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Performance test of the Multi-Channel Analyzer MCA-527 for Nuclear Safeguards Applications

Test in the PERLA Laboratory at JRC, Ispra

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0. Introduction

A new miniature MCA has been developed by the company GBS Elektronik GmbH, Rossendorf, with support of the German support Program for the IAEA. It is foreseen as follower instrument for the MCA-166 which became one of the base instruments for nuclear safeguards measurements of IAEA and EURATOM. The MCA-527 was tested at JRC, Ispra, to find out if it fulfils the requirements to an MCA for typical gamma spectrometric measurements for nuclear safeguards. The MCA-527 can also be used for neutron measurements in List mode. Its performance for neutron counting will be described in separate report [2].

All measurements with the MCA-527 mentioned in this report were made in direct comparison to the MCA-166, partially simultaneously with one and the same detector. The MCA-527 was operated with firmware version 1304. In the report on U enrichment measurements from November 2012 [1] an earlier version 1204 (appears as “FFFF” in the spectrum files) with less good performance was used. The old report is obsolete. It is recommended that for all MCA-527 the firmware is changed towards version 1304.

The technical specifications of the MCA-527 are in annex A0.

Setup files for different detector types are in Annex A1.

1. Dead time correction evaluation with two source method

The dead time was checked with the two source method and moreover with a constant source (see chapter 2 below). Two identical samples of U_3O_8 (“source1” and “source 2”) were used as radiation sources, actually CBNM standards with 4.46% enrichment. As it is usually done with the two source method, triplets of measurements were made: a) source 1 alone, b) source 1 plus source 2 together, and c) source 2 alone. The results were then three spectra. From them were determined both the total count rates S1, S12 and S2 and the net peak areas P1, P12 and P2 as explained below. The sources were placed in front of the detector as indicated in Fig. 1. Here both sources touched the detector surface (case S12) and the highest count rate of about 52 400 cps was achieved. In this example, the two individually measured count rates S1 and S2 were 24 900 and 28 000 cps, i.e. their sum 52 900 cps is rather close to the rate S12 of 52 400 cps. The Fig. 2 shows the source positions in three distances from the detector, i.e. such triplets are then measured at different count rate levels.

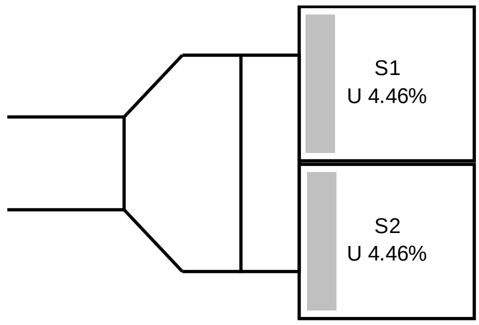

Fig. 1: Geometrical arrangement of the U standards next to the NaI detector for the two source method, here for the measurement triplet with the highest count rate

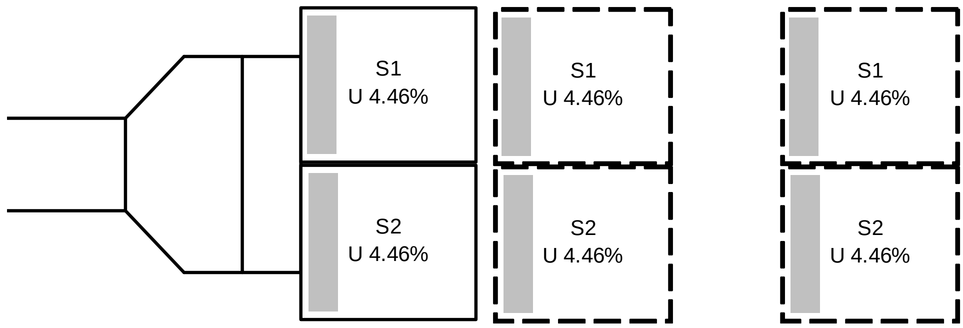

Fig. 2: Geometrical arrangement of the U standards in different distances from the detector. The same arrangement was used for the Ge detector.

1.1. NaI detector without Am source

The first dead time test was made with a NaI detector with a scintillator of 75 mm diameter and 19 mm thickness without internal Am source, actually detector no. 7 (see annex A2). No collimator or shielding was applied. Fig. 3 shows a triplet of spectra S1, S1 and S12. The net peak area of the 186 keV line is used for enrichment determination with the standard methods of nuclear material inspectors according to the enrichment meter principle. For this reason we have tested if the dead time correction of the MCA-527 works well for the net peak area of this line. The 4.46% enriched U gives a gamma spectrum, which allows well to determine the net peak area, and samples of this material were chosen for the test. It does not make sense to repeat this test with other enrichments; here we would rather look for the quality of the spectrum evaluation algorithm than for the instrument’s performance.

Fig. 4 demonstrates how the net peak areas P1, P2 and P12 were determined for this test. The left and right ROIs for the definition of a linear background below the 186 keV peak comprise 15 channels. Thus number is was used reduce the statistics error of the net peak area. For comparison: SPEC.exe or WinsSPEC.exe apply only four channels. There are small, invisible gamma lines at 163 and 203/205 keV but they do not disturb because the spectrum shape is always the same. The ROIs are in locations where small peak shifts have only negligible

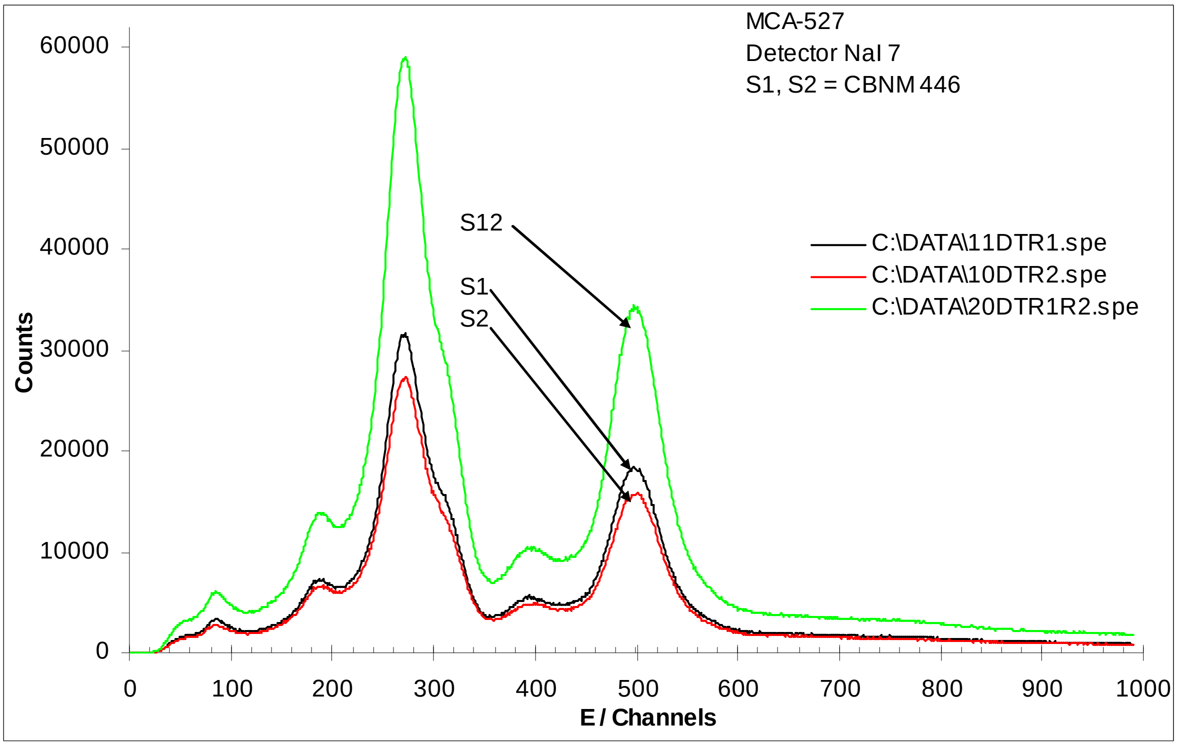

Fig. 3: U gamma spectra of a measurement triplet S1, S2 and S12
with the 186 keV line in channel 500

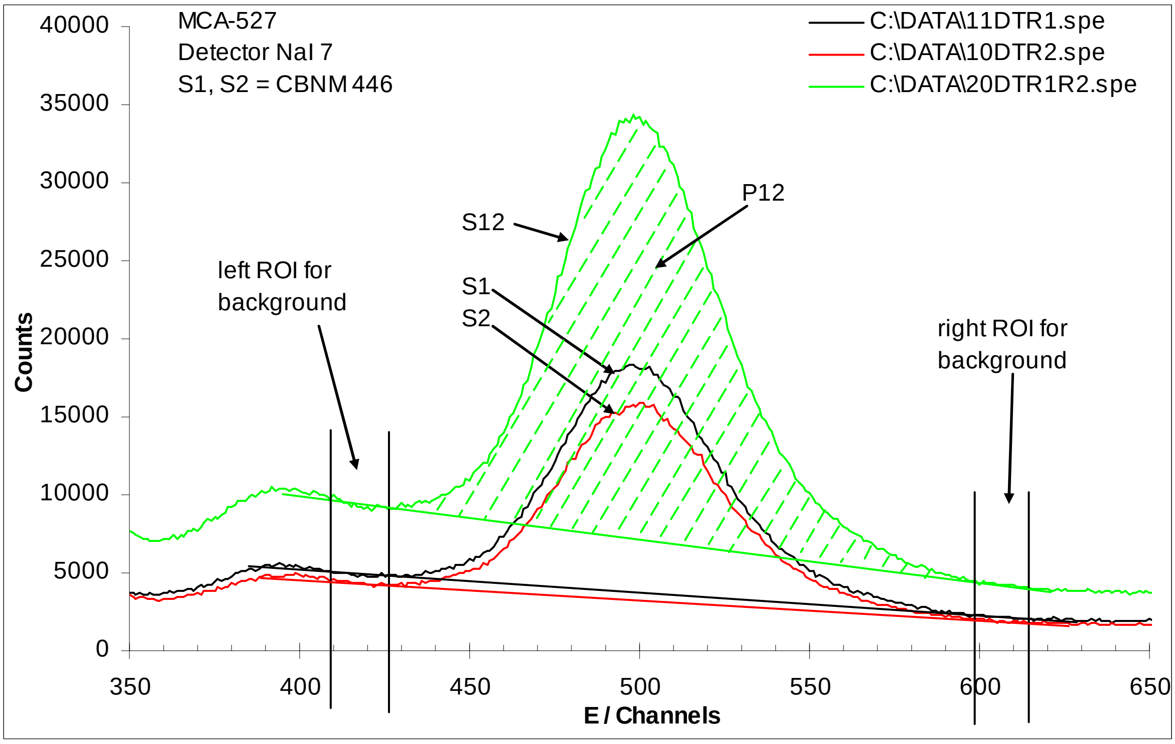

Fig. 4: Determination of the net peak area of the 186 keV peak.

effect on the net peak area. We have not used the stabilization function for the peak position.

For each triplet of spectra the ratios P12 / (P1 + P2) were calculated. For an ideal instrument it should be 1. Fig. 5 shows the deviation from 1 for an MCA-527 and an MCA-166. The data for the two instruments come from simultaneous measurements. The deviations from the ideal value are always clearly below 1% for the whole range of input count rates. The practically interesting count rate range is typically below 20 000 cps, but it is interesting to see the very good dead time correction with high input count rates.

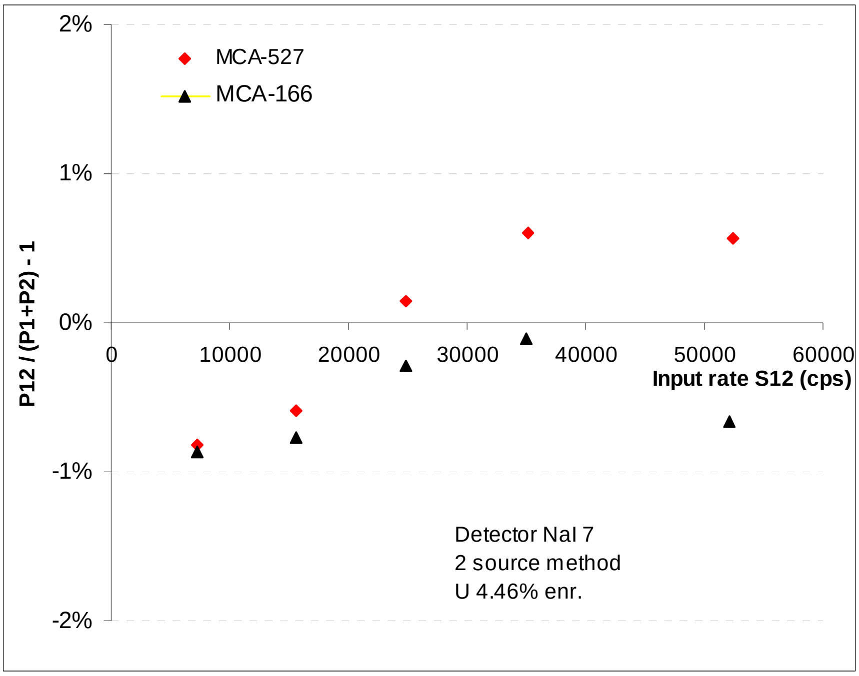

Fig. 5: Values (P12/(P1+P2) – 1) for MCA-527 and MCA-166 for a NaI detector as function of the input count rate of the measurements S12 (both sources present). Each point represents a triplet of measurements.

The same data were evaluated with NaIGEM. This code does not deliver as result a net peak area, but an enrichment value which is proportional to the net peak area. These enrichment values can be used to make the same diagram as in Fig. 5, and it is shown as Fig. 6. With this more sophisticated evaluation the very precise dead time correction for both instruments is visible, for the MCA-527 until 80000 cps and for the MCA-166 until 40000 cps. The relative errors of the ratios P12 / (P1+P2) are estimated to be below 0.5%.

For complete information Fig. 7 is added. It gives the throughput rate in comparison to the input rate. The figure demonstrates clearly the higher performance of the MCA-527 for this parameter: With an input rate of 70000 cps it provides the double throughput rate in comparison to the MCA-166.

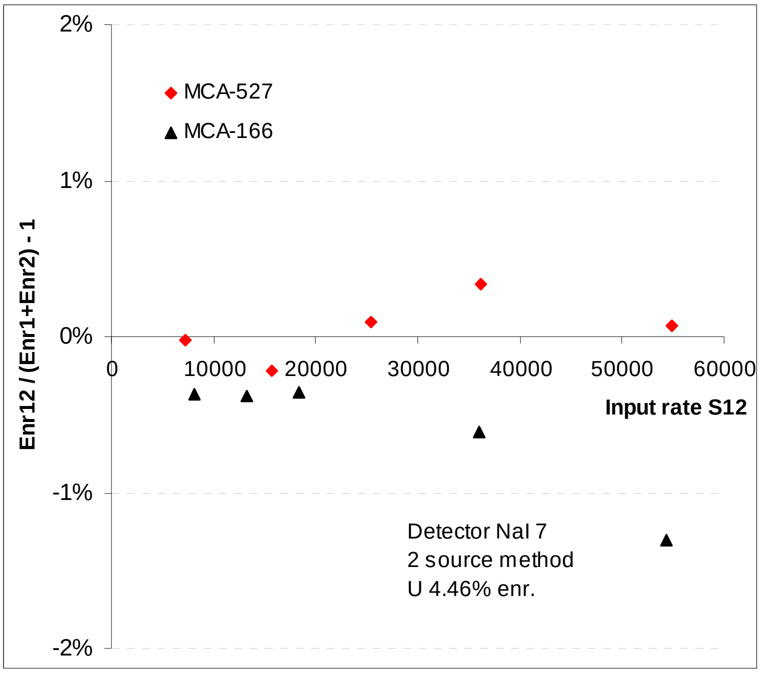

Fig. 6: Values (Enr12/(Enr1+Enr2) – 1) for MCA-527 and MCA-166 for a detector NaI 7 as function of the input count rate of the measurements S12 (both sources present). "Enr" stands for the enrichment value as determined by NaIGEM. Each point represents a triplet of measurements.

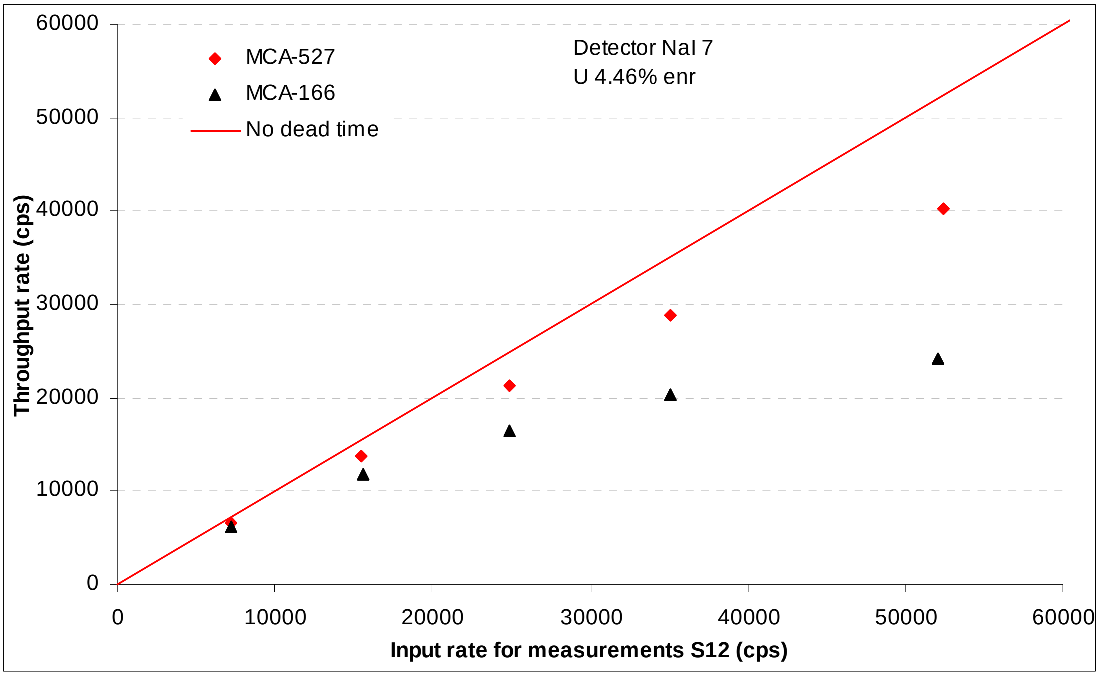

Fig. 7: Throughput rate as function of the input rate.

1.2. Coaxial Ge detector

A further dead time test of the same type as above was performed with a coaxial Ge detector of 25% efficiency of Canberra, actually detector no. C4 (see annex A2). All measurements followed the same scheme as with the NaI detector above: No collimator or shielding, use of CBNM 446 U standards (plus CBNM 295 for the triplet with the highest count rate), source placement as in Figs. 1 and 2.

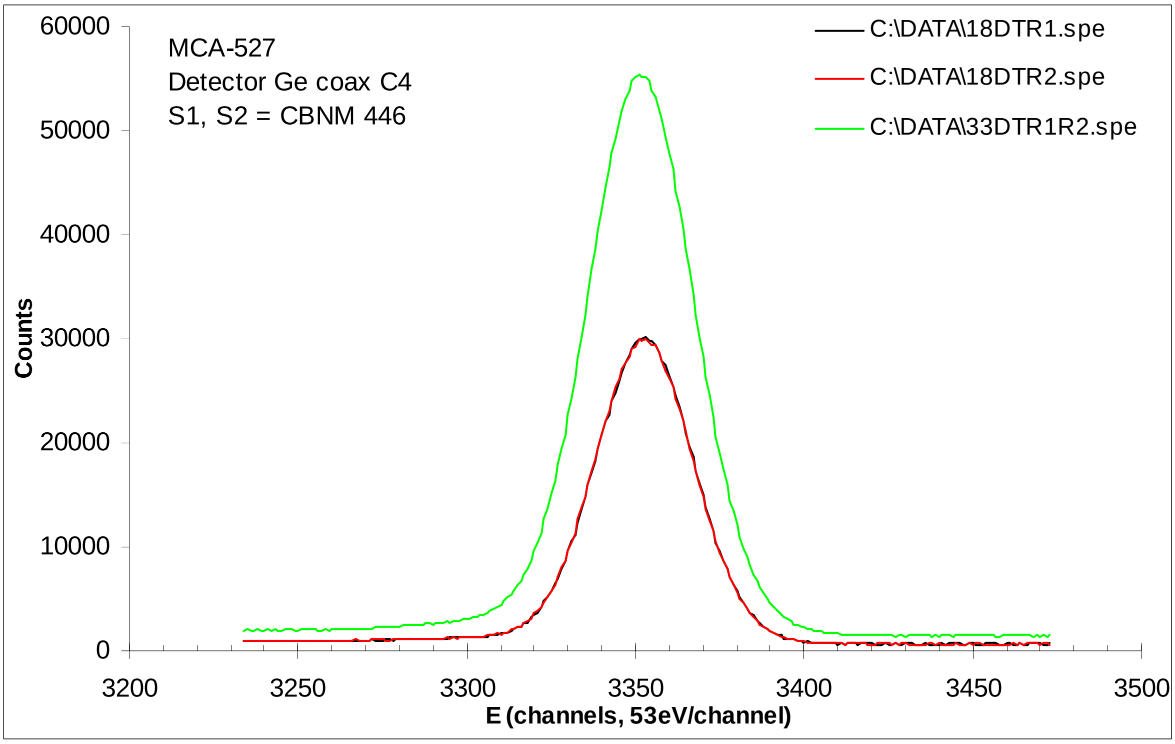

Fig. 8: 186 keV peaks for the coaxial Ge detector C4 for a triplet of measurements

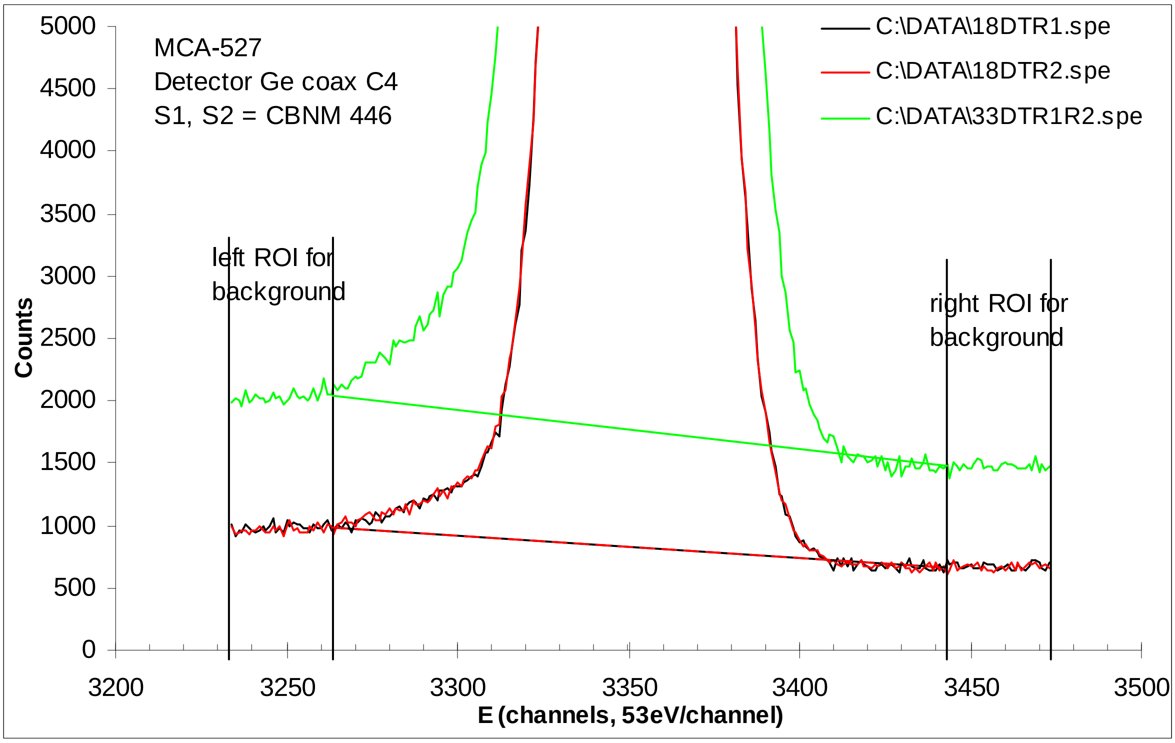

Fig. 9: Feet of the 186 keV peaks for the coaxial Ge detector C4

Fig. 8 shows the gamma lines at 186 keV for one triplet S1, S2, S12. The foot of these peaks is in more detail in Fig. 9. Here, on the low energy side of the main peak is a small peak at 182.1 keV (about channel 3300). The net peak area determination was made in the same manner as for the NaI detector. The results are presented in Figs. 10 and 11.

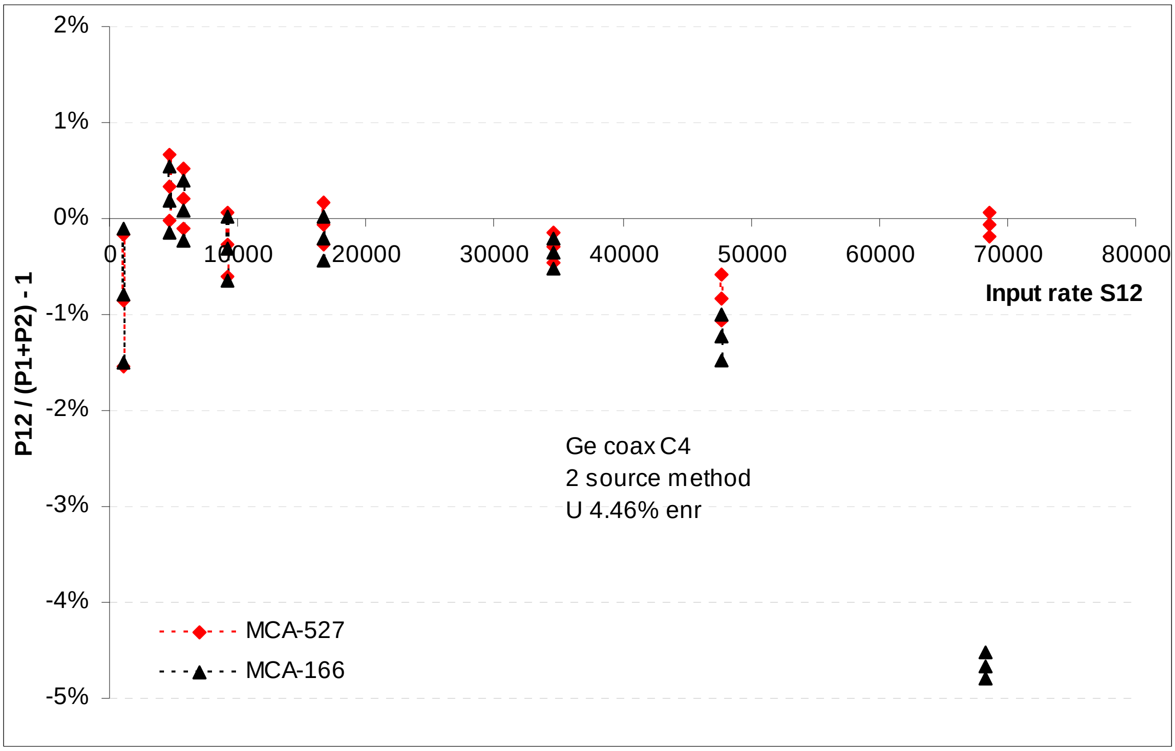

Fig 10: Ratios P12/(P1+P2) – 1 for MCA-527 and MCA-166 for a coaxial Ge detector as function of the input count rate of the measurements S12 (both sources present). Each point represents a triplet of measurements.

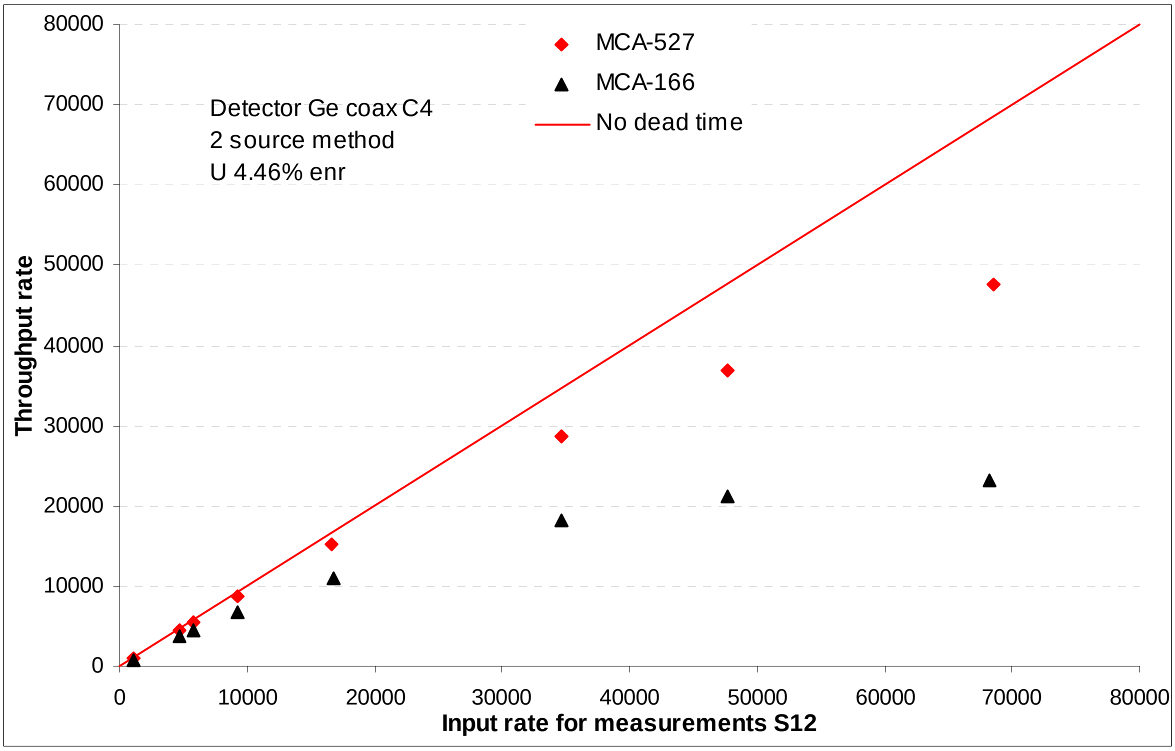

Fig. 11: Throughput rate as function of the input rate.

As in chapter 1.1., the data as represented in Fig. 10 describe always a range of a factor 2 on the x axis. This time the graph shows also the statistical errors. Both instruments perform a perfect dead time correction up to high input count rates, MCA-527 until 70000cps or more and MCA-166 until 50000 cps.

Fig. 11 gives the throughput rate in comparison to the input rate. It demonstrates clearly the higher performance of the MCA-527 for this parameter: With an input rate of 70000 cps it provides the double throughput rate in comparison to the MCA-166.

Conclusion

In the tests with the two-source-method, the MCA-527 fulfills the requirement to the dead time correction both with NaI and coaxial Ge detector at least up to count rates of 80 000 cps.

2. Dead time correction evaluation with one constant and one variable source

In addition to the test of the dead time correction with the two source method another test series was performed: One source was kept in a fixed position next to the detector and another source with another gamma spectrum was placed in changing distances to the detector thus causing changing total input count rates. The constant source was highly enriched U (UP889S), the varying source Pu with high ^{241}Am content (PIDIE 4.6). The Pu source was used without a Cd filter, like this the 60 keV line was the predominant peak and the net peak area of the 186 keV line of U could be comfortably used as constant element in the spectra. The variable peak was at much lower energy and could scarcely disturb the 186 keV peak (at least as long as there was no triple pile-up: 60 + 60 + 60 keV = 180 keV). This test was made both with a NaI detector with internal Am source and with a planar Ge detector (P5).

2.1. NaI detector with internal Am source

The internal Am source causes high energy pulses (in the order of magnitude of 2 MeV) which disturb the spectrometric measurement of photons of the U spectrum. This disturbance was avoided by making a spectrum setup with a low value of the coarse gain in combination with a spectrum length of 2048 channels and the 185.7 keV line in channel 300 for the standard software. This setup has furthermore the advantage that the 1001 keV line is always included in the spectrum (even though it is normally not evaluated).

The test setup is shown in principle in Fig. 12. The internal Am source causes a count rate of

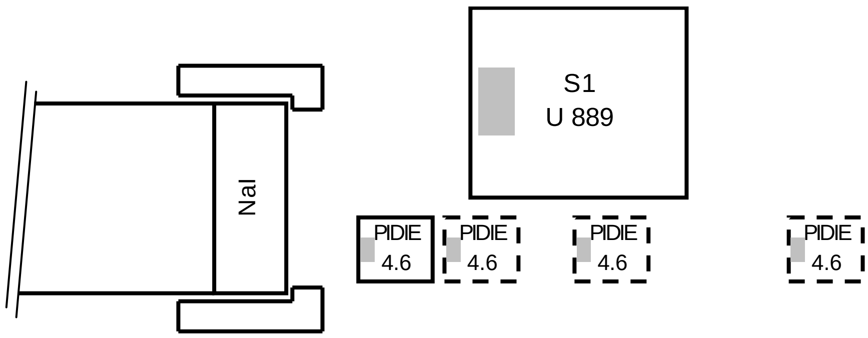

Fig. 12: Geometrical arrangement of the fix HEU sample (UP889) next to the NaI detector and the Am source (PIDIE 4.6) in varying distance to the detector. The same arrangement was used for the planar Ge detector.

about 1500 cps. It does not show a single peak at 59 keV but a doublet at lower energies. The measured spectrum is in Fig. 13 in black. The HEU sample UP889S used as constant source, and it was placed in such a distance that it caused about 2500 cps in addition to the internal source. It gives the green spectrum in Fig. 12. Then the external Am source (Pu PIDIE 4.6) was added as variable source. Fig. 13 shows in green the spectrum of all three sources rates (internal Am + HEU + external Am) with a total count rate of about 4000 cps. The 186 keV line stands well isolated and its net peak area can be determined easily. The situation changes with higher count rates: The red and blue spectra with total count rates of about 40 000 cps and 90 000 cps in Fig. 13 b demonstrate clearly the deformation of the background below the 186 keV peak. A net peak area evaluation was made as above (Fig. 4) and results in the graph in Fig. 14. Both MCAs give very similar results. Fig. 15 shows that the performances of the two MCAs agree within less than 0.5% until 40 000 cps. But the peak area of the constant source is not constant as it should be. This is due to the deformation of the spectrum.

The same spectra were evaluated once again, this time with NaIGEM for the 186 keV line. Also here may be a problem: NaIGEM is foreseen for spectra of mixtures of ^{235}U and ^{238}U, not for U plus Pu with very much Am. In agreement with this expectation NaIGEM gave very large Chi^2 values. The results in Fig. 16 show again that the Am peak area is not constant, and also here the results of the two MCAs agree within the error bars.

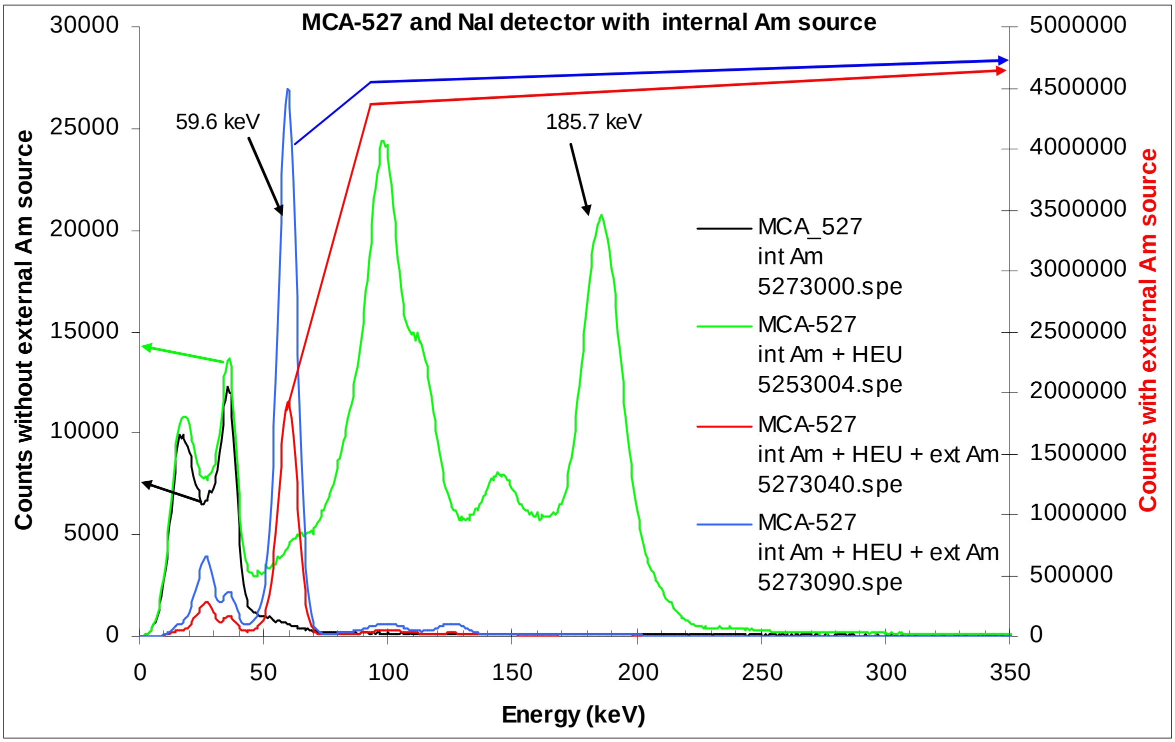

Fig. 13 a: Spectra of the NaI detector with internal Am source without sample (black), with HEU source (green) and with HEU source plus a strong Am source (red). The graph shows the spectra in a different y scales

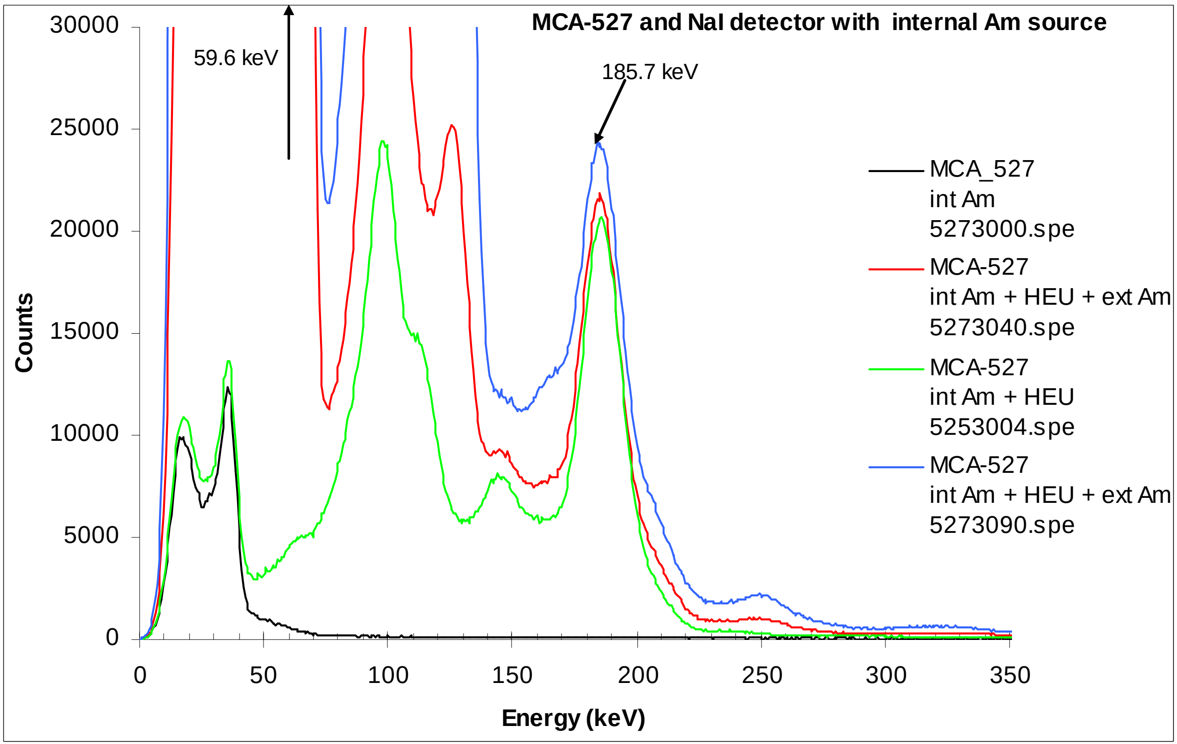

Fig. 13 b: The same spectra as in Fig 13 a with different y scale

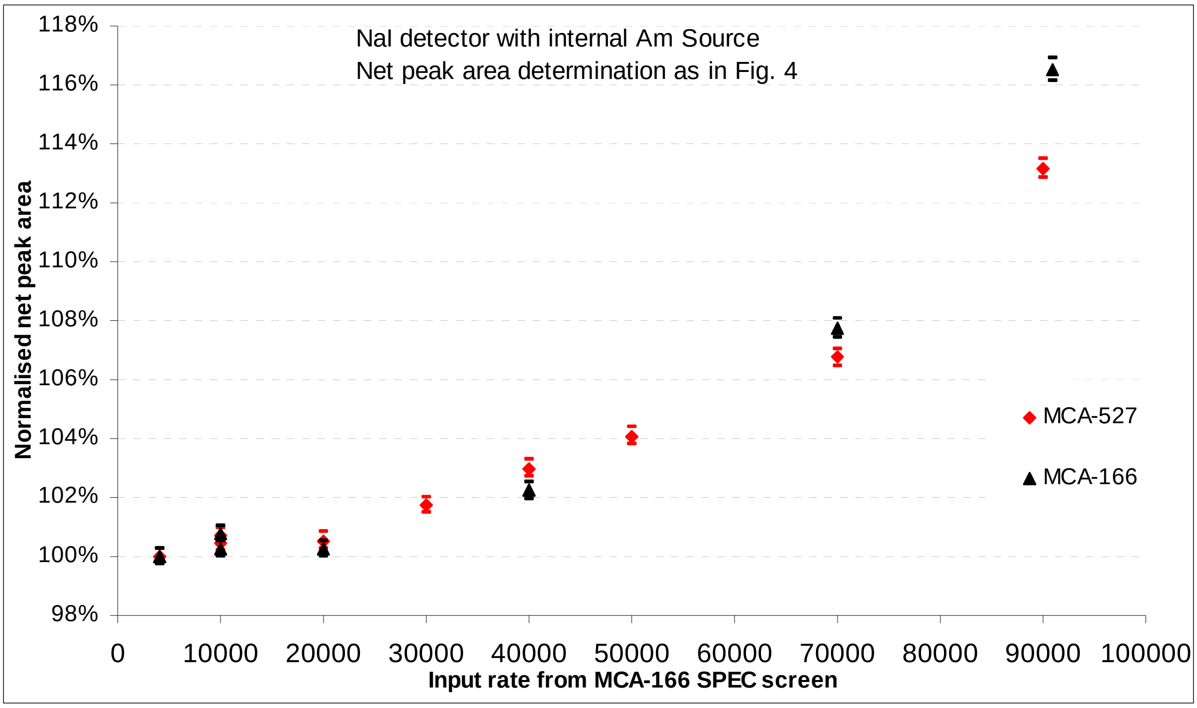

Fig. 14: Normalized net peak area of the 186 keV peak of a constant U source as function of the total input count rate, changed by an Am source

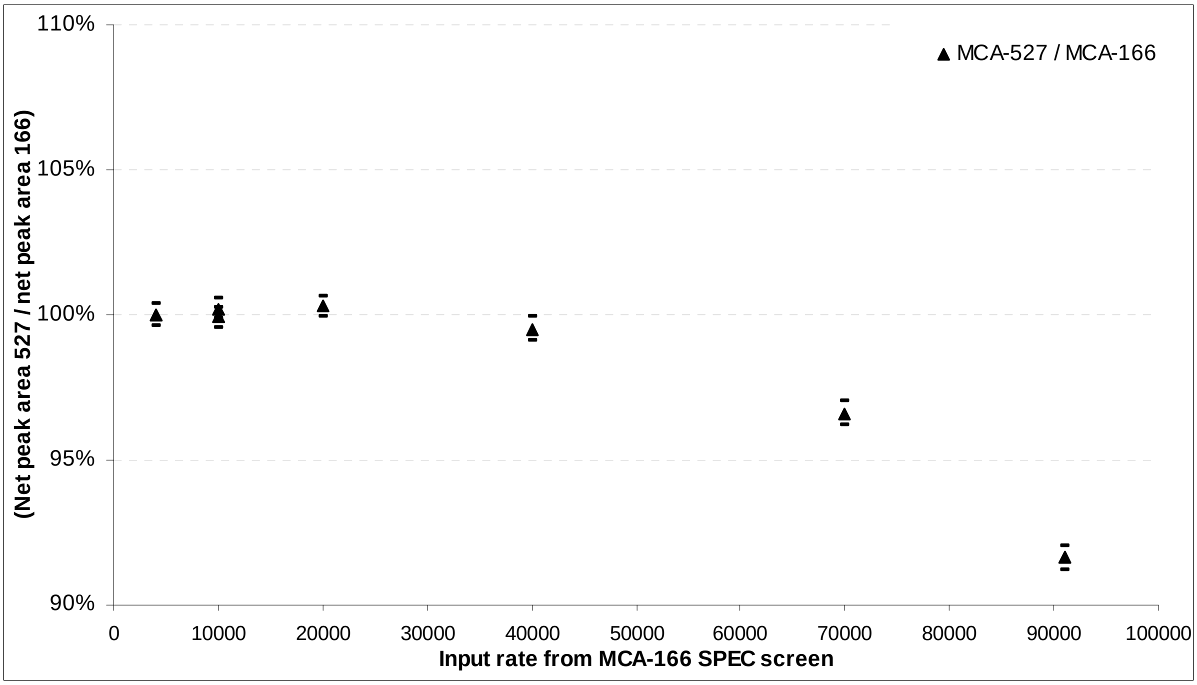

Fig. 15: Ratio of the 185 keV net peak area of MCA-527 and MCA-166 of a constant U source as function of the total input count rate, changed by an Am source

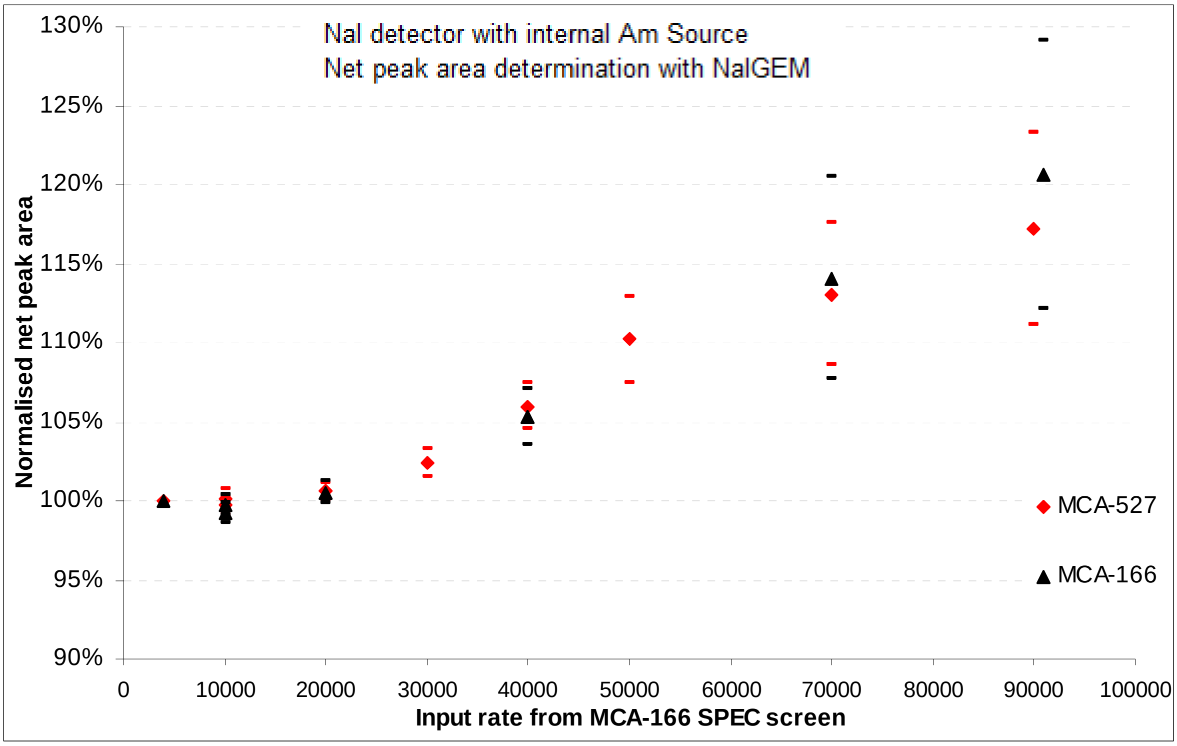

Fig. 16: Normalized net peak area of the 186 keV peak of a constant U source as function of the total input count rate, changed by an Am source, evaluation with NaIGEM

Because of the change of the spectrum shape within the measurement series, this series is obviously of limited value for the characterization of the MCA-527. It is nevertheless included in this report for two reasons: a) The NaI detectors with internal Am source are important instruments of the IAEA, b) usually, measurements on U samples have count rates below 20 000 cps and the test shows at least that both MCAs do have the same performance until 40 000 cps, hence the MCA-527 is as good as the MCA-166 in this application.

It was tried to make the same test with an NaI detector without internal Am source. But also here appear the same problems with the spectrum evaluation. The tests with a Ge detector do not suffer from this problem and give very reasonable and reliable results for this test type.

2.2. Planar Ge detector

The test with a constant U source and a variable Am source was performed also with the planar detector P5 with the same setup (Fig. 12). Figs. 17 a and b show in black the spectrum of an HEU source (UP889S). The count rate of this measurement is 2000 cps. The red spectrum comes from the HEU sample plus the Am source. In this measurement the count rate was 100000 cps. The spectrum is absolutely dominated by the 60 keV peak of ^{241}Am. If we look at the constant 186keV line in detail and in the same scale for both spectra (Fig. 17b) we still see a very good agreement. The net peak aress of the 186 keV line were evaluated as shown above in Fig. 8. Since the line is well isolated, the spectrum evaluation is possible with very small uncertainties. Fig. 18 presents the result: Both MCAs show the same behavior, the peak areas remain within a range of 1% until about 40000 cps, for the MCA-527 even until 90000 cps. In the practically interesting range for U enrichment measurements the constancy of the net peak area is within a band of 0.5 % width.

The results are in full agreement with the observations with the two source method. This allows to neglect the results of the method with one constant and one changing source with the NaI detector.

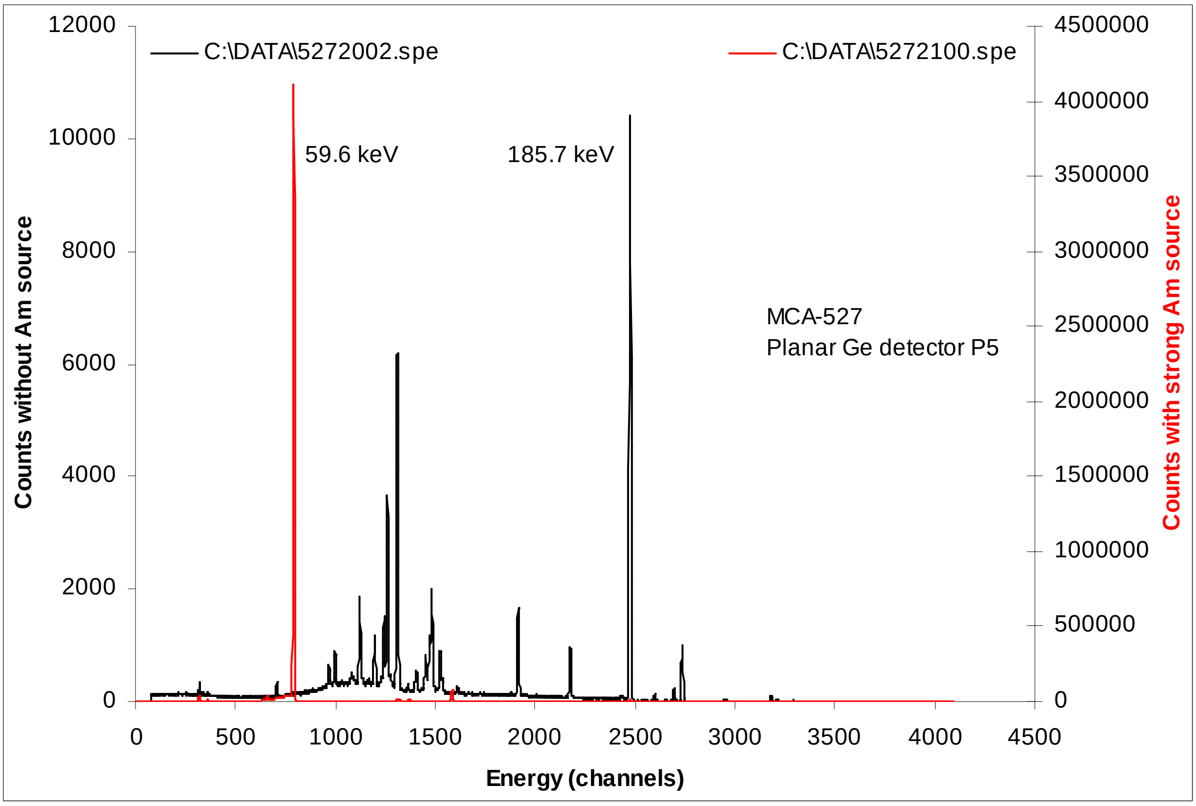

Fig. 17 a: Spectra of the planar Ge detector P5 of a HEU source (black) and of the same HEU source plus a strong Am source (red), graph a) shows the whole spectra in different y scales

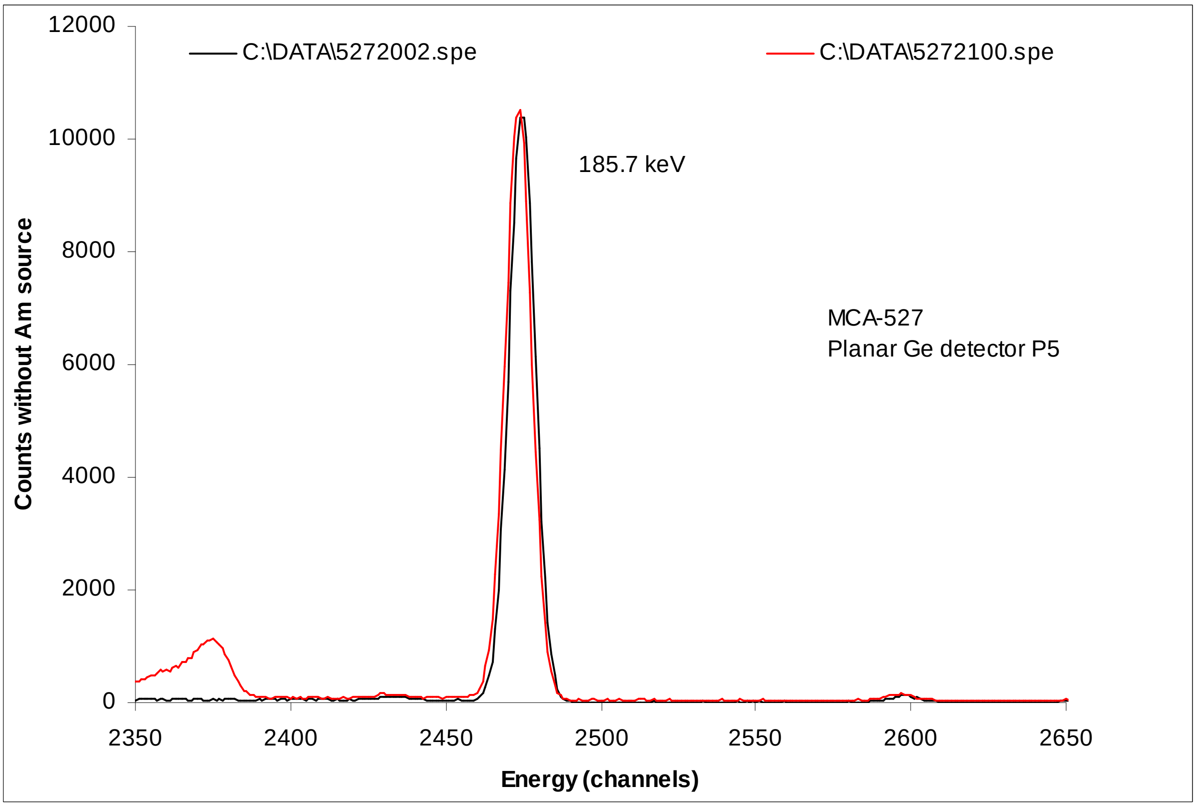

Fig. 17 b: The same spectra as Fig. 17a, 186 keV line and with the same y scale.

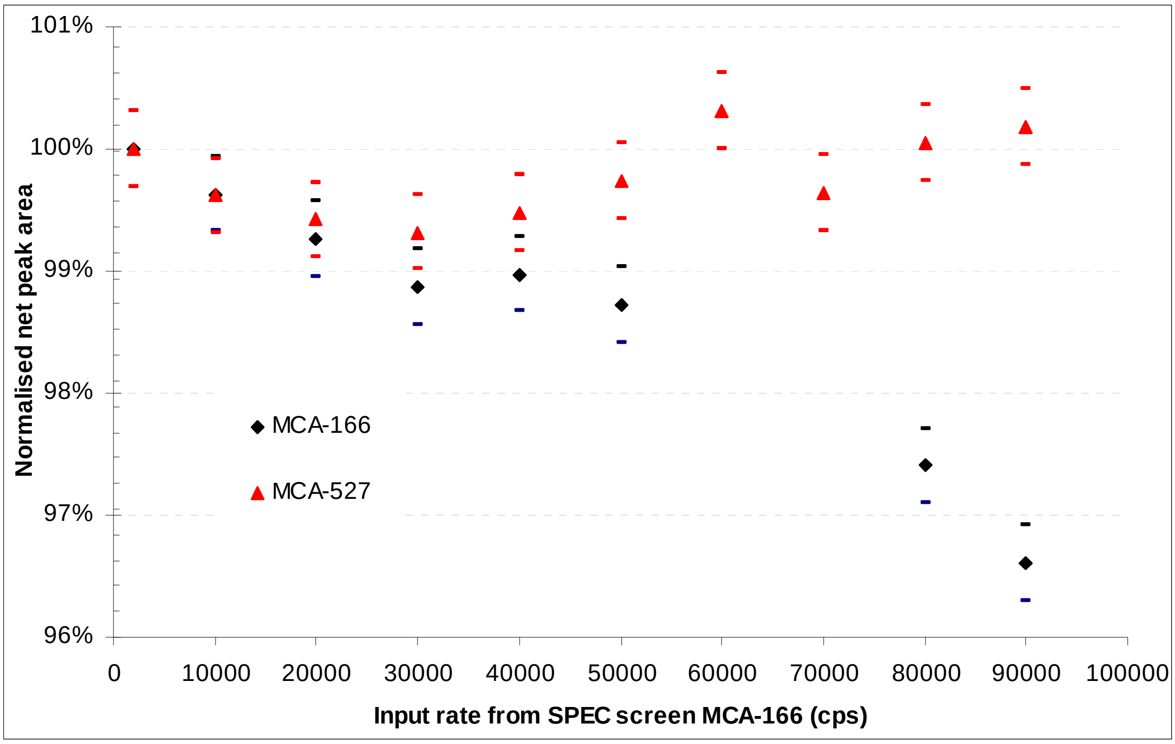

Fig. 18: Normalized net peak area of the 186 keV peak of a constant U source as function of the total input count rate

Conclusion

In the tests with a constant plus a variable source, the MCA-527 fulfills the requirement to the dead time correction with a Ge detector up to high count rates.

3. Proportionality 186keV net peak area - enrichment

Several enrichment measurement methods apply the enrichment meter principle. They are used with NaI detectors (without and with internal Am-source), $LaBr_3$ and coaxial or planar Ge detectors. The net peak evaluation is made by many users with the codes UF6 or NaIGEM. The uncertainty of the result depends in addition to the good dead time correction on the precise work of the user who has to fulfill the geometry conditions. Several tests are presented here below. All of them are made only with U samples with an Al wall of 2 mm thickness.

3.1. NaI without Am, evaluated with NaIGEM

The test series was made with NaI detector no. 6 on five samples, one of them, CBNM446 with 4.4623% enrichment, was used for the calibration. A Pb collimator of 2 cm diameter and 2 cm length was applied. The dead times were relatively low, see Tab. 2. The data evaluation was made with NaIGEM version IAEA v2.1.4. . The results are presented in Tab. 1. They show a very good agreement between the two MCAs. There is also a reasonably good agreement to the declared values except for the two results for the natural uranium which are 3 or 4 sigma below the correct value.

Item	Declared enrichment (%)	Measured enrichment (%) with MCA-527	Measured enrichment (%) with MCA-166	MCA-527 / MCA-166	Diff. in sigma, MCA-527	Diff. in sigma, MCA-166	Rel. diff. in enr, MCA-527	Rel. diff. in enr, MCA-166
UP899S	87.610 ± 1.752	86.738 ± 0.442	86.649 ± 0.441	1.001 ± 0.007	-1.97	-2.18	-1.0%	-1.1%
CBNM295	2.949 ± 0.002	2.928 ± 0.021	2.927 ± 0.021	1.000 ± 0.010	-1.02	-1.06	-0.7%	-0.8%
CBNM194	1.942 ± 0.001	1.949 ± 0.015	1.946 ± 0.015	1.002 ± 0.011	0.49	0.25	0.4%	0.2%
CBNM071	0.712 ± 0.001	0.686 ± 0.008	0.679 ± 0.008	1.010 ± 0.017	-3.28	-4.11	-3.7%	-4.6%

Tab. 1: Enrichment measured with the enrichment meter principle with NaI detector no.6 without Am source

Item name	MCA-527	MCA-166
UP899S	4.6	16.0
CBNM295	0.7	2.3
CBNM194	0.7	2
CBNM071	0.6	2.0

Tab. 2: Dead time in % for the measurement series with detector NaI no. 6

3.2. Coaxial Ge detector

The test series was made with the coaxial Ge detector C4 on six samples, and again sample CBNM446 with 4.4623% enrichment was used for the calibration. A Pb collimator of 2 cm diameter and 2 cm length was applied. The dead times were low, see Tab. 4. The data evaluation was made with an EXCEL sheet very similar to UF6.exe. The results are presented in Tab. 3. They show an excellent agreement between the two MCAs. There is also a reasonably good agreement to the declared values except for depleted uranium which are 3 or 4 sigma above the correct value.

Item	Declared enrichment (%)	Measured enrichment (%) with MCA-527	Measured enrichment (%) with MCA-166	MCA-527 / MCA-166	Diff. in sigma, MCA-527	Diff. in sigma, MCA-166	Rel. diff. in enr, MCA-527	Rel. diff. in enr, MCA-166
U36	33.890 ± 0.678	34.10 ± 0.07	34.10 ± 0.07	1.000 ± 0.003	2.99	3.05	0.6%	0.6%
U20	18.670 ± 0.373	18.72 ± 0.05	18.82 ± 0.05	0.994 ± 0.004	0.82	2.89	0.2%	0.8%
CBNM194	1.9492 ± 0.0014	1.955 ± 0.009	1.958 ± 0.008	0.999 ± 0.006	0.67	0.99	0.3%	0.4%
CBNM071	0.7119 ± 0.0005	0.716 ± 0.010	0.732 ± 0.009	0.978 ± 0.018	0.38	2.22	0.5%	2.8%
CBNM031	0.3166 ± 0.0002	0.322 ± 0.002	0.322 ± 0.002	1.000 ± 0.007	3.62	3.81	1.8%	1.9%

Tab. 3: Enrichment measured with the enrichment meter principle with coaxial Ge detector

Item name	MCA-527	MCA-166
UP362S	2.9	5.9
UP200S	2.0	3.7
CBNM446	1.2	3.0
CBNM194	1.0	2.0
CBNM071	1.0	1.9
CBNM031	1.0	1.7

Tab. 4: Dead time in % for the measurement series with coaxial Ge detector

3.3. $LaBr_3$ detector

The test series was made with the $LaBr_3$ detector (see annex A2) on five samples, one of them, CBNM446 with 4.4623% enrichment, was used for the calibration. A Pb collimator of 2 cm diameter and 2 cm length was applied. The dead times were relatively low, see Tab. 6. The data evaluation was made with NaIGEM version IAEA v2.1.4. The results are presented in Tab. 5. They show a very good agreement between the two MCAs and there is also a very good agreement to the declared values.

Item	Declared enrichment (%)	Measured enrichment (%) with MCA-527	Measured enrichment (%) with MCA-166	MCA-527 / MCA-166	Diff. in sigma, MCA-527	Diff. in sigma, MCA-166	Rel. diff. in enr, MCA-527	Rel. diff. in enr, MCA-166
U362S	33.890 ± 0.678	34.028 ± 0.193	34.100 ± 0.190	0.998 ± 0.008	0.72	1.11	0.4%	0.6%
U200S	18.670 ± 0.373	18.747 ± 0.106	18.812 ± 0.109	0.997 ± 0.008	0.72	1.31	0.4%	0.8%
	±		±	±				
CBNM194	1.9492 ± 0.0014	1.943 ± 0.012	1.939 ± 0.012	1.002 ± 0.009	-0.56	-0.85	-0.3%	-0.5%
CBNM031	0.3166 ± 0.0002	0.324 ± 0.006	0.324 ± 0.004	1.001 ± 0.022	1.27	1.80	2.4%	2.3%

Tab. 5: Enrichment measured with the enrichment meter principle with $LaBr_3$ detector

Item name	MCA-527	MCA-166
UP362S	1.5	8.0
UP200S	1.0	5.5
CBNM194	0.5	3.2
CBNM031	0.5	2.9

Tab. 6: Dead time in % for the measurement series with $LaBr_3$ detector

3.4. NaI detector with internal Am source

The test series was made on five samples with an NaI detector with internal Am source and its fix collimator of the IAEA (see annex A2). Once again sample CBNM446 with 4.4623% enrichment, was used for the calibration. The dead times were somewhat higher than for the other NaI detector, see Tab. 8. The data evaluation was made with NaIGEM version IAEA v2.1.4. The results are presented in Tab. 7. They show a very good agreement between the two MCAs. The results for the natural uranium are 2 sigma above the correct value in comparison to 3 or 4 sigma below the correct value for the other NaI detector.

Item	Declared enrichment (%)	Measured enrichment (%) with MCA-527	Measured enrichment (%) with MCA-166	MCA-527 / MCA-166	Diff. in sigma, MCA-527	Diff. in sigma, MCA-166	Rel. diff. in enr, MCA-527	Rel. diff. in enr, MCA-166
UP362S	33.890 ± 0.678	33.881 ± 0.191	33.494 ± 0.190	1.012 ± 0.008	-0.05	-2.08	0.0%	-1.2%
UP200S	18.670 ± 0.373	18.730 ± 0.105	18.637 ± 0.107	1.005 ± 0.008	0.57	-0.31	0.3%	-0.2%
CBNM194	1.942 ± 0.001	1.947 ± 0.015	1.952 ± 0.012	0.997 ± 0.010	0.35	0.87	0.3%	0.5%
CBNM071	0.712 ± 0.001	0.719 ± 0.004	0.721 ± 0.004	0.997 ± 0.008	1.80	2.28	1.0%	1.3%

Tab. 7: Enrichment measured with the enrichment meter principle with NaI detector with internal Am source

Item name	MCA-527	MCA-166
UP362S UP200S CBNM194 CBNM071	17.0 10 3 2.7	35.0 22 7.7 6.3

Tab. 8: Dead time in % for the measurement series with NaI detector with internal Am source

Conclusion

All measurements according to the enrichment meter principle present a complete agreement of the performance of the two MCA. The observed deviations are mainly concerning depleted uranium which is not ideal for instrument testing.

4. Enrichment measurement with planar Ge detector, evaluation with MGAU

The present measurements were made with the following measurement parameters:

Ge detectors:	P1, P5, P20
Collimator;	not used
Cd filter:	0 mm
Interposed shielding:	not used
Sample wall thickness:	2 mm, 0.5 mm for sample P84
Distance detector housing – source:	0 mm
Count rate:	up to 40000 cps
Samples used for the calibration:	intrinsic calibration
Version of MGAU.exe:	3.01
MCA-166 serial number:	496 (P1 and P20) 133 (P5)
MCA-527 serial number:	1057 (P1 and P20) 1128 (P5)
MCA-166 Firmware number:	9914 (P1 and P20) 9902 (P5)
MCA-527 Firmware number:	1304 (P1, P20 and P5)
Energy stabilisation:	off

Preamp power supply and HV from MCA-527

The detectors present different energy resolution as given in the table below:

Detector	Resolution in eV at 185.7 keV	
	MCA-527	MCA-166
P1	671	663
P5	749	730
P20	759	779

Tab. 9: Range of the energy resolution calculated with MGAU, the count rates were 4300 cps for detector P1, 20000 cps for P5 and 42000 cps for P20

For comparison: In the first test measurement campaign in November 2012 (MCA-527 firmware 1204, ref [1]), the detector P5 presented for the 185.7 keV peak FWHM of 0.94 keV and 0.75 keV for the MCA-527 and MCA-166 respectively. Upgrading the firmware to version 1304 lead now to a visible improvement of the resolution as observed with the MCA-527 (Fig. 19 a and b).

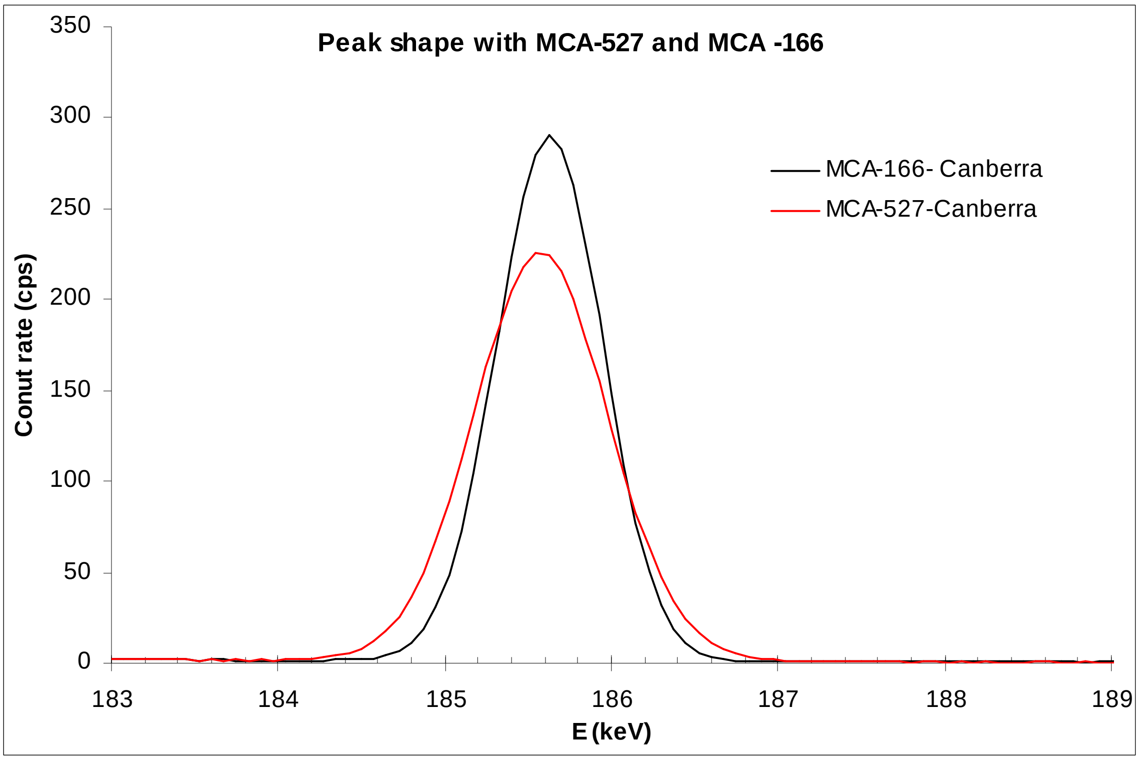

Fig. 19a: MCA-527, firmware 1204 [1]: 186 keV peak measured with detector P5 on sample UP200S and processed simultaneously with MCA-527 and MCA-166, 19000cps

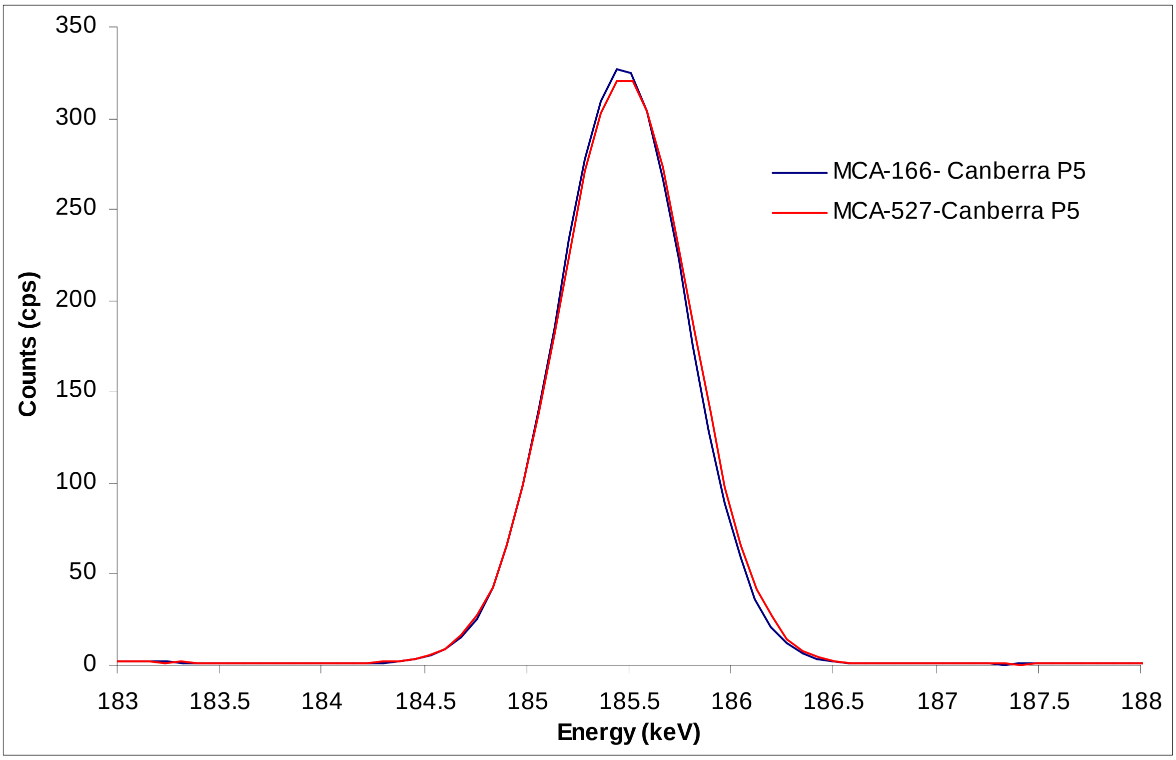

Fig. 19b: MCA-527, firmware 1304, present work: 186 keV peak measured with detector P5 on sample UP200S and processed simultaneously with MCA-527 and MCA-166, 20000 cps

The measurements were carried out with the items of Annex A3. The results are given in Tab. 10a to 10c and the corresponding dead times in Tab. 11a to 11c.

Item	Declared enrichment (%)	Measured enrichment (%) with MCA-527	Measured enrichment (%) with MCA-166	MCA-527 / MCA-166	Diff. in sigma, MCA-527	Diff. in sigma, MCA-166	Rel. diff. in enr, MCA-527	Rel. diff. in enr, MCA-166
P84	93.10 ± 0.93	93.33 ± 1.11	92.97 ± 1.06	1.00 ± 0.02	0.2	-0.1	0.3%	-0.1%
UP899S	87.61 ± 1.75	91.96 ± 0.80	88.82 ± 0.76	1.04 ± 0.01	2.3	0.6	5.0%	1.4%
UP362S	33.89 ± 0.68	34.19 ± 0.29	33.86 ± 0.34	1.01 ± 0.01	0.4	0.0	0.9%	-0.1%
UP200S	18.67 ± 0.37	18.46 ± 0.16	18.36 ± 0.16	1.01 ± 0.01	-0.5	-0.8	-1.2%	-1.7%
CBNM446	4.4623 ± 0.0032	4.534 ± 0.055	4.431 ± 0.054	1.02 ± 0.02	1.3	-0.6	1.6%	-0.7%
CBNM295	2.9492 ± 0.0021	2.952 ± 0.033	3.025 ± 0.034	0.98 ± 0.02	0.1	2.2	0.1%	2.6%
CBNM194	1.9420 ± 0.0014	2.012 ± 0.029	1.954 ± 0.028	1.03 ± 0.02	2.4	0.4	3.6%	0.6%
CBNM071	0.7119 ± 0.0005	0.771 ± 0.007	0.729 ± 0.007	1.06 ± 0.01	8.4	2.4	8.3%	2.4%
CBNM031	0.3166 ± 0.0002	0.374 ± 0.008	0.338 ± 0.008	1.11 ± 0.04	7.2	2.7	18.1%	6.8%

Tab. 10a: Results for the measurement series with detector P1

Item	Declared enrichment (%)	Measured enrichment (%) with MCA-527	Measured enrichment (%) with MCA-166	MCA-527 / MCA-166	Diff. in sigma, MCA-527	Diff. in sigma, MCA-166	Rel. diff. in enr, MCA-527	Rel. diff. in enr, MCA-166
PL84	93.10 ± 0.93	93.97 ± 1.64	93.36 ± 1.50	1.01 ± 0.02	0.5	0.1	0.9%	0.3%
U89	87.61 ± 1.75	93.02 ± 1.34	88.77 ± 1.20	1.05 ± 0.02	2.5	0.5	6.2%	1.3%
U36	33.89 ± 0.68	34.52 ± 0.80	34.02 ± 0.27	1.01 ± 0.02	0.6	0.2	1.9%	0.4%
U20	18.67 ± 0.37	18.84 ± 0.14	18.72 ± 0.70	1.01 ± 0.04	0.4	0.1	0.9%	0.2%
CBNM446	4.4623 ± 0.0032	4.416 ± 0.037	4.385 ± 0.037	1.01 ± 0.01	-1.2	-2.1	-1.0%	-1.7%
CBNM194	1.9492 ± 0.0014	1.929 ± 0.019	1.885 ± 0.018	1.02 ± 0.01	-1.1	-3.6	-1.0%	-3.3%
CBNM071	0.7119 ± 0.0005	0.731 ± 0.013	0.736 ± 0.024	0.99 ± 0.04	1.5	1.0	2.7%	3.4%
CBNM031	0.3166 ± 0.0002	0.333 ± 0.015	0.316 ± 0.030	1.05 ± 0.11	1.1	0.0	5.2%	-0.2%

Tab. 10b: Results for the measurement series with detector P5

Item	Declared enrichment (%)	Measured enrichment (%) with MCA-527	Measured enrichment (%) with MCA-166	MCA-527 / MCA-166	Diff. in sigma, MCA-527	Diff. in sigma, MCA-166	Rel. diff. in enr, MCA-527	Rel. diff. in enr, MCA-166
P84	93.10 ± 0.93	89.96 ± 1.02	87.45 ± 1.16	1.03 ± 0.02	-2.3	-3.8	-3.4%	-6.1%
UP899S	87.61 ± 1.75	91.96 ± 0.80	88.82 ± 0.76	1.04 ± 0.01	2.3	0.6	5.0%	1.4%
UP362S	33.89 ± 0.68	34.52 ± 0.21	34.40 ± 0.21	1.00 ± 0.01	0.9	0.7	1.9%	1.5%
UP200S	18.67 ± 0.37	18.87 ± 0.11	18.61 ± 0.11	1.01 ± 0.01	0.5	-0.2	1.0%	-0.3%
CBNM446	4.4623 ± 0.0032	4.425 ± 0.044	4.344 ± 0.050	1.02 ± 0.02	-0.8	-2.4	-0.8%	-2.7%
CBNM295	2.9492 ± 0.0021	2.977 ± 0.041	2.856 ± 0.041	1.04 ± 0.02	0.7	-2.3	0.9%	-3.2%
CBNM194	1.9420 ± 0.0014	1.941 ± 0.022	1.867 ± 0.022	1.04 ± 0.02	0.0	-3.4	-0.1%	-3.9%
CBNM071	0.7119 ± 0.0005	0.737 ± 0.018	0.671 ± 0.019	1.10 ± 0.04	1.4	-2.2	3.5%	-5.7%
CBNM031	0.3166 ± 0.0002	0.339 ± 0.008	0.290 ± 0.008	1.17 ± 0.04	2.8	-3.3	7.1%	-8.4%

Tab. 10c: Results for the measurement series with detector P20

P1	Dead time in %	
Item name	MCA-527	MCA-166
P84	1.0	2.0
UP899S	9.0	20.0
UP362S	7.4	15.0
UP200S	4.6	9
CBNM446	2.0	4.0
CBNM295	1.5	3.1
CBNM194	1.4	2.7
CBNM071	1.2	2.3
CBNM072	1	2.2
CBNM031	1	2.0

Tab. 11a: Dead time expressed in % for the measurement series with detector P1

P5	Dead time in %	
Item name	MCA-527	MCA-166
P84	5.0	10.0
UP899S	11.0	23.0
UP362S	10.0	22.0
UP200S	10.6	23.0
CBNM446	7.7	17.0
CBNM194	5.6	13.0
CBNM071	4.7	11.0
CBNM031	4.3	8.3

Tab. 11b: Dead time expressed in % for the measurement series with detector P5

P20	Dead time in %	
Item name	MCA-527	MCA-166
P84	2.6	6.4
UP899S	21.0	40.0
UP362S	17.0	35.0
UP200S	10	22
CBNM446	4.4	10
CBNM295	3.6	8.6
CBNM194	3	7.7
CBNM071	2.7	6.3
CBNM031	2.6	6.0

Tab. 11c: Dead time expressed in % for the measurement series with detector P20

The ratio MCA-527/MCA-166 (see also Fig. 20a and b) shows small discrepancies between the results obtained by the two MCA, esp. for the detector P1 and P20 for LEU. The QFit delivered by MGAU is practically the same for both MCA's for all measurements. The slightly higher FWHM of the MCA-527 can not be the reason for these small deviations (if so, we would see a strong effect with a comparison between detector P1 on the one hand and P5 and P20 on the other hand.).

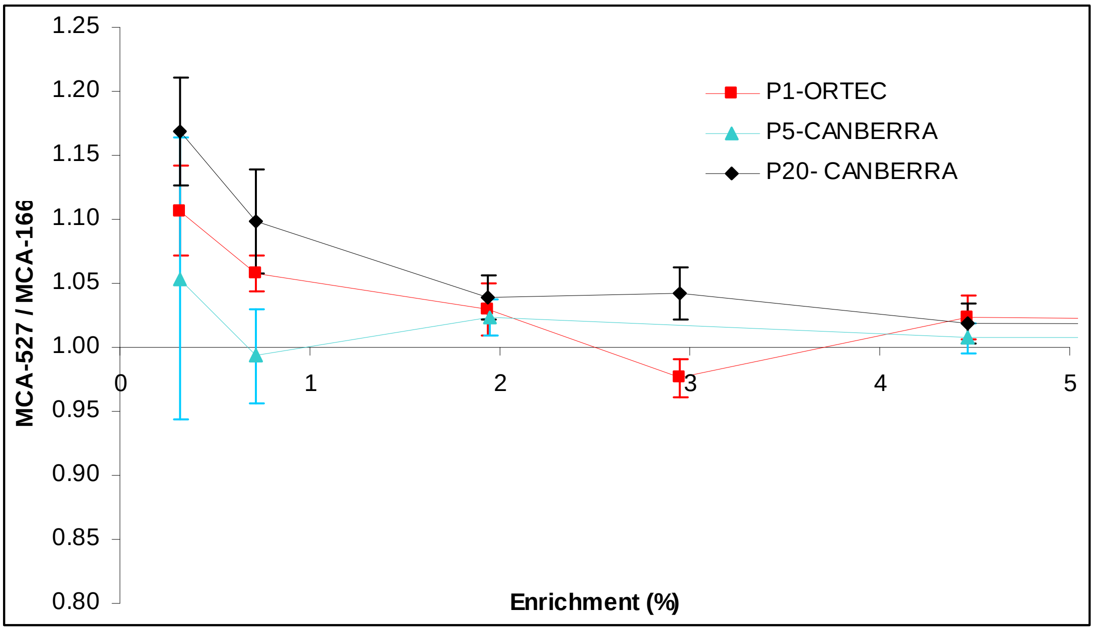

Fig. 20a: Ratio MCA-527/MCA-166 of the enrichment values measured with MCA-166 and MCA-527 simultaneously with three different detectors, up to 5% enrichment

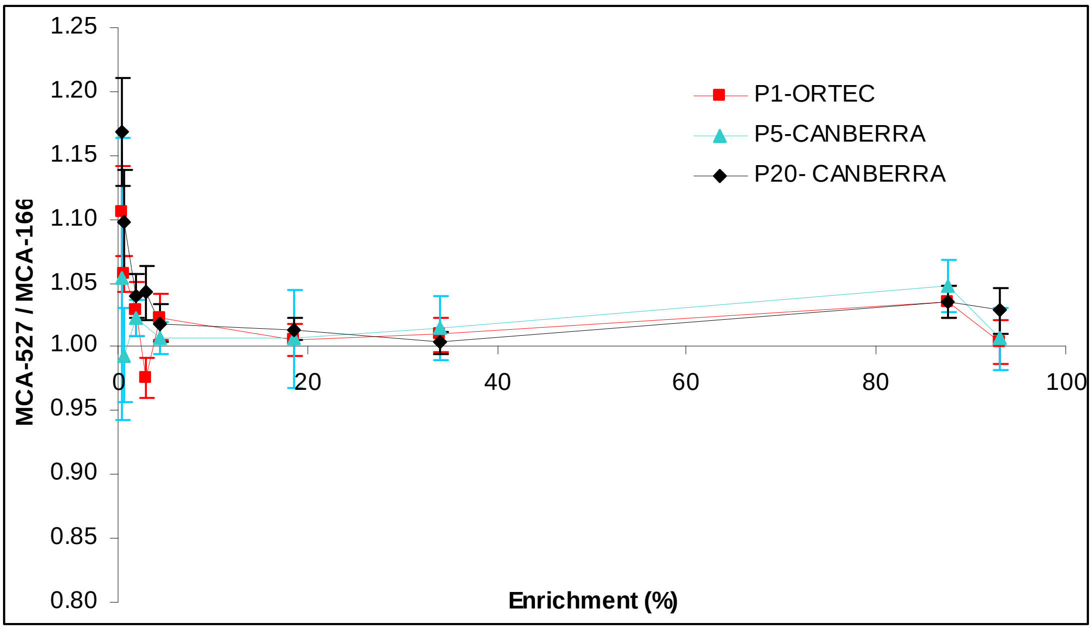

Fig. 20b: Ratio MCA-527/MCA-166 of the enrichment values measured with MCA-166 and MCA-527 simultaneously with three different detectors, up to 90% enrichment

Comparison of ORTEC and CANBERRA planar Ge detectors and preamplifiers

In the earlier test in November 2012 [1] it was observed that the performance both of analogue and of digital MCAs is affected by the preamplifier type. Measurements with detectors P5 of CANBERRA and P1 of ORTEC showed for the ratio MCA-527/MCA-166 larger deviations from 1 in the case of the P5 than in the case of the P1 (Fig. 21), particularly for LEU. However, for this first test, the old firmware version 1204 lead to energy resolution of 0.75 keV for the P5 used with the MCA-166 and 0.94 keV when used with the MCA-527.

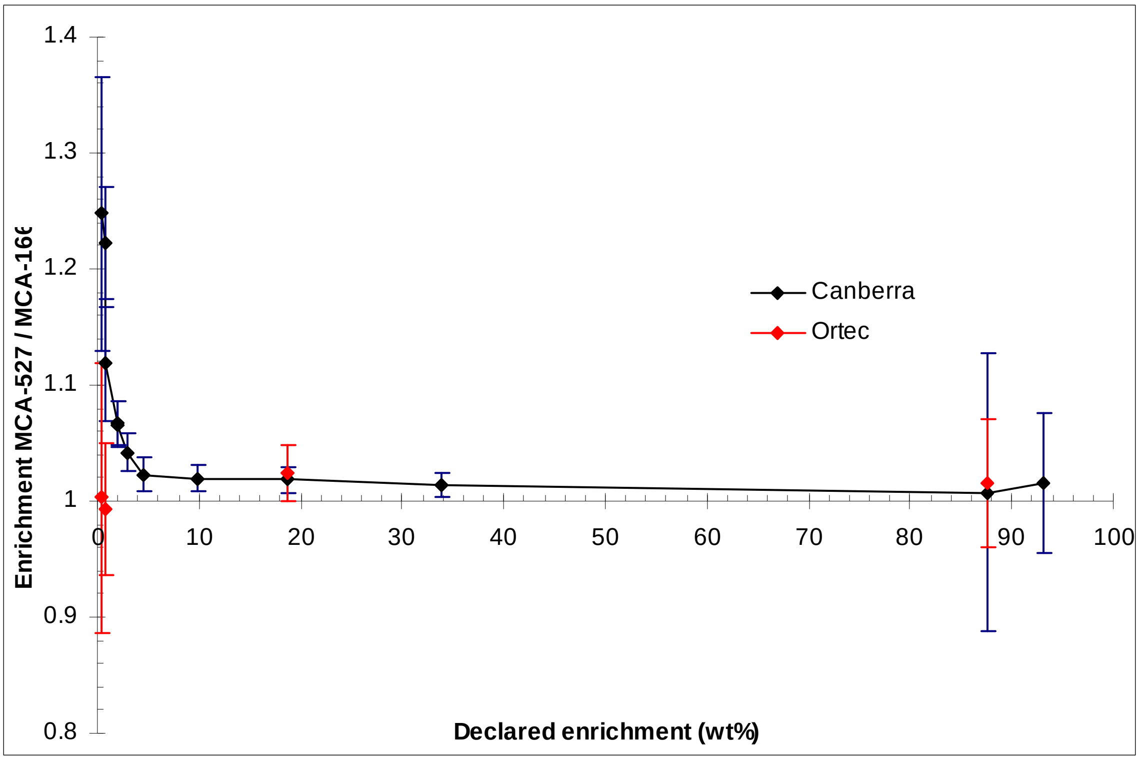

Fig. 21: MCA-527, firmware 1204 [1]: Ratio MCA-527/MCA-166 of the enrichment values measured with MCA-166 and MCA-527 simultaneously, once with a CANBERRA detector (P5) and once with an ORTEC detector (P1)

In the present work with firmware version 1304 there is no such substantial difference in resolution, the FWHM for detector P1 are 0.66 keV and 0.69 keV when used with the MCA-166 and MCA-527 respectively. The graphs in Fig. 20 give no hint on different behavior of the MCA-527 with firmware 1204 if they work with different preamplifiers.

Conclusion

As a whole, there is good agreement between the measurement results and the declared enrichment for both MCAs.

There are certain differences between MCA-527 and MCA-166, but they appear particularly in measurements with very high or very low enrichment, i.e. in those cases where MGAU has to deal with rather small peaks of either ^{235}U or ^{238}U daughter nuclides. Such cases are not appropriate for a hardware test since it is not easily possible to decide whether deviations are due to imperfections of the hardware or the software.

5. Pu isotopic abundance measurement, evaluation with MGA

The performance of the MCA-527 and MCA-166 were compared also for measurements of the isotopic composition of Pu. For the measurements we used:

- four Pu standards CBNM Pu61, CBNM Pu70, CBNM Pu 84, CBNM Pu93
- three different planar Ge detectors:
    - P1: a 200 mm^2 detector of ORTEC with liquid nitrogen cooling,
    - P5: a 1000 mm^2 detector of CANBERRA with liquid nitrogen cooling,
    - P20: a 200 mm^2 detector of CANBERRA with CryoPulse5 cooling.

Five series of measurements were carried out:

a) Detector P20, 4 Pu standards, count rates from 3 000 to 100 000 cps,
20 million counts in spectrum, i.e. always changing measurement time
simultaneous measurement with MCA-527 and MCA-166

b) Detector P1, 4 Pu standards, count rates from 10 000 to 60 000 cps,
20 million counts in spectrum, i.e. always changing measurement time
simultaneous measurement with MCA-527 and MCA-166

c) Detector P5, 2 Pu standards, count rates from 18 000 to 70 000 cps,
20 million counts in spectrum, i.e. always changing measurement time
simultaneous measurement with MCA-527 and MCA-166

d) Detector P1, CBNM Pu61, count rates from 5 000 to 70 000 cps,
Fixed real time of 600 seconds per spectrum, i.e. number of counts in the spectrum changes with count rate measurement time
simultaneous measurement with MCA-527 and MCA-166

e) Detector P1, CBNM Pu61, count rates from 5 000 to 100 000 cps,
20 million counts in spectrum, i.e. always changing measurement time
consecutive measurement with MCA-527 and MCA-166

Series a), b) and d) are to observe if the two MCAs react in different ways on the individual detectors and their preamplifiers. Moreover they should demonstrate the influence of the count rate on the MGA results for the two instruments. 20 million counts per spectrum provide reasonably good counting statistics to discover deviations between two instruments in the order of magnitude of 1%.

Series d) consists of measurements with a fixed real time of always 600 seconds with input count rates from 10 000 to 55 000 cps, i.e. each spectrum contains a different number of counts (2 700 000 to 16 000 000 counts for MCA-166 and 2 800 000 to 26 000 000 counts for MCA-527, resp.). In this case, there might be an optimum with “medium” count rates, i.e. on the one hand the counting statistics is not too bad and on the other hand, a too high count rate has not yet deteriorated the spectrum quality.

Series e) comprises measurement which should demonstrate that there is no disturbing effect in the series a) to d) because of a correlation between the simultaneously measured spectra of MCA-166 and MCA-527.

The spectrum evaluation was made with MGA version 9.65.

5.1. Isotopic abundances of Pu

The results of all measurements a) to e) of the isotopic composition of the Pu samples are in agreement within the measurement errors as show the graphs in Fig. 22. These graphs present for all isotopes i the ratios

$$\frac{(\text{abundance (i, MCA-527)} - \text{abundance (i, MCA-166)})}{(\text{error (i, MCA-527)} + \text{error (i, MCA-166)}) / 2}$$

This picture does not change if we look for the data for individual detectors (Fig. 23).

There is no effect visible if we compare measurement series d) and e) with simultaneous or consecutive measurements (Fig. 24).

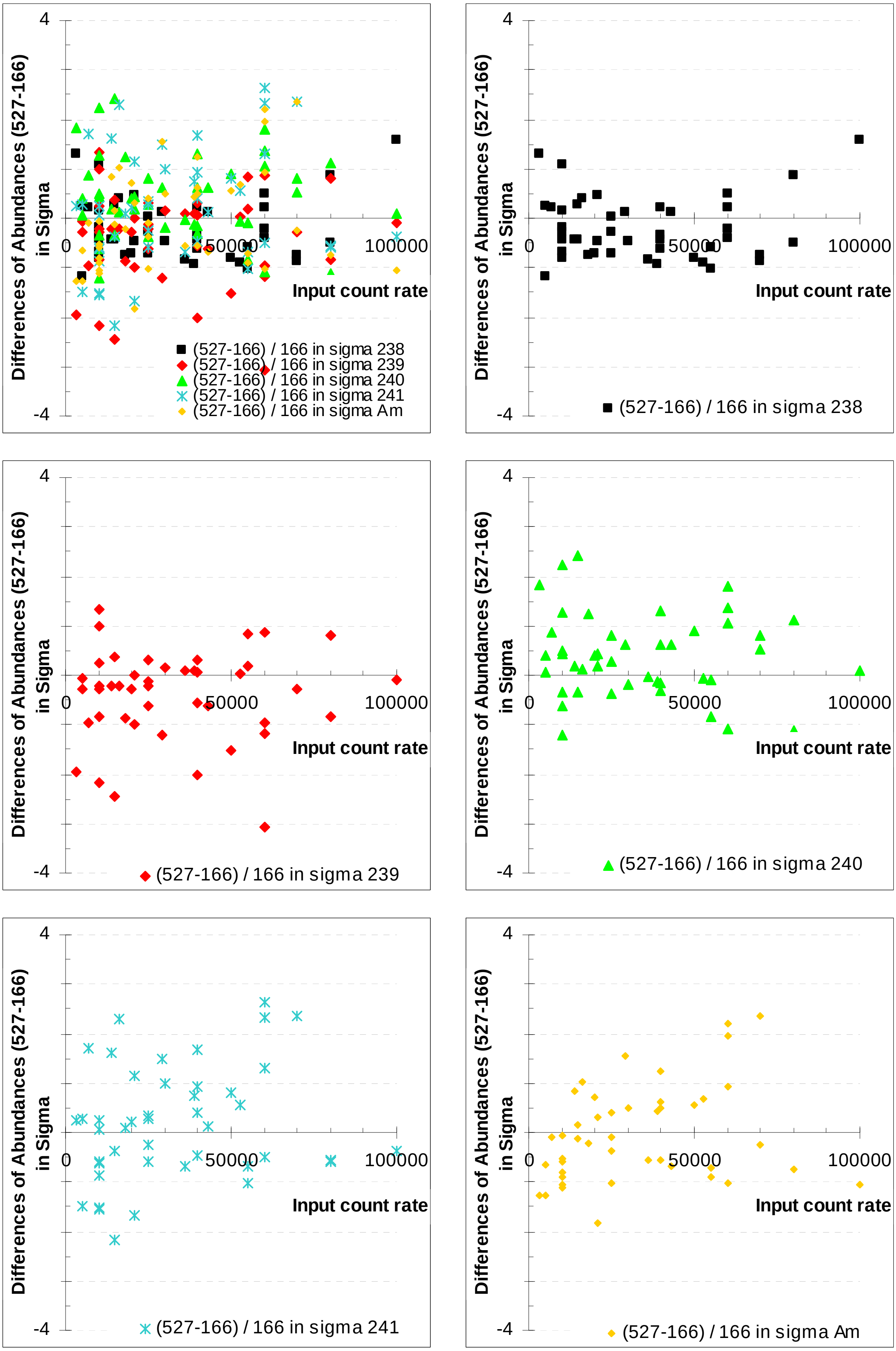

Fig. 22: Differences of the abundances of the MCA-527 and MCA-166 in sigma for all measurements for all three detectors, the first diagram presents all results, the following diagrams the same data for the Pu isotopes 238, 239, 240, 241 and for ^{241}Am.

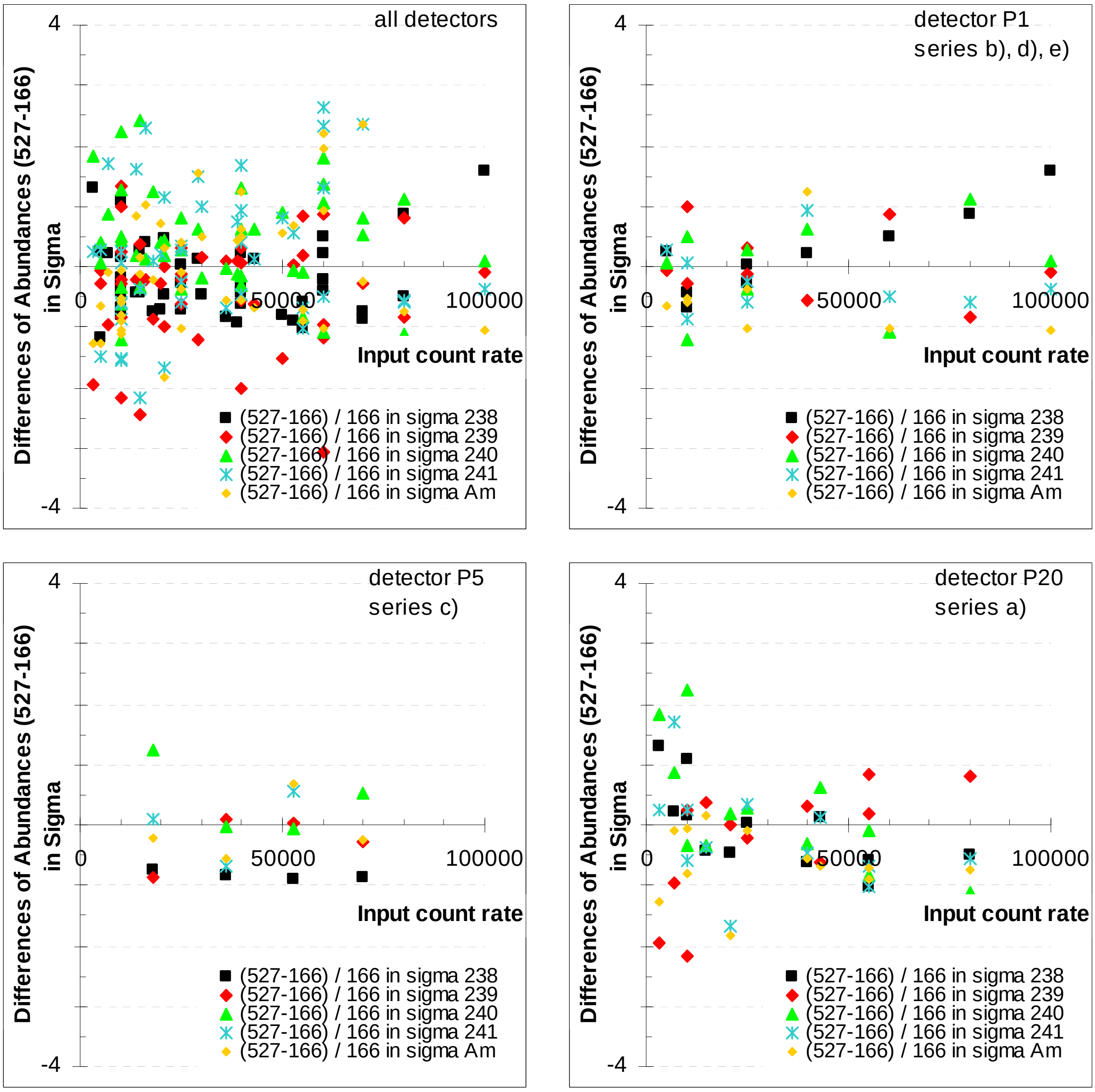

Fig. 23: Differences of the abundances for individual detectors

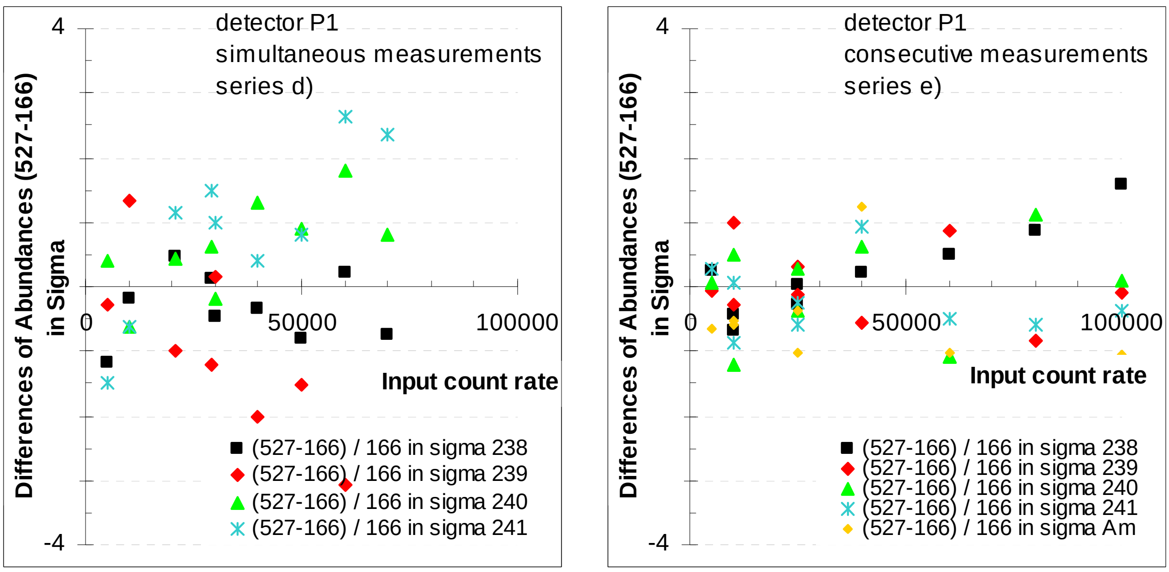

Fig. 24: Differences of the abundances for simultaneous and consecutive measurements

5.2. Error of the abundances

The relative errors of all MGA results are shown in Fig. 25. The errors for the two MCAs are in agreement, only for count rates above 60 000 cps the errors of the MCA-527 are slightly higher.

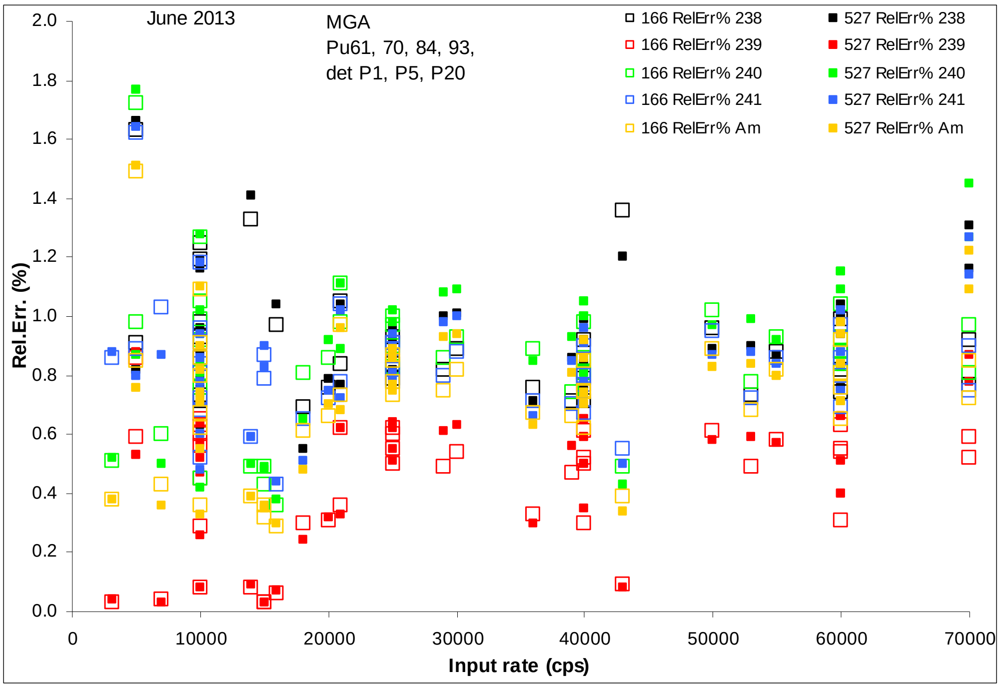

Fig. 25: Relative errors of the Pu abundances

The evaluation of series d) shows practically the same performance for the two MCAs in the most interesting range of count rates from 20 000 to 60 000 cps (Fig. 26).

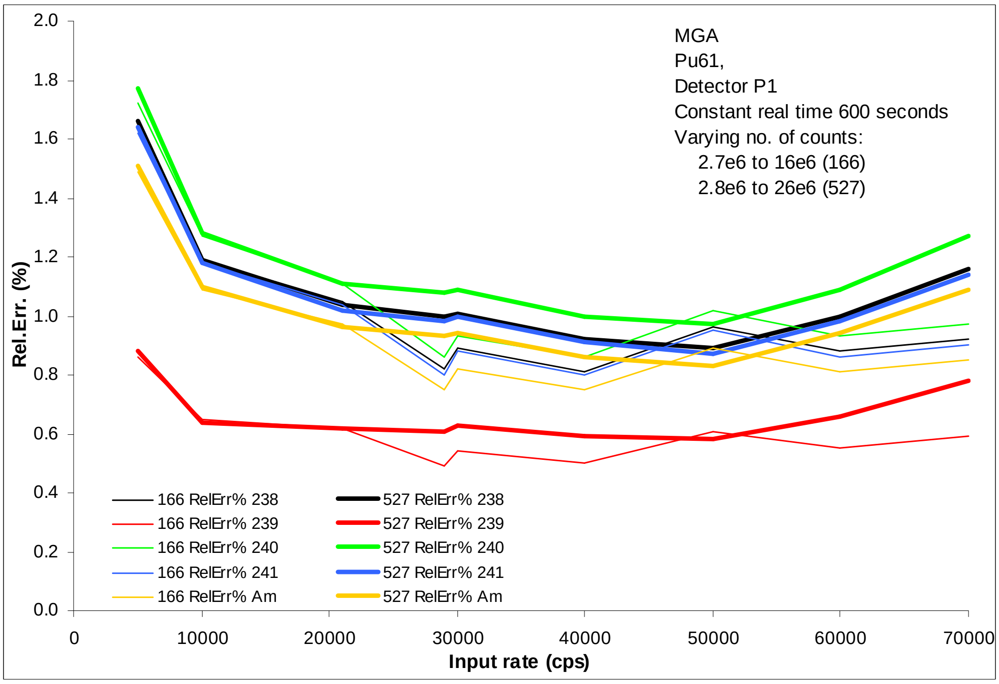

Fig. 26: Relative errors of the Pu abundances for measurements with constant measurement time of 600 seconds real time

5.3. Energy resolution

The isotopic abundances as discussed above were achieved with measurements, where the energy resolution depended in different ways on the count rate as shown in Fig. 27. The

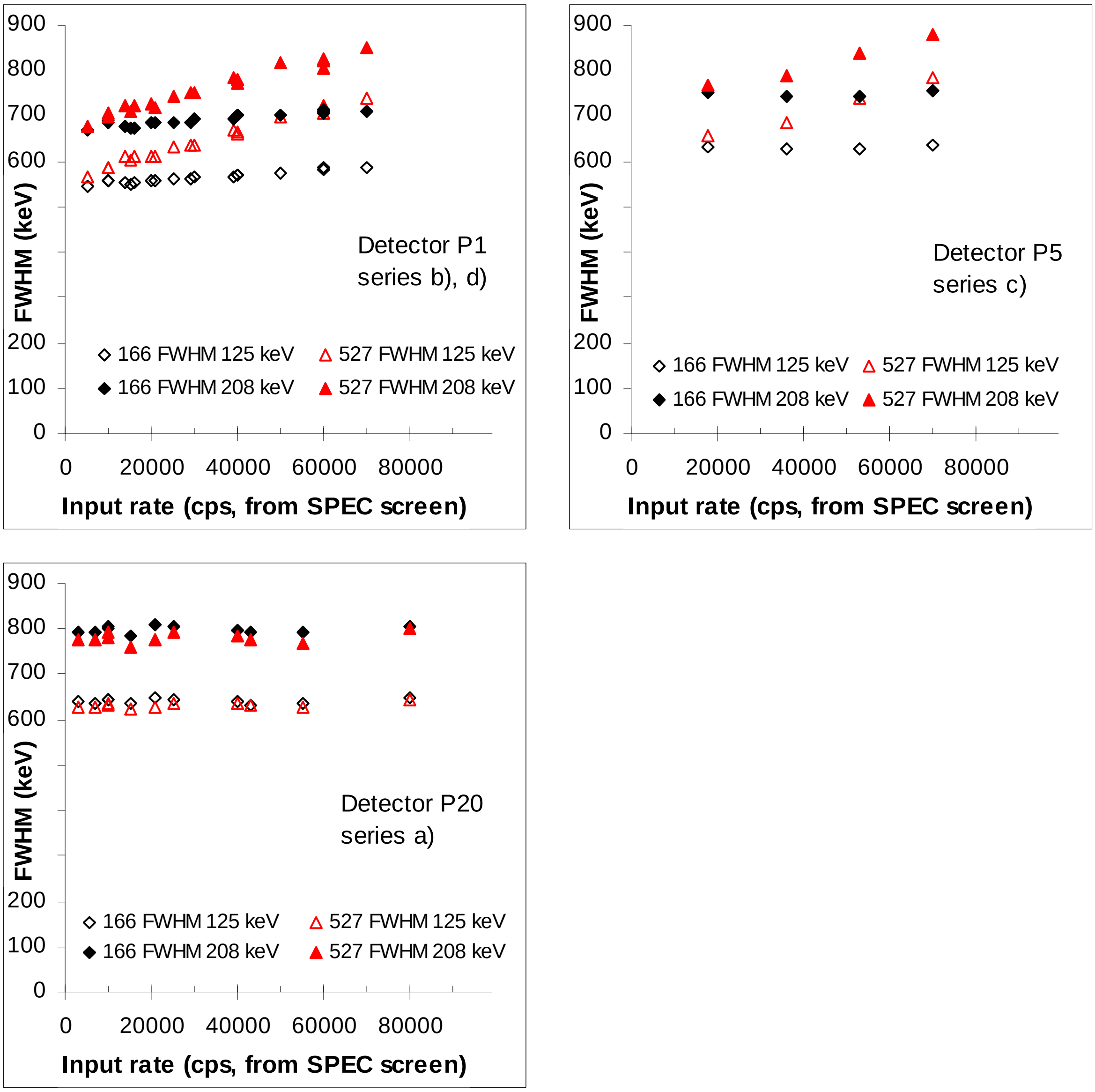

Fig. 27: Full width at half maximum at 125 and 208 keV from MGA for the two MCAs and three different planar Ge detectors (P20: electrical CP-5 cooling)

visible change in the line width for detectors P1 and P5 however does not result in an increase of the errors of the isotopic abundances as seen above. The constant FWHM for both MCAs appears with the electrically cooled detector. Obviously MGA can fit well the peak shapes of the MCA-527 spectra and the observed increase of the FWHM with the input count rate is no disadvantage-

Conclusion

The MCA-527 fulfills the requirements for the determination of the isotopic composition of Pu with planar Ge detector and MGA.

6. CZT

6.1. SDP-310

A CZT detector of type SDP-310 of RITEC was exposed to the radiation of a ^{137}Cs source up to count rates above 400 000 cps. Until about 300 000 cps it delivered with both MCAs good spectra which have shown clearly the 662 keV line (Fig. 28).

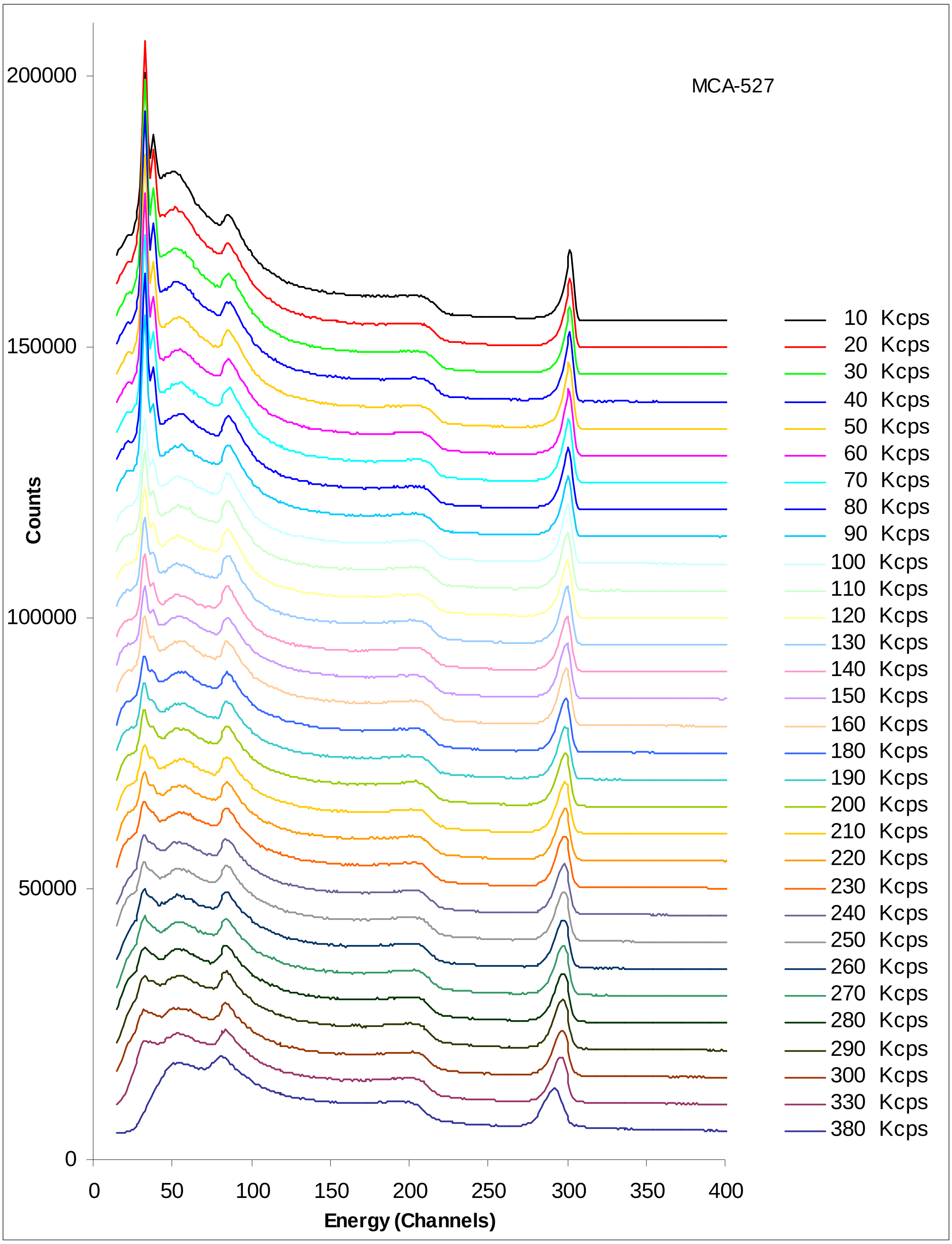

Fig. 28: Spectra of ^{137}Cs measured with a CZT detector of type SDP-310 (60mm^3) at different count rates. (The relative intensity of the X-ray fluorescence in channel 30 changes to the changing distance between the source and a Pb shielding.)

For both MCAs the line shape changed continuously with increasing count rate, see Fig. 29. This drift of both peak position and FWHM is smaller with the MCA-527.

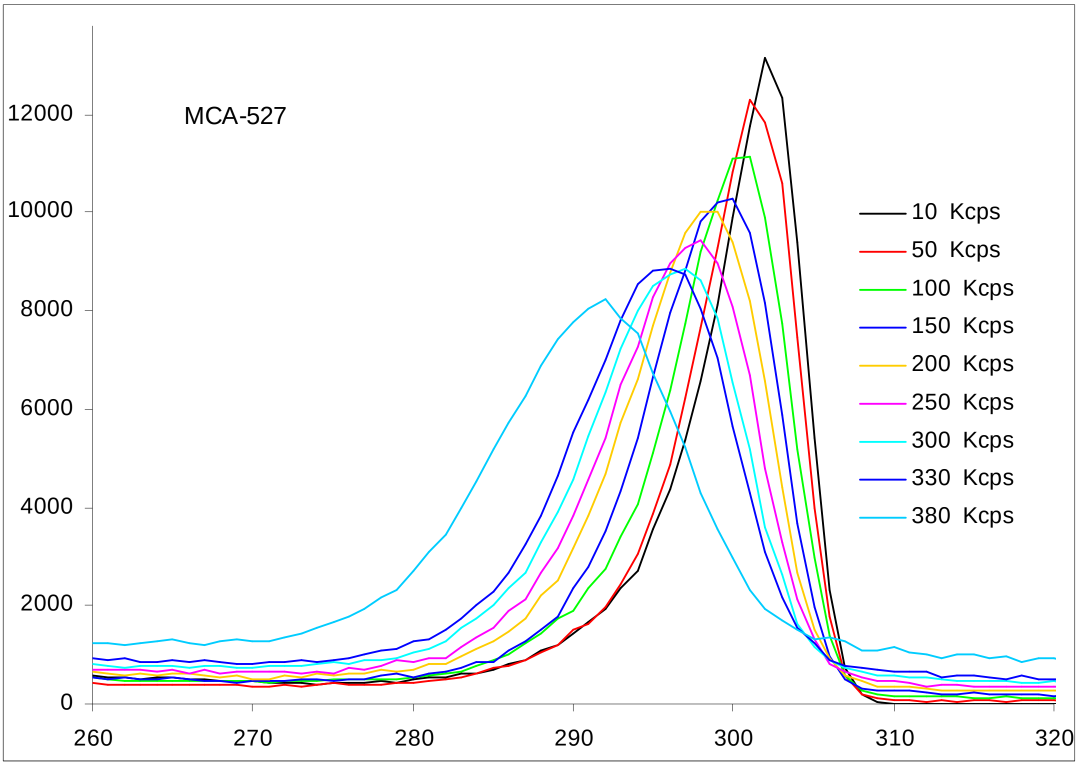

Fig. 29a: ^{137}Cs peak measured with a SDP-310 detector at different count rates for MCA-527

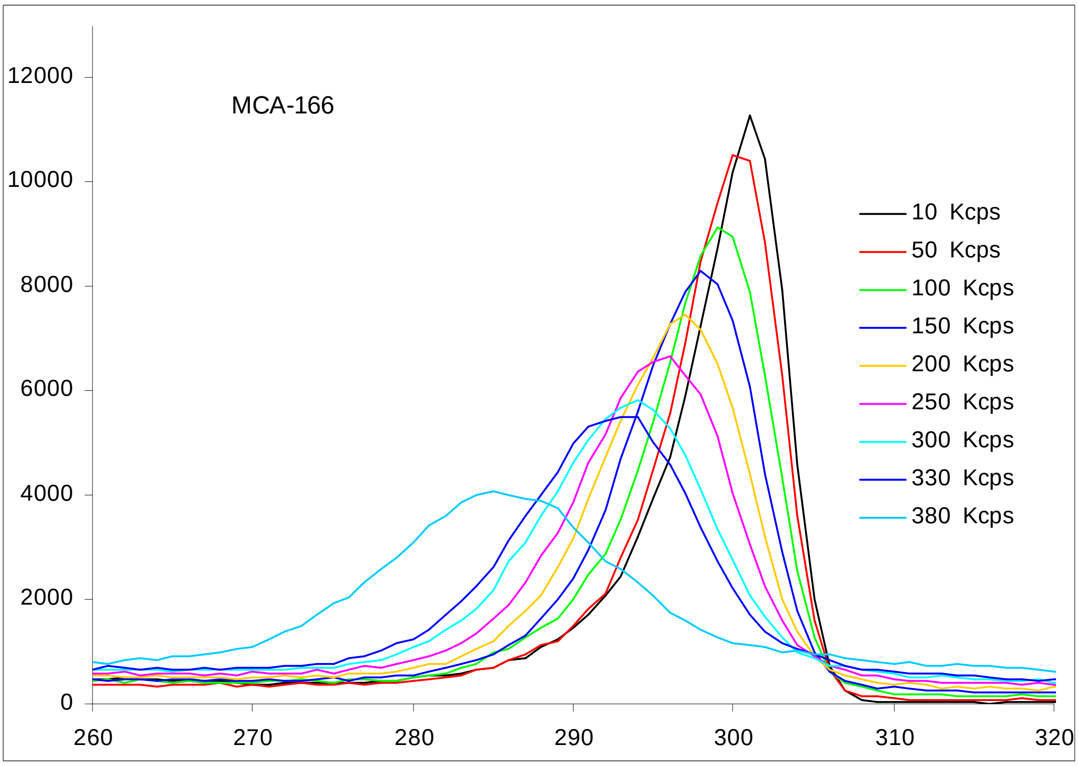

Fig. 29b: ^{137}Cs peak measured with a SDP-310 detector at different count rates for MCA-166

An additional test was made to see the performance at higher energies as required for fission product assay: At a count rate of 140 000 cps, a ^{60}Co source was added to the ^{137}Cs source, and Fig. 30 shows clearly the two lines in addition to the ^{137}Cs spectrum (at this count rate, we see also a pile-up peak of 2 * 662 keV).

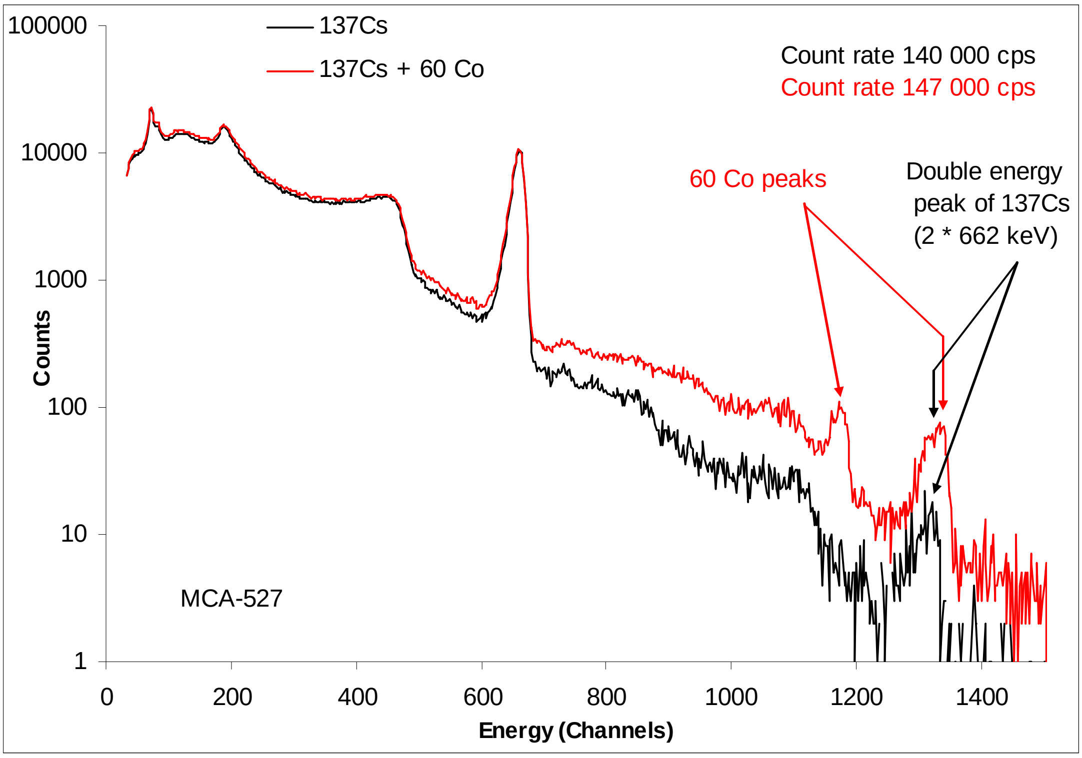

Fig. 30a: ^{60} Co peaks in the ^{137}Cs spectrum at 140 000 cps, measurement with a SDP-310 detector and MCA-527

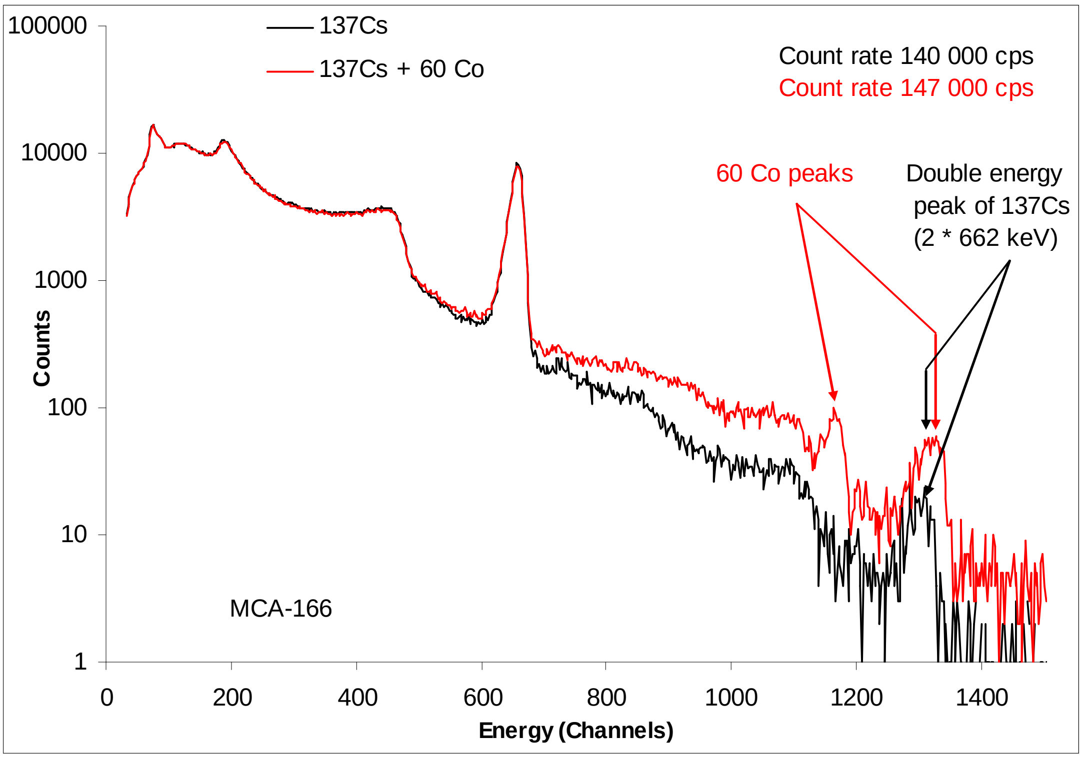

Fig. 30b: ^{60} Co peaks in the ^{137}Cs spectrum at 140 000 cps, measurement with a SDP-310 detector and MCA-166

6.2. CZT/500

The same spectrum was measured with a CZT/500 detector (500mm^3). As for the SDP-310, the spectra are of good quality and can be used for fission product verification up to count rates of 300 000 or 400 000 cps (Fig. 31).

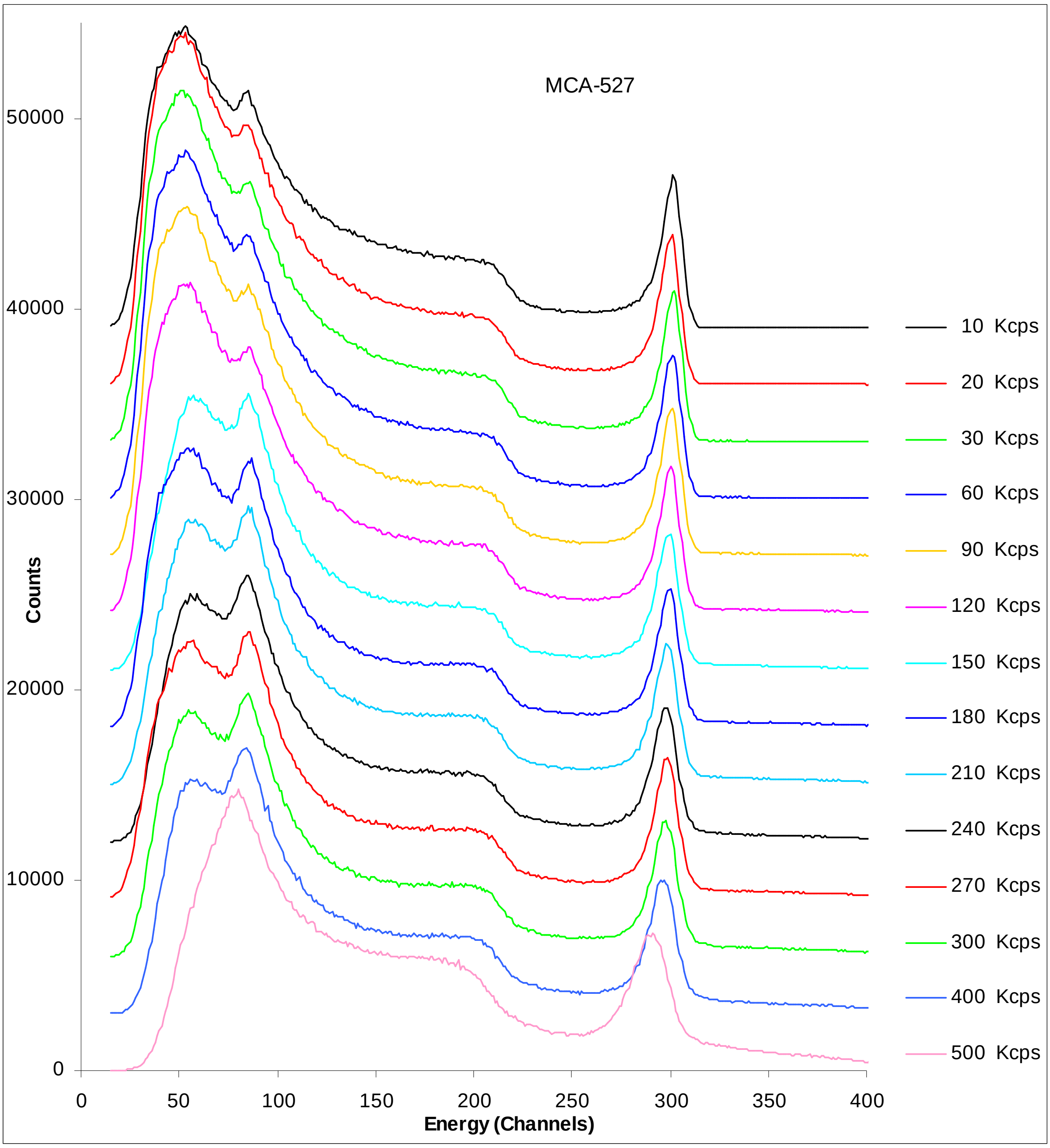

Fig. 31: Spectra of ^{137}Cs measured with a CZT detector of type CZT/500 at different count rates

Also for this detector and preamplifier type we see that the peak shape changes continuously with increasing count rate (Fig. 32a), and here the deformations much are smaller for the MCA-527. Using the peak stabilisation would result in the peaks in Fig. 32b

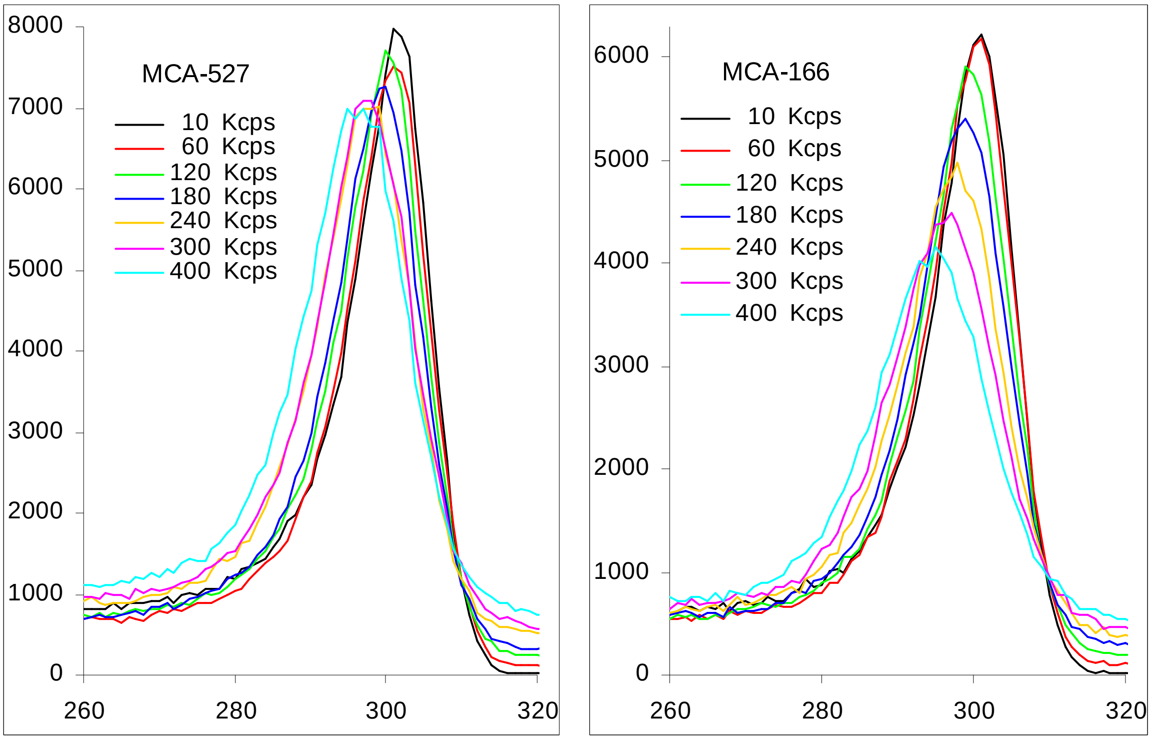

Fig. 32a: ^{137}Cs peak measured with a SDP-310 detector and MCA-527 at different count rates

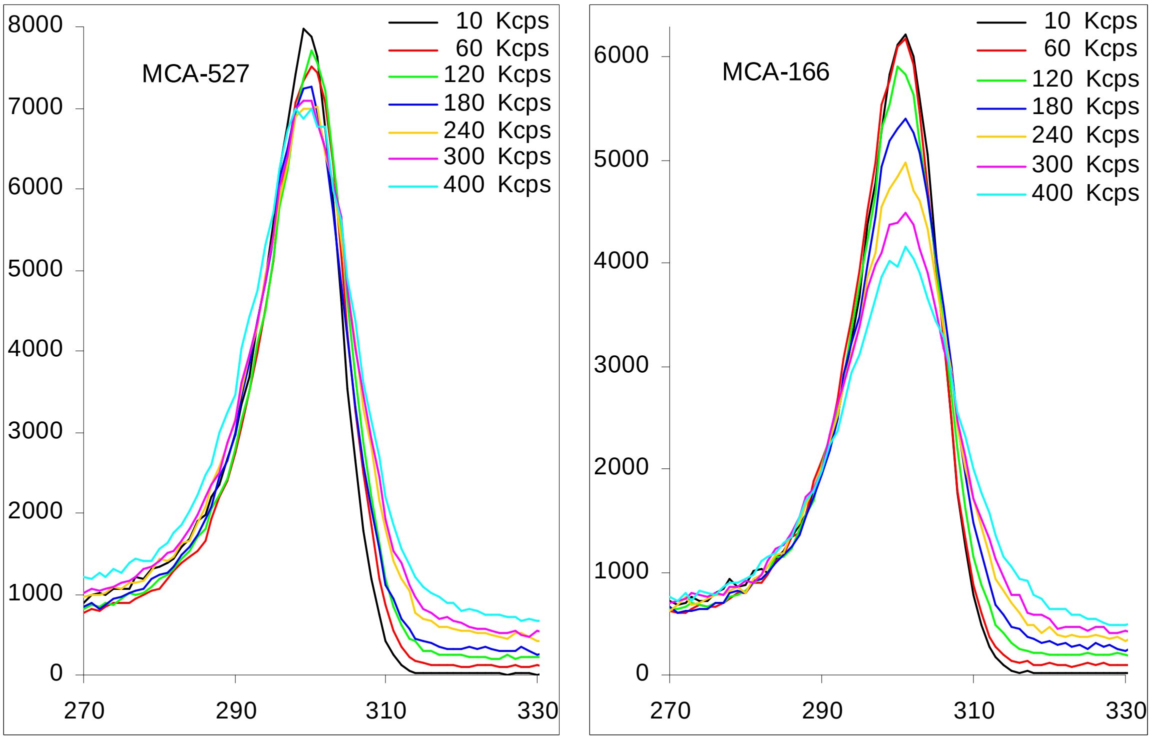

Fig. 32b: ^{137}Cs peak measured with a SDP-310 detector and MCA-166 at different count rates with stabilisation of the peak position

Conclusion

The MCA-527 can be used for gamma spectrometric measurements with CZT detectors, particularly for fission product assay, for count rates up to 300 000 cps and beyond.

7. Temperature test

For the test of the temperature dependence of the MCA, a spectrometer chain with a planar Ge detector and the two MCAs was set up. The Ge detector has a very good temperature stability. The signal was given to the two MCAs and a series of repeated measurements of always the same Pu spectrum was measured, always for a real time of 600 s. After the first hour of operation, the two MCAs were moved form the laboratory atmosphere (26 ºC) into a refrigerator (6 ºC) without interrupting the measurement series. About four hours later the MCAs were put back into the laboratory atmosphere (26 ºC). The stabilization function of the MCAs was not used.

Figures 33 and 34 show the 208 keV peak close to channel 2773. In case of the MCA-527 the peak has moved only 2 … 3 channels, i.e. about 150 … 200 eV, or by 200eV / 208000eV = 0.1%. The change was about 0.3% for the MCA-166. This very good stability is due to a dedicated correction in the device which measures the temperature inside the box and uses it for correction. The internal temperature is given in the .spe file as $TEMPERATURE: . Fig. 35 shows the course of the temperature as measured inside the MCA-527, it is about 5 degree higher than outside.

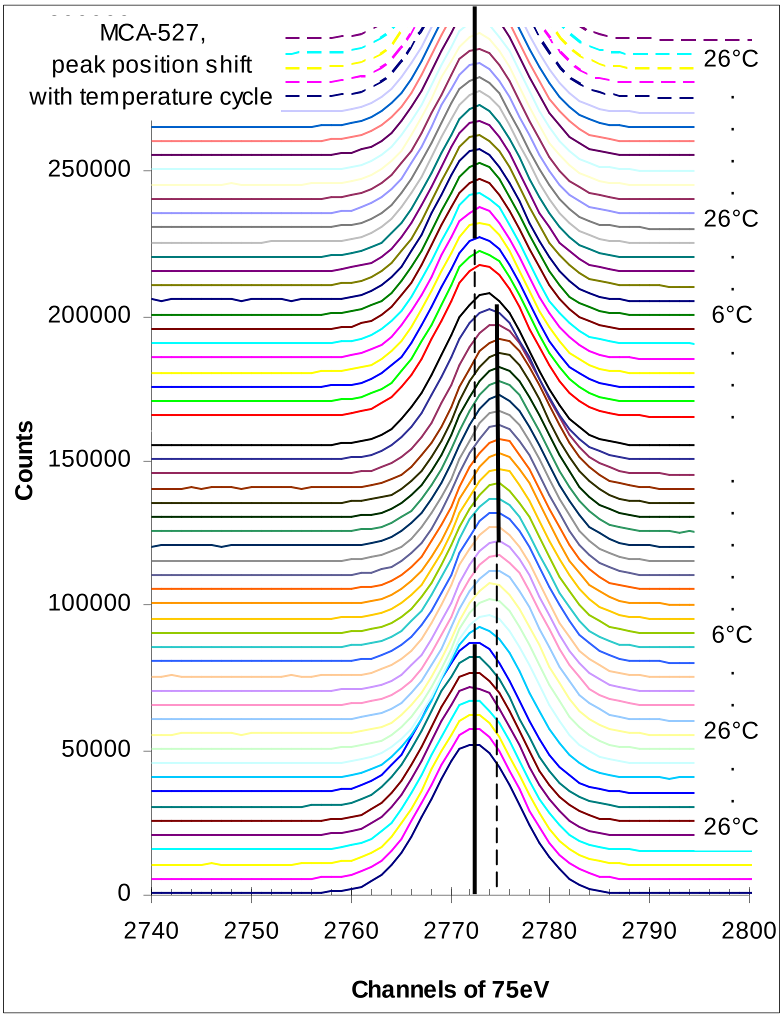

Fig. 33: 208 keV peak in a Ge detector spectrum of Pu during a temperature cycle of a MCA-527

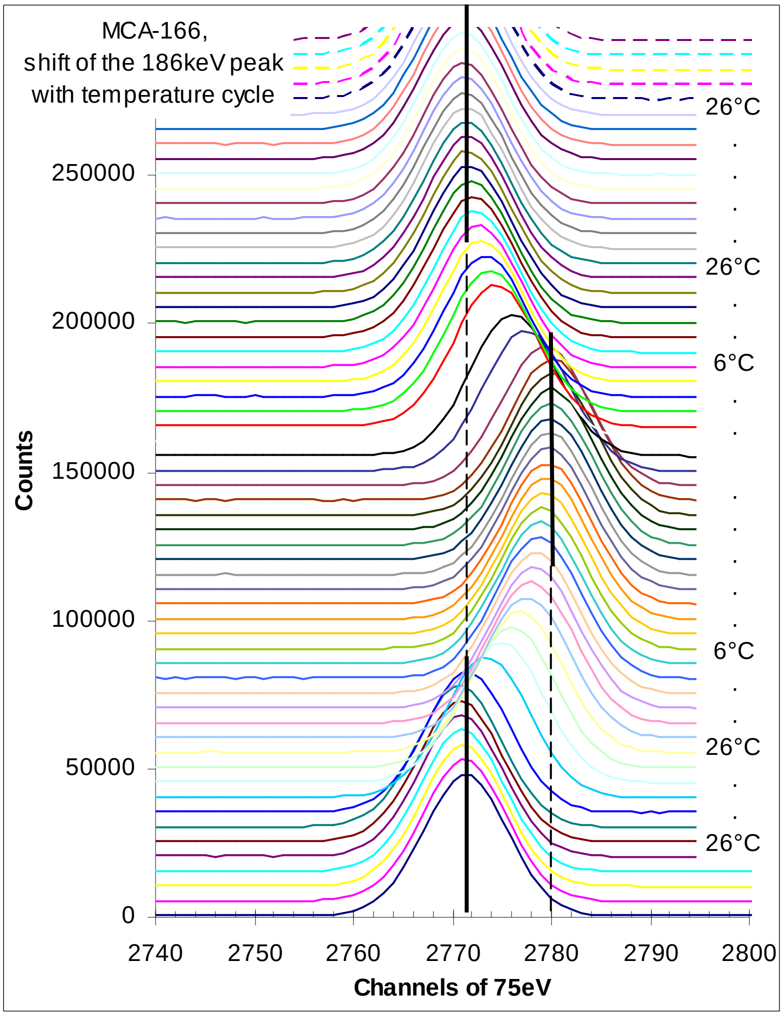

Fig. 34: 208 keV peak in a Ge detector spectrum of Pu during a temperature cycle of a MCA-166

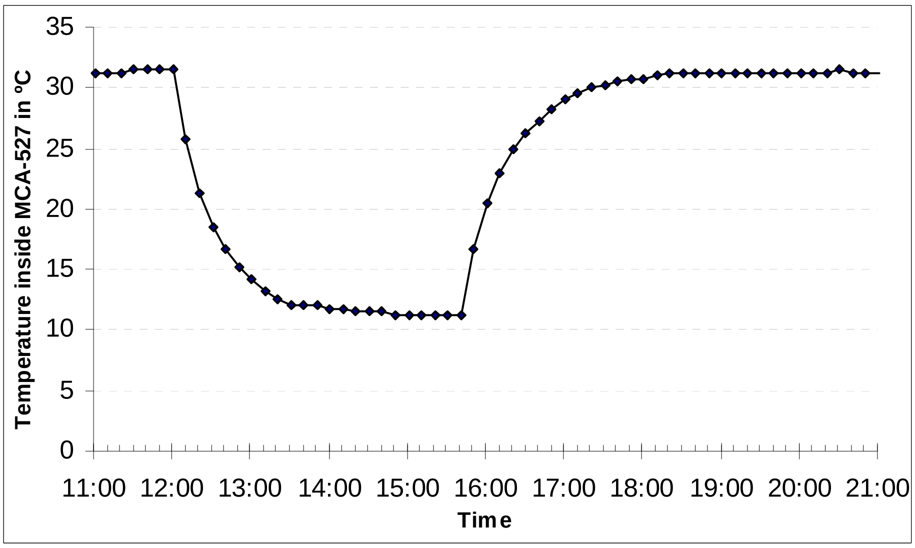

Fig. 35: Temperature change inside the MCA-527 during the stability test

Conclusion

The temperature stability of the MCA-527 is superior to the stability of the MCA-166.

8. Summary

The overall result of the test is: The performance of the MCA-527 meets the functional requirements for gamma spectrometric measurements for nuclear safeguards applications. Its parameters are as good as the ones of the MCA- 166 or sometimes superior to them.

9. References

[1] R. Berndt, P. Mortreau: 235Uranium Enrichment Determination with the MCA-527, JRC Technical Report JRC 79595, Ispra, 2013-02

[2] R. Berndt, P. Mortreau: List mode neutron counting with the MCA-527, test report, to be published

Acknowledgements

The authors would like to thank several colleagues from DG ENER, IAEA and GBS for helpful discussions during the preparation and for direct support with the performance of these tests.

Annexes

A0: Technical specifications MCA-527

MCA527

Digital Miniature Multi Channel Analyzer

The MCA527 is a battery powered high performance 16K Multi-Channel Analyzer/Multi-Channel Scaler module with the performance of a laboratory grade MCA. High voltage supply for detector and preamplifier power supply are integrated as well as an internal coarse amplifier and digital filtering and analysis. Together with a detector it forms a small-size gamma spectroscopy system, which is well suited to the demands of field measurements for international safeguards, environmental monitoring, nuclear waste treatment facilities, radioactive transport control and similar applications.

Furthermore, the MCA527 supports a vast number of different detectors and its 16k resolution is adequate to support high resolution gamma spectrometry with HPGe detectors. As the MCA527 works with digital filtering, it allows to set a broad range of filter time constants and it is also tolerant to largely differing preamplifier signal shapes.
The MiniMCA software allows to operate the device as a general purpose multi channel analyzer (SPEC, WinSPEC) and multi scaler analyzer (MCS, WinMCS). Additional user programs which support safeguards specific applications as U-235 enrichment verification, UF6, LENG, RATE, WINScan are available.

The MCA 527 is the successor of the MCA166 with completely new designed hardware. It has enhanced battery operating time and allows connection and charging by USB port. Besides this, its fully compatible to MCA166 and can be run with all existing MCA166 software.

Hardware Specification MCA527 – DMMCA

Amplifier
Coarse amplifier prefilter with amplifications in steps of 2-5-10-20-50, corresponding to a full scale ADC input range from 12V to 500mV.
Input DC coupled, offset adjustable and depending on polarity of input signal.
linearity better than 0.1%.

ADC
14bit, 10 MSps
Integral Nonlinearity <0.05%
temperature stability TK 50

digital signal processing
double differential trigger filter, or single differential low energy low count rate trigger filter.
Pile-up-suppression, pulse pair resolution ~400ns, depending on trigger filter.
Automated and manual* adjustment of trigger threshold.
Shaping time (Integration time / rise time of filter divided by 2) adjustable in the range 0.1 – 25µs.
Flat top adjustable 0-5µs.
fine adjustment of amplification in steps of <0.05%.
Channel splitting 128, 256, 512, 1k, 2k, 4k, 8k or 16k
Differential nonlinearity <1% for 4k channels and 1µs shaping time.
Base Line restorer with adjustable averaging.
Optimum spectroscopic performance for 50µs preamp decay time constant.
PZC adjustment, detector decay time constants from 40µs (*5µs) to 1ms can be compensated.
Peak stabilization possible.
Oscilloscope mode shows signal as well as trigger filter and main filter signals.

Modes of operation
- PHA (pulse height analysis), result is a histogram of pulse height.
- MCS (multi channel scaling): registers number of counts in subsequent time intervals.
- Gated operation, gated events (e.g. light pulses) are collected in a second spectrum and can be used for stabilization.
- Sample mode: Input signal is recorded without processing, similar to an oscilloscope.
- *autonomous repeat mode: makes series measurements and stores them in up to 2GB internal non volatile memory.
- *Start-Stop-mode: time difference between a start signal at the gate input and an event is recorded as histogram. May be used for time-of-flight spectroscopy and similar applications.
- *List mode: values of occurring pulse height are stored sequentially.
- List mode 2: registers sequentially the time between 2 subsequent events.
- JSR mode: emulates the behavior of the neutron coincidence counters /shift registers JSR14 and JSR12 (based on list mode 2)

Spectrometric performance:
Resolution (FWHM) for typical 500mm² planar HPGe detector for count rates < 10000cps and a Am241 source at 59keV:
<510eV at 1µs shaping time
<460eV at 2µs shaping time
Usable spectral range from 100% down to 0.13% (e.g. 3 keV to 2300 keV) with optimized system.
Throughput in memory:
>75kcps in memory at 140kcps input rate and 0.5µs shaping
>35kcps in memory at 50kcps input rate and 2µs shaping time

Preamplifier power supply, high voltage, extras:
± 12 V, 60mA
± 24V, 60mA
Detector HV up to ±3.6kV, polarity depends on module inserted. Also ±3kV modules from MCA-166 can be used.
D9/pin3: Aux. analog input, 11 bit, 0-10V
D9/pin5: HV inhibit, can also be used as auxillary analog voltage input or as resistance meter.
D9/pin8: 1-wire interface to connect temp sensors.
Internal temperature measurement, MCA temperature is saved with spectrum.
GPS receiver (adapter to extension port)

power supply:
Li-Ion batteries, operation time 10-25h, depending on detector connected.

Computer Interface
USB, RS-232 (38.4, 115.2, 307.2 kBd and 3MBd), Ethernet.
*Bluetooth (adapter to extension port)

Firmware, Software
All firmware command analog to MCA166 with some extensions. Runs with all previous MCA-166 software.

Mechanical
Housing 164 mm x 111 mm x 45 mm without connectors; weight 820g.
SHV plug for HV, BNC for Signal, Lemo00/Camac for gate input, D9 for preamp supply and aux. inputs, plugs for power supply, interface, LED for status and miniature switch for ON/OFF.

Environmental
operational: at least 0 - 50 °C, eventual larger range.
humidity up to 90%, non condensing, IP42.
EMC compliant

**optional, further development, still to be implemented*
tbd: exact values still to be determined

22.8.2013 Jörg Brutscher

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GBS ELEKTRONIK GmbH

A1. Collection of setup files of MCA-527

A1. Setup file for 1.1. NaI detector no.7

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1136
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
S1+S2
-------------------------------------------------------------------------------
0
0
C:\DATA\14DTS1S2.spe
...
...
...
38
32
27
$ROI:
1
3136  3456
$ENER_FIT:
0.000000 0.000000
$ENER_DATA:
2
0.000000 0.000000
0.000000 0.000000
$ENER_DATA_X:
2
0.000000 0.000000
0.000000 0.000000
$ADC:
16384
0
16383
$PRESETS:
Live Time (sec)
700
0
$PZC_VALUE:
1828
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
1.4712
$MCA_527_OFFSET_DAC:
13075
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
```

$INPUT:
Amplifier
neg
$PUR:
on
$STAB:
off
4
120
0
accepted
$STAB_PARAM:
10
25000
$POWER:
#NAME?
#NAME?
#NAME?
#NAME?
$HV:
-3600V
Canberra HPGe
$MODE:
MCA
$MCA_REPEAT:
0
0
$TDF:
0
$POWER_STATE:
I+12= 29mA
I-12= 21mA
I+24= 62mA
I-24= 28mA
IBAT= 245mA
IHV = 19mA
ICHR= 234mA
UBAT=8240mV
UHVs=3581mV
U+12=11.938V
U-12=11.500V
U+24=24.500V
U-24=23.750V
$COUNTS:
21116732
$PD_COUNTS:
0

$RT:
812.139
$DT:
112139
$FAST_DT:
15982
$BT:
0
$STAB_OFFSET:
0
$STAB_OFFSET_MIN:
0
$STAB_OFFSET_MAX:
0
$STAB_COUNTER:
0
$REC_COUNTER:
55492
$REC_ERROR_COUNTER:
47
$PUR_COUNTER:
1597912
$SPEC_INTEGRAL:
17741221
$ROI_INFO:
1 3136 3456 3323.41 33.66 2090386 1650496 4443
$TEMPERATURE:
not measured
32.75

A1. Part of the setup file for 1.2. Coaxial Ge detector C4

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1136
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
S2
--------------------------------------------------------------------------------
0
0
C:\DATA\5DTS2.spe
...
...
...
$DATE_MEA:
06/26/2013 13:42:01
$MEAS_TIM:
700 735
$DATA:
0 16383
0
0
...
...
...
$ADC:
16384
0
16383
$PRESETS:
Live Time (sec)
700
0
...
...
...
```

```
...
...
...
$PZC_VALUE:
1828
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
1.4712
$MCA_527_OFFSET_DAC:
13011
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 2.1. NaI detector with internal Am source

```
$APPLICATION_ID:
WSPC (WinSPEC for Automation) Version 2.03.0000
$DEVICE_ID:
MCA-527
SN# 1243
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Automation) Version 2.03.0000
$SPEC_REM:
0
------------------------------------------------------------------------
0
0
C:\DATA\5273030.spe
...
...
...
$DATE_MEA:
06/27/2013 13:22:00
$MEAS_TIM:
1000 1128
$DATA:
0 2047
0
0
...
...
...
$ADC:
2048
0
2047
$PRESETS:
Live Time (sec)
1000
0
...
...
...
...
...
...
$PZC_VALUE:
1560
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
1.8487
$MCA_527_OFFSET_DAC:
1881
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
1.6
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
0.2
...
...
...
```

A1. Part of the setup file for 2.2. Planar Ge detector P5

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1128
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\5272030.spe
...
...
...
$DATE_MEA:
06/26/2013 14:20:41
$MEAS_TIM:
400 476
$DATA:
0 16383
0
0
...
...
...
$ADC:
16384
0
16383
$PRESETS:
Live Time (sec)
400
0
...
...
...
...
...
...
$PZC_VALUE:
1681
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
0.5682
$MCA_527_OFFSET_DAC:
13074
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 3.1. NaI detector no.6

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1131
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
CBNM295/058
--------------------------------------------------------------------------------
0
0
C:\DATA\527e295.spe
...
...
...
$DATE_MEA:
06-27-2013 15:16:30
$MEAS_TIM:
2000 2015
$DATA:
0 2047
0
0
...
...
...
$ADC:
2048
0
2047
$PRESETS:
Live Time (sec)
2000
0
...
...
...
...
...
...
$PZC_VALUE:
1134
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
2.8256
$MCA_527_OFFSET_DAC:
684
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
1.6
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
0.2
...
```

A1. Part of the setup file for 3.2. Coaxial Ge detector C4

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1136
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
C4 2.94% 2*2
------------------------------------------------------------------------------
0
0
C:\DATA\5270295.spe
...
...
...
$DATE_MEA:
07/04/2013 12:01:50
$MEAS_TIM:
2000 2022
$DATA:
0 16383
0
0
...
...
...
$ADC:
16384
0
16383
$PRESETS:
Live Time (sec)
2000
0
...
...
...
...
...
...
$PZC_VALUE:
1828
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
1.4712
$MCA_527_OFFSET_DAC:
13499
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 3.3. $LaBr_3$ detector

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1134
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\527L295.spe
...
...
...
$DATE_MEA:
12-31-2001 23:57:08
$MEAS_TIM:
2000 2011
$DATA:
0 2047
0
0
...
...
...
$ADC:
2048
0
2047
$PRESETS:
Live Time (sec)
2000
0
...
...
...
...
...
...
$PZC_VALUE:
986
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
2.7789
$MCA_527_OFFSET_DAC:
14665
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
0.2
...
```

A1. Part of the setup file for 3.4. NaI with internal Am source

```
$APPLICATION_ID:
WSPC (WinSPEC for Automation) Version 2.03.0000
$DEVICE_ID:
MCA-527
SN# 1243
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Automation) Version 2.03.0000
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\5273194.spe
...
...
...
$DATE_MEA:
06/28/2013 11:10:23
$MEAS_TIM:
8000 8075
$DATA:
0 2047
0
0
...
...
...
$ADC:
2048
0
2047
$PRESETS:
Live Time (sec)
8000
0
...
...
...
...
...
...
$PZC_VALUE:
1560
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
1.8836
$MCA_527_OFFSET_DAC:
1916
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
1.6
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
0.2
...
...
...
```

A1. Part of the setup file for 4.1. Planar Ge detector P20

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1057
HW# 1001
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\a18.spe
...
...
...
$DATE_MEA:
06/26/2013 10:03:29
$MEAS_TIM:
500 602
$DATA:
0 4095
0
0
...
...
...
$ADC:
4096
0
4095
$PRESETS:
Live Time (sec)
500
0
...
...
...
...
...
...
$PZC_VALUE:
1775
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
2.2967
$MCA_527_OFFSET_DAC:
16227
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 4.2. Planar Ge detector P1

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1057
HW# 1001
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
P1  up200s
--------------------------------------------------------------------------------
0
0
C:\DATA\a36.spe
...
...
...
$DATE_MEA:
06/27/2013 11:47:09
$MEAS_TIM:
500 523
$DATA:
0 4095
0
0
...
...
...
2772.890000 208.000000
$ADC:
4096
0
4095
$PRESETS:
Live Time (sec)
500
...
...
...
...
...
...
$PZC_VALUE:
1415
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
1.8927
$MCA_527_OFFSET_DAC:
15828
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 4.3. Planar Ge detector P5

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1057
HW# 1001
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\b2.spe
...
...
...
$DATE_MEA:
06/25/2013 15:54:33
$MEAS_TIM:
300 314
$DATA:
0 4095
0
0
...
...
...
$ADC:
4096
0
4095
$PRESETS:
Live Time (sec)
300
0
...
...
...
...
...
...
$PZC_VALUE:
1775
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
2.2967
$MCA_527_OFFSET_DAC:
15209
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 5.1. Planar Ge detector P20

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1057
HW# 1001
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\a7.spe
...
...
...
$DATE_MEA:
06/25/2013 12:33:21
$MEAS_TIM:
1600 1742
$DATA:
0 4095
0
0
...
...
...
2773.090000 208.000000
$ADC:
4096
0
4095
$PRESETS:
Live Time (sec)
1600
...
...
...
```

```
...
...
...
$PZC_VALUE:
1775
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
2.2967
$MCA_527_OFFSET_DAC:
15341
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 5.2. Planar Ge detector P1

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1057
HW# 1001
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\a29b.spe
...
...
...
$DATE_MEA:
06/26/2013 16:36:38
$MEAS_TIM:
800 928
$DATA:
0 4095
0
0
...
...
...
2772.890000 208.000000
$ADC:
4096
0
4095
$PRESETS:
Live Time (sec)
800
...
...
...
```

```
...
...
...
$PZC_VALUE:
1415
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
1.8927
$MCA_527_OFFSET_DAC:
16383
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 5.3. Planar Ge detector P5

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1128
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\ispra0613\5279010.spe
...
...
...
$DATE_MEA:
06/28/2013 09:56:44
$MEAS_TIM:
300 325
$DATA:
0 16383
0
0
...
...
...
$ADC:
16384
0
16383
$PRESETS:
Live Time (sec)
300
0
...
...
...
```

```
...
...
...
$PZC_VALUE:
1681
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
10
0.5683
$MCA_527_OFFSET_DAC:
11900
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.8
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
1
...
```

A1. Part of the setup file for 6.1. SDP-310

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1131
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\ispra0613\5276005.spe
...
...
...
$DATE_MEA:
06/25/2013 13:12:49
$MEAS_TIM:
48 57
$DATA:
0 2047
0
0
...
...
...
$ADC:
2048
0
2047
$PRESETS:
        Area
100000
1
...
...
...
...
...
...
$PZC_VALUE:
2324
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
1.192
$MCA_527_OFFSET_DAC:
14720
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.7
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
0.5
...
```

A1. Part of the setup file for 6.2. CZT/500

```
$APPLICATION_ID:
WSPC (WinSPEC for Inspectors) Version 2.03.0003
$DEVICE_ID:
MCA-527
SN# 1131
HW# 1100
FW# 1304
$MCA_166_ID:
The used device has not been a MCA-166! This block is only
written to keep compatibility with older applications.
AP# WSPC (WinSPEC for Inspectors) Version 2.03.0003
$SPEC_REM:
0
--------------------------------------------------------------------------------
0
0
C:\DATA\ispra0613\5276106.spe
...
...
...
$DATE_MEA:
06/26/2013 09:59:01
$MEAS_TIM:
30 37
$DATA:
0 2047
0
0
...
...
...
$ADC:
2048
0
2047
$PRESETS:
        Area
100000
1
...
...
...
```

```
...
...
...
$PZC_VALUE:
133
15
15
$FAST_DISCR:
400
$SLOW_DISCR:
400
$THR:
0.5
$GAIN_VALUE:
20
2.5657
$MCA_527_OFFSET_DAC:
1526
$MCA_527_TRIGGER_FILTER:
3 (+1,0,-2,0,+1)
$FLAT_TOP:
0.7
$MCA_527_TRIGGER_PARAM:
7
20
0
$MCA_527_BASELINE_RESTORING:
41290
$MCA_527_JITTER_CORRECTION:
off
$MCA_527_LF_REJECTION:
off
$MCA_527_GATING:
off
low
20
off
$MCA_527_CORE_CLOCK:
4
$MCA_527_EXT_PORT:
0
0
0
0
0
0
$DTC:
1
0.5
...
```

A2. List of instruments

Detector	Size	Serial number	Model
NaI	diameter 76 mm, thickness 19 mm	F2184	Teledyne S-1203-I/W1
NaI	diameter 76 mm, thickness 19 mm	F2185	
NaI- IAEA nb 8029/194	diameter 51 mm, thickness 12.5 mm	sbe 634	Scionix 51BS12.7-E3-T-AM-X
LaBr3	diameter 76 mm, thickness 19 mm	P906CS_B	76S20_B380
CZT	10*10*0.5		CZT 500 RITEC
CZT	5*5*2.5		SDP 310 RITEC
Ge coaxial C4 CANBERRA	diameter 53 mm, lengh 54 mm	b95662	GR2520
Ge coaxial C5 CANBERRA	diameter 52.50 mm, lengh 54 mm	b99544	GR2520
Ge planar P5 CANBERRA	1000 mm^2, 20 mm thickness	b 92586	GL-1020R-7905SL-15
Ge planar P20 CANBERRA	500 mm^2, 15 mm thickness	b14511A	GL0515
Ge planar P1 ORTEC	200 mm^2, 10 mm thickness	26-C567	GLP 16250/10-S

A3. List of nuclear material samples

Item name	^{235}U enrichment (wt%)			laterial typ	$_3O_8$ mass (	Geometry
UP899S	87.61	±	1.75	U_3O_8	56	shape, smaller diameter
UP362S	33.89	±	0.68	U_3O_8	199.9	CBNM shape
UP200S	18.67	±	0.37	U_3O_8	199.9	CBNM shape
UP100S	9.80	±	0.20	U_3O_8	199.9	CBNM shape
CBNM446	4.4623	±	0.0032	U_3O_8	200	CBNM shape
CBNM295	2.9492	±	0.0021	U_3O_8	200	CBNM shape
CBNM195	1.9420	±	0.0014	U_3O_8	200	CBNM shape
CBNM071	0.7119	±	0.0005	U_3O_8	200	CBNM shape
CBNM031	0.3166	±	0.0002	U_3O_8	200	CBNM shape
UM020S	2.00	±	0.02	U metal	206.2 *)	CBNM shape
UM007S	0.71	±	0.01	U metal	219.2 *)	CBNM shape
P84	93.10	±	0.93	UAl_3	8.4 **)	ɔt infinitively thick

*) U mass, **) U mass

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Abstract

The multi channel analyzer MCA-166 of GBS Rossendorf GmbH, Germany, has been a base instrument for gamma spectrometry both of IAEA and EURATOM for nuclear safeguards applications. Since essential internal electronic chips of the MCA-166 are not provided any more IAEA and the German support program to the IAEA decided to endorse the development of a follower instrument, the MCA-527, with the same company. The performance of this new instrument was tested with respect to parameters, which are essential for safeguards applications: Dead time correction for U enrichment measurements, peak shape for high resolution applications MGA and MGAU, high count rate performance with CdZnTe detectors for spent nuclear fuel, temperature stability of the MCA itself. The tests cover all important detector types applied by IAEA and EURATOM: NaI, NaI with internal Am source, planar Ge, coaxial Ge, LaBr3, and CdZnTe detectors. The tests were made with nuclear materials U and Pu, and with 137Cs and 60Co to simulate spent nuclear fuel. They cover count rate ranges up to about 70 000 … 100 000 cps for U and Pu and with CdZnTe detectors up to 300 000 cps. The report provides a series of setup files for different detector types.

The result of the test is: The performance of the MCA-527 meets the functional requirements for gamma spectrometric measurements for nuclear safeguards applications. Its parameters are as good as or the ones of the MCA-166 or superior to them.

The MCA-527 can also be used for neutron measurements in List mode. Its performance for neutron counting will be described in separate report.

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