SUSY SEARCHES WITH OPPOSITE SIGN DILEPTONS AT CMS

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A full simulation study with the detector CMS is presented. The Leptons + Jets + Missing Energy ($l = e, \mu$) final state for SUSY events is investigated at mSUGRA benchmark point LM1. The end point in the dilepton pair invariant mass distribution is reconstructed and a scan of the $(m_0, m_{1/2})$ plane is performed in order to determine the observability reach.

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1. Introduction

The SUSY production cross section at LHC is dominated by gluinos and squarks which decay mainly through a chain to the lightest neutralinos. For low and moderate tanβ values, many decay chains end up with the decays $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 l^+ l^-$ and $\tilde{\chi}_2^0 \to \tilde{l}_{\mathrm{R}} l \to \tilde{\chi}_1^0 l^+ l^-$, with $l = e, \mu$, in which the two final state leptons provide a natural trigger. Leptons (electrons and muons) from the $\tilde{\chi}_2^0$ decay exhibit a peculiar $l^+ l^-$ invariant mass distribution with a sharp edge. In this report the method to reconstruct the dilepton end point is described [1]. We proved the feasibility of the method at benchmark point LM1 ($m_0 = 60$ GeV/c^2, $\mathrm{m}_{1/2} = 250$ GeV/c^2, $A_0 = 0$, tan$\beta = 10$, sgn$(\mu) = +1$) [2], and the observability of the signal in the mSUGRA $(m_0, m_{1/2})$ plane for tan$\beta = 10$.

2. Signal

The LM1 mSUGRA benchmark point has been chosen as the working point (total NLO cross section ~ 52 pb, calculated with PROSPINO [3]). The branching ratio of the decay $\tilde{\chi}_2^0 \to \tilde{l}_{\mathrm{R}} l \to \tilde{\chi}_1^0 l^+ l^-$ is 11.2%. The events analysed in this note have been produced using PYTHIA 6.225 [4] interfaced

with ISAJET 7.69 [5]. A full detector simulation has been employed. Low luminosity pile-up has also been taken into account. The Level-1 and High Level Trigger paths require a single isolated electron or muon to select the event.

3. Background

The Standard Model backgrounds considered for this analysis are: $t\bar{t}$, WW + jets, $DY \rightarrow 2l$, $Zbb \rightarrow llbb$, W + jets, Z + jets, QCD, ZZ + jets and $t\bar{t}b\bar{b}$. The full simulation of the detector has been used also for the backgrounds. Table I summarises the number of expected events in 1 fb^{-1} for SUSY events and the Standard Model backgrounds considered, after the following selections are applied:

- at least two same-flavour opposite-sign (SFOS) isolated leptons, with $P^{\mathrm{T}} > 10$ GeV/c and $|\eta| < 2.4$ for both electrons and muons;
- at least two jets with $P^{\mathrm{T}}_{j1} > 100$ GeV/c and $P^{\mathrm{T}}_{j2} > 60$ GeV/c and $|\eta| < 3.0$;
- $E^{\mathrm{T}}_{\mathrm{miss}} > 200$ GeV.

The total number of SUSY events after all selection cuts is 853 in 1 fb^{-1}, corresponding to an efficiency of 1.6% over the whole SUSY sample.

TABLE I

Cross section at NLO, selection efficiencies and number of events surviving cuts for signal and background processes.

Process	σ (pb)	Ev. analysed	ε	N_{ev} in 1 fb^{-1}
SUSY (LM1)	52	478k	0.016	853
$t\bar{t}$	830	913k	1.9×10^{-4}	155
WW+ jets	188	197k	1.4×10^{-4}	26
Z+ jets	5×10^{3}	606k	4.8×10^{-6}	24
$DY \rightarrow 2\mu$	3.97×10^{3}	916k	$< 1.1\times10^{-6}$	< 4
$DY \rightarrow 2\tau$	3.97×10^{3}	514k	1.1×10^{-6}	4.5
$Zbb \rightarrow llbb\,(l = e, \mu, \tau)$ $P^{\mathrm{T}}_{\mathrm{hat}} > 60\,\mathrm{GeV}/c$	57.4	621k	8.4×10^{-5}	4.83
$t\bar{t}b\bar{b}$	3.3	50k	9.8×10^{-4}	3.2
ZZ+ jets	11	37k	2.4×10^{-4}	2.7
W+ jets	1.5×10^{5}	1765k	6.7×10^{-9}	1

4. Results at LM1

The invariant mass distribution of the same flavour opposite sign lepton pairs after all selection cuts and for an integrated luminosity of 1 fb^{-1} is shown, superimposed over the $t\bar{t}$ background, in Fig. 1(a).

In SUSY events, the presence of two SFOS leptons can also be due to processes different from $\tilde{\chi}_2^0 \to \tilde{l}_{\rm R} l \to \tilde{\chi}_1^0 l^+ l^-$ decay. If the two leptons are independent of each other, one would expect equal amounts of SFOS leptons and different flavour opposite sign (DFOS) leptons. Their distributions should also be identical. The background SFOS contribution can hence be removed by subtracting the DFOS events. Fig. 1(b) shows the same SFOS distribution for SUSY events together with the distribution of the DFOS lepton pairs. The flavour subtracted SFOS dilepton pair distributions for both SUSY and $t\bar{t}$ background are shown in Fig. 2(a) for an integrated luminosity of 1 fb^{-1}. The $t\bar{t}$ background contribution after the flavour subtraction is close to zero since the lepton pairs are always uncorrelated. The numbers of SUSY and background dilepton pairs surviving cuts are respectively 913 and 224, giving a signal to background ratio of 4.1. A statistical significance of 5 sigma, calculated using S_{cP} [7], can be obtained with 14 pb^{-1} of integrated luminosity.

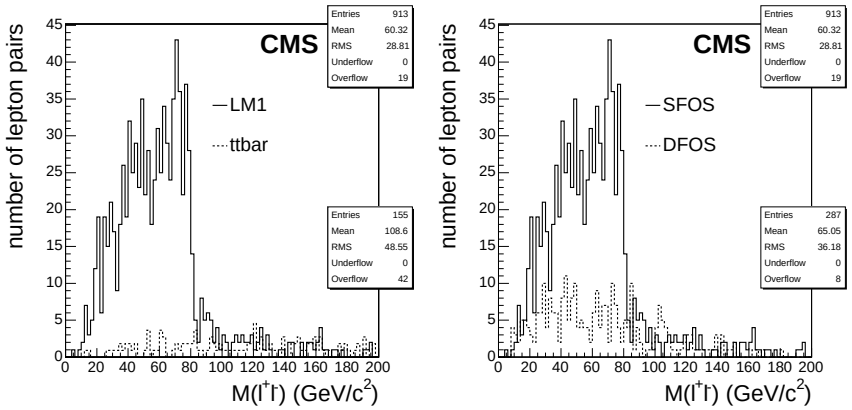

Fig. 1. (a) Same flavour opposite sign lepton pair distributions of SUSY and $t\bar{t}$ events for 1 fb^{-1}. (b) SFOS and DFOS distributions of events for 1 fb^{-1}.

The value of the end point can be extracted by fitting the flavour subtracted distribution with a convolution of a triangle and a Gaussian function (Fig. 2(b)). The value obtained from the fit is

$$M_{ll}^{\rm max} = 80.42 \pm 0.48\,{\rm GeV}/c^2\,, \tag{1}$$

where the error quoted is only statistical. The theoretical end point value is 81.04 GeV/c^2.

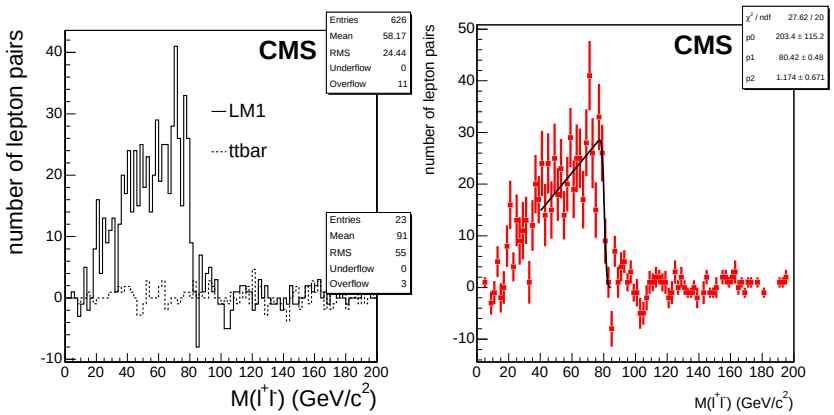

Fig. 2. (a) Flavour subtracted distributions of SUSY and $t\bar{t}$ events for 1 fb^{-1}. (b) Flavour subtracted distributions of SUSY and $t\bar{t}$ events for 1 fb^{-1}. The fit function is shown superimposed.

The analysis has been repeated using also a sample corresponding to an integrated luminosity of 9.2 fb^{-1}: the measured end point is $M_{ll}^{\max} = 80.56 \pm 0.17\,\mathrm{GeV}/c^2$.

5. Systematics

5.1. Misalignment

The effect of tracker and muon chambers misalignment expected in the first months of data taking has been evaluated. Efficiencies are lowered by $\sim 30\%$ for muons and by $\sim 10\%$ for electrons. The endpoint in the invariant mass distributions is however still visible (Figs. 3(a), 3(b)).

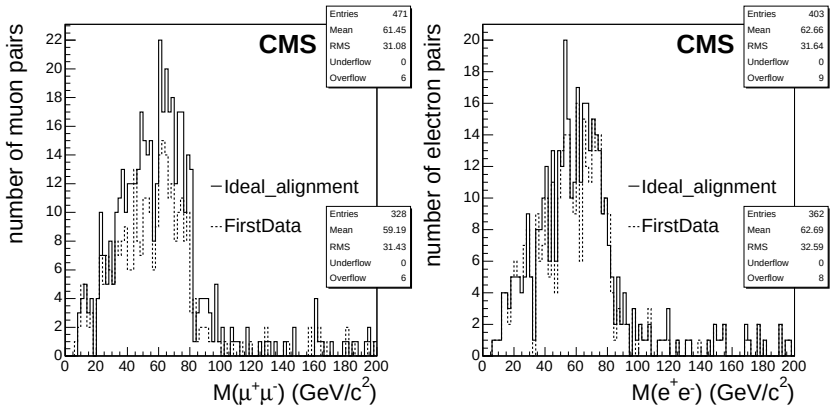

Fig. 3. (a) Muon invariant mass distribution for ideal alignment and in first data scenario. (b) Electron invariant mass distribution for ideal alignment and in first data scenario.

The final selection efficiencies for SUSY events at LM1 point are 1.2% for first data misalignment, compared to an efficiency of 1.6% expected without misalignment. The shift of the endpoint due to the misalignment is of about 1 GeV/c^2.

5.2. Jet and electron energy scale

The error due to the absolute electron energy scale (ElecES) and jet energy scale (JES) uncertainties has also been evaluated. An uncertainty of 0.25% at all integrated luminosities has been considered for the ElecES [9], while 7% for 1 fb^{-1} and of 2% for $\geq$ 10 fb^{-1} are the values used as JES uncertainty. With 1 fb^{-1}, an increase of 20% in the number of background events and of 8% in the number of signal events is estimated, mainly due to the JES. With 10 fb^{-1}, these increases are of 5% and 2% respectively. The integrated luminosity needed to reach 5 sigma significance at LM1, when a 20% systematic error is taken into account for the background, is of 17 pb^{-1}. The position of the endpoint is shifted by about $\pm$0.15 GeV/c^2 by a mismeasurement of ElecES, while the JES uncertainty gives a negligible shift.

6. Scan

In order to check the observability of SUSY events in the leptons + jets + missing transverse energy final state, a scan of the mSUGRA plane (m_0, $m_{1/2}$) has been performed using the software for the fast simulation of the CMS detector, keeping $A_0 = 0$, sign(μ) = +, and tan (β) = 10.

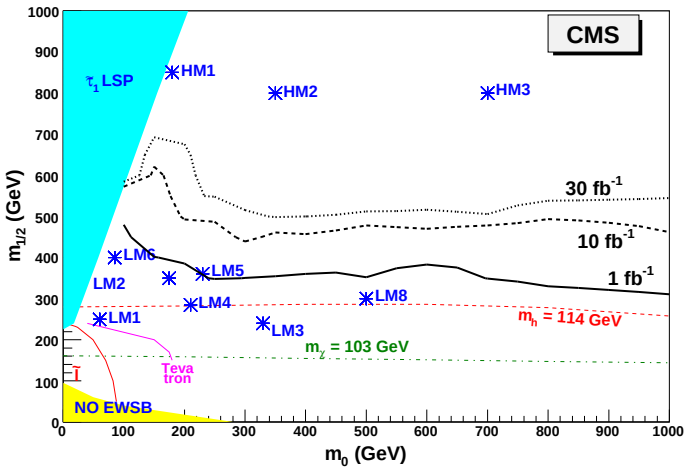

Fig. 4. Discovery reach at tanβ = 10 for an integrated luminosity of 1, 10, and 30 fb^{-1}, when no systematic uncertainties are taken into account.

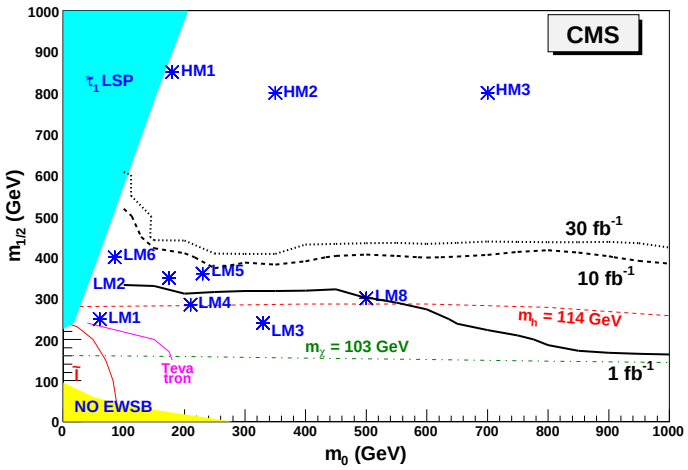

Fig. 5. Discovery reach at $\tan\beta = 10$ for an integrated luminosity of 1, 10, and 30 fb^{-1}, when systematic uncertainties are taken into account.

Background used is the same as in the analysis at LM1 point. The same selection cuts for background and signal have been used. Results of the scan are shown for 1, 10, and 30 fb^{-1} of integrated luminosity in Fig. 4. With systematic uncertainties the range is slightly reduced, but no dramatic changes are expected (Fig. 5).

7. Conclusions

The observability of the $\tilde{\chi}_2^0 \to \tilde{l}_{\mathrm{R}} l \to \tilde{\chi}_1^0 l^+ l^-$ decay produced in SUSY chains through the two same flavour opposite sign lepton pairs + Jets + Missing Transverse Energy final state has been studied at mSUGRA benchmark point LM1, with a full simulation of the CMS detector. The dilepton end point can be measured with a statistical error of ~ 0.5 GeV/c^2 at 1 fb^{-1}. The main systematic uncertainties have also been evaluated. The integrated luminosity needed to reach 5 sigma significance is 14 pb^{-1} without systematics, and 17 pb^{-1} with systematic uncertainties taken into account. The observability of the SUSY events in the m_0, $m_{1/2}$ plane has also been evaluated.

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