

Searches for New Phenomena at the LHC

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Searches for physics beyond the Standard Model (SM) with the CMS¹ and ATLAS² experiments in pp collisions at a centre of mass energy of $\sqrt{s} = 7$ TeV at the LHC are presented. The discussed results are based on data taken in 2011, making use of integrated luminosities between $\mathcal{L} = 1.1$ and 4.9 fb^{-1} . Various important theories, encompassing TeV scale gravity, quark/lepton compositeness, contact interactions, new heavy vector bosons and other exotic signatures are probed.

1 Introduction

In the following is focused on non-resonant search channels where the invariant mass of a new particle can not be fully reconstructed due to its decay modes including undetected daughter particles or where the signal does not consist of the production of a resonant particle. Only new results (after the HCP conference in November 2011) are presented. A complete list of public analysis results in exotic searches for new physics (preliminary, published and submitted or accepted for publication) can be found in ref.³ and ref.⁴.

The next section covers the search for TeV scale gravity. The subsequent searches are dedicated to numerous different model interpretations and are categorised according to their final states into lepton production (section 3), lepton plus jet production (section 4) and jet production (section 5). In each category only one analysis is discussed here exemplarily. Further presented analyses are cited accordingly. Throughout this article the convention $c \equiv 1$ is adopted for the speed of light.

2 TeV scale gravity

The CMS search⁵ for microscopic black holes is based on $\mathcal{L} = 4.7 \text{ fb}^{-1}$. Energetic multiparticle final states including jets, bosons and leptons are selected by means of the scalar transverse momentum sum S_T , taking into account also the missing transverse energy E_T^{miss} of the event. The left plot in Fig. 1 shows the S_T distribution of the data for the $N \geq 3$ final state object multiplicity bin, together with the predicted background which is dominated by multijet production and has been estimated by means of the data.

Limits are set on production cross sections (Fig. 1, right) as a function of the minimum black-hole mass. These limits are interpreted in terms of minimal Quantum Black Hole masses $m_{\text{QBH}}^{\text{min}}$ as a function of the multidimensional Planck mass M_D for several extra dimensions. Further

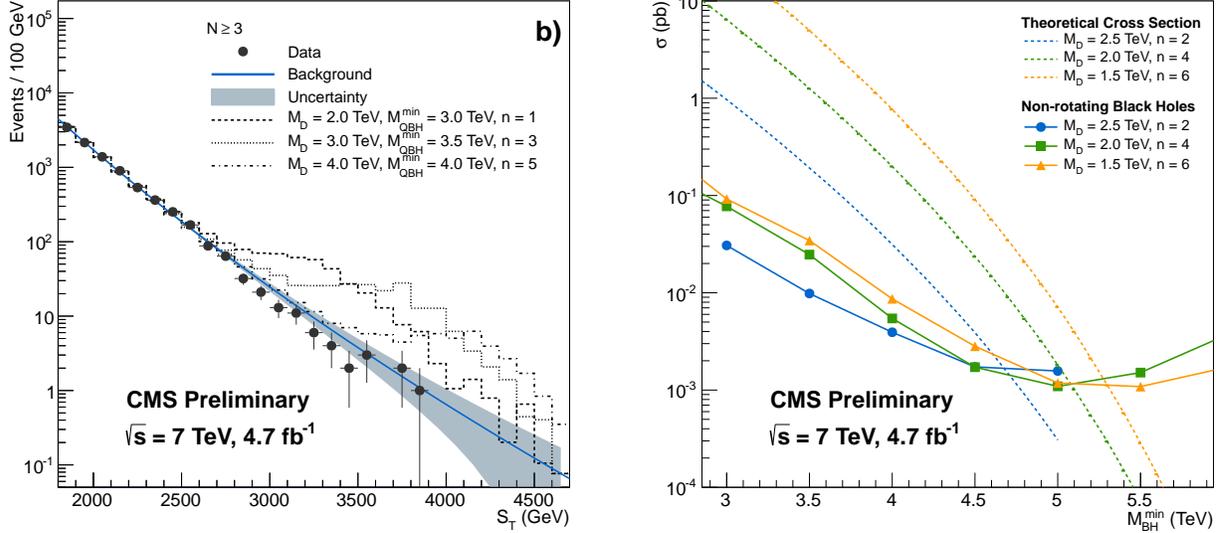


Figure 1: Left: S_T distribution in the $N \geq 3$ final state objects bin for data superposed by the background prediction with uncertainties. Some simulated signals with multidimensional Planck scale $M_D = 2 - 4$ TeV are indicated, too. At the right are shown cross section limits at 95% C.L. as a function of minimum black-hole mass for various black hole parameter sets.

limits on minimum string-ball mass and semi-classical black hole mass $m_{\text{BH}}^{\text{min}}$ are estimated, keeping in mind that the model validity breaks down for $m_{\text{BH}}^{\text{min}} \simeq 3 - 5M_D$.

Further new results in search of black holes, extra dimensions, dark matter and unparticles ^{6 7 8 9 10 11 12 13} have been presented.

3 Searches in lepton production

The ATLAS search ¹⁴ for excited leptons $\ell^* \rightarrow \ell\gamma$, $\ell = e, \mu$ is an update of the previous measurement ¹⁵ and makes use of $\mathcal{L}_{ee(\mu\mu)} = 4.9(4.8) \text{ fb}^{-1}$. The excited leptons are expected in the electromagnetic radiative decay channel $\ell^* \rightarrow \ell\gamma$, produced together with a charge conjugated same flavour lepton via a four-fermion contact interaction at a given compositeness scale Λ . The dominant background consists of Drell-Yan production plus an additional photon or jet. All background predictions are evaluated with simulated samples. Background from multijets and semileptonic heavy flavour decays is heavily suppressed by isolation requirements. In Fig. 2 left plot the invariant dilepton photon mass distribution is shown for the electron channel. The signal search region is defined by a sliding lower threshold of $m_{\ell\ell\gamma} > m_{\ell^*} + 150 \text{ GeV}$. 95% C.L. exclusion limits on the production cross section times branching ratio as a function of the excited muon invariant mass are shown in Fig. 2, right plot. For $m_{\ell^*} > 0.9 \text{ TeV}$ the observed upper limits on $\sigma \times BR$ are 1.0 fb and 1.9 fb in the e^* and μ^* channels, respectively. These limits are translated into bounds on the compositeness scale Λ as a function of the excited lepton mass. For $\Lambda = m_{\ell^*}$ masses below 2.0 TeV and 1.9 TeV are excluded for the e^* and μ^* channels, respectively.

Further new results in lepton production ^{16 17 18} have been presented.

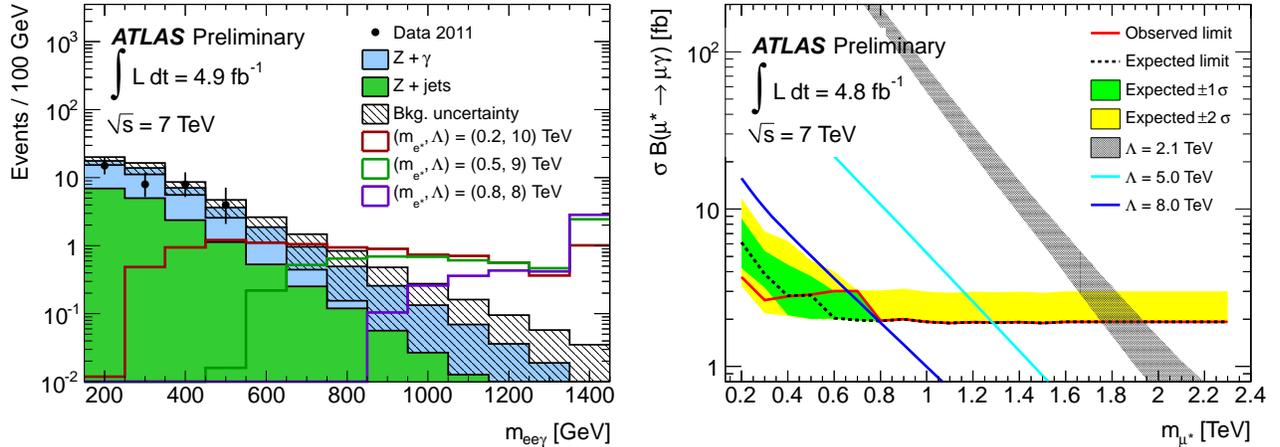


Figure 2: Left: $ee\gamma$ invariant mass distribution of data in comparison to simulation. In the right plot are shown the 95% C.L. exclusion limits on the excited muon production cross section times branching ratio as a function of its mass. Indicated are also three different compositeness scales Λ .

4 Searches in lepton + jet production

The CMS search¹⁹ for heavy bottom like quarks is based on $\mathcal{L} = 4.6 \text{ fb}^{-1}$. These b' quarks are assumed to decay exclusively to tW . Lighter b' quarks are disfavoured by results from previous experiments. The pair production $b'\bar{b}' \rightarrow tW^- \bar{t}W^+$ can be identified by the distinctive signatures of trileptons or same-sign dileptons, both accompanied by at least one b -jet. Jets are reconstructed with the anti- k_T jet algorithm making use of the distance measure $R = 0.5$ in rapidity y , azimuthal angle ϕ space. For a jet to be tagged as a b -jet the impact parameter significance of tracks is considered. The scalar sum of transverse object momenta and missing transverse energy has to exceed 500 GeV. The signal region is defined by at least four (two) jets in the same-sign dilepton (trilepton) channel. Top quark and Drell-Yan production constitute the dominant backgrounds which are determined by means of data. Top quark plus boson and diboson production background is determined by simulation. Exclusion limits at 95% C.L. on the $b'\bar{b}' \rightarrow tW^- \bar{t}W^+$ production cross section are set and translated into an exclusion limit of b' masses below 600 GeV.

Further searches in lepton plus jet production^{20 21 22 23} have been discussed.

5 Searches in jet production

The ATLAS search²⁴ for heavy vector-like quarks Q makes use of $\mathcal{L} = 1.04 \text{ fb}^{-1}$. The analysis is sensitive to the charged current via the process $pp \rightarrow Qq \rightarrow Wqq'$ and the neutral current via the process $pp \rightarrow Qq \rightarrow Zqq'$ with leptonic decay of the vector boson. If vector-like quarks exist they are expected to couple in general only to the third generation sizably. A coupling $\tilde{\kappa}_{qQ}$ is introduced to describe the model dependence of the qVQ vertex, with V being one of the vector bosons W or Z . Events with at least two jets and a leptonically decaying vector boson are selected. The dominating background is vector boson plus jet production, followed by top and diboson production which are determined from simulation. Multijet background is estimated from data. Jets are determined by means of the anti- k_T algorithm with distance measure $R = 0.4$. 95% C.L. exclusion limits on the production cross section times branching ratio into a vector boson plus jet have been set. Assuming the coupling strengths $\tilde{\kappa}_{uD}^2 = 1$ and $\tilde{\kappa}_{uU}^2 = 1$ and the branching ratio $BR(Q \rightarrow W/Z + \text{jet}) = 100\%$, heavy quark masses m_Q below 900 GeV in the charged current and below 760 GeV in the neutral current can be excluded.

Further new searches^{25 26} in jet production have been presented as well as the long-lived particle searches^{27 28}.

6 Conclusions

Various CMS and ATLAS searches for new phenomena have been presented here. Complete tables of exclusion limits for all existing analysis channels can be found in ref.²⁹, pp31.

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