Overview of the screening activities with HPGe detectors

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Material Screening

- Individual experiments have to ensure the cleanliness of their systems.
- Multiple counting methods/facilities
- Multiple vendors, individual production batches
- Stockpiling of clean materials in suitable storage

Comparison of radio-assay techniques

for primordial U/Th decay chains and K

	suited for
Ge-spectroscopy	γ emitting nuclides
Rn emanation assay	^{226}Ra, ^{228}Th
neutron activation	primordial parents
liquid scintillation counting	α,β emitting nuclides
mass spectrometry (ICP-MS; AMS)	primordial parents
graphite furnace AAS	primordial parents
Röntgen Excitation Analysis	primordial parents
α spectroscopy	α emitting nuclides

difficult to compare because each method has its special application

method	suited for	sensitivity for U/Th
Ge-spectroscopy*	γ emitting nuclides	10-100 μBq/kg
Rn emanation assay	^{226}Ra, ^{228}Th	0.1-10 μBq/kg
neutron activation	primordial parents	0. 01 μBq/kg
liquid scintillation counting	α,β emitting nuclides	1 mBq/kg
mass spectrometry (ICP-MS; AMS)	primordial parents	1-100 μBq/kg
graphite furnace AAS	primordial parents	1-1000 μBq/kg
Röntgen Excitation Analysis	primordial parents	10 mBq/kg
α spectroscopy	^{210}Po, α emitting nuclides	1 mBq/kg

* Needs counting times from several weeks to several months for large samples

Borexino , Astrop. Phys. 18 (2002) 1-25

EXO-200, Nucl. Instrum. Meth. A591 (2008) 490-509

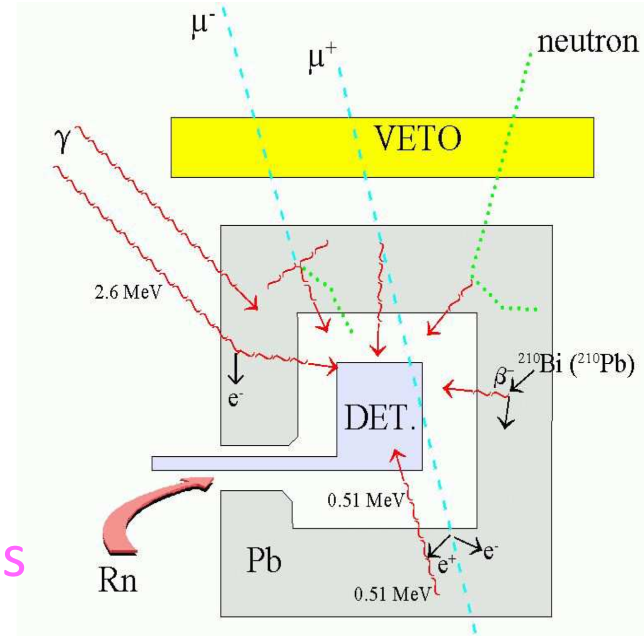
Xenon-100, Astrop. Phys. 35 (2011) 43-49

Ultra Low-level Gamma Spectrometry

i.e. low-level γ-spectrometry with additional background reduction by using active shields, material selection and/or underground laboratories

Background components in Ge spectrometry

- external gamma radiation (2.6 MeV ^{208}Tl, {up to 3.2 MeV ^{214}Bi})
- radio-impurities close to crystal (primordial, anthropogenic)
- Rn and its progenies
- cosmic rays (neutrons, muon and activation)
- neutrons from fission and (α,n) reactions



by courtesy of Dr. G. Heusser

most important: material screening U/Th chains and K dominant from Bq/kg down to μBq/kg only reliably radiopure material - Cu – but mBq/kg cosmogenics besides Si, Ge, Au, Ag, Hg, (Pb – except ^{210}Pb)

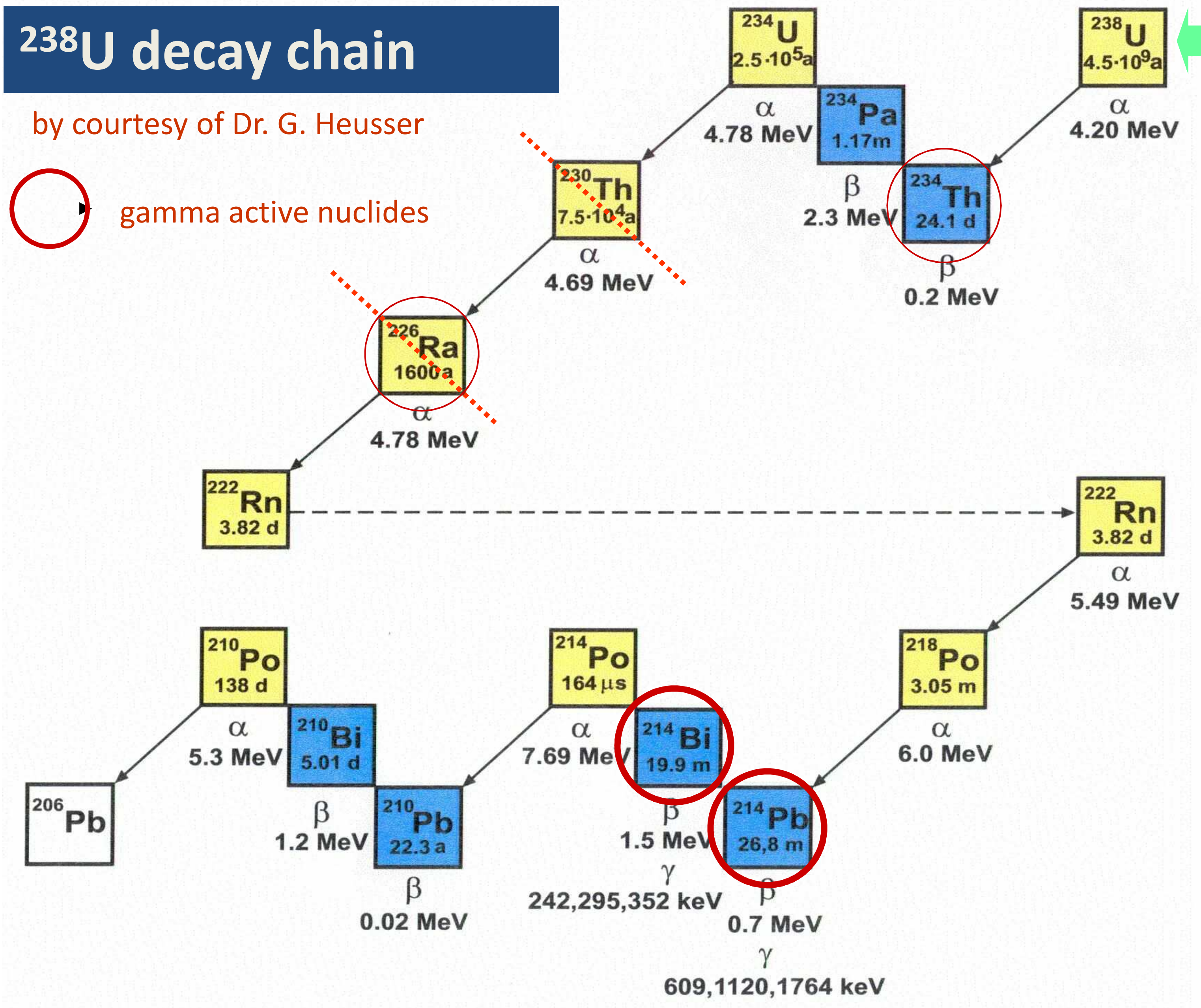
improvements in iterative steps

^{238}U decay chain

by courtesy of Dr. G. Heusser

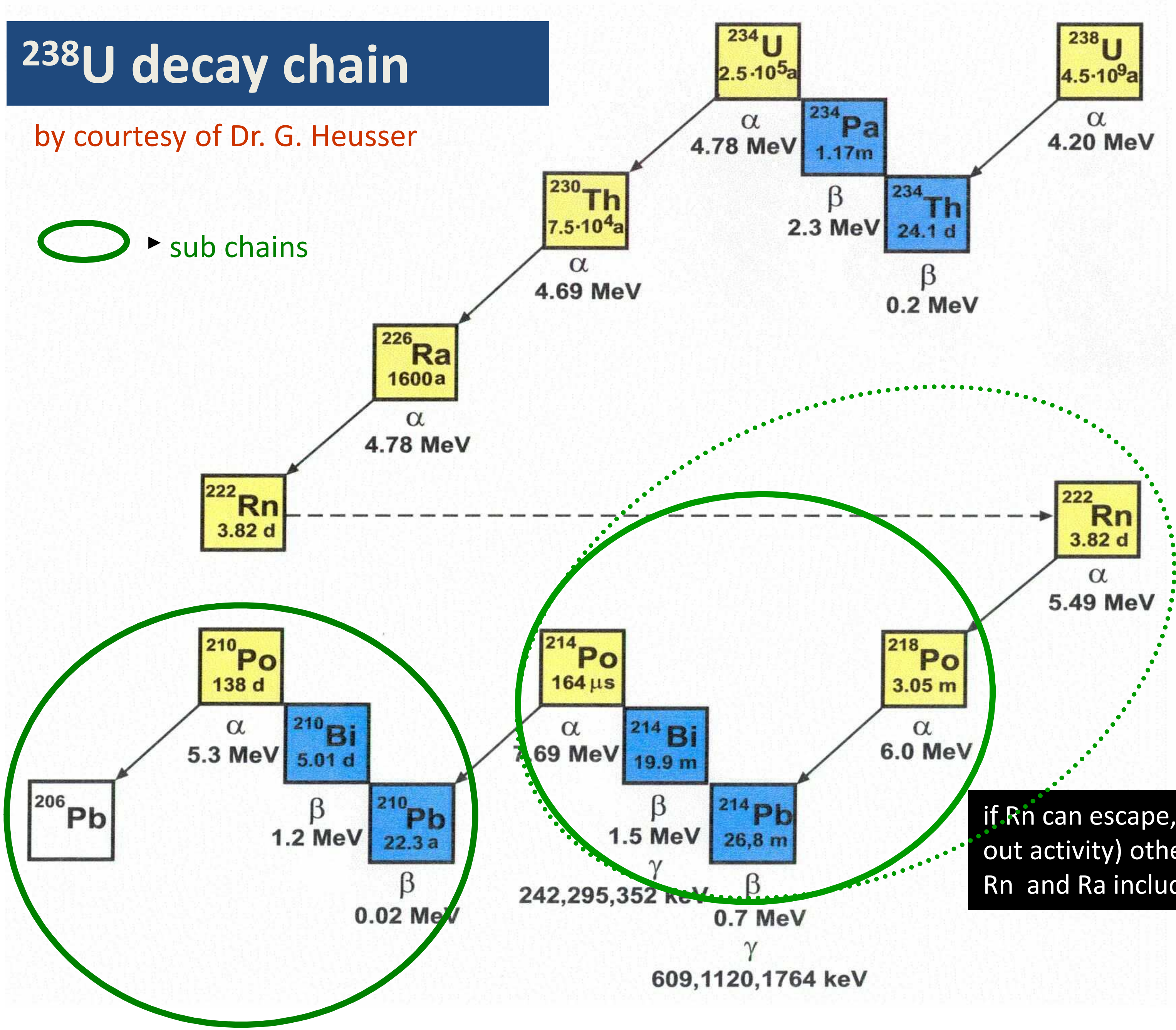
gamma active nuclides

mass spectro-metry



^{238}U decay chain

by courtesy of Dr. G. Heusser

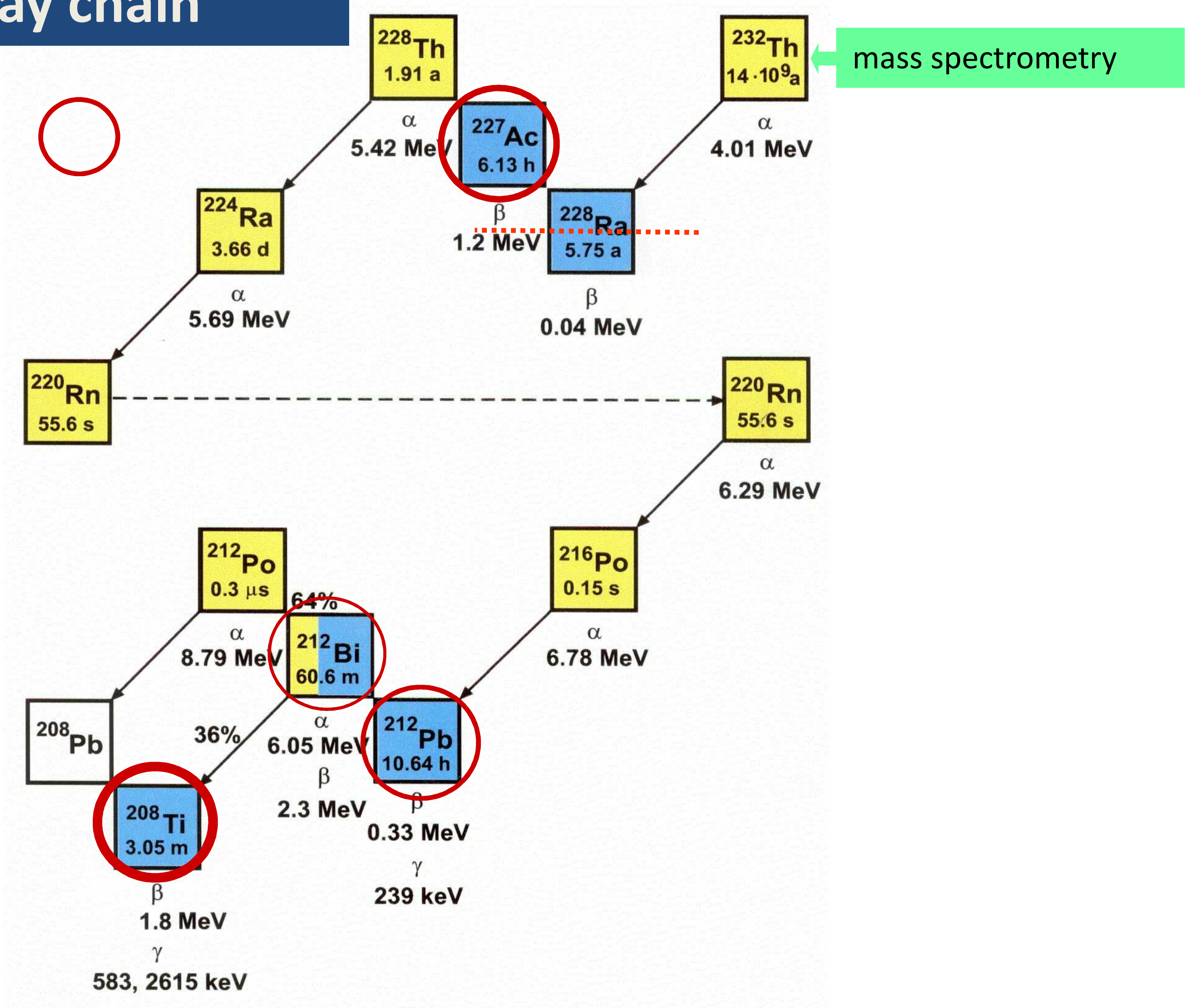


if Rn can escape, (plate out activity) otherwise Rn and Ra included

^{232}Th decay chain

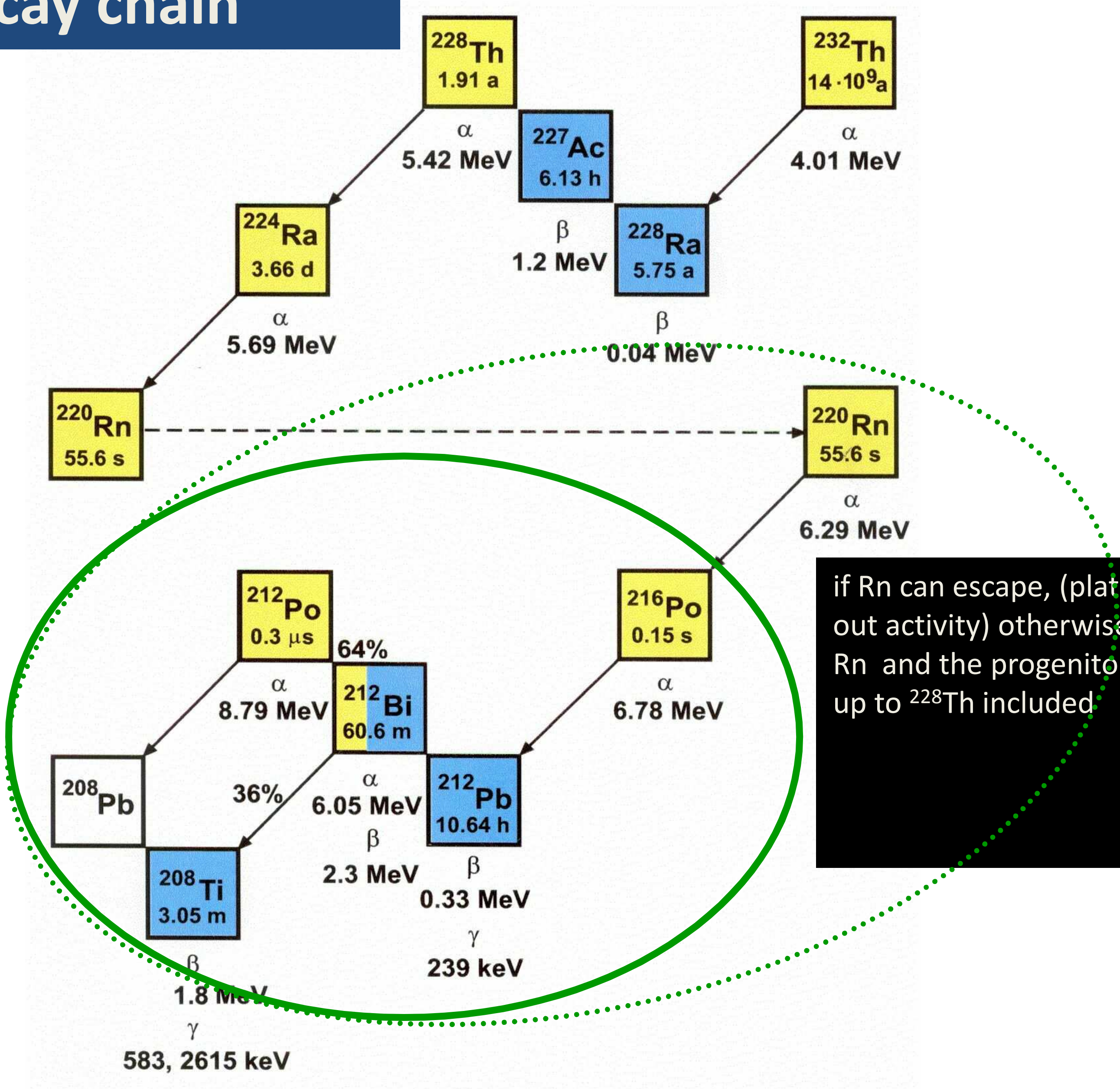
by courtesy of Dr. G. Heusser

gamma active nuclides

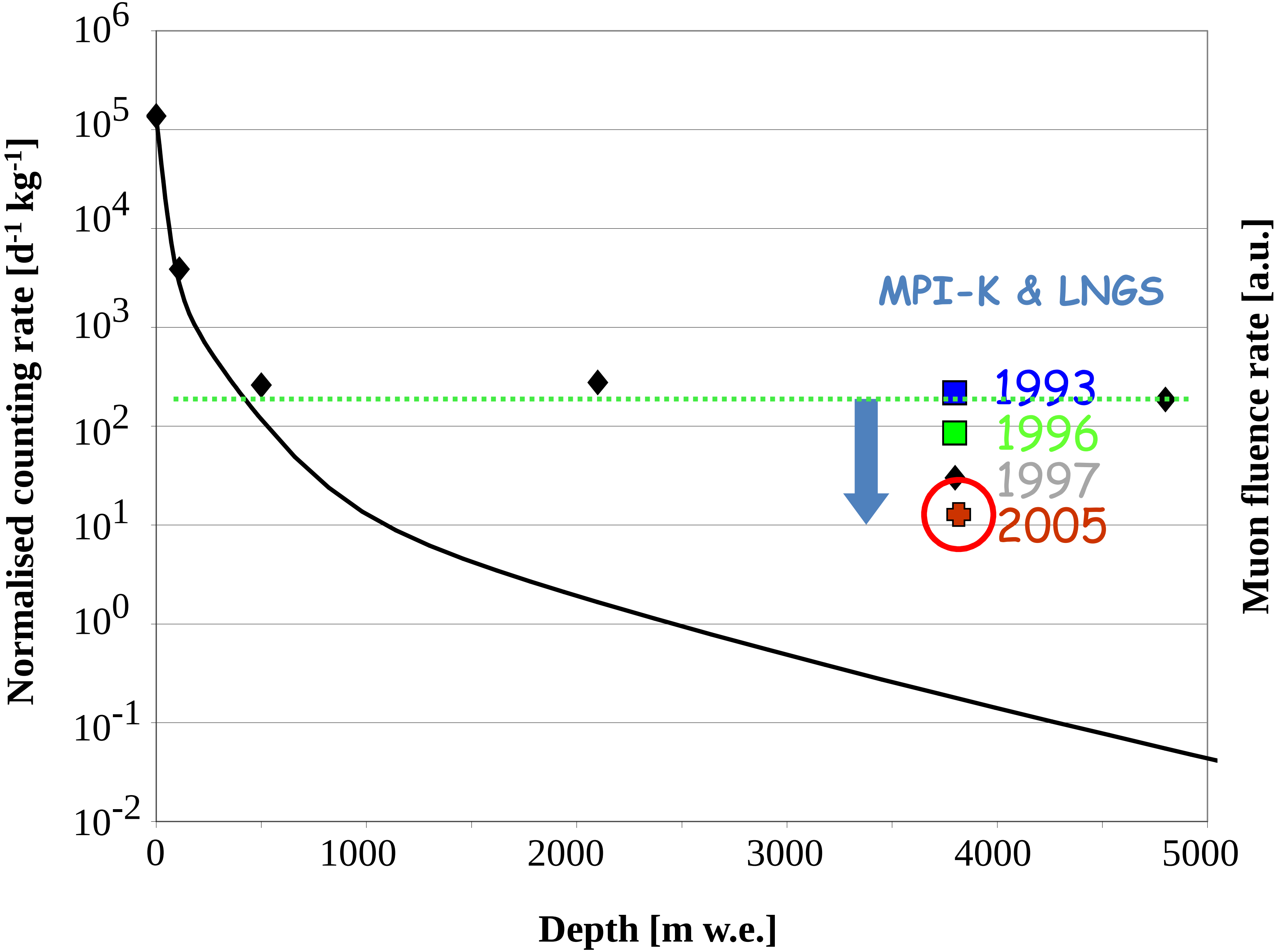


^{232}Th decay chain

by courtesy of Dr. G. Heusser



if Rn can escape, (plate out activity) otherwise Rn and the progenitors up to ^{228}Th included



MPI-K & LNGS
1993
1996
1997
2005
Normalised counting rate [d-1 kg-1]
Muon fluence rate [a.u.]
Depth [m w.e.]
10-2
10-1
100
101
102
103
104
105
106
0
1000
2000
3000
4000
5000

GeMPI (MPI-K property)

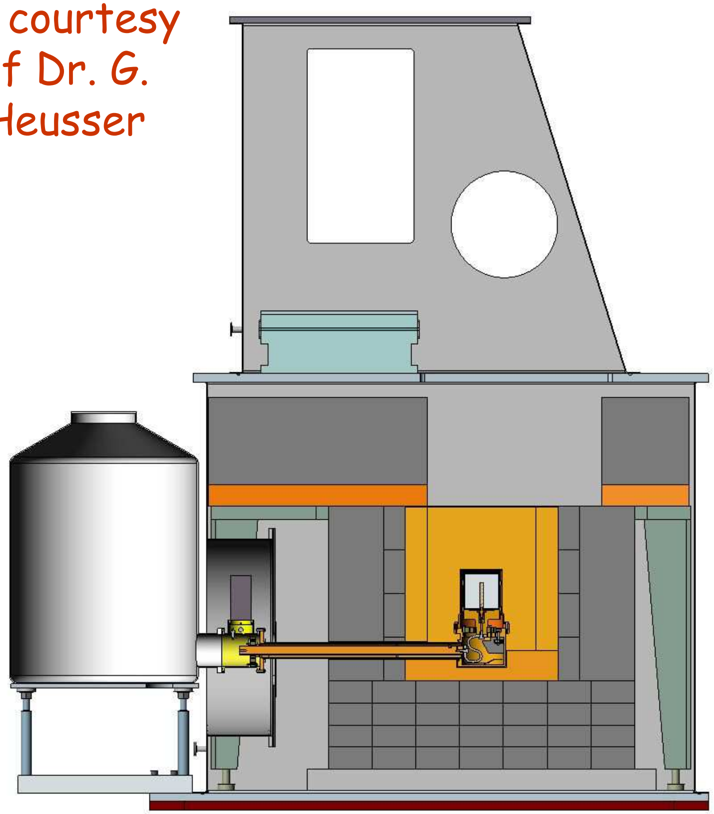
G. Heusser
B. Prokosch
H. Neder
M. Laubenstein

Operated at

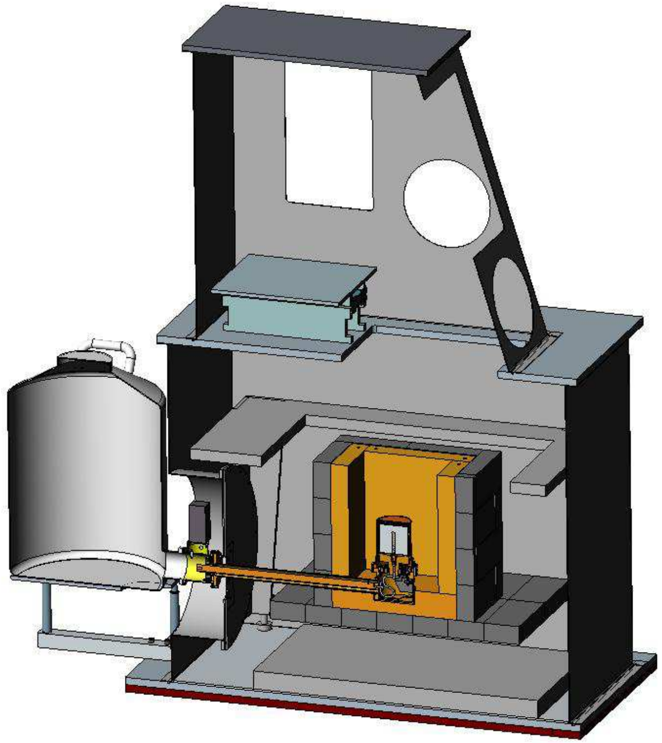
LNGS

(3800 m w.e.)

by courtesy of Dr. G. Heusser



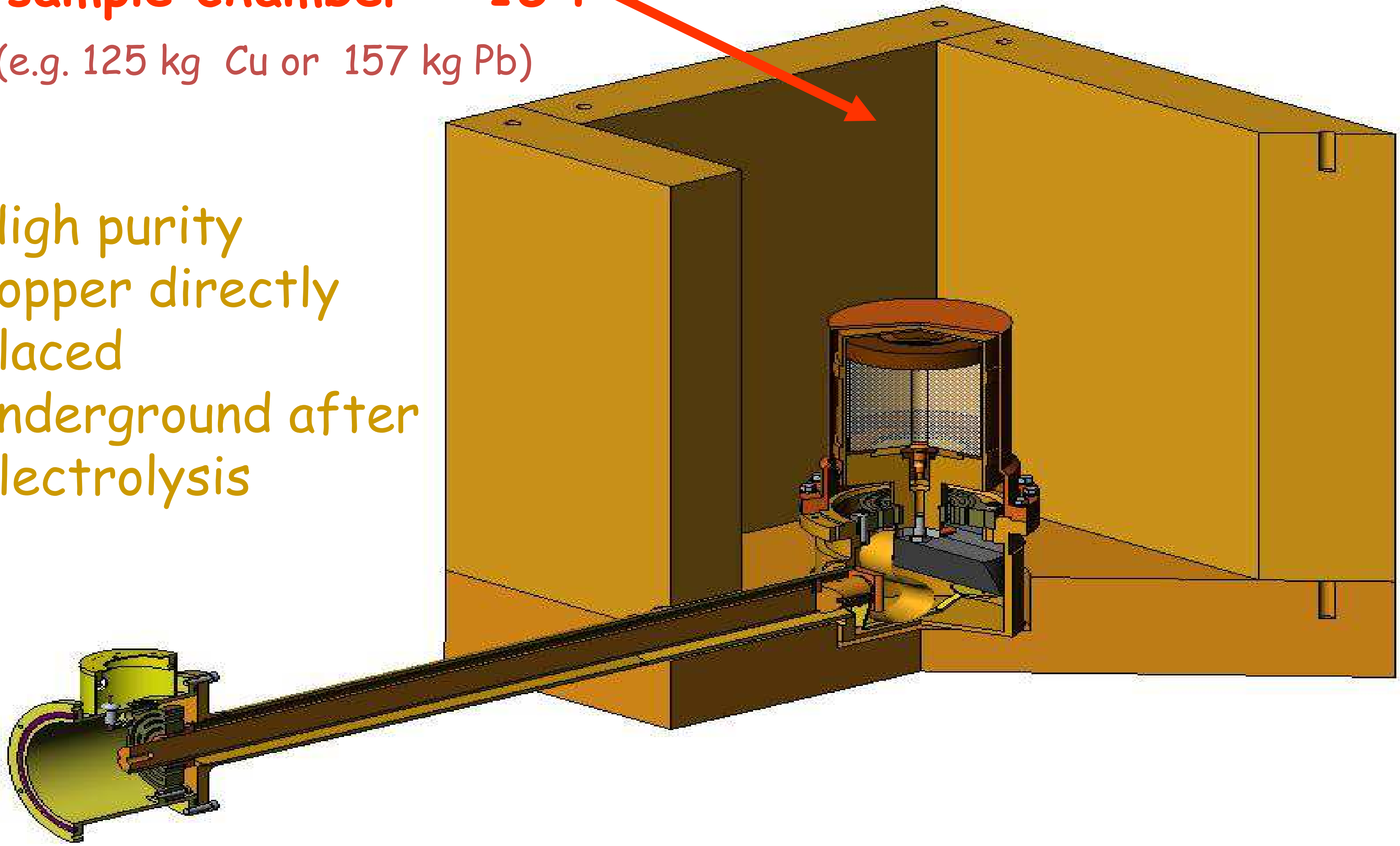
by courtesy of Dr. G. Heusser



effective volume of sample chamber ~ 15 l

(e.g. 125 kg Cu or 157 kg Pb)

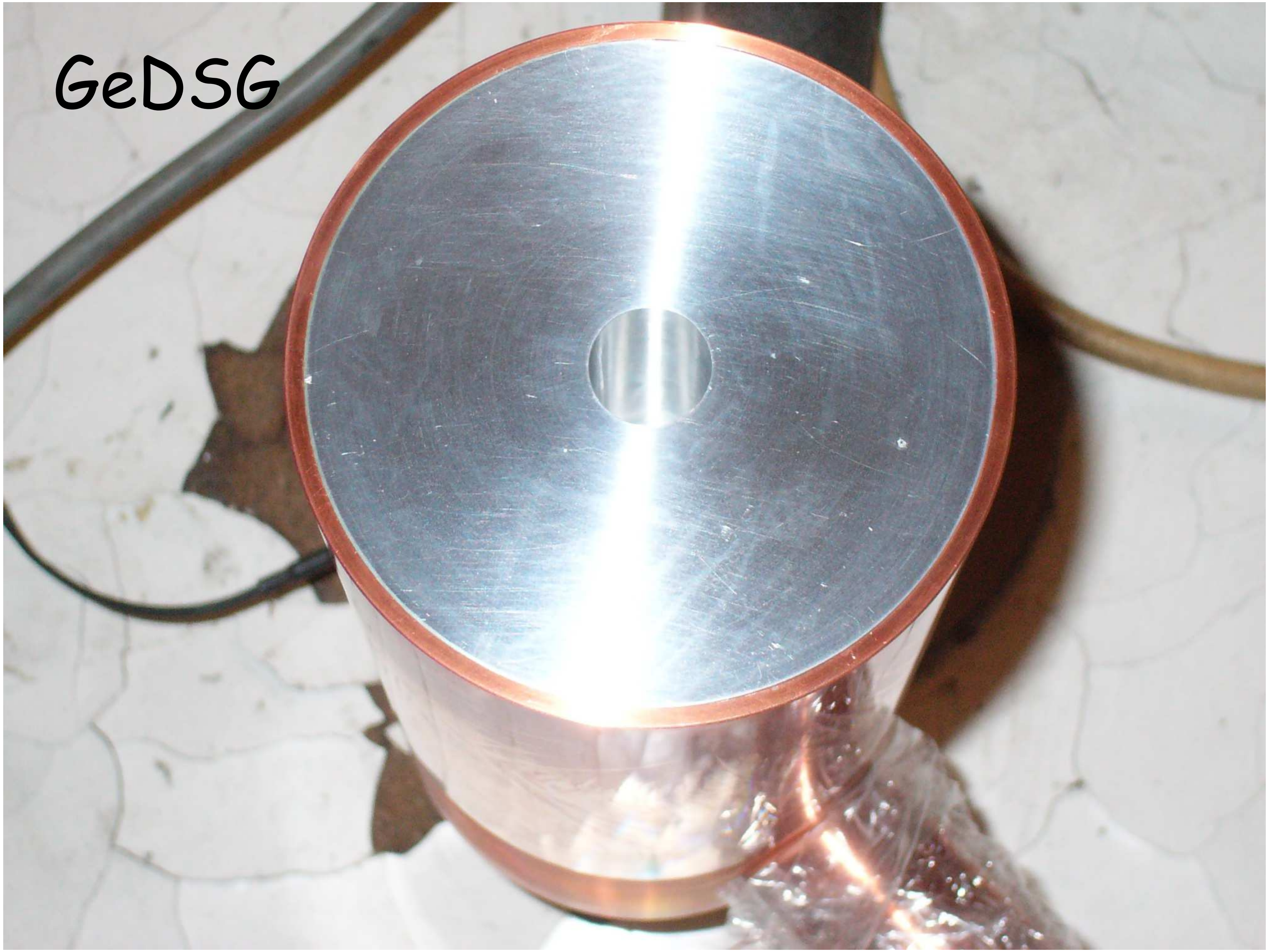
High purity copper directly placed underground after electrolysis

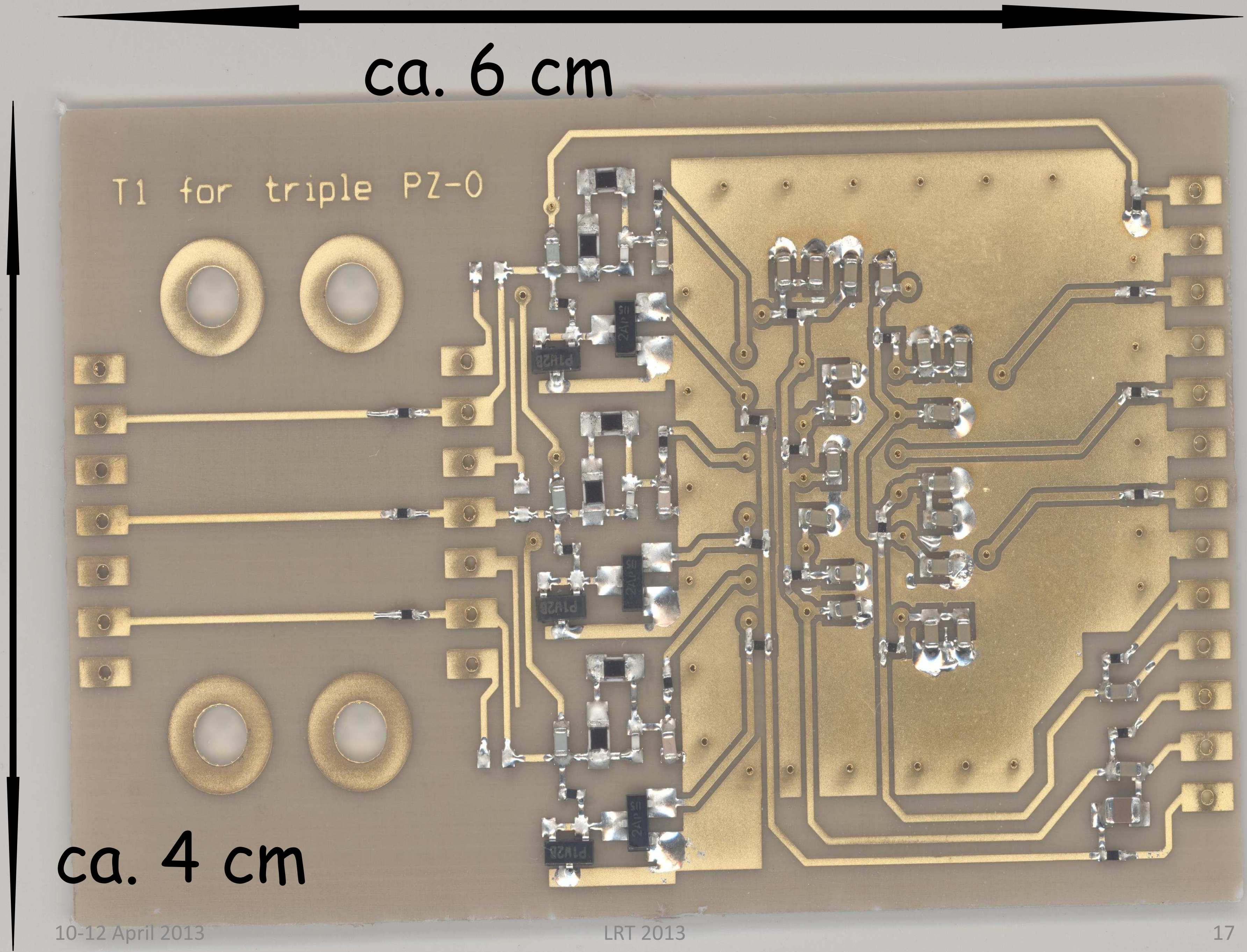


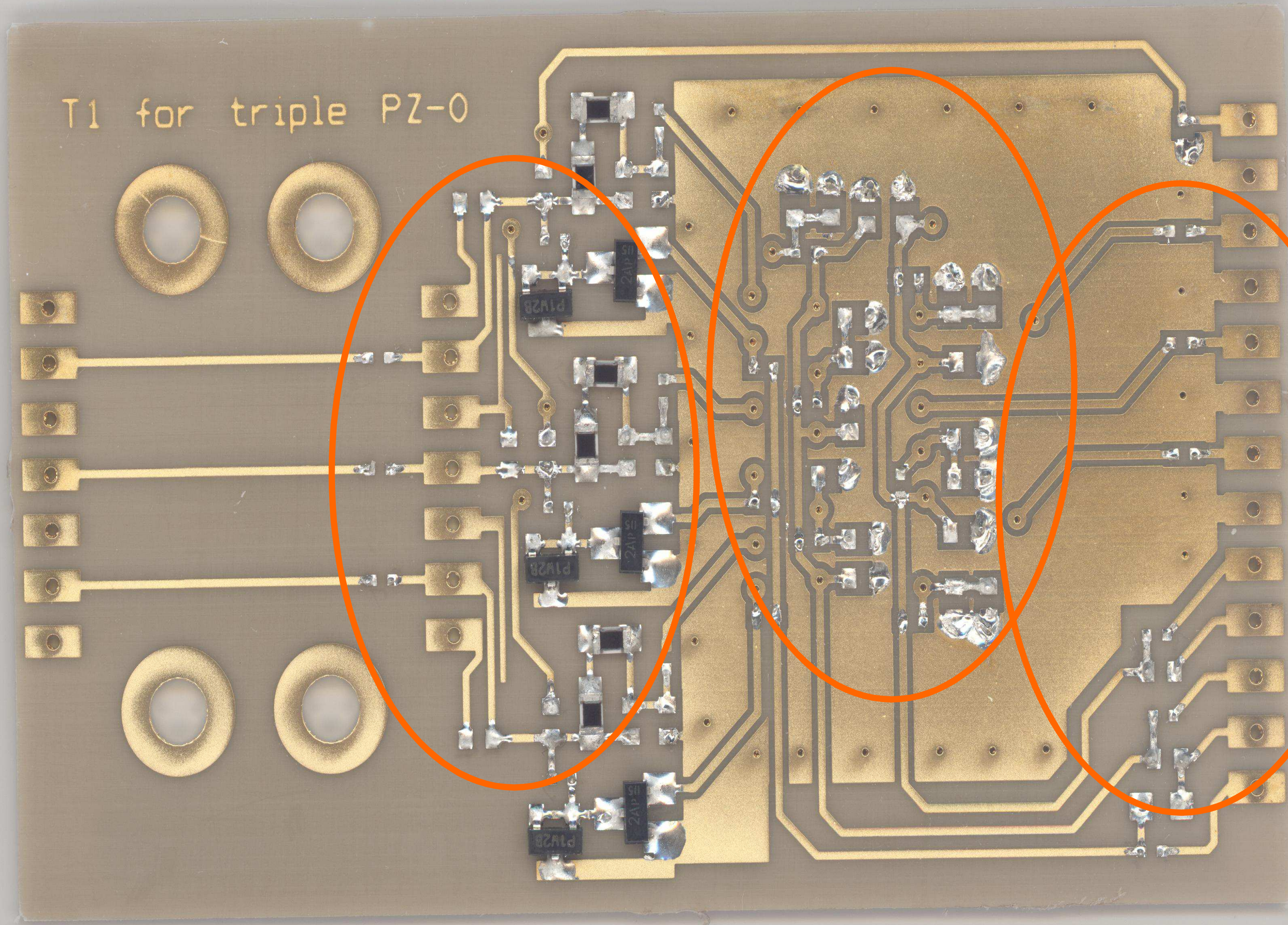
by courtesy of Dr. G. Heusser

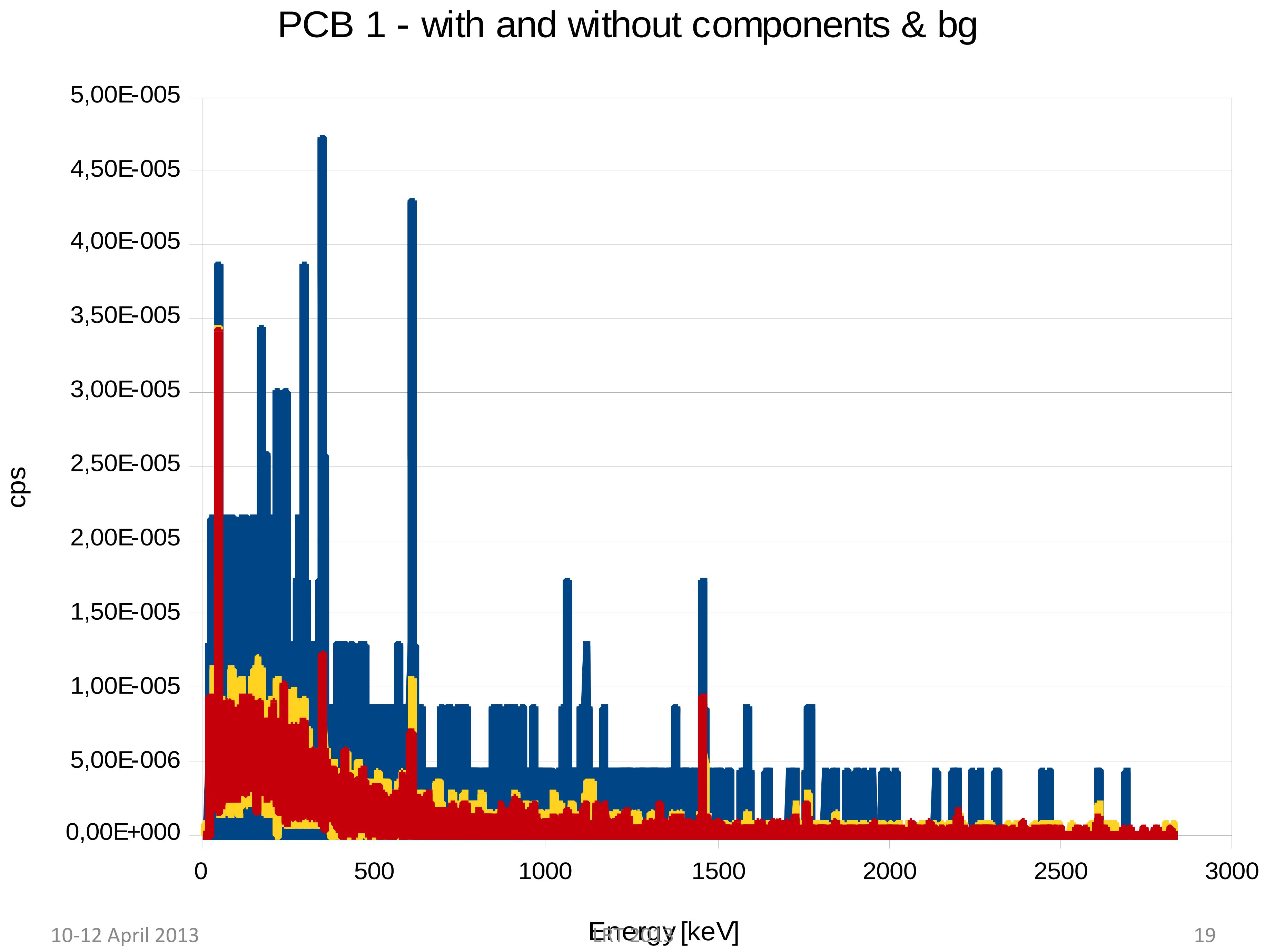
GeMPI-2, 3 and 4 design

GeMPI-2, 3 and 4 design


GeDSG


ca. 6 cm
T1 for triple PZ-0
ca. 4 cm


T1 for triple PZ-0


PCB 1 - with and without components & bg
cps
5,00E-005
4,50E-005
4,00E-005
3,50E-005
3,00E-005
2,50E-005
2,00E-005
1,50E-005
1,00E-005
5,00E-006
0,00E+000
0
500
1000
1500
2000
2500
3000
Energy [keV]

Network of HPGe counting systems

- One lab only can’t nearly handle the request for material selection of current and future ULB experiments (e.g. LNGS 150 – 200 samples /year with 12 detectors (3 GeMPI-type)) → network
- Systems with different overhead burden and intrinsic detector backgrounds.
- Optimize counting efficiency and throughput.

CELLAR

Collaboration of European Low-level underground LAboRatories

University of Iceland

IRMM

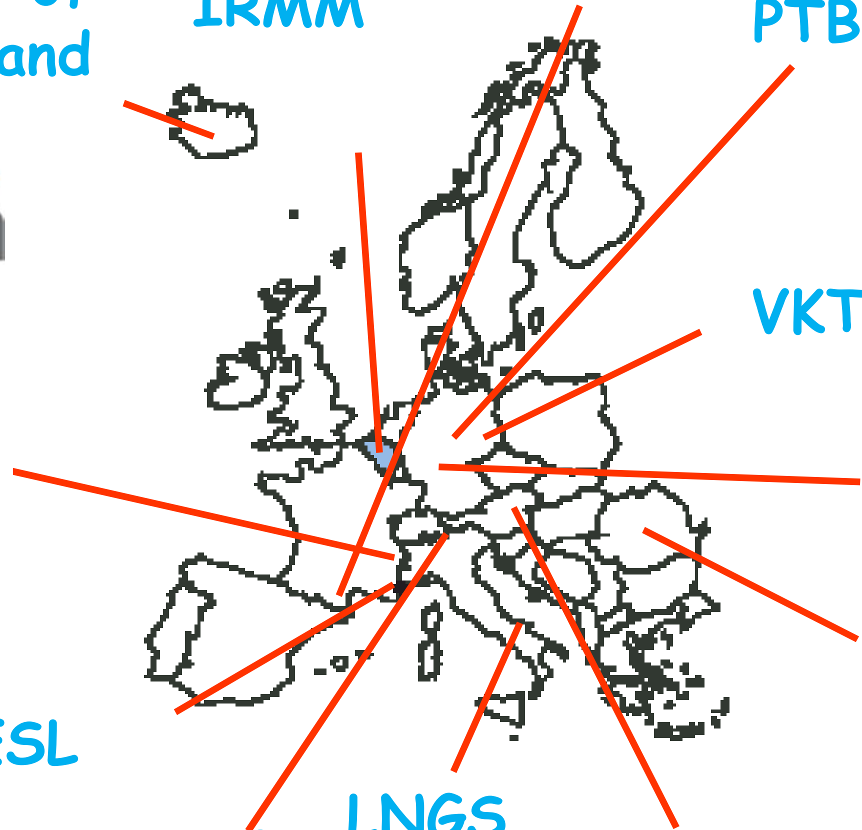
LAFARA

PTB

LSM

LSCE

IRSN



VKTA

MPI-K

IFIN-HH

IAEA-MESL

University of Insubria

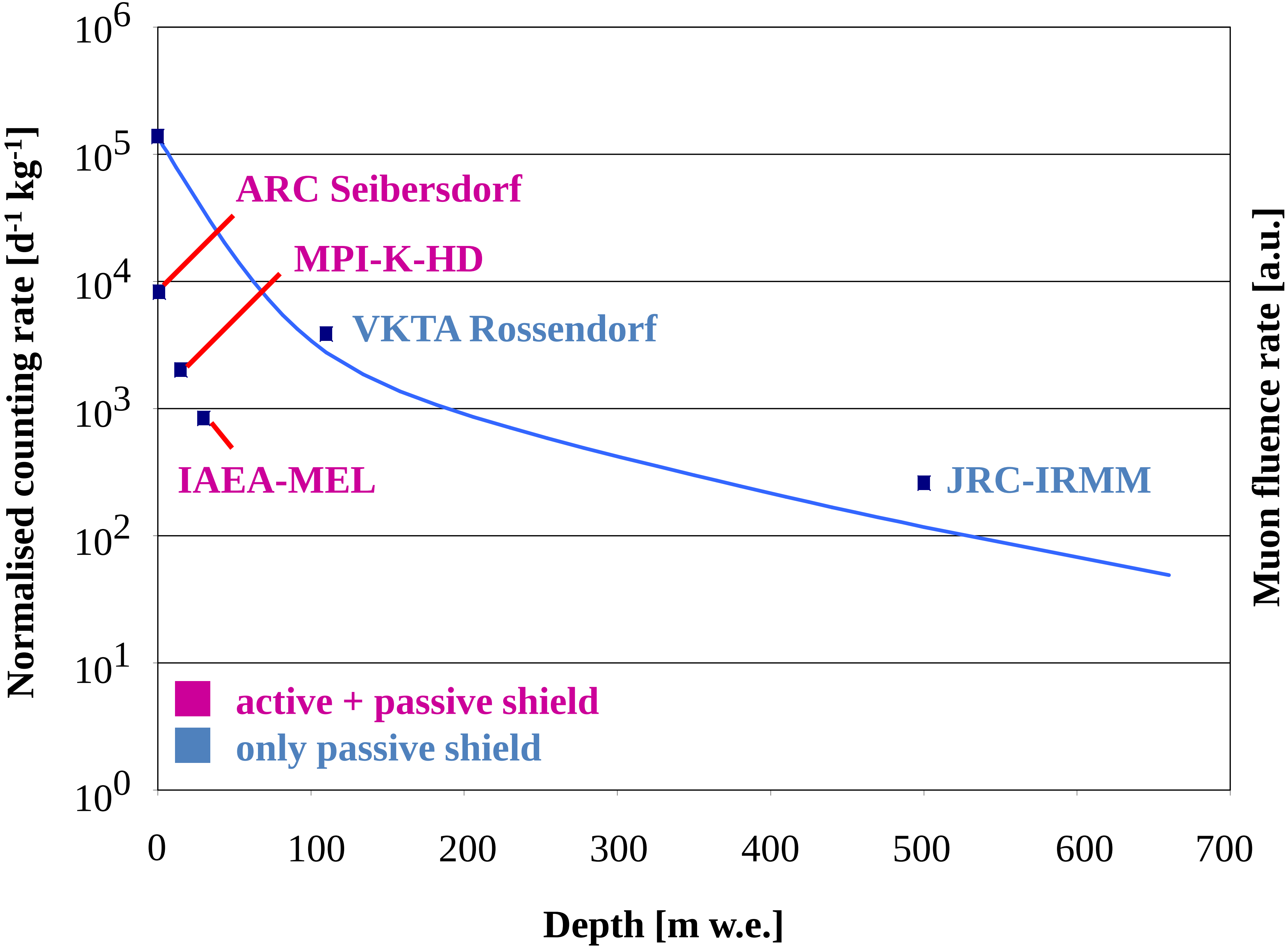
LNGS

SL

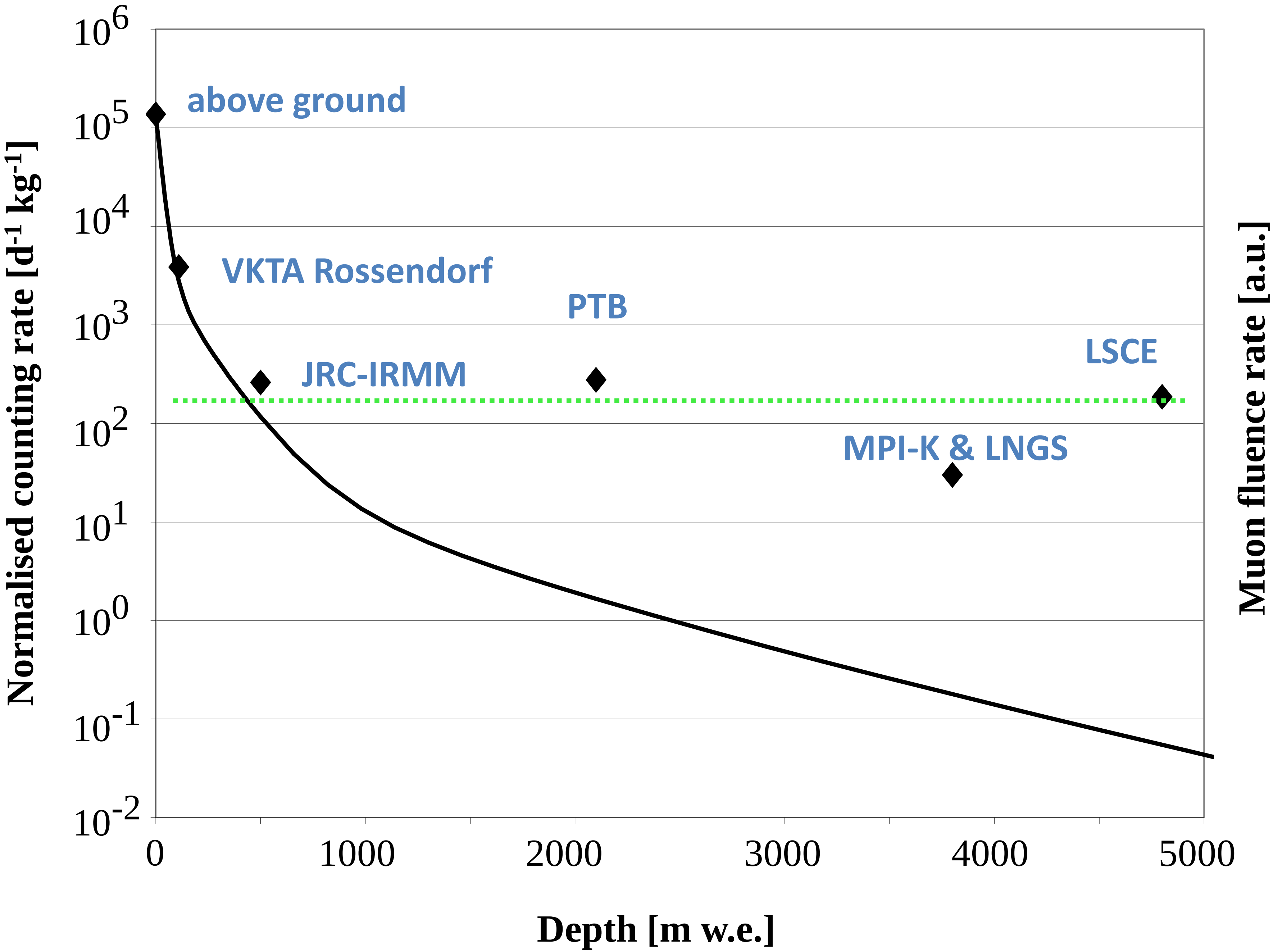
Some of the partner laboratories:

Seibersdorf Laboratories- Austria	(above ground, ~ 3 m w.e.)
MPI-Heidelberg - Germany	(~ 8 m ≅ 15 m w.e.)
IAEA-MEL - Monaco	(~ 14 m ≅ 30 m w.e.)
VKTA - Germany	(~ 50 m ≅ 110 m w.e.)
University of Iceland	(~ 165 m ≅ 350 m w.e.)
IRMM - EU - Belgium	(~ 225 m ≅ 500 m w.e.)
PTB - Germany	(~ 925 m ≅ 2100 m w.e.)
LNGS - Italy	(~ 1400 m ≅ 3800 m w.e.)
LSCE - France	(~ 1750 m ≅ 4800 m w.e.)

(m. w.e. = meter water equivalent, the height of water equivalent to that of the actual shielding material)



10^6
10^5
10^4
10^3
10^2
10^1
10^0
Normalised counting rate [d^{-1} kg^{-1}]
ARC Seibersdorf
MPI-K-HD
VKTA Rossendorf
IAEA-MEL
JRC-IRMM
active + passive shield
only passive shield
0
100
200
300
400
500
600
700
Depth [m w.e.]
Muon fluence rate [a.u.]


above ground
VKTA Rossendorf
PTB
JRC-IRMM
LSCE
MPI-K & LNGS
Normalised counting rate [d-1 kg-1]
Muon fluence rate [a.u.]
Depth [m w.e.]
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
0
1000
2000
3000
4000
5000

“Necessary” Improvements - 1

- more sensitive screening techniques (< μBq/kg for ^{226}Ra) ⇒ use of today’s (e.g. CTF, LArGe, GERDA) or tomorrow's most sensitive detectors for screening

- new detector concepts to replace HPGe detectors to be more sensitive;

- dedicated and highly sensitive screening and test techniques for measuring and monitoring *surface* contaminations

“Necessary” Improvements - 2

- reorganization and optimization of existing screening facilities is necessary, because they are costly and measurement times can be rather lengthy

- harmonization of how to report data and intercomparison programs for ultra low-level measurement techniques