Pseudocoincidence Techniques

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Overview

- Introduction
- Characteristics of Radioactive Chains
- Principles of Measurement
- Instruments
- Test & Calibration
- Applications

Introduction

- In monitoring of man made airborne radioactivity concentrations MDAs are limited by the presence of natural activities
- Therefore efficient discrimination and subtraction techniques of natural contributions are required
- The natural occuring radionuclides exhibit specific characteristics, which allow to discriminate against man made radioactivity
- a few general facts physical facts are presented on the following slides

Uranium-Radium decay chain

$^{238}U \rightarrow_{\alpha} {}^{234}Th \rightarrow_{\beta} {}^{234}Pa \rightarrow_{\beta} {}^{234}U \rightarrow_{\alpha} {}^{230}Th \rightarrow_{\alpha}$

4×10^{9} y 24 d 1.2 min 2.5×10^{4} y 7.5×10^{4} y

$^{226}Ra \rightarrow_{\alpha} {}^{222}Rn \rightarrow_{\alpha} {}^{218}Po \rightarrow_{\alpha} {}^{214}Pb \rightarrow_{\beta} {}^{214}Bi \rightarrow_{\beta} {}^{214}Po \rightarrow_{\alpha}$

1600 y 3.8 d 3 min 27 min 20 min 164×10^{-6}s

$^{210}Pb \rightarrow_{\beta} {}^{210}Bi \rightarrow_{\beta} {}^{210}Po \rightarrow_{\alpha} {}^{206}Pb$

22 y 5 d 138 d stable

Radon Progeny

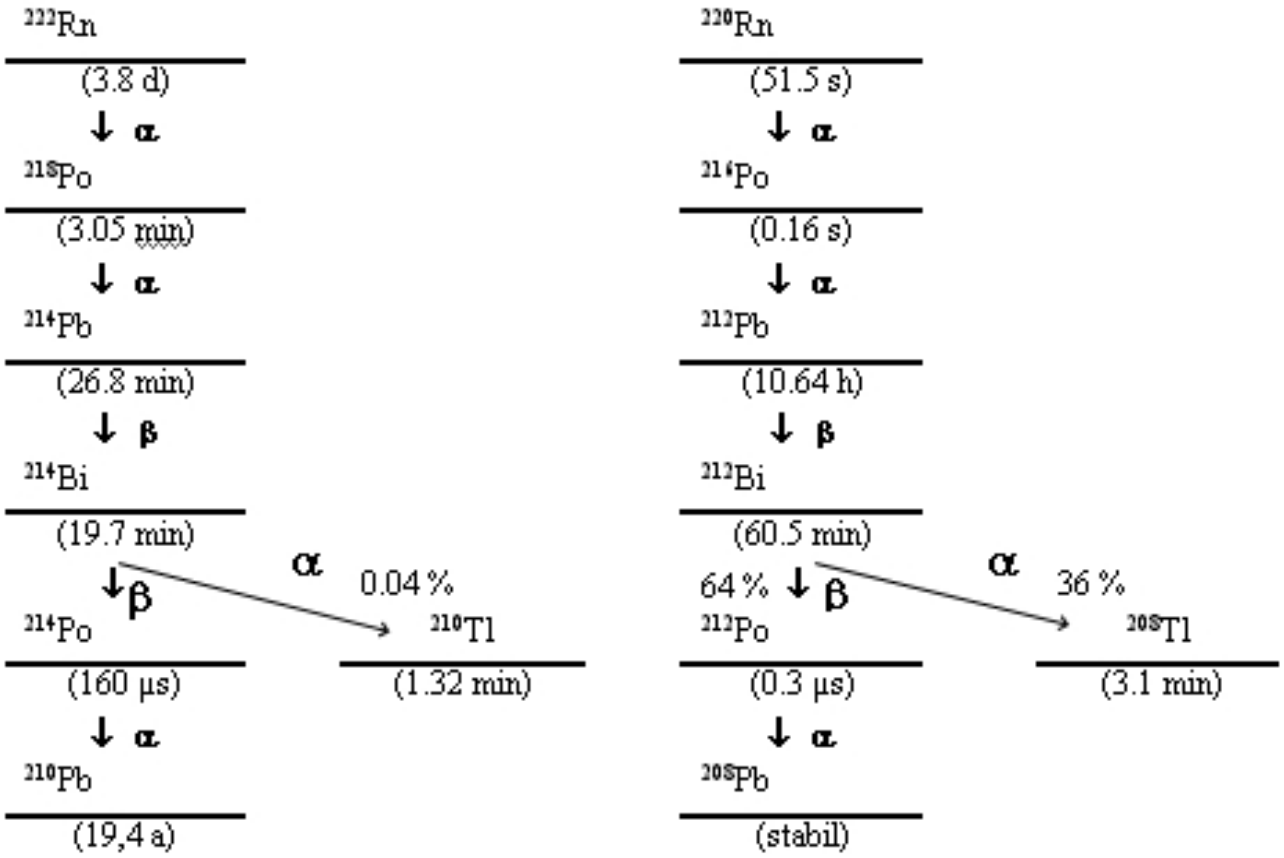
mobile gas | Radon daughters | pseudostable

$^{222}Rn \xrightarrow{\alpha} {}^{218}Po \xrightarrow{\alpha} {}^{214}Pb \xrightarrow{\beta} {}^{214}Bi \xrightarrow{\beta} {}^{214}Po \xrightarrow{\alpha} {}^{210}Pb$

3.8 d | 3 min | 27 min | 20 min | 164×10^{-6} s | 22 y

α-energies | 6002 keV | 7687 keV

Uranium and Thorium Decay Chains



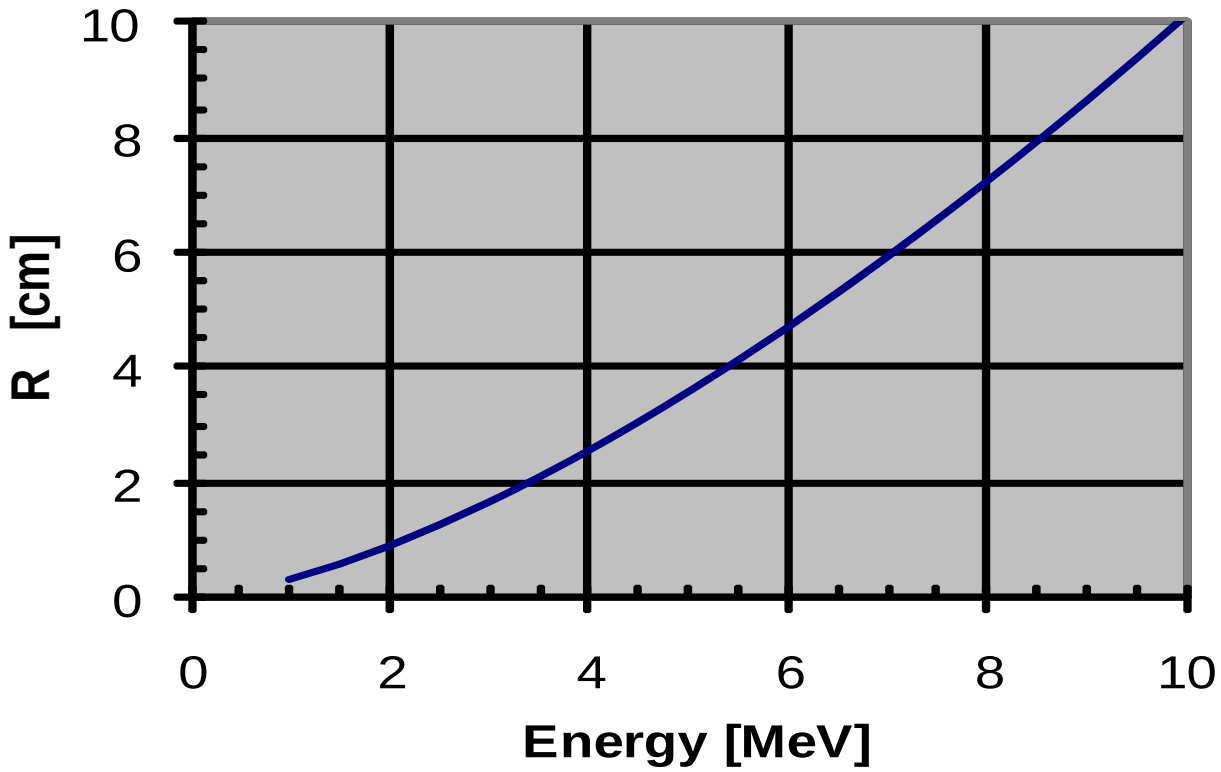
The Pseudo-Coincidence Technique

- Detection of an alpha and a beta particle within a pseusocoincidence period of about 200 µs as a measure of the Radon and Thoron concentration
- Utilizing decays in the Uranium chain (Radon)
  - $^{214}Bi \rightarrow {}^{214}Po$ + beta
  - $^{214}Po \rightarrow {}^{210}Pb$ + alpha $T_{1/2}$ = 164 µs
- Utilizing decays in the Thorium chain (Thoron)
  - $^{212}Bi \rightarrow {}^{212}Po$ + beta
  - $^{212}Po \rightarrow {}^{208}Pb$ + alpha $T_{1/2}$ = 0.3 µs
- which are unique characteristics of these decays

Examples of alpha-emitting nuclides

Nuclide	Half-live	E_α [keV]	P_α
^{235}U	7.037×10^8 a	4400 4374 4368 4218	0.570 0.061 0.123 0.062
^{238}U	4.446×10^9 a	4197 4150	0.77 0.23
^{238}Pu	8.77×10^1 a	5499 5456	0.715 0.285
^{239}Pu	2.411×10^4 a	5157 5144 5105	0.733 0.151 0.115
^{241}Am	4.320×10^2 a	5486 5443	0.852 0.131
^{218}Po	180 s	6002	1
^{218}Po	164×10^{-6} s	7687	1

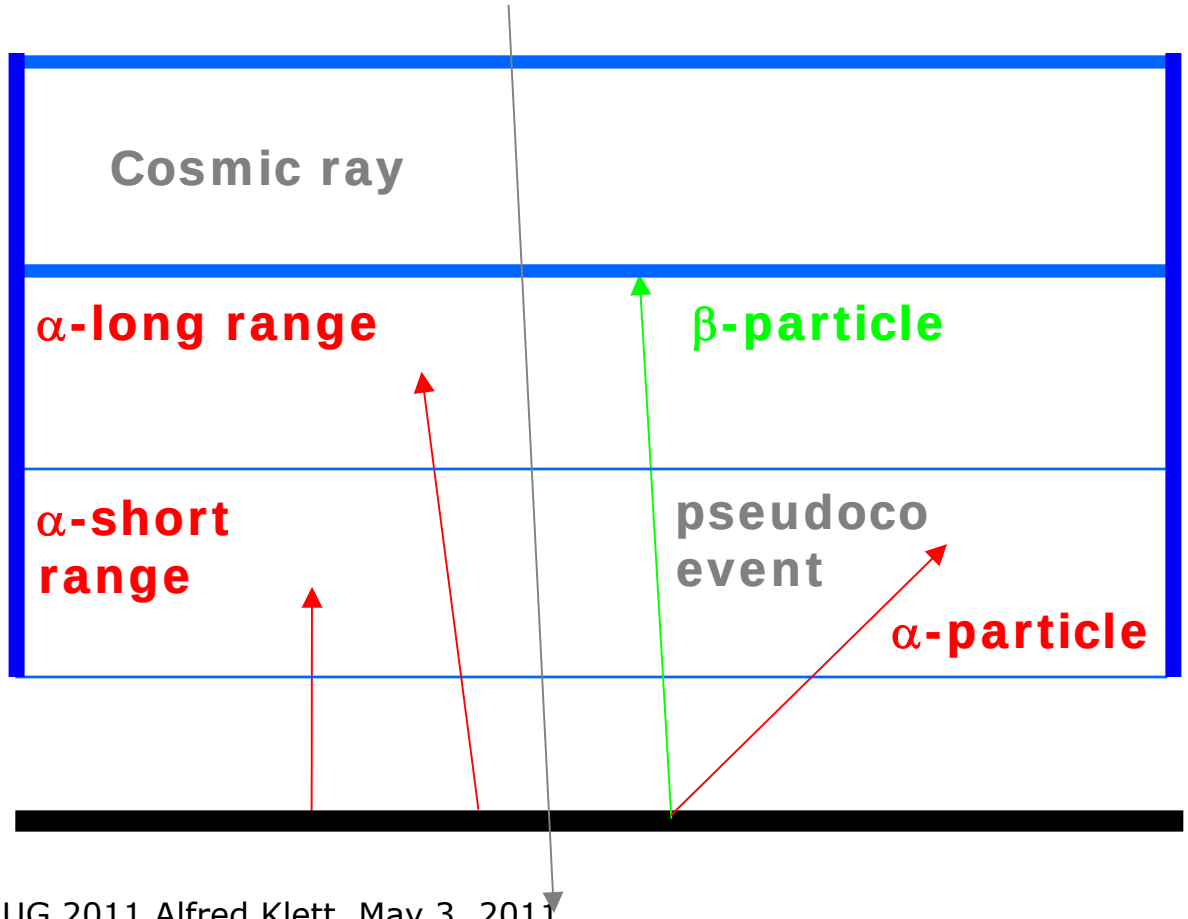
Range of alphas in air



Natural Radionuclides

- Identification
  - alpha-energies of Radon and Thoron daughters
    $E_{alpha} > 6$ MeV
  - alpha-energies of artificial alpha-emitters
    $E_{alpha} < 6$ MeV
  - pseudo-coincident alpha-beta events in the Uranium and in the Thorium decay chains
- Long range alphas $E_{alpha} > 6$ MeV are caused by natural bgrd
- Alpha-beta pseudo-coincidence events are proportional to natural background

Detection with a gas filled detector



United States Patent Office

3,546,457
Patented Dec. 8, 1970

3,546,457

RADIATION MONITORING SYSTEM UTILIZING PSEUDO-COINCIDENCE TECHNIQUES

Rainer Kurz, Oak Ridge, Tenn., assignor to Laboratorium Dr. Berthold, Wildbad, Germany, a company of Germany

Filed June 6, 1967, Ser. No. 644,013
Claims priority, application Germany, June 8, 1966, L 53,799
Int. Cl. G01t 1/16
U.S. Cl. 250—83.3 3 Claims

ABSTRACT OF THE DISCLOSURE

A radiation monitoring system with two input channels and pseudo-coincidence circuitry comprises means for delaying the pulses which arrive first in one input channel and means for stretching the other pulses in the other input channel whereon both channels are fed to an instrument forming the pseudo-coincidence.

the disadvantage that gamma background radiation causes considerable errors in the pseudo-coincidence pulse rate.

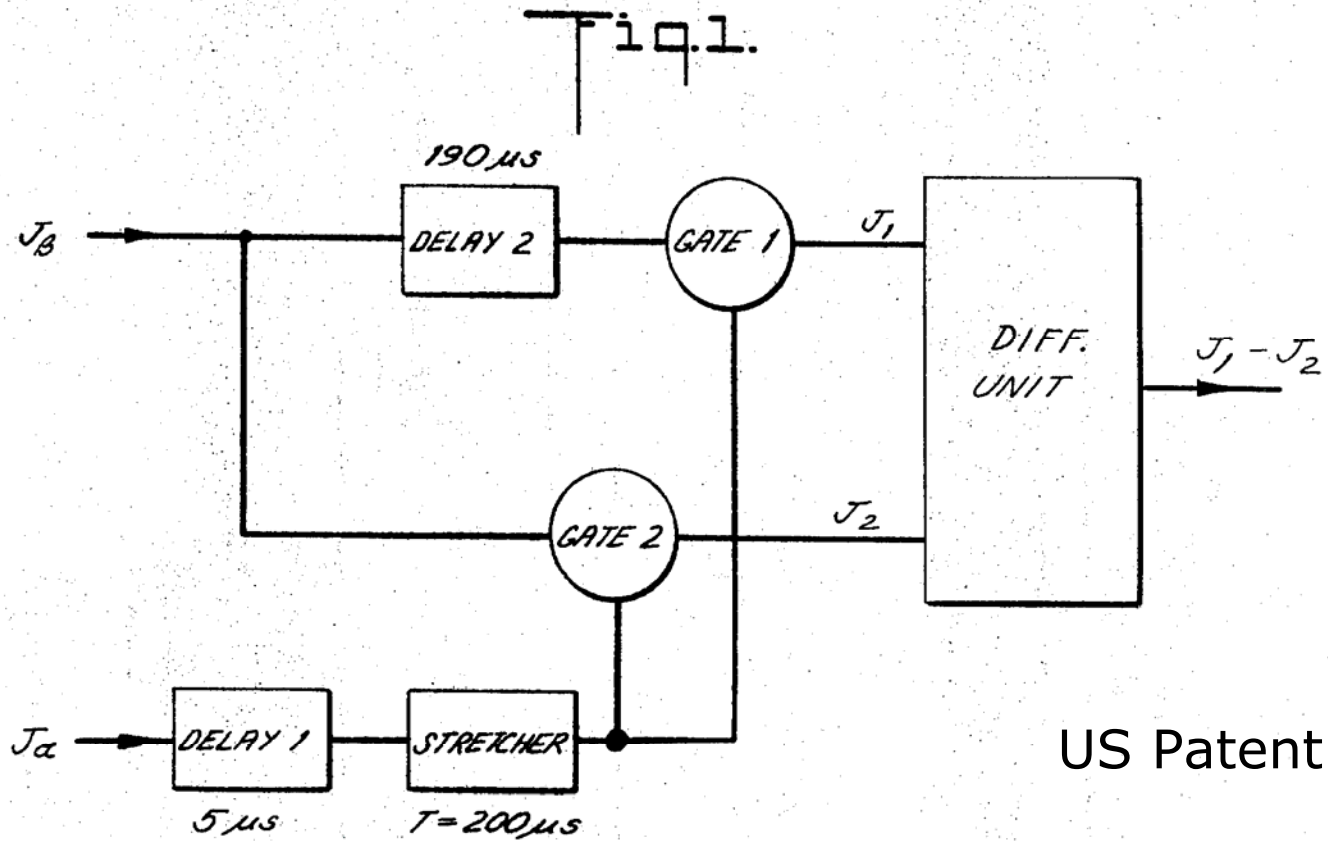
It is the primary object of the present invention to provide a system overcoming the above difficulties without complicating the installation so that the output from two input channels for pulses of different types of radiation very accurately gives the pseudo-coincidental pulses.

This object is accomplished in accordance with this invention by delaying the pulses which arrive first in one input channel, and stretching the other pulses in the other input channel, whereon both pulses are fed to an instrument forming a pseudo-coincidence.

In this manner, the gate circuit is not opened by the beta-pulses. However the alpha-pulses pass through the gate circuit and open the gate to permit the beta-pulses to pass therethrough. The advantage of this is as follows:

The circuit is not activated by the beta-pulses and the γ-pulses emanating from the background radiation which are inseparable from the beta-pulses in the instal-

Pseudo-Coincidence: Electronic Circuit



US Patent 3,546,457

Pseudo-Coincidence: Schematics

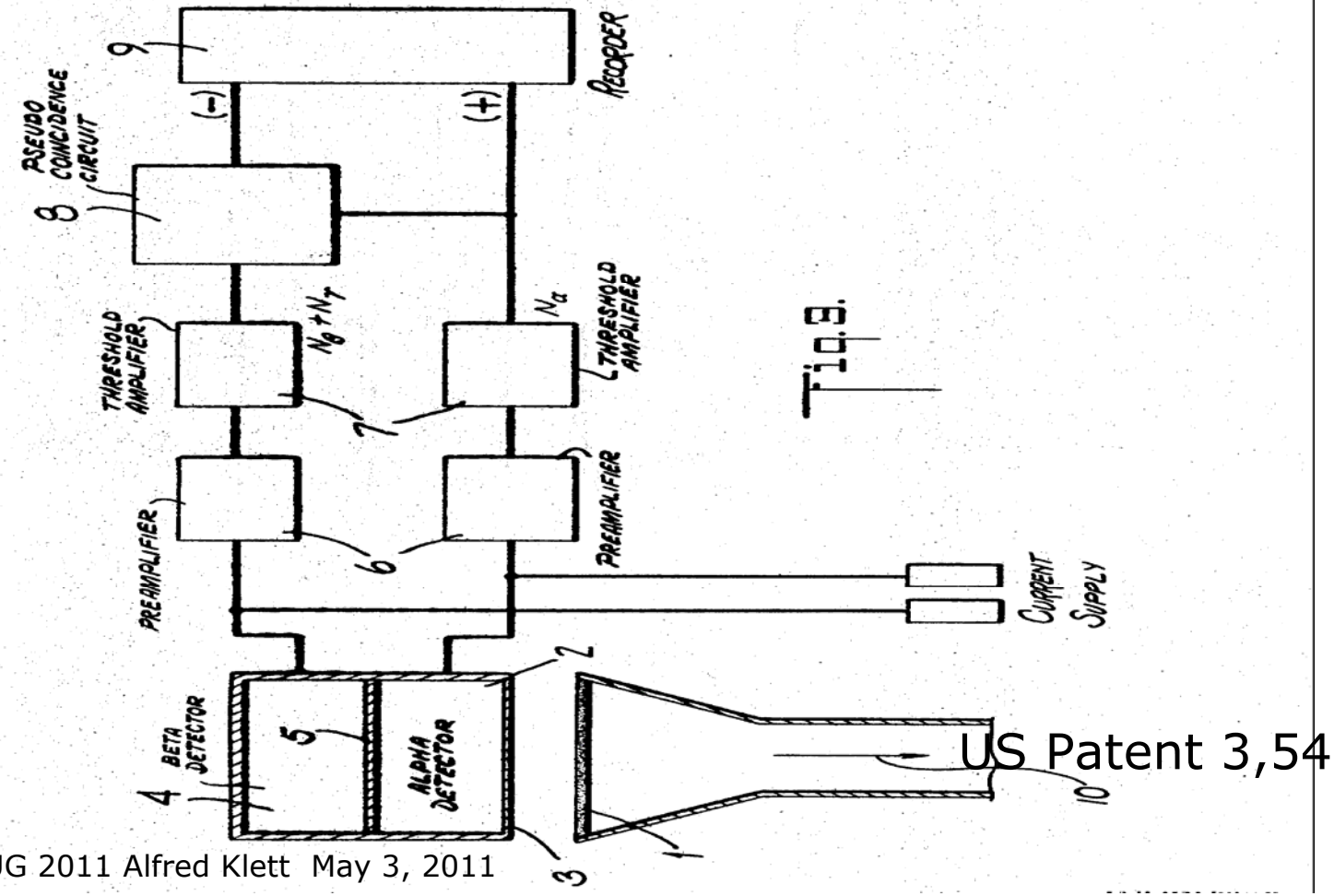


Fig. 9.

US Patent 3,546,457

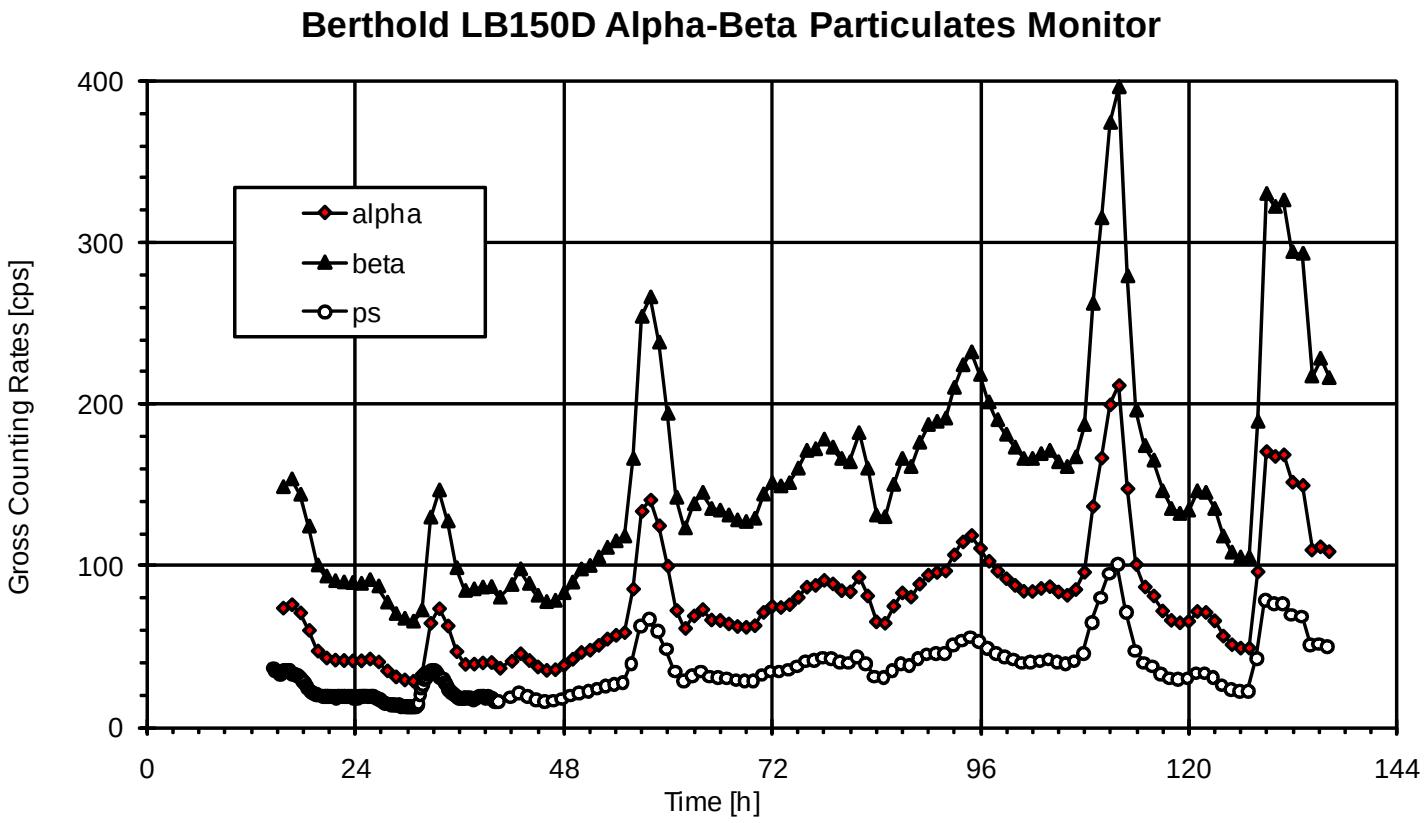
Air Monitor LB 150-DR for particulates

Type	Airborne particulates monitor
Filter	Ø 200mm fixed filter
Detector	Gas flow through proportional counter (Ø 200mm) with simultaneous alpha-, beta-measurement and with guard detector
Natural Bgrd Compensation	combined pseudo-coincidence and alpha-range
Air flow	approx. 40 m³/h
MDA	100 mBq/m³ man made alphas (1h)

Applications for LB 150 DR (α-β)

- In facilities processing and storing radioactive waste
- In installation dealing with nuclear fuel and fissionable material
- In laboratories operating with hot cells
- In general research laboratories dealing with alpha emitting radioactive substances
- Well suited for stack monitoring at lowest detection limits available on the market
- Total release calculations day/week/month

Gross Counting Rates LB150D

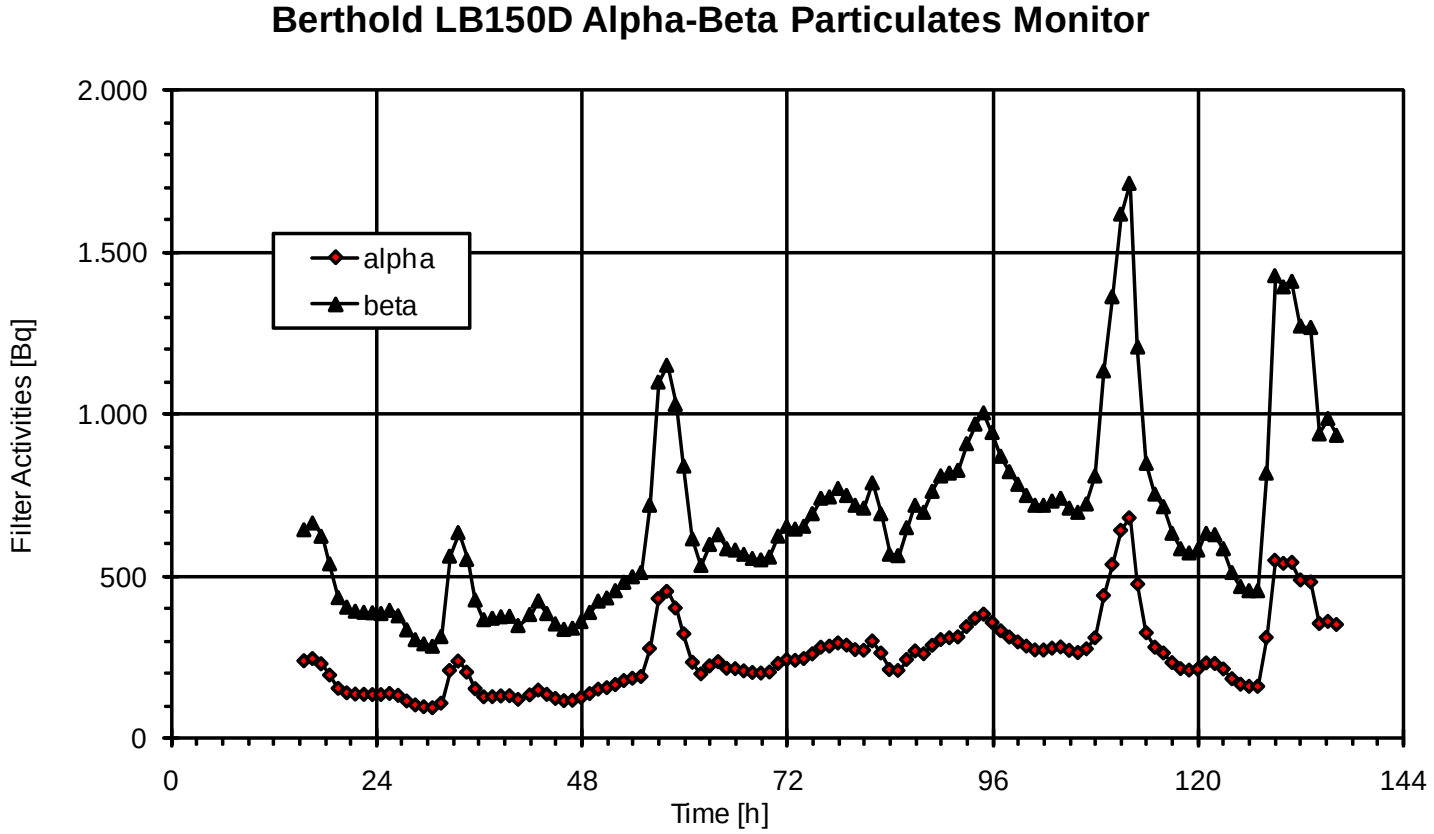


Mean: 156.4 cps
Sigma: 66.5 cps

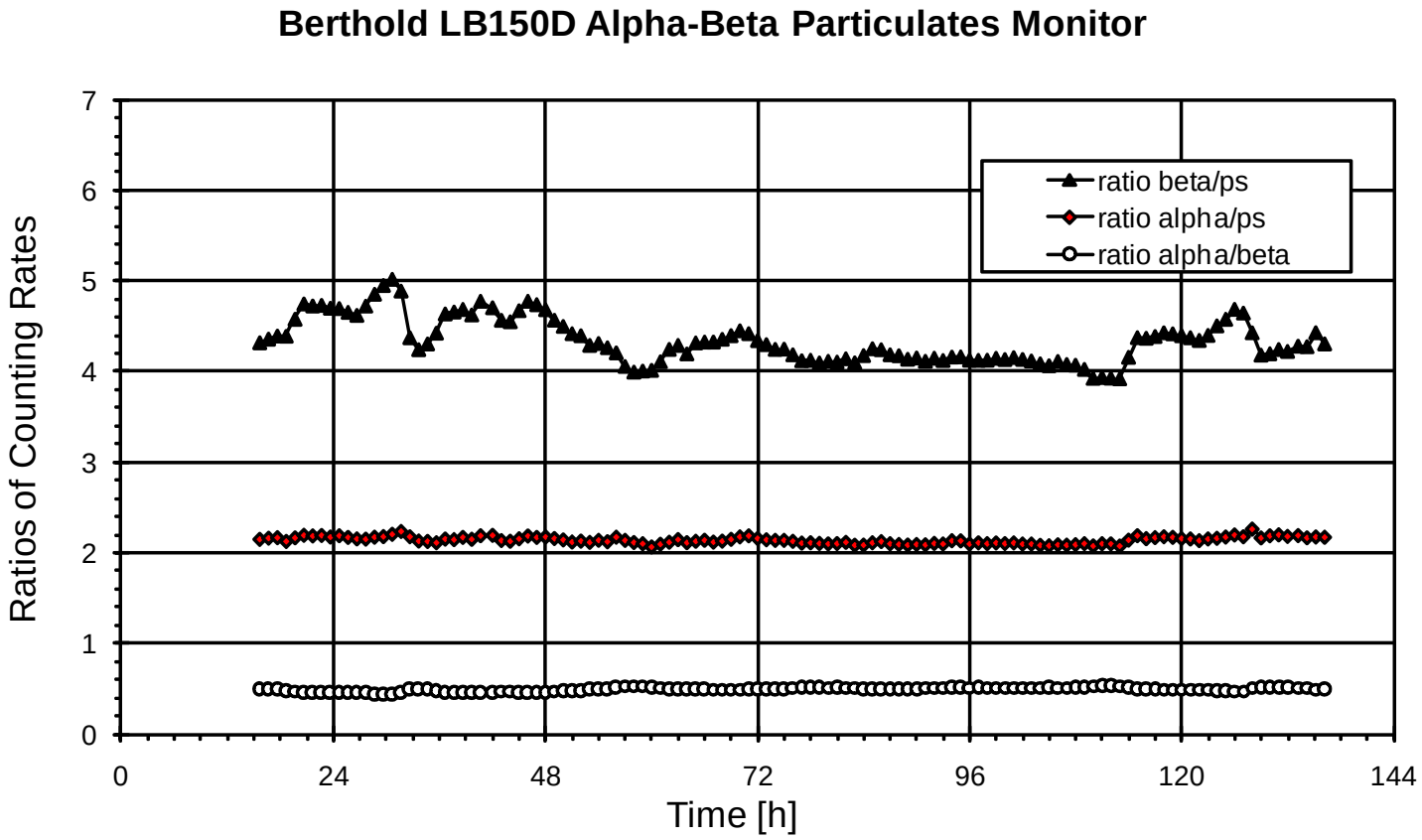
Mean: 78.5 cps
Sigma: 36.5 cps

Mean: 36.8 cps
Sigma: 17.2 cps

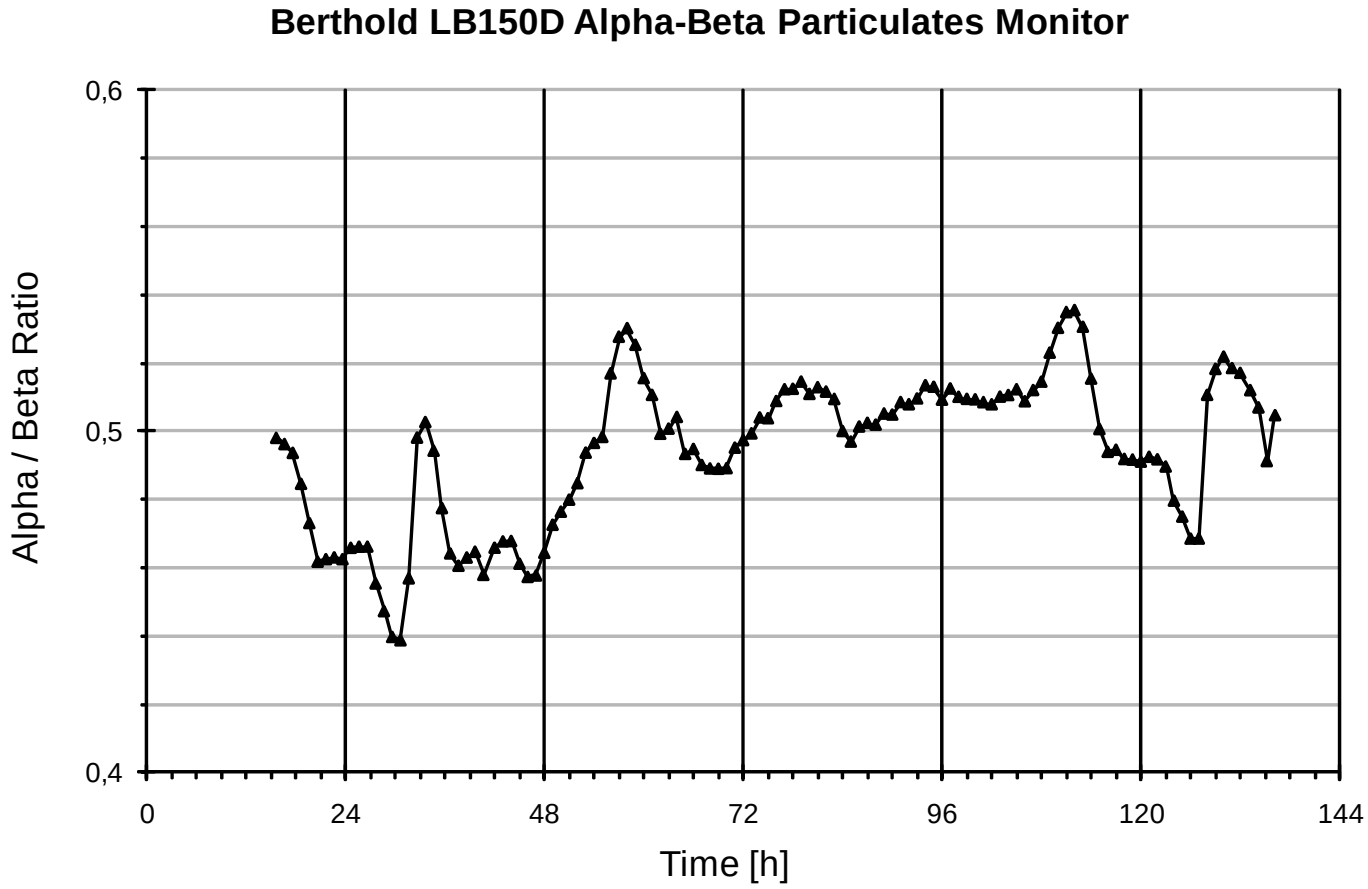
Activities Ø200mm filter at 40m³/h flow



Ratios of Gross Counting Rates

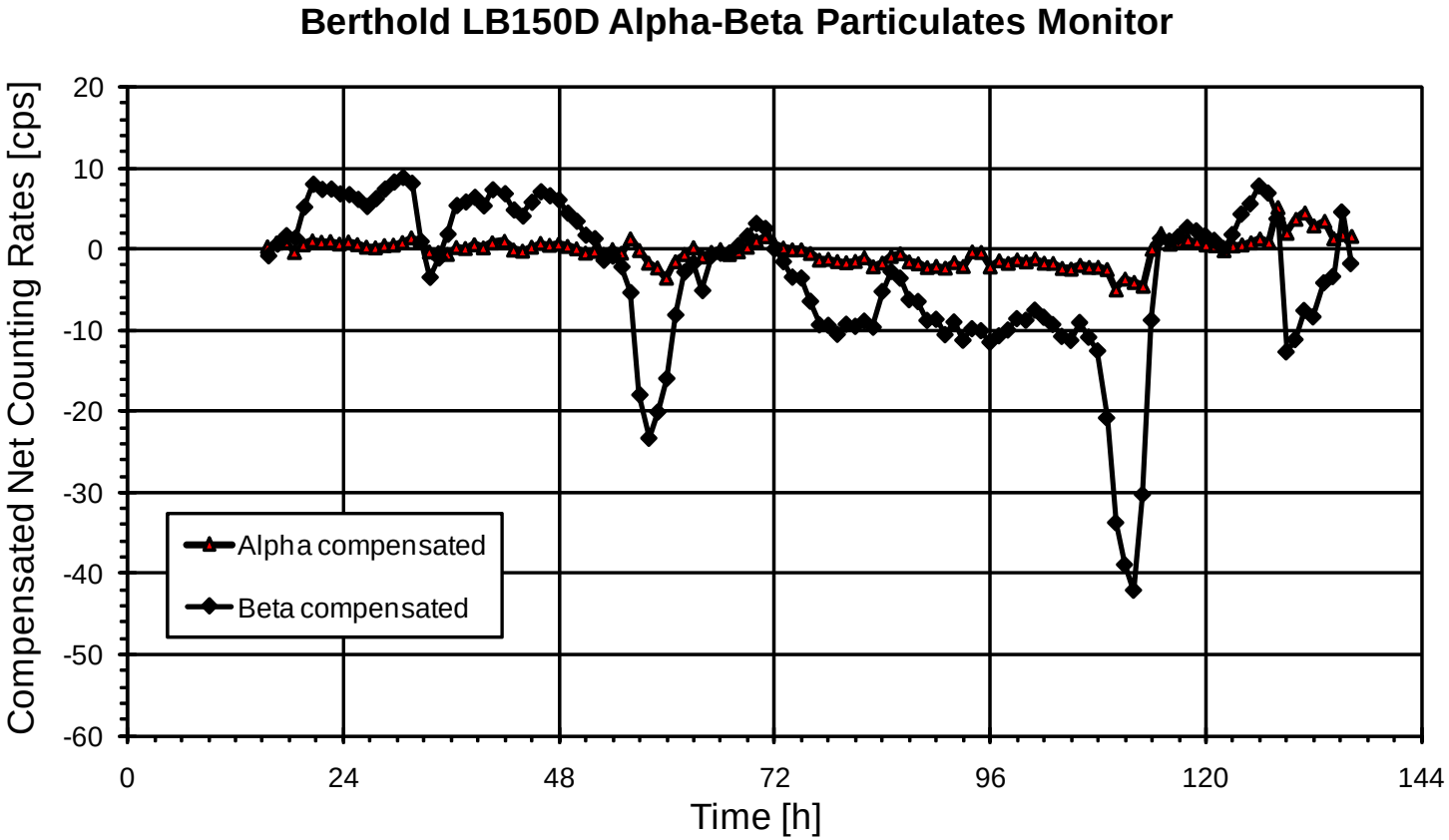


Alpha-Beta Ratio

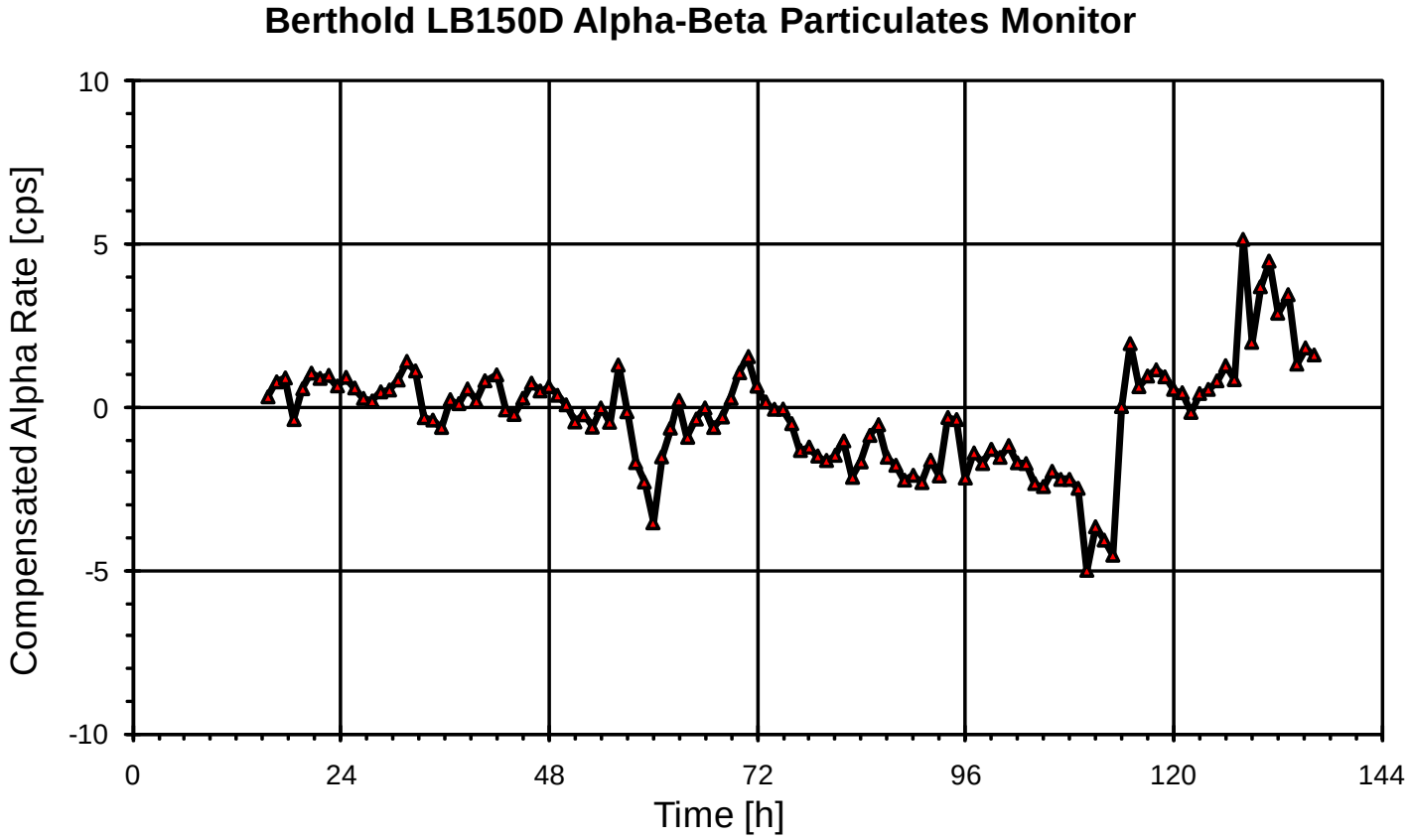


Mean: 0.49
Sigma: 0.02

Compensated Net Counting Rates

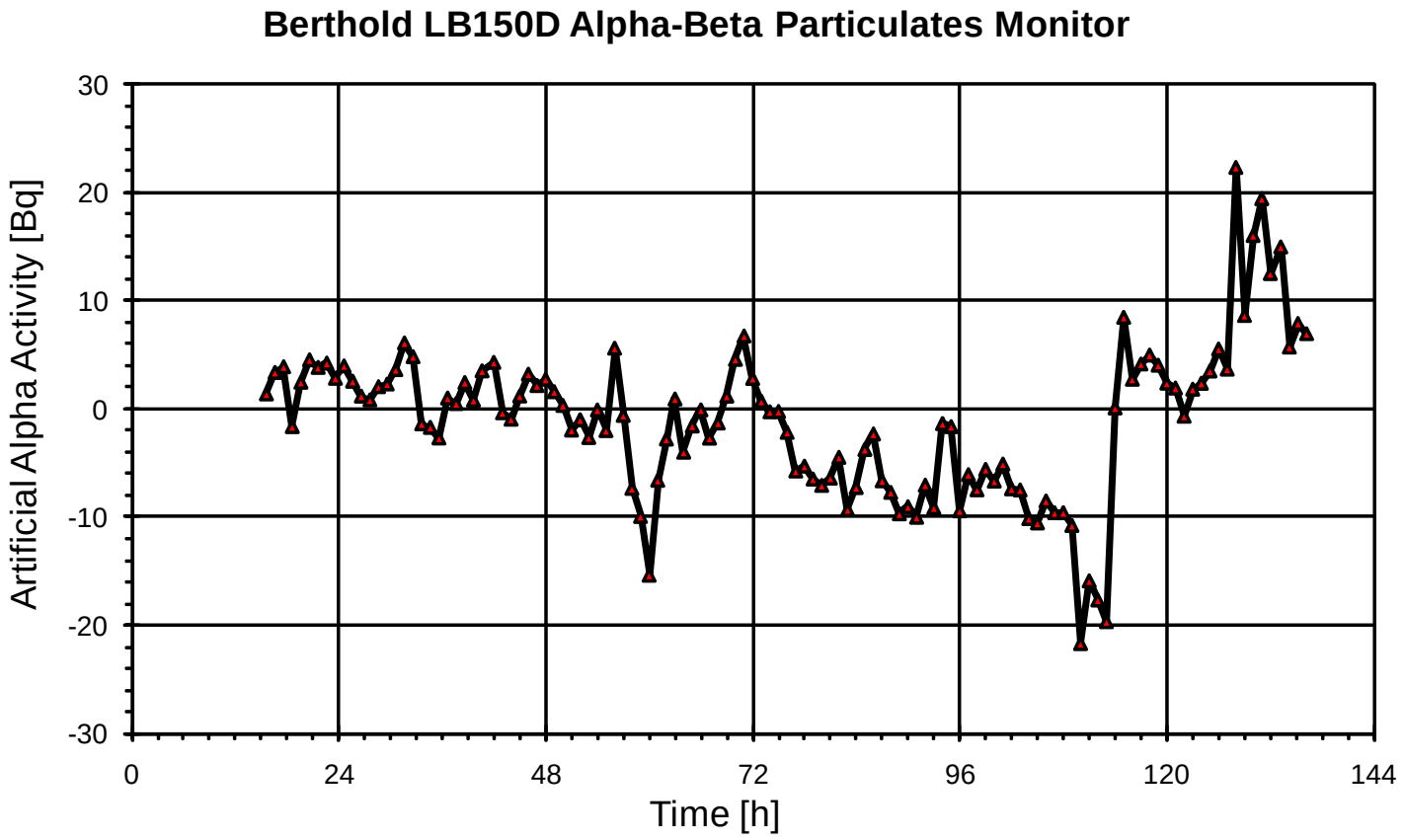


Compensated Alpha-Counting Rate



Mean: -0.23 cps
Sigma: 1.63 cps

Artificial Alpha-Activity



Mean: -1.0 Bq
Sigma: 7.1 Bq

Detection Limits LB 150-DR

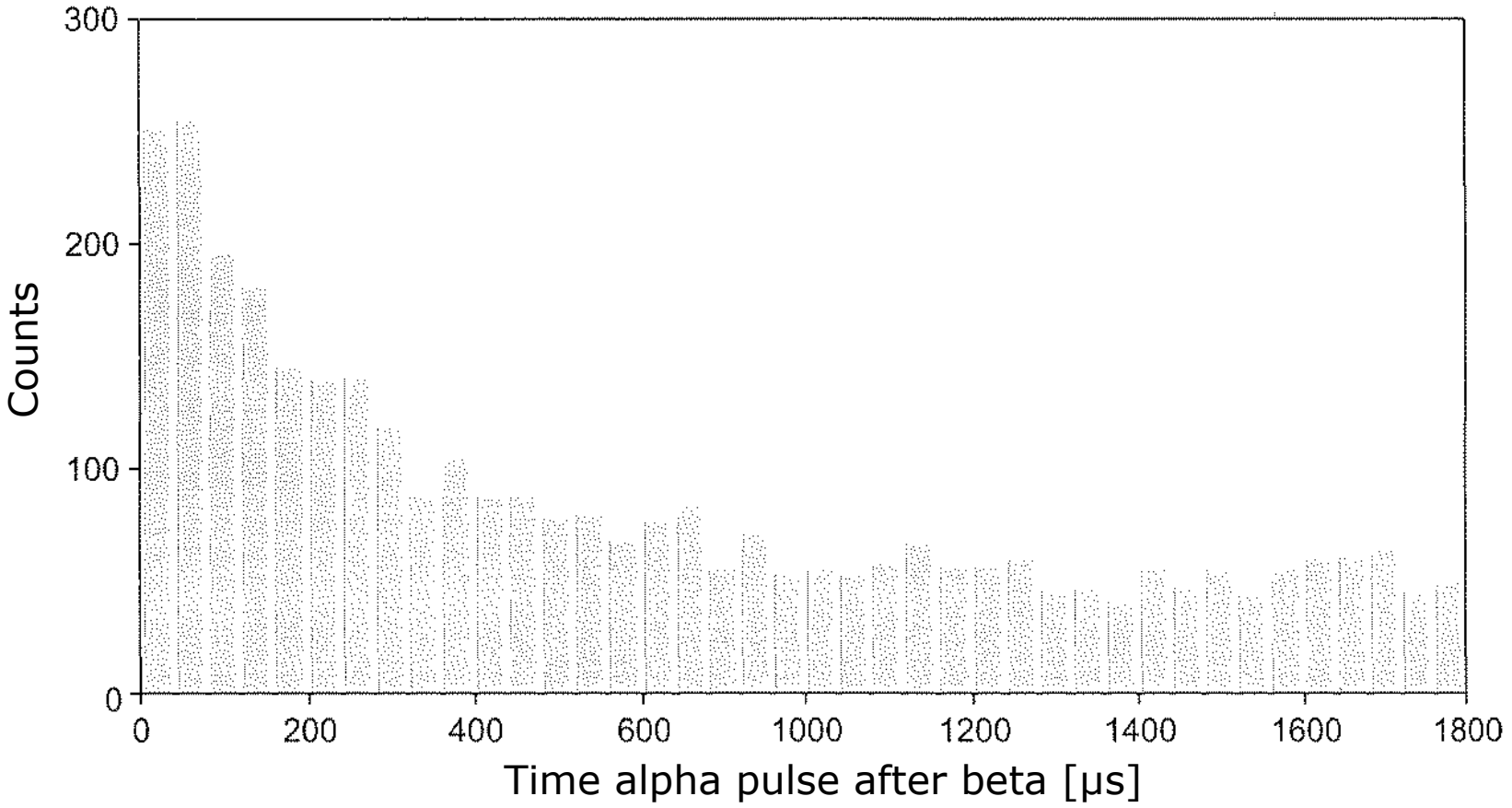
Natural Activity Concentration		MDA Man Made Activity Concentration	
Bq/m³	pCi/m³	Bq/m³	pCi/m³
0.1	2.7	0.01	0.3
1	27	0.04	1.1
10	270	0.13	3.5

Detection Requirements

1 DAC		Activity Concentration	
Isotopes	Particles	Bq/m³	pCi/m³
^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am	alpha	0.1	2.7
^{235}U	alpha	0.7	18.9
^{242}Cm	alpha	4	108
mixed fission products	beta	117	3159

2000 DAC hrs = Annual Limit of Intake

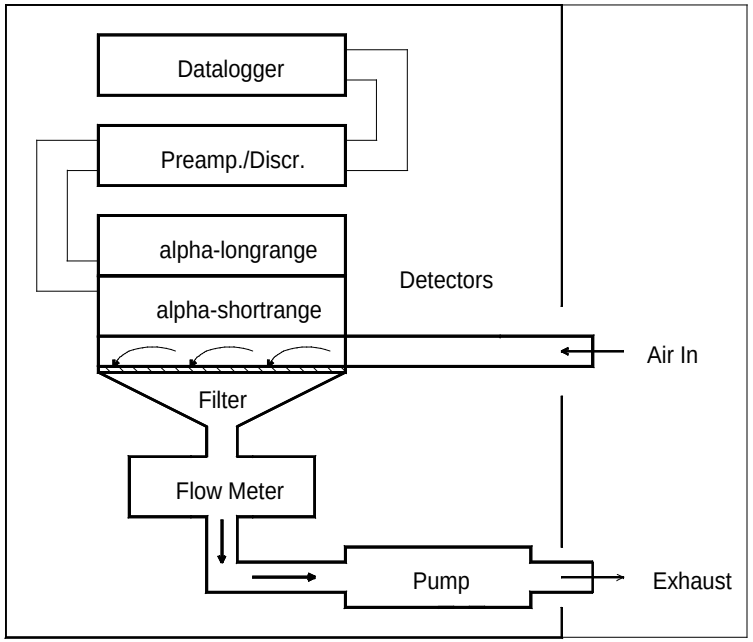
Timing Measurement alpha-beta



W. Kraut et. al. 2010

^{239}Pu Calibration at ICARE test bench in Saclay

- Institute — IPSN / CEA France
- Instrument — LB 150R with dual alpha-detector
- Particulates — AMAD diameter 0.4 µm and 4.0 µm labelled with ^{239}Pu
- Background — known radon concentrations
- Deposition of particulates — investigated with fluorescence labelled aerosols



Results LB150R ICARE Calibration

Results of calibration with ^{239}Pu

AMAD relative response [µm]	Activity [Bq/m³]	Reading [Bq/m³]	[%]
0.4	16.1 ± 0.5	12.276 ± 3	
4	41.8 ± 1.6	24.659 ±10	

MDA's LB150R determined at ICARE

Detection limits for ^{239}Pu

Radon [Bq/m³]	Meas.Time [min]	Detection limit [mBq/m³]
172	60	386
60	60	220
37	30	498
37	60	196
37	150	62
37	300	16

LB 9128-ENV Moving Filter Monitor

- Beta monitor
  - external γ-compensation
  - β/α ratio Radon compensation
- Alpha-beta monitor
  - external γ-compensation
  - Pseudo-coincidence Radon compensation

Technical Data LB 9128

Detector	Ion implanted Silicon Detector area 600 mm², 300 µm depl. simultaneous alpha + beta
Detection Efficiency (typical)	Alpha: 20% for ^{241}Am Beta: 25% for ^{36}Cl
Shielding	Pb average thickness 30 mm
Background (typical)	Alpha: 0.002 cps Beta: 0.2 cps
Gamma-sensitivity	< 0.4 cps at 1 µSv/h (^{137}Cs)
Radon Compensation Technique	Pseudocoincidence or Alpha/Beta Ratio

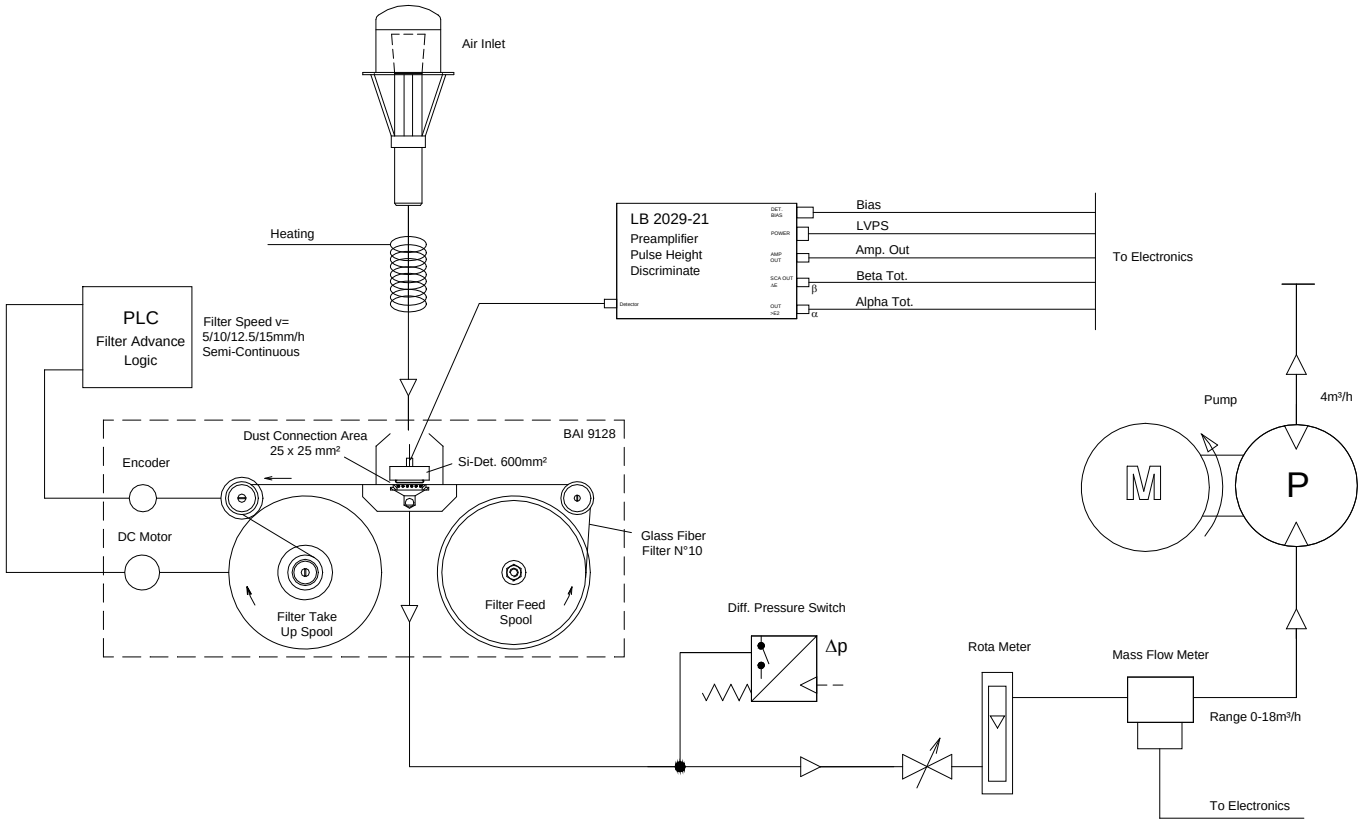
Technical Data LB 9128

Measuring Range (at 20 Bq/m³ Radon level)	Alpha: 0.3 - 10^6 Bq/m³ Beta: 0.5 - 10^6 Bq/m³
Accuracy	<15%
Maximum autonomous operation period	8000 h
Response Time	1.33 h (10% - 90%)
Temperature Range	0°C – 40°C
Dimensions	553x600x959 mm³ (WxDxH)
Weight	120 kg

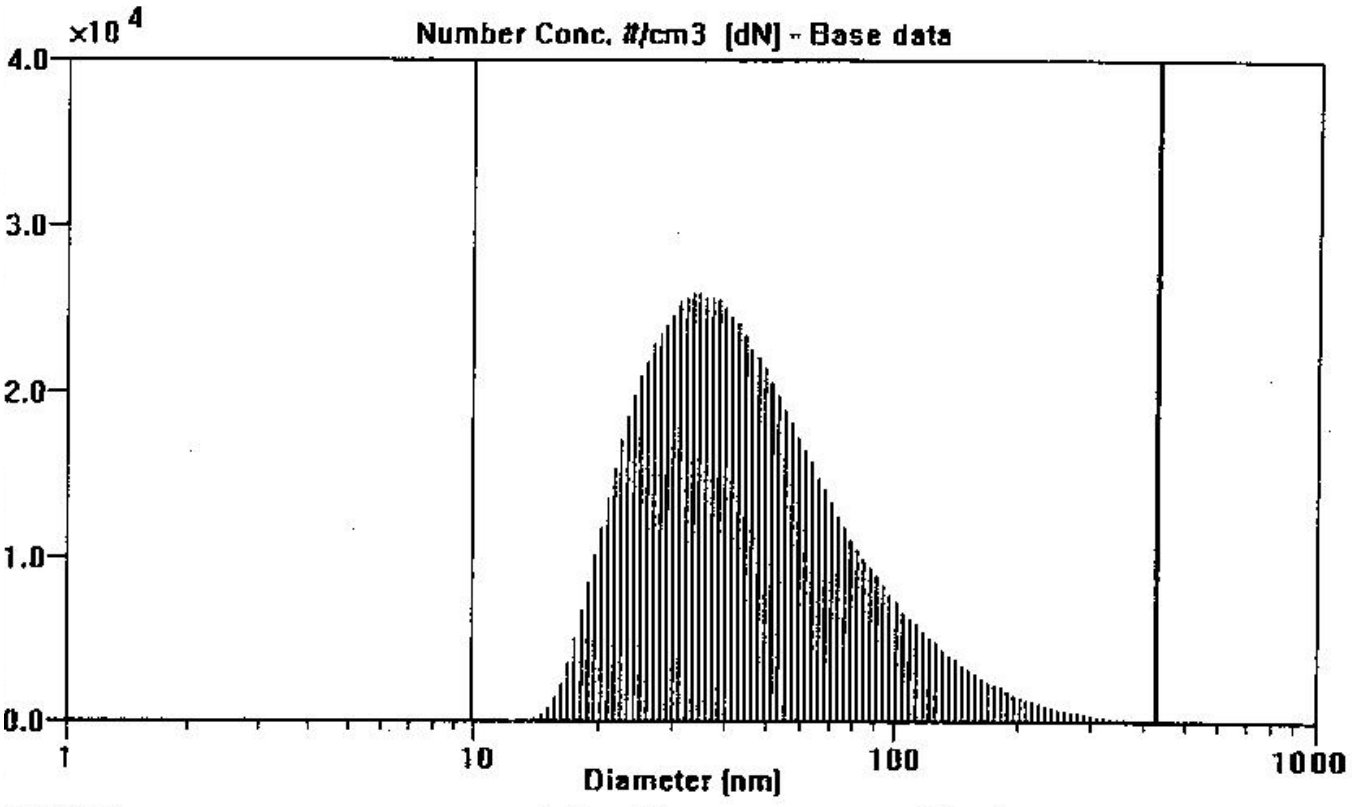
Technical Data LB 9128

Nominal Air Flow	3 resp. 4 m³/h (pump type)
Flow Meter	0 – 6 m³/h (<2%)
Filter	Schleicher Schüll No. 10 Glass fibre
Recommended Filter speed	12.5 mm/h
Selectable Filter speeds	(2.5), 5, 10, 12.5, (15) mm/h
Suction Head	Stainless Steel
Dusting Area	625 mm²
Sampling tube connecting flange	∅25 mm

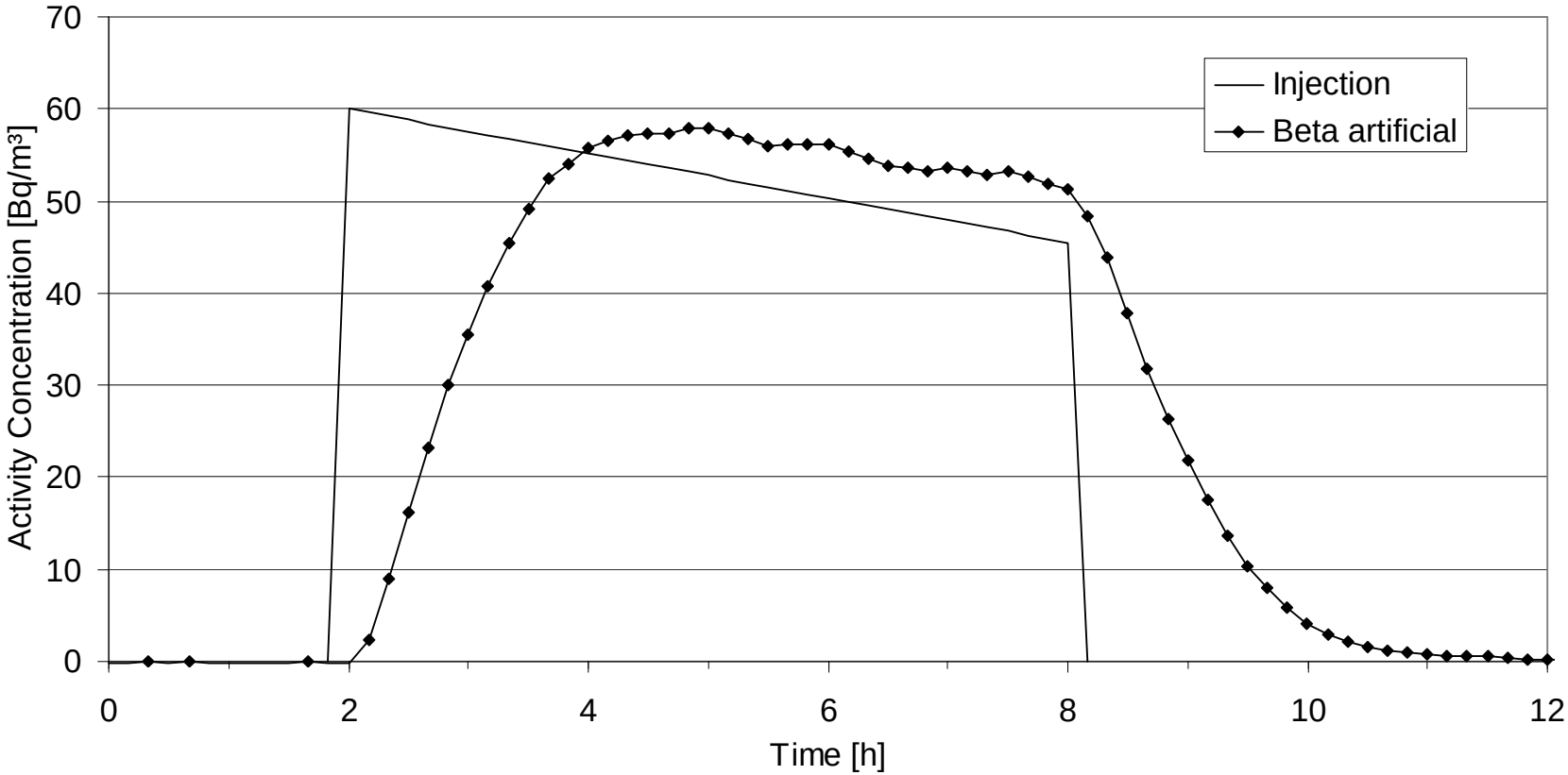
Schematical Setup LB 9128



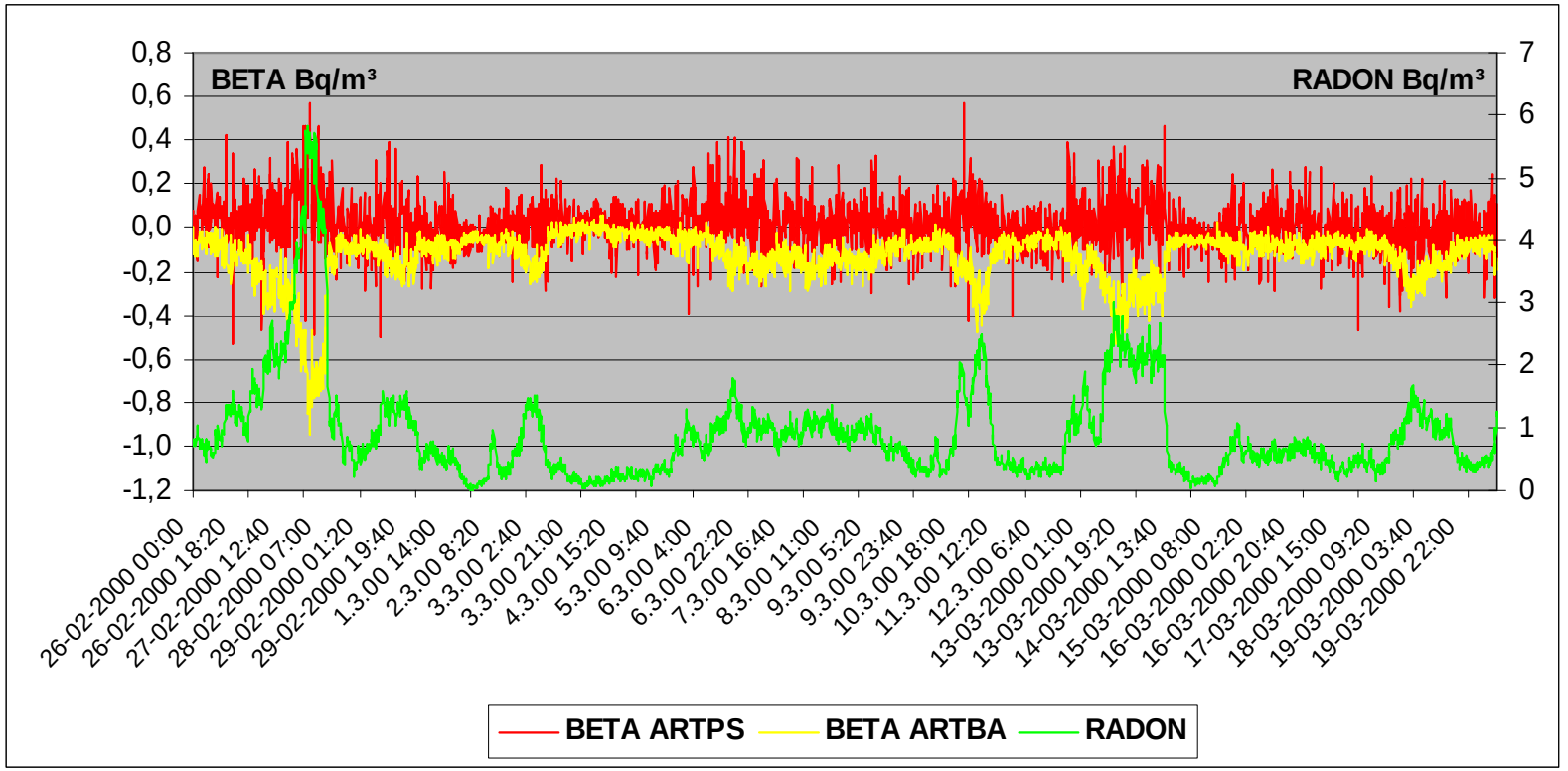
Injection of ^{24}Na labelled aerosols



Calibration LB 9128 with ^{24}Na Injection



Radon Compensation LB 9128



Detection limits LB 9128

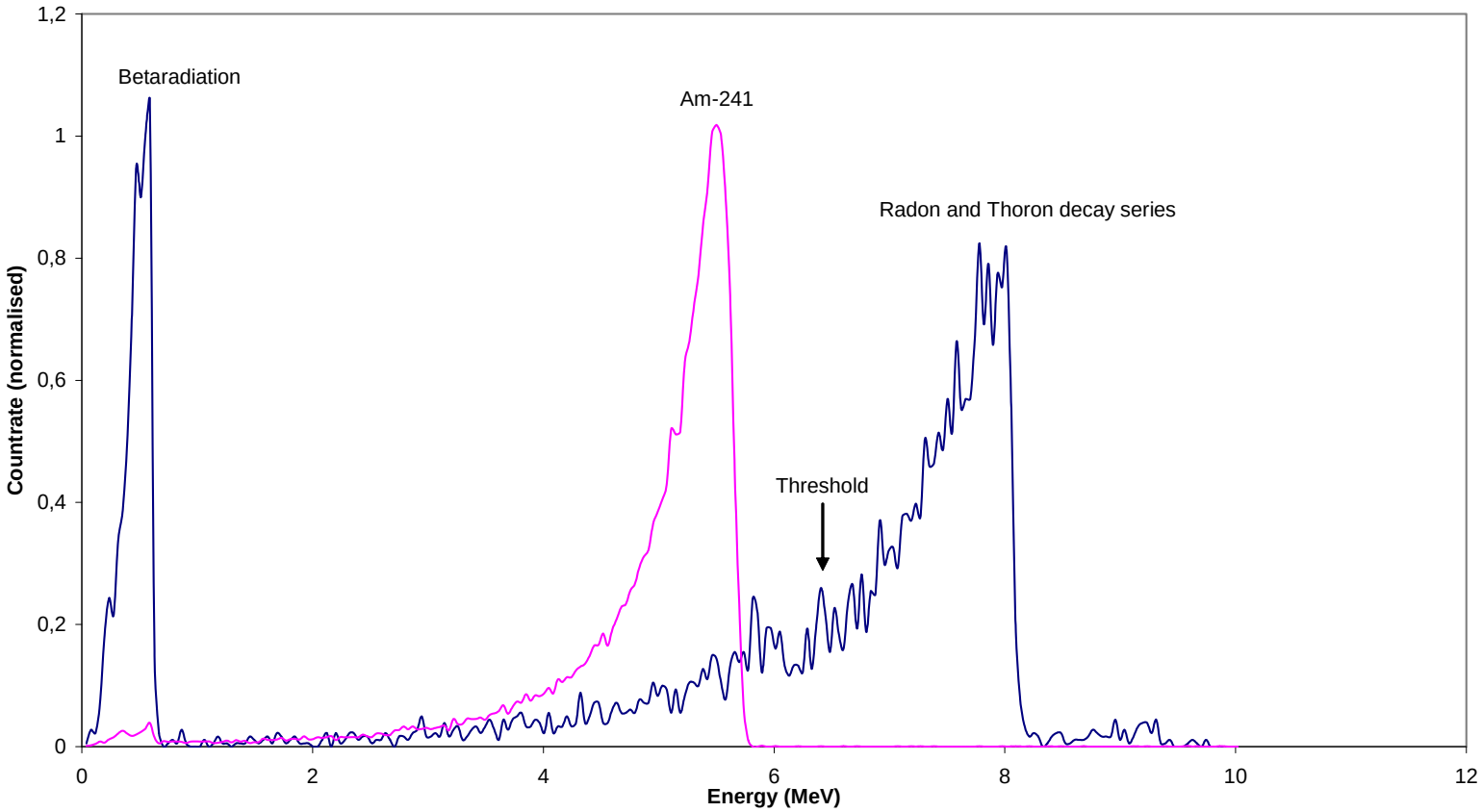
at Radon activity concentration 7 Bq/m³

Measurement	Compen-sation	MDA [mBq/m³]
Alpha artificial	Pseudo-coincidence	109
Beta artifical	Pseudo-coincidence	342
Beta artifical	α-β ratio	240

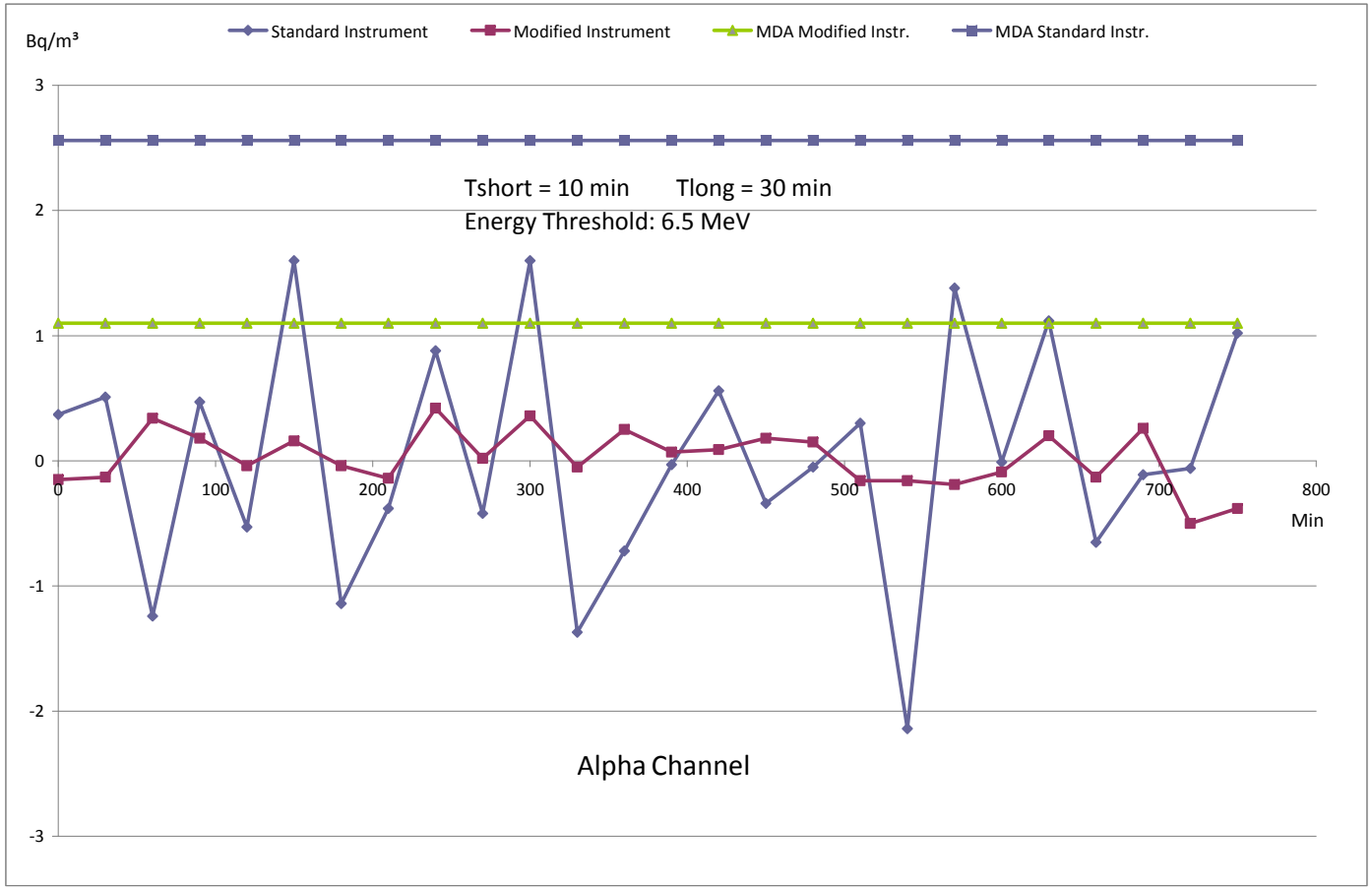
Radon Compensation with semiconducting detectors

- we utilized for air monitors with semiconducting detectors since a long time pseudo-coincidence compensation or alpha-beta ratio compensation
- the pseudo-coincidence compensation factors had been consideraby higher than with gas operated detectors
- with a combined method using pseudo-coincidence and energy discrimination a major improvement was achieved
- the combined method records the following types of events
  - high energy alphas exceeding 6 MeV
  - Pseudo-coincident alpha and beta events

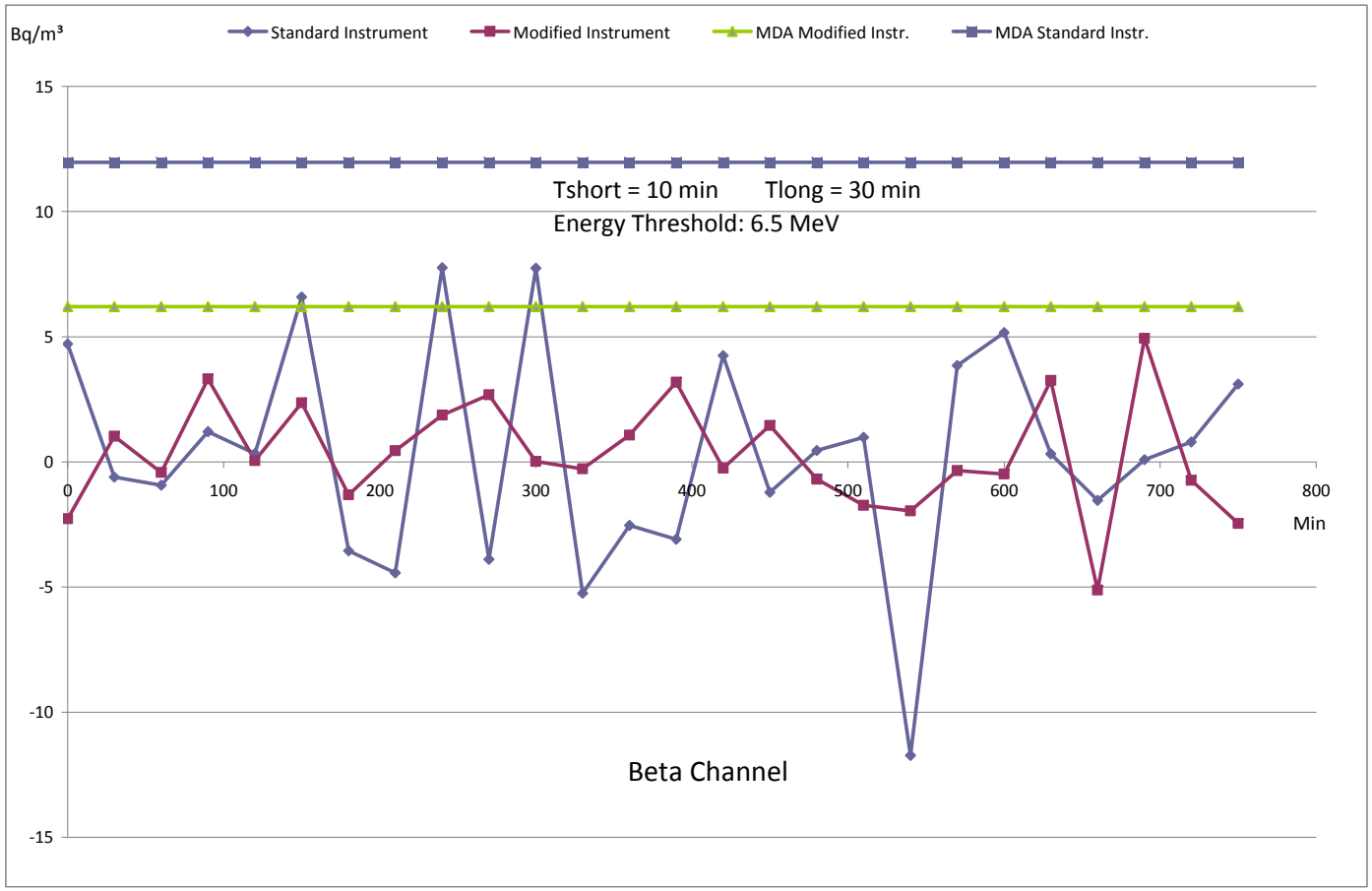
Alpha Spectrum ^{241}Am and Natural



Alpha-channel measurements



Beta-channel measurements



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9) United States Patent 4,960,998, *Method and apparatus for continuously determining gas-carried alpha-radioactivity*.

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