Background for Gerda detector from external gamma activity

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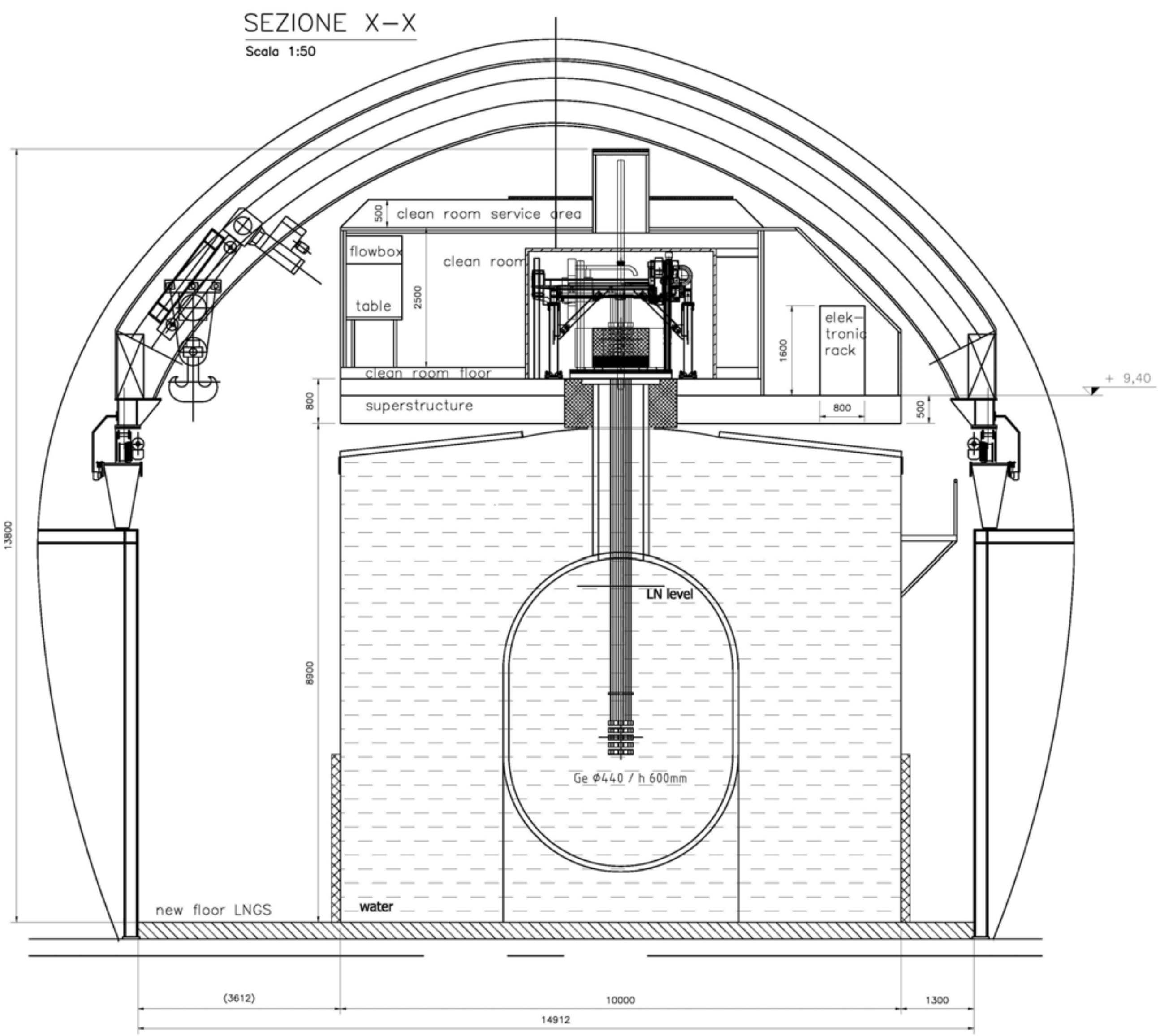
The background from external gamma activity has been considered
The germanium detectors are situated in the central position of the copper cryostat with liquid nitrogen or argon. The cryostat is placed in the steel tank filled with water.
The gamma activity can arise either in the cryostat material or in the surrounding rock.
We consider these two cases separately.
All parameters of the set up are taken from the last design

What is new ?

1) cryostat with Argon

2) background for set up with 27 crystals (second stage of Gerda)



cylindrical watertank; ø 10m; H 8,9m

The background from the cryostat material

Initial data. The all dimensions of the cryostat were taken from the last design. It is planned to be built from the copper of high purity except of the neck part. The calculations have been done by Monte Carlo simulation taking into account all parameters of the last crystat design (received from Karl-Tasso Knoepfle). The calculations were done for the Tl-208 line that gives the main contribution to the background.

The initial gamma activity data:

Copper activity is 25x10-3 mkBq/kg of Th-232.

Steel activity is 20 mBq/kg of Th-232.

Method calculation.

The calculations have been done by direct simulation of gamma rays transport to the detector through the cryostat material and liquid nitrogen. Anticoincedence between different diodes were taken into account. The background is registered in the 1800-2300 keV energy region.. All results below will be given for the background index in the units - count/keV.kg.year.

Results

Table 1

Background index for 9 and 27 detectors with 2 kg mass (c/kg.keV.year) in the center of the cryostat with **Nitrogen**.

	Cu (tank)	Steel (Neck)	**Total**
9 det	$2.0\bullet10^{-4}$	$6.0\bullet10^{-5}$	$\mathbf{2.6\bullet10^{-4}}$
27 det	$1.1\bullet10^{-4}$	$2.8\bullet10^{-5}$	$\mathbf{1.4\bullet10^{-4}}$

Table 2

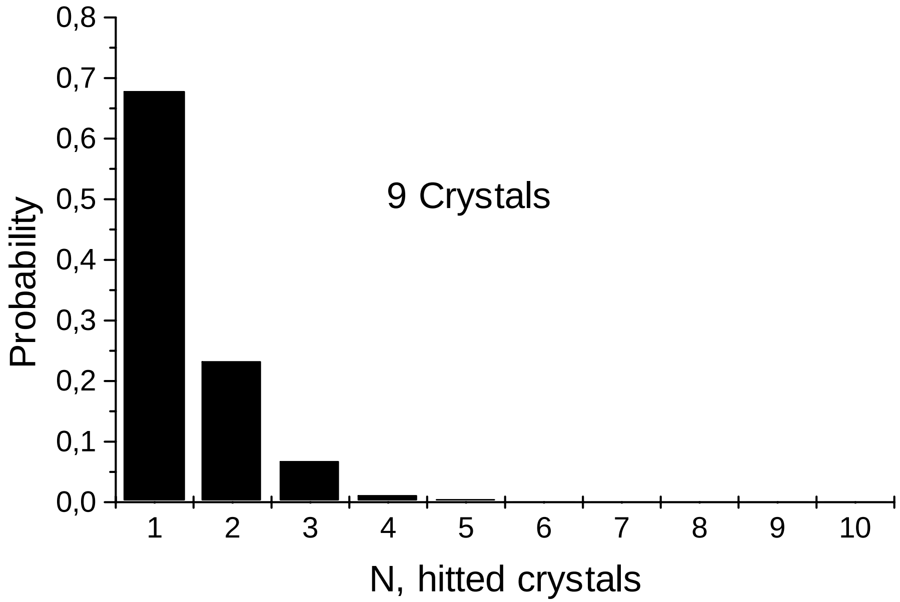
Background index for 9 and 27 detectors with 2 kg mass (c/kg.keV.year) in the center of the cryostat with **Argon**.

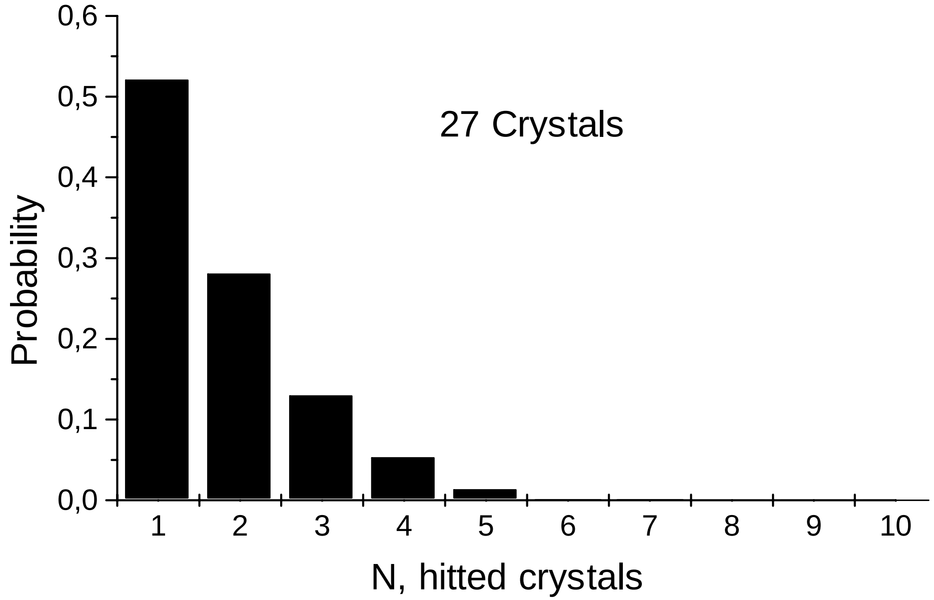
	Cu (tank)	Steel (Neck)	**Total**
9 det	$1.2\bullet10^{-5}$	$3.0\bullet10^{-6}$	$\mathbf{1.5\bullet10^{-5}}$
27 det	$7.1\bullet10^{-6}$	$1.2\bullet10^{-6}$	$\mathbf{7.3\bullet10^{-6}}$

Conclusion:

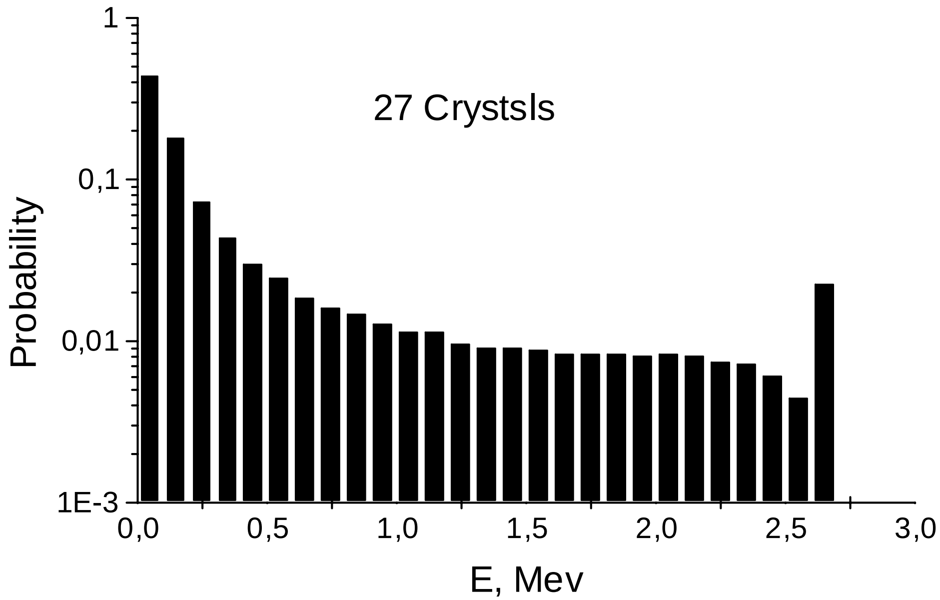
1) The background index 10^{-3} **c/kg.keV.year** that is planned for the first stages of experiment is possible.
2) Anticoincidences between the different diodes decrease the background on 35% for 9 det. and 48% for 27 det

Distribution of hitted crystals numbers




0,6
0,5
0,4
0,3
0,2
0,1
0,0
Probability
27 Crystals
1
2
3
4
5
6
7
8
9
10
N, hitted crystals

Spectrum



II. Requirement to superisolation

If the weight of superisolation is 1% from copper cryostat (~120 kg), its Th-232 activity must be less than 1 mBq/kg. The superisolation background is less than 0.8x10E-4 in this case.

III. Testing of the program. Comparing with GEANT 4

For testing of the program the additional calculations have been done in comparing with GEANT 4 for water sphere with radius of 0.5-2 m and single detector (2 kg) in the center. The results for coefficient of absorption are presented below.

The coefficient of absorption (cm2/g) for two energy regions:

	1.8-2.3 MeV	Peak (>2.6 Mev)
GEANT 4	0.036	0.042
Program	0.037	0.042
Table		0.0425

The coincidence of the results is an evidence of the program reliability.

IV. Background from external gammas.

The second step of calculation is the background from rock of underground room.

1. The thickness of the steel tank – 10 mm
2. The 9 and 27 detectors are in the cryostat center.
3. The intensity of the 2.615 MeV gamma line is 0.031 /cm^2.c with isotropic distribution.
4. The dimensions of the steel tank were taken from the report of Carla Cattadori on the Dubna meeting

Results.

Background index for 9 and 27 detectors from the rock (c/kg.keV.year)for the completely filled water tank. The thickness of the water in cylindrical part is 300 cm, upper and bottom parts are 200 cm. Anticoincidences between the different diodes are taken into account.

Table 3 **Nitrogen**

	9 det	27 det
Cylindrical part	$1.1\bullet10^{-4}$	$5.8\bullet10^{-5}$
Upper part	$1.2\bullet10^{-4}$	$6.8\bullet10^{-5}$
Bottom flat part	$1.9\bullet10^{-4}$	$1.1\bullet10^{-4}$
Open Neck	$2.4\bullet10^{-2}$	$8.4\bullet10^{-3}$
Neck with 15 cm Pb	$2.4\bullet10^{-5}$	~0

Table 3 **Argon**

	9 det	27 det
Cylindrical part	$6.1\bullet10^{-6}$	$3.1\bullet10^{-6}$
Upper part	$5.4\bullet10^{-6}$	$2.6\bullet10^{-6}$
Bottom flat part	$7.3\bullet10^{-6}$	$1.8\bullet10^{-6}$
Open Neck	$9.0\bullet10^{-4}$	$3.8\bullet10^{-4}$
Neck with 15 cm Pb	~0	~0

Table5

Background from external gammas

	9 det	**27 det**
Nitrogen	$\mathbf{2.1 \bullet 10^{-4}}$	$\mathbf{1.3 \bullet 10^{-4}}$
Argon	$\mathbf{1.0 \bullet 10^{-5}}$	$\mathbf{4.3 \bullet 10^{-6}}$

Conclusions:

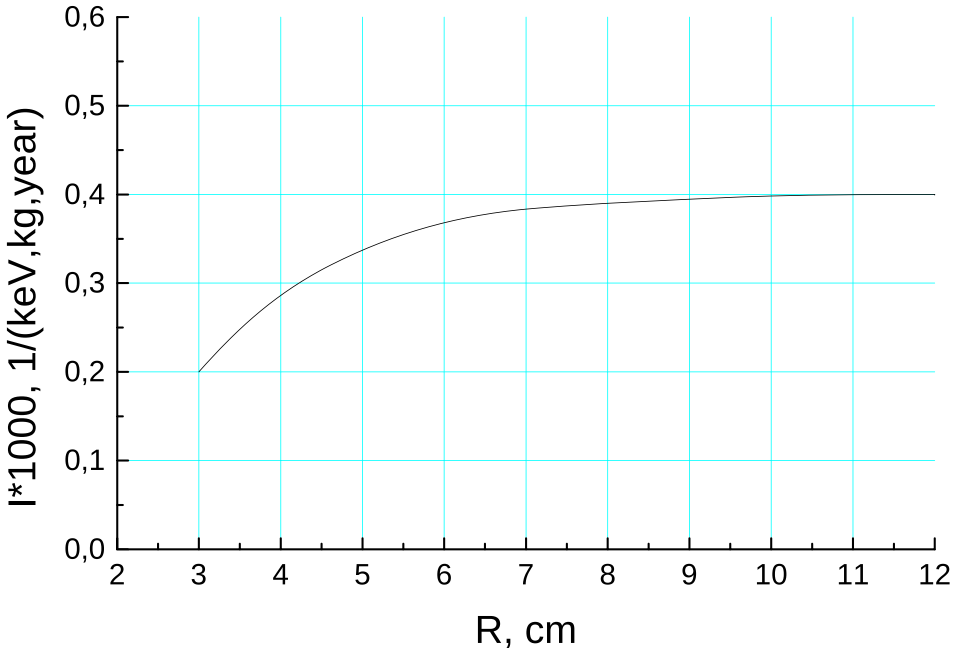
1. The background index ~$1 \bullet 10^{-3}$, which is planned for the first and second stages of the experiment is possible, without any additional shielding (without lead shoulders on the upper part of the water tank).
2. The cryostat neck must be shielded by 10-15 cm of Pb in case of Nitrogen.

The calculations for the new design are now in progress

Remarks on construction with third wall and copper shielding instead water

In case of introducing copper third wall into set up construction the background from the Th-232 in the copper can be higher.

The dependence of the index background from the copper thickness. The 232Th activity is 25 μBq/kg.



The starting point on the plot (3cm) corresponds the current cryostat project.

Conclusion : In case of introducing copper third wall into set up construction with thickness of a few cm or increasing the cryostat wall thickness the background becomes constant, equal to 0.4×10^{-4} /keV.kg.year and does not depend on copper thickness. The using water shielding does not give any improvement in background in comparing with copper. Taking into account that a meter of water (or other hydrogen material) is necessary anyway as neutron shielding, the copper shielding with thickness ~13cm in the most dangerous directions is enough for achieving background $\sim10^{-3}$ /keV.kg.year. The pure copper will be used only in the first layers (~5-6 cm) and in the most dangerous directions. The total mass of the pure copper will be ~100 t. Water shielding (as neutron shielding and muon veto) can be build separately and does not connect with copper shielding and cryostat at all.