Legend

neutrinoless double β decay

Particle Physics Annual Meeting May 2023

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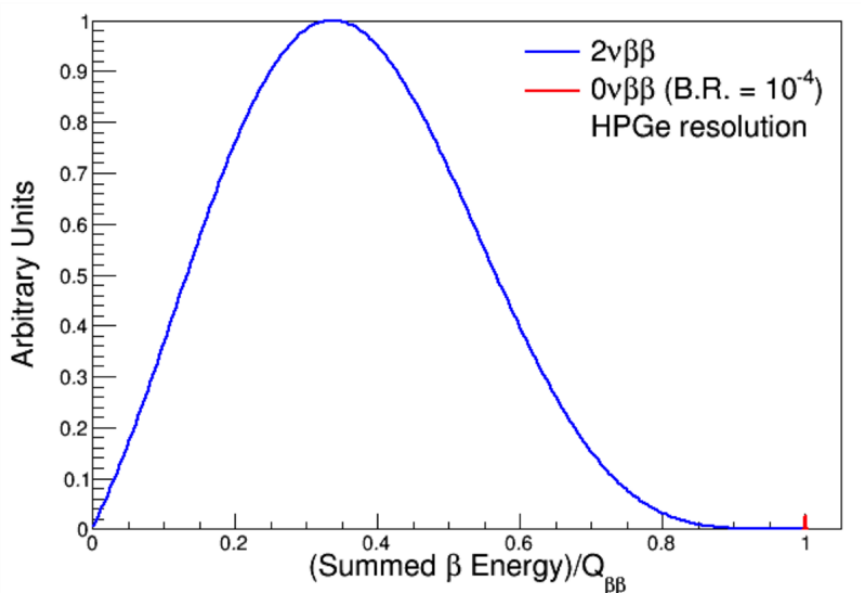
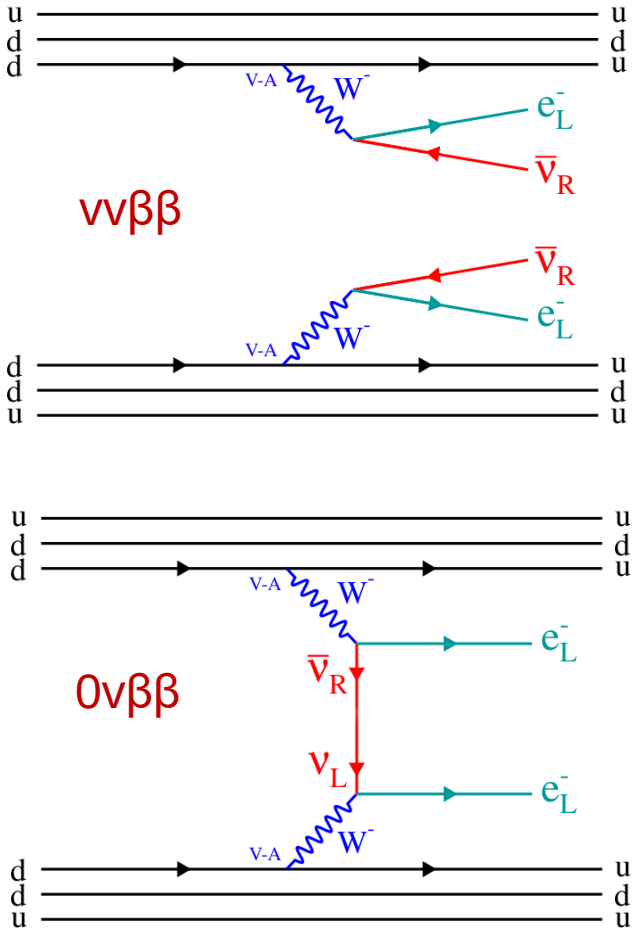
LEGEND Large Enriched Germanium Experiment for Neutrinoless ββ Decay

UNIVERSITY OF LIVERPOOL

Neutrinoless double β decay

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





https://warwick.ac.uk/study/csde/gsp/eportfolio/directory/crs/phsgbu/research/phdresearch/theory/betadecay/neutrinoless/

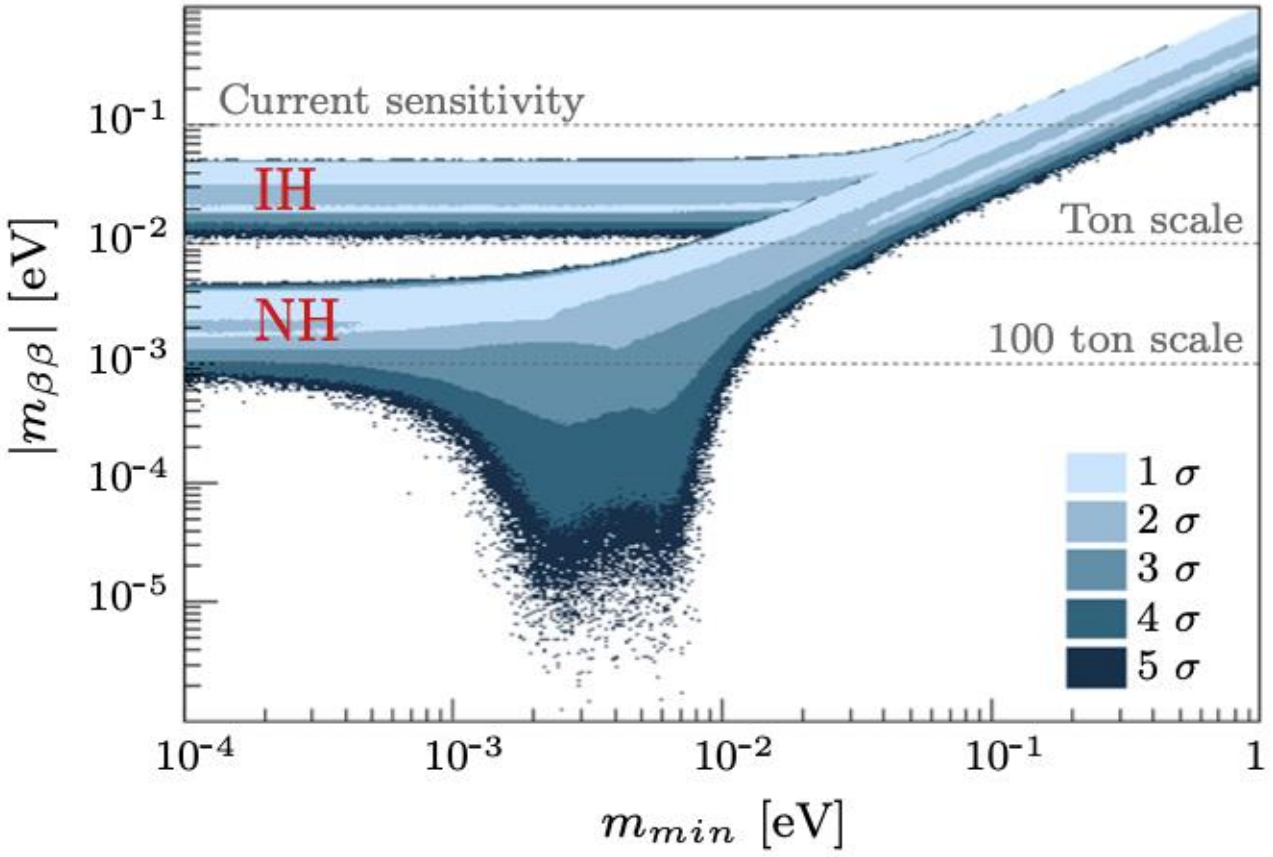
Legend Experiment

- **LEGEND-200**: a 200 kg mass experiment, installed in the GERDA LAr cryostat at LNGS, Gran Sasso
- Approved experiment at LNGS, with data taking in progress
- First results hopefully this summer

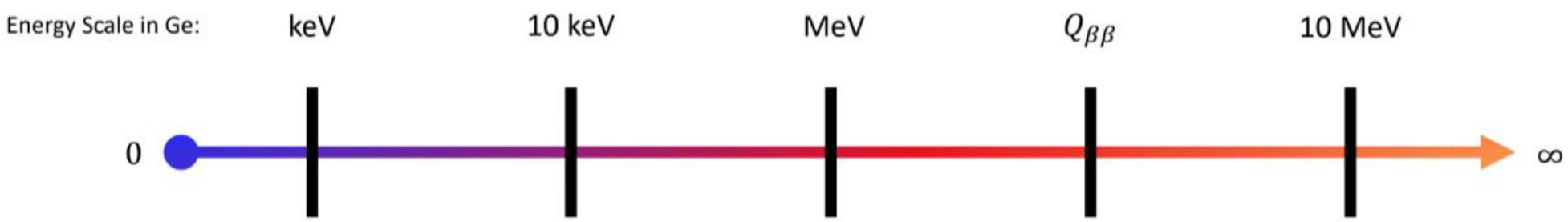
- **LEGEND-1000**: a 1T ^{76}Ge will require a new underground infrastructure and additional R&D to further reduce backgrounds
- Start running later this decade likely at Gran Sasso
- Cost in US funding terms ~$1 B

Legend Experiment Sensitivity

- Huge improvement over current experiments
- Almost all of inverted ordering probed
- And some of normal ordering



BSM Physics Opportunities beyond $0\nu\beta\beta$



Thermal WIMPs

Bosonic DM

Majoron Emission

Baryon Decay

Solar Axions

Light Fermionic DM

Lorentz Violation

Solar Neutrinos

Electron Decay

Inelastic Boosted DM

Fractionally Charged Particles

PEP Violation

Exotic Fermions

Supernova Neutrinos

Exotic Currents

Composite DM

Time-Dependent $2\nu\beta\beta$

Magnetic Monopoles

Wave Function Collapse

Presupernova Neutrinos

Legend:
- Dark Matter Candidates
- $2\nu\beta\beta$ Spectral Effects
- Tracklike Signatures
- Tests of Fundamental Physics
- Astrophysical Neutrinos

Los Alamos NATIONAL LABORATORY

LEGEND

05/17/2024 3

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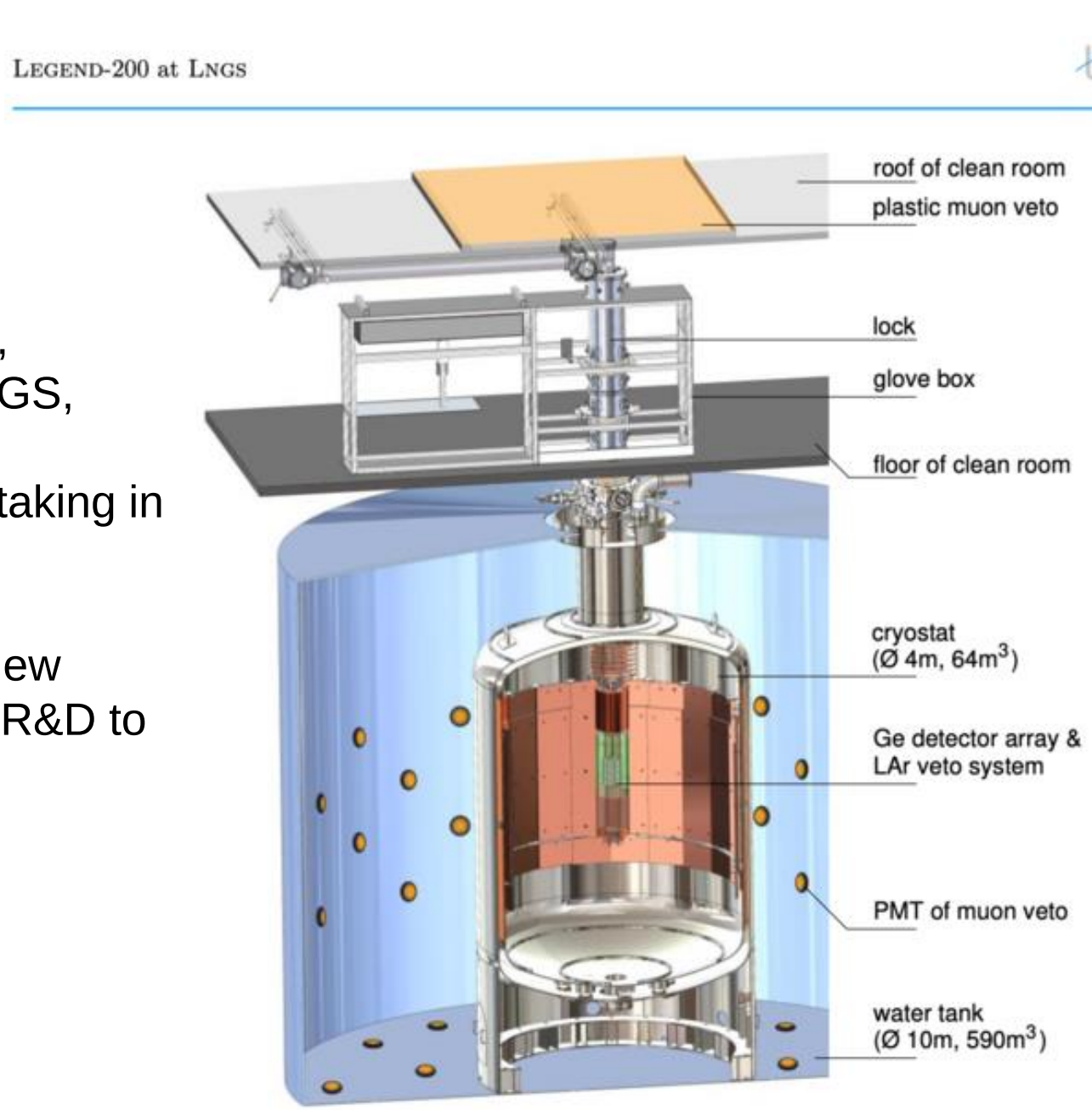
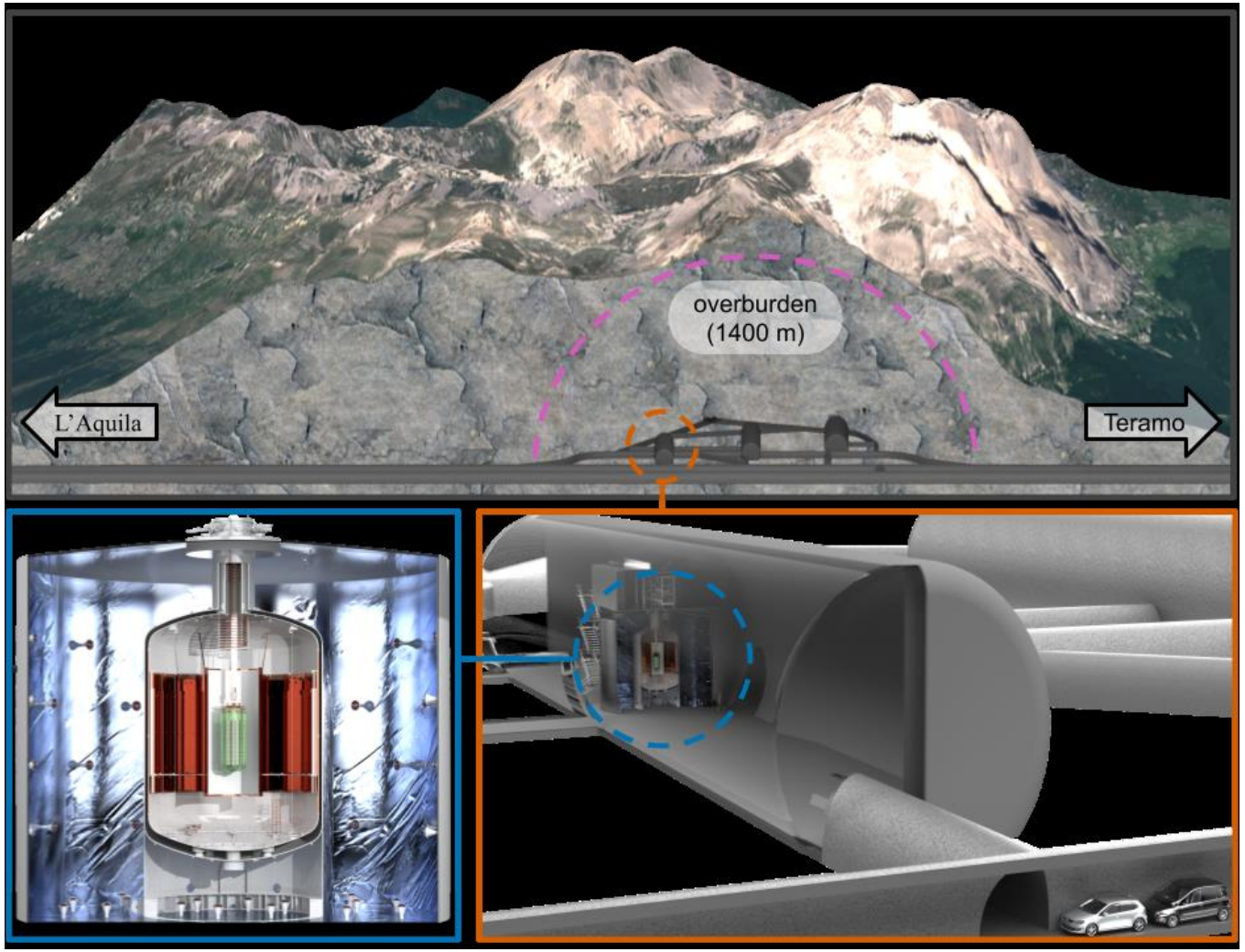
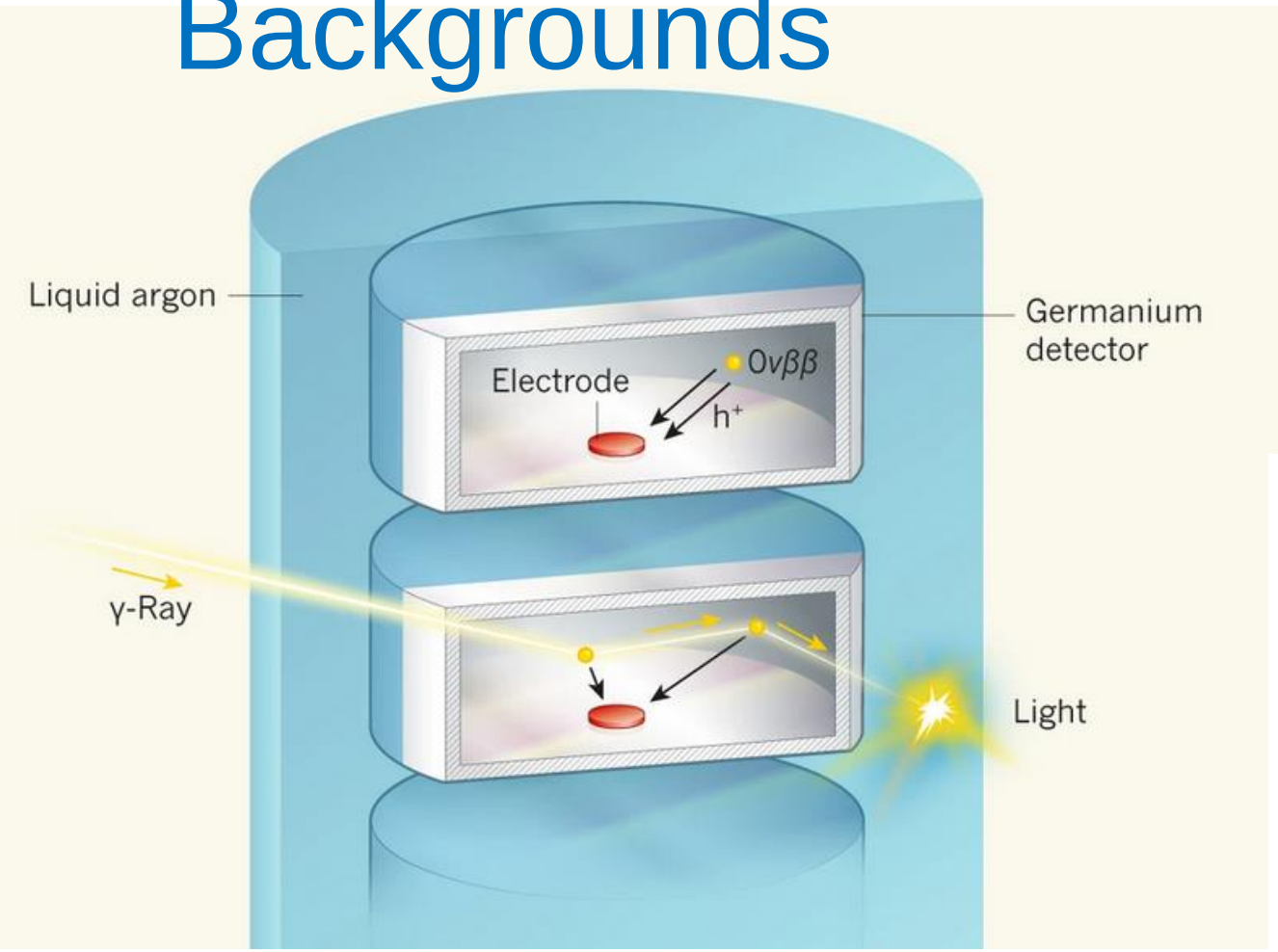
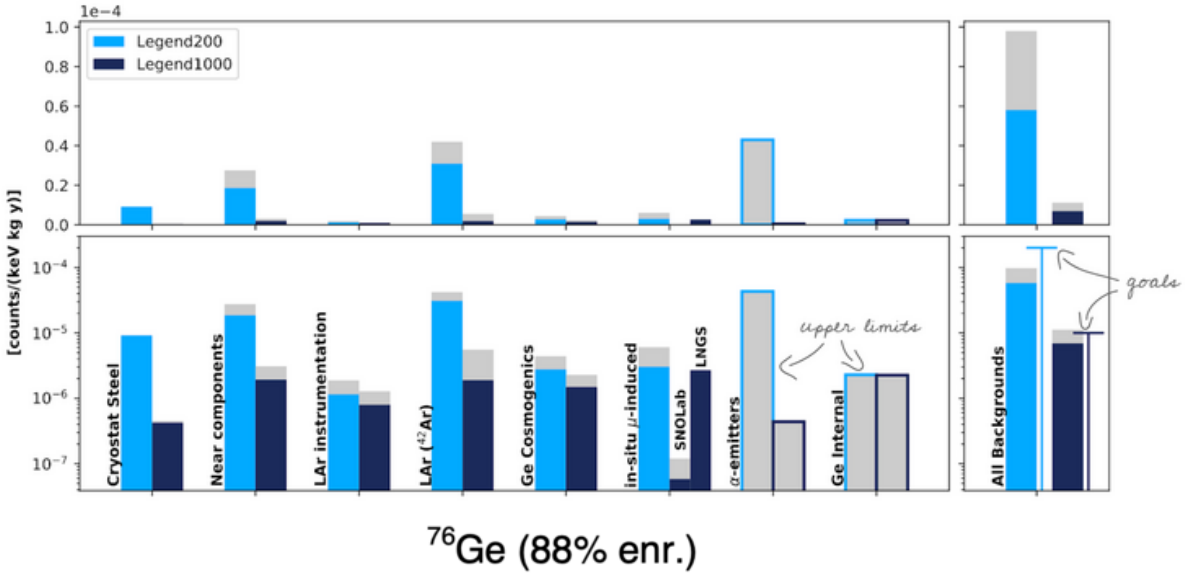


Legend at Gran Sasso

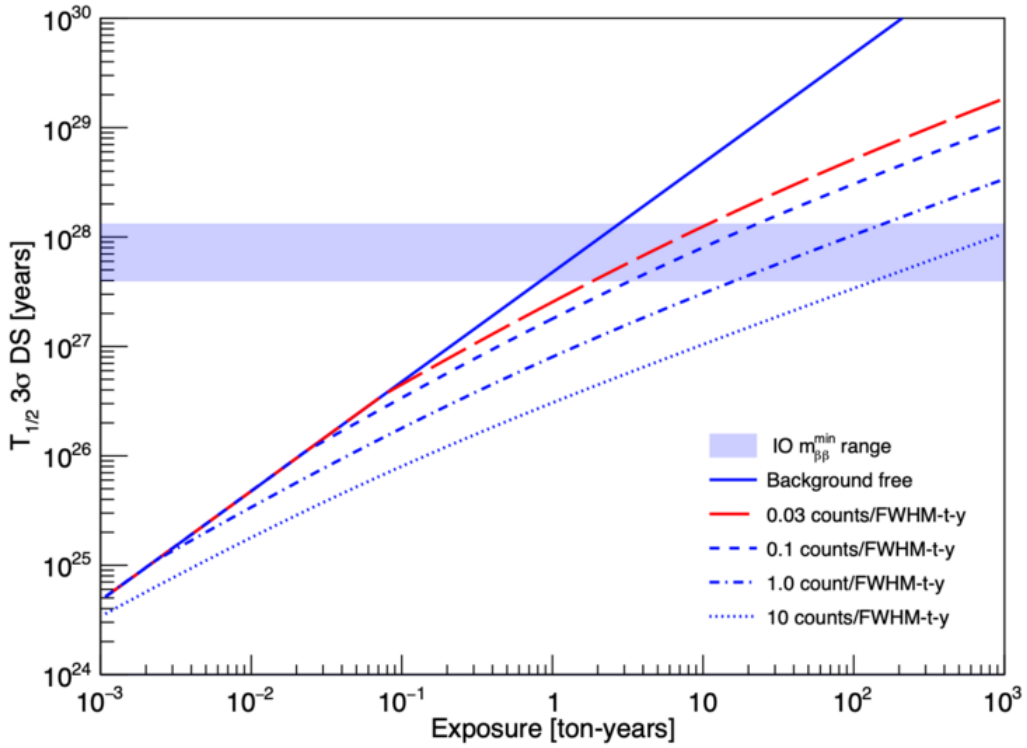


Backgrounds





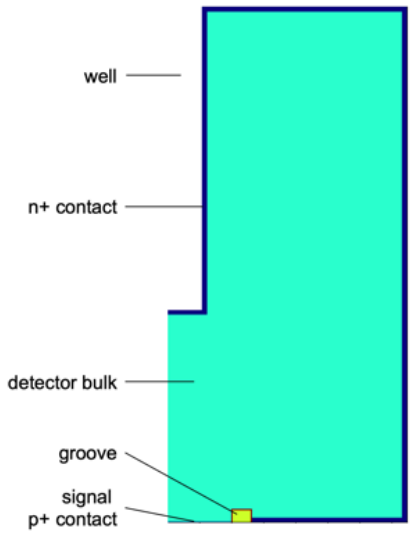
^{76}Ge (88% enr.)

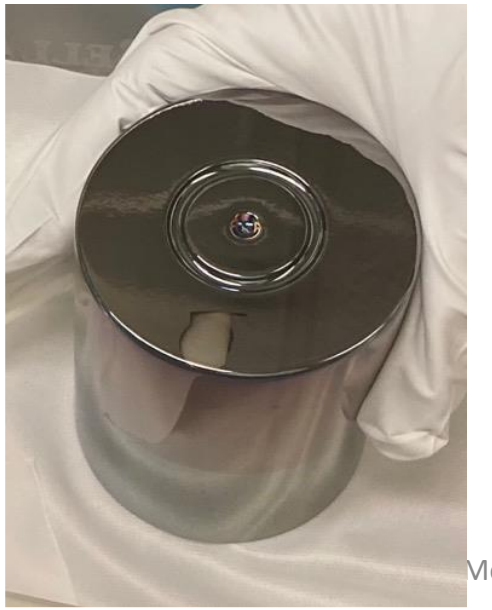


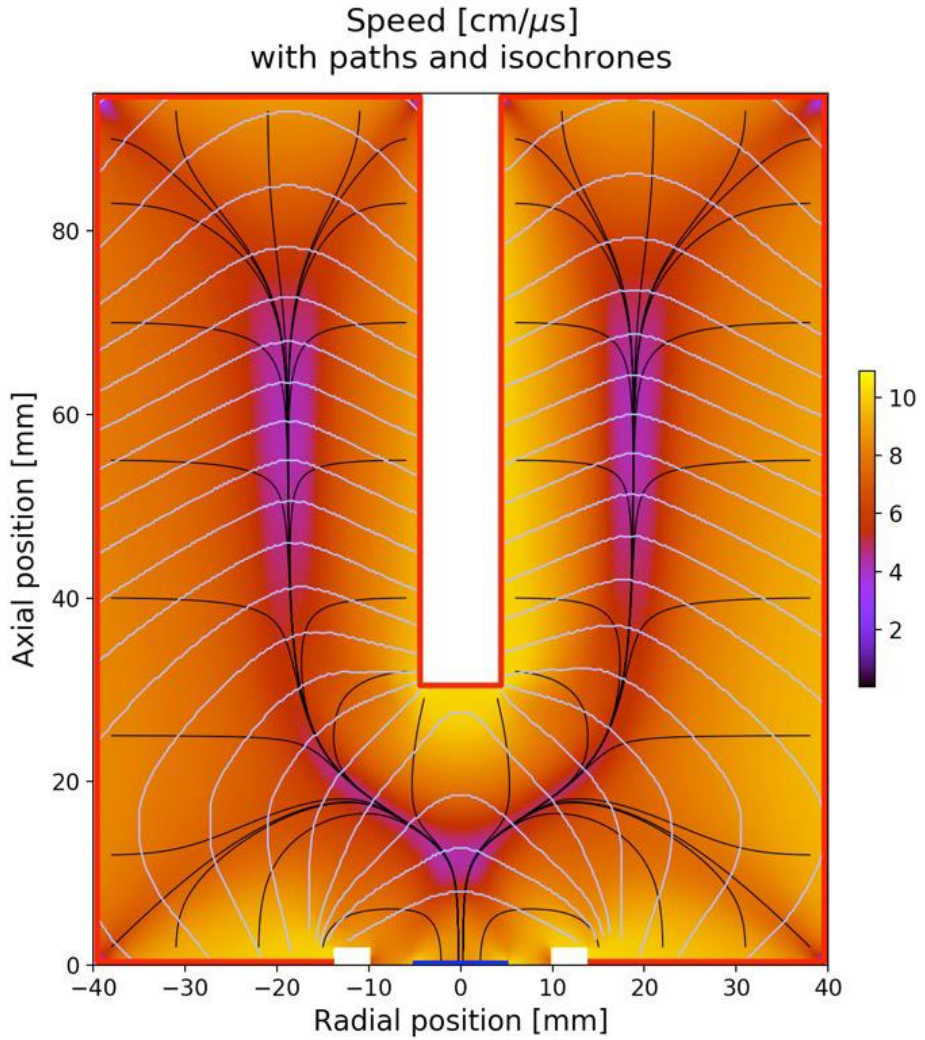
- Due to excellent energy resolution supressing non-β backgrounds is crucial
- Ge has excellent separation potential
- Ar, LAr and water vetoes crucial

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



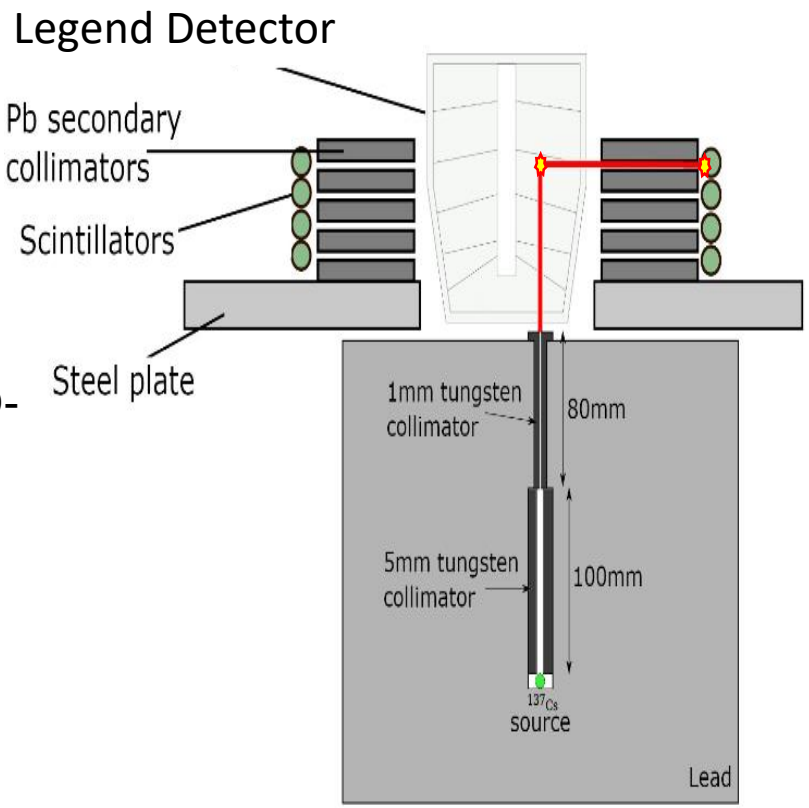




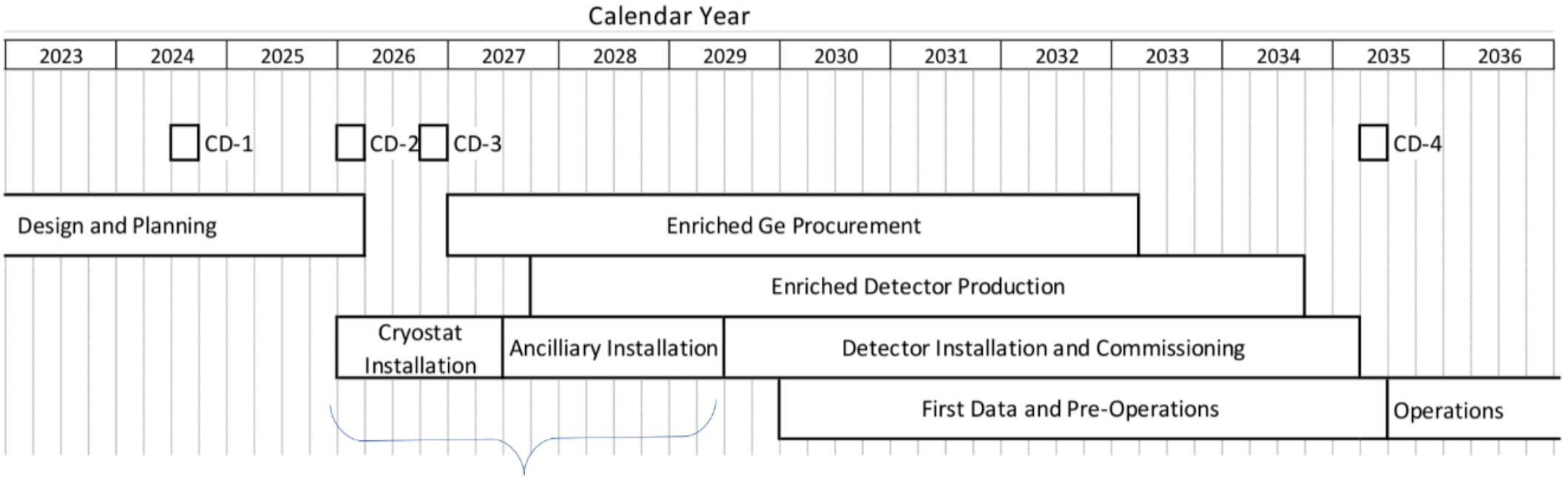
Liverpool Involvement

- Germanium detector characterisation
- Each detector needs individual calibration
- Detector calibration/data quality enhancement
- Detector procurement and characterisation for LEGEND-1000
- Data Analysis for LEGEND-200 + 1000

- Andy Boston is currently LEGEND UK PI



Summary



- 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

Backup

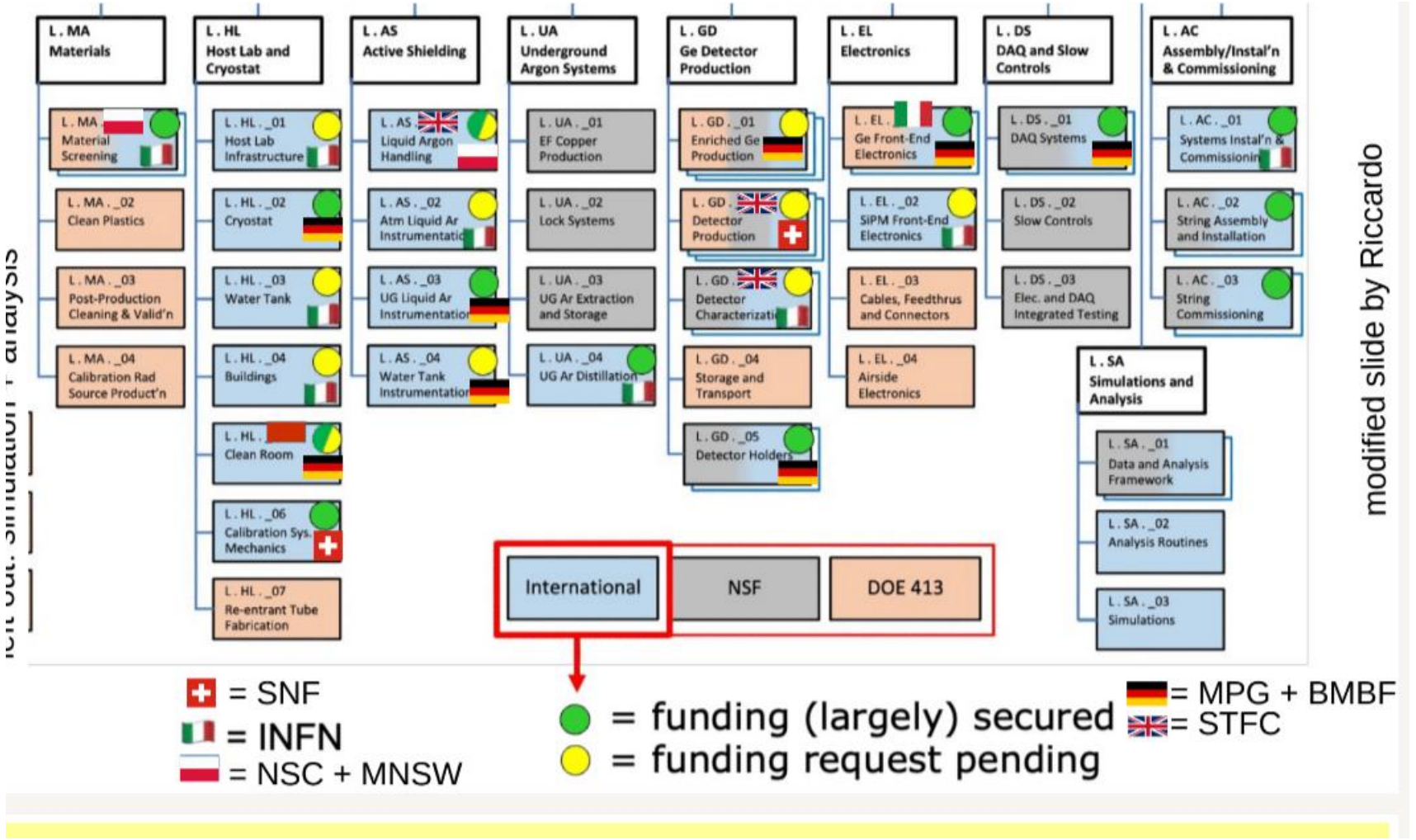
UK

STFC is in the process of developing a prioritised road-map and LEGEND has been informally asked to submit a statement of interest

several stage process

would support all UK activities (Ge, cryogenics, analysis, ...)

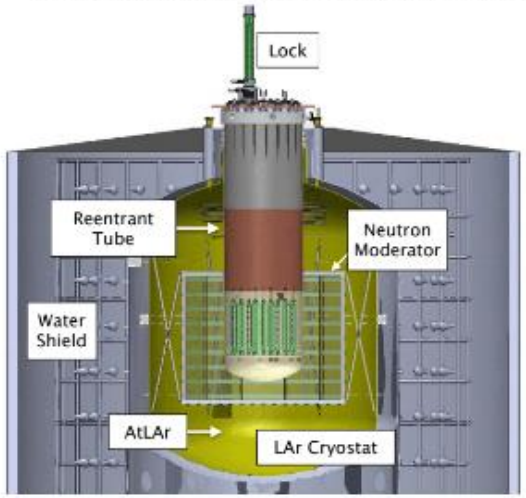
International Involvement

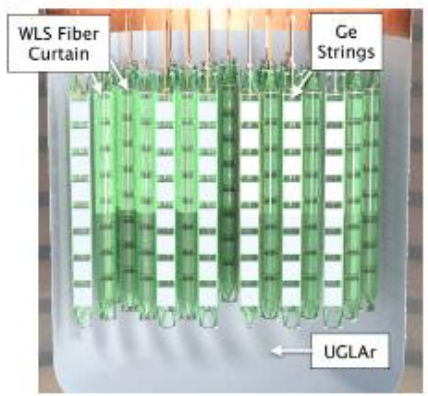


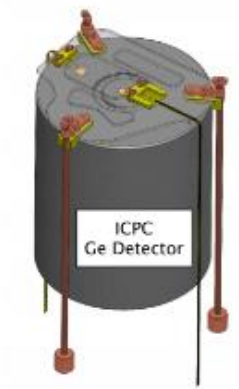
NSF Mid-scale RI-2 Process & Timeline

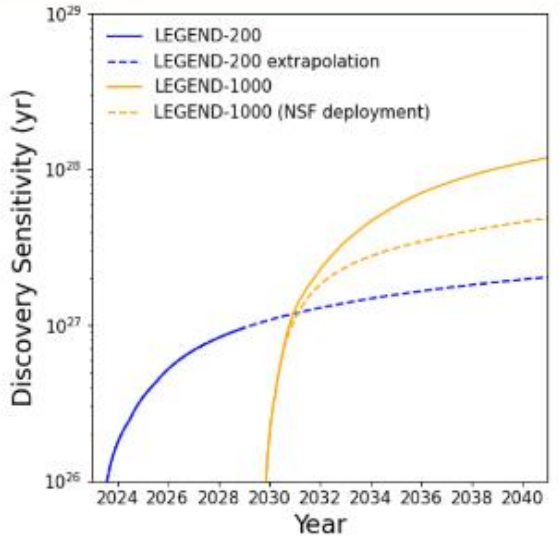
LEGEND-1000 NSF Scope — Compelling Science

- NSF Mid-scale enables first science outcome
- NSF Scope :
  - is matched to the expertise of U.S. collaborators
  - integrates activities with natural task interdependencies
  - offers excellent training opportunities for student and postdoctoral fellows









Enriched Ge	Det. Fab	Characterization	Det. Mounts	Lock	Installation	Commissioning
L.GD.N01	L.GD.N02	L.GD.N03 L.DS.N01, L.DS.N02 L.SA.N01	L.GD.N05 L.UA.N01	L.UA.N02 L.UA.N03	L.AC.N03 L.UA.N02	L.AC.N03, L.UA.N02 L.DS.N01, L.DS.N02 L.DS.N03, L.SA.N01