New FPGA processing code for JET gamma-ray camera upgrade

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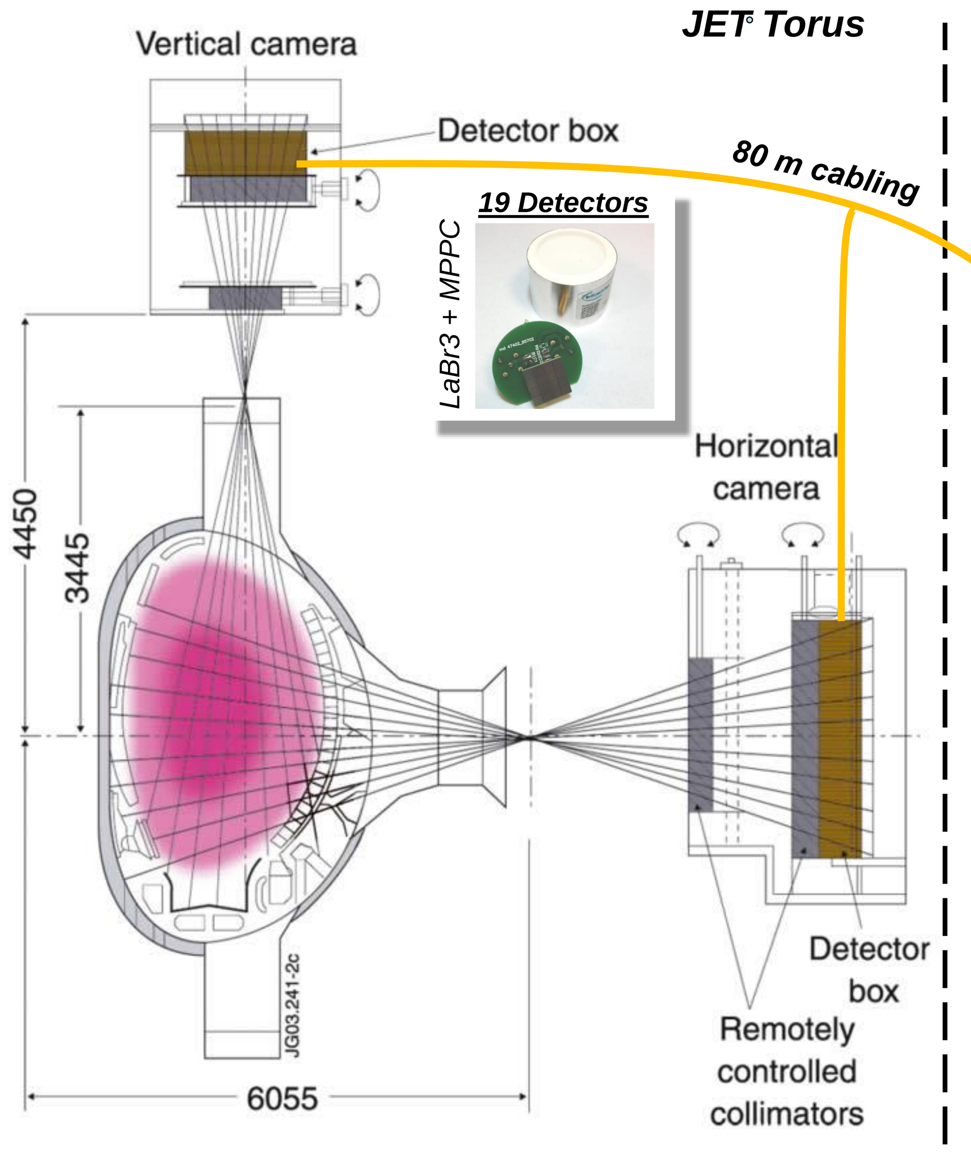
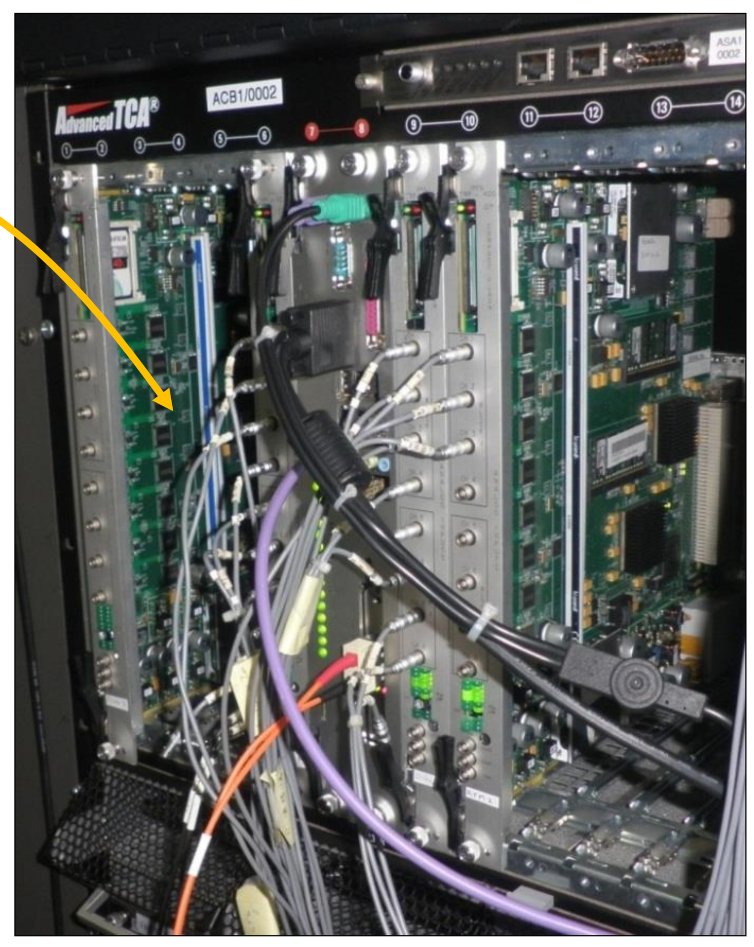
INTRODUCTION

- **The JET Gamma-ray Camera upgrade (GCU)** project aims to replace the former CsI(Tl) + PiN detectors by fast **$LaBr_3$** scintillators coupled to a Multi-Pixel Photon Counter (MPPC).
- These **fast scintillators** were designed to cope with the **high fluxes (> 500kHz)** expected **during** Deuterium-tritium (**DT**) experiments, while improving the diagnostic spectroscopic capabilities (**energy resolution of 5%@1.1MeV)** [1,2].
- GCU will benefit from the **ATCA based Data Acquisition (DAQ)** system, successfully installed and commissioned during the JET-EP2 enhancement [3]. However, to cope with the new GCU detector signals, **the DAQ FPGA codes need to be rebuilt**.
- **Dedicated codes** were designed, capable to **acquire** the new signals at full rate, and simultaneously **processing it in real-time through suitable algorithms, fitted to the new signal shape**.

JET 2D GAMMA CAMERA





GCU DAQ includes **3 digitizer modules** with:

- *8 **ADCs** (13 -bit @ 250MHz);*
- ***500 MB** of **DDR2 memory**/ADC;*
- *2 **FPGAs** for data path and data reduction (pulse storage) / **real-time processing**.*

Table: Memory requested per channel for a single discharge

	Count Rate (kevent/s)	Samples/event (1 sample =2 Byte)	Time @ max count rate (s)	Memory requested /channel (MB)
Pulse storage	500	64	10	680 ✗
	500	128	10	1320 ✗
Real-time processing	500	4	10	40 ✓
	1000	4	30	240 ✓

Real-time** processing mandatory **for DT

CONCLUSIONS & FUTURE WORK

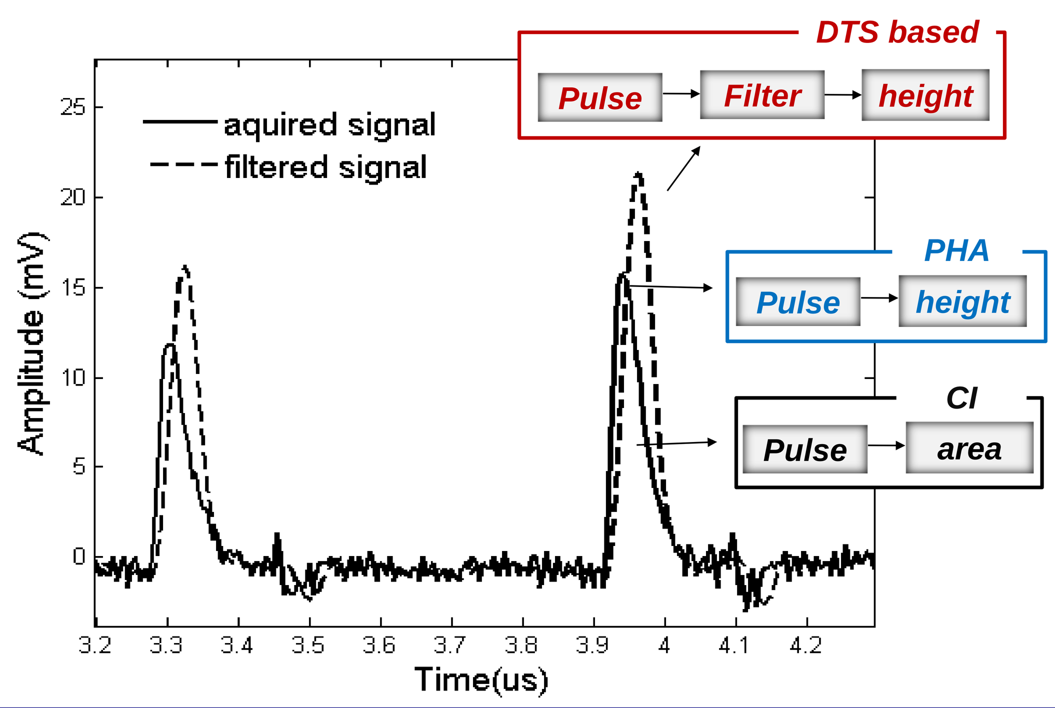
- **Two algorithms, based on PHA and DTS methods**, successfully **implemented in GCU FPGAs** and tested with new $LaBr_3$ based detectors.
- **DTS** based algorithm **provides improved resolution for the new $LaBr_3$ signals**, considered so far the most adequate method to process the GCU data at FPGA.
- **PHA** provides **fast results**, very useful during test phases.
- **Further tests needed**, with both **horizontal and vertical camera in place**, as well as **during plasma operation**.
- Benefiting from the **reconfigurable feature of the DAQ FPGAs**, algorithms can be improved (e.g. advanced pileup treatment for DT [6], instead of simple rejection/discrimination).

REAL-TIME PROCESSING CODES

Three algorithms selected, considering its **portability to FPGA** [4]:

- ***Pulse Height Analysis (PHA):*** height proportional to the energy of the event → ***fast results***.
- ***Charge Integration (CI):*** area proportional to the energy of the event → highest dependence on count rate / pileup → ***not suitable for DT***.
- ***Digital Trapezoidal Shaper (DTS):*** filter transforms pulse in trapezoid → height proportional to the energy of the pulse → ***Improved resolution for new $LaBr_3$ signals***.

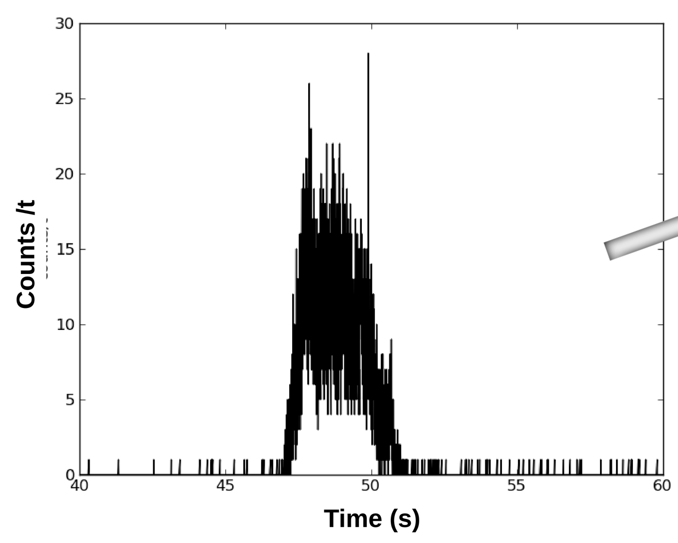
DTS parameters modified (**DTS based**) to avoid pileup - pulses from filtered signal (- - -) similar to Gaussians instead of pure trapezoids.



RESULTS

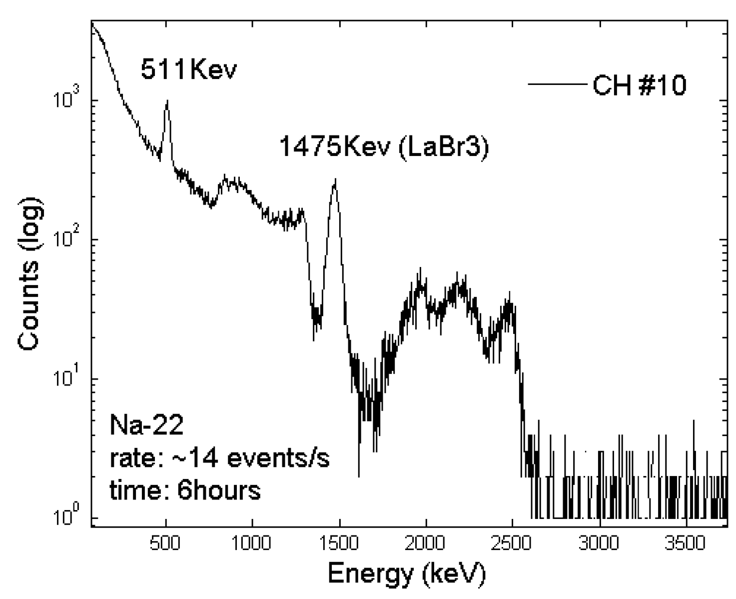
Both **PHA and DTS based methods** were successfully **implemented and tested** in GCU FPGAs.

PHA – tested during C36-B experimental campaign

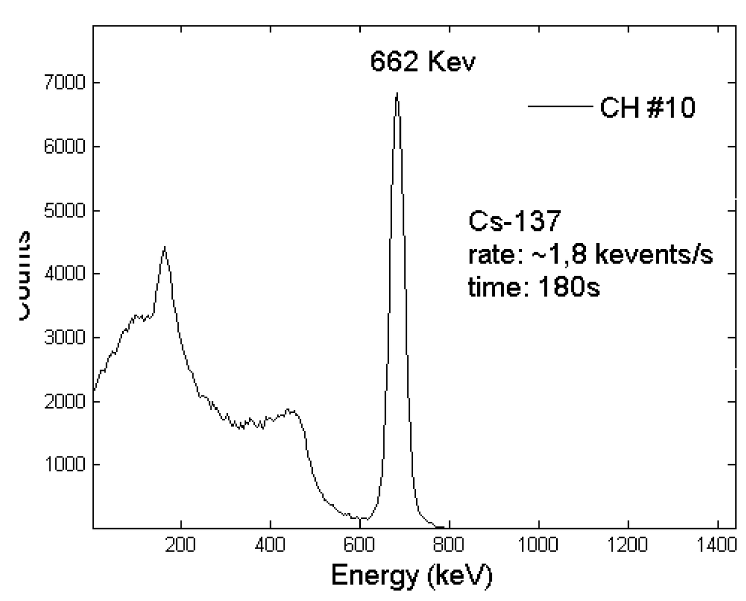


- **Time trace (counts/time)** of detector #10 ((fist prototype version) in horizontal camera during discharge **#91975**. Achieved from **real-time processed data at FPGA**.
- As expected, the gamma counts increase during NBI and ICRH windows.

DTS based - tested during installation of detectors (final version) in horizontal camera



Spectrum from detector #10 (6 hours acquisition) in presence of ^{22}**Na**



Spectrum from detector #10 (3 minutes acquisition) in presence of ^{137}**Cs*****

- **Similar spectra** obtained **for all 10 detectors in horizontal camera.**
- **Real-time spectra validated** with results from **post-processing methods**, using pulse storage data acquired in similar conditions.

**** It was achieved an **energy resolution between 4.9% and 5.7% for** ^{137}Cs **667 keV peak ,** depending on the detector, which is in agreement with detectors specification report [5].*

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