The EUROfusion_NCBJ_JET4 project for gamma-ray detectors in plasma experiments

I. Zychor, G. Bołtruczyk, M. Gierlik, M. Gosk, M. Grodzicka, J. Iwanowska-Hanke, S. Korolczuk, R. Kwiatkowski, S. Mianowski, M. Moszyński, J. Rzadkiewicz, P. Sibczyński, A. Syntfeld-Każuch, Ł. Świderski, M. Szawłowski, T. Szczęśniak, A. Szydłowski, A. Urban
National Centre for Nuclear Research, Otwock-Świerk, Poland

The EUROfusion_NCBJ_JET4 Project for Gamma-Ray Detectors in Plasma Experiments is a four-year project realized within the European Joint Programme, co-financed by EURATOM, the Research and Training Programme of the European Atomic Community (2014 - 2018) Complementing Horizon 2020 - The Framework Programme for Research and Innovation, and partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of the international co-financed project.

Since 2012 NCBJ has been involved in work on gamma-ray diagnostics for plasmas. The main objective of our activities is participation in long term projects carried out at the Joint European Tokamak facility (JET), then to prepare detectors for the International Thermonuclear Experimental Reactor (ITER) as well as for the DEMOnstration Power Plant (DEMO), see www.euro-fusion.org.

Members of the Nuclear Techniques & Equipment Department are participating in the development of detectors for gamma-ray diagnostics at JET.

At JET the α particle diagnostics are based on the $^{9}Be(\alpha,n\gamma)^{12}C$ nuclear reaction occurring between confined α particles and beryllium impurity ions typically present in the plasma. A 4.4 MeV gamma ray is emitted in the reaction:

$$^{9}Be+\alpha\rightarrow{}^{13}C\xrightarrow{n}{}^{12}C^{*}\xrightarrow{\gamma(4.44MeV)}{}^{12}C_{g.s.}$$

Gamma ray diagnostics of magnetically confined plasmas provide information on runaway electrons (fast electrons that often appear during plasma disruptions), fusion products and other fast ions due to nuclear reactions on fuel ions or main plasma impurities such as carbon and beryllium.

The following projects are currently being carried out by NCBJ within the JET4 Enhancement Projects: modernization of two detector systems at JET, the Gamma Camera (GCU) and Gamma Spectrometer (GSU) and building new diagnostics, the Lost Alpha Gamma Rays Monitor. Due to technical reasons the third project, the Lost Alpha Gamma Rays Monitor, was closed in 2015.

The gamma-ray camera is a very useful diagnostic tool to study confined α particles as well as fast ions. The information provided by the upgraded Gamma-ray Camera will complement high resolution spectroscopy measurements with the Gamma Spectrometer. Upgrade of the gamma-ray diagnostics is necessary because in planned deuterium-tritium campaigns measurements at high count rates are expected.

At NCBJ we tested the use of $CeBr_3$ scintillators, characterized by good energy resolution (4.2% for 662 keV), short decay time (~20 ns) and a relatively high detection efficiency for a few MeV gamma rays. $CeBr_3$ crystals are considered as one of the best scintillators, besides $LaBr_3$:Ce, for the upgraded gamma-ray diagnostics at JET to be used in experiments at high count rates.

Two prototype detectors, based on a $CeBr_3$ crystal coupled to a Multi-Pixel-Photon-Counter (MPPC), were prepared at NCBJ and in May 2015 mounted in the horizontal part of the Gamma-ray Camera at JET. First tests with high energy AmBe source, emitting gamma rays with an energy of 4.4 MeV, were performed in October 2015. Due to the fact that the properties of the MPPC are strongly affected by temperature, it was necessary to stabilize the MPPC operation caused by temperature variations. An MPPC temperature compensation device MTCD@NCBJ was designed and produced for real-time temperature monitoring and MPPC gain stabilization.

In 2015 we prepared a new detector for the Gamma Spectrometer based on a 3”×3” $CeBr_3$ scintillator coupled to a photomultiplier tube. $CeBr_3$ is characterized by a short decay time and low noise conditions. A dedicated active voltage divider was designed for this detector. The $CeBr_3$-based detector is now ready for further tests and installation at JET.

The current status of our activities are presented in more detail in subsequent articles of the NCBJ Annual Report 2015.

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects.

This work was carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.