

Main physics deliverable: undeniable, background-free discovery of neutrinoless double-beta decay (NDBD)

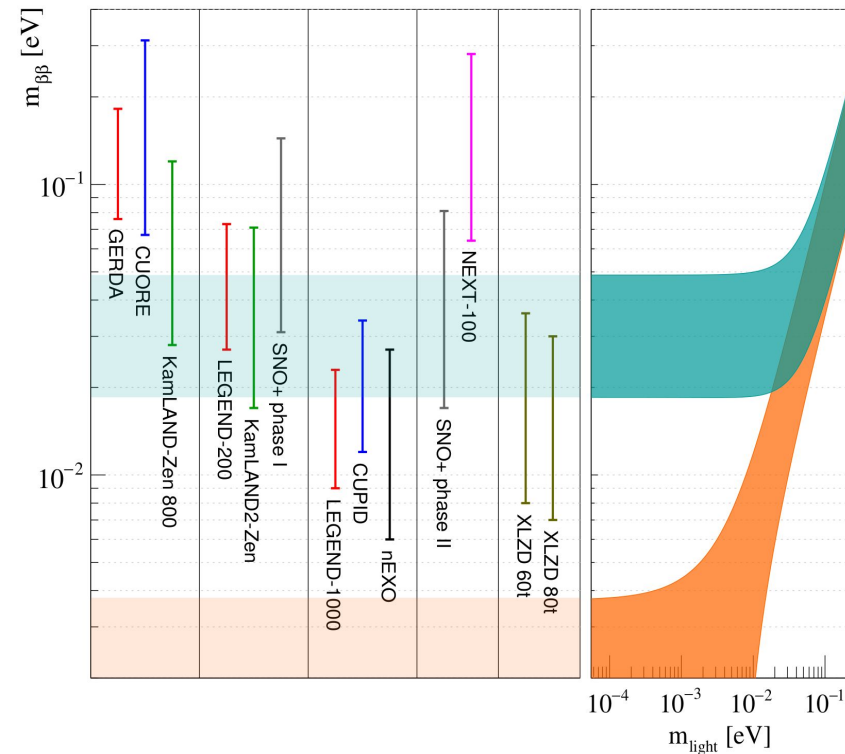
- discovery probability:
 - ↳ guaranteed **>3 σ discovery in 10 years** if neutrinos have **Majorana inverted-ordered masses**
 - ↳ **high discovery power** also if neutrinos have **Majorana normally-ordered masses**: majority of models constraining the parameter space and considerations on anarchy/naturalness favour signals within reach
 - ↳ **open search for new lepton-number-violating physics**, decay half-life proportional to new energy scale ($T_{1/2} \propto \lambda^n$)
- physics impact
 - ↳ prove that neutrinos are **Majorana fermions** and can get their mass from **alternative Higgs mechanism**
 - ↳ foundation of new **theory of fermion masses**
 - ↳ **"matter creation"**, i.e. creation of leptons without balancing antileptons
 - ↳ direct proof that B-L is not a conserved symmetry corroborating **leptogenesis theories**

Other physics deliverables: broad search for BSM physics with **world-leading sensitivity into an unexplored parameter space**

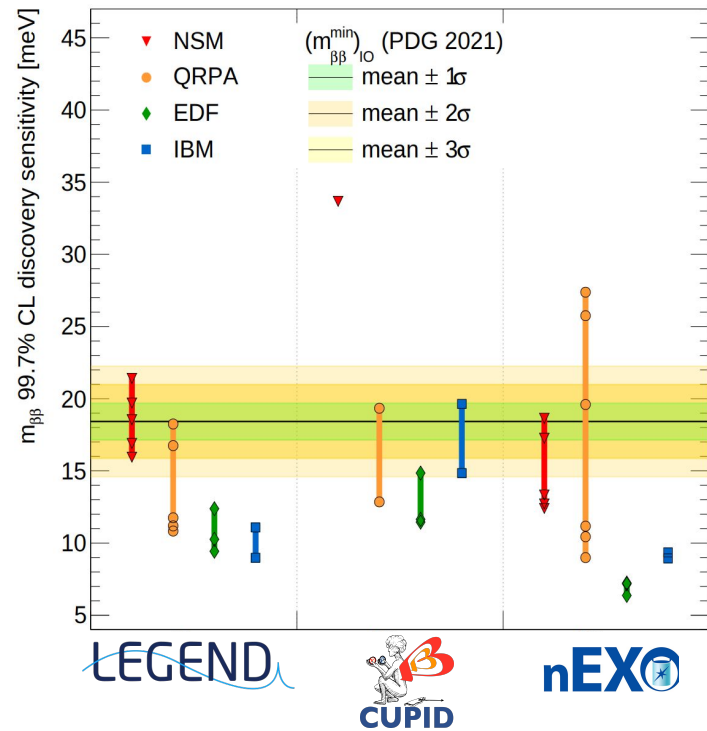
- new bosons (e.g. Majorons) and fermions (e.g. sterile neutrinos, Z_2 -odd fermions)
- violation of fundamental symmetries (e.g. Lorentz symmetry or Pauli's exclusion principle)
- non-standard interactions (e.g. right-handed leptonic currents and neutrino self-interactions)

Comparison of physics goals with the current state of the art in the area:

- parameter of interest for comparison is the **effective Majorana** mass $\rightarrow m_{\beta\beta} \sim 1/\sqrt{T_{1/2}}$
- **LEGEND-1000 will have world-best sensitivity** when considering uncertainties due to matrix elements calculations
- **>3 σ discovery sensitivity** even at the **bottom of the inverted ordering** for most of the NME calculations



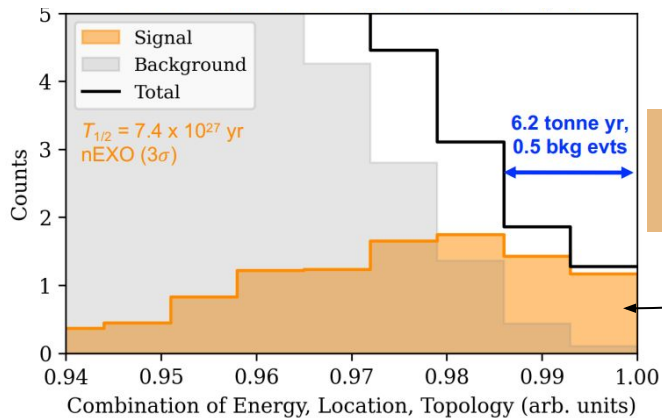
MA, Benato, Detwiler, Menéndez, Vissani
 Rev. Mod. Phys. 95, 025002 (2023)



MA, Benato, Detwiler, Menéndez and Vissani
 PRC 104, L042501

Project's main advantages compared to competitor projects:

- LEGEND is the only experiment in which a **NDBD signal will be visible to the naked eye**, making its extraction robust and irrefutable:
 - ↳ **no systematics** due to background model or signal extraction
 - ↳ **background-free** search -> no $2\nu\beta\beta$ intrinsic background
- **highest ranked** experiment in the recent DOE's NDBD portfolio review, including in the areas of **technical maturity** and **readiness**
- **LEGEND pursues a staged approach that mitigates risks**
 - ↳ LEGEND-200 currently in physics data taking
 - ↳ LEGEND-200 will be used to test technology in a realistic environment
 - ↳ staged-improvements towards LEGEND-1000 design requirements



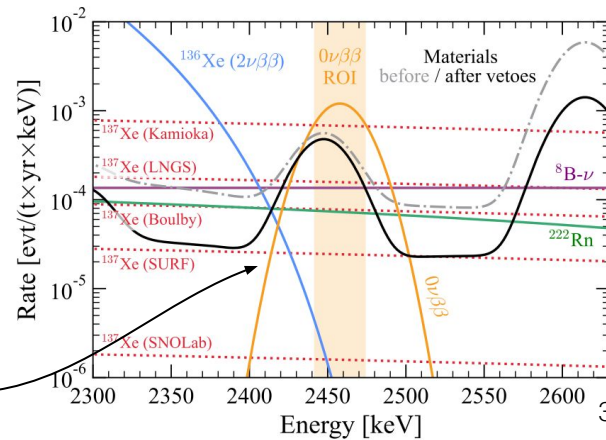
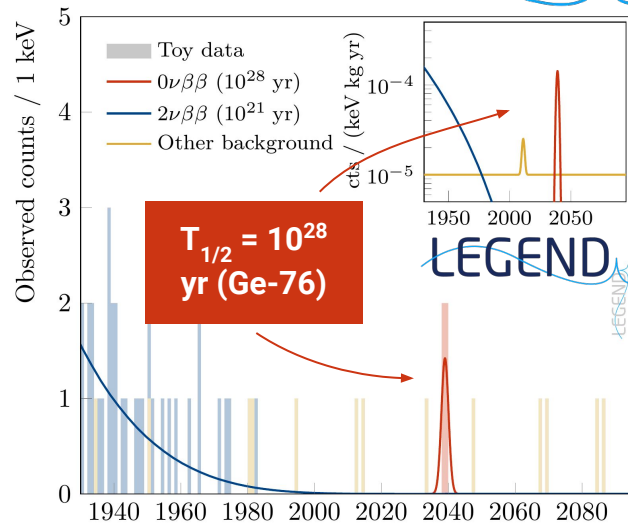
nEXO

$T_{1/2} = 7.4 \cdot 10^{27}$ yr
(Xe-136)



$T_{1/2} = 5 \cdot 10^{27}$ yr
(Xe-136)

LEGEND



Preferred location for the project

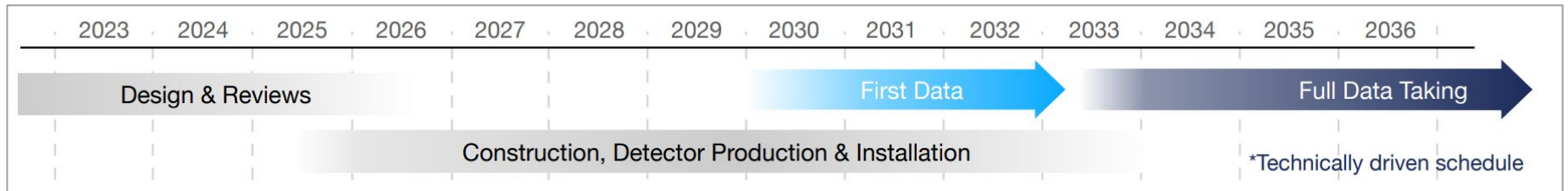
The project will be located at the **Gran Sasso Laboratory**, Italy

Project timeline (if possible provide separate by the R&D, construction and exploitation periods)

- CD0 review completed, CD1 review early next year, CD2-3 in 1-2 year after CD1
- Host preparation already started, infrastructure construction by 2029
- **first physics data in 2029-30**

Main risks/obstacles for realisation of physics goals (e.g. development of new technologies, construction of a new facility)

- **low-risk** project due to its staged approach, well-established technologies, and mature organisational structure
- **full DOE-level risk assessment** already reviewed by DOE during CD1 review and by NSF during mid-scale project review
 - ↳ **Main risk identified:** Ge procurement historically relying on Russian facilities
 - ↳ **Mitigation:** LEGEND has developed a business program to deliver the entire enriched Ge for LEGEND-1000 with URENCO, a european based company which has already delivered **on budget and ahead of time** about one-quarter of the enriched Ge used by LEGEND-200.



Anticipated area(s) of UK involvement and financial, FTEs and financial costs

- Sol to STFC (12 institution, 37 academics)
 - ↳ WP-1 Cryogenic infrastructure
 - ↳ WP-2 Radiopurity assays
 - ↳ WP-3 Computing, software, simulations, and theory calculations
 - ↳ WP-4 HPGe detector design and procurement
 - ↳ WP-5 Underground detector assembly and characterisation
- Costs:
 - ↳ \$160M total project cost (only equipment) in “european” accounting
 - ↳ £14M UK contribution (50% staff, 50% equipment)
- UK Community and FTE:
 - ↳ 37 academics
 - ↳ 7 RA/year full time on the project
 - ↳ 5.3 FTE staff effort (STFC labs)

Environmental sustainability during construction and operation



- construction
 - ↳ LEGEND-1000 construction uses existing facility and infrastructure
 - ↳ minimal environmental impact
 - ↳ environmental assessment for CD review process
 - ↳ meets all requirements of the US National Environmental Policy Act.
 - ↳ full environmental impact assessment, including carbon footprint, is being conducted now that the baseline host has been defined
- operations
 - ↳ negligible because of LEGEND’s low energy consumption and no use of high global-warming-potential substances