Previous lectures

Particles and Interactions

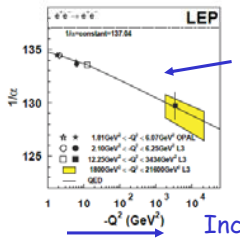
- Particles
  - Fermions and bosons
  - Mesons and baryons
  - Energy, mass and momentum
  - Cross-section in $e^+ e^-$ and "R"
- Interactions
  - [Mass versus Range
  - deBroglie wavelength
  - Vacuum polarization
  - Running e.m. coupling constant]

Today (lecture 3)

- Mass/Range of Weak Force
- de Broglie wavelength
- Vacuum polarization
- Running e.m. coupling constant
- Symmetry and Conservation Laws
  - C, P and T Symmetry in Particle Physics
- (Start) Electroweak Unification

Data: E.M. coupling "constant", α_{EM}

XXVI Physics in Collision, Búzios, Rio de Janeiro, 6-9 July 2006



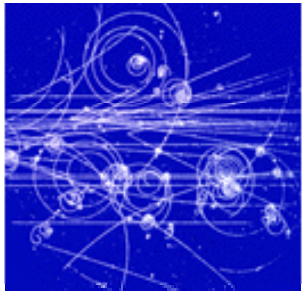
1/coupling decreasing

- Example of recent compilation of data
- Many others similar in literature

Increasing energy of probe

Figure 6: Summary of LEP results on the measurement of the running of the electromagnetic coupling. The band represents the L3 measurement at high Q^2. The full symbols represent the OPAL and the L3 measurements at low and intermediate Q^2. The open symbols are the reference values to which the measurement are anchored, as discussed in the last section of the text. The solid line shows the QED predictions of Reference [5].

Symmetry and Order



- Need to know rules (order, symmetry) to make sense of observations

Classical Symmetry

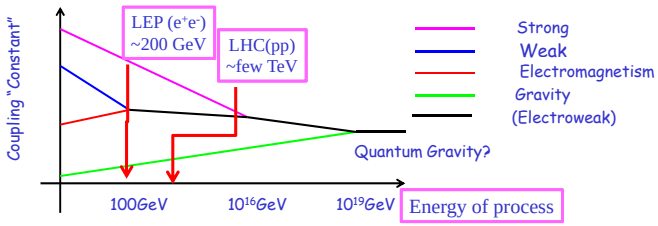
Unification of forces

- James Clerk Maxwell (1831-1879) unifies Electrostatics and Magnetism into the theory of Electromagnetism (19th Century)
- Albert Einstein (1879-1955) tried to develop a UNIFIED theory of nature without success from 1916 until 1955
- Quantum Theory of Electromagnetism developed by Feynman, Dyson, Schwinger, Tomonaga. Quantum Electrodynamics (QED) in 1940
- Glashow, Salam and Weinberg unify Electromagnetism and Weak force into the ElectroWeak theory (1979 Nobel prize)

- Unification of strong / electroweak forces at 10^{16}GeV?
- Unification of all forces of nature (Electromagnetism, Weak, Strong and Gravity) at the Planck scale of 10^{19}GeV??
  - Highly non-trivial

Running Coupling Constants

- Coupling "constants" are said to "run" (change their strength) with energy
- For electromagnetism, the coupling "constant", α_{EM}, increased with energy
- For weak force the coupling constant decreases with energy
  - E.M. and weak merge at ~100 GeV: "electroweak unification"
- For strong force coupling, α_s, decreases with energy



Next Lecture

- (Finish) Electroweak Unification
- Higgs mechanism