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

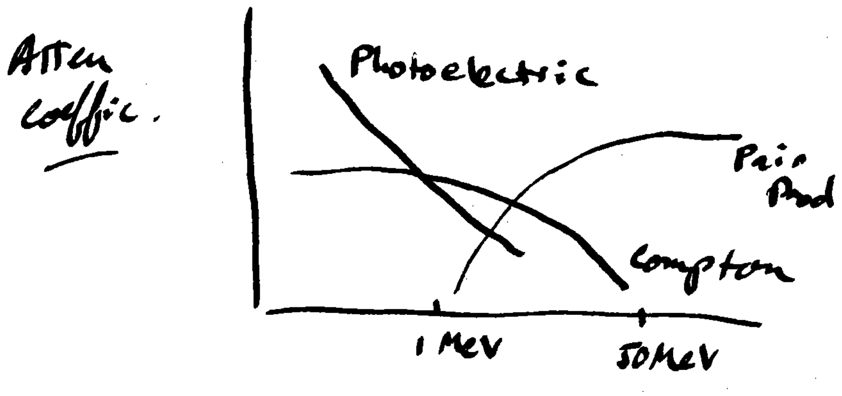
$$\left(\frac{dE}{dx}\right)_{ion} \sim \text{constant}$$

Bio damage from ionization

α worse than β (outside body)

Also penetrates less far

Interactions of γ w/ matter

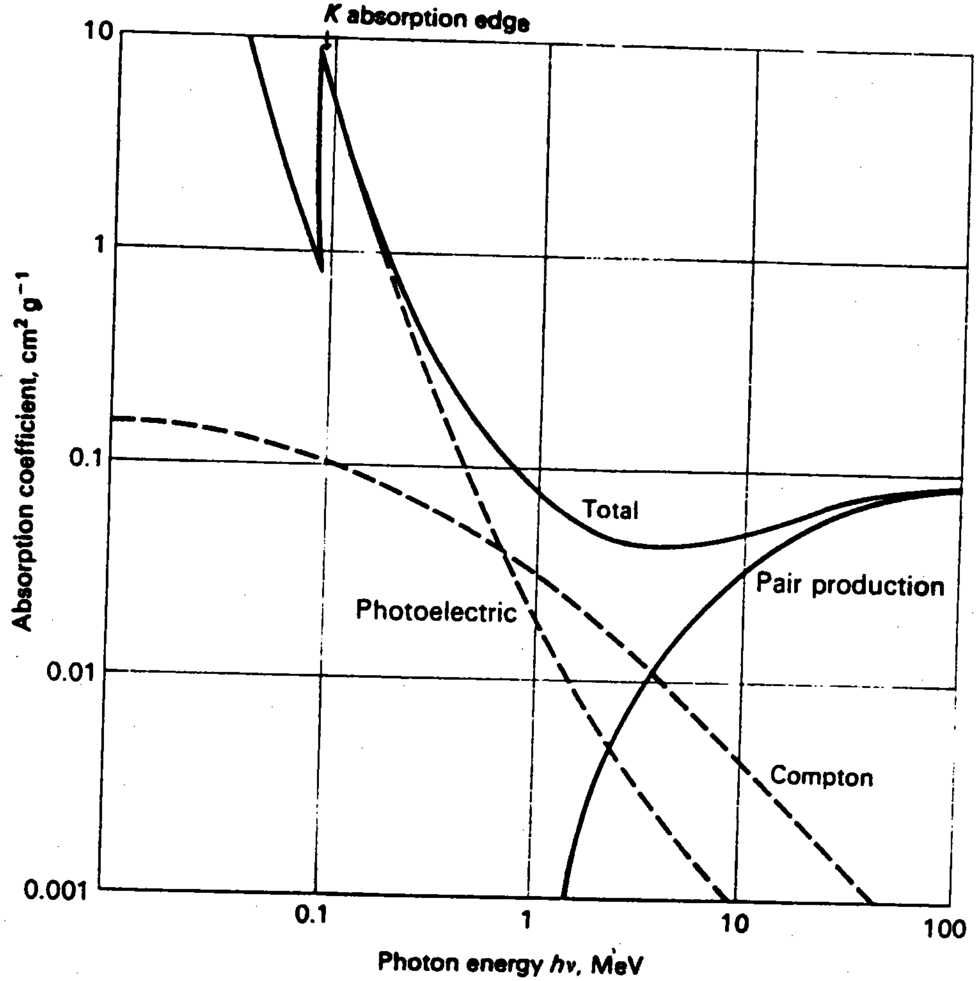


$I =$ [illegible]$_0$ e

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

$I = I_0/e$

Jer



ıe thickness of [illegible] absorber because of

:aling law for the range. The energy loss

$$\cdots \Big)$$

ı, according to Eq. 2.12, the range is given

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

ıf 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

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

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

:an often be expressed empirically in the

$$\tag{2.14}$$

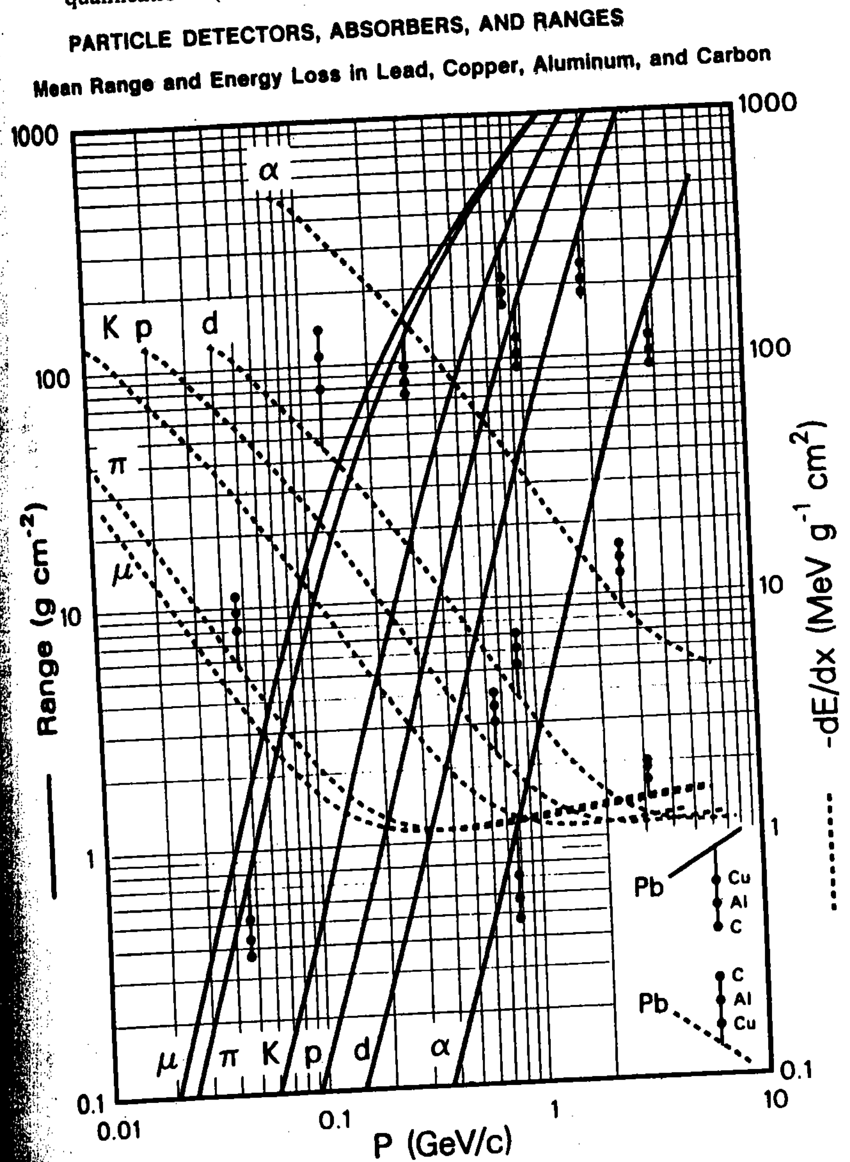
ters for low energy protons in air can be d $E_0 = 9.3$ MeV [3].

es of a number of incident particles in a re shown in Fig. 2.3. The range and dE/dx nount of mass traversed (g/cm^2) 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- ıtum nature of the particles in an ad hoc must take into account (1) the fact that

Figure 2.3 Mean range and energy [illegible] charged particles in solids. Calculations use the Bethe–Bloch equation 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.)



So one can have Nuclear Spectroscopy

i.e., TRANSitions of Nucleons between allowed energy states within nuclei

- EM radiation emitted/Absorbed ⇒ γ rays
- Energies between states much larger than for ATOMS

Emitted EM Radiation γ rays ... Very high energy EM rad.

$\alpha < \beta < \gamma$ Bio damage outside body

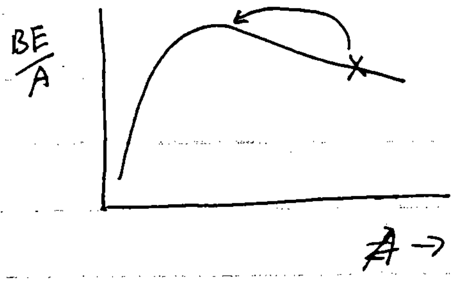
$\alpha > \beta > \gamma$ Bio damage if substance incorporated in body

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

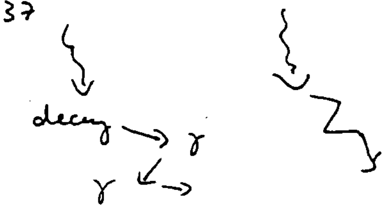
(also a fn of substance activity)

Nuclear Fission

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 new fissions

uncontrolled → bomb
Add moderator to stop neutrons → can control reaction
get a reactor

# neutrons available to start new fission Rxns	= 1	⇒ Critical
	>> 1	Bomb
	<< 1	No Rxn

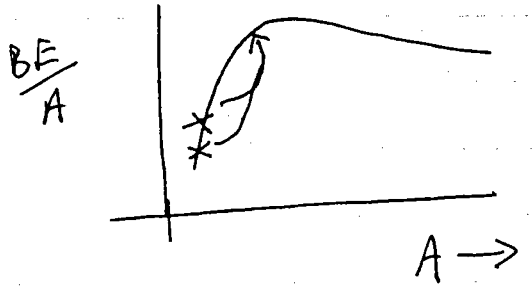
Fortunately ^{235}U ~ 0.7 percent
^{238}U ~ 99.3 percent } Hard to isolate ^{235}U

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

$\hookrightarrow \boxed{^{239}_{94}Pu} + e^- + \bar{\nu}$

Separate out
Can be used for nuclear fuel + bombs

Nuclear Fusion



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

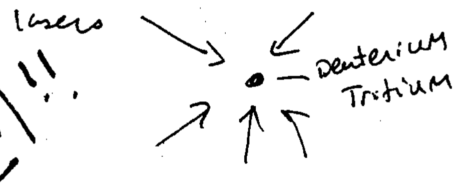
liberates ~ 1 MeV/nucleon in energy

— 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

$$\times 2 \left\{ \begin{array}{l} ^{1}_{1}H \rightarrow ^{1}_{1}H \longrightarrow ^{2}_{1}H + e^{+} + \nu \\ ^{2}_{1}H + ^{1}_{1}H \rightarrow ^{3}_{2}He + \gamma \end{array} \right.$$

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

$$Q = 26.7\ MeV$$

Stellar life cycle   if Time Allows

$$\left. \begin{array}{l} ^{12}C + ^{1}H \rightarrow ^{13}N + \gamma \\ ^{13}N \rightarrow ^{13}C + e^{+} + \nu \\ ^{13}C + ^{1}H \rightarrow ^{14}N + \gamma \\ ^{14}N + ^{1}H \rightarrow ^{15}O + \gamma \\ ^{15}O \rightarrow ^{15}N + e^{+} + \nu \\ ^{15}N + ^{1}H \rightarrow ^{12}C + ^{4}He \end{array} \right\} \text{carbon cycle}$$

Sample of N radioactive nuclei of certain type x

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

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

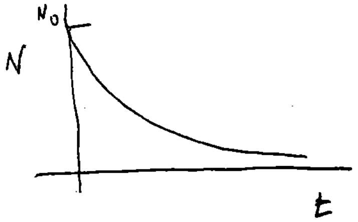
decay constant (units $\frac{1}{s}$)

activity

≡ change in # radioactive nuclei/s

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

or $\boxed{N = N_0 e^{-\lambda t}}$ Exponential Law of radioactive decay



cannot easily measure N so $\lambda N = \lambda N_0 e^{-\lambda t}$

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

activity measured in <u>curies</u>

1 curie (Ci) = 3.7×10^{10} decays/s

usually work in mCi to μCi

Half life ≡ time for a for a sample to be reduced by a factor of two

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

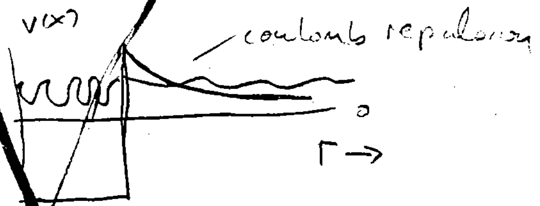
$$\boxed{t_{1/2} = \frac{1}{\lambda} \ln 2 = \frac{0.693}{\lambda}}$$

~~**α-decay**~~ ~~$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}He$~~

~~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**~~ ~~$n \to p + e$ in Nucleus~~ ~~$^{A}_{Z}X \to {}^{A}_{Z+1}X$~~

~~"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~~