Status of the GERDA experiment

Béla Majorovits for the GERDA collaboration

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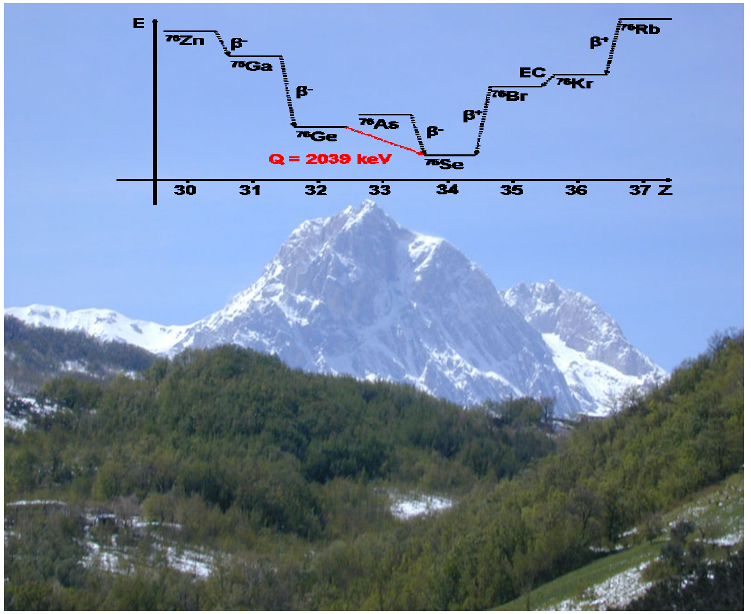


- Neutrinoless Double Beta Decay with 76Ge
- The principle of the GERDA experiment
- Phase I detectors
- Phase II Detector production
- The infrastructure at LNGS
- Prospects with GERDA

Sensitivity of 0νββ-experiments

The parameter measured in neutrinoless double beta decay experiments is its half-life. $T_{1/2}^{0\nu\beta\beta} \gtrsim 10^{15} \cdot$ age of the universe

Figure of merit for a limit sensitivity for experiment with background:

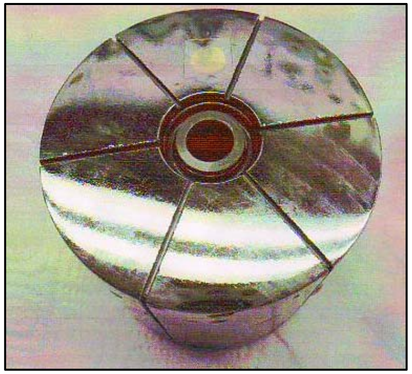
$$T_{1/2} \propto a\,\varepsilon \sqrt{\frac{M\,t}{b\,\delta E}}$$

M	active target mass of the experiment	Increase target mass
b	background rate of the experiment	Minimize and select material
a	enrichment of isotope under consideration (< 1.0)	Use isotope with high natural abundance or enrich material
ε	signal detection efficiency (<1.0)	Source =! Detector
δE	Energy resolution	Use high resolution spectroscopy
t	Measuring time (< 20y)	

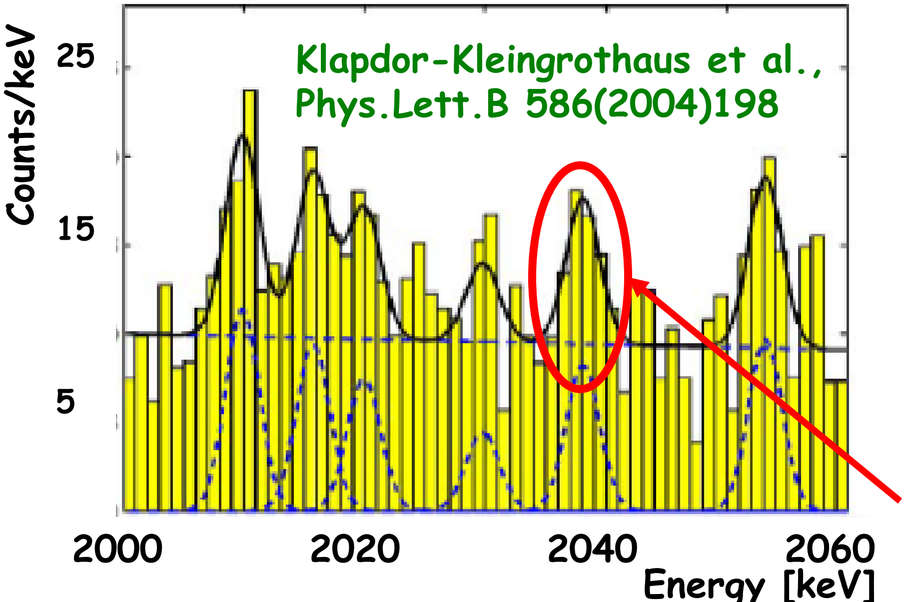
High Purity Germanium detectors:

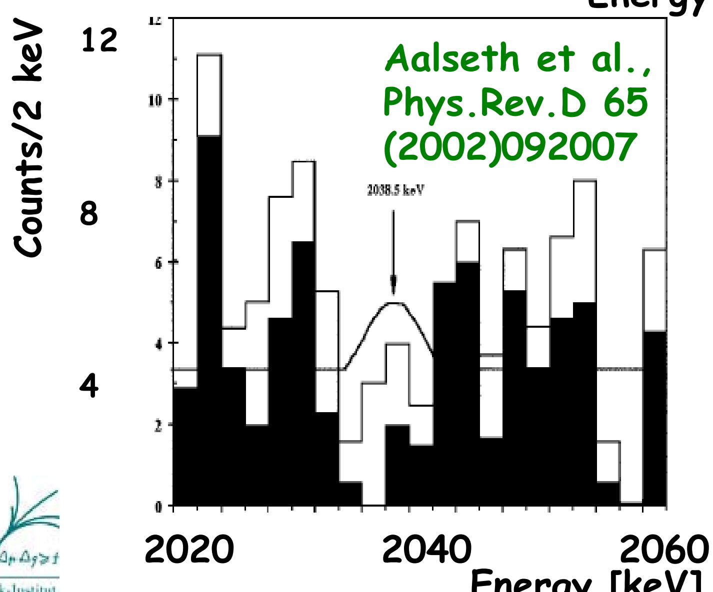
Very good energy resolution	Background due to $2\nu\beta\beta$ decay negligible
Source = Detector	High signal detection efficiency (95%)
Very high purity of detector material (zone refinement)	Very low intrinsic background
Considerable experience	Well known and reliable, improvements possible
Natural abundance of ^{76}Ge 7,44%	Enrichment necessary





Results from HPGe experiments





<u>Heidelberg-Moscow Experiment</u>:

11.5 kg of enriched Ge detectors

71.7 kg yrs of data

0.11 Counts/(kg keV y) around 2040 keV

--> Upper limit:

$T_{1/2} \geq 1.9 * 10^{25}$ years (90% C.L.)

4.2 σ claim: $T_{1/2} = 1.19 * 10^{25}$ years

--> $\langle m_{ee} \rangle$ = 440 *meV* (KK matrix el.)

<u>IGEX Experiment</u>:

6.8 kg of enriched Ge detectors

8.5 kg yrs of data

0.17 Counts/(kg keV y) around 2040 keV

--> Upper limit:

$T_{1/2} \geq 1.6 * 10^{25}$ years (90% C.L.)

Most Dangerous Background Sources

Cosmic Rays: muons and products from showers

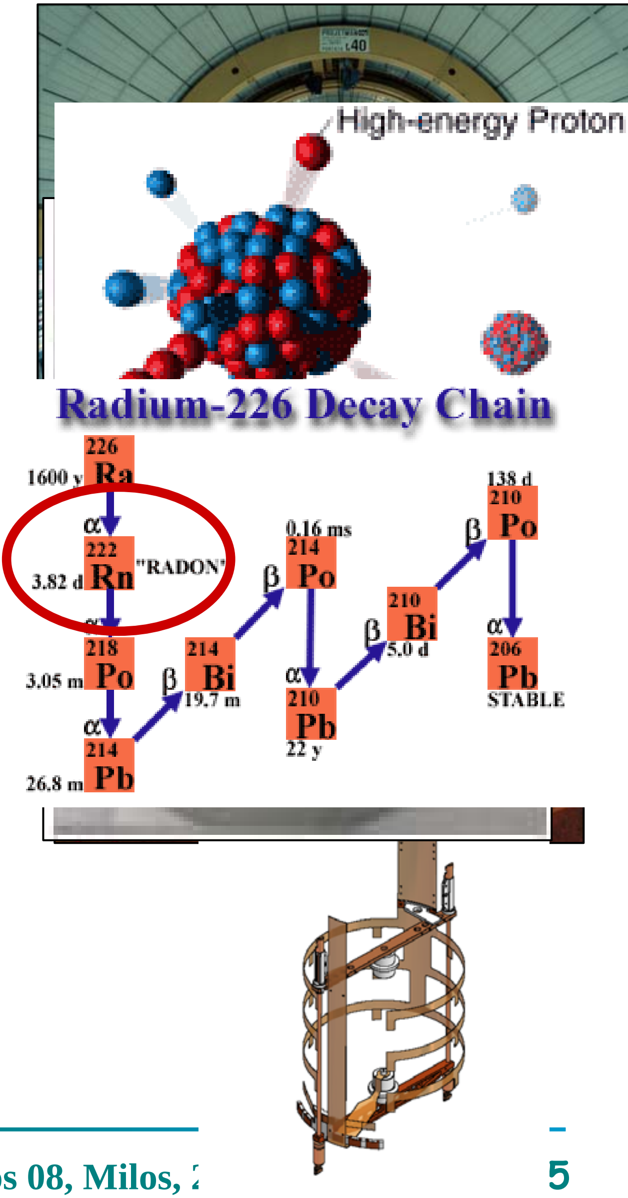
Natural radioactivity from the surrounding: Gammas and neutrons from rock, etc.

Natural radioactivity of the materials used for infrastructure and detector system: Gammas

Internal and surface contaminations of the detector: Gammas, betas, alphas

Cosmogenically produced long lived isotopes inside the germanium and the surrounding materials

Radon from the tunnel air



GERmanium Detector Array: GERDA

Increase sensitivity in order to confirm or refute the claim

--> Reduce bkg-index by at least two orders of magnitude to 10^{-3} Cts/(kg keV year)

--> Increase target mass

The principle idea of the GERDA experiment:

Use the cryo-liquid as cooling medium and shield simultaneously:

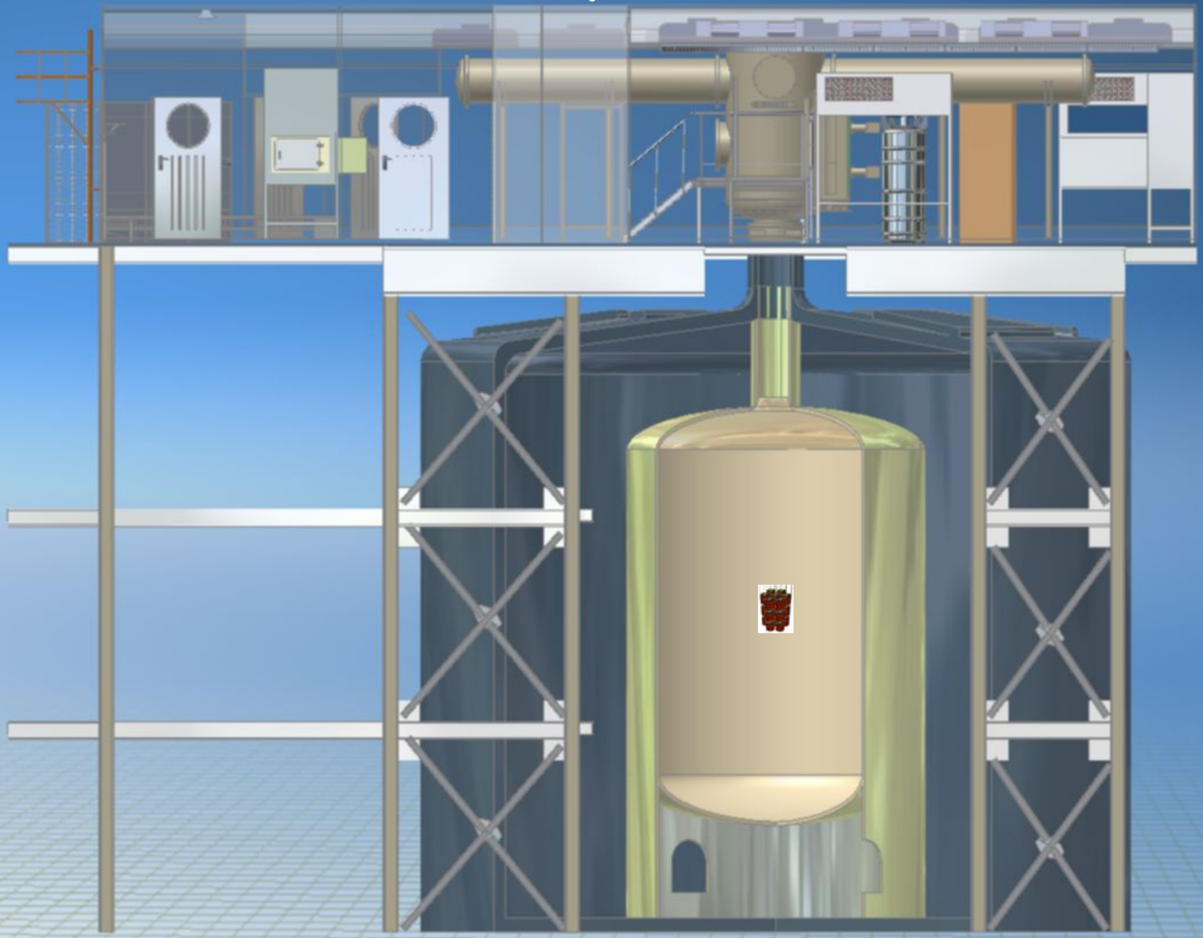
--> Radioactive background can be drastically reduced

- LN and LAr can be produced with very high purity
- Material of conventional cryostat is removed from detector surrounding

G. Heusser, Ann. Rev. Nucl. Part. Sci. 45(1995)543

GERmanium Detector Array: GERDA

➢Place array of naked HPGe-detectors enriched in ^{76}Ge in the center of a stainless cryostat filled with LAr.



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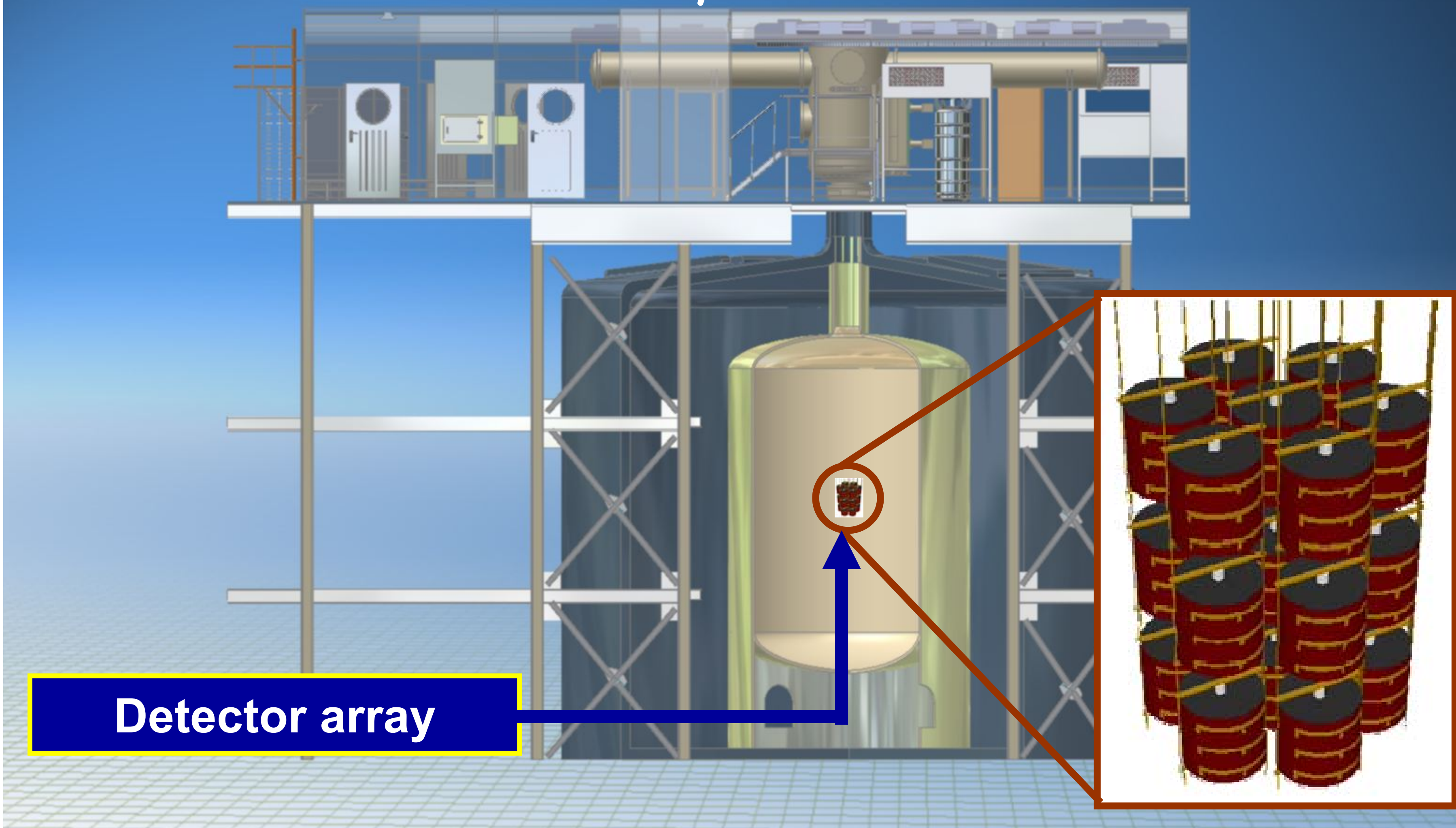

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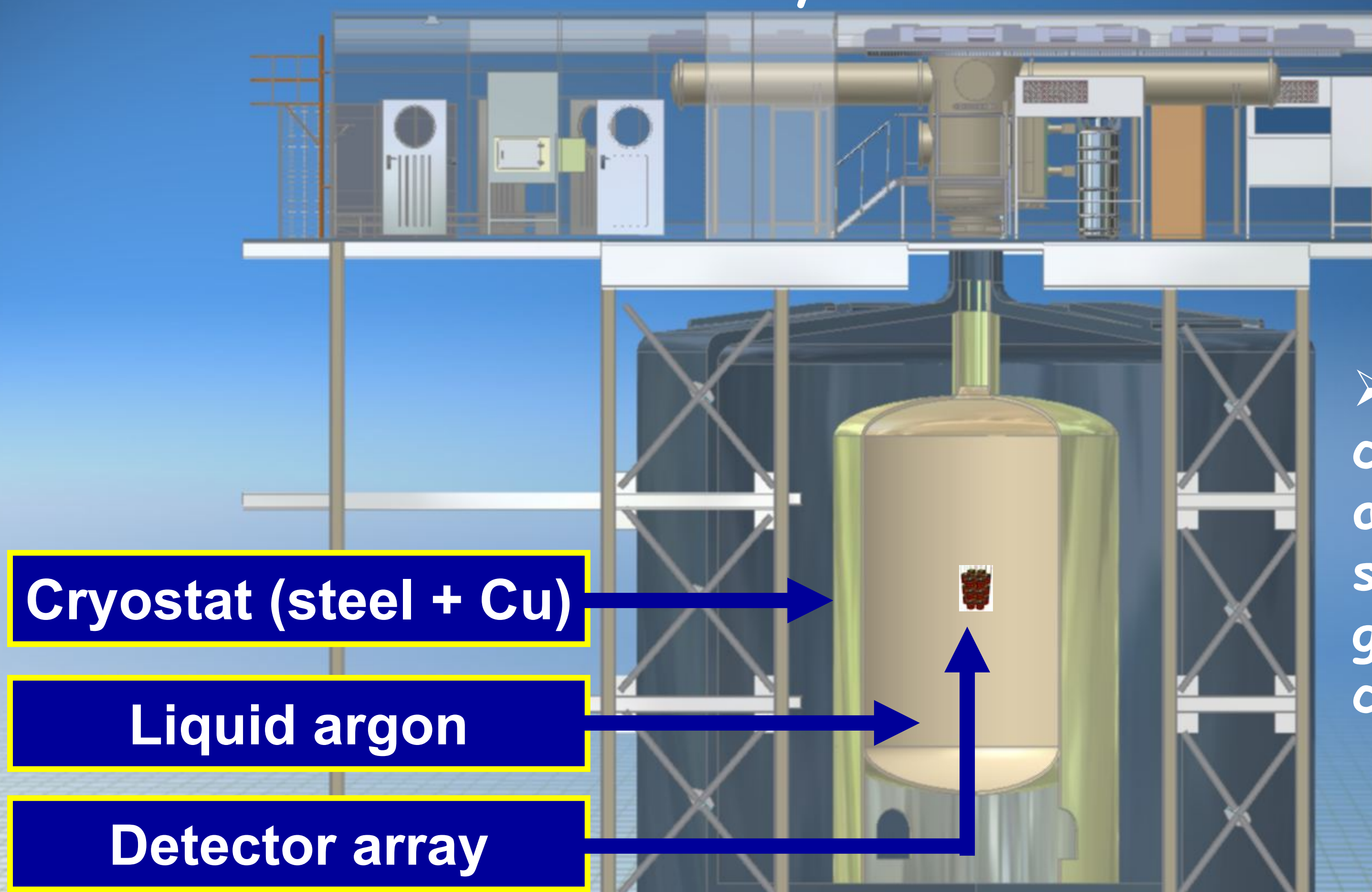
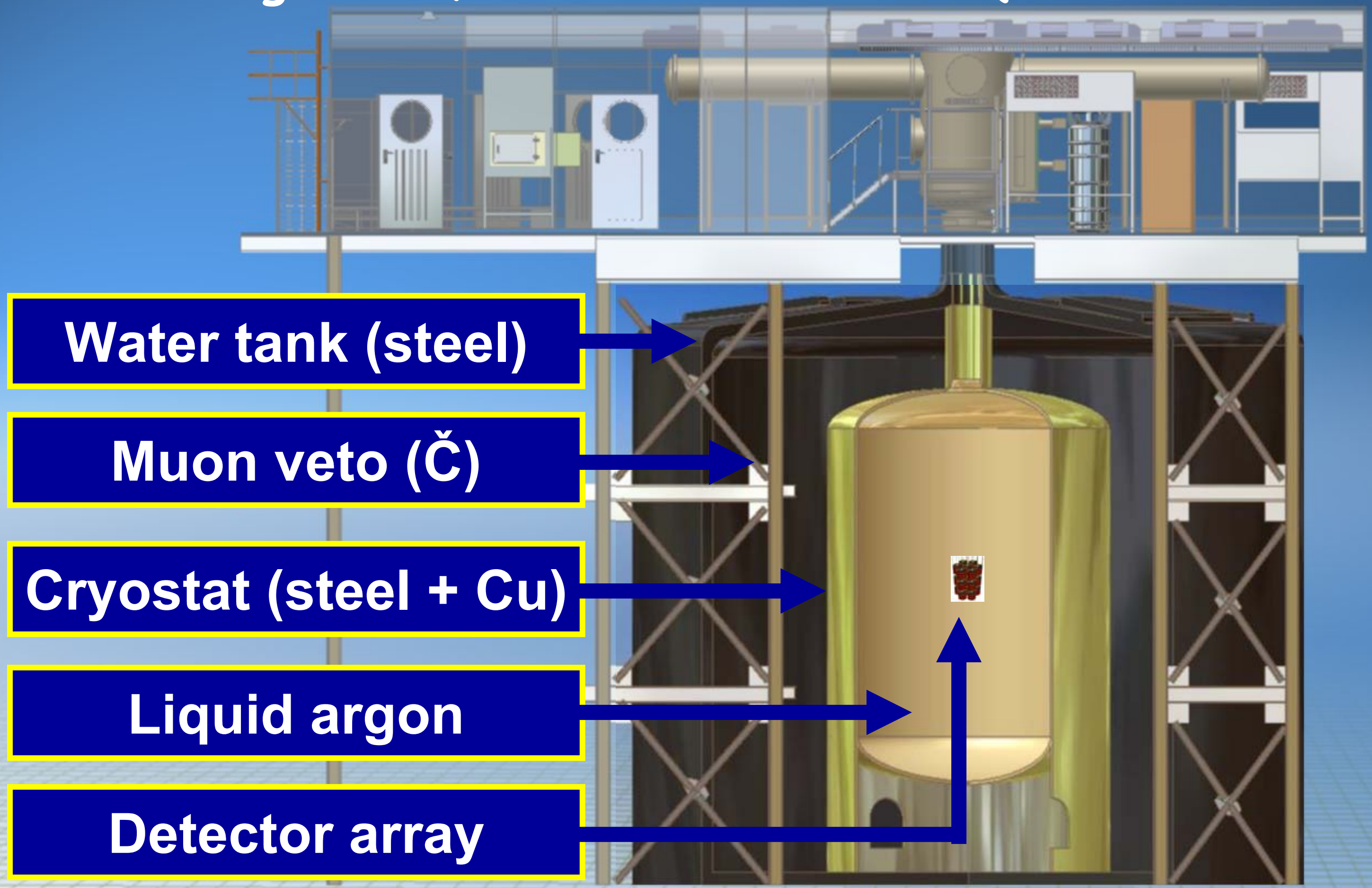


- Inner copper lining as radiation shield against gammas from cryostat

GERmanium Detector Array: GERDA

➢Surround the whole setup with water tank to shield against external gammas, neutrons and muons (water Cerenkov)



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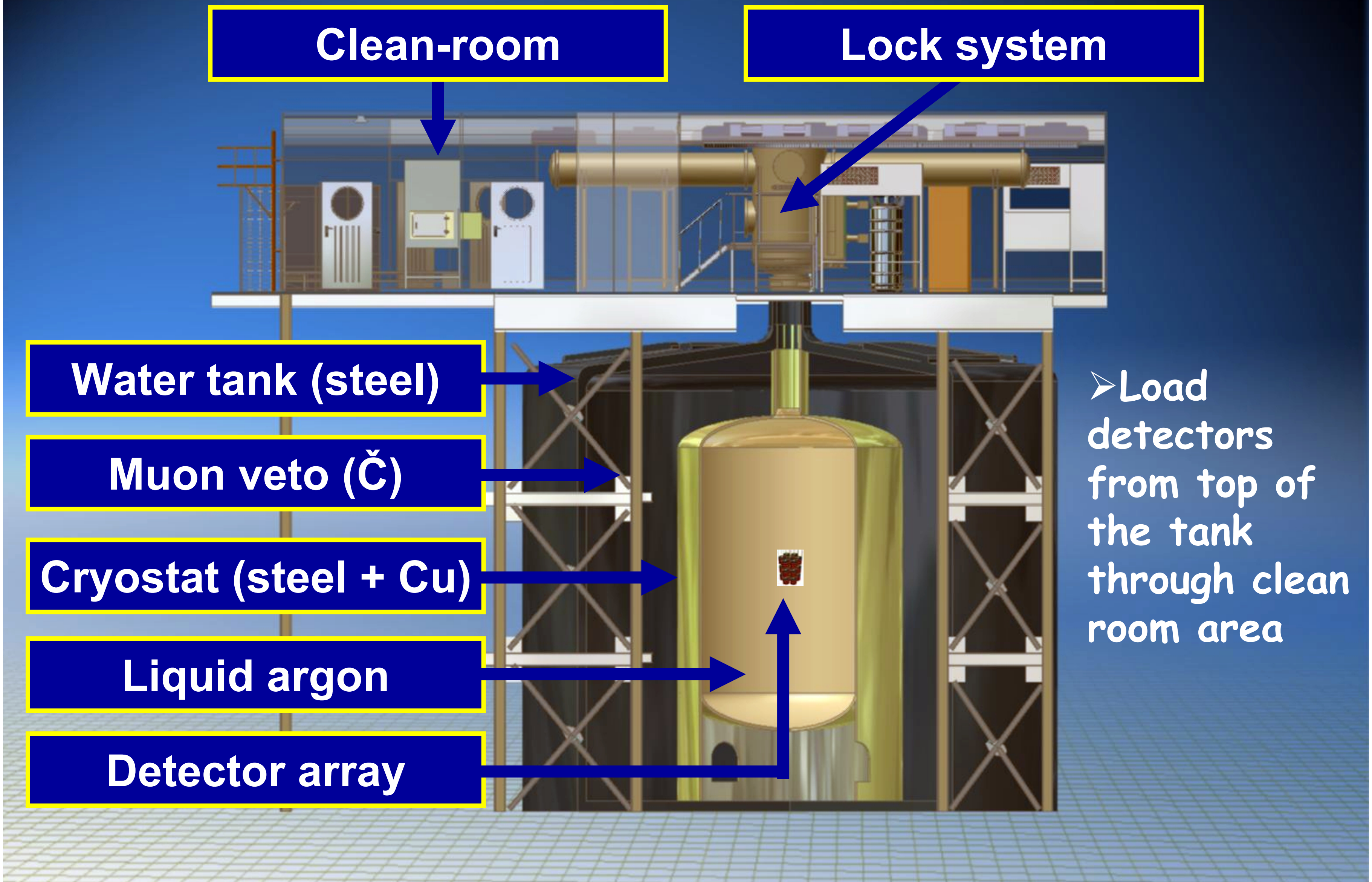


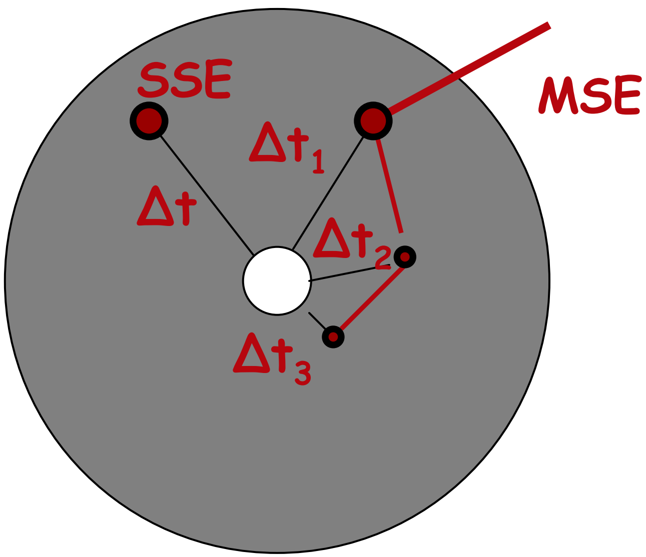
- Load detectors from top of the tank through clean room area

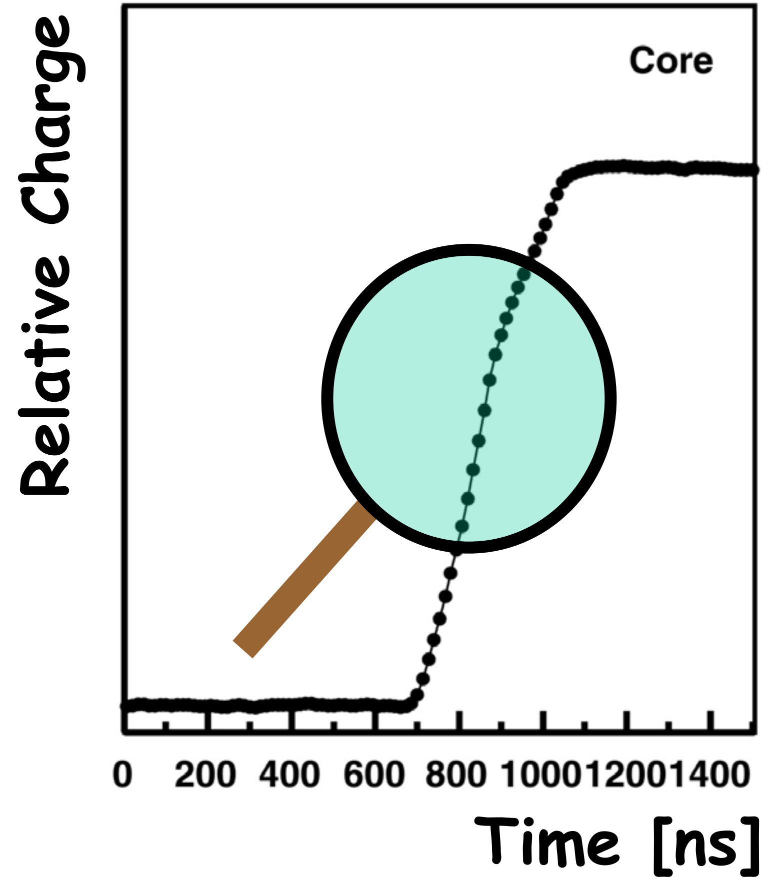
GERmanium Detector Array: GERDA

	Phase I	Phase II
Target mass of enriched material [kg]	18 kg from Hd-Mo and IGEX detectors	Additional 20 kg
Envisioned background [Counts/(kg keV y)]	0.01 (limited by cosmogenic ^{60}Co)	0.001 (improvement by segmentation and further material selections)
Exposure	15 kg y	100 kg y
	Confirm or refute claim	Push sensitivity, prove low background capability of technique Discov. potential: $T_{1/2} \approx 5 \cdot 10^{25}$ yrs, Limit setting: to $1.5 \cdot 10^{26}$ yrs. For Rodin et al. matrix element, mass sensitivity about 120 meV

Background Recognition: PSA

Arrival distribution of electron-hole pairs, i.e. current at electrodes depend on locations of energy deposit within detector:





"The Wider the spread, the broader the current pulse"
--> Background reduction up to factor ~3

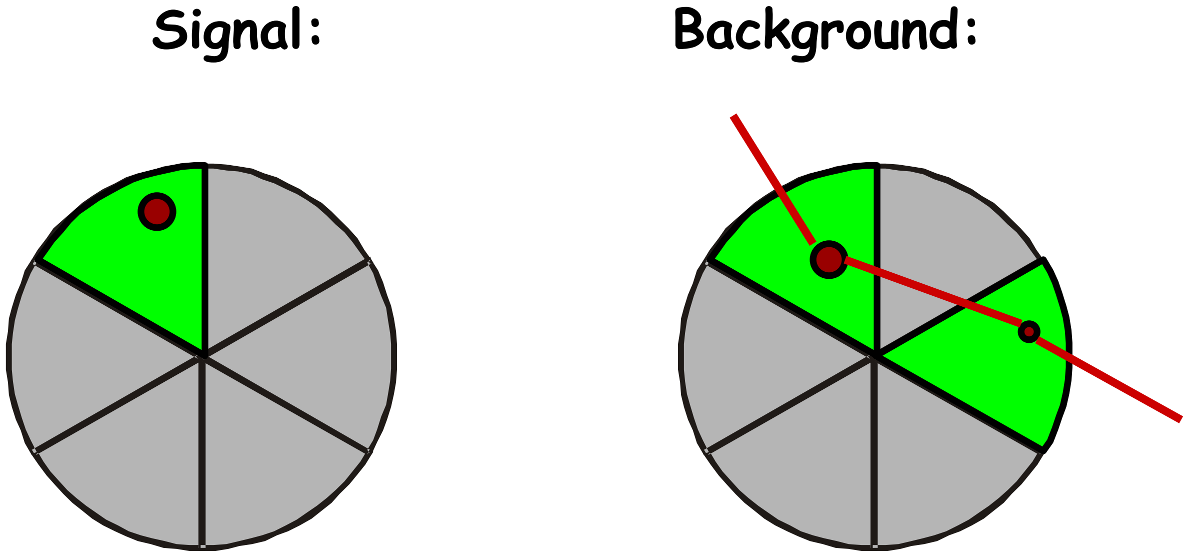
Exploited by Heidelberg Moscow and IGEX collaboration

B. Majorovits and HVKK, EPJA 6(1999)463
D. Gonzales et al., NIM A 515(2003)634

Phase II: Segmentation of detectors

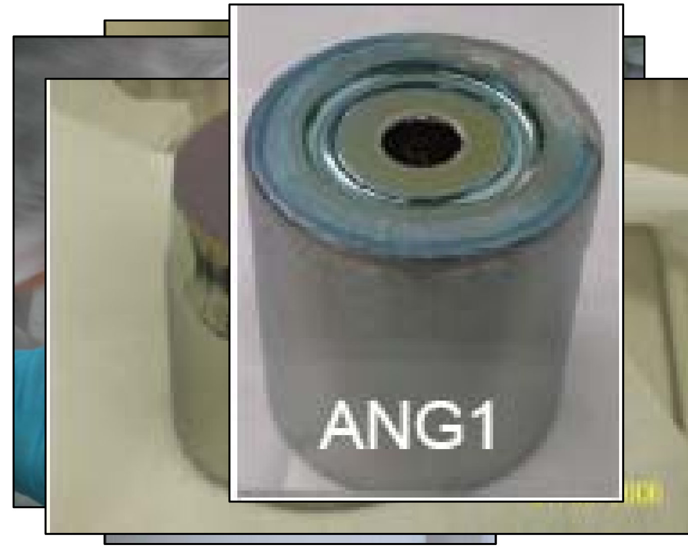
Germanium detectors can be segmented

--> Background identification through identification of multiply Compton-scattered photons by coincidences



Nominal design for phase II detectors: 18 fold segmentation: 3-fold in height, 6-fold in φ

Phase I Detectors:



	ANG1	ANG2	ANG3	ANG4	ANG5	RG1	RG2	RG3
FWHM [keV]	2.54	2.29	2.93	2.47	2.59	2.21	2.31	2.26
Mass [kg]	0.980	2.906	2.446	2.400	2.781	2.150	2.194	2.121

Acquired HdMo and IGEX detectors

Constructed detector holder out of low level materials

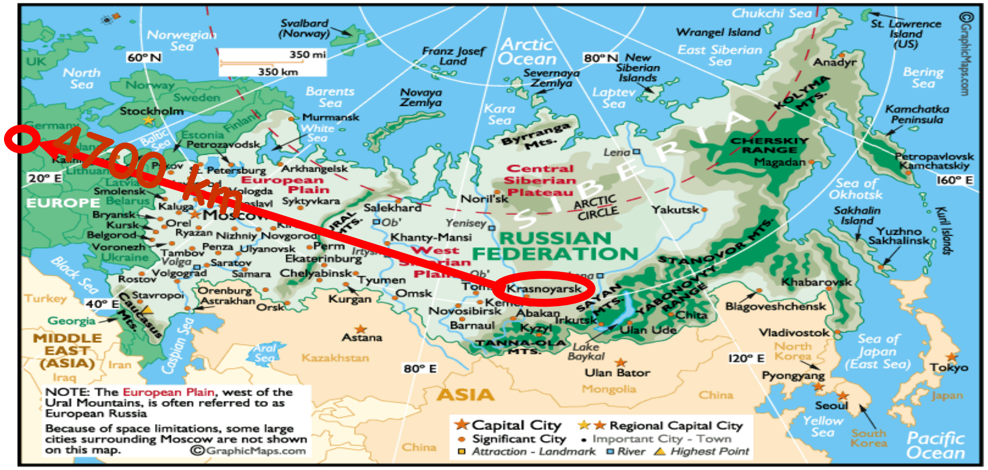
Dismounting of detectors from cryostats without problem

Prototype (nat.) detector works well in LAr

Detectors being refurbrished by Canberra

More than one year running experience with naked GE detectors

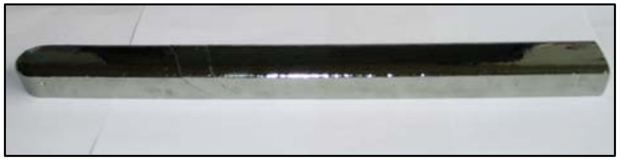
Phase II: 37.5 kg of enriched 76Ge



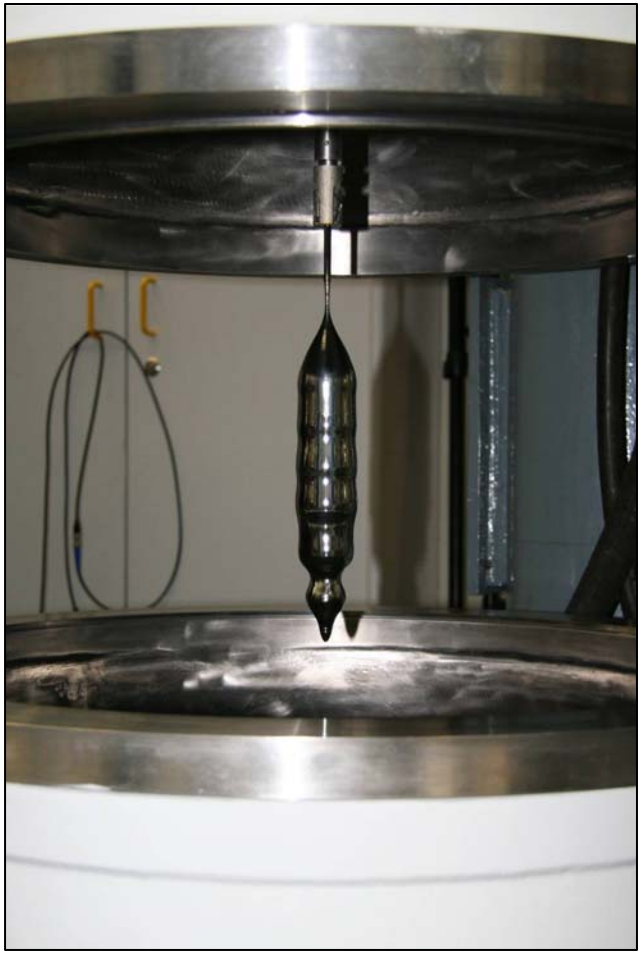
37,5 kg of enriched 76Ge have been shipped to Munich and are now stored underground

Phase II detector production:

Germanium dioxide reduced to metal bars and purified to 6N materail for Czochralski pulling

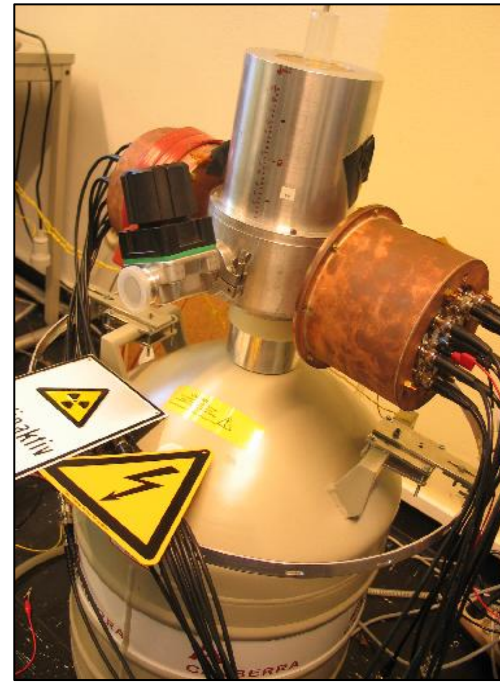


No impurities detected with ICPMS measurements



First Germanium crystal pulled with dedicated Czochralski puller at IKZ in Berlin

Phase II: Detector development



I. Abt. et al, NIM A 577(2007)574

Novel low mass contacting scheme with Cu on Kapton.

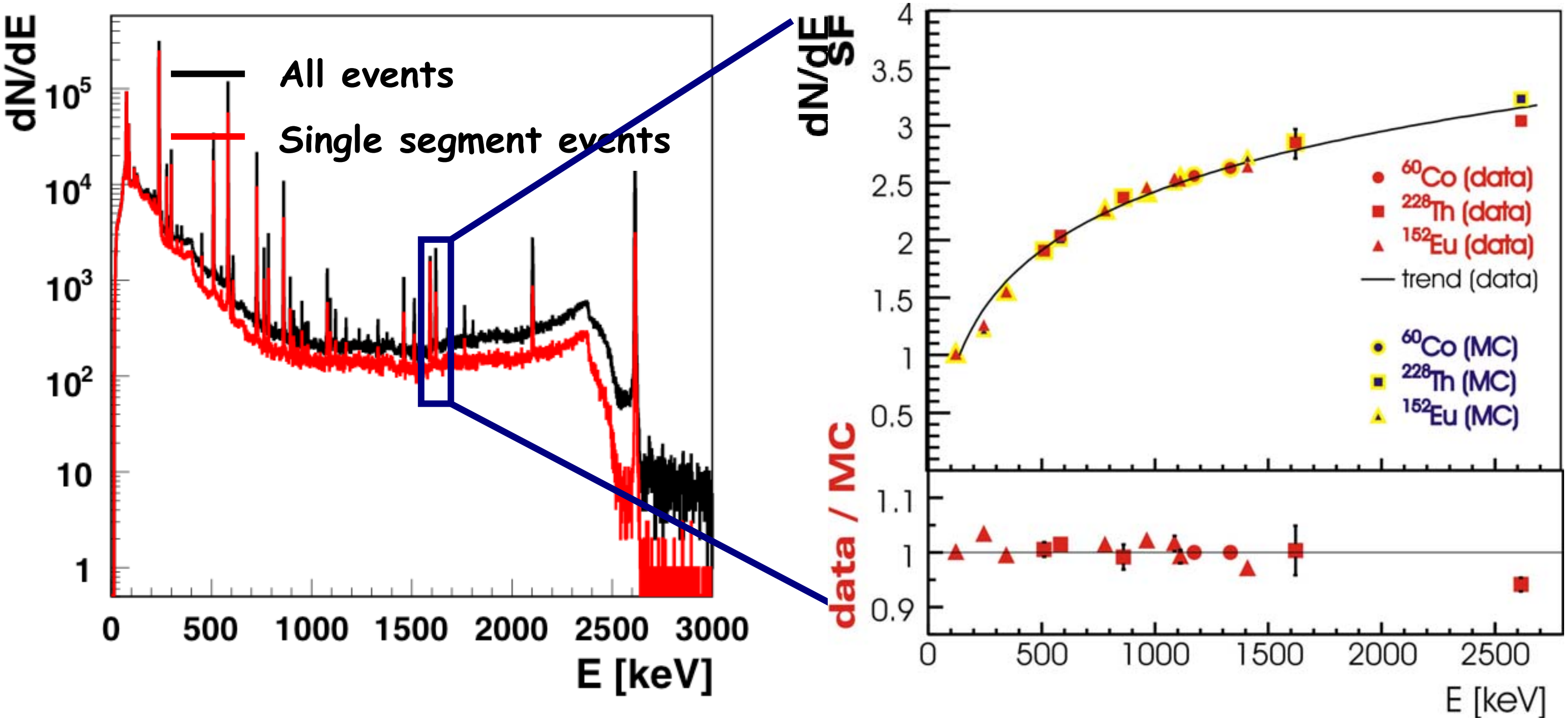
Material balance:

31g Cu,
7g Teflon,
2.5 g Kapton cable

18-fold segmented prototype detector works fine. New contacting scheme verified in conventional surrounding:

Good energy resolution for core and 18 all segments:
3 keV @ 1.3 MeV --> 0.2%

Phase II: Results with prototype detectors:

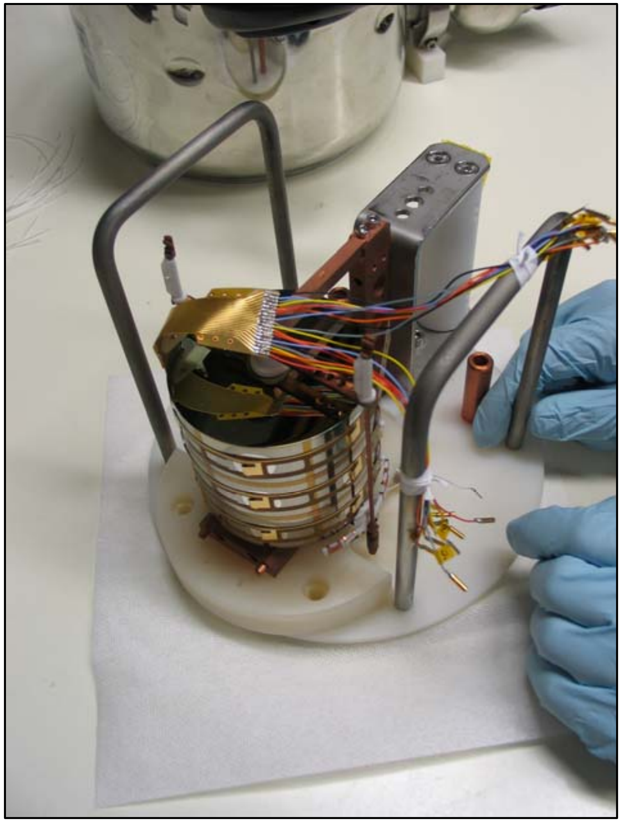


Compton Background recognition works as expected:

Photon Peak is reduced in single segment spectrum, whereas Double Escape Peak remains

Suppression factors (SF) as expected from MC

Phase II: Results with prototype detectors:



Contacting technique works in cryogenic liquid: First spectra taken with core and all 18 segments. Good energy resolution without optimization.

Arrival of the GERDA Cryostat at LNGS:

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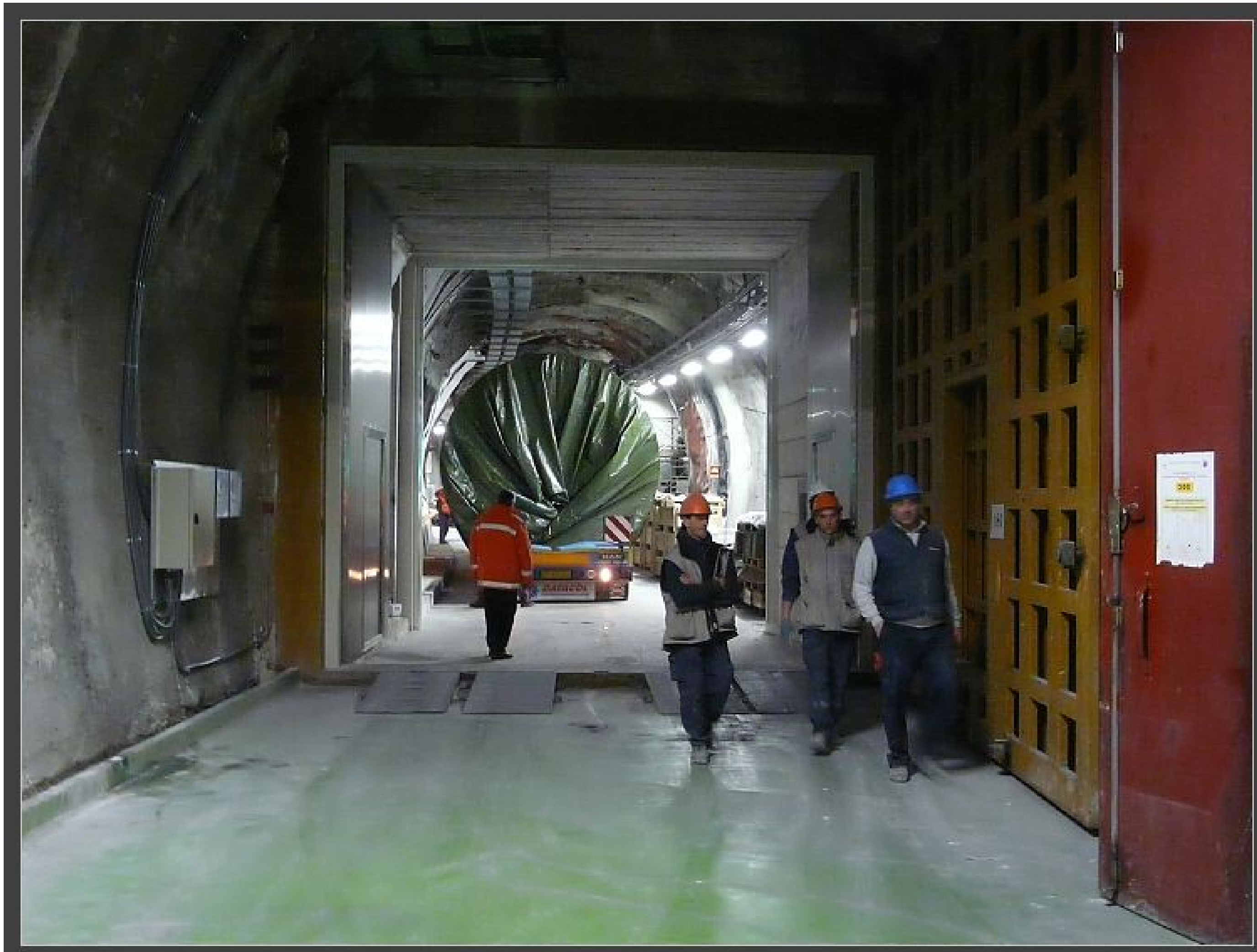

6th of March 2008

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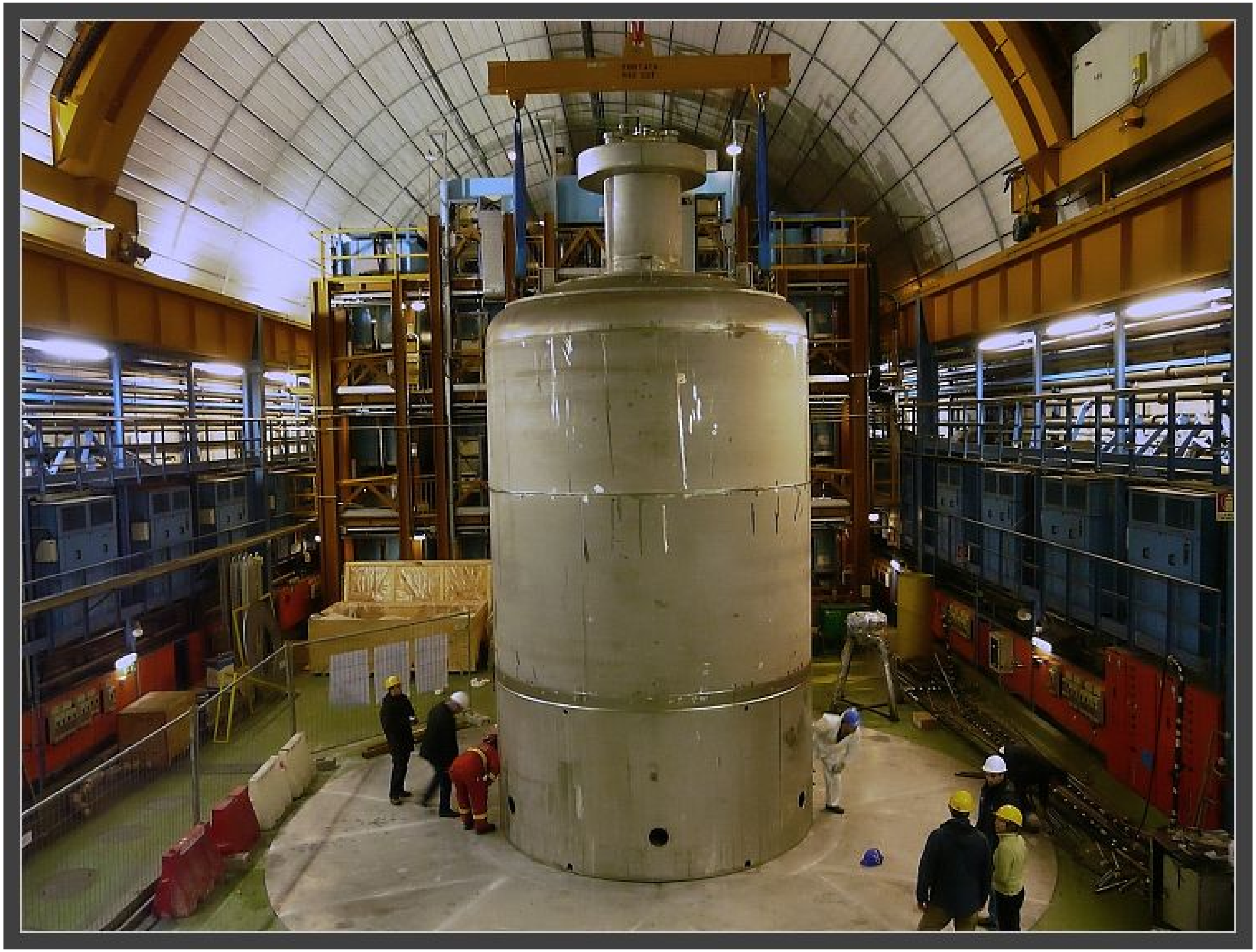


6th of March 2008

Installation of Water Tank ongoing

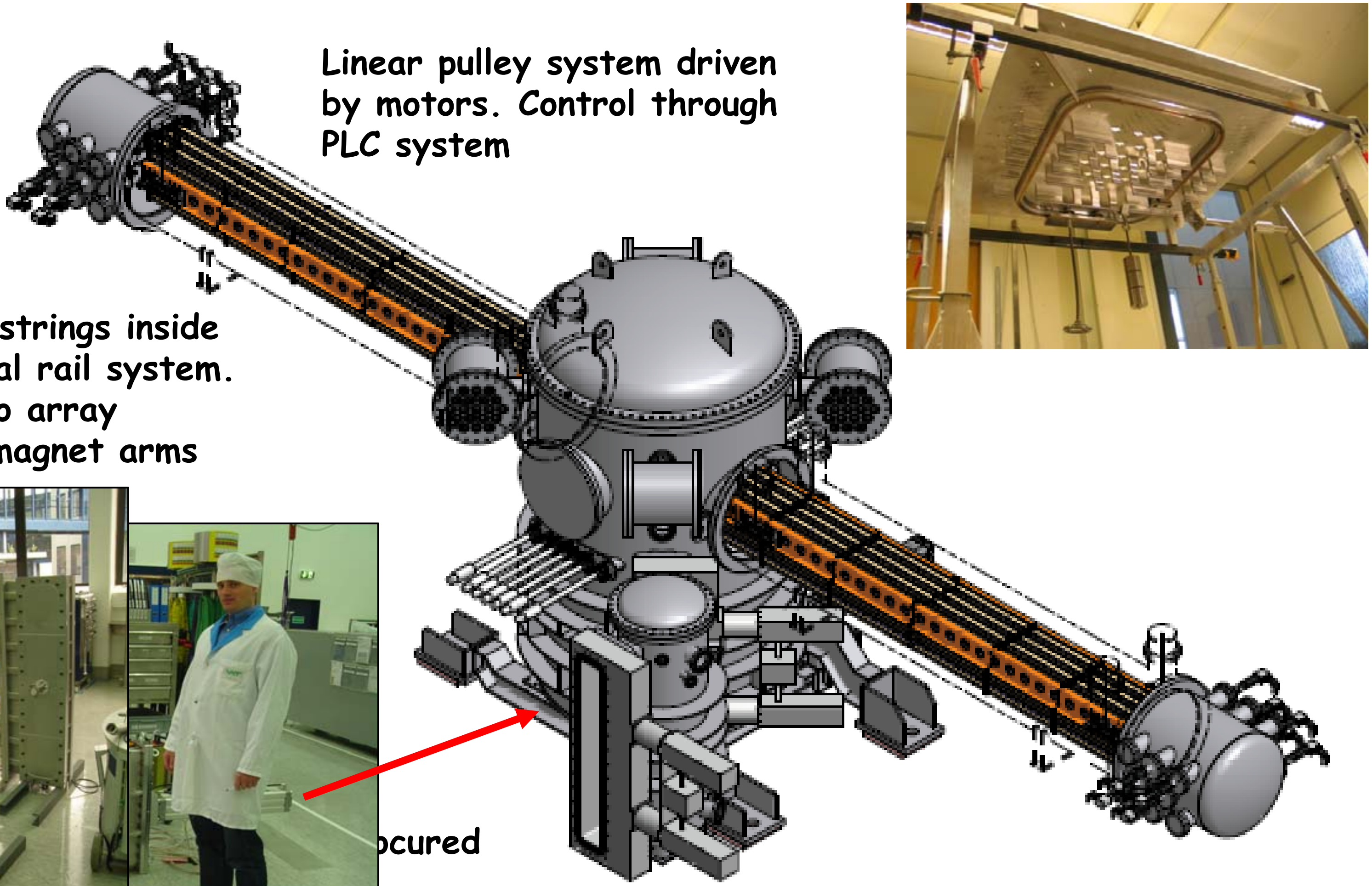
8th of May 2008

Superstructure being preassembled:

8th of May 2008

Lock Structure

Linear pulley system driven by motors. Control through PLC system

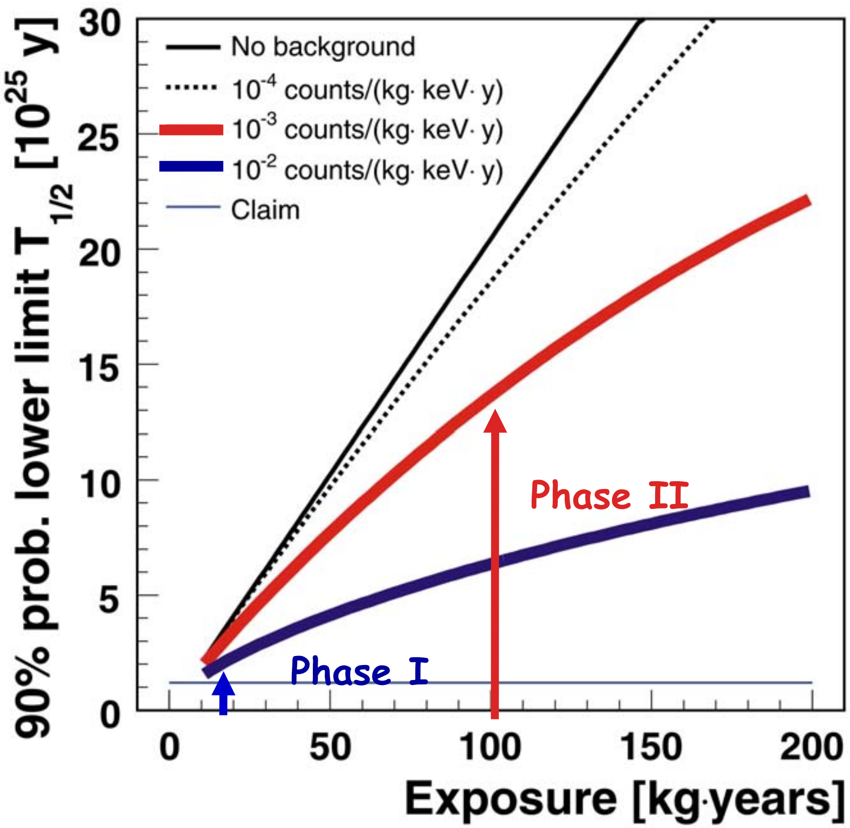


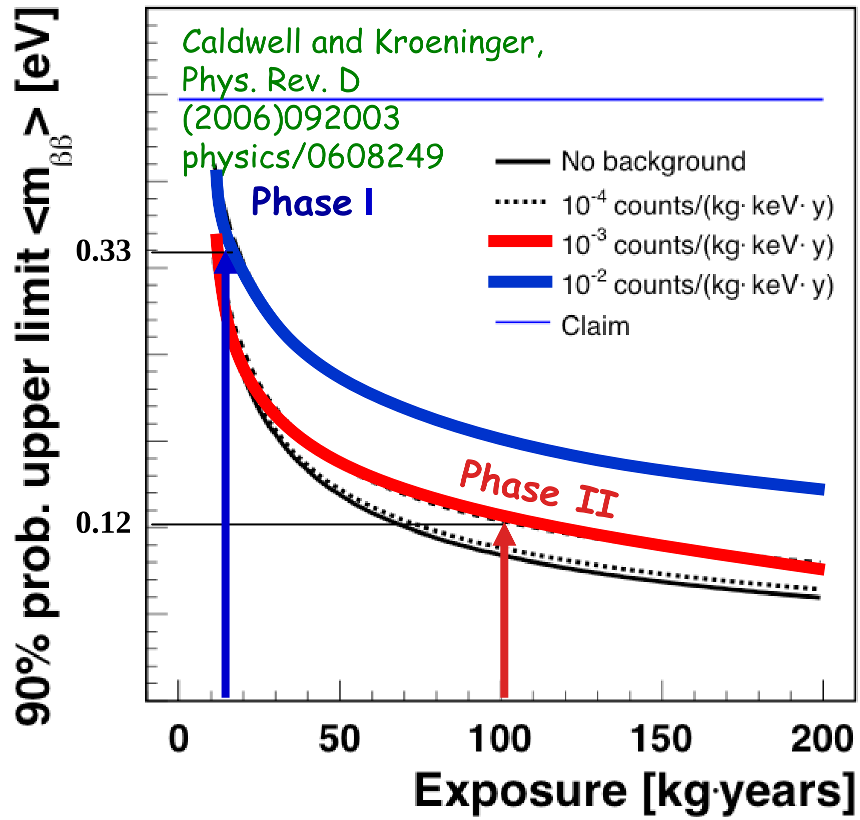
Positioning of strings inside lock by internal rail system. Push strings to array position with magnet arms

ocured

Detector string enter through outer lock

Aimed GERDA sensitivity:

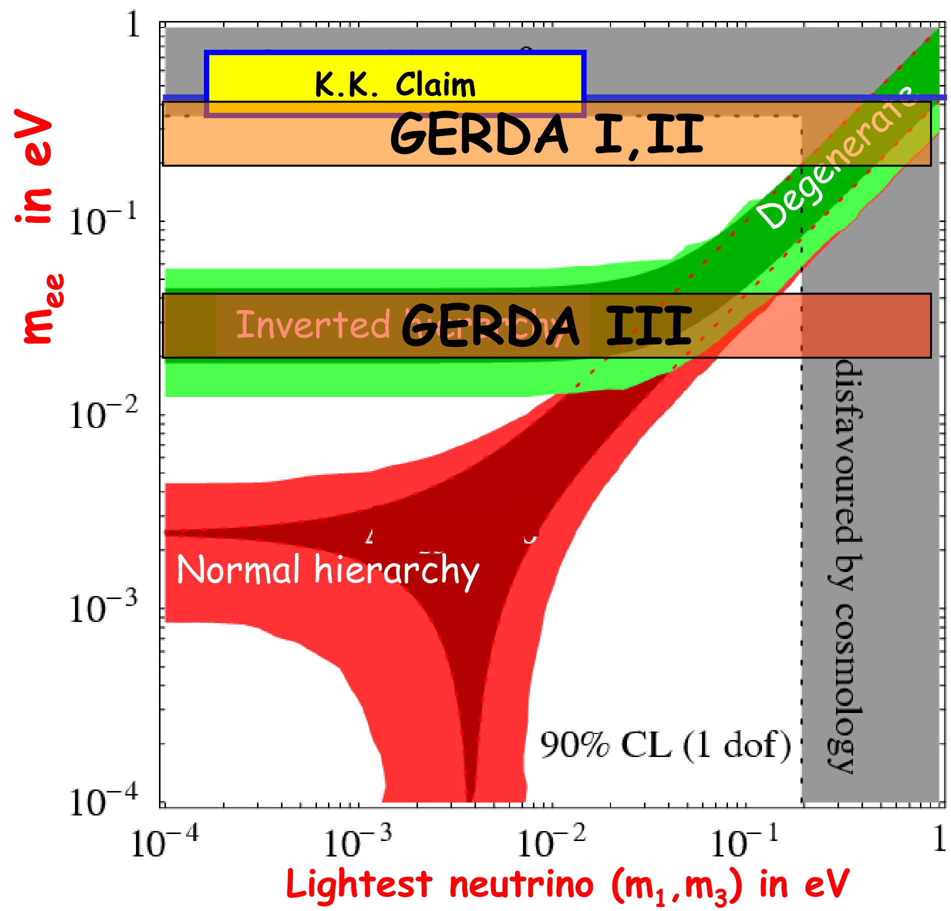


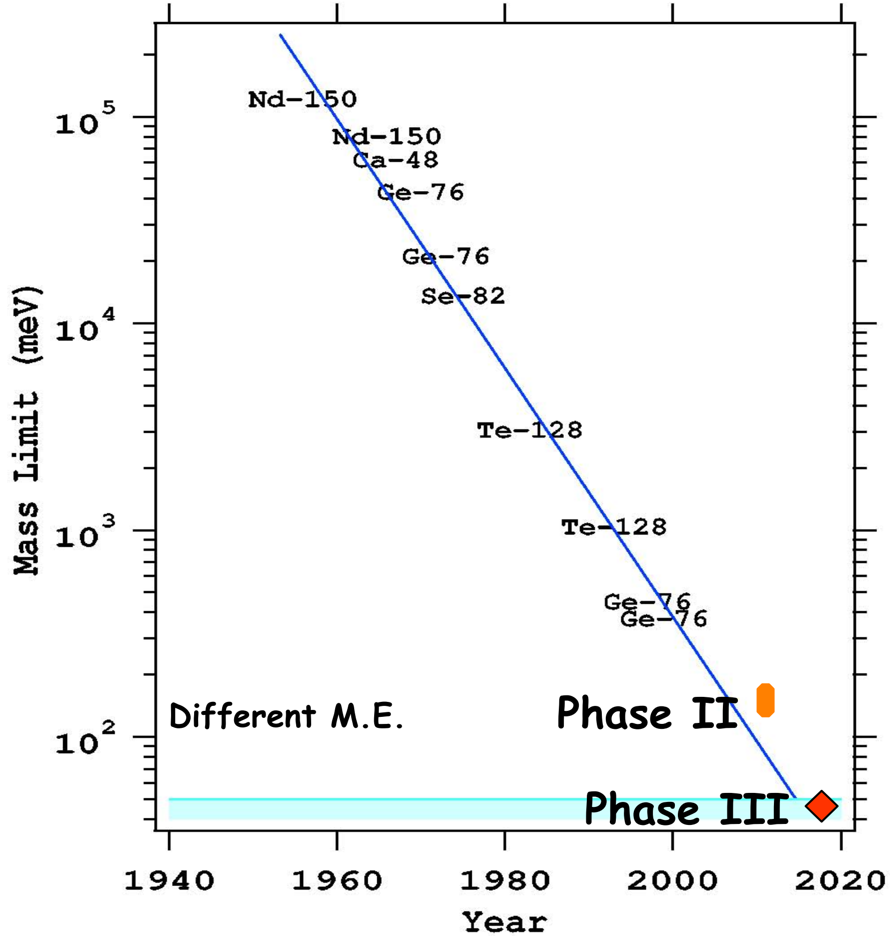


Phase I: ~7 signal events and ~2 background events are expected after ~1 year of measuring time in a 10 *keV* signal window around 2040 *keV* in case of confirmation of claim.

GERDA sensitivity

1. We will confirm or rule out the Klapdor-Kleingrothaus et al. claim (Phase I)
2. If not confirmed and background reduction to the level 10^{-3}/(kg yr keV) demonstrated (Phase II), go for
3. Phase III (ca. 1 ton, 20 meV level) for distinction of hierarchies!





Conclusions:

- Measurement of 0νββ has very high priority.
- HPGe experiments have very high discovery potential.
- The GERDA experiment will use new technique of using naked HPGe detectors in cryo liquid.
- Sensitivity of GERDA Phase I will be sufficient to confirm or refute claim.
- GERDA phase II will further improve limits in case of a negative result and prove low background capability for ton scale experiment
- GERDA infrastructure is coming together.
- World wide effort needed to probe $<m_{ee}>$ down to 10 *meV*.

Estimated Background for Phase II:

Part	Comp.	Contrib. [10^{-4} Cts /(kg keV y)]	Assumption	Means of reduction
Detector	^{68}Ge	4.3	2y underground	Wait, produce underground
	^{60}Co	0.3		
	Bulk	3.0	Upper limit	
	Surf.	3.5	Upper limit	PSA
Holder	Cu	1.4		Use e-formed Cu
	Teflon	0.3		
Cu+Kapton Cabling		1.5	2mBq/kg Kapton	PEN cables
Electronics		3.5	10g 100mBq/kg	ASICs, outside
Liquid argon		1.0		
Infrastructure		0.2		
Muons and neutrons		1.0		Go deeper
Total		21.0		R & D