Legend –search for neutrinoless double β decay

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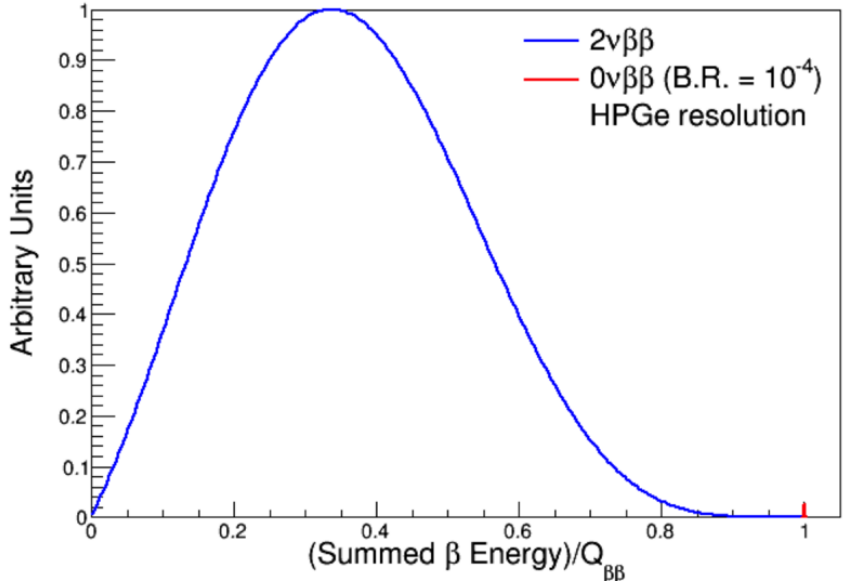
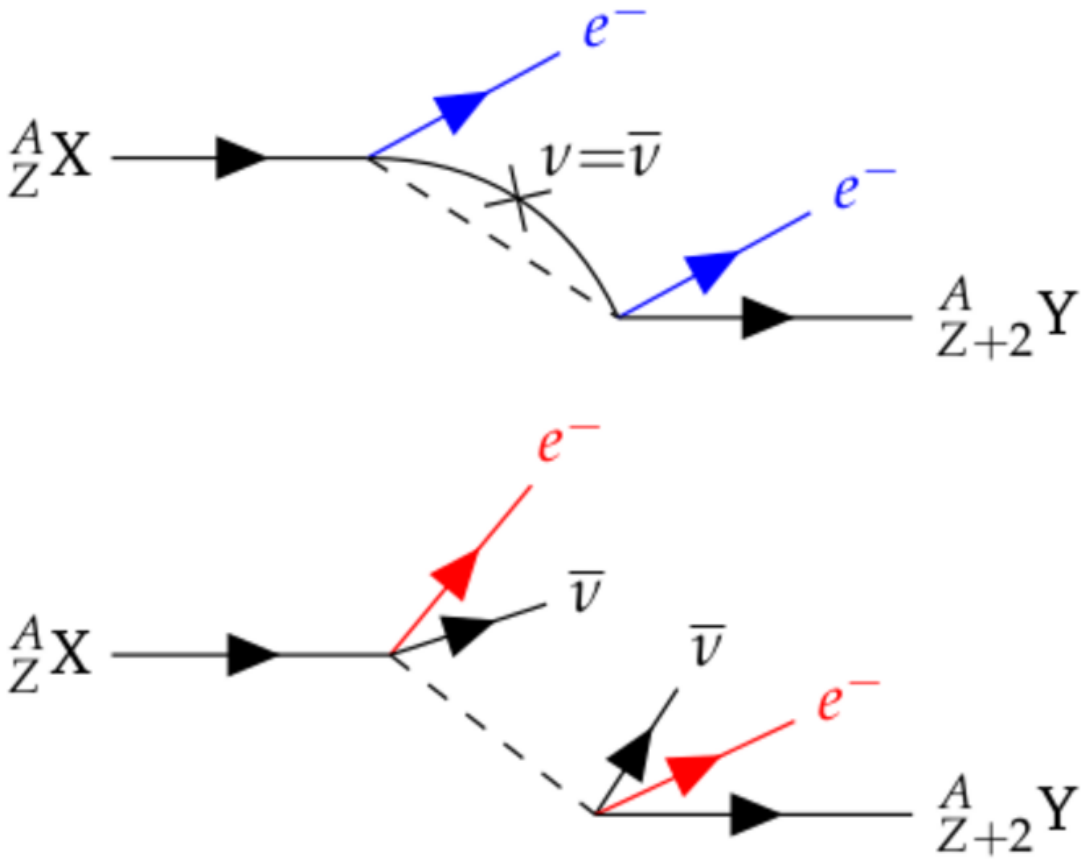
Neutrinoless double β decay

- Process could occur if neutrinos are their own anti-particle (Majorana)
- $Q=E(e_1)+E(e_2)$ for $0\nu\beta\beta$
- $Q<E(e_1)+E(e_2)$ for $\nu\nu\beta\beta$
- ^{76}Ge isotope used as it can also be part of the detector

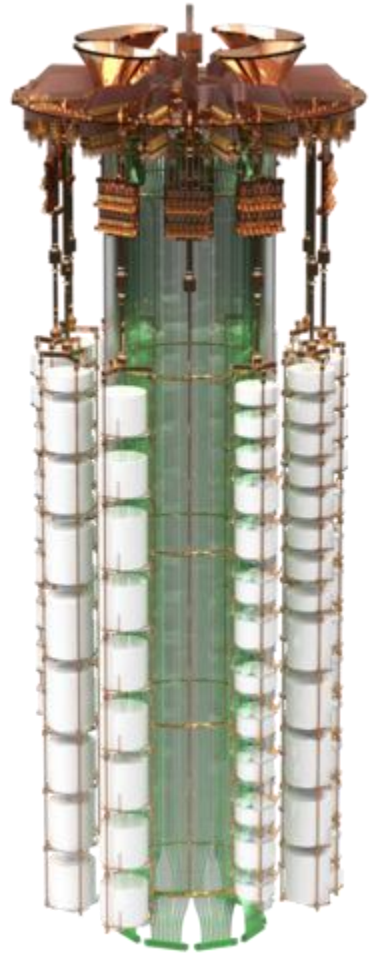




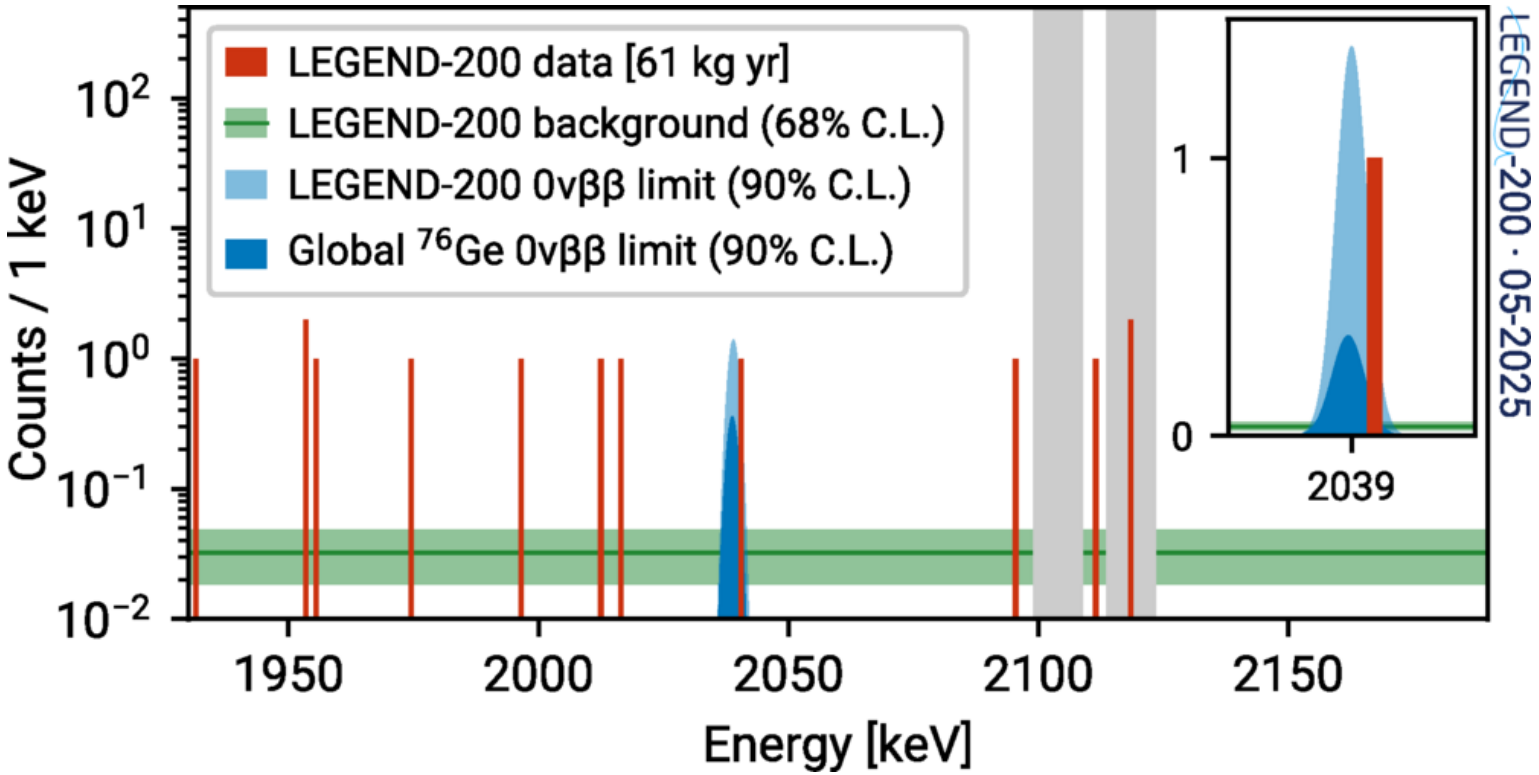
Legend Experiment

- **LEGEND-200**: a 200 kg mass experiment, installed in a LAr cryostat at LNGS, Gran Sasso
- Data taking in progress
- First results last year

- **LEGEND-1000**: a 1T ^{76}Ge requires a new underground infrastructure and additional R&D to further reduce backgrounds
- Start running later this decade likely at Gran Sasso
- Cost in US funding terms ~$1 B



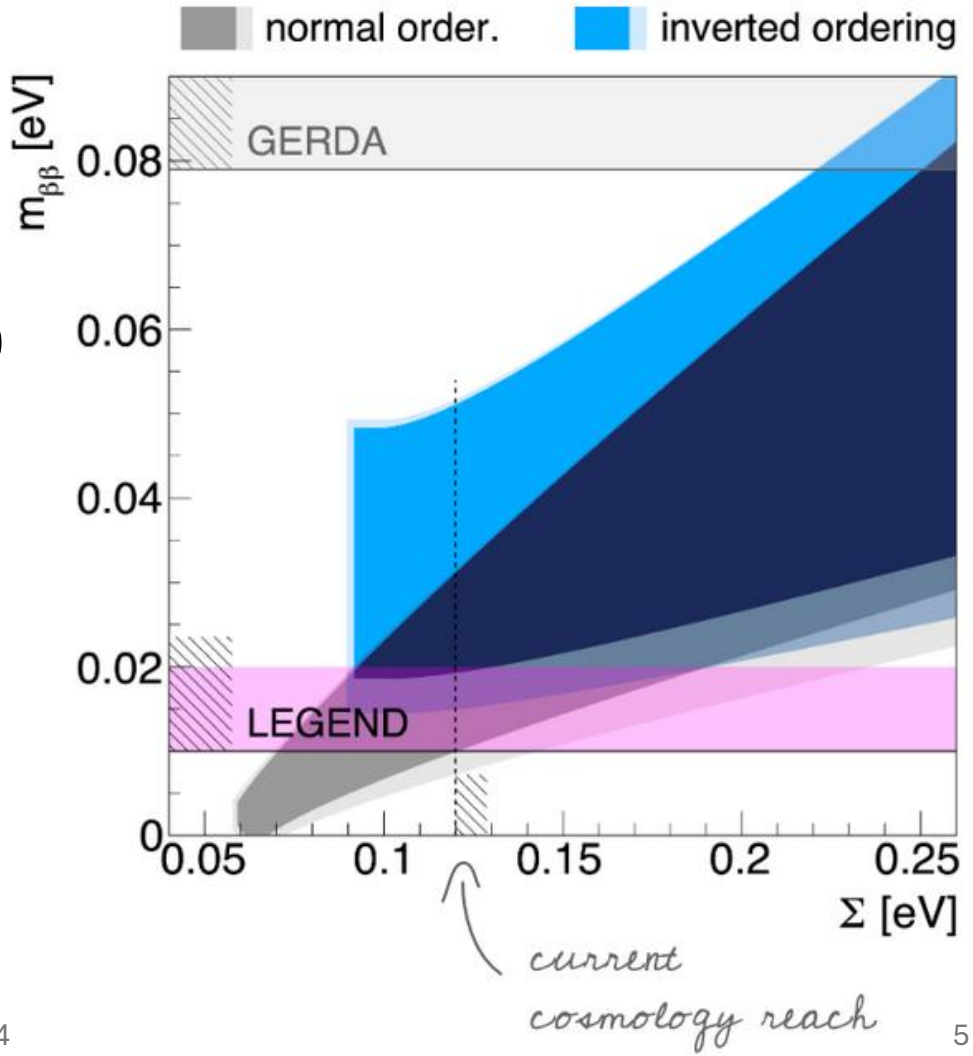
Legend 200 first published results



- Not yet as sensitive as other experiments but shows all is working with the detector and analysis
- Essential to get funding for Legend 1000
- Global combination yields $m_{\beta\beta}$< 75-200 meV depending on nuclear matrix element calculations

Legend Experiment Sensitivity

- Huge improvement over current experiments
- Almost all of inverted ordering probed
- And some of normal ordering
- Will know ordering from e.g. Juno before Legend 1000 data taking starts



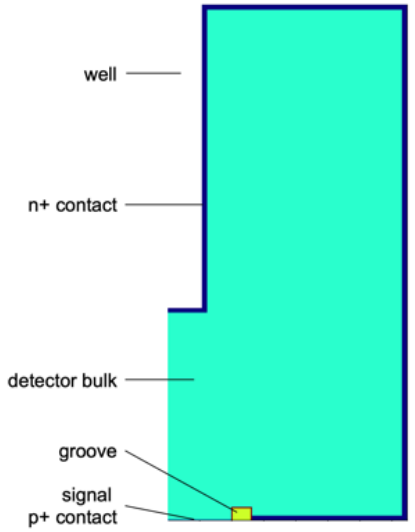
LEGEND Status

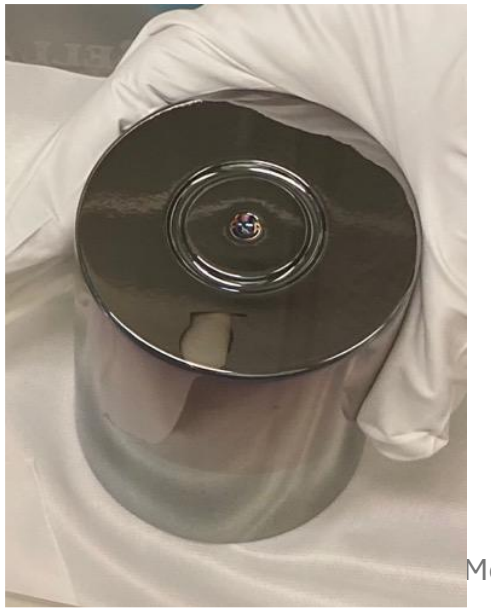
- LEGEND-200
  - First Physics Publication Phys. Rev. Lett. 136, 022701 –16 January, 2026
  - Next phase of data taking in progress at LNGS
  - Optimisation of analysis pipeline continues

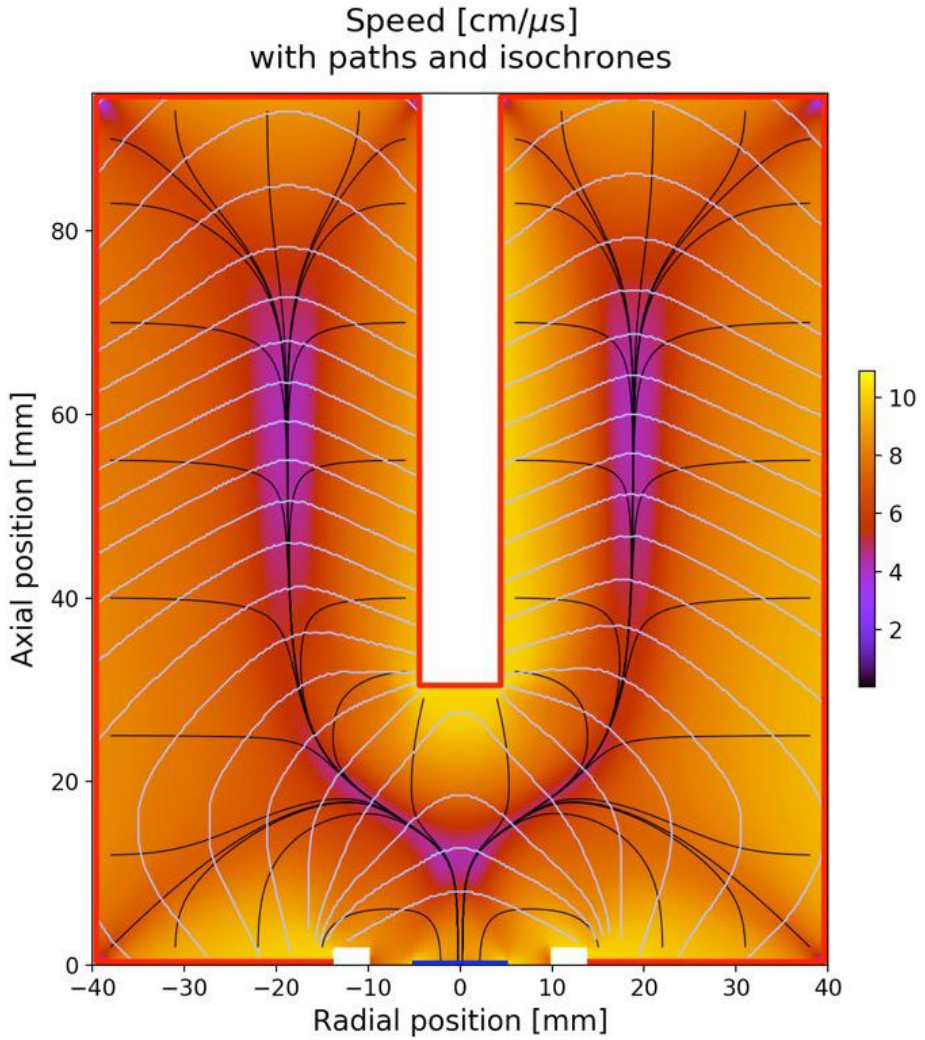
- LEGEND-1000
  - Successful DOE CD1 review in November 2025 with unanimous recommendation to proceed to CD1 (in progress).
  - NSF design packages proceeding to final design review
  - German Research Infrastructure proposal submitted to BMFTR, site visit by German Science Council in April
  - LEGEND was selected as a flagship project by INFN

Legend Detectors

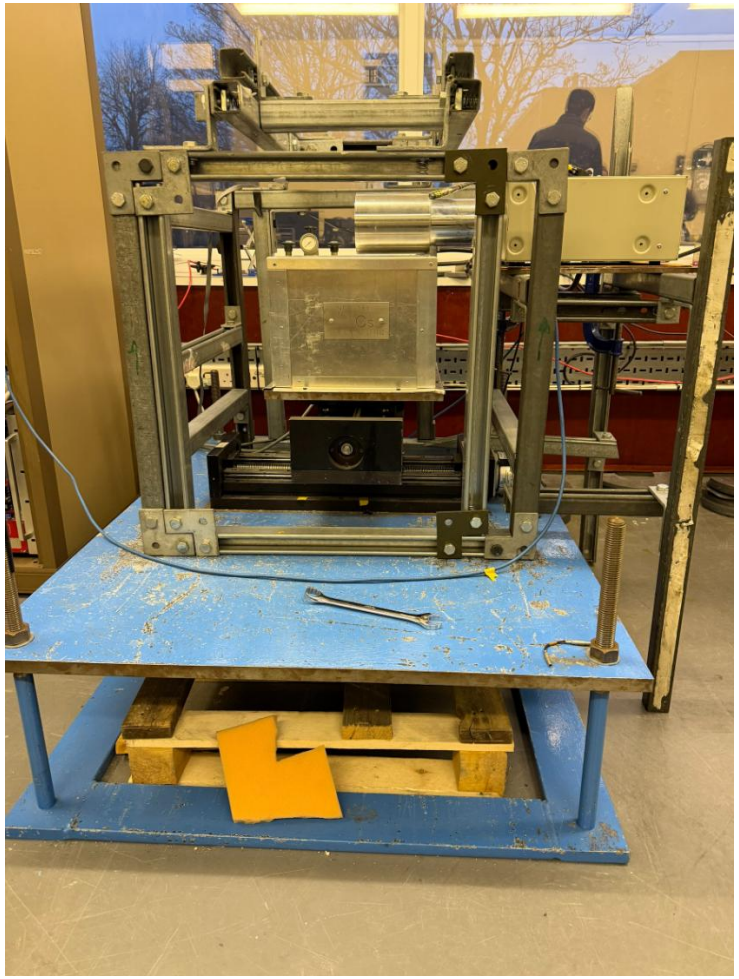
- 92% Enriched in ^{76}Ge
- Energy resolution 0.05%
- p-type detectors: Insensitive to alphas on n^+ outer contact
- Each detector 2.6 kg – 4× less background
- 400 detectors in total arrayed in strings



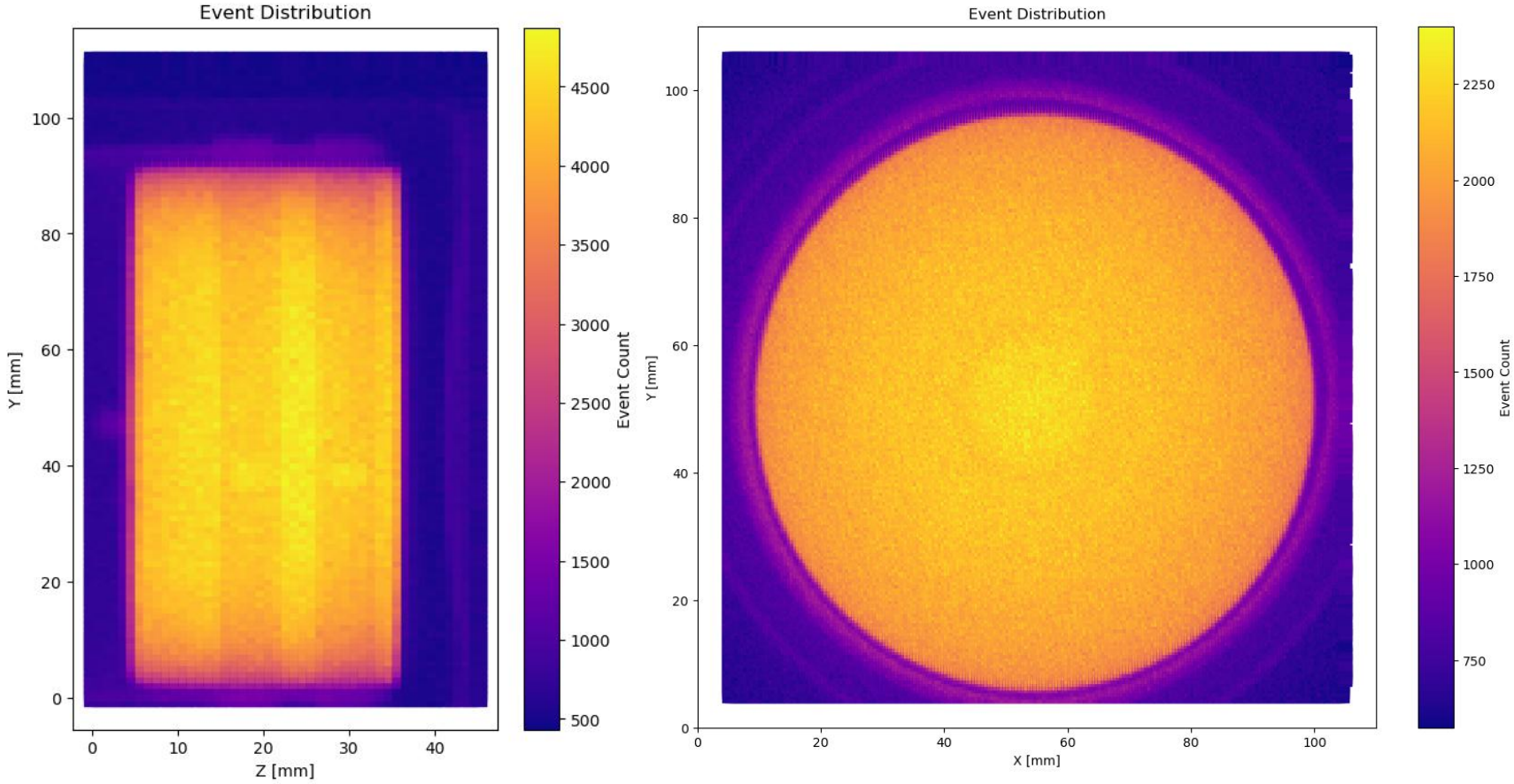




Work done in Liverpool (Holly)



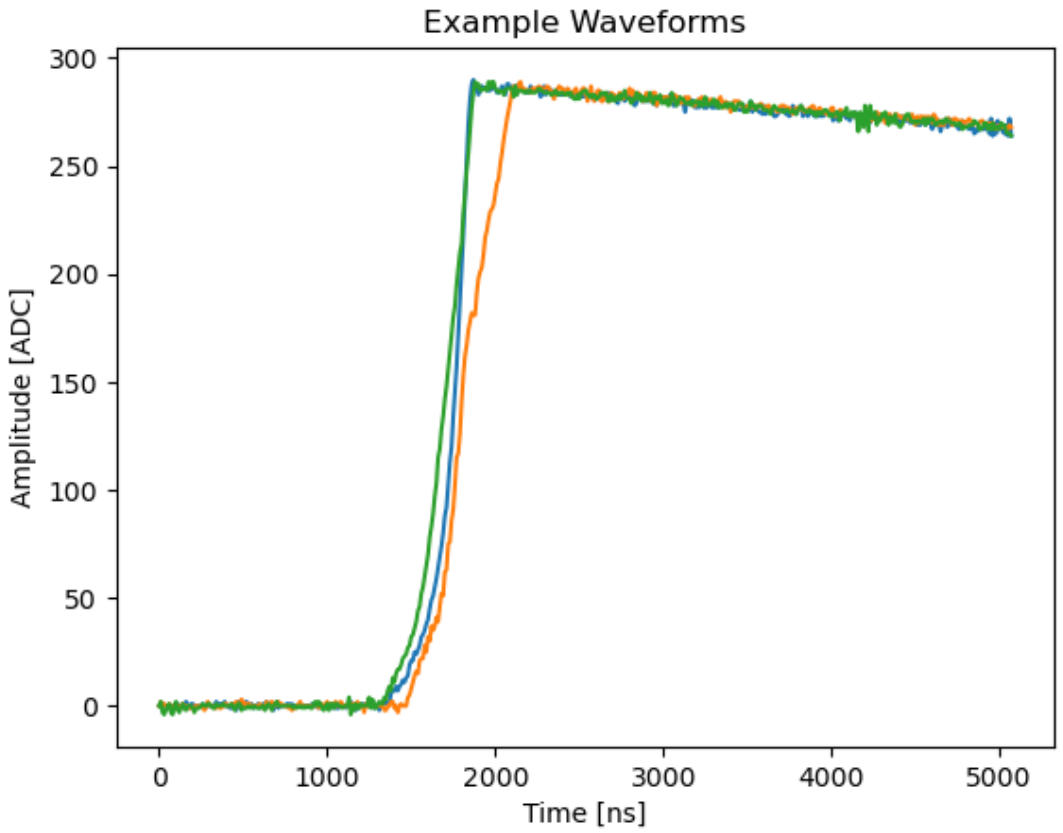
Setup for the (side) singles scan



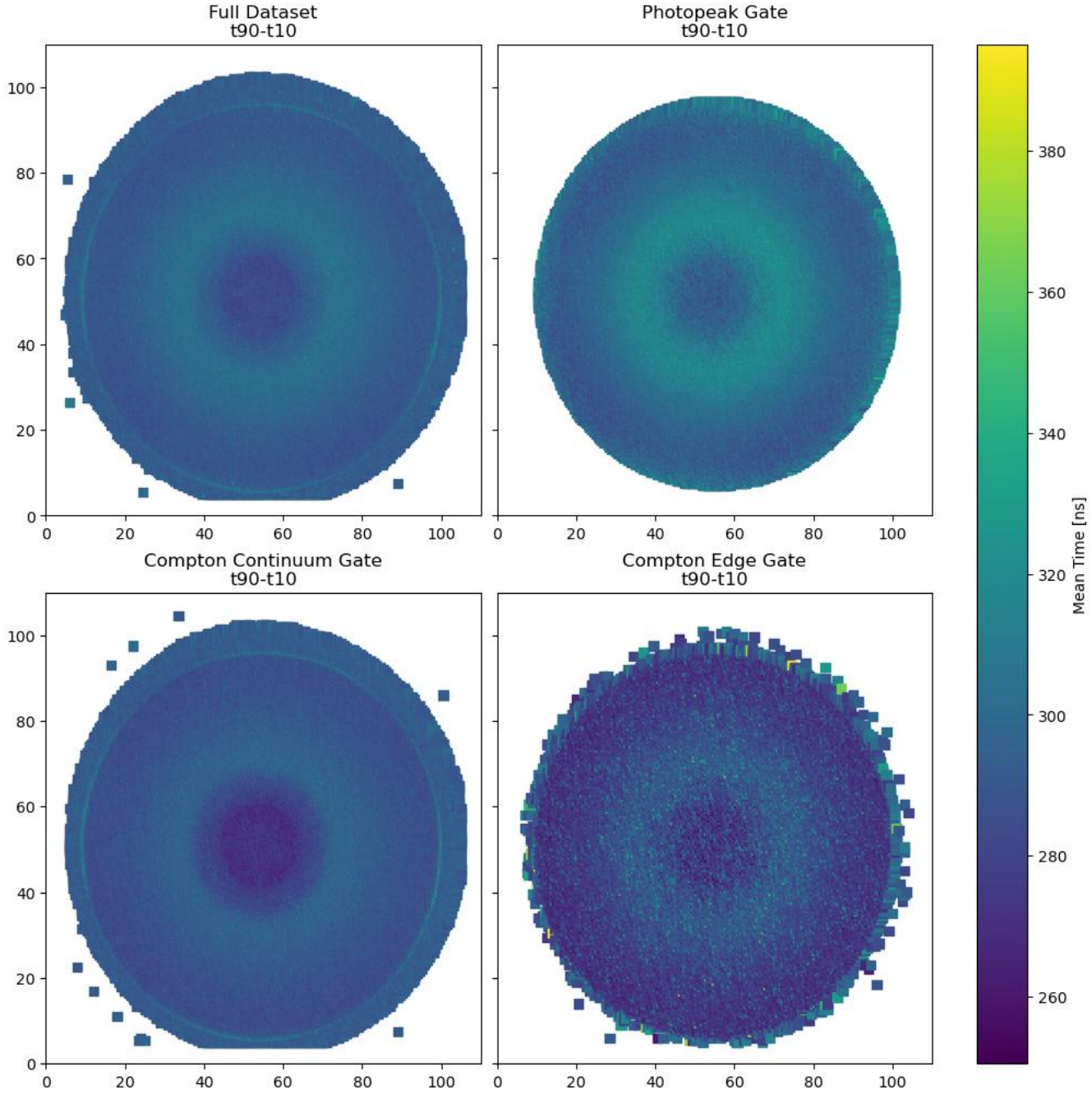
Event distributions of side and front scan in the full energy range

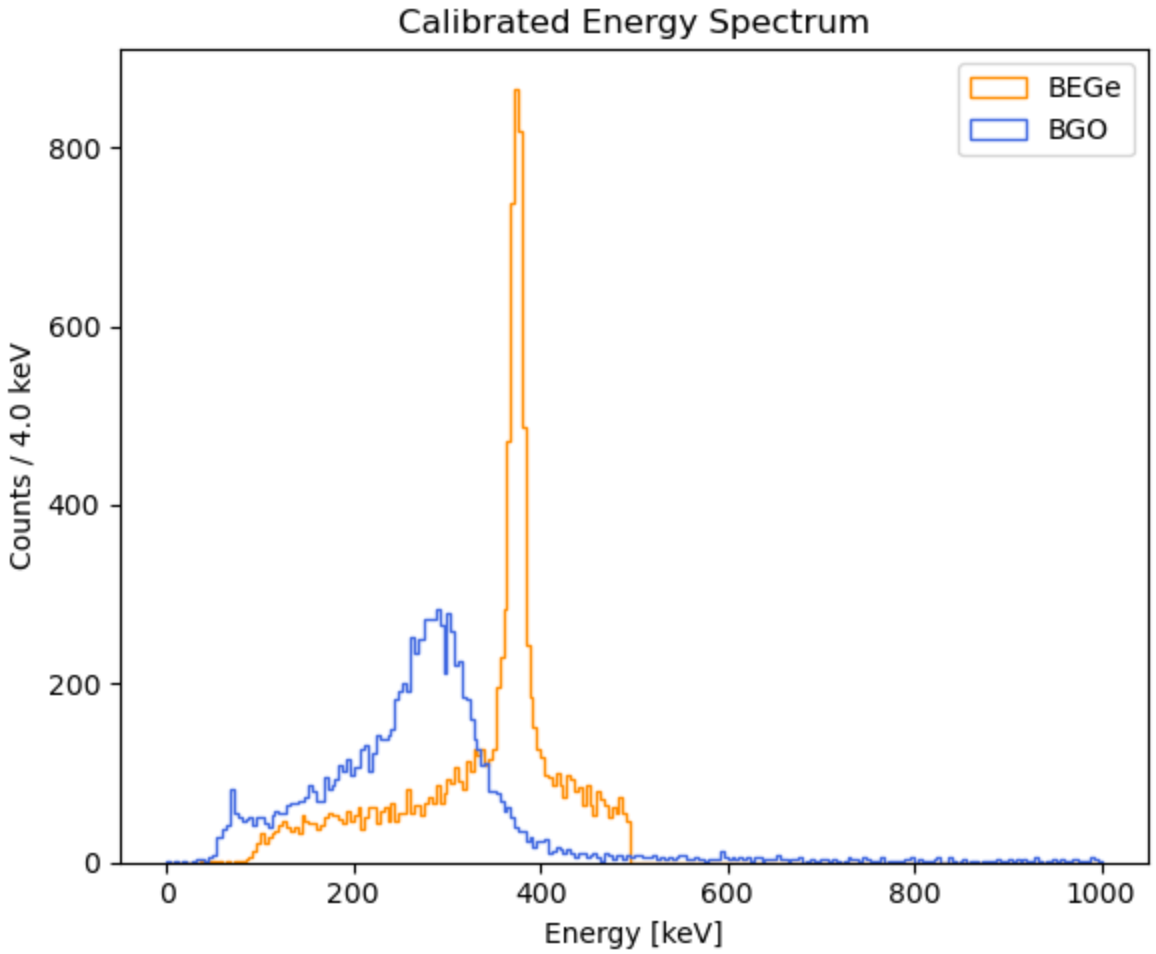
Can see structures within the detector

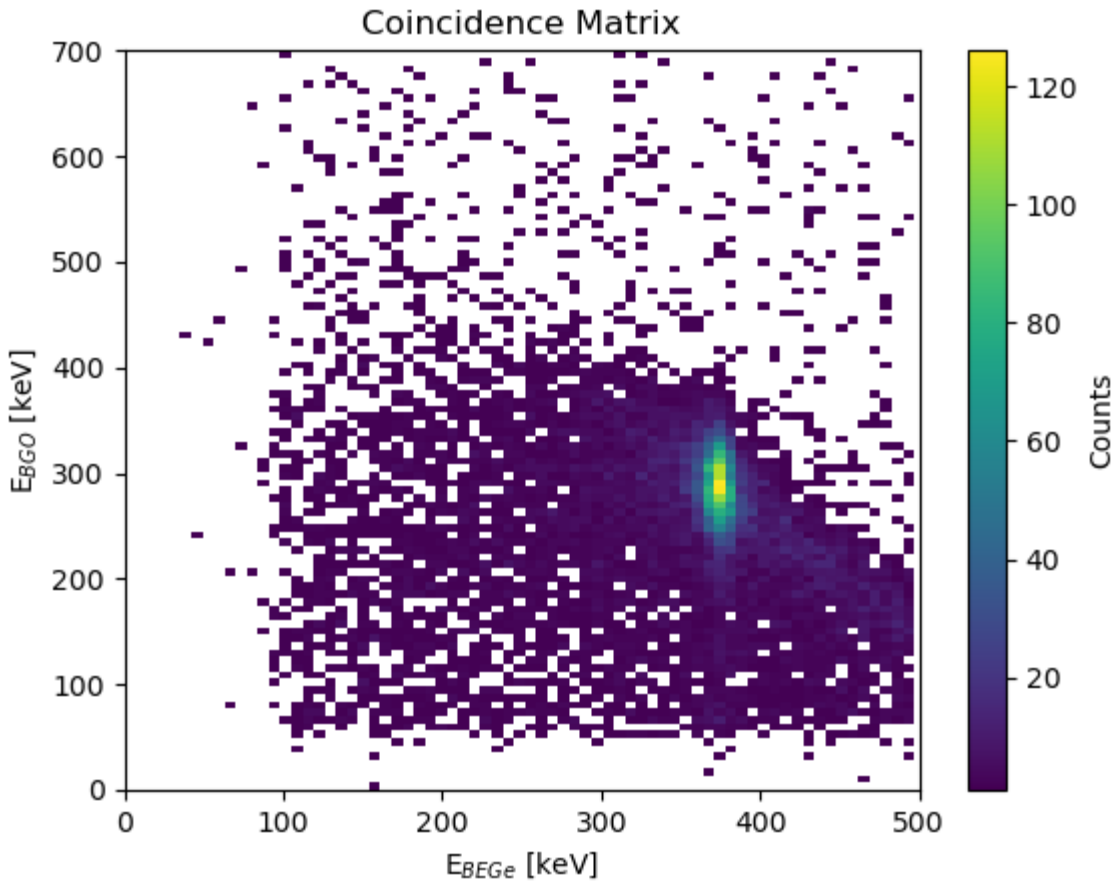
t90-t10 rise times for the front face scan under different energy gates



Kink in orange waveform signifies a multi-site event

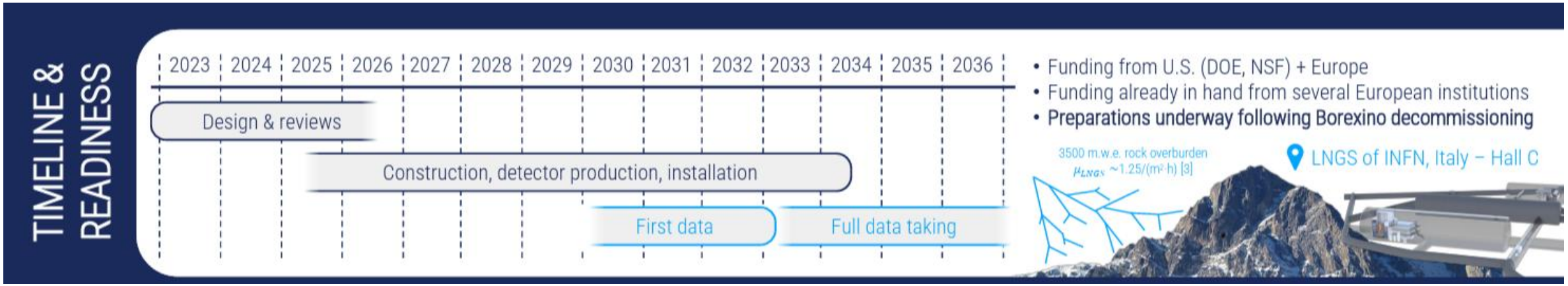






Coincidence scan: 90-degree Compton scatter so a 662 keV gamma deposits 374 keV in Ge detector and 288 keV in BGO (external detector)

Summary



- First physics result from LEGEND 200, leads to better constraints when combined with previous experiments
- LEGEND 1000 is the leading future experiment in neutrinoless double beta decay
- Has sensitivity to virtually all of inverted hierarchy phase-space
- Liverpool are involved with detector procurement and characterisation and data analysis
- Holly our first PhD student making good progress