Ph.D. Research Project
Search of the Higgs boson in the two photon final state

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Introduction

The Compact Muon Solenoid (CMS) [1] is one of two general purpose experiments at CERN along the Large Hadron Collider ring (LHC). Its physics goals range from the search for the Higgs boson to the searches for physics beyond the Standard Model (SM), to the precision measurements of already known particles and phenomena.

The excellent performances of the LHC in terms of stability, instantaneous and integrated luminosity pushed very soon the CMS experiment toward one of its main scientific goals: the search of the Higgs boson. My Ph.D. research project will focus on the Higgs boson search in the two photon decay channel.

The Higgs boson

CMS measurements are expected to shed light on the nature of the electroweak symmetry breaking. The detector has been designed, above all, in order to maximize its discovery potential of a Standard Model Higgs boson in the mass range that extends from the current LEP limit (114 GeV) to about 600 GeV. In this model the Higgs boson is assumed to be coupled to all massive elementary particles, proportionally to their mass, and its mass is a free parameter of the theory.

On the 4th of July 2012, CMS, jointly with ATLAS, announced the observation of an excess of events at a mass of approximately 125 GeV with a statistical significance of five standard deviations above background expectations. This means that the probability of the background alone fluctuating up by this amount or more is about one in three million. The evidence was strongest in the two photons final states with the best mass resolution. Physicist interpreted this to be due to
the production of a previously unobserved particle with a mass of around 125 GeV and with properties very similar to those of the Standard Model Higgs boson.

**Higgs in the $\gamma\gamma$ decay channel**

In the low mass region, where the possibility of the existence of the Higgs boson survives, the search is conducted looking at the Higgs boson decaying into two photons or 4 leptons or two taus or in $b\bar{b}$. The two photon final state represents the best compromise between the low branching ratio (from 1 to 2 per mill depending on the Higgs mass hypothesis) and a good sensitivity that permit a very good signal and background discrimination. This channel provides a clean final state topology where the identification of the two high energy photons is performed with a very high efficiency, thanks to the great precision given by the CMS high-resolution electromagnetic calorimeter (ECAL).

**Ph.D. project plan**

The LHC run in the 2012 at a higher energy (8 TeV) in the centre-of-mass system with respect to the 2011 (7 TeV), enhancing the production cross section of about 25% and providing about 4 times the amount of data of 2011. These data will enable CMS to elucidate further the nature of this newly observed particle.

If this particle is indeed the SM Higgs boson, its properties and implications for the Standard Model will be studied in detail. If it is not the SM Higgs boson, CMS will explore the nature of the new physics that it implies, which may include additional particles that are observable at the LHC.

In order to perform a measurement based on high energy photons, the properties of the ECAL have to be fully understood. In this period of my Ph.D. therefore I am actually involved in the study of the ECAL performances in photon identification. In particular we are now investigating the feasibility of exploiting the timing information [2] from the ECAL in the discrimination between photons coming from the decay of the Higgs boson (signal) and jets from QCD events (background). This will be preparatory to a proper photon-based Higgs analysis.

The second year of my Ph.D. will be focused on the search for a new Higgs boson, decaying into two high energy photons, in the high mass range (200 - 400 GeV). Indeed models beyond the SM exist, like supersymmetry (SUSY), that predict the presence of more than one Higgs boson in the theory [3]. Finally another task of the exclusive analysis in the two photon final state aims at interpreting the yields of the different Higgs production mechanisms in terms of the coupling of the Higgs to fermions and to bosons [4].
Bibliography


