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ORNL/TM-2013/161

ORNL-ARN Enrichment Measurement Capability Assessment

April 2013

Prepared by

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ORNL/TM-2013/161

Nuclear Security and Isotope Technology Division

ORNL - ARN ENRICHMENT MEASUREMENT CAPABILITY ASSESSMENT

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CONTENTS

Page

LIST OF FIGURES v
LIST OF TABLES vii
ABSTRACT 1
1. INTRODUCTION 1
2. MEASUREMENT DESCRIPTION 1
3. RESULTS 4
4. CONCLUSION 9
APPENDIX A A-1
APPENDIX B A-5

LIST OF FIGURES

Figure **Page**

Fig. 1. Enrichment results using a CZT detector and WinU235 software. 6
Fig. 2. Enrichment results using a NaI detector and WinU235 software. 6
Fig. 3. Enrichment results using a NaI detector and NaIGEM software. 7
Fig. 4. Enrichment results using an HPGe detector and MGAU software. 7
Fig. 5. Enrichment results using an HPGe detector and WinUF6 software. 8
Fig. 6. Enrichment results using an HM-5 running NaIGEM software. 8

LIST OF TABLES

Table **Page**

Table 1. SRM-969 standards.....**Error! Bookmark not defined.**
Table 2. Measurement systems (hardware/software) used for enrichment measurements 2
Table 3. Hardware used for enrichment measurements 3
Table 4. Summary of ORNL and ARN measurement results 4

ABSTRACT

In 2012, nondestructive assay experts from Oak Ridge National Laboratory (ORNL) and the Argentine Nuclear Regulatory Authority (ARN) completed a series of comparative enrichment measurements in support of the safeguards cooperation agreement between the US Department of Energy and the ARN. The measurements were performed on SRM-969 uranium standards in October and November 2012 by ORNL and ARN staff at their respective facilities to verify the nondestructive assay measurement expertise and capabilities of nuclear safeguards staff and technicians. A total of sixty measurements using a combination of 7 detector/software systems were performed on these low-enriched uranium standards. The measurement specifics and results are presented in this report. In most cases, the measurement results agreed within the measurement uncertainty of each institution and the declared enrichments of the standards; thus they confirm the technical capability of the ORNL and ARN staff.

1. INTRODUCTION

In 1994, the US Department of Energy (DOE) and the Argentine Nuclear Regulatory Authority (ARN) signed a safeguards cooperation agreement that provides for research and development in nuclear material control, accountancy, verification, physical protection and advanced containment and surveillance technologies for international safeguards applications. The scope of work for specific projects and activities are defined in documents named action sheets. Action sheet 16: "Nondestructive Assay Technician Training and Technical Support" was signed in 2006 to provide for cooperation in enhancing and maintaining the competency and training capabilities of ARN's technicians and safeguards staff in nondestructive assay (NDA) measurement methods, techniques, and systems.

In pursuant to the scope of work defined in Action Sheet 16, NDA experts from Oak Ridge National Laboratory (ORNL) provided technical support in developing instructional materials, and in the execution of an enrichment training program and laboratory exercises. Upon completion of Action Sheet 16, ARN will use the instructional materials to meet future safeguards training and measurement requirements. To assess the capability of ARN technicians and safeguards staff in performing these NDA enrichment measurements, ARN and ORNL performed a series of independent measurements of SRM-969 uranium standards (ARN received these standards under action sheet 15). This report outlines the results of the measurement campaign.

2. MEASUREMENT DESCRIPTION

Each laboratory completed independent measurements of all National Bureau of Standards SRM-969 standards using various hardware and software combinations. The SRM-969 standard specifications are listed in Table 1.

The measurement systems (hardware/software combinations) used for comparison are listed in Table 2. Discrepancies in the hardware used or software versions used for analysis of the standards are specified in footnotes to the table. For each measurement, when applicable, the enrichment, uncertainty, and spectrum were recorded. Although longer measurements may be performed in practice, 5 minute measurements were performed during this measurement campaign.

Table 3 provides pictures of the hardware used by ORNL and ARN for the measurements described in Table 2. Additional information related to the detector/MCA (multichannel analyzer) settings for each measurement scenario is provided in Appendix A.

With the exception of the cadmium-zinc-telluride (CZT) detector, similar equipment was used by both organizations. With respect to the CZT detectors, ORNL used the spectrometric detector probe (SDP 310/Z/LC/60S) and ARN used the Ritec 500. The SDP detector used by ORNL has a sensitive volume of between 50 and 60 mm^3, whereas the Ritec model used by ARN has a sensitive volume of approximately 500 mm^3. The difference in CZT crystal size (and collimators), and therefore efficiency, is reflected in the results and uncertainties for these measurement scenarios. These results are discussed in more detail in Section 3.

Table 1. SRM-969 standards

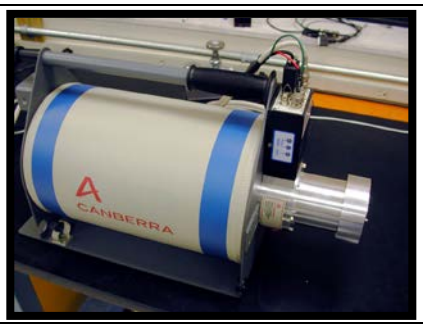
Source ID	Declared Enrichment (wt%)	Uncertainty
NBS-031-078	0.317	0.002
NBS-071-078	0.7119	0.005
NBS-194-078	1.942	0.001
NBS-295-078	2.949	0.002
NBS-446-078	4.4623	0.0032

Table 2. Measurement systems (hardware/software) used for enrichment measurements

Software	Version	Detector	MCA	Function
WinU235	1.00.0011[1]	NaI	GBS MCA-166	Spectrum acquisition and enrichment measurement
NaIGEM	1.52b			
WinU235	1.00.0011[1]	CZT-500[2]		Spectrum acquisition and enrichment measurement
NaIGEM	1.52b			
WinUF6	1.01.0000	HPGe		Spectrum acquisition and enrichment measurement
WinSpec	2.02.0002[3]			Spectrum acquisition
MGAU	3.21[4]			Spectrum acquisition and enrichment measurement
NaIGEM for HM-5		HM-5		Spectrum acquisition and enrichment measurement

[1]ARN used WinU235 v 1.01.0000.
[2]ORNL used a spectrometric detection probe model 310/Z/LC/60S CZT detector instead of the models listed above.
[3]ARN used WinSpec v 2.02.0004.
[4]ARN used MGAU v 4.0.

Table 3. Hardware used for enrichment measurements

ORNL hardware	ARN hardware
GBS Elektronik GmbH MCA-166 (MMCA)	
1 × 2 in. EFC NaI detector paired with the MMCA	
	
Canberra GL0515R HPGe detector paired with the MMCA	
SDP 310/Z/LC/60S CZT detector paired with the MMCA and used with W collimator	**Ritec CZT 500 paired with the MMCA and used with Pb collimator**
Thermo (now FLIR) HM-5 with W collimator	

3. RESULTS

The results of the round-robin enrichment measurement campaign are given in Table 4. The hardware/software packages are identified, as well as the declared enrichments of the SRM-969 standards. The term "cal" in the results table indicates that the standard was used to calibrate the system. The measurement uncertainties are also reported in the table.

Table 4. Summary of ORNL and ARN measurement results

			CZT - WinU235			
			ORNL		ARN	
Source ID	Declared Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.
NBS-031	0.317	0.002	0.2105	0.115	0.316	0.0445
NBS-071	0.7119	0.005	cal	cal	cal	cal
NBS-194	1.942	0.001	2.1069	0.1435	1.937	0.0728
NBS-295	2.949	0.002	2.8949	0.1647	2.9516	0.0928
NBS-446	4.4623	0.0032	cal	cal	cal	cal
			NaI - WinU235			
			ORNL		ARN	
Source ID	Declared Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.
NBS-031	0.317	0.002	0.3486	0.054	0.2895	0.057
NBS-071	0.7119	0.005	cal	cal	cal	cal
NBS-194	1.942	0.001	1.9568	0.0022	1.9327	0.0854
NBS-295	2.949	0.002	2.937	0.0996	2.9866	0.1048
NBS-446	4.4623	0.0032	cal	cal	cal	cal
			NAI – NaIGEM			
			ORNL		ARN	
Source ID	Declared Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Absolute Error [%]	Measured Enrichment (wt%)	Absolute Error [%]
NBS-031	0.317	0.002	0.321	0.04	0.316	0.049
NBS-071	0.7119	0.005	0.765	0.044	0.72	0.054
NBS-194	1.942	0.001	2.051	0.058	1.931	0.063
NBS-295	2.949	0.002	2.933	0.058	2.948	0.075
NBS-446	4.4623	0.0032	cal	cal	cal	cal

Table 4. Summary of ORNL and ARN measurement results (continued)

			HPGe - MGAU			
			ORNL		ARN	
Source ID	Declared Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.
NBS-031	0.317	0.002	0.294	0.093	0.3588	0.0771
NBS-071	0.7119	0.005	0.762	0.07	0.7571	0.0636
NBS-194	1.942	0.001	2.004	0.063	1.9117	0.0588
NBS-295	2.949	0.002	3.035	0.07	2.9755	0.0635
NBS-446	4.4623	0.0032	4.541	0.085	4.4798	0.0764
			HPGe - WinUF6			
			ORNL		ARN	
Source ID	Declared Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Unc.
NBS-031	0.317	0.002	0.31	0.0119	0.3266	0.0116
NBS-071	0.7119	0.005	cal	cal	cal	cal
NBS-194	1.942	0.001	1.9226	0.0517	1.9426	0.0513
NBS-295	2.949	0.002	2.9517	0.0279	2.951	0.0768
NBS-446	4.4623	0.0032	cal	cal	cal	cal
			HM5 – NaIGEM			
			ORNL		ARN	
Source ID	Declared Enrichment (wt%)	Unc.	Measured Enrichment (wt%)	Absolute Error [%]	Measured Enrichment (wt%)	Absolute Error [%]
NBS-031	0.317	0.002	0.34	0.02	0.32	0.023
NBS-071	0.7119	0.005	0.72	0.023	0.7	0.027
NBS-194	1.942	0.001	1.94	0.034	1.96	0.035
NBS-295	2.949	0.002	2.97	0.035	2.98	0.037
NBS-446	4.4623	0.0032	cal	cal	cal	cal

The results show very good agreement between the ORNL and ARN measurements and with the declared values of the SRM-969 standards. The largest difference between ORNL and ARN results occurred when the CZT detectors were used. The ORNL measurements had a larger uncertainty because of the low efficiency of the small CZT detector used. The plots summarizing the data are shown in Figs. 1–6. The measured enrichments and errors are shown on the plots.

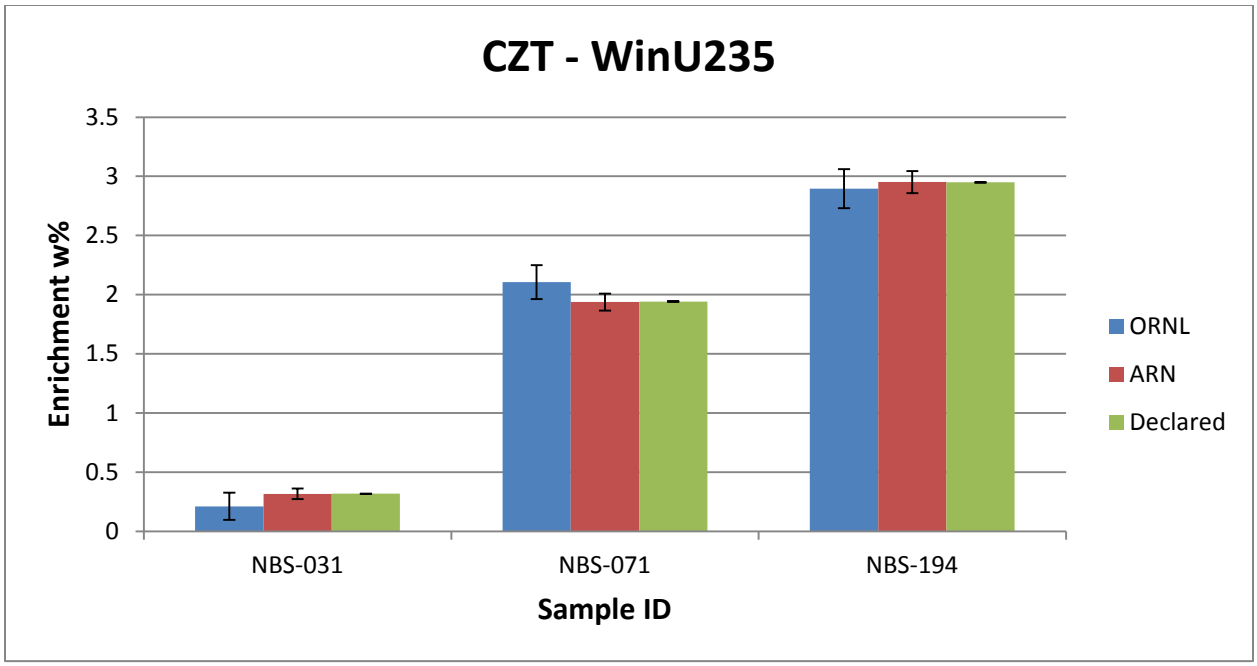


Fig. 1. Enrichment results using a CZT detector and WinU235 software.

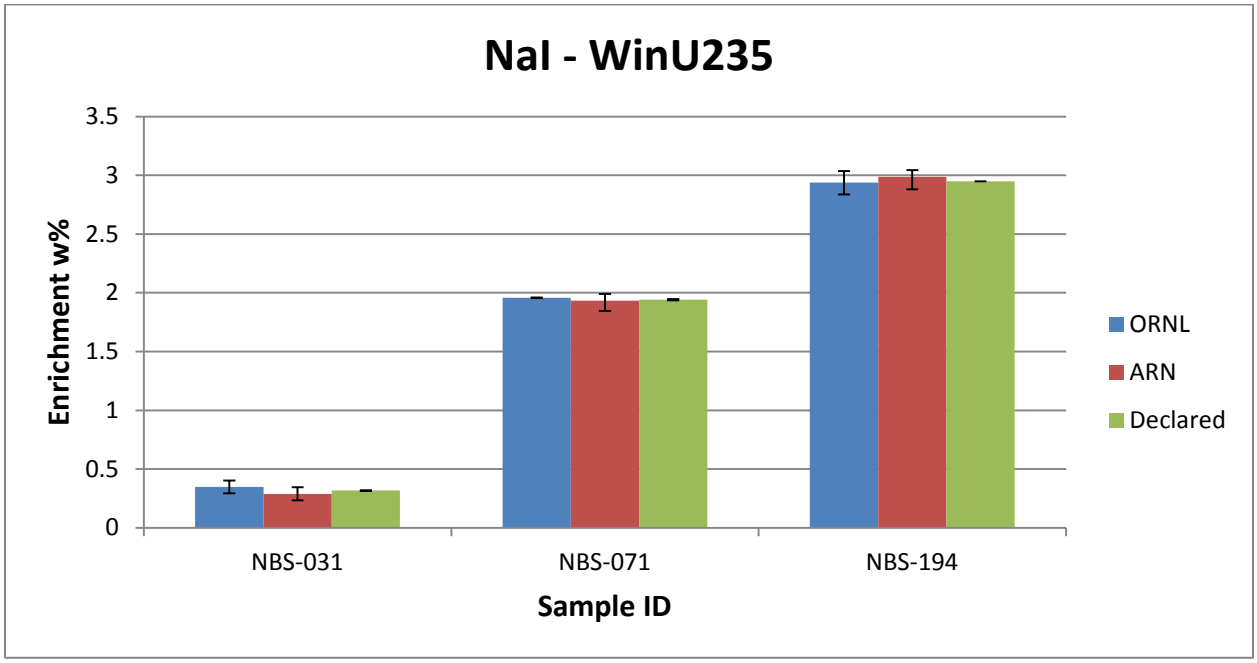


Fig. 2. Enrichment results using a NaI detector and WinU235 software.

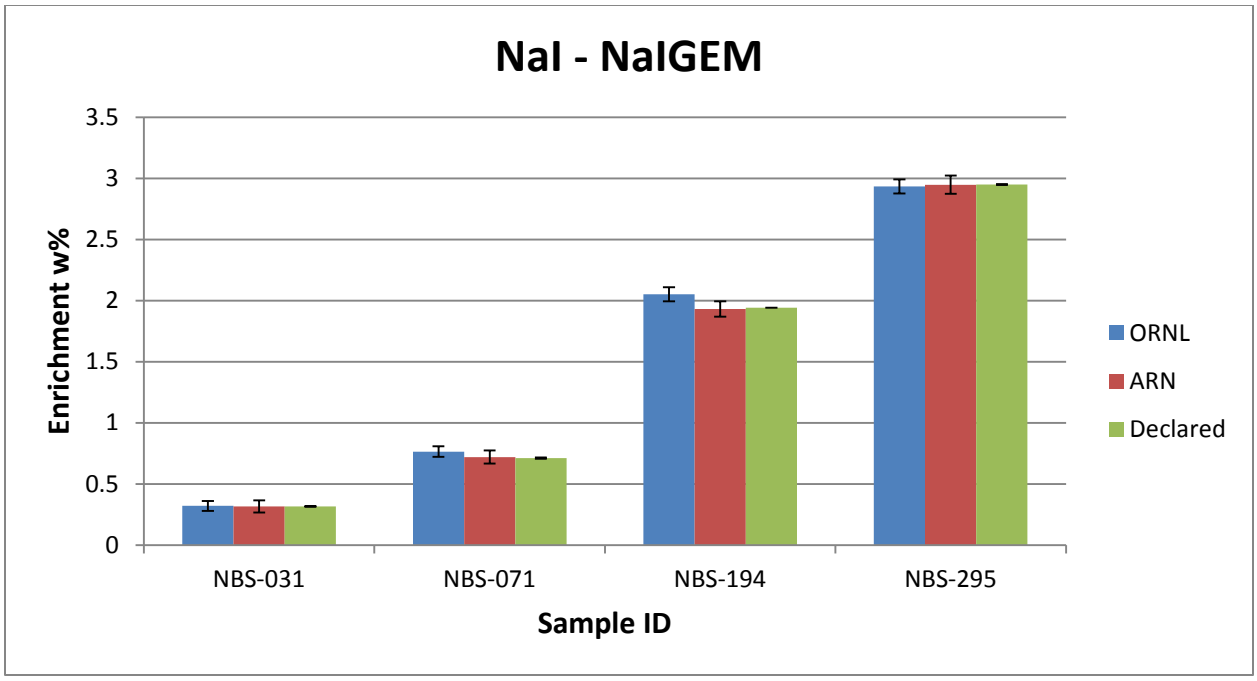


Fig. 3. Enrichment results using a NaI detector and NaIGEM software.

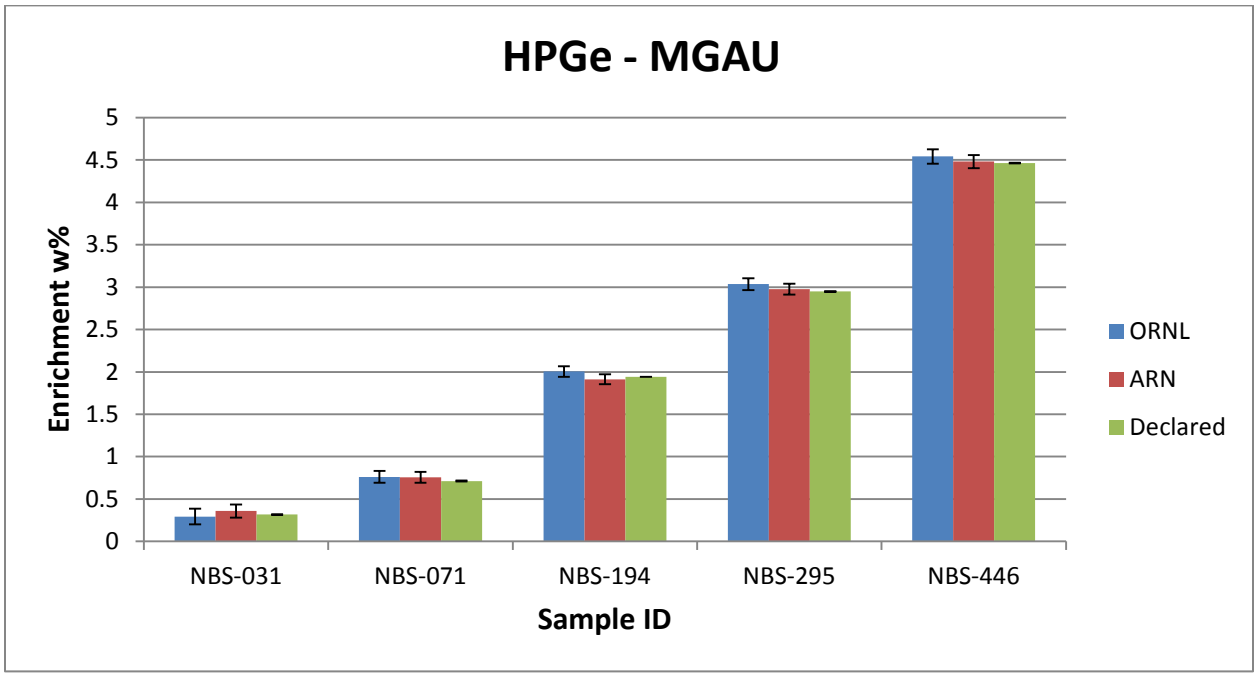


Fig. 4. Enrichment results using an HPGe detector and MGAU software.

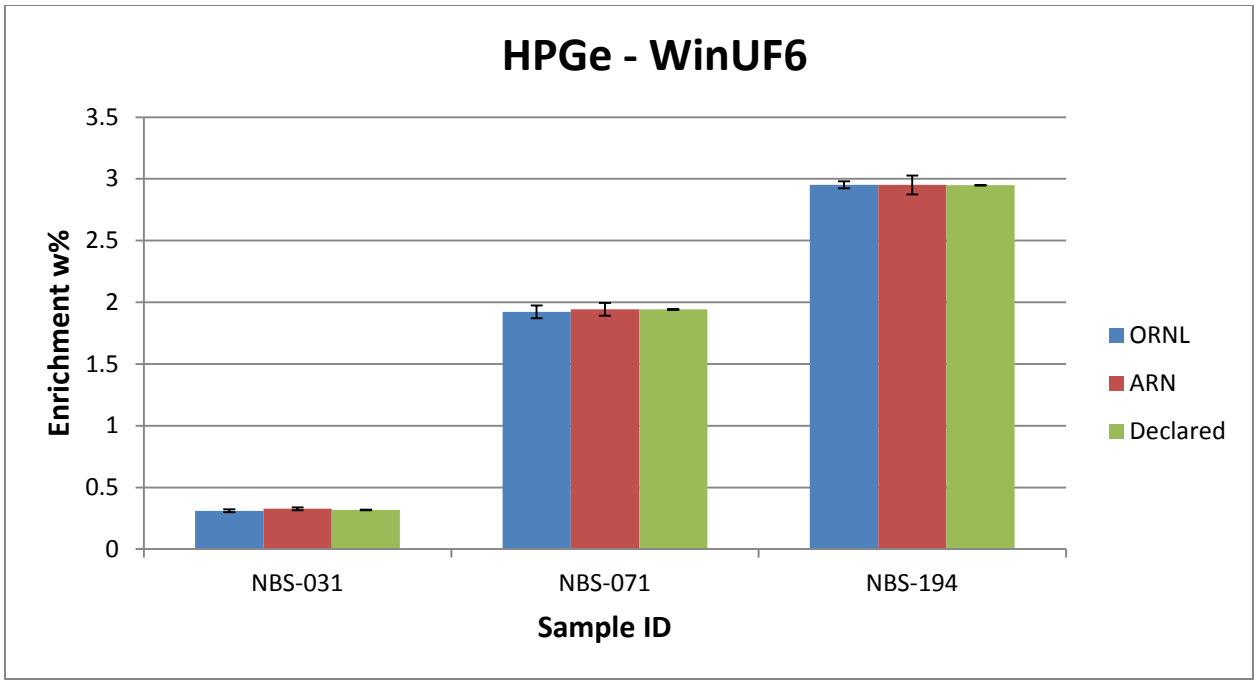


Fig. 5. Enrichment results using an HPGe detector and WinUF6 software.

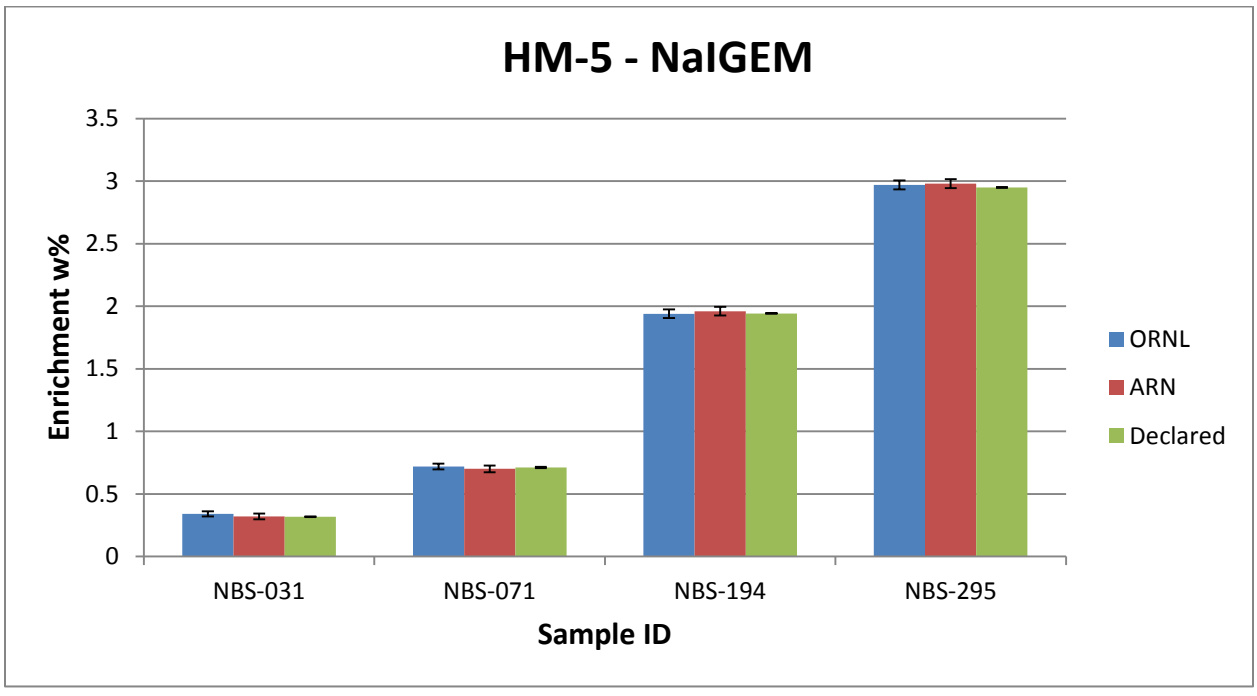


Fig. 6. Enrichment results using an HM-5 running NaIGEM software.

A number of spectra were collected during the measurement campaign. These spectra collected at ORNL and ARN were reviewed and are in reasonable agreement. The spectra are labeled and attached in Appendix B.

4. CONCLUSION

ORNL and ARN conducted a total of 60 measurements using 7 detector/software combinations. The measurements were performed using 5 NIST-traceable standards with enrichments ranging from 0.31% to 4.46% ^{235}U. The data show very good agreement between the measurements performed by ORNL staff and those performed by ARN staff. This agreement provides confidence that the ORNL and ARN safeguards staffs are well trained and capable of performing similar enrichment measurements with these instruments and software packages.

APPENDIX A

Tables A.1–A.6 list the detector/MCA settings recorded by ORNL for the systems used in the round-robin measurement campaign.

Table A.1. WinU235–CZT/MCA settings

MCA settings	Value
Channels	512
Energy threshold	2
LLD	0
ULD	495
Coarse gain	200
Fine gain	1.055
Shaping (us)	1
Input polarity	(–)
Stabilization	ON
PZC	1600
High voltage (V)	(+) 500
ROI (ch)	230–370
Target (ch)	300
Calibration constant A	7.18E-01
Calibration constant B	−9.16E-01

Table A.2. WinU235–NaI/MCA settings

MCA settings	Value
Channels	512
Energy threshold	2
LLD	0
ULD	495
Coarse gain	100
Fine gain	1.3
Shaping (us)	1
Input polarity	(+)
Stabilization	ON
PZC	2148
High voltage (V)	(+) 600
ROI (ch)	230–370
Target (ch)	300
Calibration constant A	3.65E-02
Calibration constant B	−3.81E-02

Table A.3. MGAU–HPGe/MCA settings

MCA settings	Value
Channels	4096
Energy threshold	2
LLD	0
ULD	3967
Coarse gain	10
Fine gain	1.457
Shaping (us)	1
Input polarity	(–)
Stabilization	OFF
PZC	1600
High voltage (V)	(−) 1500

Table A.4. WinUF6–HPGe/MCA settings

MCA settings	Value
Channels	4096
Energy threshold	2
LLD	0
ULD	3967
Coarse gain	20
Fine gain	0.988
Shaping (us)	1
Input polarity	(–)
Stabilization	ON
PZC	2256
High voltage (V)	(−) 1500
ROI (ch)	3291–3351
Target (ch)	3320

Table A.5. NaIGEM–HM-5 settings

Calibration settings	Value
Fe thickness [mm]	0
Fe density [g/cm3]	7.7
Al thick [mm]	2
Matrix	Oxide
Col. diam [cm]	1.995
Col. height [cm]	0.7
NaI thick [cm]	2.1
Calibration enrichment [%]	4.46
Count time real [s]	300
Count time live [s]	267
Zero [keV]	−3.705
661 FWHM	6.08
Calibration constant	1.1872E-04 ± 1.1%

Table A.6. NaIGEM–NaI/MCA settings

Calibration settings	Value
Fe thickness [mm]	0
Fe density [g/cm3]	7.7
Al thick [mm]	2
Matrix	U3O8
Col. diam [cm]	25
Col. height [cm]	27
NaI thick [cm]	50.8
Calibration enrichment [%]	4.46
Count time real [s]	
Count time live [s]	300
Zero [keV]	−11.0
661 FWHM	6.249
Calibration constant	2.686E-04 ± 1.5%

Tables A.7–A.12 list the detector/MCA settings recorded by ARN for the systems used in the round-robin measurement campaign.

Table A.7. WinU235–CZT/MCA settings

Settings	Value
Channels	512
Energy Threshold	2
LLD	0
ULD	495
Coarse Gain	200
Fine Gain	0.7929
Shaping Time (µs)	1
Input Polarity	(+)
Stabilization	ON
PZC	2003
High Voltage (V)	(+)1200
ROI (ch)	230-370
Target (ch)	300
CalibrationConstant A	4.201E-2
Calibration Constant B	-4.924E-2

Table A.8. MGAU–HPGe/MCA settings

Settings	Value
Channels	4096
Energy Threshold	2
LLD	0
ULD	3967
Coarse Gain	50
Fine Gain	1.0600
Shaping Time (µs)	1
Input Polarity	(-)
Stabilization	ON
PZC	2168
ROI (ch)	2456-2496
Target (ch)	2476
High Voltage (V)	(-)1500

Table A.9. WinU235–NaI/MCA

Settings	Value
Channels	512
Energy Threshold	2
LLD	0
ULD	495
Coarse Gain	200
Fine Gain	1.4304
Shaping Time (µs)	1
Input Polarity	(+)
Stabilization	ON
PZC	1970
High Voltage (V)	(+)470
ROI (ch)	230-370
Target (ch)	300
Calibration Constant A	4.369E-2
Calibration Constant B	-4.506E-2

Table A.10. WinUF6–HPGe/MCA settings

Settings	Value
Channels	4096
Energy Threshold	2
LLD	0
ULD	3967
Coarse Gain	50
Fine Gain	1.4308
Shaping Time (µs)	1
Input Polarity	(-)
Stabilization	ON
PZC	2167
High Voltage (V)	(-)1500
ROI (ch)	3291-3351
Target (ch)	3320
Calibration Constant A	2.242E-2 ± 1.565%

Table A.11. NaIGEM–HM-5 settings

Settings	Value
Fe Thickness [cm]	0
Fe Density [g/cm3]	7.7
Al Thick [mm]	2
Matrix	Oxide
Col. Diam. [cm]	2.000
Col. Height [cm]	0.700
NaIThick [cm]	2.54
Calibration Enrichment [%]	4.46
Count Time Real [s]	300
Count Time Live [s]	262
Zero [keV]	-6.000
661 FWHM	6.75
Calibration Constant	1.2446E-04±1.02%

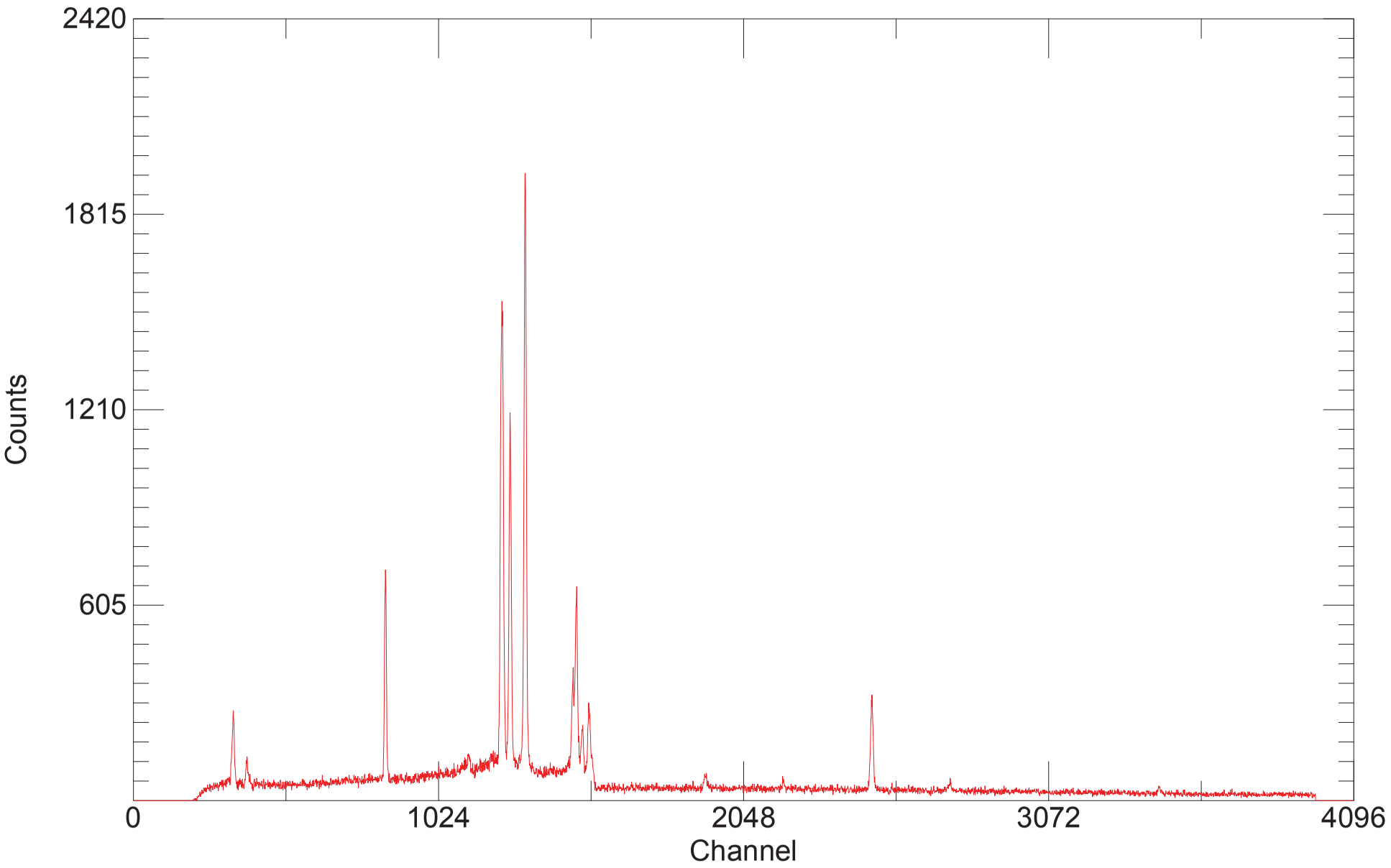
Table A.12. NaIGEM–NaI/MCA settings

Settings	Value
Fe Thickness [cm]	0
Fe Density [g/cm3]	7.7
Al Thick [mm]	2
Cd Thick [mm]	0
Matrix	U3O8
Col. Diam. [mm]	25
Col. Height [mm]	30
NaIThick [mm]	50.8
Calibration Enrichment [%]	4.4623
Count Time Live [s]	300
Zero [keV]	-12
Gain [keV/Ch]	0.65832
661 keV FWHM [%]	11.20
Channels	512
Calibration Constant	3.449E-04±1.9%

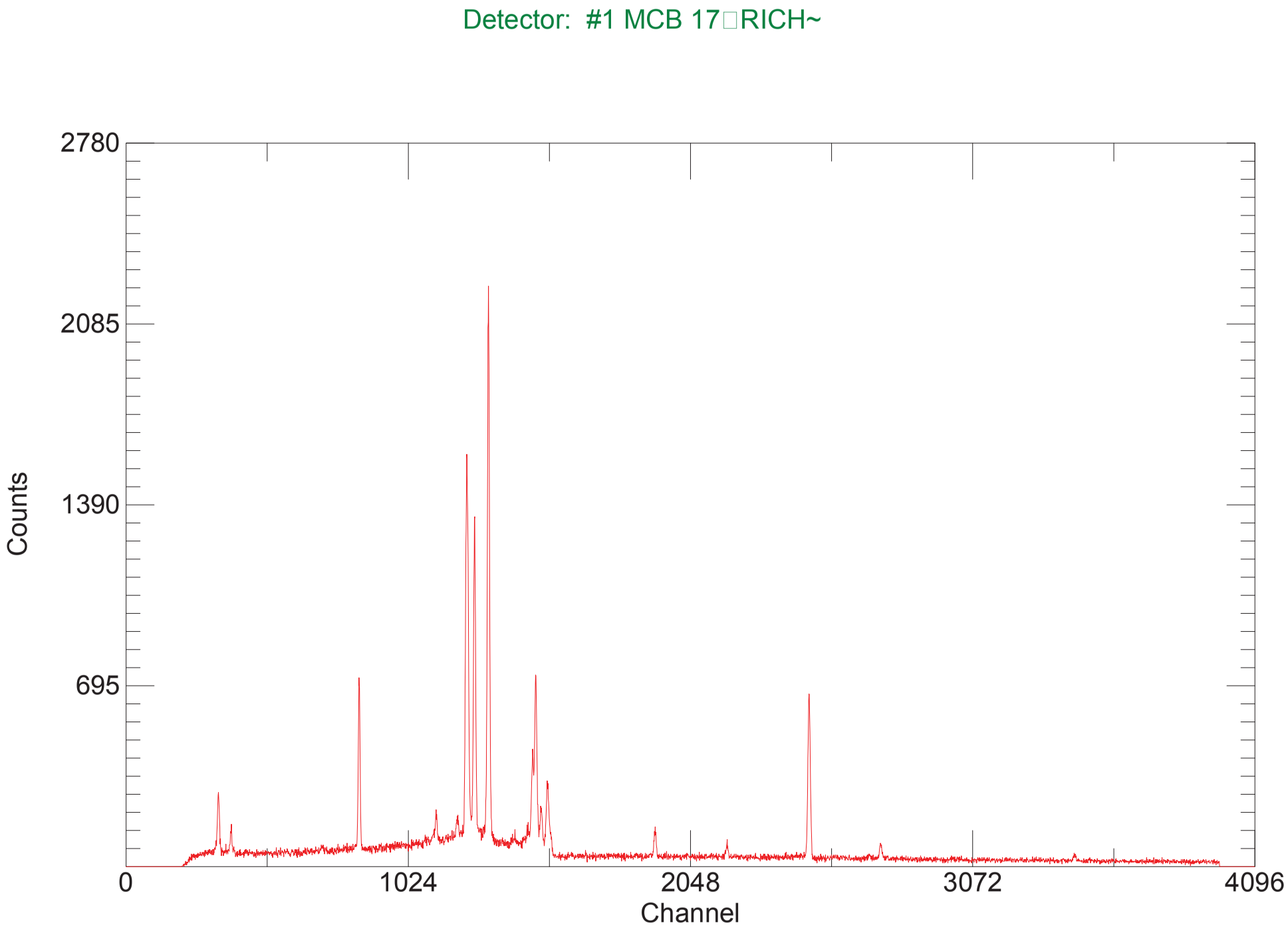
APPENDIX B

The spectra collected during this round-robin measurement campaign are given in this appendix.

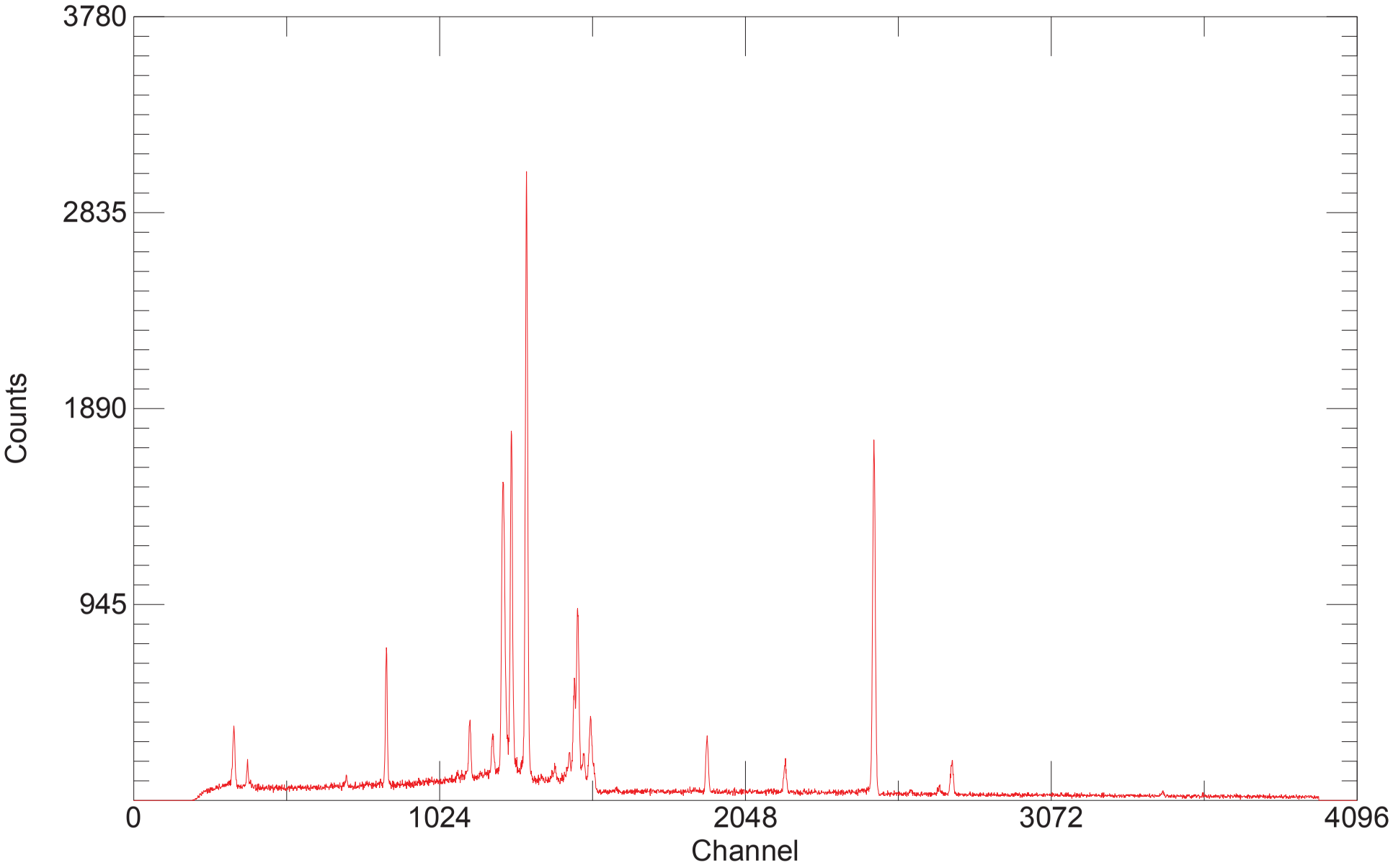
Detector: #1 MCB 17□RICH~



Acquired: 10/11/2012 12:13:28 PM Real Time: 304.00 s. Live Time: 299.04 s.
File: E:\ENRICH~1\ENRICH~1\MGAU\RR_MGAU_HPGe_MCA166_NBS031.(Channels: 4096
Detector: #1 MCB 17

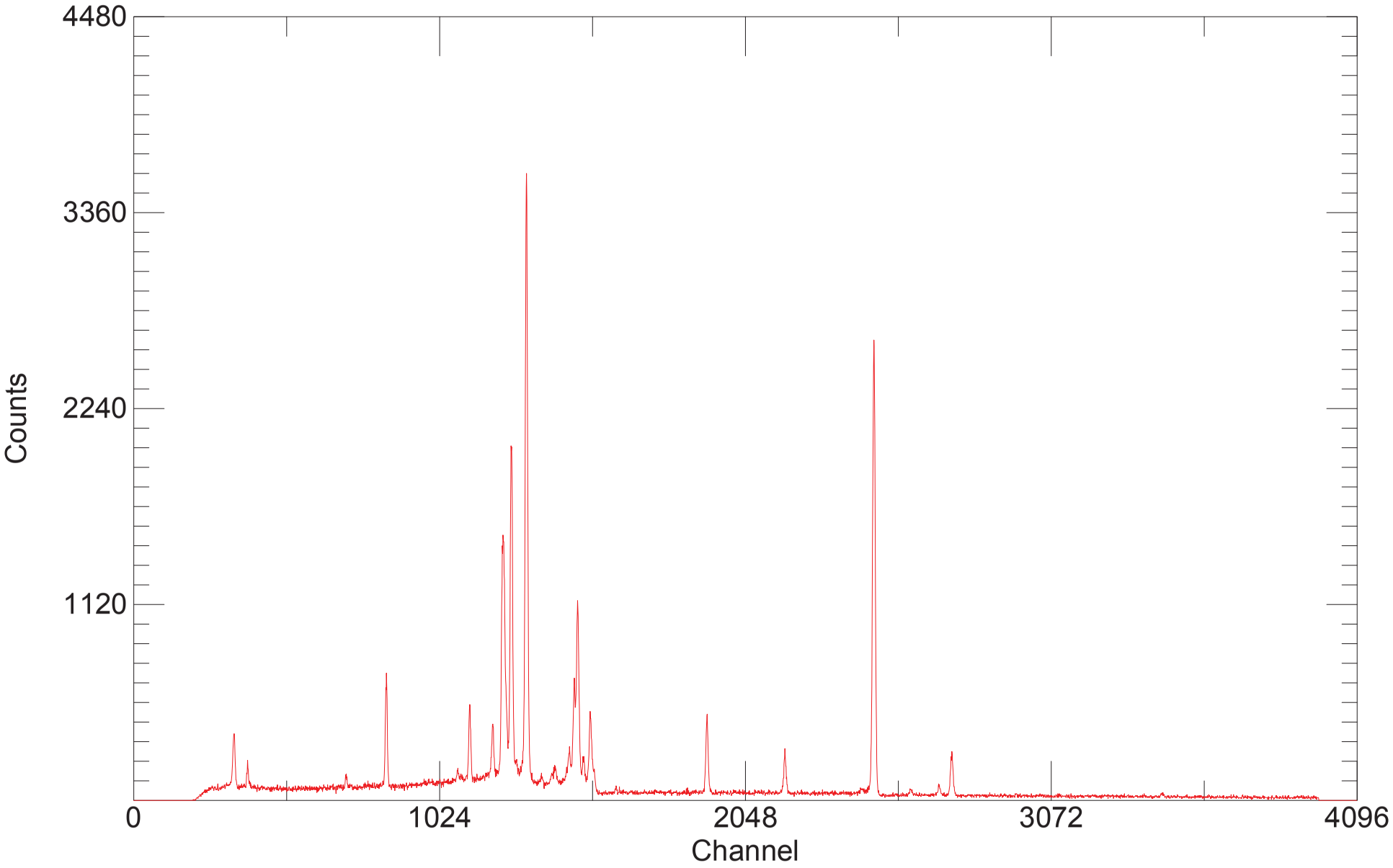

Detector: #1 MCB 17□RICH~
2780
2085
1390
695
Counts
0
1024
2048
3072
4096
Channel
Acquired: 10/11/2012 12:41:31 PM
Real Time: 305.00 s. Live Time: 299.74 s.
File: E:\ENRICH~1\ENRICH~1\MGAU\RR_MGAU_HPGe_MCA166_NBS071.
Channels: 4096
Detector: #1 MCB 17

Detector: #1 MCB 17□RICH~

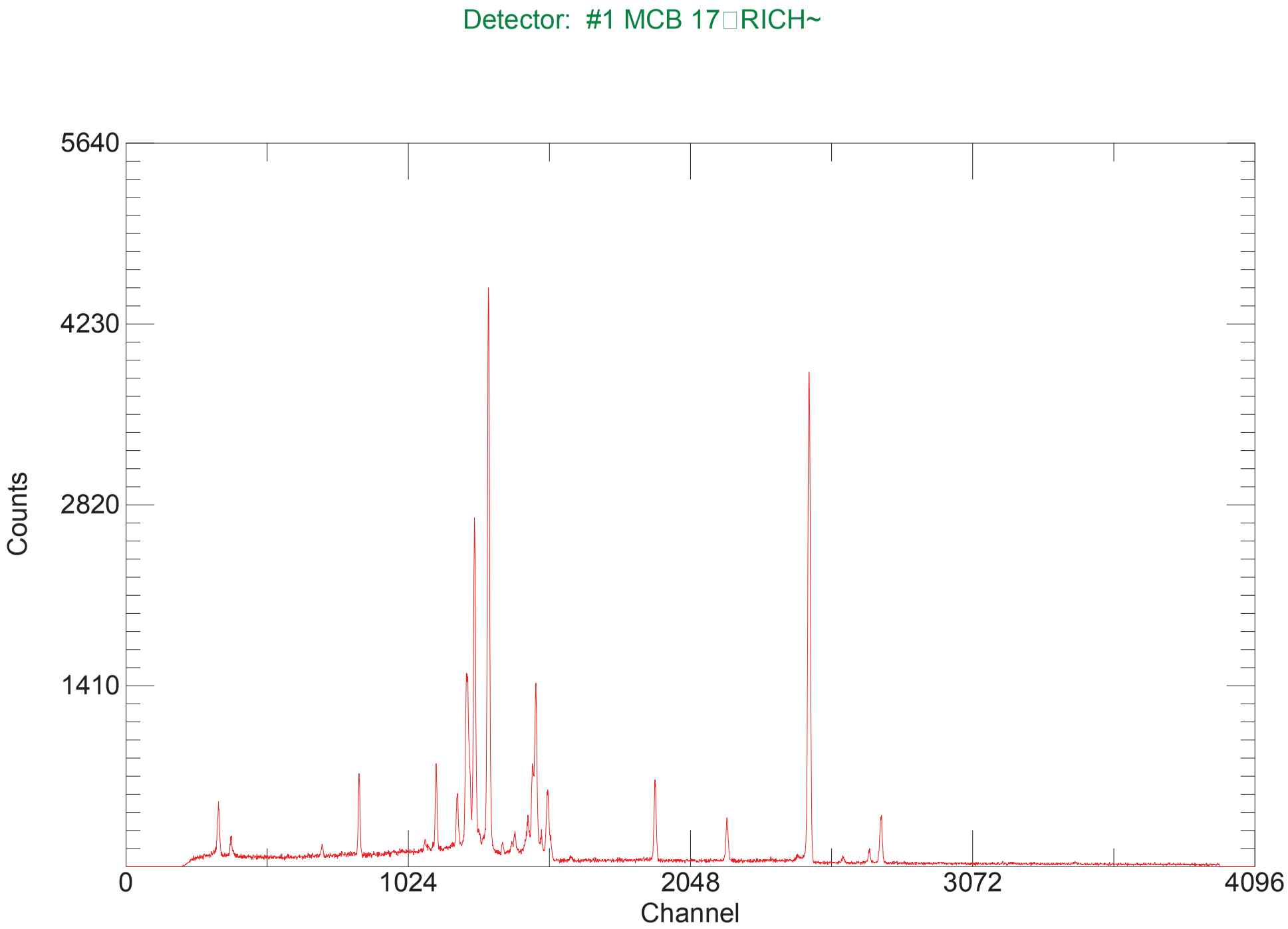


Acquired: 10/11/2012 12:34:49 PM Real Time: 306.00 s. Live Time: 299.84 s.
File: E:\ENRICH~1\ENRICH~1\MGAU\RR_MGAU_HPGe_MCA166_NBS194.(Channels: 4096
Detector: #1 MCB 17

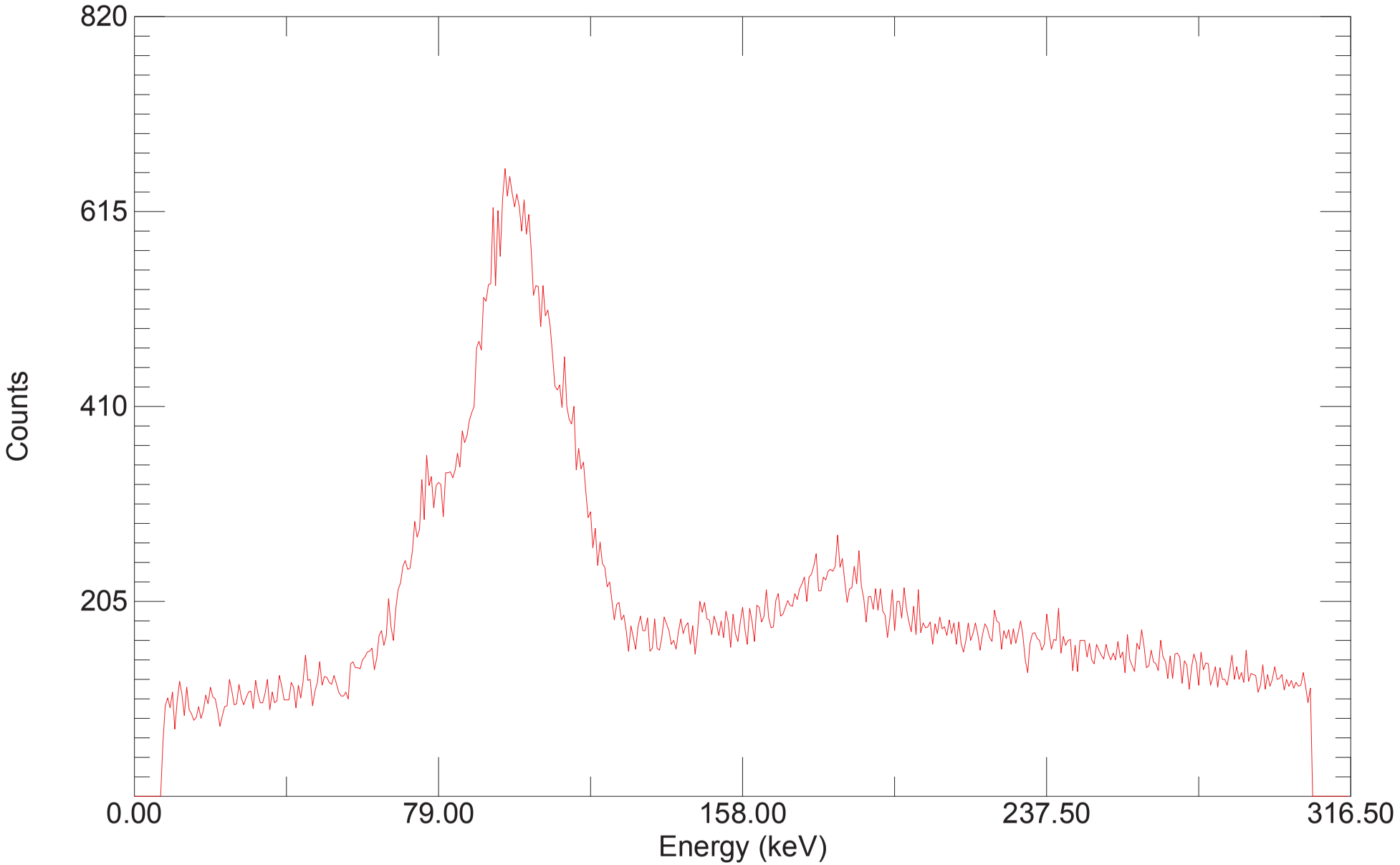
Detector: #1 MCB 17□RICH~



Acquired: 10/10/2012 4:46:48 PM Real Time: 306.00 s. Live Time: 299.08 s.
File: E:\ENRICH~1\ENRICH~1\MGAU\RR_MGAU_HPGe_MCA166_NBS295.(Channels: 4096
Detector: #1 MCB 17

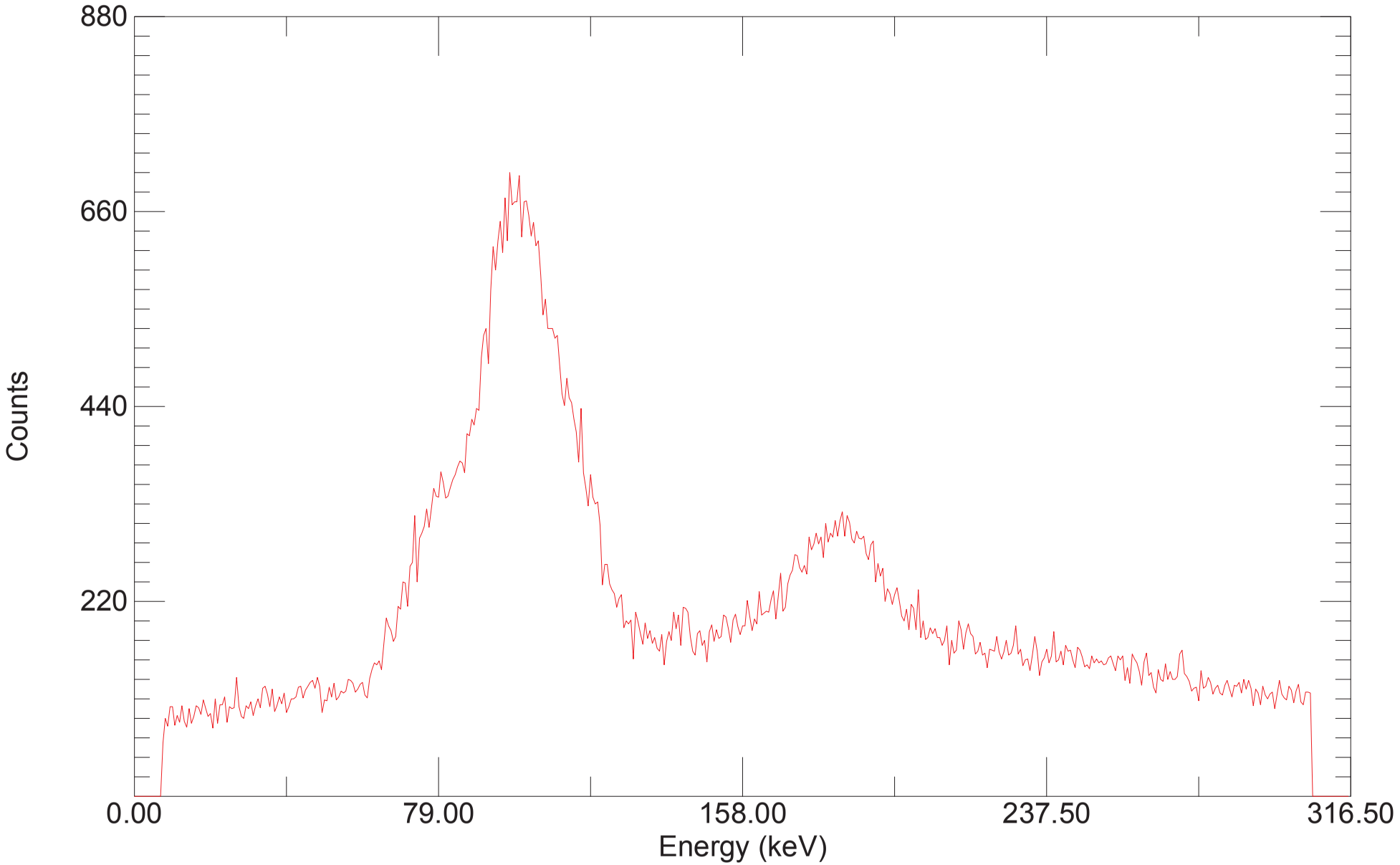

Detector: #1 MCB 17□RICH~
5640
4230
2820
1410
Counts
0
1024
2048
3072
4096
Channel
Acquired: 10/11/2012 12:28:36 PM
Real Time: 308.00 s. Live Time: 299.86 s.
File: E:\ENRICH~1\ENRICH~1\MGAU\RR_MGAU_HPGe_MCA166_NBS446.
Channels: 4096
Detector: #1 MCB 17

Detector: #1 MCB 17□RICH~1



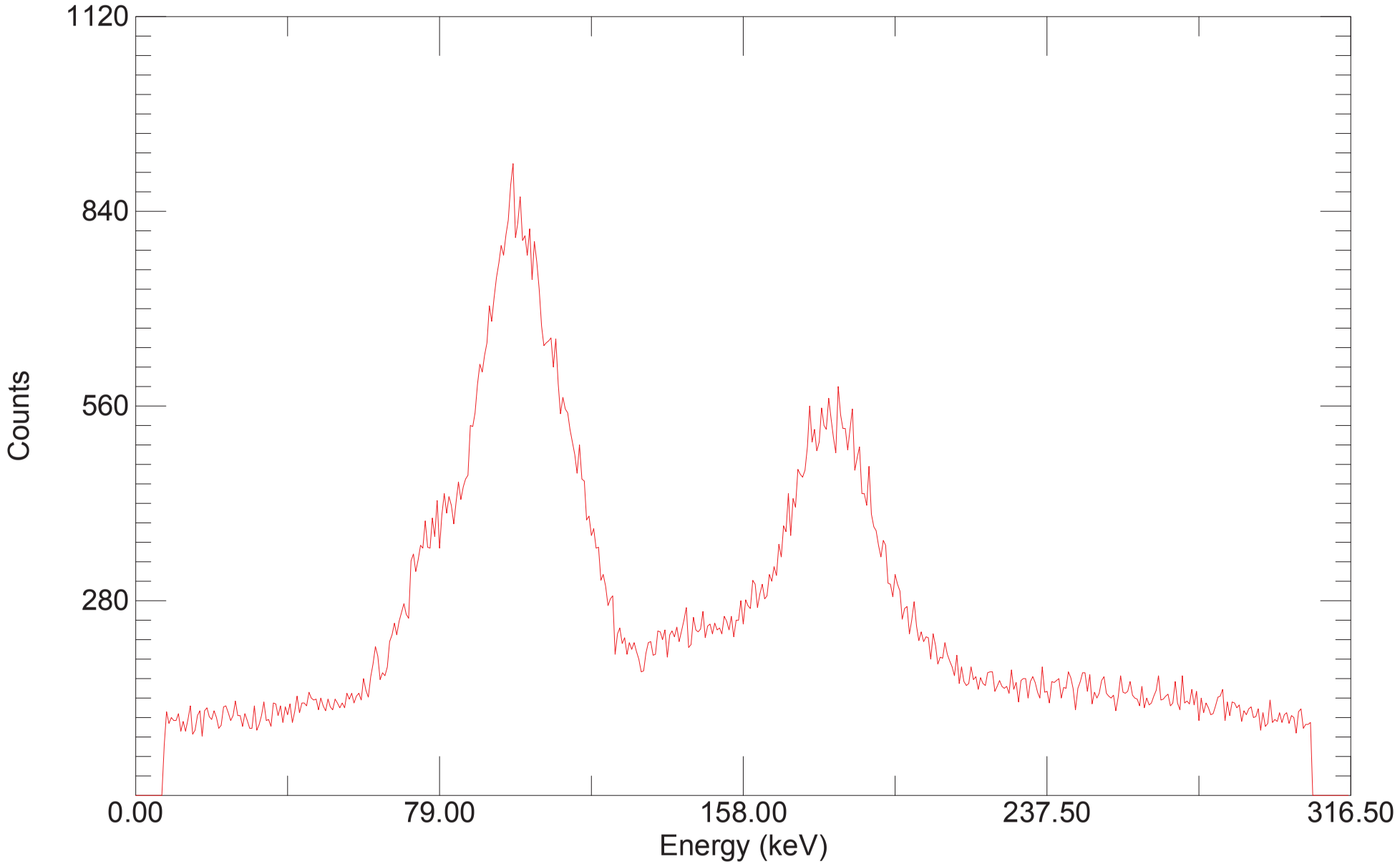
Acquired: 10/12/2012 1:48:43 PM Real Time: 302.00 s. Live Time: 299.48 s.
File: E:\ENRICH~1\ENRICH~1\NaIGEM\RR_NaIGEM_NaI_MCA166_NBS032.(Channels: 512
Detector: #1 MCB 17

Detector: #1 MCB 17□RICH~1

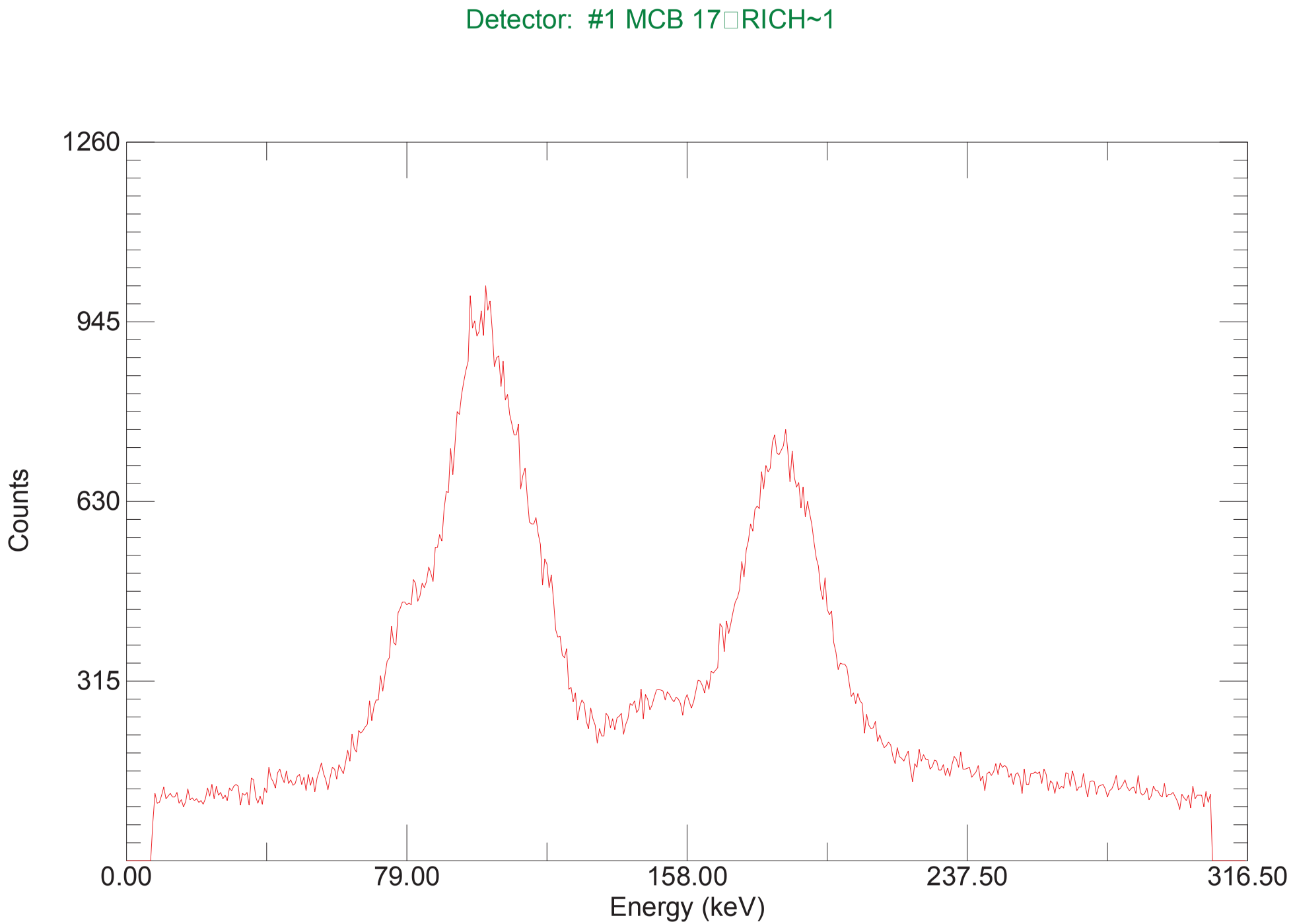


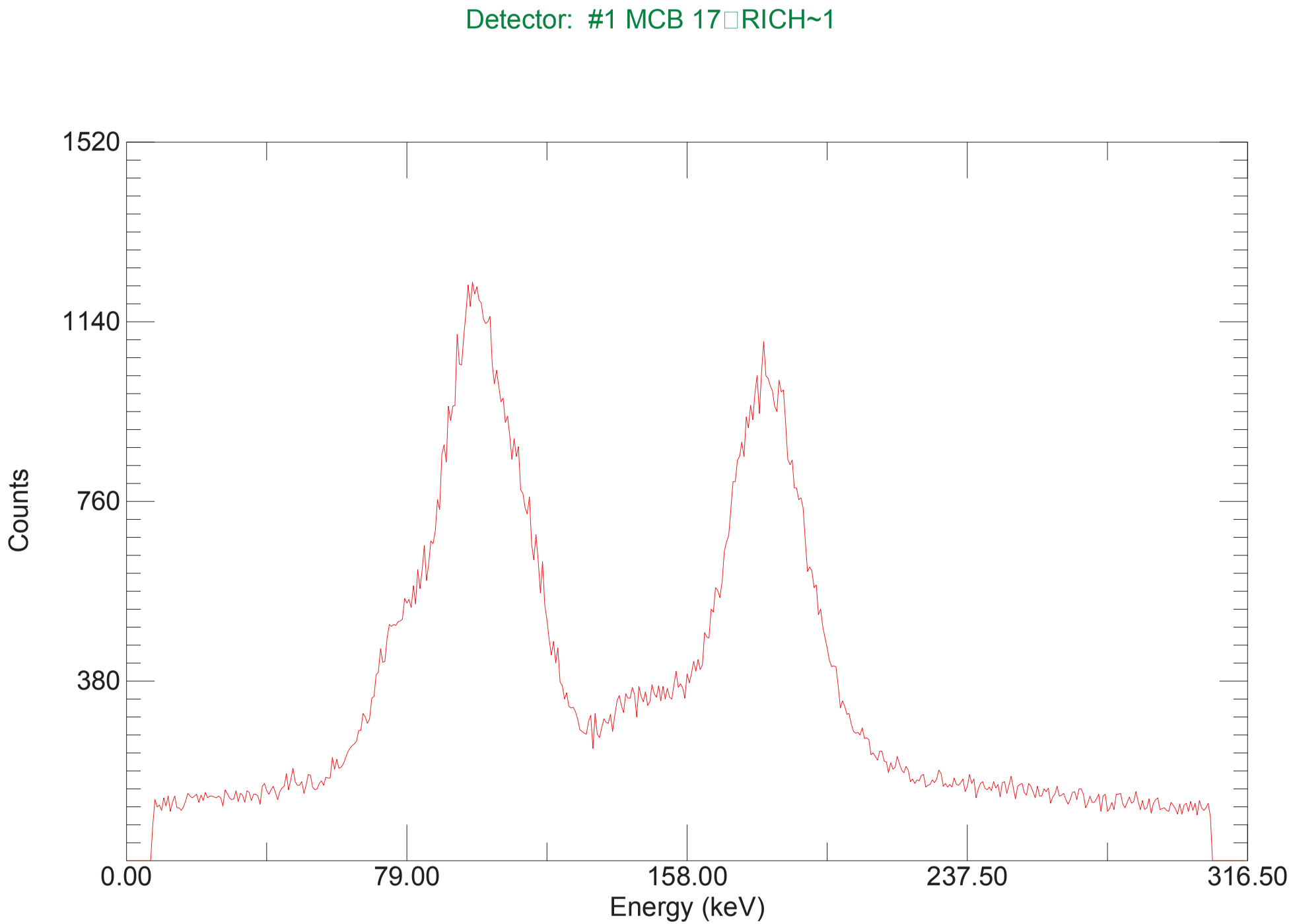
Acquired: 10/12/2012 12:06:40 PM Real Time: 302.00 s. Live Time: 299.38 s.
File: E:\ENRICH~1\ENRICH~1\NaIGEM\RR_NaIGEM_NaI_MCA166_NBS071.(Channels: 512
Detector: #1 MCB 17

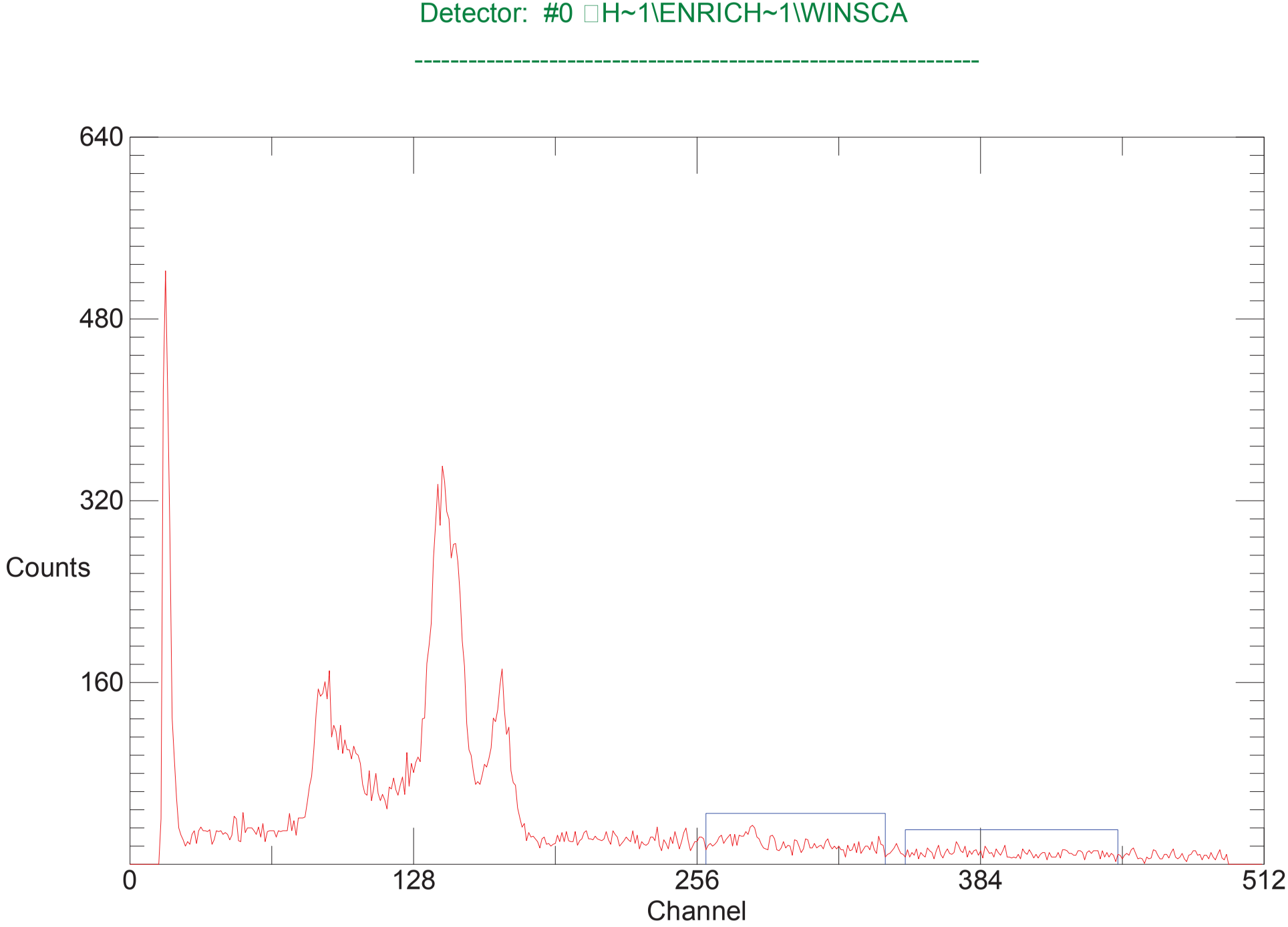
Detector: #1 MCB 17□RICH~1



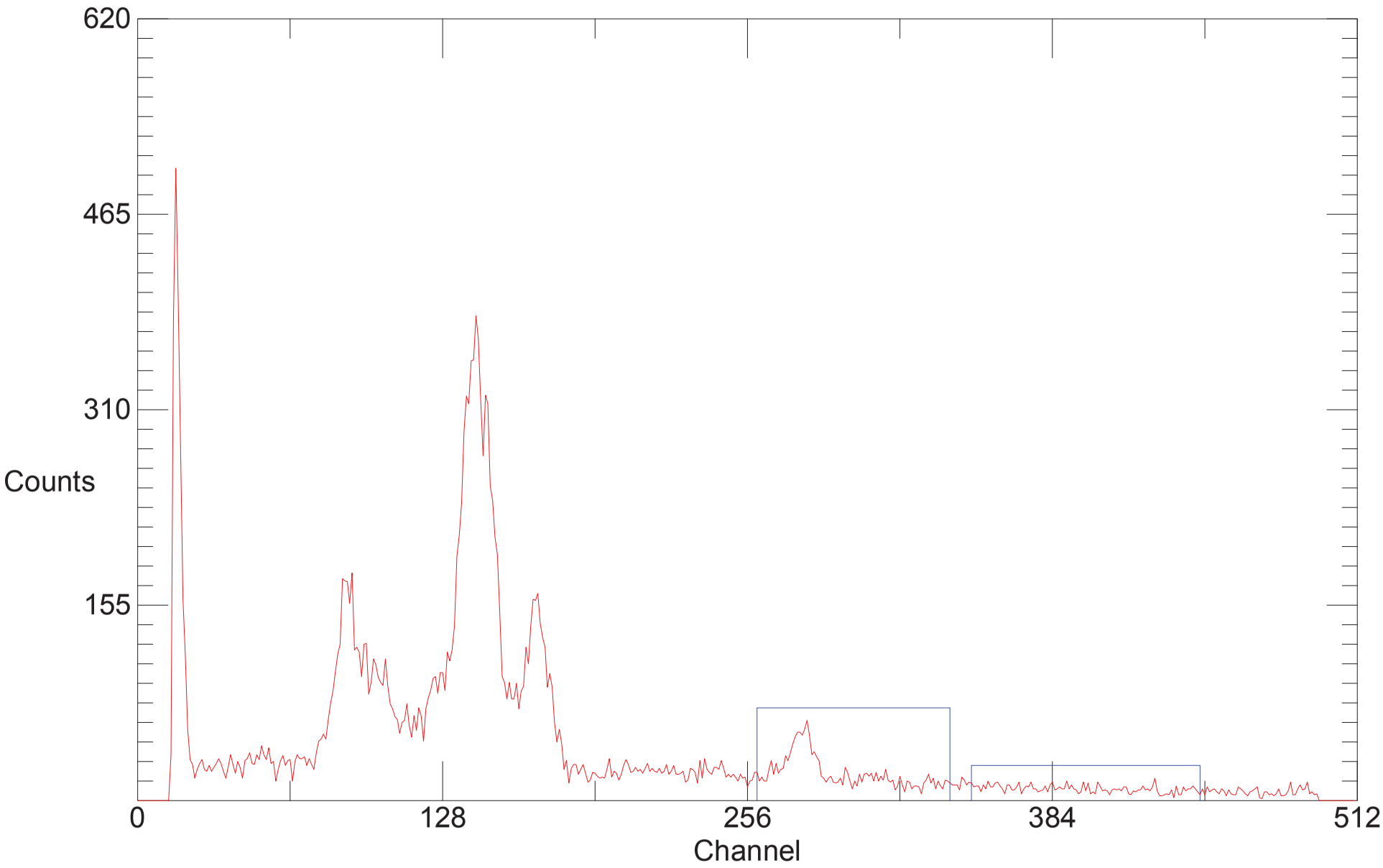
Acquired: 10/12/2012 1:55:43 PM Real Time: 302.00 s. Live Time: 299.04 s.
File: E:\ENRICH~1\ENRICH~1\NaIGEM\RR_NaIGEM_NaI_MCA166_NBS194.(Channels: 512
Detector: #1 MCB 17


Detector: #1 MCB 17□RICH~1
1260
945
630
315
Counts
0.00
79.00
158.00
237.50
316.50
Energy (keV)
Acquired: 10/12/2012 11:55:02 AM
Real Time: 303.00 s. Live Time: 299.76 s.
File: E:\ENRICH~1\ENRICH~1\NaIGEM\RR_NaIGEM_NaI_MCA166_NBS295.(
Channels: 512
Detector: #1 MCB 17


Detector: #1 MCB 17□RICH~1
1520
1140
760
380
Counts
0.00
79.00
158.00
237.50
316.50
Energy (keV)
Acquired: 10/12/2012 2:01:43 PM
Real Time: 303.00 s. Live Time: 299.22 s.
File: E:\ENRICH~1\ENRICH~1\NaIGEM\RR_NaIGEM_NaI_MCA166_NBS446.(
Channels: 512
Detector: #1 MCB 17

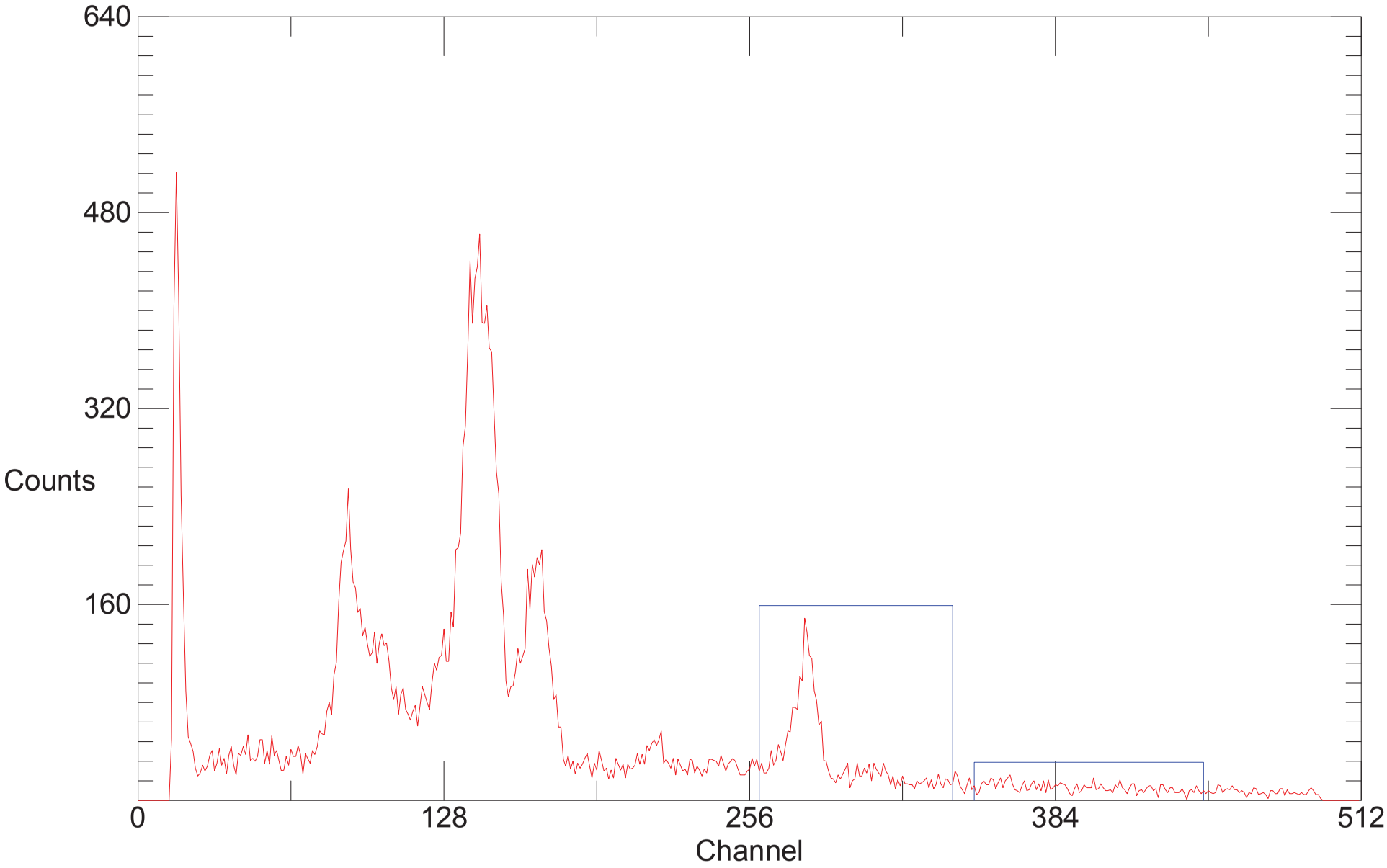

Detector: #0 H~1\ENRICH~1\WINSCA
640
480
320
160
Counts
0
128
256
384
512
Channel
Acquired: 9/17/2012 2:37:32 PM
Real Time: 600.00 s. Live Time: 600.00 s.
File: E:\ENRICH~1\ENRICH~1\WINSCAN\RR_WinU235_CZT_MCA166_NBS0Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\WINSCA



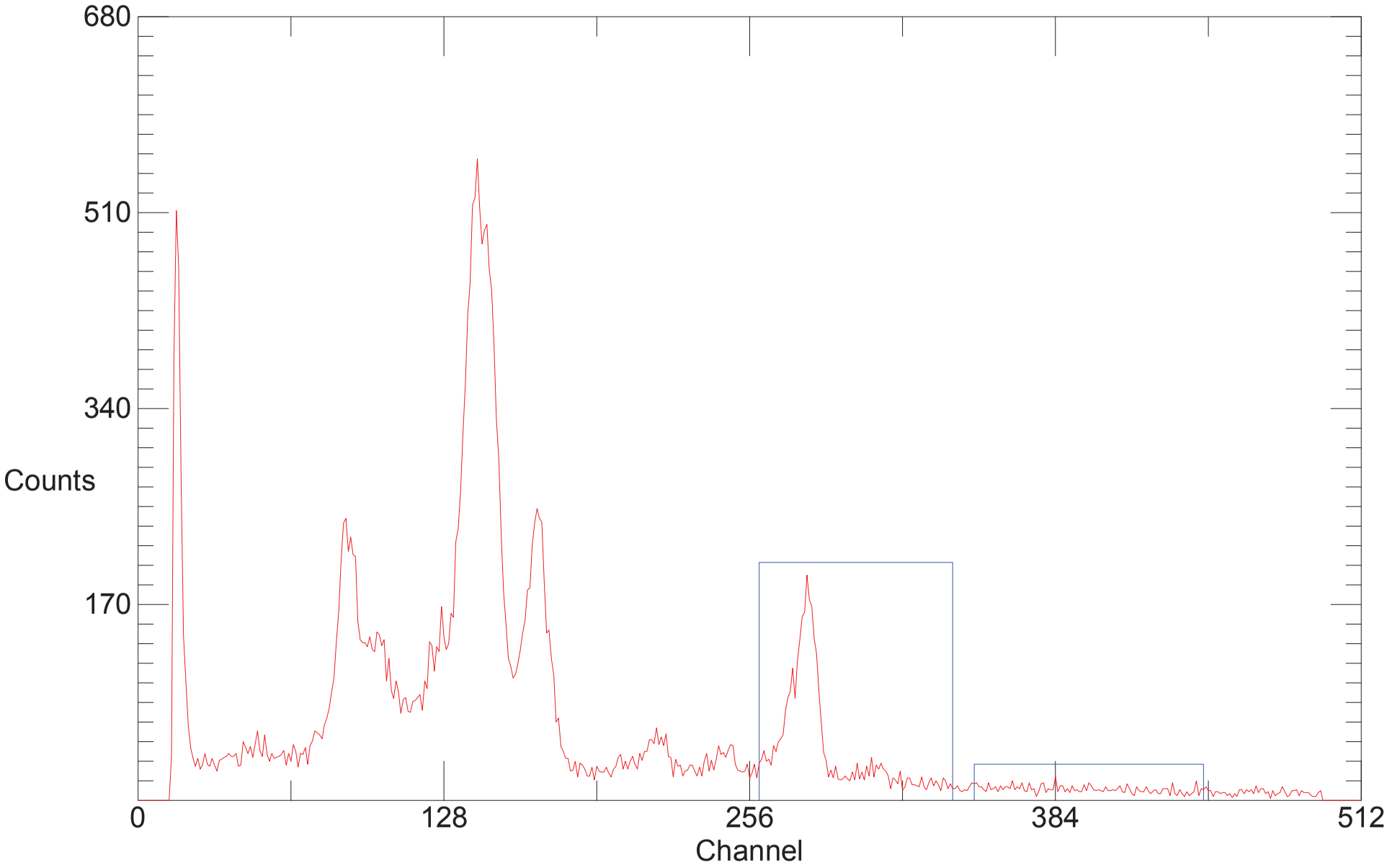
Acquired: 9/17/2012 1:58:29 PM Real Time: 600.00 s. Live Time: 600.00 s.
File: E:\ENRICH~1\ENRICH~1\WINSCAN\RR_WinU235_CZT_MCA166_NBS0Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\WINSCA



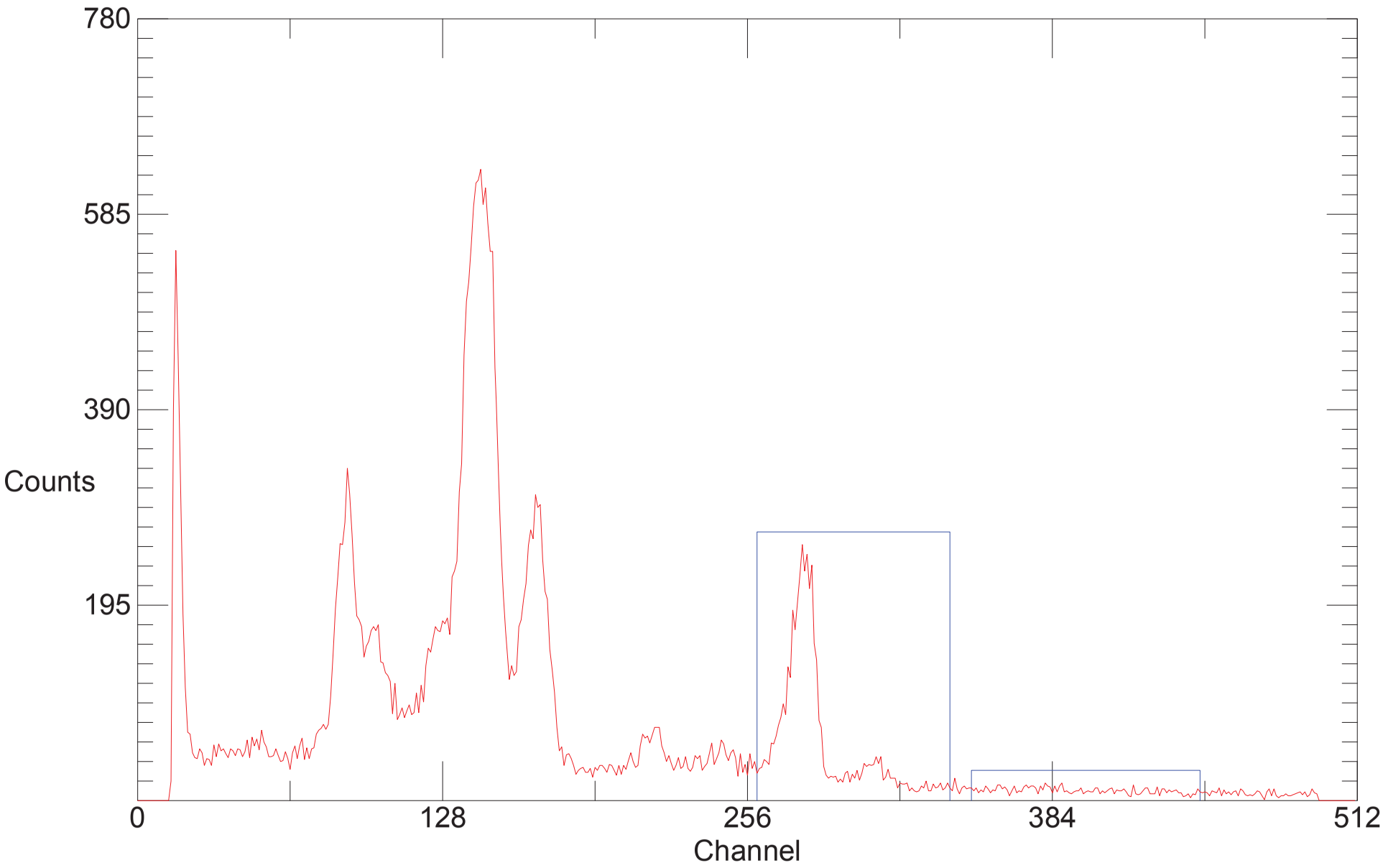
Acquired: 9/17/2012 2:24:38 PM Real Time: 600.00 s. Live Time: 600.00 s.
File: E:\ENRICH~1\ENRICH~1\WINSCAN\RR_WinU235_CZT_MCA166_NBS1Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\WINSCA



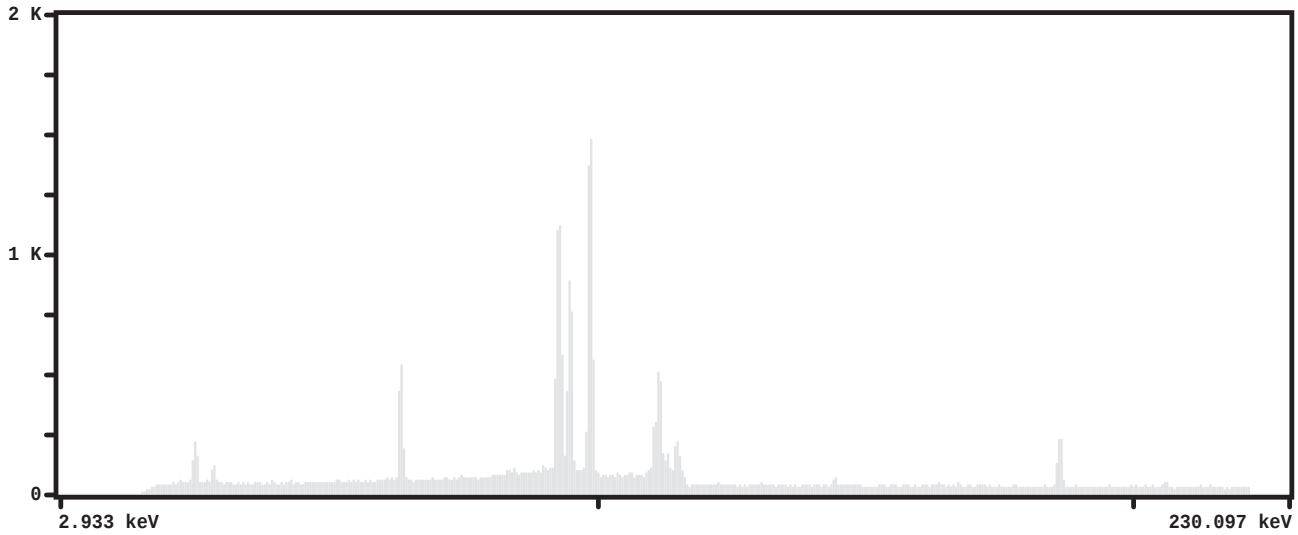
Acquired: 9/17/2012 2:12:39 PM Real Time: 600.00 s. Live Time: 600.00 s.
File: E:\ENRICH~1\ENRICH~1\WINSCAN\RR_WinU235_CZT_MCA166_NBS2Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\WINSCA



Acquired: 9/17/2012 1:34:40 PM Real Time: 600.00 s. Live Time: 600.00 s.
File: E:\ENRICH~1\ENRICH~1\WINSCAN\RR_WinU235_CZT_MCA166_NBS4Channels: 512
Detector: #0

WinSPEC (I) [E:\...\WinSPEC\NBS031.spe]

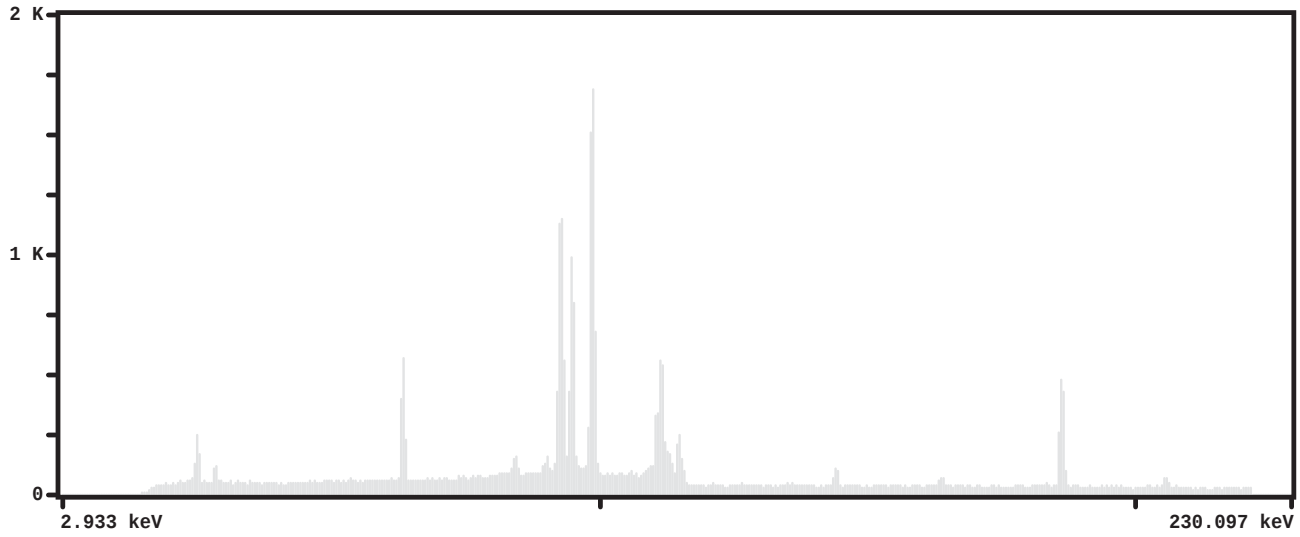


Remarks:

Start Time = 10/11/2012 15:56:30

Life Time = 299 sec Dead Time = 1.6 %

WinSPEC (I) [E:\...\WinSPEC\RR_WinSPEC_HPGe_MCA166_NBS071.spe]

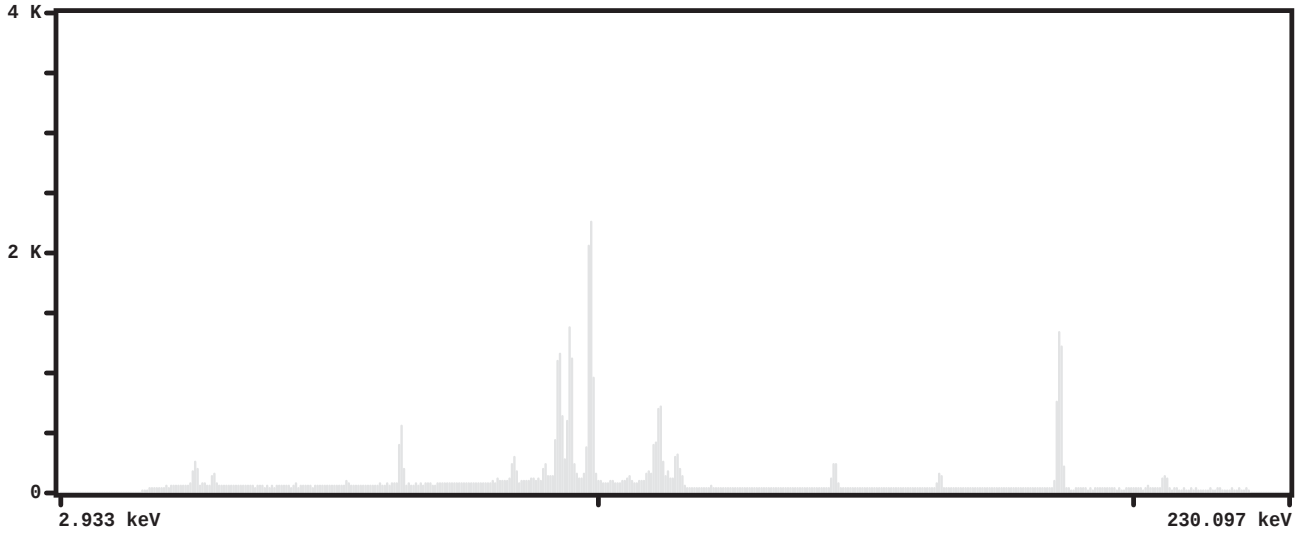


Remarks:

Start Time = 10/11/2012 16:02:45

Life Time = 300 sec Dead Time = 1.7 %

WinSPEC (I) [E:\...\WinSPEC\RR_WinSPEC_HPGe_MCA166_NBS194.spe]

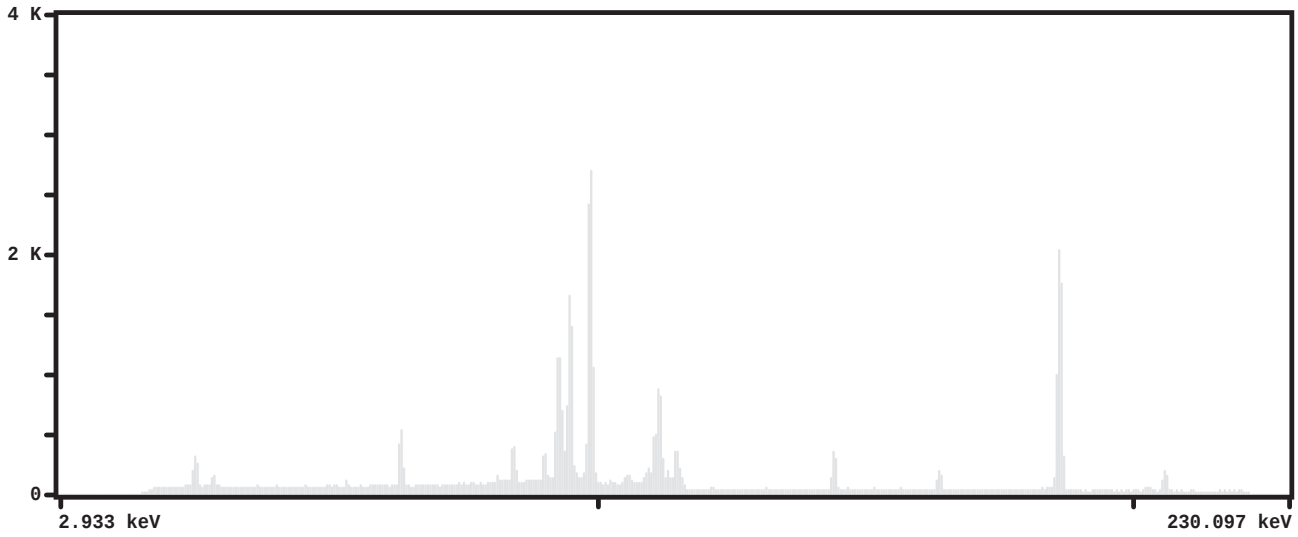


Remarks:

Start Time = 10/11/2012 15:49:07

Life Time = 300 sec Dead Time = 2.0 %

WinSPEC (I) [E:\...\WinSPEC\RR_WinSPEC_HPGe_MCA166_NBS295.spe]

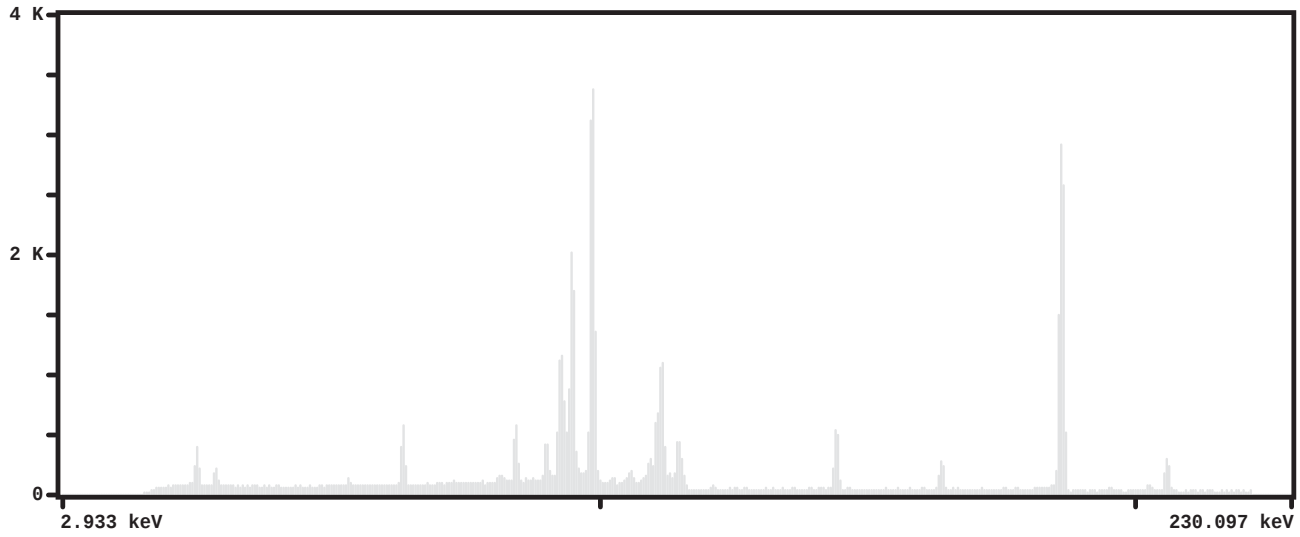


Remarks:

Start Time = 10/11/2012 16:37:03

Life Time = 300 sec Dead Time = 2.3 %

WinSPEC (I) [E:\...\WinSPEC\RR_WinSPEC_HPGe_MCA166_NBS446.spe]

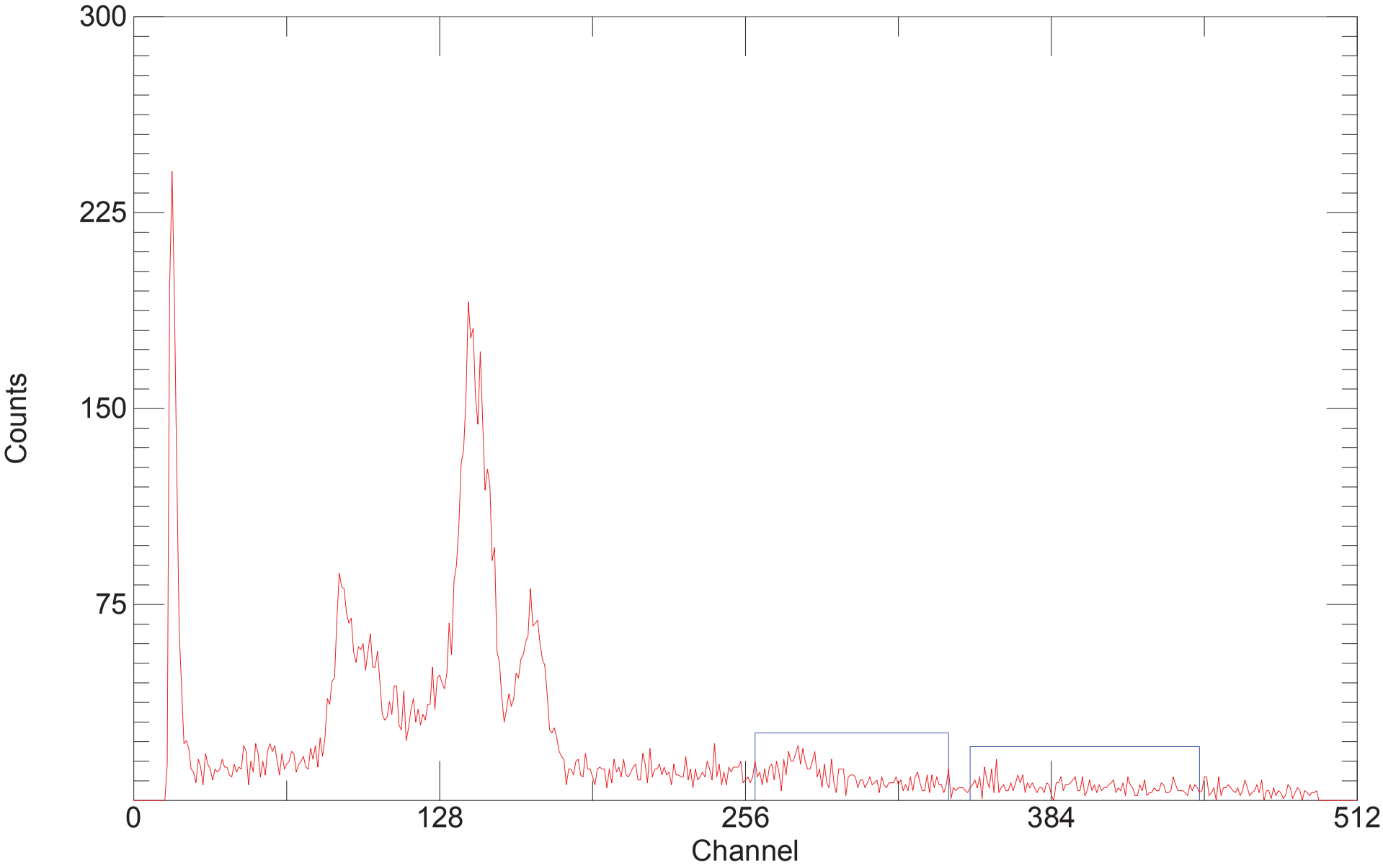


Remarks:

Start Time = 10/11/2012 16:43:21

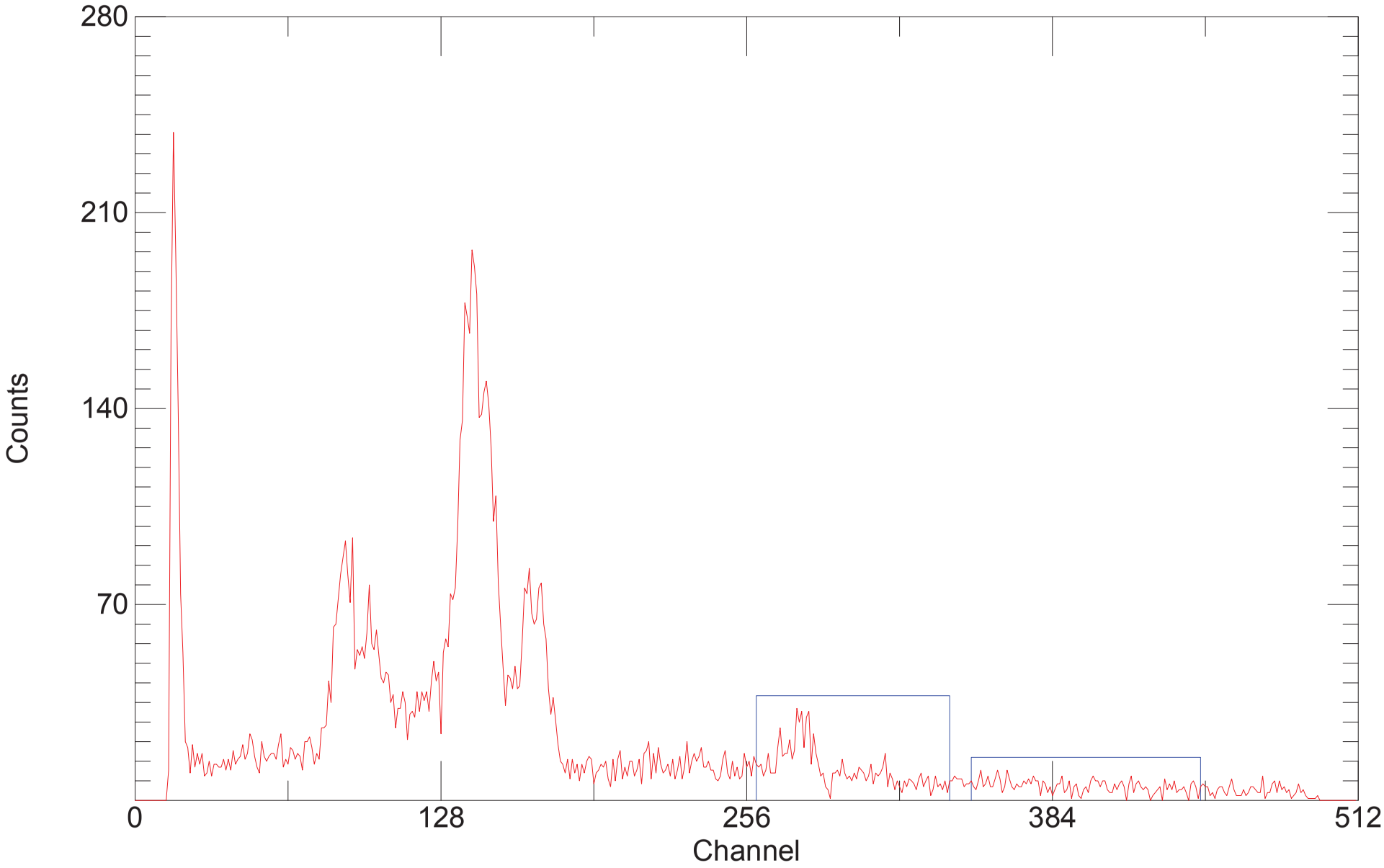
Life Time = 300 sec Dead Time = 2.7 %

Detector: #0 □H~1\ENRICH~1\



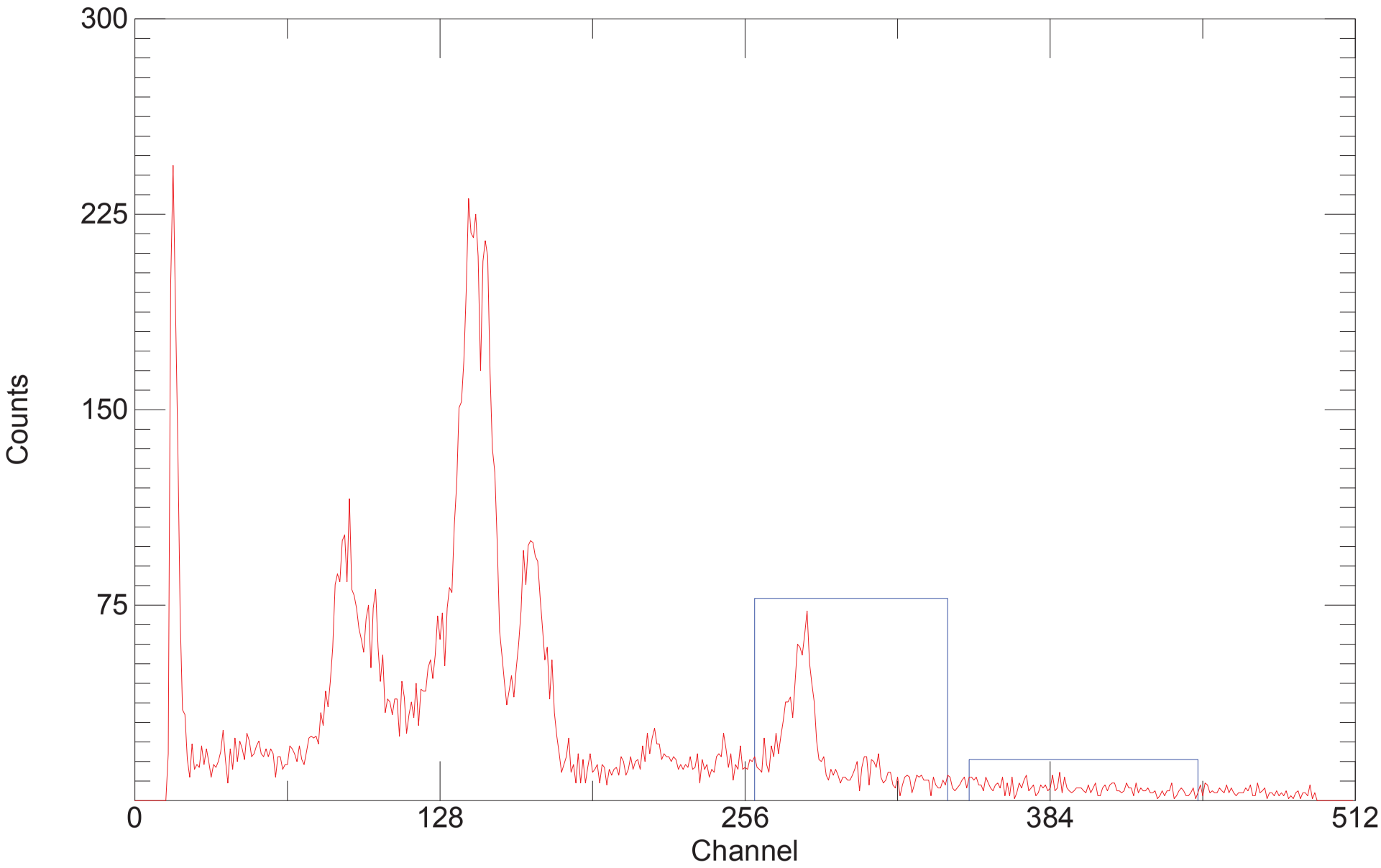
Acquired: 9/17/2012 12:14:57 PM Real Time: 300.00 s. Live Time: 300.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_CZT_MCA166_NBS03 Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



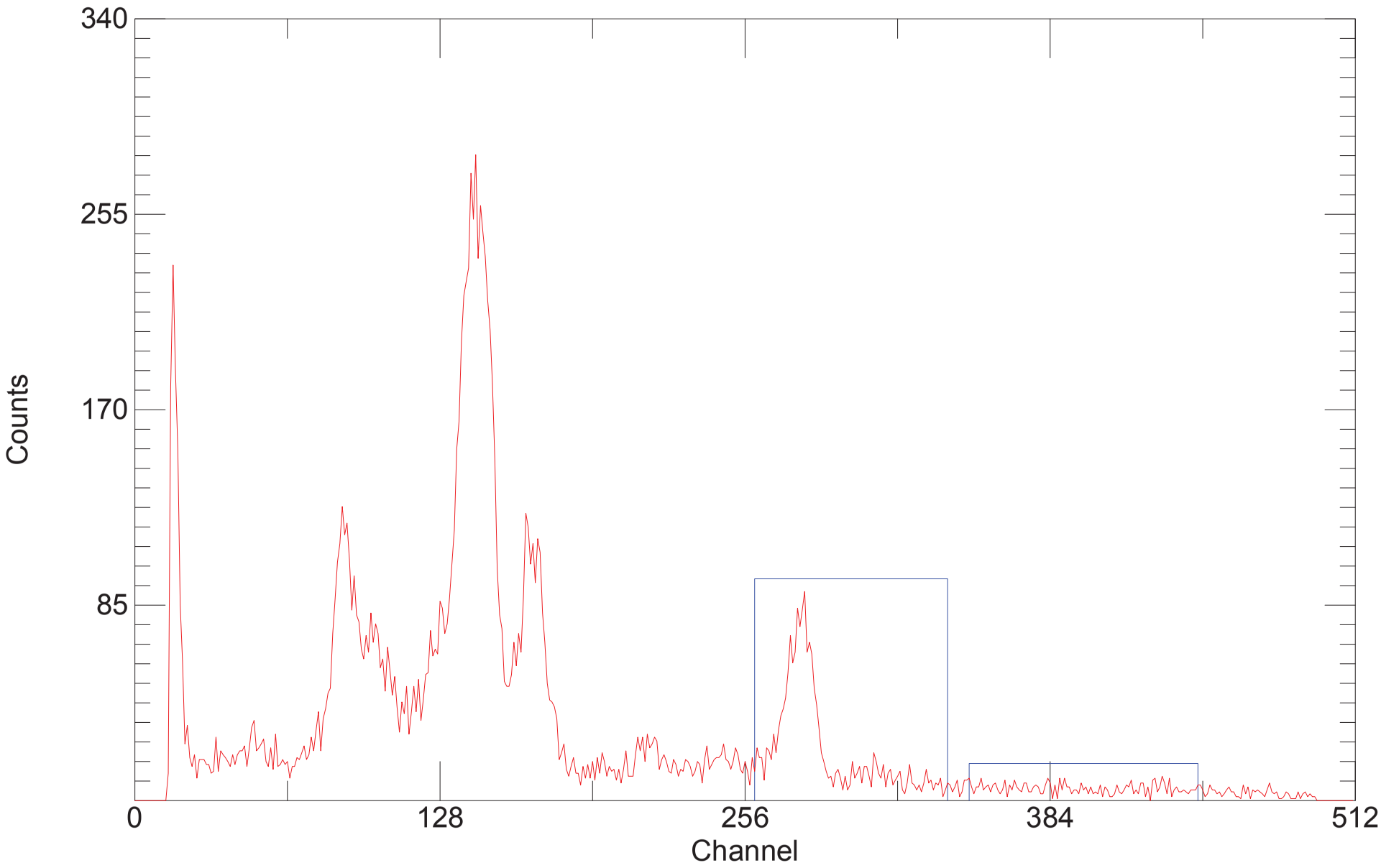
Acquired: 9/17/2012 11:20:17 AM Real Time: 300.00 s. Live Time: 300.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_CZT_MCA166_NBS07 Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



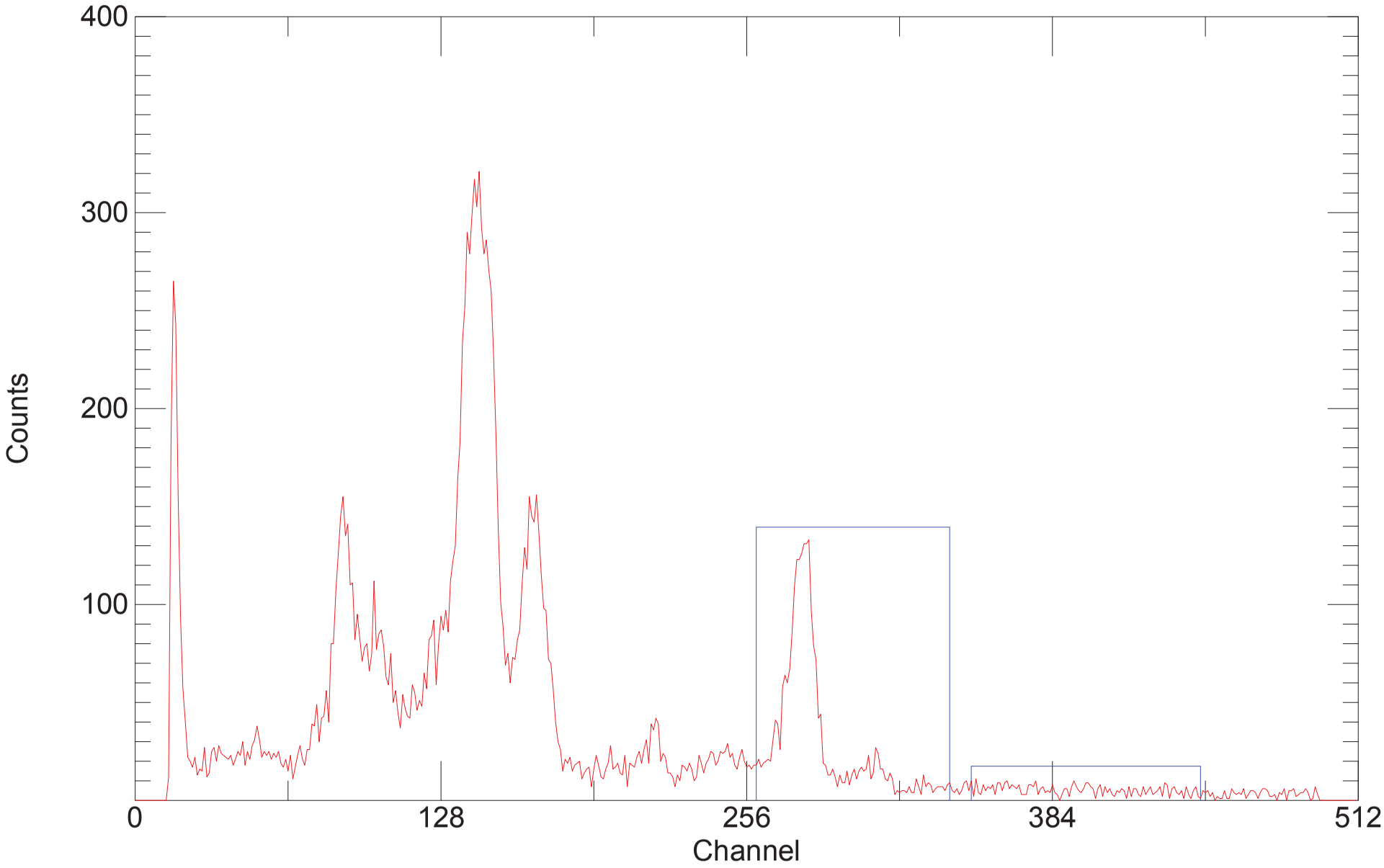
Acquired: 9/17/2012 12:05:32 PM Real Time: 300.00 s. Live Time: 300.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_CZT_MCA166_NBS19 Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



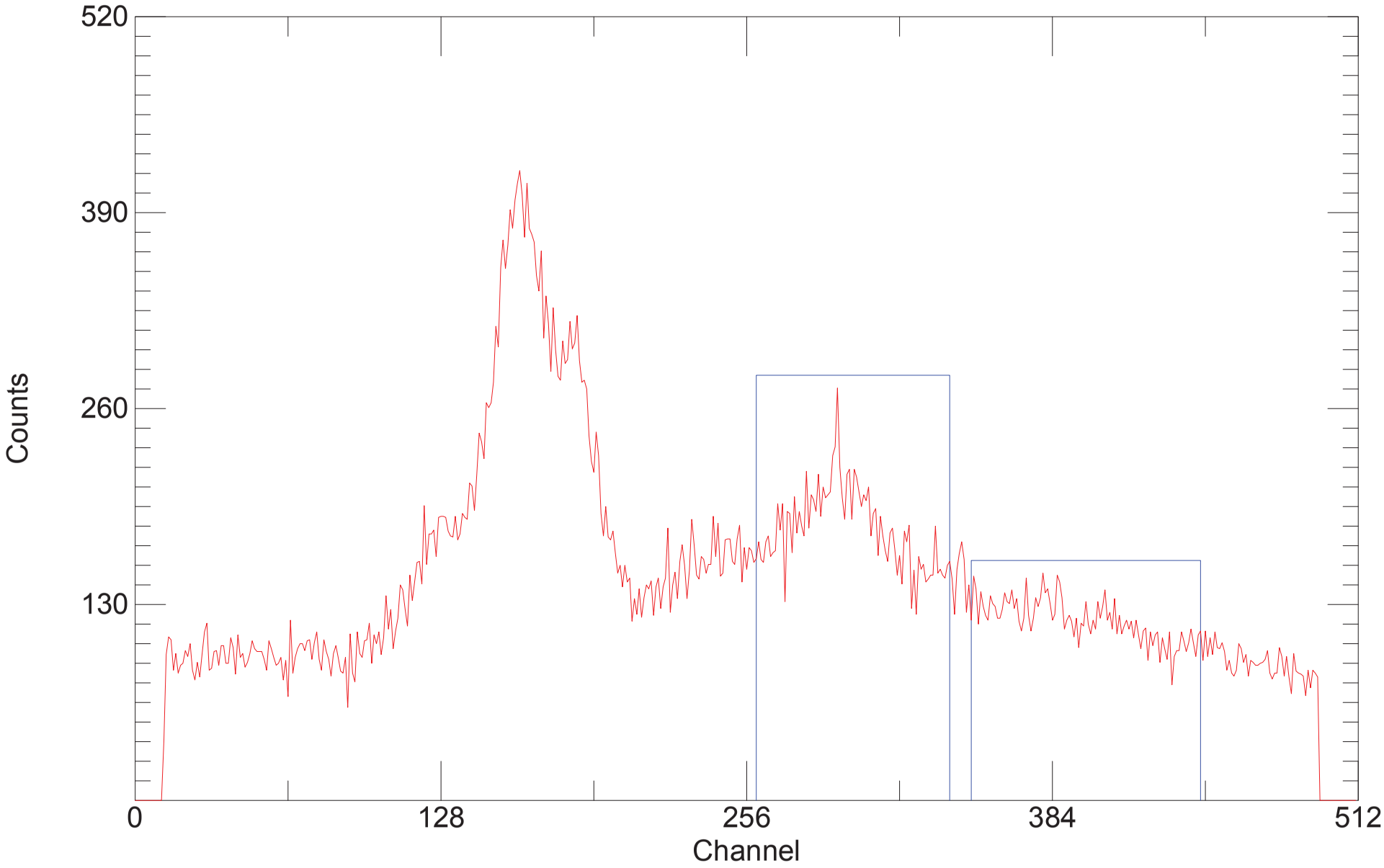
Acquired: 9/17/2012 11:27:24 AM Real Time: 300.00 s. Live Time: 300.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_CZT_MCA166_NBS29 Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



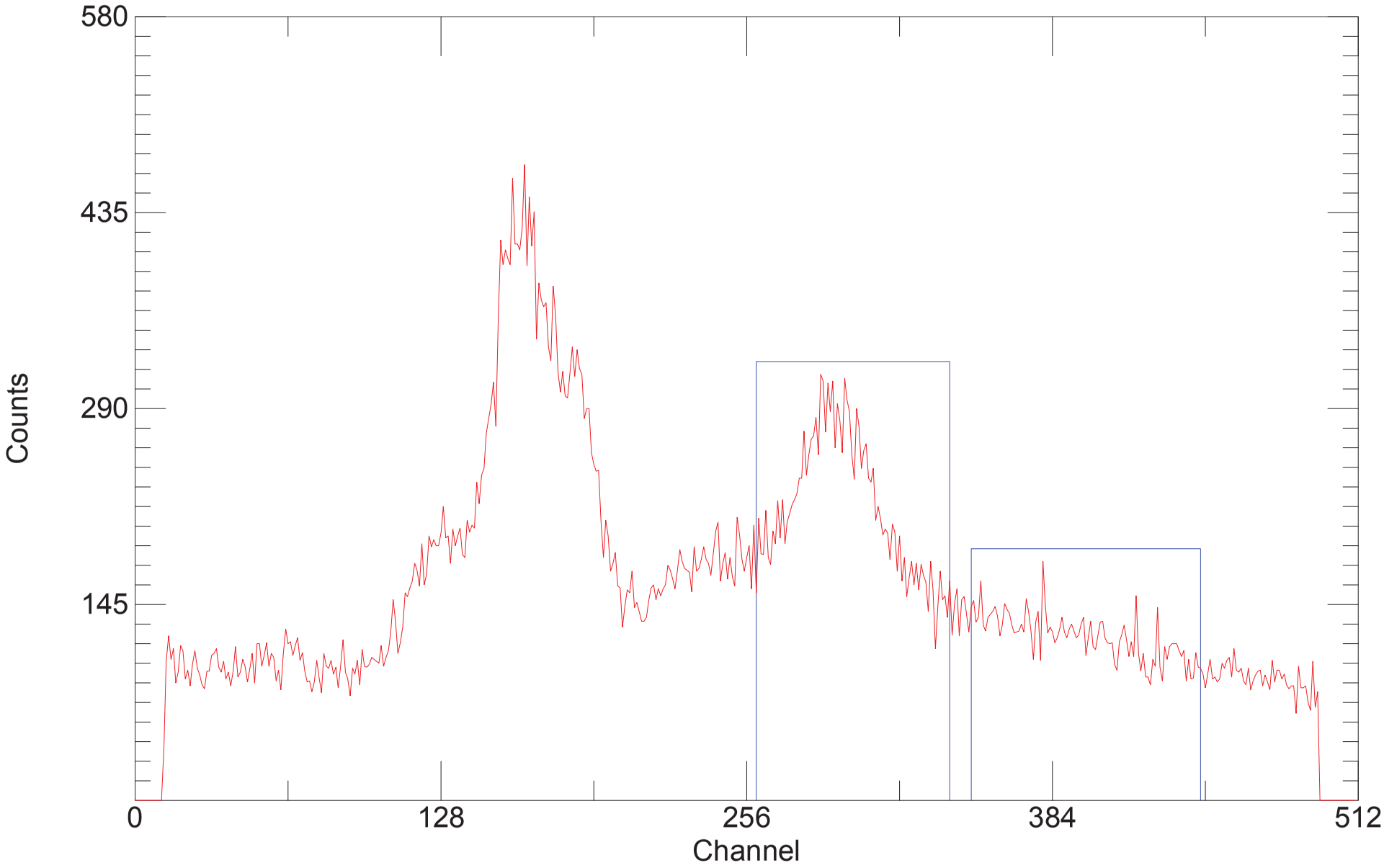
Acquired: 9/17/2012 10:56:08 AM Real Time: 300.00 s. Live Time: 300.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_CZT_MCA166_NBS44 Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



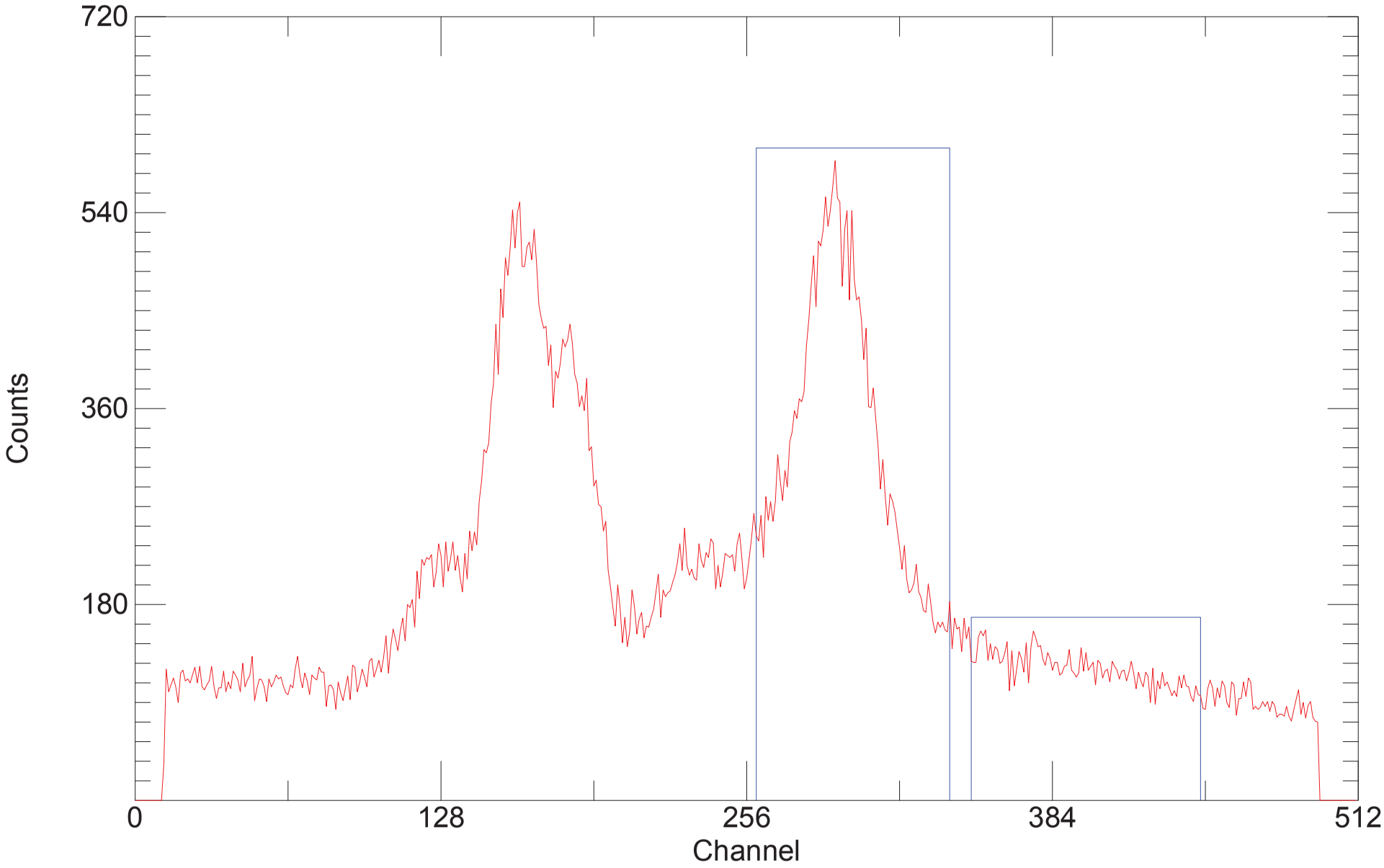
Acquired: 9/17/2012 4:25:15 PM Real Time: 300.00 s. Live Time: 301.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_NaI_MCA166_NBS031Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



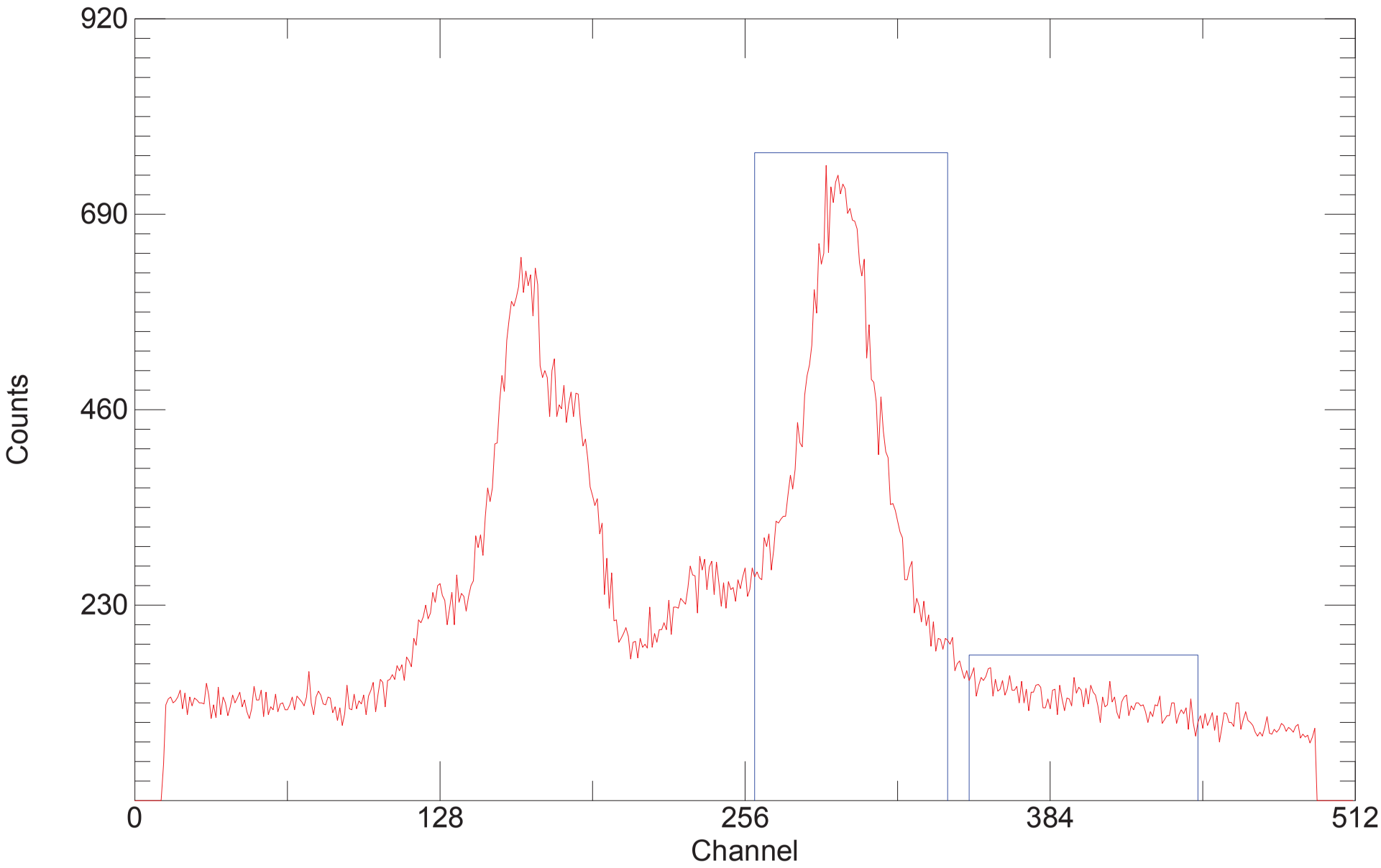
Acquired: 9/17/2012 3:52:38 PM Real Time: 300.00 s. Live Time: 301.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_NaI_MCA166_NBS071Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



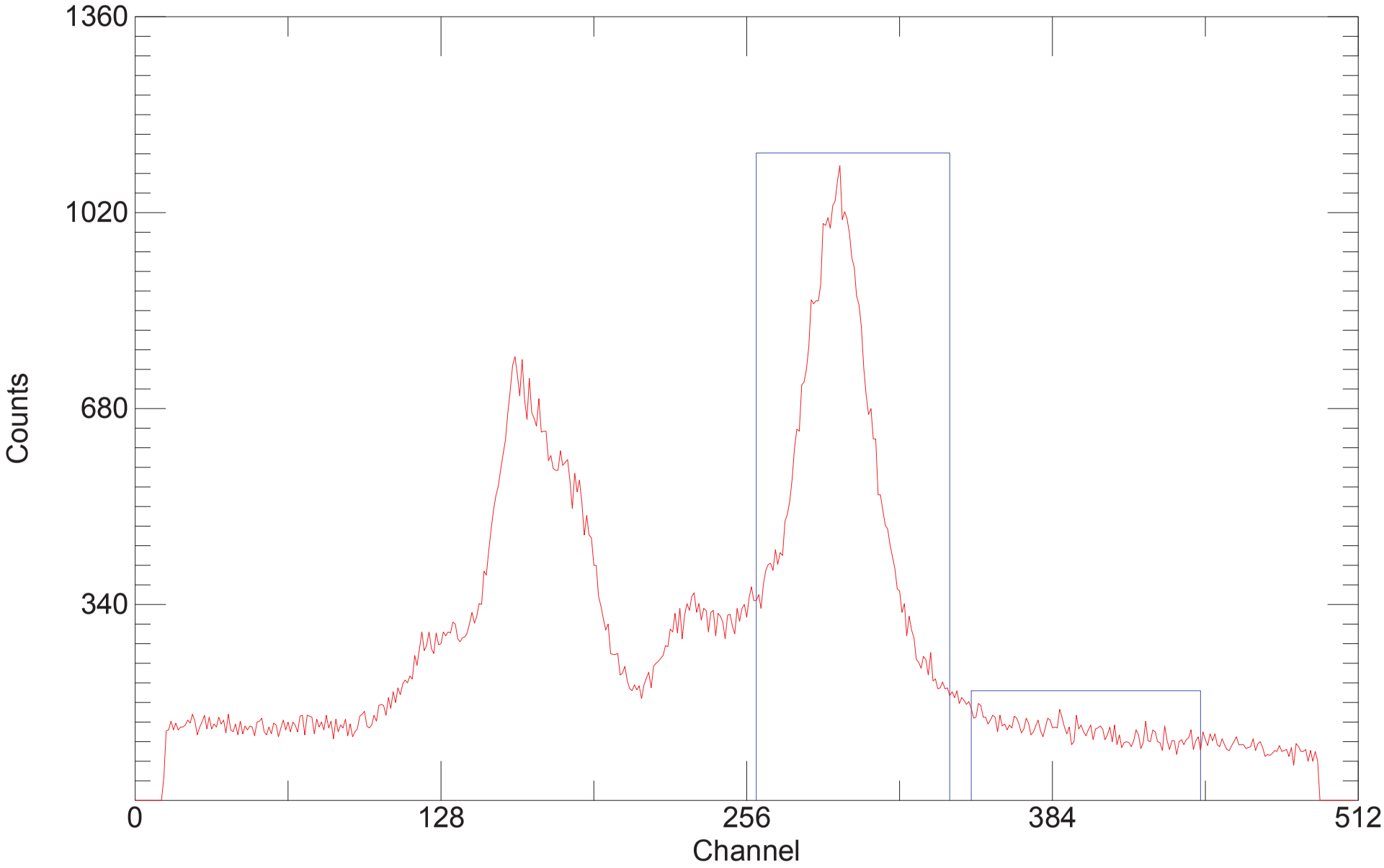
Acquired: 9/17/2012 4:04:10 PM Real Time: 300.00 s. Live Time: 301.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_NaI_MCA166_NBS194Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



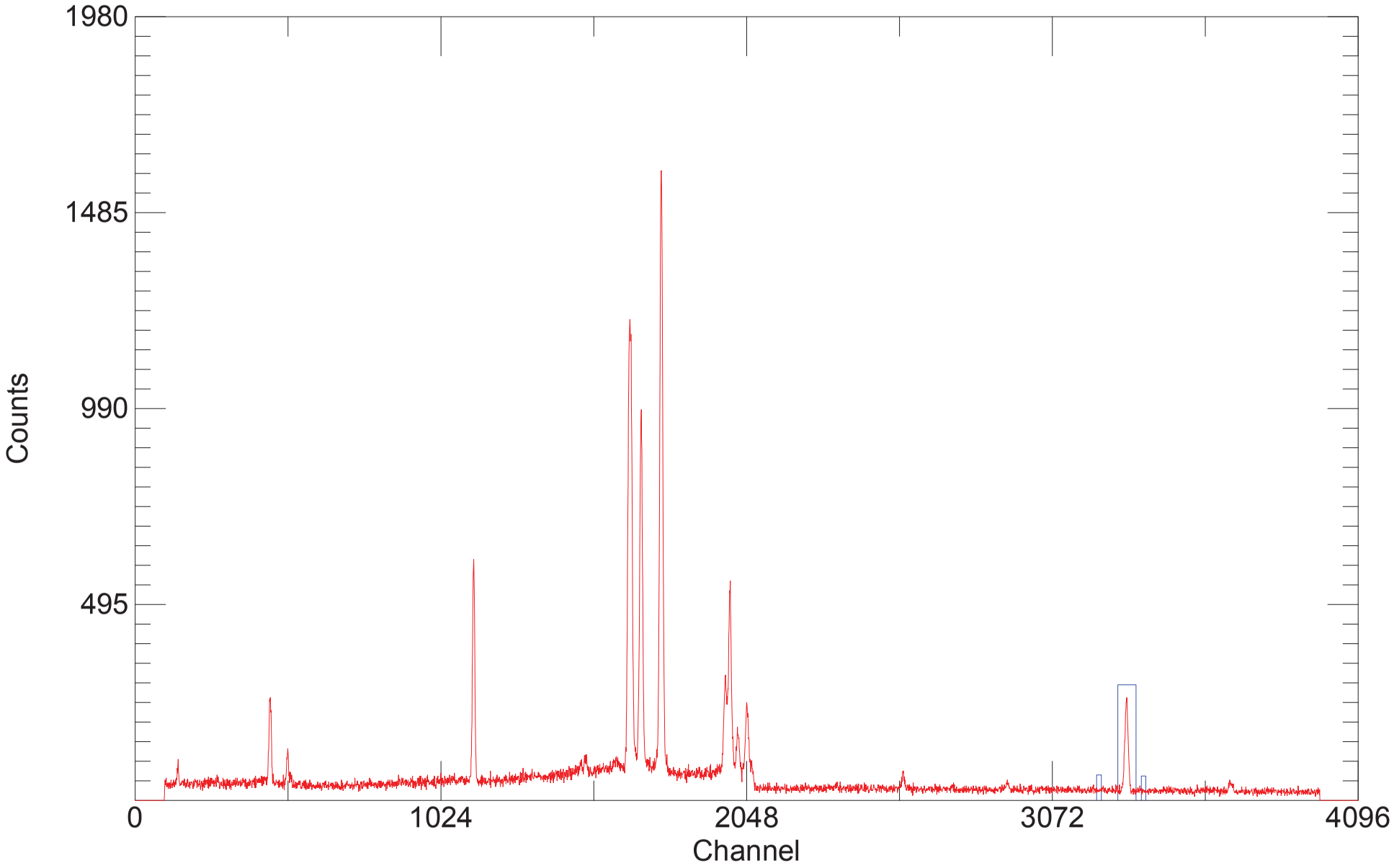
Acquired: 9/17/2012 4:12:34 PM Real Time: 300.00 s. Live Time: 302.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_NaI_MCA166_NBS295Channels: 512
Detector: #0

Detector: #0 □H~1\ENRICH~1\



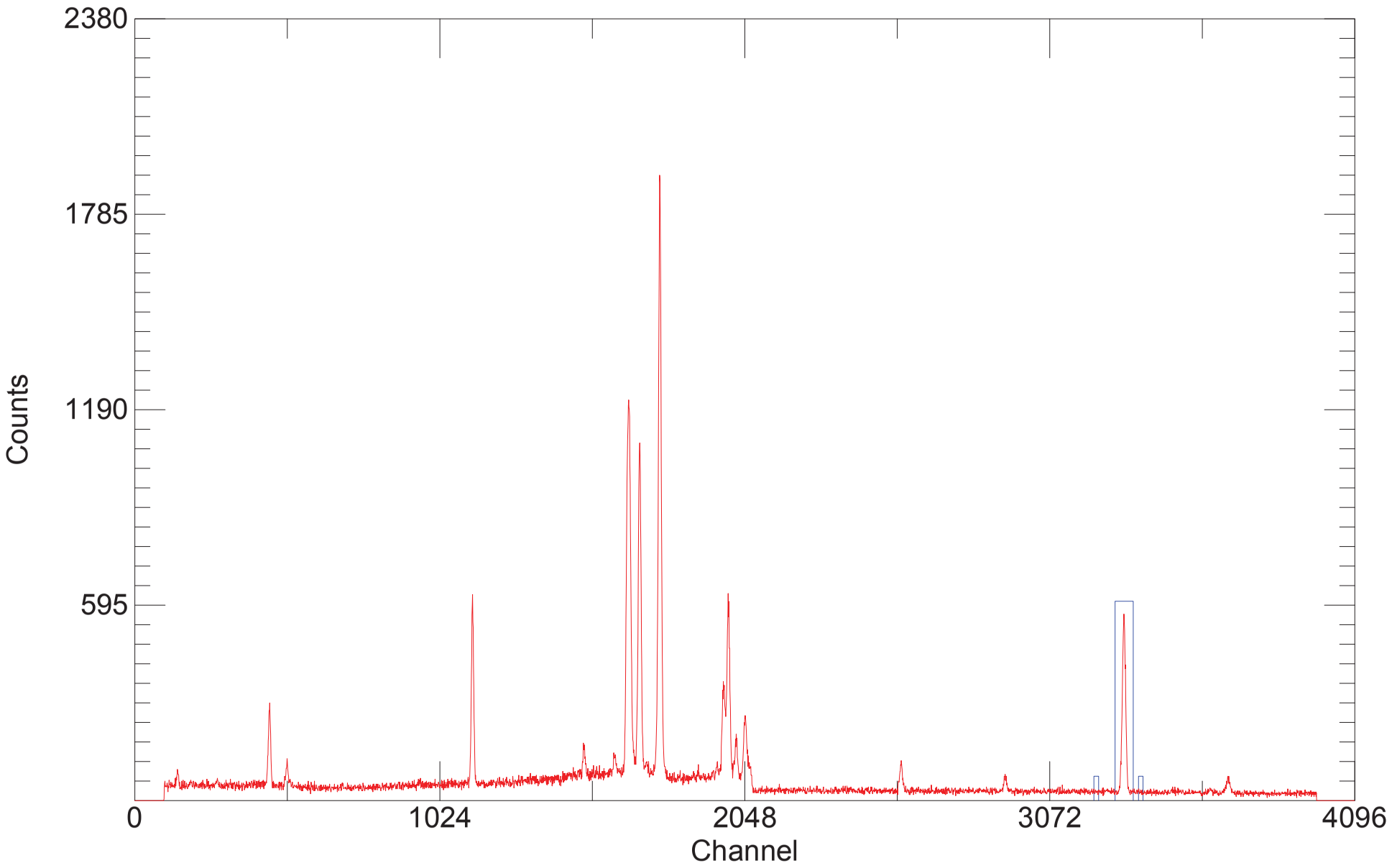
Acquired: 9/17/2012 3:44:11 PM Real Time: 300.00 s. Live Time: 302.00 s.
File: E:\ENRICH~1\ENRICH~1\WinU235\RR_WinU235_NaI_MCA166_NBS446Channels: 512
Detector: #0

Detector: #0 □□~1\ENRICH~1\



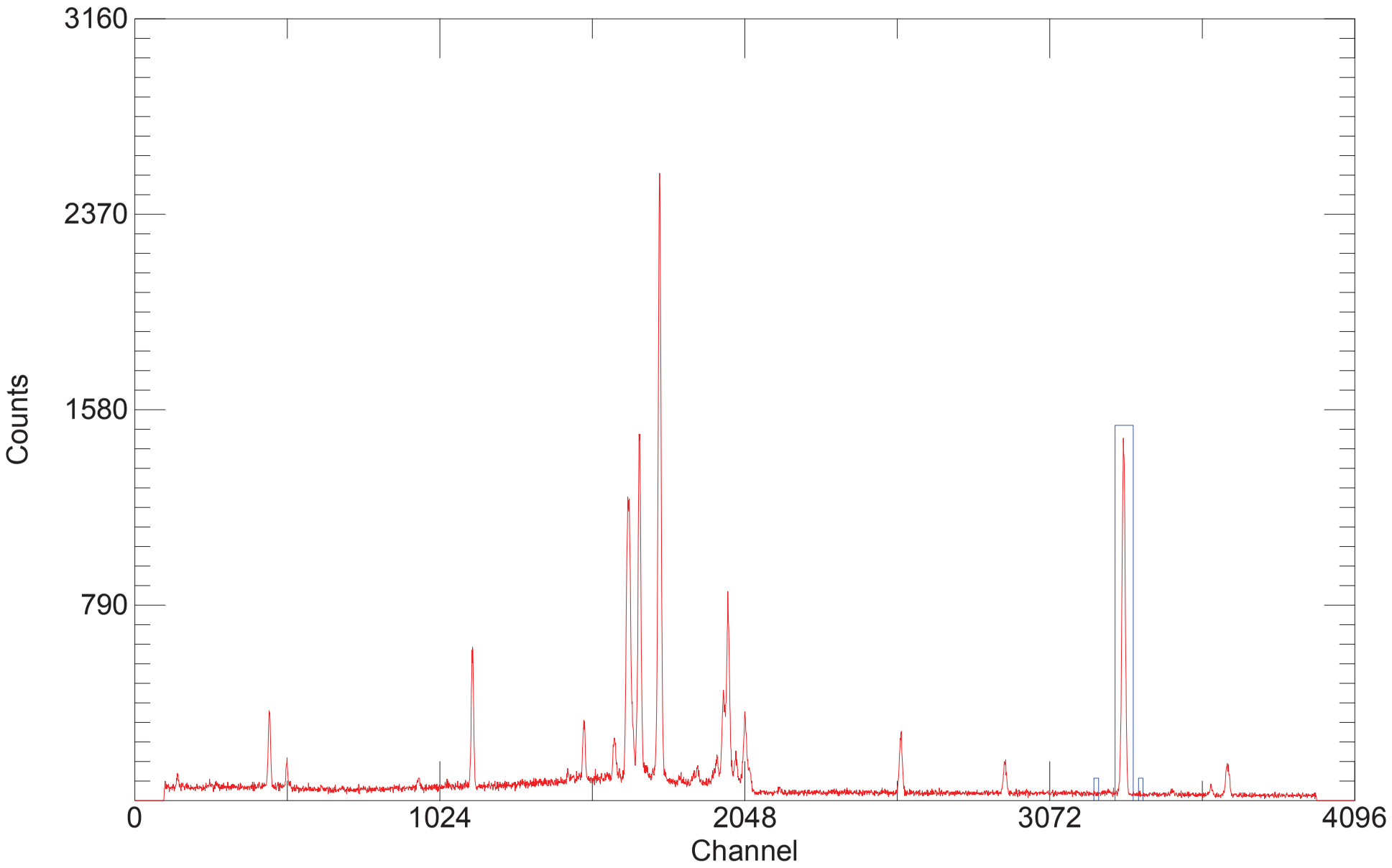
Acquired: 10/11/2012 1:46:57 PM Real Time: 300.00 s. Live Time: 303.00 s.
File: E:\ENRICH~1\ENRICH~1\WinUF6\RR_WinUF6_HPGe_MCA166_NBS0 Channels: 4096
Detector: #0

Detector: #0 □□~1\ENRICH~1\



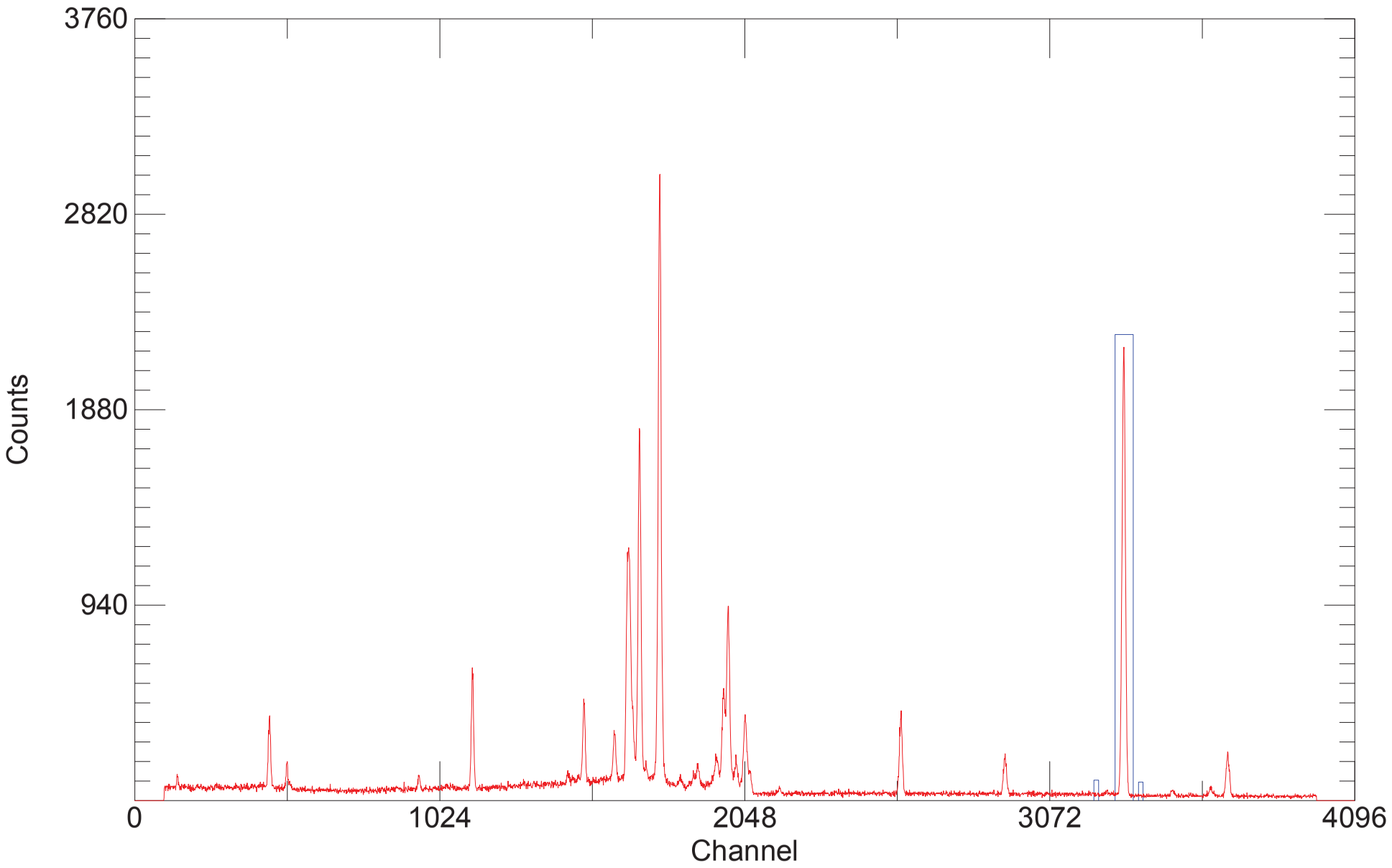
Acquired: 10/11/2012 1:31:13 PM Real Time: 300.00 s. Live Time: 304.00 s.
File: E:\ENRICH~1\ENRICH~1\WinUF6\RR_WinUF6_HPGe_MCA166_NBS07 Channels: 4096
Detector: #0

Detector: #0 □□~1\ENRICH~1\



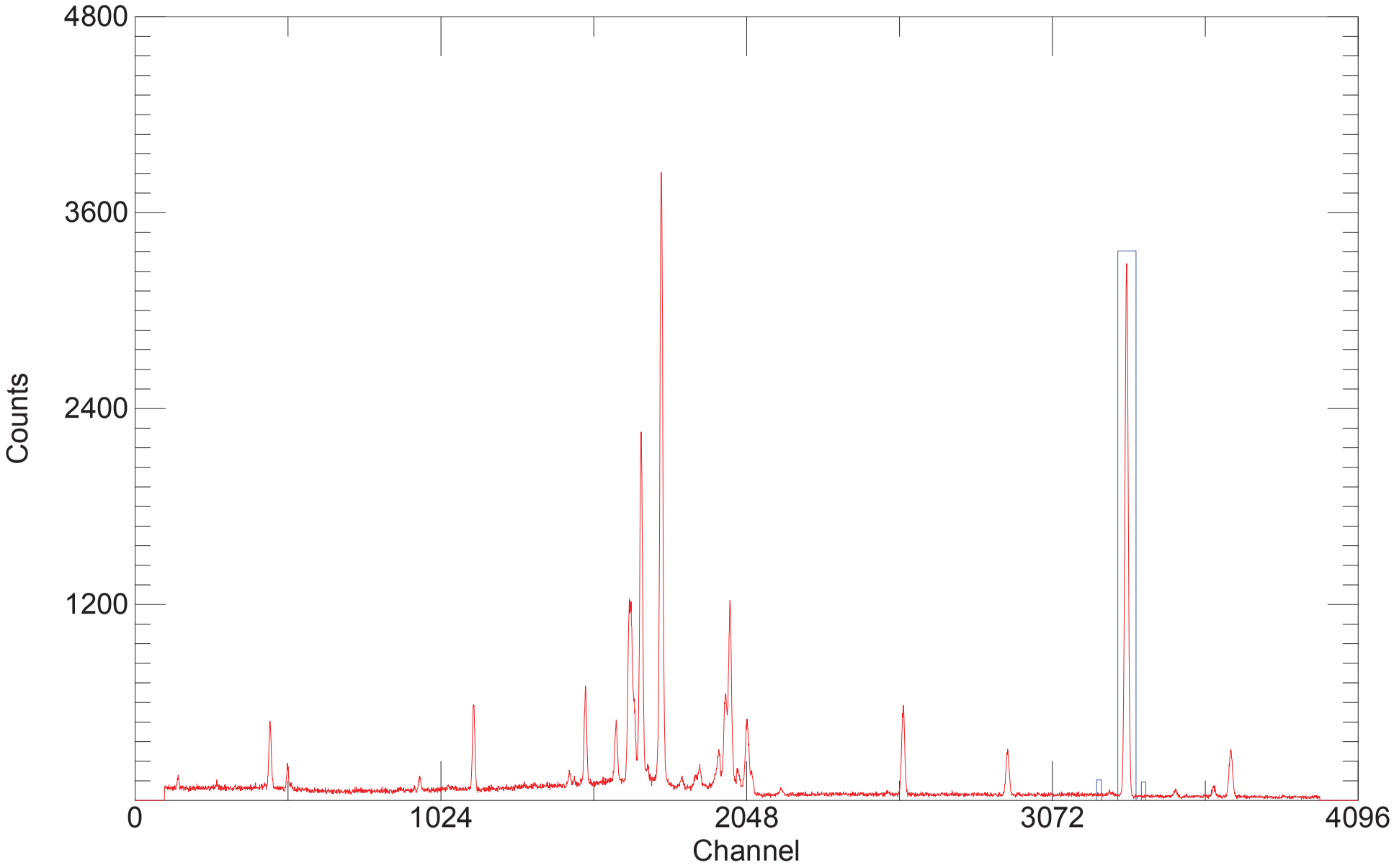
Acquired: 10/11/2012 3:04:33 PM Real Time: 300.00 s. Live Time: 304.00 s.
File: E:\ENRICH~1\ENRICH~1\WinUF6\RR_WinUF6_HPGe_MCA166_NBS19 Channels: 4096
Detector: #0

Detector: #0 □□~1\ENRICH~1\

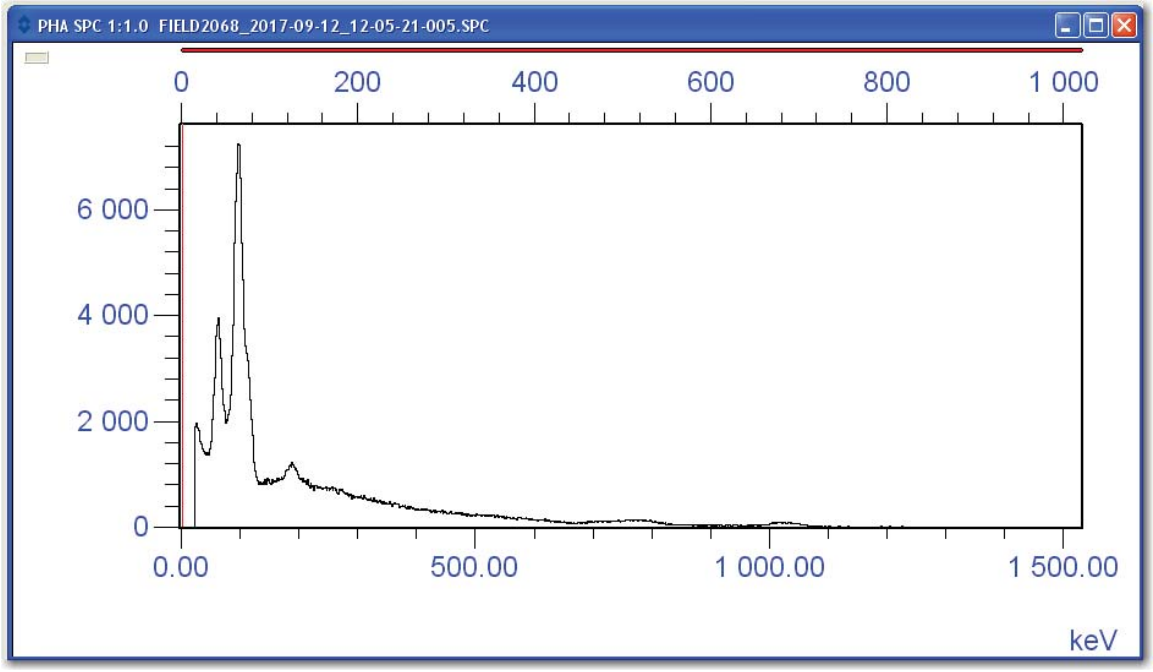


Acquired: 10/11/2012 2:56:47 PM Real Time: 300.00 s. Live Time: 305.00 s.
File: E:\ENRICH~1\ENRICH~1\WinUF6\RR_WinUF6_HPGe_MCA166_NBS2 Channels: 4096
Detector: #0

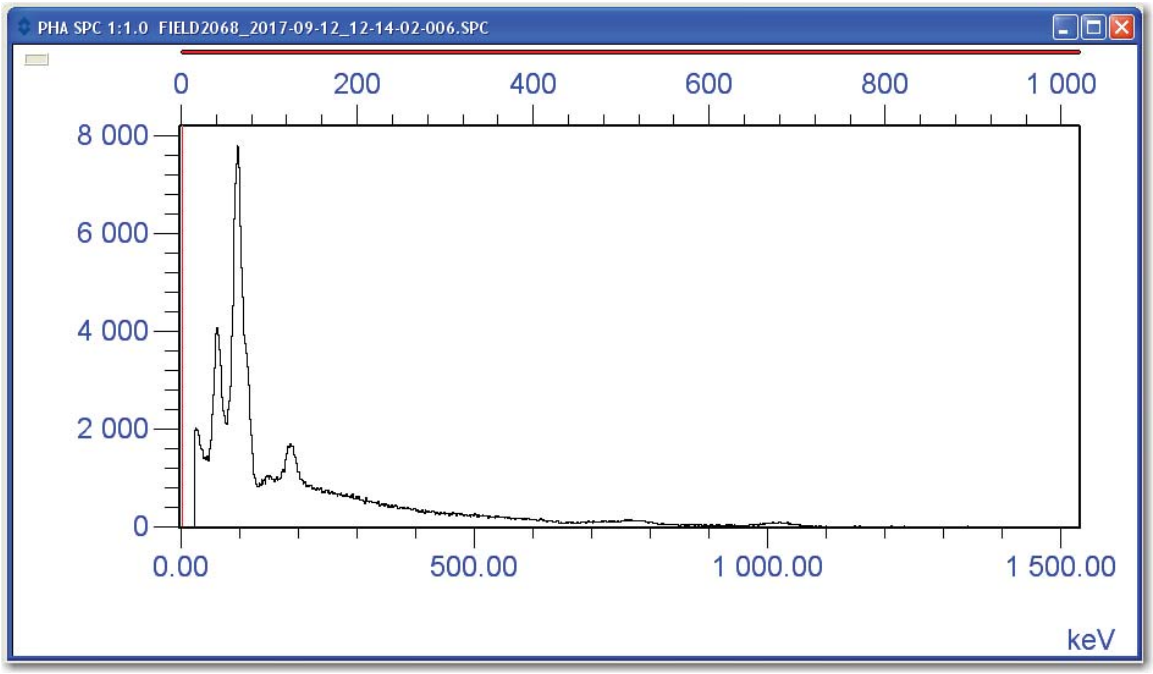
Detector: #0 □□~1\ENRICH~1\



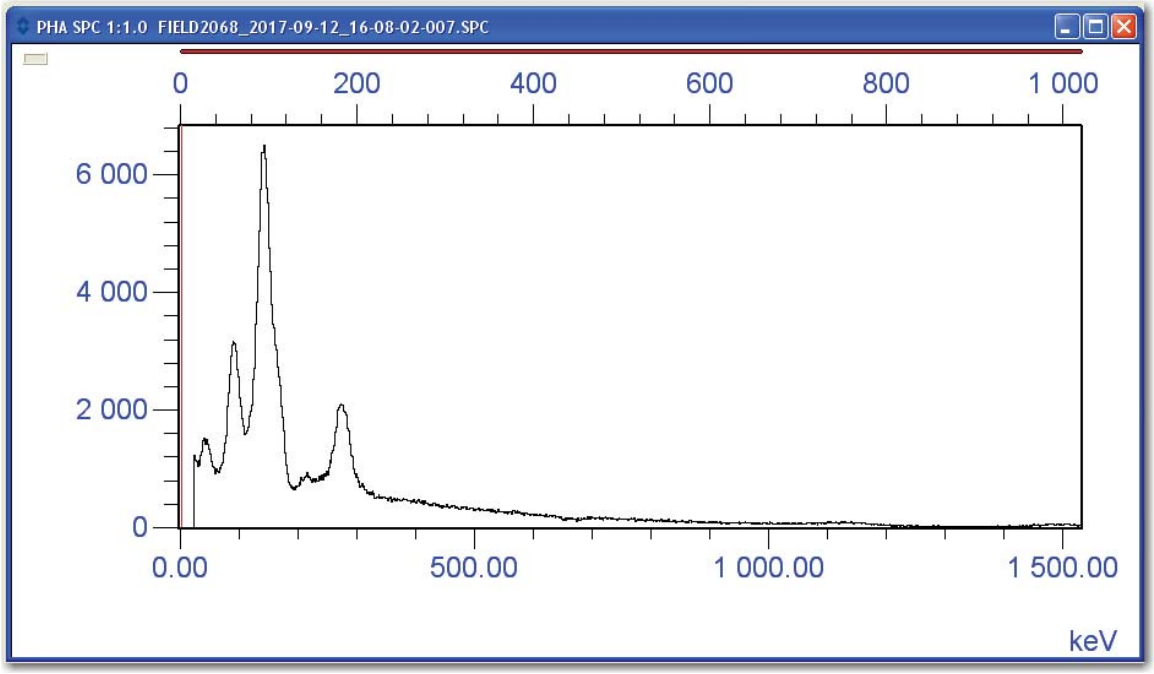
Acquired: 10/11/2012 1:38:41 PM Real Time: 300.00 s. Live Time: 306.00 s.
File: E:\ENRICH~1\ENRICH~1\WinUF6\RR_WinUF6_HPGe_MCA166_NBS4 Channels: 4096
Detector: #0



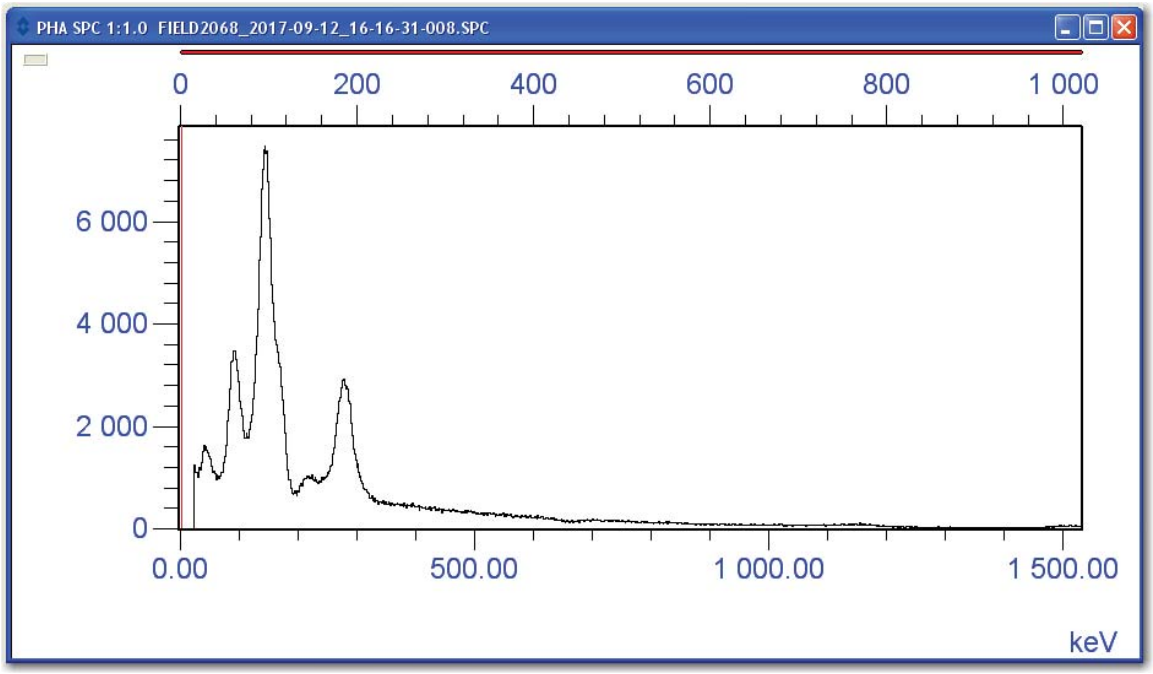
RR_NaIGEM_HM5_NBS031



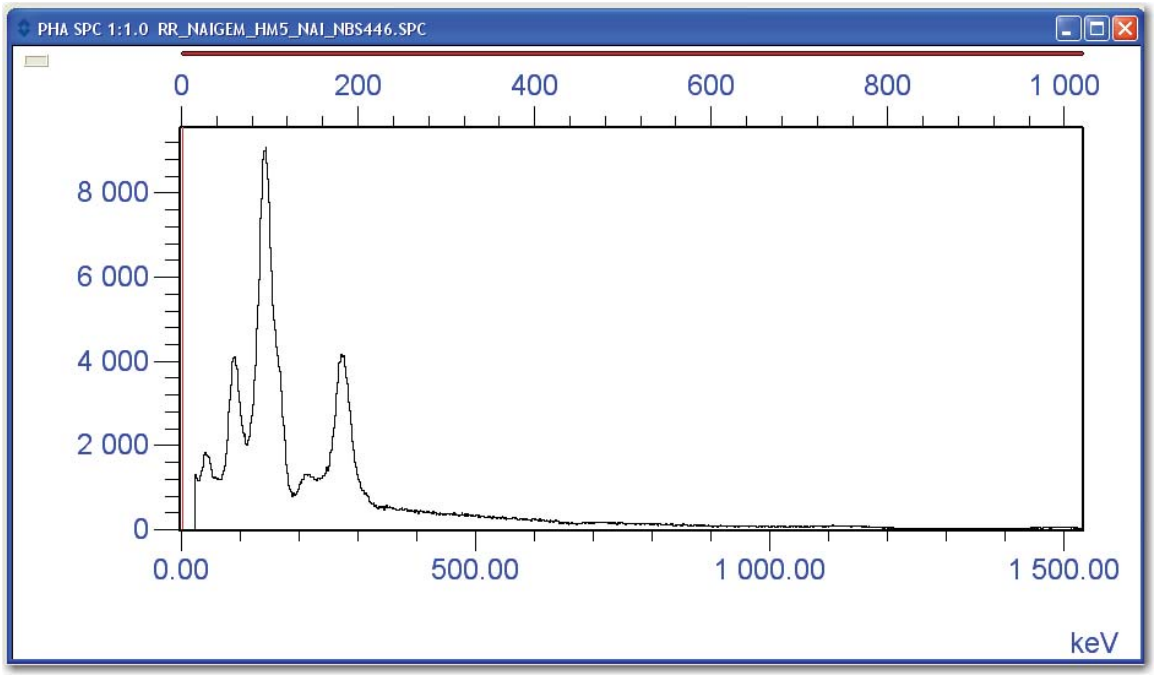
RR_NaIGEM_HM5_NBS071



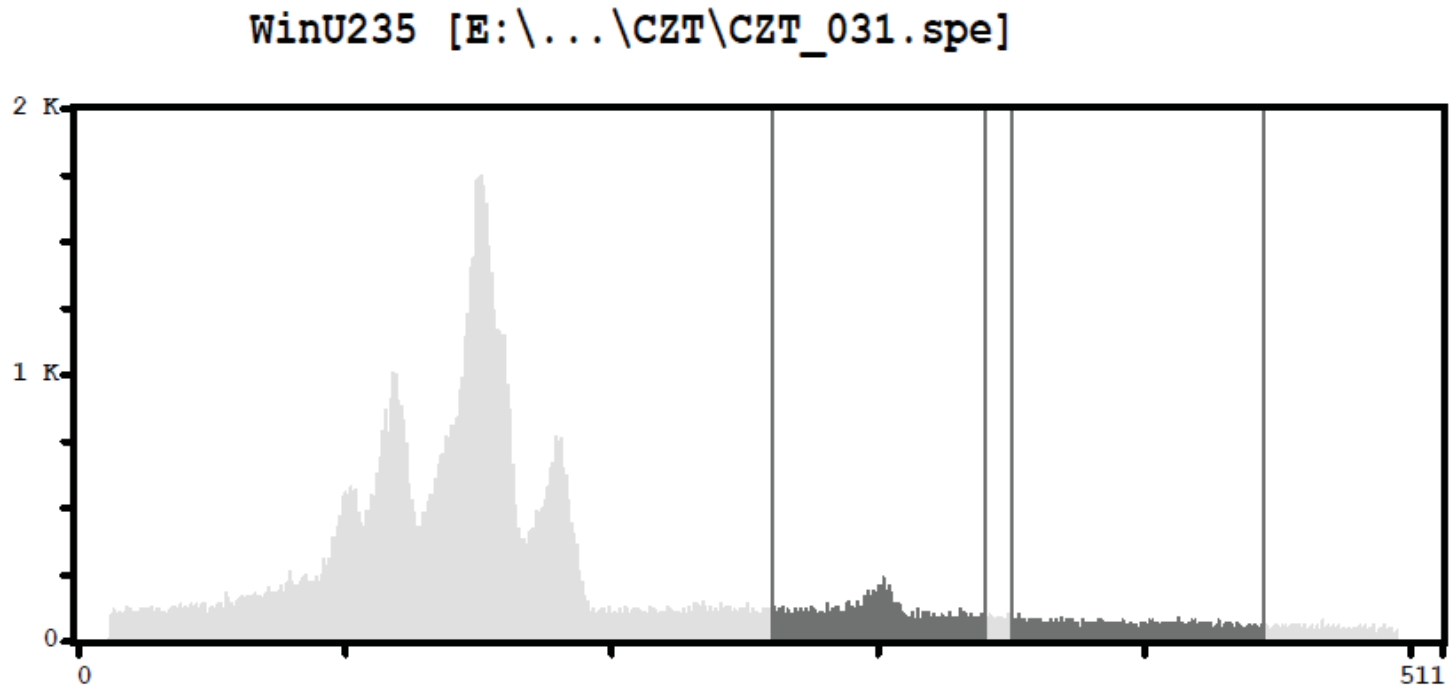
RR_NaIGEM_HM5_NBS194



RR_NaIGEM_HM5_NBS295



RR_NaIGEM_HM5_NBS446

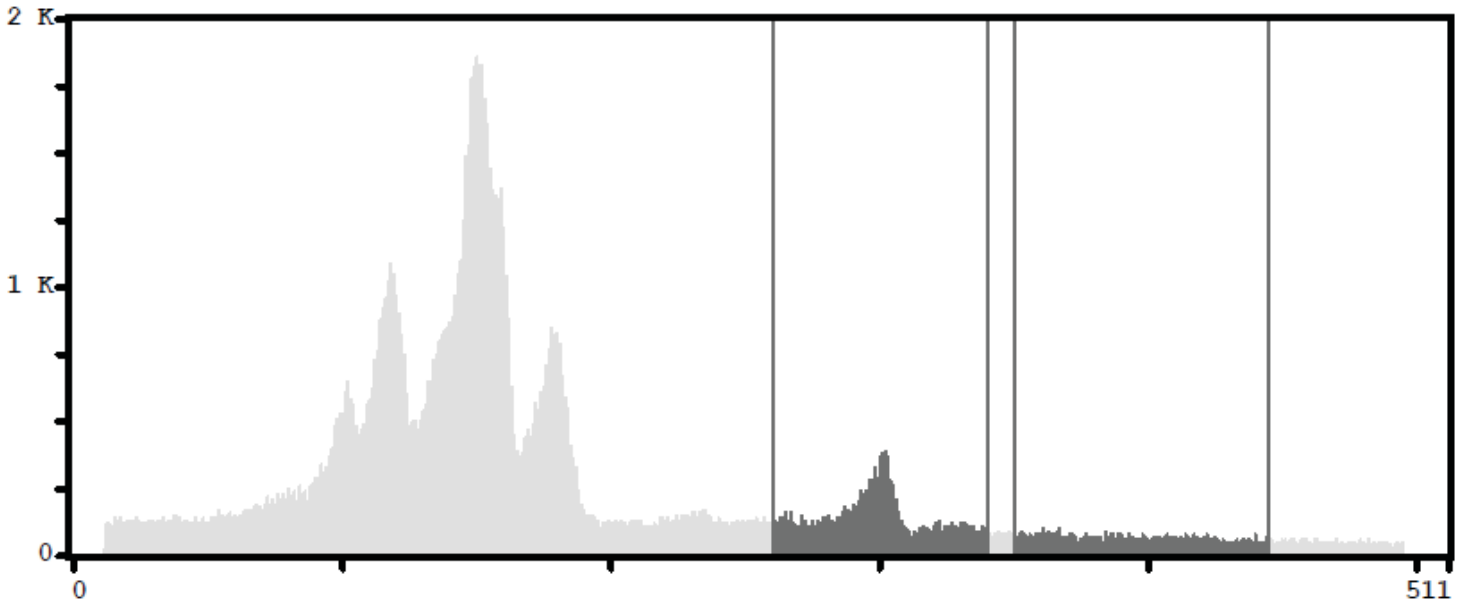


Remarks:

Start Time = 11/06/2012 16:41:31

Life Time = 300 sec Dead Time = 0.7 %

WinU235 [E:\...\CZT\CZT_071.spe]

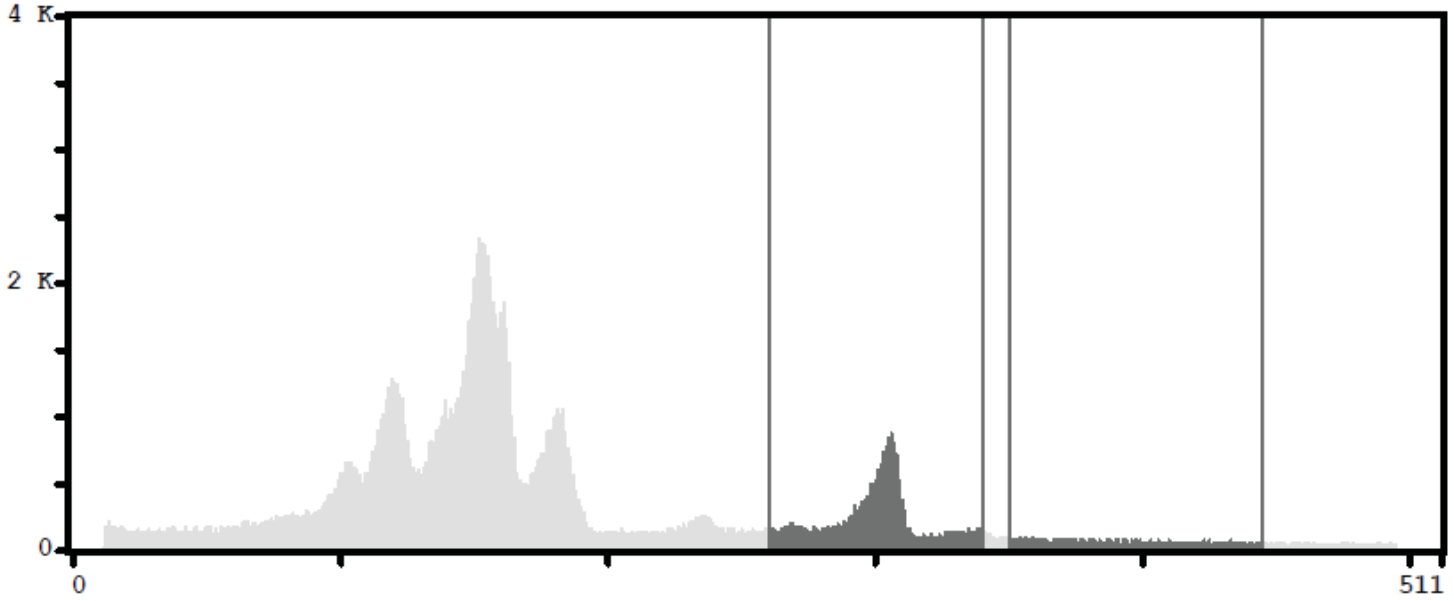


Remarks:

Start Time = 11/06/2012 11:53:07

Life Time = 300 sec Dead Time = 0.7 %

WinU235 [E:\...\CZT\CZT_194.spe]

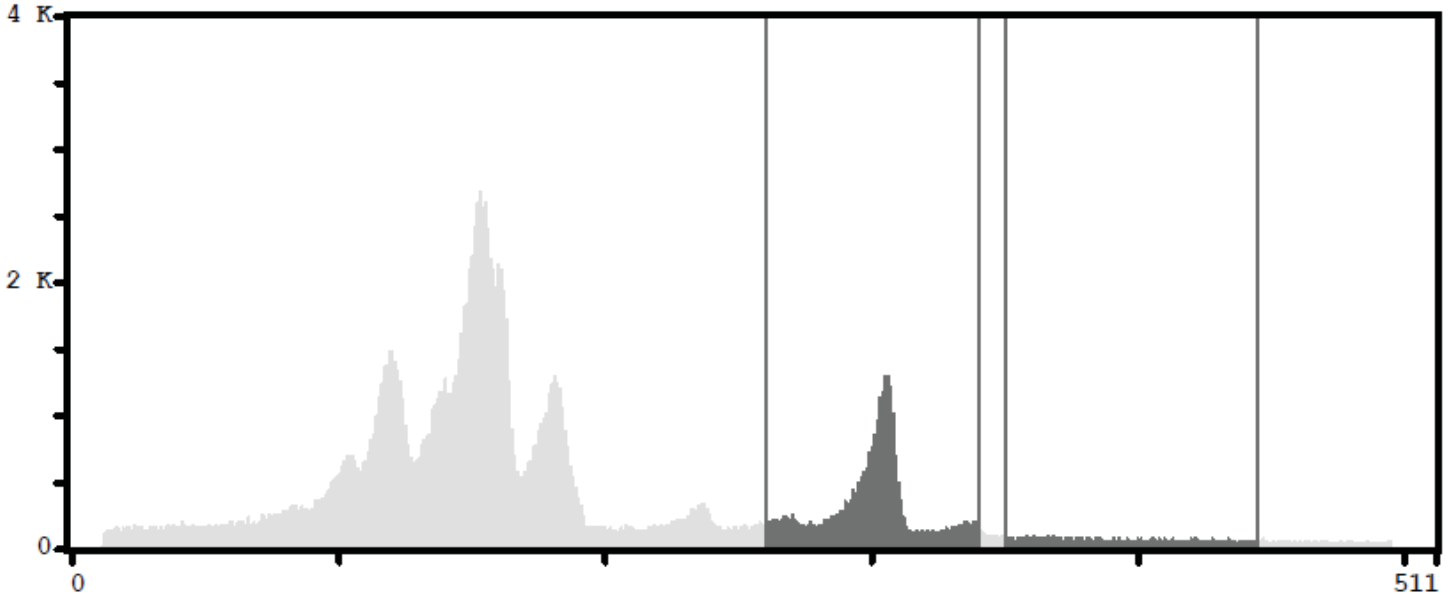


Remarks:

Start Time = 11/06/2012 12:02:39

Life Time = 300 sec Dead Time = 0.9 %

WinU235 [E:\...\CZT\CZT_295.spe]

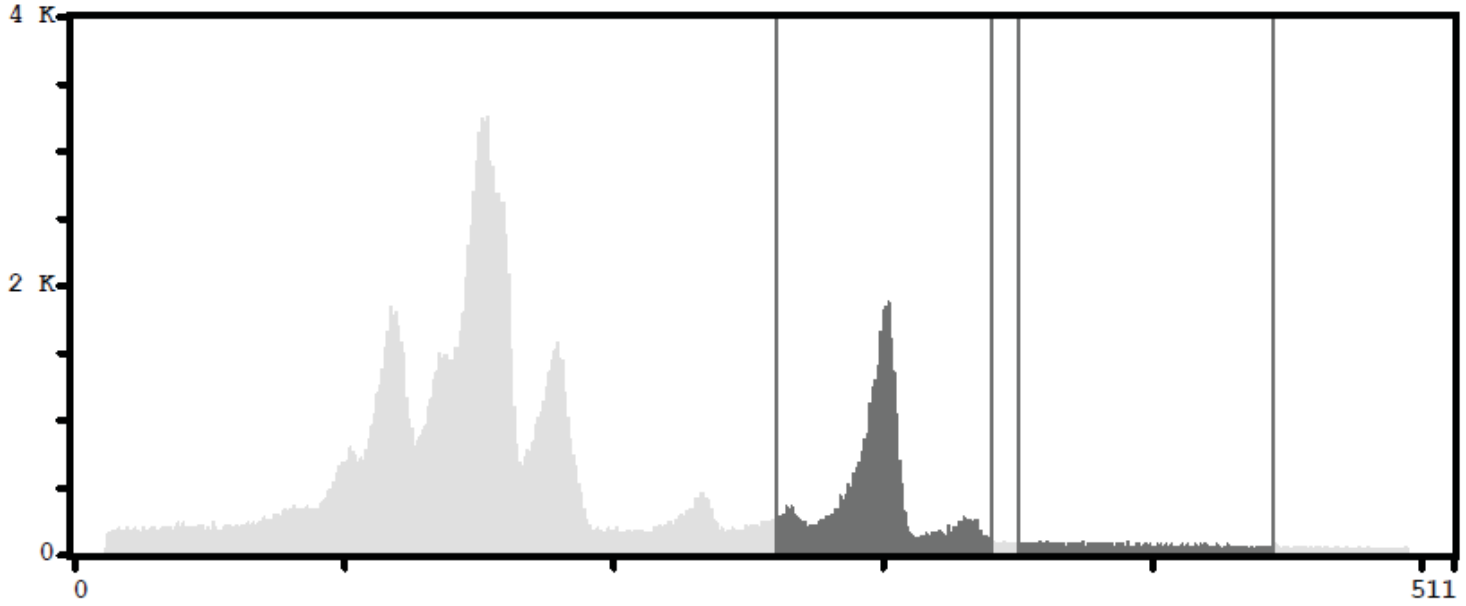


Remarks:

Start Time = 11/06/2012 16:35:24

Life Time = 300 sec Dead Time = 1.0 %

WinU235 [E:\...\CZT\CZT_446.spe]

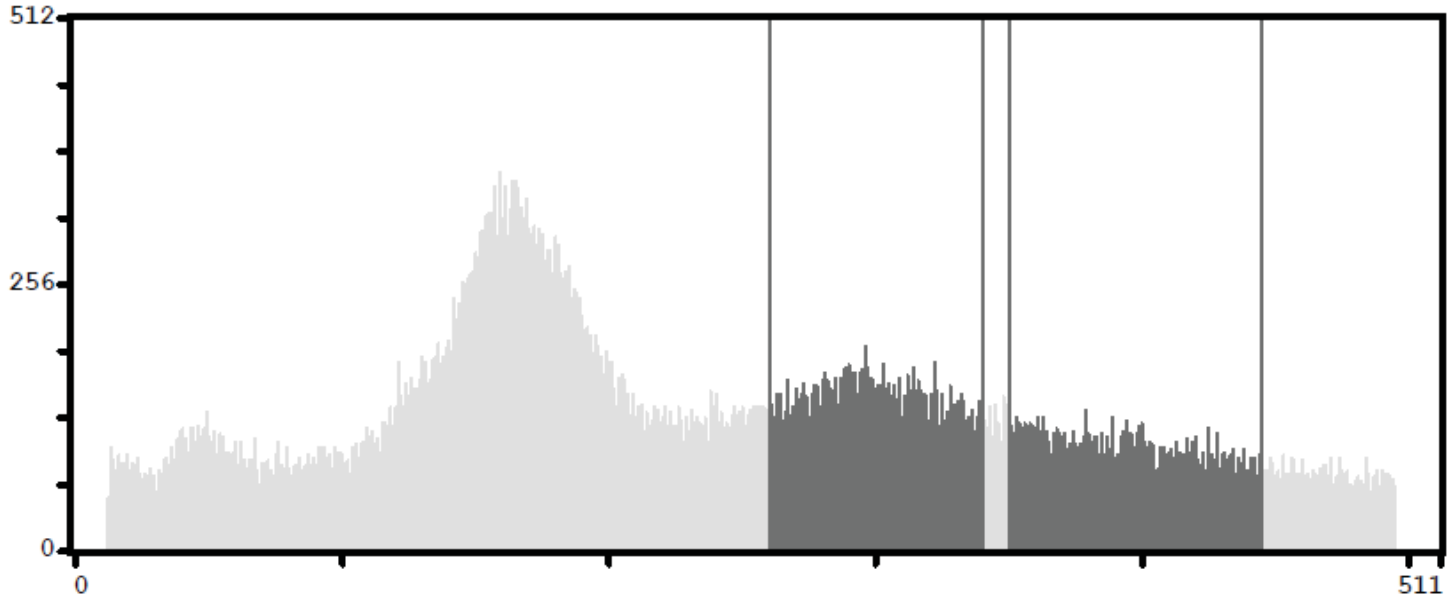


Remarks:

Start Time = 11/06/2012 11:45:03

Life Time = 300 sec Dead Time = 1.2 %

WinU235 [E:\...\NaI\EFC_031.spe]

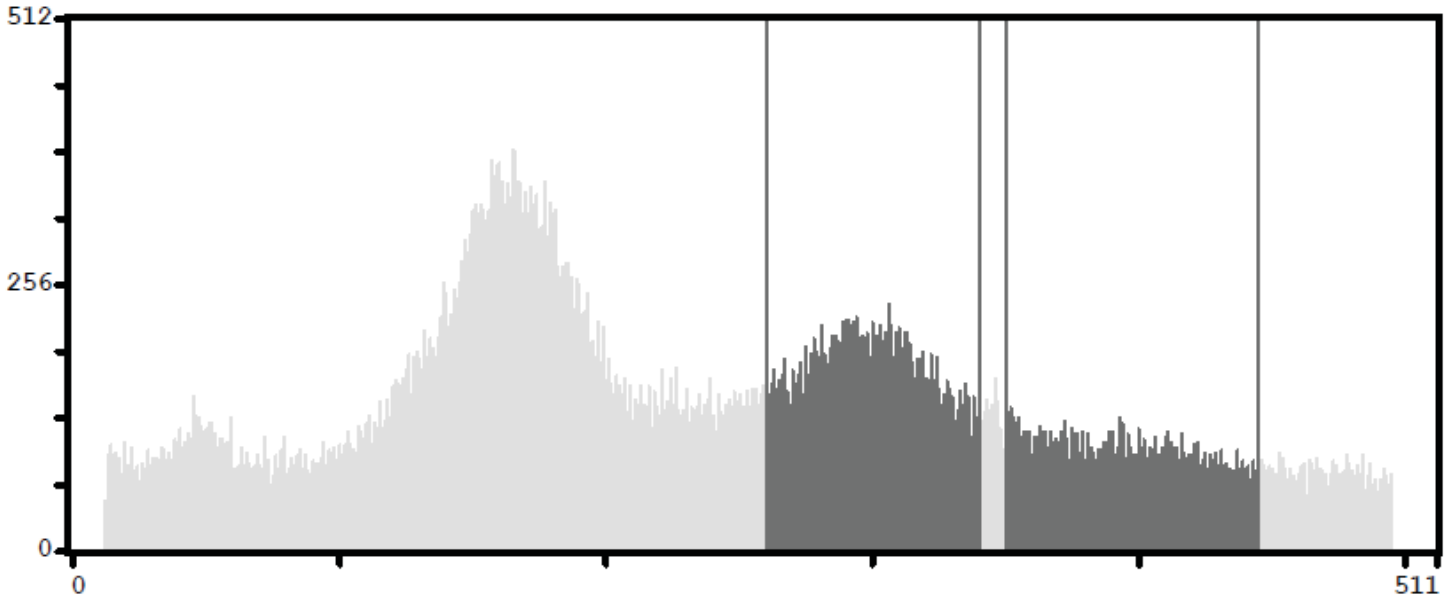


Remarks:

Start Time = 11/02/2012 14:05:45

Life Time = 300 sec Dead Time = 0.4 %

WinU235 [E:\...\NaI\EFC_071.spe]

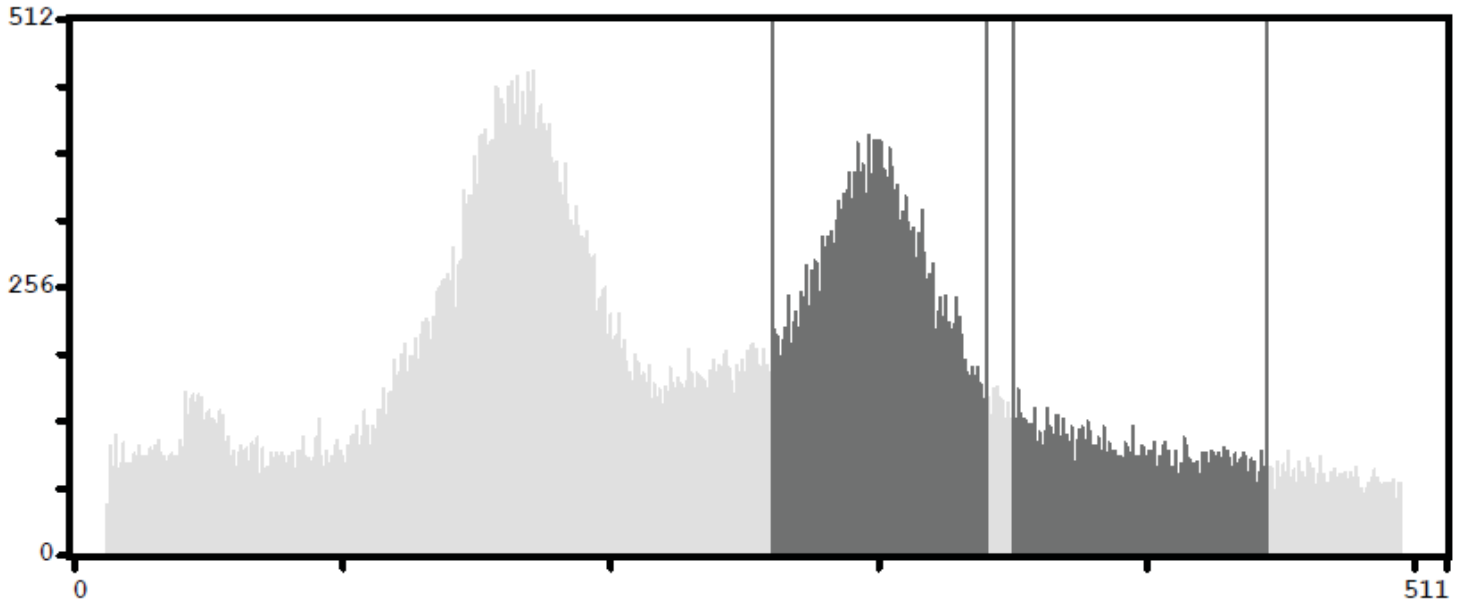


Remarks:

Start Time = 12/11/2012 16:32:23

Life Time = 300 sec Dead Time = 0.5 %

WinU235 [E:\...\NaI\EFC_194.spe]

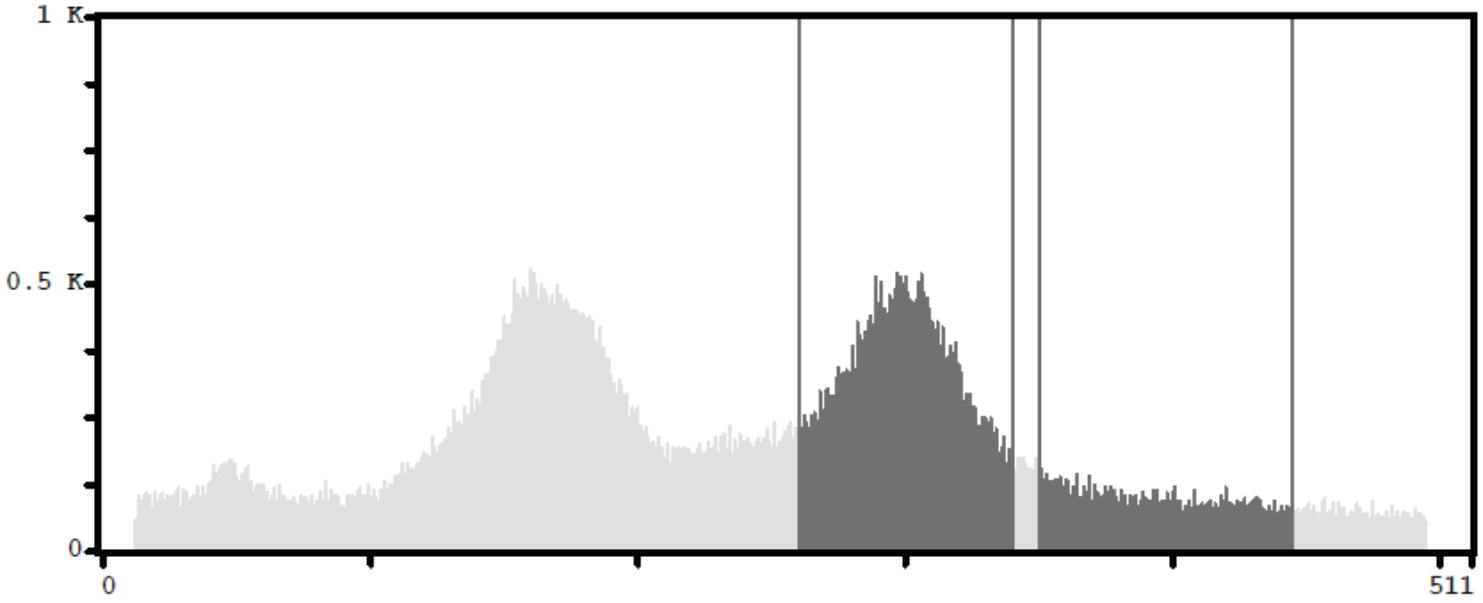


Remarks:

Start Time = 12/11/2012 16:43:38

Life Time = 300 sec Dead Time = 0.5 %

WinU235 [E:\...\NaI\EFC_295.spe]

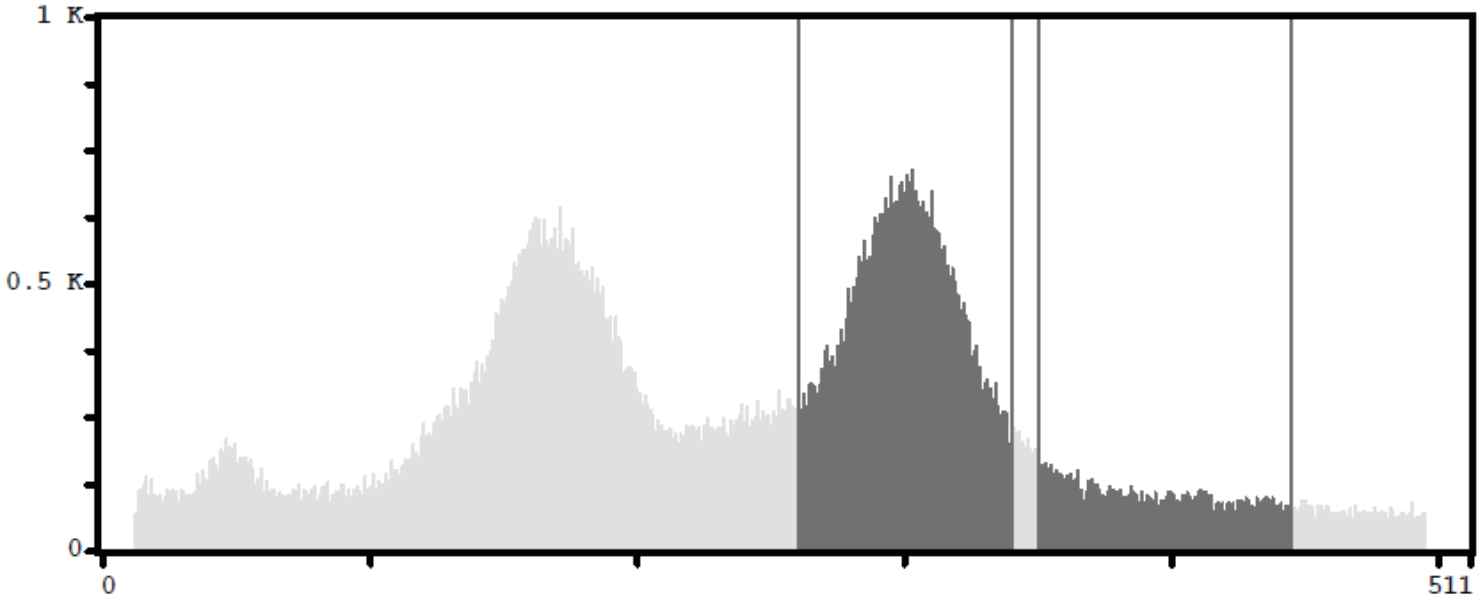


Remarks:

Start Time = 12/12/2012 09:42:07

Life Time = 300 sec Dead Time = 0.6 %

WinU235 [E:\...\NaI\EFC_446.spe]

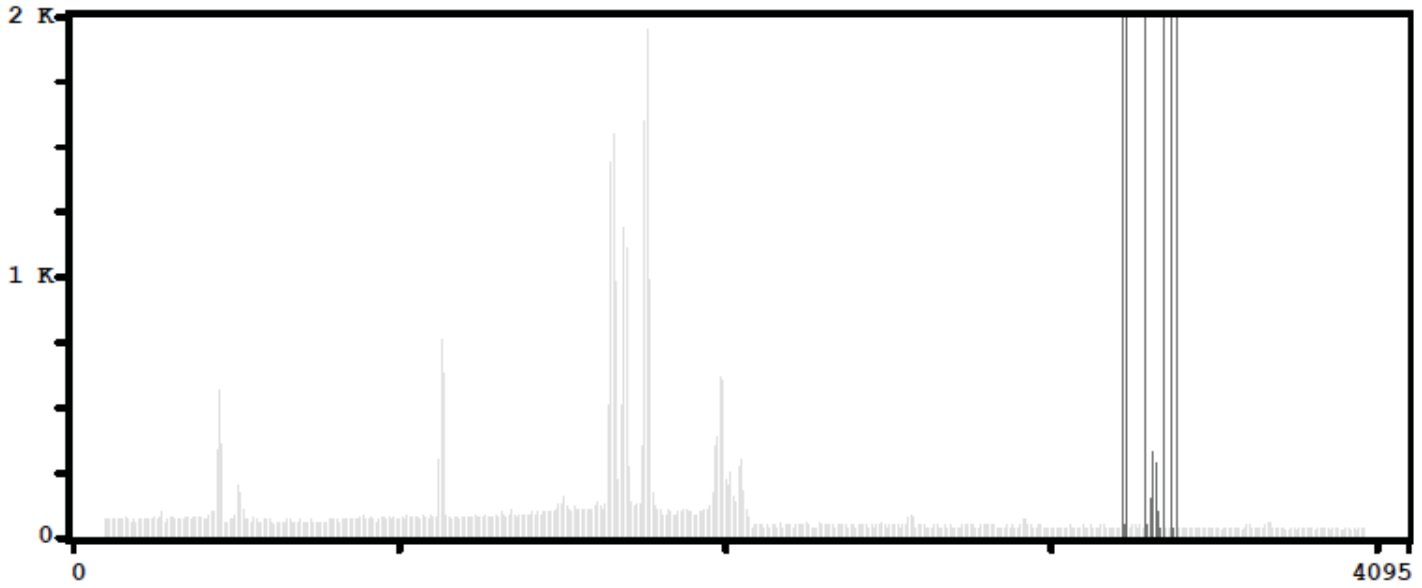


Remarks:

Start Time = 12/10/2012 14:05:05

Life Time = 300 sec Dead Time = 0.7 %

WinUF6 [E:\...\WinUF6\WINUF6_031.spe]

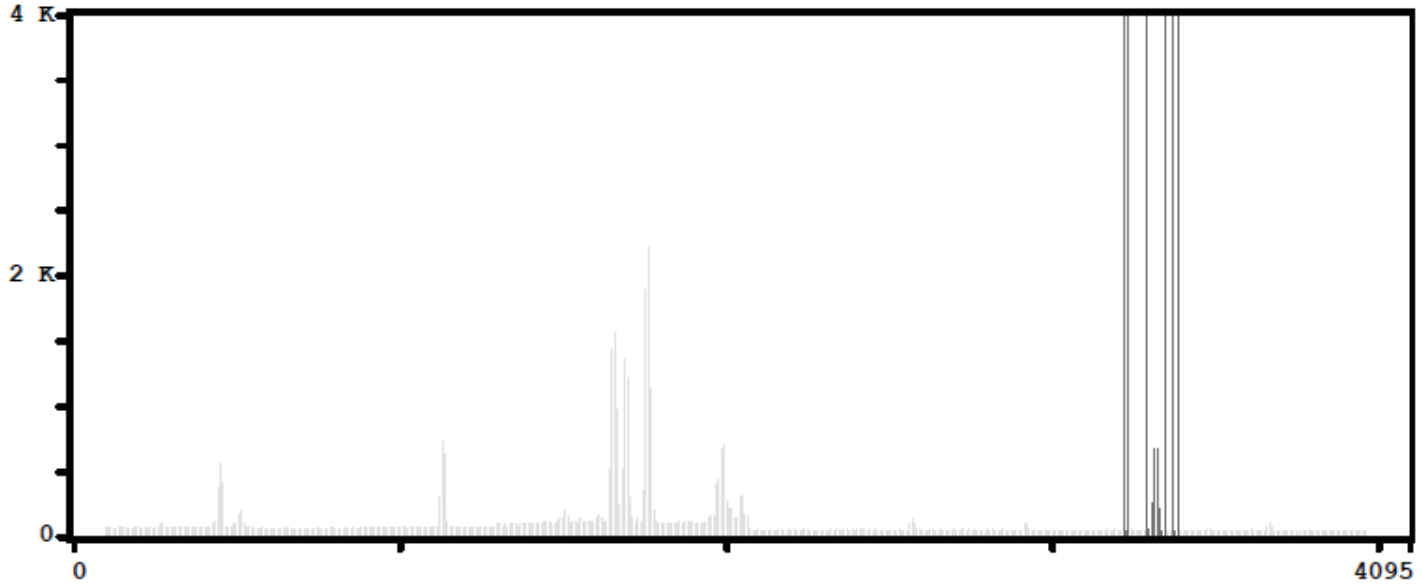


Remarks:

Start Time = 12/07/2012 16:50:49

Life Time = 300 sec Dead Time = 1.5 %

WinUF6 [E:\...\WinUF6\WINUF6_071.spe]

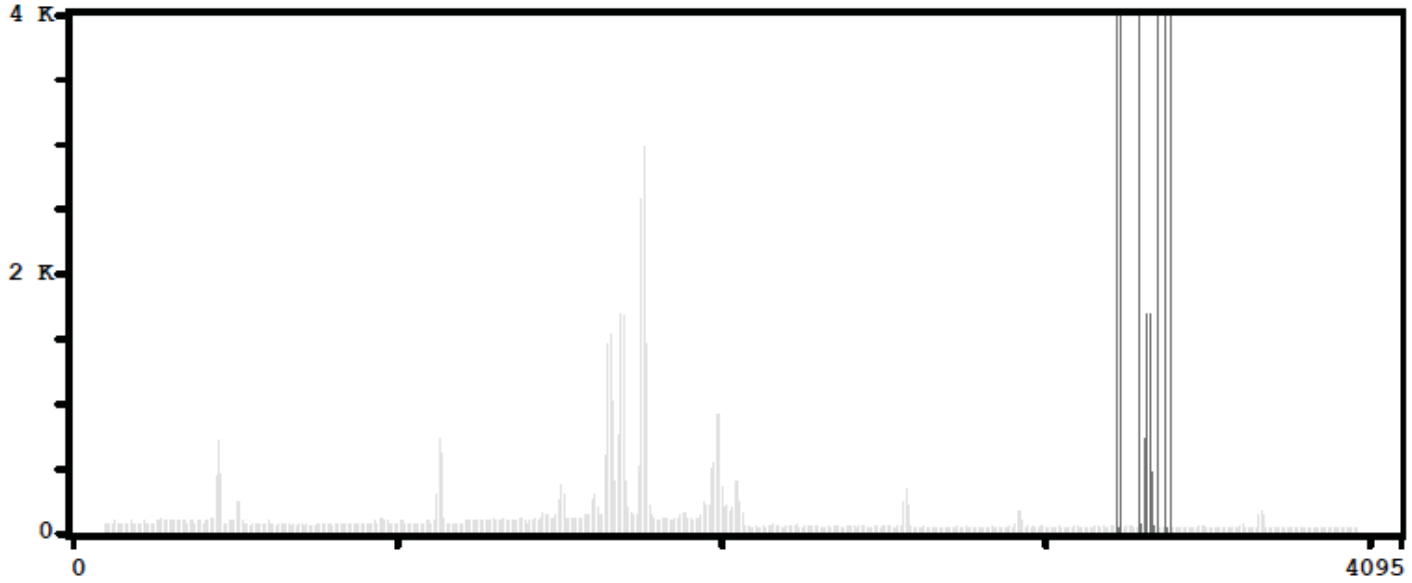


Remarks:

Start Time = 12/07/2012 16:27:06

Life Time = 300 sec Dead Time = 1.6 %

WinUF6 [E:\...\WinUF6\WINUF6_194.spe]

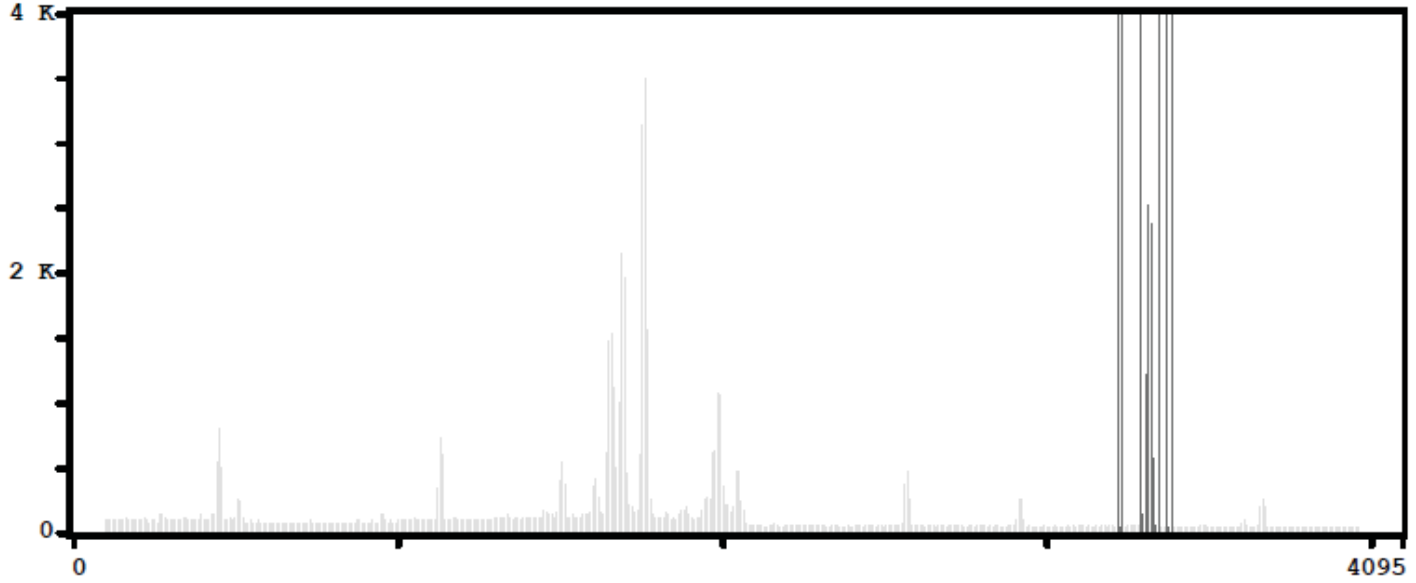


Remarks:

Start Time = 12/07/2012 16:44:41

Life Time = 300 sec Dead Time = 1.9 %

WinUF6 [E:\...\WinUF6\WINUF6_295.spe]

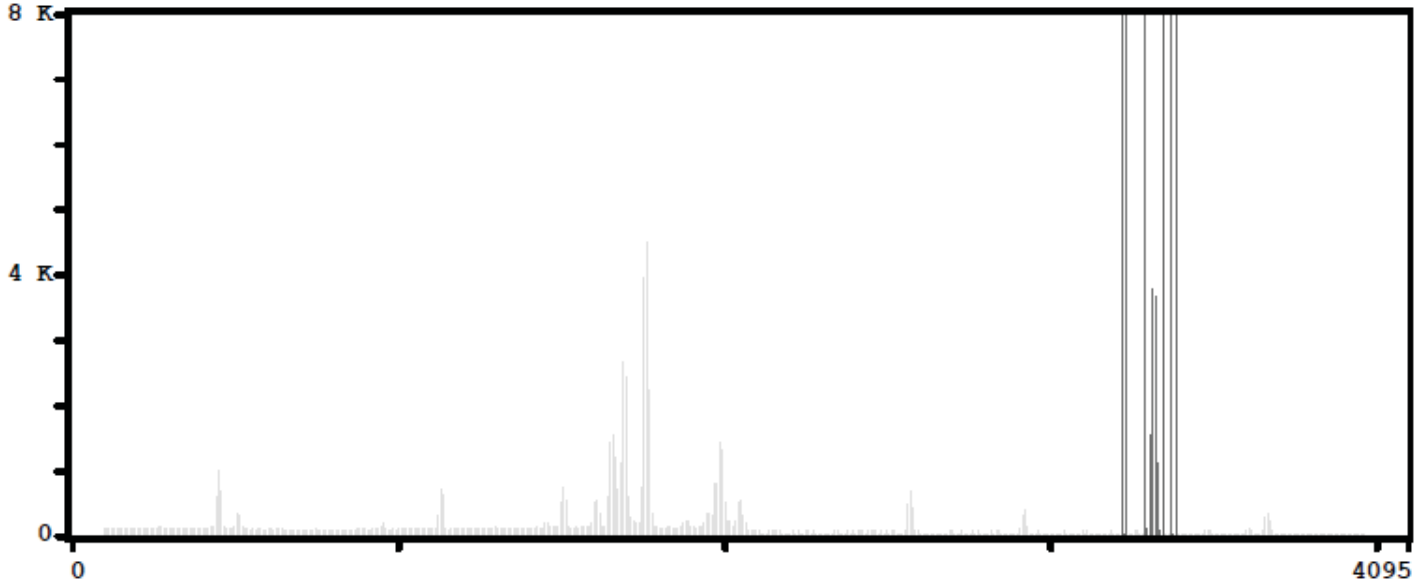


Remarks:

Start Time = 12/07/2012 16:38:31

Life Time = 300 sec Dead Time = 2.1 %

WinUF6 [E:\...\WinUF6\WINUF6_446.spe]

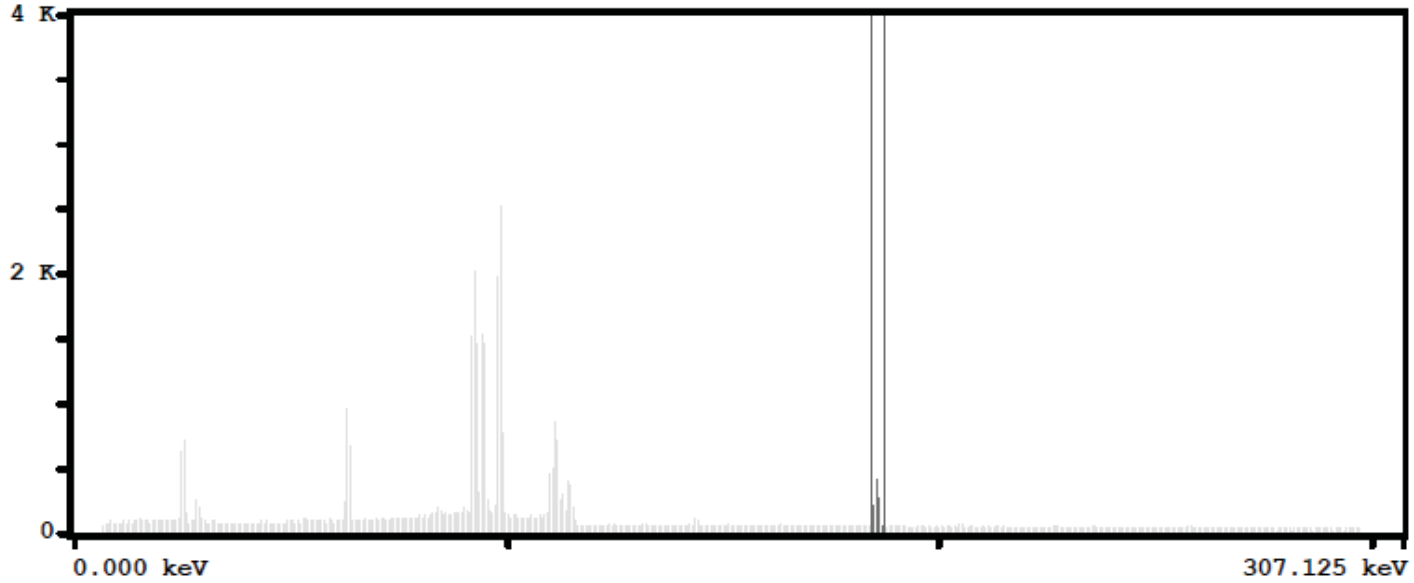


Remarks:

Start Time = 12/07/2012 17:04:20

Life Time = 300 sec Dead Time = 2.5 %

WinSPEC (I) [E:\...\MGAU\MGAU_031.spe]

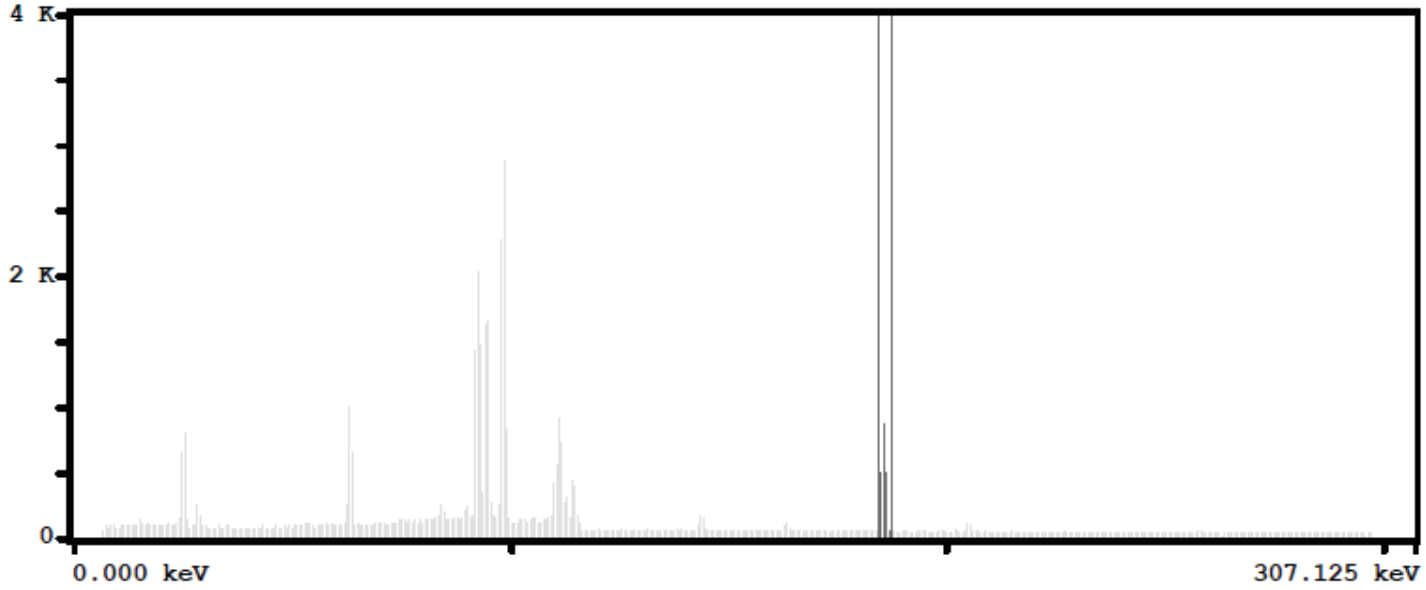


Remarks:

Start Time = 12/14/2012 17:08:21

Life Time = 300 sec Dead Time = 1.5 %

WinSPEC (I) [E:\...\MGAU\MGAU_071.spe]

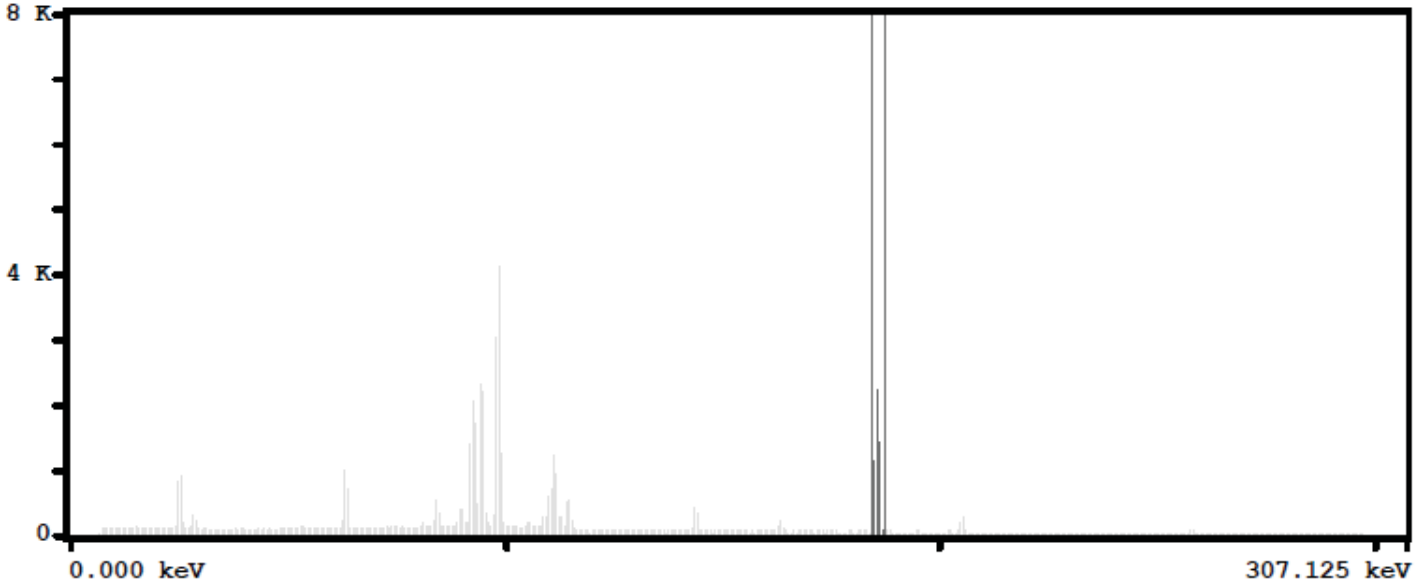


Remarks:

Start Time = 12/14/2012 17:17:26

Life Time = 300 sec Dead Time = 1.6 %

WinSPEC (I) [E:\...\MGAU\MGAU_194.spe]

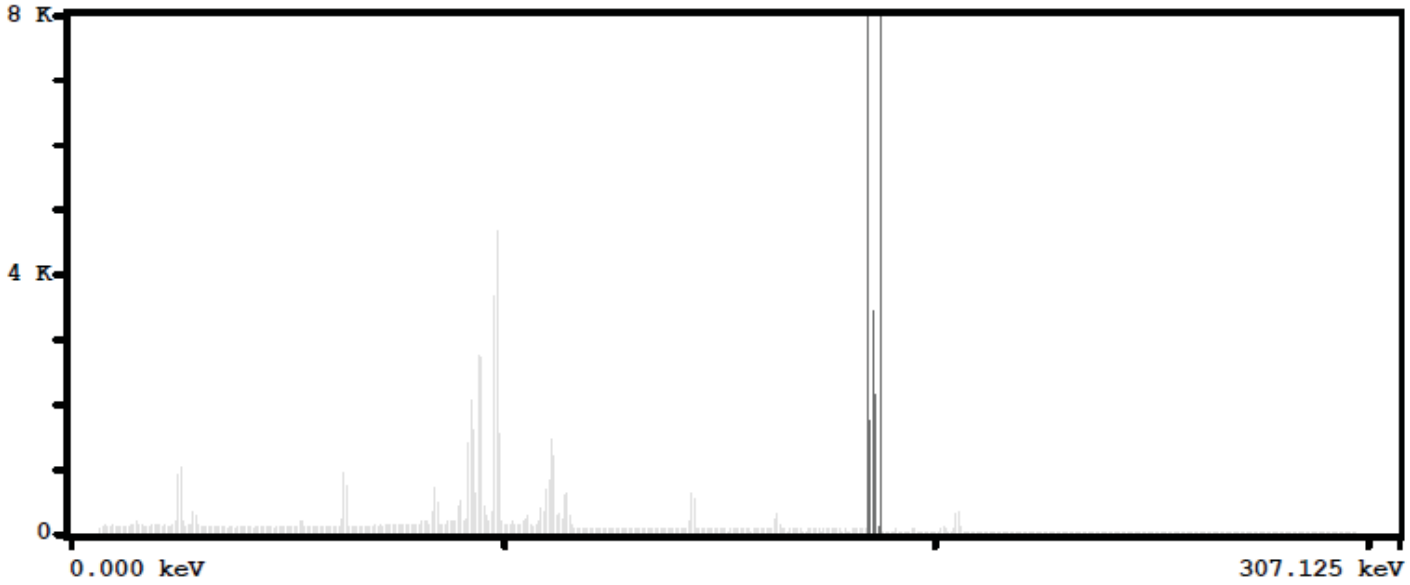


Remarks:

Start Time = 12/14/2012 17:31:19

Life Time = 300 sec Dead Time = 1.8 %

WinSPEC (I) [E:\...\MGAU\MGAU_295.spe]

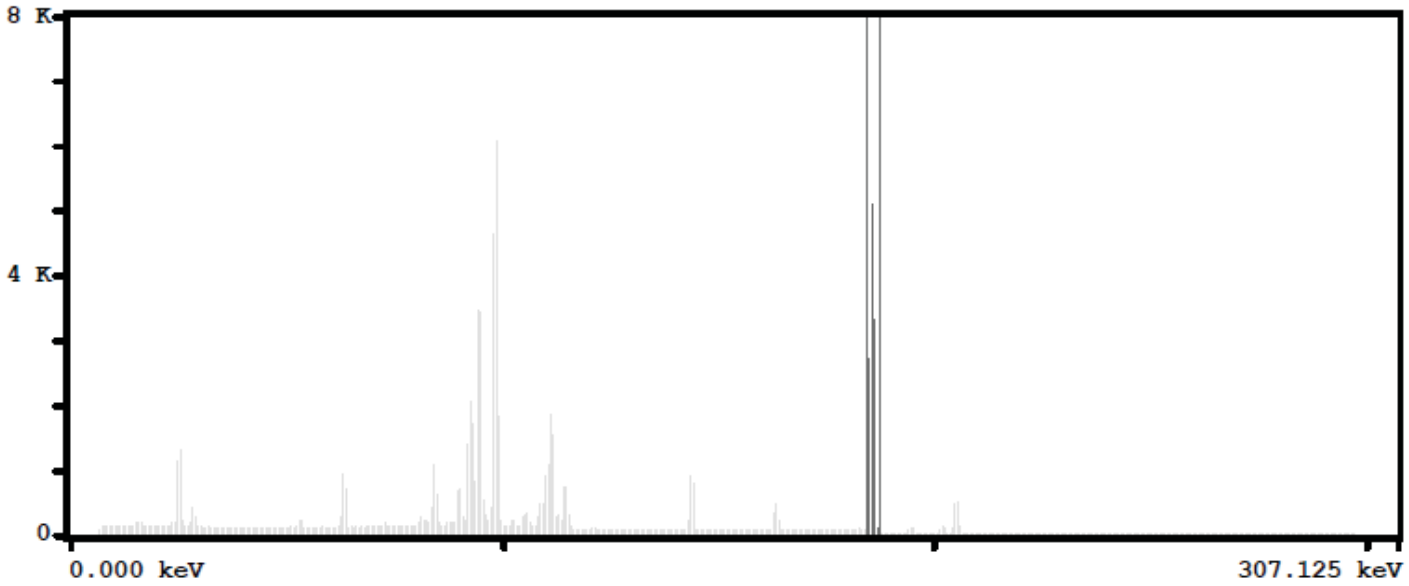


Remarks:

Start Time = 12/14/2012 16:50:35

Life Time = 300 sec Dead Time = 2.1 %

WinSPEC (I) [E:\...\MGAU\MGAU_446.spe]

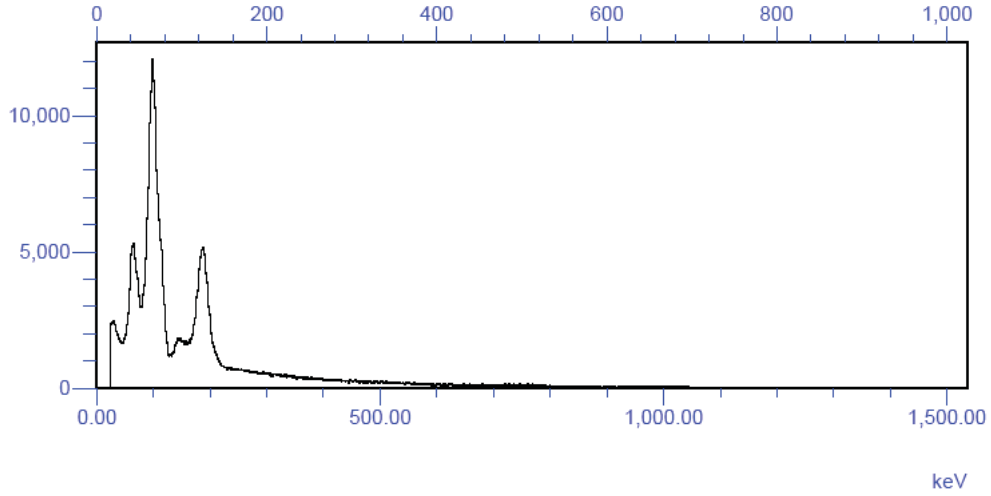


Remarks:

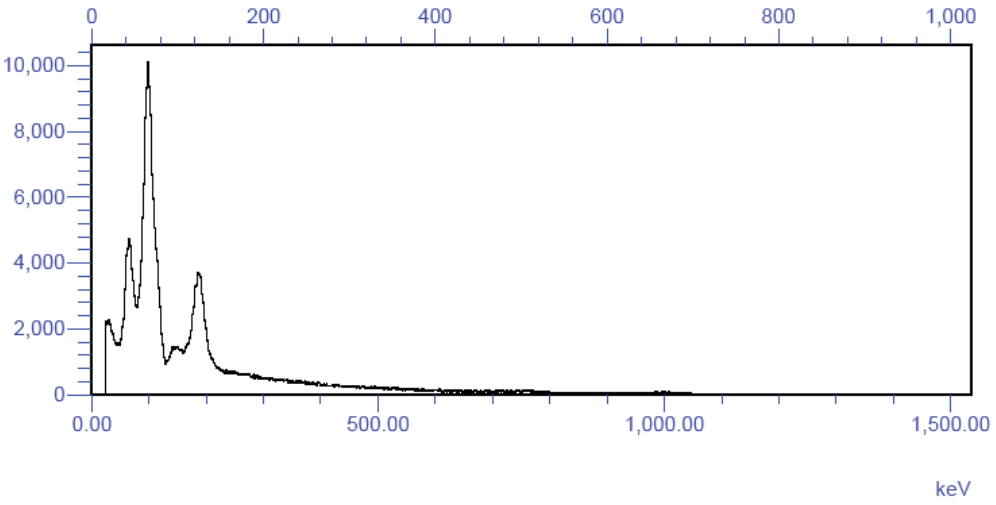
Start Time = 12/14/2012 16:37:44

Life Time = 300 sec Dead Time = 2.5 %

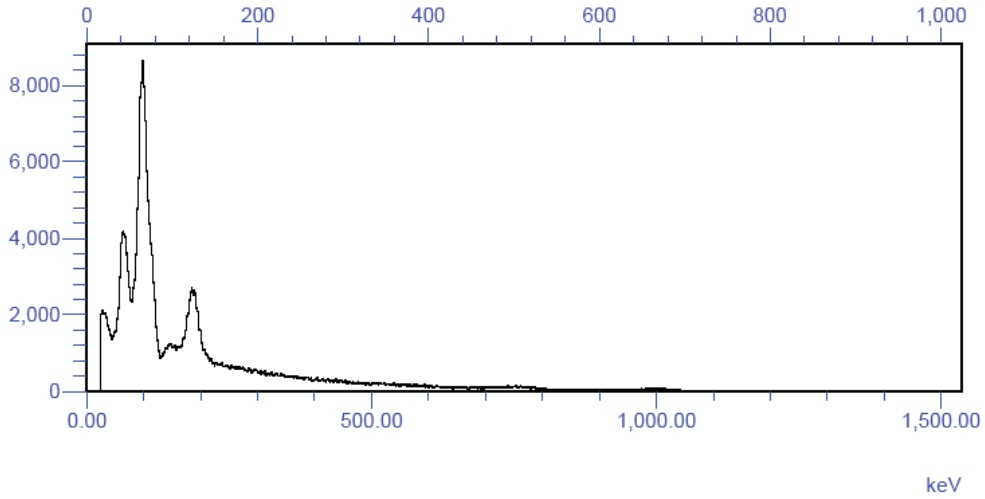
IDENT2915-5_2012-12-06_12-56-38-000.SPC 19/12/2012 14:36:56



IDENT2915-5_2012-12-06_13-03-15-001.SPC 19/12/2012 14:41:02



IDENT2915-5_2012-12-06_13-09-24-002.SPC 19/12/2012 14:42:00



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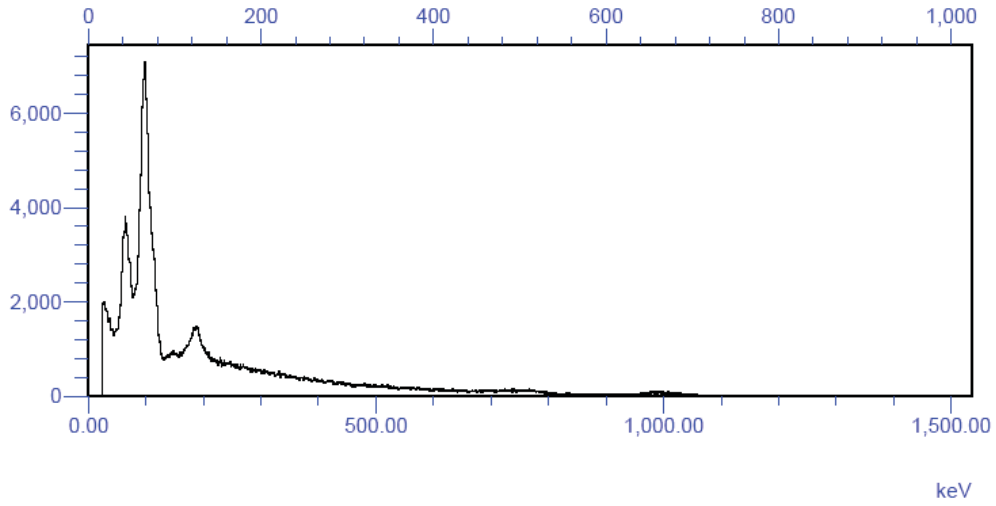

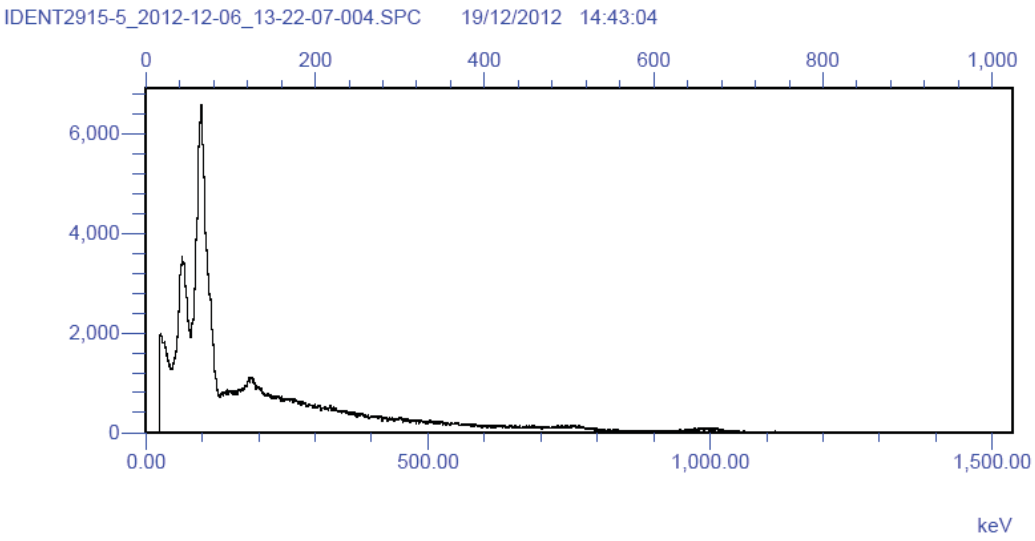
IDENT2915-5_2012-12-06_13-22-07-004.SPC 19/12/2012 14:43:04
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