Research and Production Company

ZRF "RITEC" SIA

Riga, LATVIA

Basic Company Information

- Company name: ZRF "RITEC" SIA (RITEC Ltd.)
- Legal status: Private limited company
- Date of registration: 02.04.1992. It was founded on the basis of the Room Temperature Semiconductor Detectors Laboratory of Semiconductor Detectors Department of the former Riga Research and Scientific Institute of Radioisotope Instrumentation.
- Country of registration: Latvia
- VAT Reg. No.: LV40103045390
- Address: 23 Aizkraukles Str., ofice 407, Riga, LV-1006, Latvia
- Head of the company (contact person): Mr. Victor Ivanov (Viktors Ivanovs)
- Tel. number: +371-67543304
- E-mail: ritec@ritec.lv
- Web site: www.ritec.lv

- Current number of employees: 9
- Staff professional experience: 5-35 years
- Business profile:

  Research, development and production of room temperature semi-conductor detectors (mainly based on CdZnTe) for various applications and some associated electronic.
- Main markets:

  EC countries, North America, Argentina, international organizations such as IAEA, EURATOM

Agenda

- CdZnTe detectors
- Detection probes
- Examples of applications

CZT material

Physical properties:

Typical composition	$Cd_{0.9}Zn_{0.1}Te$
Atomic numbers	48,30,52
Density	5.8 g/cm^3
Band gap	1.57 eV
Dielectric constant	10.9
Pair creation energy	4.64 eV
Specific resistance	>10^{10} Ω* cm
Electron mobility, μ_e	600-1000 cm^2/Vs
Electron lifetime, $\mu\tau_e$	>10^{-6} s
Hole mobility, μ_p	50-80 cm^2/Vs
Hole lifetime, τ_p	~10^{-6} s
$(\mu\tau)_e$	>10^{-3} cm^2/Vs
$(\mu\tau)_p$	>10^{-5} cm^2/Vs

- ✓ High atomic number, high density, wide band gap, high resistance, high value of electrons μτ product and long term stability of semi-insulating Cadmium Zinc Telluride make this material a very suitable for room-temperature semiconductor detectors fabrication.
- ✓ But because of the poor hole transport special methods and detectors designs must be applied.

CZT detectors

Types of CdZnTe detectors and detectors array:	**Main advantages:**	**Main applications:**
❖ planar counting and spectrometer detectors ❖ planar detectors with p-n, p-i-n or Schottky contacts ❖ Hemispherical, quasi-hemispherical and cylindrical detectors ❖ co-planar grid detectors ❖ various pixilated and strip detectors ❖ various Frisch grid detectors ❖ drift detectors ❖ 3D depth sensing position sensitive devices	❖ room temperature operation ❖ high spectrometric capability ❖ high registration efficiency ❖ small dimension and weight ❖ stability in time ❖ low leakage current ❖ high count rate capability	❖ X-ray and gamma-ray spectroscopic applications industrial and laboratory ❖ homeland security ❖ safeguards ❖ various X-ray and gamma-ray imaging systems ❖ Medical

CZT quasi-hemispherical detectors

Main advantages of hemispherical detectors:

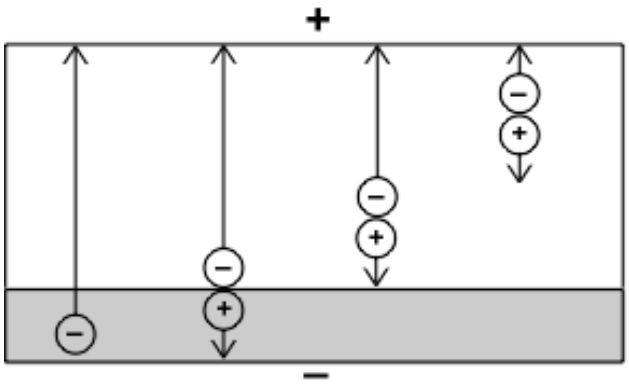
- comparative simplicity of design and production
- good spectrometric characteristic
- wide range of operation temperature
- good stability in time
- less critical for selection of initial CdZnTe crystals
- small dimensions
- ability for application in strong radiation fields and in out-of-the-way places
- commercially availability
- rather low fabrication costs

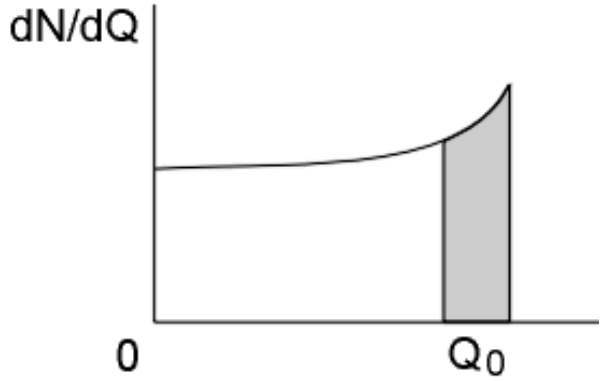
- ✓ Hemispherical detectors are well known as detectors where conditions of a single polarity charge collection are realized. Progress in improvement of CZT crystals characteristics allows fabrication of high quality hemispherical detectors.

- ✓ The high level of electrons transport characteristic ($(\mu\tau)_e \geq 10^{-2}$ cm^2/Vs) of modern CZT crystals allows fabrication hemispherical detectors with volumes from a very small of 0.5-1 mm^3 to a large volume about few cubic centimetres.

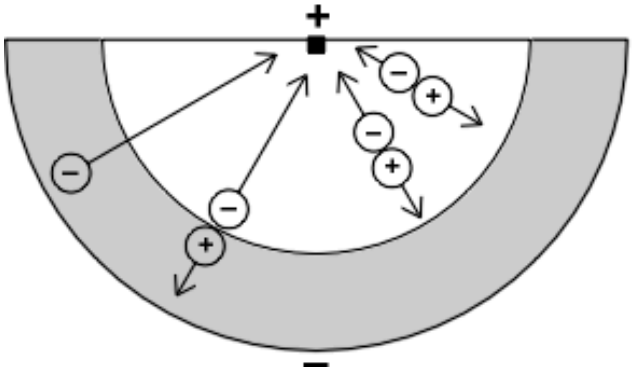
Single charge collection

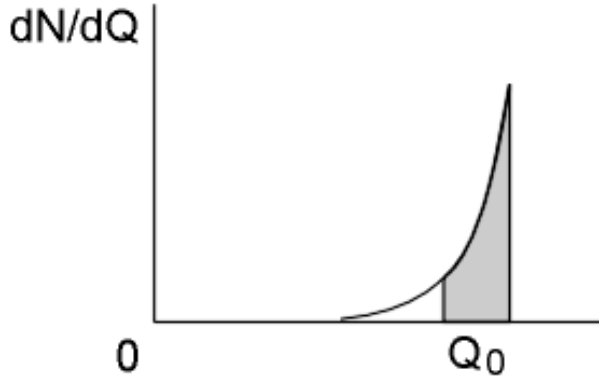
Planar Detector





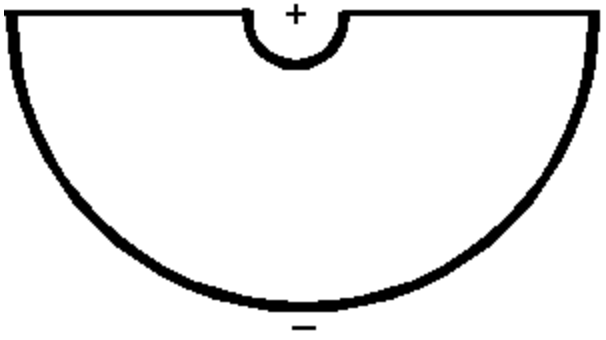
Hemispherical Detector



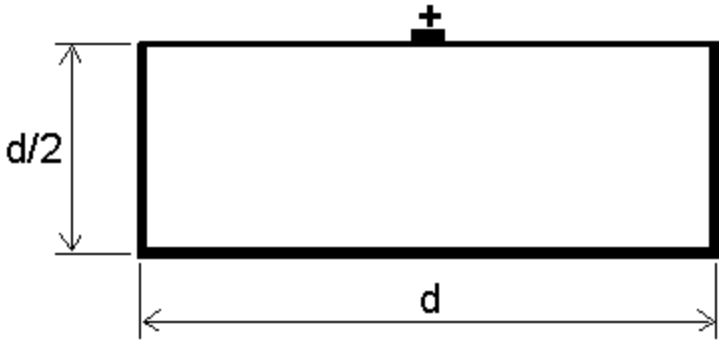


Possible types of quasi-hemispherical detectors

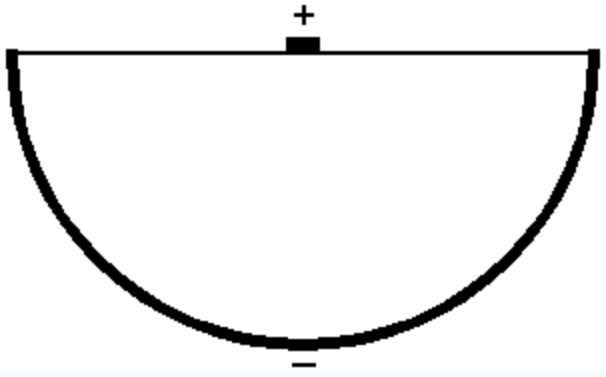
Ideal Hemispherical Detector



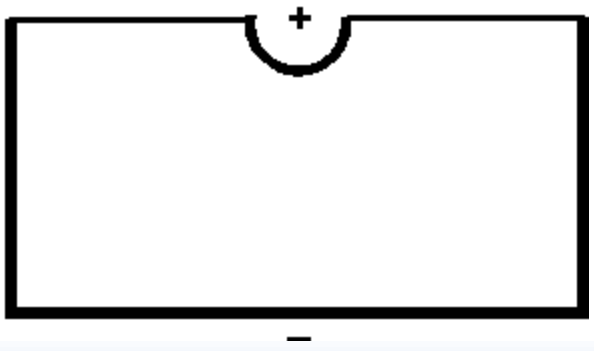
Quasi-Hemispherical Detector (Type 1)



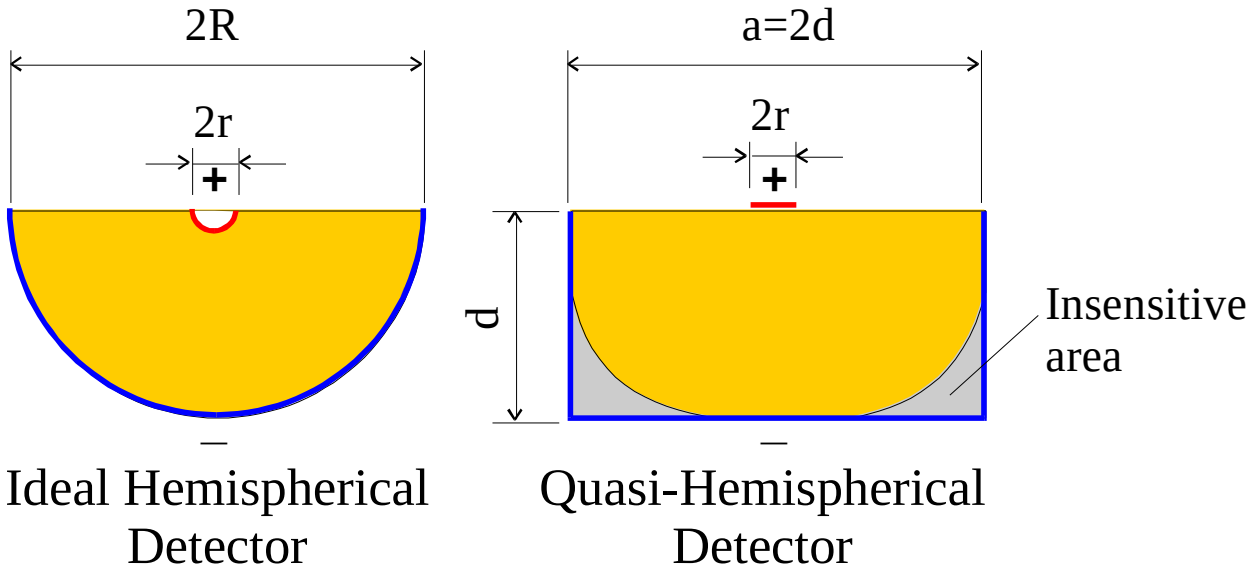
Quasi-Hemispherical Detector (Type 2)



Quasi-Hemispherical Detector (Type 3)



CZT hemispherical and quasi-hemispherical detectors

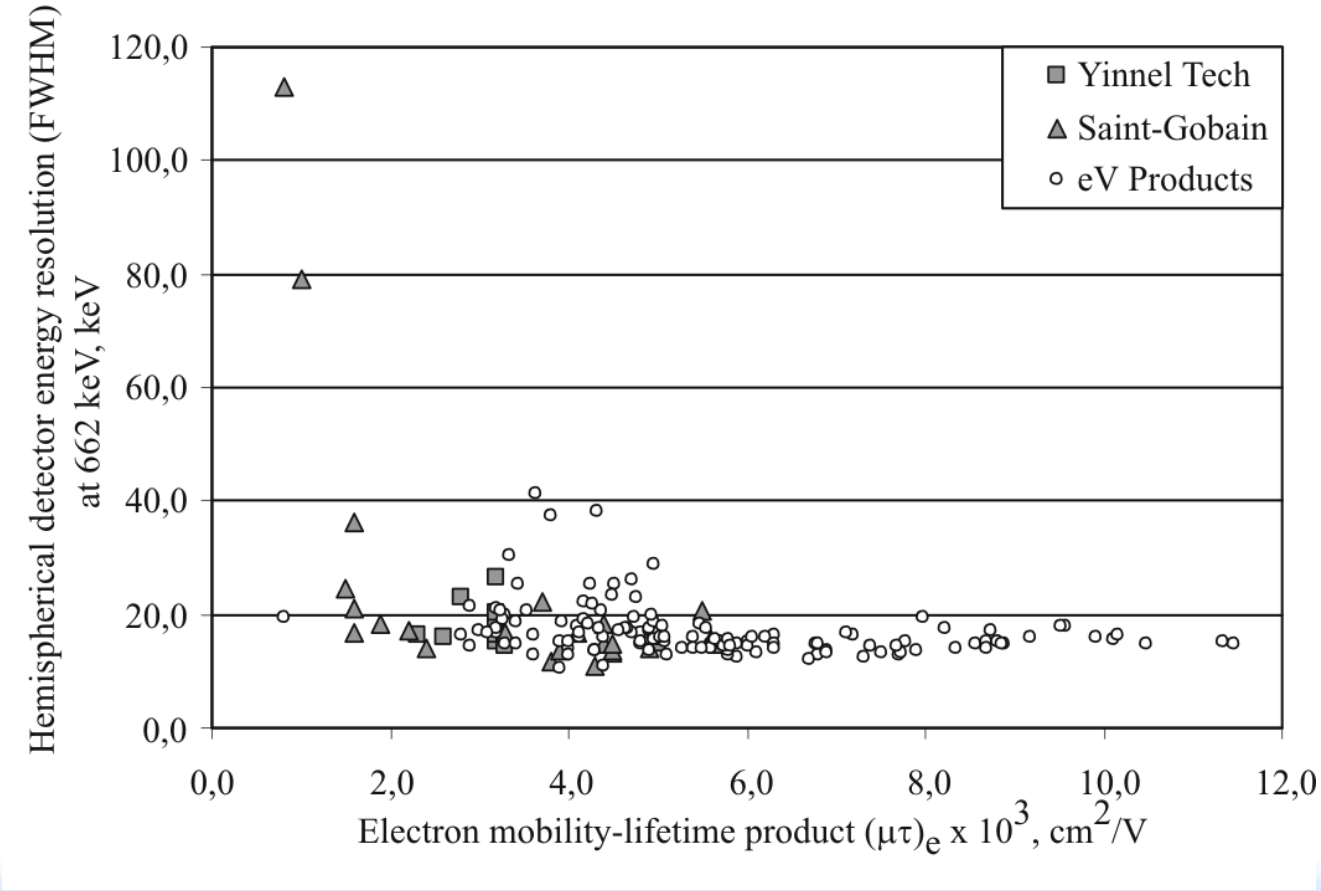


For simplification of manufacturing of hemispherical detectors, in practice are made quasi-hemispherical detectors with rectangular shape of sensitive volume with dimensions of **a**x**a**x**d**. Distribution of an electrical field in the quasi-hemispherical detector strongly differs from an ideal distribution in an ideal hemispherical detector. There are areas with a low electric field in a detector's corners.

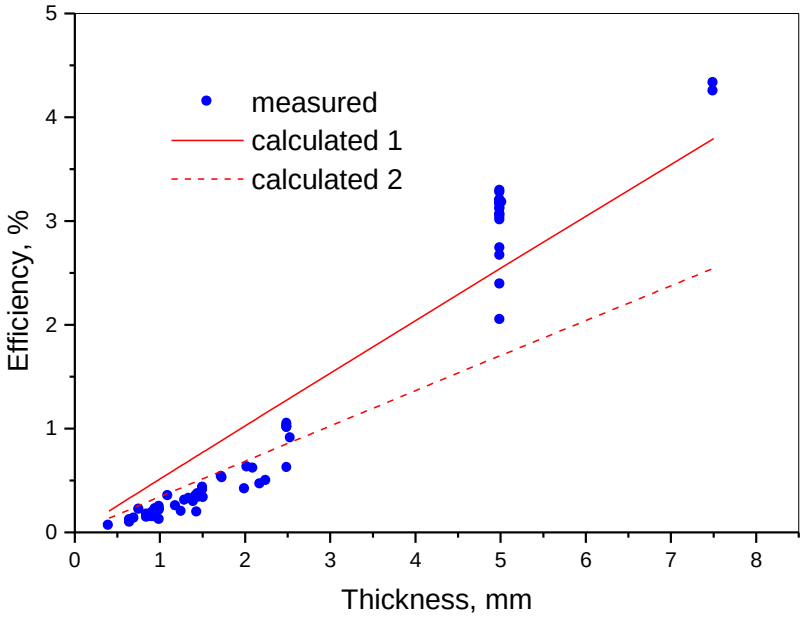
Hemispherical detectors

- $(\mu\tau)_e$ product - as high as possible, at least not less then 10^{-3} cm^2 / V
- $(\mu\tau)_p$ product - as low as possible, at least ratio $(\mu\tau)_e$ /$(\mu\tau)_p$ must be more then 20
- High level of uniformity, absence of significant composition variation and crystalline defects in the detector sensitive volume
- High specific resistance
- Optimal relation for big and small radiuses of hemispherical detector electrodes for certain sets of parameters $(\mu\tau)_e$, $(\mu\tau)_p$ and operating voltage must be kept
- Geometrical shape - for best results is necessary to use ideal hemispherical shape, but for simplification of manufacturing of hemispherical detectors, are made quasi-hemispherical detectors with rectangular sensitive volume

Measured hemispherical gamma-ray detectors energy resolution (FWHM) at 662 keV vs. electron mobility-lifetime product



Registration efficiency of CZT quasi-hemispherical detectors



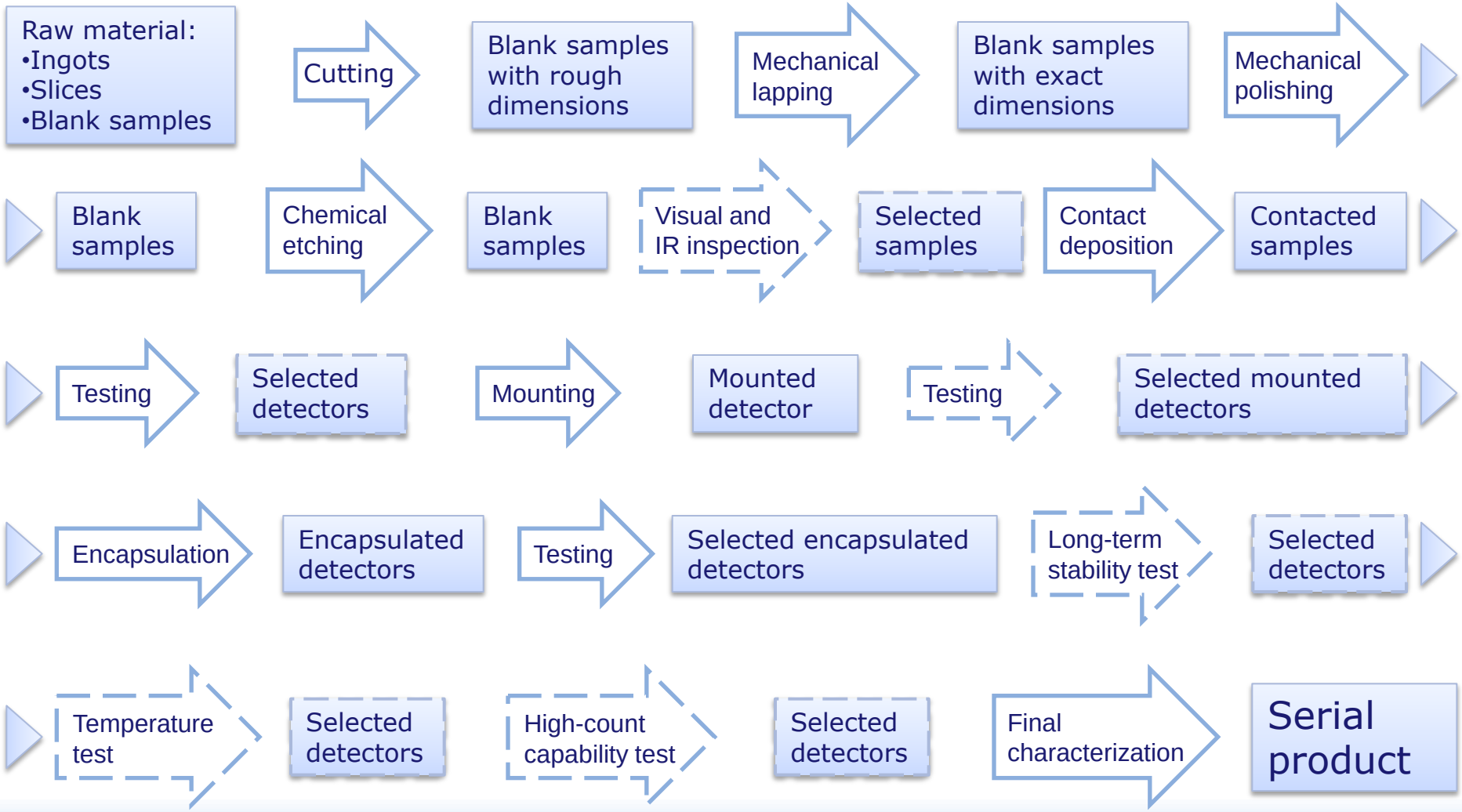
Measured (dots) total absorption peak efficiencies and calculated photoabsorption efficiency versus quasi-hemispherical detectors thickness, assuming that the whole (1) and only 78% (2) of detector volume is sensitive to the radiation.

Insensitive areas reduce the detector sensitive volume. It is the reason of essential disagreement of calculated and measured results for small detectors.

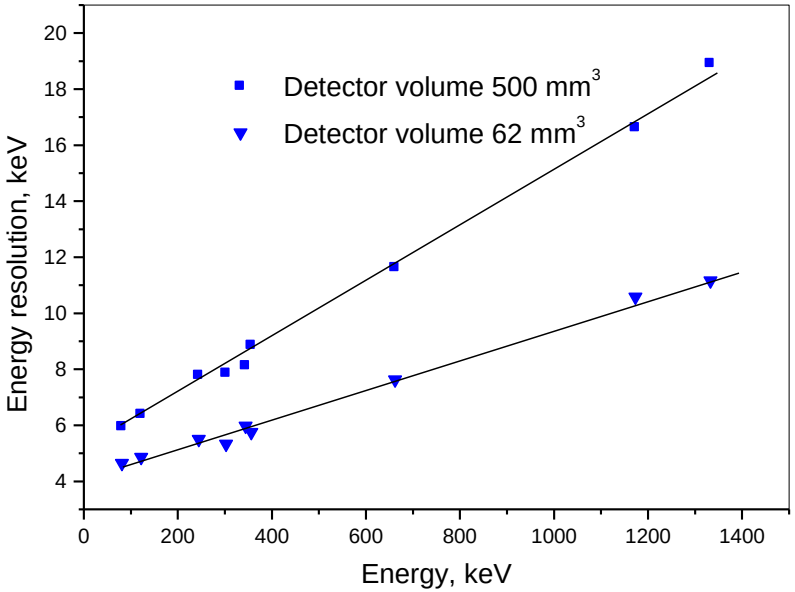
With using of experimental dates about the total absorption peak efficiency the effective sensitive volume of quasi-hemispherical detectors was calculated. For small sizes detectors it is about 80 % from the total detector volume.

The exceeding of measured efficiencies for larger detectors over-calculated is connected with an unaccounted contribution of multievent Compton absorption.

Typical detectors manufacturing process



Energy resolution of CZT quasi-hemispherical detectors

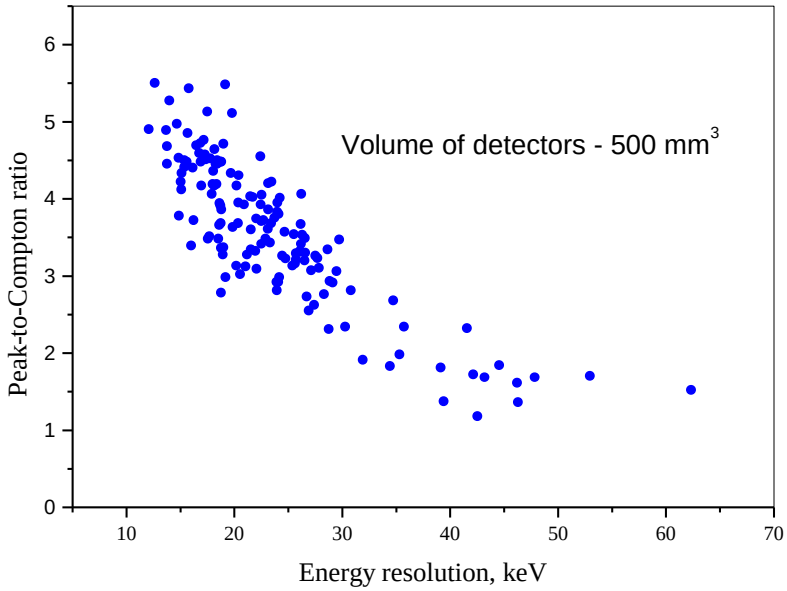


Dependence of the quasi-hemispherical detectors energy resolution versus gamma-radiation energy. In the first approximation there is linear dependence between these parameters.

The best energy resolutions at 662 keV line measured with quasi-hemispherical detectors of different volumes.

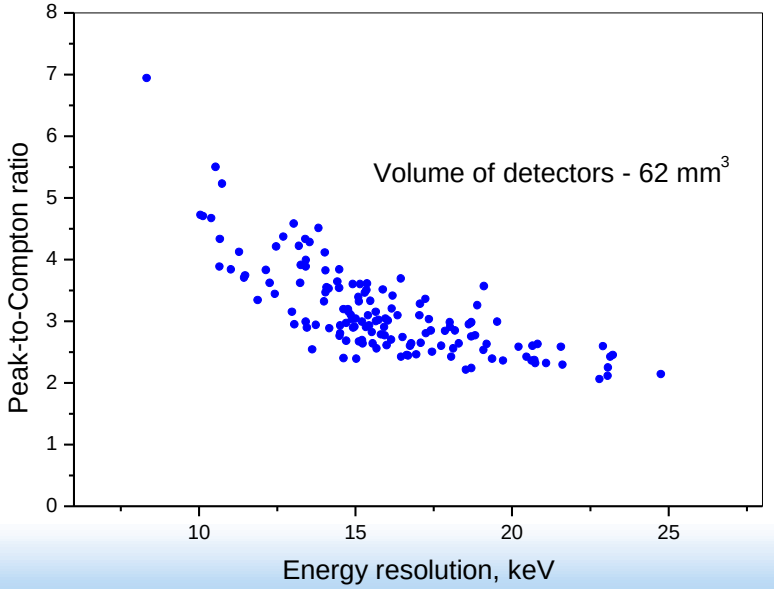
Detector sizes, mm	Volume, mm^3	Energy resolution, keV (%)	Peak-to-Compton ratio
1.0x1.0x0.5	0.5	7.1 (1.1)	2.0
1.5x1.5x0.75	1.7	5.1(0.8)	3.6
2.0x2.0x1.0	4.0	5.5(0.8)	4.4
2.5x2.5x1.25	7.8	7.6(1.2)	5.0
5.0x5.0x2.5	62	7.1(1.1)	7.2
10.0x10.0x5.0	500	8.2(1.2)	8.0
15.0x15.0x7.5	1687	15 (2.2)	7.0

Peak-to-Compton ratio of CZT quasi-hemispherical detectors



Dependencies of the peak-to-Compton ratio versus energy resolution at 662 keV line for large quantities of quasi-hemispherical detectors with two different volumes.

There is correlation between these parameters.



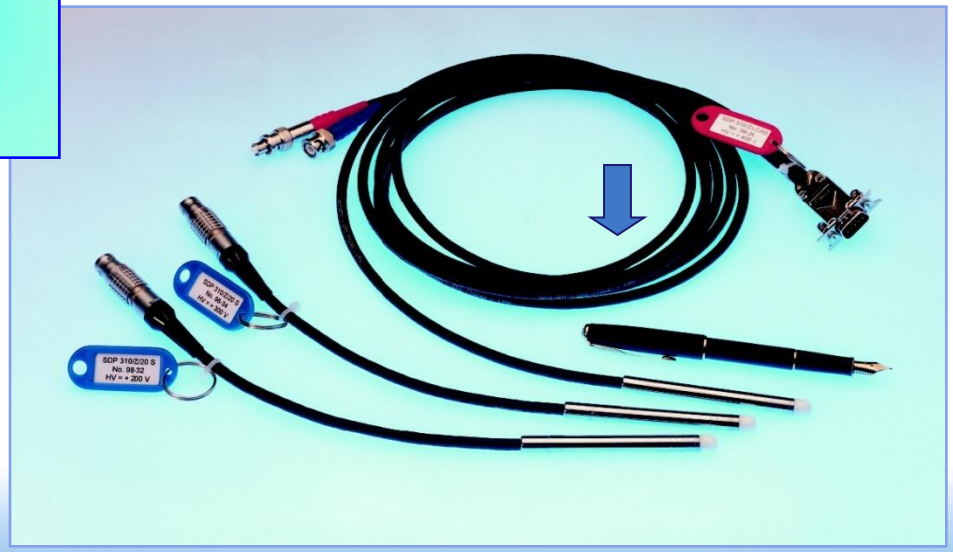
Mounted detectors, detection probes, some associated electronic

CZT Large Volume Detectors CZT/500(S), CZT/1500 and Spectrometric Detection Probe SDP310/Z

CZT500(S) with preamplifier PA101

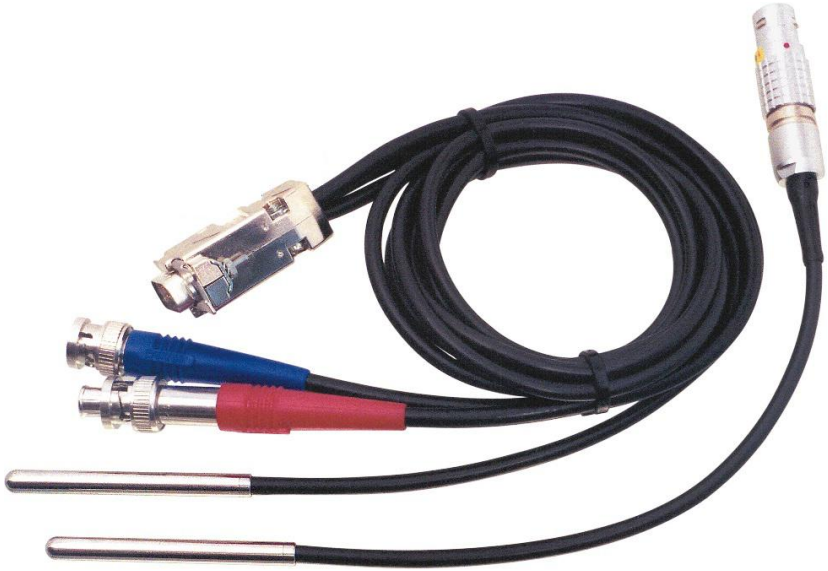
CZT/1500

SDP310/Z/(LC)/(S)



Spectrometric Detection Probe Model SDP500(S)

Subminiature Spectrometric Detection Probe SDP313



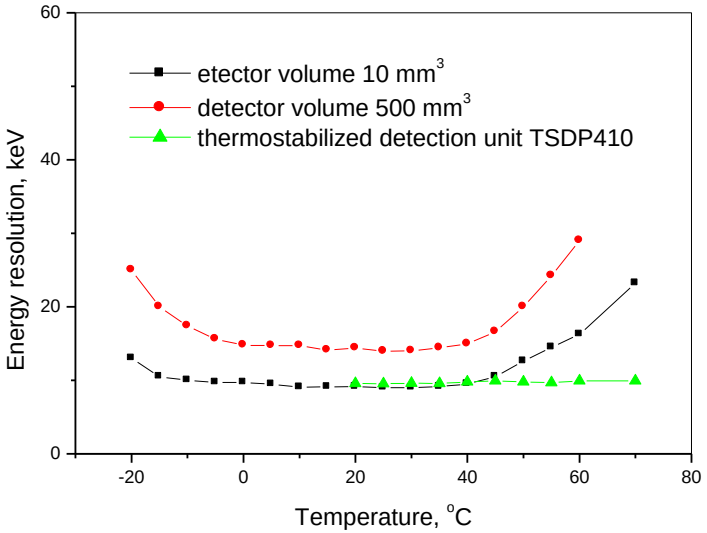
CdTe/CdZnTe Detection Probes

⇐ Miniature gamma-ray spectrometric detection probe SDP310 with hemispherical detector

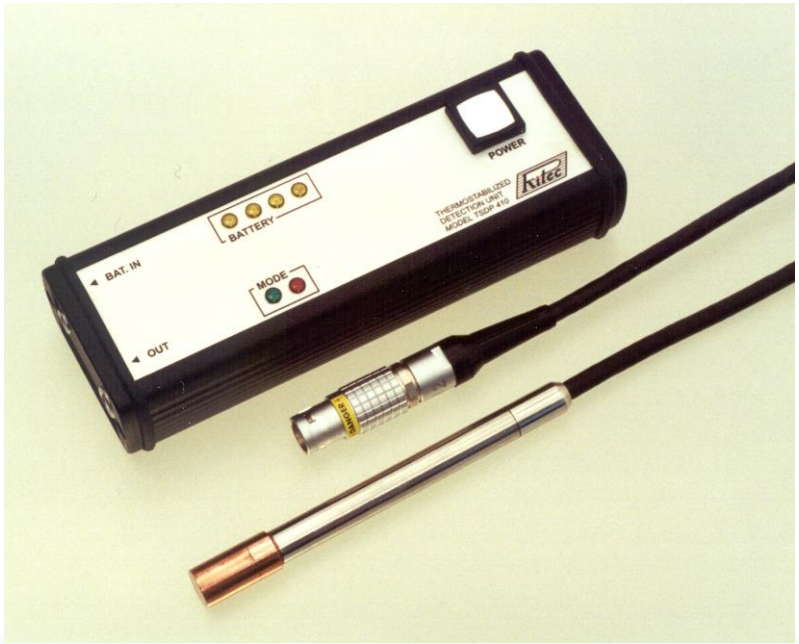
⇐ Gamma-ray spectrometric detection unit with hemispherical detector cooled by a single stage Peltier element

⇐X-Ray spectrometric detection unit with p-i-n CdTe detector cooled by two or three stage Peltier element

Temperature Stabilized Detection Unit TSDP410

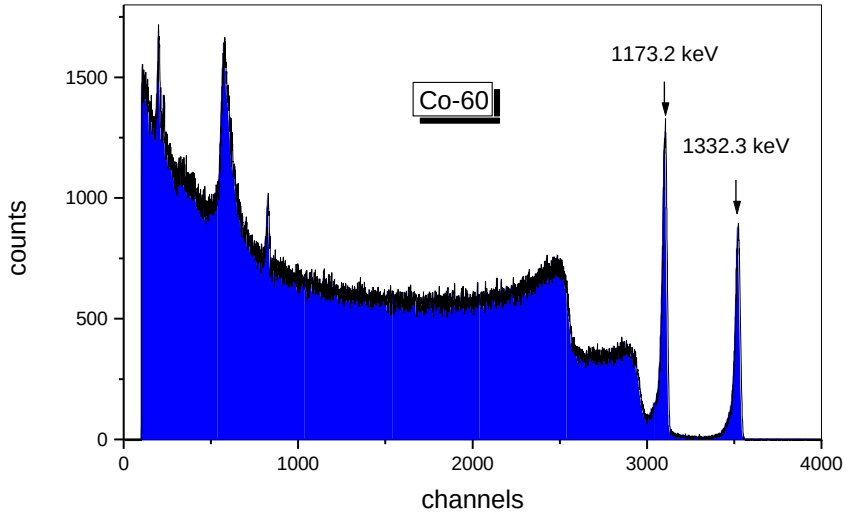


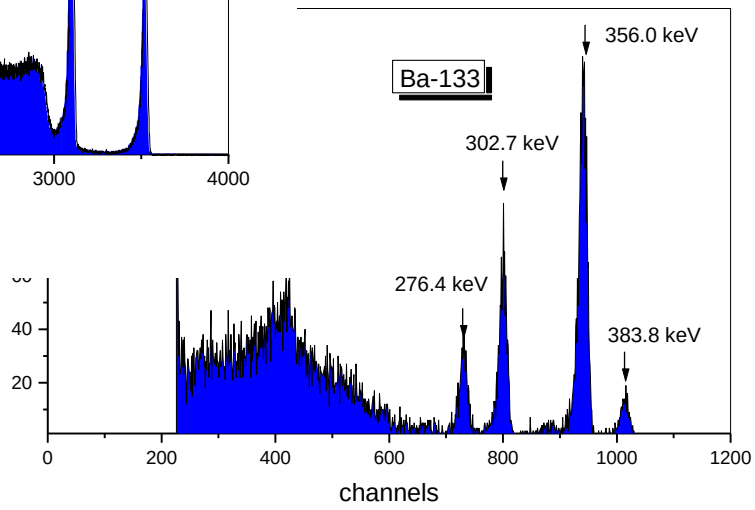
Temperature dependence of energy resolution (FWHM) at 662 keV line for two different quasi-hemispherical detectors and for detection probe TSDP410 with thermostabilized detector of 10 mm^3 .

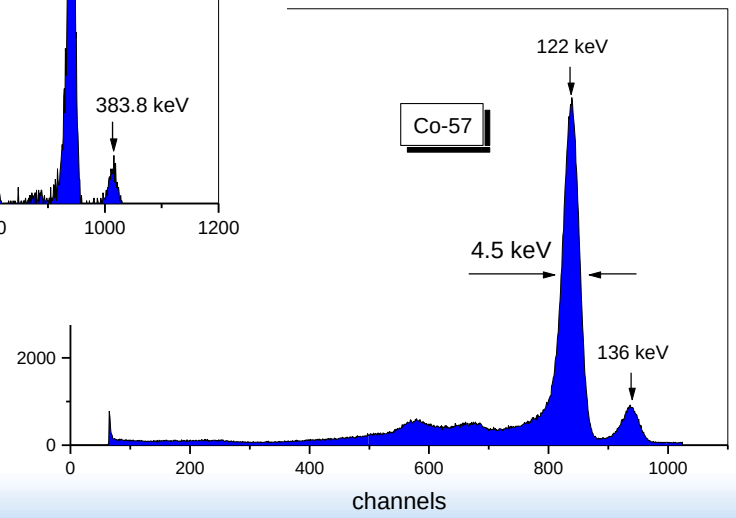


Removable probe of temperature stabilized detection unit TSDP410 can operate up to +70°C. Thermostabilization broad of TSDP410 supports the detector's operation temperature and for signals by sound and visual about operating troubles.

Spectra registered by CZT probe SDP310/Z/60S

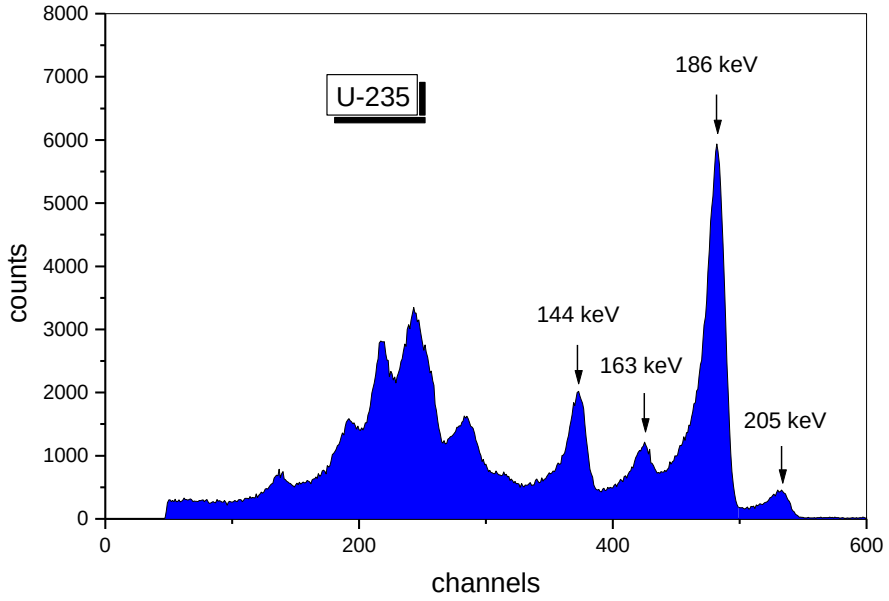


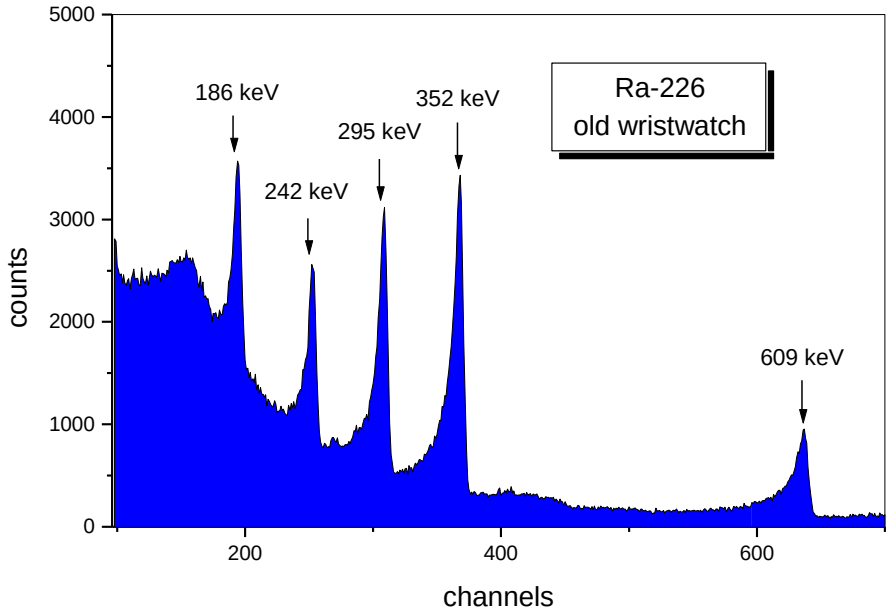




Detector volume 60 mm^3

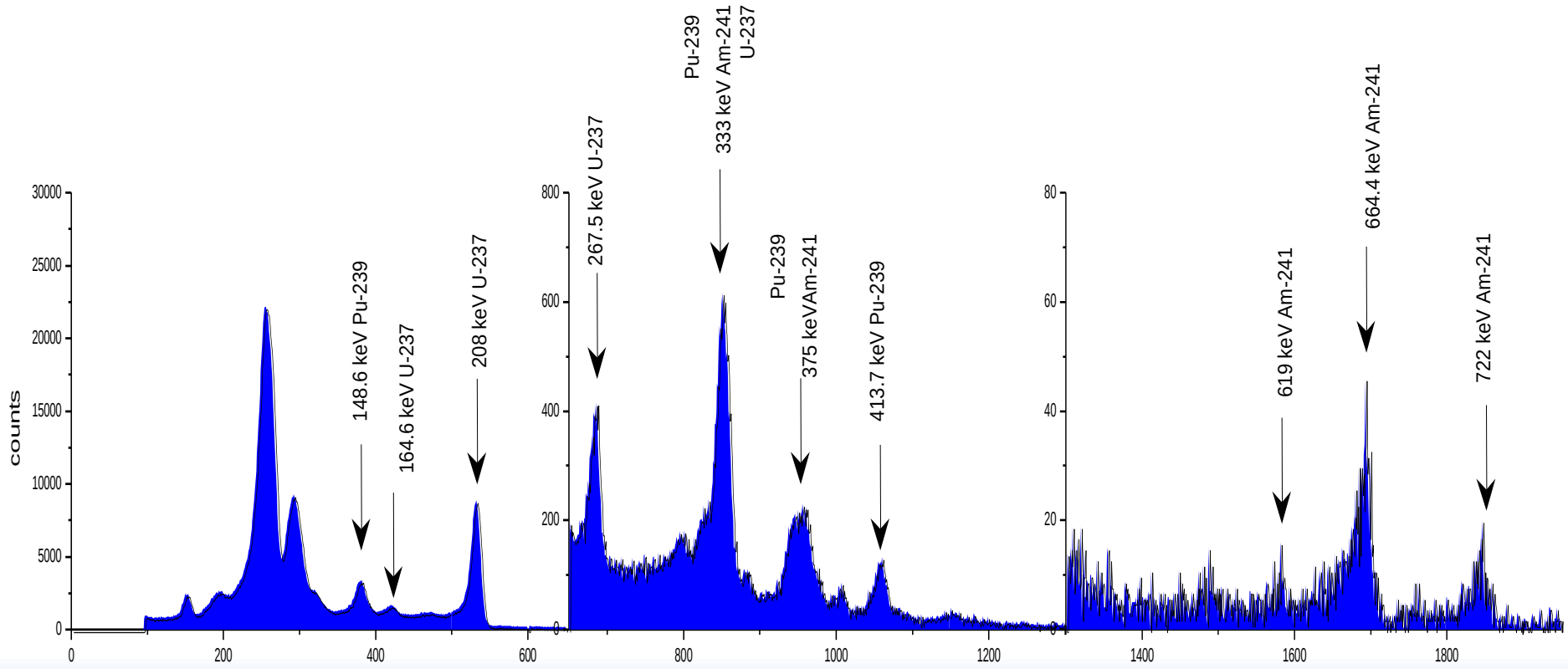
Spectra registered by CZT detector CZT/500S



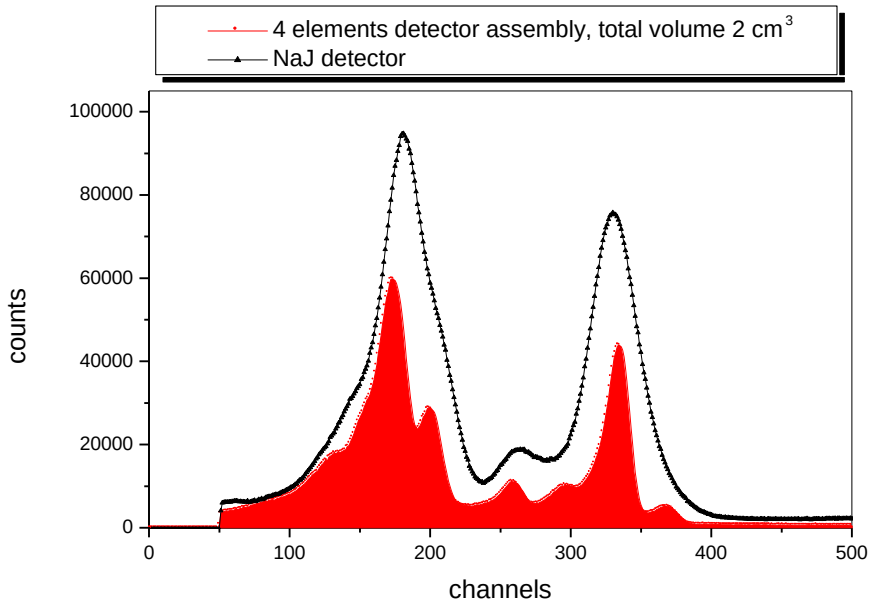


Spectrum registered by SDP310/Z/60S

Spectrum of reactor grade plutonium sample

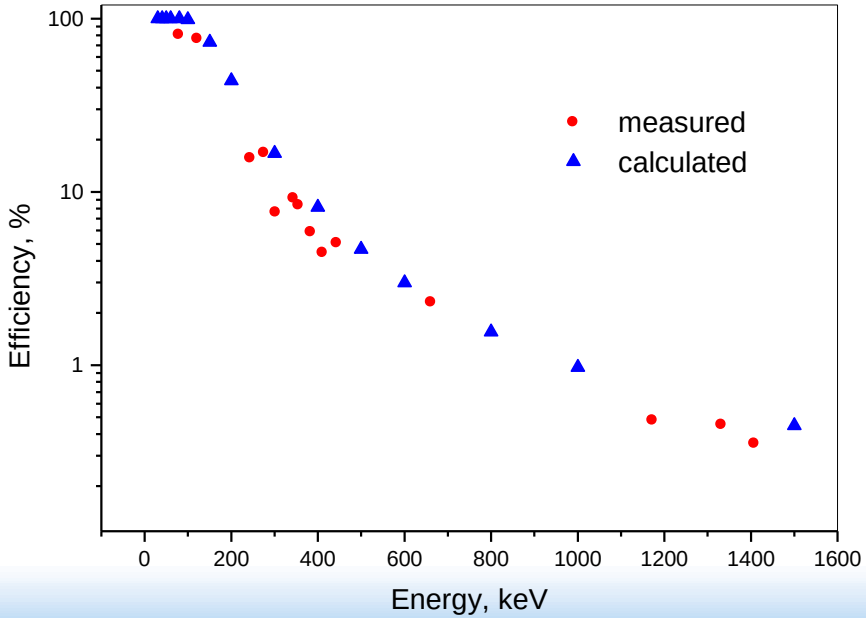


Efficiency of CZT quasi hemispherical detector



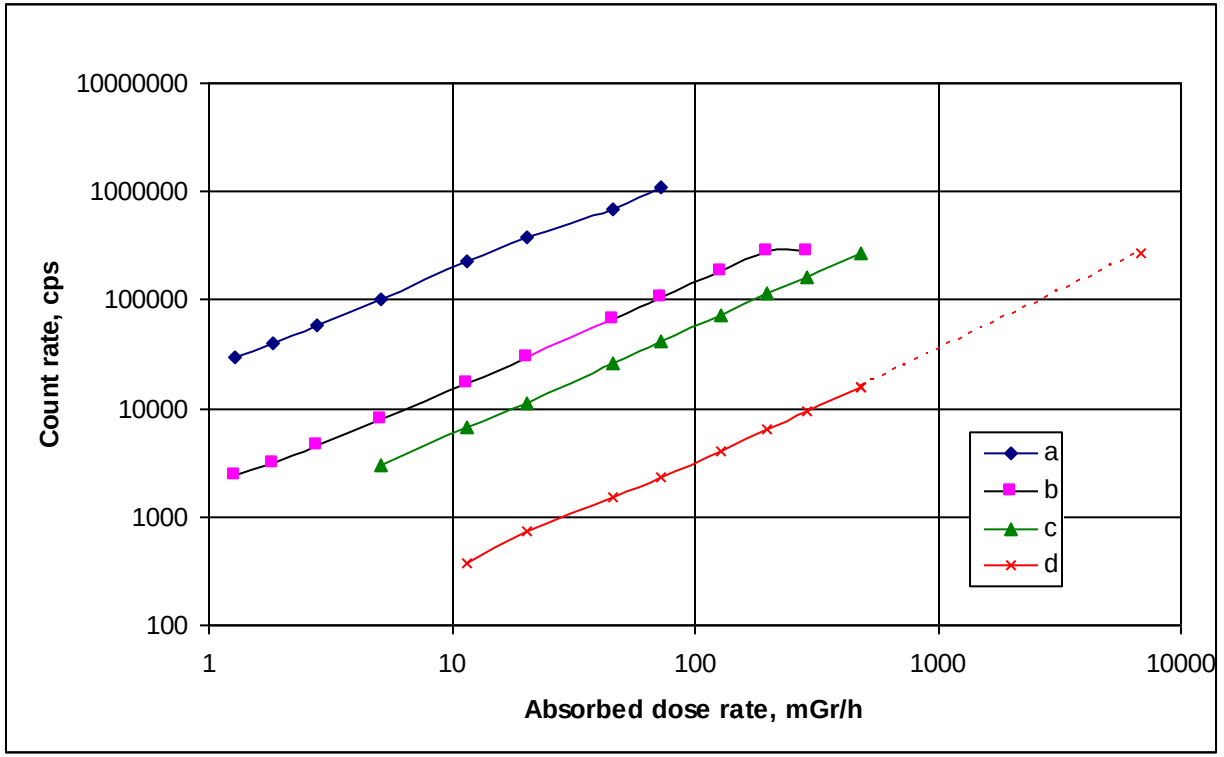
Spectra of U-235 registered by detectors assembly of 2 cm^3 and by NaJ (∅1"x1”) detector. Time and conditions of measurements are the same for both cases.

Measured total absorption peak efficiency and calculated photoabsorption efficiency versus gamma radiation energy for CZT detector for CZT detector with a thickness of 5 mm.



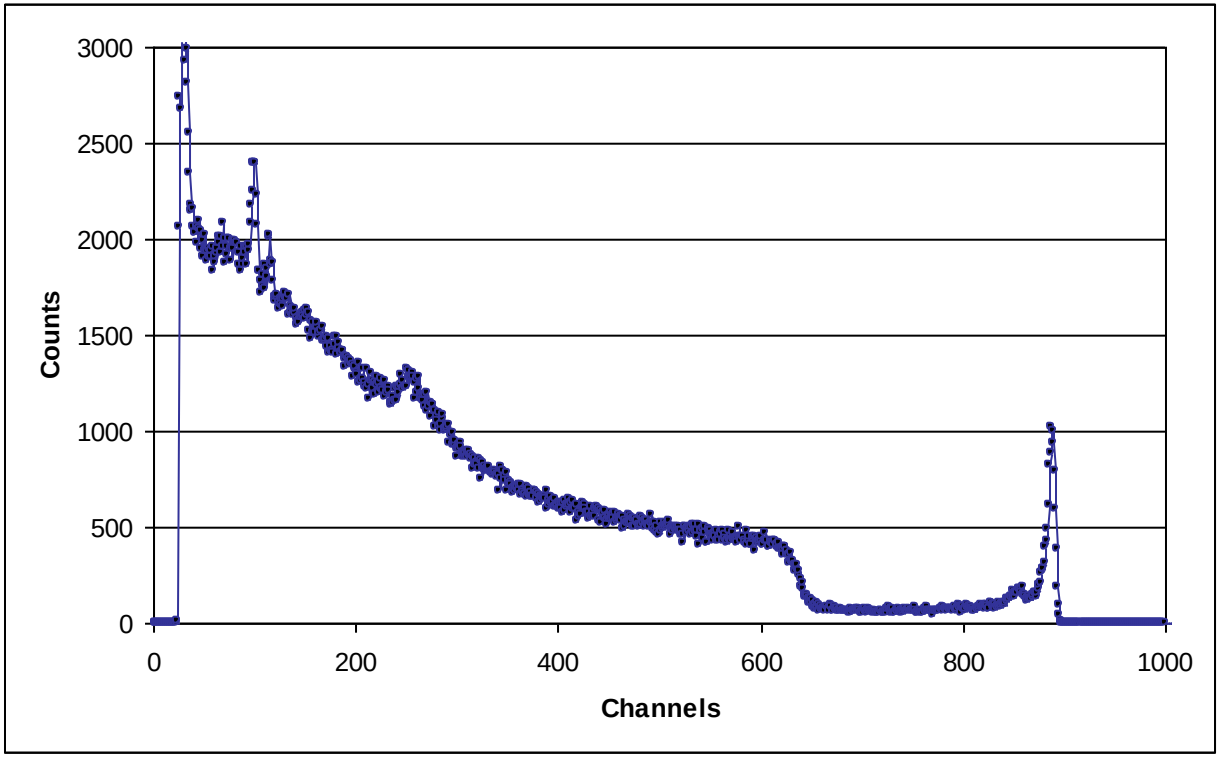
Input count rate depending on radiation dose rate for various detectors volumes

500 mm^3 (a), 40 mm^3 (b), 14 mm^3 (c), 0.5 mm^3 (d)

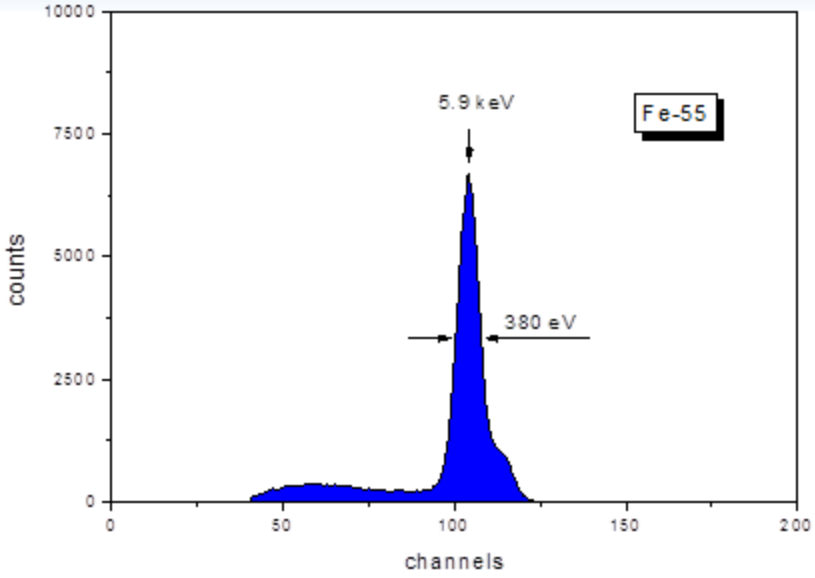


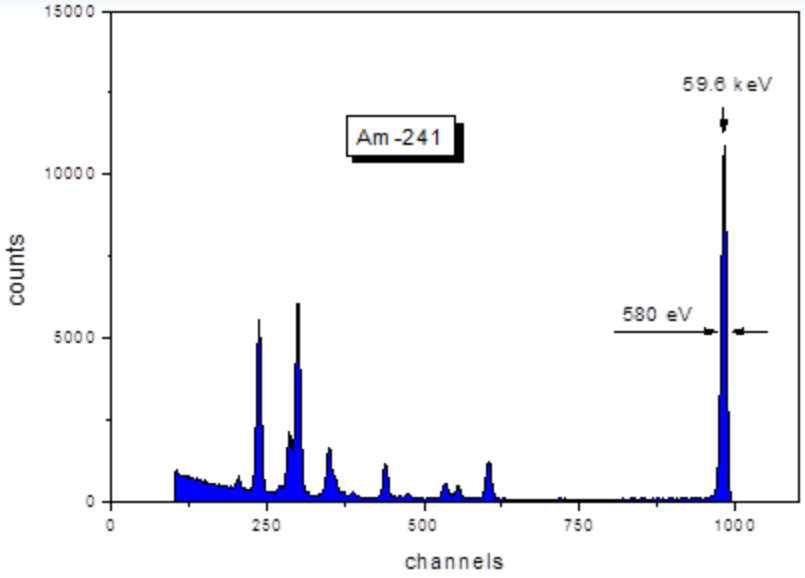
Spectrum of Cs-137

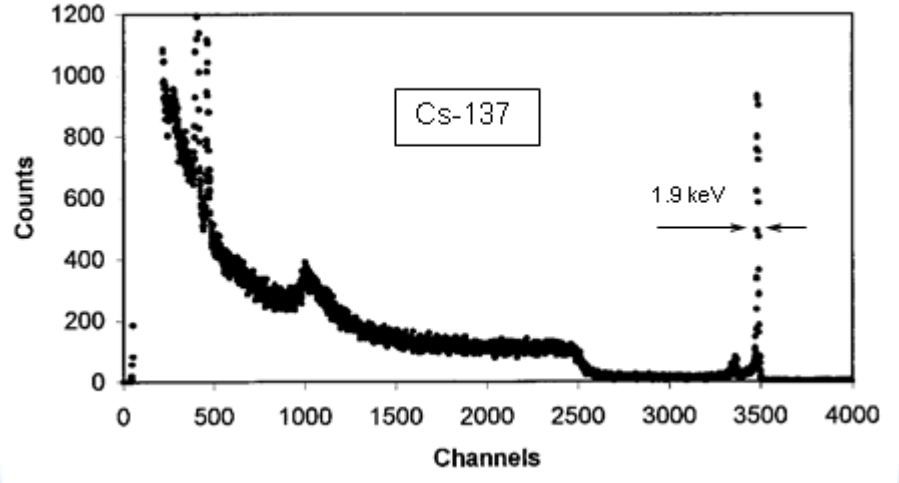
measured by the probe SDP310/Z/005
with CZT detector of 0.5 mm^3



CdTe p-i-n detector

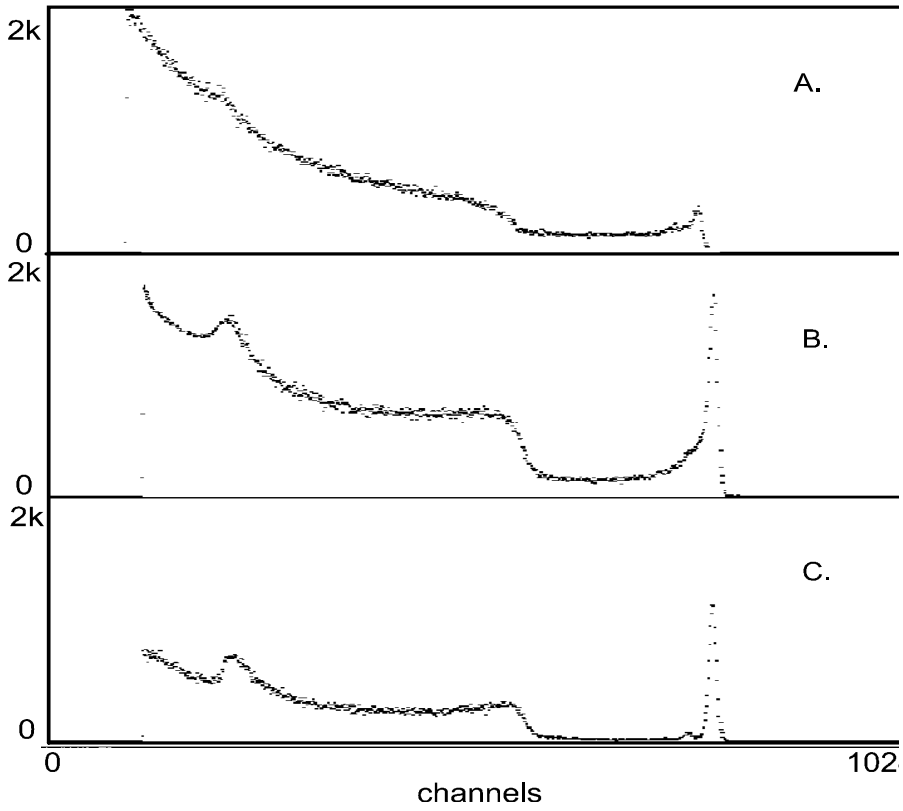






Detector size – 4x4x0.6 mm^3
Operation temperature - -35 °C

Planar detector with application of pulse selection-correction device

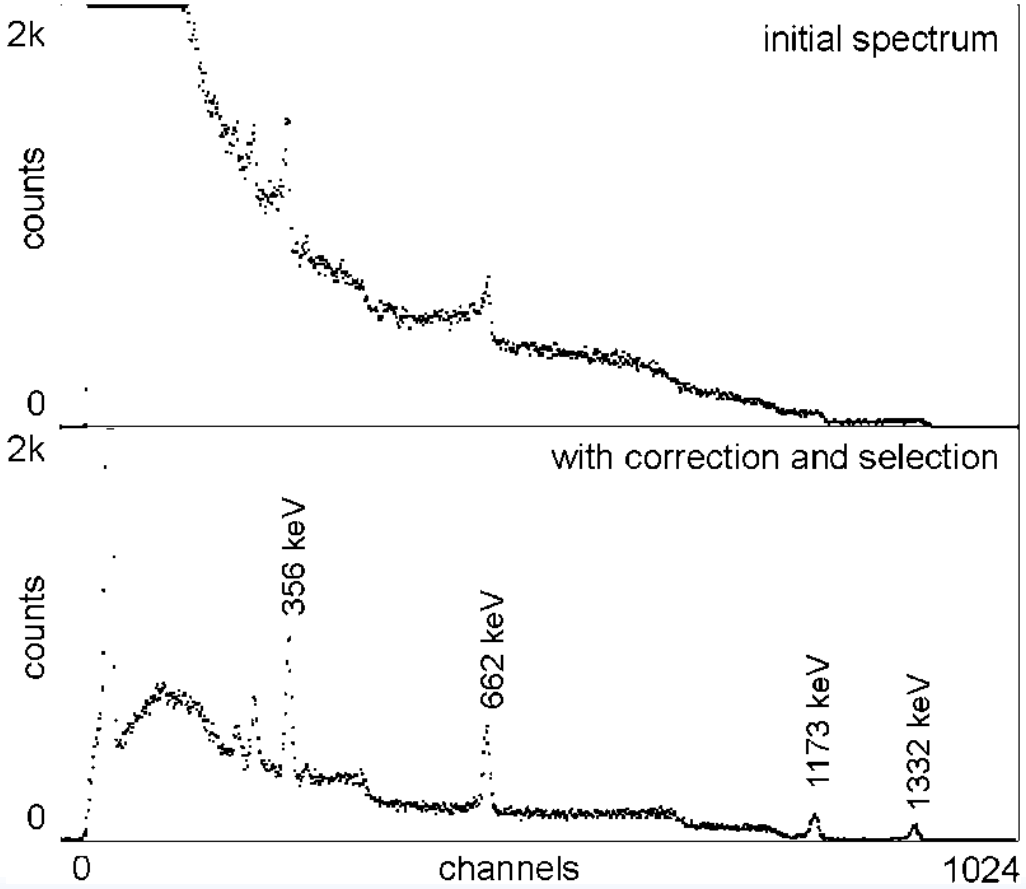


⇐Spectrum measured without application of pulse selection-correction device

⇐Spectrum measured with application of pulse correction device

⇐Spectrum measured with application of pulse correction-selection device

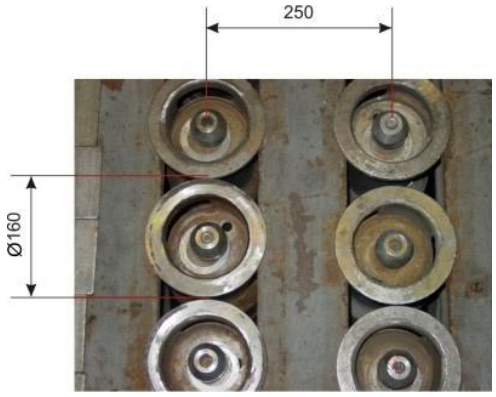
Common spectrum of Ba-133, Cs-137 and Co-60 measured with application of selection-correction device

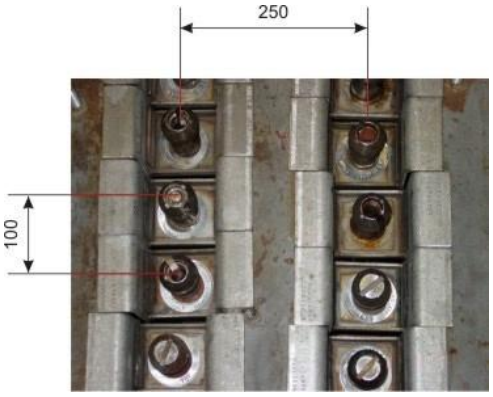


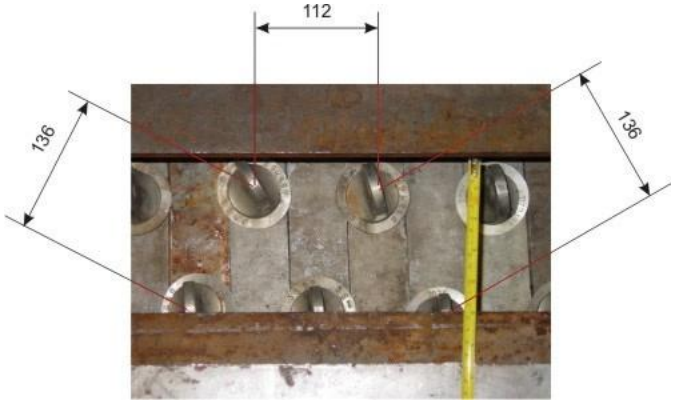
Planar CZT detector, size 10x10x2 mm^3

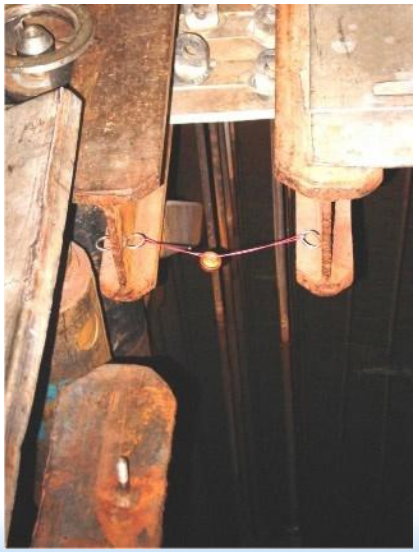
Samples of applications

Safeguards application.Three storage types of irradiated fuel assemblies in cooling pond.

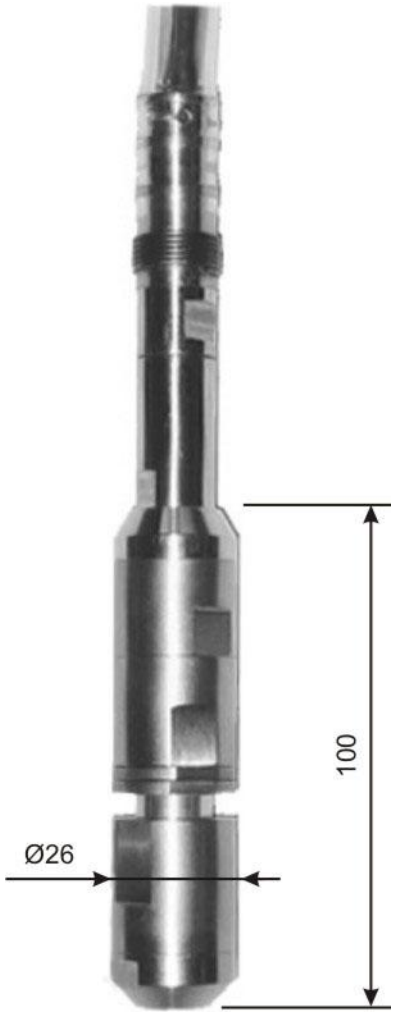


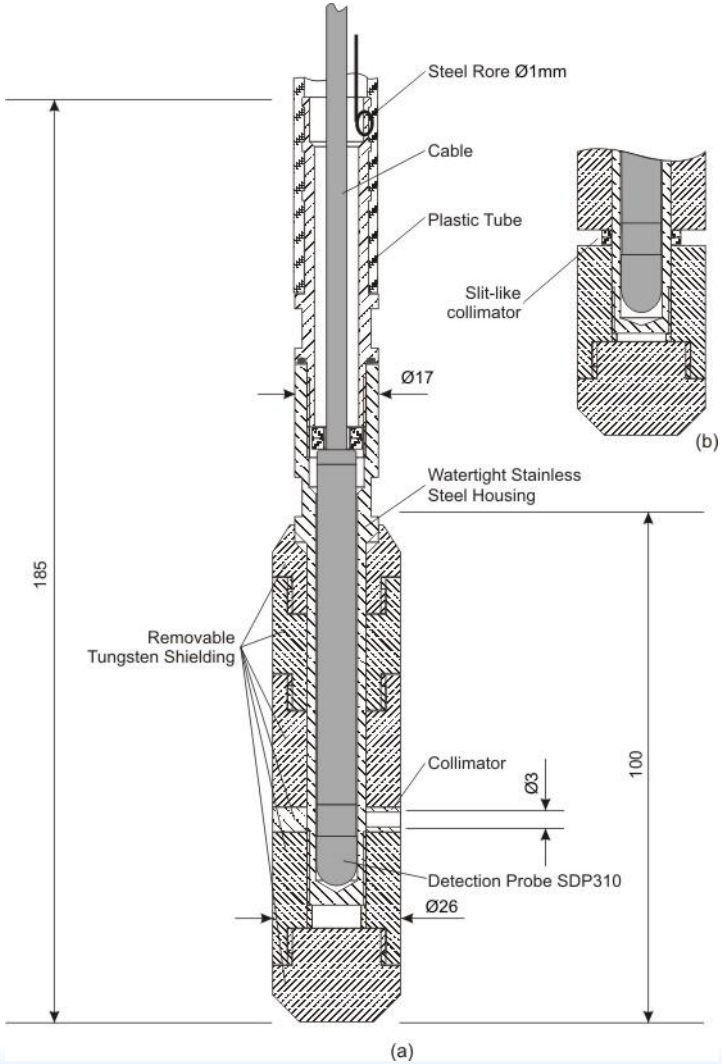


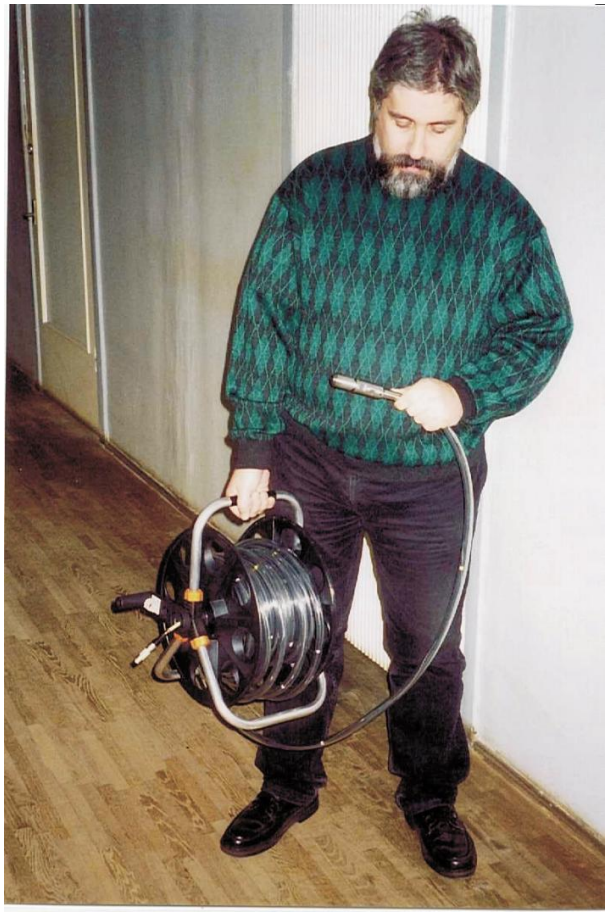




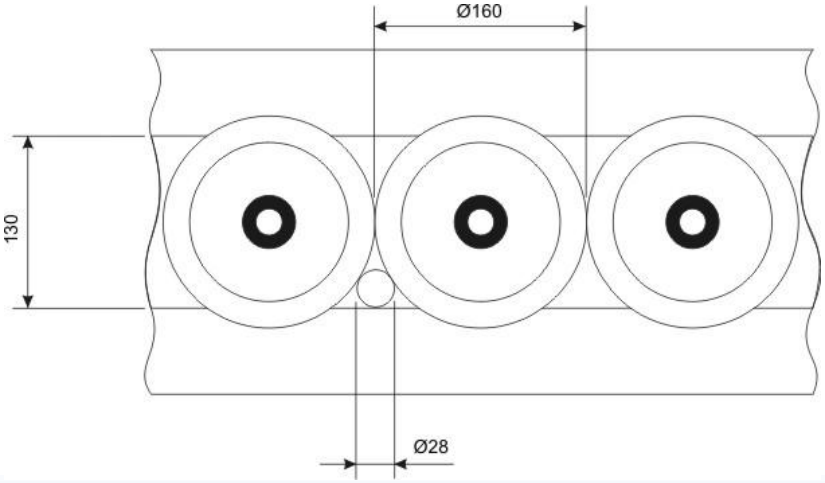
Spend Fuel Attribute Tester (SFAT). Chamber for underwater measurements.



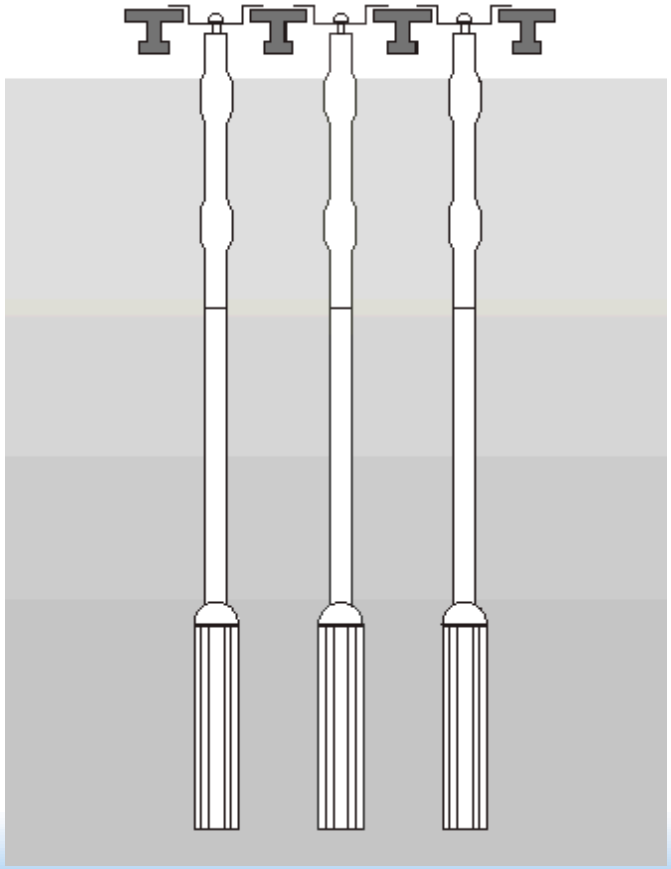




Nuclear power plant, spent fuel cooling pond. Places for measuring probe insertion.

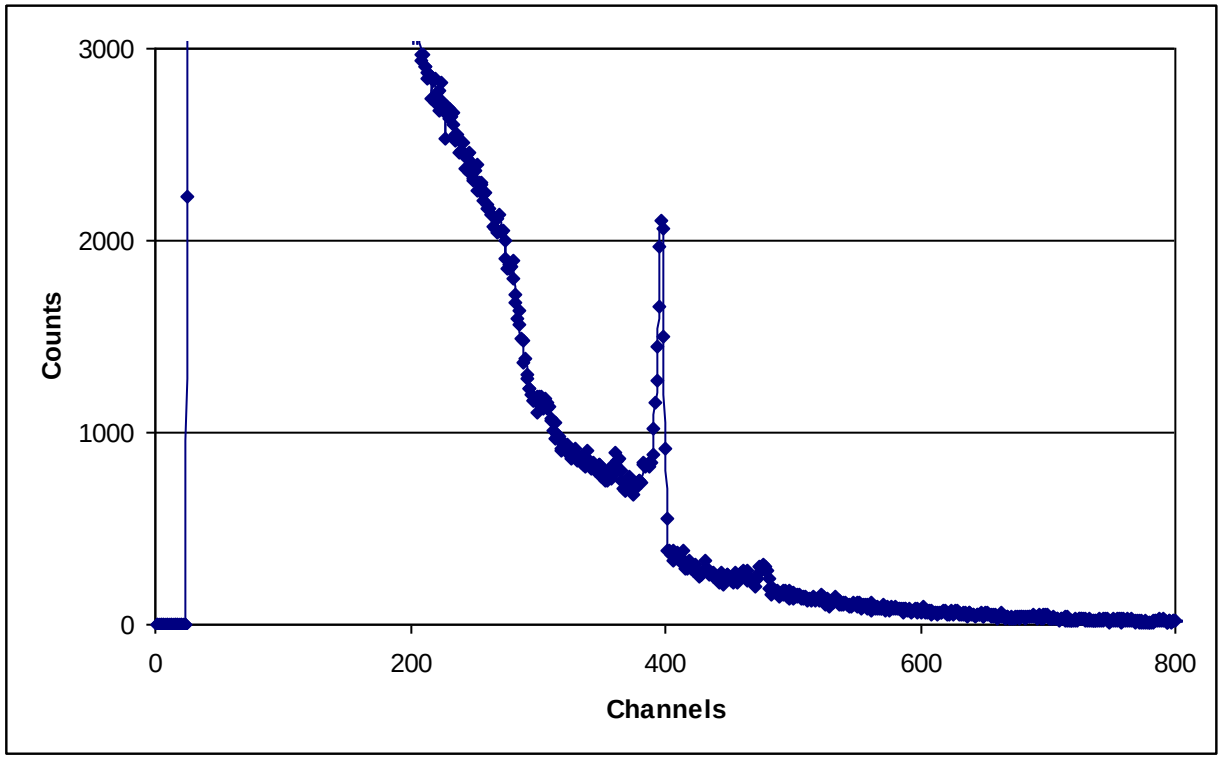


Scheme of measurements of suspended fuel assemblies

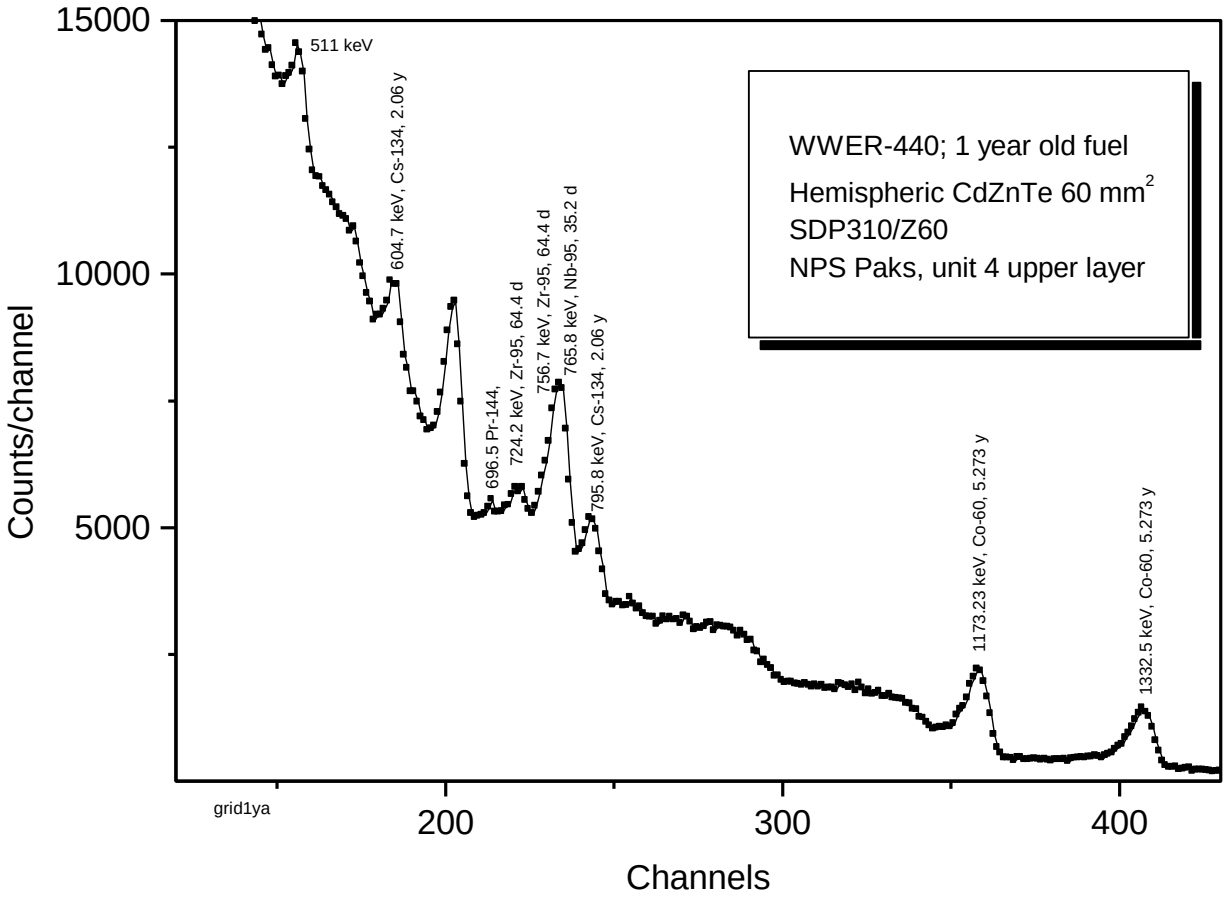


Irradiated fuel assembly spectrum

Burn-up 180 MWd/FA. Cooling time 21 months.

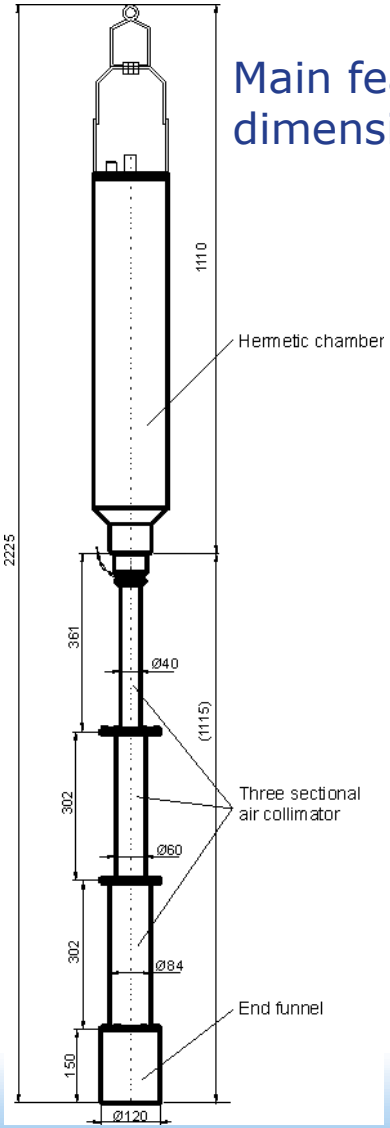


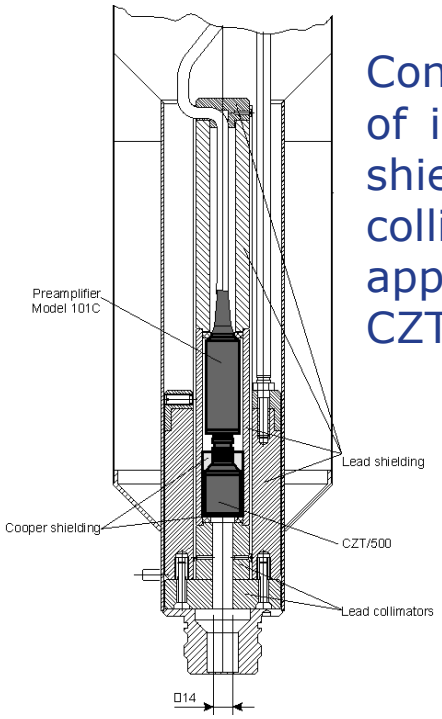
Gamma spectrum of 1 year old spent fuel measured with SFAT



Underwater measuring system of bundles of fuel elements in basket

Main features and dimensions



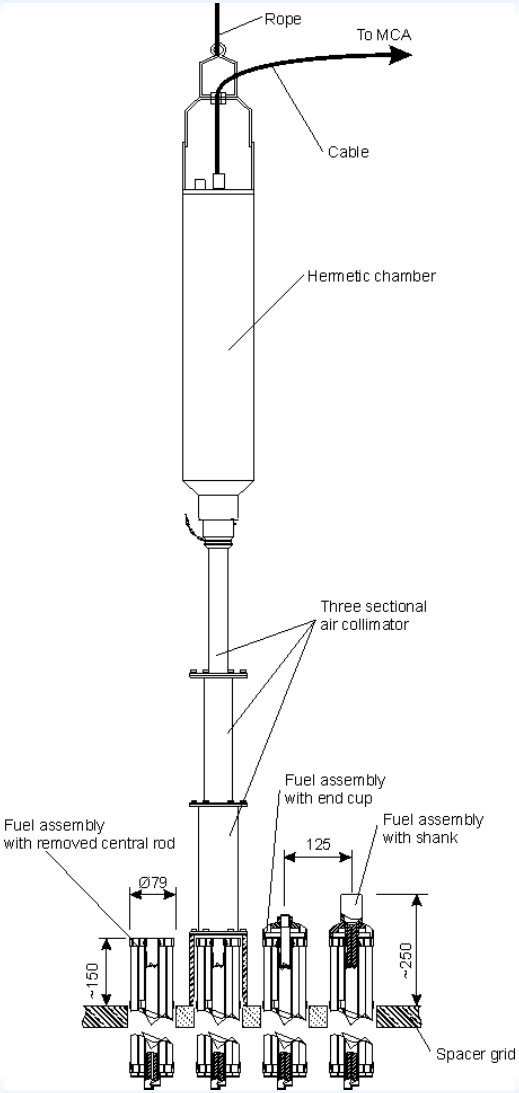


Configuration of internal lead shielding and collimators for application with CZT/500S

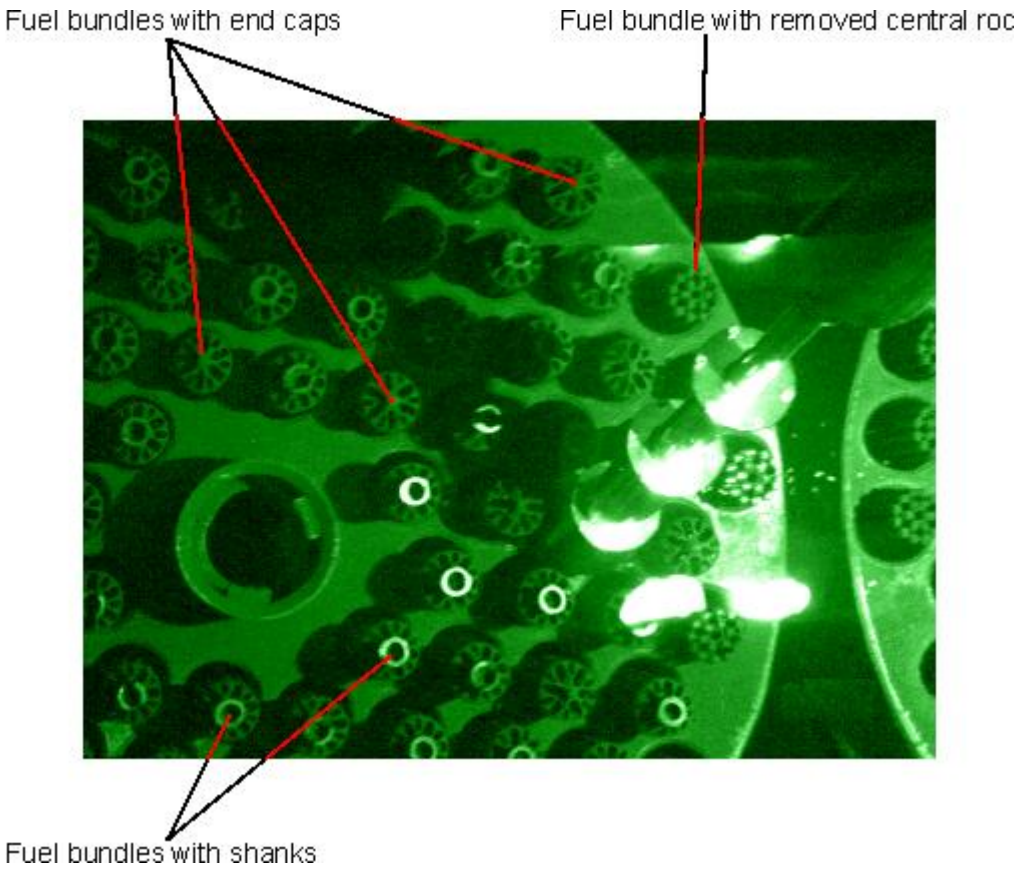
Equipped underwater measuring system

Internal lead shielding

Measuring scheme of spent fuel bundles in basket

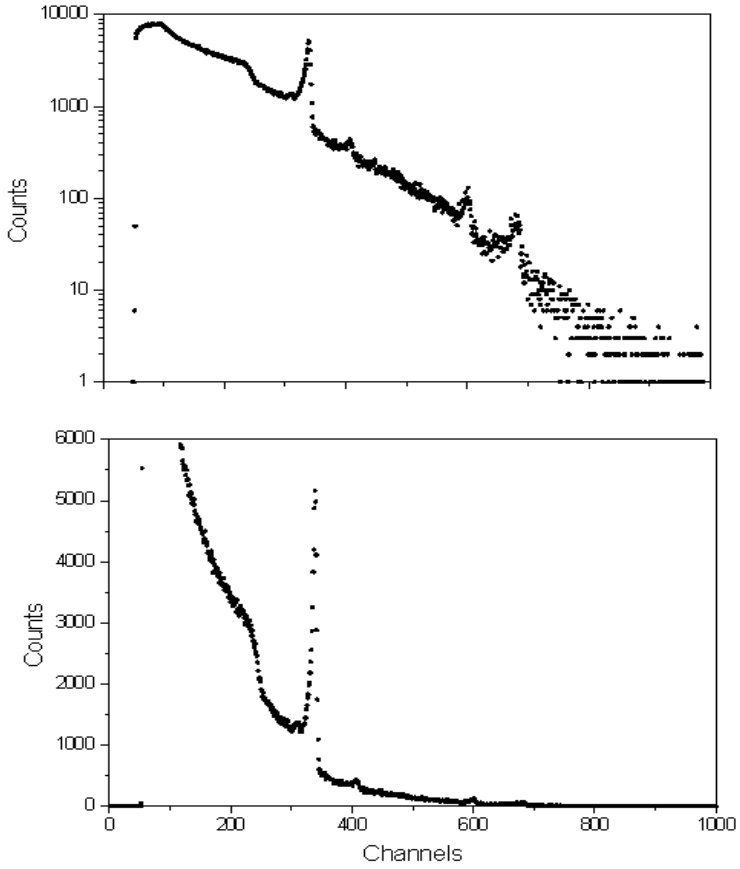


Basket with spent fuel bundles

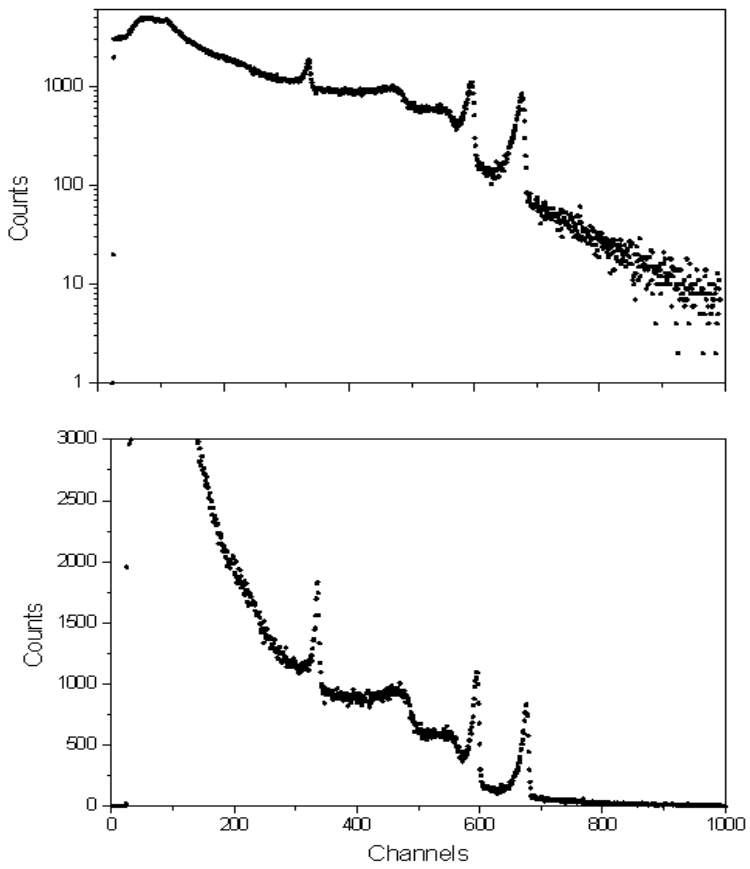


View from above,
4 m under water

Spectra of spent fuel bundles stored in baskets



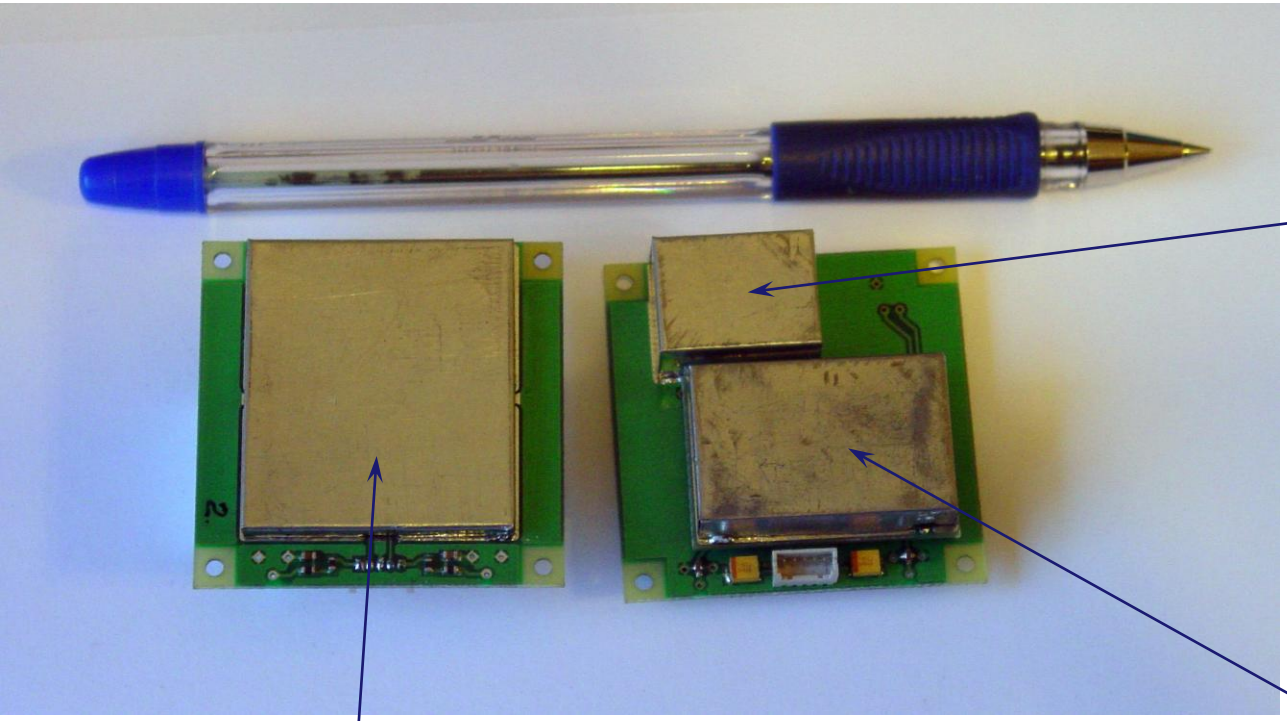
Spectrum of fuel bundle,
burn-up 1676 MWd/FA,
cooling time about 8 years



Spectrum of fuel bundle with shank,
burn-up 1857 MWd/FA,
cooling time about 13 years

PU/U attribute test system with CZT/500S detector and MCA-166

Detector module with quasi hemispherical CZT detector

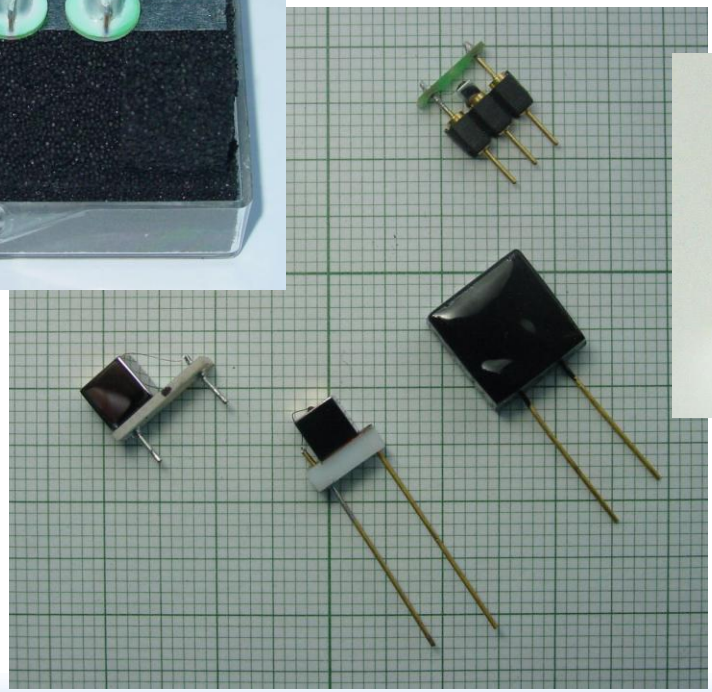


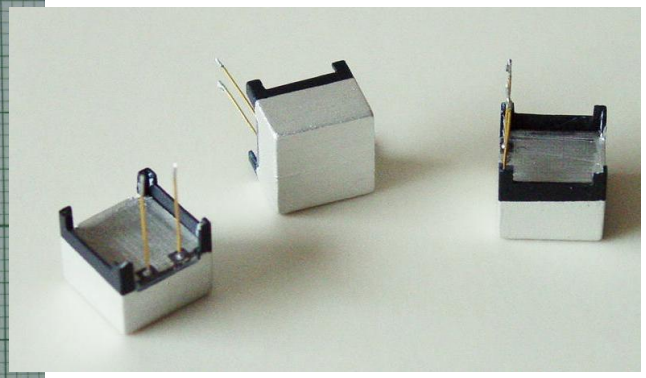
CZT detector of size 10x10x5 mm^3

High voltage power supply

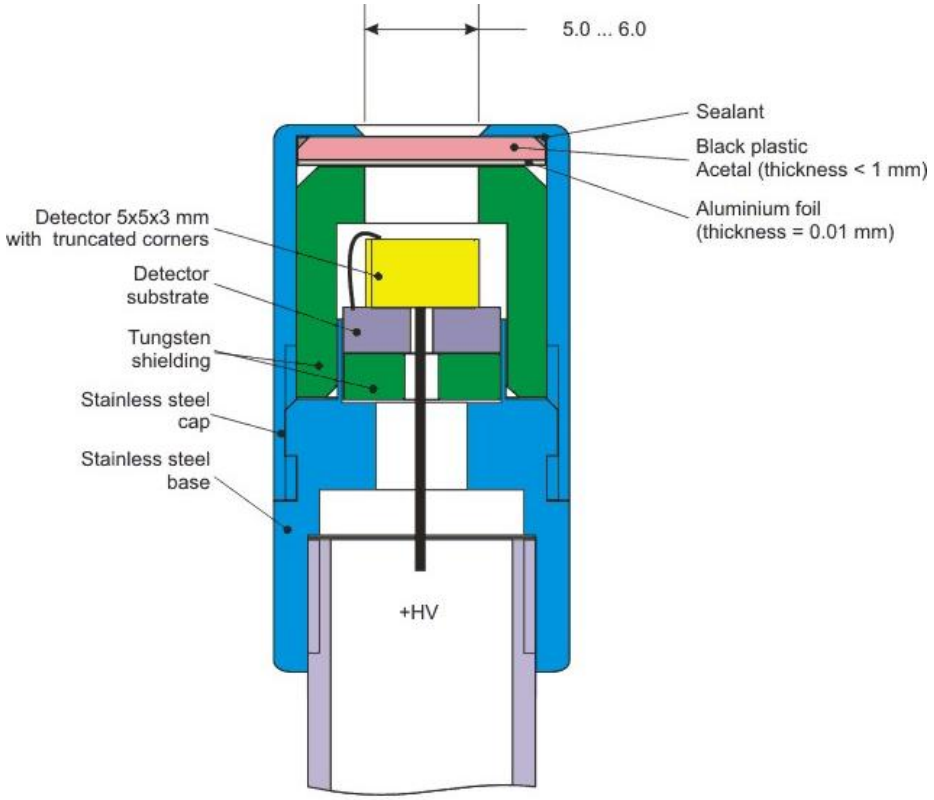
Charge sensitive preamplifier and shaping amplifier

Mounted planar CZT detectors for various application



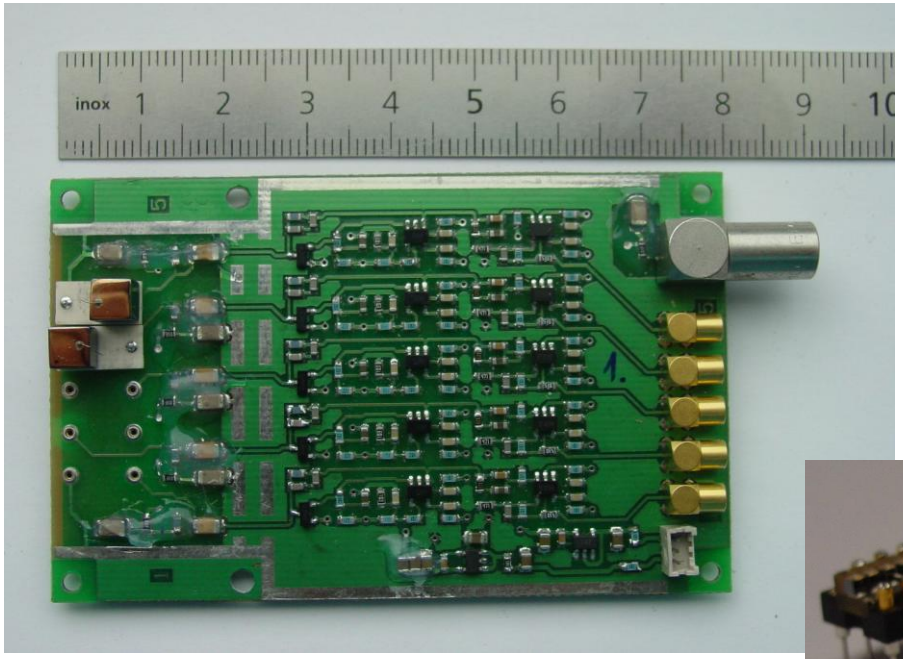


Surgical gamma-probes

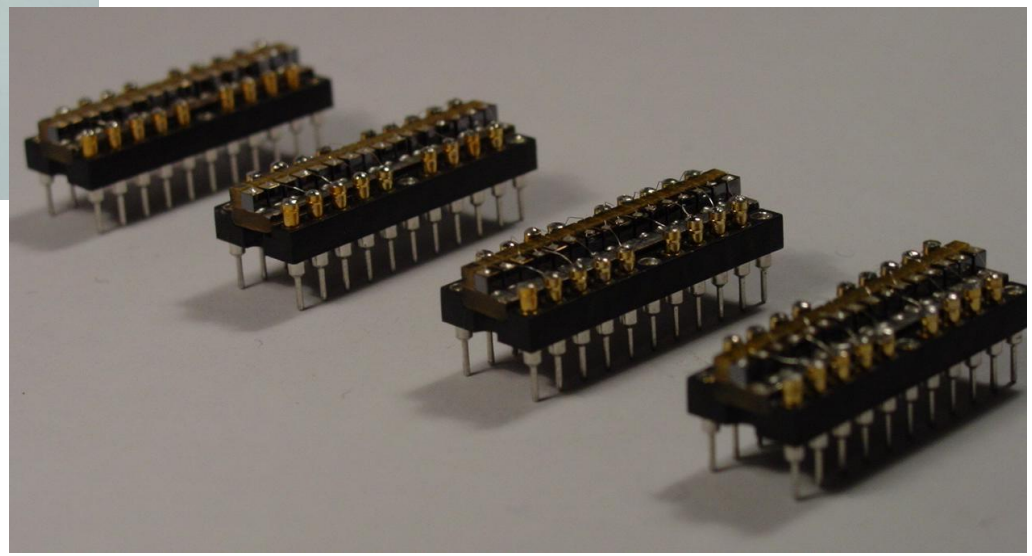


Schematic drawing of the surgical probe head

Linear arrays of planar CZT detectors

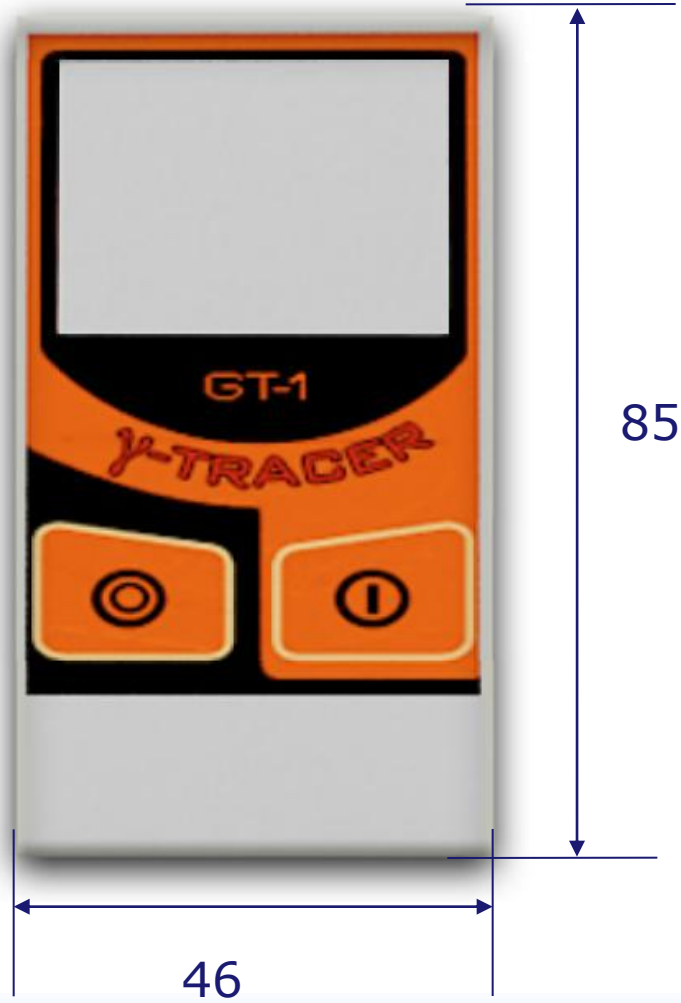


5 elements module
(with preamplifiers)



16 elements assembly

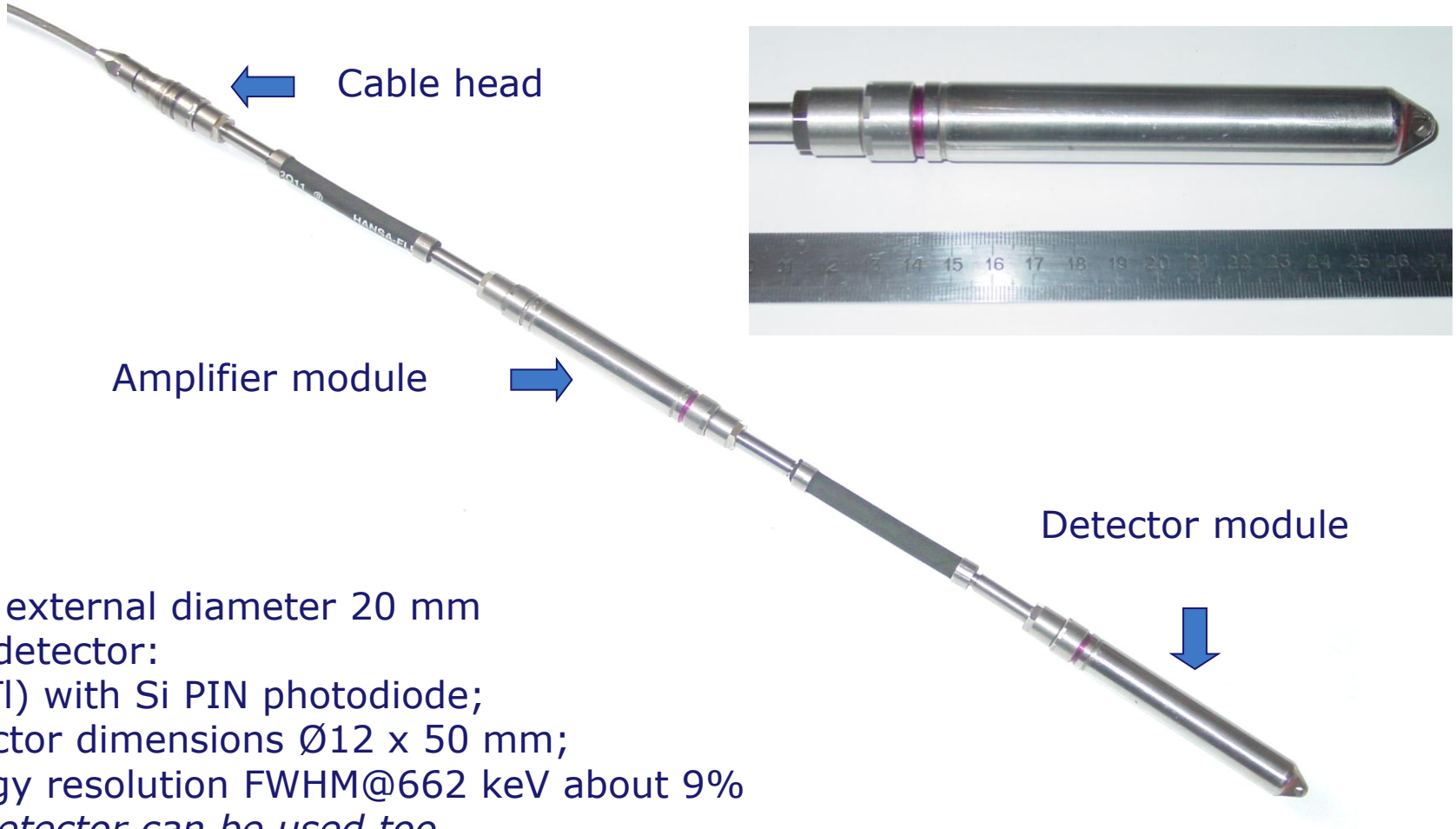
Personal radiation detector (PRD) γ-TRACER GT1



Used CZT detector:

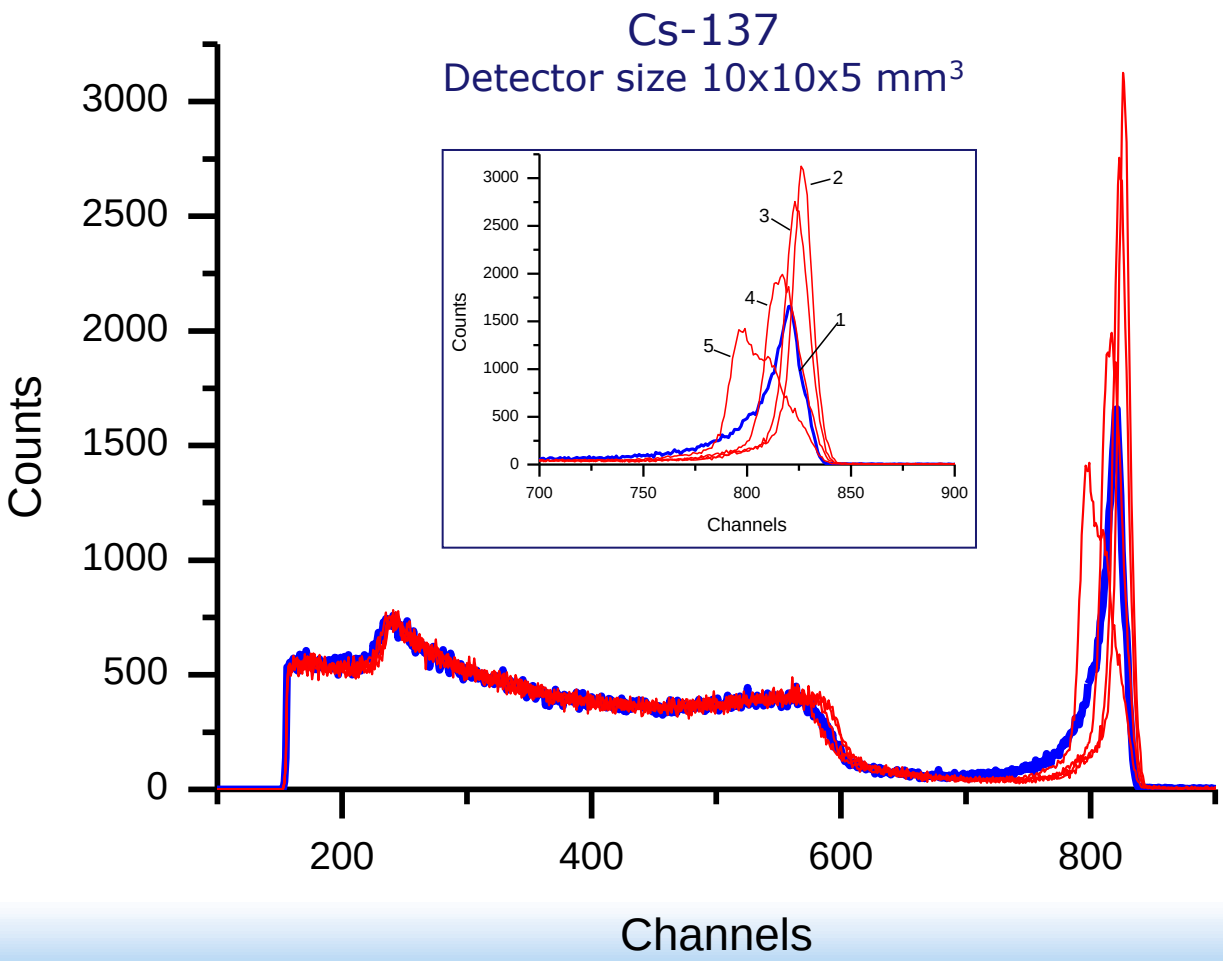
- area 2 cm^2;
- volume 0.4 cm^3.

Geological borehole logging probe



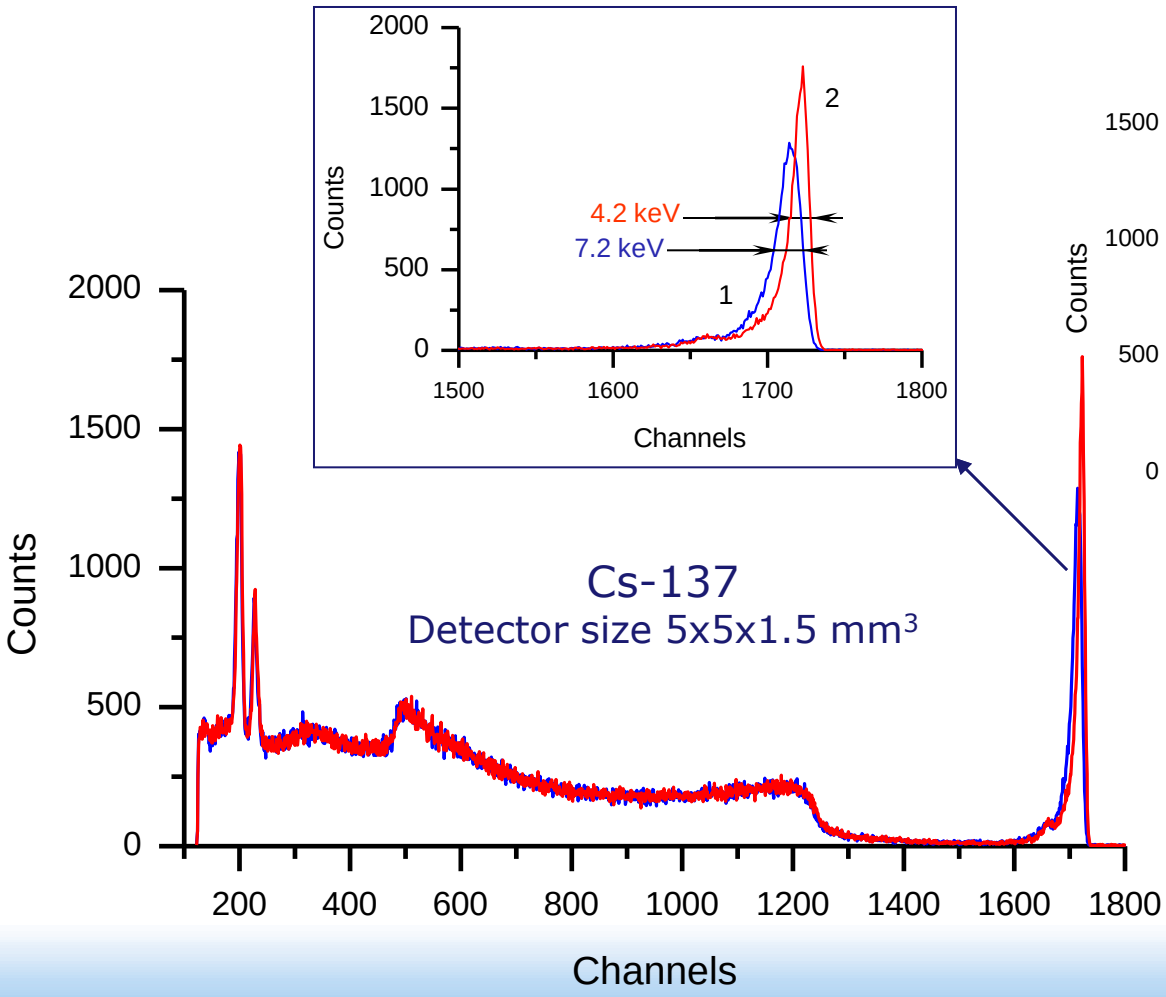
Probe external diameter 20 mm
Used detector:
-CsI(Tl) with Si PIN photodiode;
-Detector dimensions Ø12 x 50 mm;
-Energy resolution FWHM@662 keV about 9%
CZT detector can be used too.

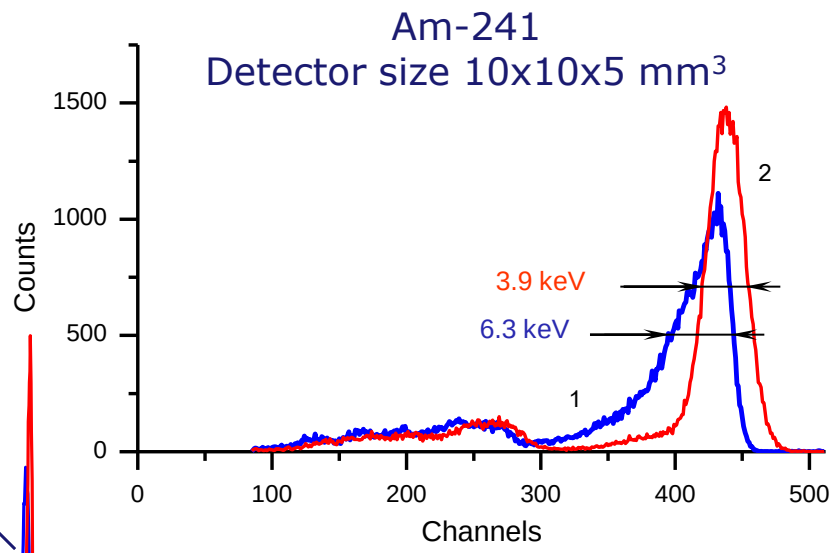
Spectra of Cs-137 measured with quasi-hemispherical detector of 10x10x5 mm^3 under IR stimulation



Operating voltage – 1000V
Illumination by IR LED IR 204, 940 nm
Radiant power:
1 – without illumination
FWHM@662 keV – 14.9 keV
2 – 200 mkW
FWHM@662 keV – 8.6 keV
3 – 250 mkW
4 – 300 mkW
5 – 340 mkW

Spectra of Am-241 and Cs-137 measured with quasi-hemispherical detectors without and with IR illumination





1 – without IR illumination

2 – with IR illumination 940 nm

Spectrometric characteristics of different CdZnTe quasi-hemispherical detectors measured without and with IR stimulation

No.	Detector size, mm^3	Operating voltage, V	Energy resolution (FWHM) at 662 keV, keV		Peak-to-Compton ratio at 662 keV		Energy resolution (FWHM) at 59.5 keV, keV	
			Without IR illumination	With IR illumination	Without IR illumination	With IR illumination	Without IR illumination	With IR illumination
1	10x10x5	900	20,6	9,6	3	7,6		
2	10x10x5	1400	9,8	8,1	7,1	10	6,3	3,8
3	7x7x3.5	600	27,1	16,2	2,5	4,2		
4	7x7x3.5	600	6,4	5,1	9,4	12,6	5,4	2,8
5	5x5x2.5	500	24,5	10,8	1,8	5,4		
6	5x5x2.5	500	7,2	4,7	7,4	10	3,3	2,4
7	3x3x1.5	300	6,9	5,5	5,4	6,3		

Thank You for attention!

http://www.ritec.lv
e-mail:ritec@ritec.lv