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Limits on Diffuse Dark Matter with HAWC

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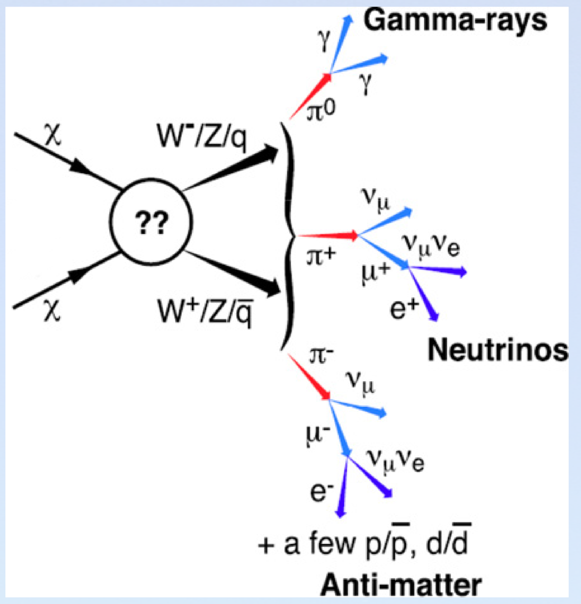
Abstract

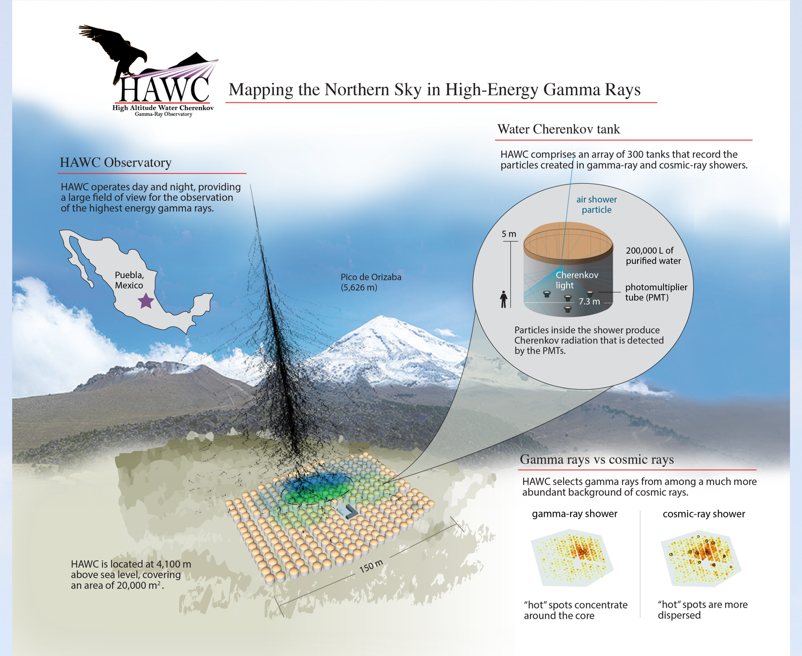
In addition to dense regions of dark matter, such as galaxy clusters and dwarf galaxies, dark matter annihilation and decay are also expected to have a nearly isotropic distribution across the sky. This isotropic component is less model-dependent than the flux from isolated dark matter targets, and would produce galactic contributions to the Diffuse Gamma-Ray Background (DGRB). With its continuous monitoring of the gamma-ray sky from a few hundred GeV to several hundred TeV and its wide field-of-view, the High Altitude Water Cherenkov (HAWC) observatory is well-suited to search for dark matter contributions in the DGRB. In this work, 535 days of HAWC data and Monte Carlo simulations were studied to set limits on annihilating or decaying diffuse dark matter at TeV energies. With this data, we consider both leptonic and hadronic dark matter channels and are able to constrain dark matter up to masses >100 TeV.

Motivation and Detector

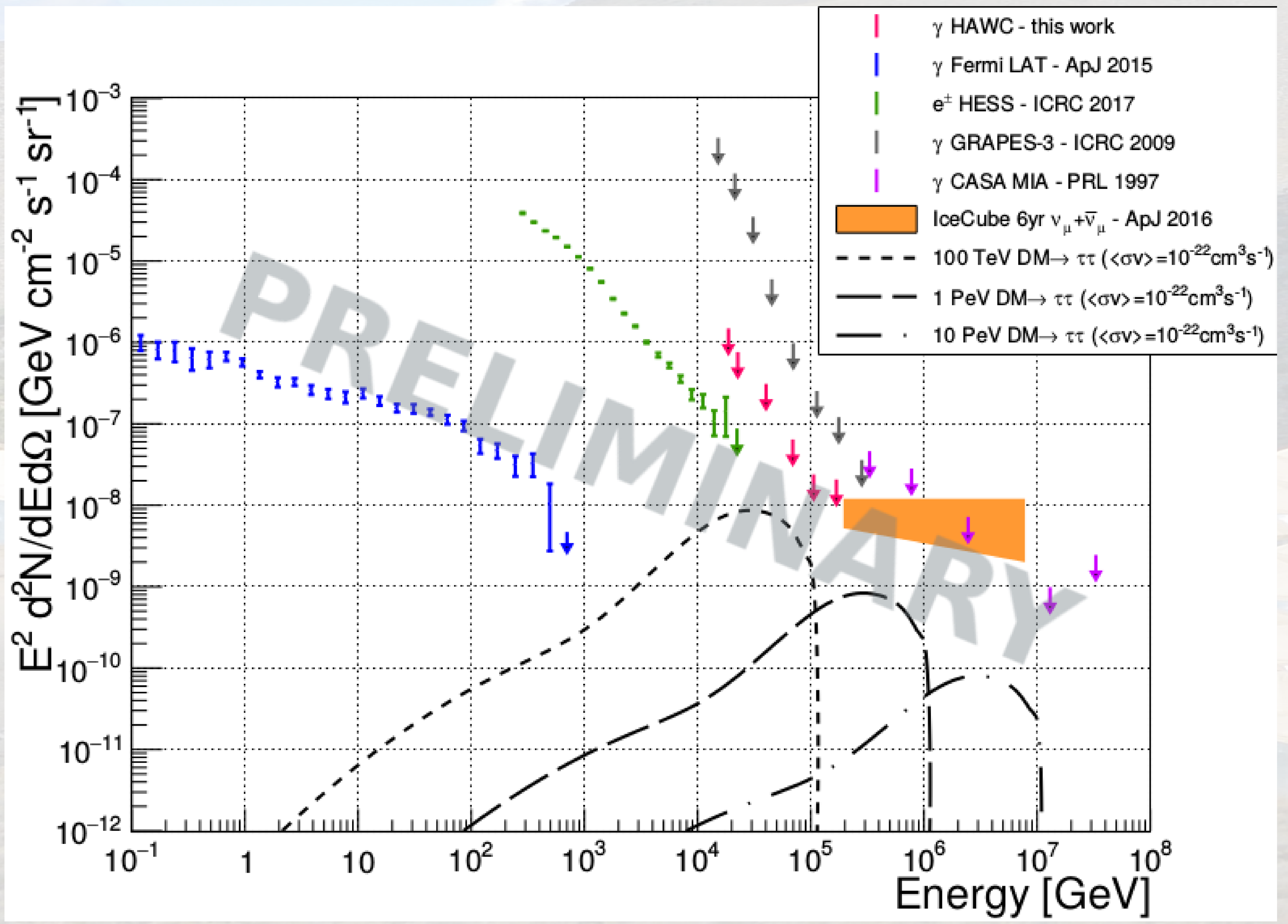


Isotropic gamma rays from the interaction of high-energy cosmic rays with matter and radiation in our Galaxy are expected to be the main provenance of the Diffuse Gamma-Ray Background (DGRB). At TeV energies, another source of diffuse gamma rays may contribute to the DGRB in the form of dark matter annihilations or decays from an extended halo around the Galaxy.

In this work we use 535 days of data from the High Altitude Water Cherenkov (HAWC) gamma-ray observatory, taken from November 2014 to June 2016.



Analysis

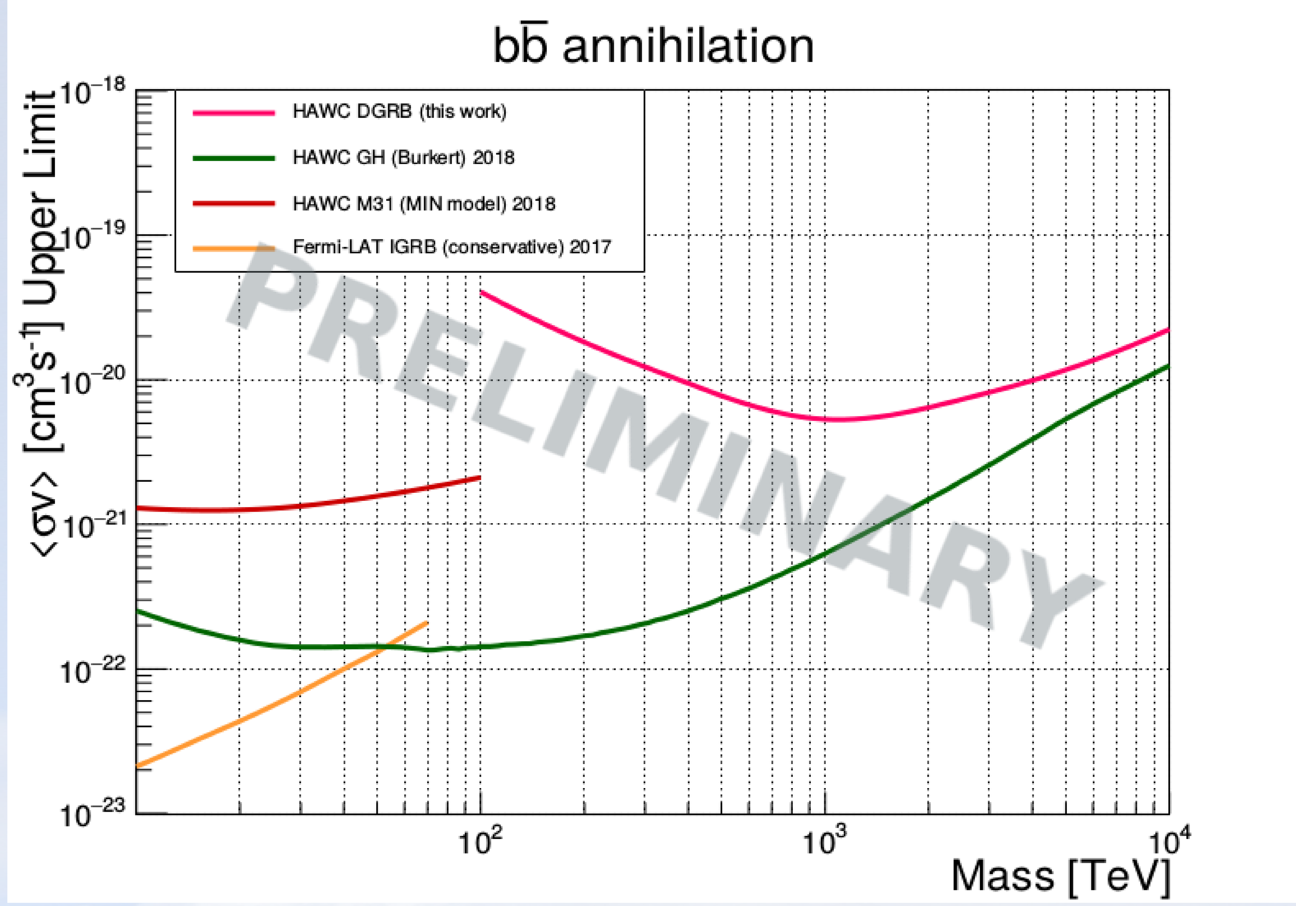


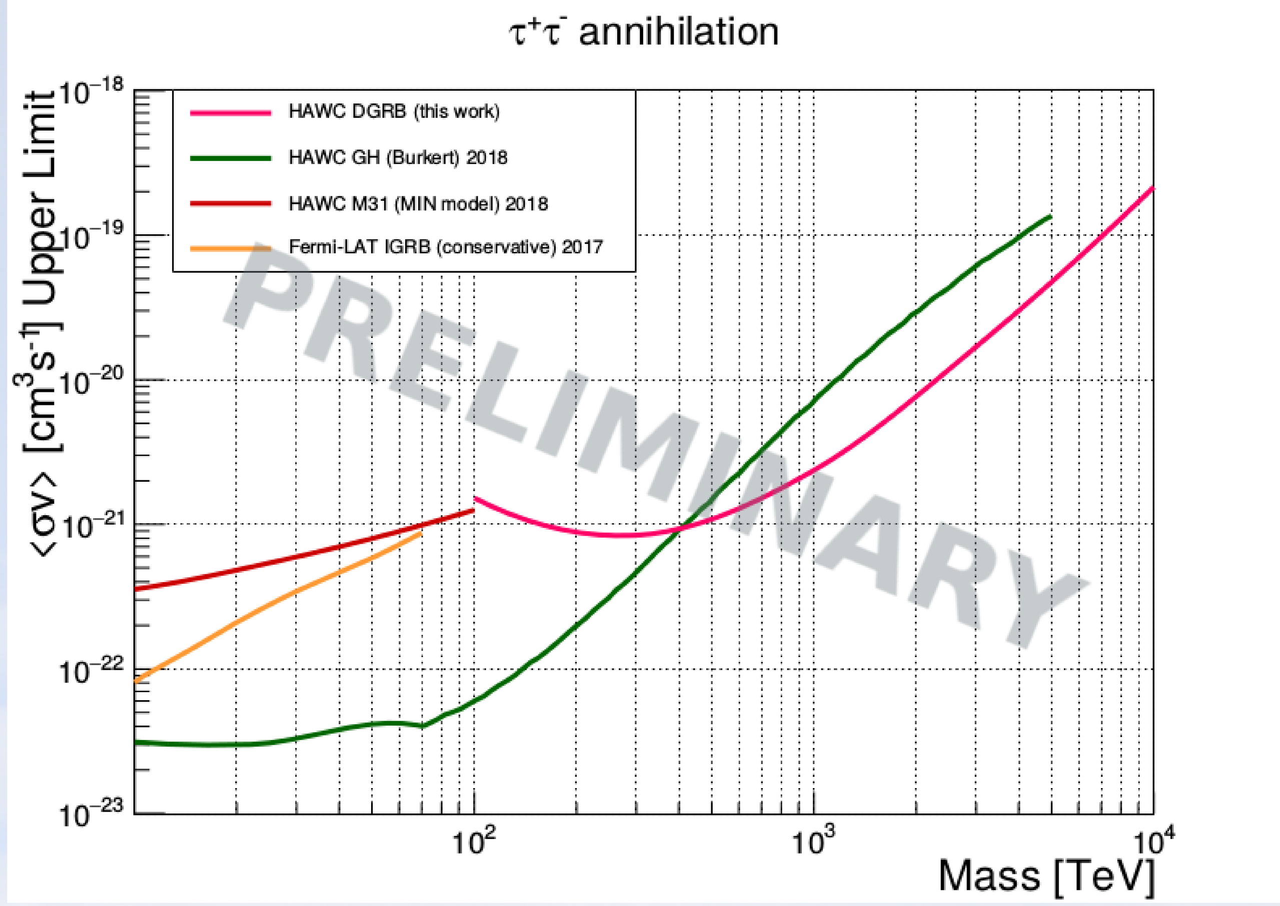
A parallel work [1] relying on the same data and using the HAWC Crab log parabola spectrum [2] is displayed on the left. In that work the limits on the DGRB are compared to the diffuse electron/positron flux observed by HESS [3][4]. Also shown is the observed IGRB by the Fermi-LAT [5], the gamma-ray flux corresponding to the IceCube $\nu_\mu + \bar{\nu}_\mu$ astrophysical flux [6], as well as previous high-energy limits by GRAPES [7] and CASA-MIA [8]. The diffuse gamma-ray emissions from galactic dark matter annihilation into tau leptons are also included and were calculated based on data and results in [9].

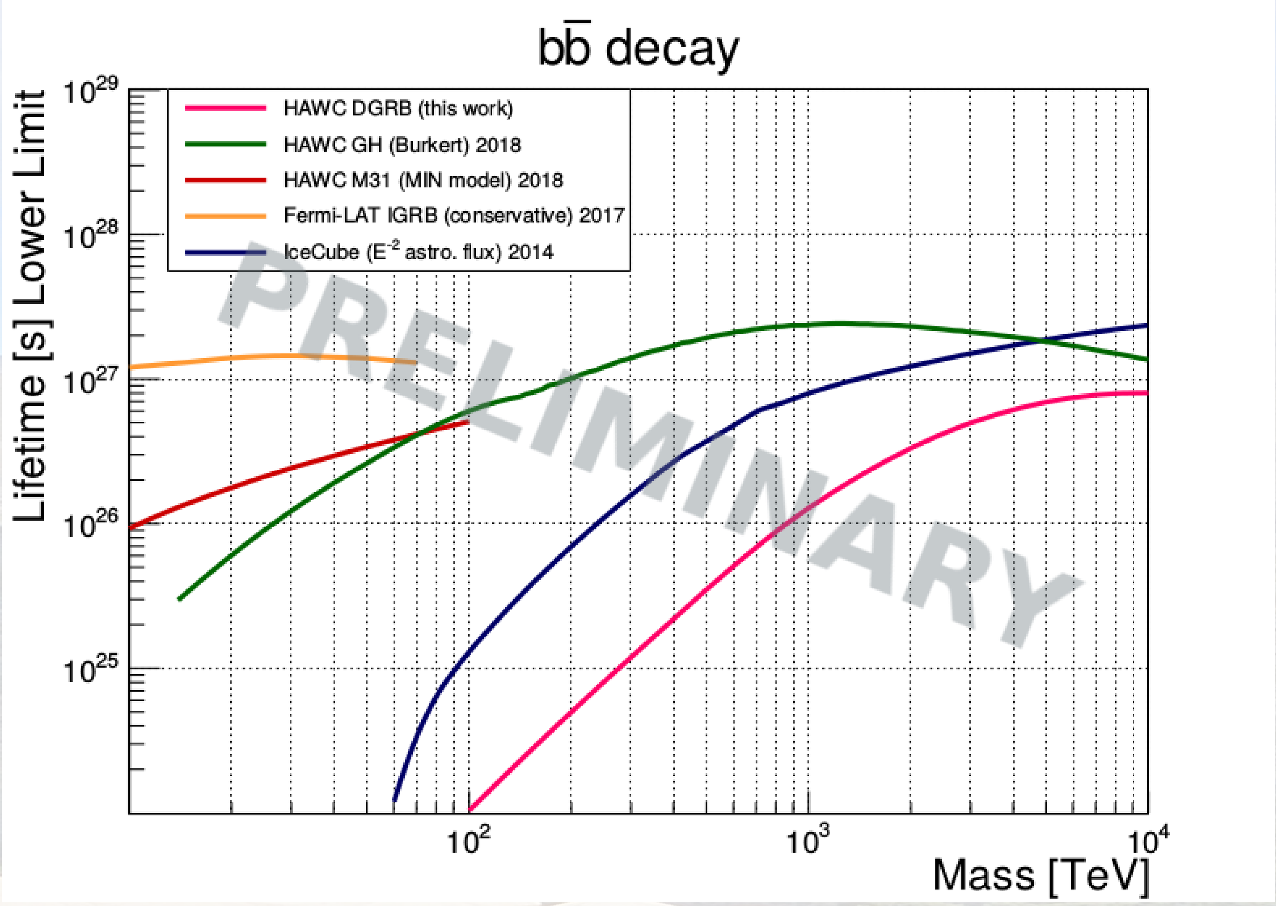
As we apply tighter gamma/hadron separation cuts, few events remain and we must rely on Poisson statistics. A binned likelihood analysis is carried out to calculate the best estimate for the overall scale of the spectrum. However, the bins are not summed but treated as separate independent “experiments”. The 95% one-sided upper limit of each bin is calculated and the one with the lowest value is selected, as it would be the one with the one with most expansive limit.

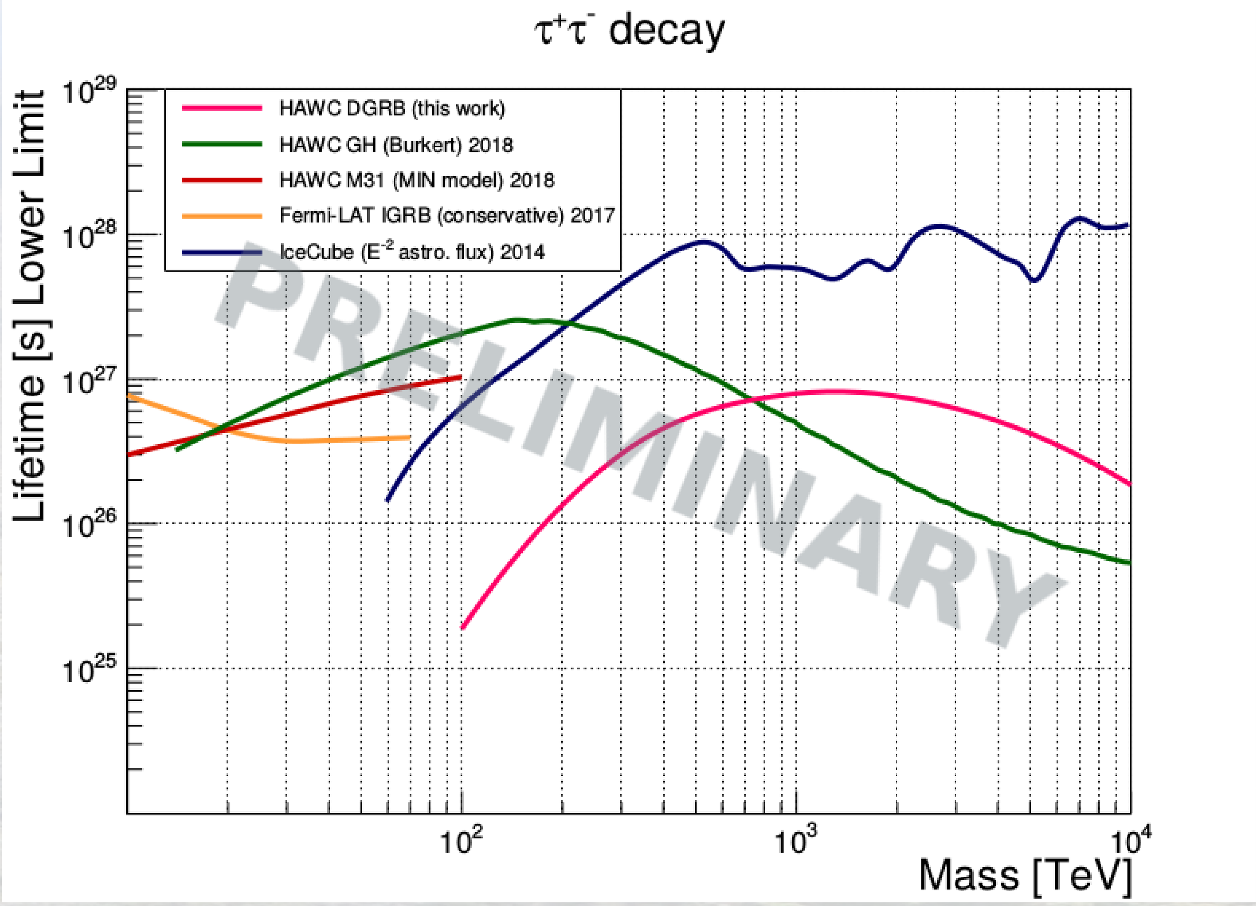
We explore the more conventional channels for dark matter annihilation and decay interactions, which are the $b\bar{b}$ and $\tau^+\tau^-$ channels. Both of these processes would lead to the creation of gamma rays. By injecting the spectra of chosen dark matter masses in our Monte Carlo simulation we can calculate the 95% containment level of the best estimate of the overall scale of said spectra, which is referred to as $\beta_{95\%}$. We then chose the best $\beta_{95\%}$ to calculate $\beta_{95\%}\times\langle\sigma v\rangle$ for annihilation upper limits and the best $\beta_{95\%}$ to calculate $lifetime \div \beta_{95\%}$ for decay lower limits. The results are shown in the right-hand panel.

Results









95% confidence level limits on isotropic and spatial-model independent gamma-ray emissions from galactic dark matter interactions into bottom quarks and tau leptons compared to recent dark matter searches with HAWC [10][11] and other experiments such as IceCube [12] and Fermi-LAT [13]. The limits obtained in this work are pushing into an energy range higher than the Fermi-LAT Isotropic Gamma-Ray Background and the HAWC Andromeda Galaxy constraints, nonetheless we can observe better limits for interactions involving tau leptons when compared to the HAWC Burkert Galactic Halo limits.

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[13] W. Liu, X.-J. Bi, S.-J. Lin and P.-F. Yin, *Constraints on dark matter annihilation and decay from the isotropic gamma-ray background*, Chinese Physics C 41 (2017) 045104