Search for Higgs Bosons Produced in Association with b-Quarks in pp collisions

Wolfgang Lohmann\textsuperscript{12}, Rainer Mankel\textsuperscript{1}, \textbf{Igor Marfin}\textsuperscript{12}, Alexei Raspereza\textsuperscript{1}, Alexander Spiridonov\textsuperscript{1}, Roberval Walsh\textsuperscript{1}

\textsuperscript{1}DESY,
\textsuperscript{2}Brandenburgische Technische Universitaet Cottbus
Outline

• Introduction

• Experimental situation

• Hbb trigger at CMS

• Analysis Strategy

• MVA Likelihood

• Summary
Introduction

- Higgs sector of MSSM requires two doublets of Higgs fields
- It incorporates 5 physical states:
  - $h, H$ (both CP even), $A$ (CP odd), $H^\pm$ (charged)
- Two main parameters
  - $\tan \beta = v_1/v_2$ (ratio of vacuum expectation values)
  - $m_A$ – mass of $A$

Main channel of production $bb\Phi$ ($\Phi = h/H/A$) at LHC: $gg \rightarrow bb\Phi$
Motivation

At large $\tan\beta$, $gg\to bb\Phi$ is dominant

- $h/H$ degenerate in mass with $A$
- doubled rate of $\Phi bb$

Cross section ($\Phi bb\to 4b$) is enhanced as $\tan^2\beta$
MSSM $bH$ Experimental Situation

- CDF on published $2.6\text{fb}^{-1}$
  - $2\sigma$ excess around $m\Phi \sim 150 \text{ GeV/c}^2$
- D0 on $5.2\text{fb}^{-1}$
  - $2\sigma$ excess around $m\Phi \sim 120 \text{ GeV/c}^2$

hep-ex/1011.1931v1

CDF-Note-10105
Higgs decay products $p_T$ spectra peaks at $\sim M\Phi/2$, centrally produced

- Associated jets with very low $<p_T> \leq 20 \text{ GeV/c}$

- Huge background mainly from QCD
- Dedicated triggers are needed
- MVA is needed to suppress background

I. Marfin

Search for Higgs production with $bb$ association
Level 1 Trigger and High Level Trigger (HLT)

Level 1 triggers events with at least two jets of $p_T > 36\text{GeV}$

- HLT triggers events
  - with two leading jets having $p_T > 46,38 \text{ GeV}/c$ and $|\eta| < 2.6$
  - when two jets among 4 leading jets are b-tagged

- B tagging:
  - Tracks passed quality cuts are ordered by descending impact parameter ($d_{3D}$) significance ($S_d$),
  - $S_d = d_{3D} / \sigma(d_{3D})$

- B tagging discriminator $S_d(2^{nd} \text{ track}) > 6$
Analysis Strategy

Offline Event Selection
At least three well-reconstructed jets:
- $(p_T^{\text{jet1}}, p_T^{\text{jet2}}, p_T^{\text{jet3}}) > (46, 38, 15) \text{ GeV/c; } |\eta|<2.6$
- Triple-b-tag sample: first 3 leading jets are btagged
- Two operation points: $S_d(3^{\text{rd}} \text{ track})>3.41$ or >6

Construct MVA Likelihood
- To separate Signal from Background
- MC samples
  - Pythia Higgs-SUSY+bb
  - Pythia QCD bEnriched
  - Alpgen 2b/2c, 4b,4c,2b2c + nJets samples
- Signal as a mixture of samples with $M_\Phi=[90,280] \text{ GeV/c}^2$
- Btagging is emulated by weighting events
  - weight for offline triple-btagging
  - weight for online double-btagging
    - corresponds to selection by Hbb trigger
**Variables to train Likelihood**

- $p_T(jet_3)/p_T(jet_1)$
- $p_T(jet_3)/p_T(jet_2)$
- $\eta(jet_1)$
- $\eta(jet_2)$
- $p_T(jet_1) - p_T(jet_2)$
- $\varphi(jet_2) - \varphi(jet_3)$
- $\eta(jet_1) - \eta(jet_2)$
- Sphericity of the event

MVA Likelihood

$\eta(jet_1)$

$\varphi(jet_2) - \varphi(jet_3)$

Sphericity

I. Marfin

Search for Higgs production with bb association
Control/Signal regions

• Background region (MVA<0.1)
  • B/S enhanced by factor of 6
    • can be used for systematic study

• Signal region (MVA>0.9)
  • S/B enhanced by factor of 10

- MVA<0.1
- MVA>0.9
Data-driven estimation of background

- Double btag
- Triple btag
- Signal MC

- btag efficiency functions
- bb purity correction
- Online btag correction

- Background Model
- Fit
- Rates

I. Marfin
Search for Higgs production with bb association
Summary

• Analysis strategy has been developed
• Variables for MVA training were identified
• MVA Likelihood was used to construct control/signal regions
• Background modeling is in the progress
Back-up slides
Under assumption of

- degeneracy of all sfermion masses
- unification of all higgsinos trilinear couplings
- unification of U(1) and SU(2) gauginos masses (M1,M2)

There are 7 parameters

- A (common trilinear Higgsino coupling)
- Msusy (universal sfermion mass)
- Mu (mass parameter of Higgsino)
- M2
- M3 (mass of gluinos)
- MA (mass of A Higgs, variable)
- tanbeta (v1/v2, ratio of vacuum expectation values, variable)

- Benchmark scenarios to probe MSSM:
  - no-mixing, large-mu etc
  
  mh-max: Msusy=1Tev, Xt=At-mu/tanβ=2Msusy, m2=200GeV, m3=800GeV, Ab=At – stop and sbottom trilinear couplings
Reconstruction of tracks and jets (kT algorithm)
3D pixel vertex reconstruction
Pixel tracks in each jet are ordered with growing Significance of Impact Parameter (SIP).
2 jets at level L2.5 and L3 must be tagged using SIP 2\textsuperscript{nd} track
(TrackCountingHighEfficiency) (TrackCountingHighPurity if SIP 3\textsuperscript{rd} track).
- L2.5 (pixel tracks): SIP(2\textsuperscript{nd} track)> 4 (change to 3 after 170248 run)
- L3 (regional tracks): SIP(2\textsuperscript{nd} track)>6
MVA Likelihood. Input variables.

**Variables to train Likelihood**

- $\eta(jet_2)$
- $p_T(jet_1)-p_T(jet_2)$
- $\eta(jet_1)-\eta(jet_2)$
- $\eta(jet_2)$
- $p_T(jet_1)-p_T(jet_2)$