Collider Physics

(as a proxy for LHC Physics Lectures)

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Abstract

The goal of these lectures is to give a broad overview of the physics at the LHC in the context of collider physics in General. The emphasis will be on the most important results achieved so far and the foreseen reach of the LHC. Future collider projects will also be discussed.

Disclaimer: These lectures will neither cover heavy ion collision physics, nor the B factory Belle II program in detail.

Draft Outline

1.- Introduction

a.- A brief history of colliders and their impact on particle physics before the LHC.
b.- The Standard Model in a nutshell
c.- The BEH mechanism and its implications
d.- Perturbative unitarity and the no-loose theorem
e.- Where do we stand, what are the big questions?

2.- Elements of colliders

a.- Elements of colliders electron-positron versus hadron
b.- Hadron colliders: machine challenges
c.- Hadron collider physics: kinematics and the collinear factorisation
d.- Measurements of the luminosity and forward physics

3.- Elements of particle detectors and event reconstruction

a.- Elements of detection techniques
b.- LHC detectors
c.- Triggering events
d.- Reconstructing events
e.- Simulating events at the LHC

4.- QCD at hadron colliders

a.- Monte Carlo generators
b.- Soft QCD measurements and tuning of Monte Carlo generators
c.- Hard QCD measurements of jets and the running of alphaS
d.- Precision Vector boson production measurements
e.- Interlude on electron-proton collisions and PDFs
f.- PDFs at the LHC.

5.- Flavor Physics at the LHC

a.- Summary of electron-positron B factories
b.- Main CKM measurements at the LHC and the angle gamma
c.- CP violation in charm decays
d.- Rare decays
e.- Lepton Flavor Universality anomalies

5.- Precision EW measurements at the LHC

a.- Measurement of the W mass
b.- Measurements of the FB asymmetry at the LHC and the weak mixing angle.
c.- Precision EW observables and fit of the Standard Model.
d.- Challenges in Precision EW measurements.

6.- EW and top measurements at the LHC

a.- Diboson and triboson measurements and implications.
b.- Vector boson scattering (including longitudinal) at the LHC.
c.- Challenges in multi boson measurements.
d.- Top quark single and pair production measurements at the LHC
e.- Top production charge asymmetry.
f.- Top rare production processes.
g.- Top quark mass measurements.
h.- Challenges in top physics.

7.- Higgs physics

a.- The discovery of the Higgs boson at the LHC
b.- Higgs boson production measurements in dibosonchannels
c.- Probing the couplings of the Higgs boson to fermions
d.- Measurements of Higgs boson couplings at the LHC

7.- Higgs physics (cont'd)

e.- Constraining the Higgs boson width at the LHC
f.- New trends in Higgs physics
g.- Challenges in Higgs physics at the LHC

8.- Searches for new physics BSM

a.- The shortcomings of the Standard Model
b.- The proposed solutions (weakly and strongly coupled)
c.- Searches for SUSY
d.- Searches for additional Higgs bosons
e.- Searches for additional Vector bosons
f.- Searches for additional (vector like) fermions
g.- Searches for leptoquarks
h.- Searches for Dark Matter
i.- Searches for a Dark sector particles
j.- Searches for unconventional signatures

9.- Precision physics at the LHC, interpretations and conclusions

a.- SM Effective Field theory
b.- What have we learned?
c.- What are the main challenges?

10.- Outlook on Future collider projets

a.- Future electron positron collider physics
b.- Future hadron colliders
c.- Muon colliders

Credits corresponding to ~20-26 hours

Lectures will be held (pending quorum of attendance) from February to June)