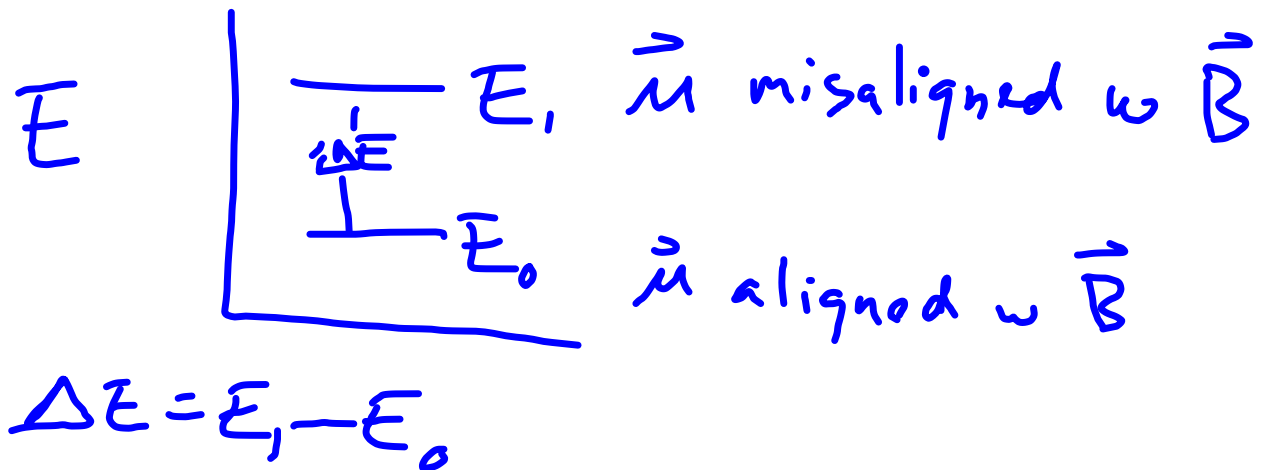


# Nuclear Magnetic Resonance

- Nuclei have angular momentum
- Nuclei have magnetic moments
- Energy of nucleus in external mag field  $B$

$$E = -\vec{\mu} \cdot \vec{B}$$

- Angular momentum quantized  
 $\Rightarrow$  magnetic moment  $\mu$  is quantized  
 $\Rightarrow E$  is quantized



- $\frac{\Delta E}{h} = f$  is radio frequency
- $\Delta E$  is unique to the particular nucleus
- Can create circuit to detect absorption at  $f = \Delta E/h \rightarrow$  identify the nucleus

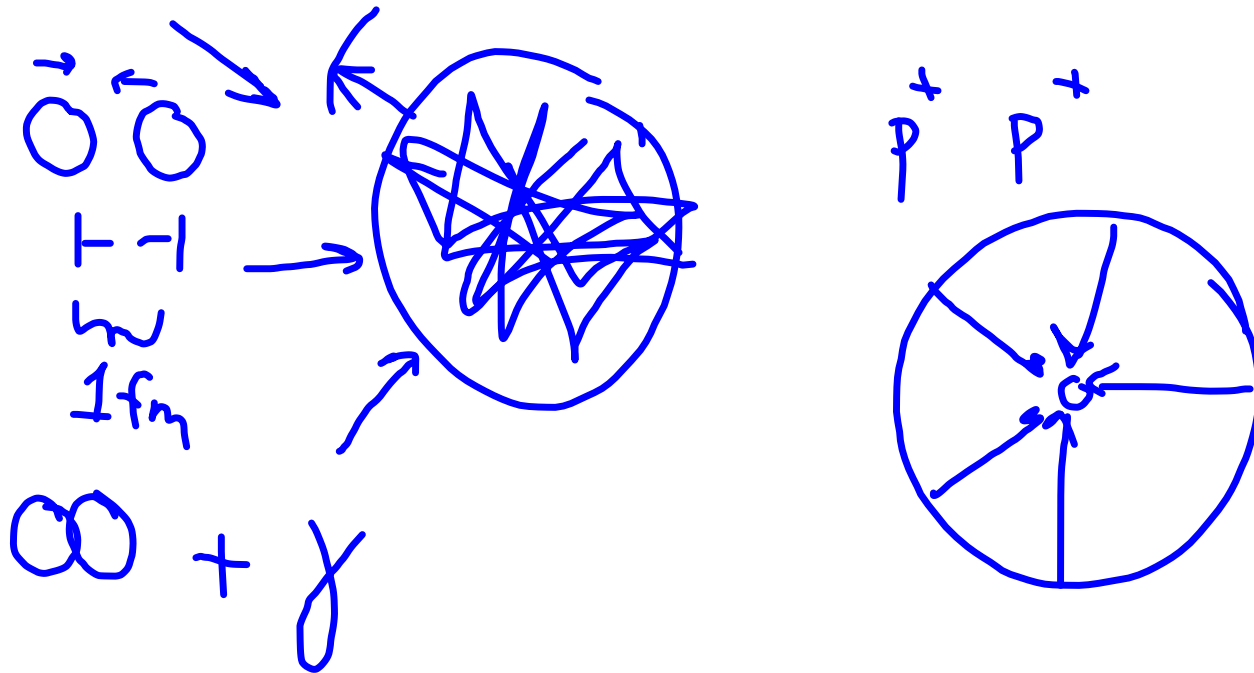
- $\Delta E \propto B$ . Can have a B field that changes with position. Then can identify the nucleus AND its spatial position.

# Nuclear Fusion

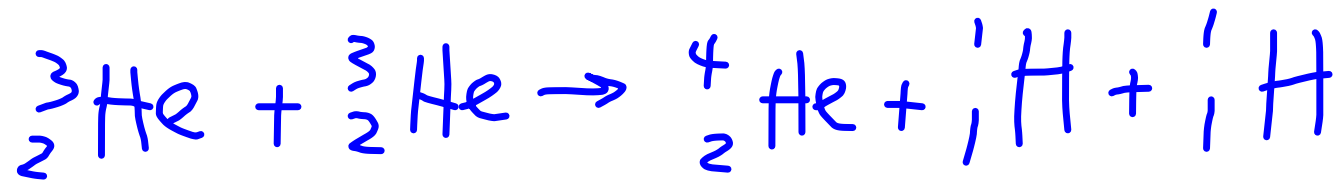
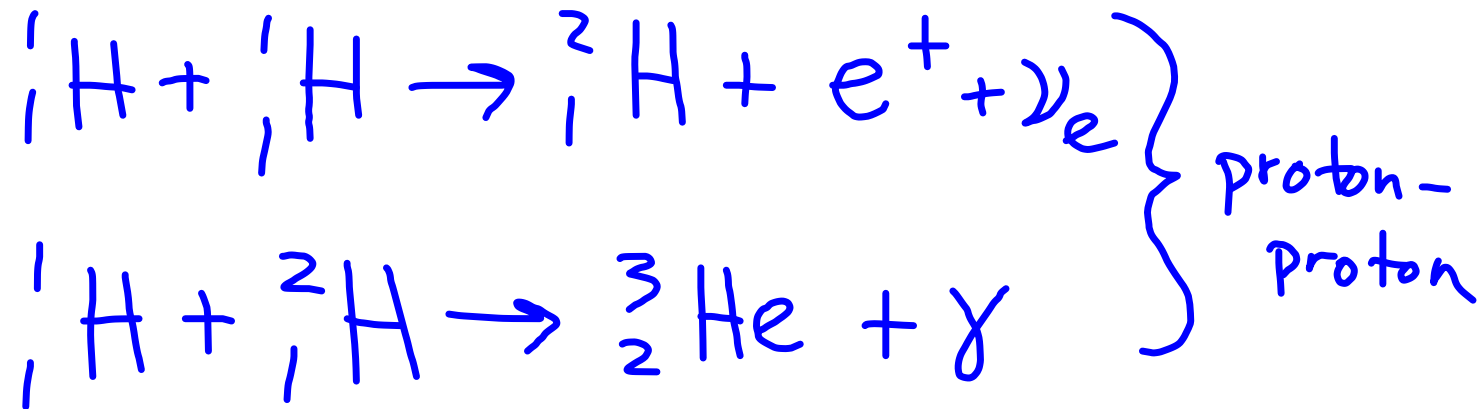
$\text{p}$

$\text{n}$

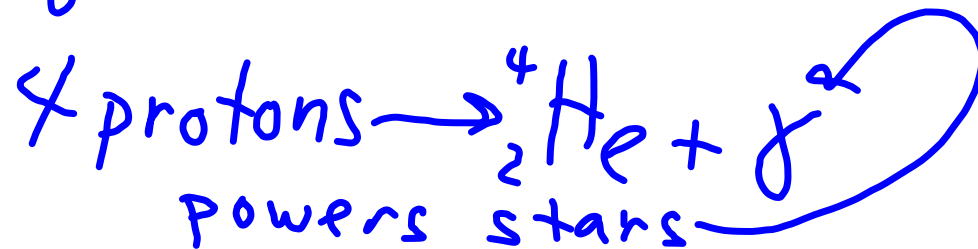
nuclear force is short range  
 $\sim 10^{-15} \text{ m}$



# Nuclear Fusion Reaction



Net effect of proton-proton chain



# Antiparticles

- Absence of a state of negative energy
- Example: positron
- All particles have antiparticles
- Antiparticle & particle annihilate to produce (gamma) photons
- Antiparticle has opposite charge, magnetic moment

- .. antiparticle has same mass & spin as particle
- Some particles are their own antiparticle  
 $\gamma, \pi^0, \eta$

# Particle Physics

Force

1. Strong
3. weak
2. electromagnetic
4. gravity

mediating particle

gluon

W, Z

$\gamma$

graviton



# Cosmology

dark matter  $\sim 23\%$   
dark energy  $\sim 73\%$   
normal/matter  $\sim 4\%$   
Energy

} Constituents of universe

96% of the contents of  
the Universe are unknown

# Unification

