Veto systems for the GERDA experiment

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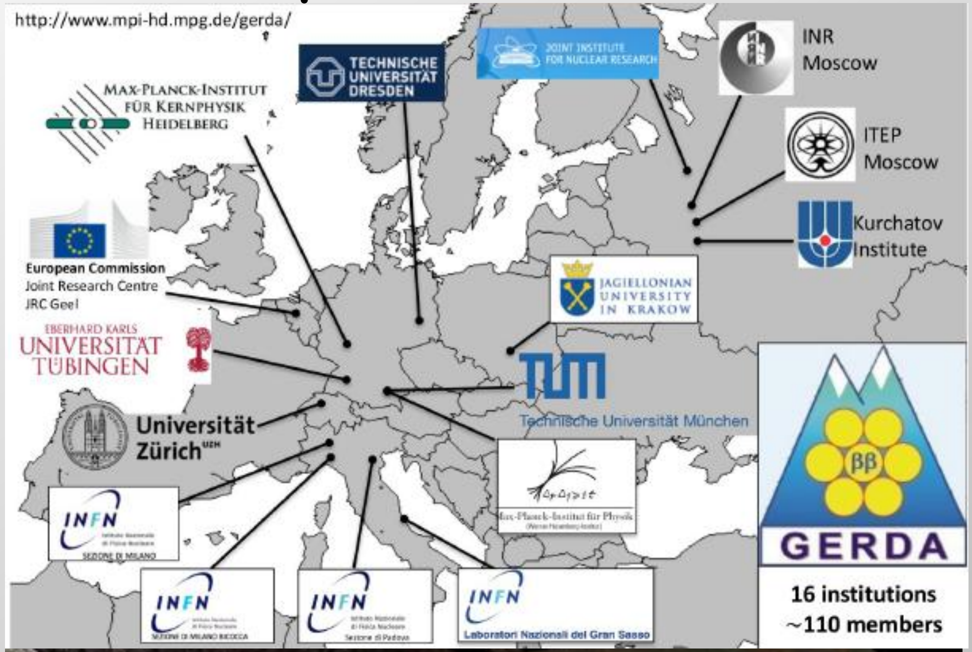
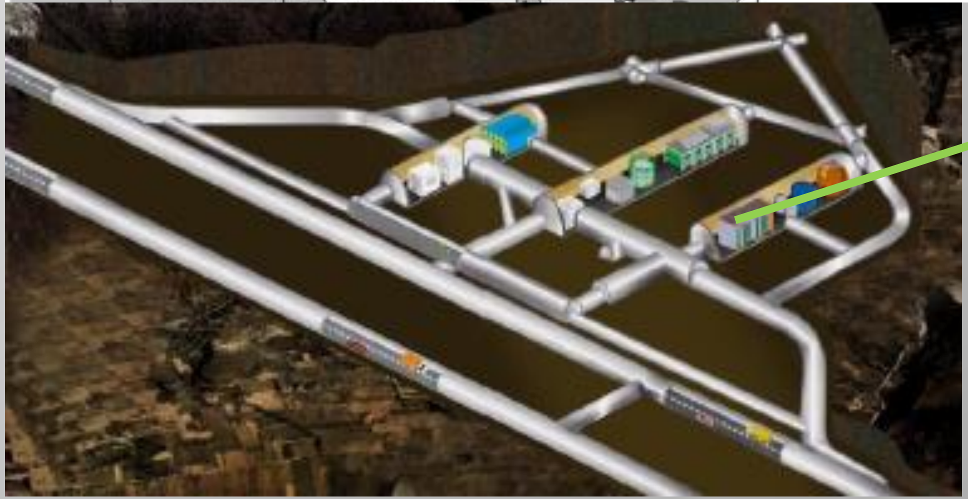
For the GERDA collaboration

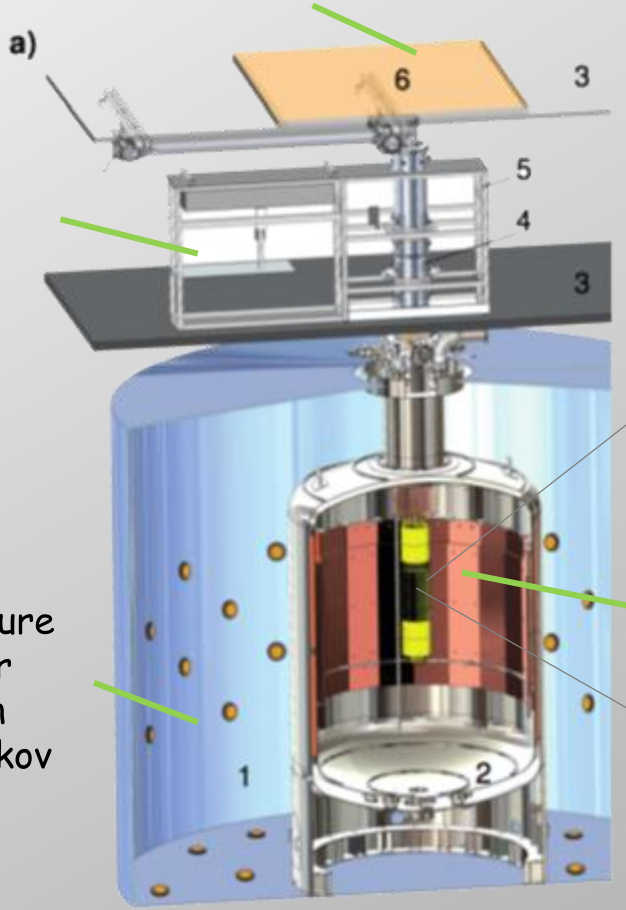
The VIII Annual Conference of Young Scientists and Specialists
"Alushta-2019", 10 - 17 June 2019

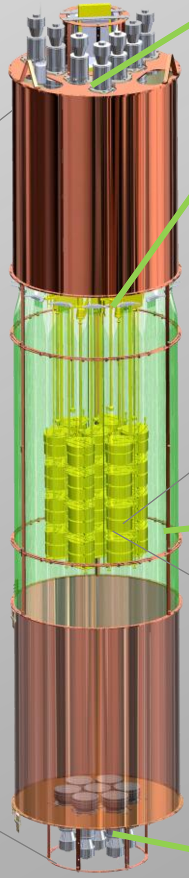
GERDA setup location

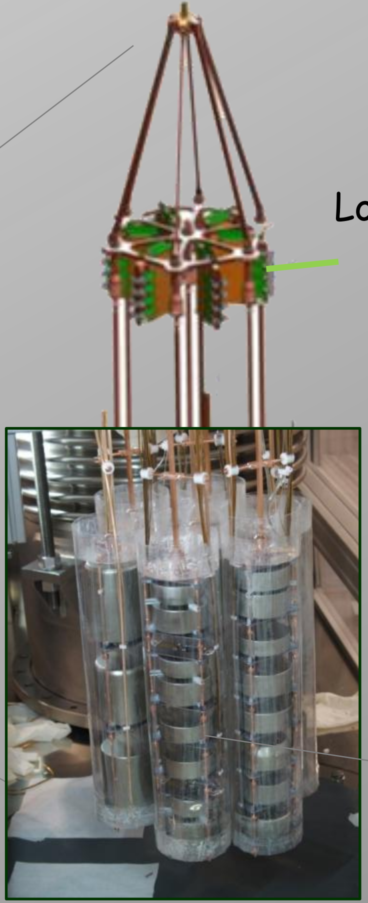




GERDA setup (Phase II)

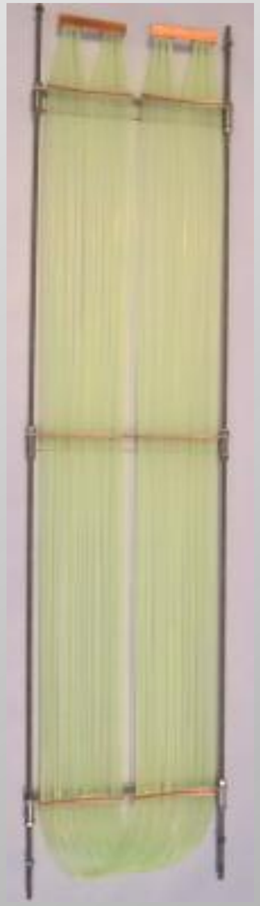




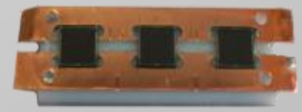


Fiber shroud (old design)

Fiber shroud with 6 double modules and 3 single modules

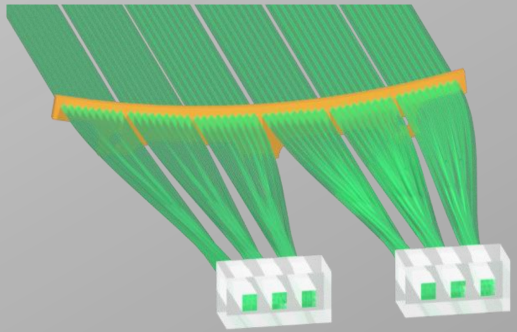


Double module

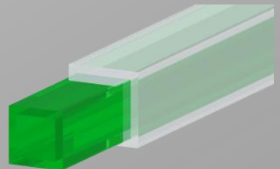


SiPM array
(3 SiPMs per array)

Silicon PMT
KETEK

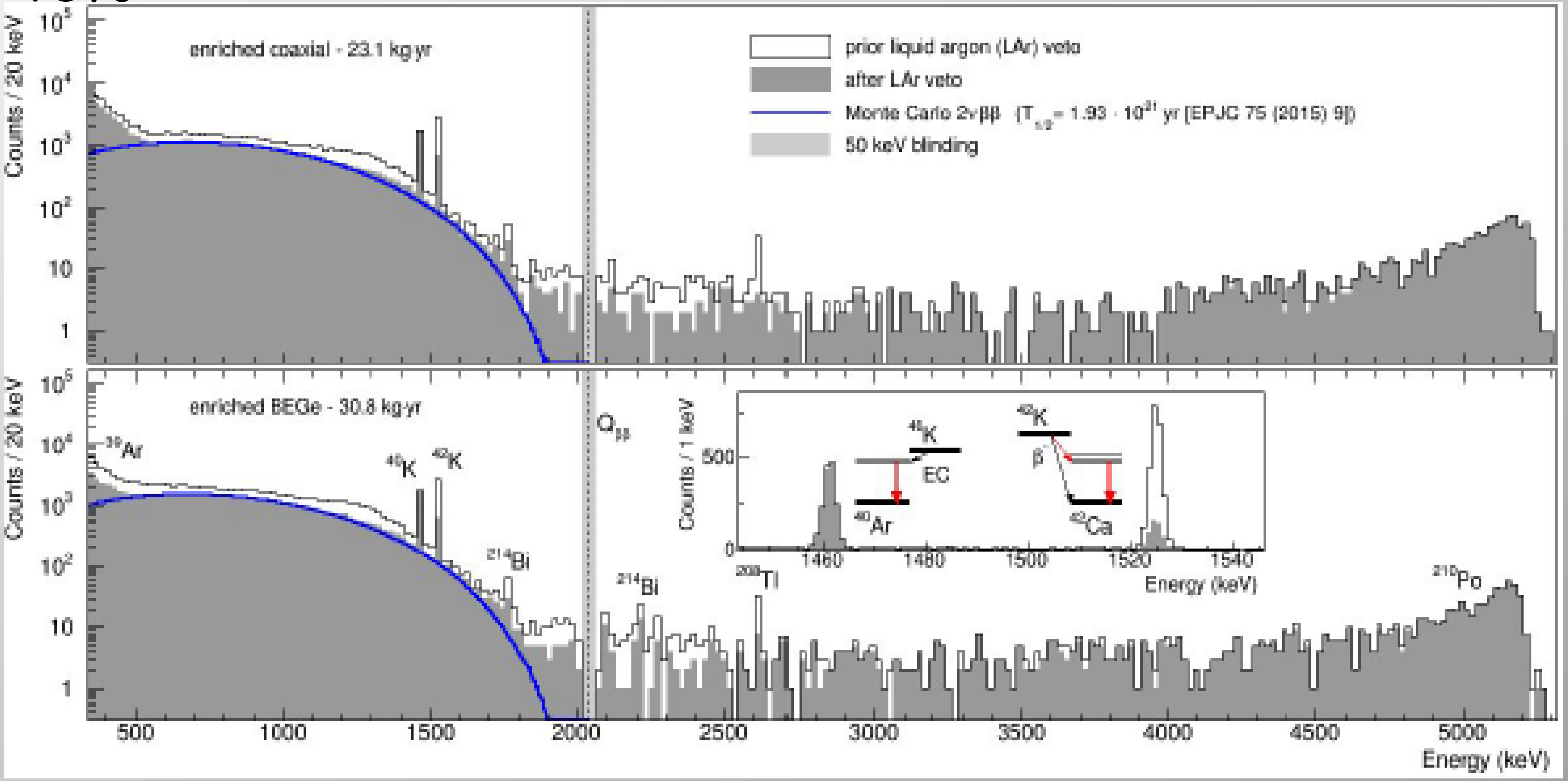


Light collection with 54 WLS optical fibers



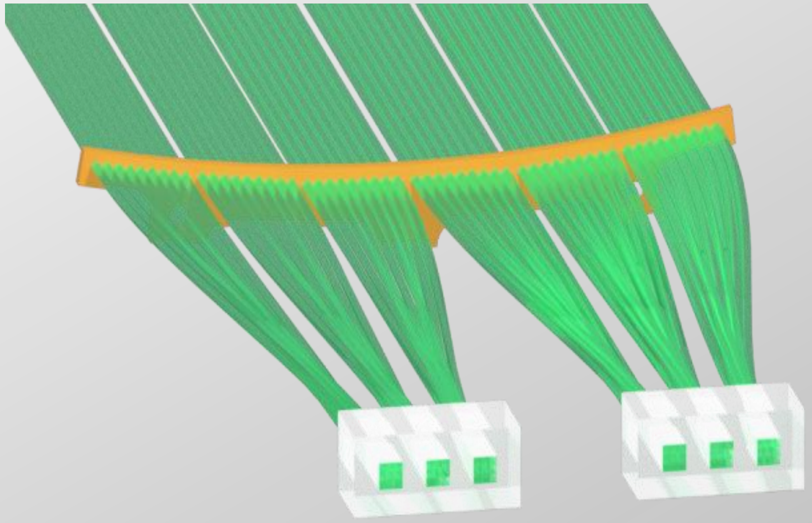
WLS optical fibers
SaintGobain BCF-91(M)
1x1 mm, with TPB coating

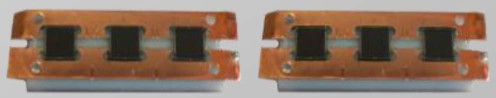
Background suppression with LAr veto



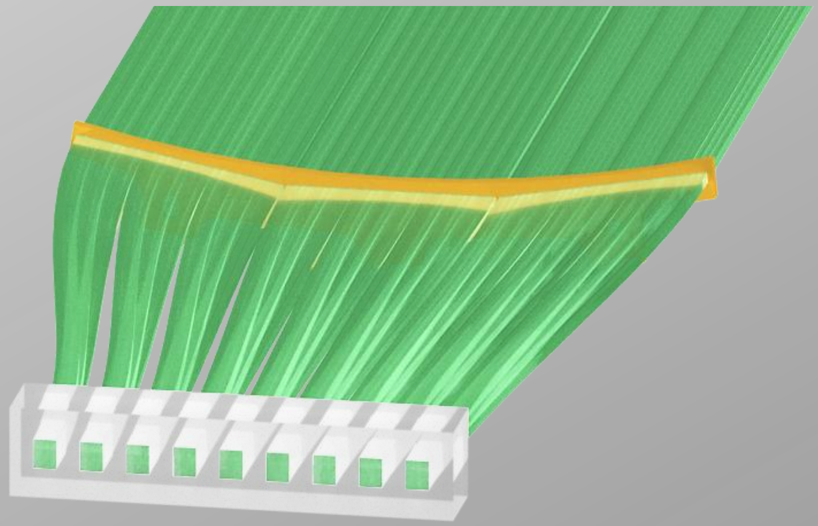
- Almost pure 2νββ spectrum after LAr veto cut (600-1300 keV)
- LAr veto cut signal acceptance 97.7(1)%

The LAr-veto modules upgrade

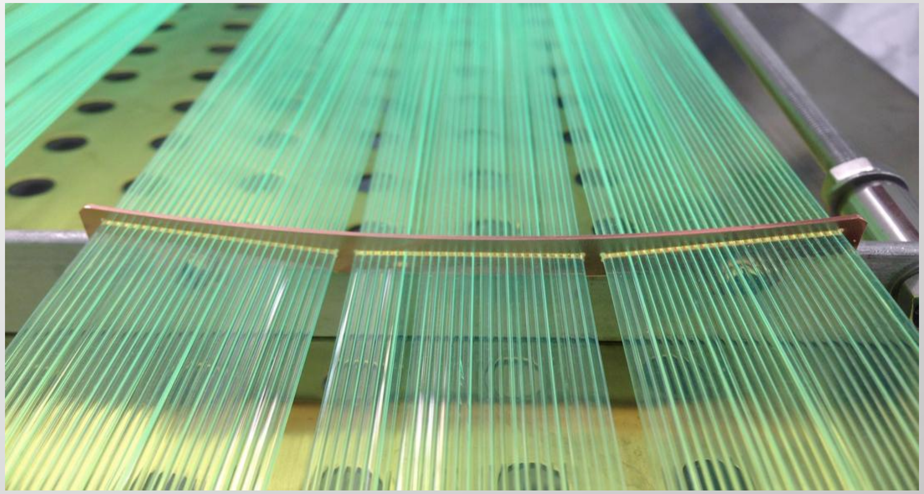


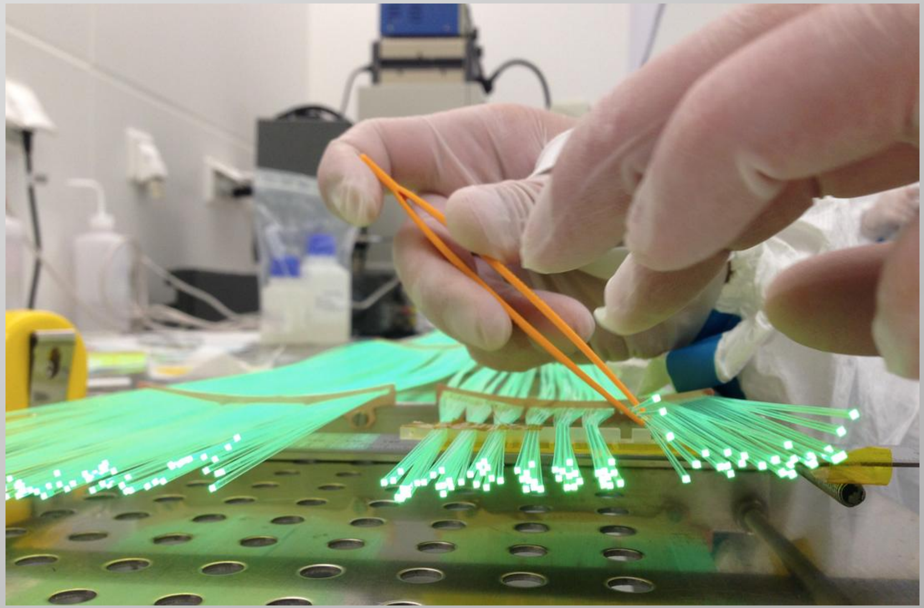


- WLS optical fibers amount increased from 54 to 81 (per module) for better light collection
- Light is collected with 9 SiPMs instead of 6
- Using of synthetic quartz for SiPMs placement instead of the acrylic pieces
- Copper holders with reduced mass produced with high-purity materials



The modules assembling





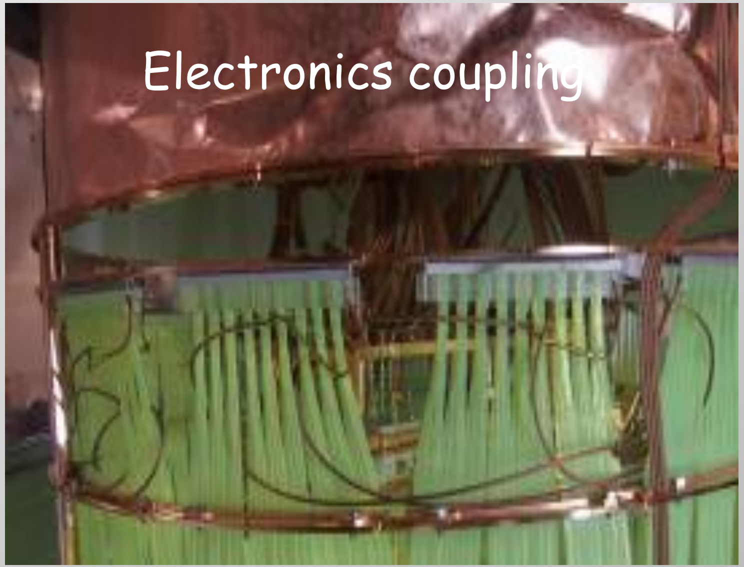
Produced and installed:

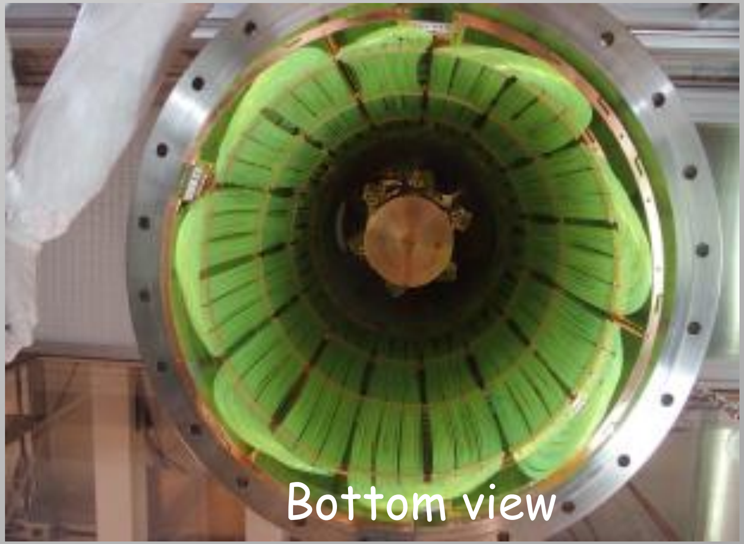
- 9 double modules
- 2 single modules

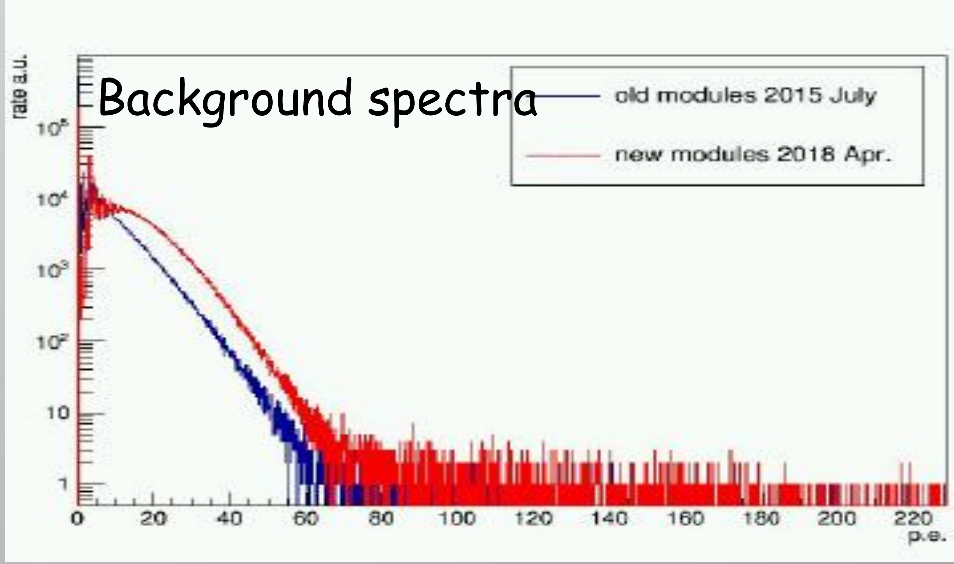
Tests provided:

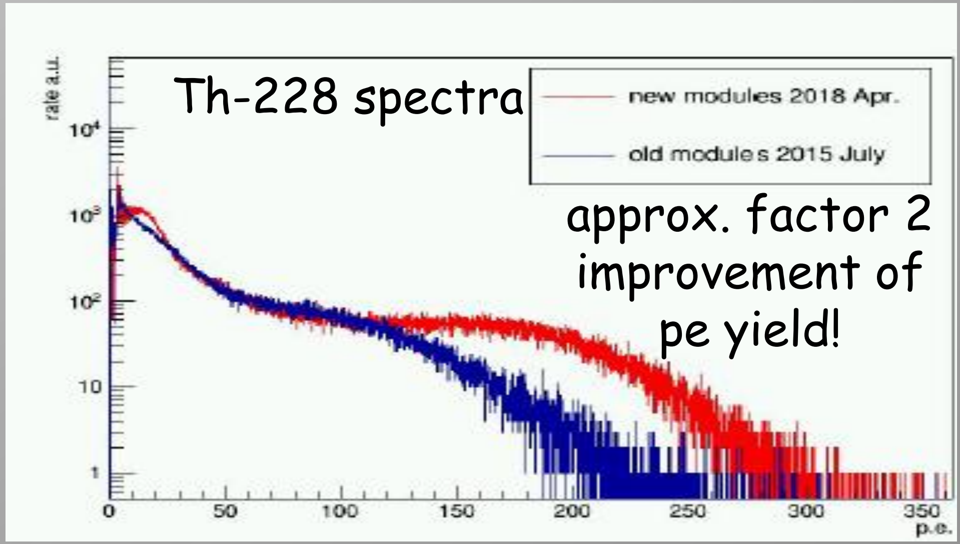
- Etching of quartz pieces and evaporating of aluminum layers
- TPB evaporating at the WLS fibers
- Electrical tests of the SiPM arrays

LAr-veto installation

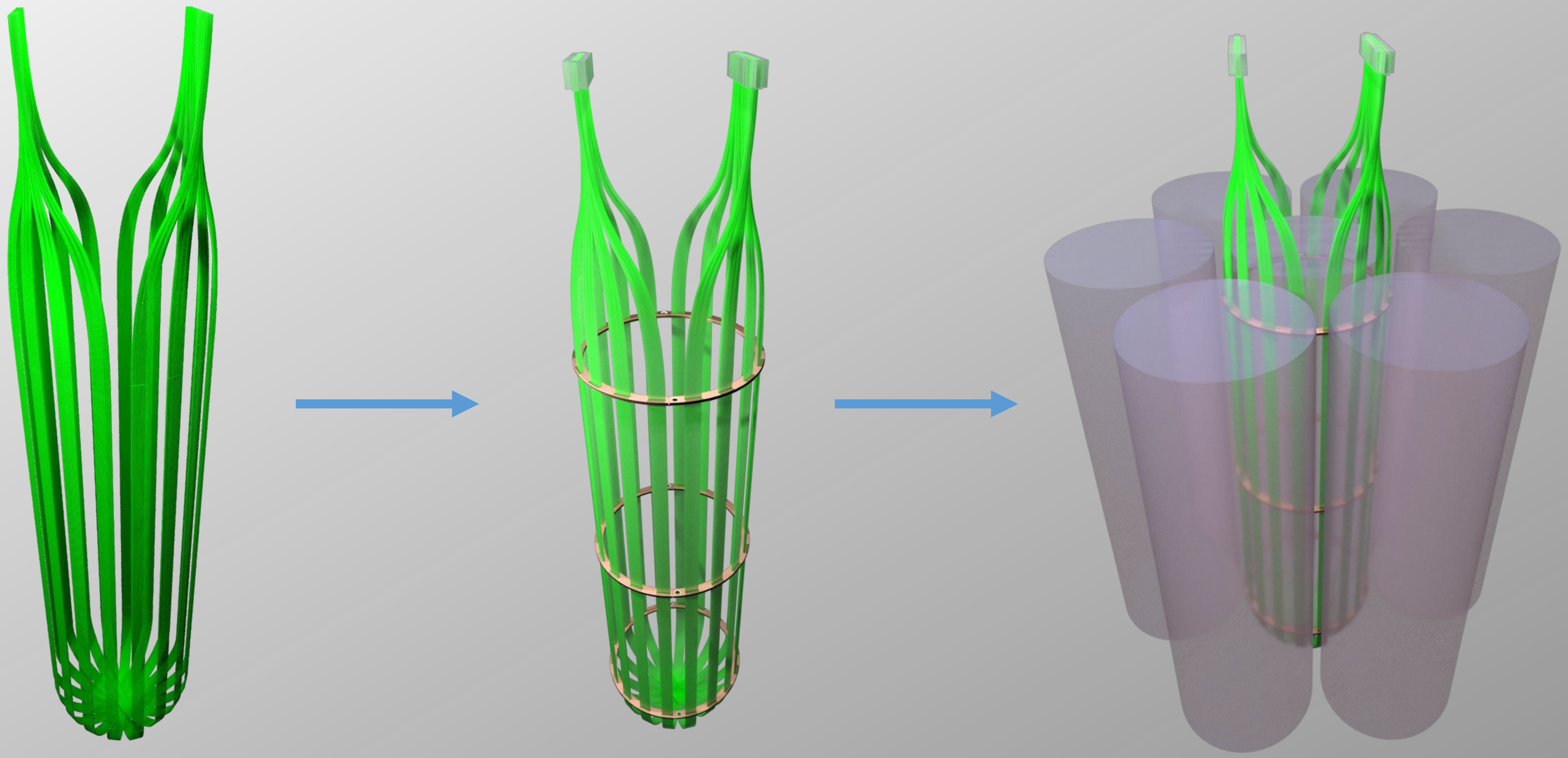








Individual shroud for the central string – first design



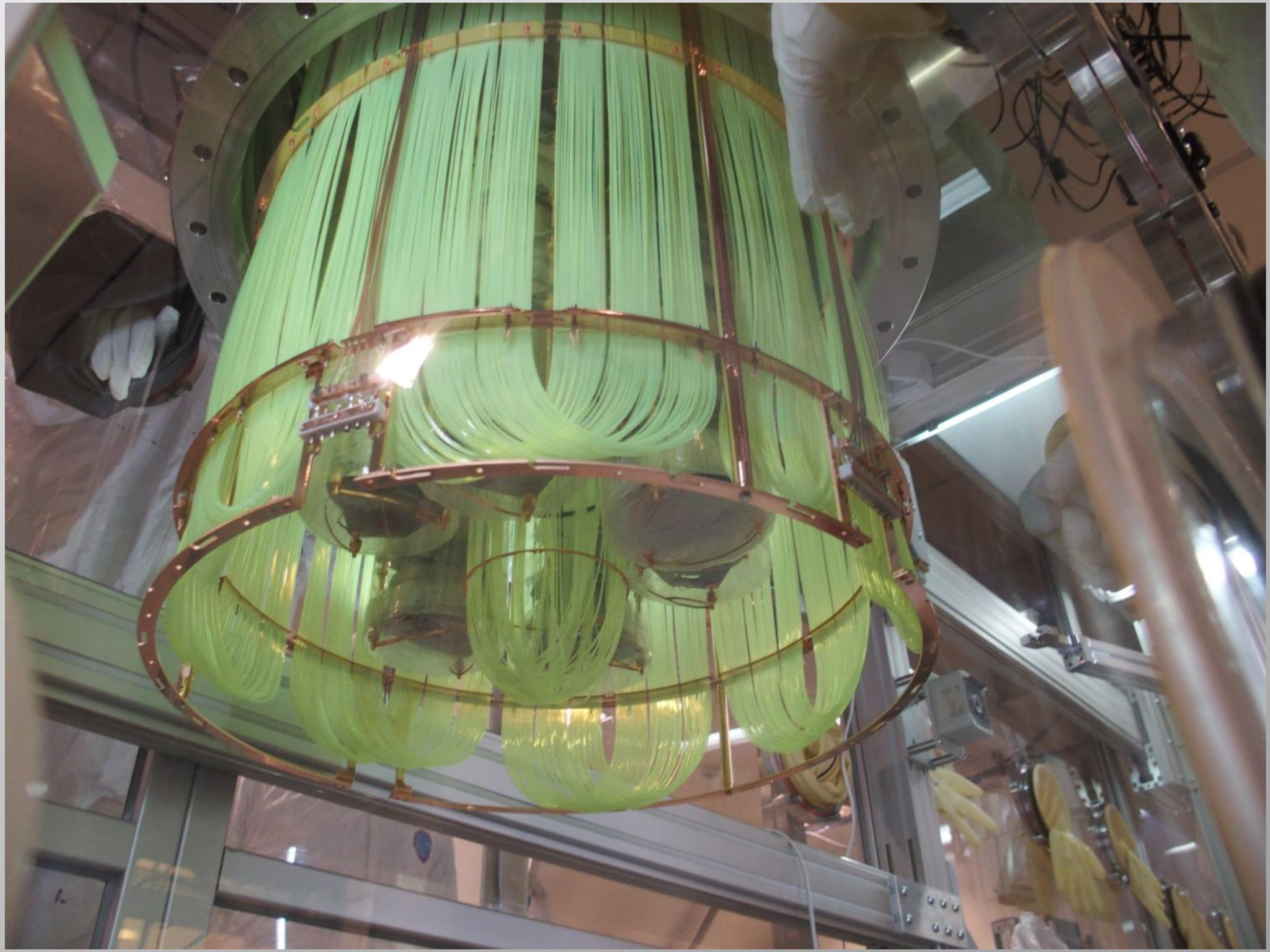
<u>Motivation</u>: Replacement of the PMT’s with high background contamination and increasing of light collection (current light collection less then 1%).

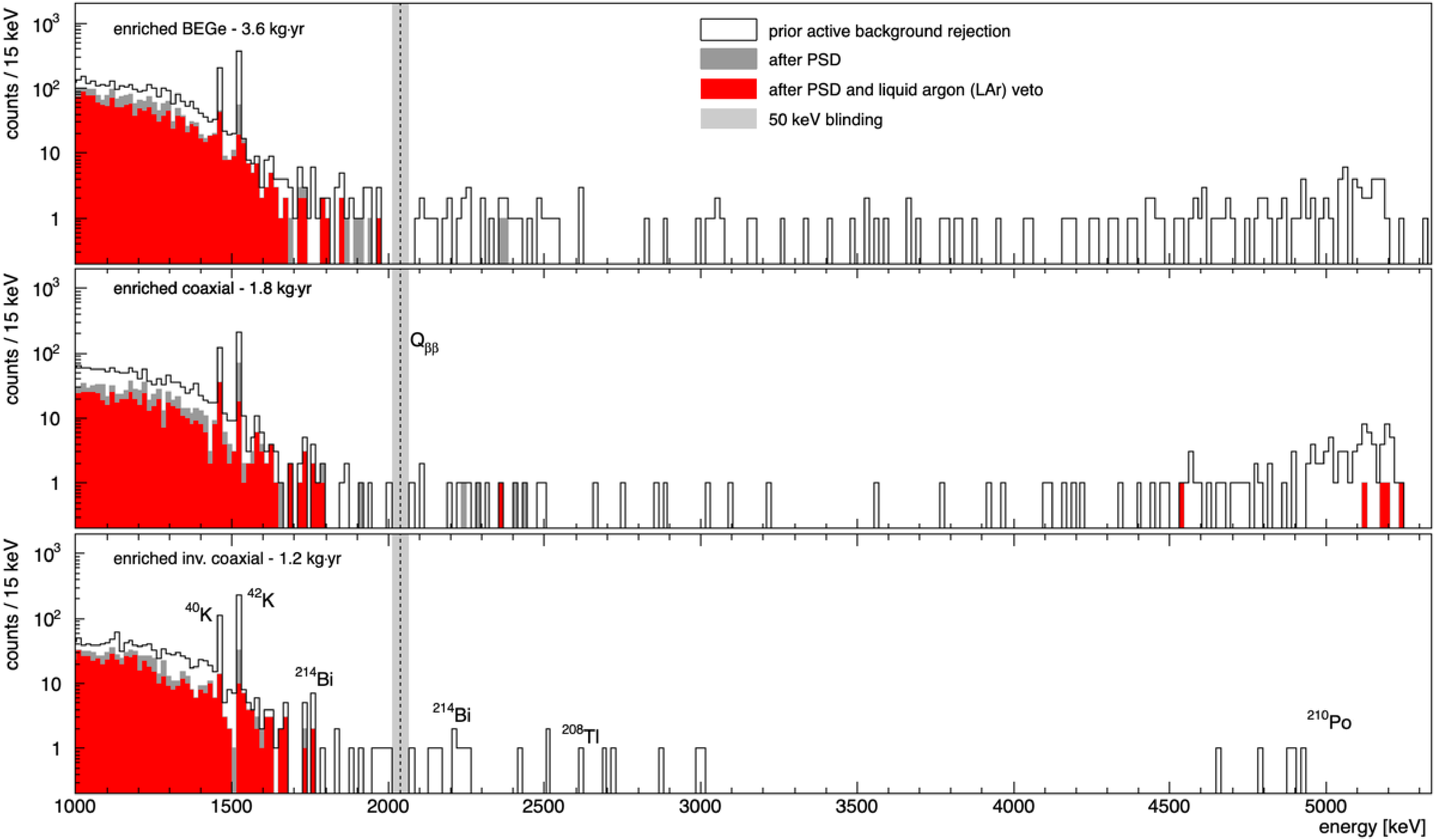
Individual shroud for the central string – final design

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%).

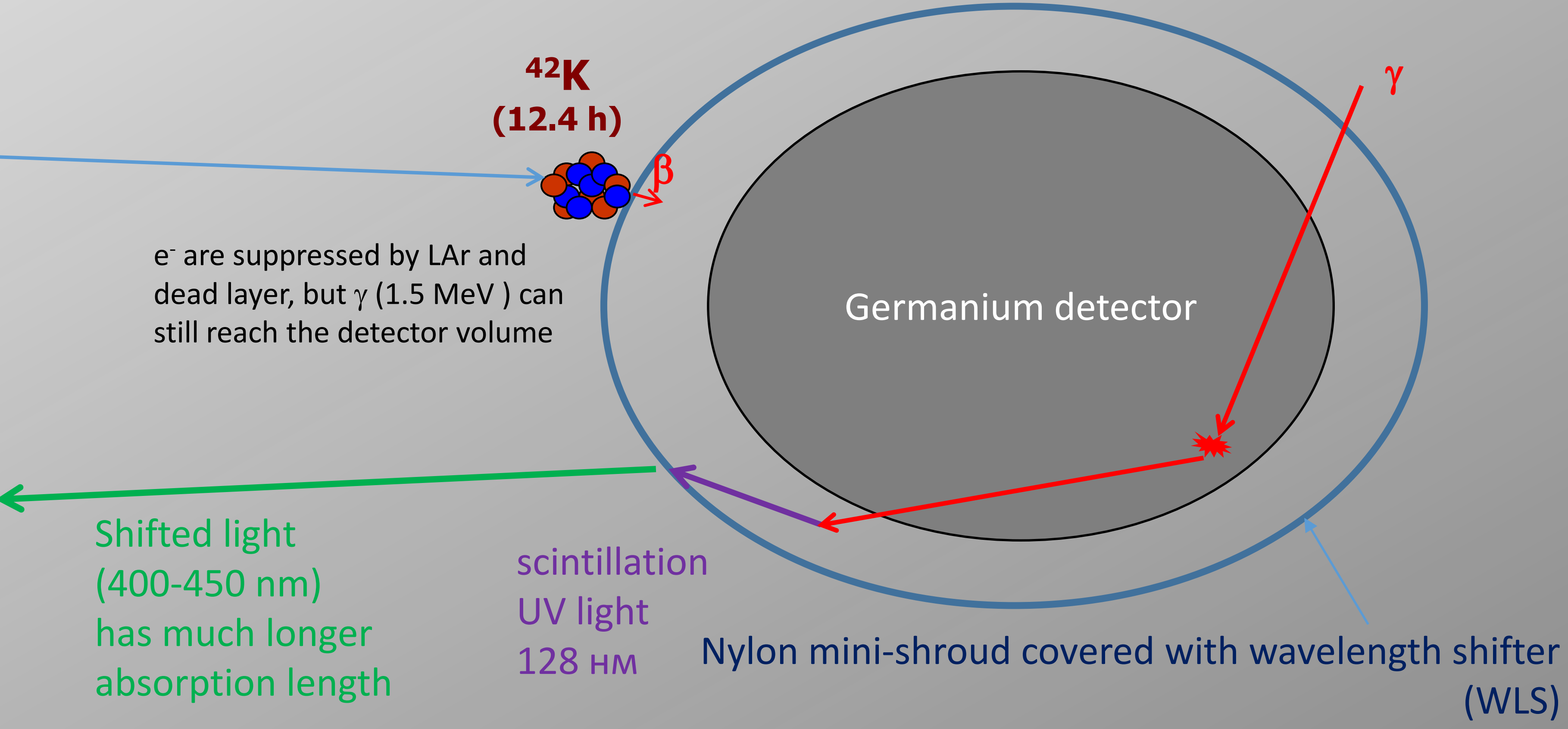
Individual shroud for the central string – installation




enriched BEGe - 3.6 kg·yr
enriched coaxial - 1.8 kg·yr
enriched inv. coaxial - 1.2 kg·yr
prior active background rejection
after PSD
after PSD and liquid argon (LAr) veto
50 keV blinding
counts / 15 keV
energy [keV]
Qββ
40K
42K
214Bi
214Bi
208Tl
210Po

Nylon Mini-Shroud concept

Background from ^{42}Ar can be suppressed with help of the mini-shroud made of ultrapure nylon foil. It creates mechanical barrier which stops the drift of ^{42}K atoms towards the detectors surface → dangerous betas from ^{42}K captured on the mini-shroud surface suppressed by LAr and dead layer of HPGe. But nylon (and most of the plastics) is not transparent for the far UV light → nylon's surface was covered with wavelength shifter (based on TPB).



Nylon mini-shroud

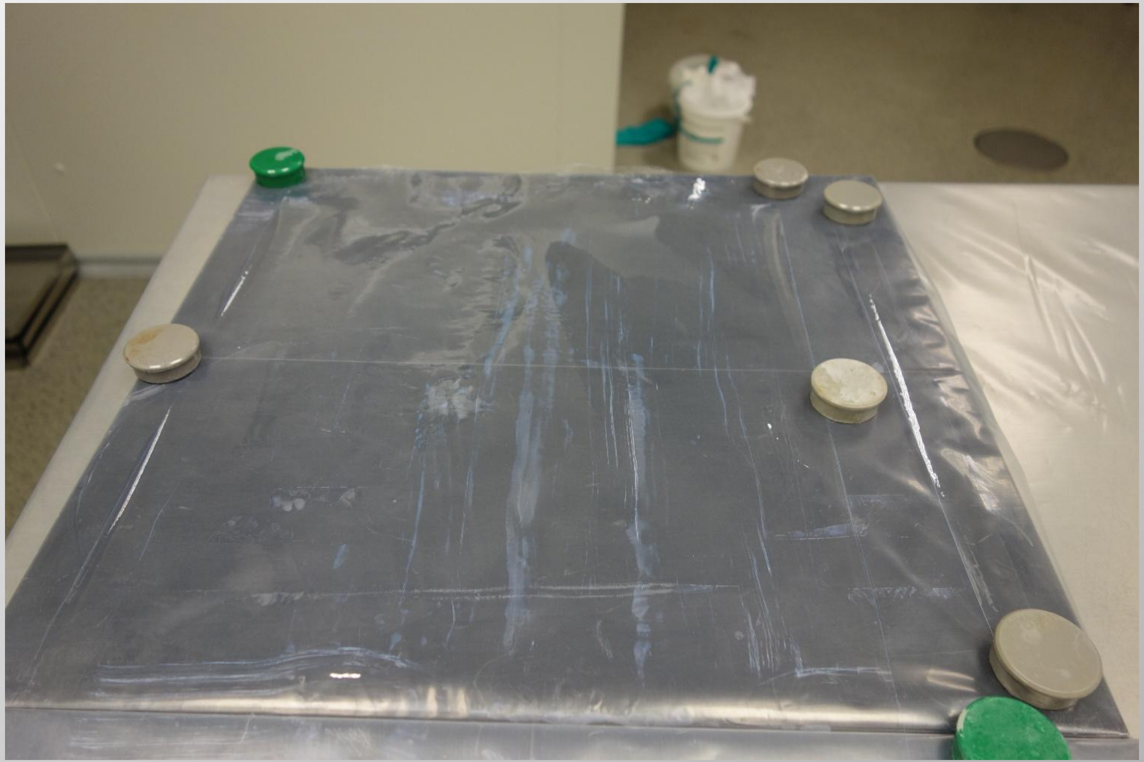
The NMS is made from nylon used for Borexino experiment. Nylon pieces are covered by WLS (based on TPB) and formed to NMS with a glue (Borexino receipt).

- It is made from very clean material
- Low mass design
- Robust and good for handling. Flexible and easy to form.
- Suitable for cryogenic usage.
- Shift and transport light which can be detected by PMTs or SiPM.

Table 5 Radioactive impurities of the components of one nylon mini-shroud (MS) from ICPMS measurements. Uncertainties are estimated to be about 30%

Component	U (ppt)	Th (ppt)	K (ppb)	Mass (g)
TPB	10	9	65	
Polystyrene	< 5	10	100	
Glue	< 10	< 10	900	
Nylon	< 10	< 15	–	27.6
Nylon coated	11	18	< 25	
Nylon glued	38	39	1200	
MS finished	6.1 μBq	2.6 μBq	242 μBq	28.1

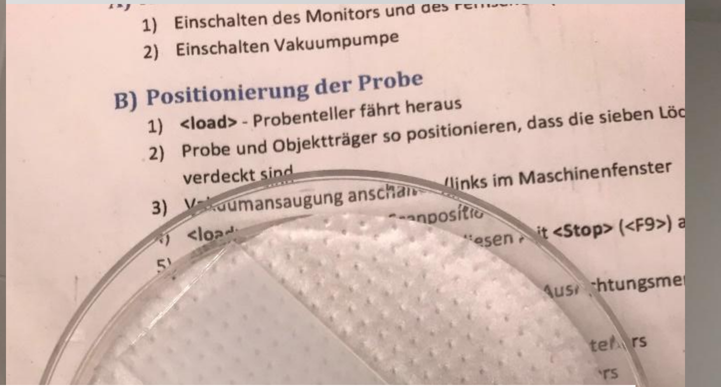
Production of NMS for GERDA

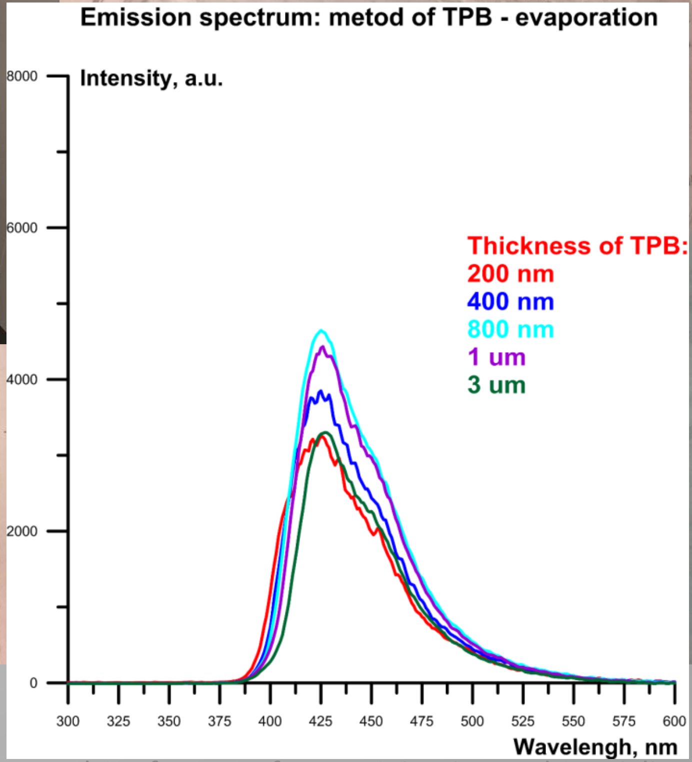


Production of NMS was performed in a clean room in order to minimize possible contamination.

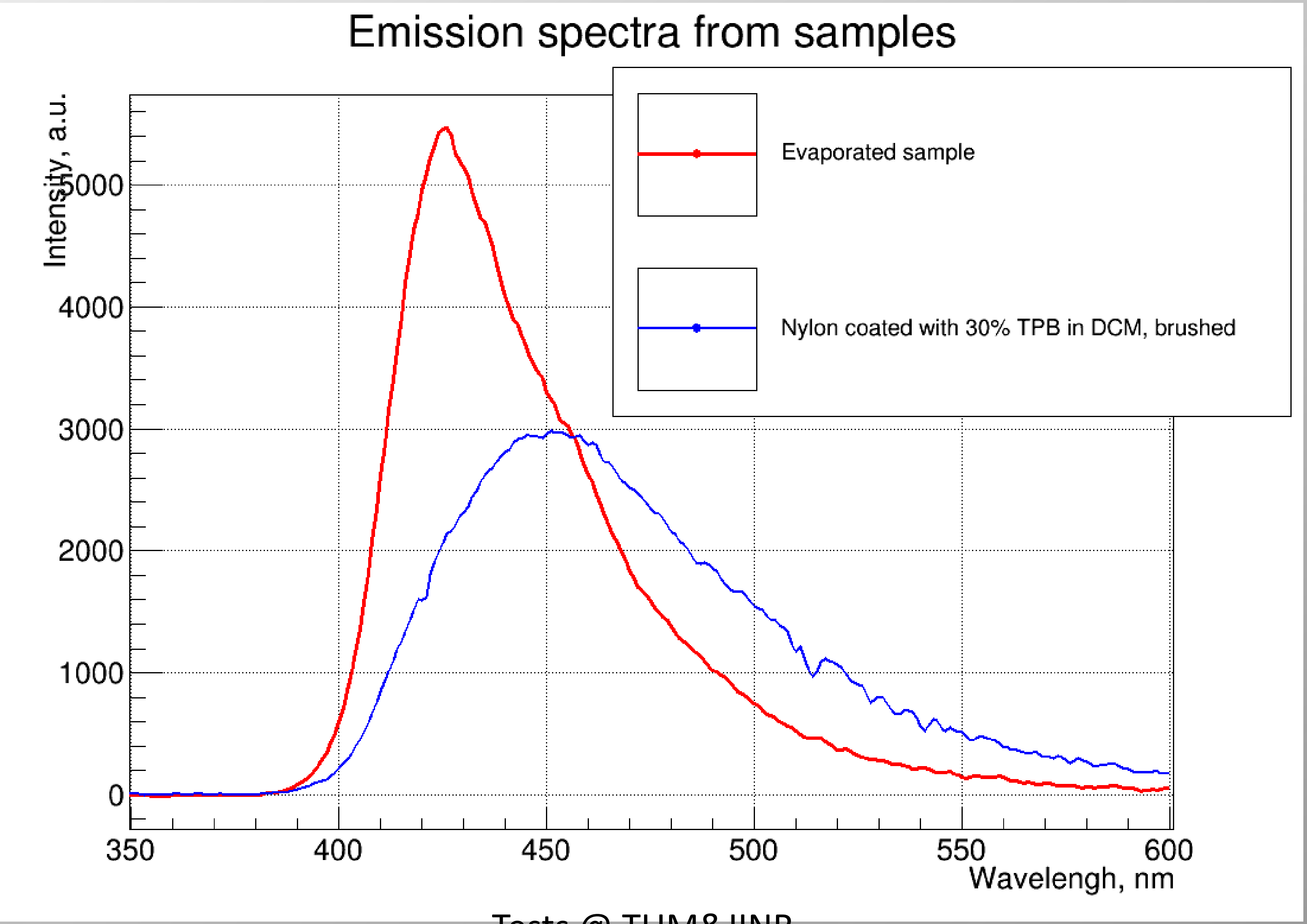
- Surface cleaning and cutting the pieces
- WLS coating (except surfaces for cleaning)
- Gluing and forming of NMS
- Packing and transport to LNGS (has to be done in N_2 atmosphere)

Evaporation of TPB @ TUM





Results



Tests @ TUM&JINR

Thank you for your attention

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
- $T_{1/2} > 0.9\cdot10^{26}$ yr (90% CL)

Bayesian analysis

Best fit → background only
$T_{1/2} > 0.8\cdot10^{26}$ yr (90% CI)