PROCEEDINGS OF SCIENCE

Searches for non-resonant new phenomena in final states with leptons and photons at CMS

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Some recent searches for hints of processes beyond the standard model performed by the CMS collaboration are presented. These focused on the detection of new phenomena more indirectly than the direct observation of a resonance indicating the presence of a new particle. No significant deviation from the standard model expectations have been observed and constraints for new physics have been set in several well-motivated scenarios.

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1. Introduction

The standard model (SM) of particles and interactions has recently been completed with the discovery of a candidate for the Higgs boson. This represents the last step of the extraordinary success of this model to describe tha basic components of nature until the tested precision or, equivalently, the energy scale reached at collider experiments.

Despite of its success describing the experimental results at the highest energies, there are many open questions about the validity of the SM up to the largest scales. Additionally there are cosmological observations and neutrino experimental properties that clearly indicates that the SM cannot be the final answer so one of the current goals of the experiments in particle physics is to search for possible hints of particles or interactions beyond the SM, or simply detect discrepancies of the measurements with respect to the SM predictions.

Within the searches performed with the CMS experiment[1] at the LHC-CERN collider[2], one interesting subset is formed by searches of continuous or broad discrepancies with respect to the SM prediction. These are more challenging than the detection of narrow resonance peaks which indicate the production of a particle, but they are worth pursuing because in several extensions of the SM the detection of a new particle is not the most sensitive approach for the discovery, either because the particle is not easily reconstructed or because topological properties of the detected final state makes it less convenient than alternative approaches, as we will discuss later.

The CMS experiment is a multipurpose detector that is perfectly suited for the investigation of anomalous final states that are needed in the indicated searches. Its great capabilities to reconstruct with high precision the full final state of the proton-proton collisions at the CERN-LHC allows the detailed comparison of the SM expectations with the measurements. Especially important are the improvements achieved with the so-called *Particle-Flow algorithm*[3] for which the information from all the subdetector components is combined to obtain a global description of the final state in terms of “particles”, i.e. four-momenta and particle type. The description of the final state in terms of this set of “particles” yields a much improved description of the event kinematics due to the usage of all the available information from the detector.

2. Search of new physics in the dilepton mass spectra

When performing any kind of study in a hadron collider, one of the first steps is to investigate the invariant mass of lepton pairs, specifically of electron-positron and muon-antimuon pairs, which are objects easy to identify and reconstruct in the large background of dijet production.

This distribution is the same one used to identify possible resonances/particles decaying into lepton pairs, as the case of Z' searches[4], although we are more interested in the non-resonant interpretation for which the idea is to look for a discrepancy between the measurements and the SM expectation for the tail of the distribution[4]. Two interpretations have been performed in this context: search for the possible presence of extra dimensions (according to the models in Ref. [5]) and possible discrepancies due to quark and lepton compositeness (in terms of a left-left isoscalar contact interaction context[6]).

No significant discrepancy has been observed and the results have been quantified in terms of 95% Confidence Level (CL) limits. In the case of the extra-dimension interpretation, the limit is at the order of 3-5 TeV on the mass-scale for quantum gravity for 2 to 7 number of additional dimensions. For the contact interaction interpretation, the limit is around 12-18.3 TeV for the scale of the new interaction, with some dependence on the type of interference of the new interaction and the SM.

It should be noted that although the interpretation is performed within those two models, CMS provided enough information for the reinterpretation of the results for any model with a similar signature. See Ref. [4] for details.

3. Excited leptons in the $\ell\ell\gamma$ final state

In the context of dilepton production, the existence of possible excited leptons may be detected by its decay into the detectable lepton and a photon. Following the formalism in Ref. [7], CMS performs the search[8] of excited leptons produced in association of a lepton of the same flavour, being the signature a high energetic central photon and two same-flavour electrons or muons.

Although a resonance is present in the final state, its reconstruction as the invariant mass of one lepton and the photon gets distorted because of the two possible choices for the lepton. For this reason, a more sensitive approach is followed by computing the two possible masses which are used to search for an excess in the 2-D plane of the minimum and the maximum mass. In this plane, the signal displays a well-identified L-shape distribution, as shown in Fig. 1, that allows a clean distinction from the background events.

No hints of an excess is observed in neither the electron nor the muon channel, and 95% CL limits are obtained on the excited lepton mass and the possible compositeness scale. For the lepton masses the limits are of the order of 3 TeV in both cases. For the scale, the limit is 14 (15) TeV for the electron (muon) channel, in good agreement with the expected sensitivity.

4. Multileptonic final states

In the context of the Type III seesaw model[9] the neutrino is considered a Majorana particle and its mass arises via new massive fermions whose production may be allowed at the CERN-LHC collisions. CMS has investigated the possibility that these fermions might be pair produced[10] and that its decay products will produce multileptonic final state with and without missing transverse energy due to neutrinos.

The analysis is performed in a flavour-democratic scenario and with a requirement of at least three leptons (electrons or muons) it is possible to investigate six signal regions having large sensitivity to the described model. The discriminant variable used is the scalar sum of the transverse momentum of all the leptons added to the missing transverse energy. In a three-lepton region where an on-shell Z is identified the discriminant variable is the transverse mass computed for the third lepton and the missing transverse energy.

Good agreement between data and prediction is observed in all the six regions and a generic limit for the new heavy fermions is set at a cross section around 0.06 pb which translates into a lower-limit mass of 850 GeV.

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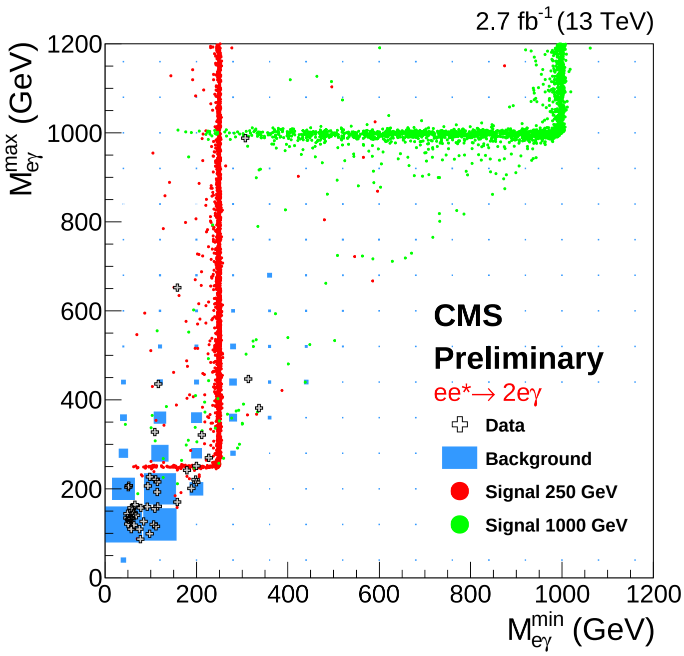

Figure 1: Distribution of events in the plane for the minimum and the maximum masses obtained combining the photon with either lepton for $ee\gamma$ events. The two signals (red and green dots) show the expected L-shape distribution while the background (blue boxes) is more evenly distributed[8].

5. Production of boosted Z bosons

Physics beyond the SM may enhance the production of Z bosons, either as decay products of new particles or as possible products of the interaction. In either case it is expected that such Z bosons are produced with large transverse momenta, reflecting the high energy scale at which the new particles or interaction are produced.

It is therefore possible to search for the presence of new physics by comparing the spectrum of transverse momentum for the Z boson to that expected in the SM. This study is performed by CMS[11] by looking at events in which the Z decays in an electron-positron pair. Since we are interested in events where the Z is produced with large transverse momentum (boosted), a special care has to be taken regarding the electron and positron selection: the isolation requirement should be modified to account for the fact that both leptons may be close enough to interfere in the calculation of the isolations. A dedicated reconstruction allows to recover for the large inefficiency such kinematical property introduces when using the standard isolation requirement.

After reconstructing the leptons and selecting events containing an on-shell Z boson, the transverse momentum is plotted and compared to the SM predictions, as shown in Fig. 2. A good agreement is observed, yielding a 95% CL limit on possible models producing these boosted Z bosons. Depending on the assumptions the limit is slightly different, but in a models of excited quarks, the obtained lower limit for the mass is 2.6 (3.0) TeV in the context of gauge (contact) interactions to produce the excited quark.

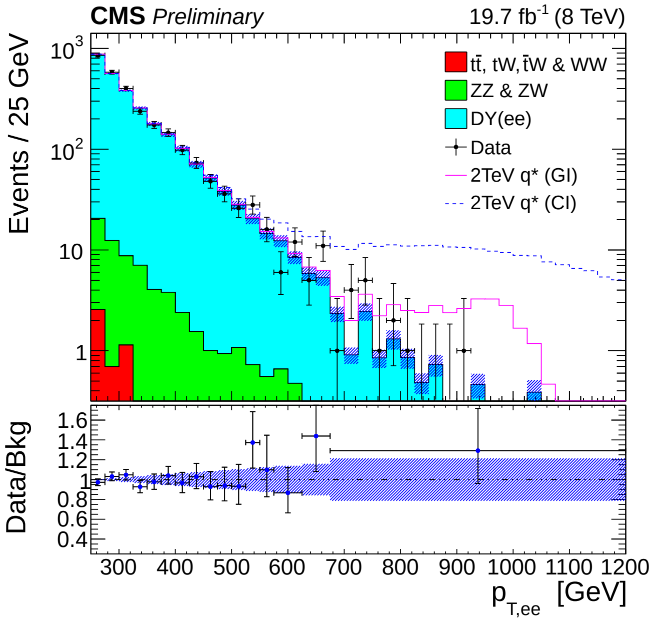

Figure 2: Distribution of the transverse momentum of the $Z(ee)$ candidates in the boosted topology. Data (dots) are compared to the expectations from the standard model (coloured filled histograms) and to two possible new-physics signals (coloured lines)[11].

6. Conclusions

Many searches for new physics have been performed at CMS to complement those focusing on the direct observation of new particles as resonant excesses over the expected SM background. In some scenarios it is expected that the direct observation of new particles may not be possible or simply not being the most sensitive approach. Therefore, in this situation, alternative studies have to be considered.

Some of the most recent searches for non-resonant phenomena have been reported here, which exploit the characteristics of the CMS detector to cover many several classes of final states. No sign of new physics has been observed in the analyzed data. However, these represent just a small fraction of the full dataset available or expected from the CERN-LHC, thus large improvements in sensitivity for this kind of searches shall be obtained in the near future.

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