Low-background aspects of GERDA

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on behalf of the GERDA collaboration

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Outline

- Introduction
- The GERDA experiment
- Selected low-background aspects:
  - Radio-purity of liquid argon
  - Cryostat fabrication
  - Frontend electronics radioactivity
  - LAr scintillation veto
- Conclusions

The GERDA collaboration

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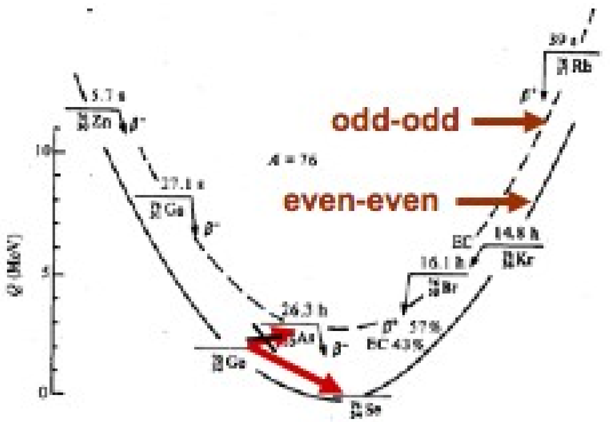
~100 physicists
18 institutions
7 countries

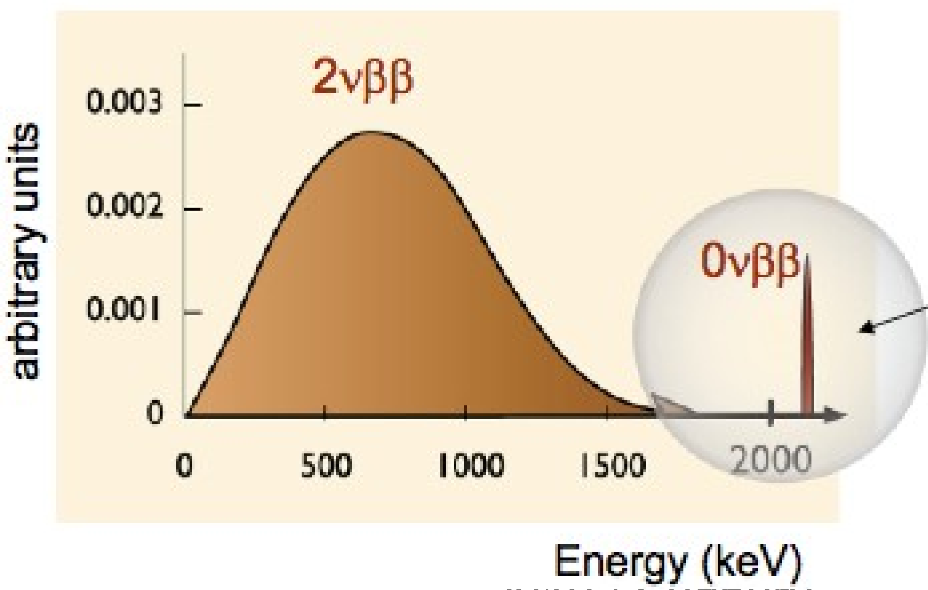
Double beta decay



$2\nu\beta\beta$: $(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$ **$\Delta L=0$**

$$T^{2\nu}_{1/2} = (10^{18}\text{-}10^{21})\text{y}$$

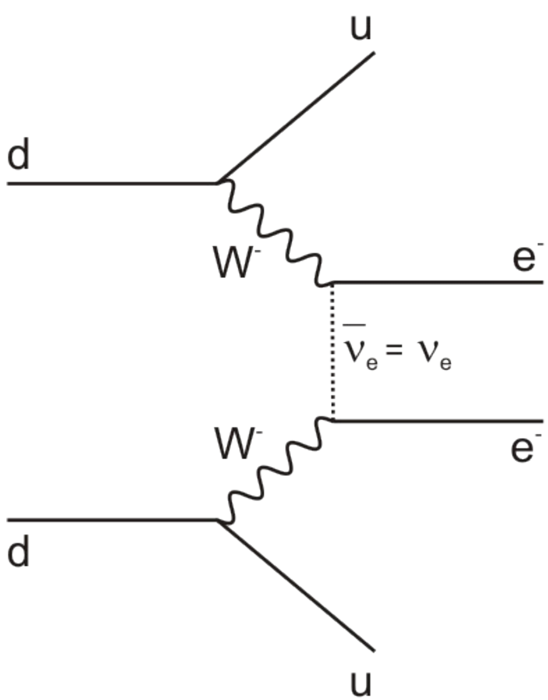
$0\nu\beta\beta$: $(A,Z) \rightarrow (A,Z+2) + 2e^-$ **$\Delta L=2$**



Experimental signatures:

- peak at $Q_{\beta\beta} = E_{e1} + E_{e2} - 2m_e$
- two electrons from vertex
- production of grand-daughter isotope

Double beta decay and Majorana neutrino mass



Phase space factor (~Qββ5)

Nuclear matrix element

Effective Majorana neutrino mass

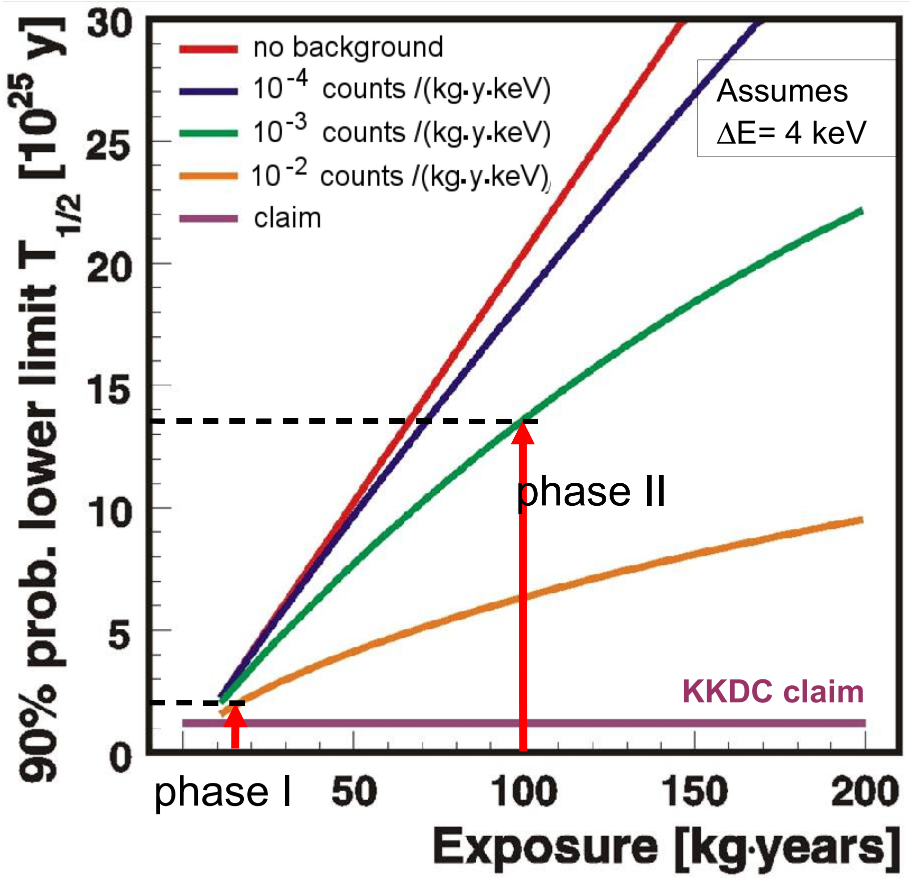
$$\langle m_{\beta\beta} \rangle = | \sum_j m_j U_{ej}^2 |$$

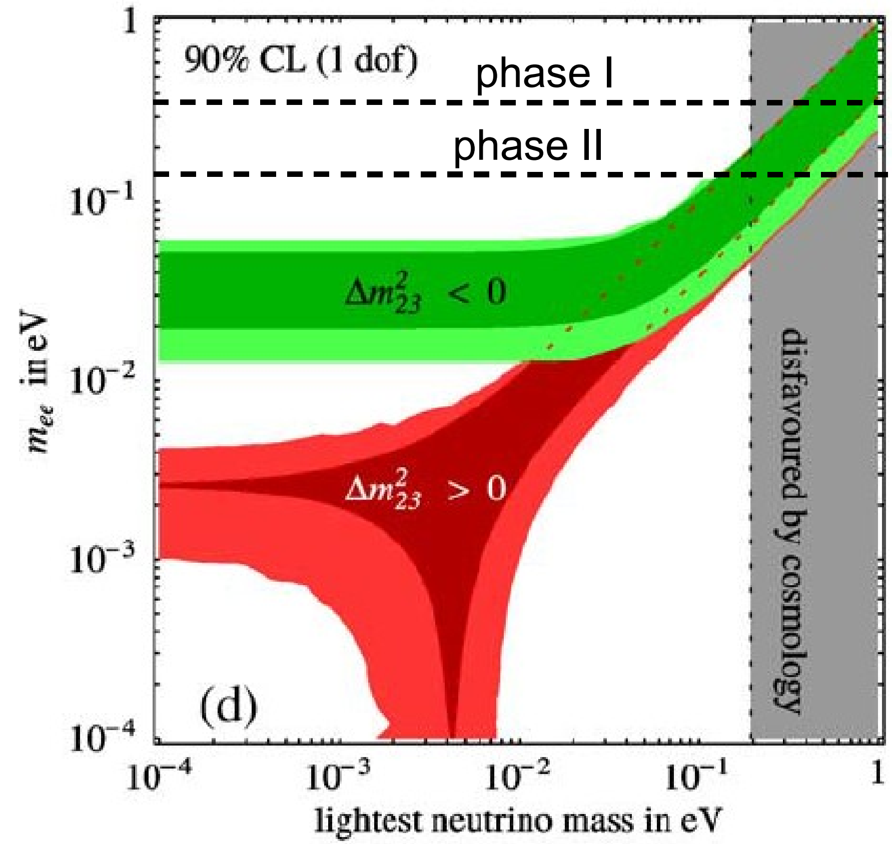
Coherent sum

If leading term is Majorana neutrino mass term

GERDA sensitivity

Feruglio, Strumia, Vissani NPB 659



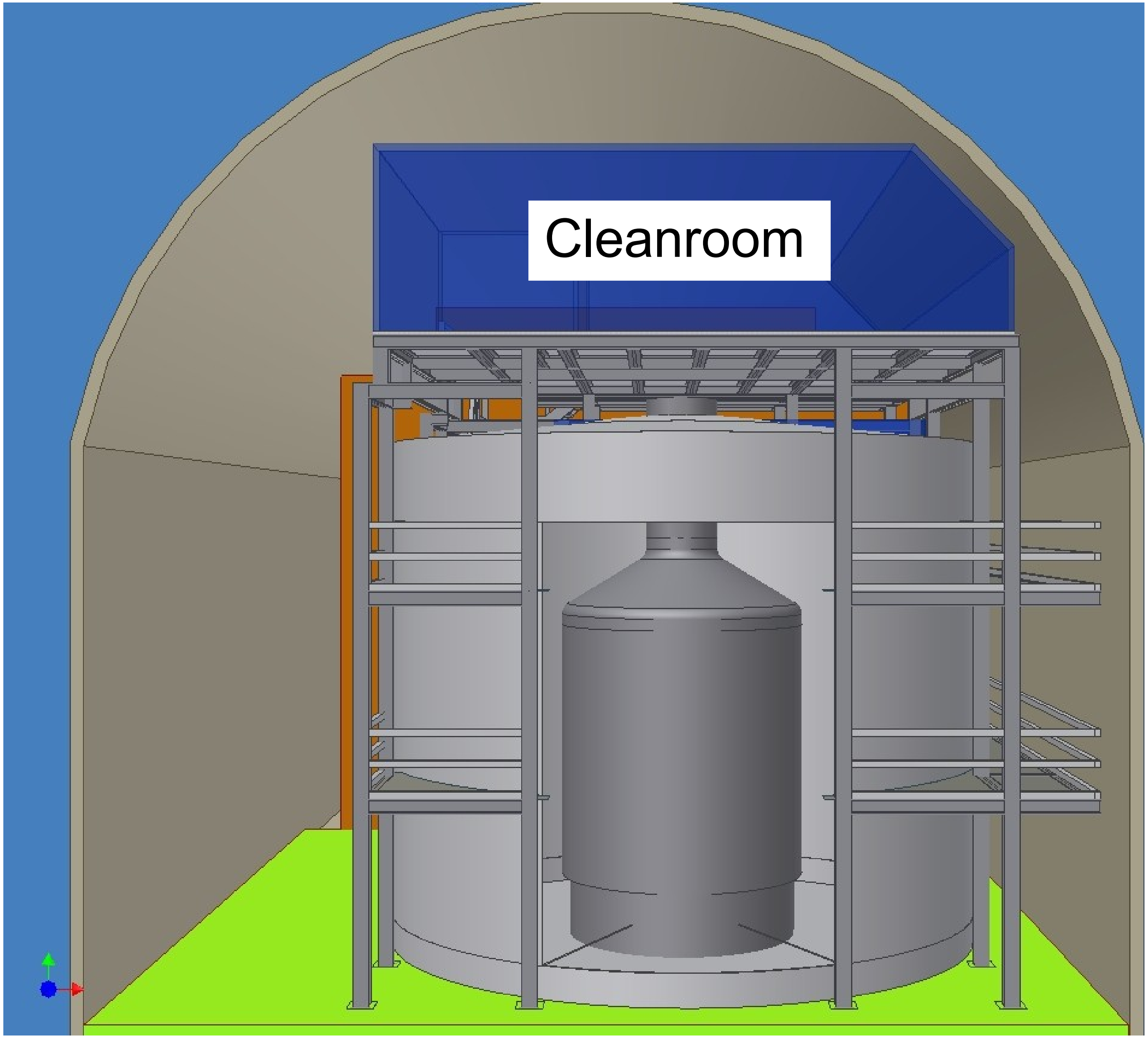


Using <M0ν>=3.92, V.A. Rodin et al., *Nucl. Phys. A 366 (2006) 107-131*
Erratum: *Nucl. Phys. A 793 (2007) 213-215*

GERDA in brief

- Ge spectroscopy with array of 76Ge-enriched diodes in ultrapure cryogenic liquid (LAr)
- Phase I:
  - Use of existing 76Ge-diodes from Heidelberg-Moscow and IGEX-experiments
  - 17.9 kg enriched diodes   ~15 kg 76Ge
  - Bkg-level <10-2 counts/(keV·kg·y) @ 2039 keV to check KKCD-claim without background
- Phase II:
  - Adding new Ge diodes (total: ~40 kg 76Ge)
  - New active background suppression techniques
  - Demonstration of bkg-level <10-3 counts/(keV·kg·y) @ 2039 keV for a future one-ton experiment

GERDA design



Lock

Water tank (590 m3 H_2O)

Cryostat (65 m3 LAr)

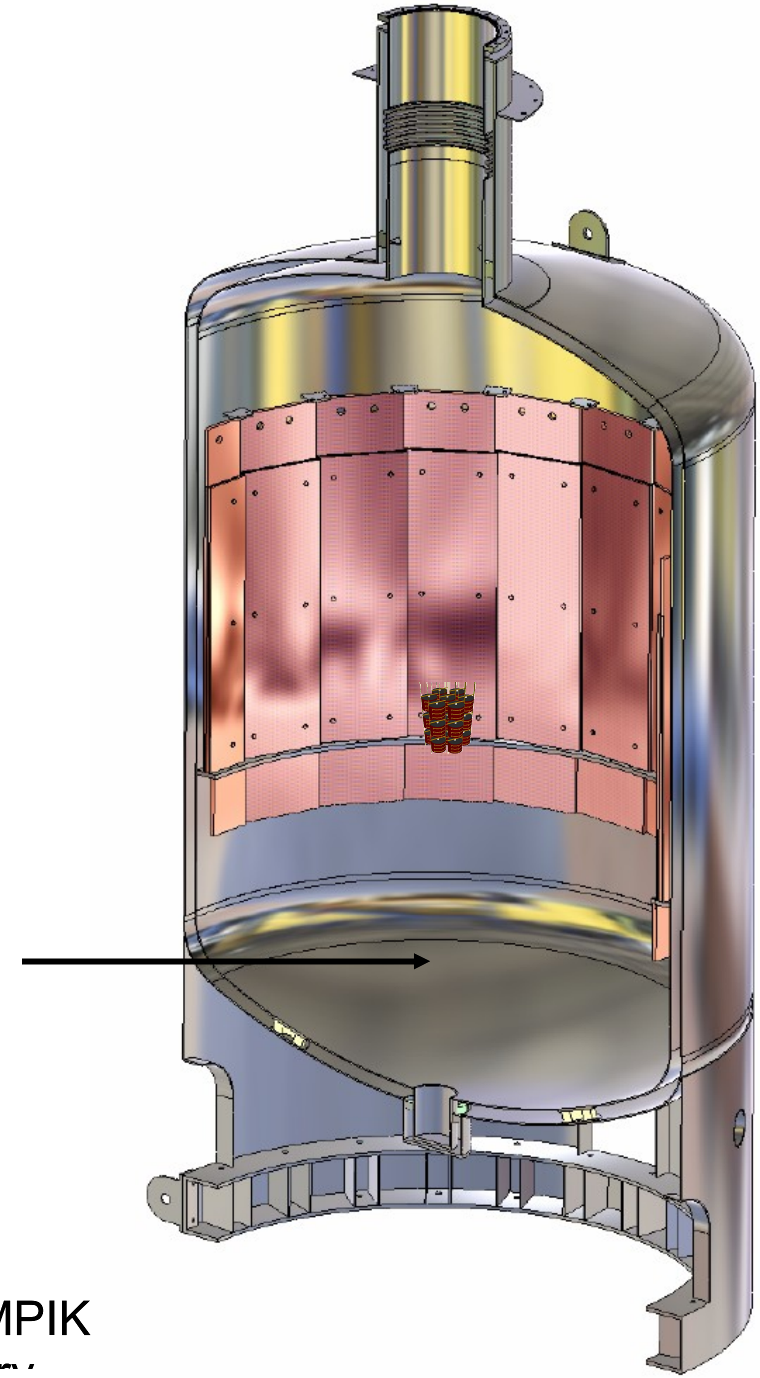
GERDA design

Additional inner copper shield

Germanium-detector array

Liquid argon

Vacuum-insulated double wall stainless steel cryostat




Cryostat delivery

Water tank construction

Installation of muon veto system


construction of clean room
27 feb 09

Glove-box for Ge-detector handling under protective atmosphere


GERDA

Recent progress and status

- December 2009: Liquid argon fill
- January 2010: Commissioning of the cryogenic system
- April/May 2010: Installation of the (commissioning-) lock
- May 2010: 1st deployment of FE electronics & detector mock-up (27 pF)
  - pulser resolution 1.4 keV (FWHM)
- June 2010: First deployment of natGe detectors
- Since July 2010: Commissioning run with natGe detector string (3 diodes):
- 1st data show more 42Ar than expected %requires dedicated analysis
- Afterwards: Start phase I physics data taking

GERDA phase II

- 37.8 kg of enrGe reduced and purified (Yield: 35.5 kg 6N grade + 1.2 kg tail)
  - Cosmic-ray exposure minimized
- Baseline for phase II: Broad Energy Ge (BEGe) diodes (Fall-back: segmented diodes)
  - Distinct pulse shapes ð excellent multi-site event rejection
  - LAr operation successfully tested

- Entire BEGe production chain successfully tested with depGe

Radio-purity of liquid argon

- GERDA 222Rn specs: <0.5 μBq/m3 Ar (STP)
- Cryo-adsorption of Rn on activated carbon proven to provide ultra-pure N2 (Borexino)
  - Try to adapt same technique for LAr, but
    - T(LAr) = T(LN2) + 10K
    - Risk of Ar freezing
- Tests performed using MoREx and low background proportional counters
  - *H. Simgen and G. Zuzel, Appl. Rad. Isot. 76 (2009) 922-925*

Results on 222Rn removal from Ar by cryo-adsorption

Gas phase results			Liquid phase results		
Volume [liter LAr]	Reduction factor R	Leaking fract. 1/R [%]	Volume [liter LAr]	Reduction factor R	Leaking fract. 1/R [%]
96	>360	<0.28	58	58.5 • 17.1	1.7 ± 0.5
169	>1120	<0.09	120	30.2 ± 9.7	3.3 ± 1.1
			120	27.7 ± 6.5	3.6 ± 0.8
			125	21.1 ± 2.7	4.7 ± 0.6
			168	42.4 ± 5.7	2.4 ± 0.3
			188	8.5 ± 1.0	11.8 ± 1.5
			193	4.9 ± 0.6	20.4 ± 2.4
			222	160 ± 28	0.6 ± 0.1
			240	10.1 ± 0.6	9.9 ± 0.6

Summary on Rn purification of Ar by cryo-adsorption

- Gas phase purification very efficient
- Liquid phase less efficient (poor kinetics)
- Unclear picture, but factor 100 reduction seems possible with GERDA's 1 kg carbon column
- Problem: CarboAct activated carbon has very irregular shape:
  - Not optimized for column purification
  - Probably formation of accidental between carbon grains
  - New product: Spherical carbon balls
    - 222Rn emanation: <0.5 mBq/kg

222Rn concentration in commercial Ar when truck is loaded

Company	Grade	222Rn [mBq/m3 (STP)]
Air Liquide	technical (4.8)	1.62 • 0.08
Air Liquide	technical (4.8)	0.38 □ 0.03
Westfalen AG	technical (4.6)	1.11 □ 0.05
Westfalen AG	technical (4.6)	1.04 □ 0.09
Westfalen AG	technical (4.6)	0.50 □ 0.02
Westfalen AG	technical (4.6)	0.007 □ 0.001
Westfalen AG	technical (5.0)	8.4 □ 0.4
Westfalen AG	high purity (6.0)	0.38 □ 0.01
LINDE	technical (5.0)	0.37 □ 0.06 *)

*) At time of delivery

Initial Ar impurities

- Ar is usually delivered from a local distribution center . Unknown storage time yields unpredictable results, because
  - Initial 222Rn decays
  - New 222Rn may be produced (emanation)

- Trend shows higher initial 222Rn concentration in Ar than in N2 (~0.1 mBq/m3 (STP))
  - Possible Explanation: Boiling points (Rn > Ar > N2)

222Rn emanation of storage tanks for cryogenic liquids

Tank from	Grade of stored gas	Vol. [m3]	222Rn activity in saturation [mBq]	specific 222Rn act. [mBq/m3]
Westfalen AG	technical	3	177 6	59 ± 2
Air Liquide	technical	0.67	1.8 ± 0.4	2.7 ± 0.6
LINDE	technical	6.3	3.5 ± 0.2	0.56 ± 0.03
Westfalen AG	6.0	0.67	42 ± 2	63 ± 3
SOL	6.0	16	65 ± 6	4.1 ± 0.4
LINDE	7.0	3	2.7 ± 0.3	0.9 ± 0.1

222Rn emanation of storage tanks for cryogenic liquids

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Westfalen AG	tec[illegible]	[illegible]	177 ± 6	59 ± 2
Air Liquide	tec[illegible]	[illegible]	1.8 ± 0.4	2.7 ± 0.6
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Selected for GERDA

The GERDA cryostat

- Vacuum-insulated stainless-steel (SS) cryostat made from low-radioactivity austenitic steel
  - 228Th <1 mBq/kg for cylindrical part
  - 228Th <5 mBq/kg for top and bottom parts
  - For all screening results see

  W. Maneschg et al., NIM A 593 (2008) 448–453
- Additional passive copper shield inside
- Active LN2 cooling system to avoid evaporation losses

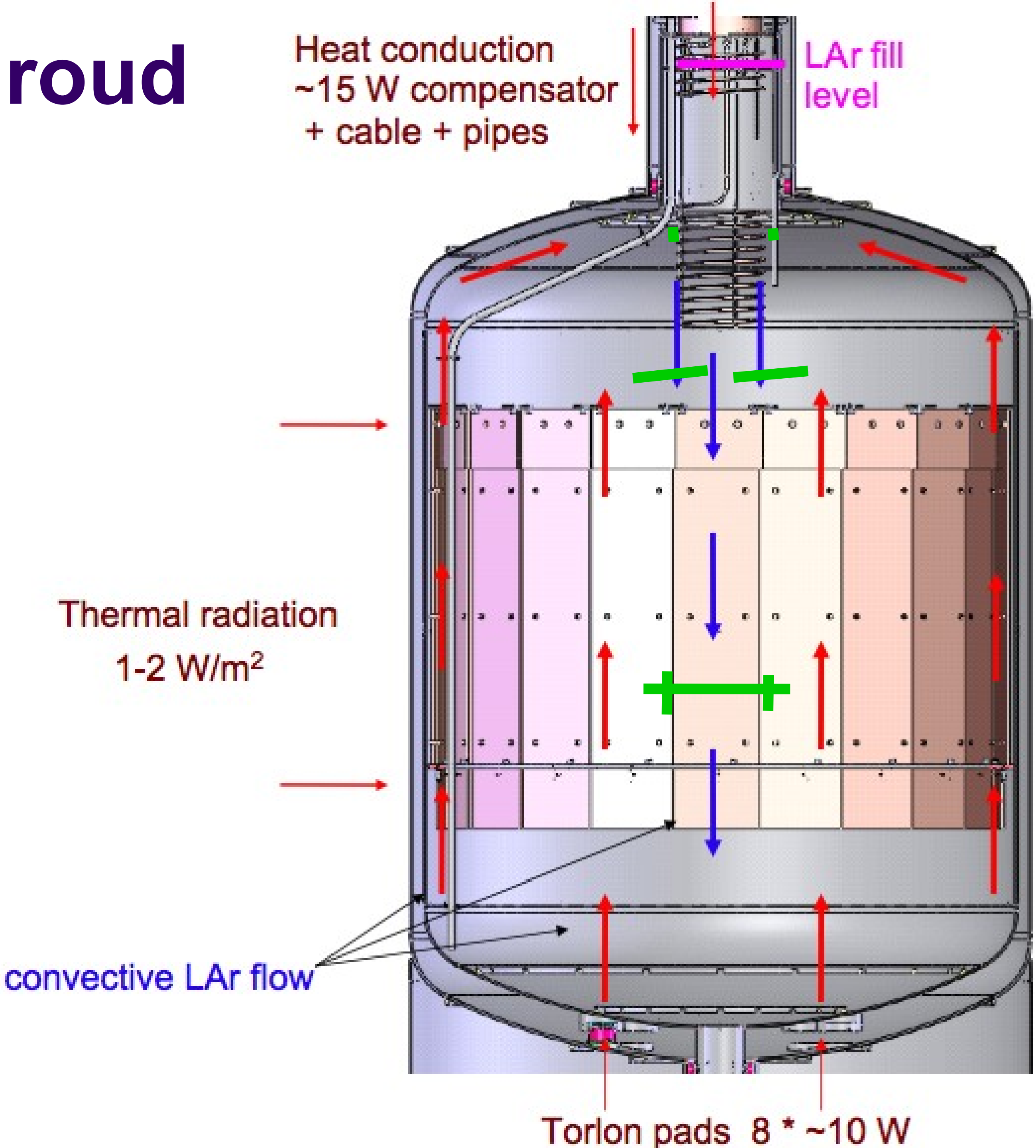
222Rn emanation test of the GERDA cryostat

1. Remove air-borne 222Rn
2. Fill with 222Rn-free N2 (purified by cryo-adsorption)
3. Wait for ≥1 week to let grow-in emanating 222Rn
4. Mix to establish homogeneous 222Rn distribution
5. Extract small fraction of N2 from cryostat and determine its 222Rn concentration
6. Scale to entire cryostat to find total 222Rn emanation rate

Cryostat 222Rn emanation

No.	Date	Description	Single results [mBq]	Average [mBq]
1	Nov 07	After construction and cleaning, no N2 mixing	16.9 1.6stat 2 3.0sys 29.8 ± 2.4stat ± 5.8sys	23.3 ± 3.6
2	Mar 08	After additional cleaning	13.6 ± 0.7stat ± 2.4sys 13.7 ± 0.7stat ± 2.7sys	13.7 ± 1.9
3	Jun 08	After Cu mounting	33.0 ± 2.8stat ± 7.0sys 35.7 ± 2.9stat ± 8.8sys	34.4 ± 6.0
4	Nov 08	After wiping of Cu / steel surfaces.	33.2 ± 3.5stat ± 1.9sys 31.3 ± 4.6stat ± 3.4sys 27.3 ± 2.4stat ±	30.6 ± 2.4

Radon shroud



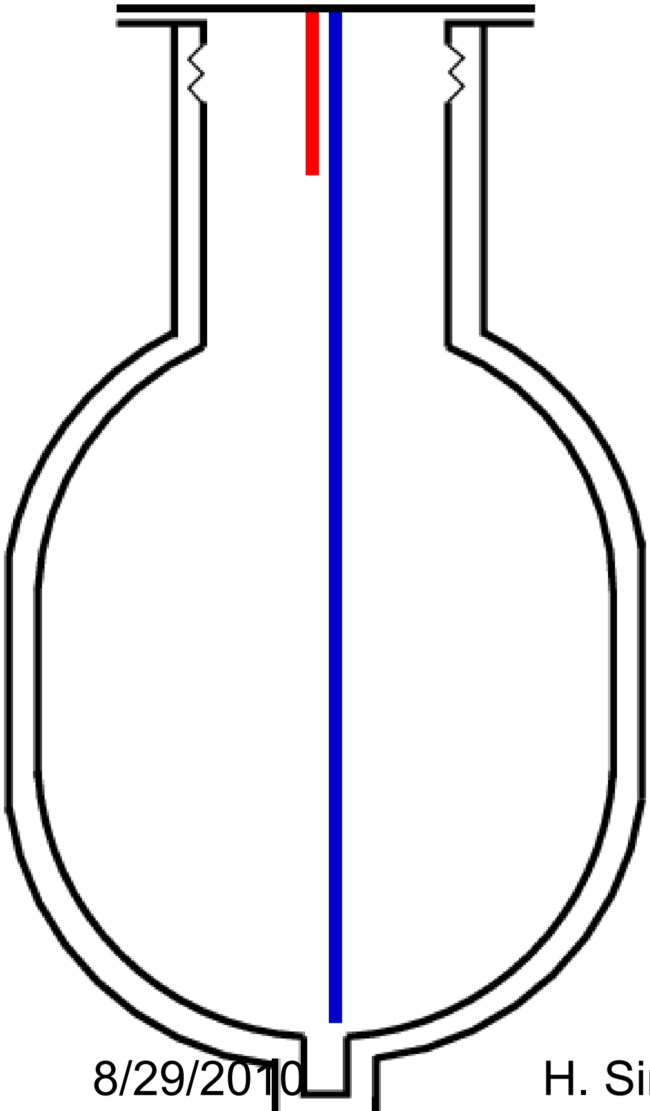
Welds as source for SS 222Rn emanantion

- SS tape: (5 – 10) µBq/m2
  - cannot explain cryostat result
- Emanation of SS welds!
- Surface effect: 226Ra can be removed by etching
- Poster on surface cleaning from 222Rn daughters by G. Zuzel
- What happens in LAr? Next talk by Sebastian Lindemann

No	Description	Result [mBq/m]
1	SS after welding	0.36 ± 0.04
2	SS after welding + etching (HF+HNO3)	<0.1
3	SS after welding + electropolishing	0.10 ± 0.04
4	Sample No. 3 + additional etching	<0.04

Results on 222Rn emanation of welds

Homogeneity test



Before mixing:

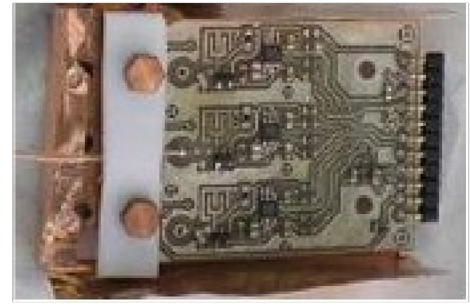
- ctop = (0.42 ± 0.05) mBq/m3 (STP)
- cbot = (0.28 ± 0.03) mBq/m3 (STP)

After mixing:

- ctop = (0.23 ± 0.03) mBq/m3 (STP)
- cbot = (0.27 ± 0.05) mBq/m3 (STP)

- If system is untouched 222Rn is NOT homogeneously distributed
- Relatively stronger 222Rn source in top part of cryostat

Screening of GERDA FE electronics

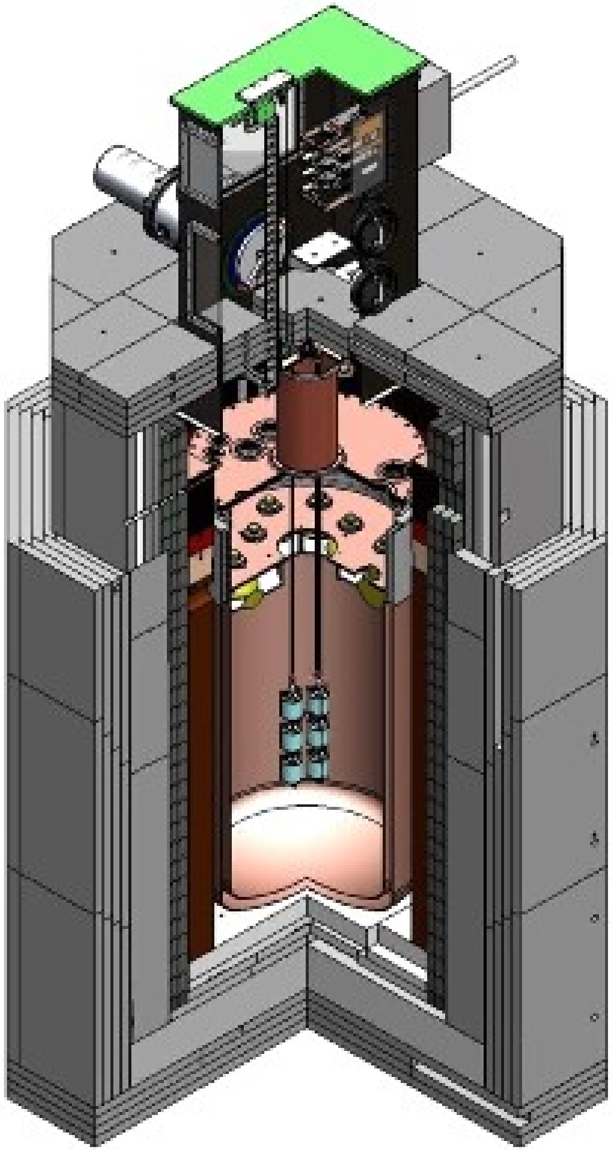


Sample	226Ra	228Th	228Ra	40K
	Units: mBq/piece			
Old frontend „PZ0“	6.3 ± 0.5	0.2 ± 0.1	0.2 ± 0.1	2.2 ± 0.7
New frontend “CC2”	0.32 ± 0.09	0.44 ± 0.10	<0.36	2.6 ± 1.3
Main source of 226Ra in PZ0: Ba containing capacitors				
X5R capacitors (Ba)	0.19 ± 0.02	0.04 ± 0.01	<0.05	<0.15
New capacitors (Ta)	<0.003	0.008 ± 0.002	<0.01	0.07 ± 0.03

- Improvements in CC2 with respect to PZ0:
  - Number of components reduced
  - Hot components removed (Ba capacitors, but also resistors, pins)
- FE still critical for phase II background index

Paper in preparation

The LArGe Setup
with 1.3 tons of LAr



Lock: Can house up to 3 strings (9 detectors)

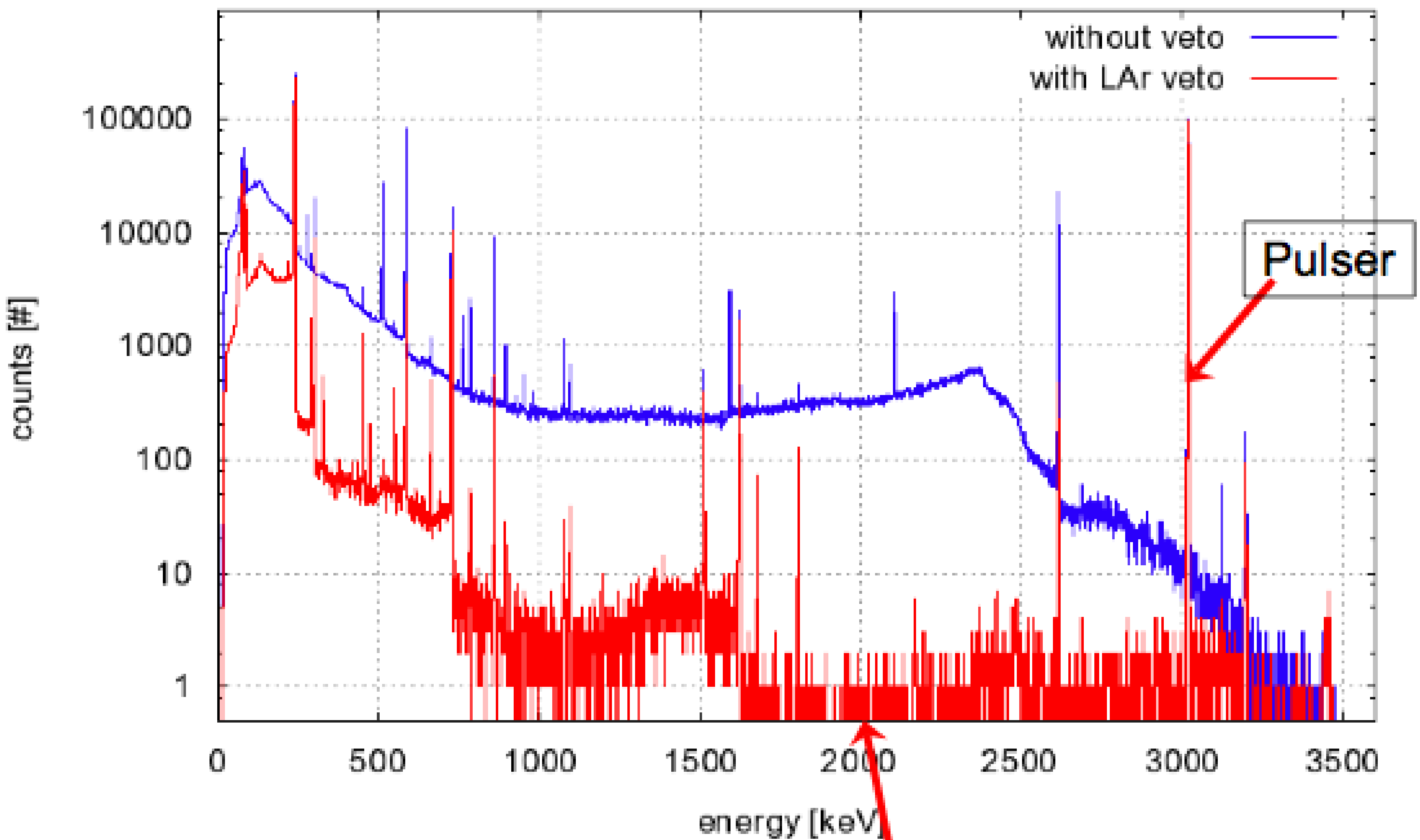
9 PMTs: 8" ETL9357

VM2000 & wavelength shifter

Cryostat: Inner diameter: 90 cm, Volume: **1000 liter**

Shield:		
	Cu	15 cm
	Pb	10 cm
	Steel	23 cm
	PE	20 cm

Th228 int



Factor 1000 reduction by LAr VETO is obtained in LArGe + BEGe

Summary and conclusions

- Many different techniques applied to control radiopurity of GERDA during construction
  - LAr purity under control
  - Cryostat emanation too high Ô shroud
  - FE electronics critical, but OK for phase I
  - Promising results from LAr scintillation veto (+ pusle shape discrimination with BEGe's)
- GERDA setup ready. Physics data taking will start after study of 42Ar issue