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Prospects for the detection of Dark Matter with Long-lived Mediators in the Sun using the Southern Wide-field Gamma-ray Observatory

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The search for dark matter is advancing into a new era with the development of next-generation gamma-ray observatories, which will significantly enhance detection capabilities. These instruments will extend the limits of detection, offering new opportunities to investigate one of the most elusive components of the universe. Among them, the Southern Wide-field Gamma-ray Observatory, SWGO, stands out for its potential to detect gamma-ray signals originating from dark matter particles trapped within the Sun. This work focuses on hidden sector models, particularly secluded scenarios, where dark matter particles annihilate into long-lived mediators. Unlike standard annihilation channels occurring deep within the Sun's core, in these scenarios, dark matter annihilates into these mediators that escape the dense solar environment before decaying into detectable gamma rays. The detection of these decay products by SWGO could provide valuable insights into dark matter interactions. Our analysis indicates that SWGO will reach a high level of sensitivity, probing spin-dependent cross-sections as low as 10^{-46} cm^2 for dark matter masses below ≈ 5 TeV. This represents a substantial improvement over current detection capabilities, improving current indirect detection constraints by over an order of magnitude. Such advancements will not only strengthen the search for dark matter but also contribute to a deeper understanding of its fundamental properties.

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Summary

This proceeding is based entirely on the results presented in Ref. [1]. For a detailed description of the methodology, analysis, and conclusions, we refer the reader to that work.

Preliminary results with updated SWGO IRFs

Beyond the results presented in Ref. [1], we have updated the sensitivities to dark matter capture in the Sun incorporating the most recent Southern Wide-field Gamma-ray Observatory (SWGO) instrument response functions (IRFs), which became available after the publication of that work. We are now using IRFs derived from the reference layout of SWGO [2], which consists of an array of 3763 independent Water Cherenkov Detectors (WCDs) distributed in a 3-zone configuration with fill factors of 70%, 4%, and 1.7%, decreasing from the center. We are also showing the performance of the first phase of SWGO, called SWGO-A, corresponding to a 385 WCD-unit segment of the inner array, with a fill factor of 65%, arranged in seven independent clusters of 55 tanks.

In addition to the changes in the SWGO IRFs, the main methodological changes to the performance analysis are: (i) we now employ the IRFs for each sky position, and not an average value, as it was the case before; (ii) the exposure is computed according to the actual selected site location, Pampa La Bola, located in the Calama commune in northern Chile, at in altitude of 4,770 meters, allowing us to use realistic observing conditions rather than assuming a fixed 6 hours of daily exposure. These updates provide a more accurate characterization of the instrument performance.

Figure 1 shows preliminary sensitivity curves for the spin-dependent dark matter–proton cross section, in the channels $b\bar{b}$ and e^+e^-, using the baseline SWGO layout as well as SWGO-A. The results indicate that SWGO-A performs comparably to HAWC, while the full SWGO array remains consistent with previous projections. These results highlight the remarkable discovery potential of SWGO: by probing spin-dependent cross-sections down to the level for dark matter masses below a few TeV, SWGO will not only surpass current indirect limits by more than an order of magnitude, but also place some of the most stringent and competitive constraints on secluded dark matter scenarios accessible in the coming years.

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References

[1] M. Andrade, J. Fagiani, C. Siqueira, V. de Souza, and A. Viana, *Prospects for the detection of Dark Matter with Long-lived Mediators in the Sun using the Southern Wide-field Gamma-ray Observatory*, JCAP **01** (2025) 012, ADS: 2025JCAP...01..012A.

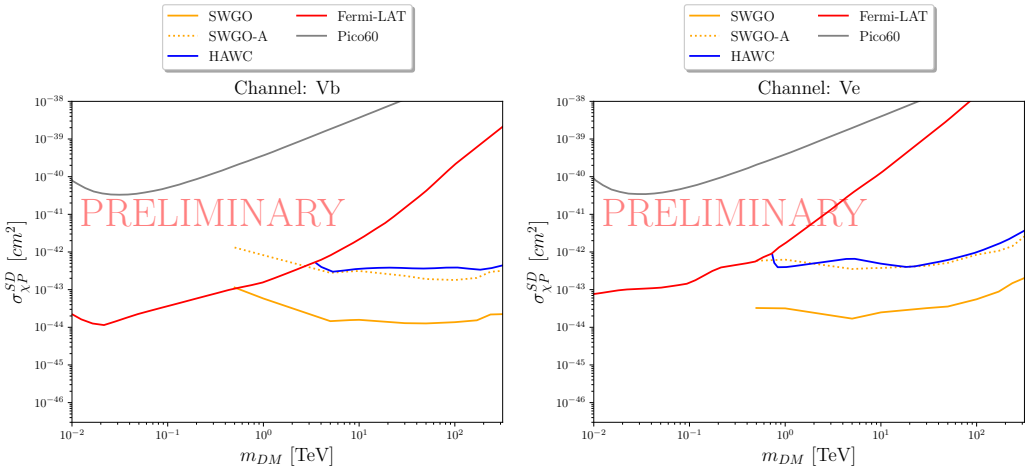

Figure 1: Preliminary SWGO sensitivity using the updated IRFs. Left: Channel $b\bar{b}$. Right: Channel e^+e^-. The results are compared to HAWC, Fermi-LAT, and Pico-60.

[2] SWGO Collaboration (P. Abreu et al.), *Science Prospects for the Southern Wide-field Gamma-ray Observatory: SWGO*, arXiv:2506.01786 [astro-ph.HE] (2025), revised version v2.