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Positron annihilation in flight as a probe of new physics

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A steady production of positrons in the Milky Way is evidenced by the long-standing observations of a diffuse 511 keV γ ray line from electron-positron annihilation. One consideration that is usually ignored is that the interaction of positrons with the interstellar medium produces not only a line, but also a continuum emission (so called) in-flight positron annihilation.
We use, for the first time, the γ-ray emission from in-flight positron annihilation as a powerful observable for constraining high-energy positron production from electrophilic Feebly Interacting Particles, demonstrating that in-flight annihilation (IA) emission can significantly constrain these particles based on diffuse γ ray observations. When applied to the case of MeV-scale sterile neutrinos, we set the most stringent constraint, excluding $|U_{\tau 4}|^2$
$gtrsim 5 \times 10^{-13}$ for sterile neutrinos mixed with the tau flavor. These constraints are more than an order of magnitude more stringent than previous limits. We remark that our approach is applicable to a host of exotic positron sources such as primordial black holes, sub-GeV dark matter, dark photons and axion-like particles as well.

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