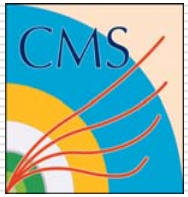


Using $\mu^{\pm}e^{\mp}$ + E_T^{miss} signature in the search for Supersymmetry and Lepton Flavour Violation in neutralino decays

Yu.Andreev, S.Bityukov[1],
N.Krasnikov, A.Toropin

INR RAS, Moscow, Russia

[1] Institute for High Energy Physics, Protvino, Russia

Forewords

The talk based on our CMS Note 2006/103:

Yu.Andreev, S.Bityukov, N.Krasnikov, A.Toropin

Using the $e^{\pm}\mu^{\mp} + E_T^{miss}$ signature in the search for supersymmetry and lepton flavor violation in neutralino decays

Forewords

The discovery of the supersymmetry (SUSY) is one of the main goals of the LHC.

One of the most interesting signatures for the SUSY discovery is $l^+l^- + E_T^{miss}$, because decays of neutralino into leptons and Lightest stable superparticle (LSP) $\tilde{\chi}_2^0 \to l^+l^-\tilde{\chi}_1^0$ contribute to this signature, and invariant mass $m_{inv}(l^+l^-)$ has the edge structure. That allows to determine some combination of the SUSY masses.

The signature $e^{\pm}\mu^{\mp} + E_T^{miss}$ can be used for the detection of lepton flavour violation (LFV) in neutralino decays by searching for the edge structure in the spectrum of $m_{inv}(e^{\pm}\mu^{\mp})$. This signature can be used as well to discover SUSY.

Decays of gluino, stop, sbottom, chargino and neutralino into the third generation of particles and sparticles are enhanced at large $\tan\beta$ ($\tan\beta > 10$) (D.Denegri, W.Majerotto and L.Rurua, Phys. Rev. D60 (1999) 035008). It increases the interest to study the signature $e^{\pm}\mu^{\mp} + E_T^{miss}$ as one of possible SUSY discovery signatures.

Forewords

In this study a set of Low Mass (LM1-LM9) test points was used:
http://cmsdoc.cern.ch/cms/PRS/subsystem/msugra_testpts/msugra_testpts.html

In this work we used combined data from the published DSTs and from the Private production.
The NLO cross sections were used to normalize backgrounds and signals.
All results presented here are obtained for the luminosity $L = 10\ fb^{-1}$.

Low Mass Test Points

The mSUGRA parameters and NLO cross sections of the Low Mass test points are shown in the table below

Point	LM1	LM2	LM3	LM4	LM5	LM6	LM7	LM8	LM9
m_0	60	185	330	210	230	85	3000	500	1450
$m_{1/2}$	250	350	240	285	360	400	230	300	175
$\tan\beta$	10	35	20	10	10	10	10	10	50
$sign(\mu)$	+	+	+	+	+	+	+	+	+
A_0	0	0	0	0	0	0	0	-300	0
σ_{NLO}, pb	54.9	9.4	45.5	25.1	7.7	4.9	6.8	12.2	41.3

Studying $\mu^{\pm}e^{\mp}$ signature in chargino decays

This signature is also interesting irrespective to the lepton flavour number violation due to SUSY cascade decays contribution and it is possible to use it as SUSY discovery signature.

For example:

$$pp \rightarrow \tilde{q}\,\bar{\tilde{q}} + \ldots$$
$$\hookrightarrow q\tilde{\chi}_1^+$$
$$\hookrightarrow q\tilde{\chi}_1^- \quad \hookrightarrow e^+\nu\chi_1^0 \,, \mu^+\nu\chi_1^0$$
$$\hookrightarrow e^-\nu\chi_1^0 \,, \mu^-\nu\chi_1^0$$

We studied it as a SUSY discovery signature.

Neutralino decays. Lepton Flavour Violation.

Normal decays of neutralino (1) and decays of neutralino in the case of Lepton Flavour Violation (2)

$$pp \rightarrow \tilde{q}\bar{\tilde{q}} + \ldots$$

$$\hookrightarrow q\tilde{\chi}_2^0$$

$$\hookrightarrow e^+e^-(\mu^+\mu^-) + \chi_1^0 \quad (1)$$

$$\hookrightarrow \mu^+e^-(\mu^-e^+) + \chi_1^0 \quad (2)$$

(2) Flavour lepton number violation in slepton decays:

Krasnikov N.V. Mod.Phys.Lett. A9 (1994) 791;
Phys.Lett. B388 (1996) 783
Arkani-Hamed N. et al Phys.Rev.Lett. 77 (1996) 1937

Used Reconstruction Algorithms

ORCA_8_7_1 and ORCA_8_7_4 were used for digitization and reconstruction:

- OfflineElectronReco was used to reconstruct electrons.
- GlobalMuonReconstructor was used for muons reconstruction.
- METfromEcalPlusHcalTower with LeptonCorrection was used for Missing E_T reconstruction.

FAMOS_1_3_1 was used to calculate discovery plot:

- EGFElectron was used to reconstruct electrons.
- FamosGlobalMuonReconstructor was used for muons reconstruction.
- Missing E_T was calculated as $P_T^{miss} = -\sum P_T^{jets} - \sum P_T^{muons}$

Kinematical Cuts and Significances Estimators

After optimization the following set of cuts was chosen:

Cuts for SUSY search

- Two isolated leptons with $p_T^{lept} > 20\ GeV$ and $|\eta| < 2.4$
- $E_T^{miss} > 300\ GeV$

These cuts were chosen to have high significance values (S_{c12},S_{cL}) and high signal to background ratio.

Significances estimators:

- $S_{c12} = 2\times(\sqrt{N_S+N_B}-\sqrt{N_B})$ S.I.Bityukov, N.V.Krasnikov, NIM A452(2000) 518

- $S_{cL} = \sqrt{2\times((N_S+N_B)\times\ln(1+N_S/N_B)-N_S)}$ V.Bartsch and G.Quast CMS NOTE 2005/004 & R.Cousins et al. CMS NOTE 2005/002

$\mu^{\pm} e^{\mp}$: Signal (LM1) & SM Background

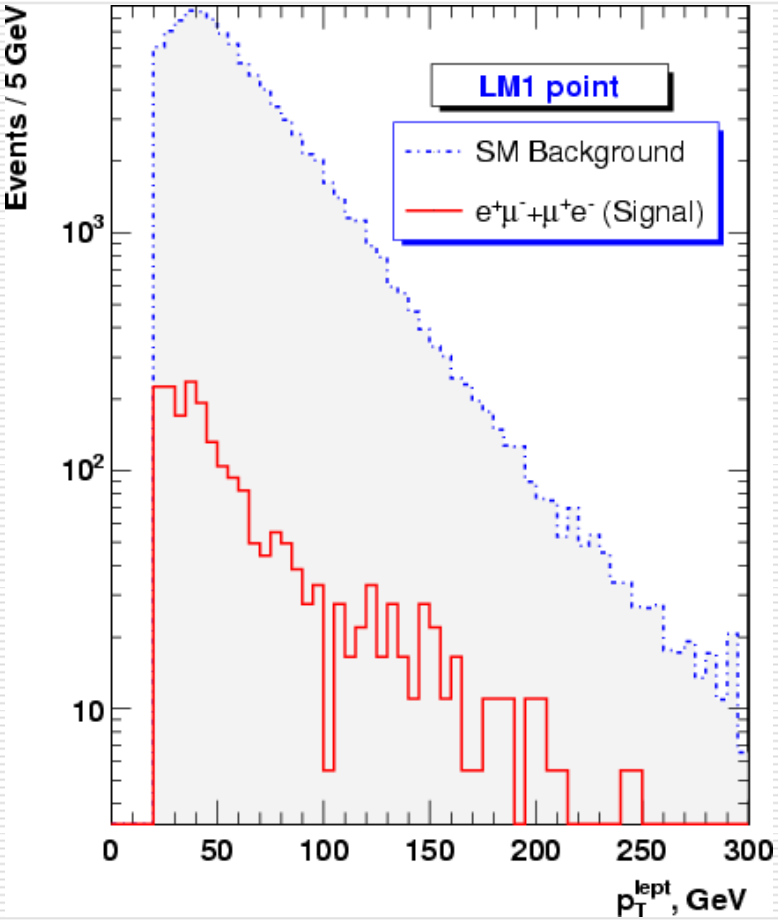
Process	2 isolated leptons, $p_T^{lept} > 20$ GeV	$E_T^{miss} > 300$ GeV
ttbar	39679	79
WW	4356	4
WZ	334	2
ZZ	38	0
Wt	3823	2
Zbbbar	315	0
Z + jet	1082	6
DY2tau	7564	0
SM background	57191	93
LM1 signal	1054	329

Points LM1–LM9: signal events and significances

Point	N events	S_{c12}	S_{cL}
LM1	329	21.8	24.9
LM2	94	8.1	8.6
LM3	402	25.2	29.2
LM4	301	20.4	22.1
LM5	91	7.8	8.3
LM6	222	16.2	18.0
LM7	14	1.4	1.4
LM8	234	16.9	18.8
LM9	137	11.0	11.9

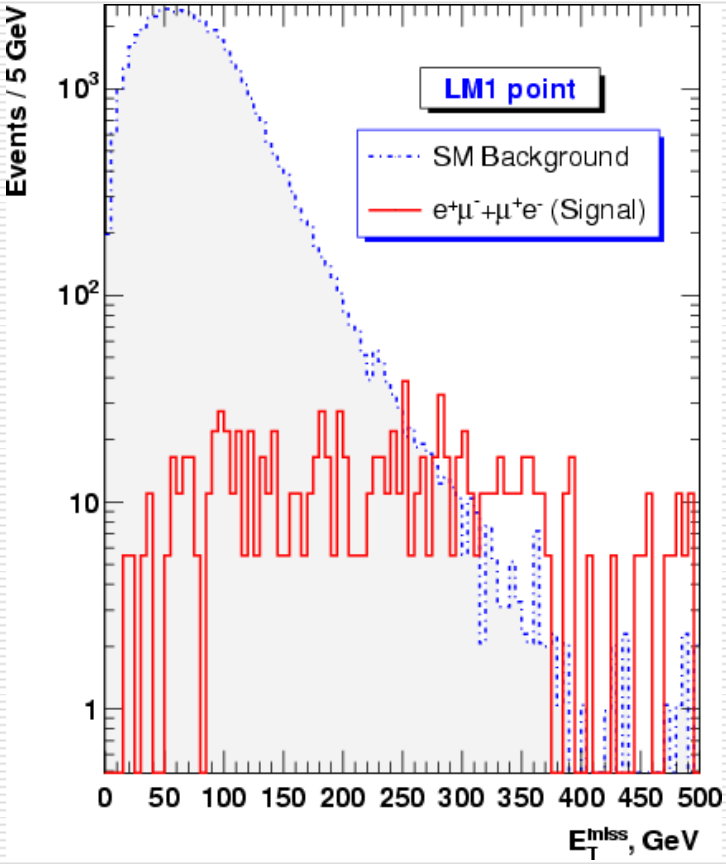
For Significances calculations N_{SMbcg} = 93 (Table from the previous slide).

Signal (LM1) and SM Background



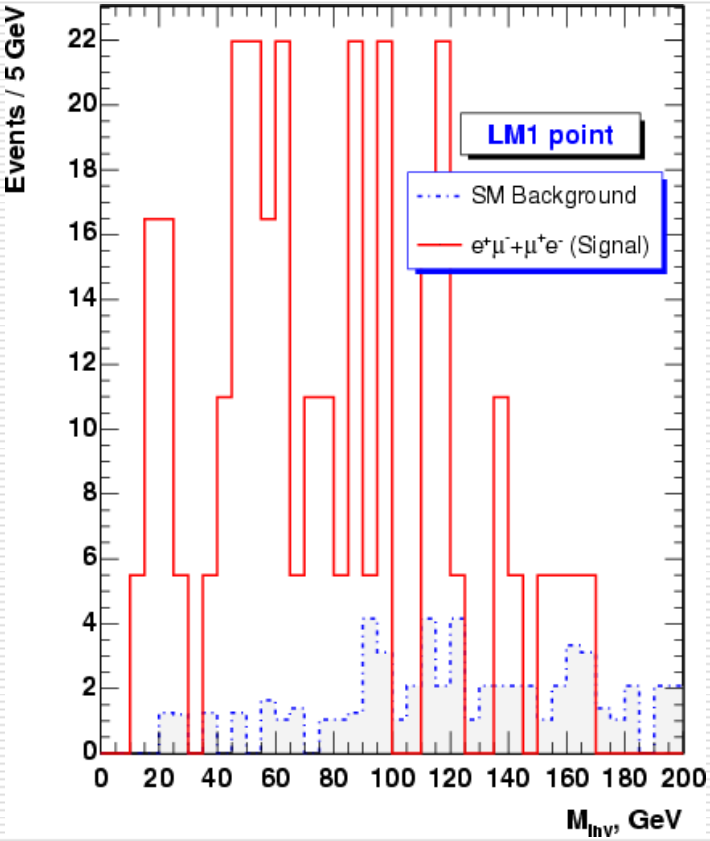
Distribution of p_T^{lept} after selection of two isolated leptons for $\mu^{\pm}e^{\mp}$ with p_T^{lept} > 20 GeV.

Signal (LM1) and SM Background



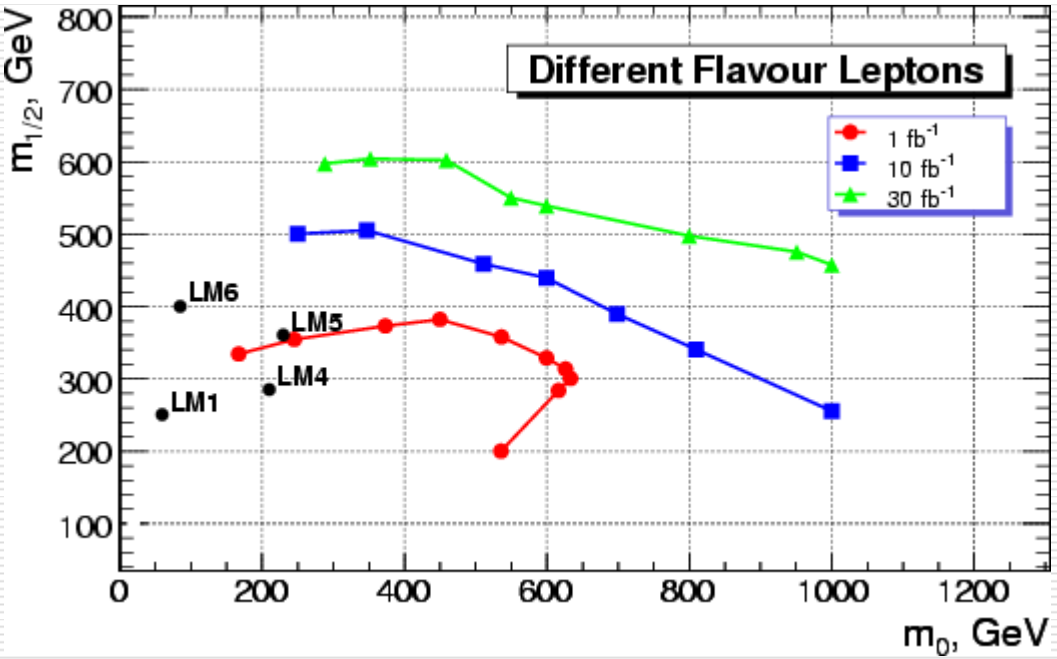
Distribution of E_T^{miss} after selection of two isolated leptons for $\mu^{\pm}e^{\mp}$ with p_T^{lept} > 20 GeV.

Signal (LM1) and SM Background



The dilepton mass M_{inv} after selection of two isolated leptons with p_T^{lept} > 20 GeV and E_T^{miss} > 300 GeV for $\mu^{\pm}e^{\mp}$.

Discovery Plot for tan $\beta = 10$, $sign(\mu) = +$, $A = 0$



Discovery plot for $e^{\pm}\mu^{\mp}$.

Lepton Flavour Violation for LM1 Point

In the case of LFV neutralino decays

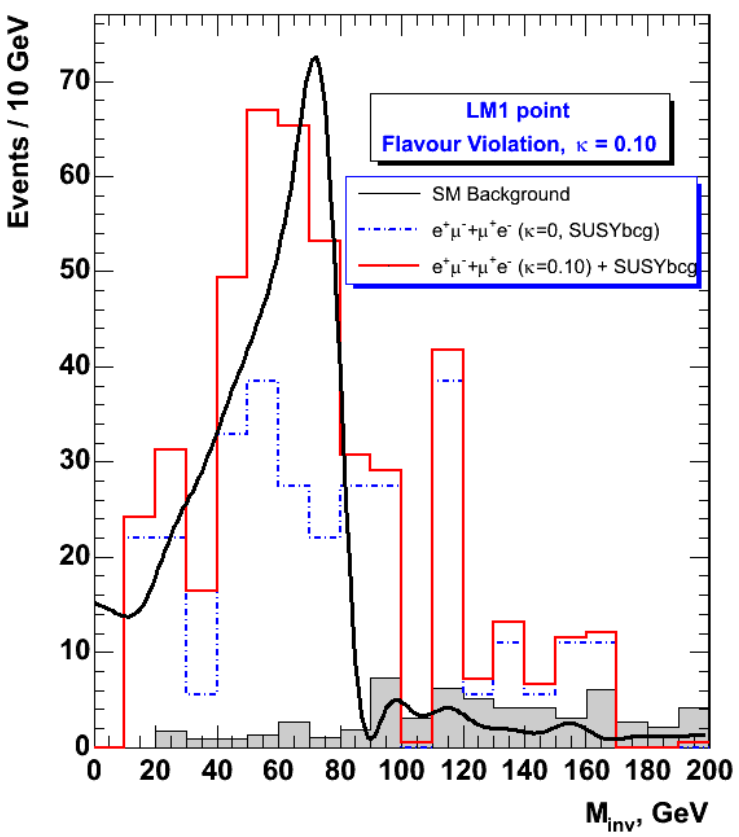
$$\tilde{\chi}_2^0 \rightarrow \tilde{l}l' \rightarrow e\mu\tilde{\chi}_1^0$$

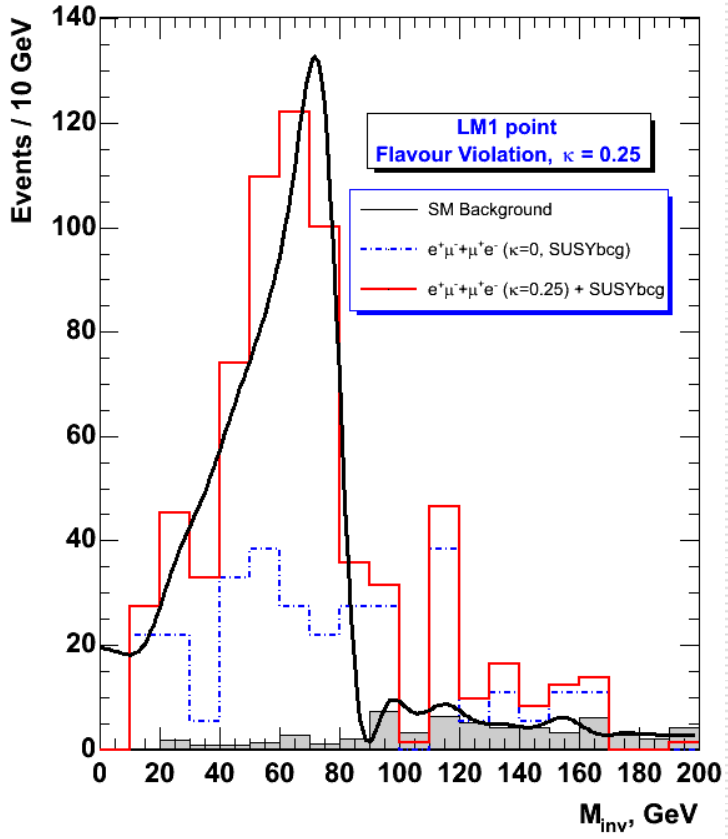
as a consequence the edge structure will appear for the distribution on $m_{inv}(e,\mu)$. The presence of such structure will indicate the existence of LFV.

To study LFV a special sample of events with 100% flavour violation was prepared and fractions of these events were added to LM1 events to simulate LFV behavior.

Distribution on Invariant Mass for Flavour Violating κ = 0.10 & 0.25

$$Br(\chi_2^0 \to \mu^{\pm} e^{\mp} \chi_1^0) = \kappa \times Br(\chi_2^0 \to e^+ e^- \chi_1^0, \mu^+ \mu^- \chi_1^0)$$





Superimposed curves are fits to the Invariant mass distribution for 100% LFV.

LM1 Lepton Flavour Violation Bound

To define Br of LFV for LM1 the following set of cuts was used:

- Two isolated leptons with $p_T^{lept} > 40\ GeV$ and $|\eta| < 2.4$
- $E_T^{miss} > 200\ GeV$
- $M_{inv}(l^+ l^-) < 85\ GeV$

The use of an additional cut

$$M_{inv}(e,\mu) < 85\ GeV$$

allows to reduce both SM and SUSY backgrounds and increase LFV discovery potential. It is possible to discover LFV in neutralino decays with $\kappa > 0.04$ at 5 sigma level for L = 10 fb^{-1} assuming we know the magnitudes of both SM and SUSY backgrounds. Here κ means

$$Br(\chi_2^0 \to \mu^{\pm} e^{\mp} \chi_1^0) = \kappa \times Br(\chi_2^0 \to e^+ e^- \chi_1^0, \mu^+ \mu^- \chi_1^0)$$

and actual value is $Br(\chi_2^0 \to \mu^{\pm} e^{\mp} \chi_1^0) > 0.005$ with respect to all neutralino decays.

$\mu^{\pm} e^{\mp}$: LFV Signal (LM1) & Background

Process	2 isolated leptons, $p_T^{lept} > 40$ GeV	$E_T^{miss} > 200$ GeV	$M_{inv} < 85$ GeV
ttbar	20715	422	8
WW	1966	18	0
WZ	188	2	0
Z Z	30	0	0
Wt	2136	33	0
Zbbbar	31	0	0
Z+jet	371	12	11
DY2tau	244	0	0
Total SM bcg	25681	487	19
LM1(SUSY bcg)	433	230	71
LFV signal (LM1)	2454	1619	1421

Conclusions

The use of the $e^{\pm}\mu^{\mp} + E_T^{miss}$ signature allows:

- For the CMS test points LM1-LM9 for L = 10 fb^{-1} it is possible to discover SUSY for all LM points except the LM7 one.
- To discover the Lepton Flavour Violation in neutralino decays for the point LM1 with Br > 0.005 with respect to all neutralino decays.