PHYS 3718 - Particle Physics II: Spring 2016 – Daniel Boyanovsky

Radiative corrections: Loops, self-energy, renormalization, dimensional regularization, ``running of coupling'', RG beta function and screening. Observables: g-2, Lamb-shift. Resonances: self-energies and Breit-Wigner propagators, resonant cross sections. Bound states in QED: positronium and its decay.

Prelude to QCD: Electromagnetic interactions of quarks: deep inelastic scattering, Rosenbluth cross section, form factors. Parton model, Bjorken scaling. Drell-Yan processes and the parton model.

A primer on QCD: the theory of strong interactions SU(3) of color: basic vertices and interactions, gluons and color factors, the color force. The QCD beta function antiscreening, running coupling, asymptotic freedom and confinement. The maximally attractive channel and the heavy quark potential, Lattice gauge theory. Mesons and Baryons: Light Quarks and flavor SU(3): recovering the eigthfold way. Heavy quark meson decay: the OZI rule. Jets.

A primer on Weak Interactions: Early theory: Fermi's theory of beta decay and its problems, intermediate vector boson hypothesis. IVB theory and the Fermi limit: pion, muon, and neutron decay: explicit calculations and decay rates. Tests of universality.

Modern Weak interactions: Spontaneous symmetry breaking: Goldstone bosons, the Higgs mechanism. Electroweak Unification: the Glashow-Salam-Weinberg model SU(2)xU(1) and the Higgs, massive vector bosons, charged and neutral currents. On the origin of mass: Yukawa couplings.
The width of Z0 and the number of neutrinos. Universality of lepton interactions (again!). Weak interactions of quarks, Cabbibo mixing and the GIM mechanism. The CKM matrix. The origin of the CKM matrix and CP violation.

CP violation: the kaon system, kaon oscillations, direct and indirect CP violation boxes and penguins. The CKM matrix, number of generations and CP violation. CP violation in B-decays, observables and the unitarity triangle. CP violation and baryon asymmetry of the Universe.

Beyond the standard model: neutrino mixing and oscillations: the evidence. The solar neutrino problem, atmospheric neutrinos. MSW effect. Seesaw mechanism of neutrino masses. Reactor and accelerator experiments.

***Grand Unification: GUT's and scales.** Leptoquarks and proton decay.

***Supersymmetry**: just the basics. The LSP. SUSY-GUT's unification of couplings.

***Particle cosmology:** The cosmic microwave background. Dark Matter: the evidence, Dark Energy: the evidence. Particle physics ``solutions''.

Strategy and course methodology:

This is an ambitious program requiring a relatively fast paced course that explores the Standard Model of Particle Physics at a level suitable for a second year graduate student. The course mixes phenomenology with a basic description of the main theoretical and experimental results, but seeks to provide a solid foundation to understand the main concepts and carry out elementary (and not so elementary!) calculations. Although I will cover most of the necessary QFT, students are strongly encouraged to take the QFT class. I will assume solid knowledge of the material covered in PPI.

Textbooks: There are several excellent textbooks with different ordering of content and focus. I will primarily follow: Particle Physics by Palash Pal, Modern Particle Physics by Mark Thomson, Introduction to Elementary Particles (2^{nd} edition) by D. Griffiths (somewhat outdated but a good primer on Feynman calculus), Quarks and Leptons by F. Halzen and A. Martin, (fairly outdated but a solid account of QCD and weak interactions), Electroweak Interactions by P. Renton (excellent book in depth treatment but somewhat harder to follow). I will draw material from all of these books, my notes will be made available.

Office hours: I will keep "official office hours" on T-Th: 3:00→ 4:00 PM in my office, however if you cannot make these, send me an e-mail and give me a few options so we can meet at a mutually convenient time in my office.

Homework and exams: I will assign 4-5 problems each week, due back the next week. A midterm and final exam, the format to be decided later in the semester. The final grade is: 0.5 * (average of hmw)+ 0.5* (average of midterm+final).

* This material will be covered time permitting.

FASTEN YOUR SEATBELTS AND ENJOY THE TRIP!!