PHY 613, Advanced Theoretical Particle Physics, Spring 2018

Instructors: Profs. R. Essig, R. Shrock, G. Sterman

Meeting Times: MW 5-6:30, P116; office hours: after class or by appointment.

Prerequisites: The course prerequisites include a working knowledge of quantum field theory and the Standard Model (SM), as covered in the PHY 610, 611, 612 sequence at Stony Brook. If a student has equivalent preparation as part of an M.A. or M.S. degree, this should be acceptable; the student should check with the instructors.

Course materials: The course does not have a formal textbook, but we will provide suggestions for useful books, articles, and websites.

Grading: The course requirements include homework and class participation. This course should help advanced students move into thesis reseach projects and/or broaden their knowlege of particle physics. We strongly encourage interested students to register for this class, rather than auditing it.

Topics: The course will cover selected topics from the list below:

- Quantum chromodynamics (QCD): deep inelastic scattering, asymptotic freedom, heavy quarks and quarkonium, infrared safety, jets, parton distributions, factorizations and resummations; nonperturbative properties: confinement, spontaneous chiral symmetry breaking, hadron mass spectrum; lattice gauge theory.
- Electroweak symmetry breaking; Higgs mechanism in Standard Model (SM); properties of the 125 GeV Higgs boson discovered by the LHC; searches for possible non-SM properties of this boson; collider phenomenology.
- Neutrino masses and lepton mixing as confirmed physics beyond the original Standard Model (SM), including theory and discussion of data on neutrino oscillations from solar and atmospheric neutrino experiments, and from reactor and accelerator neutrino experiments, as well as astrophysical/cosmological constraints; searches for neutrinoless double beta decay.
- Questions unanswered by the SM and ideas for physics beyond the SM that could answer these questions, e.g., charge quantization, relative sizes of gauge coupling, and values of fermion masses including generational dependence; problems in the SM, including the hierarchy (fine-tuning) problem, strong CP problem, absence of dark matter candidate, etc.
- Grand unified theories and searches for baryon number violation.
- CKM quark mixing and flavor physics.
- Effective field theory; application to QCD and physics beyond the SM.
- Ideas for solution to hierarchy problem.
- Dark matter, primordial nucleosynthesis, early universe cosmology.

Learning goals: Students will learn modern advanced particle theory at a level that will help them begin Ph.D. thesis research, including a selection of topics from quark masses and mixing, neutrino masses and lepton mixing, quantum chromodynamics, Higgs physics, grand unified theories, dark matter, and other material from cosmology.