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Probing Radiative Neutrino Mass Models Using Trilepton Channel at the LHC

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Overview

Model & Space Parameter

- *In this work, we consider a class of models that contain the following term in the Lagrangian*

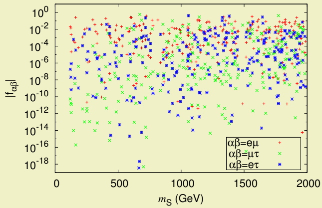
$$\mathcal{L} \supset f_{\alpha\beta} L_\alpha^T C\epsilon L_\beta S^+ \text{-m}_S^2 S^+ S^- + \text{h.c.}$$

- *The interaction above induces LFV effects via processes such as $\mu \to e\gamma$ and $\tau \to \mu\gamma$, with branching fractions..*

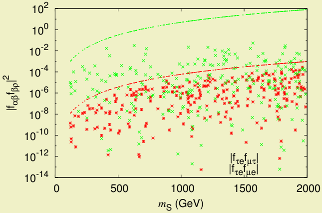
$$\mathcal{B}(\mu \to e\gamma) \simeq \frac{\alpha v^4}{384\pi} \frac{|f_{\tau e}^* f_{\mu\tau}|^2}{m_S^4}$$
$$\mathcal{B}(\tau \to \mu\gamma) \simeq \frac{\alpha v^4}{384\pi} \frac{|f_{\tau e}^* f_{\mu e}|^2}{m_S^4}$$

- *A new contribution to the muon's anomalous magnetic moment is induced at 1-loop.*

$$\delta a_\mu \sim \frac{m_\mu^2}{96\pi^2} \frac{|f_{e\mu}|^2 + |f_{\mu\tau}|^2}{m_S^2}$$

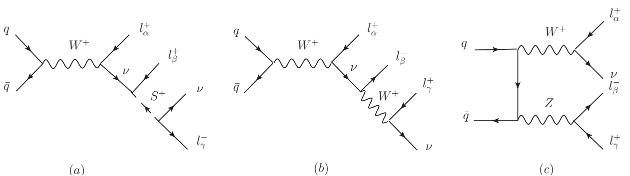


$$\mathcal{B}\,(\mu \to e + \gamma) < 5.7 \times 10^{-13}\ [J.Adam.2013]$$
$$\mathcal{B}\,(\tau \to \mu + \gamma) < 4.8 \times 10^{-8}\ [K.A.Olive.2014]$$



Trilepton signal phenomenology

There is an interesting possibility to produce a singly charged scalar at the parton level process at the LHC



Signal Vs SM Background

- *We have 9 contributions to this trilepton signal, three of them are background free*
- *CalcHEP is used to generate both the SM background events as well the events from processes due to the **LFV** interactions for* $\sqrt{s} = 8$ *and* $14\ TeV$.
- *The excess of events looked for after the selection cut is* $N_{ex} = \mathcal{L}_{int}\,(\sigma_M - \sigma_B)$*, Therefore the signal significance is given by*

$$S = \frac{N_{ex}}{\sqrt{N_{ex}+N_B}} = \frac{N_{ex}}{\sqrt{N_M}}$$

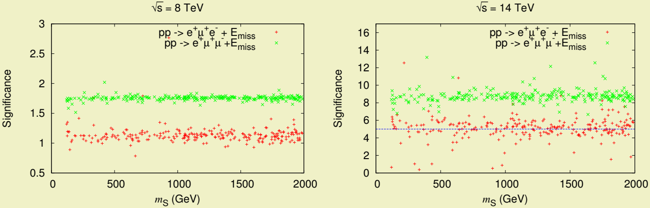
$$[N_{ex} = N_M - N_B] \propto [2\ Re\left(\mathcal{M}_{SM}^{\dagger}\mathcal{M}_{non-SM}\right) + |\mathcal{M}_{non-SM}|^2] \propto |f_{\alpha\rho} f_{\beta\rho}|^2.$$

where $|\mathcal{M}_{non-SM}| \lll$

Current Constraints at the LHC

The analysis was based on the following CMS collaboration criteria with $\mathcal{L}_{int} = 19.5\ fb^{-1}$ *at* $\sqrt{s}$ *= 8* TeV*:*

- *The presence of at least three isolated leptons (muon, electron).*
- $75\text{GeV} < M_{\ell^+\ell^-} < 105$ GeV. • $p_T^\ell > 10$ GeV. • $\not{E}_T < 50$ GeV. • $|\eta^\ell| < 2.4$.

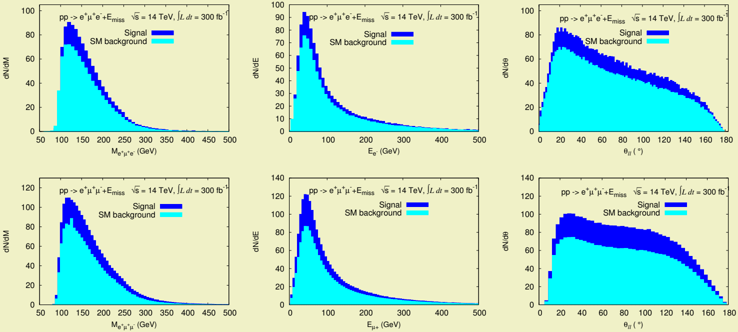


⇒ *Two benchmark points selected from the allowed parameter space of the model*

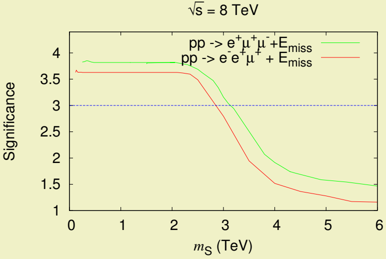
Point	m_S *(GeV)*	$f_{e\mu}$	$f_{e\tau}$	$f_{\mu\tau}$
B_1	*471.8*	$-(9.863 + i8.774) \times 10^{-2}$	$-(6.354 + i2.162) \times 10^{-2}$	$(0.78 + i1.375) \times 10^{-2}$
B_2	*1428.5*	$(5.646 + i549.32) \times 10^{-3}$	$-(2.265 + i1.237) \times 10^{-1}$	$-(0.41 - i3.58) \times 10^{-2}$

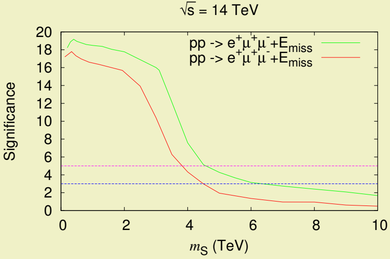
- *Due to the difficulty in identifying the tau lepton at the LHC, only the final state leptons $\ell = e, \mu$, are considered here, with $\not{E}_T$ can be $\bar{\nu}_e, \bar{\nu}_\mu$ or $\bar{\nu}_\tau$.*

$e^+\mu^+e^- + \not{E}_T$ @ 8 TeV	$e^+\mu^+e^- + \not{E}_T$ @ 14 TeV	$e^+\mu^+\mu^- + \not{E}_T$ @ 8 TeV	$e^+\mu^+\mu^- + \not{E}_T$ @ 14 TeV
$70 < M_{e^-e^+} < 110$	$70 < M_{e^-e^+} < 110$	$80 < M_{\mu^-\mu^+} < 100$	$80 < M_{\mu^-\mu^+} < 110$
$M_{e^+\mu^+} < 200$	$M_{e^+\mu^+} < 230$	$M_{e^+\mu^+} < 200$	$M_{e^+\mu^+} < 230$
$M_{e^-\nu} < 206$	$M_{e^-\nu} < 220$	$M_{\mu^-\nu} < 185$	$M_{\mu^-\nu} < 245$
$10 < p_T^\ell < 100$	$10 < p_T^\ell < 90$	$10 < p_T^\ell < 100$	$10 < p_T^\ell < 130$
$\lvert\eta^\ell\rvert < 3$	$\lvert\eta^\ell\rvert < 3$	$\lvert\eta^\ell\rvert < 3$	$\lvert\eta^\ell\rvert < 3$
$\not{E}_T < 100$	$\not{E}_T < 90$	$\not{E}_T < 90$	$\not{E}_T < 120$



Process	Benchmark	$N_{20.3}$	$S_{20.3}$	N_{300}	S_{300}
$p,p \to e^+\mu^+e^- + \not{E}_T$	B_1	70.42	3.651	1689.6	17.363
	B_2	69.69	3.618	1470	15.289
$p,p \to e^+\mu^+\mu^- + \not{E}_T$	B_1	71.21	3.831	2066.7	19.210
	B_2	70.44	3.793	1974.9	18.983

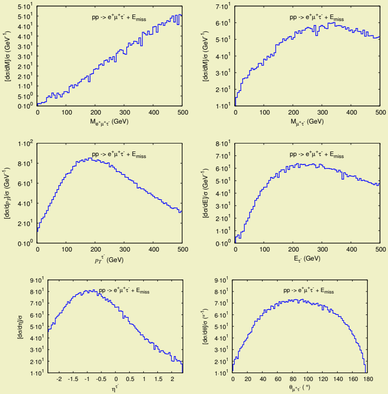


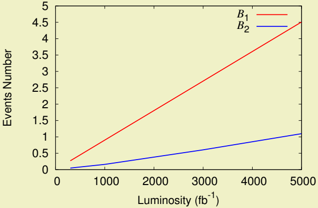


Benchmark Analysis
LFV Background Free Channel

- *Another way to probe this class of models, is to extend our analysis and consider one of the background-free channels $\ell^+\ell^+\ell^- \equiv e^+\mu^+\tau^-$, where the tau lepton is identified through its hadronic decay rather than its leptonic one in order to avoid additional source of missing energy.*

$$N_{BG-free} = L \times \sigma(pp \to e^+\mu^+\tau^- + \not{E}_T) \times \mathcal{B}(\tau \to hadrons), \qquad (1)$$





Summary & Conclusion

1. *The parameter space points B_1 and B_2 are expected to have a favorable cross sections at the LHC.*
2. *The significance differs according to the final state detected, and to the scale of the energy*
3. *The probability of observing the trilepton signal events through the signature $e^+\mu^+\mu^-$, is improved compared to that found across the $e^+\mu^+e^- + \not{E}_T$ at $\sqrt{s}$ =8 TeV and $\sqrt{s}$ = 14 TeV.*
4. *Research carried out at low mass of charged scalar, is more favorable over high mass.*
5. *From the collected results, The charged scalar $S^\pm$ seems more detectable at LHC comparing to the singly charged scalar $h^\pm$ of the Zee Babu [K. S. Babu et all. 2003] which it estimates around ten events produced at the LHC for any $h^\pm$ mass in the TeV range.*

THANKS