In-situ radionuclide quantitative characterization in aquatic ecosystems using the KATERINA detector

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Collaboration

Developed and constructed at
Hellenic Centre for Marine Research (HCMR)

Calibrations performed at
National Technical University of Athens (NTUA)

Simulations performed in collaboration with NTUA

Outline

- Status of measuring techniques for marine radioactivity
- The KATERINA system
- Laboratory facilities – calibrations
- Monte Carlo Simulations (GEANT4 code)
- Real Time operation (POSEIDON network)
- Field measurements
- Comparison
- Future Plans

Status of Measuring Techniques

- Lab based Technique

  Traditional Sampling and Laboratory Analysis by using HpGe detectors.

  The method is applied at HCMR for NORM and ^{137}Cs analysis.

- In-Situ Monitoring Technique (option to Real-Time)

  Detectors: HPGe in-situ (high consumption) and NaI(~1-2W)

Radioprotection and Oceanographic applications (Geophysical and Meteorological)

<u>Advantages in radioprotection:</u>

1) Screening of Contaminated areas concerning facilities which pollute the marine environment
2) Mapping of large areas to estimate levels and distribution of N/A radionuclides
3) Information on the nature of radioactive substances contained in underwater objects
4) Continuous monitoring and Real-Time data transmission provides early warning

<u>In situ Applications:</u>

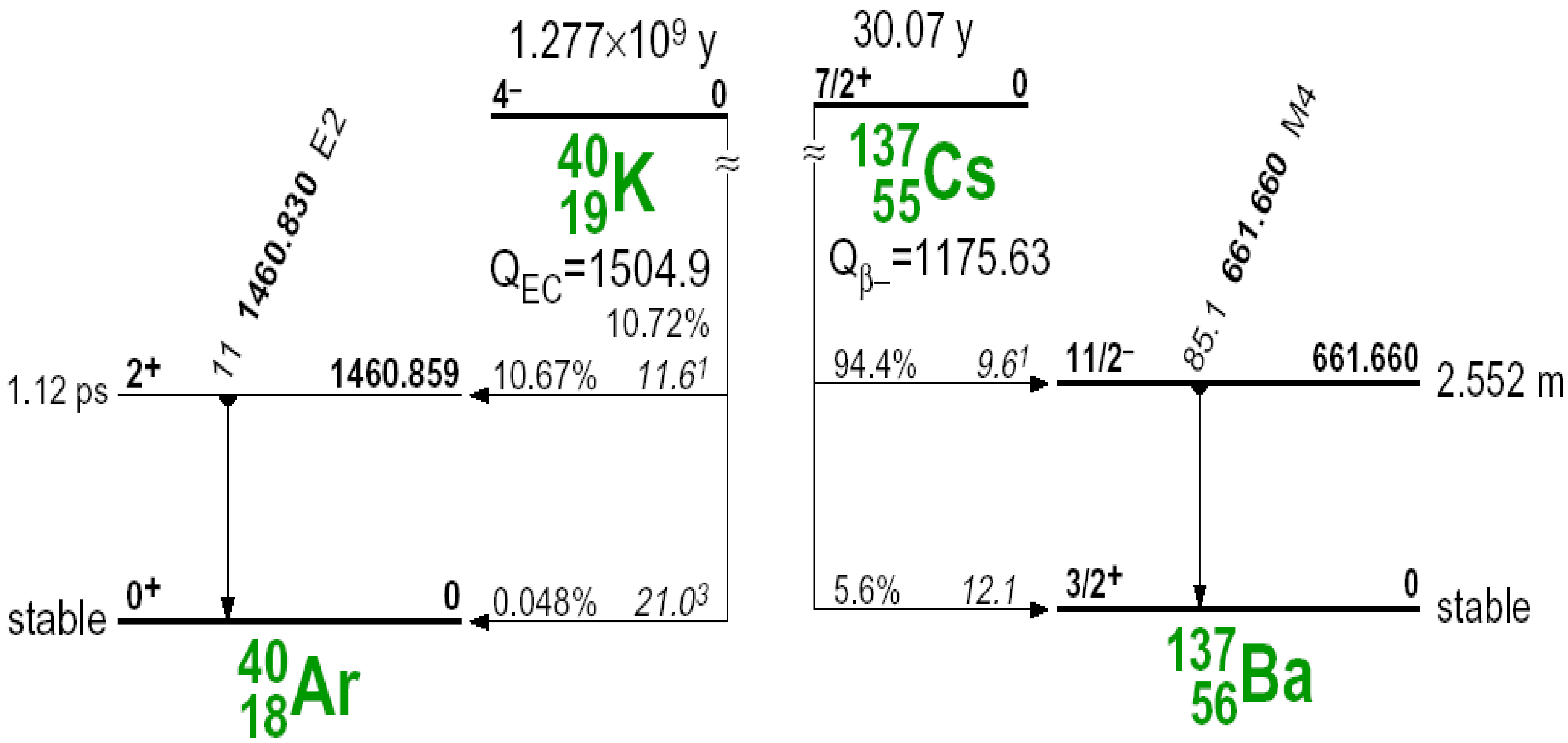
Radon daughters measurements on Submarine Groundwater Discharge

Radon daughters measurements near fault region

Radon daughters variations on rainfall

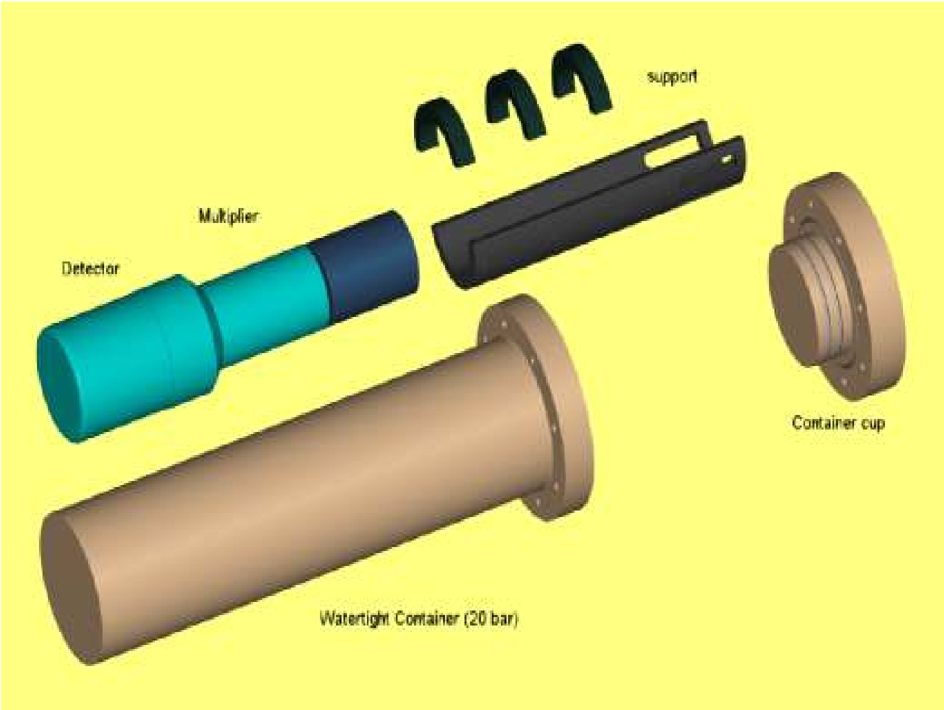
Seabed mapping

^{40}K and ^{137}Cs decay schemes



- They belong to the first group at the periodic table
- They are monoenergetic gamma emitters

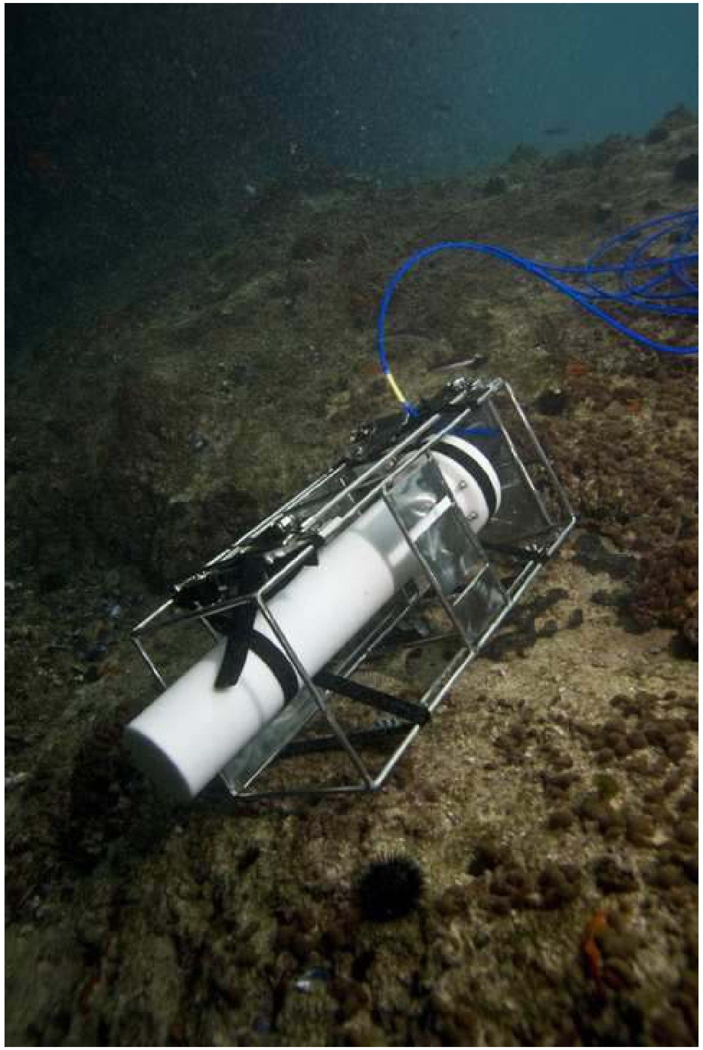
The underwater spectrometer KATERINA patented INT.CL: G01T 7/00



Specifications

- Crystal: 3x3” NaI
- Consumption ~ 1.2 W (100mA)
- Resolution at 662keV: <6**%**
- Variable Energy Range
- Adjustable spectroscopy: max of 2048 channels
- Operating Temperature: 0-50^{0}C.
- Correction for voltage drifts.
- Adjustable HV voltage
- Adjustable amplifier gain, PZC and shaping time.
- Autonomy (without PC connect)
- Option for Real Time (software independent)

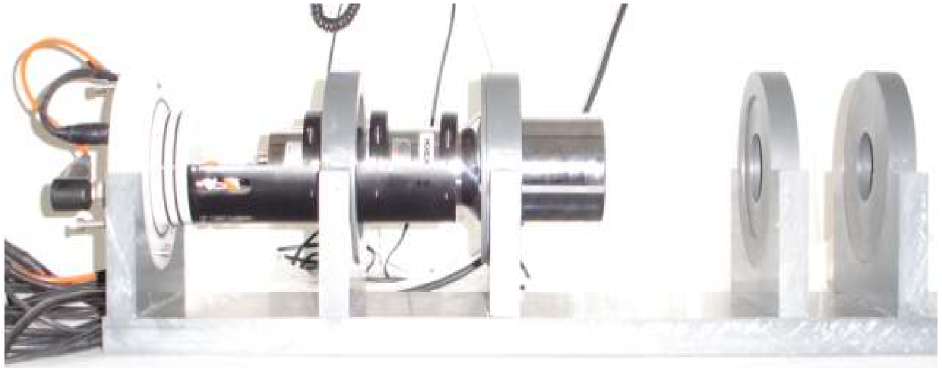
Hardware

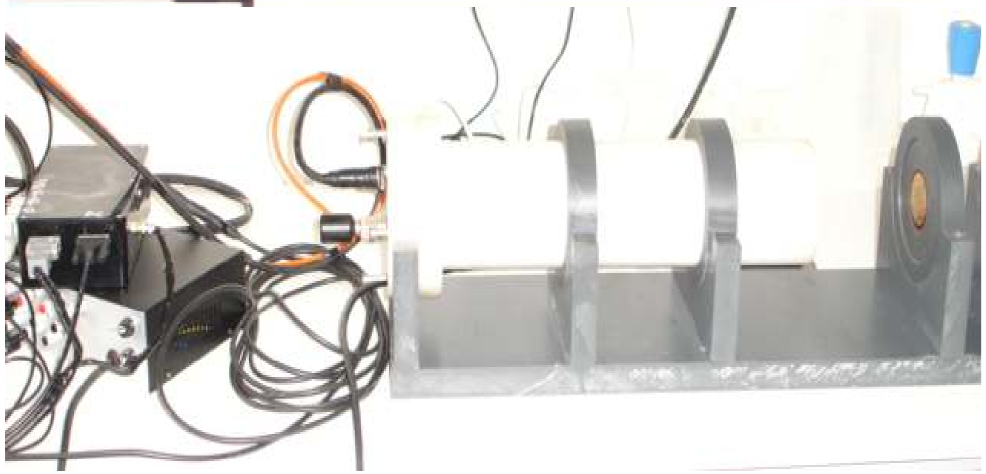


- Analog Nuclear Electronics (Pre-amplifier, Shaping Amplifier + Gain + Base Line Restoration + Pole Zero Cancellation + shaping time).
- Digital Electronics (Multichannel Analyzer + successive approximation ADC + RS232 and USB Interface).

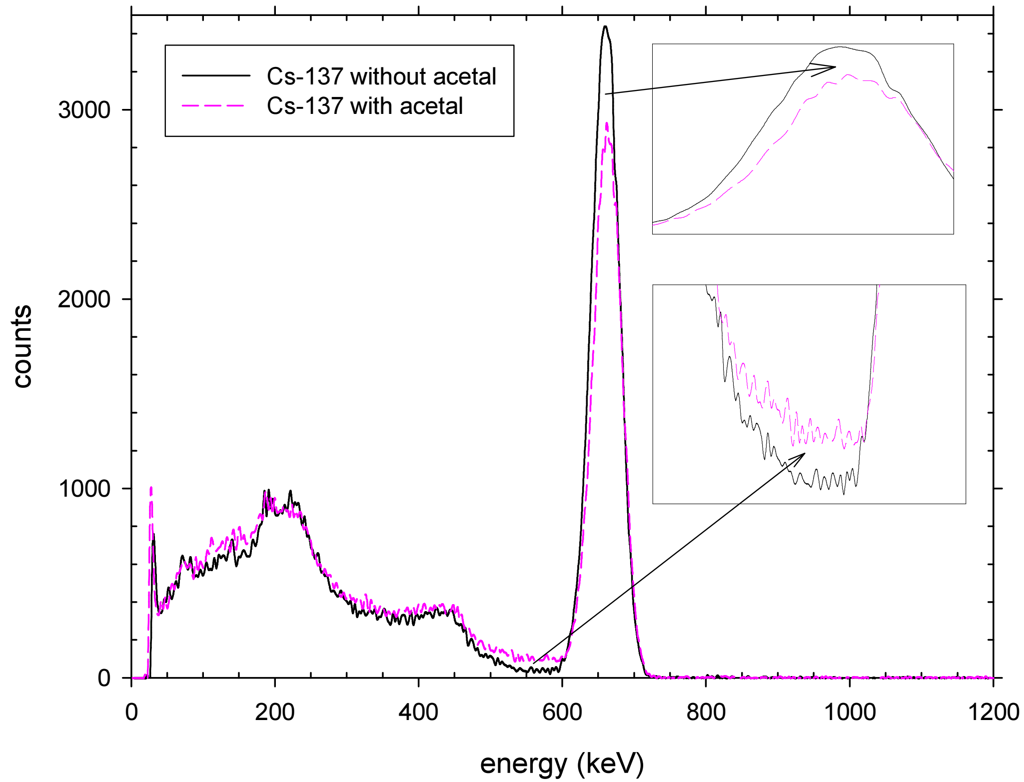
Experimental set up (lab)

- Point sources calibration (15cm and 25 cm)
- Without housing (first figure)
- With housing (second figure)





Comparison for ^{137}Cs (with and without the housing)

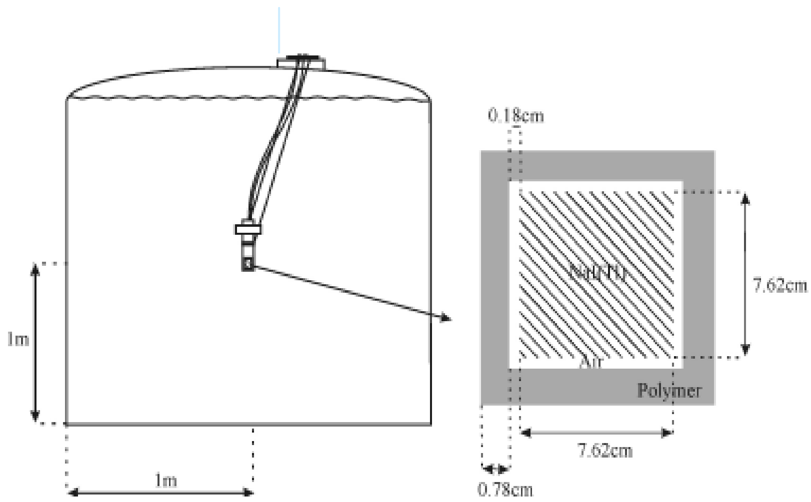


- Similar energy resolution
- Similar Compton tail
- variation of the total efficiency
- Peak to total ratio variation

Marine Calibration Sources

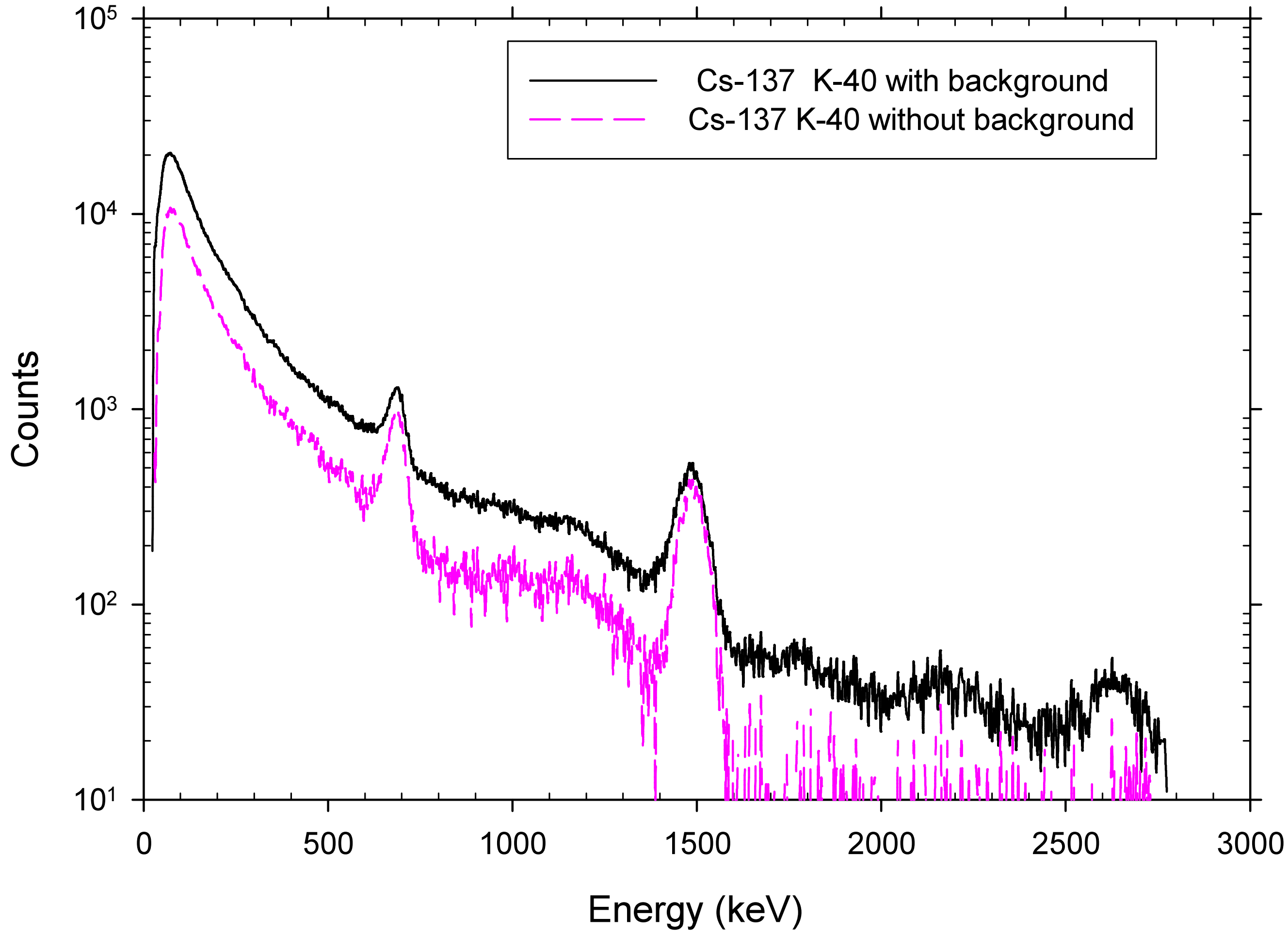
Gamma ray sources	Half Life
- ^{40}K (1461keV)	1.3×10^9 years
- ^{137}Cs (661keV)	30.17 years
- ^{99m}Tc (141 keV)	6 hours
- ^{111}In (162, 246 keV)	67.9 hours

Laboratory facility at NTUA

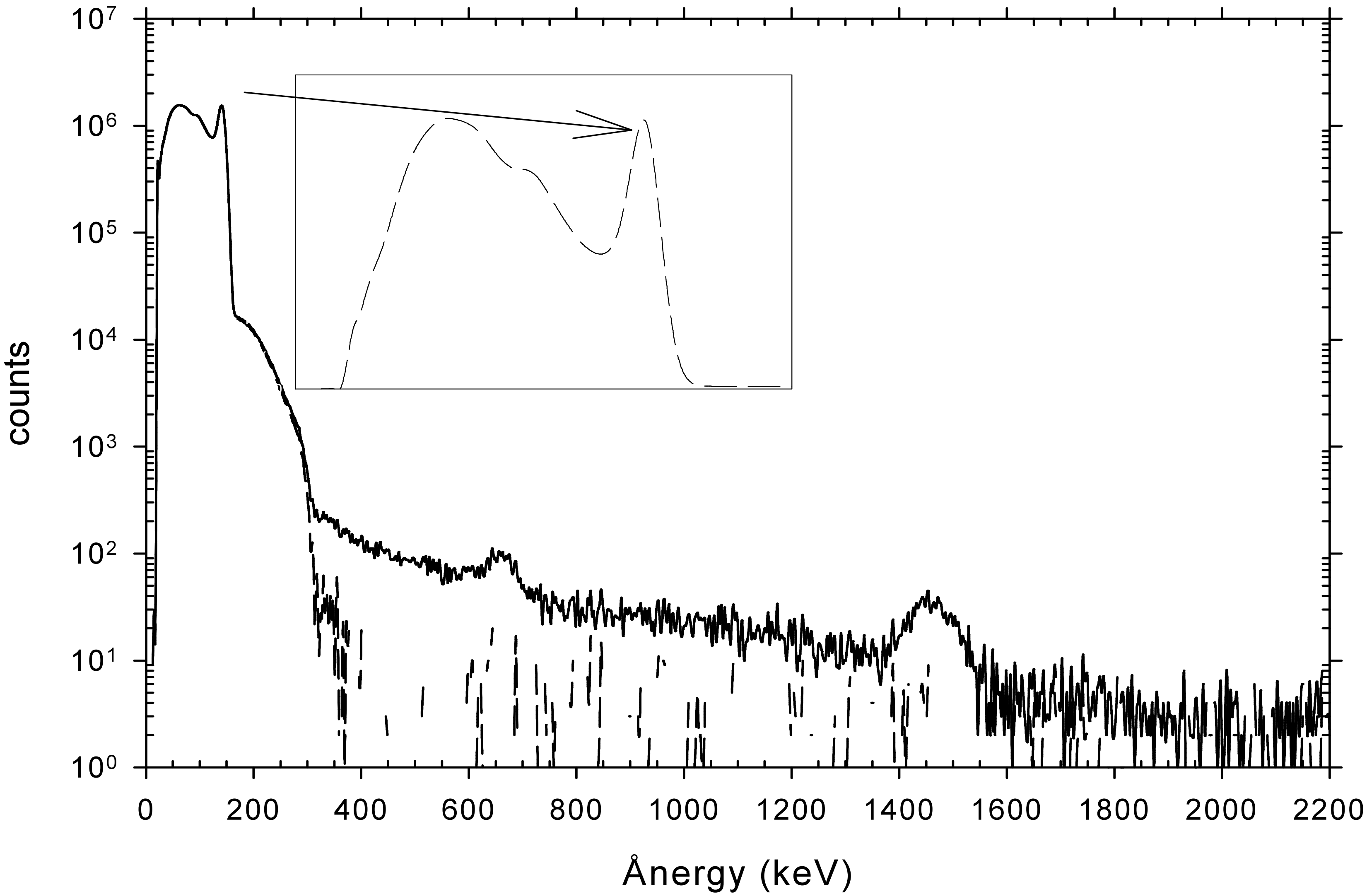


- Tank with volume of 5.5m^3
- Pump for circulation of the water
- Hardware and software for the acquisition
- The SPECTRG software package for the analysis of the measured data (NCSR "Demokritos")

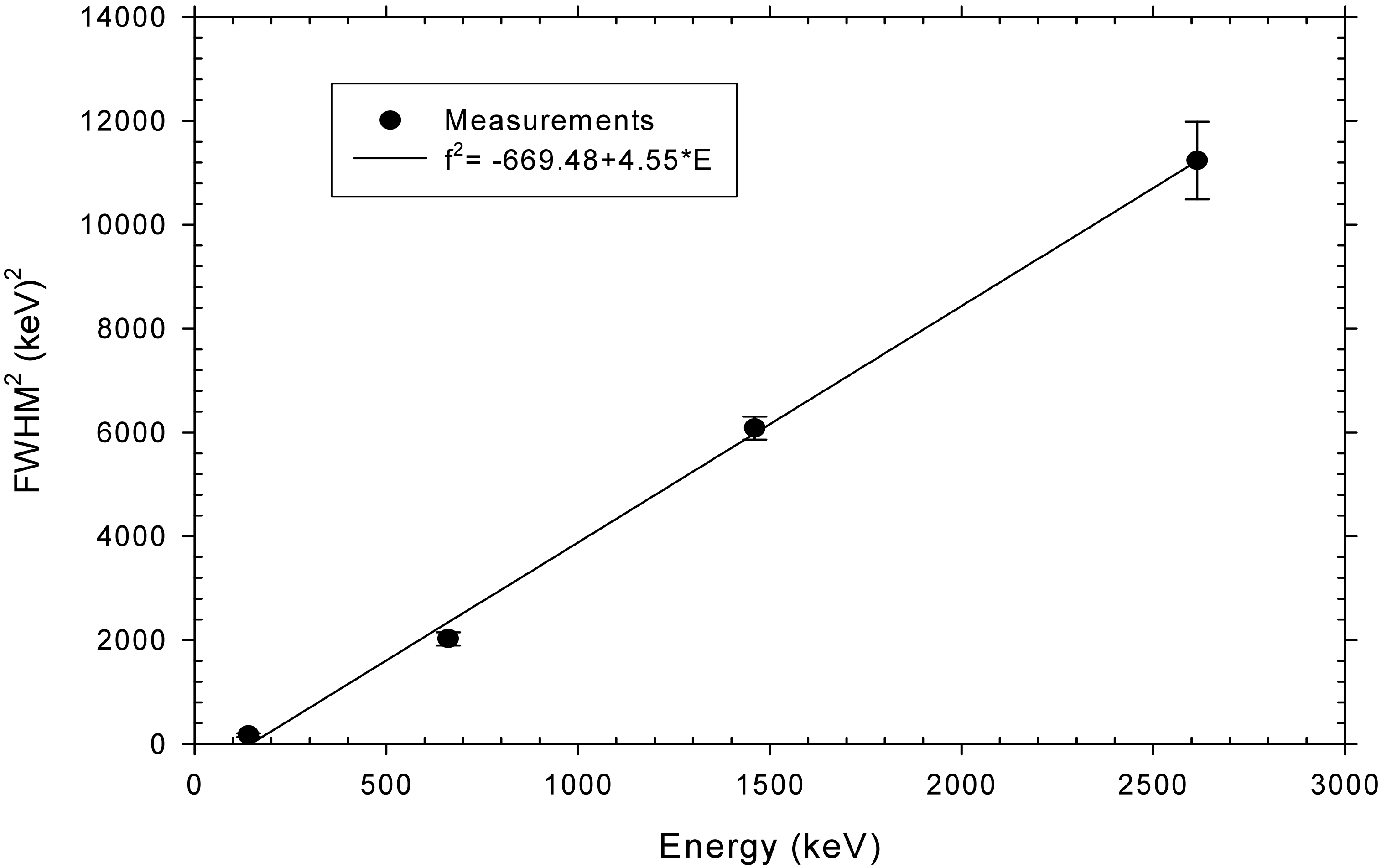
Calibration spectra



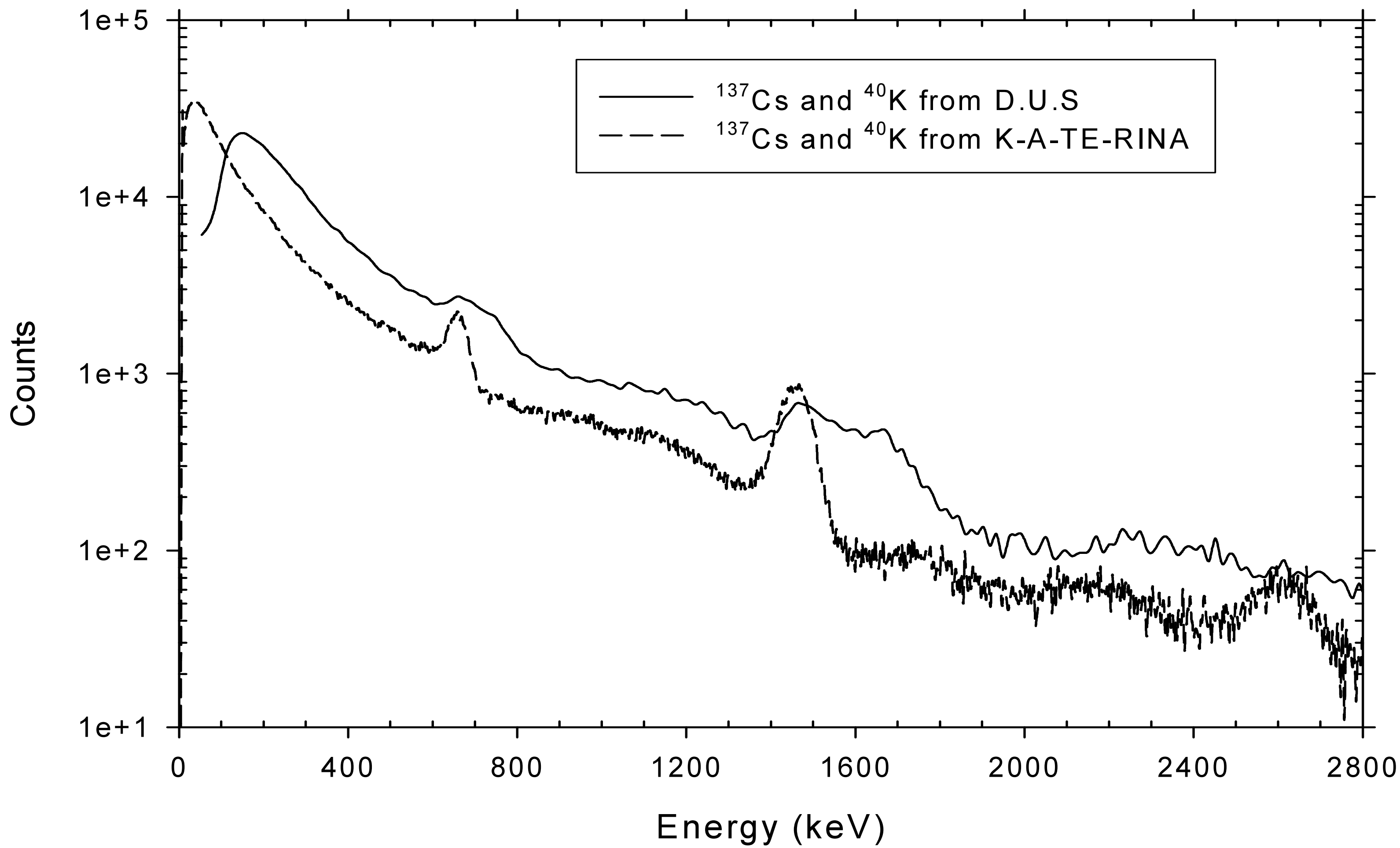
Continued (^{99m}Tc)



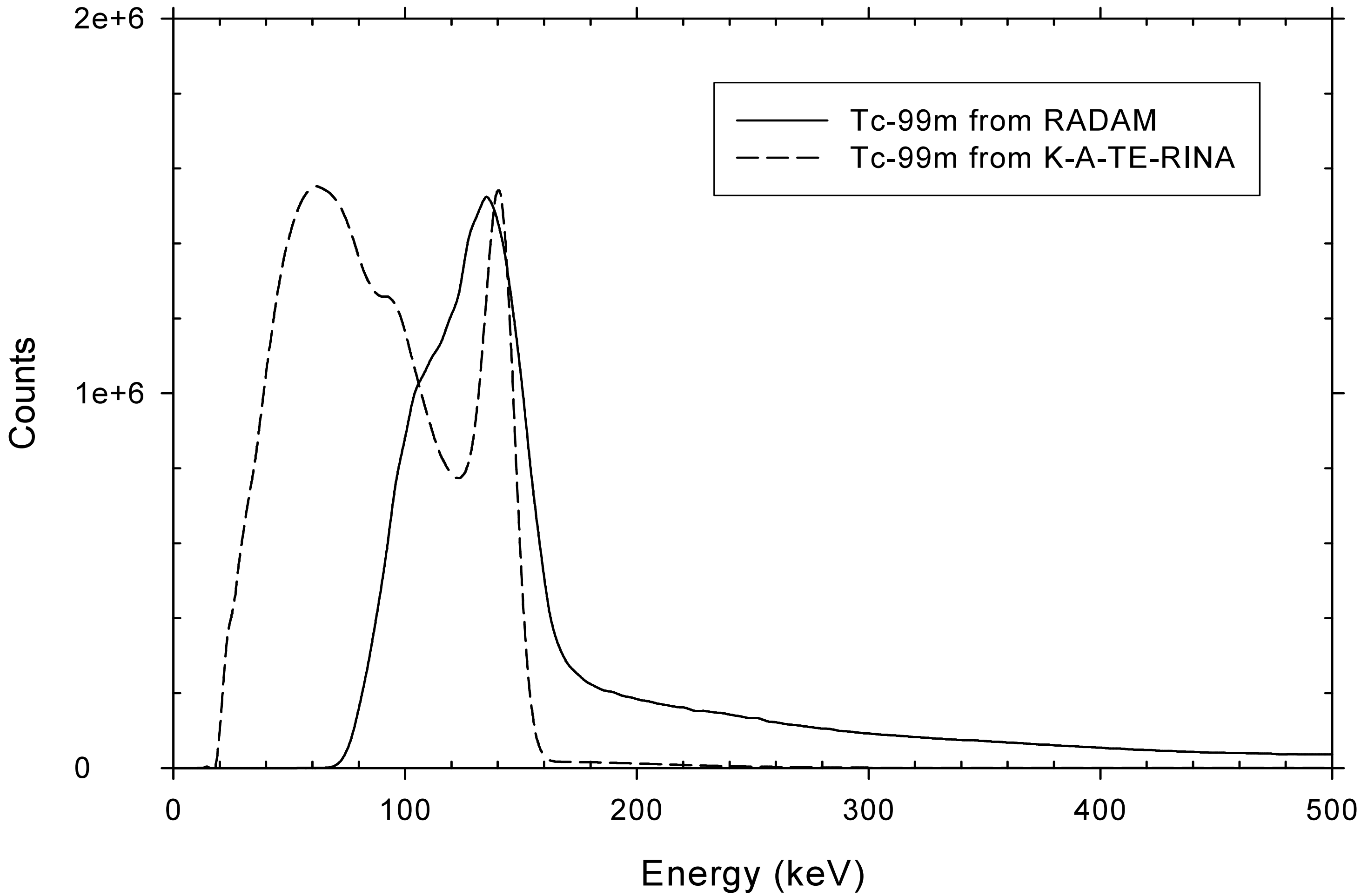
Resolution calibration



Comparison with DUS system

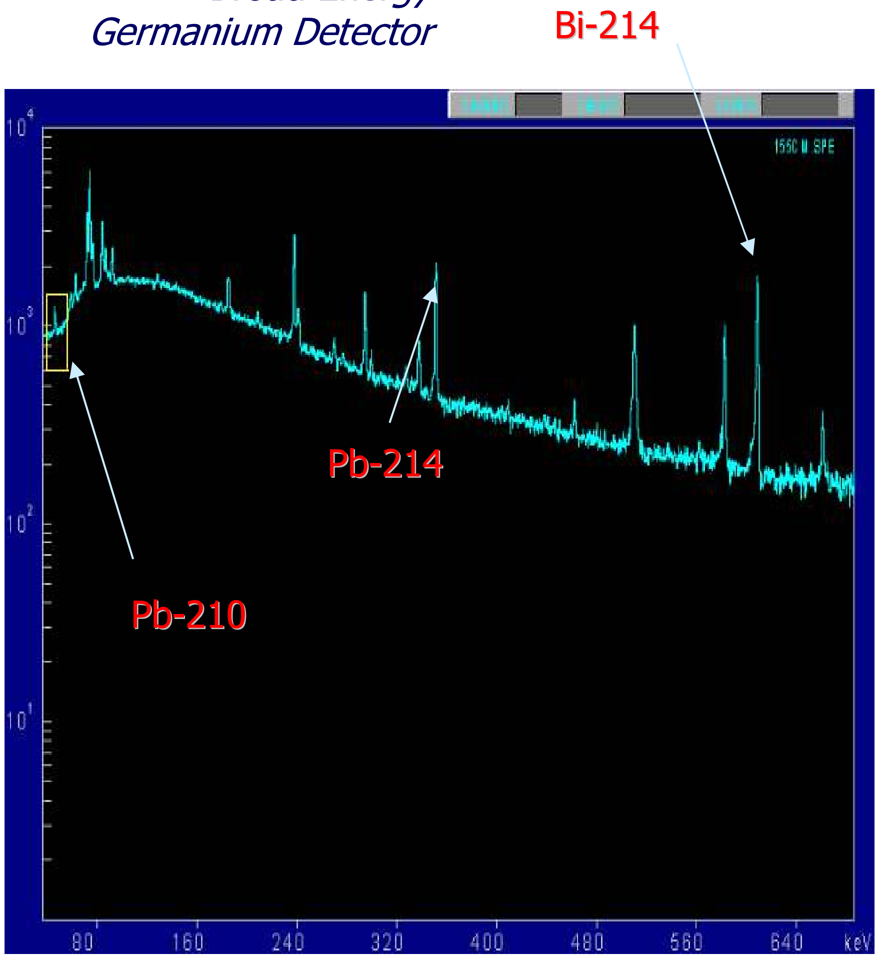


Comparison with RADAM system (^{99m}Tc)



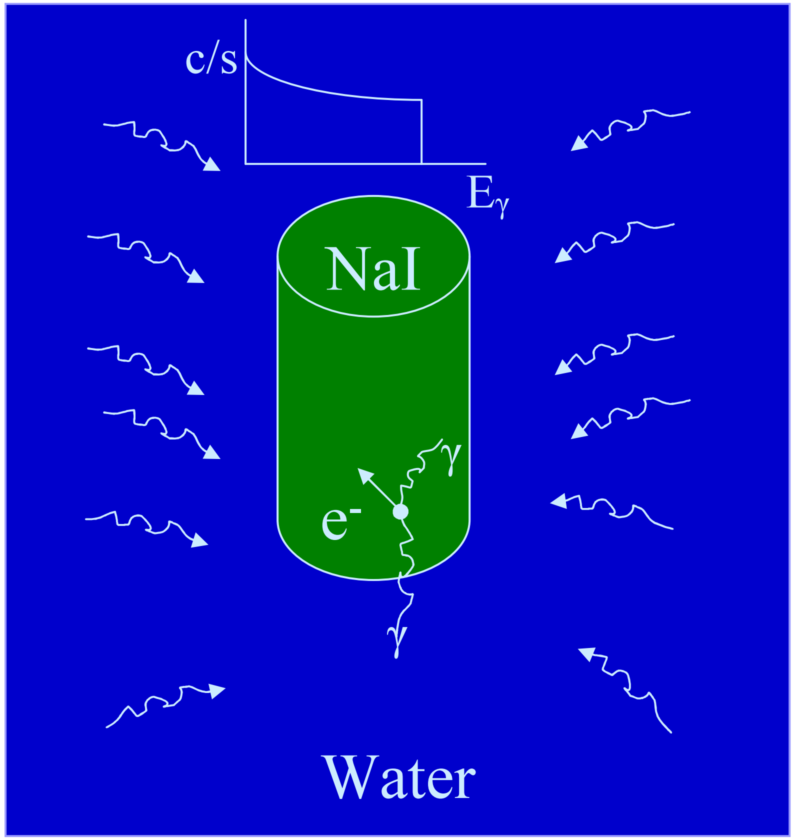
Intercalibration exercises (in-situ and lab)

Broad Energy Germanium Detector



	^{214}Pb (Bq/l)	^{214}Bi (Bq/l)	^{208}Tl (Bq/l)	^{137}Cs (Bq/l)
in-situ	1.7±0.2	1.9±0.1	0.12±0.01	0.012±0.003
lab	1.9±0.2	2.0+0.2	0.10±0.02	0.010±0.001

Monte Carlo Simulation using GEANT4

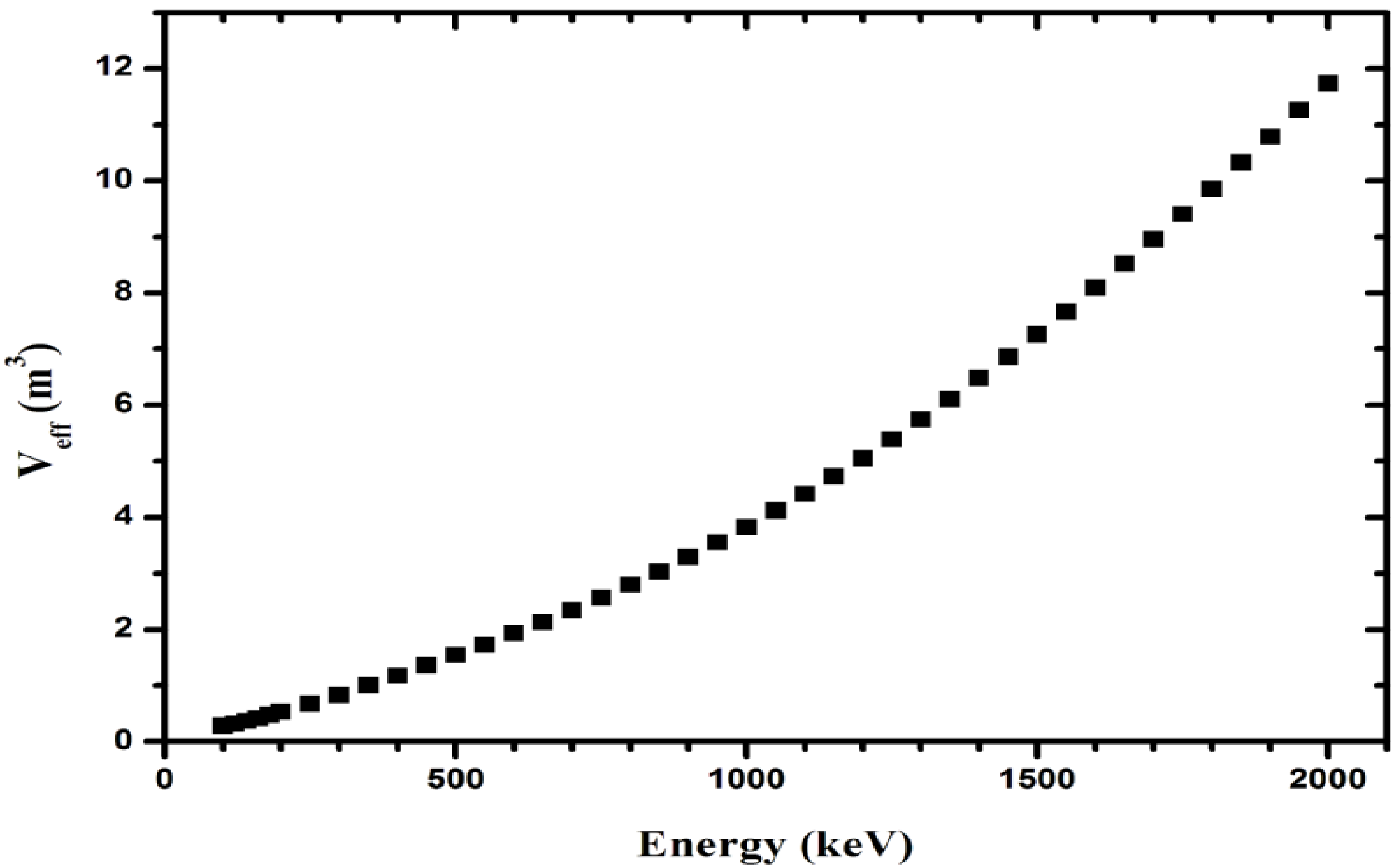


Taking into account the typical interactions in the water, in the material of the housing and in the NaI crystal.

<u>Interactions</u>

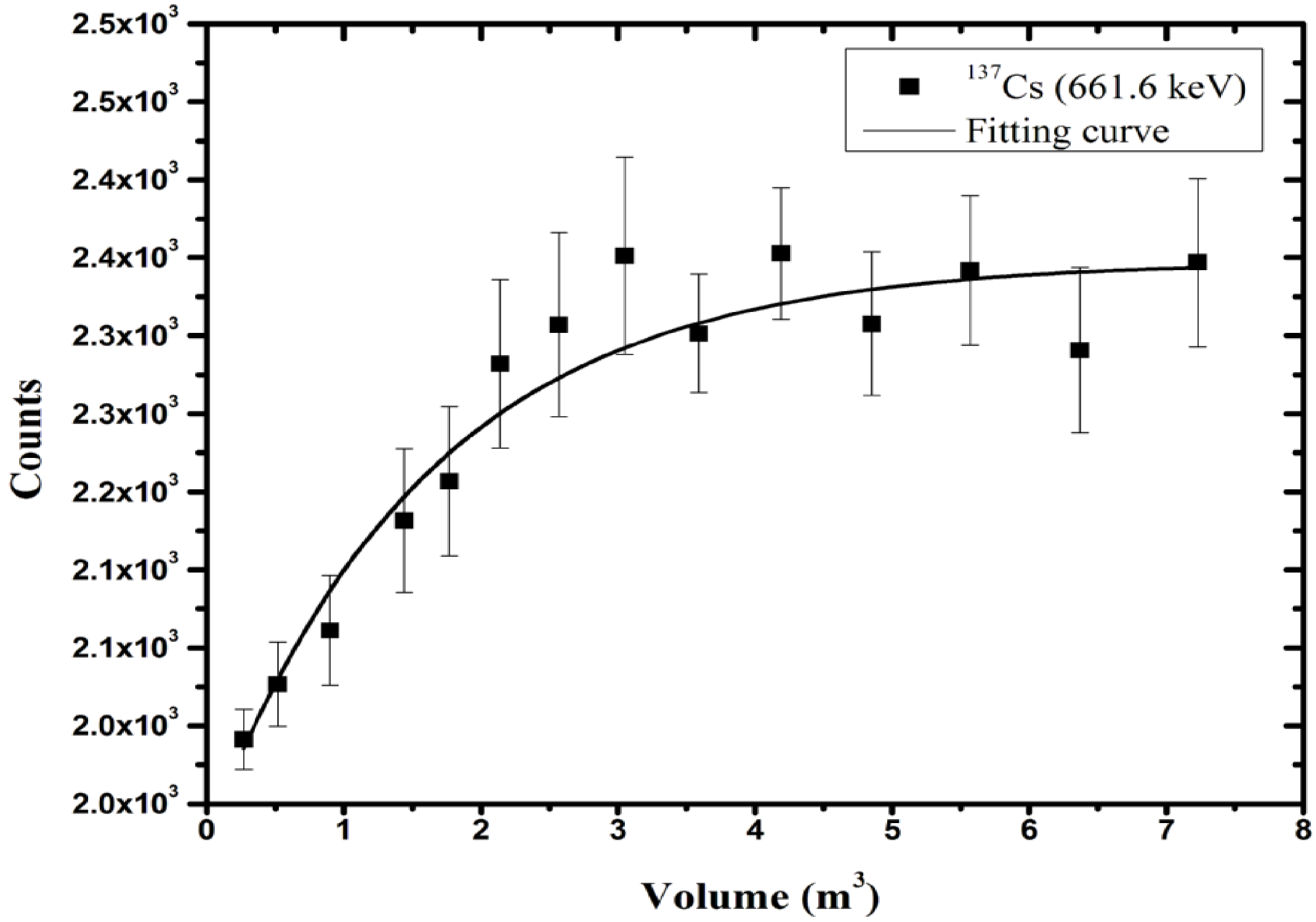
- Compton scattering
- Photoelectric
- Pair production

Effective volume of gamma rays in water

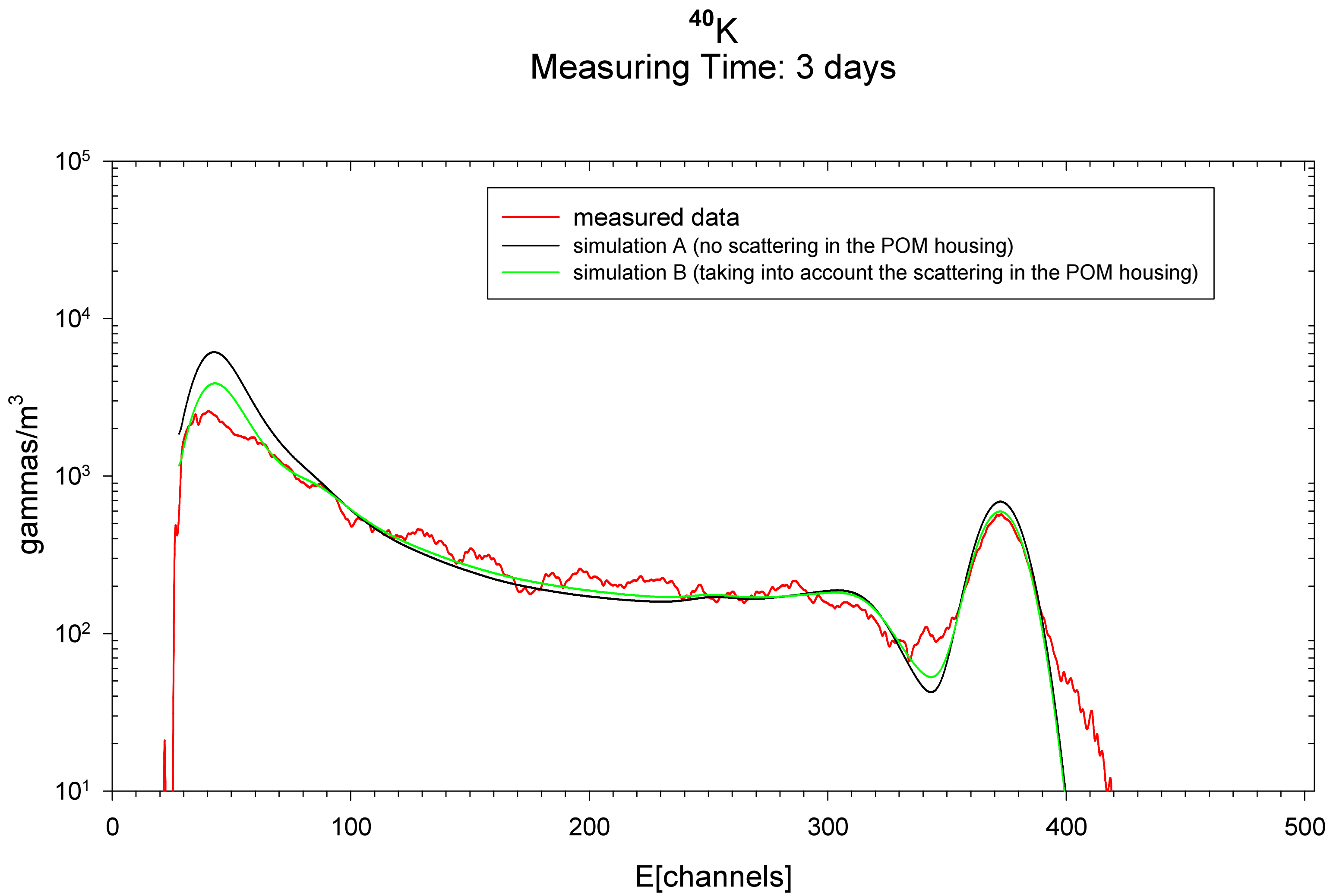


Simulated values of V_{eff}

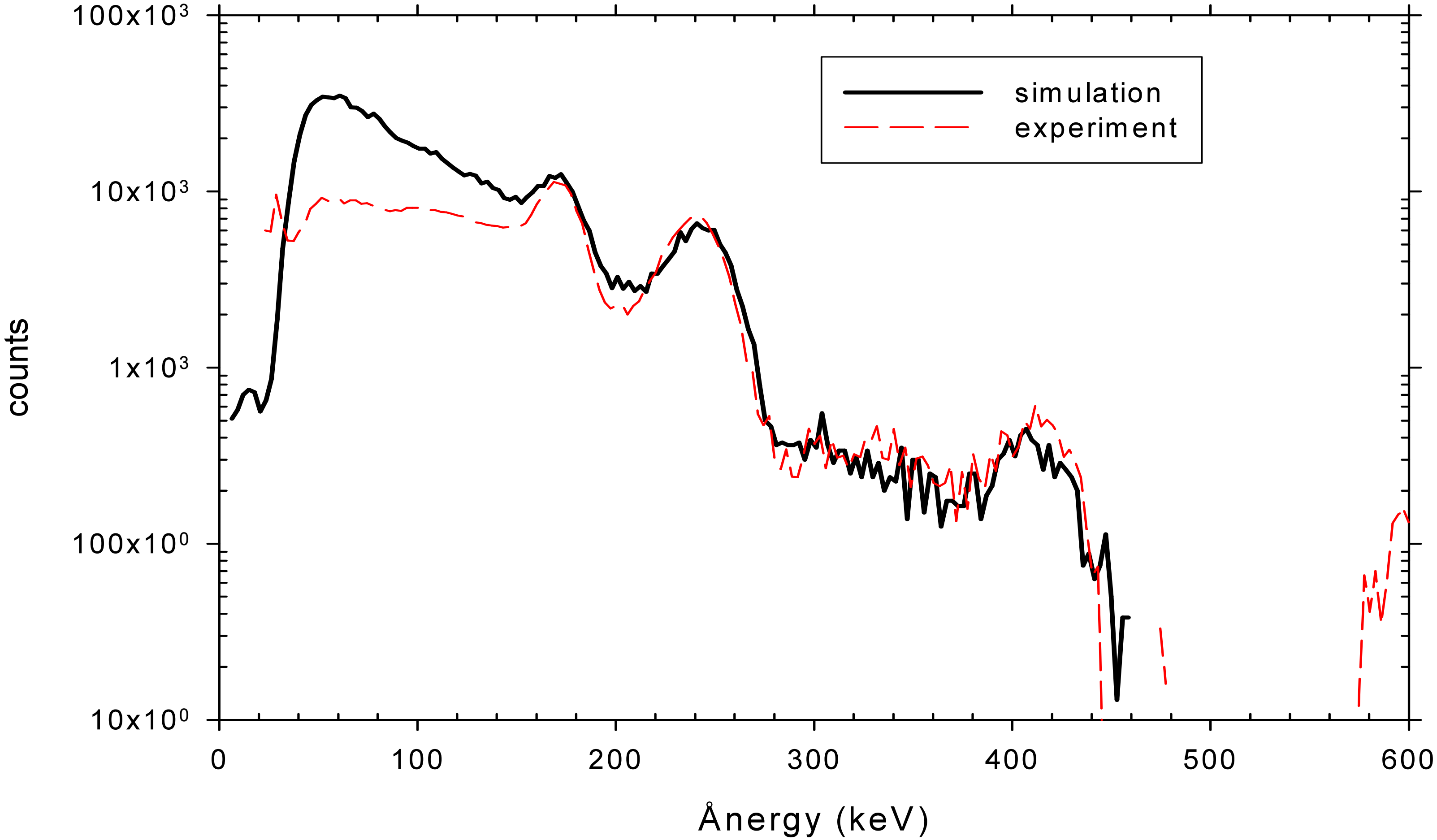
Photopeak counts versus volume, input: 2,000,000 gammas/m³



Simulated ^{40}K spectrum



Simulated spectrum of ^{111}In



Efficiency simulation with GEANT4

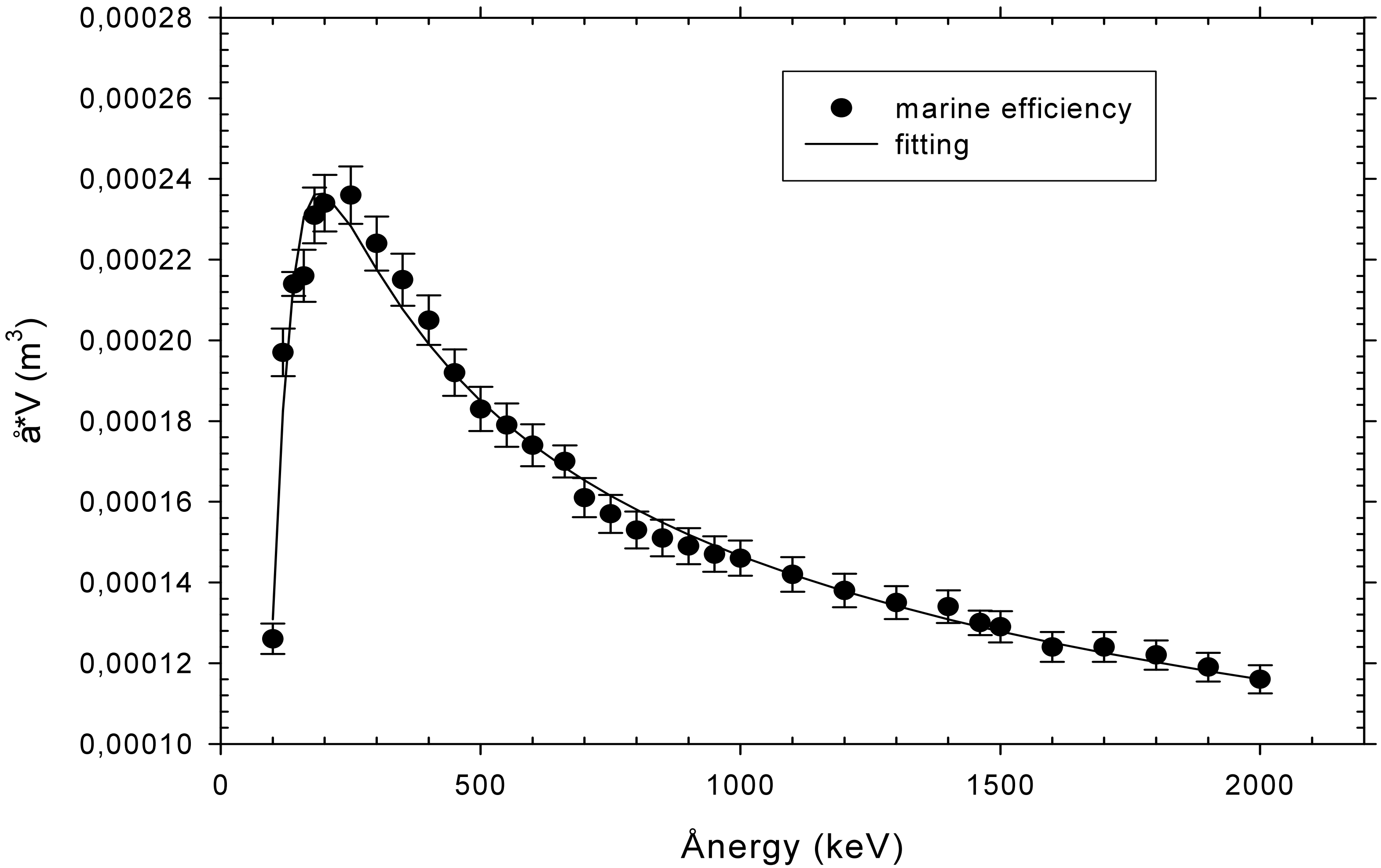
1) Running the code with constant number of gammas/m^3 (~2,000,000 gammas/m^3)

2) Volume values are above the V_{eff}

$$\varepsilon_m = \varepsilon_{ph} V_{eff} = \frac{N_{photopeak}}{N_{total} / V}$$

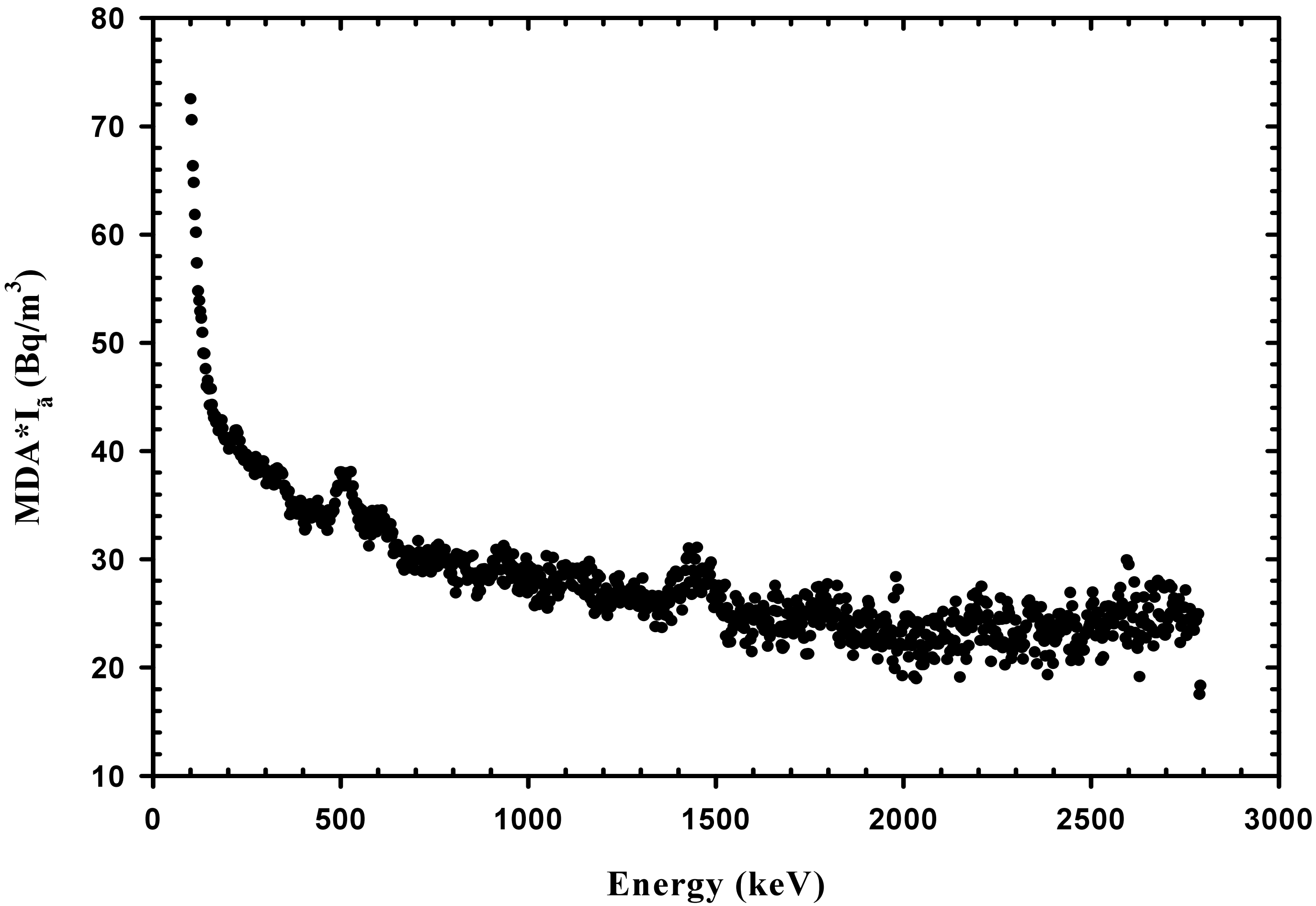
Simulated Marine efficiency

published in Env. Mon. & Assessment

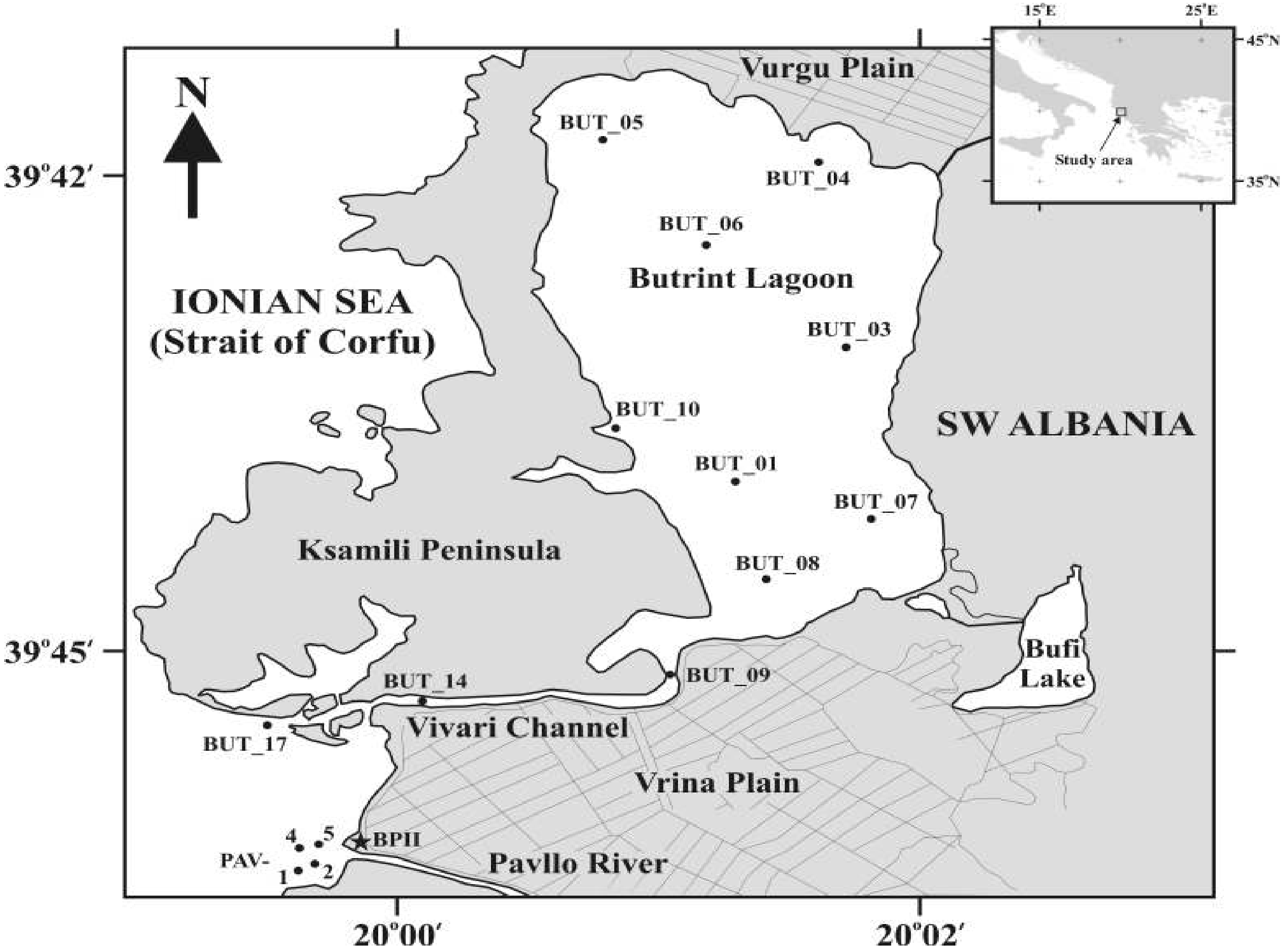


Minimum Detectable Activity

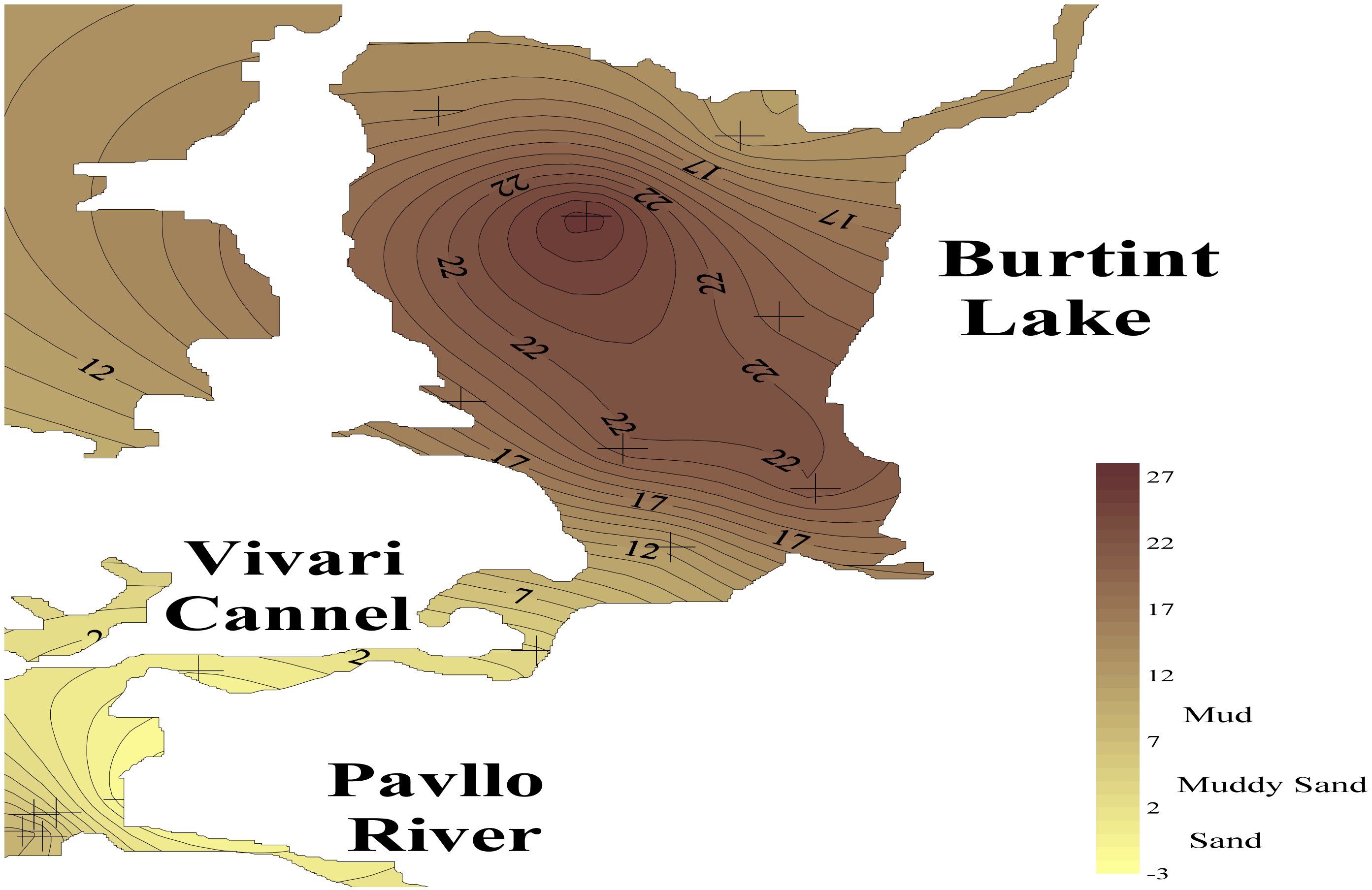
published in Env. Mon. & Assessment



Natural and anthropogenic R/N in Butrint lagoon, Albania

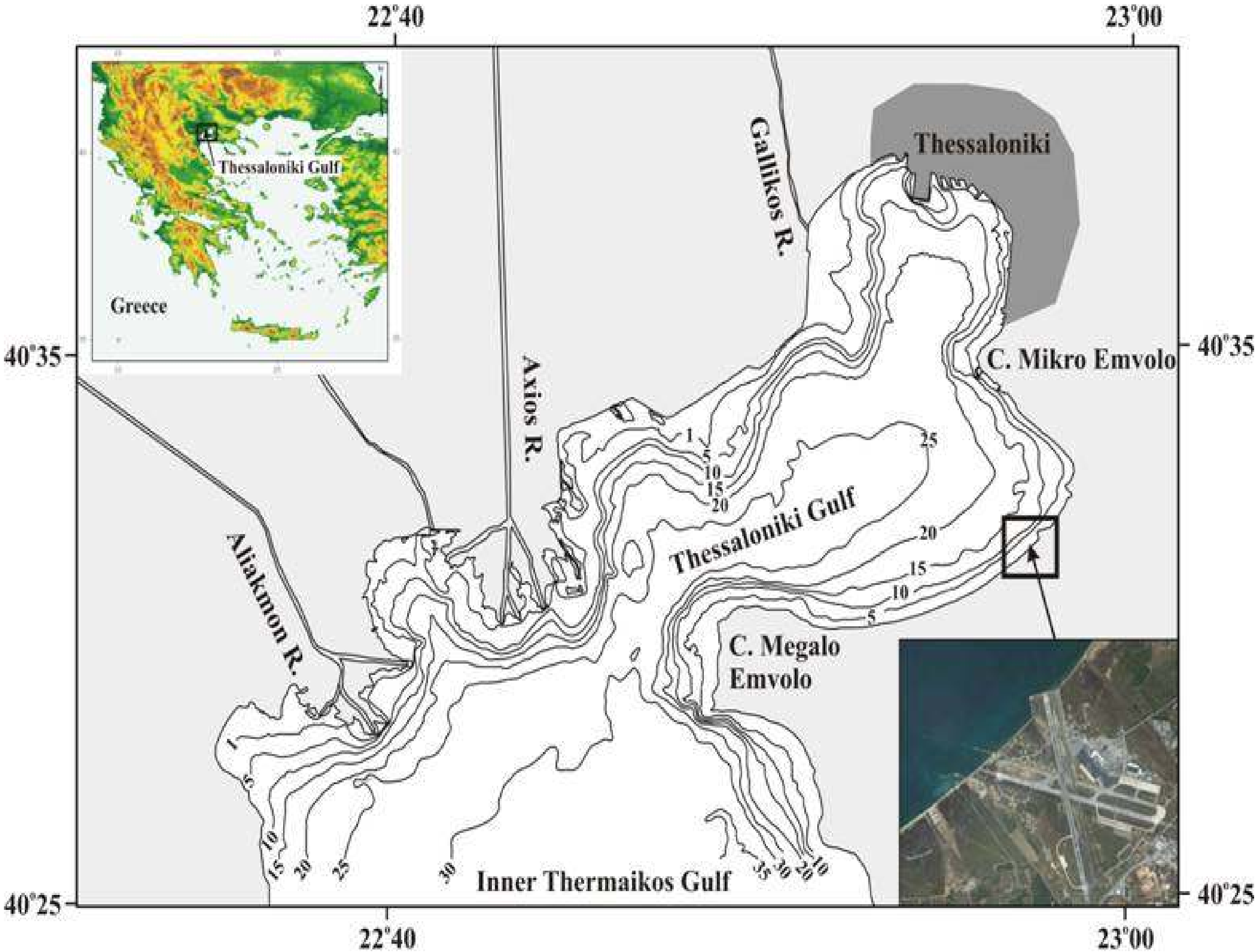


Seabed sediment characterization

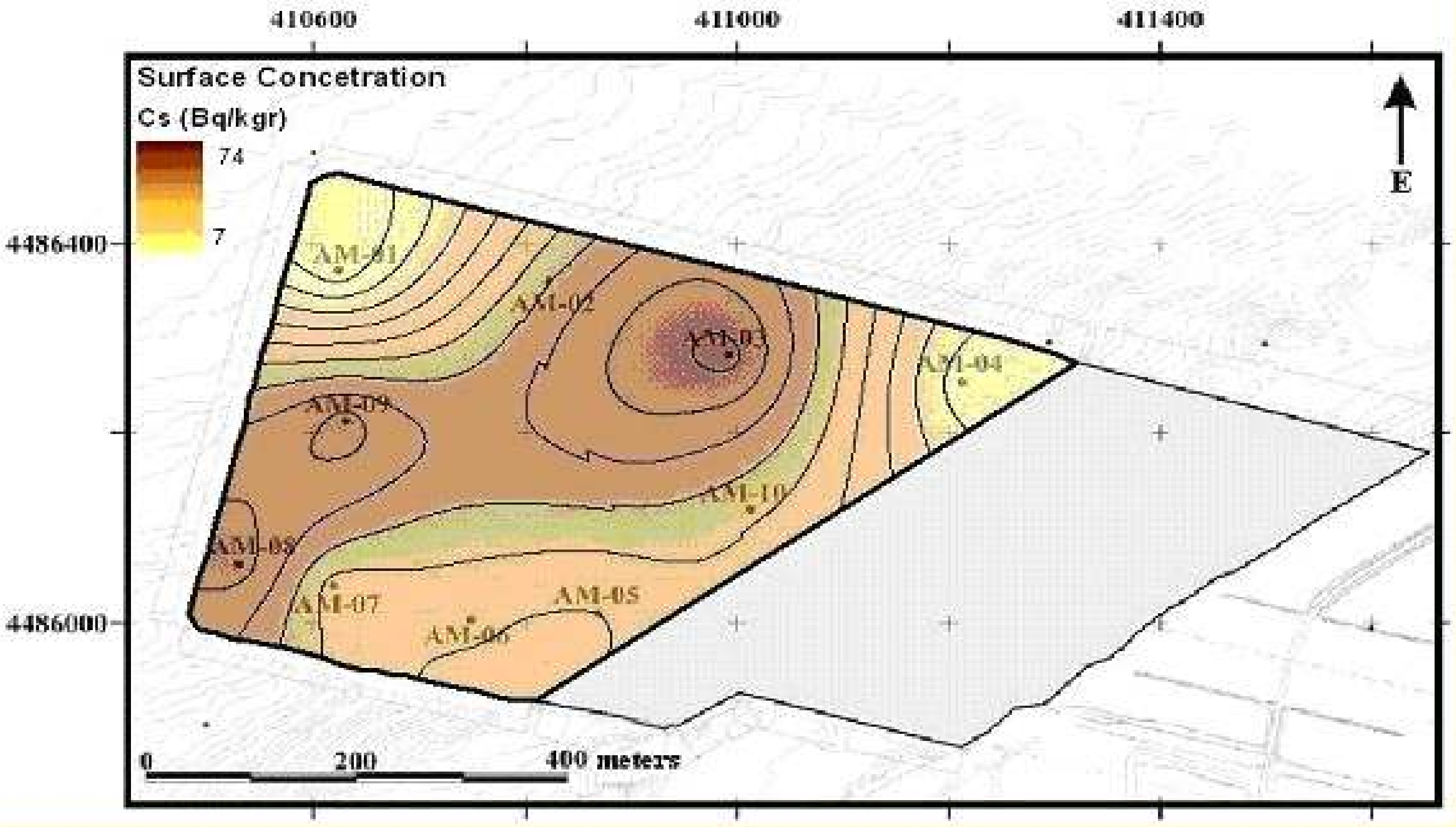


$$F = -0,048A_{Ra} + 0,24A_{Th} + 0,65A_{Cs} - 0,0020A_{K} - 3,6$$

Thermaikos Gulf (North Greece)

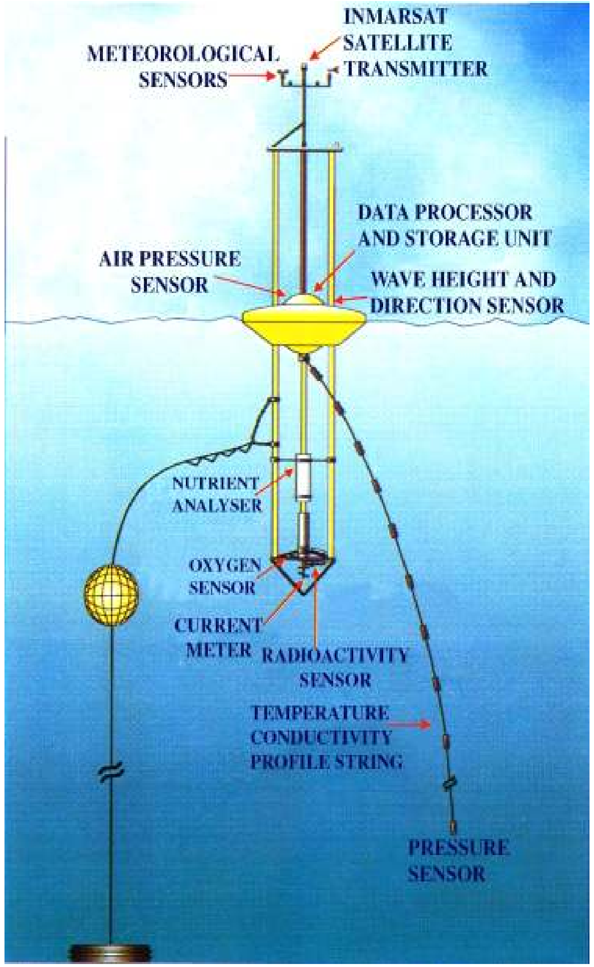


Thermaikos Gulf (surficial ^{137}Cs variation)



POSEIDON Network

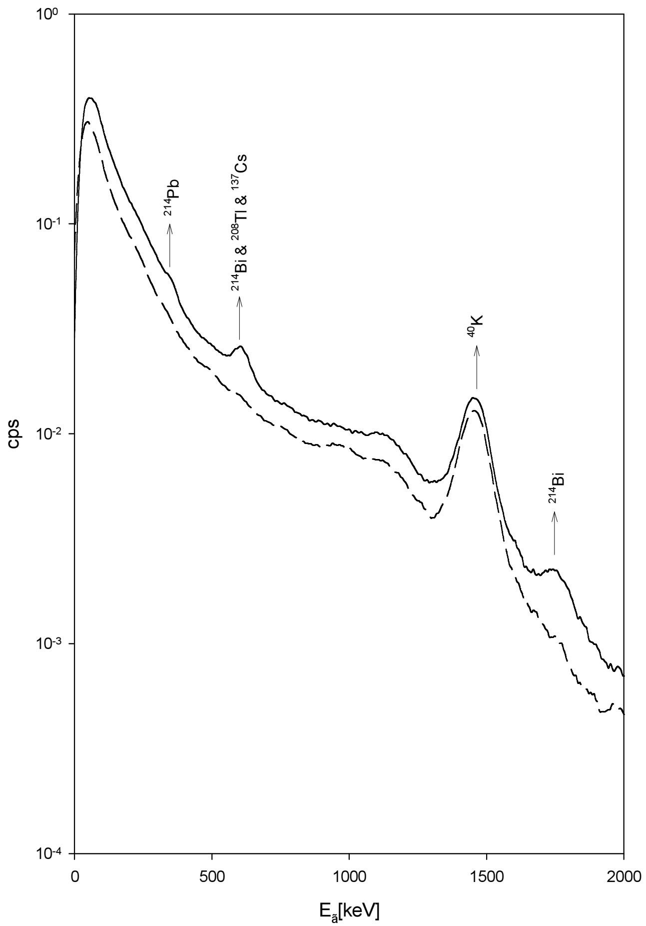
- ***Height*: 7.9 m**
- ***Width:* 1.75 m**
- ***Weight*: 900 kgr**
- ***Energy*: Solar panels + batteries**
- ***Communication*: Imarsat C, GSM every 3 hours**

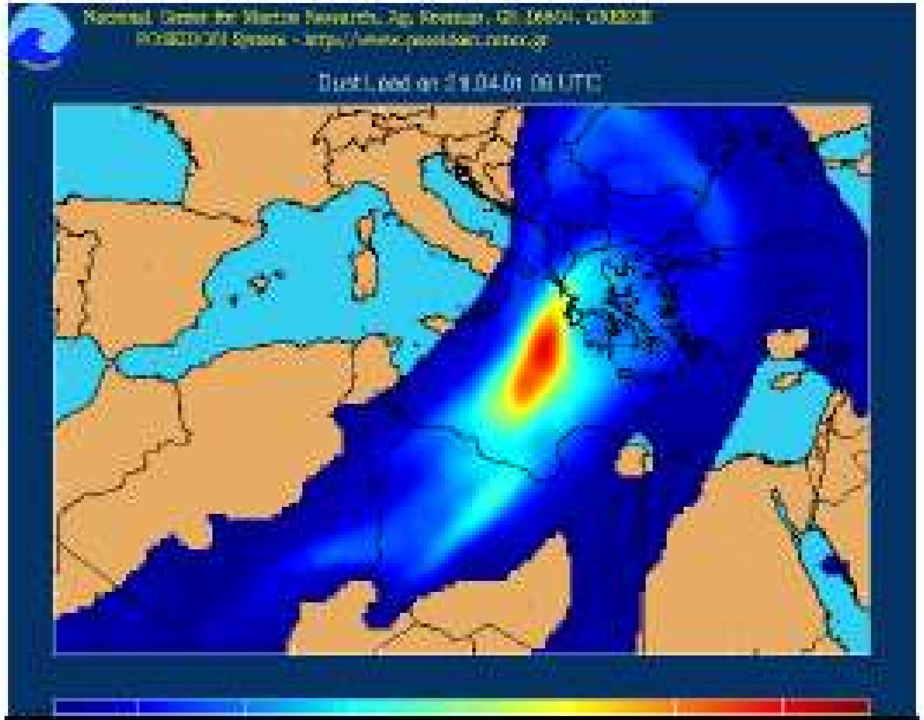


Study area

Field measurements (Aquatic measurements)

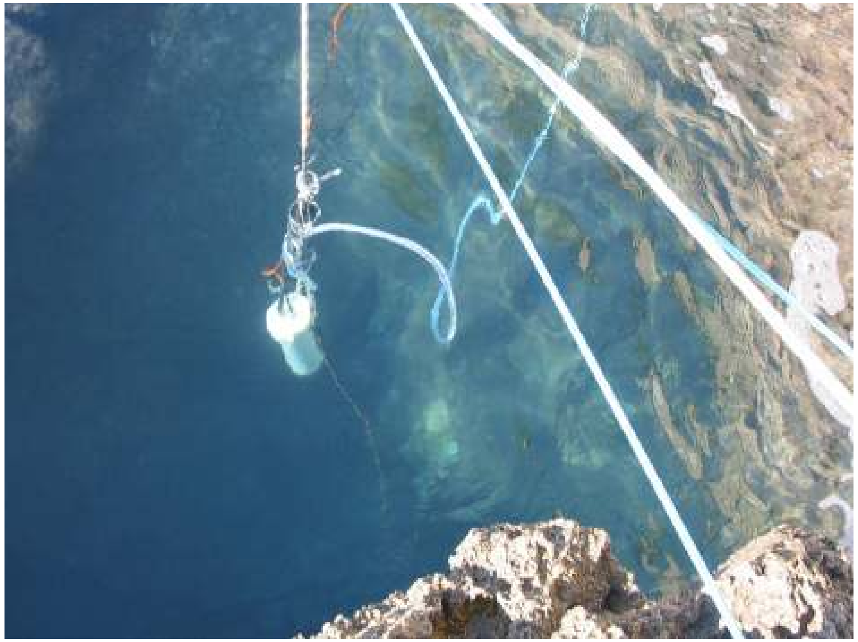
published in Applied Radiation and Isotopes

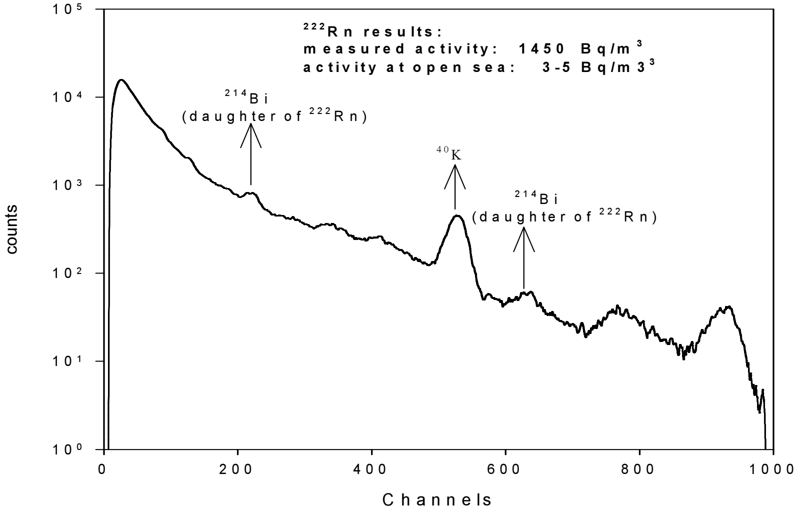


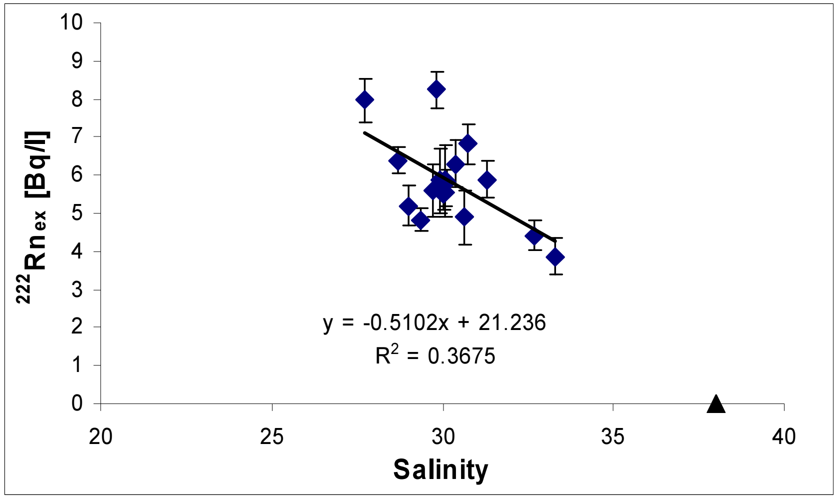


Dust load over Mediterranean, forecast image from the POSEIDON system.

Application in Monaco: Groundwater fluxes on Submarine discharges



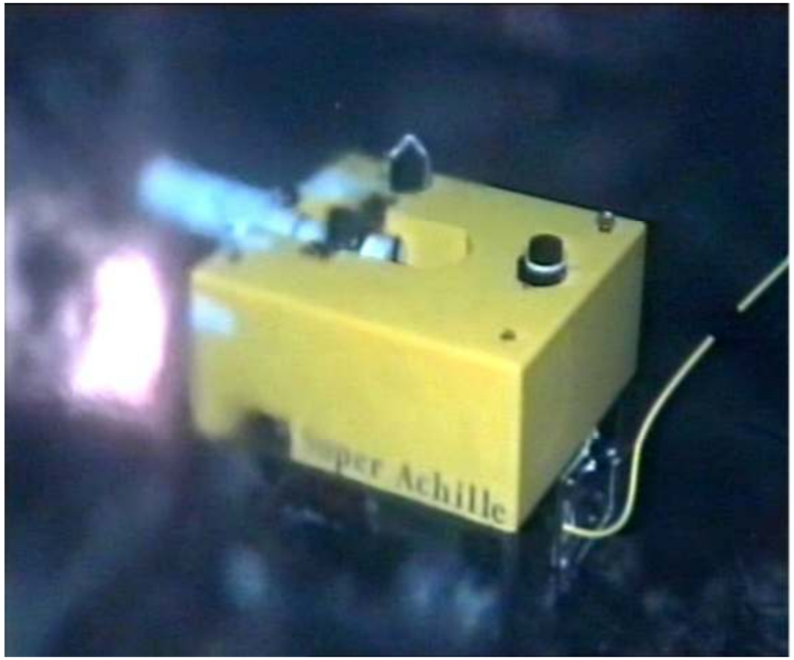


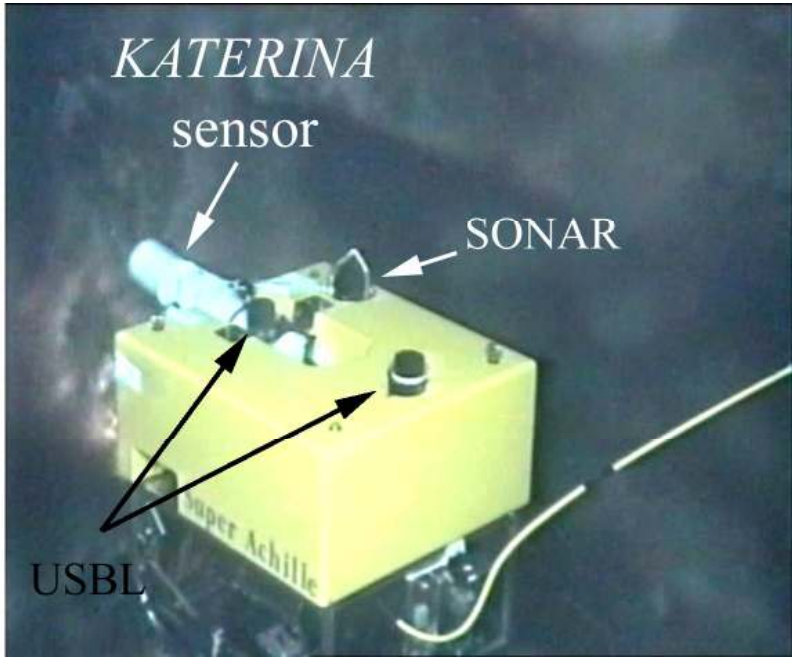


Flow rate: 6 m^3/min

Third Deployment using an ROV in Stoupa

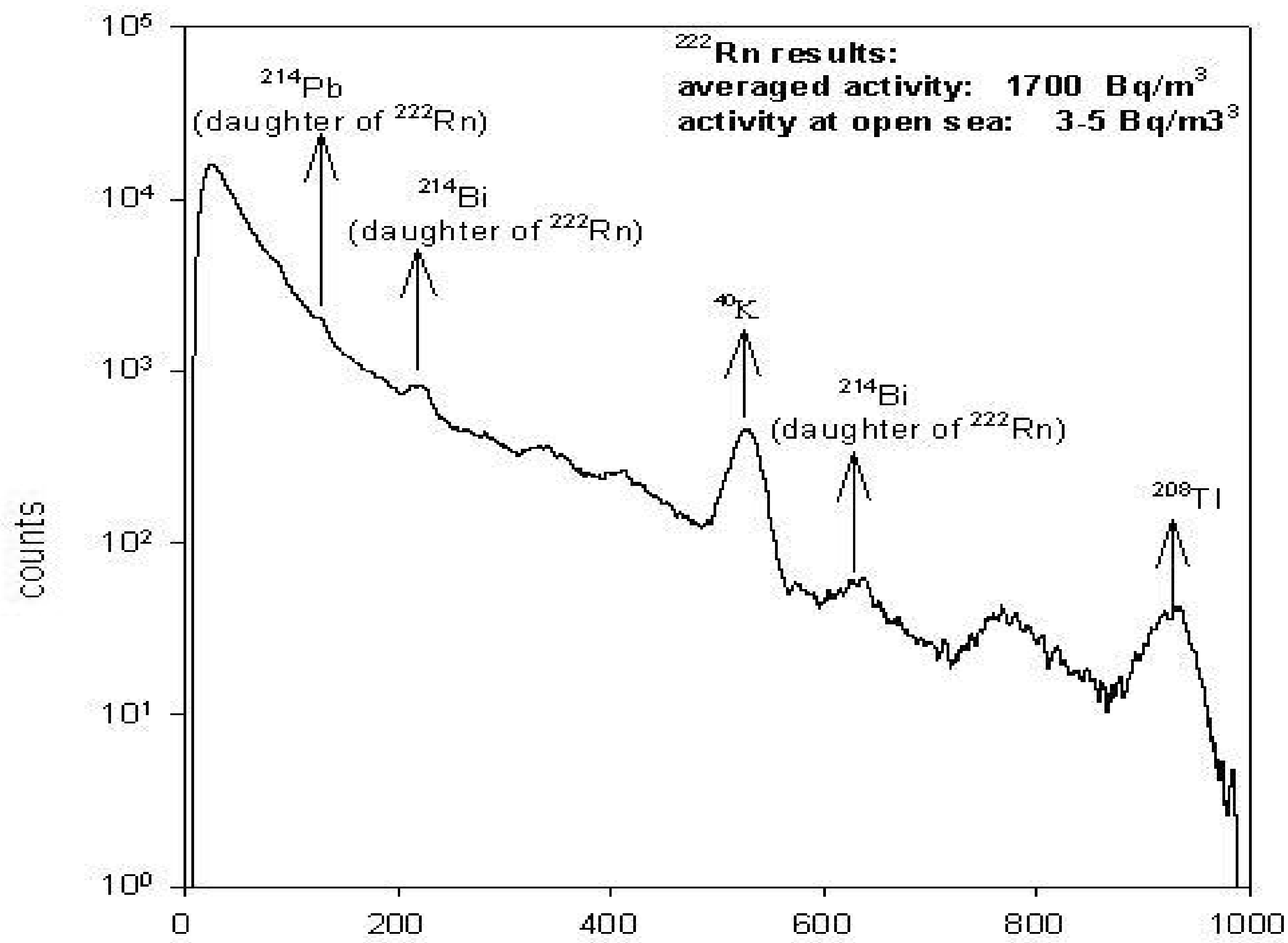
published in Sea Technology





Minimum flow rate: 16m³/min

Results (Stoupa experiment)



System Improvements

Software for automated analysis of the acquired gamma ray spectra

Installing the system in a network of floating measuring systems and platforms

Upgrade for depths up 6000m

Marine system for geophysical and radioprotection purposes

(Warning/ Alarm)

Future Plans

- GEANT4 and MCNP5 simulations on sediment spectra for efficiency estimation.
- Include special hardware for user-independent automatic gamma ray spectra analysis in order to inform directly the responsible operational centre
- Applying the system as a dosimeter in the water as well as in the sediment for NORM and ^{137}Cs.
- Applying the system in a network for monitoring radon on submarine faults (ESONET project in Marmara Sea)
- Seabed characterization at specific NORM sites with increased activity concentration (like fertilizer industry) (test in Cyprus)
- Real-Time Monitoring radioactivity in terrestrial environment as well as in air-sea interaction environment

Test deployment in Stoupa (South Peloponnesus)