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#10-216 SPID-X Gamma ray imaging spectrometer performance evaluation in real conditions for the decontamination and clean-up of a LECA STAR hot cell

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The LECA-STAR hot cell laboratory (Laboratory for Active Fuel Studies and the Treatment, Decontamination, and Reconditioning Station) is a facility dedicated to R&D activities on irradiated nuclear fuel, located at the CEA-Cadarache center. Seventeen shielded cells and a microanalysis laboratory allow the handling of fuel elements, from rod size to sub-micronic scale. Four of these cells are operated by the Laboratory for Radioelement Migration Analysis (LAMIR) to conduct tests on irradiated fuels, known as annealing tests, representative of incidental or accidental scenarios. These experiments monitor physical phenomena (temperature, pressure, gamma spectrometry ⋯) in experimental loops specifically designed to reach experimental conditions as close as possible to such desired conditions.

One of the LECA STAR cells has the unique feature of a transparent polycarbonate panel with glove ports, allowing human interactions in glove-box configuration when radiological conditions permit. In cases of unfavorable radiological conditions, this panel can be reinforced with biological shielded doors, and then, handling within the cell is carried out solely using telemanipulator arms. This hot cell has hosted three distinct experimental programs since 2010 (VERDON, VINON-LOCA, ESTER). Due to their nature, these different programs have contributed to some radiological contamination of the cell.

To reduce the contamination level of the hot cell and facilitate human interventions in glove-box mode, or even allow direct human interventions, decontamination campaigns were conducted. These clean-up phases start with dose mapping using a dose rate meter and/or smear tests, performed remotely with telemanipulators. This is followed by further decontamination phases using smears, also performed with telemanipulators. Once the contamination level is low enough, personnel wearing specific protective gear can be deployed for deeper decontamination, first through the glove box panel, then inside the cell. New mappings and delayed smear measurements are carried out throughout these phases to confirm their progress.

In an effort to improve and enhance the efficiency of this process, aiming also at lowering the dose for the operators (ALARA principle), the LAMIR, in collaboration with ALB3DO laboratory (DRF/IRFU –3D PLUS), has undertaken the implementation of a prototype of the Spid-X gamma camera, developed by ALB3DO, to perform comprehensive mapping of hot cell.

Spid-X is a portable gamma integral-field spectrometer weighing less than 4 kg. Built on the Caliste technology, Spid-X utilizes finely pixelated CdTe semiconductor detectors paired with low-noise ASICs from the IDeF-X family. Originally developed for space astronomy and high-energy solar observation in the hard X-ray and gamma-ray domains, the Caliste technology has already proven successful operations with STIX spectrometer on-board of the Solar Orbiter satellite.

Spid-X is designed to automatically identify and locate radioisotopes in real-time, compute the dosimetry at the device level, and quantify proportions when multiple radioisotopes are present in an environment. With the help of a Convolutional Neural Network trained on synthetic data, Spid-X requires only a few dozen of photons to detect one or more radioactive sources within a scene. Within Spid-X's energy range from 2 keV to 2 MeV, and depending on their type and extension, weak sources of the order of few nSv/h can be identified and localised in few minutes through either coded mask aperture imaging or Compton imaging. Compton imaging is still under development together with ongoing optimizations, including the integration of artifi-

cial intelligence algorithms, which are showing promising results, reducing localization time and improving accuracy.
In the end of 2022 and beginning of 2023, Spid-X was brought to several nuclear test facilities in order to test its performances in such conditions, and to identify potential improvements. Results from theses campaigns were presented at ANIMMA 2023. Spectroscopy, imaging and dosimetry performances were validated in unknown, yet simple environments: background levels were ten times higher than in our laboratory, but the number of sources was low, between 1 and 3, and only point sources were studied. Imagining accuracy was confirmed to be near 1 degrees for coded mask aperture imaging, and around 10 degrees for Compton imaging. Our dosimetry model was successfully compared to calibrated commercial instruments.
The hot cell gamma characterization during clean-up operation involved installing the device behind the polycarbonate panel to acquire visual images and gamma spectra maps of the cell's interior. The objective was to obtain a map of the distribution and dispersion of contamination points within the cell to guide, accelerate, and improve the decontamination phases. In this complex environment the positions and the number of sources were not known, and with a high probability of presence of extended sources.
In this contribution, a brief overview of the Spid-X system is given, and results from the acquisition campaign at LECA-STAR are discussed as well as the benefit of the use of Artificial Intelligence algorithms.

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