The GERDA Experiment

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on behalf
of the GERDA Collaboration

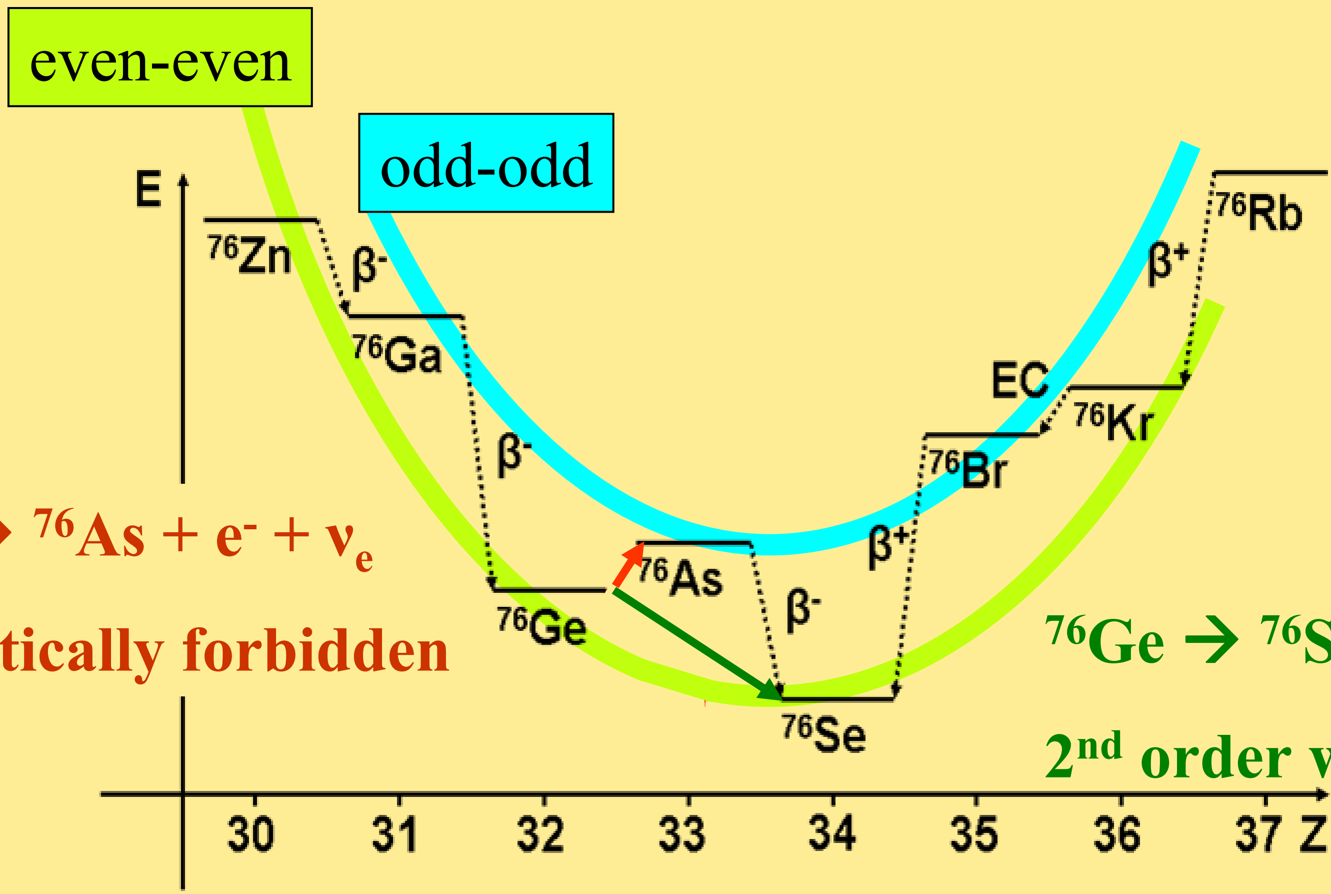
DPG-Meeting, Freiburg, 03.03.2008

Overview

- The neutrinoless double beta decay ($0\nu\beta\beta$)
- $0\nu\beta\beta$ in Germanium
- Design and Goals of GERDA
- Germanium Detectors
- Status Hardware Components
- Summary

What is the Double β Decay (ββ)?

<u>ββ:</u> •Normal β decay energetically forbidden
•Only observable in even-even nuclei



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

energetically forbidden

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

2nd order weak process

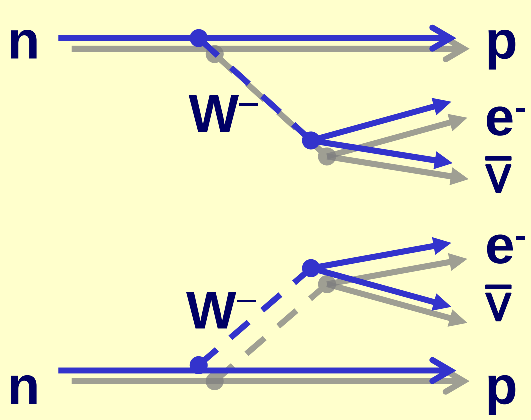
What is the 0νββ decay?

- Decay width of 0νββ: $\Gamma = G \cdot |M_{nucl}|^2 \cdot \langle m_{\beta\beta} \rangle^2$ (Phase space: G; Nuclear matrix element: $|M_{nucl}|^2$)

- Effective Majorana Neutrino Mass (coherent sum)

$$\langle m_{\beta\beta} \rangle = \left| \sum_j m_j U_{ej}^2 \right| = \left| m_1 \cdot |U_{e1}|^2 + m_2 \cdot |U_{e2}|^2 e^{i(\alpha_2 - \alpha_1)} + m_3 \cdot |U_{e3}|^2 e^{i(-\alpha_1 - 2\delta)} \right|$$

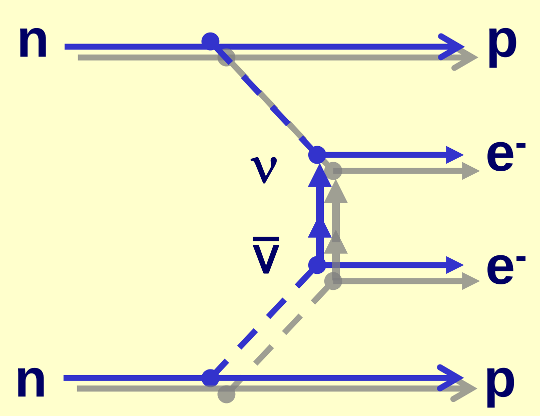
2νββ



$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^- + 2\bar{\nu}$$

$\Delta L = 0$

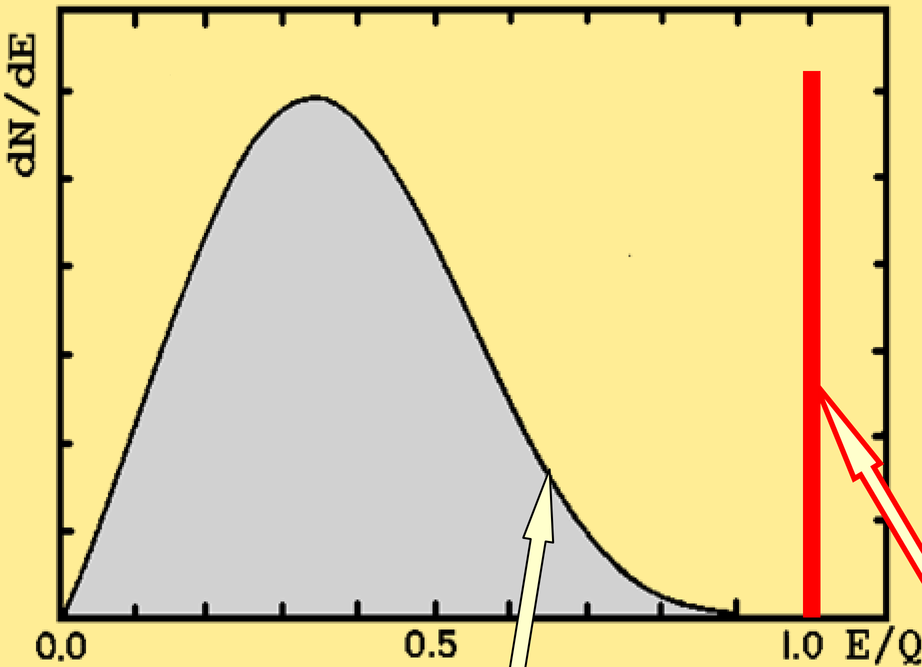
0νββ



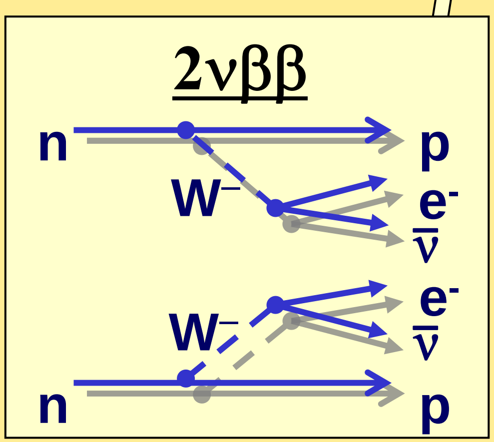
$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^- + \cancel{2\bar{\nu}}$$

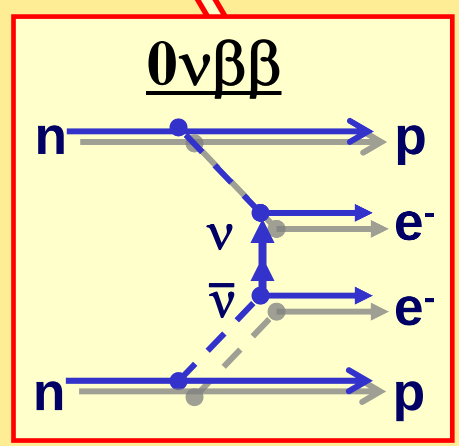
$\Delta L \neq 0, \ \nu = \bar{\nu}, \ m_\nu > 0$

Measure $T_{1/2}$ of $0\nu\beta\beta$



- Search for energy peak at Q value
- ^{76}Ge: Q = 2039keV
- $2\nu\beta\beta$: $T_{1/2} \sim 10^{11} \cdot$ age of universe





Why ^{76}Ge ?

• <u>Other candidates for ββ:</u>

^{48}Ca, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{128}Te, ^{130}Te, ^{150}Nd, …

• <u>Advantages:</u>

- Source = Detector => high signal efficiency (~90%)
- Excellent energy resolution:
  ~3keV at $Q_{\beta\beta}$=2039keV => small search window => low BG
- Ultra Pure Material => low BG level
- Experience with low-level Germanium spectrometry

• <u>"Disadvantages"</u>

- natural ^{76}Ge abundance = 7.6%,
  But: - enrichment possible (up to ~86%)
  -Use of existing Ge-Diodes from old experiments (HdM, IGEX)

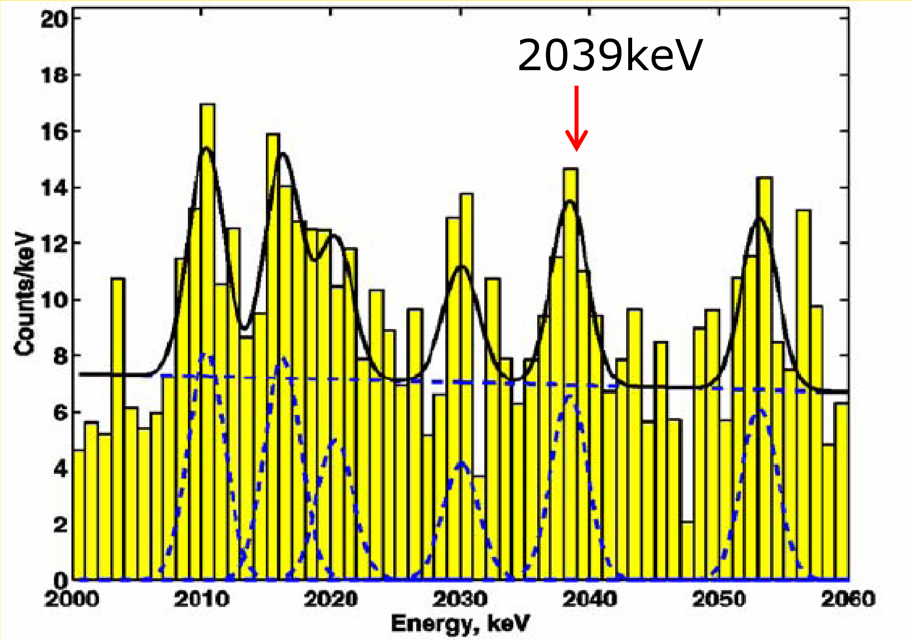
Previous ^{76}Ge Experiments

	HdMo	IGEX
exposure[kg·y]	71.1	8.87
B [counts/kg·keV·y]	0.11	0.2
$T_{1/2}$ lower limit (90%CL)[y]	$1.9\cdot10^{25}$	$1.6\cdot10^{25}$

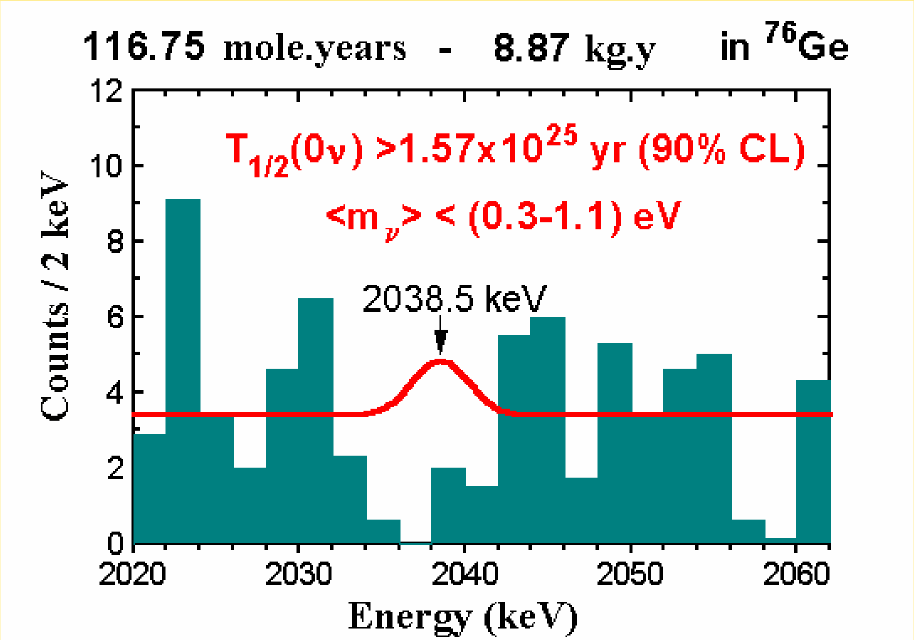
"Evidence for 0νββ" $1.2\cdot10^{25}$ (0.69-4.18 4.2σ)

H.V.Klapdor-Kleingrothaus, etc., Phys. Lett. B 586 (2004) 198-212

HdMo



IGEX



GERDA

GERmanium Detector Array

The GERDA Collaboration

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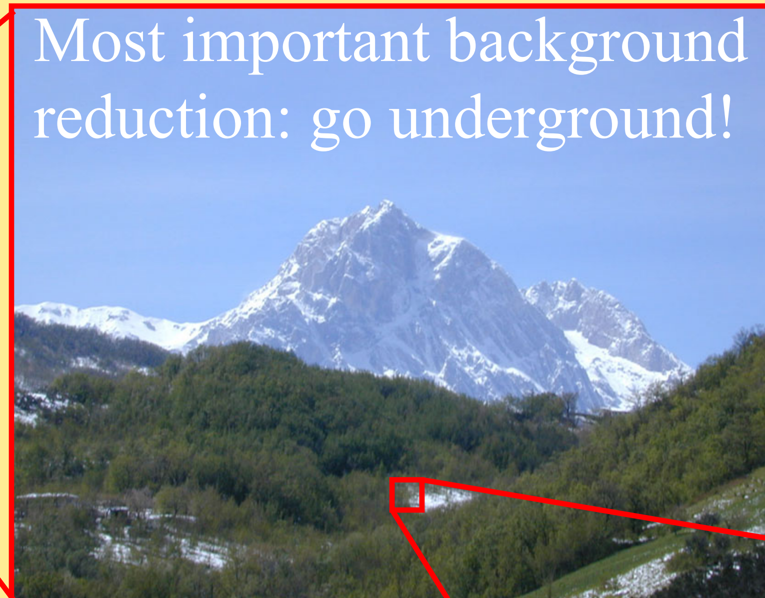
~93 members
14 institutes
6 countries

GERDA at LNGS

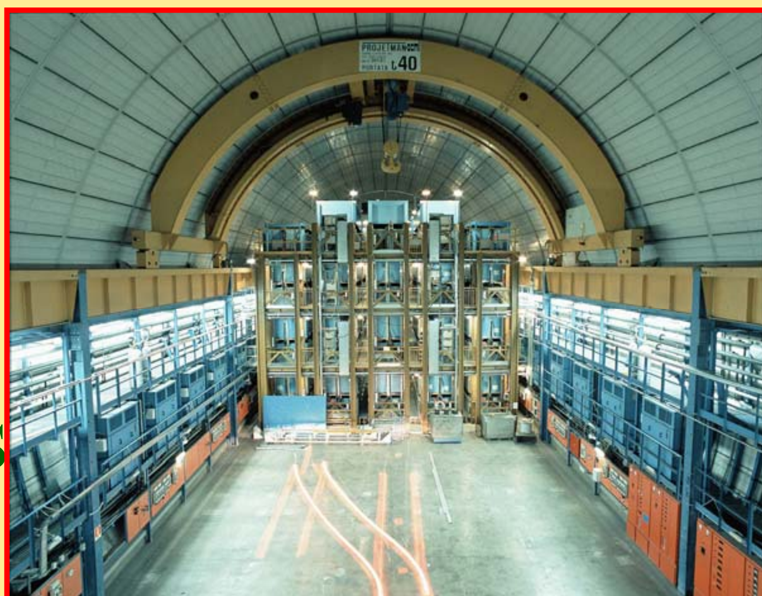
Most important background reduction: go underground!

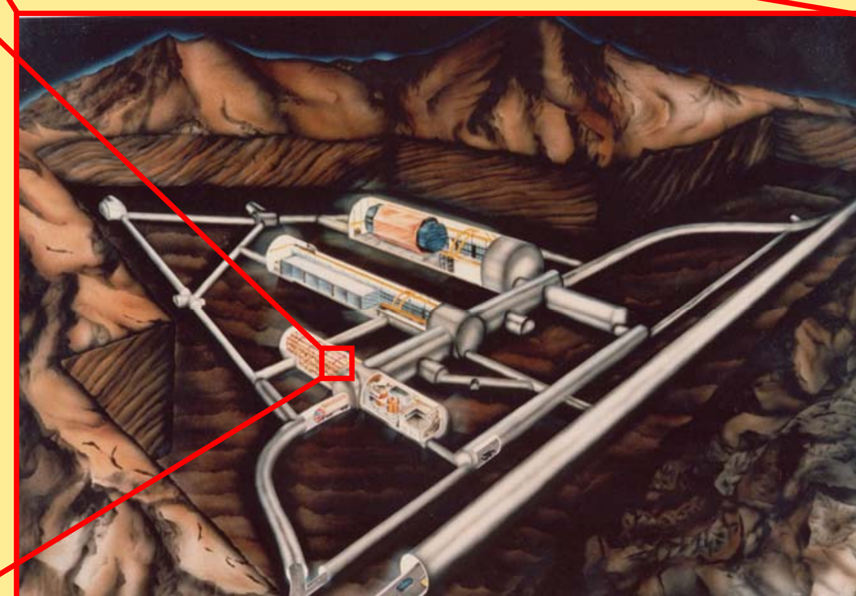


1400m
(3500m.w.e.)

Laboratori Nazionali del Gran Sasso

GERDA location: Hall A of LNGS





Main Features of GERDA

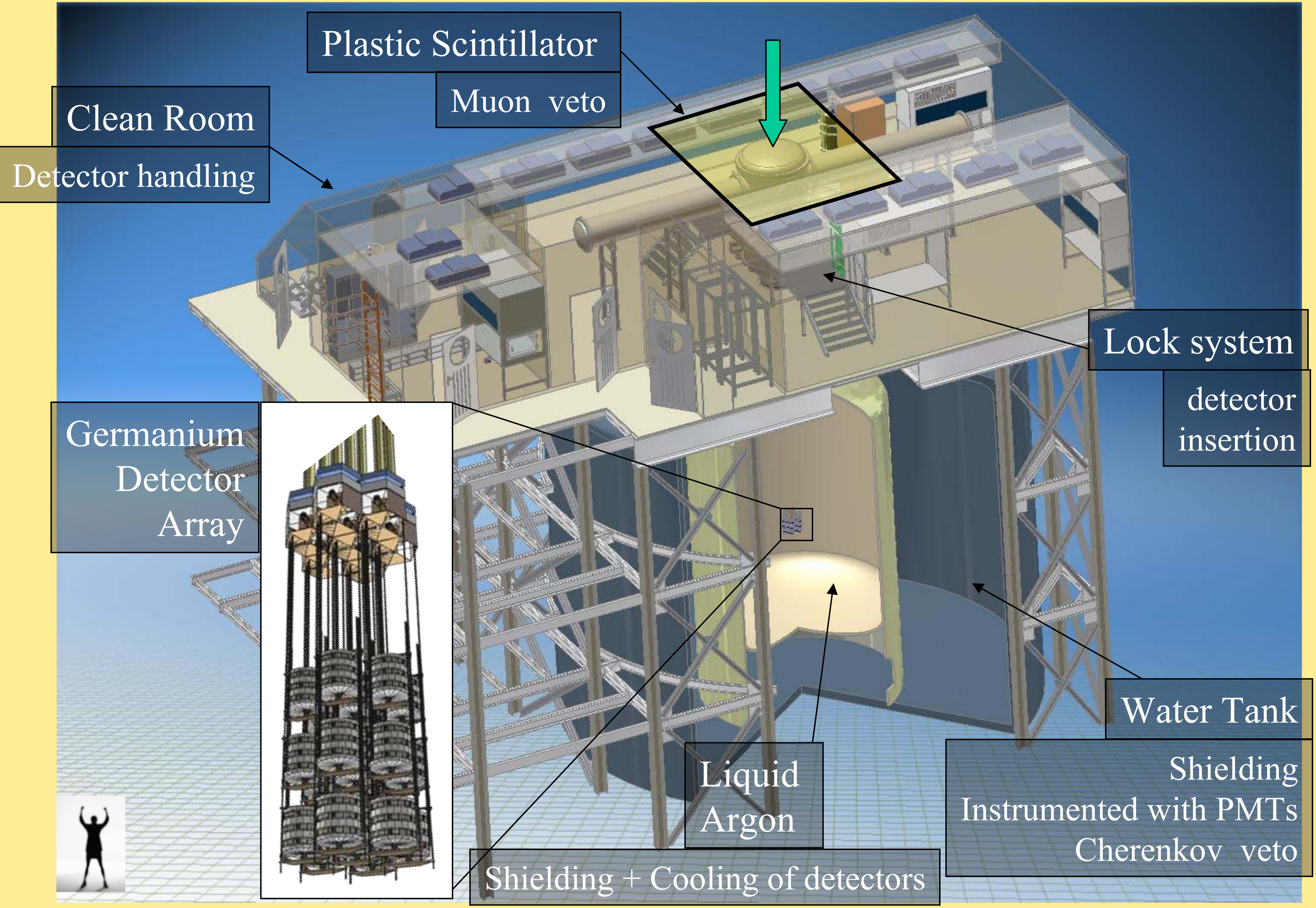
- Background in previous experiments mainly due to **cryostat** and **diode holder**
  → submerge **nacked Ge** diodes directly in **cryogenic liquid**

-Minimization of surrounding material

-Cooling
-Shielding
-Production of very radio-pure Liquid Argon possible

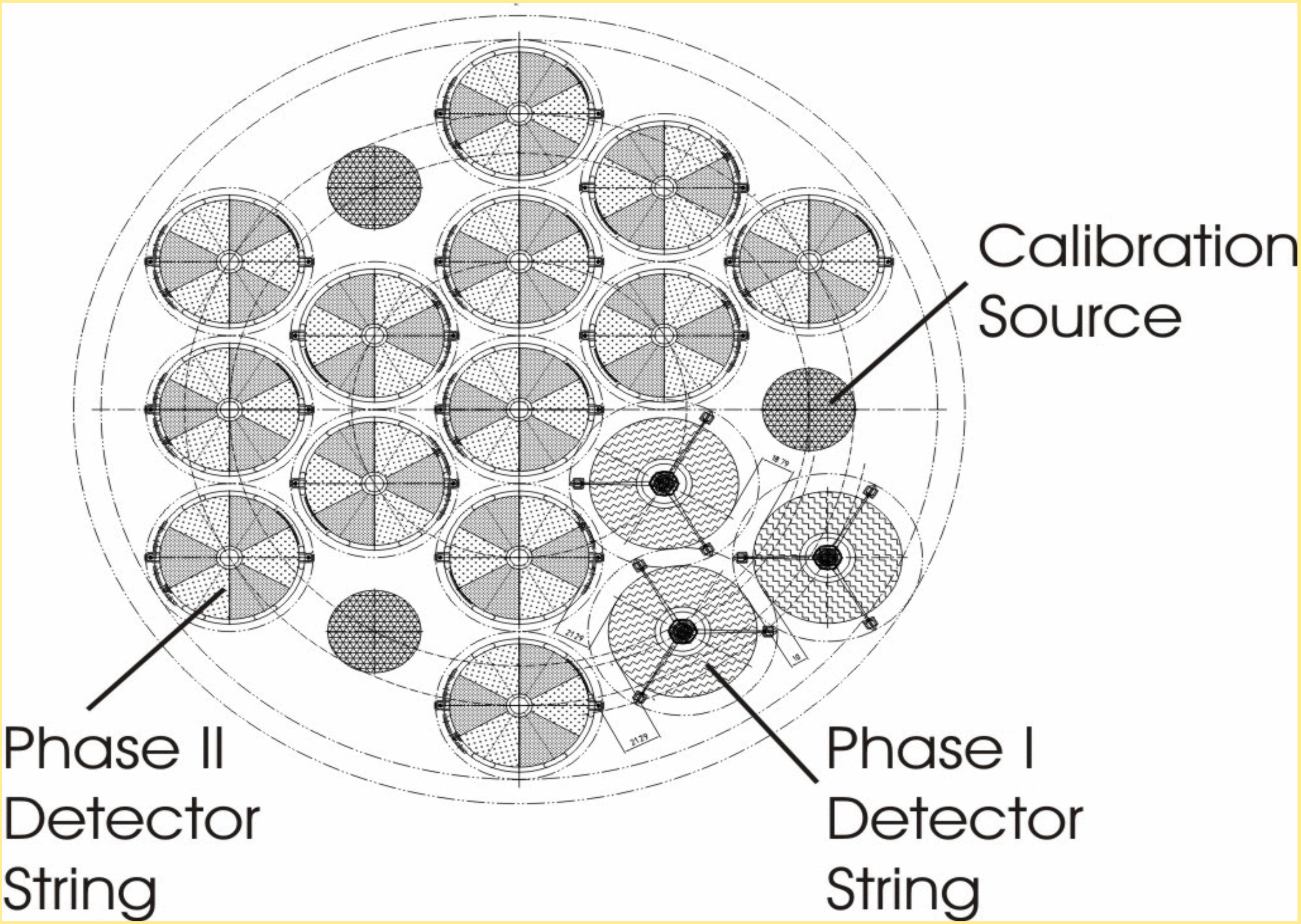
- Further BG reduction by **segmented detectors**

Design of GERDA

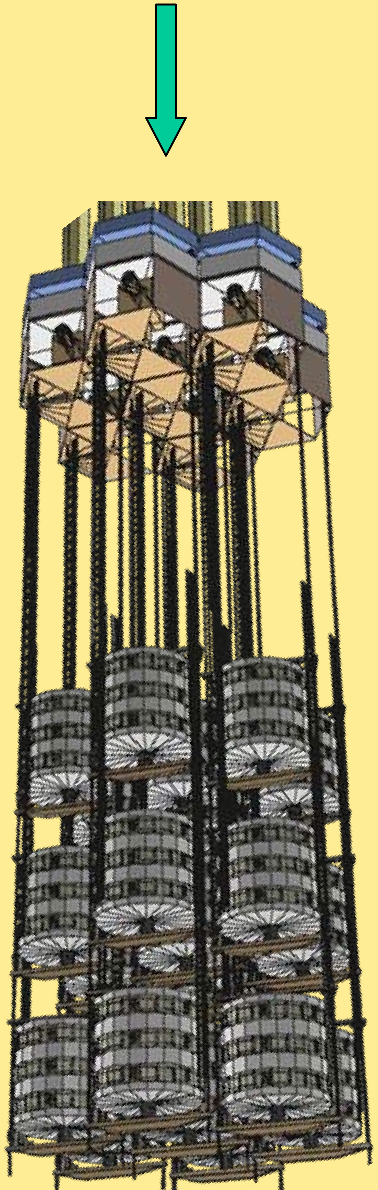


GERDA Detector Array

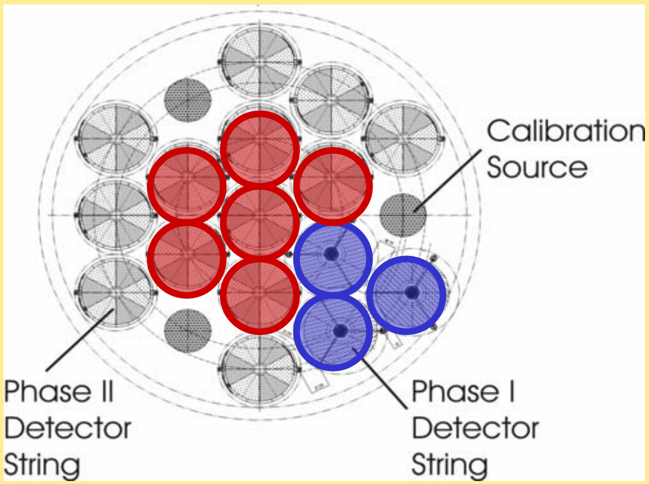
top view:



~40cm



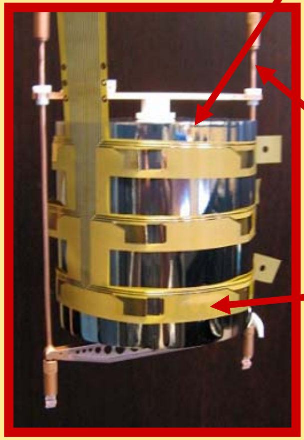
GERDA Phase Approach

phase	I	II
detectors 	5 Hd-Mo & 3 IGEX detectors, 17.9 kg 	18-fold segmented ~25kg 
exposure[kg·y]	30	100
bg [counts/(kg·keV·y)]	10E-2	10E-3
limit on $T_{1/2}$ [10E25 y]	verify/refute KK-claim	15
limit on $m_{\beta\beta}$ [eV]	0.27	0.13

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

MC Simulation of Background (Phase II)

- Simulation software **MaGe**: -Majorana & Gerda collaboration
  -based on Geant4
- Numbers correspond to the first design plans,
- new Simulation with real design is in work (→T30.7 Daniel Lenz)



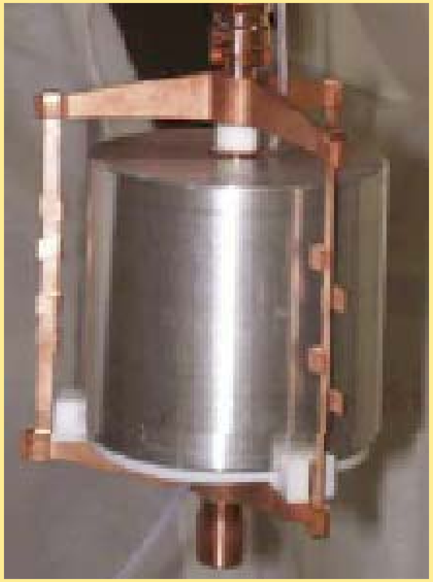
Part		Background contribution [10^{-4} counts/(kg·keV·y)]
Detector	^{68}Ge	4.3
	^{60}Co	0.3
	Bulk	3.0
	Surface	3.5
Holder	Cu	1.4
	Teflon	0.3
Cabling	Kapton	1.5
Electronics		3.5
LAr		1.0
Infrastructure		0.2
Muons and neutrons		2.0
Total		21.0

Phase-I Detectors

Heidelb.-Moscow

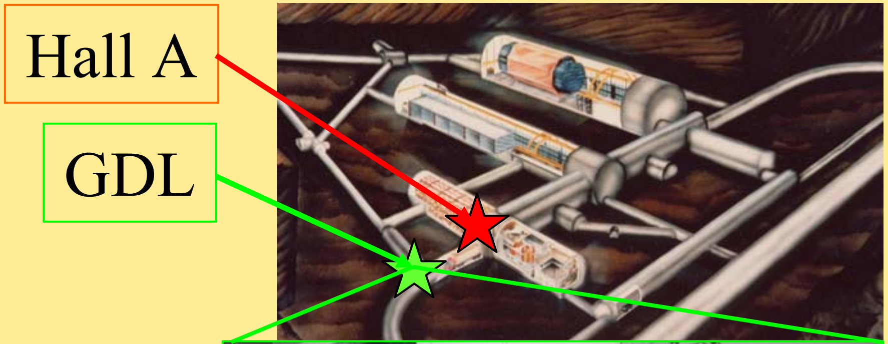
IGEX

- Inherited diodes
- Existing detectors were removed from old cryostats
- Measurement of dimensions, leakage currents, …
- Reprocessing of all diodes at manufacturer



- Underground storage in between
- Development of low-mass Detector-holders

Phase-I Prototype Testing



- performed in the GERDA Detector Lab (GDL) at LNGS

- Definition of detector handling protocol

  >40 warm up and cool down cycles in LAr

- Study of leakage current (LC) in diodes when irradiating with γ-sources

  Stable operation with LC~10pA possible

(→ T87.9 M. Barnabe Heider)

Production of Phase-II Detectors

✓ Enrichment of Material:

•37.5kg GeO_2 procured

(87% enrichment in ^{76}Ge)

R&D Reduction to Ge Metal + Zone Refinement:

Tests with 50kg depleted GeO_2

-no isotopic dilution

-high Purity (<6N), high yield (90%)

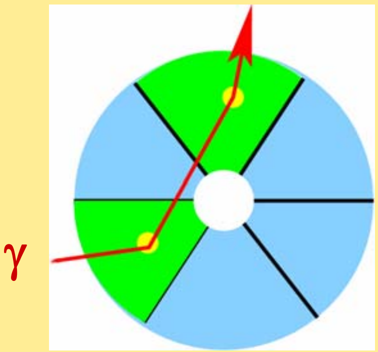
R&D Crystal Pulling:

IKZ, Berlin

✓ Detector production:

• Canberra-France: two prototype detectors good performance

Phase-II: γ Background Identification by Detector Segmentation



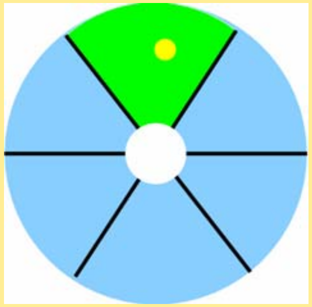
γ background

(MSE multi-site event)

$\lambda \sim$ a few cm

18 segments

6(ϕ) x 3(z)



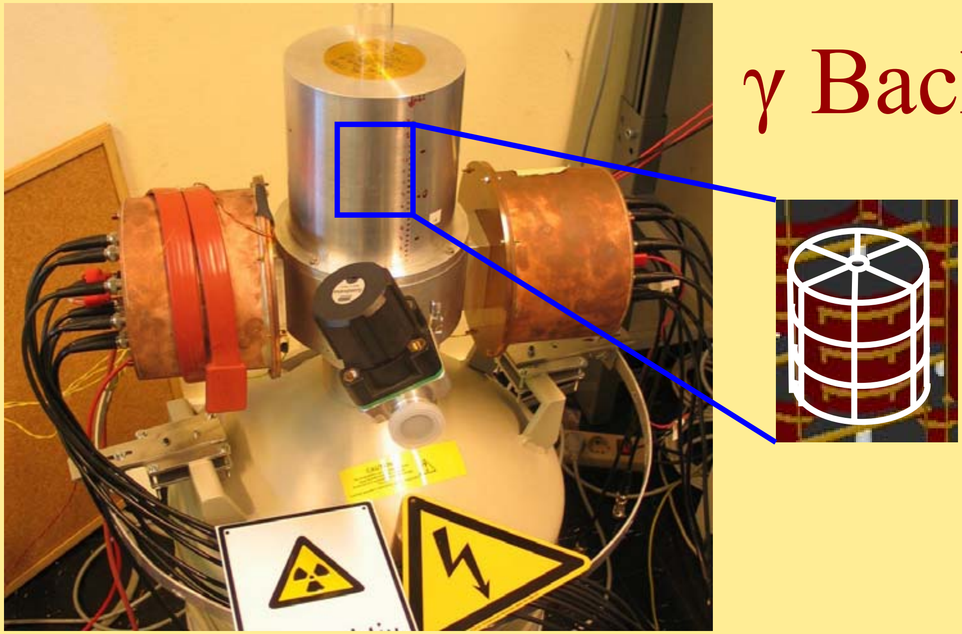
Signal: 2 electrons

(SSE single-site event)

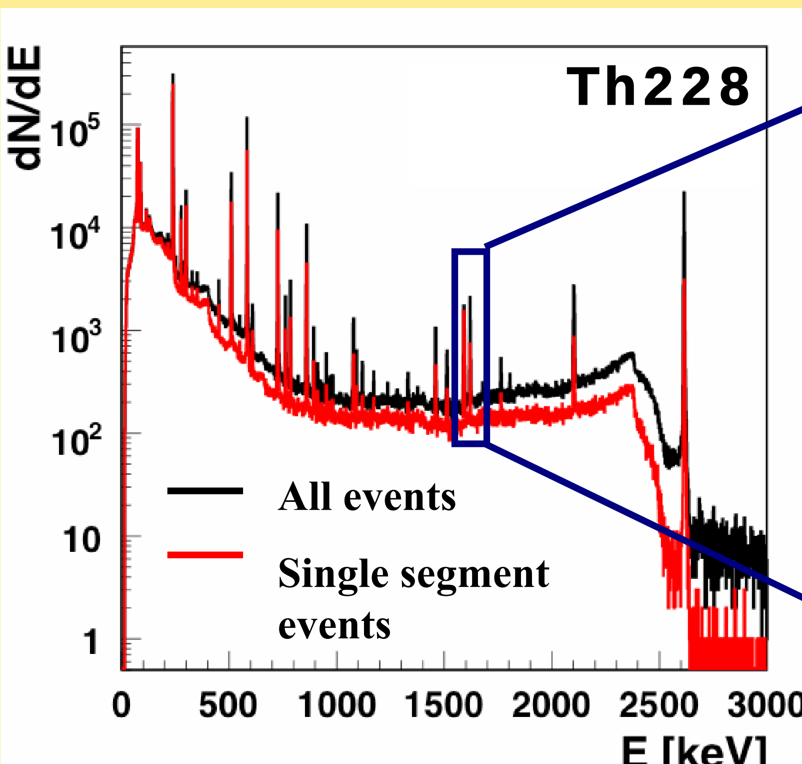
$\lambda \sim$ a few mm

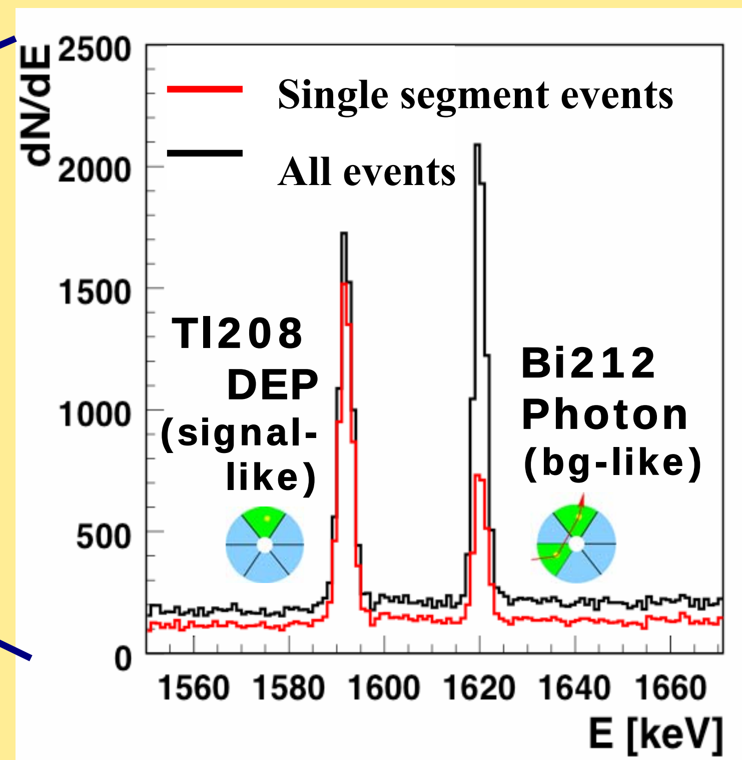
(λ = mean free path length)

γ Background Identification



- Suppression factor of 3 at $Q_{\beta\beta}$ for γ BG
- Signal-like events nearly unsuppressed
- Further BG identification by pulse shape analysis





Construction has started

Bottom plate of water tank
installed in Hall A at LNGS

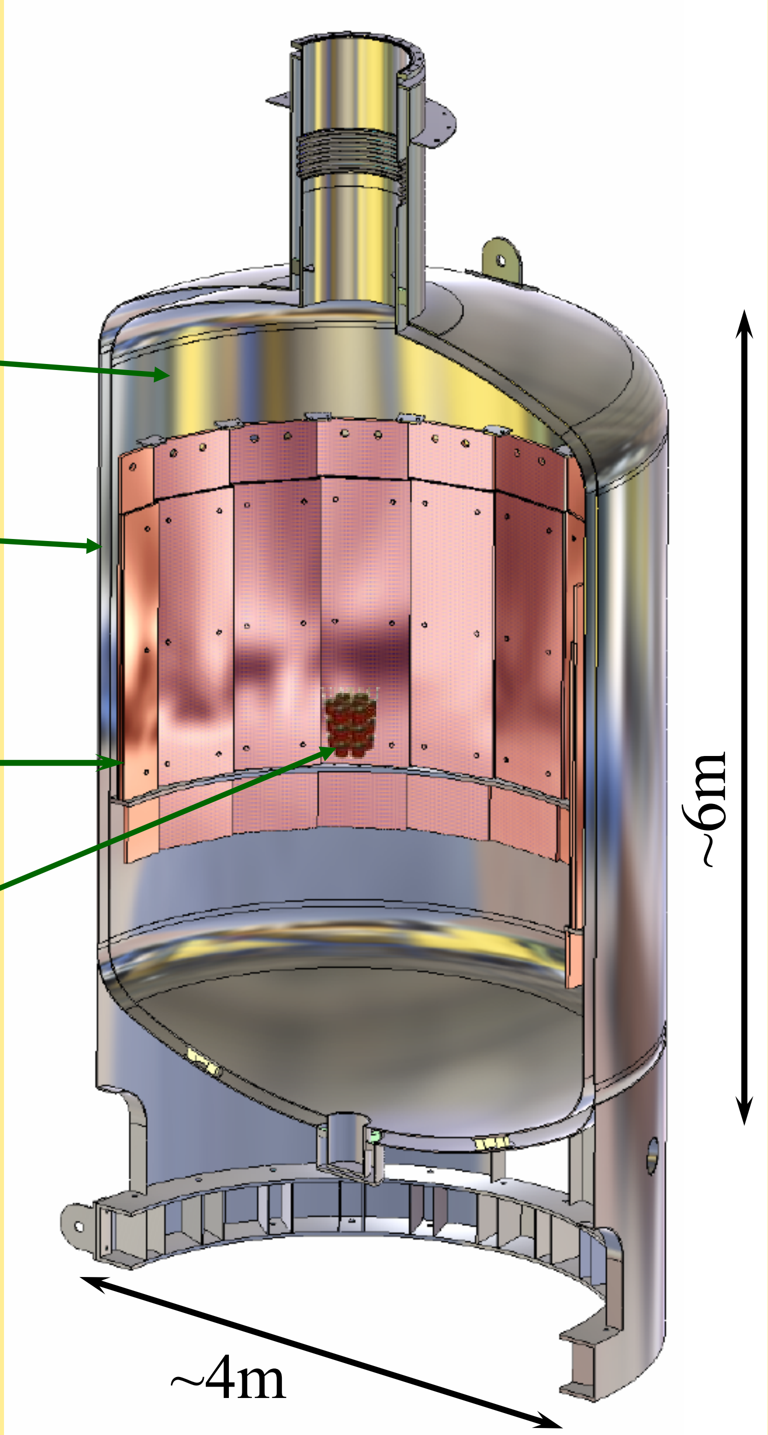
The Cryostat

~70m³ liquid Argon

Two vessels of stainless steel
(thickness : 12-20mm)
8cm vacuum gap for insulation

Copper Shield
(thickness: 6cm)

Ge Detector Array



The Cryostat

• December 2007: Insertion of inner vessel into outer vessel

• Construction completed, ready to go to LNGS

More about the Cryostat in T87.6 and T87.8

Summary

- Neutrinoless double beta decay:
  - Majorana particle? $\nu = \bar{\nu}$? $\langle m_{\beta\beta} \rangle = ?$
- GERDA
  - Phase I: KK-claim → 13signal and 3 background events
  - Phase II: sensitivity limit $T_{1/2} = 15 \cdot 10^{25}$y
- Build up at LNGS has started

DPG Talks Related to GERDA

MONDAY: Neutrinophysik mit Beschleunigern I
-Dieser Vortrag: Montag 17:35-17:55
-T30.5 Jing Liu: Neutron Interactions as seen by segmented Germanium Detectors
-T30.6 Xiang Liu: Effect of IR and UV Light on Naked Germanium Detectors
-T30.7 Daniel Lenz: Estimate of the Internal Gamma Background of the GERDA Experiment

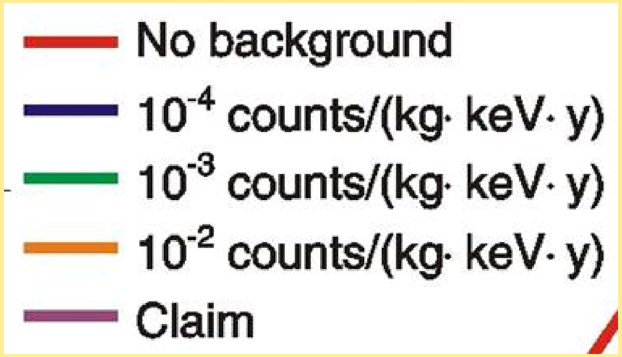
TUESDAY 1: Neutrinophysik mit Beschleunigern II
-T31.5 Georg Meierhofer: Untergrund durch n-Einfang an Ge76
-T31.6 Florian Ritter: Das GERDA Myonveto

TUESDAY 2: Niederenergie-Neutrinophysik und Suche nach Dunkler Materie II
-T87.6 B. Schwingenheuer: Design des GERDA-Kryostaten
-T87.7 P.Pfeiffer: Untersuchungen zur Untergrunddiagnose mittels LAr-Szintillator bei GERDA
-T87.8 W. Maneschg: Gammaspektroskopie-Messungen von Edelstahl fuer GERDA
-T87.9 M. Barnabe Heider: Operation of a GERDA Phase I prototype detector in liquid Argon

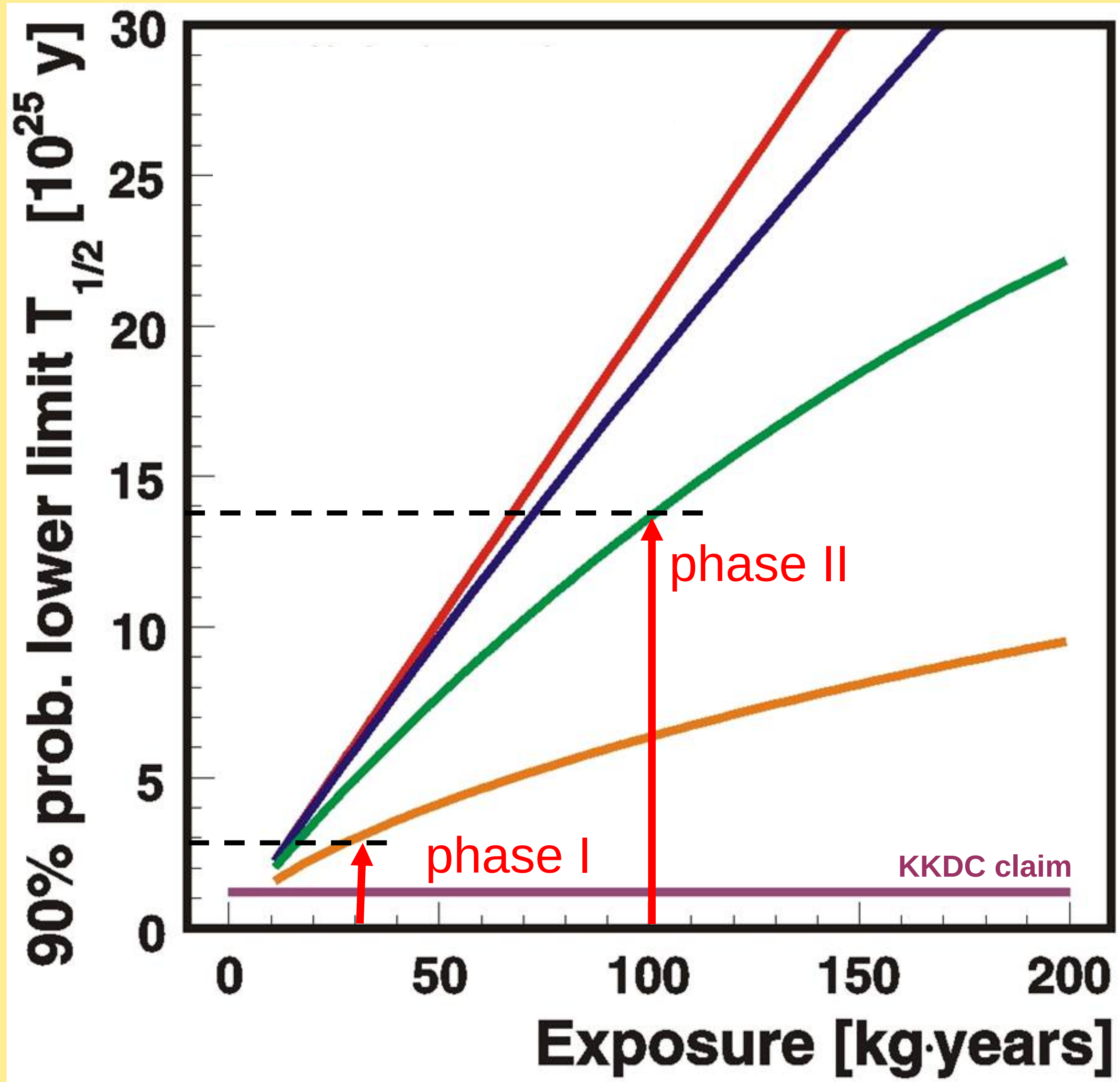
FRIDAY: Experimentelle Methoden
-T68.8 H. Simgen: Radon emanation measurements in the frame of GERDA

BACKUP SLIDES

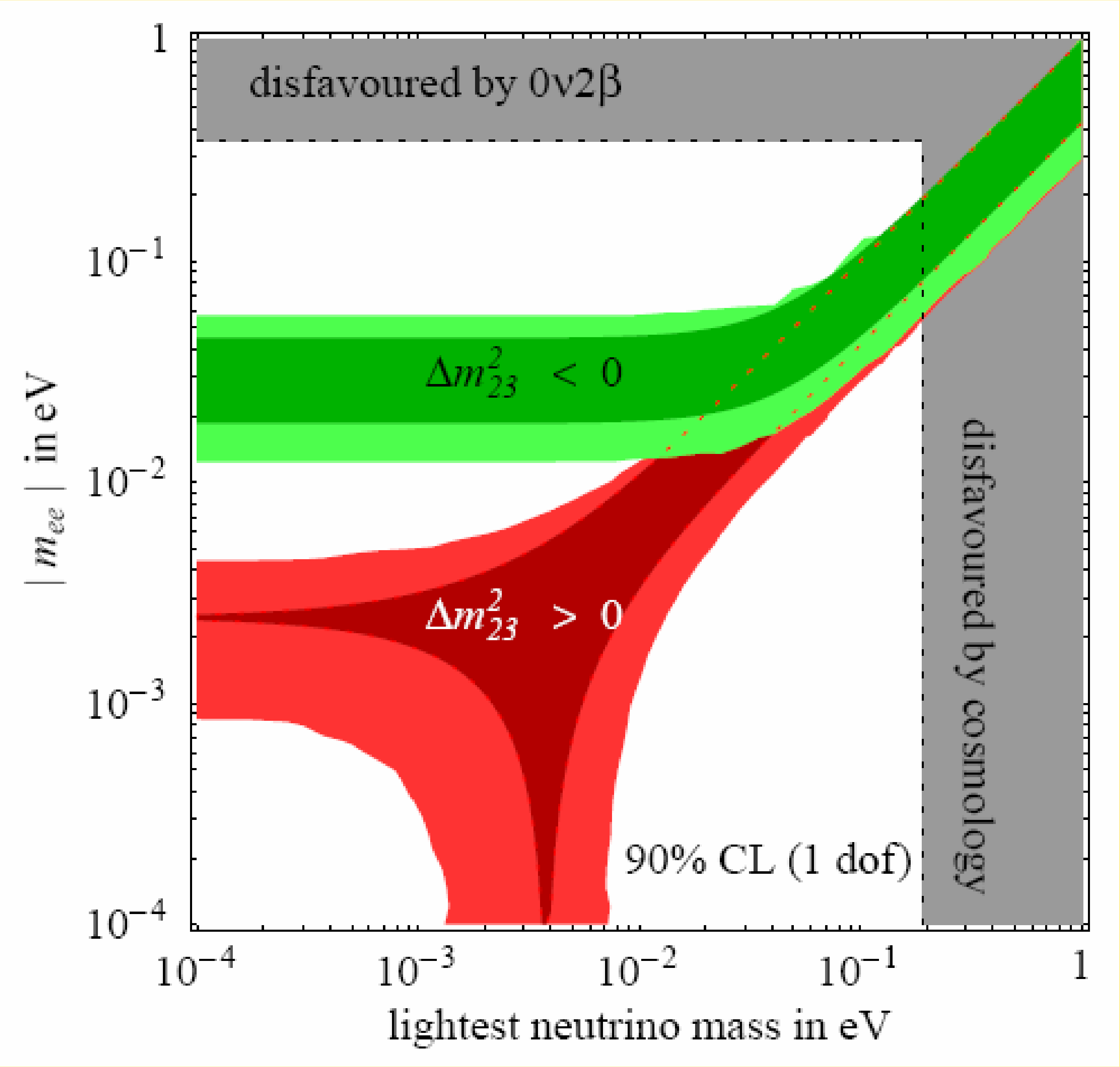
GERDA sensitivity on $T_{1/2}$



assumed energy resolution:ΔE = 4keV



Background reduction!!!


disfavoured by 0ν2β
$\Delta m^2_{23} < 0$
$\Delta m^2_{23} > 0$
90% CL (1 dof)
disfavoured by cosmology
$|m_{ee}|$ in eV
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
lightest neutrino mass in eV