See-saw implications for the LHC

See-saw implications for the LHC

Electroweak constraints on see-saw messengers and their implications for LHC

- Limits on new leptons
- Dilepton signals beyond the Standard Model
- Signatures of see-saw messengers

Limits from EWPD on see-saw messengers

F. del Aguila, J. de Blas and M. Pérez-Victoria

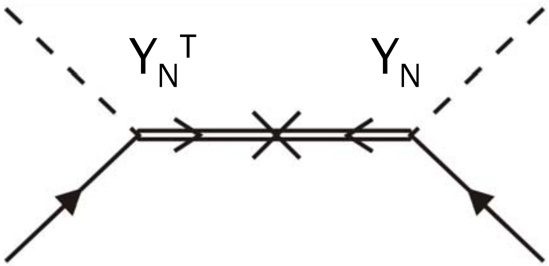
The signals of new physics at large colliders depend on the new couplings. Hence, it is important to know the existing limits on possible SM extensions.

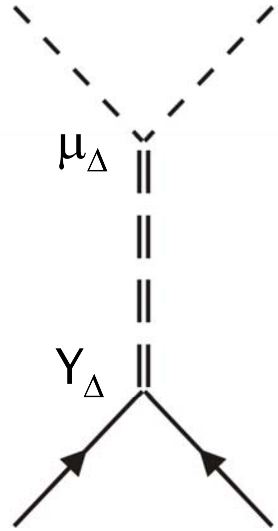
Here, we are interested in new particles which may contribute to light neutrino masses. There are 3 tree level messengers which generate Majorana masses for the 3 known ν's through the famous dimension 5 operator

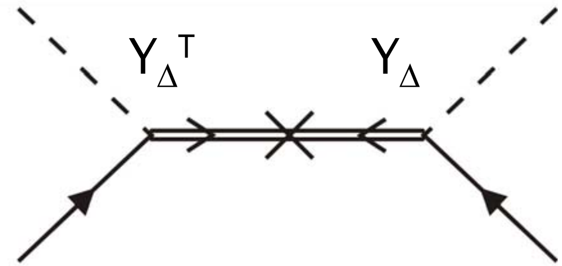
$$\mathcal{O}_5 = \bar{L}^i i\sigma_2 \phi^* \phi^\dagger i\sigma_2 (L^j)^c$$

A. Abada, C. Biggio, F. Bonnet, M.B. Gavela and T. Hambye

See-saw mechanisms of type I, II and III







$^1/_2 Y_N^T M_N^{-1} Y_N$ $\quad -2\, Y_\Delta \mu_\Delta M_\Delta^{-2}$ $\quad ^1/_2 Y_\Sigma^T M_\Sigma^{-1} Y_\Sigma$

Phase cancellation or small couplings

small coupling(s)

Phase cancellation or small couplings

Then, the question arises of the relative size of the coefficients of dimension 5 and 6. If the smallness of the neutrino masses is due to the cut-off scale $\Lambda \sim 10^{14}$ GeV, no effect of the dimension 6 operators will be seen at the electroweak scale (LHC).

On the contrary if the effective scale is the TeV, one has to explain why the dimension 5 coefficient is so small $\sim 10^{-14}$, and not ~ 1.

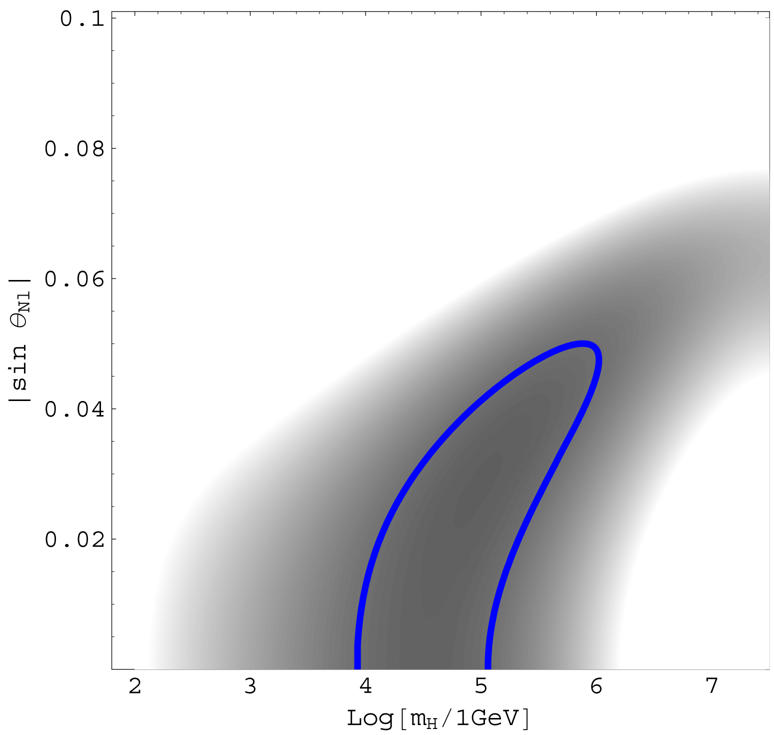
This second possibility is more interesting experimentally, for it may allow to observe new particles at LHC.

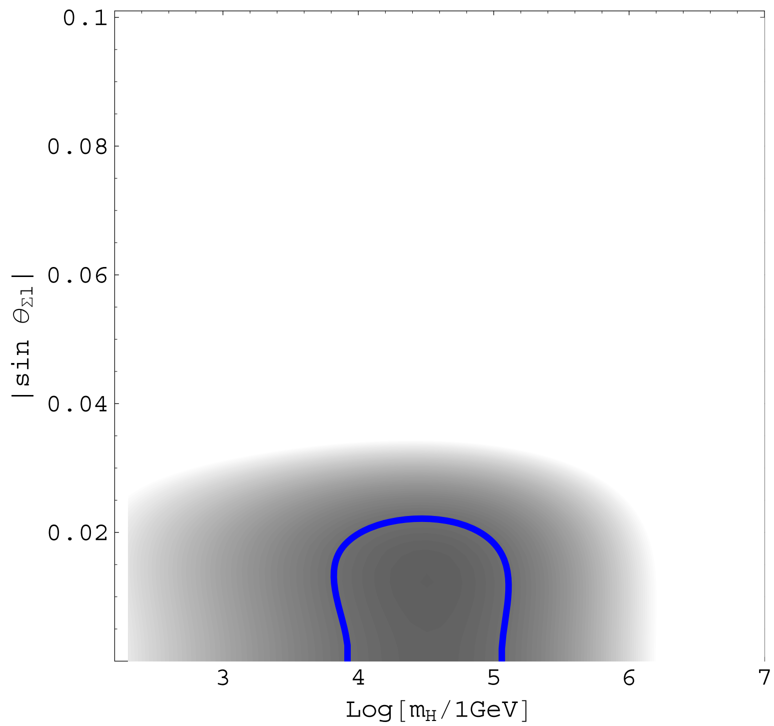
We will use the case of heavy neutrino singlets as example

J.. Kersten and A.Y. Smirnov

Limits on the new lepton mixing as a function of the Higgs mass

F. del Aguila, J. de Blas and M. Pérez-Victoria





90 % C.L.

Fermion singlet $|V_{lN}| < 0.039$

Best value $|V_{lN}| = 0.026$, $m_h = 121.5$ GeV

Scalar triplet

$$\mathcal{O}_{LL}^{(1)} = \frac{1}{2}\left(\bar{L}\gamma_\mu L\right)\left(\bar{L}\gamma^\mu L\right) \quad \left\{ \begin{array}{l} 2\,(Y_\Delta)_{e\mu}\,(Y_\Delta^{+})_{\mu e}\,M_\Delta^{-2} \\ |(Y_\Delta)_{e\mu}\,M_\Delta^{-1}| < 0.47\ \text{TeV}^{-1} \end{array} \right.$$

$$\mathcal{O}_{\phi}^{(3)} = \left(\phi^\dagger D_\mu \phi\right)\left(\left(D^\mu \phi\right)^\dagger \phi\right) \quad \left\{ \begin{array}{l} 4\,|\mu_\Delta|^2\,M_\Delta^{-2} \\ |\mu_\Delta M_\Delta^{-2}| < 0.043\ \text{TeV}^{-1} \end{array} \right.$$

Fermion triplet $|V_{l\Sigma}| < 0.018$

Best value $|V_{l\Sigma}| = 0.015$, $m_h = 116.2$ GeV

$m_N > M_W$

$$|V_{lN}|^2 < 0.0054, \; 0.0096, \; 0.016$$

S. Bergmann and A. Kagan

$$|V_{lN} V_{l'N}| < \begin{matrix} 0.0054 & 0.0001 & 0.01 \\ & 0.0096 & 0.01 \\ & & 0.016 \end{matrix}$$

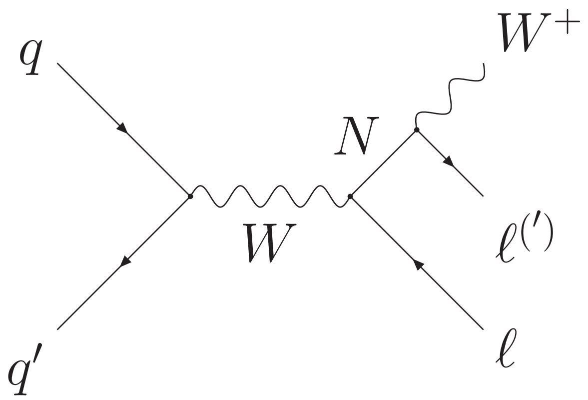
D. Tommasini, G. Barenboim
J. Bernabéu and C. Jarlskog

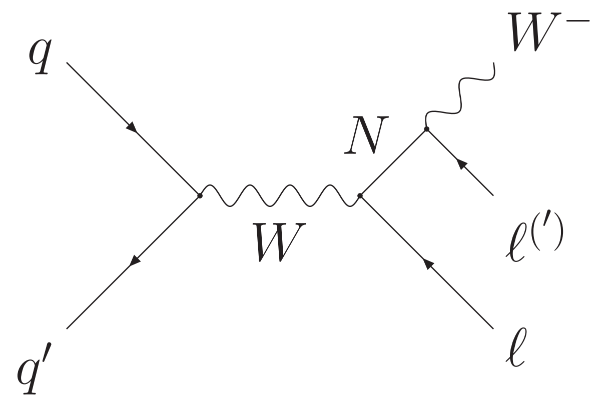
$m_N < M_W$

$$|V_{lN}|^2 < 3 * 10^{-4}$$

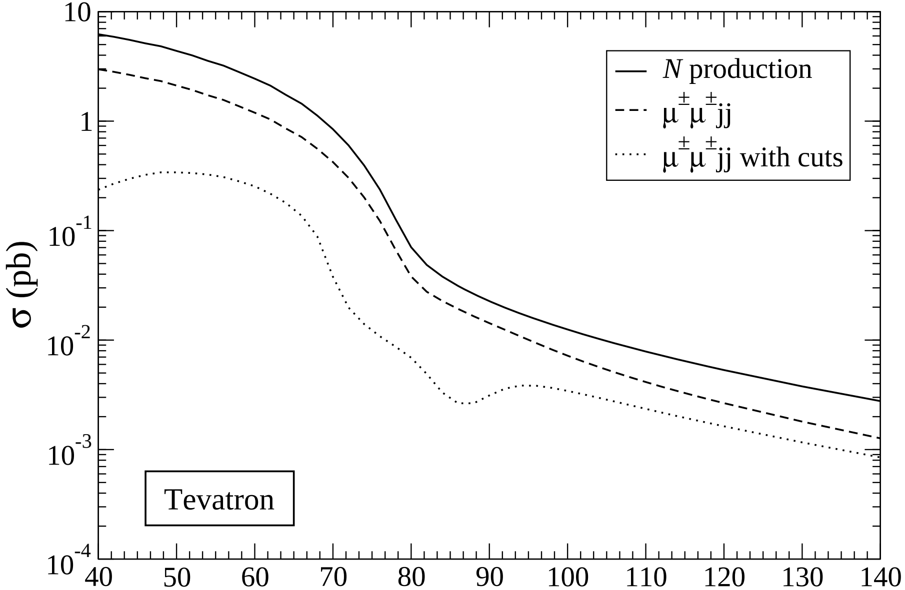
L3

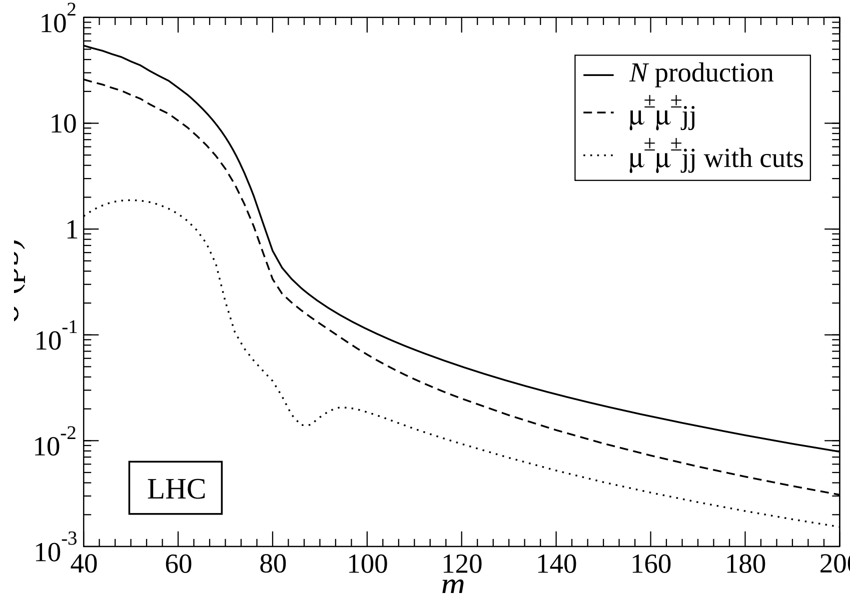
Dilepton signals beyond the Standard Model: hadron colliders





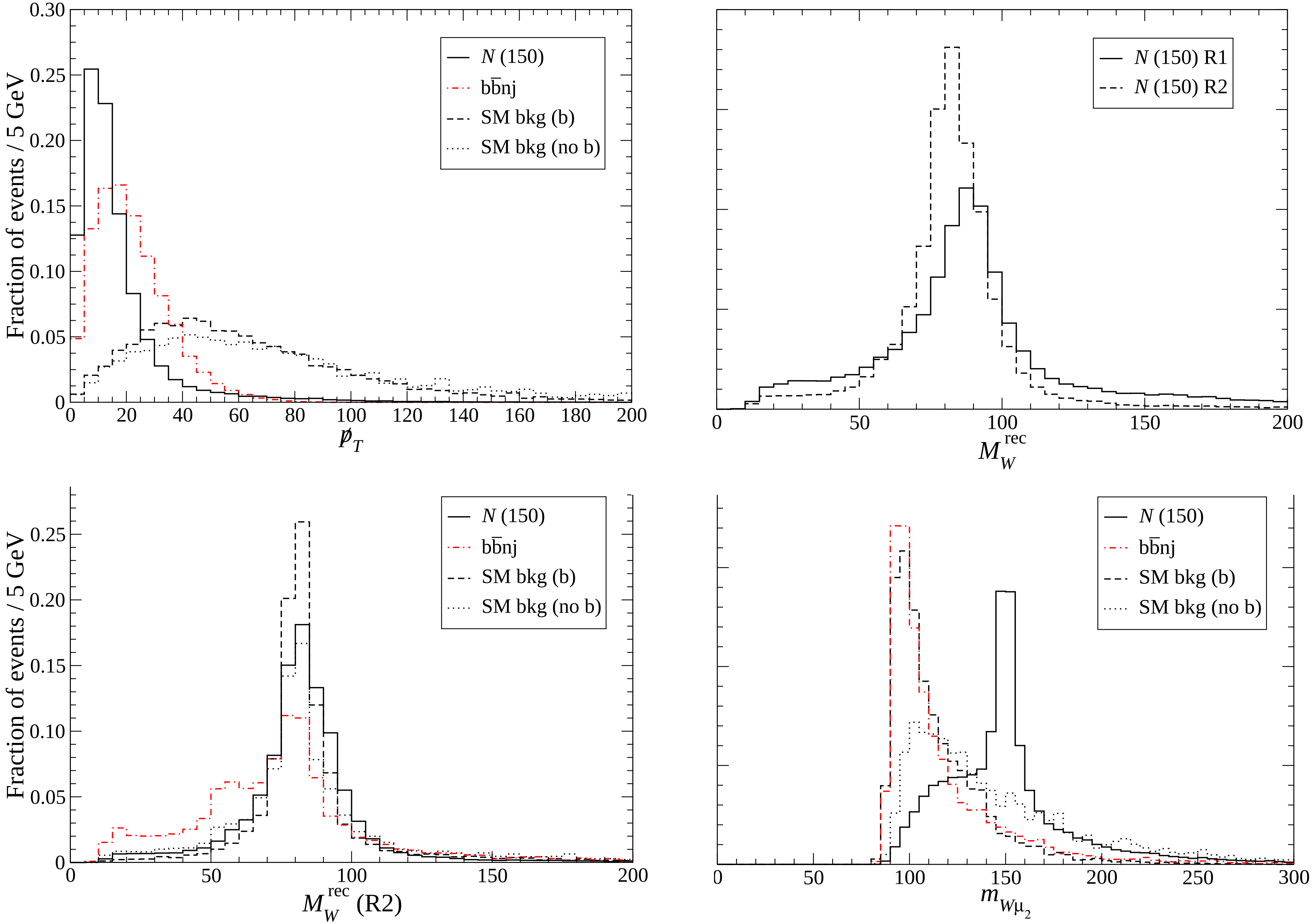
F. del Aguila, J.A. Aguilar-Saavedra and R. Pittau



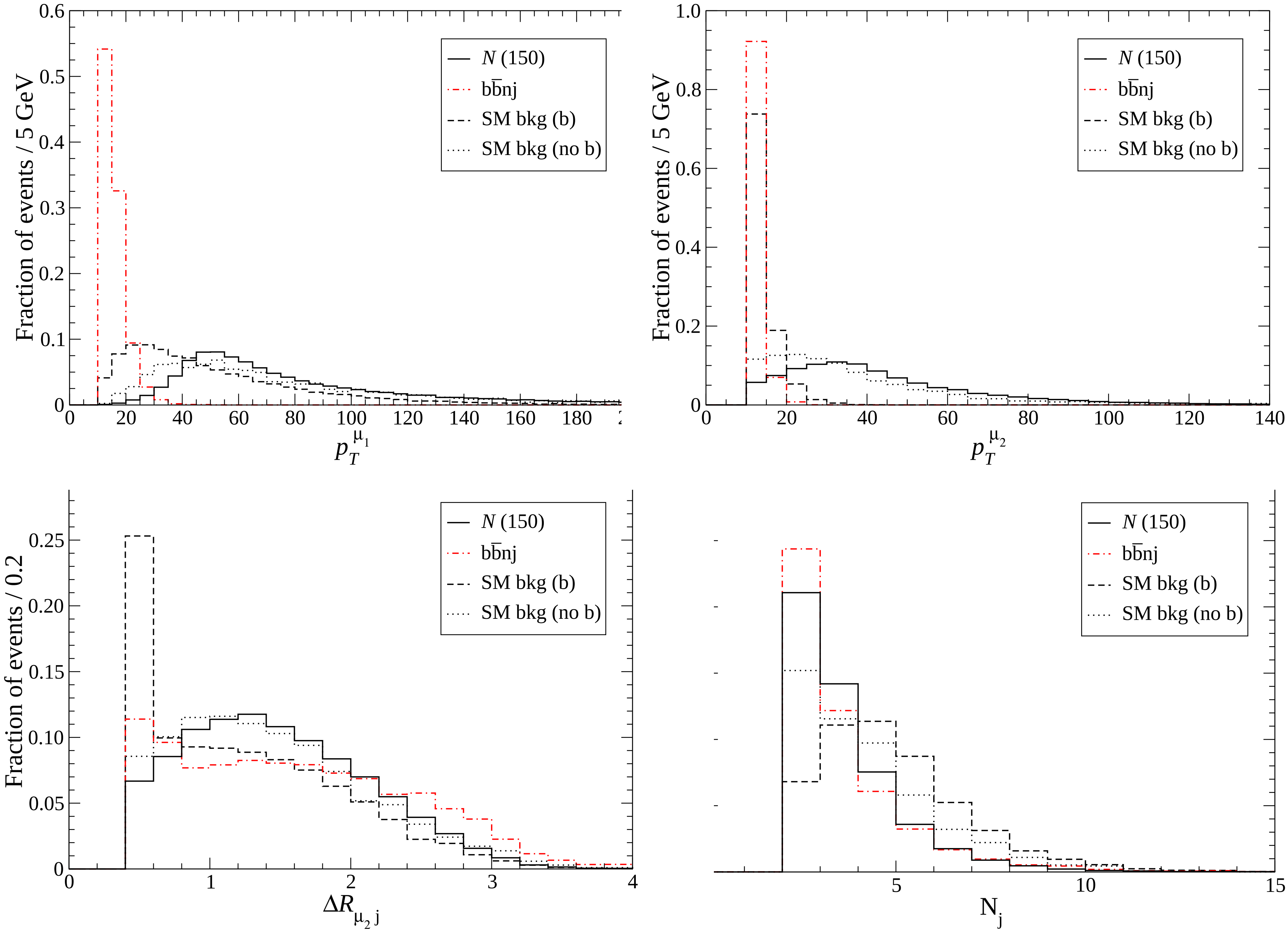


	Pre-selection			Selection		
	$\mu^\pm\mu^\pm$	$e^\pm e^\pm$	$\mu^\pm e^\pm$	$\mu^\pm\mu^\pm$	$e^\pm e^\pm$	$\mu^\pm e^\pm$
N (a)	113.6	0	0	59.1	0	0
N (b)	0	72.0	0	0	17.6	0
N (c)	78.4	25.5	82.6	41.6	4.7	22.4
$b\bar{b}nj$	14800	52000	82000	0	0	0
$c\bar{c}nj$	(11)	300	200	(0)	0	0
$t\bar{t}nj$	1162.1	8133.0	15625.3	2.4	8.3	7.7
tj	60.8	176.5	461.5	0.0	0.0	0.1
$Wb\bar{b}nj$	124.9	346.7	927.3	0.4	0.6	0.3
$Wt\bar{t}nj$	75.7	87.2	166.9	0.3	0.0	0.0
$Zb\bar{b}nj$	12.2	68.9	117.0	0.0	0.2	0.0
$WWnj$	82.8	89.0	174.8	0.5	0.1	0.7
$WZnj$	162.4	252.0	409.2	4.8	1.8	2.3
$ZZnj$	3.8	13.3	12.9	0.0	0.6	0.1
$WWWnj$	31.9	30.1	64.8	0.9	0.1	0.0

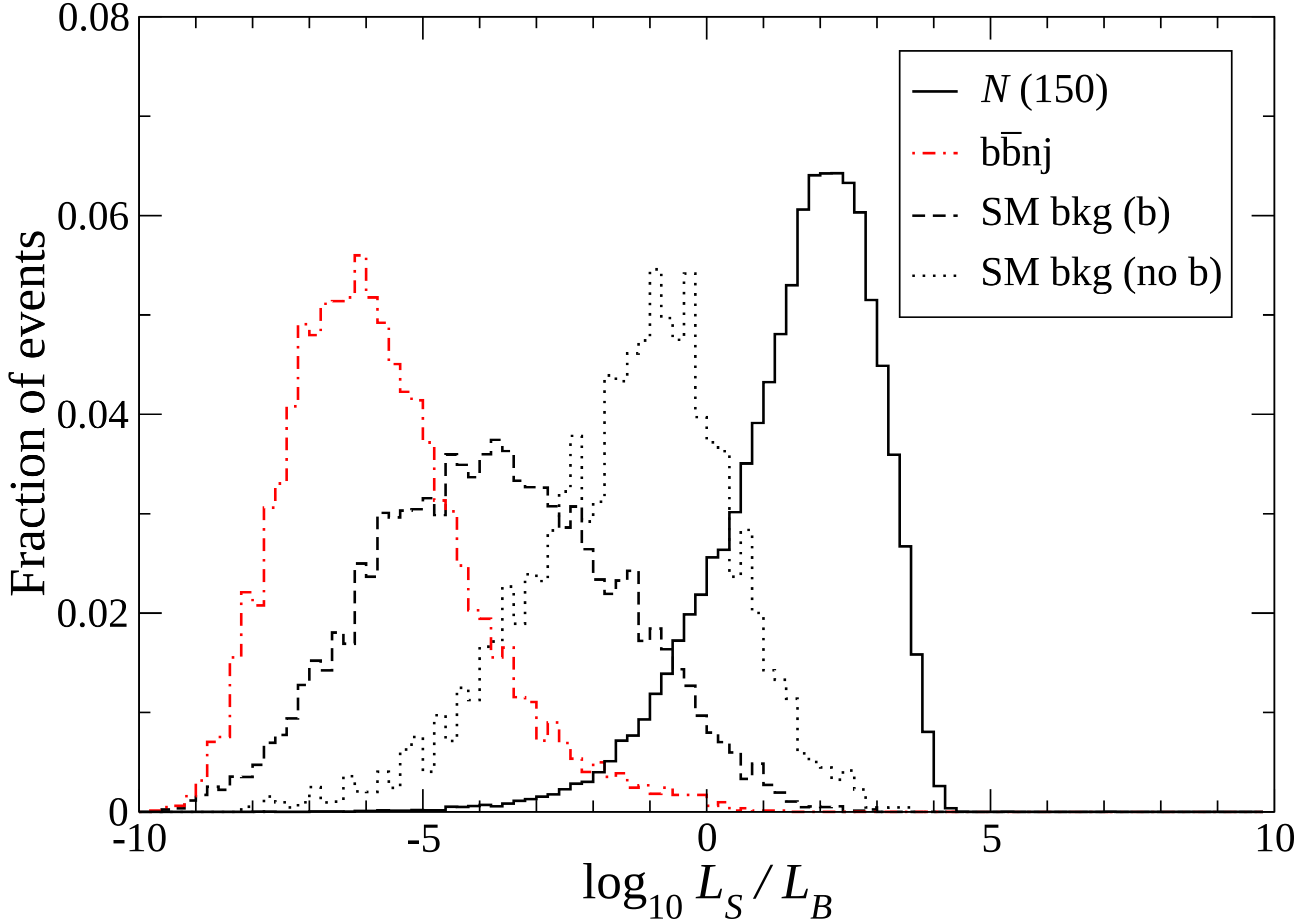
Table 1: Number of $\ell^\pm\ell^\pm jj$ events at LHC for 30 fb^{-1}, at the pre-selection and selection levels. The heavy neutrino signal is evaluated assuming $m_N = 150$ GeV and coupling (a) to the muon, $V_{\mu N} = 0.098$; (b) to the electron, $V_{eN} = 0.073$; (c) to both, $V_{eN} = 0.073$ and $V_{\mu N} = 0.098$.



Fraction of events / 5 GeV
N (150)
$b\bar{b}nj$
SM bkg (b)
SM bkg (no b)
$\not{p}_T$
N (150) R1
N (150) R2
M_W^{rec}
Fraction of events / 5 GeV
N (150)
$b\bar{b}nj$
SM bkg (b)
SM bkg (no b)
M_W^{rec} (R2)
N (150)
$b\bar{b}nj$
SM bkg (b)
SM bkg (no b)
$m_{W\mu_2}$



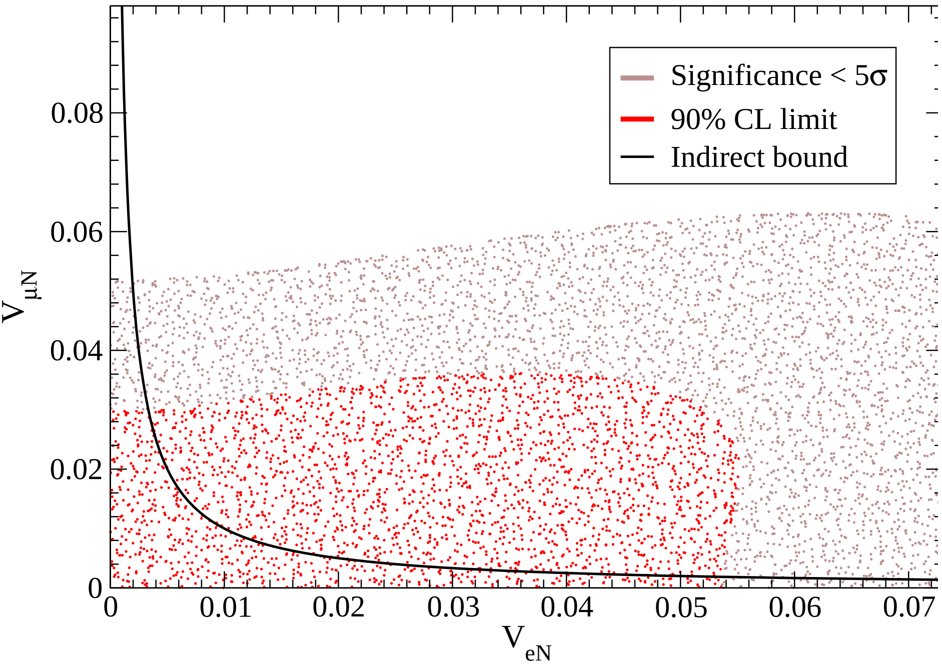
Fraction of events / 5 GeV
N (150)
bb̄nj
SM bkg (b)
SM bkg (no b)
$p_T^{\mu_1}$
Fraction of events / 5 GeV
N (150)
bb̄nj
SM bkg (b)
SM bkg (no b)
$p_T^{\mu_2}$
Fraction of events / 0.2
N (150)
bb̄nj
SM bkg (b)
SM bkg (no b)
$\Delta R_{\mu_2 j}$
N (150)
bb̄nj
SM bkg (b)
SM bkg (no b)
N_j



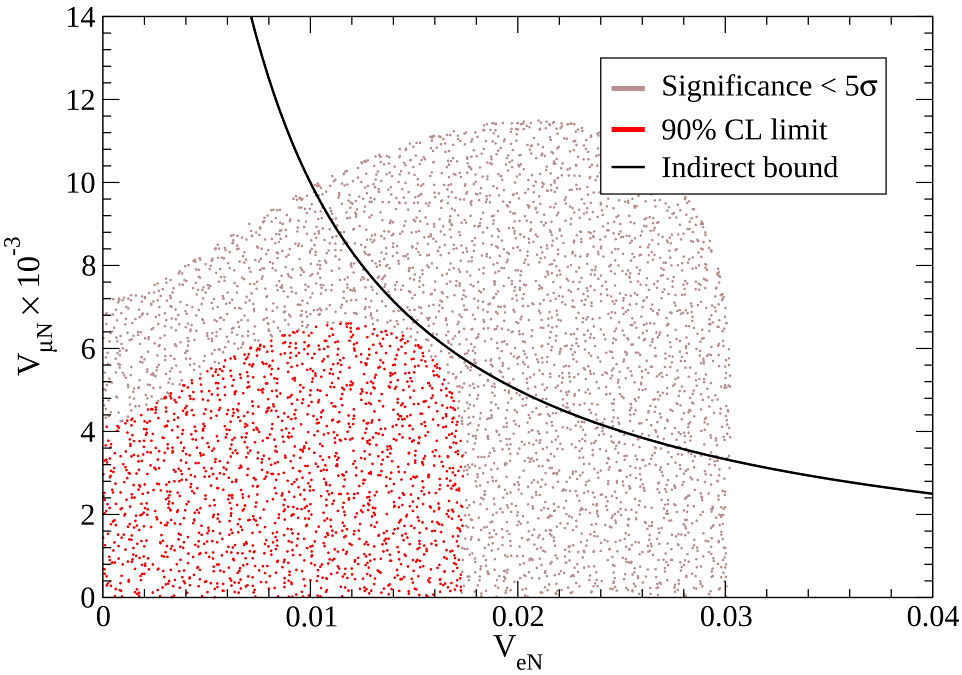
0.08
0.06
0.04
0.02
0
Fraction of events
-10
-5
0
5
10
$\log_{10} L_S / L_B$
N (150)
$b\bar{b}nj$
SM bkg (b)
SM bkg (no b)

Heavy Majorana neutrino

$m_N > M_W$

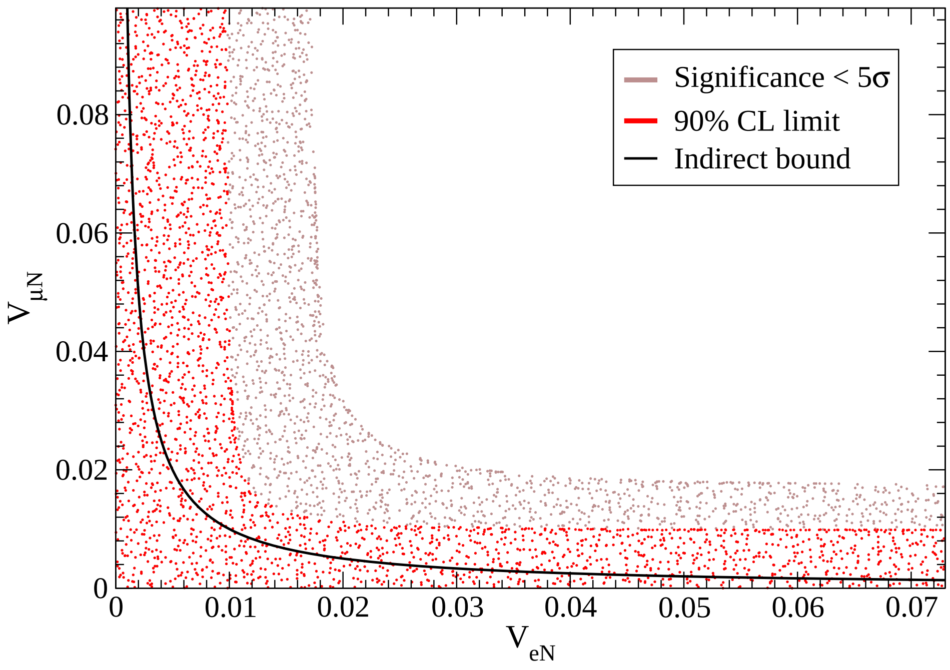


$m_N < M_W$

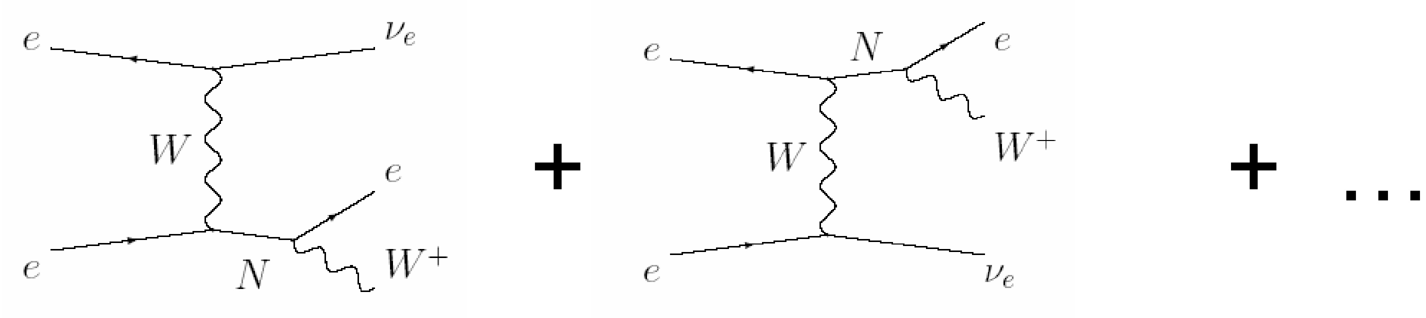


Heavy Dirac neutrino

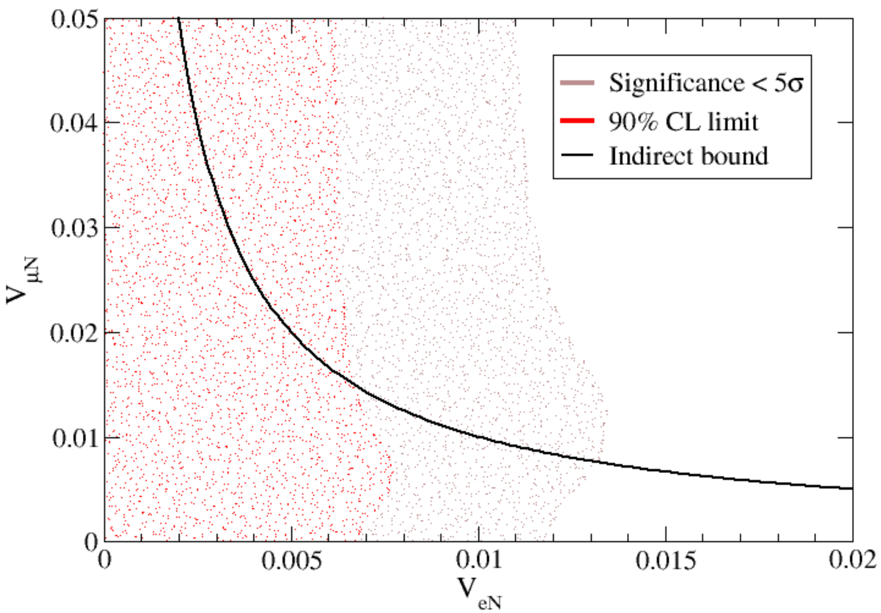
$m_N < M_W$

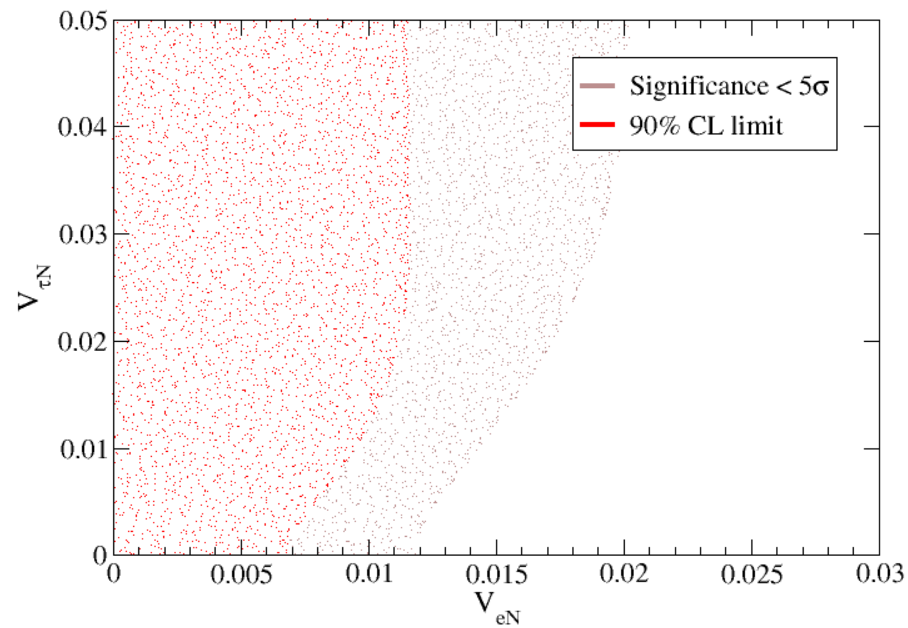


ILC



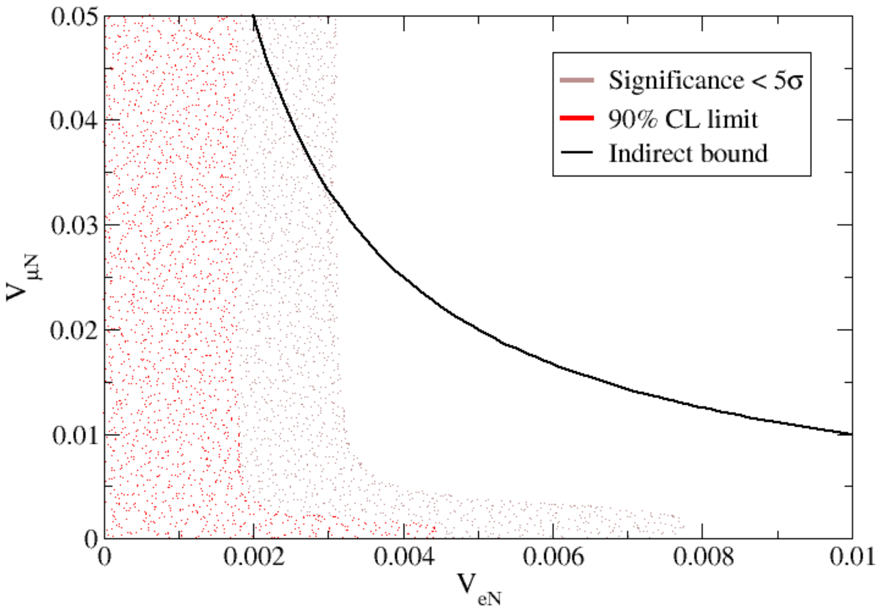
This processes will allow to detect a N with m_N = 0.2-0.4 TeV and $V_{eN} > 0.01$ increasing present bounds up to $V_{eN} < 0.007$

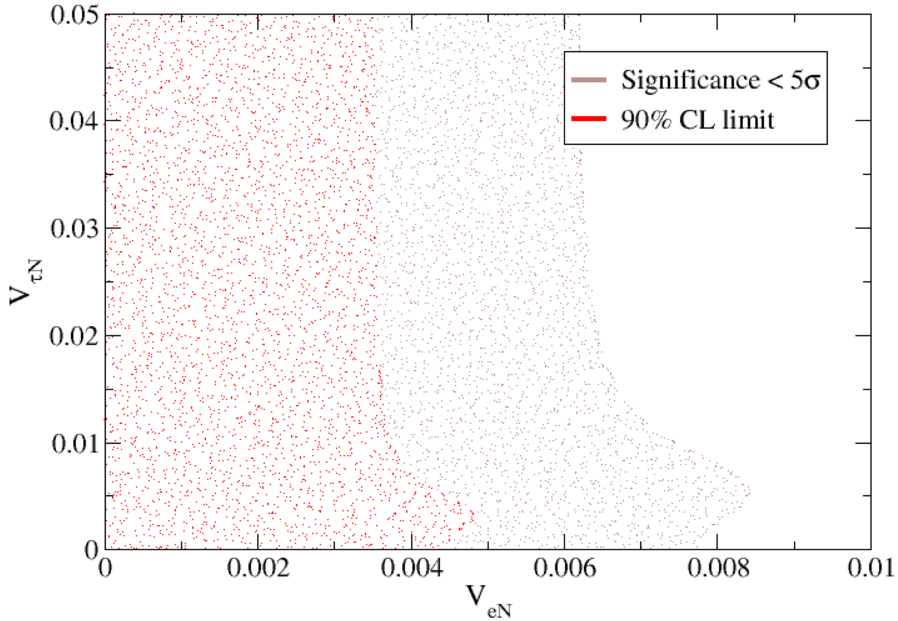


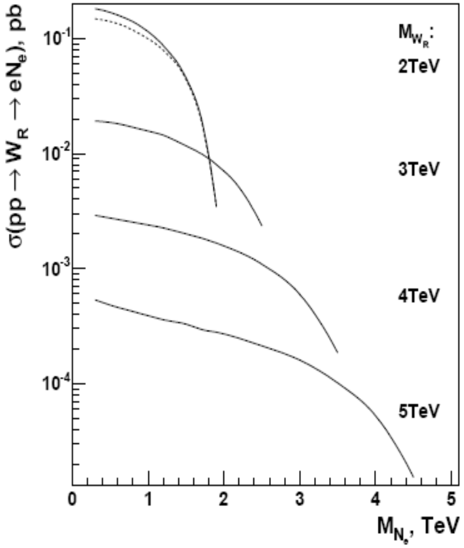


CLIC

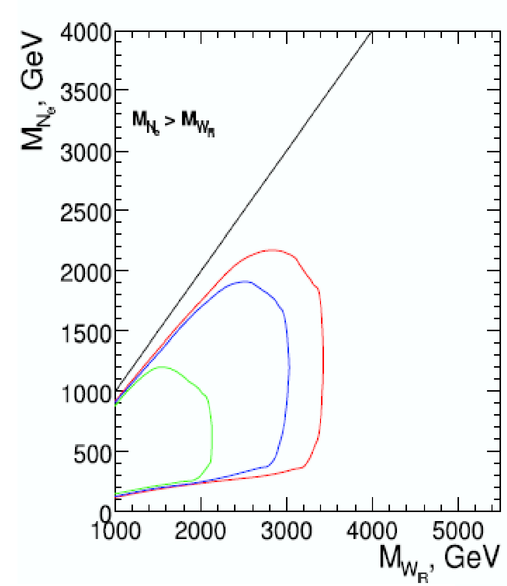
This processes will allow to detect a N with m_N = 1-2 TeV and V_{eN} > 0.004-0.01 increasing present bounds up to V_{eN} < 0.002-0.006



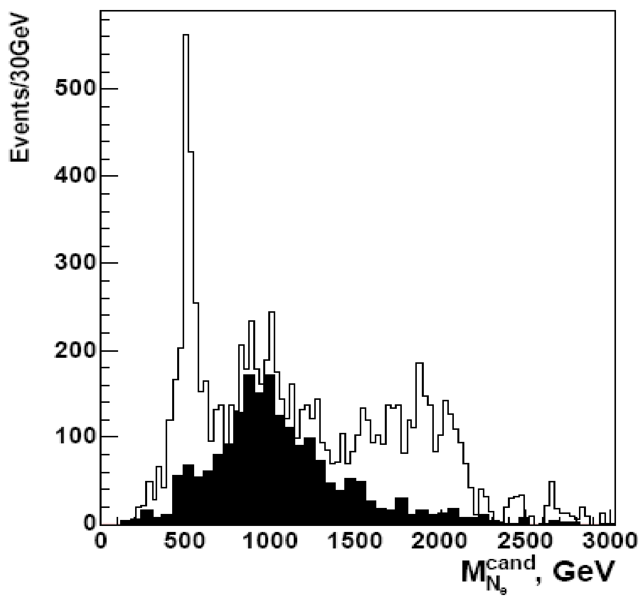


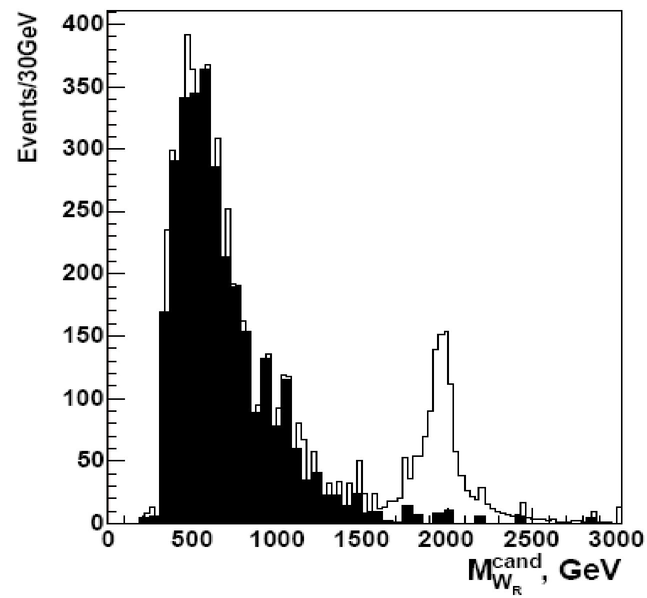


$pp \longrightarrow W_R \longrightarrow eN \longrightarrow eejj$



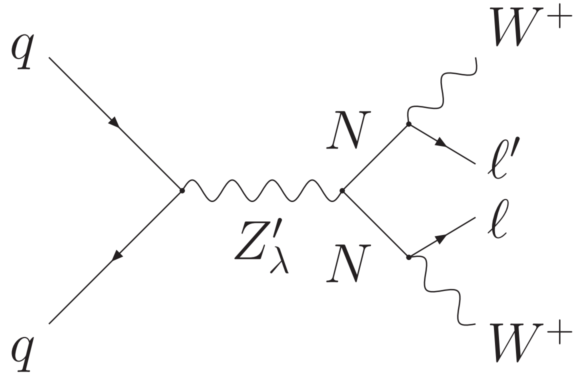
Observable for M_{W_R} and M_N up to 3.5 TeV and 2.3 TeV for $L = 30\ fb^{-1}$

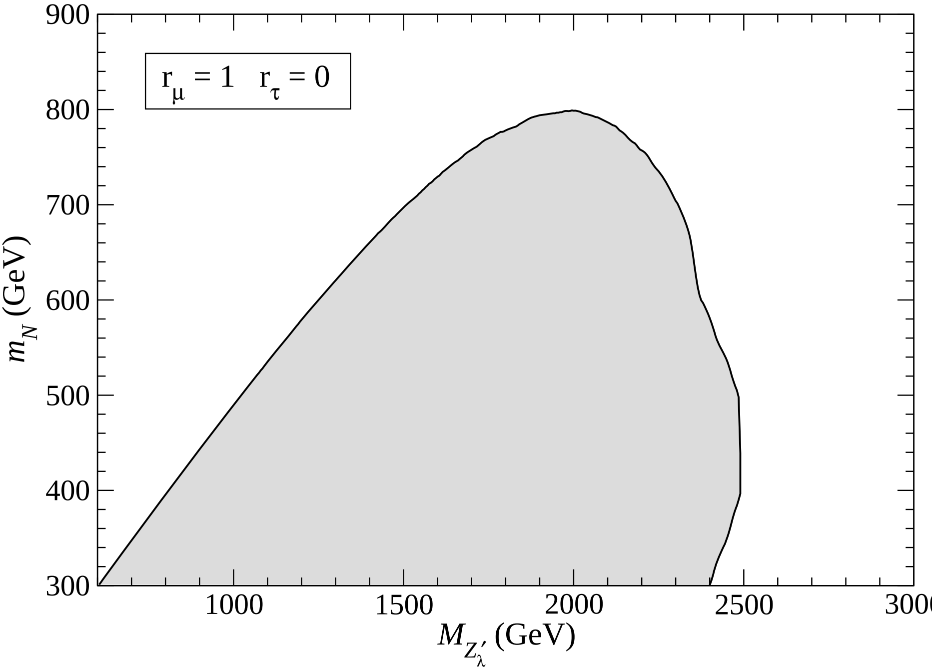


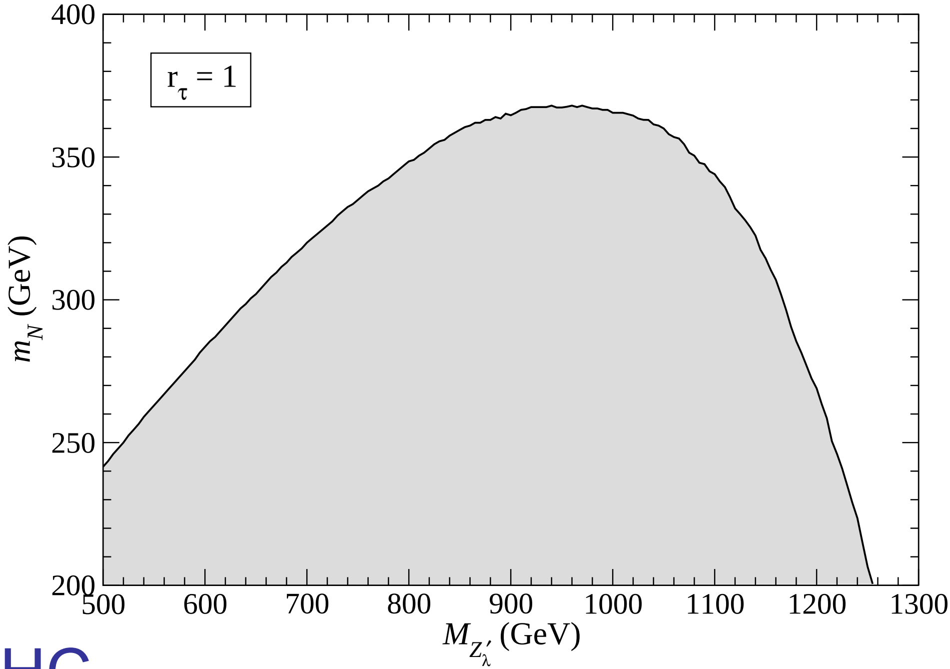


S.N. Gninenko, M.M. Kirsanov, N.V. Krasnikov and V.A.Matveev

Other dilepton processes



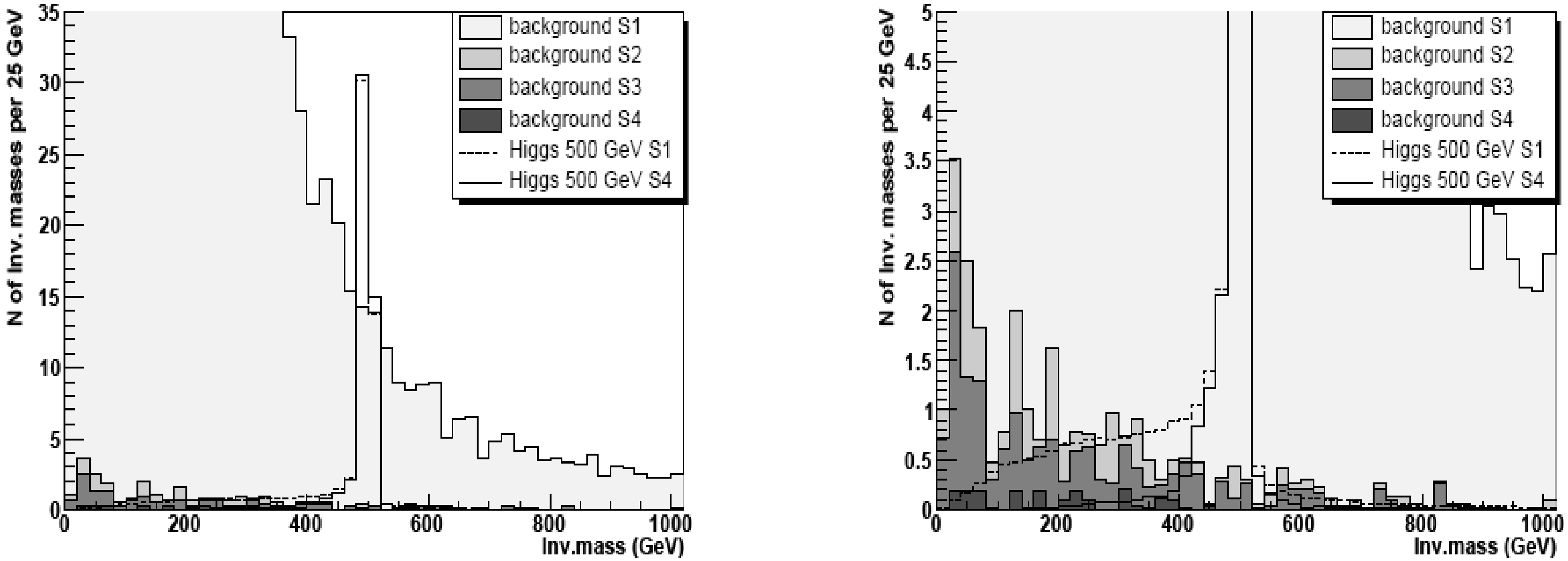




LHC

Scalar triplets

$p\, p \to \phi^{++} \phi^{--}$



A.Hektor, M. Kadastic, M. Muntel, M. Raidal and L. Rebane

Scalar masses up to 800 GeV can be discovered at LHC for a $\mathrm{L} = 30\ \mathrm{fb}^{-1}$

Fermion triplets

B. Bajc, M. Nemevsek and G. Senjanovic

F. del Aguila, Ll. Ametller, G.L. Kane and J. Vidal

		Tevatron ($M_L = 100$ GeV) $\lvert\eta\rvert < 4$ $p_t > 10$ GeV No $M_{\ell\bar{\ell},\ell\nu}$ cut	UNK ($M_L = 200$ GeV) $\lvert\eta\rvert < 4$ $p_t > 10$ GeV $M_{\ell\bar{\ell},\ell\nu} > 100$ GeV	LHC ($M_L = 500$ GeV) $\lvert\eta\rvert < 4$ $p_t > 50$ GeV $M_{\ell\bar{\ell},\ell\nu} > 200$ GeV	SSC ($M_L = 500$ GeV) $\lvert\eta\rvert < 4$ $p_t > 50$ GeV $M_{\ell\bar{\ell},\ell\nu} > 200$ GeV
$\ell\bar{\ell}$ jjjj	E	0.01	0.5	1	5
	$\begin{pmatrix} N \\ E \end{pmatrix}$	0.9	18	54	239
$\ell\nu$ jjjj	E	0.02	0.9	2	9
	$\begin{pmatrix} N \\ E \end{pmatrix}$	—	—	—	—
$\ell\bar{\ell}\ell\nu$ jj	E	7×10^{-4}	0.03	0.08	0.3
	$\begin{pmatrix} N \\ E \end{pmatrix}$	0.4	5	17	72

Conclusions

$m_N > M_W$

$|V_{lN}|^2 <$ 0.0054, 0.0096, 0.016

$|V_{lN} V_{l'N}| <$ 0.0054 0.0001 0.01,
0.0096 0.01
0.016

$m_N < M_W$

$|V_{lN}|^2 \sim 10^{-4}$ L3

Heavy Majorana neutrino coupled to muons: V_{eN} a factor 2 better at LHC, but new EWPD analysis reduces V_{eN} by a similar factor. Moreover, a complicated cancellation is needed not to disturb light neutrino masses.

Heavy Dirac neutrino can not improve indirect limits but they do not contribute to light Majorana masses.

In both cases $|V_{eN}| < 0.007$ for m_N around 300 GeV at ILC, and a factor ~ 3 better for a several TeV heavy neutrino at CLIC.

In the presence of extra interactions these limits increase up to several TeV (no mixing suppression and resonance enhancement) for both heavy fermions and gauge bosons.

Heavy scalar triplets can be observed at LHC for masses up to 800 GeV.

Fermion triplets have similar discovery limits.

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