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Background performance of the GERDA phase II with the "backup" detectors

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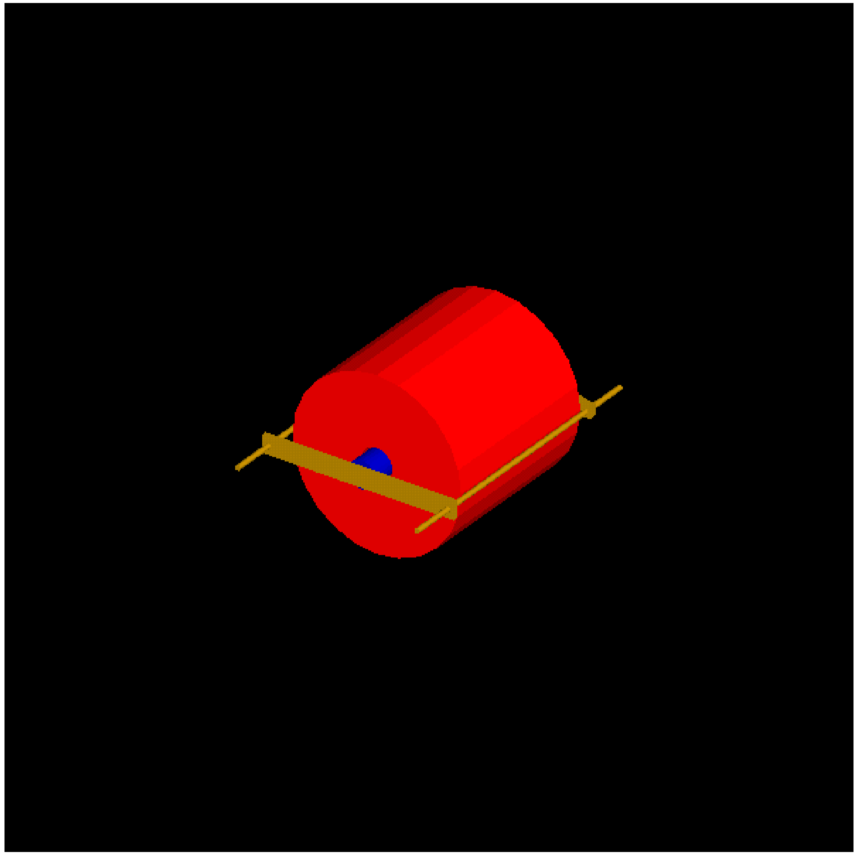
Motivation

The considered task was formulated by L. Bezrukov and supported by A. Caldwell when the first difficulties with big enriched crystal production were met by TG2.

We are trying to see **quantitatively** how the background conditions of the GERDA phase II would spoil if big segmented detectors are not affordable for any reason and **small non segmented detectors** are used.

In the optimistic case of the big detectors realization, the present work caries information about “partial” advantage achievable due to initially planned detectors size and segmentation.

"Backup" detector definition



MaGe model for small detectors:

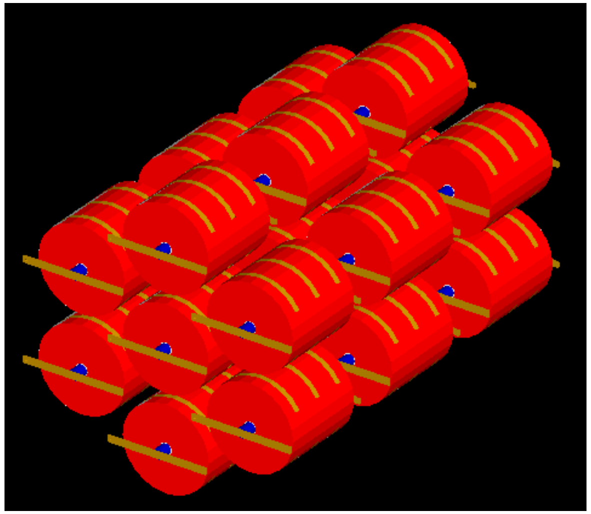
- Height: 6 cm
- Diameter: 6 cm
- Mass: 0.9 kg

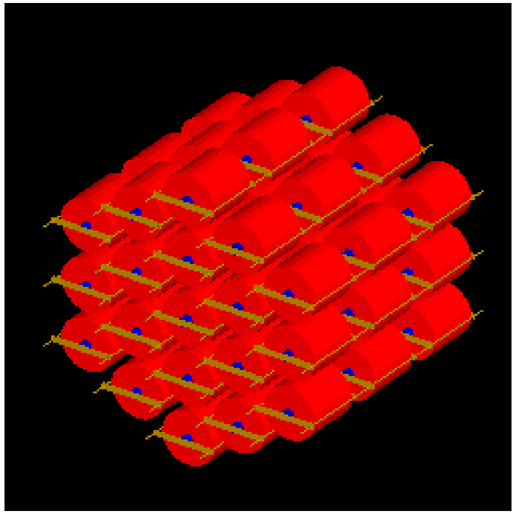
"Backup" detector definition:

Dimensions of surrounding details

Detail	Material	1 kg detectors		2 kg detectors	
		Volume, cm^3/det	Mass, g/det	Volume, cm^3/det	Mass, g/det
Detector	EnrGe	164	901	394	2169
Cable1	Copper	0.00681	0.0610	0.163	1.46
Cable3	Copper	0.0012	0.0108	0.0216	0.194
Holder Copper	Copper	1.71	15.4	4.062	36.4
Holder Teflon	Teflon	1.13	2.45	1.51	3.27
El. Board	Copper	2.68	24.1	4.77	42.8
El. Box	Copper	0.22	1.99	4.00	35.8
El. Bars	Copper	2.86	25.7	5.09	45.6

Assembly geometry





- Standard **21** detectors assembly for the **big segmented detectors**
- Symmetric configuration of **57 small non segmented detectors**
- Gaps between the small detectors are 3.75 cm in vertical direction and 0.75 cm in the horizontal one
- Total masses are **46 kg for array of the big detectors** and **51 kg for the small ones**
- We accepted this mass difference keeping in mind that the **same amount of material may be converted into smaller detectors with a higher efficiency**

Irradiation sources

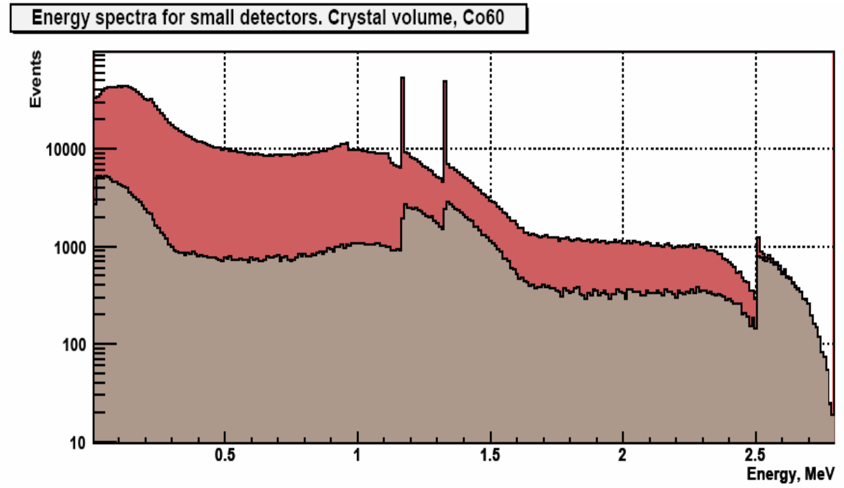
- Ge-68, Co-60 uniform in the crystal
- Bi-214, Tl-208 uniform on the crystal surface
- Bi-214, Tl-208, Co-60 uniform in the surrounding details
- Gamma energies 2039, …, 2614 keV isotropic from the sphere

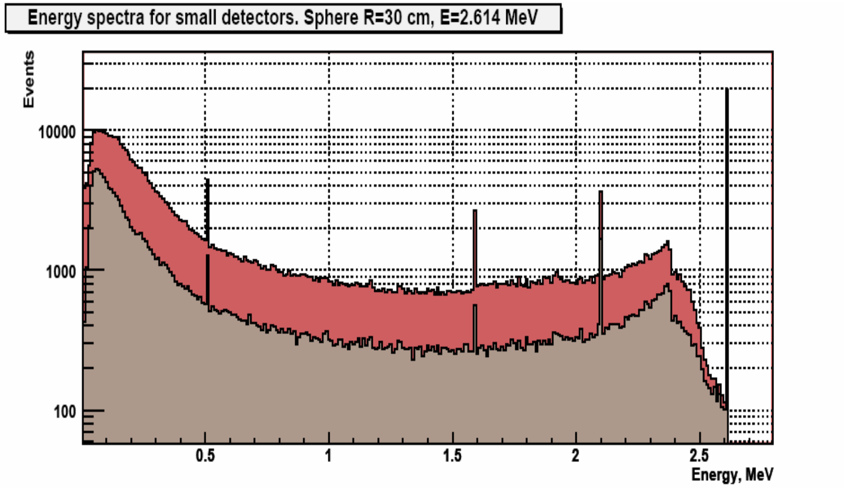
  In reality the gamma flux is concentrated around a direction of the thinnest shield, but our task should not be sensitive to this distinction

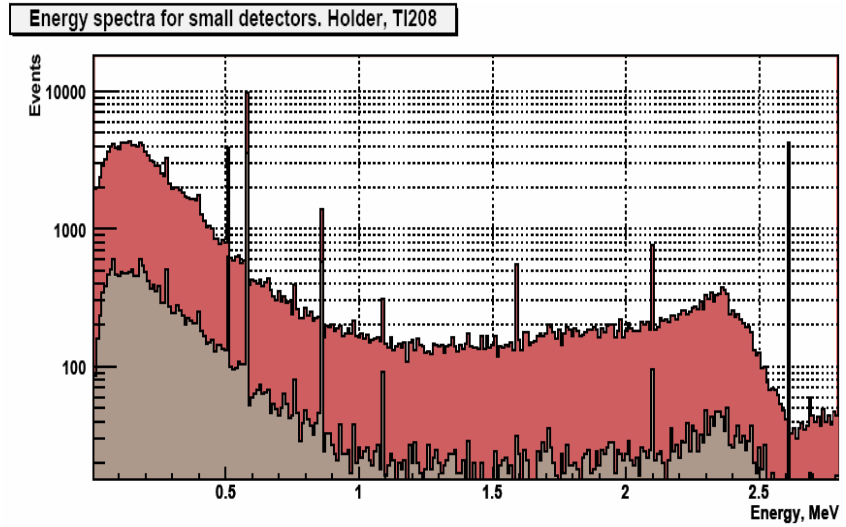
Results for AC suppression in different configurations

Results for AC suppression in different configurations:

Spectra for different sources in small detectors







Results for AC suppression in different configurations:

Internal sources

Object	Source	2.1 kg SP*10^6	0.9 kg SP*10^6	AC 0.9 kg SP*10^6	det. AC 2.1 kg SP*10^6	segm. AC 2.1 kg SP*10^6
Crystal	Co-60	1632	1127	330	720	56
	Ge-68	2366	1658	836	1510	194

SP is the probability to see an event in 10 keV window around 2039 keV.

Results for AC suppression in different configurations:

Detector surface

Object	Source	2.1 kg SP*10^6	0.9 kg SP*10^6	AC 0.9 kg SP*10^6	det. AC 2.1 kg SP*10^6	segm. AC 2.1 kg SP*10^6
Crystal Surface	Bi-214	780	660	310	510	220
	Tl-208	1840	2340	200	290	80

Results for AC suppression in different configurations:

Neighboring details

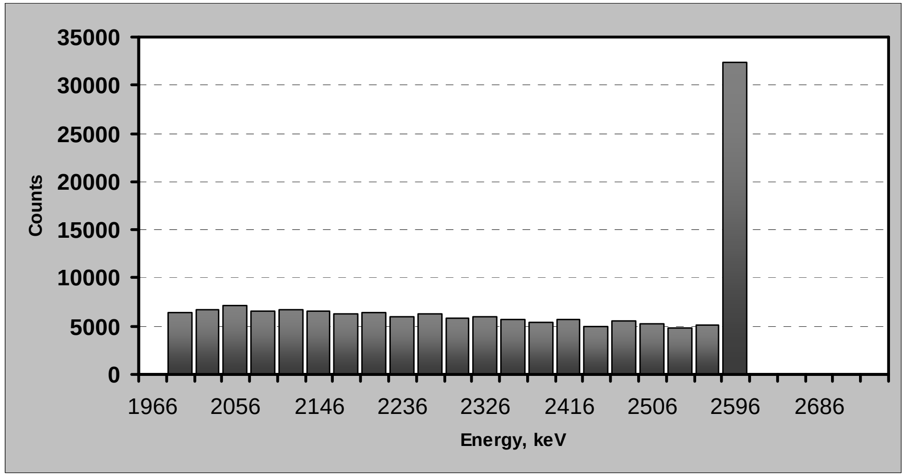
Object	Source	2.1 kg SP*10^6	0.9 kg SP*10^6	AC 0.9 kg SP*10^6	det. AC 2.1 kg SP*10^6	segm. AC 2.1 kg SP*10^6
Cable1	**Bi-214**	520	570	300	340	170
	Tl-208	1730	1970	220	380	150
	Co-60	580	440	80	230	30
Holder Copper	**Bi-214**	270	240	110	130	60
	Tl-208	1480	1780	240	350	130
	Co-60	280	270	100	160	< 10
Holder Teflon	**Bi-214**	220	280	90	140	20
	Tl-208	1810	2110	270	330	110
El. Board	**Bi-214**	3	8	5	2	< 1
	Tl-208	44	57	23	23	12
El. Bars	**Bi-214**	20	< 10	< 10	20	10
	Tl-208	120	90	30	20	20

Results for AC suppression in different configurations:

External gammas

Energy MeV	0.9 kg det. AC SP*10^6	2.1 kg segm. AC SP*10^6	Ratio
2.039	22220	8105	**2.742**
2.100	161	42	**3.833**
2.200	396	129	**3.070**
2.300	786	463	**1.698**
2.400	539	274	**1.967**
2.500	414	224	**1.848**
2.614	328	186	**1.763**

Example for 2.614 MeV γ passing the 20 interaction lengths



Ratio of non scattered gammas to scattered (E>2000 keV) is 0.272

Results for AC suppression in different configurations:

External gammas

Convolution of such a spectrum with the numbers from the table gives a factor

2.35

difference in background counting rate between big segmented and small detectors

Results for BI

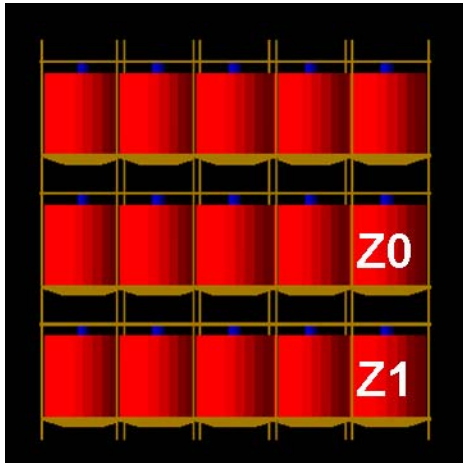
Object	Source	2.1 kg sAC $SP*10^6$	0.9 kg AC $SP*10^6$	Activity assumption	2.1 sAC BI, gbu	0.9 AC BI, gbu	Ratio
Crystal volume	**Co-60**	56	330	0.507 μBq/kg (20 days, 6 nuc/day/kg)	0.896	5.28	**5.89**
	Ge-68	194	836	4.439 μBq/kg (25 days, 5.6 ncl/day/kg)	27.16	117.04	**4.31**
Crystal surface	**Bi-214**	220	310	1.0 nBq/cm^2 (1 μm, 1 mBq/kg)	1.04	2.03	**1.95**
	Tl-208	80	200	1.0 nBq/cm^2 (1 μm, 1 mBq/kg)	0.378	1.31	**3.46**

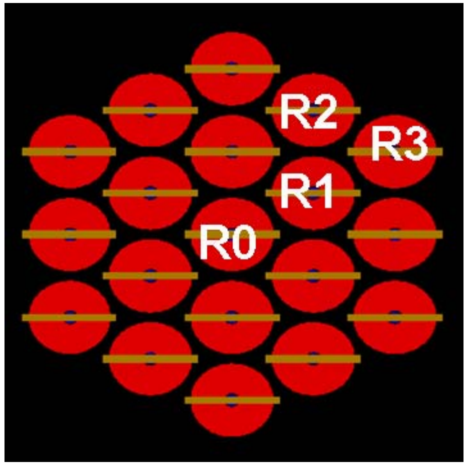
Results for BI

Object	Source	SP*10^6, 2.1 sAC	SP*10^6, 0.9 AC	Activity assumption μBq/kg	2.1 kg sAC BI, gbu	0.9 kg AC BI, gbu	Ratio
Cable1	Bi-214	170	300	10	0.036	0,0064	0.18
	Tl-208	150	220	10	0.032	0,0047	0.15
	Co-60	30	80	10	0.0064	0.0017	0.27
Holder Copper	Bi-214	60	110	10	0.32	0.59	1.86
	Tl-208	130	240	10	0.69	1.3	1.87
	Co-60	< 10	100	10	-	0.54	-
Holder teflon	Bi-214	20	90	10	0.01	0.08	8
	Tl-208	110	270	10	0.052	0.23	4.4
El. Board	Bi-214	< 1	5	10	-	0.014	-
	Tl-208	12	23	10	0.025	0.065	2.6
El. Bars	Bi-214	10	< 10	10	0.044	-	-
	Tl-208	20	30	10	0.088	0.18	2.0

AC suppression versus a detector position

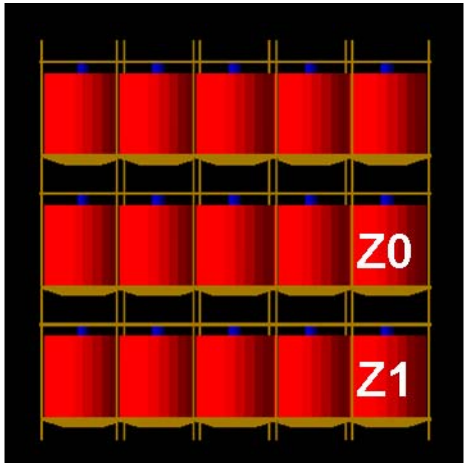
Internal source				
Co-60, SP*10^6				
Z	**R**			
	0	**1**	**2**	**3**
0	119	145	285	380
1	234	257	420	500
Ge-68, SP*10^6				
Z	**R**			
	0	**1**	**2**	**3**
0	542	598	848	959
1	717	754	968	1043

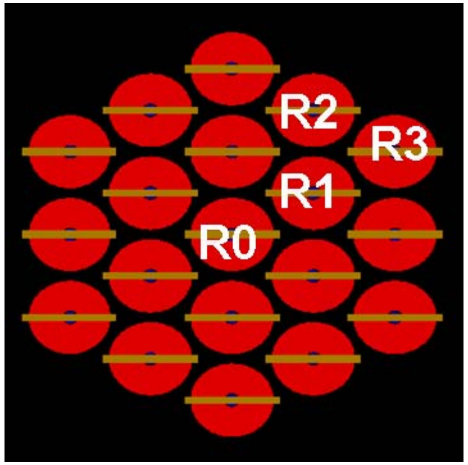




AC suppression versus a detector position

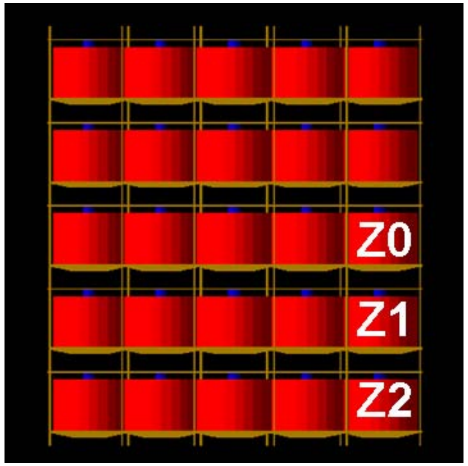
Neighboring sources: Holder copper				
Bi-214, SP*10^6				
Z	R			
	0	1	2	3
0	60	70	100	120
1	90	80	110	100
Tl-208, SP*10^6				
Z	R			
	0	1	2	3
0	70	130	230	300
1	200	210	290	260

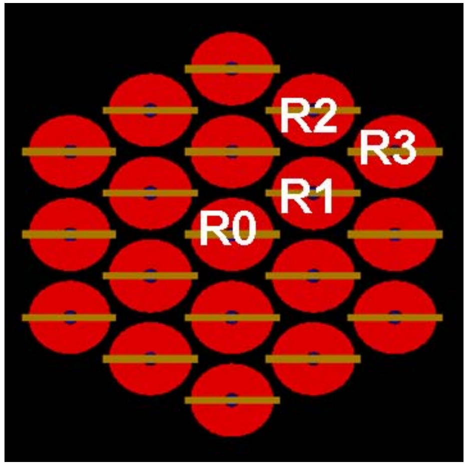




AC suppression versus a detector position

Internal Co-60 for 95 small detectors, $SP*10^6$				
Z	**R**			
	0	**1**	**2**	**3**
0	102	138	296	367
1	116	148	294	397
2	236	261	433	502





Few words about reference detectors

In the beginning of the GERDA phase II, when the 2β0ν signal is not seen yet the main goal is to reduce the background in the enriched detectors. Hence future "reference" detectors should be used here just as an active shield. Because of worse background conditions they can't serve at that time as real reference detectors.

In the case of a positive signal, the assembly should be rearranged and reference detectors should be placed in the middle of the assembly, while enriched detectors may be used for an active shielding. In principle this consideration should be valid for both types of the detectors.

To be done

Some additional simulations should be done in order to accomplish the study of the “backup” detectors. These are:

I. Muon induced backgrounds

- muons crossing the assembly
- muon induced EM showers touching the assembly
- muon induced neutrons

II. Inclusion into the assembly of the real size phase I detectors.

Conclusion

Overall background index for the assembly of small non segmented detectors would be **3-4 times worse** than for the standard GERDA Phase II configuration. This fact strongly encourages the collaboration to struggle for realization of big segmented detectors. However failing to do this wouldn't have catastrophic consequences.