IL NUOVO CIMENTO **40 C** (2017) 11
DOI 10.1393/ncc/i2017-17011-0

Colloquia: IFAE 2016

A search for heavy neutrinos in the Run II of LHC with the CMS detector

L. Alunni Solestizi
INFN and University of Perugia - Perugia, Italy

received 17 October 2016

Summary. — A new search for heavy neutrinos in the dilepton plus dijet final state is motivated by the CMS experimental results of Run I and by the sensitivity of this channel to many theoretical model beyond the Standard Model. The new proposed model includes both composite fermions and contact interactions. In our benchmark process, a heavy Majorana neutrino is produced in association with a lepton and decays in a same flavor lepton plus two jets. The contribution at vertices given by the contact interaction affects the production cross section and the final state topology of the process. The model versatility and its exclusion/discovery potential, according to a preliminary simulation, are presented.

1. – Motivations

The dilepton plus dijet final state is sensitive to many theoretical models that search for new physics and include new particles, such as scalar leptoquarks, heavy neutrinos, heavy Higgs bosons, excited bosons, etc.

The CMS results for the Run I data taking of LHC have shown an excess, in the dielectron plus dijet channel, in two independent analyses:

- the first was a search for scalar leptoquarks of the first generation [1] and has given an excess of 2.4 σ for a leptoquark mass around 650 GeV;
- the second analysis looked for heavy neutrinos arising from a LR-symmetry extension scenario [2] and has shown an excess of 2.8 σ for a mass of the W_R boson of about 2.2 TeV.

Looking at the plots resulting from the two searches in term of the cross section *versus* the mass, compared with the only SM expectations (fig. 1(b), (d)), we see that in both cases an excess of events is measured. Several theoretical works interpreting this excesses followed.

These facts give us both the theoretical and experimental motivation to explore the dilepton plus dijet channel, exploiting the first Run II data of CMS, collected at an energy of 13 TeV in the centre of mass.

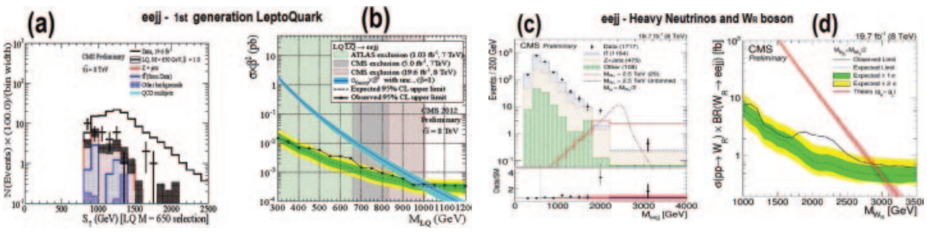

Fig. 1. – Run I CMS results in searches for first generation leptoquark (a), (b) and for heavy neutrinos in a LR-symmetry extension model (c), (d).

2. – A new model for heavy neutrinos

The compositeness of ordinary fermions is a possible scenario beyond the Standard Model. In this approach, quarks and leptons are assumed to have an internal substructure which should become manifest at some sufficiently high energy scale: the compositeness scale Λ. Ordinary fermions are then thought to be bound states of so far unobserved fundamental constituents, referred to as preons. Consequences of this picture are:

- the existence of excited states of ordinary quarks and leptons, with masses $m^* \leq \Lambda$;
- the presence of the contact interaction, the residual effect of the forces among preons, acting between ordinary fermions and between ordinary and excited fermions.

A possible excited state is the heavy Majorana neutrino, that is its own antiparticle. This can be produced in association with a lepton, via quark-antiquark annihilation: $pp \to \ell N$. The production can occur via both gauge and contact interactions, of which the dominant is the contact one, for all values of Λ and $M(N)$ (fig. 2(a)).

The preferred decay channel is in a lepton, whose flavor is the same of the lepton associated with the neutrino, plus two jets: $N \to \ell jj$. In this case, the relative contribution of gauge and contact interactions varies with the parameters of the model (fig. 2(b)).

The dominant contribution of the contact interactions at the production vertex helps in increasing the production cross section of the process, while their variable contribution, dependent on $M(N)$ and Λ, at the decay vertex can modify the topology of the final state.

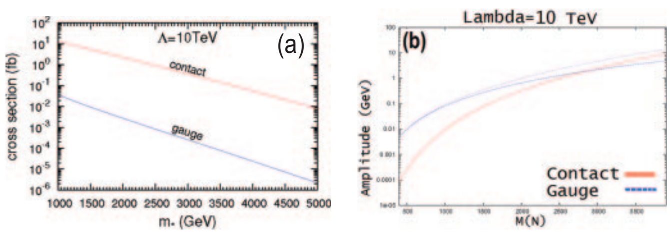

Fig. 2. – Gauge and contact contribution to the heavy Majorana neutrino cross section production (a) and to its decay amplitude (b) as a function of the heavy Majorana neutrino's mass, setting $\Lambda = 10\,\text{TeV}$.

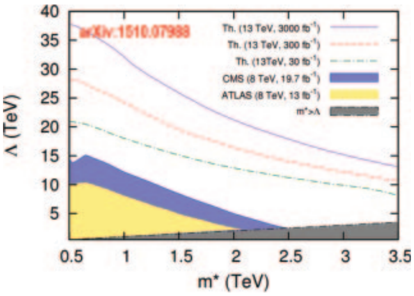

Fig. 3. – Exclusion limits projection for the new model at different integrated luminosities (lines) compared to the regions already excluded by ATLAS and CMS detectors (yellow and blue areas).

3. – Model potentialities

This new model for heavy neutrinos is quite flexible to reproduce several experimental features observed in the dilepton plus dijet channel.

- The shape of the excess observed at 8 TeV in [2] can be qualitatively reproduced setting proper model parameters.
- The fact that the excess has been observed in the $eejj$ channel and not in $\mu\mu jj$ can be explained assuming a heavier excited state for the muonic neutrino than the electronic one.
- The measured dominancy of dilepton opposite sign (OS) events on same sign (SS) ones can originate from processes giving only OS final state, such as $pp \to e^+L^{--} \to e^+e^-jj$ or $pp \to e^-L^{++} \to e^-e^+jj$. In alternative, another excited heavy neutrino state, with a slightly different mass, can interfere, suppressing the SS channel, as described in [4] and [5].

The exclusion limit of this new model in the parameter space has been estimated thanks to the Delphes simulator, for different stages of integrated luminosity (30, 300 and 3000 fb^{-1}), at 13 TeV. These curves are overlaid to the exclusion limits measured by the CMS and ATLAS experiments during Run I, see fig. 3.

REFERENCES

[1] CMS Collaboration, *Search for Pair-production of First Generation Scalar Leptoquarks in pp Collisions at 8 TeV*, CMS-PAS-EXO-12-041 (2014).
[2] CMS Collaboration, *Complete Works, in Search for heavy neutrinos and W bosons with right-handed couplings in proton-proton collisions at 8 TeV*, CMS-EXO-13-008 (2014).
[3] Leonardi R., Alunni L., Romeo F., Fanò L. and Panella O., *Eur. Phys. J. C*, **76** (2016) 593.
[4] Bhupal Dev P. S. and Mohapatra R. N., *Unified explanation of the eejj, diboson and dijet resonances at the LHC*, arXiv:1508.02277v2 (2015).
[5] Bhupal Dev P. S., Doojin Kim, Rabindra N. Mohapatrad, *Disambiguating Seesaw Models using Invariant Mass Variables at Hadron Colliders*, arXiv:1510.04328v2 (2016).