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Self-supervised Pretraining and ^{42}K Surface Beta Events Tagging for LEGEND

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The LEGEND experiment searches for neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge using high-purity germanium detectors (HPGe). In LEGEND-200, these detectors are operated in atmospheric liquid argon (LAr), which provides active shielding against background radiation and acts as a coolant. However, atmospheric LAr contains the cosmogenically activated isotope ^{42}Ar, whose progeny, ^{42}K, undergoes beta decay (Q_β =3.5 MeV) on the HPGe surface. If the baseline mitigation strategy of using underground-sourced LAr (UGLAr), depleted in ^{42}Ar, were unavailable, this decay would become the dominant background at the $0\nu\beta\beta$ Q-value ($Q_{\beta\beta}$ =2.039 MeV) in LEGEND-1000. Pulse-shape discrimination (PSD) methods in HPGe, used for detecting and distinguishing such background events from $0\nu\beta\beta$ candidate events, rely on summary statistics that only partially exploit the information within signal traces, leaving potential for improvement if more, or all, of the raw data were utilized. However, full utilization of raw signal pulses for PSD presents technical challenges due to the high dimensionality of the data, non-linear feature relationships, noise, and energy dependence. We present an analysis of a gradient-based optimization strategy using a regularized autoencoder model to construct an invertible, lower-dimensional latent representation of the data, based on measurements of HPGe in ^{42}Ar-enriched LAr at the SCARF LAr test facility at TU-Munich. We evaluate the suppression of ^{42}K surface events via pulse-shape classification using these latent variables and compare the results to standard PSD methods used in LEGEND. This research is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Excellence Cluster ORIGINS EXC 2094-39078331; SFB1258-283604770.

Primary author: LAY, Niko (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany)

Co-authors: LEONHARDT, Andreas (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); HASHEMI, Baran (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); HACKETT, Brennan (Max Planck Institute for Physics, Boltzmannstr. 8, 85748 Garching, Germany); MAJOROVITS, Béla (Max Planck Institute for Physics, Boltzmannstr. 8, 85748 Garching, Germany); VOGL, Christoph (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); GUSEV, Konstantin (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); HEINRICH, Lukas (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); SCHWARZ, Mario (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); NEUBERGER, Moritz (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); RUMYANTSEVA, Nadezda (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); KRAUSE, Patrick (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); SCHÖNERT, Stefan (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany); COMELLATO, Tommaso (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck-Str. 1, 85748 Garching, Germany)

Presenter: LAY, Niko (Physics Department, School of Natural Sciences, Technical University of Munich, James-Franck--Str. 1, 85748 Garching, Germany)

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