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Spid-X : a Gamma camera with spectro-identification and dosimetry embedded functions

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The Caliste Technology and the ALB3DO laboratory

For almost 20 years, 3D PLUS and CEA IRFU have been involved in the development of the Caliste technology for space applications. Caliste is a miniature CdTe based imaging spectrometer capable of achieving high energy resolution (better than 1 keV FWHM at 60 keV and 7 keV FWHM at 662 keV) and high imaging resolution in the gamma range.

Caliste technology has been successfully launched on board the Solar Orbiter satellite, in the STIX instrument, proving its high reliability and high performances in harsh conditions. Given its excellent performances, the idea to adapt the technology to nuclear applications has emerged and Caliste-O, a dedicated detector version to the nuclear field has been developed.

Strengthened by this history of mutual developments in advanced detection technologies and the desire to go further, 3D PLUS and CEA IRFU decided to combine their skills in a joint laboratory and founded ALB3DO: Advanced Laboratory for 3D Detection Devices Development. Thanks to the combined expertise of research and industry, ALB3DO creates and promotes breakthrough technologies for sensors and systems beyond the state of the art.

The Caliste-O 3D module is the latest development of the Caliste technology which started in 2006. It is made of 8 IDeF-X ASICs moulded with the 3D PLUS technology to form a 3D electronic part, on which a CdTe cristal of 1.4 x 1.4 cm² and 2 mm thick is mounted.

Spid-X : the next generation of Gamma camera

Gamma cameras are powerful devices to locate radioactive sources and hot spots, specifically in nuclear industry for monitoring, D&D or waste management for instance. However, complete diagnostics require not only source localization but radioisotopes identification and dosimetry. Spid-X gamma camera, brings to the user all these information in one system. Spid-X relies on Caliste-O technology and uses state-of-the-art algorithms to perform imaging, spectro-identification and dosimetry in real time and simultaneously.

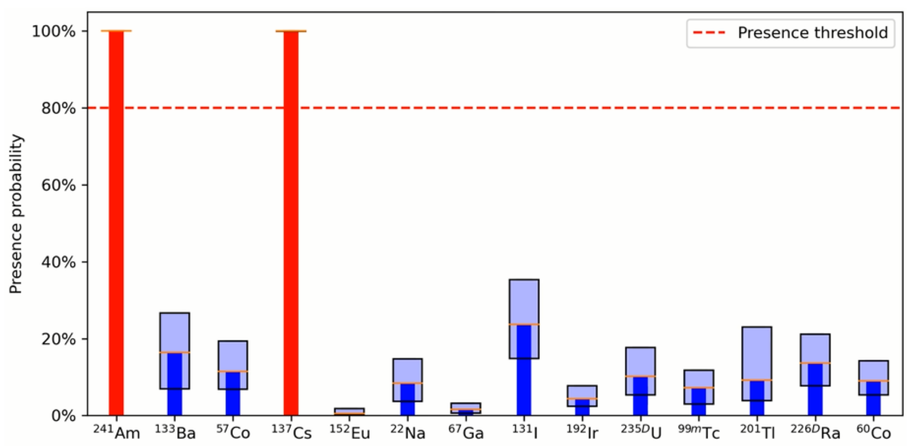
- Real Time data acquisition, data processing and data display via dedicated GUI
- Two imaging modes, using coded mask aperture and Compton mode, to allow the localization of radioactive sources in a wide energy range from 12 keV to 1.5 MeV
- Imaging angular resolution is better than 1.5° in coded mask aperture imaging and better than 15° in Compton mode used above 300 keV. Those are state-of-the-art performances for imaging, at both low and high energies
- The spectrometric performances are among the best in the market, with an energy resolution of 2% at 662 keV and 1.5 keV at 60 keV
- Those spectrometric performances are coupled with a patented Deep Learning technology which allows automatic and real time spectro identification of detected radionuclides
- High-sensitivity automatic source recognition enables identification under laboratory conditions in less than 1 min:
  - ^{241}Am source providing a dose rate of 5 nSv /h at the device level
  - ^{137}Cs source providing a dose rate of 200 nSv /h at the device level
- IP65, device 4.5 hrs of autonomy, less than 3.5 kg, portable device 323 x 110 x 180 mm³

Spectro-identification

Caliste technology enables precise reconstruction of the energy of gamma-ray events detected in the dynamic range from 12 keV to 1.5 MeV. Thanks to this high level of precision, the radioactive isotopes detected can be identified even when they are mixed with others.

The automatic spectro-identification algorithm is based on advanced convolutional neural networks (CNN)* trained with synthetic data. The algorithm is able to identify the radioisotopes that are at the origin of a measured spectrum, even in the case of multiple sources and low counting statistics.
In addition, the algorithm provides information on the relative proportions of the different sources present, as well as an estimate of the error.

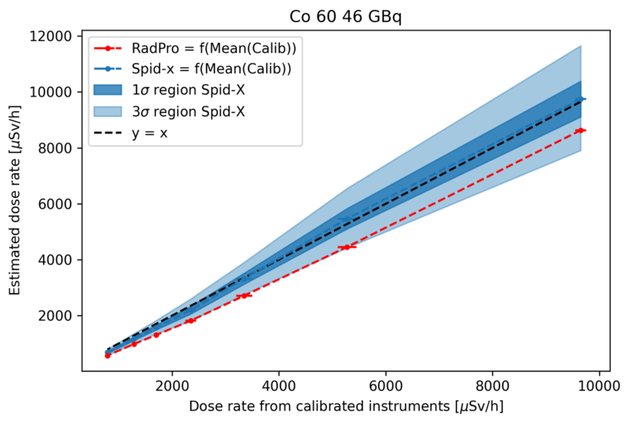
**Patented Method and device for identifying atomic species emitting X or Gamma radiation, WO2020239884A1*



The presence probability of various isotope when the camera is placed in front of ^{137}Cs and ^{241}Am sources.
This presence is given with error bars to associate the result with confidence level. When the presence probability is greater than 80% with an error bar of less than 2% the isotope is considered as identified. ^{241}Am and ^{137}Cs have been clearly identified.

Dosimetry

Based on spectroscopic measurements, Spid-X performs real-time dosimetry. The dose is provided with an estimated error. Dose prediction was characterized with a ^{60}Co source for different dose rates, and the results were compared to a reference measurement with a calibrated instrument.

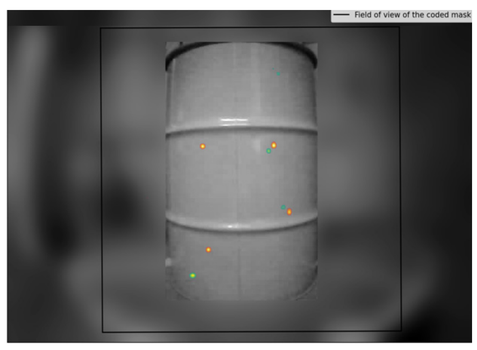


Estimated dose rate as measured by Spid-X against a reference dose rate as measured with a calibrated instrument.

Imaging

Two imaging methods are used in Spid-X: coded mask imaging and Compton imaging, both coupled with specific reconstruction algorithms. Typically, wide-field Compton imaging is useful beyond 300 keV. Both techniques enable precise localization of isotopes of different kinds.

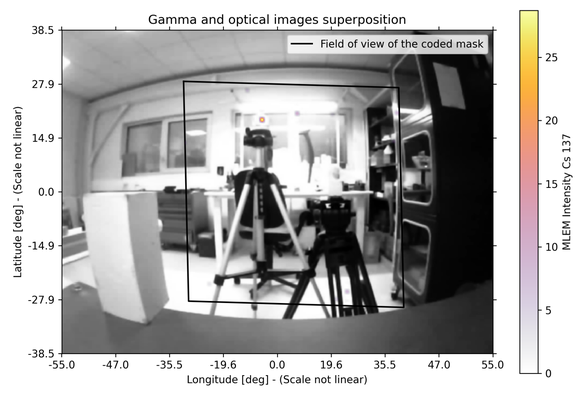
Coded mask aperture : localization of ^{241}Am and ^{152}Eu sources



Green : ^{152}Eu sources, 10 MBq per source
Orange : ^{241}Am sources, 3,6 MBq per sources

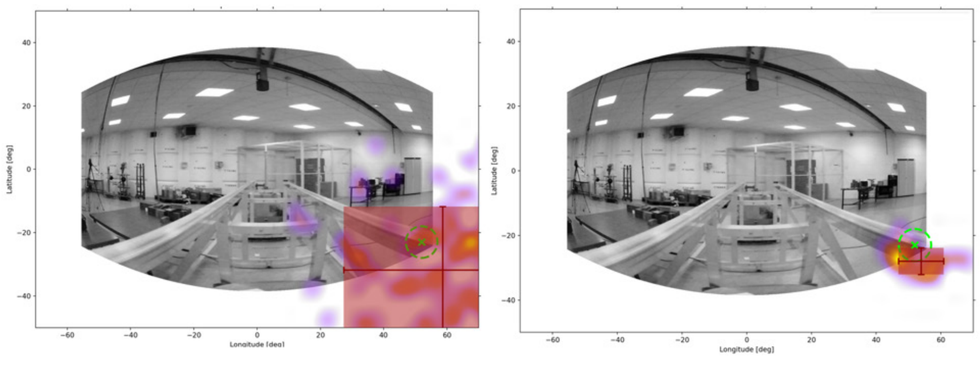
- The container is placed 1 m from the device
- Angular resolution is better than 1°
- Presence of ^{241}Am and ^{152}Eu is confirmed in less than 30 s. The following reconstruction allows a clear separation of the different sources.

Coded Mask aperture reconstruction of ^{137}Cs source



Once the ^{137}Cs is recognized it is possible to use the coded mask reconstruction to refine the localization of the source and get faster results.

Imaging of ^{137}Cs source of 1.5 GBq



Results after 45 seconds *Results after 40 minutes*

The rough position of the source is given in few seconds.

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