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Search for heavy lepton partners of neutrinos in the context of type-III Seesaw Mechanism at CMS

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Summary. — The Seesaw Mechanism was introduced to explain why the masses of neutrinos are many orders of magnitude smaller than the other lepton masses. Considering neutrinos as Majorana particles, "natural" Yukawa couplings yield neutrinos with very small masses, along with heavy partners. Such particles may be observable at the LHC experiments. CMS searched for a fermionic triplet (CMS Collaboration, `http://cds.cern.ch/record/2000982?ln=en`; *Phys. Lett. B*, **718** (2012) 348) (type-III Seesaw Mechanism) by selecting events with three isolated leptons, jets and missing transverse energy in the final state. Backgrounds are due to events with leptons from electroweak processes either leptons coming from secondary vertices or "fake leptons". The estimate of fake leptons is a crucial point of the analysis. Results obtained with data collected in 2012, corresponding to $19.7\,\text{fb}^{-1}$ and $\sqrt{s} = 8\,\text{TeV}$, show no evidence of signal, and so we have set lower limits on the masses of the fermionic triplet.

1. – Seesaw type-III search at CMS

Seesaw type-III fermionic triplet ($\Sigma^+, \Sigma^-, \Sigma^0$) can be produced in proton-proton collisions through quark-antiquark annihilation via a virtual boson, $q\bar{q} \to W^\pm \to \Sigma^0\Sigma^\pm$ or $q\bar{q} \to Z \to \Sigma^+\Sigma^-$. We consider a final state with three leptons and missing transverse energy due to neutrinos, allowing the decays of the partners into leptons and vector bosons: $\Sigma^0 \to W^\pm l^\mp$; $W^\pm\nu$ or $\Sigma^\pm \to Zl^\pm$.

Final states are reconstructed by the CMS detector combining informations coming from all subdetectors. We consider leptons from muons and electrons.

2. – Background, event selections, systematic uncertainties

The dominant electroweak backgrounds are from diboson processes, WZ and ZZ. Tribosonic background (WWW) also contribute, while other sources ($t\bar{t}W, t\bar{t}H, t\bar{t}\gamma$, $WW\gamma, WWZ$) are negligible. The electroweak background is simulated using Monte Carlo generators (PYTHIA 6.4 and MADGRAPH 5) at LO. The diboson samples are normalized using the measured cross section, the triboson sample is normalized at

NLO using the aMC@MLO cross section. The detector response is simulated through a GEANT4 model of the CMS detector. Asymmetric photon conversion in the process $Z\gamma \rightarrow l^+l^-\gamma \rightarrow l^+l^-l^+l^-$ contributes to the background if one of the leptons from the photon conversion carries most of the momentum, whilst the other lepton, with low momentum, is undetected.

The third source of background is due to non-prompt leptons (fake leptons). These are leptons that do note originate from the primary vertex, but instead from decays of heavy flavour quarks or jets misidentified as leptons. The Monte Carlo simulation of fake leptons is unsatisfactory, so they are evaluated with real data in a control region with high hadronic activity, where the contribution of prompt leptons is suppressed. The fake rate, *i.e.* the probability of a fake electron or muon of passing the analysis selections, does not depend on the momenta of the leptons, but on their relative isolation values with respect to other detector activity. The number of fake events is predicted applying the fake rate to data.

Dileptonic triggers are used with cuts on dilepton momenta of $p_T > 17\,\mathrm{GeV}$ and $p_T > 8\,\mathrm{GeV}$.

The background contributions are suppressed applying kinematical selections on physics objects, in order to maximize significance. Three isolated leptons with $p_T >$30, 20, 10 GeV are required. Leptons charge sum must be ±1, missing transverse energy $> 50\,\mathrm{GeV}$, hadronic activity $< 150\,\mathrm{GeV}$, b tag CSV veto on the leading p_T jet < 0.244. Vetos are applied on dilepton and trilepton candidates to suppress contribution from Z boson and asymmetric photon conversions.

Systematic uncertainties on acceptance, trigger efficiency, reconstruction of the physics objects are evaluated on the type-III Seesaw signal Monte Carlo samples generated with MADGRAPH 5. The uncertainty on luminosity is 2.6%. The uncertainties on electroweak backgrounds correspond to 26.6% for WZ, 15.4% for ZZ, 50% for WWW. The uncertainty on the fake lepton background is evaluated as 50% by using consistency tests with Monte Carlo samples of QCD processes and electroweak processes with jets.

3. – Results and their interpretation

The expected background and signal events are compared with the observed data after all the selections. The events are divided into categories based on the sum of the charges of the three leptons. We expect 31.9 ± 4.0 events for the $+1$ category (23.5 ± 3.3 for the -1 category). There are 31 (16) events observed. The results show no evidence of signal. We interpret the data as a lower limit on the mass of the triplet. We assume a democratic scenario, where all leptons couple to their partners with a natural mixing angle of 10^{-6}. The limits are 260 GeV for Σ^+, 238 GeV for Σ^-, 278 GeV if combining the events of the two categories. A more general interpretation sets the mass limit at 320 GeV when the particles of the triplet are coupled only with electrons and muons.