Production of long lived particles with charged leptons

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February 23, 2018

1 Description of the Simplified Model

In this simplified model we introduce three heavy neutrinos N_1, N_2, N_3 (N_1 lightest) and a right handed charged gauge boson W_R. The Lagrangian contain following new interactions:

$$\begin{aligned}\Delta\mathcal{L} &= \frac{g}{\sqrt{2}}W_L^\mu\left(\frac{M_{W_L}^2}{M_{W_R}^2}(\sin 2\beta)k_q\ \bar{u}_{iR}V_{ij}^{CKMR}\gamma^\mu d_{jR}+\frac{M_{W_L}^2}{M_{W_R}^2}(\sin 2\beta)k_l\ \bar{N}_{iR}(Y_{lN})_{ij}\gamma^\mu l_{jR}\right.\\ &\left.+\sqrt{\epsilon-\frac{M_\nu}{M_{N_1}}}k_l\ \bar{N}_{iR}^c(Y_{lN})_{ij}\gamma^\mu l_{jL}\right)\\ &+\frac{g}{\sqrt{2}}W_R^\mu\left(k_{Rq}\ \bar{u}_{iR}V_{ij}^{CKMR}\gamma^\mu d_{jR}+k_{Rl}\ \bar{N}_{iR}(Y_{lN})_{ij}\gamma^\mu l_{jR}\right)\end{aligned} \tag{1}$$

where g is the weak coupling constant, the ratio $M_{W_L}^2/M_{W_R}^2$ represents the scale of the mixing between W_L and W_R, $\tan\beta = v_2/v_1$ is the ratio of the vacuum expectation value (vev) of two neutral scalar in the bi-doublet. $\epsilon = v_L/v_R$ is the ratio of the vev of left handed triplet and right handed triplet, the ratio M_ν/M_{N1} represents scale of the mixing between the left and right handed neutrino. The dimensionless parameters k_q, k_l, k_{Rq}, k_{Rl} are set to 1 by default, the 3 matrix V^{CKMR} and Y_{lN} are set to be identity by default, M_ν represents the scale of the mass of light neutrinos and set to be 0.1 eV by default.

2 Production and Decay Processes

We provide the following production and decay processes with corresponding `proc_card` and `madspin_card`:

production of N_1	$pp \to \ell^\pm N_1$	`proc_card_N1l.dat`
decay of N_1	$N_1 \to \ell^\pm jj$	`madspin_card_ljj.dat`
	$N_1 \to \ell^\pm\ell^\mp\nu$	`madspin_card_3l_MET.dat`
production of N_1	$pp \to e^+ N_1$	`proc_card_Nep.dat`
decay of N_1	$N_1 \to e^+\mu^-\nu$	`madspin_card_epmu.dat`
	$N_1 \to e^+e^-\nu$	`madspin_card_epe.dat`
	$N_1 \to e^-\mu^+\nu$	`madspin_card_emup.dat`

3 Description of the Parameters

Parameter	Default Value	Description
`mN1`, `mN2`, `mN3`	$40, 10^{12}, 10^{14}$GeV	The mass of heavy neutrinos, only the lightest one is active
`MWR`, `WWR`	15000, 100 GeV	The mass and width of the right handed W boson
`kq`, `kl`	1.0, 1.0	scaling factor of the W_L couplings for quark and lepton
`kRq`, `kRl`	1.0, 1.0	scaling factor of the W_R couplings for quark and lepton
`Mnu`	0.1 eV	The mass scale of light neutrino
`tanb`	0.1	ratio of v_2 and v_1
`epsi`	0.0	ratio of v_L and v_R
`VCKMR`	Idendity	Right handed quark CKM matrix
`YlN`	Idendity	Right handed lepton mixing matrix

We also provide a plot to illustrate the length of the displaced vertex produced by the lightest heavy neutrino N_1 in the M_{W_R} vs M_{N_1} plane, all the other parameters are set to their default values.

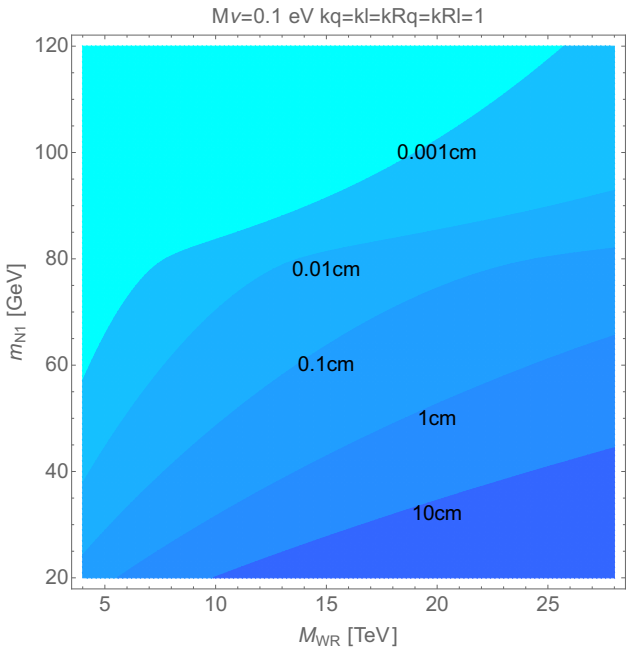

Figure 1: The contour of the length of the displaced vertex.

4 User Guide

One should first copy the model file `ChargeWN_UFO` to the `models` folder in the Madgraph. Then one can use `./bin/mg5_aMC proc_card_N1l.dat` to produce the process folder `LLP_N1l`. Go into the process folder `LLP_N1l` and copy the madspin card into the `Cards` folder and

rename as `madspin_card.dat` for different process. One can use the `proc_card_Nep.dat` in the similar way to specify the flavor of the leptons in the decay chains.

For the simplest use, one only need to change the mass of right handed W_R boson, `MWR` and the mass of the lightest heavy neutrino N_1, "`mN1`" to obtain different travel length of the long-lived particle. Every time the user changes the parameters in the `param_card.dat`, one should set the width "`WN1`" of the longlived particle to `Auto` such that Madgraph will calculate the Width of N_1 automatically.

We also provide a python script "mgrun" to help to do the parameter scan. people needs to first generate a table of parameters by themselves in the following format:

mN1	WN1	MWR	...
100	Auto	6000	...
200	Auto	6000	...
...	...	...	...

where the first line are the names of the parameters you want to scan, and the following lines are the value of the parameters. To scan this table one only need to copy the script "mgrun" and the "table" to the process folder like `LLP_N1l` you generated, and run the following line in the terminal:

mgrun ./ ./table.txt

The first argument is the path of your process folder, if one use this script on a cluster one can replace "./" to the global path of your process folder.