SUSY Discovery Potential and Dijet/Dilepton Mass Measurements with the CMS Detector at LHC

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SUSY discovery potential at the Large Hadron Collider is investigated. The possibilities to look for squark, gluinos, sleptons and $h^0 \to b\bar{b}$ are discussed. We investigate SUSY discovery potential studying an excess of events in specific signatures and dijet/dilepton mass distributions. The sensitivity of dilepton mass spectra to the model parameter are also investigated.

1 Introduction

Low energy supersymmetry (SUSY) predicts that the supersymmetric partners of the Standard Model particles have masses in the range of 100 GeV$-\mathcal{O}(1)$ TeV. Therefore, the Large Hadron Collider (LHC) will be the appropriate machine to produce the whole sparticle spectrum. We investigate its SUSY discovery potential studying the excess of events over Standard Model background expectations in a number of specific signatures and in dijet/dilepton mass distributions. For the detailed study, the 'minimal supergravity model' (mSUGRA) [1] is chosen. The possibilities of constraining the mSUGRA model parameters at LHC are also investigated. The mSUGRA model has only five parameters [1] $[m_0, m_{1/2}, A_0, \tan\beta, \text{sign}(\mu)]$ allowing one to study systematically the whole parameter space.

2 Gluino/Squark Searches

Gluinos and squarks are expected to be the heaviest sparticles. They decay to lighter ones producing quarks, gluons, charginos, neutralinos, sleptons, W, Z and Higgs bosons in the decay chains. As the result, final states from $\tilde{g}/\tilde{q}$ production contain a variable number of jets and leptons in addition to a significant E_T^{miss}, due to the weakly interacting lightest supersymmetric particle ($\tilde{\chi}_1^0$). Figure 1 shows the mSUGRA signal reach [2] with an integrated luminosity of

$100 fb^{-1}$ in low and large $\tan\beta$ scenarios. When more leptons are required, a smaller parameter region can be explored.

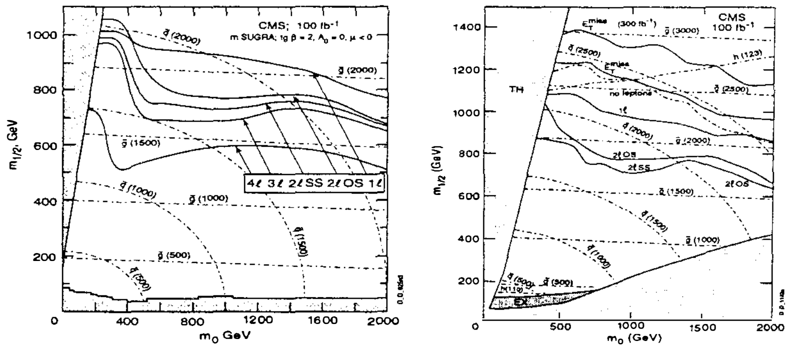

Figure 1: 5σ reach contours for various final states with 100 fb^{-1} for a) $\tan\beta = 2$, $\mu < 0$ all muons are isolated and b) $\tan\beta = 35$, $\mu > 0$, muons are non-isolated.

3 Dijet Mass Spectra

An advantageous way to look for h^0 can be found if one tries to use its abundant production in the decay chains of gluinos and squarks exploiting the dominant decay into $b\bar{b}$. Figure 2 gives an example of h^0 production from $\tilde{g}\tilde{q}$ with a relevant decay pattern and a typical final event configuration. Thus, SUSY Higgs production is characterised by the presence of large E_T^{miss},

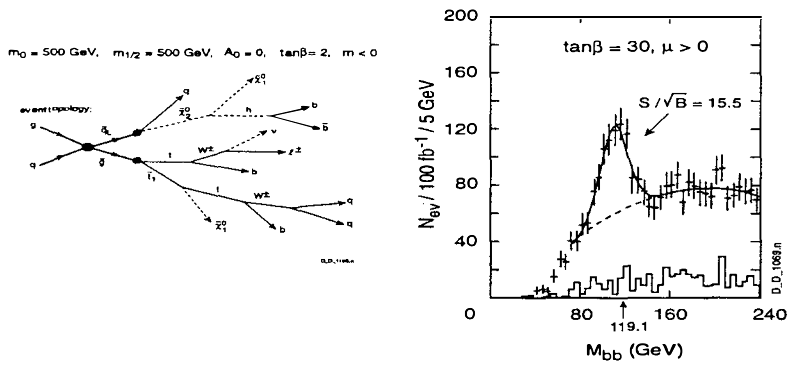

Figure 2: a) Example of typical event topology from Higgs production. b) The invariant mass distribution for closest tagged b-jet pairs at $m_0 = m_{1/2} = 500$ GeV, $\tan\beta = 30$, $\mu > 0$, $A_0 = 0$ mSUGRA point.

high jet multiplicity and two b-jets from the $h^0 \to b\bar{b}$ decays. Figure 2 shows the invariant mass distribution of two b-jets closest in $\eta - \phi$ space [3]. The background can be suppressed by means of b-jet tagging and by requiring large E_T^{miss}. Efficient b-tagging allows one to reconstruct a real Higgs signal by suppressing the jet-jet SUSY background due to abundantly produced $W's$. As a result the Higgs peak is clearly seen on top of the SM background ($t\bar{t}$, Wtb and QCD $2 \to 2$). The main background is internal SUSY background due to wrong b-jet pair combinations (additional b-jets can come from stop decays). The parameter range where the Higgs can be explored is determined by the opening of the decays $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 h^0$ and by the production cross-section of $\tilde{g}$'s and $\bar{q}$'s. Its observation is therefore limited by the masses of the squarks and gluinos.

4 Dilepton Mass Spectra

The shape of the dilepton invariant mass spectra in two *same-flavor* opposite-sign leptons $+E_T^{miss}$ + jets (SFOS) and two *different-flavor* opposite-sign leptons$+E_T^{miss}$ + jets (DFOS) final states reflects presence of the $\tilde{\chi}_2^0 \rightarrow \tilde{\ell}^{\pm}\ell^{\mp} \rightarrow \ell^+\ell^-\tilde{\chi}_1^0$ decays, where $\ell = e, \mu, \tau$ and τ decaying leptonically [4,5]. Figure 3 shows the expected dilepton invariant mass distributions in the SFOS and DFOS channels for two different parameter points with decays $\tilde{\chi}_2^0 \rightarrow \tilde{\ell}_R^{\pm}\ell^{\mp}$ and $\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_1^{\pm}\tau^{\mp}$, respectively. At low $\tan\beta$ a pronounced edge is visible in the $M_{\ell^+\ell^-}$ distribution

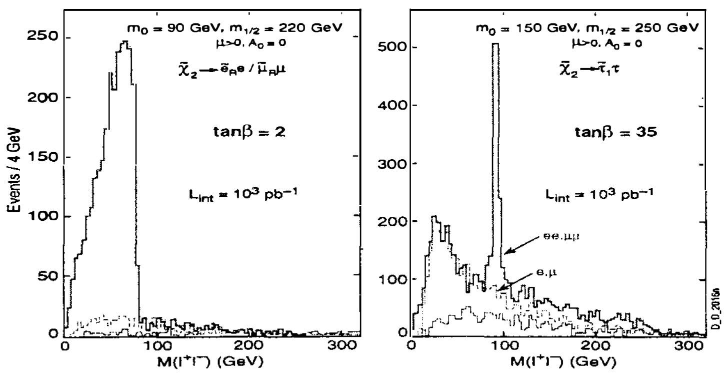

Figure 3: The invariant mass distributions of e^+e^- and $\mu^+\mu^-$ (solid line) and $e^{\pm}\mu^{\mp}$ (dotted line) lepton pairs at the parameter point with a) $\tan\beta = 2$ and b) $\tan\beta = 35$. SM background is also shown (dotted histogram).

in the SFOS channel with the maximum at $M_{\ell^+\ell^-}^{max} = \sqrt{(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{\ell}}^2)(m_{\tilde{\ell}}^2 - m_{\tilde{\chi}_1^0}^2)}/m_{\tilde{\ell}}$, while no characteristic structure in the $M_{\ell^+\ell'^-}$ spectrum is expected in the DFOS case, see Fig. 3(a). For large $\tan\beta$ when the decays into $\tilde{\tau}$'s are the only decay modes contributing to the final states considered [4,5], the dilepton mass spectra in the SFOS and DFOS channels become similar with a strong low-mass enhancement and comparable event rates, see Fig. 3(b). The spectrum of the SFOS and DFOS channels proceeding through the dominant $\tau \rightarrow \ell\nu\nu$ decays at large $\tan\beta$ are not so striking as the SFOS channel at low $\tan\beta$, having no sharp edge due to the missing momentum taken by four neutrinos from τ decays. Comparison of Figs. 3(a) and (b) clearly illustrates the sensitivity of the dilepton mass spectra shapes in the SFOS and DFOS channels to the $\tan\beta$ parameter.

5 Slepton Searches

The possibility of detecting directly produced sleptons is investigated by the observation of an excess of the $e^+e^-/\mu^+\mu^-$ + $E_T^{\rm miss}$ + *no jets* events over the expected SM and SUSY background at low $\tan\beta = 2$ ($\mu < 0$) and large $\tan\beta = 35$ ($\mu > 0$). The slepton production cross section depends on the mass only. Masses of the first two generations of sleptons contributing to the final states considered depend weakly on $\tan\beta$ and do not depend on the sign of μ. Contribution from Drell-Yan stau pair production to the signature with two electrons or two muons is negligible. The branching ratios of the relevant slepton decays leading to the signature considered also change slightly with these parameters. Thus, the $e^+e^-/\mu^+\mu^-$ + $E_T^{\rm miss}$ + *no jets* event rate is expected to be rather stable with increase of $\tan\beta$ and a change of the sign of μ at a fixed $(m_0, m_{1/2})$ point. The slepton signal gets little background from SUSY itself, as the main SUSY background is expected from charginos/neutralinos decaying to stau's at large $\tan\beta$. Figures 4 show the parameter reach in slepton searches at $\tan\beta = 2$ and $\tan\beta = 35$ with $\mathcal{L}_{int} = 10^5$ pb^{-1} for the negative and positive signs of μ, respectively. In both cases the parameter reach corresponds to slepton masses $\simeq 350 - 400$ GeV [5].

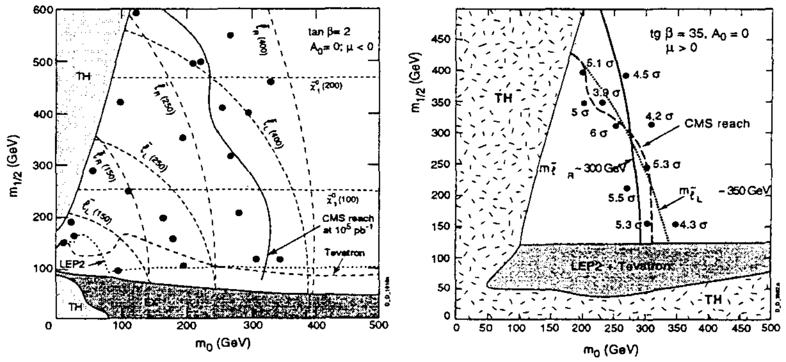

Figure 4: Expected 5 σ parameter reach for slepton searches within the 2 *leptons* + E_T^{miss} + *no jets* final states with $\mathcal{L}_{int} = 10^5$ pb^{-1} for $\tan\beta = 2, \mu < 0$ and $\tan\beta = 35, \mu > 0$ ($A_0 = 0$).

6 Conclusions

If low energy SUSY is realized in nature it is expected to show up at the LHC which probes the TeV energy scale via searches for the most copiously produced $\tilde{g}$'s and $\tilde{q}$'s with masses up to $2 - 3$ TeV.

Due to appropriate signature provided by SUSY, $h^0(\to b\bar{b})$ can be discovered in gluino and squark cascade decays with mass up to 130 GeV with a $S/B \sim 1$.

The $e^+e^-/\mu^+\mu^-$ + E_T^{miss} + *jets* signature selects decays $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\ell^+\ell^-$, $\tilde{\chi}_2^0 \to \tilde{\ell}^\pm\ell^\mp$ ($\ell = e, \mu, \tau$). The $e^\pm\mu^\mp$ + E_T^{miss} + *jets* signature selects $\tilde{\chi}_2^0 \to \tilde{\tau}_1^\pm\tau^\mp$ and $\tilde{\chi}_2^0 \to \tau^+\tau^-\tilde{\chi}_1^0$, with τ's decaying leptonically. The characteristic shapes of $e^+e^-/\mu^+\mu^-$ and $e^\pm\mu^\mp$ spectra provide a handle to identify $\tilde{e}$, $\tilde{\mu}$ and $\tilde{\tau}$'s produced from $\tilde{\chi}_2^0$ decays and give information on $\tan\beta$.

To search for direct production of sleptons we have to use the $e^+e^-/\mu^+\mu^-$ + E_T^{miss} + *nojets* final state. In most of the explorable $(m_0, m_{1/2}, \tan\beta)$ space, slepton production is the dominant contribution to this final state; this allows to probe slepton masses up to $m_{\tilde{\ell}} \sim 400$ GeV at low $\tan\beta$ scenario and up to $m_{\tilde{\ell}} \sim 350$ GeV at large $\tan\beta$.

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References

1. S. Dawson, hep–ph/9712464; R. Arnowitt and P. Nath, hep–ph/9708254.
2. S. Abdullin, CMS TN/1996-095; S. Abdullin, F. Charles, Nucl.Phys. B547 (1999) 60-80
3. S. Abdullin, D. Denegri, CMS NOTE/1997-070.
4. D. Denegri, W. Majerotto and L. Rurua, Phys. Rev. D60 035008, 1999.
5. L. Rurua, doctoral thesis, CMS 1999-103/THESIS.