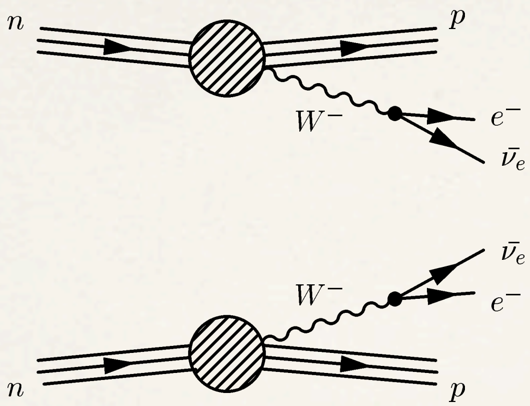
A liquid argon scintillation veto for GERDA and LArGe

Janicskó-Csáthy József for the GERDA collaboration

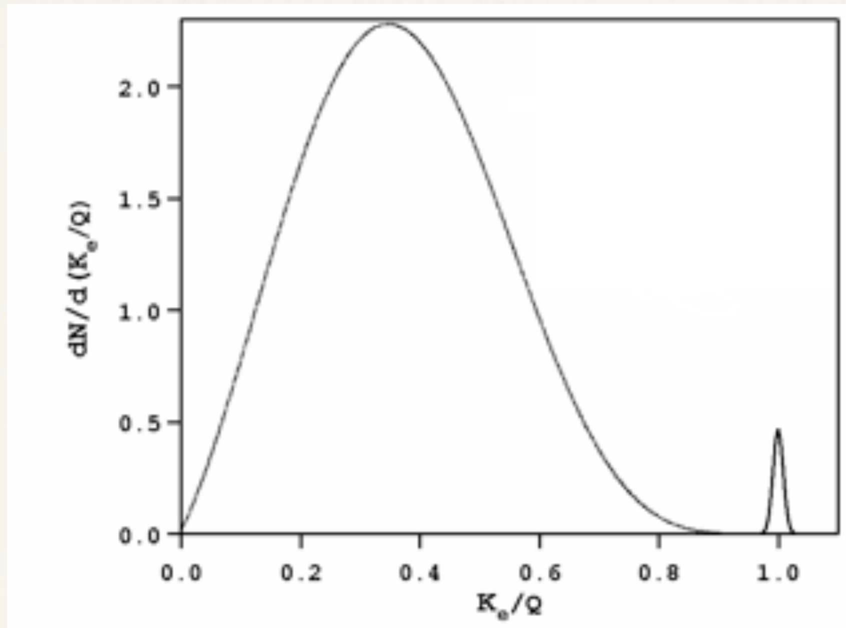
Date

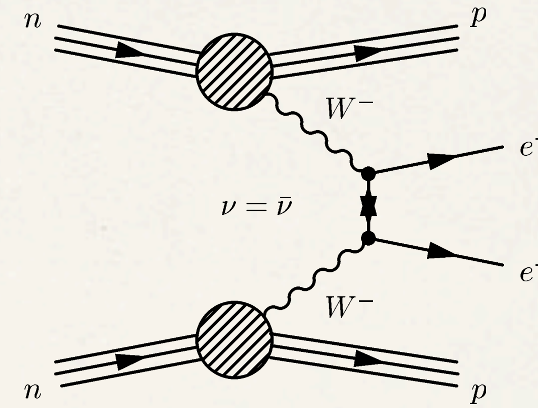
DPG Mainz 2012, HK 18.2

2β decay



2β decay with 2 neutrinos





2β decay with 0 neutrinos

$(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$

allowed and observed

$(A,Z) \rightarrow (A,Z+2) + 2e^-$

violates lepton number conservation

$$\left(T^{0\nu}_{1/2}\right)^{-1} = F^{0\nu} \cdot \left|\mathcal{M}^{0\nu}\right|^2 \cdot m^2_{\beta\beta}$$

$$\langle m_{\beta\beta} \rangle = \left|\Sigma_i U^2_{ei} m_{\nu i}\right|$$

$\mathcal{M}^{0\nu}$ - nuclear matrix element

$F^{0\nu}$ - phase space integral depends on the Q value

$\langle m_{\beta\beta} \rangle$ - effective neutrino mass

GERDA

See talks: HK 40. 2-6

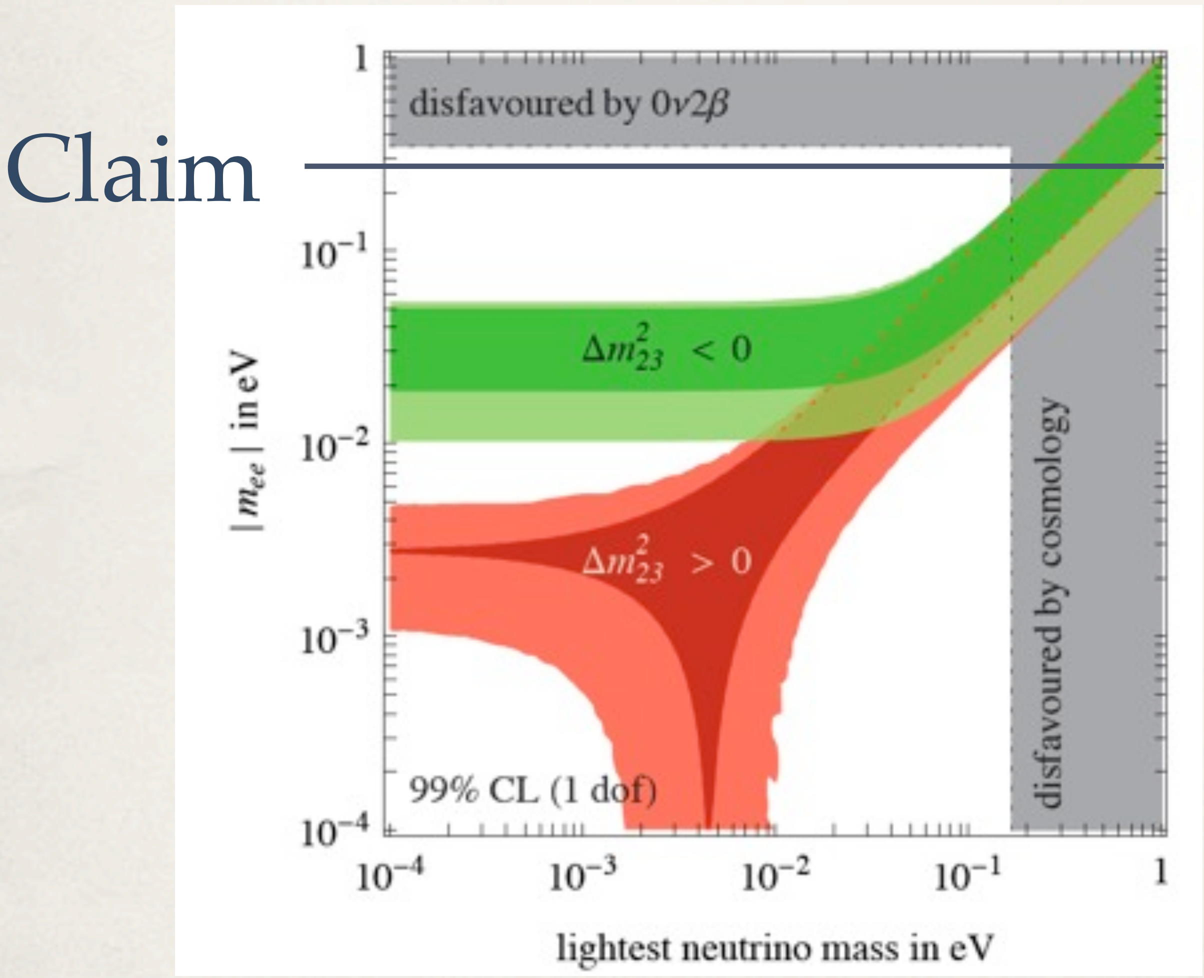
$$T^{0\nu}_{1/2} \sim \sqrt{\frac{M \cdot t}{B \cdot \Delta E}}\ [y] \longleftarrow$$

For a better limit we need:

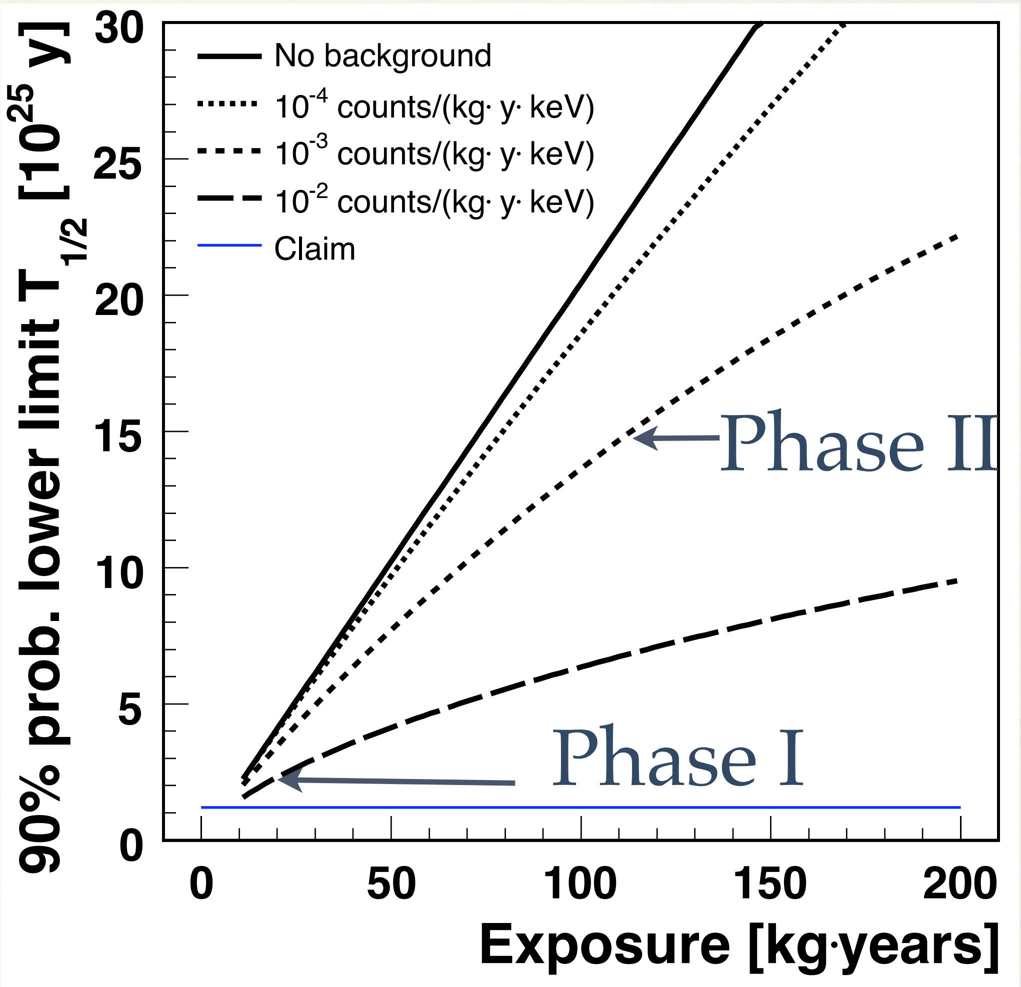
- more mass
- lower background
- better energy resolution
- measure longer ??

M - mass of the isotope
t - time

B - background
ΔE - resolution



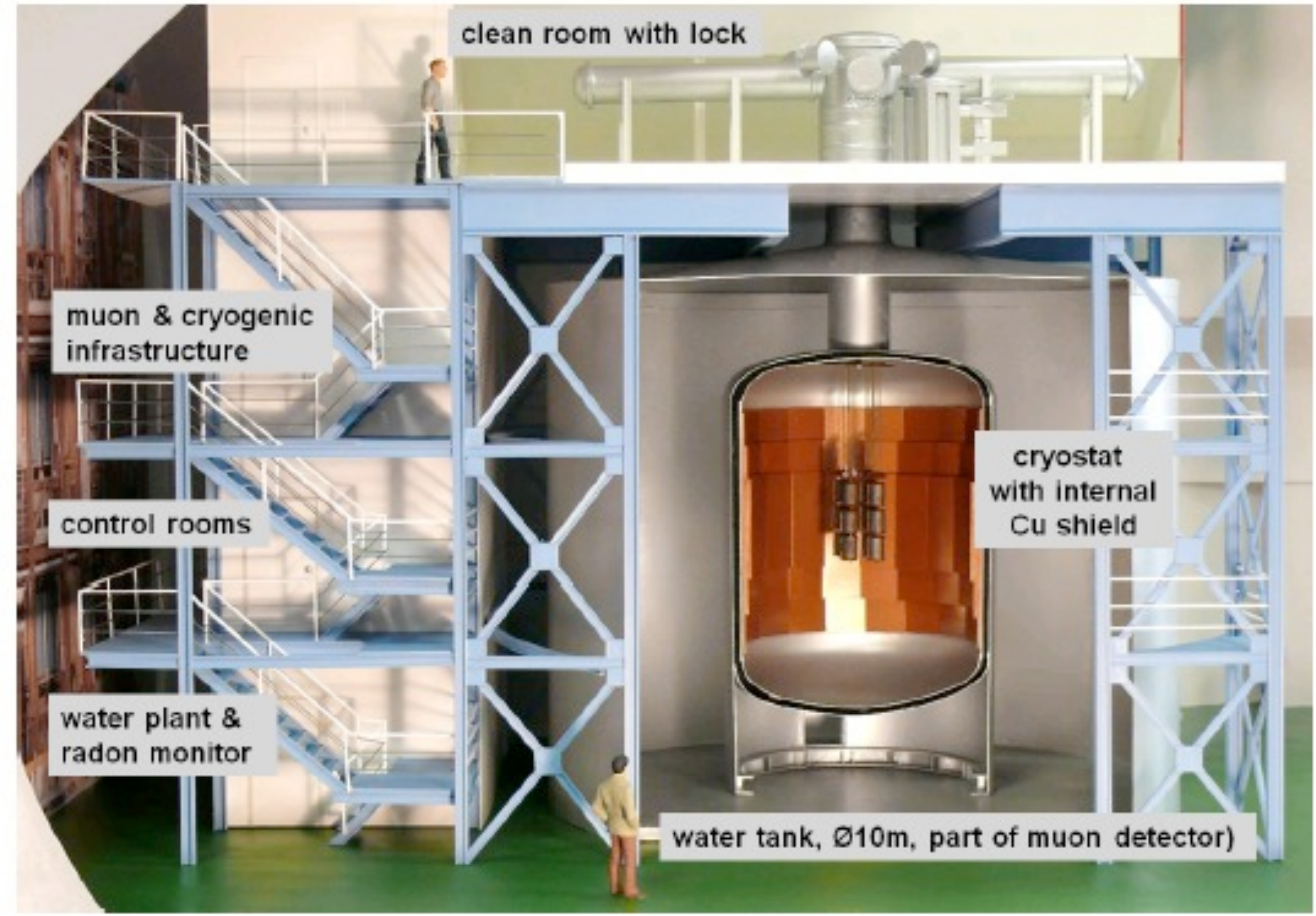
F.Feruglio et al. Nucl.Phys.B 637 (2002)



A. Caldwell et al. Phys.Rev. D 74 (2006) 092003

GERDA

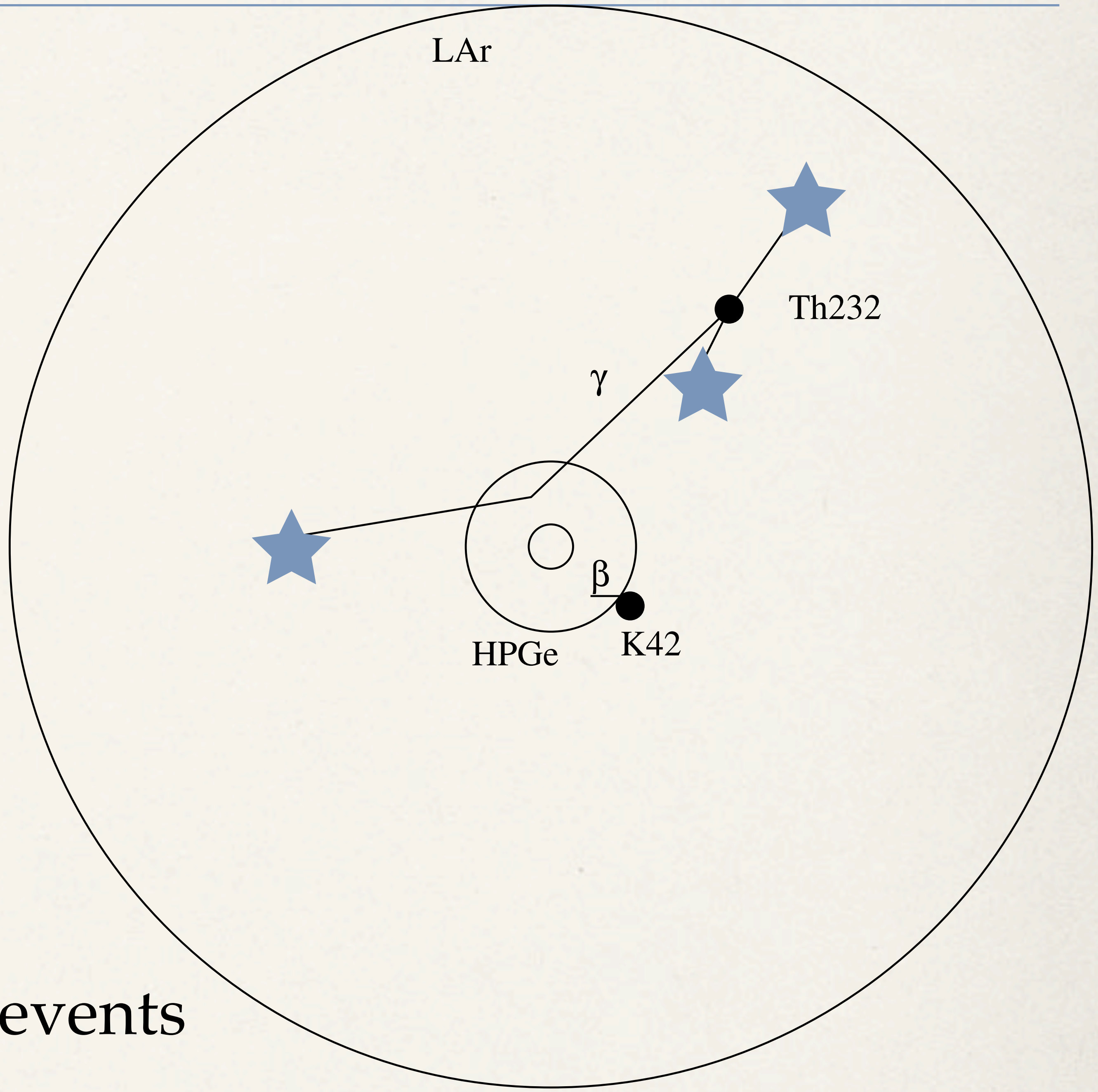
See talks: HK 40. 2-6



LAr veto - The concept

In the Region of Interest around 2040 keV

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



LArGe test facility

lock system

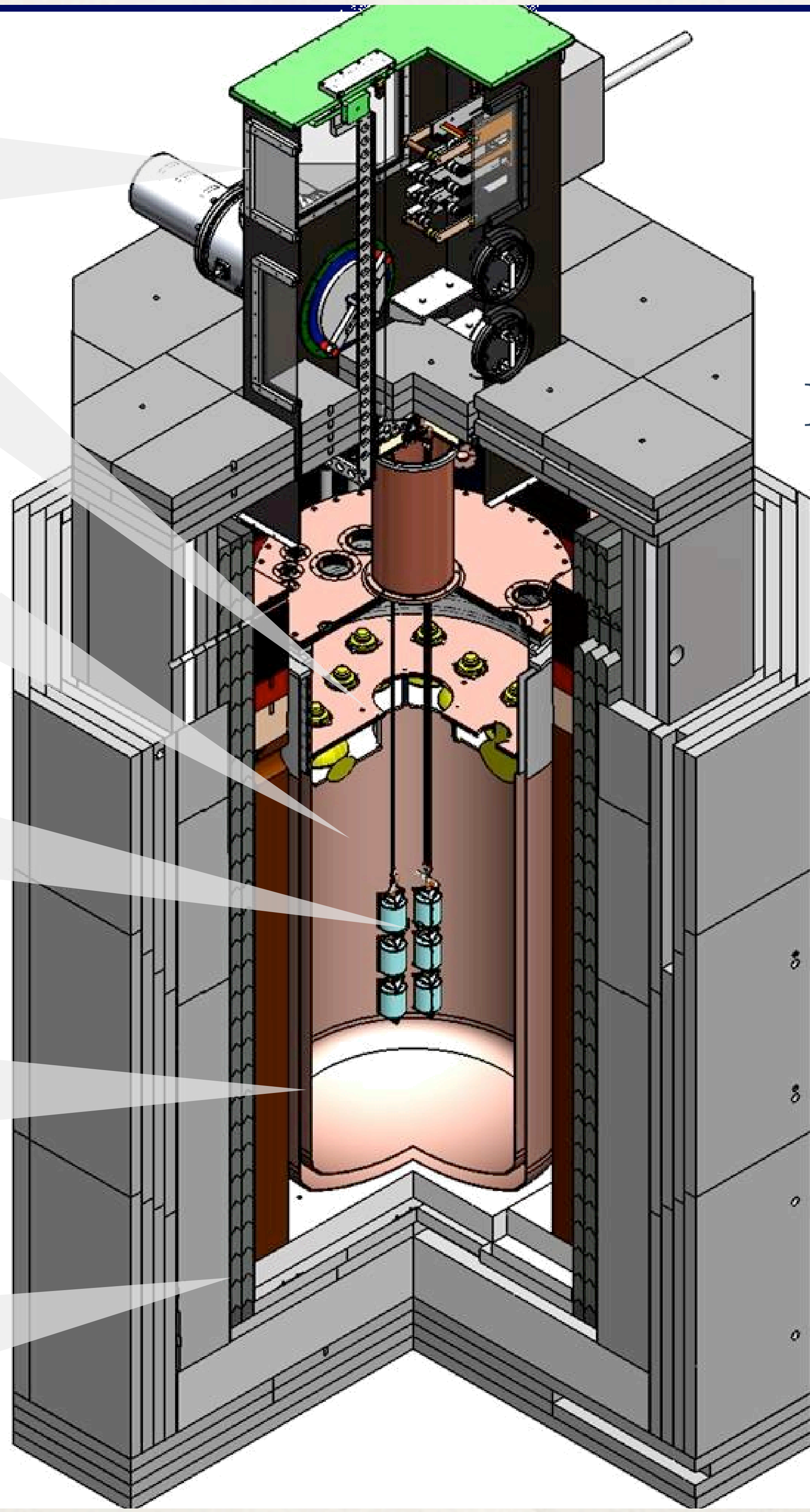
9x 8“ PMTs

reflector foil
& wavelength shifter

bare Ge-detector

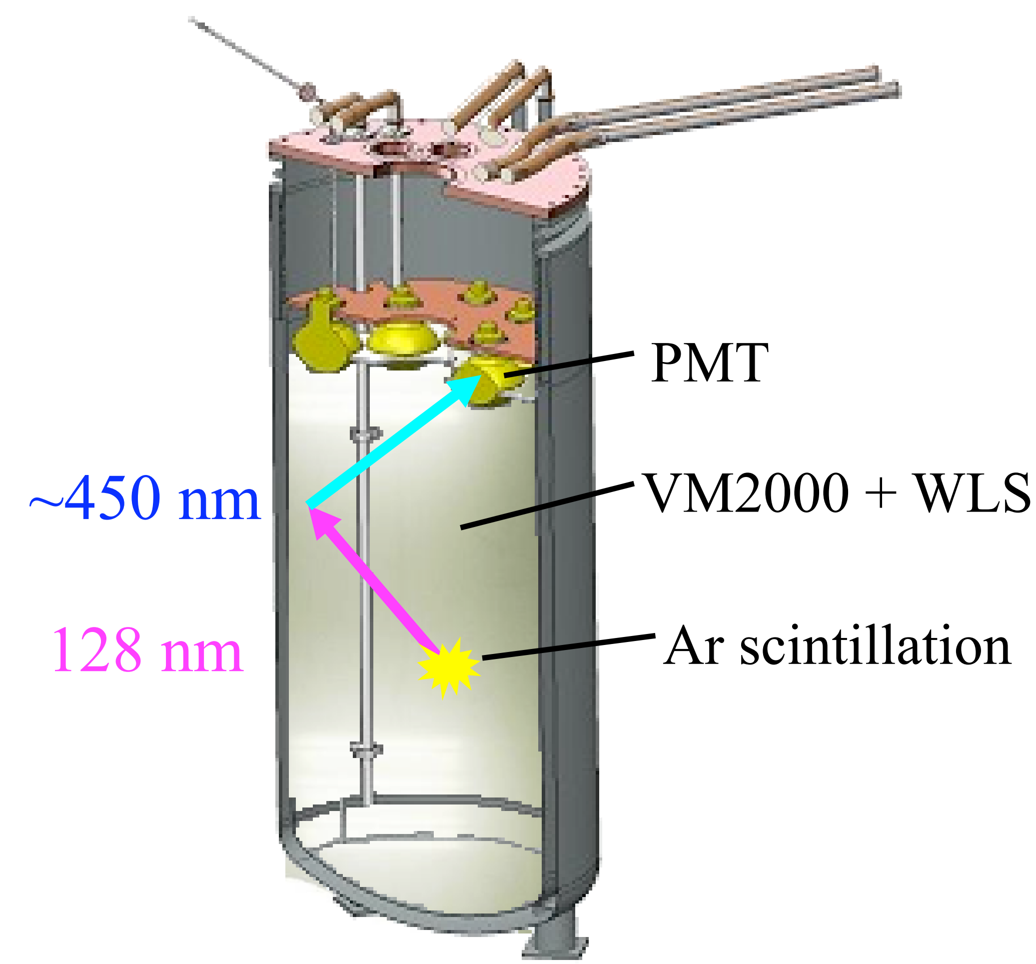
cryostat with LAr
volume 1000 l

Shield (unfinished)
Cu 15 cm, Pb 10 cm,
Steel 23 cm, PE 20 cm



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

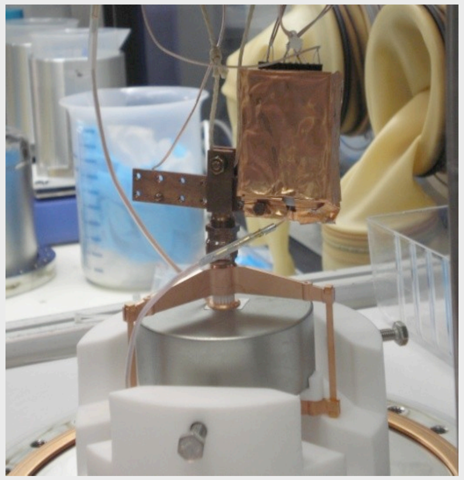
Ref:arXiv:0701001, TAUP2011 proc.



LArGe test facility

LArGe, Suppression of internal ^{228}Th

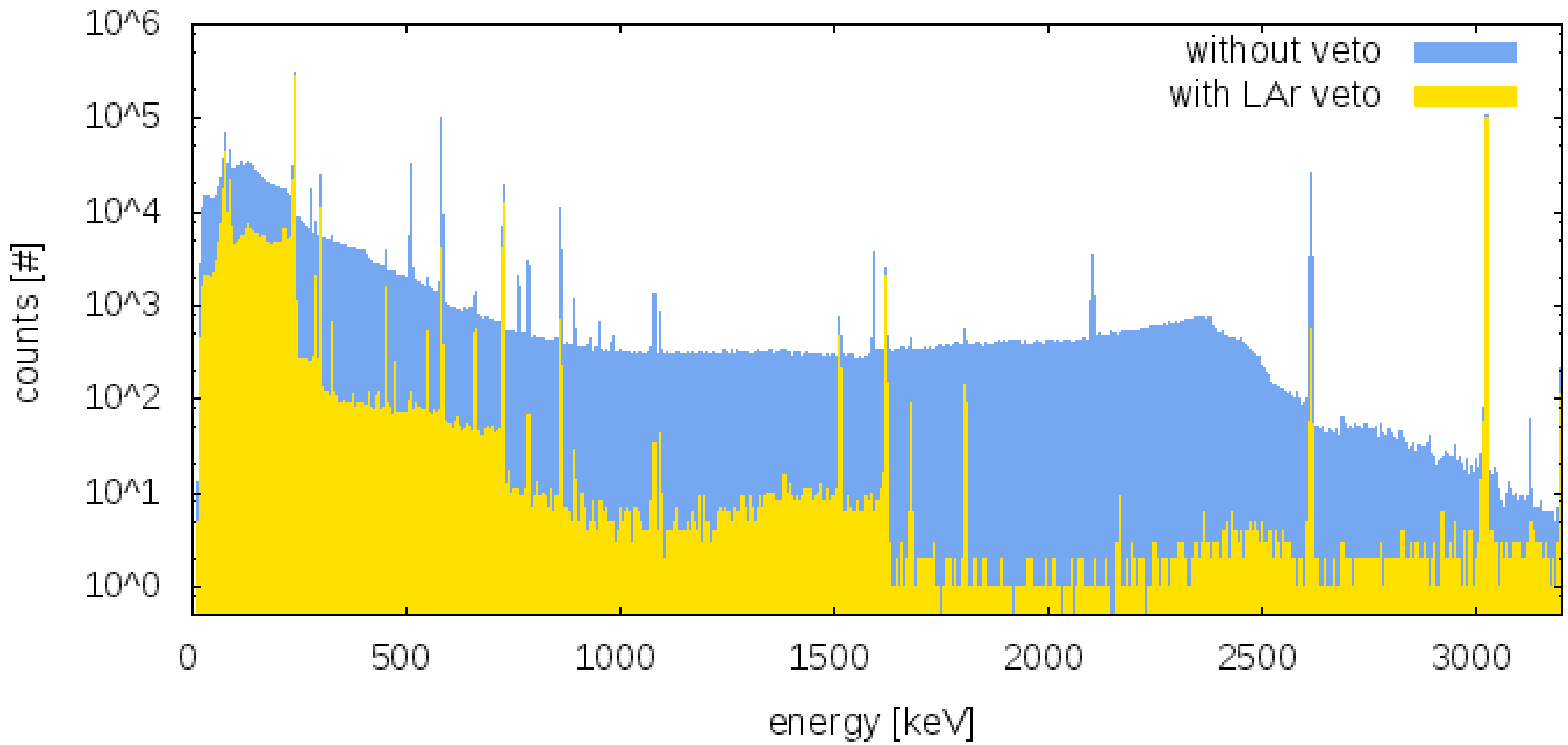
- detector: BEGe

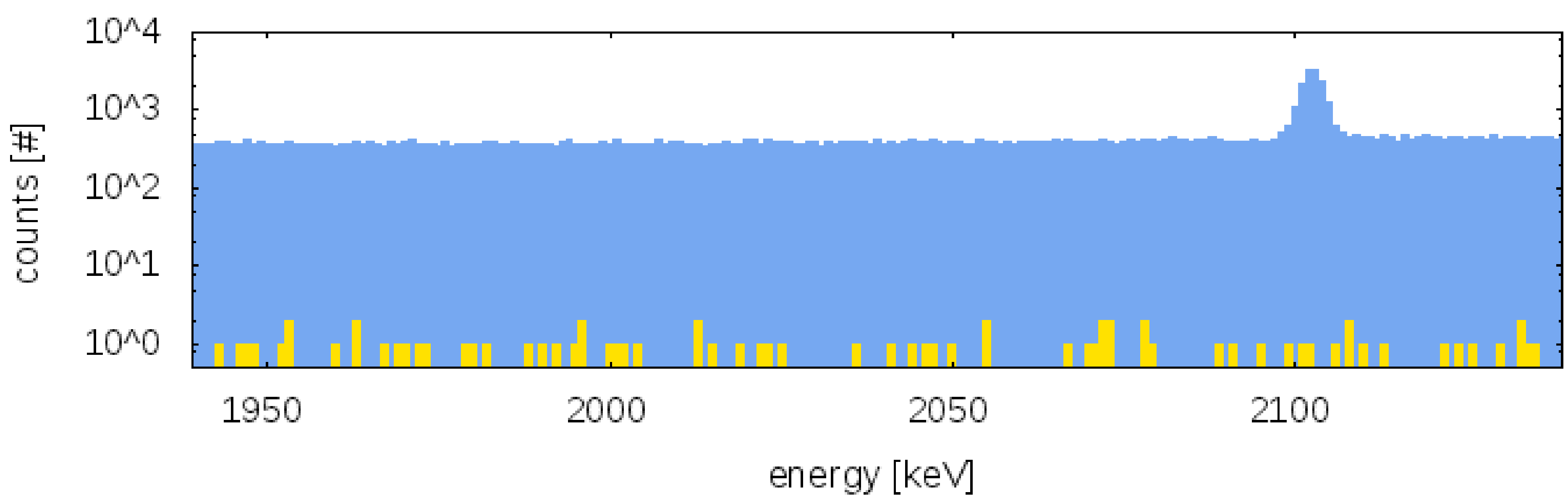


- ^{228}Th source
  distance ~7 cm
- DAQ via FADC

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

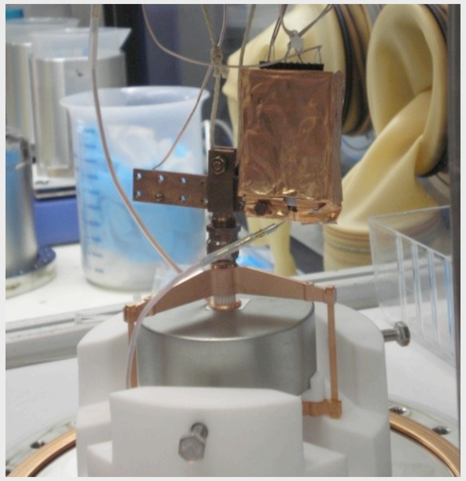
LAr veto ~1200





LArGe, Suppression of internal ^{228}Th

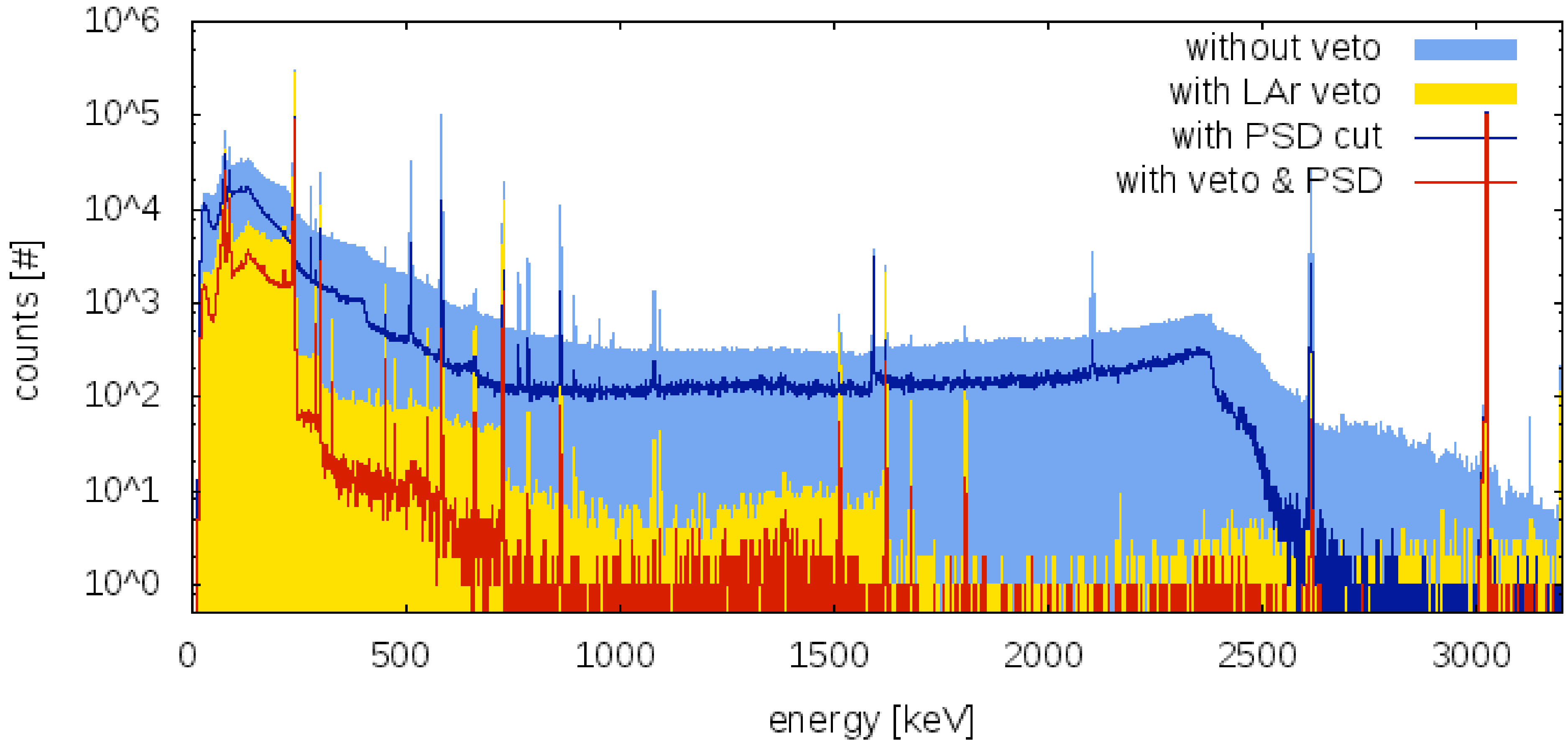
- detector: BEGe

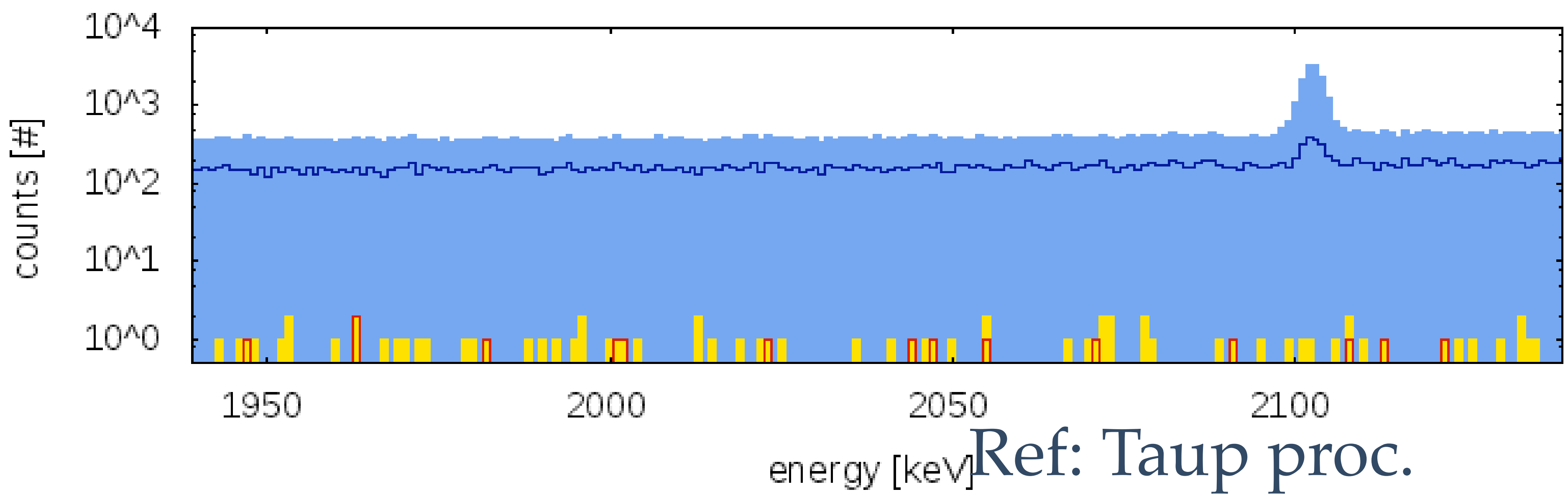


- ^{228}Th source
  distance ~7 cm
- DAQ via FADC

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

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

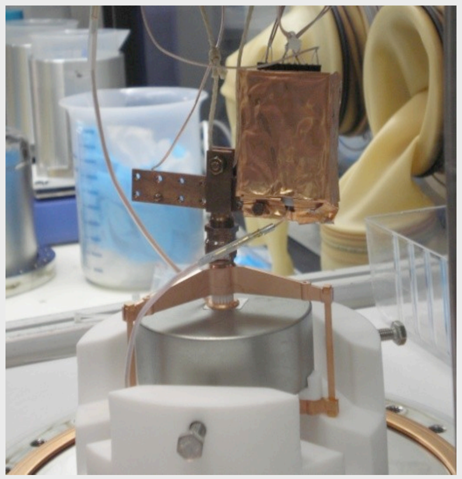




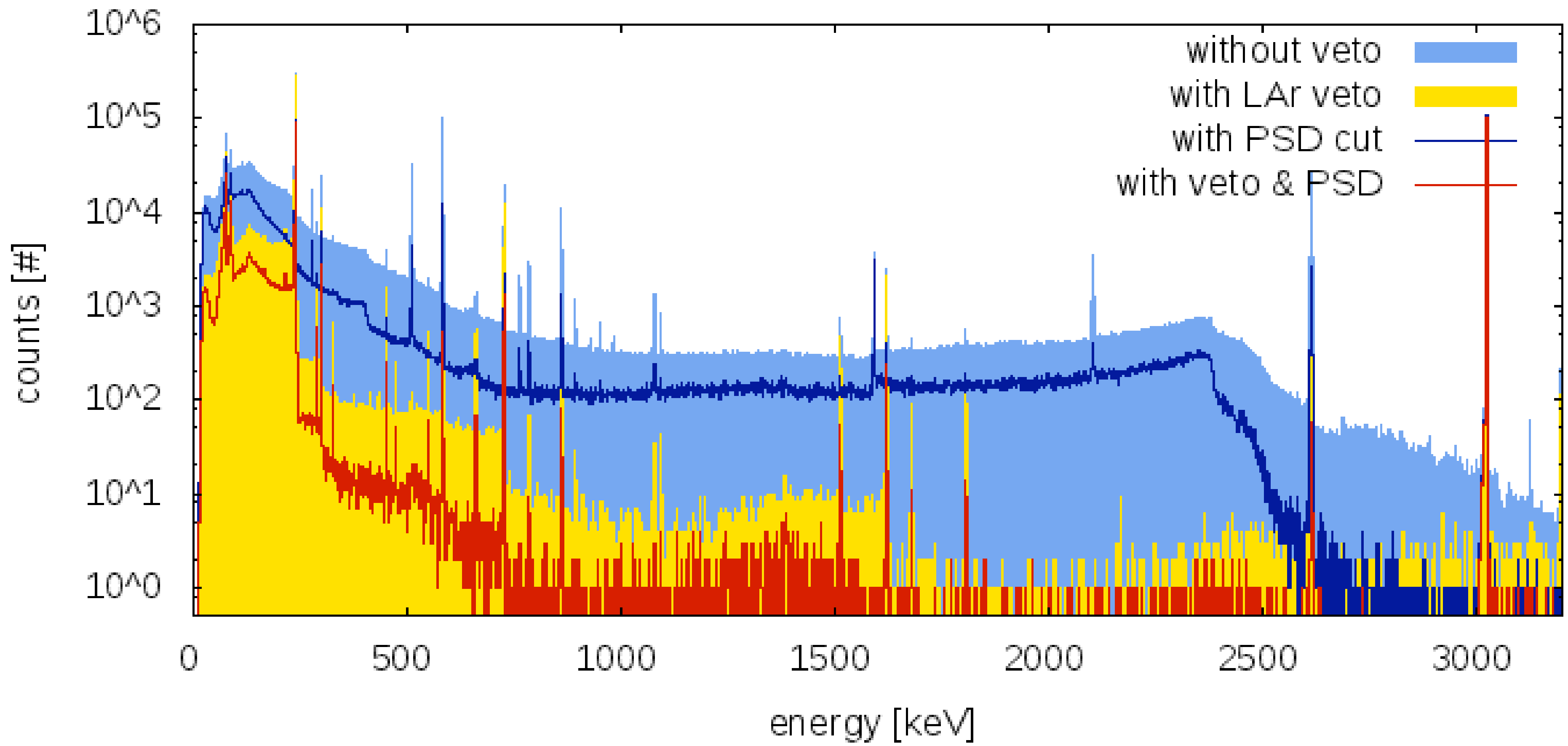
Ref: Taup proc.

LArGe, Suppression of internal ^{228}Th

- detector: BEGe

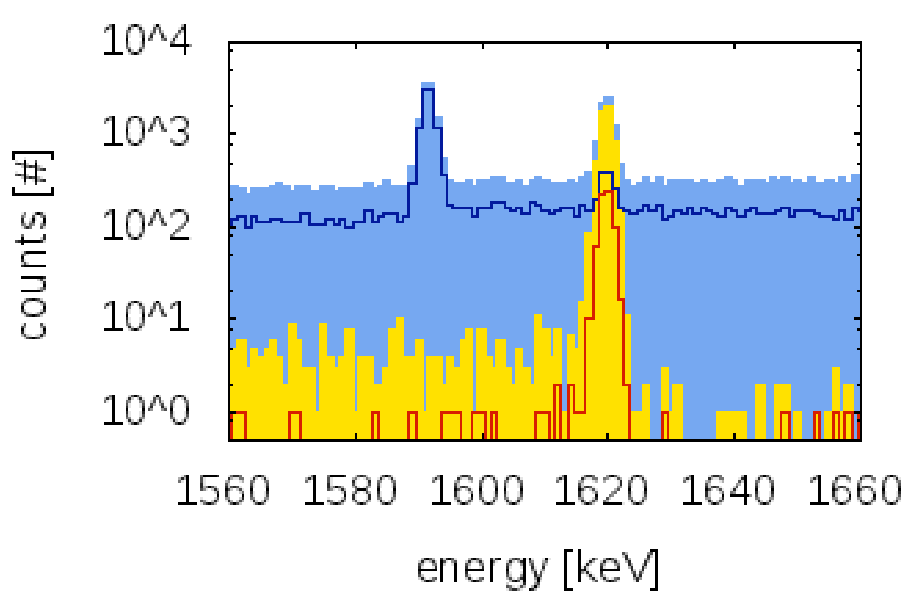


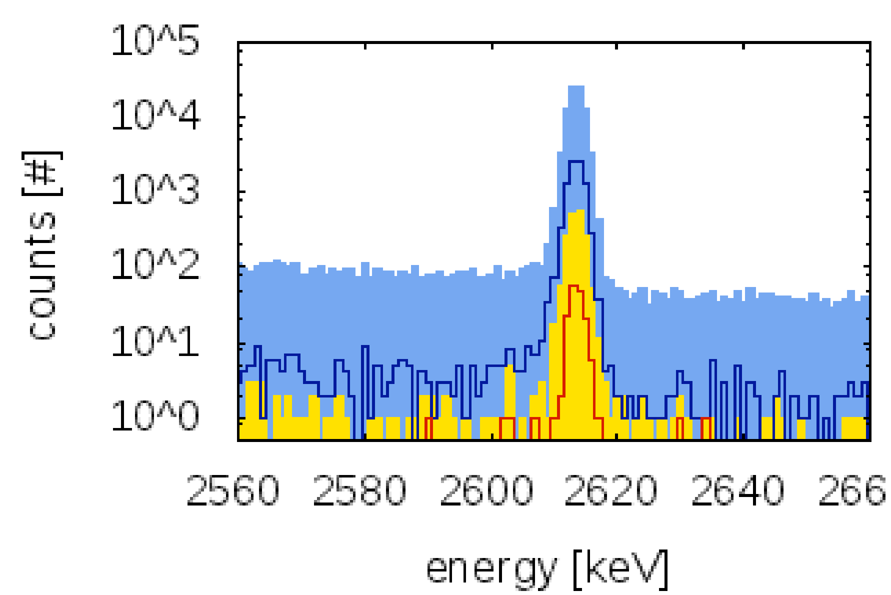
- ^{228}Th source
  distance ~7 cm
- DAQ via FADC



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

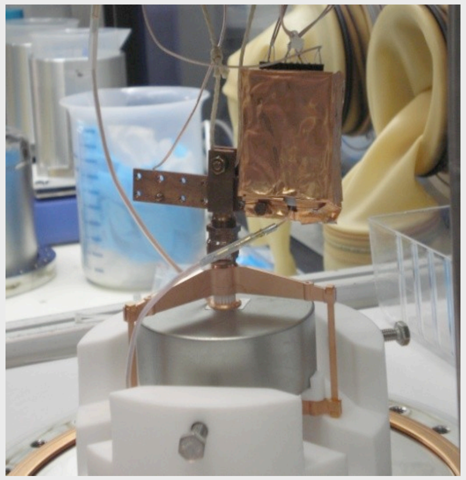
<u>Right:</u>
2615 keV (^{208}Tl)





LArGe, Suppression of internal ^{226}Ra

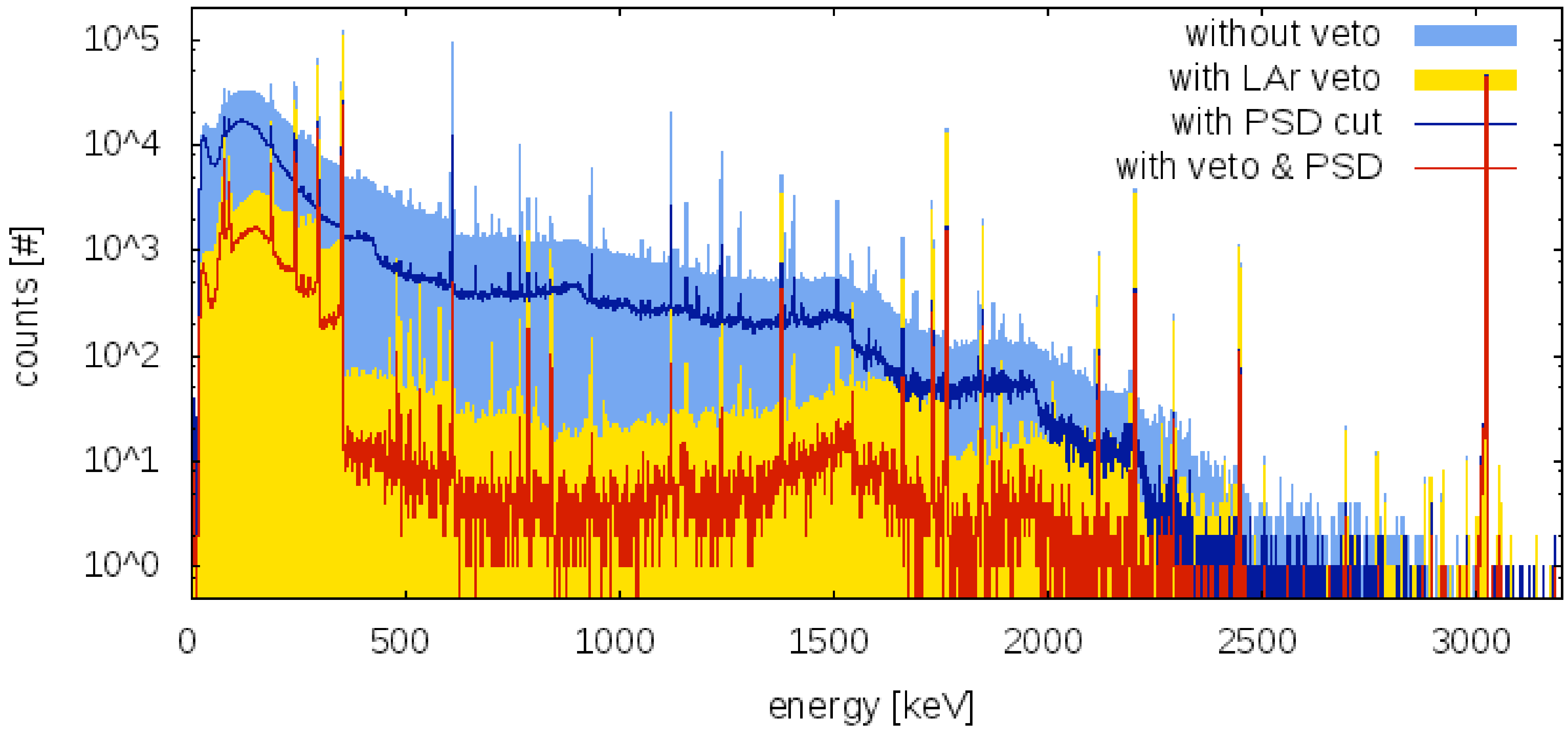
- detector: BEGe

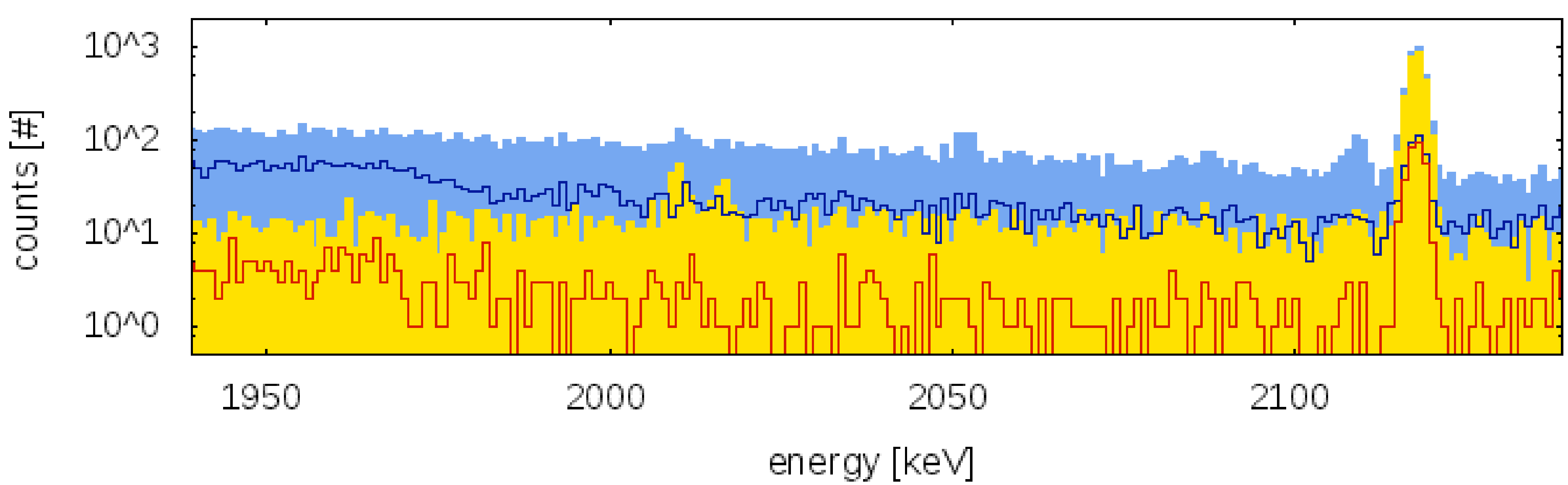


- ^{226}Ra source
  distance ~7 cm
- DAQ via FADC

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

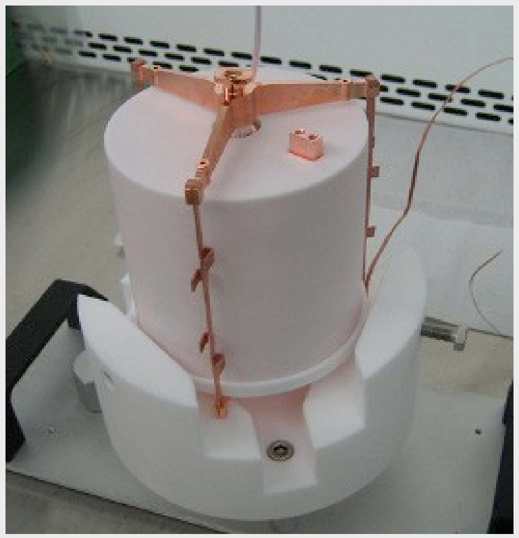
LAr veto	~4.6
PSD	~4.1
veto+PSD	~45



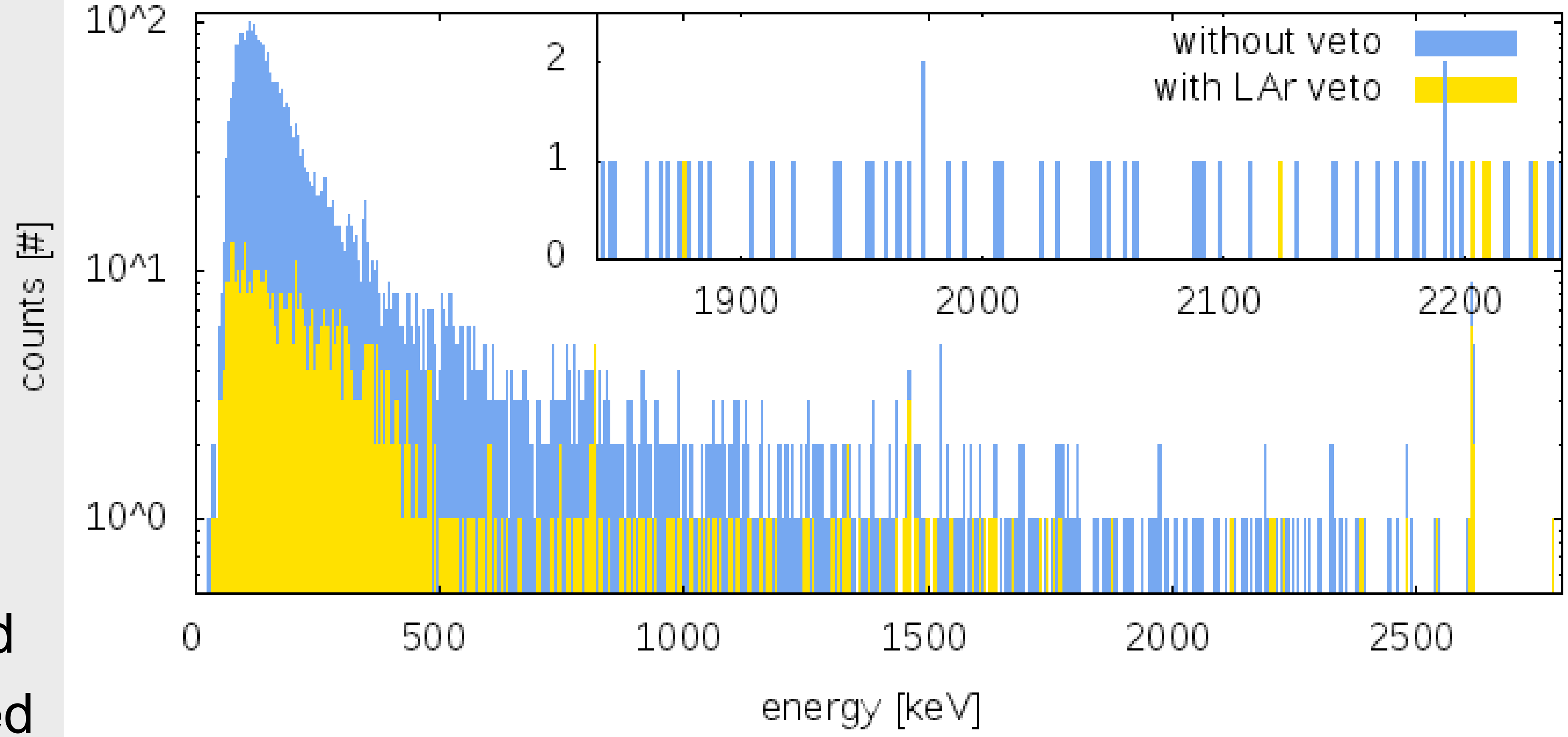


LArGe, Background spectrum

- detector: GTF44 (non-enriched Ge)

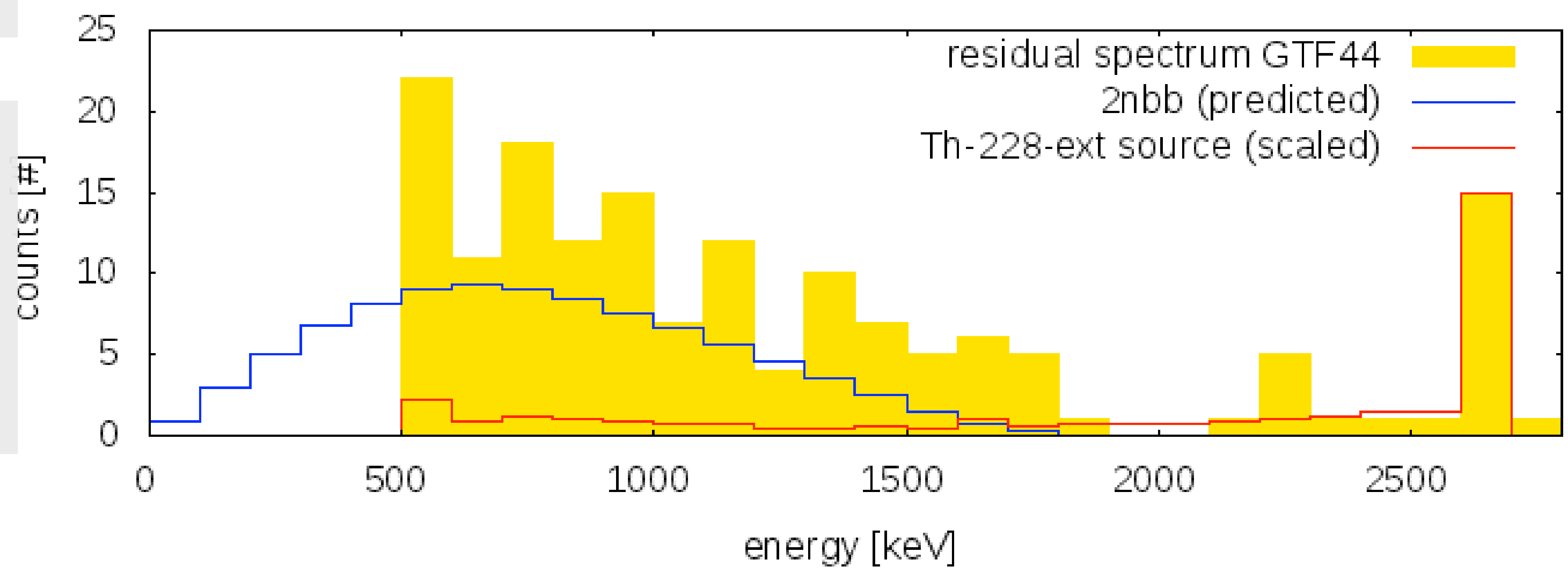


- exposure: 116 kg·d
- shielding unfinished



- background index at $Q_{\beta\beta}$ ± 150 keV:

0.12 – 4.6 · 10^{-2} cts / (keV·kg·y)



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%

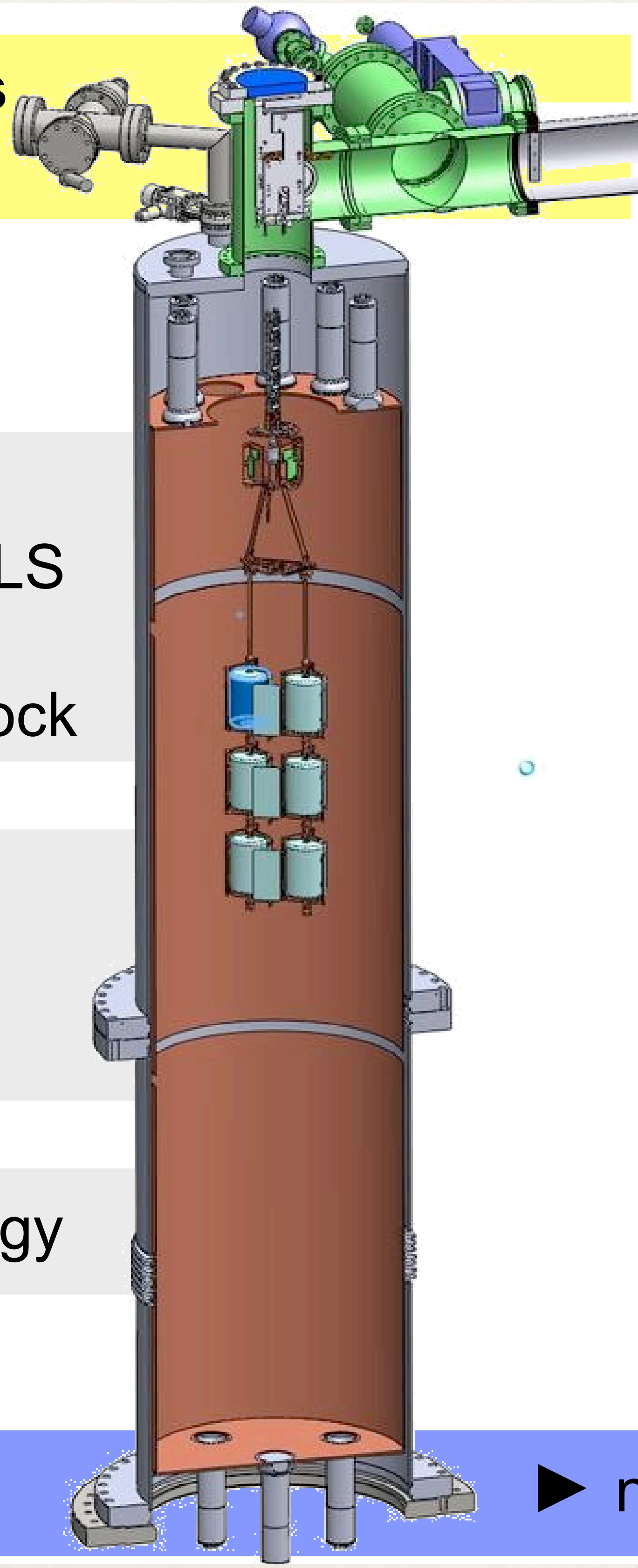
Combined suppression:

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

Ref. M. Heisel, PhD thesis, 2011

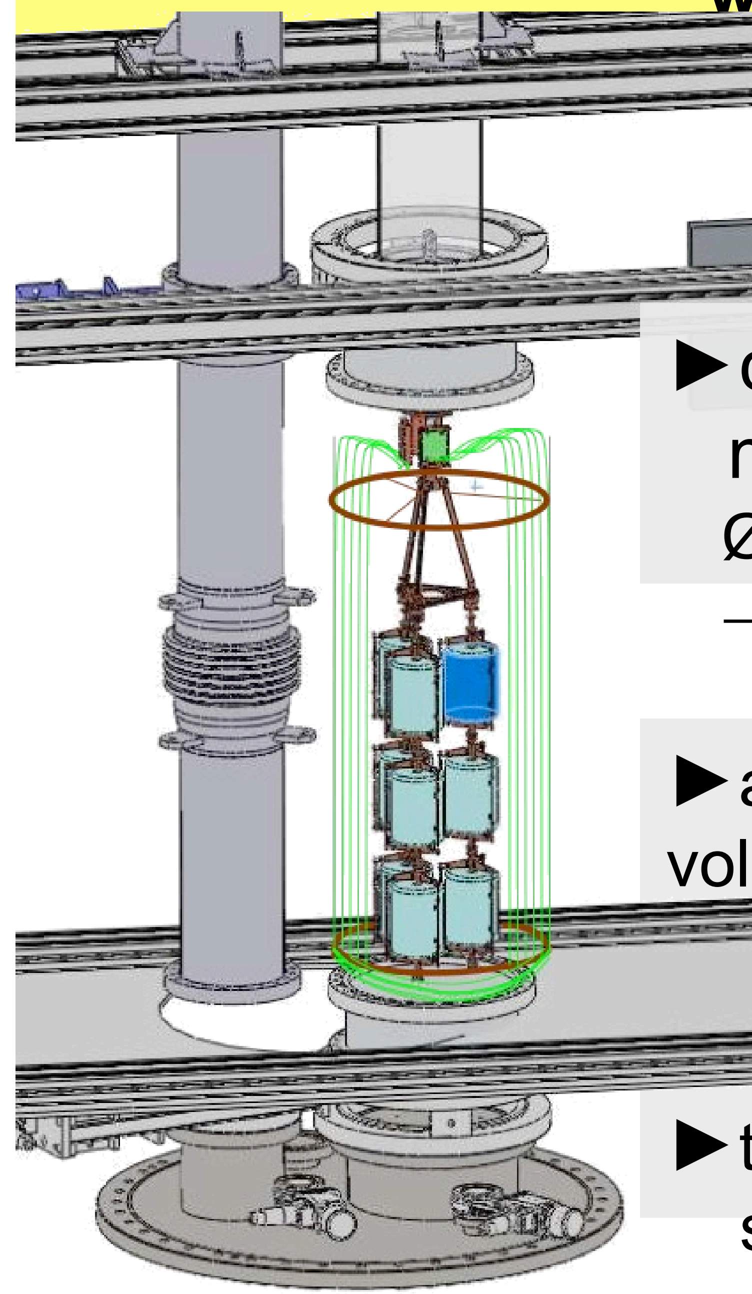
Options for GERDA

design with PMTs



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

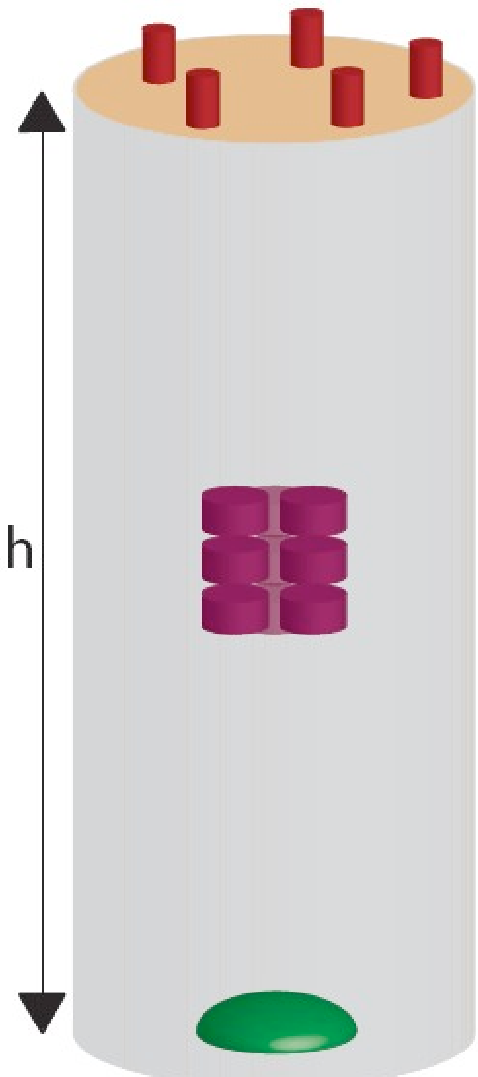
scintillating fibres with SiPM readout



- ▶ closed cylinder
  made of. fibres
  Ø = 250 mm
  → fits present lock
- ▶ active LAr
  volume not confined
- ▶ the least invasive
  solution

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

PMT option - hardware



h = 210 cm

Ø = 50 cm

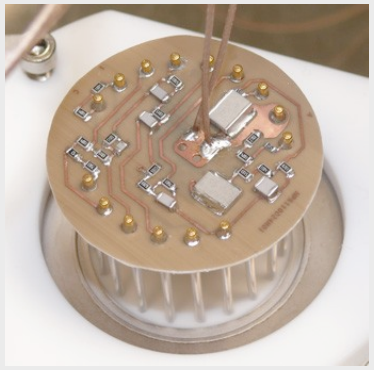
low-background PMTs available:

- ►QE ~25%
- ►LAr teststand at MPIK

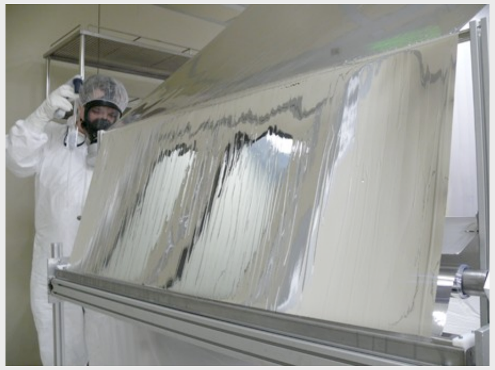
	R5912-02 MOD (8-inch)	R11065-10 MOD (3-inch)
activity ^{228}Th:	165 mBq/PMT	1.0 mBq/PMT
^{238}U:	374 mBq/PMT	<0.94 mBq/PMT

voltage dividers

→ low-bg CuFlon-based



VM2000 reflector foil
+ wavelength shifter (TPB)



Wavelength shifter - Basic Idea

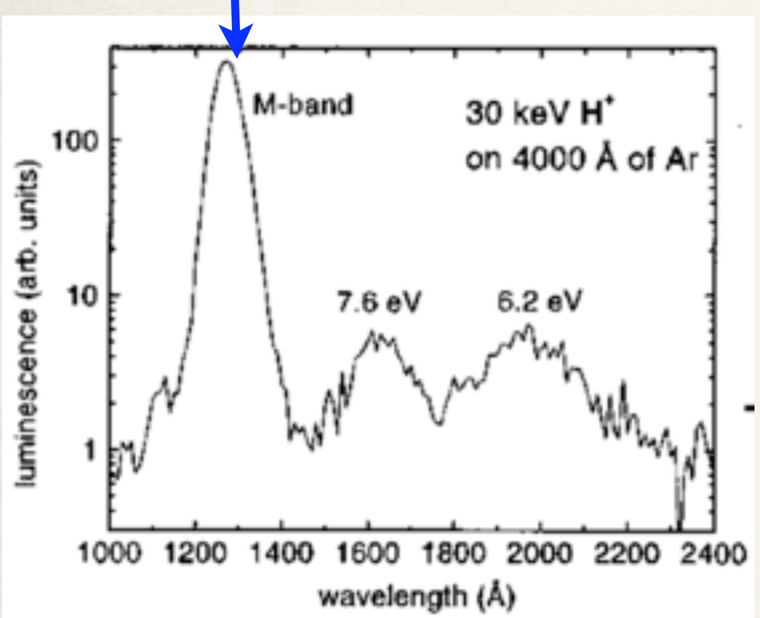
TPB

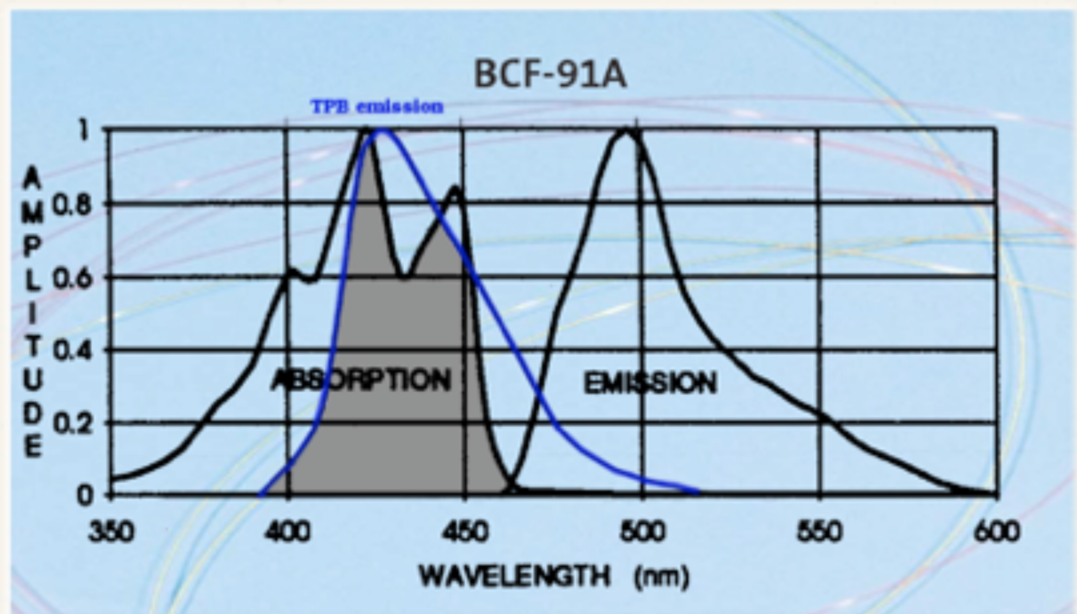
128 nm (VUV) → 430 nm

→ Detected with PMT

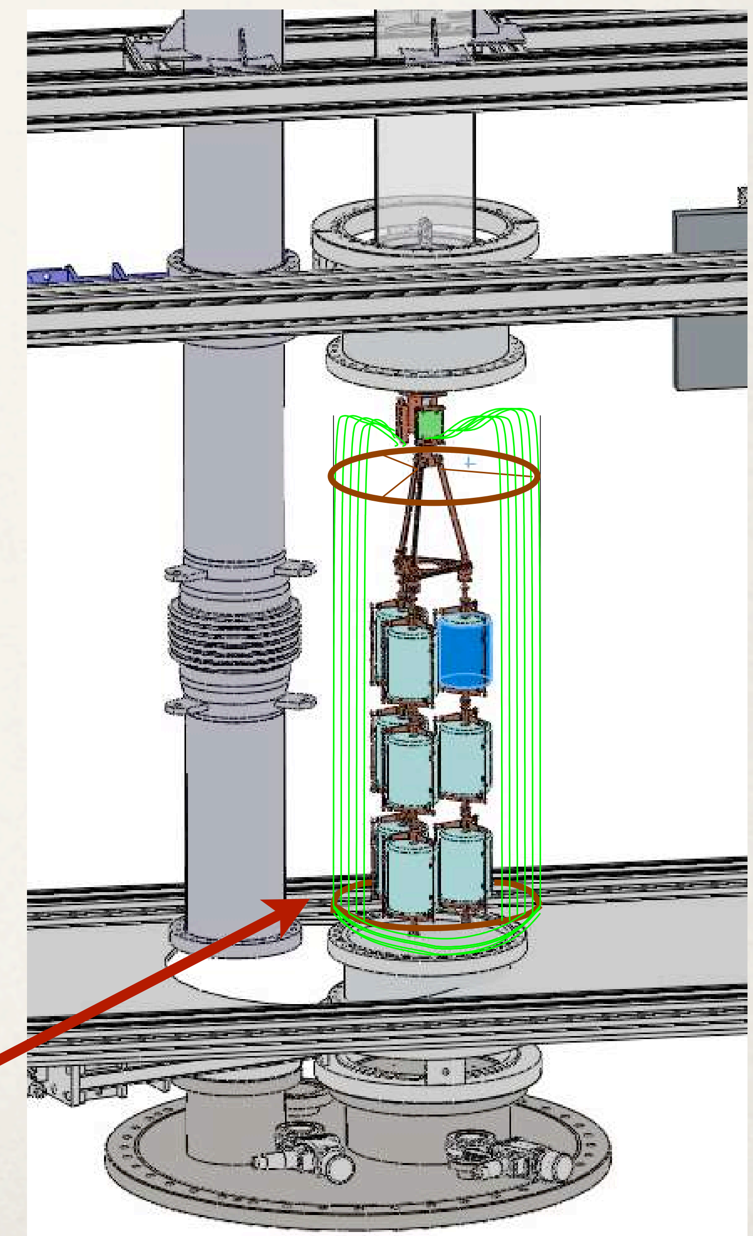
→ Collected with WLS fiber

Emitted





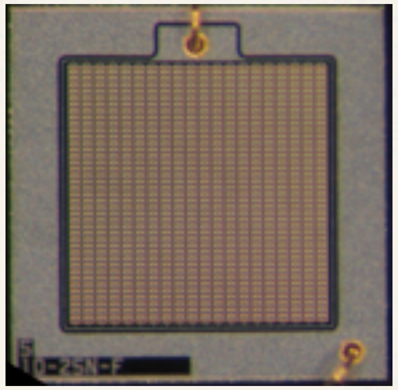
Inefficient (~50%), but it works

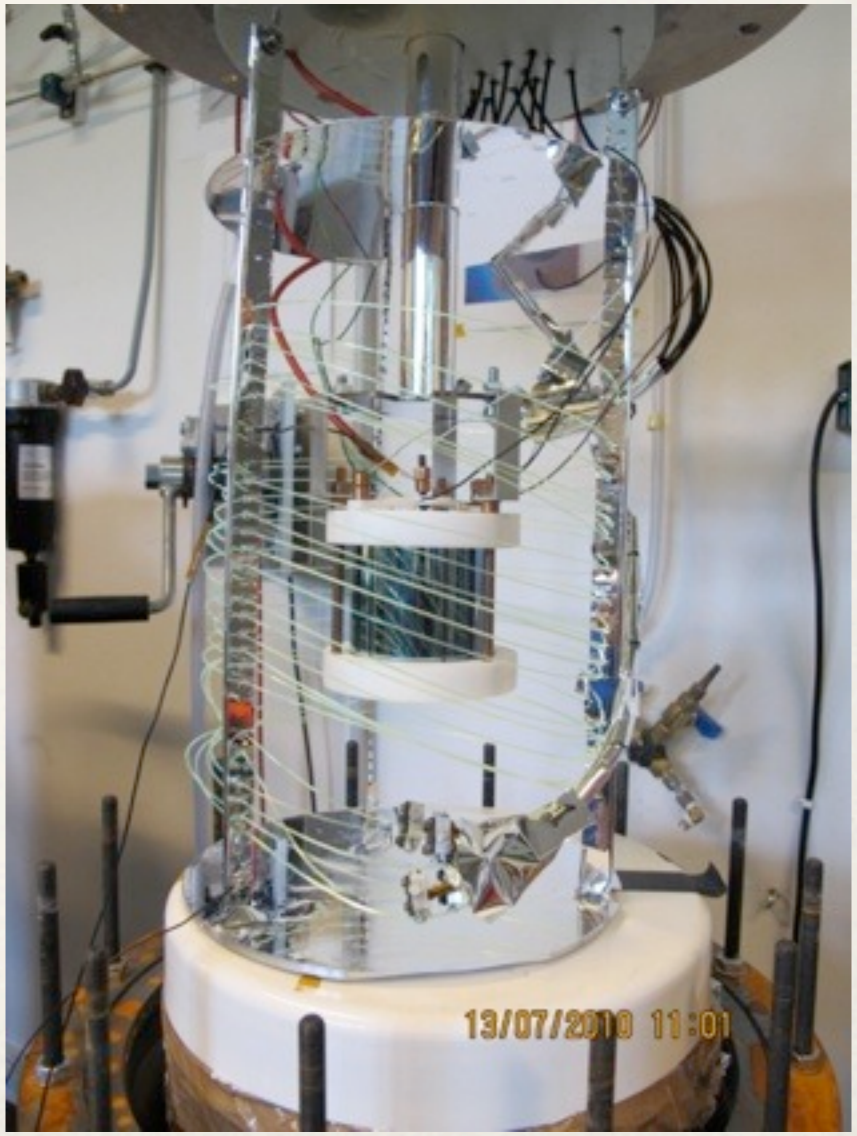


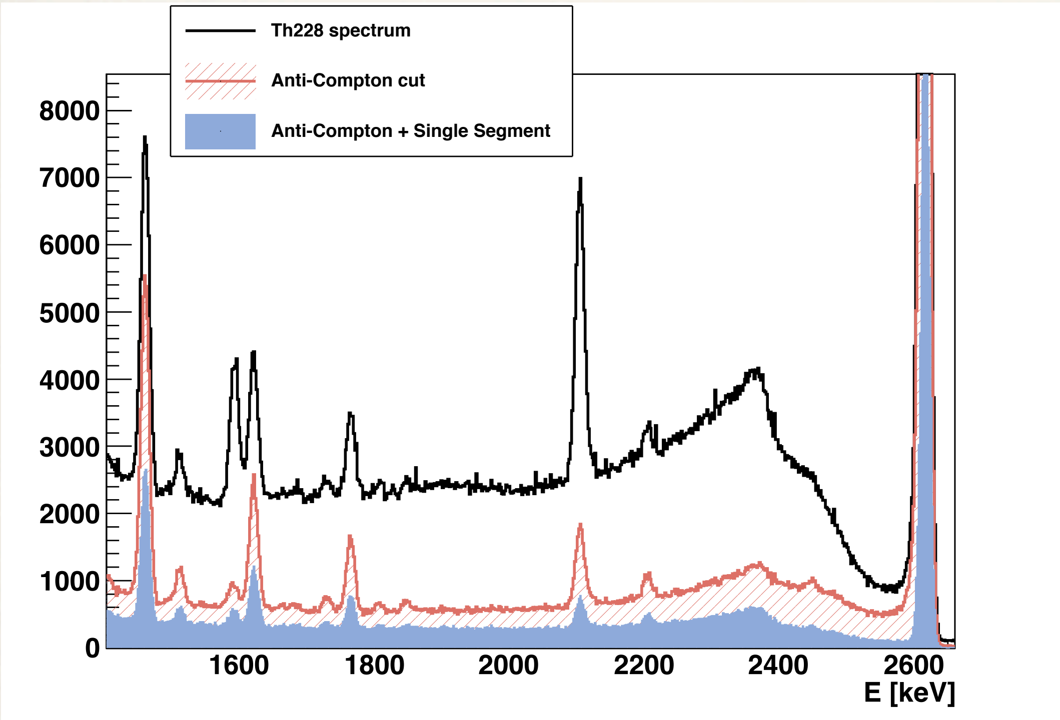
WLS Fiber coated with TPB

SiPM + WLS fiber design

- Idea was tested at small scale
- SiPMs work at cryogenic temperatures
- TPB + WLS fiber concept works







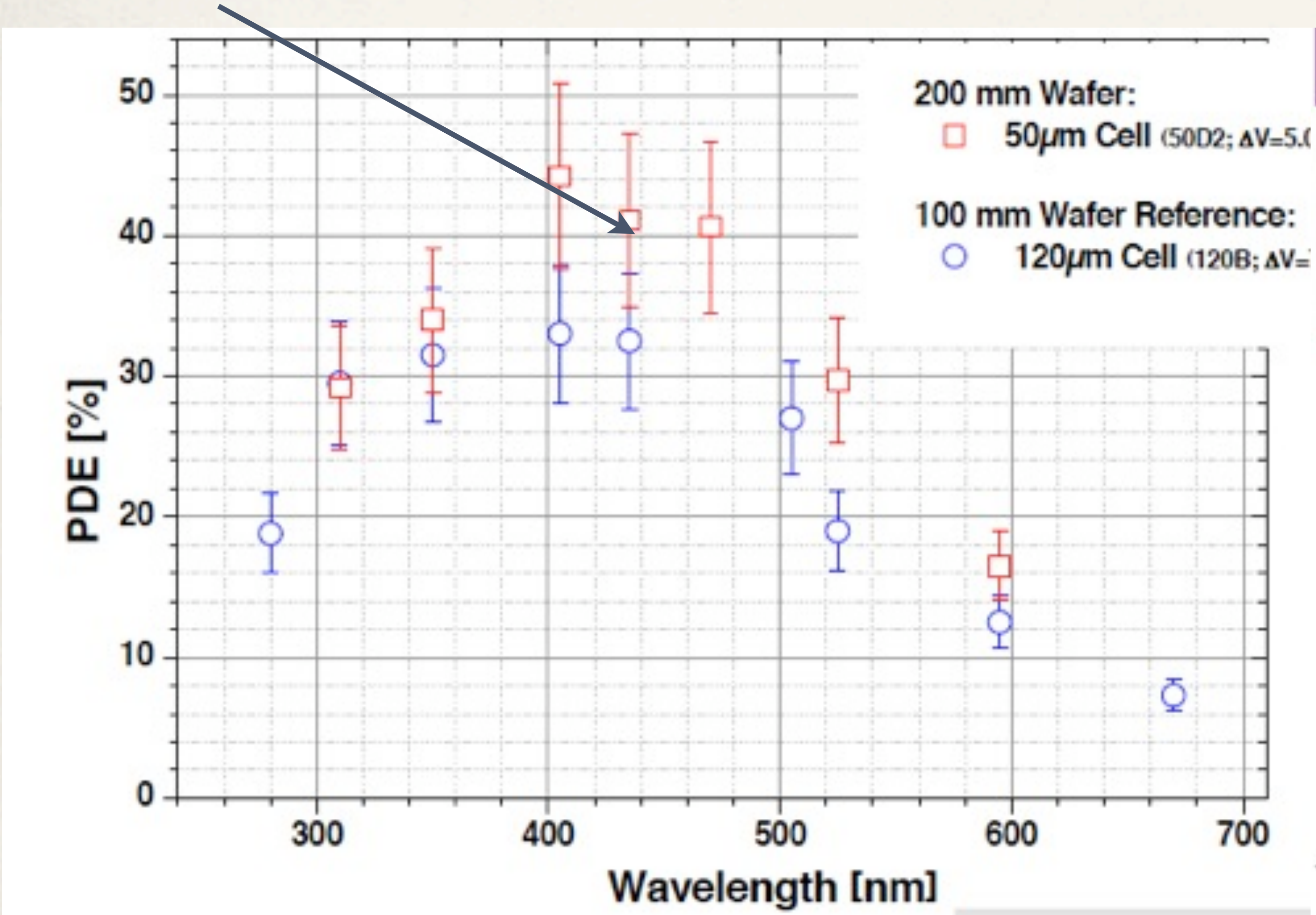
Ref: NIM A 654 (2011), pp. 225-232

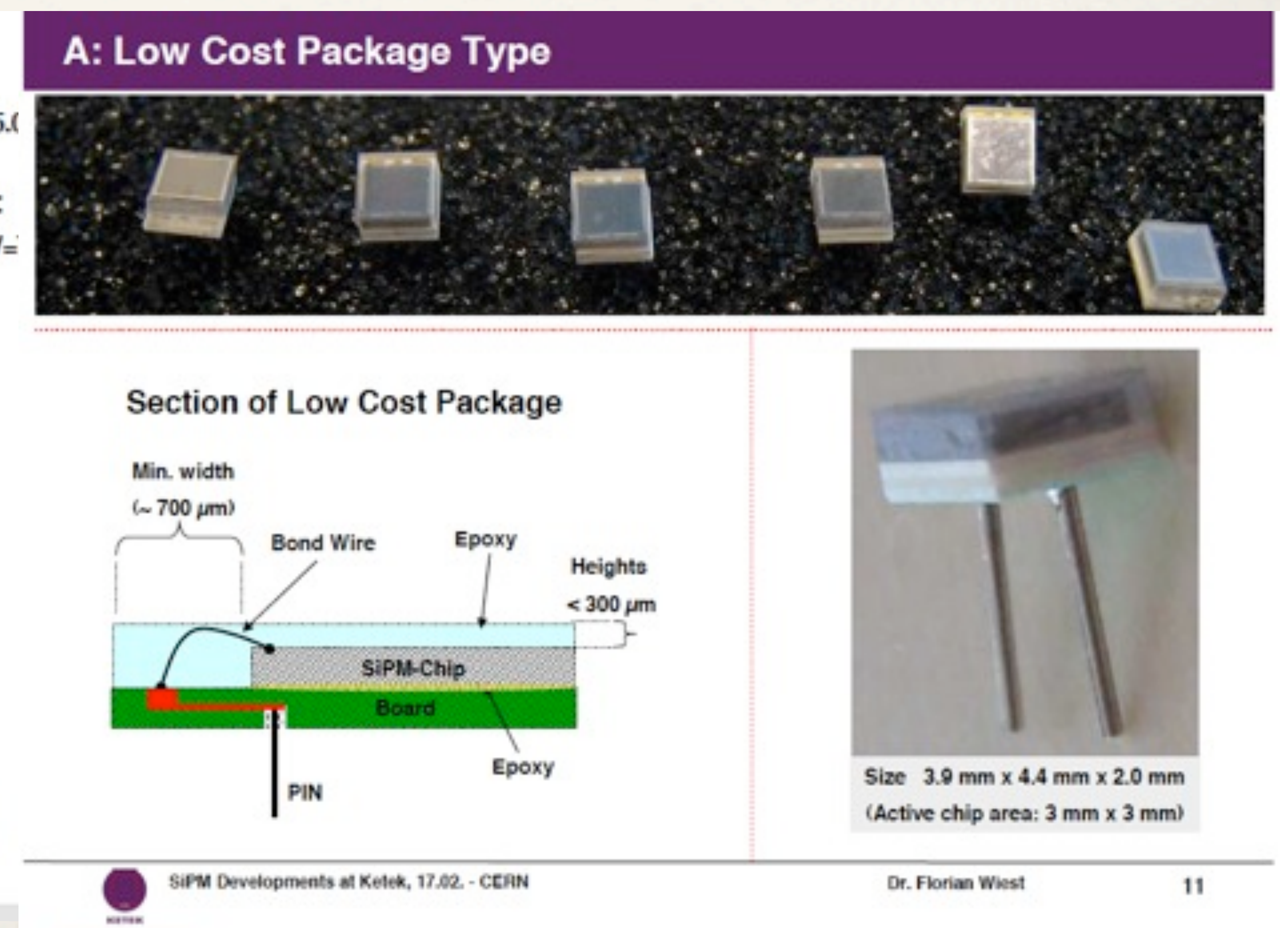
SiPMs

- Ketek GmbH Munich based company. Willing to sell SiPMs in ‘die’.
- Purchased 100 pieces. Already delivered. (~60 needed)

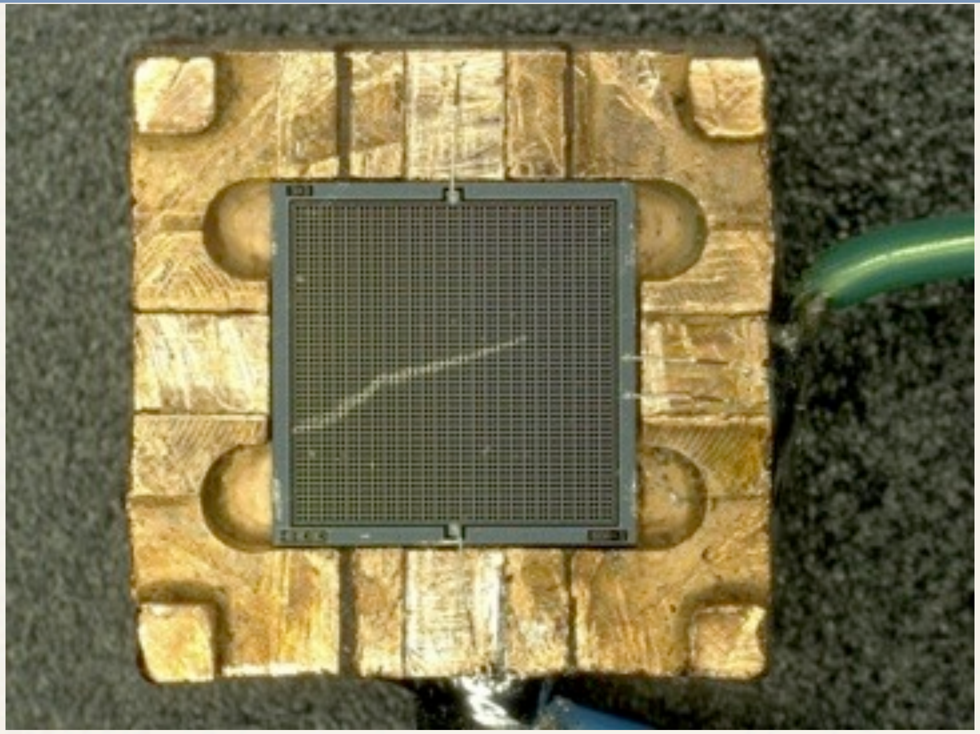
http://indico.cern.ch/getFile.py/access?contribId=23&sessionId=3&resId=0&materialId=slides&confId=117424

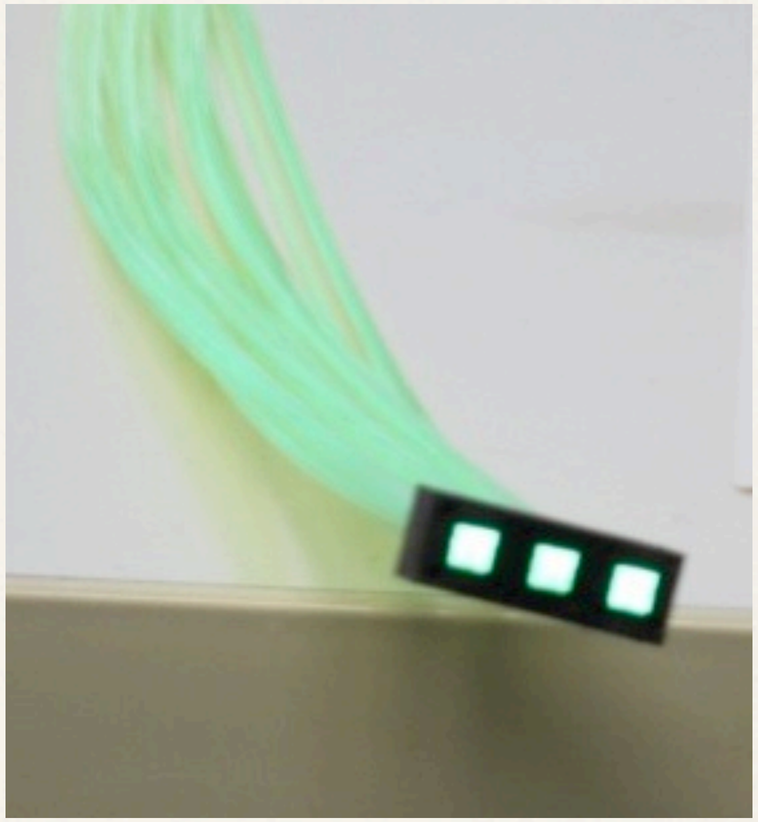
PDE

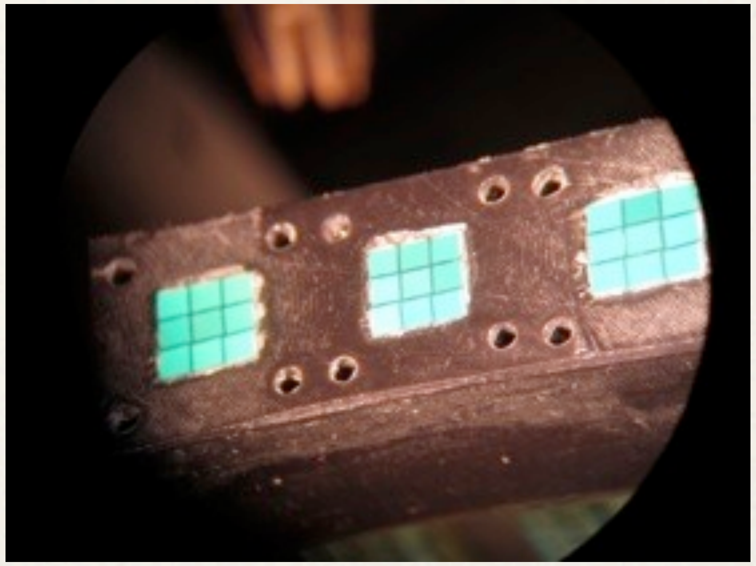




SiPM holder







- SiPM delivered in 'die', low background packaging is developed
- 9 fiber coupled to 1 SiPM
- units of 27 fibers = 38 mm x 2 , full coverage = 10 strips , manageable quantity

Induced background

ICPMS results: WLS fiber measured at LNGS

Element	Conc.	Activity Bq/kg	Background cts/(keV kg Year)
K	15 ppb	4.6×10^{-4}	-
Th	14.3 ppt	5.8×10^{-5}	8×10^{-4}
U	3.4 ppt	4.2×10^{-5}	7.9×10^{-5}

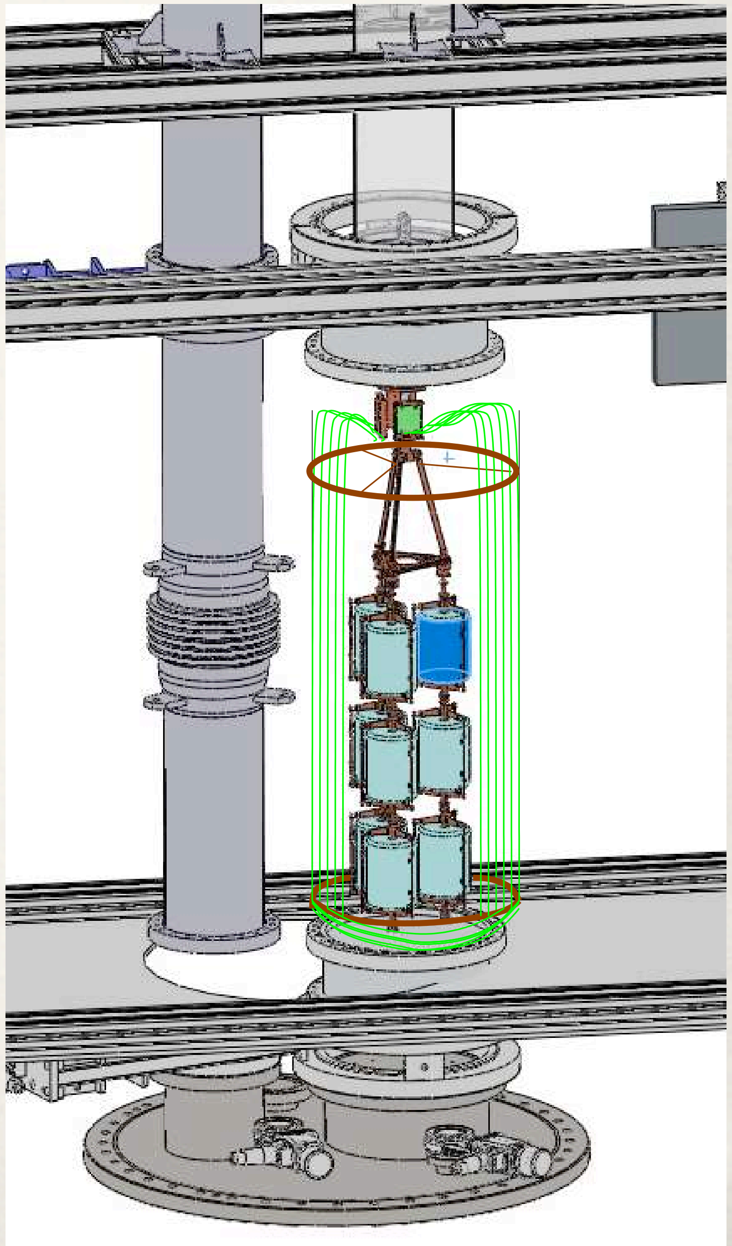
- The whole setup consists of about 0.5 kg fiber (2 m^2 photon detector)
- Relevant activity: $\mathcal{O}$(~10 μBq)
- Compatible with the background goal of GERDA Phase II

Expected Suppression Factors

- Fibers are sensitive also on the outer side ($E_{inside} + \Omega^* E_{outside}$) > $E_{eff.thr.}$
- Nearby source: Simulated in the copper holder of the Ge detectors
- External source single gamma (2.6 MeV) hitting the array
- At least 10x suppression expected

Threshold keV	Internal Tl208	external Tl208	Tl208 in fiber	Bi214 in fiber
10	40.7	61.6	4863	12.0
100	13.0	11.2	503	4.1
130	10.0	7.6	286	2.9

suppression factors for different thresholds, only energy deposited in LAr, no delayed coincidence



Summary - Outlook

- Significant reduction of the background was demonstrated
- LAr instrumentation will be implemented in GERDA
- Two competing concepts are being developed
- To be deployed in Phase II