Background suppression in neutrinoless double beta decay experiments using segmented detectors – a Monte Carlo study for the GERDA setup

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Overview

- Introduction
- Physics Processes
- Simulations
- Results
- Conclusions

Introduction

- GERDA background reach $<10^{-3}$ counts/(kg keV y) (Phase II)
- ***Idea:*** identify and separate multiply scattered photons from electrons using segmented detectors
- Phase II detector design forsees 6-fold φ- and 3-fold z-segmentation

  → ***First time usage of segmented Ge-detectors in 0νββ-experiments***

  (Majorana: studies of 2-fold longitudinal segmentation)
- Impact on background suppression: Monte Carlo study for the GERDA setup

Physics processes/signatures

Classes of signatures:

I. Two electrons. Energy deposition on millimeter scale. ***0νββ*** and ***2νββ***.

II. Photon(s) and electron. Photons scatter on centimeter scale. ***Co-60***.

III. Photon(s) and positron. ***Ge-68***.

IV. Photon(s) only. Sources of classes II and III in large distances. ***Tl-208***.

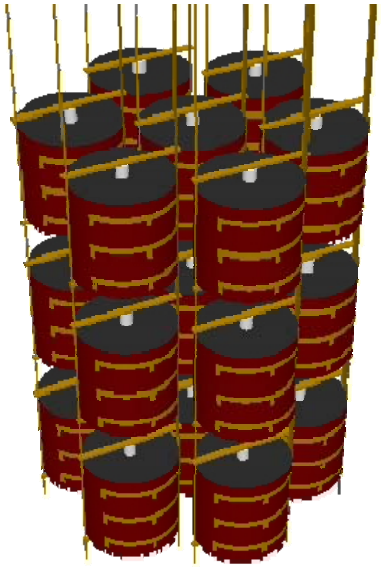
V. α-particles. Energy deposit mostly on crystal surface. ***Pb-210***.

→ ***Separate Class I from Classes II-IV.***

Simulation

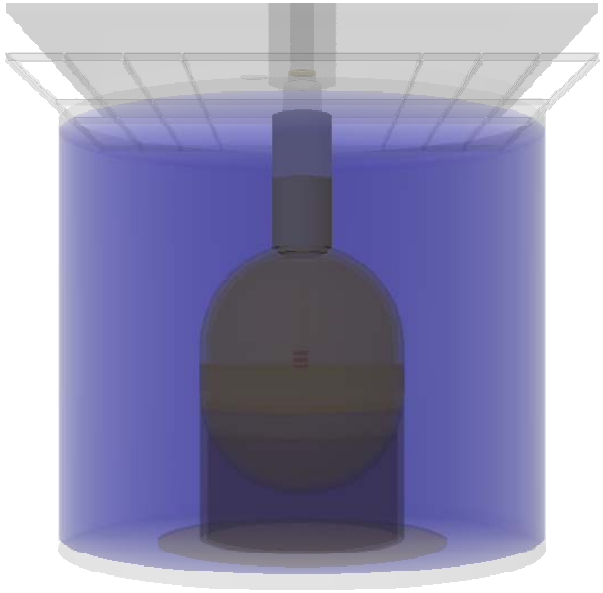
• ***MaGe:*** use geometry with nominal detector array and 3-walled copper cryostat, liquid nitrogen

Detector with cabling



Detector array

(3x7 detectors)

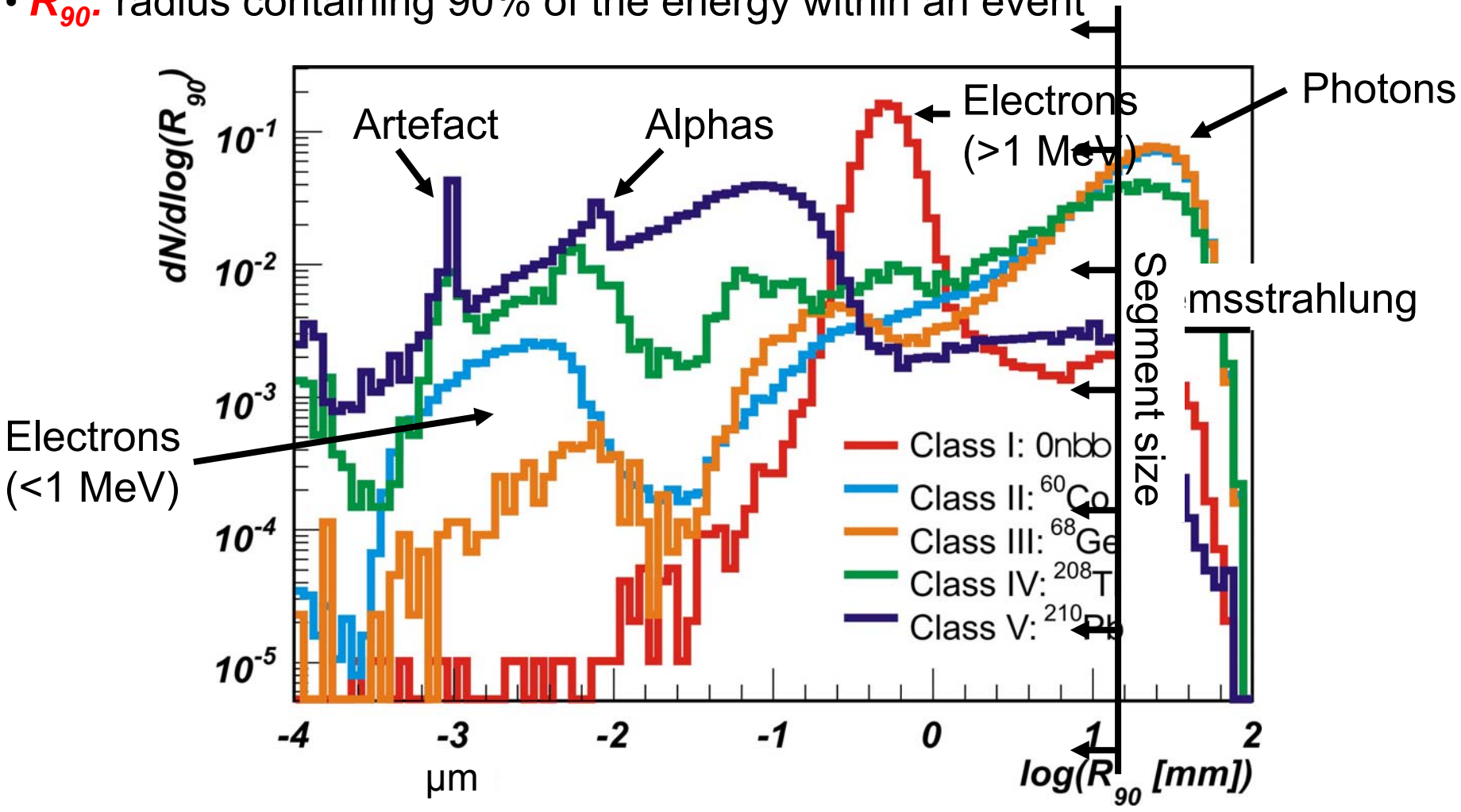


Cryostat and

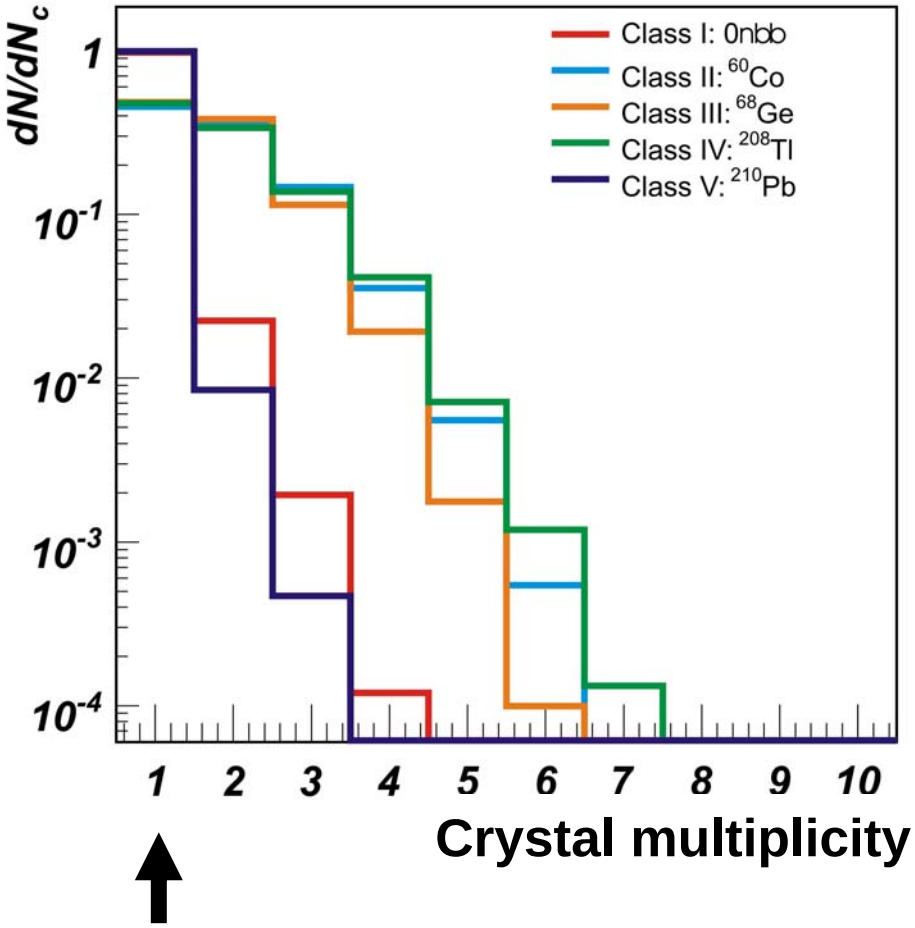
water tank

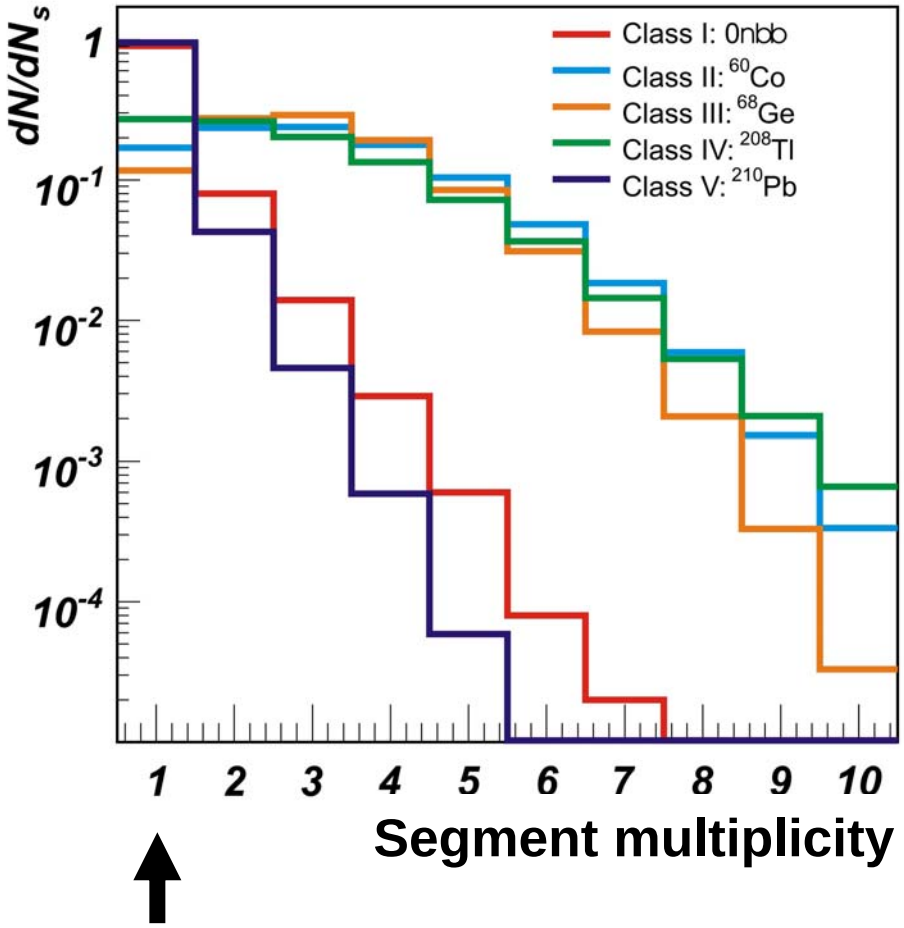
Energy distribution

- R_{90}: radius containing 90% of the energy within an event

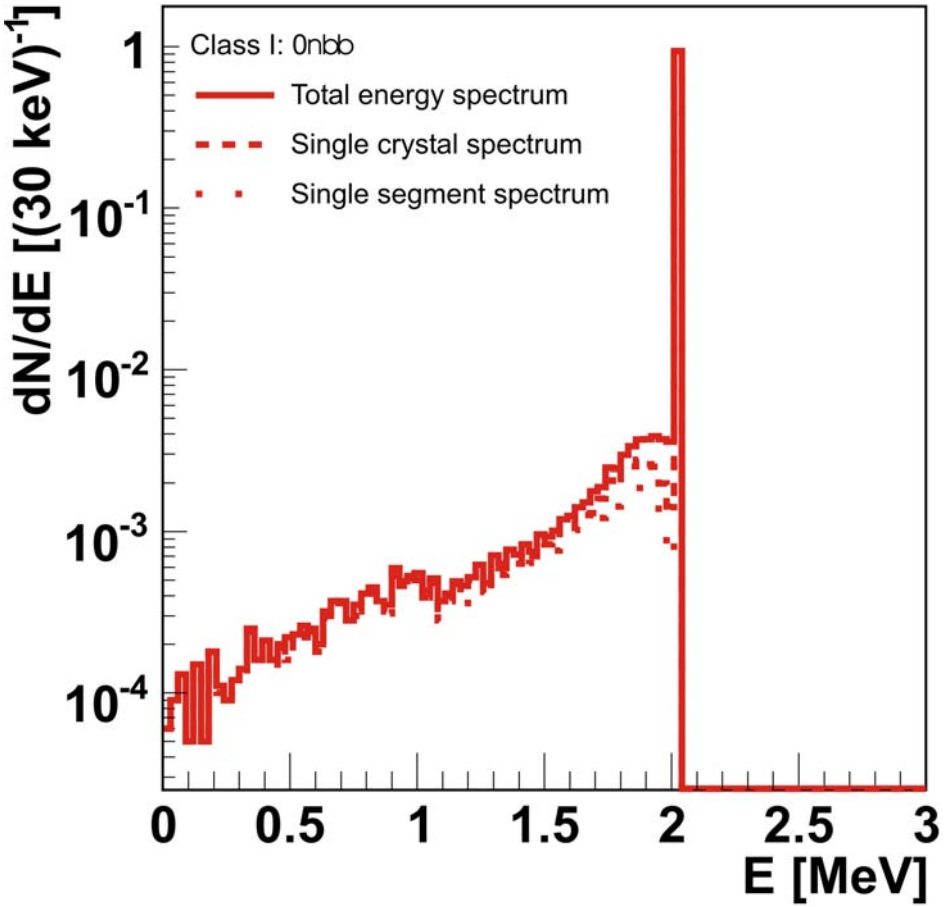


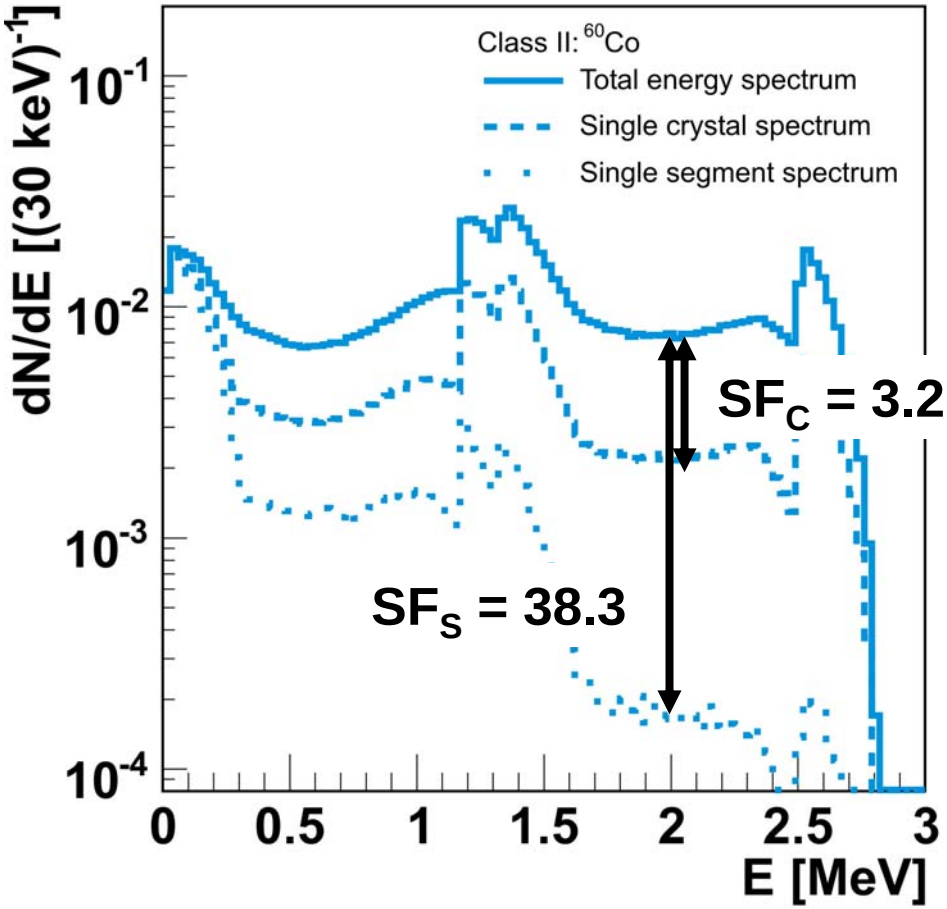
Multiplicities





Energy spectra – 2 examples





Results

Table 1
Summary of suppression factors for single crystal (SF_c) and single segment (SF_s) events from a representative selection of isotopes. A detector unit consists of the crystal, a holder structure (copper and Teflon), Capton cables and electronics. The electronics is placed about 30 cm above the detector array.

Material	Source	Class		SF_c	SF_s
Crystal					
Germanium	Bi-214	II	$(e^- + \gamma)$	1.8 ± 0.1	5.5 ± 0.3
	Tl-208	II	$(e^- + \gamma)$	2.6 ± 0.4	13.0 ± 3.7
	Co-60	II	$(e^- + \gamma)$	3.2 ± 0.1	38.3 ± 1.0
	Ge-68	III	$(e^+ + \gamma)$	2.4 ± 0.1	18.0 ± 1.4
Surface	Pb-210	V	(α)	$1.0^{+0.4}_{-0}$	$1.0^{+0.4}_{-0}$
Detector holder					
Copper	Bi-214	IV	(γ)	2.8 ± 0.5	6.0 ± 1.4
	Tl-208	IV	(γ)	2.2 ± 0.4	4.6 ± 0.9
	Co-60	IV	(γ)	6.7 ± 0.2	157.2 ± 26.7
Teflon	Bi-214	IV	(γ)	2.2 ± 0.3	12.8 ± 3.7
	Tl-208	IV	(γ)	2.5 ± 0.3	10.0 ± 2.1
	Co-60	IV	(γ)	3.8 ± 0.1	106.3 ± 7.6
Cables					
Kapton	Bi-214	(II) IV	(γ)	3.3 ± 0.5	7.4 ± 1.3
	Tl-208	(II) IV	(γ)	3.1 ± 0.7	4.7 ± 1.2
Electronics					
Misc.	Tl-208	IV	(γ)	1.5 ± 0.3	2.9 ± 0.6

Suppression works well on Co-60 and other background sources with photons in the final state

Additional suppression:
$SF_S/SF_C \sim 2 - 30$

Suppression does not work on alpha sources.

No additional suppression.

Conclusions/Outlook

- Monte Carlo simulation performed for GERDA setup (ideal Phase II):
  - ***Segmentation scheme for Phase II detectors suitable***
  - ***Identification and suppression of events with photons in the final state is feasible (additional factor ~ 2 – 30)***
- Prototype detector at MPI Munich → experimental confirmation.
- Pulse shape analysis is can give an additional factor of 2.