High Energy Physics

Fall 2006 - Elementary Particle Physics
UCSB Physics 225a and UCSD Physics 214

Mondays 3:30-5:00 and Tuesdays 2:00-3:30
UCSB: Kerr Hall Studio B
UCSD: CLICS, Room 260 Galbraith Hall

What this course is about

Welcome to the homepage of the first joint UCSB/UCSD elementary particle physics class.

This is the first quarter of a two quarter sequence in elementary particle physics. This course is intended to give the student a broad foundation in the phenomenology of modern particle physics.

This is not intended to be a formal course in particle theory. The emphasis is on the understanding of the basic concepts as applied to real world situations and on doing simple calculations. Most students will be concurrently taking a more formal course in field theory. The expectation is that the field theory course will serve as a more formal complement to the treatment given in this class.

No previous background in particle physics is assumed. Understanding of quantum mechanics at the graduate level would be very helpful, but undergraduate quantum mechanics would suffice.

Instructors

Lectures are given by Professor Campagnari from UCSB. Professor Wuerthwein is the contact person at UCSD. Scott Fraser from UCSB is the TA. Contact information is given below.

Who	Office	Phone	email	Office Hours
Claudio Campagnari	Broida 5119 (UCSB)	Phone: 805 893-7567	claudio@hep.ucsb.edu	Monday 11-12 (or anytime you can find him)
Frank Wuerthwein	Mayer 3310 (UCSD)	Phone: 858 822-3219	fkw@fnal.gov	xxxx
Scott Fraser	Broida 6216	Phone: 805 893-5260	scottf@physics.ucsb.edu	xxxx
Debbie Ceder (UCSB administrative assistant)	Broida 5014 (UCSB)	Phone: 805 893-8597	dla@hep.ucsb.edu	-

Announcements

Announcements are usually sent out via email and archived here.

- 6 October: Miscellaneous stuff.
- 15 October: Error in homework 2, problem 1.
- 15 October: Hint for homework 2.

Syllabus

First Quarter
- General Introduction, Natural Units
- Lifetimes and branching fractions, partial widths, Breit-Wigner
- Interactions of particles with matter (very basic).
- Symmetries, Conservation Laws
- Group Theory for dummies
- Isospin, SU(3)flavor, quark model of hadrons
- Quarkonium discoveries
- Neutrino masses, mixing, and oscillations
- Electrodynamics of S=0 particles
- Cross-sections
- Review of Dirac equation (if needed)
- Electrodynamics of S=1/2 particles (QED)
- Deep inelastic scattering, parton model
- Parton distribution functions, hadronic cross-sections
- QCD corrections, scaling violations, Altarelli-Parisi equation (may need to go in 2nd quarter)

Second Quarter - Fermi Theory, V-A
- Intermediate Vector Boson idea
- GIM Mechanism
- Spontaneous Symmetry Breaking, Goldstone Bosons, Higgs Bosons
- Electroweak Theory, SU(2)xU(1)
- Precision electroweak tests
- Standard Model Higgs Phenomenology: mass, naturalness, production mechanisms, decay modes, experimental prospects
- Mixing and CP violation (K, D, and B systems)
- One (or more, time permitting) beyond-the-standard-model model, TBN

Textbook

The textbook is Quarks and Leptons: An Introductory Course in Modern Particle Physics by Halzen and Martin. This is an excellent book at about the right level for this course. The main problem with it is that it is 20 years old, so many of the new developments in particle physics are missing. We will provide additional material to supplement it.
In addition, we recommend that you obtain a copy of the *Review of Particle Physics*. This includes a comprehensive compilation of data on particle physics as well as short review articles and miscellaneous other useful stuff. The Review of Particle Physics is published every two years (on even years). It can be obtained for free from the Particle Data Group (PDG). (At the moment the website says that the 2006 version will be available in the *near future*. However we know that they have already started to distribute copies to their long time subscribers). While you wait for the PDG to send your very own

copy, you may be able to borrow an older copy from your instructor (just ask). Note also that the content of the Review of Particle Physics is also available online from the PDG website.

Other books that you might find useful include:

- Particle Physics: a Comprensive Introduction by Seiden. Also an excellent book, which could have easily been chosen as the main textbook for the class. It came out in 2004, so it is up-to-date. The mathematical treatment is a bit more sophisticated than in Halzen and Martin.
- Introduction to High Energy Physics by Perkins. A classic. The treatment of the subject is at the boundary between the undergraduate and graduate level.
- An Introduction to Gauge Theories and Modern Particle Physics (two volume set) by Leader and Predazzi. Very clear. A little more theoretical than the ones above.
- High Pt physics at hadron colliders by Green. Very focussed on Tevatron and LHC.
- Collider Physics by Barger and Phillips.
- Detectors for Particle Radiation, by Kleinknecht; Experimental Techniques in High-Energy Nuclear and Particle Physics, by Ferbel. These are good introductions to experiemntal techniques.

Links to Additional Material

These will be added as time goes on. Please chack this section of the web page often.

Whenever possible we provide links that can be accessed without passwords or subscriptions. Unfortunately this is not always possible, since sometime the only available link is to the electronic version of the journal where the paper was published. For copyright reasons we are not allowed to post these papers directly on our website. However, UCSB and UCSD have electronic subscriptions to most Physics journals, and if you work on a machine with a ucsb.edu or ucsd.edu domain you should be able to get to the paper without any problem. If you are trying to access the paper from home, while logged on through a commercial ISP, you may encounter problems. However, if you are a UCSB student there are ways to setup your browser to circumvent these issues, see the instructions posted here.

- A good overview of the interaction of particles with matter can be found in the PDG. The references in this review are a good place to start if you want to go deeper.
- My lectures on neutrino physics are based on Lectures at the 2004 SLAC Summer school, also by Boris Kayser.
  Other material on neutrino physics that you might find interesting is listed below:
  1. A general review of neutrino physics for the PDG, also by Boris Kayser
  2. A review of solar neutrino physics for the PDG by Nakamura
  3. If you want to know why the neutrino mixing matrix has three phases if neutrino are Majorana particles, you should read this paper.
  4. Here is a detailed discussion of the Quantum Mechanics of neutrino oscillations.
  5. In the late eighties several experiment claimed evidence for a neutrino mass of order 17 keV. They turned out to be wrong. Read all about it here.
  6. A number of future neutrino experiments are being planned around the world. A panel of experts recently wrote a report (in two parts) to advise the funding agencies on the best course of action: part 1 and part 2.

Lecture Notes

By popular demand, I am also posting my lecture notes. Note that I did not write these notes with the intent to distribute them. The handwriting is barely legible and not a lot of effort went into trying to explain things clearly on the written page. Use them at your own risk.

- Lectures 1 and 2
- Lectures 3 and 4

Figures shown during lectures

- October 9.
- October 10. Some of these will probably be shown next week.
- October 16 and 17. Note: none of the figures of October 10 were shown on October 10. So on October 16-17 we will show the figures from October 10 as well.

Presentations on detector techniques

As a complement to the normal lectures, we would like to have some presentations on detector techniques in experimental particle physics. The idea would be for students to **volunteer** to learn about a specific detector technnique and then give short (20 minutes?) presentation to the class. The instructors would be available to help guide the students and suggest reading materials.
This has worked well in the past, which each student making a presentation. This year the enrollment is much higher, and it is not feasible to have each student make a presentation. However, we would still like to try it and ask for a small number of volunteers.
Possible topics are listed below:
- Scintillators, photomultipliers, photodiodes
- Gaseous tracking detectors
- Silicon strip detectors
- Detection of axions
- Detection of dark matter
- Pixel detectors
- Calorimeters
- Cherenkov detectors
- Transition radiation detectors

Grading

Grading will be based on the final (50%) and the homework (50%). The date and time of the final will be announced later.

Homework

UCSB students should place their homeworks in the TA mailbox on the 5th floor of Broida Hall. UCSD students should scan their homeworks into pdf files and email them to the TA. Graded homeworks will be returned in class (for UCSB students) or scanned and emailed back (for UCSD students).
Solutions to the homework will be also posted on this page after the due date.

Homework 1 pdf	Solutions: pdf
Homework 2 pdf	Solutions: Not yet