Collider Physics & QCD

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Introduction

We are all eagerly awaiting the start of the Large Hadron Collider at CERN. The (re)start should happen towards the end of the year and the machine will initially run at 3,5 TeV per beam. The design energy of 7 TeV / beam should be reached later.

The LHC will be able to test a wide variety of new physics models. It will find the Higgs boson, or whatever else is responsible for electroweak symmetry breaking.

However, to achieve the physics goals of the LHC program will require a great deal of understanding of Standard Model physics. The biggest challenge in this respect are QCD effects.

QCD at high energy colliders will be the focus of these lectures. In the first part we'll provide an introduction to perturbative QCD. After this, we'll try to answer the question why (or better when) the use of perturbation theory is appropriate. The naive answer to this question is that QCD perturbation theory can be used in high-energy collisions because of asymptotic freedom, i.e. the statement that the strong interaction becomes weak at high energies. However, even in the highest-energy colliders, we observe hadrons, and not quarks and gluons – so how can perturbation theory ever be appropriate?

Indeed, most observables at colliders cannot be calculated perturbatively. However, for a limited set of observables the non-perturbative hadronic effects are suppressed like $m_{Hadron}/E_{c.m.}$ and are thus small. At hadron colliders, no such observables exist, because all reactions depend on non-perturbative properties of the incoming hadrons. However, this dynamics is the same irrespective of the final state of the collision. Using factorization theorems, it can be seperated from the rest of the scattering process.

Because of the complexity of hadron collisions, we'll first discuss e^+e^- collisions and move then to e^-p and then pp scattering.

Since the classical factorization "proofs" are very technical, many books avoid discussing the issue in any detail. However, in the past few years, an effective field theory has been developed which provides a better language to address these issues. The framework is called Soft-Collinear Effective Theory and will be covered as part of the course.

Literature:

QCD

There are many excellent books covering QCD.

Two I particularly like are

* Peskin & Schröder "Intro to QFT"

* G. Sterman "An intro to QFT"

Sterman is the expert on factorization and his book is one of the few to address the topic.

Collider physics

The most useful reference for our course is

* Ellis, Stirling and Webber "QCD and Collider Physics"

another relevant book is

* Barger and Phillips "Collider physics"

however this one is much more focussed on phenomenology. (QCD only appears on p. 200.)