# The Liquid Argon Instrumentation of GERDA and LEGEND-200

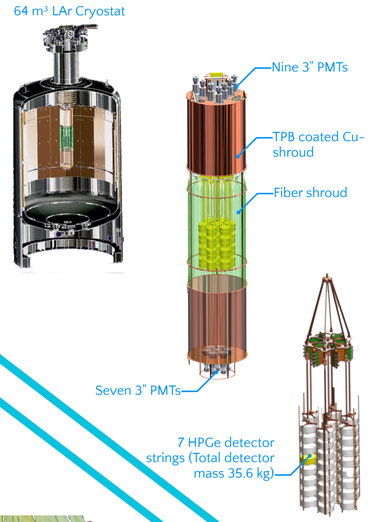
Patrick Krause (Technical University of Munich) for the GERDA and LEGEND collaborations

## GERDA

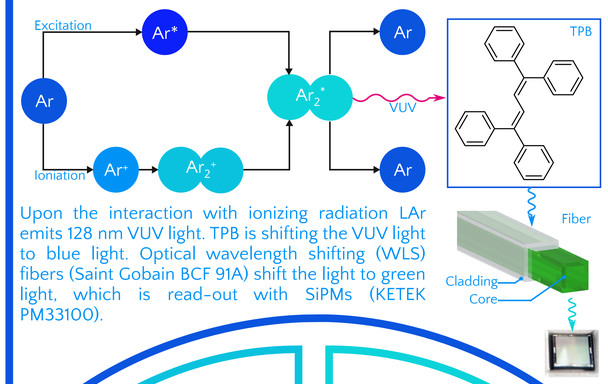
GERDA (Germanium Detector Array) searches for the 0νββ-decay of $^{76}$Ge in the LNGS underground laboratory (3500 m.w.e.).

35.6 kg of bare high purity Germanium (HPGe) detectors enriched in $^{76}$Ge are operated in 64 m³ of liquid argon (LAr).

Key technologies, such as pulse shape discrimination (PSD) and the detection of coincident scintillation light from the LAr, make GERDA a quasi background-free experiment.

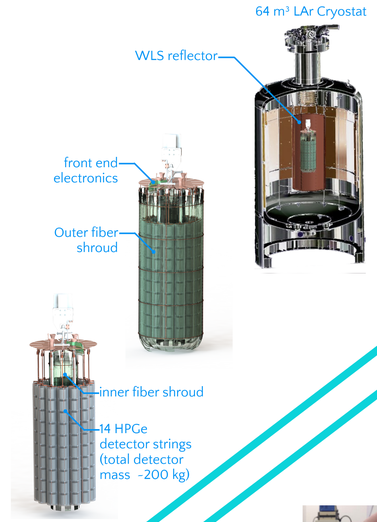



## Liquid Argon Scintillation & WLS Principle




Upon the interaction with ionizing radiation LAr emits 128 nm VUV light. TPB is shifting the VUV light to blue light. Optical wavelength shifting (WLS) fibers (Saint Gobain BCF 91A) shift the light to green light, which is read-out with SiPMs (KETEK PM33100).

## LEGEND-200

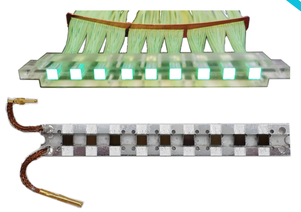



LEGEND-200 combines technologies developed in GERDA (e.g. LAr veto) and MAJORANA DEMONSTRATOR (e.g. underground formed copper), as well as from other groups to:

- deploy 200 kg HPGe detectors in the GERDA infrastructure.
- achieve a background index below $2 \cdot 10^{-4}$ cts/(keV kg yr).
- obtain a discovery sensitivity at a half-life of $10^{27}$ years.
- start data taking in 2021.

## GERDA LAr Veto Fiber Shroud

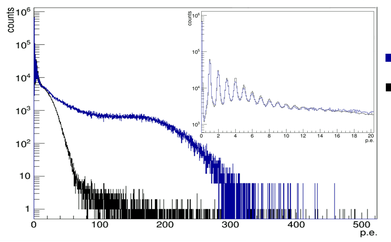
Each channel of the LAr Veto consists of 9 SiPMs connected in parallel. Each channel is connected to 81 fibers. In total 17 channels are deployed in GERDA.



Fibers are coupled to the SiPMs with an acrylic connecting device
→ optimal geometrical coverage to maximize PDE.

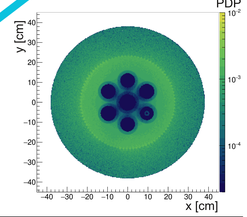
The SiPMs are procured in dye and are packaged in synthetic quartz (see right bottom).
→ minimal background contribution
→ mechanical reliability.

Single p.e. resolution in the summed spectrum of 135 SiPMs is achieved (see left bottom)..

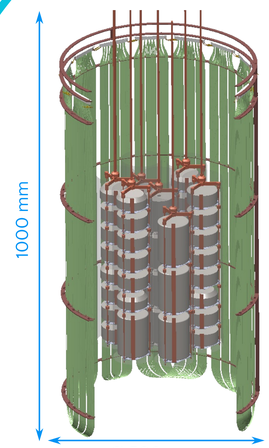



$^{228}$Th Spectrum

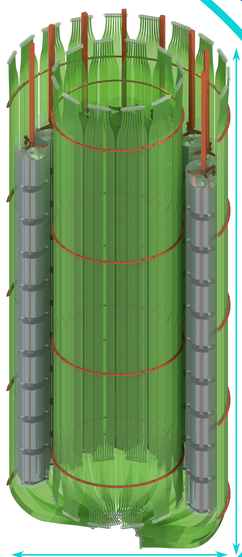
Background (e.g. $^{42}$Ar) Spectrum




## GERDA

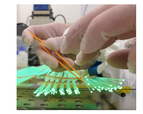



## LEGEND-200




## LEGEND-200 Fiber Shroud

- 60 channels (each with 9 SiPMs) in two concentrical fiber shrouds.
- Improved version of the GERDA fiber modules.
- Outer shroud is bended inwards at the bottom.



- Read out new fiber modules on both ends → minimize the light attenuation inside the fibers.
- Take 9 SiPMs of an array close to each other from one wafer (middle picture) → uniform properties between the SiPMs.
- Select materials thouroughly → Minimal background contribution (e.g. fibers: 4±2 ppt U and 15±3 ppt Th)

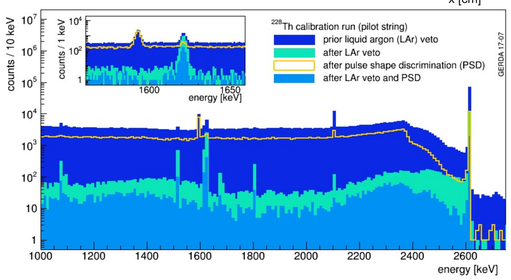
## GERDA Background Suppression

**Measurements:**

- $^{228}$Th calibration spectrum (right bottom) quantifies the performance of the LAr veto of Gerda.
- LAr veto suppresses the continuum by two orders of magnitude.

**Simulations:**

A MC simulation replicates the photon detection probability (PDP) of GERDA Phase II (see plot right top).

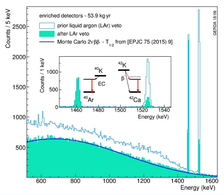



## Background Suppression Performance

For the LAr veto to work, a part of the energy has to be deposited in the surrounding LAr.

$^{40}$K and $^{42}$K lines are suppressed differently due to the different transitions.

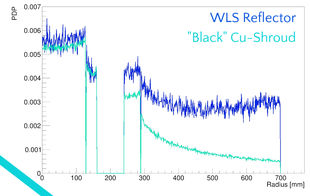
Compton scattered events are efficiently suppressed by LAr veto. See spectrum after LAr veto overlaid with 2νββ expectation.

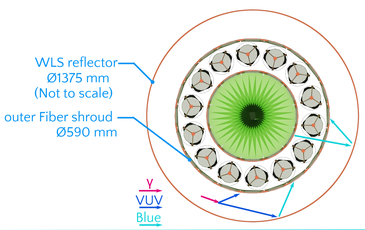



## LEGEND-200 WLS Reflector

The WLS reflector consists of a copper shroud, lined with TPB coated TetraTex.

Incoming VUV light is shifted to the blue spectrum and reflected back towards the fiber shrouds, Improving the light yield of the LAr veto (see plot left) .



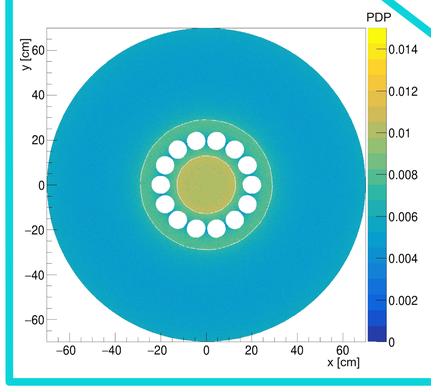

## LEGEND-200 MC Simulations

**Principle:**

- Use fast optical simulation to sweep optical parameter (e.g. attenuation length of the LAr).
- Next a detailed simulation produces more accurate results.

**Results:**

- Plot shows the expected photon detection probability (PDP) for LEGEND-200
- Expected PDP is more homogenous and higher compared to Gerda.




1. Agostini M. et al. Active background suppression with the liquid argon scintillation veto of GERDA. Phase II. J. Phys. 888 (2017)
2. Agostini M. et al. Probing Majorana neutrinos with double-β decay. Science 365 (2019).
3. S. I. Alvis et al. Search for neutrinoless double-β decay in 76Ge with 26 kg yr of exposure from the Majorana Demonstrator. Phys. Rev. C 100 (2019).
4. Abgrall N. et al. The Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay (LEGEND). AIP Conf. Proceedings 1894 (2017)