CeBr$_3$ – based detector for Gamma Spectrometer Upgrade at JET

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** See the Appendix of F. Romanelli et al., Proceedings of the 25th IAEA Fusion Energy Conference 2014, Saint Petersburg, Russia*

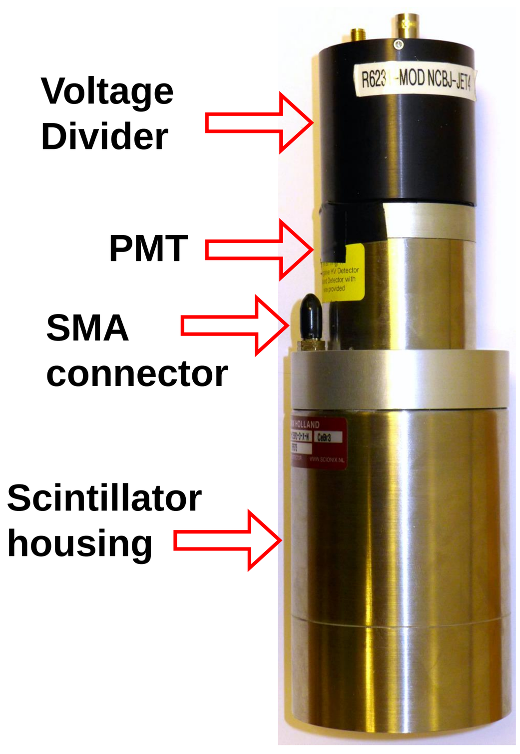
Introduction

The diagnostic of fast ions at JET is based on the measurements of gamma-rays which are produced as a result of nuclear reactions between ions and plasma impurities. The gamma-ray spectra provide information on energetic tail of ion energy distribution. The JET tangential gamma-ray spectrometer uses, in its present configuration, a BGO scintillator with a diameter of 3″ and a height of 3″. The existent BGO detector, with a scintillation decay time of ~300 ns, is sufficient during DD campaigns. The strong neutron and gamma-ray fluxes during D-T experiments induce new requirements for the spectrometer. In addition to good energy resolution it must also be characterized by high signal-to-noise ratio and allows to perform measurements at high counting rates.

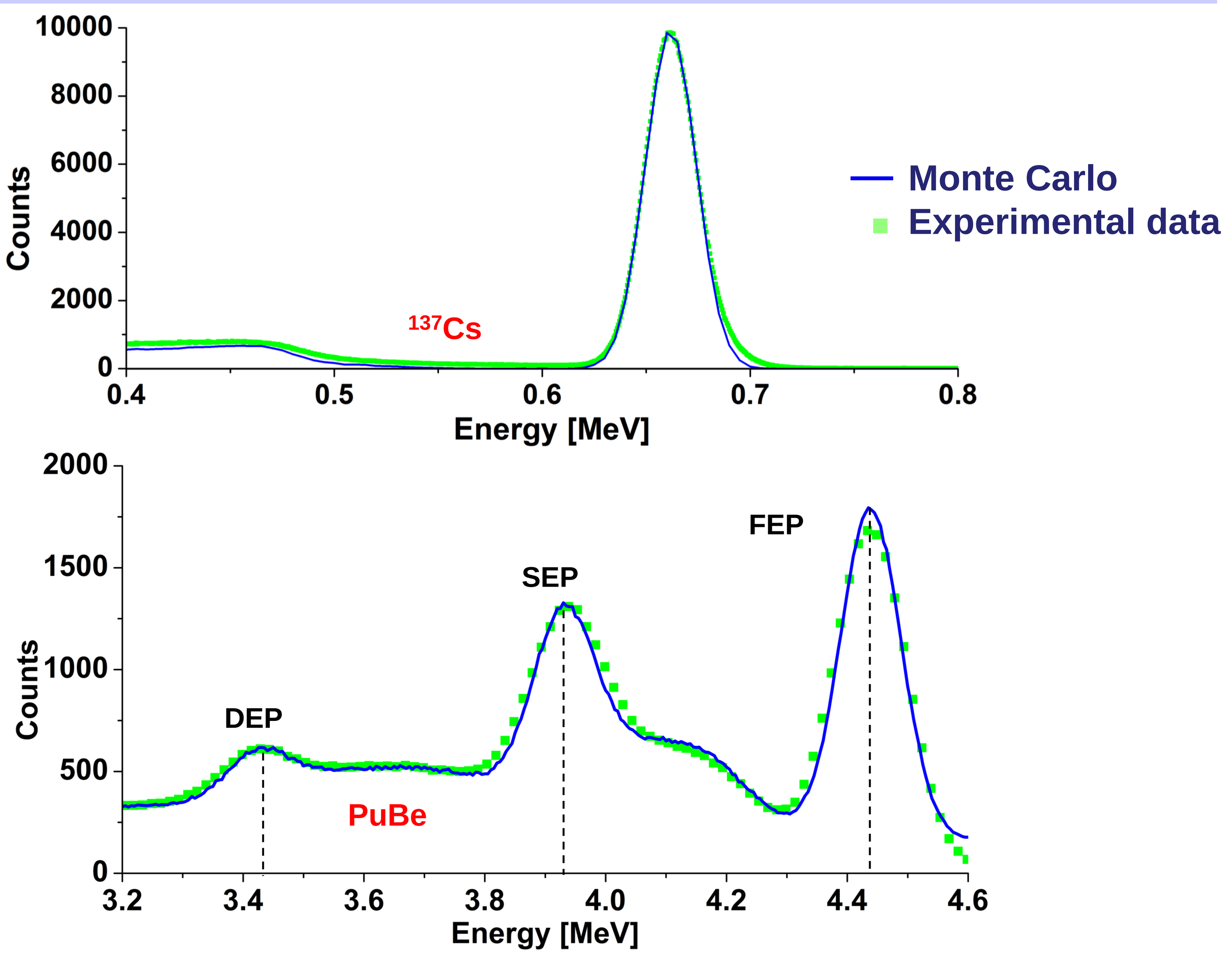
Gamma Spectrometer module

The detector, built of 3" in diameter and 3" in height CeBr$_3$ scintillator produced by Scionix, is encapsulated in 1 mm thick aluminum housing and coupled to a R6233-100 photomultiplier tube (PMT) which provides a fast signal. An additional μ-metal housing around the PMT assures a proper operation in a varying magnetic environment. The voltage divider (VD) is easily disconnected from the PMT.

The scintillator is characterized by a scintillation decay time of ~20 ns, good radiation resistance and low internal activity.



Monte Carlo simulations with GEANT4 code 3"x3" CeBr$_3$ scintillator response



Comparison of measured and simulated spectra

upper: ^{137}Cs source with full energy peak at 662 keV and Compton edge at ~477 keV

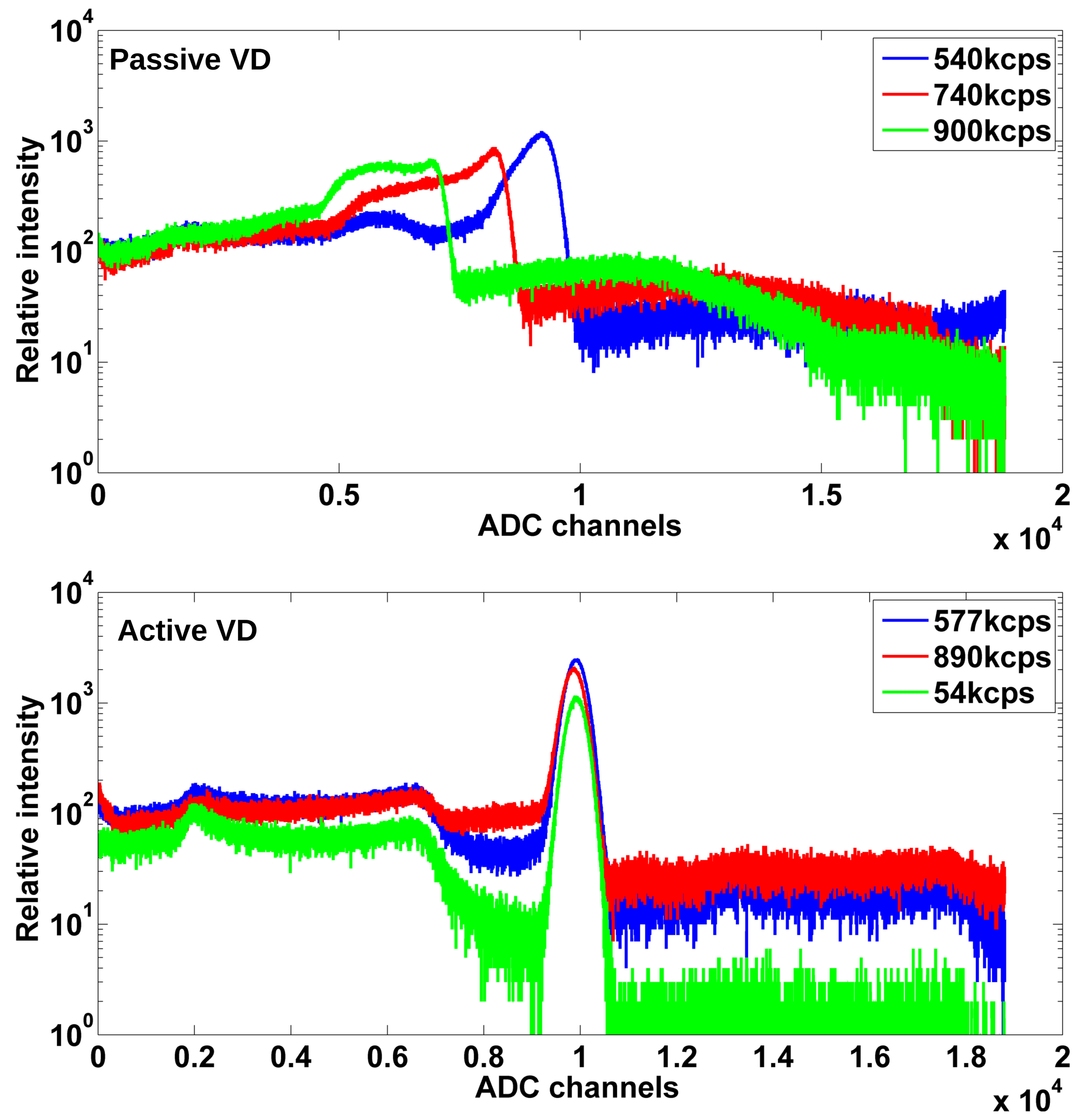
lower: PuBe source with full energy peak (FEP) at 4.4 MeV, single escape peak (SEP) at 3.9 MeV, double escape peak (DEP) at 3.4 MeV

3"×3" CeBr$_3$ scintillator properties

γ energy (MeV)	γ-ray source	FWHM (%)	detection efficiency (%)
0.51	^{22}Na	4.9±0.1	58±3
0.67	^{137}Cs	4.3±0.1	49±2
1.12	^{65}Zn	3.5±0.1	37±2
1.17	^{60}Co	3.3±0.1	34±1
1.28	^{22}Na	3.3±0.1	33±2
1.33	^{60}Co	3.3±0.1	33±1
3.93	PuBe (SEP)	3.2±0.1	-
4.44	PuBe (FEP)	3.0±0.1	14±2

Active voltage divider

Performance of a PMT-based detector depends on a voltage divider (VD). High current and pile-up effects change an operating point and a gain of a passive divider. Therefore, in order to properly register high flux spectra of gamma-rays an active voltage divider was designed and produced at NCBJ. The active voltage divider can be used up to 1.5 kV supply voltage with a 14 pin socket standard PMT. It ensures a constant gain during measurements with high counting rates.



^{137}Cs gamma-ray spectra registered with 3"×3" CeBr$_3$–based scintillator during measurements with various counting rates.

The detection efficiency and energy resolution observed during measurements with low rates are independent of a divider. At high counting rates the difference in spectra recorded with the active and passive VD are easily noticeable.

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