Searches for new Physics with Leptons and/or Jets at CMS

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Using up to 4.98 fb^{-1} of proton-proton collision data accumulated at a center-of-mass energy of 7 TeV in 2011, CMS has searched for signs of new physics in final states with leptons and jets. Many different production and decay signatures have been investigated, showing good agreement with Standard Model predictions. Mass limits for the production of new, heavy particles have been set ranging from few hundred GeV up to several TeV, including limits on the mass of the Z' and W' of the Sequential Standard Model of $M(Z') >$ 2.3 TeV and $M(W') > 2.5$ TeV at 95% confidence level.

1 Introduction

The CMS [1] experiment at the CERN LHC [2] successfully recorded proton-proton collisions with an integrated luminosity of $\mathcal{L} = 4.98\ \mathrm{fb}^{-1}$ during data taking in 2011. These data have been used to search for signs of new physics beyond the Standard Model.

We report the progress on searches for new heavy electroweak gauge bosons (Z', W') with leptons in the final state, searches for a right-handed W_R-Boson and heavy neutrino in the leptons+jets final state, and on searches for particles produced and decaying through the strong force in final states with two or more jets.

2 Searches for resonances decaying to leptons

A new, neutral, heavy Boson Z' naturally arises in Grand Unified Theories and is a prime candidate for these searches [3]. Under the assumption of couplings equal to those of the Z Boson, the decay to leptons $\ell = e, \mu$ is an experimentally sensitive search channel. Here, two well isolated electrons or muons are required, with a vertex requirement for the muons in order to reduce background from cosmic muons. The muons need to be oppositely charged, whereas this requirement is not applied for electrons due to the worse momentum resolution and thus difficult charge measurement at high transverse momenta. In order to reduce fakes, one electron is required to be in the barrel region. The dominating background in this search is Drell-Yan production, which is estimated from simulation and scaled to the data in a region 80–120 GeV around the Z peak. Systematic uncertainties due to a p_T dependent k-factor have been estimated with FEWZ [4] and are below 10%. Top-Pair production and other background with prompt lepton pairs have been taken from simulation, and the signal-free distribution of $e\mu$ pairs shows a good agreement between data and simulation. QCD jet data has been estimated from data outside the signal region. PDF uncertainties contribute less than 10% to the total systematic uncertainty of $\approx 12\%$ in the range 200 GeV–2 TeV.

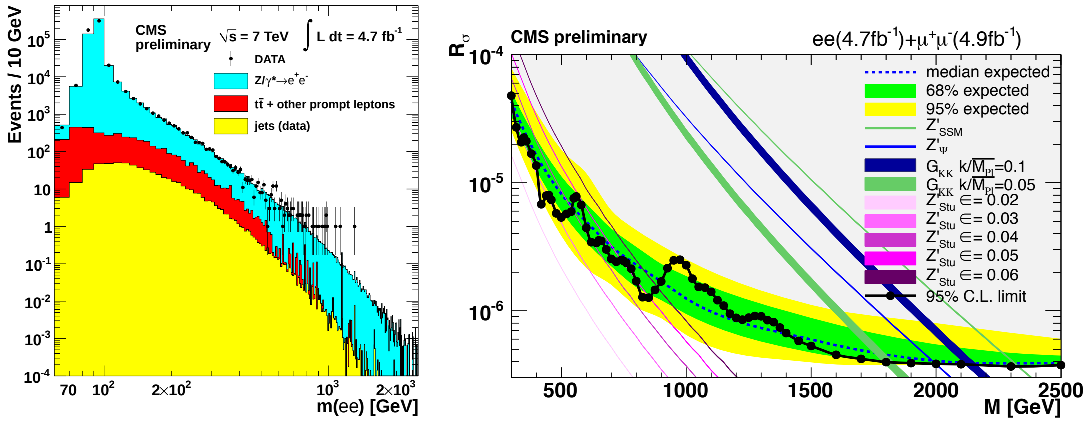

Figure 1: Search for resonances in dileptons (ee, $\mu^+\mu^-$). Left: Invariant mass of two electrons after selection. Right: Exclusion limits on Z' and other models.

Figure 1 (left) shows the invariant mass of the two electrons for the electron selection, and a good agreement between simulation and data is found, whereas the right part shows exclusion limits for some Z' and other physics models. A Z' with mass $M > 2.3$ TeV in the Sequential Standard Model can be excluded with 95% confidence level (CL).

Searches for a new charged heavy W' Boson with couplings equal to those in the Standard Model have been performed in the lepton and missing energy channel [5]. In this search, an isolated electron or muon is required. In the r-ϕ-plane, the neutrino from the W' carries away an amount of energy approximately equal to the lepton momentum p_T^ℓ but in opposite direction. The selection therefore requires the transverse missing energy E_T^{miss} to be in the range $0.4 < p_T^\ell / E_T^{miss} < 1.5$ and $\Delta\phi > 2.5$ between lepton and E_T^{miss}.

The transverse mass $M_T = \sqrt{2 \cdot E_T^{miss} \cdot p_T^\ell (1 - \cos\Delta\phi)}$ is used as a test distribution, shown in the left part of Figure 2. A good agreement between data and simulation is observed. In order to be independent from possible interference effects, the function $f(M_T) = a/(M_T + b)^c$ is fitted to simulation and scaled to data in the range 200 GeV $< M_T <$ 500 GeV. This function is used to determine the number of background events above an optimized M_T threshold. The limits are obtained from a Bayesian single-bin counting experiment with event numbers taken above the M_T threshold. Systematic uncertainties mainly arise from the measurement of E_T^{miss} and are about 2% on the number of events above the M_T threshold. Expected and observed limits on the W' mass are shown in Figure 2 on the right, and $M(W') > 2.5$ TeV at 95% CL. Considering constructive interference between W and W', the exclusion limit changes to $M(W') > 2.63$ TeV and to $M(W') > 2.43$ TeV for destructive interference.

3 Searches with leptons and jets

A fully left-right symmetric extension of the Standard Model predicts the existence of both right-handed charged gauge bosons W_R and heavy neutrinos N_ℓ. Under quite general assumptions,

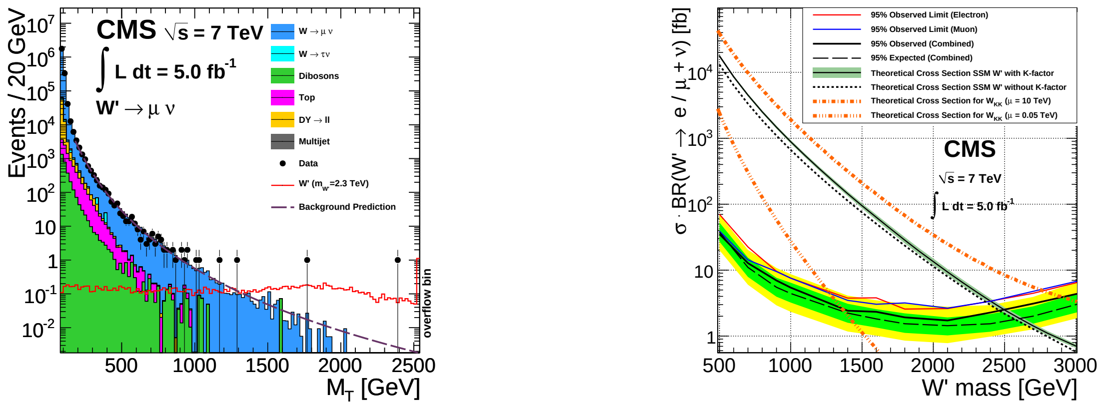

Figure 2: Search for W'. Left: Transverse mass of W' candidates in the $e\nu_e$ channel after selection. Right: Exclusion limits on W' and other models for the $e\nu_e + \mu\nu_\mu$ channels combined.

the W_R can be resonantly produced and decays via a heavy Neutrino N_ℓ in a two jet two lepton final state. In this search [6], a pair of isolated same-flavour leptons $\ell = e, \mu$ is required. The two highest p_T jets in the events are considered as candidates from the W_R decay. Contribution from Z+jets is reduced by requiring the invariant mass $M_{\ell\ell} > 200$ GeV $\gg M_Z$. The cross-section for the Z+jets process has been estimated at the Z-peak, and QCD jets background is estimated from the data themselves. A further reduction of Standard Model backgrounds is achieved by requiring a high dijet invariant mass $M_{jj} > 520$ GeV.

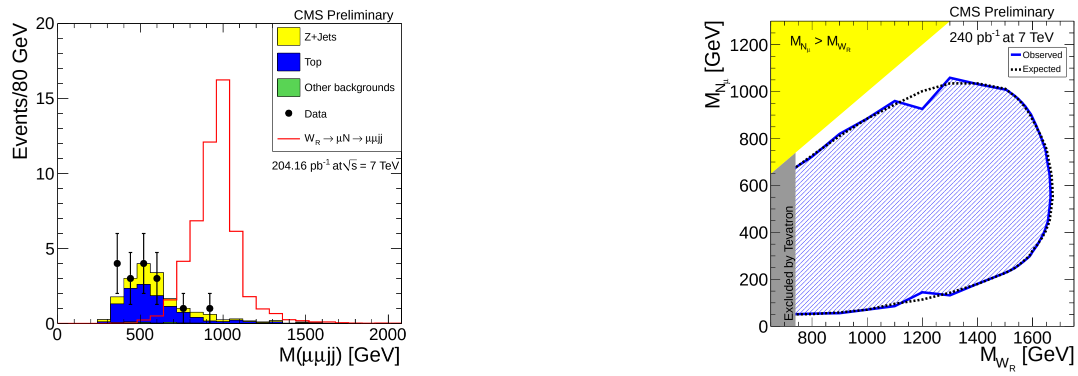

Figure 3: Search for a right-handed W_R Boson. Left: $M_{\mu\mu jj}$ mass after selection. Right: Expected and measured exclusion contour in the $M(W_R)$-$M(N_\ell)$ plane.

Figure 3 (left) shows the distribution of the $M_{\mu\mu jj}$ mass after selection, with a signal $M(W_R) = 1$ TeV and $M(N_\ell) = 600$ GeV overlaid. The figure shows a good agreement between data and simulation and no signs for a signal. Systematic uncertainties on event numbers are 10-25% with large contributions from the jet energy scale and the QCD jets background estimate. Exclusion limits, which are shown in Figure 3 (right) in the $M(W_R)$-$M(N_\mu)$ plane, have been set with a multibin Bayesian counting experiment including systematic uncertainties. A very similar exclusion is obtained for the W_R decay to N_e.

4 Searches with jets

Searches for new physics have also been performed in a two-jet final state [7]. Here the assumption is the resonant production of strongly coupling and decaying new narrow resonances. Two "wide jets" are formed and their invariant mass is used for the search for new physics. Detector effects dominate the mass resolution and thus generic templates are used for excluding resonances decaying to quark-quark, quark-gluon and gluon-gluon final states. Exclusion limits at 95% CL are shown in Figure 4 (left). The observed limits at 95% CL are $M > 4.00$ TeV for string resonances, $M > 2.49$ TeV for excited quarks, $M > 2.47$ TeV for axigluons/colorons, $M > 3.52$ TeV for E_6 diquarks and $M > 1.51$ TeV for W'. The largest systematic uncertainties are the jet energy resolution and scale with approximately 15% uncertainty on the number of background events.

Figure 4 (right) shows the 95% CL exclusion limits obtained from the search for pair-produced particles in the four-jet final state [7], with the example of a coloron exclusion in the range 320 GeV $< M(C) <$ 580 GeV.

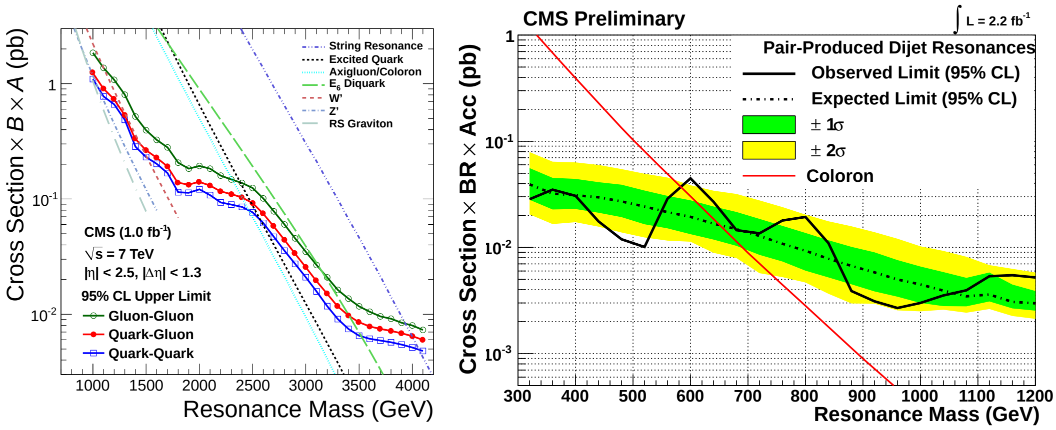

Figure 4: Exclusion limits on various models in the di-jet (left) and four-jet final state (right).

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