

Collider Physics

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The purpose of these lectures is to give an introduction to physics at the CERN Large Hadron Collider for students who have some knowledge of Quantum Field Theory. This is not really a task that can be accomplished in a week of lectures. Physics at the LHC touches all aspects of the strong, weak, and electromagnetic interactions. For these lectures, I have chosen a selection of topics that I consider necessary background for understanding the main aspects of LHC physics within the Standard Model.

I will assume that you are familiar with the equations of the Standard Model of particle physics, gauge invariance, spontaneous symmetry breaking, and other essential concepts. On the other hand, I will review some important aspects of the experimental implications and tests of the Standard Model. There will be no deep use of quantum field theory in this courses. In particular, I will not discuss the formalism of perturbative QCD or effective field theory. We will pick up just enough of what we need in these domains to discuss the relation between the Standard Model and the data.

Here is the outline of the lectures:

1. Collider physics at e^+e^- colliders
2. The parton model
3. Altarelli-Parisi evolution
4. Structure of events at the LHC
5. The Goldstone boson equivalence theorem
6. Properties of the Standard Model Higgs boson
7. Aspects of the search for new elementary particles

There are a number of excellent textbooks on elementary particle physics, at a variety of levels. For background on elementary particle experimentation, see:

- Abraham Seiden, *Particle Physics: a Comprehensive Introduction*
- Mark Thomson, *Modern Particle Physics*

For necessary Quantum Field Theory background, and the QFT topics described in this course, see:

- Michael Peskin and Daniel V. Schroeder, *An Introduction to Quantum Field Theory*
- Matthew Schwartz, *Quantum Field Theory and the Standard Model*

For more detailed theoretical descriptions of collider physics, see:

- Francis Halzen and Alan Martin, *Quarks and Leptons*
- R. Keith Ellis, W. James Stirling, and Brian Webber, *QCD and Collider Physics*

For the physics of the Higgs boson, the classical and still very useful resource is:

- Howard Haber, John Gunion, Gordon Kane, and Sally Dawson, *The Higgs Hunter's Guide*

Up-to-date predictions of the Standard Model Higgs properties are given in the reports of the LHC Higgs Cross Section Working Group

- *Handbook of LHC Higgs Cross Sections, vol. 1: Inclusive Observables*, arXiv:1101.0593
- *Handbook of LHC Higgs Cross Sections, vol. 2: Differential Distributions*, arXiv:1201.3084
- *Handbook of LHC Higgs Cross Sections, vol. 3: Higgs Properties*, arXiv:1307.1347

The following sets of lecture notes will be useful for some of the QCD topics discussed in this course:

- Gavin Salam, *Towards Jetography*, arXiv:0906.1833.
- Michael Peskin, *Simplifying Multi-Jet QCD computation*, arXiv:1101.2414.

A comprehensive discussion of the LHC accelerator and detectors is given in the set of articles in JINST, vol. 3 (2008):

- *The CERN Large Hadron Collider: Accelerator and Experiments*, <http://jinst.sissa.it/LHC/>.

The publications of the ATLAS and CMS collaborations are most easily accessed through the collaboration web sites:

- *ATLAS Experiment - Public Results*, <https://twiki.cern.ch/twiki/bin/view/AtlasPublic>
- *CMS Physics Results*, <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults>

Finally, the web site of the Particle Data Group

- <http://pdg.lbl.gov/>

is an invaluable resource. There you will find up to date summaries of the properties of all elementary particles and comprehensive reviews of many areas of the theory and experimental techniques of elementary particle physics.