



SPECTRA 5011, SPECTRA 5041

PORTABLE ALPHA-BETA-GAMMA  
SPECTROMETER

“SURFACE INVESTIGATOR”  
“SURFACE INVESTIGATOR *PRO*”

*User's Manual*  
(Short description 08/2002)



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# 1 Unpacking

First make sure that every item of the below described packing list is part of the delivery. Take all the materials out of the packing boxes and place them on a clean table for best view.

If anything is missing, please call SARAD GmbH immediately at ++49-351-6580721 or via e-mail [support@sarad.de](mailto:support@sarad.de)

## 1.1 Packing list:

SPECTRA 5011 portable spectrometer  
NaJ Scintillation probe FHZ 502 E 2"x2" (optional)  
SI-alpha detector MOD 01-03 / 400 or AMP 01-03 with AS 400 (for Vacu Tube)  
**(do not touch the surface mirror!)**  
CAN Dongle for USB port  
Two wire cable connection from CAN dongle (subD) to SPECTRA 50xx (two wire)  
Cable connection SPECTRA 5011 (5-pole) to FHZ 502 E (one BNC, one LEMO) (optional)  
Software  
    SPECTRA CONTROL user interface (on CD)  
    IAEA ANGES gamma spectroscopy software  
    SARAD Peak Explorer (on CD)  
    CAN dongle driver (on CD)  
User manuals  
Calibration and guarantee certificates

## 1.2 General safety instructions

The SPECTRA 5011 is a state-of-the-art measurement system, versatile to use for all your needs. Although its use is easy, for your own safety and for a proper operation of the device, please read carefully the following instructions:

- Do not expose the device to rain or any other excess moisture.
- Avoid excess dust content as well as hard mechanic shocks.
- Read the manuals very carefully.
- The SPECTRA 50xx is operated with 220 V (wall plug battery charger for AC main power)(110 V on request) power supply. Take care for the risk!

Do not open or try to repair any item of the device in case of a failure!

## 1.3 Maintenance

Clean the surfaces of the SPECTRA and the NaJ scintillation crystal from time to time with a dry towel. Do not clean the Si-detector neither touch it!

## 2 Preliminary

### 2.1 About alpha spectroscopy

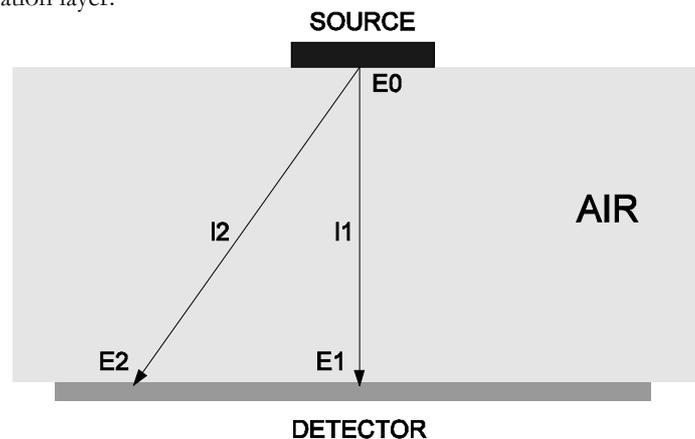
Radionuclides performing an alpha decay are emitting alpha particles with a nuclide-specific kinetic energy. Therefore, this energy may be used to identify each alpha-emitting isotope. The energy must be only transformed into an electrical voltage pulse by using a semiconductor detector and amplifier stages. Then, the pulse height increases strongly proportional to the particles energy.

To analyse a probe, the incoming pulses have to be sorted with respect to their equivalent energy. For this reason, the whole energy range will be divided into a number of sequential energy windows. All pulses matching with such a window will be counted in an assigned counter channel. The sequence of all counter contents along the energy axis gives the alpha spectrum of the probe.

The number of detected pulses, which are matching with a nuclide's energy during a defined time slot is a value for its activity.

### 2.2 Geometrical effects

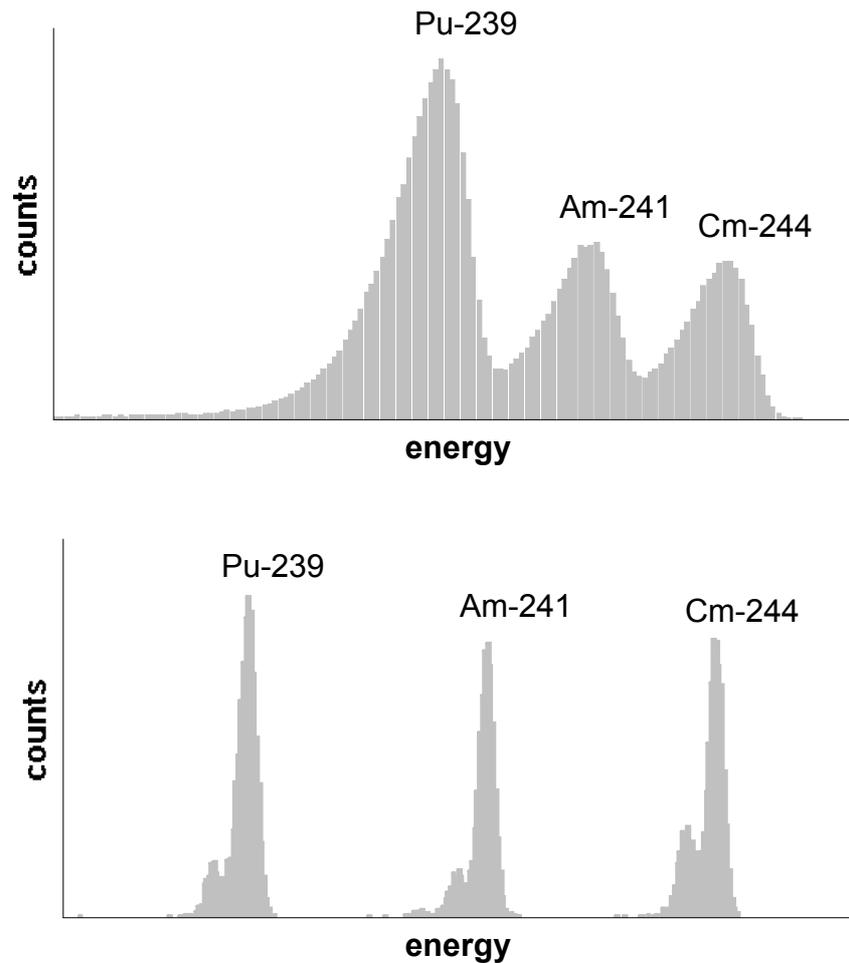
Each alpha particle loses some energy during the movement inside a media. The amount of energy loss depends from the material's density and the length of flight through this material (about 1MeV/cm in air). Beside the losses in air also retardation effects in the detector's dead layer must be considered. This influence increases for detectors with a thick light tight passivation layer.



The particle's different emission angle leads to different distances ( $l_1$ ,  $l_2$ ; fig.) from radiation source to detector surface. Therefore, particles emitted with the same energy will have different energy levels in case of an impact at the detector. The energy spectra will be 'over shaped' by this effect. Large tailings, maxima- and peakshifts result.

In general, high resolved analysis is performed inside a vacuum chamber. Detectors with very thin protective layers are used. So it is possible to minimize the energy losses and to get a perfect peak separation. For several applications it is sufficient to acquire the spectra under ambient air conditions. A mathematical post processing should be added to refine the results.

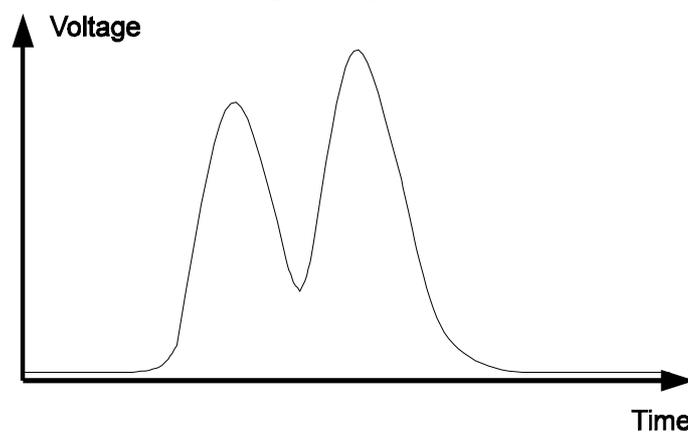
The following figure compares both spectra of the same probe in air and vacuum (lower spectra).



The user should optimise the efficiency in accordance to the required spectrometric resolution. This is done by a good choice of distance between probe and detector (the wider the distance, the lower the efficiency, and the better the resolution).

### 2.3 Electronically effects

To get a good spectroscopy performance, the detector's signal must be processed by several pulse shaping stages. The result is a characteristic pulse shape and pulse width. In case of two simultaneous incoming pulses a electronic overlay ('pile up') occurs (fig.). The height of the second pulse will be added to the falling slope of the first pulse and is therefore not suitable to indicate the particle's alpha energy.



To avoid a large number of pile ups, the statistical time interval between two alpha events at the detector should be about 10 times higher than the pulse width. This can be easily obtained by increasing the probe/detector distance.

## 2.4 Dead time effects

During the time required to convert the peak voltage into a digital word, to calculate the assigned channel number, and to increment the counter value, the system is unable to process further pulses. Therefore this time is called 'dead time'. A dead time correction is recommended for quantitative measurements, because the lost pulses are not visible in the spectra. This may be done by the following formula:

$$N' = N * \text{real time} / (\text{real time} - N * \text{dead time})$$

where:

N	total number of pulses in the spectrum
real time	time from start to stop the analysis
dead time	system's dead time, described before
N'	real number of incoming pulses during real time.

## 3 About gamma spectroscopy

Portable gamma spectroscopy is enabled by the use of large volume NaJ-scintillation probes as well as thump-sized Cd: Tl-photodiodes (only 5041). Refer to the short compendium list at the end of this manual for energy emission of certain nuclides.

Just like the alpha analysis, a gamma measurement is in the need of a calibration spectrum with known energy emission to translate the content of certain channels to the energy of the emitted gamma quants. For this purpose, a radium dial is delivered together with the device to you. Do not open the case of the compass! Radium is toxic, the numbers are painted with a mixture of Radium and Zinc sulphide.

This "standard" will emit gamma rays with known energy: Ra-226 (186 keV), Pb-214 (295, 241, 351 keV) and Bi-214 (609, 1120 keV). See the information list upon the decay chains in the end of the manual for more energy lines.

Because of the use of NaJ for detector material, the energy range for counting a signal is fixed to an energy >30 keV up to about some MeV. Real gamma spectroscopy that differs from the total count analysis is limited to a smaller range, but enable the determination of the nuclides.

### 3.1 Connection of the NaJ-crystal to the SPECTRA 5011

The SPECTRA 5011 will provide the needed power supply for the scintillation probe (5V), the probe itself will generate the high voltage supply. Two sockets are mounted at the rear panel of the probe : The BNC to transfer the energy signal and the LEMO socket to provide the power supply. Both are fixed together in the typical SPECTRA plug with 5 poles. Connect the both device via cable.

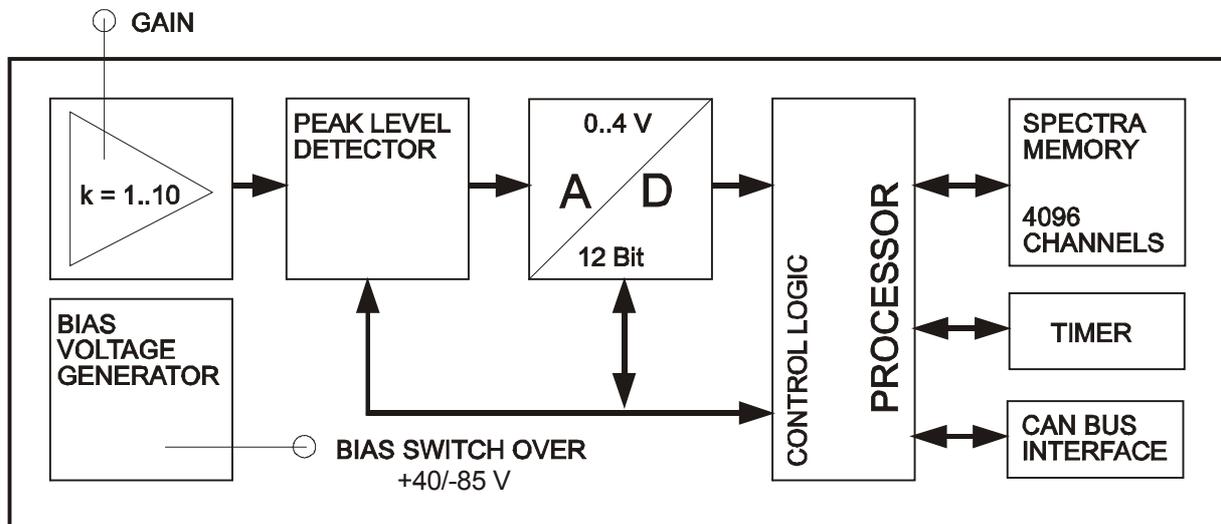
Place the radiation source in front of the detector and record a first spectrum.

Hint: You are allowed to use both, alpha as well as gamma probes with the SPECTRA 5011. This world-unique portable spectrometer give you the reliable answer upon the quality of an radioactive contamination by determining both, alpha but gamma, even beta emitting nuclides. Just connect the suitable probe to the detector input, adjust the gain as you like (the energy resolution) and run the spectrometer.

A detailed handbook concerning the application of SPECTRA 5011 for alpha / gamma analysis is in preparation. Do not hesitate to contact our customer support if you need assistance or technical description.

## 4 Theory of operation

The following figure shows the signal flow chart of the SPECTRA 5011:



The energy output of the pulse processing unit (preamp/shaping) will be connected to a calibration amplifier with an adjustable gain via the input socket. Its output drives the positive peak level detector, to hold the peak value during conversion performed by the following ADC. The resulting digital word indicates an assigned counter channel in the spectrum memory.

A low power microprocessor controls the pulse height analysis. The data transfer via the serial CAN network is realized by a special communication controller. The CAN bus enables high transfer rates at large distances (up to 1000 meter, depending from transmission rate).

### 4.1 Configuration

The following parameters are configurable by software:

#### 4.1.1 ADC resolution

The resolution of the ADC may be selected from 8 to 12 bit. This refers to a number of 256 to 4096 channels. Each channel represents a 32 bit counter.

#### 4.1.2 Peak detector delay time

This feature is used to match the ADC sample point to the amplifier's pulse shaping. Four different delay times are selectable:

$$T1 = 7.5\mu\text{s}$$

$$T2 = 15\mu\text{s}$$

$$T3 = 30\mu\text{s}$$

$$T4 = 60\mu\text{s}$$

The delay time must be chosen greater than the amplifier's time to peak in any case, but should be as close as possible to this point. For example, the right choice for an 11 $\mu\text{s}$  time to peak amplifier is  $T2 = 15\mu\text{s}$ .

Note: The rise time of a Gaussian shaped pulse is approximately 2,2 times greater than the time constant given by the amplifier's data sheet.

### 4.1.3 Sample timer

The SPECTRA device contains a precision timer to control the running analysis. Two different operation modes are selectable by software.

#### 1. Normal mode:

The timer only observes the actual sample time of the current analysis. A sample time greater than 768 000 seconds causes a timer overflow and the timer starts again with zero. The current analysis will be not effected.

#### 2. Automatic analysis stop mode:

The user may select a sample time between one and 768 000 seconds in one second time steps. If the actual sample time matches to the selected value, the analysis will be stopped automatically.

In this mode, no sample time overrun occurs in case of a disconnection from the CAN bus.

### 4.1.4 Controlling the device

All SPECTRA functions are controlled via CAN bus. Following operations are supported:

- start and stop a sample
- clear spectra memory
- MCA configuration
- preset the sample time
- read out the spectra
- read out the status and sample start time
- read out the current and preset sample time

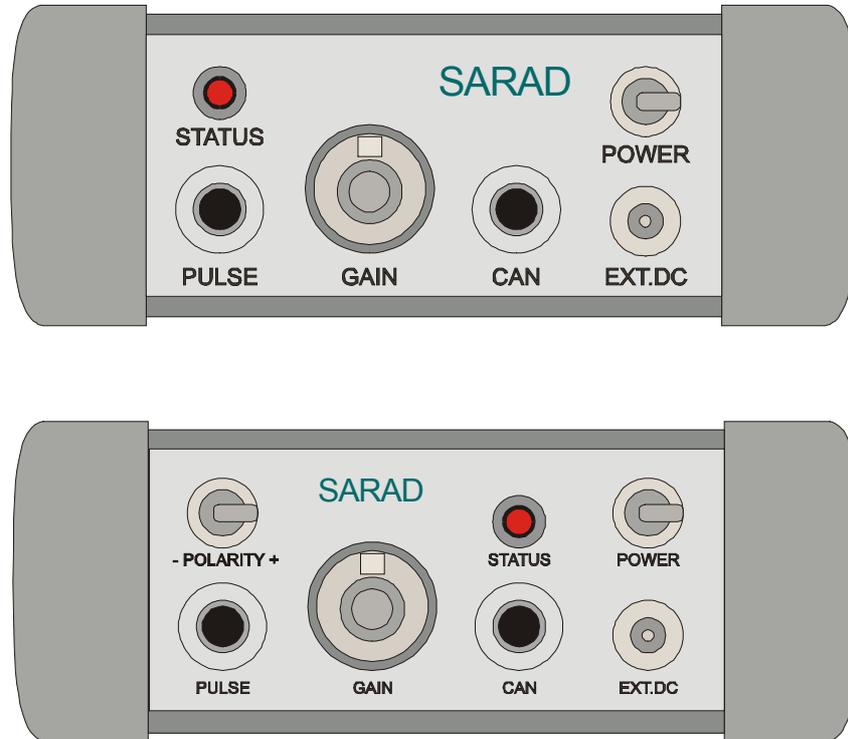
The kind of implementation of these functions depends from the used software and is described there. A running sample is indicated by the green status LED at the device's front panel.

**Once a SPECTRA is started, you may disconnect it from the CAN cable to let it operate autonomously. If you like to control the device later or transfer the data, connect the CAN cable, scan the CAN bus for connected devices (certain CAN address) and set the appropriate commands.**

## 5 Instructions for use

### 5.1 Connectors and controls

(5011 top; 5011 PRO bottom)



- EXT. DC input for battery charger  
 STATUS status LED indicates „Running Sample (green)“, „Stand by (fast flash)“ and „Battery discharged (slow flash)“  
 PULSE input connector to Detector/Amplifier module  
 GAIN gain adjustment to fit the input signal to ADC  
 CAN CAN bus socket for network/PC connection  
 POWER power ON/OFF switch  
 POLARITY bias voltage switch over (+35 V/-85V), at 5011 bias voltage on / off (+ / -)

### 5.2 Starting Operation

The device is powered by a 9VDC wall adapter either or by the internal lead acid battery. For battery operation turn the power control switch into the 'ON' position. The switch is mechanical locked against unintentional switching. Please pull the lever during switchover. A fast blinking status LED indicates the devices 'stand by' modus. In case of a discharged battery, the LED will be blinking much slower. If the battery voltage drops below the 'discharged' detection limit, a running sample will be stopped and the device enters into a power save modus. The acquired spectra remains in the internal memory for some hours and may be transferred to a PC or notebook. It is impossible to start a new sample, while the power save modus is detected. To cancel this state, charge the battery via the wall adapter and turn off/on the device.

In the power switch's 'OFF' position, the device operates directly from the external power supply and the battery will be charged independently. So it is possible to use the device with a discharged battery.

**Attention:** The disconnection from the wall adapter during 'OFF' position leads to the sample breakdown. No data will be available in this case. In 'ON' position the device operates from battery, but the battery will be charged simultaneous.

A battery protection circuit avoids the total discharging (below 5,5V) of the battery. All components will be disconnected from the battery until the voltage increases above this level. All stored data will be lost.

The screwable CAN bus connector has to be placed carefully into its socket .

### 5.3 Detector bias voltage

Each semiconductor detector needs a bias voltage to reach its spectrometric performance.

This voltage is generated by the SPECTRA 5011 and was factory adjusted to +35 V.

The 5041-device supports an additionally negative bias voltage of -85V.

To switch over the bias use the POLARITY-switch at the front panel. Both voltages are short circuit protected.

**Attention:** There is no additional switch to turn on/off the bias voltage. That means, the voltage is applied to the PULSE-socket if the SPECTRA device is turned on.

### 5.4 Connecting Detector/Amplifier modules

The SPECTRA enables the connection of detector and amplifier modules using a single cable for power supply, bias voltage and energy output. Following modules can be connected directly via the PULSE-socket:

*SPECTRA 5011 and 5041 (pos. bias voltage required)*

MOD 01-03 (Alpha/Beta Detector/Amplifier module)

AMP 01-03 (Amplifier module with Microdot connector for standard detectors)

AMP 02-02 (Amplifier module with Microdot connector for standard detectors)

Thermo Eberlein ESM (NaJ-scintillation crystal FHZ) 1"x1" up to 3"x3"

*SPECTRA 5041 only (neg. bias voltage required)*

CXS-Sz (Gamma Detector/Amplifier module 40keV..3MeV)

CXS-S (Gamma Detector/Amplifier module 2keV..60keV)

Take care for choosing the right polarity assigned to the different modules. Normally, all detector modules are protected against worse polarity over a short time, but longer operation may cause damages.

### 5.5 Setting energy range, calibration

#### 5.5.1 Coarse gain adjustment

The adjusted **gain** of the calibration amplifier **defines the sampled energy range**. This feature also enables the compensation of energy losses in air over a wide range. To set the gain use the following two procedure:

For energy calibration a commercial source or a natural probe may be used. The probe should be located in the same geometry used for later nuclide analysis. After acquisition of a test spectra the gain will be adjusted using the energy information of a known nuclide peak.

For gamma measurements using NaJ scintillation crystals together with SPECTRA 5011, adjust coarse gain to zero. Other gains are as well allowed but led to a sampling of impulse in the first and last channels and the build up of "strange peaks". Keep in mind the detector noise is amplified as well (left side of a "strong gained" spectrum will show a high peak!) whereby the high energy gamma quants cannot be counted using the NaJ but will contribute to the spectrum at the right, high energy side.

See some examples in the appendix.

#### 5.5.2 Energy calibration, FWHM calculation

The fine calibration of the spectroscopy system is usually done by PC software SPECTRA Control. The channels which contain the maxima of two peaks (two point calibration) with a well known energy are used to determine the parameters m and n in the calibration formula:

$$E(k) = mk + n$$

where:

k            number of the channel

E(k)	energy equivalent of channel k
m	ascent coefficient; energy window per channel
n	energy offset

The wider the distance of the used peaks, the better the result. After the calibration process the PC-code is able to calculate the FWHM value of each peak. The FWHM is defined as energy interval from the left to right edge of a peak in half of its height.

The product of the factor 'm' and the peak width as number of channels in half maxima is sufficient for a fast, but rough overview. Interpolation techniques are used to get a higher accuracy.

## 5.6 Dead time correction

During the time required to convert the peak voltage into a digital word, to calculate the assigned channel number, and to increment the counter value, the system is unable to process further pulses. Therefore this time is called 'dead time'. A dead time correction is recommended for quantitative measurements, because the lost pulses are not visible in the spectra. This may be done by the following formula:

$$N' = N * \text{real time} / (\text{real time} - N * \text{dead time})$$

where:

N	total number of pulses in the spectrum
real time	time from start to stop the analysis
N'	real number of incoming pulses during real time.
dead time	system's dead time

The SPECTRA operates with a fixed dead time of 72.5  $\mu\text{s}$  + delay time (refer 2.2.2)

Example: If delay time is set T2 (15  $\mu\text{s}$ ) than the dead time of 72,5 + 15 = 87,5 $\mu\text{s}$  results.

## 5.7 Network operation

The SPECTRA's standard CAN interface enables the communication of up to 15 devices with a PC or SARAD's Terminal via a simple twisted pair line. For easy computer connection a converter using the parallel printer port (CENTRONICS) is available. The screwed 2-pin CAN socket is located at the SPECTRA's front panel.

### 5.7.1 CAN bus conditions

For trouble less working it is necessary to meet the following conventions:

- a maximum of 15 devices may be connected to the CAN line
- assign a address between 1 and 15 to each device (usually done by SARAD factory)
- any address can exist only for one device
- the address zero is reserved for PC or other master devices
- use only twisted pair cable with an impedance of 120 Ohm
- the maximum length of bus line should not exceed 100 meters (depends on Baud rate)

### 5.7.2 Address selection

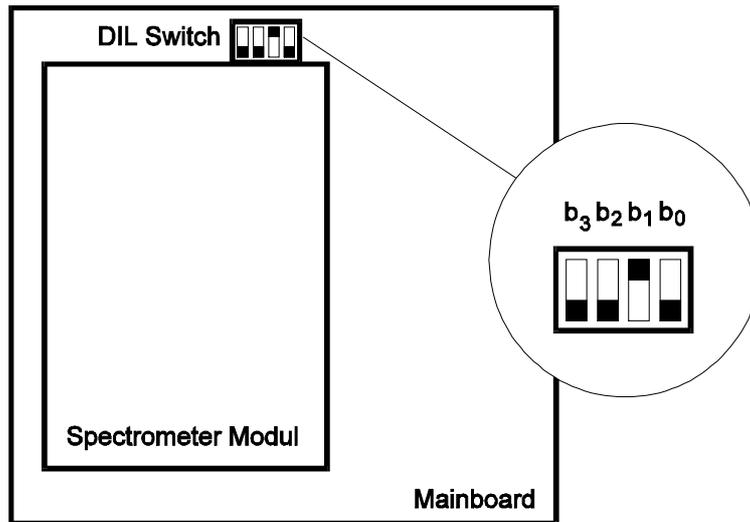
The address of each device will be defined via a quad DIL switch at the device's main board. The switch positions refer to the hexadecimal value of the address and may be calculated by the formula:

$$\text{Adr.} = b_0 + 2b_1 + 4b_2 + 8b_3$$

where

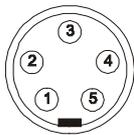
$b_n$  = switch position of switch n; b(ON = 0), b(OFF) = 1

For changing an address open the device and manipulate the switches according to your selection. The new settings are active after turning OFF/ON the SPECTRA.

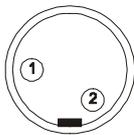


## 6 Appendix

### 6.1 Sockets



**PULSE**



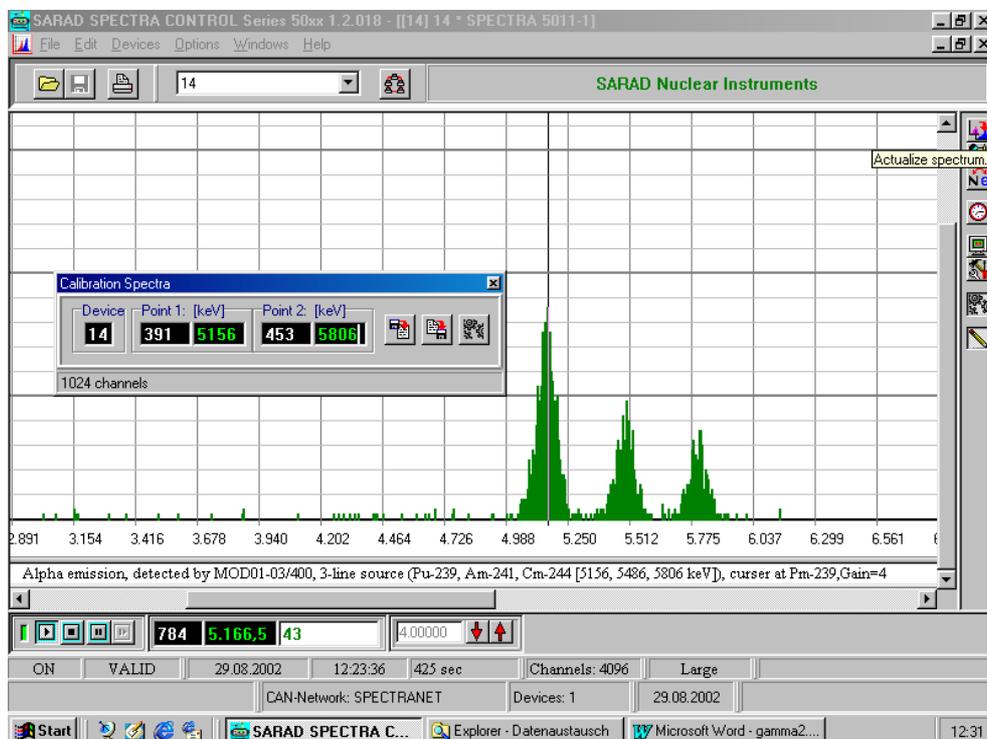
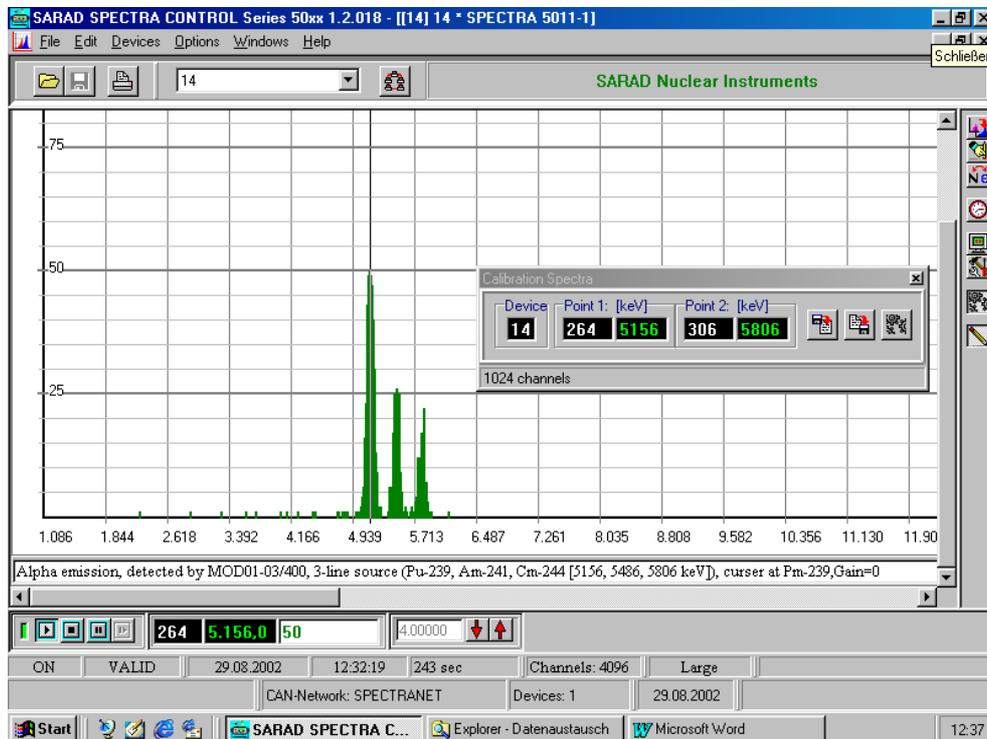
**CAN**

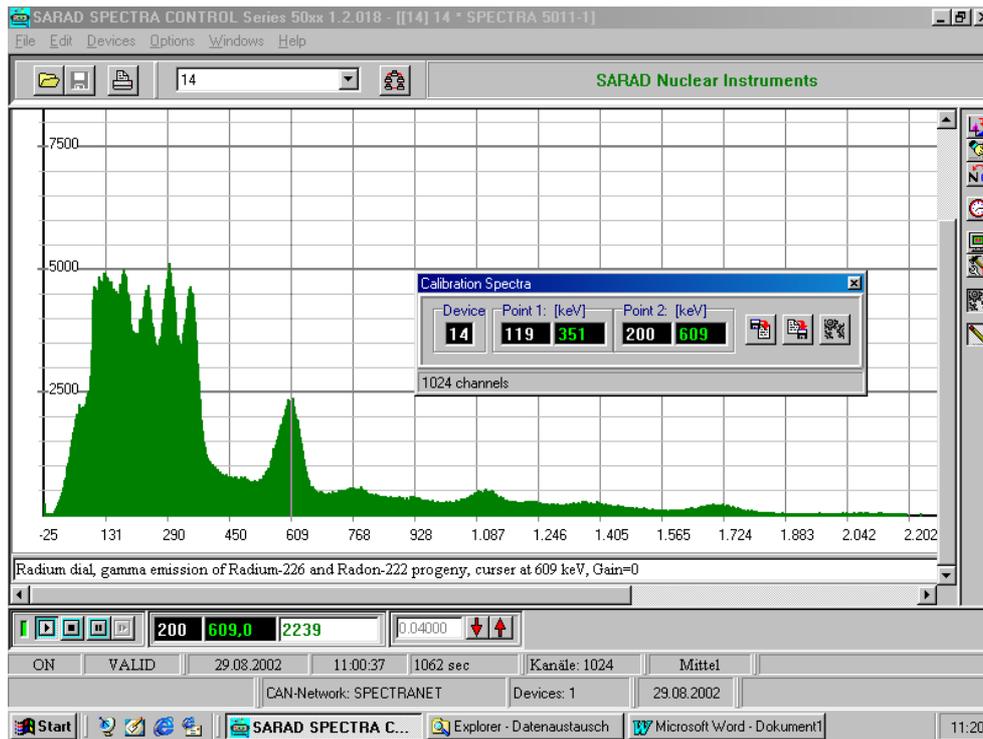


**EXT.DC**

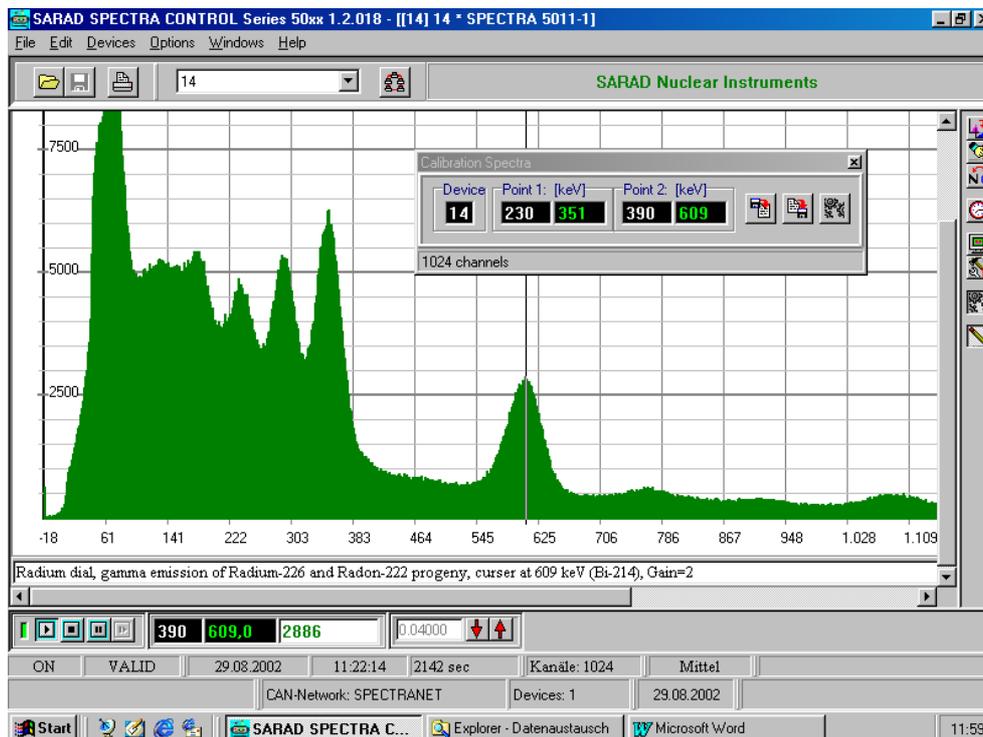
PREAMP:	1	Input signal from amplifier
	2	+5VDC (max. 30mA) power output
	3	-5VDC (max. 30mA) power output
	4	+40/-85 VDC bias voltage output
	5	GND
CAN:	1	CAN_L
	2	CAN_H
EXT. DC	inner	9VDC external supply
	outer	GND

## 6.2 Examples

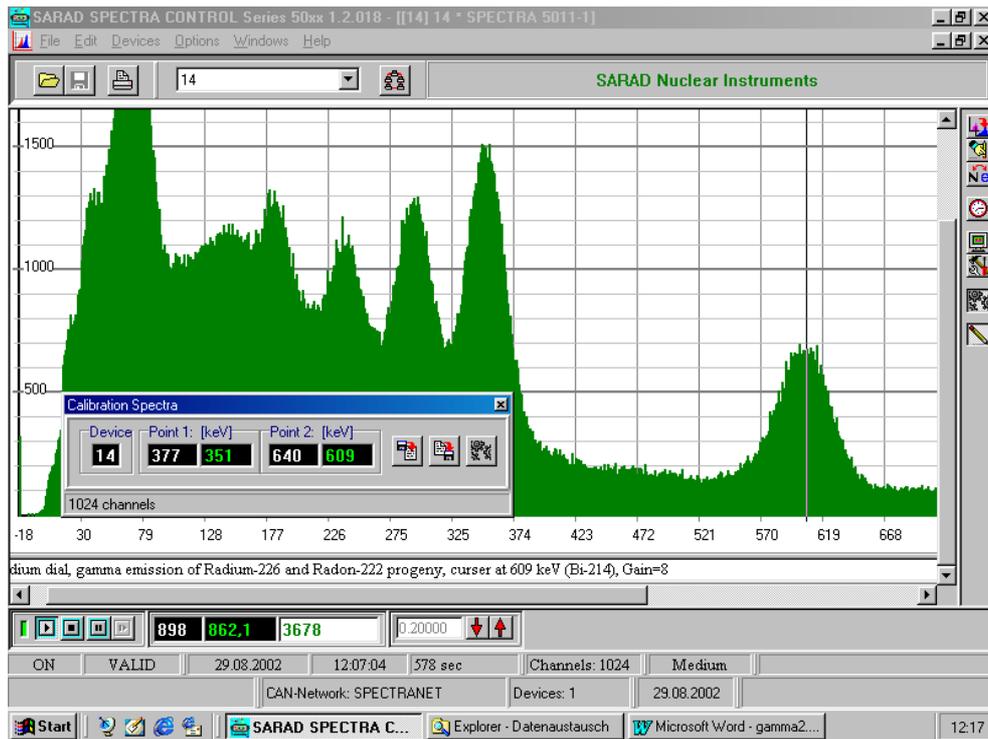




Analysis at the low energy range is possible., energy resolution 3.1 keV / chn.



Energy resolution is higher (1.6 KeV / chn) but significant peak at low energies caused by electronic amplified noise.



Energy resolution 0.9 keV/chn

## 7 Technical data

### 2.1. Detector bias

Bias voltage: 35 V (-85 V additionally 5041)

### 2.2. Pulse height analysis

sampled input range: 0...2 V  
noise cut off: about 20 mV  
min. pulse rise time: 5 $\mu$ s (about 2,5  $\mu$ s gaussian shaping time constant)  
max. pulse rise time: 50 $\mu$ s (about 25  $\mu$ s gaussian shaping time constant)  
gain adjustment: 1 to 10 linear  
max. pulse frequency: 12 kS/s  
ADC resolution: 8...12 bit  
accuracy:  $\pm$  1,5 LSB  
system dead time: 72,5  $\mu$ s fixed + adjustable delay time  
spectra memory: 4096 channels, 32 bit wide

### 2.5. Sample timer

frequency resolution: 20 s<sup>-1</sup>  
max. sample interval: 768.000 s (9 days)  
min. time step: 1 s  
accuracy: 5 ppm

### 2.6. Common

interface: CAN bus serial network  
power supply: Wall adapter 9VDC/300mA  
dimensions: 140 mm x 190 mm x 55 mm  
weight: 1500 gr. incl. battery