13th International Symposium on
Capture Gamma-Ray Spectroscopy
and Related Topics

Prompt Gamma Rays in ^{77}Ge after Neutron Capture on ^{76}Ge

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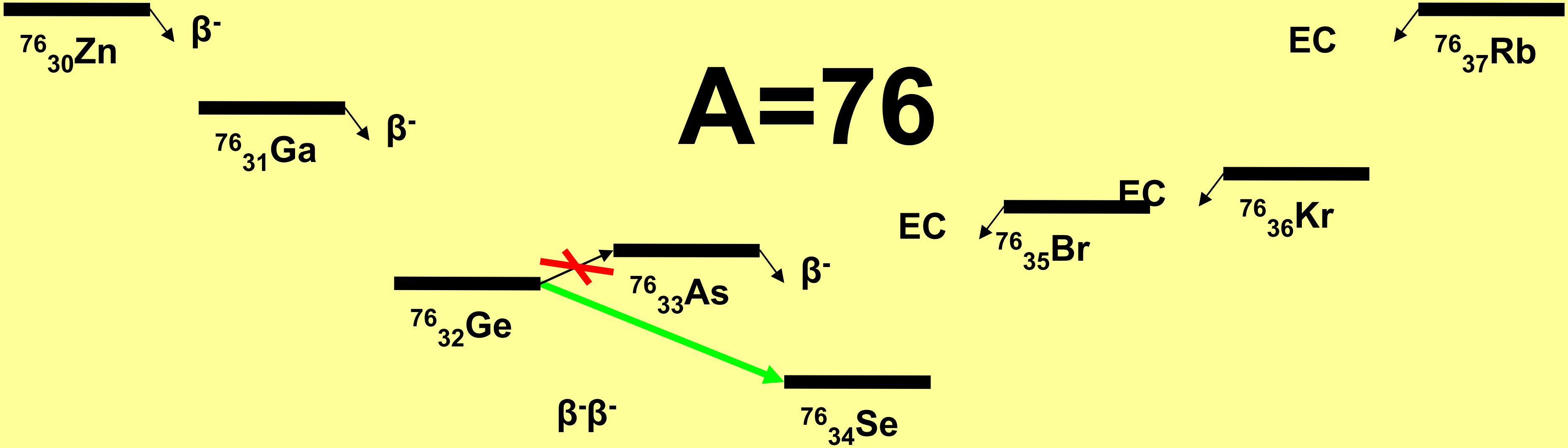
Outline

- Motivation
  - Neutrinoless double beta decay
  - GERDA
- Cross section of ^{76}Ge(n,γ) reaction
- Prompt gamma ray spectrum
- Status of GERDA
- Summary

Double Beta Decay

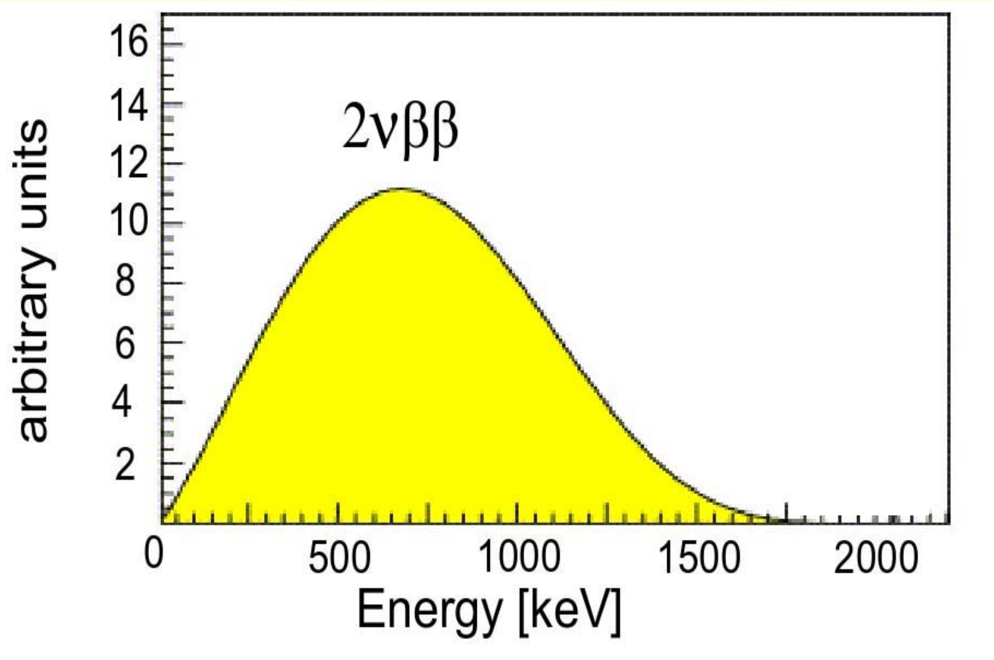
Double beta decay (2vββ) occurs if single beta decay is energetically forbidden, but the transition of two neutrons into two protons (or pp -> nn) is allowed. The nucleus emits two electrons (positrons) and two anti-neutrinos (neutrinos).

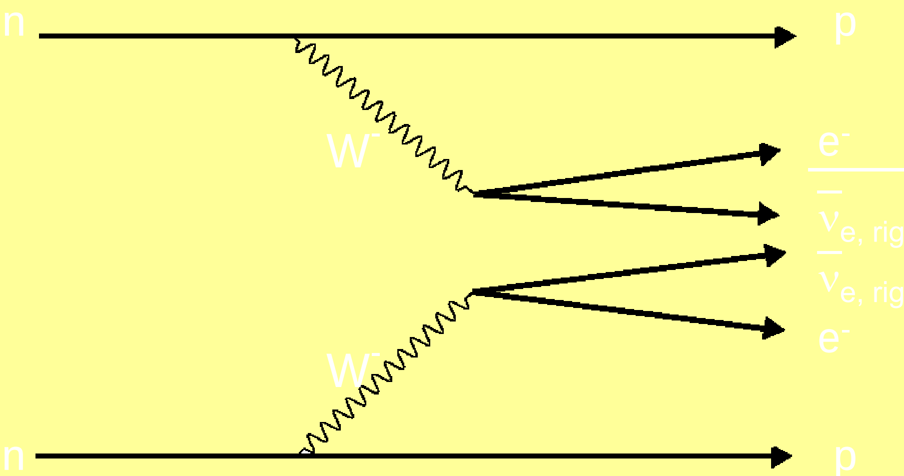
2vββ was observed in 11 isotopes: ^{48}Ca, ^{76}Ge, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{128}Te, ^{130}Te, ^{150}Nd, ^{238}U, ^{130}Ba ($\beta^+\beta^+$)



2νββ Decay

ΔL=0 no lepton
number violation





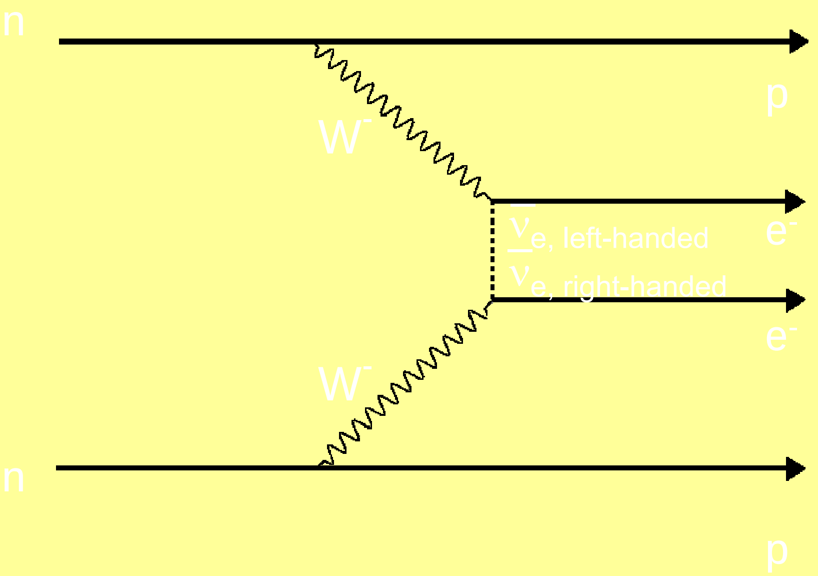
0νββ Decay

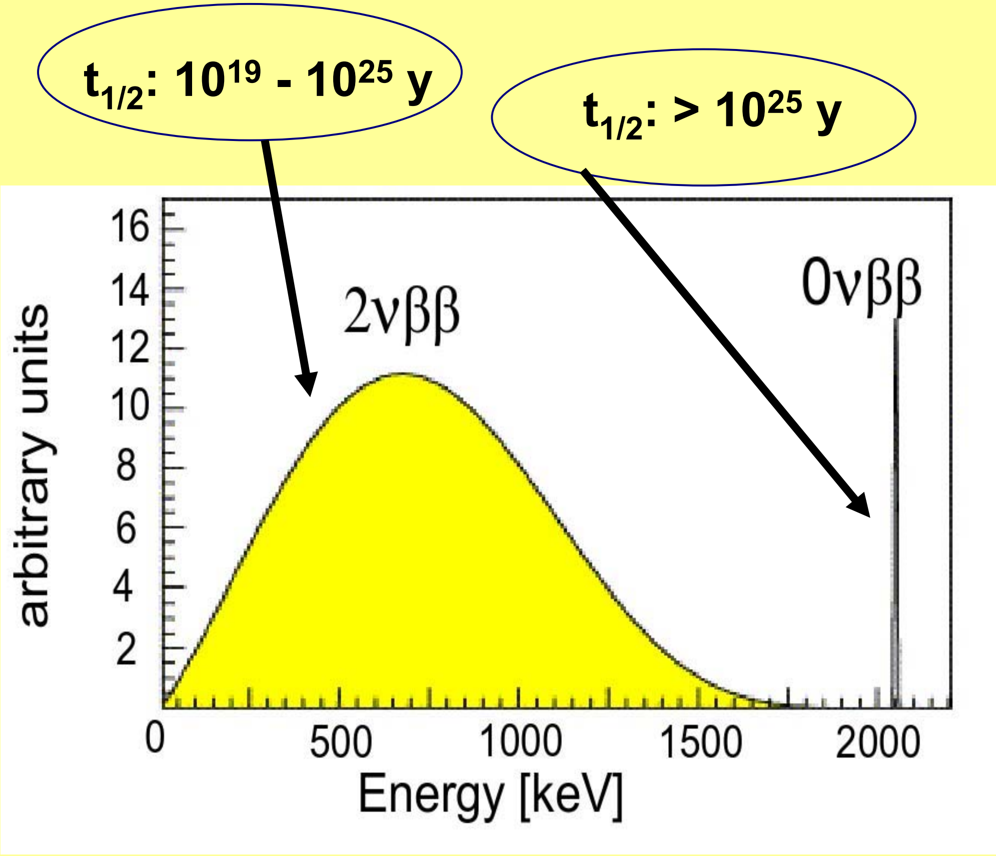
Conditions for 0ν2β:

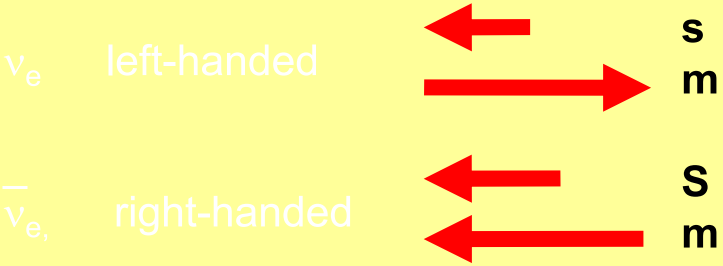
$\bar{\nu} = \nu$ Majorana particle

$\Delta L=2$ Lepton number violation

$P(\bar{\nu}_{e,\text{ left-handed}}) \sim (m/E)^2$ for $m_\nu > 0$







What can we lern from 0νββ?

If 0νββ is observed:

- ✓ Neutrino is a Majorana particle
- ✓ Neutrino mass

$$[T^{0\nu}_{1/2}]^{-1} = \overset{\text{phase space}}{\overset{\downarrow}{G^{0\nu}(E_0, Z)}} \; \overset{\text{nuclear matrix element}}{\overset{\downarrow}{|M^{0\nu}|^2}} \; \overset{\text{effective Majorana mass}}{\overset{\downarrow}{m_{ee}^2}}$$

$$m_{ee} = |\sum U_{ei}^2 m_i|$$

- ✓ Mass hierachy (degenerate, inverted or normal)

Experiments

Past

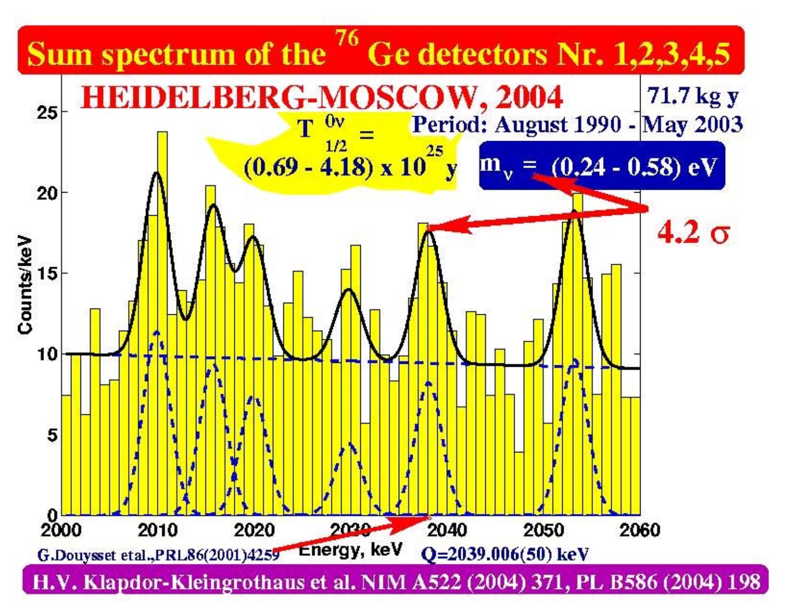
- Heidelberg-Moscow (^{76}Ge): **limit $t_{1/2}$ > 1.19 x 10^{25} y**, claim for observation by a small group of the collaboration
- IGEX (^{76}Ge): **limit $t_{1/2}$ > 1.6 x 10^{25} y**

Present

- Courecino
- Nemo3

Future

- Coure
- Majorana
- SuperNemo
- Majorana
- GERDA



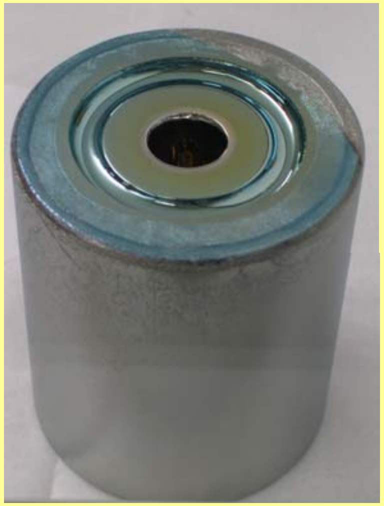
GERDA: The GERmanium Detector Array

Location: LNGS, Gran Sasso, Italy

Isotope: ^{76}Ge

$Q_{\beta\beta}$ = 2039 keV

$t_{1/2} > 1.6 \times 10^{25}$ y

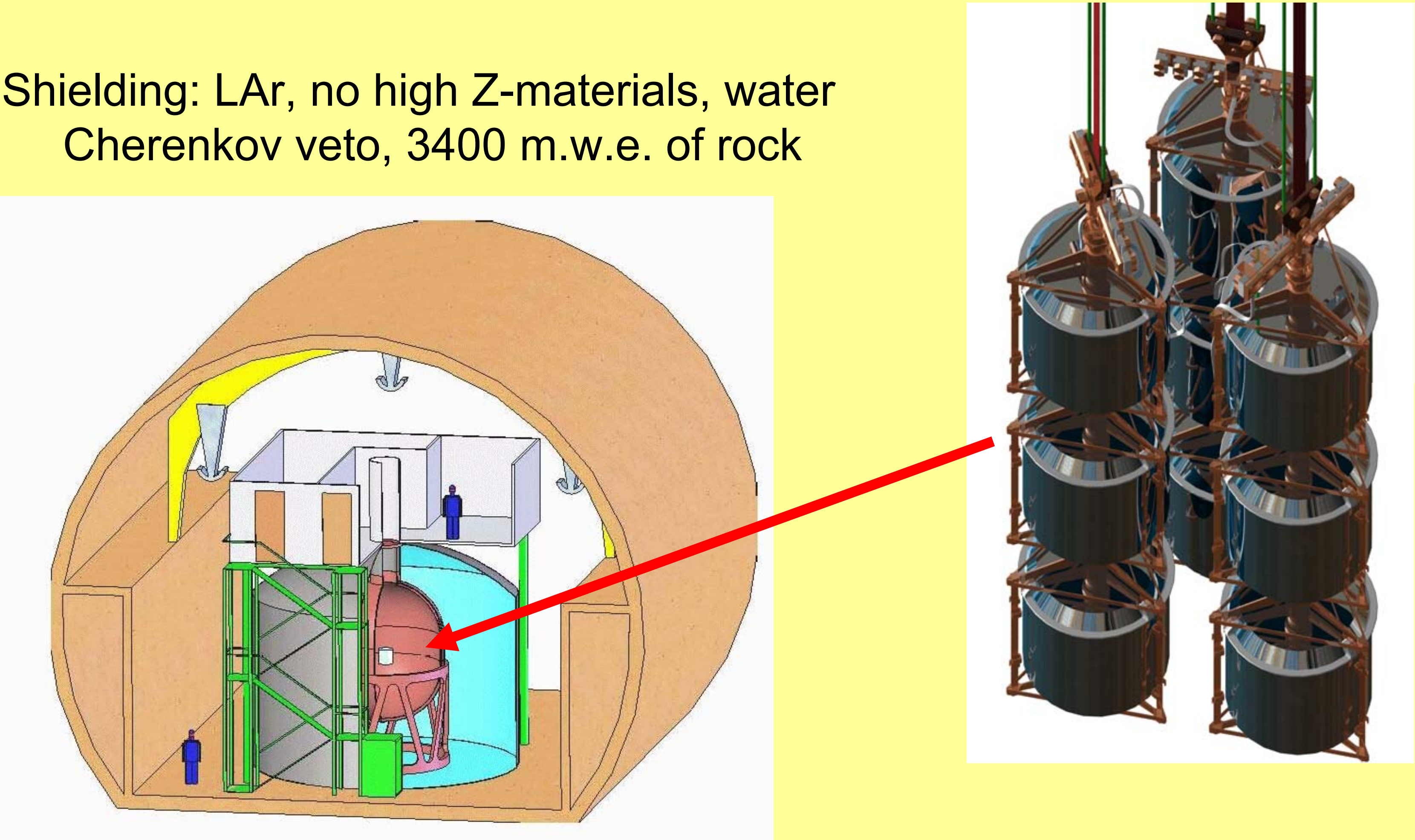


Source ⇔ Detector

enriched material (~87% ^{76}Ge)

GERDA: The GERmanium Detector Array

Shielding: LAr, no high Z-materials, water Cherenkov veto, 3400 m.w.e. of rock

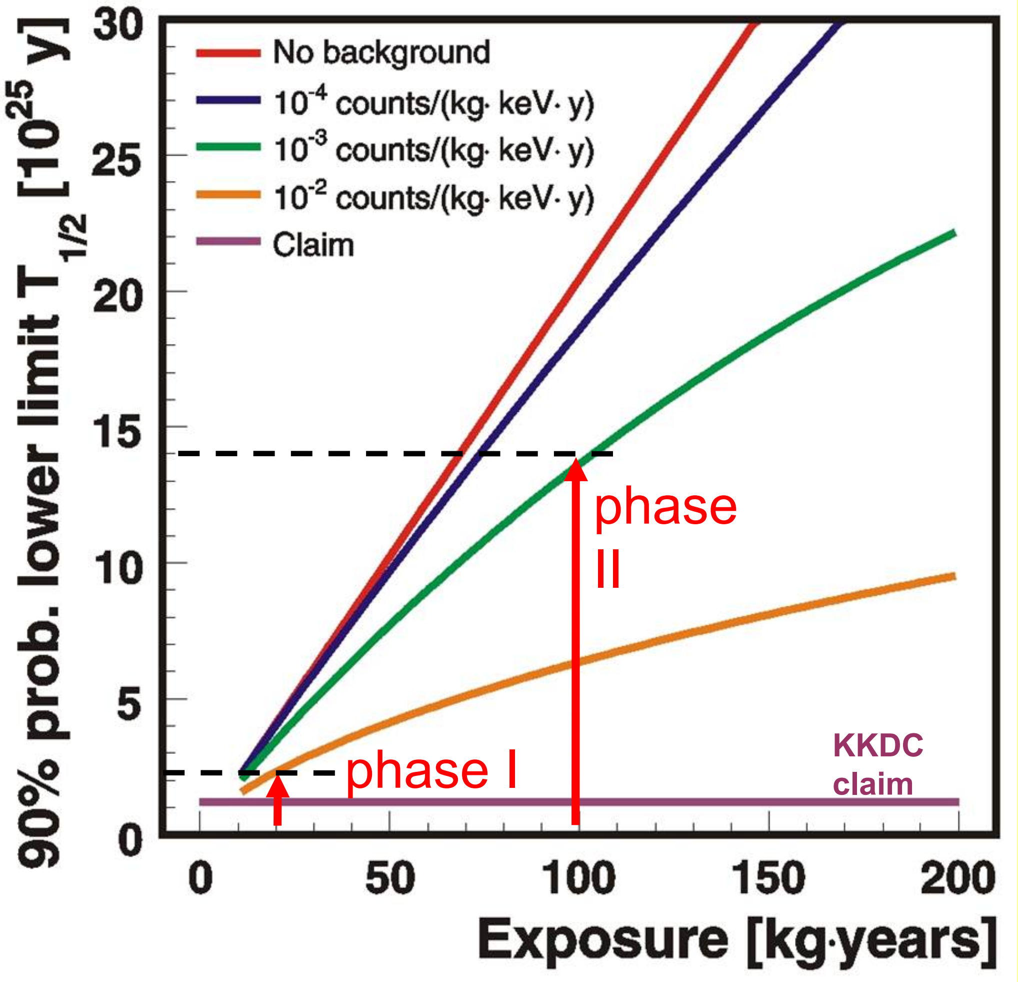


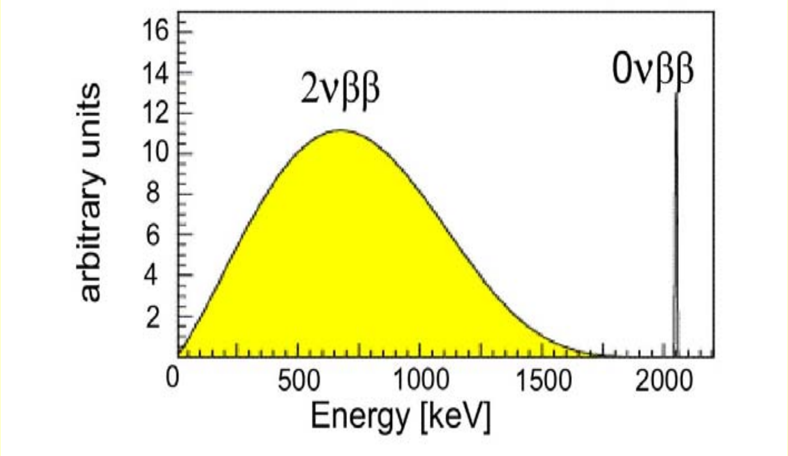
Sensitivity

Background

Phase I: 10^{-2} cts/(keV kg y)

Phase II: 10^{-3} cts/(keV kg y)





Background

Radiopurity of:
Germanium detector (Cosmogenic ^{68}Ge)
Germanium detector (Cosmogenic ^{60}Co)
Germanium detector (bulk)
Germanium detector (surface)
Cabling
Copper holder
Electronics
Cryogenic liquid
Infrastructure

Sources:
Natural activity of rock
Muons and neutrons

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Neutron Capture by ^{76}Ge

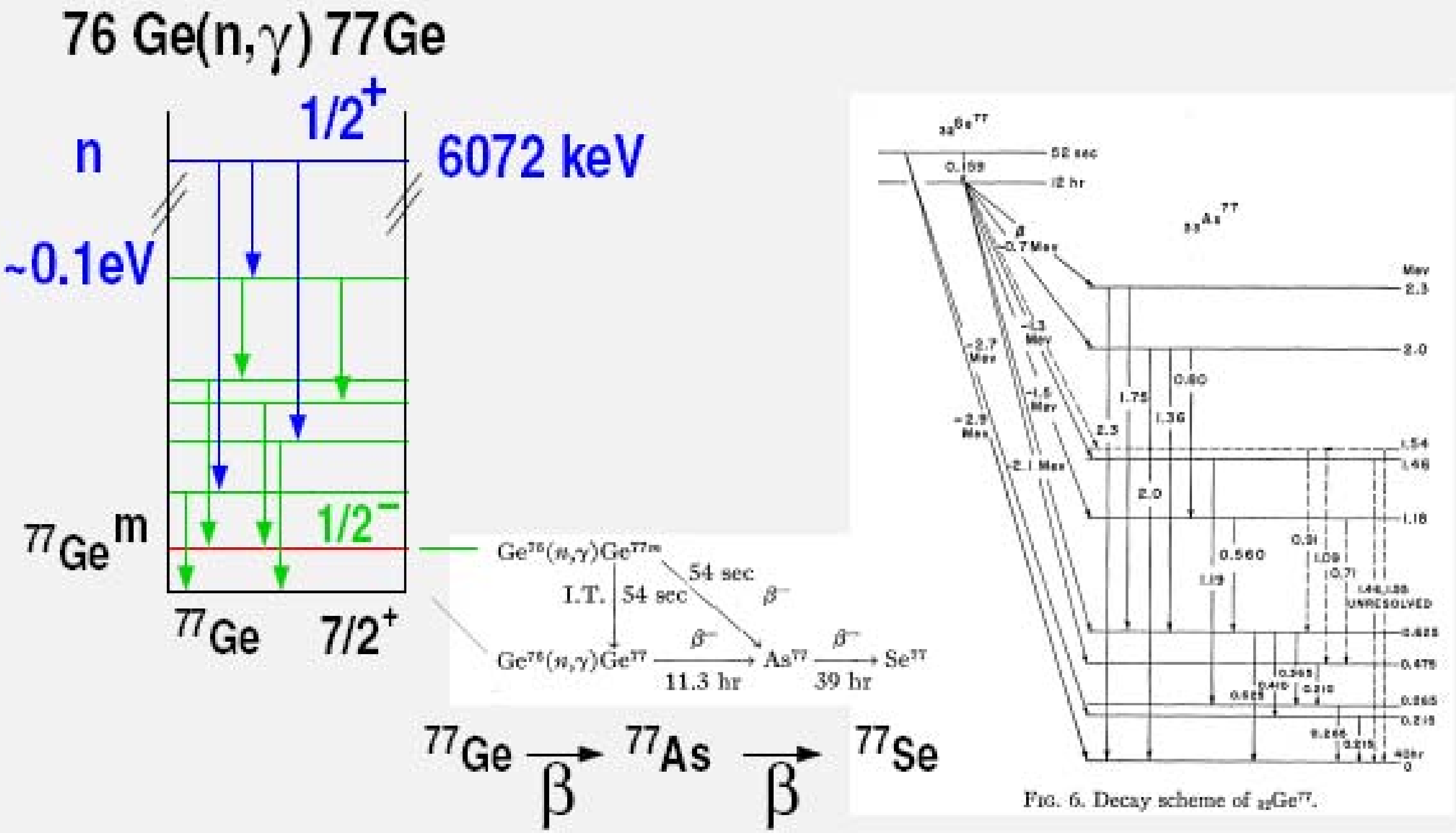


Fig. 6. Decay scheme of $_{32}$Ge^{77}.

$$^{77}\text{Ge} \xrightarrow[\beta]{} {}^{77}\text{As} \xrightarrow[\beta]{} {}^{77}\text{Se}$$

Q_β = 2703 690 keV

Burson. Et.al. 1957

Neutron Capture in GERDA

- ⇒ 1 n-capture/(kg y) (MC simulation)

- ⇒ Possible background in the region of interest (2039 keV)

  Segemented detectors allow to distinguish single site events ⇔ multi site events

- ⇒ If prompt spectrum is known, chance to trigger a veto on the prompt gammas after neutron capture to reduce the background from beta decay of $^{77}\text{Ge}^{m}$

But: Only 15% of the energy weighted intensity known

PGAA @ FRM II

TALK on Monday by P. Kudejova

Prompt Gamma Activation Analysis

Samples of enriched Germanium were irradiated with cold neutrons at the FRM II (Munich)

$<\lambda>=6,7$ Å

$\Phi=2x10^9$ n/(cm^2 s)

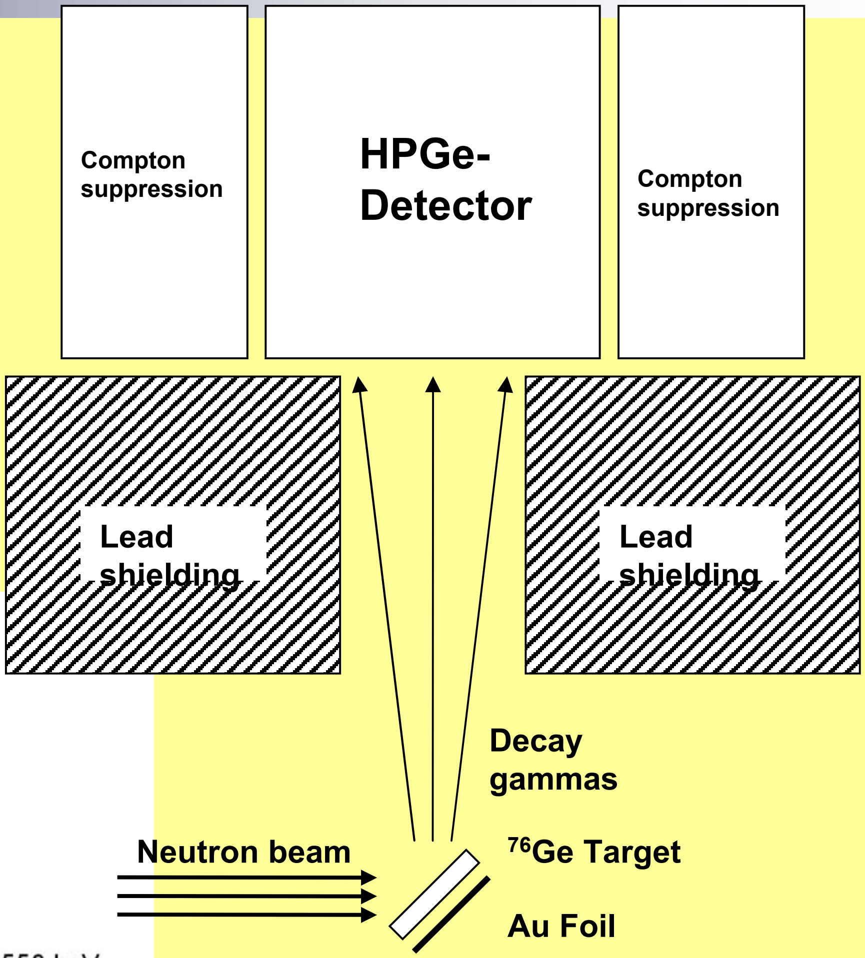
Using the PGAA technology the

- cross section of ^{76}Ge(n,gamma)^{77}Ge^m and ^{76}Ge(n,gamma)^{77}Ge^m
- prompt gamma spectrum (single/coincidence)

were measured

Cross Section

^{76}Ge target was activated and after irradiation the γ-radiation of the β-decay was measured by HPGe detectors.



Compton suppression

HPGe-Detector

Compton suppression

Lead shielding

Lead shielding

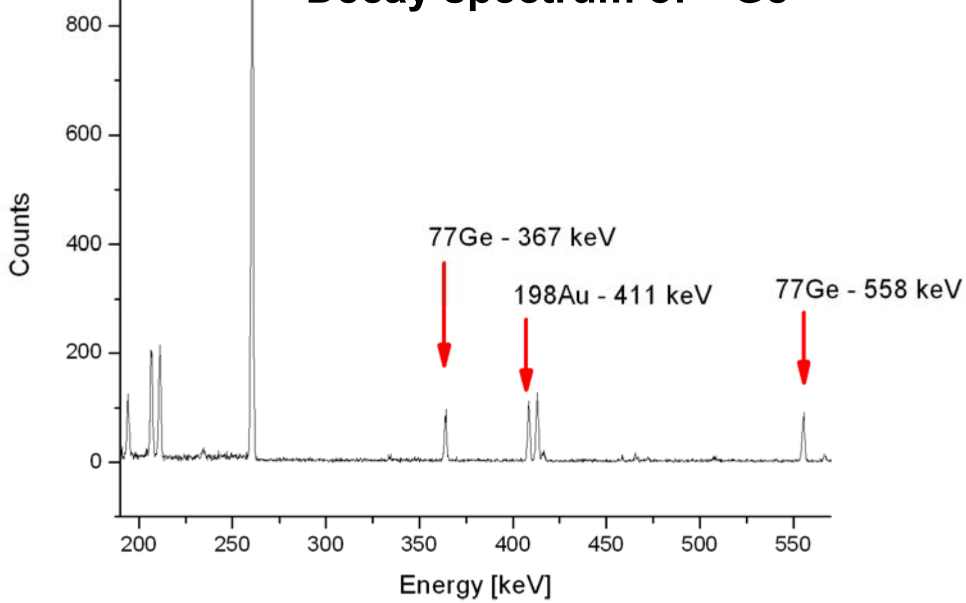
Decay gammas

Neutron beam

^{76}Ge Target

Au Foil

Decay spectrum of ^{77}Ge

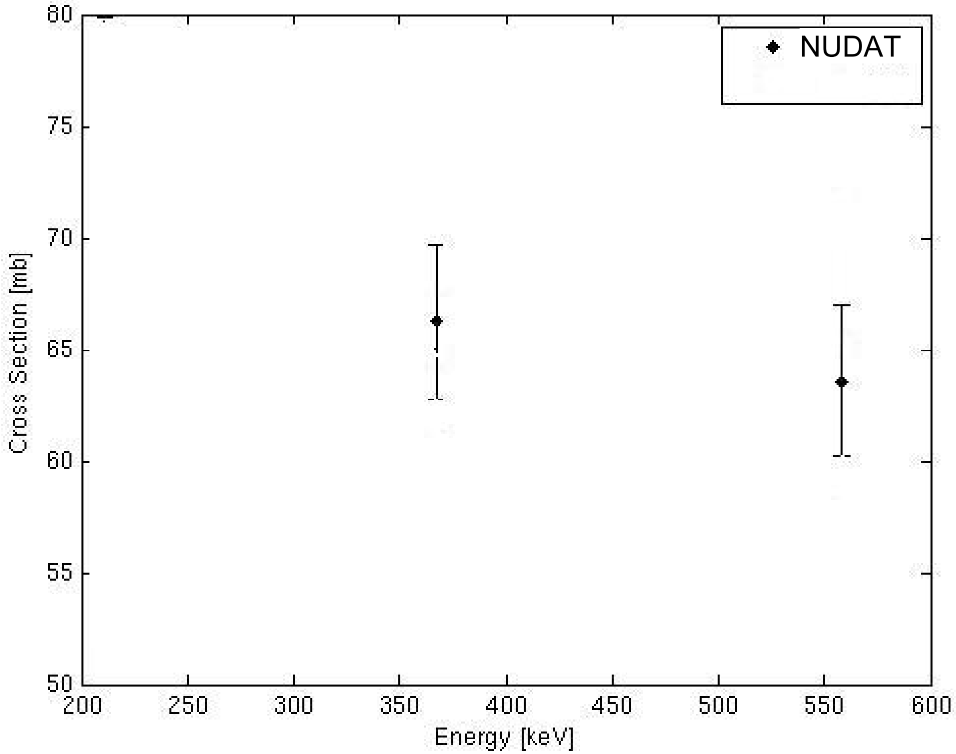


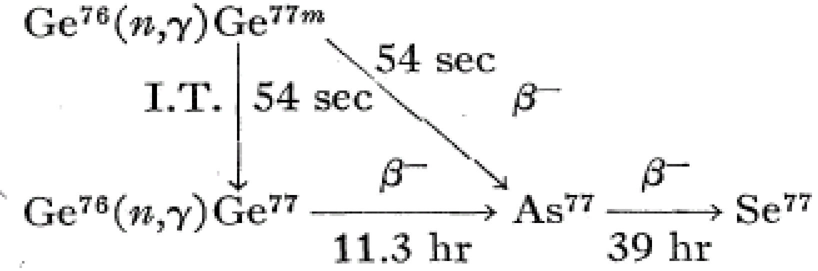
The total cross section was calculated using the emission probabilities given in NUDAT.

Cross Section

Preliminary results:

	Our measurement
	cross section [mbarn]
σ(^{77}Ge^{g} direct)	46.0 ± 5.0
σ(^{77}Ge^{g})	64.3 ± 4.4
σ(^{77}Ge^{m}) using IT using β-decay	 98 ± 12 112 ± 14





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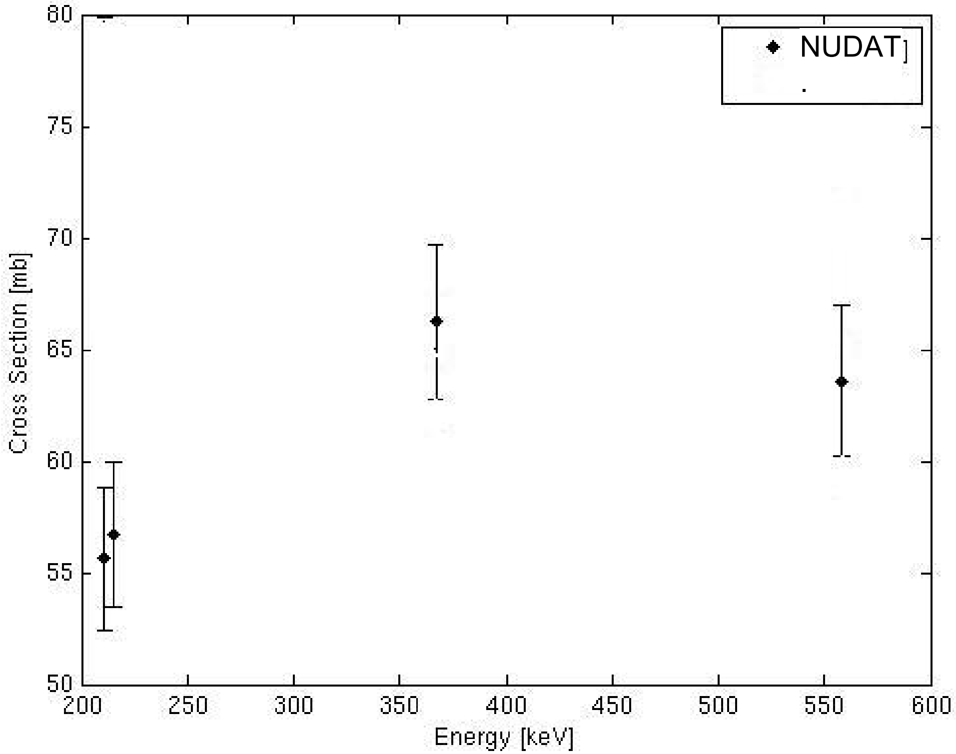

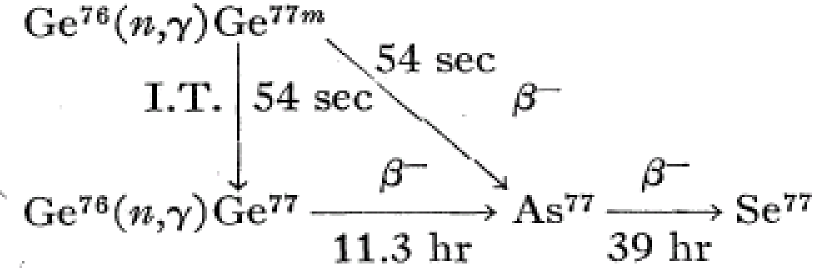

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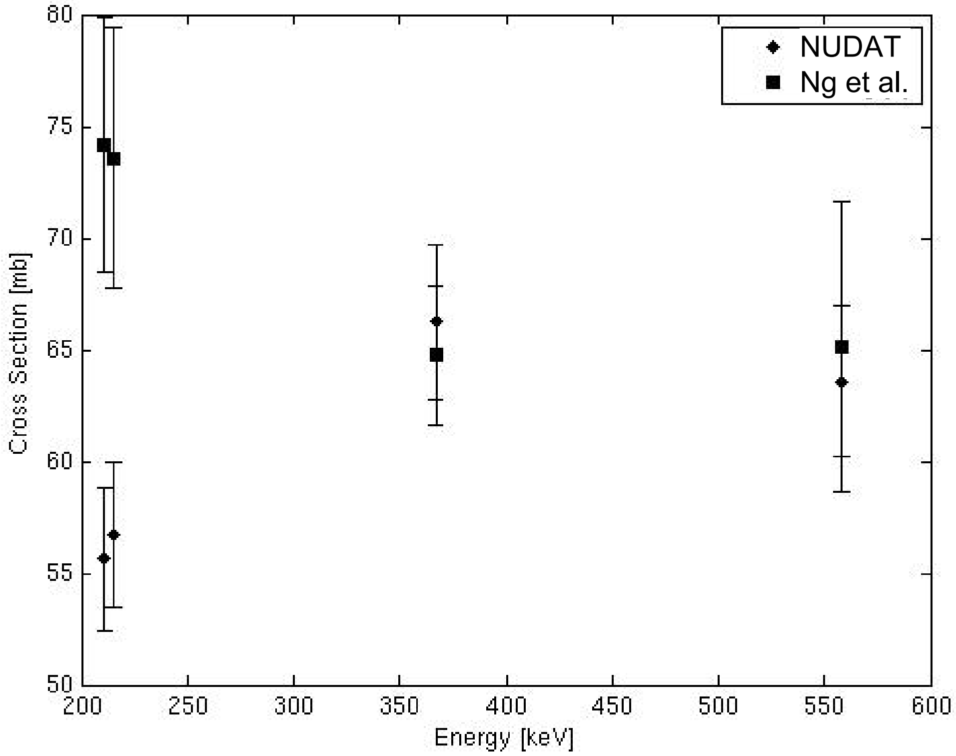
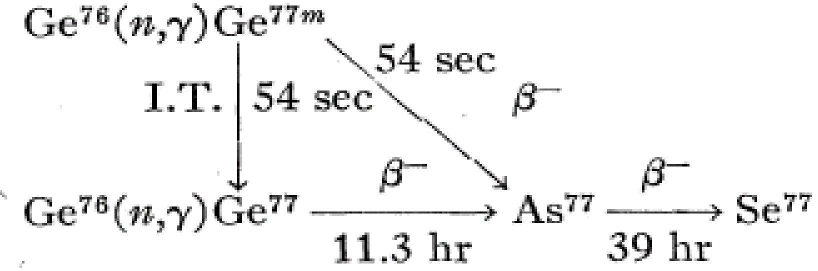


Ng: relative data, normalised to NUDAT
(A. Ng, Phys. Rev. 176, (1968), 1329

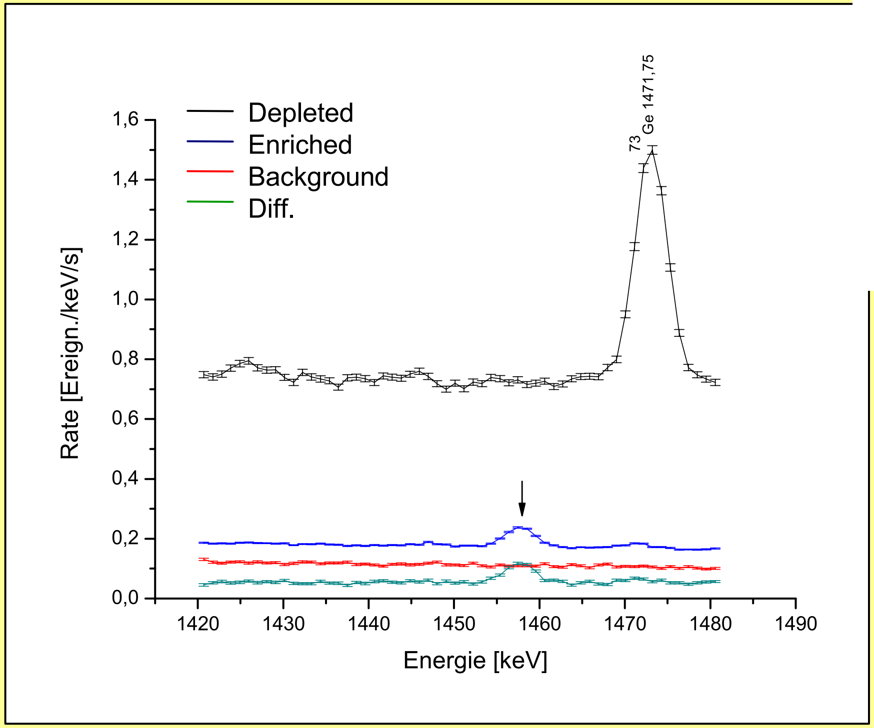


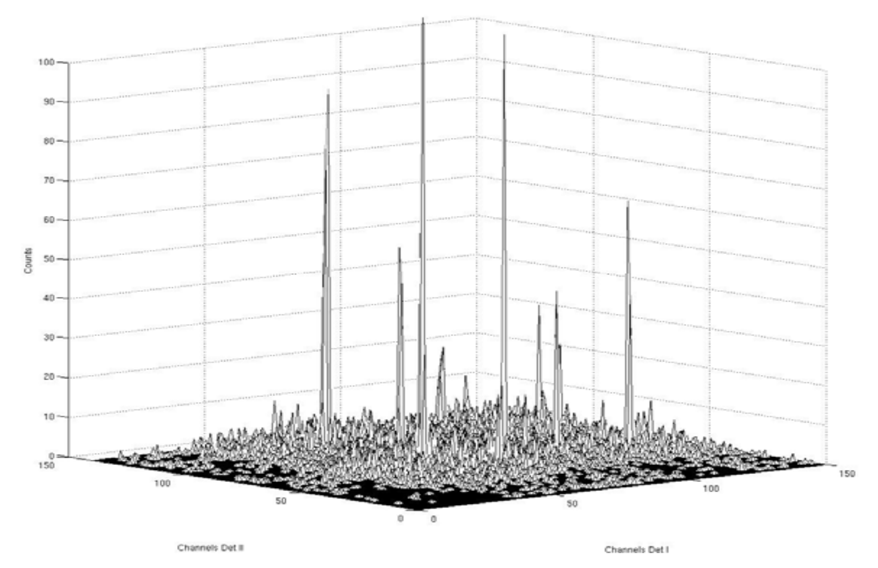
Prompt Gamma Ray Spectrum

Single spectra

m ~ 300 mg

Irradiation time > 50 000 s





Coincidence spectra

m ~ 300 mg

Irradiation time 10 d

Status GERDA

- Phase I detectors ready
- Cryostat, water tank built
- „Superstructure“ under construction
- Moun veto to be installed in autumn
- Tests, commissioning spring 2009
- Start of measurement 2009

Summary

- GERDA is a new type of 0vββ Decay experiment with ^{76}Ge (bare Ge diodes in cryogenic liquid)
- Background reduction and rejection major task in GERDA
- With good knowledge of the prompt gamma ray spectrum a veto on the delayed beta decay of ^{77}Ge can be triggert
- Therefore the cross section and the prompt gamma spectrum of the ^{76}Ge(n,gamma)^{77}Ge^{g,m} was measured