GIOVE (Germanium spectrometer with Inner and Outer Veto), a new low background Ge-spectrometer at MPI-K

Gerd Heusser*

Max-Planck-Institut für Kernphysik

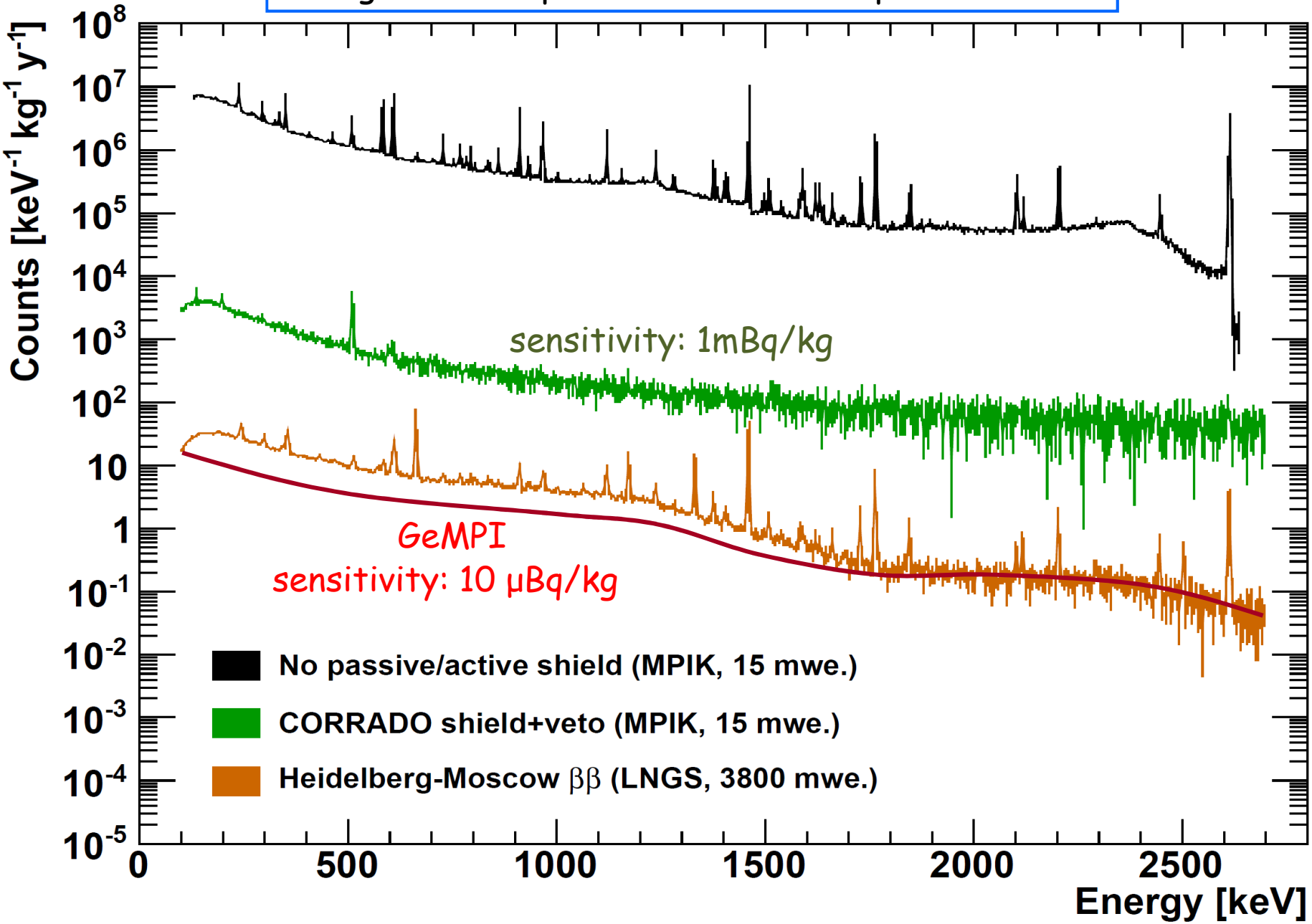
Heidelberg

outline:

- o motivation: screening for ββ (Gerda II) and dm (Xenon 1 t) experiments
- o neutron background studies
- o inner and outer veto system
- o screening measurements
- o spectrometer performance, including first sample measurements
- o summary

*for the GIOVE crew at MPI-K: Tobias Denz, Janina Hakenmueller, Reinhard Hofacker, Ralf Lackner, Manfred Lindner, Werner Maneschg, Michael Reisfelder, Hardy Simgen, Jochen Schreiner, Dominik Stolzenburg, Herbert Strecker, **Marc Weber**, Jonas Westermann

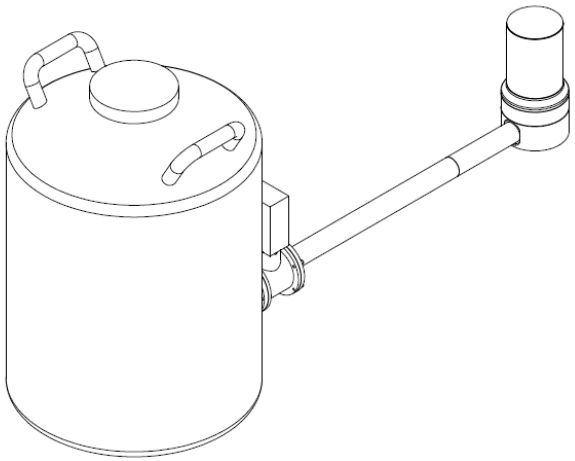
background comparison at shallow depth and LNGS

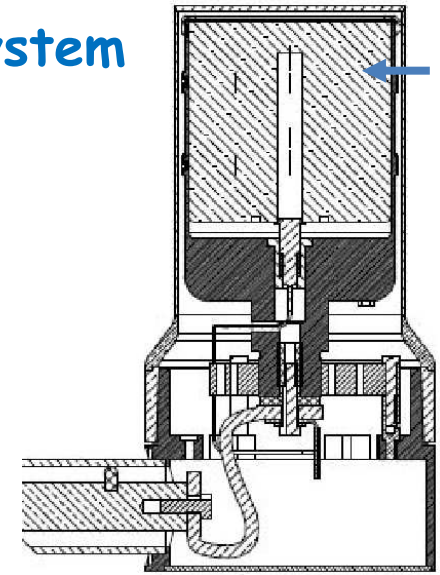


design criteria for GIOVE - sensitivity about 100 μBq/kg

	action
❖ muon veto efficiency better than 99 %	inner and outer layer of plastic scintillator
❖ keep shield as compact as possible	plastic scintillator also used as moderator
❖ primordial line background below 1 cpd	material screening at 10 μBq/kg – 10 mBq/kg
❖ large sample capacity as with GeMPI's	
❖ Rn-equilibrium at start of counting	gas tight sample container and glovebox system

cryostat system

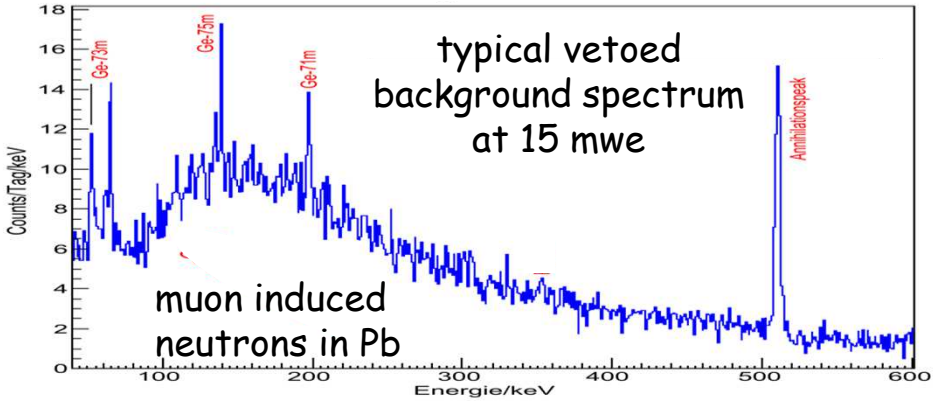


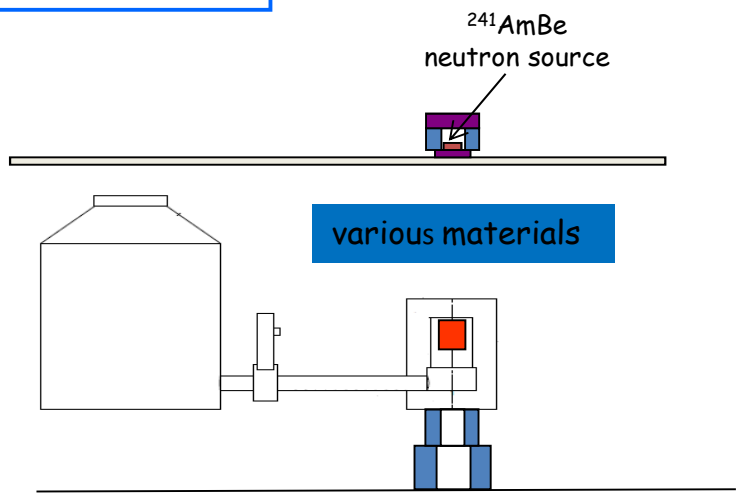


Diode: Ø 80x80 mm,
mass: 2.11 kg
Bias voltage: 6000 V
FWHM (1.332 MeV) :
2.2 keV

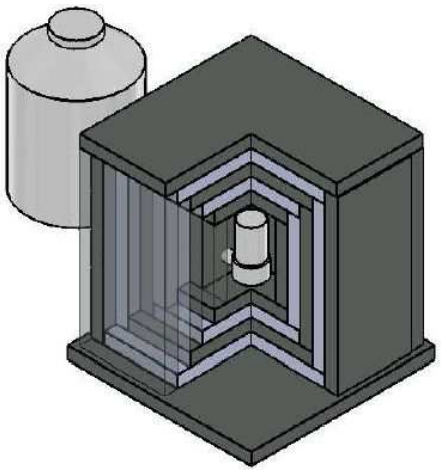
produced in 2004
for GERDA
stored at HADES
until 2011/12

neutron attenuation/absorption studies



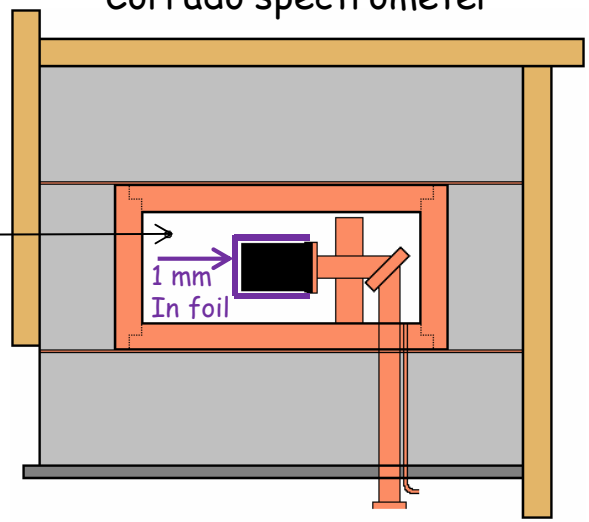


test shield of alternate Pb/borated PE layers



Corrado spectrometer

different neutron absorbers placed around detector



radiopurity measurements

sample	activity [mBq/kg] [mBq/pc]					
	^{226}Ra	^{228}Th	^{228}Ra	^{40}K	^{60}Co	^{54}Mn
plastic-scintillator EJ-200, 7.26 kg	0.09 ± 0.05	0.5 ± 0.1	0.4 ± 0.1	1.5 ± 0.5		
plastic-scintillator NE- 102A, 7.30 kg	0.96 ± 0.13	9.3 ± 0.3	9.2 ± 0.4	2.2 ± 0.7		
"GALLEX" carbon-steel 51.18 kg	0.13 ± 0.03	≤ 0.04 ≤ 0.28*	0.10 ± 0.04	0.5 ± 2.3	0.14±0.02	2.3±0.03
PMT R8520 for Xenon 100 exp. 10 pc	0.38 ± 0.6	0.14 ± 0.03	≤1.3	10 ± 1		

Matthias Laubenstein, LNGS, Oct.. 2010 ; * without 2.615 MeV line

PMT R 8520-106 MOD 3 pc	≤ 1.8	≤ 2.3	≤.3	≤ 15
B_2O_3 pa, for silicate anal., Merck 4.0 kg	≤ 2.9	≤ 3.9	≤ 3.3	76 ± 9
black Lexan for scint. coverage 1.43 kg	11 ± 3	≤ 8	≤ 9	100 ± 19

MPI-K

no boron compounds found with less than 80 mBq/kg ^{40}K at reasonable cost!!

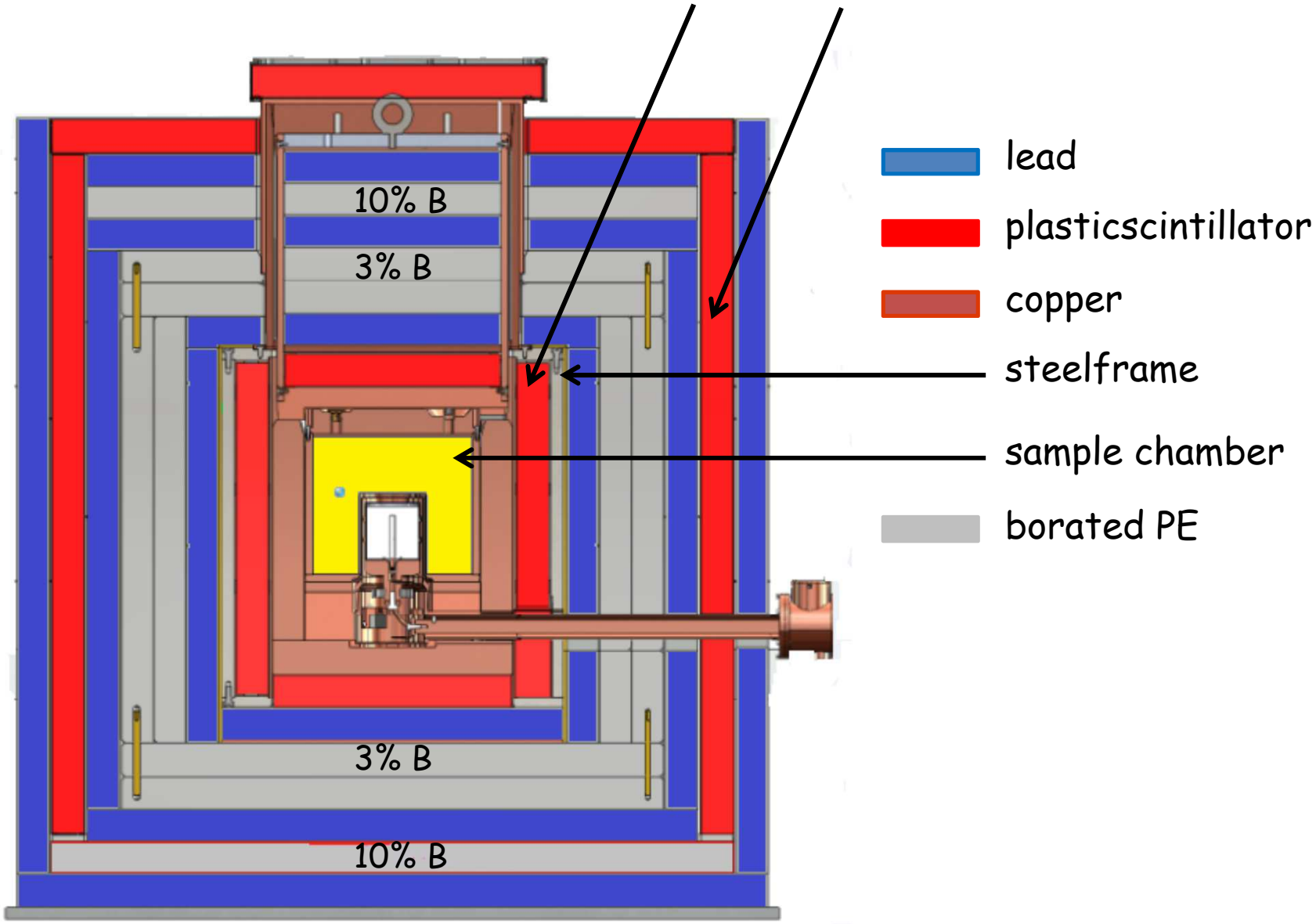
→ can not be used near detector

neutron absorber in sample chamber of Corrado spectrometer

Setup	Count rate [counts per day]					
Neutron induced line	53 keV ^{73m}Ge	66 keV ^{73m}Ge	139 keV ^{75m}Ge	198 keV ^{71m}Ge	477 keV ^{7}Li*	2223 keV ^{2}H*
background	8.2(3.2)	23.0(4.5)	14.5(3.9)	23.8(4.4)		
Polyethylene pure	42.6(6.1)	60(6)	53(6)	55.6(5.4)		52.1(3.1)
Plastic-scintillator	35.9(3.9)	82.8(4.9)	64.9(4.3)	56.3(4.1)		46.0(2.2)
PE 1%B	13.5(2.5)	26.0(3.1)	12.0(3.1)	14.0(2.8)	78.2(3.3)	2.9(0.6)
In foil around detector cap			1097 keV ^{116m}In	1293 keV ^{116m}In		
Polyethylene pure			70.6(2.1)	91.2(2.2)		35.6(1.4)
Plastic-scintillator			78.3(4.6)	105(4.9)		21.9(2.5)
PE 1%B			18.0(2.2)	15.7(2.4)	65.3(4.7)	2.0(0.8)
PE 5%B			6.7(1.3)	5.4(1.2)	46.8(4.3)	< 0.52
PE 10%B			8.9(1.8)	8.5(1.6)	61.9(5.8)	1.3(0.7)

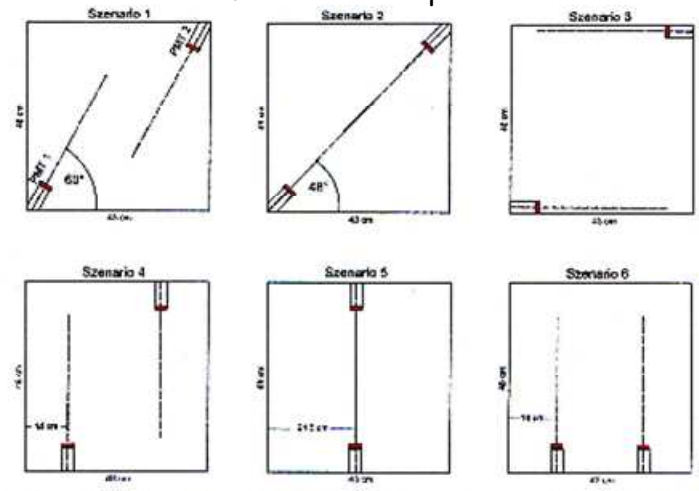
→ 3 % B is sufficient

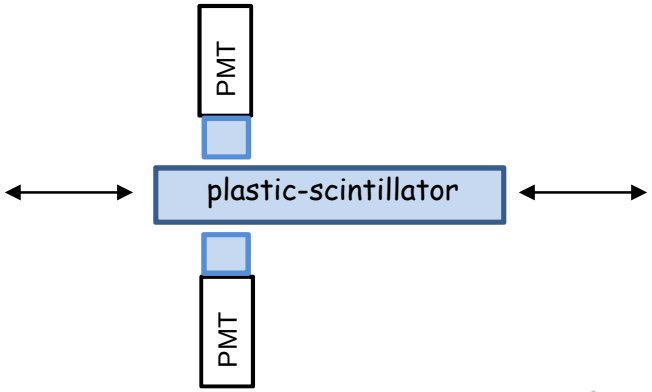
compromise design for GIOVE



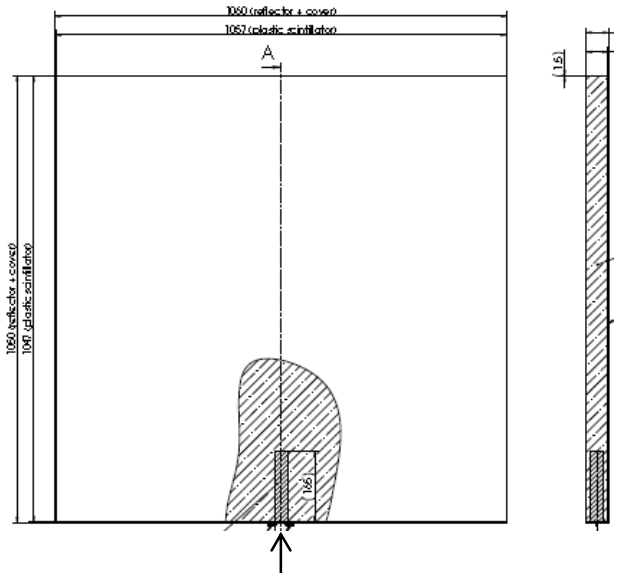
optimization of plastic-scintillator readout

simulation of different PMT configurations for inner veto plates → validation by scanning measurements with muon telescope

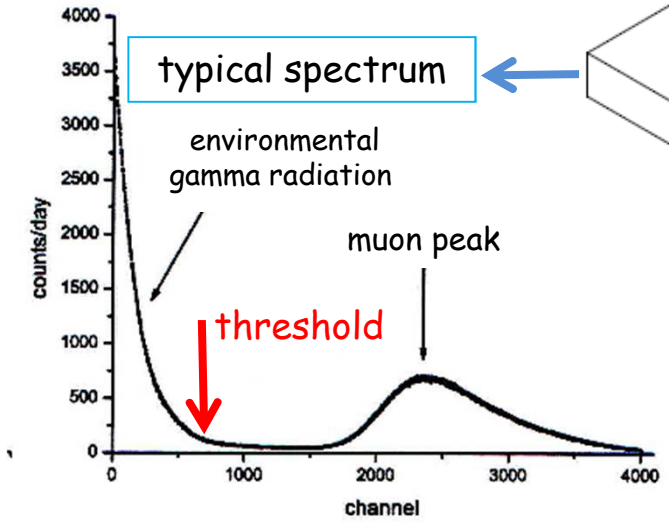


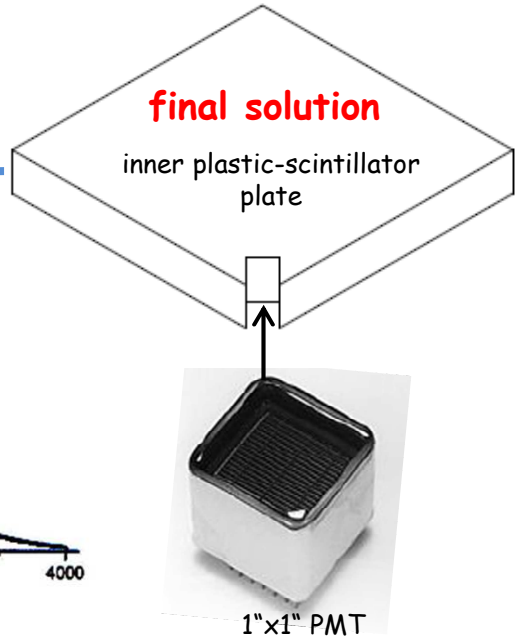


outer plastic-scintillator plate



PMT with front and side photocathode





Monte Carlo simulation with full shield by MaGe

dead layer determination

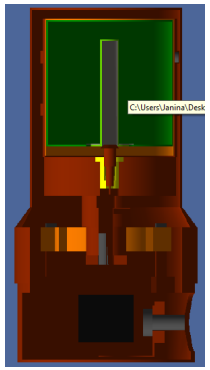
scanning of detector with collimated ^{241}Am source, GERDA system

+ extensive measurement with calibrated sources: ^{241}Am, ^{133}Ba, ^{60}Co

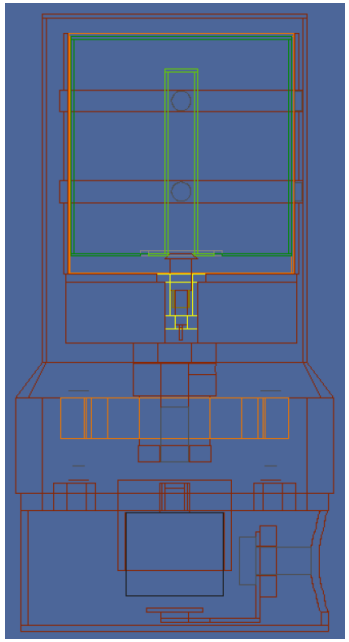
with tools developed for GERDA

dead layer: ~1.5 mm

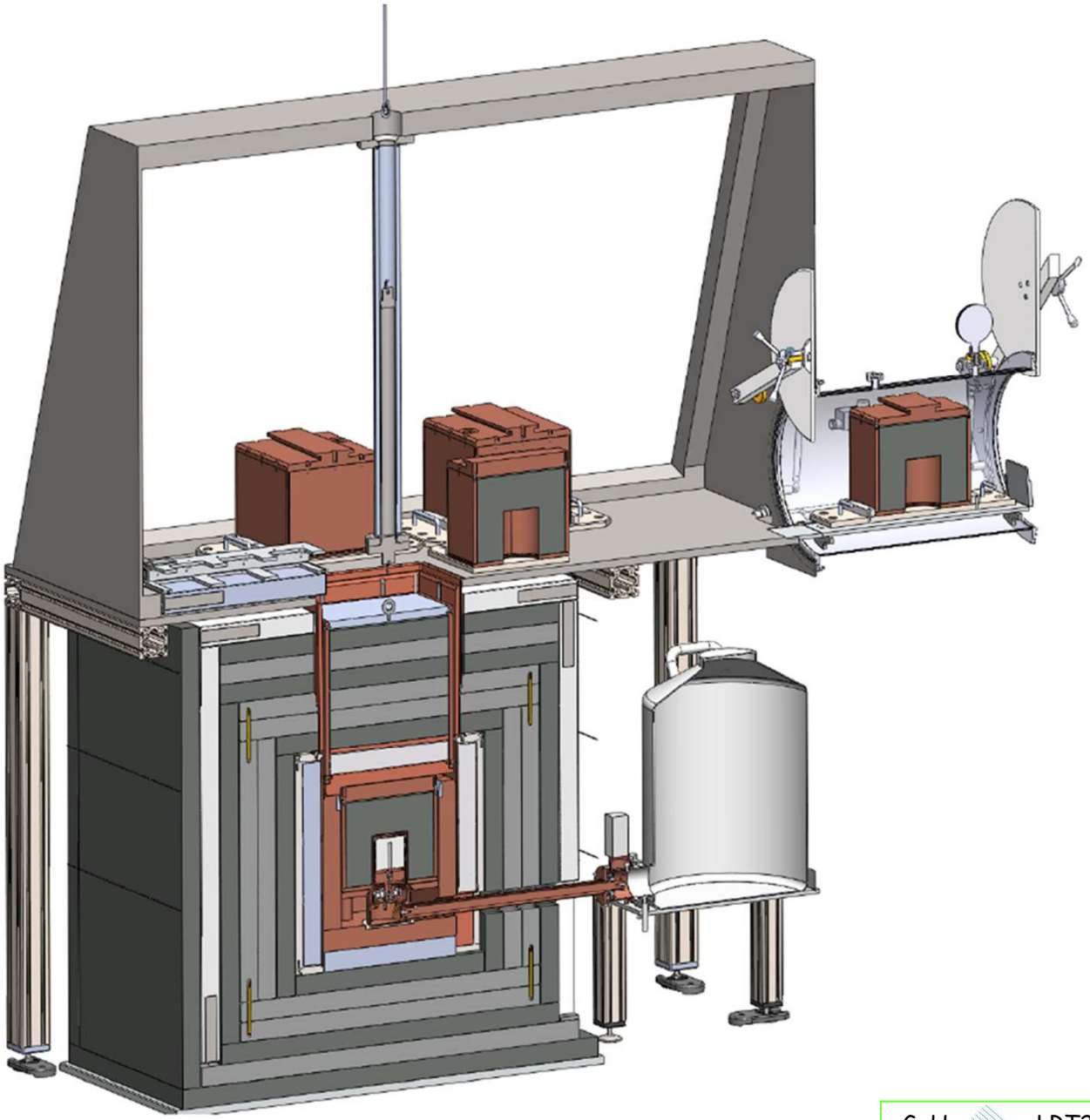
active volume: 1807 +- 124 g ≈86 %



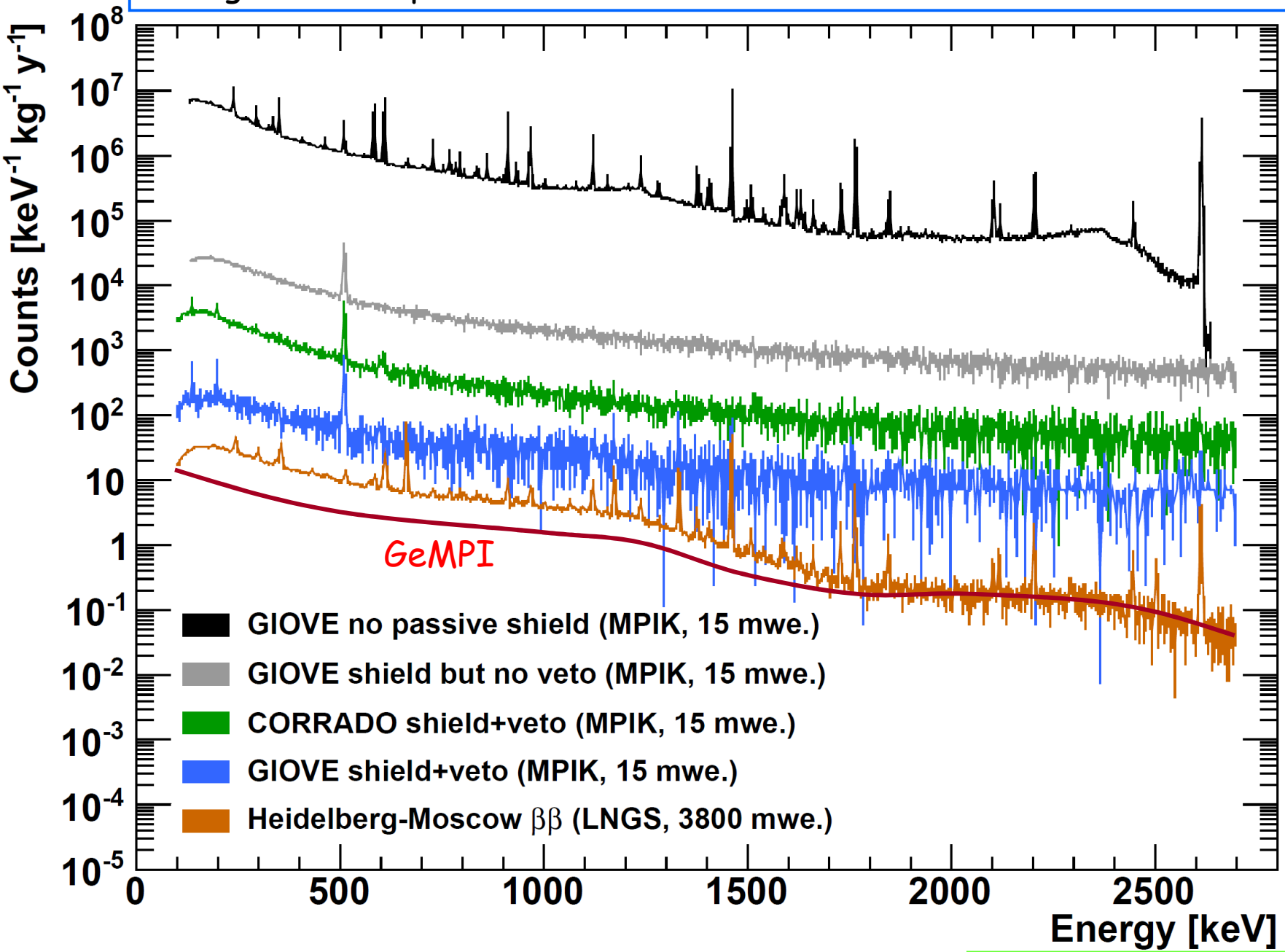
crystal, cryostat and shield implementation into MaGe



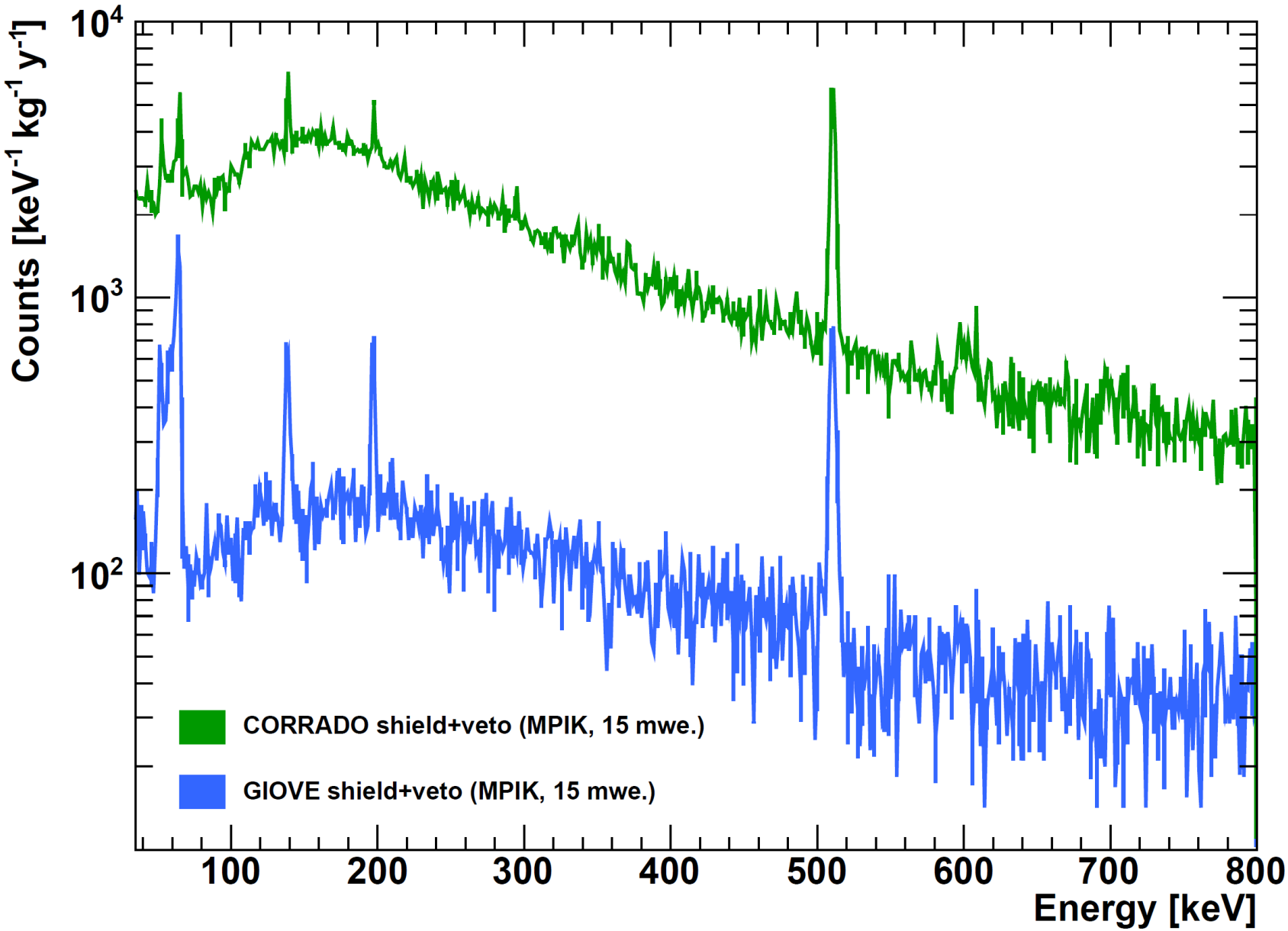
GIOVE shield with glovebox system



background comparison of GIOVE with other MPI detectors and HDM



low energy spectra of Corrado and GIOVE



priliminary data of performance

background (25 days measurement):

(40 -2700 keV) : 293 c (d kg)$^{-1}$; veto on/off = 95

Dario	HD	4160	14
Corrado	HD	3720	11
GeMPI's	LNGS	35 - 70	

backgroundlines:

	Energy keV]	Isotope	Rate [cpd]
neutron	53	(^{73m}Ge)	8 +- 2
	65	(^{73m}Ge)	30 +- 3
	139	(^{75m}Ge)	9 +- 1
	198	(^{71m}Ge)	10 +- 1
cosmogenic	352	(^{212}Pb)	1.3 +- 0.6
	511	e^+e^-	18 +- 1
	835	(^{54}Mn)	0.8 +- 0.5
	1173	(^{60}Co)	1.1 +- 0.4
	1332	(^{60}Co)	0.9 +- 0.3
	1461	(^{40}K)	1.6 +- 0.3
	2.615	(^{208}Tl)	0.4 +- 0.2

≙ ~ 50 μBq/kg

~ 230 kg Cu near detector

sea level PR: ~ 1000 μBq/kg

enhanced PR within lead shield
due to high neutron multiplicity?

will be checked:
Cu sample available,
exposed since > 20 years

in situ PR at 15 mwe. ?!

first sample measurements

1 6 PMT for GERDA phase 2

activity concentration [mBq/PMT] (preliminary)				
^{226}Ra	^{228}Th	^{228}Ra	^{40}K	^{60}Co
0.7 ±- 0.2	0.6 ± 0.3	1.0 ± 0.4	27 ± 4	4.0 ± 0.3

2 borated polyethylene as used in shield

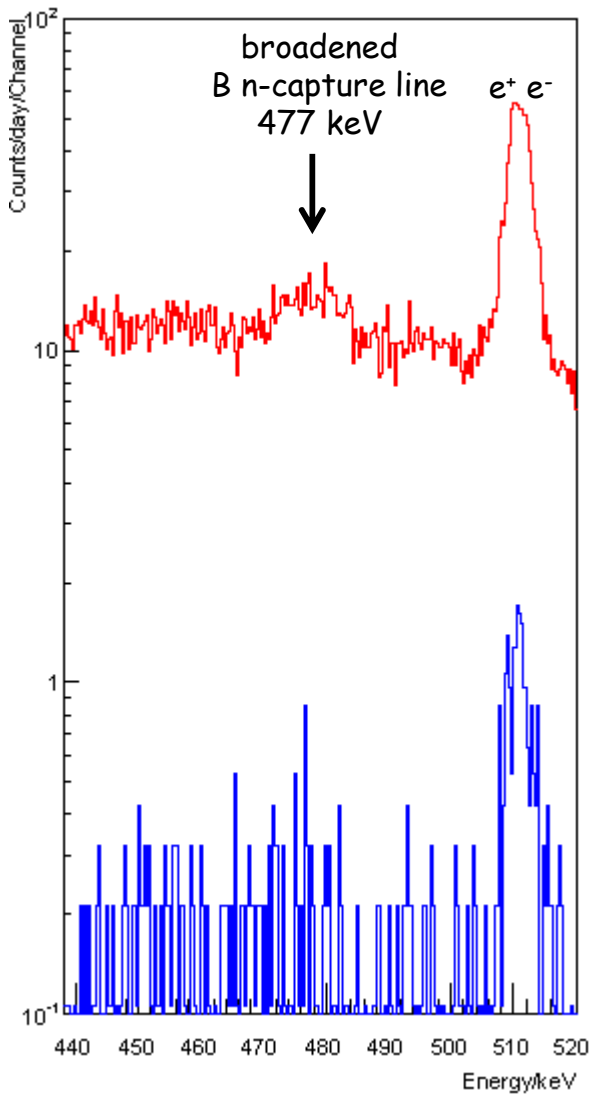
3 aged lead bricks to locate ^{40}K contamination

in progress

sample: 3 % borated PE

Veto off

Veto on



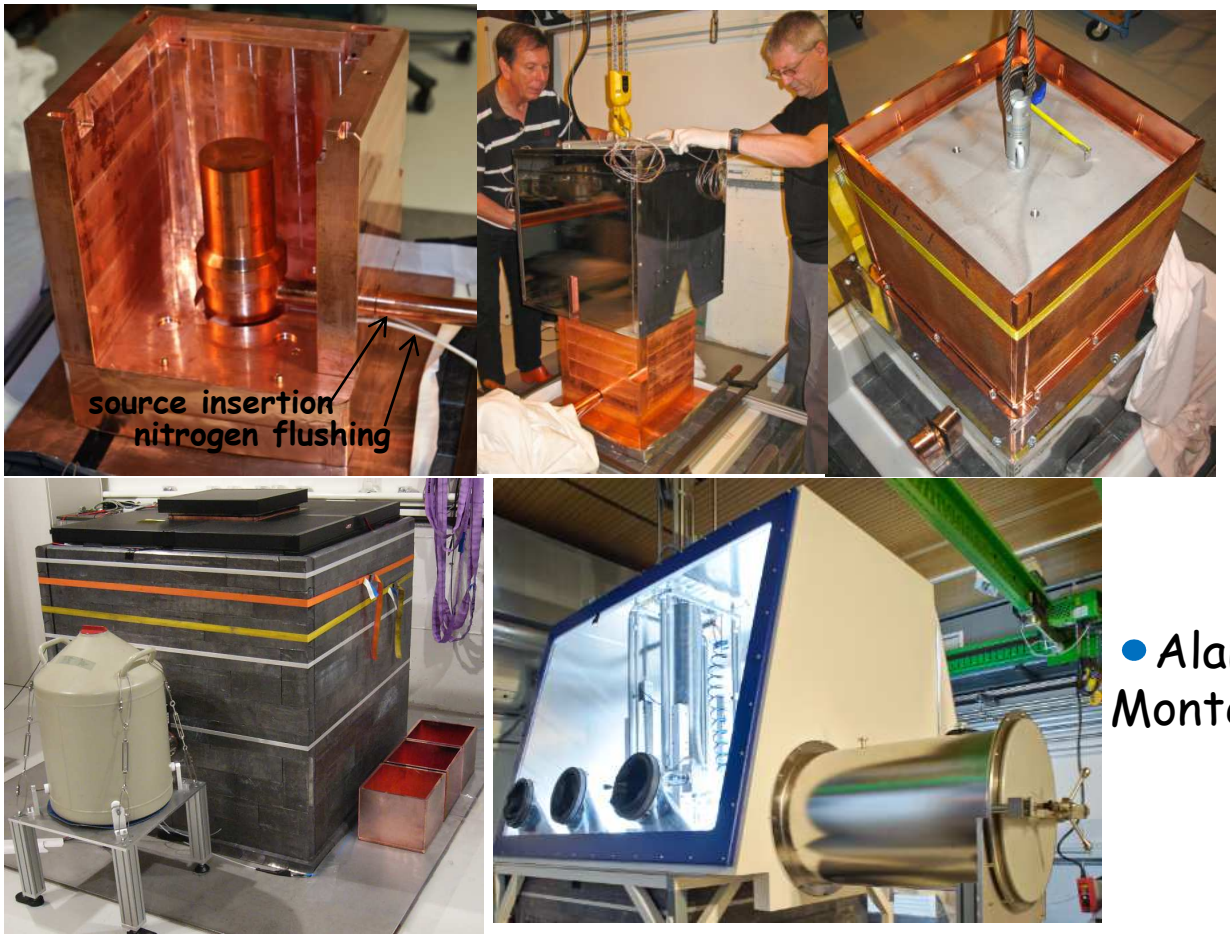
	447 keV:	**511 keV:**
Veto off	(110 +- 11) cpd	(597 +- 12) cpd
Veto on	(2.4 +- 1.1) cpd	(16.8 +- 1.5) cpd

veto also very effective on neutron event suppression

blocking time:
of outer veto: 80 μsec
of inner veto: 330 μsec

summary

- GIOVE is a new state of the art screening Ge-spectrometer at the home base of MPI-K
- background better than anticipated, except for ^{40}K
- slight improvement still possible by fine tuning of veto blocking time and radiopure neutron catcher; cosmogenic activation absolute limit
- pending to check: radon supression quality by gas tight sample containers (pumping, flushing) and nitrogen flushed glove box system

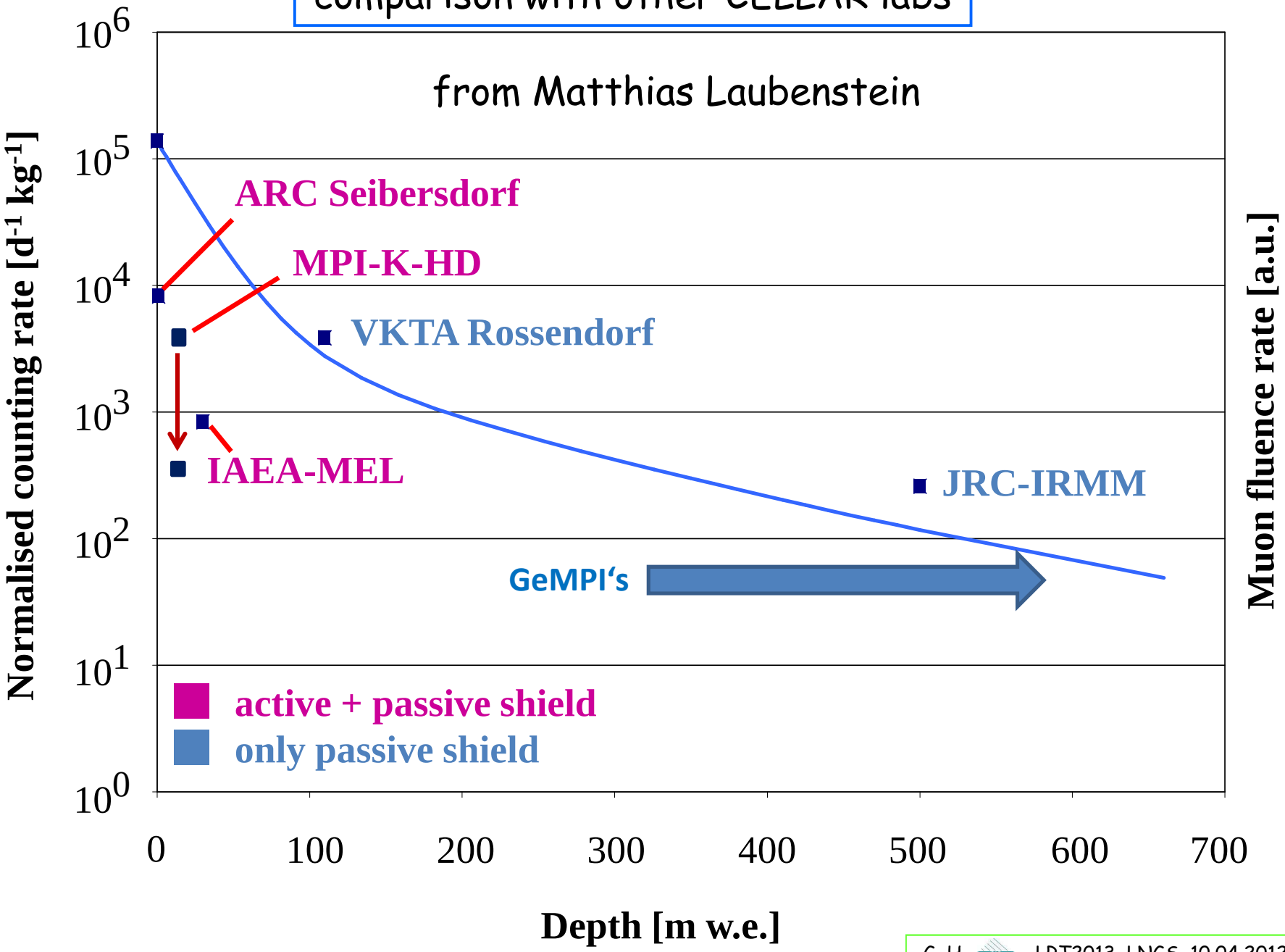


many thanks to:

- Matthias Laubenstein for material screeening
- Canberra Olen for kind collaboration in the detector construction
- Mikael Hult and Gerd Marissens for hosting the GIOVE crystal and many transfers to Olen
- Alan Poon of LBNL for starting Monte Carlo simulations on neutron and gamma attenuation

backup slides

comparison with other CELLAR labs

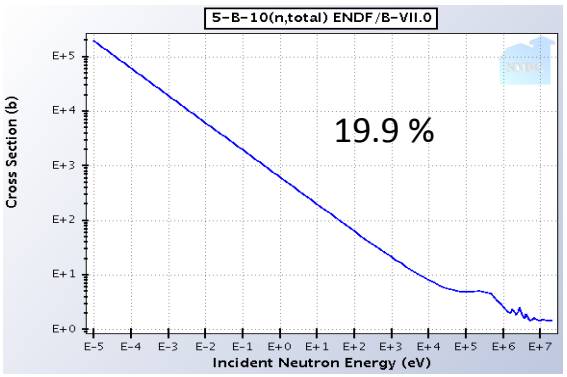


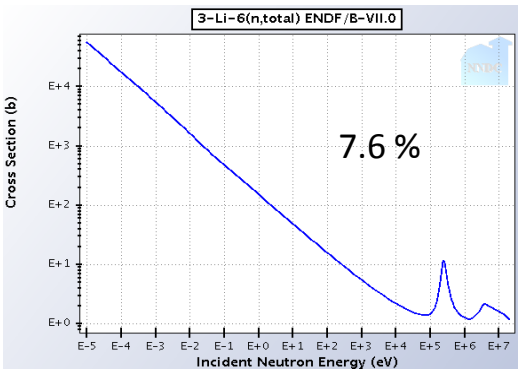
open options for further background reduction

finetuning of veto conditions:
veto blocking time and coincidence
conditions between inner and outer veto

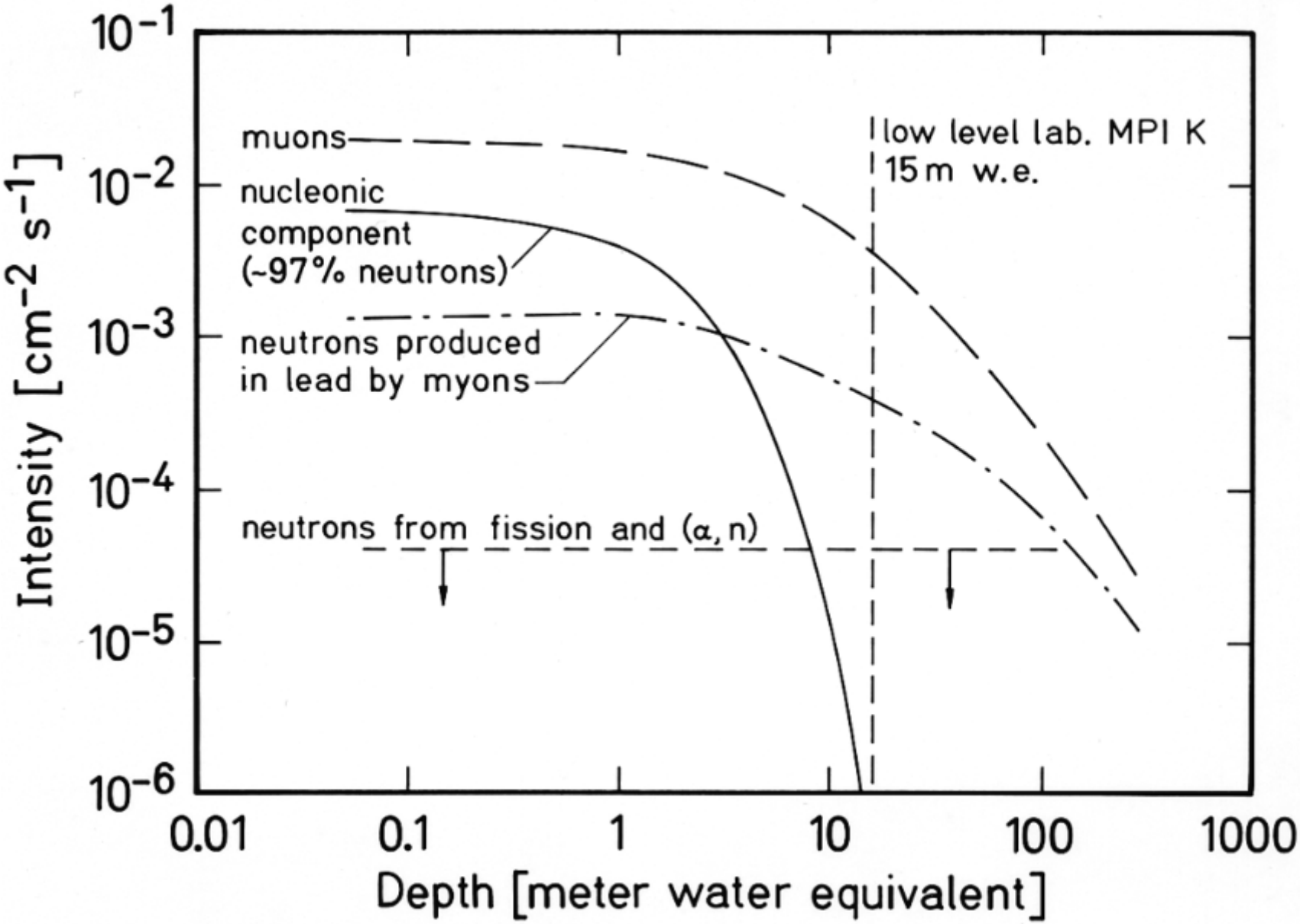
more lead: so far only 16 cm Pb, 10 cm PE, 10 cm
plastic-scint., 0.5 cm brass, 2 cm Fe, 6.5 cm Cu

radiopure B or Li next to detector for thermal n capture





cosmic ray intensities as function of depth



cosmogenic production rates at LNGS (surface lab) for copper

radionuclide	half-life[a]	(saturation) activity [μBq kg^{-1}]		
cosmogenic		**exposed**	**unexposed**	**estimated[b]**
^{56}Co	77.236 d	230 ± 30		557
^{57}Co	271.80 d	1800 ± 400		2147
^{58}Co	70.83 d	1650 ± 90		3878
^{60}Co	5.271 a	2100 ± 190	< 10	2367
^{54}Mn	312.13 d	**828 ± 82**		791
^{59}Fe	44.495 d	**118 ± 32**		157
^{46}Sc	83.788 d	53 ± 18		93
^{48}V	15.9735 d	110 ± 40		
primordial				
^{226}Ra (U)	1600 a	< 35	< 16	
^{228}Th (Th)	698.60 d	< 20	< 19	
^{40}K	1.265x10^{9} a	< 110	< 88	

S. Cebrian et al.

Astroparticle Physics 33 (2010) 316–329

corrected after publication

Applied Radiation and Isotopes 67 (2009) 750–754