Dark matter searches with CMS

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Abstract

The existence of dark matter, indicated by astronomical observations, is one of the main proofs of physics beyond the standard model. Despite its abundance, dark matter has not been directly observed yet. This talk presents several searches for dark matter production in proton-proton collisions at 7, 8, and 13 TeV at the LHC, performed by the CMS collaboration. They are interpreted in terms of simplified models with different structures and mediators, as well as generic effective theory terms.

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Dark-Matter searches with CMS

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The CMS collaboration has performed searches for Dark-Matter production based on data taken in in proton-proton collisions at 7, 8, and 13 TeV with the CMS detector [1] at the LHC. They have been interpreted in terms of simplified models with different structures and mediators as well as by using generic effective theory terms.

For spin-independent processes (due to vector or scalar interactions) experimental cross-section limits are currently dominated by direct-detection experiments for Dark-Matter particle masses above about 10 GeV while the lower mass range appears better accessible to collider experiments. Spin-dependent processes (caused by axial-vector or pseudoscalar interactions) are hard to measure by direct detection and limits are dominated by collider results over a wide range of Dark-Matter particle masses.

The Run-1 analyses of data taken at collisions energies of 7 and 8 TeV formulated the interpretation of results mostly in terms of Effective Field Theories assuming a contact interaction, which is valid in cases where the mass of the mediator particle is much higher than the momentum transfer in the process. At higher energies this assumption becomes less justified and newer analyses interpret results in terms of explicitly defined mediator particles [2, 3].

As the Dark-Matter particles themselves would be invisible for the CMS detector, they should show up in terms of missing transverse momentum or missing transverse energy (“MET” for “missing $E_T$”) together with visible Standard-Model particles that could arise from initial-state radiation (ISR) or in decay cascades. Many analyses target one such object plus MET and are therefore dubbed “mono-X” searches, such as “mono-jet” [4], “mono-photon” [5], “mono-Z” [6] and “mono-W”.

Just as in the case of any analysis of hadron collider data, it is essential to correctly define and assess background events. Background is usually measured in control regions (data-driven approach) and applied to signal regions by using Monte-Carlo simulations to calculate the corresponding “transfer factors”. So, in the monojet analysis, which requires a high-energy jet plus MET and vetoes leptons, the dominant background channels are $(Z \to \nu \nu) + \gamma$/jets and $(W \to \ell \nu) + \gamma$/jets (where the lepton is lost). These backgrounds can be best studied by using control regions with $Z \to \mu \mu$ and $W \to \mu \nu$ events.

Another analysis targets heavy-flavor quarks, which could strongly couple to scalar and pseudoscalar mediators. This analysis requires events with one or two b-tagged jets and is also sensitive to top decays. Also in this case, $(Z \to \nu \nu) + \text{jets}$ and $(W \to \ell \nu) + \text{jets}$ are the dominant sources of background [8].

Another possibility are the so-called “Higgs-Portal” models of Dark Matter, in which the Higgs boson would be the mediator between Standard-Model and Dark-Matter particles [9]. In this case, the Higgs boson would in some cases decay into invisible particles. Such decays can be investigated using Higgs production by vector boson fusion or in associated ZH production, where the final state contains jets or leptons in addition to the Higgs boson. The combined limit from the different analyses on the invisible branching ratio of Higgs decays is 32%.

So far, no signals of Dark Matter have been seen at the LHC from the data taken in Run 1 (at $\sqrt{s} = 7$ and 8 TeV) or at the beginning of Run 2. The start-up of the LHC after “Long Shutdown 1” at the increased collision energy of $\sqrt{s} = 13$ TeV required many technical adjustments and only a few fb$^{-1}$ of luminosity could be acquired in 2015. Therefore, in spite of higher cross sections at higher energy in most cases the 2015 data have not allowed to improve limits over LHC’s Run 1 but the present fast luminosity build-up of LHC lets expect that this situation will soon change, resulting either in a discovery of Dark-Matter particles or in significantly
improved limits.
Bibliography


CMS Collaboration, Search for dark matter with jets and missing transverse energy at 13 TeV; CMS-PAS-EXO-15-003


