Physics 102 - October 26, 2009

- Project Topic Selection

  Sheet to me by Noon Tomorrow

Last Time

Nuclear Physics

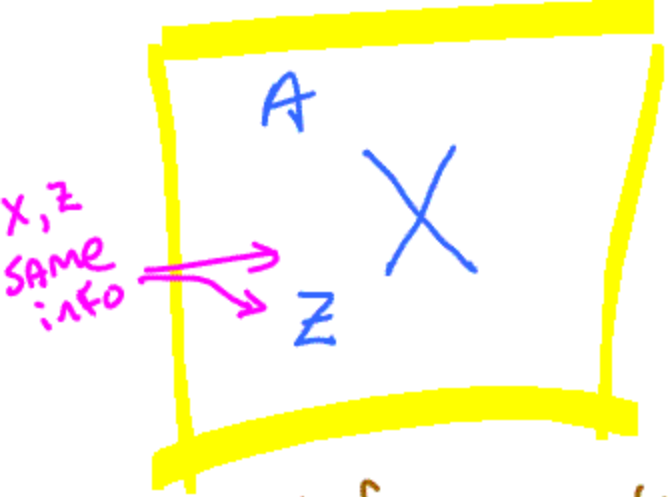
Strong Nuclear force
range of $\sim 10^{-15}$ m
much stronger than electromagnetic force

Strong Attractive nuclear force
+
Quantum Mechanics
(Schrödinger equation)

Protons
neutrons

Nucleons populate
discrete Nuclear quantum states
(Similar to electrons in Atom)

MeV energy differences



Symbol for a nucleus

$X \equiv$ Atomic Symbol

$Z \equiv$ # protons (Atomic #)

$A \equiv$ Atomic Mass

$N \equiv A - Z \equiv$ # neutrons

$${}^{A}_{Z}X^{*} \longrightarrow {}^{A}_{Z}X + \gamma$$

GAMMA radiation γ

$${}^{A}_{Z}X' \longrightarrow {}^{A}_{Z+1}X + e^{-}$$

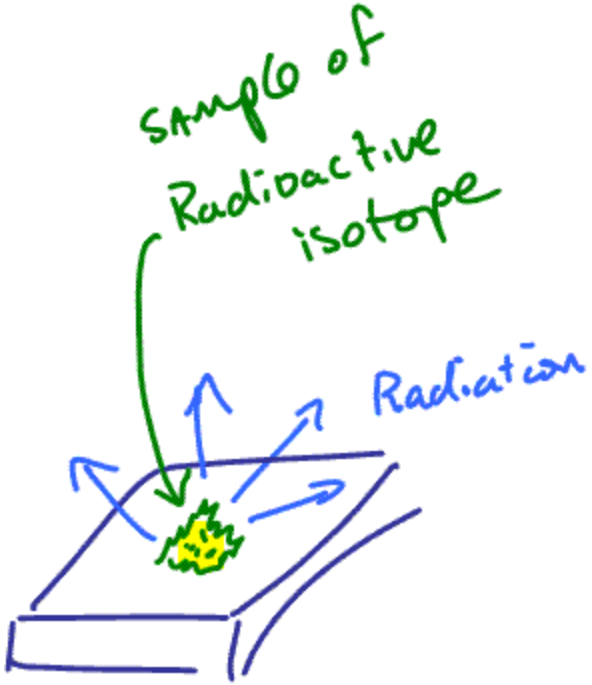
$${}^{A}_{Z}X' \longrightarrow {}^{A}_{Z-1}X + e^{+}$$

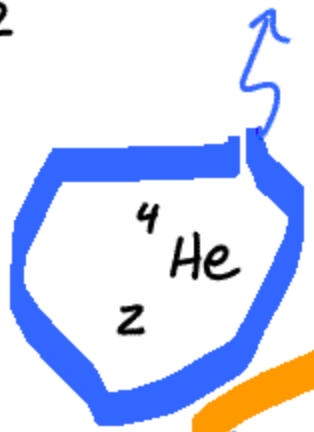
β

β radiation

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

Alpha radiation





decay CONSTANT

$$\frac{\Delta N}{\Delta t} = \lambda N$$

N ≡ # radioactive nuclei in SAMPLE

Activity ≡ # nuclei decaying per second

$$t_{\frac{1}{2}} = \frac{0.693}{\lambda} \equiv \text{half-life} \equiv \text{time for } \tfrac{1}{2} \text{ the nuclei to decay}$$

$t_{1/2}$
λ
} ≡ both characterize how prone a specific type of nucleu is to break down (decay)

large λ, small $t_{1/2}$ means nuclei prone to decay quickly

Small λ, large $t_{1/2}$ nuclei tend to Stick around longer

λ and $t_{1/2}$ ... measures of the same characteristic

Sort of like a fingerprint for specific type of radioactive nucleus

N atoms in sample at time = 0

$$\text{Activity} \equiv \frac{\#\text{decays}}{\text{second}} = \frac{\Delta N}{\Delta t} = \lambda N$$

λ: decay CONSTANT

half-life $\equiv t_{1/2}$ = time for ½ sample to decay

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

Radioactive [redacted] Dating

"[redacted] carbon"

Normal $^{12}_{6}C$

$^{14}_{6}C$ Produced by cosmic rays Hitting ATMOSPHERE

^{14}C is naturally radioactive

β-emitter

$t_{1/2}$ = 5730 years

- ^{14}C incorporated into living tissue
- Stops at death
- $^{14}C/^{12}C$ ratio gives estimate of time since death
- ^{14}C concentration in ATMOSPHERE varies, calibrate w/ tree rings

A sample of bone

^{14}C activity to be 25% of that in living material. How old is the bone?

^{14}C $t_{1/2} = 5730$

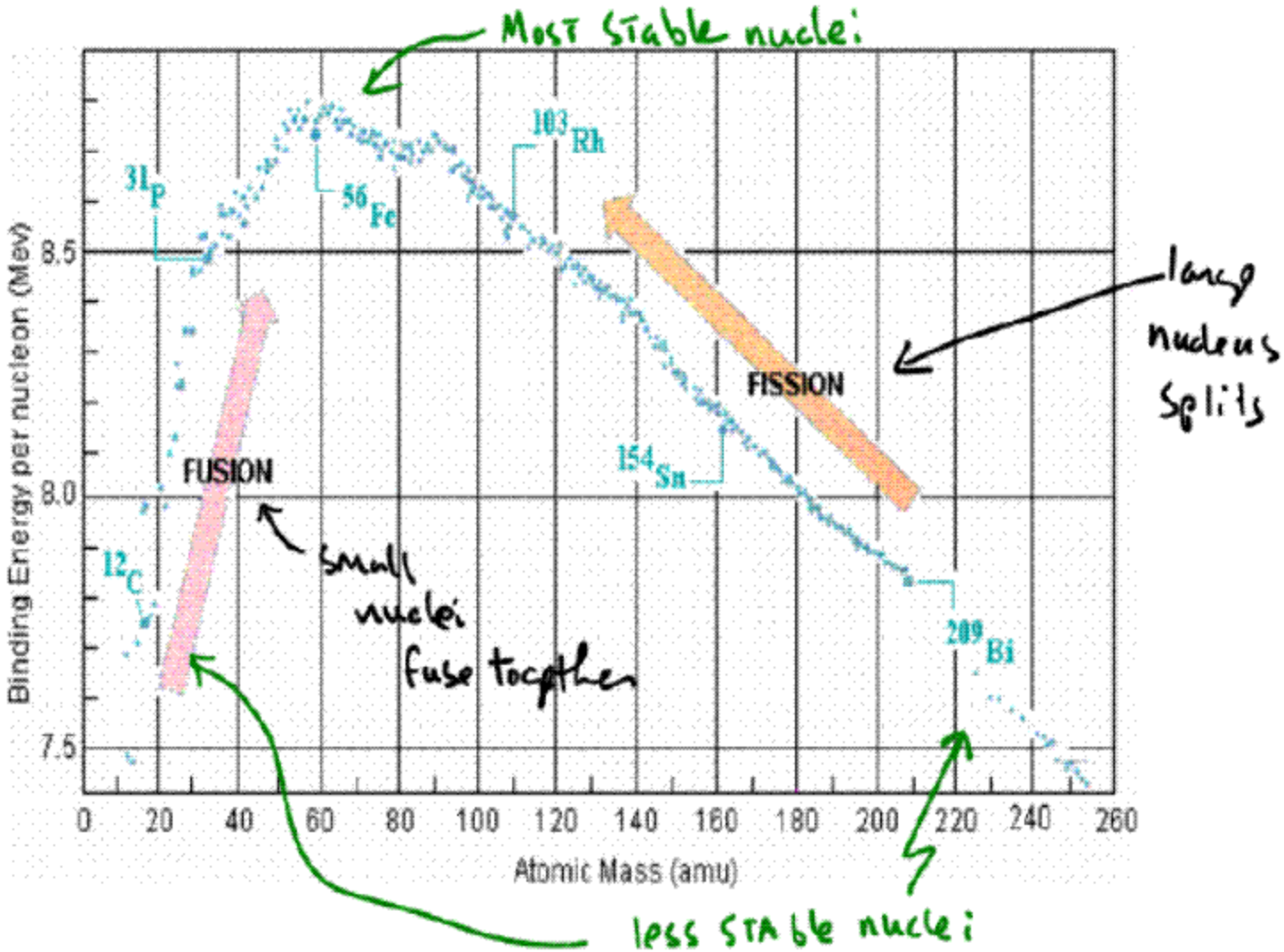
after 1 half life Activity = 50% of original

after 2 " " = 25% of original

Age ~ (2) 5730 years ~ 11,400 years

The secret of nuclear power ...

measure of how difficult it is to remove a nucleon (p or n) from the nucleus



A very important nuclear process ...

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

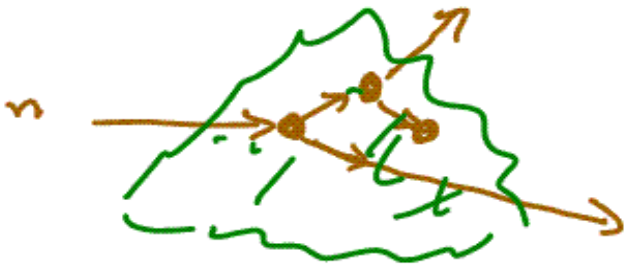
γ γ γ γ

cascade of decays

Σ mass $= M_{initial}$

Σ mass $= M_{final}$

$M_{initial} - M_{final} > 0$

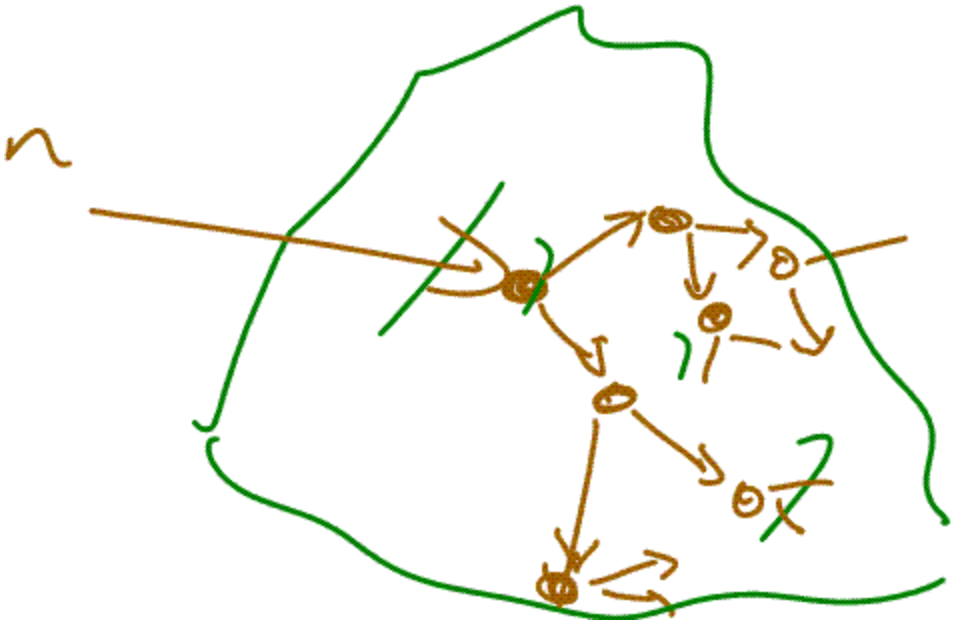


Critical

1 Split per Split

Subcritical

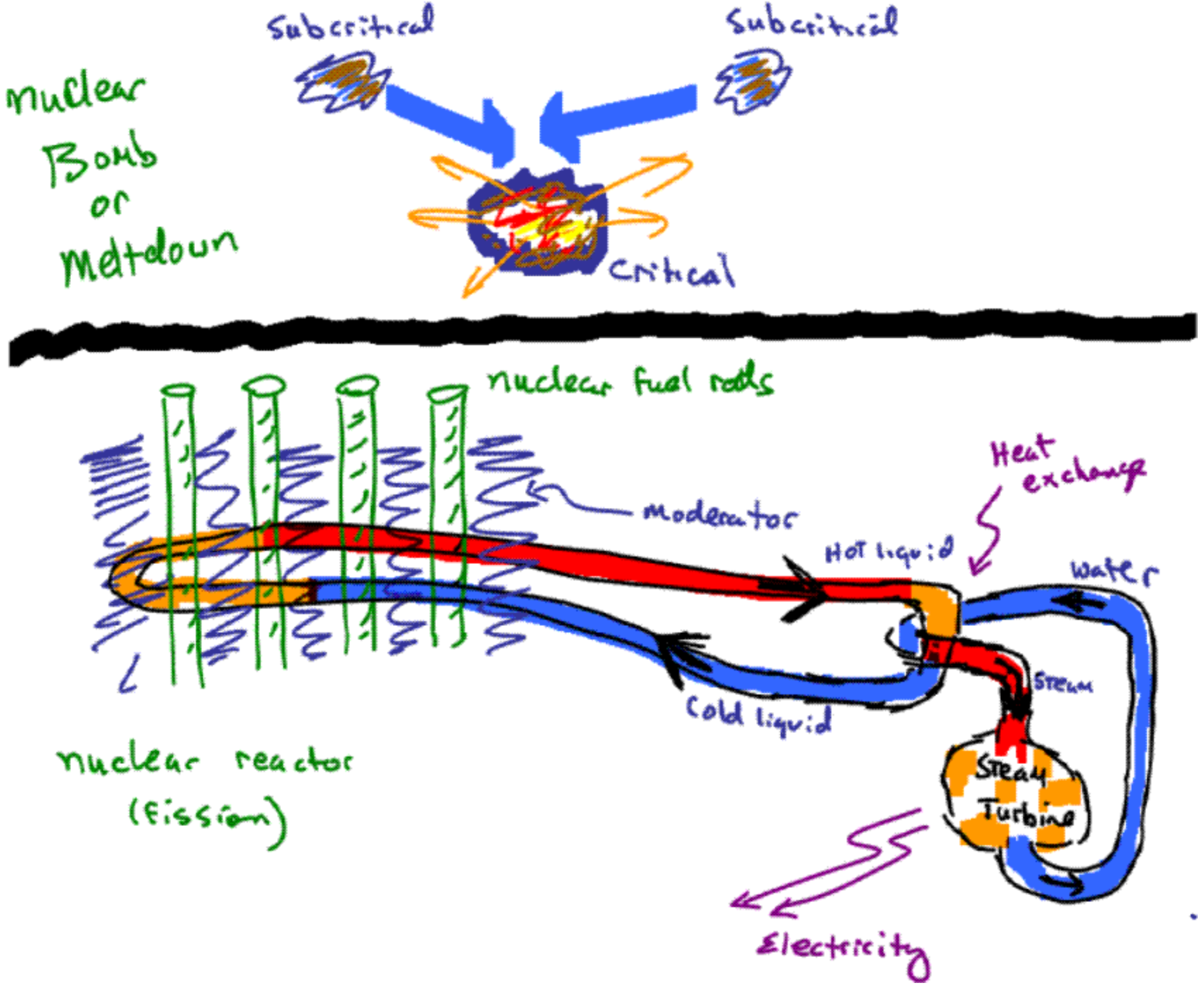
<1 Split per Split

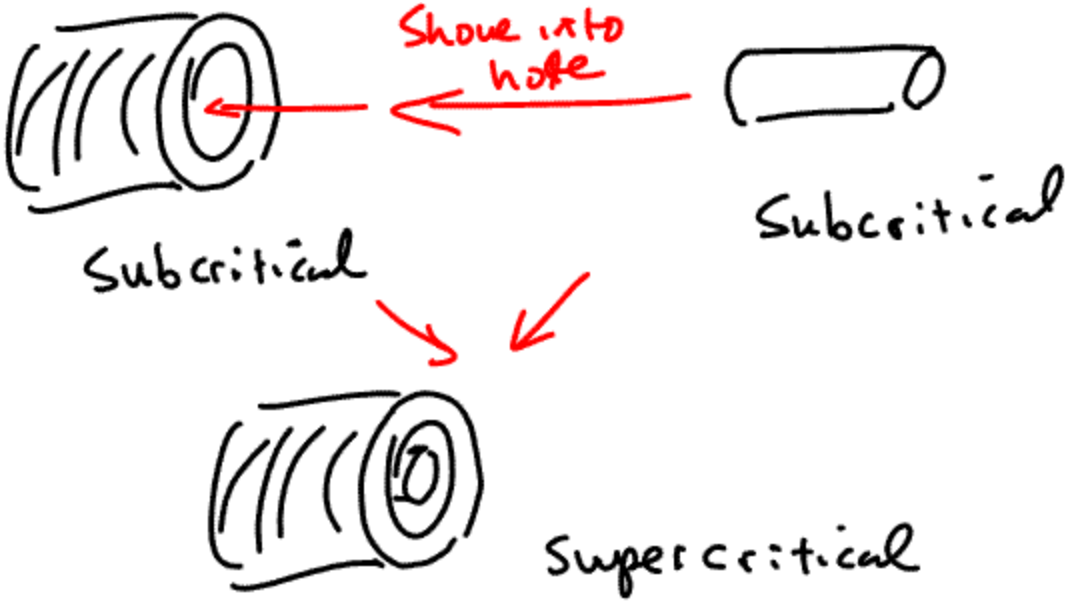


Supercritical

> 1 split per split

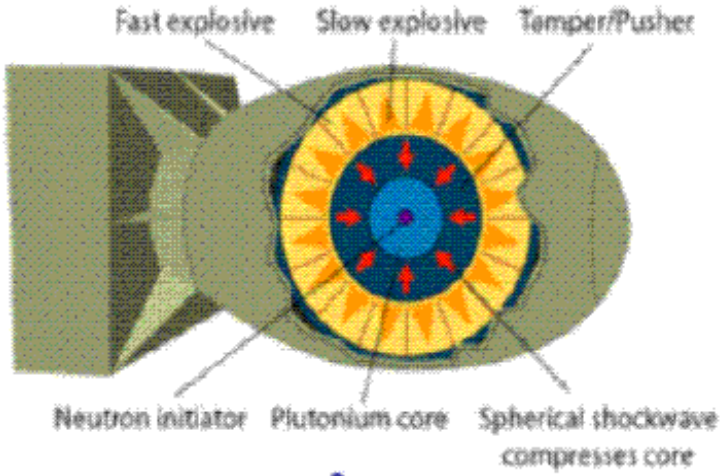
Watch out!


Subcritical
Subcritical
nuclear Bomb or Meltdown
Critical
nuclear fuel rods
moderator
Heat exchange
HOT liquid
water
Cold liquid
Steam
Steam Turbine
nuclear reactor (fission)
Electricity



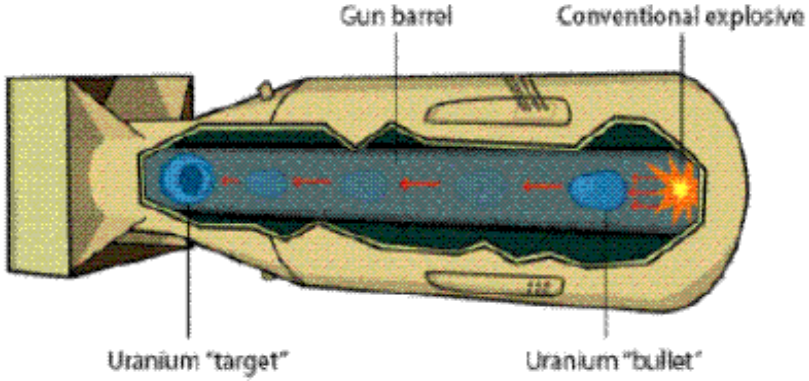
"gun" design for nuclear bomb

... like "little boy" which was used on Hiroshima



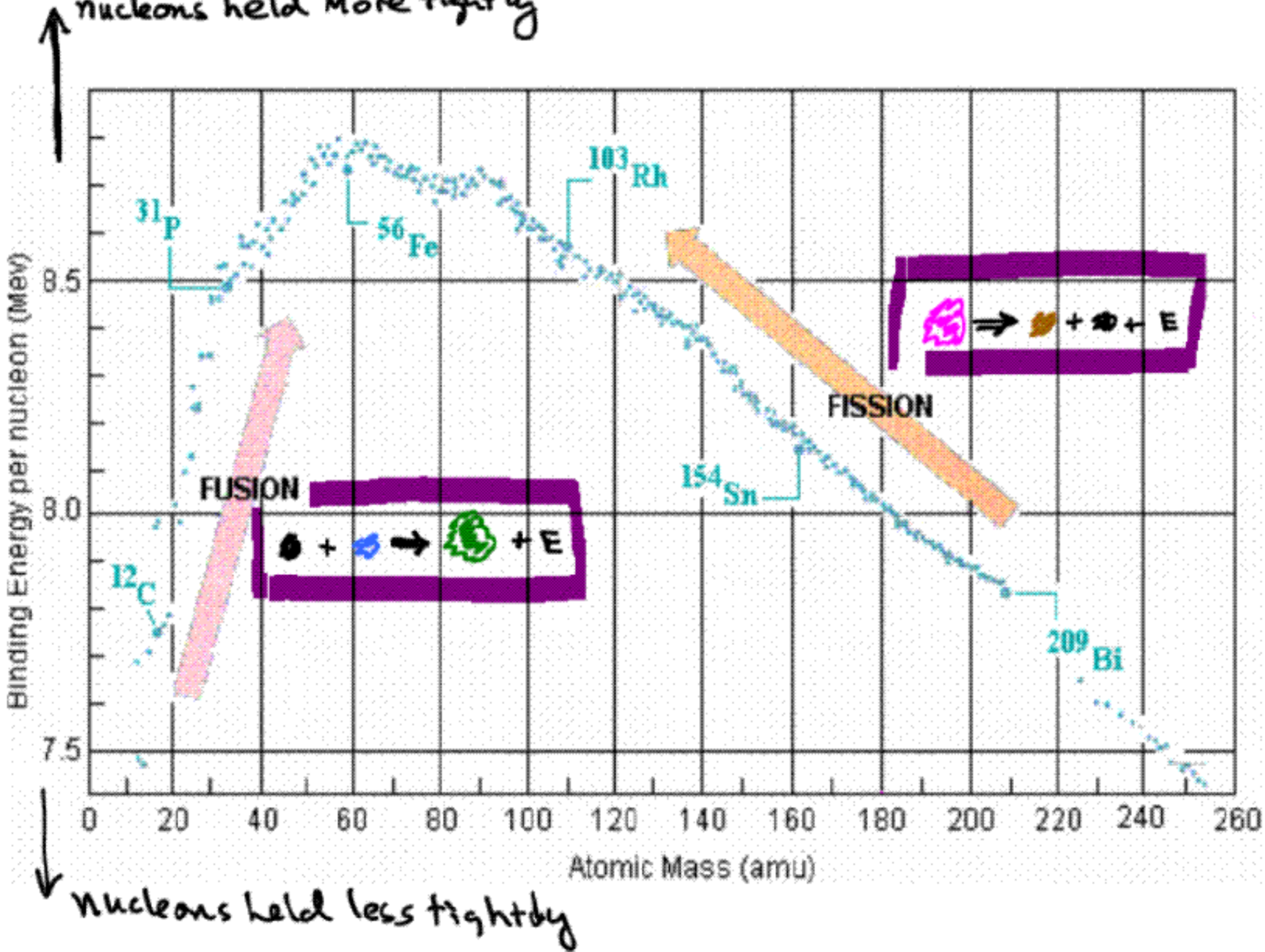
Similar to Fat Man
used on Nagasaki
Aug 9, 1945

Similar to Little Boy
used on Hiroshima
August 6, 1945



Diagrams from Wikipedia

Inherent Nuclear STABILITY as function of nuclear size



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

Atomic Bombs = Fission

Thermonuclear bomb (uses fusion)

Inertial confinement fusion

Fusion in lab on Earth

LLE lab. for laser Energetics (on UR campus)

NIF = National Ignition Facility

HOT Plasma = "TOKOMAK"