A low neutron-emission source for GERDA

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- Motivation for the ^{228}Th calibration source
- Expected neutron background from (α-n) reactions
- New source-setup for a reduced neutron background
- Characterization of the new source
  → Lab activities
  → Monte Carlo simulations
- DAQ / Slow Control - Zurich
- Outlook

^{228}Th source

^{208}Tl: 2615 keV
^{208}Tl SEP: 2103 keV
^{212}Bi: 1621 keV
^{208}Tl DEP: 1592 keV

⇔ $Q_{\beta\beta}$ = 2039 keV

- Half life: 1.9 years
- Photon-emission: 0.063 – 2.6 MeV
- α – emission: 5.2 – 8.8 MeV

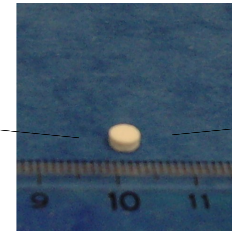
γ background under control with absorber

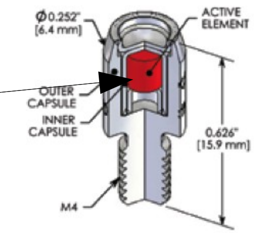
Neutron background induced by (α-n)-reactions with α irradiated materials ?

Expected neutron background from (α-n) reactions

$NaAlSiO_2$ ceramic

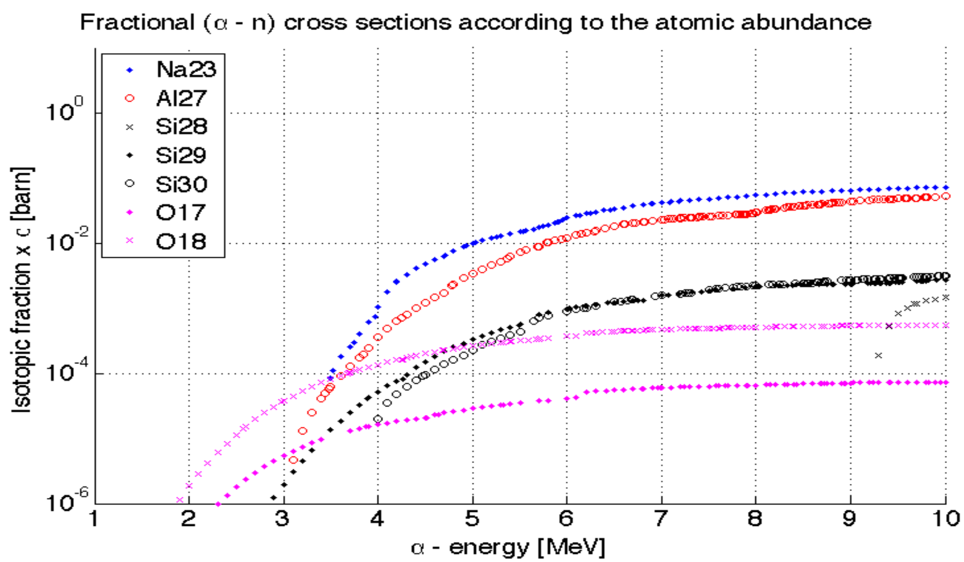
Element	Na	Al	Si	O
Atomic number	11	13	14	8
Atomic fraction	1/5	1/5	1/5	2/5





Natural abundance

Isotope	^{23}Na	^{27}Al	^{28}Si	^{29}Si	^{30}Si	^{16}O	^{17}O	^{18}O
Atomic fraction [%]	100	100	92	4.683	3.087	99.757	0.038	0.205



<u>^{228}Th chain</u>

- $E_{mean}(\alpha) \sim 6.5$ MeV
- $E_{max}(\alpha) = 8.785$ MeV

Calculations of the neutron flux from (α–n) reactions performed with 'SOURCES4mv'

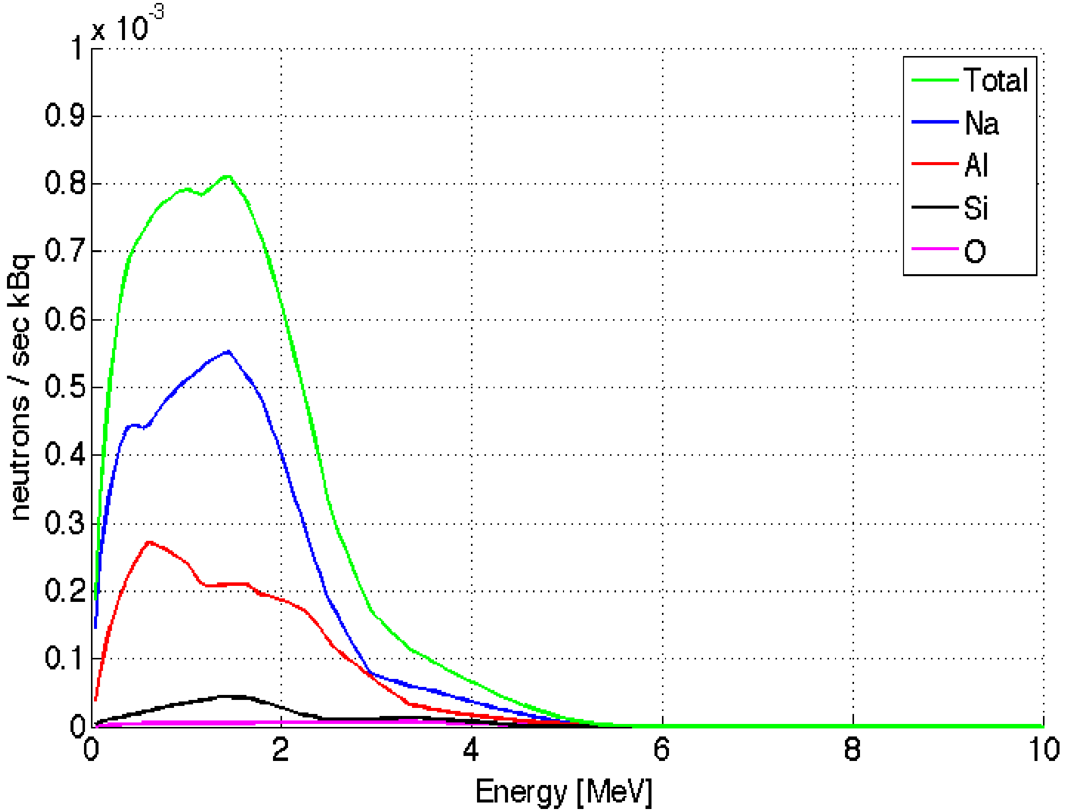
Expected neutron background from (α-n) reactions

Isotope	^{23}Na	^{27}Al	^{28}Si	^{29}Si	^{30}Si	^{16}O	^{17}O	^{18}O
Threshold energy [MeV]	3.482	3.034	9.252	1.736	3.959	15.171	< 0.1	0.851

n-rate = $3.8 \cdot 10^{-2}$ n/s/kBq

$E_{Mean} = 1.45$ MeV

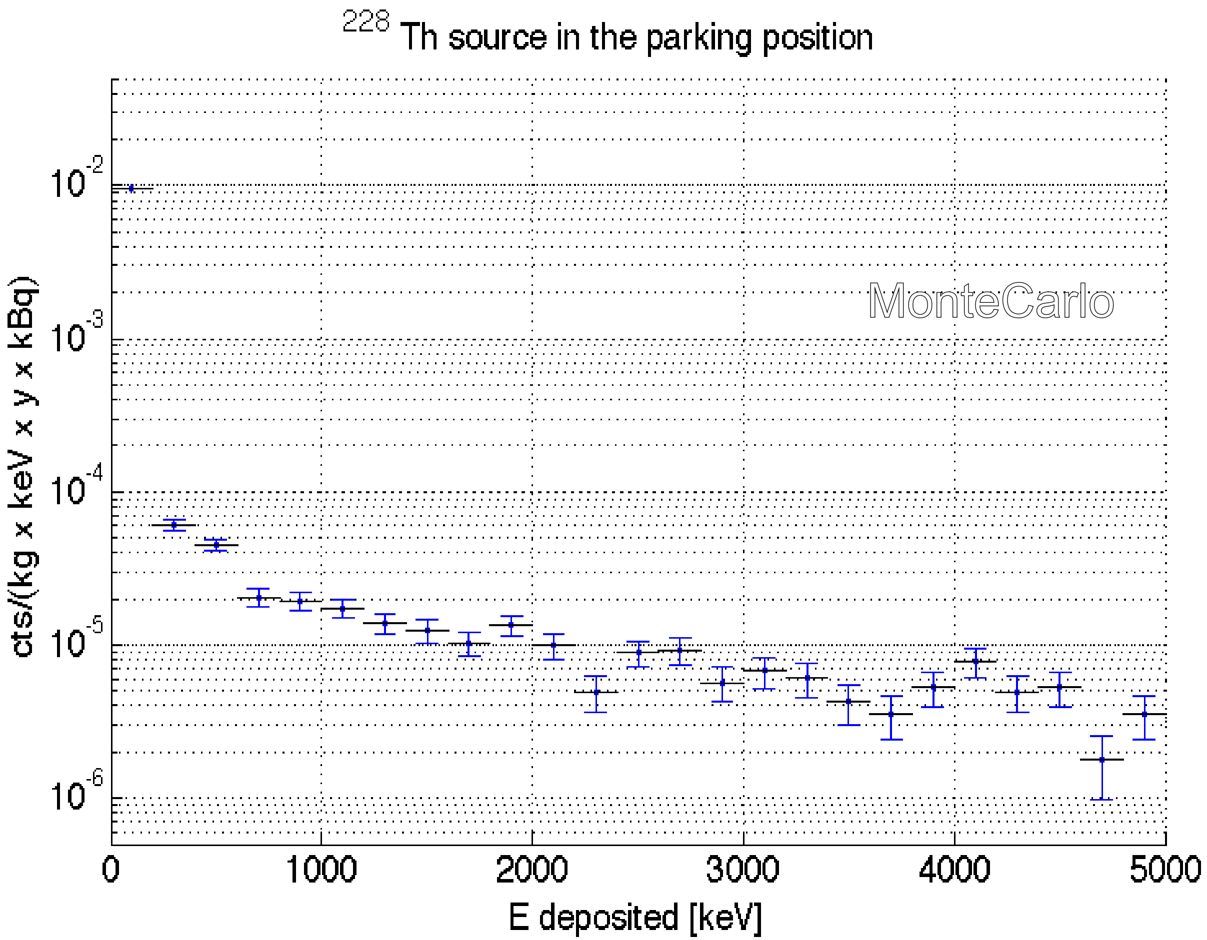
- Na & Al dominate the neutron production
- No (α-n) reactions on ^{28}Si & ^{16}O targets



Expected neutron background from (α-n) reactions

Background goal GERDA:

Phase I: $1\cdot10^{-2}$ cts/(kg·y·keV)
Phase II: $1\cdot10^{-3}$ cts/(kg·y·keV)
Phase III: < $1\cdot10^{-4}$ cts/(kg·y·keV)



MC

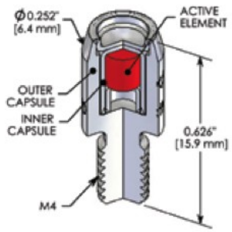
^{228}Th 350cm above Ge-array

$B_0 \sim 1\cdot10^{-5}$ cts/(kg·y·keV·kBq)

In an energy range: 1.5 -2.5 MeV

Example: 100kBq source → $B_0 \sim 1\cdot10^{-3}$ cts/(kg·y·keV)

New source-setup for a reduced neutron background

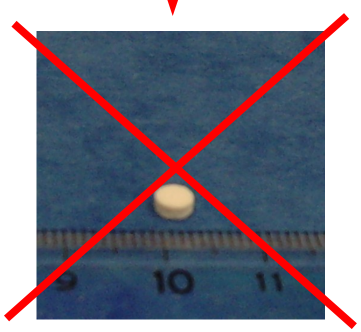


Alternative materials

- Gold:
  - → No oxidation
  - → Threshold energy = 9.94 MeV > $E_{max}(\alpha)$
- Tungsten:
  - → Threshold energy = 9.4 - 11.9 MeV > $E_{max}(\alpha)$
- ^{90}Zr:
  - → Threshold energy = 7.95 MeV
  - → Replacing $NaAlSiO_2$ ceramic by **ZrO_2** ceramic

- No (α-n) reactions occur in contact with Au or W
- Au easy to handle, Au-foils available
- Au chemically inert

Gold instead of ceramic



New source-setup for a reduced neutron background

Collaboration with **PSI** started for the new ^{228}Th source development

R.Dressler
R.Eichler
D.Schumann

<u>Strategy</u>

- ^{228}Th solution from Isotopic Products
- Processing the solution at PSI
- Encapsulation + certification at Isotopic Products
- Determining the limit on the n-flux in LNGS

Process

$3ThCl_4 + 16HNO_3 \rightarrow 200°C \rightarrow 3Th(NO_3)_4 + 4NOCl + 8H_2O + 4Cl_2$ in teflon crucible

$3Th(NO_3)_4$ → 750 °C → $3ThO_2$

$4NOCl + 8H_2O + 4Cl_2$ → Evaporation

In gold crucible $3ThO_2 + 12NO_2 + 3O_2$

$12NO_2 + 3O_2$ → Evaporation

- ^{16}O: 99.757 %, E_{Th} = 15.171 MeV
- ^{17}O: 0.038 % , E_{Th} = < 0.1 MeV
- ^{18}O: 0,205 % , E_{Th} = 0.851 MeV

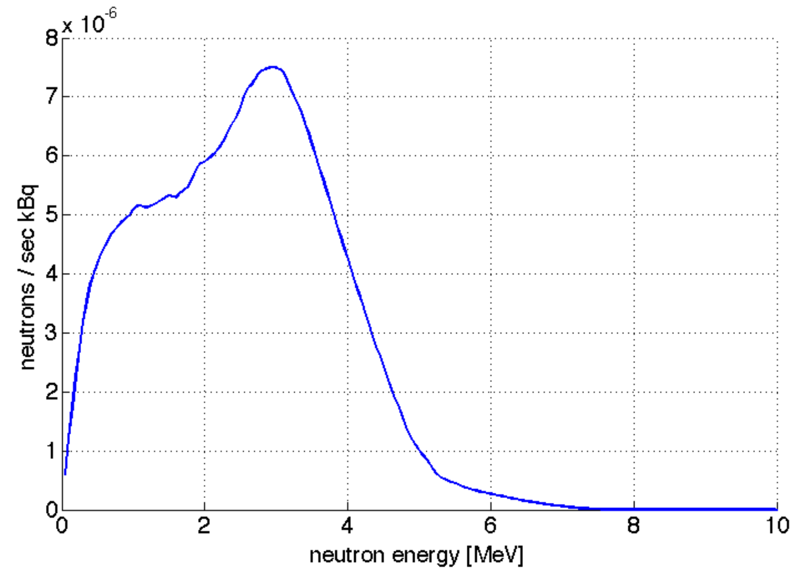
Endproduct: ThO_2 in goldfoil

New source-setup for a reduced neutron background

$\text{n-rate} = 5 \cdot 10^{-4}\ \text{n/s/kBq}$

<u>ThO_2</u>

$E_{Mean} = 2.5\ \text{MeV}$



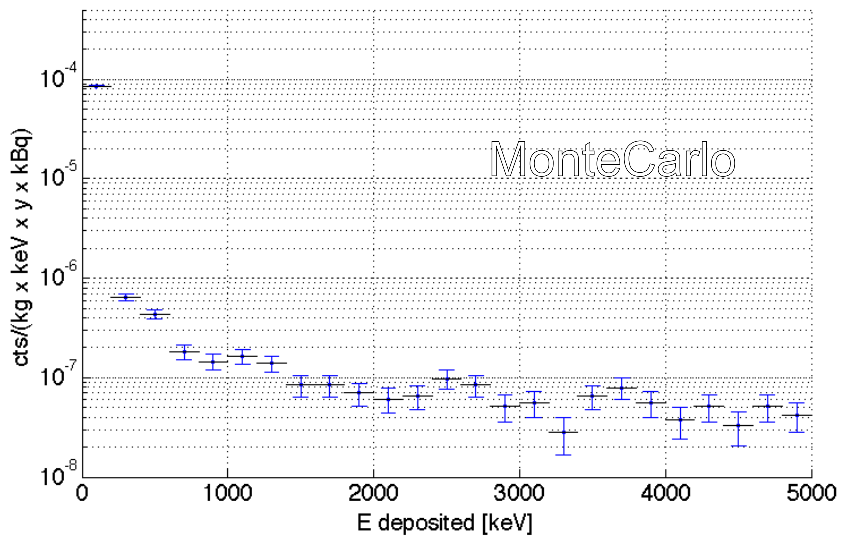
$^{228}ThO_2$ source in the parking position

In an energy range: 1.5 -2.5 MeV

$B_0 \sim 8.6 \cdot 10^{-8}$ cts/(kg·y·keV·kBq) — Customized source

vs

$B_0 \sim 1 \cdot 10^{-5}$ cts/(kg·y·keV·kBq) — Commercial source



n - background reduction by ~116

New source-setup for a reduced neutron background

- 17.3'09: 20 kBq $^{228}ThCl_4$ - solution delivered to PSI
- 30.3'09: source preparation
- 4.5'09
  Source arrived in the Zurich laboratory

Preparing the gold crucible

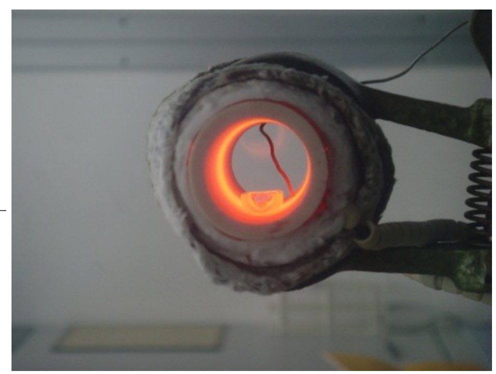
Adding nitric acid to the $^{228}ThCl_4$ solution

200 °C

Refilling $^{228}Th(NO_3)_4$ into the goldcrucible

200 °C

Burning out remanents



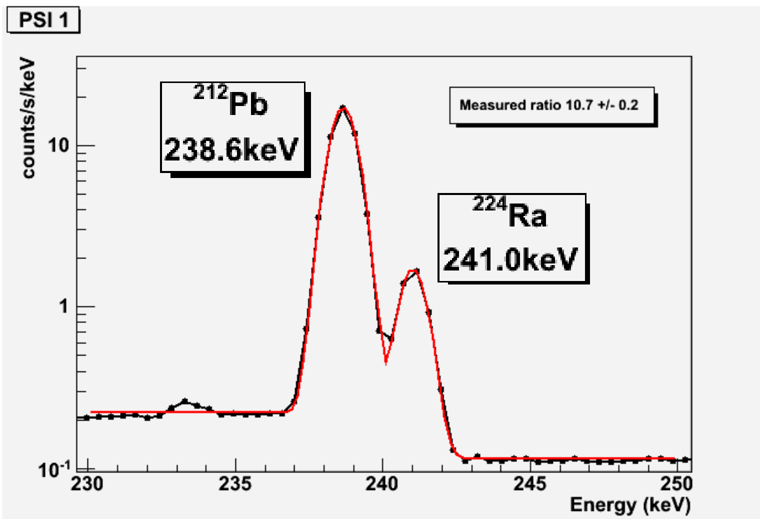
750 °C

Rolling the Au crucible, encapsulating & certficating at IP

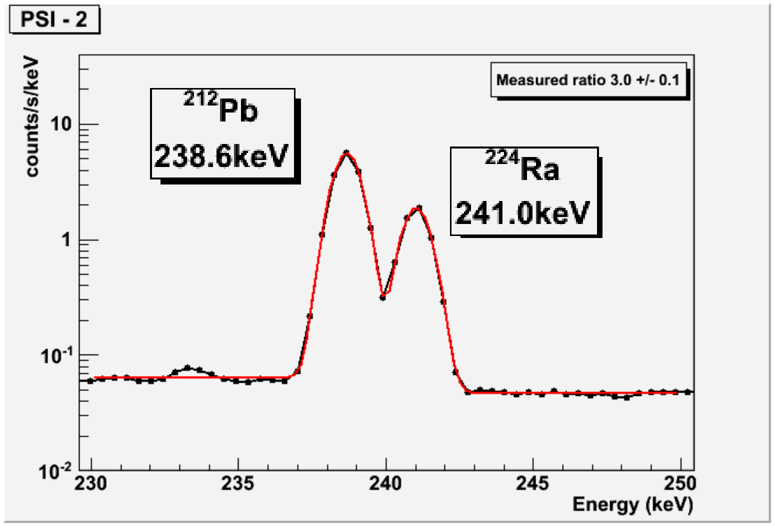
$$^{228}Th \rightarrow {}^{224}Ra \rightarrow {}^{220}Rn \rightarrow {}^{216}Po \rightarrow {}^{212}Pb \rightarrow {}^{212}Bi \left| \begin{array}{l} \rightarrow {}^{212}Po \\ \rightarrow {}^{208}Tl \end{array} \right| \rightarrow {}^{208}Pb$$

Rn gas development during annealing breaks the chain

Relative peak height ratio: $^{212}Pb/^{224}Ra = 43.5/4.1 = 10.6$

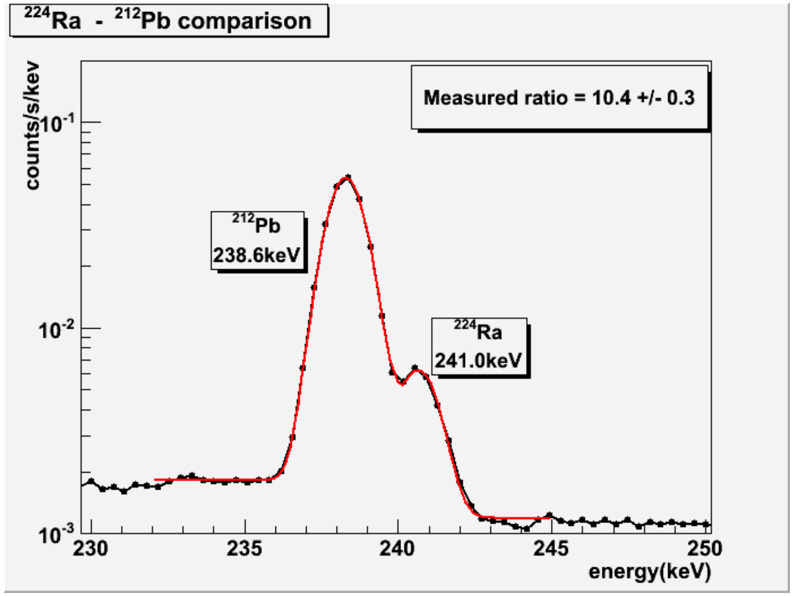


Before Treatment
$^{212}Pb/^{224}Ra = 10.7 +/- 0.2$



~1h after treatment
$^{212}Pb/^{224}Ra = 3.0 +/- 0.1$

Characterization of the new source

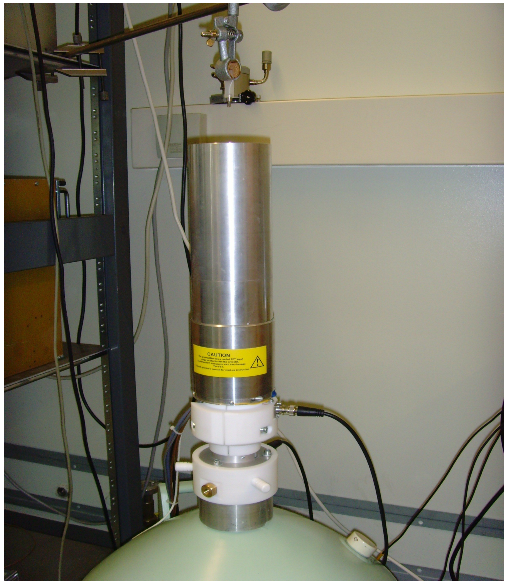


~ 2 month after treatment
$^{212}Pb/^{224}Ra$ = 10.4 +/- 0.3

→ chain recovered from treatment

Ge detector at UZH

•Designed also for immersion tests



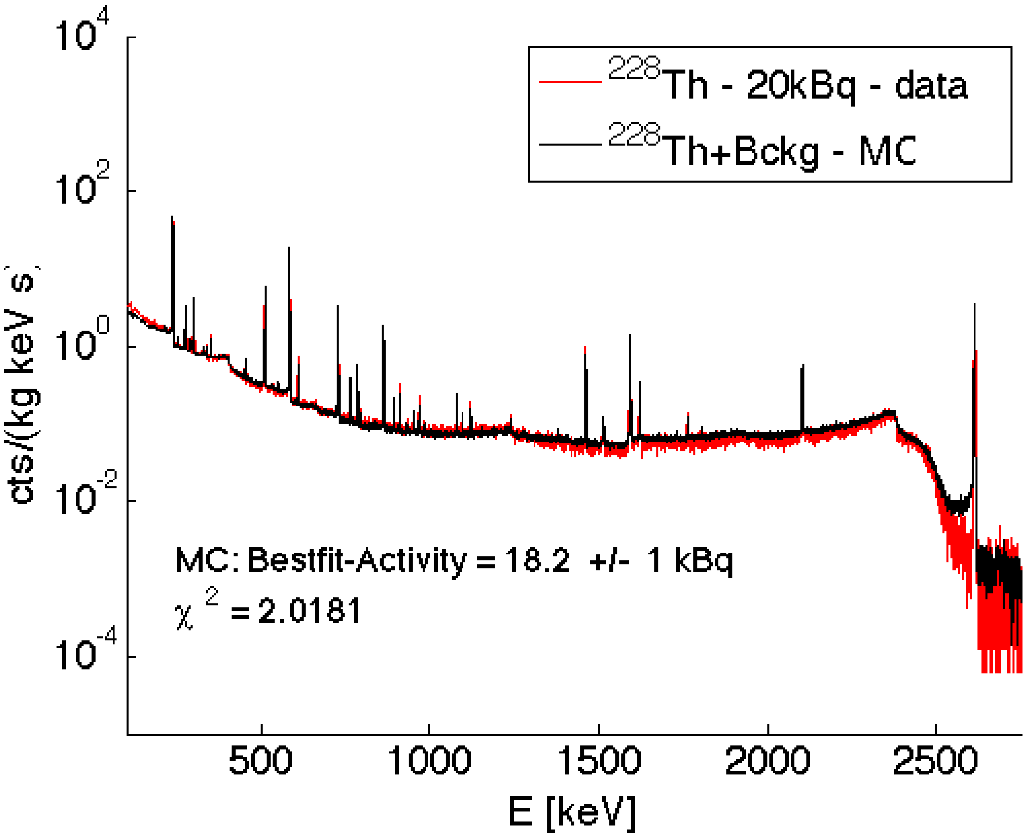
- Ge 40x40 mm
- n-type crystal
- M = 268 g
- Rel. Efficiency at 1332keV: 9.5 %
- Resolution at 1332 keV: ~2keV
- Peak to compton: 41

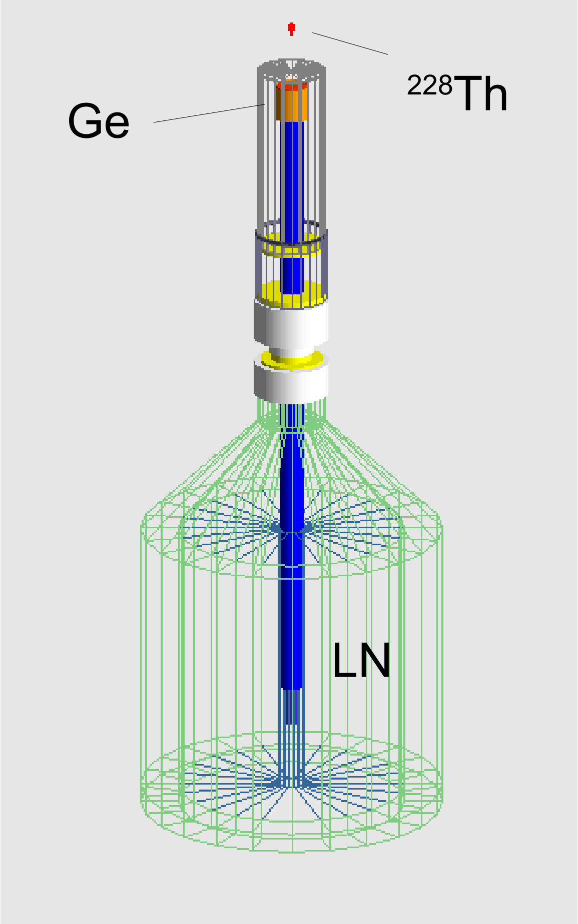
Activity losses during source preparation

Nominal activity before treatment: A = 20 kBq
@ PSI - Activity losses during treatment estimated on ^{224}Ra peak: 16.5% , A = 16.7 kBq

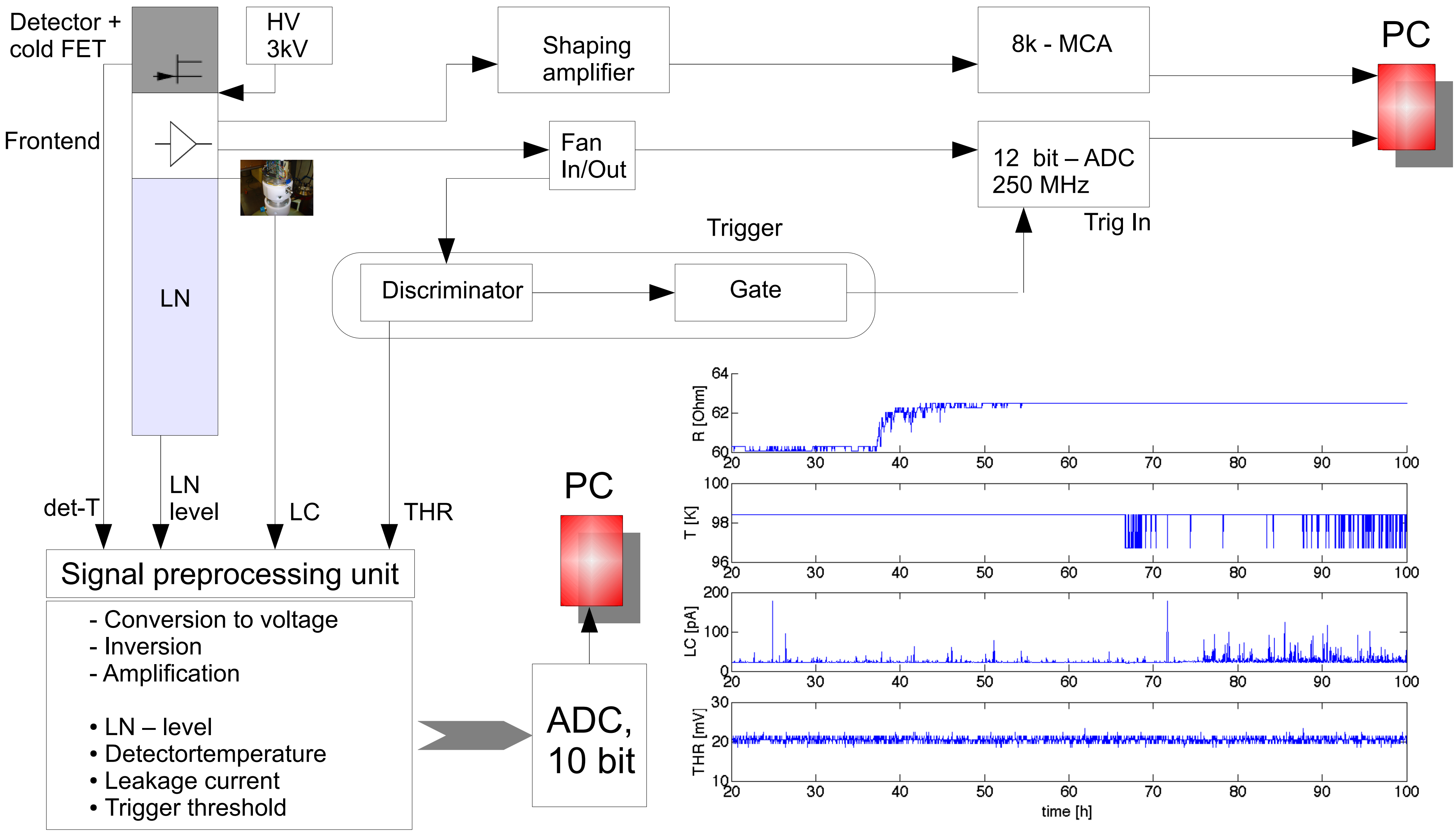
@ UZH - Best fit MC to data with minimal χ^2 : A = 18.2 +/-1 kBq

Source: 6cm above endcap
MC decays started: $2.4 \cdot 10^8$
Data taken for 21 h at ~ 17kBq





DAQ / Slow Control



Outlook

done

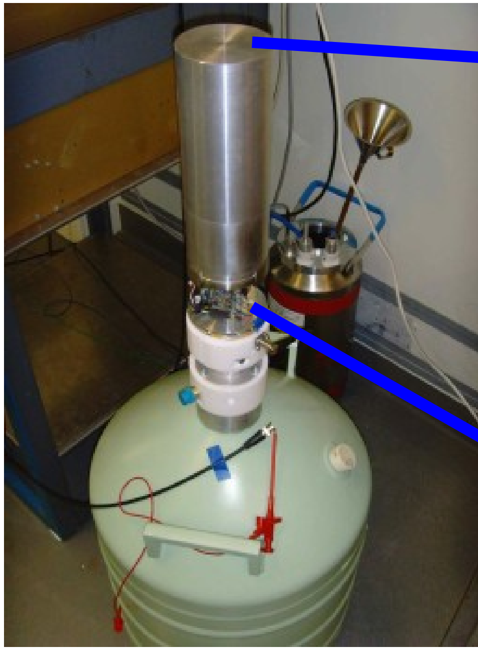
- ^{228}Th solution from Isotopic Products
- Processing the ^{228}Th solution at PSI
- Encapsulation + certification at Isotopic Products
- γ measurements of the source

ongoing

- Wipe tests measurements of the source at LNGS site

to be done

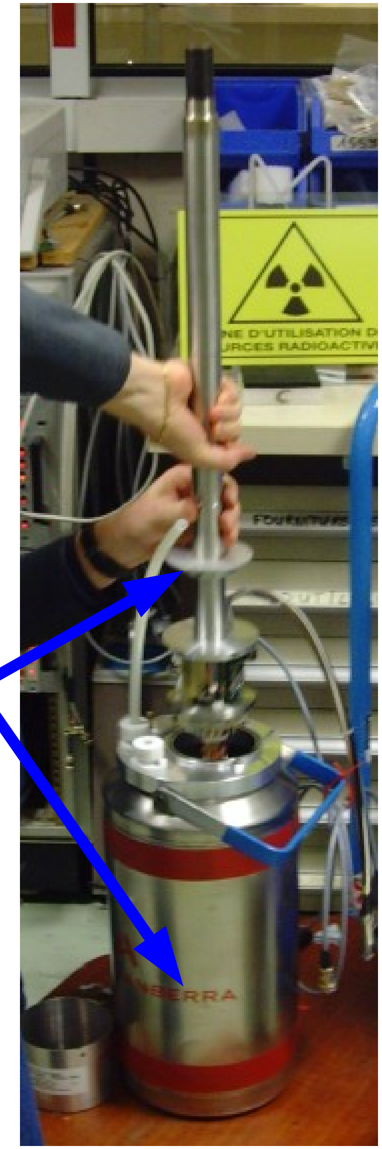
- Determining the n-flux / limit at LNGS site with a He-3 detector
- Production of a source > 20kBq
- Considering further n-reduction:
  electroplating on Au?, ^{232}Th in metallic form?



Vacuumoperation

Cooling via coldfinger

Dismounted endcap for immersion test



Immersion in liquid nitrogen