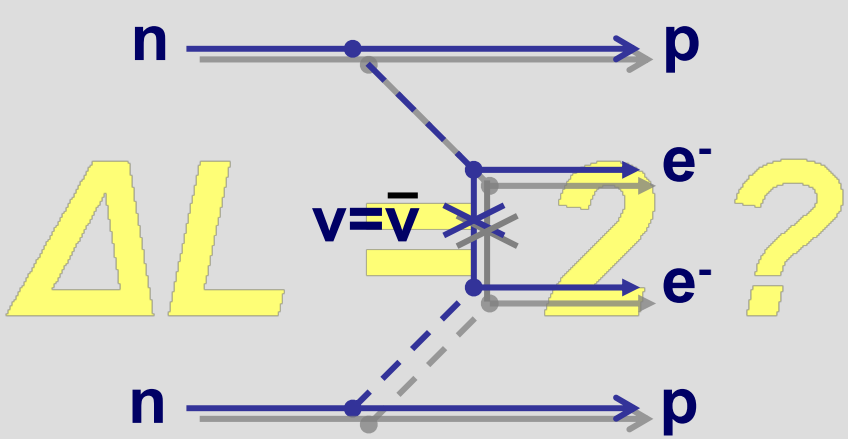
The GERmanium Detector Array



Outline:

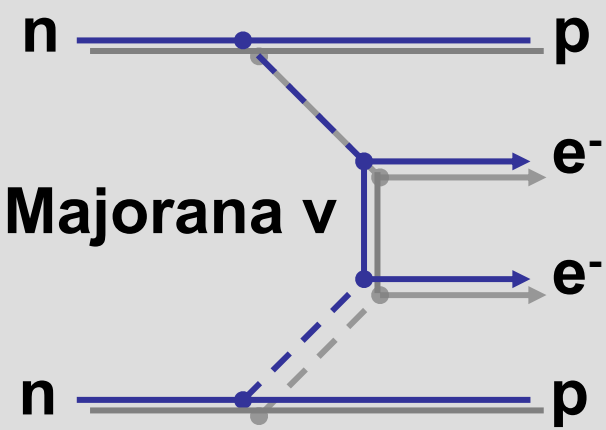
- Exp. issues of 0νββ-decay of ^{76}Ge
- Concept of GERDA
- Status of the experiment
- Summary and conclusions

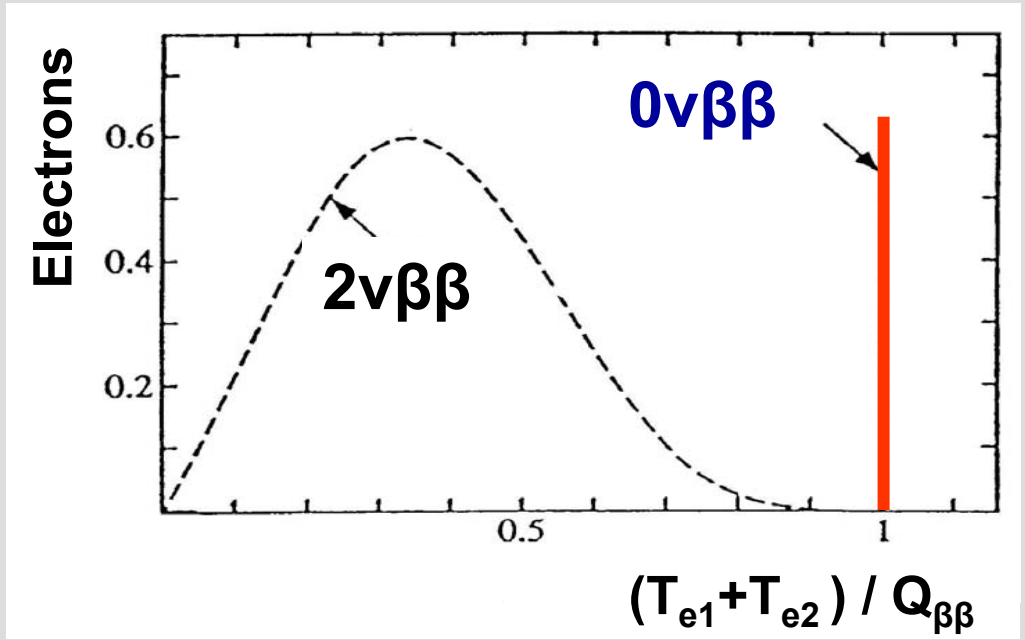
Kevin Kröninger

(Max-Planck-Institut für Physik, München)

on behalf of the GERDA collaboration

Experimental issues of 0νββ-decay of ^{76}Ge





(2039 keV)

- **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(20) signal events**[1)]
- **Background reduction drives design of the experiment**
- About 35 candidate isotopes, here: **^{76}Ge**

[1)] assuming $T_{1/2} \sim 2 \cdot 10^{25}$y

Previous (and recent) experiments

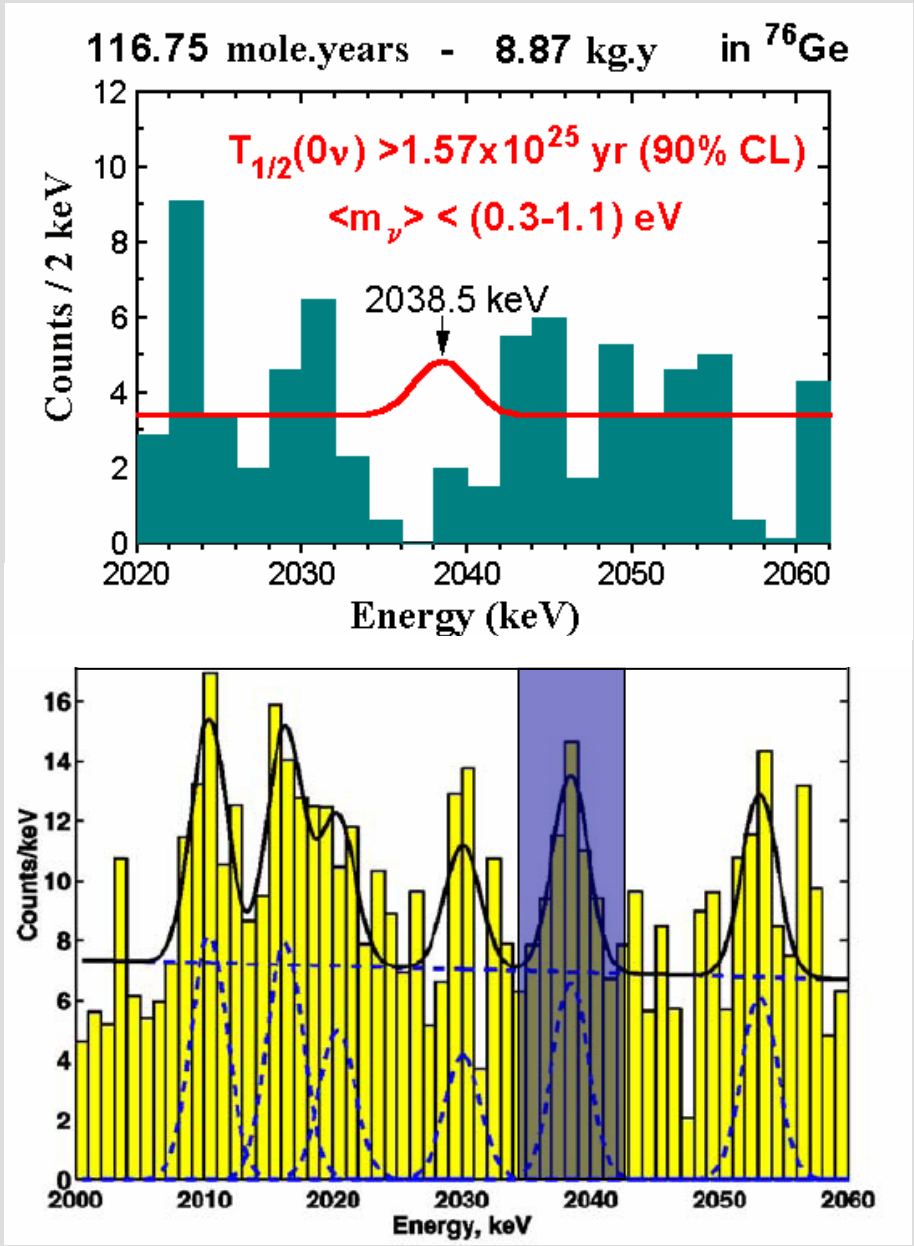
IGEX (Canfranc)

- 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**
- $T_{1/2} = (0.7 - 4.2) \cdot 10^{25}$ y (3 σ)



GERDA – the concept

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)

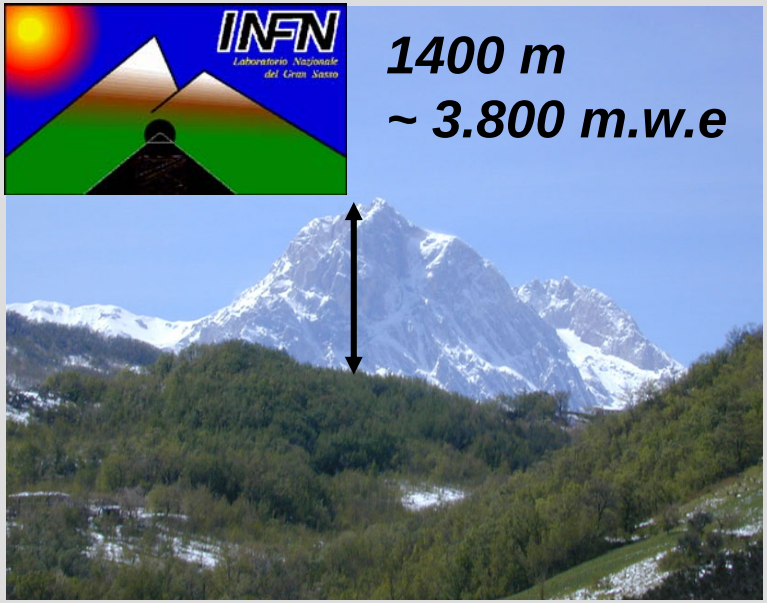
Reduction of background to **10^{-3} counts/(kg·keV·y)**

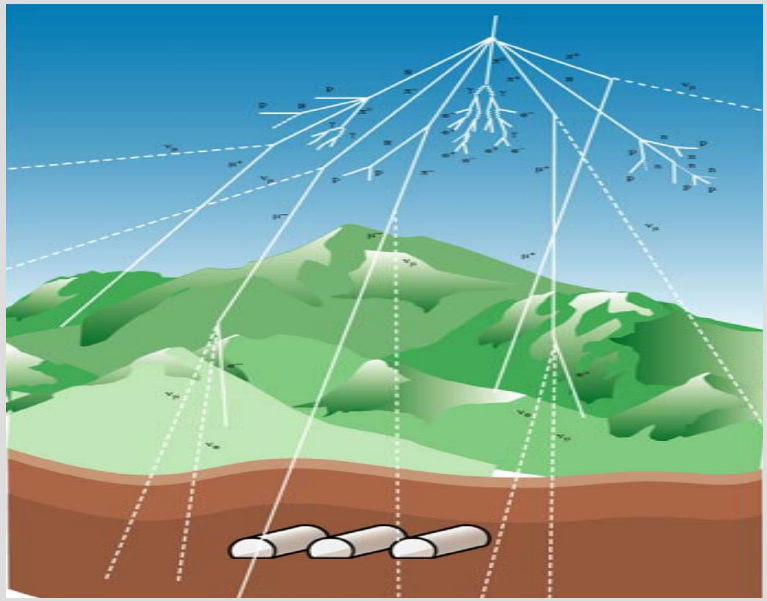
- Minimize radioactive contaminations close to the detectors
- **Use of segmented germanium detectors in second phase** **NEW**
- 2 orders of magnitude below that of previous experiments

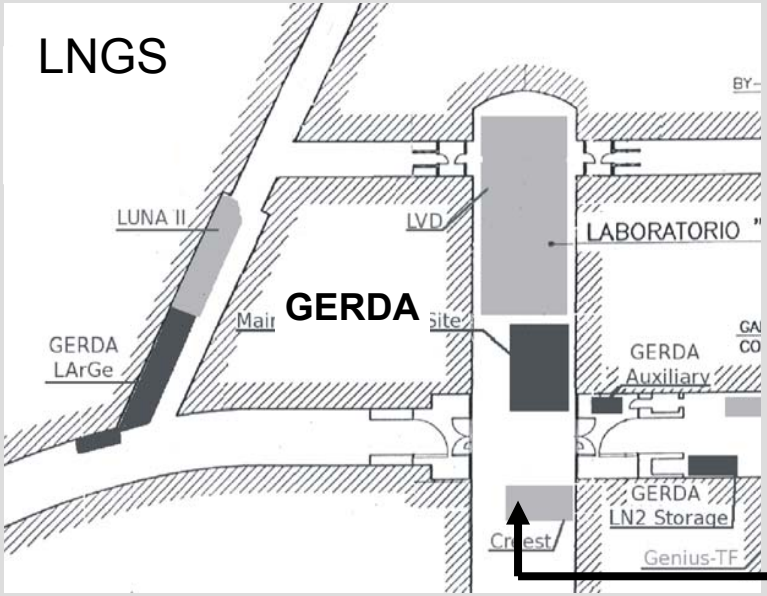
Sensitivity aimed at: **140 meV** (limit[1)]) at an exposure of 100 kg·y

[1)] using NME from arXiv:0706.4304

GERDA @ LNGS

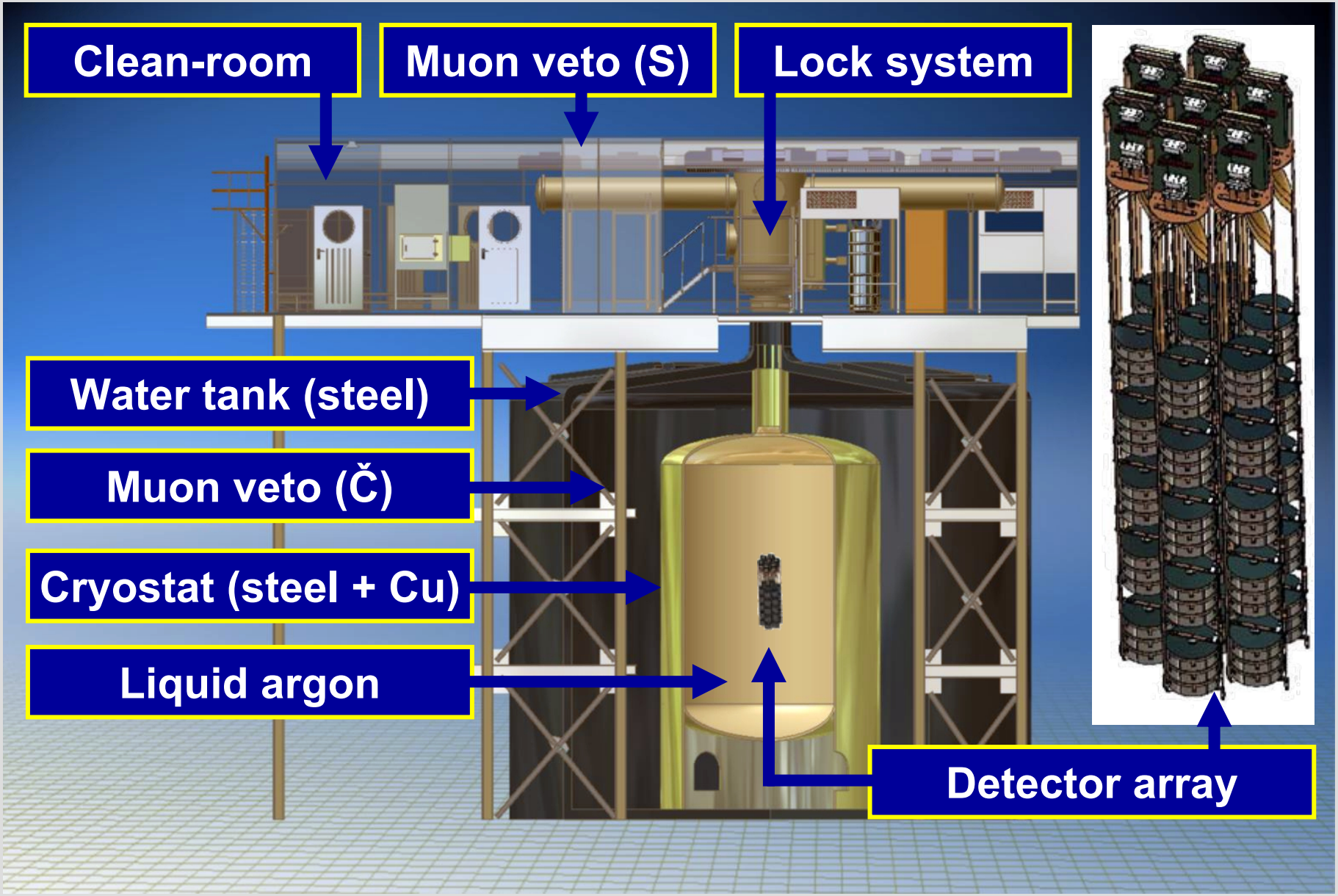

INFN
Laboratorio Nazionale del Gran Sasso
1400 m
~ 3.800 m.w.e




LNGS
LUNA II
LVD
LABORATORIO
GERDA
GERDA LArGe
GERDA Auxiliary
GERDA LN2 Storage
Genius-TF


Hall A

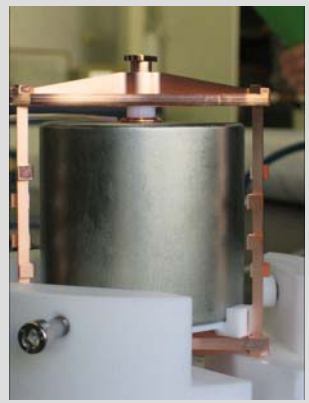
Technical realization



Phase I detectors

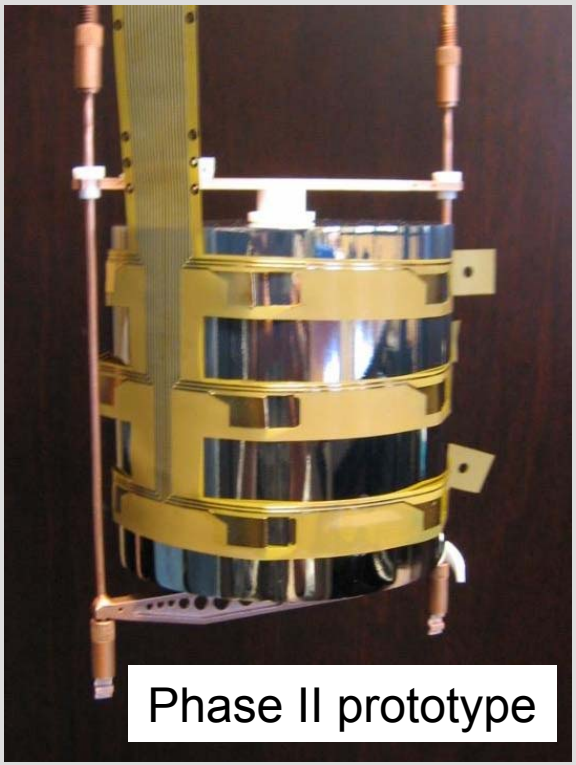
- Use enriched detectors from HdM and IGEX experiments (prev. stored at LNGS / Canfranc)
- Need to be refurbished and mounted into new holders

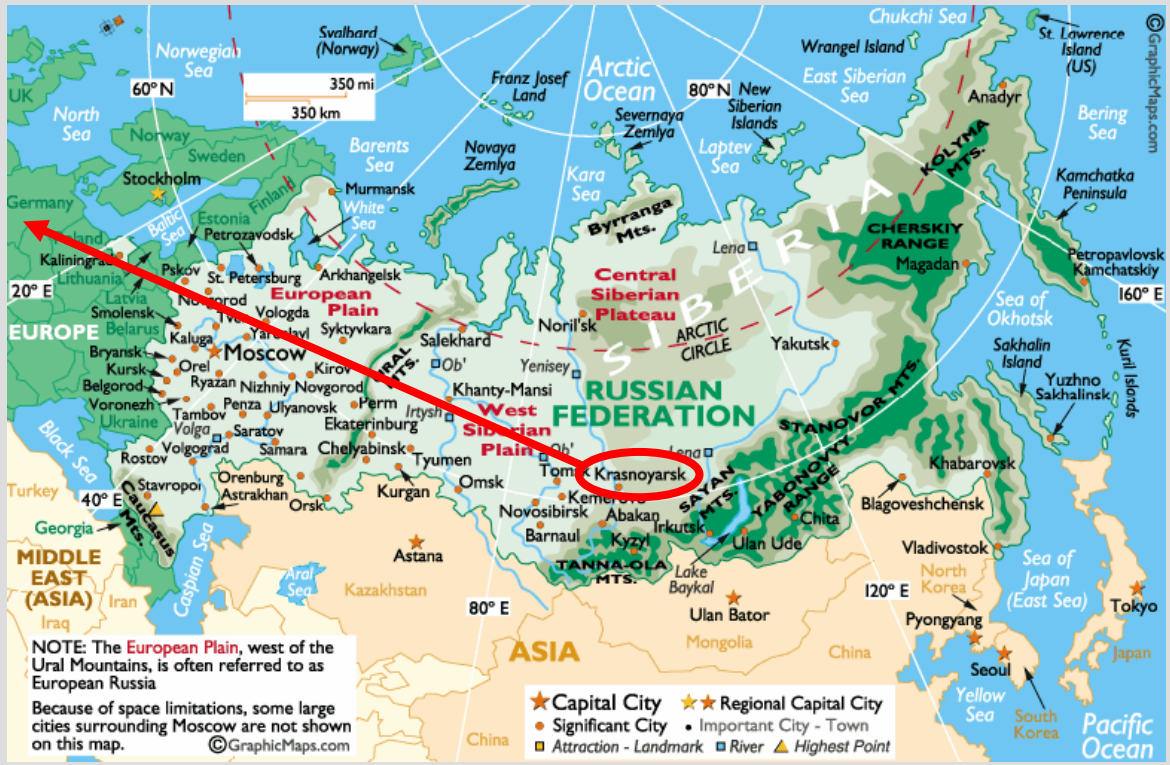
- **All detectors were tested and perform well**
- Energy resolution ~ 2-3 keV (at 1.3 MeV)
- Mass 1-3 kg, total ~ 18 kg
- Refurbishment in progress



Phase II detectors

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





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

  ← Depth and laboratory dependent
- Radioactive isotopes in the surrounding:
  - Electrons/positrons
  - **Photons**

  ← Choice of material close to detectors
  - Alphas (surface) ← Purity of the LAr + handling

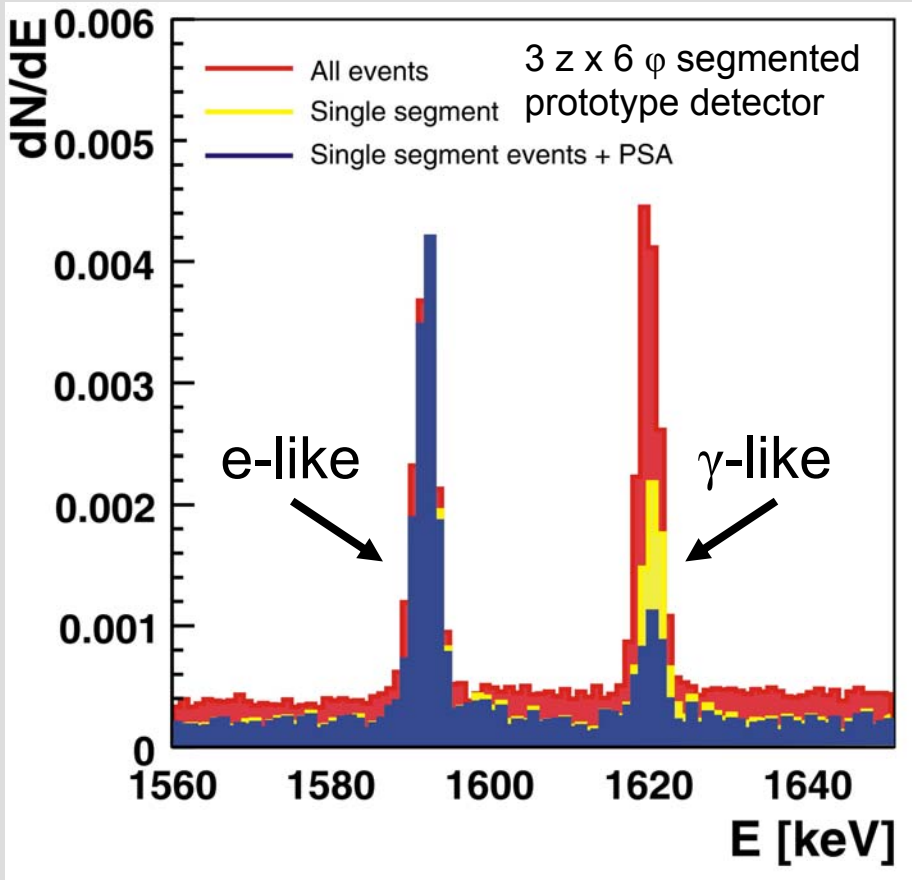
Background units:

counts / (kg·keV·y)

- total mass
- around $Q_{\beta\beta}$
- measuring time

Rejection techniques (studies with a prototype detector)

- **Rejection principle: study volume over which energy is distributed (e/γ)**
- Detector anti-coincidences
- Segmented detectors (*poor man's pixelation*)
- Analysis of the detector response function (pulse shape analysis)
- R&D: active LAr 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	
	Bulk	3.0	
	Surf.	**3.5**	
Holder	Cu	1.4	
	Teflon	2.0	
Cabling		**7.6**	
Electronics		**3.5**	
Liquid nitrogen		0.1	
Infrastructure		2.9	
Muons and neutrons		2.0	
Total		37.1	(30.6)

Gain through segmentation factor ~10

Reducible via PSA

Redesign: Reduced material

Will change with LAr

Phase I:

18 kg germanium

20 kg·y exposure

10^{-2} counts/(kg·keV·y)

Phase II:

35 kg germanium

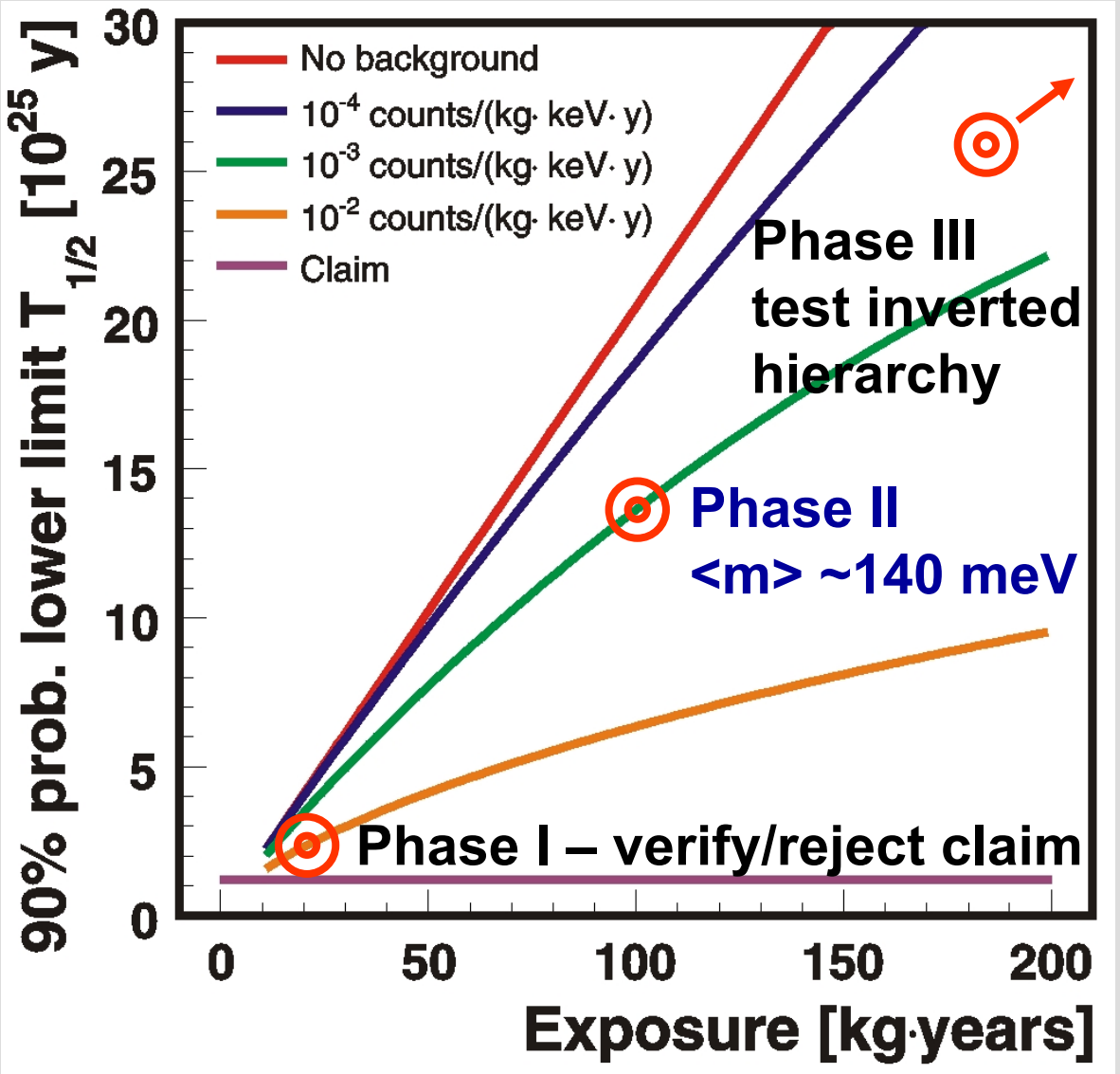
100 kg·y exposure

10^{-3} counts/(kg·keV·y)

Phase III:

1000 kg germanium

$\lesssim 10^{-4}$ counts/(kg·keV·y)



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

Status

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

Summary and conclusions

- GERDA is currently being built with the aim to search for neutrinoless double beta-decay
- Detector concept: germanium detectors submerged into LAr
- Reduction of background is the most critical issue
- Background identification techniques have been shown to work (segmentation, pulse shape analysis, active LAr veto, etc.)
- Construction is ongoing
- Commissioning expected early 2009
- Expected sensitivity: $T_{1/2} > 13.5 \cdot 10^{25}$ y $\leftrightarrow$ $m_\nu < 140$ meV (90% prob.)

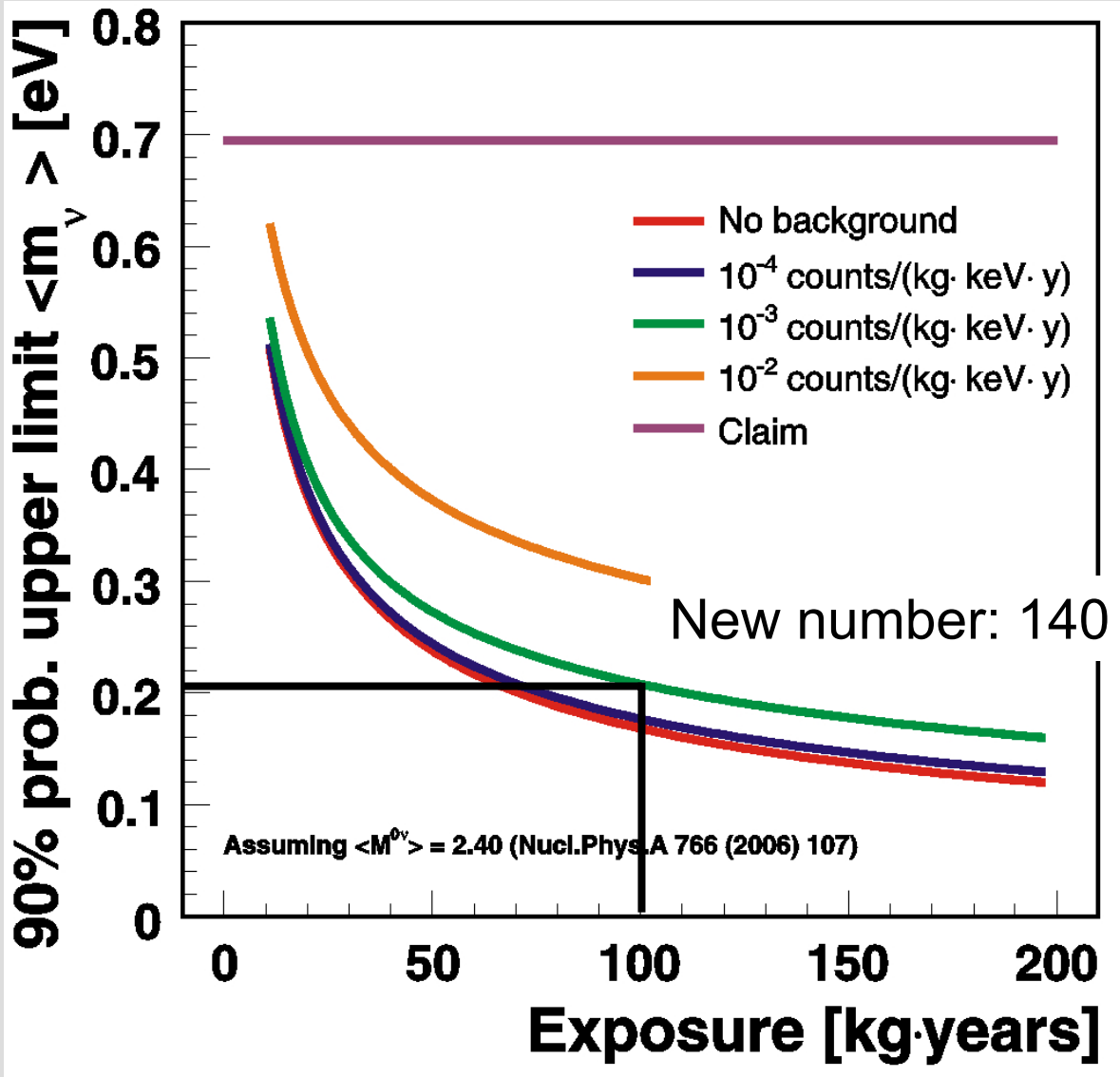
  assuming 100 kg·years exposure and a

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

The GERDA collaboration

Backup slides

Neutrino mass sensitivity



New number: 140 meV [1)]

[1)] using NME from arXiv:0706.4304

Neutrino mass and hierarchy