Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
Świerk

EUROfusion

# Detectors for upgraded gamma-ray diagnostics for JET


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The EURO*fusion*_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 the Horizon 2020 - The Framework Programme for Research and Innovation, and partly supported by 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.

The main objective of our activity is a 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.

At JET alpha particle measurements are performed using gamma ray emission spectroscopy of the nuclear reaction

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

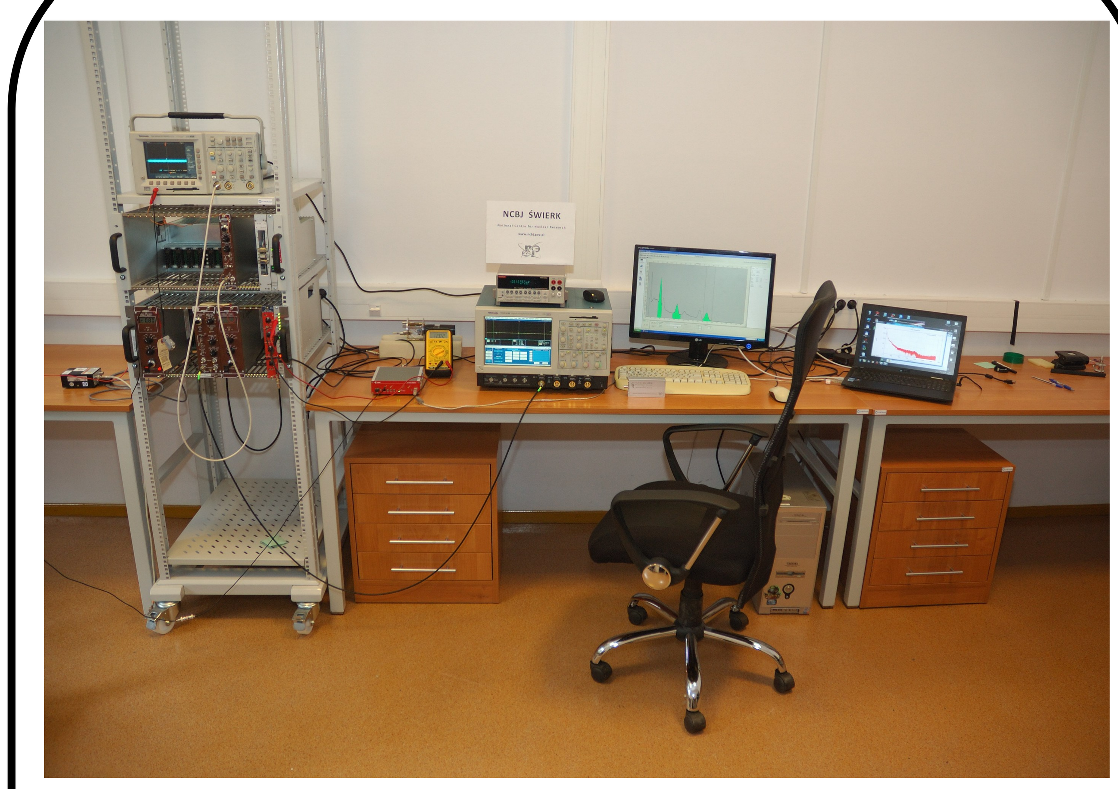
between alpha particles and beryllium impurities present in plasma.

Investigation of $\alpha$ particles behaviour for interpreting main mechanisms of their slowing down, redistribution and losses is a priority task for the planned deuterium-tritium experiments on JET in order to develop optimal plasma scenarios.

Different diagnostics upgrades are necessary for fusion alpha particle measurements to take a full benefit from the deuterium-tritium (DT) campaign at JET planned for the year 2017.

New detector system must fulfil requirements for high count rate measurements expected in DT campaigns and they will be based on $CeBr_3$ and $LaBr_3$ scintillators characterized by a good energy resolution, a relatively high detection efficiency for a few MeV gamma rays and a fast response time. Such scintillators are rather resistant to neutron damage and they are oxygen-free to avoid reactions induced by neutrons.

The spatial and energetic characteristics of the alpha particles are going to be investigated by two types of gamma-ray diagnostics systems, the gamma-ray cameras and the gamma-ray spectrometers, respectively.



New laboratory dedicated to JET4 projects established in the Nuclear Techniques & Equipment Department

Since 2012 NCBJ has been involved in works on gamma-ray diagnostics for plasma. In years 2014-2017 we participate in three of JET4 Enhancement Projects

**Gamma Camera Upgrade (GCU)** - replacing 19 CsI:Tl detectors with fast $CeBr_3$ scintillators;

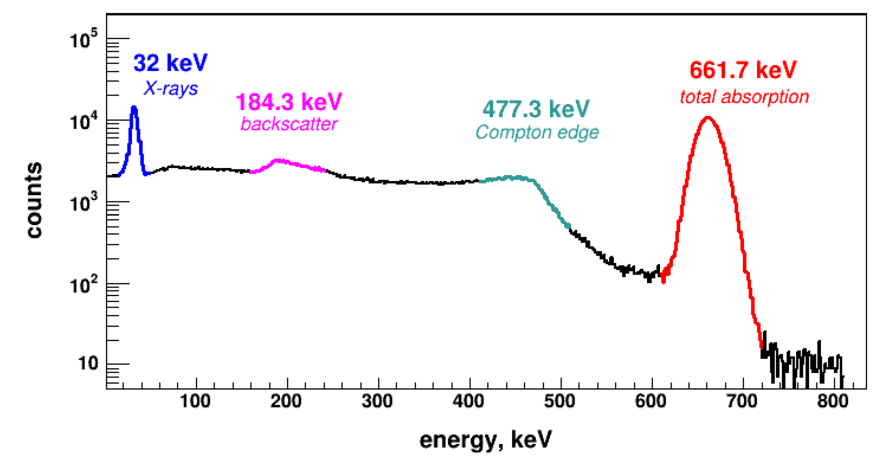
**Gamma Spectrometer Upgrade (GSU)** - replacing the existent BGO detector with a detector module based on $CeBr_3$ crystal;

**Lost Alpha Gamma Rays Monitor (LRM)** - a new diagnostic to monitor escaped alpha particles.

## MEASUREMENTS at NCBJ

Deuterium-tritium plasma experiments, planned at JET, demand measurements of a few MeV gamma-ray spectra at Mcps count rates with a good energy resolution. Measurements at NCBJ were performed using gamma-ray sources with energies up to a few MeV: PuBe and PuC, emitting 4.4 and 6.1 MeV gamma rays, respectively.

Basic properties of $CeBr_3$ scintillators - light output, energy resolution, decay time and full energy peak detection efficiency - were studied as a function of crystal volume between 0.5 and 350 cc.



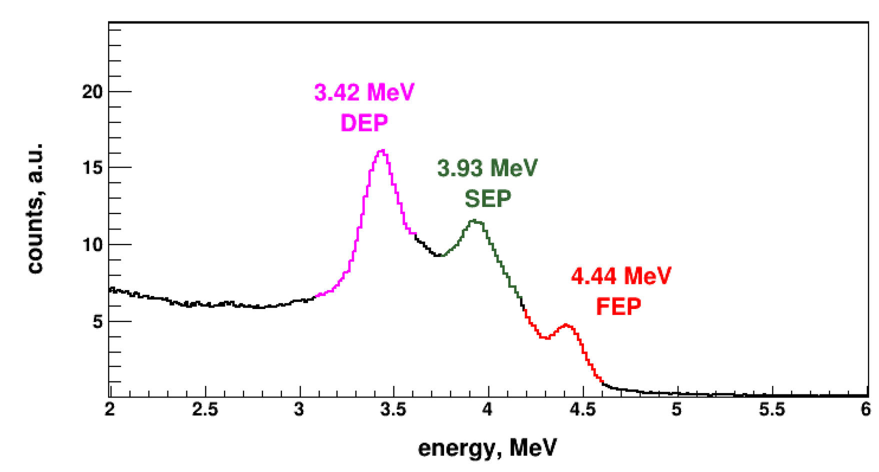

Energy spectrum of 661.7 keV $\gamma$-rays emitted from a $^{137}Cs$ source measured with 1”×1” $CeBr_3$ scintillator.

The full energy peak (total absorption peak) appears at 661.7 keV.

If the photon is not absorbed, it deposits a part of its energy in a Compton continuum, with a Compton edge equal to 477.3 keV.

Because $\gamma$-rays rays are scattered in a backward direction, the backscatter peak is also noticeable at 184.3 keV.

An absorption peak of 32 keV KX-rays emitted by the $^{137}Cs$ source is seen.

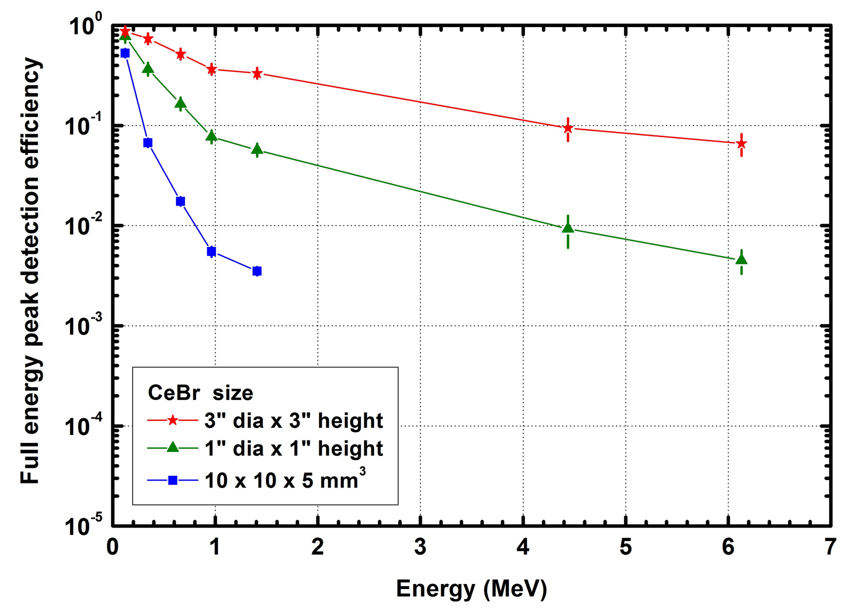



Response of 1”×1” $CeBr_3$ scintillator to PuBe source emitting 4.44 MeV $\gamma$-rays.

FEP (full energy peak) is detected at 4.44 MeV.

After annihilation of a positron inside the crystal, two 511 keV photons are emitted. It is possible that one or two of those photons can escape a scintillator, which gives rise to the single escape peak (SEP) at 3.42 MeV and double escape peak (DEP) at 3.93 MeV.

FEP is used to detect high energy $\gamma$-rays — however, SEP and DEP and may also be used for this purpose.




Full energy peak (FEP) detection efficiency measured for three $CeBr_3$ crystals in gamma energy range between 0.122 and 6.13 MeV.

The results for 4.44 MeV and 6.13 MeV $\gamma$-rays are not available for the smallest sample because the mean free path is too long to produce FEP is in this scintillator during acceptable acquisition time.

## DETECTORS AND PHOTODETECTORS


## OUTLOOK

1. In 2015 we concentrate on investigations to find the best detectors for gamma radiation measurements in high-temperature plasma in a strong magnetic field and intensive neutron and gamma fluxes.
2. We study both scintillator and photodetector properties for use in plasma experiments.
3. Monte Carlo simulations are used to optimise detectors to measure gamma rays produced in reactions induced by alpha particles in tokamak experiments.
4. Separate posters presented on “Gain stabilisation system for MPPC in plasma diagnostics” by M.Gosk *et al.* and “Digital approach to high rate gamma-ray spectrometry” by S.Korolczuk *et al.*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