Background measurements with open IGEX and ANG 2 detectors: effective masses.

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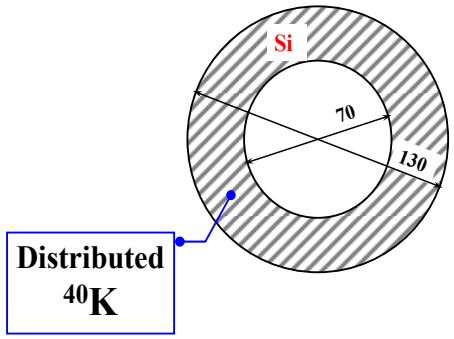
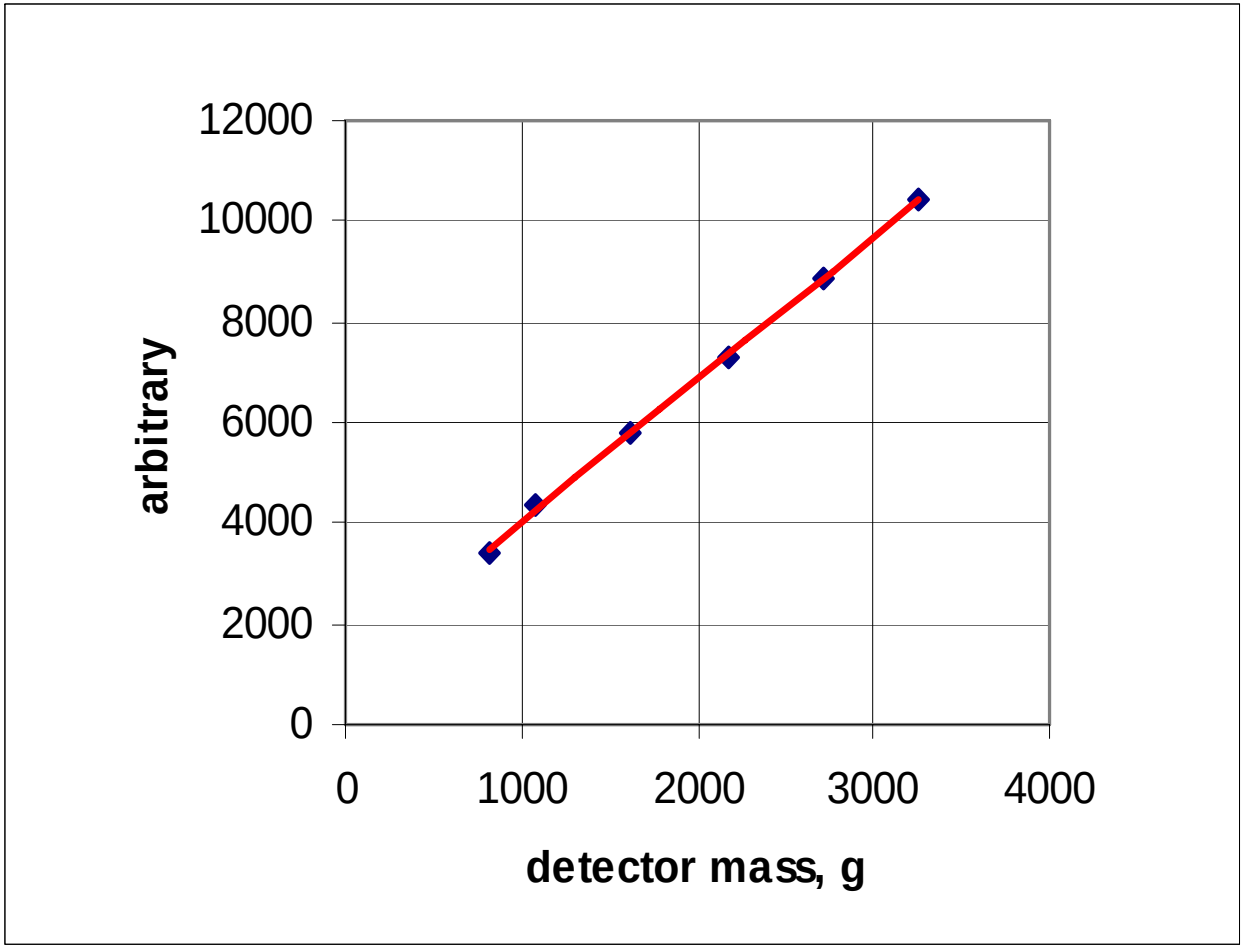
The three IGEX detectors were delivered from Canfranc underground laboratory to LNGS on November 18, 2005. The detectors were warm and out of liquid nitrogen for a long time, and demanded a full cycle of a restoration. Results of the procedure were given in a note GSTR-06-004, February 2006 . As the changes of the effective volumes were also possible, measurements of them seemed to be necessary. The procedure of comparative measurements was used for this purpose .

It included simultaneous measurements of background with open (without any shielding) detectors. A comparison of the collected spectra provided information about relative effective masses of the IGEX and one of HM (ANG-2) detectors.



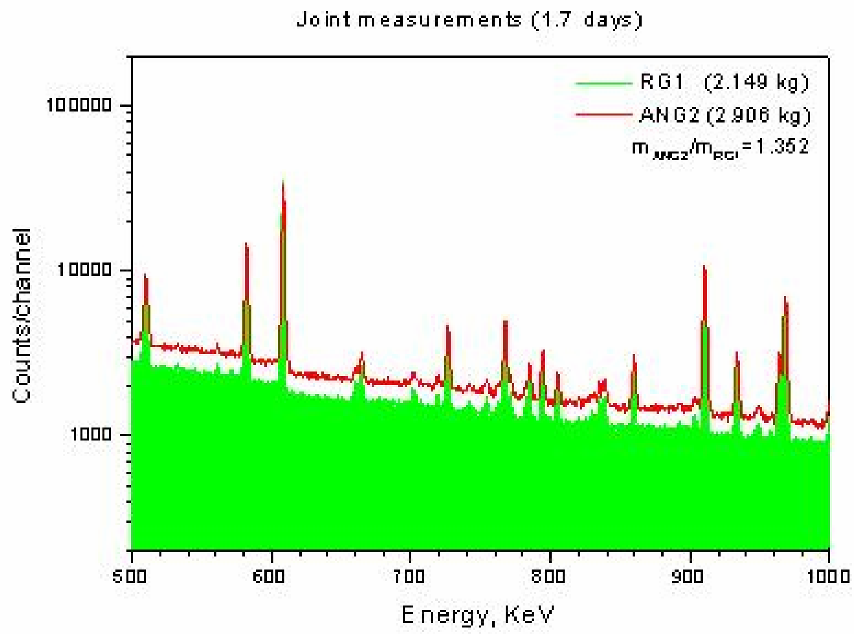
Number of events in (500-1000)KeV energy interval:
a distributed K-40 gamma-source (Eγ =1461 KeV)

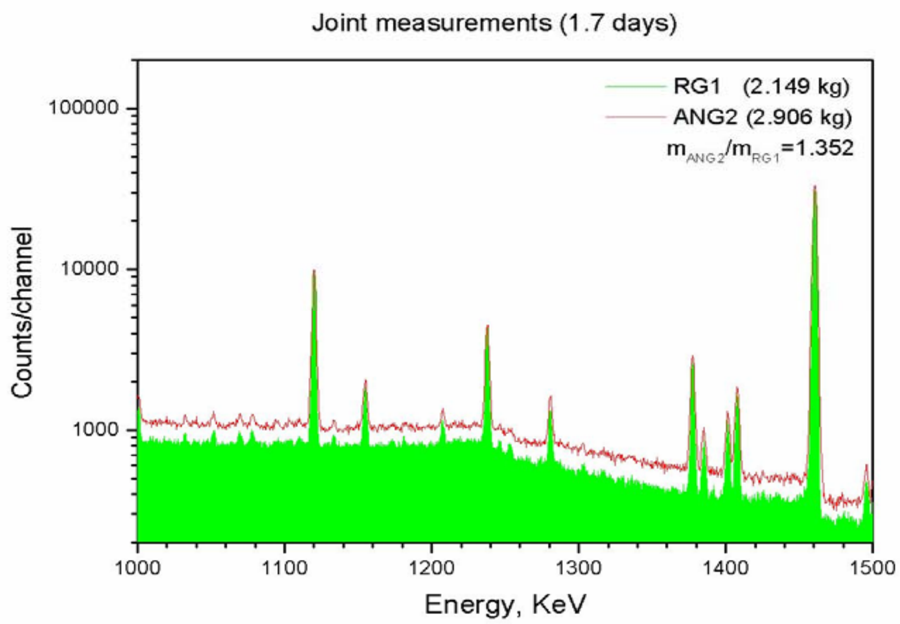


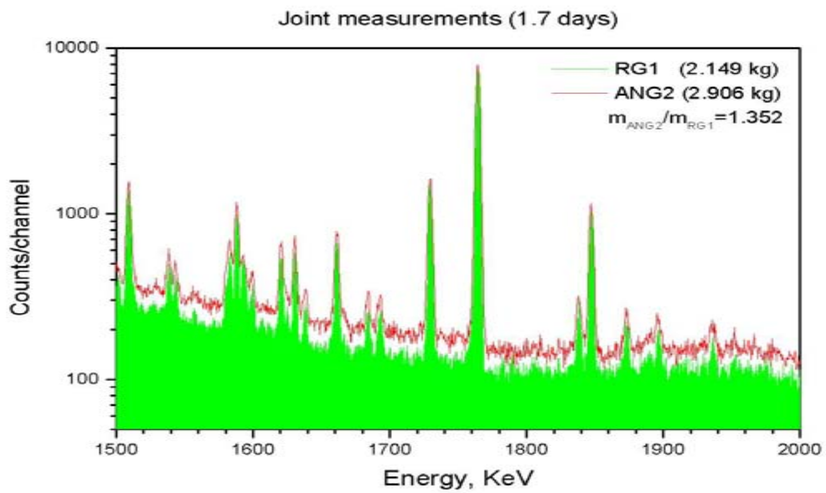
To make the first estimation of the active volumes, one of the IGEX detectors (RG1) was compared with one of Heidelberg-Moscow (ANG2) detectors, as simulations of HM detectors have demonstrated good agreement with the known values of their active volumes. The measurements were performed in November-December of 2005 in GERDA room. The two detectors were placed close to one another, outside of any shielding, at a distance a half of a meter, and their backgrounds were measured simultaneously. The collected statistics are presented for energy intervals 0-500, 500-1000, 1000-1500, 1500-2000, 2000-2500, 2500-3000 and 2000-2100 KeV.

Energy, KeV.	Detector RG1 T=1,73398 days	Detector ANG2 T=1,73398 days	Ratio RG1/ANG2	Ratio ANG2/RG1
0-500	10.844.138	10.971.293	0,99	1,01
500-1000	2.079.526	2.736.733	0,76	1,32
1000-1500	1.014.146	1.329.443	0,76	1,31
1500-2000	267.734	360.508	0,74	1,35
2000-2500	127.256	176.817	0,72	1,39
2500-3000	53.040	80.577	0,66	1,52
mass of detector, kg	2,1499	2,906	0,74	1,352

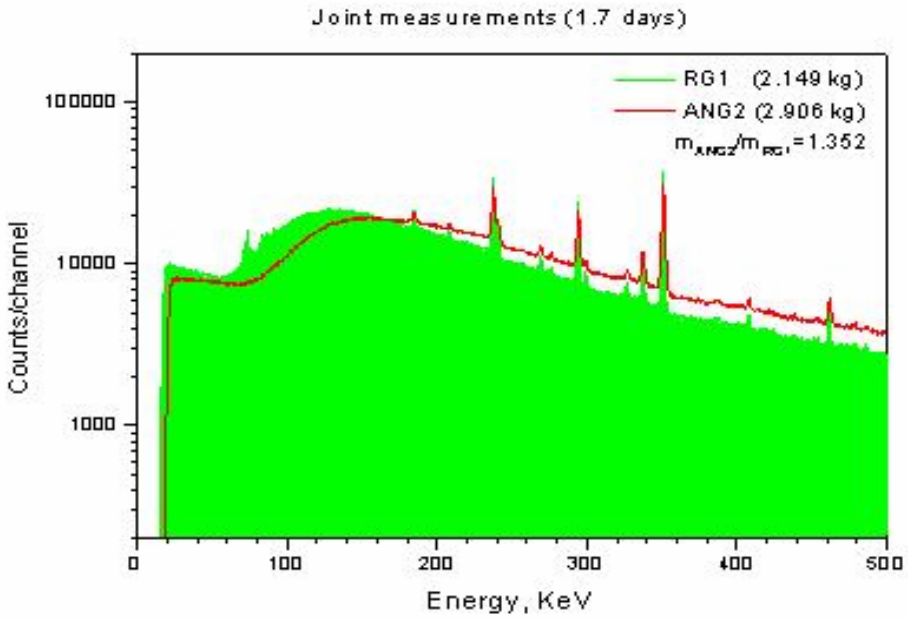
Ratios of number of counts in energy intervals 500 -1000 and 1000 – 1500 KeV should be close to the ratios of the effective masses . Results given in the Table indicated that no considerable change has happened with active volume of the IGEX detector RG1.



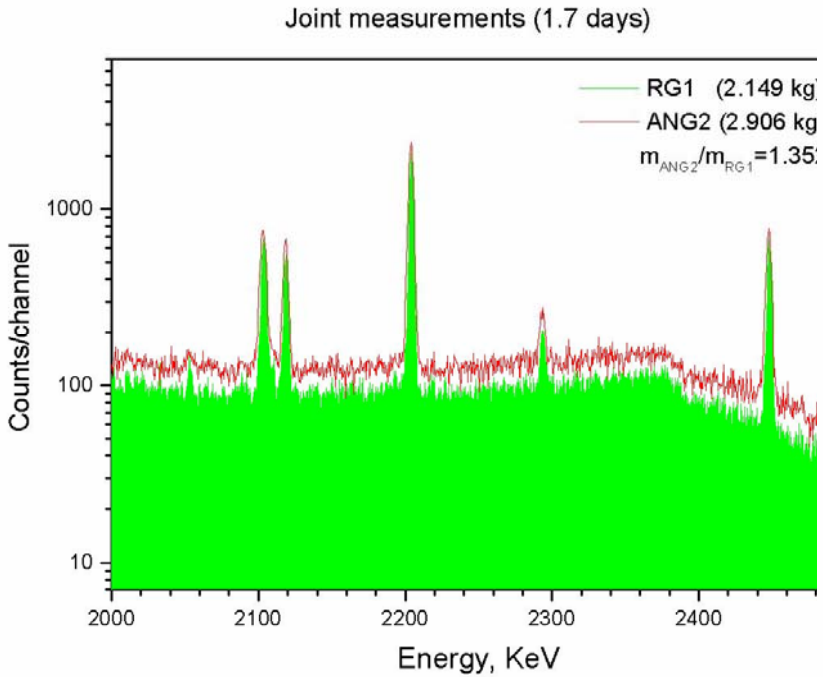


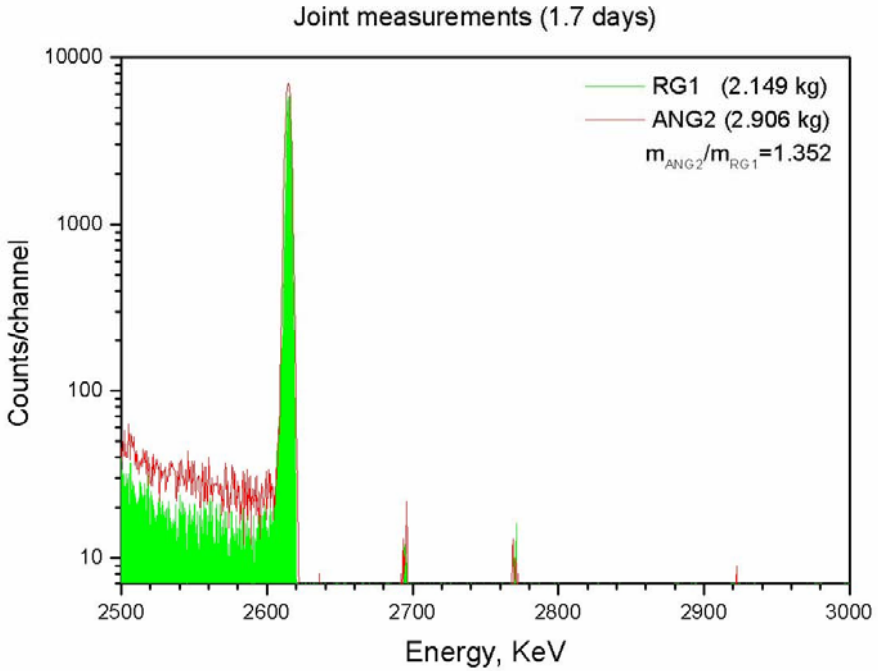


Parts of spectra which can be used for the estimations. Peaks should be excluded. The most prominent feature of the spectra - identity of the continuum shapes.



1. Low energies – shape of the spectra depend on constructions of the detectors.
2. High energies – strong influence of the background peaks.

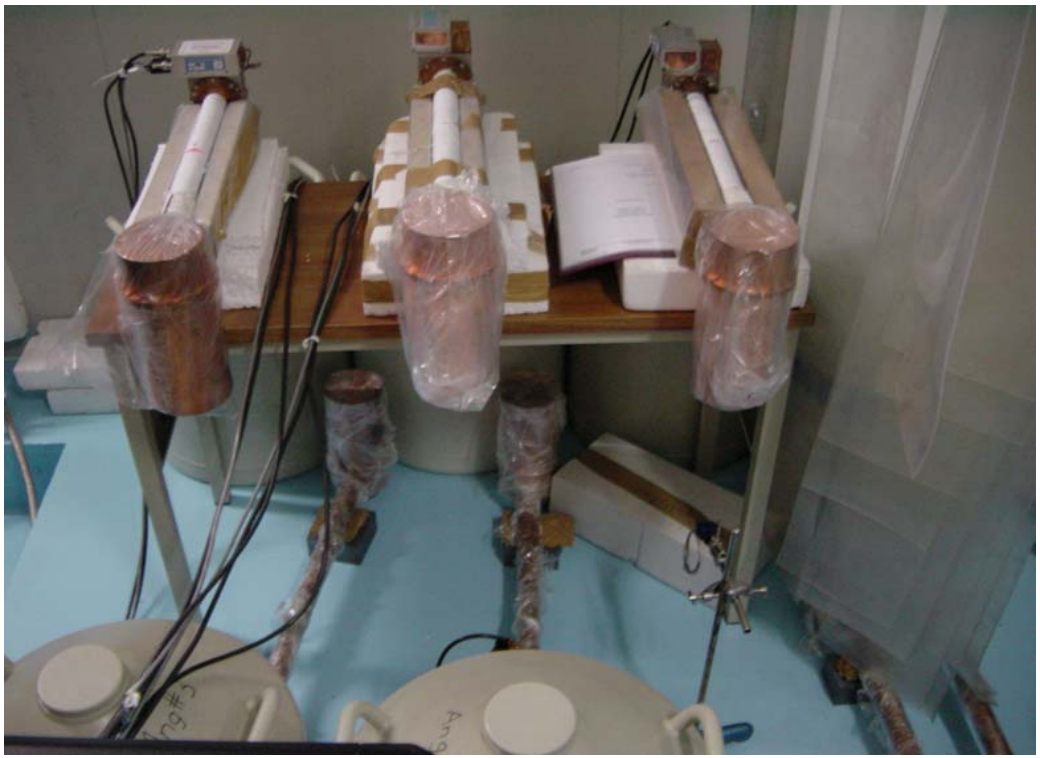




The second phase of the measurements (February 2006) included comparison of three IGEX detectors RG I, RG II and RG III, and the same ANG 2 detector of Heidelberg-Moscow . The passport parameters of all the detectors are presented in the Table .

	RG-1	RG-2	RG-3	ANG2
Diameter and Length, mm	77.6; 84.3	78.6; 84.0	79.2; 82.5	80.0; 108.0
Total Mass, g	2150	2194	2121	2906
Dead Layer, microns	~800	~800	~500	~800
Mtot / Meff	~0.95	~0.95	~0.98	~0.95
Energy resolution at 1332 KeV (FWHM KeV)	2,16	2,37	2,13	1,98
Operating Voltage, V	+4800	+3800	+3800	+4000

Geometry of the experiment is presented in the Figure.



The detectors have been put as much as possible close to each other. The three IGEX detectors were fixed on a table, with distance between them about 25 cm. The ANG 2 detector was placed at the floor below, at the distance about 50 cm from the table surface.

The result count rates for 500 KeV intervals are presented below. Time of measurements has been $\Delta t = 42.22$ h (1.759 days).

ΔE_γ	RG I	RG II	RG III	ANG 2
0-500	9.765.432	1.108.1972	10.746.933	9.681.023
500-1000	1.872.002	2.063.876	2.049.379	2.363.426
1000-1500	924.782	1.019.628	1.016.741	1.161.811
1500-2000	236.377	262.088	261.653	297.114
2000-2500	113.625	124.427	124.585	151.535
2500-3000	46.839	50.763	51.127	69.614

The data normalized to numbers of events in ANG2 spectrum

ΔE_γ	N(rg1)/ N(ang2)	N(rg2)/ N(ang2)	N(rg3)/ N(ang2)	N(ang2)/ N(ang2)
0-500	1,009	1,145	1,110	1,0
500-1000	0,792	0,873	0,867	1,0
1000-1500	0,796	0,878	0,875	1,0
1500-2000	0,796	0,882	0,881	1,0
2000-2500	0,750	0,821	0,822	1,0
2500-3000	0,673	0,729	0,734	1,0
mass /ANG2	0,740	0,755	0,730	1,000

The calculated effective masses of the detectors are given in the next Table .
The results were normalized to the mass of RG3,
as it had the highest value of the ratio Meff/Mt .

				experiment				
	total mass	passport		number of counts, ratio	without correction*		corrected for crystal size	
	M_t	M_{eff}	M_{eff}/M_t	RG_i / RG_3	M_{eff}	M_{eff}/M_t	M_{eff}	M_{eff}/M_t
RG1	2149	2042	0,95	0,913	1899	0,884	1860	0,866
RG2	2194	2084	0,95	1,007	2093	0,954	2020	0,921
RG3	2121	2015	0,98	1,000	2079	0,98**)	2079	0,98**)
ANG2	2906	2758	0,95	1,153	2398	0,825	2460	0,847

*) correction took into account difference in the crystal sizes
**) the passport value

The control measurements with a Co-60 source have been performed after the background measurements. The source was placed sideways of the detectors, in the central plane of the crystals, at a distance of 50 cm from their vertical axis. The relative intensities of Co peaks (normalized to ANG 2 detector) and 1461 kev peak of ^{40}K (backgrounds) are presented in theTable (the K-40 gammas were a main source of background in (500-1500) kev energy interval). The results of measurements with a Co-60 source agree with results of the analysis of background spectra within the limits of 2-3 % . It indicated absence of noticeable effects due to different positions of the detectors.

E_γ , KeV	RG I	RG II	RG III	ANG2
1173	0,822	0,890	0,883	1,000
1332	0,802	0,884	0,879	1,000
1461*	0,785	0,831	0,850	1,000

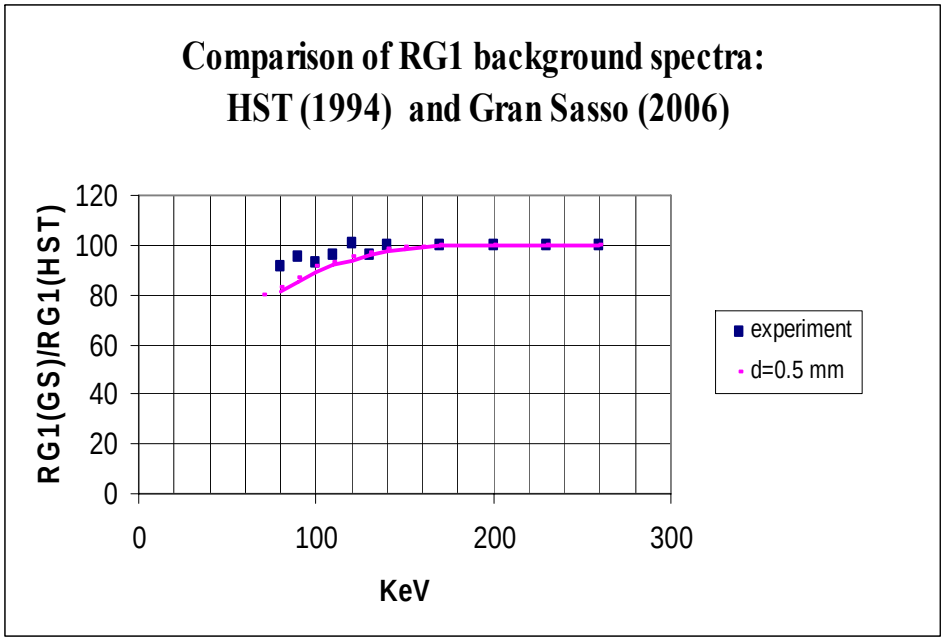
SUMMARY

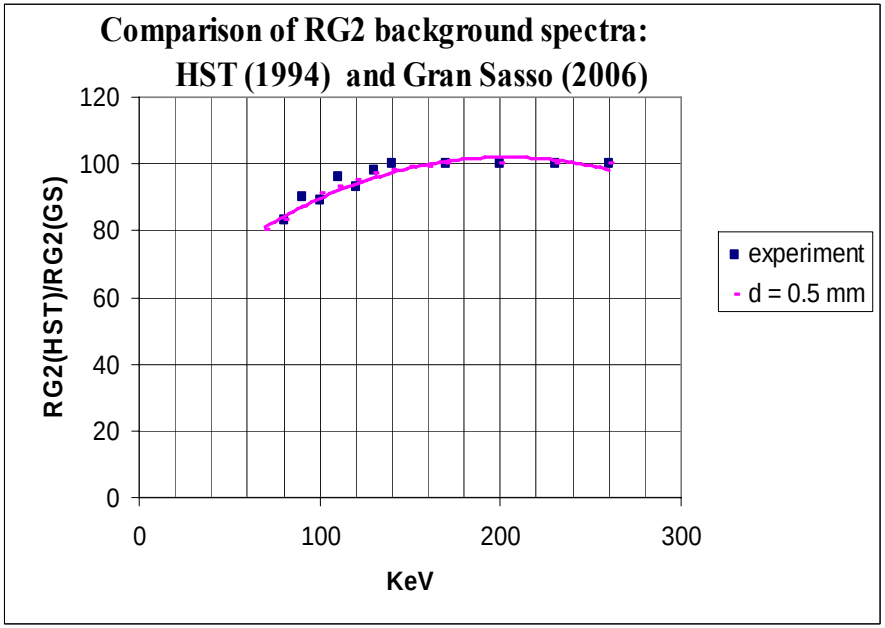
Effective volumes of the RG1, RG2 and ANG2 detectors were found being some less (up to ~10 %) then it has been estimated from the passport values of their dead layers (Meff/Mtot=0,95 corresponded approximately 800 μ dead layer). For RG2, and partially for RG1, it could be attributed to some increasing of thickness of the dead layer on their surfaces . The smaller value of the Meff/Mtot of RG1 is in agreement with measurements in Homestake in 1994.

The difference between the passport values and results of measurements can be even higher, as the estimations were made supposing maximum possible value of Meff/Mtot=0,98 for RG3 detector (500 μ dead layer).

	M_{total}	M_{eff} passport	M_{eff} experiment	experiment/ passport
RG1	2149	2042	1860	0,91
RG2	2194	2084	2020	0,97
RG3	2121	2079	2079*	1,0
ANG2	2906	2758	2460	0,89

*) passport value d=500 μ





PRELIMINARY

To get the changes of dead layer on the surfaces of RG1 and RG2 we have compared our measurements with open RG1 and RG2 detectors in Homestake (1994) and the recent measurements in Gran Sasso (2006). Results are given in these two figures.

It should be pointed out, that uncertainties due to the possible difference in constructions of the detectors were absent in this case.

Measured increasing of the dead layers:

RG1 ≈ (150 – 200) μ

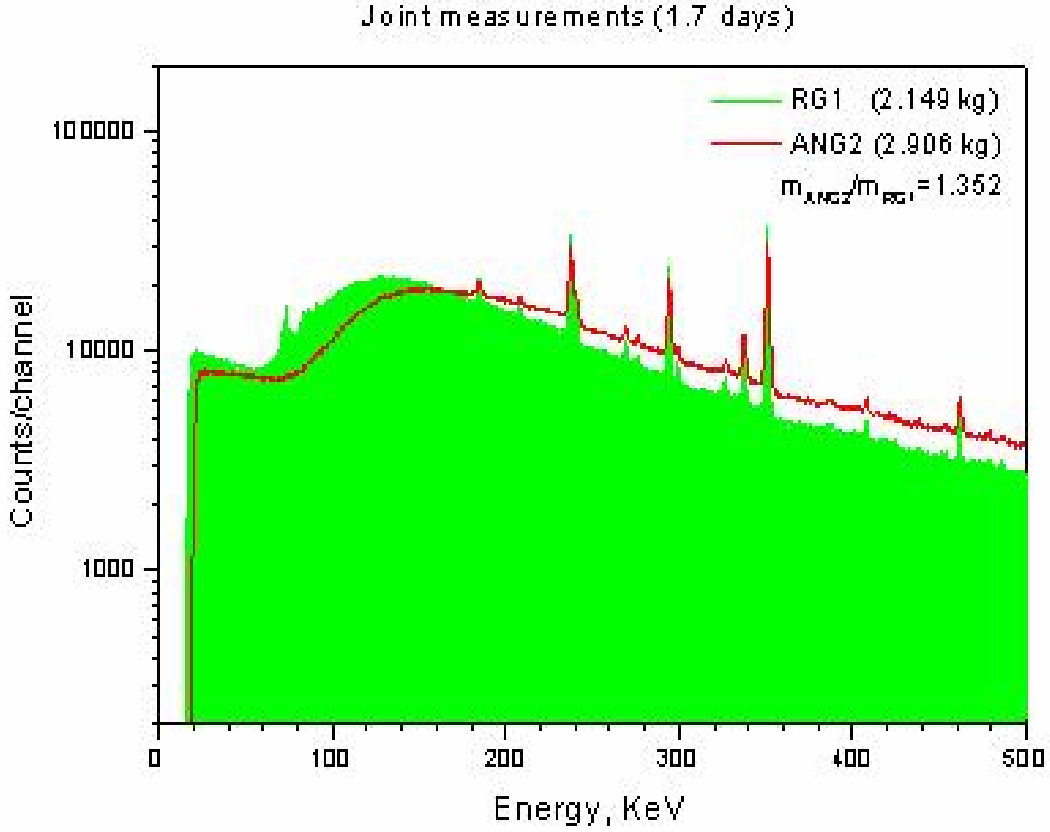
RG2 ≈ (450 – 500) μ

Measured dead layer of RG1

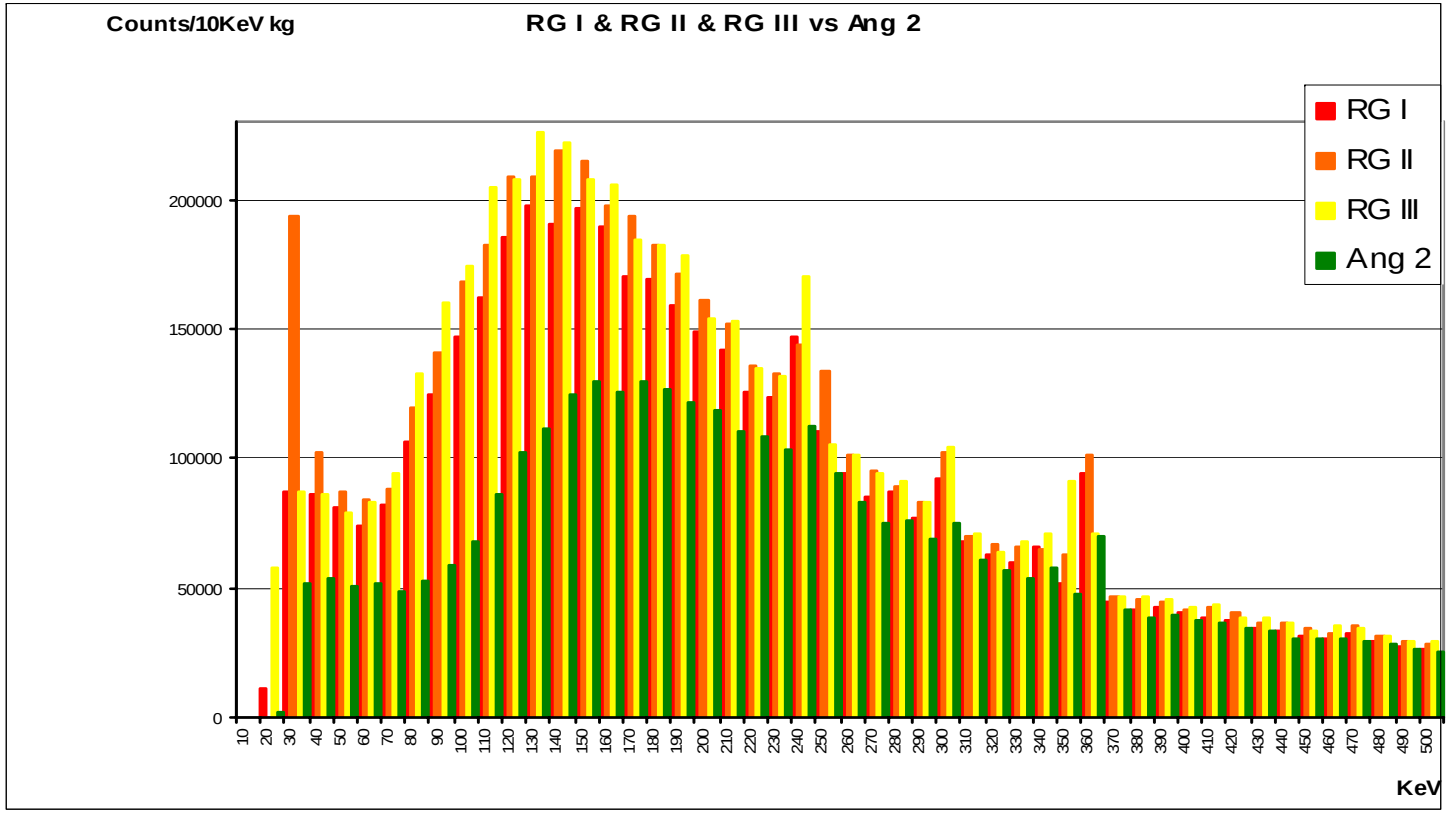
d = ~920 μ bottom

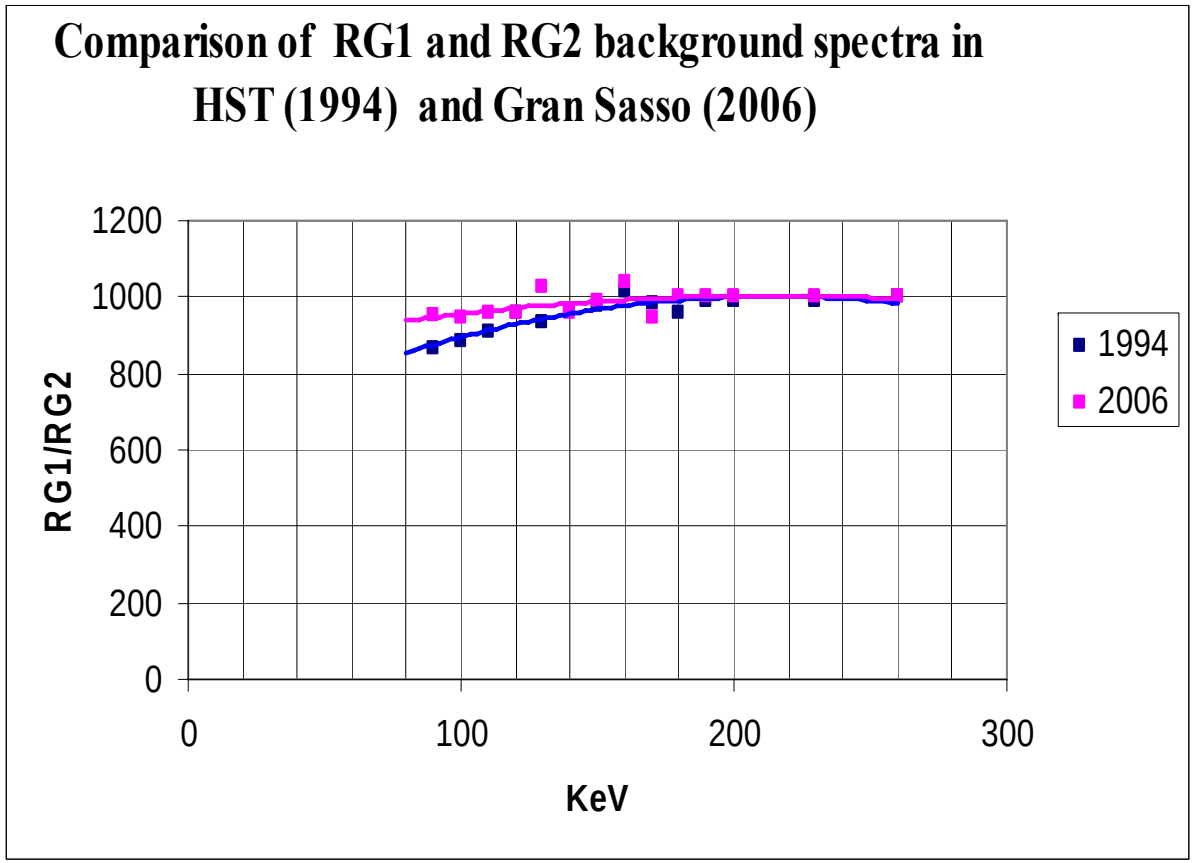
(800 μ - the passport value)

Number of counts at low energies was much higher in the spectra of IGEX detectors oul in ANG2 spectrum. The most probable explanation could be connected with the difference in construction of HM and IGEX detectors. The IGEX detectors have lead shielding disks in a close vicinity of the germanium crystals. The backscattering gammas together with X-Rays are causing the higher count rate at low energies. These discs do not affect the higher part of energy spectra.



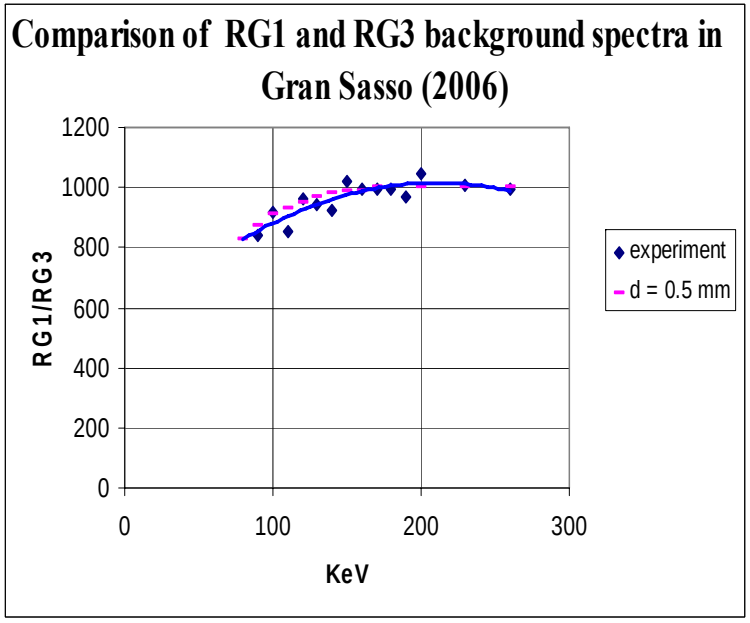
The same low-energy part of spectra for all four detectors (10 KeV/channel). All three IGEX detectors have practically the same excess of events over ANG2 below ~300 KeV

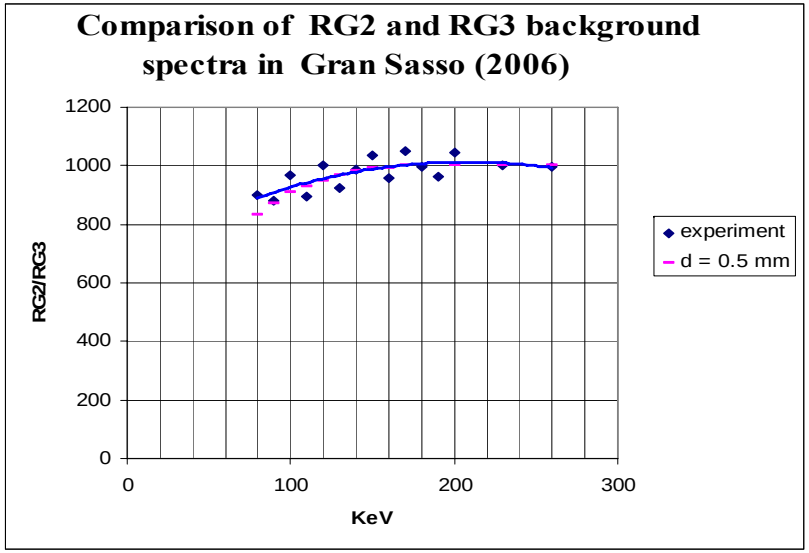



Comparison of RG1 and RG2 background spectra in HST (1994) and Gran Sasso (2006)
RG1/RG2
1200
1000
800
600
400
200
0
0
100
200
300
KeV
1994
2006

The measured value of the dead layer for RG1 is ~920 μ.

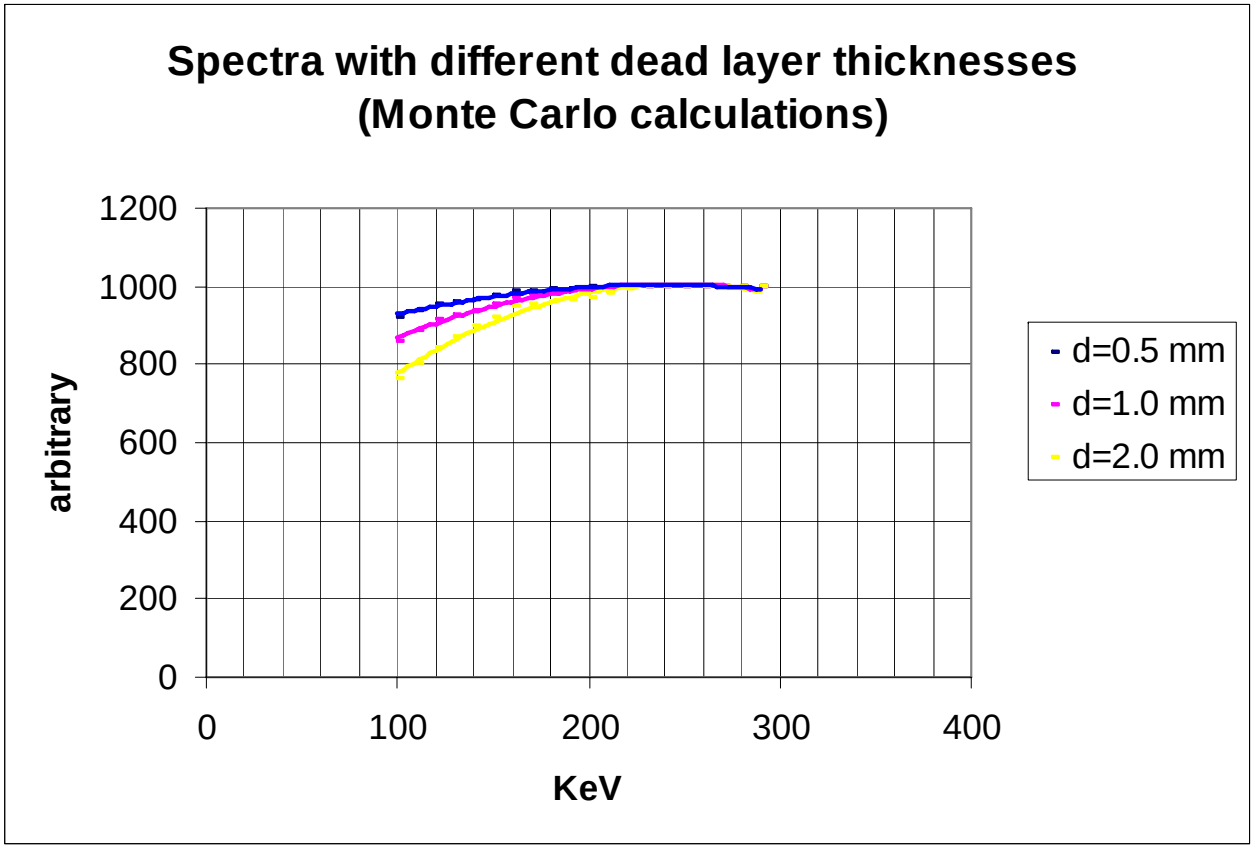
An estimate of the dead layer of the RG3 detector could be made from the recent comparison of RG1 and RG3 background spectra (Gran Sasso). It indicated an excess of the RG1 dead layer over RG3 one some above 500 μ. Since that the RG3 did not demonstrate increasing of the dead layer.





Changes in dead layer thicknesses of the IGEX detectors (preliminary results)

An analysis of low-energy parts of spectra provides possibility to observe small changes in the dead layer thicknesses. The next figure illustrates changes in spectra of the same detector with different thicknesses of the dead layer, d=0.5, 1.0 and 2.0 mm (the spectra were normalized to the data with d=0 mm).



Final conclusions

Measured increasing of the dead layers:

RG1 $\Delta d \approx (150\text{-}200)\ \mu$

RG2 $\Delta d \approx 450\ \mu$

Measured dead layer of RG1

d= ~920 μ bottom (800 μ - the passport value)

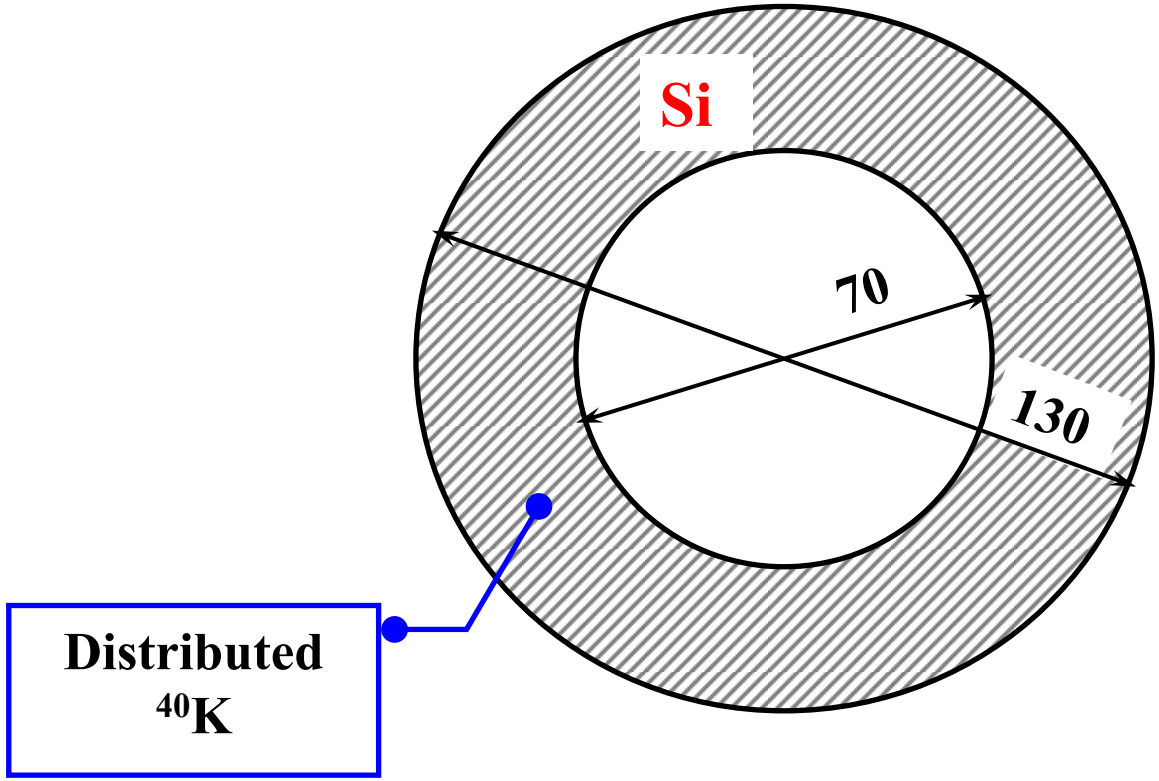
The dead layer thicknesses were estimated for all three IGEX detectors.

RG1 d= ~920 μ bottom GS

RG2 d= ~750 μ ??? GS

RG3 d= ~ 320 μ ??? GS RG1/RG3 (Δd = ~ 600 μ)

d= ~ 350 μ ??? GS RG2/RG3 (Δd = ~ 400 μ)


Si
70
130
Distributed
^{40}K