GEMS: underwater spectrometer for long-term radioactivity measurements

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Abstract

GEMS (Gamma Energy Marine Spectrometer) is a prototype of an autonomous radioactivity sensor for underwater measurements, developed in the framework of the KM3NeT Design Study (DS) EC project. The spectrometer is sensitive to gamma rays produced by ^{40}K decays and it is also able to detect other natural (e.g., ^{238}U, ^{232}Th) and anthropogenic radionuclides (e.g. ^{137}Cs). The decay of ^{40}K, contained in sea salt, particulate and sediments, is one of the main sources of photon background in the underwater environment.
GEMS was first calibrated in the laboratory using reference sources, also in order to evaluate the performance of the instrument. In November 2008 GEMS was deployed at a depth of 3200 m in the area of Capo Passero (in the Ionian Sea) to acquire data autonomously. After recovery of the spectrometer six months later (May 2009) it was found that the instrument had worked within the specifications and acquired data over the full deployment period. These data allowed us to investigate over a long period the possible variations of activity at the Capo Passero site.
GEMS is suitable to be used either in autonomous mode or as payload of seafloor observatories or vehicles.

Prototype development and test

Fig.1 An image of the sensor outside of its vessel

Gems is a NaI(Tl) scintillator(1) (15x10 cm) assembled with a photomultiplier tube (2). It is provided with a microprocessor(4) which performs the analog to digital conversion (3) as far as a preliminar analysis of the signal.

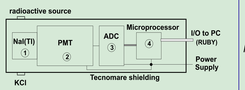

Fig.2 Marinization of the sensor

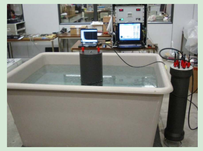

Fig.3 Laboratory Test

The realization of a version capable to operate in deep-sea conditions, integrated in a seafloor observatory or in a multidisciplinary instrumented module, was performed by Tecnomare S.p.A. It included design and manufacturing of a pressure vessel to host the sensor and power electronics circuitry

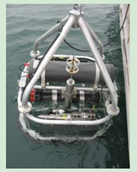

Fig.4 GEMS first test at sea, integrated into a multidisciplinary instrumented module

Experimental Calibration

We performed a calibration of the instrument analising its respons in presence of some reference radioactive sources. Each spectrum, included the background one, was acquired in presence of ^{40}K source, since the instrument uses it as a reference for an autocalibration process.
The background spectrum was then subtracted from each other set of data in order to perform spectra analysis.

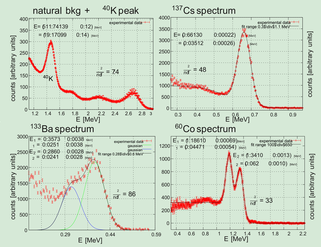

Fig.5 Some examples of spectra acquired with the refence sources

Energy Calibration

The energy calibration was performed obtainig, for each reference source, , the mean value of photon energy in ADC channels, namely the photopeack, and comparing this with the nominal energy of the source.
A small non linearity of the crystal response was accounted by a second order polinomial function:

$$f(x) = ax^2 + bx + c$$

a= (380 0:16) 10^{-3} [MeV Channels^{-2}]
b= (2670 0:012) 10^{-3} [MeV Channels^{-1}]
c= (4:2 1:7) 10^{-3} [MeV]

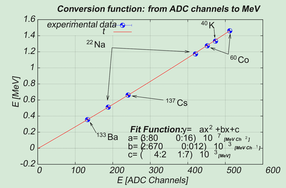

Fig.6 ADC channels to MeV conversion function

Energy Resolution Evaluation

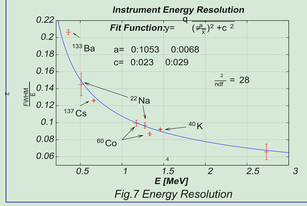

Fig.7 Energy Resolution

The characterization of GEMS's energy resolution provides a prevision of its ability of discriminate sources at similar energies. The data's trend is described by:

$$R_E = \frac{FWHM}{E} = \sqrt{\left(\frac{0.1053}{\sqrt{E(MeV)}}\right)^2 + (0.023)^2}$$

$\frac{1}{\sqrt{E}}$ ⟶ Statistical Contribution
$const$ ⟶ Intrinsic Contribution

which provides 12% of energy resolution at 661 KeV

First long-term deep-sea mission

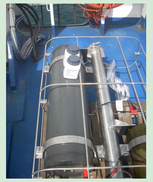

Fig.8 Calibration of GEMS before the deployment

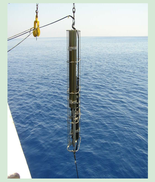

Fig.9 GEMS just recovered after 6 months of autonomous acquisition

Fig.10 The mooring chain 3400 m long

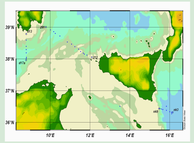

Fig.11 Capo Passero site, offshore Eastern Sicily (3618.915'N, 1665.531'E)

- System configuration and mission details:
  - Self-recording
  - Battery powered
  - One measure every 6 hours
- Attached to a mooring line 3400 m long
- Installed Eastern Sicily, offshore Capo Passero
  - Approx installation depth 3200 m
  - Deployed 08/11/08
  - Recovered 09/05/09

EXAMPLES OF RESULTS OBTAINED

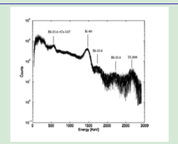

Fig.12 An example of spectrum collected

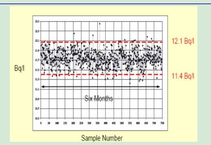

Fig.13 Activity values registered during the deployment

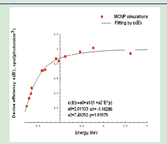

Fig.14 Efficiency of photon detection as a function of energy

The calculated average value of ^{40}K specific activity is about 11.7 Bq/l (= 0.1 Bq/l), while the activity values recorder for ^{238}U and ^{232}Th are respectively 0.43 and 0.28 Bq/l,as expected. The temporal series show very stable values; so mean activity due to ^{40}K can be considered constant in the Capo Passero area, referred to the time window of the experiment.

Next Developments

- Extend the analysis to the other radionuclides
- Perform the study of the correlations with the oceanographic variables

-Seafloor Gamma Ray Measurements around Active Faults and Seepage Sites

References

[1] F. Massa, Eur. Phys. J. C 22, (2002) 749.
[2] F. Ameli *et al.*, Phys. J. C 25, (2002) 67.
[3] R.A.Ligero *et al.*, J. Environ. Radioact. 87, (2006) 325.
[4] R.A. Ligero *et al.*, J. Environ. Radioact. 57, (2001) 7.
[5] C. Tsabaris *et al.*, Appl. Radiat. Isot. 62, (2005) 83.
[6] D.S. Vlachos *et al.*, Nucl. Instrum. Meth. Phys. Res. A 539,(2005) 414.
[7] P. Pani, Bachelor Thesis, Universit Sapienza Roma, 2007.
[8] U.F. Katz, Prog. Part. Nucl. Phys. 57, (2006) 273.
[9] R. Vlastou *et al.*, Appl. Radiat. Isot. 64, (2006) 116.
[10] P.P.Povinec *et al.*, J. Radioanal. Nucl. Chem. 248, 3 (2001) 713.
[11] P.H.G.M. Hendriks *et al.*, J. Environ. Radioact. 53, (2001) 365.

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