WEEK 3 REVIEW

① Interactions and detection of charged particles

Bethe- Bloch Equation

Ionization energy loss per unit length

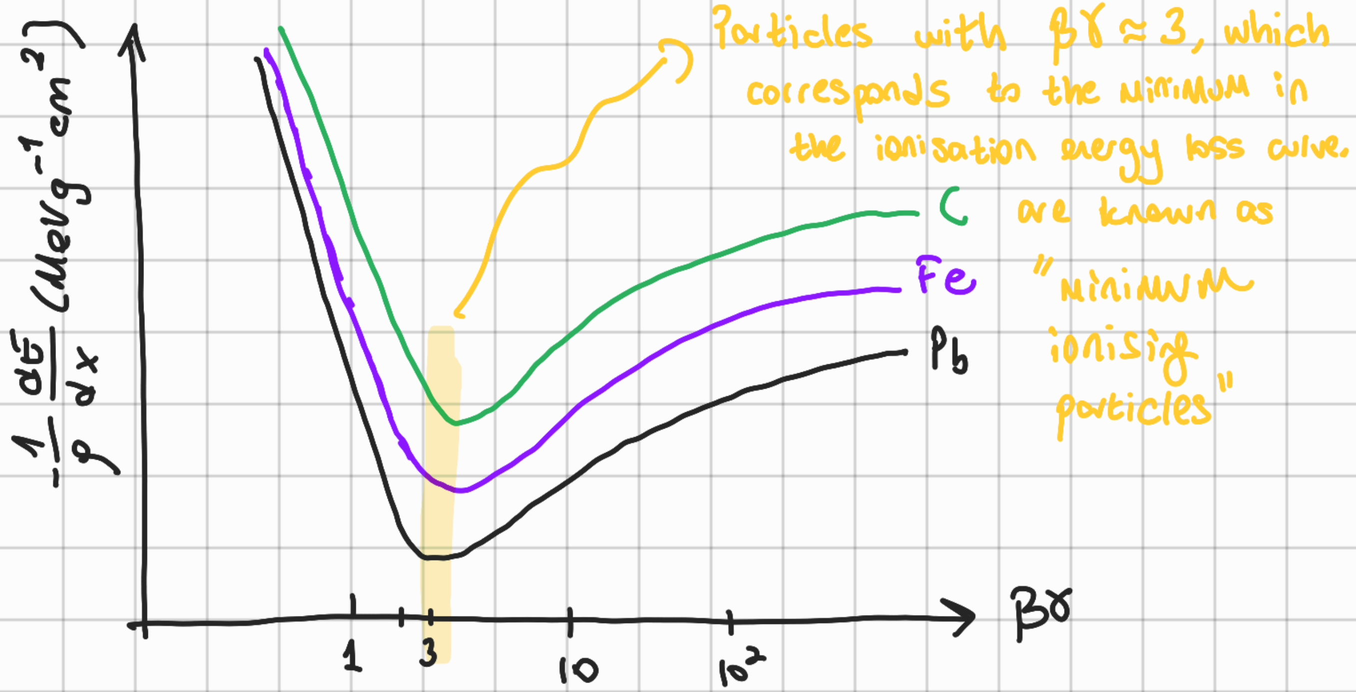
$$\frac{dE}{dx} \approx -4\pi\hbar^2 c^2 \alpha^2 \frac{nz}{m_e v^2} \left\{ \ln\left[\frac{2\beta^2\gamma^2 c^2 m_e}{I_e}\right] - \beta^2 \right\}$$

I_e → effective ionization potential

For modern particle physics where $v \approx c$

In this case, for a given medium $\frac{dE}{dx}$ depends logarithmically on $(\beta\gamma)^2$ where

$$\beta\gamma = \frac{v/c}{\sqrt{1-(v/c)^2}} = \frac{p}{mc}$$

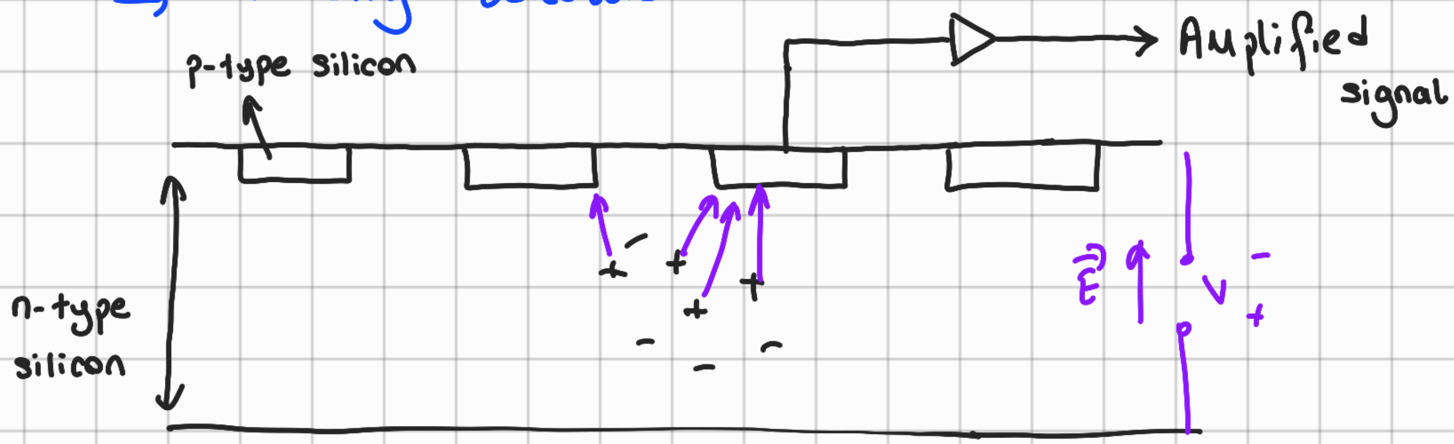


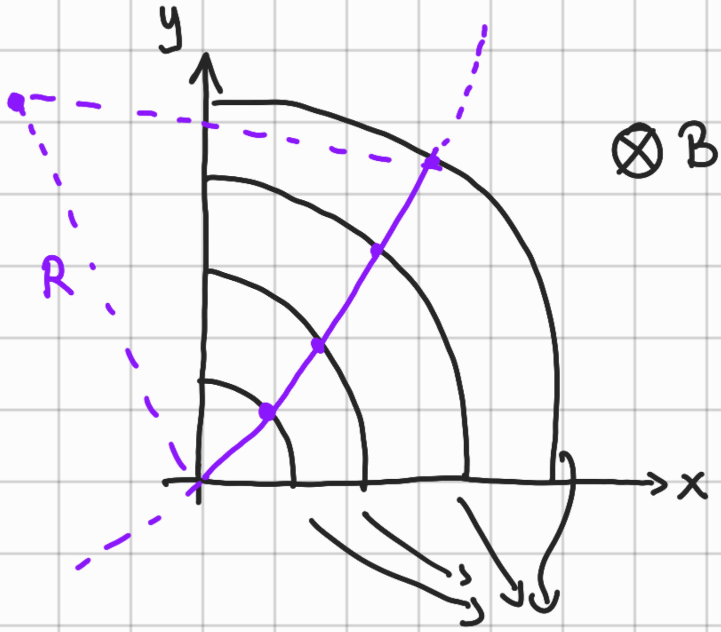
$$\frac{1}{\rho}\frac{dE}{dx} \approx -\frac{4\pi\hbar^2 c^2 \alpha^2}{m_e v^2} \frac{Z}{A m_u} \left\{ \ln\left[\frac{2\beta^2\gamma^2 m_e c^2}{I_e}\right] - \beta^2 \right\}$$

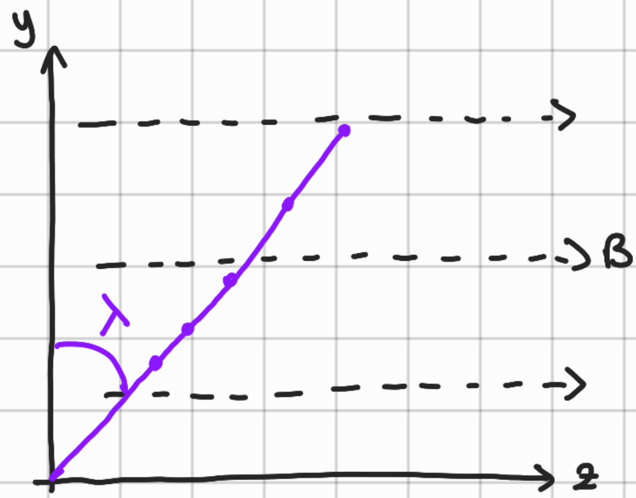
Z: atomic mass number

m_u: atomic mass unit

→ Tracking Detectors







Several cylindrical surfaces of silicon wafers

$$p\cos\lambda = 0.3\,BR$$

Measuring hits yield λ and R, so that p can be calculated

→ Scintillation Detectors

In an organic scintillator, passage of a charged particle leaves some of the molecules in an excited state

Decay of the excited state ⇝ emission of UV light

↓

Add fluorescent dyes to the scintillator

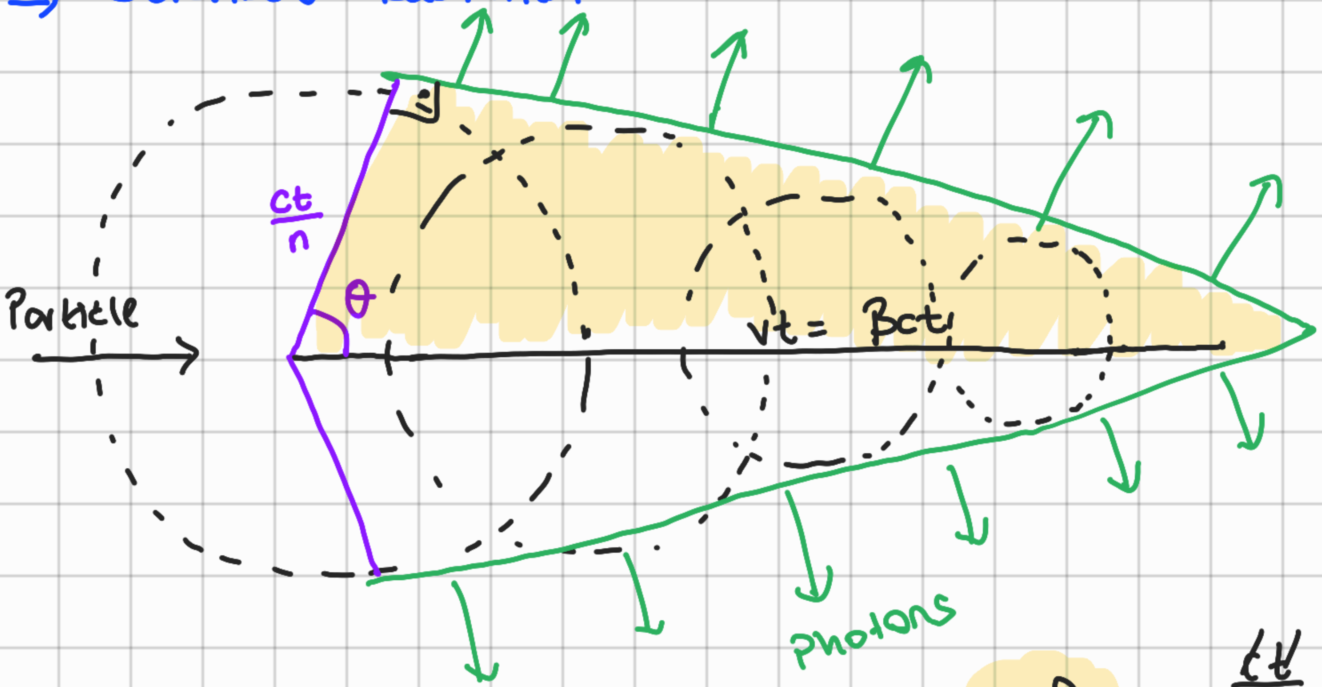
↓

Dye absorb UV light ⇝ re-emit blue photons

↓

Blue light can be detected by photomultiplier

→ Čerenkov Radiation



$$\boxed{\cos\theta} = \frac{\frac{\cancel{ct}}{n}}{\beta \cancel{c} \cancel{t}} = \boxed{\frac{1}{\beta n}}$$

v = Particle's velocity

$\frac{c}{n}$ = Speed of the light in the medium

If $v > c/n$ constructive interference occurs

Čerenkov is only emitted only when $\beta > 1/n$

for a relativistic particle

$$\left.\begin{aligned} p &= \gamma m v = \overbrace{\gamma m}^{E} \beta c^{\nearrow 1} \\ E &= \gamma m c^2 \xrightarrow{c=1} E = \gamma m \end{aligned}\right\} \quad p = E\beta \qquad \beta = \frac{pc}{E} = \frac{p}{\sqrt{p^2 + m^2 c^2}}$$

$$\beta > \frac{1}{n} \qquad \frac{p}{\sqrt{p^2 + m^2 c^2}} > \frac{1}{n}$$

$$\frac{p^2}{p^2 + m^2c^2} > \frac{1}{n^2}$$

$$n^2 > \frac{p^2 + m^2 c^2}{p^2} = 1 + \frac{m^2c^2}{p^2}$$

$$\sqrt{n^2 - 1} > \sqrt{\frac{m^2c^2}{p^2}}$$

$$(n^2-1)^{1/2} > \frac{mc}{p}$$

$$\boxed{mc < (n^2-1)^{1/2}\, p}$$

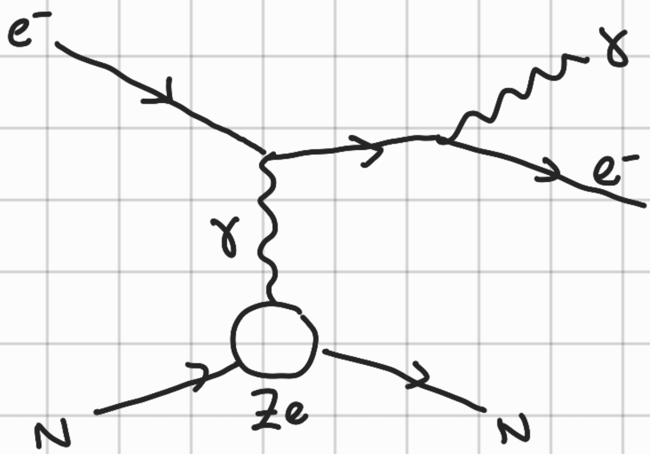
Only particles with this "m" will produce Čerenkov Radiation

② Interactions and detection of electrons and photons

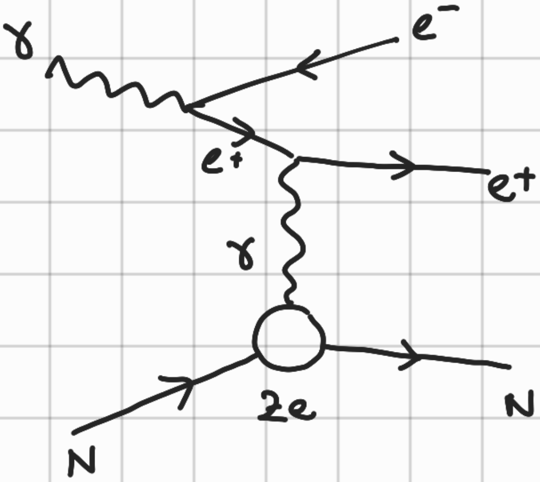
At low energies, the energy loss of electrons is dominated by ionisation.

Energies $> E_c$ (critical energy) "Bremsstrahlung" is the main energy loss mechanism

$$E_c \sim \frac{800}{Z}\ \text{MeV}$$



(nucleus of charge)



X_0 : The radiation length

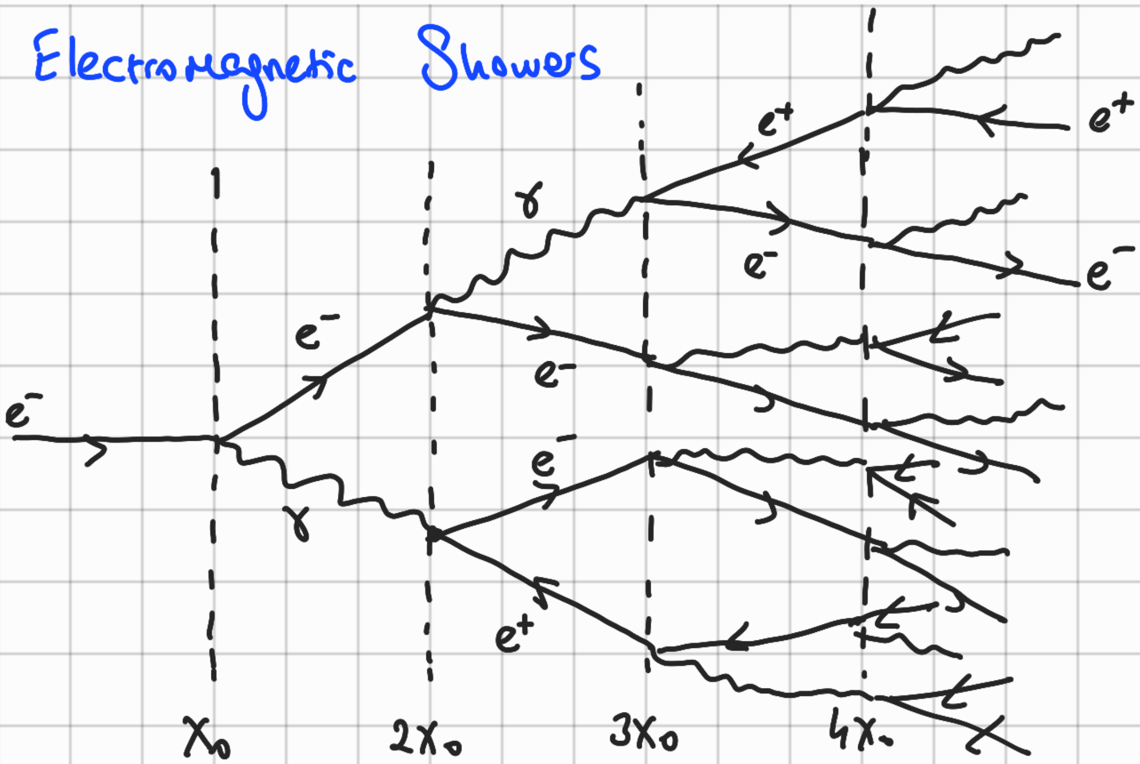
(Avg distance over which the energy of an electron is reduced by bremsstrahlung by a factor $1/e$)

$$X_0 \approx \frac{1}{4\alpha n Z^2 r_e^2 \ln(287/Z^{1/2})}$$

Z: atomic number

r_e: 2.8×10^{-15} m (classical radius of the e^-)

→ Electromagnetic Showers



$$\langle E \rangle \approx \frac{E}{2^x}$$

avg. energy of
the particles after x rad. length

$$x_{max} = \frac{\ln(E/E_c)}{\ln 2}$$

Collider Experiments

detection from missing momentum