

# Prospects of vector like leptons at LHC

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Work done with Stephen P. Martin

# Presentation Outline

Motivations

Production and Decays

Events and Selections

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- Vector-like leptons have only a very small effect on Higgs observables and precision electroweak constraints, unlike new heavy chiral leptons.
- Vector like leptons occur in extensions of SM. (Falkowski, Straub, Vicente , 1312.5329; Dermisek, Hall, Lunghi, Shin, 1408.3123; Holdem and Ratzlaff, 1405.4573; Carpenter, Rajaraman, Whiteson, 1010.1011.)

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- Limit exists for vector like quarks, No limits set by LHC on vector like leptons. LEP limit for vector like leptons  $M_{\tau'} \gtrsim 100 \text{ GeV}$

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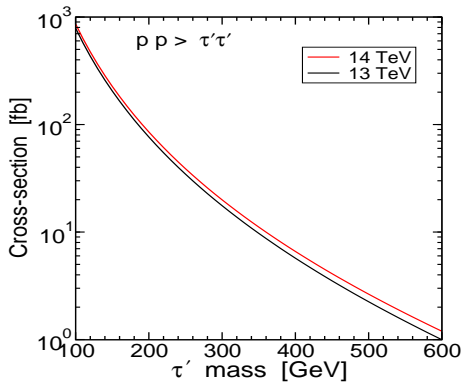
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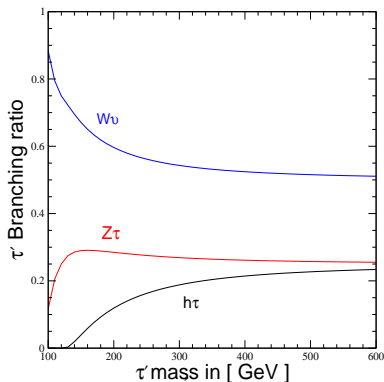
# Production Cross section



From 13 TeV to 14 TeV the production cross section increases by a factor of 1.1

## Two scenarios considered

- Optimistic case:  $\text{BR}(\tau' \rightarrow Z\tau) = 100\%$
- Minimal Model:  $W_{mix} = -\epsilon H_d L_3 \bar{\tau}'$



Arxiv:1206.2956, S.P. Martin, J.D Wells



# Decays of $\tau'$

$\tau'$  can decay into :  $W\nu_\tau \rightarrow$  Large Background

$h\tau \rightarrow$  may be good candidate !

$Z\tau \rightarrow$  Smaller background in leptonic channels

We consider purely leptonic signatures:

$$pp \rightarrow Z, \gamma \rightarrow \tau'^+ \tau'^- \rightarrow 2\ell + 2\tau_h$$

$$3\ell + \tau_h$$

$$4\ell$$

“4 lepton”

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$$4\ell + \tau_h$$

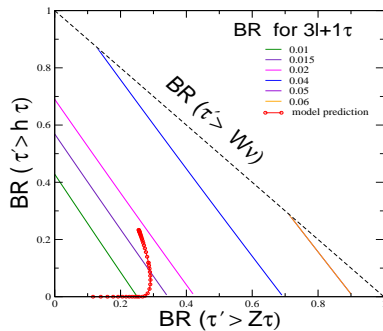
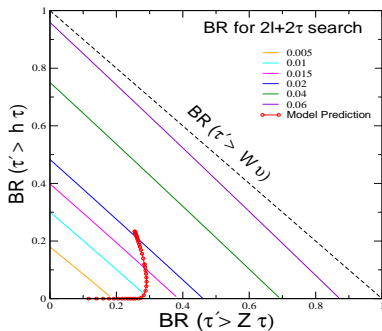
$$5\ell$$

“5 lepton”

where  $\ell = e, \mu$

# Estimation of Branching Ratios

If particles are forced to decay leptonically, the variations in Branching ratios are shown



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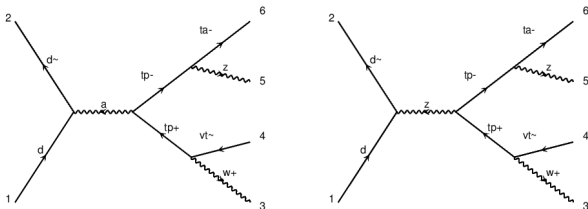
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# Model implementation

We have 9 final states. One such is

$$pp \rightarrow \tau'^+ \tau'^- \rightarrow W \nu_\tau Z \tau$$



SM extension in FeynRules, new particle added ( $\tau' \equiv t_p$ ) with

$$\gamma \tau'^+ \tau'^- , Z \tau'^+ \tau'^- , Z \tau'^{\pm} \tau'^{\mp} , h \tau'^{\pm} \tau'^{\mp} , W^{\pm} \tau'^{\mp} \nu_\tau$$

couplings in the Lagrangian.

(couplings are taken from Arxiv:1206.2956, S.P. Martin, J.D Wells)

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charm = 0.1 and  $u, d, s = 0.001$ .
- Tau tagging efficiency = 0.4

# Event Selection

- $26 \text{ GeV} < p_{T_{\ell_1}}$
- $15 \text{ GeV} < p_{T_{\ell}}, \ell = \text{any other lepton including tau}$
- $\eta_{\ell_1} < 2.5$
- $\eta_{\ell} < 2.4, \ell = \text{any other lepton including tau}$
- $\Delta R_{\ell\ell} > 0.1$
- $\Delta R_{\ell j} > 0.3$
- $\Delta R_{ij} > 0.1, \text{ for } i, j = \text{leptons, tau}$
- b-jet veto

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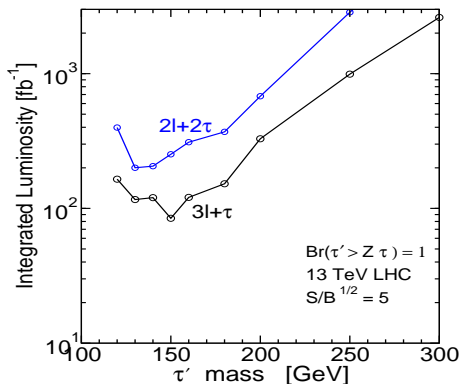
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Signal and Backgrounds: Example  $3\ell + 1\tau$ 

Backgrounds	$\sigma_{\text{pass}}$ (fb)	
	Initial cuts	b veto
$pp \rightarrow WZ$	0.0403	0.0403
$pp \rightarrow ZZ$	0.3815	0.3795
$pp \rightarrow t\bar{t}Z$	0.0644	0.0158
$pp \rightarrow t\bar{t}W$	0.0139	0.0058
$pp \rightarrow hh$	0.0016	0.0016
$pp \rightarrow hZ$	0.0956	0.0956
$pp \rightarrow t\bar{t}h$	0.0023	0.0006
$pp \rightarrow WWZ$	0.0108	0.0107
$pp \rightarrow ZZZ$	0.0007	0.0007
$pp \rightarrow WZZ$	0.0029	0.0029
Total Background	0.6139	0.5535
Signal for 150 GeV	0.0856	0.0819

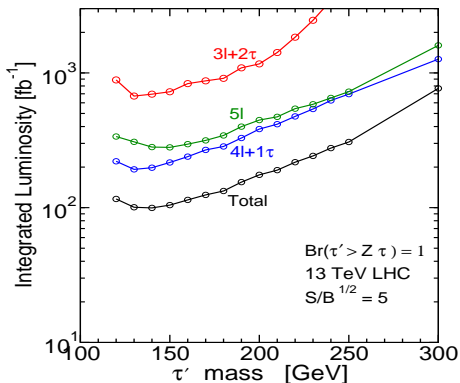
# Integrated Luminosity needed for $5\sigma$ excess

4 lepton signals ,  $\text{BR}(\tau' \rightarrow Z\tau) = 1$



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5 lepton signal ,  $\text{BR}(\tau' \rightarrow Z\tau) = 1$

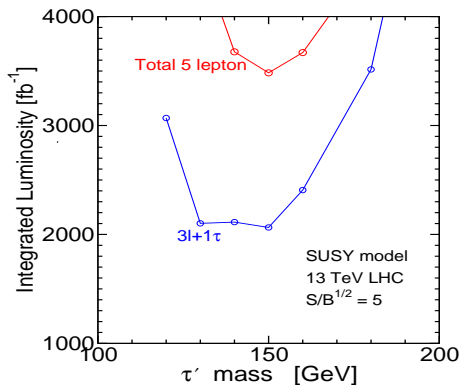


Total 5 lepton = Sum of  $3l + 2\tau$ ,  $4l + \tau$ ,  $5l$  channels



# Minimal model prediction

With Branching Ratios from minimal model, prospects are much more challenging.



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- Signals requiring b jets where  $h \rightarrow b\bar{b}$  are worth looking at
- Isodoublet vector like leptons are also interesting as the production cross section is larger and  $\text{BR}(\tau' \rightarrow Z\tau)$  is closer to the optimistic case.