# Search for Heavy Higgs with Associated b Production

### Introduction

The Standard Model (SM) with a single Higgs boson is the simplest scenario to give masses to the weak bosons to explain the electroweak symmetry breaking, yet nature has always given us more puzzles to ruin our naive wishes. 3 fermion families, the beautifully minimal SU(5) GUT turned out to be not what nature had in mind, to name a few. The Higgs sector may well also hold more rich secrets than the minimal SM would suggest, and additional Higgs doublets are well known extensions of the SM which are just as likely. In the popular extension of the Higgs sector with Two Higgs Doublet Models (2HDM) that includes Minimal Super-Symmetric Model (MSSM) as a special case, the extended Higgs sector mostly have the neutral Higgs  $h^0$  behaving very similar to the SM Higgs, while there are additional heavy neutral Higgs  $H^0$ , $A^0$  and charged  $H^+$ . The ratio of u/d vacuum polarization values is denoted as tan(beta). Among the remaining parameter space not ruled out by existing searches, a large fraction is in the regime of moderate or large tan(beta) with preferred large couplings of  $A^0/H^0$  to b quark in particular while couplings to top quark and W/Z are suppressed. An interesting consequence is that the production of H/A in association with b quarks being significantly enhanced by ta factor proportional to tan<sup>2</sup>(beta) to allow possible early observations. Further more, the decays of H/A are dominated by bb(bar) mode followed by tau pairs and all other modes much smaller. This also puts a premium on the search for the H/A -> bb(bar) decay mode. While in some 2HDM models the bb and tautau decays tend to have stable ratios, in some other 2HDM types b and tau have opposite tan(beta) dependence so that they cover complementary parameter regions as dominant decay channel.

The early studies of the MSSM Higgs production concentrated on the bbH/A production:



while later studies found that the cross section with just a single b quark in the proton sea being struck by a gluon and picking up a large Pt to allow b-tags is a more relevant production mechanism with larger cross section:



Our analysis is therefore a search for H/A decays to bb(bar) and an additional associated b quark from production. The analysis challenge starts with the trigger as the cross section of just 3 jets with rather moderate Pt has a substantial QCD background. b-tags at trigger and analysis level become a crucial element. The initial analysis with the ATLAS 8 TeV data from Run 1 led to the Stanford Ph.D thesis of Katie Malone in 2015, while the ongoing much improved analysis with 13 TeV data from Run 2 is targeting for result release for 2017 summer conferences.

## Working Information

Run 1 Analysis team: Katie Malone, Giacinto Piaquadio, Tim Barklow and Su Dong (former analyst: Emanuel Strauss)

Run 2 Analysis team: Tim Barklow, Su Dong + collaborating groups from Cracow, Belgrade and Uppsala.

bH analysis working Twiki (ATLAS internal)

ATLAS Higgs WG Complex Final State subgroup (ATLAS internal page)

### Literature

#### **Current results**

- ATLAS Higgs Papers and conference notes
- CMS Higgs results
- CDF Higgs results
- D0 Higgs results

#### **Reference papers**

- A Supersymmetry Primer (Stephen Martin): HEP-PH/9709356 (updated 2008)
- Higgs Boson Theory and Phenomenology (M.Carena, H.Haber): hep-ph/0208209
- Standard Model cross section calculation series on MCFM page
- LHC Higgs cross section working group Twiki
- MSSM Higgs Boson Searcheas at the LHC: Benchmark Scenarios after the Discovery of a Higgs-like Particle (M. Carena et. al.): arXiv 1302.7033
- Theory and phenomenology of two-Higgs-doublet models (G.C Branco et. al.): arXiv 1106.0034