STELLA - the LNGS ultra low background facility: multi disciplinary science applications

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Underground Synergies with Astro-Particle Physics
Durham, UK
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Introduction

- Many fundamental experiments aim to detect very weak signals. They have to fight against background of different origin.
  - cosmic radiation
  - particles of nuclear decays
  - intrinsic natural radioactivity

Ultra low background α and γ spectroscopy @ L.N.G.S.

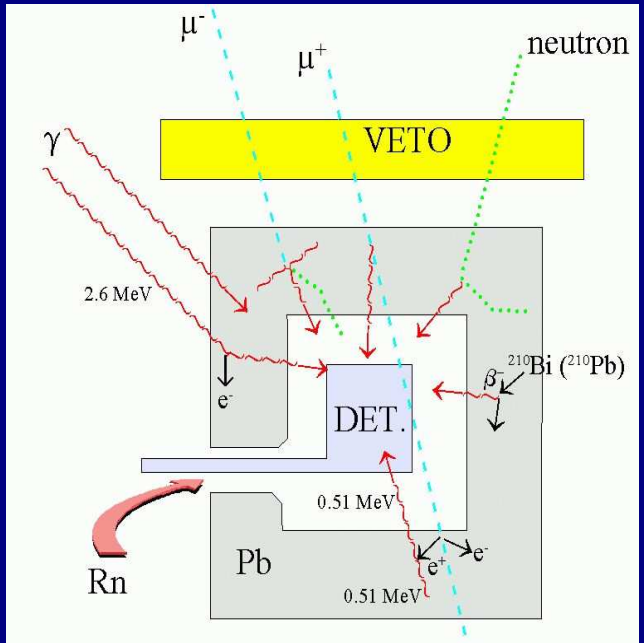
STELLA = **S**ub**TE**rranean **L**ow **L**evel **A**ssay

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

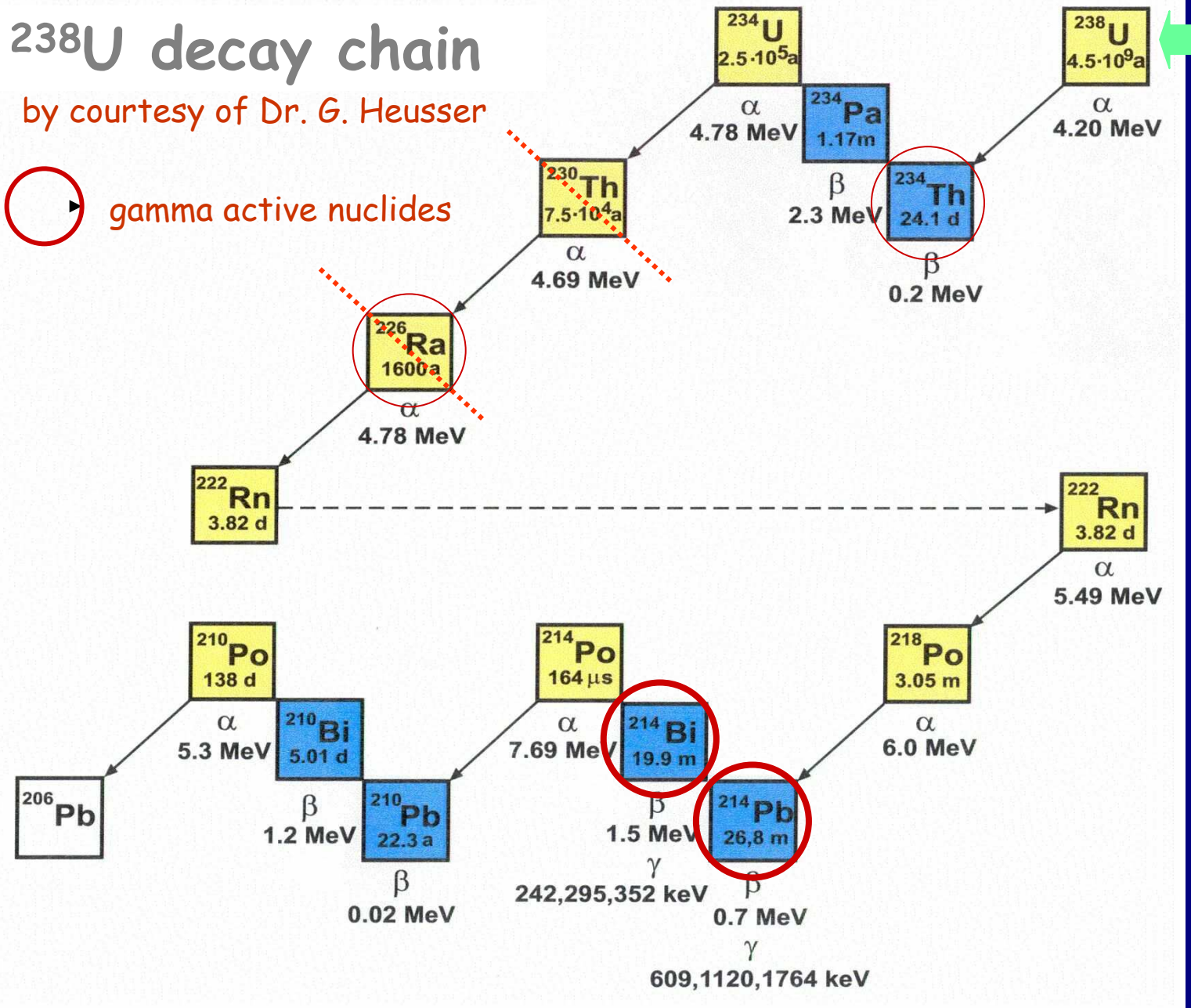
most important: material screening

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

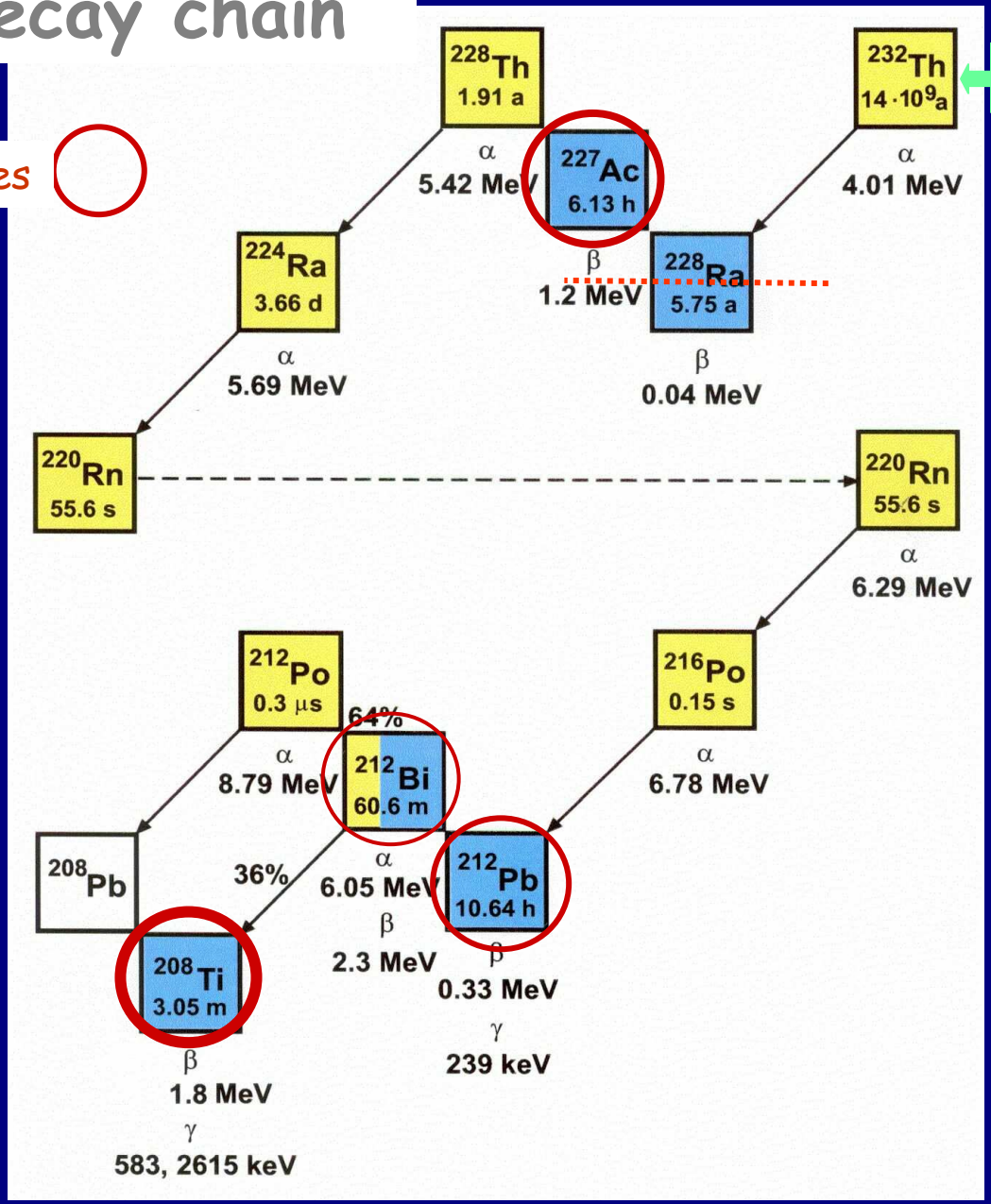


mass spectro-metry

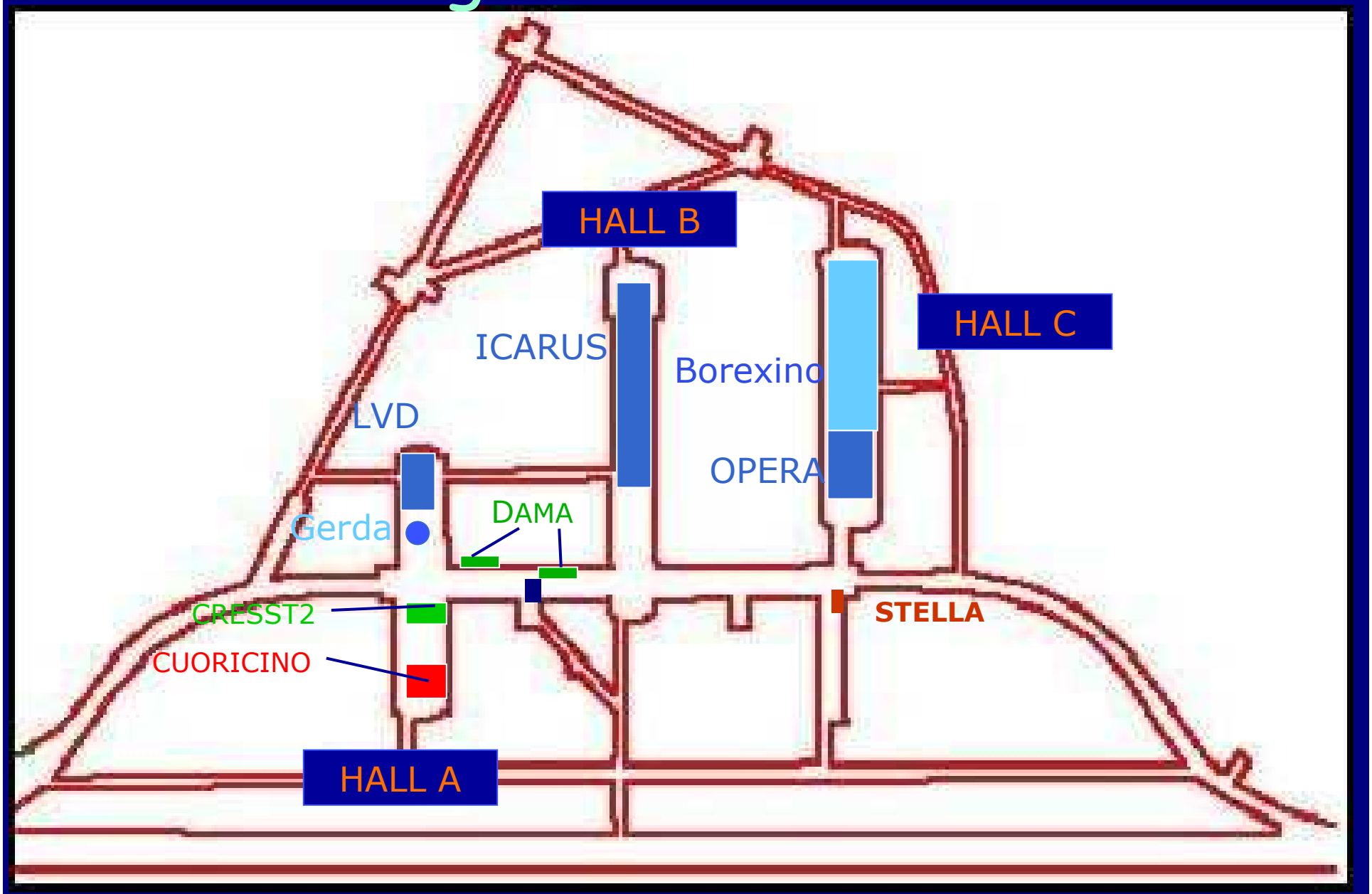
^{232}Th decay chain

by courtesy of Dr. G. Heusser

gamma active nuclides



Underground laboratories




EG&G ORTEC

Activities

- material screening (GerDA, CUORE, Darkside, Xenon et al.);
- small fundamental physics research projects (mainly with DAMA, KINR);
- meteorite measurements;
- CELLAR activities;
- environmental radioactivity (ERMES);
- Detector development;

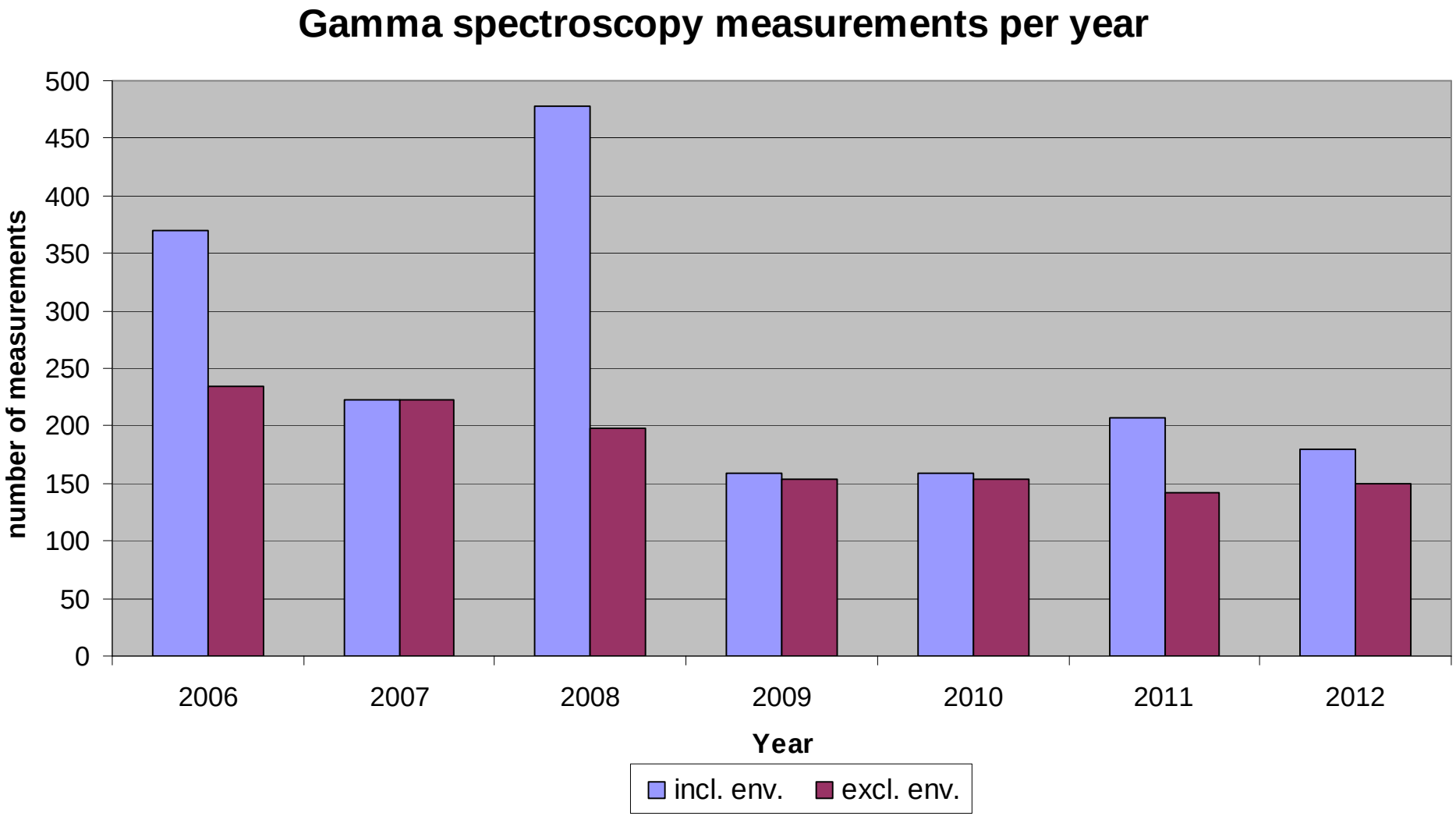
Activities-2

As already mentioned not only γ spectroscopy is performed, but also studies on radon.

Average radon concentration in the experimental halls is in the range of (30-150) Bq m^{-3} with the ventilation working properly.

Continuous monitoring is performed with commercial radon monitors.

Moreover R&D on radioprotection equipment (bronchial dose meter) has been performed.


Gamma spectroscopy measurements per year
number of measurements
500
450
400
350
300
250
200
150
100
50
0
2006
2007
2008
2009
2010
2011
2012
Year
incl. env.
excl. env.

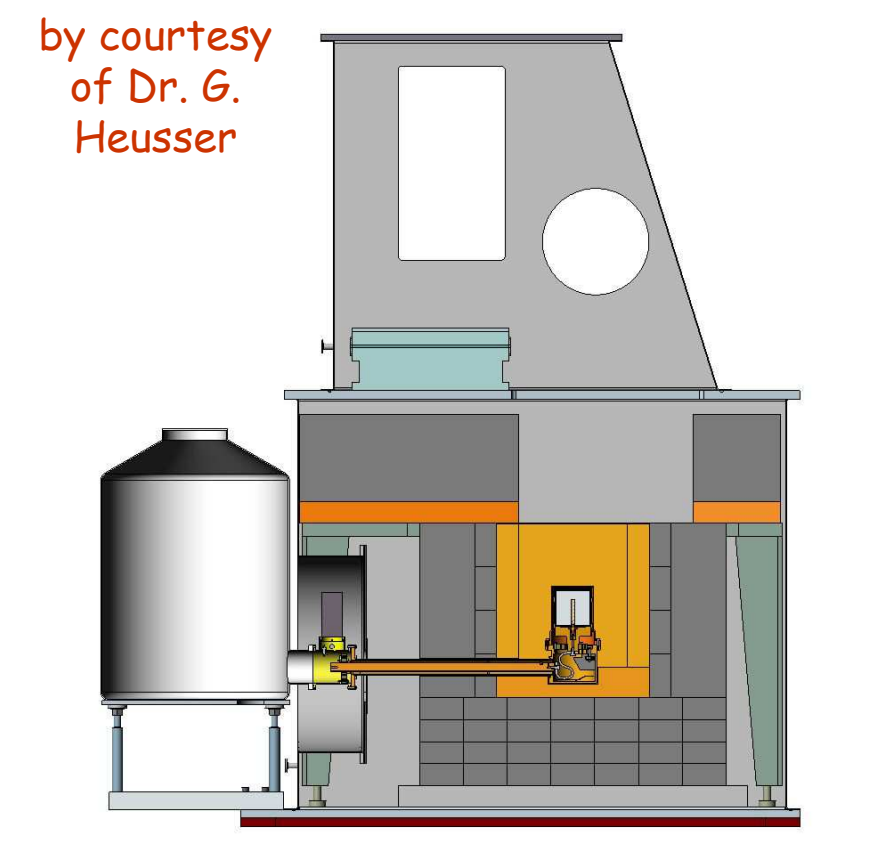
GeMPI (MPI-K development)

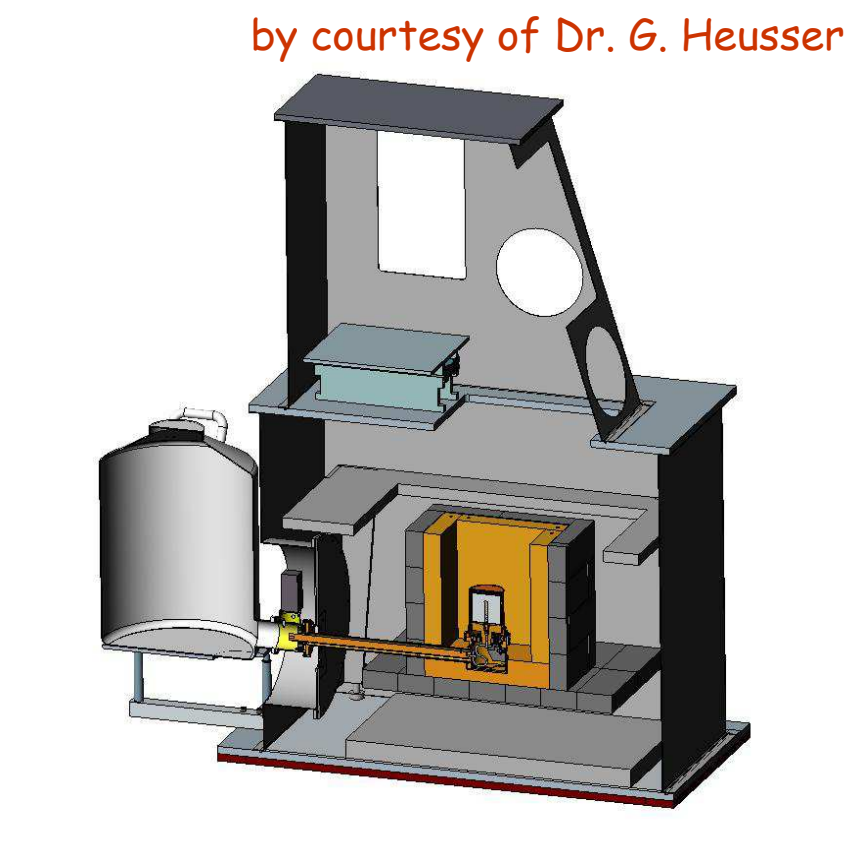
G. Heusser
B. Prokosch
H. Neder
M. Laubenstein

Operated at

LNGS

(3800 m w.e.)

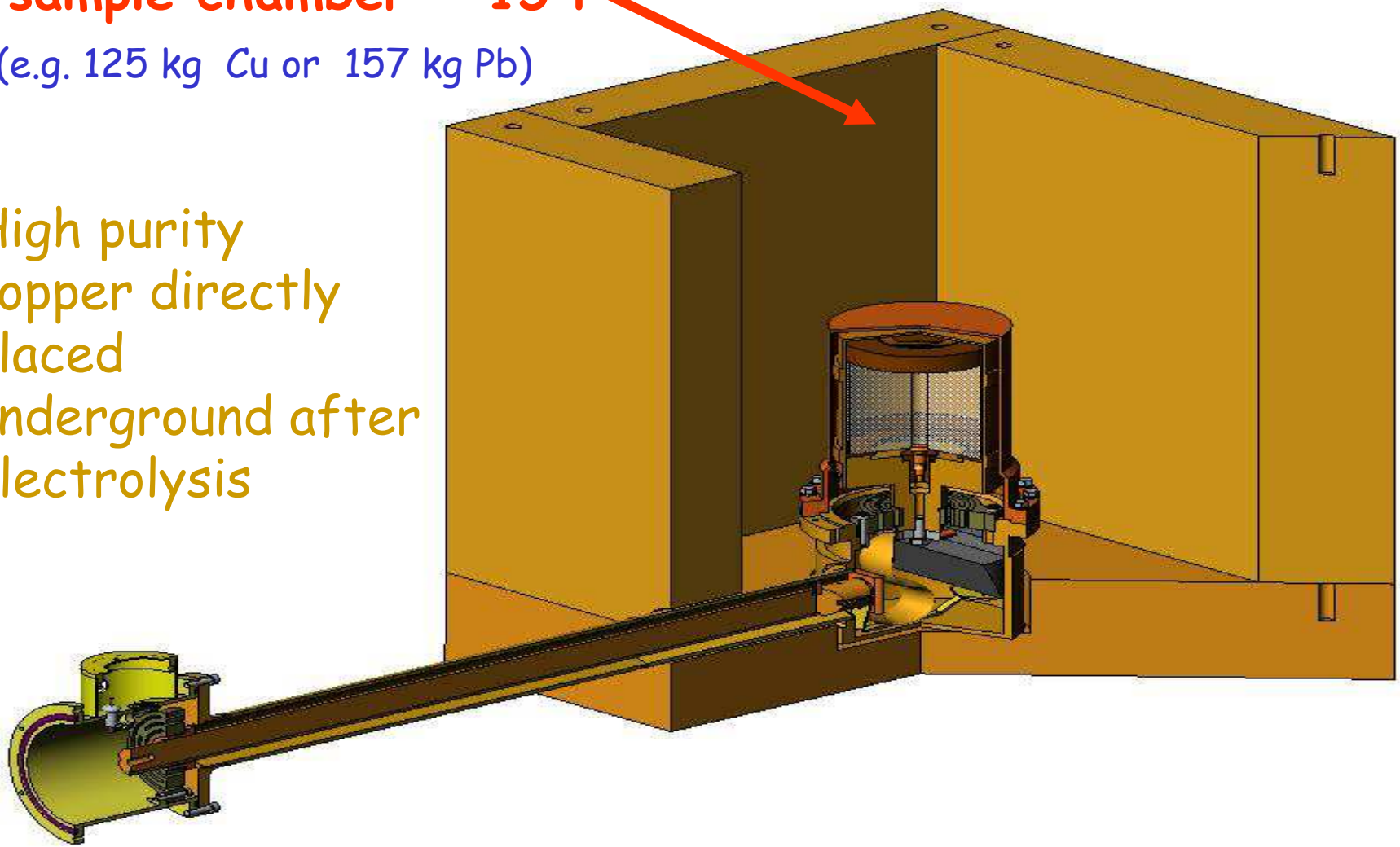




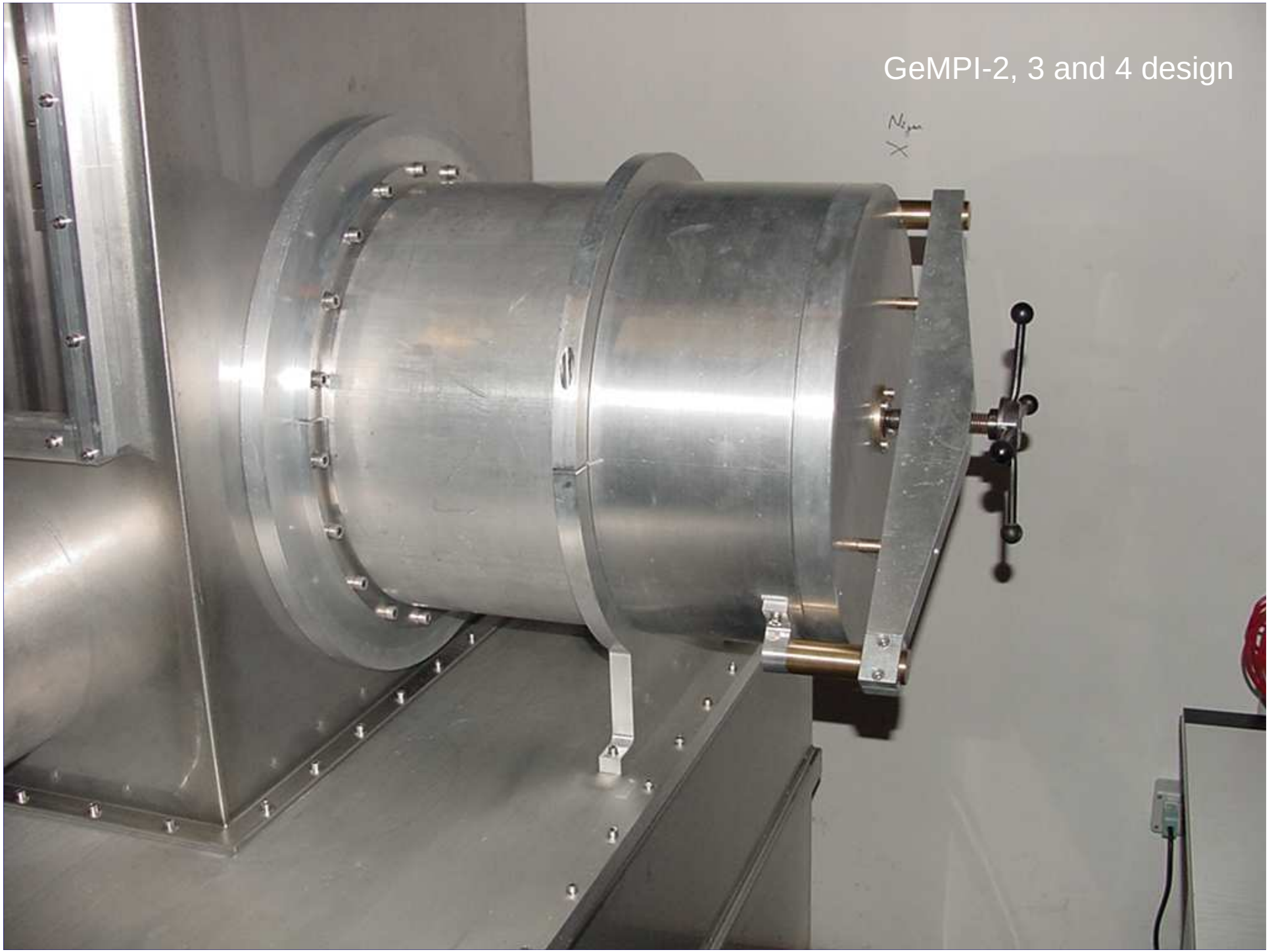
effective volume of sample chamber ~ 15 l

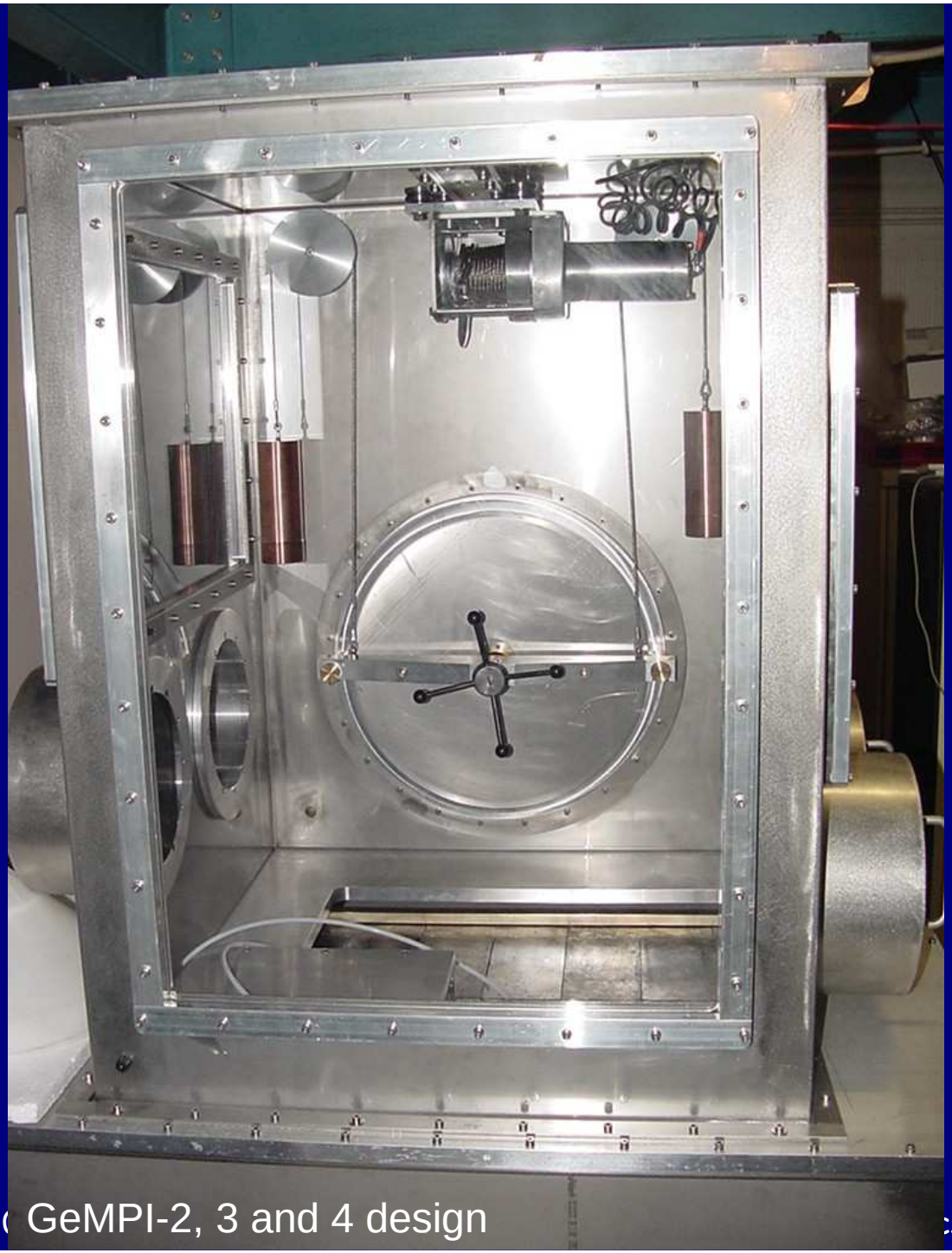
(e.g. 125 kg Cu or 157 kg Pb)

High purity copper directly placed underground after electrolysis



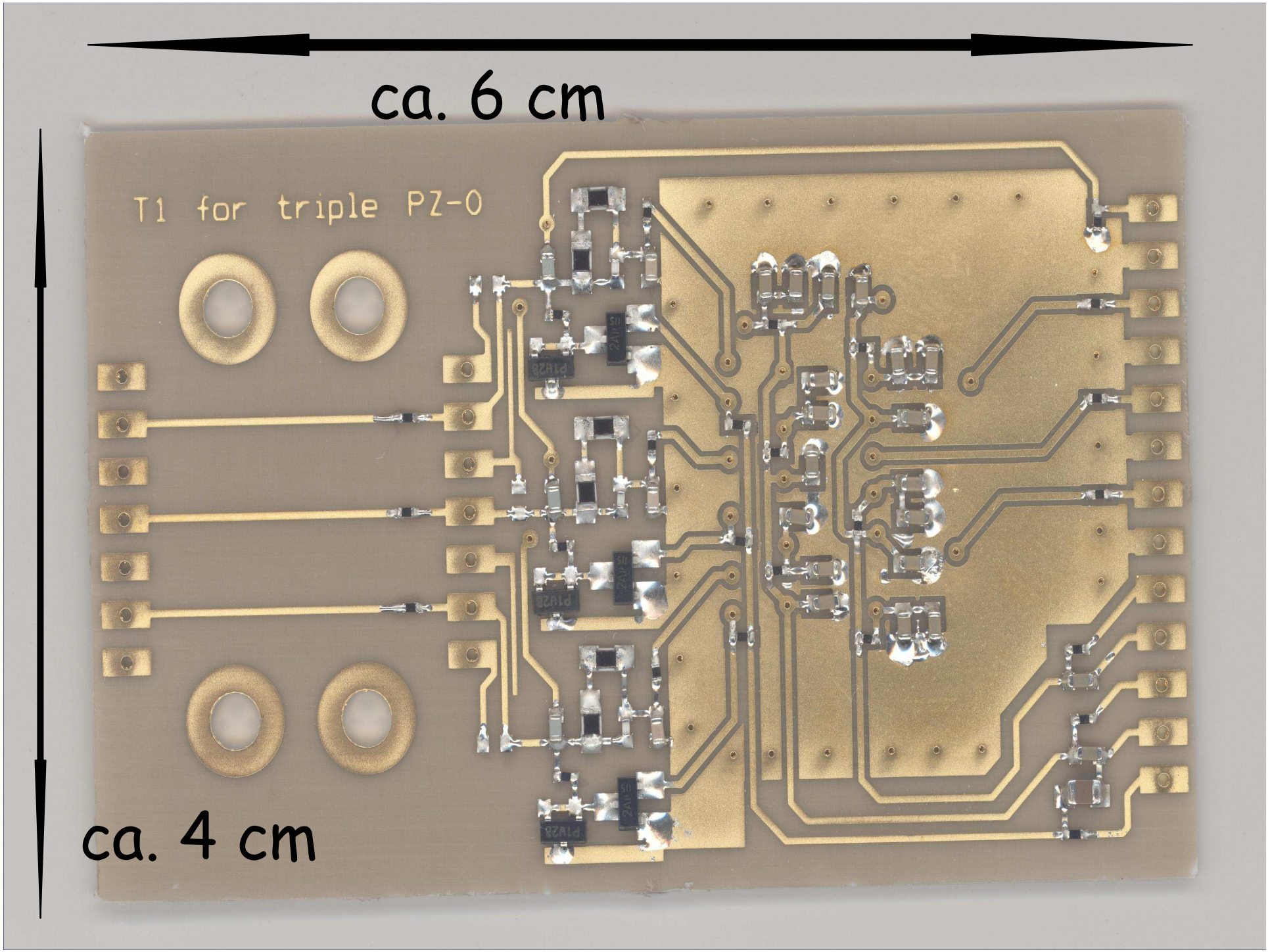
by courtesy of Dr. G. Heusser

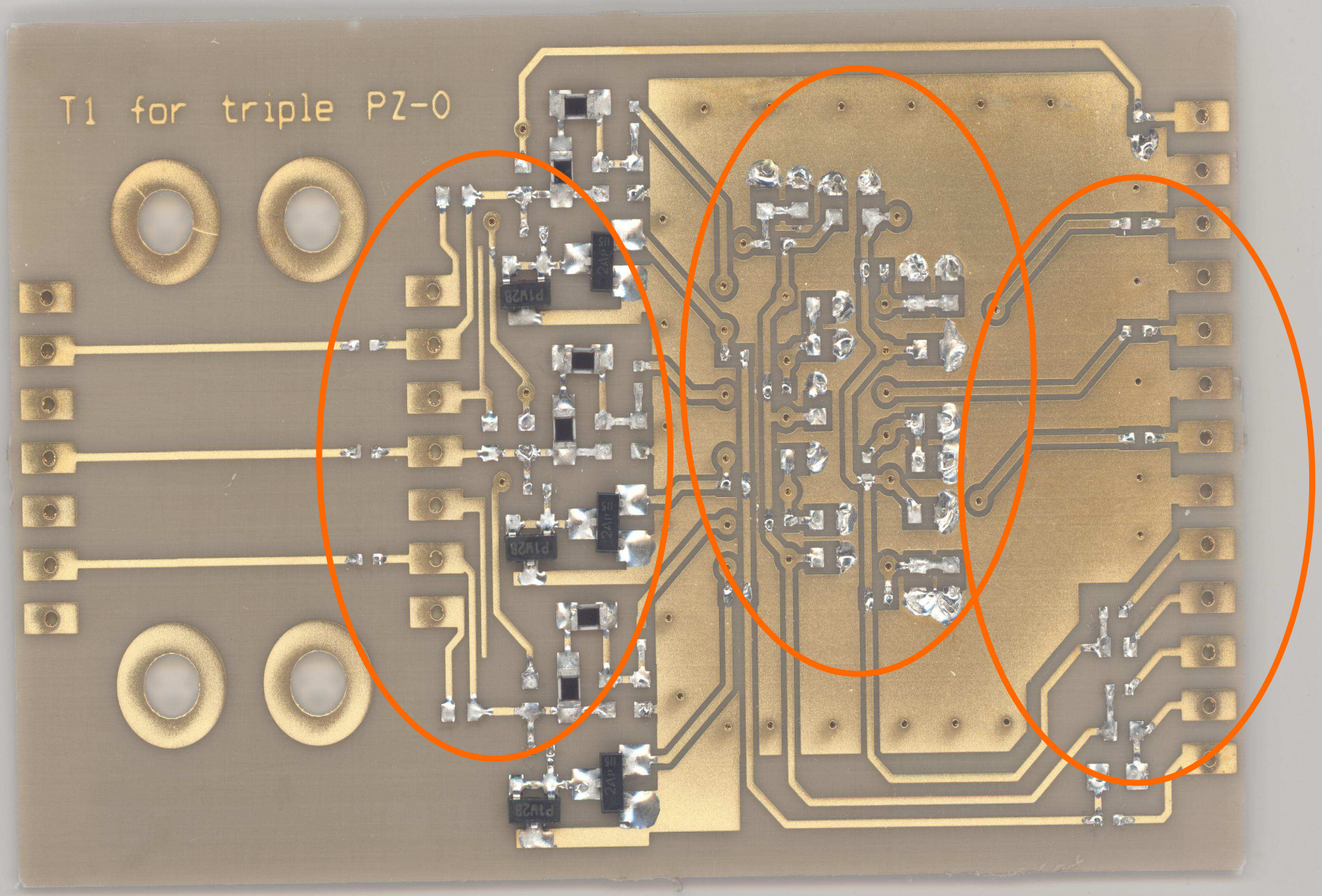

GeMPI-2, 3 and 4 design



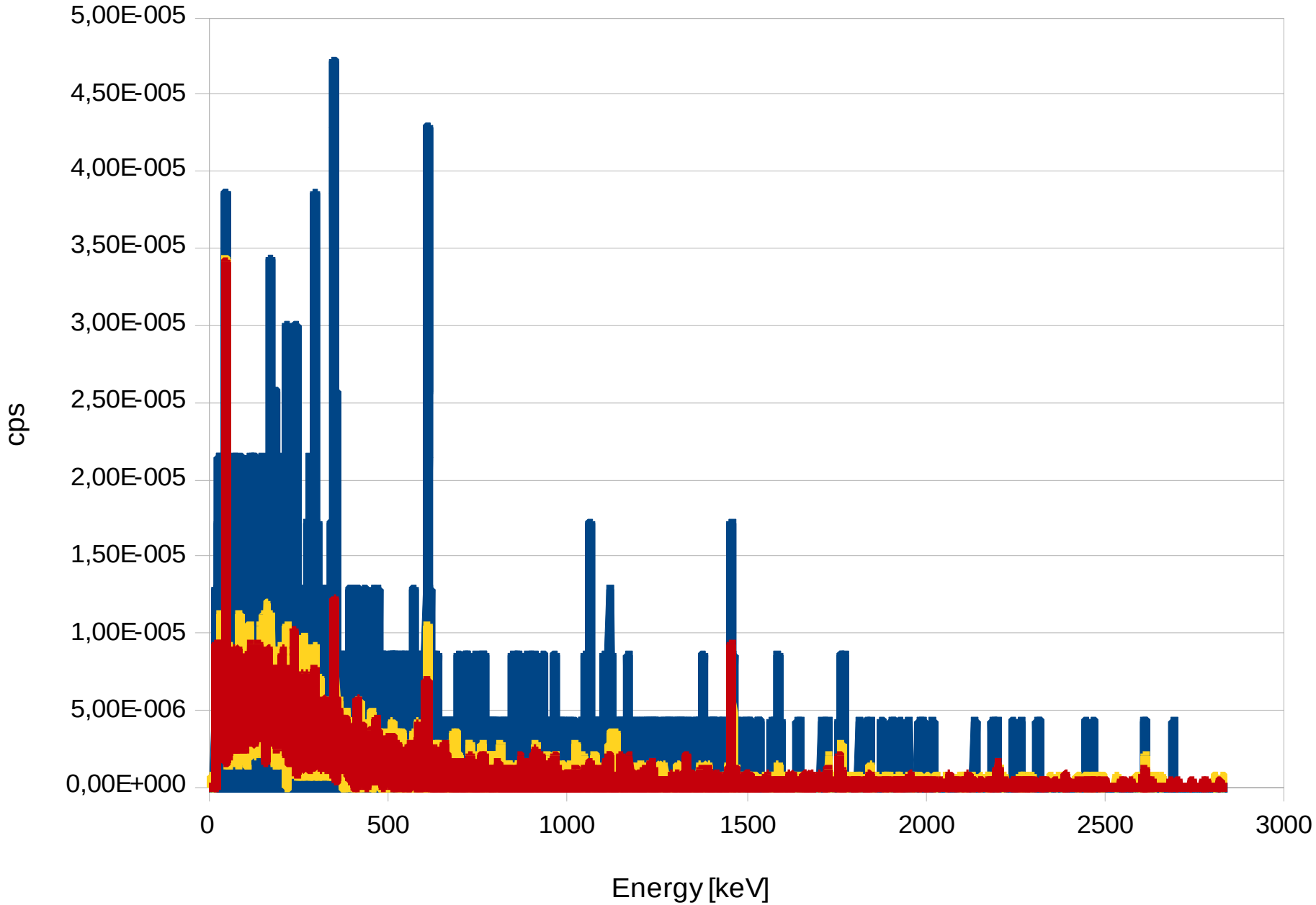
GeMPI-2, 3 and 4 design


GeDSG

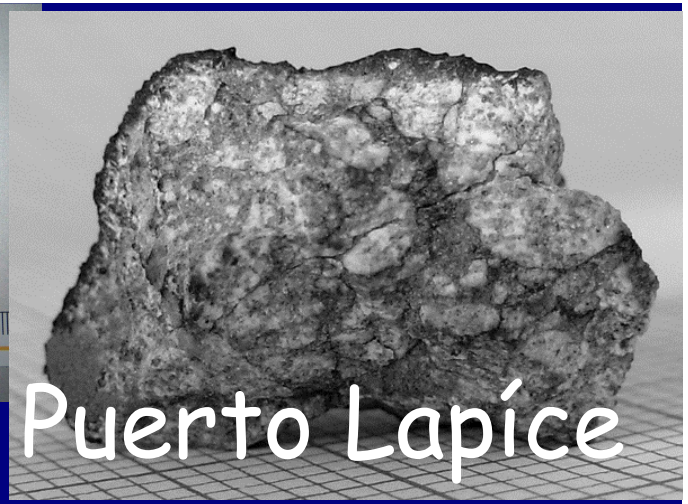

ca. 6 cm
T1 for triple PZ-0
ca. 4 cm


T1 for triple PZ-0

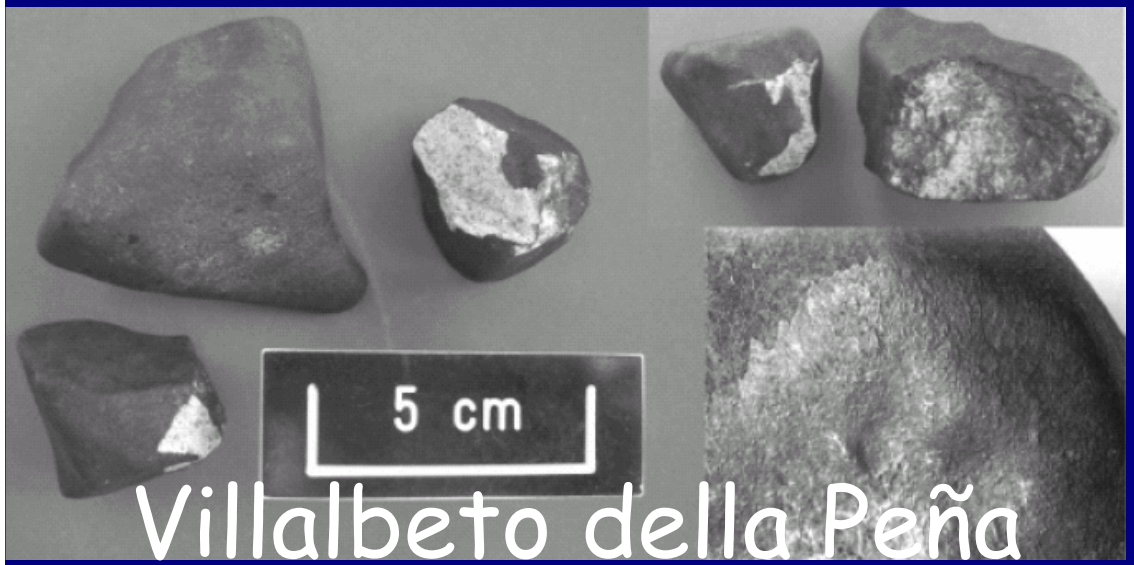
PCB 1 - with and without components & bg



MPS 47, Nr 1, 30–50 (2012)

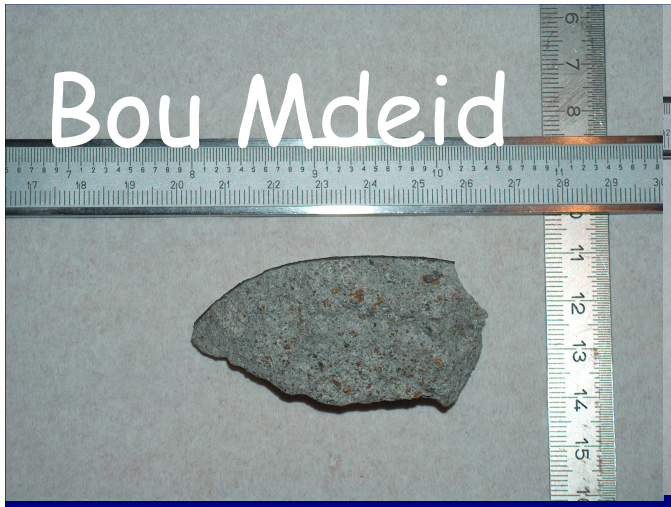


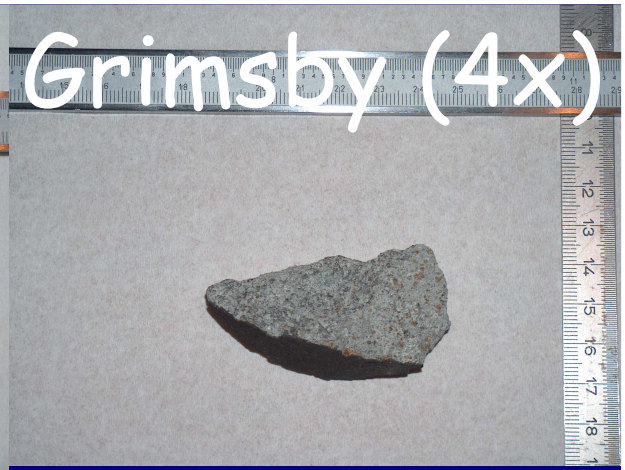
MPS 44, Nr 2, 159–174 (2009)



MPS 40, Nr 6, 795–804 (2005)

MPS 45, Nr 10-11, 1638-1656 (2010)
MPS 45, Nr 10-11, 1657-1667 (2010)





… and Jesenice, Mifflin, Bunburra Rockhole, Kosice, Battle Mountain, Novato

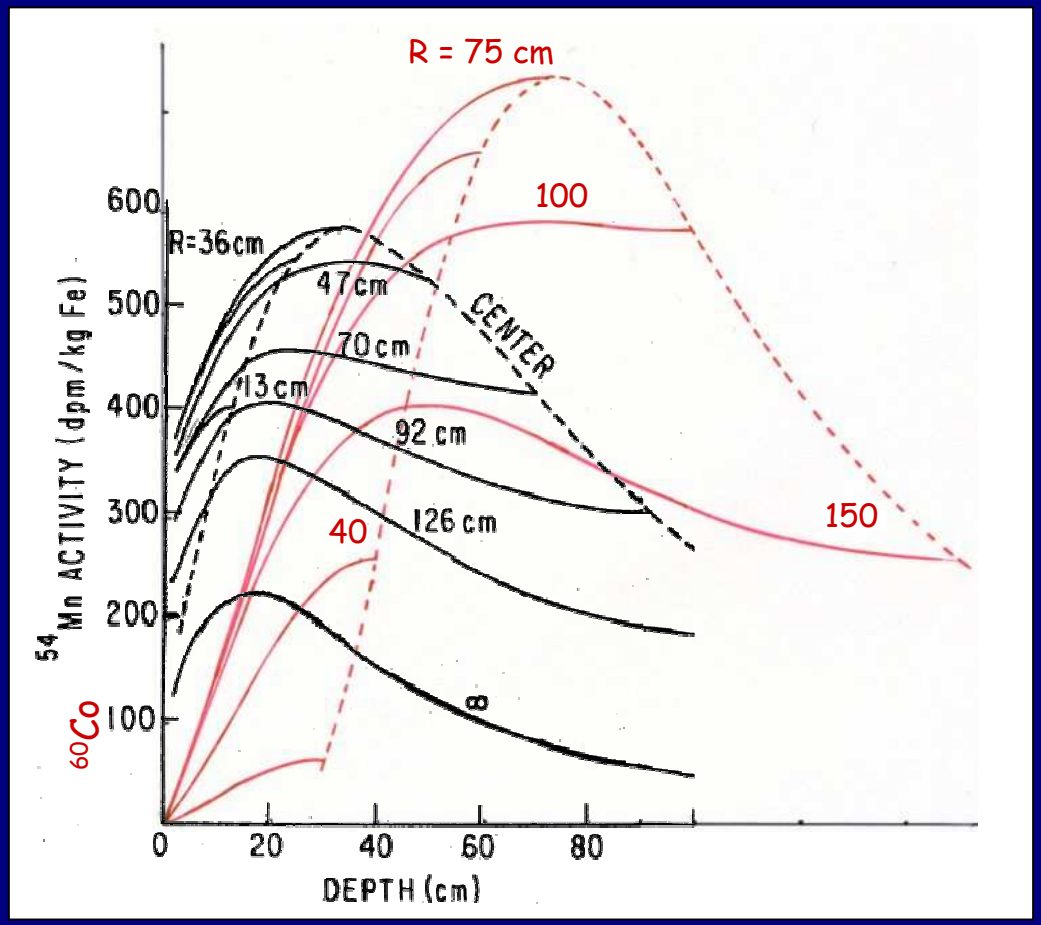
in meteorites

^{26}Al (7.16×10^5 a) β^+

^{22}Na (2.602 a) β^+

^{60}Co (5.27 a)

^{54}Mn (312.15 d)



Physics measurements - 1

- Search for ^{7}Li solar axions using resonant absorption in LiF crystal: Final results (PLB 711 (2012) 41-45)
- Search for time dependence of the ^{137}Cs decay constant (PLB 710 (2012) 114-117)
- First search for double-beta decay of platinum by ultra-low background HP Ge gamma spectrometry (EPJ A 47 (2011))
- First search for double beta decay of dysprosium (NP A 859 (2011) 126-139)
- First observation of alpha decay of ^{190}Pt to the first excited level (E_{exc}=137.2 keV) of ^{186}Os (PRC 83 (2011))

Physics measurements - 2

double EC in ^{136}Ce to excited levels of ^{136}Ba (Nucl. Phys. A 824 (2009) 101–114)

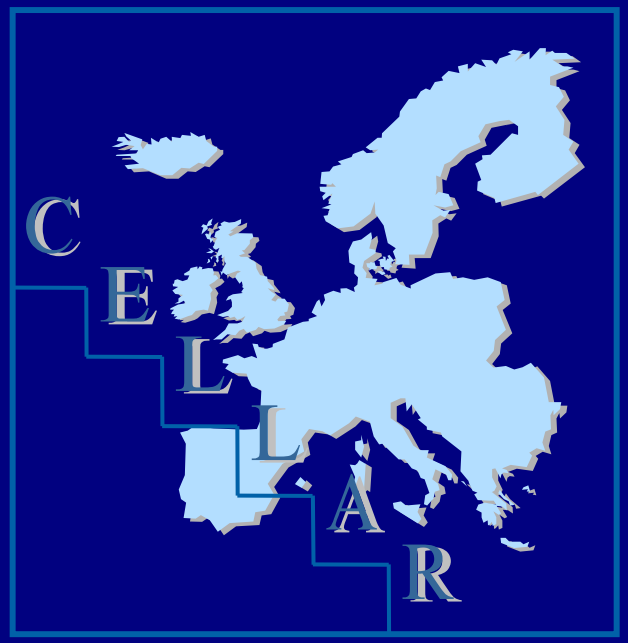
2β-decay of ^{104}Ru to excited level of ^{104}Pd (Eur. Phys. J. A 42 (2009) 171–177)

α decay ^{151}Eu→^{147}Pm, E_{exc}=91.1 keV (Nucl. Instr. Meth. A572 (2007) 734–738)

β-decay of ^{115}In to ^{115}Sn* (Nucl. Phys. A748 (2005) 333–347)

CELLAR

Collaboration of European Low-level underground LAboRatories



University of Iceland

IRMM

LAFARA

PTB

LSM

VKTA

LSCE

MPI-K

IRSN

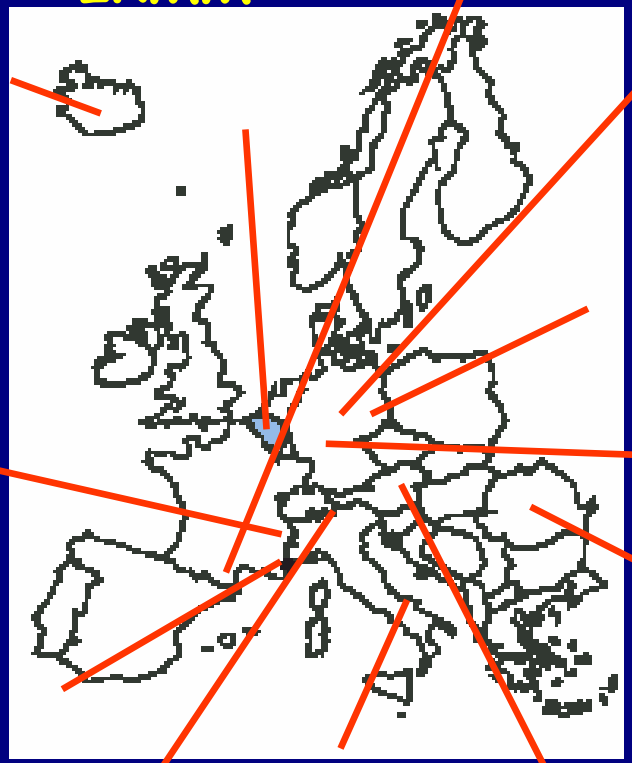
IFIN-HH

IAEA-MESL

LNGS

SL

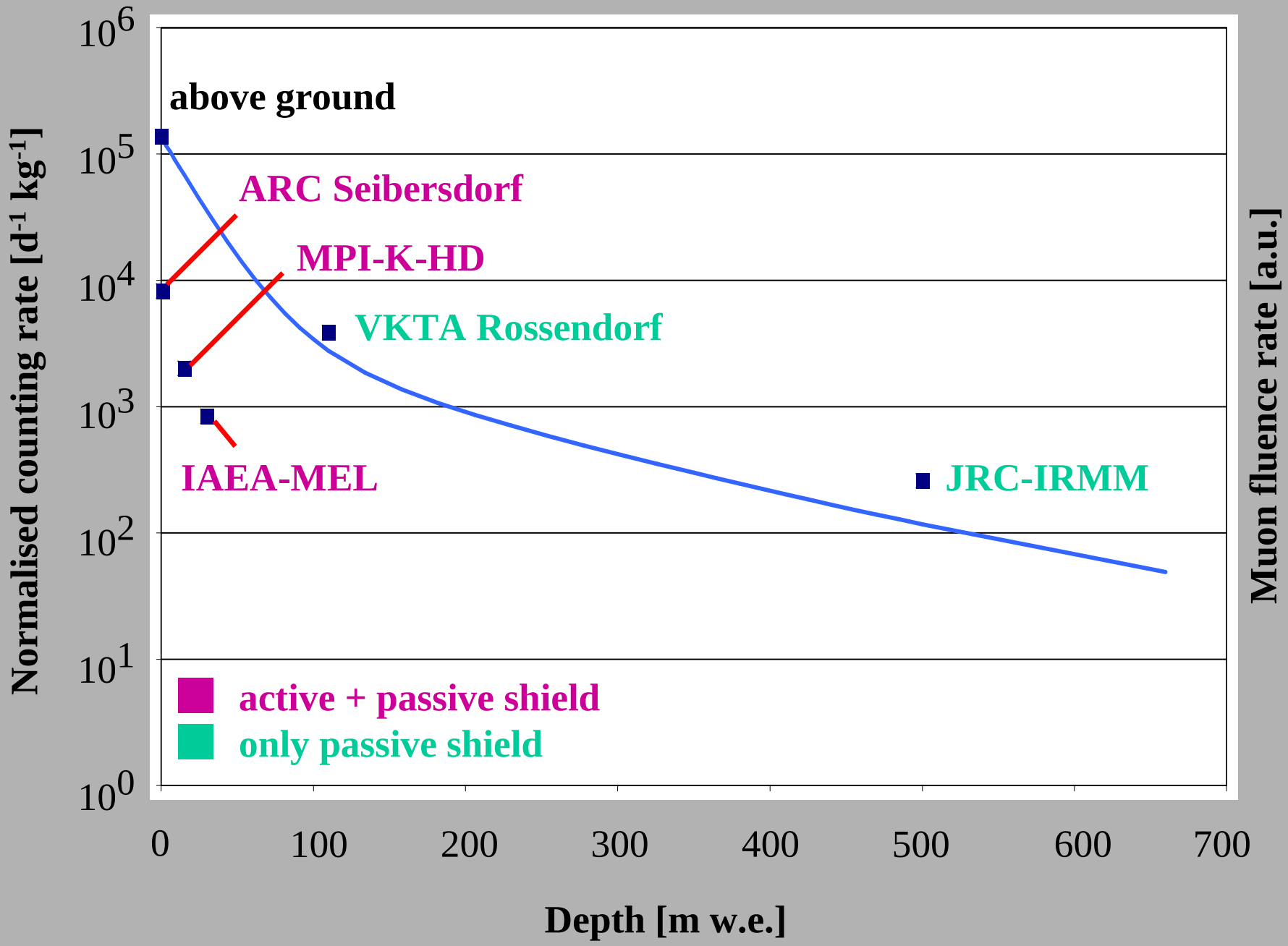
University of Insubria

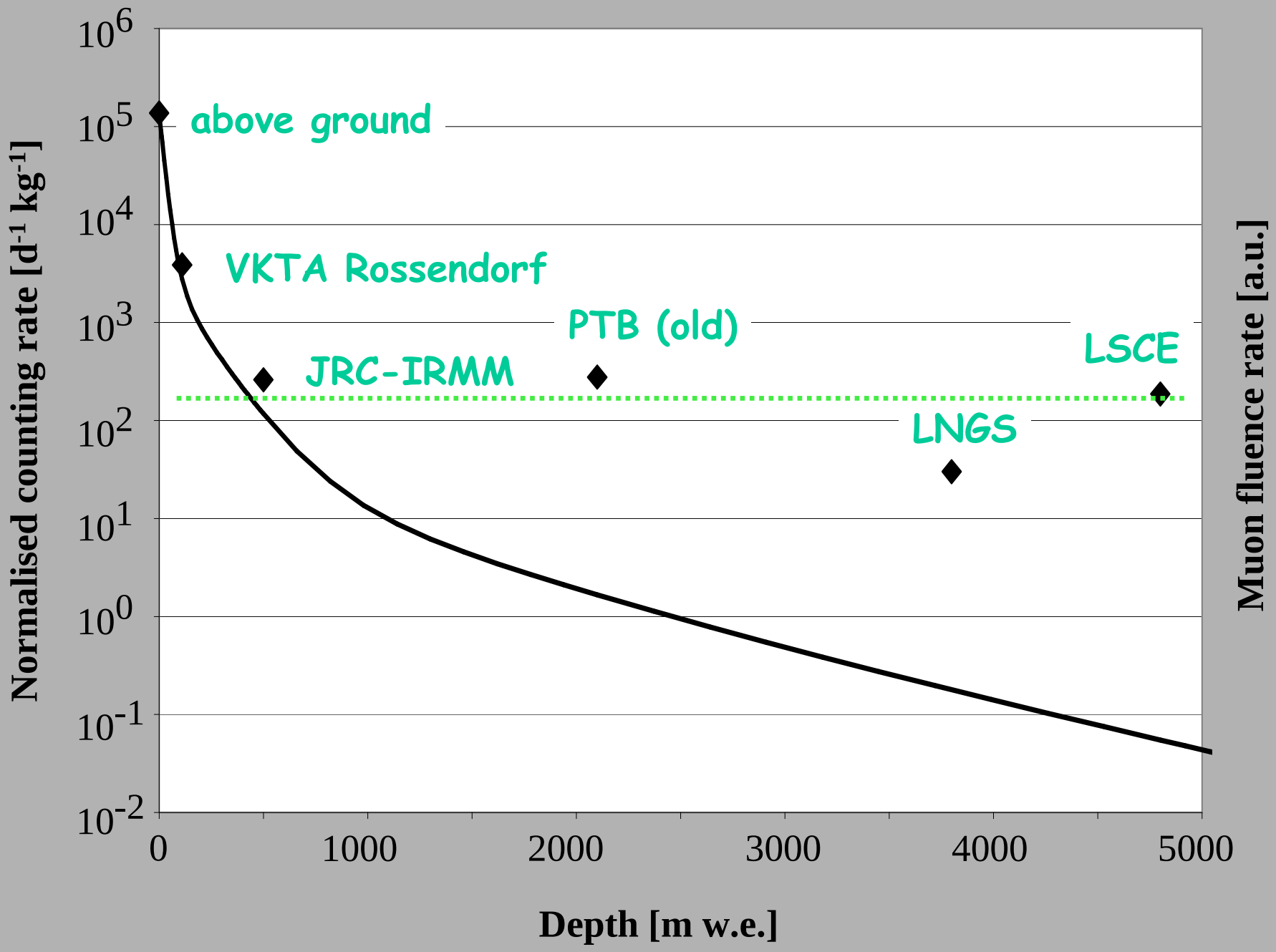


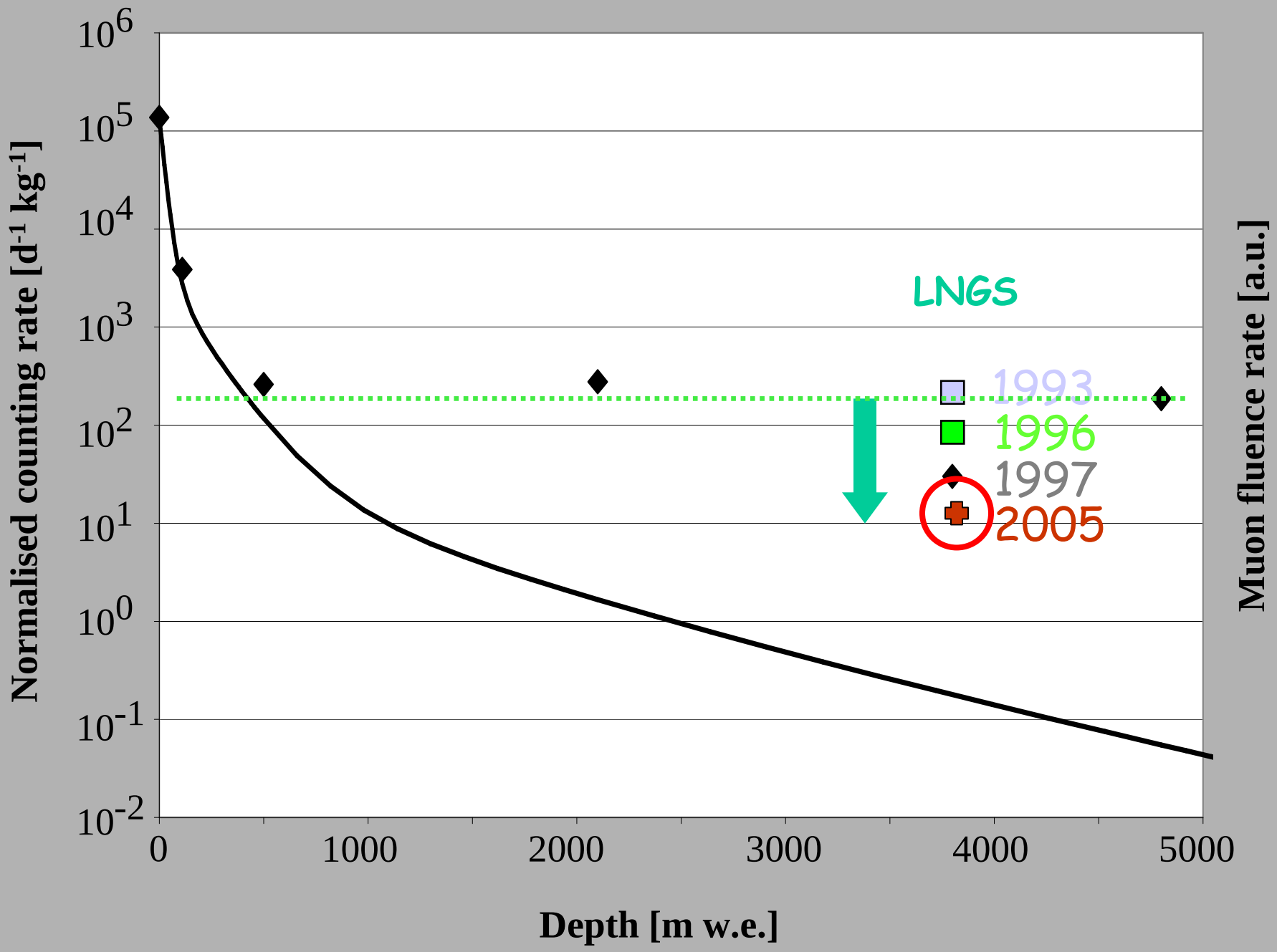
Some of the partner laboratories:

Seibersdorf Laboratories- Austria	(above ground, ~ 3 m w.e.)
MPIK-Heidelberg - Germany	(~ 8 m ≅ 15 m w.e.)
IAEA-MESL - 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	(~ 400 m ≅ 1000 m w.e.)
LNGS - Italy	(~ 1400 m ≅ 3800 m w.e.)
LSCE/IRSN/LSM - 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)

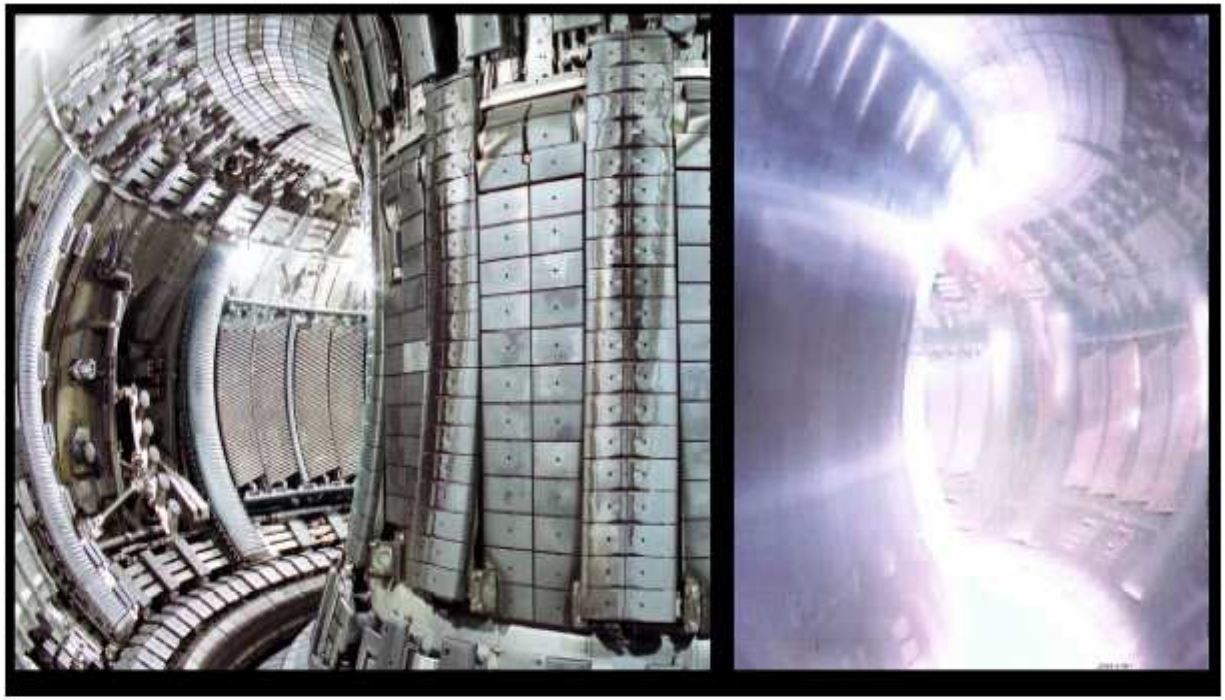

above ground
ARC Seibersdorf
MPI-K-HD
VKTA Rossendorf
IAEA-MEL
JRC-IRMM
active + passive shield
only passive shield
Normalised counting rate [d-1 kg-1]
Muon fluence rate [a.u.]
Depth [m w.e.]
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
100
200
300
400
500
600
700


above ground
VKTA Rossendorf
PTB (old)
JRC-IRMM
LSCE
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


Normalised counting rate [d-1 kg-1]
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
0
1000
2000
3000
4000
5000
Depth [m w.e.]
Muon fluence rate [a.u.]
LNGS
1993
1996
1997
2005

Use of activation technique to be able to determine the loss of charged particles from the plasma

ULGS measurements : need low background due to **very low activity & small samples.**



- Analyse also short lived radionuclides like V-48 (16 d) and Sc-47 (3.4 d) and Cr-51 (28 d)
- Use 18 detectors (2 samples for one week on each detector)

CELLAR measurements

Monitoring the leakage of 3.0 and 14.7 MeV protons from a fusion plasma (NIM A 632 (2011) pp. 89-100)

Angular distribution of proton leakage from a fusion plasma using ultra low-level γ-ray spectrometry (ARI 68 (2010) pp. 1226-1230)

Low-level gamma-ray spectrometry for analysing fusion plasma conditions (NIM A 591 (2008) pp. 383-393)

Measurement of ^{60}Co in massive steel samples exposed to the Hiroshima atomic bomb explosion (Health Physics 102(4), pp. 400-409 (2012))

Reference measurements of low levels of ^{60}Co in steel (ARI 61, 2-3 (2004) pp. 207-211)

Measurements of ^{60}Co in spoons activated by neutrons during the JCO criticality accident at Tokai-Mura in 1999 (JER 73 (3) (2004) pp. 307-321)

Conclusions

Further "necessary" Improvements - 1

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

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

Further "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