Search for Neutral MSSM Higgs Bosons in the $\mu^+\mu^-$ final state with the CMS experiment in $pp$ Collisions at $\sqrt{s} = 7$ TeV

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Motivation

- minimal supersymmetric standard model (MSSM):
- two Higgs doublets with five physical Higgs bosons:
  - $A'$ (CP-odd)
  - $H^0'$
  - $H^0$ and $H^0$ (CP-even)
- described by two parameters:
  - $m_{h'}$ and $\tan\beta$ (vacuum expectation ratio of the two doublets)
- estimation of the MSSM parameters:
  - $m_{h'} = M_{h',s}$ (clean experimental signature)
  - $\tan\beta$ can be extracted from the signal mass ($M_{h',s}$) and its width ($\Gamma_{h',s}$)

Higgs Production in MSSM $m_{h'/A'}$-scenario

- Higgs coupling to $b$-quarks:
  - $\frac{g_{h'bb}}{\sqrt{s}} = \tan\beta \cdot g_{h'BB}$
- $bb$ associated production dominates over the $gg$ fusion
- the kinks at $m_{h'} \approx 300 \text{ GeV}/c^2$ due to the opening of the $t\bar{t}$ decay channel
- event signature:
  - two isolated $\mu$
  - small missing energy in transverse plane ($E_T$)
  - $b$-tagged jet

Event Categories

- Category 1:
  - events with at least one jet tagged as a $b$-jet
    - $\mu^+\mu^-$ final state
    - $kT_{T}\text{jet} > 40 \text{ GeV/c}$ and $|\eta| < 2.1$
- Category 2:
  - events where no $b$-tagged jet is reconstructed
  - additional $\mu$ required as a signature of the $b$-quark semileptonic decay
  - also candidates for the process $bb\bar{b}/h'/h^0$ fusion
- Category 3:
  - events that do not belong to Category 1 or 2
  - candidates of the $gg$-fusion process
  - main systematic uncertainties:
    - background fit procedure: from $1\%$ to $6\%$ ($m_{h'}$)
    - $b$-tag: $3\%$
    - theory (signal acceptance): $5\%$ to $13\%$ ($m_{h'}$)

Signal and Background Estimation

- signal: shape extracted from Pythia Monte Carlo with $F_{WW} = a \cdot F_{WW} + b \cdot F_{WW} + (1 - a - b) \cdot F_{WW}$
- background: shape estimated from data with $F_{bg}$:
  - $F_{bg} = c \cdot \left( \frac{\text{data}}{\text{MC}} \times \frac{\text{m}_{h'/A'}}{\text{MC}_{h'/A'}} \right)$
  - where $x = M_{h'/A'}$
- function used to fit the data:
  - $F = N \cdot \left( b_{\text{background}} + b_{\text{background}} + b_{\text{background}} \cdot F_{bg} \right)$
  - $b_{\text{background}}$: signal expectation for $100 < M_{h'/A'} < 300 \text{ GeV}/c^2$ relative to the number of events in data (it is not a fit parameter)
  - invariant mass distribution fit of the expected signal for $m_{h'} = 140 \text{ GeV}/c^2$, $\tan\beta = 50$
- test of the fit procedure where the expected Monte Carlo signal is artificially added to the data
  - no evidence of the MSSM $m_{h'/A'}$ scenario Higgs boson production is found within the sensitivity of the analysis

Event Selection

- Integrated Luminosity: $4.96 \text{ fb}^{-1}$
- High Level Trigger:
  - single isolated $\mu$ in barrel region ($|\eta| < 2.1$
  - two isolated $\mu$
    - $p_T > 20(30) \text{ GeV}/c$ and $|\eta| < 2.1$
    - removes contributions from QCD, $W^\pm$, single $t$
    - $E_T^{miss} < 30 \text{ GeV}$
    - reduces contribution from $t\bar{t}$ events
  - $b$-tagged jet
    - anti-$b$-jets, jets with $p_T > 20 \text{ GeV}/c$ and $|\eta| < 2.1$
    - $\Delta R > 0.5$ with respect to each of the two hard $\mu$
  - additional $\mu$
    - $b$-hadron semileptonic decays

MSSM Exclusion Limits in $m_{h'/A'}$ Scenario at $\sqrt{s} = 7$ TeV

- are excluded at 95% CL values of $\tan\beta$ between 16 and 26 for Higgs masses from 115 to 175 GeV/c$^2$
- $\tan\beta$ values between 26 and 40 are excluded for higher values of the Higgs mass up to 300 GeV/c$^2$

Reference

Search for Neutral MSSM Higgs Bosons in the $\mu^+\mu^-$ final state with the CMS experiment in $pp$ Collisions at $\sqrt{s} = 7$ TeV
CMS Collaboration, CMS-PAS-HIG-12-011
http://cdsweb.cern.ch/record/1453716?ln=en