PROCEEDINGS OF SCIENCE

Search for new physics at 13 TeV with the CMS detector

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The first 13 TeV data recorded by the CMS experiment are used to search for di-jet resonances. With an integrated luminosity of 42 pb^{-1}, di-jet resonances with invariant masses lower than 2.3 to 5.1 TeV, depending of the interpretation model, are excluded at 95% of confidence level. While other searches requires more integrated luminosity, analyses are being prepared by estimating selection efficiencies and backgrounds contamination from data, and by performing first data-to-MC comparisons. Good descriptions of the data from the simulation are observed, which show the good performance of the CMS detector.

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1. Introduction

The Standard Model (SM) of particle physics was successfully validated by many experimental measurements performed over many years. The LHC results have consolidated the SM, as multiple extremely precise measurements were performed during Run 1, and predicted SM processes and particles were observed. The brightest example is the discovery of the Higgs boson by the ATLAS and CMS experiments [2, 3]. However the MS is known to be incomplete and new heavy particles, arising from a extension of the SM (BSM), might be observed in the future. Indeed, despite it's successful predictions, the SM suffers from limitations/imperfections. For example, it does not predict the Dark Matter (DM) nor the Dark Energy, it does not explain the observed matter/antimatter asymmetry in the universe, it does not account for the mass of neutrinos, nor has an explanation for the observed hierarchy of masses. Finally, the Higgs boson mass received heavy quantic corrections that requires fine tuning. There exists several BSM models, which propose solutions to solve some of these problems. Let's quote for example Super-symmetric (SUSY) models, or models with extra-dimension. This proceeding presents the status of searches for new physics by the CMS collaboration [1], at the time of summer 2015.

One can consider basically two ways to search signs of new physics at colliders : either with direct searches, if the collision energy is big enough to produce new particles with heavy masses, or from the re-interpretation of precision measurements, where usually a large luminosity is required. With the limited integrated luminosity used in the results presented in this document, the level of precision is not enough to perform indirect searches, while the increase of energies from 8 to 13 TeV already opened a new unexplored energy regime. In this proceeding, I'll present early results from the CMS collaboration on the search for new physics with the 13 TeV data, performed over summer 2015. The integrated luminosities used in the discussed analyses ranges from 42 to 175 pb^{-1}, and allow the direct search of heavy resonances, or to commission the observables used in other searches, where the luminosity is too small to be competitive with the results based on Run 1 data.

2. Search for resonances

A limited luminosity already allows to search for heavy resonances decaying into a pair of jets, by analyzing the di-jet invariant mass spectra [4]. This analysis has been already performed with the 8 TeV dataset [6]. At the Run 2, it is based on H_T trigger with a threshold of 800 GeV. Then, "wide jets" are reconstructed : starting from the 2 highest p_T jets (reconstructed with a cone of $\Delta R = 0.4$, and satisfying $p_T > 30$ GeV) used as seeds, other close by jets (within ΔR <1.1) are added to form 2 large jets. To avoid trigger bias, an offline cut on the di-wide-jet invariant mass is applied $M_{jj} > 1.1$ TeV. Wide-jets are further required to satisfy $|\Delta\eta| < 1.3$, in order to reject QCD t-channel events.

The corresponding di-jet invariant mass is presented in Fig.1. The signal and QCD background contributions are determined from a fit of the M_{jj} distribution, modeling the background using a empirical function. The dominant systematic uncertainties come from the luminosity (12%), the Jet Energy Resolution (10%) and Jet Energy Scale (5%).

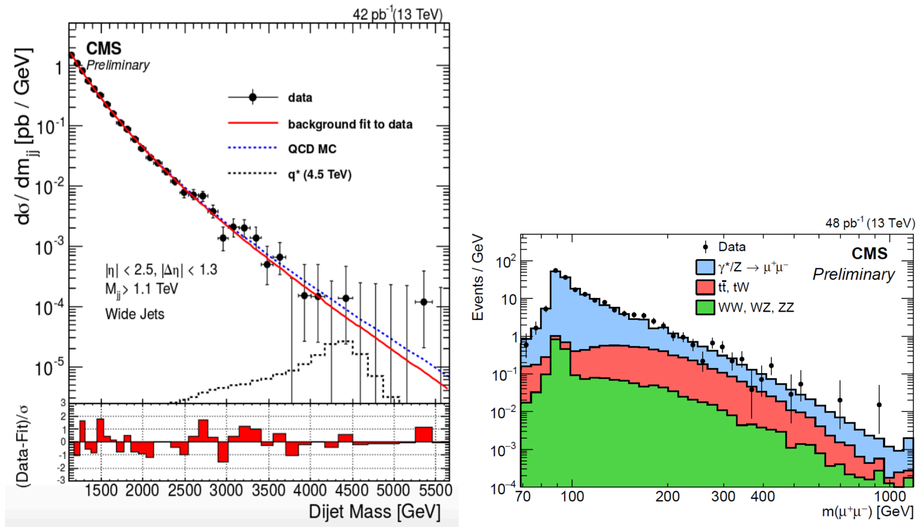

Figure 1: Left : Dijet mass spectrum (points) compared to a fitted parameterization (solid curve) and to the prediction of the PYTHIA8 QCD MC event generator including simulation of the detector (dashed curve). The lower panel shows the difference between the data and the fitted parametrization, divided by the statistical uncertainties. Right : The observed opposite-sign dimuon invariant mass spectrum together with the background expectation obtained from simulation. Background contributions are normalized to NLO predictions and to the estimated luminosity of 48 pb^{-1}. Contributions from W+jets and multijet events are negligible and not shown. The largest invariant mass observed is 920 GeV. The last bin includes the overflow.

No evidence of new di-jets resonances as been observed and exclusion limits at 95% confidence level are estimated assuming 3 different final states : qq, qg and gg. Exclusion limits ranges from 2.3 to 5.1 TeV, depending on the theoretical interpretation. Since the TOP2015 conference, this analysis has been updated with a larger luminosity [5].

Other searches for resonances can be performed in multiple channels (charged dilepton, or charge lepton and a neutrino). An example of the di-muon invariant mass [7] can be seen on the right plot of Fig.1. A good agreement can be seen between data and predictions.

3. Commissioning the performance of key observables for SUSY analyses

In the presented SUSY results, there is not enough integrated luminosity to be competitive with Run 1 analyses. However, a small amount of data can still be used for preparing SUSY searches, by first controlling selection efficiencies and background contamination, but also by performing preliminary data-MC comparisons of key observables. As discussed earlier, with first data, analyses focus on inclusive searches. Three main decay channels are studied [8] : first the all hadronic channels with the α_T, razor, and $MT2$ variables, the semi-leptonic channels with the $\Delta\phi$ and "sum-jet masses" variables and the dileptonic channel with the same-sign signatures.

As an example, in the all-hadronic channel, α_T is defined as $E_T(j_2)/M_T$, where j_2 refers to the second leading jet in the event. For di-jet QCD events, jets are mainly produced back-to-back in ϕ, that corresponds to $\alpha_T = 0.5$. Such variable appears to be robust against jet mis-reconstruction, as a jet imbalance in dijet events would yield to $\alpha_T < 0.5$. It can also be generalized to multi-jets events by merging jets into two large pseudo-jets. In the presence of missing transverse energy $\not{E}_T$, as it can be in SUSY events with neutralinos, α_T is expected to be larger than 0.5. The observed distribution of α_T in 13 TeV data is shown on the left plot of Fig.2.

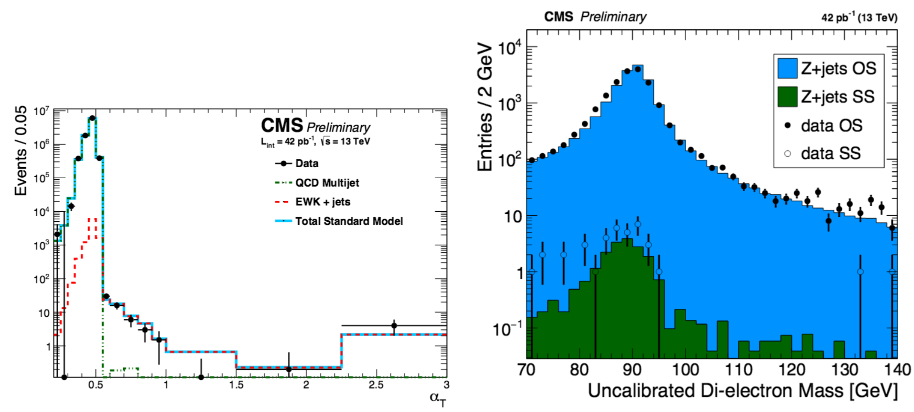

Figure 2: Left : the α_T distribution as measured in data for events that satisfy the event selection. Events satisfying $\alpha_T < 0.55$ are collected with a suite of prescaled low-threshold H_T triggers. The data yields are corrected to account for the prescale of the triggers. Events satisfying $\alpha_T > 0.55$ are recorded with the $H_T - \alpha_T$ signal triggers and must fulfill the signal region selection criteria [8]. Right : Opposite-sign and same-sign di-electron events that are used to extract the charge mis-identification probability. Electrons in both EE and EB are included, but the full procedure for energy calibration has not yet been applied.

Another example of early analyses is the search for events with same sign dilepton. Indeed, same sign di-leptons appear in many BSM processes, but are rare in the SM. The main background contributions are then arising from charge mis-reconstruction (especially important in electron channels, and estimated using Z events), the fake-lepton backgrounds from b/c semi-leptonic decays or from misidentification, and the SM processes with same sign di-lepton (such as $t\bar{t}$ produced in association with W or Z bosons, or diboson events). The opposite-sign and same-sign data-MC comparisons of the di-electron invariant mass are shown on the right histogram of Fig.2. A good agreement between data and prediction can be seen.

4. Search for $t\bar{t}$+DM

The direct search for new physics, in BSM event containing top-quarks, can also be prepared with a small integrated luminosity. Here is discussed the production of $t\bar{t}$ event in association with weakly interacting particles [9], which are possible candidates for Dark-Matter (DM) and thus are possibly inducing large $\not{E}_T$. The search is performed in the semi-leptonic channel (electron or muon), using events containing at least 3 jets with $p_T < 30$ GeV and $|\eta| <2.5$, and at least one jet passing tight b-tagging requirement. An additional requirement on the $\not{E}_T >160$ GeV is applied. The azimuthal angle between the two leading jets and the $\not{E}_T$, and the cosine of the azimuthal angle between the b-tagged jet and the $\not{E}_T$are shown in the left and right plots of Fig.3. A good description of the data is achieved through the simulation.

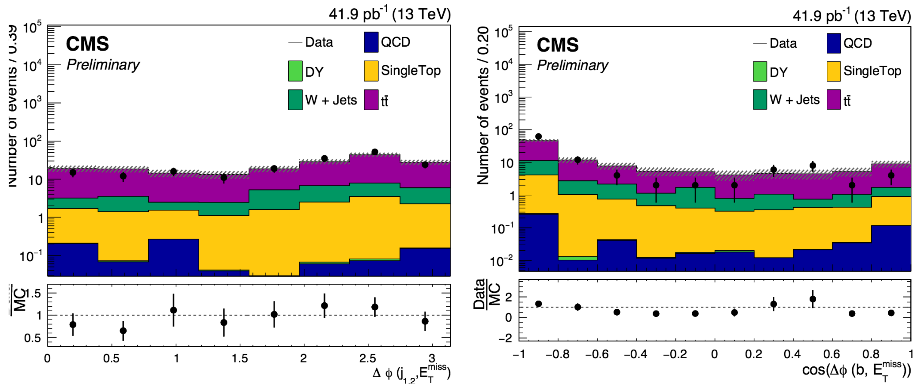

Figure 3: Left : azimuthal angle between the two leading jets and the $\not\!\!E_T$Ṙight : cosine of the azimuthal angle between the b-tagged jet and the $\not\!\!E_T$.

5. Conclusion

As a conclusion, one can observe that first 13 TeV data could already be used to search for new physics. In the case of the search for di-jet resonances, a better sensitivity than during Run 1 has even been achieved for the high mass region. While for most of the other searches, there is not enough statistics to be competitive with Run 1 analyses, the commissioning of analyses already started during summer 2015, and it shows good performances of the CMS detector.

References

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