This class is the first semester of a two-semester course in graduate level particle physics (followed by PHYS 778). We will use Elementary Particle Physics (Perkins) and Gauge Theories in Particle Physics (Aitchison and Hey) as the main texts. Books for suggested/supplementay reading include: Griffithsa, Leader and Preddazi, Nachtmann, Lee, Fayazuddin and Riyazuddin, Close, Cheng and Lee, Halzen and Martin, Okun, Ho-Kim and Yem.

In the first term we will focus on the interactions of particles (the leptons and hadrons) rather than the underlying interactions of quarks, the fundamental constituents of hadrons.

Topics to be covered:

- Overview of the four fundamental interactions of particles
- Lightning quantum field theory. Although this is not a prerequisite for the class, it is the language of particle physics and essential for basic calculations.
- Techniques for evaluating cross sections and decay rates
- Invariance principles and conservation laws
- Discrete symmetries, C, P, T; electric charge, baryon and lepton number conservation. Are these exact symmetries of the various interactions?
- Discovery of "strange" particles and the associated strangeness quantum number; conserved in strong and em interactions, but not in weak interactions.
- Strong interactions and isospin and some applications to hadronic processes
- Strange particles; extension of isospin to $SU(3)$ symmetry of flavour.
- Masses and magnetic moments of hadrons. The quark model.
- How the discovery of $J\psi$ and other charmed particles established the "reality of quarks". Quarkonium. The bottom quark family and associated quarkonia. New (but not exactly conserved) quantum numbers.
- Establishing quarks as dynamical objects inside hadrons; elastic electron scattering of elementary spin zero and spin half particles; elastic electron-proton scattering (form factors establish the proton has structure); deep-inelastic electron proton scattering and comparison with SLAC scaling data; evidence of point-like charged "partons" inside a proton.
- The quark-parton model; charge and momentum sum-rules; evidence for free neutral point-like constituents of the proton. The qualitative picture of QCD-parton model, with gluons and (anti-)quarks (of all flavours) in

a nucleon. Resolve how quarks can appear free inside a hadron yet never emerge out.

- Jets in high energy collisions of leptons and/or hadrons. Applications of the quark-parton model to explain various collider data.

- Collider physics kinematics; the Drell-Yan process and the discovery of the Z boson at CERN. Similarly the W-boson.

- Phenomenology of neutral kaon systems. Mass eigenstates are not strangeness eigenstates; $K^0\overline{K^0}$ oscillations (aside on flavour oscillations of neutrinos); the long and short-lived neutral kaons and K_S regeneration. CP violation in kaon systems (similar phenomena in bottom-meson systems); the need of CP violation for baryogenesis; qualitative discussion of the inadequacy of the CP violation in the Standard Model, and how new physics models typically have too much CP violation.

The grade for the course will be based on the satisfactory completion of HW assignments.

The class will teach you the phenomenology of particle interactions and how the data allowed us to arrive at the (possibly approximate) symmetries of fundamental interactions and the associated conservation laws. It will also teach you how quarks gained recognition as the dynamical constituent of hadrons even though no one has seen (or according to present day theory, never will see) a free quark. This will prepare you for PHYS 778 where the Standard Model of the underlying interactions of the elementary quarks and leptons as a non-Abelian gauge theory will be developed.