Eurofusion_NCBJ_JET4 project for gamma-ray detectors in plasma experiments

I. Zychor, A. Brosławski, G. Bołtruczyk, M. Gosk, S. Korolczuk, M. Linczuk, 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 EUROATOM, 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 international co-financed projects. The project was prolonged in 2017 to the end of 2018.

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 Torus (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.

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 line is emitted in the reaction:

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

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.

Two projects are currently being carried out by NCBJ within JET4 Enhancements Projects: modernization of two detector systems at JET, the Gamma-ray Camera (GCU) and Gamma-ray Spectrometer (GSU).

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 the high resolution spectroscopy measurements with the Gamma-ray Spectrometer. An upgrade of the gamma-ray diagnostics is necessary because in planned deuterium-tritium campaigns measurements at high count rates are expected.

Our special interest is in measurements at high count rates and for this purpose $CeBr_3$ and $LaBr_3$:Ce scintillators were used with a decay time of about 20 ns.

The multi Pixel Photon Counter (MPPC) is one of these devices known as silicon photomultipliers. It is characterized by a fast response time, high gain coefficient, high photon detection efficiency resulting in good energy resolution, low voltage operation, resistance to mechanical shocks, compactness and immunity to a magnetic field. The MPPC gain is temperature dependent, so it is necessary to use a device which will allow itto be maintained at a constant value. For the upgraded Gamma-ray Camera, a detector based on a $LaBr_3$:Ce scintillator is equipped with MTCD@NCBJ, an MPPC Temperature Compensation Device to stabilize the MPPC gain. In addition, the basic performance of a photomultiplier tube (PMT) was determined and compared with an MPPC. 19 detector systems consisting of an MPPC, MTCD@NCBJ and a $LaBr_3$:Ce scintillator were delivered to JET and laboratory tests were performed there with radioactive sources.

A new detector for the Gamma-ray Spectrometer based on a 3″×3″ $CeBr_3$ scintillator coupled to a photomultiplier tube will be installed in the JET hall in 2018. The results of laboratory tests already performed have shown that this detector based on $CeBr_3$ with an active voltage divider is well suited for measurements at rates up to ~1 Mcps.

Monte Carlo simulations were performed with the Geant4 code to determine a response function for modernized detectors.

We started to analyse runaway electrons observed with the Gamma-ray Camera.

An upgraded version of the Digital Neutron Gamma@NCBJ (DNG@NCBJ) data acquisition system for high resolution spectrometry measurements at Mcps rates was prepared.

Measurement results of activation of aluminium capsules by 14 MeV neutrons are presented.

A dedicated program used for a determination of peak parameters registered with scintillators was developed and tested.

Our activities are presented in more detail in subsequent articles of the NCBJ Annual Report 2017 and in 7 publications in peer-reviewed journals.

This scientific work was partly supported by Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of the international co-financed project.