Towards the Neutrino Direct Mass Ordering with $0\nu\beta\beta$ decay

GERDA and LEGEND experiments

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&
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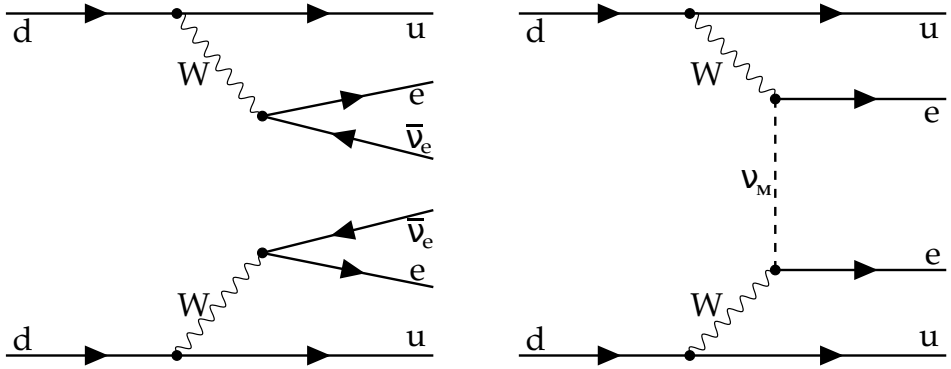
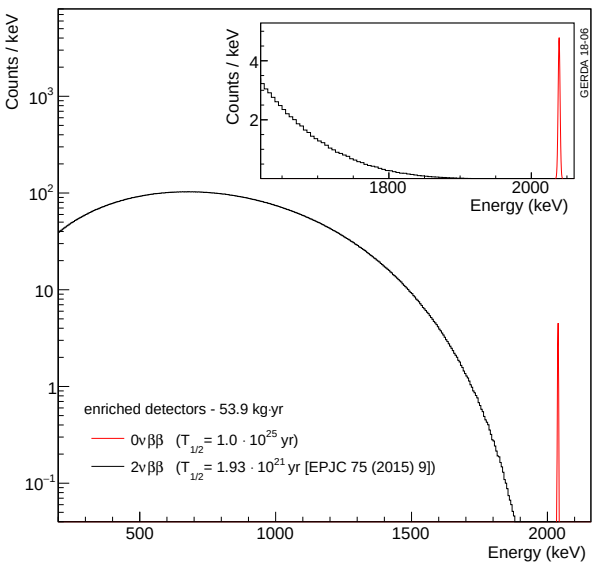
Why search for Neutrinoless Double Beta ($0\nu\beta\beta$) decay

Powerful method to investigate the unknown neutrino properties

- determination of neutrino nature
  $\Rightarrow$ **Majorana nature $\nu = \overline{\nu}$**
- lepton number violation (ΔL=2)
  beyond Standard Model Physics
- determination of ν absolute mass



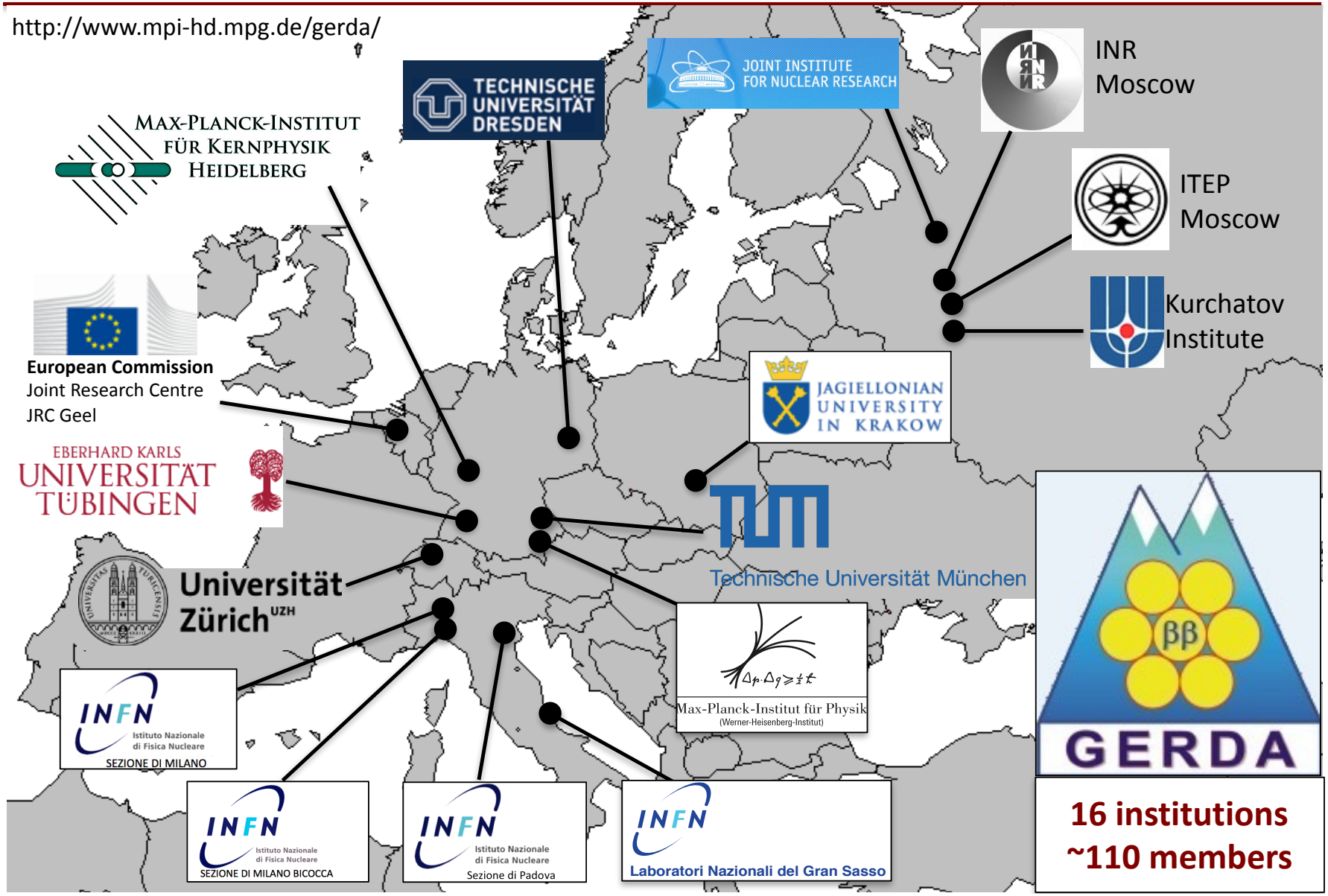


Signature: peak at Q-value

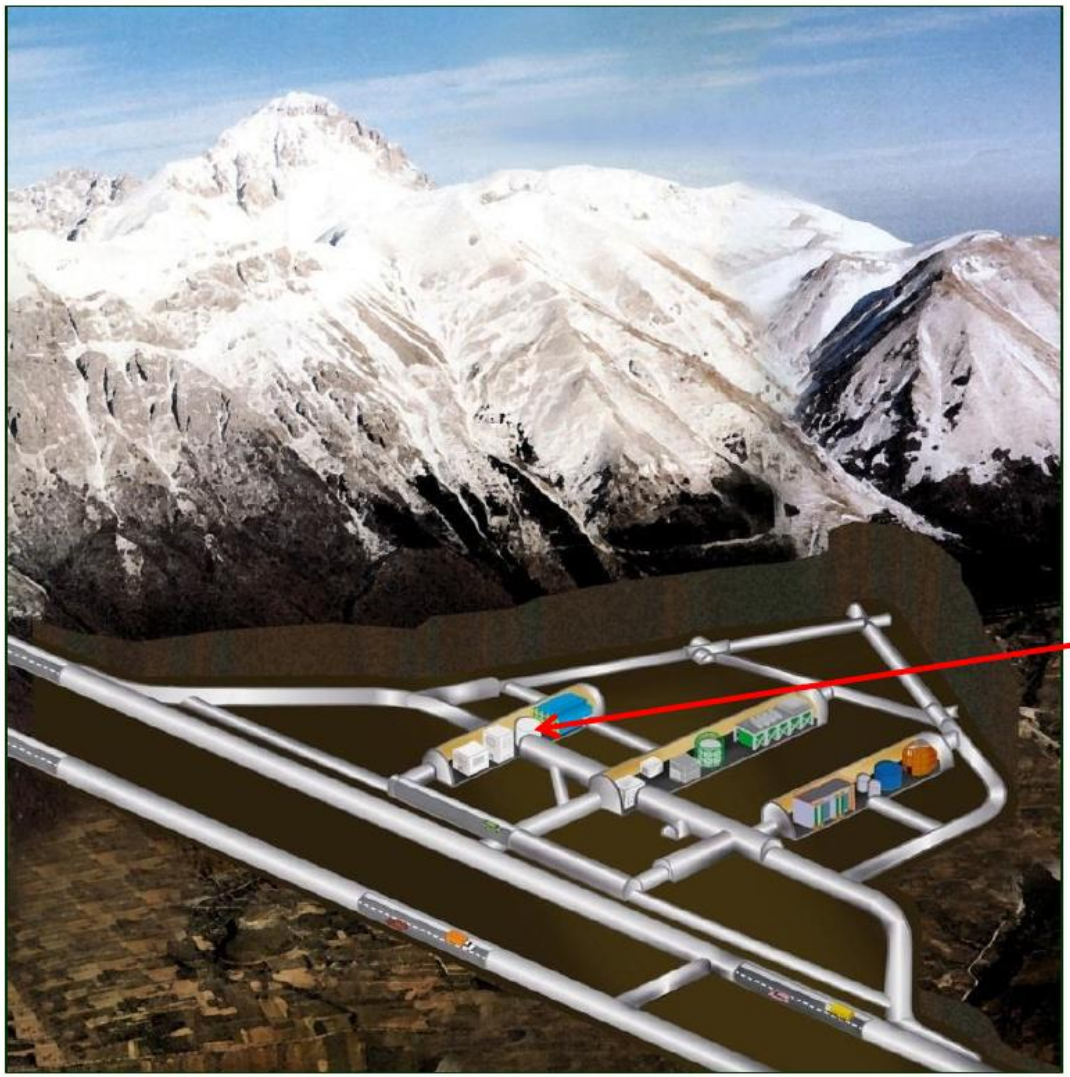
Decay not observed until now,
best limits with half-life of $\sim 10^{26}$ yr

Experimental sensitivity depends on:
$\beta\beta$ emitter exposure, energy resolution
and background reduction

The GERDA Collaboration



Location: INFN, Laboratori Nazionali del Gran Sasso

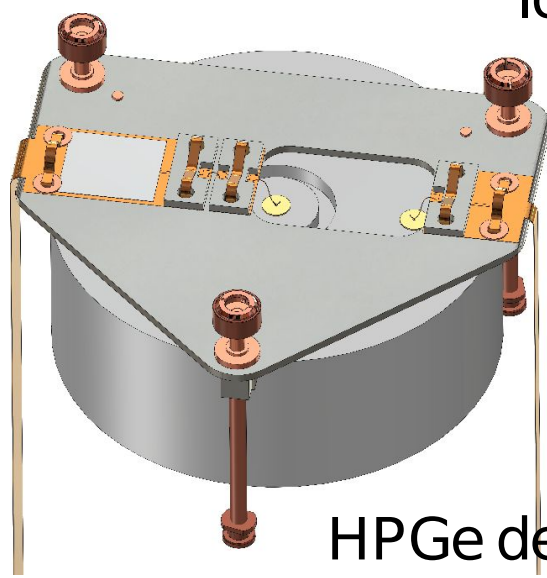


Shielded by $\sim$ 1500 m of rock $\rightarrow$ 3500 m.w.e.

GERDA detectors

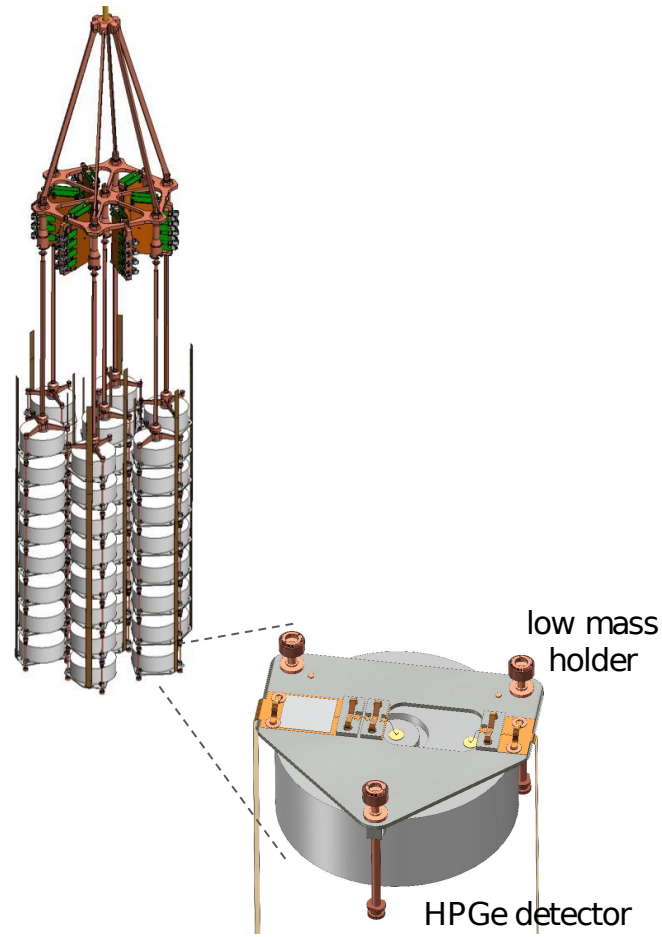
The detectors are High Purity Germanium detectors enriched up to $\sim 88\%$ in the ^{76}Ge $\beta\beta$ emitter

- high purity material $\rightarrow$ **no intrinsic background**
- source = detector $\rightarrow$ **high detection efficiency**
- semiconductor diode $\rightarrow$ **excellent energy resolution** (FWHM $\sim 0.1\%$ at $Q_{\beta\beta}$)



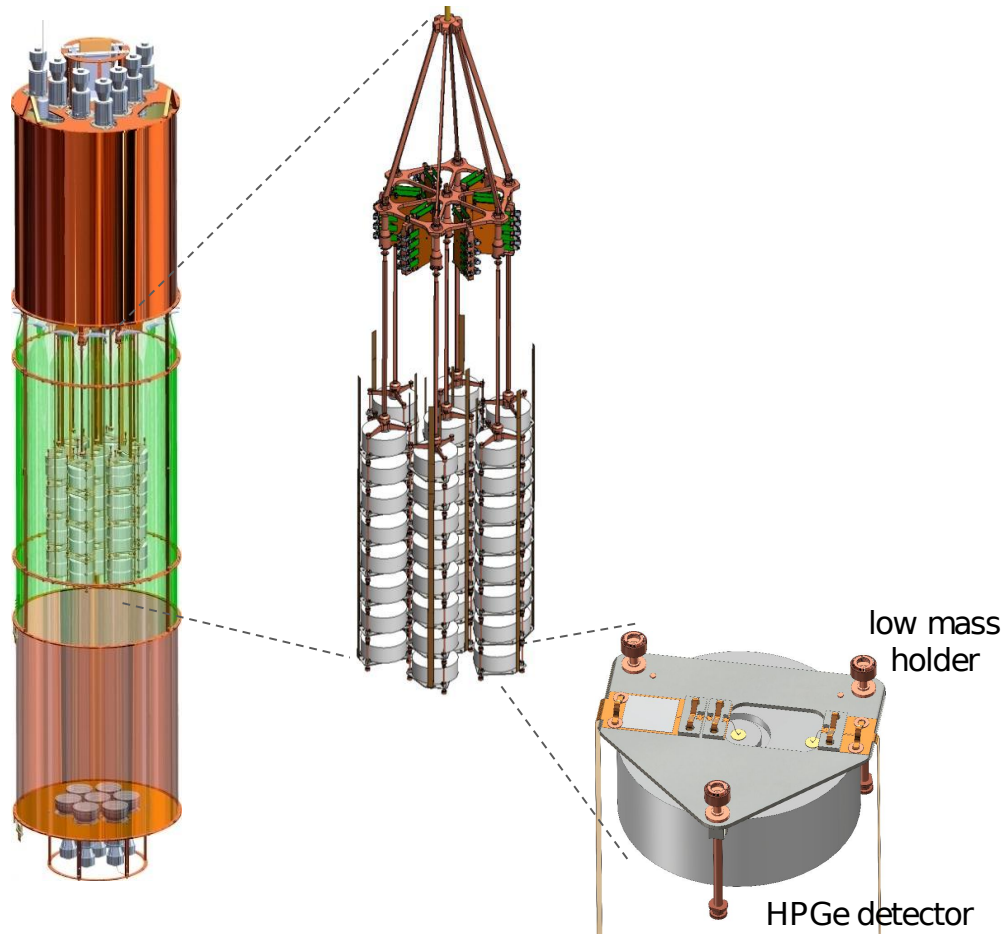
GERDA experiment

- detectors arranged in strings



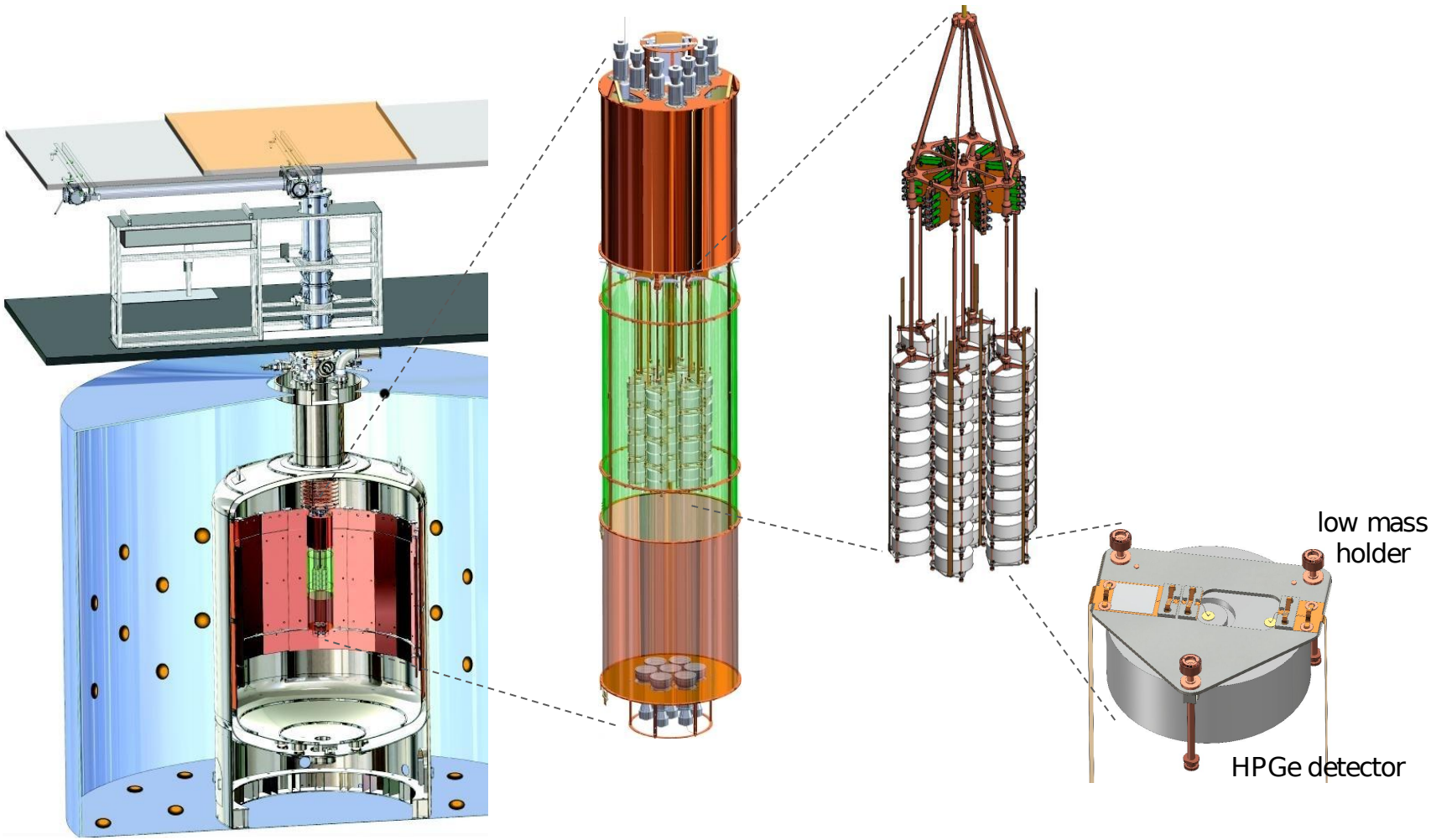
GERDA experiment

- detectors arranged in strings
- instrumented volume with PMTs + WLS fibers coupled to SiPMs

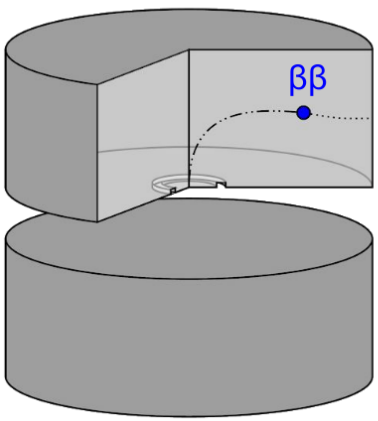


GERDA experiment

- detectors arranged in strings
- instrumented volume with PMTs + WLS fibers coupled to SiPMs
- multi-layer approach: water tank and LAr cryostat

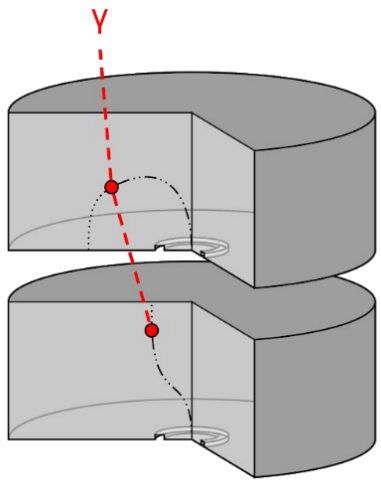


Active Background suppression in GERDA



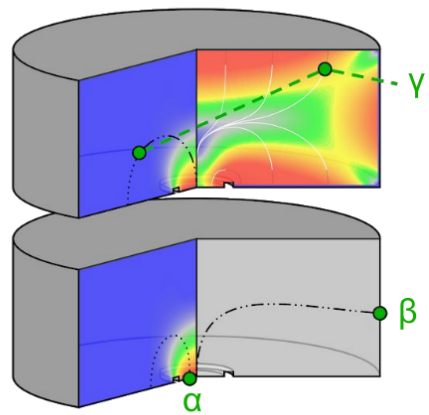
differentiate **point-like** (single-detector, single-site) ββ topology from:

detector anti-coincidence



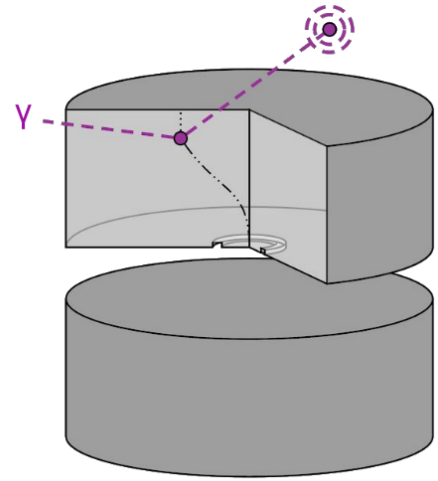
multi-detector interactions

pulse shape discrimination (PSD)



multi-site/surface interactions

detector-LAr anti-coincidence (LAr veto)

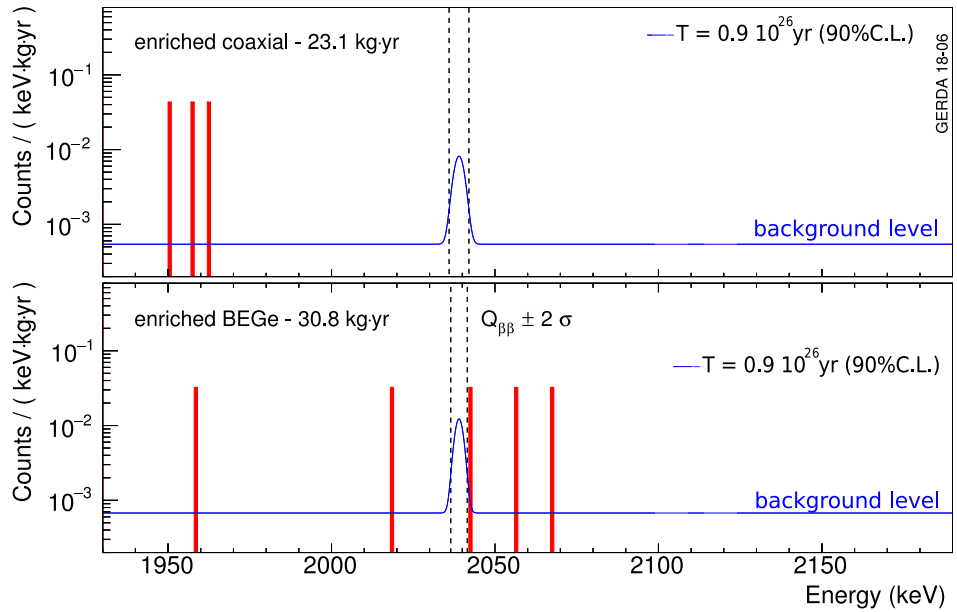


interactions with **coincident energy deposition** in surroundings

GERDA results

LAST RESULTS WITH 82.4 kg·yr OF EXPOSURE PUBLISHED ON Science, 0036-8075 (2019)

- **excellent energy resolution $\sim 0.1\%$**
- **lowest background in the field: $6 \cdot 10^{-4}$ cts/(keV·kg·yr)**
- **best $0\nu\beta\beta$ decay sensitivity of $1.1 \cdot 10^{26}$ yr (90% C.L.)**



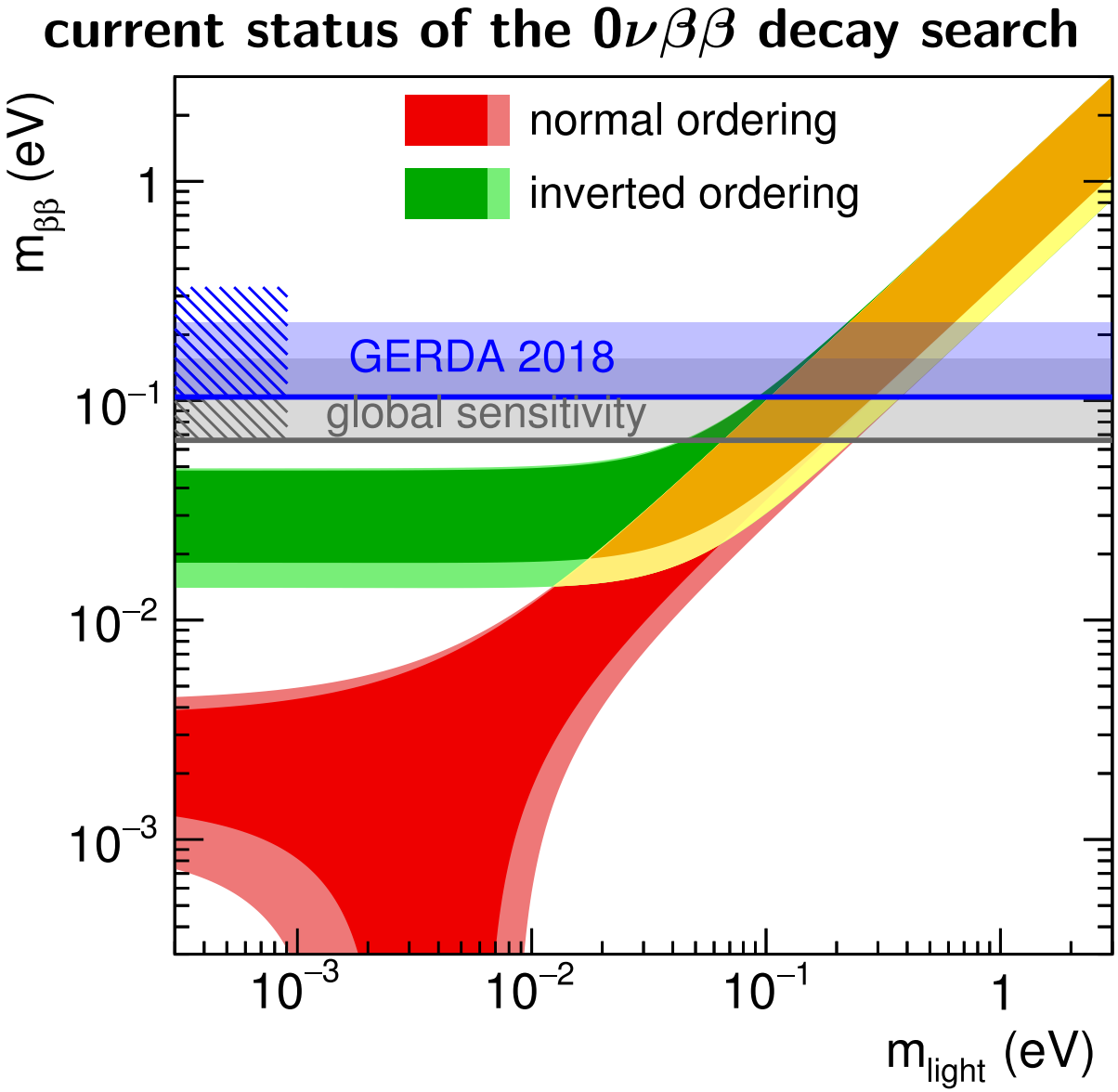
GERDA DATA TAKING STOPPED LAST DECEMBER, SOON NEW RESULTS WITH $>$ 100 kg·yr OF EXPOSURE

After GERDA: the LEGEND Experiment

$0\nu\beta\beta$ decay experimental program with discovery potential at half-life of 10^{28} years, based on GERDA and MAJORANA techniques

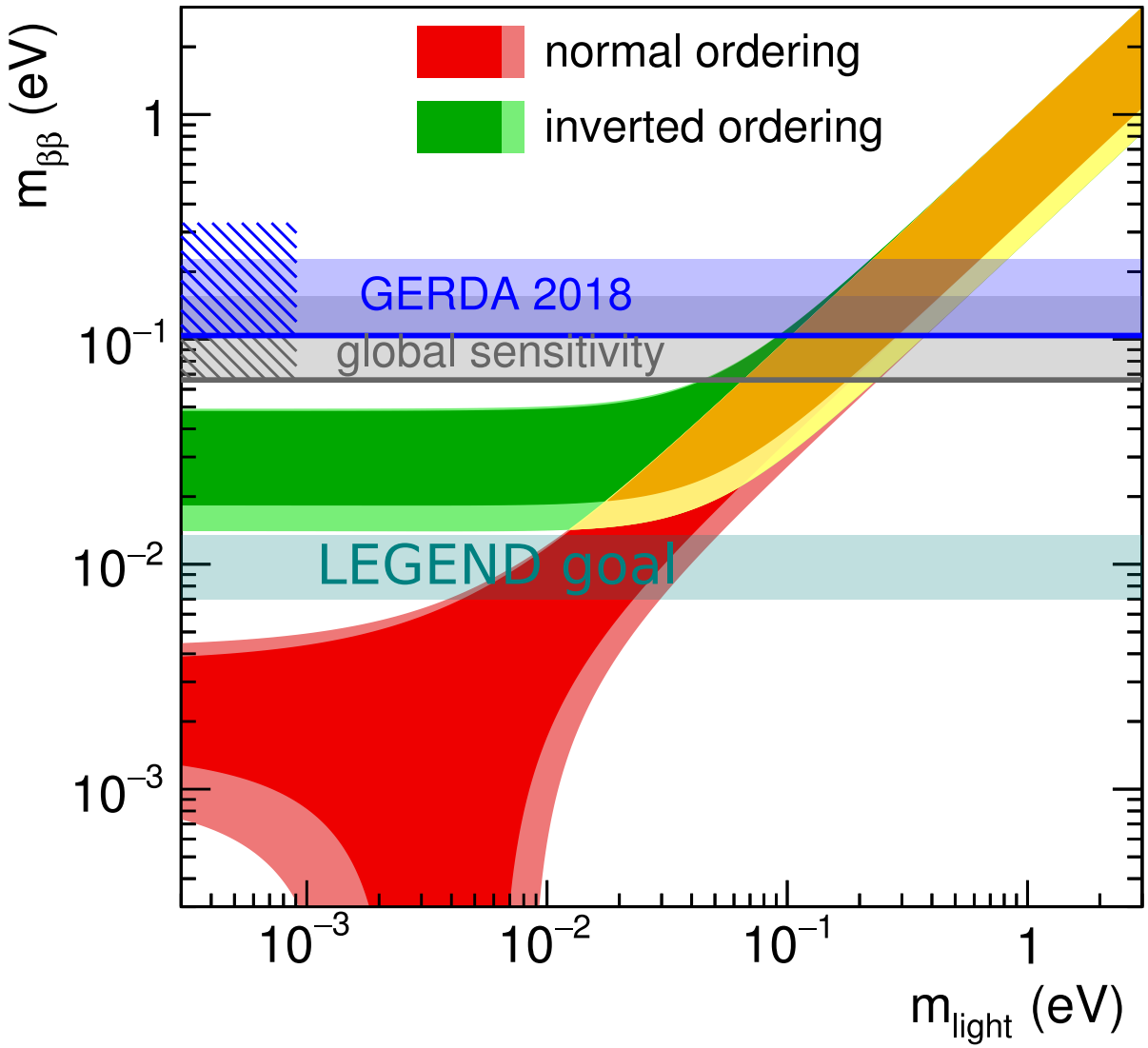
- 53 institutions, $\sim$ 250 members
- from GERDA and MAJORANA and external contributors

After GERDA: the LEGEND Experiment

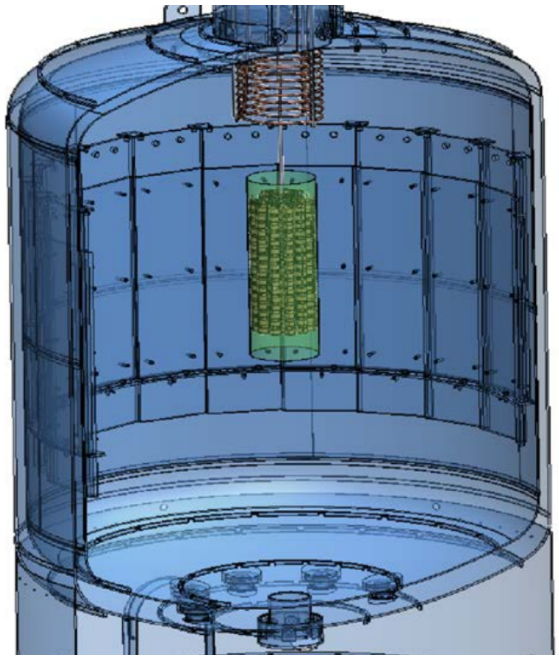


After GERDA: the LEGEND Experiment

LEGEND aims to cover the inverted ordering region



The LEGEND Experiment [arXiv:1709.01980]



First Stage: LEGEND-200

- 200 kg of enriched HPGe detectors
- location of GERDA at LNGS
- improved background 0.6 cts/(FWHM·t·yr)
- **preparation started in 2019**
- **efforts to start data taking in 2021!**

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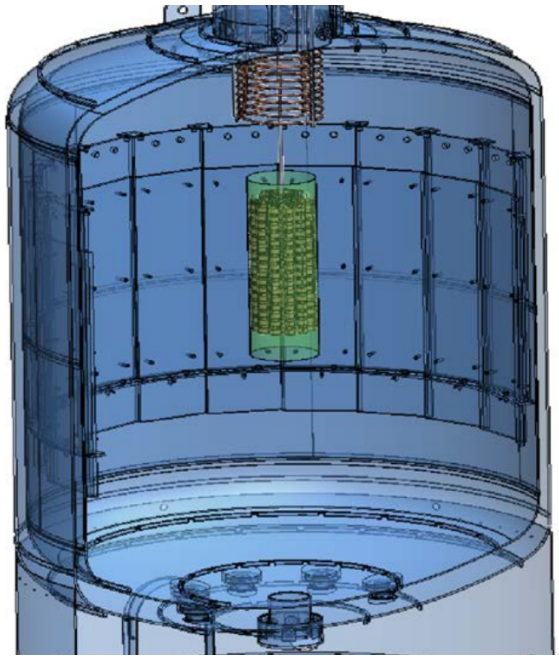

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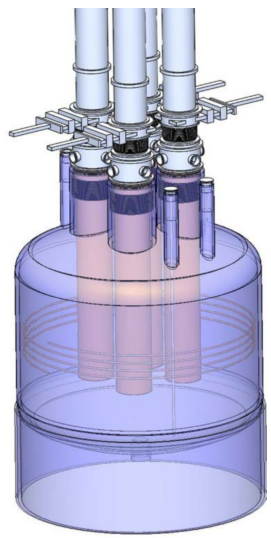
Subsequent Stage: LEGEND-1000

- 1000 kg of ^{76}Ge
- location tbd, required depth under investigation
- background goal < 0.1 cts/(FWHM·t·yr)
- timeline connected to review process



PhD in GERDA/LEGEND

- work in an international collaboration, scientist from best institutes and universities (Max Planck Institute, Princeton U., Zurich, U. Berkeley National Lab., California U., MIT, London U.)
- **publish $\sim$ 4 articles/years in refereed scientific journals**: GERDA published in last 3 years in Nature 544 7648 (impact factor 43) Phys. Rev. Lett. 120 132503 (i.f. 9.2) Science, 0036-8075 (i.f. 41)

Our LNGS/Univaq/GSSI group

- Univaq: Valerio D'Andrea, Francesco Salamida
- GSSI: Natalia Di Marco
- LNGS: Matthias Laubenstein, Carla Macolino, Matthias Junker, Chiara Vignoli, Marco Balata, Francesco Ferella

Our activities

- data analysis of last GERDA data
- development of the new LEGEND software (python based)
- activity on material screening
- work on the LEGEND-200 setup
- **data analysis of new LEGEND-200 data from 2021**