Collider signals of models with radiatively-induced neutrino masses

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in collaboration with **A. Santamaria** and **J. Alcaide**.

Based on hep-ph:1709.XXXXX.

Where is new physics?

(the LHC paradox)

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- The hierarchy problem suggests that there should be new physics at the TeV scale
- All of the (around 2.000) papers published by ATLAS and CMS have seen nothing

I think the question is rather "where are we looking at?"

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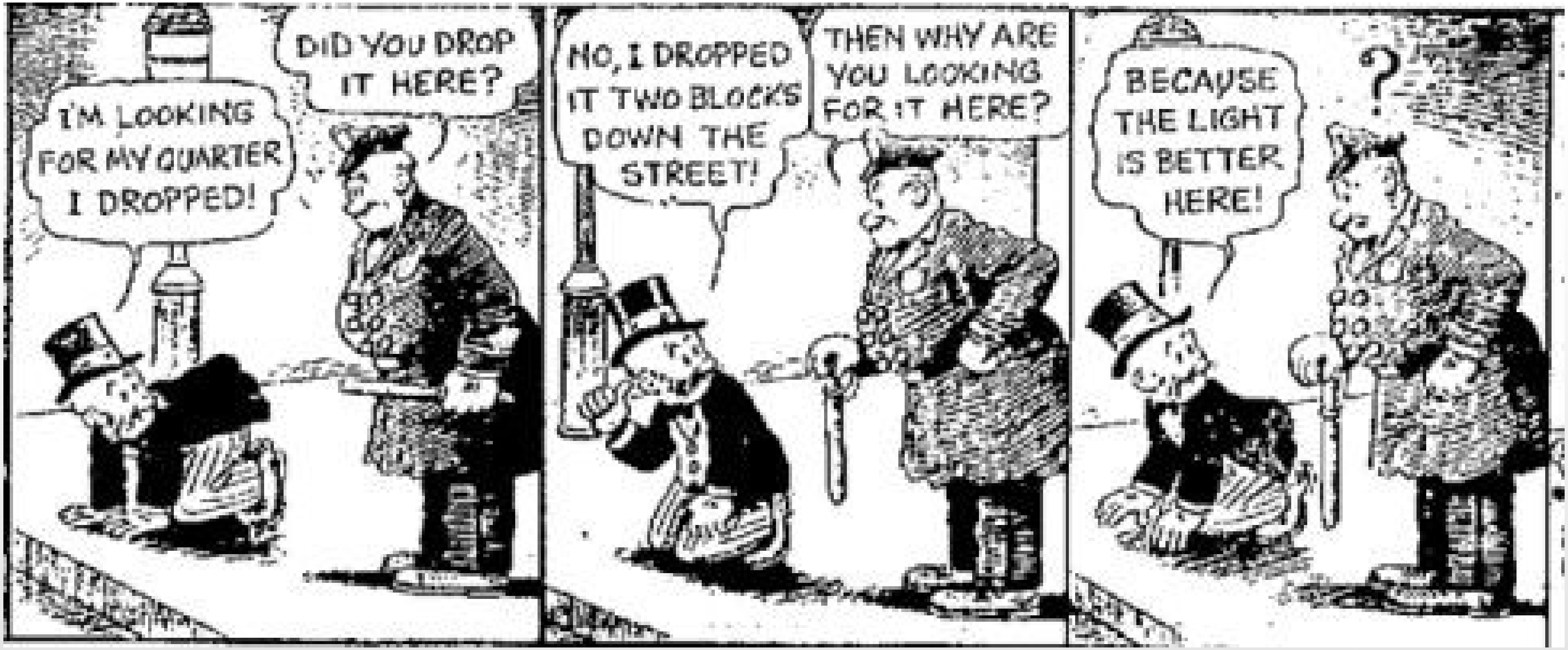

Searches consider oversimplified models

(three examples)

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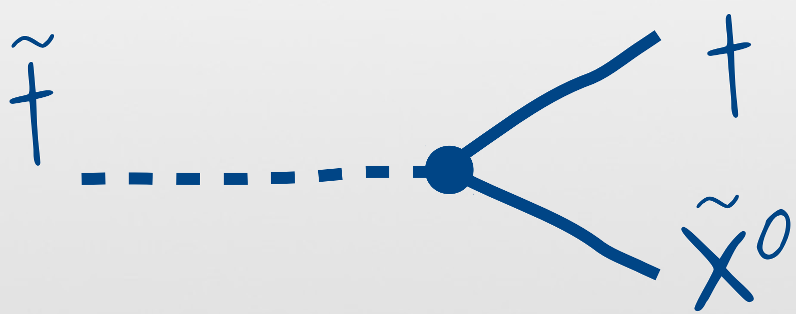
- SUSY searches assume R-parity conservation, lightest neutralino is dark matter



$m_{\tilde{t}} > 1$ TeV

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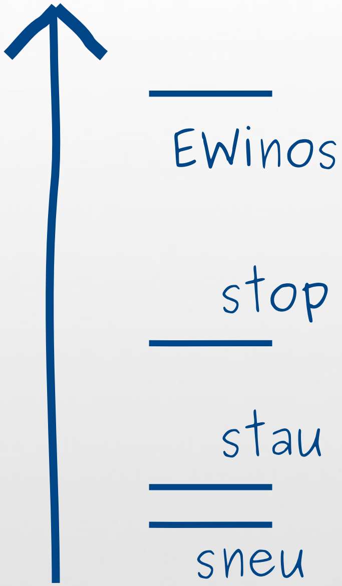

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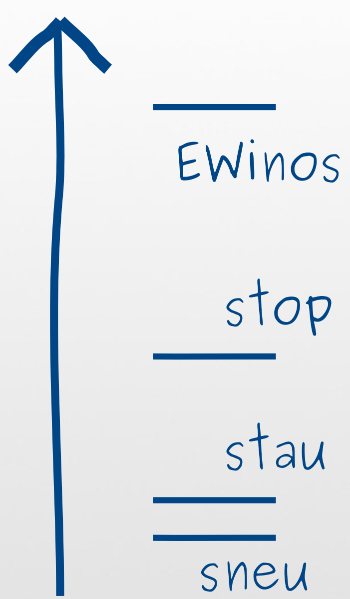

SSSB

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GMSB

$m^2_{1/2} / m^2_0 \sim N$

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(three examples)

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GMSB

$m^2_{1/2} \, / \, m^2_0 \sim N$

$m_{\tilde{t}} > 350$ GeV

[MC, Delgado, Nardini, Quirós, 1702.07359]

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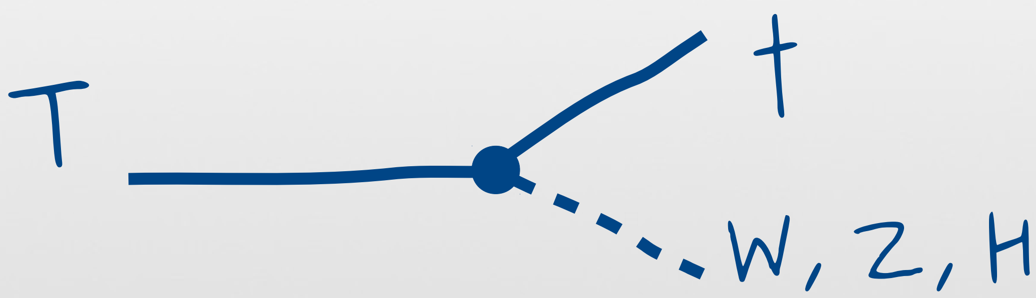
(three examples)

- VLQ searches assume decays into SM particles only



$m_T > 1$ TeV

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(three examples)

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[MC, 1705.03013]

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4d UV completion, DM, BAU, ... and most models are non-minimal!

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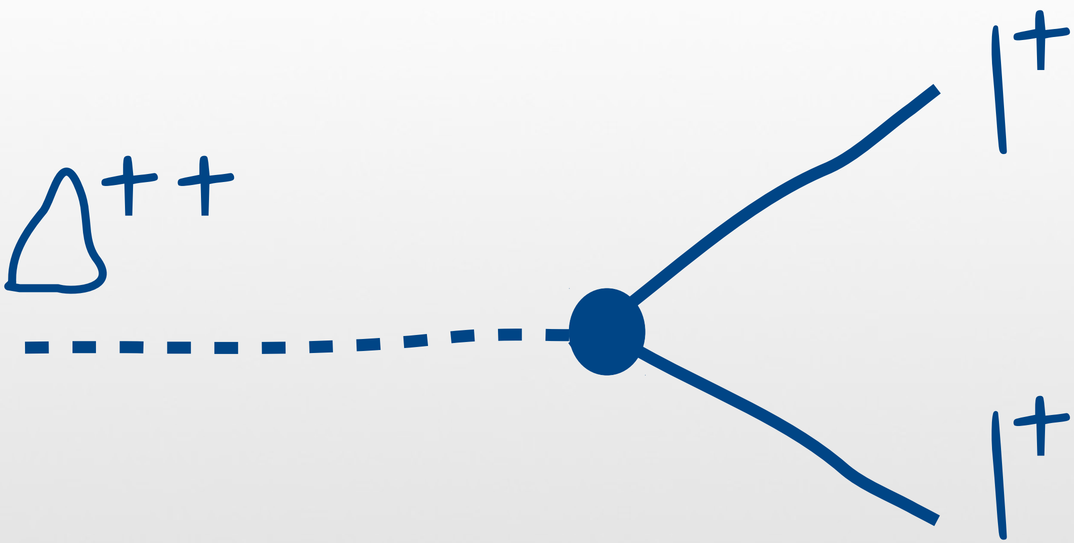
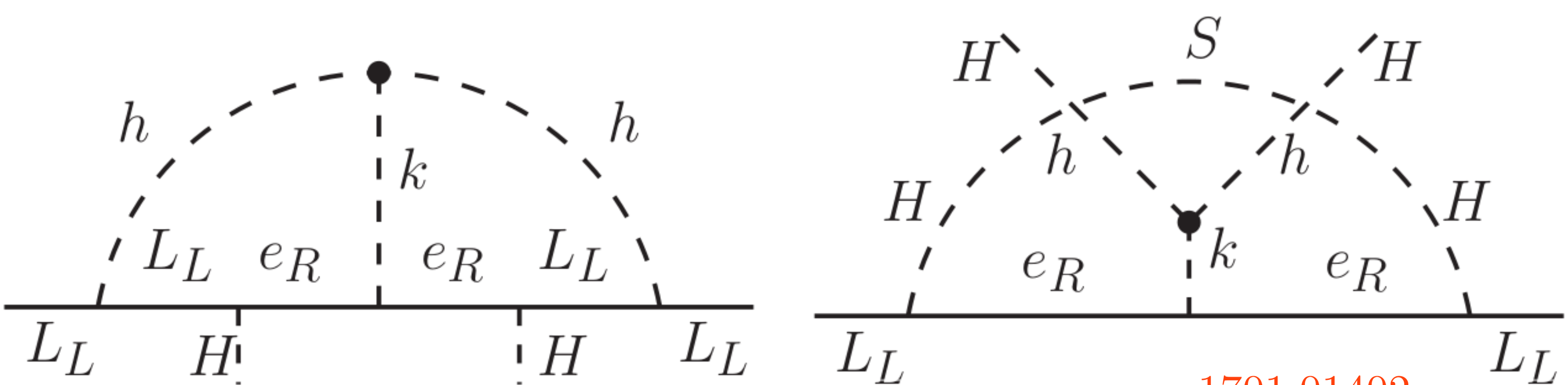


Scalar exotic decays are probably present

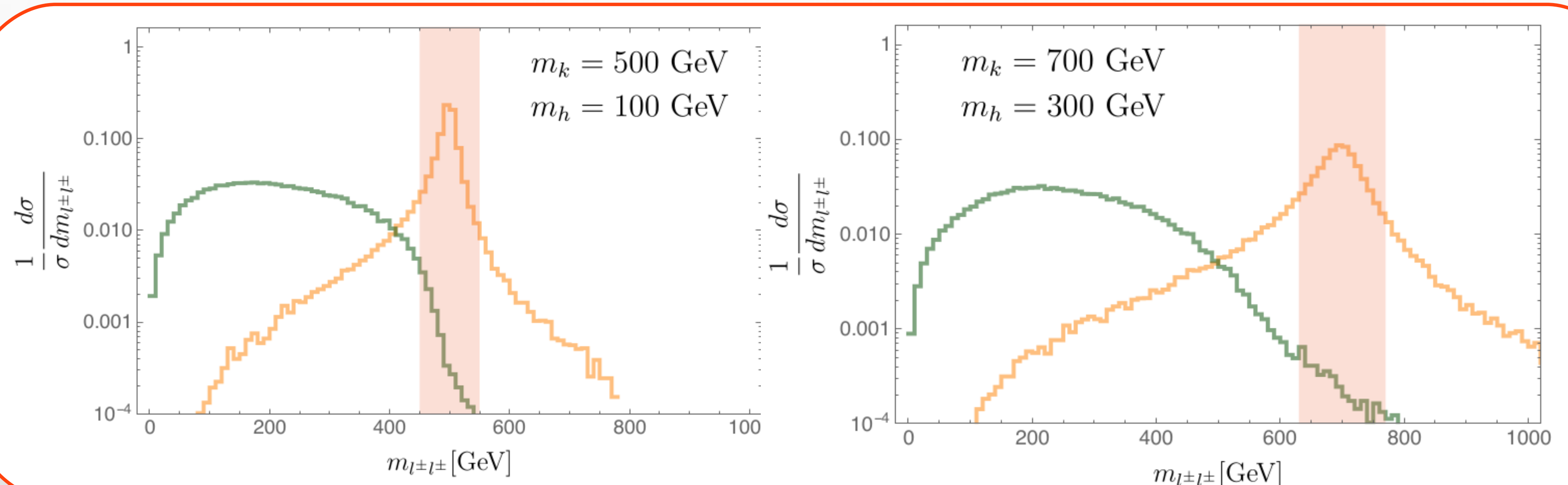
- Models with radiatively-induced neutrino masses do contain new (scalar) particles at the TeV scale
- LNV scalars must coupled linearly to non-leptonic fields



1701.01402

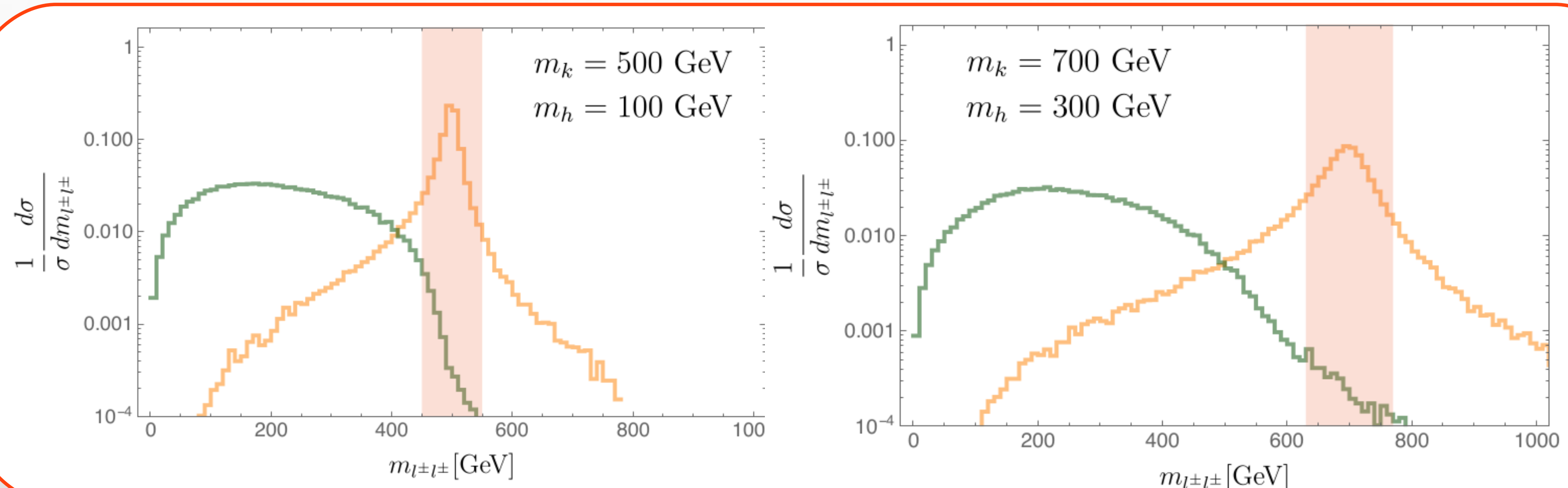
The status of current analyses

- Many searches for doubly-chaged scalars (e.g. 1211.6312, 1210.5070, 1207.2666, ATLAS-CONF-2016-051, ...)
- They all set a narrow cut on $m_{\ell^\pm\ell^\pm}$



The status of current analyses

- SUSY searches (e.g. 1602.09058) are also non-constraining (checked with CheckMate 2)
- Broad-scope analyses are also not sensitive



A general search for new phenomena with the ATLAS detector in pp collisions at $\sqrt{s} = 8$ TeV

The ATLAS Collaboration

Abstract

This note presents a model-independent general search for new phenomena in proton-proton collisions at a centre-of-mass energy of 8 TeV with the ATLAS detector at the LHC. The data set corresponds to a total integrated luminosity of 20.3 fb^{-1}. Event topologies involving isolated electrons, photons and muons, as well as jets, including those identified as originating from b-quarks (b-jets) and missing transverse momentum are investigated. The events are subdivided according to their final states into exclusive event classes. For the 697 classes with a Standard Model expectation greater than 0.1 events, a search algorithm tests the compatibility of data against the Monte Carlo simulated background in three kinematic variables sensitive to new physics effects. Although this search approach is less sensitive than optimized searches for specific models, it provides a more comprehensive investigation for new physics signals. No significant deviation is found in data. The number and size of the observed deviations follow the Standard Model expectation obtained from simulated pseudo-experiments.

ATLAS-CONF-2014-006
04 March 2014

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We need to know where to look

- We propose a broad but still sensitive search for doubly-charged scalars in neutrino models
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$$m_T^2 = \left[\sqrt{(p_T^{\ell^\pm \ell^\pm})^2 + m_{\ell^\pm \ell^\pm}^2} + E_T^{\text{miss}}\right]^2 - \left[p_x^{\ell^\pm \ell^\pm} + E_x^{\text{miss}}\right]^2 - \left[p_y^{\ell^\pm \ell^\pm} + E_y^{\text{miss}}\right]^2$$

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$$m_{T2} = \min_{\mathbf{q}_T} \left\{ \max \left[p_T^{L_1} E_T^{\text{miss}} - \mathbf{p}_T^{L_1} \cdot \mathbf{q}_T , \right.\right.$$
$$\left.\left. p_T^{L_2} E_T^{\text{miss}} - \mathbf{p}_T^{L_2} \cdot (\mathbf{E}_T^{\text{miss}} - \mathbf{q}_T) \right] \right\} .$$

- In addition, we consider the observables $m_{\ell^\pm\ell^\pm}$, S_T. For each SR, we look for the category with highest $S/\sqrt{B}$

$m_{T2} \backslash S_T >$ [GeV]	100	200	300	400	500	600	700	800	900
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$m_{T2} \backslash S_T >$ [GeV]	100	200	300	400	500	600	700	800	900
100	19	5.5	1.7	0.65	0.2	0.11	0.063	0.056	0.047
200	1.1	0.97	0.55	0.21	0.08	0.051	0.036	0.031	0.02
300	0.19	0.19	0.17	0.058	0.047	0.03	0.02	0.02	0.017
400	0.035	0.035	0.034	0.034	0.024	0.021	0.022	0.02	0.017
500	0.021	0.021	0.021	0.021	0.021	0.018	0.017	0.017	0.017
600	0.018	0.018	0.018	0.018	0.018	0.018	0.017	0.017	0.017
700	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
800	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
900	0	0	0	0	0	0	0	0	0

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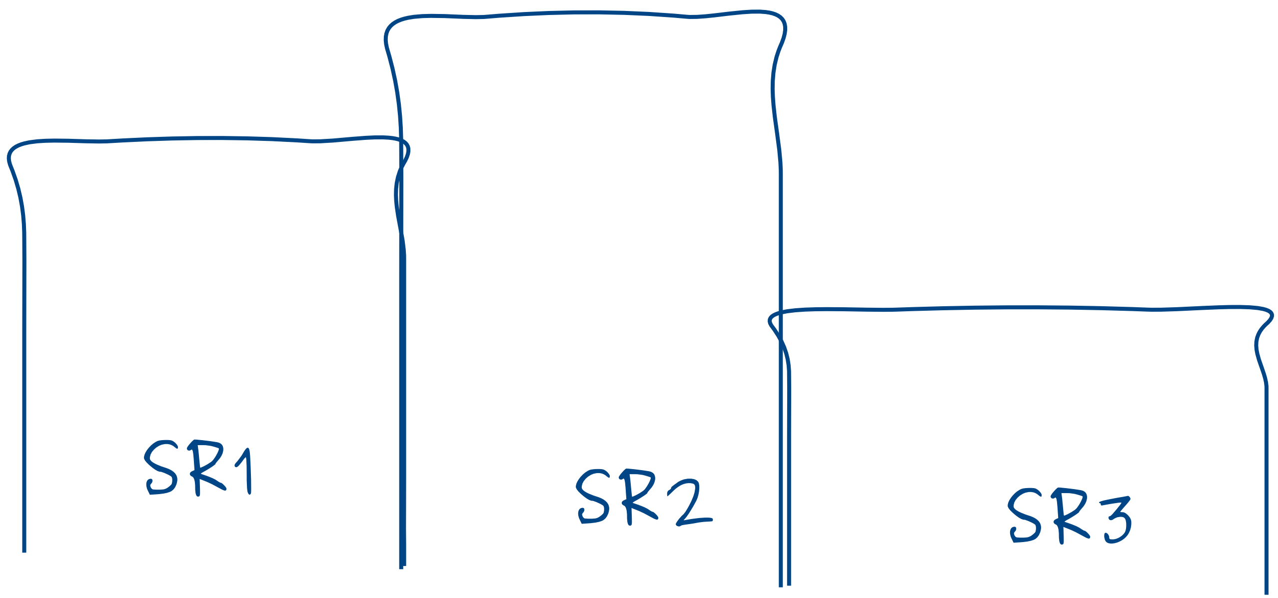

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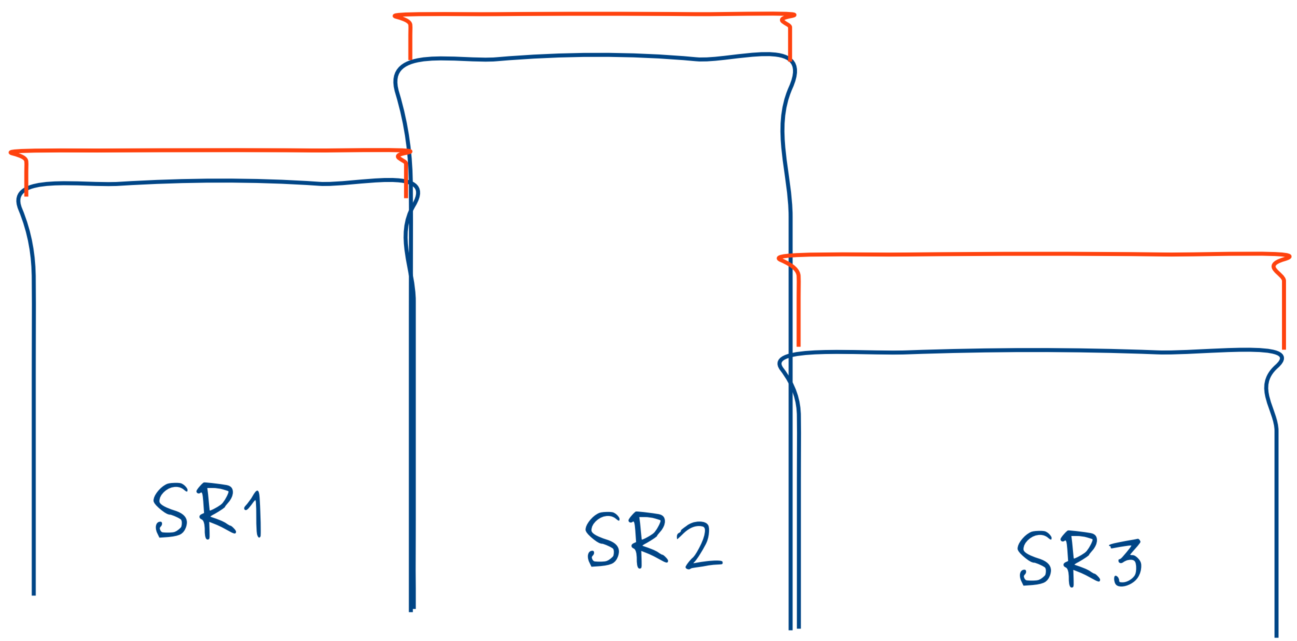

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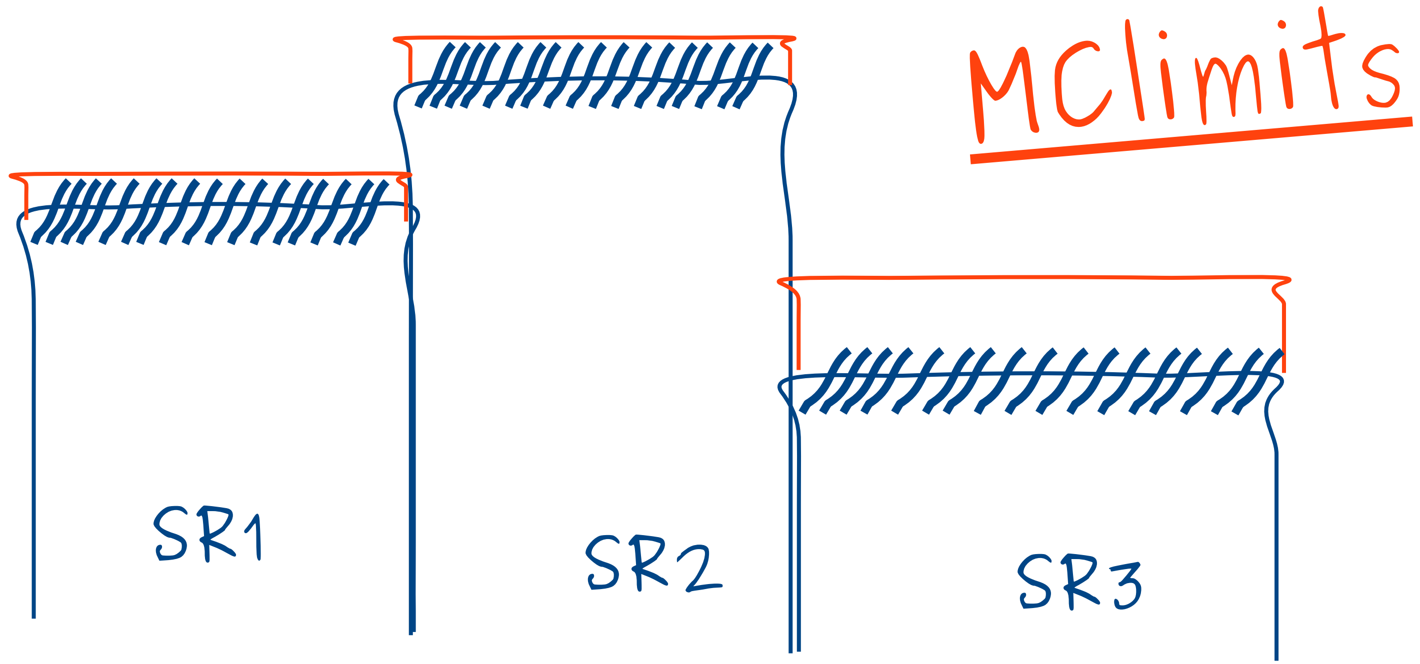
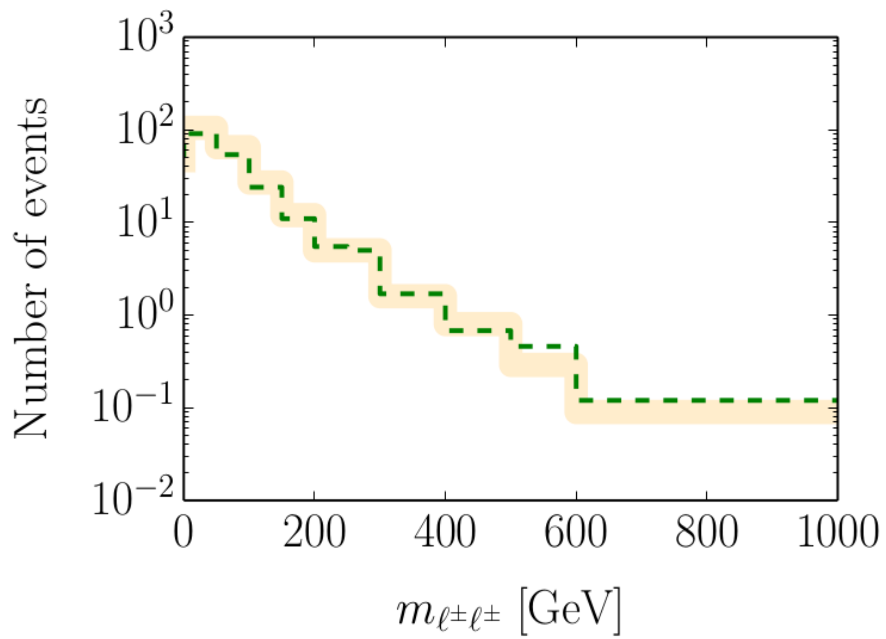


First, the background simulation is validated

- We consider Z+jets, tt, WW, WZ, ZZ, WWW, WWZ, WZZ, ZZZ, ttW, ttZ [NLO accuracy]



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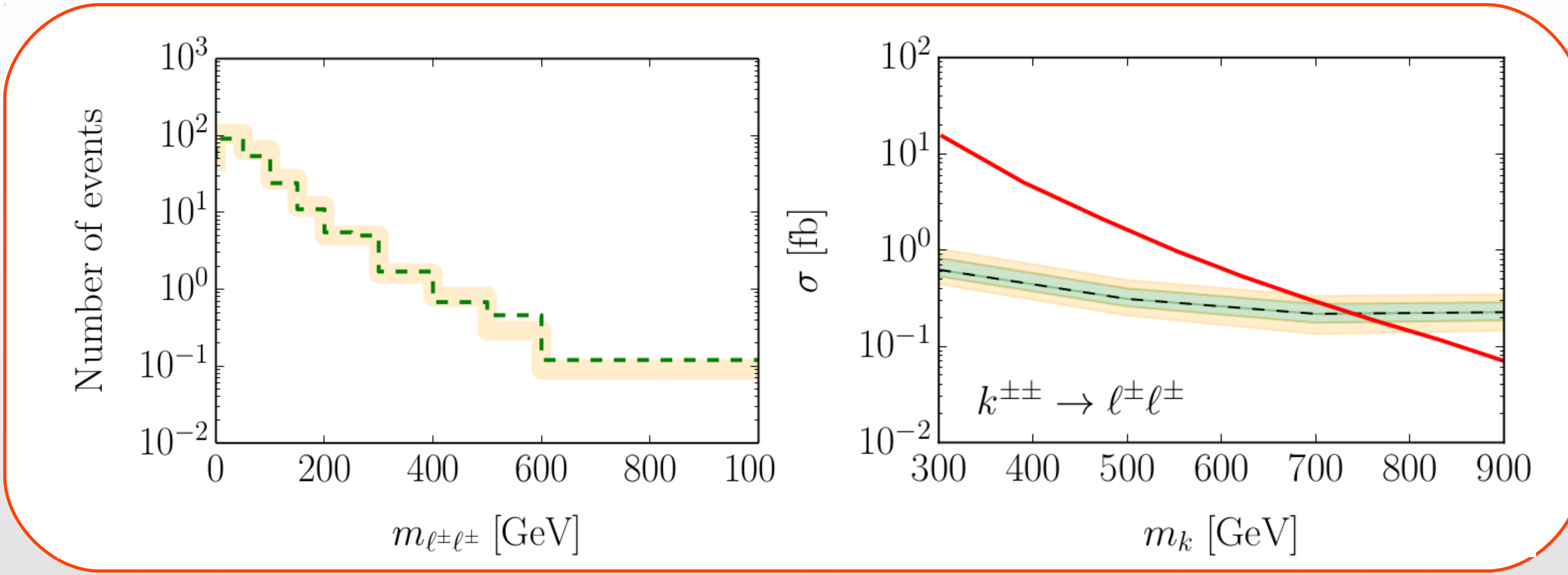
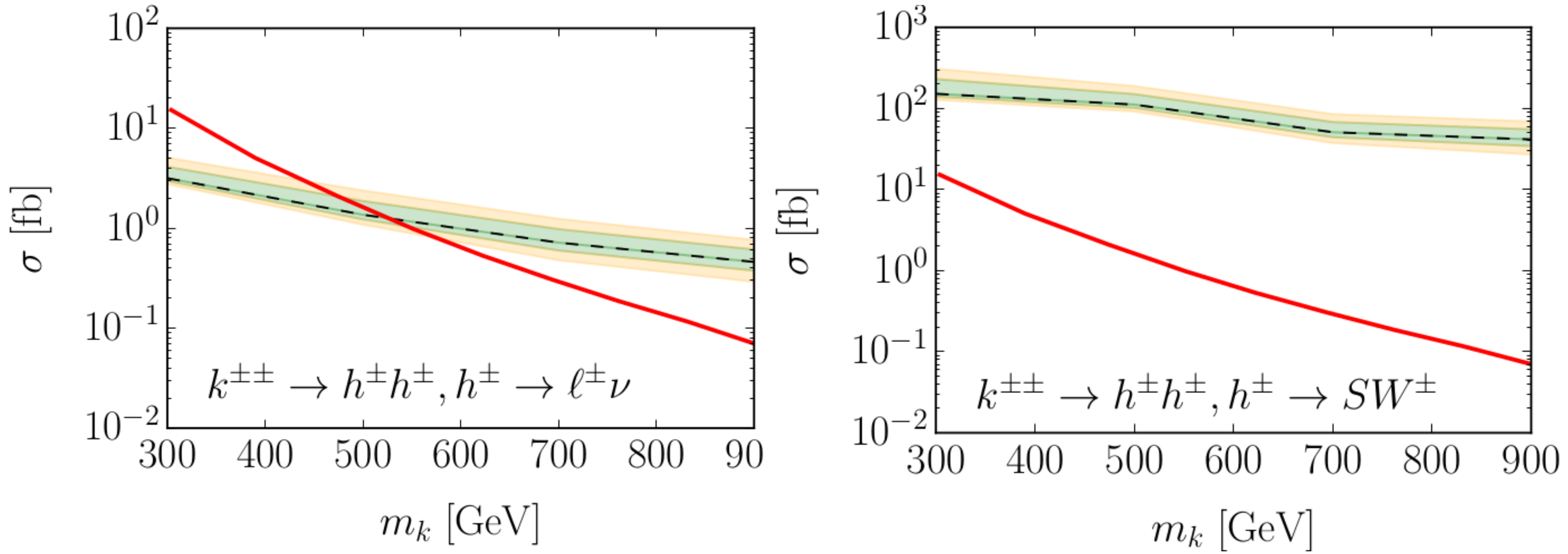


Some constraints

- We assume 100% into a given final state, and a total collected luminosity of 37/fb



Implications for the Zee-Babu model

- Extend the SM with a singly-charged scalar and a doubly-charged one:
- Most of the parameter space already constrained by neutrino and low-energy data

$$L = L_{\rm SM} + f^{ab}\overline{\tilde{L}_{aL}}L_{Lb}h^+ + g^{ab}\overline{e^c_a}e_b k^{++} \\ - \mu k^{++}h^-h + \text{h.c.} + \cdots$$

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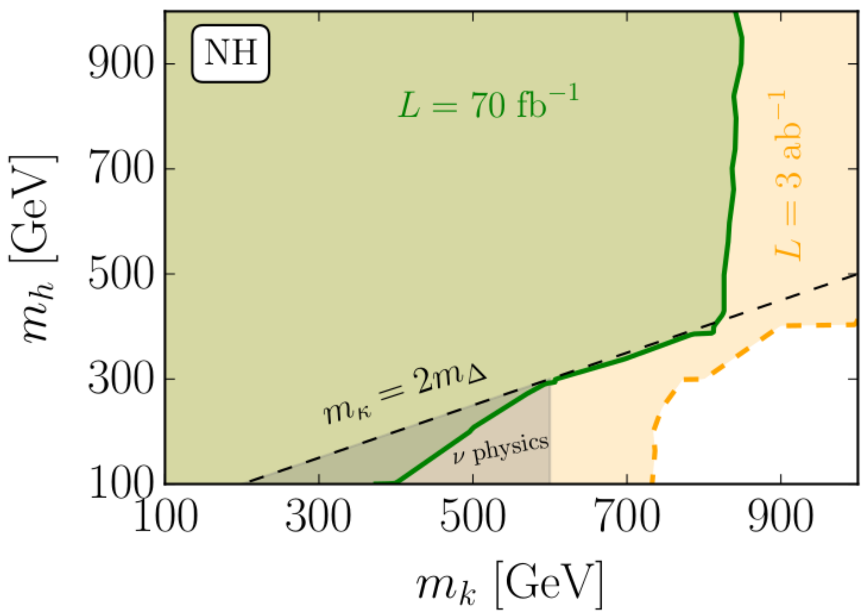
- For example, in the normal hierarchy: $g_{11} = g_{22} = 0.1$, $g_{12} = g_{13} = g_{33} = 0.001$, $f_{12} = f_{13} = 0.01$, $f_{23} = 0.02$,



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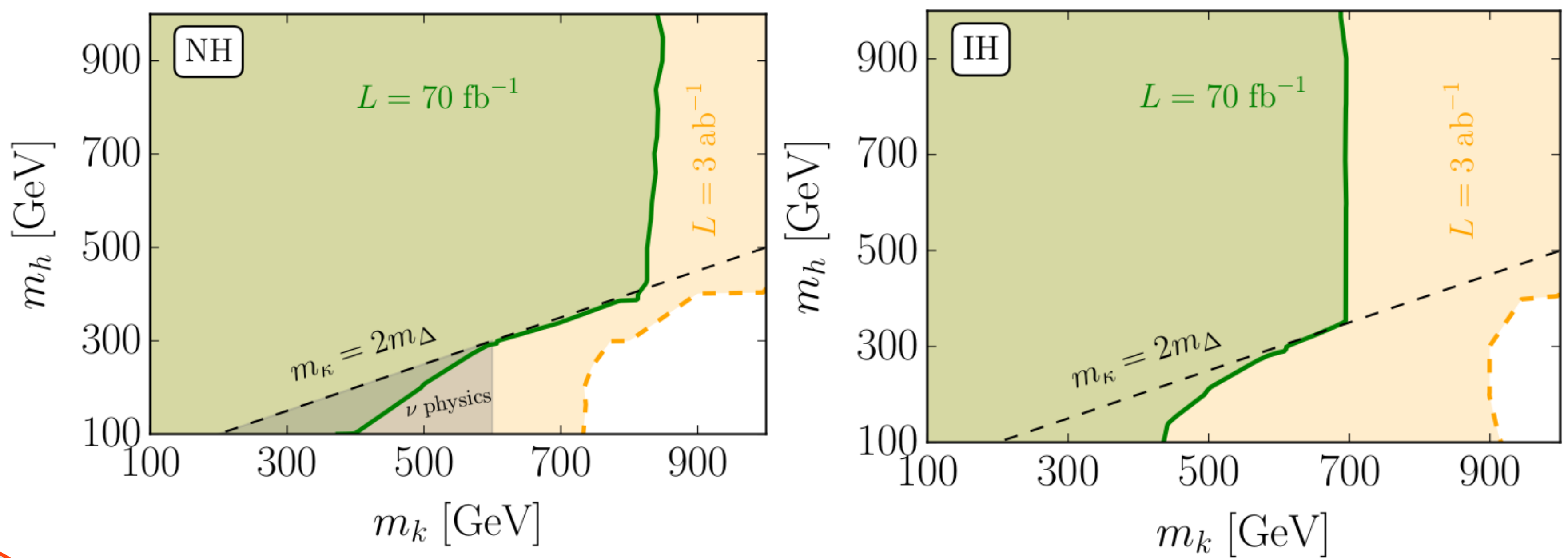

Conclusions

- Realistic models of new physics are not necessarily ruled out (not at all!). New searches must be worked out,
- We proposed a broad analysis sensitive to scalars appearing in neutrino models. Background estimations are provided,
- New modes not previously constrained can be already tested with current data. Others (mainly those arising in DM models), are still far from reacheable
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Thank you very much for your attention!

Backup