EUROFUSION_NCBJ_JET4 project for gamma-ray detectors in plasma experiments

I. Zychor, A. Brosławski, G. Bołtruczyk, M. Gosk, S. Korolczuk, R. Kwiatkowski, 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 carried out within the European Joint Programme, co-financed by EUROATOM, the Research and Training Programme of the European Atomic Community (2014 - 2018) Complementing the 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 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. The 4.4 MeV gamma line is emitted in the reaction:

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

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 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. Upgrade of 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 $CeBr_3$ scintillators were used with a decay time of about 20 ns. Since in such experiments short output signals are needed, we used a transimpedance amplifier (TIA) to obtain signals as short as 110 ns. In addition, TIA minimizes gain shift, by stabilizing the detector parameters, defining both static and dynamic working points, when the detected event count rate rapidly changes in time.

The Multi Pixel Photon Counter (MPPC) is one of the devices called a silicon photomultiplier. 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 magnetic fields. The MPPC gain is temperature dependent, so it is necessary to use a device which allows to a constant value of MPPC gain to be maintained. A detector, based on a $CeBr_3$ scintillator, is equipped with MTCD@NCBJ, MPPC Temperature Compensation Device to stabilize MPPC gain. We studied the performance of Hamamatsu MPPCs as a function of both temperature and bias voltage. A climate chamber was used to control the change of detector temperature. A detector system consisting of an MPPC, MTCD@NCBJ, TIA and a fast scintillator is considered to replace detectors based on CsI:Tl in the present JET Gamma-ray Camera. The results obtained prove the correct and effective operation of a detector consisting of an MPPC, MTCD@NCBJ, TIA and a scintillator in measurements at count rates up to ~1 MHz.

In 2016 we delivered to JET a new detector for the Gamma-ray Spectrometer based on a 3”×3” $CeBr_3$ scintillator coupled to a photomultiplier tube. A dedicated active voltage divider was designed for this detector. In the case of measurements at NCBJ a strong ^{137}Cs source with an activity of ~400 MBq was used to check the stability of the detector performance at high count rates. The results of at already performed tests NCBJ and JET have shown that the new detector based on $CeBr_3$ with the active voltage divider is well suited for measurements at count rates up to ~1 MHz.

Our activities are presented in more detail in subsequent articles of the NCBJ Annual Report 2016.

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