LAr instrumentation for GERDA Phase II

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DPG Frühjahrstagung, Wuppertal, 9 March 2015

LAr scintillation veto for background suppression

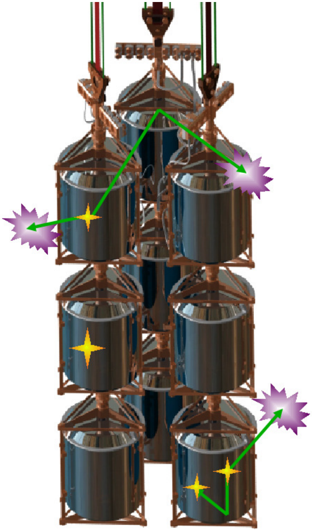
How does an active LAr veto work?

signal

$0\nu\beta\beta$ event deposits its energy locally in the Ge-crystal
$\rightarrow$ single site event

backgrounds

- γ background: mainly compton scattered events from natural decay chains (^{228}Th, ^{226}Ra)
- α and β decays near/on detector surface (^{226}Ra, ^{42}K)



LAr instrumentation

- energy deposition in LAr creates scintillation light @ $\lambda = 128\,\mathrm{nm}$, 40000 pe/MeV
- can be used as anticoincidence veto

"Hybrid" LAr veto design for GERDA Phase II

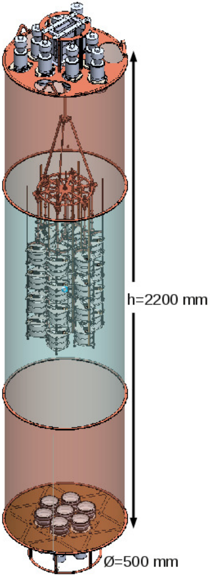
"hybrid" design is outcome of an extensive MC simulation campaign using photon tracking

photomultipliers

- type: 3 " R 11065-20 MOD
- 9* top, 7* bottom

scintillating fibers and SiPMs

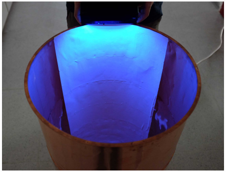
- build the middle shroud
- type: BCF-91A coated with TPB
- light readout at both ends by SiPMs on top



“Hybrid” LAr veto design for GERDA Phase II

top/bottom copper shroud + reflective foil

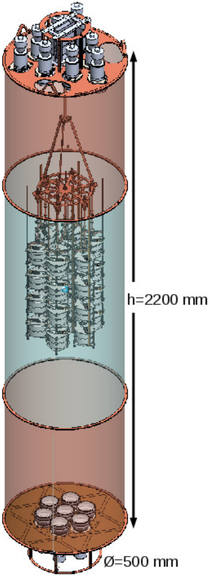
- Tetratex coated with TPB as wavelength shifter
- installed on inner side of copper shrouds



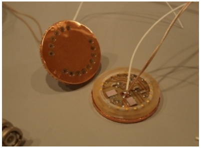
nylon mini-shrouds

- around each detector string
- transparent & WLS

⇒ usable together with light instrumentation



Photomultiplier - Hardware

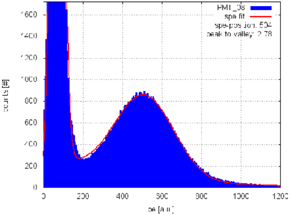


screening results [mBq/pc]

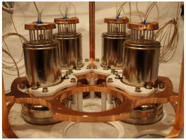
	^{228}Th	^{226}Ra
PMT *	< 1.94	< 1.7
VD	< 0.5	< 1.14

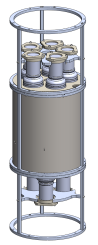
* calculated from component screening

peak-to-valley: 4:1



teststand





test of up to 10 PMTs in LAr

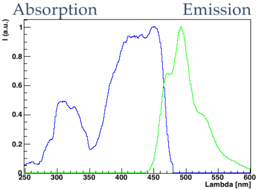
- ➢ light yield measurements with internal sources
- ➢ gain calibration with LED
- ➢ signal rate monitoring
- ➢ longterm test up to 6 weeks performed

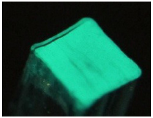
⇒ 18 PMTs classified as good enough for operation in GERDA

Fibers - Hardware

scintillating fibers coated with TPB

- fibers themselve are WLS





- screening results

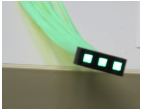
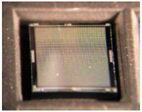
^{228}Th: 0.058 $\mathrm{Bq/kg}$

^{226}Ra: 0.042 $\mathrm{Bq/kg}$

9 fibers per SiPM

- readout at the top

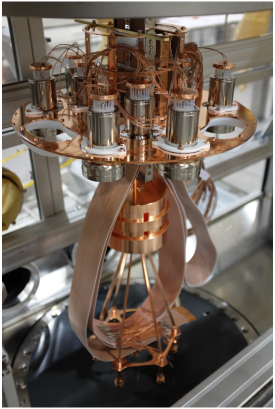
⇒ far from detectors

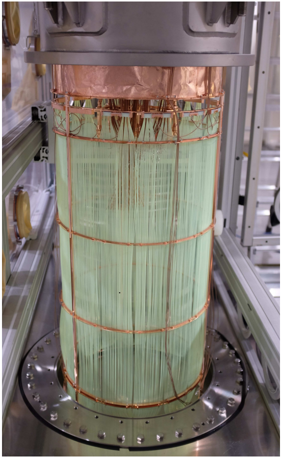



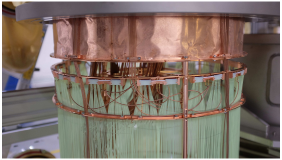
SiPMs at LN temperature

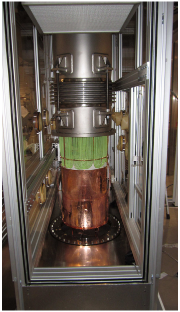
- good QE, negligible dark rate
- Ketek SiPMs in 'die' → low background packaging

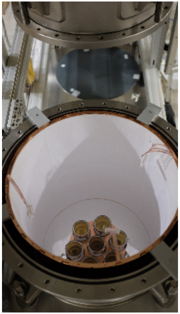
LAr veto integration in GERDA

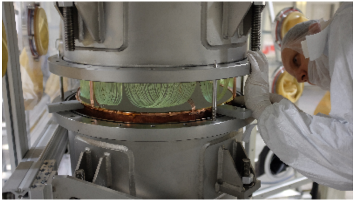












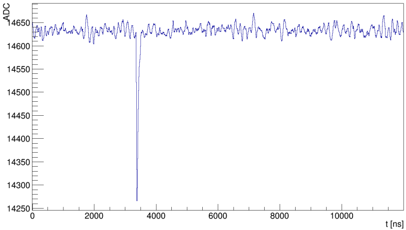
- integration started in summer 2014
- finished in November 2014

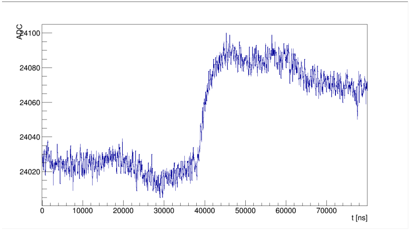
LAr veto integration in GERDA

LAr veto commissioning in GERDA

November 2014: first commissioning run w/o Ge diodes

- mechanical test
- learn about noise, rates, coincidences between SiPMs and PMTs, read-out window
- apply analysis tools to real data





December 2014: first test with one working BEGe and ^{232}Th source

- learn about veto efficiencies of LAr instrumentation

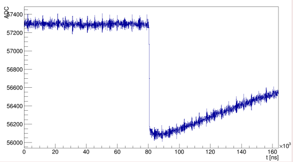
February 2015: data taking with one BEGe string and a ^{228}Th calibration source

- learn about interplay of PSD and LAr veto

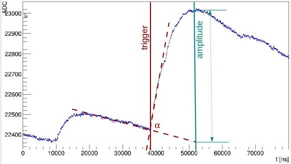
LAr veto analysis

saved traces for every trigger in a Ge-diode

Ge trace

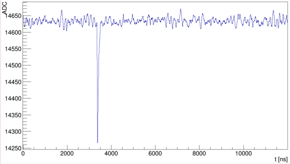


SiPM traces



use as filter parameter angle $\alpha \cdot |\textit{slope}|$ for hit identification

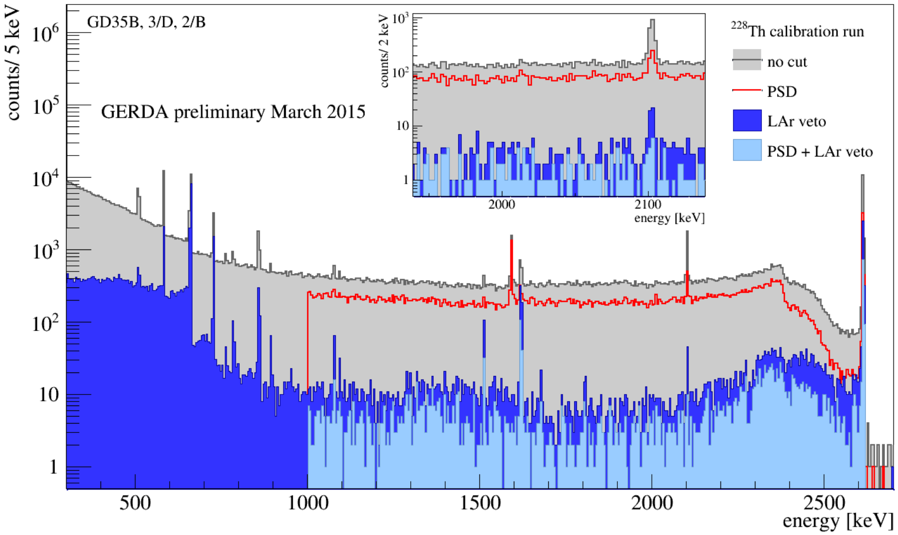
PMT traces



use simple leading edge filter

1. hit identification in whole trace
2. determine veto threshold & window for each channel
   - for this analysis set by eye
   - later: maximize suppression factor/random coincidence rate as function of veto window, veto threshold, multiplicity,...
3. set veto flag

First LAr veto suppression in GERDA



Summary

- LAr light instrumentation with PMTs and Fibers/SiPMs has been installed in GERDA:
  - ➢ hardware tests of individual components completed prior to the installation
- first commissioning runs have been conducted
  - ➢ PMTs & SiPMs show good signal-to-noise ratio (PMTs: peak-to-valley 4:1)
- First results **(preliminary !)**
  - ➢ LAr veto: SF $\approx$ 50 for nearby ^{228}Th calibration source (only 6 of 15 fiber modules were working)
  - ➢ **PSD + LAr veto: SF $\approx$ 100**
  - ➢ broken SiPMs exchanged & much higher suppression expected for the next runs

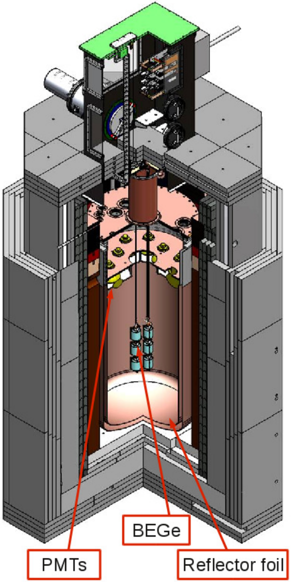
outlook

- optimize LAr veto algorithms with respect to the suppression factors and random coincidence rate
- perform MC simulations to verify the agreement between the measured and the expected suppression factors
- **commissioning is ongoing...**

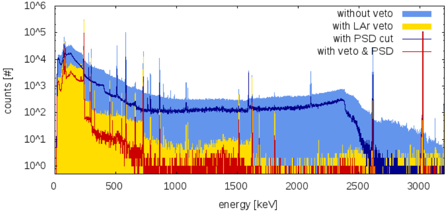
Thank you for your attention !

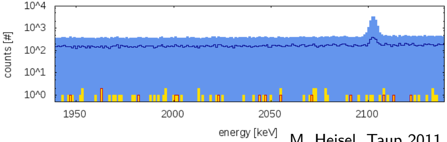
LArGe - a test facility for GERDA

Proof of LAr-veto concept in low background environment



energy spectrum for an internal ^{228}Th source:



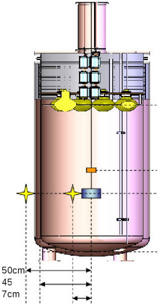


M. Heisel, Taup 2011

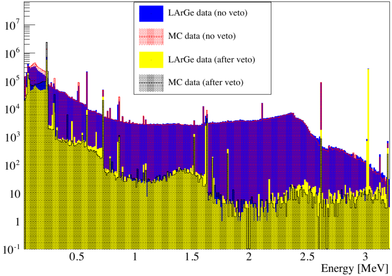
source	position	suppression factor		
		LAr veto	PSD	total
^{228}Th	int	1180 ± 250	2.4 ± 0.1	5200 ± 1300
	ext	25 ± 1.2	2.8 ± 0.1	129 ± 15
^{226}Ra	int	4.6 ± 0.2	4.1 ± 0.2	45 ± 5
	ext	3.2 ± 0.2	4.4 ± 0.4	18 ± 3
^{60}Co	int	27 ± 1.7	76 ± 8.7	3900 ± 1300

Physics validation of Monte Carlo using photon tracking

Comparison to LArGe data



- simple geometry
- data with various sources in different locations available



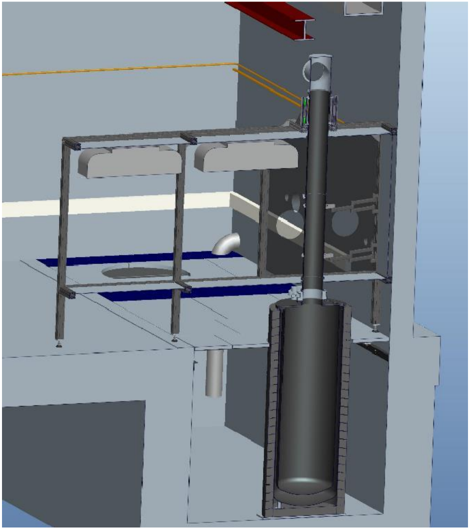
- tuning of optical properties
  - ➢ material reflectivities (Ge, Cu, VM2000, ...)
  - ➢ absorption and emission spectra
  - ➢ LAr attenuation length, light yield and triplet lifetime
- good MC description after tuning

$\Rightarrow$ can be used to design the LAr veto for GERDA

bg	LArGe data	MC
	internal	
^{208}Tl	1180 ± 250	909 ± 235
^{214}Bi	4.6 ± 0.2	3.8 ± 0.1
^{60}Co	27 ± 2	16.1 ± 1.3
	external	
^{208}Tl	25 ± 1.2	17.2 ± 1.6
^{214}Bi	3.2 ± 0.2	3.2 ± 0.4

Fibers - Hardware

TUM cryostat



Fibers -filter algorithm