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Search for Dark Matter with mono-X Signatures in CMS

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Searches in CMS for dark matter in final states with invisible particles recoiling against visible states are presented. Various topologies and kinematic variables are explored, including jet substructure as a means of tagging heavy bosons. In this talk, we focus on the recent results obtained using the full Run-II dataset collected at the LHC

XVIII International Conference on Topics in Astroparticle and Underground Physics 2023,
28 August-1 September 2023,
Vienna(Austria)

*Speaker

https://pos.sissa.it/

PoS(TAUP2023)074

1. Introduction

It is known from several astrophysical and cosmological tests that Dark Matter (DM) exists. Despite indirect studies measuring it at around 27% [2] of the universe's overall energy density, It's not yet known precisely what makes up DM particles. What we know is that it has no connection with normal baryonic matter, is electrically neutral, and is only detected through gravitational interactions. The CMS collaboration looks to identify particle production at CERN's LHC and translate the data into simplified models that incorporate new interactions between particles that defy standard model (BSM). Interaction of the dark sector and standard model (SM) is carried out through the BSM boson. Four parameters characterize the BSM models, which include a fermion DM particle and a BSM boson: mediator's mass m_{med}, dark matter's mass m_{DM}, coupling constants of mediator to dark matter (g_{DM}) and coupling constants of mediator to quarks g_q [4]. These hunts depend on an absence of transverse momentum p_T^{miss} alongside a viewable particle, being that DM particles alone could be unable to impart signals in the LHC detectors. The findings shown here use the entire Run-2 data set that corresponds to 137 fb^{-1} interactions of protons that occurred at $\sqrt{s}$ = 13 TeV and were captured by the CMS detector.

2. Mono-jet/V

Through events with a distinctness in transverse momentum and several powerful jets that arise from vector boson hadronic decay or initial state radiation, a mono-jet topology is achieved(W^{+-} or Z). Couple of signal types are specified one for events with a known V candidate, and another without it. The most prevalent backgrounds (W+jets and Z+jets) has been determined through certain control regions. For the extraction of the signal, a simultaneous shape fit is being carried out, taking advantage of the allocation of complete transverse momentum rebounds contrary to hadronic enterprise in an events. No notable departure from the background prediction is noticed. This leads to newly excluded areas within these models' domain of parameters by imposing limitations within the signal levels of the BSM scenarios under examination. Figure 1 displays the exclusion limits for the m_{med} - m_{DM} plane signal strength at 95% CL[1].

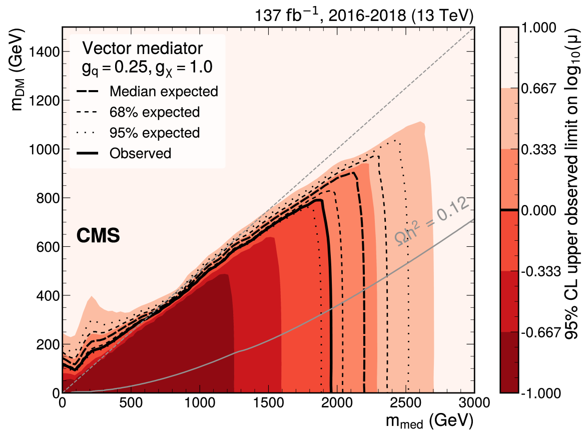

Figure 1: Exclusion limits for the signal strength $\mu = \sigma / \sigma_{theory}$ at 95% CL in the m_{med} - m_{DM} plane, where the coupling parameters are g_q=0.25 and g_{DM}=1.0

3. Mono-Z

The formation of a couple of leptons ($e^+ \, e^-$ or $\mu^+ \, \mu^-$) similar to being derived using the Z boson plus considerable amount of missing transverse momentum, is the final state of this analysis. No less than a single lepton in the duo should have P_T > 25 GeV, whereas other lepton should carry P_T > 20 GeV. To minimize the non-resonant background, the dilepton invariant mass is applied, which must fall within the average Z boson mass by 15 GeV m_Z [5]. A simultaneous fit is performed on P_T^{miss} and m_T distributions in two distinct BSM models to obtain the signal. The observed events appears to be in accordance with background predictions within the scheme of simplified model and 2HDM+a, with upper limits on Dark Matter production set. Fig. 2 (left) displays the vector mediators' limits with respect to the mediator mass m_{med} and dark matter mass m_{DM}, Mediator mass up to 850 GeV has been excluded. The limits on the heavier and lighter pseudo-scalar mediators have been shown in Figure 2(right) along with the mixing angle $sin(\theta)$ =0.35 and $tan(\beta)$= 1. Mediator mass with more sensitivity is m_A =1000 GeV, where observed(expected) limit on m_a is 440(340) GeV. The limit on m_a for small values of m_a is around 1200 GeV.

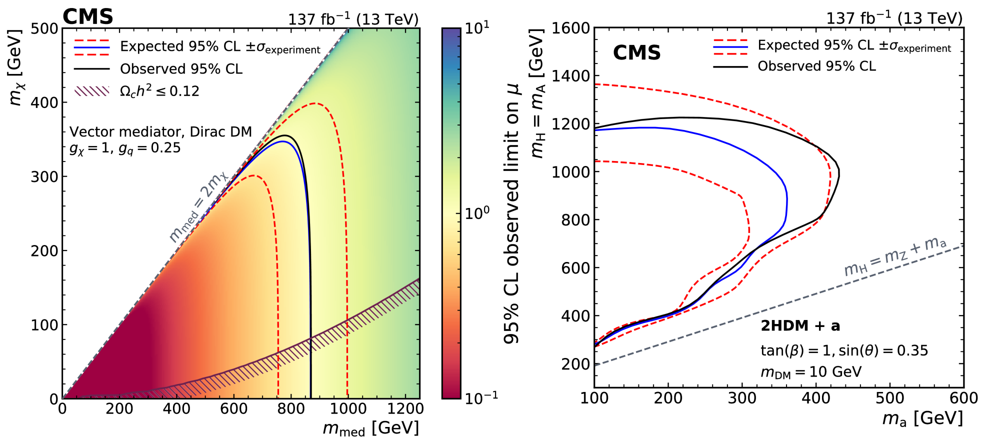

Figure 2: The 95% confidence level for the vector simplified models(left) and on the 2HDM+a model with the mixing angles set to $tan(\beta)$= 1 and $sin(\theta)$= 0.35 and additionally, the DM particle has mass m_χ= 10 GeV (right)

4. Mono-Higgs

Dark matter particle search is conducted using higgs boson candidate events and a substantial missing transverse momentum. The investigation was conducted on proton-proton collision data gathered through the CMS experiment within the LHC during 2016 at a center-of-mass energy of 13 TeV, equivalent to an integrated luminosity of 35.9 fb^{-1}. The search takes place through the five Higgs boson decays channels: H $\longrightarrow$ b$\bar{b}$, $\gamma\gamma$, $\tau^+\tau^-$, W^+W^- and ZZ, and the outcomes from particular channels are pooled to increase the sensitivity of the search. None of the five channels, alone or in combination, have any excess above the standard model background. Production limits for DM have been defined in the framework of both simple models. For both the model, H $\longrightarrow$ b$\bar{b}$ dominates the senstivity, hence combined result are dominated by this channel. For the Z'-2HDM model $\rightarrow b\overline{b}$ has no senstivity below $m_{Z'} < 800$ GeV, h($\gamma\gamma$) and h($\tau^+\tau^-$) contribute most here as shown in figure3(left). Baryonic Z' model is dominated by $b\overline{b}$ channel as shown in figure 3(right).

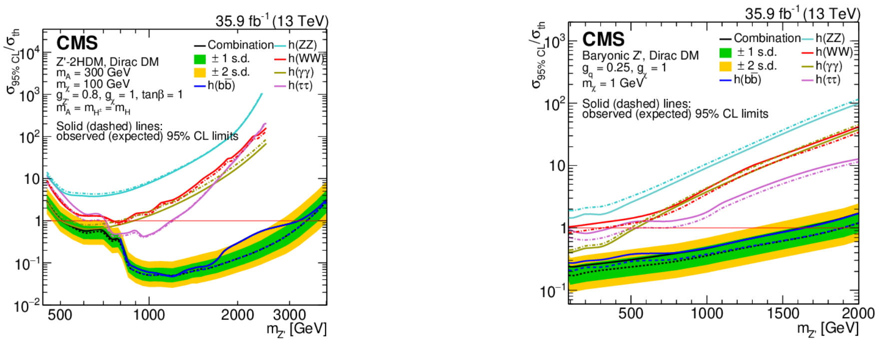

Figure 3: The upper limit at 95% CL on the observed and expected σ/σ_{th} for the five individual decay channels of the higgs boson and their combination in the Z'-2HDM(left) and Baryonic Z'(right) models

5. Summary

Numerous new dark matter search results using a broad mass range have been presented by the CMS collaboration. The strictest bounds are placed on a range of signal theories. In the near future, more searches using the entire Run-II dataset in search of dark sector mediators are anticipated.

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