Searches for Neutral Higgs Bosons in MSSM-like Topologies with ATLAS and CMS

Markus Klute
Massachusetts Institute of Technology

On behalf of the ATLAS and CMS collaborations
ATLAS & CMS

- experiments are preparing for first collision data in 2008.
- see previous talks or EPS 2007 talks on detector status.

Installation of the ATLAS pixel detector
06/28/2007

Lowering of CMS central barrel wheel
02/28/2007
Outline

• Higgs Sector in the MSSM
• Searches in:
  \[ bb\Phi \rightarrow bb\mu\mu \]
  \[ bb\Phi \rightarrow bb\tau\tau \]
  \[ A \rightarrow Zh \]
• Conclusion
Higgs Sector in the MSSM

- 2 Higgs doublets, 5 physical bosons
  - 2 CP-even $h, H$, 1 CP-odd $A$ and 2 charged $H^+, H^-$
- at Born level 2 parameter: $\tan \beta, m_A$ \((m_h < m_Z)\)
- large loop corrections from SUSY parameters
  - $m_h < 133$ GeV (for $m_{\text{top}} = 175$ GeV, $M_{\text{SUSY}} = 1$ TeV)
- corrections depend on 5 SUSY parameter:
  - $X_t, M_0, M_2, M_{\text{gluino}}, \mu$
  - fixed in benchmark scenarios
MSSM Benchmark Scenarios

- as suggested by M. Carena et al. (hep-ph/0202167)
- The $m_h^{\text{max}}$ scenario
- The no-mixing scenario
- The large-$\mu$ scenario (completely ruled out by LEP)
- The gluophobic Higgs scenario
  - designed to affect discovery via $gg \rightarrow h, h \rightarrow \gamma\gamma$ and $h \rightarrow ZZ$
- The small $\alpha^{\text{eff}}$ scenario
  - coupling of $hbb$ ($h\tau\tau$) suppressed
  - designed to affect discovery via VBF, $h \rightarrow \tau\tau$ and $tth, h \rightarrow bb$
Higgs Sector in the MSSM

- high tan $\beta$ main LHC search area:
  \[ pp \rightarrow b\bar{b}\phi \quad (\phi = h, H, A) \quad \text{and} \quad \phi \rightarrow \mu\mu, \tau\tau \]
- low tan $\beta$ is not completely excluded:
  \[ pp \rightarrow A; A \rightarrow Zh \]
Higgs Sector in the MSSM

Tevatron exclusion region in MSSM in no mix. & $m_h^{\text{max}}$ scenario.
(see I. Kravchenko's talk yesterday)
MSSM Higgs Boson Production

$m_h^{\text{max}}$ scenario, $m_{\text{top}} = 178 \text{GeV}$
CP-odd Higgs Boson Decay

\[ \text{BR}(A) \]
\[ \tan \beta = 3 \]

\[ \tan \beta = 30 \]
Search for neutral Higgs Bosons

**high tan $\beta$:**

\[ pp \rightarrow bb\phi \ (\phi = h, H, A) \]
\[ \phi \rightarrow \mu\mu \]
\[ \phi \rightarrow \tau\tau \]

**low tan $\beta$:**

\[ pp \rightarrow A \]
\[ A \rightarrow Zh \]
\[ Z \rightarrow ll \ (l = e, \mu) \]
\[ h \rightarrow bb \]
b-tagging

- b-tagging essential for:
  - $b\bar{b}$, $\phi \to b\bar{b}$, ttH, top final states

- algorithm ranging from track counting, 2d impact parameter to secondary vertex reconstruction

- key performance issues:
  - charge hadron reconstruction
  - high efficiency and impact parameter resolution
  - control fake track reconstruction

- ongoing studies: performance measurements with data

CMS secondary vertex tagger

EPS '07 talk by I. Tomalin
Higgs Search: $bb\Phi \rightarrow bb\mu\mu$

- small branching ratio ($3 \cdot 10^{-4}$)
- precise Higgs mass reconstruction
- measurement of the Higgs width
- main backgrounds: Z+jets, ttbar, Zbb
- signal and background rates can be determined from data.
Higgs Search: \( bb\Phi \rightarrow bb\mu\mu \)

- cross section and width exhibits large sensitivity to \( \tan \beta \)

\[
\begin{align*}
M_{\text{SUSY}} &= 1 \text{ TeV/c}^2 \\
\mu &= 200 \text{ GeV/c}^2 \\
M_{\tilde{g}} &= 200 \text{ GeV/c}^2 \\
X_t &= \sqrt{6} M_{\text{SUSY}}
\end{align*}
\]

- similar results from ATLAS
Higgs Search: \( bb\Phi \rightarrow bb\tau\tau \)

- branching ratio \( \sim 10\% \)
- Higgs mass reconstruction using collinear approximation method. Requires excellent missing \( E_T \) resolution.
- main backgrounds: Z+jets, ttbar, Zbb
τ-tagging

- $c\tau \sim 87\mu m$, $m_\tau = 1.78$ GeV/c$^2$
- leptonical decays
  - $\tau \rightarrow e(\mu) \nu \nu$: $\sim 35.2 \%$
    - Identification done through the final lepton
- hadronical decays
  - 1 prong
    - $\tau \rightarrow \nu_\tau + \pi^{+/-} + n(\pi^0)$: $49.5 \%$
  - 3 prongs
    - $\tau \rightarrow \nu_\tau + 3 \pi^{+/-} + n(\pi^0)$: $15.2 \%$
    - "τ jet"

very active area:
- track based
- impact parameter
- mass tag
- calorimeter based
- particle flow
- performance with data
Z and Higgs Mass Reconstruction with $\tau$ Decays

- $\tau\tau$ decay modes
  - 12% $l l \nu$
  - 46% $l$ jet $\nu$
  - 42% jet jet $\nu$

\[ p(l) = x \cdot p(\tau) \], collinear approximation

\[ p_T(H) = p_T(\tau_1) + p_T(\tau_2) = p_T(e) + p_T(\mu) + p_T' \]

\[ m_{\tau\tau}^2 = m_{e\mu}^2 / (x_{e\tau} \cdot x_{\mu\tau}) \]
Higgs Search: $bb\Phi \rightarrow bb\tau\tau$

- ATLAS and CMS developed analyses in various channels
  - $e^+\text{jets}$, $\mu^+\text{jets}$, two jets, $e^+\mu$

### μ+jets (CMS)

![Graph for μ+jets (CMS)]

- Background parametrisation
- Signal+Bkg. for $\tan(\beta)=20$, $m_A=200$ GeV/$c^2$
- Signal+Bkg. for $\tan(\beta)=30$, $m_A=500$ GeV/$c^2$

### two jets (ATLAS)

![Graph for two jets (ATLAS)]

- $30 fb^{-1}$
- $m_A=800$ GeV
- $\tan\beta=50$
Discovery Potential

\[ \phi \rightarrow \tau\tau \rightarrow e+jet \]

CMS, 30 fb\(^{-1}\)

\[ pp \rightarrow bb\phi, \phi = h, H, A \]

**\(m_{\phi}^{\text{max}}\) scenario**
- \(M_{\text{SUSY}} = 1\) TeV/c\(^2\)
- \(M_2 = 200\) GeV/c\(^2\)
- \(\mu = 200\) GeV/c\(^2\)
- \(m_{\text{gluino}} = 800\) GeV/c\(^2\)
- Stop mix: \(X_1 = 2M_{\text{SUSY}}\)

\[ M_A, \text{GeV/c}^2 \]

\[ \tan\beta \]

---

27-Jul-2007

Markus Klute - SUSY 2007
Higgs Search: \( A \to Z h \)

- low \( \tan \beta \) region
- final state: \( Z \to ll \ (l = e, \mu) \ \ h \to bb \)
- low \( \tan \beta \) and \( m_Z + m_h \leq m_A \leq 2m_{\text{top}} \)
- depends strongly on MSSM parameter
- exclusion from \( b \to s \gamma \)
- main backgrounds: \( Zbb \), \( tt\bar{t} \) and \( Z + \text{jets} \)
- systematic uncertainty important
Conclusion

- ATLAS & CMS are preparing for first collision data.
- Discussed MSSM-like neutral Higgs topologies.
- SM-like topologies and charged Higgs very powerful.
- Discovery potential of MSSM Higgs bosons has been estimated by ATLAS & CMS.
- First data has potential to exclude entire MSSM parameter space.
- Exiting times ahead!