Light NMSSM Higgs Boson Search in bb Final States with the CMS Experiment

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Abstract

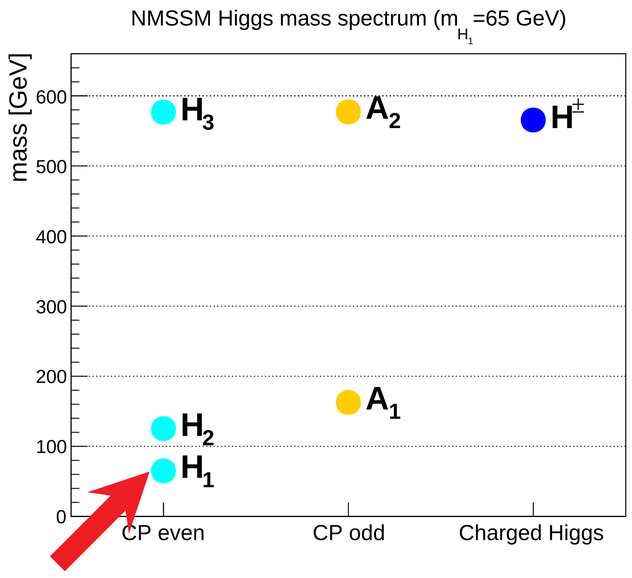
On July 4th, 2012 the discovery of a boson compatible with the Higgs boson of the Standard Model of particle physics was announced. However, the exact properties of this particle and the precise structure of a possible Higgs sector still need to be investigated. A very important question is whether additional Higgs bosons exist, as they are predicted e.g. by various extensions of the Standard Model.

In the **Next-to-Minimal Supersymmetric Standard Model (NMSSM)**, scenarios are possible in which one of the Higgs bosons has a mass below that of the Z boson. Due to reduced couplings to the electroweak gauge bosons, such a particle may have evaded the previous searches at the LEP collider. This work presents a search for such light NMSSM Higgs bosons decaying in the bb channel with the CMS experiment at the LHC. The analysis strategy is discussed and feasibility studies using simulated events have been performed. The analysis of the 8 TeV collision data is currently in progress.

Extended NMSSM Higgs Sector

NMSSM

- Simplest supersymmetric extension of MSSM
  - Additional singlet superfield
    - No gauge interactions
    - Interacts with itself and Higgs doublets
  - Resulting additional particles wrt. MSSM
    - 1 neutralino
    - 1 CP-odd Higgs
    - 1 CP-even Higgs
- Light Higgs scenarios may evade LEP constraints
- Offers a solution to the μ problem of the MSSM
  - $\mathcal{W}_{\text{MSSM}} = \mu(\hat{H}_d \cdot \hat{H}_u) + \cdots$
    - Natural scale of μ? M_{GUT}?
    - EWSB yields a relation suggesting $\mu \sim M_W$, M_Z
  - μ term created dynamically in the NMSSM



Modified "P4 benchmark scenario"

- Interesting NMSSM scenario pointed out by [1]
  - Lightest CP-even H_1 lighter than m_Z
    - "Signal" in this analysis
  - Second lightest CP-even H_2 is SM like
    - Can be identified with $H(126\text{ GeV})$
- Not excluded by existing Higgs searches

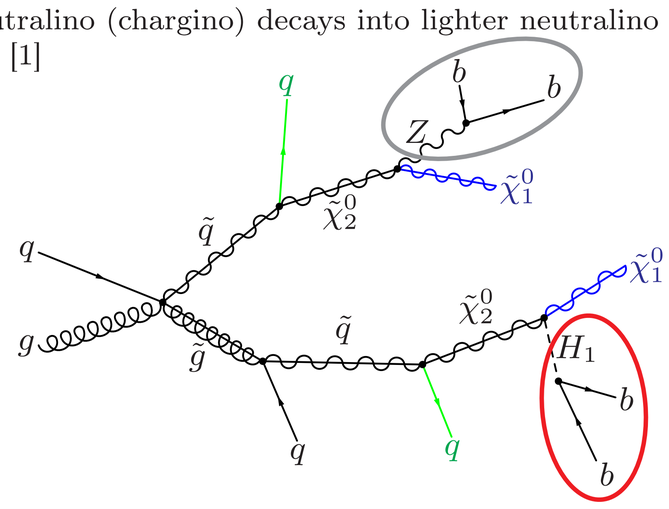
Search Strategy

Standard production channels (VBF, gluon fusion, associated production)

- In P4 scenario, production of H_1 is suppressed due to reduced couplings
  - Hard to find H_1, unless $H_2 \to H_1 H_1$ is kinematically allowed

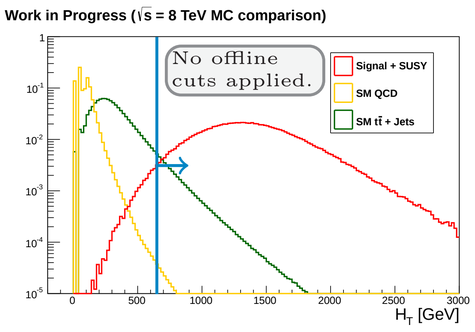
SUSY cascades

- Process related to $H_2 \to H_1 H_1$, where heavier neutralino (chargino) decays into lighter neutralino (chargino) and Higgs boson offers better prospects [1]
- Signature of squark/gluino cascade decays
  - Two hard light jets
  - Two b jets from H_1 decay
  - } Large H_{T}
  - Large $\not{E}_{\text{T}}$ from LSPs
  - b jets emanating from H_1 are correlated
    - Small $\Delta R(bb)$
  - Gives also rise to SUSY background
  - Main SM background: $t\bar{t}$, QCD



Event Selection

Trigger selection

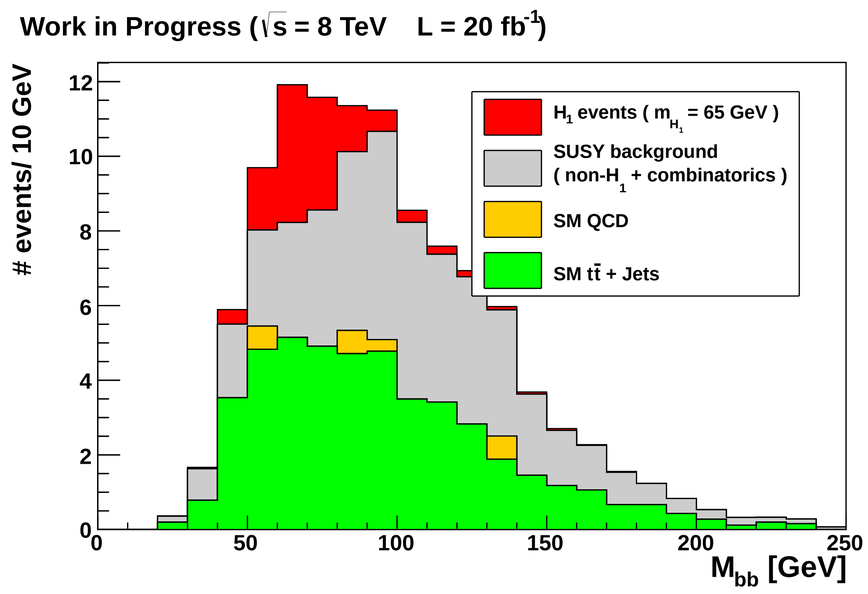


- Hadronic activity H_{T}
  - Scalar sum of all jet-$\vec{p}_{\text{T}}$
  - CMS triggers for 2012
    - Particle flow methods
    - Pile-up corrected
- Considered trigger cut
  - $H_{\text{T}} > 650$ GeV

Offline selection

- General cuts on jets: $p_{\text{T}} > 25$ GeV, $|\eta| < 2.5$
- $H_{\text{T}} > 750$ GeV, $\not{E}_{\text{T}} > 150$ GeV
- Require minimum #jets
  - 2 leading non-b jets $\to p_{\text{T,min}}^{\text{Lead,1|2}} = (250, 100)$ GeV
  - 2 b jets
- Additional $\Delta\phi$ cuts between $\vec{\not{E}}_{\text{T}}$ and jets
- Select two b-jets with minimum $\Delta R \to \min[\Delta R(bb)] < 1.5$

Signal vs. Background Studies



m_{H_1}	N_{H_1}	$N_{\text{Non-}H_1}$	$N_{t\bar{t}}$	N_{QCD}	$\frac{S}{B}$	$\frac{S}{\sqrt{B}}$	$\frac{S}{\sqrt{S+B}}$
40 GeV	62	13	47	2.5	1.0	7.8	5.5
65 GeV	30	28	47	2.5	0.4	3.4	2.9
80 GeV	13	34	47	2.5	0.2	1.4	1.3

- Events counted over full mass range $\to M_{bb} \in [0, \infty)$
- With full 2012 statistics a statement about the existence of H_1 according to P4 scenario is within reach
- Outcome of the analysis will constrain NMSSM parameter space

Outlook

- With the full 8 TeV data, reasonable sensitivity is expected
  - Foundation for future analysis at 13 TeV
- Current efforts and next steps
  - Optimization of selection and signal significance
  - Modelling of background and signal
  - Signal extraction

References

[1] O. Stål, G. Weiglein, Light NMSSM Higgs bosons in SUSY cascade decays at the LHC, *JHEP* **1201**, 071 (2012), 1108.0595.

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