Development of a mobile modular system for the detection of Special Nuclear Material (MODES_SNM) 284842 FP7-SEC-2011-1

<table>
<thead>
<tr>
<th>MODES_SNM PARTNERS</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIVERSITA’ DEGLI STUDI DI PADOVA</td>
<td>Italy</td>
</tr>
<tr>
<td>ARKTIS RADIATION DETECTORS LTD</td>
<td>Switzerland</td>
</tr>
<tr>
<td>Narodowe Centrum Badań Jądrowych - National Centre for Nuclear Research</td>
<td>Poland</td>
</tr>
<tr>
<td>Eidgenössische Technische Hochschule Zürich</td>
<td>Switzerland</td>
</tr>
<tr>
<td>COSTRUZIONI APPARECCHIATURE ELETTRONICHE NUCLEARI C.A.E.N. SPA</td>
<td>Italy</td>
</tr>
<tr>
<td>UNIVERSITA’ DEGLI STUDI DELL’INSUBRIA</td>
<td>Italy</td>
</tr>
<tr>
<td>THE REVENUE COMMISSIONERS</td>
<td>Ireland</td>
</tr>
<tr>
<td>THE UNIVERSITY OF LIVERPOOL</td>
<td>United Kingdom</td>
</tr>
</tbody>
</table>

X Latin American Symposium on Nuclear Physics and Applications
SEC-2011.1.5-1 Call Requirements

**Topic SEC-2011.1.5-1 Development of detection capabilities of difficult to detect radioactive sources and nuclear materials**

**REQUIREMENTS**
- 1) fast relocatable solution
- 2) end-user oriented
- 3) detection and localization of sources
- 4) improve the detection capability of “difficult sources”
- 5) identification of the source

**BASIC TECHNOLOGIES:**
- High pressure noble gas scintillators
- Digital Electronics
- On-line event processing

**MODES SNM DISTINCTIVE FACTS**
- Neutron/gamma alarms
- Identification of gamma ray sources
- Discrimination between fission and \( (\alpha,n) \) neutron sources
- Information on the presence of shielding materials around the neutron source
THE NEUTRON CASE

Origin of the terrestrial neutron background: spallation reaction induced by the cosmic ray particles (typically 20 counts/s per m² of detector, $1/E$ dependence)

State-of-the art: $^3$He-poly assembly with good efficiency from thermal to 10 MeV but without information on the neutron energy

MODES_SNM: fast neutron detector (0.1-10 MeV) with efficiency centered in the SNM fast neutron spectrum. Terrestrial background is minimized thus enhancing the detection capability of weak fast neutron signal. Pulse height analysis to distinguish between fissile and $(\alpha,n)$ sources.

Special thermal neutron detectors (without poly moderator). The measure of the fast/thermal neutron ratio will provide information about the presence of shield.
MODES_SNM Detectors: fast neutron detector $\text{HP}^4\text{He}$ (top) gamma-ray detector $\text{HPXe}$ (middle) extended neutron detector $\text{HP}^4\text{He}+\text{Li}$ (bottom).
CAEN NEW FADC. The new electronic will allow to select on line neutron events for off-line software QC.
FAST NEUTRON DETECTOR WORKING IN HIGH GAMMA RAY BACKGROUND

Figure 4: Blue line: Neutron rate in presence of a constant AmBe neutron field. The Co60 field is varied between 0, 10 and 100 μSv/h. The bending at high gamma field is given by saturation effects in the electronics. The red line represent the neutron background rate measured at different Co60 intensities.
Figure 10: The gamma detector based on Xenon gas at 50 bar.

HP Xe scintillation detector prototype
see
Suitability of high-pressure xenon as scintillator for gamma ray spectroscopy
F. Resnati\textsuperscript{a}, U. Gendotti\textsuperscript{b}, R. Chandra\textsuperscript{b}, A. Curioni\textsuperscript{a}, G. Davatz\textsuperscript{b}, H. Friederich\textsuperscript{b}, A. Gendotti\textsuperscript{a}, L. Goeltl\textsuperscript{b}, R. Jebali\textsuperscript{b}, D. Murer\textsuperscript{b}, A. Rubbia\textsuperscript{a}
HP Xenon detector summary

Dimensions 10 cm x 20 cm  
Volume 1.6 liters  
Working pressure approx 45 bar  
Density 0.4 g/mL  
Temperature range -20° – 40° C  
Active mass 640g  
Efficiency 30% at 662 keV (predicted)  
Total weight 6-8 kg  
Cross section area 200 cm²
186 keV gamma ray emitted from $^{235}\text{U}$

<table>
<thead>
<tr>
<th>Detector</th>
<th>Peak Efficiency at 186 keV (%)</th>
<th>Resolution at 186 keV (%)</th>
<th>Front Area cm²</th>
<th>$P\times A/\sqrt{\text{Resolution}}$</th>
<th>Price USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5&quot; x 1.5&quot; LaBr(Ce)</td>
<td>0.7</td>
<td>5</td>
<td>11</td>
<td>3.4</td>
<td>20000</td>
</tr>
<tr>
<td>1.5&quot; x 2.2&quot; NaI(Tl)</td>
<td>0.7</td>
<td>10</td>
<td>11</td>
<td>2.4</td>
<td>2000</td>
</tr>
<tr>
<td>3&quot; x 3&quot; NaI(Tl)</td>
<td>0.8</td>
<td>10</td>
<td>44</td>
<td>11</td>
<td>5000</td>
</tr>
<tr>
<td>HP Xe</td>
<td>0.45</td>
<td>10</td>
<td>206</td>
<td>23</td>
<td>tbd</td>
</tr>
</tbody>
</table>

Data from PNNL Report 15831
Li-based Fast and Thermal neutron detector

Figure 5: $^6$LiF based thermal neutron detector.

- **5% intrinsic efficiency over 125 cm$^2$ for thermal neutrons**

Advantages
- No moderator required
- Keep spectral information
- Keep time information
Background

$^{252}\text{Cf source}$

$^{252}\text{Cf source} + \text{poly}$
SiPM read out of high pressure cells

- Two SiPMs with dedicated electronic board and flex cable (Hamamatsu)
- High-pressure tube with integrated wavelength shifter and the SiPMs mounted along the wall (ARKTIS)
- High pressurized $^4$He: optimal for neutron detection
- Caen 2-ch ampl. with leading edge discr. PSAU (SP5600A)
- Arktis home-made digitizer 150 mV - 10 bit - 1 GS/s - wave dump functionality
SiPM Results
(presented at the ANIMMA 2013 conf)

Signals from neutrons are clearly higher and longer
DPP-PSD firmware: block diagram

\[ PSD = \frac{Q_{LONG} - Q_{SHORT}}{Q} \]
DT5730: Desktop digitizer 500 MHz sampling rate, 14 bit resolution
DT5533: Desktop HV Power Supply 4 channels
The dependence of the FoM on the digitizer’s parameters (sampling rate and resolution) has been studied.
The integration of the system is under way at the Liverpool University.

Detectors in the containers
Interfacing the Electronics with IS and Detectors

- OPERATOR PC for REMOTE MANAGEMENT (subpart of IS)
- WI-FI WIRELESS LINK
- DAQ + IS
- USB
- AC 110V/230V Plug
- AC/DC Power Supply
- OR
- Battery System
- BOX A2
- BOX A1 – FE/HV-PS/DAQ/IS
- BOX B1/B2/B3 – Detectors
- PMT/SiPM SIGNALS
- HV POWER
- OPTICAL
- PCI-e
The final qualification of the detectors will be performed by National Centre for Nuclear Research (NCBJ) Swierk (Warsaw, Poland) during the next months.

Laboratory tests are aimed at determining the performance of the individual detectors and of the entire prototype with respect to the requirements from international bodies (IAEA) and standards (IEC, ANSI).
The MODES_SNM prototype will be prepared in a van mounted version.

The prototype will be qualified for SNM detection at the PERLA Laboratory located at JRC Ispra.

After this test the system will be transferred to end-users for final field test in the spring 2014.

At the present time we are making arrangements with:
Italian Customs
Duch Customs
UK Customs
Ireland Customs.
To have end-user performing field tests in the seaports of Venice, Rotterdam, Liverpool and Dublin.