

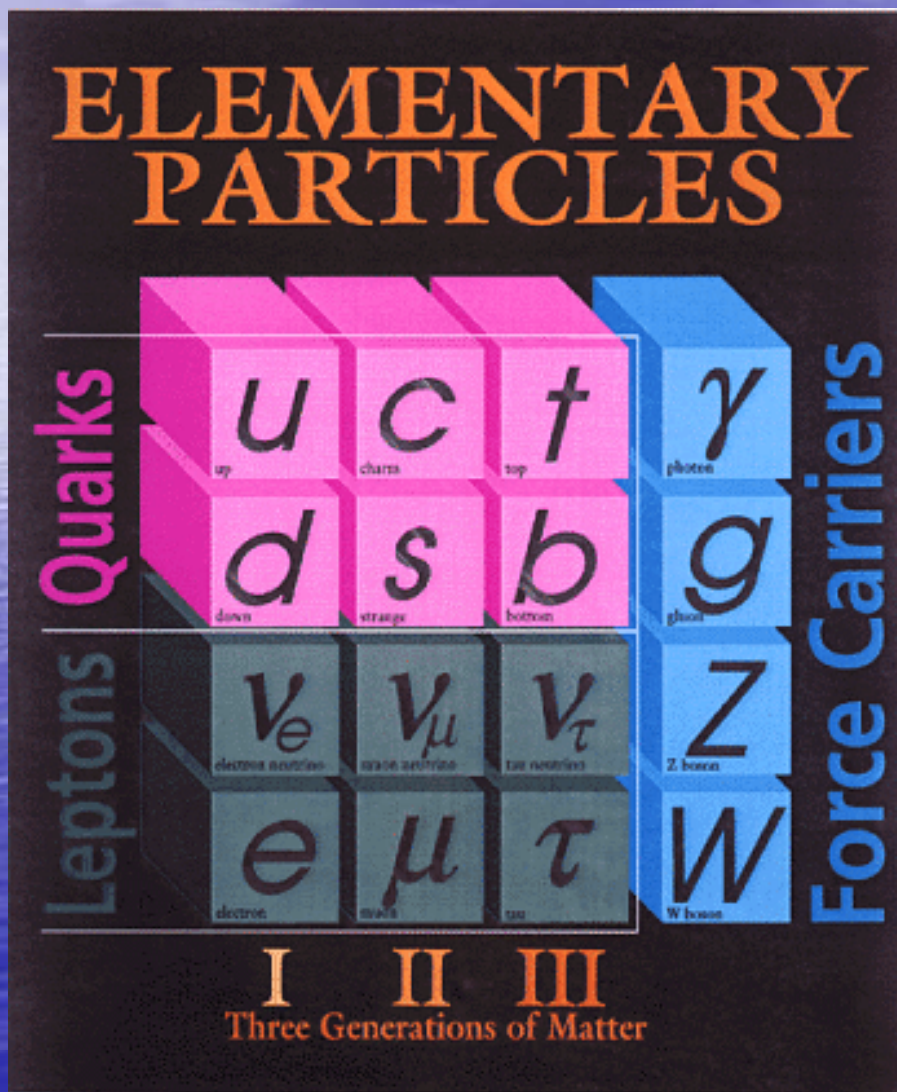
# A Day in the Life of a Cosmic Ray

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# Purpose of this introduction...

- This is NOT meant to teach you everything you always wanted to know about particle physics...
- This is some “starter” background that will

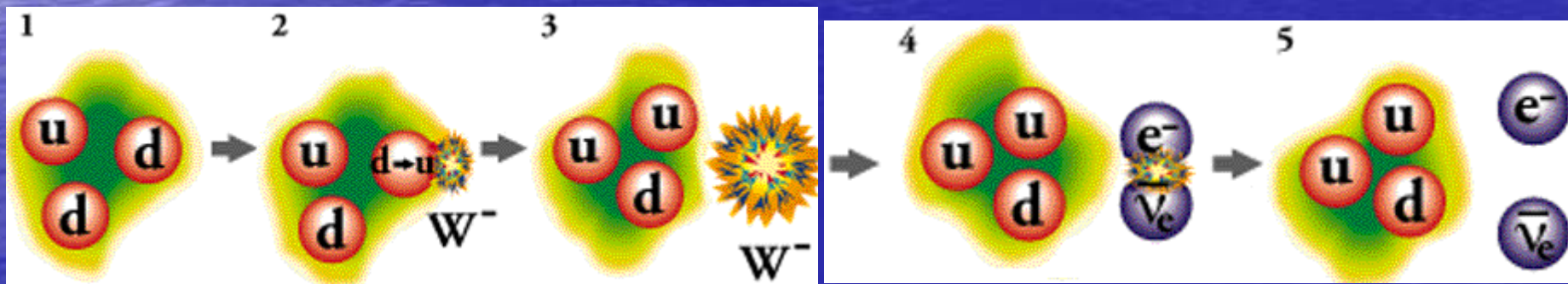
# What is the matter?



- These are the building blocks
  - Quarks (and gluons) combine to form “hadrons”
  - Hadrons and leptons don’t combine until atomic scale
  - Photon is the only “force carrier” found outside bound systems
  - Anti-matter partners of each particle annihilate with matter into energy

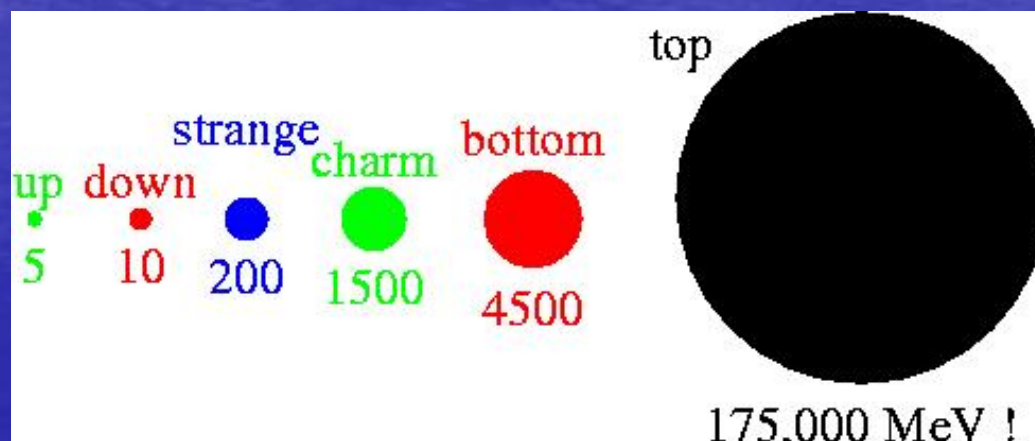
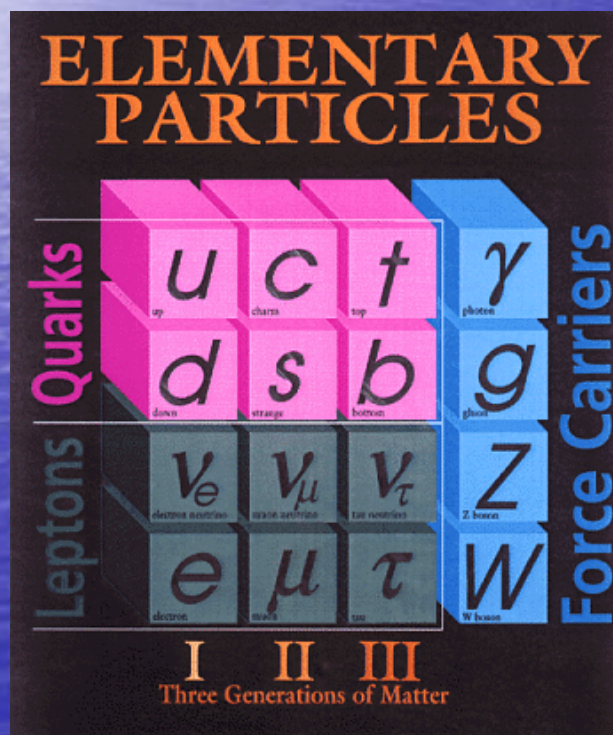
# The Fate of Matter

- It wants to find its “ground state”
  - Lowest mass particles
- Transition mechanism is the weak force



# Masses of Particles

- Successive “generations” of matter appear to be heavy copies of first generation



Weak decays cascade from heaviest to lightest states!

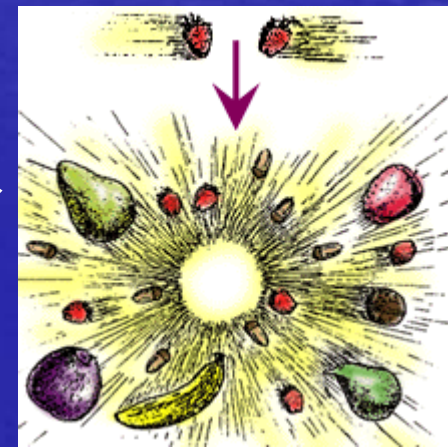
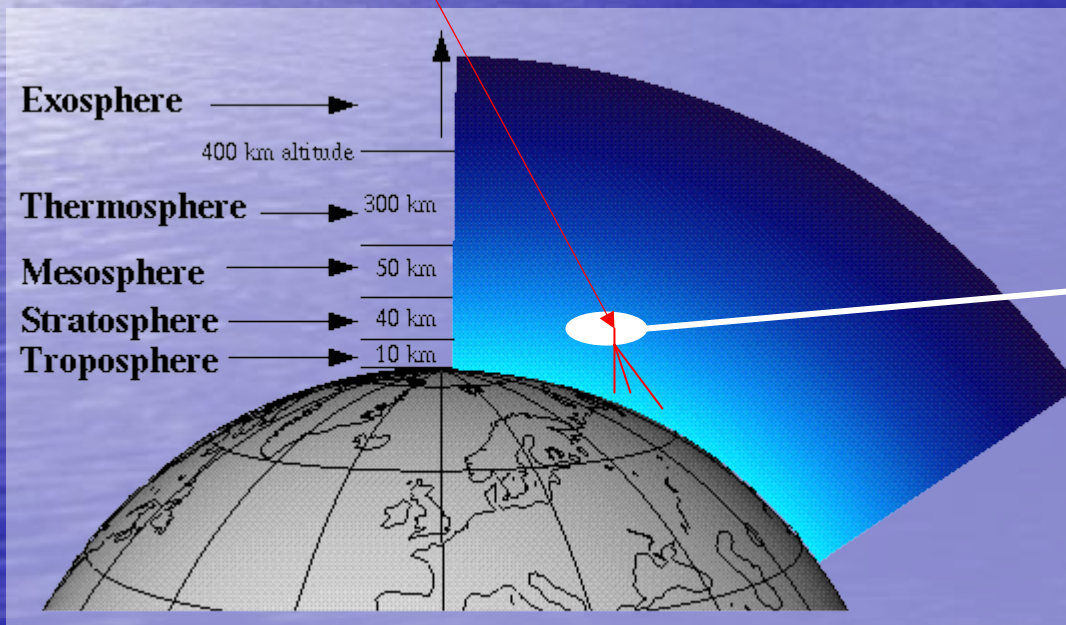
# So what are cosmic rays?

- Cosmic rays are believed to initiate with very high energy (relativistic) protons
  - Acceleration mechanism is unknown
  - Except for small component from solar flares, cosmic rays originate outside solar system
  - Probably galactic (rates, energy)



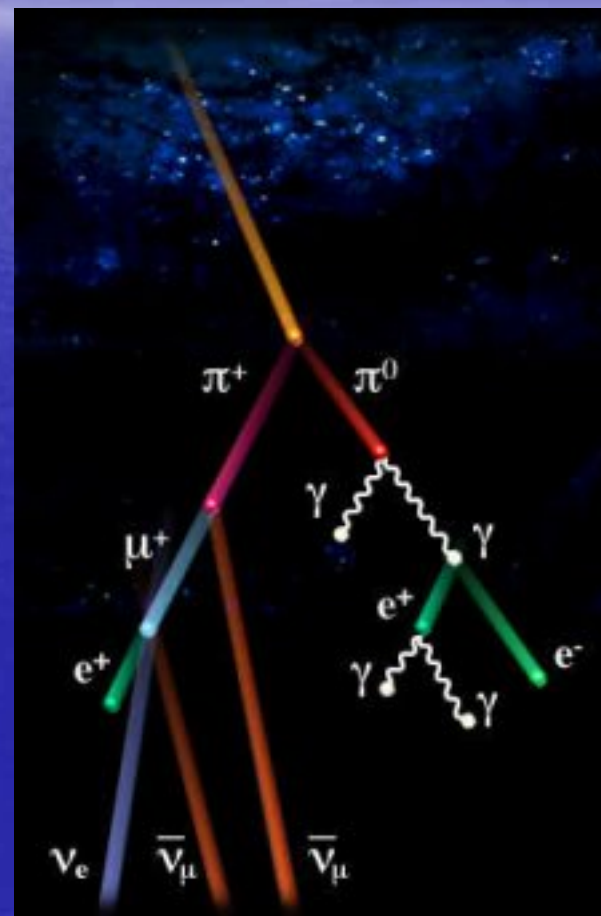
# What on earth happens?

- “Primary” cosmic rays interact in atmosphere
  - Kinetic energy of cosmic ray creates a shower of matter and anti-matter particles



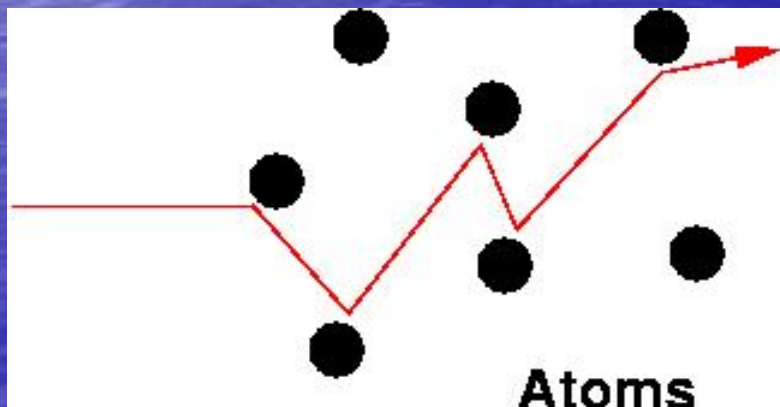
# Cosmic Ray Showers

- Shower of matter & anti-matter particles
  - Weak decays into lightest states naturally progress from hadrons → lighter leptons
  - On the ground: muons, electrons, neutrinos
    - Muon horizontal flux is  $\sim 1/\text{cm}^2/\text{min}$

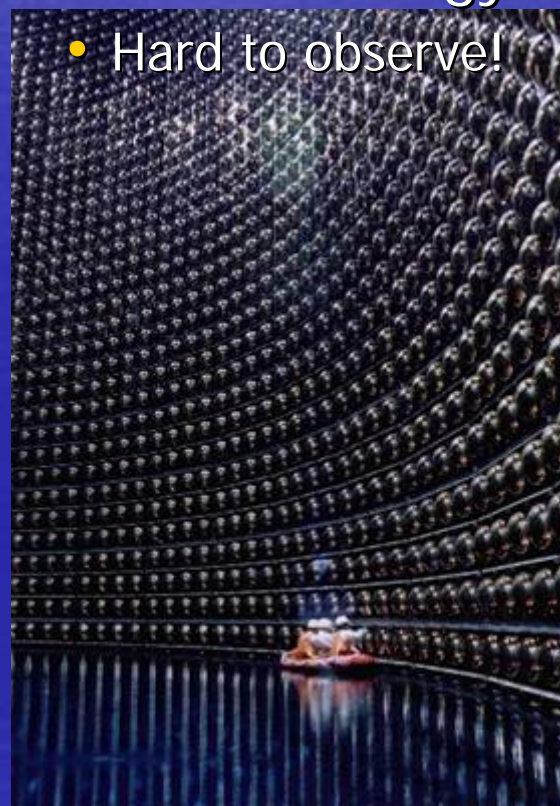


# Observing Cosmic Rays

- Charged particles (muons and electrons) scatter in matter
  - Lose energy (ionization)
  - Electrons particularly!

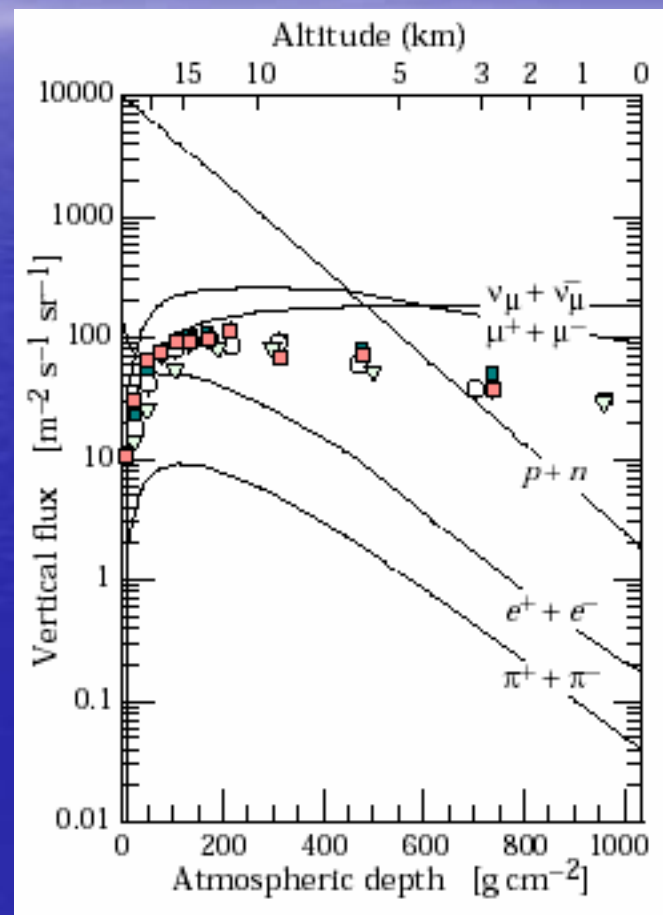


- Neutrinos
  - Only interact weakly
  - Lose little energy



# The Great Race

- Everything conspires against cosmic ray observation on earth
  - Atmosphere slows electrons and muons
  - Muons decay (half-life of 1.5 microseconds)
  - Neutrinos... another story



# What are the properties of the cosmic rays we observe?

- Mostly muons  
(lose energy most slowly of detectable particles)
- If half life is  $1.5\mu\text{s}$ , then how do they get to earth?
  - Even at light speed,  $1.5\mu\text{s} \times 300000000\text{ m/s} \rightarrow 450\text{ m}$
  - But atmosphere is  $\sim 10000\text{ m}$  thick
  - So if they make it here, they get here from relativistic time dilation!
  - That means they are going near light speed

# What angles do they come from?

- Atmospheric thickness distorts spectrum
  - Only the most energetic survive, but most energetic are rare!

