Lecture Content

- Approx. lecture content
  1. PP intro
  2. PP intro.
     - Feynman diagrams; strong/e.m./weak;
  3. ν props 1:, no. neutrino generations
  4. ν props 2: lepton no., ν existence
     - Examples of decay/production
  5. Neutrino mass
     - Fermi-Kurie plot
     - Phase space kinematics/4-momentum
  6. Parity and CP violation… (why so important in lepton sector?)
     - Wu et al., ^{60}Co experiment
  7. Detection & observation
     - Liquid, solid, bubble chamber
     - "Direct" methods (DONUT)
  8. Solar and atmospheric neutrinos
     - Puzzle: relative abundances != SSM prediction
     - Two-flavour neutrino oscillation formalism
  9. Neutrino oscillations and mixing
     - Possible solutions to solar/atm. ν problems
  10. Current and future experiments
      - SK, SNO, KAMLAND, CHOOZ
      - MINOS, miniBOONE,..
      - NDBD (NEMO, etc.)
      - JPARC, νF,
  11. Implications for cosmology
      - Open vs. closed scenarios. various m_ν regions
      - ν as DM candidate?
      - Subject outlook (JPARC, MICE, Neutrino Factory, …)

Previous lecture

- Review C1 PP

BOSONS force carriers spin = 0, 1, 2, …

Unified Electroweak spin = 1

Name	Mass GeV/c²	Electric charge
γ photon	0	0
W^-	80.4	−1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1

Name	Mass GeV/c²	Electric charge
g gluon	0	0

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, …

Leptons spin = 1/2

Flavor	Mass GeV/c²	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0
e electron	0.000511	−1
ν_μ muon neutrino	<0.0002	0
μ muon	0.106	−1
ν_τ tau neutrino	<0.02	0
τ tau	1.7771	−1

Quarks spin = 1/2

Flavor	Approx. Mass GeV/c²	Electric charge
u up	0.003	2/3
d down	0.006	−1/3
c charm	1.3	2/3
s strange	0.1	−1/3
t top	175	2/3
b bottom	4.3	−1/3

PROPERTIES OF THE INTERACTIONS

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong: Fundamental	Strong: Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at: 10^{-18} m	10^{-41}	0.8	1	25	Not applicable to quarks
Strength relative to electromag for two u quarks at: 3×10^{-17} m	10^{-41}	10^{-4}	1	60	
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

Today

- Quark content of hadrons
  - http://pdg.lbl.gov/2008/reviews/quarkmodrpp.pdf
- Anatomy of Feynman diagrams
- Compare relative strength of forces
  - Strong, $\Delta^{++}\rightarrow p\pi^+$
  - e.m., $\pi^0\rightarrow\gamma\gamma$
  - Weak, $\pi^+\rightarrow\mu^+\nu_\mu$

Q: How do these reactions help to measure no. ν generations?