Contents

Chapter 1

Analysis

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1.1 Introduction

Discovering the mechanism responsible for electroweak symmetry-breaking and the origin of mass for elementary particles has been one of the major goals of the physics program at the Large Hadron Collider (LHC) [1]. In the Standard Model (SM) this mechanism requires the existence of a single scalar particle, the Higgs boson [2, 3, 4, 5, 6]. In the Minimal Supersymmetric extension of the Standard Model (MSSM) [7, 8] the Higgs sector is composed of two Higgs doublets of opposite hyper-charge, resulting in five observable Higgs bosons. Two of these Higgs bosons are neutral and CP-even (h,H), one is neutral and CP-odd (A) and two are charged ($H^{\pm}$). At tree level their properties such as masses, widths and branching ratios can be predicted in terms of only two parameters, often chosen to be the mass of the CP-odd Higgs boson m_A, and the ratio of the vacuum expectation values of the two Higgs doublets $\tan\beta$. For relatively large values of $\tan\beta$ one of the CP-even Higgs bosons is almost degenerate in mass with A. Moreover, Higgs couplings to down (up) type fermions are enhanced (suppressed) by $\tan\beta$, meaning that for large $\tan\beta$ bottom-quark and τ lepton will play a more important role than in the SM case either for production and decay.

The production of the neutral CP-even MSSM Higgs bosons at hadron colliders proceeds via the same processes as for the SM Higgs production. However, the pseudoscalar A instead cannot be produced in association with gauge bosons or in vector boson fusion (VBF) at tree-level, as this coupling is forbidden due to CP-invariance. At the LHC one of the most relevant production mechanisms for the MSSM Higgs bosons is gluon-gluon fusion, $gg \to A/H/h$. In addition, the production in association with b-quarks becomes important for large value of $\tan\beta$. The decays of the neutral MSSM Higgs bosons (in the assumption that all supersymmetric particle are heavy enough) are the same as for the SM one with the already cited exception of A, however the decay rates depend on a large extent to the couplings with fermions and gauge bosons.

Searches for neutral MSSM Higgs bosons have been performed at LEP [9], the Tevatron [10, 11, 12, 13, 14, 15] and the LHC [16, 17]. In this note a search for neutral MSSM Higgs bosons with the ATLAS experiment at CERN is presented, using proton-proton collisions at centre-of-mass energy of 8 TeV, with a recorded integrated luminosity of $20.3 fb^{-1}$. The results of this search are interpreted in a model independent fashion, as limits on the product of the cross section and branching ratio for such a new particle, as well a limits on the MSSM in the m_h^{max} scenario [34]. Only b-quark associated and gluon fusion are considered as production mode for the Higgs bosons, the search then focuses on the subsequent decay into a $\tau^+\tau^-$ pair. Furthermore, only cases in which both τ decays leptonically, with one decaying to an electron and the other to a muon, are considered. This final state corresponds to a total $\tau^+\tau^-$ branching ratio of approximately 6%. The analysis strategy is to split the selected events in two categories by requesting the presence (b-tag) or absence (b-veto) of a jet coming from a b-quark. This solution helps to separate the contribution of the two production modes and allows for optimisation of selections due to the different backgrounds for the different final states..

The signal topology is characterised by a final state with an electron, a muon, and missing transverse energy due to the presence of four neutrinos from the τ decays. Furthermore, the final state may be split by the presence or absence of a b-quark initiated jet, depending on the production process. The background processes which are considered in this study are the production of W and Z bosons in association with jets (W/Z+jets), pairs of top quarks ($t\bar{t}$), single top quark (the so-called single-top) and pairs of electroweak gauge bosons (WW, WZ, ZZ). Finally QCD multi-jet also forms a non-negligible background due to its large production cross-section. Where possible these backgrounds are estimated using data driven methods.

This note is structured as follows: The ATLAS detector is briefly described in Section **??**. In Section **??** the collision data set, the Monte Carlo-simulated event samples as well as hybrid (tau-embedded) data samples used in this study are described. The reconstruction of physics objects, the trigger requirements and the offline event selection are discussed in Sections **??** and **??**. Background estimation methods are described in Section **??**, and the systematic uncertainties are discussed in Section **??**. A statistical analysis and resulting exclusion limits are described in Section **??**, followed by conclusions in Section **??**.

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