The calibration system of the LEGEND-200 experiment

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University of Zurich UZH

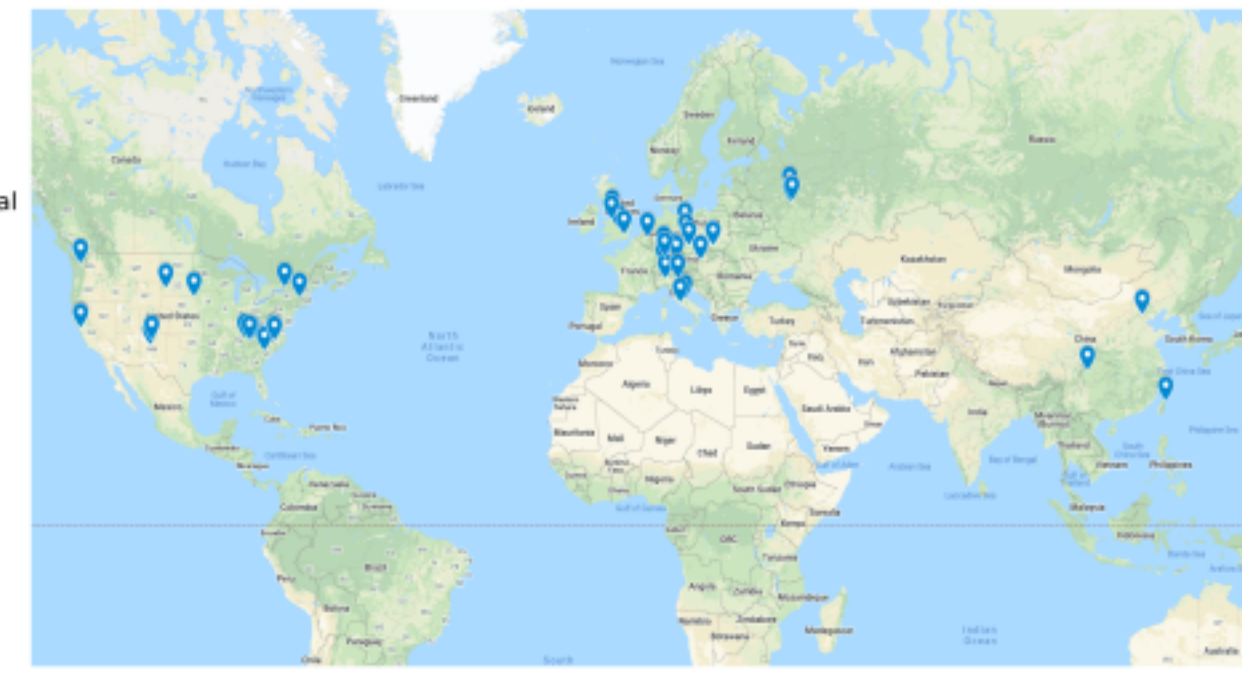LEGEND — Large Enriched Germanium Experiment for Neutrinoless ββ Decay

The Large Enriched Germanium Experiment for Neutrinoless ββ Decay (LEGEND)

Mission

"The collaboration aims to develop a phased, ^{76}Ge based double-beta decay experimental program with discovery potential at a half-life beyond 10^{28} years, using existing resources as appropriate to expedite physics results."
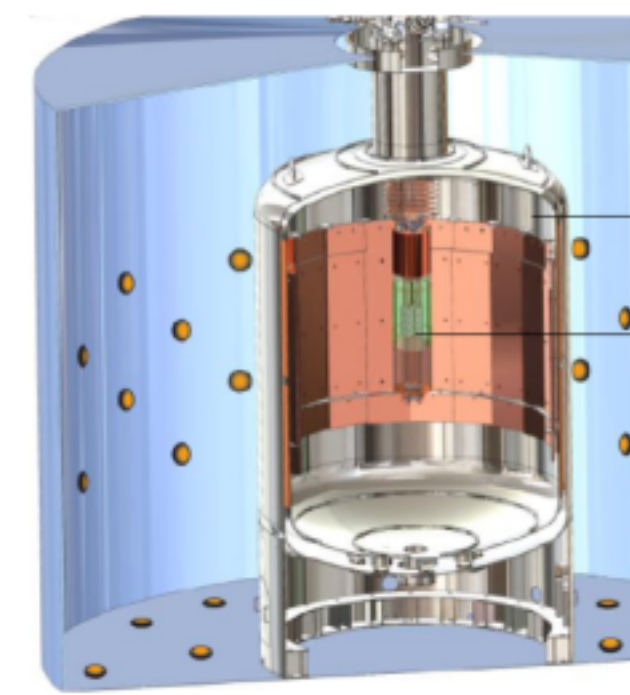
LEGEND: 48 institutions, around 240 scientists

- Univ. of New Mexico • L'Aquila Univ. and INFN • Laboratori Nazionali del Gran Sasso • Univ. of Texas Austin
- Tsinghua Univ. • Lawrence Berkeley National Laboratory • Univ. California Physics, Berkeley
- Univ. California Nuclear Engineering • Leibniz Institute for Crystal Growth (IKZ Berlin) • Comenius Univ.
- Univ. of North Carolina • Sichuan Univ. • Univ. of South Carolina • Tennessee Tech Univ. • Univ. of Warwick
- Jagiellonian Univ., Krakow • Technical Univ. Dresden • Joint Institute for Nuclear Research (Dubna) • Duke Univ.
- Triangle Univ. Nuclear Laboratory • Joint Research Centre, Geel • Max-Planck-Institute for Nuclear Physics Heidelberg
- Queens Univ. • Univ. of Tennessee • Lancaster Univ. • Univ. of Liverpool • Univ. College London
- Los Alamos National Laboratory • INFN Milano Bicocca • Milano Univ. and Milano INFN • National Research Center
- Kurchatov Institute (NRC KI) • Institute of Nuclear Research, Russian Academy of Sciences • Laboratory for Experimental
- Nuclear Physics of MEPhI (Moscow Engineering and Physics Institute) • Max-Planck-Institute for Physics - Munich
- Technical Univ. Munich • Oak Ridge National Laboratory • Padova Univ. • Padova INFN • IEAP Czech Technical
- Univ. Prague • North Carolina State Univ. • South Dakota School of Mines and Technology • Roma Tre Univ.
- and INFN Roma Tre • Univ. of Washington • Univ. Tuebingen • Academia Sinica • Univ. of South Dakota
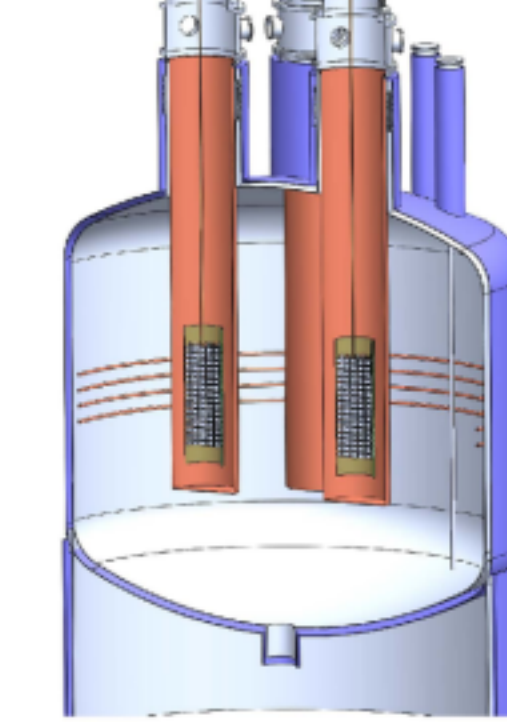- Williams College • Univ. of Zurich

LEGEND-200

- ~200 kg of enriched Ge
- Reuse of GERDA infrastructure at LNGS

- Water shield and active liquid Argon veto
- BG: 0.6 cts/(FWHM t yr)
- Half-life sensitivity: $\sim 10^{27}$ yr
- Start planned in 2021

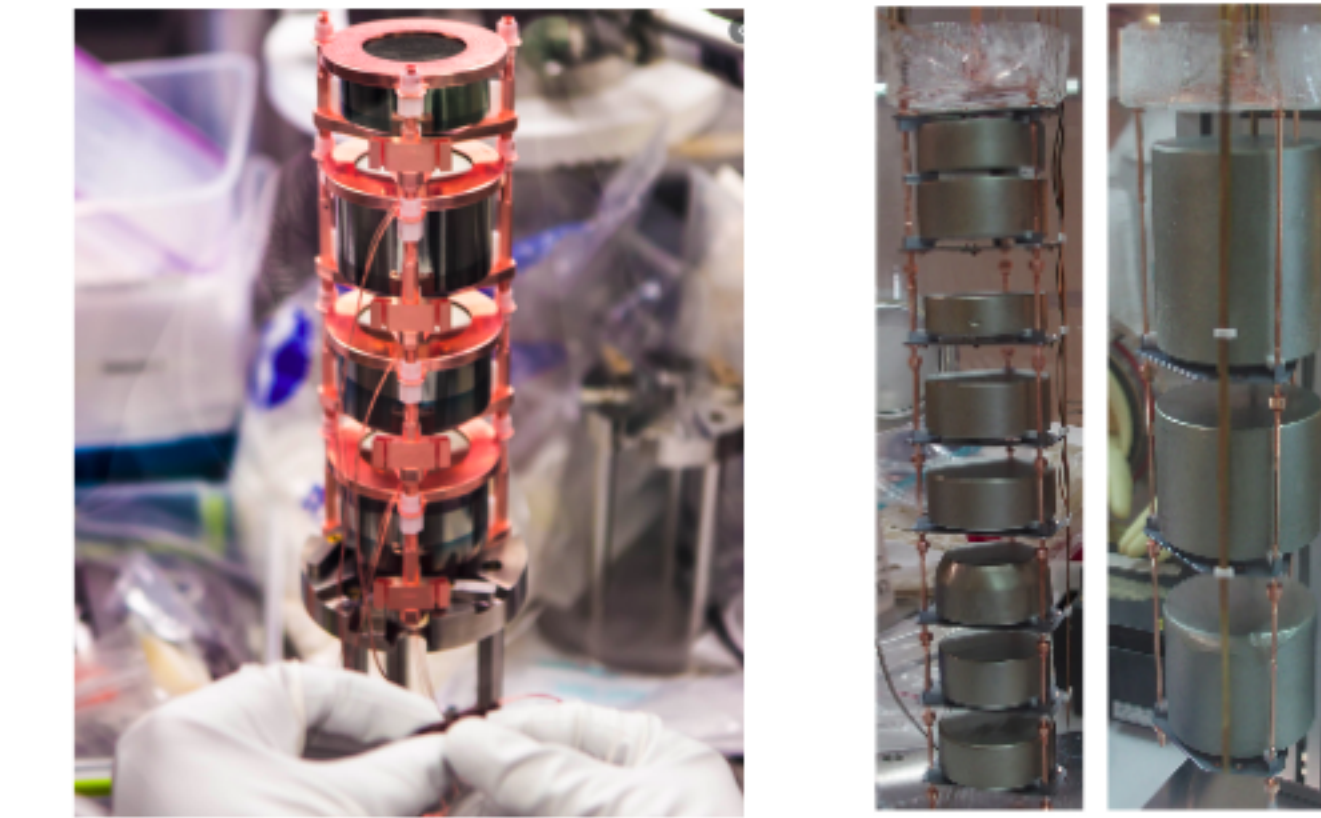FWHM: Full width at half maximum

LEGEND-1000

- ~1000 kg of enriched Ge
- Baseline design concept for a new cryostat (Location TBD)

- Reduction of cosmogenic backgrounds
- BG: 0.03 cts/(FWHM t yr)
- Half-life sensitivity: $>10^{28}$ yr
- Staged installation

Detector calibration

- Detectors from MAJORANA (l.) and GERDA (r.)
- Additional 150 kg of recycled or newly developed Ge detectors

- Immersion of multiple ^{228}Th sources for a homogeneous γ-event distribution over the detector array
- Identification of event peaks from decay chain in channel event spectrum
- Linear fit of peak positions to convert channel signals (ADC) into event energies (keV)

Multiple source strategy

Monte Carlo simulations to determine:
- No. of sources → 4 per insertion system, 4 systems
- Source activities → 4-5 kBq
- Source spacing → 10-12 cm (detector unit spacing)
- Calibration time → 2-3 h of data taking
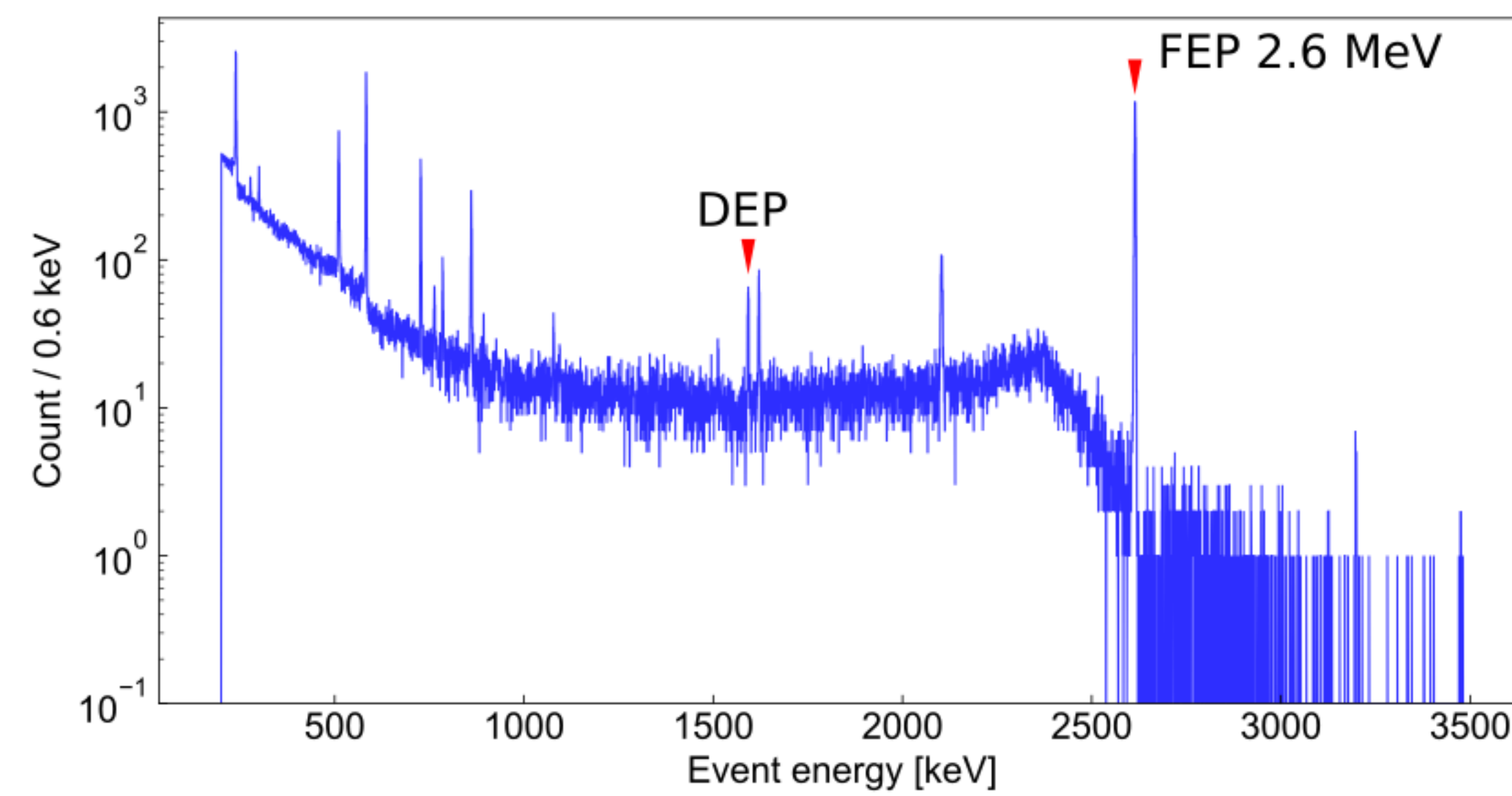
Simulated energy event spectrum

Peak position precision (2 h calibration):
- FEP (full-energy peak) at 2.6 MeV → 0.02 keV at 4 keV FWHM
- DEP (double-escape peak) at 1.6 MeV → 0.08 keV at 3.5 keV FWHM
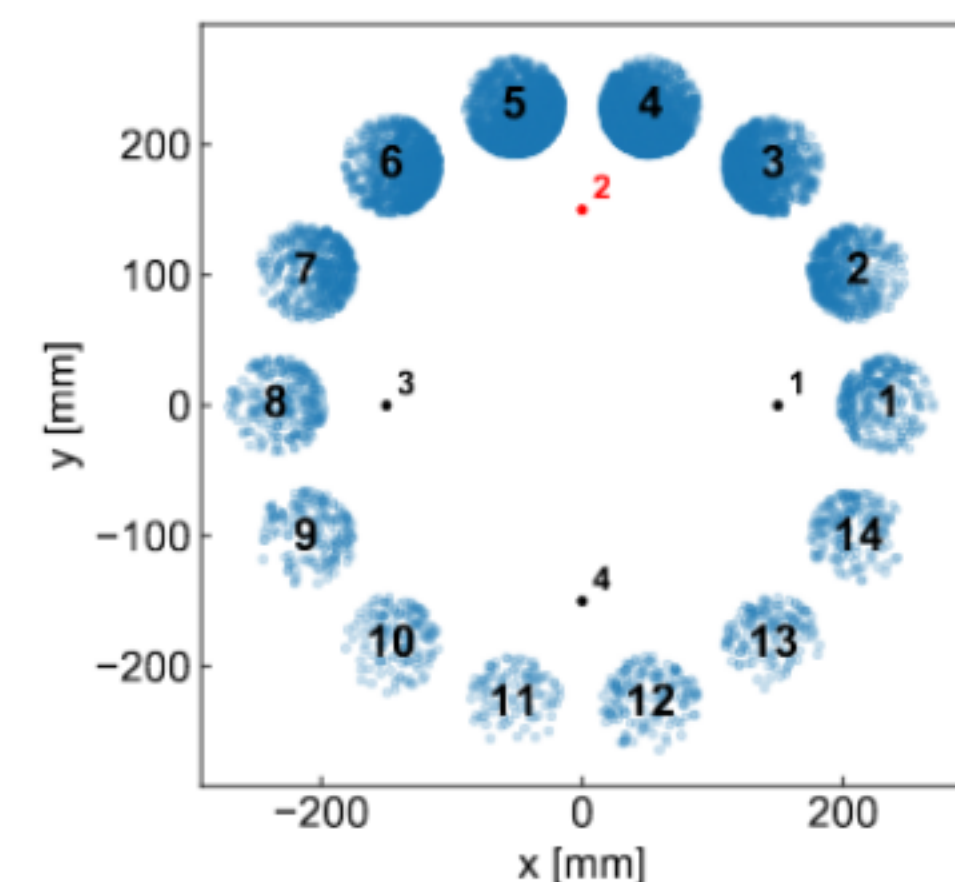
Simulated hits in the detectors

Source insertion system

Immersion of the calibration sources into the LAr cryostat at 87 K:

- Movement by deploying a 10.5 m long steel band with laser drilled holes, connected to a motor powered by a microcontroller
- Multiple source holders resistance spot-welded onto the steel band
- An absorber and the horizontal storage position prevent from additional background contributions
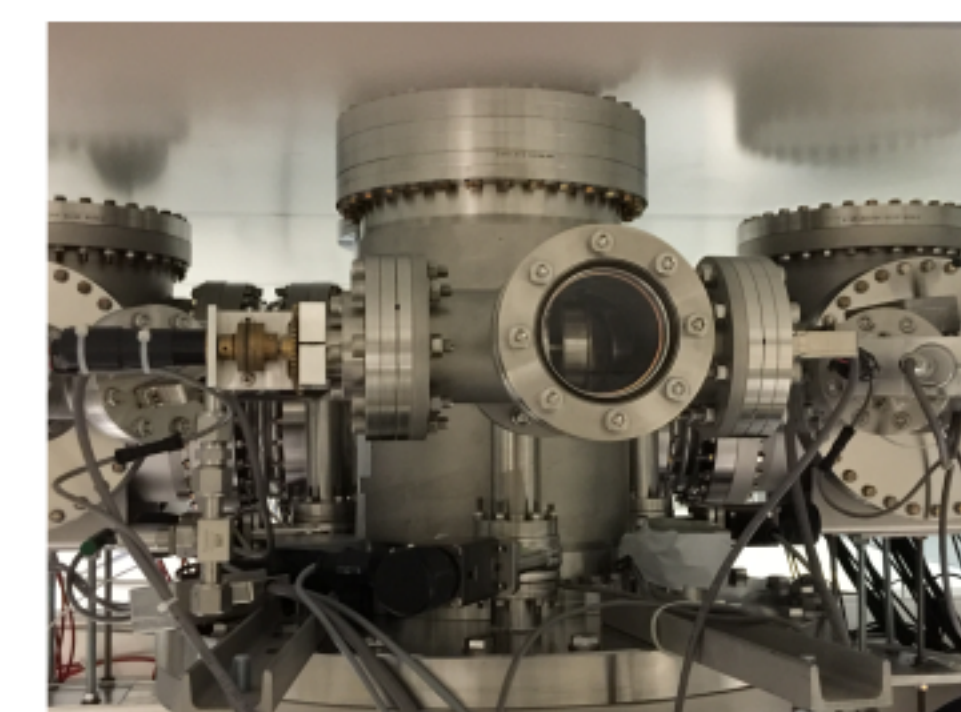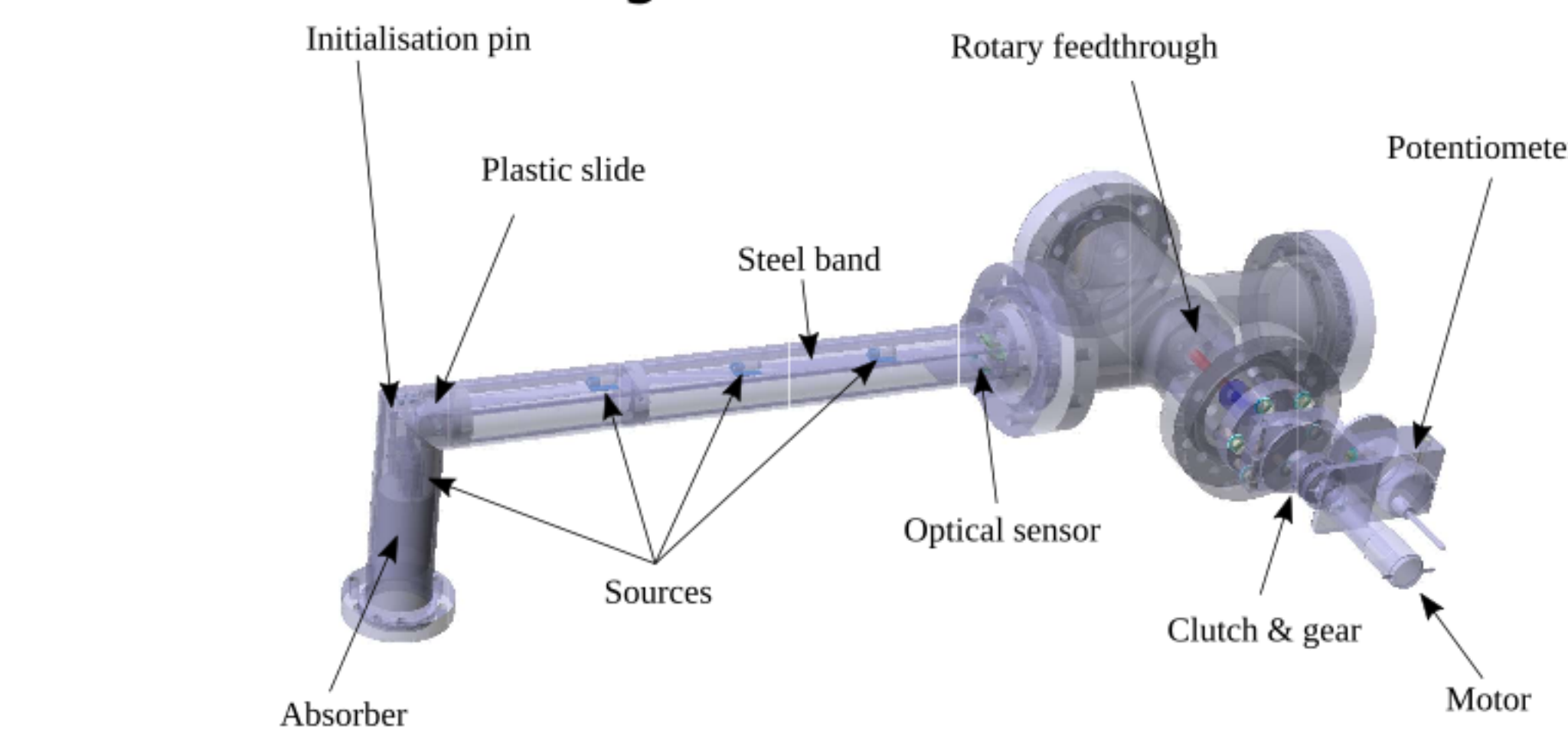
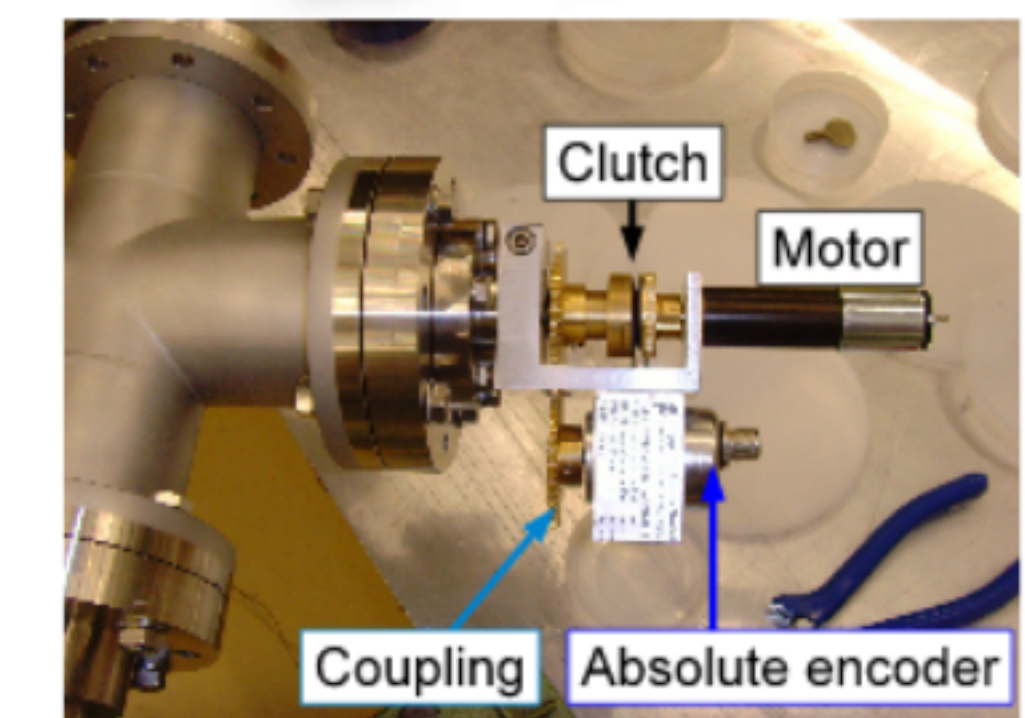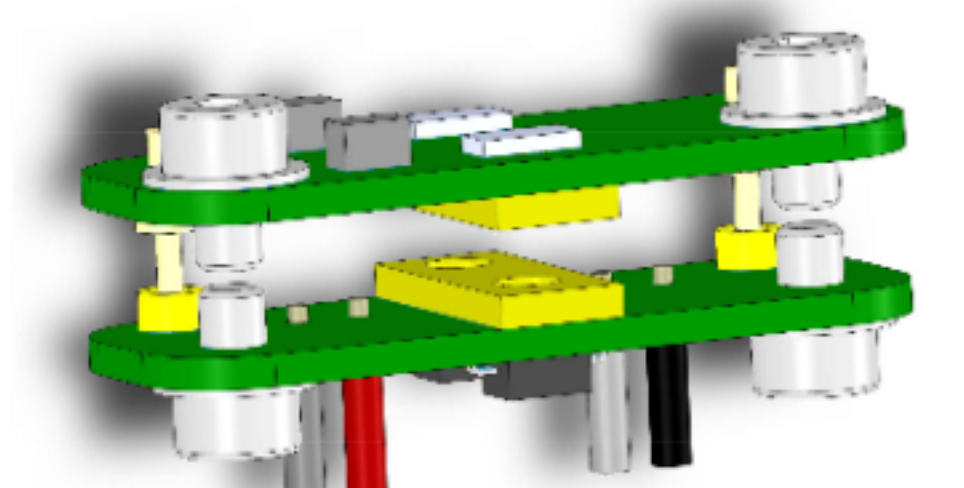Test system, mounted on top of lock system and cryostat

Spot-welded source holders

Source position determination

Two independent position sensing systems:

- **Incremental**: Optical sensor, counting holes in steel band → Main system
- **Absolute**: Potentiometer, stores multi-turn counts and single-turn angle → Control system

Test of the source position precision with an external laser at a 6 m high test stand at UZH:

Absolute vs Incremental
Laser vs Incremental

→ Position accuracy ~ mm
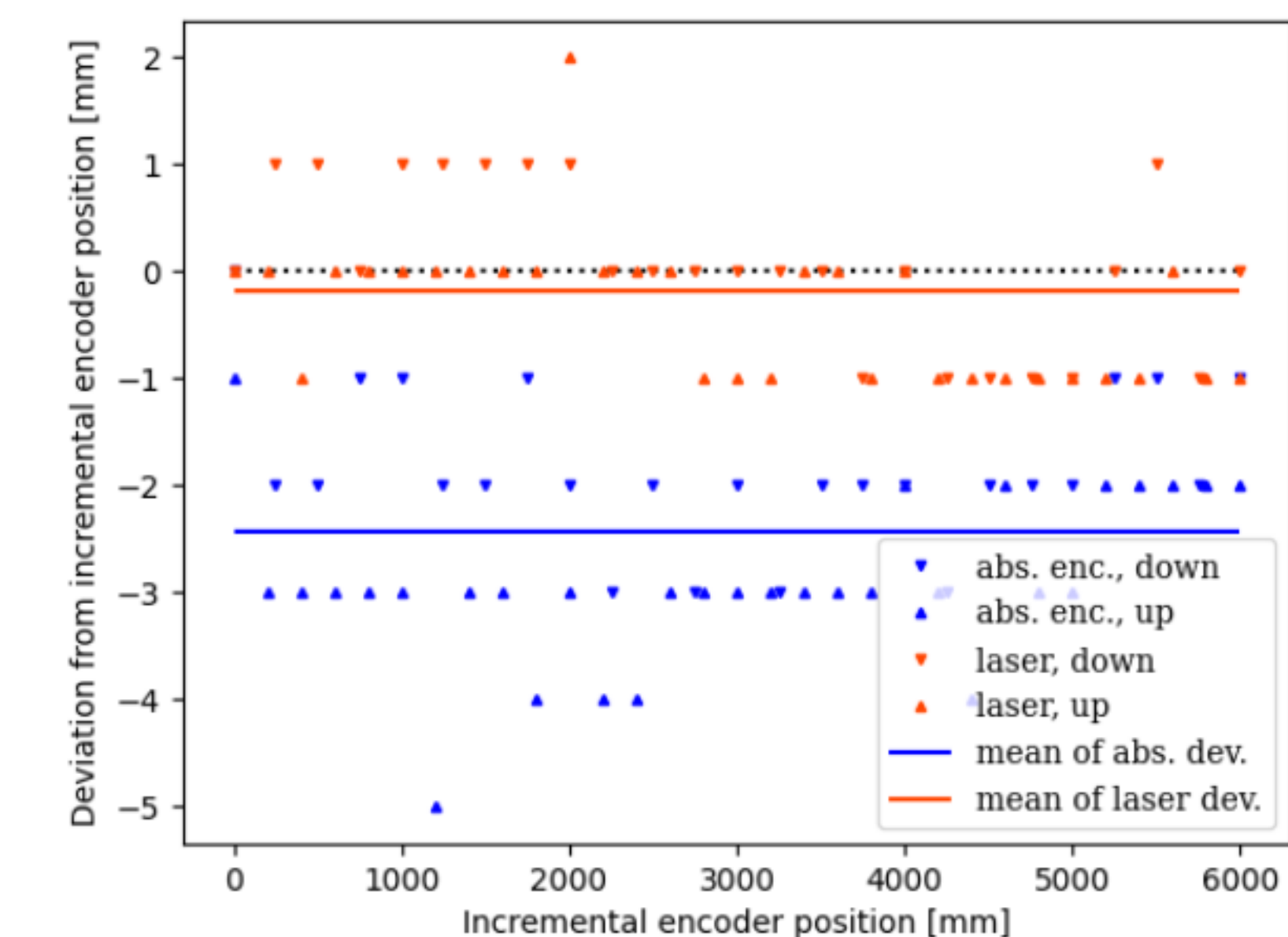
References:

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[2] A. Lazzaro for the GERDA collaboration: Status of the GERDA Experiment, Proceedings of Science, HQL 2016 (2017)
[3] MAJORANA Collaboration (C. E. Aalseth et al.): Search for Neutrinoless Double-β Decay in 76Ge with the MAJORANA DEMONSTRATOR, Phys. Rev. Letters (2018)
[4] F. Frobourg: Calibration of Phase I of the GERDA Double Beta Decay Experiment, PhD thesis, UZH (2012)
[5] M. Tarka: Studies of Neutron Flux Suppression from a γ-ray Source and the GERDA Calibration System, PhD thesis, UZH (2012)
[6] L. Baudis, J. Huang, Y. Müller, C. Ransom: Status of the Source Insertion System, LEGEND collaboration meeting (2020)

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