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### ► To cite this version:

Guillaume Sannié, Stéphane Normand, P. Peerani, H. Tagziria, H. Friedrich, et al.. Scintilla: A new international platform for the development, evaluation and benchmarking of technologies to detect radioactive and nuclear material. 2013 3rd International Conference on Advancements in Nuclear Instrumentation, Measurement Methods and their Applications (ANIMMA), Jun 2013, Marseille, France. pp.6728040, 10.1109/ANIMMA.2013.6728040 . cea-01822347

**HAL Id: cea-01822347**

**<https://cea.hal.science/cea-01822347v1>**

Submitted on 2 Aug 2023

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# Scintilla: a New International Platform for the Development, Evaluation and Benchmarking of Technologies to Detect Radioactive and Nuclear Material

G. Sannie, S. Normand, P. Peerani, H. Tagziria, H. Friedrich, S. Chmel, R. De Vita, M. Pavan, M. Grattarola, E. Botta, A.S Kovács, L. Lakosi, C. Baumhauer, M. Equios, G. Petrossian, J. M. Picard, G. Dermody, G. Crossingham

**Abstract—** For Homeland Security, enhanced detection and identification of radioactive sources and nuclear material has become of increasing importance. The scintilla project aims at minimizing the risk of radioactive sources dissemination especially with masked and shielded material. SCINTILLA offers the capacity to finding a reliable alternative to Helium-3 based detection systems since the gas which is predominantly used in nuclear safeguards and security applications has now become very expensive, rare and nearly unavailable. SCINTILLA benchmarks will be based on international standards. Radiation Portal testing being carried out at the Joint Research Centre (JRC) in Ispra (Italy).

**Index Terms—** Homeland security, Nuclear instrumentation, Neutron, Helium 3

## I. INTRODUCTION

SCINTILLA is a European Commission (EC) funded (FP7) project which aims to build an innovative and comprehensive toolbox of devices and best-of-breed technologies for the enhanced detection and identification of difficult-to-detect radioactive and nuclear material by:

- Finding a reliable **alternative to Helium-3 based neutron detection systems** since the gas which is predominantly used in nuclear safeguards and security

This work was supported the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n°285204.

G. Sannie and S. Normand are with CEA Tech - LIST, 91191 Gif sur Yvette Cedex - FRANCE. (guillaume.sannie@cea.fr).

P. Peerani, H. Tagziria are with European Commission, Joint Research Centre, ITU, Nuclear Security Unit, Ispra, Italy ()

H. Friedrich, S. Chmel are with Fraunhofer Institut für Naturwissenschaftlich - Technische Trendanalysen (INT), Euskirchen, Germany

R. De Vita, M. Pavan, are with Istituto Nazionale di Fisica Nucleare, Sezione di Genova, Genova,

M. Grattarola, E. Botta are with Ansaldo Nucleare S.P.A, Genova, Italy, A.S Kovács, L. Lakosi are with Hungarian Academy of Sciences, Centre for Energy Research, Budapest,

C. Baumhauer, M. Equios are with ARTTIC, Paris, France

G. Petrossian, J. M. Picard are with SAPHYMO, Massy, France

G. Dermody, G. Crossingham are with Symetrica Security Ltd, Southampton, United Kingdom

applications has now become very expensive, rare and nearly unavailable [1-4].

- Innovative technologies: gamma spectrometry and neutron detection
- 4 types of scintillator-based technologies (organic and inorganic scintillation materials that exhibit fluorescence light when excited by ionizing radiation)
- 2 CZT technologies (CdZnTe – Cadmium Zinc Telluride) complemented by advanced image processing technologies

The SCINTILLA project provides the international community with a common benchmark platform to compare technologies with each other. SCINTILLA benchmarks will be based on international standards namely ANSI [5], IEC, NSS1 [6] recommendations of the IEAE as well on ITRAP+10 testing and evaluation of commercial instrumentation being carried out at the Joint Research Centre (JRC) in Ispra (Italy) within another EC-funded project.

The proposed equipment and technologies will satisfy the end-users requirement for:

- Radiation Portal Monitors for trucks or containers, light vehicles, luggage and pedestrian.
- Portable devices for Front Line Officers.
- Miniature communication devices for first responders.

SCINTILLA is innovating in two technology areas that offer complementary capabilities for detecting and identifying neutron and gamma, addressing different contexts:

- Scintillation materials (organic and inorganic) that exhibit fluorescence light when excited by ionizing radiation.
- CZT (CdZnTe or Cadmium Zinc Telluride) whose direct band-gap semiconductor capabilities makes it adequate for radiation detection and gamma spectrometry.

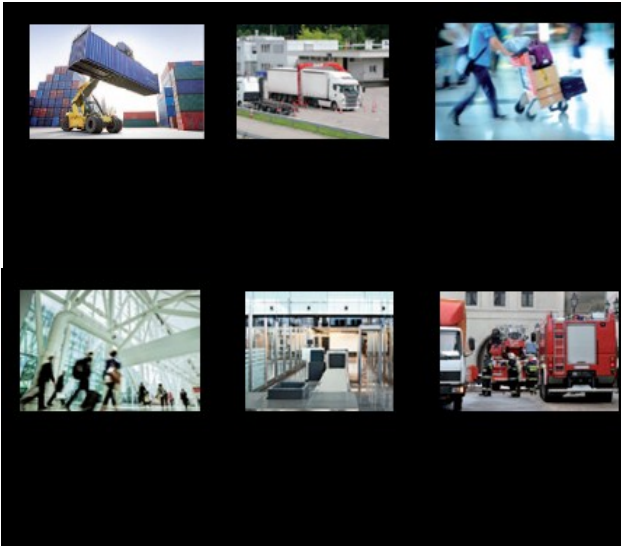


Fig. 1. Use cases defined and assessed to enable the development of devices for detection of radioactive sources and shielded material

The first year benchmark exercise has taken place at the JRC premises in Ispra in February 2013, the results of which are presented here

## II. DESCRIPTION OF TESTING FACILITIES

The first SCINTILLA benchmark has been performed at the JRC premises in Ispra using the existing ITRAP facility for dynamic tests here described. This facility has been designed to host irradiation tests with moving sources in order to reproduce transit situations at fixed portals or search with moving detectors.



Fig. 2. ITRAP facility

The laboratory is placed in a large hall hosting a conveyor system placed on 30-meter long rails. The conveyor can be programmed to perform multiple passages at predefined speed: maximum is up to 3 m/s, but typical testing speeds are 8 km/h (2.2 m/s) for vehicular portals and 1.2 m/s for pedestrian portals. A number of instruments can be placed beside the rails and exposed to sources mounted on the conveyor passing by the detectors. The conveyor has a vertical bar on which the source holder can be raised to the required

height from a minimum of 30 cm above ground level up to 4 m.

The laboratory can use for the irradiation tests a large inventory of radioactive sources and nuclear material including:

### A. Gamma Sources

A large variety of available sealed radioactive sources that cover the needs of all tests based on the ANSI and IEC standards. The sources cover the entire energy range from low (Am-241, Co-57, Ra-226), to intermediate (Ba-133, Cs-137) to high (Co-60, Na-22, Tl-208).

### B. Neutron Sources

Most of the tests on response of detectors to neutrons are performed using Cf-252 sources, due to the strong similarity of the neutron spectrum of Cf sources with that of Pu metal. Cf sources of various intensities are available up to a neutron emission of 100'000 n/s, including a source with emission of 20'000 n/s as required by ANSI/IEC standards.

### C. Special Nuclear Material

Nuclear materials are the utmost threat due to the possibility to produce a nuclear weapon, so high attention is paid to the detection of fissile materials. Among various SNM samples available in the inventory of PERLA, the most relevant for testing instruments for nuclear security are: a sample of 90%-enriched uranium (HEU) and various samples of reactor-grade Pu oxide and weapon-grade Pu metal.

### D. Naturally Occurring Radioactive Materials

NORM's are a major concern in nuclear detection because of the possibility to trigger innocent alarms due to the presence of radionuclides in commonly traded materials, such as fertilisers, fruits, construction materials, ceramics and other. The capability of discrimination between NORM and other radioactive sources is an added value for any detection system, so they have to be available for testing purposes. The most common NORM's are natural uranium, natural thorium and K-40.

### E. Medical Isotopes

Isotopes used for medical applications have the particularity of an extremely short life (few hours or days). Therefore they cannot be stored for long time and must be produced every time the tests are performed. There is a cyclotron facility on the Ispra site for commercial production of medical isotopes. So it is possible to procure on demand, if needed isotopes such as Ga-67, Tc-99m, In-111 and others.

## III. DESCRIPTION OF TEST PROCEDURES

The SCINTILLA technologies ready for the first technological benchmark were:

- Gd-lined plastic scintillator (INFN/Ansaldo)
- LiZnS neutron detector (Symetrica)
- NaI(Tl) gamma spectrometer composed by two 3"x3" crystals (Symetrica)
- PVT spectrometer – 2 sizes: 6 and 20 litres (Symetrica)

- Plastic with PSD – 2 prototypes: with a set of 3 and 4 detectors (SAPHYMO and CEA)

All these technologies are suitable for portal configurations. General testing conditions are:

- Dynamic test at a source speed of 8 km/h for UC1 and UC2 and 1.2 m/s for UC3 and UC4
- Distance from source 2.5 m for UC1 and UC2 and 1 m for UC3 and UC4

The types of the performed tests can be categorized as:

#### A. Response To Gamma Radiation

The response to gamma radiation for RPM-type of equipment is generally performed in dynamic conditions. When a testing gamma source passes through a portal at the constant reference speed (as stated above), it should trigger an alarm with at least 95% probability. The activity of the testing source depends on the nuclide and is defined by the standards (ANSI and IEC).

#### B. Response to Neutron Radiation

The response to neutron radiation for RPM-type of equipment is also performed in dynamic conditions. When a testing neutron source passes through a portal at the constant reference speed (as stated above), it should trigger an alarm with at least 95% probability. In order to assure the required probability the RPM should alarm at least 29 times out of 30 trials. The reference neutron testing source is a Cf-252 source with emission of 20'000 n/s ( $\pm 20\%$ ) shielded with 1 cm steel and 0.5 cm lead.

#### C. Influence of Gamma Radiation on Neutron Response

The presence of a strong gamma radiation may affect the performance of the neutron detector. Tests should be carried out in order to verify that gamma radiation does not induce a false neutron signal in absence of neutron field and gamma radiation does not mask a real neutron signal in presence of neutron field. The tests were executed by placing a Cs-137 source of 370 MBq at 36 cm from the detector surface. This allowed reaching a gamma dose rate of 0.02 mSv/h at the detector surface.

#### D. Radionuclide Categorization/Identification

Identification means the capability to state which isotope is transiting through the portal; categorisation means the possibility to define to which family of nuclides the isotope belongs to without identifying it precisely. The categories are SNM (Special Nuclear Material: U, Pu), NORM (Naturally Occurring Radioactive Material: natural Th, Ra-226 and K-40), medical and industrial isotopes.

#### E. Masking

The spectroscopic portal should be able to identify SNM material masked by a medical isotope (mainly for pedestrian portals) or by NORM (vehicle portals only). The following combinations have been tested: Ga-67 + HEU (masking ratio 5:1); Ba-133 + WG-Pu (masking ratio 1:1); K-40 + HEU; K-40 + WG-Pu; Ra-226 + HEU (masking ratio 3:1).

## IV. RESULTS

All the systems have alarmed in 100% of cases with the gamma sources of medium and high energy, passing the test with considerable margin; but plastic-based systems failed for the low energy sources: Am-241 and Co-57 sources.

All the neutron detectors have detected the presence of the neutron source. The LiZnS paddle detector has alarmed in 100% of cases with non-moderated and moderated neutron source. The Gd-lined plastic detector alarmed in 100% of cases with non-moderated neutron source. In the plastic detectors with PSD, even though it was possible to see visually the increase in the neutron signal, the pre-set alarm level was not reached every time. Moreover the signal came with a certain delay with respect to the source transit. The four-detector system from CEA was performing better than the three-detector system from SAPHYMO, pointing to the need to increase the detection volume together with the signal dynamics. The alarming criterion might also be revised.

No false neutron alarms have been observed by exposing the neutron detectors at a gamma dose rate of 20  $\mu$ Sv/h. No significant deterioration of neutron signal in presence of gamma was observed in the system that was not saturated by the gamma count rate: the LiZnS paddle. The plastic with PSD and the Gd-lined plastic detector could not cope with the high count rate. In the CEA system the problem was just a limitation of data transfer rate and can be possibly solved with a modification of the communication hardware. A similar problem affected the INFN system that was able to obtain the same neutron count rates recorded in absence of the gamma sources by increasing the energy thresholds applied to the PMT signals.

The NaI crystal system passed most of the identification tests for the tested bare and shielded gamma sources. The plastic systems with deconvolution were assessed only with respect to categorization, and the pedestrian system passed all tests, whereas the vehicular portal experienced some minor failures.

In masking scenarios, The HEU masked in Ga-67 was not detected, probably due to the high activity of the masking medical isotope (5:1 in terms of activity) ) and the HEU being  $\frac{1}{4}$  of the activity of an ANSI test source. The HEU masked with Ra-226 was detected 7 times out of 10. The WG-Pu masked with Ba-133 was detected 7 times out of 10, but Am-241 was detected in all the trials.

## V. CONCLUSIONS

The first SCINTILLA benchmark was an important milestone in the project and provided interesting and useful results for the continuation of the instrument developments.

In this first run, limited to portals for usage cases UC1 to UC4, the tests were mostly organised in form of verification of compliance with international standards. This was due to the fact that we profited of the experience, facilities and existing testing procedures developed in the context of the ITRAP+10 project. In the next benchmarks the tests could be redesigned in order to prove a beyond-the-standard capability. The testing

was carried out at a slightly reduced distance in order to partially compensate for the fact that single-sided instruments were provided for benchmarking rather than complete portals. Even though the instruments did not pass 100% of tests, the results were extremely encouraging, confirming the quality of the underlining technologies and of the instrument implementation.

The failures have given clear indications on the needed improvements and the developers have already highlighted the corrective actions and the next steps to improve the performance of their detectors.

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