Status of the GERDA experiment

Béla Majorovits for the GERDA collaboration

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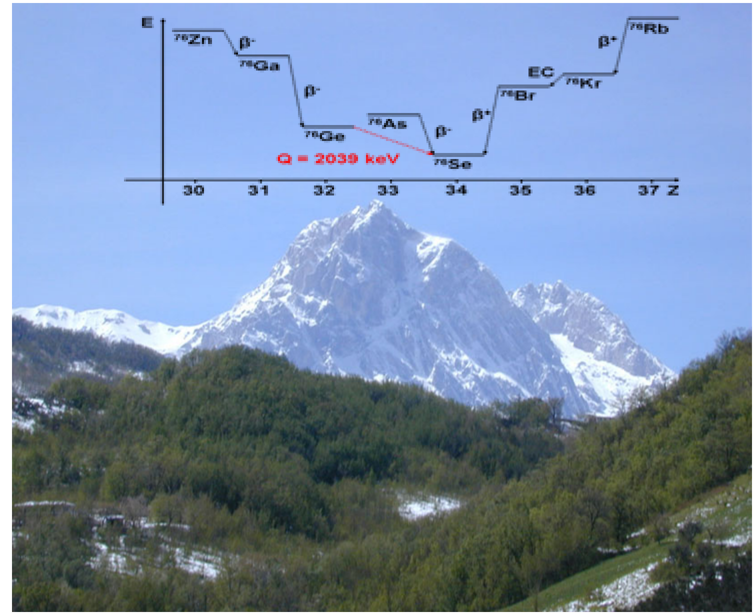


- Neutrinos: a piece of the cake
- Neutrinoless Double Beta Decay
- 0vbb with HPGe detectors
- The principle of the GERDA experiment
- Present status

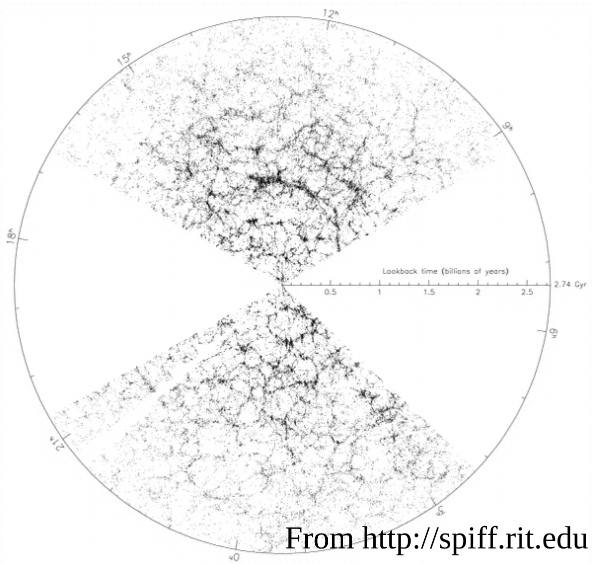
Neutrinos in the Universe

•Relic from Big Bang:	100 cm^{-3}
•Neutrinos from the sun at earth:	$6 \bullet 10^{10}$ $cm^{-2}s^{-1}$
•Neutrinos from 1GW nuclear reactors:	$6 \bullet 10^{11}$ $cm^{-2}s^{-1}$ in 100m distance
•Supernova Neutrinos:	Up to 10^{58} emitted within 10s

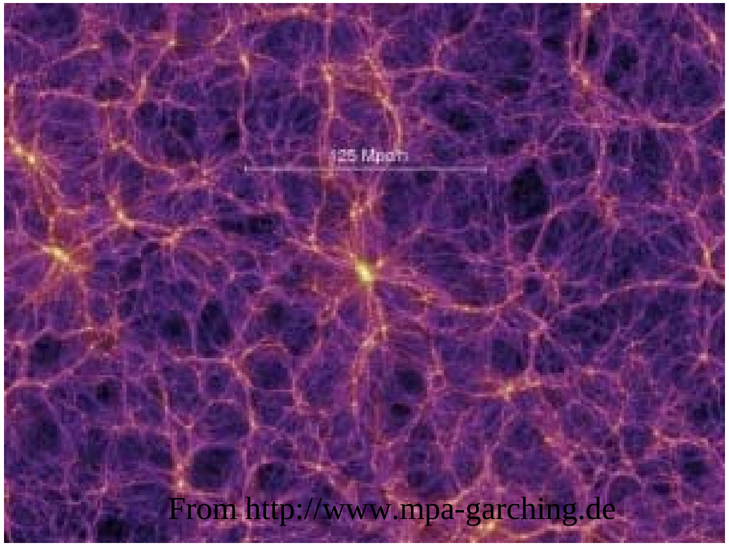
Neutrinos are nearly as abundant in our universe as photons!

→Even a small rest mass has large cosmological influence!

→Not the whole of Dark Matter, but non negligible contribution



From http://spiff.rit.edu



From http://www.mpa-garching.de

Neutrino Mass Hierarchy

Neutrino-oscillation experiments have taught us:
Neutrinos must have a non vanishing rest mass!

We only have information on the squared mass difference between the eigenstates

→ Absolute mass scale still unknown

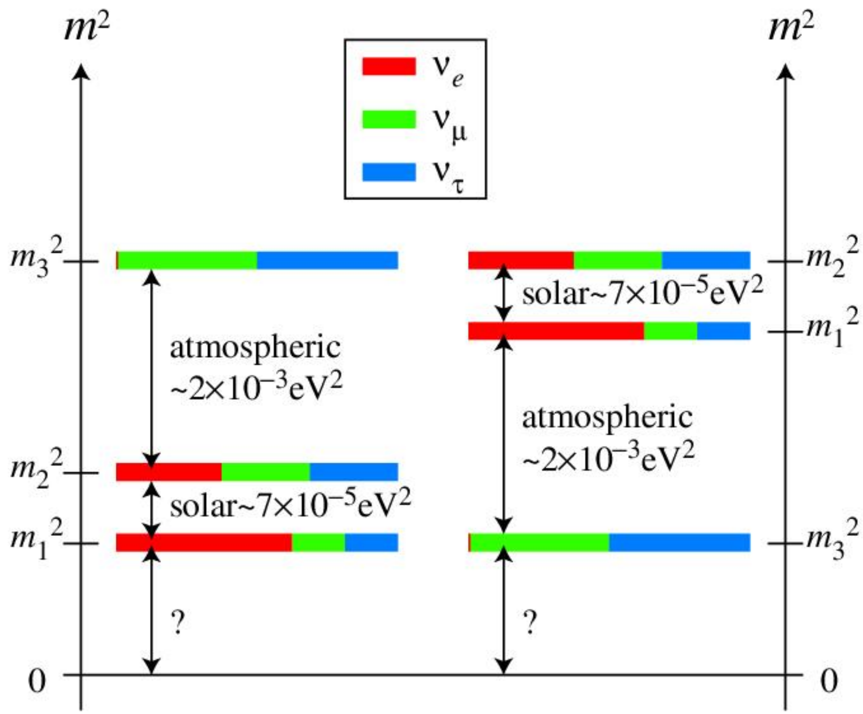
We do not know the sign of Δm_{32}

→ Mass hierarchy is still unknown

Are Neutrinos their own Antiparticles, ie Majorana particles?

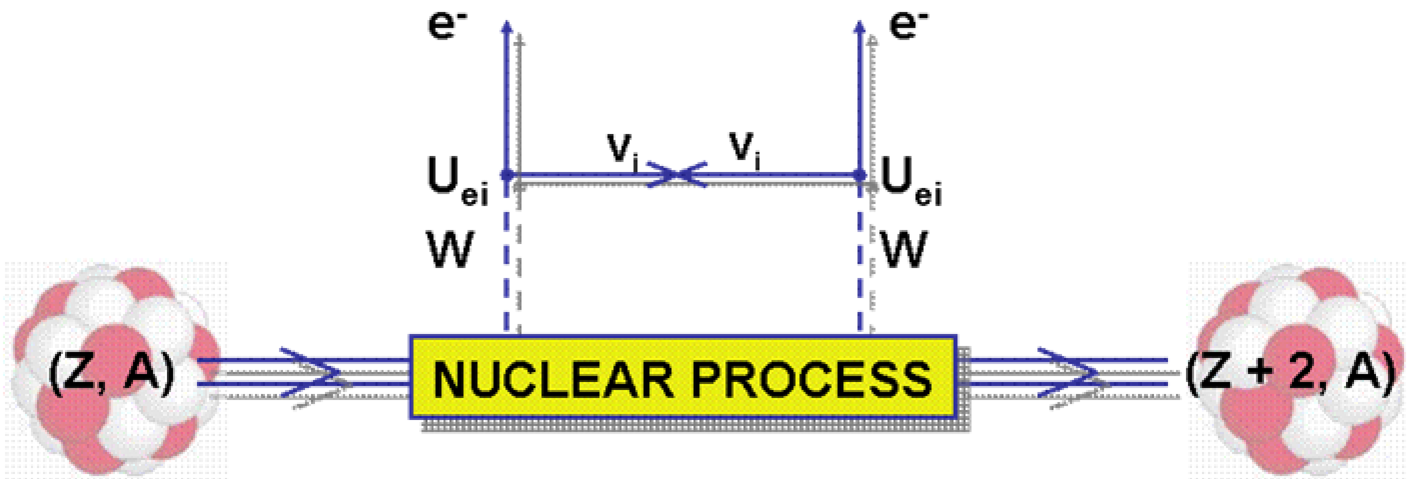
→ Nature of the Neutrinos still unknow

Normal hierarchy $\Delta m_{32} > 0$ eV | Inverted hierarchy $\Delta m_{32} < 0$ eV



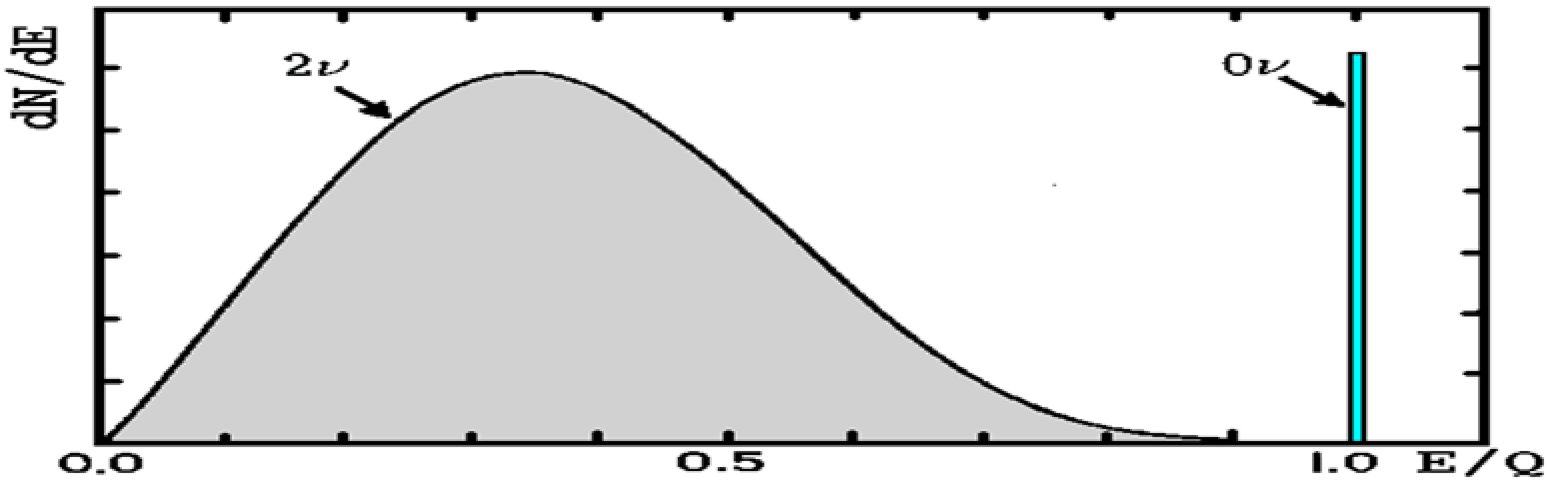
Neutrinoless Double Beta-Decay

- Double Beta-Decay is an allowed 2nd order weak process
- It's half life is of the order (the age of the universe)^2 ~10^{20} years
- If Neutrinos are massive and their own anti-particles, ie Majorana particles, the process could occur without the emission of Neutrinos



Neutrinoless Double Beta-Decay

- Double Beta-Decay is an allowed 2nd order weak process
- It's half life is of the order 10^{10} times the age of the universe
- If Neutrinos are massive and their own anti-particles, ie Majorana particles, the process could occur without the emission of Neutrinos



Signature: Sharp peak at Q-value of the decay

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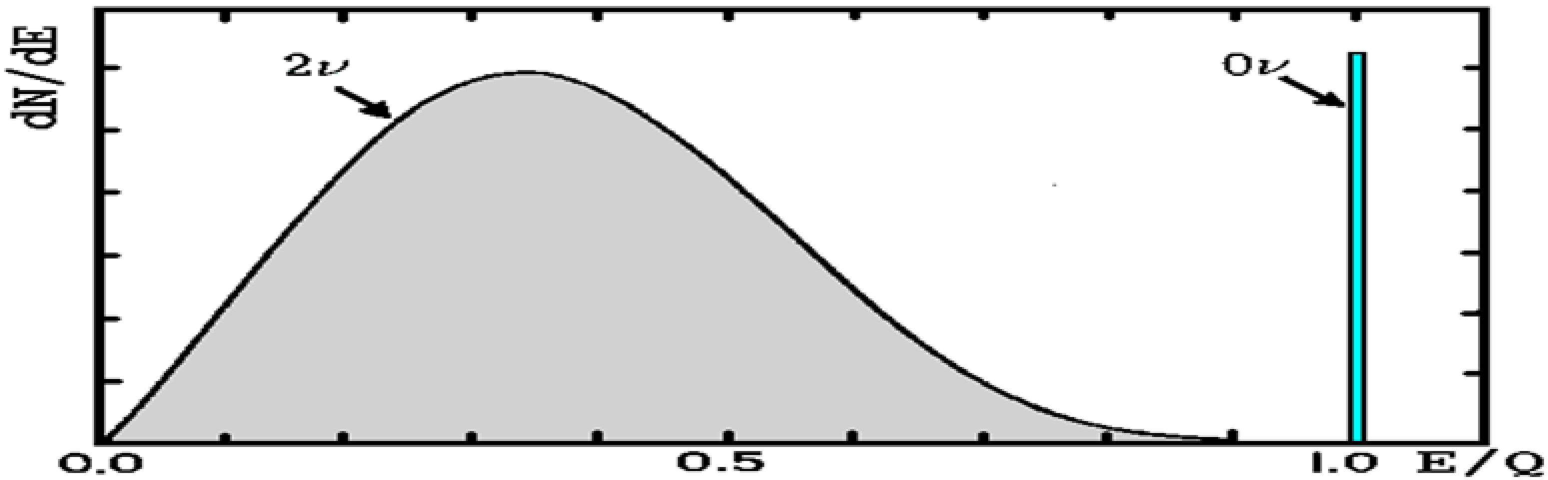
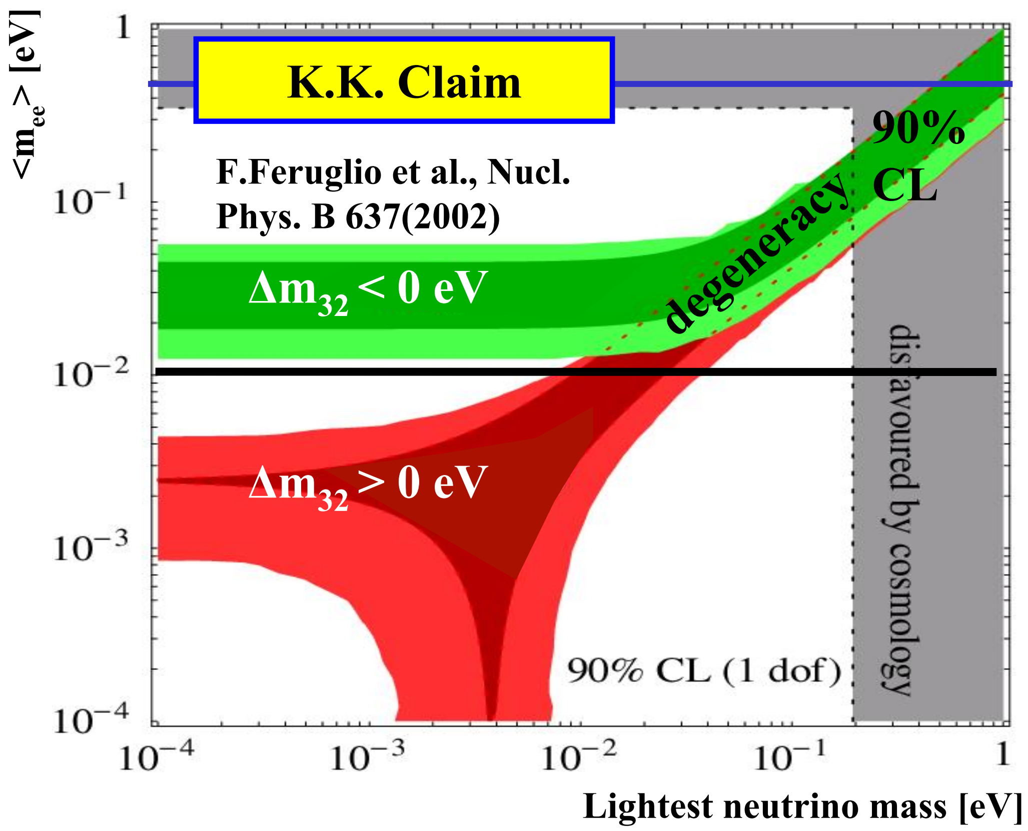


$$1/\tau = G(Q,Z)\,|M_{nucl}|^2\,\langle m_{ee}\rangle^2$$

Neutrinoless Double Beta-Decay and the Mass Hierarchy

In order to discriminate between normal and inverted hierarchy, we need an experiment with sensitivity down to 10 meV !



Sensitivity of 0νββ-experiments

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

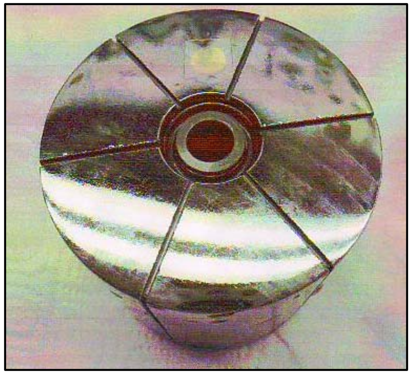
The parameter measured in neutrinoless double beta decay experiments is its half-life.

$$T_{1/2} \propto a\,\varepsilon \sqrt{\frac{m\,t}{b\,\delta E}} \cdot M_{nucl}$$

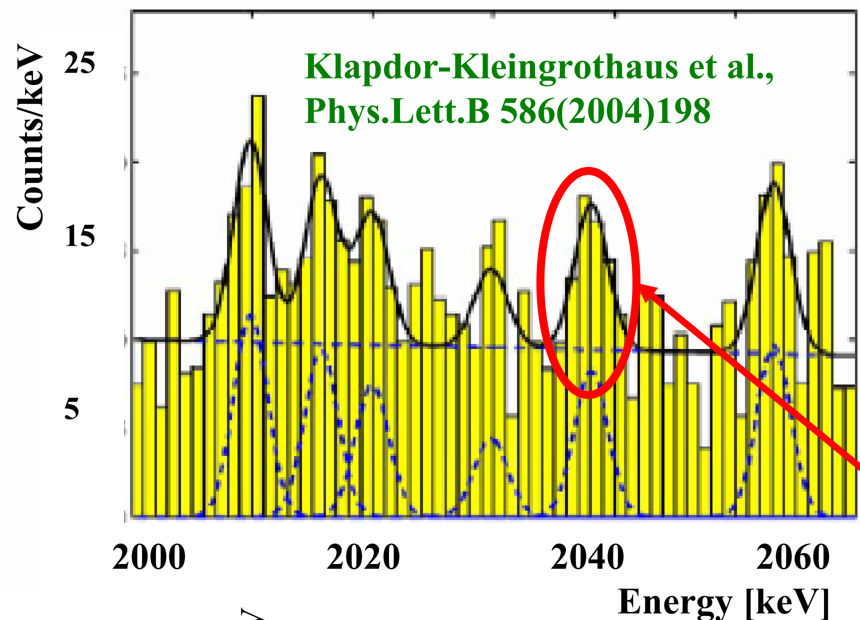
m	active target mass of the experiment	Increase target mass
b	background rate of the experiment	Minimize and select material
a	enrichment of isotope under consideration (< 1.0)	Use isotope with high natural abundance or enrich material
ε	signal detection efficiency (<1.0)	Source =! Detector
δE	Energy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

High Purity Germanium detectors:

Very good energy resolution	Background due to 2νββ 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
Low Q-value: 2.04 MeV	Background reduction!
Natural abundance of ^{76}Ge 7,44%	Enrichment necessary!



Results from HPGe experiments



Heidelberg-Moscow Experiment:

11.5 kg of enriched Ge detectors

71.7 kg yrs of data

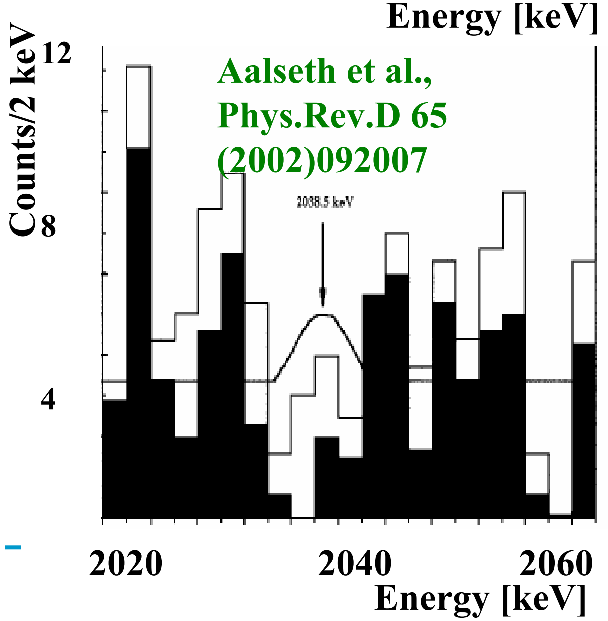
0.11 Counts/(kg keV y) around 2040 keV

→ 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.)



IGEX Experiment:

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.)

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:

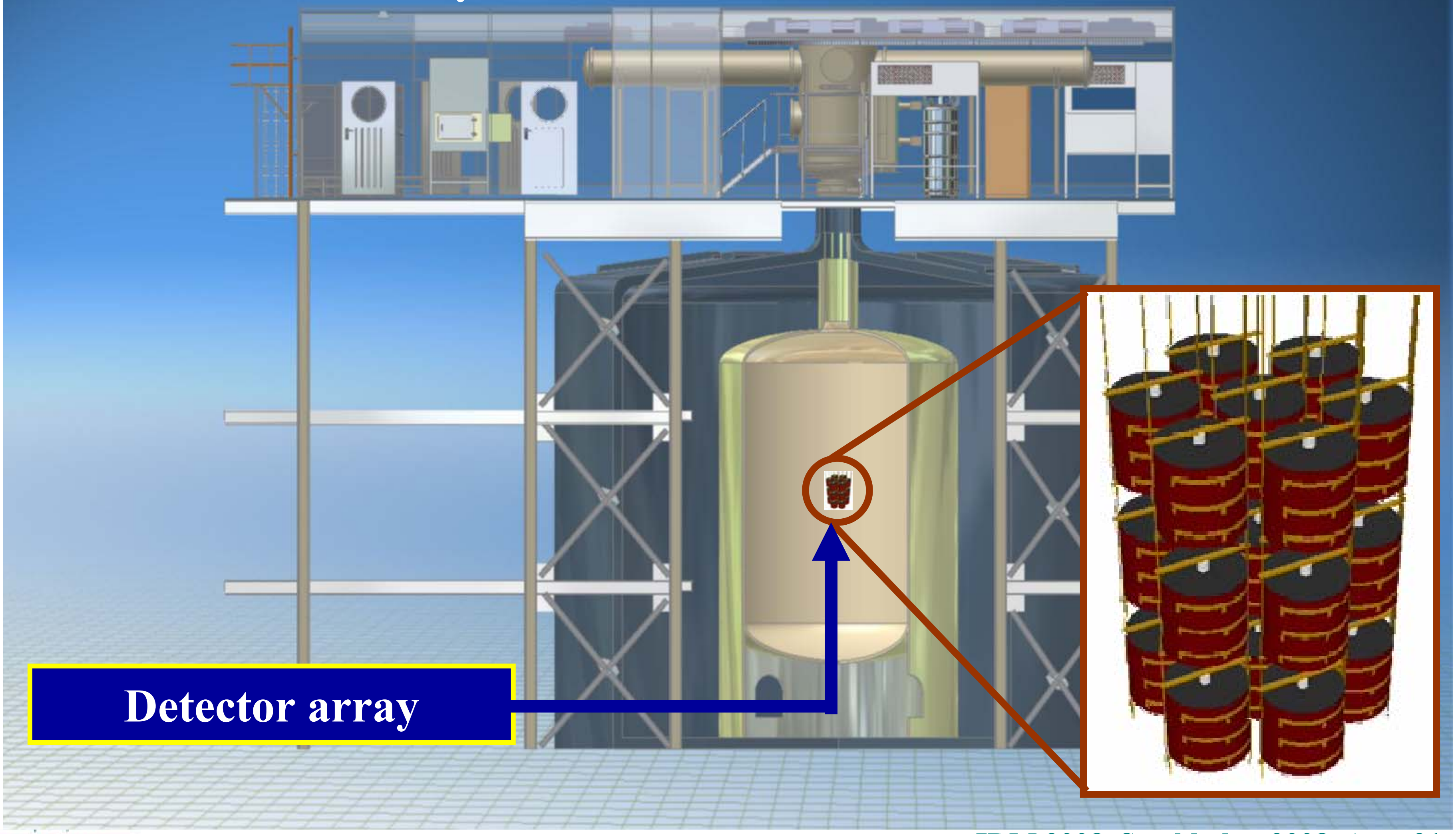
→ Radioactive background can be drastically reduced

- 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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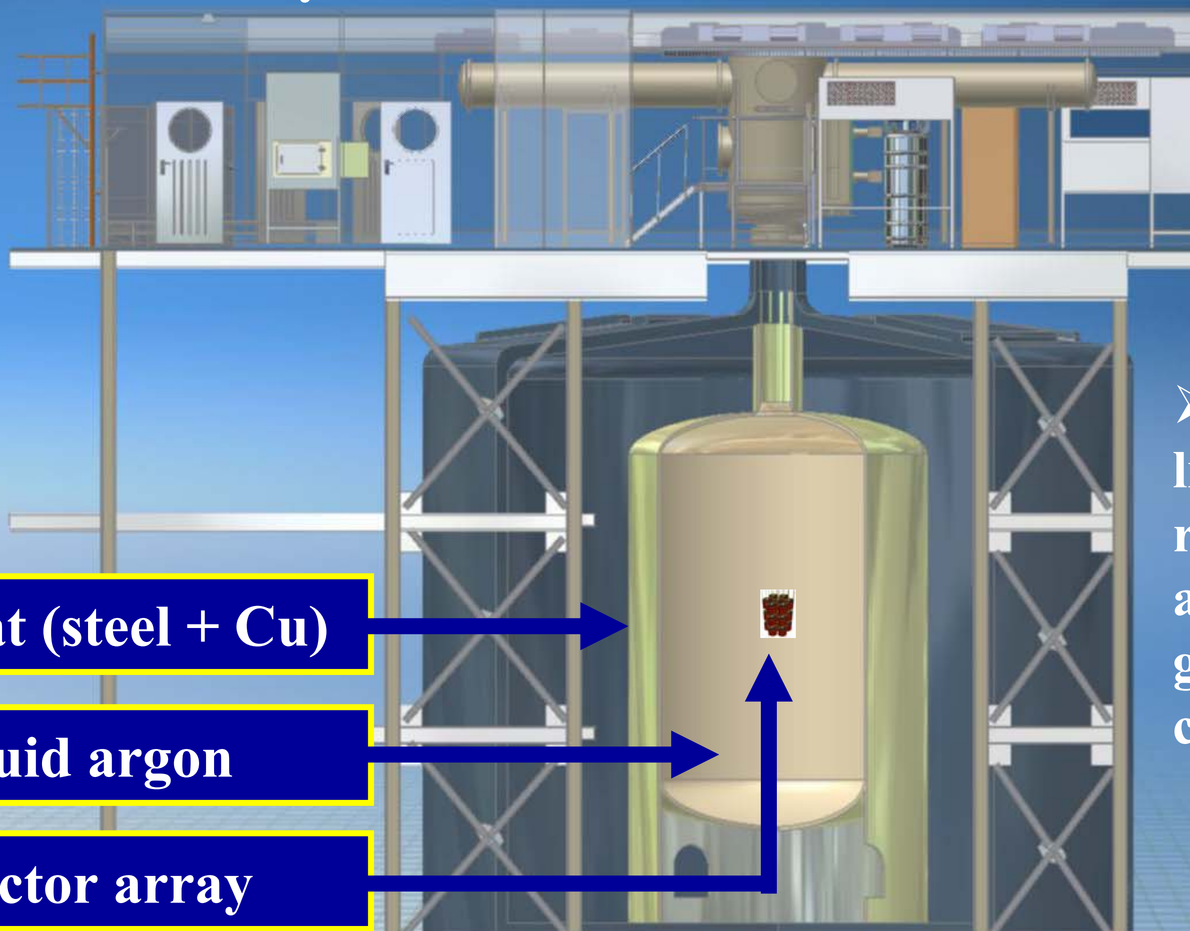
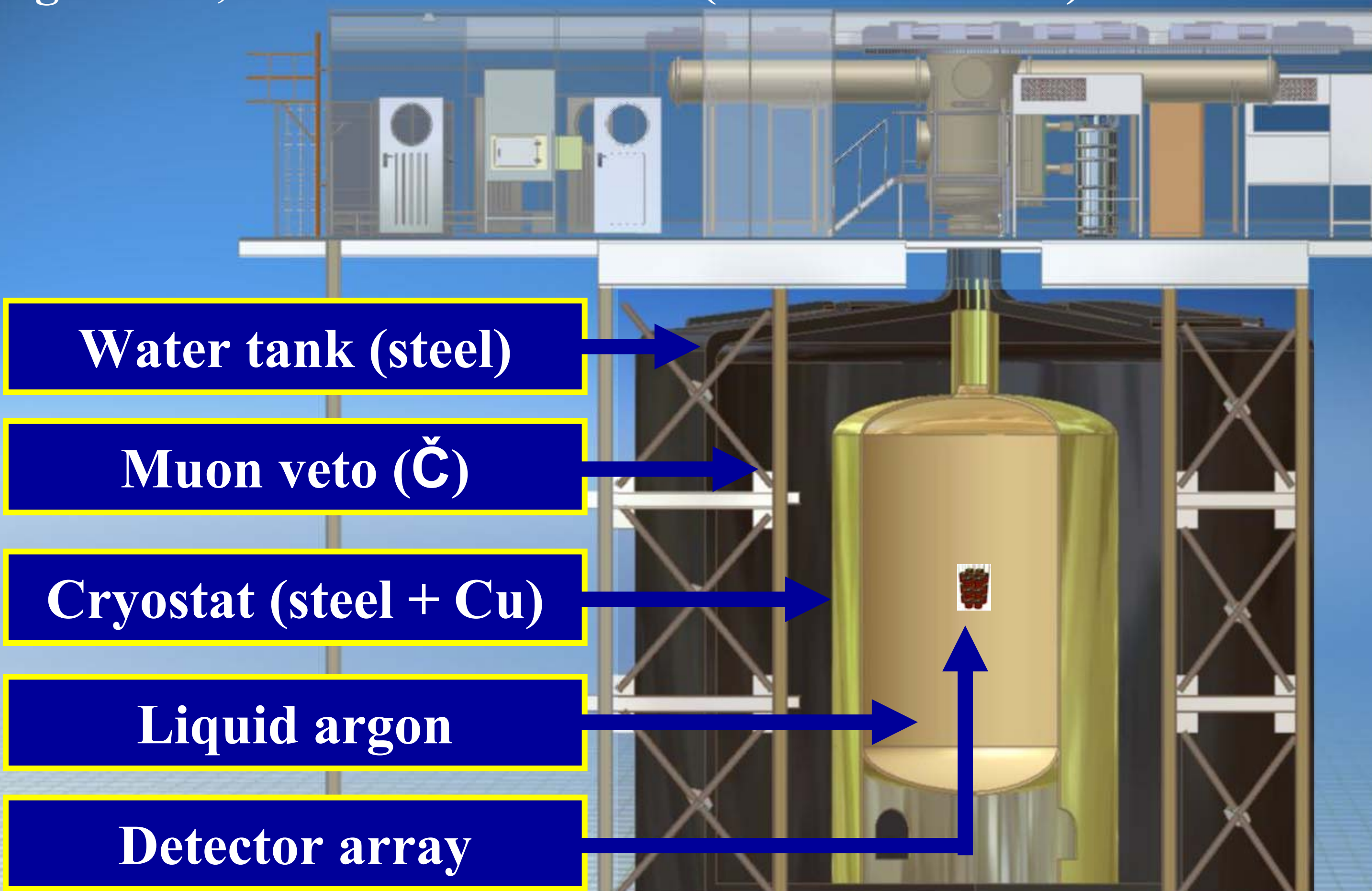


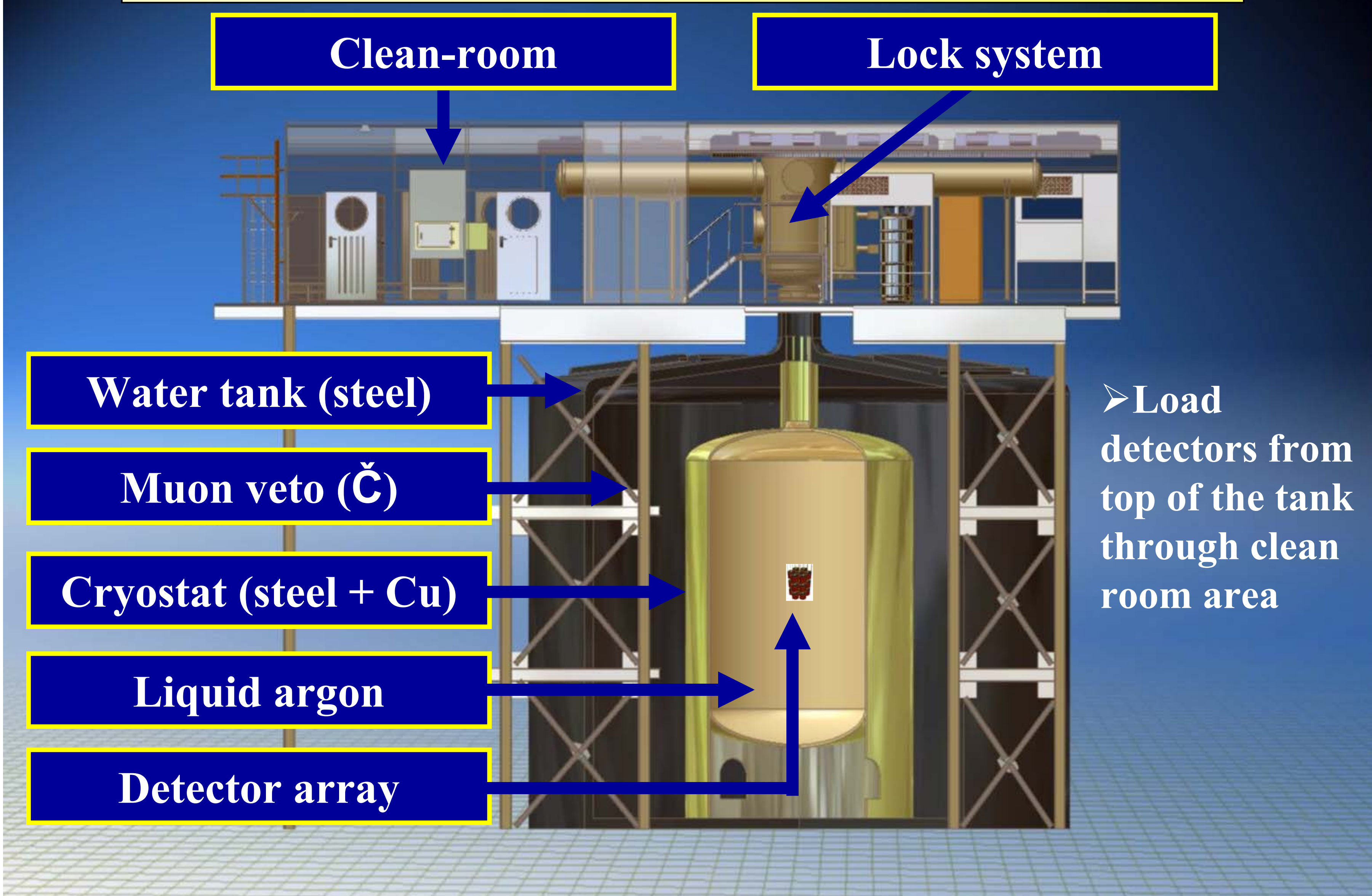
- Inner copper lining as radiation shield against gammas from cryostat

GERmanium Detector Array: GERDA

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



GERmanium Detector Array: GERDA

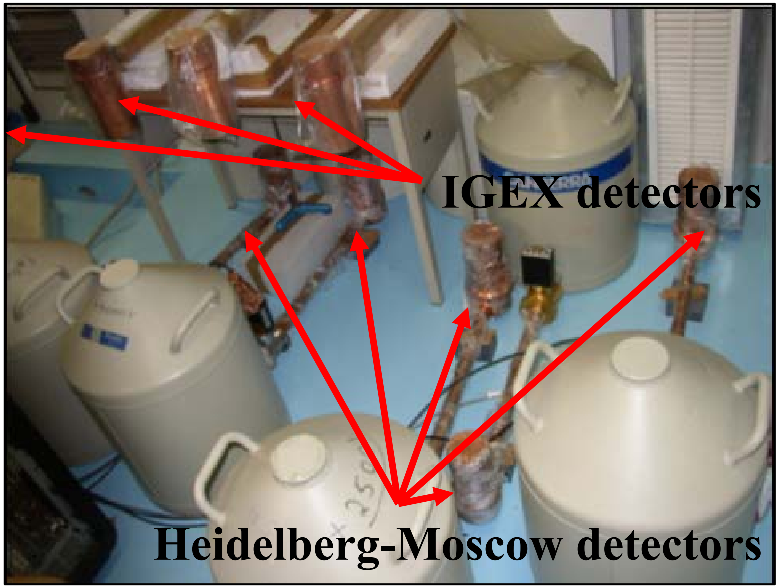


- Load detectors from top of the tank through clean room area

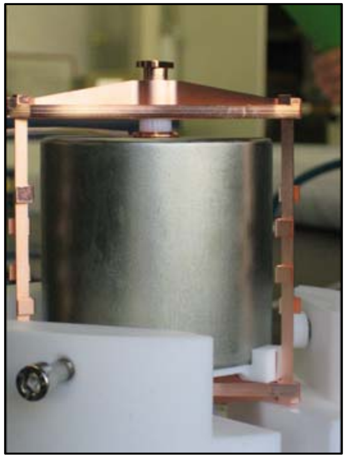
GERmanium Detector Array: GERDA

	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

Phase I Detectors:



- Acquired HdMo and IGEX detectors
- Constructed detector holder out of low level materials
- Detectors refurbished by Canberra
- All detectors back at Gran Sasso since July 2008. Only a few days of exposure at sea level
- More than one year running experience with naked HPGe detectors inside LAr.

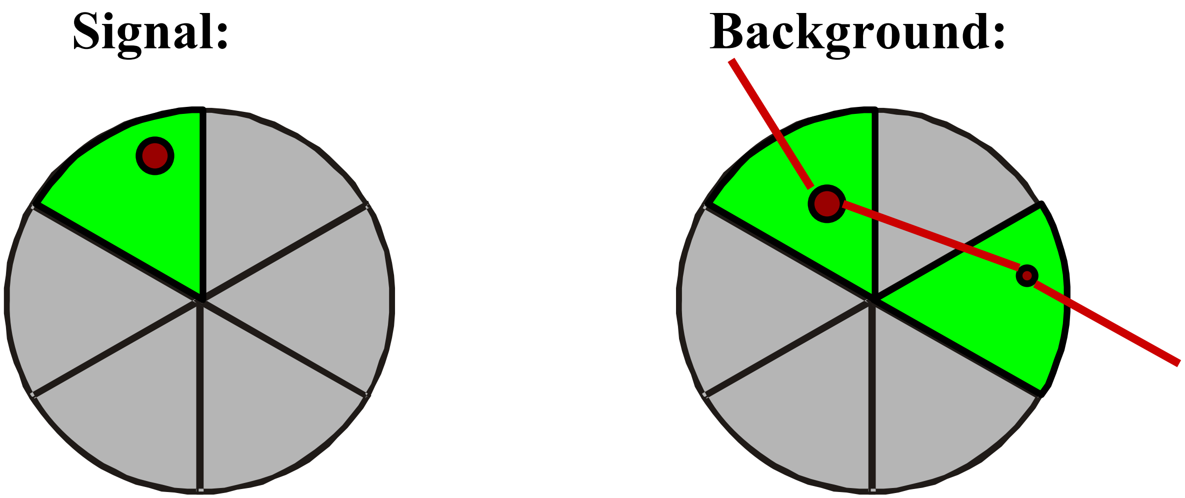


Phase II: Segmentation of detectors

Germanium detectors can be segmented

→ Multiple Compton scattered photons can be itentified as background

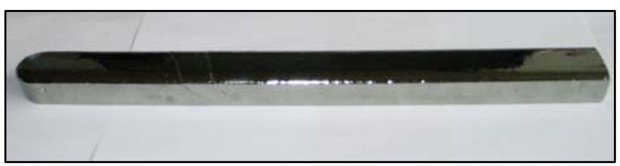
(Mean free path of a 2 MeV gamma in Ge ~ few cm)



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

Phase II detector production:

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



No impurities detected with ICPMS measurements

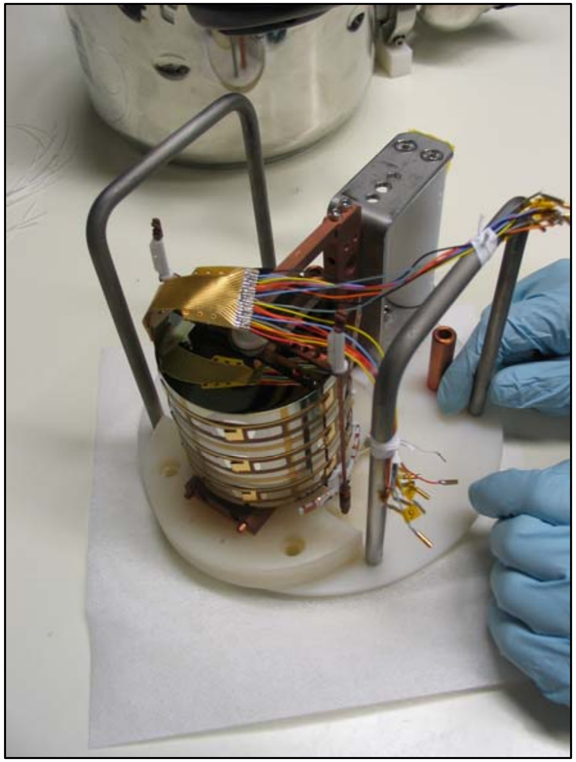
First Germanium crystals pulled with dedicated Czochralski puller at IKZ in Berlin. Charge carrier density at first try: 10^{-11} cm^{-3} to 10^{-13} cm^{-3} (requ.: 10^{-10} cm^{-3})

Phase II: Detector development

Designed and tested low mass copper holder for phase II detectors:

31g Cu,

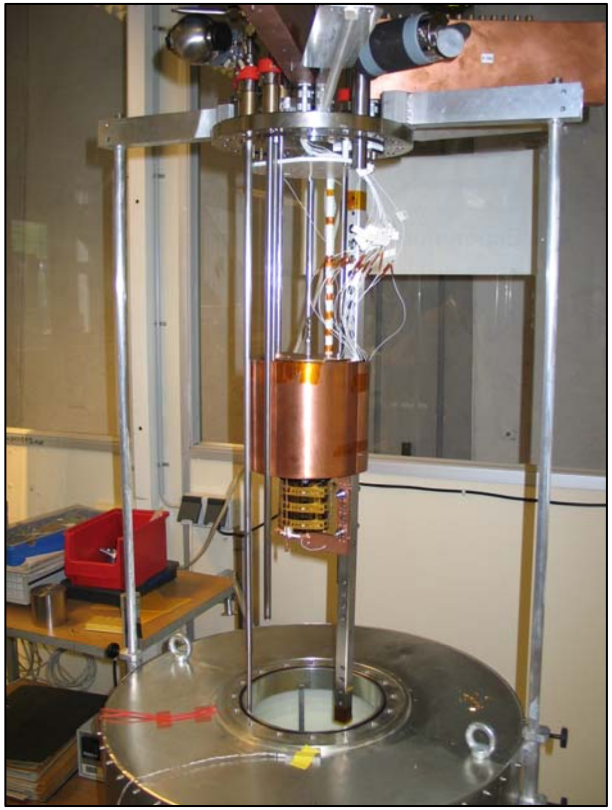
7g Teflon

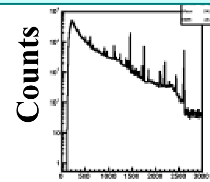


Developed low mass contacting scheme with Cu on Kapton (to be replace by electropure material).

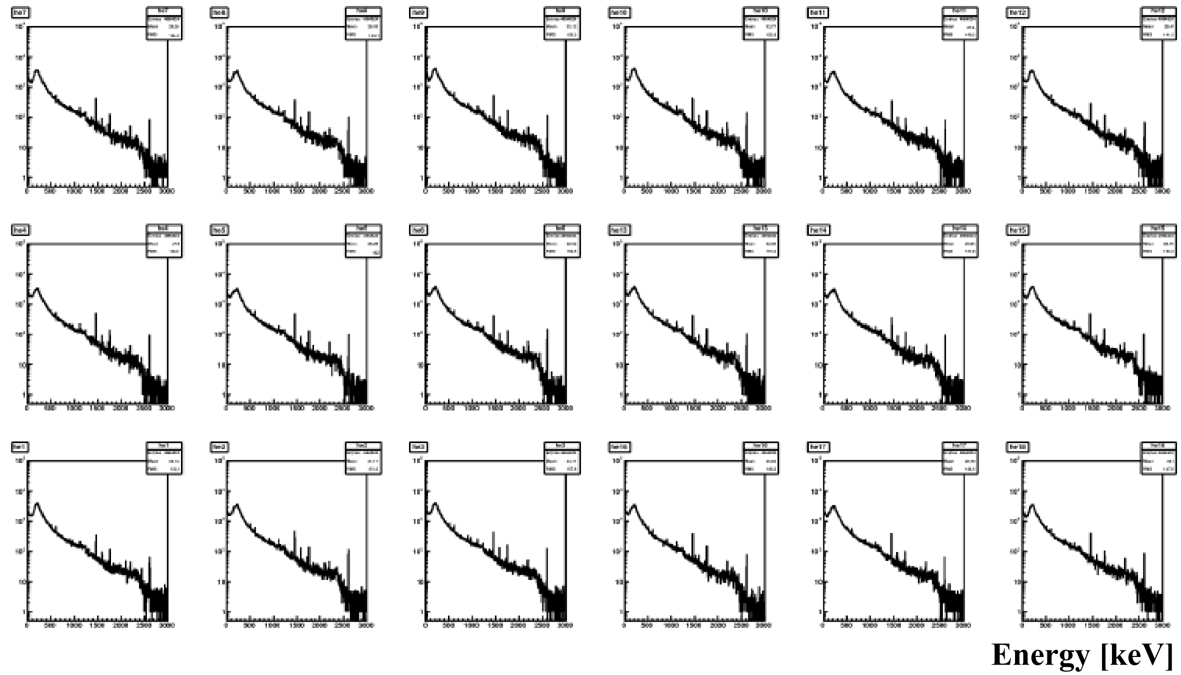
2.5 g Kapton cable (incl. Cu)

Phase II: Detector development





Core Energy spectrum: FWHM ~4 keV at 1.3MeV
Segment energy spectra: FWHM ~3 keV at 1.3 MeV



Contacting technique works in cryogenic liquid: Reasonable energy resolution Stable operation since three months in liquid nitrogen! No change in leakage current observed!

→ First successful operation of segmented n-type HPGe detector in cryoliquid!

Arrival of the GERDA Cryostat at LNGS:

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6th of March 2008

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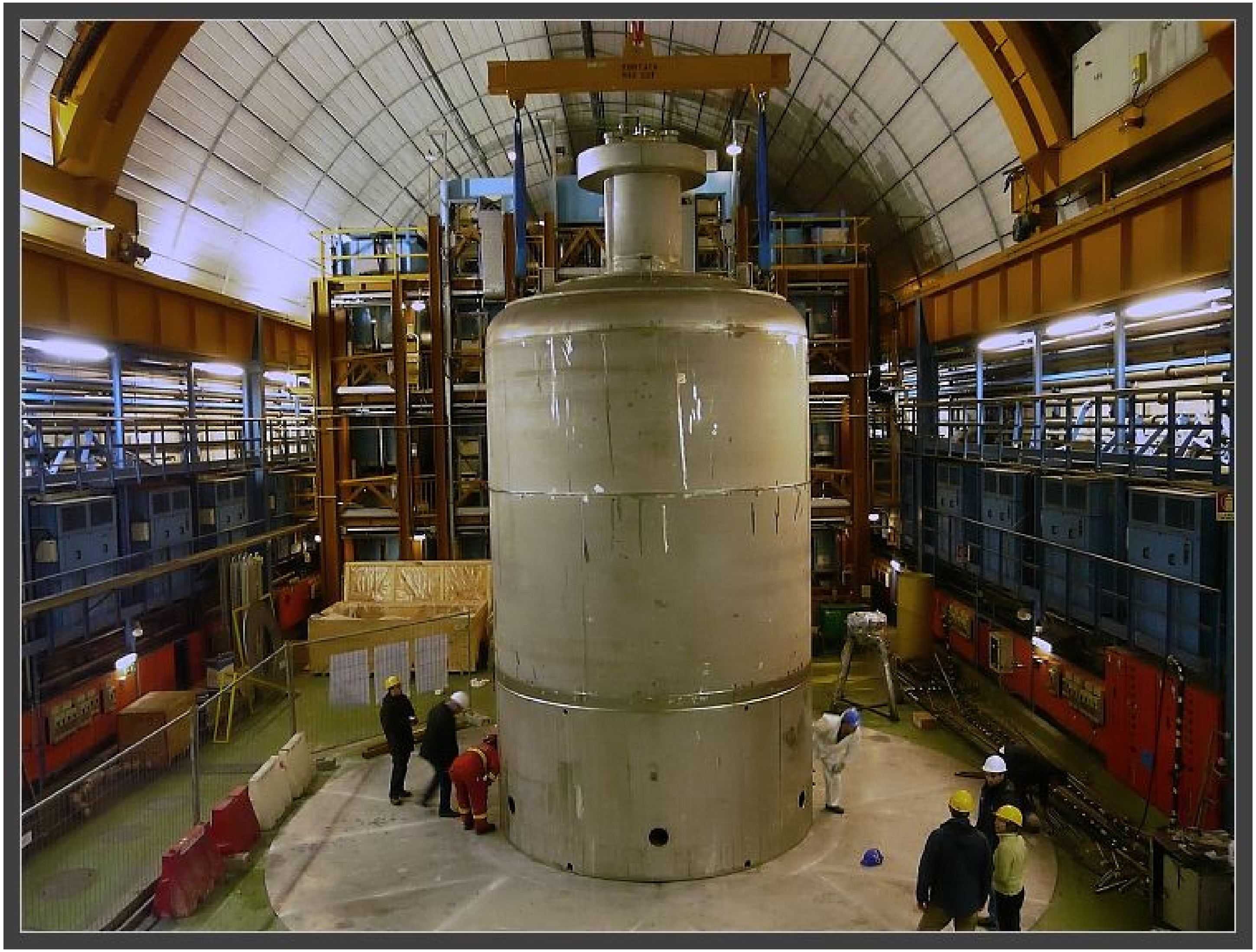


6th of March 2008

Installation of Water Tank completed

8th of May 2008

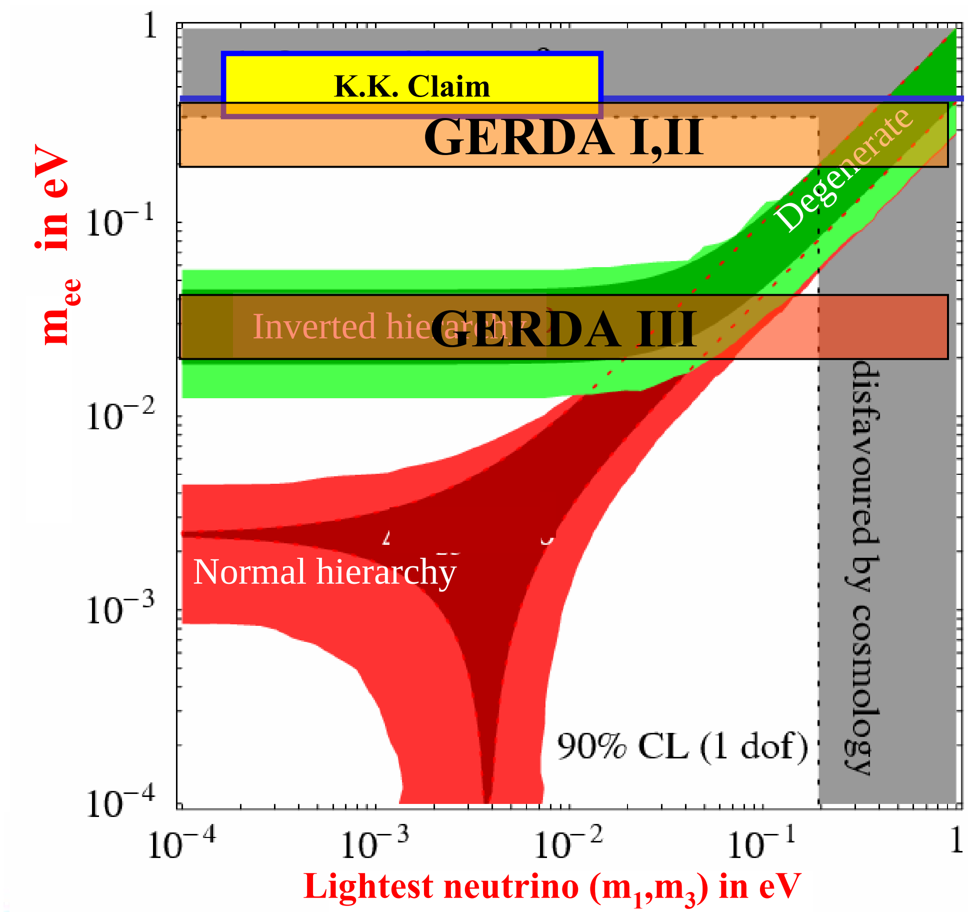
Installation of Water Tank completed

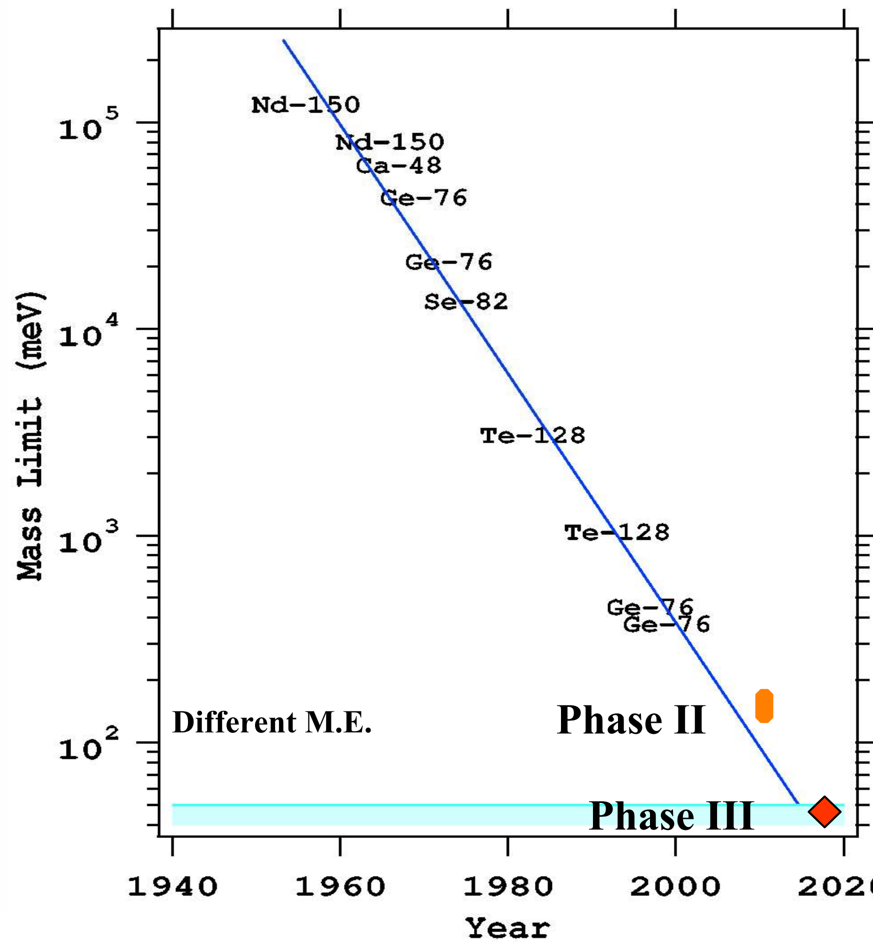
Installation of Superstructure ongoing

- **Clean Room installation will start end of this year.**
- **Lock system: Mechanical infrastructure for deployment of detectors into the cryostat scheduled for early next year.**

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, 10 meV level) for distinction of hierarchies!



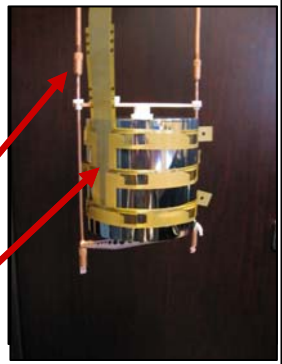


Conclusions:

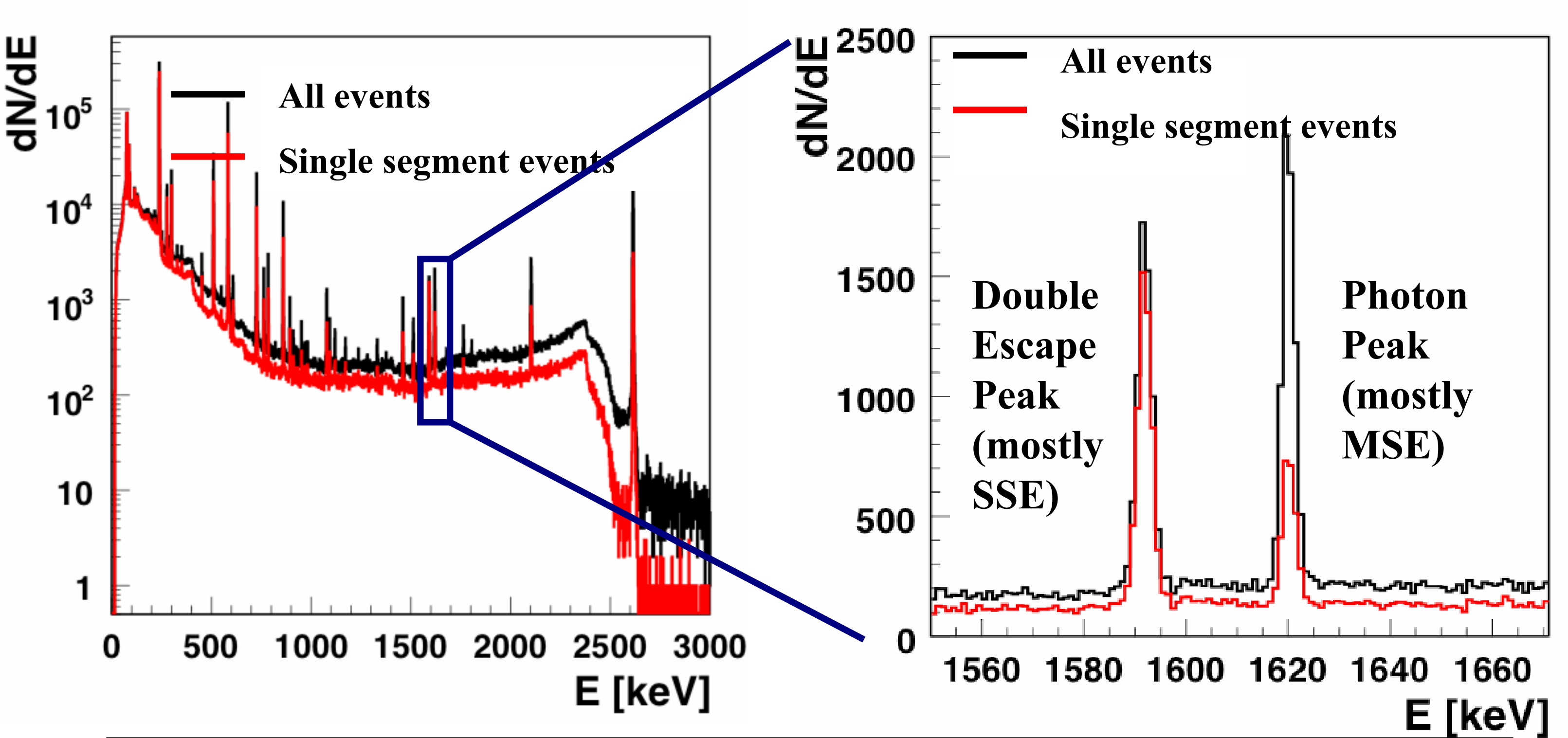
- Measurement of 0νββ has very high priority.
- HPGe experiments have very high discovery potential.
- The GERDA experiment will use new technique of using naked HPGe detectors in cryo liquid.
- Sensitivity of GERDA Phase I will be sufficient to confirm or refute claim.
- GERDA phase II will further 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
	^{60}Co	0.3		underground
	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**



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

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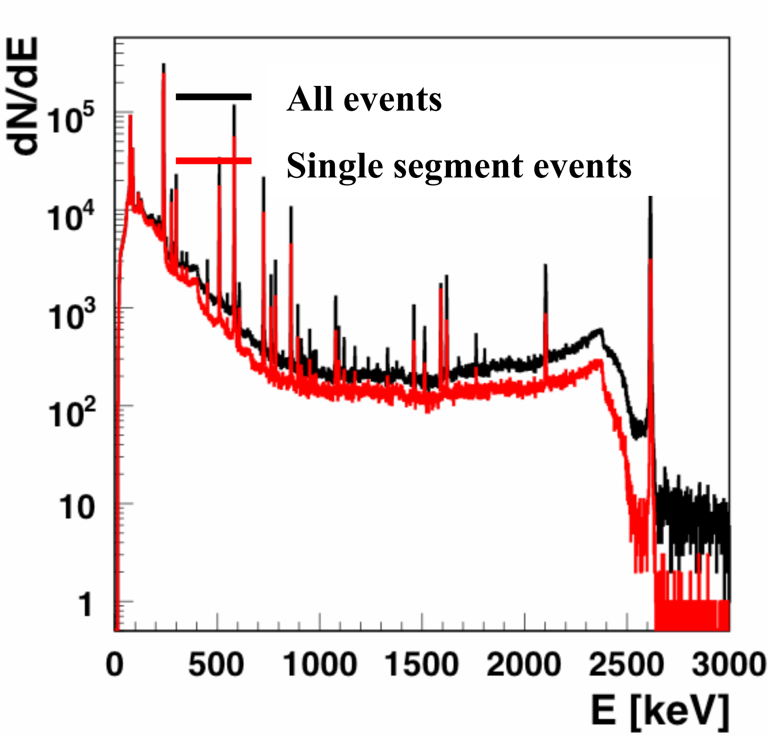

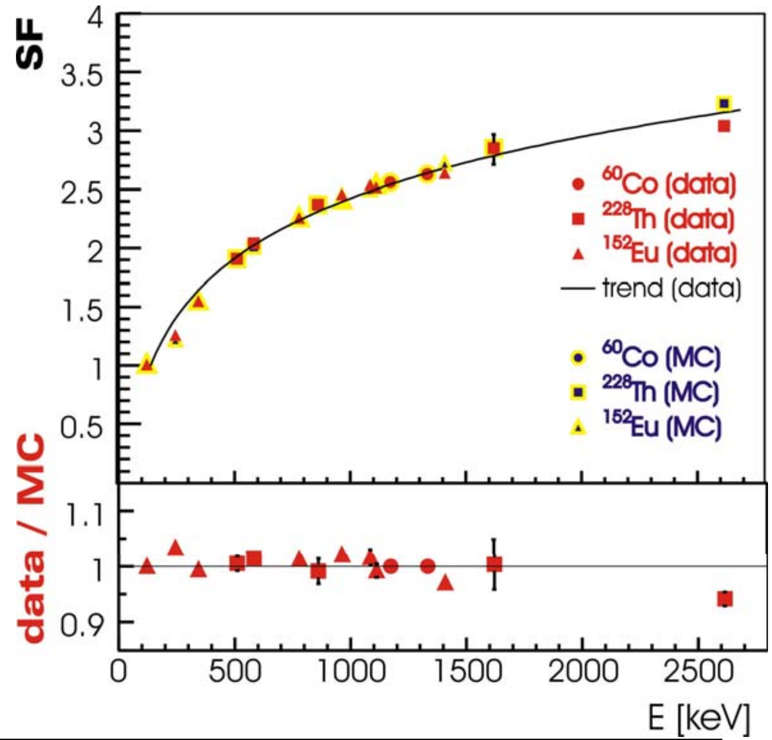

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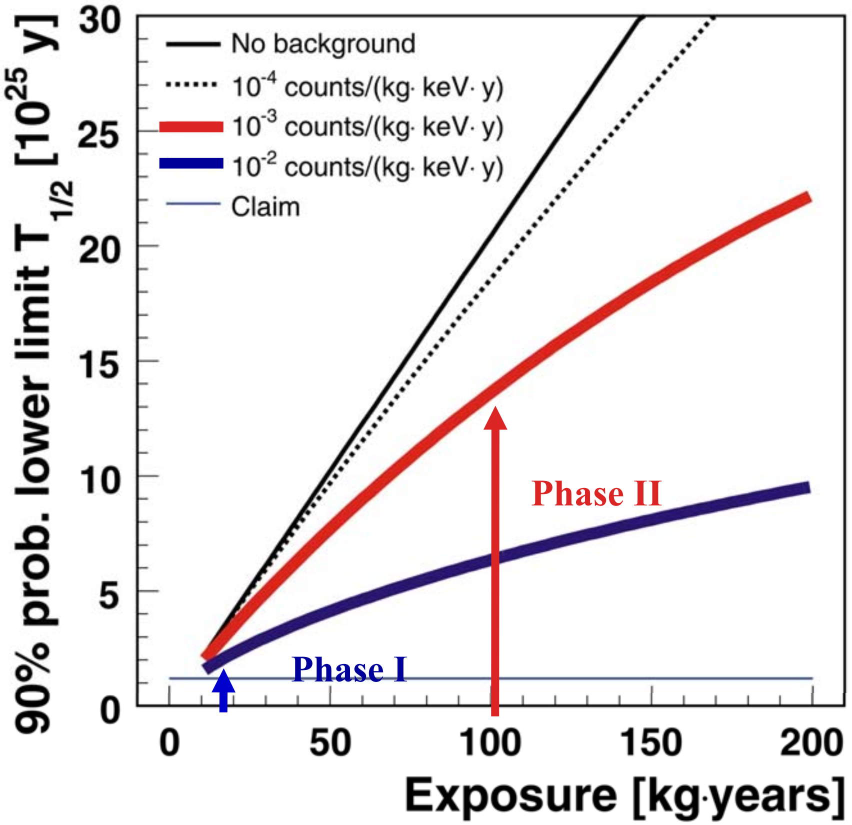
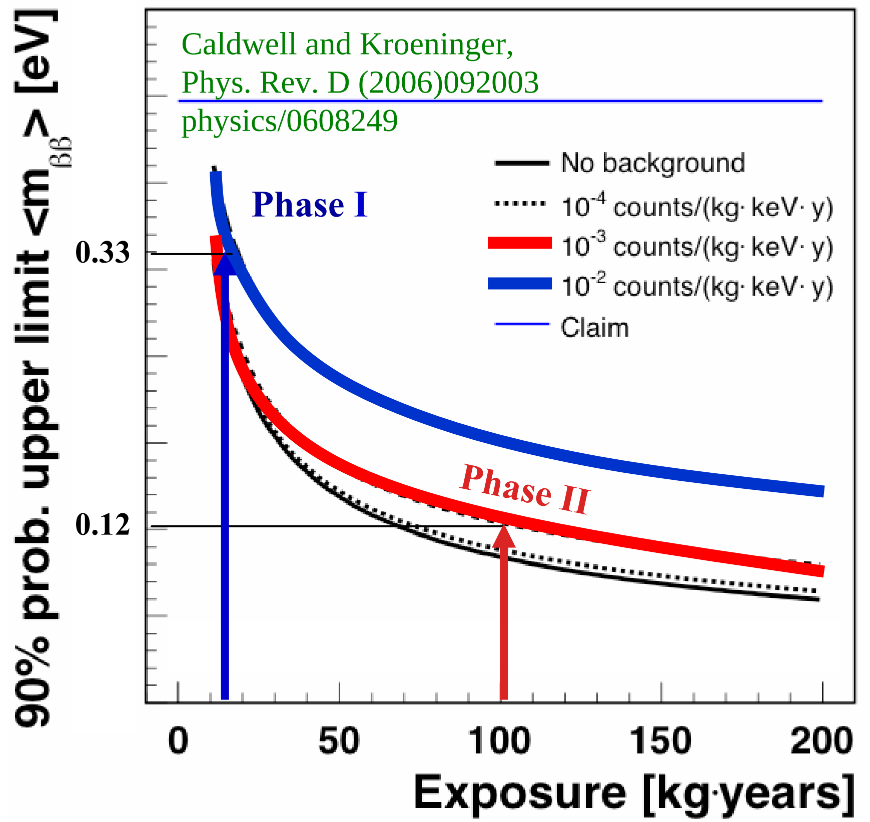
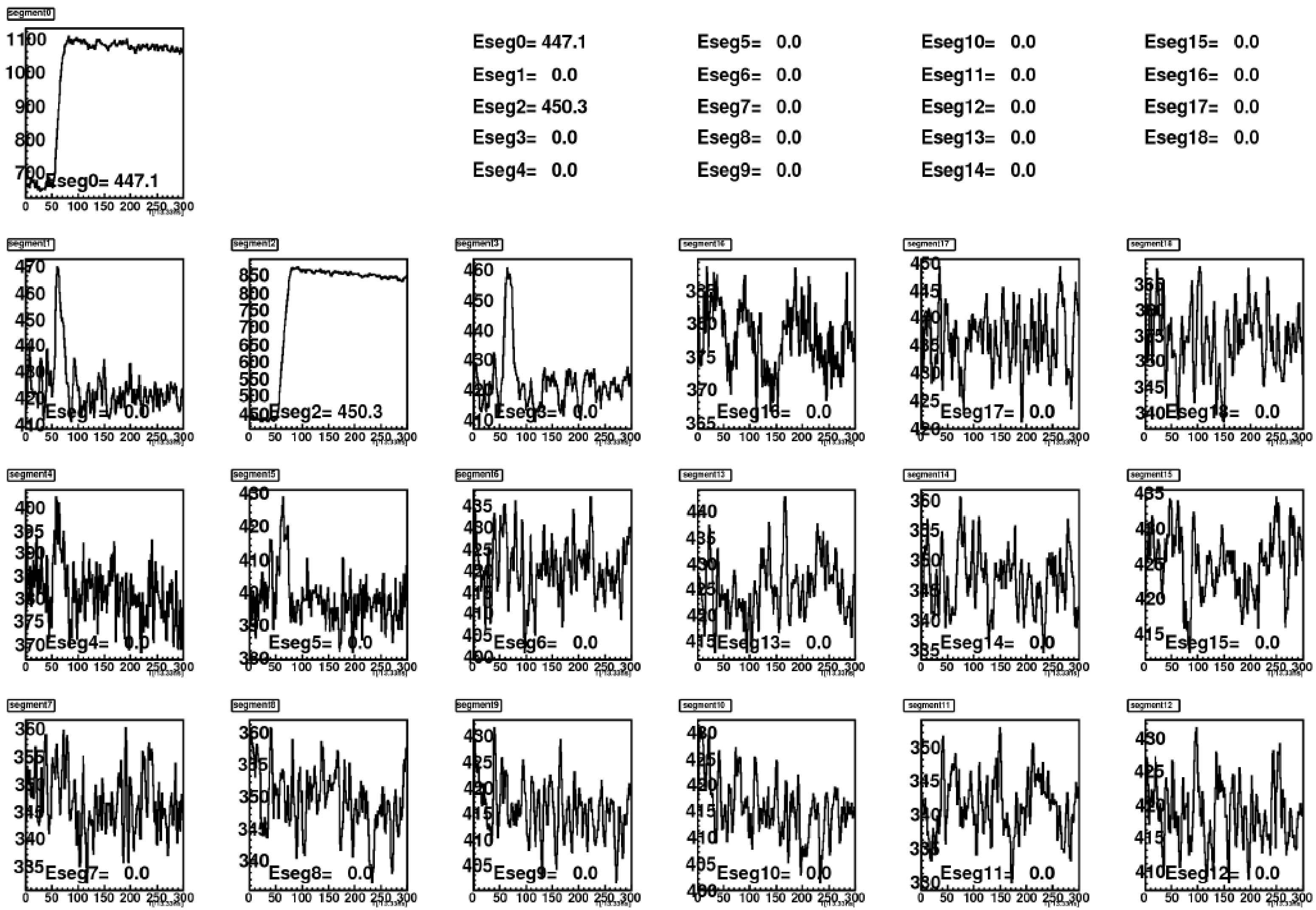
Aimed GERDA sensitivity:





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.

Prototype detector pulse shapes:



Phase II: Detector transport

Novel detector transport system : The GERDA detectors travel just as safely as your kids without losing their aroma!