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Search for dark matter at LHC through the monojet signature

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Summary. — Dark matter is one of the most fascinating topics of modern physics. Its existence is confirmed by many astrophysical observations, yet the Standard Model (SM) does not provide any particle that can explain its abundance in the universe. In this paper we describe the search for dark matter in events with large missing transverse energy and one or more high energy jets with the CMS detector at the CERN Large Hadron Collider (LHC). Results obtained with the 13 TeV data collected during 2015 are presented and compared to 8 TeV data. The discovery potential for the 13 TeV analysis is also discussed.

1. – Introduction

Many astrophysical observations suggest that a large fraction of the universe energy content is made of dark matter (DM). DM is observed through its gravitational interaction with visible matter and is neutral with respect to strong and electromagnetic interactions. However, it might be composed of weakly interacting massive particles (WIMP) and could couple to SM particles. Therefore, it might be possible to produce DM at LHC through partons (quarks and gluons) interaction in proton-proton collisions. According to so-called "simplified models", DM is resonantly produced in pairs through the exchange of a heavy mediator from the colliding partons. Benchmarks for the interpretation of results obtained in DM collider searches were organized by the Dark Matter Forum [1].

DM particles do not produce any visible signal in the detector. In order to infer their presence, the initial state radiation (ISR) of a quark or gluon from the colliding partons is exploited to trigger on signal events. The ISR parton is detected as a jet, which is a spray of hadrons produced as a consequence of the fragmentation of quarks and gluons. In the transverse plane (orthogonal to the beam axis) the total momentum must

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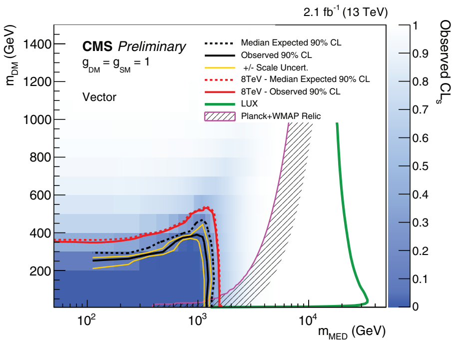

Fig. 1. – Figure shows 90% CL exclusion contours in the $m_{\mathrm{DM}} - m_{\mathrm{med}}$ plane (DM and mediator mass) under the assumption of a vector mediator, with g_{DM} and g_{SM} couplings to dark matter and quarks respectively. The excluded region is to the bottom left of the contours. Limits from direct and indirect DM searches are shown for comparison.

be zero because of momentum conservation. Undetected particles produce a transverse momentum imbalance whose magnitude is called missing transverse energy or $E_{\mathrm{T}}^{\mathrm{miss}}$. The experimental signature for DM production is thus given by one or more high energy jets and high values of $E_{\mathrm{T}}^{\mathrm{miss}}$ [2]. The expected signal is an excess of events in the high $E_{\mathrm{T}}^{\mathrm{miss}}$ region and is extracted through a binned maximum-likelihood fit to the $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution. The main backgrounds consist of Z($\nu\nu$)/W(lν)+jets events. They are identical to the signal due to the production of undetected neutrinos (the lepton from the W can fall outside the detector acceptance) and are estimated through 5 control regions in data consisting of Z/W/γ+jets events, where the Z/W boson decays either to muons or electrons. Other backgrounds are estimated through Monte Carlo simulations.

2. – Data analysis and results

The analyzed dataset corresponds to 2.1 fb^{-1} collected with a centre of mass energy of 13 TeV. Signal events are selected requiring $E_{\mathrm{T}}^{\mathrm{miss}} > 200$ GeV, at least one jet with transverse momentum $p_T > 100$ GeV and $\Delta\phi > 0.5$ between $E_{\mathrm{T}}^{\mathrm{miss}}$ and any of the leading four jets. The last requirement ensures a back-to-back topology and reduces QCD background where $E_{\mathrm{T}}^{\mathrm{miss}}$ originates from bad jets' energy measurements. Events with well identified and isolated photons, charged leptons or b-quark jets are rejected to suppress contamination from electroweak or top quark backgrounds.

Results are interpreted in terms of a vector mediator decaying to a pair of DM particles. No significant excess is observed in the $E_{\mathrm{T}}^{\mathrm{miss}}$ spectrum and 90% CL exclusion contours in the $m_{\mathrm{DM}} - m_{\mathrm{med}}$ plane (DM and mediator mass) are set. As shown in fig. 1, the 13 TeV analysis excludes mediator masses up to 1.3 TeV and is almost competitive with the 8 TeV one [3] (with 19.7 fb^{-1}). Limits are also compared to those from direct and indirect search experiments. The former, like Fermi-LAT, look for annihilation of DM into SM particles while the latter, like LUX, try to detect the scattering of DM particles on nuclei (see references in [2]). It is expected that the 13 TeV analysis will reach the same sensitivity as the 8 TeV one already with 5 fb^{-1} of integrated luminosity as a consequence of the higher centre of mass energy that enhances the cross-section for heavy particle production.

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