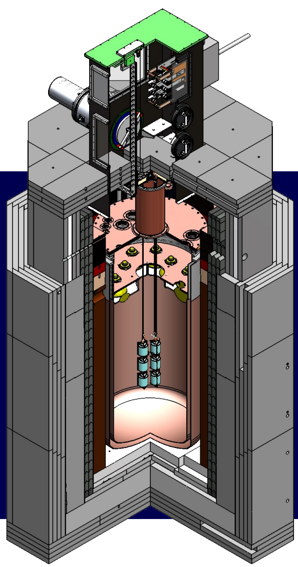
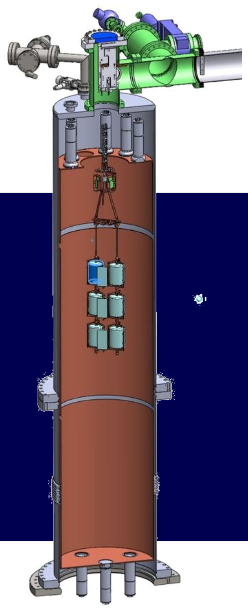
A liquid argon scintillation veto for GERDA and LArGe

Part 1:
Veto concept
& LArGe measurements

Part 2:
light instrumentation
design options in GERDA

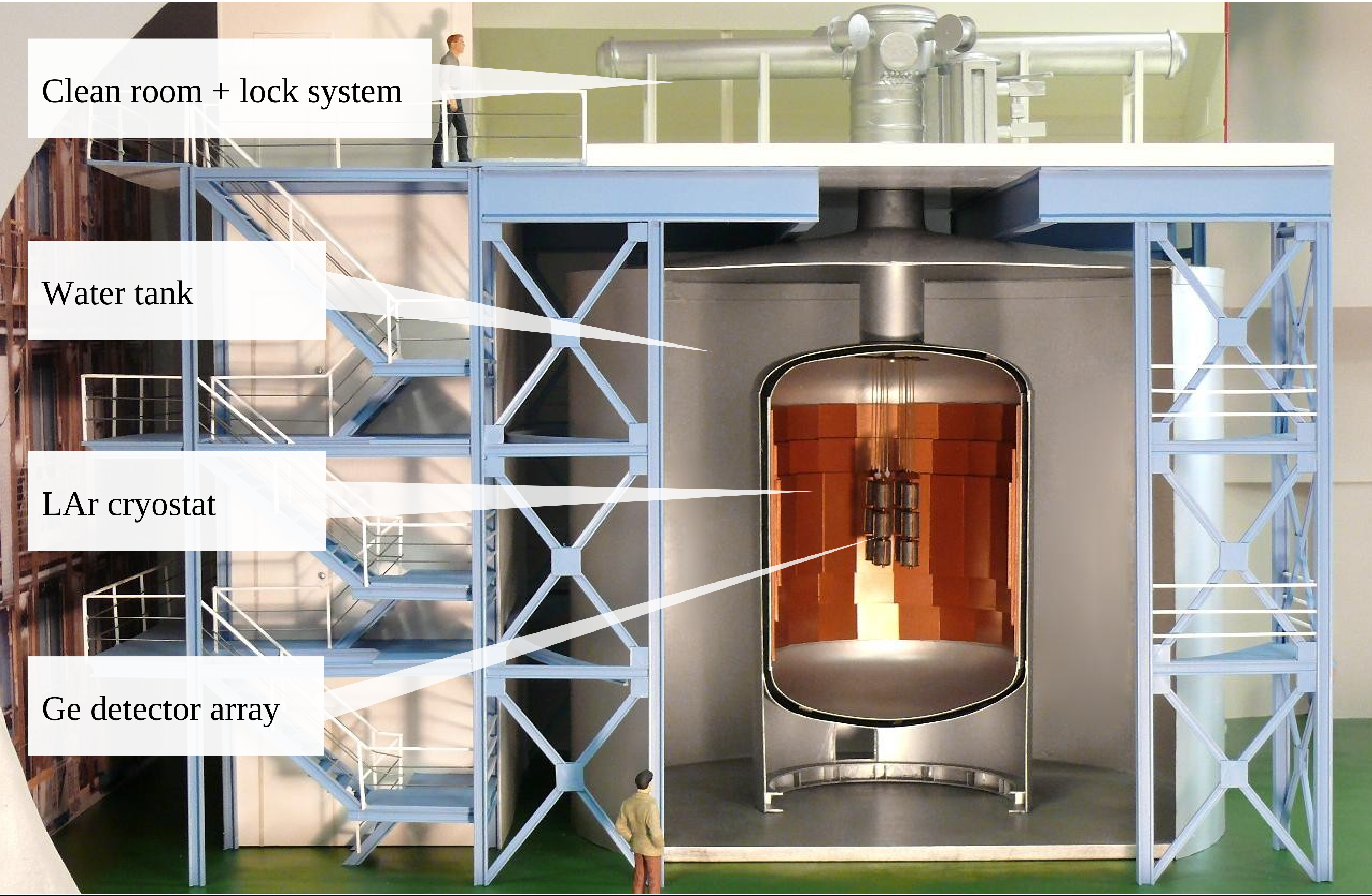




Mark Heisel
for the GERDA Collaboration

DPG Göttingen, 2012

Germanium Detector Array



Germanium Detector Array

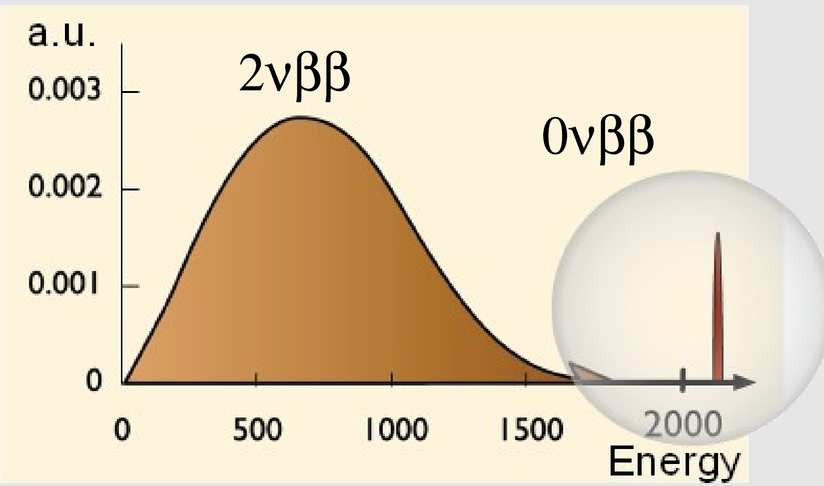
Double beta decay:

$2\nu\beta\beta$: $^{76}Ge \rightarrow {}^{76}Se + 2e^- + 2\nu$

$0\nu\beta\beta$: $^{76}Ge \rightarrow {}^{76}Se + 2e^-$

Detector = Source

ββ-energy spectrum:



fight background here

at $Q_{\beta\beta}$ = 2039 keV

The GERDA background challenge

Background index (BI)

[cts / (keV·kg·y)]

- ► present (Phase I): 1.7×10^{-2}
- ► Phase II: 1.0×10^{-3}

Active background suppression:

- ► water cherenkov muon veto
- ► detector anti-coincidence
- ► pulse shape discrimination (PSD)

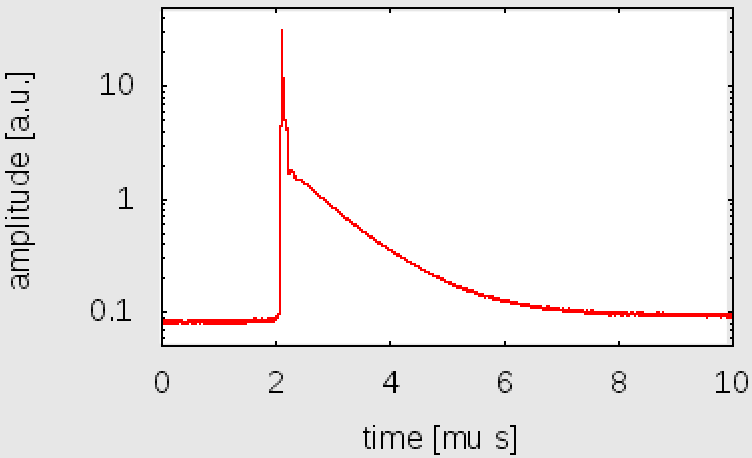
- ► **LAr veto: detect argon scintillation light from background events that deposit energy in the LAr**

Argon scintillation veto concept

Ar scintillation properties:

- 40,000 photons / MeV
- λ = 128 nm (XUV)
- singlet- & triplet component

Average scintillation pulse:



Argon scintillation veto concept

Examples for events in $Q_{\beta\beta}$:

ββ-event → is not vetoed

Argon scintillation veto concept

Examples for events in $Q_{\beta\beta}$:

ββ-event → is not vetoed

surface beta (^{42}K, ^{214}Bi)
→ often not vetoed

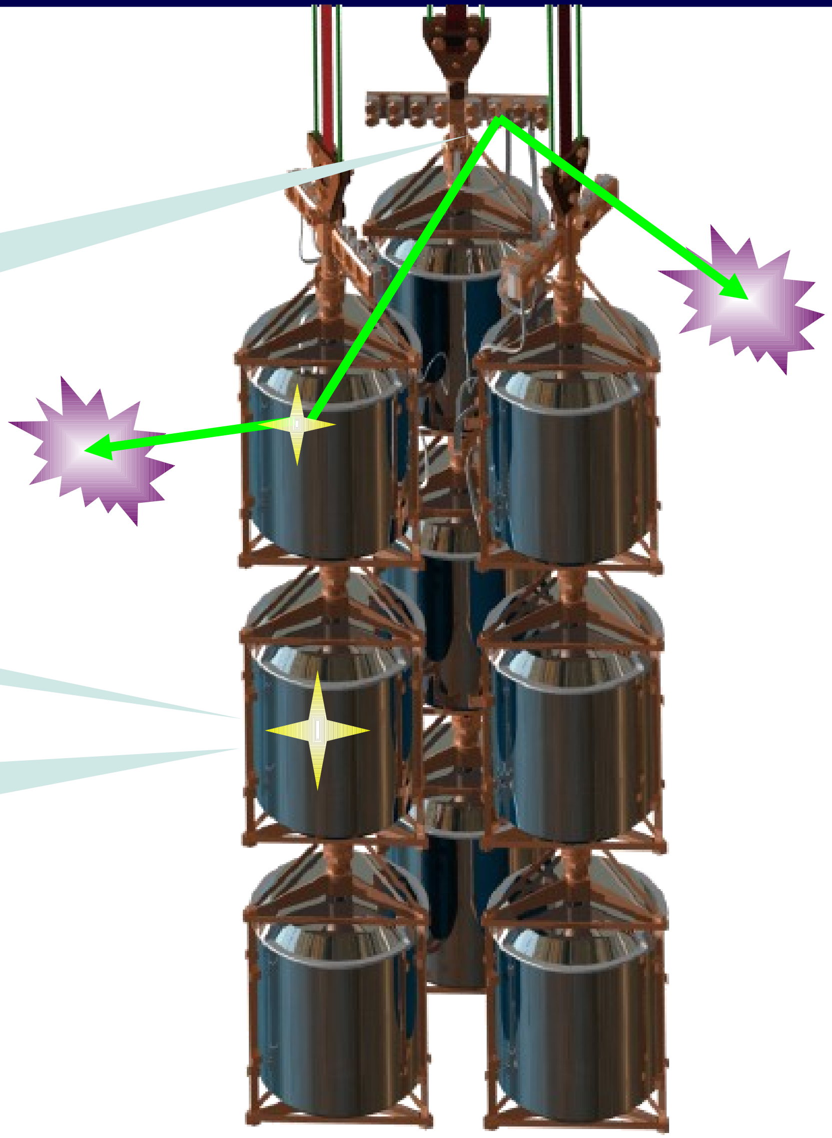
Argon scintillation veto concept

Examples for events in $Q_{\beta\beta}$:

external (^{208}Tl, ^{214}Bi)
→ can be vetoed

ββ-event → is not vetoed

surface beta (^{42}K, ^{214}Bi)
→ often not vetoed



Argon scintillation veto concept

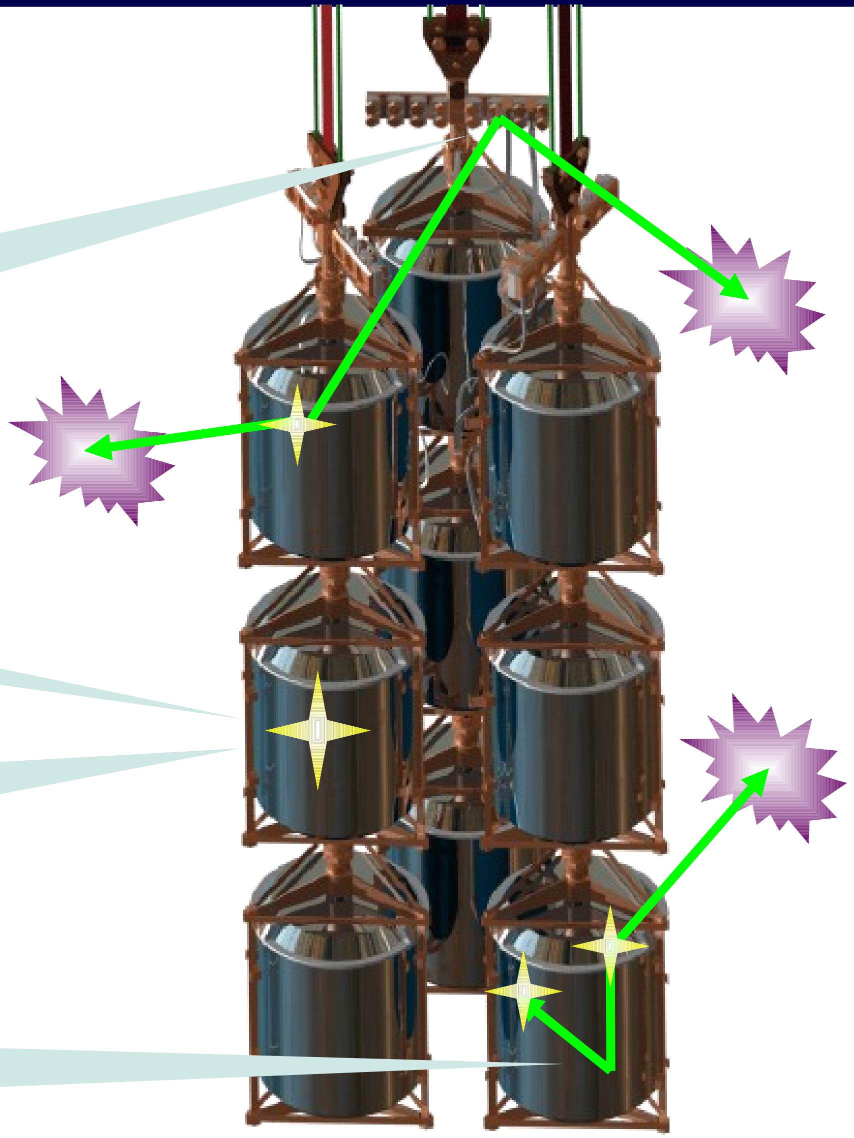
Examples for events in $Q_{\beta\beta}$:

external (^{208}Tl, ^{214}Bi)
→ can be vetoed

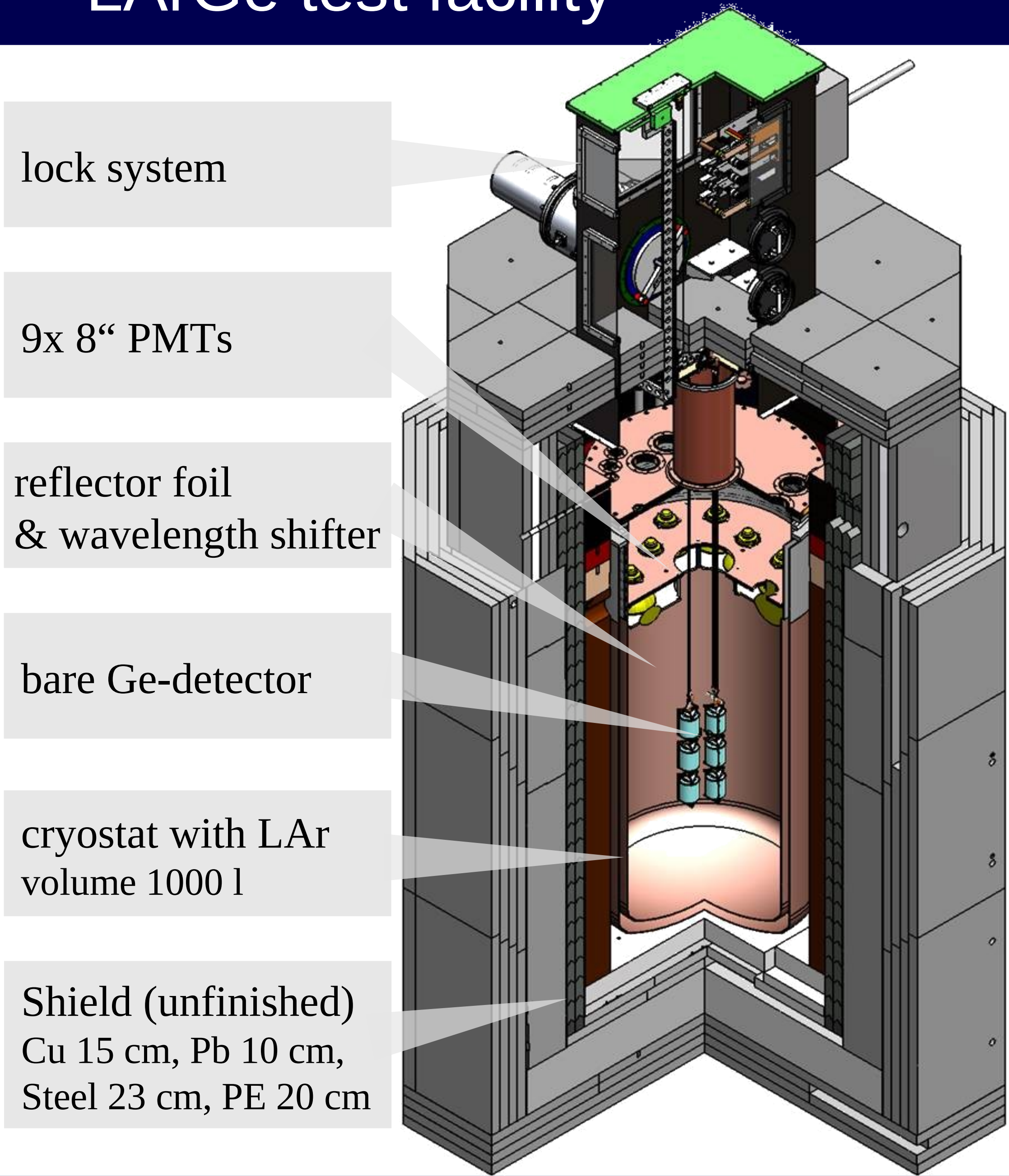
ββ-event → is not vetoed

surface beta (^{42}K, ^{214}Bi)
→ often not vetoed

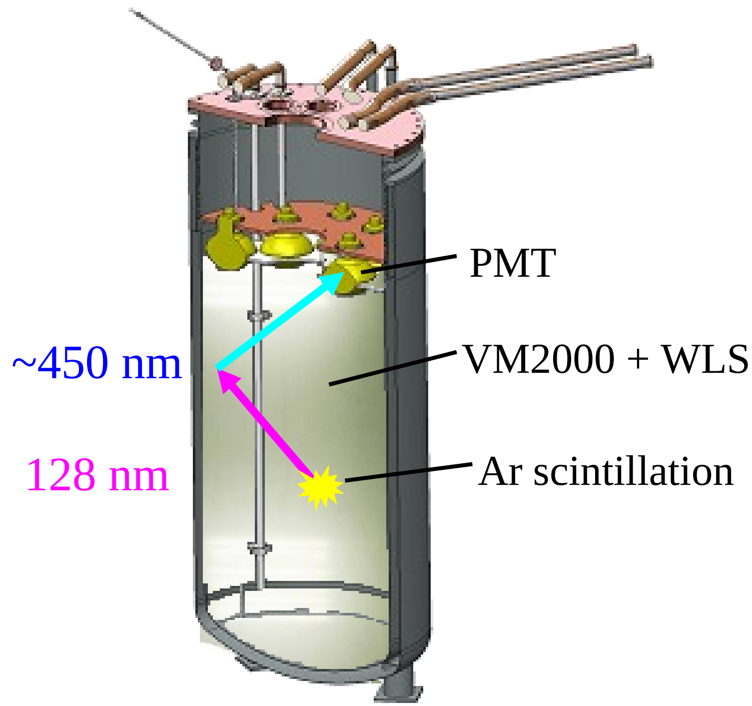
intrinsic cosm. bg (e.g ^{60}Co)
→ can be vetoed



LArGe test facility

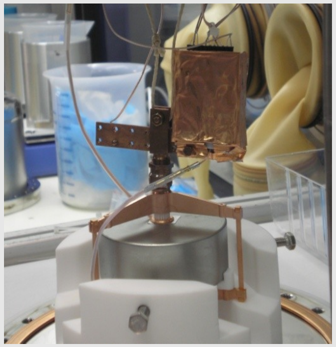


Location:
Germanium detector lab
LNGS @ 3800 m w.e.

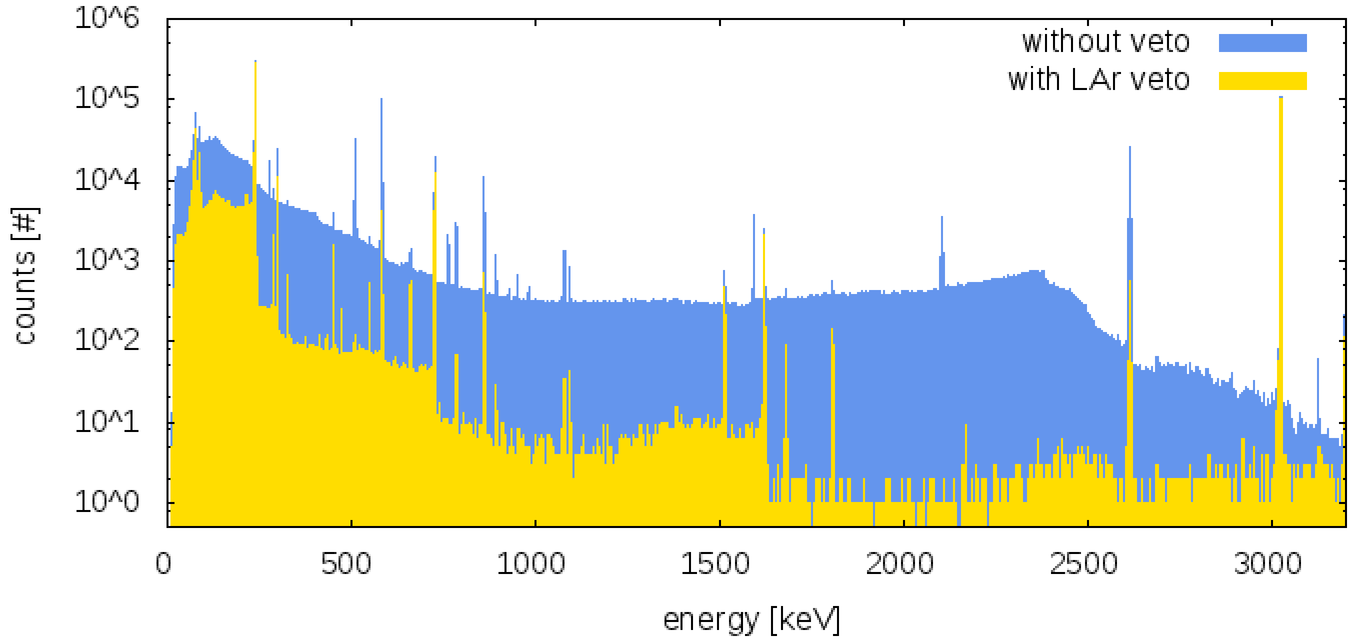


LArGe test facility

- detector: BEGe

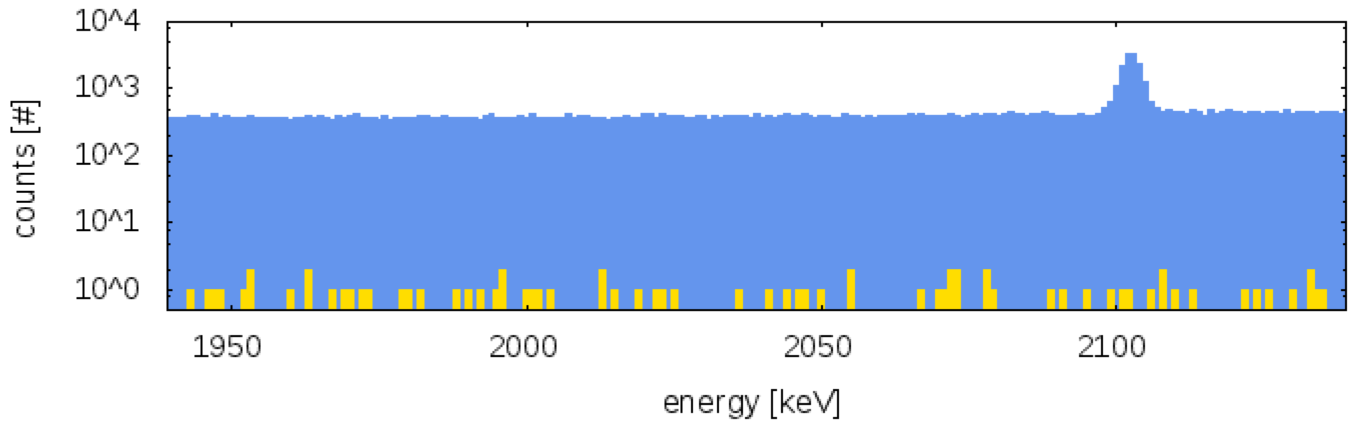


- ^{228}Th source
  distance ~7 cm
- DAQ via FADC



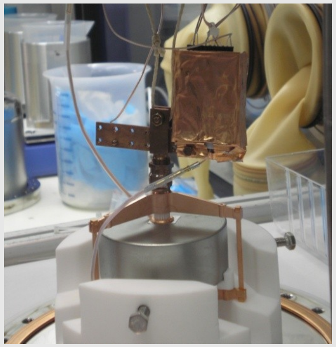
Suppression factor at $Q_{\beta\beta}$ ± 35 keV:

LAr veto ~1200



LArGe – suppression of internal ^{228}Th

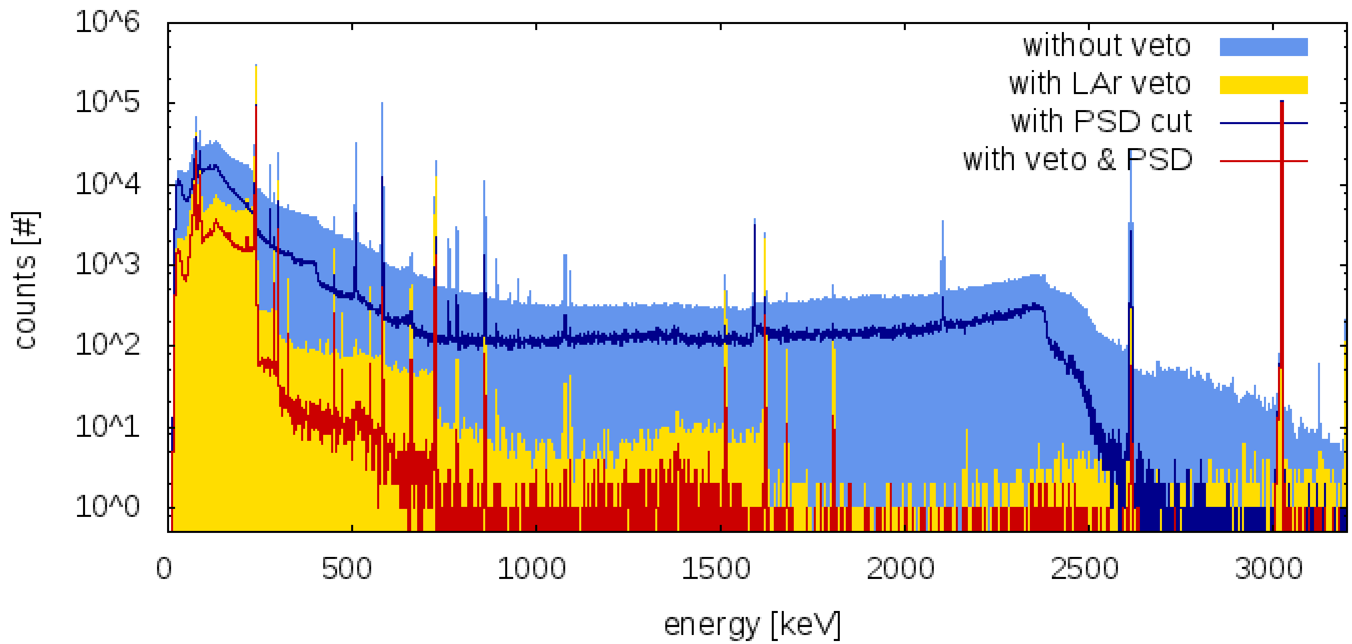
- detector: BEGe

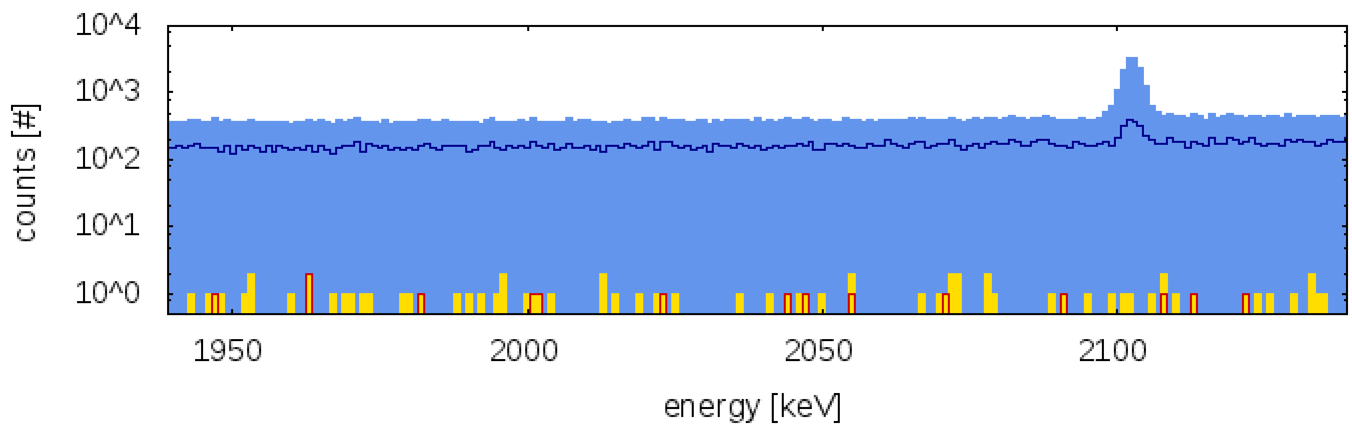


- ^{228}Th source
  distance ~7 cm
- DAQ via FADC

Suppression factors at $Q_{\beta\beta}$ ± 35 keV:

LAr veto	~1200
PSD	~2.4
veto+PSD	~5200





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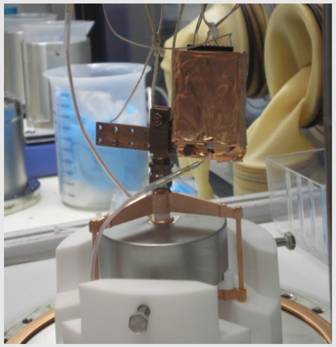

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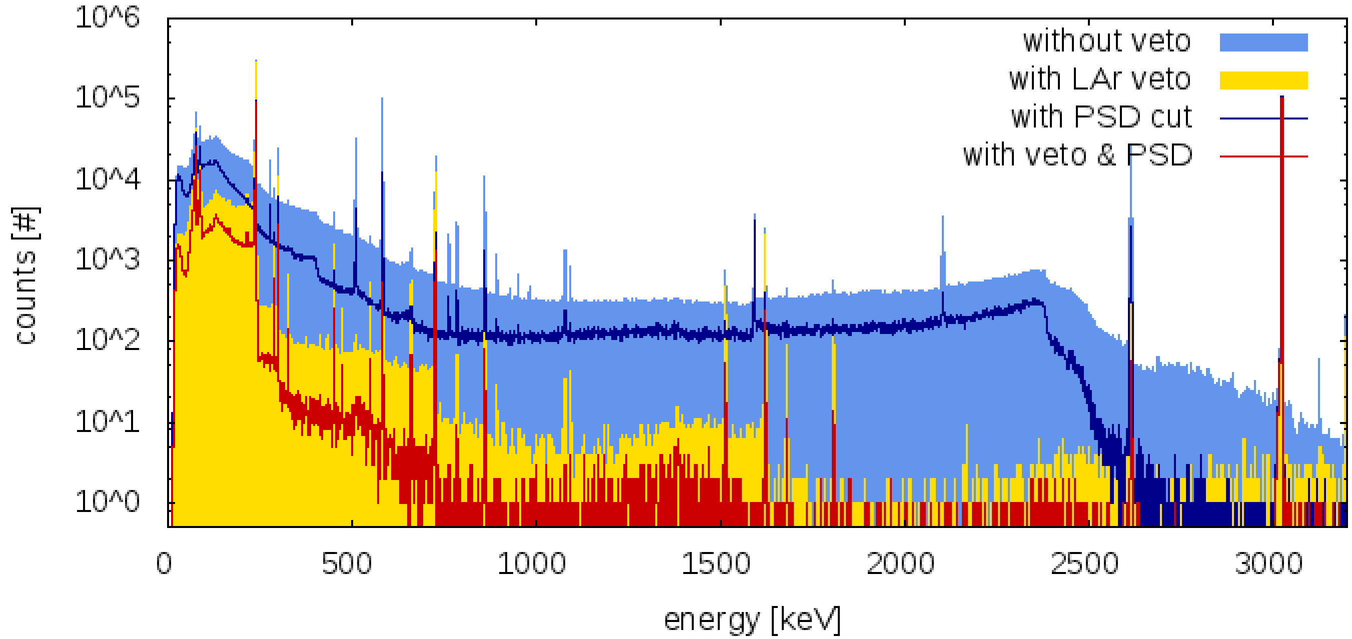
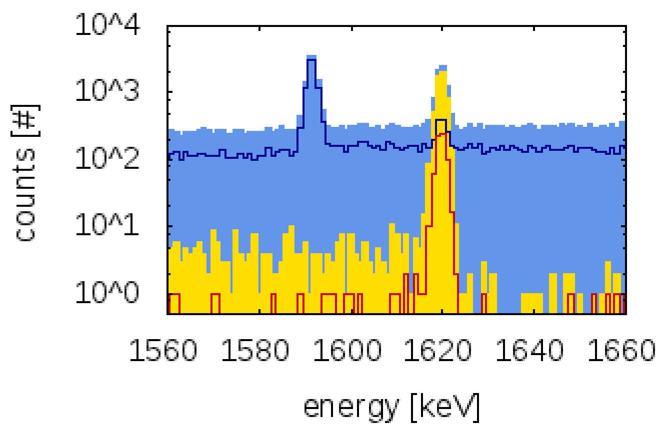
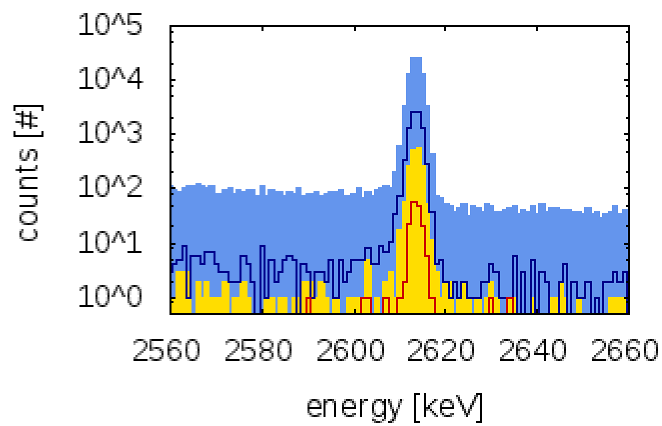




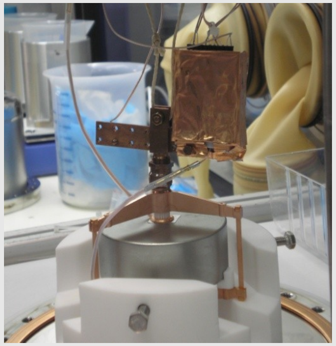


<u>Left:</u>
DEP (^{208}Tl)
& 1621 keV (^{212}Bi)

<u>Right:</u>
2615 keV (^{208}Tl)

LArGe – suppression of internal ^{226}Ra

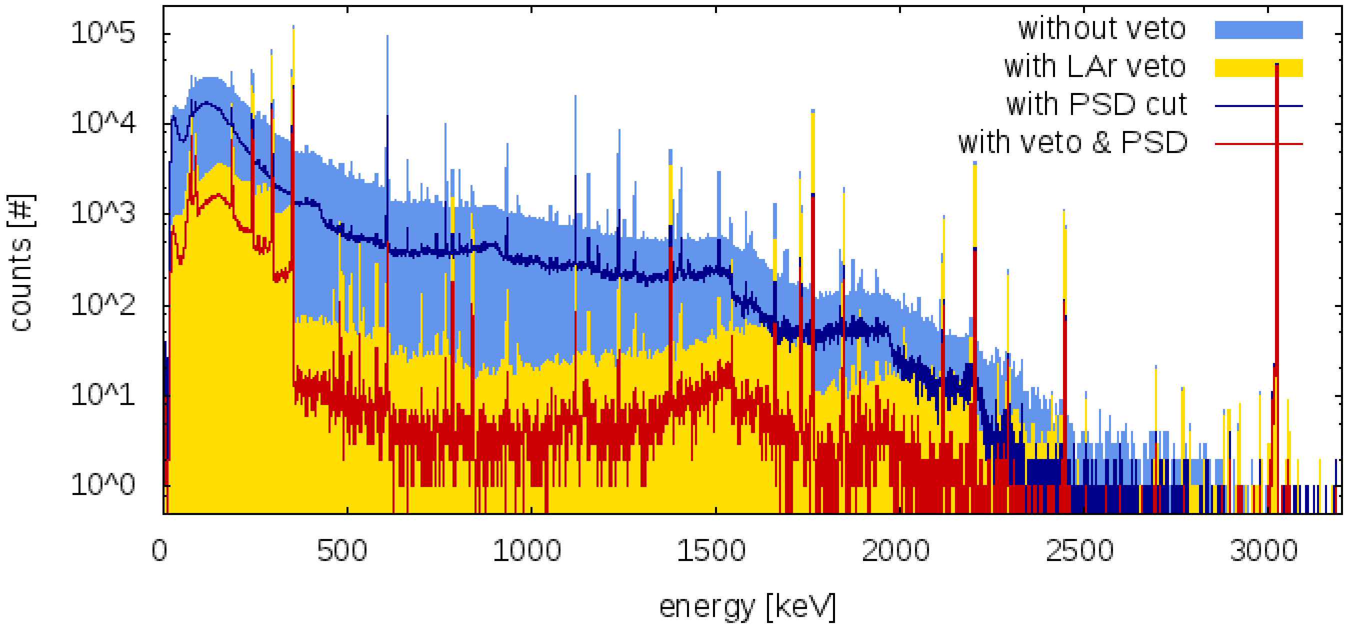
- detector: BEGe

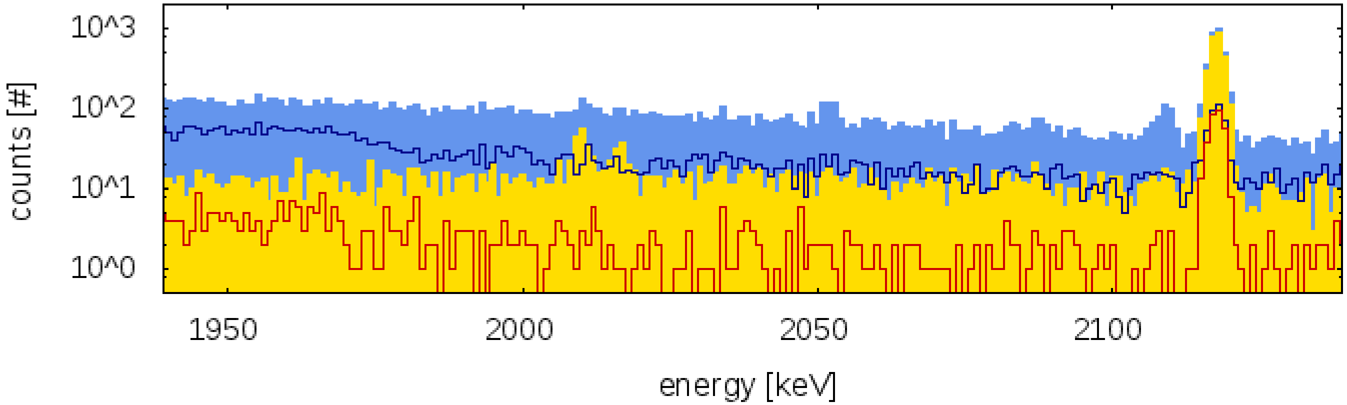


- ^{226}Ra source
  distance ~7 cm
- DAQ via FADC

Suppression factors at $Q_{\beta\beta}$ ± 35 keV:

LAr veto	~4.6
PSD	~4.1
veto+PSD	~45





LArGe – summary of suppression factors

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

Acceptance for ββ-events:

LAr veto >97%

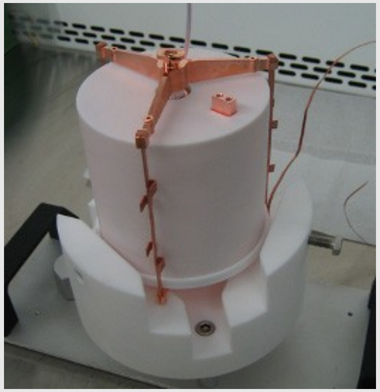
PSD 90%

Combined suppression:

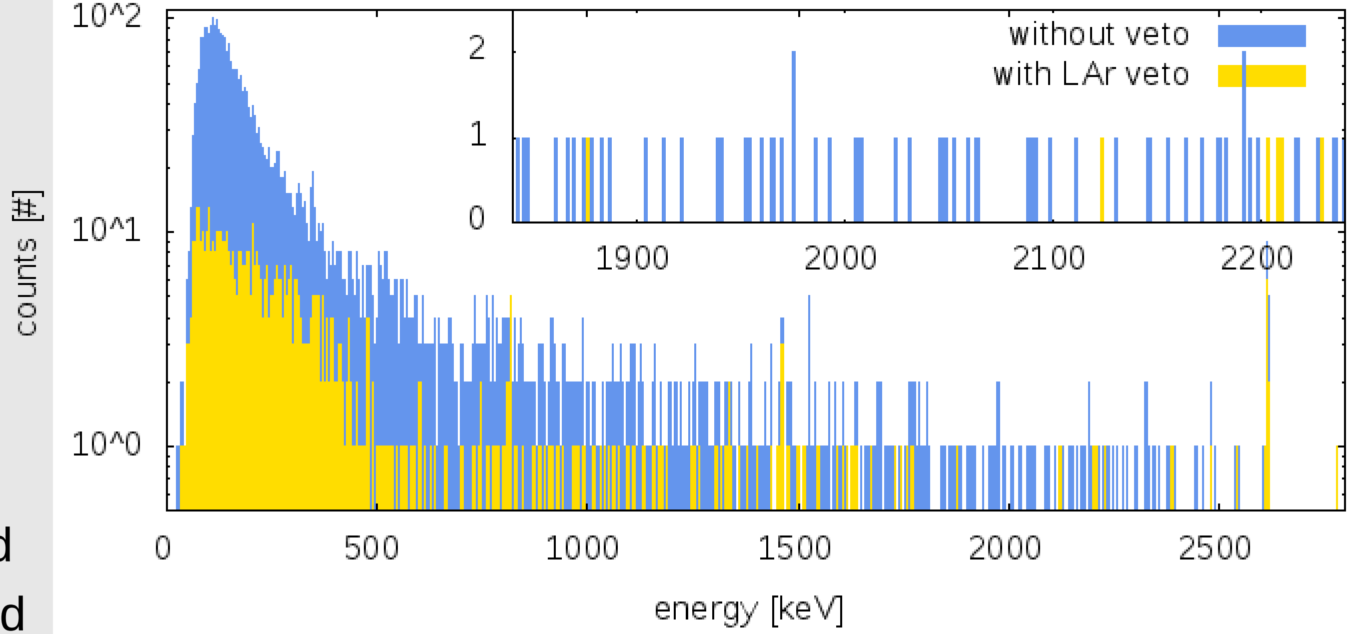
$$SF_{total} \sim 1.8 \times (SF_{LAr} \times SF_{PSD})$$

LArGe – background spectrum

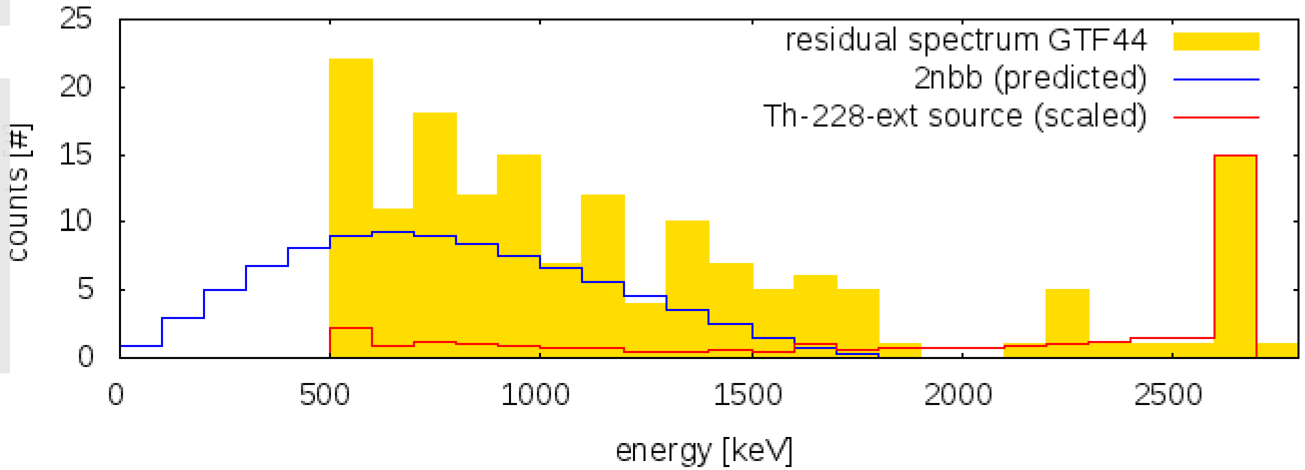
- detector: GTF44 (not-enriched Ge)



- exposure: 116 kg·d
- shielding unfinished



- background index at $Q_{\beta\beta}$ ± 150 keV:
  0.12 – 4.6 · 10^{-2} cts / (keV·kg·y)

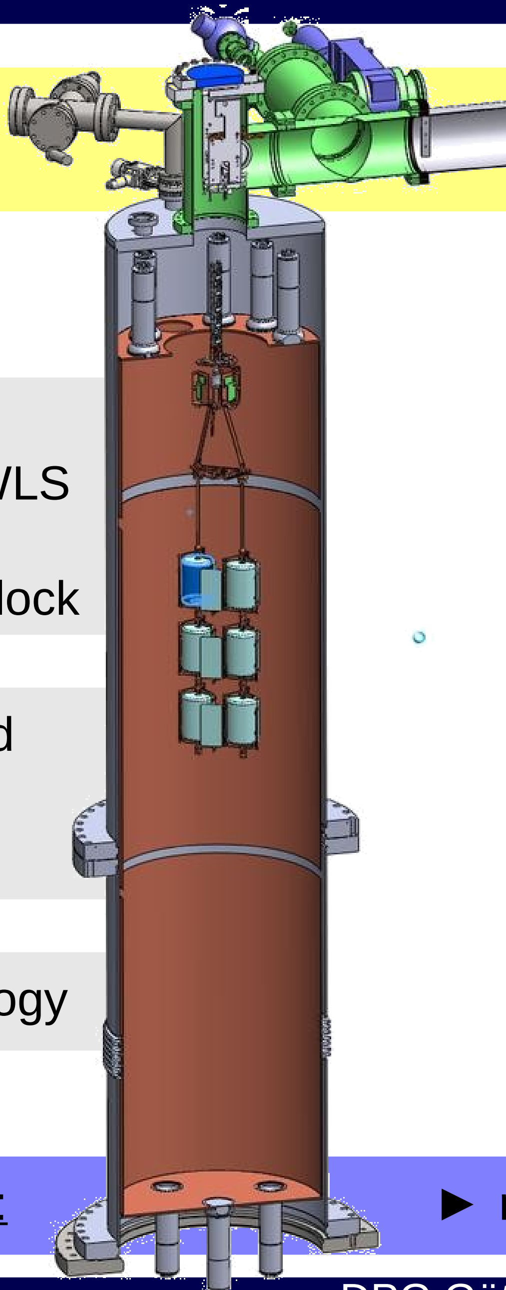


<u>Part 2:</u>

light instrumentation
design options for GERDA

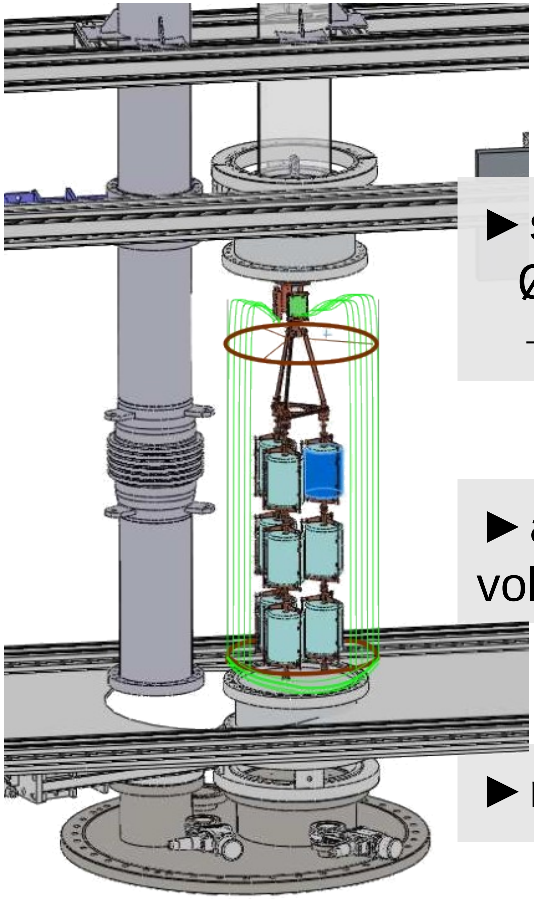
PMT option vs. scintillation fibres

baseline design using PMTs



- copper shroud reflector foil + WLS Ø = 500 mm → wait for new lock
- low-background PMTs from top & bottom
- proven technology

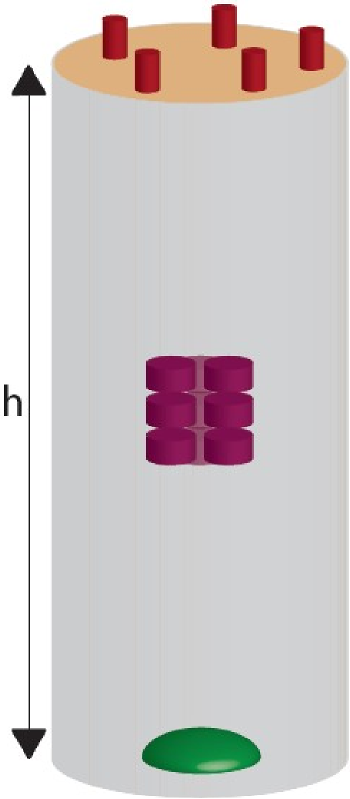
scintillating fibres with SiPM readout



- scint. fibres Ø = 250 mm → fits present lock
- active LAr volume not confined
- more R&D

<u>common features:</u> ► no LAr drainage needed ► exchangeable

PMT option: hardware



h = 210 cm

Ø = 50 cm

talk by A. Wegmann T113.7

low-background PMTs available:

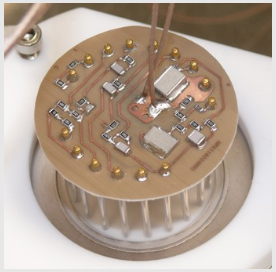
▸ QE ~25%

▸ LAr teststand at MPIK

	R5912-02 MOD (8-inch)	R11065-10 MOD (3-inch)
activity ^{228}Th:	165 mBq/PMT	1.0 mBq/PMT
^{238}U:	374 mBq/PMT	<0.94 mBq/PMT

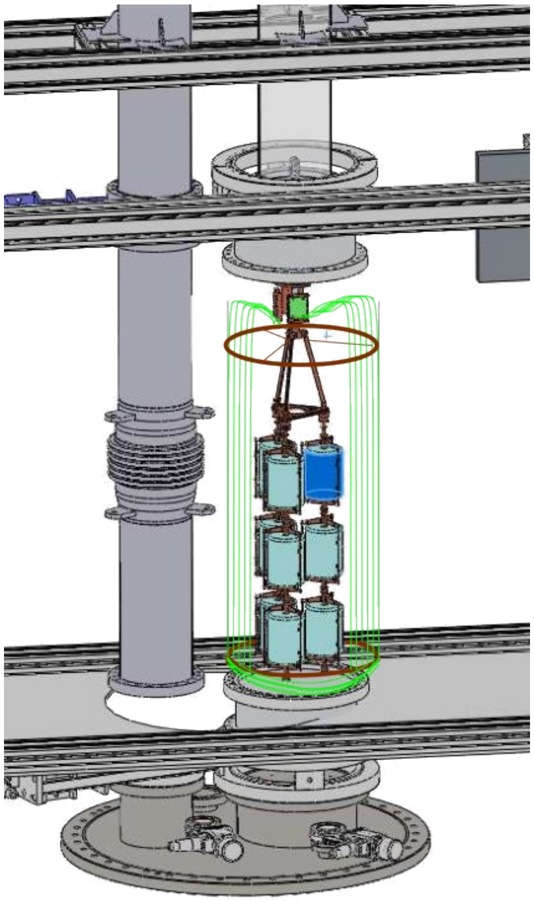
voltage dividers

→ low-bg CuFlon-based

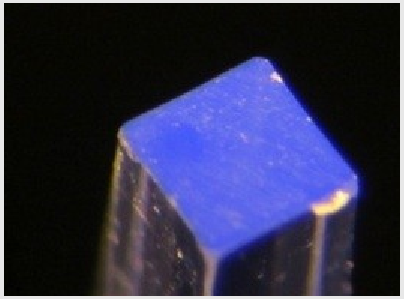


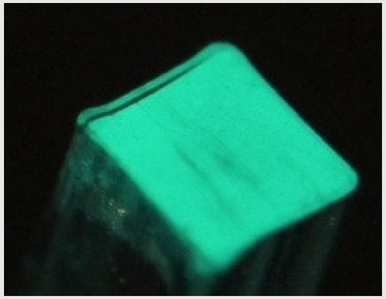
VM2000 reflector foil + wavelength shifter (TPB)

Fibre design – hardware (1)



2 fibre types investigated



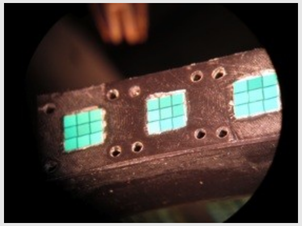


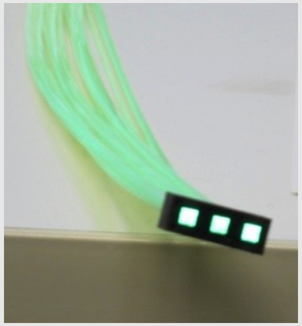
BCF-10 blue scintillator no cladding	BCF-91A green + WLS multiclad

- radiopurity

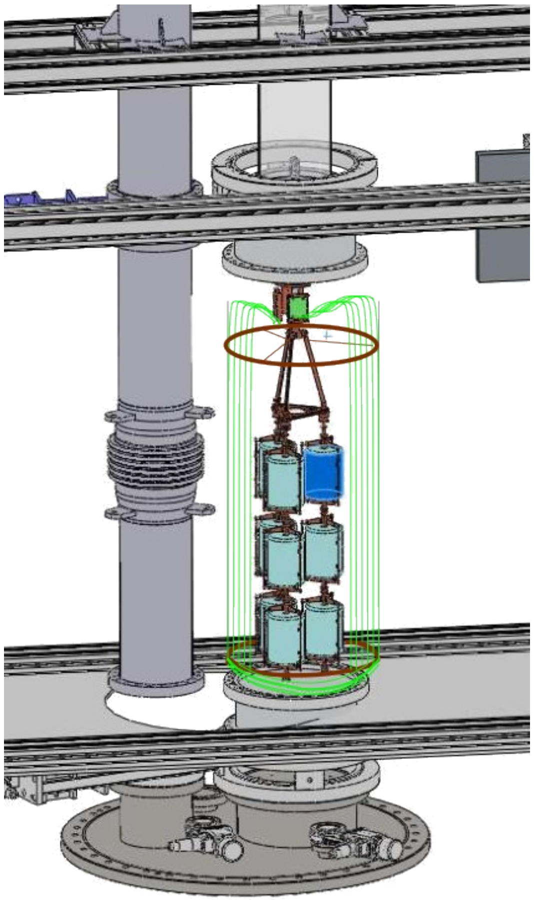
γ-screening:	^{228}Th,^{226}Ra	<16 mBq/kg	(BCF-91A)
ICPMS:	Th, U	<0.06 mBq/kg	(both types)

- coupling: 9 fibres on 1 SiPM
- read-out both ends
- <u>total:</u>
  10 strips á 27 fibres





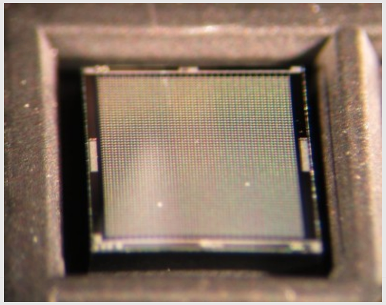
Fibre design – hardware (2)

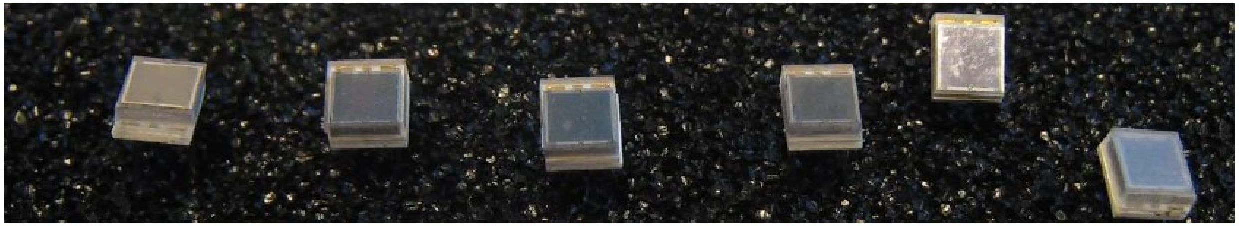


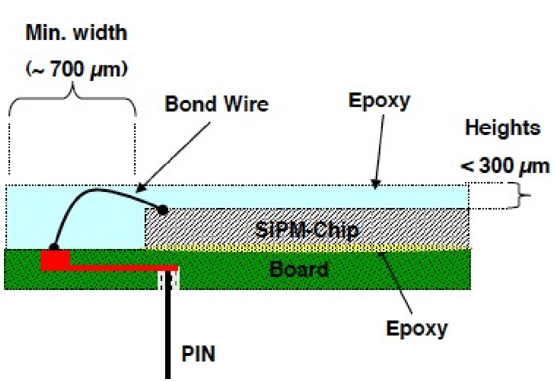
KETEK SiPMs

- ► sensitive surface 3x3 mm²
- ► 100 pieces available (~60 needed)
- ► summing ampl. in developm.: 30 SiPM → 1 channel

low-bg holder







Size 3.9 mm x 4.4 mm x 2.0 mm
(Active chip area: 3 mm x 3 mm)

Suppression factors & BI (preliminary!)

- ▶ Monte Carlo for cylindrical active LAr volume ø = 600 mm

isotope	location	suppression factor	
		100 keV	10 keV
^{208}Tl	detector holders	254	354
^{214}Bi	detector holders	3.5	4.4
	detector surface	13.8	20.1
^{42}K	homogeneously in LAr	6.0	54.8
	detector surface	1.3	1.4
^{60}Co	homogeneously in Ge	57	68
^{210}Po	detector surface	2.1	2.2

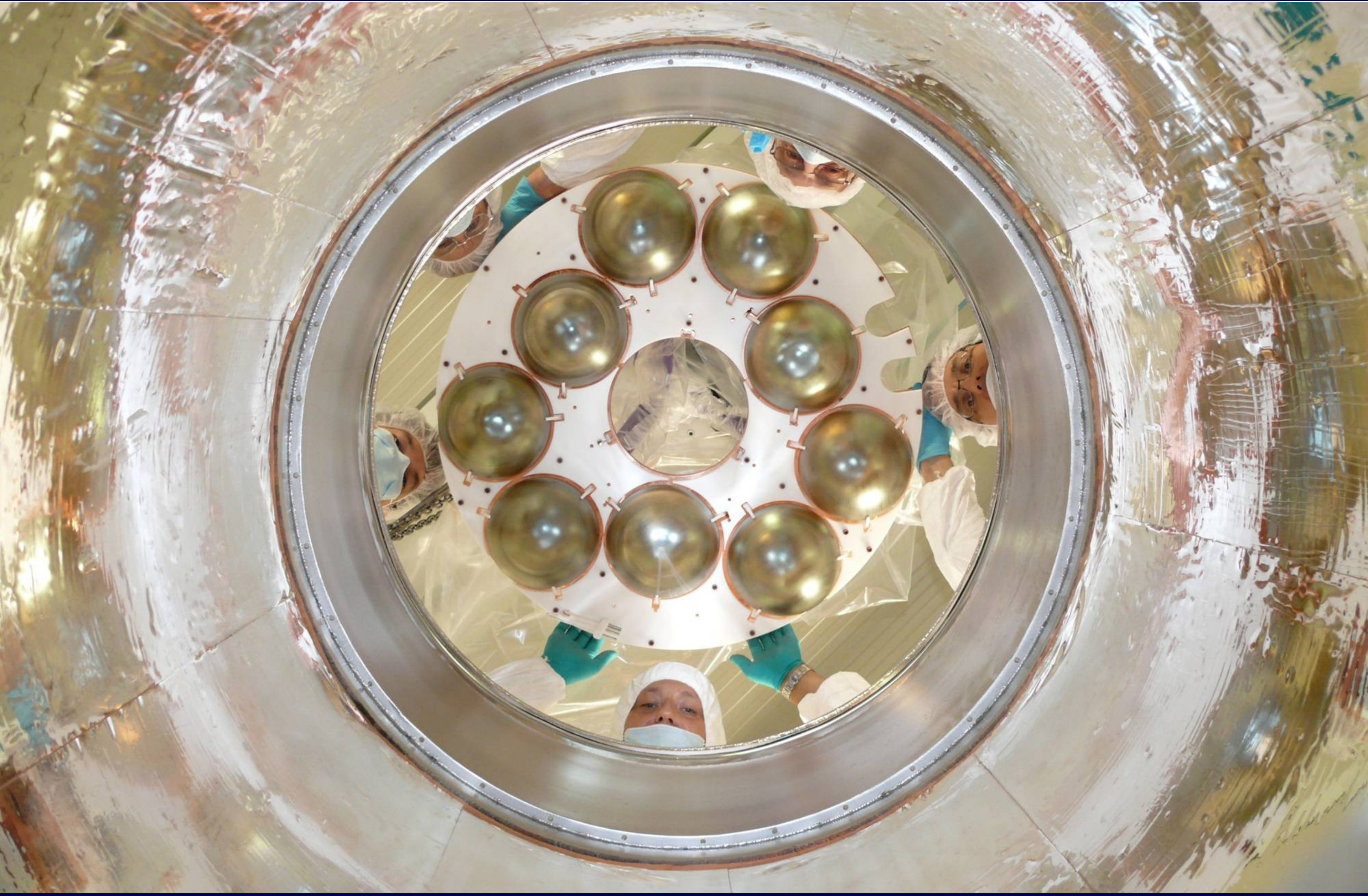
→ talk by N. Barros T109.5

- ▶ Instrumentation induced background index (preliminary)

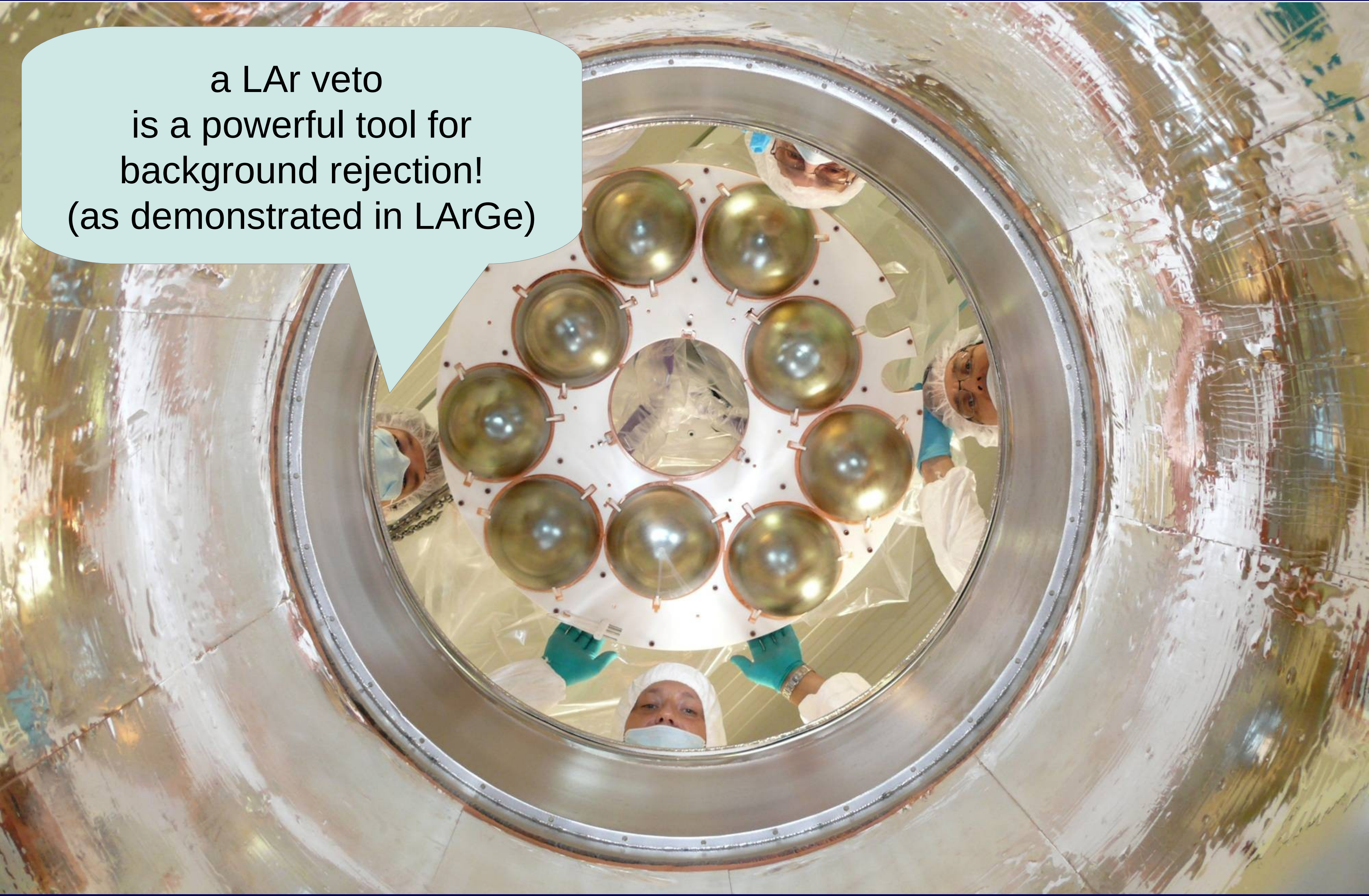
PMT option		fibre option (w\o self-veto)	
no veto	self-veto	blue	green
1.2	0.067	<0.32	0.88

10^{-3} cts/(keV·kg·y)

Conclusions & outlook

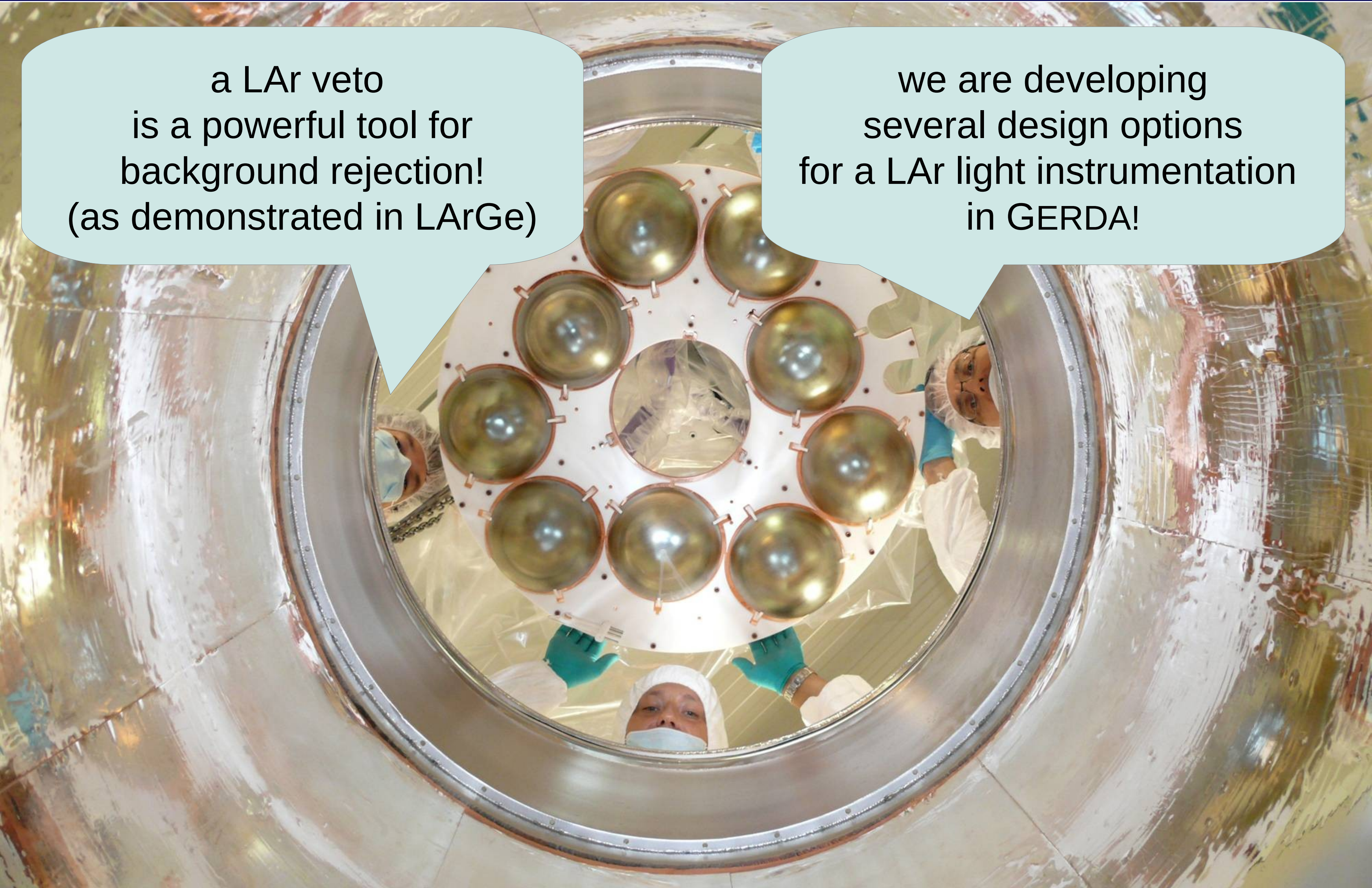


Conclusions & outlook



a LAr veto
is a powerful tool for
background rejection!
(as demonstrated in LArGe)

Conclusions & outlook



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we are developing
several design options
for a LAr light instrumentation
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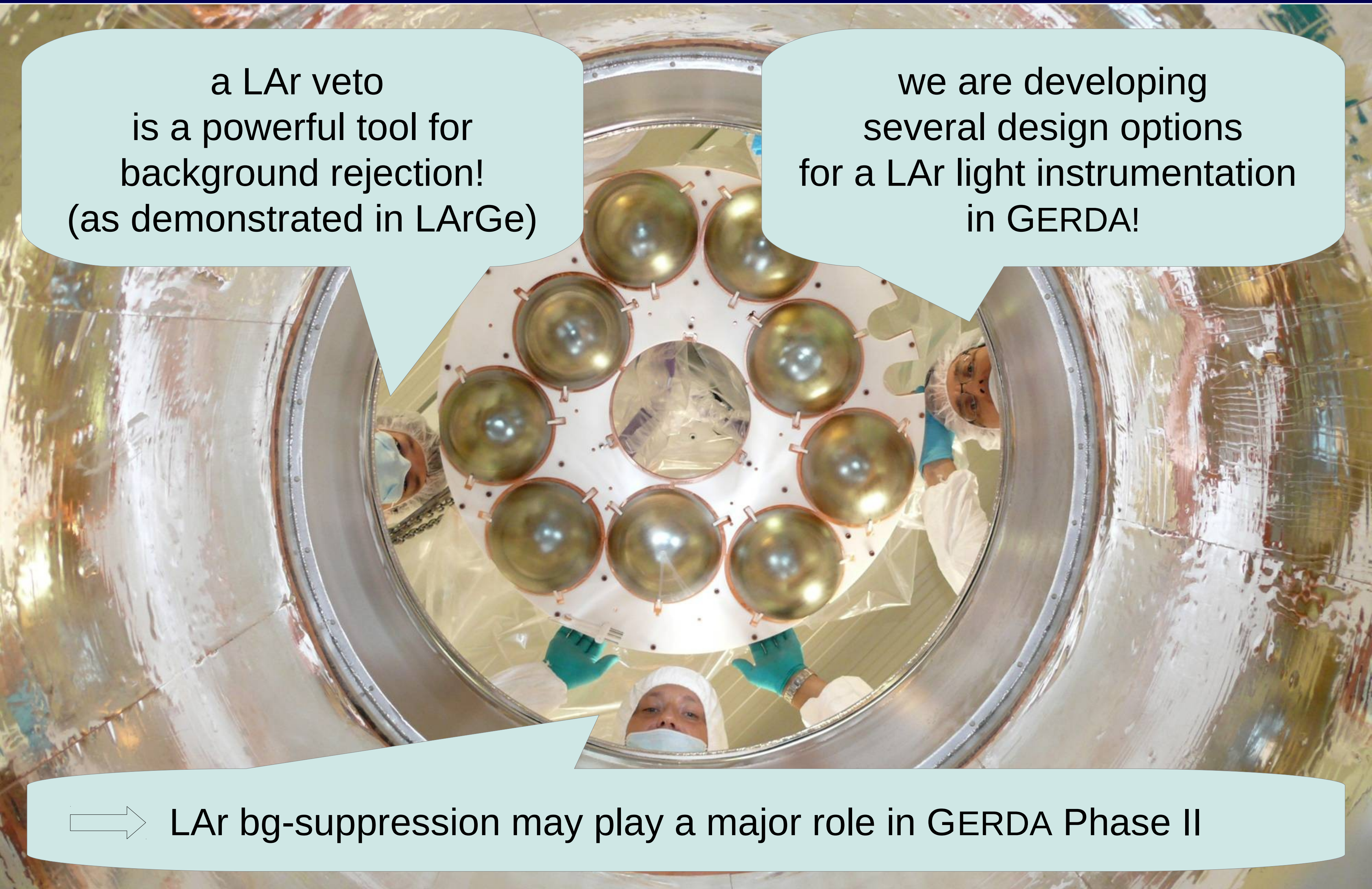
Conclusions & outlook



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⇨ LAr bg-suppression may play a major role in GERDA Phase II