IL NUOVO CIMENTO **47 C** (2024) 60
DOI 10.1393/ncc/i2024-24060-9

COLLOQUIA: COMEX7

Status of the ELIADE γ-ray spectrometer for NRF Experiments at ELI-NP

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received 31 October 2023

Summary. — The ELIADE γ-ray spectrometer constructed at the Extreme Light Infrastructure Nuclear Physics (ELI-NP, Romania) is featured for Nuclear Resonance Fluorescent studies to be performed using a mono-energetical almost fully polarized γ-ray beam. This paper reports on the progress of implementation of ELIADE.

1. – Nuclear Resonance Fluorescence

Reactions induced by photons are an important tool for different aspects of nuclear structures and modeling of astrophysical scenarios. Moreover, they have a number of social important applications. If the energy transferred by an absorbed γ-ray to a nucleus can excite only quantum state(s) below the particle separation energy, during deexcitation the nucleus will emit only resonant γ-rays. This process is called the Nuclear Resonance Fluorescence (NRF) [1].

Photons can be usually generated using the electron bremsstrahlung leading to a continuous γ-ray energy distribution up to the end-point, which is the energy of the primary electron beam. However, nowadays nuclear physics experiments require also high-brilliance and intense photon beams generated by the Laser Compton Scattering. In this process photons are scattered by a relativistic electron beam. Controlling the properties of the laser and electron beams allows to generate a quasi-monochromatic and almost polarized γ-ray beam [2, 3]. The ELI-NP laboratory aims at becoming the first facility in Europe to deliver γ-ray beams at variable energy up to the the maximum of $\sim$19.5 MeV and total flux of 10^{11}/s produced by the VEGA system [4]. The linear polarization of 95% as well as the average relative bandwidth of 5% will trigger numerous experiments to study various phenomena below the particle emission threshold in (stable) nuclei [5] and industrial applications [6]. The paper briefly discusses the status of the implementation of the ELIADE γ-ray.

2. – ELIADE γ-ray spectrometer

The spectrometer consists of 8 Clover 32-folded High Purity Germanium (HPGe) [7] detectors arranged into two rings at 90° and 135° with respect to the beam direction. Each ring comprises 4 Clover detectors. The 90° ring has 2 Clover detectors in horizontal and vertical plane each, which is a typical arrangement for NRF measurements. In order to enhance sensitivity to the high-energy γ-rays 4 ancillary large volume 3 x 3 inch $CeBr_3$ detectors are installed in the same ring in a way that the polar angle between the Clover and $CeBr_3$ detectors is 45° with respect to the target position fig. 1. The 90° support structure can be rotated up to $\pm$45° without interruption of operation of the detectors. This permits to place $CeBr_3$ or Clover detectors at the angles relevant to the polarization measurement without dismounting them. Moreover, it allows swapping the Clover detectors and in the horizontal and vertical planes to estimate the systematic errors. Finally, the rotation facilitates mounting of the Clover detectors in the ring. The support structure of the backward ring can be moved for $\sim$1 m away from the reaction chamber allowing easy access to the detectors. The target-to detector distance can be continuously modified in the range from 15 cm to 30 cm. It is foreseen in the near future to install the segmented Compton suppression to veto events related to escaping of γ-rays from germanium crystals. The effect of the anti-Compton shield on the quality of γ-ray spectra recorded by ELIADE is discussed by simulations in ref. [8].

The HPGe Clover detectors of the ELIADE γ-ray spectrometer are maintained at a stable cooled temperature by filling the detectors with liquid nitrogen (LN2) in a regular 12-hour interval. For this purpose a dedicated LN2 filling station was designed and home produced. It contains solenoid valves, external Pt100 temperature sensors embedded inside holders, as well as Teflon tubes for LN2 distribution between the storage tank and the clovers. The filling process is automatized and controlled by the CompactRIO (cRIO) system from National Instruments through a custom LabVIEW software. The associated Graphic User Interface (GUI), Command Line Interface (CLI) and Text User Interface (TUI) are used for both controlling the filling process and temperature monitoring. Alert and warning email messages are sent via cRIO system to a registered user in case of emergency (increasing temperature, technical fault, etc). The system every 1 s stores the data on the temperature of Ge-crystals as well as of external Pt100 sensors in a database (InfluxDB). The online graphical monitoring system Grafana allows real time visualization of the data and additional warning messages by Telegram. A complementary python script duplicates the alarms by a SIM-call via a GPRS modem. The details of the LN2 cooling and control system are reported in the ref. [9].

Before putting in operation all eight HPGe Clover detectors were a subject for the annealing procedure and the initial source characterization using analog electronics. The details about the annealing and post-annealing testing are reported in ref. [10]

Forty output signals from each Clover detector (32 segments and 8 core signals) are fed to inputs of four CAEN v1725 digitizers (14 bit resolution at 250 MS/s) and signals

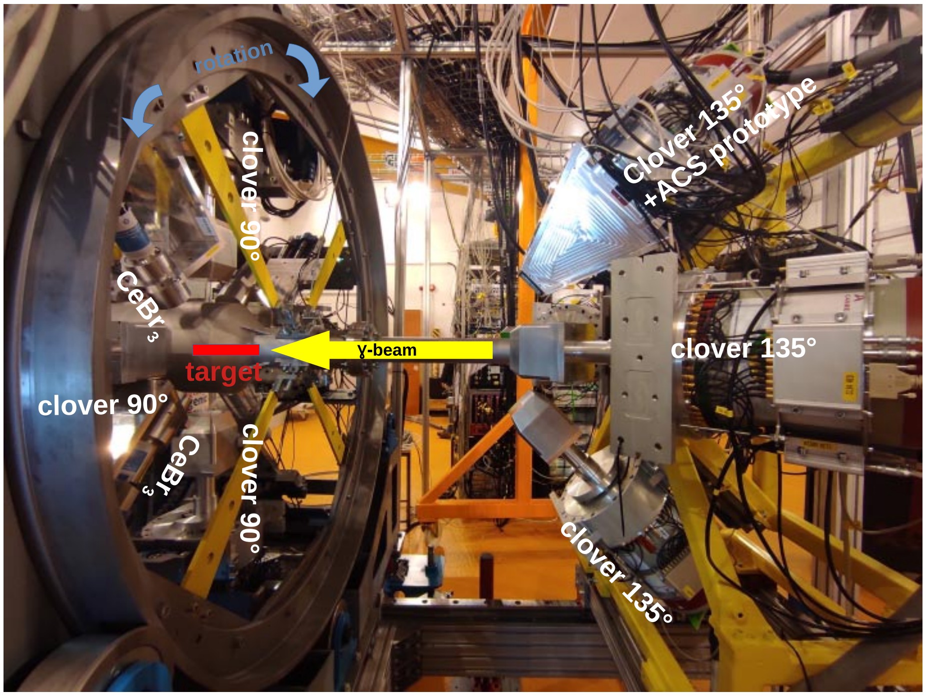

Fig. 1. – The ELIADE γ-ray spectrometer installed in the experimental hall. Clover and $CeBr_3$ detector arrangements in the 90° structure (on the left) are visible; the 135° structure (right) containing 4 Clover detectors is moved $\sim$1 m upstream to allow the picture.

from four $CeBr_3$ detectors are processed by a CAEN v1730 (14 bit resolution at 500 MS/s). The home designed Digital Extreme Light Infrastructure Listmode Acquisition system (DELILA) controls all 34 digitizer boards and dumps the collected data on the disk. DELILA, based on the Middleware-DAQ [11], has web-based interface and allows online visualisation of the data using a root server. The development of DELILA is discussed in ref. [12]. In fig. 2 it is shown one of the first γ-spectrum measured by the ELIADE spectrometer using a ^{60}Co source.

The full realistic simulations were used to reproduce the response of ELIADE to γ-rays emitted from a ^{60}Co source. The detector geometry was the same as in ref. [8]. The physics lists used were G4DecayPhysics, G4RadioactiveDecayPhysics, G4EmStandardPhysics and Neutron HP. As is seen from fig. 2, the simulations reproduce very well the position and height of the ^{60}Co γ-ray peaks. The differences are mainly due to background radioactivity which was not considered in the simulation routing.

Our further efforts are devoted to complete the full characterization of the array.

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This work was supported by the Romanian Ministry of Research, Innovation and Digitalization under contract 10N/PN 23 21 01 06, 13/ELI-RO/2017 and 16/ELI-RO/2016.

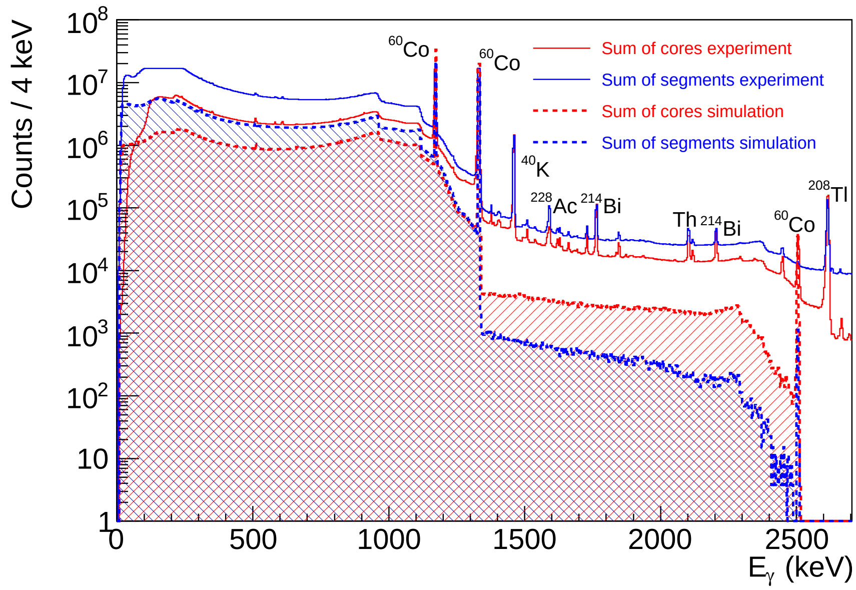

Fig. 2. – One of the first γ-ray spectra recorded by ELIADE using a ^{60}Co source, alongside with the results of a GEANT4 simulation reproducing the source in term of activity and time exposure.

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