Gamma-ray spectroscopy of fusion plasmas at MHz counting rates with a compact $LaBr_3$ detector and silicon photomultipliers

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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

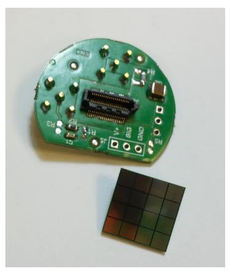
- Measurements of the **gamma-ray emission** profile resulting from **nuclear reactions between fast ions and impurities** are a powerful tool to study the dynamics of **energetic ions** in a fusion plasma
- An essential reaction for studying DT plasmas is $\alpha+{}^{9}Be \rightarrow n + {}^{12}C^*$. We want to measure the **emission profile of the 4.44 MeV peak** from this reaction as a way to determine the **α particle profile**.
- The **Gamma-Ray Camera Upgrade (GCU)** project at JET aims at upgrading the present set detectors of the JET gamma-ray camera by the development of **detectors with spectroscopy capabilities and than can operate at counting rates up to 1 MHz and above**, as expected in a JET DT plasma at full power.
- In this work we **demonstrate gamma-ray spectroscopy measurements in the MHz range** with the GCU detectors.

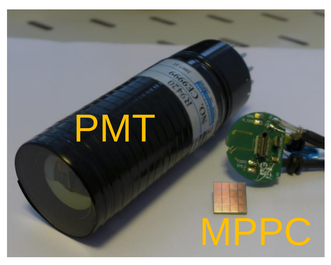
THE DETECTOR

Requirements

✓ ***Insensitivity to magnetic fields***
✓ ***Limited space: the detector must fit a 35 mm x 25 mm capsule***
✓ ***Sufficient energy resolution to identify characteristic peaks***
✓ ***High counting rate (1 MHz and above) capability***

Our solution





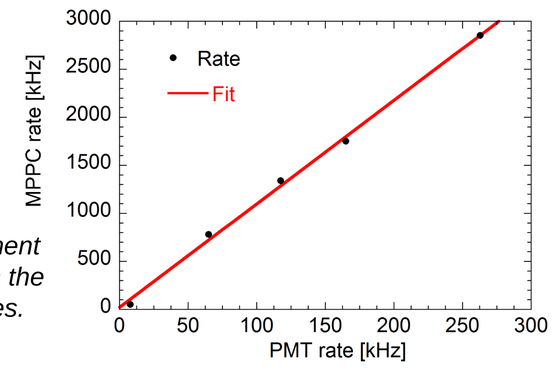
Multi Pixel Photon Counter
+
$LaBr_3$ or $CeBr_3$

- Array of **avalanche photodiodes operated in Geiger mode**
- They have revolutionised **PET applications**
- **Gamma-ray spectroscopy in the MeV range** with MPPC very recently demonstrated at low counting rates [1,2]
- **Ad hoc read-out solutions** have been developed to combine spectroscopy and high counting rate capabilities with our detector (see D. Rigamonti's poster) [3]

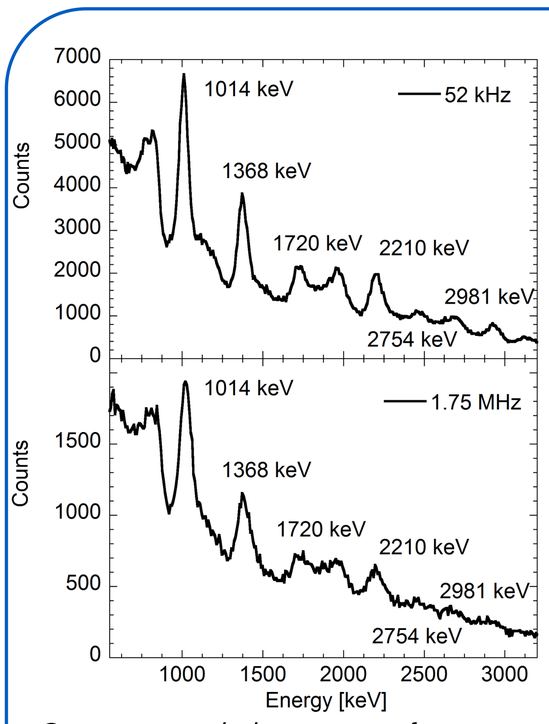
HIGH COUNTING RATE EXPERIMENT

- Experiment performed at the **Tandem accelerator of the Legnaro National Laboratories**
- We observed multi gamma-ray emission lines from **reactions between 10 MeV protons and a ^{27}Al target**
- A fast **CAEN DT5730 digitizer** and a dedicated software algorithm based on **pulse fitting and pile up rejection** [4] were adopted to reconstruct the emission spectrum after each measurement.
- **Counting rates between 50 kHz and up to about 3 MHz** were obtained on the MPPC by changing the beam current

Correlation between the counting rate obtained on the MPPC in each measurement and that on a monitor PMT sitting far from the target and operated at lower counting rates.



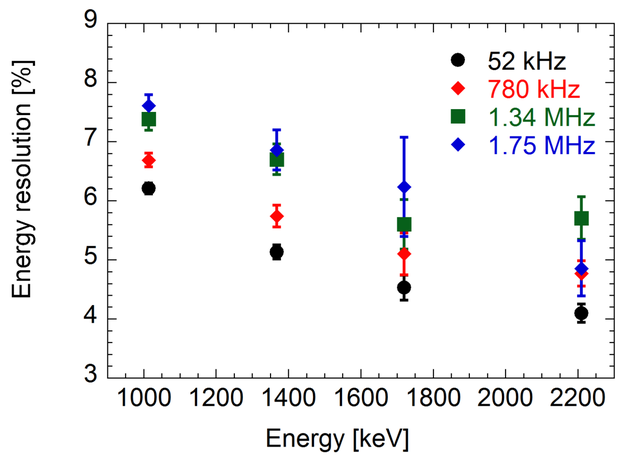
RESULTS



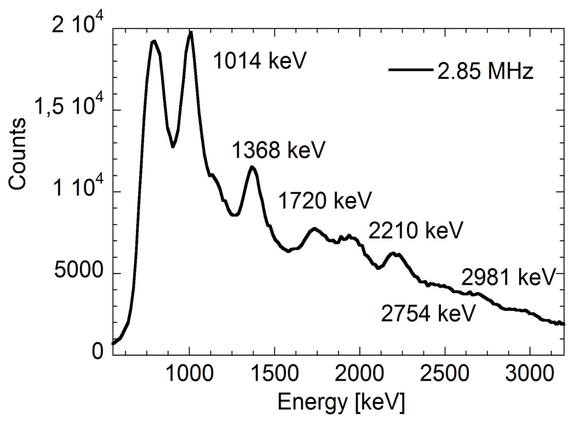
Gamma-ray emission spectrum from p+^{27}Al reactions measured at 52 kHz and 1.75 MHz counting rates

- Both at relatively low (52 kHz) and high (1.75 MHz) counting rates were are **capable to observe all of the peaks!**
- Although a moderate worsening of the energy resolution is observed as the counting rate is increased, **the resolution still improves as 1/√E at each counting rate**
- An **energy resolution of about 4%** can be expected for the **4.44 MeV peak** from the $\alpha+{}^{9}Be$ reaction at JET at a counting rate of 1.75 MHz.

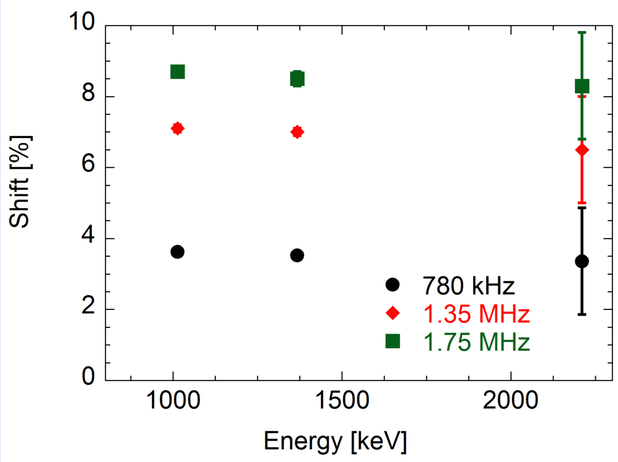
- A **shift of the peak position** has been observed. This is due to both temperature and current effects. **The current shift is independent of the gamma-ray energy, as expected**. ***These shifts are of no concern for JET***, as we can recalibrate the device thanks to time resolved measurements.
- ***Counting rates up to about 3 MHz have also been reached*** by operating the MPPC at reduced HV, at the price of a somewhat coarser energy resolution.



Energy resolution at the different peaks observed and as a function of the MPPC counting rate



Gamma-ray emission spectrum from p+^{27}Al reactions measured at 2.9 MHz



Shift of the mean peak position of the gamma-ray peaks born from p+^{27}Al as a function of the counting rate and due to the increasing signal current of the MPPC

For time demonstration that good energy resolution, MHz counting rate capability, compact dimensions and insensitivity to magnetic fields can ALL be combined within a single device!
We are ready to measure gamma-rays in a DT plasma!

CONCLUSIONS

- Detectors for the upgrade of the JET gamma-ray camera have been developed and are based on MPPCs. **Strict requirements** on space limitation, insensitivity to magnetic fields, energy resolution and high counting rate capabilities must be all satisfied by one single device.
- A dedicated experiment to test the high counting rate of the detector envisaged has been performed. The results show that **counting well above 1 MHz can be reached** with this detector. **The capability to perform high counting rate gamma-ray spectroscopy with compact detectors have been demonstrated for the first time in this experiment.**

REFERENCES:

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