Interactions of charged particles w/ Matter

⇒ ionization (lower energies)

Show dE/dx curve

more w/ higher Mass!

⇒ Radiation - Bremsstrahlung

$$\left(\frac{dE}{dx}\right)_{rad} \propto E$$

whereas

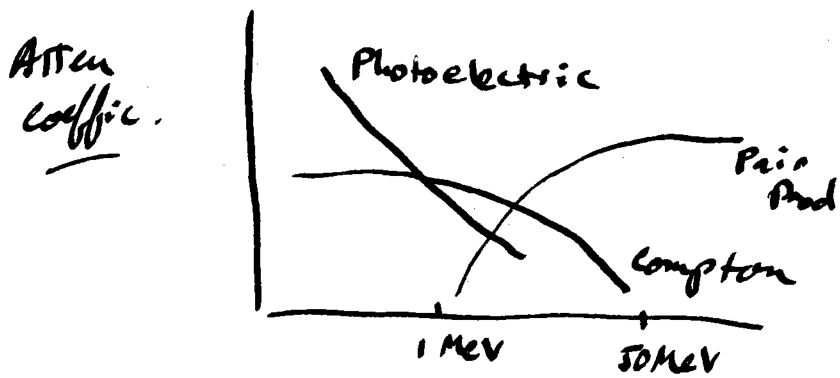
$$\left(\frac{dE}{dx}\right)_{ion} \sim \text{constant}$$

Bio damage from ionization

α worse than β (outside body)

Also penetrates less far

Interactions of γ w/ matter

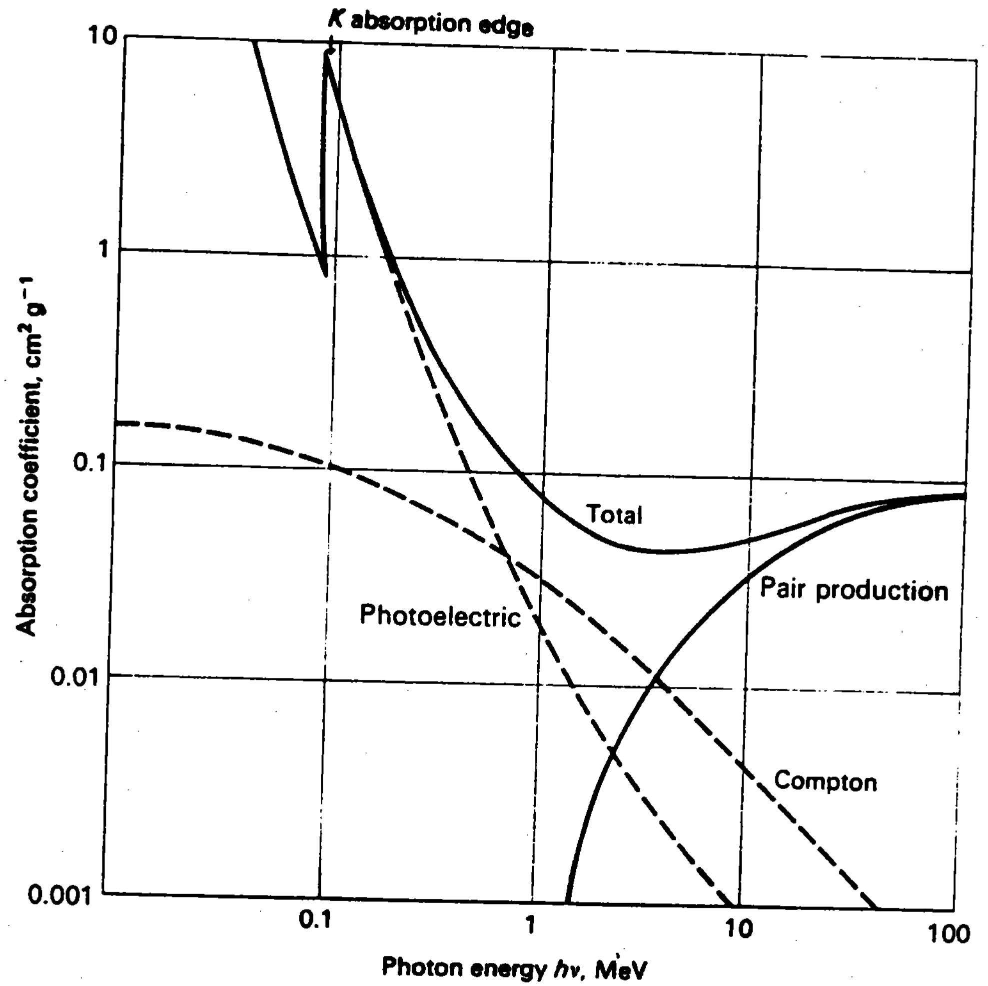


$I = I_0 e$

$\frac{9X_0}{7} \equiv$ Conversion length $\quad \frac{I_0}{I} \quad$ ~~$I = I_0 e$~~

$I = I_0/e$

Jer



ie thickness of absorber because of

:aling law for the range. The energy loss

$\left.\right)$

, according to Eq. 2.12, the range is given

$$M\frac{dE}{M} \tag{2.13}$$

of E/M. To illustrate the usefulness of Eq. some particle, a proton, for example, has v or of E/M. Then the range of another xample, with energy E_α can be related to

$$\left(\frac{E_\alpha}{M_\alpha}\right)$$

$$\left(\frac{E_\alpha}{M_\alpha}\right)$$

an often be expressed empirically in the

$$\tag{2.14}$$

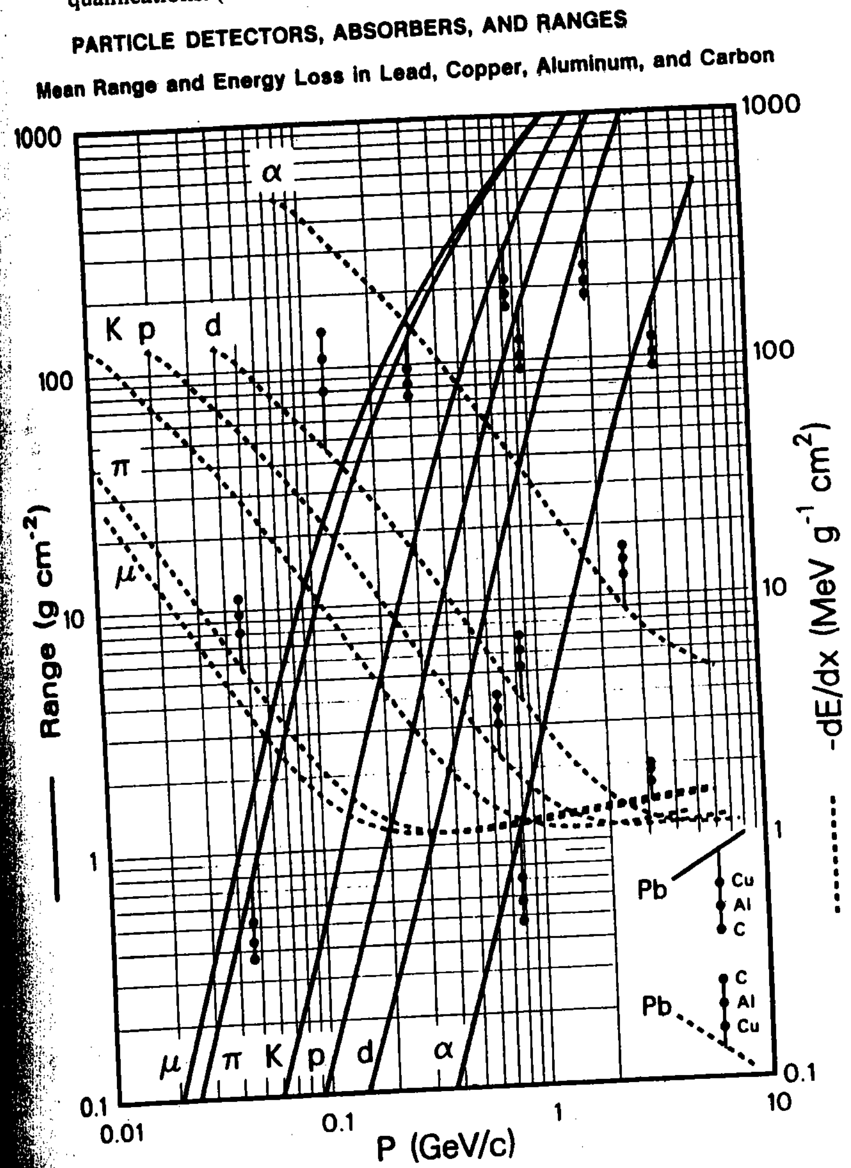
ters for low energy protons in air can be d $E_0 = 9.3$ MeV [3].

es of a number of incident particles in a e shown in Fig. 2.3. The range and dE/dx nount of mass traversed (g/cm²) instead of $/dx$ curves show the $1/v^2$ drop for small nimum ionization for higher momentum. rticles in liquid hydrogen in Fig. 2.4.

f the energy loss

tment of the energy loss given in the pre- itum nature of the particles in an ad hoc must take into account (1) the fact that

Figure 2.3 Mean range and energy charged particles in solids. Calculations use the Bethe–Bloch eq…ion with density effect corrections. Refer to the cited reference for a discussion of assumptions and qualifications. (Particle Data Group, Rev. Mod. Phys, 56: S1, 1984.)



<u>So</u> one can have <u>Nuclear</u> Spectroscopy

i.e., TRANSitions of Nucleons between allowed energy states within nuclei
- EM radiation emitted/Absorbed $\Rightarrow$ γ rays
- Energies between states much larger than for ATOMS

Emitted EM Radiation <u>γ rays</u> ... Very high energy EM rad.

$$\alpha < \beta < \gamma$$ Bio damage <u>outside</u> body

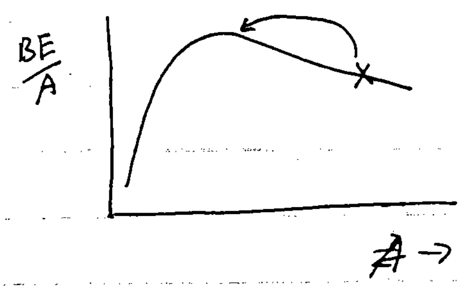
$$\alpha > \beta > \gamma$$ Bio damage if Substance incorporated in body

(This is a fn of where/if Substance is concentrated in some organ also)

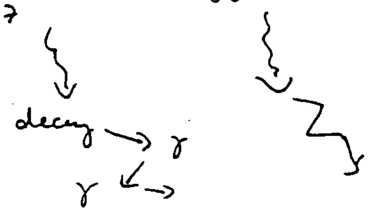
(also a fn of Substance activity)

<u>Nuclear Fission</u>

useful for winning wars & heating tea



$^{235}_{92}U + n \rightarrow \,^{93}_{37}Rb + \,^{141}_{58}Cs + 2n$



~200 MeV of energy released (KE + γ rays)
+ 2n to start <u>new</u> fissions

<u>uncontrolled</u> → bomb
Add moderator to stop neutrons → can control reaction
get a reactor

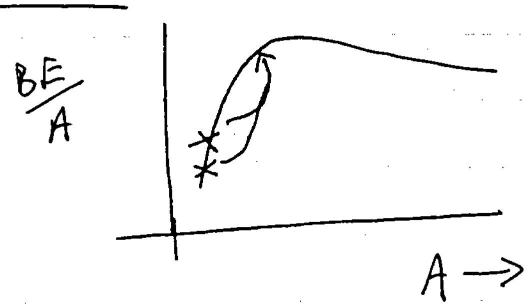
\# neutrons available to start new fission Rxns = 1 ⇒ Critical
$\gg 1$ Bomb
$\ll 1$ No Rxn

Fortunately ^{235}U ~ 0.7 percent
^{238}U ~ 99.3 percent } Hard to isolate ^{235}U

Breeder Reactor $^{238}_{92}U + n \rightarrow \,^{239}_{92}U \rightarrow \,^{239}_{93}Np + e^- + \bar{\nu}$
$\hookrightarrow \,^{239}_{94}Pu + e^- + \bar{\nu}$

Separate out
Can be used for nuclear fuel + bombs

Nuclear Fusion



$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{1}He + ^{1}_{1}H$$

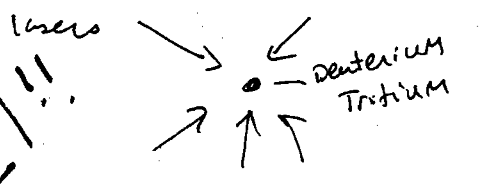
liberates ~ 1 MeV/nucleon in energy

- get H from water ⇒ ∞ supply !
- byproducts are "clean"

problem:
Must overcome Coulomb repulsion
Hard to do on large scale in a controlled self sustaining manner

2 Approaches:

(inertial confinement)



LLE !!

Tokamak (Magnetic confinement)
Heat
Plasma
until thermal energy sufficient to ignite fuel.

Fusion is important . . . Stars work by Nuclear fusion i.e. our sun

x2 { $^{1}_{1}H \rightarrow ^{1}_{1}H \rightarrow ^{2}_{1}H + e^{+} + \nu$

$^{2}_{1}H + ^{1}_{1}H \rightarrow ^{3}_{2}He + \gamma$ }

$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2\,^{1}_{1}H$

$Q = 26.7$ MeV

Stellar life cycle if Time Allows

$^{12}C + ^{1}H \rightarrow ^{13}N + \gamma$
$^{13}N \rightarrow ^{13}C + e^{+} + \nu$
$^{13}C + ^{1}H \rightarrow ^{14}N + \gamma$
$^{14}N + ^{1}H \rightarrow ^{15}O + \gamma$
$^{15}O \rightarrow ^{15}N + e^{+} + \nu$
$^{15}N + ^{1}H \rightarrow ^{12}C + ^{4}He$

} carbon cycle

Sample of N radioactive nuclei of certain type x

$$\frac{dN}{dt} \propto N$$

$$a \equiv \frac{dN}{dt} = -\lambda N$$

a ↑ activity; λ ↑ decay constant (units $\frac{1}{s}$)

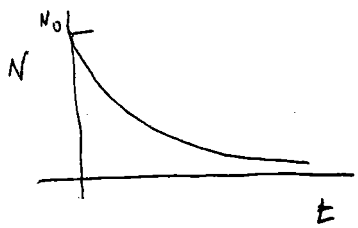
$\equiv$ change in # radioactive nuclei/s

$$\frac{dN}{N} = -\lambda dt \qquad \ln N = -\lambda t + c$$

or

$$N = N_0 e^{-\lambda t}$$

Exponential law of radioactive decay



Cannot easily measure N so

$$\lambda N = \lambda N_0 e^{-\lambda t}$$

$$a = a_0 e^{-\lambda t}$$

Activity measured in <u>curies</u>

1 Curie (Ci) = 3.7×10^{10} decays/s

usually work in mCi to μCi

Half life $\equiv$ time for a for a sample to be reduced by a factor of two

$$a = a_0 e^{-\lambda t} \qquad \tfrac{1}{2} a_0 = a_0 e^{-\lambda t_{1/2}}$$

$$\boxed{t_{1/2} = \frac{1}{\lambda} \ln 2 = \frac{0.693}{\lambda}}$$

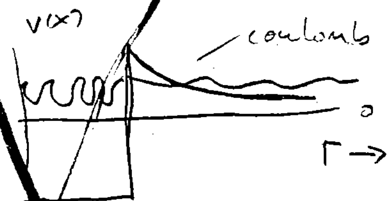
α - decay

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}He$$

(${}^{4}_{2}He$ = α - particle)

Nucleons (p's & n's) exist bouncing around inside the "bag" of the Nucleus

Nuclear potential ⟶



Quantum Tunneling occurs ... α particle escapes from Nucleus

α - particle Heavy ... charge of +2
- Heavily ionizing
- Easily stopped

} • least harmful Radiation if outside body!
• MOST harmful Radiation if ingested!
(given a certain activity & position in body)

do in several pages

β - decay $n \rightarrow p + e$ in Nucleus ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}X$

"Q - Value" = K.E given to products = $(m_n - m_p - m_e)c^2$

Assume No/little nuclear recoil

expect a spike in β decay spectrum