PARTICLE PHYSICS:
PHYS 3717

Instructor: Daniel Boyanovsky, 208 Allen Hall, (412)-624-9037, boyan@pitt.edu

Class time and place: MWF 3:00pm → 3:50 am, 106 Allen Hall

Prerequisites: Quantum Mechanics I, II, E&M.

First semester content:

Brief history: photons, cosmic rays, leptons, baryons, mesons, strange mesons, the eightfold way: baryon and meson multiplets, prelude to the quark model: color and confinement. Deep inelastic scattering and partons. The content of the Standard Model. Beyond the Standard Model: Dark Matter?.

Dynamics: Relativistic kinematics, invariants, Mandelstam variables. Thresholds, fixed target vs. collider experiments.

Field quantization: Quantization of E&M: photons and gauge invariance. The massive vector boson field, degrees of freedom and quantization: a peek at the weak vector bosons. Propagators. Quantization of real and complex scalar fields: a peek at the Higgs. Internal symmetries and conservation laws. Quantization of the Dirac field: conservation laws. Gauge invariance, conserved currents. Propagators and time evolution. Gauge theories: the mother of all interactions. continuous symmetries and conservation laws, discrete symmetries: C,P,T and CPT. Dirac vs. Majorana fields. Intrinsic parity. Consequences on bound states. Neutrinos: C and P violation in weak interactions.

Interactions: S-matrix, decay rates and cross sections. Feynman rules and Feynman diagrams: the language of particle physics. Simple examples.

The first gauge theory: **QED**: Gauge invariance (again!!), interactions, QED processes: cross sections. Basic idea of renormalization: mass, vertex and charge renormalization, consequences: the lamb shift in atoms, the running coupling and the beta function: screening. Particle interactions with matter, Bremmstralhung and energy losses. Cerenkov emission. Bound states in QED: positronium as a model of bound states in QCD.
*Particle detectors: some modern accelerators.

Radiative corrections: self-energies and resonances. Breit-Wigner description of resonances (propagators). Resonant cross sections: going on shell.

Second semester content (very brief description):

A primer on QCD: the theory of strong interactions SU(3) of color: basic vertices and interactions, gluons and color factors, the color force. Electromagnetic interactions of quarks: Rosenbluth, deep inelastic scattering, form factors: partons and Bjorken scaling, antiscreening, running coupling, asymptotic freedom and confinement. The maximally attractive channel and the heavy quark potential. 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: Fermiõs theory of beta decay and its problems, intermediate vector boson hypothesis.

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 Fermi limit: pion, muon, and neutron decay: explicit calculations and decay rates. 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-GUTõs unification of couplings.

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

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 tools, but seeks to provide a solid foundation to understand the main concepts and carry out elementary calculations.

Textbooks: There are several excellent textbooks with different ordering of content and focus. I will primarily follow: An introductory course of Particle Physics by Palash Pal. A good alternative is Modern Particle Physics by Mark Thomson, both are more modern and pedagogical but skimp on QFT, I will fill-in the (many) details. 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 upon request.

Useful websites: http://pdg.lbl.gov/ (this is the most comprehensive database for particle properties and summary reviews); http://freescience.info/index.php (this is a list of ``freeôô articles with links to the arXiv). http://arxiv.org/ (the arXiv is the most comprehensive database of articles across fields).

Office hours: I will keep ``official office hoursôô 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. Probably there will be 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.