Thursday, January 14, 2016
7:53 AM

This course is called "Particle Physics" but really it should be called "Physics at the fundamental frontiers with which we are currently confident". I say that because not only will we find that the notion of "particles" as we usually understand them is not part of it, but also because the subject itself has undeniable hints at physics beyond what it is currently capable of describing.

Let's start with some high-level nomenclature*:

- Mechanics - a framework for describing the evolution of a system
- Theory - a framework applied to a particular context

} contrast SR w/ GR

- Model - an effective theory that requires some inputs that are not predicted by the theory itself, but are selected to match desired behavior

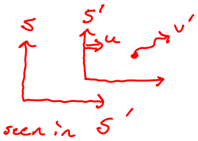
* Note, not everyone agrees on the use of these terms, but then again this is not mathematics!

Let's start by establishing the appropriate mechanics for our purposes.

Thursday, January 14, 2016
8:08 AM

$\boxed{\text{Non-relativistic (Newtonian) Mechanics}} \longleftarrow \boxed{\text{Relativistic Mechanics}}$

- valid for low speeds
- 3D space + absolute time
- Galilean relativity $\underset{\uparrow \atop \text{as seen in } S}{v} = \underset{\uparrow \atop \text{as seen in } S'}{v'} + u$



- valid for <u>any</u> speeds
- 3+1 D spacetime
- Special relativity $\underbrace{v = \frac{v'+u}{1+v'u/c^2}}_{\text{gives constancy of } c}$

Correspondence principle: If $v'u \ll c^2 \Rightarrow v = \frac{v'+u}{1+\frac{v'u}{c^2}} \simeq v'+u$

But do we <u>need</u> to work with relativity? Well to compare w/ experiment where speeds approach 0.9999999 c (7 mph < c) we do!

But more importantly, if we want a fundamental description, we want one that is right in any situation.

Non-relativistic (Newtonian) Mechanics

- valid for large decoherent systems
- deterministic, i.e. given initial conditions and dynamics, solution is unique behavior
- H or $L \Rightarrow$ e.o.m. w/ b.c.s $\Rightarrow x(t)$

Non-relativistic Quantum Mechanics

- valid for all systems
- probabilistic, i.e. given initial conditions and dynamics, solution is probability distribution for possible behaviors
- $i\hbar \frac{\partial \psi}{\partial t} = H\psi$ w/ b.c.s $\Rightarrow \psi(x,t)$
  $|\psi|^2 \sim$ prob.

Correspondence principle: harder to pose because the "questions" change, but generally when $S = \int L\,dt >> \hbar$, we get classical behavior dominating.

Do we need QM? Well we are studying a small number of hella small things, so yeah! But again, to be fundamental the description should always work.

Thursday, January 14, 2016
9:02 AM

Of course we are then led to ask, "What about small things at high speeds?"

The answer naively would be $\boxed{\text{Relativistic Quantum Mechanics}}$, but this is slightly problematic.

QM relies on $\underbrace{\int |\psi|^2 dx = 1}_{\text{The particle has to be somewhere!}}$ wavefunction normalization to establish probabilities

But...
Relativity allows particles to be created and destroyed!

To get around this we could introduce a Fock space of particle states to allow particle creation/annihilation in QM. This does work to some degree, but it is cumbersome and incomplete!

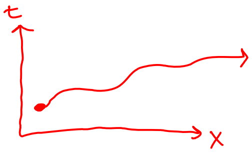
So what do we we?

Thursday, January 14, 2016
9:07 AM

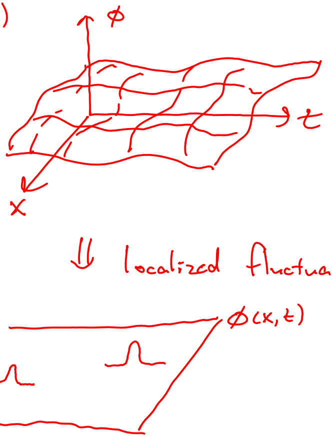
Quantum Field Theory

?

Particle: $x(t)$



Field: $\phi(x,t)$



Correspondence Principle

⇓ localized fluctuations

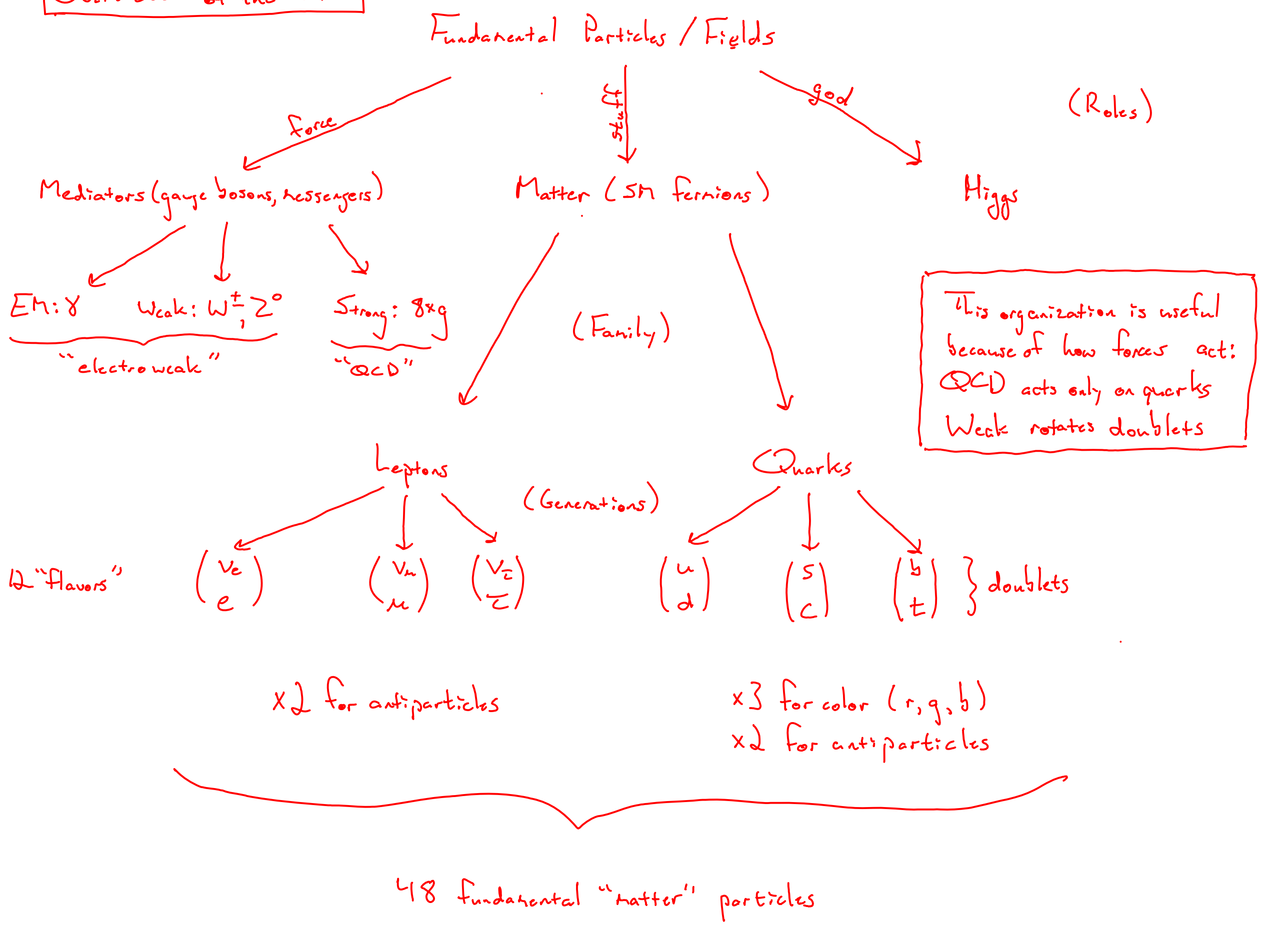
look like particles!

QFT achieves many things:

- Gives natural origin of identical particles
- Gives natural weights to creation/annihilation processes
- Yields spin-statistics theorem
- Allows non-perturbative phenomena

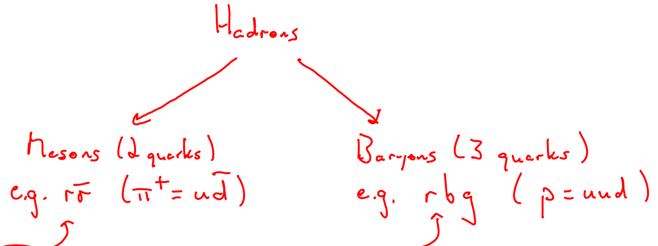
Wednesday, January 08, 2014
1:12 PM

Overview of the SM



This organization is useful because of how forces act: QCD acts only on quarks Weak rotates doublets

We typically see lightest leptons (ν_e, e) and $\underbrace{\text{quark bound states}}$ (color neutral).



Actually: $|g\rangle = \frac{1}{\sqrt{3}}(r\bar{r} + b\bar{b} + g\bar{g})$

Actually: $\frac{1}{\sqrt{6}}(rbg + bgr + grb - rgb - gbr - brg)$

This <u>model</u> has 19 parameters which can only be deduced from experiment.

Thursday, January 14, 2016
9:48 AM

Outline of cours :

Formalism

- Develop systematic approach to transformations and symmetries
- Review special relativity
- Review Lagrangian mechanics
- Develop Lagrangian mechanics of scalar, spinor and vector fields
- Introduce interactions through local gauge invariance
- Discuss SSB and Higgs
- Special topics

Calculations

- Layout an approach to calculations
- Review perturbation theory
- Develop and apply Feynman calculus
- Review classic calculations
- Renormalization
- Special topics