Neutrons from ^{228}Th sources (commercial and custom)

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(These data are also reported in the preliminary note GSTR-10-001)

Heavy nuclei, like U, Th, Am… emit α, β and γ rays; they are commonly used to calibrated instruments and detectors.

These sources also emit neutrons, which are produced in materials surrounding by (α,n) reactions.

The produced neutron flux can be computed by the standard formula

$$N_n = N_\alpha \, n \int \sigma(E) \, dE/(dE/dx)$$

N_n	n. of emitted neutrons;
$N\alpha$	n. of emitted α's
n	n. of target nuclei/cm^3
σ	cross section
dE/dx	energy loss

Am	
energy keV	intensity %
5388	1,60
5442	13,00
5486	84,50
5511	0,20
5545	0,30

228Th		
energy keV	intensity %	parent
5340,00	27,20	228Th
5423,00	72,20	228Th
5449,00	5,10	224Ra
5607,00	0,50	212Bi
5685,00	94,90	224Ra
5768,00	0,60	212Bi
6051,00	25,20	212Bi
6090,00	9,80	212Bi
6288,00	100,00	220Rn
6778,00	100,00	216Po
8784,00	64,00	212Po

A few numbers

Am-Be
esoenergetic

"228Th" Al2O3
Q value = 2.64 MeV
En. thresh.= 3.03 MeV

	Am		228 Th	
Energy (MeV)	σ (mb)	dE/dx MeV/cm2/g	σ (mb)	dE/dx MeV/cm2/g
1	0,5	1600	–	1350
3.5	130	935	0.3	800
5	488	738	20	640
8	650	530	150	460

Am-Be standard neutron sources emit

~6 10 $^{-5}$ n/s/Bq

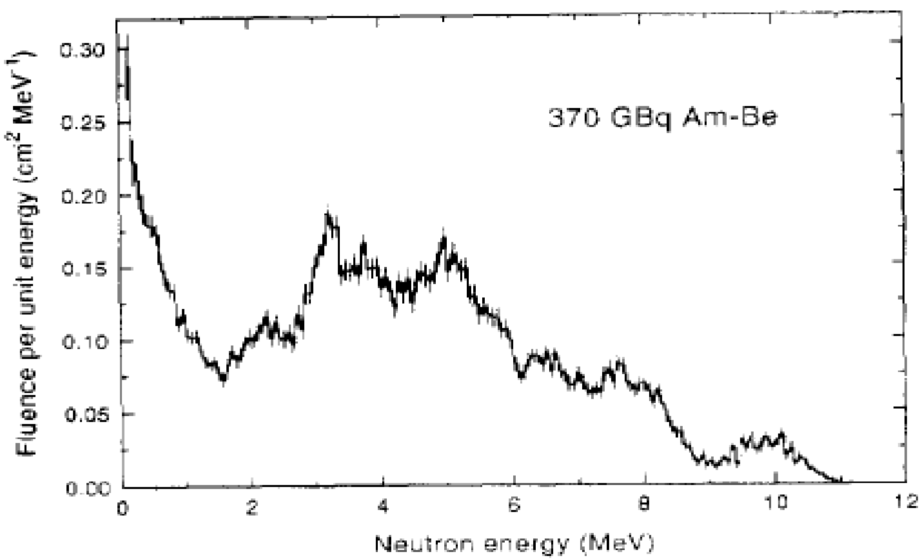


Fig. 4. Measured neutron energy spectrum from the 370 GBq Am–Be neutron source normalized to unit fluence, (uncertainties are due to counting statistics only).

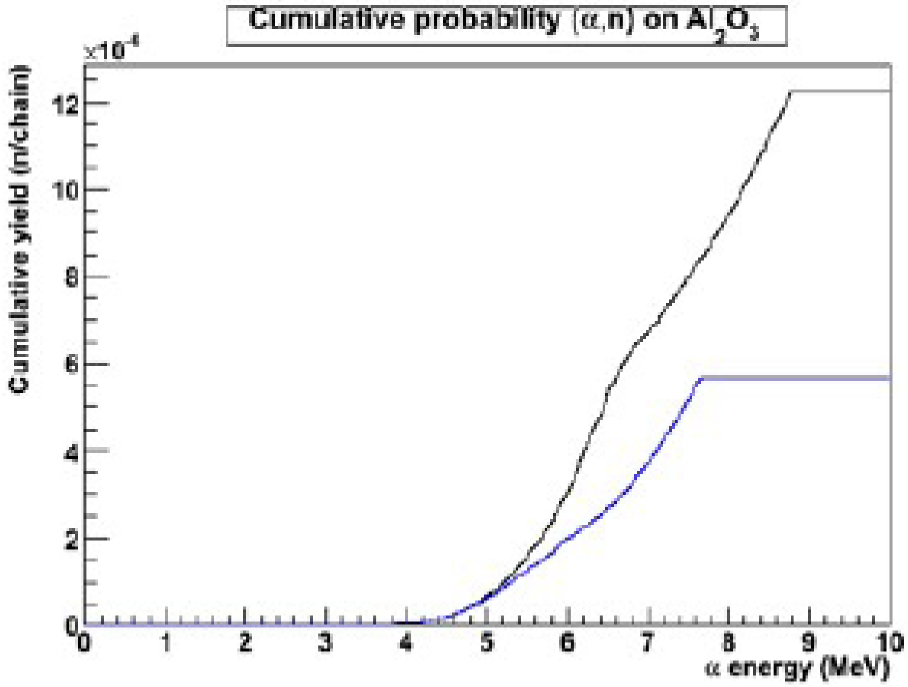


Figure 11: Comparison of the cumulative probability distribution for (α,n) production on Al_2O_3 for ^{228}Th (black) and ^{226}Ra decay (blue) chains as a function of the α particle energy, taking into account the slowing down in the substrate.

Commercial 228 Th source – Al2O3 substrate
Emission 5.710-6 n/s/Bq

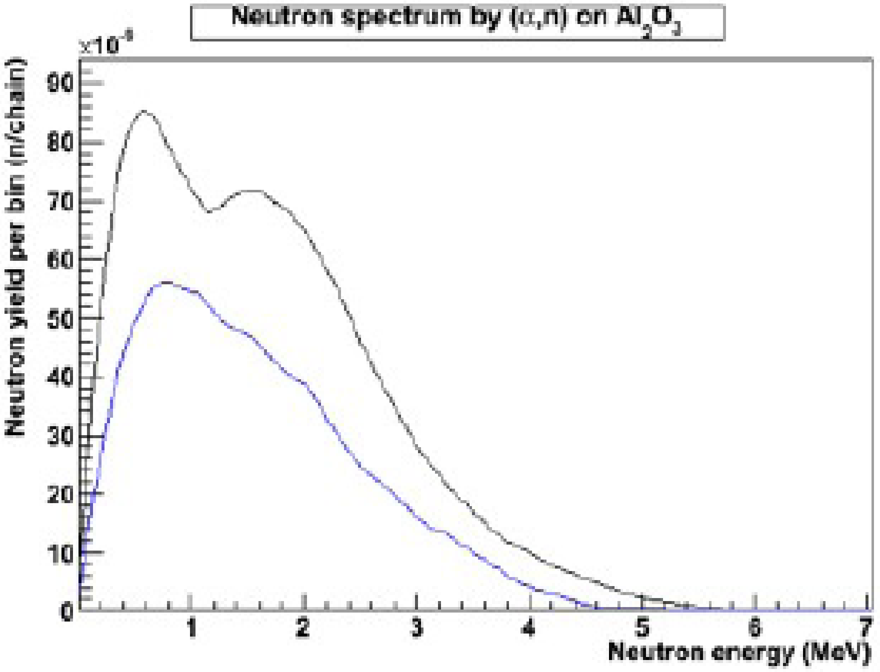


Figure 12: Neutron spectra from (α,n) production on Al_2O_3 for ^{228}Th (black) and ^{226}Ra decay (blue) chains.

Detector, shielding and electronic chain

- He-3 detector

• Diam.	47.75 mm
• Length	203 mm
• Vol.	364 cm^3
• Pres.	6 bar
• Oper. V	1950 V (2000V)
• Sensitivity	134 cps/nv
• Energy res.	6%

Standard electronic chain:

HV Silena,   preamp. Ortec,   spectroscopy amp. Ortec, ADC Ethernim (Ortec)

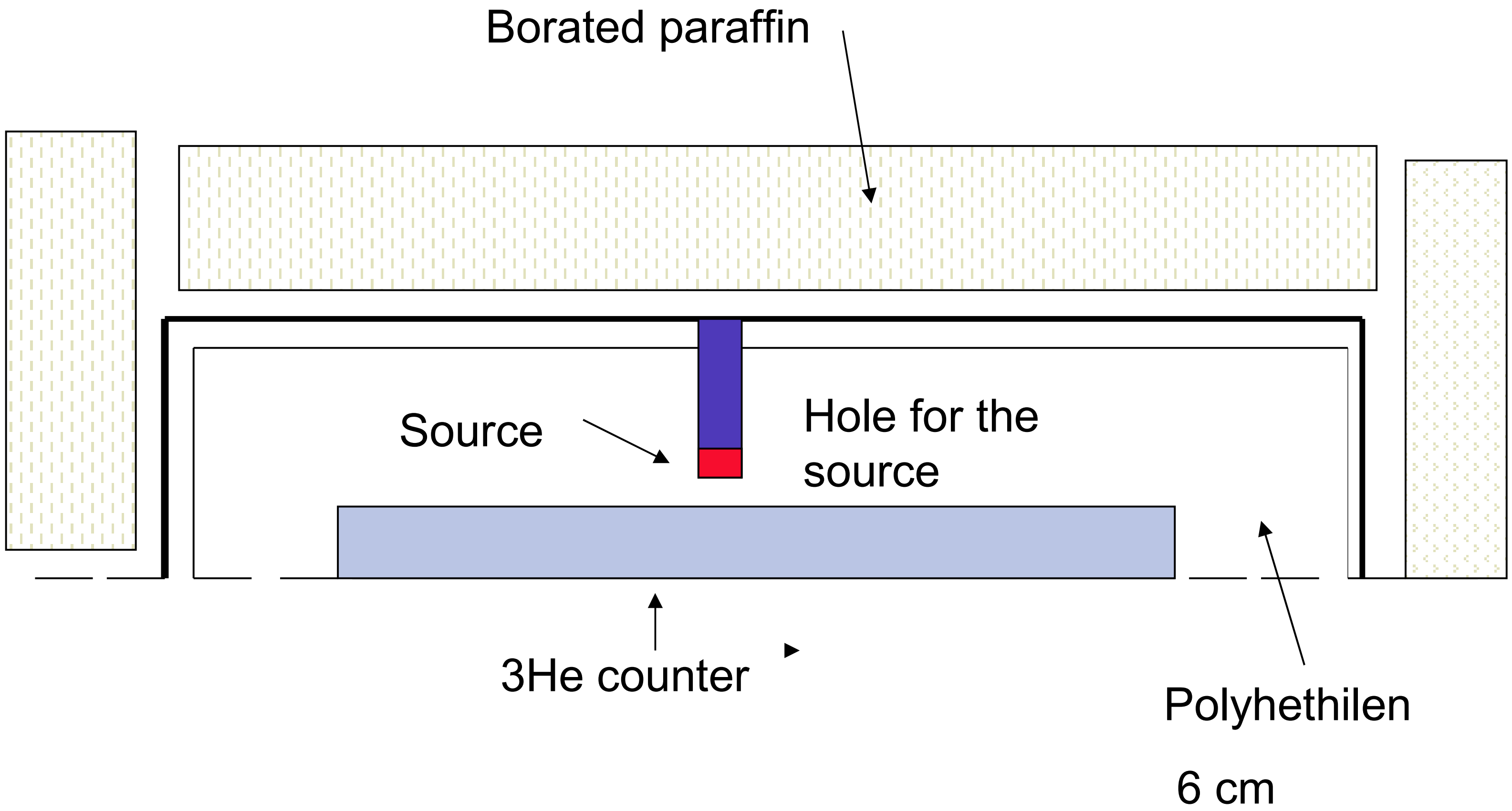
Software Maestro 32

Shielding:

6 cm polyethylene

Cd foil

Borated paraffin



Schematic drawing of detector, moderator and neutron absorber

Figure 1 Set-up for neutron measurement.

Figure 2 Detail of the hole made for source insertion. The remaing PE thickness is 1 cm

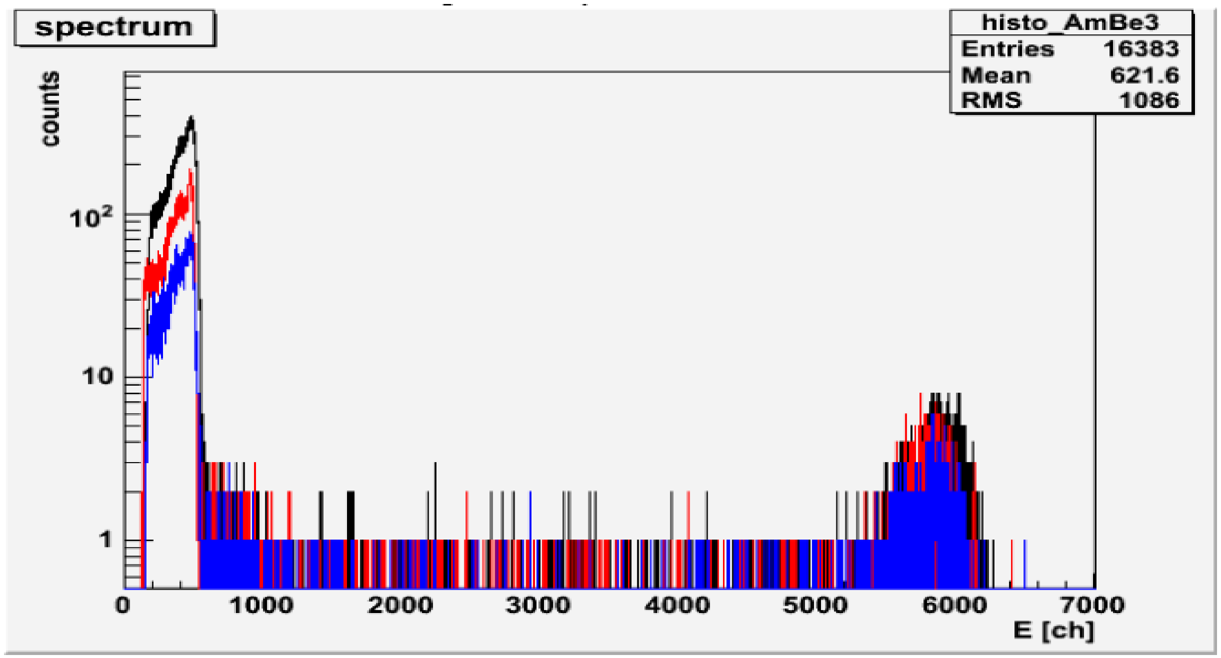


Figure 5 Spectra collected irradiating the ^{3}He counter with a AmBe source (10 n/s emitted) placed at the inner position (black line), intermediate position (red line) and outer position (blue line).

Meas.time 2000 s

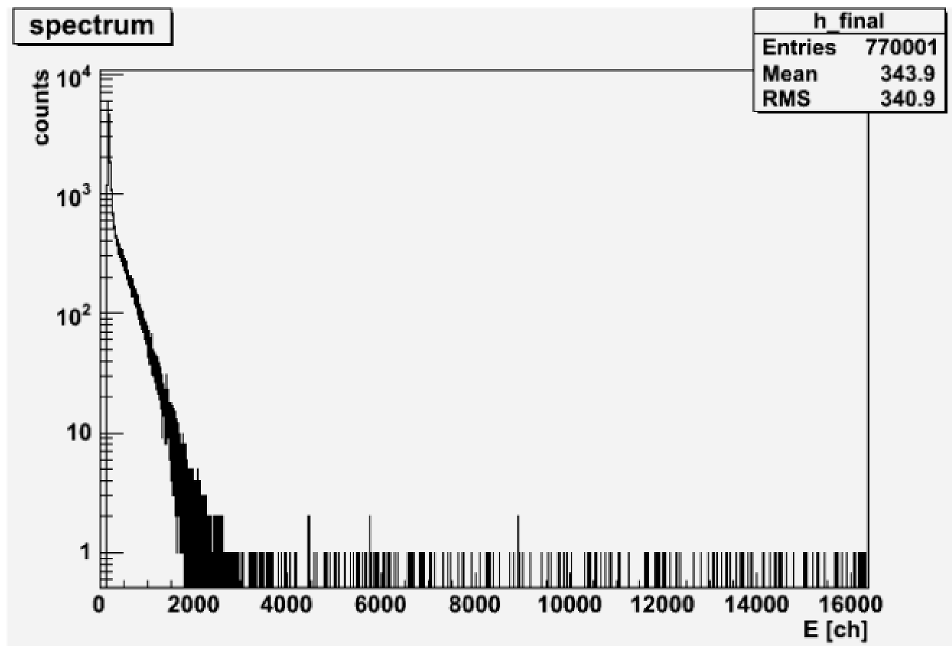


Figure 10 Background spectrum

Meas.time 1.7 10^6 s

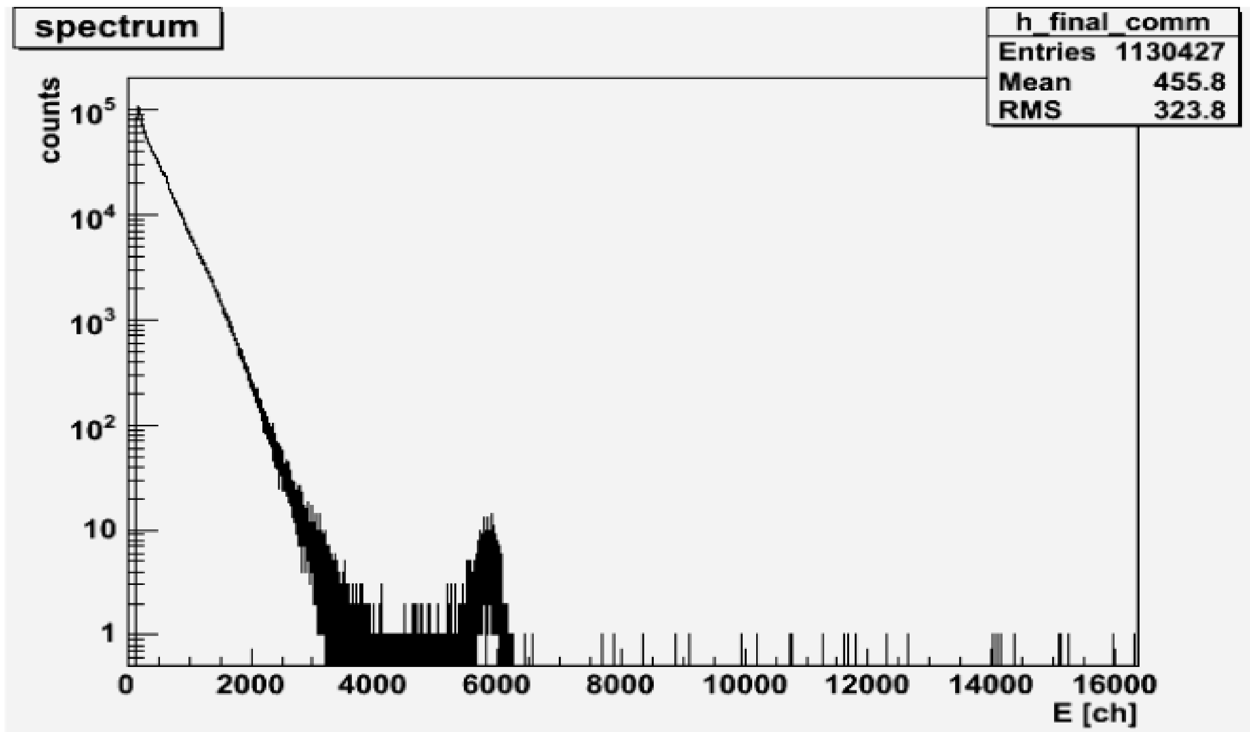


Figure 8 Spectrum of the ^{228}Th commercial source

Meas.time 188185 s

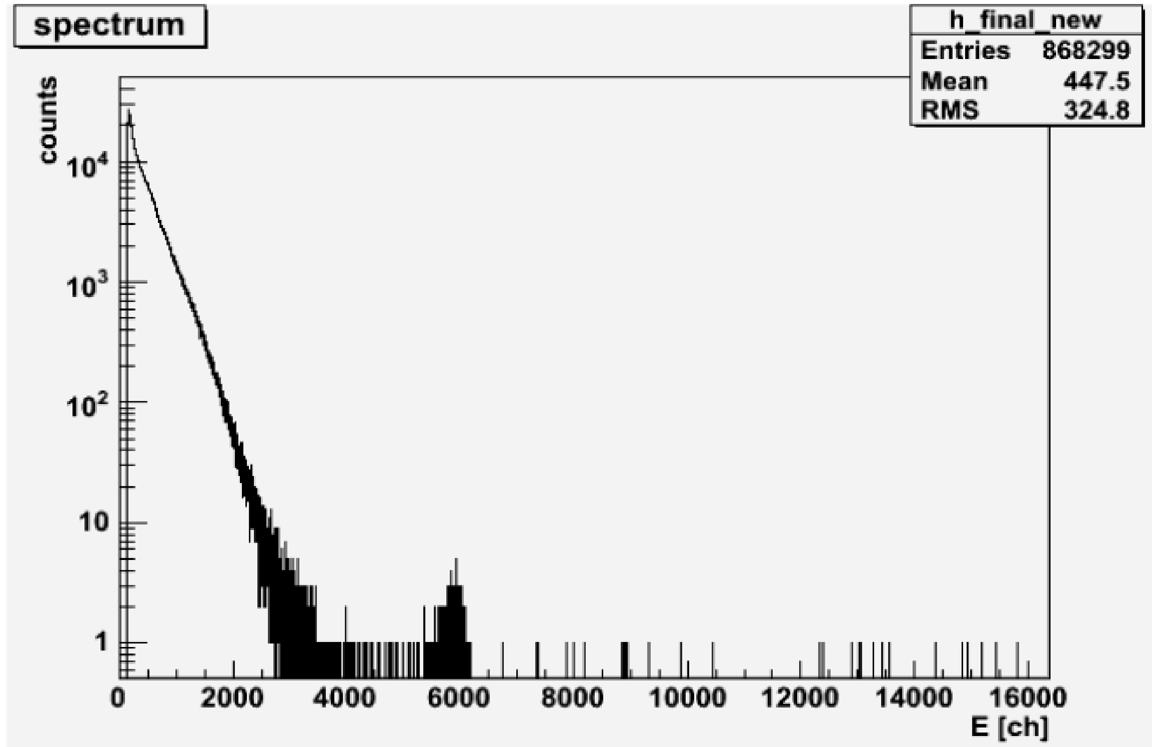


Figure 9 Spectrum of the ^{228}Th custom-built source.

Meas.time 582000 s

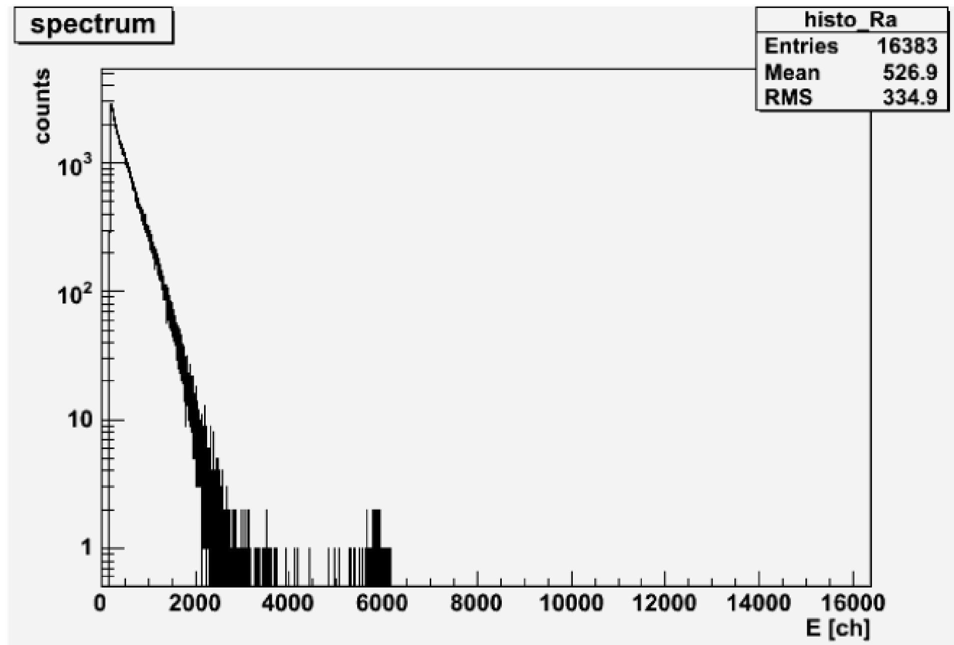


Figure 11 Spectrum of the ^{226}Ra source

Meas.time 3600 s

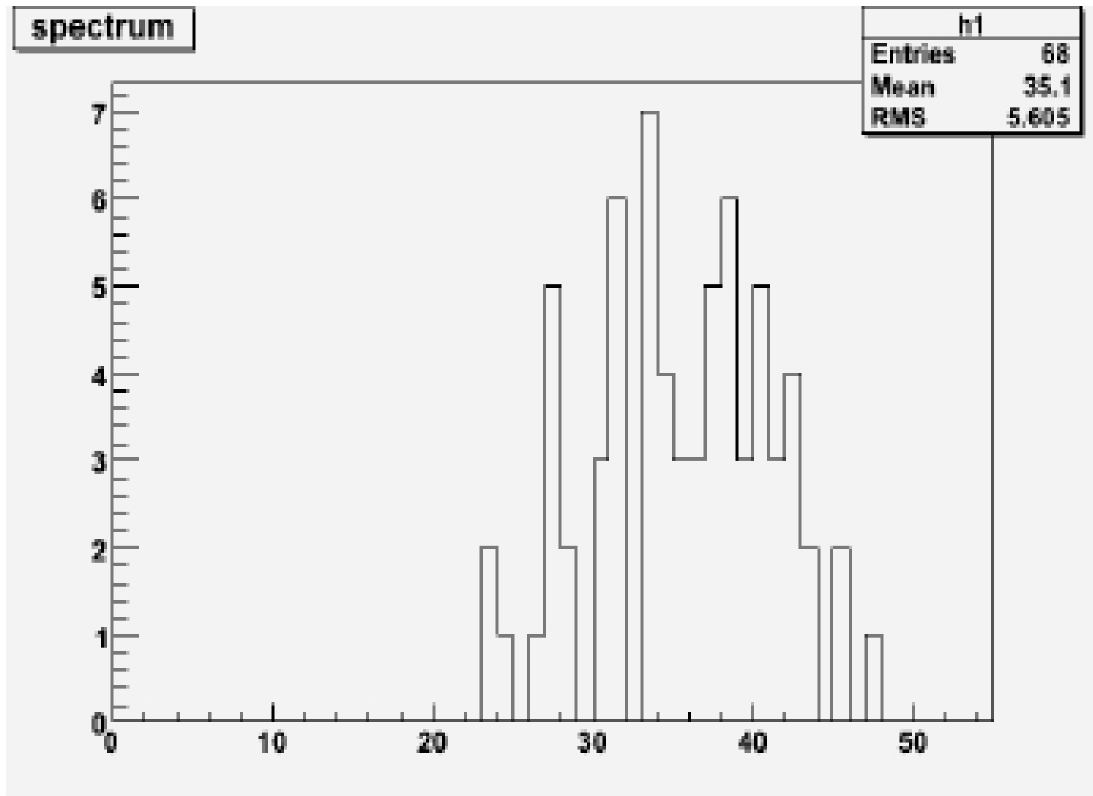


Figure 8: Count rate (cts/h) distribution of the 69, 1h long independent measurements of the commercial, 43 kBq, ^{228}Th source.

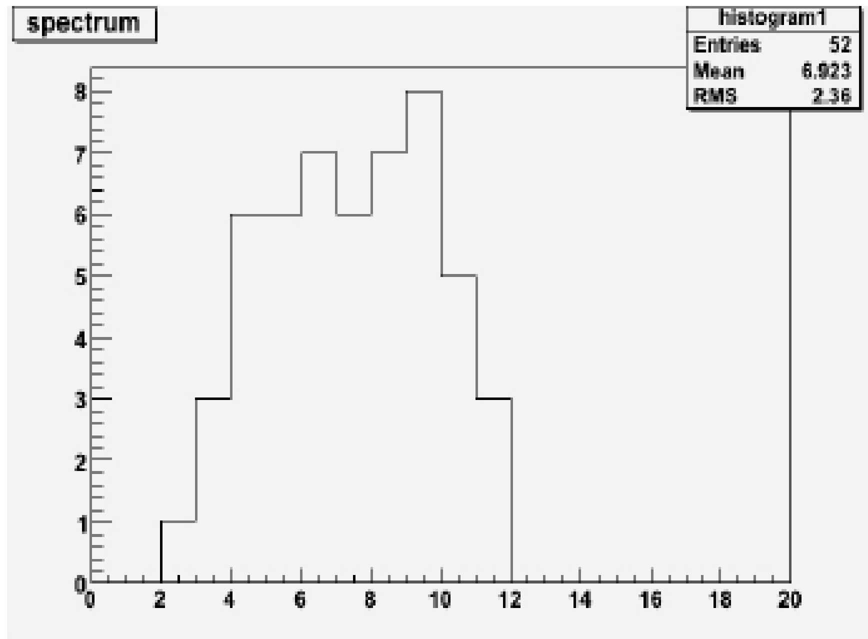


Figure 9: Count rate (cts/h) distribution of the 52, 1h long independent measurements of the custom, 14.6 kBq, ^{228}Th source.

Summary of results

Intrinsic background and gamma-ray background are completely negligible

AM-Be source 185 19 kBq 10 1 n/s

Position	Time [s]	Counts	Rate [Hz]
Inner	2000	1449	0.725 ± 0.019
Intermediate	2000	994	0.497 ± 0.016
Outer	2000	536	0.268 ± 0.012

Results cont.d

Source	Activity [kBq]	Time [s]	Counts	Rate (*) [10^{-3} Hz]	Rate/kBq [10^{-4} Hz/kBq]
^{228}Th (comm.)	44 ±7	246793	2394	9.70 ± 0.2	2.26
^{228}Th (custom)	14.6 ±2	771385	1605	2.08 ± 0.05	1.425
^{226}Ra	95 ±14	3600	110	30.6 ± 2.9	3.23

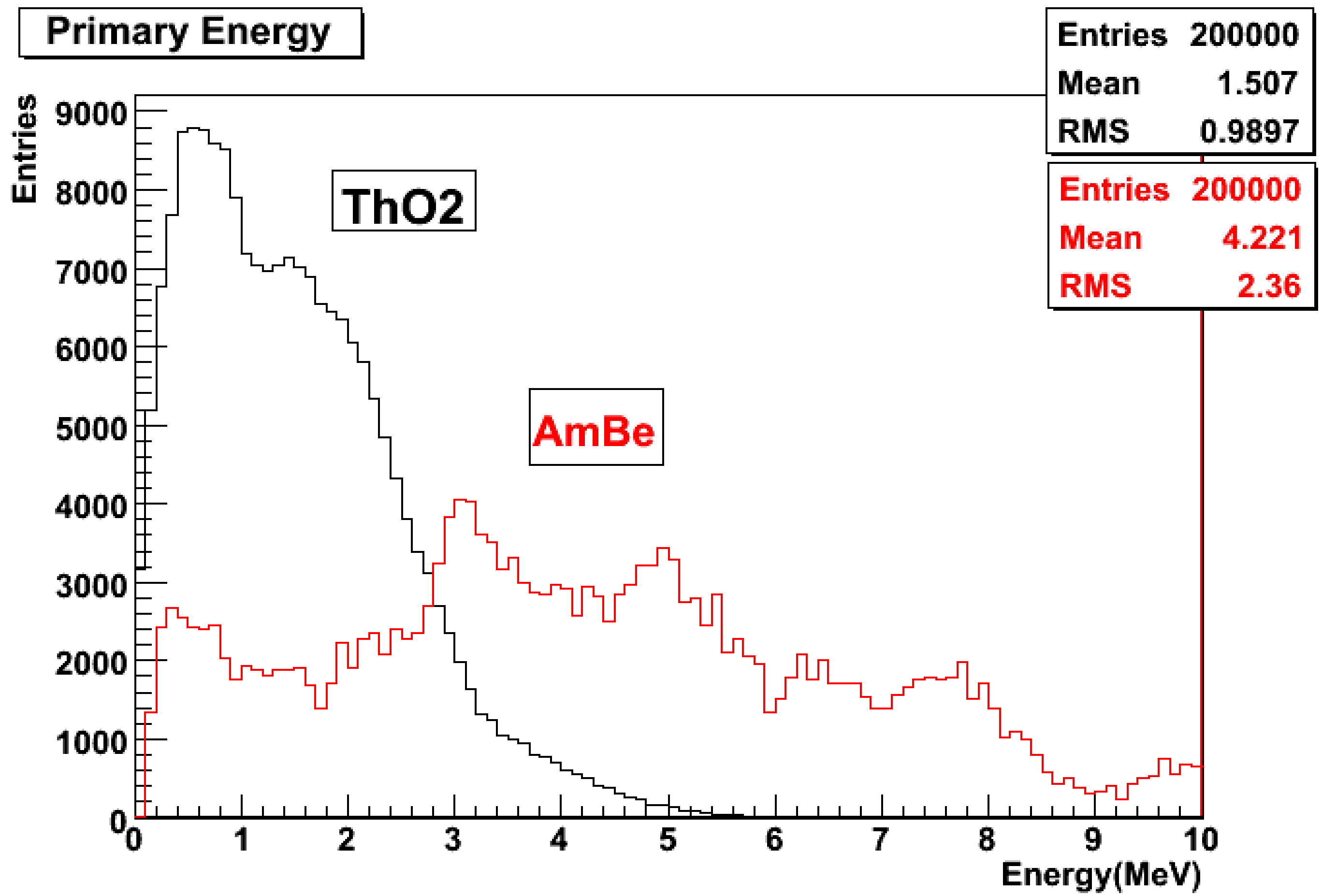
(*) Errors are statistical only

A first estimate of the efficiency can be deduced from Am-Be data :

(7.2 ± 0.9) %

	^{226}Ra	^{228}Th (comm.)	^{228}Th (cust.)
	10^{-2} n/s/kBq	10-2 n/s/kBq	10^{-2} n/s/kBq
2003 (above gr.)	0.3	---	---
2003 (underground)	0.5	0.84	---
2009-2010 underground	0.46 ± 0.04	0.30 ± 0.05	0.21 ±0.03

Primary energy comparison



AmBe MC efficiency : 9.5 %

ThO2 MC efficiency : 15.2 %

Simulations with different primary spectra currently on going

M.C. simulation :

Am-Be source 9.5% instead of 7%

Not bad disagreement

Problem: the primary neutrons energy spectrum which is not well known at low energies

Custom 228Th source: the origin of neutrons is (at least to me) not clear

In any case, a good fist step in efficiency estimate.

Conclusions

- The 228 Th custom source is also a weak neutron source:

~ 2 10^{-3} n/s/kBq

(commercial source ~ 3 10^{-3} n/s/kBq)

The estimated mean n energy is ~ 2 MeV

To improve the accuracy on the knowledge of the n flux emitted by the source, some more work is necessary:

Better knowledge of the Th sources strength

Knowledge of the source structure

To continue the calculation of the efficiency, by M.C simulation

Investigate the effects of these neutrons on detectors; for comparison neutrons emitted by:

the cryostat and reaching the detectors are ~ 30/year,

the calibration source , are a few thousand /y