Liquid argon veto for the GERDA experiment

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For the GERDA collaboration

The VII Annual Conference of Young Scientists and Specialists
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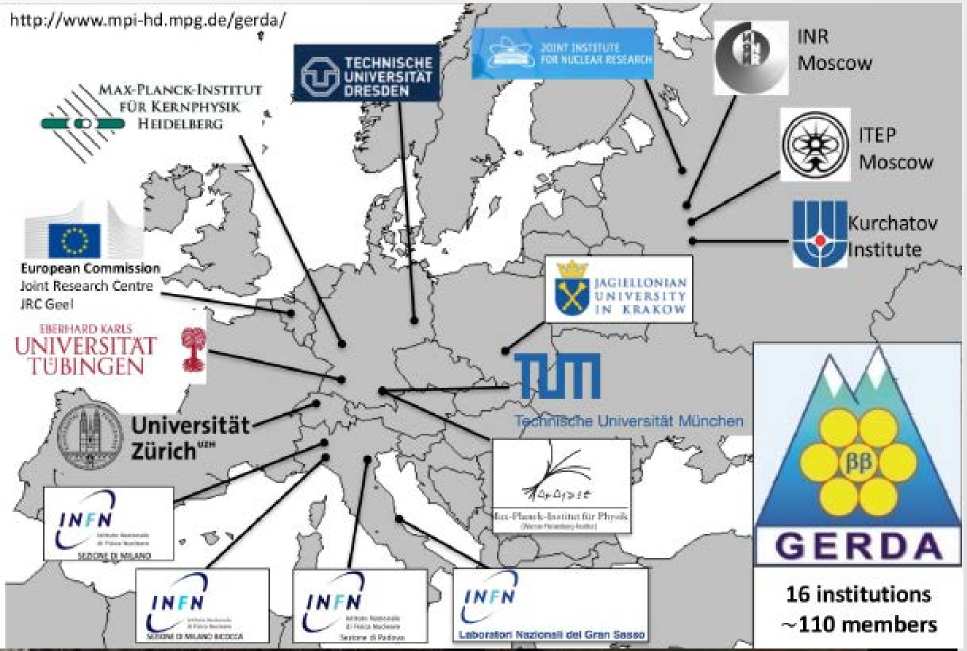
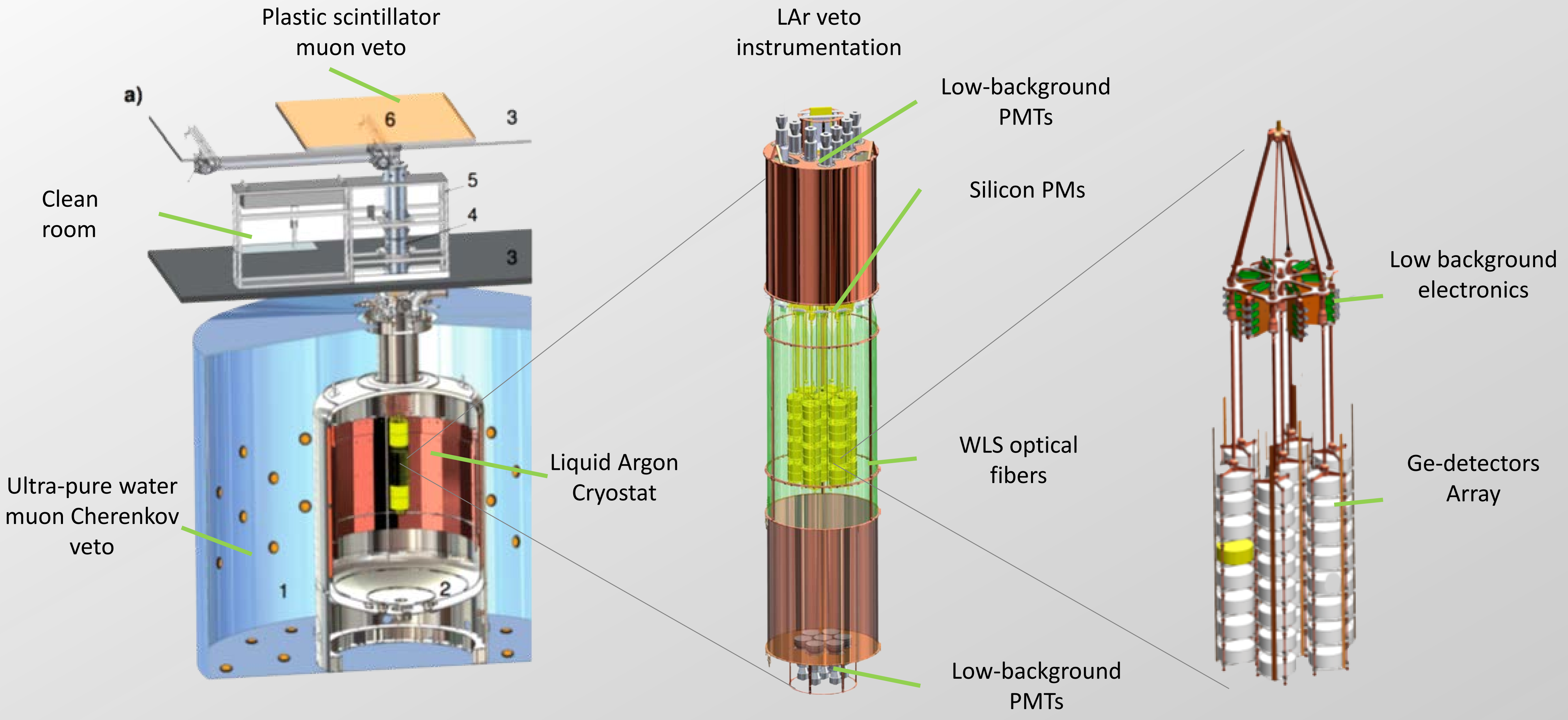
GERDA setup location

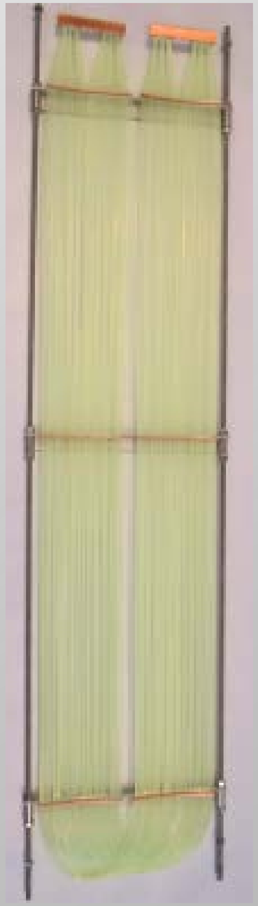


GERDA setup (Phase II)

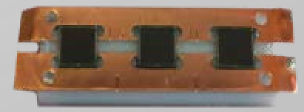


Fiber shroud (old design)

Fiber shroud with 6 double modules and 3 single modules

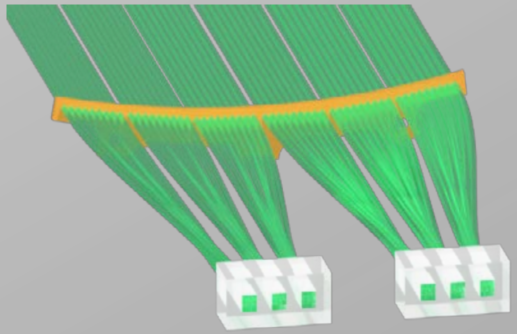


Double module

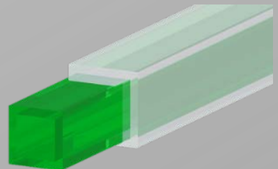


SiPM array
(3 SiPMs per array)

Silicon PMT
KETEK

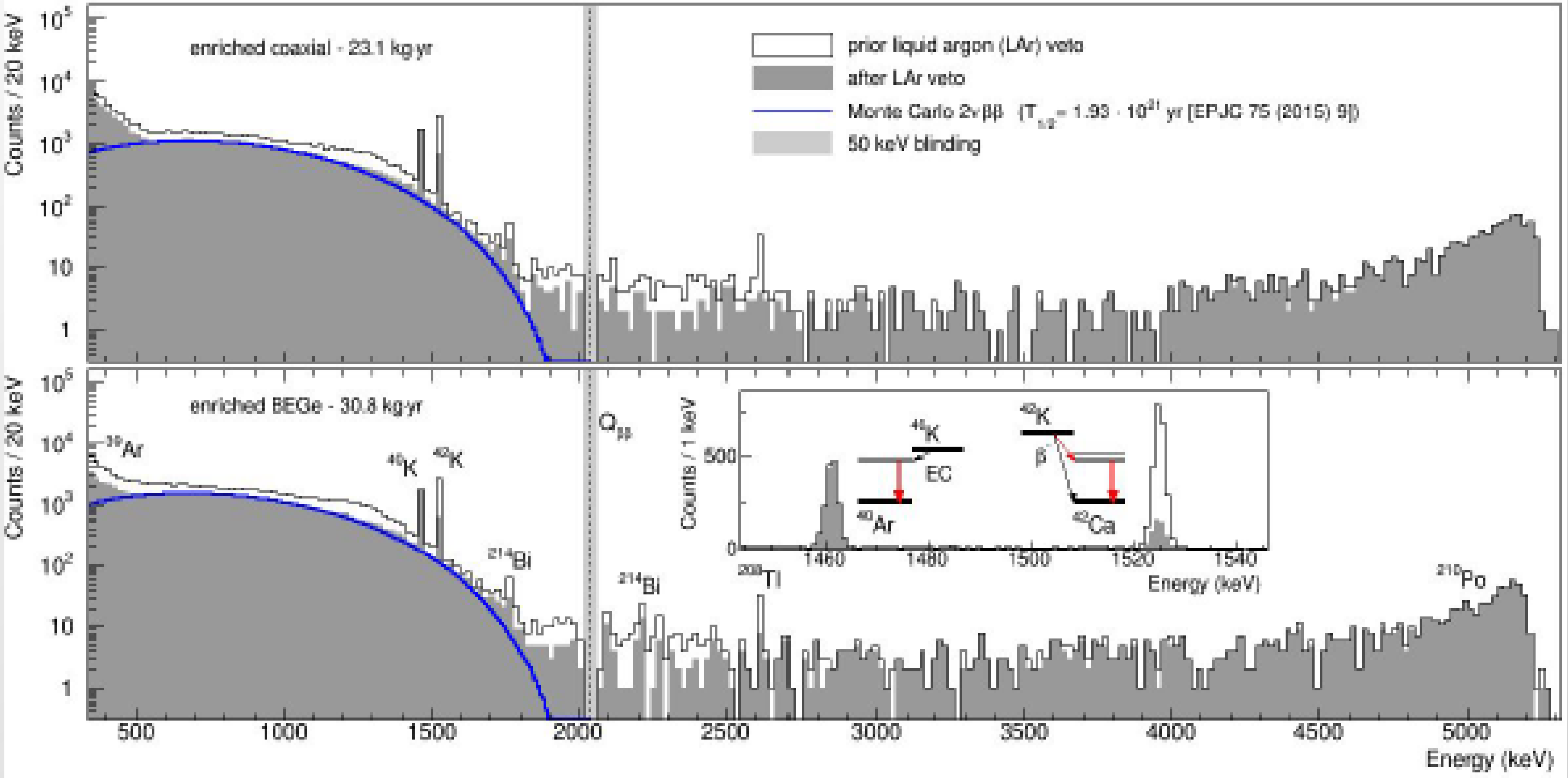


Light collection with 54 WLS optical fibers



WLS optical fibers SaintGobain BCF-91(M) 1x1 mm, with TPB coating

Background suppression with LAr veto



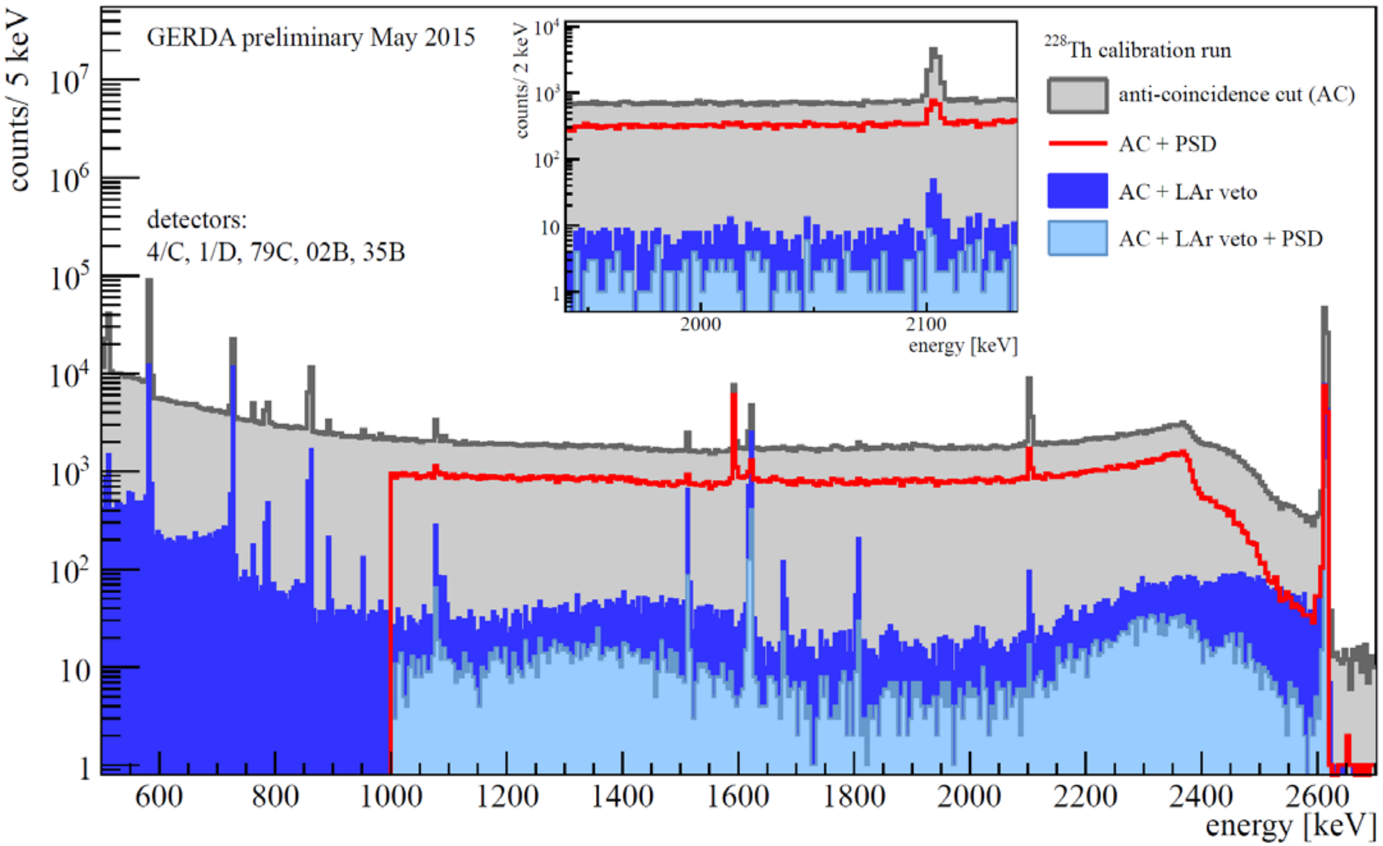
- Almost pure 2νββ spectrum after LAr veto cut (600-1300 keV)
- LAr veto cut signal acceptance 97.7(1)%

^{228}Th calibration

	SF(data)	SF (MC)
top PMTs	4.7 ± 0.1	43.3 ± 0.5
bot PMTs	12.9 ± 0.1	46.1 ± 0.6
all PMTs	22.5 ± 0.3	68.0 ± 1.0
SiPMs	48.0 ± 0.9	97.0 ± 1.7
all	60.0 ± 1.2	97.4 ± 1.7

⇒ SF and pe yield significantly lower than predicted by MC simulations

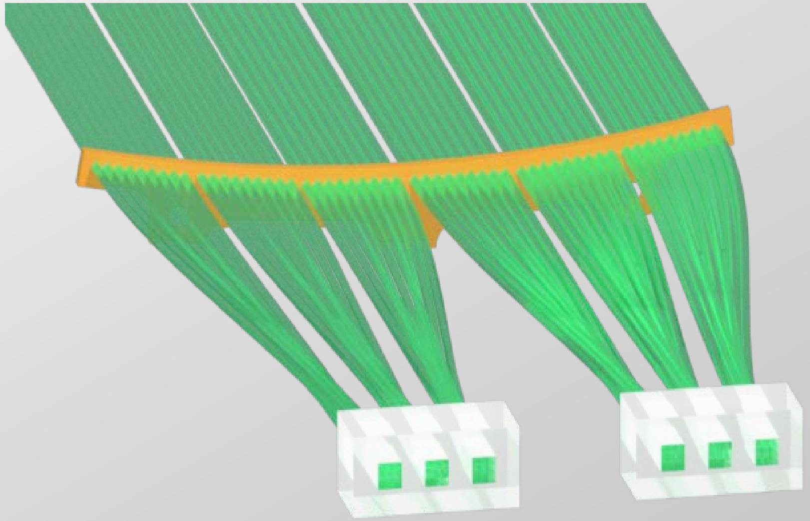
- possible reasons:
  - fiber implementation in MC
  - optical properties



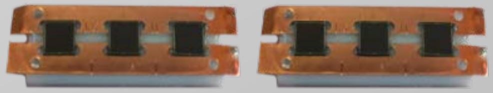
	AC	LAr veto	PSD	LAr+PSD
SF in ROI	1.256 ± 0.003	97.9 ± 3.7	2.19 ± 0.01	344.6 ± 24.5

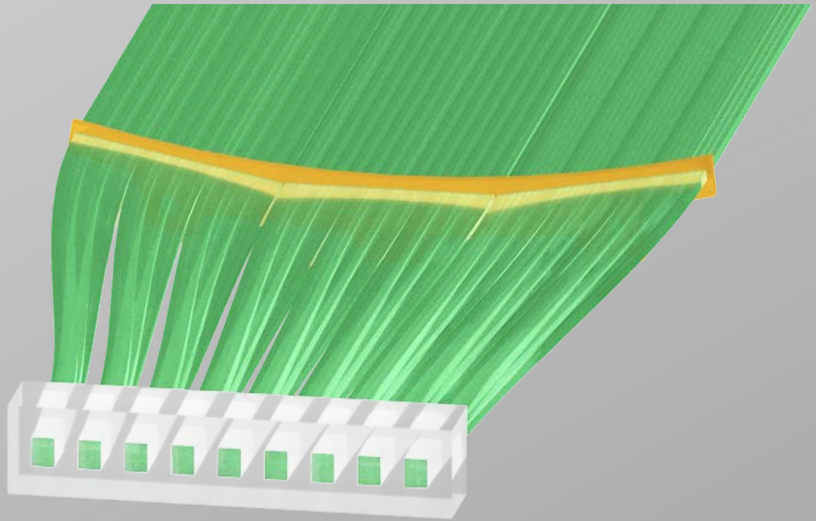
% acceptance for pulser, ROI: $Q_{\beta\beta} \pm 100\,\mathrm{keV}$, excl. SEP of ^{208}Tl.

The LAr-veto modules upgrade

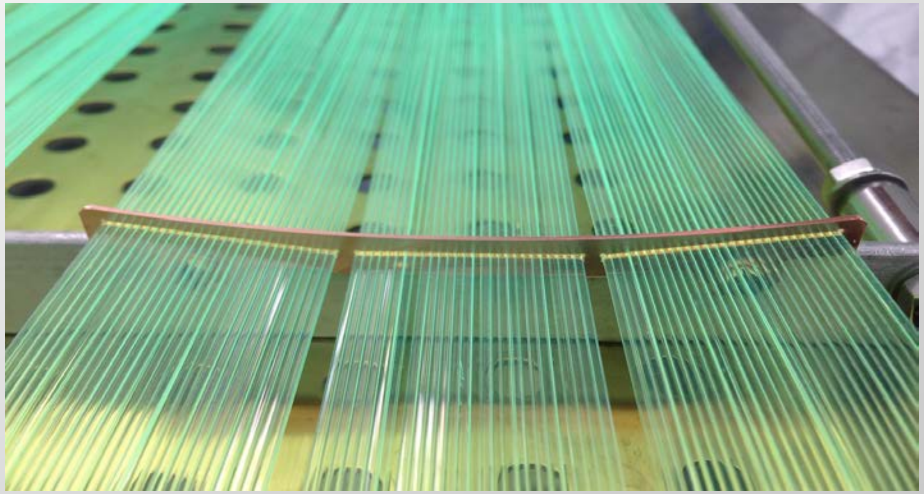


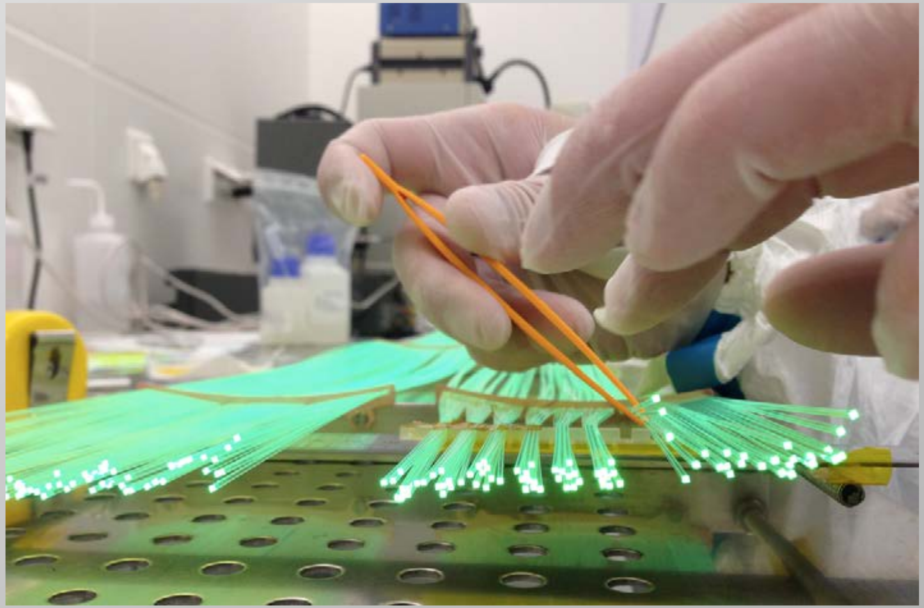
- WLS optical fibers amount increased from 54 to 81 (per module) for better light collection
- Light is collected with 9 SiPMs instead of 6
- Using of synthetic quartz for SiPMs placement instead of the acrylic pieces
- Copper holders with reduced mass produced with high-purity materials





The modules assembling





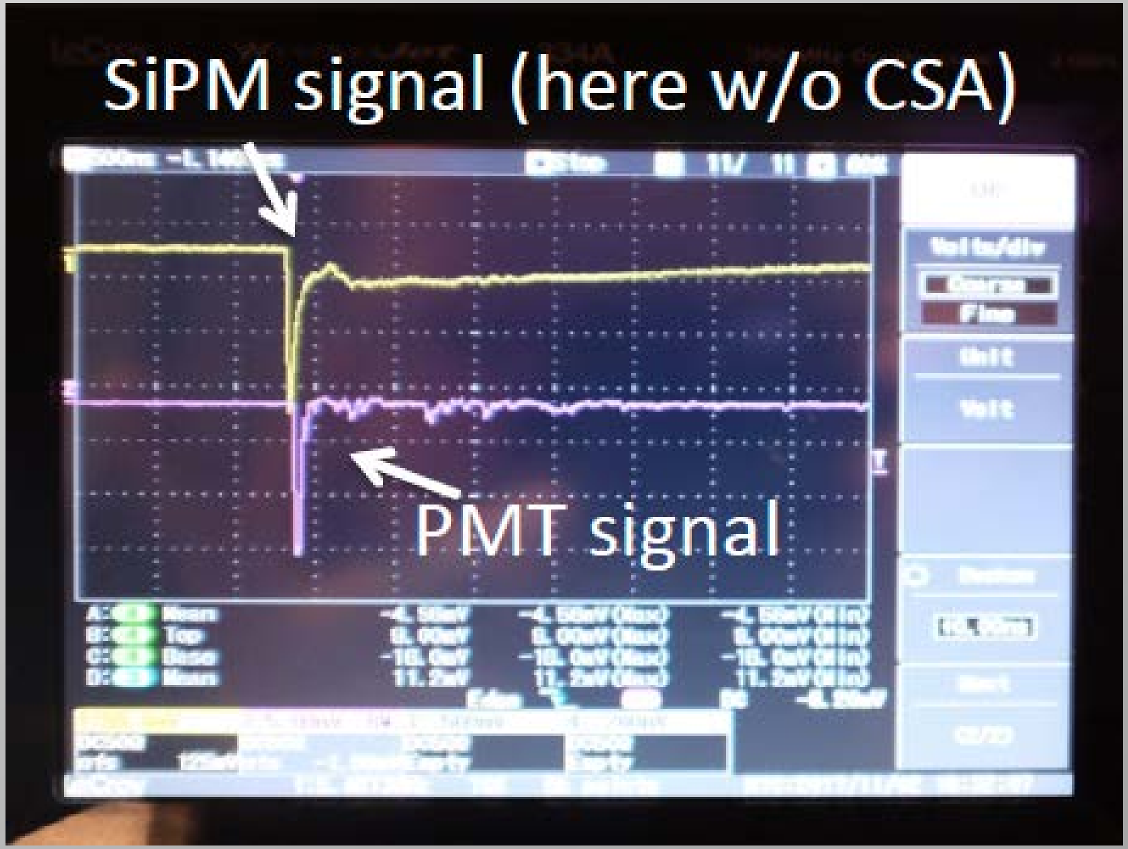
Produced and installed:

- 9 double modules
- 2 single modules

Tests provided:

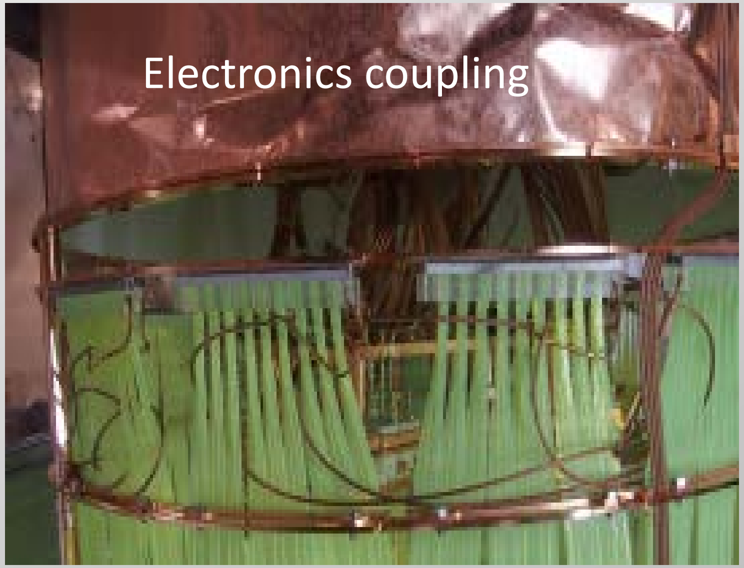
- Etching of quartz pieces and evaporating of aluminum layers
- TPB evaporating at the WLS fibers
- Electrical tests of the SiPM arrays

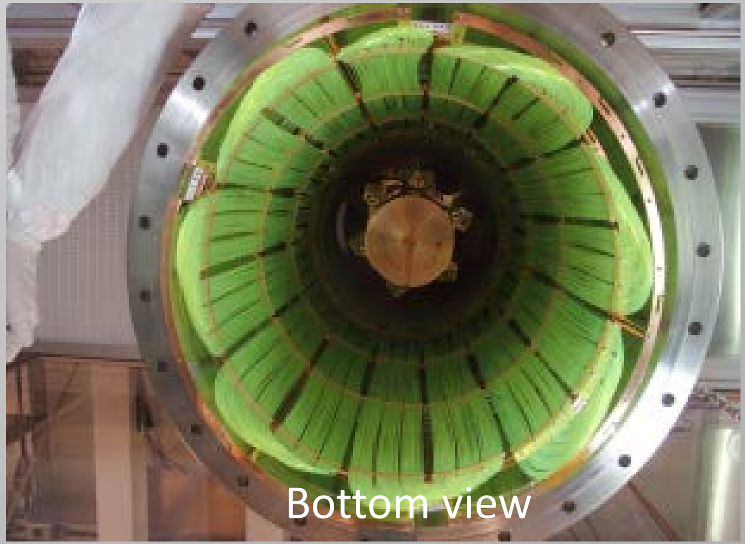
LAr-veto tests

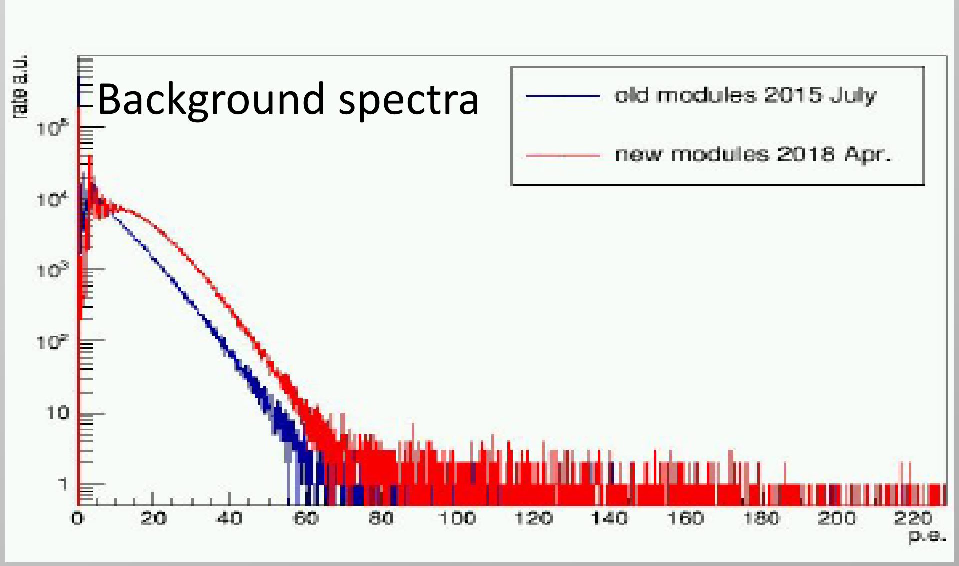


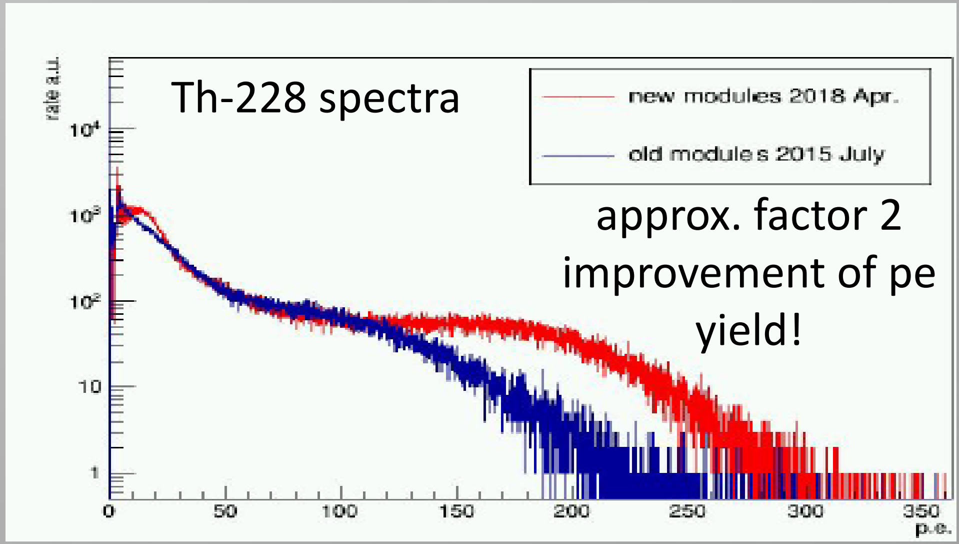
First cryotests of the double module with 9 SiPM array and PMT R11065-20 at TUM liquid argon cryostat (Munich)

LAr-veto installation









From GERDA to LEGEND

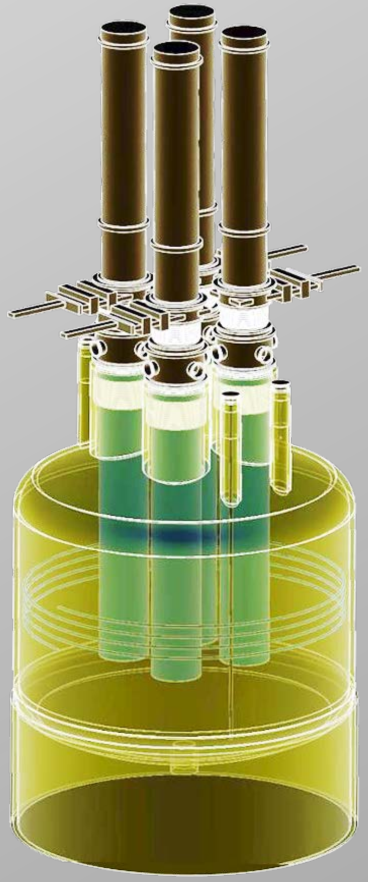
LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double Beta Decay) – This collaboration is the combination of GERDA + Majorana + some other new groups around the globe.

To be done:

LEGEND 200

First stage:

- (up to) 200 kg of HPG inn upgraded GERDA experimental setup
- Goal for the BI: 3-5 times better than current GERDA BI
- New LAr veto shroud with better Suppression Factor



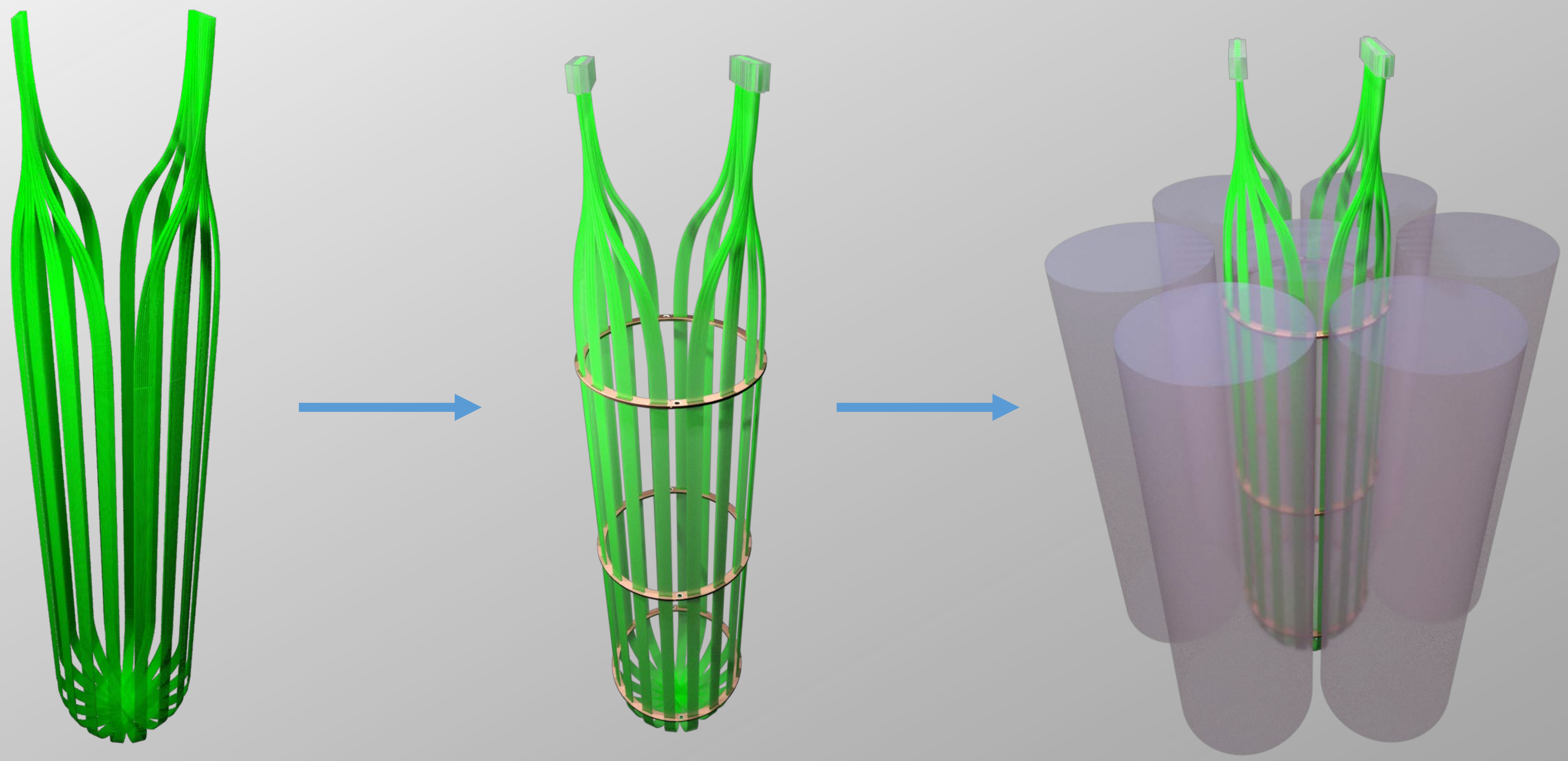
LEGEND 1000

Second stage:

- 1000 kg of HPGe
- Location to be determined
- Goal for the BI: ~30 times better than current GERDA BI
- New improved LAr veto instrumentation design

The LEGEND collaboration aims to improve the ^{76}Ge half-life discovery level to 10^{27}yr (3σ) in its first phase with further improvement to 10^{28}yr in its second phase.

Individual shroud for the central string – first design



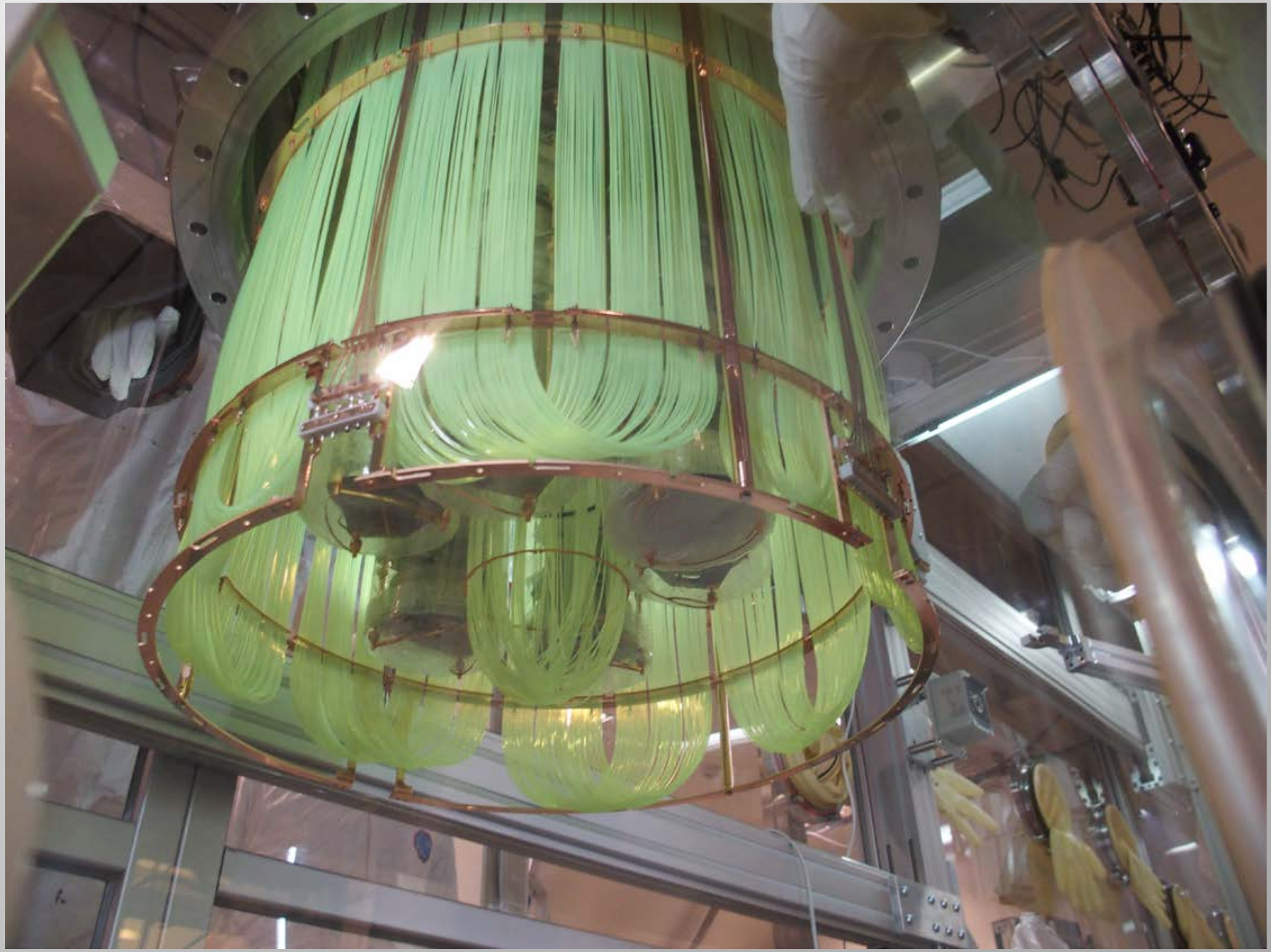
Motivation: Replacement of the PMT’s with high background contamination and increasing of light collection (current light collection less then 1%). The way to LEGEND LAr veto technique.

Individual shroud for the central string – final design

Silicon rings with lower background contribution instead of copper ones

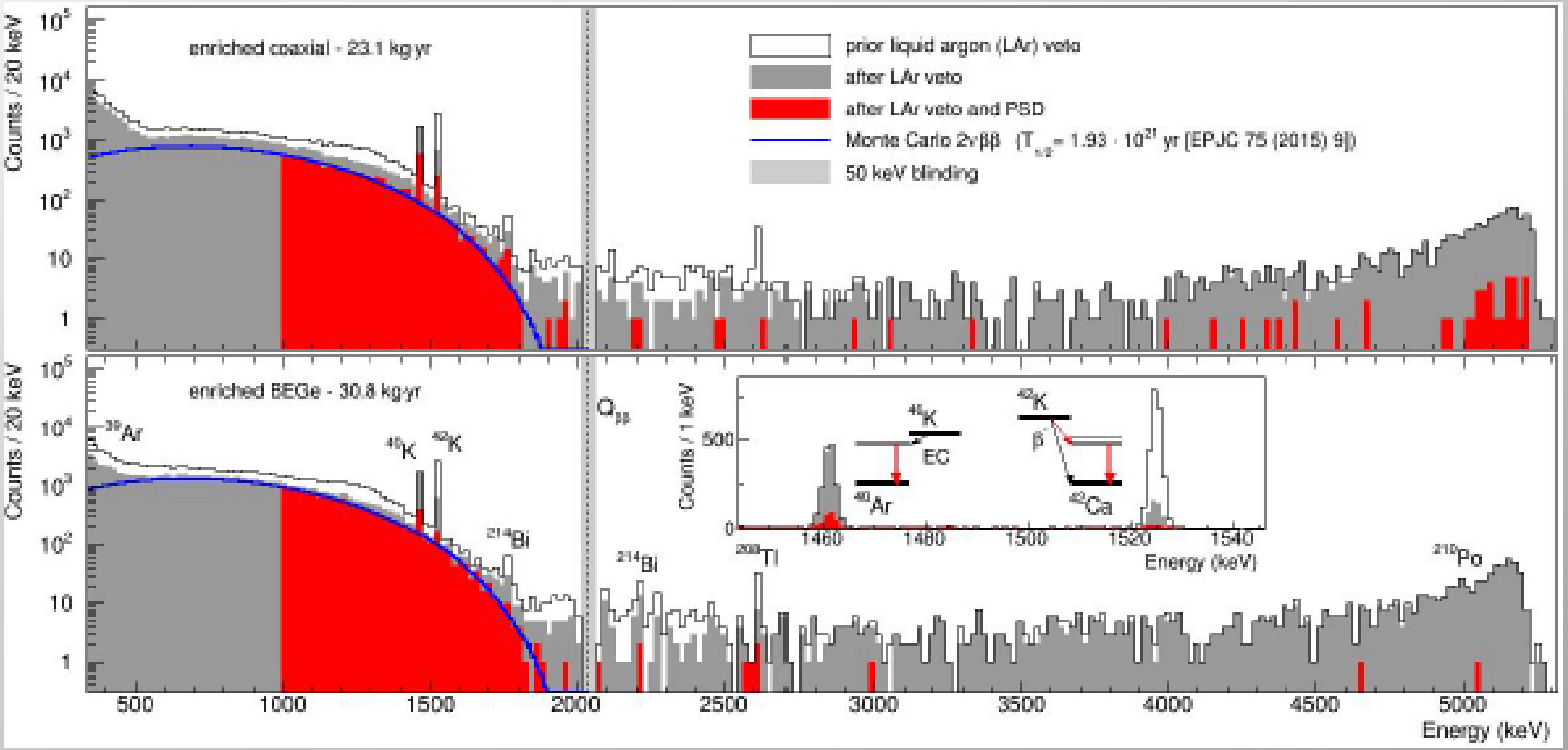
Motivation: Replacement of the PMT's with high background contamination and increasing of light collection (current light collection less then 1%). The way to LEGEND LAr veto technique.

Individual shroud for the central string – installation



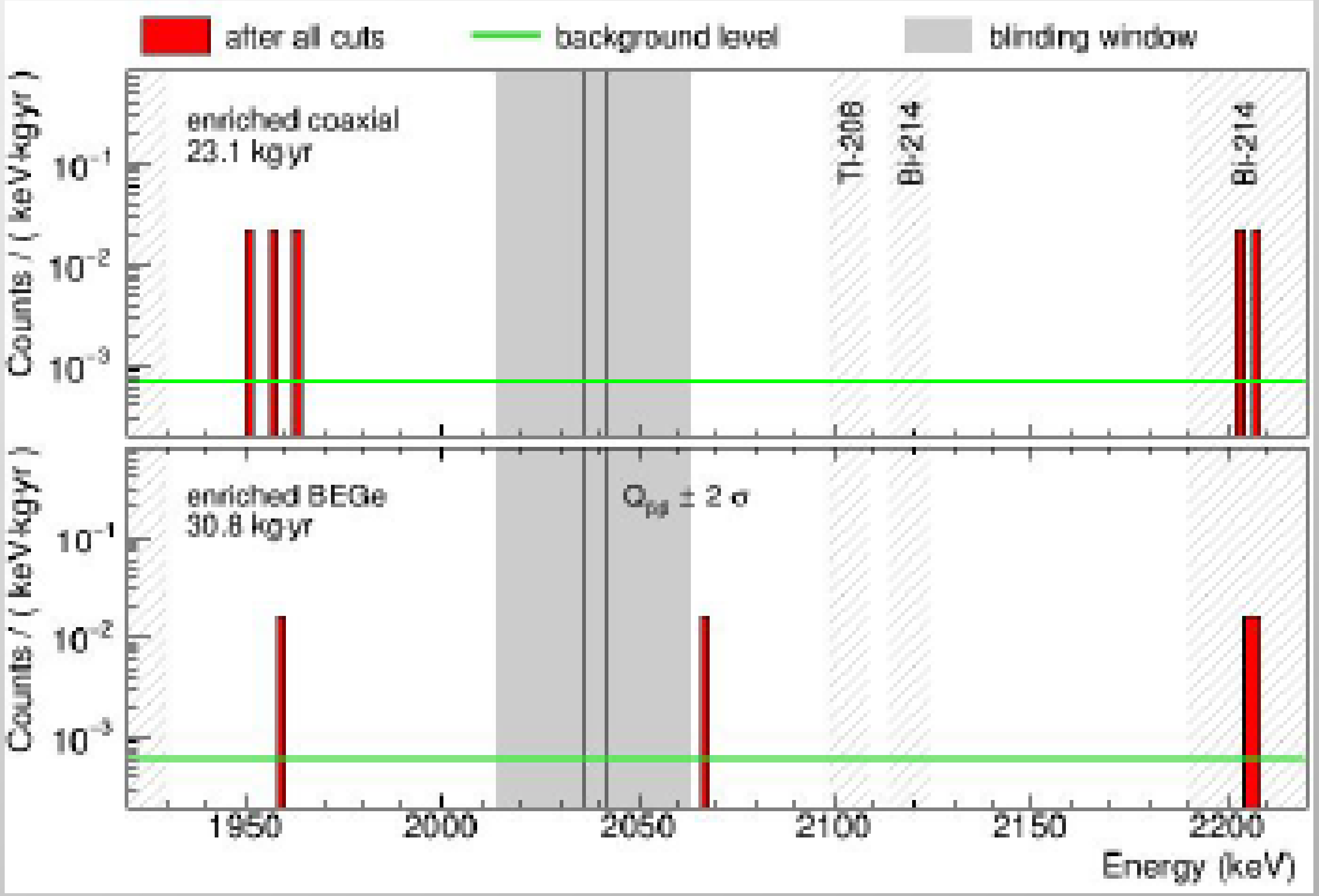
Thank you for your attention

Background suppression with PSD



- Both K lines and high energy α events strongly suppressed
- High 0νββ signal efficiency(71.2 ± 4.3)% for Coax and (87.6 ± 2.5)% for BEGe detectors

Background index

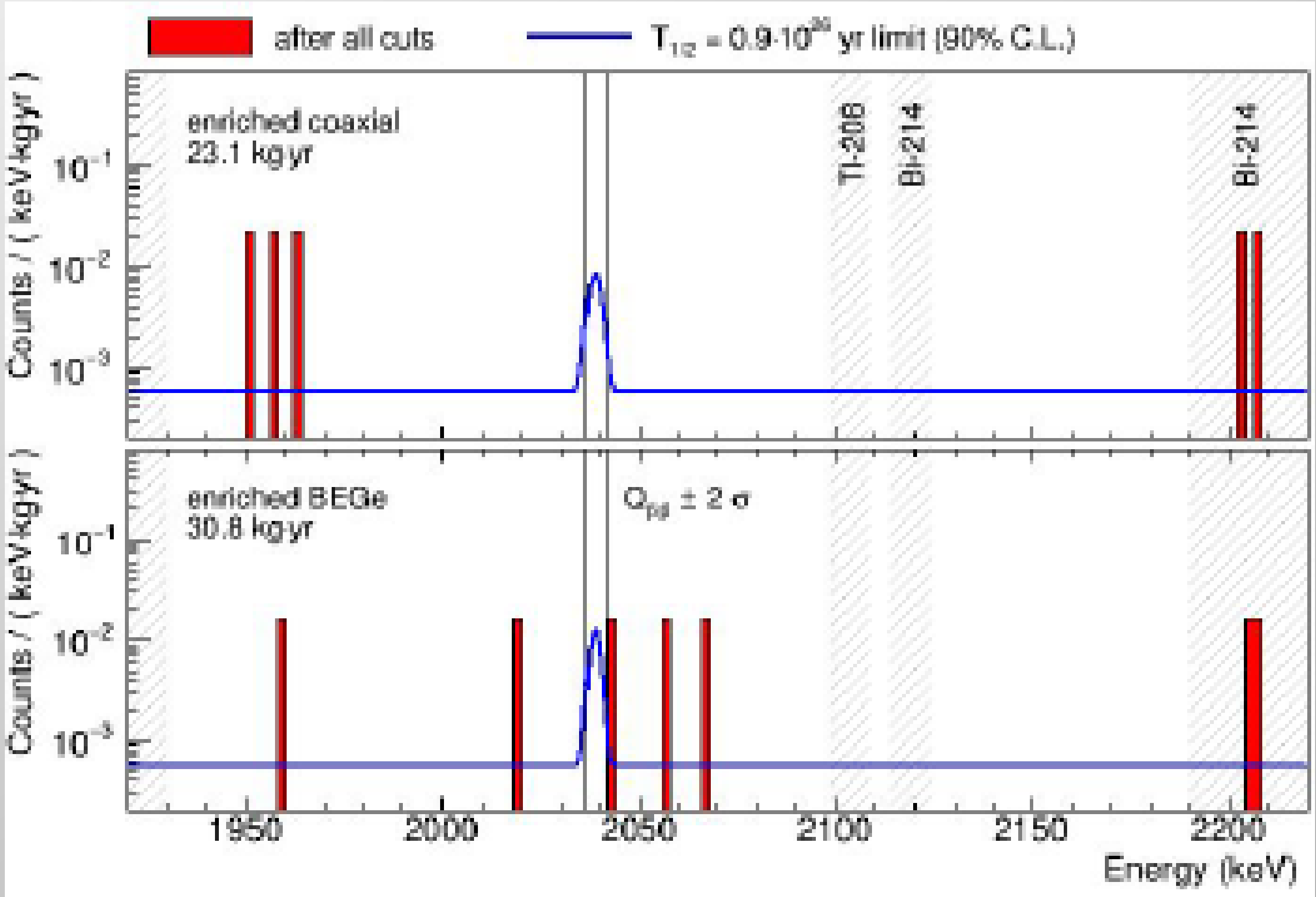


Coax*: $5.7^{+4.1}_{-2.6}\cdot 10^{-4}$ cts/(keV·kg·yr)

BEGe: $5.6^{+3.4}_{-2.4}\cdot 10^{-4}$ cts/(keV·kg·yr)

*Coax: new dataset with improved PSD BEGe: full Phase II dataset

Background index window: 1930-2190 keV, excl. ±5 keV around two known γ lines and around $Q_{\beta\beta}$



Coax*: $5.7^{+4.1}_{-2.6} \cdot 10^{-4}$ cts/(keV·kg·yr)

BEGe: $5.6^{+3.4}_{-2.4} \cdot 10^{-4}$ cts/(keV·kg·yr)

One new event in the BEGe dataset with energy 2042 keV

Statistical analysis

- Total exposure 82.4 kg·yr incl. Phase I
- Combined fit of 7 datasets → flat background + gaussian signal

Dataset	Exposure [kg·yr]	FWHM [keV]	ε	BI [10^{-3} cts/(keV·kg·yr)]
Phase I golden	17.9	4.3 ± 0.1	0.57 ± 0.03	11 ± 2
Phase I silver	1.3	4.3 ± 0.1	0.57 ± 0.03	30 ± 10
Phase I BEGe	2.4	2.7 ± 0.2	0.66 ± 0.02	5.0^{+4}_{-3}
Phase I extra	1.9	4.2 ± 0.2	0.58 ± 0.04	5.0^{+4}_{-3}
Phase II coax-1	5.0	3.6 ± 0.1	0.52 ± 0.04	$3.5^{+2.5}_{-1.5}$
Phase II coax-2	**23.1**	**3.6 ± 0.1**	**0.48 ± 0.04**	$\mathbf{0.6^{+0.4}_{-0.3}}$
Phase II BEGe	**30.8**	**3.0 ± 0.1**	**0.60 ± 0.02**	$\mathbf{0.6^{+0.4}_{-0.2}}$

Limits on half-life

Frequentist analysis

- Best fit → no signal
- $T_{1/2} > 0.9 \cdot 10^{26}$ yr (90% CL)

Bayesian analysis

Best fit → background only
$T_{1/2} > 0.8 \cdot 10^{26}$ yr (90% CI)