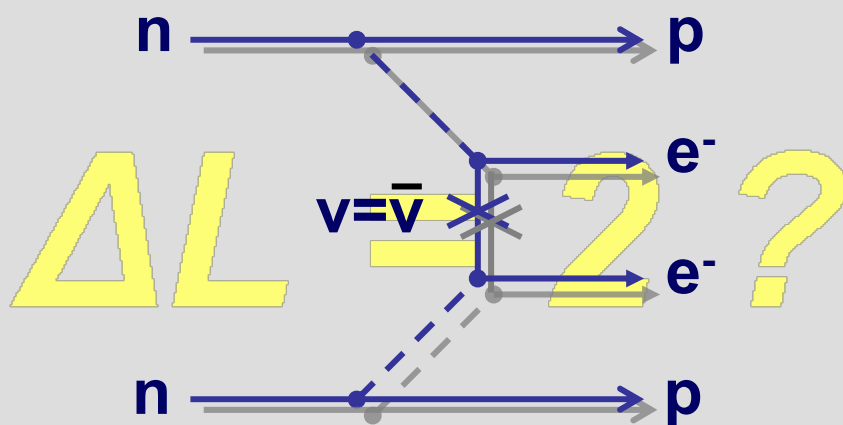




The GERmanium Detector Array



Outline:

- Exp. issues of $0\nu\beta\beta$ -decay of ^{76}Ge
- Concept of GERDA
- Status of the experiment
- Summary and conclusions

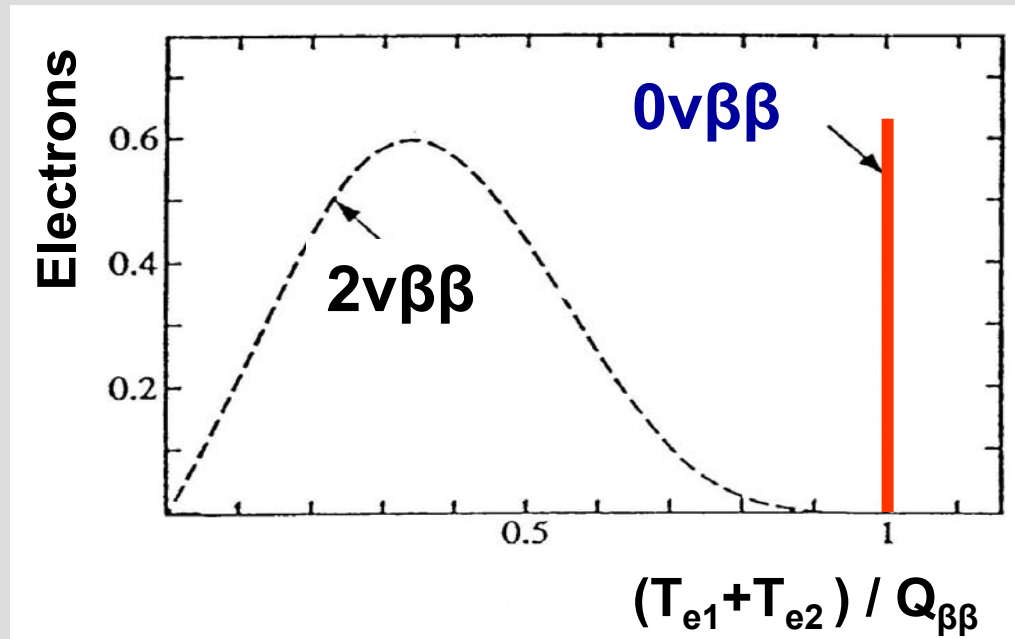
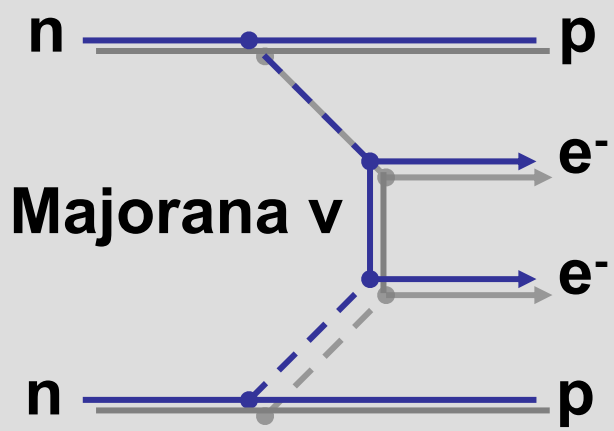
Kevin Kröninger

(Max-Planck-Institut für Physik, München)

on behalf of the GERDA collaboration

HEP2007 Manchester 19.07. - 25.07.2007

Experimental issues of $0\nu\beta\beta$ -decay of ^{76}Ge



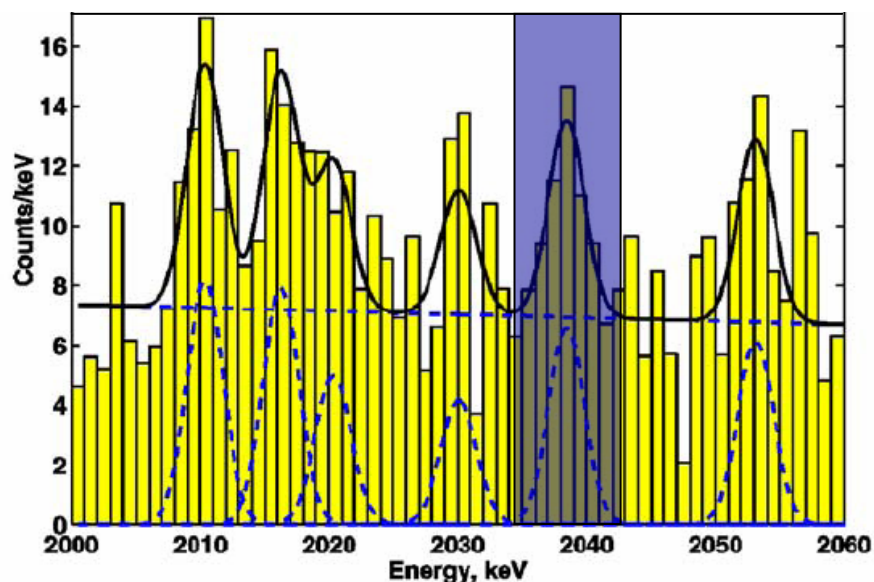
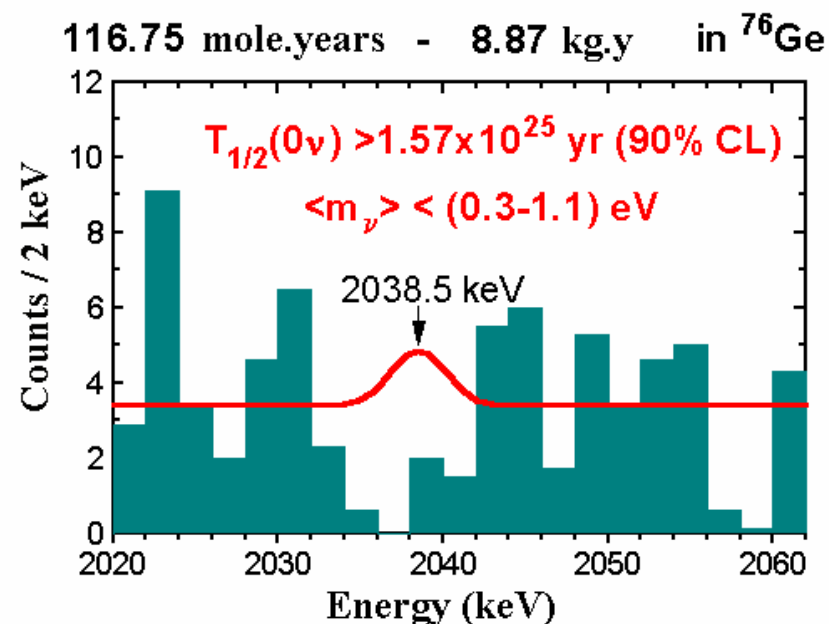
- **Detection principle:** measure ionization energy inside detector
- **Observable:** number of events at Q-value
 - half-life ($T_{1/2} \gtrsim 1.6 \cdot 10^{25}$ y)
 - Majorana ν mass ($m \lesssim 0.3$ eV)
- **Expect $O(10-20)$ signal events**
- **Background reduction drives design of the experiment**
- About 35 candidate isotopes, here: ^{76}Ge

IGEX (CanFranc)

- Enriched Ge detectors
- Total exposure ~ 8.87 kg·y
- **No signal observed**
- $T_{1/2} > 1.57 \cdot 10^{25}$ y

Heidelberg-Moscow (INFN)

- Enriched Ge detectors
 - Total exposure ~ 71.7 kg·y
 - $T_{1/2} > 1.9 \cdot 10^{25}$ y
-
- Part of collaboration: **claim**
 - $T_{1/2} = 1.2 \cdot 10^{25}$ y



High-purity germanium crystals as **source and detector**

Germanium can be used as semiconductor detector at ~ 80 K

Measure ionization energy in shielded detector

High signal efficiency 86% - 96%

Operation of detectors directly inside a **cryogenic liquid**

NEW

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

→ GENIUS (1999), GEM (2001), **GERDA** (2004)

Reduction of background to **10^{-3} counts/(kg·keV·y)**

Minimize radioactive contaminations close to the detectors

Use of segmented germanium detectors in second phase

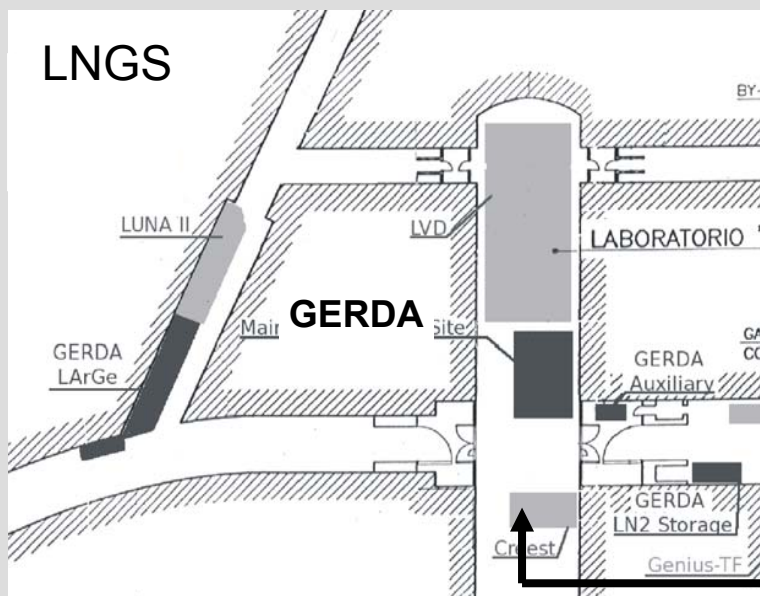
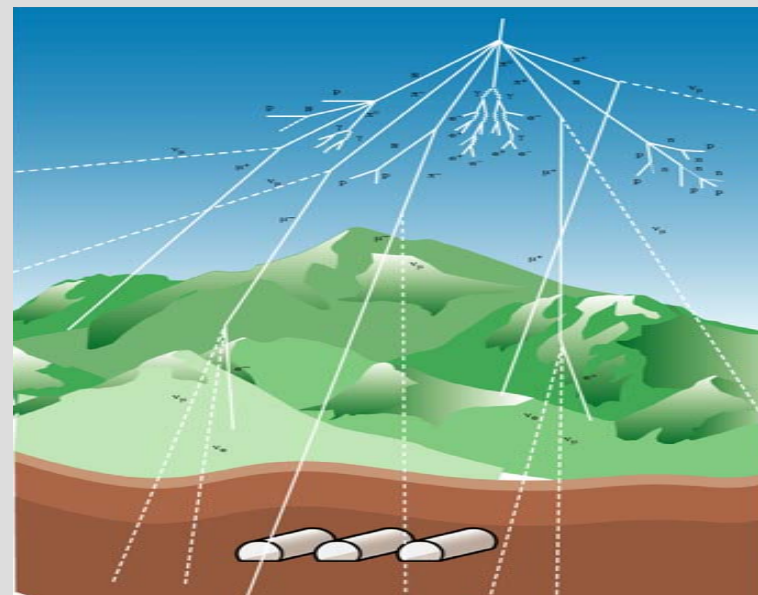
NEW

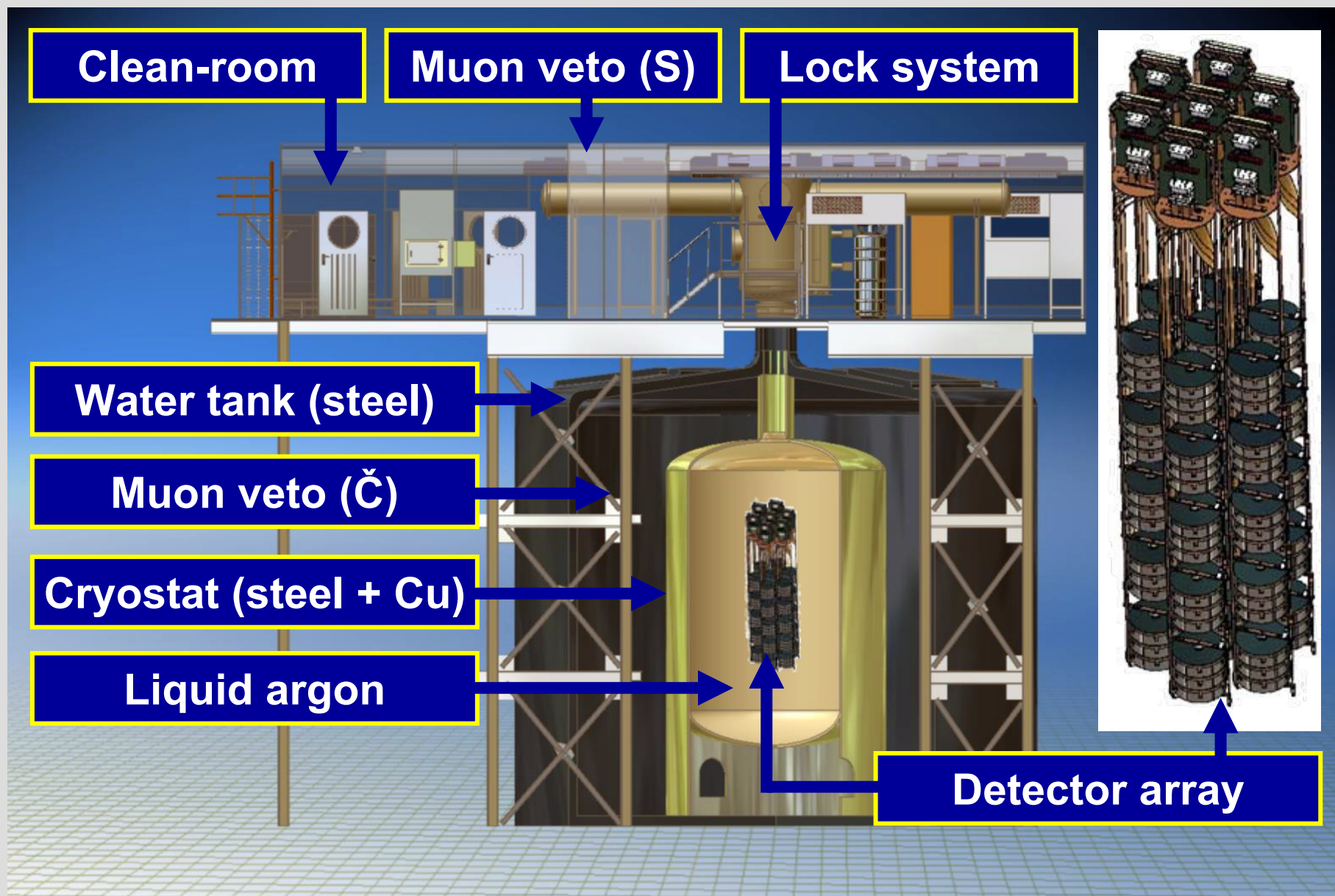
2 orders of magnitude below that of previous experiments

Sensitivity aimed at: **200 meV** (limit) at an exposure of 100 kg·y



1400 m
~ 3.800 m.w.e

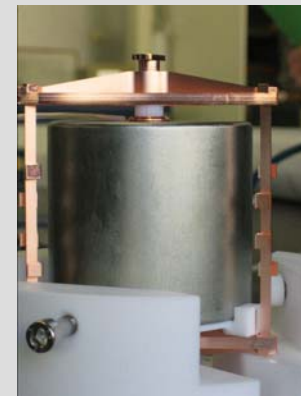




- Use enriched detectors from HdM and IGEX experiments (prev. stored at LNGS / CanFranc)
- Need to be refurbished and mounted into new holders

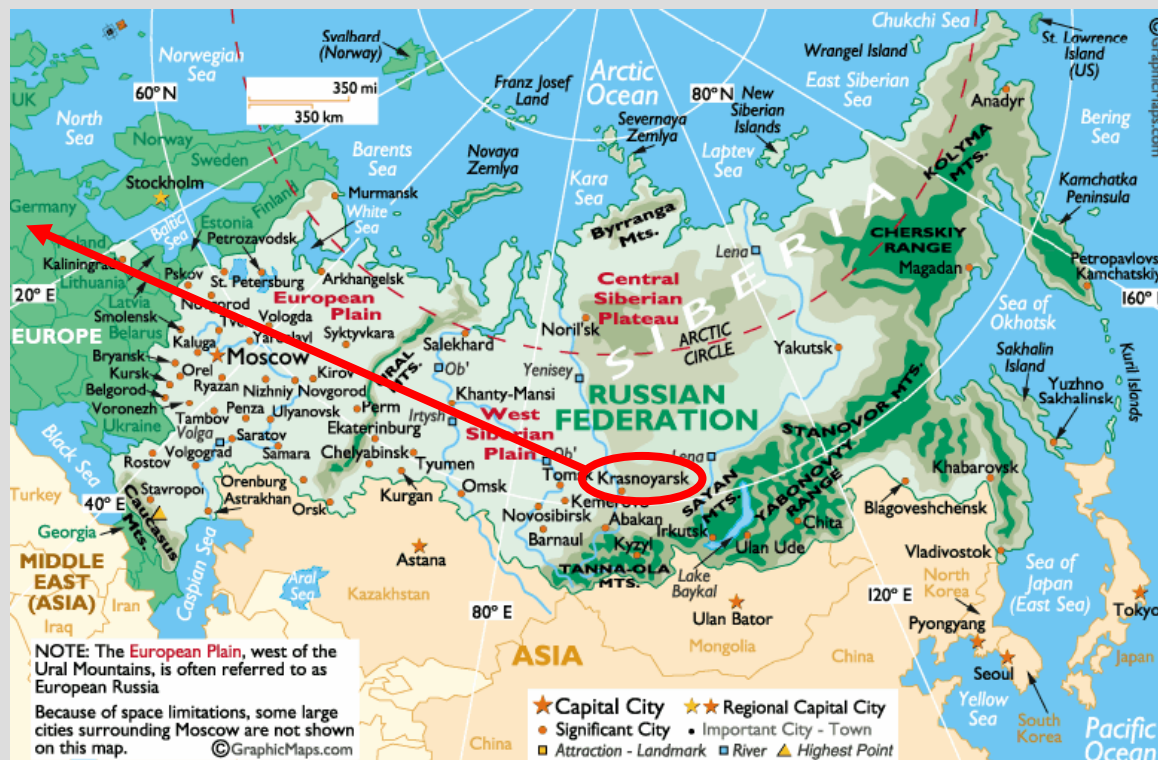


- **All detectors were tested and perform well**
- Energy resolution
~ 2-3 keV (at 1.3 MeV)
- Mass 1-3 kg,
total ~ 18 kg
- Refurbishment
in progress



Phase II detectors

- 37.5 kg germanium enriched in ^{76}Ge ~88%
- Stored underground (avoid cosmic rad.)
- Next: purification, crystal pulling, detector manufacturing



Phase I:

18 kg germanium

20 kg·y exposure

10^{-2} counts/(kg·keV·y)

Phase II:

35 kg germanium

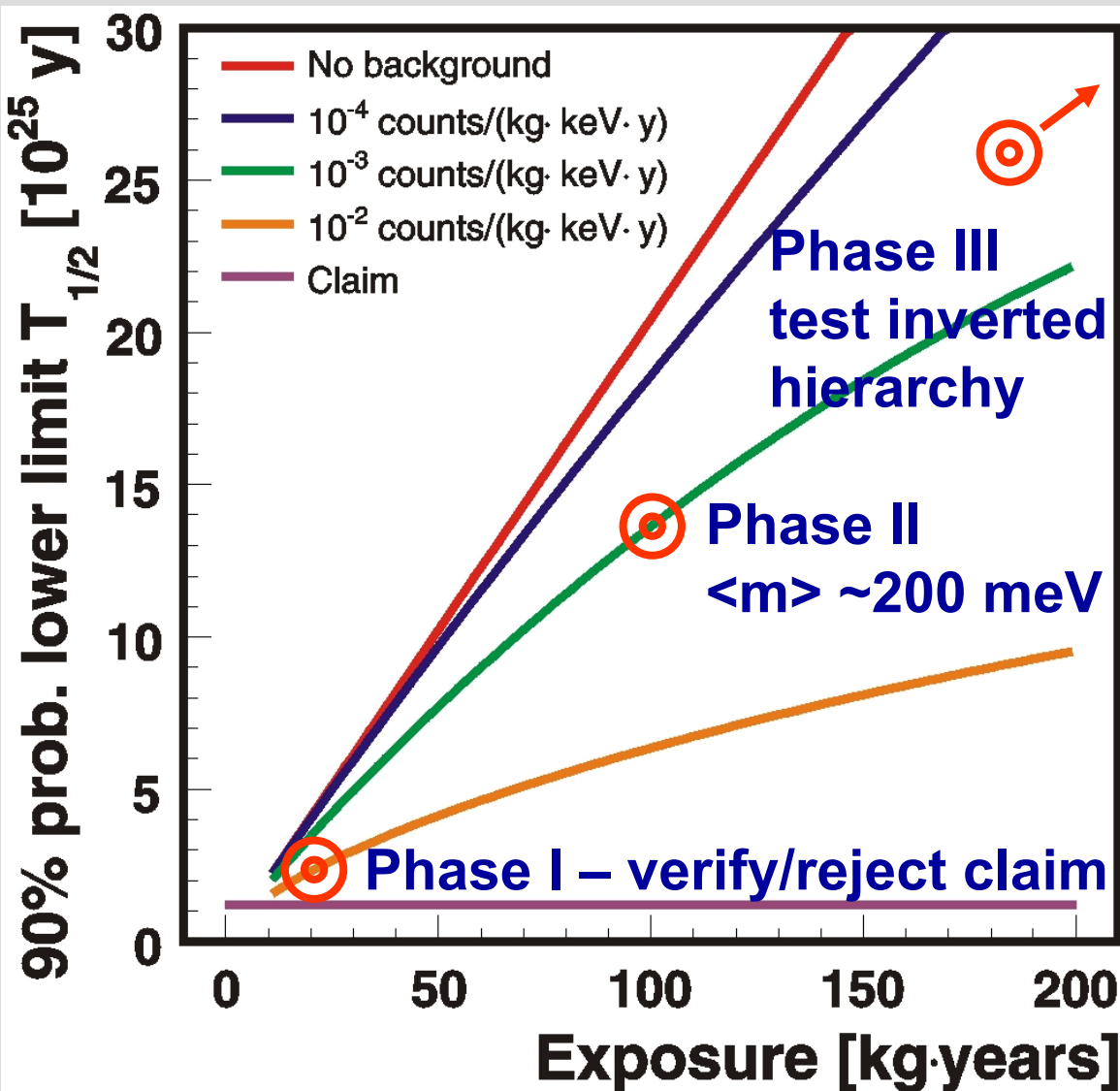
100 kg·y exposure

10^{-3} counts/(kg·keV·y)

Phase III:

500 kg germanium

$<10^{-3}$ counts/(kg·keV·y)



A. Caldwell, KK, Phys. Rev. D 74 (2006) 092003

Background: processes which cause energy deposition at Q-value

- **Cosmogenic production of radioactive isotopes**

Detector
production
and storage

- Cosmic muons

- Neutrons:

- Muon induced

- From radioactive isotopes in the rock

- Radioactive isotopes in the surrounding:

- Electrons/positrons

- **Photons**

- Alphas (surface)

Depth and
laboratory
dependent

Choice of
material close
to detectors

Purity of the
liquid argon

Background units:

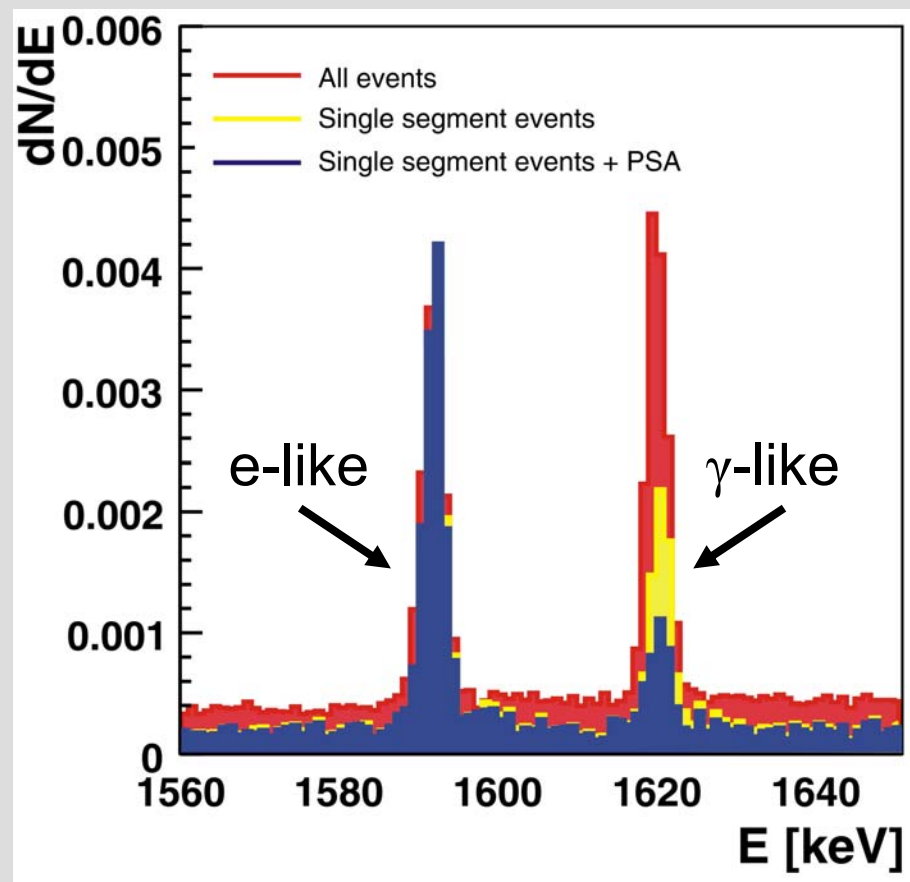
counts / (kg·keV·y)

total mass

around $Q_{\beta\beta}$

measuring time

- Rejection principle: study volume over which energy is distributed (e/γ)
- Detector anti-coincidences
- Segmented detectors (*poor man's pixilation*)
- Analysis of the detector response function (pulse shape analysis)
- R&D: active liquid argon veto (use of scintillation light)



Successful R&D program:

- I. Abt *et al.* NIMA **577** (2007) 574
- I. Abt *et al.* arXiv:0704.3016 (accepted by EPJC)
- I. Abt *et al.* arxiv:nucl-ex/0701005 (sub. to NIMA)
- I. Abt *et al.* NIMA **570** (2007) 479
- P. Peiffer *et al.*, Nucl. Phys. B. Proc. Supp. **143** (2005) 511

MC simulation of 21 detectors with 18-fold segmentation

Part		Background contribution [10^{-4} counts/(kg·keV·y)]	
Detector	^{68}Ge	10.8	
	^{60}Co	0.3	Gain through segmentation factor ~10
	Bulk	3.0	
	Surf.	3.5	Reducible via PSA
Holder	Cu	1.4	
	Teflon	2.0	
Cabling		7.6	Redesign: Reduced material
Electronics		3.5	
Liquid nitrogen		0.1	Will change with l. argon
Infrastructure		2.9	
Muons and neutrons		2.0	
Total		37.1	(30.6)

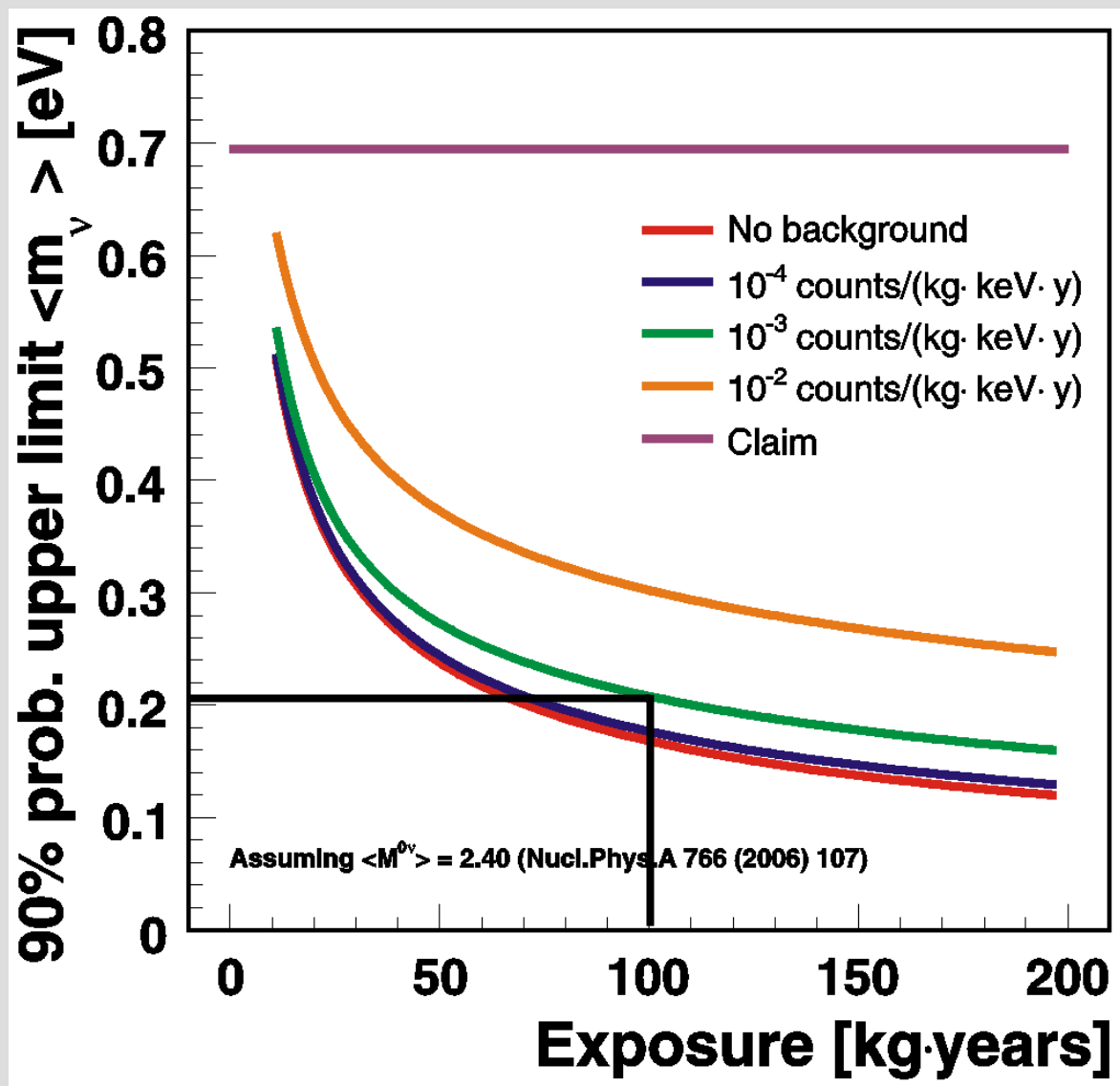
- **Construction has started**
- 2007/08: water tank and cryostat installation
- 2008: clean-room installation
- early 2009: commissioning



- GERDA is currently being built with the aim to search for neutrinoless double beta-decay
- Detector concept: germanium detectors submerged into l. argon
- Reduction of background is the most critical issue
- Background rejection techniques have been shown to work (segmentation, pulse shape analysis, liquid argon veto, etc.)
- Construction is ongoing
- Commissioning expected early 2009
- Expected sensitivity: $13.5 \cdot 10^{25}$ y (200 meV) with 100 kg·years exposure and background of 10^{-3} counts/(kg·keV·y)

The GERDA collaboration





Neutrino mass and hierarchy

