Search for neutral MSSM Higgs bosons decaying into two muons with CMS

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on behalf of the

CMS Collaboration

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Higgs Hunting
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motivation

Why muons?

- $\varphi \rightarrow b\bar{b} \approx 90\%$ dominant for small $m_A$ but hard to reconstruct due to the 4 $b$-jets in the final state
- $\varphi \rightarrow \tau^+\tau^- \approx 9\%$ but the reconstruction of $m_A$ and $\Gamma_A$ is very difficult
- $\varphi \rightarrow \mu^+\mu^- \approx 0.03\%$ is small, but it gives a clean signature in the detector and gives the opportunity to reconstruct $m_A$ and $\Gamma_A$ and through that $\tan \beta$

MSSM Higgs bosons masses and decay width
associated production (dominant for high $\tan \beta$)

branching ratio drops for low $\tan \beta$ when decay into $t \bar{t}$ becomes available
signal & backgrounds

**signal**
- two isolated muons with high $p_T$
- two $b$-jets with relatively low $p_T$
- low missing transverse energy $E_T$

**Drell-Yan $Z/\gamma^* \rightarrow \mu\mu$**
- no $b$-jets
- low $E_T$

**top quark pairs**
- non-isolated muons with low $p_T$
- high $E_T$ due to the neutrinos from the $W^{\pm}$-decay

**$bbZ/\gamma^* \rightarrow \mu\mu$**
- same event topology as the signal
- two isolated muons
- two $b$-jets
- low $E_T$
- 5.56 fb$^{-1}$ recorded through 2011
- 4.96 fb$^{-1}$ certified and used for this analysis
- data is splitted into two runs (A & B) with different pile-up scenario
- corrections on MC concerning the pile-up are applied
the CMS detector

Compact Muon Solenoid
event selection

pre-selection:

- basic muon selection
  - $p_T \mu_1 > 30 \text{ GeV}$ & $p_T \mu_2 > 20 \text{ GeV}$
    (asymmetric due to trigger thresholds)
  - $|\eta_\mu| < 2.1$
  - isolation
- $E_T < 30 \text{ GeV}$

event categories:

- 1 tagged b-jet
  - $p_T^{\text{Jet}} > 20 \text{ GeV}$
  - $|\eta_{\text{Jet}}| < 2.4$
  - loose b-tag ID
- 1 additional muon
  - $p_T^\mu > 3 \text{ GeV}$
  - $|\eta_{\text{Jet}}| < 2.4$
  - separation to other muons
- everything else

invariant di-muon mass after pre-selection
- category 1 has best signal to background ratio
- category 3 has highest statistics
- category 1 and 3 have highest sensitivity
- category 2 has low sensitivity, but serves as verification if a signal appears in category 1 or 3
background estimation from data

- background model: linear combination of
  - Breit-Wigner at the Z peak
  - photon propagator contribution
  - both multiplied with a falling exponential for the pdf contribution
  - Z parameters fixed from fit to data with crystal ball (outside of signal region)

- signal model:
  - linear combination of three Breit-Wigner peaks, convoluted with a common detector resolution
  - signal parameters fixed by a fit to simulation
background estimation from data

- fit of $s + b$ hypothesis to data
- signal strength as free parameter
- signal and background shapes used in limit calculation:
  - signal shape from fit to simulation
  - background shape from fit to data
- confidence level scanned in $m_A - \tan \beta$ plane
- limits calculated with signal samples closest to 95% C.L. in the scan

CMS Preliminary 2011 $\sqrt{s}=7$ TeV
$m_A=140$ GeV/c$^2$ $\tan \beta=50$ Cat.1
$L=4.96$ fb$^{-1}$
$\chi^2$/ndf: 0.65
$P(\chi^2)$: >0.99
$\lambda: -0.009 \pm 0.001$ [(GeV/c$^2$)$^{-1}$]
$f_{BWS}^0: 0.022 \pm 0.004$
$f_{\text{Background}}: 1.000 \pm 0.004$
$f_{\text{Signal}}: 0.047 \pm 0.004$
Combination

biggest contribution to the combination from categories 1 & 3
conclusions

- \( m_A = 110 - 180 \text{ GeV} \) excluded at \( \tan \beta = 30 \)
- single mass points with \( \tan \beta = 15 \) can be excluded
- overall good agreement with expectations
- no significant excess (\( > 2 \sigma \)) observed
- expectations for 60 fb\(^{-1}@14 \text{ TeV} \) from TDR exceeded with only 5 fb\(^{-1}@7 \text{ TeV} \)

outlook

- update to \( \sqrt{s} = 8 \text{ TeV} \)
- contribution to the final limit combination for CMS
Backup
Category 1 (b-tagged jet)

limits calculated using the asymptotic algorithm using the CLs method
Category 2 (additional muon)

poor sensitivity due to very low statistics in this category
Category 3 (everything else)

- Observed limit
- Expected limit
- Expected limit ± 1σ
- Expected limit ± 2σ

good sensitivity due high statistics in this category