PHYS 575 (Particle Physics I), Spring 2020

Contact Information

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Course website: http://courses.physics.illinois.edu/phys575/sp2020

Overview

PHYS 575, "Particle Physics I," is a quantitative introduction to the Standard Model of Particle Physics. No background in quantum field theory will be assumed, but prior exposure to the topics in PHYS 582 and/or PHYS 583 will be extremely helpful in understanding the justification and context for many of the calculations we will do. (Note that PHYS 570 is listed in the course catalogue as a prerequisite, but the material covered in that course is not actually required to understand what we will do in this course.) By the end of the course, students will be familiar with the particles, forces, and interactions of the Standard Model, and will be able to perform basic calculations which can be directly compared with experimental results to justify our understanding of the Standard Model as the correct description of elementary particle processes at energies up to 1 TeV.

The language of high-energy physics in general, and the Standard Model in particular, is mathematics. The first 4 weeks of the course will be devoted to group theory and understanding how the observed symmetries of nature impose themselves on the structure of fundamental particle interactions. As a reward for this mathematical introduction, we will be able to write down the complete Lagrangian for the Standard Model by the end of Week 4. After an interlude devoted to the experimental details of elementary particle detection, the remaining 7 weeks of the course will be devoted to pulling apart this Lagrangian, term by term, and comparing its predictions with concrete experimental results. In the final week of the course, we will take stock of the Standard Model and see where old and new experimental results might point to physics beyond the Standard Model.

Textbooks

We will primarily use the following three textbooks for this course, all of which are required. All three will be available in the bookstore and on reserve at Grainger Engineering Library. In particular, the books by Larkoski and Peskin do not require any knowledge of quantum field theory, and perform many of the same calculations as Schwartz using reasoning motivated by quantum mechanics.

Schwartz, **Quantum Field Theory and the Standard Model**
Larkoski, **Elementary Particle Physics: An Intuitive Introduction**
Peskin, **Concepts of Elementary Particle Physics**

For additional reading, you many find the following books useful:

Peskin and Schroeder, **An Introduction to Quantum Field Theory**
Chen (ed.), **Quantum Field Theory Lectures of Sidney Coleman**

Grading

Grading will be based on a combination of homework, class participation, and a take-home problem set which will serve as the final exam. Most homework will be assigned weekly, but occasional problem sets will cover multiple weeks and will be longer (and worth more points) – see schedule below. The final exam will be due on 5/13 at 5pm; it can be submitted either by email or to my mailbox. More details on grading and point values can be found on the course webpage. **Please note: Unless a valid, verifiable excuse is given, homework sets which are submitted late will receive a 10% penalty per day (between Friday and Monday a 20% penalty applies). Homework sets which are turned in more than a week late will receive no credit.**

Your final grade for Physics 575 will be based upon your total score on all the components of the course. The total possible score is 2000 points. Homework will count for 1200 points, attendance and participation for 500 points, and the take-home final for 300 points. Letter grade cutoff values can be found on the course website.

Schedule

- **Week 1** (1/22) – Introduction to group theory and representations of the Lorentz group
- **Week 2** (1/27, 1/29) – Representations of the Poincaré group and classification of elementary particles by mass and spin
  - HW #1 due 1/29

- **Week 3** (2/3, 2/5) – Relativistic Lagrangians for spin-0 particles; space-time and internal symmetries
  - HW #2 due 2/5
- **Week 4** (2/10, 2/12) – Relativistic Lagrangians for spin-1 and spin-1/2 particles; gauge invariance; Lagrangian for the Standard Model
- **Week 5** (2/17, 2/19) – **NO CLASS**. Mandatory reading assignments on elementary particle experiments and detectors
- **Week 6** (2/24, 2/26) – Quantum electrodynamics (QED) at e^+e^- colliders: cross sections, Feynman rules, angular dependence
  - HW #3 due 2/24
- **Week 7** (3/2, 3/4) – QED at low energies; electron and muon $g-2$, soft and collinear singularities
  - HW #4 due 3/4
- **Week 8** (3/9, 3/11) – QED with quarks: electron-proton fixed-target experiments and deep inelastic scattering, resonances in e^+e^- annihilation
  - HW #5 due 3/11
- **Week 9** (3/16, 3/18) – **NO CLASS: spring break**
- **Week 10** (3/23, 3/25) – Quantum chromodynamics (QCD) at high-energy colliders: gluons, asymptotic freedom, and jets
- **Week 11** (3/30, 4/1) – Discovery of the top quark and collider observables; chiral symmetry breaking and pions as pseudo-Goldstone bosons
  - HW #6 due 4/1
- **Week 12** (4/6, 4/8) – The Higgs mechanism, classically
  - HW #7 due 4/8
- **Week 13** (4/13, 4/15) – 3 generations and flavor: CKM and PMNS matrices, Feynman rules for electroweak interactions, neutrino oscillations
  - HW #8 due 4/15
- **Week 14** (4/20, 4/22) – Discovery of the W, Z, and Higgs; parity-violating observables
- **Week 15** (4/27, 4/29) – Weak interactions at low energies: muon decay, integrating out the W, introduction to effective field theories

- HW #9 due 4/29

- **Week 16** (5/4, 5/6) – Putting it all back together: lingering issues with the Standard Model and how to look for physics beyond it
  - **Take-home final due 5/13 at 5pm**