The Mu2e Experiment
STM HPGe Detector Update

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Wednesday 28th April 2021

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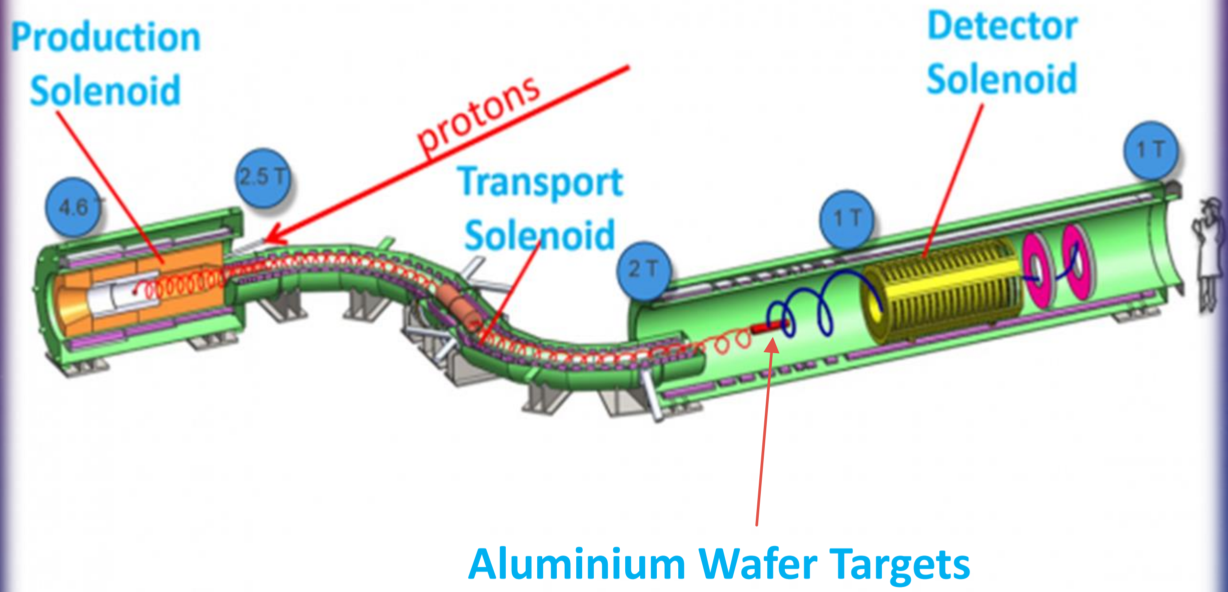
- High Rate Studies
- DAQ Setup At Liverpool

STOPPING TARGET MONITOR- RECAP

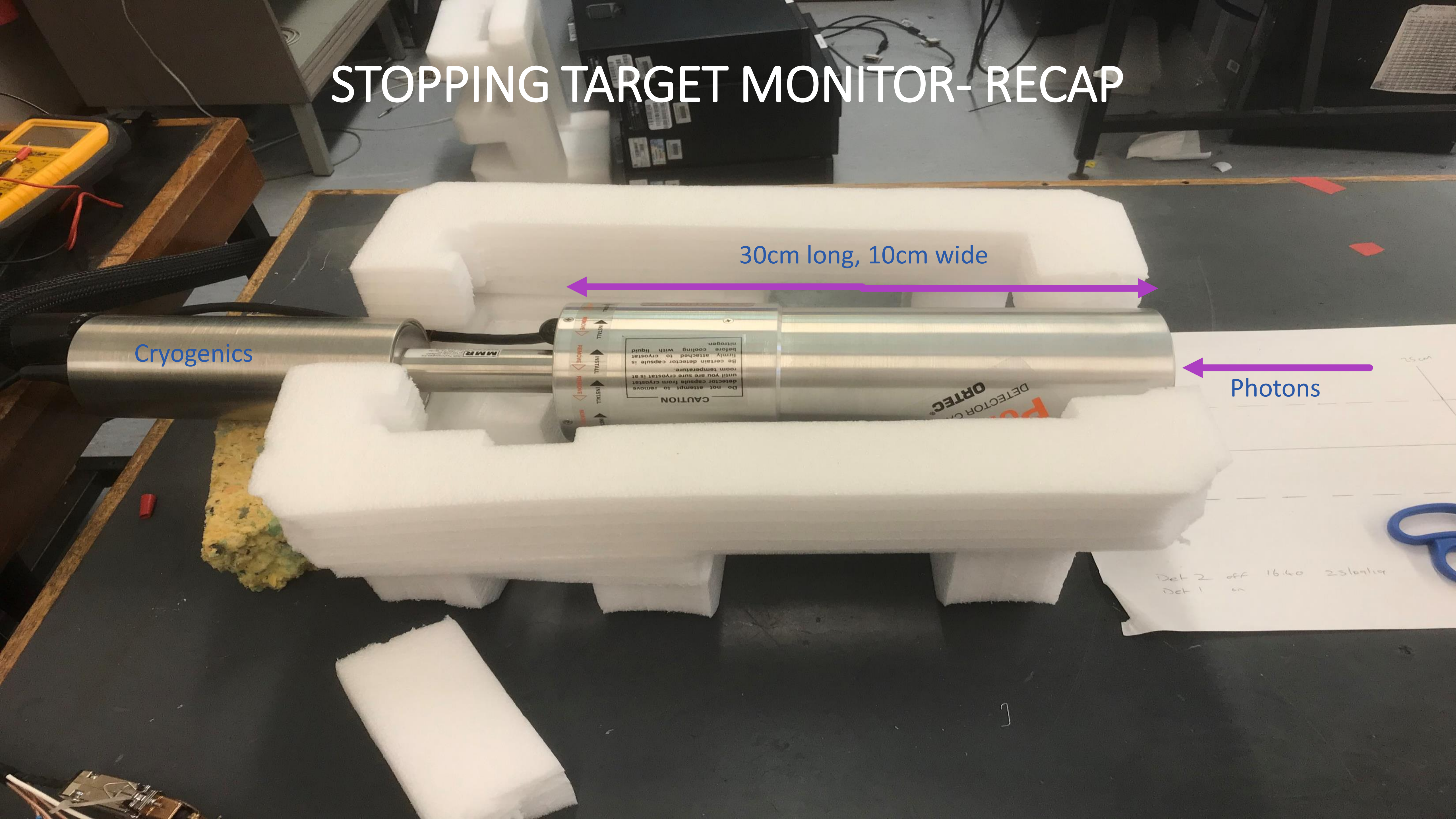
$$R_{\mu e} = \frac{\mu^- N \rightarrow e^- N}{\mu^- N \rightarrow \text{all muon captures}}$$



- The STM is a high purity germanium crystal as a solid state detector that measures captured muon rate by measuring the characteristic photons.
- Gamma photons from transitions in the aluminium target are also detected and are our primary background.
- A muon to electron conversion is a sure sign of new physics implying Charged Lepton Flavour Violation.
- STM data is used to normalise the signal measured by trackers and calorimeters.

STM is actually 34m from the end of the detector solenoid on the right side!

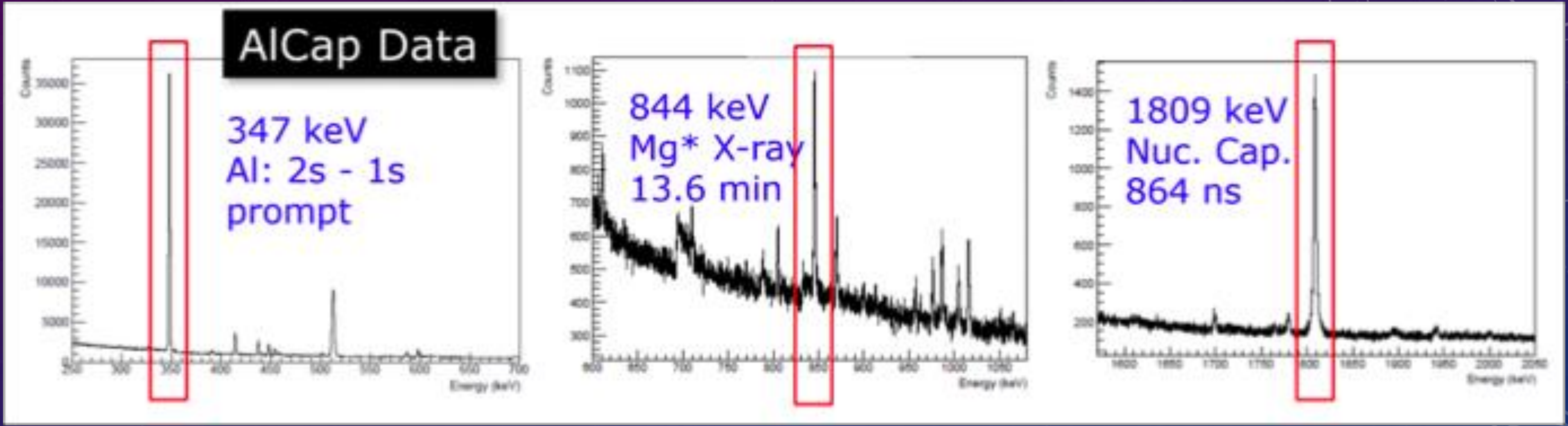
STOPPING TARGET MONITOR- RECAP



STOPPING TARGET MONITOR- RECAP

- Have an energy resolution (Full Width at Half Maximum) of ~2keV for all decays of interest (347keV, 1809keV, 844keV)
- Be able to handle ~1-4kHz photon count rate @ 0-2 MeV
- Electronics support for collection within 800-1000ns windows
- Withstand fast neutron radiation damage during operation ~E+12/cm^2

STOPPING TARGET MONITOR- RECAP



HPGe systems are very well suited to identify the unique sharp peaks associated with the different decays.
The main three are prompt X-rays from captures in orbit (CIO) (347keV), synthesised magnesium decays (due to nuclear captures) (844keV), and gamma rays from the newly made magnesium isotopes (1809keV).
These photon counts indicate the number of successful capture events that occur with each muon bunch.

HPGE PERFORMANCE BENCHMARK - LIVERPOOL

Measurements for Detector 1

- Resolution (FWHM) @ 1.33MeV (2.49±0.01keV measured, 2.3keV warranted)
- Peak-to-Compton ratio: (58.6:1 measured, 60 warranted)
- Relative efficiency @ 1.33MeV (80±4% measured, 70% warranted)
- Peak shape FWTM/FWHM (1.93 measured, 2 warranted)
- Resolution at 122keV (1.09keV measured, 1.5keV warranted)

This is acceptable for our needs.

Measurements for Detector 2

- Resolution (FWHM) @ 1.33MeV (2.14±0.01keV measured, 2.3keV warranted)
- Peak-to-Compton ratio: (63:1 measured, 60 warranted)
- Relative efficiency @ 1.33MeV (71±4% measured, 70% warranted)
- Peak shape FWTM/FWHM (1.87 measured, 2 warranted)
- Resolution at 122keV (0.88keV measured, 1.5keV warranted)

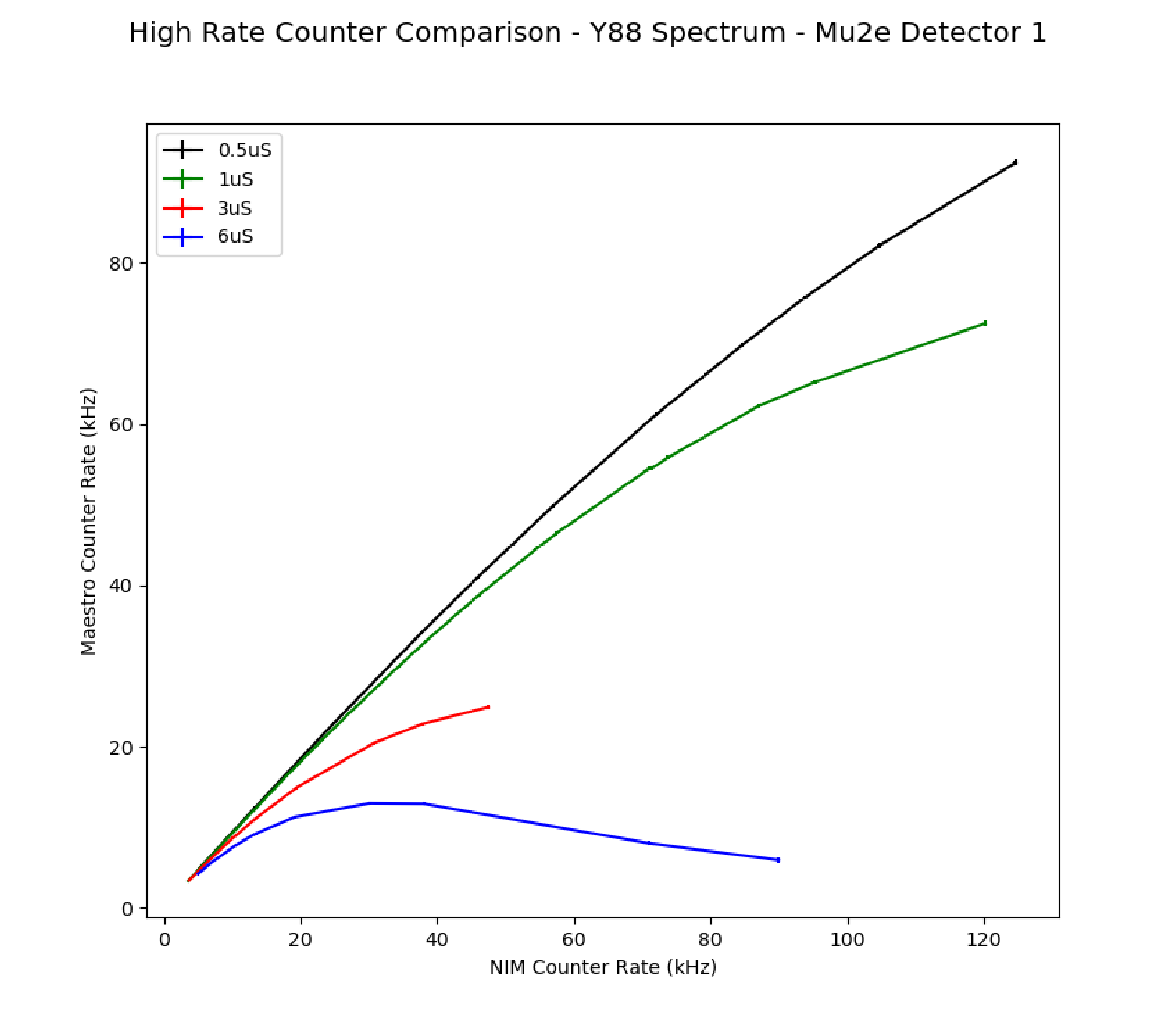
This is good! Detector 2 performs better.

Performance benchmarks will improve with higher statistics.

PRELIMINARY HIGH RATE STUDIES

- Measure detector performance in signal regions
- Collect point sources of Y88 strong enough for ~1MBq
- Y88 gammas of 898keV and 1836keV are very similar to expected signal regions for aluminium capture events
- Test both detectors that are going to the experiments

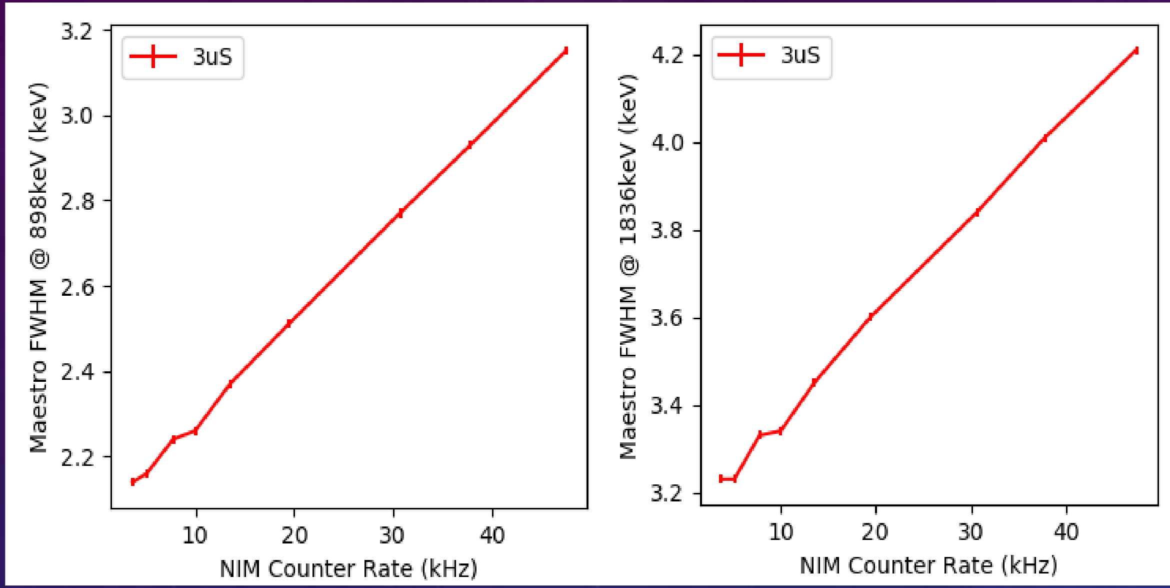
PRELIMINARY HIGH RATE STUDIES



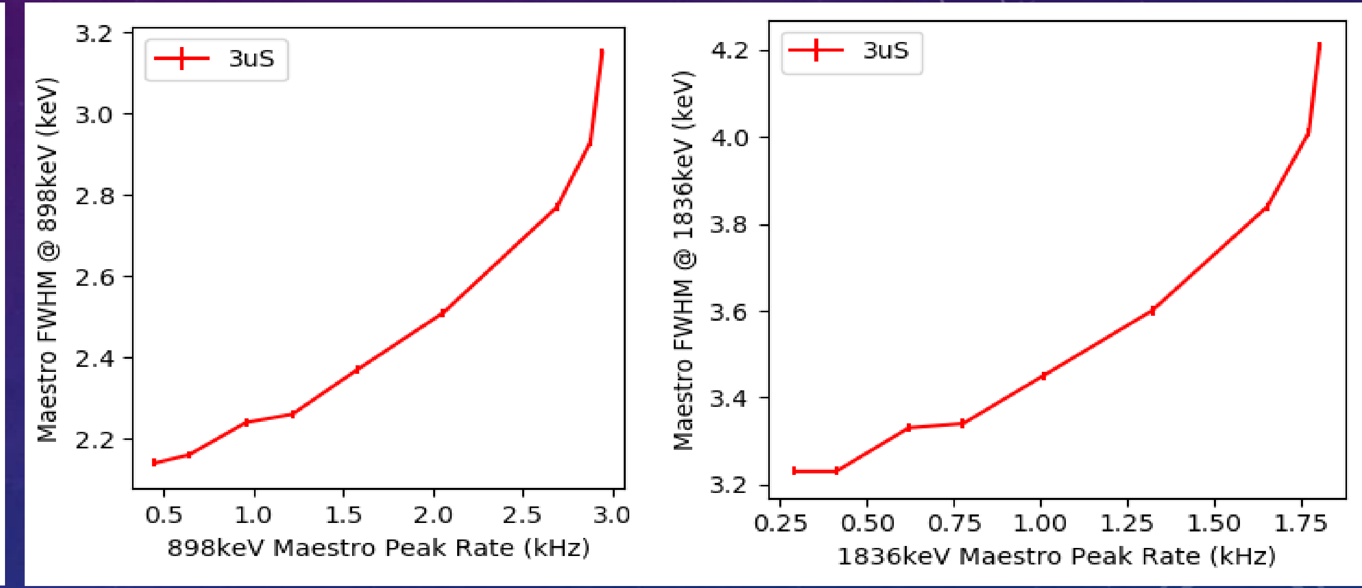
- Amplifier shaping time affects the window that the machine can identify information about the peak.
- Smaller times mean less time for accurate measurement of the energy leading to larger uncertainties, but with the ability to count many more events in a signal region.
- NIM counters are hardware counters counting off the output of a timing filter amplifier (TFA) which gives raw pulses.
- Maestro rates are software defined counters after slower shaping amplifiers report to the 8k multi channel analyser (MCA)

PRELIMINARY HIGH RATE STUDIES

Hardware Counter



Software Counter



Counting all events and background (left) is a fairly linear relationship, but specific sharp peaks (right) do not behave this way

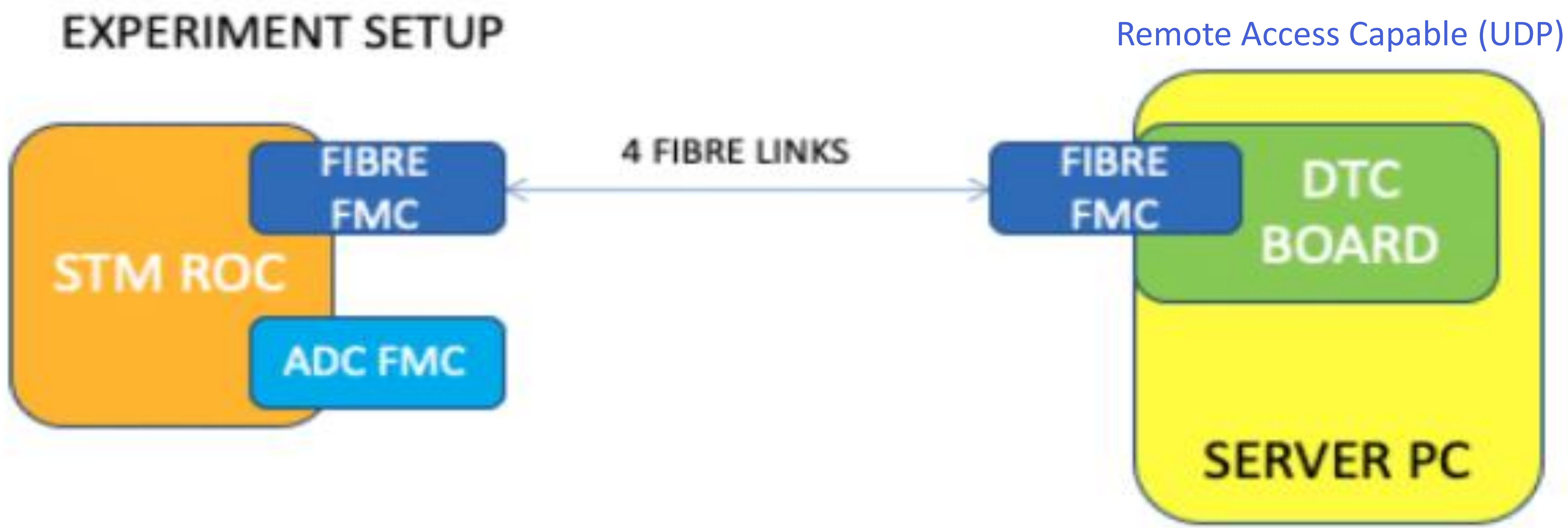
However, signal regions are operating within resolution expectations around 1-4kHz
The faster we measure, the more information about the signal we lose.

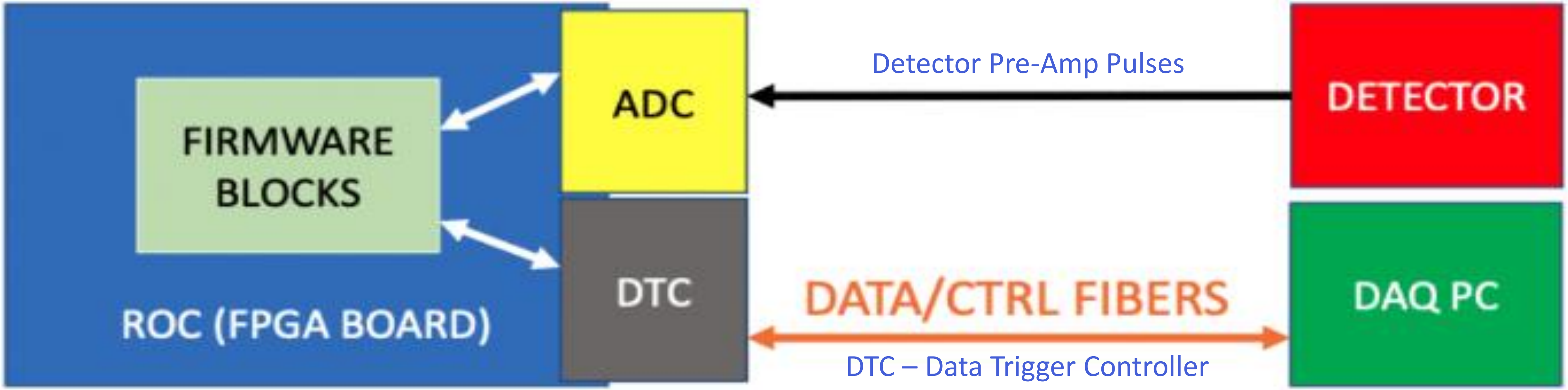
PRELIMINARY HIGH RATE STUDIES

- Specific signal regions are able to handle 1-4kHz/region
- Individual signal calibration may not produce linear relationships
- More data taking is needed to fit curves properly once laboratories re-open after COVID
- Amplifier trade off: More events at 1uS but high FWHM, 3uS preserves required rates at expected resolutions, 6uS cannot handle expected rates

DAQ SETUP AT LIVERPOOL

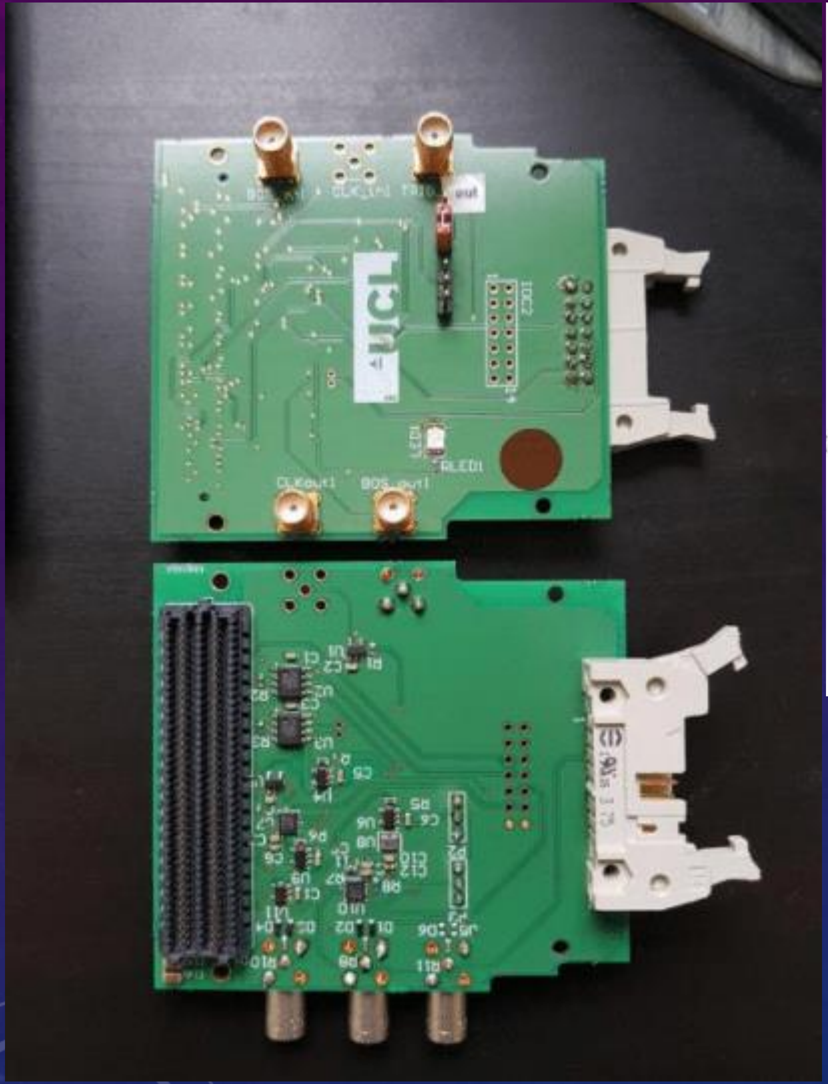
- UCL and UoM are providing dedicated data acquisition hardware to Liverpool
- DAQ systems will log all the event data from the crystal for analysis instead of manually transcribing data or exporting from Maestro
- DAQ will be set up with it’s own PC and connected to digital readout cards instead of ORTEC analogue systems
- Maestro is not great at estimating energies or count rates and often disagrees with the discriminator/TFA at higher rates

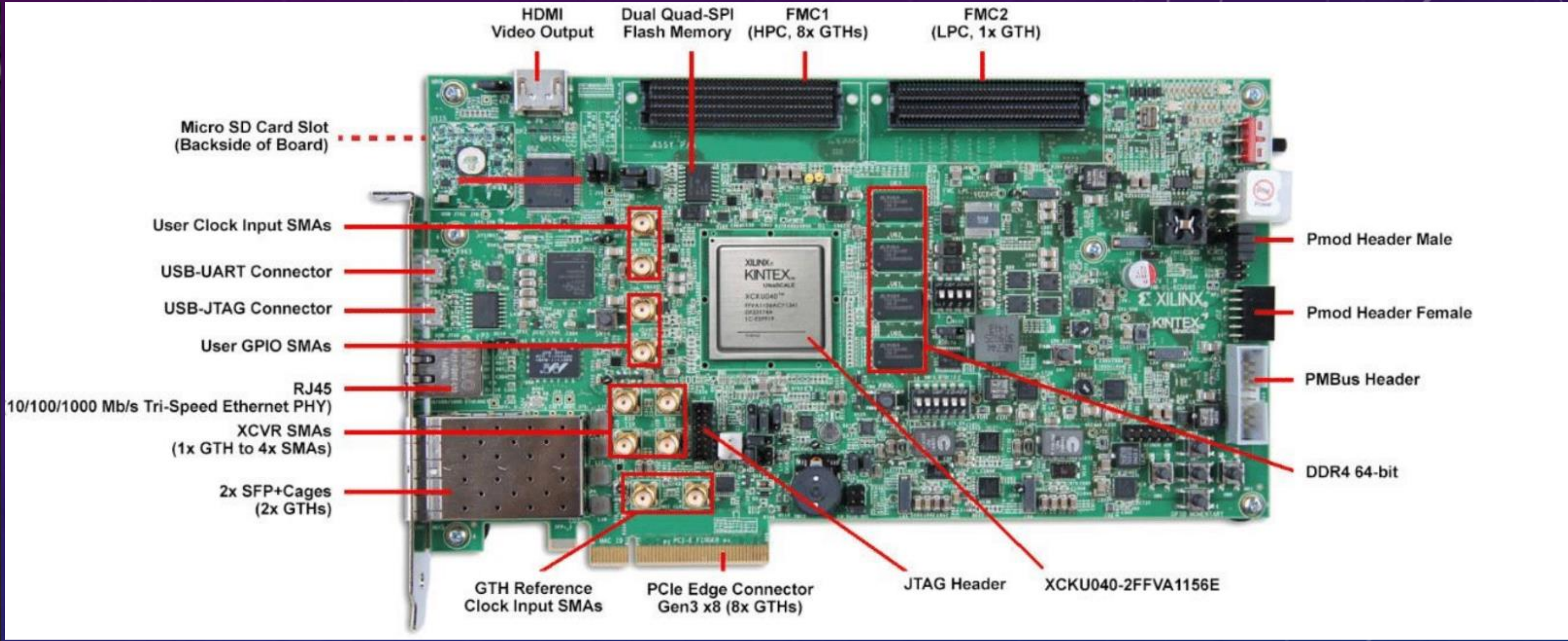

EXPERIMENT SETUP
Remote Access Capable (UDP)
STM ROC
FIBRE FMC
ADC FMC
4 FIBRE LINKS
FIBRE FMC
DTC BOARD
SERVER PC


FIRMWARE BLOCKS
ROC (FPGA BOARD)
ADC
DTC
Detector Pre-Amp Pulses
DETECTOR
DATA/CTRL FIBERS
DTC – Data Trigger Controller
DAQ PC

FMC – FPGA Mezzanine Card

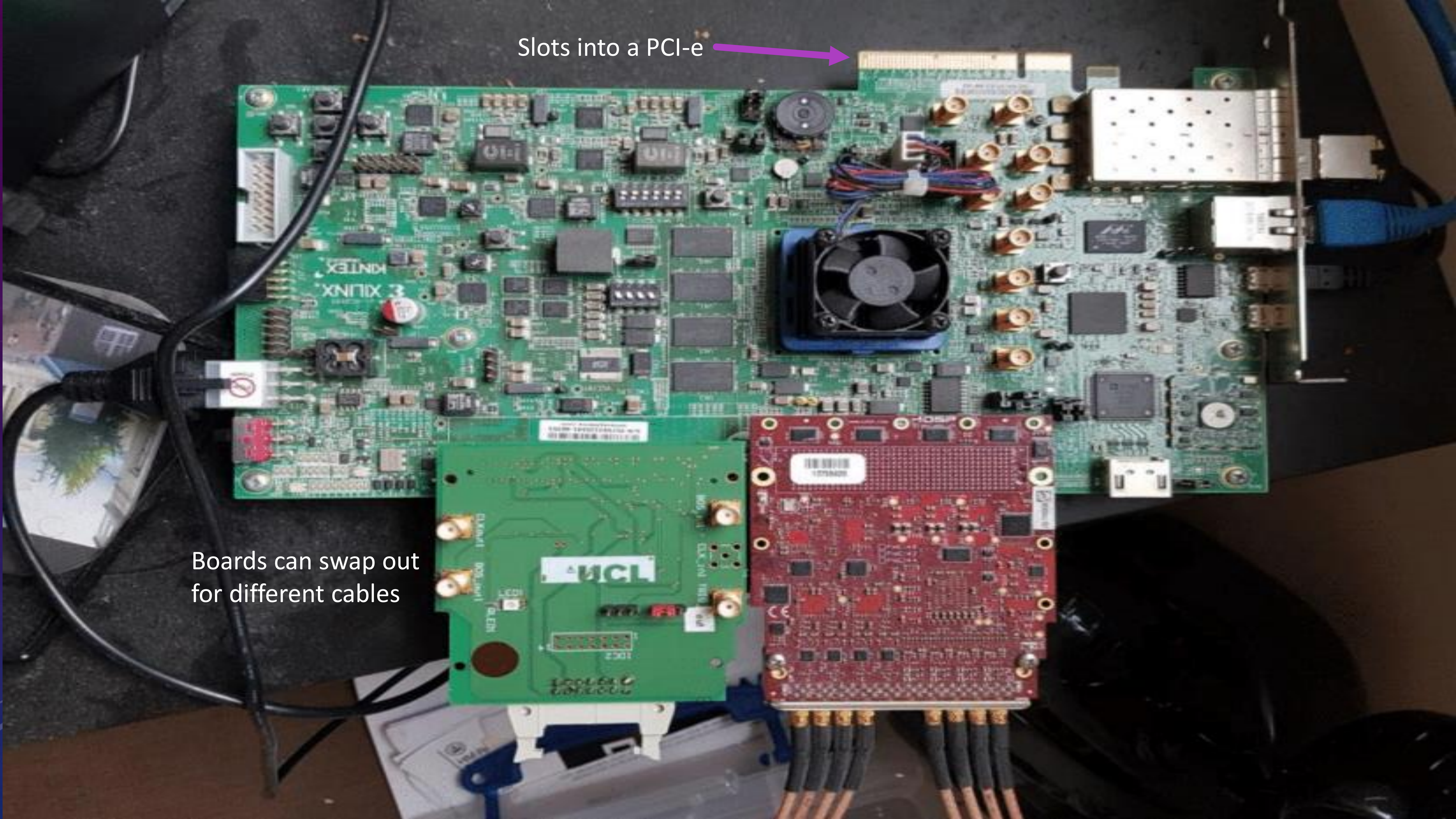
DTC – Data Trigger Controller





Two different DTC Boards allow for external triggering and clocks on one but high speed data transfer on another

BNC cables to Detectors


Slots into a PCI-e
Boards can swap out
for different cables

WHAT NEXT?

- Modelling particle flux at the STM location to calibrate for values expected in live testing at ELBE test beam and FNAL
- Assembling the PC, DAQ and Detector potentially permitting remote access, depending on logistics
- Retaking high rate studies with single powerful sources in 3rd signal region and higher sampling using the DAQ readout
- Y88 samples have a half life of 106.6 days. New sources will need to be purchased as the old samples are no longer sufficient for high rate studies.