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Search for narrow resonances in dilepton mass spectra in p-p collisions at $\sqrt{s} = 13$ TeV and combination with 8 TeV data

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Summary. — Many well-established models extending beyond the standard model predict the existence of new heavy neutral bosons that would decay in two leptons. A search for new narrow resonances, generically referred to as Z', in the dielectron and dimuon decay channels has been performed using data collected by the CMS experiment in 2016 from proton-proton collisions at a center-of-mass energy of $\sqrt{s} = 13$ TeV (corresponding to an integrated luminosity of $13\,\text{fb}^{-1}$) and combining the 2015 13 TeV data ($2.9\,\text{fb}^{-1}$) with a previous analysed set of data obtained at $\sqrt{s} = 8$ TeV ($20\,\text{fb}^{-1}$). In the absence of a significant deviation from the standard model predictions, 95% confidence level limits are set on the ratio of the production cross-section times branching fraction for high-mass resonances to that for the Z boson. For several models, lower limits on the resonance mass are derived.

1. – Introduction

The dilepton (ee or $\mu\mu$) final-state signature is a key search channel for various new phenomena expected in theories that go beyond the standard model (SM). One of the most clean signatures would be the observation of a narrow resonance in the invariant-mass spectrum of lepton pairs, predicted by many models at the TeV scale. Examples include models described with extended gauge groups, featuring additional $U(1)$ symmetries such as the sequential standard model (SSM) that includes a Z'_{SSM} boson with SM-like couplings and the grand unification theories (GUT) inspired models, based on the E_6 gauge group, with a Z'_{ψ} boson. This search channel benefits from high signal selection efficiencies and relatively small, well-understood, backgrounds.

2. – The CMS detector

CMS (compact muon solenoid) is one of the most important detectors at the LHC [1]. Its name is due to the superconducting solenoid providing an axial magnetic field of

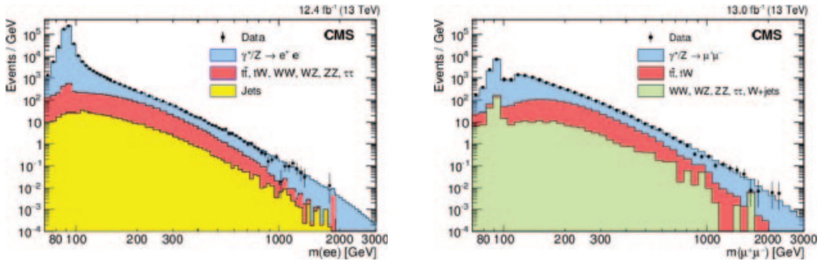

Fig. 1. – The invariant-mass spectrum, together with the predicted SM backgrounds, for the ee channel on the left and for the $\mu\mu$ channel on the right [2]. No evidence for a signal deviation from the SM expectations is observed.

3.8 T: it encloses an inner tracker, an electromagnetic calorimeter (ECAL), and a hadron calorimeter (HCAL). The muon detection system consists of up to four layers of gas-ionization chambers installed outside the solenoid and sandwiched between the layers of the steel flux return yoke. The CMS experiment uses a two-level trigger system: the former, L1, selects events of interest using information from the calorimeters and muon detectors; the second, the high-level trigger (HLT), uses software algorithms accessing the full event information.

3. – Event selection

Event selection requires some conditions on the final-state object: at the HLT, it is requested for the electron to have a transverse energy $E_T > 33\,\text{GeV}$, while for muons a transverse momentum $p_T > 50\,\text{GeV}/c$ and $|\eta| < 2.4$. In the offline reconstruction, the electron must have $E_T > 35\,\text{GeV}$ and $|\eta_C| < 1.4$ or $1.56 < |\eta_C| < 2.5$; the muon instead must have $p_T > 53\,\text{GeV}/c$. It is required that the electrons must pass the HEEP (high-energy electron pair) selection while the muons must pass the high-p_T muon ID. Finally, the isolation criterion is imposed on both electrons and muons. The selected leptons are used to form dielectron or dimuon candidates. If more than one dilepton candidate is found in the event, only the one with the two highest-p_T leptons is retained.

4. – Background

The dominant and irreducible SM background to a Z' decaying to a lepton pair (ee, $\mu\mu$) arises from the Drell-Yan process ($Z/\gamma^* \to \text{e}^+\text{e}^-/\mu^+\mu^-$). Additional sources of background are Drell-Yan $\tau^+\tau^-$, diboson (WW, ZZ, WZ), top-antitop quark ($t\bar{t}$) and single top quark (tW) in which the two prompt leptons are from different particles. Multijet, $W +$jets and $\gamma +$jets processes contribute, mainly in the electron channel, due to non-prompt and misidentified leptons (see fig. 1).

5. – Analysis strategy and results

Using a Bayesian approach with an unbinned extended likelihood function, limits are derived for the production of a narrow spin-1 (Z'_{SSM}, Z'_{ψ}) and spin-2 heavy resonance (G_{KK}) —see fig. 2. The likelihood function is based on probability density functions that describe the signal and the background contributions to the invariant-mass spectra: the

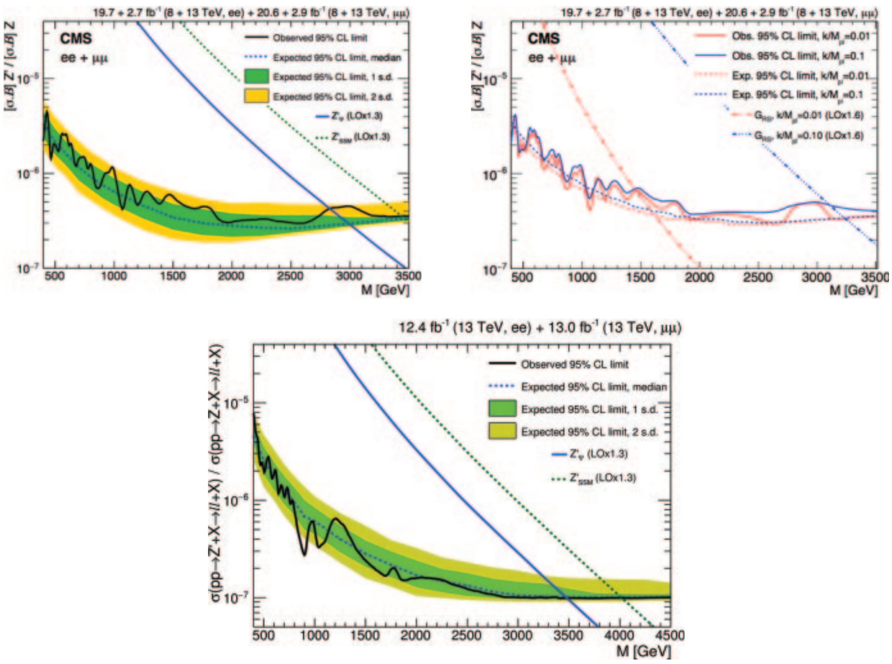

Fig. 2. – The 95% CL upper limits on the production cross-section times branching fraction for a spin-1 (top left) and for a spin-2 (top right) resonance relative to the production cross-section times branching fraction for a Z boson, for the combined dielectron and dimuon channels using data collected during Run I ($20\,\mathrm{fb}^{-1}$) and during 2015 Run II ($2.9\,\mathrm{fb}^{-1}$) [3]. Bottom: the 95% CL upper limits for a spin-1 resonance for the combined dielectron and dimuon channels using data collected during Run II in 2016 ($13\,\mathrm{fb}^{-1}$) [2].

signal is parametrized by the convolution of a Breit-Wigner and a Gaussian function while the parametrization of the background is obtained by fitting the background distribution. The limit are set on the parameter R_σ which is the ratio of the cross-section for dilepton production through a Z' boson to the cross-section for dilepton production through a Z boson.

For the Z'_{SSM} particle and for the superstring inspired Z'_ψ particle, 95% confidence level lower mass limits are found to be 4.0 TeV and 3.5 TeV. The corresponding limits for Kaluza-Klein gravitons (G_{KK}) with coupling parameters of 0.01 and 0.1 are 1.46 and 3.11 TeV respectively.

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