GERDA double beta decay experiment

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for the GERDA Collaboration

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GERDA experiment at Gran Sasso

The **GERmanium Detector Array** *experiment will look for $0\nu 2\beta$ decay in ^{76}Ge using HP-Ge detectors enriched in ^{76}Ge*

The experiment will be hosted in the Gran Sasso National Laboratory, under the Gran Sasso mountain (Italy), 3800 m w.e.

cosmic μ flux reduced of a factor 10^6

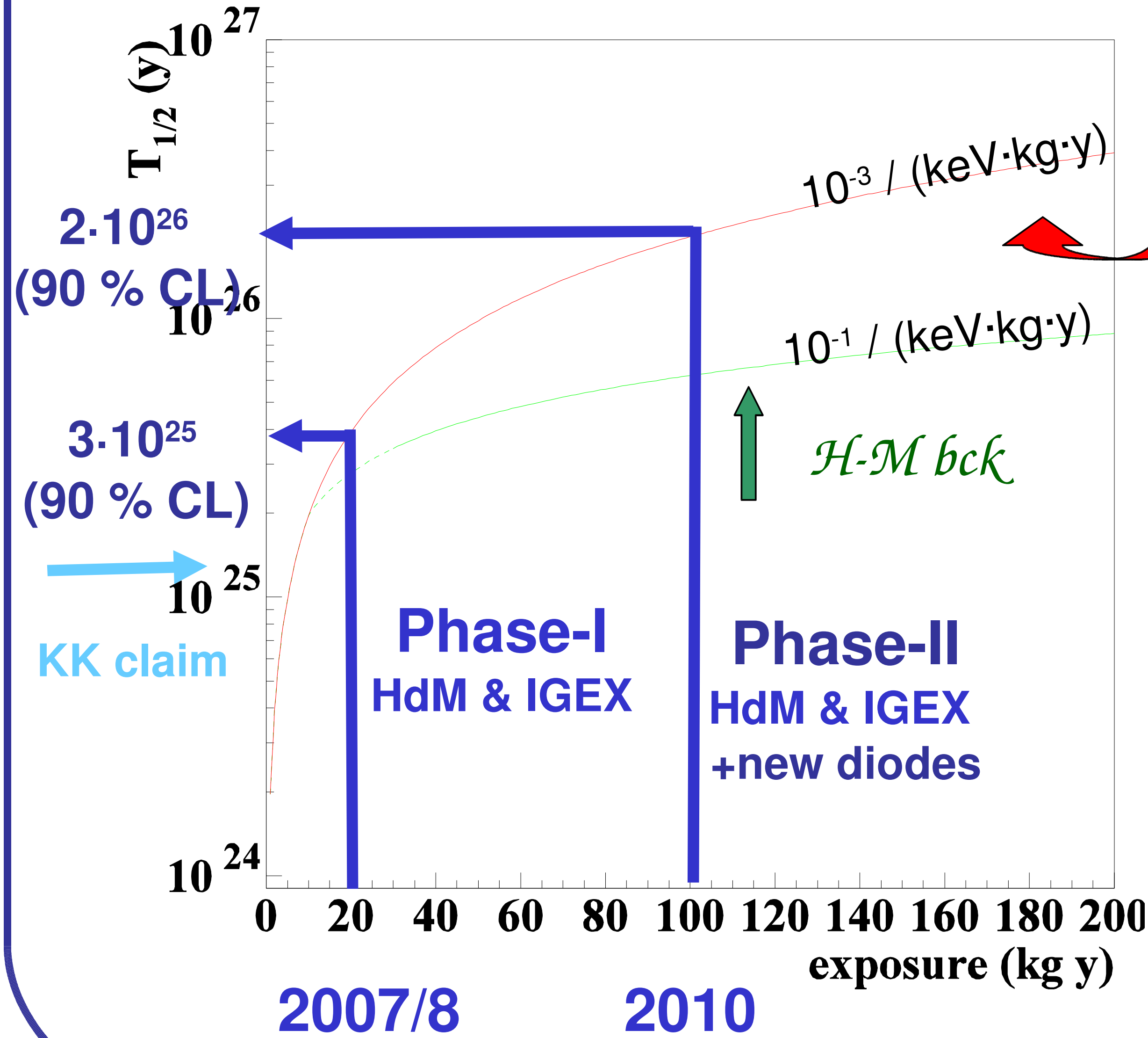
GERDA Collaboration

60 physicists

12 institutions

Italy, Germany, Russia

Phases and physics reach of Gerda



Our Goal: background index 10^{-3} *cts/(keV kg y)*

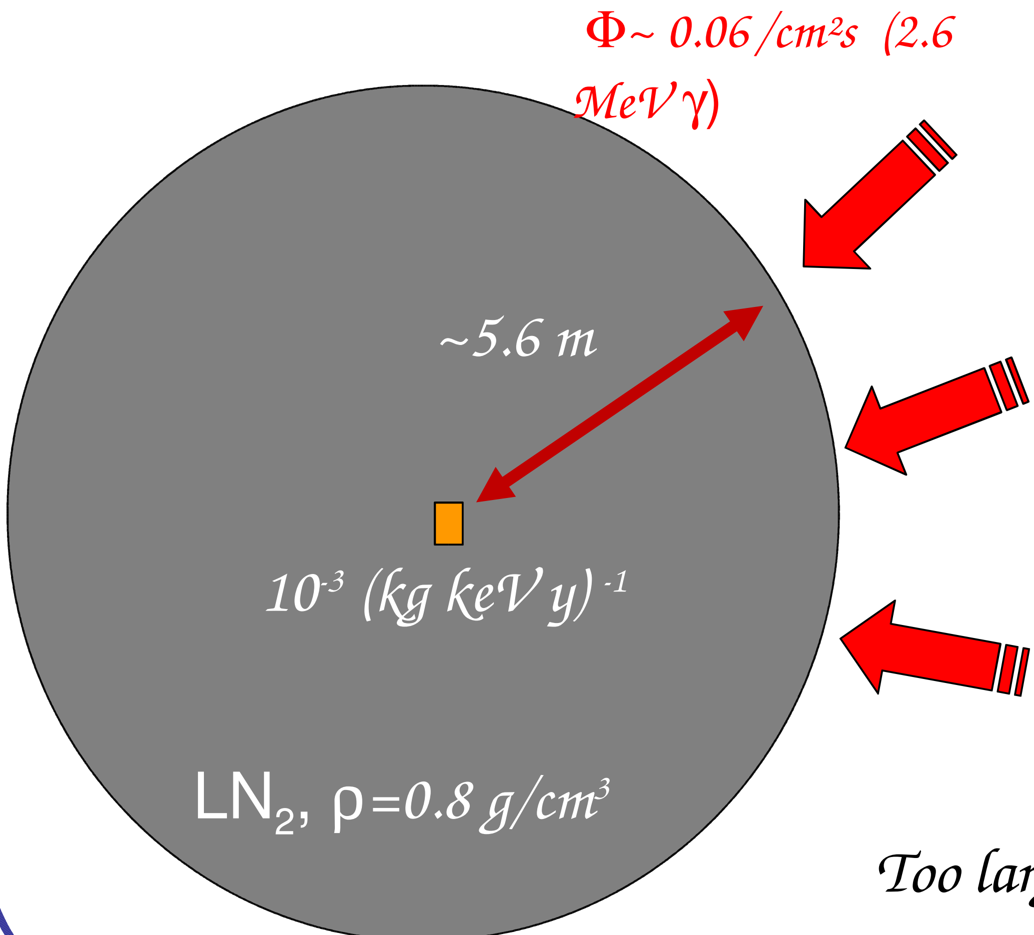
***Phase I**: existing detectors of HM & IGEX, establish background reduction*

***Phase II:** new detectors*

***Phase III**: worldwide new collaboration O(ton) experiment → 10^{27} y. Cooperation with Majorana*

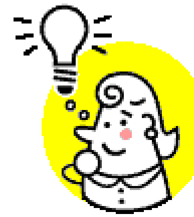
... how to reach 10^{-3} cts/keV kg y?

The background index of **10^{-3} counts/keV·kg·y** *is* **2 orders of magnitude** *smaller than the current state-of-the-art !*



Learn from Borexino!

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



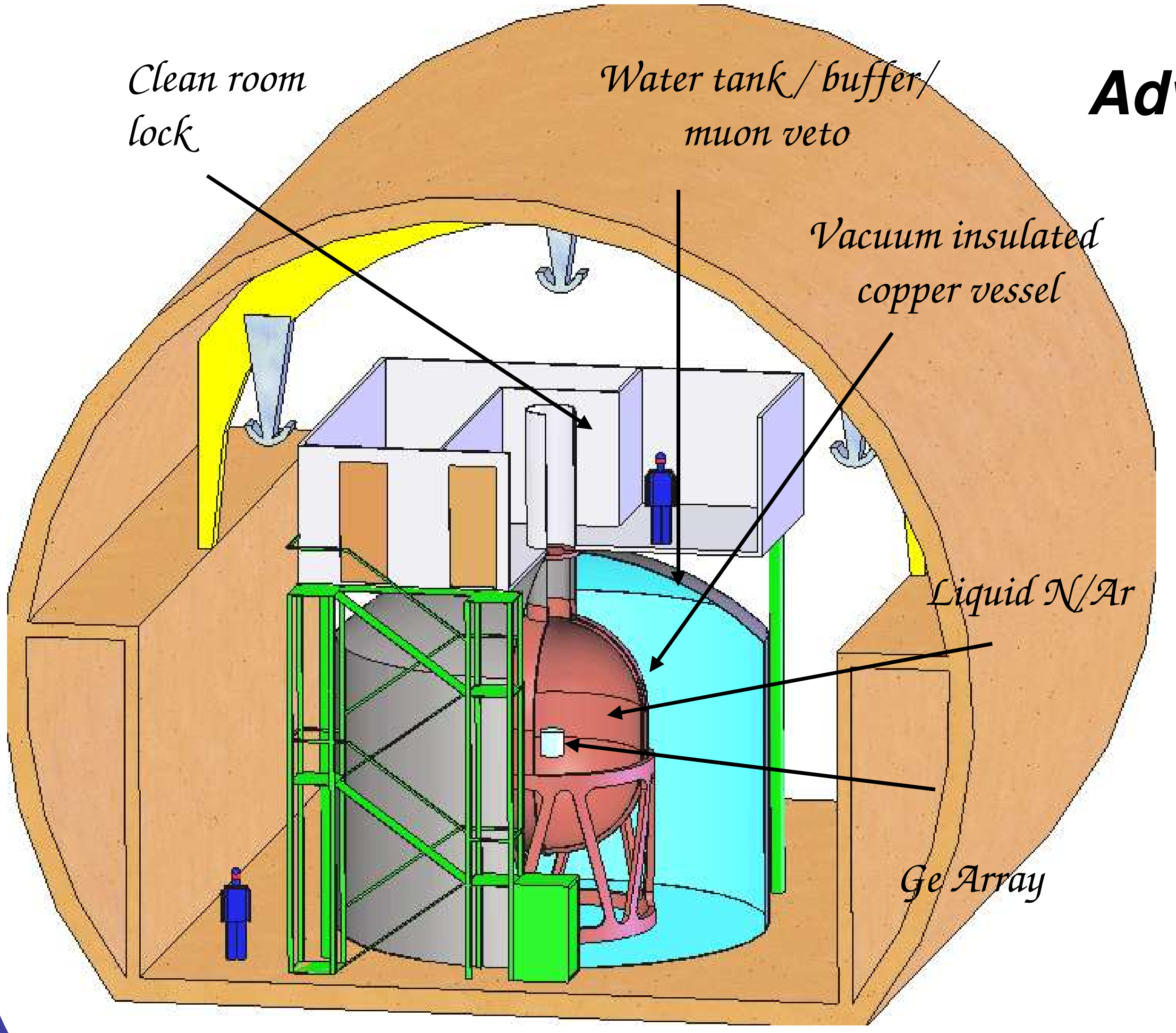
Shield against external γ operating **naked Ge crystals** *suspended in high purity liquid* **N_2/Ar**

< 0.3 μBq ^{222}Rn/m^3

(same concept of GENIUS and GEM)

Too large for GS → graded shielding (water buffer)

Gerda baseline design



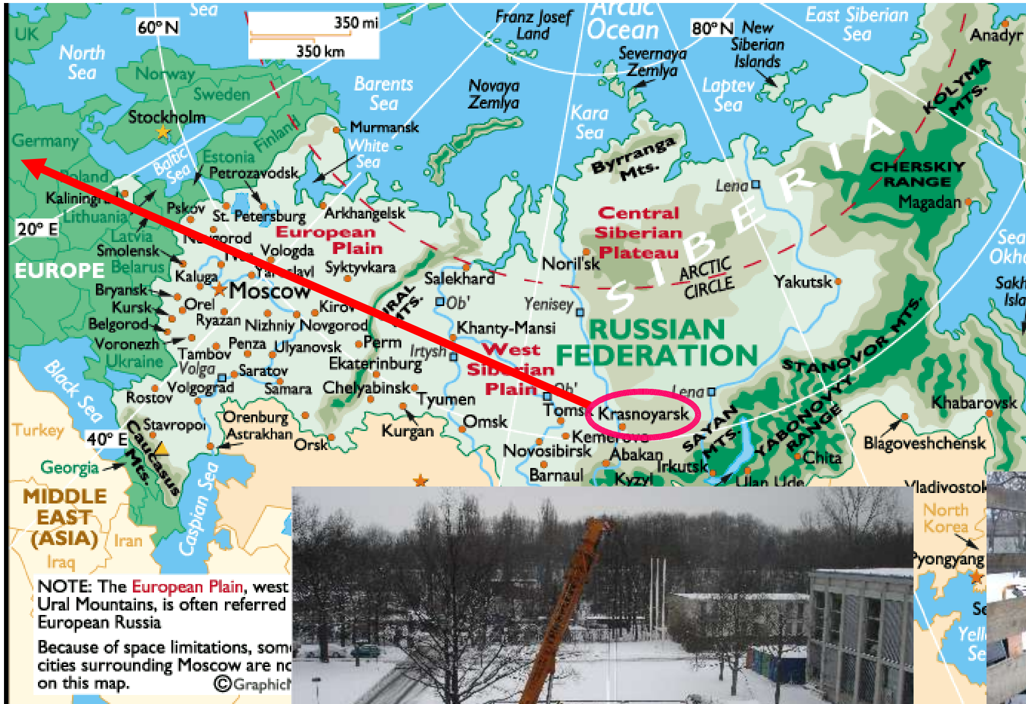
Advantages of water:

- better shielding than LNitrogen
- cheaper
- safer
- neutron moderator
- Cerenkov medium for 4π muon veto

External background < 10^{-3} cnt/(keV kg y) for LN_2,
factor ~10 smaller for LAr

New detectors for Phase II

Procurement of enriched germanium:



1) procurement of 15 kg of natural Ge ('test run')

2) procurement of 30-35 kg of ^{76}Ge ('real run') at 86%

Specially designed **protective steel container** reduces activation by cosmic rays by factor 20

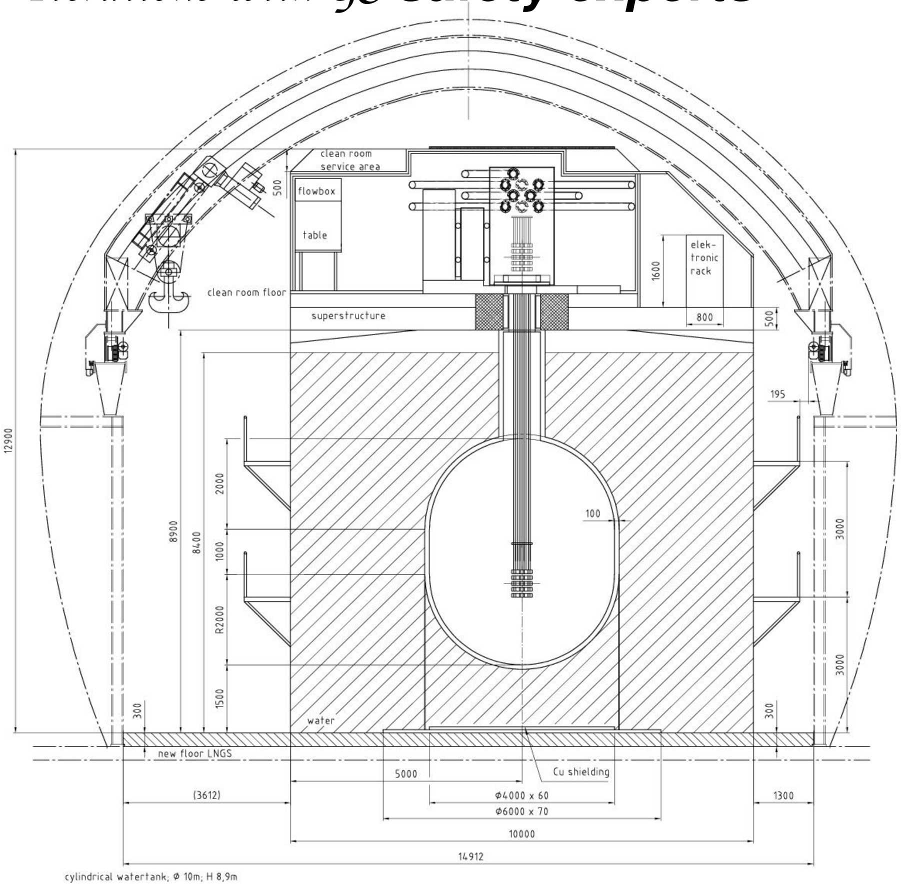
^{nat}Ge sample received March 7, 2005 $\Rightarrow$ 30-35 kg of ^{76}Ge in next weeks

enrichment completed in Sept 2005

Infrastructures & structures

Complete technical project

Iterations with GS **safety experts**

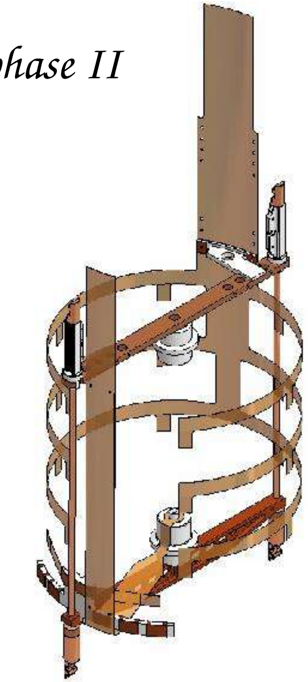


Tenders are going to start

Third wall for cryostat to be added

Crystals hanging system

phase II



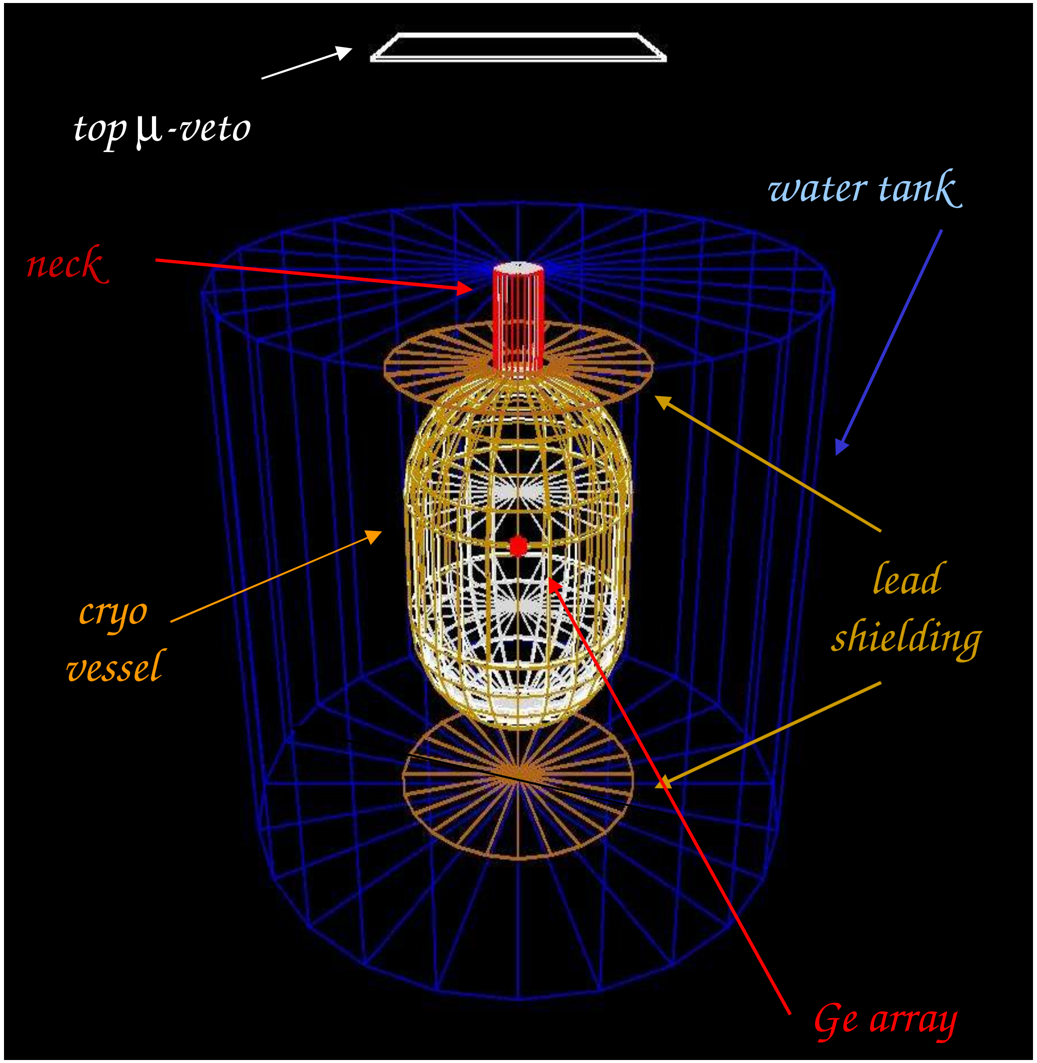
Goal: *minimize the total mass of the holder*

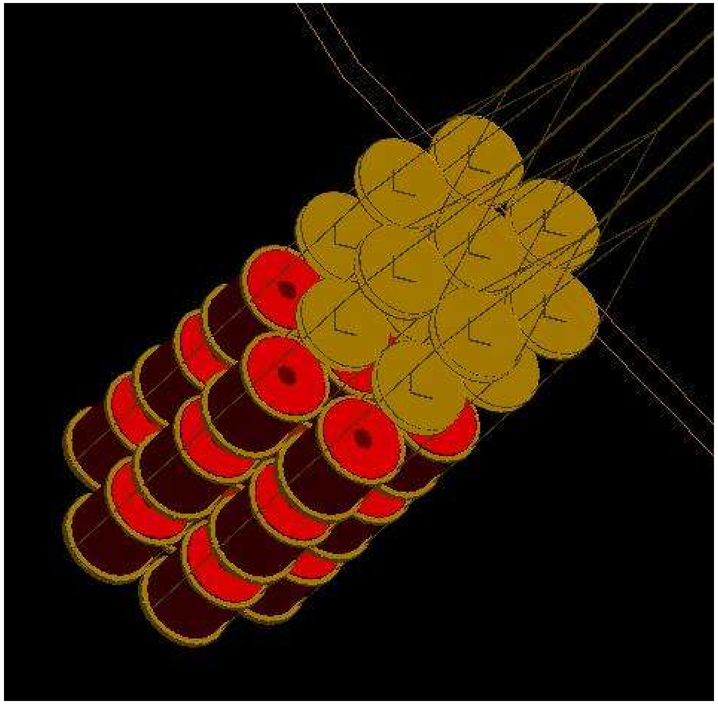
Test with a prototype

Distance between the crystals optimized by Monte Carlo studies

Background simulations with MaGe

(common Majorana–Gerda Geant4 MC framework)

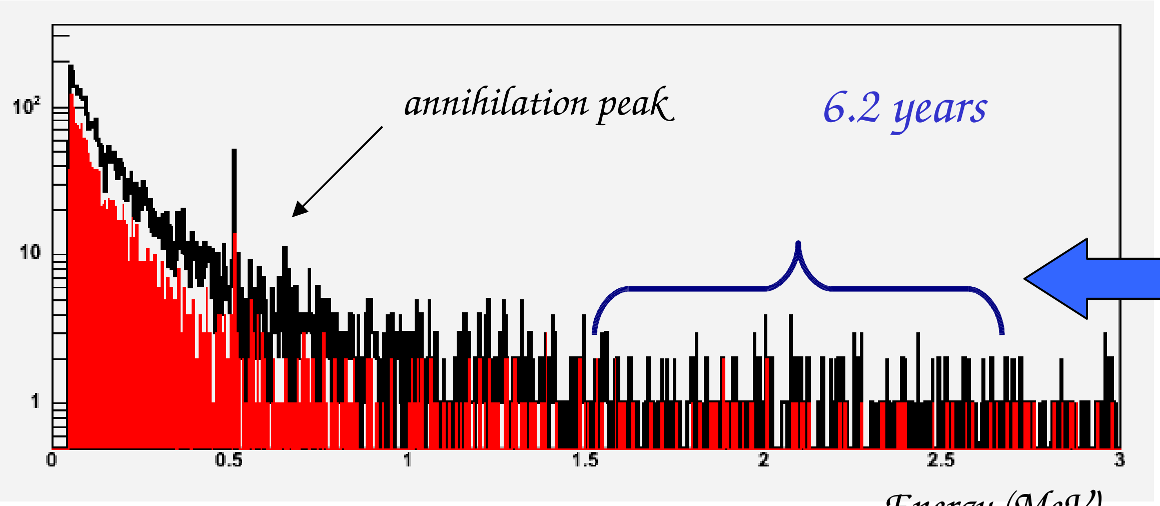




Description of the Gerda setup *including shielding (water tank, Cu tank, liquid Nitrogen), crystals array and kapton cables*

Physics studies with MaGe: muons

Phase I: 9 Ge crystals (total mass: 19 kg). Energy threshold: 50 keV



Energy spectrum without and with the crystals anti-coincidence

background reduction of a **factor of 3-4**

(1.5 → 2.5 MeV): **2.1·10^{-3} counts/keV kg y**

No cuts	2.1 · 10^{-3} (cts/keV kg y)
Crystals anci-coincidence	6.4 · 10^{-4}
Anti-coincidence+ top μ-veto (plastic scint)	5.4 · 10^{-4}
Cerenkov μ-veto	**< 3 · 10^{-5} (95% CL)**

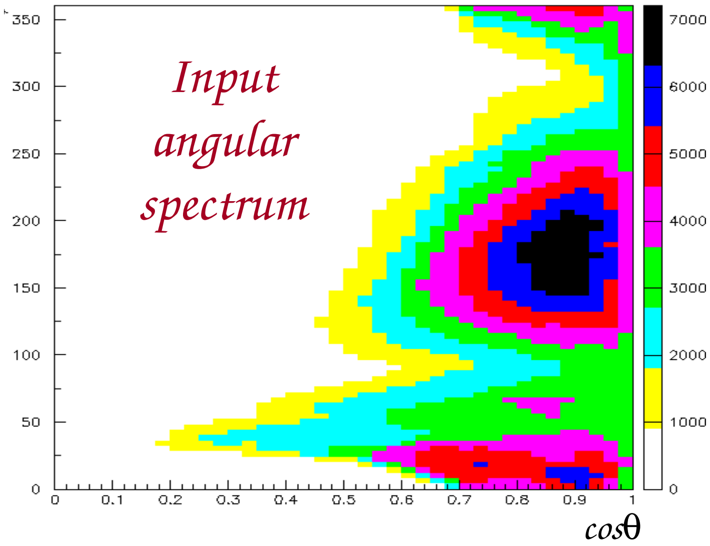
Limit comes from μ-induced activation → **6 · 10^{-5}** *cts/keV kg y*

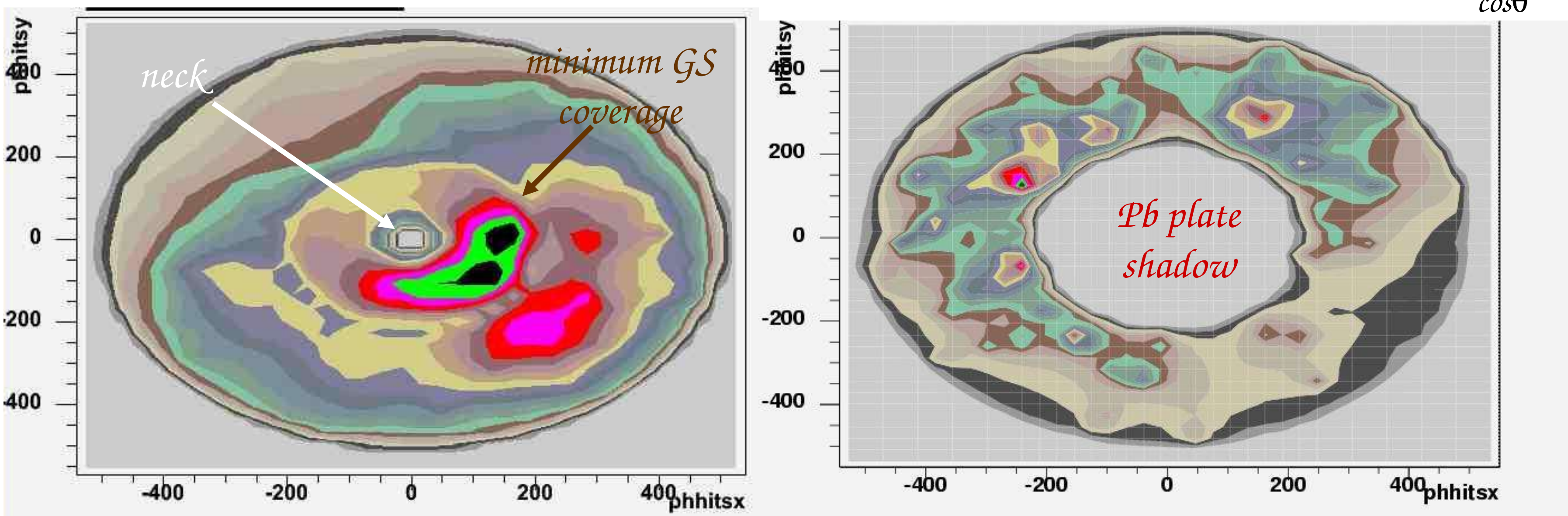
Optimization of Cerenkov veto

Assumptions on Cerekov veto threshold: 120 MeV (~60 cm)

40 p.e. (0.5% coverage + VM2000) → 80 PMTs

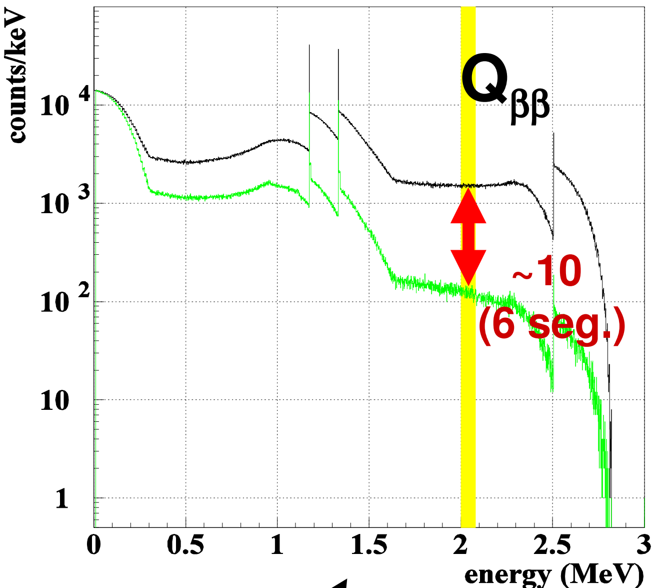
Detailed Monte Carlo studies with **optical photons** *to optimize the placement of the PMTs*



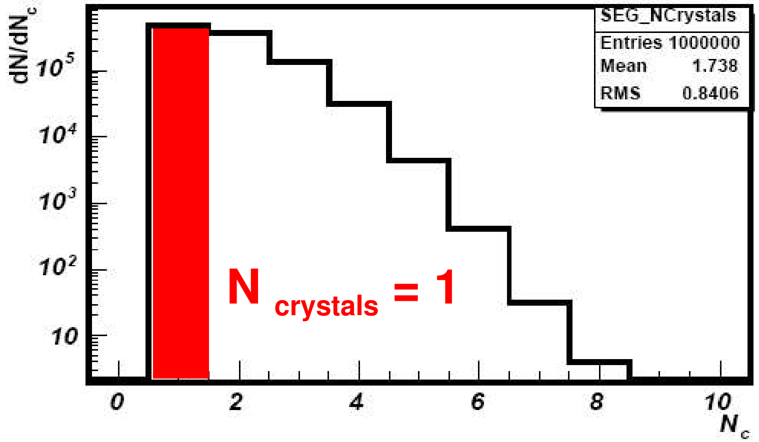


Light maps *on top and bottom of the water tank*

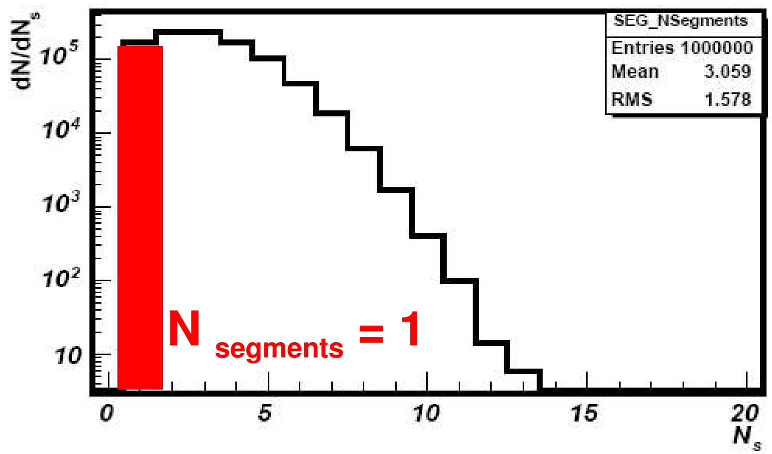
MaGe: Internal backgrounds (^{60}Co)

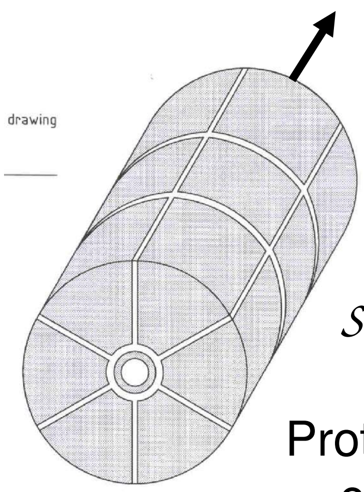


Number of crystals



Number di segments





Segmentation

6ϕ-3z

Prototype under costruction

The probability that a ^{60}Co decay gives energy deposition within **$Q_{\beta\beta}$±5 keV** *in a single segment (18-fold segmented detector) is:*

$P = 4.7\cdot10^{-5}$

(improvement of a factor of **35** *with respect to a single unsegmented detector)*

Underground facility for LAr R&D (LArGe)

Washstand with high-purity water supply

Use **LAr scintillation** *to make an active shield*

Clean bench & Rn-free clean bench

Fume hood with charcoal filter

LArGe shield

Status and perspectives

GERDA experiment will search for **^{76}Ge 0ν2β decay** with background of **10^{-3} counts/keV kg y**

challenging!

Test the result from *Klapdor-Kleingrothaus* in *1 year* (phase I). Start construction next year.

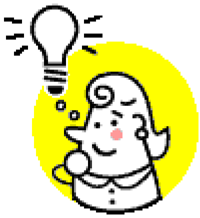
Intensive activity ongoing on *technical design* and *detector optimization* (supporting structures, cryovessel, electronics, μ veto), also driven by *Monte Carlo background studies* (MaGe)

36 kg of *enriched ^{76}Ge* produced

Positive *co-operation with Majorana* in Monte Carlo (common framework) and LAr R&D

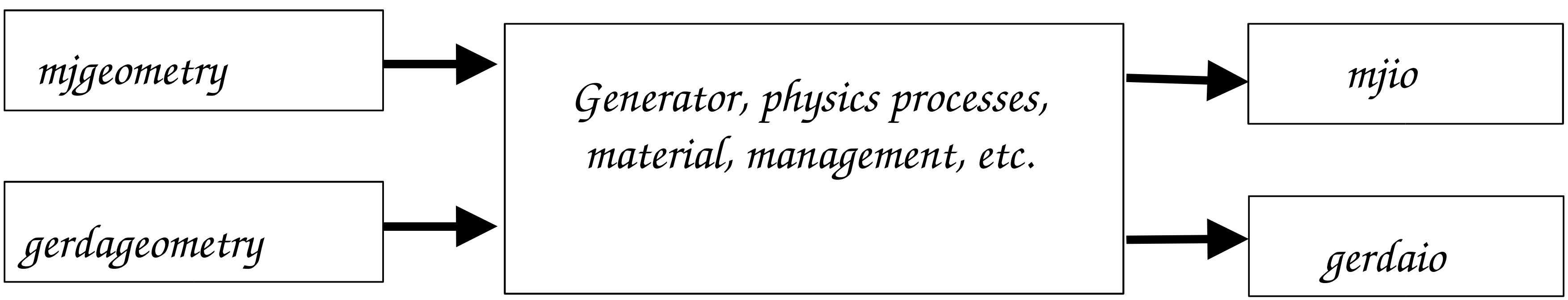
Backup slides

The MaGe framework



***Idea**: collaboration of Gerda and Majorana MC groups for the development of a common framework based on Geant4*

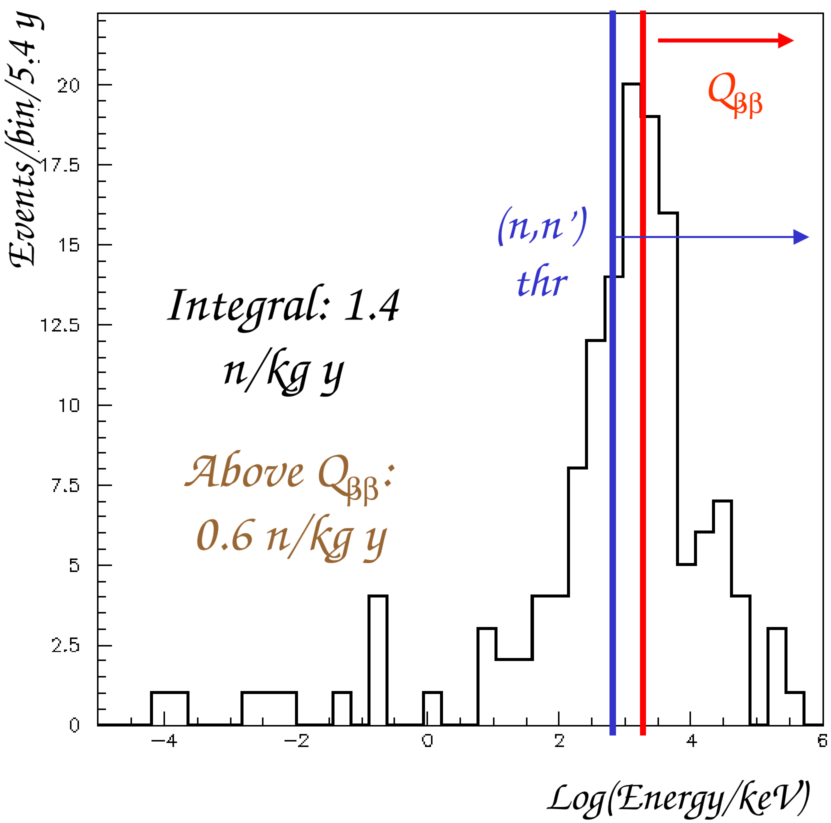
- ✓ *avoid the work* **duplication** *for the common parts (generators, physics, materials, management)*
- ✓ *provide the complete simulation chain*
- ✓ *more extensive* **validation** *with experimental data*
- ✓ *runnable by* **script;** *flexible for experiment-specific implementation of geometry and output;*



Muons crossing the detector (2)

The contribution coming from neutrons and hadronic showers is **< 0.1 %.** *Due to the specific Gerda set-up:*

- *crystals surrounded by low-Z material* (**low n yield** *from* μ)
- *water and nitrogen are effective neutron moderators*



Spectrum of neutrons in the crystals from QGSP_BIC_ISO physics list (good for μ-induced neutrons): agreement with FLUKA **within a factor of 2**

[M.Bauer, Proc. of V Workshop on the Identification of DM] [Araujo et al. NIM A 545 (2005) 398]

In the assumptions that **all neutrons** *above threshold give (n,n') interaction, neutron signal is conservatively* **< 10%** *of the EM signal (without any cut)*

Muons interacting in the rock

Estimate the contribution of **high-energy neutrons** *produced in the surrounding rock by cosmic ray μ 's*

Spectrum and total flux (~ 300 n/m^{2}y) from Wulandari et al., hep-ph/0401032 (2004) → agrees with LDV measurements

$$\frac{dN_n}{dE} \propto E^{-1.19}$$

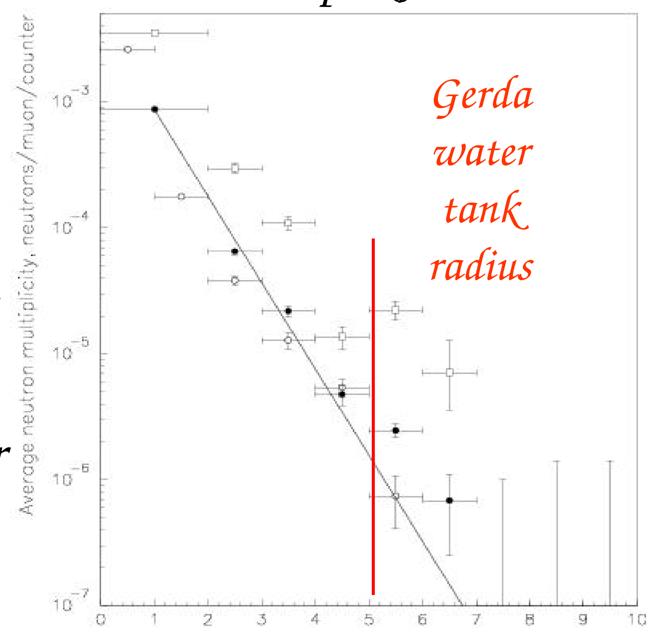
Background: ~ 4 · 10^{-5} cts/keV kg y

(without any cut: can be further reduced by anti-coincidence)

Water and nitrogen are effective neutron moderators

*Conservative estimate: the distance μ-n is <R> = 0.6 m (from LVD) → good chances that neutrons in the crystal are accompained by the primary μ in the water (***veto is effective***!)*

LVD, hep-ex/9905047



distance from track (m)

Mu-induced activation

Muon-induced interactions can create long-lived (> ms) unstable isotopes in the set-up materials with **$Q > Q_{\beta\beta}$**

cannot be vetoed or shielded against

Isotopes in the crystals are relevant (detected with high-efficiency). From the MC → **$6 \cdot 10^{-5}$ cts/keV kg y**

μ^- and π^- capture

^{74}Ga	8.1 m	<0.08 ev/kg y	^{69}Ge	39 h	<0.05 ev/kg y
^{75}Ga	2 m	0.09 ev/kg y	^{77}Ge	11 h	<0.02 ev/kg y
^{76}Ga	33 s	0.06 ev/kg y	^{71}Ge and ^{75}Ge not dangerous		

n capture, γ inelastic

Isotopes in LN_2 (^{12}B, ^{13}N, ^{16}N), copper (^{60}Co, ^{62}Cu) and water (^{16}N, ^{14}O, ^{12}B, ^{6}He, ^{13}B) give contributions **below 10^{-6} cts/keV kg y**

Notice: **^{16}N production rate in water** *is in good agreement with FLUKA (& data from SK) [hep-ph/0504227]* → *good MC cross-check*