1. The LEGEND Project

LEGEND [1] is an experimental program to search for the neutrinoless double beta (0νββ) decay of 76Ge aiming to reach a discovery potential at half-life beyond 1030 yr.

- based on existing resources and technologies from GERDA [2] and MAJORANA [3] experiments, contributions from other groups and experiments
- first phase (LEGEND-200) with 200 kg of High Purity Germanium (HPGe) detectors enriched in 76Ge, subsequent stage with 1000 kg (LEGEND-1000)

2. LEGEND-200 Experiment

The first stage of the project LEGEND-200 already started:
- 200 kg of HPGe detectors in the GERDA [2] infrastructure at Gran Sasso Laboratory, operated directly in Liquid Argon (LAr)
- energy resolution of 2.5 keV (FWHM) in the region of 0νββ decay of 76Ge (2039 keV)
- reduced background, goal of 0.6 cts/(FWHM-ton-yr)
- data taking foreseen in 2021!

Status of LEGEND-200
- GERDA infrastructure now operated by LEGEND from February 2020 with installation of the first setup
- Electronics chain: demonstrated with 20 channels in the first setup
- New Detectors: production of 155 kg of Inverted Coaxial HPGe in progress
- New Active LAr veto: production of fiber shroud and SiPMs in progress
- Monte Carlo Simulations and Analysis Software in preparation

3. Read-out Electronics Design in LEGEND-200

The peculiar situation of HPGe detectors deployed directly in LAr and the requirement of very low radioactive background, introduces several constraints on the design of the read-out.

The LEGEND-200 read-out electronics consists in a Charge Sensitive Amplifier separated in 2 stages in order to both improve performance and reduce background:
- first stage based on the MAJORANA Low-Mass Front End (LMFE) (see section 4)
- main amplifier stage based on the GERDA design (see section 5)

In addition, the system consists of a novel active, room-temperature, receiver and data acquisition system to read out up to 200 detectors

4. First Stage: Low-Mass Front End (LMFE)

The Low-Mass Front End (LMFE) is placed in the proximity of the Ge detector where very stringent radiopurity constraints have to be met; it has been designed and assembled in the Lawrence Berkeley National Laboratory

- substrate: Suprasil 500 µm thick
- traces in thin, sputtered, Ti/Au
- JFET: bare-die Moxtek MX-11, attached to substrate with conductive silver epoxy and Al wire bonds
- feedback resistor: sputtered aGe thin film with ~ 1 GΩ at 87 K
- feedback and pulser capacitance: stray capacitance between traces

5. Main Preamplifier Stage: CC4

The CC4 design is based on GERDA design and is placed 40 - 140 cm above the HPGe detector, radiopurity requirements are less stringent w.r.t. LMFE

- low-mass Kapton circuit board
- footprint: SMD components
- differential signal output: to reduce potential noise and cross talk while driving 10 m long cable
- 7 read-out channels each CC4, up to 30 CC4 in LEGEND-200
- axon pico-coax cables to connect the LMFE with a strain relief provided by clamp made from electro-formed copper

6. Integration with HPGe detectors

The LEGEND-200 detector array utilizes a ultra-low-background mechanical design:

- clean structural materials: underground electro-formed copper, silicon detector plates and polyethylene naphthalate (PEN)
- detectors are connected to the read-out and high voltage via aluminum wire bonds
- modular electronics mount using clean engineering plastics (polyetherimide - PEI / ULTEM)

7. Outlook: Read-out Electronics for LEGEND-1000

For LEGEND-1000, the background coming from the signal read-out electronics has to be further reduced with a new radiopure solution

- the collaboration is actively developing novel, ASIC-based, signal read-out electronics
- that can integrate all the components into a single, low-mass and low-background silicon chip
- work to reduce the number of signal cables and find new structural materials and mechanical designs

References