PROCEEDINGS OF SCIENCE

Searches for dark matter with CMS

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A wealth of searches for models featuring dark matter candidates is pursued at the Large Hadron Collider, featuring a large variety of signatures and theoretical models of the so-known as dark sector. In this note, several recent representative CMS summary plots, condensing results for different CMS searches will be presented. A few examples of searches with unconventional signatures will be briefly discussed as well.

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1. Introduction

The existence of dark matter (DM) is inferred from astrophysical observations coming from galaxy rotation curves, bullet clusters or strong gravitational lensing. A myriad of experiments take part in the hunt for dark matter, using complementary approaches commonly known as direct detection, indirect detection or collider searches. At the Large Hadron Collider (LHC), many extensions beyond the standard model (BSM) are considered in order to cover as much theory of the dark sector (DS) as possible. The models can be classified as simplified models and sectors, and extended dark sectors. In the first case, a single mediator is considered, such as a spin-1 portal featuring vector or axial-vector mediators, dark photons, etc; or a spin-0 portal, including scalar or pseudoscalar mediators, dark Higgs, etc. In the extended case, more complex dynamics of the dark sector are included. Some examples are supersymmetry, hidden valleys, 2HDM+a models or inelastic dark matter.

Recently, an extensive summary of the different models covered by CMS [1] has been released [2]. In this note, some representative summary plots included in that document will be presented. In Section 2, a selection of the plots will be shown, while in Section 3, results for some dark QCD models, as an example of an extended DS featuring unconventional signatures, will be presented.

2. Summary plots for simplified dark sectors

In the case of the spin-1 portal, exclusion limits can be presented in the two-dimensional plane of the masses of the mediator and the dark matter particle, assuming a universal quark coupling, g_{q}, of 0.25, and a DM coupling, g_{DM}, of 1. The mediator can be vector or axial-vector, and leptophobic or non-leptophobic. The 95% confidence level (CL) exclusion for the leptophobic axial-vector case are shown in Figure 1. This kind of limits can be converted into limits on the spin-dependent (-independent) DM-nucleon scattering cross section for an axial-vector (vector) mediator, as illustrated in Figure 2 for the spin-dependent cross section. The plot shows as well a comparison with respect to the exclusion obtained from direct-detection experiments. A dark-photon portal, with a spin-1 mediator (A') with a pure vector coupling that mixes with the SM photon and the Z boson, is also considered. Figure 3 shows the exclusion on terms of the squared kinetic mixing coefficient, ϵ^2, versus the mass of A' combining two different dimuon CMS searches [3, 4]. These results benefit from scouting triggers [5] for the lower mass phase space.

Results from searches and summary plots are available as well in [2] for the spin-0 portal considering scalar, pseudoscalar, dark Higgs, or axion-like particle portals.

3. Dark QCD searches

Extended DS searches that present less conventional signatures are also considered. Namely, in this section we present a few representative CMS searches for dark QCD. In this case, non-minimal strongly-coupled dark sectors are studied. They could be probed at LHC at a high energy corresponding to the mass of the mediator between the DS and the SM. The signatures depend strongly on the parameters of the model, such as the number of flavors of dark quarks. Some of examples, for which CMS has presented recent searches, are semivisible jets, emerging jets or soft unclustered energy patterns (SUEPs).

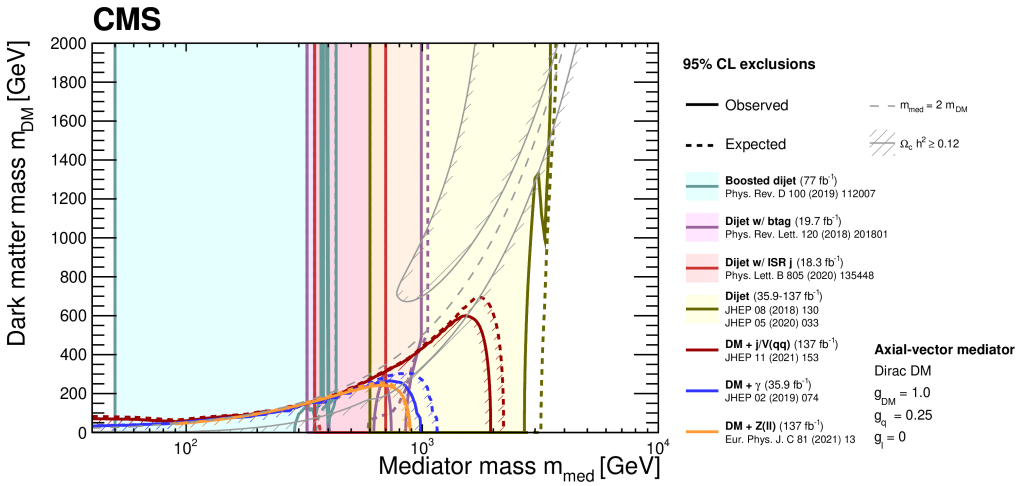

Figure 1: 95% CL exclusion limits for a spin-1 axial-vector mediator for diverse CMS searches. The figure is taken from Ref. [2].

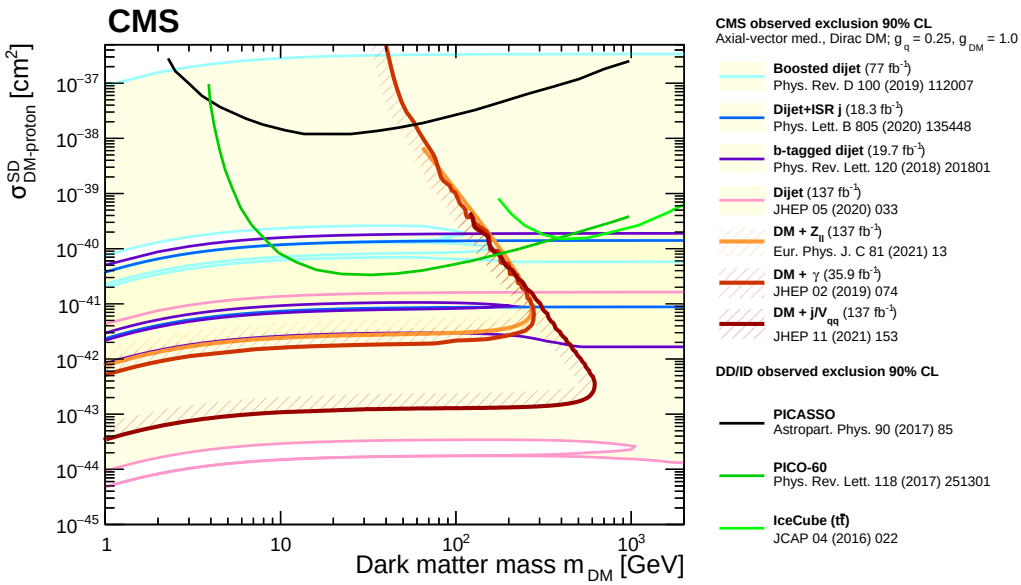

Figure 2: 90% CL exclusion limits on the nucleon-DM scattering spin-dependent cross section obtained from diverse CMS searches. Direct and indirect detection results from other experiments are also shown for comparison. The figure is taken from Ref. [2].

Semivisible jets could arise from the shower and hadronization of dark quarks. Stable dark hadrons become then DM candidates, while unstable dark hadrons can decay to SM particles. Figure 4 shows 95% CL exclusion limits on r_{inv}, a parameter that represents the fraction of stable invisible dark hadrons, versus the mass of a leptophobic Z' boson mediator for a dedicated semivisible jet search [6], and shows a comparison with dijet and monojet searches. In the case of emerging jets, parton shower and hadronization in the dark sector present a shorter timescale than the dark meson decay to SM particles, leading to long-lived dark mesons. The exclusion limits for a track-based

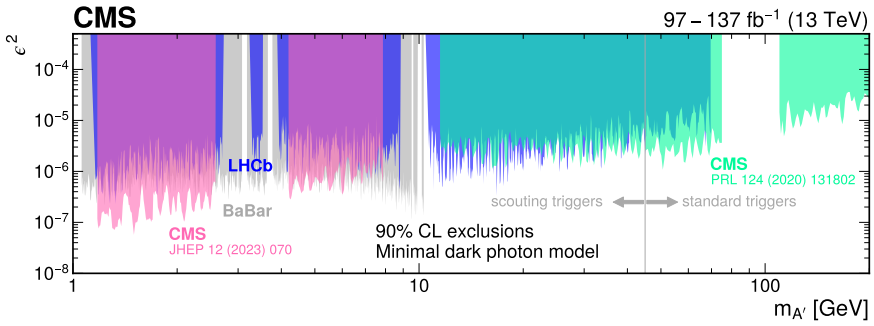

Figure 3: 90% CL exclusion upper limits on the square of the kinetic mixing coefficient for the minimal model of a dark photon. The plot shows results from two dimuon CMS searches [3, 4]. The results are compared with existing limits from LHCb and BaBar. The figure is taken from Ref. [2].

[7] and a muon-detector based [8] CMS search for emerging jets are shown in Figure 5. Lastly, for SUEPs, instead of collimated jets, dark showers result in a large multiplicity of spherically-distributed low-momentum charged particles. Recently, CMS has presented the first search for a dedicated SUEP signature [9], excluding significant fractions of the parameter space of the employed benchmark model, which considers gluon-fusion production of a scalar mediator with SUEP-like decays.

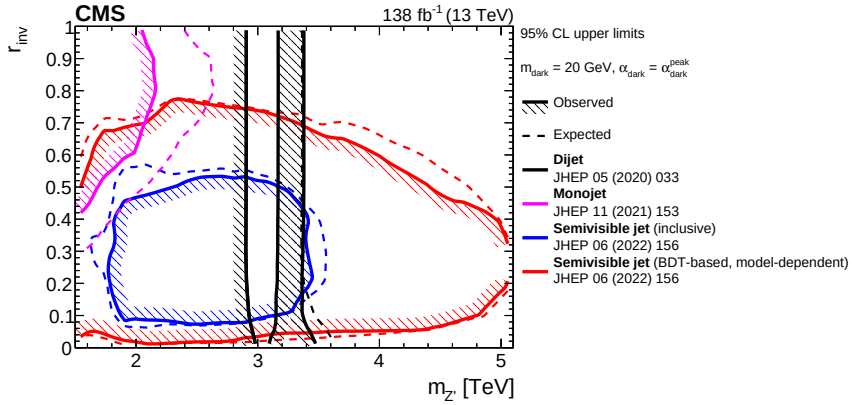

Figure 4: 95% CL exclusion limits on the r_{inv}-$m_{Z'}$ plane for a dedicated CMS search for semivisible jets [6]. The results are compared with those from a monojet and a dijet search. The figure is taken from Ref. [2].

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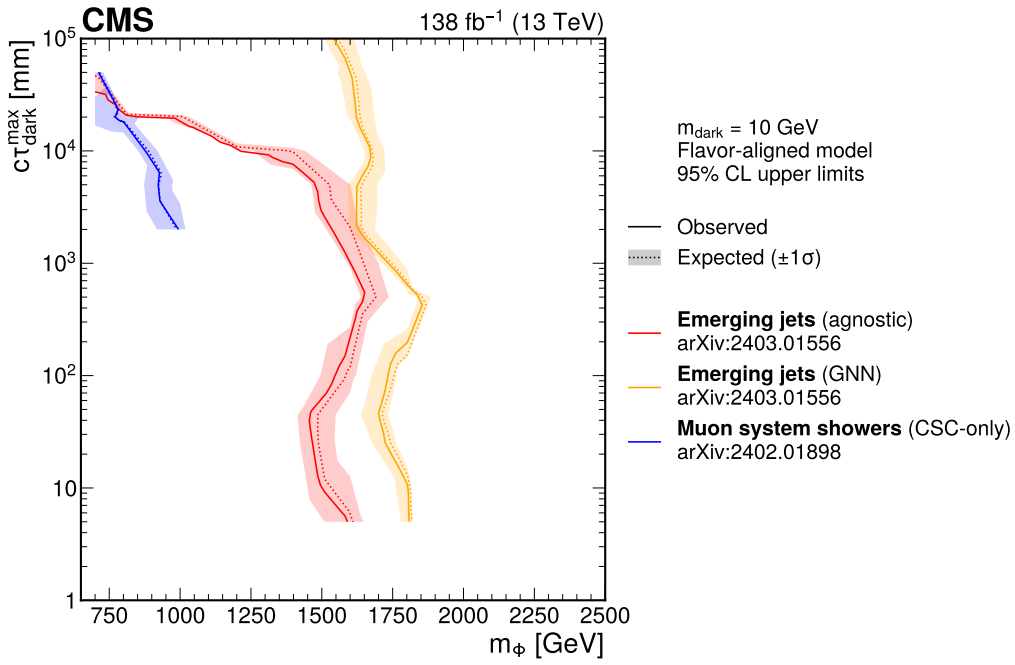

Figure 5: 95% CL exclusion limits on the proper decay length of dark mesons versus the mass of a bifundamental mediator that decays to a jet and an emerging jet for a flavor-aligned model with a dark meson mass of 10 GeV. The results are shown for a track-based [7] and a muon detector shower-based [8] CMS search. The figure is taken from Ref. [2].

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