GERDA and Photosensors

Peter Grabmayr

Kepler Center for Astro and Particle Physics
Eberhard Karls Universität Tübingen
Germany

Deutsche Forschungsgemeinschaft DFG

bmb+f - Förderschwerpunkt Astroteilchenphysik Großgeräte der physikalischen Grundlagenforschung

INFN Istituto Nazionale di Fisica Nucleare

Russia
Poland
Belgium
Switzerland

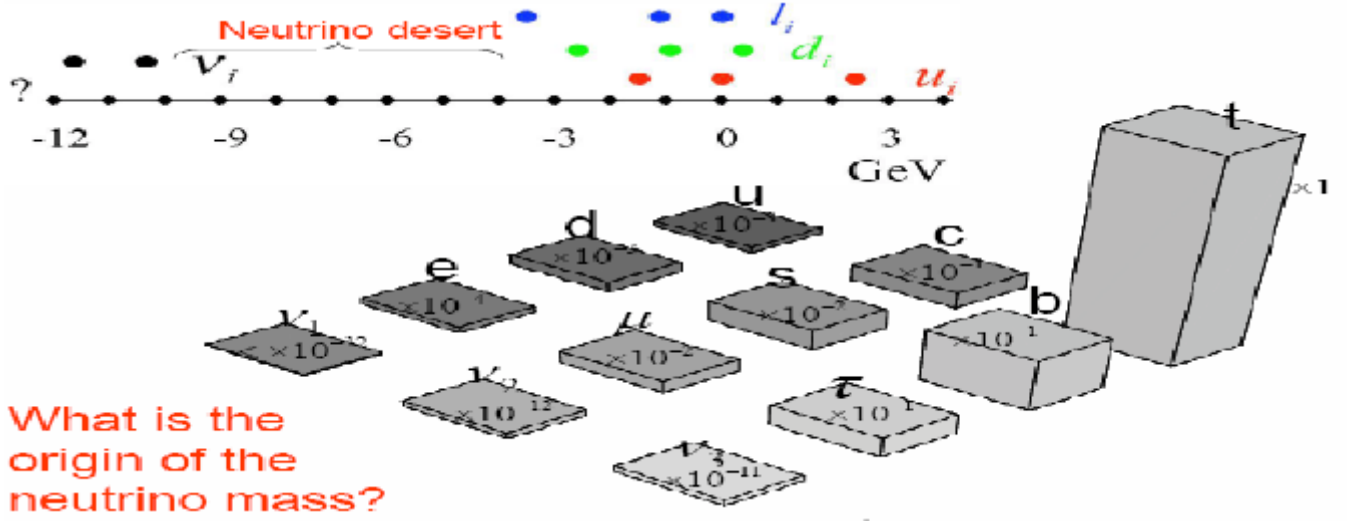
neutrino mass

Oscillations: neutrinos have finite mass !

Neutrinos: are they Dirac or Majorana particles ?

What is the origin of the neutrino mass ?

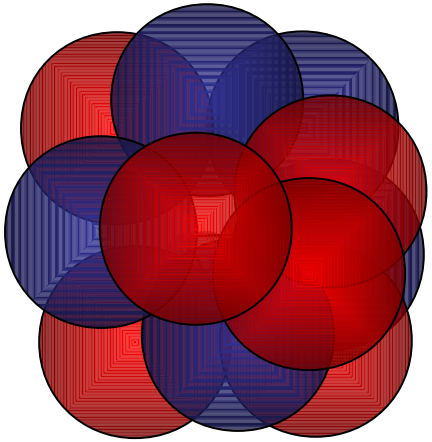
Masses in the Standard Model SUSY / Higgs

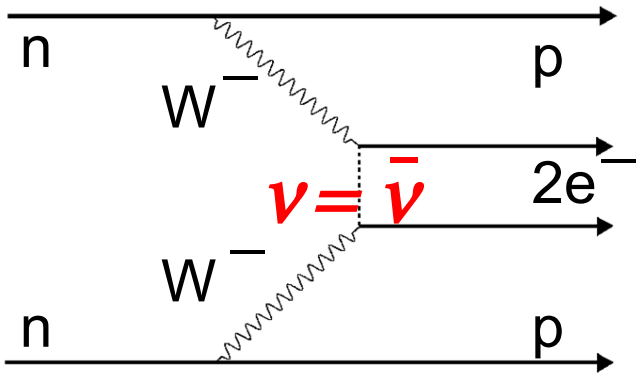


neutrinoless double beta decay

2nd order allowed weak process

$(A,Z) \rightarrow (A,Z+2) + 2\,e^-$ $\quad (0\nu\beta\beta)$





signature →

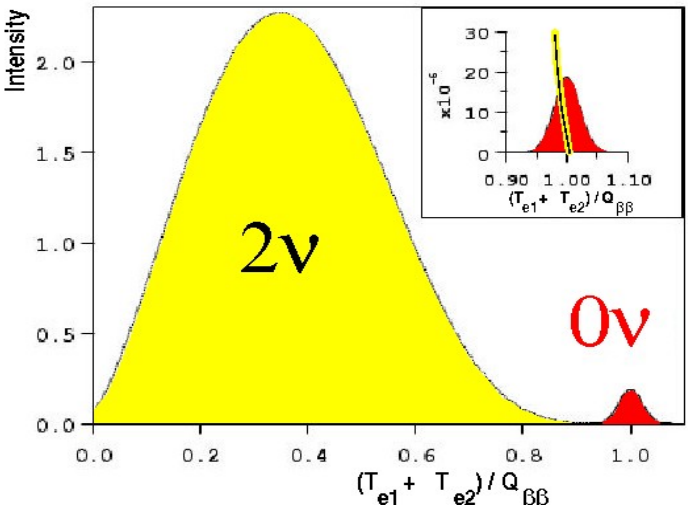
signature →

Gamow-Teller and Fermi

$$\left| M_F - (g_a/g_v)^2 M_{GT} \right|^2$$

Neutrino = Anti-Neutrino
(Majorana type)

- must have finite mass
- violation of lepton number conservation $\Delta L=2$



back of the envelope

assume background free experiment with $T_{1/2} >> t$

For half-lifes of $T_{1/2} = 10^{25}$ yrs

$N_{\beta\beta} / t = 1$ event / yr

$$T_{1/2} = \ln 2 \cdot (N_A / A) \cdot M \cdot (N_{\beta\beta} / t)^{-1}$$

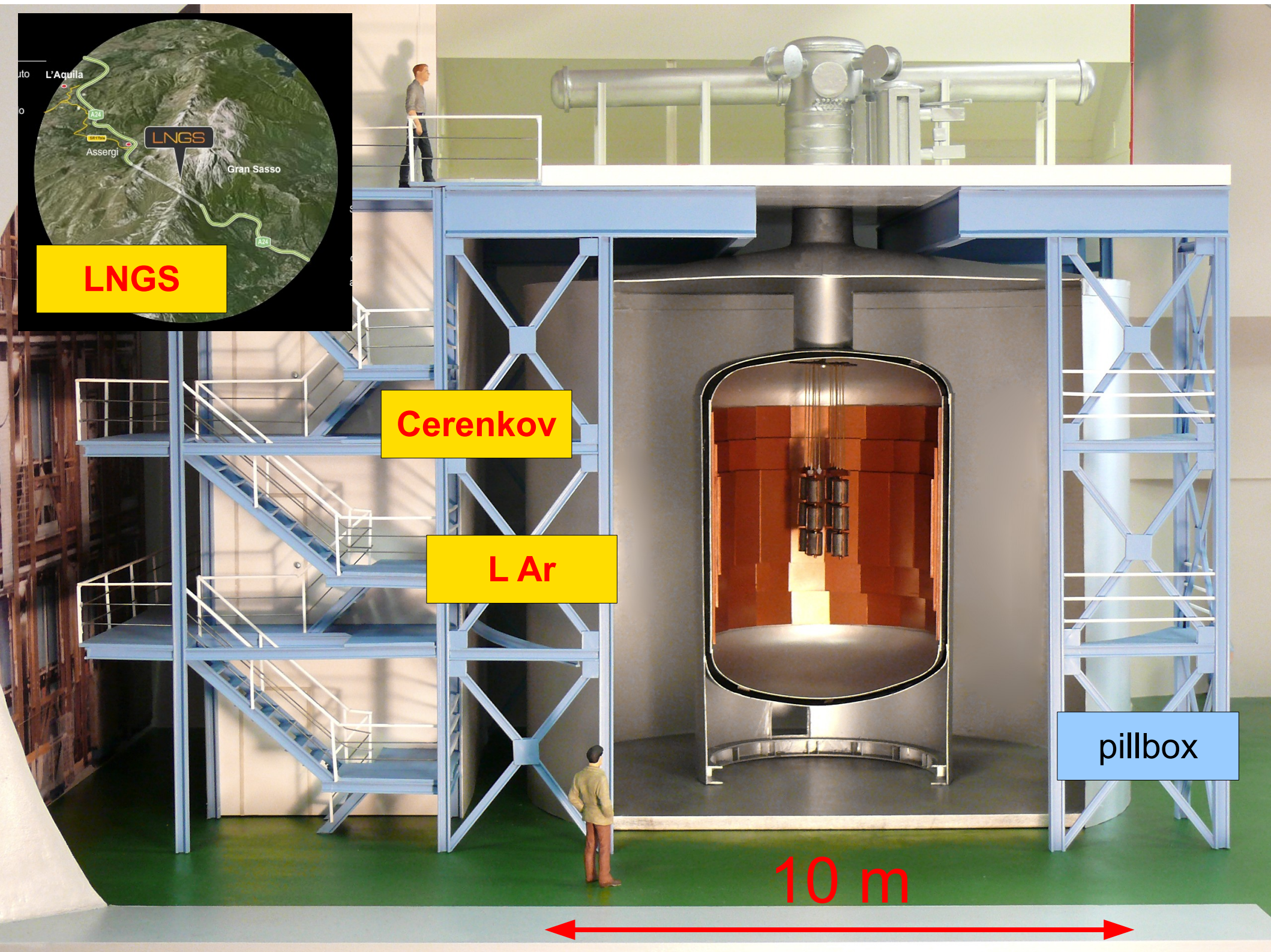
This is about 10 moles of isotope, implying ~kg

for ^{76}Ge : 2,1 kg @ 86% enriched

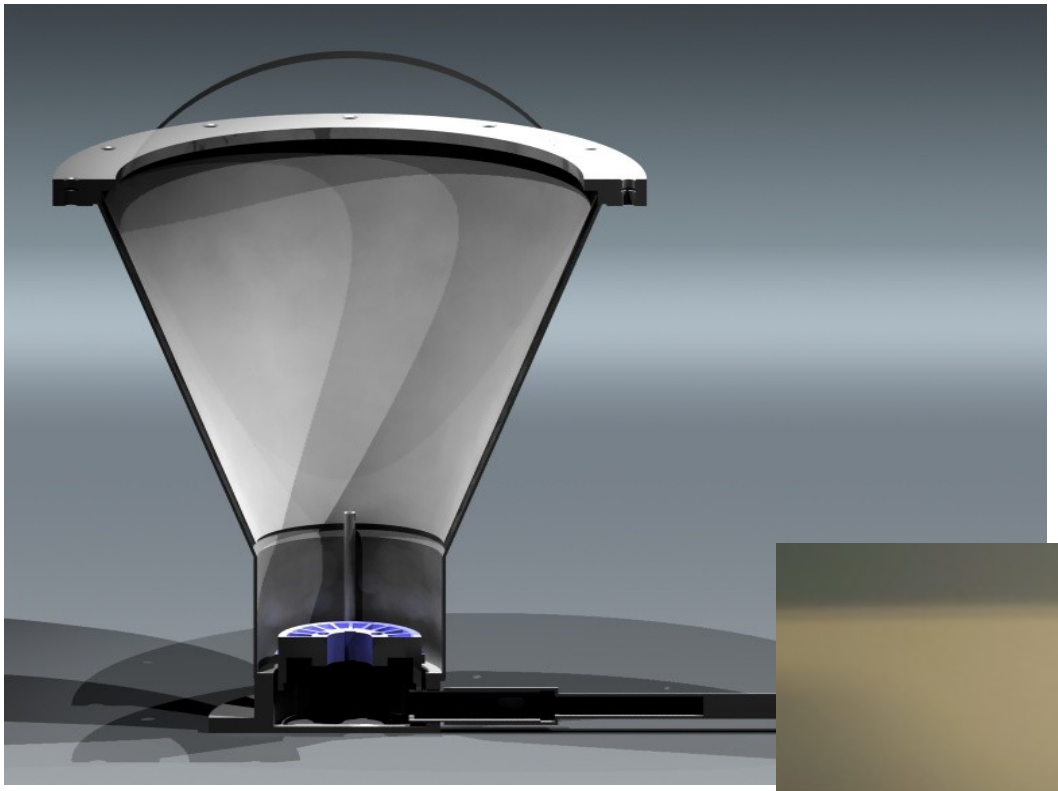
Now you only can loose:

nat. abundance a, efficiency ε, background B, ...

1g GeO_2 for 50 €

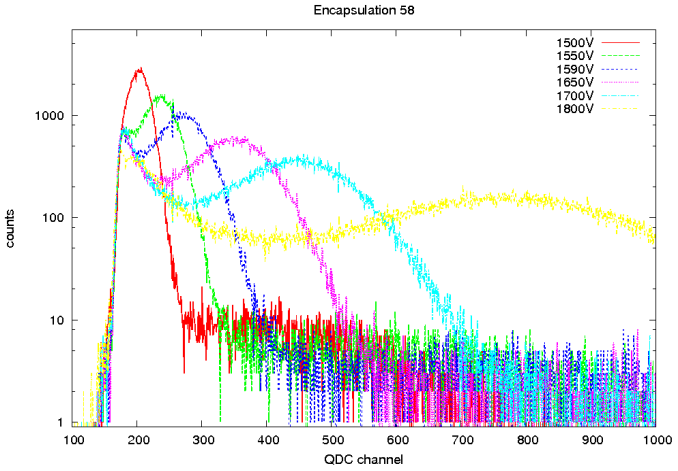

L'Aquila
A24
LNGS
Assergi
Gran Sasso
A24
LNGS
Cerenkov
L Ar
pillbox
10 m

Cerenkov muon veto in water tank

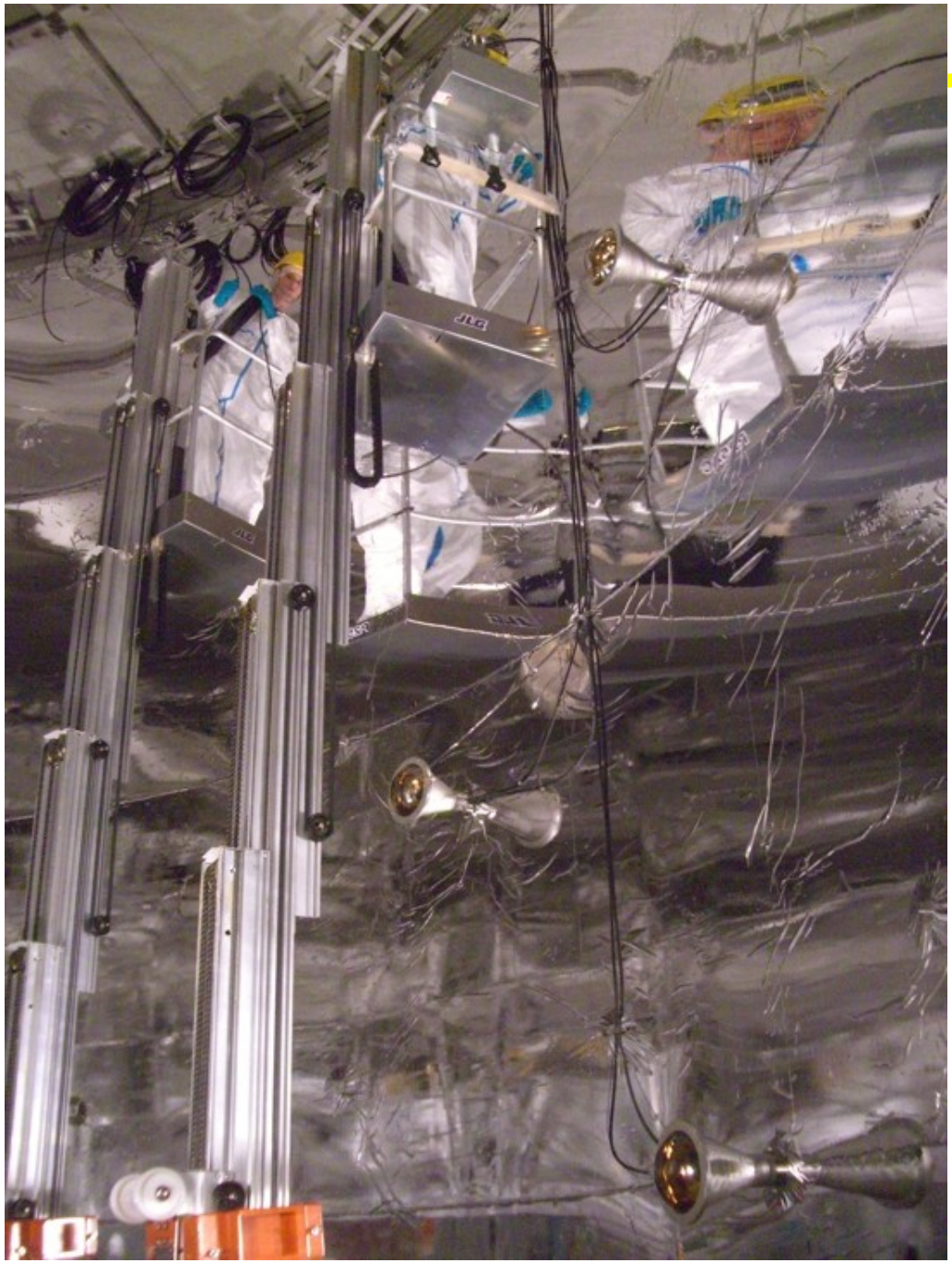


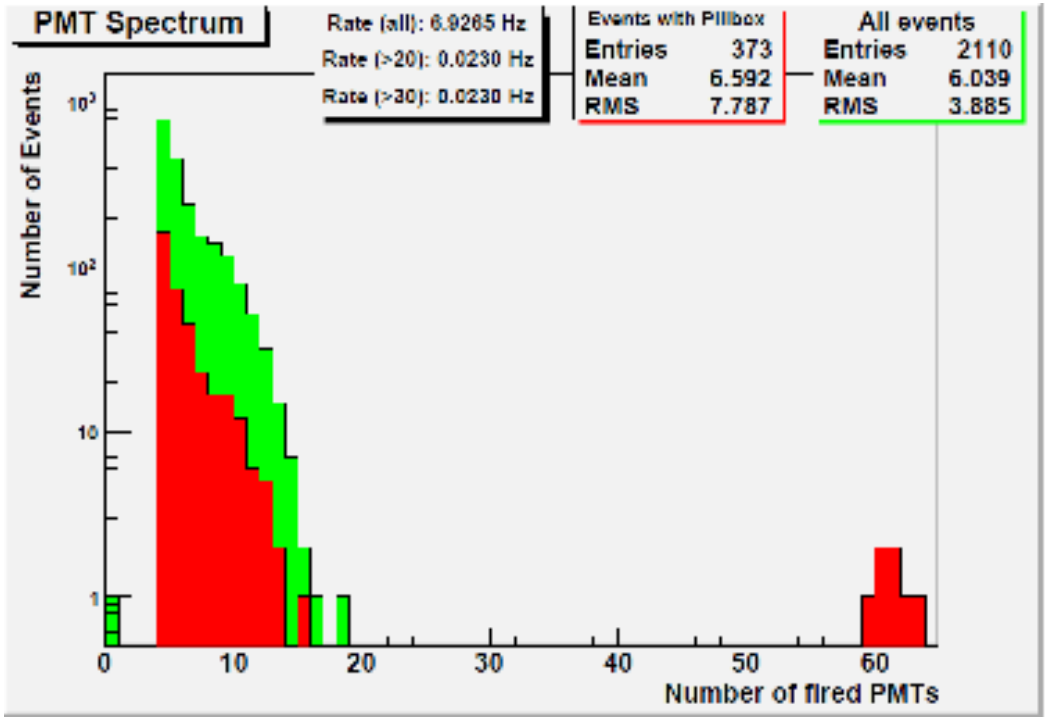
ETL9350
ETL9354

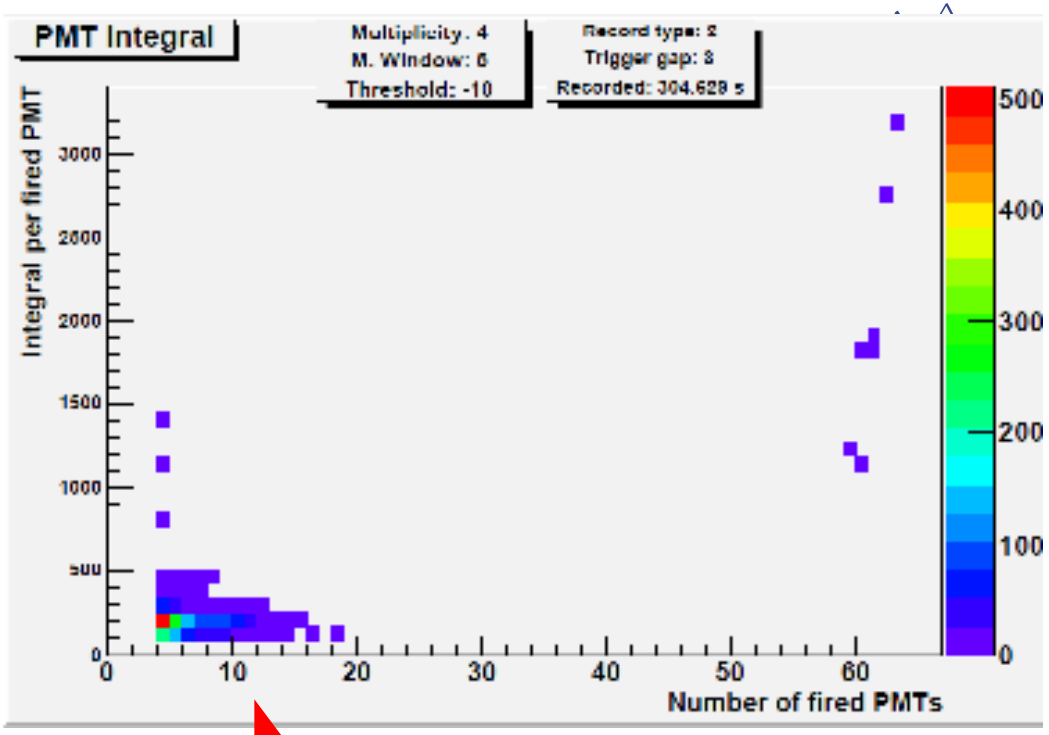
8"



VM 2000



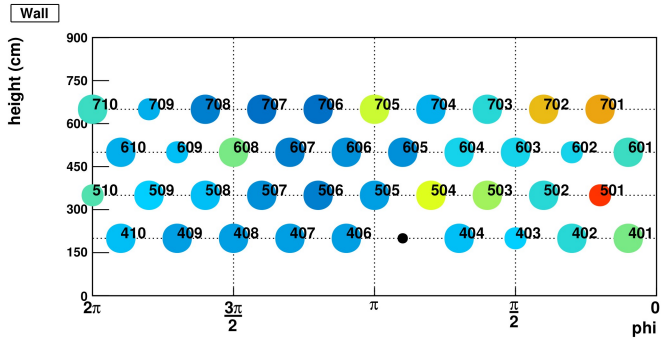


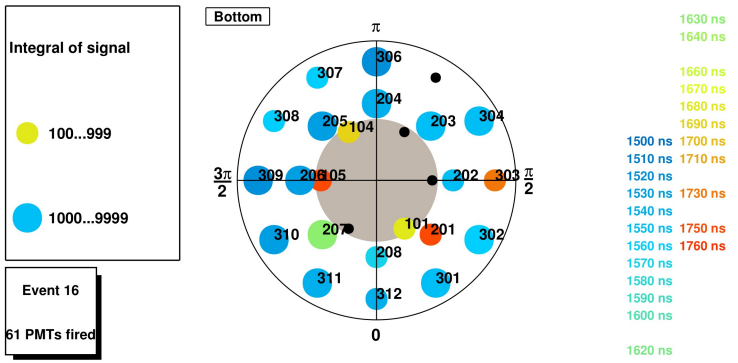


8 PMT in FADC
14 FADC
Struck 100 MHz

trigger:

1/5 p.e. Peak
4 FADC fire
within 60 ns

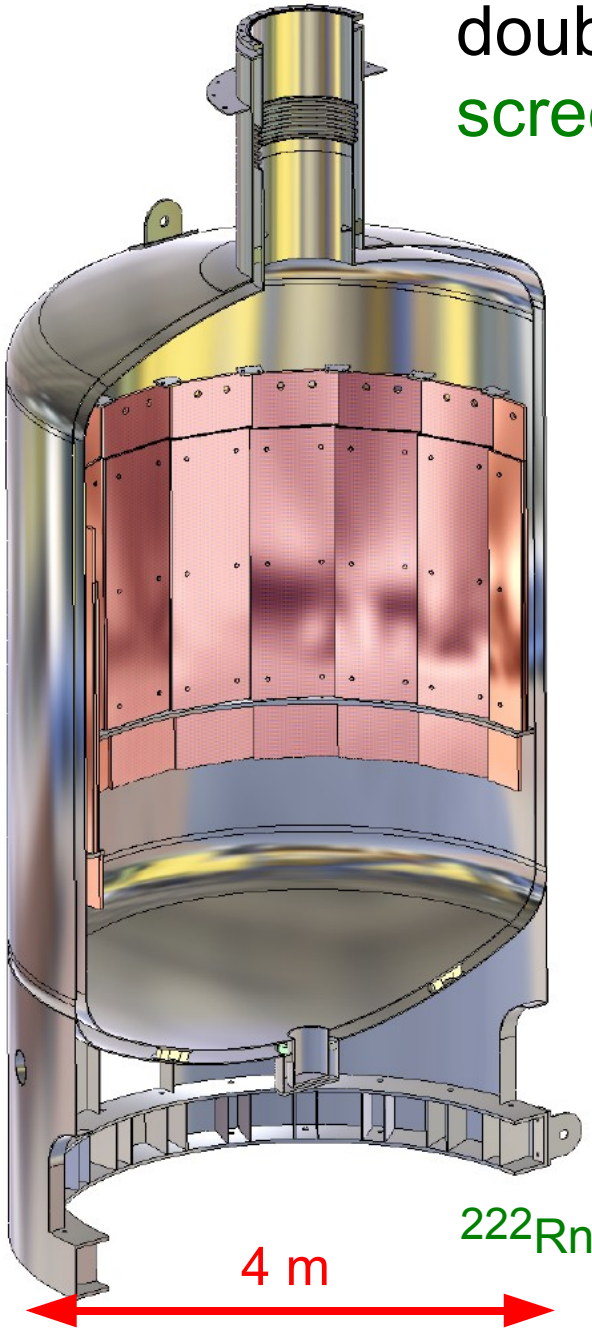




which background:

noise or late pulses
scintillation of VM2000
neutrons
gammas

Stainless Steel Cryostat



double walled SS container

screening of SS sheets from different producers (~ 27 tons of SS 1.4571)

<0,8 mBq/kg ^{228}Th & < 17mBq/kg ^{60}Co

LN_2 test

evaporation

< 4Nm^3/h

300 W

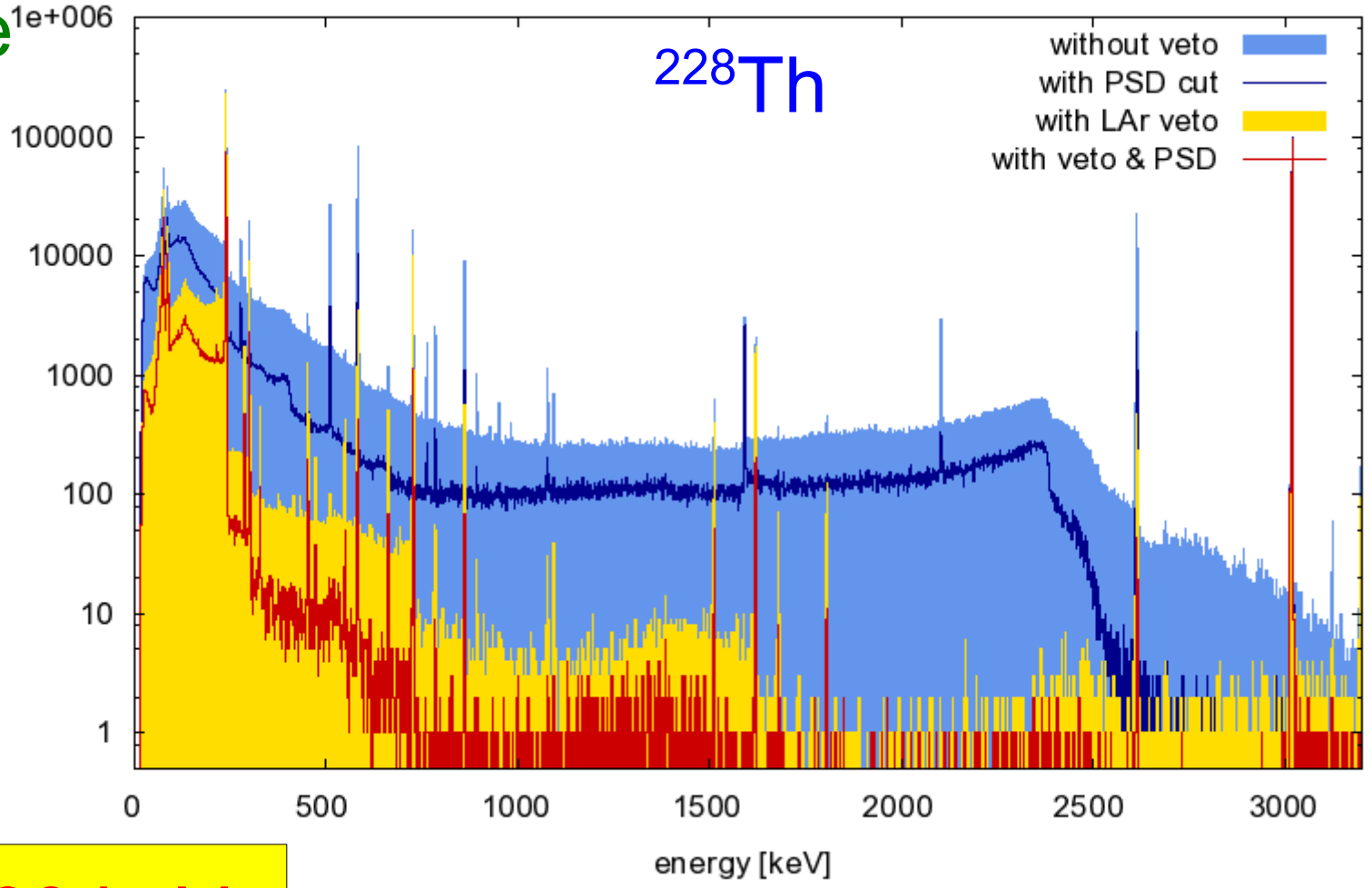
^{222}Rn: ~ 30 mBq

reduce Cu shield from 40 to 16 t (1t ~ 8000 €)

P. Grabmayr, Kepler Center Tübingen

veto through scintillation in LAr

Tests in LArGe



In ROI @ 2039 keV

red. factor ~1000

ETL ultra-low background PMT glass samples
MPIK internal note, 15.9.2005

Gamma spectrometry:

Longlived mother	Measured Isotope	Neck (MPI-K Heidelberg) A [Bq/kg]	Neck (MPI-K Heidelberg) Conc. [ppb]	Bulb (MPI-K Heidelberg) A [Bq/kg]	Bulb (MPI-K Heidelberg) Conc. [ppb]	Bulb (IRMM Geel) A [Bq/kg]	Bulb (IRMM Geel) Conc. [ppb]
^{226}Ra	^{214}Pb + ^{214}Bi	2.04(21)	165(17)*	2.01(19)	163(15)*	1.67(10) [1)]	
^{226}Ra	^{226}Ra	1.62(42)		2.01(48)		1.95(18)	
^{238}U	^{234}Pa	< 6.4		< 4.5		---	
^{238}U	^{234}U	---		---		< 0.065	< 5.2*
^{228}Th	^{212}Pb + ^{208}Tl	0.29(7)	72(18)**	0.21(6)	51(14)**	0.165(13)	
^{228}Ra	^{228}Ac	0.21(14)		0.25(10)		0.190(20)	47(5)**
^{40}K	^{40}K	2.47(59)	80000(19000)***	1.75(43)	57000(14000)***	1.69(15)	54000(4800)***
^{137}Cs	^{137}Cs	< 0.37		< 0.37		0.018(3)	

* ^{nat}U concentration (secular equilibrium assumed, although broken)
** ^{nat}Th concentration (secular equilibrium assumed)
*** ^{nat}K concentration (secular equilibrium assumed)
1) Maybe some ^{222}Rn escaped?

Comment: The uncertainties for the measurements done at MPI-K were artificially enlarged to take into account systematic errors due to poorly known efficiencies. Future studies will improve that.

ICP-MS measure-ments:

Measured element	Neck (ETL Southampton) A [Bq/kg]	Neck (ETL Southampton) Conc. [ppb]	Bulb (ETL Southampton) A [Bq/kg]	Bulb (ETL Southampton) Conc. [ppb]	Datasheet (ETL Southampton) A [Bq/kg]	Datasheet (ETL Southampton) Conc. [ppb]
U		21		24		30
Th		26		29		30
K		140000		120000		60000

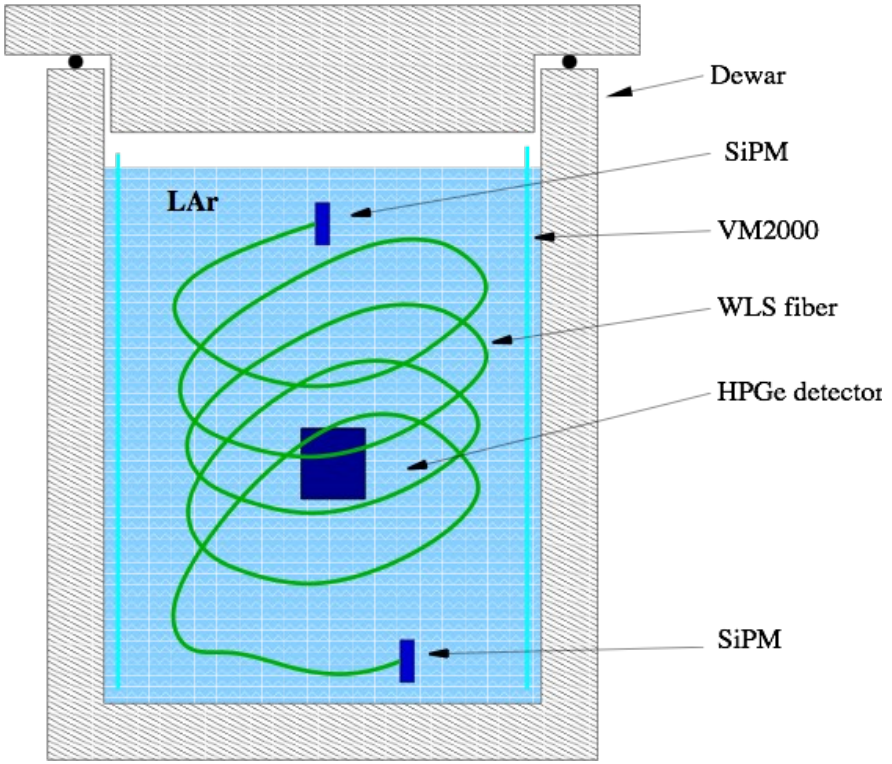
Atomic absorption spectroscopy:

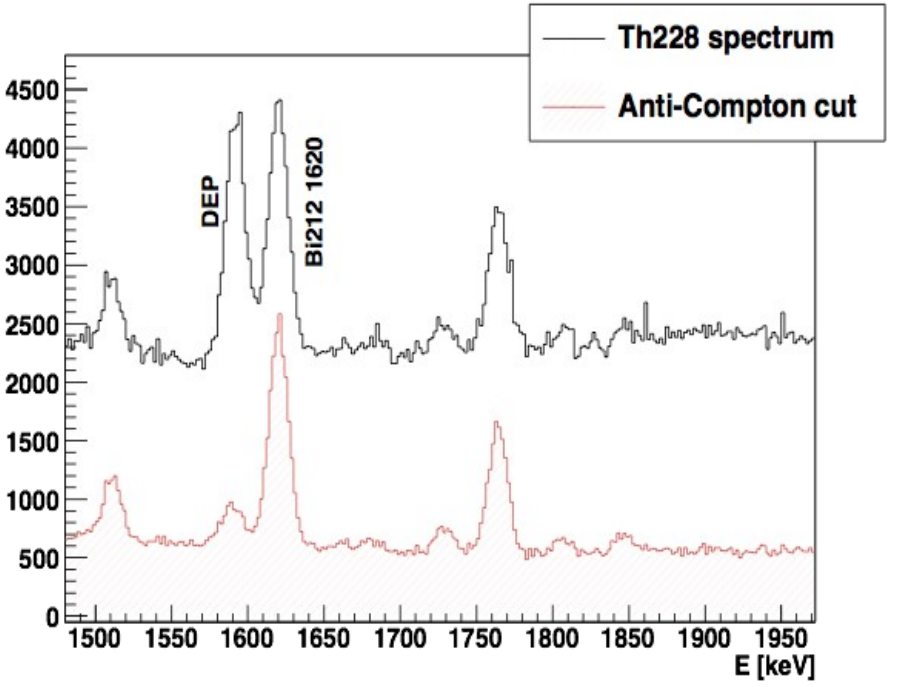
Measured element	Neck (MPI-K Heidelberg) A [Bq/kg]	Neck (MPI-K Heidelberg) Conc. [ppm]	Bulb (MPI-K Heidelberg) A [Bq/kg]	Bulb (MPI-K Heidelberg) Conc. [ppm]
K		82		58

Anti-Compton Veto

Hamamatsu MPPC S10362-11-025C/050C/100C

- To increase the surface the light yield SiPMs are attached to wavelength shifting fibers (WLS)
- Two step wavelength shifting:
  - 128 to 430 nm TPB coated VM2000
  - 430 to 500 nm BCF-91A WLS fiber
- Fluor efficiency < 50%
- 12 SiPM with 6 - 2.5 m WLS fiber
- More than 100 p.e./MeV seen
- The Compton background suppressed by a factor > 4 in the ROI of GERDA





Janicskó-Csáthy József, Hossein Aghaei, MPP

performance of photosensors

photomultiplier in water	Cerenkov	RT
photomultiplier in liquid Argon	Scintillation	LAr
Silicon-PMT in liquid Argon	Scintillation	LAr

general wishes:

high QE (angular independent)
low radioactivity of glass
pressure up to ~ 2 bar
good afterpulse performance (pre- & late pulses)

[[timing not important, as long no tracking foreseen]]

for PM in lAr:
QE & radioactivity !! Quartz needed ?
Present problems: high dark rate (3 kHz)
el. Field of cold glass: days needed to rise HV

for SiPM in lAr:
dark rate, sensitive wave lengths, coupling to WLS

timeline

- Presently starting Phase I (18 kg running for 1 year)
- Phase II with total of 40 kg detectors enriched in ^{76}Ge (~ 3y)
- Parallel R&D on

  background reduction

  PMT for Liquid Argon veto

  SiPM for Liquid Argon veto
- MC for Phase III design (1t, jointly with Majorana)

guess: less than 1000 PMT for Phase III

?? use of hybrids ??
?? use of SiPM at mK range for active polarized targets ??