Snowmass2021 - Letter of Interest

Search for $t + j + \mathrm{MET}$ signals from dark matter models at future e^+e^- collider

Thematic Areas: (check all that apply □/■)

□ (EF01) EW Physics: Higgs Boson properties and couplings
□ (EF02) EW Physics: Higgs Boson as a portal to new physics
□ (EF03) EW Physics: Heavy flavor and top quark physics
□ (EF04) EW Precision Physics and constraining new physics
□ (EF05) QCD and strong interactions: Precision QCD
□ (EF06) QCD and strong interactions: Hadronic structure and forward QCD
□ (EF07) QCD and strong interactions: Heavy Ions
□ (EF08) BSM: Model specific explorations
□ (EF09) BSM: More general explorations
■ (EF10) BSM: Dark Matter at colliders
□ (Other) *[Please specify frontier/topical group]*

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Abstract: It is an interesting possibility that there exists flavor structure in the interaction between Dark Matter (DM) and the Standard Model (SM). Under the assumptions of gauge invariance and renormalizable vectices for DM interaction, mediators carrying the same quantum numbers as the quarks with which DM interacts can decay into DM plus mixed jet flavors, such as $t + j + \mathrm{MET}$ signals. Lepton colliders such as FCC-ee, CEPC and CLIC have clean environment related to Quantum Chromodynamics (QCD) and well controlled beam collision energy, therefore provide good opportunities of probing the DM models generating $t + j + \mathrm{MET}$ signals.

The flavor structure in the Standard Model (SM) yields rich hadron physics phenomenon and numerous precision electroweak measurements. Naturally, it is an interesting possibility that there exists flavor structure in the interaction between Dark Matter (DM) and the SM. Especially, the interplay between DM and quark flavors including top quark is further intriguing since top quark as the heaviest SM particle may reveal crucial information about the electroweak breaking mechanism.

Assuming gauge invariance and renormalizable interactions in the simplified DM models, the mediators carry the same quantum number as the quark with which the DM interacts, while the coupling of the vertex can contain mixed flavors. When mediators are pair-produced, the decay products can yield $t + j + \mathrm{MET}$ signals with j being the light jets. If one focuses on the case with top quark decaying leptonically, the signal topology will become $\ell + jets + \mathrm{MET}$ with $\ell = e, \mu$. Although various SM backgrounds can mimic this type of signal such as $t\bar{t}, t\bar{t}V, tV, tVV, VV, V + jets$ where $V = W, Z$, the DM models which can generate on-shell top quark in $t + j + \mathrm{MET}$ may still be distinguished from the SM backgrounds.

Future e^+e^- colliders such as FCC-ee, CEPC and CLIC can benefit from the cleaner environment with respect to Quantum Chromodynamics (QCD) compared to hadron colliders such as LHC, also from the well controlled beam collision energy. Taking the Circular Electron Positron Collider (CEPC) as an example, it is expected to have excellent performance in the flavor tagging [1;2]. The top quark reconstruction from its decay products requires the reconstruction of secondary vertex for which the performance of the vertex system is important. Moreover, compared with the b-jet tagging, c-jet tagging is particularly difficult which suffers more from backgrounds originating from light-quark and gluon jets. Benefiting from the high precision vertex system, the CEPC detector provides reasonable separation of c-jets from other flavor jets. Therefore, the prospected improvement in top quark tagging efficiency at CEPC can provide a great potential to probe the $t + j + \mathrm{MET}$ signal existing in a wide range of DM models with flavor structures.

References

[1] [CEPC Study Group], "CEPC Conceptual Design Report: Volume 1 - Accelerator," [arXiv:1809.00285 [physics.acc-ph]].

[2] J. B. Guimarães da Costa *et al.* [CEPC Study Group], "CEPC Conceptual Design Report: Volume 2 - Physics and Detector," [arXiv:1811.10545 [hep-ex]].