Performance of the prototype $LaBr_3$ spectrometer developed for the JET Gamma-ray Camera Upgrade

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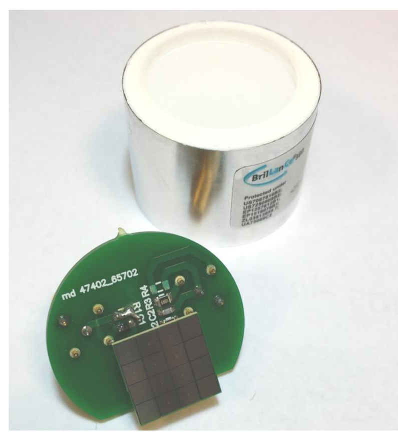
* *See the Appendix of F. Romanelli et al., Proceedings of the 25th IAEA Fusion Energy Conference 2014, Saint Petersburg, Russia*

INTRODUCTION

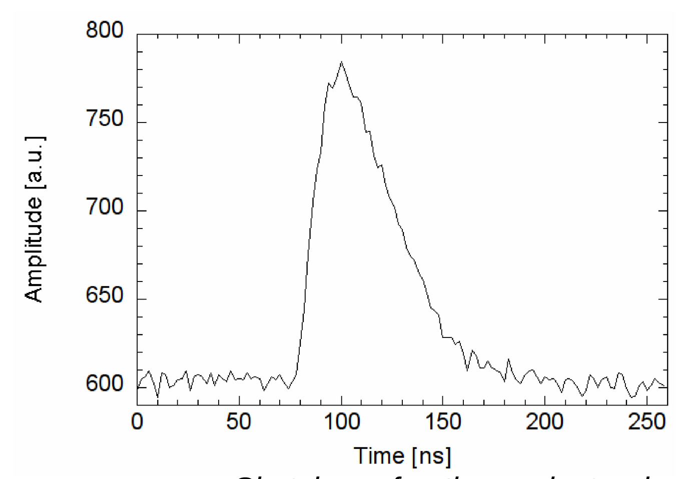
- **Gamma-ray spectroscopy** is a plasma diagnostic technique investigating the behaviour of fast ions in high temperature fusion plasmas
- The detection of the **4.44 MeV** γ-rays from the $^9Be(\alpha,n\gamma)^{12}C$ reaction gives information on alpha particles in deuterium-tritium (DT) plasmas.
- The Gamma-ray Camera Upgrade (GCU) project aims to **improve the spectroscopic properties** of the existing γ-ray camera of JET in terms of **energy resolution (5%@1.1MeV)** and **high counting rate capability** (>500 kHz) in order to operate in the DT campaign.
- Important existing **constraints** (available space for detectors and shielding, use existing cables)
- In this work we describe the solution developed to meet the requirements and enable gamma-ray spectroscopy in JET DT plasmas.

PILOT SPECTROMETER

- A dedicated pilot spectrometer based on a $LaBr_3$ scintillator crystal (25.4 x 16.9 mm^2) coupled to a Silicon Photo-Multiplier SiPM (12x12 mm^2) has been developed.
- SiPMs represent a good alternative to PMT -> insensitivity to magnetic field and **extremely compact size**.
- **Read-out electronic circuit was ad hoc built to combine the high counting rate capability with the good energy resolution**
- A proper pole zero cancellation network able to shorten the output signal to 120 ns has been implemented allowing spectroscopy at MHz count rates.



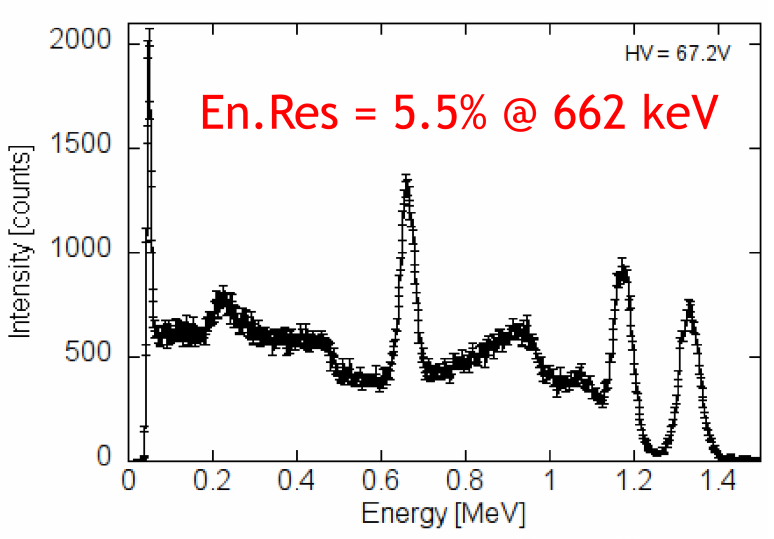
LaBr3 crystal and Silicon Photo-Multiplier with its read-out circuit board.



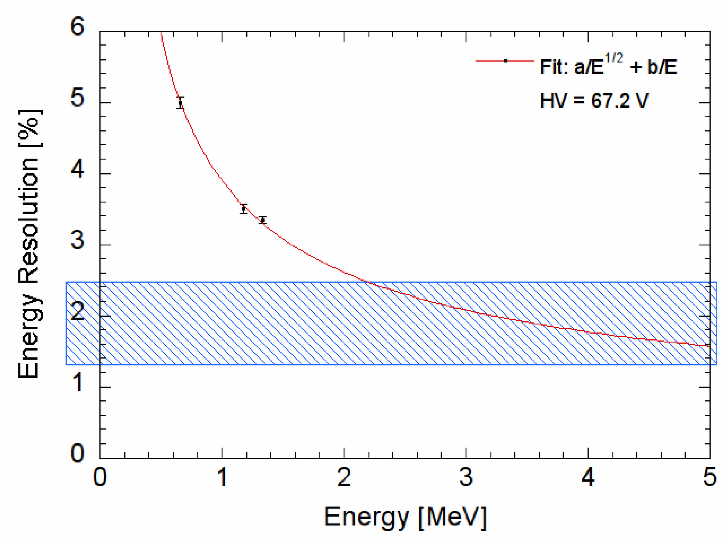
Sketch of the electronic readout circuit

MEASURED SPECTRA AND ENERGY RESOLUTION

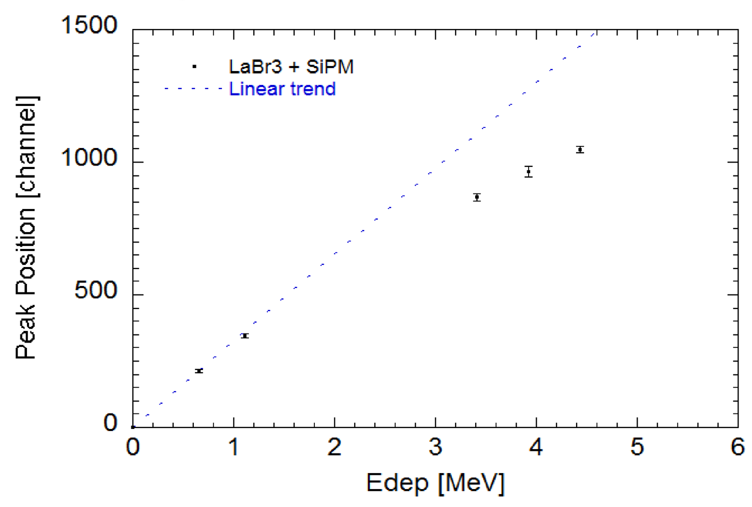
- Laboratory measurements with standard radioactive sources have been performed in order to characterize the MPPC response and its dedicated electronic readout circuit.
- Several measurements performed at different bias voltage, revealing an improvement in the energy resolution (En.Res.) with increasing the bias voltage up to 67.5 V
- The trend of the energy resolution is well fitted by the curve $f(E) = (a/\sqrt{E} + b/E)$ which extrapolates favorably in the energy range of interest (<2.5% in the range 3 – 5 MeV)
- The measured energy resolution is compatible to the one reached by a conventional PMT with same collectin area



Pulse Height Spectrum recorded with ^{137}Cs and ^{60}Co sources at bias voltage of 67.2V.



Measured energy resolution as function of the energy.



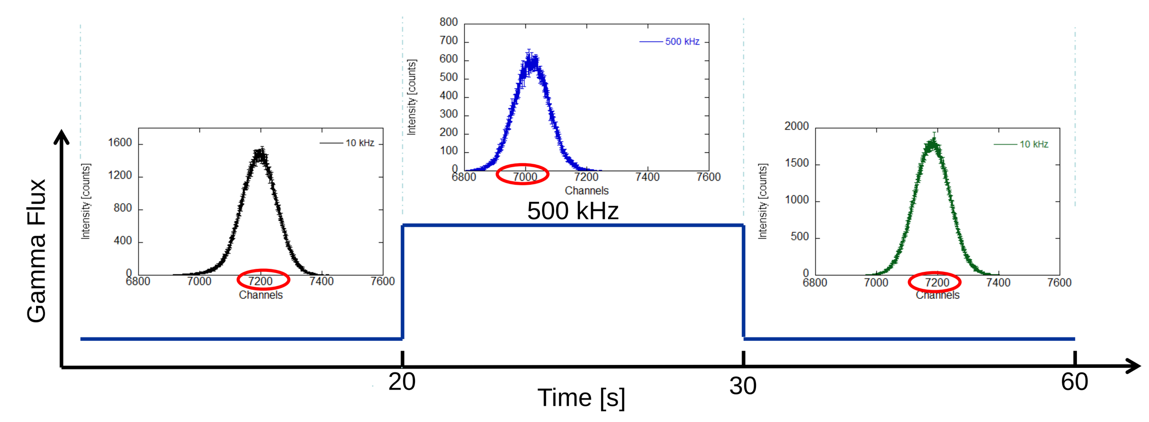
Limited linearity of the MPPC

Peak Energy (keV)	Measured En.Res (%)	Calculated En.Res (%)
PMT with mask (12x12 mm^2)		
662 1173 1333	4,71 3,81 3,43	4,11 3,09 2,90
MPPC12x12 mm^2		
662 1173 1333	5,50 3,97 3,69	5,05 3,82 3,89

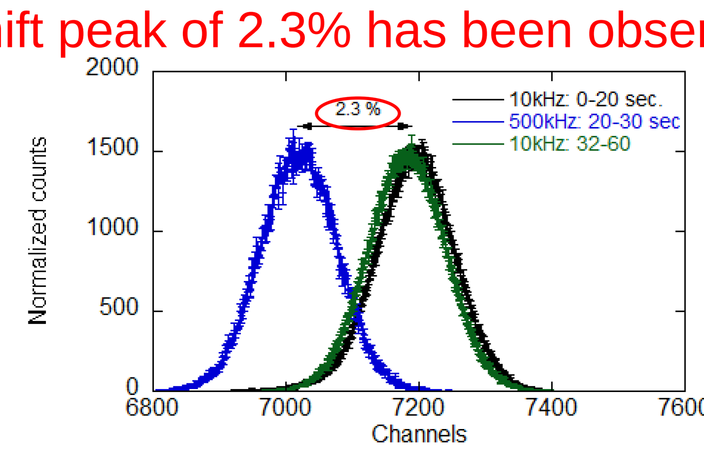
Comparison between the En.Res. of a conventional PMT and the one of a MPPC with same collecting area

MEASUREMENTS at HIGH COUNTING RATE

- High counting rate measurements have been performed in laboratory by using a blue LED connected to a pulse generator
- First meauserementes have highlighted a deviation in the reference peak position (^{137}Cs) in the pulse height spectrum
- To simulate a JET shot, a 60 seconds measurement with 2 LEDs has been performed
  - **LED2** → Reference LED with fixed amplitude≈3 MeV, repetition rate 10 kHz
  - **LED1** → Perturbation LED with fixed amplitude ≈ 660keV, **variable repetition rate** (Variable rate: 0-20 s → ν = 10 kHz; 20-30 s → ν = 500 kHz; 30-60 s → ν = 10 kHz;)
- Further investigations are needed to evaluate the real equivalent energy of the 10 seconds of high gamma background flux at JET



A shift peak of 2.3% has been observed



**more details about the high rate behaviour are presented in M. Nocente's poster*

CONCLUSIONS

- A dedicated pilot spectrometer based on a $LaBr_3$ crystal coupled to a SiPM has been developed in Milano to meet the requirements for the GCU project
- **Read-out electronic circuit was ad hoc built to combine the high counting rate capability with the good energy resolution**
- A fast pulse of 120 ns was obtained -> allowing spectroscopy at MHz count rates.
- Energy resolution of **5.5%@662 keV** has been obtained and can be favorably extrapolated in the energy range of interest for plasma diagnostic (<2.5% at 3-5 MeV)
- Measurements at high counting rate with LEDs have shown a gain loss in the MPPC which produces a peak shift in the measured spectra of 2.3 % in the JET-Like measurement, which is still acceptable.
- The intrinsic activity of the LaBr3 can be used as a rough MPPC gain monitor due to temperature change. Shifts of the order of 5%, in fact, can be well appreciated in between two JET shots (20 minutes).

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