Gamma camera upgrade at JET

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The DT-experiment at the JET tokamak performed in 1997 has shown that direct measurements of confined alpha particles are very difficult. Alpha-particle studies require a significant development of dedicated diagnostics. JET now has an excellent set of confined and lost α-particle diagnostics. However, in order to take full benefit from the extensive DT campaign in the future, a number of diagnostic upgrades are necessary.

Among these necessary upgrades, the gamma camera plays an important role as a very useful diagnostic tool for the study of confined α particles as well as fast ions. The information provided by the upgraded gamma-camera will complement high resolution spectroscopy measurements.

The upgraded camera will measure nineteen line integrated γ-ray emission spectra associated with specific reactions among fast ions or fusion alphas with impurities, e.g., $^{9}Be(\alpha, n\gamma)^{12}C$ with a 4.4 MeV gamma emitted.

The upgraded detectors should have an energy resolution of about 5% FWHM at 1.1 MeV and the ability to register counting rates higher than 500 kHz. This is a challenging upgrade given the existing constraints (available space for detectors and shielding, use of existing cabling).

Tests were performed with a $CeBr_3$ crystal coupled to a Multi-Pixel-Photon-Counter (MPPC).

The $CeBr_3$ scintillator is characterized by good energy resolution (4.2% for 662 keV), a short decay time (~20 ns) and a relatively high detection efficiency for a few MeV γ -rays.

MPPC is a silicon–based monolithic array of micro-pixel avalanche diodes operating in Geiger mode. The main advantages of MPPC are: large internal gain, high photon detection efficiency, high – speed response, excellent time resolution, wide spectral response, immunity to magnetic fields and compactness.

Due to the fact that the properties of MPPC are strongly affected by temperature, it was necessary to stabilize the MPPC operation caused by temperature variations. A MPPC temperature compensation device MTCD@NCBJ was designed and produced for real - time temperature monitoring and MPPC gain stabilization. MTCD@NCBJ is based on the ATmega microcontroller family and temperature readout from a high precision, longterm stable temperature sensor (model TSic™ 506F). The block scheme of the prototype photodetector with the temperature compensation device is presented in Fig. 1.

For stabilization the feed forward gain control method was used (see Fig. 2.).

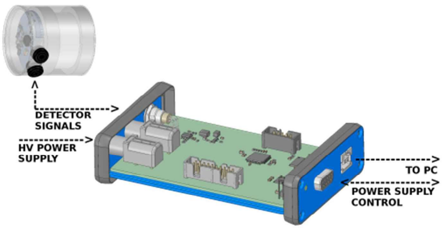

Fig. 1. Scheme of prototype detector based on MPPC with a temperature sensor placed in an aluminium capsule and the MTCD@NCBJ device.

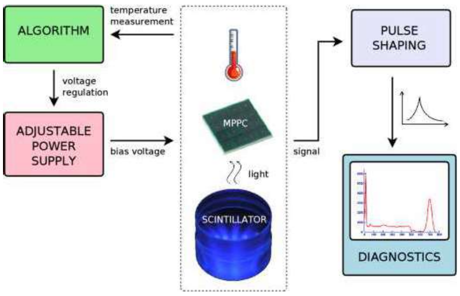

Fig. 2. Block scheme of the MTCD@NCBJ device for real - time temperature monitoring and MPPC gain stabilization.

In May 2015 two prototype γ-ray detectors were mounted in the horizontal part of the gamma camera at JET. First tests with a high energy gamma source of AmBe (4.4 MeV) were performed in October 2015. Due to the short measuring time, only the double escape peak from the 4.4 MeV line is clearly visible. A calibration source of ^{22}Na with two lines: 0.511 MeV and 1.274 MeV was used to get reference points. Fig. 3 presents the spectra obtained.

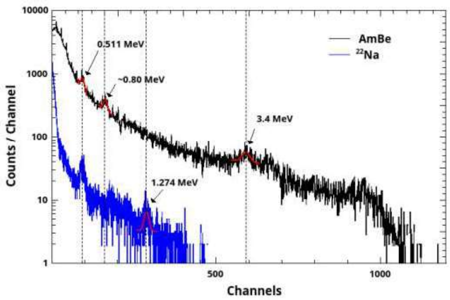

Fig. 3. Gamma energy spectrum of AmBe and ^{22}Na registered with the KN3G digitizer. Red lines correspond to fitted Gaussian functions.

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