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Exotica Searches

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Abstract

The searches for non-SUSY physics beyond Standard Model are presented, usingthe 7 TeV and 8 TeV data at LHC. The CMS collaboration hasinvestigated numerous scenarios, including the possibility of new heavy gaugebosons, extra-dimensions, compositeness or dark matter production. The fulldatasets (5 /fb in 2011 and 20 /fb in 2012) allowed to set lower limits on themass scale for a large number of models.

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1 Introduction

The exotica searches are covering all beyond Standard Model (SM) searches but supersymetric extensions of SM. All data collected in 2011 and 2012 by the CMS detector were used and limits set in a large variety of models on the typical mass scale or an upper limit on the cross sections of the new phenomena.

2 Data taking and experiment

All the data collected at the LHC by the CMS detector in 2011 at 7 TeV and in 2012 at 8 TeV were used for these exotica searches. The delivered luminosities by the LHC were 6.1 /fb and 23.3 /fb respectively in 2011 and 2012. The data taking efficiency in CMS was very good, leading to 5.6 /fb and 21.8 /fb of recorded luminosity [1]. Finally, after all checks of data quality, the usuable integrated luminosities declared good for physics were about 5 /fb and 20 /fb respectively in 2011 and 2012 [1]. The instantaneous maximal luminosity reached $6{\cdot}10^{33}$ cm^{-2}s^{-1} at the end of the data taking in 2012. The mean number of interactions per crossing also reached a maximum of 40, while the average number was about 20 during 8 TeV operations.

The CMS detector [2] is a multi-purpose experiment using several technologies so as to perform the triggering and identification of the physics objects (electrons, photons, jets, muons). The full silicon tracking system (66 millions of pixels and 10 millions of strips) is able to measure the tracks with the following resolution : $\sigma_{p_T}/p_T \approx 1.5 \cdot 10^{-4} p_T(GeV) \oplus 0.5\%$. The electromagnetic calorimeter, made of 75.8 thousands of PbWO4 crystals, can reach a 1% resolution at 100 GeV. The hadronic calorimeter uses scintalling material and brass interleaved, and allows to measure the hadronic objects with the energy deposit resolution $\sigma_E/E \approx 120\%/\sqrt(E)(GeV) \oplus 6.9\%$. Finally the muon system, localized outside the 3.8T magnet, is composed of three kind of gas detectors (drift tubes in the barrel, cathode strips chambers in the endcaps and resistive plate chambers in both barrel and endcaps). The muon momentum resolution is lower than 1% up to 100 GeV and still lower than 10% for TeV muons.

3 Exotica searches

The exotica searches are embedding the non-SUSY beyond SM analyses. Several questions can be addressed : is there any additionnal extra-dimensions, some new heavy gauge bosons, is there any compositeness, what the dark matter is made of. More generally, we are looking to any new phenomena beyond SM. This new physics should typically appears with a final state involving some TeV objects (electrons, photons, muons or jets) or higher number of leptons than the SM backgrounds.

3.1 New heavy gauge bosons

Several scenarios are predicting new additionnal heavy gauge bosons: models with extended gauge sectors or also theories with extra spatial dimensions. In all cases, they are expected to give some significant deviations from the SM background prediction. First of all, the final state with one charged lepton (electron or muon) with high p$_T$(transverse momentum) and missing transverse energy (MET) is used to look for a W' heavy gauge boson [3]. The results are given for a sequential SM (SSM) W' boson, with the couplings set to be identical as in the SM and a lower mass limit of 3.3 TeV at a 95% confidence level (CL) is obtained. The interpretation in the split Universal Extra Dimension (UED) model is giving a lower mass limit of 1.7 TeV (3.7 TeV) for the Kaluza-Klein state W$_{KK}$ with a bulk mass parameter of 0.05 TeV (10 TeV).

The search for narrow high-mass resonances to decay into electron or muon pairs has been performed [4]. Fig.1 shows as example the invariant di-electron mass spectrum using the full dataset at 8 TeV. As no excess was detected, a 95% CL upper limit has been set on the ratio of cross section times branching fraction of such new heavy gauge boson compared to the Z boson, as shown in Fig.2. In the case of a SSM Z' boson, the lower mass limit is found to be 3.0 TeV and 2.6 TeV for a superstring inspired Z'$_\psi$ boson.

3.2 Extra-dimensions

Extra dimension ADD (Arkani-Hamed, Dimipolous and Dvali) model gives a solution to the hierachy problem in the SM, constraining the SM particles into a four-dimensional space-time while the gravity can propagate in all dimensions. The searches for large spatial extra dimensions are performed in both dielectron channel [5] and dimuon channel [6], using the full dataset at the center-of-mass energy of 8 TeV. Both dielectron and dimuon invariant mass spectra agree well with the SM expectation. Fig.3 shows the lower limits on the model parameter

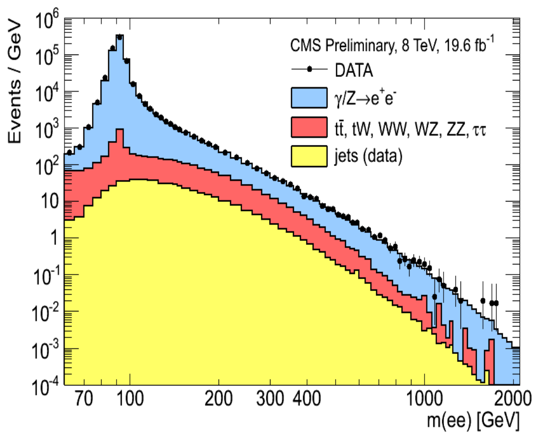

Figure 1: The invariant mass spectrum of di-electron events. The blue histogram represents the Z/γ* SM background, the red one is the top anti-top background with other sources of prompt leptons and the yellow one is showing the multi-jet backgrounds.

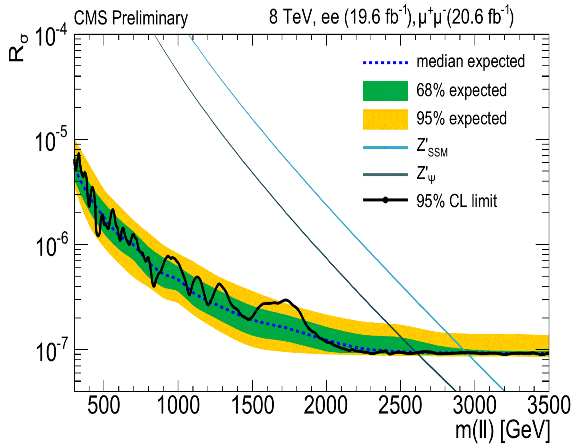

Figure 2: Upper limit on the production ratio R_σ of cross section times branching fraction of a new boson, compared to a Z boson, including both electron and muon final states and using all 8 TeV data.

M_S as a function of the validity range of the theory, and depending on the number of extra dimensions. In the dielectron channel, limit on M_S is set up to 4.8 TeV while the dimuon channel sets the limit at 4.5 TeV, in both cases at a 95% CL.

The search for large extra dimensions is also performed using the high p_T photon and transverse missing energy final state [7], which is motivated by the process $q\bar{q} \to \gamma$G where the graviton G is escaping the detection. If the three dimensional brane of the SM particles of the ADD model can fluctuate, then the scalar particles associated (called branons) can give the same final state. Fig.4 presents the limit on the model parameter M_D as a function of the number of extra dimensions, also with previous results superimposed. The new lower limit on M_D is set up to 2.3 TeV at a 95% CL.

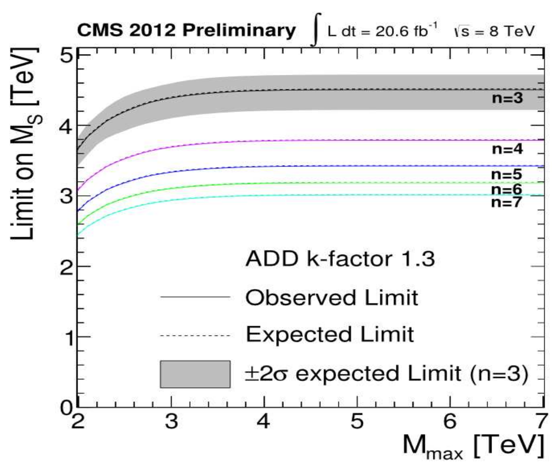

Figure 3: Lower limit on M_S using NLO signal cross section (k-factor 1.3).

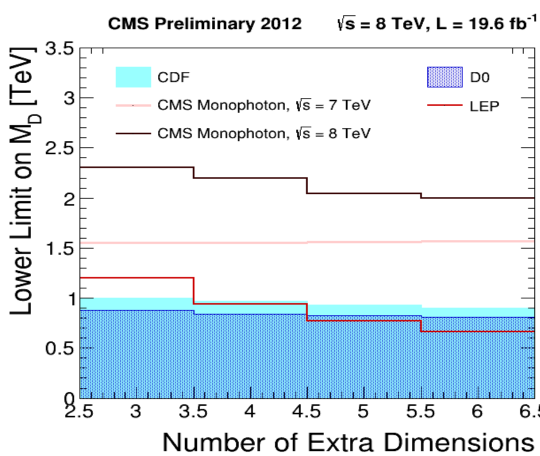

Figure 4: Lower limit on M_D as a function of the number of extra dimensions, compared also to LO results from Tevatron and LEP.

3.3 Compositeness

The compositeness of quarks and leptons is a possible explanation for the existence of the three families of fermions. The confinement of the more fundamental constituents will be achieved introducing a new strong gauge interaction, called metacolor in this contact interaction (CI) model, that will bind the constituents below a given interaction energy scale Λ.

In the case of the dilepton final state, the Drell-Yan SM process and the CI production can interfere constructively or destructively. Using the dilepton mass spectra, the following 95% CL lower limits on Λ are obtained : in the dimuon final state, 12.0 TeV and 15.2 TeV for destructive and constructive interference with Drell-Yan process respectively [8], 13.5 TeV and 18.3 TeV respectively in the dielectron final state [8]. Fig.5 shows the combined results.

The quark substructure can be observed through the existence of excited quark states. The production and decay of such excited states would occur via CI or gauge interactions. In the second case, the decay of the excited quark will be a quark accompagnied by a gauge boson. The final state presented on Fig.6 is γ + jet. An excited quark would appear as a resonance in the invariant mass spectrum. Assuming unit couplings to their SM partners, the excited quarks masses below 3.5 TeV are excluded at a 95% CL [9].

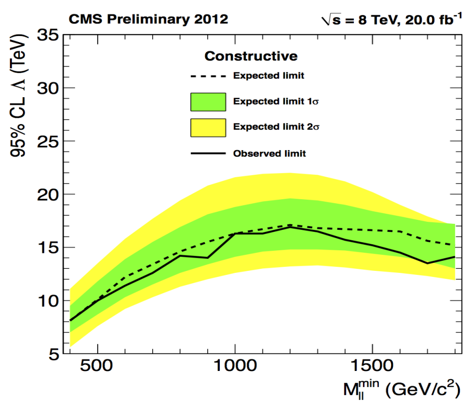

Figure 5: Lower limit on Λ as a function of minimum mass for dileptons with constructive interference. Both observed (continuous line) and expected (dashed line) limits are shown, with the 1 and 2 sigma expected limit bands.

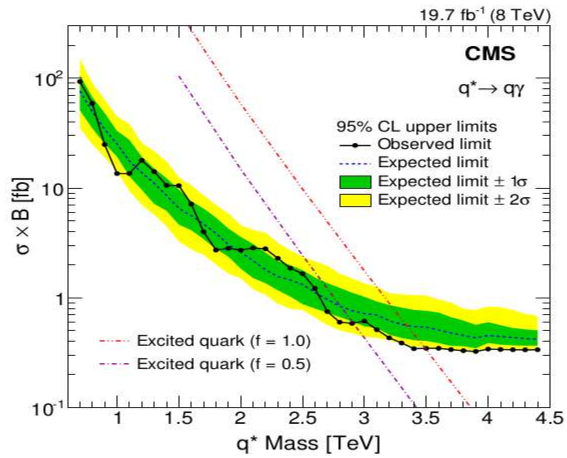

Figure 6: Upper limits on $\sigma\times$ BR for the production of excited quarks in the γ + jet final state. The expected limit for excited quark production, for two values of the coupling strenghts (0.5 and 1.0) is superimposed.

3.4 Generic searches

Some generic searches are also performed using the monojet events [10]. Several scenarios (dark matter (DM), extra dimensions or unparticles) predict indeed a jet and high MET final state. In particular, an upper limit is set on the DM-nucleon scattering cross section, for both spin-dependent and spin-independent interactions. The results are presented on Fig.7 in the spin independent case, as a function of the DM particle mass. They are also compared to the direct DM searches. The CMS upper limit is competitive in the region below 10 GeV for the DM particle mass.

The search for narrow resonances in the dijet mass spectrum is also emblematic in the exotica searches, as it could lead to a discovery in a large variety of models (string resonances, excited quarks, axigluons, colorons, E6 diquarks, s8 resonances, W' and Z' bosons, and Randall-Sundrum gravitons) [11]. The measured dijet mass spectrum is compared to the predicted QCD background and an upper limit is set on the resonance cross section, as shown on Fig.8, as a function of the resonance mass. Depending on the model the lower mass limit is set up to 5.1 TeV.

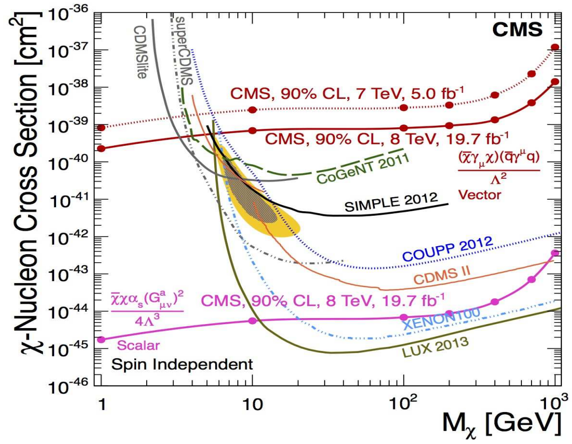

Figure 7: Upper limits at a 90% CL on the DM-nucleon cross section as function of the DM particle mass, in the case of the vector and scalar operators (spin independent). The CMS results are compared with CoGeNT, SIMPLE, COUPP, CDMS, SuperCDMS, XENON100 and LUX collaborations.

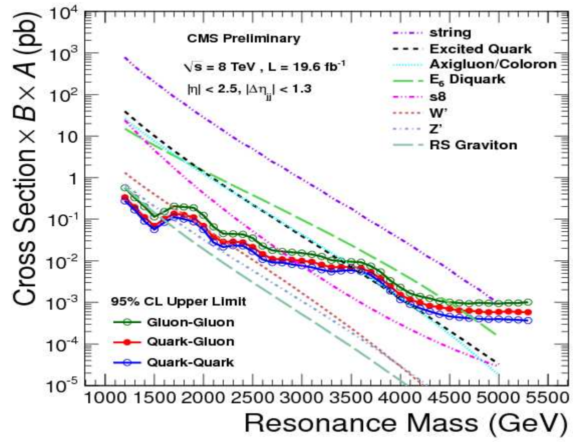

Figure 8: Upper limits at a 95% CL on $\sigma \times B \times A$ for dijet resonances of type gluon-gluon, quark-gluon, and quark-quark, compared to different theoretical scenarios.

4 Conclusion

Despite the large number of final states looked for, no excess has been detected in the exotica searches. All new limits are summarized in the CMS EXO public results web page [12]. Only a subset of searches were presented in this document. Most of these searches will benefit from the new center-of-mass energy at 13 TeV in 2015 and afterwards at 14 TeV, and also the higher expected integrated luminosity (300 /fb at the end of the run2 around 2022 and 3000 /fb for the high luminosity LHC program up to 2035).

Acknowledgments

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References

[1] https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults

[2] CMS Collaboration, *The CMS experiment at the CERN LHC*, JINST 3:S08004 (2008).

[3] CMS Collaboration, *Search for Physics beyond the Standard Model in Final States with a Lepton and Missing Transverse Energy in proton-proton Collisions at* $\sqrt{s}$ *= 8 TeV*, CMS-PAS-EXO-12-060.

[4] CMS Collaboration, *Search for Narrow Resonances in Dilepton Mass Spectra in pp Collisions at* $\sqrt{s}$ *= 8 TeV*, CMS-PAS-EXO-12-061.

[5] CMS Collaboration, *Search for Large Extra Spatial Dimensions in Dielectron Production with the CMS Detector*, CMS-PAS-EXO-12-031.

[6] CMS Collaboration, *Search for Large Extra Dimensions in Dimuon Events in pp Collisions at* $\sqrt{s}$ *= 8 TeV*, CMS-PAS-EXO-12-027.

[7] CMS Collaboration, *Search for Dark Matter and Large Extra Dimensions in the Photon + Missing Transverse Energy final state in pp Collisions at* $\sqrt{s}$ *= 8 TeV in the CMS Experiment with 19.6 fb-1 of data*, CMS-PAS-EXO-12-047.

[8] CMS Collaboration, *Search for Contact Interactions in Dilepton Mass Spectra in pp Collisions at* $\sqrt{s}$ *= 8 TeV*, CMS-PAS-EXO-12-020.

[9] CMS Collaboration, *Search for Excited Quarks in the gamma + jet Final State in proton-proton Collisions at* $\sqrt{s}$ *= 8 TeV*, CMS-PAS-EXO-13-003. 10.1016/j.physletb.2014.09.048

[10] CMS Collaboration, *Search for new Physics in monojet Events in pp Collisions at* $\sqrt{s}$ *= 8 TeV*, CMS-PAS-EXO-12-048.

[11] CMS Collaboration, *Search for Narrow Resonances using the Dijet Mass Spectrum with 19.6 fb-1 of pp Collisions at* $\sqrt{s}$ *= 8 TeV*, CMS-PAS-EXO-12-059.

[12] https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO