GERDA

the new neutrinoless double beta experiment on ^{76}Ge

Georg Meierhofer

Kepler Center for Astro and Particle Physics, University Tübingen

on behalf of the

GERDA Collaboration

Outline

- Motivation

- Neutrinoless double beta decay

- GERDA – experiment

- Summary

Motivation

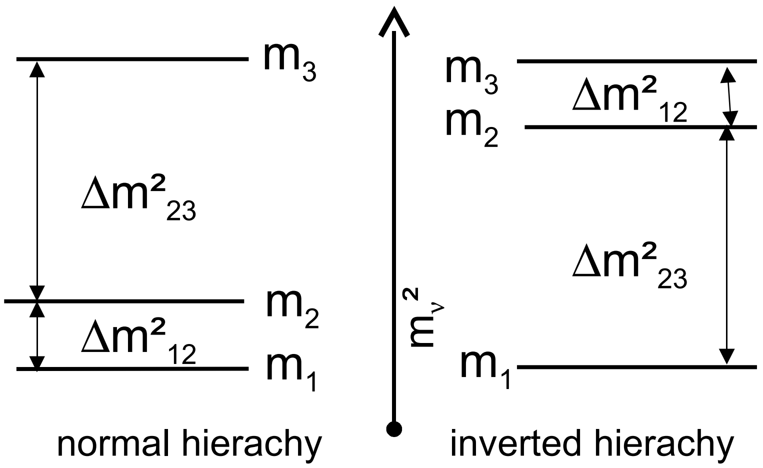
The GERmanium Detector Array (GERDA) experiment is designed to search for neutrinoless double beta decay ($0\nu\beta\beta$). The observation would imply:

- neutrino is a Majorana particle ($\nu = \bar{\nu}$)

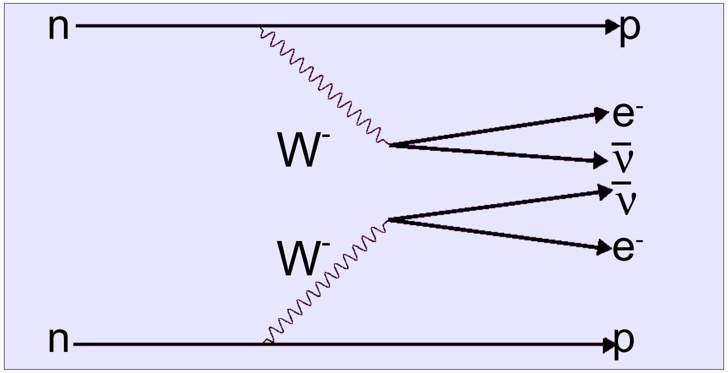
- lepton number violation $\Delta L=2$ $(A,Z) \rightarrow (A,Z+2) + 2e^-$

- effective neutrino mass

- determination of neutrino mass hierachy

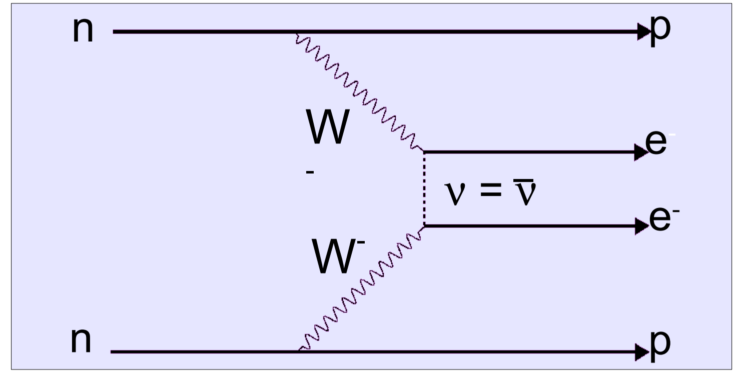


2νββ decay



Observed for several isotopes

0νββ decay



Beyond the Standard Model

$T_{1/2}(^{76}Ge) \geq 1.9 \times 10^{25}$ y (90% C.L.)

Eur. Phys. J. A12, 147-154 (2001)

claim of signal from parts of HdM

NIM A 522 (2004) 371-406

phase space

effective Majorana mass

nuclear matrix element

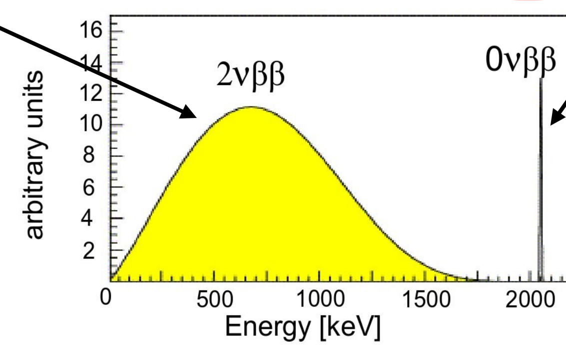
$$\left[T^{0\nu}_{1/2}\right]^{-1} = G^{0\nu}(E_0, Z)\ |M^{0\nu}|^2\ \langle m_{ee}\rangle^2$$

$$|m_{ee}| = |\sum_j m_j U_{ej}^2|$$

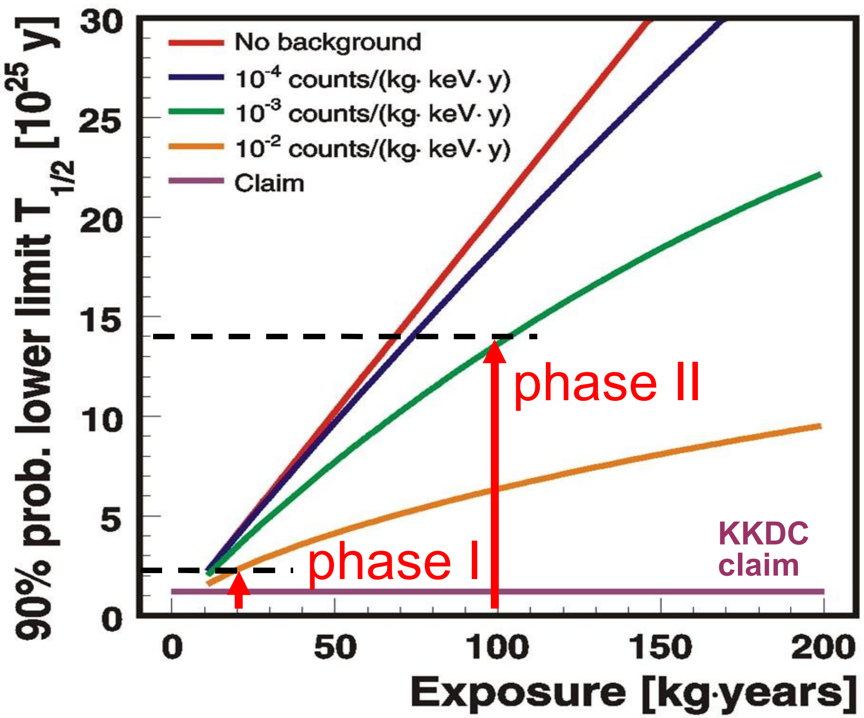
effective neutrino mass

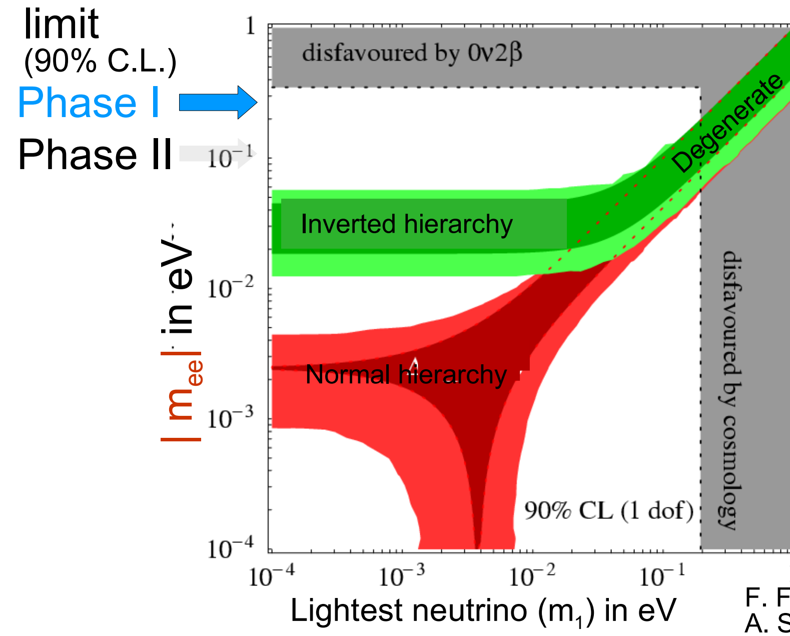
$t_{1/2} \sim 1.5 \times 10^{21}$ y

$t_{1/2} \geq 1.9 \times 10^{25}$ y



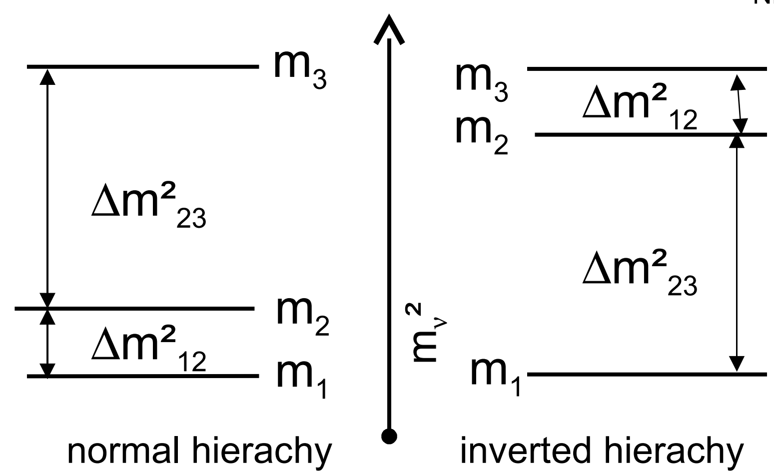
Sensitivity





F. Feruglio, A. Strumia, F. Vissani, NPB 637

	exposure	background
Phase I:	~15 kg y	10^{-2} cts/(keV kg y)
Phase II:	~100 kg y	10^{-3} cts/(keV kg y)

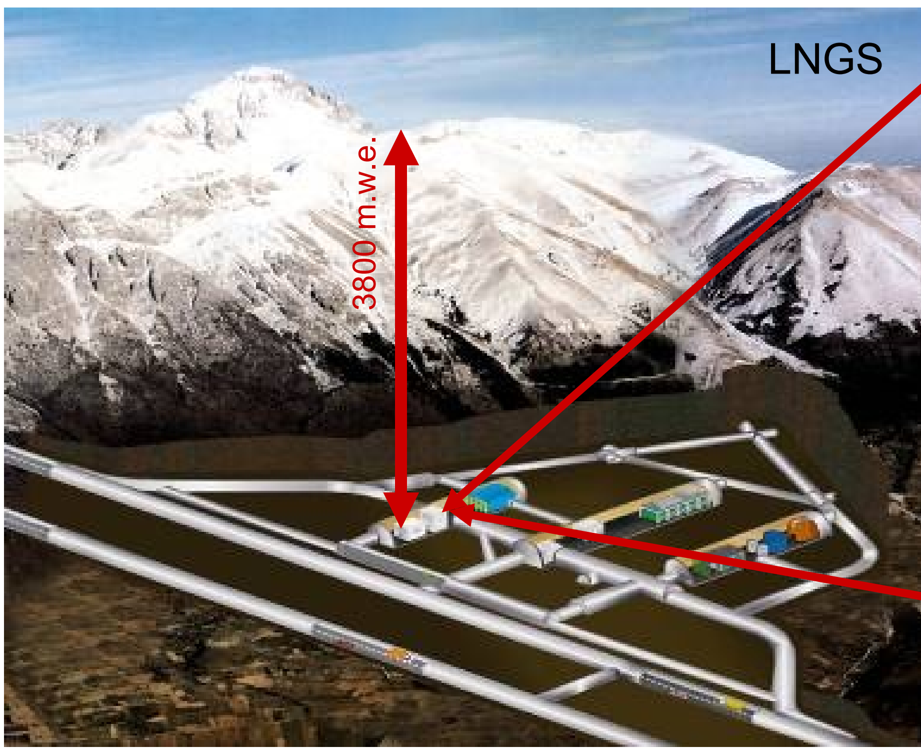


Phase III:
joint venture with MAJORANA collaboration

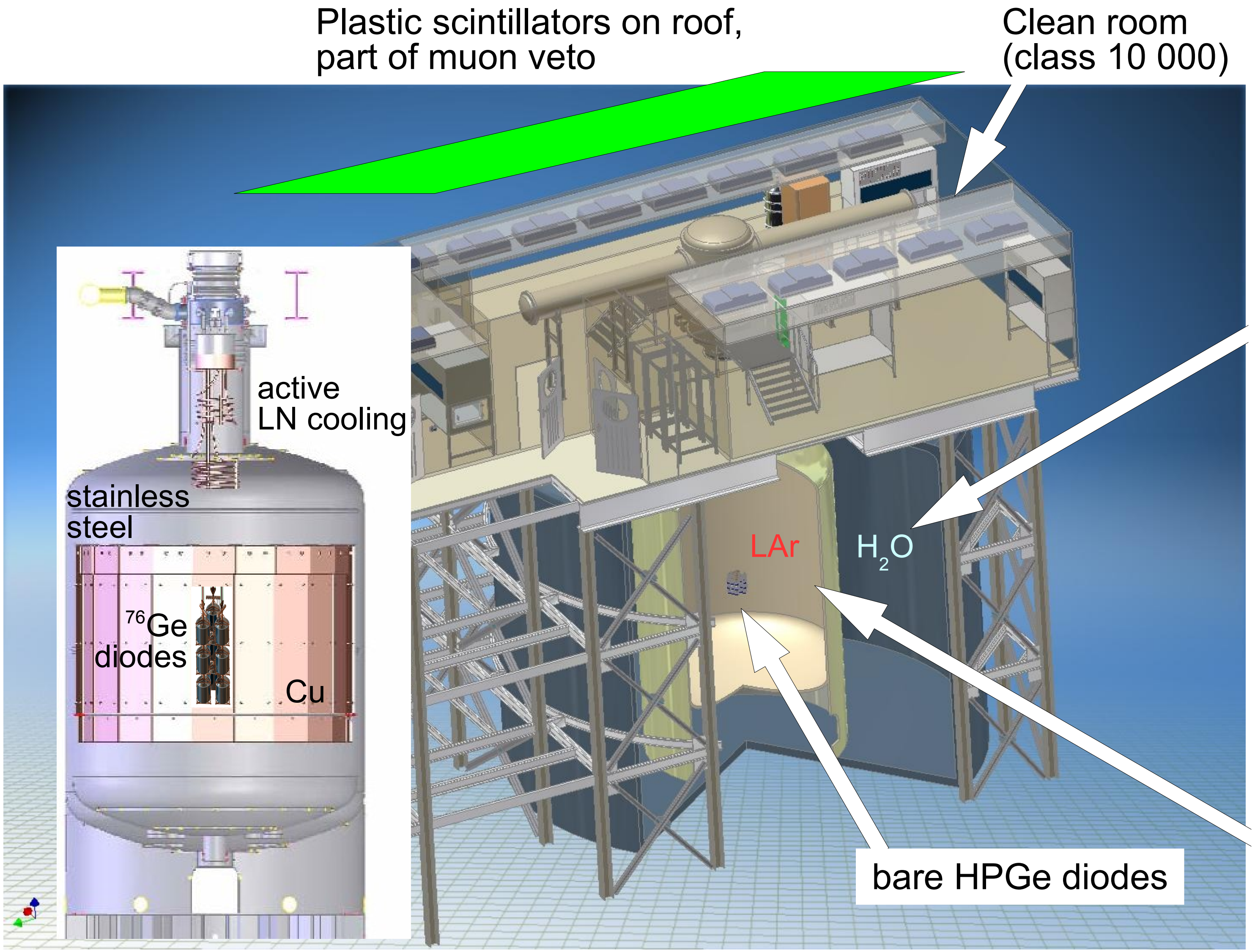
GERDA experiment

LNGS underground laboratory:

- located 150 km from Rome, Italy
- access via highway tunnel
- overburden: 1400 m of rock
- reduction of μ-flux > 10^6



Setup



<u>Water tank:</u>

stainless steel
r = 10 m, h = 9 m
630 m^3

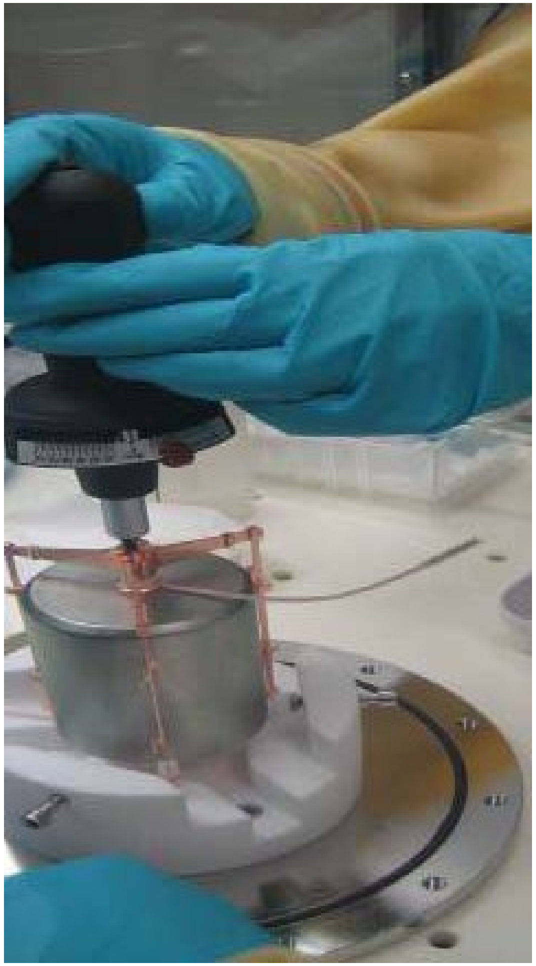
- shielding
- muon veto

<u>LAr cryostat:</u>

stainless steel
copper lining
r = 4 m, h = 5 m
64 m^3
200W thermal loss

- shielding
- cooling medium for detectors

Phase I diodes



Bare diodes are operated in LAr
- p-type, coaxial
- low mass holder

8 diodes (HdM, IGEX)
- isotopically enriched (86%)
- total mass of 17.66 kg

6 diodes (Genius-TF)
- ^{nat}Ge detectors
- 15.60 kg

All diodes reprocessed and tested
they work stable in LAr
FWHM (1.33MeV) ~ 2.5 keV

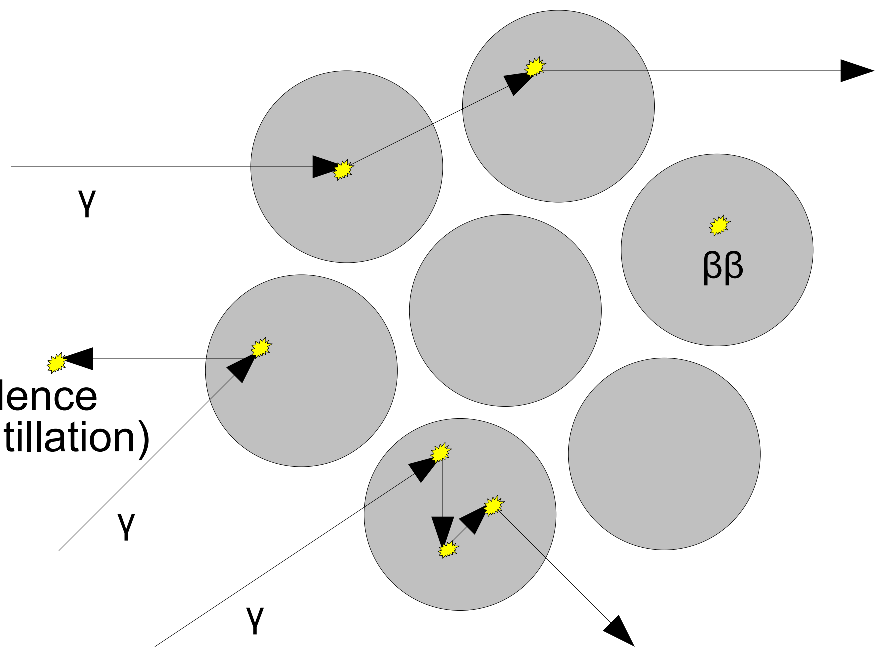
Event signature

Multi site events by Compton scattering

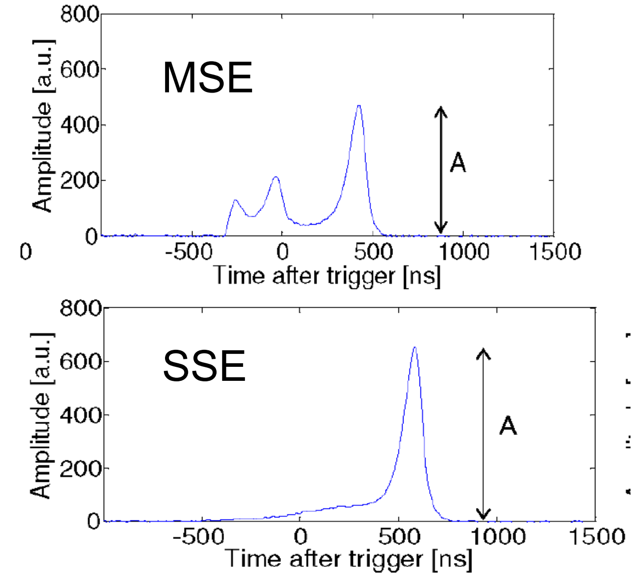
Single site events by photoelectric effect, electrons (0νββ)

Anti-coincidence of detectors

Optional: anti-coincidence in LAr (scintillation)



Anti-coincidence of segments/pulse shape analysis

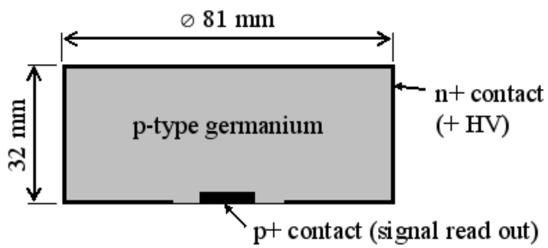


Pulse shape analysis and/or segmentation will be used in Phase II for background rejection

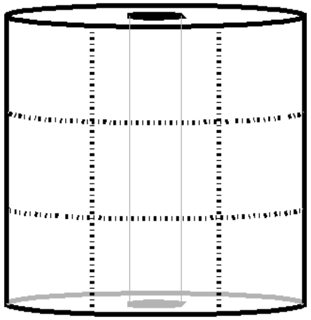
Phase II diodes

Two types of detectors for phase II under discussion

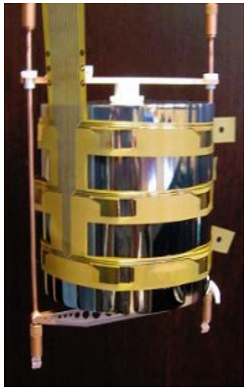
BEGe p-type



18-fold segmented n-type



- 37.5 kg of 86% $^{enr}GeO_2$ reduced to Ge metal of 6N grade
- 84 kg of $^{depl}GeO_2$ (same chemical history) used to test production procedure



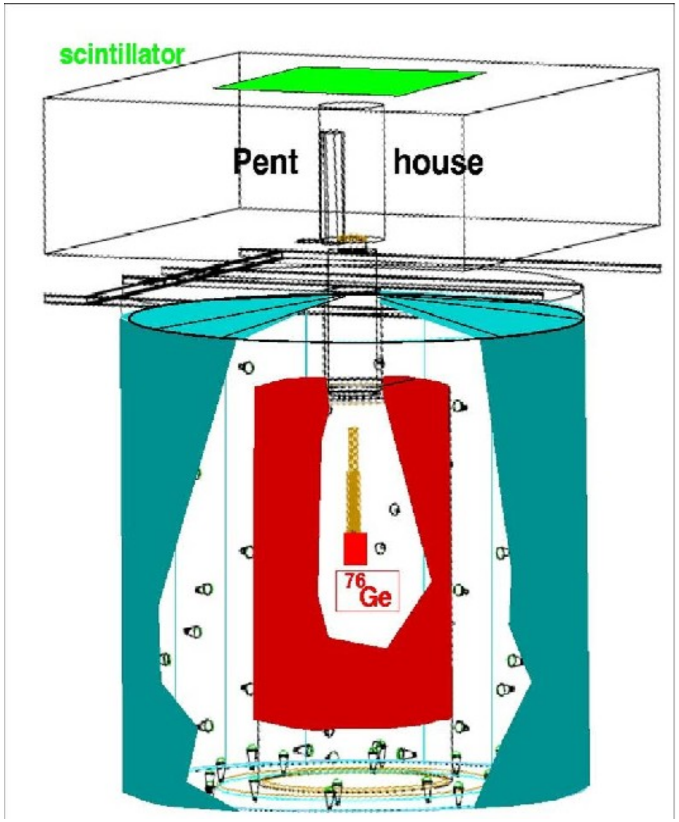
First ^{depl}BEGe detectors are working in test stand

Muon veto

Water Cherenkov veto with 66 PMT + plastic scintillator panels
high reflectivity foil (VM2000)

Efficiency of 99.56 %

Background by muons
- without moun veto: 10^{-3} cts/(keV kg y)
- with muon veto: 10^{-5} cts/(keV kg y)



Water tank after installation of muon veto (August 2009)

“Pillbox” below cryostat

Status

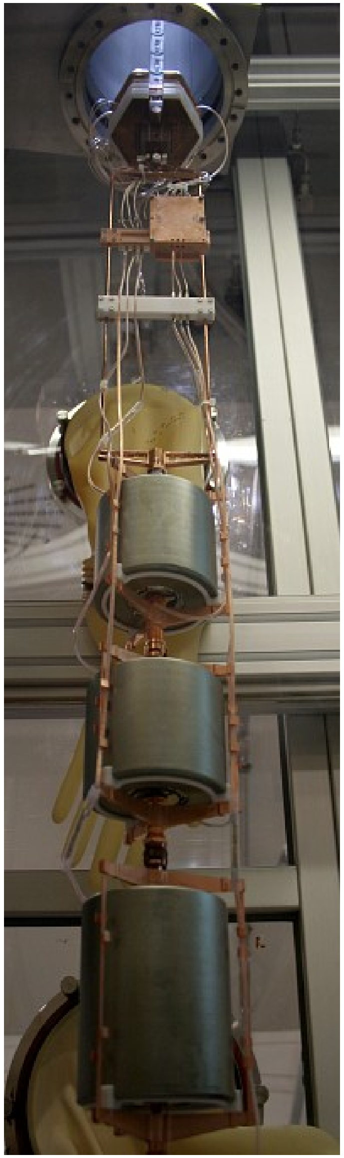
June ‘10:
Commissioning run with ^{nat}Ge detector string, GERDA is ready for phase I:

One month run with ^{nat}Ge detector string to measure:

- background
- stability (weekly calibration with ^{228}Th source)

Subsequently

operation of enriched detector strings



Status

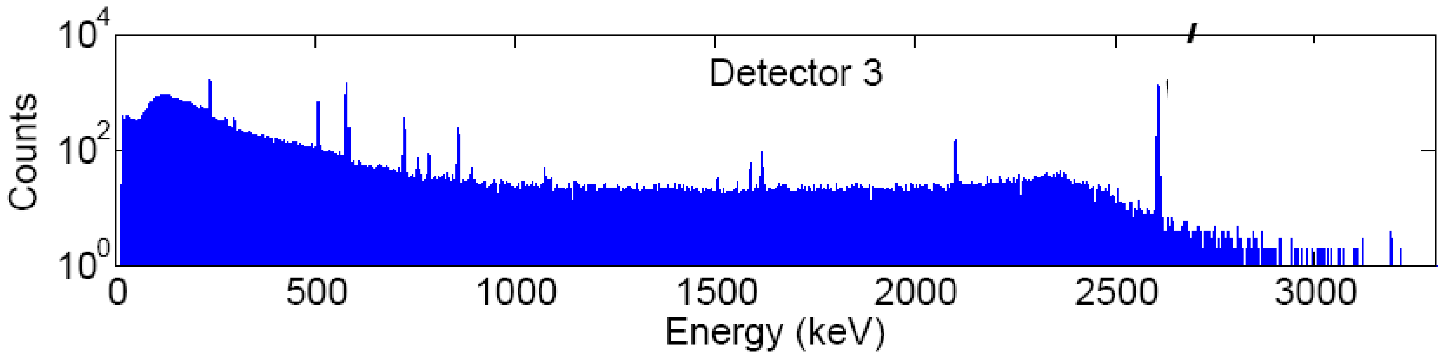
June ‘10:
Commissioning run with ^{nat}Ge detector string, GERDA is ready for phase I:

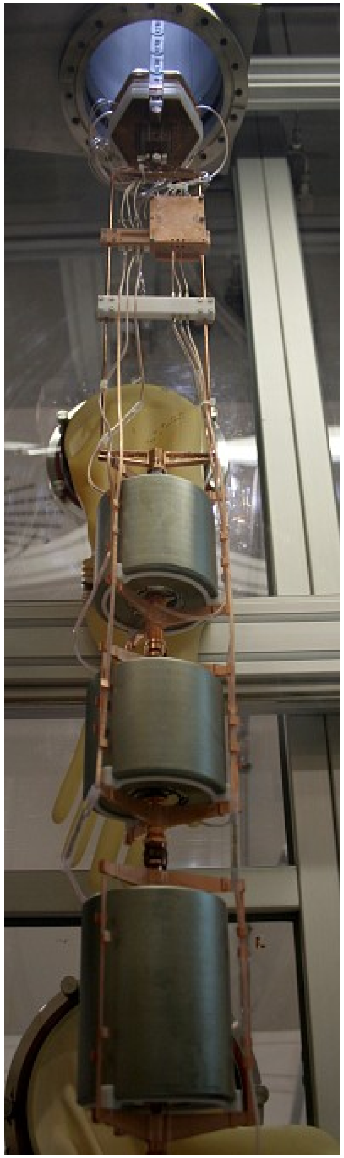
One month run with ^{nat}Ge detector string to measure:

- background
- stability (weekly calibration with ^{228}Th source)

Subsequently

operation of enriched detector strings





Summary

Neutrinoless double beta decay experiments will answer:

- Majorana or Dirac nature of the neutrino
- half-life of $0\nu\beta\beta \Rightarrow$ effective neutrino mass

GERDA

Phase I
- all detectors for phase I ready
- successful operation of bare HPGe detectors in LAr
- within 1 year of data taking KKDC-claim will be confirmed/ruled out
- first test run started in June 2010
- enriched diodes will be submerged into the cryostat after test run

Phase II

- more enriched germanium for new detectors purified
- R&D for active anti-coincidence veto in LAr

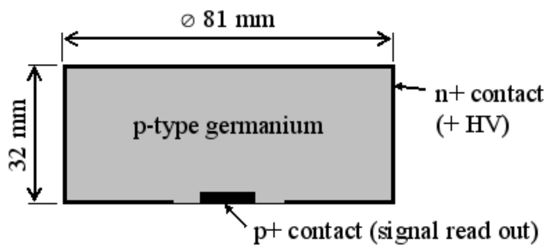
H. Aghaei [m], M. Agostini [f], M. Allardt [c], A.M. Bakalyarov [l], M. Balata [a], I. Barabanov [j], M. Barnabe-Heider [f], L. Baudis [q], C. Bauer [f], N. Becerici-Schmid [m], E. Bellotti [g,h], S. Belogurov [k,j], S.T. Belyaev [l], A. Bettini [n,o], L. Bezrukov [j], V. Brudanin [d], R. Brugnera [n,o], D. Budjas [f], A. Caldwell [m], C. Cattadori [g,h], F. Cossavella [m], E.V. Demidova [k], A. Denisiv [j], A. Di Vacri [a], A. Domula [c], A. D'Andragora [a], V. Egorov [d], A. Ferella [q], K. Freund [p], F. Froborg [q], N. Frodyma [b], A. Gangapshev [j], A. Garfagnini [n,o], S. Gazzano [f,a], R. Gonzalea de Orduna [e], P. Grabmayr [p], K.N. Gusev [l,d], V. Gutentsov [j], W. Hampel [f], M. Heisel [f], S. Hemmer [m], G. Heusser [f], W. Hofmann [f], M. Hult [e], L.V. Inzhechik [j], J. Janicsko [m], J. Jochum [p], M. Junker [a], S. Kionanovsky [j], I.V. Kirpichnikov [k], A. Klimenko [d,j], M. Knapp [p], K-T. Knoepfle [f], O. Kochetov [d], V.N. Kornoukhov [k,j], V. Kusminov [j], M. Laubenstein [a], V.I. Lebedev [l], B. Lehnert [c], D. Lenz [m], S. Lindemann [f], M. Lindner [f], I. Lippi [o], X. Liu [m], B. Lubsandorzhiev [j], B. Majorovits [m], G. Meierhofer [p], I. Nemchenok [d], L. Pandola [a], K. Pelczar [b], F. Potenza [a], A. Pullia [i], S. Riboldi [i], F. Ritter [p], C. Rossi Alvarez [o], R. Santorelli [q], J. Schreiner [f], B. Schwingenheuer [f], S. Schönert [f], M. Shirchenko [l,d], H. Simgen [f], A. Smolnikov [d,j], L. Stanco [o], F. Stelzer [m], M. Tarka [q], A.V. Tikhomirov [l], C.A. Ur [o], A.A. Vasenko [k], A. Vauth [m], O. Volynets [m], M. Weber [f], M. Wojcik [b], E. Yanovich [j], S.V. Zhukov [l], D. Zinatulina [d], F. Zocca [i], K. Zuber [c], G. Zuzel [b],

[a]) INFN Laboratori Nazionali del Gran Sasso, LNGS, Assergi, Italy
[b]) Institute of Physics, Jagellonian University, Cracow, Poland
[c]) Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
[d]) Joint Institute for Nuclear Research, Dubna, Russia
[e]) Institute for Reference Materials and Measurements, Geel, Belgium
[f]) Max Planck Institut für Kernphysik, Heidelberg, Germany
[g]) Dipartimento di Fisica, Università Milano Bicocca, Milano, Italy
[h]) INFN Milano Bicocca, Milano, Italy
[i]) Dipartimento di Fisica, Università degli Studi di Milano e INFN Milano, Milano, Italy
[j]) Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
[k]) Institute for Theoretical and Experimental Physics, Moscow, Russia
[l]) Russian Research Center Kurchatov Institute, Moscow, Russia
[m]) Max-Planck-Institut für Physik, München, Germany
[n]) Dipartimento di Fisica dell'Università di Padova, Padova, Italy
[o]) INFN Padova, Padova, Italy
[p]) Physikalisches Institut, Eberhard Karls Universität Tübingen, Tübingen, Germany
[q]) Physik Institut der Universität Zürich, Zürich, Switzerland

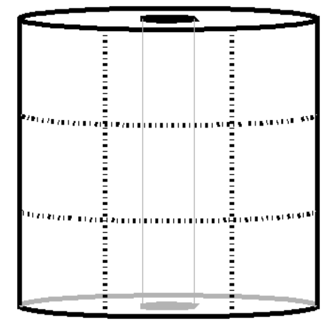
Phase II diodes

Two types of detectors for phase II under discussion

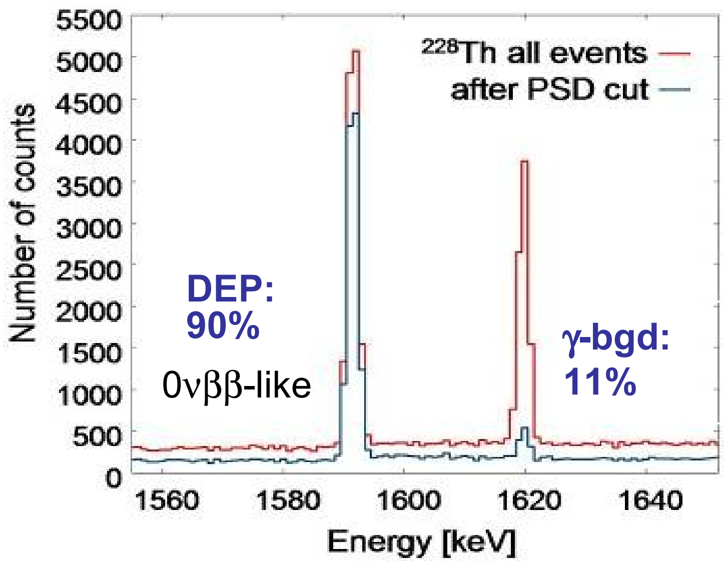
BEGe p-type

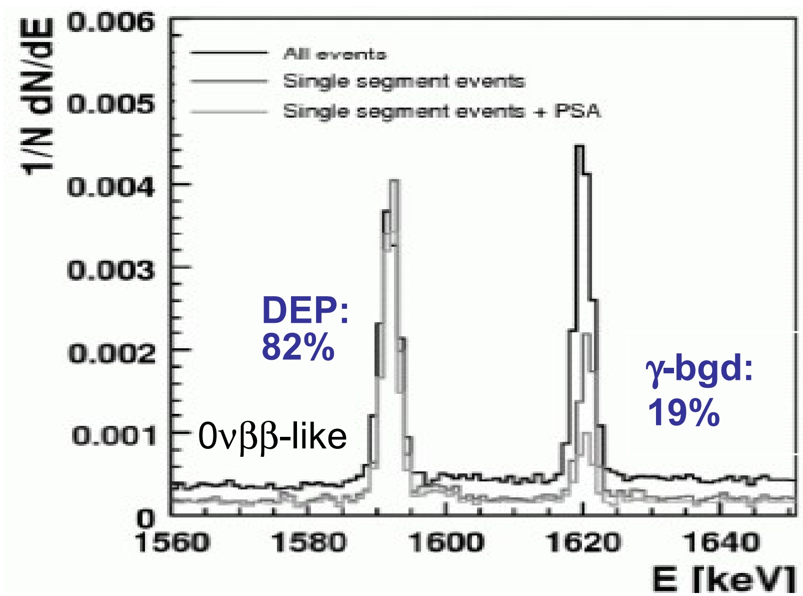


18-fold segmented n-type



D. Budjas et al., JINST 4 P10007 (2009)





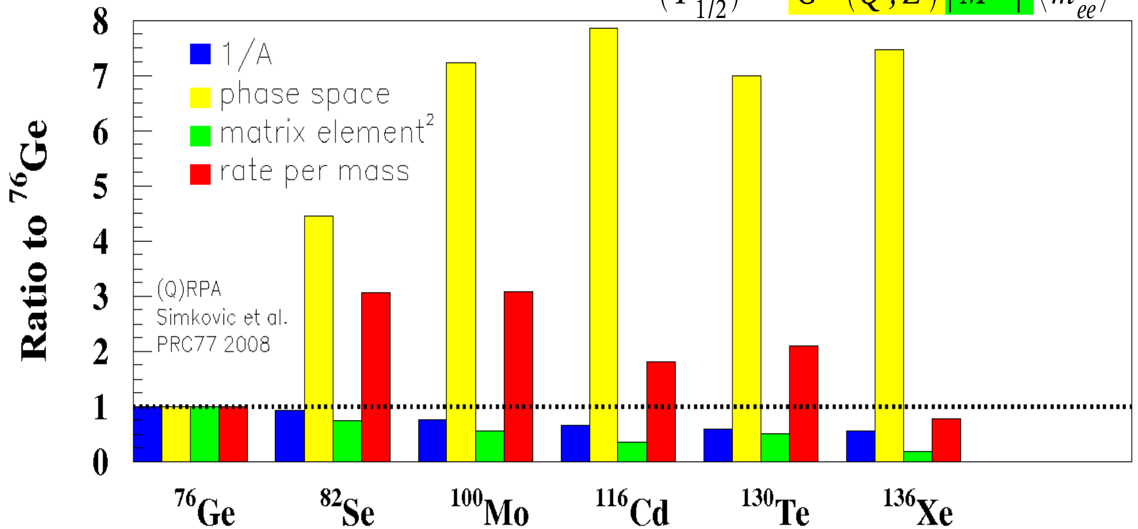
I.Abt et al., NIMA 583 (2007), Eur. J. Phys. C 52 (2007)

Why ^{76}Ge

+ Ge as source and detector
+ HPGe detector technologies well established
+ Industrial techniques and facilities available to enrich from 7% to ~88%
+ Good energy resolution: FWHM ~3 keV at 2039 keV (0.16%)
+ Pulse-shape analysis

- Rather low $Q_{\beta\beta}$ value (2039 keV)

$$(T^{0\nu}_{1/2})^{-1} = G^{0\nu}(Q,Z)\,|M^{0\nu}|^2 \langle m_{ee} \rangle^2$$



QRPA, (Simkovic et al. PRC 77, 2008)

Limits for 0νββ decay

Heidelberg-Moscow experiment (^{76}Ge):

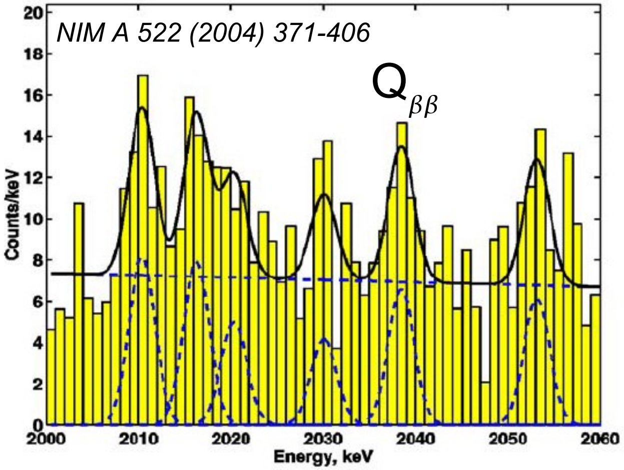
background level ~0.1 cts/(keV kg y)

$T_{1/2} \geq 1.9 \times 10^{25}$ y (90% C.L.)   35.5 kg y

Eur. Phys. J. A12, 147-154 (2001)

part of collaboration claims a signal

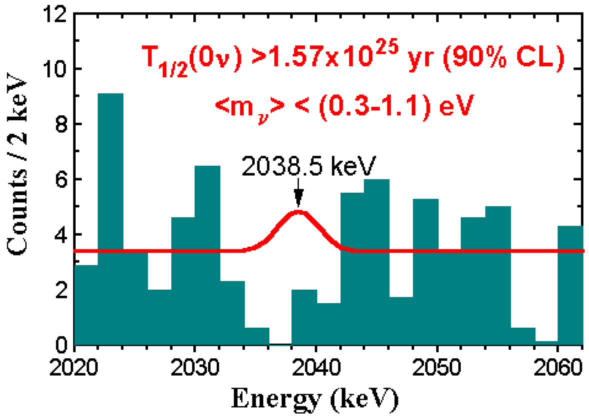
Mod. Phys. Lett. A16 2409-2420 (2001), NIM A 522 (2004) 371-406



IGEX (^{76}Ge):

$T_{1/2} \geq 1.57 \times 10^{25}$ y (90% C.L.)   8.87 kg y

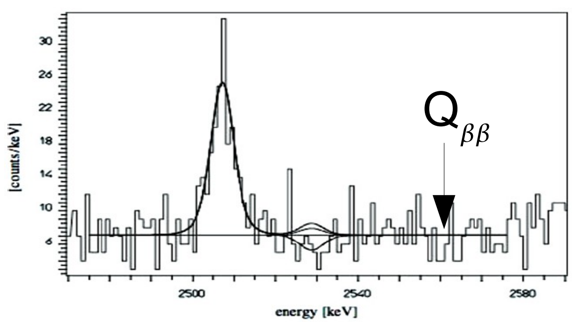
NP B (Proc.Suppl.) 87 (2000) 278



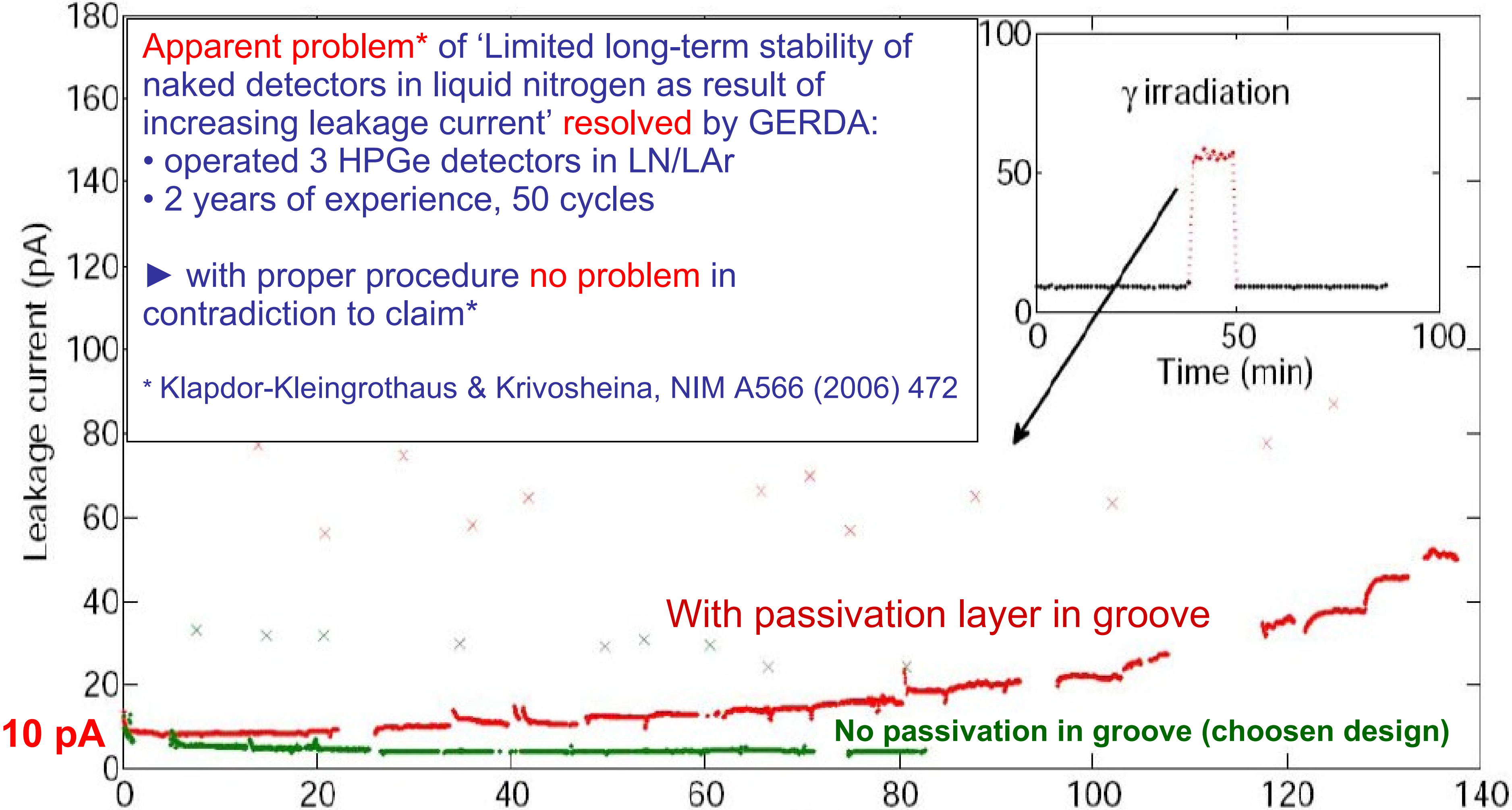
Cuoricino (TeO_2 bolometers):

$T_{1/2} \geq 3.0 \times 10^{24}$ y (90% C.L.)   11.83 kg y

Phys. Rev. C 78 (2008) 035502



Long-term stability of phase I detectors in LAr/LN_2



Apparent problem* of ‘Limited long-term stability of naked detectors in liquid nitrogen as result of increasing leakage current’ resolved by GERDA:

- operated 3 HPGe detectors in LN/LAr
- 2 years of experience, 50 cycles

► with proper procedure no problem in contradiction to claim*

* Klapdor-Kleingrothaus & Krivosheina, NIM A566 (2006) 472

no deterioration after 1 year of operation in LAr

M. Barnabé-Heider, PhD thesis ‘09

Status

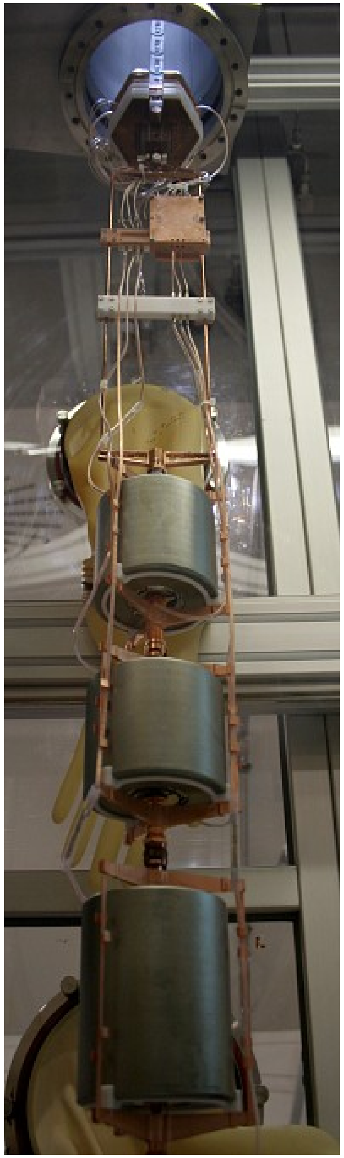
- Summer/autumn ‘09: Integration test of Phase I detector string, FE, lock, DAQ
- Nov/Dec.’09: Liquid argon filling
- Apr/May’10: Installation of 1-string lock in the GERDA cleanroom
- May ’10: Employment of FE & detector mock-up, followed by first employment of a non-enriched detector
- June ‘10: Water tank filling
- June ‘10: Commissioning run with ^{nat}Ge detector string GERDA is ready for phase I:

One month run with ^{nat}Ge detector string to measure:

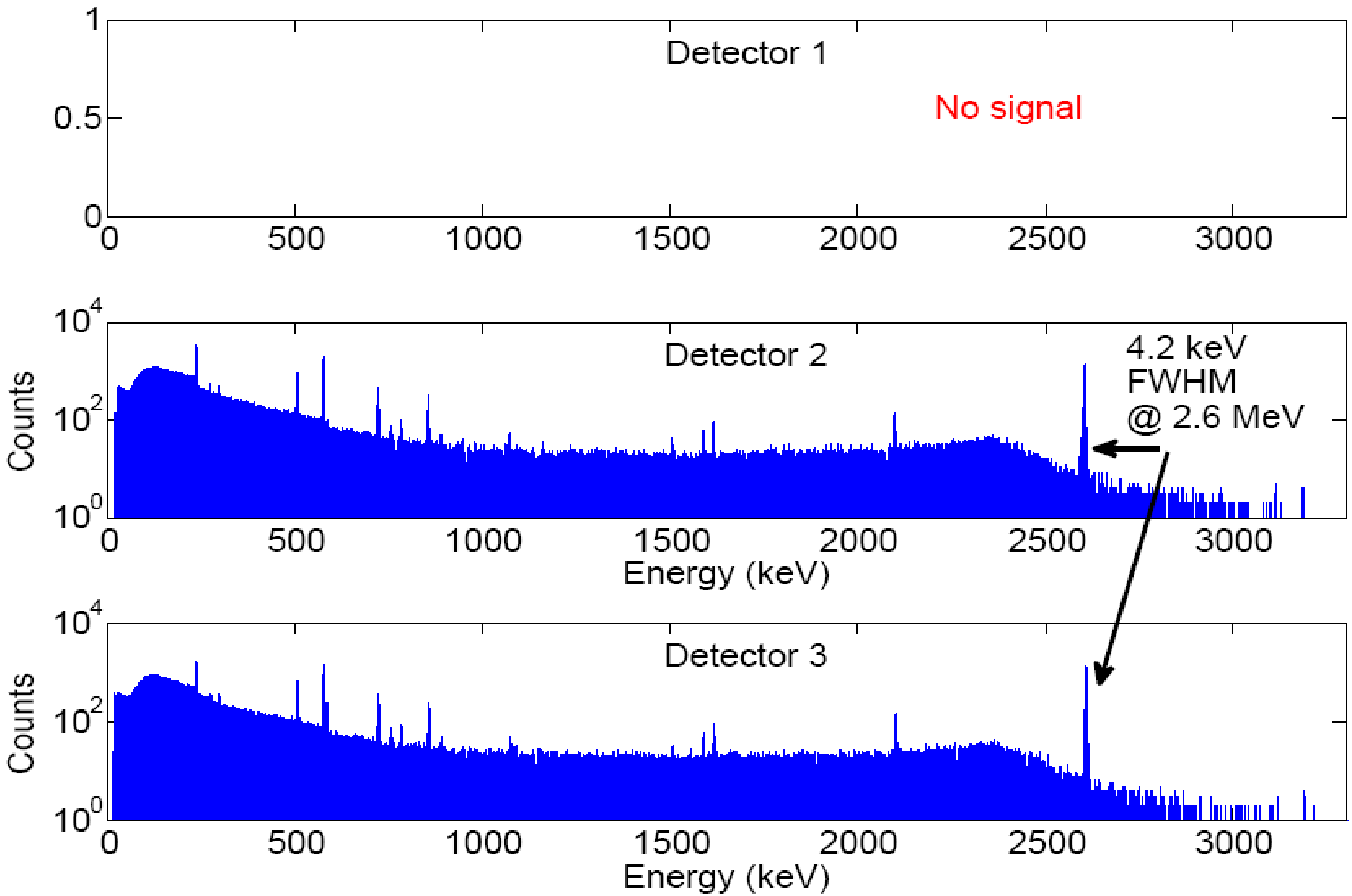
- background
- stability (weekly calibration with ^{228}Th source)

Subsequently

operation of enriched detector strings



Status



Detector 1
No signal
1
0.5
0
0
500
1000
1500
2000
2500
3000
Detector 2
4.2 keV
FWHM
@ 2.6 MeV
Counts
10^4
10^2
10^0
Energy (keV)
Detector 3
Counts
10^4
10^2
10^0
0
500
1000
1500
2000
2500
3000
Energy (keV)