LAr Veto for a future ^{76}Ge experiment

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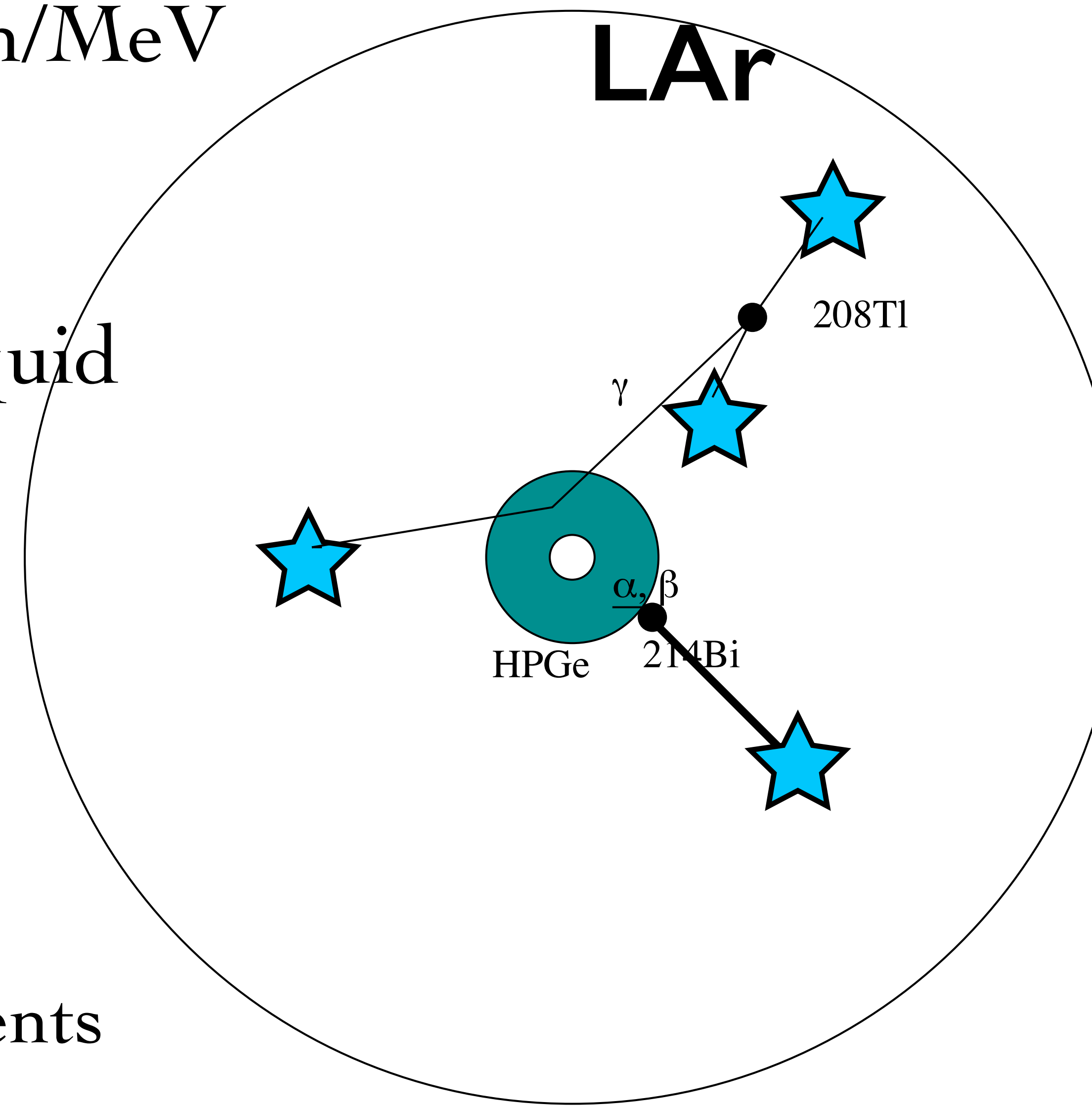
LAr veto - The concept

- LAr used for cooling and passive shielding
- LAr excellent scintillator: ~40000 photon/MeV
- Emmission maximum at 128 nm
- Cheap, high density, high purity cryo-liquid



  - Nearby ^{208}Tl events can be easily vetoed with very high efficiency
  - Veto for ^{214}Bi is less effective
  - Does not work well for surface α and β events
    - Veto efficiency in GERDA will strongly depend on the origin of the background

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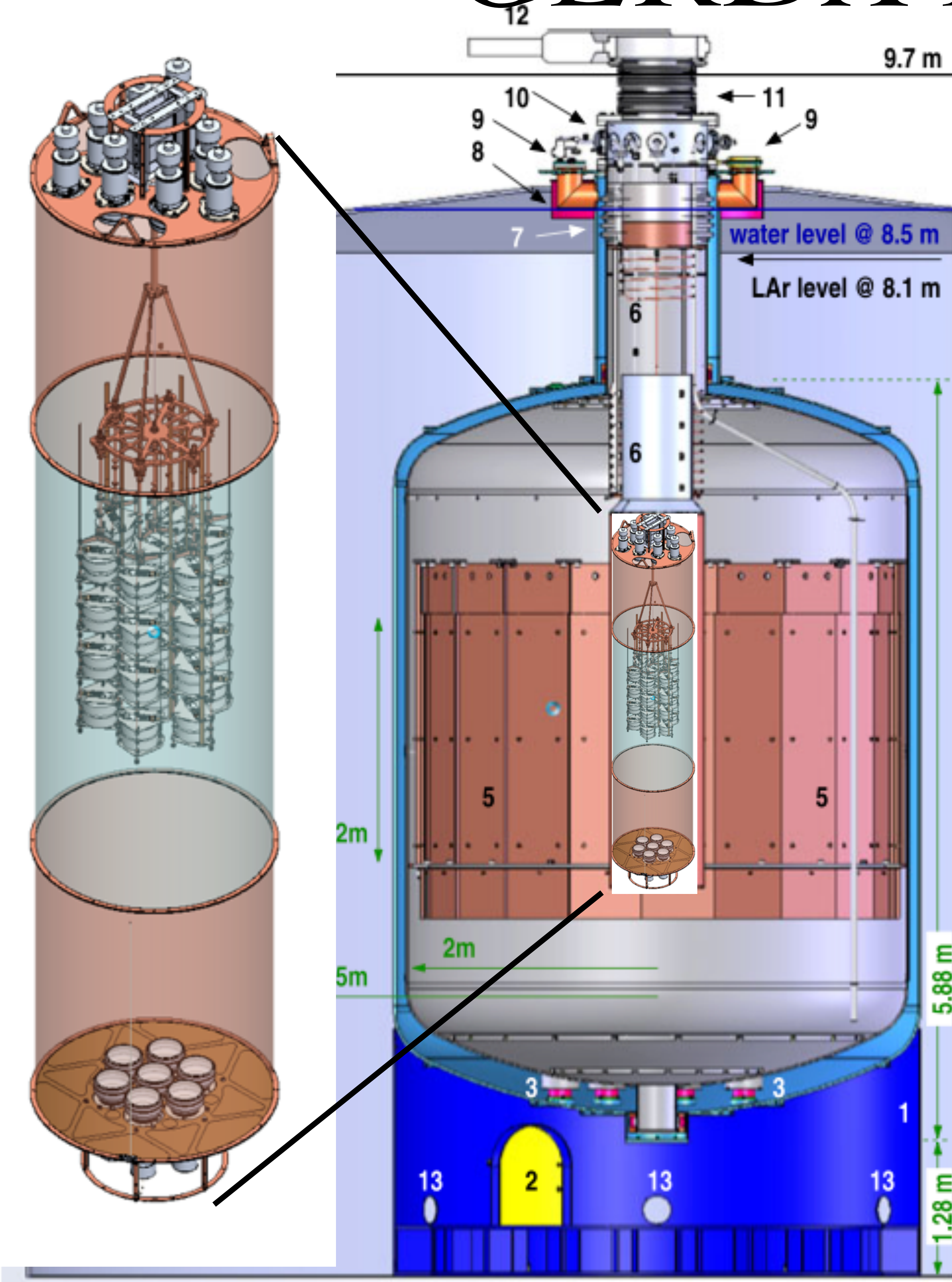
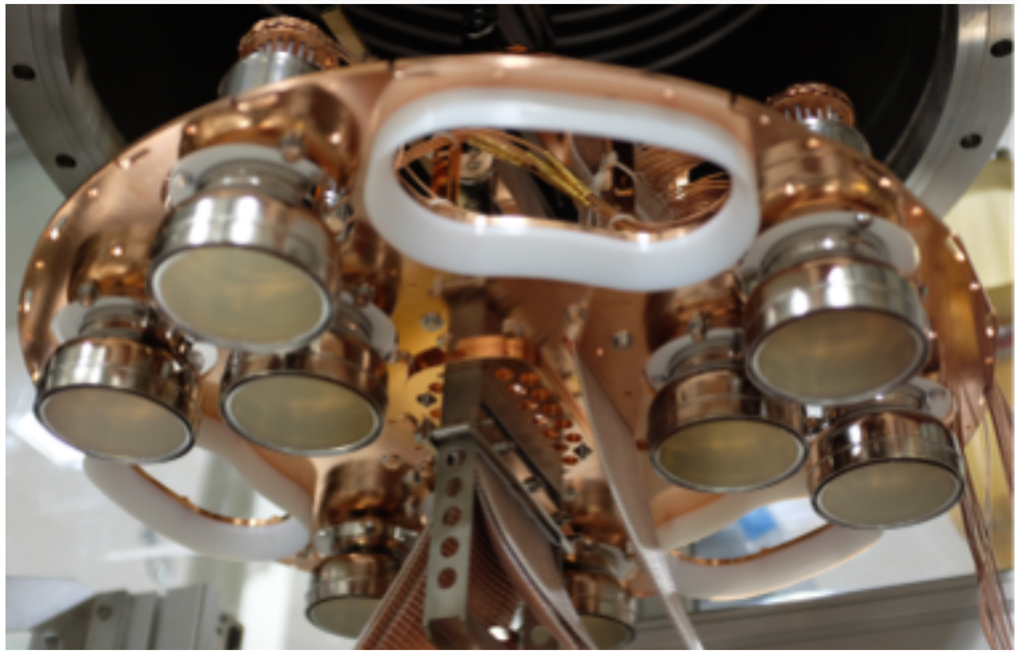
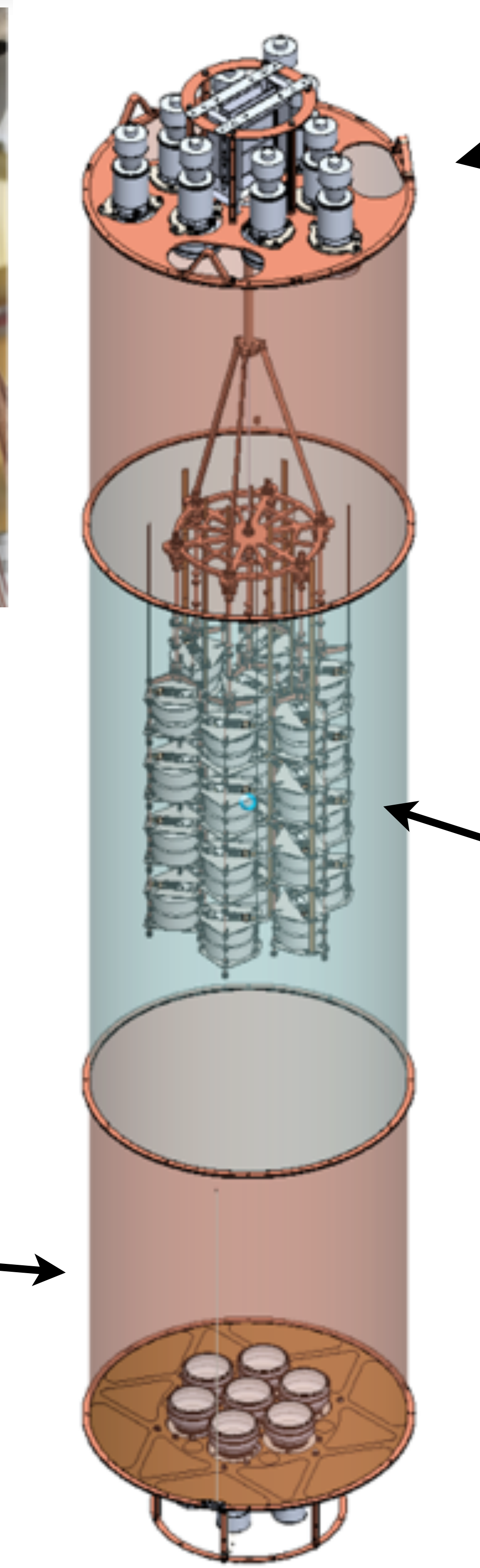
GERDA LAr veto



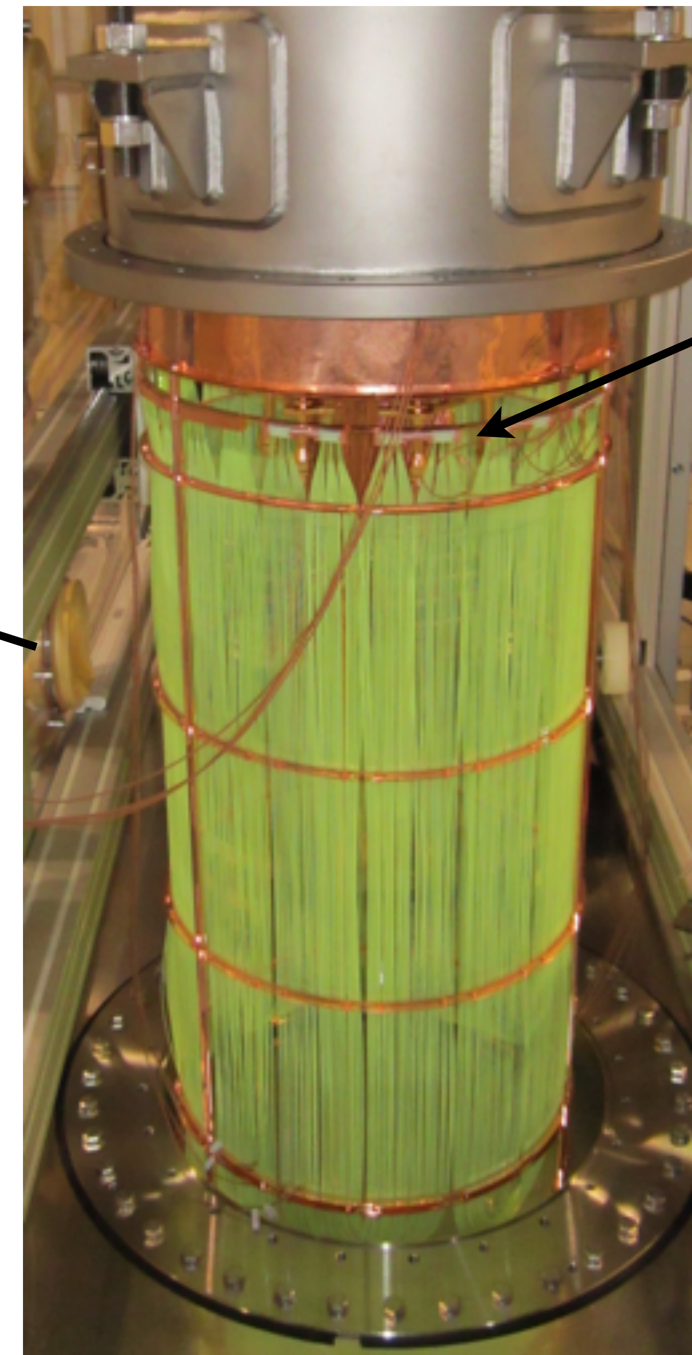
- “Deployed together with the HPGe detectors
- Limited in diameter and length
- Number of electronic channels is limited
- Can be replaced/repaired with each cooling cycle
- Operational since Nov.2014

GERDA LAr - veto





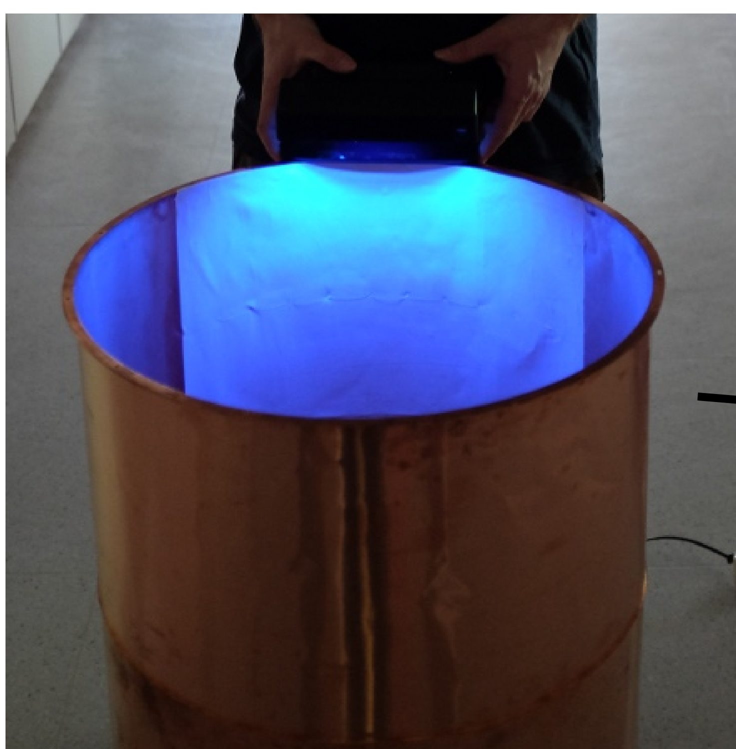
3" low-background PMT
Hamamatsu R11065-20



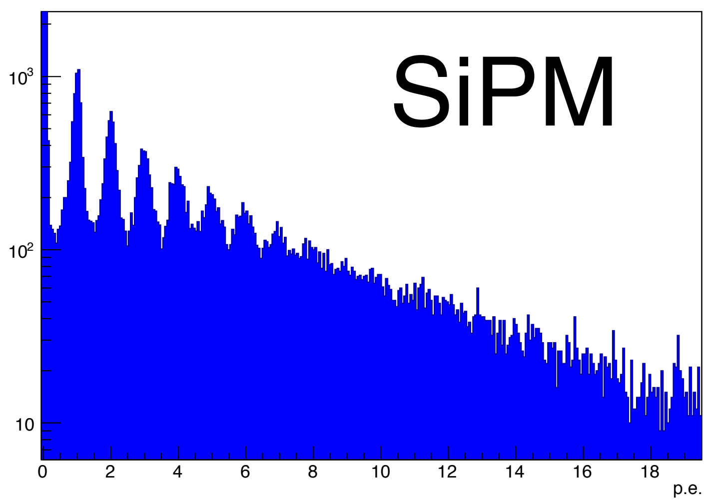
SiPMs

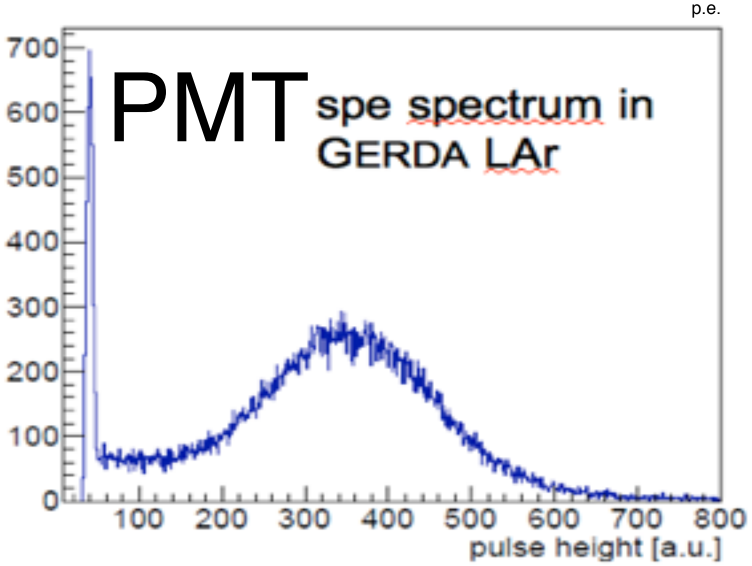
Fiber "shroud"
800 m WLS
fibre coated
with TPB

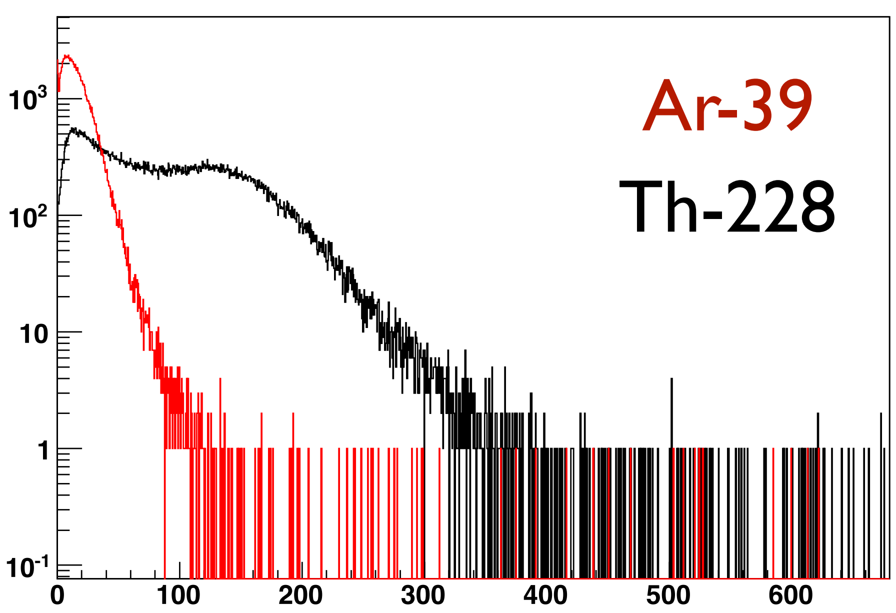
Copper "shroud" with
Tetratex reflector coated
with TPB



LAr veto commissioning

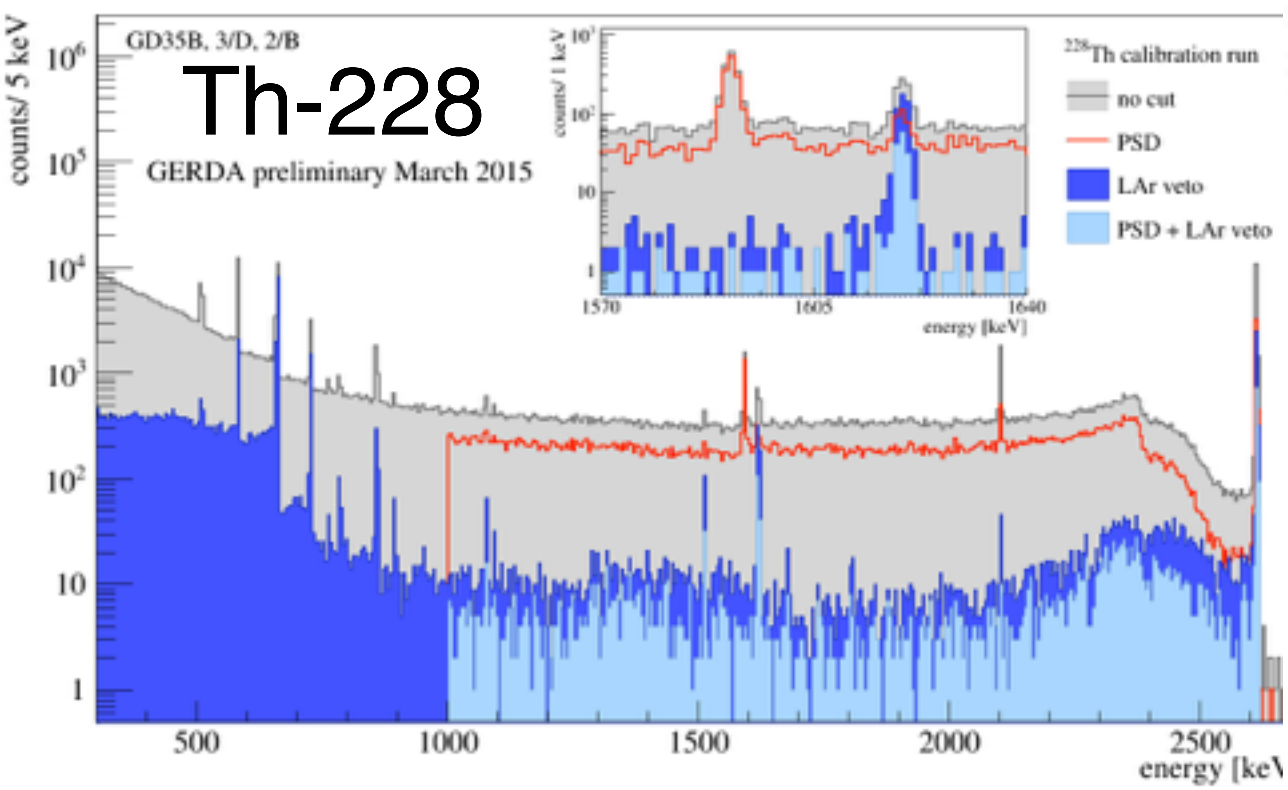


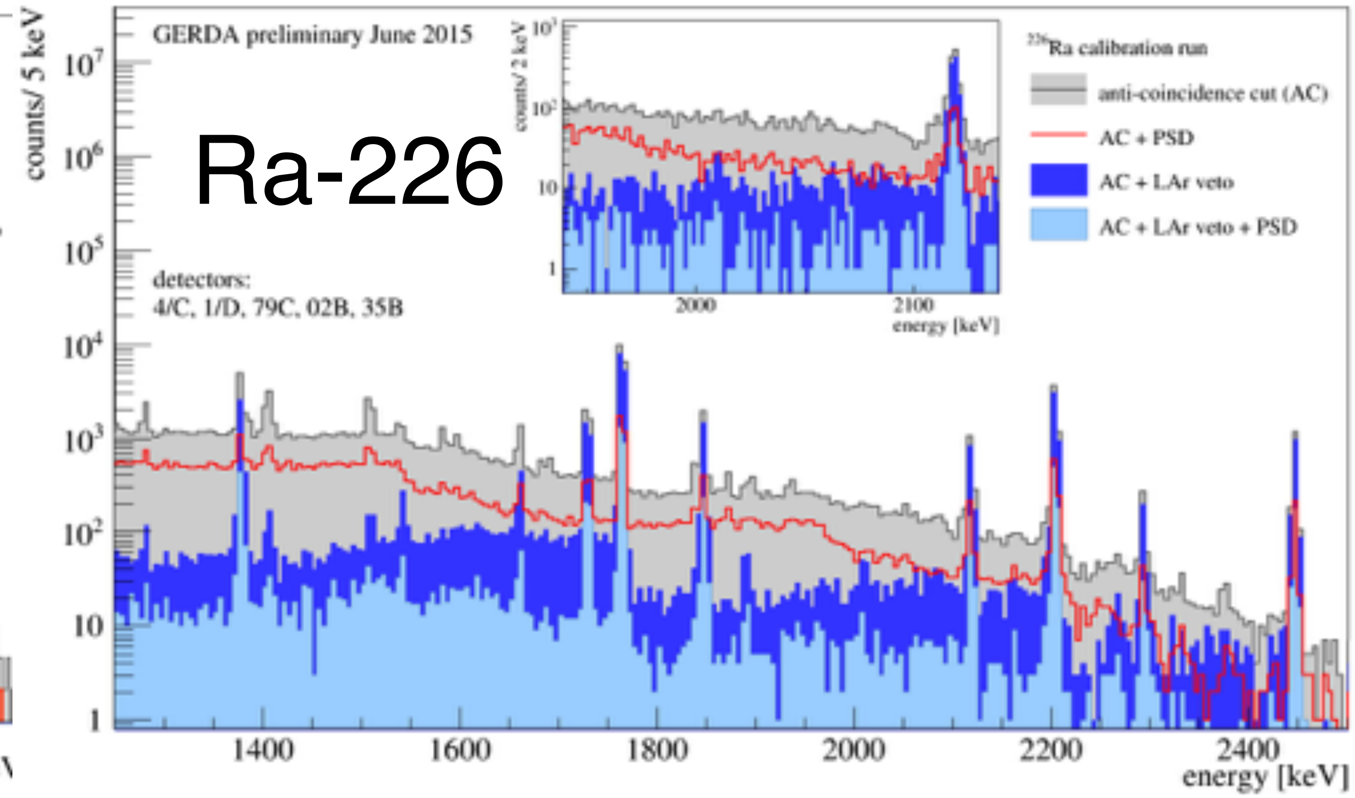




- "Photo-electron" peaks recognisable in the amplitude spectrum - in both SiPMs and PMTs spectra
- Veto on one photo-electron in any channel
- After single channels calibrated and summed up: light yield: 50 - 60 p.e./MeV - with ^{228}Th source
- Count rate dominated by ^{39}Ar
- LAr -veto Suppression Factor tested with one detector string with ^{228}Th and ^{226}Ra sources

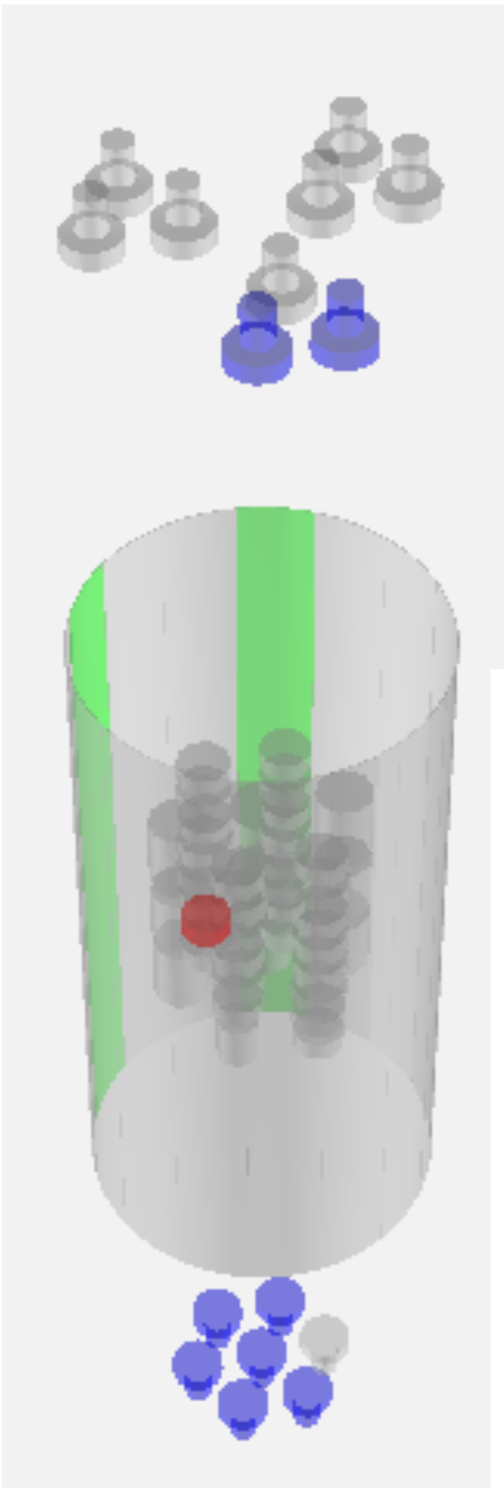
LAr veto commissioning





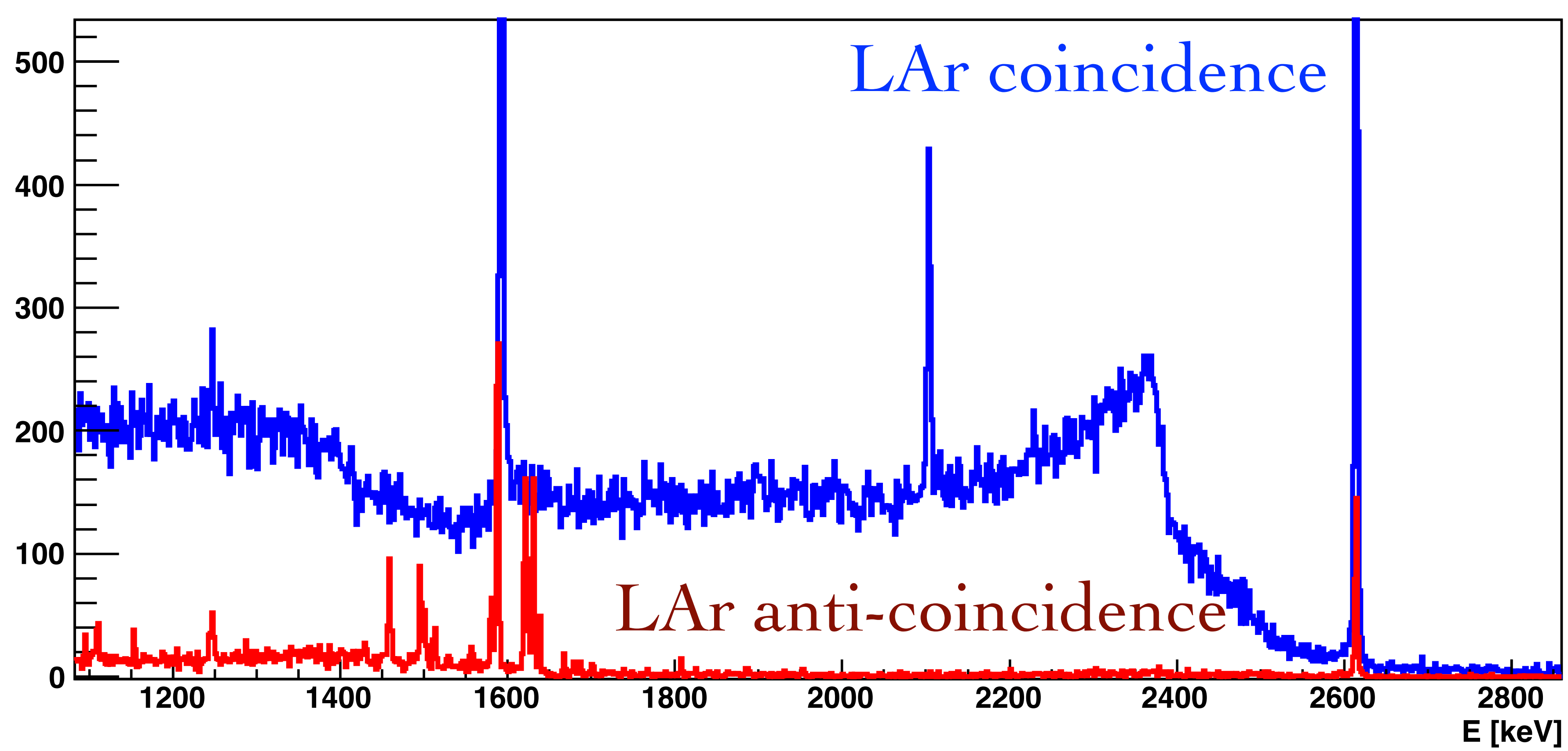
Suppression of:	Ge Anti-Coincidence	LAr-veto	PSD	LAr + PSD	Acceptance
^{228}Th	1.26 ± 0.01	97.9 ± 3.7	2.19 ± 0.01	344.6 ± 24.5	86.8%
^{226}Ra	1.26 ± 0.01	5.7 ± 0.2	2.98 ± 0.06	29.4 ± 2.5	89.9%

More than just a veto



- Geometrical distribution of the hits can help locate the source
- Background model fit with 3 spectra: all hits, LAr anti-coincidence and LAr coincidence

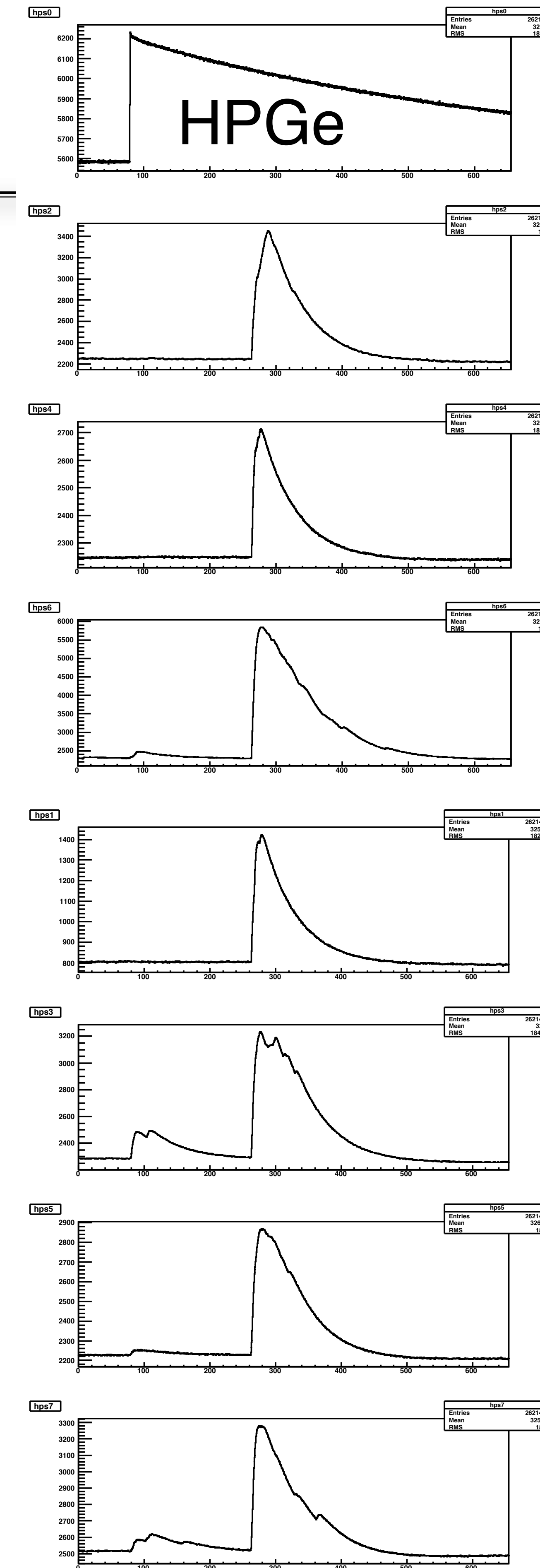
➡ Precision in background modelling

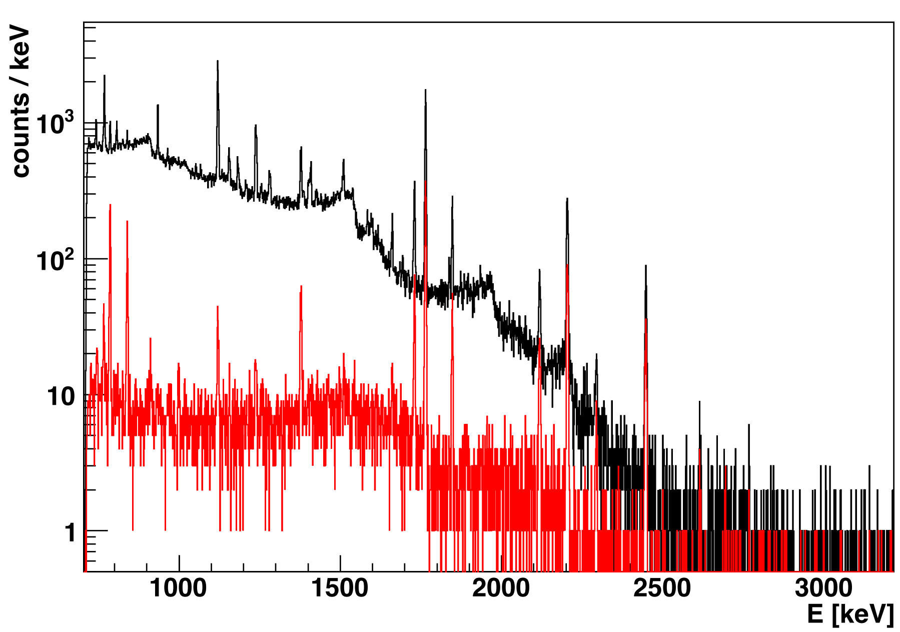


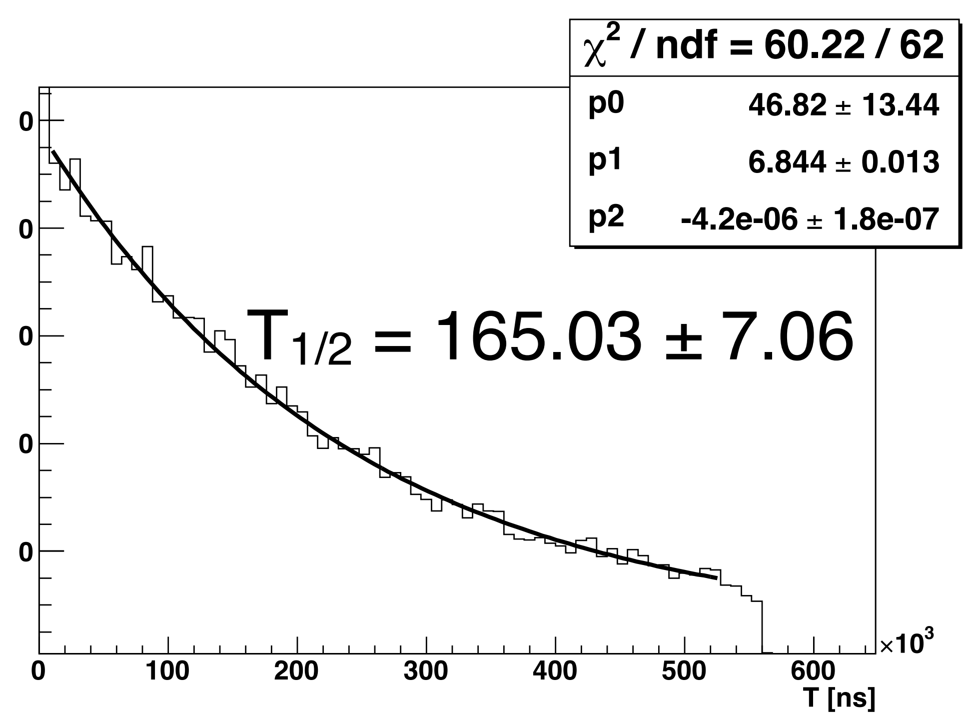
^{214}Bi-^{214}Po coincidence

- α-decay is an intensive point-like light source
- Clear signature of a ^{214}Bi decay
- Can be only on the surface of s.th.

➡ Hint on the type and source of the background



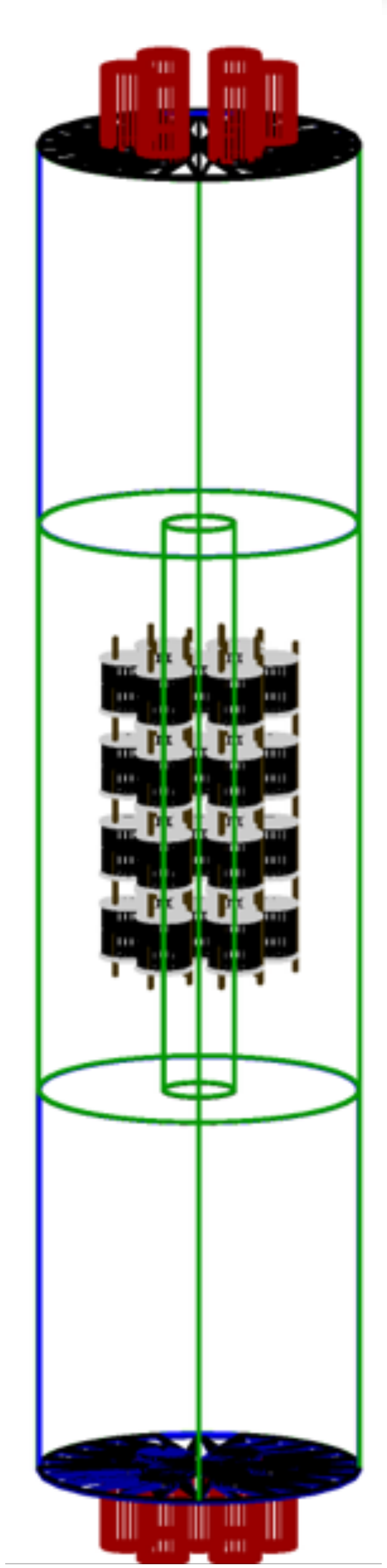




Future of the LAr veto

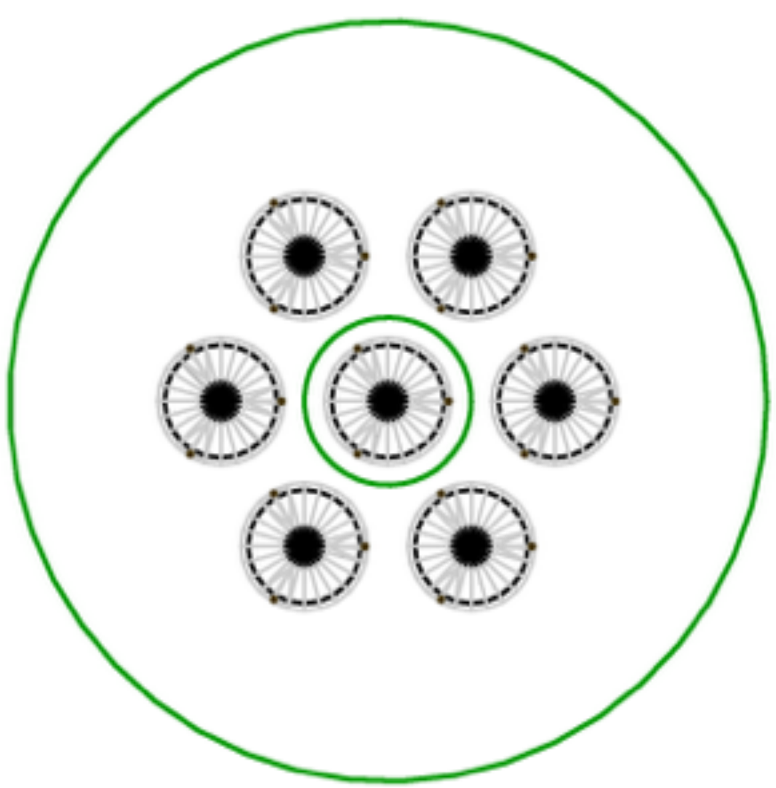
- **Improve the photo-electron yield (by factor 10 - 100)**
  - Background suppression will not improve too much (MC) but more light is always better
  - Higher p.e. yield helps to compensate geometrical limitations (shadowing)
- **Reduce radioactivity of the light detectors**
  - We are already very clean, further reduction would be a major effort (current design)
- **Get rid of Ar-39, Ar-42 !**
  - Reducing Ar-42 background is a major effort in Gerda
  - Ar-39 is not a background for 0ν2β but it covers up 20% of the gamma ray spectrum

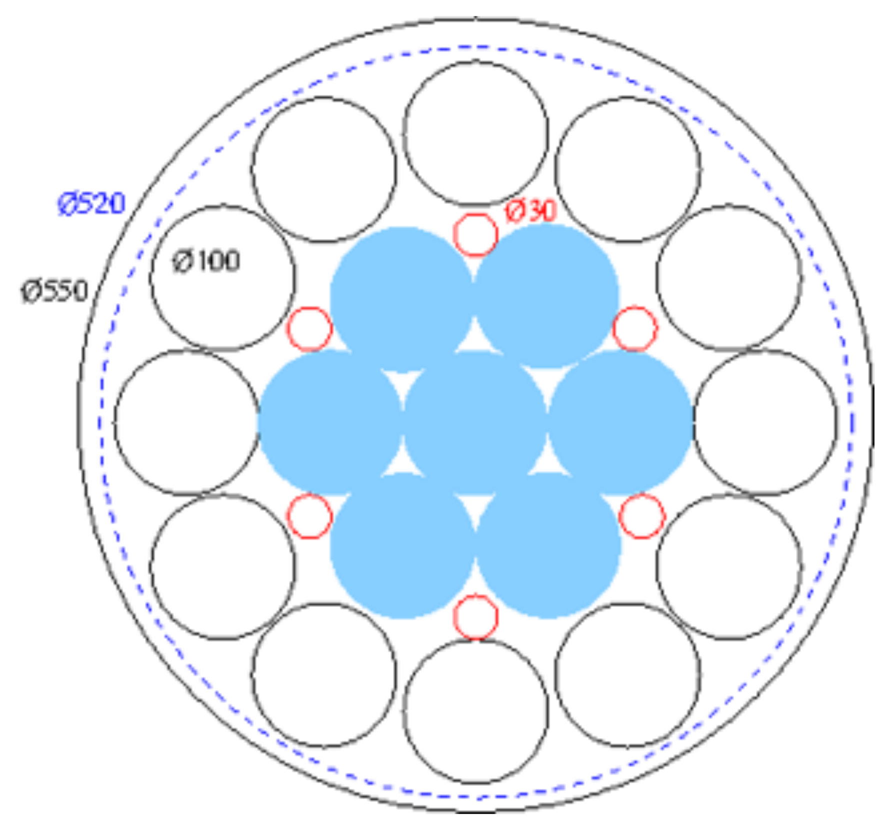
High density array

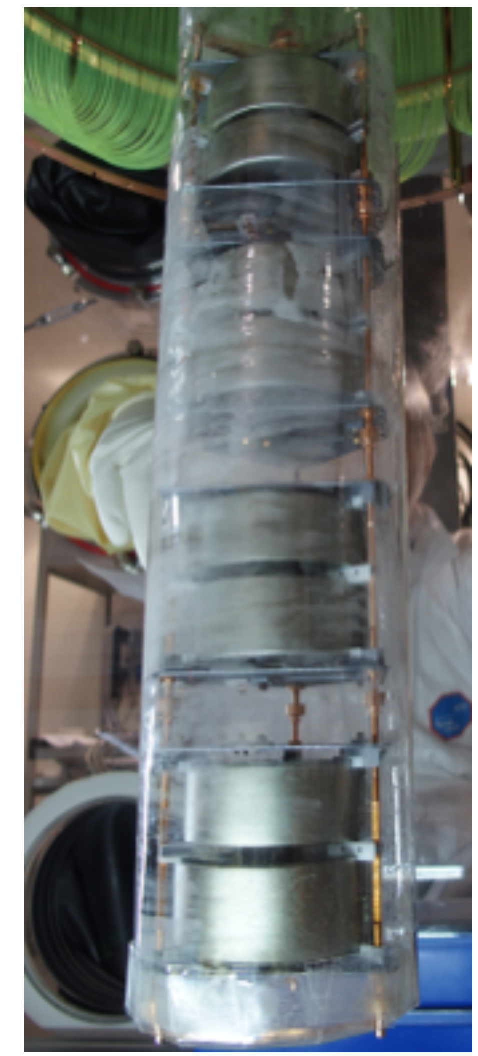


Little light can escape from a tightly packed array

- Instrumentation between the HPGe arrays
  - "Mini-shroud" made of fibers
- It was present in the first version of the MC
- Hardware implementation not tested (yet)

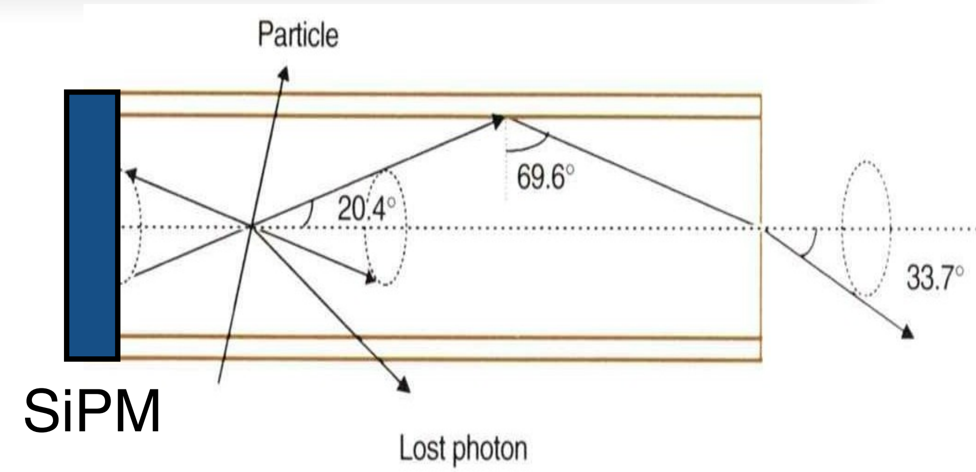




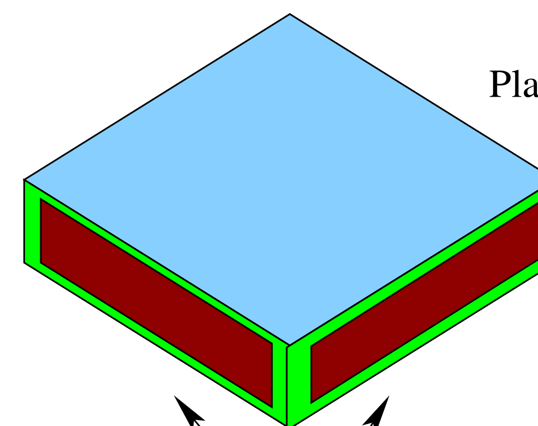


Light detector technology

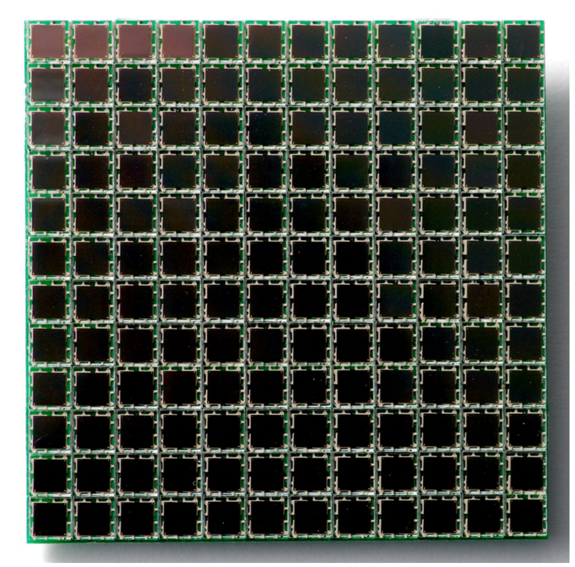
- WLS fibers with SiPM read-out: continuation of the Gerda concept
  - Max. 14% trapping efficiency, total efficiency up to ~5%



- 2D WLS 'fiber': WLS plates with SiPMs on the edges
  - trapping efficiency up to 30% possible at
  - 10% overall detection efficiency
  - combination of large SiPM array + WLS technology, surface increases ~(Nb. of SiPMs)^2

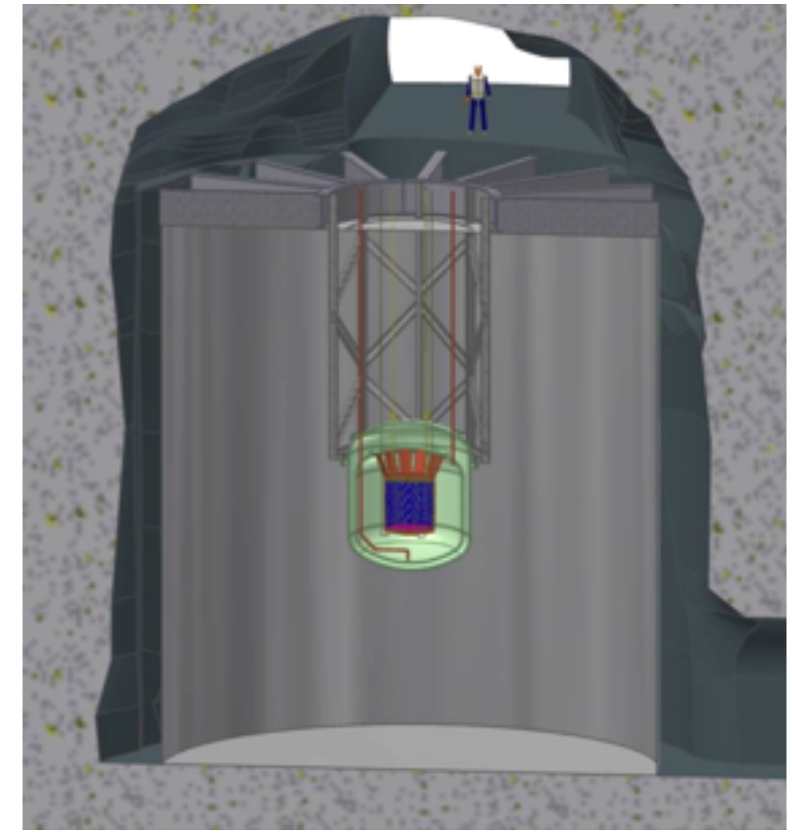


- Highest possible p.d.e. ⇒ large SiPM array
  - 40 - 60 % p.d.e. possible
  - Pure Si detector = lowest possible background

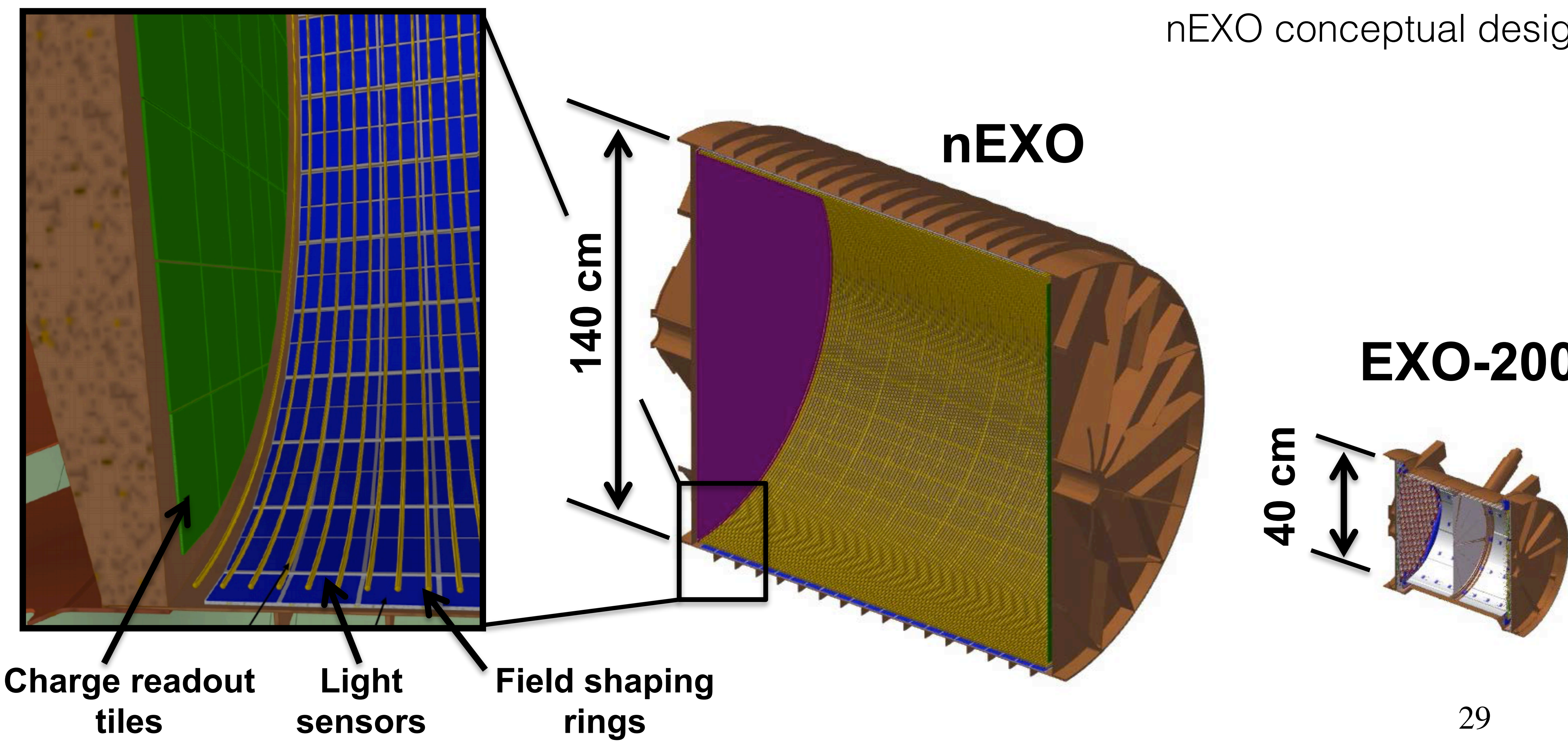


The nEXO detector

- A large monolithic LXe detector can build on the technology demonstrated by EXO-200
- Single-sided TPC: 1.3-m diameter, 5-ton LXe



nEXO conceptual design



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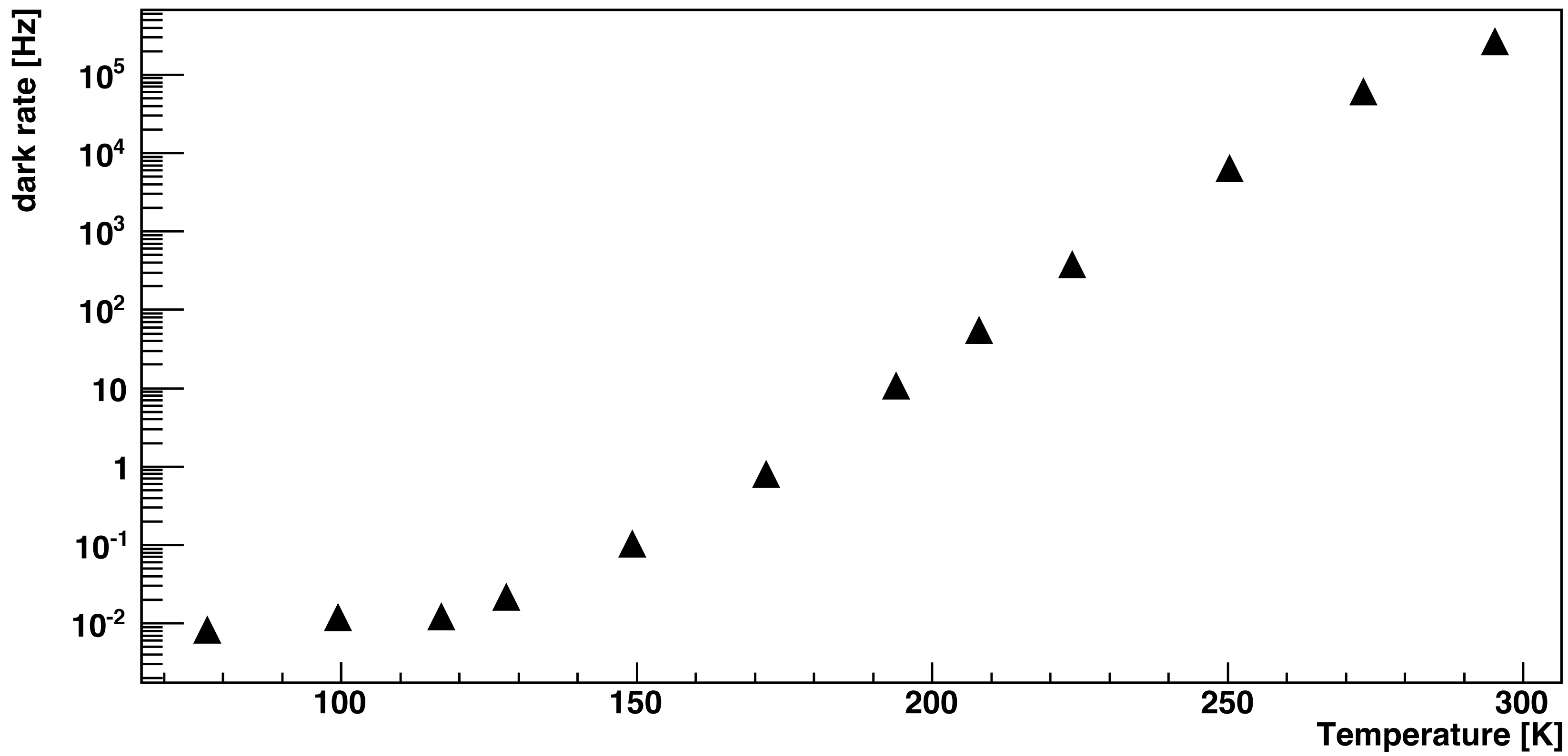
SiPM Dark Rate



- Measured with Hamamatsu MPPC 50 μm pixel 10^{-2} Hz/mm^2 in **LN**
- Ketek 3x3 mm, 50 μm, ~ 1 Hz = 10^{-1} Hz/mm^2
- 100 cm^2 SiPM array would have ~1 kHz dark rate in **LAr**
- **Gerda:** 8 cm^2 divided over 15 channels
- With an ASIC design to deal with large number of devices one can build a large area arrays today

Induced background

Background source		activity	Backgr. in ROI [cts/(keV kg yr)]	Backgr. after veto [cts/(keV kg yr)]
PMTs	^{228}Th	< 2.44 mBq/PMT	$< 3.1(1)*10^{-4}$	$< 3.1(5)*10^{-6}$
	^{226}Ra	< 2.84 mBq/PMT	$< 5.5(2)*10^{-5}$	$< 2.7(5)*10^{-6}$
cables	^{228}Th	< 14.4 µBq/m	$< 2.4(1)*10^{-4}$	$< 7.0(2)*10^{-6}$
	^{226}Ra	< 11.2 µBq/m	$< 3.9(1)*10^{-5}$	$< 5.5(2)*10^{-6}$
top & bottom shroud	^{228}Th	< 103 µBq/m^2	$< 2.7(1)*10^{-5}$	$< 9.9(5)*10^{-7}$
	^{226}Ra	< 282 µBq/m^2	$< 1.2(1)*10^{-5}$	$< 1.5(1)*10^{-6}$
fibers	^{228}Th	58 µBq/kg	$3.4*10^{-4}$	$6.4*10^{-8}$
	^{226}Ra	42 µBq/kg	$2.3*10^{-5}$	$6.3*10^{-7}$
total	^{228}Th		$< 9.2(1)*10^{-4}$	$< 1.1(1)*10^{-5}$
	^{226}Ra		$< 3.4(1)*10^{-4}$	$< 1.0(1)*10^{-5}$
	sum		$< 1.3(1)*10^{-3}$	$< 2.1(1)*10^{-5}$

- Further optimisation could reduce the background contribution max. by a factor two
- Or for the background rate caused by the PMTs one could get another 800 m fiber close by

Noble liquids

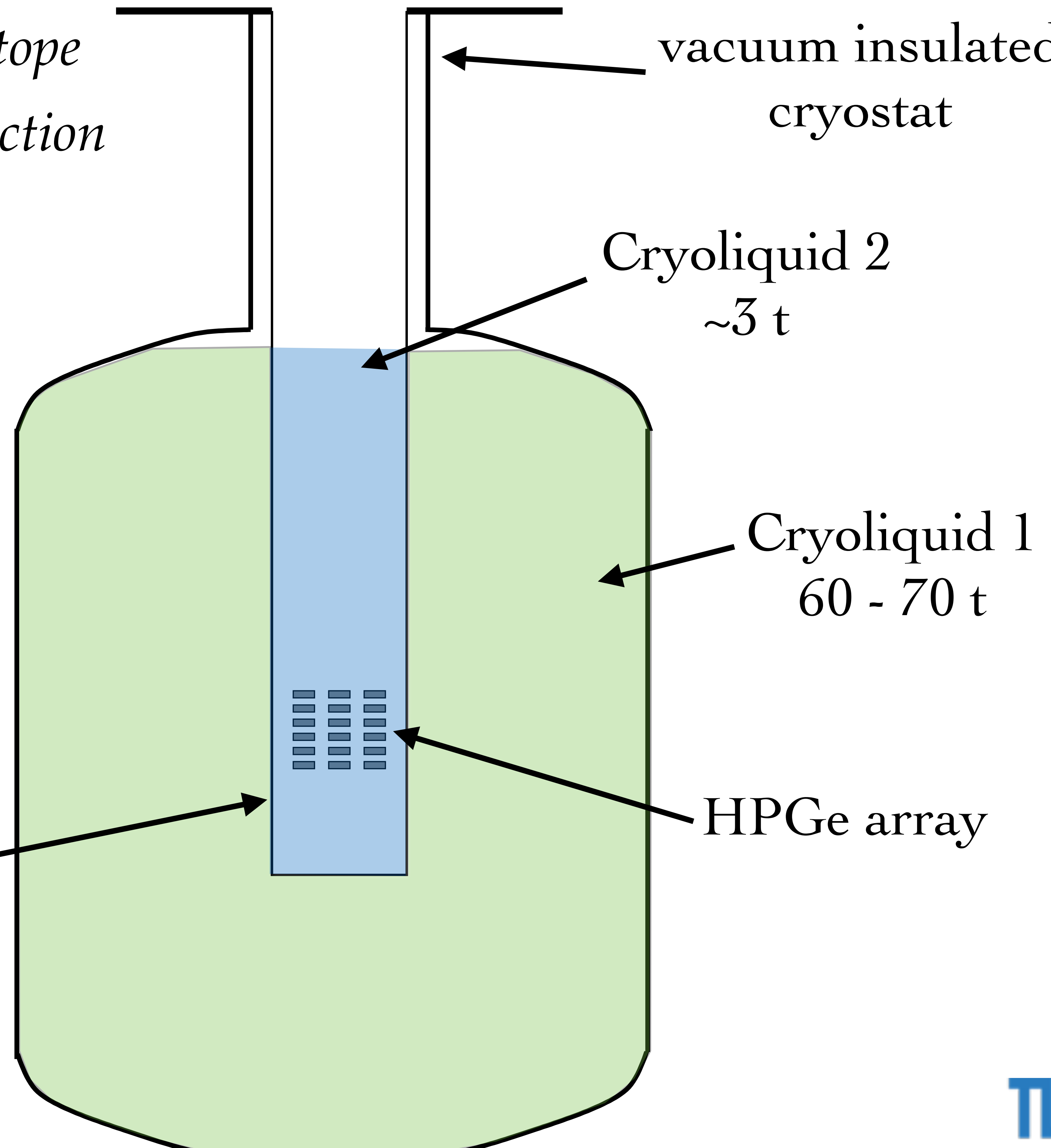
	A	ρ [kg/l]	T [K]	X_0 [cm]	λ [nm]	Rad. Isotopes	
He	4	0.125	4	756	80	-	too cold
Ne	20	1.2	27	24	80	no long lived rad. isotope	?
Ar	40	1.39	87	14	128	^{39}Ar, ^{42}Ar (kBq/l)	the cheapest
Kr	84	2.41	120	4.5	148	^{85}Kr (MBq/l)	only with isotope separation
Xe	131	2.94	165	2.9	170	-	too warm

- All noble liquids scintillate
- Ne, Ar, Kr are all potential candidates for scintillator veto

GERDA LAr improved

Do the purification and/or isotope separation only for a small fraction of the volume

- Cryoliquid 1:
  - LN or LAr
- Cryoliquid 2:
  - depleted LAr (or LKr)
  - Neon ?
  - purified in situ



Inner vessel
- thin copper LAr option
- insulating mat. for LNe, LKr

Summary

- LAr-veto in GERDA works: proven design
- With small incremental improvements we can fulfil the requirements of the next generation experiments
- To be considered for future experiment:
  - Optimised setup
  - Large SiPM arrays
  - Depleted Argon (Neon, Krypton)

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