
CMS Conference Report

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Potential to Discover Inclusive Supersymmetry using the CMS Detector

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Abstract

Generic signatures of supersymmetry with R-parity conservation include energetic jets and missing transverse energy accompanied with leptons. The ability of CMS to discover supersymmetry with these signals is estimated for $1\,\mathrm{fb}^{-1}$ of data collected. The selection criteria are optimized and the corresponding systematic effects studied for a single low-mass benchmark point of the Constrained MSSM with $m_0 = 60\,\mathrm{GeV}/c^2$, $m_{1/2} = 250\,\mathrm{GeV}/c^2$, $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$.

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1 Introduction

The Compact Muon Solenoid (CMS) is a multi-purpose, nearly 4π-solid-angle-coverage detector, which is being constructed at the future Large Hadron Collider (LHC) located at CERN near Geneva, Switzerland. More details of the CMS detector and its expected performance may be found in [1].

The results presented here are obtained with the full CMS detector simulation and reconstruction software, including pile-up effects corresponding to an instantaneous luminosity of $2 \times 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. For all analyses presented in this report, the selection criteria are optimized and systematic effects studied for a single low-mass benchmark point (henceforth designated as LM1) of the Constrained Minimal Supersymmetric extension to the Standard Model (CMSSM), which is chosen to be just beyond the expected reach of the Tevatron: $m_0 = 60\,\mathrm{GeV}/c^2$, $m_{1/2} = 250\,\mathrm{GeV}/c^2$, $\tan\beta = 10$, $A_0 = 0$, $\mu > 0$. The LM1 benchmark-point has a leading order cross section of 49 pb. Further details of the full studies performed by CMS, which form the basis for this brief summary, may be found in [2].

2 Standard Model Backgrounds Considered

Since the number of multi-jet QCD events expected for an integrated luminosity of $1\,\mathrm{fb}^{-1}$ is so large at small $\hat{p}_T$ (defined as the transverse momentum of one of the two original hard scattered partons), it is impossible to simulate enough events and so, events were simulated almost uniformly in 21 $\hat{p}_T$ bins corresponding to an equivalent integrated luminosity of $2.5\,\mathrm{fb}^{-1}$ at $\hat{p}_T > 800$ GeV. Top pair production is a particularly important source of background, due to its modestly large cross section and intrinsic multi-jet, high E_T^{miss} (plus significant leptonic final state nature). An equivalent integrated luminosity of $6.9\,\mathrm{fb}^{-1}$ inclusive $\mathrm{t\bar{t}}$ events were simulated. The production of single W and Z bosons $+$ jets is also expected to be plentiful at the LHC and events were correspondingly simulated nearly uniformly in $20\,\hat{p}_T$ bins resulting in an integrated luminosity of 1.9 fb^{-1} at $\hat{p}_T > 200$ GeV for single W boson production and 2.6 fb^{-1} at $\hat{p}_T > 125$ GeV in the case of single Z production. Finally, diboson production, such as WW + jets, WZ + jets, and ZZ + jets, also contribute as sources of background. The equivalent integrated luminosities simulated and used in this work are: $L_{\mathrm{WW}} \sim 2.6\,\mathrm{fb}^{-1}$, $L_{\mathrm{WZ}} \sim 6.3\,\mathrm{fb}^{-1}$ and $L_{\mathrm{ZZ}} \sim 43\,\mathrm{fb}^{-1}$.

3 Missing Energy Clean-up Requirements

In anticipation of real data, a pre-selection is used to reject accelerator- and detector-related backgrounds (such as beam halo background or electronic noise), and cosmic ray events. Based on experience at the Tevatron, where similar requirements have been used to clean the high P_T multi-jet plus large E_T^{miss} datasets, at least one primary vertex is required in the event and the pre-selection uses the event electromagnetic fraction, F_{em} (defined as the E_T–weighted jet electromagnetic fraction sum over the electromagnetic calorimeter acceptance, $|\eta_d| \leq 3.0$) and event charged fraction, F_{ch} (defined as the average over the jets ratio of the sum of the P_T of the associated to the jet tracks for jets within $|\eta| < 1.7$, over the calorimetric jet transverse energy) to distinguish between real and fake jet and missing energy events.

4 Inclusive SUSY Selection Strategies

Three examples of inclusive and semi-inclusive SUSY analyses conducted by CMS are summarized in this report. Further details and examples may be found in Ref. [2].

The missing transverse energy plus multi-jets final state remains a canonical signature for SUSY because it is expected to be the most sensitive search strategy. Following the application of the missing energy clean-up, this study selects events with at least three jets (two of which have high P_T) and large E_T^{miss}. The large E_T^{miss} originates from the two LSPs in the final states of the squark and gluino decays. The three or more hadronic jets result from the hadronic decays of the squarks and/or gluinos. An additional distinguishing feature is the azimuthal angles between the E_T^{miss} vector and jets. SUSY events are selected with 26% efficiency and, for 1 fb^{-1} of collected data, an estimated total of 6319 signal events against 244.5 background events are expected.

Signatures involving at least one muon are less sensitive, but experimentally cleaner and have the anticipated advantage of an efficient and well-understood trigger shortly after LHC start-up. Topological requirements on the jets and missing energy are similar to the fully inclusive analysis, but with significantly harder cuts. Since the muon originates later in the SUSY cascade, the muon tends to be softer than the jets and so no additional tightening of the muon p_T is performed. For 1 fb^{-1} of collected data, 31.1 signal events are expected to be selected with a background estimated to be 0.25 ± 0.05 total background events.

Requiring an additional, same-sign, isolated muon provides an even cleaner signature, allowing the intriguing possibility of selecting particular SUSY diagrams. The leading muon, for both signal and background, already tends to be isolated and so does not discriminate well. However, the second leading muon tends to be more isolated in the signal than in the background. For 1 fb^{-1} of data, 34.1 signal events are expected to be selected with a total background estimated to be 0.15 ± 0.03 events. Due to the careful isolation requirements, events corresponding to SUSY diagrams with prompt muons are expected to be selected with $\sim 65\%$ efficiency and over $\sim 90\%$ purity.

5 Electroweak Standard Candle Calibration

Because the $Z + N$-jets cross-section is proportional to α_s^N, the ratio of the number of events in adjacent jet multiplicity bins is expected to be constant and proportional to the strong coupling constant. Hence, Monte Carlo predictions for the rate of $Z+\geq$ 3-jets events can be normalised to the observed rate of $Z(\rightarrow \ \mu\mu)+$ 2-jets in real data via the measured $R = \frac{dN_{events}}{dN_{jets}}$ ratio. In addition, the ratio $\rho \equiv \frac{\sigma(pp\rightarrow W(\rightarrow \mu\nu)+jets)}{\sigma(pp\rightarrow Z(\rightarrow \mu^+\mu^-)+jets)}$ can be used to normalise the W+jets Monte Carlo predictions. By normalising the Monte Carlo predictions to real data, large systematic effects[1] can be avoided. The total uncertainty is estimated to be ~5% and is dominated by the uncertainty on the luminosity measurement, the uncertainty on the measured ratio $R = \frac{dN_{events}}{dN_{jets}}$, and the uncertainty on the ratio ρ as a function of the jet multiplicity, N_{jet}.

6 Detector Systematics

Approximately 15% of all jets fall in the non-gaussian tails of the energy resolution and are classified as being "mis-measured". To estimate the systematic uncertainty of the E_T^{miss} due such mis-measured jets, mis-measured events are re-weighted according to a grading of the mis-measurement: a larger weight is assigned to events with a mis-measured jet thus exaggerating the non-Gaussian jet resolution tail. The systematic effect is to increase the acceptance of the E_T^{miss} cut by about 7%. Due to the steeply falling spectrum of the jet energy, the jet energy scale (JES) uncertainty plays an important systematic role. By the time 1 fb^{-1} of integrated luminosity is gathered, the CMS Jet Energy Scale (for jets with $E_T > 50$ GeV) is expected to be calibrated at the level of 3% via a W mass constraint in semi-leptonic $\mathrm{t\bar{t}}$ events. Accordingly, all reconstructed jet E_T's and the E_T^{miss} are scaled by ±3%. Similarly, the CMS Jet Energy Resolution is expected to be known to within 10% and a Gaussian smearing is applied to all reconstructed jet E_T's and the E_T^{miss}, event by event. Finally, the uncertainty on the measured integrated luminosity is expected to be $\sim 5\%$.

7 Results and Conclusions

With less than 1 fb^{-1} of collected data, the low mass CMSSM benchmark point LM1 is easily observable in all inclusive analyses studied, including systematic uncertainties. In order to determine the CMS reach for 1 fb^{-1}, a scan of the CMSSM $(m_0, m_{1/2})$ plane was made using a fast CMS detector simulation [1]. Figure 1 shows the 5σ reach contours for all analyses studied by CMS (including systematic uncertainties) and demonstrates that, with an integrated luminosity of 1 fb^{-1}, all of the low mass region for $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$ can be observed and SUSY mass scales of up to ~ 1.4 TeV/c^2 (assuming $m_{\tilde{g}} \approx 2m_{1/2}$) can be probed.

8 Acknowledgements

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References

[1] CMS Collaboration, **CERN/LHCC 2006-001** (2006).

[2] CMS Collaboration, **CERN/LHCC 2006-021** (2006).

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[1] Due to, for example, the QCD renormalisation scale, the choice of parton density functions, initial- and final-state radiation, and the absolute jet energy scale

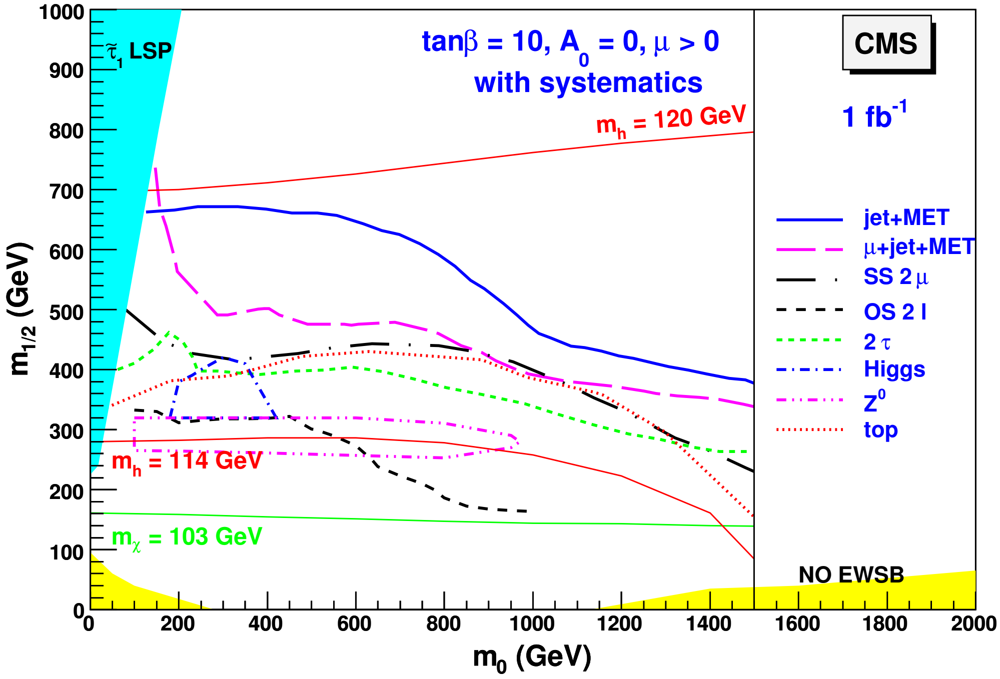

Figure 1: 5σ reach contours in the CMSSW $(m_0, m_{1/2})$ plane assuming 1 fb^{-1} of collected data for several search strategies studied by CMS (including systematic uncertainties) as presented in Ref. [2].