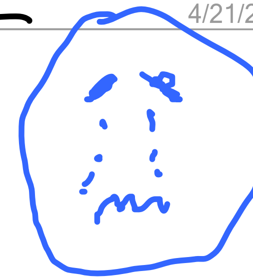
Physics 114 – April 28, 2015

Note Title 4/21/2010



- Posted Solns to P.S. 11
- Posted P.S. 12 – Not to be turned in
- Also posted solutions to P.S. 12
- Final Exam – May 6 Hubbell 7:15 pm
  Formula Sheet, Calc, etc. ...
- Q+A session TBA

Final is cumulative — 30% ish on new material

Since Exam 3:

light, refraction	Ch 32 (NOT spherical mirrors 32-3, NOT 32-8)
Thin lenses, optical instr	Ch 33 (NOT 33-4, 33-5, 33-10)
Interference	Ch 34 (NOT 34-6, 34-7)
Diffraction, Polarization	Ch 35 (NOT 35-12, 35-13)
Rise of QM, Bohr	Ch 37
QM	Ch 38 (NOT 38-9, 38-10)
ATOMS	Ch 39 (NOT 39-7 thru 39-10)
Nuclear	Ch 41

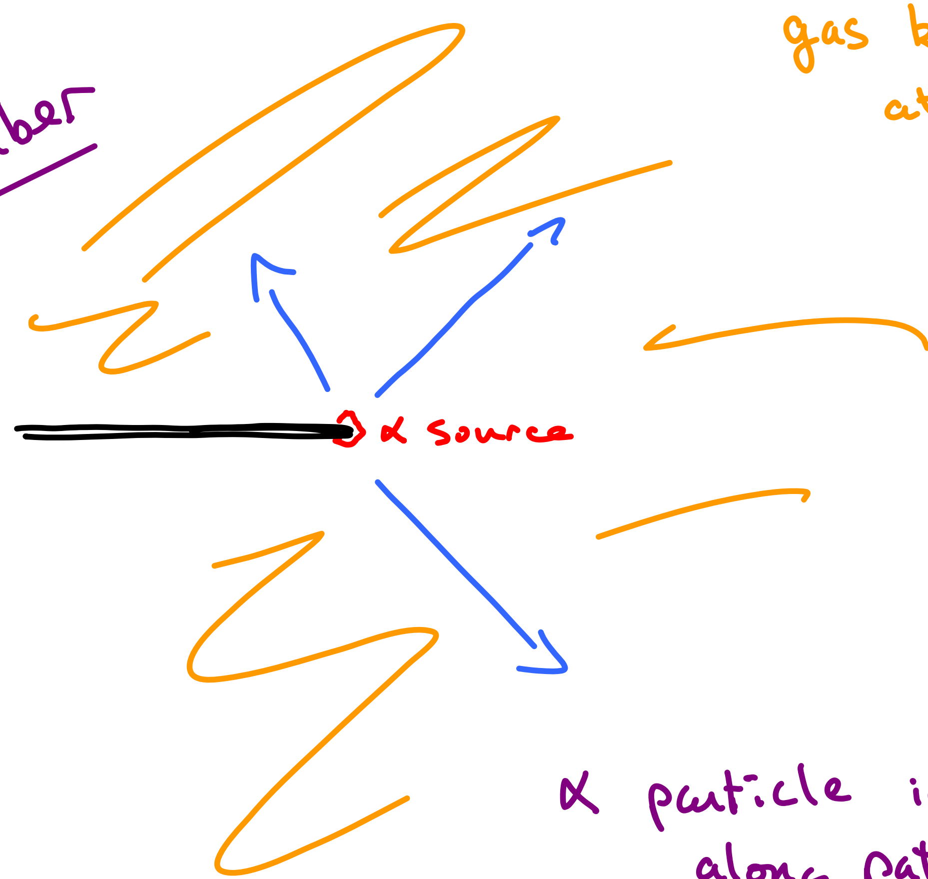
Exams Here if you still need to pick up
one of yours

regrade requests to date done + here

Dar
Miyamoto
Kim
Ritter
O'Brien
Chen
Liew
Shinaman

Cloud chamber

gas kept just at point of condensation



α particle ionizes gas along path

gas condenses at points of energy deposition

"See" track

Max Born German (1882-1970)

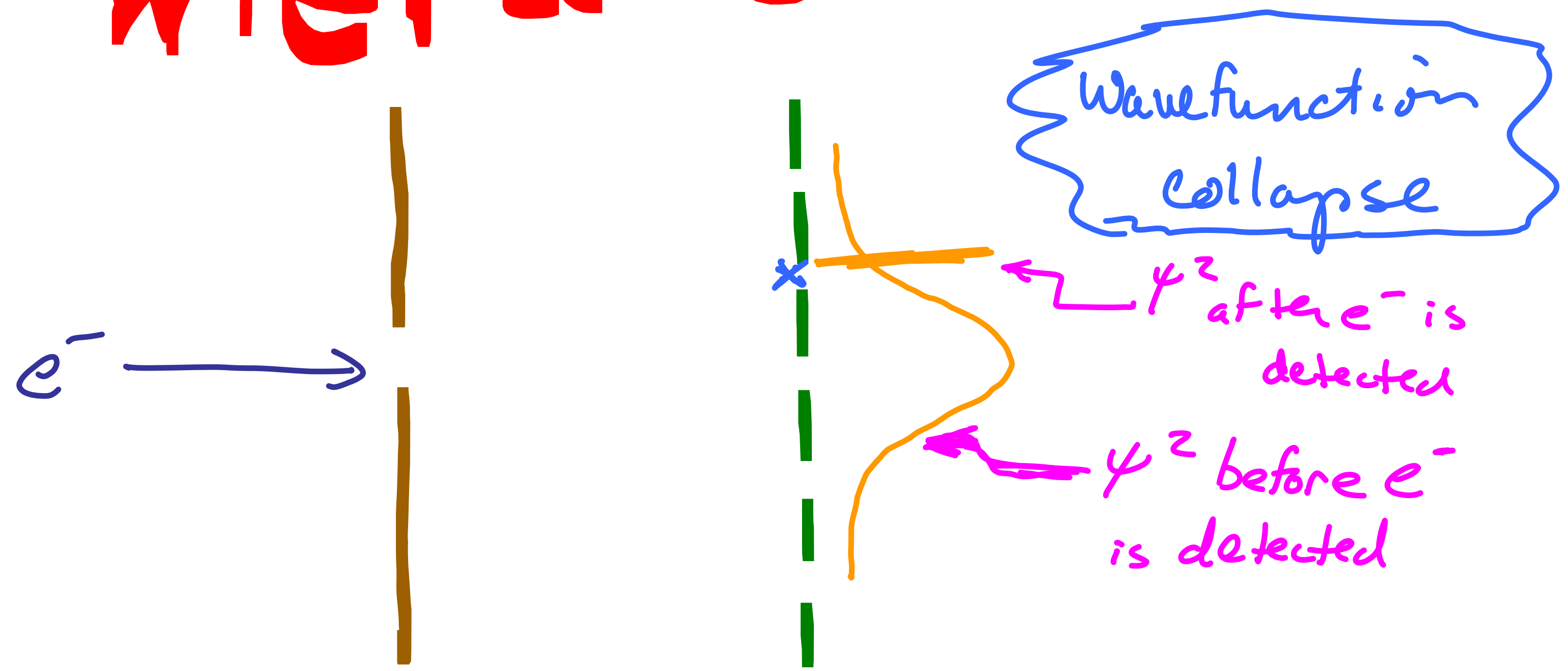
1954 Nobel Prize in physics

"For his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction"

$\psi(x)$ wave function

$\psi^2_{(x)}$ ~ probability of finding particle in region of space

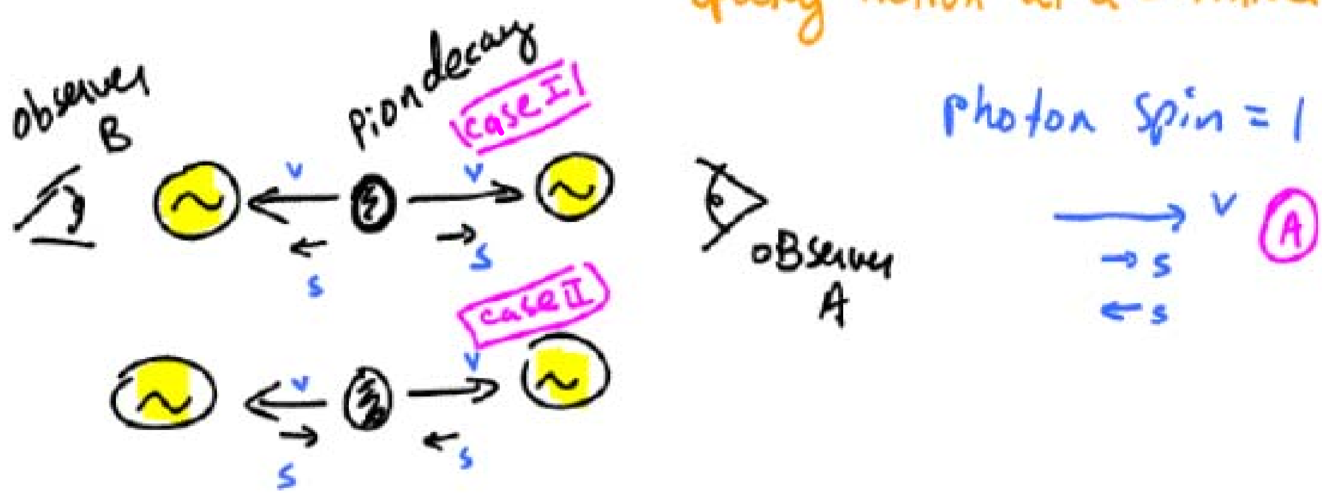
Quantum wierdness!



Once electron hits the film/Detector we know with 100% certainty where the electron hits
- So wavefunction has to "collapse"

EPR Paradox — Einstein, Podolski, Rosen 1935

"Spooky Action at a distance"



Two photons are produced at once — They are correlated.

If one has spin one way the other has spin the other way.

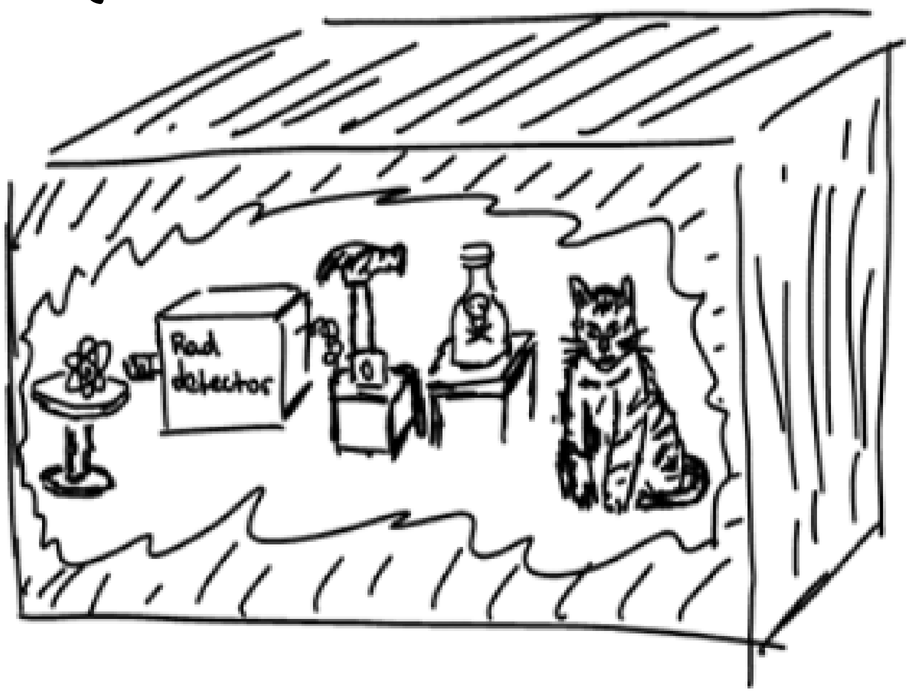
They are in an "entangled quantum STATE"

When observer A observes the spin of photon — The wavefunction collapses and the spin of the photon observer B will observe is determined.

But collapse instantaneous and observers A + B far apart

Does this mean information conveys faster than speed of light?

Schrödinger's Cat



thought experiment
nucleus has 50:50 chance of decaying + killing the cat.
What is the "state" of the cat before box opened?

Copenhagen Interpretation

$$\text{nucleus quantum state} = \frac{1}{2}(\text{decayed}) + \frac{1}{2}(\text{not decayed})$$

$$\text{cat state} = \frac{1}{2}(\text{dead}) + \frac{1}{2}(\text{alive})$$

Hugh Everett (1957)

Bryce DeWitt 1960's + 70's

→ Many Worlds interpretation

Overall wavefunction does not collapse. It evolves in time. "Decoherence" forces wavefunction to evolve into different streams that do not interact.

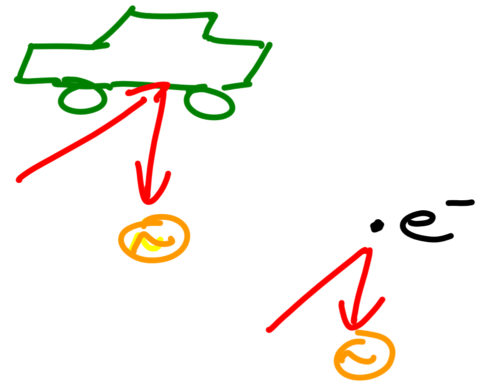
Heisenberg's Uncertainty Principle

~1927

$$\Delta x \, \Delta p \geq \frac{h}{2\pi}$$

Δx: uncertainty in position

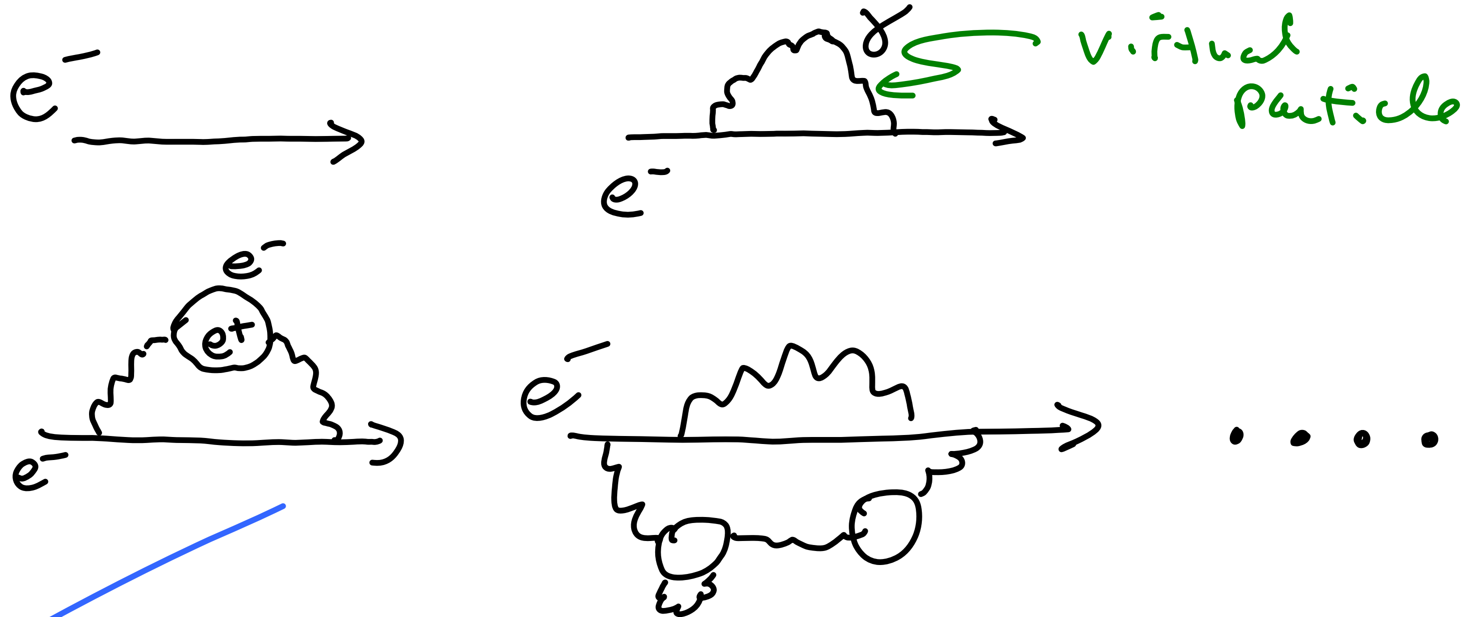
Δp: uncertainty in momentum (mv)



$$\Delta E \, \Delta t > \frac{h}{2\pi}$$

ΔE: uncertainty in energy

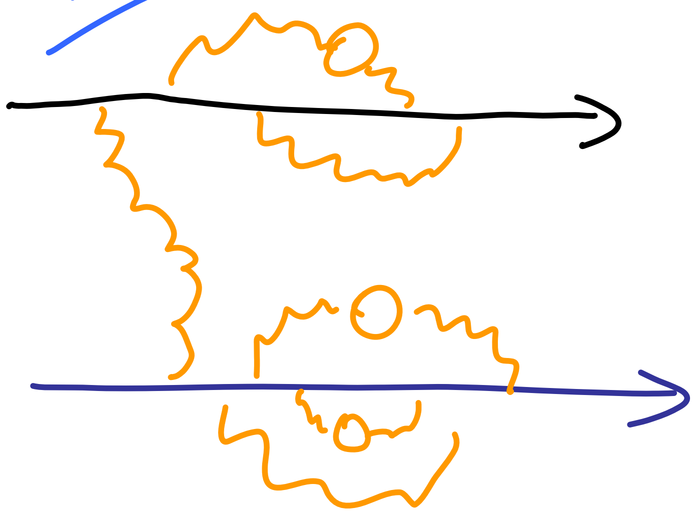
Δt: Time over which system exists



Quantum Field theory

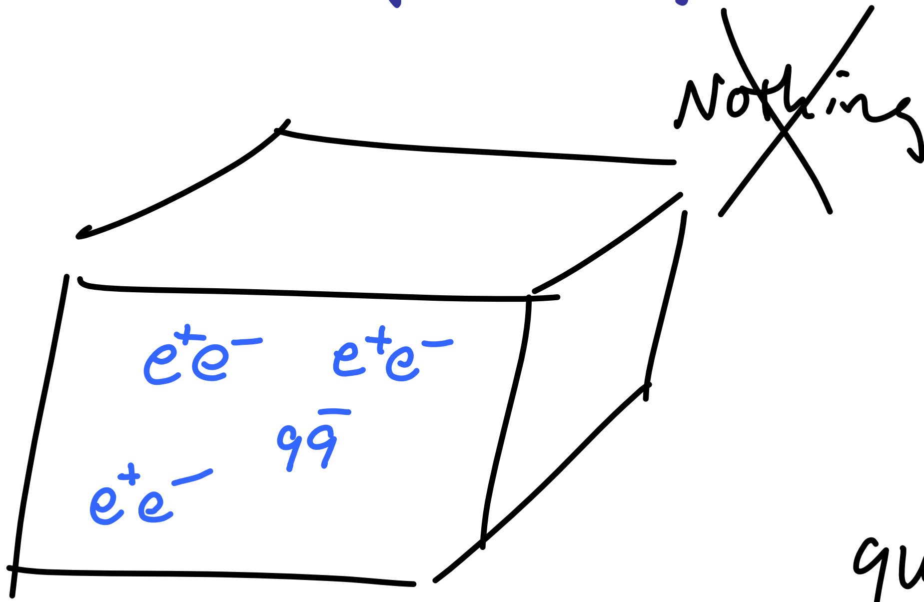
Quantum Electrodynamics

Richard Feynman + others

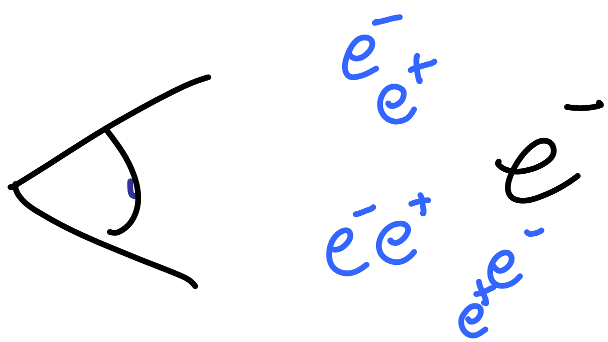


essence of force in quantum field theory is exchange of virtual particles

Vacuum is not empty - fleeting Particle - Antiparticle pairs Appear consistent w/ Heis. Unc. Principle



quantum Vacuum



Vacuum polarization -

can actually see an effect on Atomic spectra (Lamb shift)

The Journey into Inner Space

Nuclear physics

By the way, the word
'nuclear' is pronounced

nūk-lē-ər

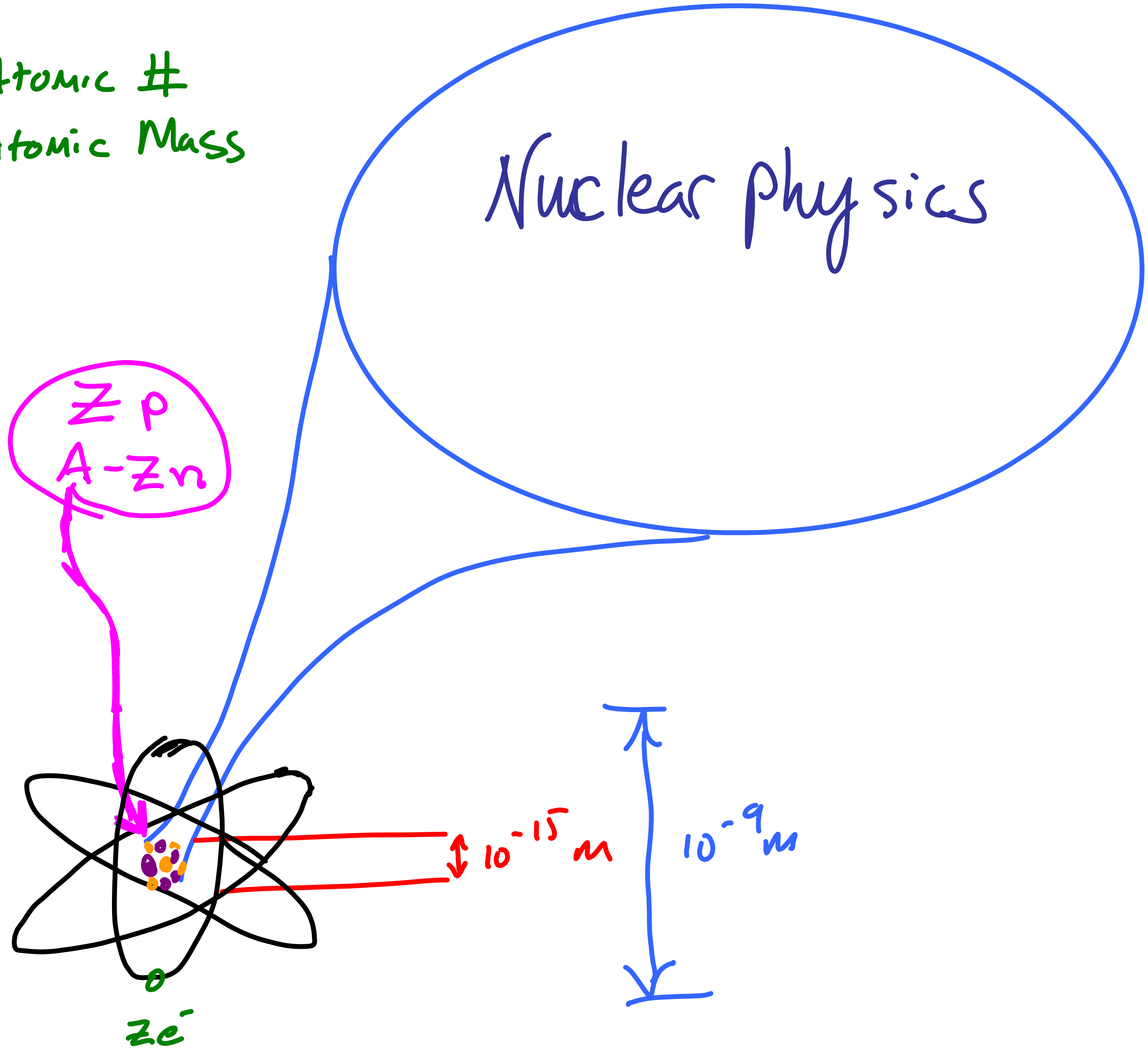
and *not*

nūk-ū-lər.

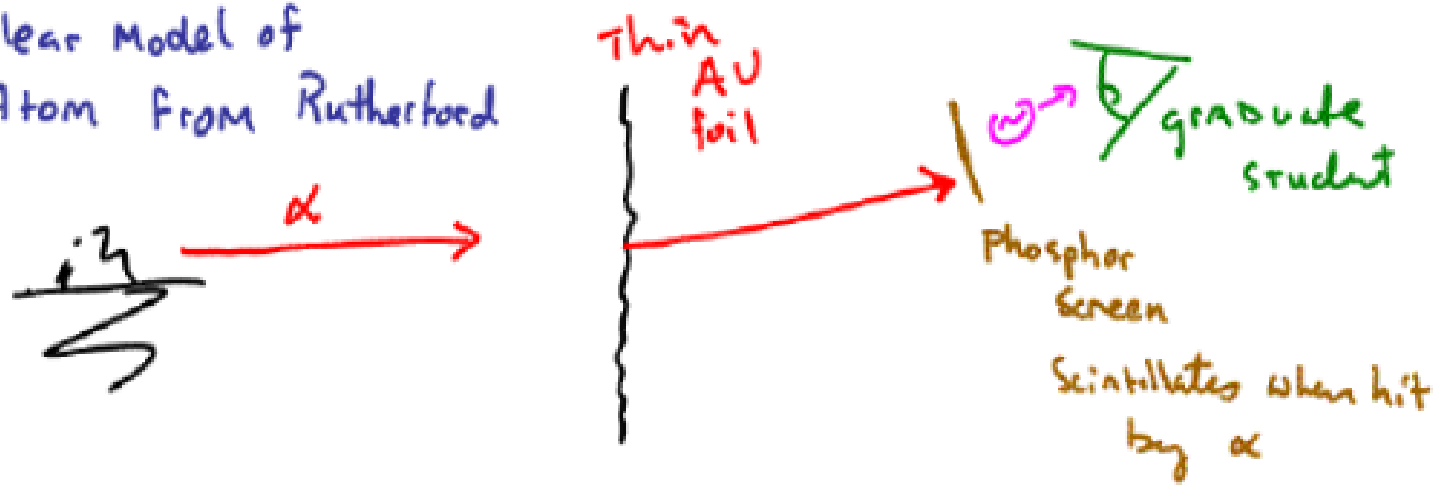
Got that Mr.
President!?

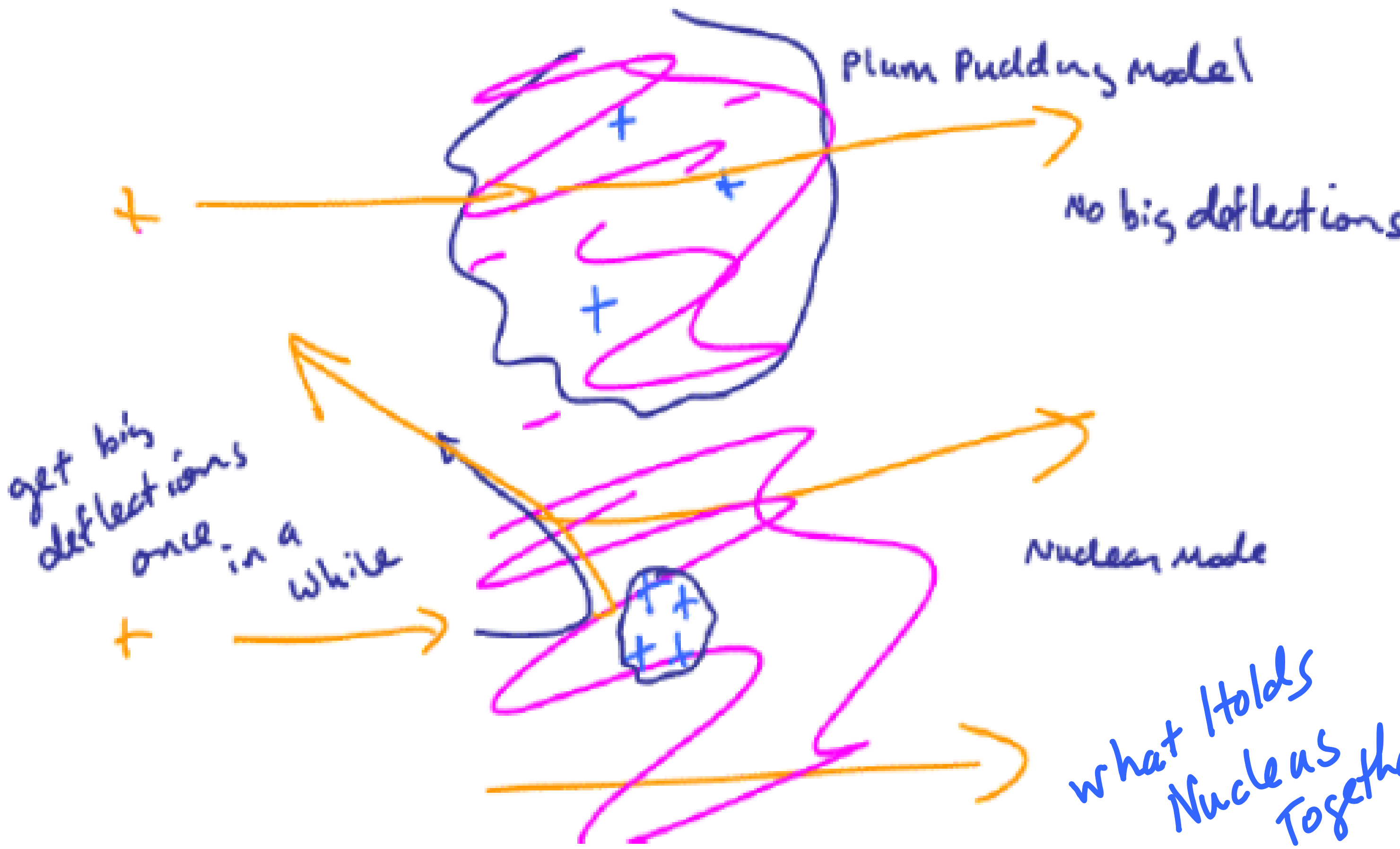
$Z \equiv$ Atomic #

$A \equiv$ Atomic Mass

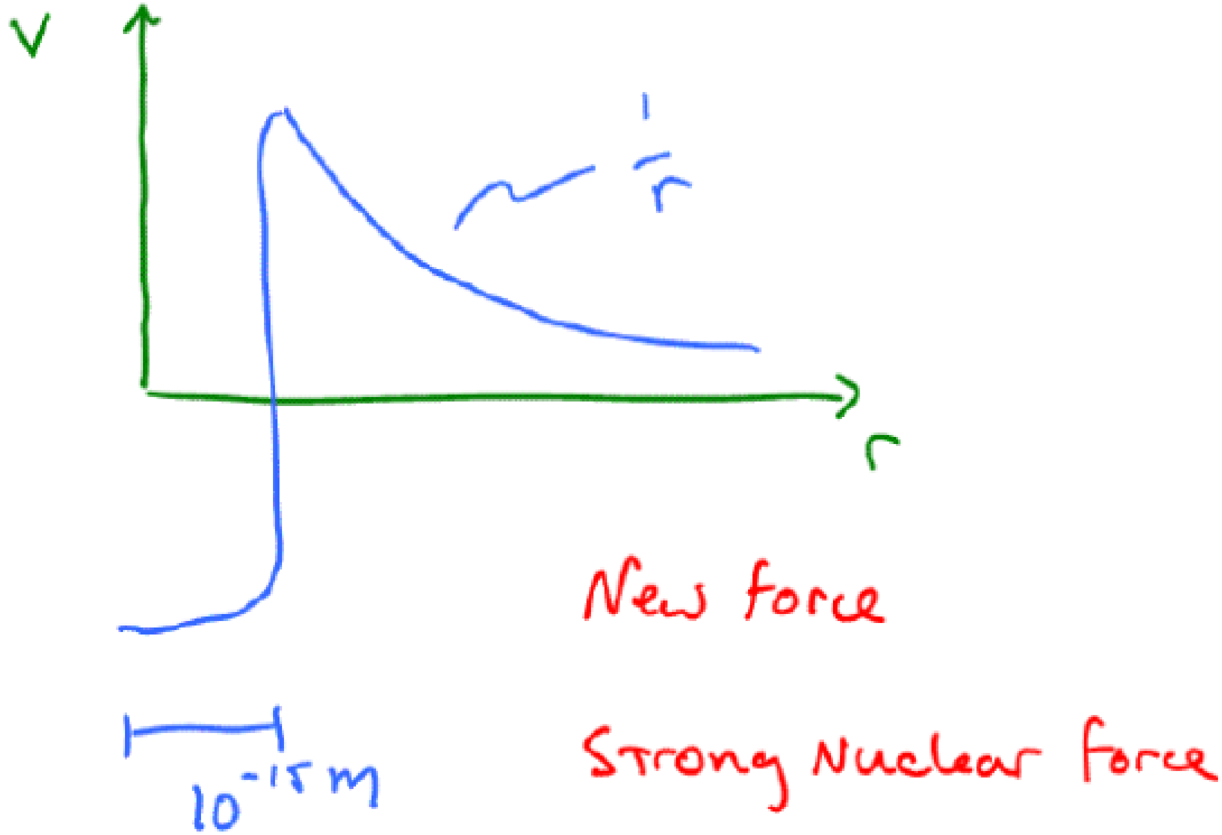


Nuclear Model of Atom from Rutherford





what Holds
Nucleus
Together?!



Nuclear radius ~ 1–10 Fermi (10^{-15} m)

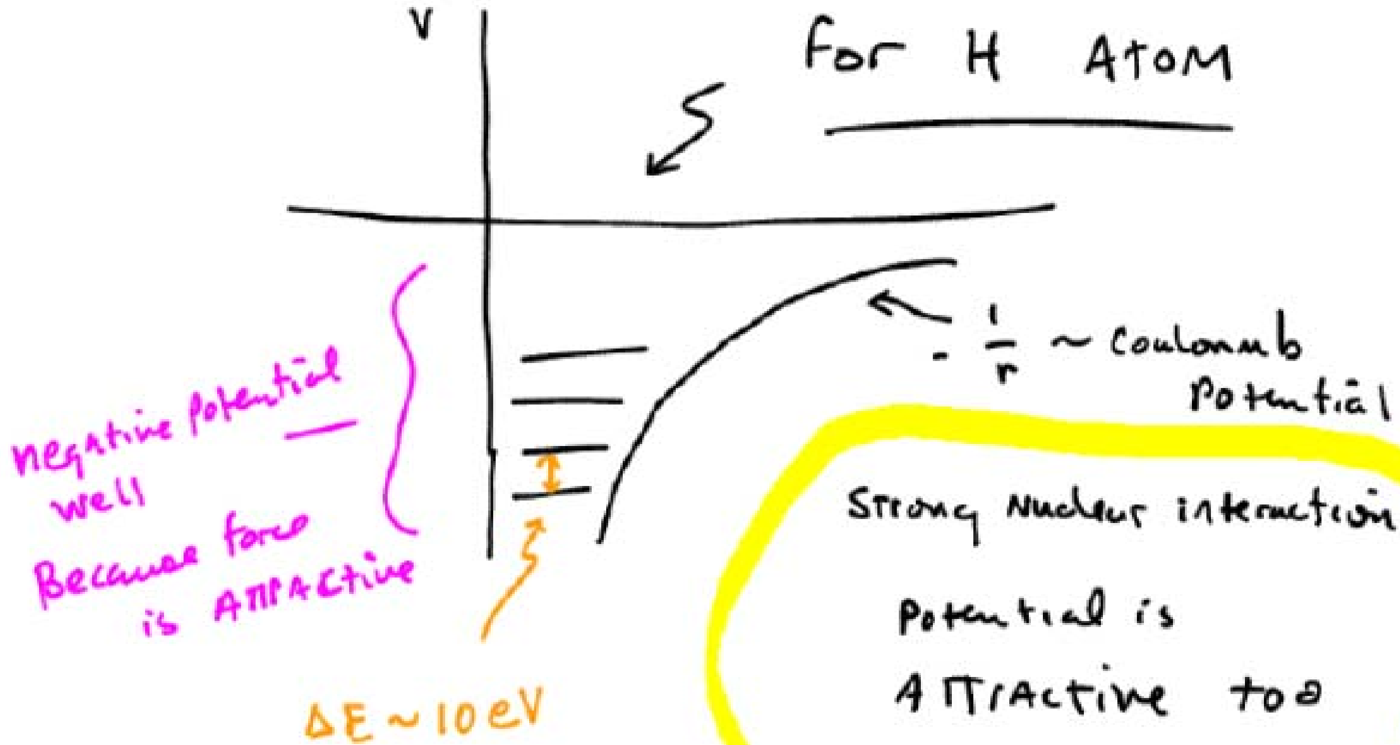
Nuclear density is constant

$$\frac{A}{\frac{4}{3}\pi R^3} \sim \text{const.} \qquad A \sim R^3 \qquad R \sim A^{1/3}$$

$\rho \sim 10^{17}\ kg/m^3$

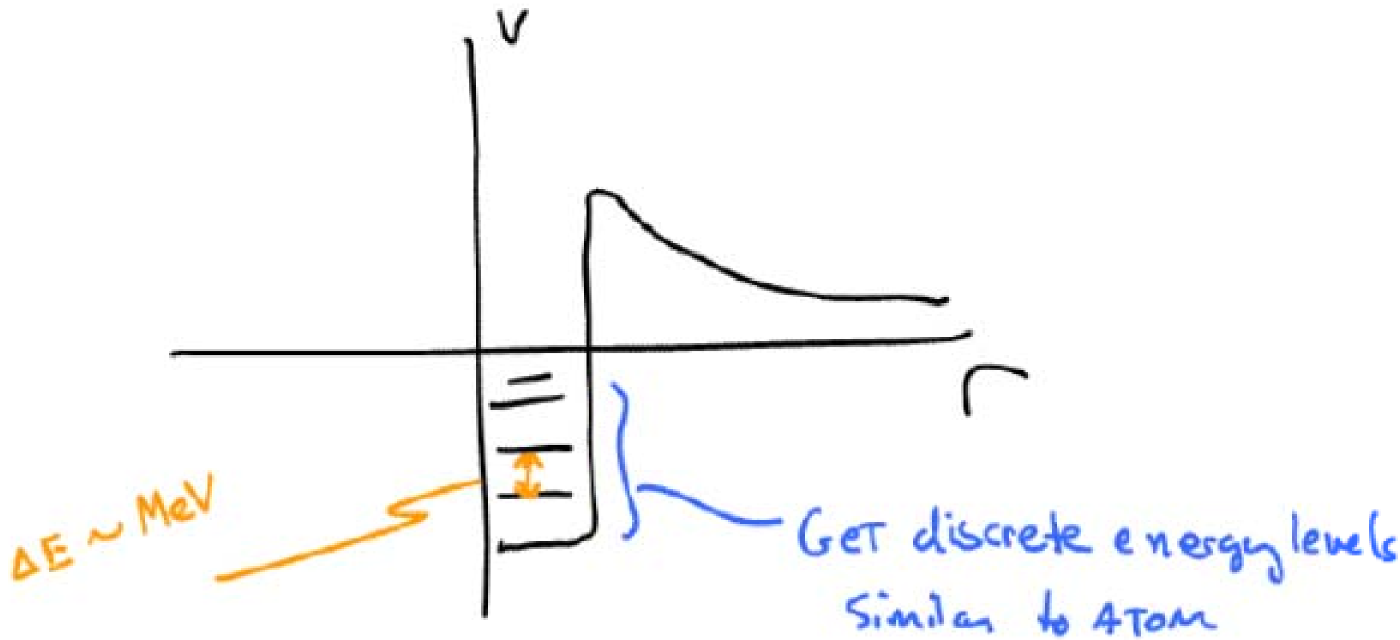
At this density

$M_{earth} \rightarrow$ ball 140 m in radius



Strong Nuclear interaction

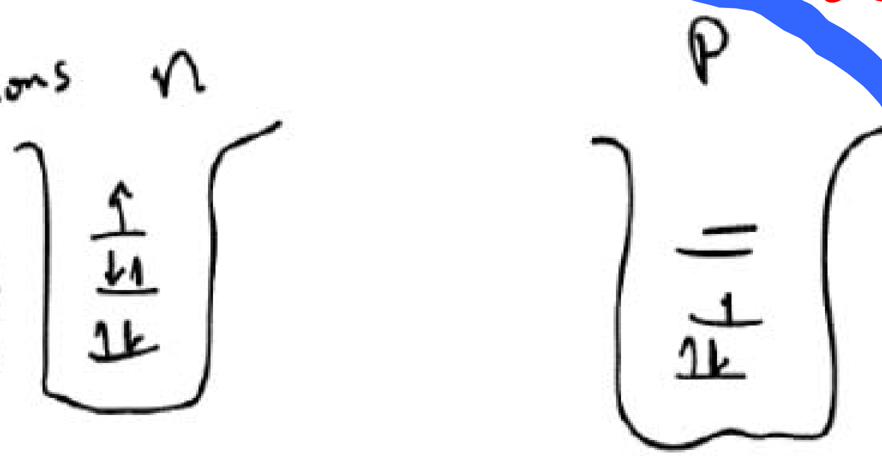
Potential is ATTRACTIVE too



But separation O(MeV) instead of O(10 eV)

p, n Spin 1/2

fill shells w/ protons + neutrons in much the same way we fill atomic shells



Nuclear physics units

$E = mc^2$ from Special theory of relativity

[Not covered yet]

recall the electron-Volt ≡ eV

Chemistry typical energy scale $O(10\text{ eV})$

Nuclear physics typical energy scal $O(10^6\text{ eV})$

$E \sim \text{MeV}$

Mass units MeV/c^2 or MeV ... loose + incorrect

$m_e = 0.511\ \text{MeV}/c^2$

$m_p = 938\ \text{MeV}/c^2$

1 GeV = 1000 MeV or (1 billion eV)

LHC Now ≈ 7 TeV = 7000 GeV = 5×10^{12} eV

$${}^{A}_{Z}X$$

X, Z same info

Symbol for a nucleus

$X \equiv$ Atomic Symbol

$Z \equiv$ # protons — Atomic #

$A \equiv$ Atomic Mass

$N = A - Z \equiv$ # neutrons

Isotope → same Z, different A

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

Gamma radiation γ

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

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

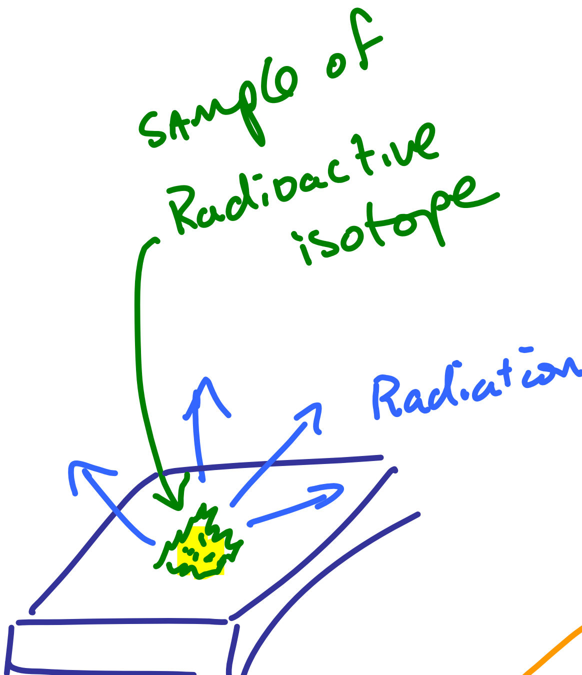
β

β radiation

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

Alpha radiation

$$\alpha = {}^{4}_{2}He$$



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

λ: decay constant

$N \equiv$ # radioactive nuclei in sample

$\frac{dN}{dt}$: Activity $\equiv$ # nuclei decaying per second

measured in Curies

$1\,Ci = 3.7 \times 10^{10}$ dec./s

$$\frac{dN}{N} = -\lambda\, dt$$

$$\int_{N_0}^{N} \frac{dN}{N} = -\int_0^t \lambda\, dt$$

$$\ln \frac{N}{N_0} = -\lambda t$$

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

→ $$N = N_0 e^{-\lambda t}$$

$\lambda \equiv$ decay constant

nuclei drop by $\frac{1}{e}$ when $t = \frac{1}{\lambda}$

"fast decay" → large λ

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

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

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

$^{14}_{6}C$, 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 $t_{\frac{1}{2}} = 5730$

after 1 half life Activity = 50 % of original

after 2 " " = 25 % of original

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

Nuclear Binding Energy

consider atomic binding energy (ionization energy)

$$m_e c^2 + m_p c^2 - M_H c^2 = 13.6\,\text{eV}$$

Energy of separate parts

energy of Bound beast

Binding energy

For Atoms ... ionization energy is what we call it.

For a nucleus "x" with A, Z:

$$(A-Z) M_n c^2 + Z M_p c^2 - M_x c^2 = \text{Total Nuclear Binding Energy}$$

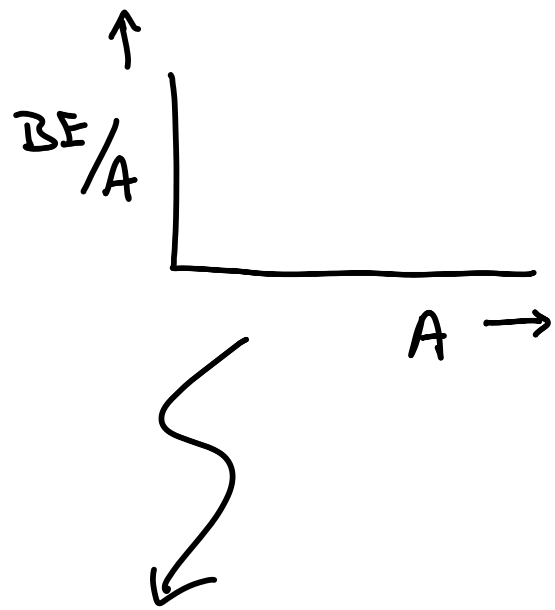
Binding Energy Per Nucleon = Total BE/A

≡ Amount of E to remove a nucleon if you will "ionization energy for a nucleon" sort of

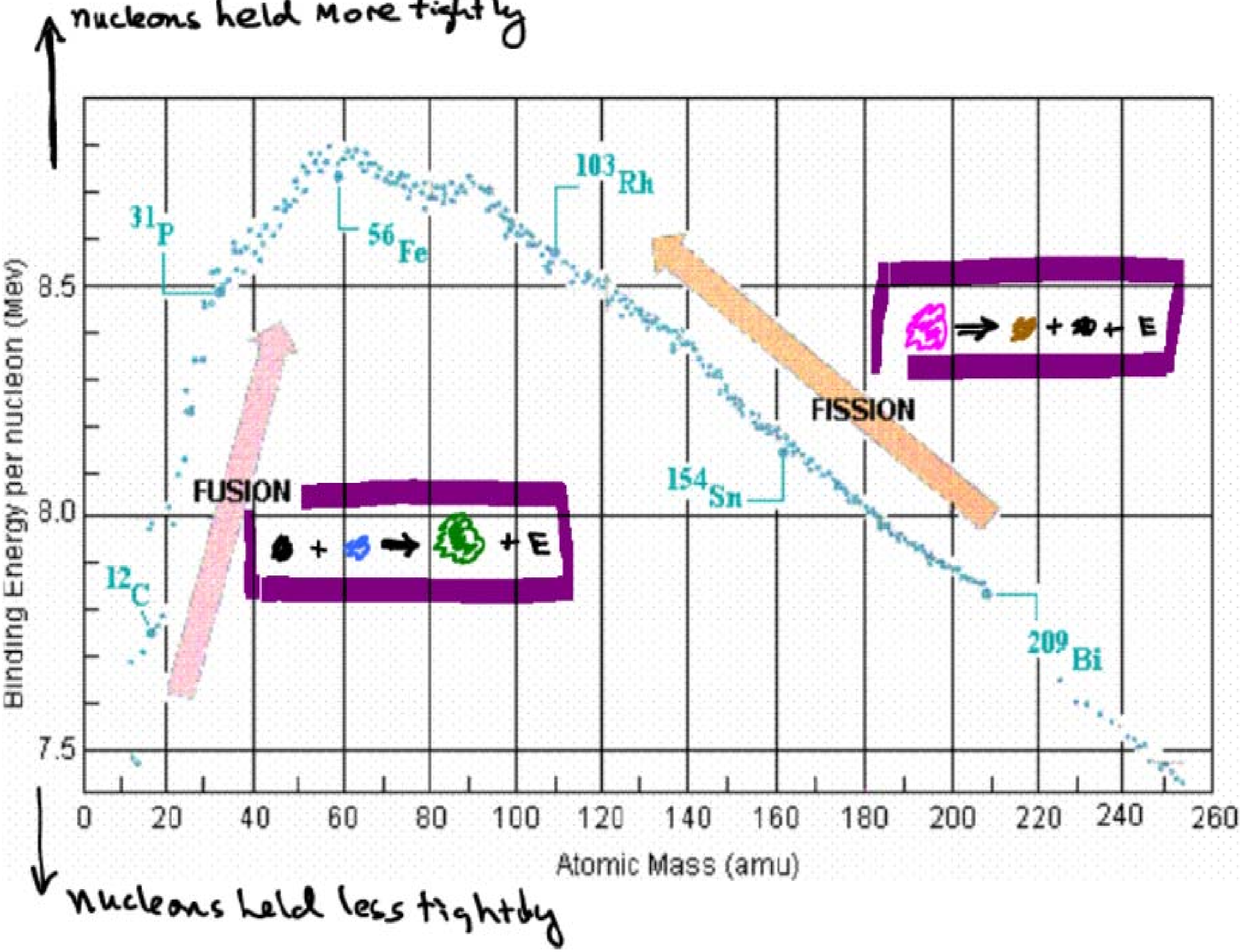
High BE/A → Very Stable nucleus

Low BE/A → less Stable nucleus

let's look at



Inherent Nuclear stability as function of nuclear size



A very important nuclear process ...

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

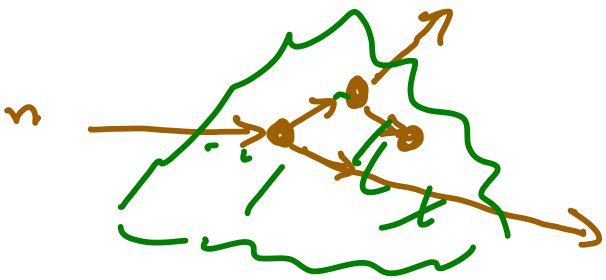
Σ mass $= M_{initial}$

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

cascade of decays

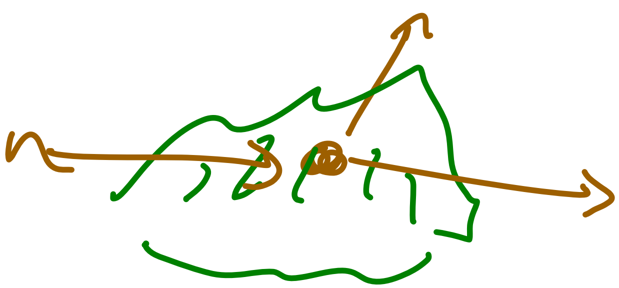
Σ mass $= M_{final}$

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



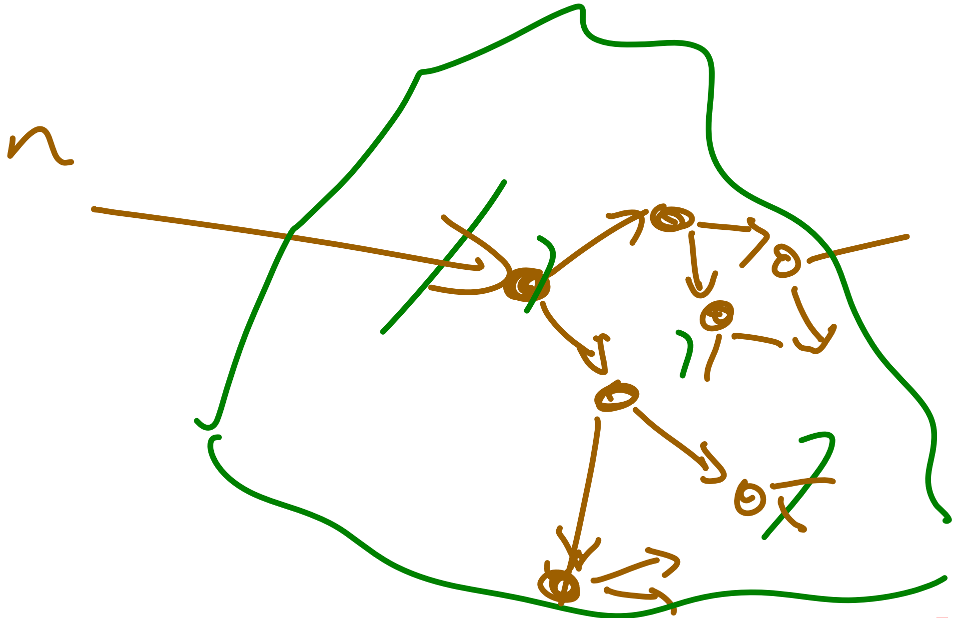
Critical

1 split per split



Subcritical

<1 split per split



Supercritical

> 1 split per split

Watchout!

kablooey!

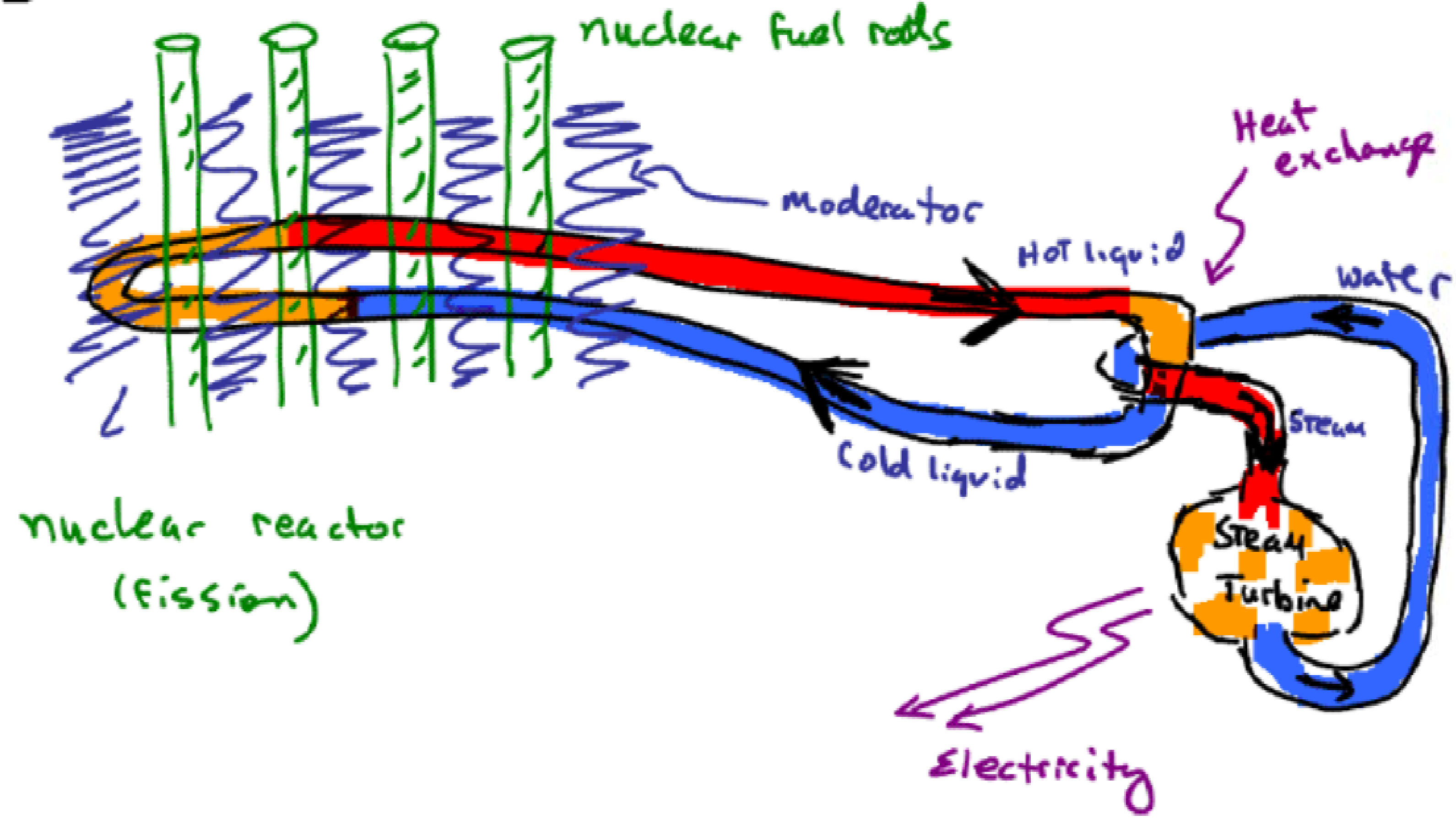
or

meltdown

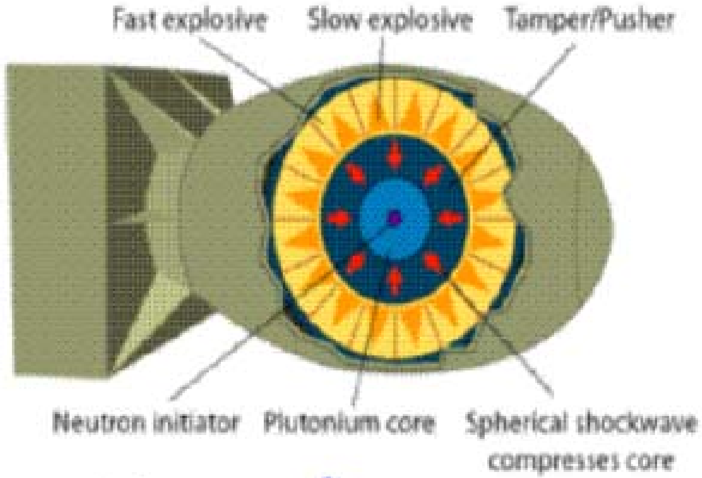
+

Fire

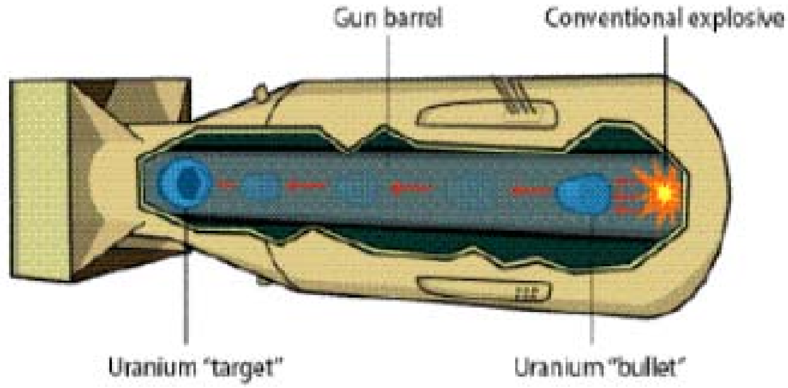
Nuclear Fission for Power



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



Similar to Fat Man
used on Nagasaki
Aug. 9, 1945



Diagrams from Wikipedia

Natural U
~99% ^{238}U
Must enrich in ^{235}U to
use as Nuclear fuel or bomb

Stars - from dust to dust

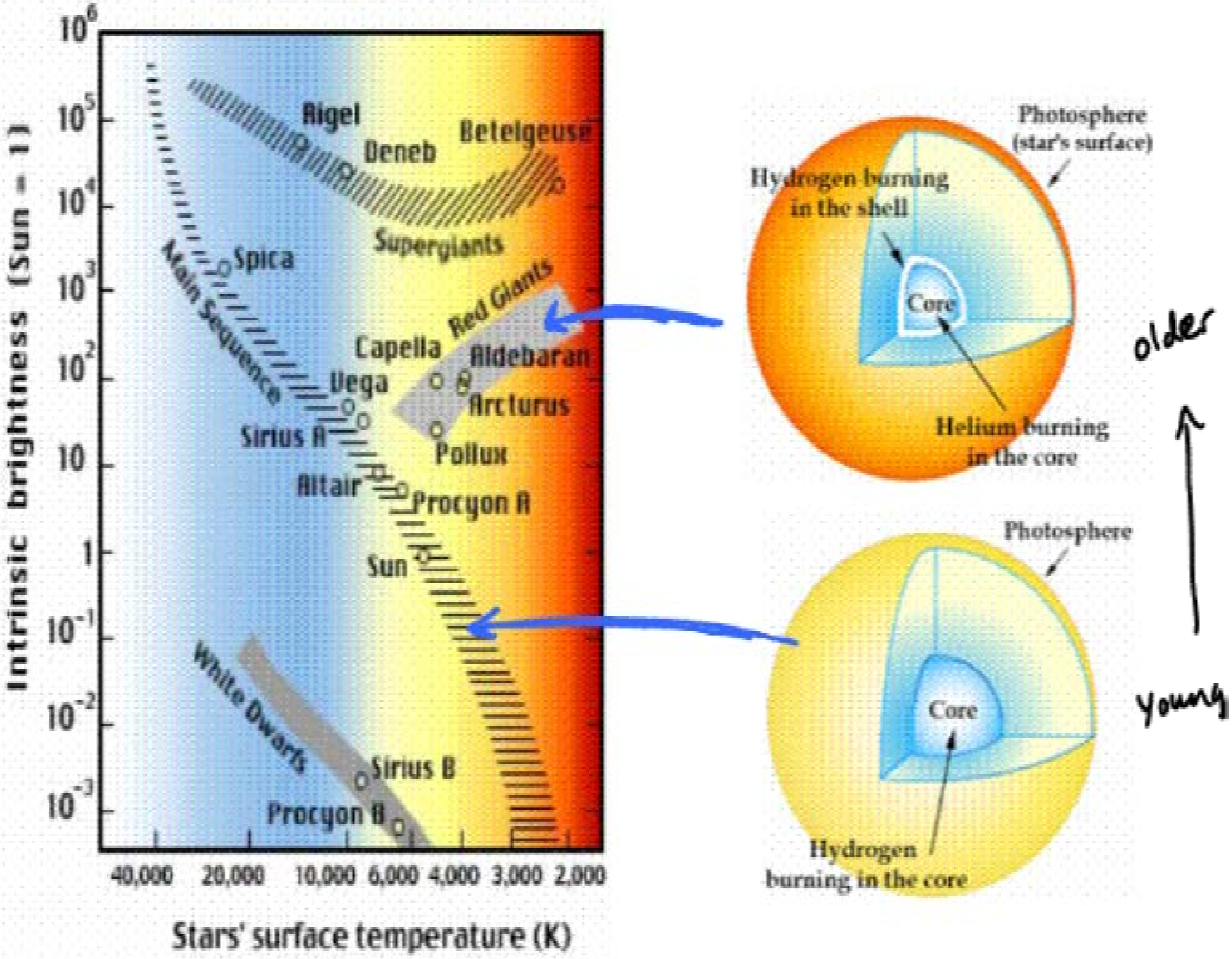
Star-Birth Clouds · M16 HST · WFPC2
PRC95-44b · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

Stars form from
condensation of gas/dust
due to gravitation

mostly hydrogen gas

The Pleiades

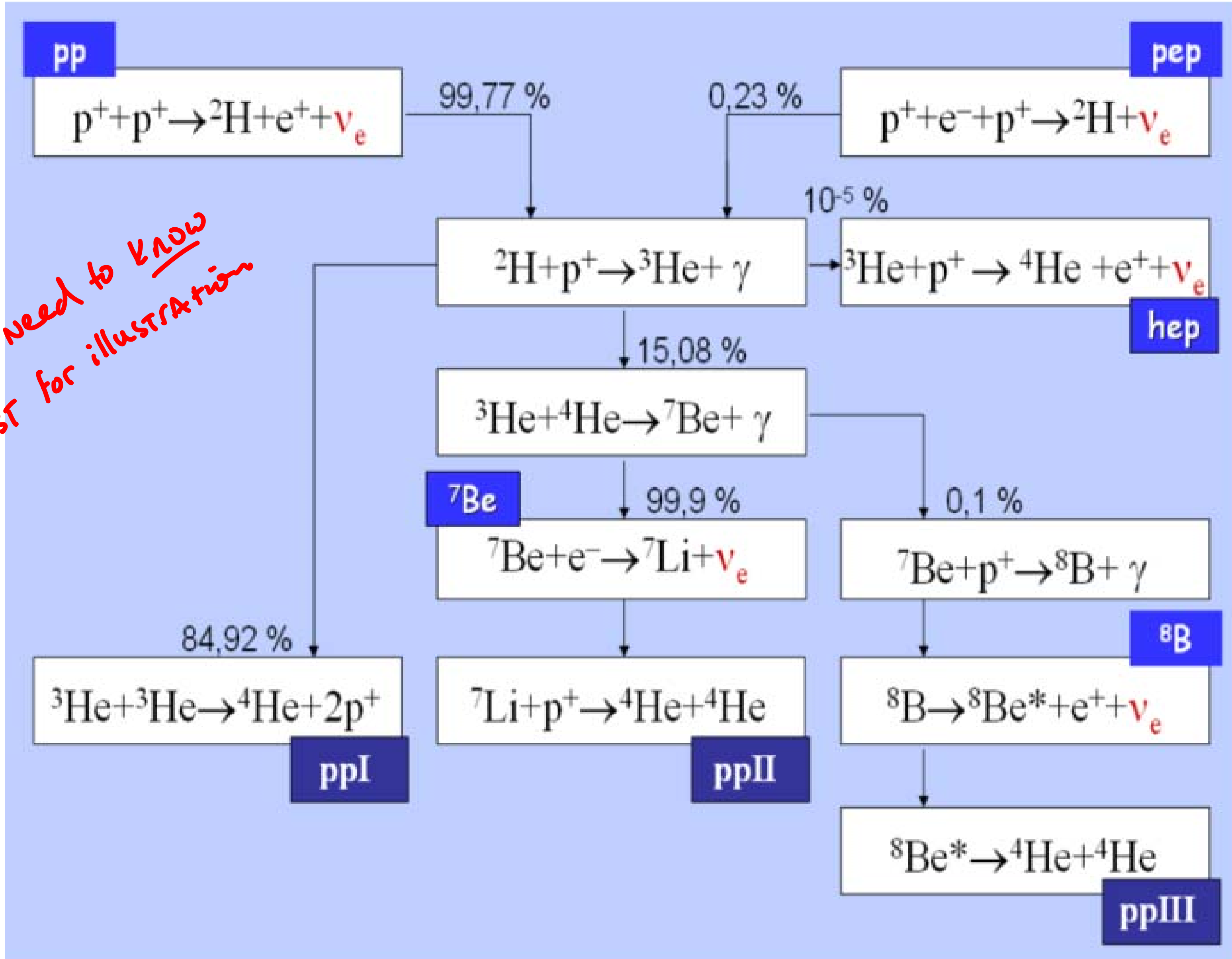
Young stars residual dust
surrounding them



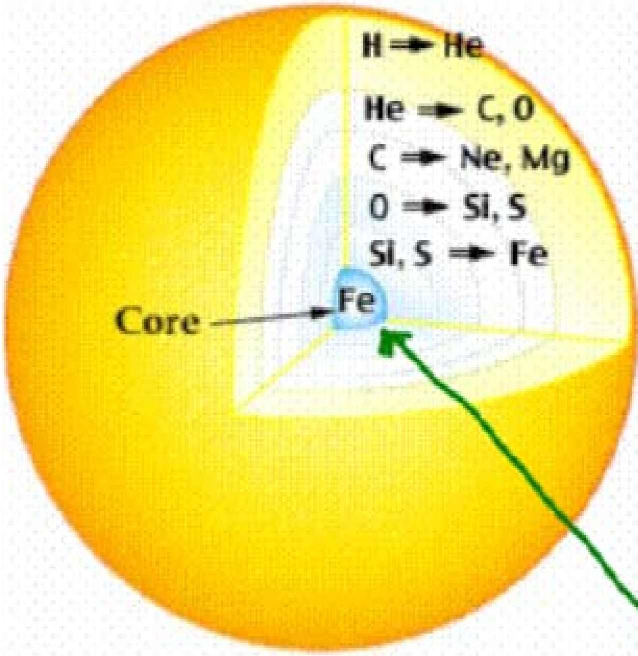
Intrinsic brightness (Sun = 1)
Stars' surface temperature (K)
Rigel
Deneb
Betelgeuse
Supergiants
Spica
Main Sequence
Red Giants
Capella
Aldebaran
Vega
Arcturus
Sirius A
Pollux
Altair
Procyon A
Sun
White Dwarfs
Sirius B
Procyon B
40,000 20,000 10,000 6,000 4,000 3,000 2,000
Photosphere (star's surface)
Hydrogen burning in the shell
Core
Helium burning in the core
older
Photosphere
Core
Hydrogen burning in the core
young

Primary Fusion Processes in the Sun

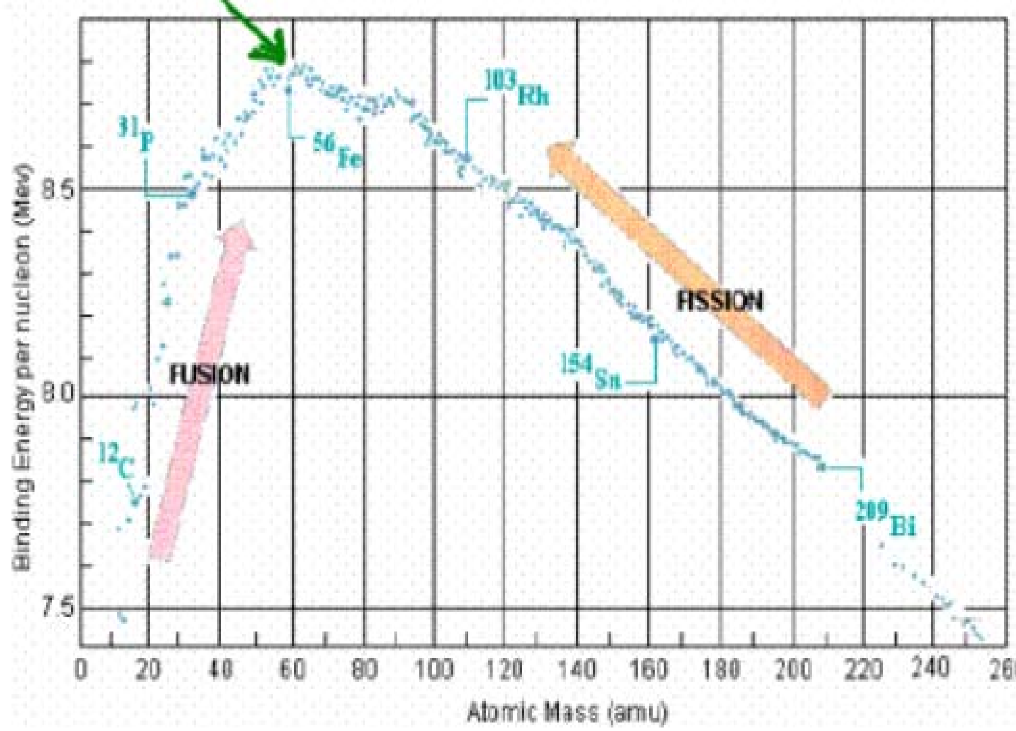
No need to know
just for illustration

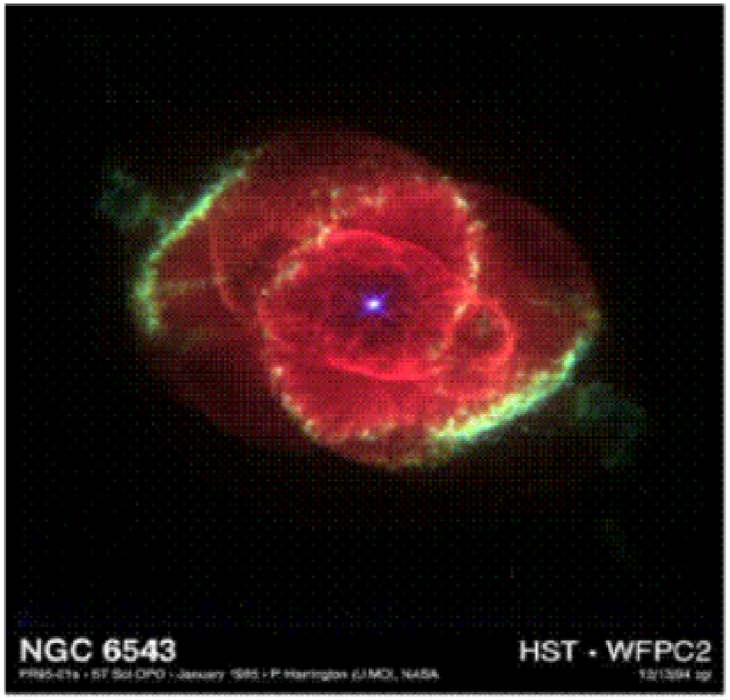


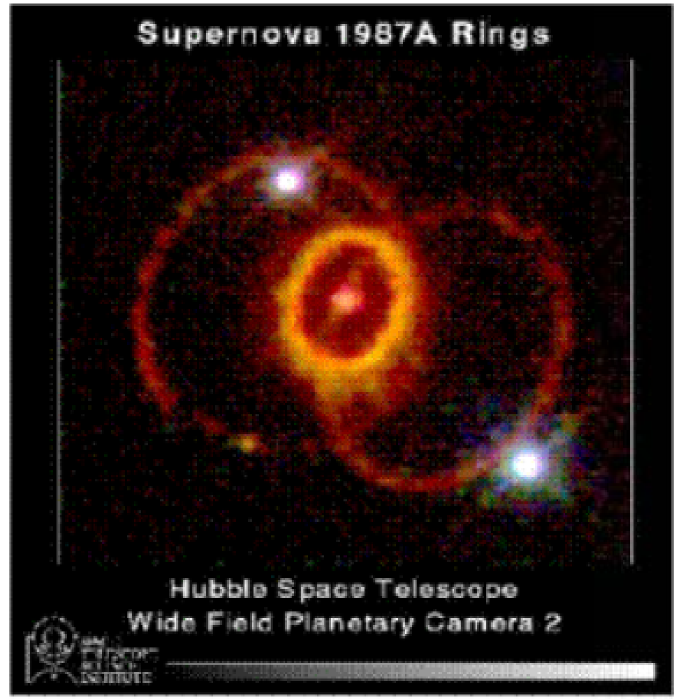
late life massive star



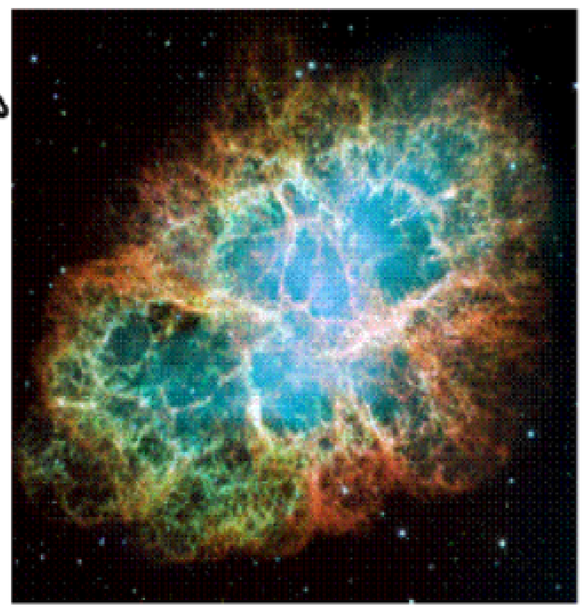
Fusion process into nuclei larger than ^{56}Fe takes energy rather than releasing energy







STAR went supernova in 1054 — observed during day by Chinese and Arab Astronomers

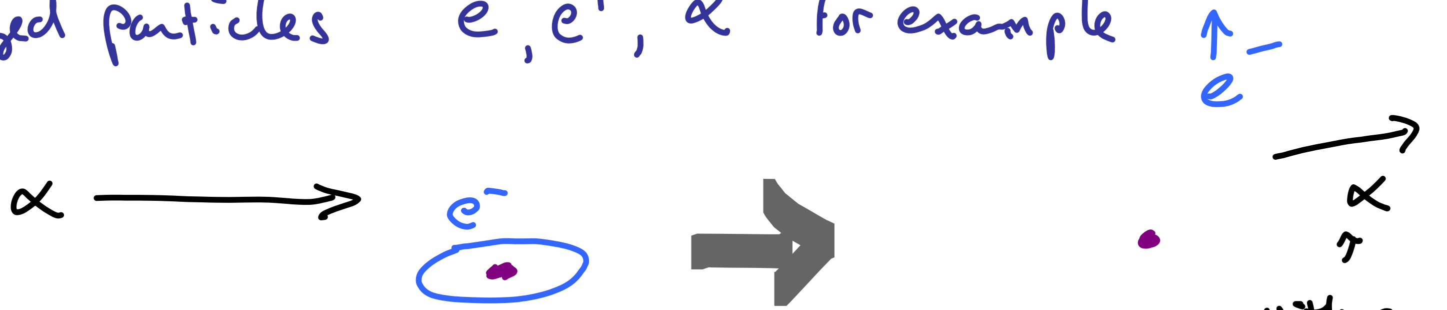


Crab Nebula

Star went Supernova in 1054

Interaction of radiation with matter

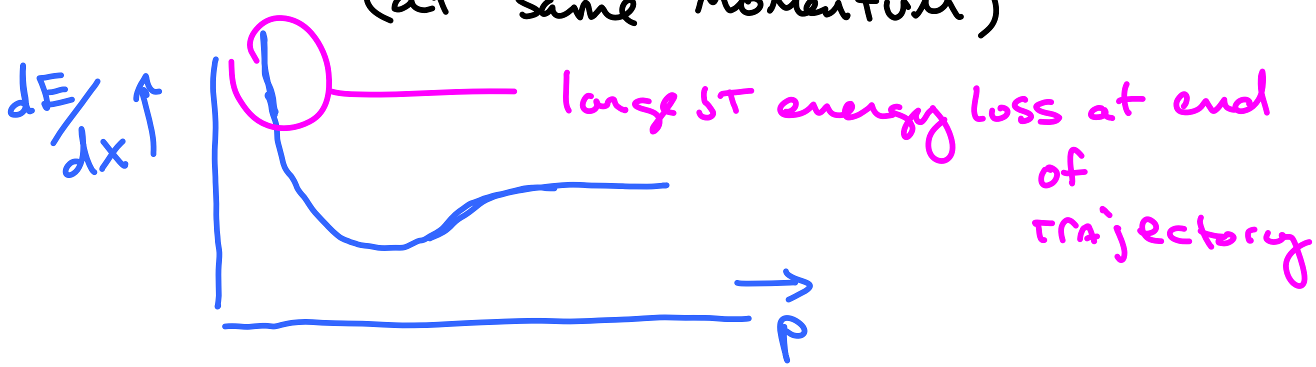
Charged particles e^-, e^+, α for example



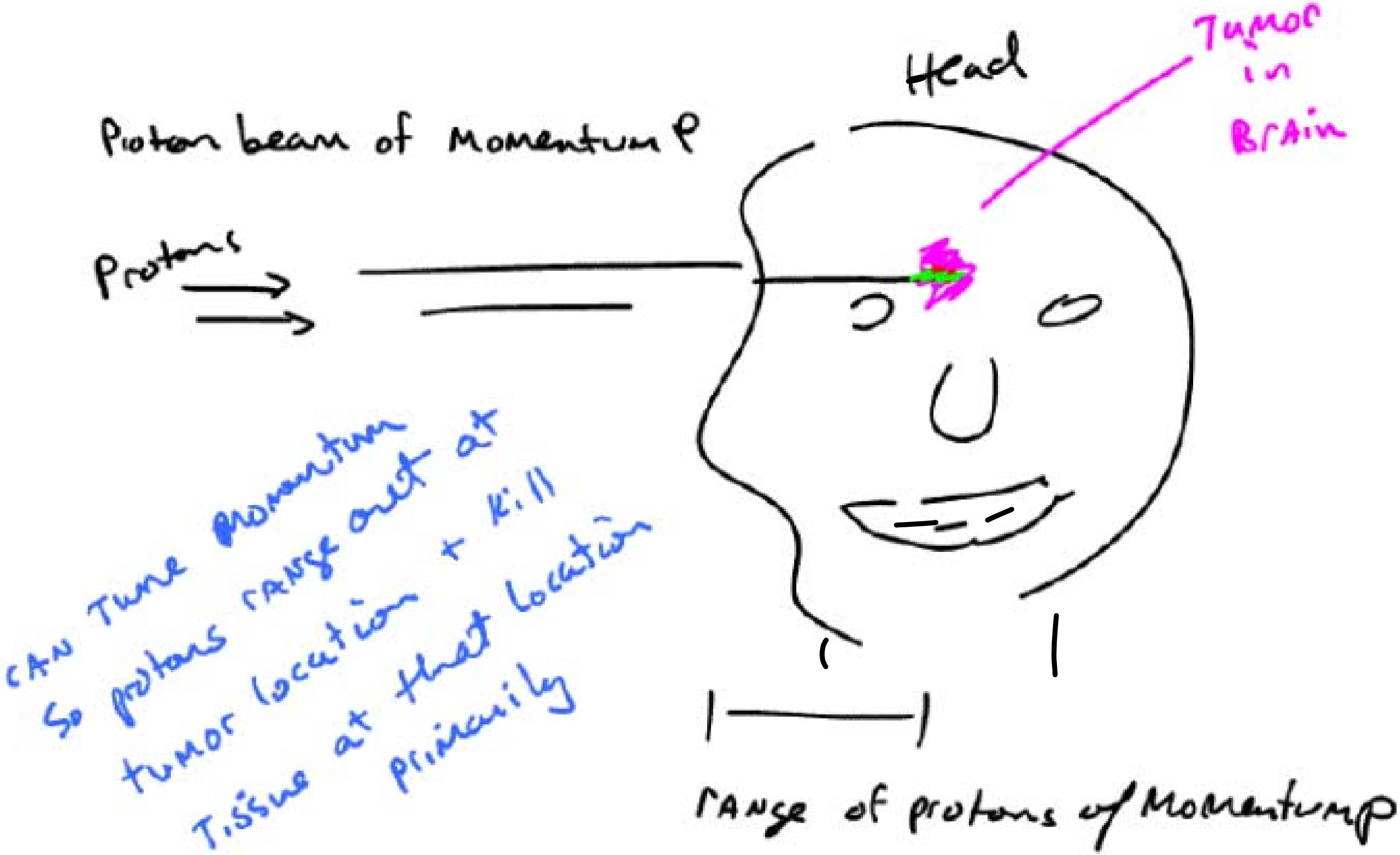
Primary mechanism – energy loss by ionization

Higher for large m, large q

∴ Range of α is shorter than e^- for example (at same momentum)



CAN use this



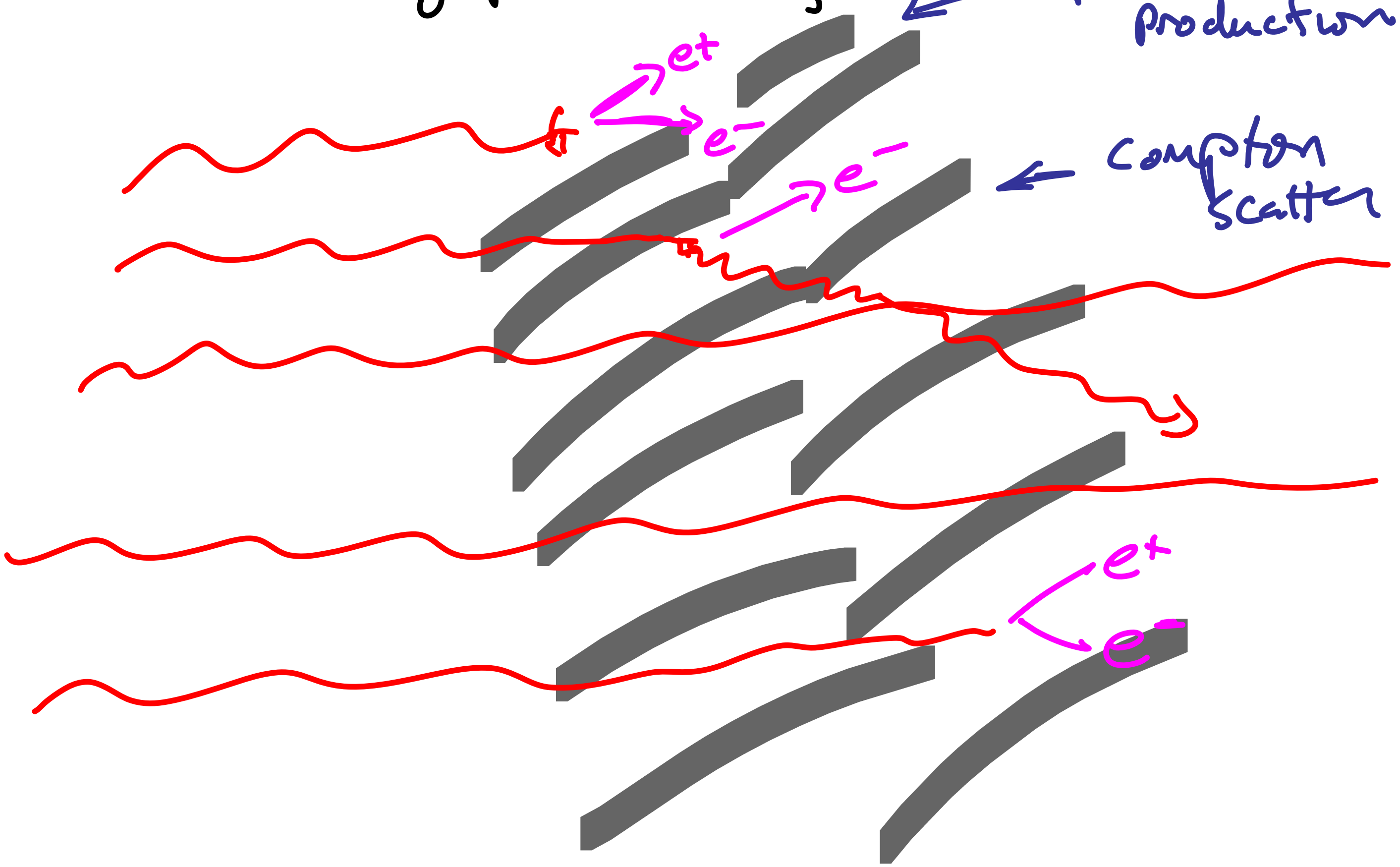
ionization energy loss greatest when proton almost stops . . . Energy deposition and Tissue destruction greatest at end of path

Natural α stopped by paper

β " " plexiglass or glass

γ-rays

↳ very penetrating



Radiation Danger Depends on

- Activity of Material
- location of Material relative to you + vital organs
- Exposure time
- Type of Radiation

	outside body	inside body
Danger (relative)	$\gamma > \beta > \alpha$	$\alpha > \beta > \gamma$

moral to this story: Don't ingest your α sources