Distinguishing LNV scalars at the LHC

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F. Águila, A. Santamaría and J. Wudka

based on

1305.3904, 1307.0510, 1309.xxxx

Scalars 2013, Warsaw

Outline

- About neutrino masses and LNV
- LHC searches of LNV scalars
- Unraveling the physics behind LNV

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- Neutrino masses, one of the few evidences of new physics

$$\nu_R^i \; ?$$

- Likely related to the scalar sector?

$$\mathcal{L}_{SM} = \cdots + \mathcal{L}_S + \sum y_{ij} \bar{q}_L^i \Phi q_R^j + \cdots$$

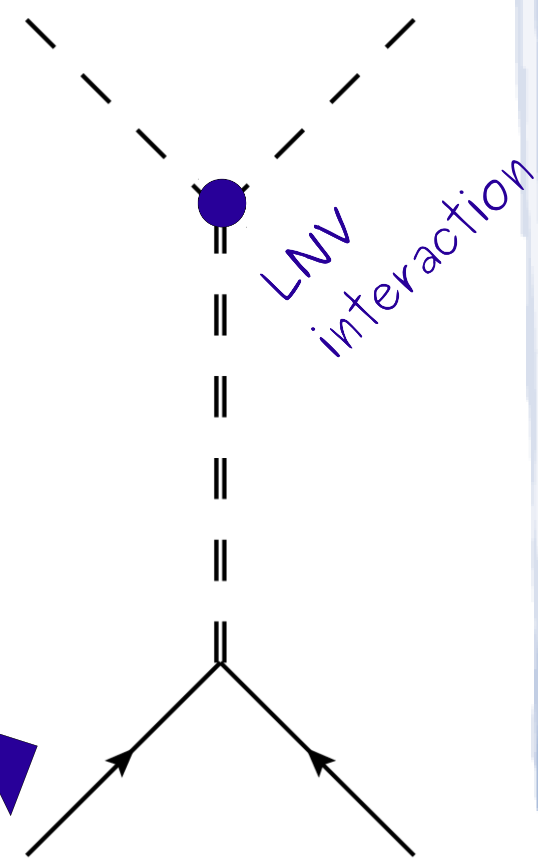
↳ Hierarchy, fermion masses, stability...

$$\mathcal{L}^{(5)}_{m_\nu} = -\frac{x_{ij}}{\Lambda}\mathcal{O}^{(5)} + \text{h.c.}$$

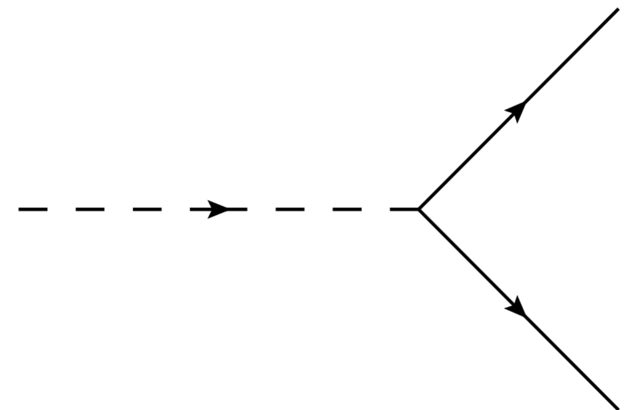
$$\mathcal{O}^{(5)} = \left(\overline{L^c_L}\tilde{\phi}^*\right)\left(\tilde{\phi}^\dagger L_L\right)$$

LHC!

- Either small couplings or large scale (no LHC)
- See-saw mechanisms with fermions and scalars



- Same-sign dilepton resonances are often present
- But not necessarily from a triplet...



Potentially tree-level generated operators

Dimension 4	Triplet Δ	$(\overline{\tilde{L}_L}\tau^a L_L)\Delta^{-a}$
	Singlet κ	$\overline{l_R^c} l_R \kappa$
Dimension 5	Quadruplet Σ	$(-1)^{\frac{1}{2}-b} C_{a,b}^{1\times\frac{1}{2}\to\frac{3}{2}} (\overline{\tilde{L}_L}\tau^a L_L)\phi^b \Sigma^{-a-b}$
	Doublet χ	$(-1)^{1-a}(\overline{\tilde{L}_L}\tau^a L_L)(\phi^\dagger \tau^{-a}\chi)$, $\overline{l_R^c} l_R(\tilde{\phi}^\dagger \chi)$
Dimension 6	Quintuplet Ω	$C_{a,b}^{1\times 1\to 2}(\overline{\tilde{L}_L}\tau^a L_L)(\tilde{\phi}^\dagger \tau^b \phi)\Omega^{-a-b}$

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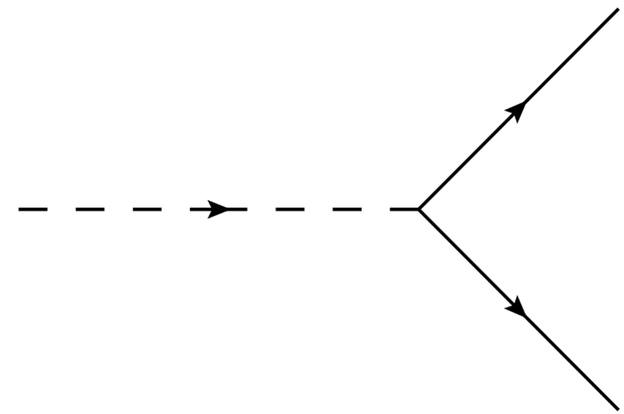

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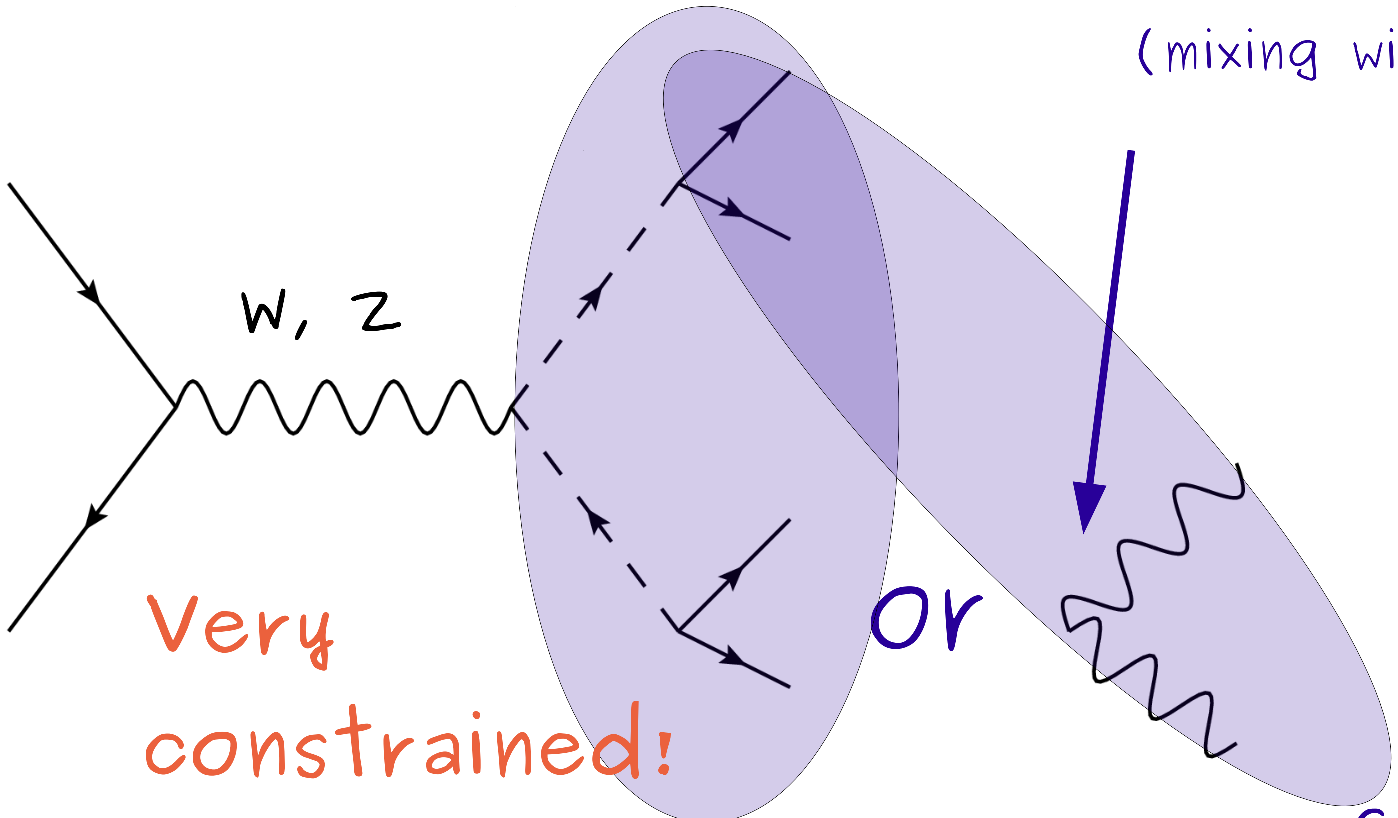
Two different structures!

Main (in general)

production mechanism



Produced from (mixing with) LNV VEV

Very constrained!

or

LNV process!

Small in general.

Large in non-minimal extensions [Babu el all, '09]

What does (can) LHC say about?

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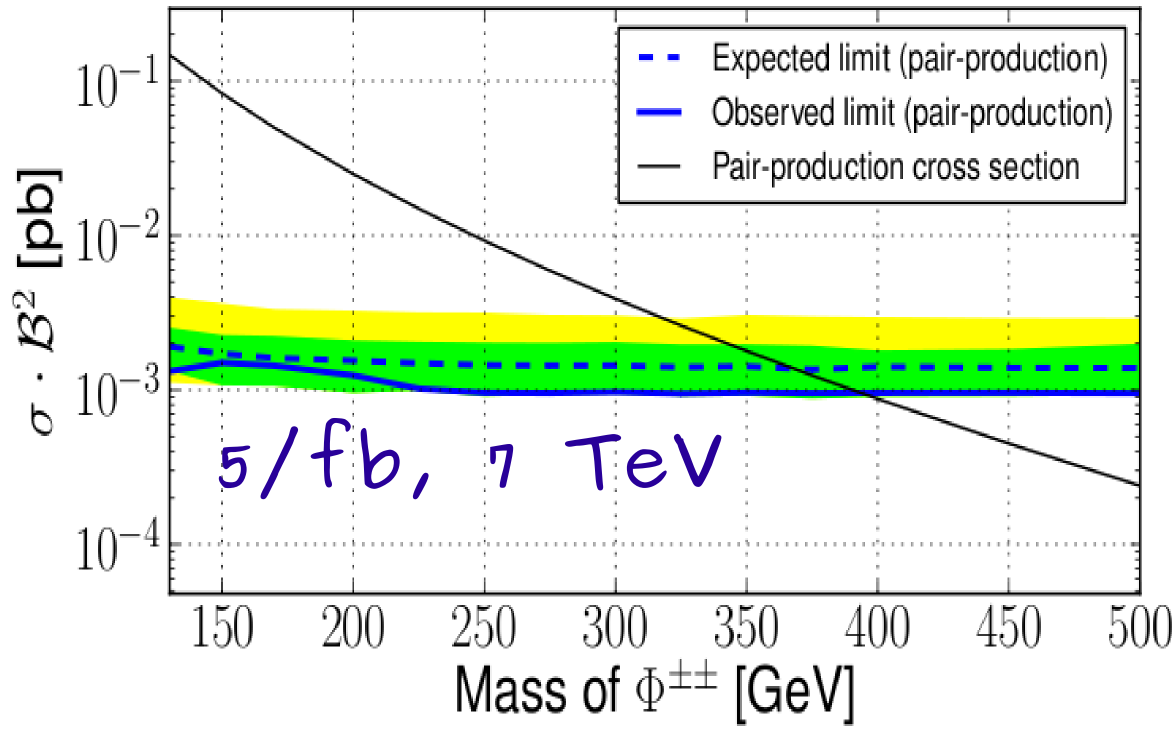
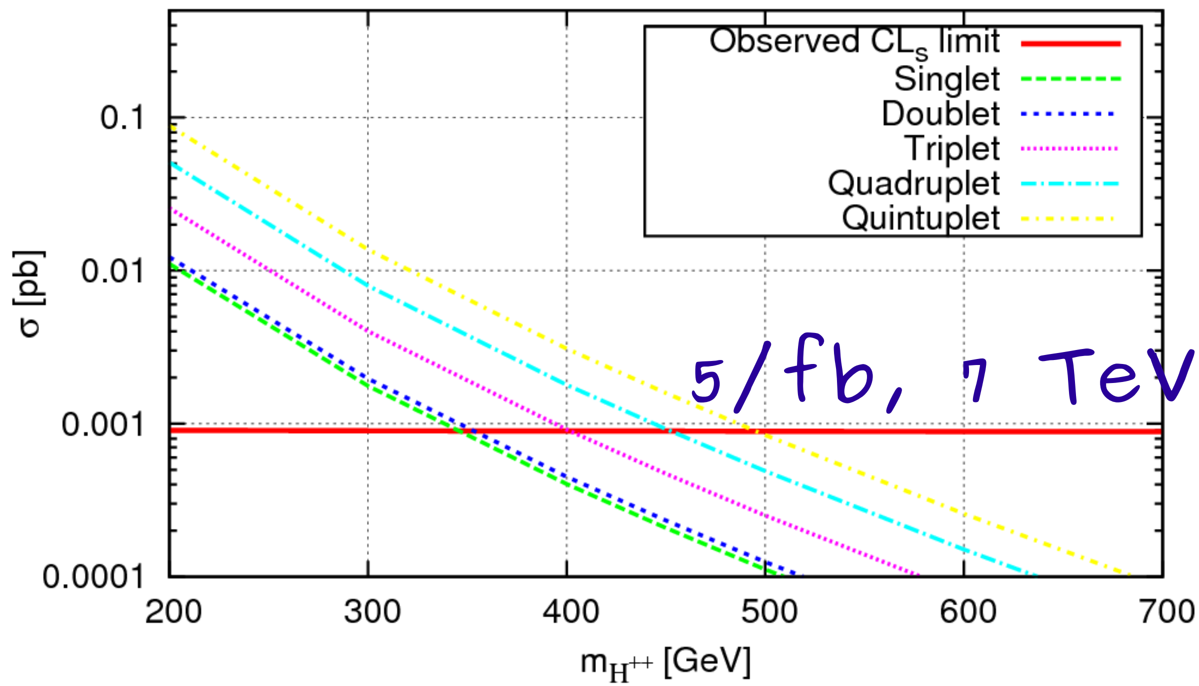
Bounds on four (light) leptons

Already bounds larger than m = 400 GeV

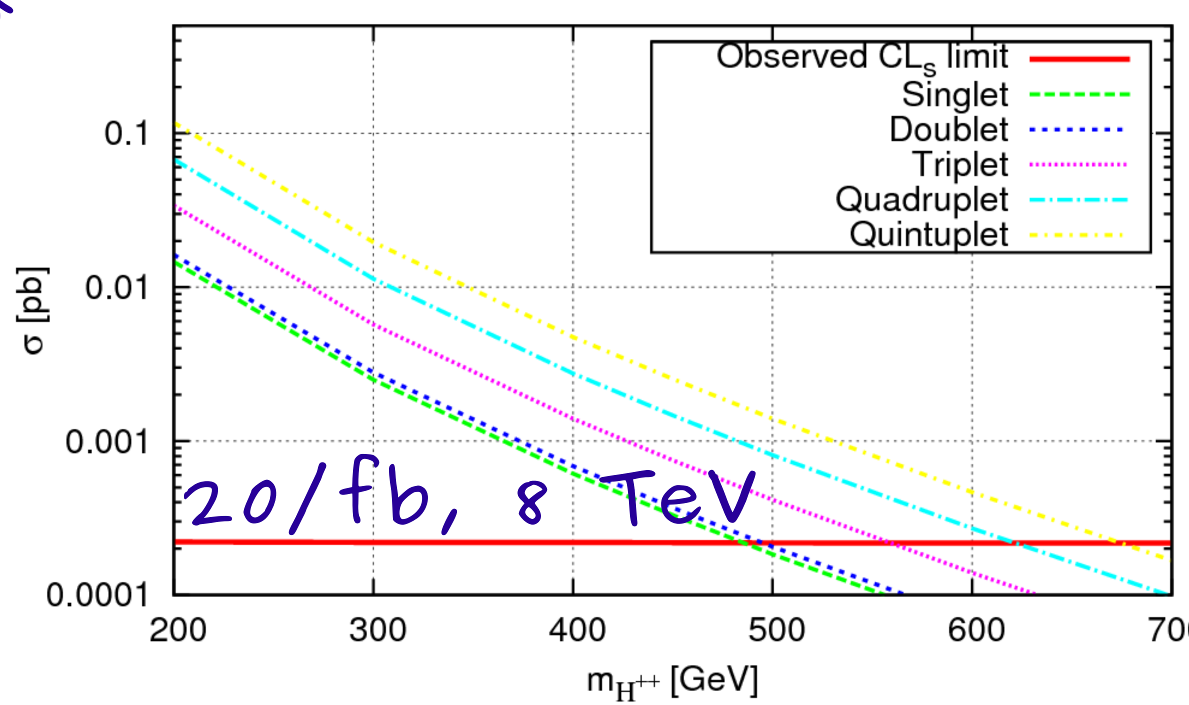


S. Chatrchyan et al. [CMS Collaboration]

Bounds on four (light) leptons

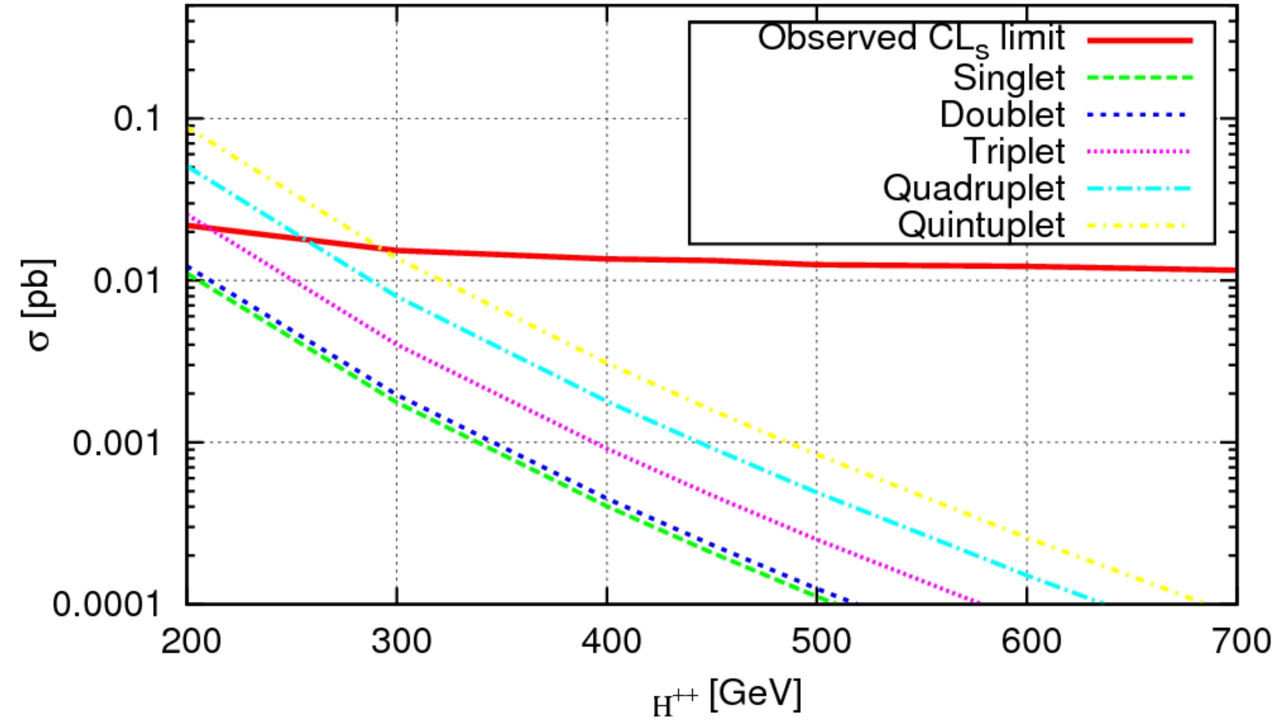


Already bounds larger than m = 400 GeV

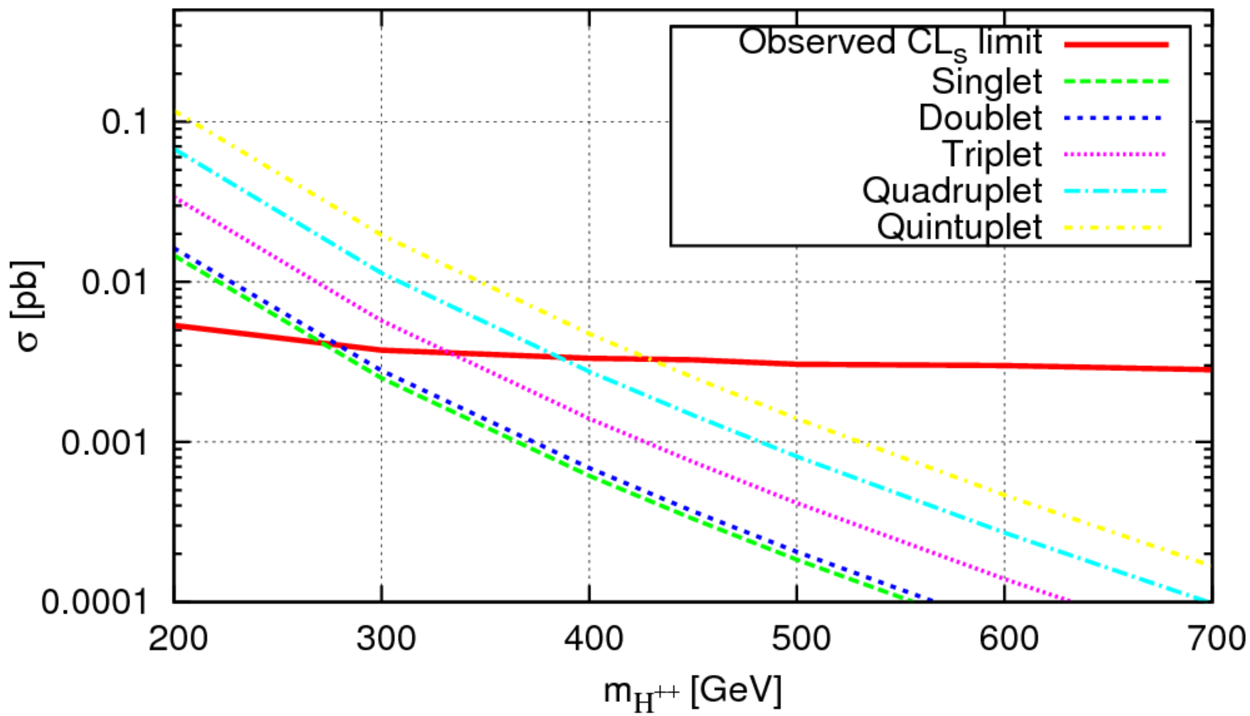


Bounds larger than 600 GeV are expected!

Similarly with taus...



20/fb, 8 TeV



5/fb, 7 TeV

- So far, only a small set of decay channels have been considered
- Bounds on generic models can not been (completely and) easily set
- In general (if not -bizarre- three-body decays): 22 channels
- Construct a matrix of efficiencies

Efficiencies in %

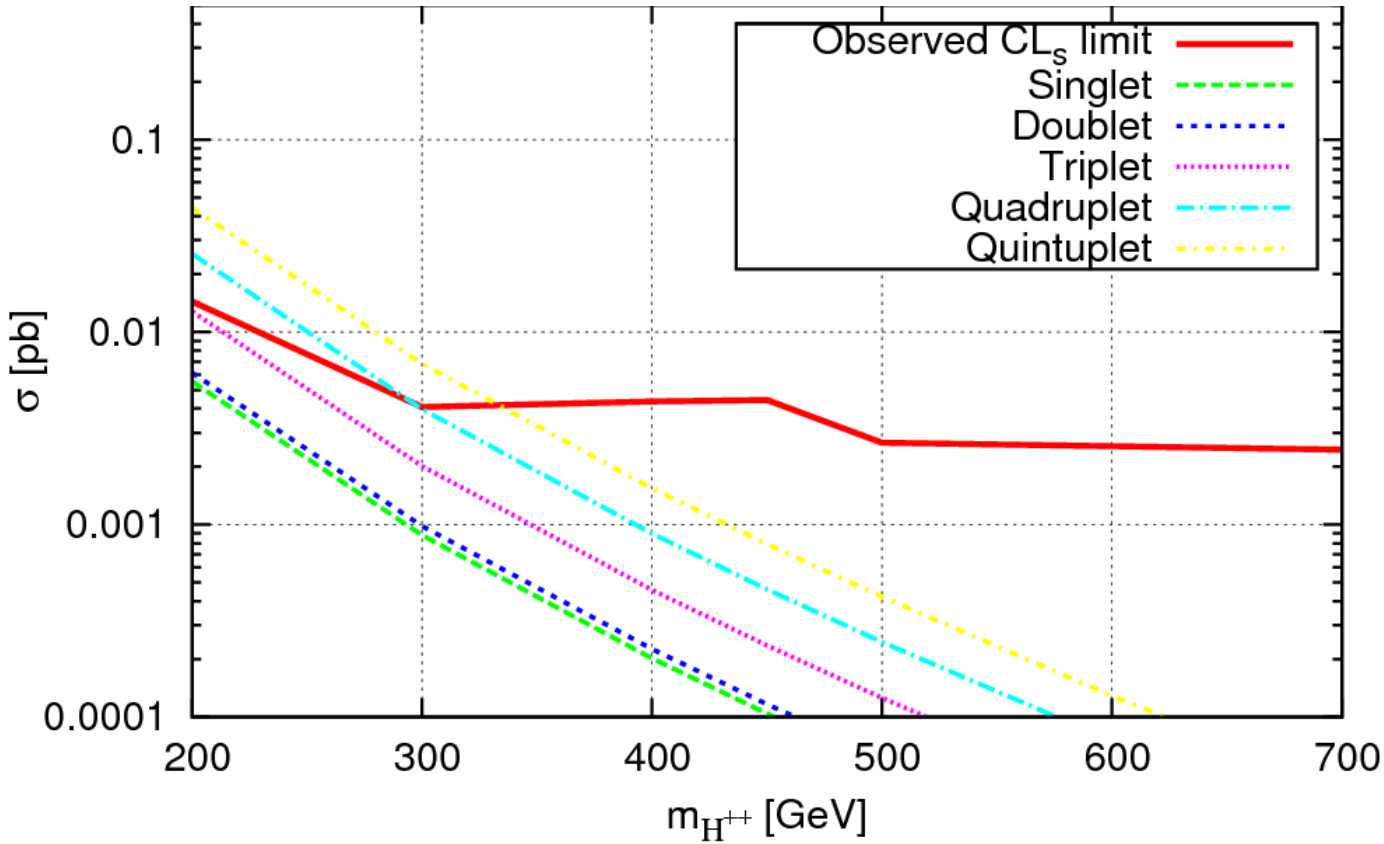
$llll$	53	62	67	68	69	70	71
$ll l\tau$	23	27	30	31	32	32	33
$ll\tau\tau$	7.2	8.7	9.4	9.4	9.5	9.7	9.9
$llWW$	0.6	1.1	1.3	1.3	1.4	1.4	1.5
$l\tau l\tau$	9.0	11	13	14	14	14	14
$l\tau\tau\tau$	2.0	2.6	3.3	3.4	3.4	3.4	3.7
$l\tau WW$	0.2	0.4	0.6	0.6	0.6	0.7	0.7
$\tau\tau\tau\tau$	0.3	0.5	0.6	0.7	0.7	0.7	0.7
$\tau\tau WW$	0.1	0.1	0.2	0.2	0.2	0.2	0.2

Preliminary work! (del Águila, M.C.)

Soon in a forthcoming publication

Obtain the expected number of signal events and constrain!

In particular, LNV signals:



Pair-production
5/fb, 7 TeV
50% ll, 50% WW

WW

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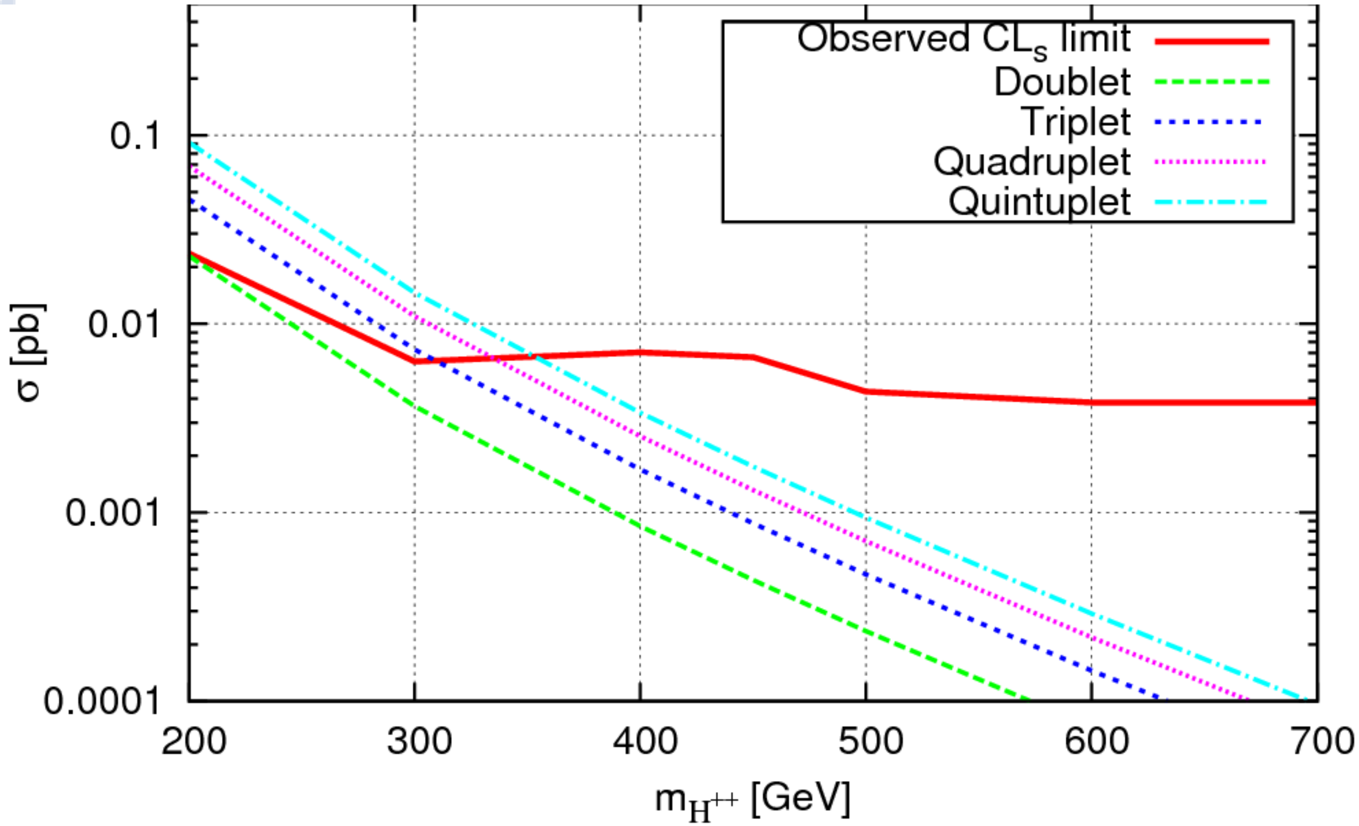

Associated-production
5/fb, 7 TeV
100% ll, 100% WZ

WZ

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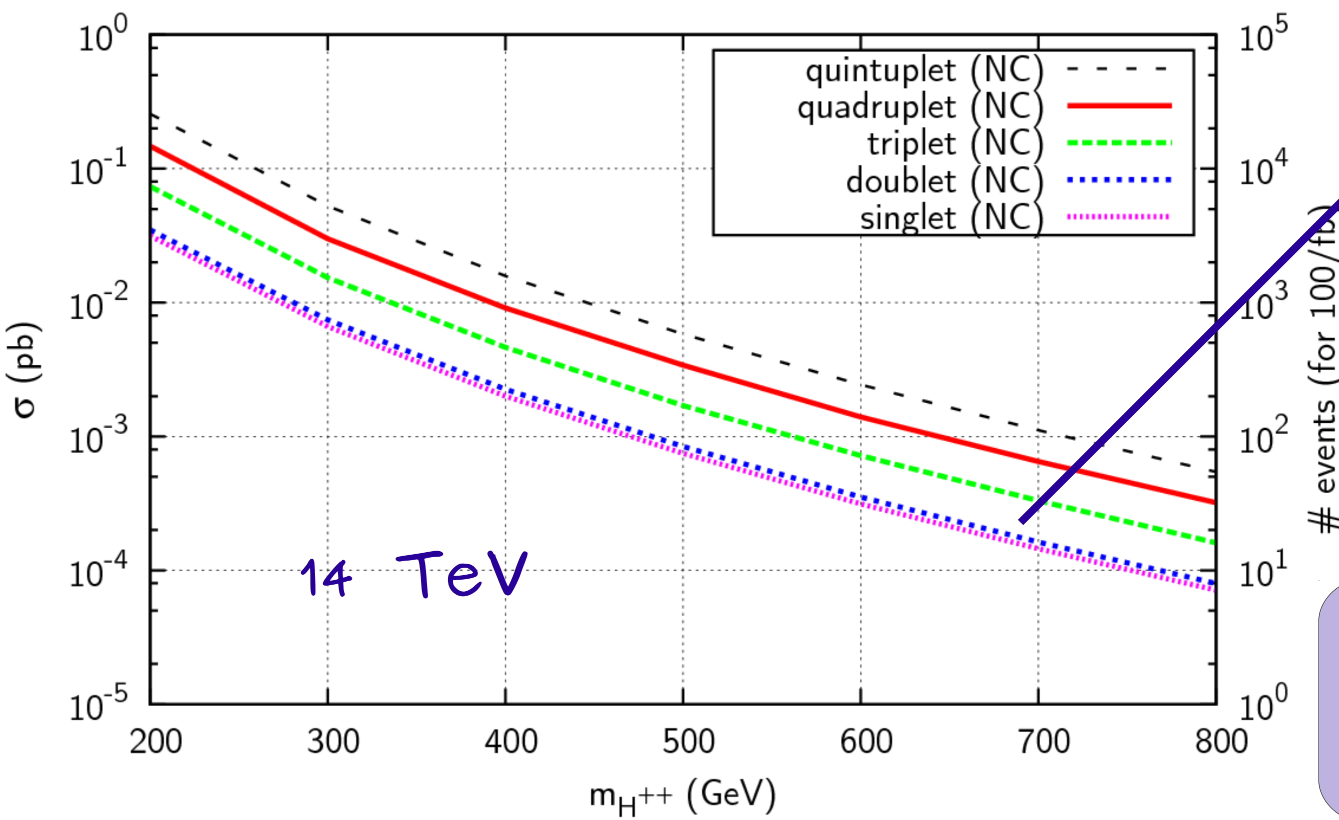
What if an excess is observed?

Measure the (neutral) cross section to distinguish among the multiplets

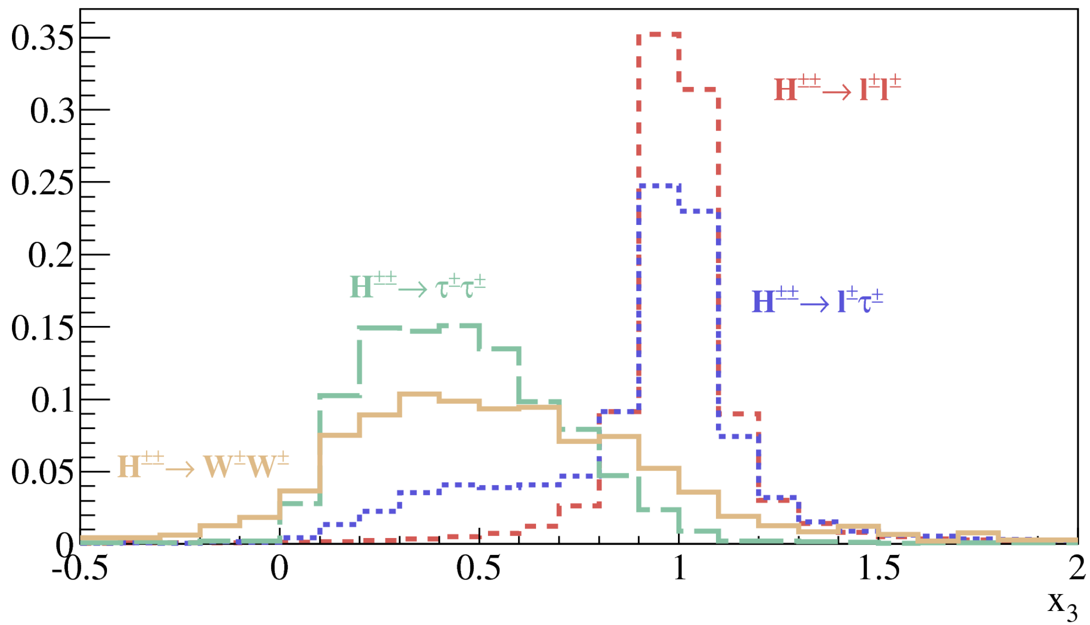


Similar for singlet and doublet!

Look into Charged channel

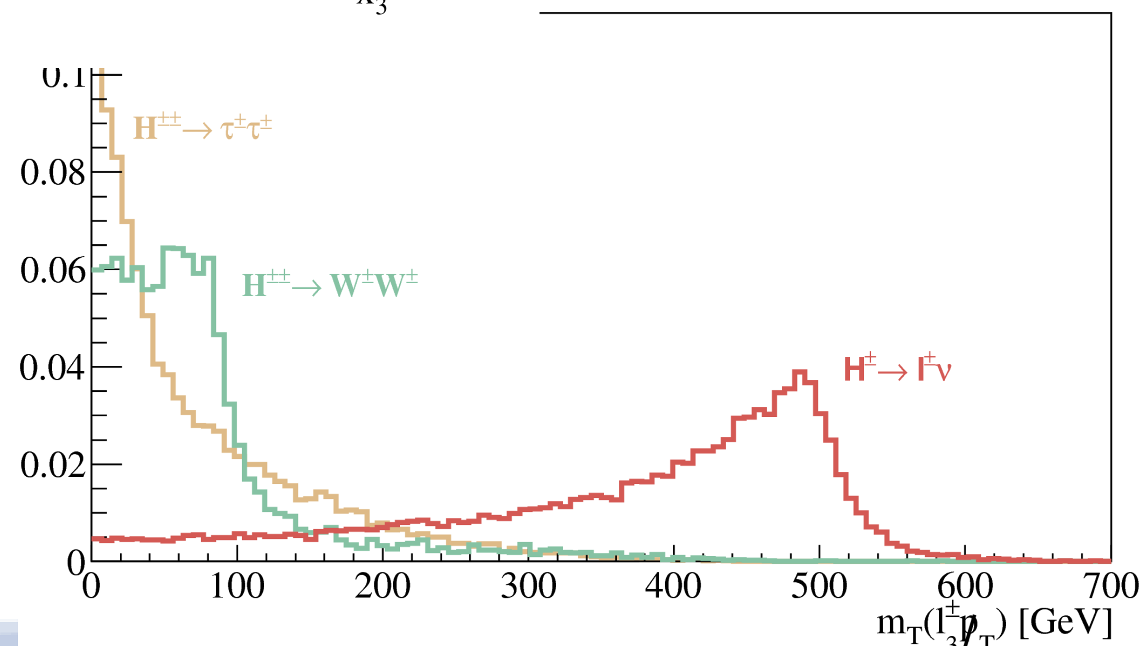
And VBF?

What if an excess is observed?

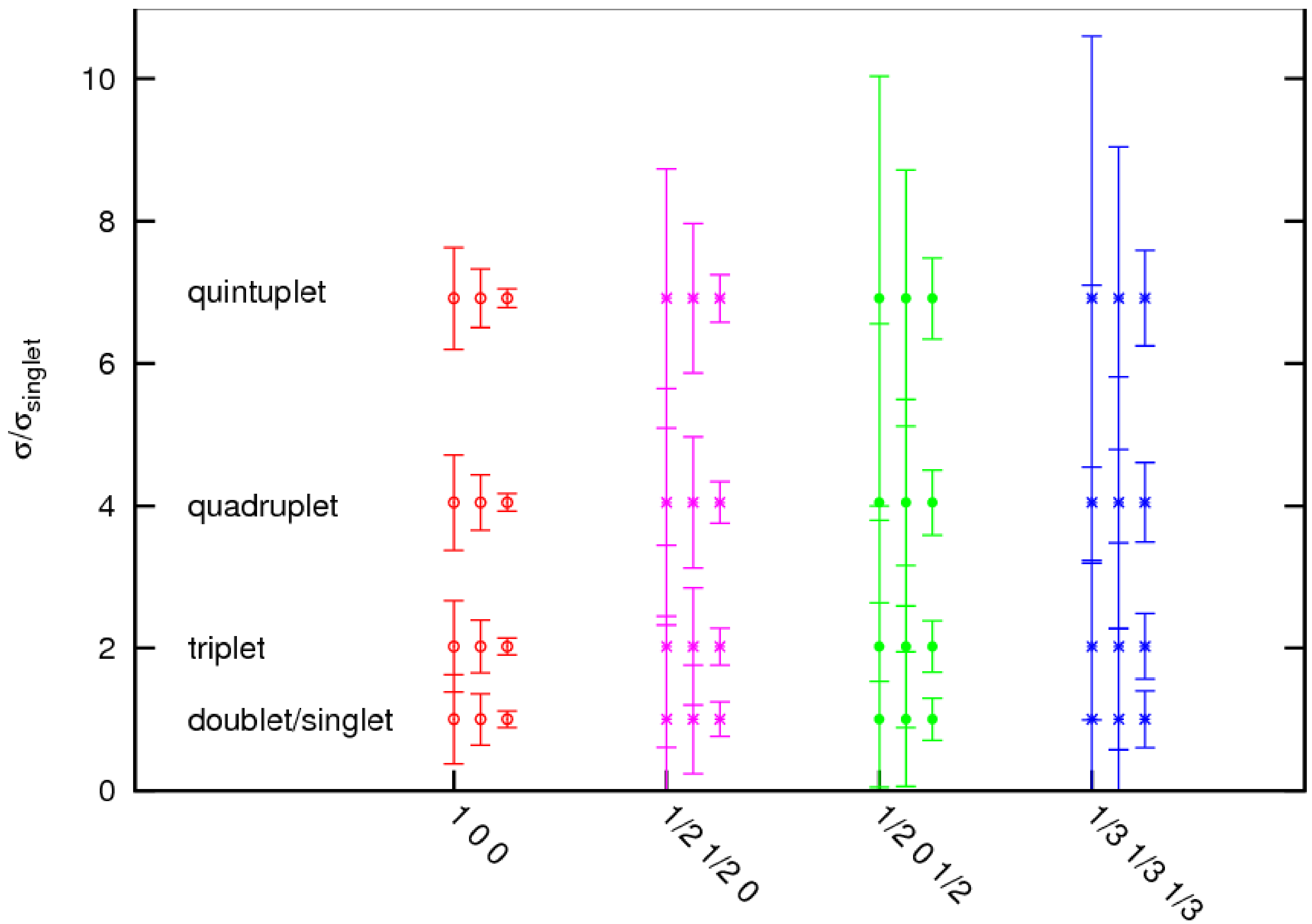


Momentum fraction of the hardest lepton from those that worst reconstruct the scalar mass

Transverse invariant mass: distinguish real charged channel from impostor neutral channels



14 TeV, 300/fb



10
8
6
4
2
0
$\sigma/\sigma_{singlet}$
quintuplet
quadruplet
triplet
doublet/singlet
1 0 0
1/2 1/2 0
1/2 0 1/2
1/3 1/3 1/3

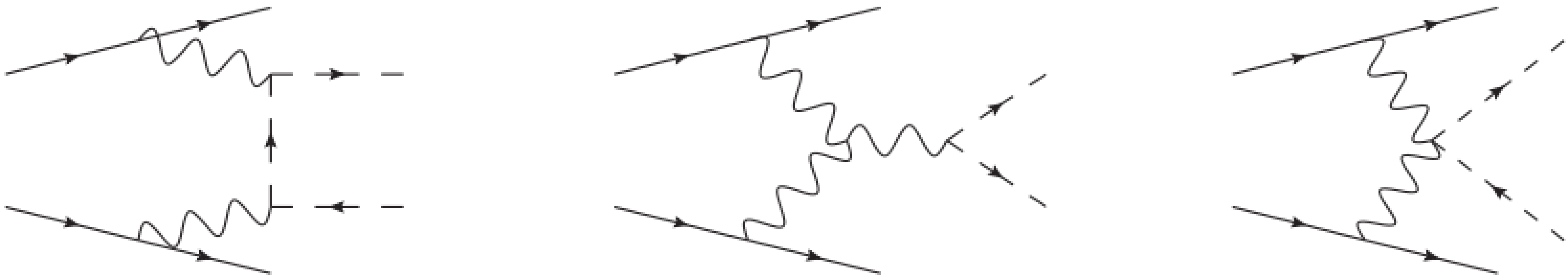
Conclusions

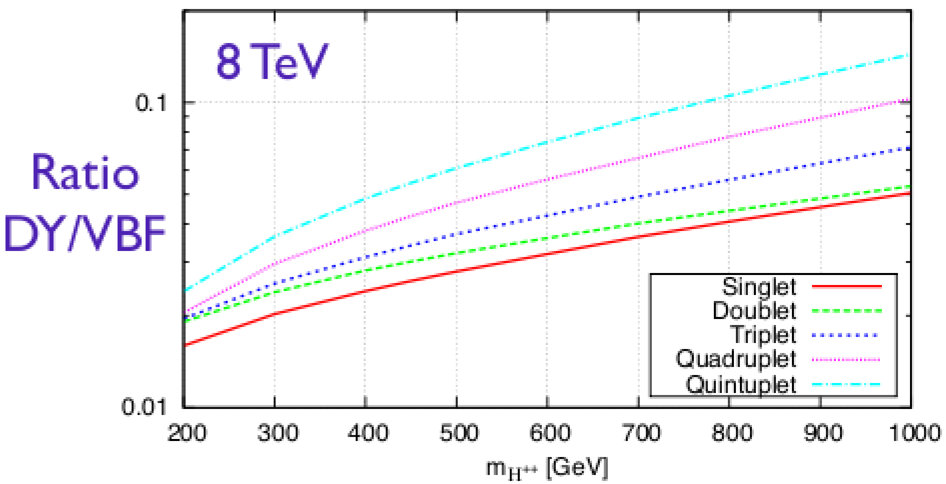
- LN symmetry could be tested at **LHC.**

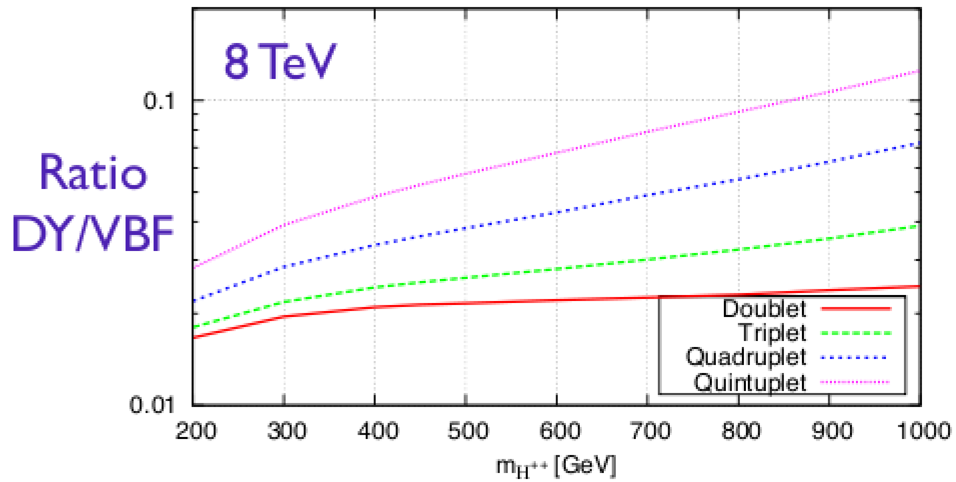
- Extend current searches to more general models and decays: models, software and limits tools will be provided in a forthcoming publication.

- If an excess is observed, its nature could be established by studying 4 and 3 leptons events.

Backup




8 TeV
Ratio
DY/VBF
Singlet
Doublet
Triplet
Quadruplet
Quintuplet
0.1
0.01
200
300
400
500
600
700
800
900
1000
$m_{H^{++}}$ [GeV]


8 TeV
Ratio
DY/VBF
Doublet
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0.1
0.01
200
300
400
500
600
700
800
900
1000
$m_{H^{++}}$ [GeV]

$$\sigma_{lla} \equiv 2\sigma z_{ll} z_a, a \neq ll$$

$$\sigma_{lllp_T^{miss}} = \sigma_{llll} + 2 \sum_{a=l\tau,\tau\tau,WW} \sigma z_{ll} z_a Br(a \to ll + p_T^{miss})$$

How well can we measure the total cross-section ?

$$\sigma = \left(\sigma_{llll} + \frac{1}{2} \sum_{a \neq ll} \sigma_{lla} \right)^2 / \sigma_{llll}$$

$$1 = \sum_{a=ll,l\tau,\tau\tau,WW} z_a, z_a \equiv Br(H \to a)$$