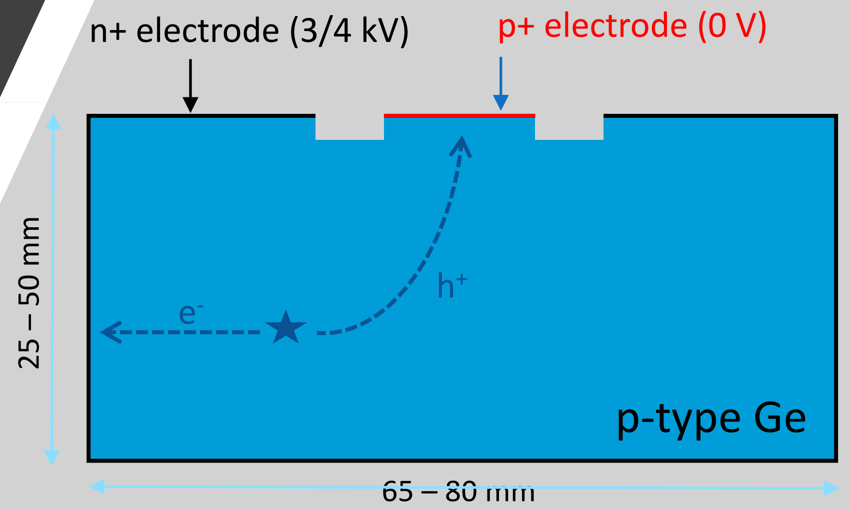
$0\nu\beta\beta$ with Ge detectors: 10^{26} yr and beyond

Natalia on behalf of the

LNGS-UNIVAQ-GSSI GERDA/LEGEND group

Searching for $0\nu\beta\beta$ of ^{76}Ge

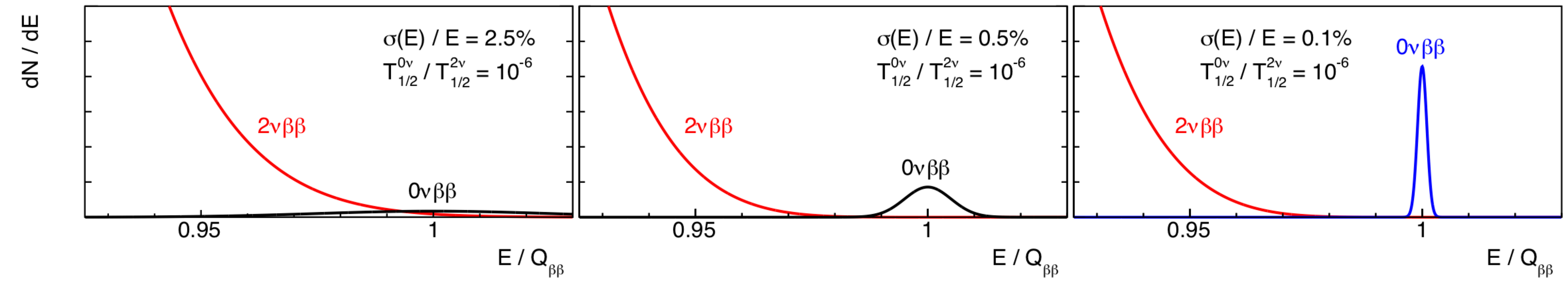


Why high purity Ge detectors?

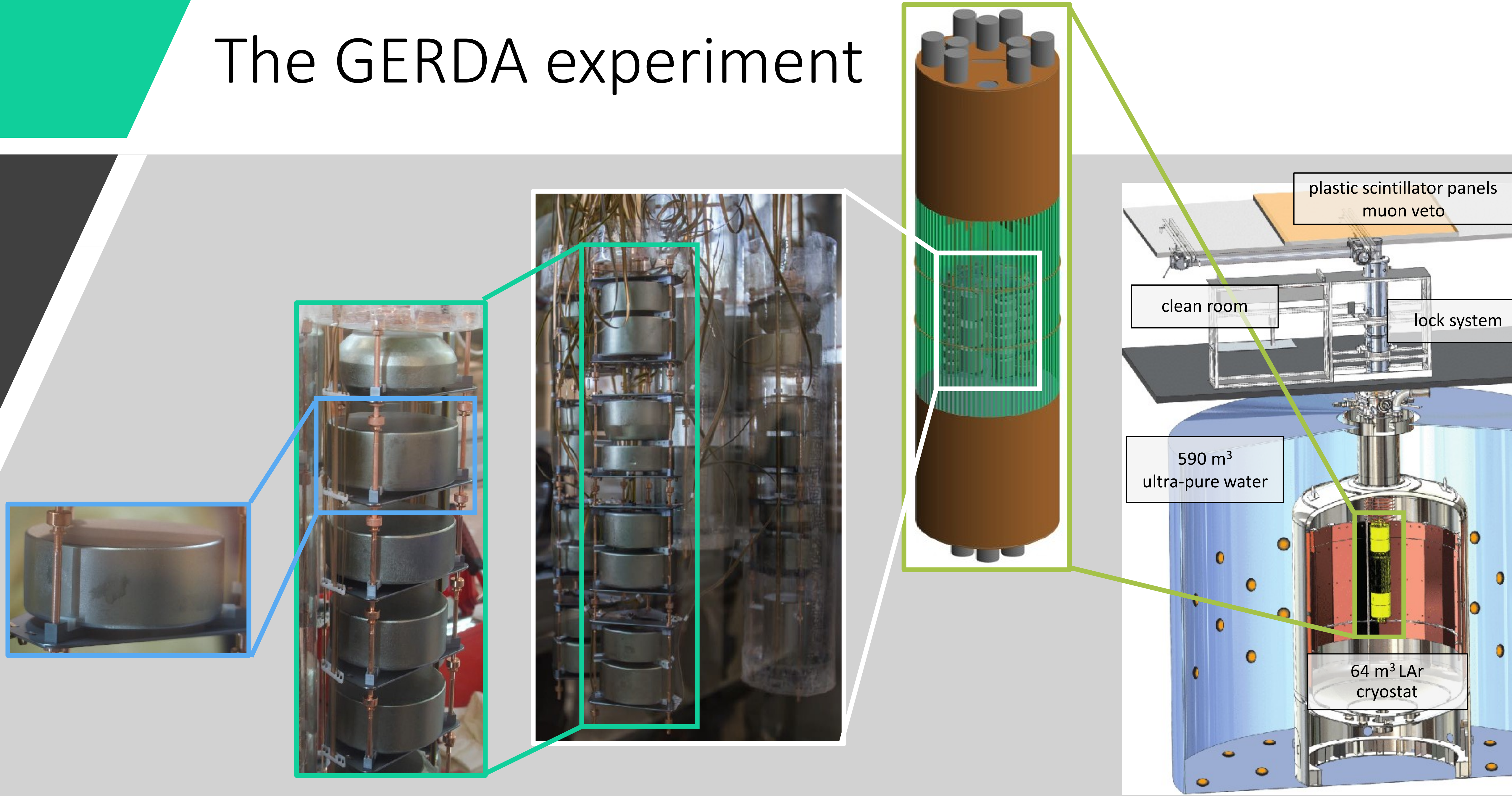
- source = detector → high efficiency
- radio-pure → no intrinsic background [Astropart.Phys. 91 (2017) 15-21]
- high density → e^- absorbed in 1-2 mm
- semiconductor → $\sigma(E)/E < 0.1\%$ at $Q_{\beta\beta}$
- enrichment up to 87% in ^{76}Ge

$0\nu\beta\beta$ signature:

- point-like energy deposition in detector bulk volume
- sharp energy peak at 2039 keV (FWHM = 3-4 keV)



The GERDA experiment



The GERDA experiment

Phase I
- Nov 2011 – Sept 2013: exposure 23.5 kg yr, BI 11 x 10^{-3} cts/(keV kg yr) @ $Q_{\beta\beta}$

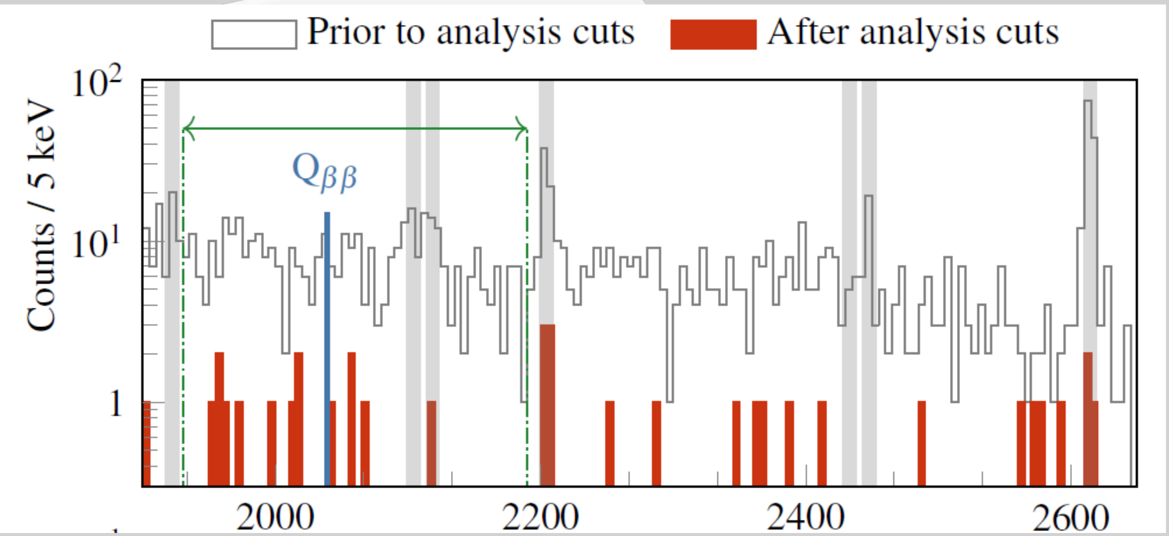
major upgrade
- Sep 2013 – Dec 2015 [Eur.Phys.J. C78 (2018), 388: + 20 kg BEGe, + Lar instrumentation

Phase II
- Nature 544 (2017) 47, PRL 120 (2018) 13, Science 365 (2019) 1445
- Exposure = 58.9 kg yr - BI = 5.6 x 10^{-3} cts/(keV kg yr) – $T^{0\nu}_{1/2} > 0.9 \cdot 10^{26}$ yr @ 90% C.L.

minor upgrade
- Apr-Jul 2018: +9.6 kg Inverted Coaxial (IC)

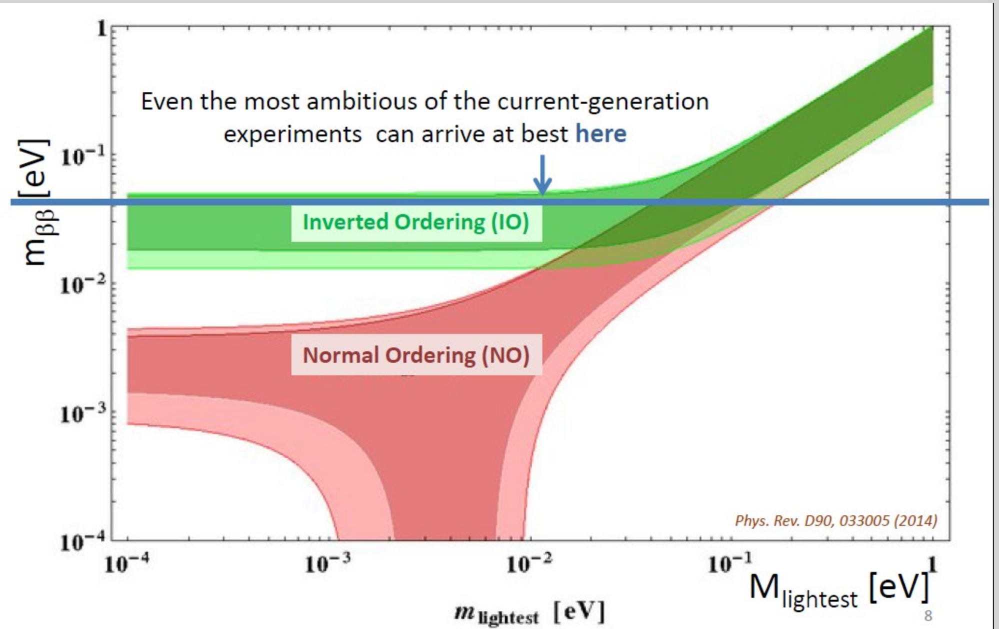
Phase II
- PRL 125 (2020) 252502
- Phase II final exposure= 103.7 kg yr - BI =5.2 x 10^{-4} cts/(keV kg yr) – $T^{0\nu}_{1/2} > 1.8 \cdot 10^{26}$ yr @ 90% C.L.
- (PI+PII combined): exposure = 127.2 kg yr -

PGT
- 2020 - 2021: post GERDA test → LEGEND 200



10^{26} yr and beyond

EXPERIMENT	Isotope	Exposure [kg yr]	$T^{0n}_{1/2}$ [10^{25} yr]	<mbb> [MeV]
GERDA	^{76}Ge	127.2	18	79-180
MAJORANA	^{76}Ge	26	2.7	200-433
KamLAND-zen	^{136}Xe	594	10.7	61-165
EXO	^{136}Xe	234.1	3.5	93-286
CUORE	^{130}Te	115.9	1.5	110-520



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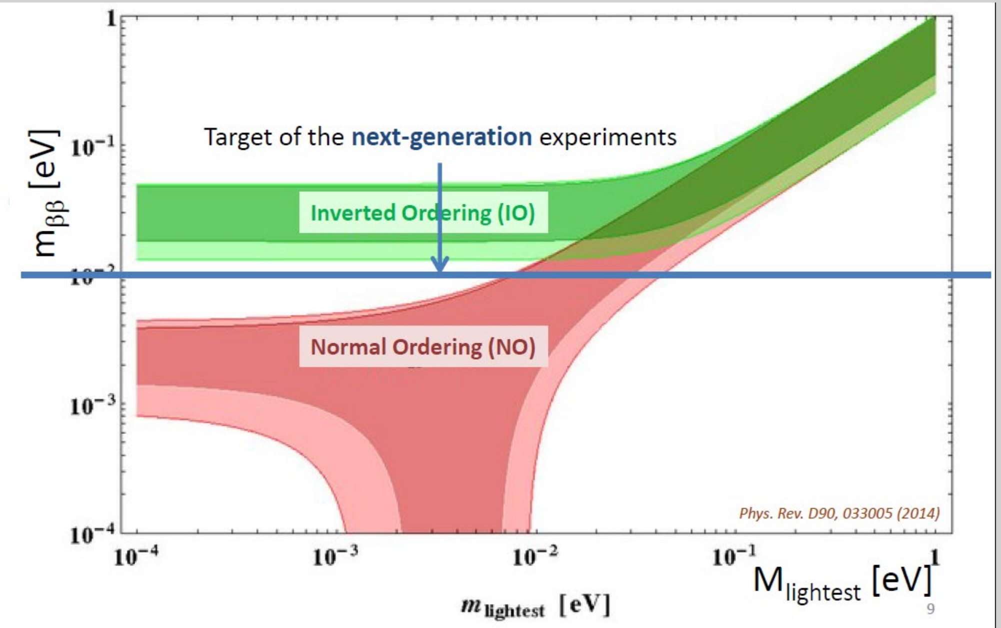

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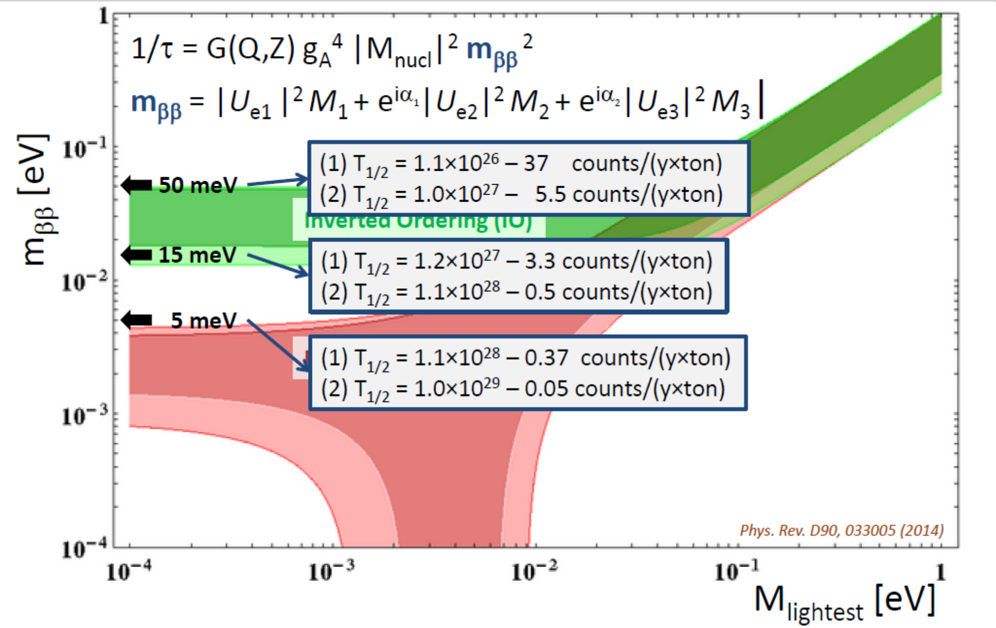
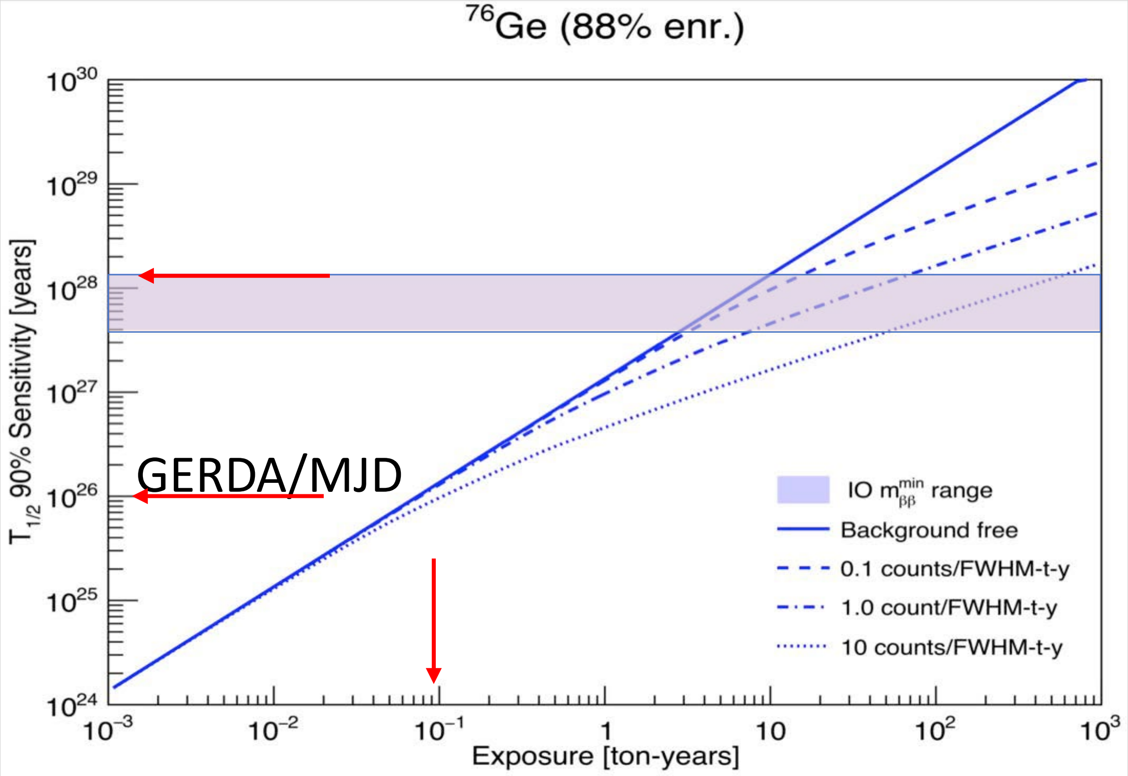
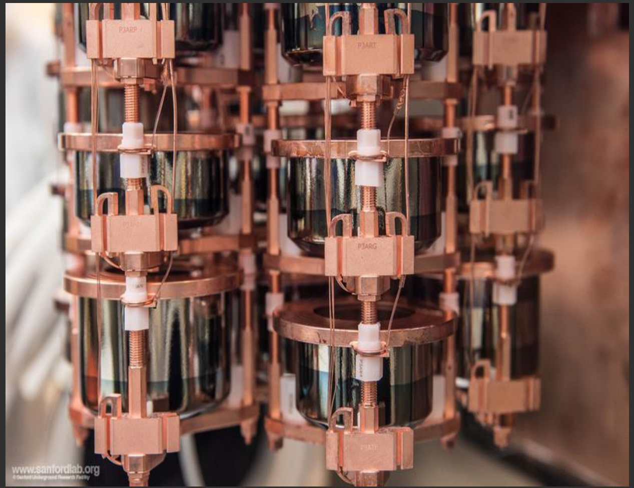
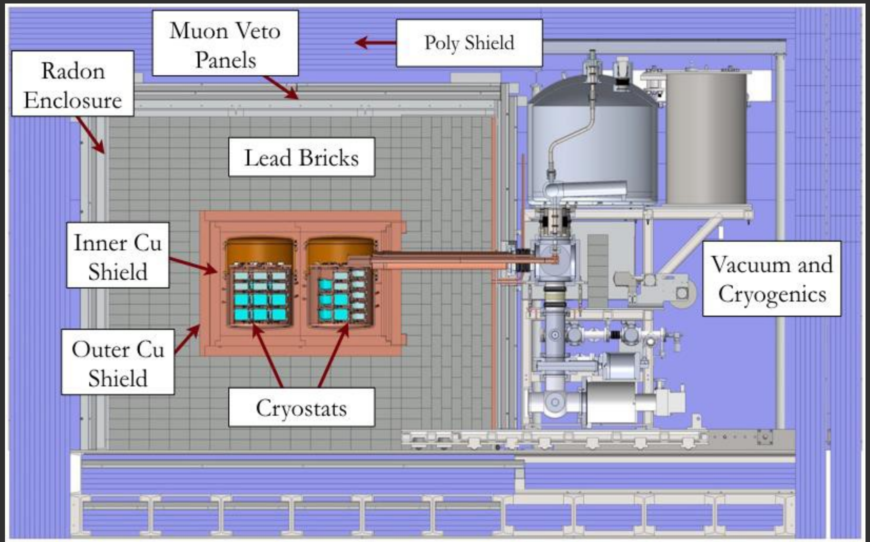


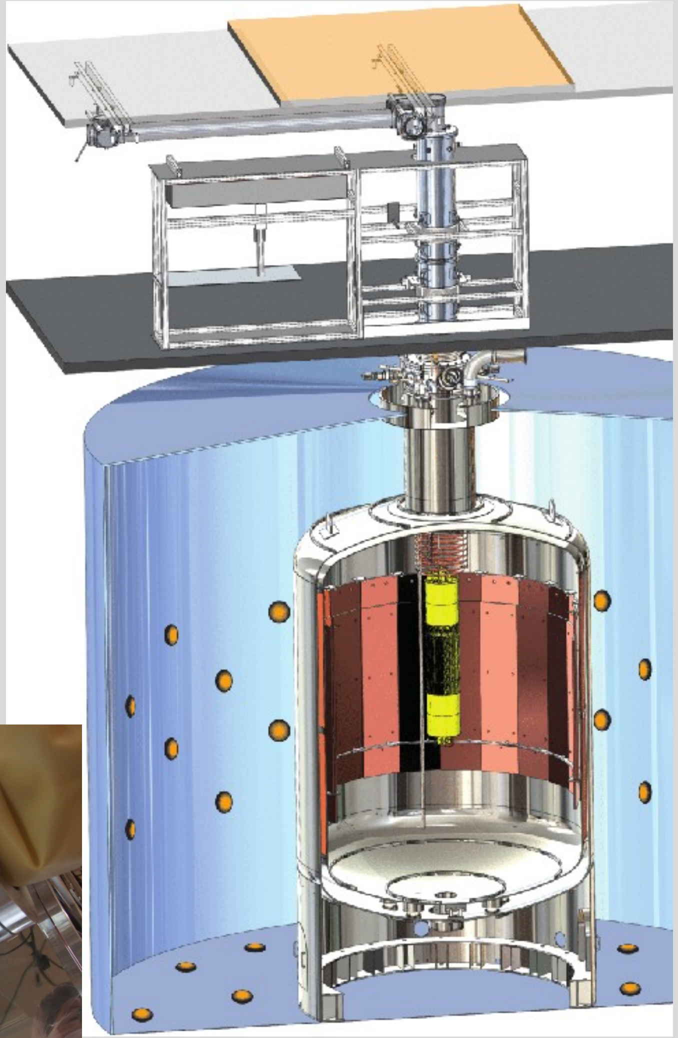




Majorana
DEMONSTRATOR



GERDA



GERDA

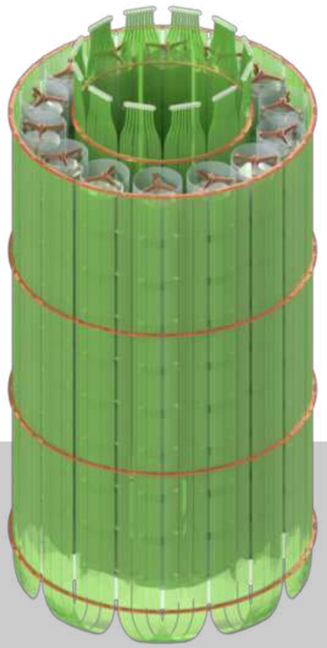
- LAr veto
- Low-A shield, no Pb

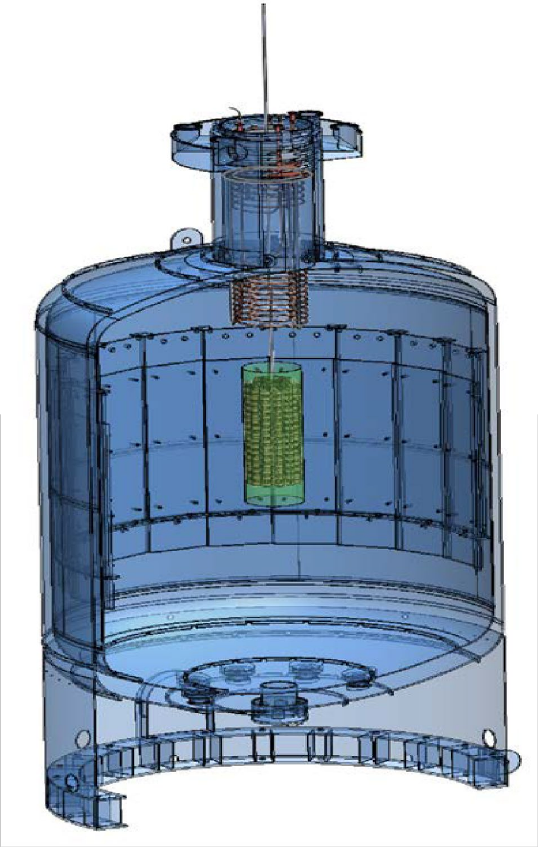
Both

- Clean fabrication techniques
- Control of surface exposure
- Development of large point-contact detectors
- Lowest background and best resolution $0\nu\beta\beta$experiments

MAJORANA

- Radiopurity of nearby parts (FETs, cables, Cu mounts, etc.)
- Low noise electronics improves PSD
- Low energy threshold (helps reject cosmogenic background)





- 70 inverted coax detectors (1.5-2 kg), about 140 kg
- 28 BEGe's (0.7 kg) about 20 kg
- 5 ICPC's (2.0 kg) about 10 kg
- 33 PPC's (0.8 kg) about 28 kg

- Semi-Coax detectors (either use as is, or recycle) about 15 kg

Total ~200 kg

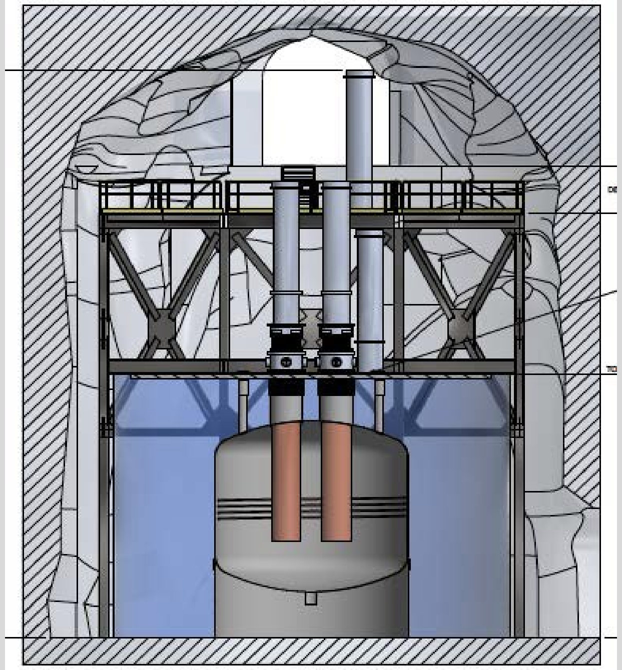
LEGEND

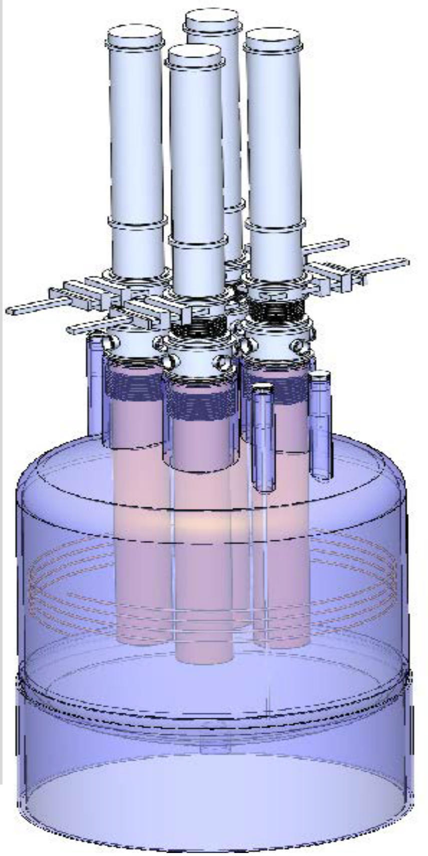
First phase:

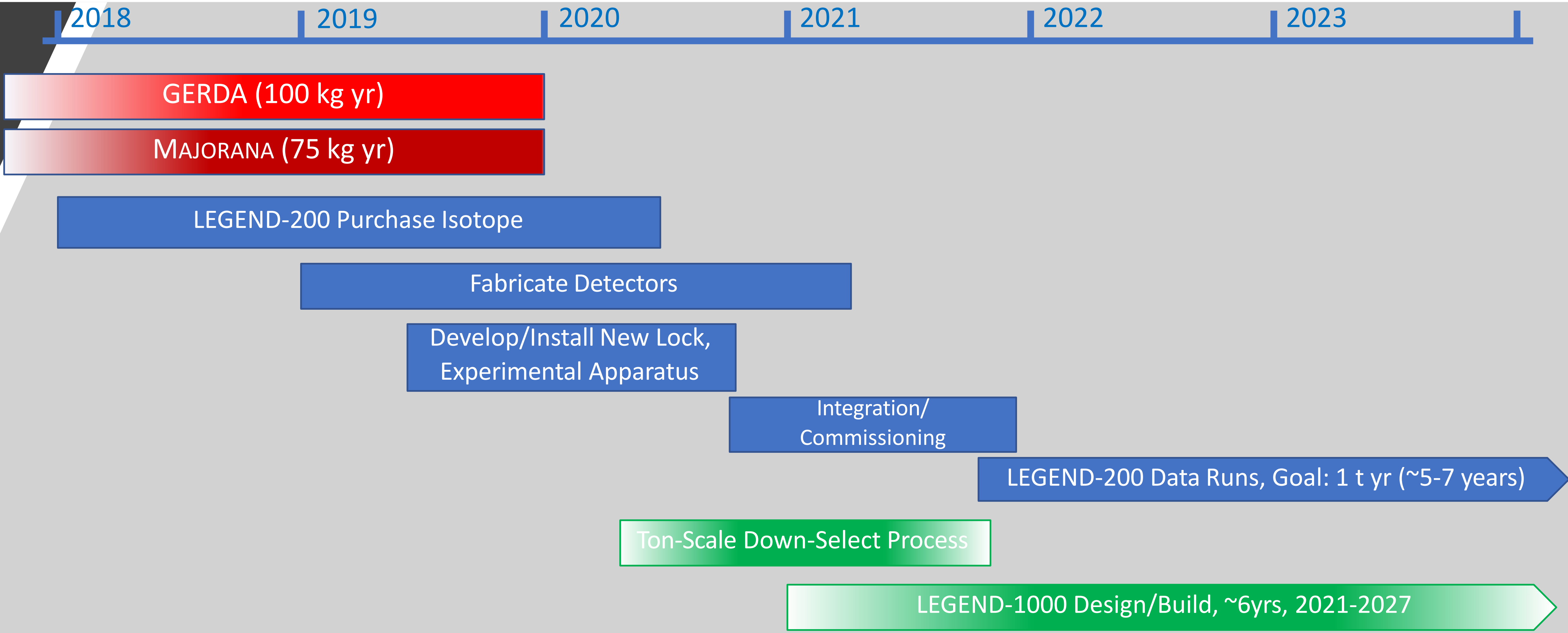
- (up to) 200 kg in upgrade of existing infrastructure at LNGS
- BG goal: <0.6 c /(FWMH t y)
- Discovery sensitivity at a half-life of 10^{27} years
- Data start end of 2021

Subsequent stages:

- 1000 kg, staged via individual payloads
- Background goal <0.03 cts/(FWHM t yr)
- Discovery sensitivity at a half-life of 10^{28} years
- Location to be selected







Earliest, and optimistic, LEGEND-1000 Data Start 2025/6

LEGEND 1000

BSM Physics program

Mechanism	Signature	Energy range	Status	*Recent* Germanium References
Bosonic Dark Matter	Peak at m_b	5 — 100keV	Done in MJD, GERDA	PRL 118 (2017) 161801 PRL 125 (2020) 011801
Baryon Decay	Time Correlation, High Energy	0-10 MeV	Done in MJD	PRD 99 (2019) 072004
Fractionally Charged Cosmic rays	High Multiplicity-coincidence events	Few keV	Done in MJD	PRL 120 (2018) 211804
WIMP searches	Exponential Excess + Annual Modulation. Migdal Effect	< 10 keV	CDEX/MALBEK/ CoGeNT	PRL 120 (2018) 241301; 1401.6234; Phys.Procedia 61 (2015) 77
Solar axions	Peaked Spectra + daily modulation	< 10 keV	Partially Done in MJD	PRL 118 (2017) 161801; Astropart.Phys. 89 (2017) 39, Wiseman PhD Thesis
Majoron Emission	2νββ spectral distortion	$Q_{\beta\beta}$	Done in GERDA	Eur. Phys.J. C75 (2015) 416
Lorentz Violation	2νββ spectral distortion	$Q_{\beta\beta}$	TBD GERDA	PRD 88 (2013) 071902
Electron Decay	Peak at 11.8 keV	~10 keV	Done in MJD	PRL 118 (2017) 161801
Pauli Exclusion Principle Violation	Peak at 10.6 keV	~ 10 keV	Done in MJD	PRL 118 (2017) 161801
BSM physics in Ar	Features in Ar Veto spectrum		ECEC in Ar36 (GERDA)	Eur. Phys. J. C75 (2015) 416

+ Prompt Supernova Neutrinos, SuperWIMPS, Solar Neutrinos, …

PEOPLE

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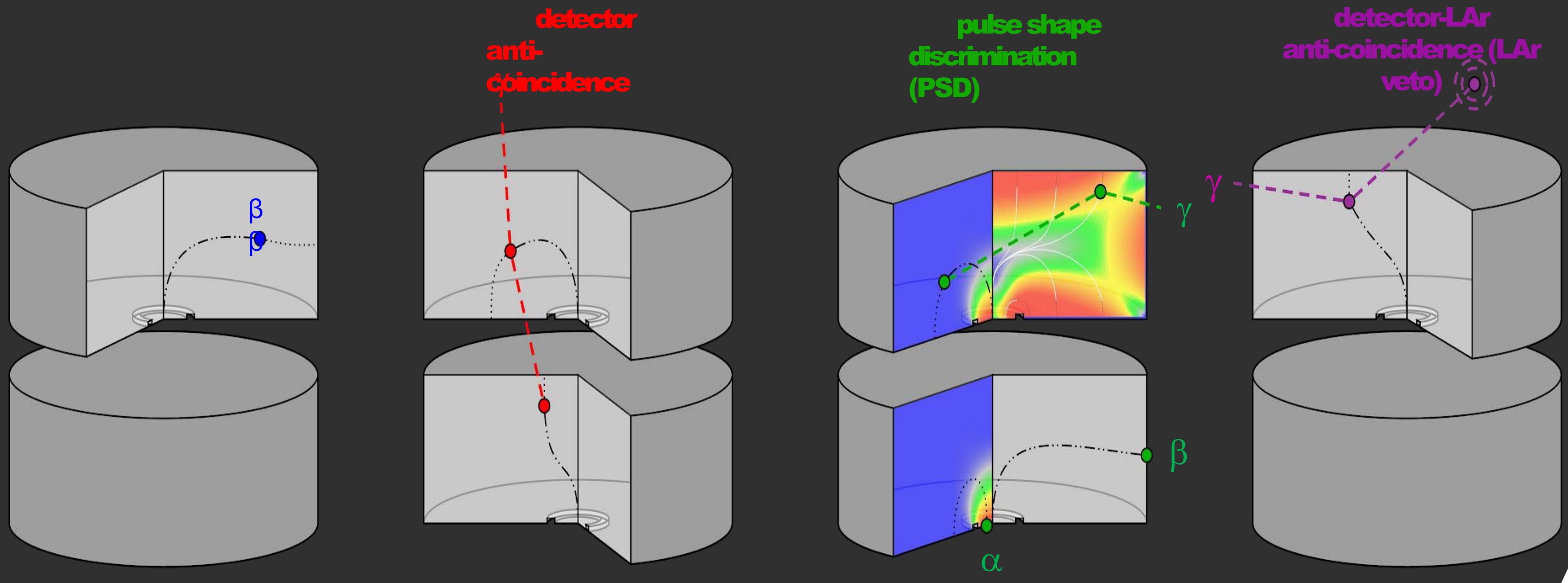
http://legend-exp.org/

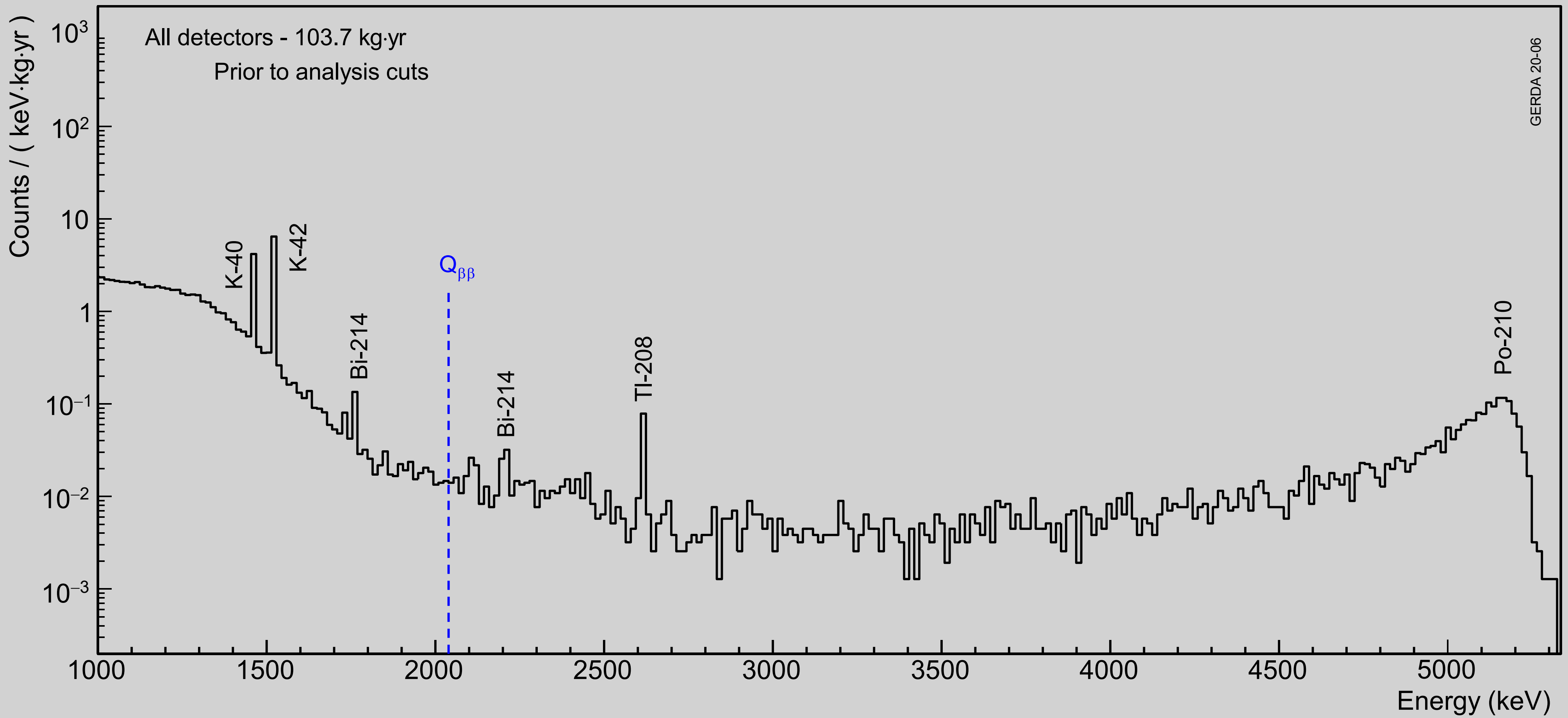
The GERDA experiment



Discriminate **point like** (single site) **ββ** topology from:

- **multi-detector** interactions
- **multi-site/surface** interactions
- interactions with **coincident energy**
- **deposition** in surroundings

The GERDA experiment



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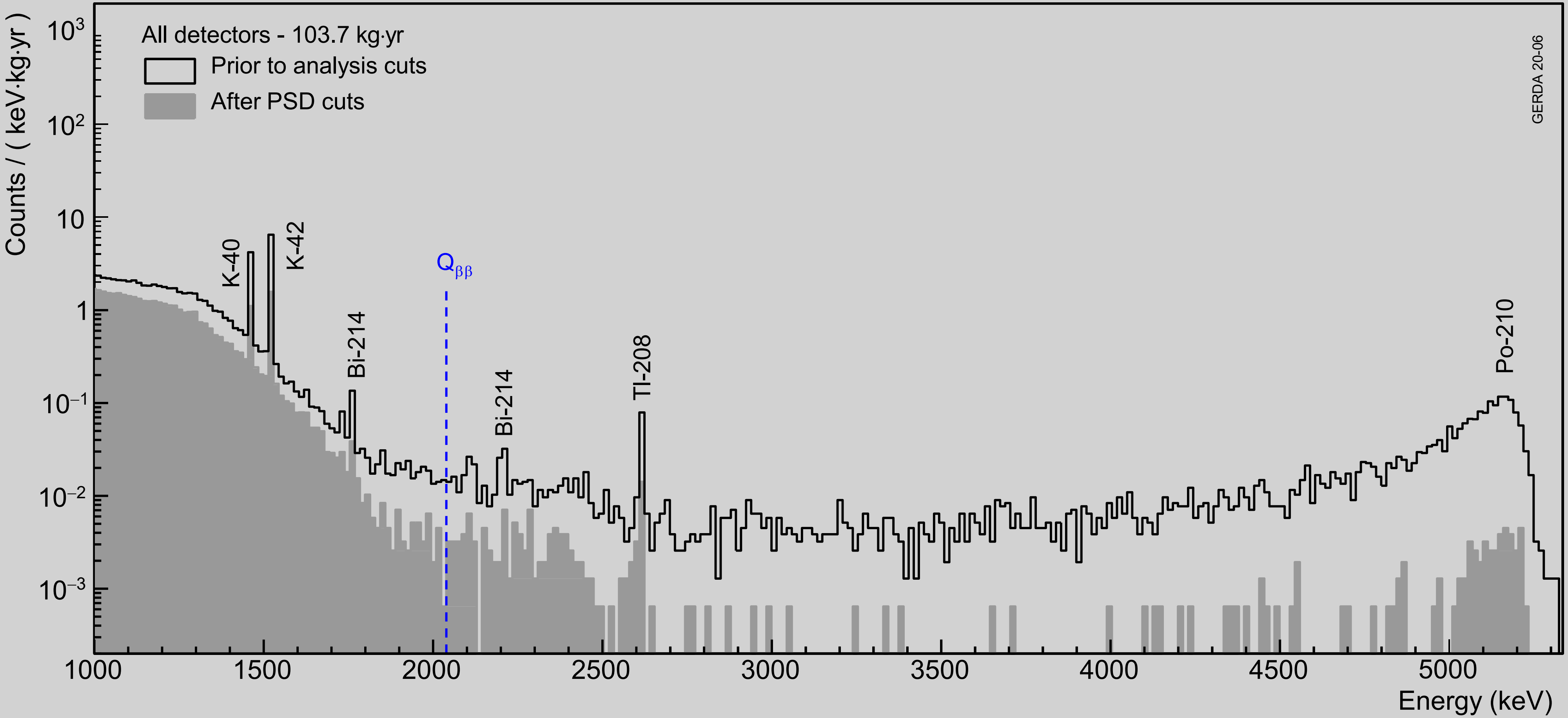

The GERDA experiment