Fission Chambers for Neutron Flux Measurements on MAST-U

C. Vincent[1,2], S. Allan[2], G. Naylor[2], R.M. Sharples[1]
1) Centre for Advanced Instrumentation, Durham University
2) Culham Centre for Fusion Energy

EPSRC Engineering and Physical Sciences Research Council

1. Data Acquisition with FPGAs

- MAST-U is a new and advanced fusion experiment and requires a vast array of flexible and reliable diagnostics.
- Field Programmable Gate Arrays (FPGAs) use programmable logic to enable fast signal processing.
- Koheron Software Development Kit[1] facilitates programmable logic and processing system communication, as well as providing a network interface.
- Red Pitaya development board[2] provides two Analogue-to-Digital converters and two Digital-to-Analogue converters at 125 MS/s.
- Neutron pulses are approximately 250 ns in duration so 8 ns sample time can define pulses well.

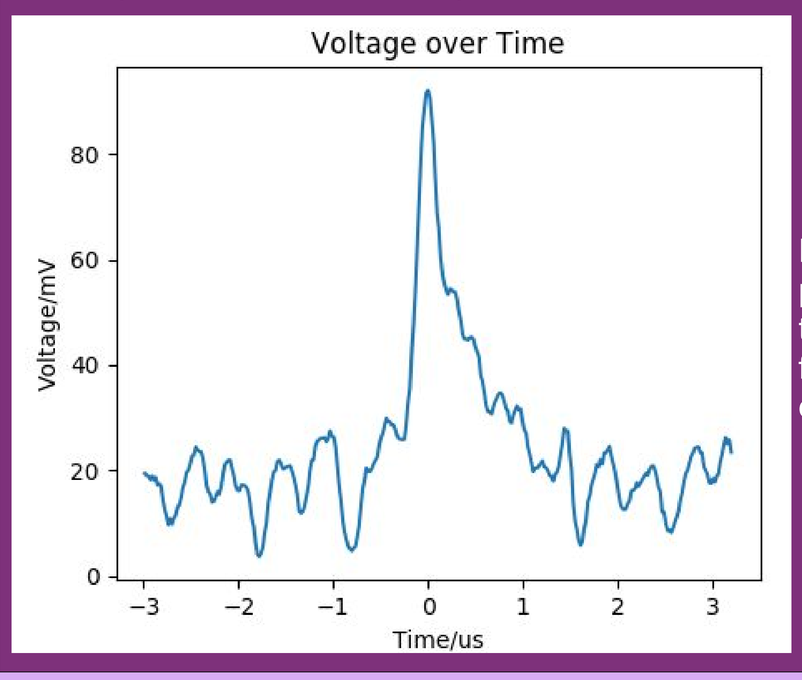


Figure 1: Measurement of possible neutron pulse taken with oscilloscope function of the Red Pitaya development board.

2. The Fission Chambers

- An aluminium casing contains signal and high voltage electrodes, manufactured by Centronic. The electrodes are covered in a neutron sensitive uranium coating.
- Neutrons incident on the uranium coating generates a radiation cascade causing ionisation within the low pressure vessel and a current pulse on the signal electrode.
- Fission chambers encased in lead, polyethylene and cadmium:
  - Lead coating shields chambers from electromagnetic radiation.
  - Polyethylene moderates fast neutrons for a greater cross-section with uranium sensitive coating.
  - Thin cadmium layer filters thermal neutrons to improve time resolution.

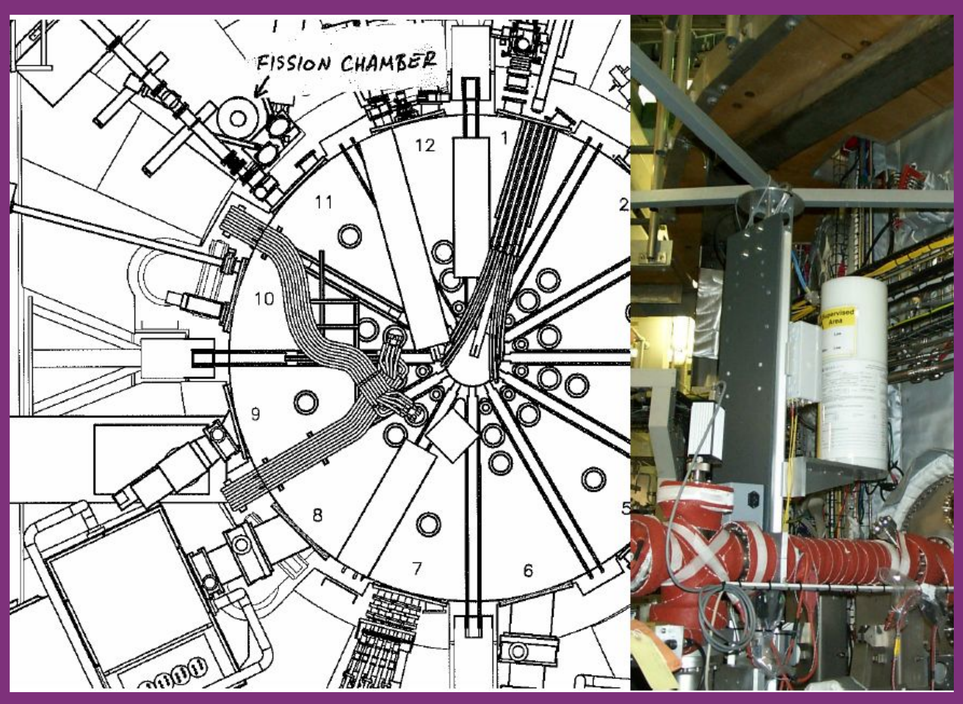
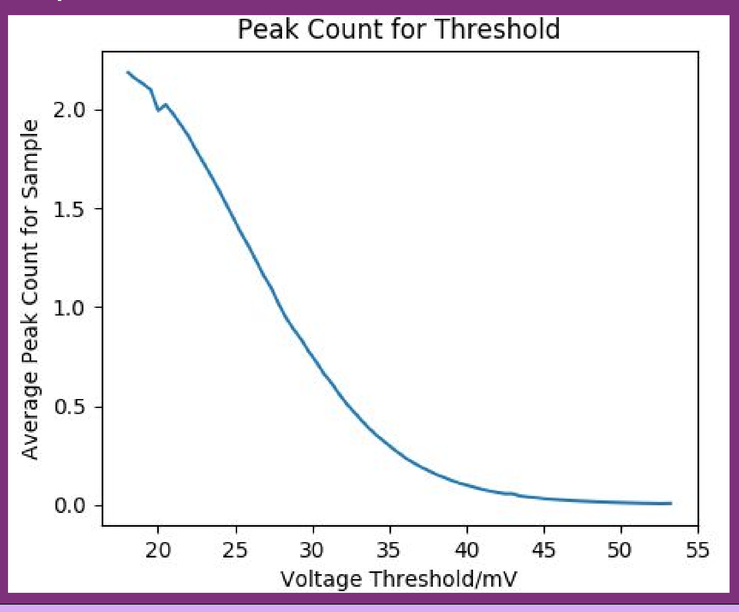


Figure 2[3]: Technical drawing and picture of old fission chamber installed on MAST.

3. Neutron Flux Measurements

- Neutron flux measurements are important for dose monitoring (safety case) and physics studies (indication of total fusion product).
- Fission chamber current sampled at 125 MS/s. The mean and variance (Campbell mode) are calculated for 125 samples into a 1 MHz data output.
- Peaks above a preset threshold are counted to estimate the pulse count for the same sample period.

Figure 3: Peaks detected over a given threshold. Fall is due to a reduction in background alpha pulses above the threshold. Data was collected over a three second acquisition time.



4. Real-time Filtering

- Fast data processing on programmable logic allows real-time filtering of current signal to better define peaks.
- Helps in improving pulse discrimination and reducing effect of pile-up.

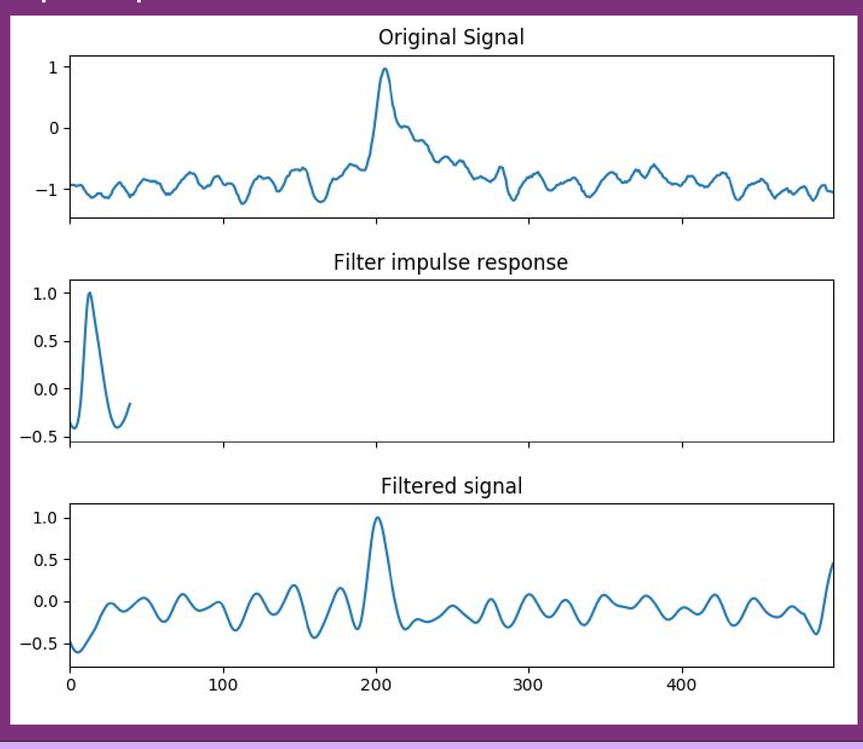


Figure 4: Comparison between filtered signal and original signal using the appiled Finite Impulse Response filter

5. Summary

- FPGA technology has been used to implement a data acquisition system for two fission chambers.
- Fission chamber signals will be used for neutron dose monitoring and physics studies.
- Fast signal processing capabilities of the FPGA have allowed for real-time signal filtering to improve current peak detection.
- New improvements in FPGA technologies allow advanced diagnostics to be built in-house improving long term support and reducing costs.

References: 1) Koheron SDK, https://github.com/Koheron/koheron-sdk 2) Red Pitaya Developers Guide, http://redpitaya.readthedocs.io/en/latest/developerGuide/hardware.html# 3) Development of a Fission Chamber Electronic Acquisition System; G.Naylor, R.Stephen et al

This work is supported by the Engineering and Physical Sciences Research Council [EP/L01663X/1] and by the RCUK Energy Programme [Grant Number EP/P012450/1]