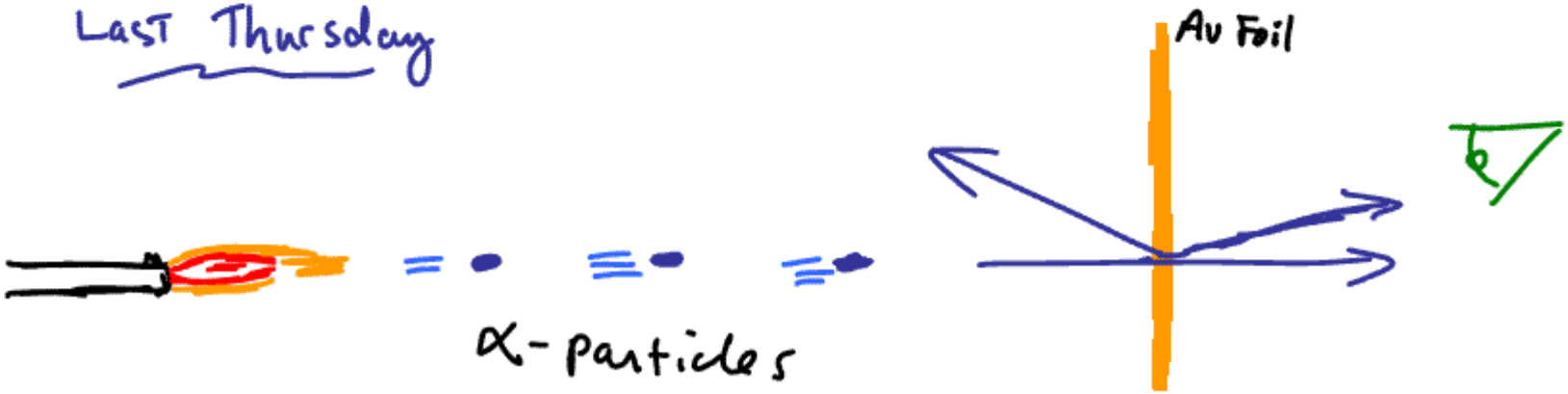
Physics 100 - October 29, 2007

- Last week's lectures
- presentation groups ... let's set times to meet w/ me

Last Tuesday — Heisenberg's Uncertainty Principle

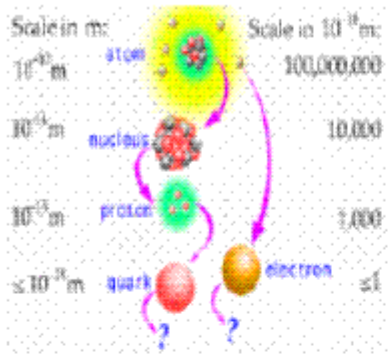
$$\Delta x \, \Delta p \sim h \qquad \Delta E \, \Delta t \sim h$$

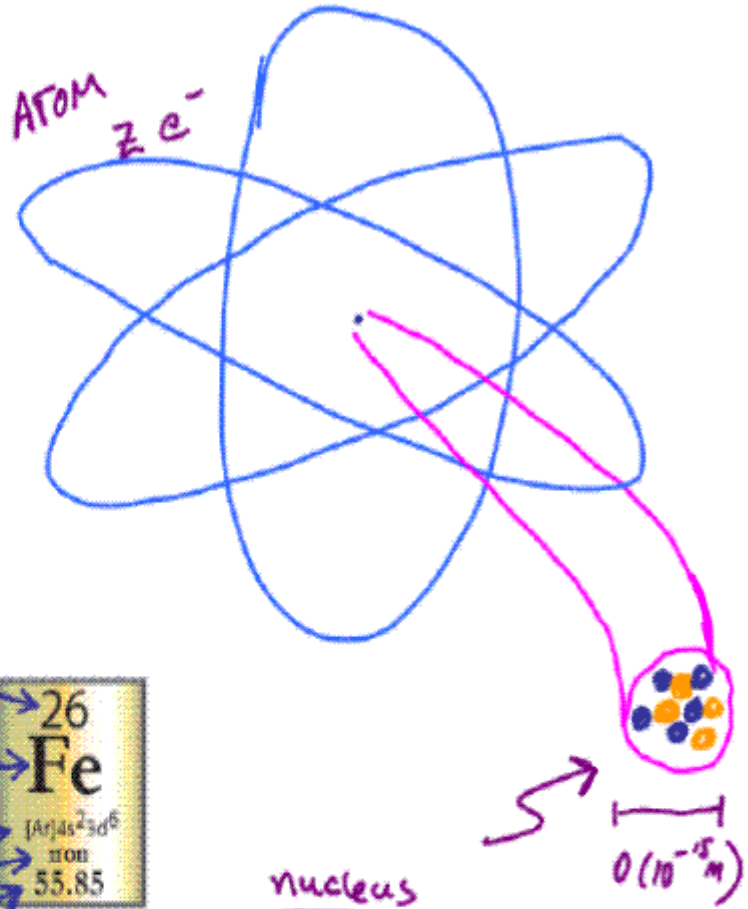
Last Thursday

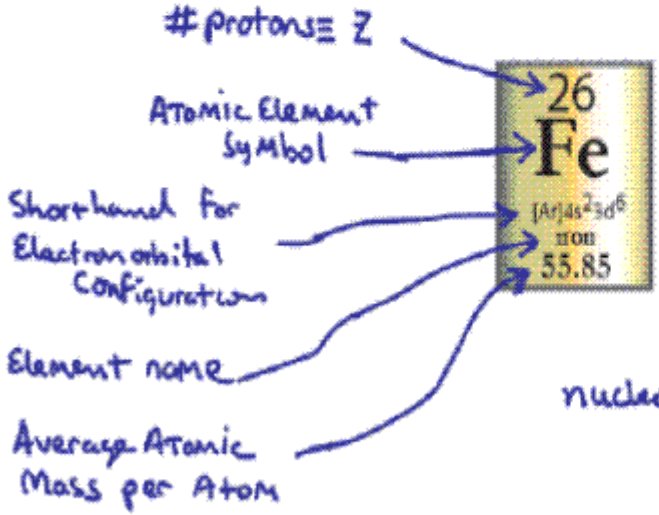


Nuclear model of atom

nuclear physics







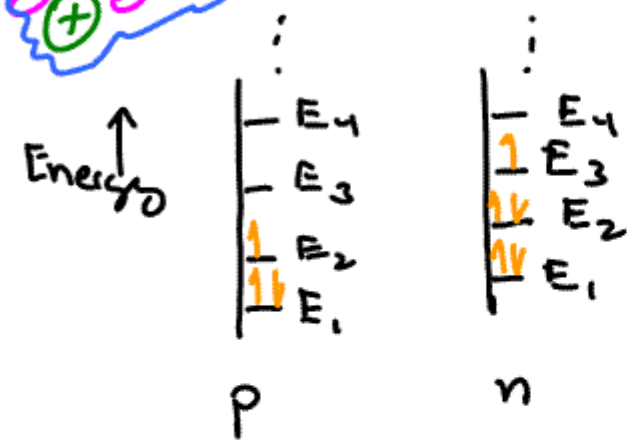
nucleus

nucleons [Z protons
A-Z neutrons

A ≡ Atomic Mass

Why does nucleus NOT Blow Apart?

The nucleus

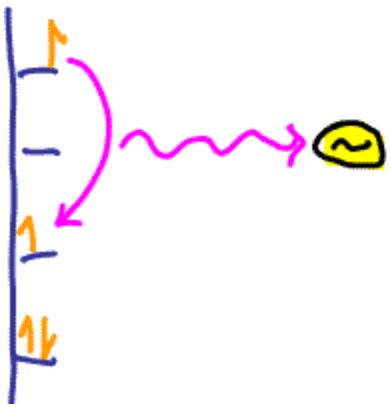


Strong Nuclear force

Discrete quantum states

TRANSITIONS between discrete STATES

similar to e^- in atom



γ-ray

TRANSITION Energies ~ 10^6 eV !

There exists a Strong nuclear force that is

Much stronger than gravitation and electromagnetism

but has a range limited to $\sim 10^{-15}$ m

$\Rightarrow$ Pop this force into Schrödinger's equation

get discrete energy levels for nucleons

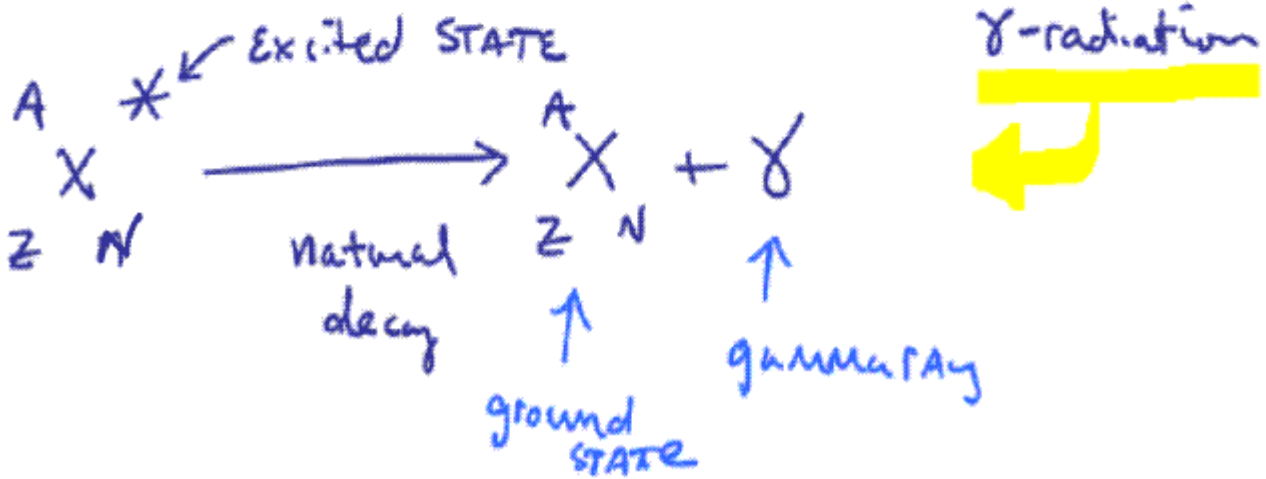
$$ {}^{A}_{Z}X_{N} $$

A ≡ # protons + neutrons

Z = # protons

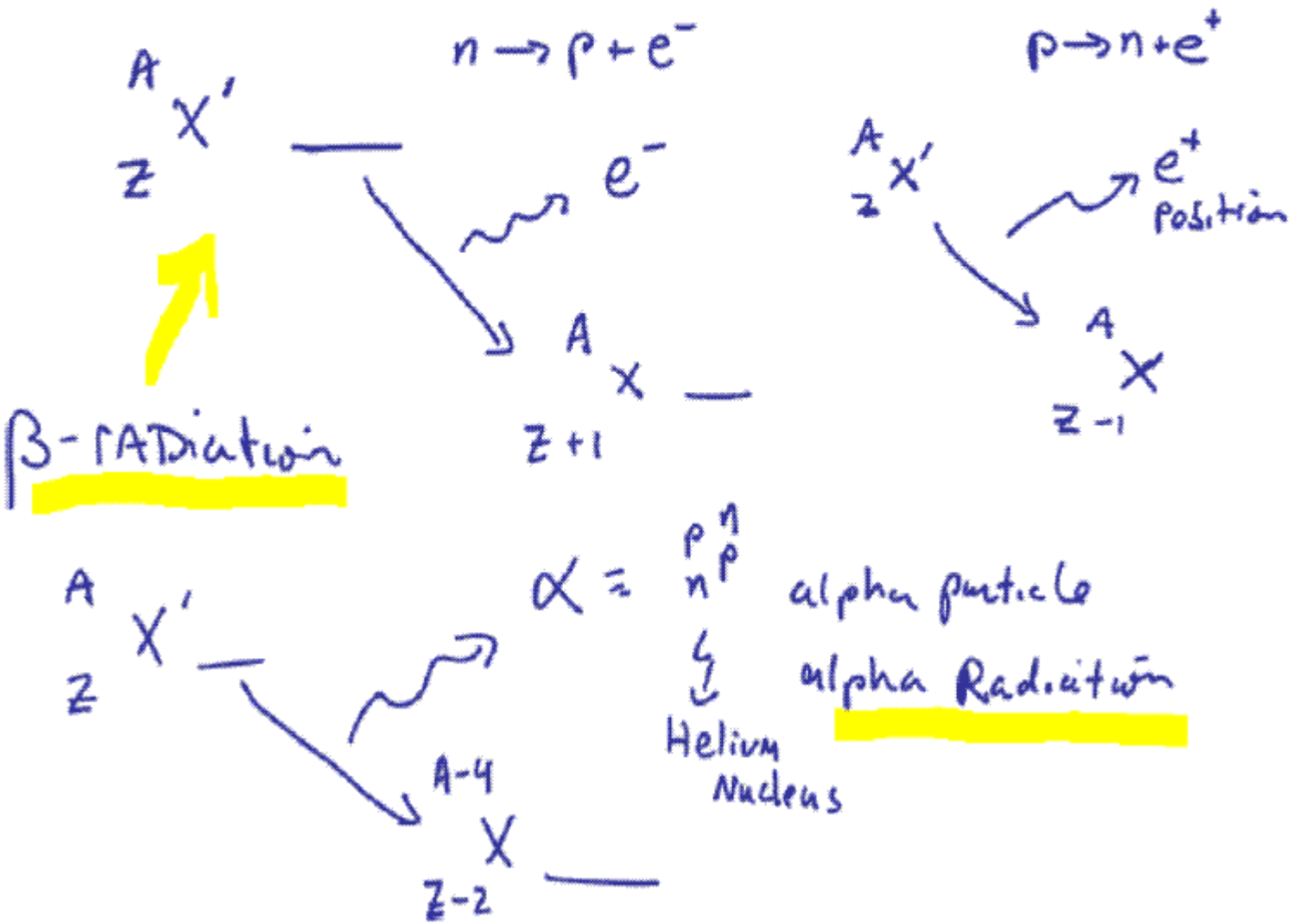
N = # neutrons

X = Atomic Element Symbol



Naturally radioactive substance

$E = mc^2$



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

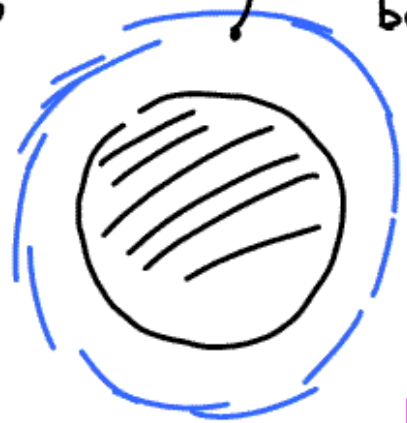
$$t_{1/2} = \frac{0.693}{\lambda}$$

Radioactive Dating

" 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 from an archeological dig has a ^{14}C activity that is 25% of that in a living material. How old is the bone?

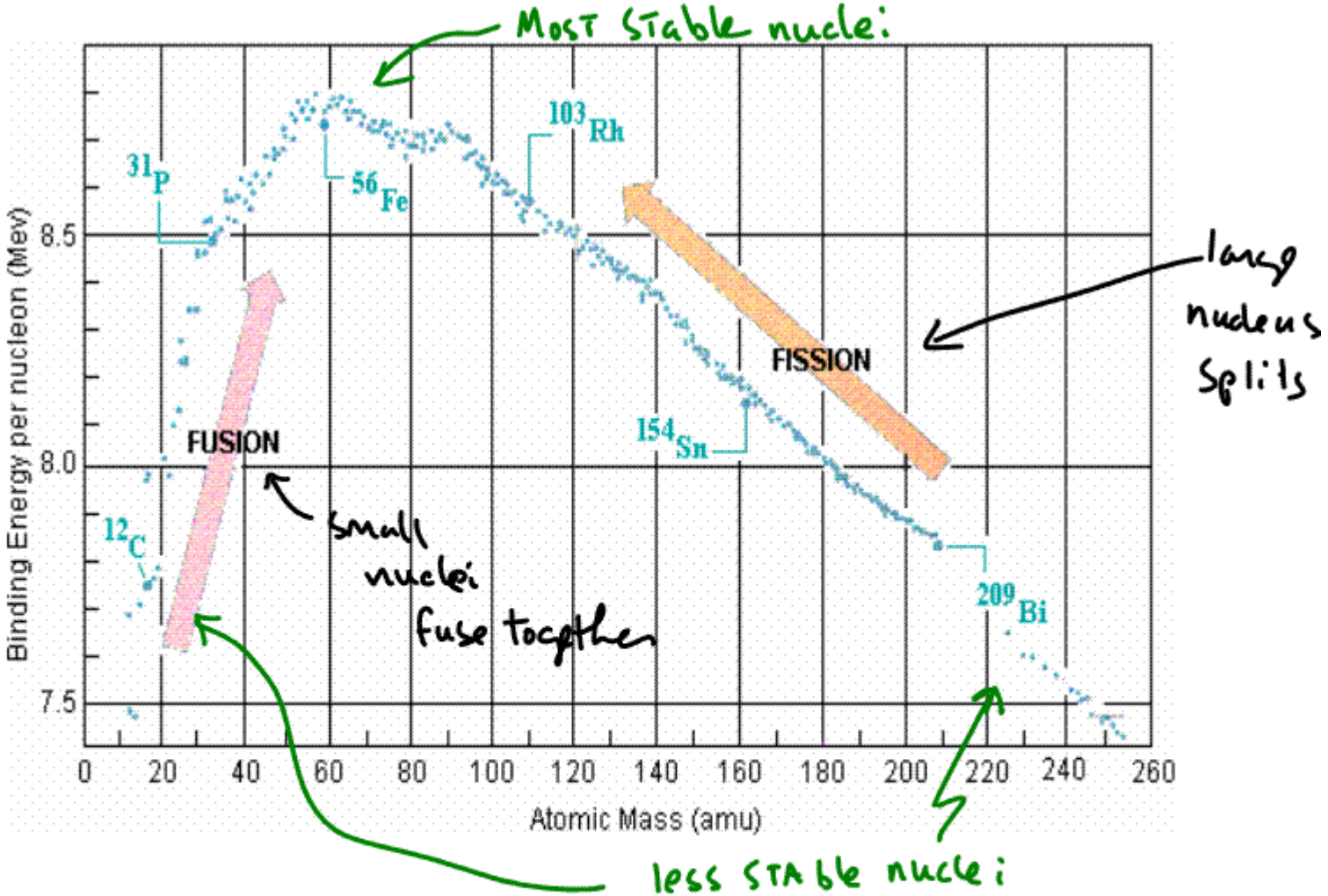
^{14}C $t_{1/2} = 5730$ years

Solution

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

1 halflife : Activity falls to 50% of original
2 halflives : " " " 25% " "

Age $\sim$ (2) 5730 years $\sim$ 11,400 years



Binding energy/nucleon is a measure of how hard it is to remove a nucleon from the nucleus ... similar to how ionization energy is a measure of how hard it is to remove e^- from atom

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

neutron

cascade of decays

$\gamma\gamma \quad \gamma\gamma$

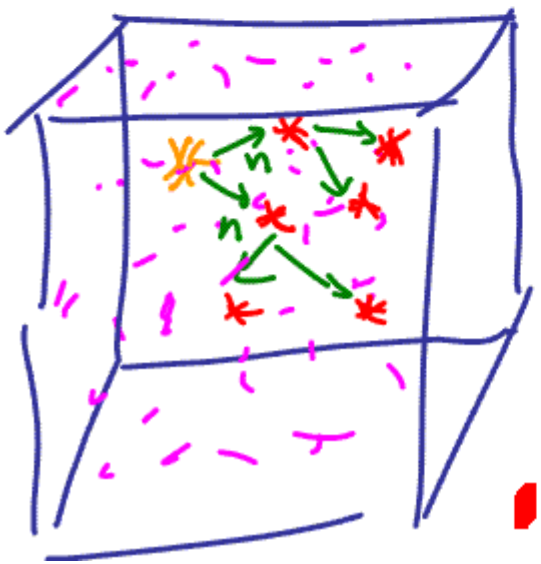
$\Sigma Mass = M_i$

$\Sigma Mass = M_f$

nuclear fission

$E = mc^2$

$M_f - M_i > 0$



Chain reaction

- critical 1 split for 1 split
- Subcritical <1 split per neutron (split)
- Supercritical >1 split per split

$^{235}U \sim 0.7\%$ } naturally occuring
$^{238}U \sim 99.3\%$ }

$$^{238}U + n \rightarrow {}^{239}U \rightarrow {}^{239}Np + e^- + \bar{\nu}$$

($\bar{\nu}$: neutrino)

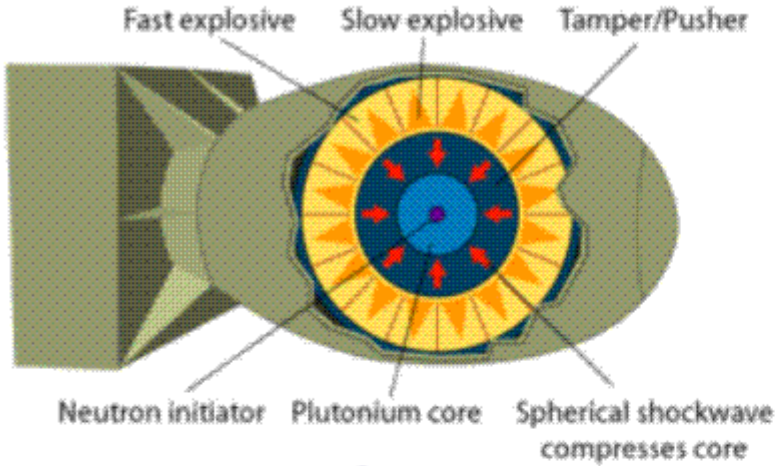
$^{239}Np \hookrightarrow {}^{239}Pu$ — can be used as nuclear fuel

Breeder reactor process

^{235}U useful for fission bombs because you can make a "chain reaction"

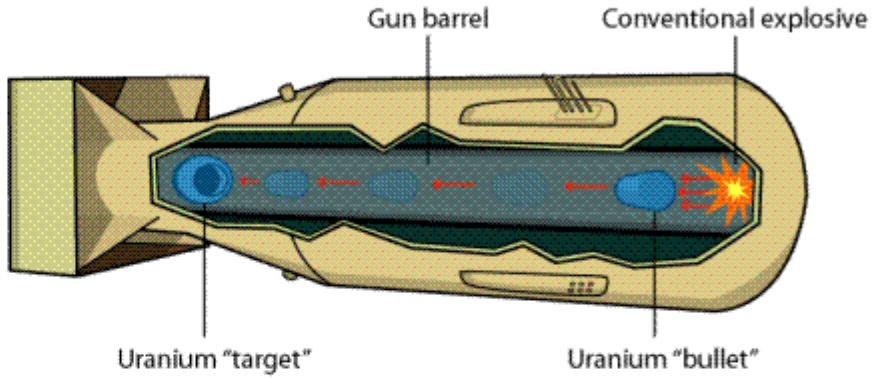
$$n \rightarrow {}^{235}U \Rightarrow {}_{0}^{0} + 2n \rightarrow {}^{235}U,\ {}^{235}U$$

Not what happens with ^{238}U



Similar to Fat Man
used on Nagasaki
Aug 9, 1945

Similar to "Little Boy"
used on Hiroshima
August 6, 1945



Diagrams from Wikipedia

Fortunately ^{235}U makes small % of natural uranium ore

must purify to separate ^{235}U from ^{238}U

This is hard.

Plutonium easy enough to get from bombarding ^{238}U w/ neutrons. Bomb is technically harder to make work.