Measurement of the ^{85}Kr Activity in the GERDA Liquid Argon

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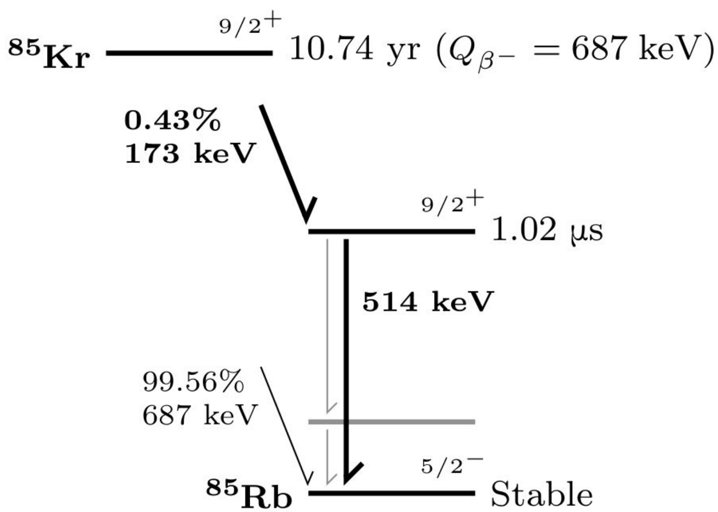
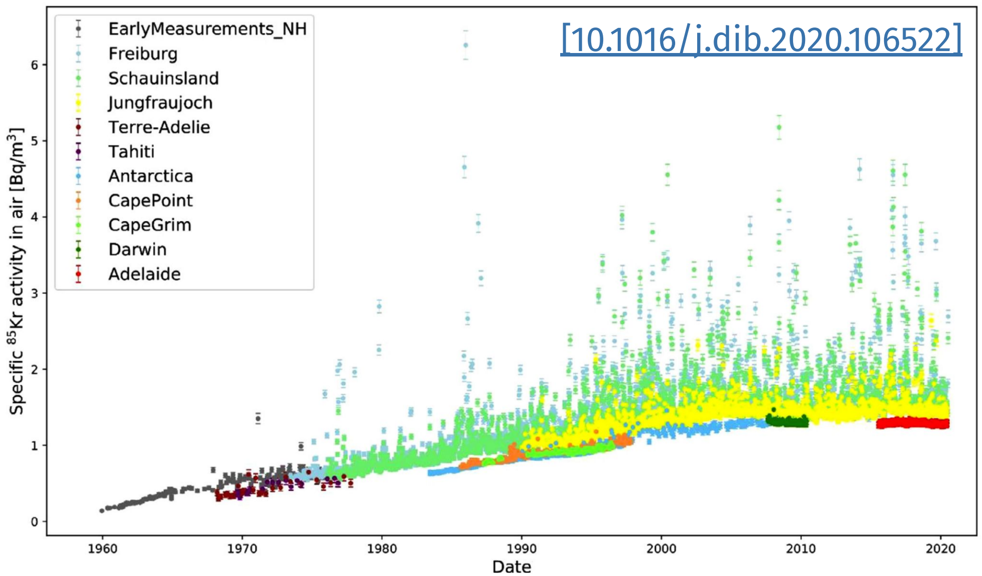
- ^{85}Kr presence in atmosphere (1–2 Bq/m^3) is mainly **anthropogenic**
  - Most importantly: spent reactor fuel reprocessing activities
- Concentration **varies in space and time**
  - and therefore in gases/liquids distilled from air
- Its β-decay (Q_β= 687 keV) is a **dangerous background** for low-threshold rare event searches employing noble gases or liquids





Some concentration measurements in noble liquids

- Liquid Argon
  - WARP: **(0.12 ± 0.09) Bq/kg** [10.1016/j.nima.4902007.01.106]
  - DarkSide (*UAr*): **(2.05 ± 0.13) mBq/kg** [10.1103/PhysRevD.93.081101]
- Liquid Xenon (typically removed through purification)
  - XENONnT after filling: **~0.14 µBq/kg**, after purification: ~16 nBq/kg [10.1140/epjc/s10052-024-12982-5]
  - LZ after purification: ~27 nBq/kg [10.1103/PhysRevD.108.012010]
- Liquid Nitrogen
  - BOREXINO: https://doi.org/10.1016/j.apradiso.2004.03.045
  - See discussion yesterday

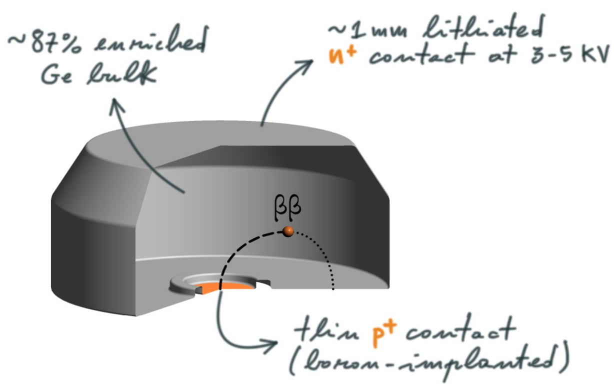
Different values reflect space-time dependence and re-contamination during handling

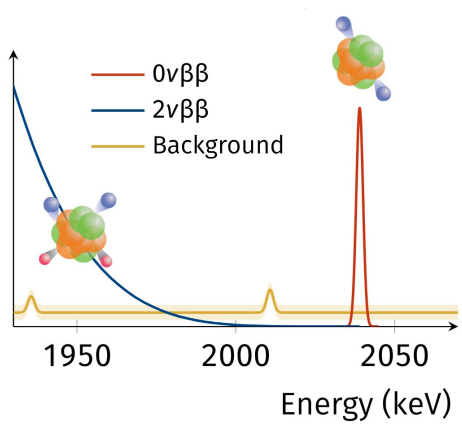
The search for 0νββ is compelling:

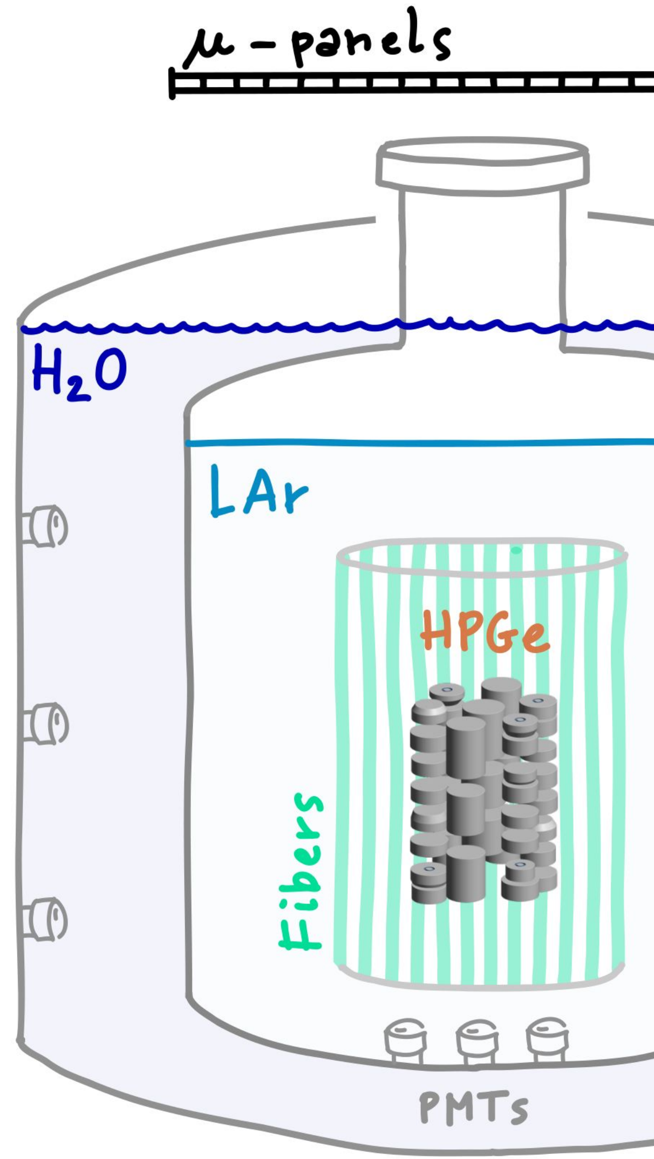
- Lepton Number Conservation
- Majorana neutrino
- New physics / Baryogenesis

High-Purity Germanium (HPGe) detectors enriched in ^{76}Ge (~88%)

$$^{76}\mathrm{Ge} \xrightarrow{0\nu\beta\beta} {}^{76}\mathrm{Se} + 2e^{-}$$

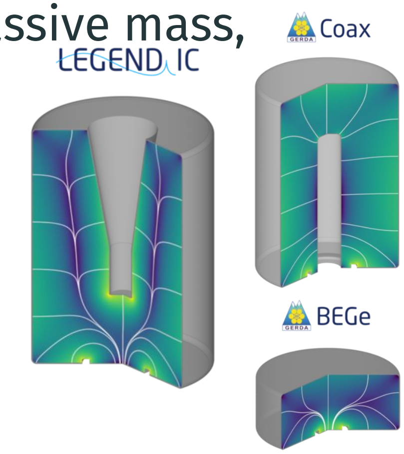


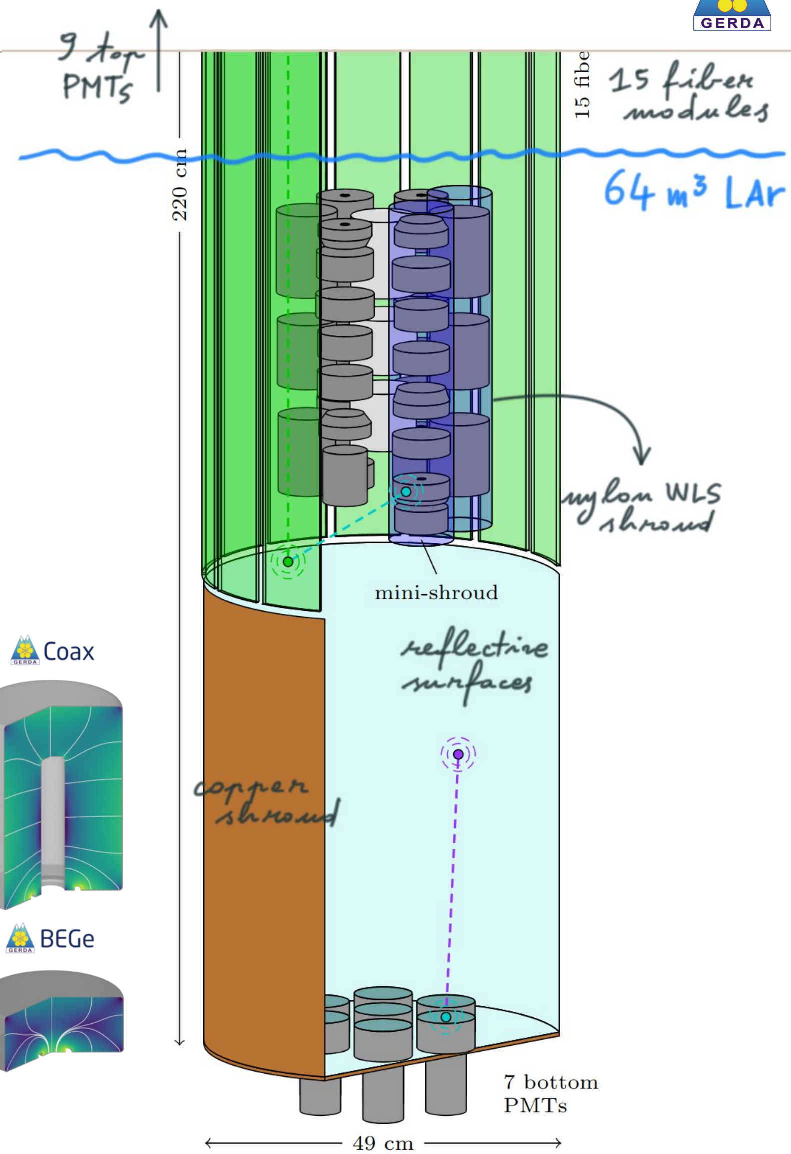




The GERDA Phase II Experimental Setup

- **35.6** kg (later **44.2** kg) of HPGe
- 64 m^3 / **5.0-grade Liquid Argon** cryostat
- Hybrid **LAr light collection system**
  - WLS fibers / SiPMs / PMTs
- μ-veto: water Cherenkov, scintillating panels
- Radio-pure materials, small passive mass, deep underground (LNGS)
- Upgraded in 2018
  - Inverted-Coax (IC) detectors
  - improved LAr instrumentation





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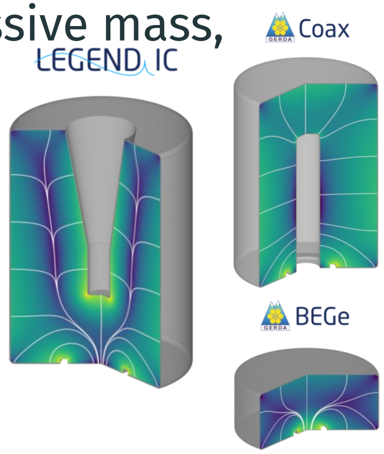
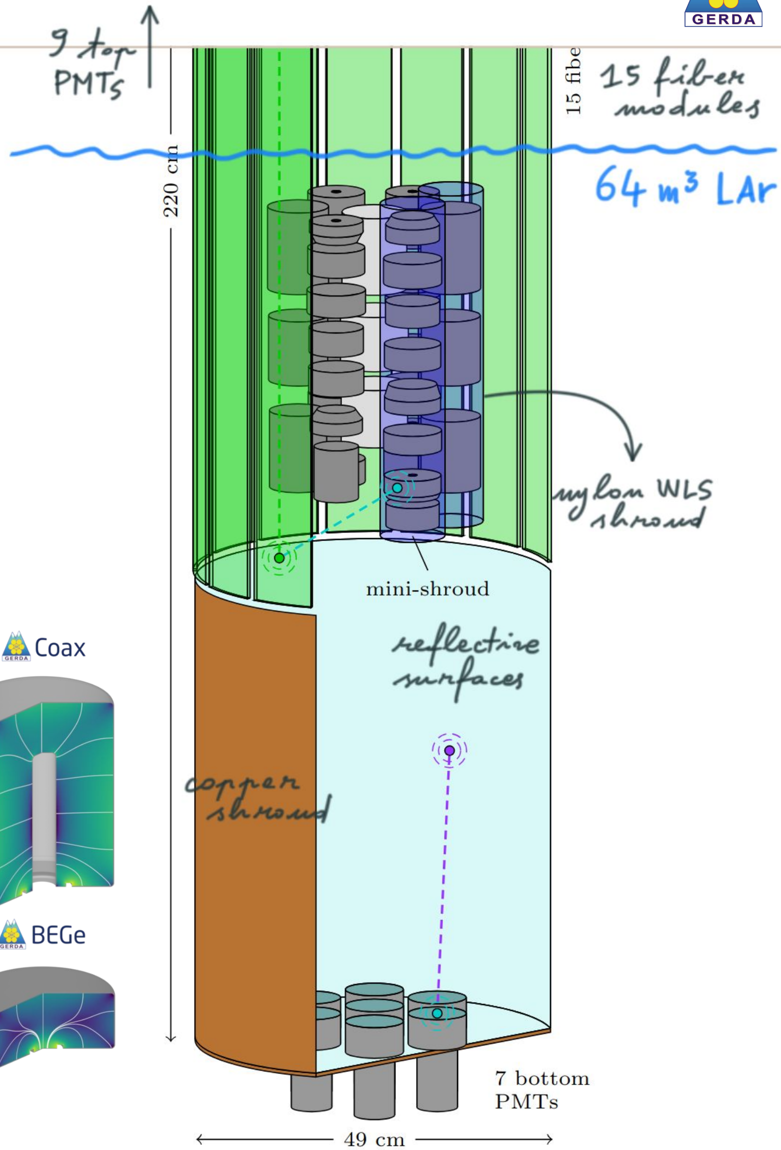
- Radio-pure materials, small passive mass, deep underground (LNGS)
- Upgraded in 2018
  - Inverted-Coax (IC) detectors
  - improved LAr instrumentation
- Cryostat filled in year 2010
  - no online purification
  - minimal handling
  - occasional (small) top-ups
- -> **Low *in-situ* re-contamination probability**

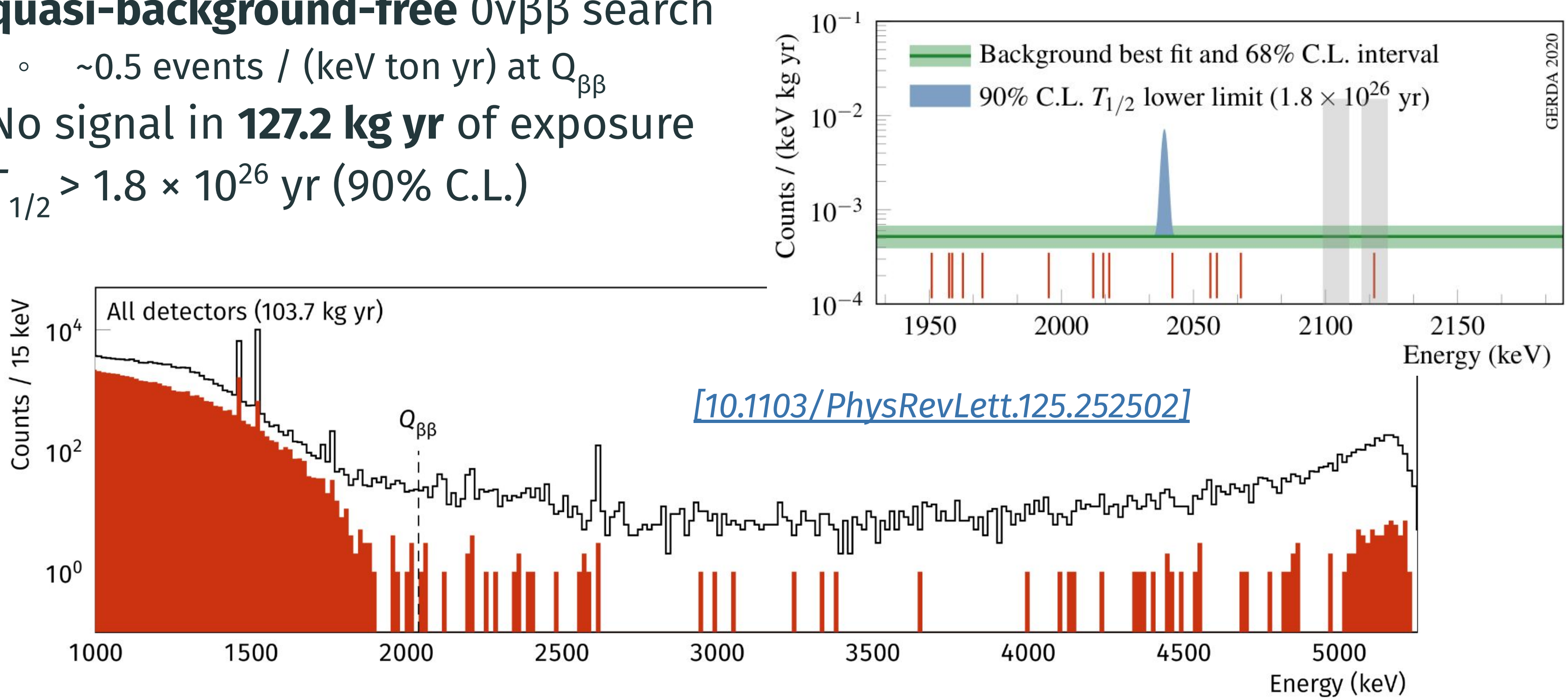




The GERDA final result on $0\nu\beta\beta$

"One of the world's best-performing $0\nu\beta\beta$ experiments"

- **~2.5 keV** FWHM energy resolution at $Q_{\beta\beta}$
- **quasi-background-free** $0\nu\beta\beta$ search
    - ~0.5 events / (keV ton yr) at $Q_{\beta\beta}$
- No signal in **127.2 kg yr** of exposure
- $T_{1/2} > 1.8 \times 10^{26}$ yr (90% C.L.)



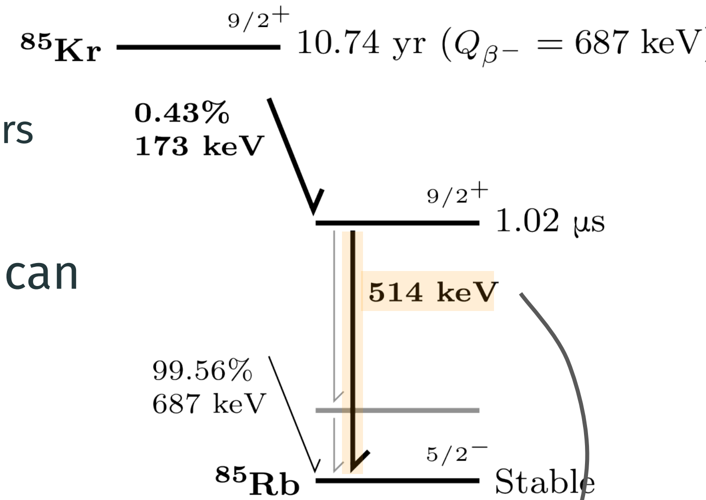
[10.1103/PhysRevLett.125.252502]

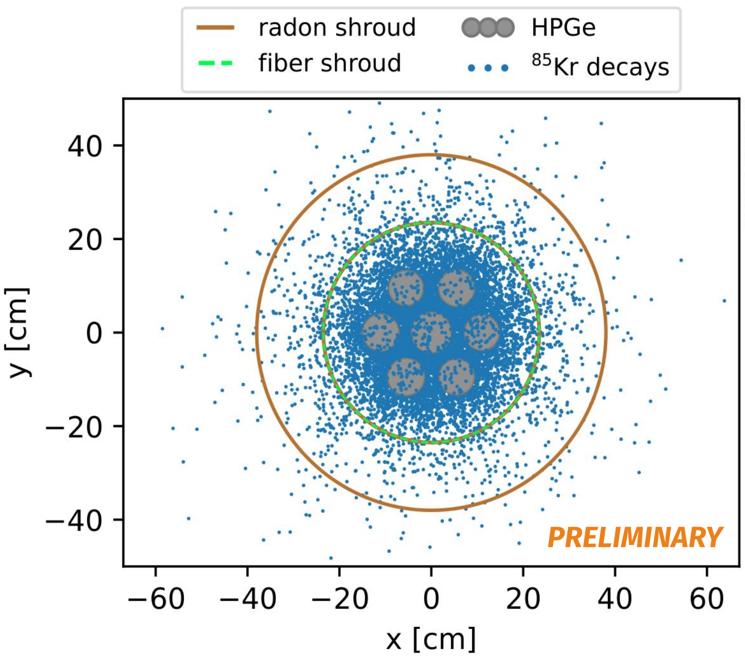
This talk:

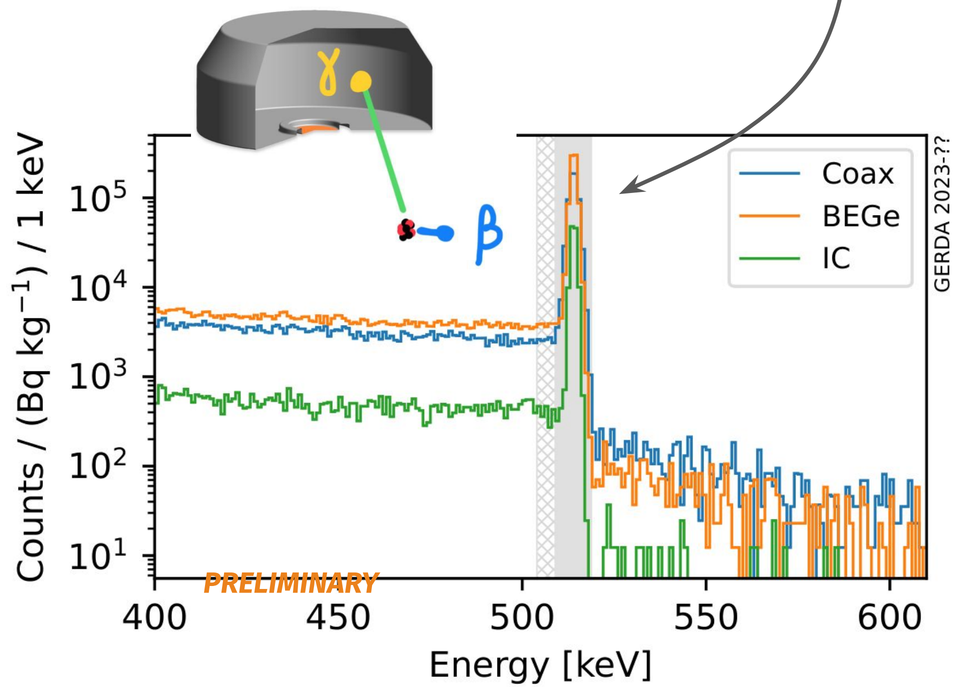
measurement of the ^{85}Kr concentration in the LAr

^{85}Kr signature and detection efficiency in GERDA

- ^{85}Kr simulation in GERDA geometry
  - Data post-processed to fold runtime parameters and $T_{1/2}$ = 10.8 yr decay
- β-particle absorbed in LAr // **514 keV γ-ray** can be fully **absorbed in germanium**
- Excellent energy resolution -> **no detailed background model** needed

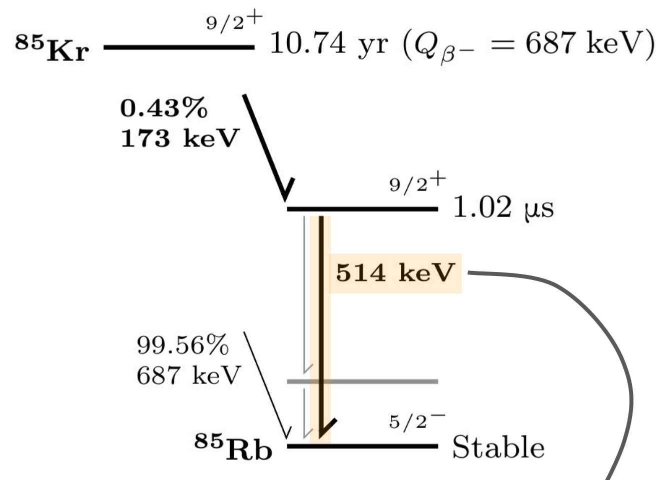


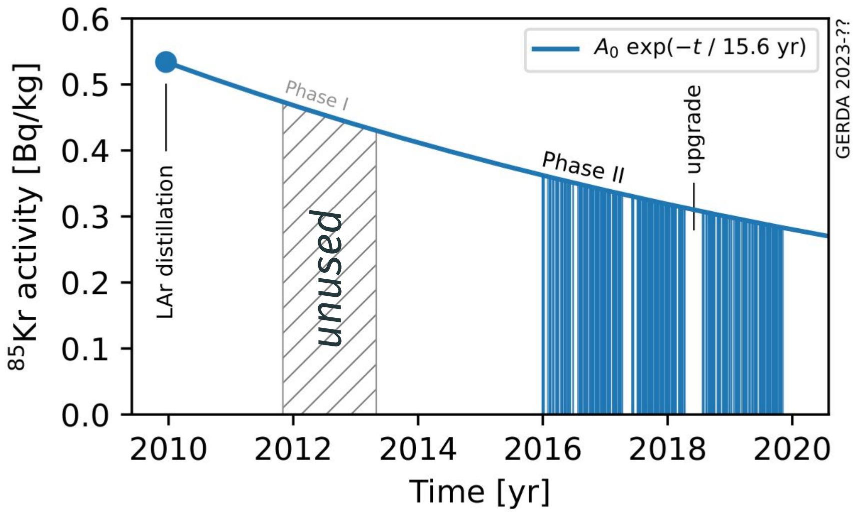


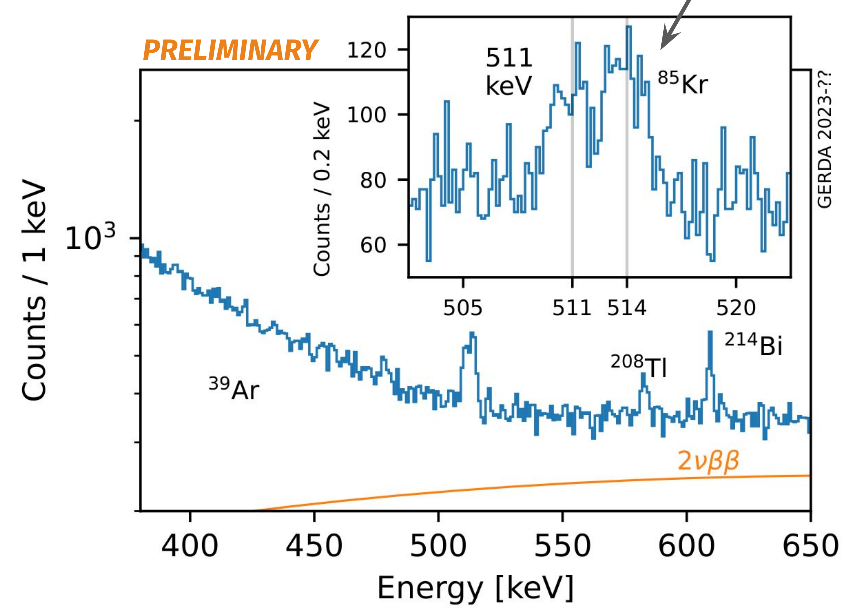


Data selection

- Phase II data set: Dec 2015 -> Nov 2019
  - **105.5 kg yr** of germanium exposure
- Data partitioned according to energy resolution and signal strength
  - detector type
  - before and after upgrade
- **Note:** partial overlap with 511 keV peak
  - e^+e^- annihilation + ^{208}Tl γ-ray







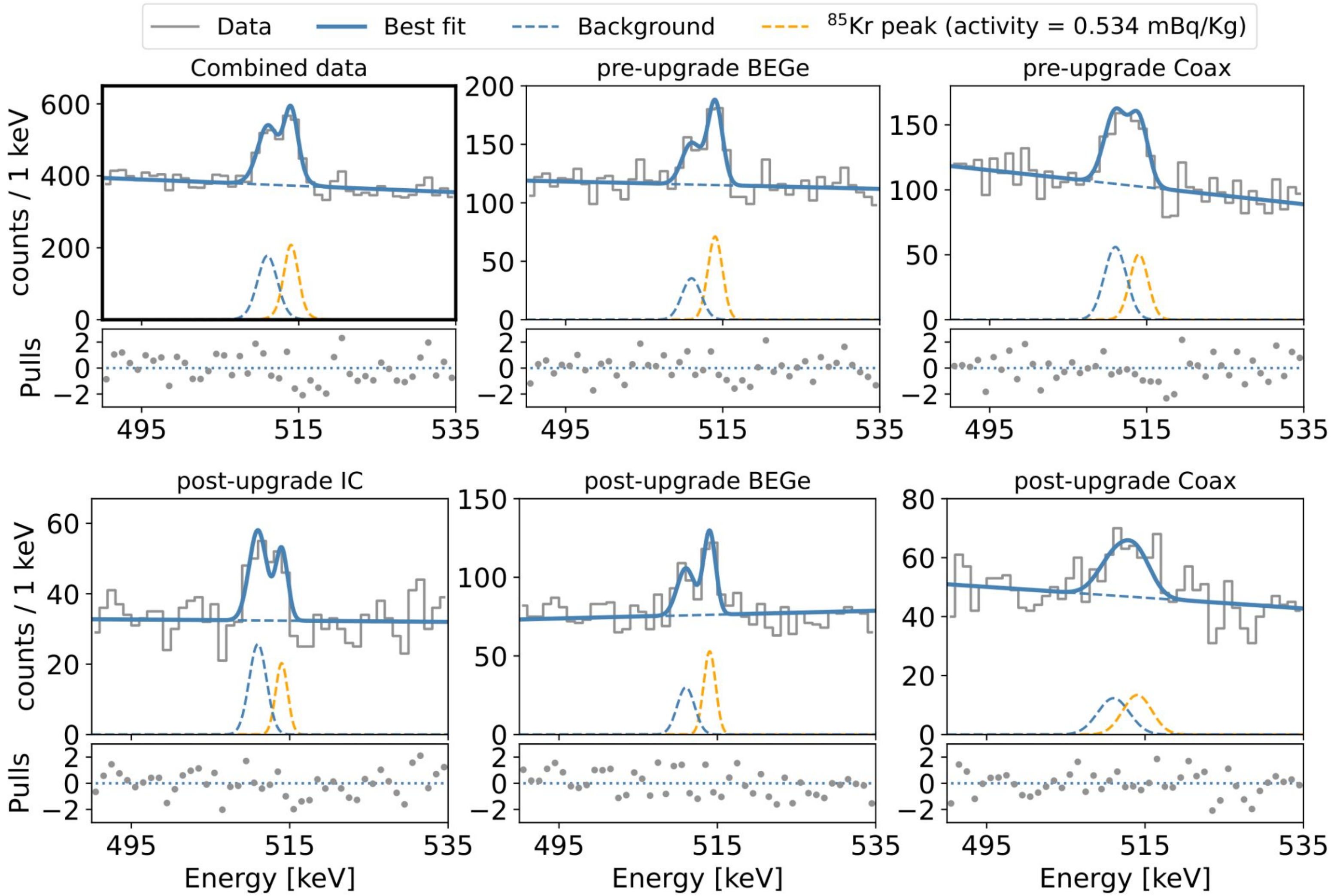
Analysis methods

- Maximum binned likelihood (best fit) and profiling (uncertainty)

$$\mathcal{L}(\mathrm{data} \,|\, A_0, \vec{\vartheta}) = \prod_i^{\mathrm{ds}} \prod_j^{\mathrm{bins}} \mathrm{Pois}(\nu_{ij} \,|\, \mu_{ij}(A_0, \vec{\vartheta}_i)) \times \mathrm{Pull}(\vec{\vartheta}_i)$$

- Signal modeled as gaussian peak
  - σ constrained to measured energy resolution (pull term w/ uncertainty)
  - Intensity constrained to detection efficiency (pull term w/ uncertainty)
- Background (continuum) modeled as linear function
- 511 keV peak modeled as gaussian
  - free-floating intensity (modeling is hard)
  - additional Doppler broadening factor

PRELIMINARY



- Results dominated by statistical uncertainty
- Systematic uncertainty includes:
    - HPGe active volume
    - cryostat top-ups
- At start of Phase II: **(0.36 ± 0.03) mBq/kg**
    - Activity at cryostat filling: (0.53 ± 0.05) mBq/kg

Other LAr measurements:

- WARP: (0.12 ± 0.09) Bq/kg
- DarkSide: (2.05 ± 0.13) mBq/kg

Low concentration compared to other experiments!