Improvements in neutron and gamma measurements for material testing reactors

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In order to ensure quality and relevance of irradiation programs in the future Jules Horowitz Reactor (JHR), the CEA has significantly increased its R&D efforts in the field of in-pile instrumentation. Major progresses have thus been achieved in capability to perform accurate in-pile measurements using reliable and updated techniques. Improvements in neutron and gamma measurements are illustrated below.

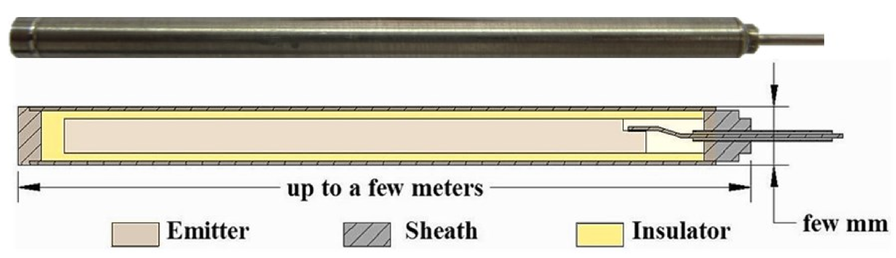
Progress in Self-Powered Neutron Detector simulation

Self-Powered Neutron Detectors (SPND) are major contributors to neutron flux evaluation, due to their robust construction, simple use and relatively low cost. Nevertheless SPND response calibrations need to be adapted to diverse irradiation conditions, requiring numerous and fastidious calibration tests. In this perspective, **the MATiSSe numerical toolbox has been developed for SPND design, simulation and operation**.

Between 2011 and 2014, successive dedicated experiments have been performed to validate MATiSSe : different types of SPNDs, including Rhodium, Cobalt and Silver emitter materials and various geometries, have been tested at the Slovenian TRIGA Mark II reactor, at the French OSIRIS reactor, and at the Polish MARIA reactor. Results show the good agreement between the SPND currents evaluated by MATiSSe and the measurements.

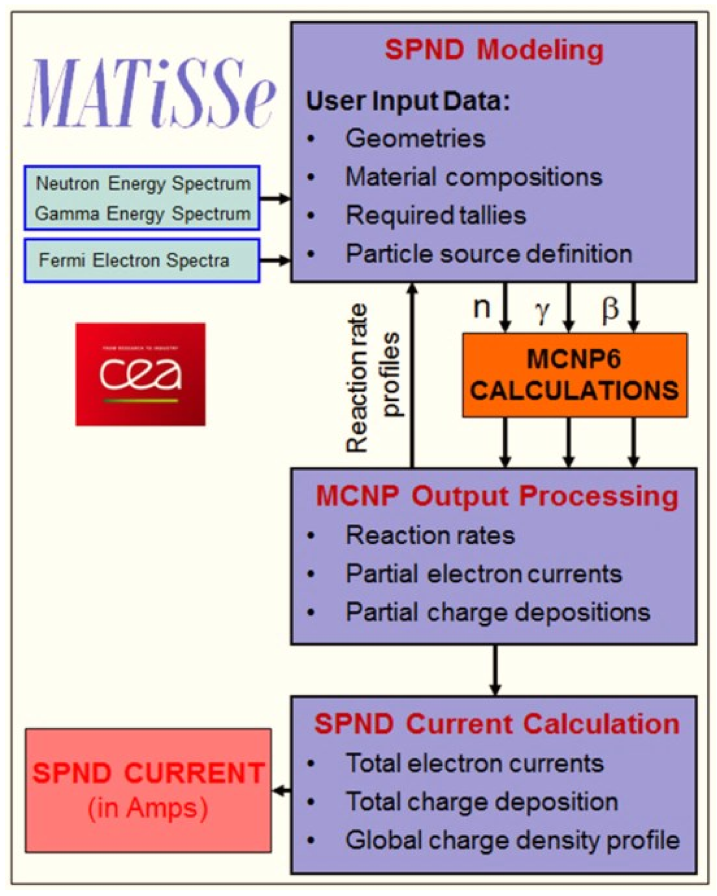
L. Barbot et al., 'Experimental Validation of a Monte Carlo based Toolbox for Self-Powered Neutron and Gamma detectors in the OSIRIS MTR', PHYSOR conference, Sun Valley, Idaho, USA, May 1–5, 2016

L. Barbot et al., 'Calculation to experiment comparison of SPND signals in various nuclear reactor environments', ANIMMA conference, Lisbon, Portugal, April 20-24, 2015

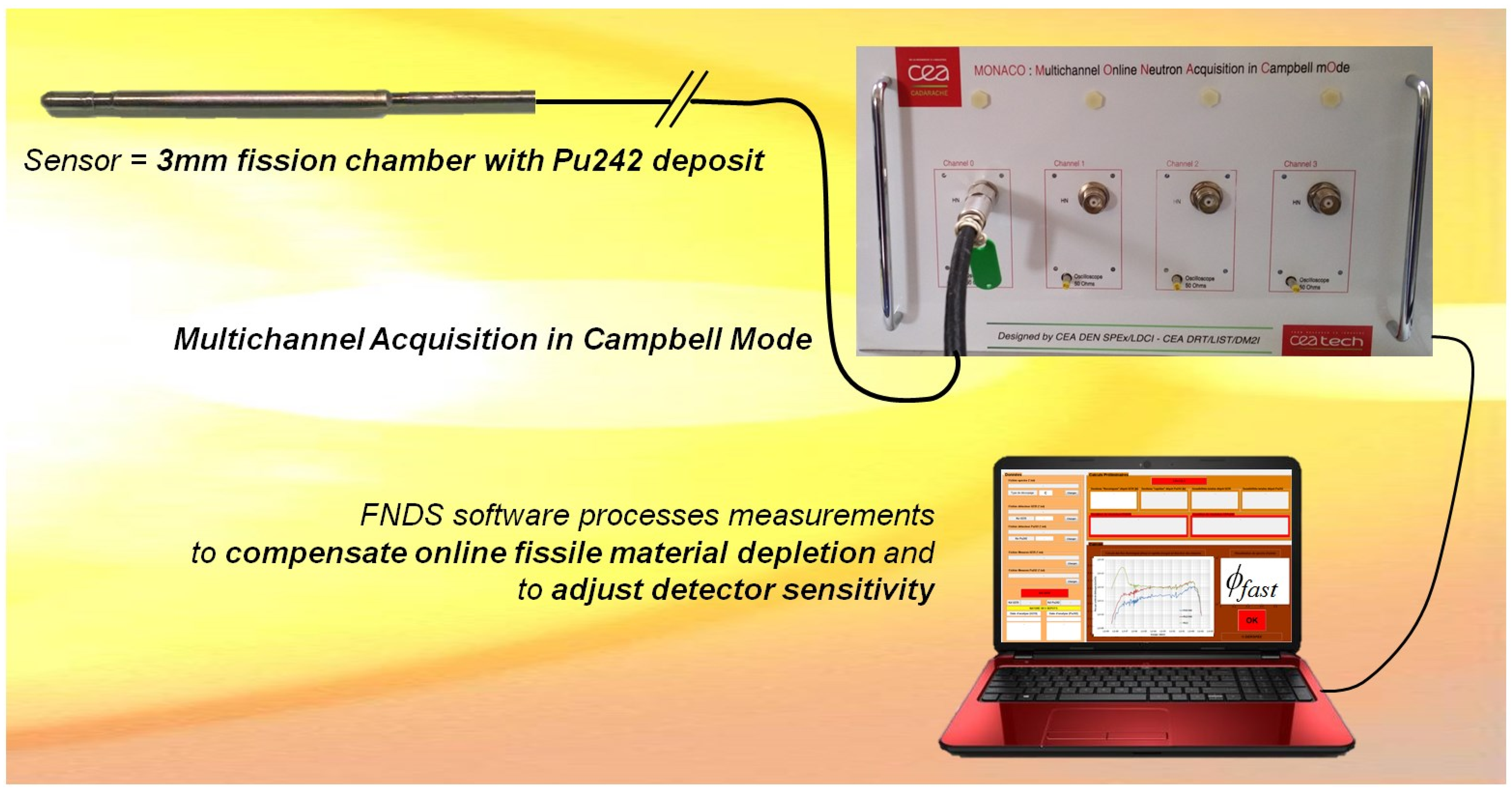


Typical SPND

CEA's MATiSSe toolbox is now operational for SPND design, simulation and data analysis. It is particularly relevant for the study of neutron detection systems to be implemented in future reactors.



Qualification of the Fast-Neutron-Detection-System



While most fission chambers are primarily used for thermal neutron detection, the CEA and the SCK•CEN have jointly developed and patented the **first and unique acquisition system able to provide an online measurement of the fast neutron flux (E>1MeV) in typical MTR conditions**, where overall neutron flux level can be as high as 10^{15} n.cm^{-2}.s^{-1} and is generally dominated by thermal neutrons, and where high gamma flux can disturb fission chamber measurement.

FNDS has been validated in 2015 after successive tests at the Belgium BR2 reactor and at the French ISIS reactor. FNDS signal was compared to reference thermal and fast neutron flux measurements using activation dosimeters analyzed under COFRAC® Quality Certification. FNDS proved its ability to measure online both thermal and fast neutron flux with an overall accuracy better than 10%.

J.-F. Villard et al., "Advanced In-pile Measurements of Fast Flux, Dimensions and Fission Gas Release," Nuclear Technology, 173, pp 89-97, January 2011

B. Geslot et al.," New measurement system for on line in core high-energy neutron flux monitoring in materials testing reactor conditions", Review of Scientific Instruments 82, 2011

Development of miniature gas ionization chambers

The CEA developed a miniature gas ionization chamber (MIC) designed to be operated on a large range of photon flux levels covering MTR conditions, up to a few 10^{14} γ.cm^{-2}.s^{-1}.

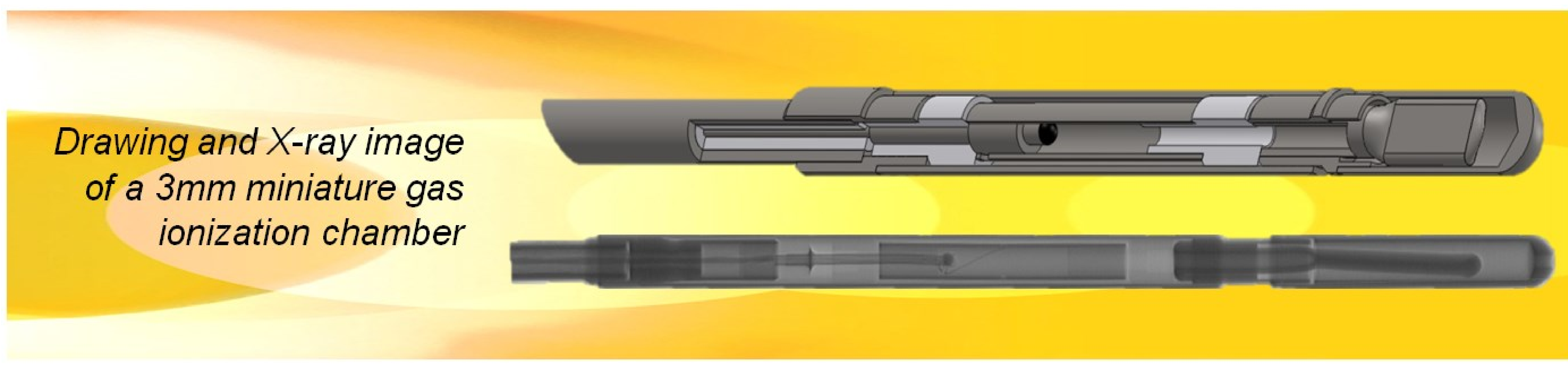
Tests performed from 2012 to 2015 at the French OSIRIS reactor and at the Polish MARIA reactor proved the consistency of the MIC signal with other evaluations of gamma flux.

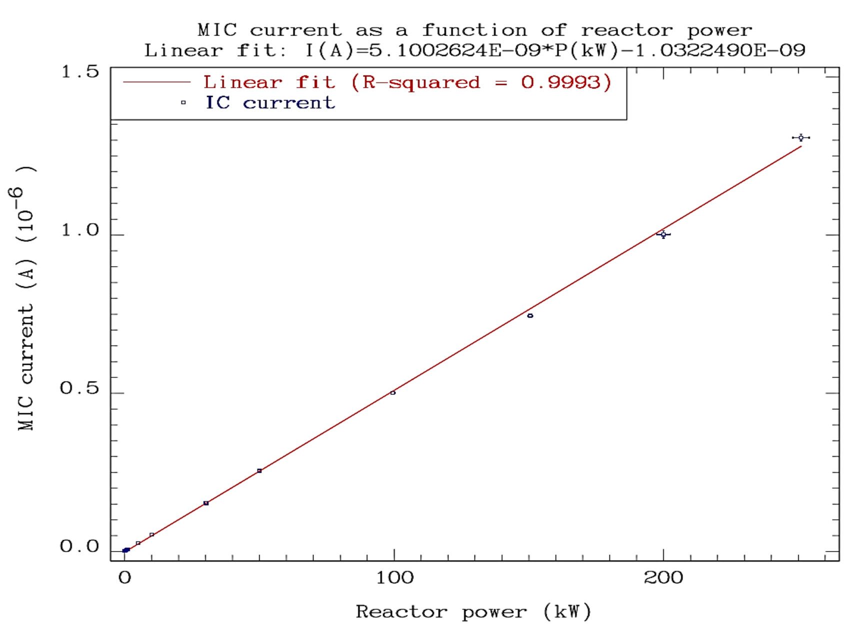
Furthermore, tests performed in 2014 at the Slovenian TRIGA Mark II reactor confirmed the relevance of MIC sensor for online and real-time evaluation of gamma flux over a wide range of flux level. MIC has proven to be particularly appropriate to monitor real-time the reactor power, but also to follow reactor SCRAMs (reactor shutdown with rapid insertion of control rods).

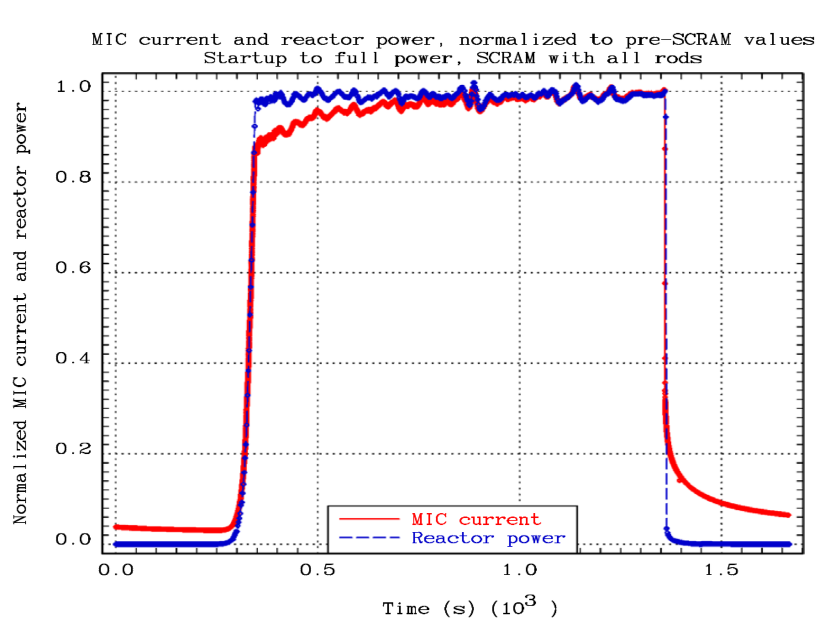
Finally, MIC are versatile sensors with a **large dynamic measuring range. They are excellent candidates for gamma flux characterization, as well as real-time monitoring of reactor power**.

D. Fourmentel et al., "Measurement of photon flux with a miniature gas ionization chamber in a Material Testing Reactor", Nuclear Instruments and Methods in Physics Research A 724 (2013) 76–82

V. Radulovic et al.," Measurements of miniature ionization chamber currents in the JSI TRIGA Mark II reactor demonstrate the importance of the delayed contribution to the photon field in nuclear reactors", Nuclear Instruments and Methods in Ph. Res. A 804 (2015) 149–154







Significant advances in the capability to monitor online and real-time neutron and gamma flux in MTRs have recently been achieved. Calibration processes have also been improved using combination of modelling and comparison with dosimetry measurements, leading to substantial reductions to the uncertainty budget, and extending the operating range of sensors from relative to absolute neutron or gamma flux evaluation. Furthermore, the released instrumentation covers also a large range of potential applications in other research and power reactors.

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