blue to green wavelength region, which in turn is detected by the photomultiplier in only 2% of the cases. In a gas detector filled with Ar, 26 eV are necessary to ionize a gas atom. In a Silicon semiconductor diode the energy deposit required to create an electron-hole pair is 3.6 eV.
All of these processes are statistical and can be described with the Poisson distribution.

a. How thick do these detectors have to be, so that a minimum ionizing particle deposits 1 MeV of its energy?

b. What is the relative energy resolution $\delta E/E$ of the three devices for this energy? Estimate the detection efficiency for detector type!

c. Discuss possible applications of these detectors!