WPJET4 Gamma Spectrometer Upgrade (GSU)

Additional report	Report on the calibration and installation of DM2@NCBJ I. Zychor and S. Korolczuk

1. Introduction

On JET the α-particle diagnostic is based on the nuclear reaction $^{9}Be(\alpha,n\gamma)^{12}C$ between confined α-particles and beryllium impurity ions typically present in the plasma, *see GSU Project Management Plan* and references therein. The applicability of gamma-ray diagnostic is strongly dependent on the fulfilment of rather strict requirements for the definition and characterization of the neutron and gamma radiation fields (detector Field-of-View, radiation shielding and attenuation, parasitic gamma-ray sources). For operating this diagnostic at the high DT neutron fluxes expected in the future high-power DT campaign on JET, specific improvements are needed in order to provide good quality measurements in the D-T campaign, characterized by a more challenging radiation environment.

In order to enable the gamma-ray spectroscopy diagnostic for α-particle diagnostic during the DT campaigns the following goals should be achieved:

- Maximization of the signal-to-background ratio at the spectrometer detector; this ratio is defined by terms of the plasma-emitted gamma radiation and the gamma-ray background.
- Establishing high count rate signal processing and energy-resolved gamma-ray detection.

In the DT experiments the gamma-ray detector must fulfil requirements for high count rate measurements. The existent BGO-detector with a relatively long decay time, about 300 ns, can be replaced by a new detector module (DM2) based on $CeBr_3$ scintillator, with an associated digital data acquisition system. The $CeBr_3$ scintillator are characterized by short decay time (~20 ns) and a high light yield about 45 000 photons/MeV. The coupling of the scintillators with photomultiplier tubes in specially designed detector modules will permit the operation at count rates over 2 Mcps. The $CeBr_3$ scintillator is an alternative to already tested at JET detectors based on $LaBr_3$:Ce scintillators. Both detector systems, called DM1 and DM2, are prepared to be installed exclusively at the KM6T operational position inside the J1D Mezzanine with an equatorial line of sight.

2. Detector module DM2

The DM2 detector module prepared for the upgraded Gamma-ray Spectrometer at JET comprises a 3”×3” cylindrical $CeBr_3$ scintillator, encapsulated in a 0.5 mm thick Al housing and coupled to a R6233-100 PMT. It is equipped with a SMA connector for tests with LED sources.

The specification of a detector module DM2 based on $CeBr_3$:

- scintillator dimensions: 3”×3” (76 mm diameter, 76 mm high),
- low background,
- high resolution <4.3% FWHM at 662 keV scintillation crystal,
- 0.5 mm thick aluminium housing.

The photomultiplier R6233-100 PMT:
a 76 mm diameter PMT surrounded by an extra-long solid mu metal shield.

Additional features:
a fiber optics stabilization port with SMA connector.

Active voltage divider designed at NCBJ.

Fig. 1. Left: Detector module DM2 with CeBr3 scintillator and a holder.
Right: Holder with a bigger hole for C&M system cut at JET on January 29th, 2020.

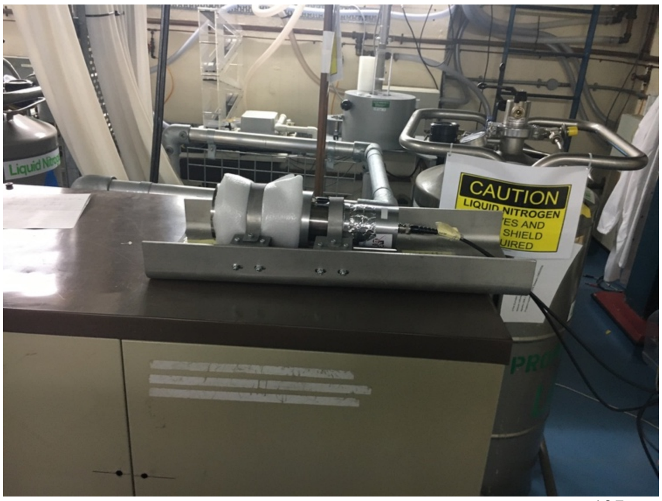

Fig. 2. Stand for measurements at JET lab with radioactive sources: ^{137}Cs, ^{60}Co and ^{22}Na.

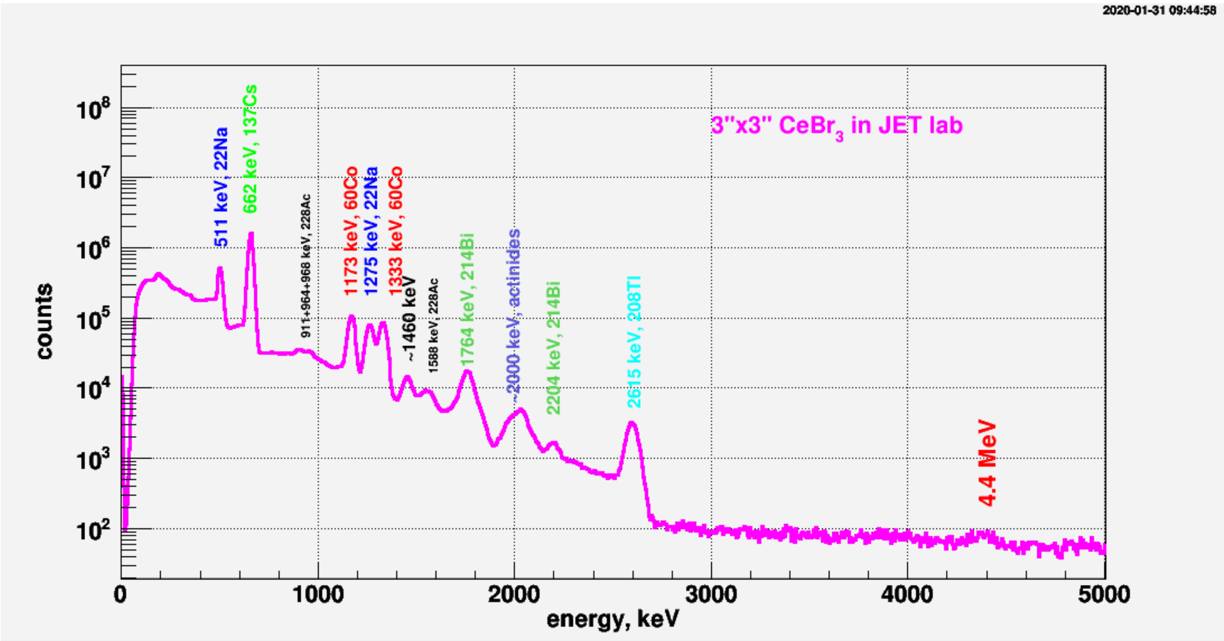

Fig. 3. Spectrum measured at JET on January 29-30, 2020 at -700 V.

Table. 1. Comparison of FWHM measured for three gamma lines.

Nuclide	Energy (keV)	FWHM (%) March 2018	FWHM (%) January 2020
^{137}Cs	662	4.61 ± 0.08	4.47 ± 0.01
^{60}Co	1173	3.38 ± 0.02	3.4 ± 0.1
^{60}Co	1333	3.26 ± 0.02	3.3 ± 0.1

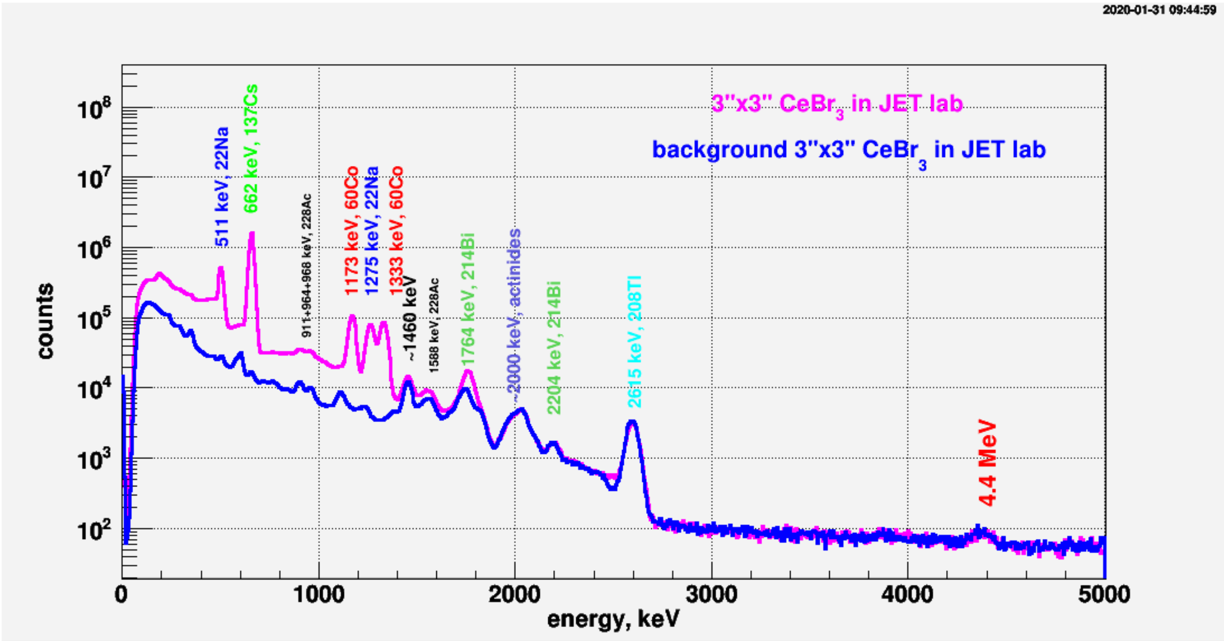

Fig. 4. Spectrum measured at JET:

magenta - on January 29-30, 2020 at -700 V with radioactive sources;
blue – on January 30-31, 2020 at -700 V without radioactive sources.