Physics of Detectors - SoSe 2009

1. Interaction of radiation with matter

1.1 Heavy charged particles

- heavy $\hat{=}$ $\geq m(\text{proton})$
- charged $\hat{=}$ $\neq$ neutron

($m(p) \sim 938\ \text{MeV}/c^2$, $m(\mu^-) \sim 106\ \text{MeV}/c^2$, $m(e^-) \sim 0{,}511\ \text{MeV}/c^2$)

- main interaction: Coulomb with atomic electrons
- maximum energy transfered per collision

$$\frac{\Delta E}{\text{nucleon}} = 4E \cdot \frac{m(\text{target})}{m(\text{projectile})} \sim E \cdot \frac{(4 \cdot 0{,}5\ \text{MeV})}{1000\ \text{MeV}}$$

$$\simeq \frac{1}{500} E(\text{projectile})$$

↗ many interactions necessary to loose substantial amount of energy

(a) STOPPING POWER

$$S = -\frac{dE}{dx}$$ ↗ Bethe formula

$$-\frac{dE}{dx} = \frac{4\pi \cdot e^4 \cdot z^2}{v^2 \cdot m_0} \cdot N \cdot Z \left[\ln \frac{2 m_0 v^2}{I} - \ln\left(1 - \frac{v^2}{c^2}\right) - \frac{v^2}{c^2} \right]$$

vanishes for $v \ll c$

$v \hat{=}$ velocity projectile

$z \cdot e \hat{=}$ charge projectile

$m_0 \hat{=}$ rest mass electron $= 511\ \text{keV}/c^2$

$Z \cdot e \hat{=}$ charge absorber

$I \hat{=}$ average ionization potential $\sim 10\ \text{eV} \cdot Z$ (Bloch, empirical)

$N \hat{=}$ number density of absorber electrons ($\neq \rho$)

$\Rightarrow$ mainly $\frac{z^2}{v^2} \cdot N \cdot Z \sim \frac{z^2}{E} \cdot N \cdot Z$

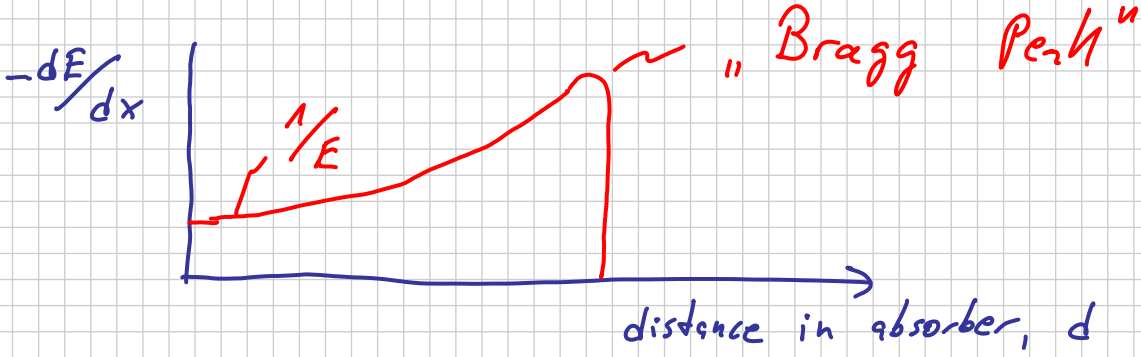
(E: projectile energy)

$\Rightarrow$ large stopping power for

- small velocities
- large z of projectile
- large Z and density of absorber

- Bethe formula fails at very low projectile energies (ion captures e^- and becomes neutral)

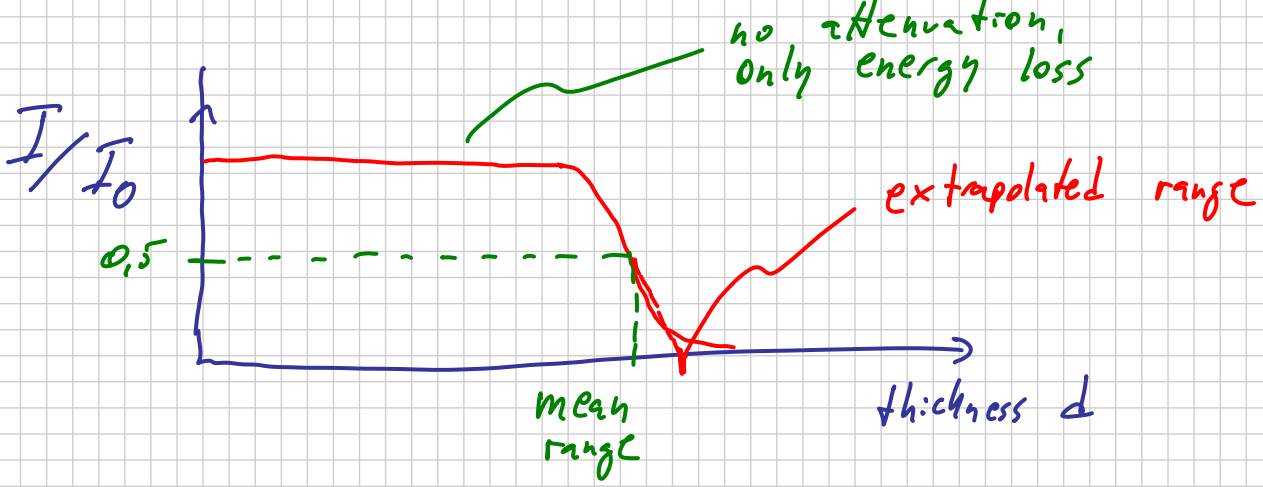
(b) BRAGG CURVE



- Energy straggling

(c) PARTICLE RANGE

Let projectile beam with intensity I_0 pass through absorber with variable thickness → measure intensity I



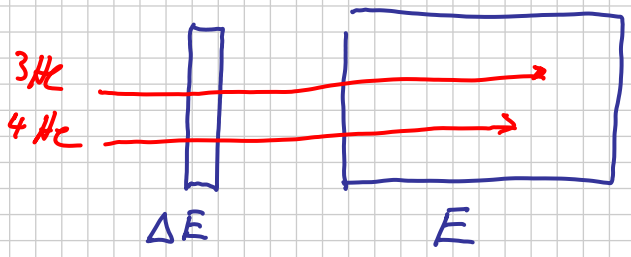
- Range straggling, typically a few %

(d) ENERGY LOSS IN THIN ABSORBERS

$$\Delta E = -\left(\frac{dE}{dx}\right)_{avg.} \cdot d$$

energy averaged over thickness d

- ΔE - E detectors



3He 75 MeV
4He 90 MeV
E = 10 MeV

- energy loss in target