Editorial Board: proposal for a paper about 2ν2β decay to excited states of ^{76}Se

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Paper draft

Feasibility study of the observation of the neutrino accompanied double beta-decay of ^{76}Ge to the 0^+_1-excited state of ^{76}Se using segmented germanium detectors

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Original idea from E. Bellotti

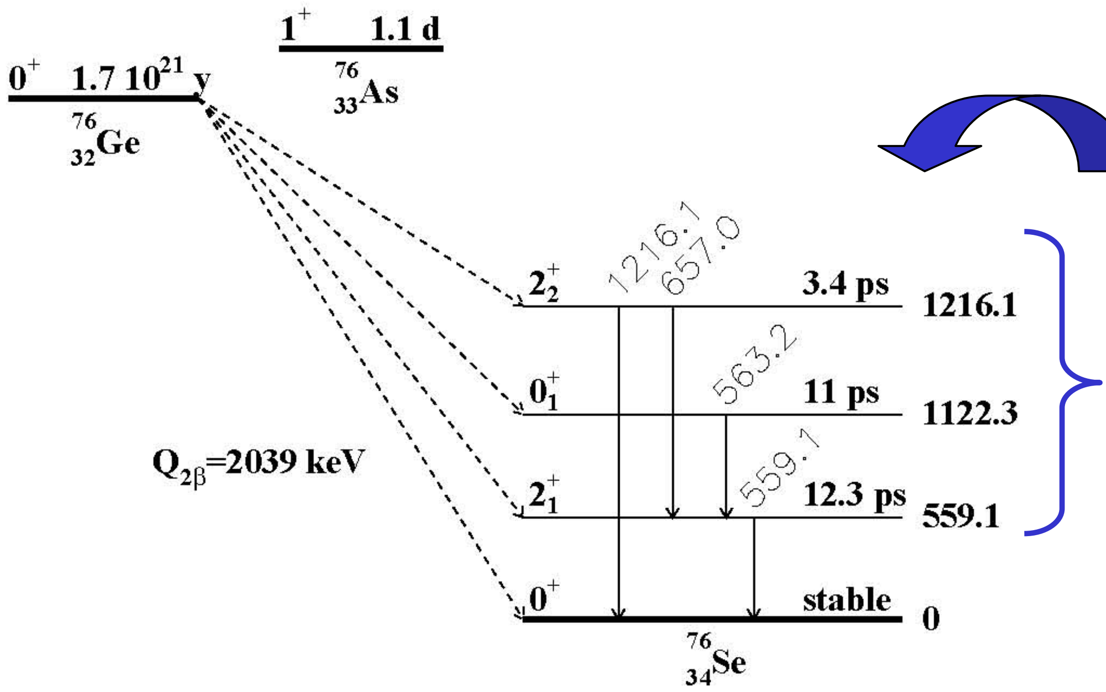
Paper based on internal note GSTR-06-003

2ν2β decay of ^{76}Ge to **excited states** of ^{76}Se has never been observed experimentally (but it must be there: **SM process**)

Not strictly a **GERDA paper**, but it evaluates the sensitivity for the Phase-II GERDA array

Idea: Nuclear Physics A

The present situation



Three excited levels can be populated by $2\nu2\beta$ decay of ^{76}Ge

The measurement of the $T_{1/2}$ could give a **extra handle** for NMEs theoretical calculations for $0\nu2\beta$ (**tuned on** $2\nu2\beta$)

Level	Theoretical predictions for $T_{1/2}$ (y)	Experimental limit for $T_{1/2}$ (y)
2^+_1 (559 keV)	$5.8 \cdot 10^{26} - 1.2 \cdot 10^{30}$	$> 1.1 \cdot 10^{21}$ (90%)
0^+_1 (1122 keV)	$7.5 \cdot 10^{21} - 3.1 \cdot 10^{23}$	$> 6.2 \cdot 10^{21}$ (90%)
2^+_2 (1216 keV)	$7 \cdot 10^{27} - 1.3 \cdot 10^{29}$	$> 1.4 \cdot 10^{21}$ (90%)

The 0^+_1 level at 1122 keV

We did concentrate on the 0^+_1 level (1122 keV) because:

- the decay is not suppressed by spin-change and the predicted half-life is substantially smaller (10^{21}-10^{23} y). The predictions cover a **factor of 40**!

- the decay is followed by a **γ-ray cascade** (γ_1 = 559 keV and γ_2 = 563 keV), which makes easier to tag events

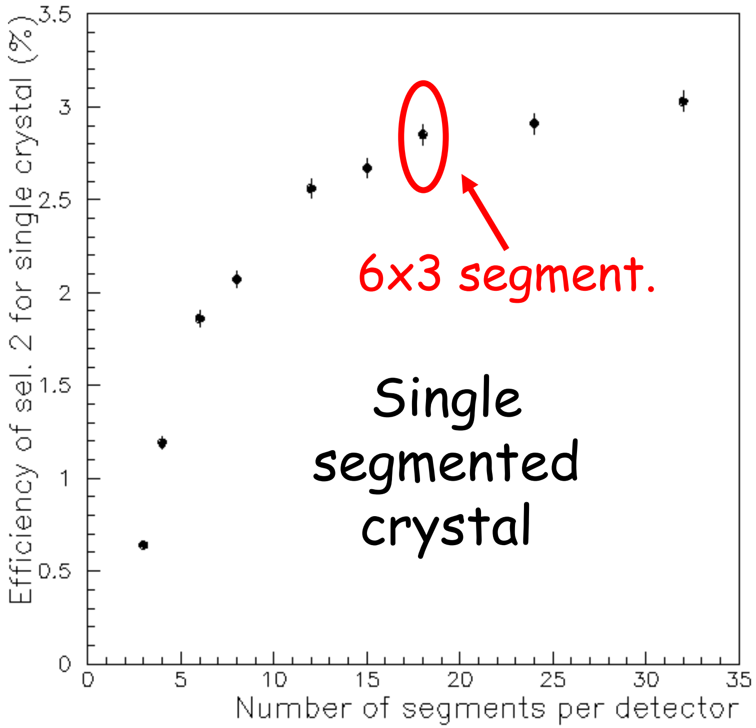
Segmented detectors are best suited to tag these events: **three-fold segment coincidence** between e^-'s and two γ-rays

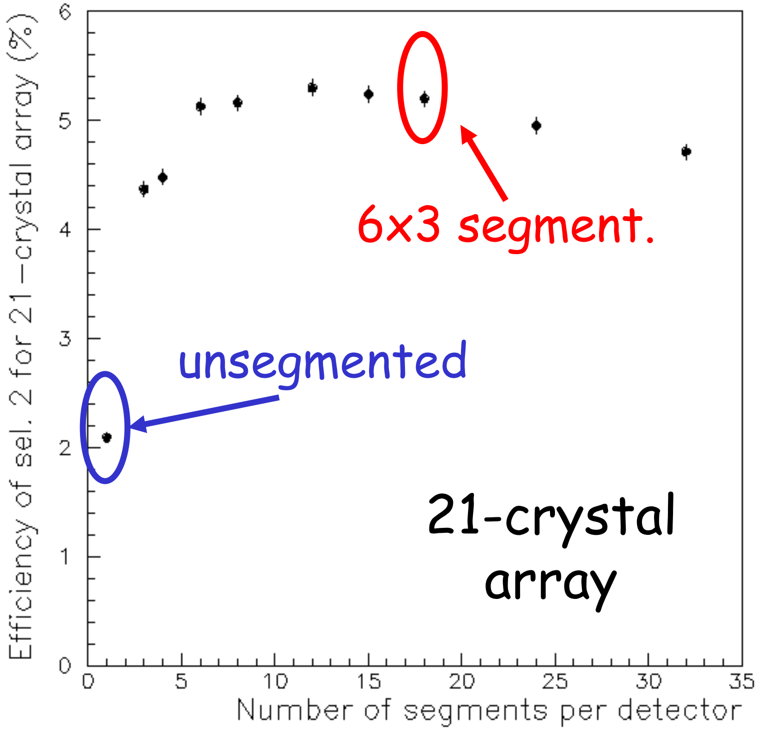
→ the tagging can be made more restrictive including also an **energy cut** (e.g. the energy measured in one or two segments is compatible with γ_1 or γ_2). Different selection cuts explored and compared

→ clear advantage with respect to an equivalent array of **unsegmented detectors**

Monte Carlo studies

The signal identification efficiency and residual background were studied using the **MaGe framework**. Signal events were generated using DECAY0 (accounts for angular correlation between γ-rays)





One possible tag (**best sensitivity**, "a posteriori"):
three-fold coincidence, with at least one segment with energy compatible with γ_1 or γ_2 (≈560 keV)

Background & sensitivity

Background is due to residual radioactive sources (^{60}Co, ^{208}Tl, etc.) that are able to **mimic** the **signal tag**. The mis-identification probability depends on isotope and location.

^{60}Co has the highest mis-identification probability because two γ-rays are emitted

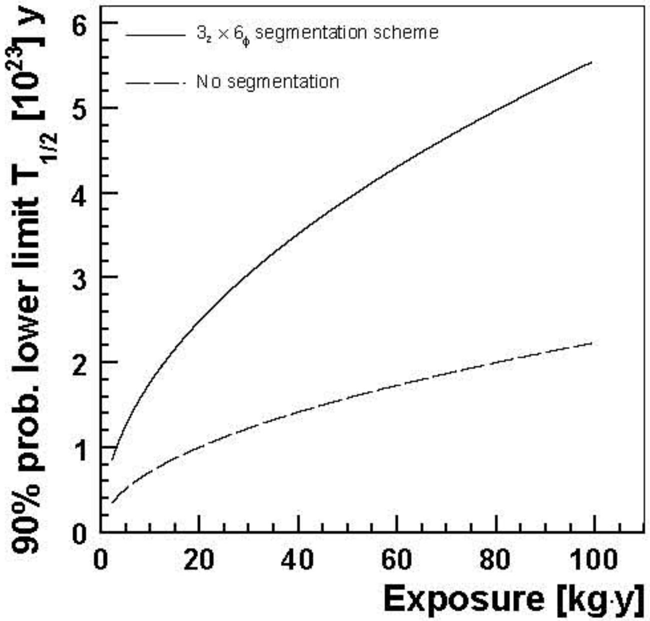
100 kg·y exposure (applies to the last two columns)

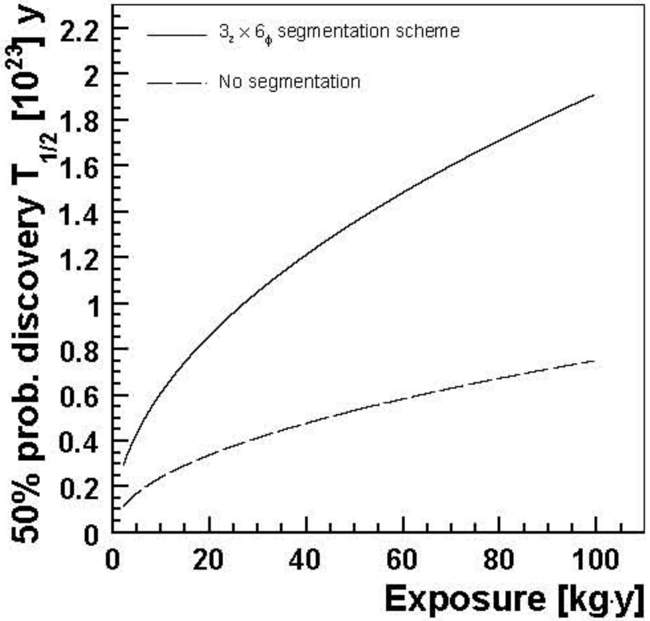
Considered array	Background counts/(kg·y)	$T_{1/2}$ discovery potential (y)	$T_{1/2}$ lower limit (90%) (y)
21 crystals, unsegmented in LAr	2.7 (conserv.)	$0.8 \cdot 10^{23}$	$2.2 \cdot 10^{23}$
21 crystals with 6x3 segment. in LAr	2.7	$1.9 \cdot 10^{23}$	$5.6 \cdot 10^{23}$

↑ ($1.9 \cdot 10^{23}$) same definition as in the GERDA sensitivity plots

Sensitivity and conclusions

lower limit





discovery potential

With **100 kg·y exposure**, discovery potential for the segmented array is $1.9 \cdot 10^{23}$ y and achievable lower limit is $5.6 \cdot 10^{23}$ y (unsegmented array is a factor 2.5 worse)

Well in the range of theoretical predictions ($7.5 \cdot 10^{21} - 3.1 \cdot 10^{23}$) y. In any case a **factor of 100 better** than the present experimental limit. Valuable **by-product** of **GERDA**; it comes for **free**; may add **knowledge** for **NMEs**