Status of the calibration

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10.11'08

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GERDA Meeting
LNGS 10-12 Nov. 2008

Part I

- Overview of possible calibration sources
- Internal structure of a calibration source
- Neutron emission rates due to (α-n) reactions
- Resulting neutron background
- Possible reduction of the (α-n) contribution

Part II

- γ - Background
- Absorber
- Calibration simulation

^{56}Co source
- Halflife: 77.2 days
- photon-emission: 0.7 - 3.6 MeV
- no α-emission

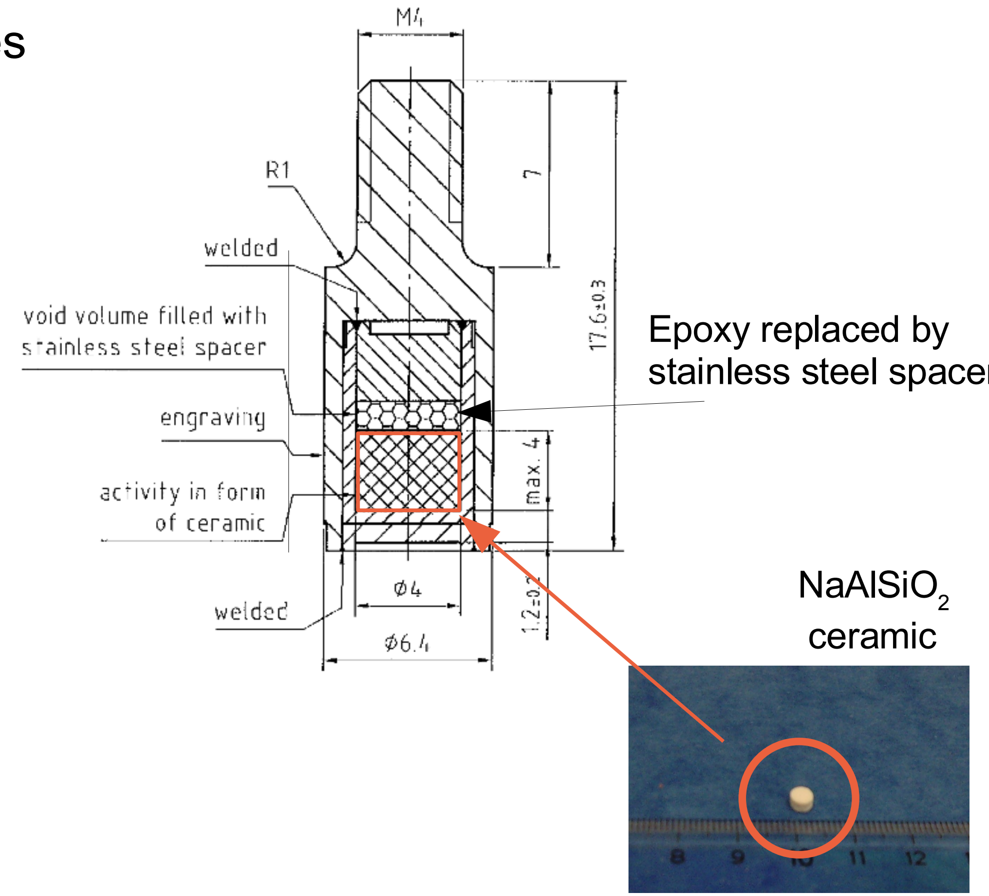
^{228}Th source
- Halflife: 1.9 years
- photon-emission: 0.063-2.6 MeV
- α -emission: 5.2 – 8.8 MeV

Two backgrounds to consider when source is in parking position

- γ - background
- n - background

(α-n) reactions with adjacent materials

- Ceramic pallet which contains the radionuclides
- Stainless steel spacer
- Stainless steel encapsulation

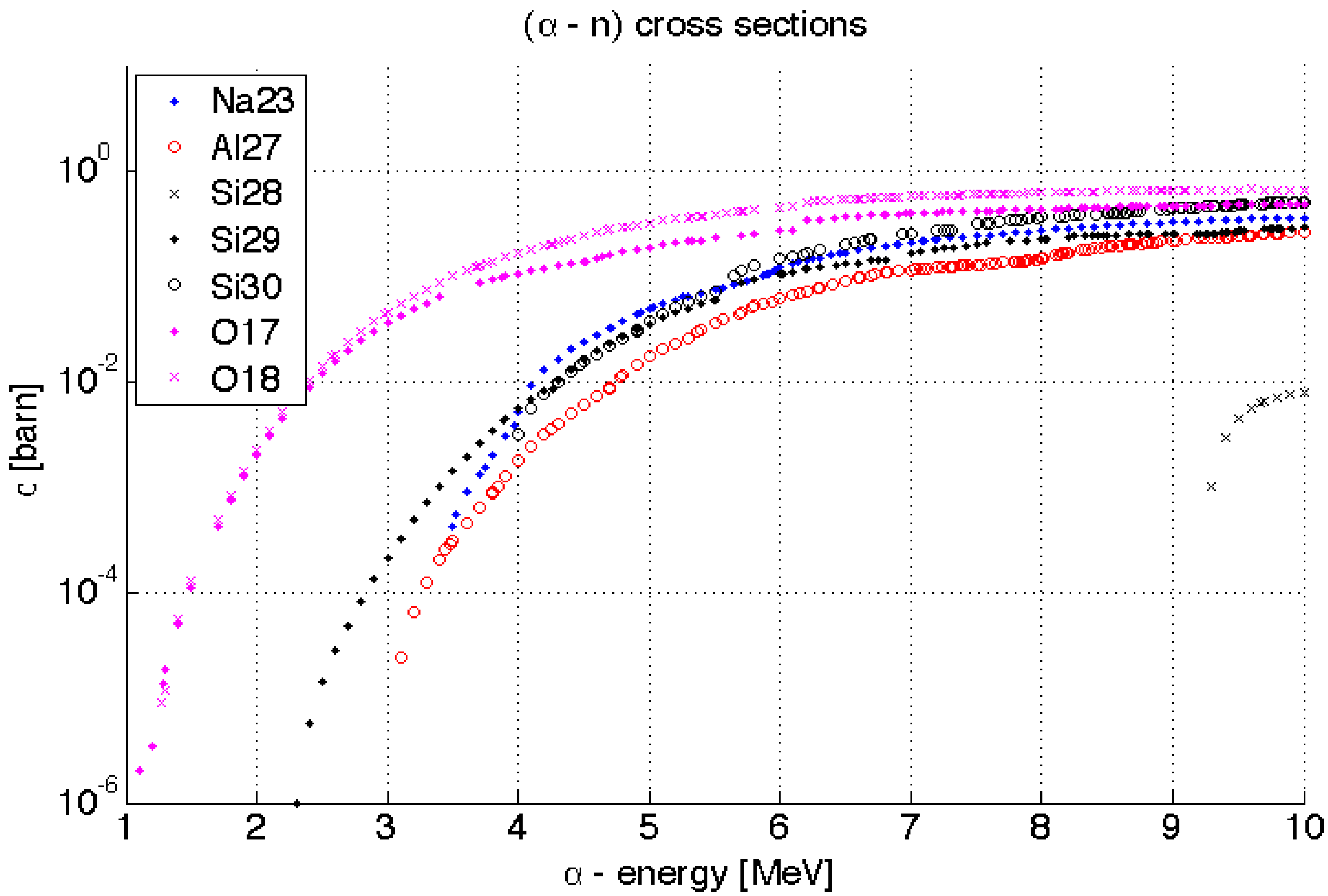


Ceramic pallet - $NaAlSiO_2$

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

Natural abundance

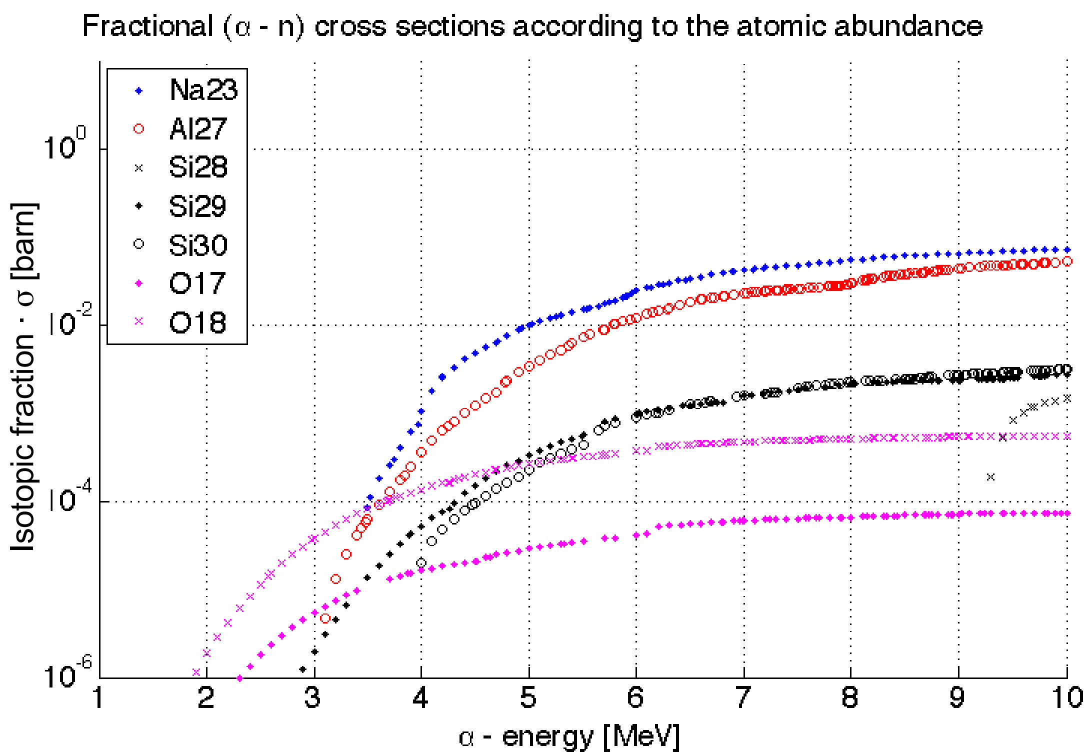
Isotope	^{23}Na	^{27}Al	^{28}Si	^{29}Si	^{30}Si	^{16}O	^{17}O	^{18}O
Atomic fraction [%]	100	100	92	4.683	3.087	99.757	0.038	0.205


(α - n) cross sections
Na23
Al27
Si28
Si29
Si30
O17
O18
σ [barn]
10^0
10^-2
10^-4
10^-6
1
2
3
4
5
6
7
8
9
10
α - energy [MeV]

Neutron emission rates due to (α-n) reactions

^{228}Th chain

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



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

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

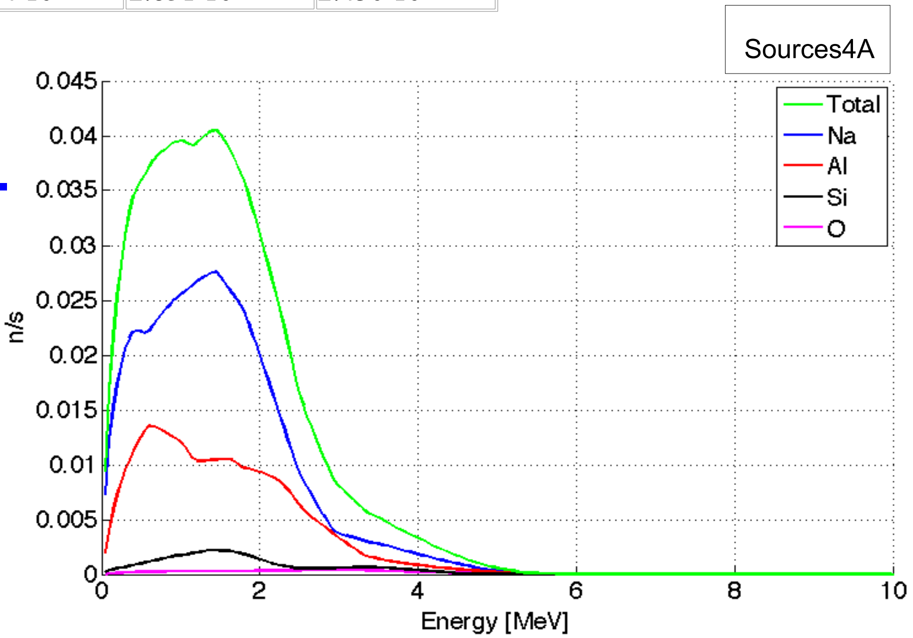
Neutron emission rates due to (α-n) reactions

Source strength: 50kBq

Target	^{23}Na	^{27}Al	^{28}Si	^{29}Si	^{30}Si	^{17}O	^{18}O
R [1/s]	$1.198\cdot10^{0}$	$5.862\cdot10^{-1}$	$1.816\cdot10^{-7}$	$4.689\cdot10^{-2}$	$4.174\cdot10^{-2}$	$2.831\cdot10^{-3}$	$2.450\cdot10^{-2}$

R_{tot}(Source) = 1.9 n/s

E_{Mean} = 1.45 MeV



For comparison

(α-n) neutrons emitted by cryostat:

ϱ_{cryo} = 7.98 g/cm^3 , M_{cryo} = 21.9 t

R_{tot}(Cryostat)= $1.33\cdot10^{-3}$ n/s

~ 1400 smaller than R_{tot} (Source) !!!

E_{Mean} = 1.66 MeV

Rate consistant with Luciano's estimation of ~ $1.3\cdot10^{-3}$ n/s

Gerda note: GSTR-08-022

Monte Carlo simulation in the parking position

- Distance between source & detector: 350 cm
- Neutrons emitted: $67.5 \cdot 10^6$ corresponding to ~1y of exposure
- Total Ge mass: 250 kg
- Total hits: 27855

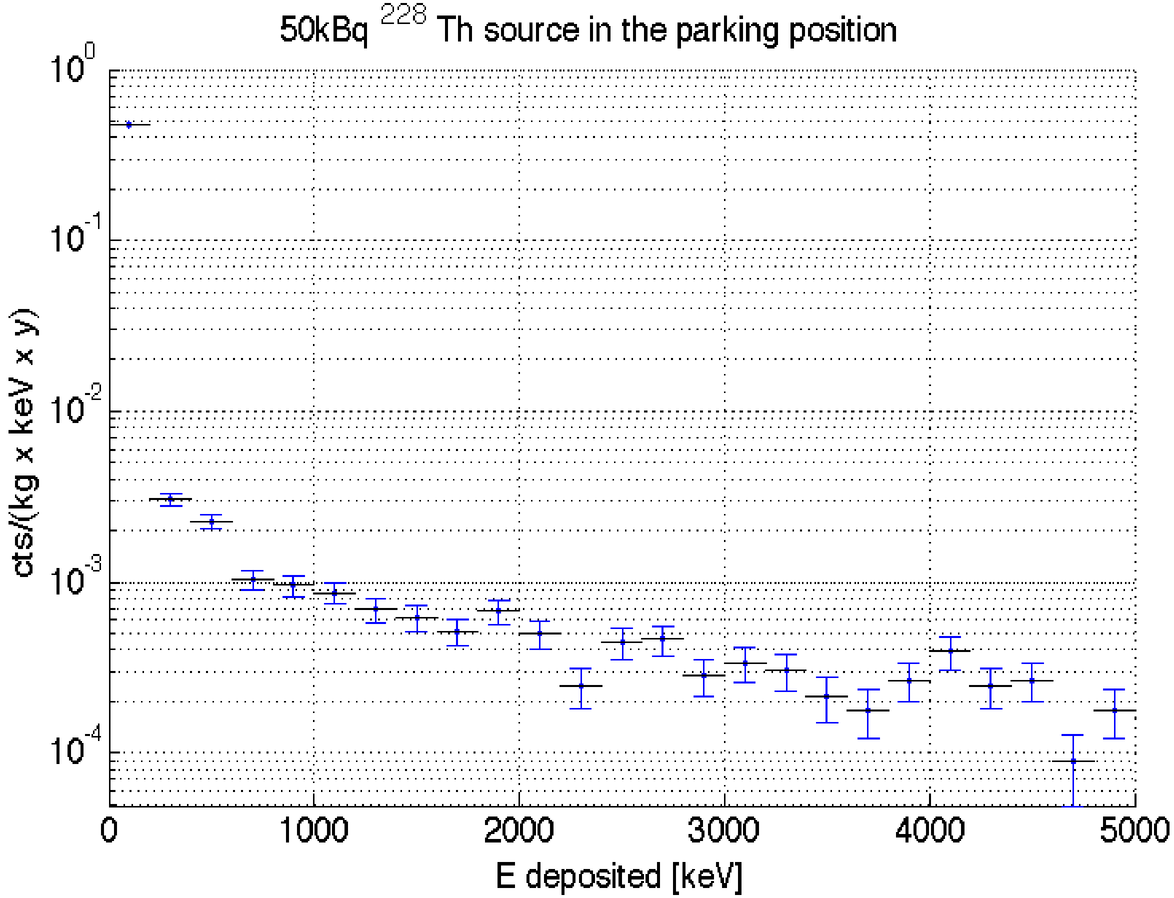
→ Mean interaction probability ~ $4 \cdot 10^{-4}$

→ Background at 1.5 - 2.5 MeV

B ~ $5.2 \cdot 10^{-4}$ cts/(kg·y·keV) @ 50kBq

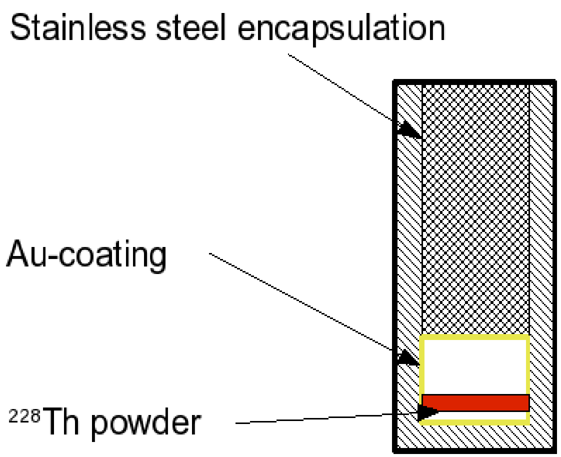
^{228}Th

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



Possible reduction of the (α-n) contribution

- Gold:
  - → No oxidation
  - → Threshold energy = 9.94 MeV > $E_{max}(\alpha)$
- Tungsten:
  - → Threshold energy = 9.4 - 11.9 MeV > $E_{max}(\alpha)$



No (α-n) reactions can occur in contact with Au or W

- ^{90}Zr:
  - → Threshold energy = 7.95 MeV
  - → Replacing $NaAlSiO_2$ ceramic by $\mathbf{ZrO_2}$ ceramic

In the ^{228}Th chain only ^{212}Po emits α's which can overcome this threshold energy

- also interesting: Ge & Mo → next (in Sources4A available) neighbours to Zr

$R_{(\alpha\text{-}n)}(NaAlSiO_2)/R_{(\alpha\text{-}n)}(\text{nat. Ge}) \sim 188$

$R_{(\alpha\text{-}n)}(NaAlSiO_2)/R_{(\alpha\text{-}n)}(\text{nat. Mo}) \sim 28177$

New product development necessary in the upper cases

Part II

γ - Background

γ Background - Analytical Estimate

Assumptions

- Linear attenuation: $\phi = \phi_0 \, e^{-d/l}$
  d: thickness of absorber material, l: mean free path
- In parking position conservatively $d = 350$cm LAr
- Absorber made of W and Cu with $d = 6$cm

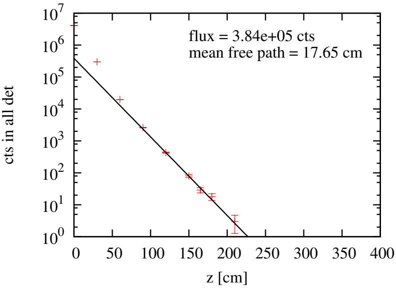
Results for full energy range

No Absorber:	$l_{LAr} = 17.48$cm	$\phi_{LAr} = 0.25$ cts/kg/y/kBq
Cu Absorber:	$l_{Cu} = 2.67$cm	$\phi_{Cu,LAr} = 26.8 \times 10^{-3}$ cts/kg/y/kBq
W Absorber:	$l_W = 1.17$cm	$\phi_{W,LAr} = 1.54 \times 10^{-3}$ cts/kg/y/kBq

Monte Carlo Simulations

Setup

- One detector at each possible position, 3 layers
- 3 naked ^{228}Th sources in different z positions above detectors
- 10 million events for each simulation



Results for full energy range

No Absorber:	$l_{LAr} = 17.65\text{cm}$	$\phi_{LAr} = 0.31\,\text{cts/kg/y/kBq}$
Cu Absorber:	$l_{Cu} = 2.67\text{cm}$	$\phi_{Cu,LAr} = 32.6 \times 10^{-3}\,\text{cts/kg/y/kBq}$
W Absorber:	$l_{W} = 1.17\text{cm}$	$\phi_{W,LAr} = 1.82 \times 10^{-3}\,\text{cts/kg/y/kBq}$

Material Tests

Materials

Tungsten

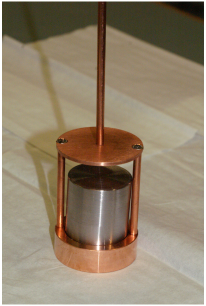
- Purity of 99.97 %
- Problem: brittle

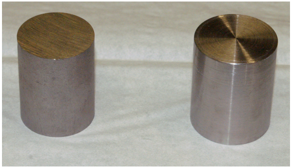
Densimet

- 92% W, Rest Ni and Fe
- Better machinable

Tests in LN

- First test with both materials in LN without any problems
- Thermal expansion of W not measurable
- Thermal expansion of Cu: $\alpha = (14.1 \pm 0.3) \times 10^{-6}/\mathrm{K}$

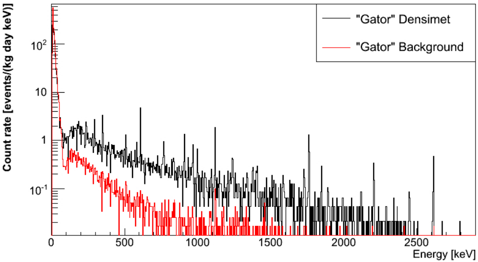




Screening

Densimet D176

- Screening with GATOR
- 4.5kg
- 5.5d screening



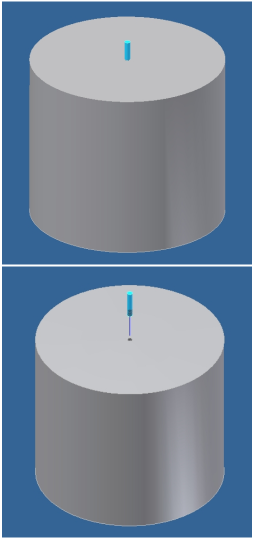
Results

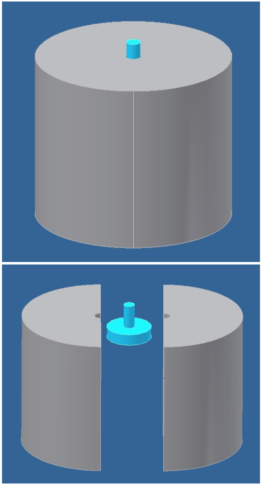
Biggest background contribution from ^{238}U

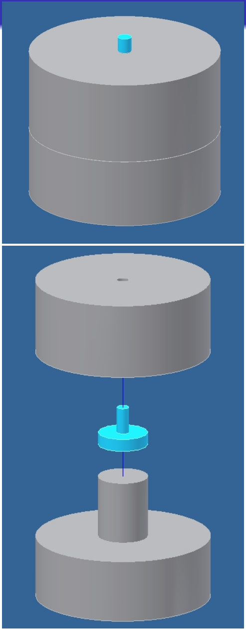
Line	Activity	Background
1120 keV	860 ± 170 [mBq/kg]	1.74×10^{-4}cts/kg/y
1765 keV	840 ± 170 [mBq/kg]	7.61×10^{-5}cts/kg/y

⇒ Alternatives: Ultra pure W (99.99%), Tantalum

Geometries

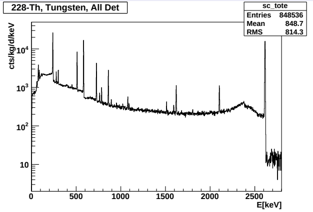






Possibilities

^{228}Th



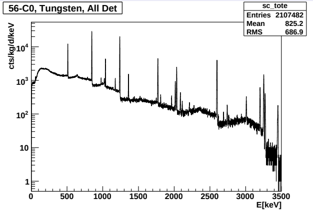
Pros:

- Enough lines for energy calibration
- Line in the region of interest
- Double escape peak with sufficient statistics for pulse shape calibration

Cons:

- α emitter which lead together with the standard ceramic used in the capsule to neutron background

^{56}Co



Pros:

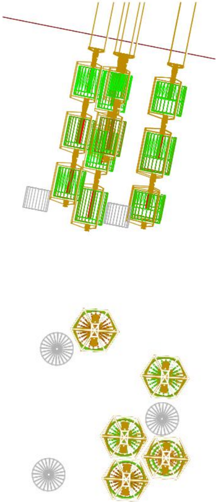
- Enough lines for energy calibration
- Lines in the region of interest
- No α emitter

Cons:

- Short lifetime
- Double escape peaks probably not with sufficient statistics for pulse shape analysis

Setup - Phase I

- Absorber: W cylinder with $h = 60$mm and $r = 35$mm
- Spherical source with $r = 0.4$mm in steel cylinder with $h = 10$mm and $r = 0.5$mm
- Three ^{228}Th sources
- One run per layer with 10 million events each



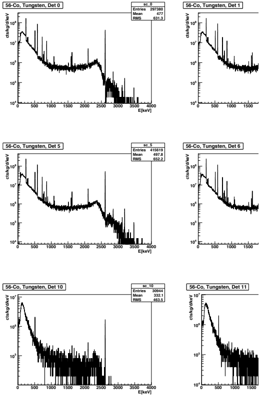
First Results for ^{228}Th

Estimate of Source Strength

- Using spectrum from one detector for first estimate
- Using line with $E = 2615$keV as well as its double escape peak
- Gaussian fit for peak, linear fit for background
- Integration over 5 σ region to estimate peak efficiency
- $A_{min} = \frac{N}{T\epsilon}$

Results

- Min. source strength for energy calibration: $\sim$ 45kBq
- Min. source strength for pulse shape calibration: $\sim$ 60kBq
- Optimization of z position of sources needed to lower source strength
- Background level gives upper limit



Conclusion

Part I

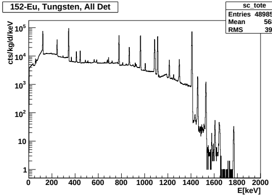
- Neutron rate from a 50kBq ^{228}Th source: 1.9n/s
- (α-n) n background from ^{228}Th in parking postition: $B_0 \sim 10^{-5}$cts/kg/keV/y/kBq
- New product developments can provide background reduction

Part II

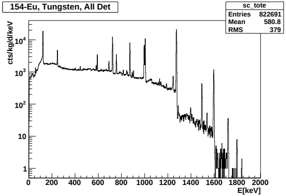
- γ background from ^{228}Th with W absorber in parking position for full energy range: $B_0 \sim 1.5 \times 10^{-3}$cts/kg/y/kBq
- Densimet as absorber material not an option, pure W still a possibility
- Minimum source strength for ^{228}Th $\sim$ 50kBq

Tested Sources

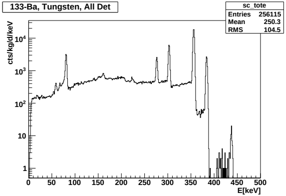
^{152}Eu



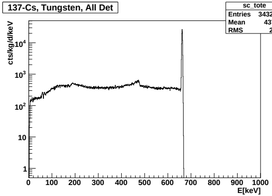
^{154}Eu



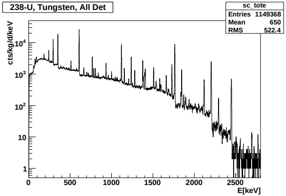
^{133}Ba



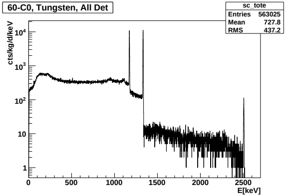
^{137}Cs



^{238}U



^{60}Co



Problems: No line in the region of interest, α emitter and/or not strong enough