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Sensitivity study of $\mu^+ \to e^+ a\gamma$ cLFV decay with the MEG~II apparatus

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The MEG II experiment, located at the Paul Scherrer Institute in Switzerland, operates with the highest continuous muon beam intensity currently achievable, reaching up to $10^8 \quad \mu^+/s$. The MEG II experiment has been dedicated for several years to the search for the charged lepton flavour violating (cLFV) decay $\mu^+ \to e^+\gamma$, setting the world's most stringent upper limits on the Branching Ratio for this process.
In this study, we investigate the Single Event Sensitivity (SES) of the MEG II apparatus for a cLFV three-body decay involving an axion-like particle (ALP). Such a decay—and the existence of ALPs—is not predicted by the Standard Model but is featured in various Beyond the Standard Model scenarios. Therefore, its observation would serve as compelling evidence for New Physics. We focus on the decay channel: $\mu^+ \to e^+ a\gamma$ assuming a vector-minus-axial (V–A) chirality structure and a light ALP mass ranging from 0 eV up to few MeV. The study is based on detailed Monte Carlo simulations using the GEANT4 toolkit, with data analysis performed using the ROOT-CERN framework. Our analysis shows that operating the muon beam at a reduced intensity, compared to MEG II working point, of approximately $1 \times 10^6 \ \mu^+/s$, together with a relaxed trigger selection on events, significantly improves the experimental efficiency and SES for the muon ALP decay. Under these optimized conditions, only a few weeks of data collection would be sufficient to achieve competitive sensitivity compared to current best experimental limits on this decay. Taking into account the dataset accumulated by the MEG II collaboration over the past four years—corresponding to roughly 10 days of data-taking at low beam intensity—we estimate that the sensitivity to the ALP decay constant could reach a level comparable to the best current limit, which was set by the TWIST experiment in 2015.
In conclusion, our results highlight that the MEG II apparatus, under optimized operating conditions, provides a powerful platform for probing rare ALP-mediated decay channels. This study demonstrates MEG II's strong potential to contribute significantly to the search for physics beyond the Standard Model.

Secondary track

T02 - Dark Matter

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