GERDA and GeDet Status Report

OUTLINE:

Neutrinoless Double Beta-Decay

HPGe for 0vbb Detection

The Concept of GERDA

Where is GERDA now?

GERDA Activities at MPP

GeDet news

Who is GERDA/GeDet at MPP?

Director: Allen Caldwell

Projector leaders: Béla Majorovits (GERDA), Iris Abt (GeDet)

Postdocs: Josef Janicsko, Xiang Liu, Jens Schubert

Ph.D.s: Daniel Lenz, Jing Liu

Group engineer: Franz Stelzer, Markus Kästle (until 12/08)

Werkstudenten/in & Interns: Sabine Hemmer, Ping Li ,Christopher Meier, Annika Vauth, Andreas Glück (until 07/08) Gregor Volk (until 07/08)

Construction: Karlheinz Ackermann, Stefan Mayer, Sven Vogt

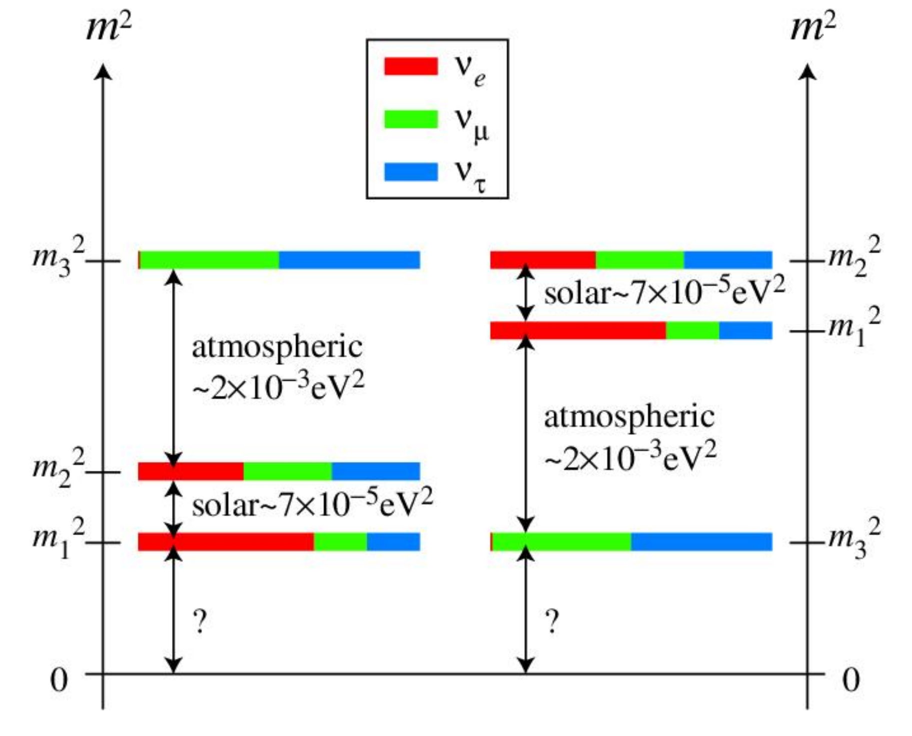
Many thanks to colleagues from electronic & mechanic departments!

The Neutrino Mass

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

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

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



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?

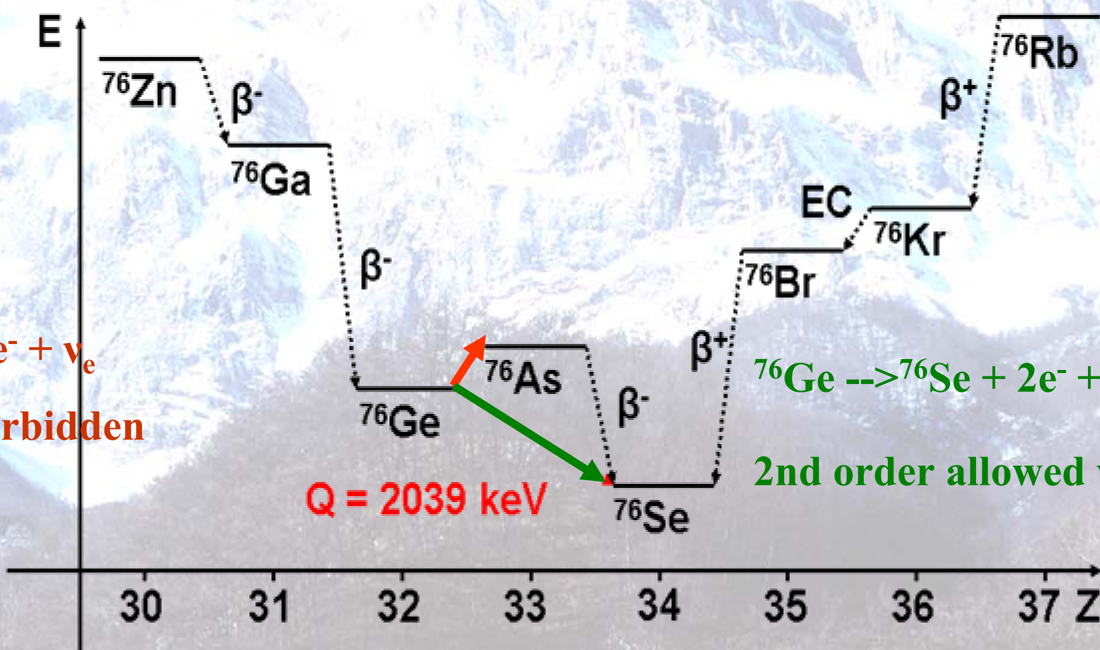
→ Nature of the Neutrinos still unknow

Double Beta-Decay

Initial state nucleus has to be bound less than final state nucleus, but stronger than intermediate.

Only possible in even-even nuclei.

35 isotopes decay via 2νββ.



$^{76}Ge \rightarrow ^{76}As + e^- + \nu_e$

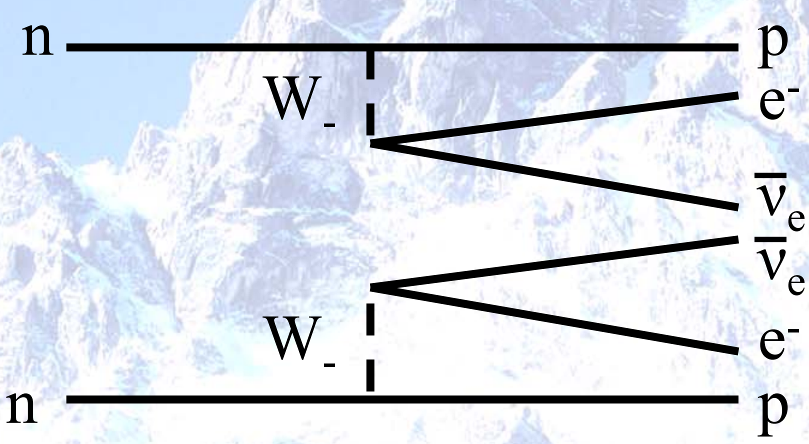
energetically forbidden

$^{76}Ge \rightarrow ^{76}Se + 2e^- + 2\nu_e$

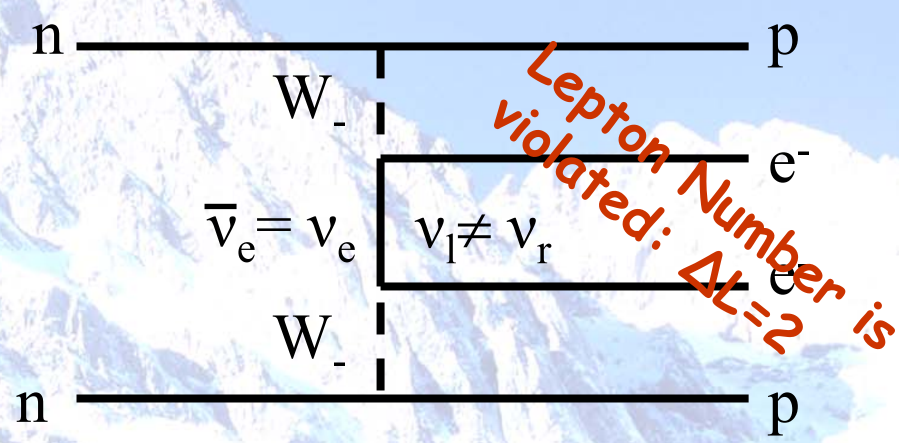
2nd order allowed weak process

Neutrinoless Double Beta-Decay

Neutrino accompanied Double-Beta Decay:



Neutrinoless Doubel-Beta Decay:



Neutrinoless mode of double beta decay can only occur if:

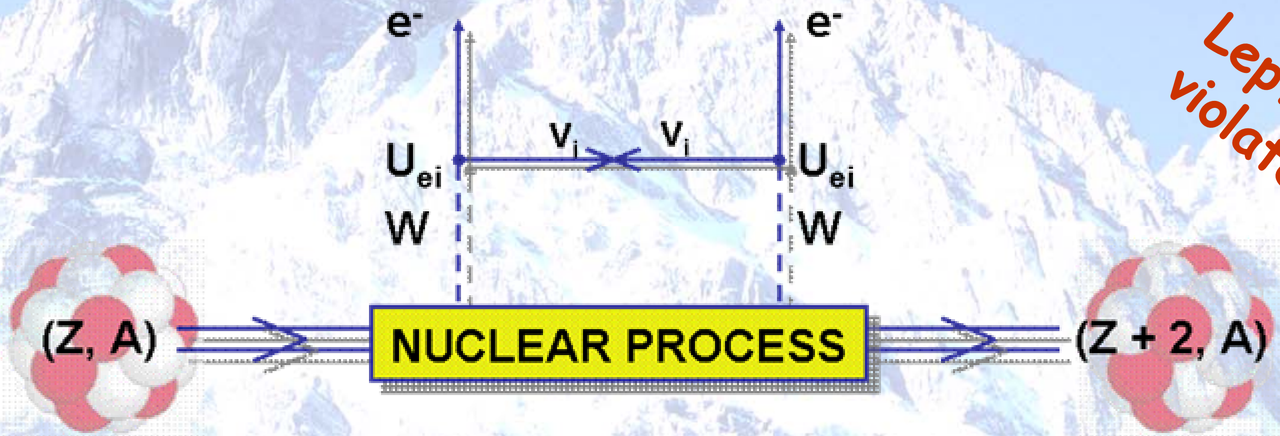
1. **Neutrino is identical with its antiparticle (Majorana particle)**
2. **Neutrino is massive (helicity flip required)**

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

0νββ Decay rate	**Phase space factor (~Q^5)**	**Matrix element**	**Effective Majorana Neutrino mass**

Neutrinoless Double Beta-Decay

Neutrino accompanied Double-Beta Decay: **Neutrinoless Doubel-Beta Decay:**



Lepton Number is violated: ΔL=2

Neutrinoless mode of double beta decay can only occur if:

1. **Neutrino is identical with its antiparticle (Majorana particle)**
2. **Neutrino is massive (helicity flip required)**

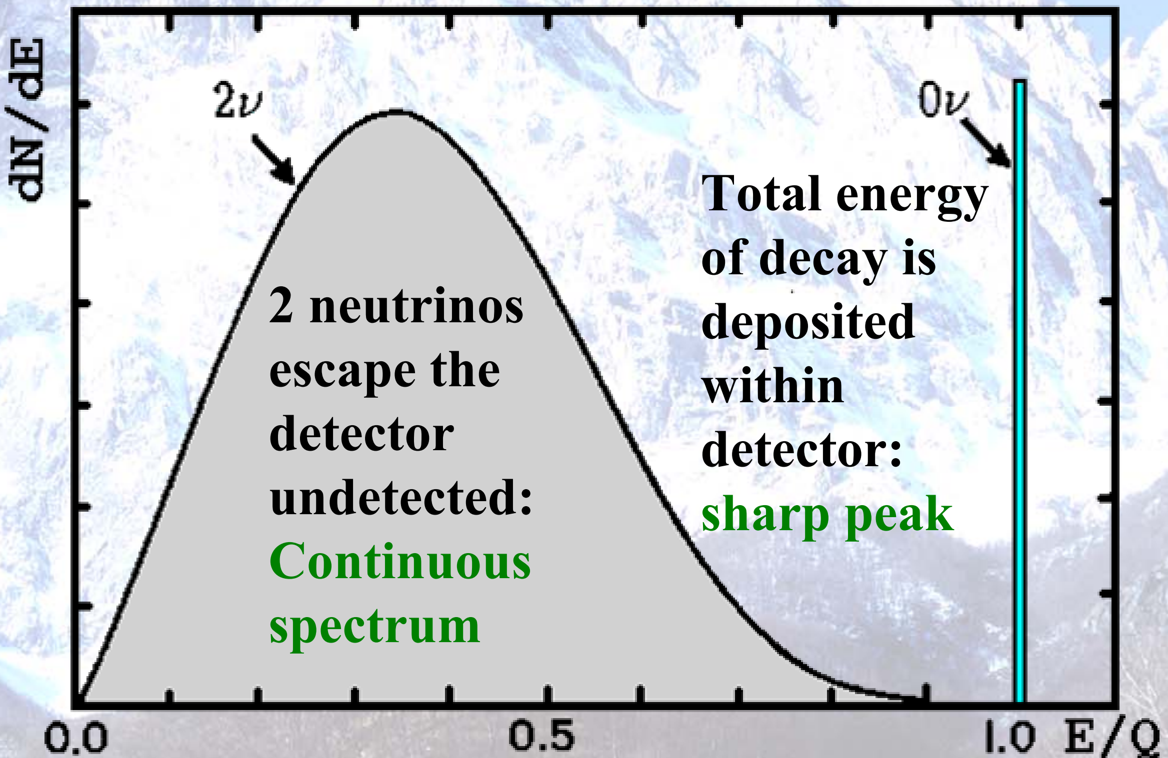
$$1/\tau = G(Q,Z)\,|M_{nucl}|^2\,\langle m_{ee}\rangle^2$$

0νββ Decay rate — Phase space factor (~Q^5) — Matrix element — Effective Majorana Neutrino mass

Neutrinoless Double Beta-Decay

Signature: Sharp peak at Q-value of the decay

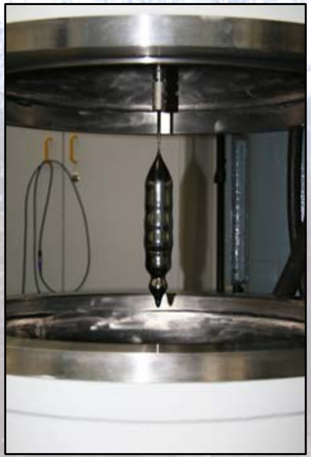
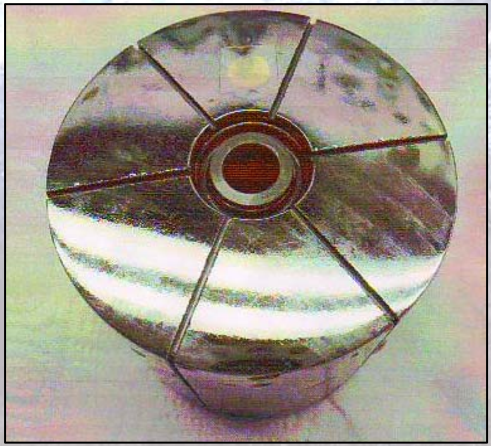
(2039 keV for 76Ge)



The observable of neutrinoless double beta decay experiments is its half-life. $T_{1/2}^{0\nu\beta\beta} > 10^{15}$ **• age of the universe**

^{76}Ge as Source and Detector

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
Natural abundance of ^{76}Ge 7,44%	Enrichment necessary

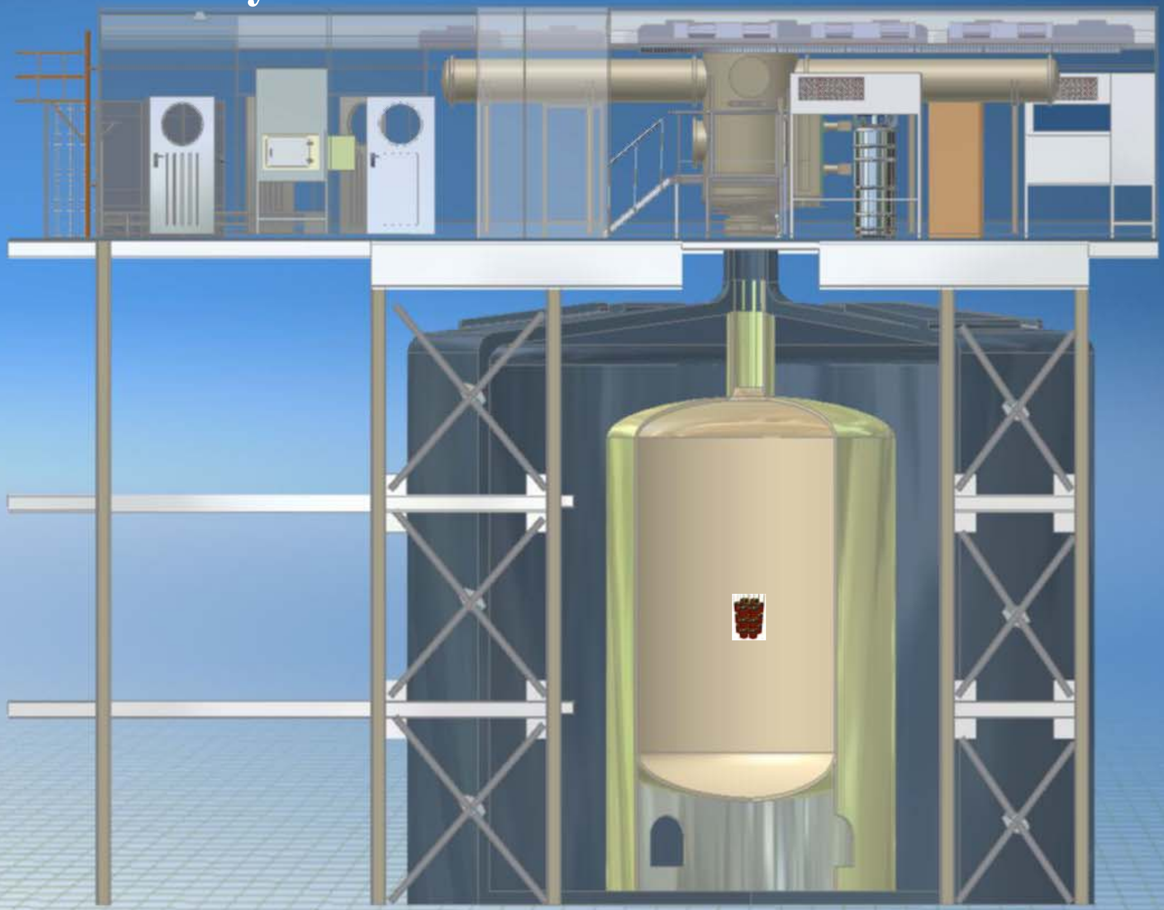




The GERDA Collaboration

Institute for Reference Materials and Measurements, Geel, Belgium
Max-Planck-Institut für Kernphysik, Heidelberg, Germany
Max-Planck-Institut für Physik (Werner-Heisenberg-Insititut), München, Germany
Physikalisches Institut, Universität Tübingen, Germany
Institut für Kern- und Teilchenphysik, Universität Dresden, Germany
Dipartimento di Fisica dell'Univeristá; di Padova e INFN Padova, Padova, Italy
INFN Laboratori Nazionali del Gran Sasso, Assergi, Italy
Universitá; di Milano Bicocca e INFN Milano, Milano, Italy
Jagiellonian University, Cracow, Poland
Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
Institute for Theoretical and Experimental Physics, Moscow, Russia
Joint Institute for Nuclear Research, Dubna, Russia
Russian Research Center Kurchatov Institute, Moscow, Russia
University Zurich, Switzerland

The Concept of 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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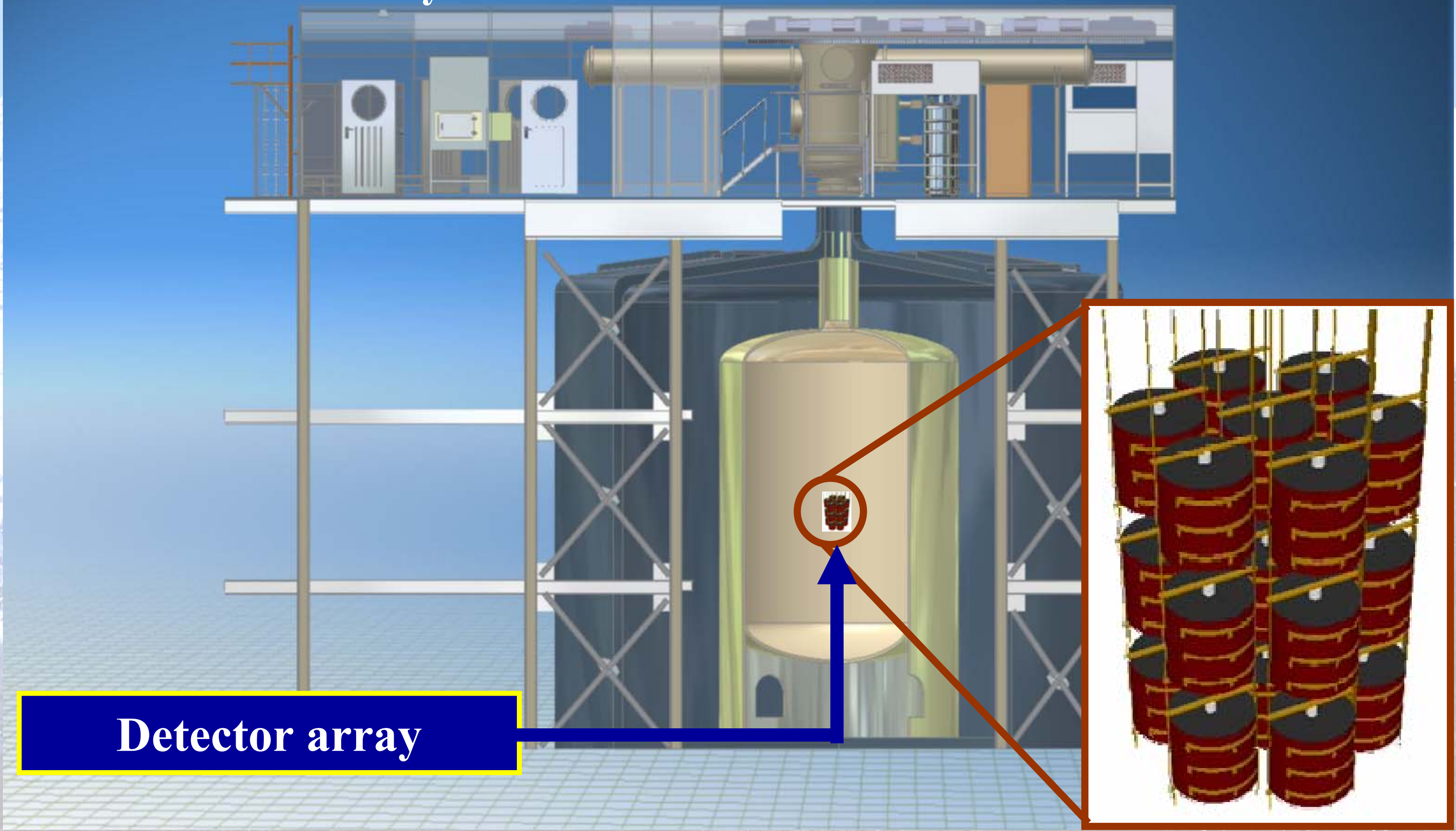
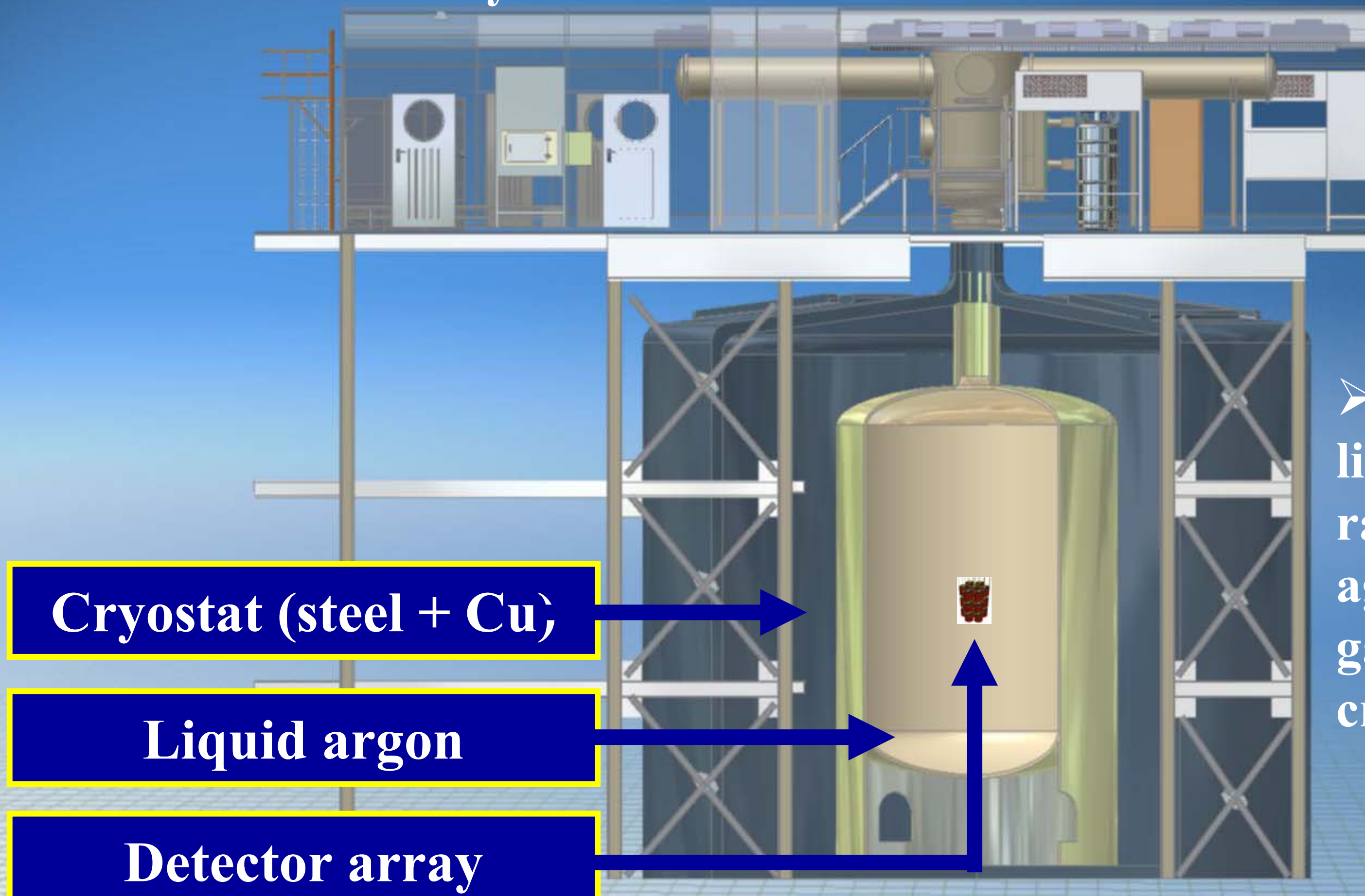


The Concept of GERDA

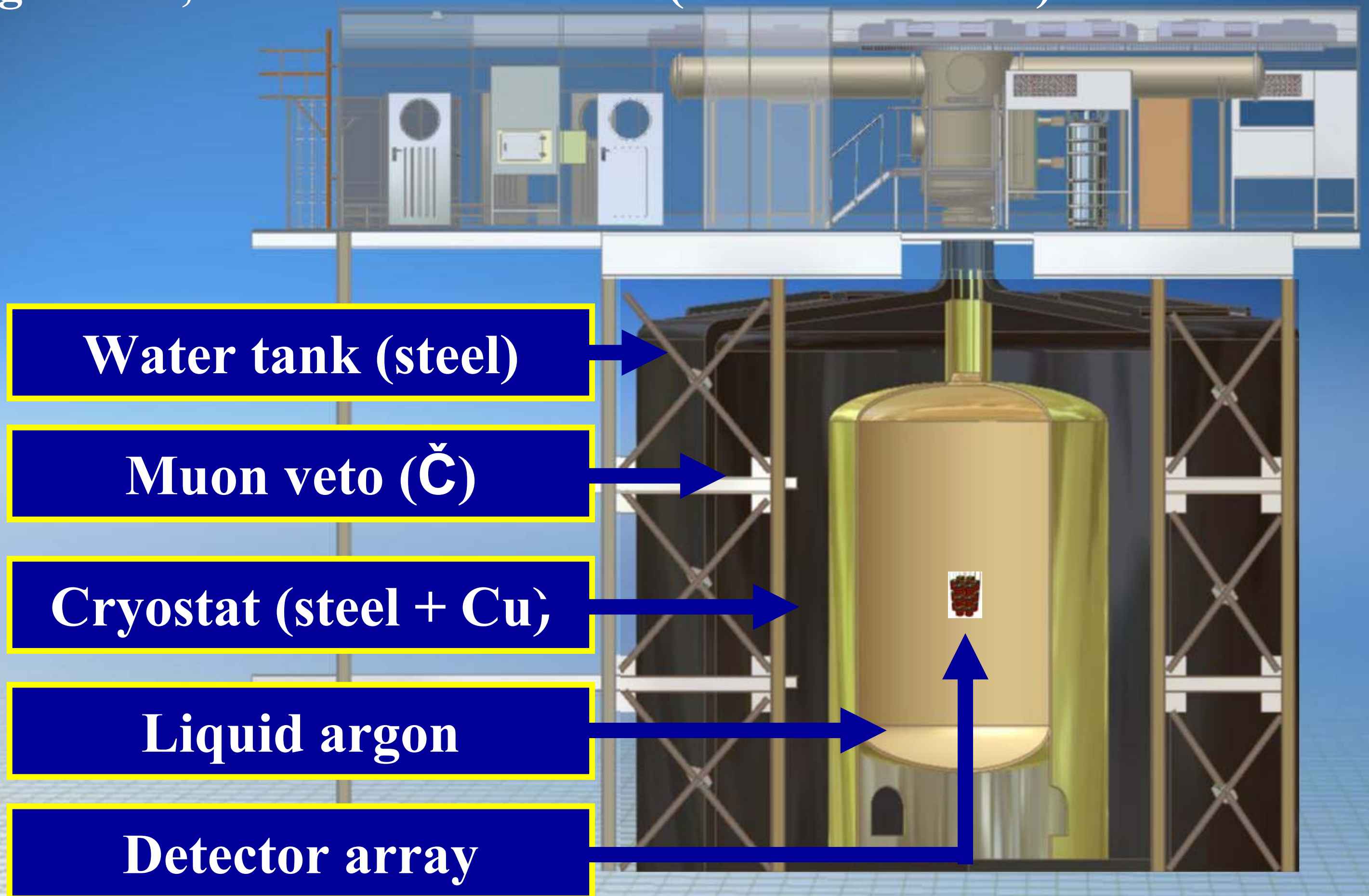
- Place array of naked HPGe-detectors enriched in ^{76}Ge in the center of a stainless cryostat filled with LAr.



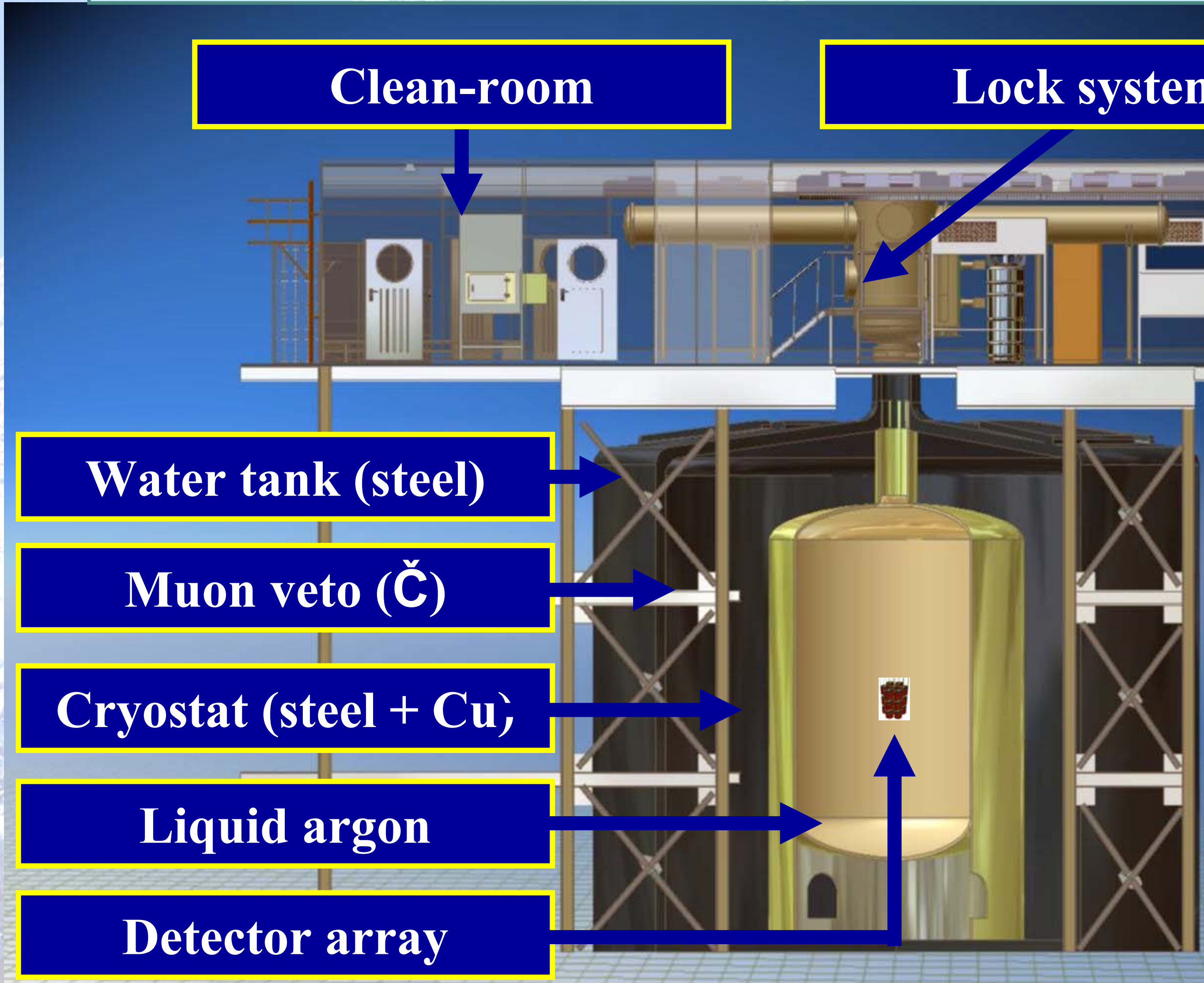
- Inner copper lining as radiation shield against gammas from cryostat

The Concept of GERDA

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

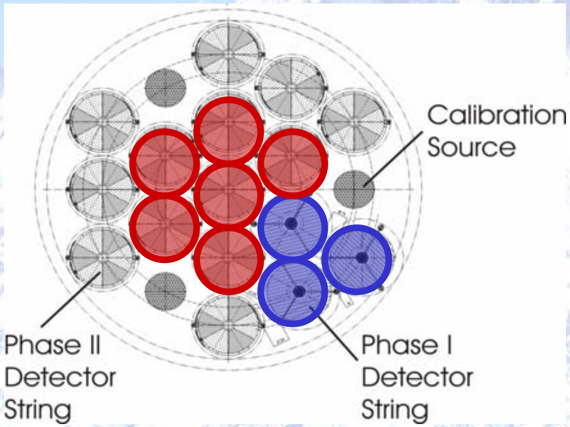


The Concept of GERDA



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

The Phases of GERDA

phase	I	II	III
detectors 	5 Hd-Mo & 3 IGEX detectors, 17.9 kg 	18-fold seg., ~25kg 	1 ton scale
exposure[kg·y]	30	100	>10000
bg [counts/kg·keV·y]	10E-2	10E-3	<10E-4
limit on $T_{1/2}$ [10E25 y]	3 (verify/veto KK-claim)	15	>1000
limit on $m_{\beta\beta}$ [eV]	0.27	0.11	~0.02

If Klapdor-Kleingrothaus claim is true, phase-I expect ~13 signal events, and3 bg. events in 10keV window at Q

Where is GERDA now:

Arrival of the cryostat at LNGS on 6th of March 2008

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Arrival of the cryostat at LNGS on 6th of March 2008

Where is GERDA now:

Construction of Water Tank on 30th of April 2008

Where is GERDA now:

Construction of Water Tank 7th of May 2008

Where is GERDA now:

Construction of Water Tank on 19^{th} of May 2008

Where is GERDA now:

Construction of Water Tank on 26th of May 2008

Where is GERDA now:

Construction of Water Tank on 28th of May 2008

Where is GERDA now:

Superstructure on 11th of July 2008

Where is GERDA now:

Superstructure on 18th of July 2008

Where is GERDA now:

Superstructure as of now

Presently the water tank is filled with water to the top.

Static tests are being performed.

Emergency drainage will be simulated.

Ventilation system for hall A at Gran Sasso is being worked out

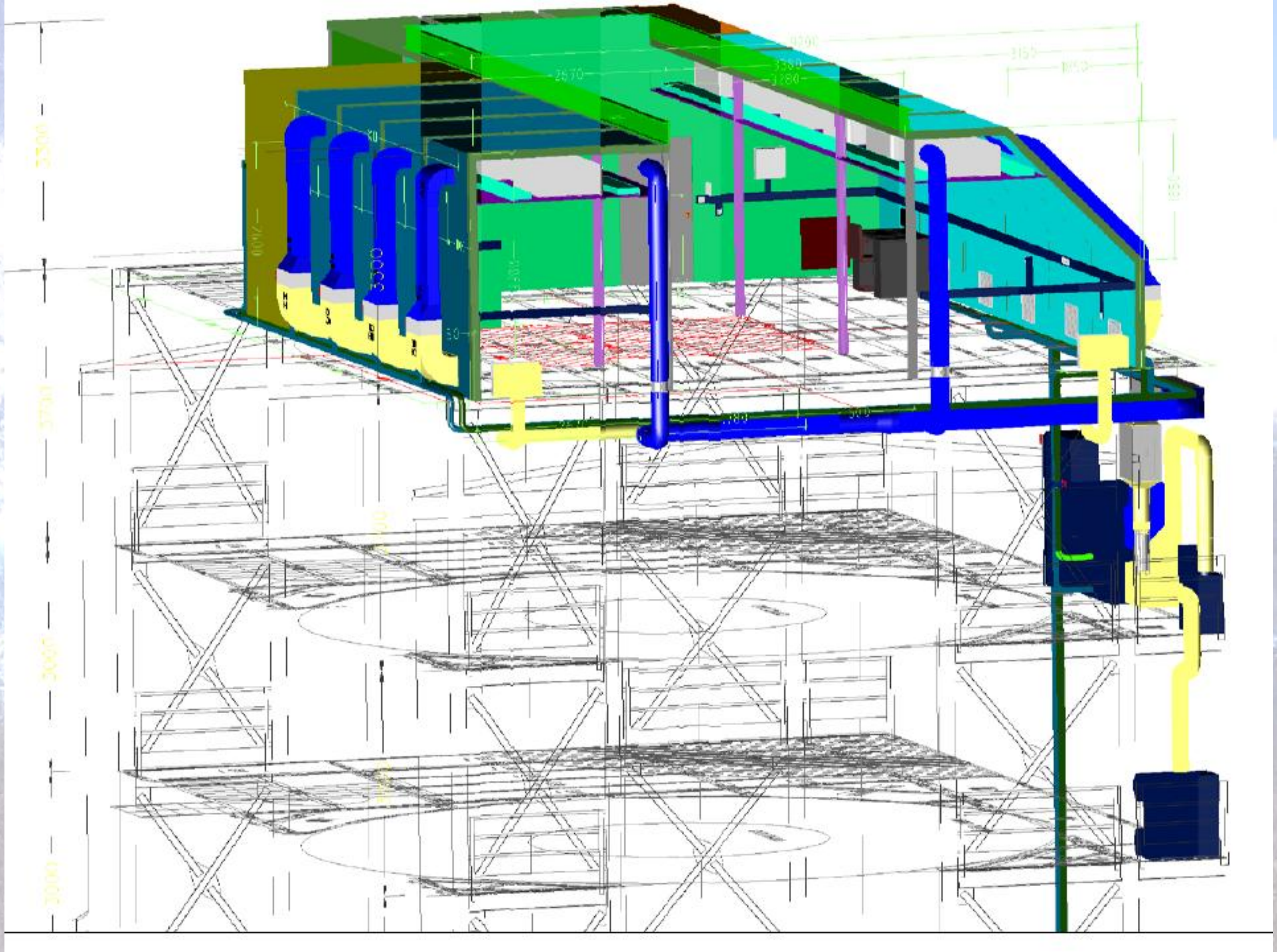
The GERDA Clean-Room:

Installation of Clean Room at Gran Sasso will start January 26 2009

Class 10.000 clean room

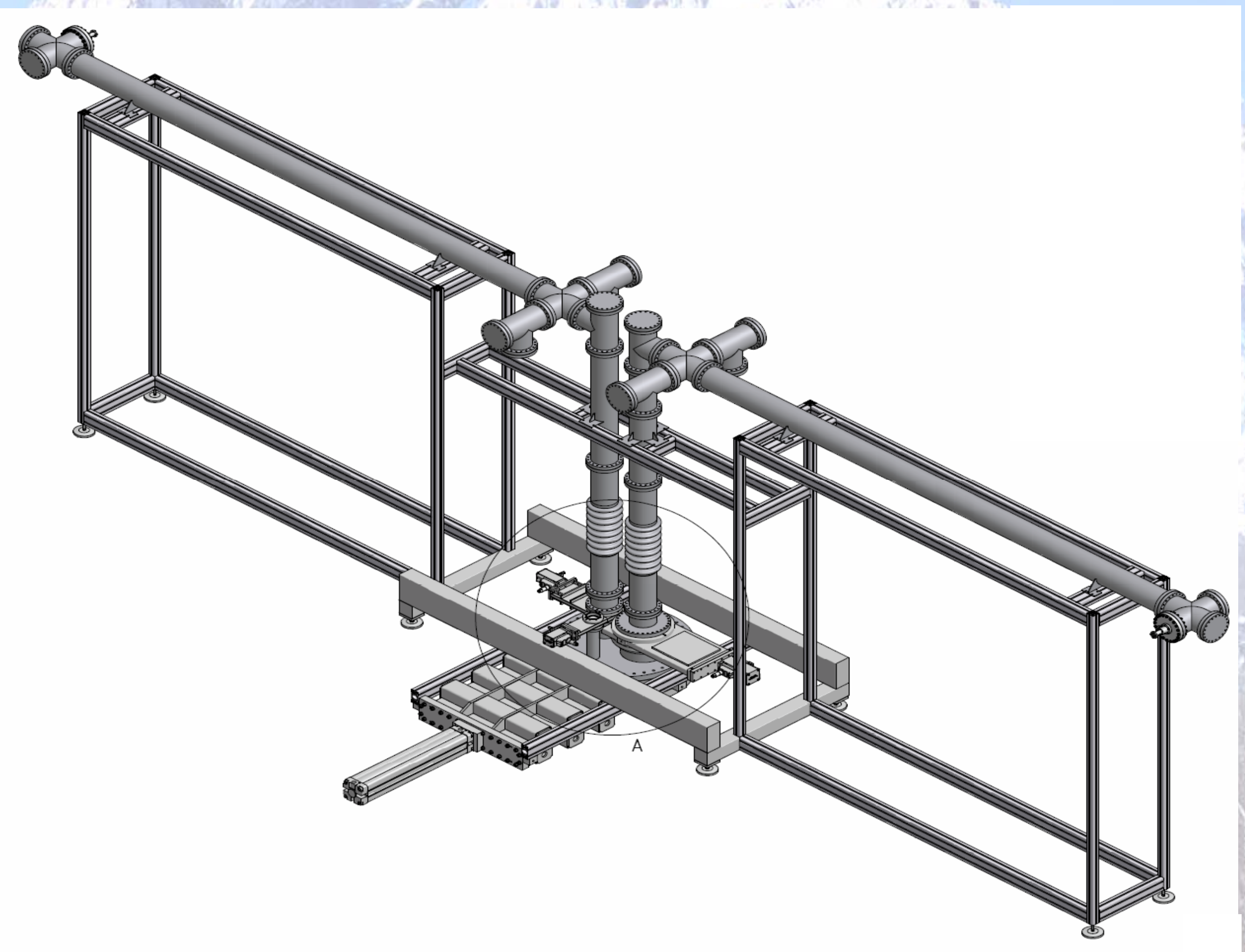
Steel construction welded onto the superstructure

Removable roof for installation of final lock



The GERDA Commissioning Lock:

For Commissioning a preliminary lock system will be installed:
Two strings with a total of 6 detectors can be insrted



The GERDA Commissioning Lock:

Last parts are presently being worked on: Welding, Leak testing, Electropolishing

Installation of the GERDA Commissioning Lock:

Infrastructure for cleaning sequence is established.

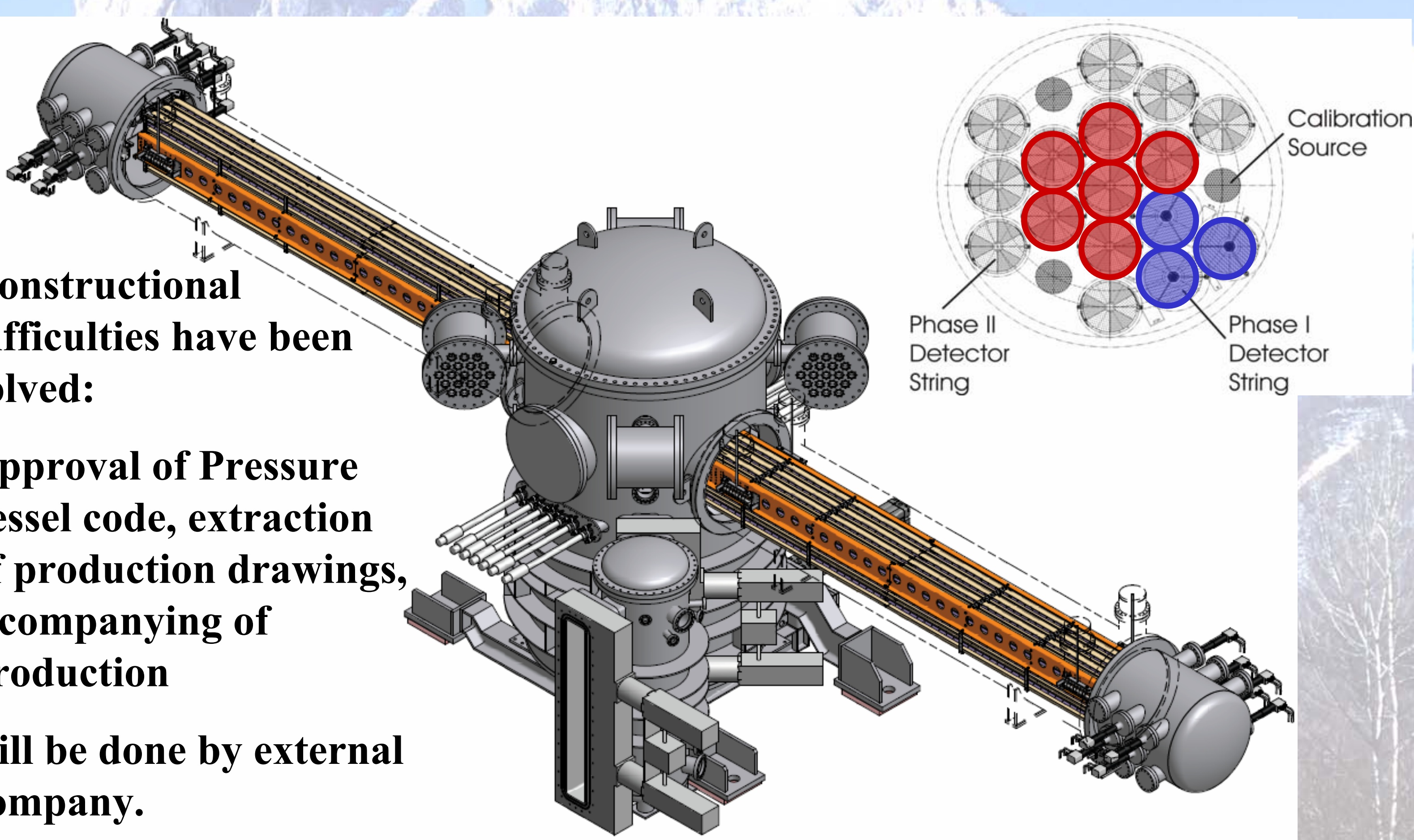
Clean Room cabin for installation also of final lock has been erected

The Commissioning lock will be assembled and mechanically tested early 2009

The Commissioning lock will be sent for detector integration to LNGS in March 2009

The GERDA Final Lock:

The final lock system will allow for insertion of up to 74 detectors on 16 linear pulleys.



Constructional difficulties have been solved:

Approval of Pressure vessel code, extraction of production drawings, Acompanying of production

will be done by external company.

Germanium Purification and Crystal Growing:

Purification: PPM, Germany

90% yield for 6N material.

No isotopic dilution with depleted material detected!

Underground storage near PPM found, logistics tested

Enriched material will be processed in 2009

	Resistvity (Ωcm)		Electron conc. (10^{13} cm^{-3})		Mobility (cm^2/Vs)	
Temperature	*297 K*	*77 K*	*297 K*	*77 K*	*297 K*	*77 K*
CZ4_1-2	46.9	11.8	5.20	1.44	2561	36600
CZ4_2-2	51.6	11.5	4.14	1.50	2921	36090
CZ4_3-2	54.3	9.7	3.55	1.78	3238	36190
CZ4_5-2	44.2	7.8	4.60	2.22	3066	36120
CZ4_6-2	42.7	6.9	4.60	2.58	3182	35100
CZ4_8-2	30.2	4.3	6.36	4.11	3246	34970
CZ4_9-2	25.6	3.2	6.89	5.57	3539	34620
CZ4_11-2	13.4	1.6	12.3	12.24	3772	32170
CZ4_12-2	5.8	-	45.3	-	2366	-

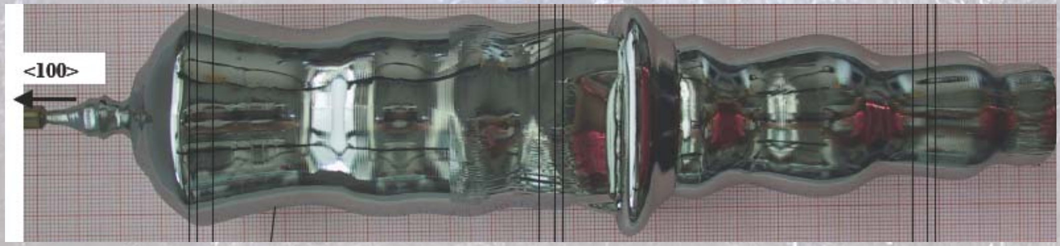
	Resistvity (Ωcm)		Electron conc. (10^{13} cm^{-3})		Mobility (cm^2/Vs)	
Temperature	297 K	77 K	297 K	77 K	297 K	77 K
Ge-FZ-V3105_A	57,9	3379	7,1[illegible]	0,01	[illegible]569	25130
Ge-FZ-V3105_E	49	-	12,9	-	990	-

Crystal Growing: IKZ, Berlin:

Dedicated Czochralski puller operational. 8 crystals already pulled, more expected still this year.

Characterization by Hall effect measurements (charge carrier density) and PTIS (impurity identification) by IKZ.

Uni Dresden will do Photoluminescence measurements.

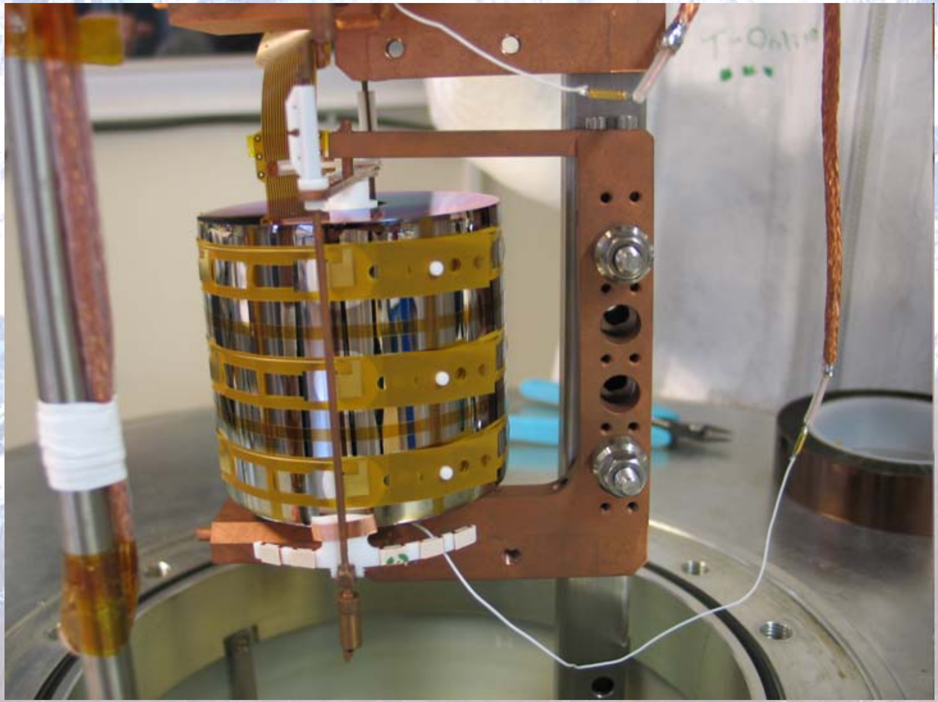


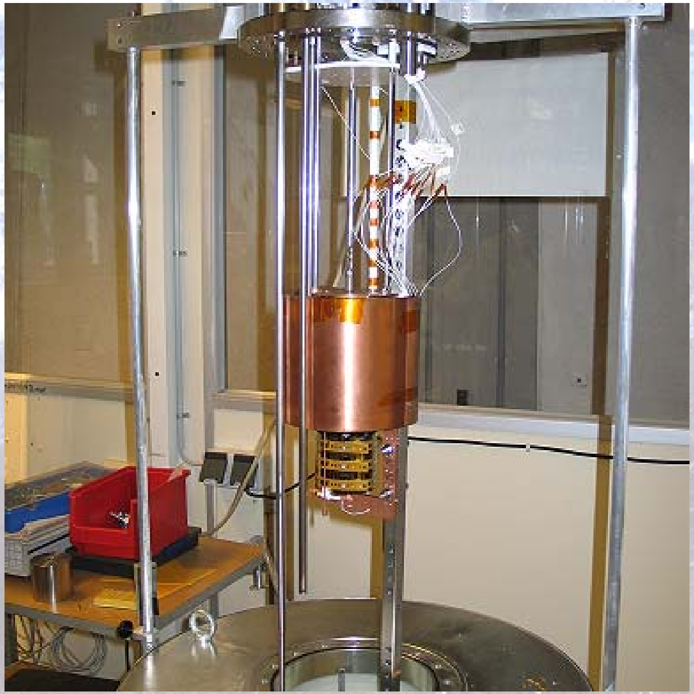
GeDet: Germanium Detector Development

Phase II will make use of extra background reduction efficiency by distinction of multi-site and single-site events:

18-fold segmentation of detectors

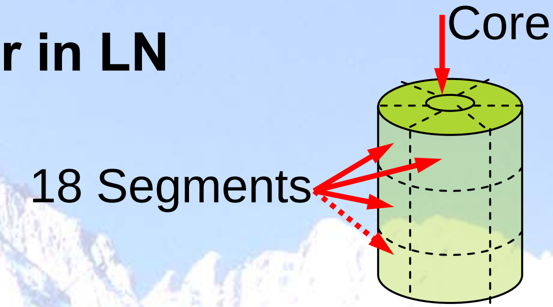
It has been shown previously that this design works well.

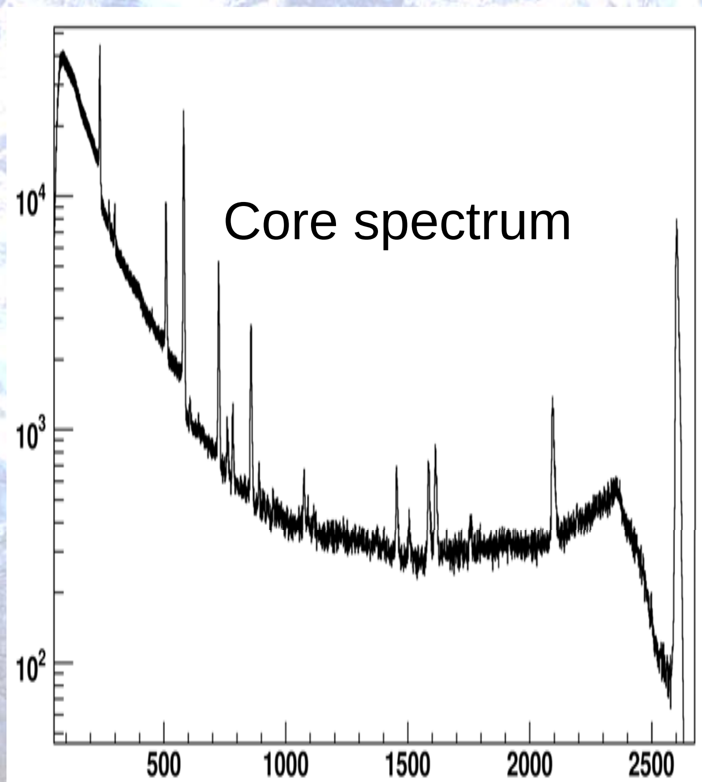




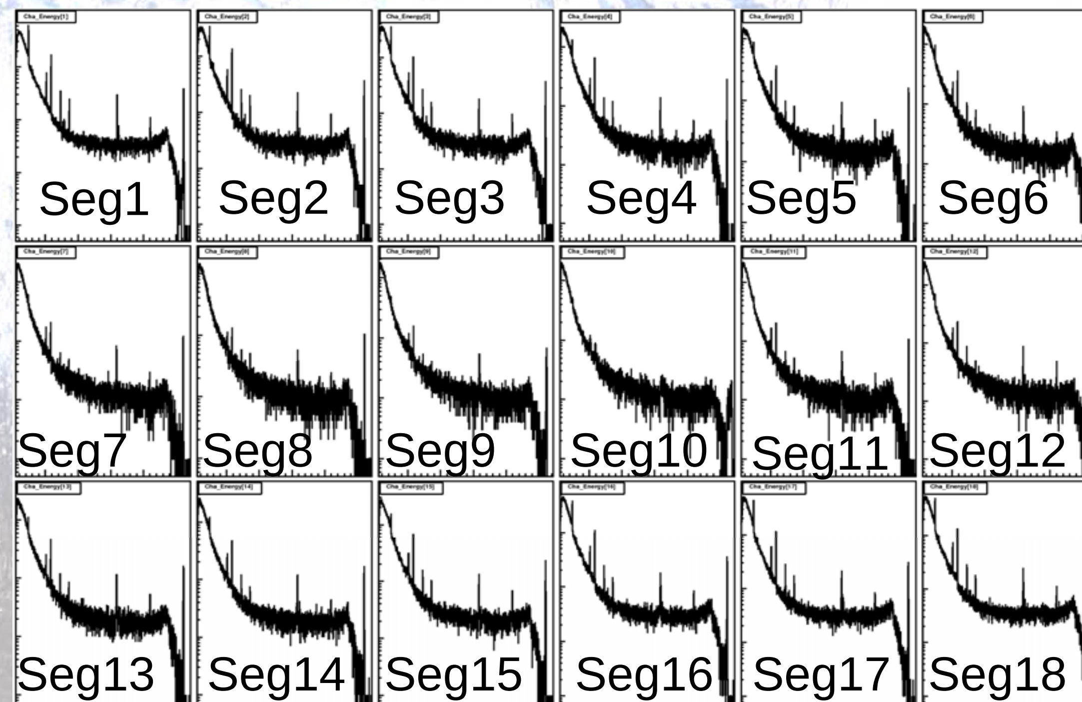
Prototype Detector in Cryoliquid:

- 1st time: operation of segmented n-type detector in LN
- Constant leakage current: < 6pA
- Calibration Spectrum Th-228,
  19 spectra are taken at the same time:





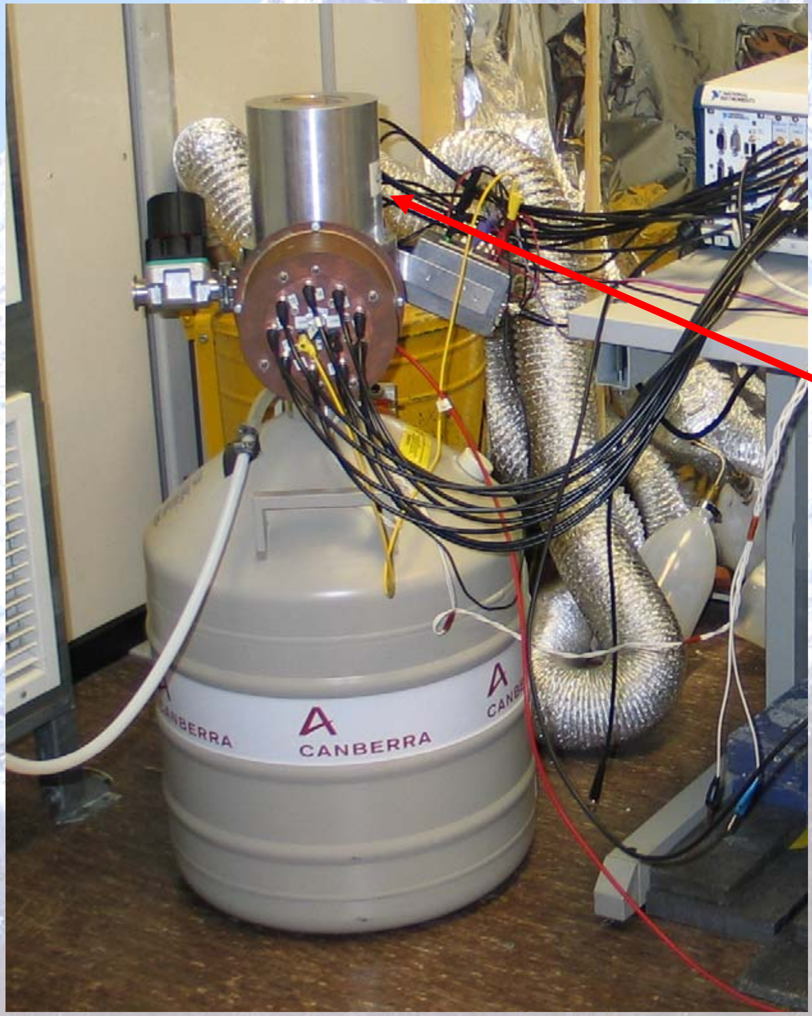
Energy measured in core



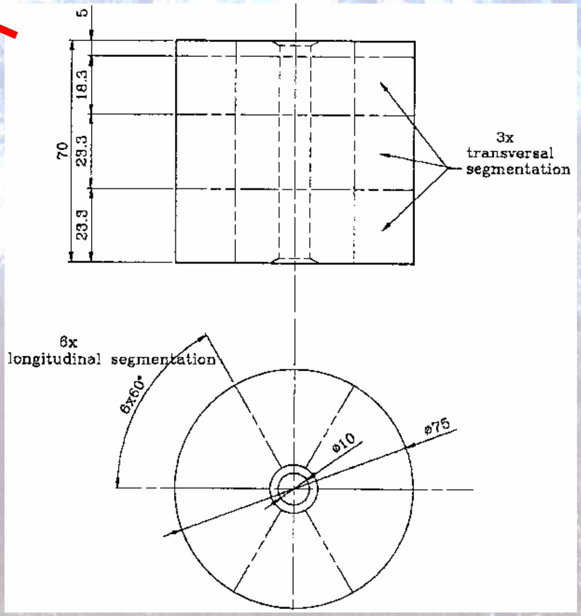
Energy measured in a single segment

GeDet: Germanium Detector Development

Special detector for study of surface effects: 18+1 fold segmented detector



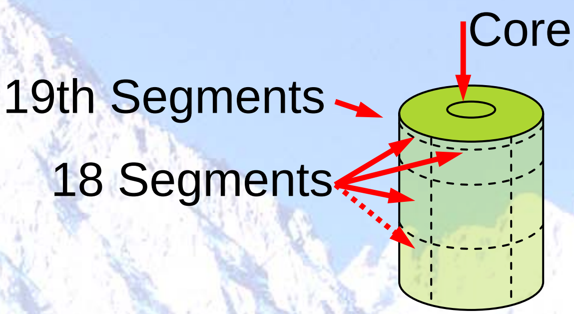
- Same size as 18-fold segmented detector
- 19^{th} segment: 5mm thick
  idea: study surface effects,
  Dead layer thickness, α sources

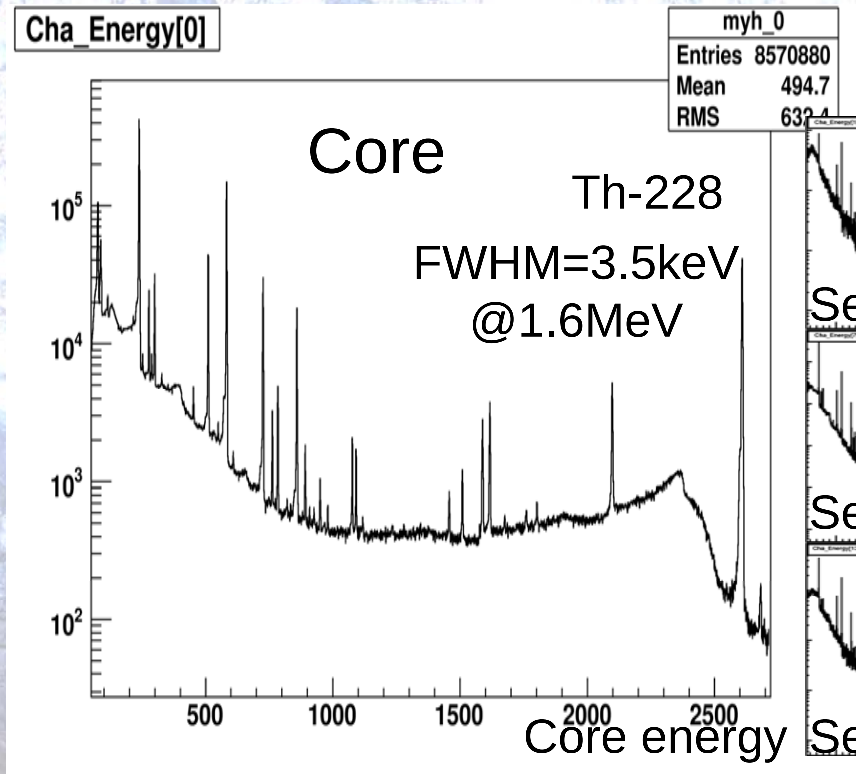


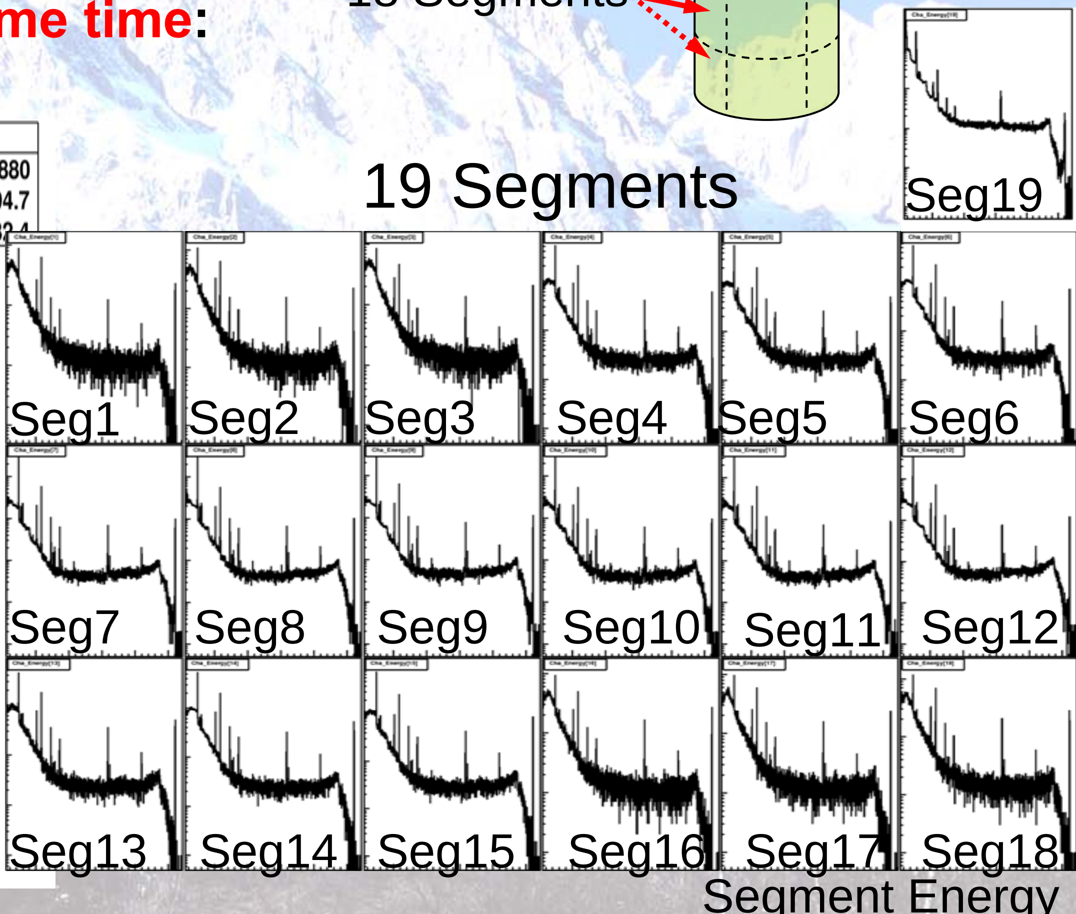
GeDet: Germanium Detector Development

Very good performance:

- **Constant leakage current: < 20pA**
- **Calibration Spectrum Th-228,**
  19 spectra are taken at the same time:

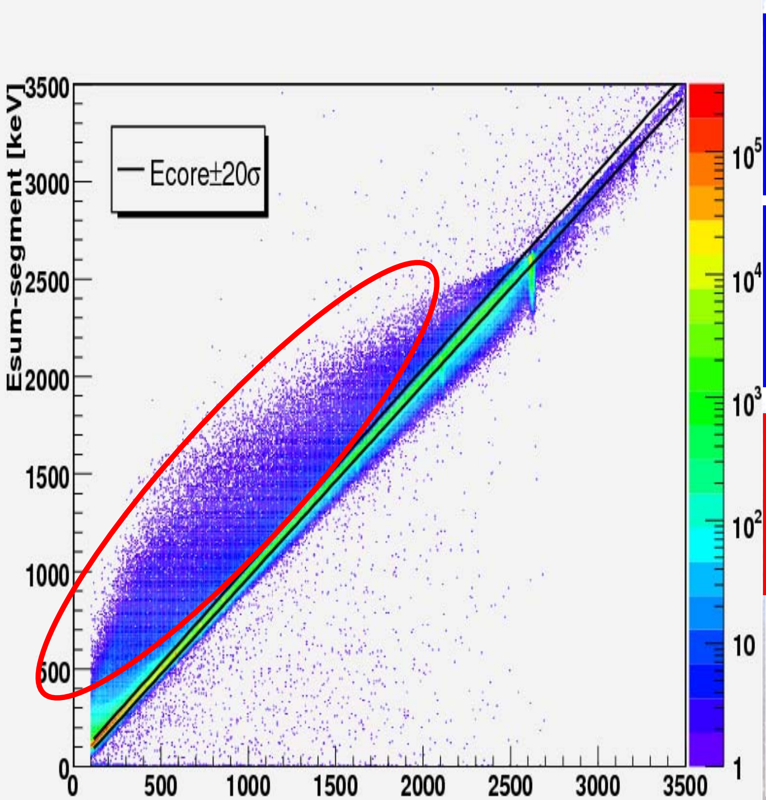


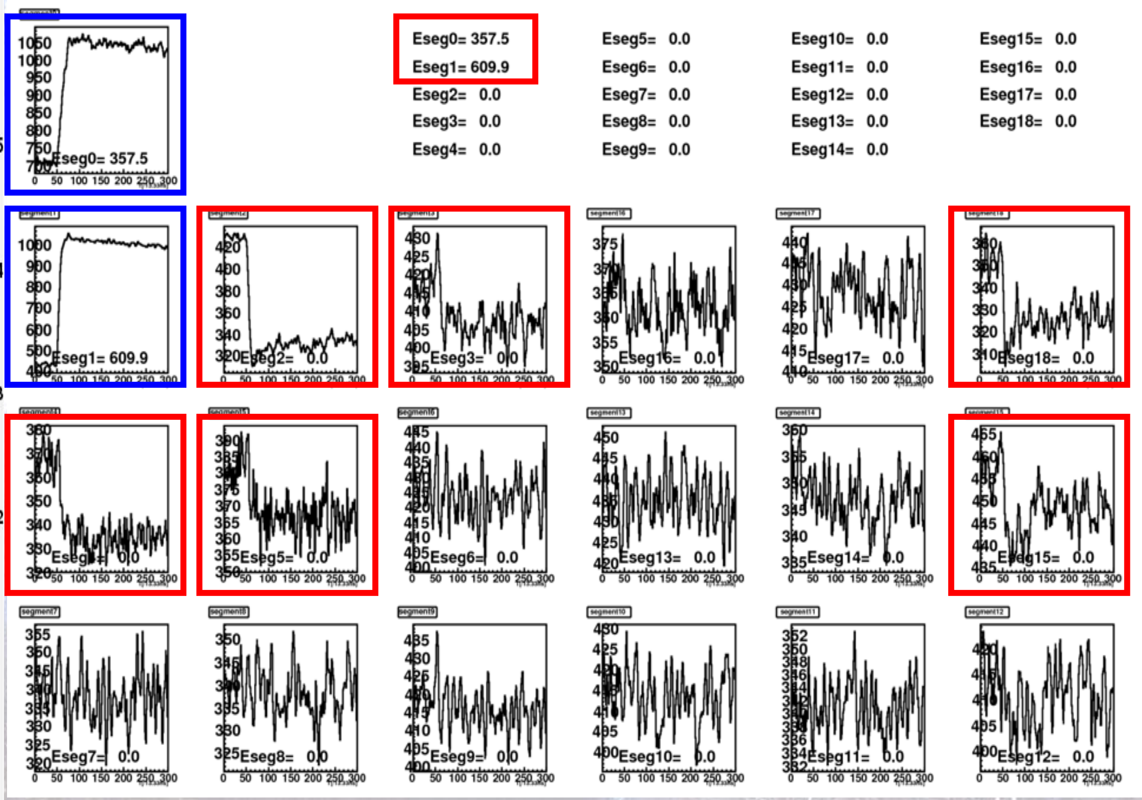




GeDet: Germanium Detector Development

- Physically expected: Sum of segment energies = Core energy
- observed events with: Sum of segment energies >> Core energy



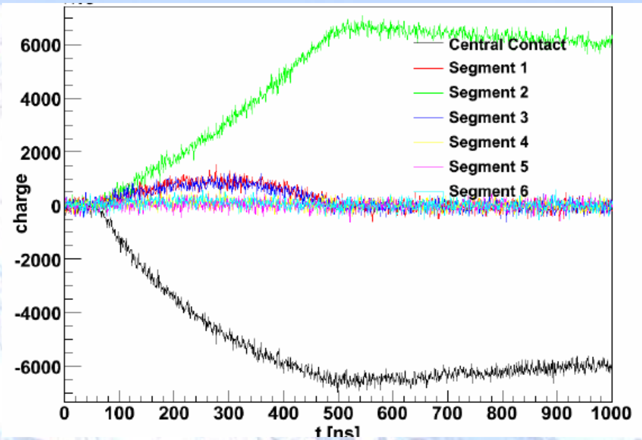


- Some events show unexpected negative pulses
- Can be explained by trapped charges
- Surface effect, no strange evt. in middle, only top/bottom

GeDet: Germanium Detector Development

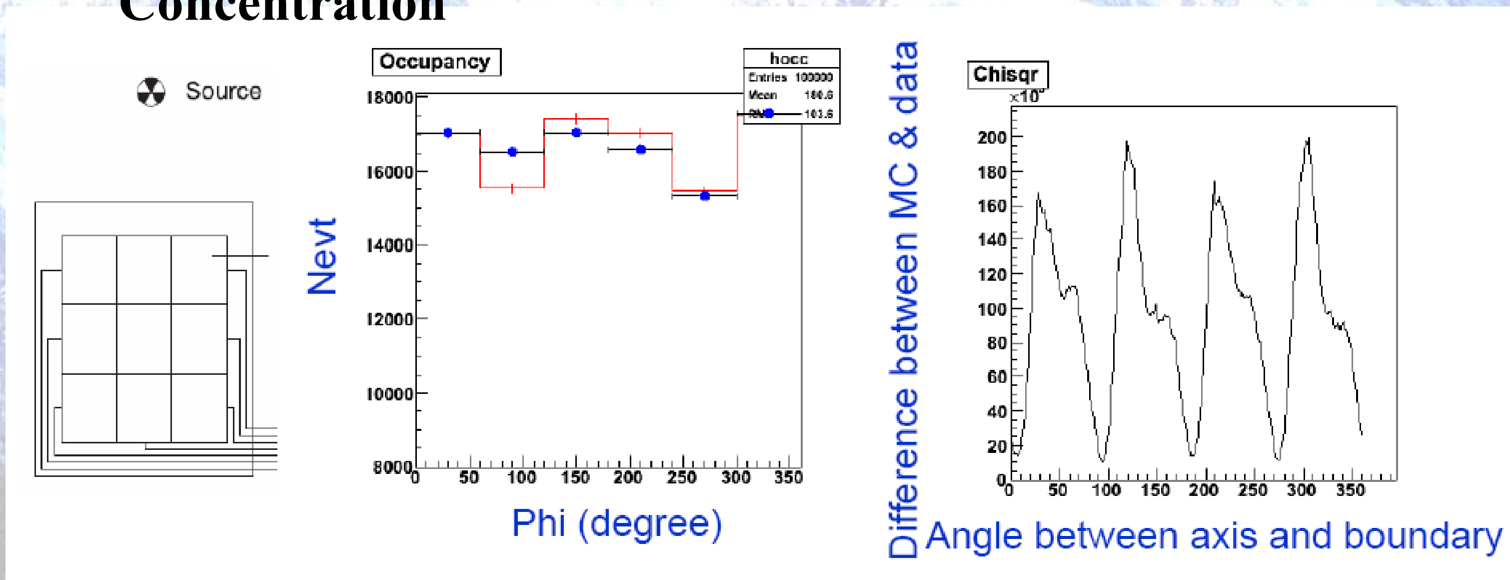
Simulation of pulse shapes:

- Calculation of fields
- Calculation of trajectories
- Extraction of pulse shapes



→ Determination of crystal axis by occupancy distribution

→ Reconstruction of Impurity Concentration



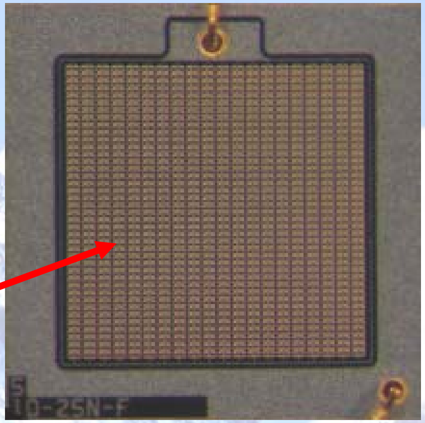
SiPMs for LAr scintillation light detection

GERDA uses LAr as shield against external background
→ Use 128nm scintillation light of LAr as veto against background.

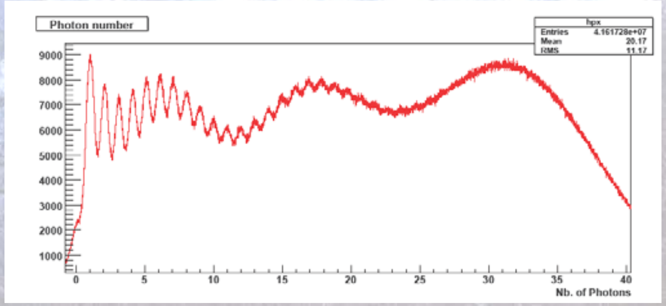
Typical values	PMT	SiPM
HV	1000 V	30 - 70 V
Dark rate	kHz	100 kHz - MHz
Gain	10^6	10^6
QE	20 - 30 %	20 - 60 %
Dyn. range	?	Nb. of pixels
Linearity	Linear	Nonlinear
Weight	kg	100 mg
Surface	cm^2	mm^2
B field	sensitive	insensitive

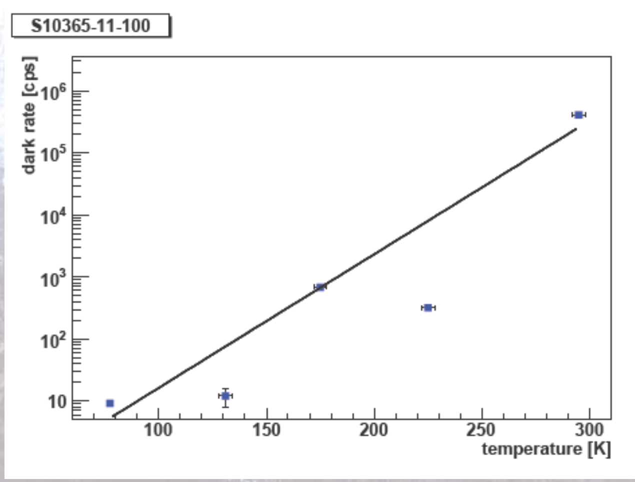
SiPMs are under study for many applications: MAGIC, ILC, … now also for GERDA.

Pixelized silicon APDs in Geiger mode



Very high QE (up to 60%?)
→ Do photon counting!

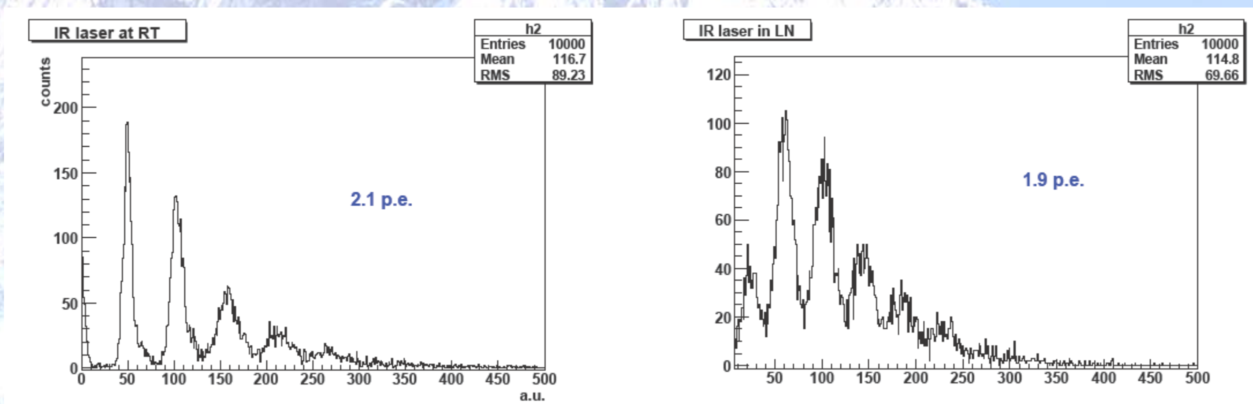




Nice feature: Dark count rate at LAr temperature is nearly six orders of magnitudes lower than at room temperature!

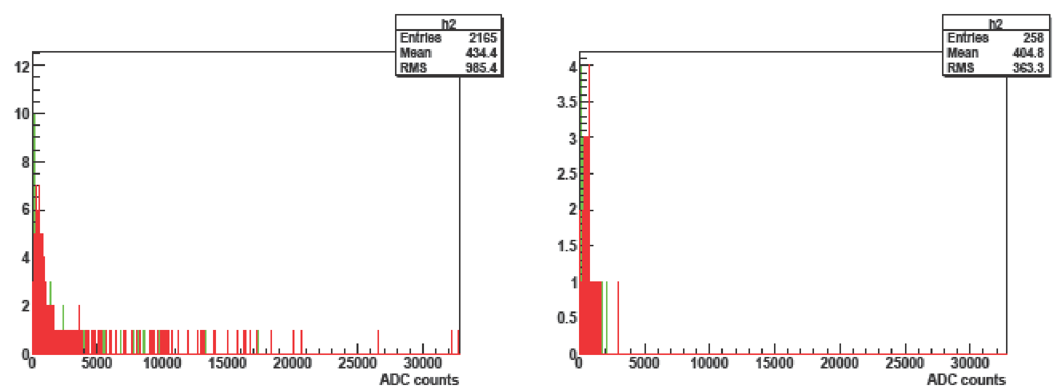
SiPMs for LAr scintillation light detection

Photon Counting still works at LAr temperature despite deteriorated pulse shapes (integration does the job)!



Convert 128nm scintillation light to visible (scintillating fibre plus TPB on VM2000 foil) → SiPM can detect radiation in LAr.

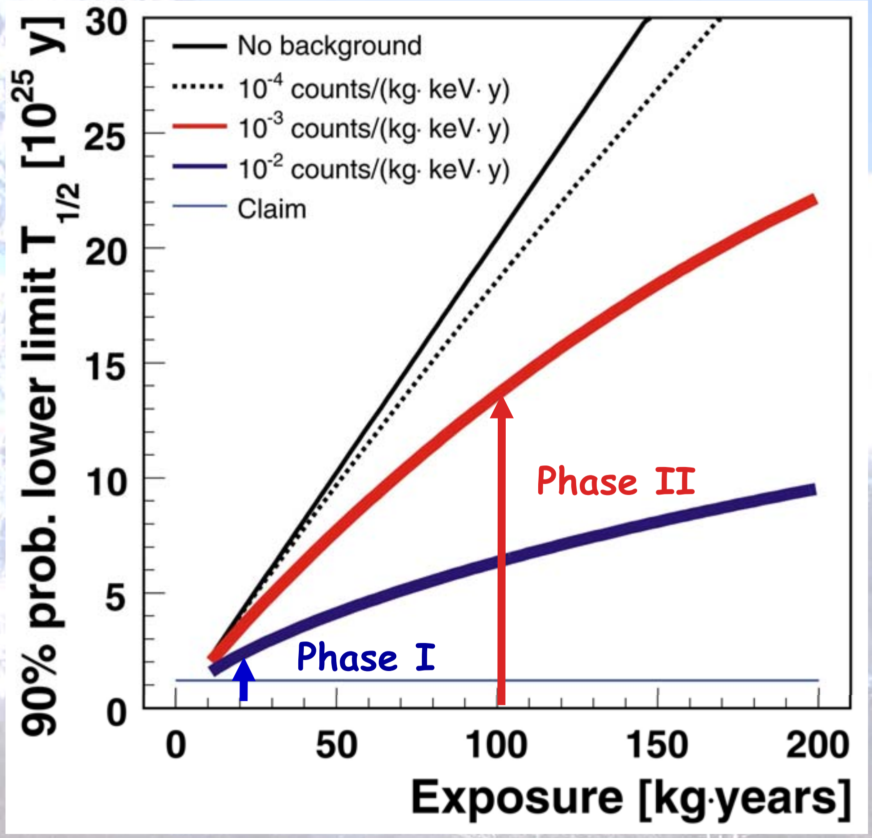
Performance not yet satisfactory, but improvement in the way (keep LAr Oxygen free)



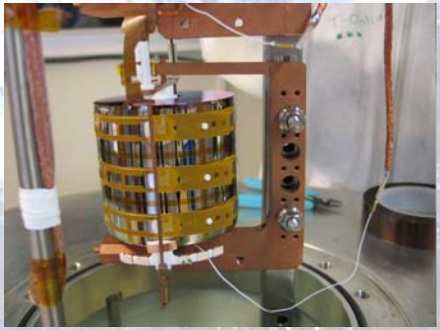
LAr + Th source left, right LN with no source

Conclusions:

- GERDA hardware at LNGS well advanced
- Clean Room to be installed until March 2009
- Commissioning lock operational early 2009
- Operation of 18-fold n-type HPGe detector in LN successful
- New 18+1 fold segmented detector for understanding of surface effects
- Simulation of Pulse Shapes
- GERDA data taking will start next year



GERDA Phase II Detectors Deliverables:

1. Enrichment	2. Purification	3. Crystal growing	4. Detector Fabrication
✓	✓	✗	✓
ECP,Russia  37,5 kf of enriched Material delivered	**PPM, Germany** 20% World supply 90% High yield. No isotopic dilution with depleted material Enriched material will be processed in 2009	**IKZ,Berlin:** •Grown first crystal •Purity needs improvement **Canberra, Oak Ridge:** Alternative to n-type segmented detectors: p-type BeGE detectors with high pulse shape discrimination efficiency	**Canberra-France** Prototype detector working  Operated detector inside cryoliquid