PROCEEDINGS OF SCIENCE

INTERNATIONAL ATOMIC ENERGY AGENCY PROGRAM FOR DETECTION OF ILLICIT MATERIALS

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In light of a global upsurge of high-profile illicit activities, there is an increased awareness to protect citizens and supply infrastructures from acts of terrorism and the smuggling of contraband (nuclear materials, illicit drugs, biological materials, and landmines or explosives). A number of global initiatives have been implemented to strengthen measures that enhance the safety and security of transportation network. Technology support for such measures has been a natural corollary. The transport of illicit materials including radioactive materials and explosives is of major concern to many countries.

Nuclear detection methods, using new types of neutron generators and combined systems, have a great penetration capability and can determine the elemental composition and density of contraband. These methods provide a huge potential for quickly inspecting a large number of and a variety of suspected materials. It would be difficult to shield contraband against probing radiation, especially neutrons.

In view of this, the International Atomic Energy Agency (IAEA) has during recent years initiated several Coordinated Research Projects entitled Nuclear Methods for Landmine Identification, Improvement of Technical Measures to Detect and Respond to Illicit Trafficking of Nuclear Material and Other Radioactive Materials, and recently Neutron Based Techniques for Detection of Illicit Materials and Explosives as well as Application of Nuclear Forensics in Illicit Trafficking of Nuclear and Other Radioactive Materials.

The outcome of such projects will be a strengthening of the nuclear technology contributions for an important societal issue. The IAEA is in a unique position to encourage the use of nuclear techniques and its General Conference has adopted a resolution encouraging the Agency to further strengthen its promotion of R & D activities concerning nuclear methods. This paper will describe the IAEA's current programme and proposed future activities in this area.

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1. General Role of the International Atomic Energy Agency

The International Atomic Energy Agency (IAEA) works for the safe, secure, and peaceful applications of nuclear science and technology. Its key roles contribute to international peace and security, and to the World's Millennium Goals for social, economic and environmental development.

1.1 Promoting Safeguards and Verification

The IAEA is the world's nuclear inspectorate with more than four decades of verification experience. Inspectors work to verify that safeguarded nuclear material and activities are not used for military purposes. The IAEA inspects nuclear and related facilities under safeguards agreements with more than 140 Member States. Most agreements are with Member States that have internationally committed themselves not to possess nuclear weapons. They are concluded pursuant to the global Treaty on the Non–Proliferation of Nuclear Weapons (NPT), for which the IAEA is the verification authority.

1.2 Promoting Safety and Security

The IAEA helps Member States to upgrade nuclear safety and security, and to prepare for and respond to emergencies. Work is keyed to international conventions, standards and expert guidance. In the safety area, the IAEA Department of Nuclear Safety and Security cover nuclear installations, radioactive sources, radioactive materials in transport, and radioactive waste. A core element is setting and promoting the application of international safety standards for the management and regulation of activities involving nuclear and radioactive materials. In the security area, they cover nuclear and radioactive materials, as well as nuclear installations. The focus is on helping Member States prevent, detect, and respond to terrorist or other malicious acts — such as illegal possession, use, transfer, and trafficking — and to protect nuclear installations and transport against sabotage.

1.3 Promoting Science and Technology

The IAEA is the world's focal point to mobilize peaceful applications of nuclear science and technology for critical needs in developing countries. The work contributes to fighting poverty, disease, pollution of the environment, and to other goals of sustainable development. The Agency fosters R & D in safety of the general population.

- Technical Cooperation: The IAEA supports cooperative projects achieving tangible social and economic benefits for people in developing countries.
- Research & Development: Jointly with institutes and laboratories worldwide, the IAEA supports research and development on critical problems facing developing countries. Work targets food, health, water, and environmental areas where nuclear and radiation technologies can make a difference.

Three IAEA Departments lead programs in fields of nuclear science and technology: Department of Technical Cooperation; Department of Nuclear Sciences and Applications; and Department of Nuclear Energy.

2. Description of Coordinated Research Projects

The IAEA encourage and assist research on, and development and practical application of, atomic energy for peaceful purposes throughout the world and to foster the exchange of scientific and technical information, as well as the exchange of scientists in the field of peaceful uses of atomic energy. The Agency's Coordinated research activities are designed to contribute to this mandate, by stimulating and coordinating the undertaking of research by scientists in IAEA Member States in selected nuclear fields.

These Coordinated research activities are normally implemented through Coordinated Research Projects (CRPs) that bring together research institutes in both developing and developed Member States to collaborate on the research topic of interest. The research that is supported encourages the acquisition and dissemination of new knowledge and technology generated through the use of nuclear technologies and isotopic techniques in the various fields of work covered by the Agency's mandate.

The Agency's principle role is to act as the sponsoring and coordinating body for research on selected topics carried out by selected participating institutions. The Agency designates a Project Officer for the CRP, usually from its technical staff, who will liaise with the persons nominated as Chief Scientific Investigators for the participating institutes. Between them, they manage and liaise on the research program, which has duration normally of between 3 to 5 years.

Within the broad range of CRPs topics, the four projects given below are strongly connected with this workshop. The first projects has been completed with the outputs published in a special issue of the "Applied Radiation and Isotopes" journal [1]. The second CRP is scheduled for completion in spring 2006.

- Nuclear Methods for Landmine Identification
- Improvement of Technical Measures to Detect and Respond to Illicit Trafficking of Nuclear Material and Other Radioactive Materials
- Application of Nuclear Forensics in Illicit Trafficking of Nuclear and Other Radioactive Materials
- Neutron Based Techniques for Detection of Illicit Materials and Explosives

The last two projects, starting in 2006, are jointly coordinated by the Department of Nuclear Sciences and Applications and the Department of Nuclear Safety and Security. Their background and objectives are now described.

2.1 Application of Nuclear Forensics in Illicit Trafficking of Nuclear and Other Radioactive Materials

Illicit trafficking of nuclear material and other radioactive material has been an lightened issue of concern since the major seizures in the early 1990's. Application of nuclear forensics test and analysis technique can assist in the identification and composition of nuclear and other radioactive material providing valuable information to assist in determining the point-of-origin and routes of transit of such material.

The objective of this CRP is to enhance ongoing national and international efforts to combat illicit trafficking of nuclear and other radioactive material. In particular, the CRP would result

in procedures and improved techniques for; categorization and characterization of seized nuclear and other radioactive material; preservation of forensics evidence; sampling and transporting for forensics analysis; nuclear forensics interpretations. The CRP will also improve procedures for providing nuclear forensics support to regulatory and law enforcement authorities. A new series of publications [2] has recently been created by the Office of Nuclear Security.

The following outputs are planned from the CRP: Improved capabilities for categorization of nuclear and other radioactive material, improved procedures and techniques for preservation of evidence, improved procedures, guidelines and techniques for transportation of evidence, improved procedures and techniques for forensics investigation, improved procedures and guidelines for nuclear forensics interpretation, and improved procedure for providing nuclear forensics support to requesting IAEA Member States.

2.2 Neutron Based Techniques for Detection of Illicit Materials and Explosives

Neutron based techniques constitute an important component of nuclear techniques and offer a powerful tool for a variety of investigations in material sciences, analytical sciences, etc. The CRP objectives are to foster development and awareness enabling Member States to apply small neutron sources or other nuclear systems and a combination of nuclear techniques and conventional methods for the detection of bulk explosive materials.

The scope will cover the development of entire systems, including neutron sources, detectors, signal processing (including digital signal processing, position sensitive detectors, etc.), data processing and imaging. It will include work on the modeling aspects of proposed systems – e.g., radiation transport calculations, signal processing, imaging, validation, etc. Additionally, it will take careful consideration how proposed techniques could be integrated into a complete system to be used by non-specialists. In particular, projects will include:

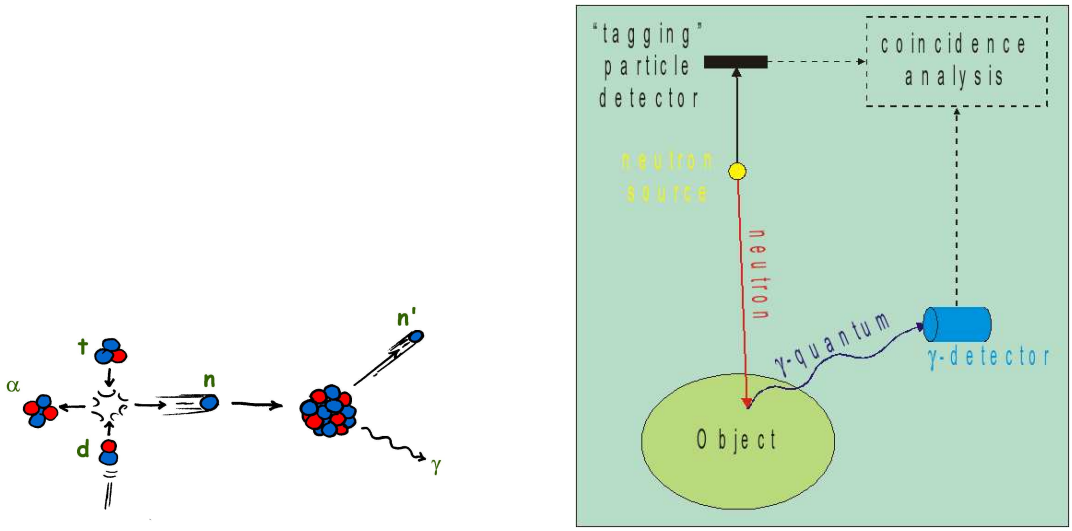

Figure 1: *Left: Neutron and alpha emission from DT fusion. Right: the Associated particle technique description. Courtesy of D. Vakhtin [5].*

- Using existing neutron generators for availing pulsed neutrons to probe materials and simulated samples.
- Custom evaluation of systems using thermal or fast neutron backscattering techniques.
- Gamma signals, both prompt and activation gammas as the case may be, to be acquired and analyzed to throw light on likely elemental composition of test samples.
- Optimization and validation of probing and detection to establish sensitivity achievable.
- Custom designs and construction of neutron generators for specific applications, field testing.
- Detector and signal processing systems to aid the investigations planned, with possible scope to apply elsewhere for other applications too.
- Evaluating applicability of radioisotope based neutron sources for similar purposes, after appropriate modifications to allow for the energy and fluence of neutrons.
- Computational and modeling contributions to facilitate design and implementation of the above systems and techniques.

The CRP will be focused on real-world applications and include full consideration of systems and integration issues. It will exclude applications regarding the detection of sub-kilogram quantities of explosives in both landmines and in routine screenings of aircraft luggage, as neutron techniques have been shown to be limited due to practical issues such as analysis time and sensitivity for such applications. The CRP will include applications of both neutron generators and radioisotope neutron sources. The term "neutron generator" is used here to refer to non-radioisotope sources and includes not only small particle accelerators but also sealed-tube DD and DT devices. Similarly, the use of both gamma rays from radioisotope sources and high-energy x rays generated by linacs and other accelerators will be covered.

The first research coordination meeting [4] took place in Vienna (April 19-21, 2006) with 13 participants from 11 Member States. Due to the safety considerations which exist for the utilization of nuclear techniques, one major goal which is aimed by each participants is to use "smart neutrons". Here, there is no need to increase the neutron source strength, but to more apply techniques that more effectively utilize every available neutron. This should be able to improve the sensitivity of our system such that they better detect signal over the background. Figure 2 shows a good example of such a technique. Applying a discrimination technique (as described in Fig. 1),

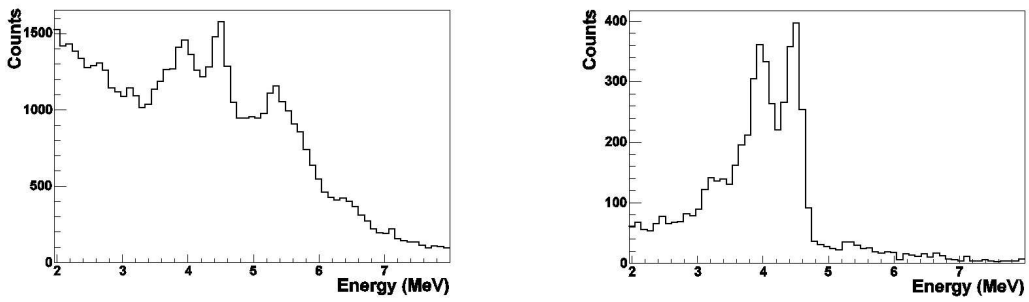

Figure 2: *Gamma ray spectrum of a graphite sample without (left) and with (right) "neutron tagging" by the associated particle technique. Courtesy of G. Nebbia [6].*

one succeeds to enhance a small signal from an important background. The signature is then very clean.

There is clear understanding that the neutron techniques will not be used in the first line of defense. They are foreseen to identify a threat which has already been spotted as a possible candidates by other faster methods.

3. Conclusions

A description of each CRP can be requested via the IAEA Coordinated Research Projects website [3]. A project could not be realized without the strong work of participants from all Member States. We are the research facilitator, you are the actors. Thanks to everyones work, we will have success within projects described in this paper.

References

[1] Editors: J. Csikai, E. Hussein and U. Rosengard, *Application of Nuclear Techniques to Anti-personnel Landmine Identification*, *Applied Radiation and Isotopes* **61** (2004) 1–81.

[2] Office of Nuclear Security, *Nuclear Security Series*.

[3] http://www-crp.iaea.org/

[4] http://www-naweb.iaea.org/napc/physics/ps/rcm.htm

[5] D. Vakhtin: *CRP project # 13474*.

[6] G. Nebbia: *CRP project # 13470*.