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Technical Challenges in Metrological Response to a Nuclear Detonation (TEMEDET)

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Abstract

Current developments have increased focus on the use of nuclear weapons and it is imperative that countries improve their capacity to respond to incidents within their borders and where assistance is requested by another state. The TEMEDET activity addresses technical challenges posed in responding to the detonation of a nuclear device. Measurement of contamination is fundamental in response to any event involving nuclear or radioactive material. In many countries, “response” and the metrological approaches involved have been developed within the context of nuclear accidents in the conventional sense or dispersal of limited suites of isotopes (dispersal devices etc). Nuclear detonations generate suites of isotopes that are, for many, outside of their experience and that can present challenges. TEMEDET addresses some aspects of this problem and aims to provide a means of practicing metrological response to a nuclear detonation through the development of a series of gamma spectrometric data sets of the type that may be generated in responding to a nuclear incident that will reflect the complexities involved in nuclear detonations.

Key words

Gamma spectrometry, nuclear weapons, fallout

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Final Report from the NKS-B Project TEMEDET (Contract: AFT/B(23)1).

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Table of Contents

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While every effort has been made to ensure fit-for-purpose materials, the developed materials should not be used in any predictive capacity related to emergency preparedness for nuclear weapon or other events. The materials do not:

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1.0 Introduction

Geopolitical shifts since the end of the Cold War have led to a refocus in some elements of emergency preparedness and response. With a reduced risk for the use of nuclear weapons, emergency preparedness was, understandably, directed more towards large scale nuclear accidents and the malevolent use of nuclear materials and response to such events shifted in the direction of radiological dispersion devices (RDDs) and similar scenarios. The developments during 2022, the change in tone expressed by some nuclear weapons states with regard to their use and shifts in perception in recent years as to how nuclear weapons may be used in scenarios short of a full strategic exchange, necessitates an appraisal of response capacities in the event of the use of a single weapon or a limited use of multiple low-yield weapons where the emergency response necessitates the deployment of measurement capacity.

The years since the end of the 1990s and the lowering of tensions between nuclear powers has seen a rapid expansion and development of measurement capacity – especially in the area of emergency response. New detector platforms mean that measurements of a type previously considered impractical can now be made in the field. There has been a quantum leap in the technological response capacities that can be brought to bear, and this has happened during a period where the use of nuclear weapons was considered relatively low in terms of probability. Changes in the European and wider security contexts have led to the realization that individual nuclear weapons may be used in a variety of contexts and that the use of low yield nuclear weapons is viewed as more likely. The problem thus arises as to response to the use of a single nuclear weapon where the countries response capacity remains largely intact or where a country is called to assist another state on whose territory a nuclear weapon has been used. From a metrological[1] standpoint, the primary parameter for measurement in such instances, as it was during the Cold War, will be dose rate but given the current preponderance of advanced, portable spectrometric equipment – it is inevitable that such capacities will be employed to ensure an effective as possible response to the situation.

In considering the probable deployment of such detector types to a situation involving a nuclear weapon, a number of issues arise. Unlike a nuclear reactor accident, the fallout produced by a nuclear detonation is comprised of a series of individual components, the relative importance of each to the overall fallout signature varying with time and distance from the detonation as well as characteristics of the detonation itself:

[1] *Metrology* is the science of instruments and their behaviour. *Meteorology* is the science of the atmosphere and its phenomena.

1. Activation of air

2. Activation of soil/ground

3. Activation of the weapon casing/components

4. Actinides from unfissioned nuclear material

5. Fission products

The relative contributions of these vary with both time and distance and the average gamma energy per decay for the five components varies to some extent.

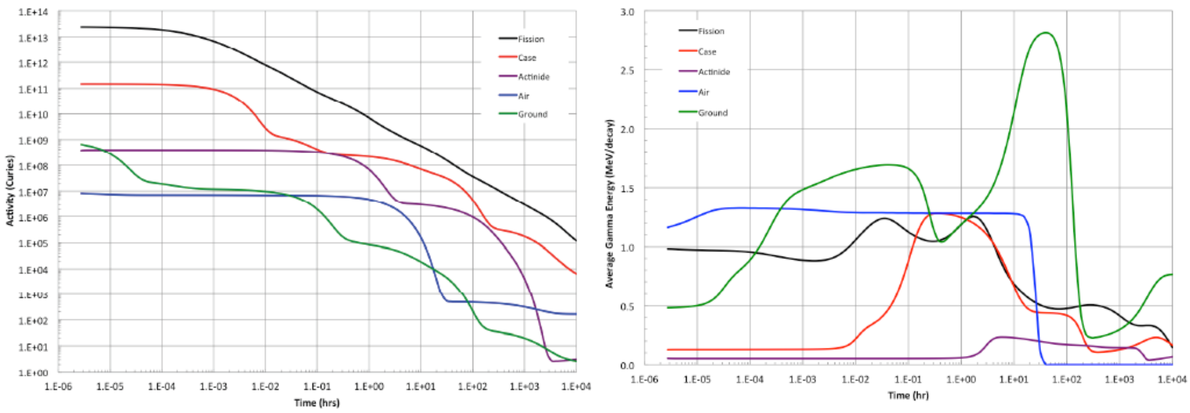

Figure 1. Radiation source term for the Hiroshima detonation (aggregate decay of ~1200 radionuclides) (left) and average total gamma energy released per decay for each source term (right). From: Spriggs G.D. and Egbert, S.D., LLNL-TR-814785, 2017)

The nature of these individual components and their relative contributions to the overall gamma signal is such that a complex gamma signature is to be expected in the hours and days following a detonation and during which response measures within the fallout field may be expected to be conducted. It is only after a period of some years that the fission fallout characteristics come to approximate those that would be typical after a conventional nuclear power plant accident.

Isotope	Half Life	Activity % @ 100 days	Activity % @ 1 year	Activity % @ 10 years
Sr-89	50 d	11%	3%	
Sr-90	29 y	0.2%	3%	**36%**
Y-91	59 d	**22%**	7%	
Zr-95	66 d	**19%**	2%	
Ru-103	40 d	**19%**	2%	
Ru-106	369 d	3%	**24%**	0.5%
Cs-137	30 y	0.3%	3%	**46%**
Ce-141	33 d	14%	0.7%	
Ce-144	284 d	8%	**34%**	0.2%
Pm-147	2.6 y	1.4%	13%	14%

Figure 2. Temporal variation in primary fission product fallout contributors expressed as activity fraction (From: Buddemeier, B.R., LLNL-TR- 754319, 2018).

In light of the above, response to an event involving a nuclear detonation, whether as part of a state's response to a detonation on its own territory or in provision of assistance to another state, is likely to present significant challenges with respect to deployment of detection/measurement resources that extend beyond simple dose rate measurements. There has never been a situation involving a weapons detonation where modern detection systems have been brought to bear. There has never been an assessment of how such detection systems may perform in such a context or how the challenges posed by the situation may be best addressed. The TEMEDET project was aimed primarily at addressing some of these challenges.

1.1 Objectives

The aims of the TEMEDET project proposal were:

1. to address potential weaknesses in technical response capacities to a potential nuclear detonation,
2. to provide learning and training opportunities for actors with responsibilities in this area,
3. to strengthen the collective Nordic capacity to respond to or provide assistance in scenarios involving the use of nuclear weapons,
4. to provide materials and methods such that contamination after such an incident can be fully contextualized within the technological detection development that have taken place over the past two decades.

1.2 Residual Radiation

The residual radiation source term (hereafter referred to as the "residual radiation") that is generated by detonation of a nuclear weapon can be conveniently divided into several categories:

- fission products generated by the detonation

- un-fissioned nuclear fuel (uranium or plutonium)
- bomb components made radioactive by neutron activation
- air made radioactive by neutron activation
- soil and other materials made radioactive through neutron activation near the detonation point

In general, the fission products generated by the detonation constitute the main portion of the residual radiation after a nuclear detonation. Usually found in the upper portion of the mushroom cloud, fission products contribute to local fallout to an extent that depends on the Scaled Height of Burst (SHOB). A commonly accepted rule is that if the stem does not reach the fireball, then the contribution of fission products to local fallout is little if any at all. As a nuclear weapon detonation does not consume all of the nuclear material present in the weapon, nuclear material that has not undergone fission will be present although its contribution to the overall residual radiation will be very low, albeit persistent given the half-lives of the isotopes involved. The detonation of a weapon results in an excess of neutrons as the number of neutrons generated exceeds the number required to instigate the subsequent fissions. These excess neutrons can generate radioactivity in the non-nuclear bomb components (steel casings, other structures), in the air and in the soil and other materials near the detonation point. Activation of the air results primarily in the generation of radioactive gasses which do not settle as fallout. For low -altitude detonations neutrons that activate the ground and other materials (such as buildings etc.) result in a contribution to the residual radioactivity that may either be (1) lifted into the fireball or (2) remain in or on the ground. The amount carried up into the fireball depends on the SHOB and the nature of the ground surface – relatively high detonations over non-frangible surfaces such as concrete or packed earth result in only small amounts of activated materials being carried up while low altitude detonations over frangible surfaces can result in most of the neutron generated activity being carried up into the fireball. The materials that remain on the ground surface and that are not carried into the fireball are typically found within 20 cm of the ground surface and remain in position. These materials contribute to dose rates on the ground due that decrease as distance from the detonation increases.

For the purposes of TEMEDET, two aspects of the residual radiation components were focused upon. The first of these was the fission products generated by the detonation and the second was the neutron activated soil generated by interaction of the nuclear flux with the ground. Activated air was not included as it is unlikely to constitute a significant part of the on-site radiological environment after some hours. Activated bomb components were not included as it was considered that they, qualitatively, fall within the category of activate soil. Unfissioned bomb material was not included as analytical challenges posed by this material has been the subject of other NKS initiatives. It should be noted that for an actual detonation, the residual radiation will most likely be composed of all four components with the amounts of each present depending on a wide range of factors. Fractionation was not considered in TEMEDET outside of any consideration of the matter included in the SILAM dispersion modelling.

1.3 Nuclear weapon source terms

Determining source terms for nuclear weapons in terms of residual radiation is a relatively complex matter given the number of variables that play a role and the complexity of calculations involved. While a number of tools and models exist for making such calculations, many are, given nuclear weapons classified nature, less than accessible. In most cases or studies, recourse is made to previous non-classified compilations of data . In this context, the work of Harry Hicks is featured most often. Hicks compiled a series of reports throughout the 1980s describing radionuclide compositions and external dose rates from weapons detonations conducted during US weapons testing programs (both with within the US and in the Pacific) in addition to a series of hypothetical 1 Mt detonations. Later work by Kraus and Foster (2013) and Spriggs and Egbert (2020) also provided valuable information as to isotope assemblages that may be expected in the residual radiation. These works vary somewhat in terms of how the lists of isotopes are constructed - some use lists based on activity generated, others base their lists on dose contribution or other parameters. For the purpose of TEMEDET, the work of Spriggs and Egbert was used as the starting point. This work was chosen due to the weapon size being at the lower end of the spectrum of weapons that may be deployed, the data being easily converted to electronic form and the various contributors to the overall residual radiation source term being considered discretely and clearly. In this context, TEMEDET focused on detonation of a 16 kT uranium device at two different heights – 600 m and 20 m.

2. Methodology

2.1 Detectors.

For the TEMEDET project, three generic detectors were considered as being representative of those typically deployed in field situations.

The first was a standard coaxial HPGe detector with a crystal height of 8 cm and a radius of 4.25 cm. Resolution for the HPGe detector was described as:

$$FWHM = \sqrt{C^2 + A^2 \times \frac{E}{E_0}}$$

where C = 2 keV, A = 0 keV and E_o= 662 keV.

The second was a generic standard 3 x 3" NaI detector in a conventional housing and with a generic PMT assembly. Resolution for the HPGe detector could be described using the same function as in [1] above where C = 0 keV, A = 52.96 keV and E_o= 662 keV. The third was a 1.5 x 1.5" LaBr detector in a conventional housing. Resolution for the LaBr detector could be described using the same function as in [1] above where C = 0 keV, A = 19.2 keV and E_o= 662 keV. Spectra for the HPGe detectors were accrued over 8192 channels covering the interval 10 keV to 4000 keV. The NaI and LaBr spectra were accrued over the same energy interval but at 2048 channels and 4096 channels respectively.

2.2 Positioning.

For the *in situ* measurements, all three detectors were mounted "face down" in two positions on an axis extending vertically upwards from the center of the active soil disk. The first was at 1 m above the soil surface to represent typical *in situ* type measurements and the second was at a position 10 m above the soil surface to represent a possible drone mounted configuration.

2.3 Soil sample measurements.

The primary focus of the TEMEDET activity was qualitative analysis. Being cognizant of the fact that some users of the materials may wish to do their own energy calibrations, spectra were provided to facilitate energy calibration for all relevant geometries. It should be noted that for the in-situ/drone type measurements these calibration spectra should not be utilized to determine efficiency curves as this was outside the scope of the project but there is nothing to prevent a user from attempting to do so.

The isotopes employed for these energy calibrations were as follows: ^{60}Co, ^{241}Am, ^{65}Zn, ^{54}Mn, ^{139}Ce, ^{113}Sn, ^{137}Cs. For the spectra intended to be representative of a soil sample, the following activities were employed for calibration: 10 kBq each of ^{60}Co, ^{241}Am, ^{65}Zn, ^{54}Mn, ^{139}Ce, ^{113}Sn, ^{137}Cs. These activities were presented to the detectors in exactly the same geometry as the simulated soil measurements. This geometry consisted of a cylindrical container of 10 cm height and 10 cm diameter. For practicality the soil density was assumed to be 1 g/cm^3.

2.4 Simulations

The simulations were performed with GEANT4 (Agostinelli et al., 2003) software. Physics lists were QGSP_BIC_HP plus PENELOPE plus Radioactive Decay. For all cases, the lower energy limit was 10 keV and the range cut-off for gamma photons was 0.01 cm at which point the remaining energy was dumped locally. Details as to geometries are provided in relevant subsequent sections.

All nuclear data for the project was taken from http://www.lnhb.fr/Laraweb/ as of June 2023. Where data was not available from that source, the following data source was used http://nucleardata.nuclear.lu.se/toi/ as of the same date. It should be noted that a significant number of isotopes present in both the low- and high-altitude materials do not have significant gamma emissions or are present at activities so low that their presence does not contribute in any significant way to the spectrum. The presence of such isotopes is due to procedural conveniences in the generation of the materials.

2.5 Conditions

No attempts were made to include true coincidence summation or aspects of the detection systems which may be of relevance in high-count rate environments such as pile up.etc. No attempts were made to include any possible effects due to radiation other than gamma. Subtle effects such as Doppler broadening etc. were not accounted for. No attempts were made to represent the presence of internal contaminants in detectors such as LaBr. Resolution for each detector was represented by a relatively crude function as described earlier that, while reflective for detectors of each type, does not capture aspects such as variation of FWHM with energy or differences in resolution between X-rays and gamma rays. As it is impractical to attempt to simulate geometries of sizes that may be representative for actual *in situ* measurements, more limited geometries as described in following sections were employed. This may result in some bias for lower or higher energies although these should be relatively minor. No attempt was made to include scattering from objects other than the ground and air as represented in the geometries. In actuality, there would in all probability be a much stronger signal from scattered photons in the lower energy portion of the spectrum. This however should not impinge on the materials generated fulfilling the overall objectives of the TEMEDET activity. It should be noted that gamma spectra features that may arise from other particles than gamma were not included.

3.0 High-altitude detonation

For the purpose of attempting to simulate the radiation signature from isotopes generated in the underlying soil due to the neutron flux arising from the detonation, the following geometry was devised: Air was represented by a half sphere of 2000 cm radius. This was mounted on a disk made of sand with a density of 1.6 g/cm^3 which was 20 cm thick and of 2000 cm radius. Under the sand disk was a corresponding half-sphere of non-active sand. For the purpose of the simulation, the activity was spread evenly throughout the entire volume of the active soil. This may not represent reality in that it can be posited that activation products would not be homogenously distributed but the homogenous approach was adopted as a simplification. Simulations were confined to three distances for the 3-day period and two for 30 and 100 days. At distances beyond 1000 m for 30 days and 100 days, the available information indicated that the signal would be very minor.

Table 1. Distances, times after detonation and simulated count times for simulated *in situ* and drone type measurements after the high-altitude detonation.

	3 days after detonation Distance from GZ m			**30 days after detonation Distance from GZ m**		**100 days after detonation Distance from GZ m**	
	200	1000	1500	200	1000	200	1000
HPGe	4 s	240 s	1500 s	150 s	2000 s	80 s	2000 s
NaI	4 s	240 s	1500 s	150 s	2000 s	80 s	2000 s
LaBr	4 s	240 s	1500 s	150 s	2000 s	80 s	2000 s

The fractional contributions of various isotopes are presented in Table 2. As can be seen, the extent to which any one isotope contributes to the overall signal varies with time however possible variations in the composition with distance were ignored for practicality. Representations of the main qualitative features for the spectra corresponding to the high-altitude detonation are provided in Figures 3, 4 and 5.

Table 2. Fractional activities for neutron activation products in soil at three time periods after the high-altitude detonation. It was assumed the fractional composition does not change with distance.

Time after detonation: 3 days		Time after detonation: 30 days		Time after detonation: 100 days	
Isotope	**Fractional activity**	**Isotope**	**Fractional activity**	**Isotope**	**Fractional activity**
Na-24	0.76290621	Pa-233	0.1782643	Fe-55	0.30461773
K-42	0.16717748	Fe-55	0.1576804	Co-60	0.16753975
Np-239	0.01310178	Sc-46	0.1022722	Sc-46	0.10698640
La-140	0.01148017	Co-60	0.0844458	Mn-54	0.09543102
Sm-153	0.00992649	Fe-59	0.0702571	Cs-134	0.07287556
Pa-233	0.00465059	Rb-86	0.0600687	Ta-182	0.05703650
Eu-152m	0.00385633	Mn-54	0.0559131	Pa-233	0.04566622
Cu-64	0.00360377	Hf-181	0.0543467	Fe-59	0.04072147
Y-90	0.00244548	Ar-39	0.0531556	Hf-181	0.02956273
Fe-55	0.00215983	Cr-51	0.0524566	Eu-152	0.02356292
Ga-72	0.00213370	Ta-182	0.0455305	Zn-65	0.01433977
Rb-86	0.00211106	Cs-134	0.0384362	Cr-51	0.01417345
Sc-46	0.00170330	Eu-152	0.0116677	Hf-175	0.00722357
Sc-47	0.00167247	Zn-65	0.0088328	Eu-154	0.00689594
As-76	0.00151676	Hf-175	0.0078766	Rb-86	0.00605534
Fe-59	0.00141312	Cs-131	0.0043062	Tb-160	0.00329341
Cr-51	0.00134588	Tb-160	0.0035008	Ag-110m	0.00087226
Co-60	0.00114680	Eu-154	0.0034369	Co-58	0.00068893
Hf-181	0.00111492	Ba-131	0.0024469	Sb-124	0.00061431
Mn-54	0.00079652	Sb-124	0.0007631	Nb-95	0.00037220
Ta-182	0.00071588	Co-58	0.0007440	Zr-95	0.00026760
Ba-135m	0.00053386	Sc-47	0.0007245	Se-75	0.00025047
Cs-134	0.00052951	Ag-110m	0.0005345	Sr-85	0.00021286
Zn-69	0.00033564	Np-239	0.0004901	Sr-89	0.00018518
Sb-122	0.00031439	Zr-95	0.0003144	Cs-131	0.00017383
Zn-69m	0.00031283	Sr-89	0.0002747	Eu-155	0.00015160
Eu-152	0.00015755	Sr-85	0.0002473	Ba-133	0.00004927
Ba-131	0.00015487	Y-90	0.0002247	Ba-131	0.00003901
Hf-175	0.00013682	Se-75	0.0001959	Sm-151	0.00003846
Zn-65	0.00012788	Nb-95	0.0001640	Kr-85	0.00002726
Ba-133m	0.00010221	Eu-155	0.0000767	Ca-41	0.00001678
Tb-160	0.00006032	Sm-153	0.0000691	Y-91	0.00001642
Eu-154	0.00004651	Xe-133	0.0000455	Cl-36	0.00001186
Br-82	0.00004595	Ca-47	0.0000440	Ag-110	0.00001186
Cs-131	0.00003403	Nb-92m	0.0000323	H-3	0.00000498
Ca-47	0.00003050	Sb-122	0.0000310	Rb-84	0.00000484
Sb-124	0.00001382	Ba-133	0.0000245	Nb-95m	0.00000306
Co-58	0.00001286	Y-91	0.0000210	Hg-203	0.00000209
Cu-67	0.00001222	La-140	0.0000201	Lu-177m	0.00000172
Xe-133	0.00001201	Sm-151	0.0000189	Pu-239	0.00000133
Hf-180m	0.00001118	Kr-85	0.0000135		
Mo-99	0.00000994	Rb-84	0.0000126		
Tc-99m	0.00000963	Cs-136	0.0000103		
Xe-133m	0.00000920	Ca-41	0.0000082		
Ag-110m	0.00000772				

Table 3. Activities present in the measured soil samples taken after a high-altitude detonation at 200 m, 1000 m and 1500 m distance at 3 days, 30 days, and 100 days after detonation. Values represented as Bq/sample.

	3 days				30 days			100 days	
	200 m	**1000 m**	**1500 m**		**200 m**	**1000 m**		**200 m**	**1000m**
Isotope	**Bq**	**Bq**	**Bq**	**Isotope**	**Bq**	**Bq**	**Isotope**	**Bq**	**Bq**
Na-24	4.38E+04	2.43E+02	4.86E+00	Pa-233	5.98E+02	4.79E+00	Fe-55	4.04E+02	1.01E+00
K-42	9.59E+03	5.33E+01	1.07E+00	Fe-55	5.29E+02	4.23E+00	Co-60	2.22E+02	5.55E-01
Np-239	7.51E+02	4.17E+00	8.35E-02	Sc-46	3.43E+02	2.75E+00	Sc-46	1.42E+02	3.54E-01
La-140	6.58E+02	3.66E+00	7.32E-02	Co-60	2.83E+02	2.27E+00	Mn-54	1.26E+02	3.16E-01
Sm-153	5.69E+02	3.16E+00	6.33E-02	Fe-59	2.36E+02	1.89E+00	Cs-134	9.66E+01	2.41E-01
Pa-233	2.67E+02	1.48E+00	2.96E-02	Rb-86	2.02E+02	1.61E+00	Ta-182	7.56E+01	1.89E-01
Eu-152m	2.21E+02	1.23E+00	2.46E-02	Mn-54	1.88E+02	1.50E+00	Pa-233	6.05E+01	1.51E-01
Cu-64	2.07E+02	1.15E+00	2.30E-02	Hf-181	1.82E+02	1.46E+00	Fe-59	5.40E+01	1.35E-01
Y-90	1.40E+02	7.79E-01	1.56E-02	Ar-39	1.78E+02	1.43E+00	Hf-181	3.92E+01	9.80E-02
Fe-55	1.24E+02	6.88E-01	1.38E-02	Cr-51	1.76E+02	1.41E+00	Eu-152	3.12E+01	7.81E-02
Ga-72	1.22E+02	6.80E-01	1.36E-02	Ta-182	1.53E+02	1.22E+00	Zn-65	1.90E+01	4.75E-02
Rb-86	1.21E+02	6.73E-01	1.35E-02	Cs-134	1.29E+02	1.03E+00	Cr-51	1.88E+01	4.70E-02
Sc-46	9.77E+01	5.43E-01	1.09E-02	Eu-152	3.92E+01	3.13E-01	Hf-175	9.57E+00	2.39E-02
Sc-47	9.59E+01	5.33E-01	1.07E-02	Zn-65	2.97E+01	2.37E-01	Eu-154	9.14E+00	2.28E-02
As-76	8.70E+01	4.83E-01	9.67E-03	Hf-175	2.64E+01	2.12E-01	Rb-86	8.03E+00	2.01E-02
Fe-59	8.11E+01	4.50E-01	9.01E-03	Cs-131	1.45E+01	1.16E-01	Tb-160	4.37E+00	1.09E-02
Cr-51	7.72E+01	4.29E-01	8.58E-03	Tb-160	1.18E+01	9.40E-02	Ag-110m	1.16E+00	2.89E-03
Co-60	6.58E+01	3.65E-01	7.31E-03	Eu-154	1.15E+01	9.23E-02	Co-58	9.13E-01	2.28E-03
Hf-181	6.39E+01	3.55E-01	7.11E-03	Ba-131	8.21E+00	6.57E-02	Sb-124	8.14E-01	2.04E-03
Mn-54	4.57E+01	2.54E-01	5.08E-03	Sb-124	2.56E+00	2.05E-02	Nb-95	4.93E-01	1.23E-03
Ta-182	4.11E+01	2.28E-01	4.56E-03	Co-58	2.50E+00	2.00E-02	Zr-95	3.55E-01	8.87E-04
Ba-135m	3.06E+01	1.70E-01	3.40E-03	Sc-47	2.43E+00	1.95E-02	Se-75	3.32E-01	8.30E-04
Cs-134	3.04E+01	1.69E-01	3.37E-03	Ag-110m	1.79E+00	1.44E-02	Sr-85	2.82E-01	7.05E-04
Zn-69	1.93E+01	1.07E-01	2.14E-03	Np-239	1.65E+00	1.32E-02	Sr-89	2.45E-01	6.14E-04
Sb-122	1.80E+01	1.00E-01	2.00E-03	Zr-95	1.06E+00	8.44E-03	Cs-131	2.30E-01	5.76E-04
Zn-69m	1.79E+01	9.97E-02	1.99E-03	Sr-89	9.22E-01	7.38E-03	Eu-155	2.01E-01	5.02E-04
Eu-152	9.04E+00	5.02E-02	1.00E-03	Sr-85	8.30E-01	6.64E-03	Ba-133	6.53E-02	1.63E-04
Ba-131	8.88E+00	4.93E-02	9.87E-04	Y-90	7.54E-01	6.03E-03	Ba-131	5.17E-02	1.29E-04
Hf-175	7.85E+00	4.36E-02	8.72E-04	Se-75	6.58E-01	5.26E-03	Sm-151	5.10E-02	1.27E-04
Zn-65	7.33E+00	4.07E-02	8.15E-04	Nb-95	5.51E-01	4.40E-03	Kr-85	3.61E-02	9.03E-05
Ba-133m	5.86E+00	3.26E-02	6.51E-04	Eu-155	2.57E-01	2.06E-03	Ca-41	2.22E-02	5.56E-05
Tb-160	3.46E+00	1.92E-02	3.84E-04	Sm-153	2.32E-01	1.85E-03	Y-91	2.18E-02	5.44E-05
Eu-154	2.67E+00	1.48E-02	2.96E-04	Xe-133	1.53E-01	1.22E-03	Cl-36	1.57E-02	3.93E-05
Br-82	2.64E+00	1.46E-02	2.93E-04	Ca-47	1.48E-01	1.18E-03	Ag-110	1.57E-02	3.93E-05
Cs-131	1.95E+00	1.08E-02	2.17E-04	Nb-92m	1.09E-01	8.68E-04	H-3	6.60E-03	1.65E-05
Ca-47	1.75E+00	9.72E-03	1.94E-04	Sb-122	1.04E-01	8.33E-04	Rb-84	6.42E-03	1.60E-05
Sb-124	7.93E-01	4.40E-03	8.81E-05	Ba-133	8.22E-02	6.57E-04	Nb-95m	4.06E-03	1.01E-05
Co-58	7.38E-01	4.10E-03	8.20E-05	Y-91	7.03E-02	5.63E-04	Hg-203	2.78E-03	6.94E-06
Cu-67	7.01E-01	3.89E-03	7.79E-05	La-140	6.73E-02	5.39E-04	Lu-177m	2.28E-03	5.69E-06
Xe-133	6.89E-01	3.83E-03	7.65E-05	Sm-151	6.33E-02	5.07E-04	Pu-239	1.76E-03	4.40E-06
Hf-180m	6.41E-01	3.56E-03	7.13E-05	Kr-85	4.54E-02	3.64E-04			
Mo-99	5.70E-01	3.17E-03	6.34E-05	Rb-84	4.24E-02	3.39E-04			
Tc-99m	5.52E-01	3.07E-03	6.14E-05	Cs-136	3.46E-02	2.77E-04			
Xe-133m	5.28E-01	2.93E-03	5.86E-05	Ca-41	2.76E-02	2.21E-04			
Ag-110m	4.43E-01	2.46E-03	4.92E-05						

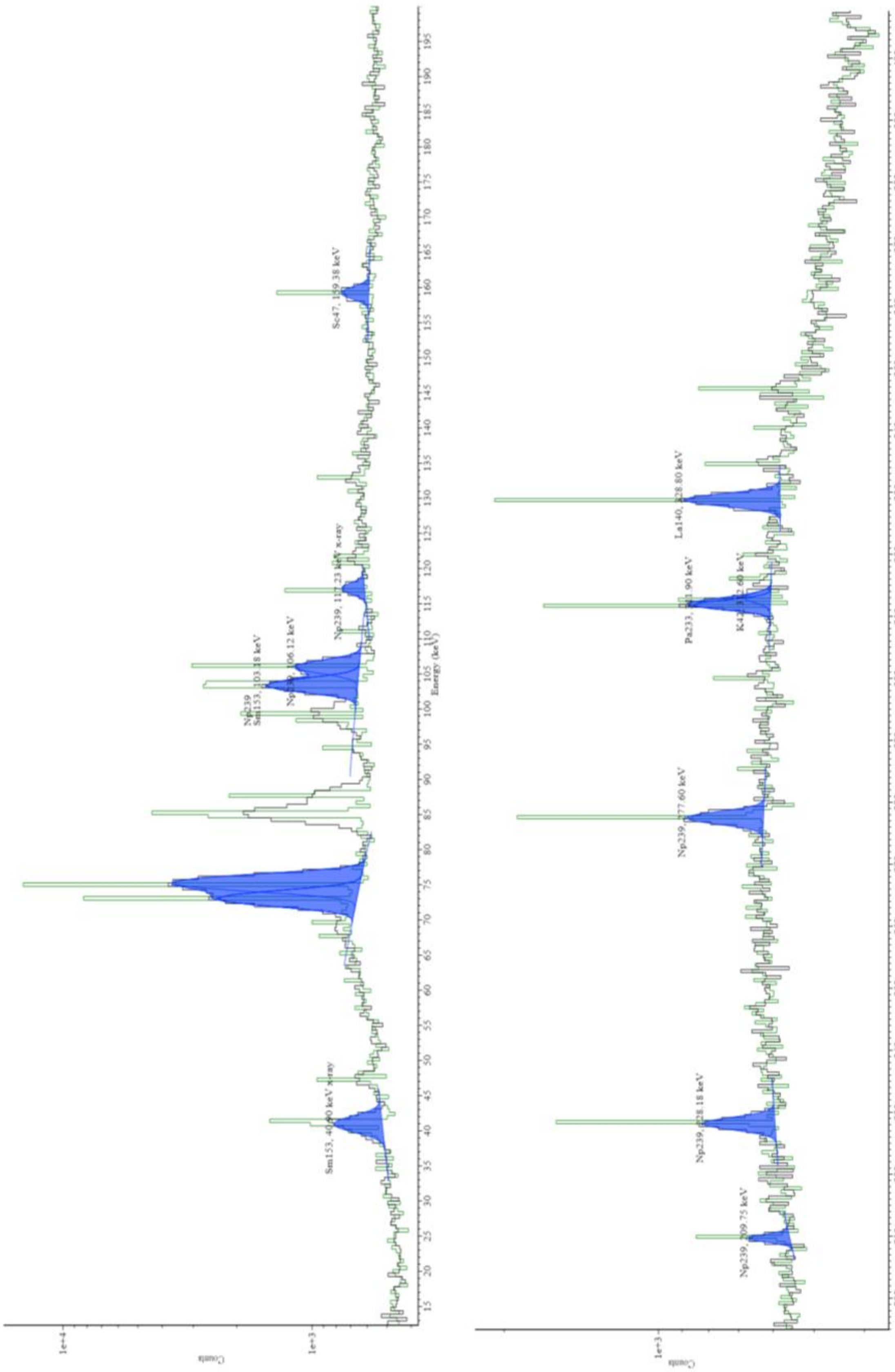

Figure 3a. Main qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 200m, 3 days after the high-altitude detonation. Green trace – no resolution. 0- 400 keV.

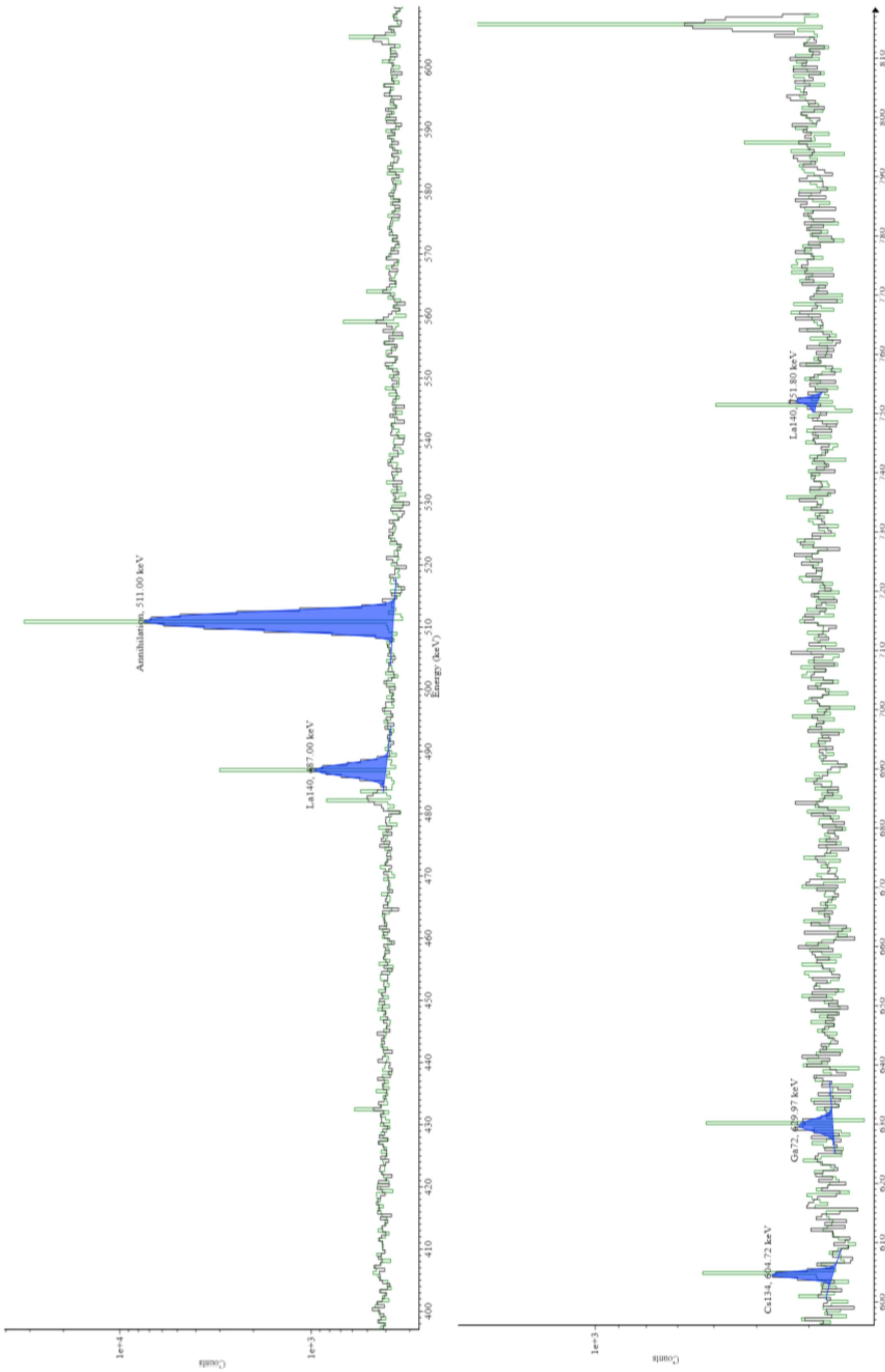

Figure 3b. Main qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 200m, 3 days after the high-altitude detonation. Green trace – no resolution. 400- 800 keV.

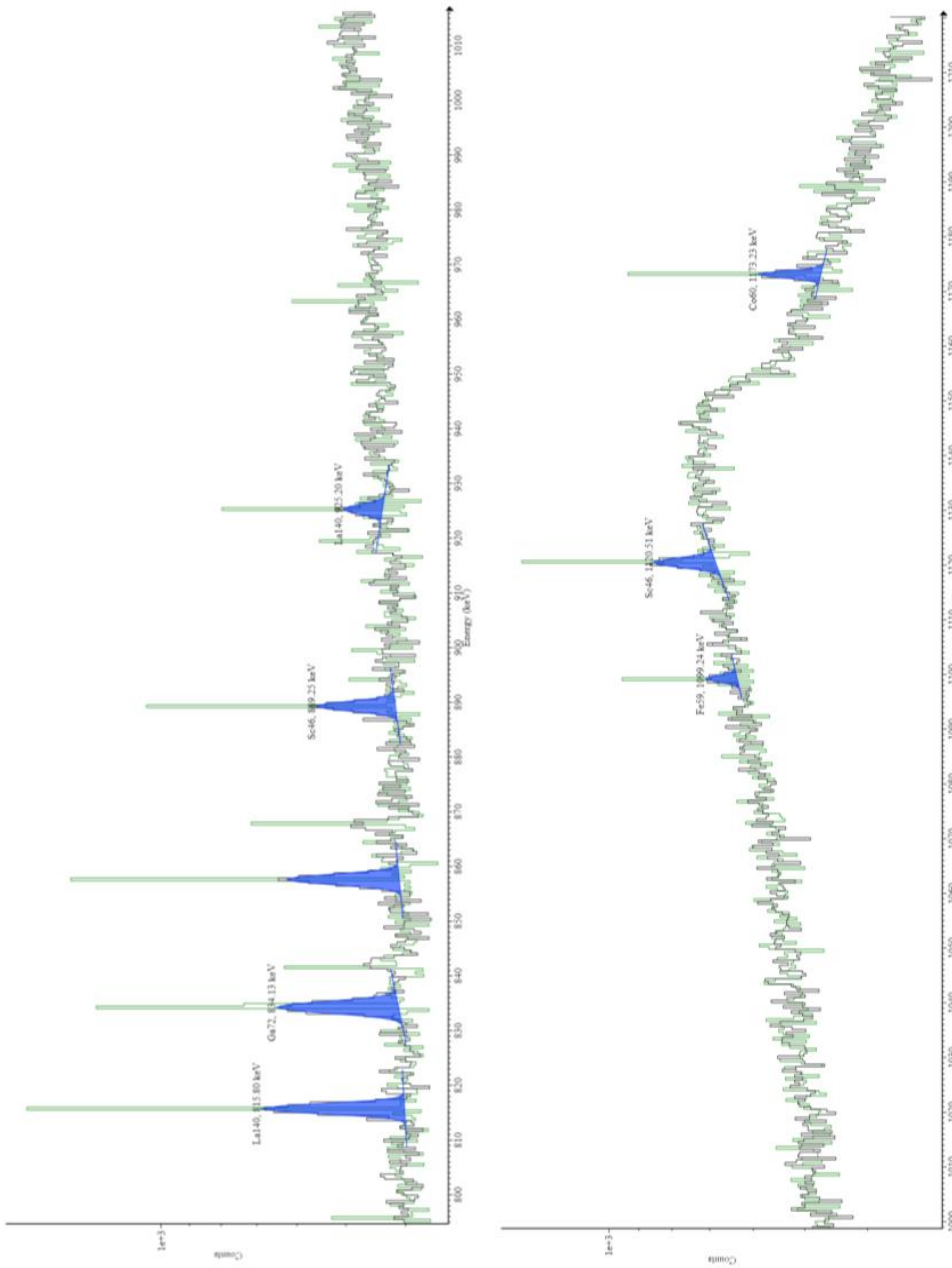

Figure 4a. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 200m, 3 days after the high-altitude detonation. Green trace – no resolution. 800- 1200 keV.

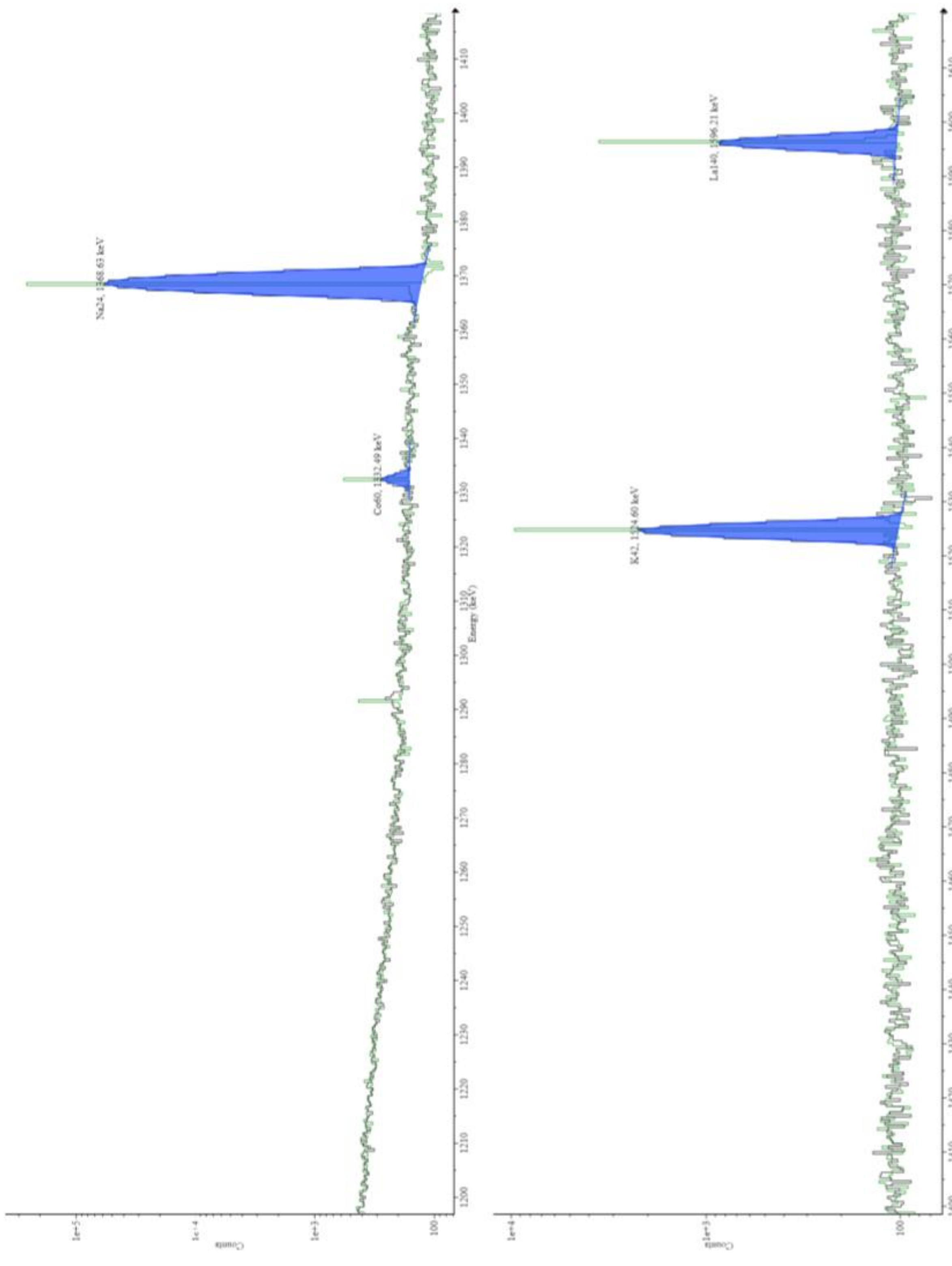

Figure 4b. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 200m, 3 days after the high-altitude detonation. Green trace – no resolution. 1200- 1600 keV.

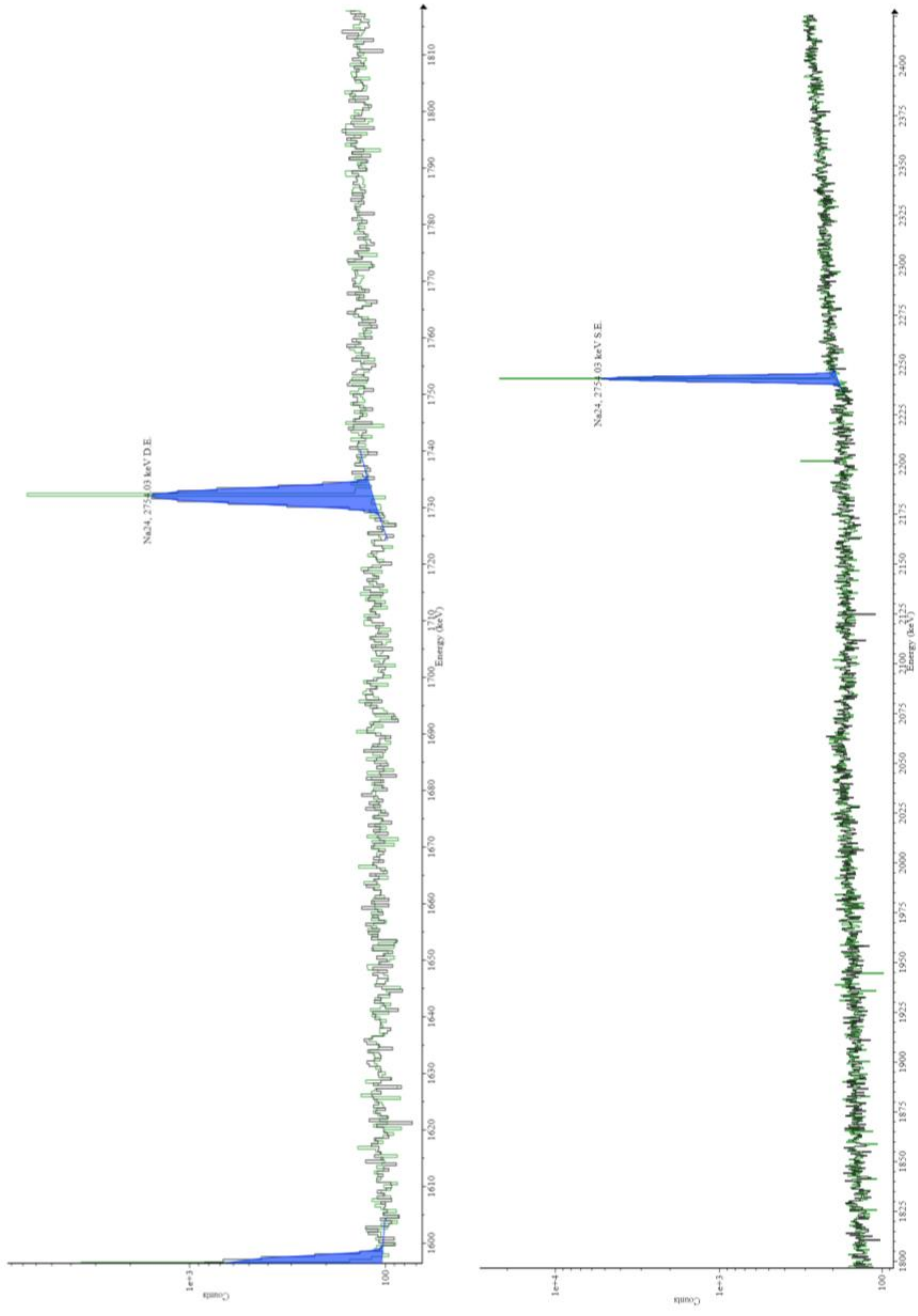

Figure 5a. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 200m, 3 days after the high-altitude detonation. Green trace – no resolution. 1600- 2400 keV.

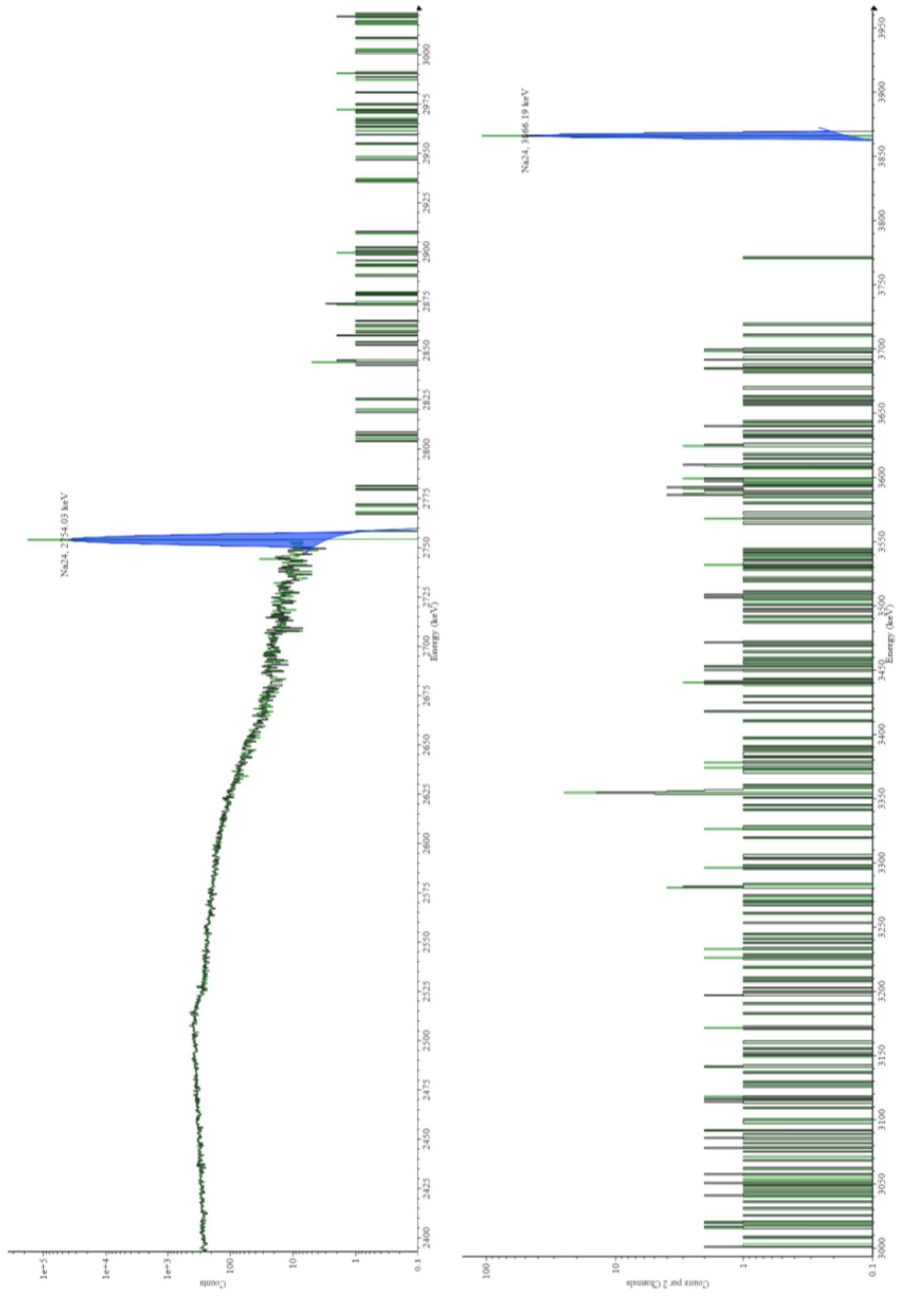

Figure 5b. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 200m, 3 days after the high-altitude detonation. Green trace – no resolution. 2400- 4000 keV.

4.0 Low-altitude detonation

For the purpose of attempting to simulate the radiation signature from fission products, the following geometry was devised: Air was represented by a half sphere of 500 cm radius. This was mounted on a disk made of sand with a density of 1.6 which is 20 cm thick and of 500 cm radius. Under the sand disk is a corresponding half sphere of non-active sand. For the purpose of the simulation, the activity was spread evenly throughout the entire volume of the active soil. This may not represent reality in that it can be posited that fission products would not be homogenously distributed but the homogenous approach was adopted as a simplification.

The dispersion and deposition were modelled using SILAM model developed by Finnish Meteorological Institute (Sofiev et al. 2015). SILAM includes a simple nuclear detonation model to setup the initial distribution of radionuclides (Harvey et al. 1992). The detonation model assumes that the mushroom cloud has been fully developed and that there is a constant concentration of radionuclides in the stem and cap. The inventory includes the radionuclides that have been assessed as being the major contributors to the radiation dose (Kraus and Foster 2014). The inventory includes only the fission products and doesn’t consider the activation of the air, soil or water. The particle distribution has different modes for air and surface bursts (Baker 1987, Harvey et al. 1992). The surface burst is assumed when the fireball caused by the burst touches the stem.

ERA5 global weather prediction data was used in the dispersion modelling (Hersbach et al. 2023). The location of the burst was selected so that the weather was relative stable during the analysis and with no significant precipitation. Dispersion and deposition were modelled for 15 kt uranium-fueled nuclear detonation at height of 50 m. The maximum concentrations of radionuclides were extracted from the deposition data at distances of 5 km, 50 km and 200 km. After the modelling, the concentrations of radionuclides were determined 3 days, 30 days, 100 days, and 365 days after the detonation.

Details as to inputs to the model in terms of activities are presented in Table 4., and information as to fractional compositions and activities in simulated soil samples in Tables 6,7 and 8. Representations of the primary qualitative features are provided in Figures 6,7 and 8.

Table 4. Inputs, expressed as Bq/kT for a uranium device, for the SILAM dispersion model.

Isotope	Bq/kT	Isotope	Bq/kT
Kr-85M	8.24E+16	Mn-54	8.45E+12
Kr-85	8.66E+09	Mn-56	7.65E+17
Kr-87	5.45E+17	Mo-99	2.52E+16
Kr-88	3.27E+17	Mo-101	5.83E+18
Xe-133M	2.15E+13	Ru-103	9.96E+14
Xe-133	3.10E+12	Ru-106	2.09E+13
Xe-135M	1.93E+17	Sb-128	1.27E+14
Xe-135	3.48E+15	Sb-129	5.37E+16
Xe-137	2.63E+19	Sb-130	1.27E+17
Xe-138	6.93E+18	Sb-131	2.10E+18
Ba-140	5.37E+15	Sn-128	1.44E+17
Ba-141	5.31E+18	Sr-89	9.88E+14
Ba-142	8.48E+18	Sr-90	5.84E+12
Ce-141	1.08E+10	Sr-91	1.63E+17
Ce-143	1.11E+13	Sr-92	5.88E+17
Ce-144	2.10E+14	Tc-104	2.04E+18
Co-58	4.54E+13	Te-131	5.32E+16
Co-58M	8.43E+15	Te-131M	2.23E+15
Cs-137	2.38E+11	Te-132	1.67E+16
Cs-138	2.60E+17	Te-133	3.39E+18
I-131	1.47E+12	Te-133M	8.46E+17
I-132	1.32E+15	Te-134	2.57E+18
I-133	5.24E+15	Y-92	2.16E+14
I-134	2.27E+17	Y-93	1.69E+17
I-135	2.62E+17	Y-94	5.37E+18
La-141	3.16E+14	Y-95	9.76E+18
La-142	5.15E+15	Zr-95	2.54E+12

Table 5. Distances, times after detonation and simulated count times for simulated in-situ and drone type measurements after the low altitude detonation.

	3 days after detonation			**30 days after detonation**			**100 days after detonation**			**1 year after detonation**		
	Distance from detonation km			**Distance from detonation km**			**Distance from detonation km**			**Distance from detonation km**		
	5	50	200	5	50	200	5	50	200	5	50	200
HPGe	1 s	10 s	100 s	1 s	5 s	100 s	1 s	5 s	100 s	1 s	5 s	100 s
NaI	1 s	10 s	100 s	1 s	5 s	100 s	1 s	5 s	100 s	1 s	5 s	100 s
LaBr	1 s	10 s	100 s	1 s	5 s	100 s	1 s	5 s	100 s	1 s	5 s	100 s

Table 6. Fractional activities for fission products in soil at four time periods after the low altitude detonation. It was assumed the fractional composition does not change with distance, *i.e.* no fractionation was considered.

Time after detonation: 3 days		**Time after detonation: 30 days**		**Time after detonation: 100 days**		**Time after detonation: 365 days**	
Isotope	**Fractional activity**	**Isotope**	**Fractional activity**	**Isotope**	**Fractional activity**	**Isotope**	**Fractional activity**
Ba-140	1.26E-02	Ba-140	4.50E-03	Ba-140	1.32E-04	Ba-140	9.10E-11
La-140	1.50E-02	La-140	5.17E-03	La-140	1.52E-04	La-140	1.05E-10
La-141	1.68E-07	Ce-141	4.82E-02	Ce-141	1.42E-02	Ce-141	5.91E-05
Ce-141	5.54E-02	Ce-143	3.88E-08	Pr-143	1.31E-03	Pr-143	2.04E-09
Ce-143	2.05E-02	Pr-143	3.59E-02	Ce-144	9.53E-04	Ce-144	5.93E-04
Pr-143	8.99E-02	Ce-144	8.64E-04	Pr-144m	1.36E-05	Pr-144m	8.48E-06
Ce-144	5.97E-04	Pr-144m	1.24E-05	Pr-144	9.53E-04	Pr-144	5.93E-04
Pr-144m	8.53E-06	Pr-144	8.64E-04	Co-58	2.66E-03	Co-58	2.36E-04
Pr-144	5.97E-04	Co-58	4.04E-03	Cs-137	1.37E-06	Cs-137	1.60E-06
Co-58	3.40E-03	Cs-137	1.05E-06	Ba-137m	1.30E-06	Ba-137m	1.52E-06
Co-58m	1.40E-05	Ba-137m	9.96E-07	I-131	8.55E-06	Mn-54	1.43E-05
Cs-137	6.82E-07	I-131	2.73E-03	Mn-54	2.17E-05	Tc-99	2.61E-01
Ba-137m	6.45E-07	I-132	1.10E-04	Tc-99	2.20E-01	Ru-103	1.09E-05
I-131	1.77E-02	Mn-54	1.93E-05	Ru-103	9.79E-04	Rh-103m	1.09E-05
I-132	2.22E-02	Mo-99	4.82E-05	Rh-103m	9.78E-04	Ru-106	7.23E-05
I-133	1.13E-02	Tc-99m	4.70E-05	Ru-106	1.00E-04	Rh-106	7.23E-05
I-135	5.65E-05	Tc-99	1.68E-01	Rh-106	1.00E-04	Te-128	1.33E-03
Mn-54	1.33E-05	Ru-103	2.57E-03	Te-128	1.12E-03	Te-129m	1.19E-05
Mn-56	3.78E-11	Rh-103m	2.56E-03	Te-129m	2.37E-03	Te-129	7.49E-06
Mo-99	2.81E-02	Ru-106	8.74E-05	Te-129	1.49E-03	I-129	4.52E-02
Tc-99m	2.74E-02	Rh-106	8.74E-05	I-129	3.80E-02	Sr-89	4.52E-05
Tc-99	1.09E-01	Te-128	8.56E-04	Sr-89	1.44E-03	Sr-90	3.93E-05
Ru-103	2.67E-03	Te-129m	7.68E-03	Sr-90	3.36E-05	Y-90	3.93E-05
Rh-103m	2.67E-03	Te-129	4.84E-03	Y-90	3.37E-05	Y-91	6.77E-03
Ru-106	5.95E-05	I-129	2.91E-02	Y-91	1.32E-01	Zr-93	3.42E-01
Rh-106	5.95E-05	Te-130	3.31E-09	Zr-93	2.88E-01	Nb-93m	3.42E-01
Sb-128	2.18E-06	Te-131m	3.94E-09	Nb-93m	2.88E-01	Zr-95	1.43E-04
Te-128	5.54E-04	Te-131	1.03E-09	Zr-95	2.13E-03	Nb-95m	1.22E-06
Sb-129	1.07E-07	Sr-89	2.87E-03	Nb-95m	1.81E-05	Nb-95	3.11E-04
Te-129m	8.67E-03	Sr-90	2.58E-05	Nb-95	3.76E-03		
Te-129	5.46E-03	Y-90	2.58E-05				
I-129	1.88E-02	Y-91	2.30E-01				
Te-131m	1.88E-03	Te-132	1.06E-04				
Te-131	4.93E-04	Zr-93	2.20E-01				
Sr-89	2.69E-03	Nb-93m	2.20E-01				
Sr-90	1.67E-05	Zr-95	3.47E-03				
Y-90	1.81E-05	Nb-95m	4.44E-05				
Sr-91	6.69E-04	Nb-95	4.79E-03				
Y-91m	4.21E-04						
Y-91	2.05E-01						
Y-92	1.27E-07						
Te-132	2.15E-02						
Y-93	1.02E-03						
Zr-93	1.42E-01						
Nb-93m	1.42E-01						
Zr-95	3.01E-03						
Nb-95m	1.76E-03						
Nb-95	3.28E-03						
Zr-97	6.97E-03						
Nb-97m	6.60E-03						
Nb-97	7.51E-03						

Table 7. Activities present in the measured soil samples taken after a low-altitude detonation at 5 km, 50 km and 200 km distance at 3 days and 30 days after detonation.

	3 days				30 days		
Isotope	5 km Bq	50 km Bq	200 km Bq	Isotope	5 km Bq	50 km Bq	200 km Bq
Ba-140	1.55E+04	8.43E+02	3.63E+01	Ba-140	3592.765	195.1941	8.398494
La-140	1.85E+04	1.01E+03	4.32E+01	La-140	4134.553	224.6293	9.664983
La-141	2.07E-01	1.13E-02	4.85E-04	Ce-141	38506.39	2092.043	90.01296
Ce-141	6.85E+04	3.72E+03	1.60E+02	Ce-143	0.031042	0.001687	7.26E-05
Ce-143	2.53E+04	1.37E+03	5.91E+01	Pr-143	28665.87	1557.503	67.01228
Pr-143	1.11E+05	6.04E+03	2.60E+02	Ce-144	690.1883	37.49775	1.613389
Ce-144	7.37E+02	4.00E+01	1.72E+00	Pr-144m	9.869866	0.536227	0.023072
Pr-144m	1.05E+01	5.73E-01	2.46E-02	Pr-144	690.2117	37.49902	1.613444
Pr-144	7.37E+02	4.01E+01	1.72E+00	Co-58	3227.863	175.369	7.545488
Co-58	4.20E+03	2.28E+02	9.83E+00	Cs-137	0.84148	0.045717	0.001968
Co-58m	1.72E+01	9.37E-01	4.03E-02	Ba-137m	0.79604	0.043248	0.001862
Cs-137	8.43E-01	4.58E-02	1.97E-03	I-131	2181.529	118.522	5.09957
Ba-137m	7.97E-01	4.33E-02	1.87E-03	I-132	87.67774	4.763514	0.204956
I-131	2.19E+04	1.19E+03	5.12E+01	Mn-54	15.46192	0.84004	0.036144
I-132	2.74E+04	1.49E+03	6.40E+01	Mo-99	38.5091	2.092191	0.090019
I-133	1.39E+04	7.57E+02	3.26E+01	Tc-99m	37.54234	2.039667	0.087759
I-135	6.98E+01	3.79E+00	1.63E-01	Tc-99	134335	7301.96	314.0948
Mn-54	1.64E+01	8.92E-01	3.84E-02	Ru-103	2052.637	111.5193	4.798266
Mn-56	4.66E-05	2.53E-06	1.09E-07	Rh-103m	2049.268	111.3363	4.790391
Mo-99	3.47E+04	1.88E+03	8.11E+01	Ru-106	69.87488	3.796289	0.16334
Tc-99m	3.38E+04	1.84E+03	7.91E+01	Rh-106	69.87494	3.796293	0.16334
Tc-99	1.34E+05	7.30E+03	3.14E+02	Te-128	684.3064	37.68391	1.607965
Ru-103	3.30E+03	1.79E+02	7.72E+00	Te-129m	6134.507	333.344	14.34121
Rh-103m	3.30E+03	1.79E+02	7.71E+00	Te-129	3864.163	209.9754	9.033613
Ru-106	7.35E+01	3.99E+00	1.72E-01	I-129	23241.4	1262.881	54.33287
Rh-106	7.35E+01	3.99E+00	1.72E-01	Te-130	0.002645	0.000144	6.18E-06
Sb-128	2.69E+00	1.48E-01	6.32E-03	Te-131m	0.003147	0.000171	7.36E-06
Te-128	6.84E+02	3.77E+01	1.61E+00	Te-131	0.000825	4.48E-05	1.93E-06
Sb-129	1.32E-01	7.19E-03	3.09E-04	Sr-89	2295.839	124.7324	5.366779
Te-129m	1.07E+04	5.82E+02	2.50E+01	Sr-90	20.64572	1.121684	0.048262
Te-129	6.74E+03	3.67E+02	1.58E+01	Y-90	20.65252	1.122053	0.048278
I-129	2.32E+04	1.26E+03	5.43E+01	Y-91	184203.6	10008.34	430.6074
Te-131m	2.32E+03	1.26E+02	5.43E+00	Te-132	85.09898	4.623411	0.198928
Te-131	6.10E+02	3.31E+01	1.43E+00	Zr-93	175759.6	9548.988	410.8578
Sr-89	3.32E+03	1.81E+02	7.77E+00	Nb-93m	175759.6	9548.988	410.8578
Sr-90	2.07E+01	1.12E+00	4.83E-02	Zr-95	2775.251	150.7788	6.487461
Y-90	2.24E+01	1.22E+00	5.23E-02	Nb-95m	35.50948	1.929224	0.083007
Sr-91	8.27E+02	4.49E+01	1.93E+00	Nb-95	3826.761	207.91	8.945557
Y-91m	5.20E+02	2.82E+01	1.22E+00				
Y-91	2.54E+05	1.38E+04	5.93E+02				
Y-92	1.57E-01	8.54E-03	3.67E-04				
Te-132	2.66E+04	1.44E+03	6.21E+01				
Y-93	1.26E+03	6.82E+01	2.94E+00				
Zr-93	1.76E+05	9.55E+03	4.11E+02				
Nb-93m	1.76E+05	9.55E+03	4.11E+02				
Zr-95	3.72E+03	2.02E+02	8.69E+00				
Nb-95m	2.17E+03	1.18E+02	5.08E+00				
Nb-95	4.05E+03	2.20E+02	9.47E+00				
Zr-97	8.61E+03	4.68E+02	2.01E+01				
Nb-97m	8.16E+03	4.43E+02	1.91E+01				
Nb-97	9.27E+03	5.04E+02	2.17E+01				

Table 8. Activities present in the measured soil samples taken after a low-altitude detonation at 5 km, 50 km and 200 km distance at 100 days and 365 days after detonation.

	100 days				365 days		
	5 km	50 km	200 km		5 km	50 km	200 km
Isotope	**Bq**	**Bq**	**Bq**	**Isotope**	**Bq**	**Bq**	**Bq**
Ba-140	8.09E+01	4.39E+00	1.89E-01	Ba-140	4.68E-05	2.54E-06	1.09E-07
La-140	9.31E+01	5.06E+00	2.18E-01	La-140	5.38E-05	2.93E-06	1.26E-07
Ce-141	8.65E+03	4.70E+02	2.02E+01	Ce-141	3.04E+01	1.65E+00	7.10E-02
Pr-143	8.01E+02	4.35E+01	1.87E+00	Pr-143	1.05E-03	5.69E-05	2.45E-06
Ce-144	5.82E+02	3.16E+01	1.36E+00	Ce-144	3.05E+02	1.66E+01	7.13E-01
Pr-144m	8.32E+00	4.52E-01	1.95E-02	Pr-144m	4.36E+00	2.37E-01	1.02E-02
Pr-144	5.82E+02	3.16E+01	1.36E+00	Pr-144	3.05E+02	1.66E+01	7.13E-01
Co-58	1.63E+03	8.84E+01	3.80E+00	Co-58	1.21E+02	6.60E+00	2.84E-01
Cs-137	8.38E-01	4.55E-02	1.96E-03	Cs-137	8.24E-01	4.48E-02	1.93E-03
Ba-137m	7.93E-01	4.31E-02	1.85E-03	Ba-137m	7.79E-01	4.23E-02	1.82E-03
I-131	5.22E+00	2.84E-01	1.22E-02	Mn-54	7.36E+00	4.00E-01	1.72E-02
Mn-54	1.32E+01	7.19E-01	3.09E-02	Tc-99	1.34E+05	7.30E+03	3.14E+02
Tc-99	1.34E+05	7.30E+03	3.14E+02	Ru-103	5.62E+00	3.05E-01	1.31E-02
Ru-103	5.98E+02	3.25E+01	1.40E+00	Rh-103m	5.61E+00	3.05E-01	1.31E-02
Rh-103m	5.97E+02	3.24E+01	1.40E+00	Ru-106	3.72E+01	2.02E+00	8.69E-02
Ru-106	6.12E+01	3.33E+00	1.43E-01	Rh-106	3.72E+01	2.02E+00	8.69E-02
Rh-106	6.12E+01	3.33E+00	1.43E-01	Te-128	6.84E+02	3.77E+01	1.61E+00
Te-128	6.84E+02	3.77E+01	1.61E+00	Te-129m	6.12E+00	3.32E-01	1.43E-02
Te-129m	1.45E+03	7.87E+01	3.38E+00	Te-129	3.85E+00	2.09E-01	9.01E-03
Te-129	9.12E+02	4.95E+01	2.13E+00	I-129	2.32E+04	1.26E+03	5.43E+01
I-129	2.32E+04	1.26E+03	5.43E+01	Sr-89	2.32E+01	1.26E+00	5.43E-02
Sr-89	8.79E+02	4.78E+01	2.06E+00	Sr-90	2.02E+01	1.10E+00	4.72E-02
Sr-90	2.05E+01	1.12E+00	4.80E-02	Y-90	2.02E+01	1.10E+00	4.72E-02
Y-90	2.06E+01	1.12E+00	4.81E-02	Y-91	3.48E+03	1.89E+02	8.14E+00
Y-91	8.04E+04	4.37E+03	1.88E+02	Zr-93	1.76E+05	9.55E+03	4.11E+02
Zr-93	1.76E+05	9.55E+03	4.11E+02	Nb-93m	1.76E+05	9.55E+03	4.11E+02
Nb-93m	1.76E+05	9.55E+03	4.11E+02	Zr-95	7.38E+01	4.01E+00	1.73E-01
Zr-95	1.30E+03	7.07E+01	3.04E+00	Nb-95m	6.26E-01	3.40E-02	1.46E-03
Nb-95m	1.10E+01	5.99E-01	2.58E-02	Nb-95	1.60E+02	8.70E+00	3.74E-01
Nb-95	2.30E+03	1.25E+02	5.37E+00				

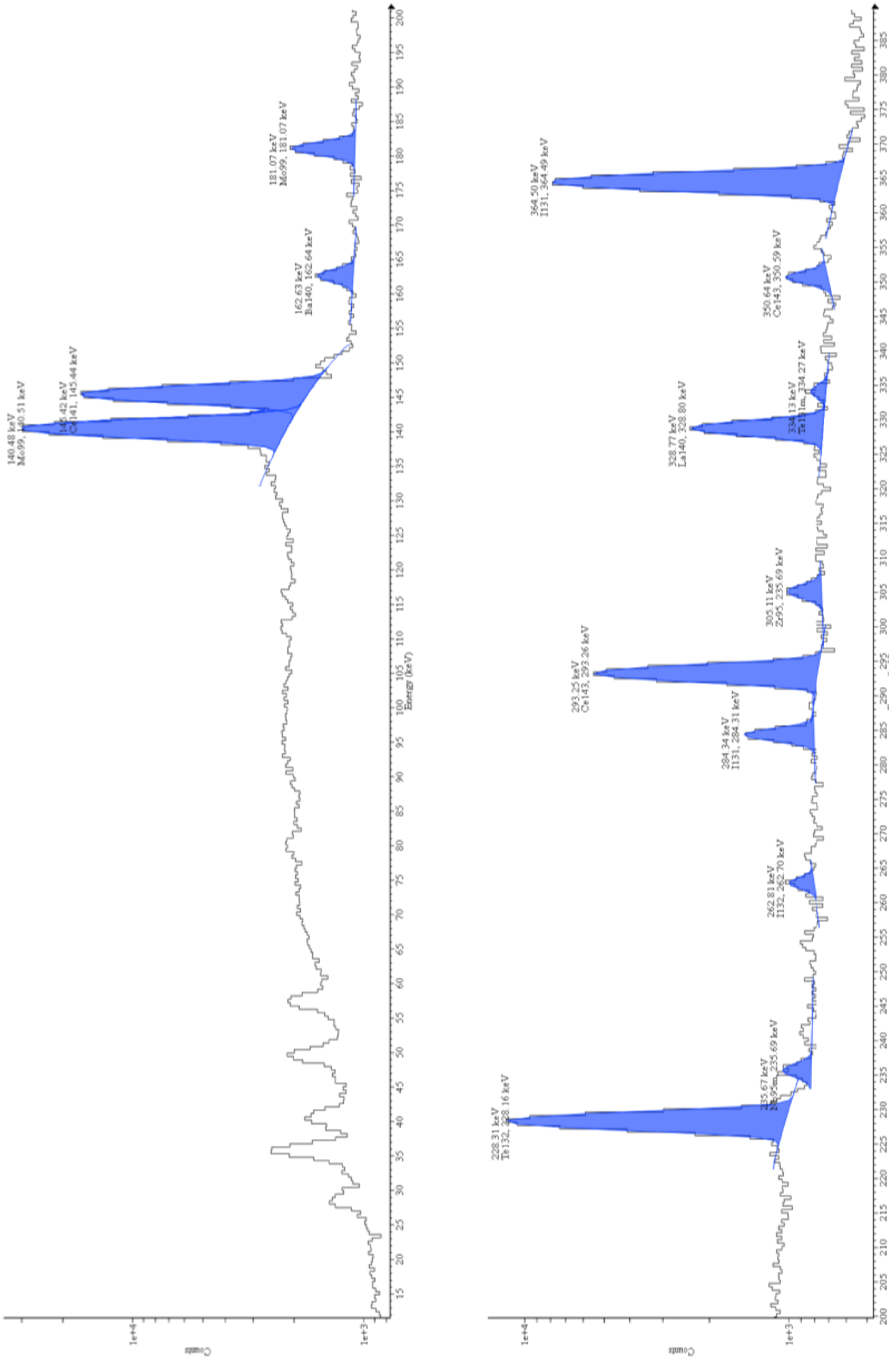

Figure 6a. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 5 km, 3 days after detonation. 0-400 keV.

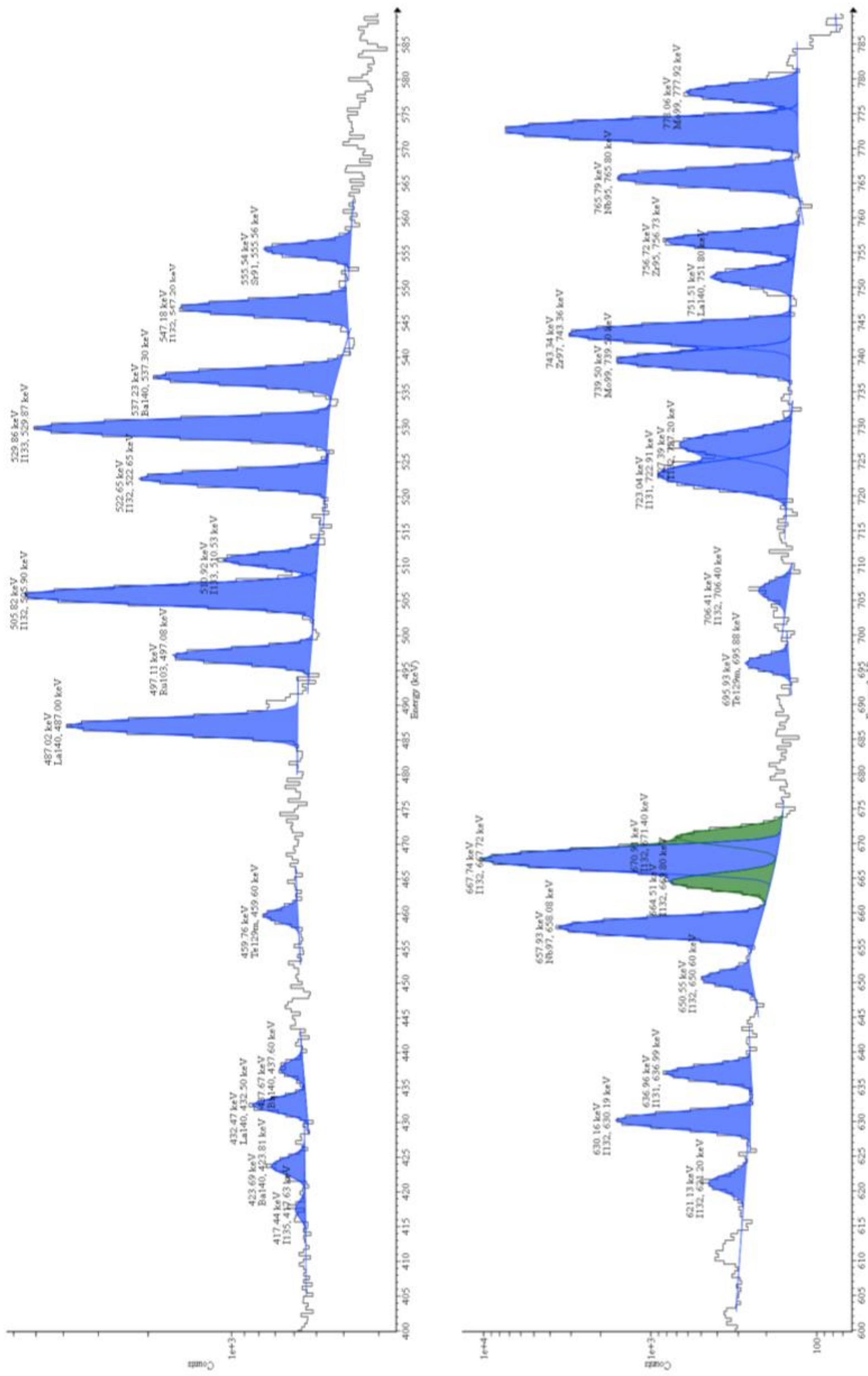

Figure 6b. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 5 km, 3 days after detonation. 400 – 800 keV.

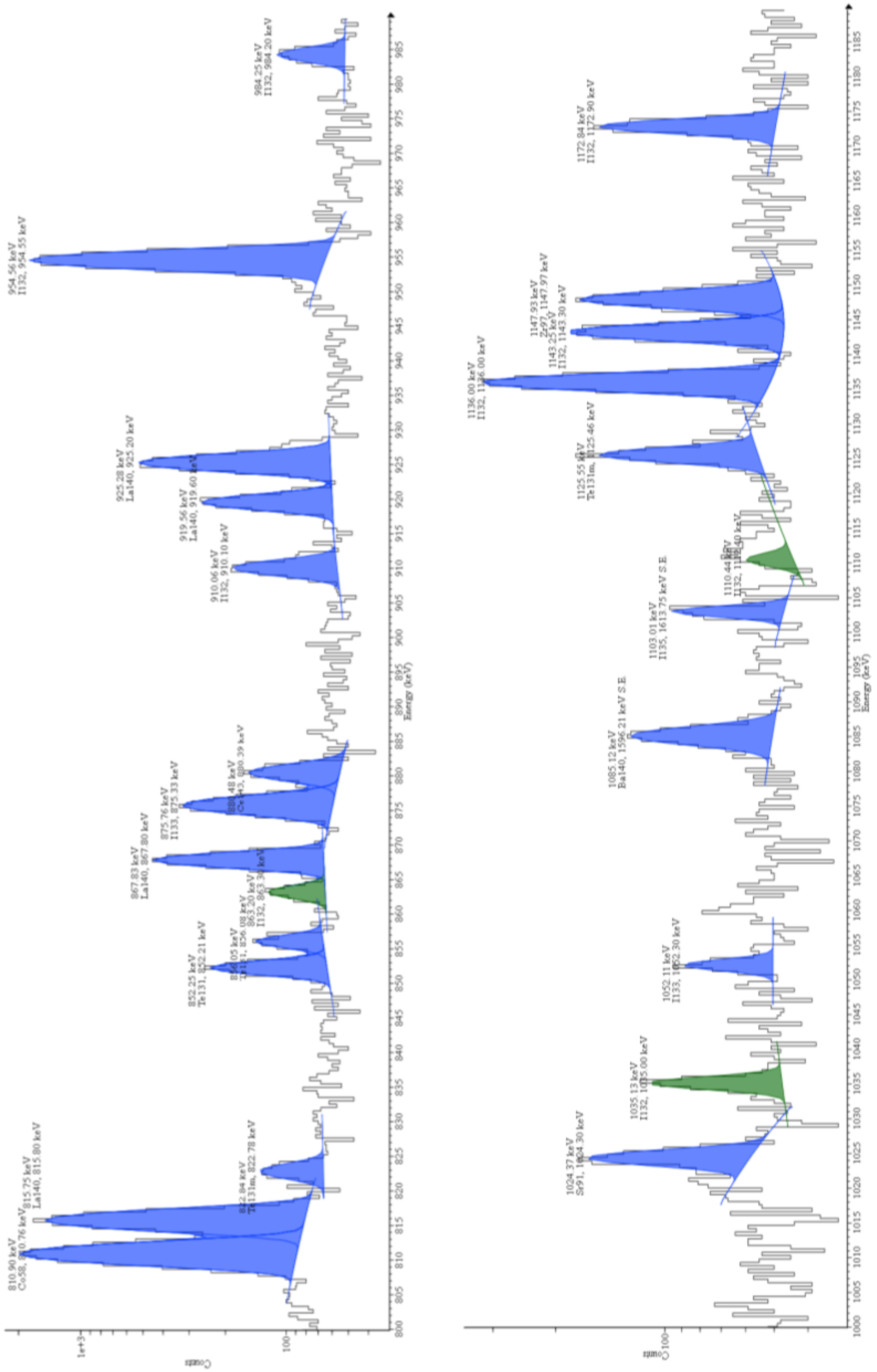

Figure 7a. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 5 km, 3 days after detonation. 800 – 1200 keV.

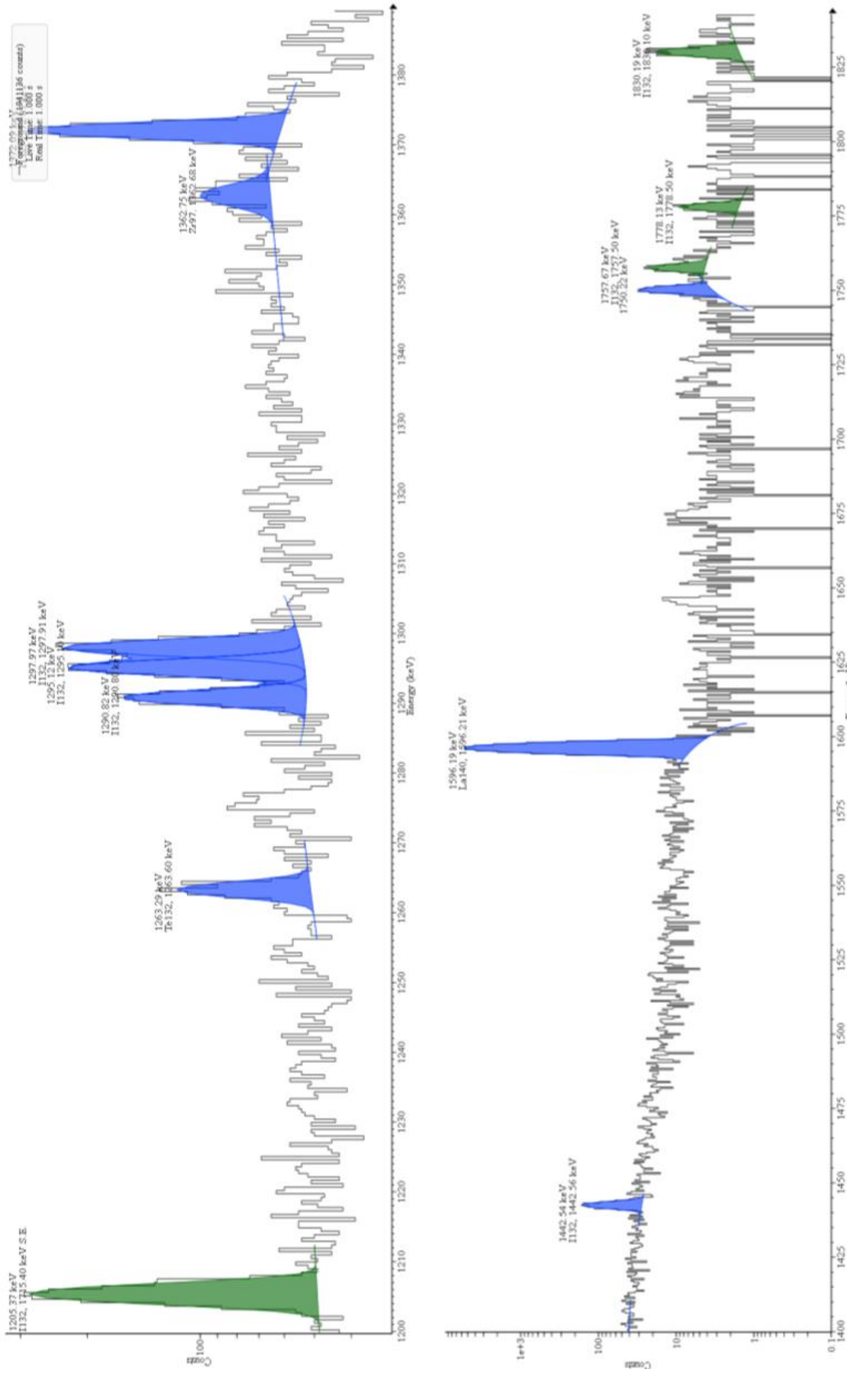

Figure 7b. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 5 km, 3 days after detonation. 1200 – 1800 keV.

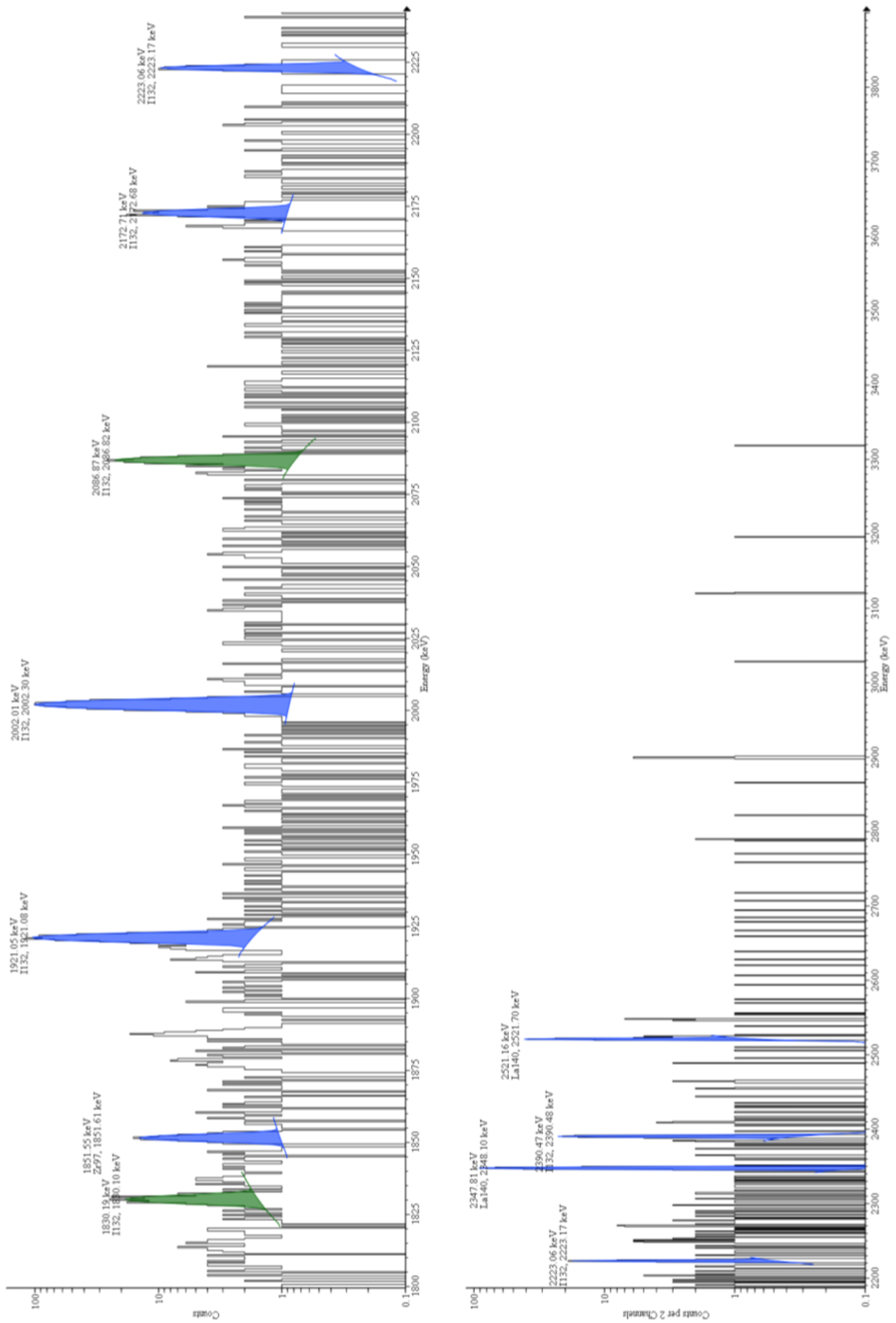

Figure 8. Qualitative features of the gamma ray spectrum for the HPGe detector at a distance of 5 km, 3 days after detonation. 1800 – 400 keV.

5. Ancilliary data

For each detector a background was simulated. This background was comprised of a typical surficial flux in terms of photons per unit area per second from natural radionuclides and is detailed in Figure 9. Time normalized background contributions were added to all spectra with normal resolution for both high and low altitude data sets.

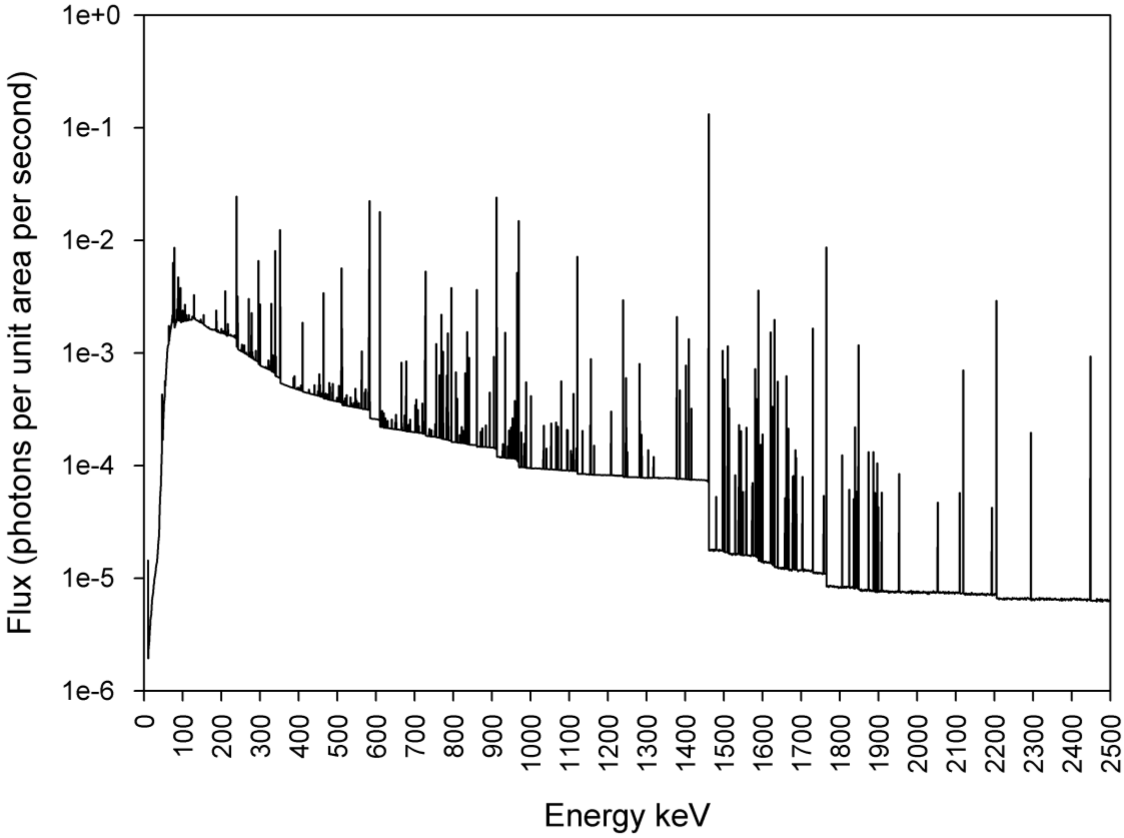

Figure 9. Background photon flux as added to the spectra.

6. Spectra formats

Two different spectrum types were produced to ensure maximum utility to anyone using the spectra. Each spectrum was generated using both normal resolution typical for the detector type and with no resolution function applied. This would facilitate identification of peaks comprising multiplets etc. Background was added to the spectra with normal resolution. The background signal was time normalized and then added to the spectrum. Spectra were generated in ORTEC .chn format and Canberra .cnf format. No other formats were provided as it was felt that these two were sufficient to cover the majority of potential users and the .chn format is easily converted to other formats. It should be noted that the proprietary .cnf format is a relatively complex file format containing a variety of information in addition to the actual spectra data and no assurances can be made as to how the format will behave for any particular version of the software for which it is primarily intended. Users should therefore exercise caution with spectra in this format.

7. Discussion

The primary focus of the TEMEDET activity was the generation of materials that would facilitate users having access to gamma spectra of the type that may be expected in the aftermath of a nuclear weapons detonation. As the number of variables that underly what would be produced and how much are somewhat large, obvious generalizations had to be applied. The first of these is obviously the division of the data sets into high and low altitude with respect to the isotopic signature. Such a division is obviously arbitrary to some extent and in reality, there would most probably be a mixing of the signatures with spectra featuring contributions from fissions fallout isotopes and neutron activation products. For the purposes of TEMEDET however, the division was of utility and it was felt that users could simply add spectra together in various proportions to represent any combination of the two main residual radiation components they desired. With respect to what isotopes are featured in the spectra, there are also limitations. For the neutron activation products which constitute the primary expression of the residual radiation for a high-altitude detonation, the source term used was a relatively well known one developed for the Hiroshima detonation. In reality, and for a modern city, the isotopes present and the relative proportions of them in the signal is likely to vary substantially from that of the TEMEDET spectra. This is largely due to the differences in composition between the constituents of modern building materials and those represented in the Hiroshima source term. Nonetheless, it was felt that those isotopes present in the TEMEDET spectra were to a large extent representative of those that may be expected. For the low altitude data, composed of fission product isotopes, the selection of isotopes was based on the well-known data sets in relation to the main dose contributors. It is possible that in actuality there would be other isotopes present that may have significant gamma lines that are not represented in the data sets derived based on dose contributions. It should be noted that the dispersion model was employed simply to provide a data set reflecting distance and time impacts on the isotope assemblage. As such, the data sets should not be assumed as being representative of any particular type of detonation or weather pattern or to have included any other factor that may have some role to play in fission product fallout.

As for any synthetic spectrum of the type featured in TEMEDET, there are technical limitations in relation to how well the spectra represent actual data. Of most relevance in this regard are aspects related to the nature of the spectra themselves such as varying peak widths with energy and aspects in relation to quantitative determinations such as coincidence summation. It is noted however that for soil samples, it would be most likely to count high activity samples at a distance from the detector to avoid pile-up and this would ameliorate the coincidence issue. For the former, provision of the energy calibration spectra was intended to ameliorate any problems arising due to assumptions being made by a user as to how a typical HPGE or LaBr spectrum would appear. For aspects of quantitative relevance, the aim of TEMEDET was not quantitative and associated documentation makes this clear to the user. Given that any quantitative measurement made in the aftermath of a detonation would probably be subject to less stringent requirements and technical observations made earlier in the report, it was felt that not including features such as coincidence summation would be of little impact.

In terms of what challenges are likely to be faced by an analyst, these are obviously dependent on the skill and the experience of those working with the spectra. For the high-altitude spectra, the main challenge is likely to be in relation to a lack of familiarity with the isotopes represented for many analysts. The high-altitude spectra were not overly complex due to the relative dominance of the spectra by a limited set of isotopes. For the low altitude detonation, the spectra are relatively complex in terms of the numbers of peaks but none of the isotopes should be unknown to the vast majority of analysts.

What may represent a greater challenge for any analyst working with gamma spectra in the context of a scenario such as that which TEMEDET is focused upon, are aspects that were not included in TEMEDET and may be difficult to incorporate in simulations of this type. For the high-altitude scenario, the isotopes present may well be distributed throughout a three-dimensional environment due to activation of building materials and the nature of surfaces in a modern urban environment. The spectra will also be heavily impacted by scattered radiation from surrounding objects which may have significant effects on the spectra themselves, primarily in the lower energy region. In addition, high count rates such as those that would be present for at least some of the distances and times represented in TEMEDET would have impacts on the spectra unless instrumental precautions were taken to mitigate the problem.

7.0 References

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Appendix 1

Table A1. List of isotopes, energies and intensities as inputs to the low-altitude simulations.

Isotope	Energy keV	Intensity	Isotope	Energy keV	Intensity
Te-128	11.00	1.04E-05	Te-131m	744.20	1.70E-02
Ba-140	13.88	1.16E-02	Sr-91	749.80	2.37E-01
Sr-91	14.88	1.43E-04	Rh-106	751.26	1.21E-05
Y-91m	14.88	8.70E-03	La-140	751.65	4.40E-02
Sr-91	14.96	2.76E-04	Sb-128	754.00	1.00E+00
Y-91m	14.96	1.68E-02	Zr-95	756.73	5.44E-01
Nb-95m	16.52	1.22E-01	Sb-129	761.12	4.32E-02
Zr-95	16.52	1.67E-03	Sr-91	761.40	5.76E-03
Nb-95m	16.61	2.34E-01	Mo-99	761.77	2.30E-05
Zr-95	16.62	3.19E-03	Nb-95	765.80	9.98E-01
Sr-91	16.78	6.90E-05	Ce-143	767.70	3.20E-05
Y-91m	16.78	4.20E-03	I-133	768.36	4.57E-03
Sr-91	17.03	9.50E-06	Te-129	768.77	4.20E-05
Y-91m	17.03	5.80E-04	Te-129m	768.77	2.90E-05
Nb-95m	17.37	2.31E-04	Sb-129	768.98	3.21E-03
Nb-95	17.37	2.86E-04	I-132	771.70	2.00E-04
Nb-95	17.48	5.46E-04	I-132	772.60	7.56E-01
Nb-95m	17.48	4.39E-04	Sb-129	773.37	2.83E-02
Mo-99	18.25	3.19E-02	Te-131m	773.67	3.95E-01
Mo-99	18.37	6.06E-02	Sb-128	773.70	1.50E-02
Nb-95m	18.61	1.83E-02	Te-131m	774.10	6.00E-03
Nb-95m	18.62	3.55E-02	Zr-97	775.00	1.90E-03
Zr-95	18.67	8.20E-04	Mo-99	777.92	4.28E-02
Nb-95m	18.95	8.05E-03	I-132	780.00	1.18E-02
Zr-95	18.97	1.24E-04	Te-131m	782.45	7.90E-02
Nb-95m	19.59	3.52E-05	I-132	784.40	3.80E-03
Nb-95m	19.61	6.81E-05	I-135	785.48	1.52E-03
Nb-95	19.66	1.43E-04	Nb-95m	786.19	1.34E-04
Nb-95m	19.97	1.49E-05	Sb-129	786.36	1.07E-02
Nb-95	19.98	2.21E-05	Sb-129	787.16	1.74E-02
Rh-103m	20.07	2.17E-02	Ce-143	787.40	2.60E-05
Ru-103	20.07	2.52E-02	Sb-128	787.60	7.10E-02
Ru-103	20.22	4.77E-02	Sb-129	788.70	3.40E-02
Rh-103m	20.22	4.10E-02	I-133	789.69	5.00E-04
Mo-99	20.67	1.61E-02	Ce-143	791.07	1.33E-04
Mo-99	21.02	2.54E-03	I-132	791.20	9.90E-04
Rh-103m	22.70	3.40E-03	Sr-91	793.60	6.40E-04
Rh-103m	22.72	6.60E-03	Te-131m	793.75	1.41E-01
Ru-103	22.81	1.29E-02	I-135	795.50	2.30E-04
Rh-103m	23.17	1.59E-03	Zr-97	795.90	1.23E-03
Ru-103	23.20	2.20E-03	Sb-129	796.21	4.00E-04
La-140	24.60	6.89E-06	I-135	797.71	1.70E-03
Co-58m	24.88	3.50E-04	Te-129	802.10	1.92E-03
Te-129m	27.20	8.00E-02	Sb-128	802.70	1.20E-02
Te-131m	27.20	3.30E-02	Zr-97	804.52	6.60E-03
Te-129m	27.47	1.50E-01	Te-129	804.60	2.20E-04
Te-131m	27.47	6.20E-02	Ce-143	806.34	2.87E-04
Te-129	27.81	1.63E-01	I-135	807.20	4.60E-04
Te-131	28.32	3.76E-02	I-132	809.50	2.60E-02
Te-132	28.32	2.06E-01	Ce-143	809.98	3.12E-04
Te-131m	28.32	3.70E-02	Co-58	810.76	9.94E-01

Te-131	28.61	6.90E-02	I-132	812.00	5.50E-02
Te-132	28.61	3.82E-01	Sb-129	812.97	4.82E-01
Te-131m	28.61	6.90E-02	Sb-128	813.60	1.30E-01
I-131	29.46	1.52E-02	Zr-97	814.30	5.70E-04
I-133	29.46	1.63E-03	Pr-144m	814.31	2.00E-04
I-135	29.46	1.28E-03	Pr-144	814.31	3.31E-05
I-132	29.46	2.99E-03	La-140	815.78	2.37E-01
I-131	29.78	2.81E-02	Te-129m	817.04	9.00E-04
I-133	29.78	3.03E-03	Sb-129	819.51	1.39E-02
I-135	29.78	2.37E-03	I-133	820.51	1.54E-03
I-132	29.78	5.53E-03	Nb-95m	820.62	3.40E-06
Ba-140	29.96	1.44E-01	Sr-91	820.80	1.61E-03
Nb-97m	30.00	4.90E-04	Te-131m	822.74	6.20E-02
Nb-93m	30.77	5.91E-06	Mo-99	822.97	1.32E-03
Zr-93	30.77	4.30E-06	Sr-91	823.70	6.70E-04
Te-129m	31.10	4.30E-02	Sb-129	826.75	6.70E-04
Te-131m	31.10	1.80E-02	Zr-97	829.79	2.27E-03
Te-129m	31.76	9.40E-03	Te-129	829.93	6.40E-05
Te-131m	31.76	3.60E-03	I-132	831.30	3.00E-04
Cs-137	31.82	1.99E-02	Sb-129	832.99	6.30E-04
Cs-137	32.19	3.64E-02	Te-129	833.28	4.50E-04
Te-131	32.36	2.00E-02	La-141	834.80	2.00E-05
Te-132	32.36	1.10E-01	Mn-54	834.85	1.00E+00
Te-131m	32.36	2.00E-02	Nb-95m	835.15	3.00E-07
Ba-140	33.03	5.62E-03	Sb-128	835.80	1.00E-02
Te-131	33.11	4.20E-03	I-135	836.80	6.69E-02
Te-132	33.11	2.49E-02	Sb-129	840.17	2.70E-04
Te-131m	33.11	4.20E-03	Te-131	841.97	2.00E-03
Ba-140	33.44	1.03E-02	Sb-128	844.00	2.20E-02
Ce-144	33.56	2.25E-03	Y-92	844.30	1.25E-02
I-131	33.69	8.16E-03	Te-129m	844.81	3.50E-04
I-133	33.69	8.77E-04	Sb-128	845.80	2.50E-02
I-135	33.69	7.00E-04	Mn-56	846.76	9.89E-01
I-132	33.69	1.63E-03	I-132	847.90	1.70E-04
La-140	34.28	5.91E-03	Sb-129	849.57	7.60E-04
I-135	34.49	1.65E-04	Te-131	852.21	4.50E-04
I-131	34.49	1.93E-03	Te-131m	852.21	2.14E-01
I-133	34.49	2.07E-04	La-141	853.00	3.10E-05
I-132	34.49	3.80E-04	Te-131	853.80	9.60E-04
La-140	34.72	1.08E-02	Zr-97	854.89	3.41E-03
Ce-143	35.55	1.75E-01	Te-131	856.06	1.30E-03
Ce-144	35.55	2.41E-02	Te-131m	856.06	5.90E-03
Ce-141	35.55	4.80E-02	I-133	856.28	1.23E-02
Ce-141	36.03	8.76E-02	Nb-97	857.50	4.50E-04
Ce-143	36.03	3.15E-01	Sb-128	860.80	4.00E-03
Ce-144	36.03	4.40E-02	Sb-129	861.00	6.80E-04
Cs-137	36.30	3.48E-03	Mo-99	861.20	7.00E-06
Cs-137	36.38	6.72E-03	I-132	863.00	5.60E-03
Te-131m	36.85	1.20E-04	Co-58	863.96	7.00E-03
Cs-137	37.26	2.13E-03	Pr-144	864.36	2.69E-05
Ba-140	38.17	3.07E-03	I-132	866.00	3.60E-04
Ba-140	39.16	7.80E-04	La-140	867.84	5.58E-02
La-140	39.33	3.26E-03	Te-131m	872.29	1.20E-03
I-129	39.58	7.42E-02	Rh-106	873.46	4.35E-03
Ru-103	39.75	7.00E-04	Sb-129	874.89	5.34E-03
Rh-103m	39.76	6.80E-04	I-133	875.33	4.47E-02
La-140	40.29	8.28E-04	I-132	876.60	1.04E-02

Mo-99	40.58	1.02E-02	Sb-129	876.65	2.75E-02
Ce-143	40.65	3.08E-02	Sb-128	878.00	3.50E-02
Ce-143	40.75	5.96E-02	Sr-91	879.70	1.88E-03
Ce-141	40.82	2.67E-02	Ce-143	880.46	1.03E-02
Ce-144	40.82	1.34E-02	Te-131	881.20	3.00E-04
Ce-144	40.92	3.20E-03	I-132	886.10	2.50E-04
Ce-143	41.76	1.93E-02	I-132	888.70	3.50E-04
Ce-144	41.87	3.43E-03	Ce-143	891.47	8.10E-05
Ce-141	41.87	6.82E-03	Sr-91	892.90	7.00E-04
Ru-103	42.63	1.10E-05	Te-131	898.57	1.70E-03
Te-132	49.72	1.51E-01	Sr-91	901.30	9.40E-04
Ru-103	53.27	3.76E-03	Sb-129	903.19	1.40E-03
Ce-144	53.40	1.01E-03	I-132	904.40	1.30E-04
Ce-143	57.36	1.17E-01	Ce-143	907.10	1.30E-05
Ce-144	59.03	9.40E-06	Sb-128	908.30	2.30E-02
Pr-144m	59.03	8.18E-04	Sb-128	908.80	1.00E-02
Ru-103	62.41	1.00E-05	Sr-89	909.00	9.56E-05
Te-131m	62.70	4.00E-03	Nb-97	909.57	3.90E-04
Ba-140	63.18	3.00E-07	I-133	909.68	2.12E-03
La-140	64.13	1.40E-04	Te-131m	909.96	3.40E-02
La-140	68.92	7.70E-04	I-132	910.10	9.30E-03
Te-131m	73.21	2.80E-04	I-133	911.45	4.60E-04
Te-131m	78.54	1.60E-04	Y-92	912.80	6.30E-03
Te-131m	79.00	1.30E-03	Sb-129	914.96	2.33E-01
Ce-144	80.12	1.40E-02	La-140	919.53	2.73E-02
I-131	80.19	2.61E-02	Te-131m	920.56	1.20E-02
Te-131m	81.11	4.20E-02	Te-131m	923.40	1.20E-03
I-131	85.90	5.10E-05	La-140	925.20	7.04E-02
Te-131m	86.40	1.50E-03	Sr-91	925.80	3.85E-02
Tc-99	89.52	5.80E-06	I-132	927.60	4.10E-03
Tc-99m	89.60	1.04E-05	Te-131	934.47	1.00E-02
Sb-129	95.42	4.50E-04	Y-92	934.50	1.39E-01
Ba-140	99.48	2.00E-07	Ce-143	937.82	2.61E-04
Ce-144	99.95	4.10E-04	Sb-129	939.52	1.92E-03
Te-131m	100.10	8.00E-04	Sb-129	940.51	7.66E-03
Te-131m	100.80	1.70E-03	Te-131m	941.27	9.00E-03
Te-131m	102.06	7.70E-02	Rh-106	942.63	6.00E-06
Sb-128	102.80	4.00E-03	Y-93	947.10	2.10E-02
Te-131m	103.40	5.00E-04	I-132	947.20	4.40E-04
Te-131m	104.70	3.00E-04	Te-131	948.50	2.40E-02
Te-129m	105.50	1.40E-03	La-140	950.99	5.31E-03
Te-131	109.41	6.00E-04	Te-131	951.38	3.80E-03
La-140	109.42	2.17E-03	I-132	954.55	1.76E-01
Zr-97	111.60	5.70E-04	Ce-143	956.90	1.30E-05
Te-132	111.81	1.85E-02	I-135	960.30	3.00E-04
I-135	112.80	1.26E-04	Mo-99	960.75	9.50E-04
I-135	113.10	6.89E-05	I-135	961.40	1.50E-03
Ru-103	113.25	3.60E-05	Y-93	962.30	1.20E-04
Ba-140	113.48	1.72E-04	La-141	964.00	1.50E-05
Ru-103	114.97	8.00E-05	I-132	965.80	3.50E-04
Sb-129	115.84	8.70E-04	Sb-129	966.78	8.96E-02
Te-132	116.34	1.97E-02	Y-93	971.00	6.70E-05
Sb-128	118.40	6.00E-03	Zr-97	971.34	2.94E-03
Sr-91	118.50	7.40E-04	I-135	972.00	8.90E-03
Ba-140	118.82	6.10E-04	Sb-128	972.30	1.00E-02
Ce-143	122.40	9.00E-05	Y-92	972.30	6.80E-04
Sb-129	130.90	5.10E-02	I-135	972.60	1.21E-02

La-140	131.12	4.70E-03	Sr-91	973.90	4.00E-04
Ba-140	132.70	2.02E-03	Te-129	982.27	1.60E-04
Ce-144	133.52	1.08E-01	I-132	984.20	5.90E-03
Te-131m	134.86	7.20E-03	Mo-99	986.44	1.40E-05
I-132	136.70	7.90E-04	Y-93	987.70	1.00E-04
Ce-143	139.74	7.70E-04	Te-131m	987.80	1.60E-03
Mo-99	140.51	8.96E-01	Sr-91	992.20	4.40E-04
Tc-99m	140.51	8.85E-01	La-140	992.64	1.00E-04
Te-131	141.15	3.00E-04	Sb-129	992.70	1.05E-03
Mo-99	142.68	2.11E-04	I-135	995.09	1.50E-03
Tc-99m	142.68	2.30E-04	Te-131m	995.20	9.00E-05
Ce-141	145.44	4.83E-01	I-132	995.80	3.00E-04
Sb-129	146.11	9.10E-04	Sb-129	996.54	1.76E-03
I-132	147.40	2.37E-03	Te-131	997.20	3.60E-02
Te-131	149.72	6.89E-01	Te-131	999.20	3.00E-04
Te-131m	149.72	2.00E-01	Te-131m	999.20	1.70E-03
I-133	150.38	2.90E-04	Sb-129	1000.50	5.00E-04
Te-131	151.20	2.00E-03	Mo-99	1001.34	4.30E-05
Sb-128	152.60	5.00E-03	I-132	1002.50	2.60E-04
Mo-99	158.78	1.45E-04	Ce-143	1002.85	7.53E-04
Te-131m	159.71	1.30E-03	I-132	1005.40	1.60E-04
Mo-99	162.37	1.14E-04	Te-131m	1005.78	1.10E-03
I-135	162.65	1.00E-04	Te-131	1007.98	9.00E-03
Ba-140	162.66	6.49E-02	I-132	1009.00	4.60E-04
I-131	163.93	2.11E-04	Te-129	1013.57	1.30E-05
I-135	165.74	3.10E-04	Ce-143	1014.30	1.30E-05
I-133	167.97	7.80E-04	Mo-99	1017.00	7.00E-06
La-140	173.55	1.26E-03	I-133	1018.10	6.00E-05
I-131	177.21	2.77E-03	Zr-97	1019.00	2.84E-03
Nb-97	178.00	4.90E-04	Te-129	1019.43	2.20E-05
Sb-129	180.42	2.84E-02	Zr-97	1021.20	1.04E-02
Mo-99	181.07	6.01E-02	Sb-129	1022.12	2.90E-04
Te-131m	182.32	8.00E-03	Te-129m	1022.43	1.80E-04
Te-131m	182.41	8.00E-03	Te-131m	1023.38	1.20E-03
Zr-97	182.90	2.80E-04	Sr-91	1024.30	3.35E-01
Te-131m	183.20	1.60E-03	Nb-97	1024.53	1.08E-02
I-132	183.60	1.38E-03	Zr-97	1026.70	2.84E-03
I-135	184.49	2.35E-04	Sb-129	1030.65	1.51E-01
Te-131m	188.10	2.20E-03	Ce-143	1031.22	2.01E-04
Te-131m	189.79	6.00E-03	I-132	1035.00	5.10E-03
Te-131m	190.40	1.20E-03	Te-131m	1035.50	1.10E-03
Sb-128	193.50	1.00E-02	I-133	1035.53	8.60E-05
I-135	197.19	3.30E-04	Sb-129	1037.29	3.07E-03
Ce-143	197.60	2.60E-05	Mn-56	1037.83	4.00E-04
Te-131m	200.64	7.50E-02	I-135	1038.76	7.90E-02
Zr-97	202.50	6.60E-04	Nb-95m	1039.26	3.00E-08
I-133	203.79	4.32E-03	Sb-128	1040.90	9.60E-03
Nb-95	204.12	2.80E-04	Sb-129	1042.30	4.20E-04
Nb-95m	204.12	2.28E-02	La-140	1045.02	2.00E-04
Sb-128	204.40	1.00E-02	Rh-106	1045.82	1.31E-04
Te-129	208.96	1.80E-03	Ce-143	1046.78	1.20E-04
Te-129	210.66	1.30E-05	Sb-128	1047.50	3.50E-02
Te-131m	213.90	4.60E-03	I-132	1049.60	4.60E-04
Sb-128	214.80	1.00E-02	Te-129m	1050.21	1.80E-04
Nb-95m	218.64	0.00E+00	Rh-106	1050.39	1.49E-02
Zr-97	218.90	1.80E-03	I-133	1052.39	5.51E-03
I-135	220.50	1.75E-02	Sb-129	1053.02	5.30E-04

Te-131	221.50	4.00E-04	Sr-91	1054.60	2.24E-03
I-133	223.22	2.93E-03	Mo-99	1056.20	1.03E-05
Sb-128	227.30	1.50E-02	Te-131m	1059.67	1.60E-02
Te-132	228.33	8.81E-01	I-133	1060.06	1.38E-03
I-135	229.72	2.41E-03	Ce-143	1060.22	3.64E-04
Te-131m	230.60	2.80E-03	Rh-106	1062.14	3.07E-04
Ce-143	231.55	2.05E-02	Mo-99	1072.20	1.20E-05
I-131	232.18	2.30E-05	Te-131m	1072.39	2.00E-04
Te-131m	232.20	1.00E-03	Sb-128	1078.60	2.00E-02
I-132	234.30	3.00E-04	I-132	1081.80	3.50E-04
Sb-128	235.00	3.00E-03	Te-129	1083.85	4.90E-03
Nb-95m	235.69	2.51E-01	I-132	1086.20	8.00E-04
Zr-95	235.69	2.70E-03	I-133	1087.67	1.21E-04
Nb-97	238.37	4.90E-04	Sb-129	1087.98	4.11E-03
Te-131m	240.93	7.70E-02	I-135	1096.86	8.90E-04
Ru-103	241.88	1.50E-04	I-132	1096.90	4.40E-04
La-140	241.96	4.36E-03	La-140	1097.58	2.30E-04
Mo-99	242.29	1.40E-05	Te-131	1098.22	2.00E-03
Sb-129	244.53	4.03E-03	Sb-128	1098.40	2.90E-03
I-133	245.84	3.50E-04	I-135	1101.58	1.61E-02
I-135	247.50	2.90E-04	Sb-128	1101.80	3.90E-03
Mo-99	249.03	3.50E-05	Ce-143	1103.25	4.15E-03
Sb-128	249.70	6.00E-03	Sb-129	1104.52	3.41E-03
Te-129	250.62	3.80E-03	Rh-106	1108.71	5.60E-05
I-132	250.80	1.80E-04	Zr-97	1110.44	1.14E-03
Nb-95m	253.07	6.00E-09	Te-129	1111.64	1.91E-03
Te-131m	253.16	7.00E-03	I-132	1112.40	7.00E-04
Zr-97	254.17	1.29E-02	Sb-128	1112.70	2.00E-02
I-135	254.74	2.30E-04	Rh-106	1114.45	1.17E-04
I-132	255.10	2.40E-03	Nb-97	1117.01	8.60E-04
Te-131m	255.55	3.20E-03	Sb-129	1122.48	9.20E-04
Sr-91	261.20	4.49E-03	I-135	1124.00	3.62E-02
I-133	262.70	3.56E-03	Te-131m	1125.44	1.20E-01
I-132	262.90	1.30E-02	I-132	1126.50	5.00E-04
I-135	264.26	1.84E-03	Sb-129	1126.57	1.20E-03
La-140	266.55	4.92E-03	Rh-106	1128.01	3.98E-03
Y-93	266.90	7.30E-02	Te-131m	1128.02	1.00E-02
I-133	267.17	1.17E-03	Sb-129	1128.60	1.50E-01
Sb-129	268.48	2.14E-03	Sb-128	1129.60	8.00E-03
Te-129	270.37	4.60E-05	I-135	1131.51	2.26E-01
Zr-97	272.40	2.84E-03	Y-92	1132.40	2.40E-03
I-131	272.50	5.81E-04	I-132	1136.00	3.01E-02
Sr-91	272.60	2.60E-03	Sr-91	1140.80	1.27E-03
Ce-143	272.90	4.00E-05	Sb-128	1141.70	7.70E-03
Y-93	273.00	7.10E-04	I-132	1143.30	1.35E-02
Sr-91	274.70	1.04E-02	Te-131	1146.93	5.80E-02
Te-131	278.20	9.00E-04	Sb-129	1147.59	8.90E-04
Sb-128	278.30	6.00E-03	I-132	1147.80	2.70E-03
I-132	278.40	3.90E-04	Zr-97	1147.97	2.65E-02
Te-129	278.43	5.70E-03	Te-131	1148.50	1.10E-03
Te-131m	278.57	1.80E-02	Nb-97	1148.60	4.90E-04
Te-129	281.26	1.65E-03	Te-131m	1148.73	1.70E-02
Te-129	281.70	1.50E-05	Te-131	1148.90	6.00E-04
Te-131m	283.20	4.00E-03	Rh-106	1150.08	2.87E-05
Cs-137	283.50	5.80E-06	Te-131m	1150.86	7.00E-03
I-131	284.31	6.14E-02	I-135	1152.00	1.00E-04
I-132	284.90	7.10E-03	Sb-128	1158.00	1.74E-02

Y-93	287.00	7.50E-04	Y-93	1158.50	3.00E-04
I-135	288.45	3.10E-02	I-135	1159.90	1.03E-03
Te-131m	290.20	8.00E-04	Rh-106	1159.90	2.30E-06
I-135	290.27	3.04E-03	Ce-143	1160.58	2.40E-05
Sb-129	290.48	6.00E-04	Te-131m	1165.50	1.80E-03
Ru-103	292.70	3.00E-05	Sb-129	1167.95	2.53E-03
Ce-143	293.27	4.28E-01	Y-93	1168.60	1.00E-04
Zr-97	294.80	7.60E-04	I-135	1169.04	8.80E-03
Ru-103	294.98	2.51E-03	I-132	1172.90	1.09E-02
Sb-129	295.26	8.28E-03	Sb-129	1179.63	5.40E-04
I-131	295.80	1.20E-05	Rh-106	1180.79	1.44E-04
Te-131m	296.70	5.00E-04	Sb-128	1181.60	4.50E-02
Te-131	297.13	5.00E-04	Pr-144	1182.06	6.00E-07
Zr-97	297.20	3.80E-04	Y-93	1183.50	4.80E-04
Te-131	300.00	4.00E-04	Y-93	1184.70	1.90E-04
I-132	302.00	1.00E-04	Rh-106	1194.58	5.73E-04
I-131	302.40	4.60E-05	Sb-129	1196.42	8.50E-04
Te-131m	303.90	4.00E-04	Y-93	1203.30	1.07E-03
I-135	304.91	3.20E-04	Y-91	1205.00	2.60E-03
Ba-140	304.97	4.33E-02	Te-131m	1206.65	1.01E-01
Zr-97	305.10	1.90E-04	Sb-129	1209.03	9.40E-03
I-135	305.83	9.50E-04	Rh-106	1209.79	3.90E-06
I-132	306.70	9.90E-04	Te-131m	1211.45	6.00E-04
La-140	307.08	2.20E-04	Sb-129	1211.89	3.81E-03
Te-131m	309.44	4.00E-03	I-132	1212.30	1.20E-04
I-132	310.10	9.00E-04	I-135	1225.60	4.30E-04
Sb-128	314.00	6.10E-01	Te-129	1232.82	7.50E-05
Sb-129	314.40	1.23E-03	Sb-129	1233.20	5.30E-04
I-132	316.70	1.30E-03	Te-131m	1237.26	6.90E-03
Sb-128	317.70	3.00E-02	Y-93	1237.40	2.90E-04
Ru-103	317.77	6.00E-08	Sb-129	1237.81	2.41E-03
I-131	318.09	8.07E-04	Mn-56	1238.27	9.70E-04
Sb-129	318.36	2.27E-03	I-135	1240.47	9.00E-03
Sb-128	322.30	3.00E-02	I-132	1242.60	8.90E-05
La-141	324.60	1.30E-05	Sb-128	1250.50	1.00E-02
I-131	324.65	2.44E-04	I-132	1254.10	5.90E-04
I-131	325.79	2.74E-03	I-135	1254.80	5.70E-05
I-135	326.00	2.34E-05	Sb-129	1258.44	4.02E-03
La-140	328.76	2.08E-01	Rh-106	1258.71	6.60E-06
Sb-129	330.33	7.30E-04	Sb-128	1259.50	1.00E-02
Zr-97	330.43	1.52E-03	I-135	1260.41	2.87E-01
Sb-129	333.21	1.71E-03	Te-129	1260.63	1.12E-04
I-135	333.60	3.70E-04	Sb-129	1263.30	9.10E-03
Te-131m	334.27	9.80E-02	I-133	1263.44	1.49E-02
Te-131m	335.60	1.40E-03	I-132	1263.60	2.76E-04
Ce-143	338.30	9.00E-06	Te-129	1264.16	8.20E-05
Y-93	341.50	4.40E-04	Rh-106	1266.03	1.09E-05
I-135	342.52	9.00E-06	Nb-97	1268.63	1.47E-03
Te-129	342.54	8.50E-05	I-132	1272.80	1.70E-03
Te-131	342.95	7.60E-03	Sb-129	1273.10	1.64E-03
I-132	343.60	9.00E-04	Zr-97	1276.07	9.50E-03
I-133	345.46	1.04E-03	Sb-129	1276.13	1.03E-03
Ce-143	350.62	3.23E-02	Te-131	1277.42	1.20E-03
Te-131m	351.34	2.40E-03	I-135	1277.83	5.80E-04
Sb-129	351.46	7.50E-04	Sr-91	1280.90	9.30E-03
Te-131	351.75	2.10E-04	Sb-129	1281.72	5.59E-03
I-132	351.80	8.00E-04	Sb-129	1287.45	1.00E-03

Te-131	353.60	2.00E-04	I-132	1290.80	1.13E-02
Sb-129	354.13	9.70E-04	Te-131	1294.33	5.60E-03
Te-131m	354.98	3.20E-03	I-132	1295.10	1.88E-02
Zr-97	355.40	2.38E-02	I-132	1297.91	9.00E-03
Sb-128	357.00	1.50E-02	I-133	1298.23	2.33E-02
Ru-103	357.40	9.00E-05	Sb-129	1298.70	1.16E-03
Ce-143	357.80	6.00E-06	Sb-129	1301.45	2.02E-03
I-131	358.40	1.70E-04	La-140	1303.34	4.50E-04
Sr-91	359.10	5.00E-04	Sr-91	1305.30	1.70E-04
Sb-129	359.20	2.39E-02	Rh-106	1305.33	1.09E-05
I-133	361.12	1.10E-03	Te-131	1308.00	6.70E-04
I-135	361.85	1.87E-03	I-132	1314.00	6.00E-04
I-132	363.34	4.90E-03	Te-131m	1315.22	8.10E-03
Sb-129	364.21	3.05E-03	Rh-106	1315.66	3.00E-05
I-131	364.49	8.12E-01	I-135	1315.77	6.60E-04
Te-131m	364.97	1.20E-02	I-132	1317.90	1.18E-03
Sb-128	366.10	1.50E-02	Sb-129	1318.30	4.62E-03
Mo-99	366.42	1.19E-02	Te-131m	1318.40	4.00E-04
Ce-143	371.29	2.50E-04	Ce-143	1324.48	1.58E-05
I-133	372.14	9.00E-05	Sb-129	1326.98	6.95E-03
Sr-91	379.90	1.47E-03	I-133	1327.23	2.20E-06
Mo-99	380.13	9.10E-05	Sr-91	1327.40	4.00E-04
I-133	381.58	4.50E-04	Te-131m	1334.00	6.00E-04
Te-131m	383.82	2.00E-03	I-135	1334.80	3.20E-04
Te-131	384.06	1.00E-02	Sb-128	1339.80	1.00E-02
I-133	386.78	5.90E-04	Ce-143	1340.10	3.08E-05
Y-93	387.50	7.00E-05	Te-131m	1340.65	1.60E-03
I-132	387.90	3.00E-03	I-135	1343.66	7.70E-04
Ce-143	389.64	3.64E-04	I-133	1350.37	1.49E-03
Mo-99	391.70	2.50E-05	Te-131	1350.93	6.20E-04
Sr-91	393.00	5.00E-04	Sr-91	1353.50	2.30E-04
La-140	397.67	7.50E-04	La-141	1354.52	1.64E-02
Sb-129	398.97	6.90E-04	Sb-128	1354.60	5.80E-03
Zr-97	400.42	3.88E-03	Rh-106	1355.60	6.00E-06
I-135	403.03	2.32E-03	I-132	1360.00	6.00E-05
Sb-128	404.30	1.00E-02	Rh-106	1360.17	1.80E-05
Sb-129	404.64	1.17E-02	Zr-97	1362.68	1.33E-02
I-131	404.81	5.52E-04	I-135	1367.89	6.10E-03
Sb-129	409.71	2.31E-03	La-141	1368.70	4.90E-05
Mo-99	410.27	1.60E-05	I-132	1372.07	2.47E-02
Mo-99	411.49	1.61E-04	Rh-106	1372.28	1.99E-05
I-135	414.83	3.01E-03	Pr-144	1376.34	4.10E-06
Sb-129	415.17	9.60E-04	Te-131m	1376.80	4.00E-04
Ce-143	416.57	6.80E-05	Sb-128	1378.00	1.80E-02
I-132	416.80	4.70E-03	Ce-143	1382.00	3.90E-06
I-133	417.55	1.53E-03	Sb-129	1384.98	1.00E-03
I-135	417.63	3.53E-02	I-133	1386.15	8.66E-05
Te-131m	417.70	4.00E-03	Pr-144	1388.11	7.06E-05
Te-131	421.30	3.40E-04	I-132	1390.70	1.50E-04
Sb-129	421.72	5.00E-04	Te-131m	1394.98	1.30E-03
I-133	422.90	3.09E-03	Rh-106	1397.51	2.77E-05
Ba-140	423.79	3.13E-02	I-132	1397.57	7.00E-02
Rh-106	428.29	7.04E-04	Te-129m	1401.36	3.60E-05
I-135	429.93	3.04E-03	La-140	1404.66	6.20E-04
I-132	431.80	4.70E-03	Y-92	1405.40	4.80E-02
Te-131m	432.44	7.00E-03	I-132	1410.60	4.30E-04
La-140	432.51	3.00E-02	Sr-91	1413.40	9.80E-03

Ce-143	433.00	1.59E-03	I-135	1416.30	3.10E-04
I-135	433.74	5.54E-03	Sb-129	1419.40	3.94E-03
Sb-129	433.76	6.20E-01	Sb-129	1421.23	3.80E-04
Rh-106	434.23	2.00E-04	Y-93	1425.40	2.40E-03
Sb-129	434.74	1.11E-03	Te-131	1427.14	1.10E-03
La-141	435.00	7.00E-06	Sb-129	1437.52	3.16E-03
Sb-129	435.04	2.12E-03	I-135	1441.80	1.70E-04
Ba-140	437.67	1.94E-02	I-132	1442.56	1.40E-02
La-140	438.18	1.70E-04	I-135	1448.35	3.20E-03
Ce-143	438.43	4.30E-05	I-132	1450.00	7.90E-05
I-133	438.93	4.00E-04	Y-93	1450.50	3.30E-03
Rh-106	439.23	1.11E-04	I-132	1456.50	5.00E-04
Ru-103	443.80	3.22E-03	I-135	1457.56	8.70E-02
La-140	444.57	3.00E-05	Y-93	1470.10	6.50E-04
I-132	445.00	9.87E-04	Sr-91	1473.80	1.67E-03
Sb-128	445.70	1.50E-02	Sb-129	1475.91	7.00E-04
Ce-143	446.02	1.50E-04	I-132	1476.70	1.30E-03
I-132	446.20	6.00E-03	Sb-129	1480.94	3.73E-03
Ce-143	447.45	6.00E-04	Sb-129	1483.04	4.10E-04
Y-92	448.50	2.28E-02	Sr-91	1486.40	1.30E-04
I-135	451.64	3.16E-03	Pr-144	1489.15	2.86E-03
Te-131	452.36	1.88E-01	Rh-106	1489.61	1.80E-05
Te-131m	452.36	1.30E-02	Te-131m	1496.24	6.00E-04
Sb-129	453.44	5.38E-03	Rh-106	1496.37	2.40E-04
Sb-128	454.50	1.50E-02	La-141	1497.00	1.82E-04
Mo-99	457.60	7.40E-05	Rh-106	1498.73	6.80E-05
Sb-128	459.50	1.50E-02	Te-131	1500.65	1.40E-03
Te-129	459.60	7.70E-02	Sb-129	1501.04	6.00E-04
Te-129m	459.60	1.30E-05	I-135	1502.79	1.08E-02
Te-131m	463.00	1.90E-02	La-141	1512.10	9.20E-05
Te-131m	468.36	3.10E-03	Nb-97	1515.59	1.22E-03
Mo-99	469.63	2.70E-05	I-132	1519.60	7.90E-04
Sb-129	471.54	4.50E-04	I-135	1521.99	3.70E-04
I-132	473.40	1.70E-03	Sb-129	1526.84	5.48E-03
Zr-97	473.50	7.60E-04	Te-131	1527.77	6.00E-03
La-141	474.90	7.00E-06	I-132	1531.90	6.00E-05
I-132	478.20	1.70E-03	Sb-129	1541.47	6.70E-04
Sr-91	486.50	0.00E+00	I-132	1542.30	1.60E-04
La-140	487.02	4.61E-01	I-135	1543.70	2.60E-04
Te-129	487.39	1.42E-02	Sr-91	1545.90	6.70E-04
I-132	488.00	4.10E-03	Te-131m	1547.79	8.00E-04
Ce-143	490.37	2.16E-02	Sr-91	1553.60	1.70E-04
Te-129	491.93	1.16E-05	I-132	1559.00	9.00E-05
Y-92	492.60	4.90E+01	Pr-144	1560.91	2.10E-06
Te-131	492.67	5.10E-02	Rh-106	1562.24	1.56E-03
Te-131	494.87	1.00E-03	I-135	1566.41	1.29E-02
Ru-103	497.08	8.95E-01	Sb-129	1570.09	8.72E-03
Ce-143	497.81	4.50E-04	Rh-106	1572.47	1.85E-05
Sb-129	499.99	4.30E-03	Rh-106	1577.27	1.05E-05
I-131	503.00	3.54E-03	Te-131	1580.10	7.50E-05
Sb-129	505.33	5.18E-03	Sb-129	1582.11	3.40E-04
I-132	505.79	4.94E-01	Sb-128	1585.20	2.90E-03
Sr-91	506.70	4.40E-04	I-133	1589.93	2.90E-05
Zr-97	507.64	5.31E-02	I-132	1592.90	4.70E-04
Zr-97	508.00	6.60E-03	Sb-128	1593.20	5.00E-03
I-133	510.53	1.81E-02	La-140	1596.20	9.54E-01
I-133	510.82	4.00E-05	Sb-129	1600.13	5.79E-03

Co-58	511.00	2.99E-01
Mn-54	511.00	6.00E-09
Sr-90	511.00	6.38E-05
Y-90	511.00	6.38E-05
Ru-106	511.85	2.05E-01
Rh-106	511.85	2.05E-01
Zr-97	513.41	6.60E-03
Sb-129	514.43	1.47E-03
Ru-103	514.60	4.80E-05
Sr-91	520.80	3.40E-04
I-133	522.52	4.00E-04
I-132	522.65	1.60E-01
Ce-143	523.00	1.70E-05
Sb-129	523.13	1.55E-02
Te-131m	524.70	1.40E-03
Sb-129	525.23	1.64E-03
Sb-128	526.50	4.50E-01
Mo-99	528.79	5.41E-04
I-133	529.87	8.63E-01
Te-131m	530.50	1.10E-03
I-135	530.80	3.20E-04
Te-129	531.83	8.80E-04
Sr-91	533.90	7.70E-04
I-132	535.50	5.23E-03
Ba-140	537.26	2.46E-01
I-133	537.54	3.50E-04
Mo-99	537.79	1.50E-05
Sb-129	539.52	7.70E-04
Te-131m	541.50	1.20E-03
Sb-129	544.56	1.54E-01
Te-131	544.85	4.20E-03
I-135	546.56	7.15E-02
La-141	547.10	1.00E-05
I-132	547.20	1.14E-01
Nb-97	549.25	4.90E-04
Ba-140	551.14	4.90E-05
Te-129	551.50	3.50E-05
Te-129	551.98	1.39E-05
I-133	554.48	4.00E-06
Sr-91	555.57	6.20E-01
Y-91m	555.57	9.50E-01
I-133	556.19	2.00E-04
Te-129m	556.65	1.20E-03
Ce-143	556.87	3.17E-04
Ru-103	557.05	8.36E-03
I-132	559.70	9.00E-04
Te-129	560.05	6.10E-05
Y-92	561.10	2.39E-02
La-141	561.80	1.00E-05
Nb-95	561.88	1.50E-04
Sb-129	566.96	1.36E-03
I-133	567.10	3.60E-05
Te-131	567.32	1.00E-03
Ru-103	567.97	1.60E-05
Ce-143	569.91	5.10E-05
I-132	572.50	6.00E-04
Te-131	574.93	3.40E-04
La-141	1604.80	8.50E-05
Sb-129	1606.72	2.00E-04
Sb-128	1608.50	4.80E-03
I-135	1613.75	2.60E-04
I-132	1617.90	1.00E-04
I-132	1618.90	7.00E-05
Sb-129	1622.46	2.08E-03
Sr-91	1626.80	1.30E-04
Nb-97	1629.13	2.40E-04
Pr-144m	1631.36	3.00E-04
I-132	1636.50	1.20E-04
I-132	1639.10	8.00E-05
Y-93	1642.70	5.20E-04
I-132	1644.00	1.30E-04
Te-131m	1645.96	1.30E-02
Sr-91	1646.00	3.00E-05
Sb-129	1646.79	2.70E-04
Te-131	1651.00	9.50E-05
Sr-91	1651.40	2.91E-03
Y-93	1651.70	2.30E-04
Sb-129	1656.10	1.31E-02
I-132	1661.40	1.60E-04
Sb-129	1669.16	2.20E-04
I-132	1671.30	2.20E-04
Pr-144	1672.25	2.10E-06
Co-58	1674.70	5.30E-03
I-135	1678.03	9.60E-02
I-132	1679.30	6.00E-05
Sb-128	1685.70	5.00E-03
Rh-106	1687.20	5.50E-05
Sb-129	1691.24	4.20E-04
Rh-106	1693.20	8.20E-06
La-141	1693.30	7.40E-04
I-135	1706.46	4.10E-02
Sb-128	1707.90	3.00E-03
I-132	1715.40	5.50E-04
I-132	1720.60	5.40E-04
Sr-91	1724.00	1.61E-03
Sb-129	1724.31	1.33E-03
I-132	1727.20	6.70E-04
Sb-129	1727.77	2.90E-04
Rh-106	1730.44	2.09E-05
Sb-129	1738.16	7.45E-02
La-141	1739.00	1.56E-04
Zr-97	1750.24	1.18E-02
I-132	1752.30	2.50E-04
I-132	1757.40	3.00E-03
I-132	1760.40	6.00E-04
Sb-129	1762.42	3.20E-04
Rh-106	1766.24	3.00E-04
I-132	1768.50	2.50E-04
Rh-106	1774.44	9.40E-06
I-132	1778.50	7.90E-04
Sb-129	1779.78	7.80E-04
Rh-106	1784.08	4.30E-06
Sb-128	1785.50	4.00E-03
I-132	1786.50	1.09E-04

I-135	575.97	1.29E-03
Rh-106	578.42	9.00E-05
Mo-99	580.51	3.60E-05
La-141	581.10	1.10E-05
Mo-99	581.30	1.00E-06
Nb-95m	582.08	4.80E-04
Sb-128	582.90	1.00E-02
Te-131m	586.29	2.20E-02
Ce-143	587.20	2.67E-03
I-135	588.28	5.20E-04
La-141	589.90	1.00E-05
Sb-129	589.98	2.20E-04
I-132	591.10	7.00E-04
Sb-129	592.77	4.10E-04
Sr-91	593.10	9.40E-04
Sb-128	594.10	3.30E-02
Sb-128	594.30	1.00E-02
Ce-143	594.50	1.10E-05
I-132	600.00	1.30E-03
Zr-97	600.60	2.37E-03
Te-131	602.08	4.60E-02
Te-131m	602.08	3.00E-03
Zr-97	602.37	1.37E-02
Sb-128	603.00	1.70E-02
Te-131	605.55	1.40E-03
Sb-129	606.22	1.46E-03
Te-131m	609.30	1.40E-03
I-132	609.80	4.00E-04
Ru-103	610.33	5.64E-02
Ru-103	612.02	8.00E-02
Ce-143	614.22	1.20E-04
Rh-106	616.16	7.31E-04
Nb-95m	616.51	9.50E-07
I-135	616.90	3.70E-04
I-133	617.98	5.39E-03
Pr-144m	618.11	3.00E-04
La-140	618.12	4.10E-04
Mo-99	620.03	2.40E-05
Sr-91	620.10	1.78E-02
I-132	620.90	3.90E-03
I-132	621.20	1.60E-02
Mo-99	621.77	2.62E-04
Rh-106	621.90	9.87E-02
Te-129	624.34	9.70E-04
Pr-144	624.83	1.18E-05
Sr-91	626.80	4.40E-04
Sb-128	628.70	3.10E-01
I-132	630.19	1.33E-01
Sr-91	631.30	5.56E-03
Sb-129	633.74	2.53E-02
Sb-128	636.20	3.60E-01
I-131	636.99	7.12E-02
I-132	642.20	3.95E-04
I-131	642.72	2.18E-03
Sb-129	647.94	1.24E-03
I-133	648.75	5.60E-04
I-135	649.85	4.60E-03
I-135	1791.20	7.72E-02
Rh-106	1796.95	2.74E-04
Mn-56	1810.73	2.69E-01
I-132	1814.00	1.60E-04
Y-93	1827.80	2.30E-04
I-132	1830.10	2.80E-03
I-135	1830.69	5.80E-03
Sb-129	1843.49	2.10E-04
I-135	1845.30	6.00E-05
Y-92	1847.30	3.60E-03
Zr-97	1851.61	4.55E-03
Rh-106	1854.89	1.25E-05
Sb-129	1871.58	3.56E-03
La-140	1877.33	4.10E-04
I-132	1879.20	1.40E-04
Te-131m	1880.10	6.30E-04
Y-92	1885.10	2.80E-04
Pr-144m	1885.75	1.00E-04
Te-131m	1887.68	1.50E-02
Sb-129	1891.10	1.60E-04
Rh-106	1909.28	1.07E-05
I-132	1913.70	3.00E-04
Sb-129	1917.36	5.40E-04
Y-93	1917.80	1.54E-02
I-132	1921.08	1.23E-02
La-140	1924.50	1.10E-04
I-132	1925.70	2.00E-05
Rh-106	1927.23	1.47E-04
I-135	1927.30	2.96E-03
Sb-129	1934.24	5.40E-04
Te-131m	1936.17	8.00E-04
La-141	1943.70	3.30E-05
I-135	1948.49	6.30E-04
Rh-106	1954.90	2.00E-06
Rh-106	1973.40	1.70E-06
Pr-144	1979.04	9.60E-06
I-132	1985.64	1.20E-04
Rh-106	1988.44	2.58E-04
Y-92	1988.60	6.00E-05
Te-131m	2000.94	2.20E-02
I-132	2002.20	1.14E-02
Sb-129	2002.36	3.10E-04
Sr-91	2016.00	4.00E-05
La-141	2030.20	5.10E-05
Te-131	2040.80	7.00E-05
I-135	2045.88	8.70E-03
Pr-144	2046.41	3.00E-06
La-141	2049.20	2.30E-05
Y-92	2067.00	1.40E-05
Sb-129	2071.36	7.29E-03
Te-131	2072.80	6.00E-05
Pr-144	2072.89	2.40E-06
La-140	2083.22	3.60E-04
Sb-129	2086.11	5.40E-04
I-132	2086.82	2.60E-03
Rh-106	2093.33	2.90E-06
Y-92	2105.60	1.90E-04

I-132	650.50	2.57E-02	I-135	2112.40	6.90E-04
Ru-103	651.80	2.00E-06	Rh-106	2112.52	3.51E-04
Sr-91	652.30	2.97E-02	Mn-56	2113.09	1.42E-01
Sr-91	652.90	8.00E-02	Sb-129	2114.67	4.18E-03
Sr-91	653.00	3.70E-03	Sb-129	2134.86	3.70E-04
Sb-128	654.20	1.70E-01	I-135	2151.50	2.20E-04
Te-131	654.26	1.60E-02	Te-131m	2168.31	3.60E-03
Sb-129	654.28	2.97E-02	La-141	2171.10	2.03E-04
I-135	656.09	7.50E-04	I-132	2172.68	2.10E-03
Nb-97	657.94	9.82E-01	La-141	2173.90	1.64E-04
Sr-91	660.90	1.01E-03	I-135	2179.70	4.00E-05
Cs-137	661.66	8.51E-01	Y-93	2184.60	1.57E-03
La-141	662.06	2.59E-04	Pr-144	2185.65	2.40E-06
Ce-143	664.57	5.69E-02	Rh-106	2185.70	2.50E-06
Te-131m	665.05	4.50E-02	Sr-90	2186.25	1.40E-08
Sb-128	667.10	2.50E-02	Y-90	2186.25	1.40E-08
I-132	667.72	9.87E-01	I-132	2187.00	7.00E-05
I-132	669.80	4.60E-02	I-135	2189.40	1.30E-04
Ce-143	670.12	8.10E-05	Y-93	2190.80	1.69E-03
I-133	670.12	4.20E-04	Rh-106	2193.17	4.95E-05
Sb-129	670.31	9.59E-03	Zr-97	2203.00	9.50E-05
I-132	671.40	3.50E-02	I-132	2204.20	3.00E-05
Te-129m	671.84	2.50E-04	La-141	2207.30	7.90E-05
Pr-144	674.88	2.99E-05	I-132	2223.17	1.20E-03
Ce-143	675.50	9.00E-06	Sb-129	2223.42	2.80E-04
La-141	676.80	1.30E-05	Rh-106	2242.45	1.95E-05
I-133	678.49	2.20E-04	I-132	2249.10	3.40E-04
I-135	679.22	5.50E-04	I-135	2255.46	6.10E-03
Y-93	680.20	6.60E-03	Sb-129	2265.27	3.40E-04
Rh-106	680.23	1.03E-04	La-141	2267.00	4.10E-04
I-133	680.25	6.45E-03	Te-131m	2270.42	3.80E-03
Sb-129	682.77	5.76E-02	Rh-106	2271.86	1.17E-05
Ce-143	682.82	8.60E-05	I-132	2290.60	3.60E-05
Sb-128	683.90	3.00E-02	Rh-106	2309.09	5.75E-05
Sb-129	684.18	6.22E-03	Rh-106	2316.41	6.22E-05
I-132	684.40	8.00E-04	La-141	2328.90	5.00E-06
I-135	684.60	2.30E-04	Te-131m	2332.70	2.80E-04
Rh-106	684.80	5.52E-05	Y-92	2339.90	1.40E-04
Te-131m	685.72	2.20E-03	La-140	2347.85	8.45E-03
I-132	687.80	4.00E-04	Rh-106	2366.04	2.32E-04
Sb-129	688.59	1.64E-03	Pr-144	2368.80	5.00E-07
Mo-99	689.60	4.20E-06	I-132	2390.48	1.88E-03
I-135	690.13	1.29E-03	Rh-106	2390.60	6.59E-05
Zr-97	690.52	2.37E-03	Rh-106	2405.98	1.45E-04
Sb-128	692.90	2.00E-02	I-135	2408.65	9.60E-03
Sb-129	694.77	4.03E-03	I-132	2408.90	9.40E-05
La-141	694.90	1.10E-05	Sr-91	2412.30	4.40E-05
Te-131m	695.60	5.00E-03	I-132	2416.90	2.80E-05
Te-129m	695.88	3.10E-02	Y-92	2437.00	3.00E-05
Te-131	696.15	2.10E-03	Rh-106	2439.07	4.64E-05
Pr-144m	696.51	6.00E-04	I-132	2444.00	5.60E-05
Pr-144	696.51	1.40E-02	I-135	2452.80	9.00E-05
Sb-129	697.78	2.54E-03	I-132	2454.80	2.10E-05
Zr-97	699.20	1.04E-03	Rh-106	2456.79	2.20E-06
Te-129	701.10	1.30E-05	Y-93	2457.30	6.70E-05
Te-129m	701.70	2.50E-04	La-140	2464.03	9.70E-05
Te-131m	702.49	4.60E-03	I-135	2466.07	7.20E-04

Rh-106	702.80	2.90E-06	Y-92	2473.40	5.10E-05
Sb-129	703.36	9.50E-04	Y-93	2473.80	1.12E-04
Zr-97	703.76	1.04E-02	I-135	2477.10	1.40E-05
Te-129m	705.52	5.00E-05	Rh-106	2484.63	7.60E-06
I-132	706.40	2.00E-04	I-132	2487.80	8.00E-06
I-133	706.58	1.49E-02	La-140	2521.39	3.41E-03
Sb-129	707.08	1.38E-03	Mn-56	2523.06	1.02E-02
Zr-97	707.40	2.80E-04	I-132	2525.14	3.90E-04
I-135	707.92	6.60E-03	Rh-106	2525.43	1.10E-06
Ce-143	709.59	8.60E-05	Rh-106	2542.79	2.89E-05
La-141	710.40	3.10E-05	I-132	2546.60	1.60E-05
Te-131m	713.14	1.50E-02	La-140	2547.18	1.02E-03
Y-93	714.40	1.70E-04	I-132	2569.70	5.00E-05
Sb-129	715.49	5.10E-04	Rh-106	2571.16	1.33E-05
Rh-106	715.86	9.90E-05	I-132	2593.80	1.20E-05
Rh-106	717.44	6.70E-05	Mn-56	2598.44	2.00E-04
Nb-97	719.53	9.00E-04	I-132	2603.20	1.50E-05
Ce-143	721.93	5.39E-02	Y-93	2605.00	1.10E-04
Sb-129	722.69	1.42E-01	I-132	2614.50	4.00E-05
I-131	722.91	1.79E-02	Rh-106	2651.39	6.80E-06
Zr-95	724.19	4.43E-01	I-132	2653.80	1.60E-05
I-132	727.00	2.20E-02	Pr-144	2655.51	1.80E-06
Te-131	727.01	5.00E-03	Mn-56	2657.56	6.45E-03
I-132	727.20	3.20E-02	Rh-106	2705.26	2.48E-05
Sb-128	727.60	4.00E-02	Rh-106	2709.48	3.73E-05
I-132	728.40	1.60E-02	I-132	2717.50	3.50E-05
Te-129	729.57	1.20E-05	Rh-106	2740.10	2.10E-06
Te-129m	729.57	7.60E-03	I-132	2757.80	1.30E-05
Ce-143	729.87	3.00E-05	Rh-106	2788.20	8.20E-07
Te-129	732.62	1.31E-05	Rh-106	2809.10	6.20E-06
Sb-128	734.30	1.00E+00	Y-92	2819.80	4.20E-05
Sb-129	737.07	4.44E-03	Rh-106	2821.20	1.20E-05
Te-131m	738.80	7.00E-04	Rh-106	2865.00	1.40E-07
Mo-99	739.50	1.21E-01	La-140	2899.53	6.60E-04
Te-129	740.96	3.70E-04	Mn-56	2959.92	3.07E-03
Te-129m	740.96	2.80E-04	La-140	3118.49	2.60E-04
Pr-143	742.10	1.18E-06	Y-92	3263.90	1.10E-05
Zr-97	743.36	9.48E-01	La-140	3319.52	3.90E-05

Appendix 2

Table A2. List of isotopes, energies and intensities as inputs to the high-altitude simulations.

Isotope	Energy keV	Intensity	Isotope	Energy keV	Intensity
Hf-180m	10.52	0.0155	Eu-152	566.44	0.00131
Hf-180m	10.73	0.000236	Eu-154	569.23	0.0001
Hf-180m	10.83	0.0013	Cs-134	569.33	0.1537
Hf-180m	10.89	0.0019	As-76	571.5	0.00139
Hf-180m	10.9	0.00000068	Eu-152	571.83	0.000048
Hf-180m	11.13	1.75E-09	Sb-124	572.01	0.000176
Hf-180m	11.22	0.000000087	Ba-131	572.69	0.001563
Hf-180m	11.28	0.000000126	Ag-110m	572.8	0.000173
Ba-133m	12.327	0.0153	Zn-69m	573.9	0.00033
Np-239	17.0545	0.513	Sm-153	574.1	0.0000016
Mo-99	18.251	0.0319	As-76	575.3	0.00068
Mo-99	18.3672	0.0606	Sm-153	578.75	0.000034
Np-239	18.43	0.0002	Mo-99	580.51	0.000036
Sm-153	19.81	0.00000105	Mo-99	581.3	0.000001
Mo-99	20.669	0.0161	Eu-154	582.01	0.00866
Mo-99	21.0235	0.00254	Sm-153	584.55	0.0000107
Ag-110m	21.99	0.00198	Ba-131	585.04	0.01193
Ag-110m	22.163	0.00372	Eu-152m	586.27	0.000127
Ag-110m	22.984	0.00153	Eu-152	586.27	0.00462
Ag-110m	23.174	0.00288	Ga-72	587.44	0.00121
La-140	24.595	0.00000689	Sm-153	587.6	0.0000048
Ag-110m	25.002	0.00103	Sm-153	590.96	0.0000122
Sb-122	25.0443	0.0054	Eu-154	591.76	0.0495
Sb-122	25.271	0.01	Eu-152	595.61	0.000031
Ag-110m	25.484	0.000179	Ba-131	596.5	0.000016
Ag-110m	26.154	0.0008	Sm-153	596.7	0.000099
Ag-110m	26.673	0.000146	Eu-154	597.5	0.000055
Sb-122	27.202	0.00088	Eu-154	598.3	0.000062
Sb-124	27.202	0.001252	Sm-153	598.3	0.00002
Sb-122	27.4726	0.00165	Sm-153	598.54	0.00002
Sb-124	27.4726	0.00233	Eu-154	600	0.00006
Sb-122	28.5479	0.0029	Ga-72	600.95	0.055
Pa-233	28.56	0.00071	Sb-124	602.726	0.97775
Sb-122	29.1316	0.0003	Eu-154	602.81	0.000033
Cs-134	29.46	0.0000006	Ag-110m	603.08	0.00011
Cs-134	29.78	0.0000012	Sm-153	603.6	0.000049
Xe-133	30.6254	0.1354	Sm-153	604.03	0.000049
Ba-131	30.63	0.277	Cs-134	604.72	0.9762
Cs-131	30.631	0.214	Eu-152m	605	0.00004
Ba-131	30.97	0.514	Br-82	606.33	0.0125
Xe-133	30.9731	0.25	Sm-153	609.5	0.000129
Cs-131	30.978	0.396	Sm-153	609.95	0.000129
Sb-124	31.0589	0.000667	Eu-154	613.26	0.00093
Sb-122	31.104	0.00048	Eu-152m	615.14	0.000446
Ta-182	31.74	0.0084	Hf-181	615.17	0.00233
Sb-122	31.762	0.000055	Sm-153	615.51	0.000005
Sb-124	31.7623	0.000145	Sm-153	615.8	0.000005
Ba-135m	31.8174	0.154	Eu-152	616.05	0.000092
Cs-134	31.82	0.00238	Sm-153	617.9	0.0000067
Cs-134	32.19	0.00434	La-140	618.12	0.00041
Ba-135m	32.1939	0.284	Hf-181	618.66	0.00025

Cs-134	33.56	0.00000011	Br-82	619.106	0.433
Cs-134	33.62	0.00000021	Mo-99	620.03	0.000024
La-140	34.2793	0.00591	Ba-131	620.11	0.01437
Cs-134	34.42	0.00000006	Ag-110m	620.355	0.0272
La-140	34.72	0.01082	Eu-154	620.52	0.00091
Cs-131	34.925	0.037	Mo-99	621.773	0.000262
Cs-131	34.993	0.072	Eu-154	625.26	0.00317
Ba-131	35.05	0.153	Ag-110m	626.26	0.00214
Xe-133	35.053	0.0731	Ga-72	629.96	0.248
Cs-131	35.252	0.000354	Sm-153	630.5	0.0000009
Cs-131	35.266	0.00052	Ag-110m	630.61	0.00033
Cs-131	35.828	0.0231	Sb-124	632.4	0.001029
Ba-131	35.9	0.0373	Ba-133m	632.56	0.0001
Xe-133	35.9003	0.0178	Eu-152m	632.8	0.000011
Cs-131	35.98	0.00229	Sm-153	634.8	0.000005
Cs-134	36.3	0.000416	Sm-153	636.5	0.00000195
Cs-134	36.38	0.000803	As-76	639.5	0.000036
Ba-135m	36.4457	0.085	Eu-154	642.4	0.000044
Cs-134	37.26	0.000254	Eu-152	644.37	0.000063
Ba-135m	37.3317	0.022	Sb-124	645.852	0.07422
La-140	39.3258	0.00326	Eu-152m	646.9	0.000007
Eu-152m	39.52	0.061	Eu-154	649.44	0.00078
Eu-152	39.52	0.208	Eu-154	650.6	0.000098
Eu-154	39.52	0.00006	As-76	657.05	0.062
Eu-152m	40.12	0.11	Sm-153	657.21	0.0000037
Eu-152	40.12	0.377	Sm-153	657.55	0.0000037
Eu-154	40.12	0.0001	Ba-131	657.6	0.0000035
La-140	40.285	0.000828	Ag-110m	657.76	0.9438
Pa-233	40.35	0.000236	Sb-124	662.33	0.00024
Mo-99	40.58323	0.01022	Sm-153	662.4	0.0000007
Sm-153	40.9	0.1663	Eu-154	664.68	0.00029
Ca-47	41.06	0.000064	As-76	665	0.0004
Sm-153	41.54	0.3	As-76	665.34	0.0036
Pa-233	41.66	0.00024	Ag-110m	666.6	0.00028
Pa-233	41.663	0.00014	Eu-154	668.9	0.00013
Eu-152m	42.31	0.0003	Eu-152	671.16	0.000194
Eu-152	42.31	0.00243	Ba-131	674.43	0.00132
Eu-154	42.31	0.072	Eu-152	674.68	0.001871
Ta-182	42.71	0.00269	Ag-110m	676.58	0.0014
Eu-152m	43	0.00054	Eu-154	676.6	0.00157
Eu-152	43	0.00437	Sm-153	677	0.0000004
Eu-154	43	0.131	Ag-110m	677.62	0.1056
Np-239	44.663	0.0013	Eu-152	678.62	0.0047
Tb-160	45.2083	0.0598	Sm-153	682	0.0000015
Eu-152m	45.48	0.034	Tb-160	682.31	0.00596
Eu-152	45.48	0.1178	Eu-152	683.32	0.000031
Eu-154	45.48	0.00003	Eu-152m	684.85	0.000087
Tb-160	45.999	0.1069	Eu-152	686.61	0.0002
Eu-152m	46.7	0.0089	Ag-110m	687.01	0.0645
Eu-152	46.7	0.0304	Eu-152	688.67	0.00841
Eu-154	46.7	0.00001	Eu-152m	688.69	0.00065
Sm-153	47.11	0.0945	Mo-99	689.6	0.0000042
Sm-153	48.38	0.0244	Eu-154	692.42	0.01779
Eu-152m	48.77	0.00017	Sb-122	692.79	0.0371
Eu-152	48.77	0.00138	K-42	694	0.000032
Eu-154	48.77	0.041	Sm-153	694.1	0.0000002
Np-239	49.415	0.00145	As-76	695.2	0.00009

Eu-152m	50.09	0.000045	Ba-131	696.49	0.00145
Eu-152	50.09	0.000363	Eu-152	696.87	0.000029
Eu-154	50.09	0.0108	Br-82	698.374	0.284
Pa-233	51.8	0.000005	Eu-152m	699.27	0.0007
Tb-160	52.191	0.0343	Eu-152m	700.3	0.000106
Hf-175	52.9656	0.266	Sm-153	701.8	0.00000029
Tb-160	53.635	0.00892	Eu-152	703.25	0.000053
Hf-175	54.0704	0.467	Ba-131	703.44	0.000064
Hf-180m	54.08	0.0000613	Eu-152m	703.54	0.00066
Sm-153	54.19	0.000019	Eu-152m	703.7	0.000007
Hf-180m	54.61	0.0976	Ag-110m	706.68	0.1644
Ba-131	54.89	0.00102	Sm-153	706.8	0.00000023
Hf-180m	55.74	9.5E-09	Tb-160	707.6	0.0001
Hf-180m	55.79	0.17	Ag-110m	708.13	0.0023
Hf-181	56.278	0.0908	Sb-124	709.33	0.01363
Hf-180m	56.28	0.0000137	Eu-152	712.84	0.000961
Np-239	57.273	0.0012	Sb-124	713.776	0.02273
Np-239	57.3	0.00012	Sm-153	713.9	0.00000231
Hf-181	57.533	0.158	Ag-110m	714.9	0.000092
Hf-180m	57.54	0.0000238	Eu-154	715.77	0.0019
Hf-180m	57.56	0.48	Sm-153	719	0.00000025
Ta-182	57.98	0.1006	Eu-152	719.35	0.00327
Eu-154	58.4	0.000039	Sb-124	722.782	0.10708
Ta-182	59.32	0.1748	Eu-154	723.3	0.2005
Hf-175	61.355	0.154	As-76	727	0.000184
Np-239	61.46	0.0129	Eu-152	727.99	0.000106
Hf-180m	62.99	0.0187	Eu-152	735.4	0.000058
Hf-175	63.1233	0.0405	Br-82	735.6	0.0008
Hf-180m	63.24	0.036	Ga-72	735.75	0.00367
Hf-180m	63.66	0.00079	Sb-124	735.78	0.001312
La-140	64.129	0.00014	Eu-154	737.6	0.000063
Hf-180m	64.94	0.0124	Ga-72	738.5	0.00054
Hf-180m	64.95	0.00000264	Mo-99	739.5	0.1212
Hf-180m	65.13	0.00213	As-76	740.1	0.00117
Hf-180m	65.22	0.00000509	Ag-110m	744.28	0.04712
Hf-181	65.276	0.0525	Ba-131	745.5	0.000014
Hf-180m	65.65	0.000000115	La-140	751.653	0.04397
Ta-182	65.72	0.0297	Eu-152	756.12	0.000054
Hf-180m	66.98	0.00000175	Eu-154	756.8	0.0453
Hf-181	67.1733	0.0142	Ba-131	757	0.0000047
Hf-180m	67.18	0.000000271	Sm-153	760.5	0.00000032
Ta-182	67.29	0.0579	Mo-99	761.77	0.000023
Ta-182	67.75	0.436	Sm-153	763.8	0.00000044
Np-239	67.841	0.001	Ag-110m	763.94	0.2231
Sm-153	68.26	0.000013	Eu-152m	764.9	0.000004
La-140	68.923	0.00077	Eu-152	764.9	0.0019
Ta-182	69.27	0.0159	Tb-160	765.28	0.0214
Sm-153	69.67	0.04691	Sb-124	766.17	0.000103
Pa-233	75.27	0.0132	Ca-47	767	0.00195
Sm-153	75.42	0.00169	Zn-65	770.64	0.0000269
Ba-131	78.73	0.00735	As-76	771.74	0.0012
Xe-133	79.6142	0.0028	Ga-72	772	0.00043
Eu-154	80.4	0.000028	Eu-154	774.4	0.00008
Xe-133	80.9979	0.37	Ag-110m	774.7	0.00006
Eu-154	81.99	0.000031	Sb-124	775.27	0.000098
Ba-131	82.58	0.00014	Br-82	776.517	0.834
Sm-153	83.37	0.00193	Mo-99	777.921	0.0428

Ta-182	84.68	0.0262	Eu-152m	778.9	0.000019
Pa-233	86.6	0.0199	Eu-152	778.9	0.1297
Tb-160	86.787	0.132	Ba-131	785.92	0.000023
Np-239	88.06	0.00006	Ga-72	786.44	0.032
Hf-175	89.36	0.024	Eu-154	790.2	0.0001
Sm-153	89.49	0.00158	Sb-124	790.706	0.007415
Tc-99m	89.6	0.0000104	Sb-122	793.2	0.00011
Cu-67	91.266	0.07	Eu-152	794.81	0.000263
Pa-233	92.16	0.000024	Cs-134	795.86	0.8546
Br-82	92.184	0.0072	Eu-152m	796.1	0.000034
Ba-131	92.28	0.00585	As-76	797	0.000045
Cu-67	93.311	0.161	Ba-131	797.45	0.00036
Hf-180m	93.33	0.171	Eu-154	800.2	0.00032
Tb-160	93.919	0.000566	Eu-154	801.21	0.00012
Pa-233	94.66	0.091	Cs-134	801.95	0.08688
Sm-153	96.88	0.00007	Eu-152	805.7	0.000125
Sm-153	97.43	0.00769	Ca-47	807.85	0.068
Pa-233	98.43	0.146	As-76	809.8	0.000171
Np-239	99.525	0.135	Ga-72	810.2	0.02
Ta-182	100.11	0.1422	Eu-152m	810.45	0.00025
Hf-180m	100.7	0.00017	Eu-152	810.45	0.00317
Br-82	100.9	0.0007	Co-58	810.76	0.9944
Np-239	101.96	0.00008	Eu-154	815.53	0.00512
Sm-153	103.18	0.2919	La-140	815.784	0.2372
Np-239	103.734	0.214	Sb-124	817.15	0.000744
Pa-233	103.86	0.00854	Ag-110m	818.025	0.0733
Np-239	106.125	0.259	Mo-99	822.972	0.001321
Np-239	106.5	0.00049	Eu-152m	825.5	0.000007
La-140	109.417	0.00217	Eu-152m	826.01	0.000007
Ta-182	110.39	0.001073	Co-60	826.1	0.000076
Pa-233	111.227	0.0525	Br-82	827.828	0.241
Ga-72	112.52	0.00136	Ta-182	829.8	0.000141
Ga-72	113.5	0.00006	Eu-154	830.3	0.00008
Ta-182	113.67	0.01869	Ba-131	831.62	0.002279
Hf-175	113.81	0.0029	Ga-72	834.03	0.956
Pa-233	114.932	0.018	Mn-54	834.848	0.999752
Ta-182	116.42	0.00445	Eu-152	839.36	0.00016
Ag-110m	116.48	0.00008047	Ba-131	840.92	0.000019
Np-239	117.13	0.0784	Eu-152	841.57	0.00163
Eu-152m	117.3	0.000168	Eu-152m	841.63	0.142
Sm-153	118.11	0.0000023	Eu-152m	845.4	0.00009
Ag-110m	120.23	0.0001698	Eu-154	845.42	0.00586
Np-239	121.0173	0.0272	Cs-134	847	0.000003
Ta-182	121.5	0.000021	Eu-154	850.64	0.00241
Eu-152m	121.78	0.07	As-76	852.8	0.000022
Eu-152	121.78	0.2841	Sb-124	856.87	0.000227
Eu-154	123.07	0.404	Ga-72	861.11	0.0091
Ba-131	123.81	0.29	Mo-99	861.2	0.000007
Np-239	124.4	0.00016	As-76	863.8	0.000112
Eu-152	125.69	0.00019	Co-58	863.96	0.007
Fe-55	125.949	1.3E-10	Eu-152	867.38	0.0423
Ba-131	128.09	0.00014	As-76	867.64	0.0013
Br-82	129.4	0.00025	La-140	867.839	0.0558
Eu-154	129.5	0.00014	Eu-152m	870.13	0.00088
La-140	131.121	0.0047	Zn-69	871.7	0.0000025
Eu-154	131.58	0.000111	Tb-160	872.03	0.00218
Hf-181	133.021	0.433	Eu-154	873.18	0.1217

Ag-110m	133.33	0.000736	Ga-72	878.32	0.00073
Ba-131	133.61	0.0212	Tb-160	879.378	0.301
Eu-154	134.84	0.000072	Eu-154	880.6	0.00081
Hf-181	136.26	0.0585	As-76	882.13	0.00058
Hf-181	136.86	0.0086	Ag-110m	884.68	0.74
Br-82	137.23	0.0012	Sc-46	889.271	0.9998374
Ba-131	137.36	0.000374	Ta-182	891.97	0.00057
Mo-99	140.511	0.896	Eu-154	892.78	0.00514
Tc-99m	140.511	0.885	Ga-72	894.25	0.0987
Ag-110m	142.06	0.00026	Eu-154	898.36	0.00002
Ga-72	142.53	0.00011	Sb-124	899.32	0.000179
Fe-59	142.651	0.00978	K-42	899.39	0.00052
Mo-99	142.675	0.000211	Eu-152	901.18	0.00084
Tc-99m	142.683	0.00023	Eu-154	904.06	0.0089
Eu-154	146.05	0.00026	Eu-152	906.01	0.00016
Eu-152	148.01	0.00035	As-76	907.5	0.000018
Sb-124	148.02	0.000037	Ba-131	914.07	0.000463
Sm-153	151.62	0.0001033	Eu-152m	915.7	0.0001
Ta-182	152.43	0.0701	Eu-152	919.34	0.00429
Eu-152m	152.9	0.000014	La-140	919.533	0.0273
Eu-154	156.2	0.000098	Ba-131	919.6	0.000089
Ta-182	156.39	0.02662	Ba-131	923.87	0.00721
Ba-131	157.15	0.00176	Ga-72	924.22	0.00142
Mo-99	158.782	0.000145	Eu-154	924.63	0.00062
Sc-47	159.373	0.681	La-140	925.198	0.0704
Sb-124	159.867	0.000049	Eu-152	926.32	0.00273
Eu-154	159.9	0.00001	Ta-182	927.98	0.00614
Eu-152m	160	0.0000071	Eu-154	928.4	0.000045
Xe-133	160.612	0.00068	Eu-152	930.58	0.000729
Hf-175	161.3	0.00023	Eu-152	937.05	0.000027
Eu-154	162.09	0.000011	Ag-110m	937.49	0.3451
Mo-99	162.37	0.000114	Ga-72	938.4	0.00076
Eu-154	165.9	0.000025	Ga-72	939.36	0.00259
Np-239	166.39	0.00016	La-140	950.988	0.00531
Sm-153	166.55	0.000006	Br-82	951.95	0.0038
Sm-153	172.3	0.000004	As-76	954.6	0.000018
Sm-153	172.85	0.000736	Ba-131	954.61	0.000328
La-140	173.546	0.00126	Ag-110m	957.35	0.000093
Tb-160	176.49	0.000062	As-76	957.6	0.000018
Ta-182	179.39	0.03099	Eu-152	958.63	0.00021
Eu-154	180.7	0.00004	Ta-182	959.72	0.00348
Mo-99	181.068	0.0601	Mo-99	960.754	0.00095
Np-239	181.7	0.00086	Eu-152m	961.06	0.00198
Cu-67	184.577	0.49	Tb-160	962.311	0.0981
Eu-154	184.72	0.000037	Eu-152m	963.39	0.117
Eu-154	188.24	0.00239	Eu-152	963.39	0.001341
Sb-124	189.57	0.000043	Eu-152	964.08	0.145
Eu-152m	191.6	0.0000073	Tb-160	966.16	0.251
Fe-59	192.349	0.0291	Sb-124	968.195	0.01887
Eu-152	192.6	0.000068	Ba-131	968.94	0.000365
Eu-154	195.5	0.00002	Eu-152m	970.35	0.0059
Eu-154	197	0.000016	Ga-72	970.55	0.011
Tb-160	197.034	0.0518	Eu-152	974.09	0.000138
Ta-182	198.35	0.01461	Ga-72	975.5	0.00033
Eu-154	202.5	0.0003	Sb-124	976.25	0.000832
Eu-152	207.64	0.000059	As-76	980.9	0.00041
Cu-67	208.95	0.00115	Eu-154	981.3	0.000084

Eu-154	209.4	0.000023	Eu-154	984.5	0.000094
Eu-152	209.41	0.000055	Mo-99	986.44	0.000014
Np-239	209.753	0.0342	Eu-152	990.19	0.000315
Sb-124	210.4	0.000053	La-140	992.64	0.0001
Eu-152	212.57	0.000196	Eu-152m	995.87	0.00068
Hf-180m	215.26	0.813	Eu-154	996.25	0.105
Tb-160	215.645	0.0402	Na-24	996.86	0.0000145
Ba-131	216.08	0.1966	Ag-110m	997.24	0.00128
Eu-152m	218.1	0.00000044	Sb-124	997.8	0.000033
Ag-110m	219.35	0.00072	Ga-72	999.86	0.00798
Eu-154	219.4	0.000023	Eu-152	1001.1	0.000046
Eu-152m	220.8	0.0000013	Mo-99	1001.343	0.000043
Ag-110m	221.08	0.0006814	Ta-182	1001.69	0.0207
Br-82	221.48	0.0227	Tb-160	1002.88	0.01038
Ta-182	222.11	0.0754	Eu-154	1004.76	0.1786
Xe-133	223.2368	0.0000017	Tb-160	1005	0.00039
Np-239	226.383	0.00255	Eu-152	1005.27	0.00665
Np-239	227.834	0.005	Br-82	1007.54	0.0127
Np-239	228.183	0.1132	Eu-154	1012.8	0.00003
Pa-233	228.57	0.000042	Mo-99	1017	0.000007
Eu-154	229.01	0.000024	Ag-110m	1018.95	0.000141
Ta-182	229.32	0.03634	K-42	1022.71	0.00025
Ag-110m	229.423	0.0001191	Eu-154	1023	0.000066
Hf-175	229.6	0.0068	Ga-72	1032.3	0.00065
Ga-72	230.6	0.00023	Eu-154	1033.4	0.000119
Tb-160	230.628	0.000807	Ta-182	1035.8	0.00006
Eu-154	232.01	0.00024	Ba-131	1037	0.0000047
Cs-134	232.6	0.000005	Ga-72	1037.2	0.00021
Xe-133m	233.219	0.1012	Cs-134	1038.61	0.0099
Eu-154	237	0.00006	Eu-152m	1039.2	0.000081
Eu-152	237.31	0.000025	Br-82	1044.002	0.275
Tb-160	237.64	0.00006	Ta-182	1044.4	0.002381
Eu-152	239.42	0.00008	La-140	1045.02	0.0002
Ba-131	239.63	0.0241	Sb-124	1045.125	0.01825
Tb-160	239.7	0.000021	Ba-131	1046.4	0.0009
La-140	241.959	0.00436	Eu-154	1047.4	0.00049
Mo-99	242.29	0.000014	Ba-131	1047.6	0.01324
Tb-160	242.5	0.0000075	Eu-154	1049.4	0.000172
Cs-134	242.76	0.000241	Ga-72	1050.69	0.0691
Eu-152m	244.7	0.00025	Sb-124	1053.9	0.000053
Eu-152	244.7	0.0755	Mo-99	1056.2	0.0000103
Tb-160	246.481	0.000208	As-76	1060.6	0.000018
Ba-131	246.89	0.00632	Tb-160	1069.09	0.000999
Eu-154	247.93	0.0689	Eu-154	1072.2	0.000035
Pa-233	248.38	0.000609	Mo-99	1072.2	0.000012
Mo-99	249.03	0.000035	Br-82	1072.6	0.0007
Ba-131	249.43	0.0281	Rb-86	1076.8	0.0871
Eu-152	251.63	0.00067	Br-82	1081.3	0.0063
Np-239	254.404	0.0011	Eu-152	1084	0.00244
Sb-124	254.42	0.000142	Ag-110m	1085.44	0.00072
Eu-152m	256.99	0.00001	Eu-152	1085.84	0.1013
Pa-233	258.45	0.000274	Sb-124	1086.67	0.000367
Eu-154	260.9	0.000022	Eu-152	1089.74	0.0173
Ta-182	264.07	0.03602	Sb-122	1095	0.0011
La-140	266.554	0.00492	La-140	1097.58	0.00023
Eu-152m	266.91	0.000011	As-76	1098.2	0.000036
Ag-110m	266.913	0.00041	Fe-59	1099.245	0.5651

Eu-154	267.44	0.000136
Ba-135m	268.227	0.16
Eu-154	269.8	0.00007
Eu-152	269.86	0.00006
Eu-152m	271.06	0.00076
Eu-152	271.13	0.00078
Pa-233	271.55	0.00323
Eu-152m	272.41	0.000101
Np-239	272.84	0.00077
Br-82	273.47	0.0081
Eu-154	274	0.000039
Eu-152	275.45	0.000323
Ba-133m	275.925	0.178
Np-239	277.599	0.144
Eu-154	279.9	0.00003
Pa-233	280.61	0.00011
Np-239	285.46	0.0078
Eu-152	285.98	0.0001
Ba-133m	288	0.0000006
Pa-233	288.42	0.00016
Ga-72	289.31	0.00191
Eu-154	290	0.000033
Sb-124	291.79	0.000069
Ba-131	294.52	0.00166
Eu-154	295.7	0.000024
Eu-152	295.94	0.00442
Eu-154	296	0.000014
Tb-160	297.3	0.00009
Tb-160	298.57	0.261
Pa-233	298.81	0.0012
Pa-233	300.13	0.0663
Cu-67	300.217	0.008
Eu-154	301.25	0.000102
Pa-233	301.99	0.0001
As-76	302.2	0.00009
Xe-133	302.8508	0.000058
Eu-154	305.1	0.000174
Ga-72	306	0.00021
La-140	307.08	0.00022
Eu-154	308.2	0.000024
Tb-160	309.561	0.00863
Np-239	311.7	0.00002
Pa-233	311.9	0.385
Eu-154	312.3	0.00018
K-42	312.746	0.0032
Eu-152	315.17	0.000496
Eu-154	315.4	0.00007
Np-239	315.88	0.0159
Eu-152	316.2	0.000031
Ga-72	317.5	0.00022
Zn-69	318.4	0.000012
Hf-175	318.9	0.0017
Eu-154	320	0.00001
Eu-152	320.03	0.000017
Cr-51	320.0835	0.0989
Pa-233	320.73	0.000051
Eu-154	322.02	0.00066
Tb-160	1102.6	0.00582
Eu-152m	1109.17	0.0000028
Eu-152	1109.17	0.00186
Eu-154	1110	0.00003
Eu-152	1112.08	0.1341
Ta-182	1113.41	0.00442
Tb-160	1115.12	0.0157
Zn-65	1115.539	0.5022
Eu-152m	1116	0.00001
Ag-110m	1117.46	0.000488
Eu-154	1118.52	0.00108
Sc-46	1120.537	0.9997
Ta-182	1121.29	0.3517
Eu-154	1124.2	0.000069
Ag-110m	1125.7	0.000304
Ba-131	1125.97	0.000027
Eu-154	1128.55	0.00317
As-76	1129.87	0.00126
As-76	1130	0.00018
Eu-154	1136.1	0.00007
Eu-152m	1137.5	0.00013
Eu-152	1139	0.000013
Sb-122	1140.46	0.0074
Eu-154	1140.7	0.00235
Eu-154	1153.1	0.00011
Ga-72	1155.7	0.0001
Ta-182	1157.3	0.0083
Ta-182	1158.07	0.00295
Eu-154	1160.36	0.000436
Ga-72	1163.12	0.00074
Ag-110m	1163.14	0.00074
Ag-110m	1164.95	0.00043
Cs-134	1167.97	0.0179
Eu-152m	1168.16	0.0006
Ba-131	1170.53	0.000016
Eu-154	1170.7	0.000036
Eu-152	1170.93	0.000365
Co-60	1173.228	0.9985
Br-82	1173.3	0.0011
Tb-160	1177.954	0.149
Br-82	1180.2	0.0012
Ta-182	1180.82	0.000869
Ag-110m	1186.7	0.000001607
Sb-122	1188	0.000005
Eu-154	1188.34	0.00093
Ta-182	1189.04	0.1658
Ga-72	1192.4	0.00035
Tb-160	1199.89	0.0238
Eu-152	1206.11	0.000135
Eu-152m	1207.3	0.00003
Ba-131	1208.43	0.000017
As-76	1212.92	0.0144
Eu-152	1212.95	0.01416
Ga-72	1215.15	0.0079
As-76	1216.08	0.0342
Eu-154	1216.8	0.000033
Ba-131	1218.3	0.0000047

Np-239	322.3	0.000052
Eu-152	324.83	0.000738
Cs-134	326.585	0.000171
La-140	328.761	0.208
Eu-152	329.43	0.00129
Eu-154	329.9	0.000091
Eu-152	330.54	0.00006
Hf-180m	332.28	0.941
Br-82	333.2	0.00001
Np-239	334.61	0.0204
Fe-59	335	0.0026
Sb-124	335.8	0.000725
Ga-72	336.63	0.00107
Tb-160	337.32	0.00339
Eu-152m	340.1	0.00005
Eu-152	340.4	0.00031
Pa-233	340.48	0.0445
Ag-110m	341.3	0.000022
Hf-175	343.4	0.84
Eu-152	344.28	0.2659
Eu-152m	344.31	0.024
Zn-65	344.95	0.0000254
Hf-181	345.93	0.1512
Eu-154	346.72	0.00029
Co-60	347.14	0.000075
Tb-160	349.92	0.000144
Ta-182	351.02	0.0001157
Ba-131	351.2	0.00091
Eu-152	351.66	0.00014
Hf-175	353.3	0.00228
Eu-152	357.26	0.00004
As-76	358.4	0.000135
Ag-110m	360.23	0.00008
Ag-110m	365.448	0.00092
Mo-99	366.421	0.01194
Eu-152	367.79	0.00862
Eu-154	368.21	0.00003
Ba-131	369.12	0.00014
Sb-124	370.27	0.000286
Eu-154	370.71	0.000056
Ba-131	373.25	0.1404
Eu-154	375.2	0.00002
Pa-233	375.4	0.00679
Eu-152	379.37	0.0000083
Tb-160	379.41	0.000141
Mo-99	380.13	0.000091
Pa-233	380.28	0.000037
Ga-72	381.24	0.00273
Eu-154	382	0.000099
Fe-59	382.46	0.000215
Xe-133	383.8485	0.000028
Eu-152	385.69	0.00005
Ag-110m	387.07	0.000518
Eu-152m	387.8	0.0000071
Eu-152	387.9	0.0000296
Ba-131	390.05	0.000019
Eu-152	391.32	0.0000125
Ta-182	1221.4	0.2727
Ta-182	1223.79	0.00204
K-42	1227.7	0.000023
As-76	1228.52	0.0122
Ga-72	1230.86	0.0145
Ta-182	1231	0.1162
Eu-154	1232.1	0.00008
Sb-124	1235	0.000073
Eu-154	1241.43	0.00133
Eu-154	1246.12	0.00862
Eu-152	1249.94	0.00186
Ag-110m	1250.97	0.00026
Tb-160	1251.27	0.0106
Sb-122	1256.91	0.0078
Ta-182	1257.41	0.01511
Ga-72	1260.1	0.0113
Eu-152	1261.34	0.000336
Sb-124	1263.45	0.000422
Tb-160	1271.873	0.0744
Ta-182	1273.72	0.00658
Eu-154	1274.43	0.349
Ga-72	1276.76	0.0156
Tb-160	1285.58	0.000154
Ta-182	1289.15	0.01374
Eu-152m	1290	0.0000089
Eu-154	1290.5	0.00025
Ga-72	1291.3	0.00056
Fe-59	1291.59	0.4323
Eu-154	1292	0.000127
Eu-152	1292.78	0.00104
Eu-154	1295.5	0.000091
Ca-47	1297.09	0.075
Eu-152	1299.14	0.01633
Tb-160	1299.3	0.000054
Ag-110m	1300.07	0.000189
Sb-124	1301.14	0.000364
La-140	1303.34	0.00045
Tb-160	1312.14	0.0286
Eu-152m	1314.67	0.0093
Eu-152	1314.7	0.000048
Eu-154	1316.4	0.00017
Br-82	1317.476	0.27
Sb-124	1325.504	0.01587
Co-60	1332.49	0.999826
Ag-110m	1334.34	0.001412
Ba-131	1341.88	0.0000108
Ta-182	1342.72	0.002562
Cu-64	1345.77	0.004784
Eu-152	1348.1	0.000175
Sb-124	1355.2	0.010412
Eu-152	1363.77	0.000256
Cs-134	1365.19	0.03017
Sb-124	1368.157	0.0262
Na-24	1368.63	0.999934
Ta-182	1373.82	0.00226
Sb-124	1376.1	0.004999
Ag-110m	1384.3	0.247

Mo-99	391.7	0.000025	Sb-124	1385.49	0.00062
Np-239	392.4	0.000016	Eu-154	1387	0.00019
Tb-160	392.514	0.0134	Ta-182	1387.39	0.000725
Cu-67	393.527	0.002	Eu-152m	1389	0.0075
Ag-110m	396.895	0.00037	Eu-152	1390.36	0.000048
Eu-154	397.1	0.00029	Ga-72	1390.42	0.00085
La-140	397.674	0.00075	Eu-154	1397.4	0.000031
Pa-233	398.49	0.01391	La-140	1404.66	0.00062
Sb-124	399.97	0.001264	Eu-152m	1406.5	0.000007
Br-82	401.15	0.001	Eu-152	1408.01	0.2085
Eu-154	401.26	0.00189	Eu-154	1408.5	0.00023
Ga-72	401.3	0.00032	Ta-182	1410.14	0.0004
As-76	403.2	0.00024	Eu-152m	1411.7	0.00044
Eu-154	403.55	0.00026	Eu-154	1415	0.0004
Ba-131	404.05	0.0131	Eu-154	1418.6	0.00011
Eu-152	406.74	0.0000083	Eu-154	1419	0.00002
Ag-110m	409.4	0.000126	Eu-152m	1420	0.0000057
Mo-99	410.27	0.000016	Eu-154	1425.9	0.000012
Eu-152	411.12	0.02238	Sb-124	1436.554	0.01234
Mo-99	411.491	0.000161	As-76	1439.1	0.00279
Eu-152m	412	0.0000073	Sb-124	1445.09	0.00334
Sm-153	412.05	0.0000191	Ta-182	1453.11	0.00037
Eu-154	414.3	0.000049	Eu-152	1457.64	0.00498
Pa-233	415.764	0.01747	Eu-152m	1460.64	0.000016
Eu-152	416.05	0.00109	Ga-72	1464	0.0355
Eu-154	419.4	0.000034	Tb-160	1468.6	0.0000057
Eu-154	422.1	0.000022	Br-82	1474.884	0.164
Eu-152	423.45	0.000032	Ag-110m	1475.79	0.04017
Sm-153	424.4	0.0000195	Fe-59	1484.7	0.00059
Ba-131	427.57	0.000955	Sb-124	1488.94	0.00677
Ga-72	428.42	0.00197	Eu-154	1489.6	0.000029
Np-239	429.5	0.000039	Eu-154	1494.05	0.00698
La-140	432.513	0.03	Ga-72	1500.9	0.00019
Tb-160	432.66	0.000232	Ag-110m	1505.04	0.1316
Hf-175	433	0.0144	Eu-154	1510	0.000048
Np-239	434.7	0.00013	Eu-152m	1510.83	0.000064
Eu-154	435.9	0.000038	Ga-72	1519.4	0.00031
Sm-153	436.9	0.0000158	Eu-154	1522	0.000006
As-76	437.3	0.000013	K-42	1524.665	0.179
La-140	438.178	0.00017	Sb-124	1526.48	0.00414
Eu-152	440.86	0.000133	Eu-152	1528.1	0.00281
Hf-180m	443.09	0.819	Eu-154	1531.4	0.00006
Sm-153	443.2	0.0000041	Eu-154	1537.81	0.00053
Eu-152m	443.96	0.00025	Ga-72	1541.2	0.00016
Eu-152	443.97	0.0312	Eu-154	1554	0.000011
Sb-124	444	0.00195	Tb-160	1556.6	0.0000048
Eu-154	444.49	0.0056	Eu-152m	1558.73	0.000078
La-140	444.57	0.00003	Ag-110m	1562.3	0.0121
Ag-110m	446.81	0.0365	Sb-124	1565.97	0.000109
Np-239	447.6	0.0000026	Ga-72	1568.1	0.002
Ga-72	449.55	0.00094	Ga-72	1571.6	0.0082
Ba-131	451.42	0.000407	Sb-124	1579.65	0.00412
Np-239	454.2	0.0000082	Ag-110m	1592.76	0.0002091
Pa-233	455.96	0.000011	La-140	1596.203	0.954
As-76	456.9	0.00036	Eu-154	1596.48	0.01783
Mo-99	457.6	0.000074	Ga-72	1596.68	0.0423
Ba-131	461.26	0.00056	Eu-152	1605.61	0.000081

Np-239	461.9	0.000016	Eu-152	1608.36	0.000053
Sm-153	462	0.0000158	Ga-72	1613.6	0.00039
Ba-131	462.68	0.00047	Sb-124	1622.1	0.000416
Sm-153	463.6	0.000127	Ag-110m	1629.69	0.00005773
Eu-154	463.9	0.000042	Ga-72	1630	0.00032
As-76	466.5	0.00004	Eu-152	1643.6	0.0000015
Ag-110m	467.03	0.000249	Eu-152	1647.41	0.000064
Eu-154	467.84	0.000604	Br-82	1650.339	0.0075
Sb-124	468.84	0.000459	Eu-154	1667.3	0.000019
Mo-99	469.63	0.000027	Eu-154	1674	0.000017
Np-239	469.8	0.000011	Eu-152	1674.3	0.00006
As-76	472.8	0.00049	Co-58	1674.7	0.0053
Ba-131	474.2	0.000023	Eu-152m	1680.52	0.000052
Cs-134	475.365	0.01479	Ga-72	1680.77	0.009
Hf-181	475.99	0.00703	Sb-124	1690.971	0.4746
Eu-154	478.27	0.00224	Ag-110m	1698.58	0.00001798
Ga-72	479.23	0.00091	Ga-72	1710.9	0.00388
Ba-131	480.41	0.00328	Ga-72	1711.15	0.00045
Eu-154	480.61	0.000048	Eu-154	1716	0.000006
Sb-124	481.36	0.000232	Sb-124	1720.67	0.000946
Hf-181	482.18	0.805	Sb-122	1752.8	0.00007
Eu-152	482.31	0.0002929	Eu-152m	1755.94	0.000026
Zn-69m	483.634	0.9477	Eu-152	1769.09	0.000092
Eu-154	483.74	0.00005	Ag-110m	1775.43	0.00006341
Np-239	484.3	0.00001	Br-82	1779.58	0.00116
Eu-154	484.64	0.000039	Ag-110m	1783.47	0.00009938
As-76	484.8	0.000058	As-76	1787.66	0.00292
Sm-153	485	0.0000038	K-42	1837.28	0.000097
Tb-160	486.06	0.000846	Ga-72	1837.6	0.00209
Ba-131	486.52	0.02087	Eu-154	1838	0.000008
La-140	487.022	0.461	Sb-124	1852.22	0.00003
Sm-153	487.75	0.0000036	Ga-72	1861.09	0.0525
Eu-154	488.26	0.00007	La-140	1877.33	0.00041
Eu-152	488.68	0.00414	Ga-72	1877.9	0.00231
Ca-47	489.23	0.069	Ca-47	1878	0.00029
Np-239	492.3	0.00006	Ag-110m	1903.53	0.000147
Ag-110m	493.43	0.000095	Sb-124	1918.74	0.000529
Eu-152	493.51	0.000368	Ga-72	1920.2	0.00158
Ga-72	495.88	0.00056	K-42	1922.16	0.00041
Ba-131	496.33	0.468	La-140	1924.5	0.00011
Eu-152	496.4	0.000042	Ga-72	1991.3	0.00112
Np-239	497.8	0.000032	Ag-110m	2004.72	0.00001041
Np-239	498.7	0.00001	Sc-46	2009.785	0.00000013
Hf-180m	500.64	0.143	Sb-124	2016.34	0.000098
Eu-152	503.47	0.00153	Ga-72	2029.4	0.00123
Np-239	504.2	0.0000078	Sb-124	2039.27	0.000631
Ba-131	506.1	0.000019	Sb-124	2079.75	0.000224
Eu-154	506.4	0.000063	La-140	2083.219	0.00036
Sm-153	509.15	0.000019	Sb-124	2090.93	0.05493
Eu-154	510	0.00059	As-76	2096.3	0.0055
Co-58	511	0.2988	Sb-124	2098.88	0.000471
Cu-64	511	0.3504	Sb-124	2108.27	0.000444
Eu-152m	511	0.0001	Ga-72	2109.5	0.0104
Fe-59	511	0.0000115	As-76	2110.8	0.0033
Eu-152	511	0.00054	Co-60	2158.57	0.000012
Mn-54	511	0.0000006	Sb-124	2172.32	0.000029
Na-24	511	0.00144	Sb-124	2182.37	0.000415

Sb-122	511	0.000126
Sc-46	511	0.0000034
Y-90	511	0.000068
Zn-65	511	0.02842
Eu-154	512	0.000032
Ba-131	517.5	0.000014
Eu-154	518	0.00047
Eu-152	520.23	0.000536
Ga-72	520.74	0.00055
Sm-153	521.3	0.000067
Eu-152	523.13	0.000113
Sb-124	525.36	0.001451
Eu-152	526.88	0.000129
Mo-99	528.788	0.000541
Ca-47	530.4	0.00095
Sb-124	530.46	0.00036
Sm-153	531.4	0.000544
Eu-154	533.1	0.00011
Sm-153	533.2	0.000294
Ba-131	533.7	0.000014
Eu-152	534.25	0.000368
Eu-152	535.4	0.00006
Mo-99	537.79	0.000015
Eu-152	538.29	0.000042
Sm-153	539.1	0.000207
Sm-153	542.7	0.0000234
Ag-110m	544.55	0.00018
Eu-154	545.6	0.000014
Sm-153	545.75	0.000009
Ba-131	546.28	0.000035
Eu-152m	547.35	0.000092
Ba-131	550.39	0.000022
Br-82	554.348	0.706
Sm-153	554.95	0.000047
Eu-152	556.56	0.000177
Eu-154	557.58	0.00267
Eu-152	557.91	0.000044
As-76	559.1	0.45
Eu-152	561.26	0.0000108
Ba-131	562.87	0.000036
Eu-152m	562.93	0.0022
Eu-152	562.93	0.00038
As-76	563.23	0.012
Cs-134	563.246	0.08342
Eu-154	563.4	0.0000028
Eu-152	563.99	0.00457
Sb-122	564.09	0.7055
Y-90	2186.254	0.000000014
Ga-72	2201.66	0.259
Ga-72	2214.3	0.00178
Sb-124	2283.62	0.000059
Sb-124	2293.69	0.000327
Sb-124	2323.39	0.000025
La-140	2347.847	0.00845
Ga-72	2402.2	0.00024
Ga-72	2404.3	0.00015
K-42	2424.17	0.00021
Sb-124	2454.93	0.000016
La-140	2464.031	0.000097
Ga-72	2490.98	0.077
Co-60	2505.69	0.00000002
Ga-72	2507.78	0.128
Ga-72	2515	0.0025
La-140	2521.39	0.00341
La-140	2547.18	0.00102
Ga-72	2583.4	0.00014
Ga-72	2605.5	0.00018
Ga-72	2621.06	0.00132
Ga-72	2633.9	0.00015
Sb-124	2682.47	0.000000176
Sb-124	2693.65	0.000032
Na-24	2754.049	0.99862
Ga-72	2785.1	0.0003
Sb-124	2807.52	0.000012
Ga-72	2844	0.0043
Na-24	2869.38	0.0000025
Ga-72	2897.1	0.000048
La-140	2899.53	0.00066
Ga-72	2939.6	0.0001
Ga-72	2942.4	0.00026
Ga-72	2950	0.00004
Ga-72	2981.14	0.00055
Ga-72	3034.6	0.00046
Ga-72	3067	0.0003
Ga-72	3093.7	0.00017
La-140	3118.49	0.00026
La-140	3319.52	0.000039
Ga-72	3324.6	0.00003
Ga-72	3338.3	0.0003
Na-24	3866.12	0.00066
Na-24	4327.84	0.0000084

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Abstract max. 2000 characters	Current developments have increased focus on the use of nuclear weapons and it is imperative that countries improve their capacity to respond to incidents within their borders and where assistance is requested by another state. The TEMEDET activity addresses technical challenges posed in responding to the detonation of a nuclear device. Measurement of contamination is fundamental in response to any event involving nuclear or radioactive material. In many countries, “response” and the metrological approaches involved have been developed within the context of nuclear accidents in the conventional sense or dispersal of limited suites of isotopes (dispersal devices etc). Nuclear detonations generate suites of isotopes that are, for many, outside of their experience and that can present challenges. TEMEDET addresses some aspects of this problem and aims to provide a means of practicing metrological response to a nuclear detonation through the development of a series of gamma spectrometric data sets of the type that may be generated in responding to a nuclear incident that will reflect the complexities involved in nuclear detonations.
Key words	Gamma spectrometry, nuclear weapons, fallout

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