STATUS OF THE MICROTCA BASED BEAM INSTRUMENTATION DAQ SYSTEMS AT GSI AND FAIR

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MO4AO07

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Abstract

As the first **FAIR** accelerator buildings are soon to be completed, **MicroTCA-based data acquisition** (DAQ) systems for FAIR beam instrumentation are ready for use. By using **commercial off-the-shelf** (COTS) components as well as **open hardware** with in-house expertise in **FPGA** programming, there are now DAQ solutions for almost all major detector systems in MicroTCA in operation at the existing GSI accelerators. Applications span a wide range of detector systems and hardware, often taking advantage of the **high channel density** and data transmission **bandwidth** available with MicroTCA. All DAQ systems are synchronised and triggered using a comprehensive **White Rabbit** based timing system. This allows correlation of the data from the distributed acquisition systems on a nanosecond scale.

We present some examples of our DAQ implemented in MicroTCA covering the range of beam current, tune, position and profile measurements. While the latter uses GigE cameras in combination with scintillating screens, the other applications are based on ADCs with different sampling frequencies between 125MSa/s up to 2.5GSa/s or latching scalers with up to 10MHz latching frequency.

FAIR@GSI, Darmstadt, Germany

Figure 1: Aerial view of the FAIR construction site in April 2023 (Photo: D.Fehrenz/GSI/FAIR)

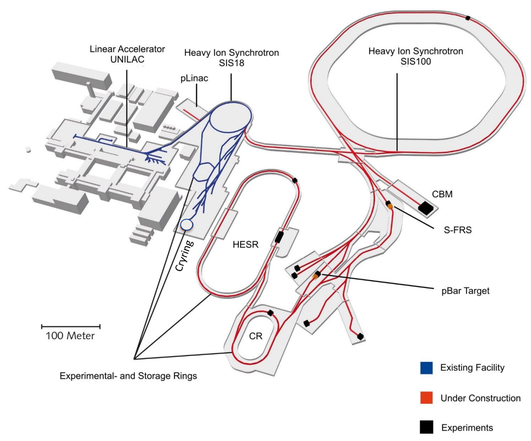


Figure 2: Scheme of existing GSI (blue) and the new FAIR accelerators (red) plus attached experiments (black). The complete antiproton chain (pLinac, pBar, CR & HESR) is on hold as the CR (Russian In-kind contribution) will not be delivered.

FAIR will provide:

primary beams:
up to 35 GeV/u Uranium
up to 90 GeV/u Protons

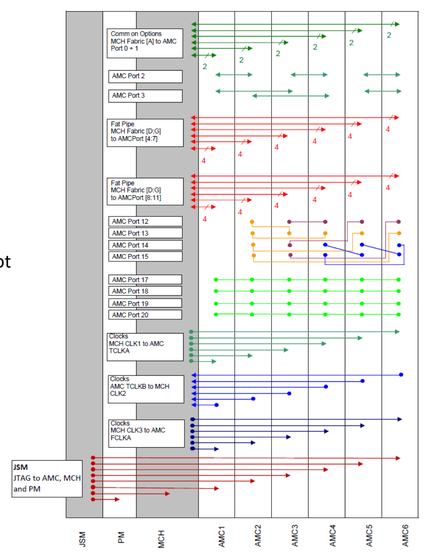
secondary beams:
- broad range of radioactive beams
- (antiprotons 0 - 30 GeV)

storage and cooler rings:
- radioactive beams
- (10^{11} stored and cooled 0.8 - 14.5 GeV antiprotons)

- very high diversity
- all elements from p to U
- parallel beam operation

MicroTCA Hardware

1. Type:
- 6-slot, 2U MTCA.4 chassis (nVent) + JSM slot
- NAT AC600D PS (600W)
- NAT-Phys-80 MCH
- CCT AM-G64 XEON CPU



2. Type:
- 12-slot, 9U MTCA.4 chassis (nVent) + JSM slot
- Wiener PS (1000W)
- NAT-Phys-80 MCH
- CCT AM-G64 XEON CPU

MicroTCA based Beam Instrumentation Data Acquisition Systems

1. CRYRING@ESR BPM System

Figure 3: CRYRING@ESR Beam Position Monitoring system using AFC V3.1 FMC carrier modules with 250MSPS/4Ch/16 Bit ADC FMCs.

- Open Hardware / FMC technology
- Gate pulse from FTRN via M-LVDS lines
- FPGA based data evaluation:
  - ➢ Raw ADC data
  - ➢ Position data
  - ➢ Averaged position data

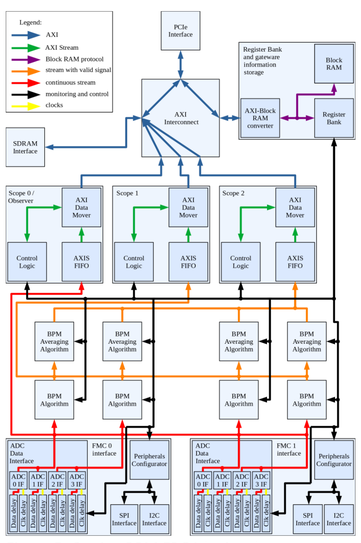


Figure 5: Cryring BPM FPGA logic scheme

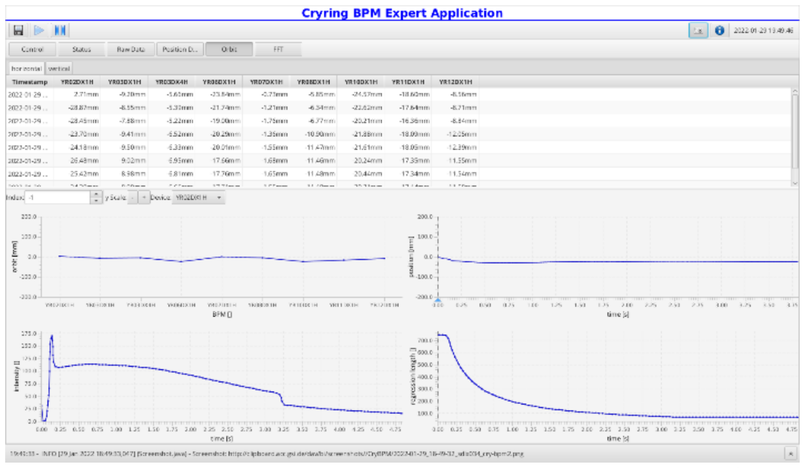


Figure 4: Cryring BPM data, here orbit tab with global orbit (hor.), BPM intensity and position, and fit length (regression)

2. Fast Current Transformer System

- Intensity and bunch structure measurement of fast extracted ion beam (max. 2µs bunch length)
- GSI-Rings (SIS18, ESR, Cryring) and transfer lines (HEBT), later also at FAIR SIS100, HEBT
- Triggered by RF master (bunch synchronous)
- Data reduction by rate divider in FPGA logic (FMC 5-channel Digital I/O)

Bunch dynamics during RF manipulations:

Figure 5: Li+ beam from local injector over 2 seconds from injection to flattop with rebunching from h=8 to h=6 in the middle (Cryring)

Figure 6: SIS18 40Ar18+ beam, 300MeV/u, bunch merging h=4 to h=1

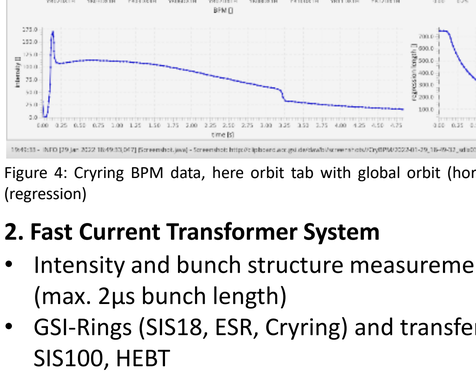


Figure 7: FCT DAQ systems for HEBT, ESR and SIS18

Modular FCT DAQ concept with:

- FTRN-AMC (timing receiver)
- SIS8160/SFMC01 ADC
- SIS8864 I/O
- Rate divider (AFC+5CH DIO)

3. Resonant Transformer DAQ System

- Intensity measurement for fast extracted ion beam (max. 2µs bunch length)
- Triggered acquisition
- Open hardware components (FMC 100MSPS 14B 4CHA ADC on AFC V4)
- FFT for offset and high frequency noise suppression
- Fit against damped oscillation (exponential function) delivers pulse charge on the first maximum of the signal.

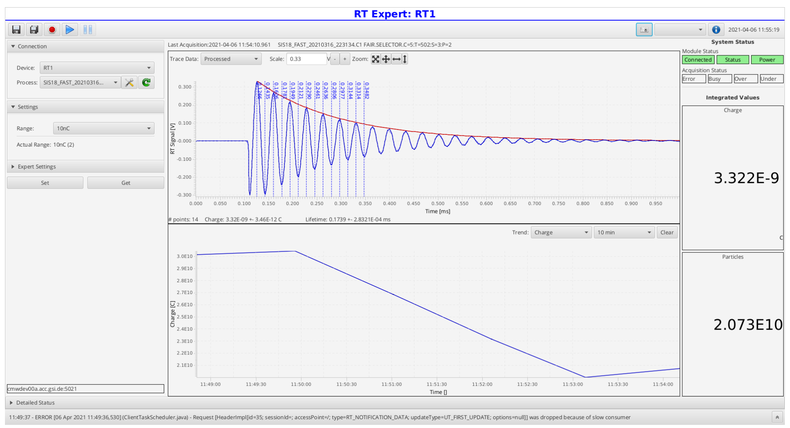


Figure 8: : Typical resonant intensity signal using a resonant transformer with fast extracted ion beam.

4. Profile Video Imaging for Scintillating Screens

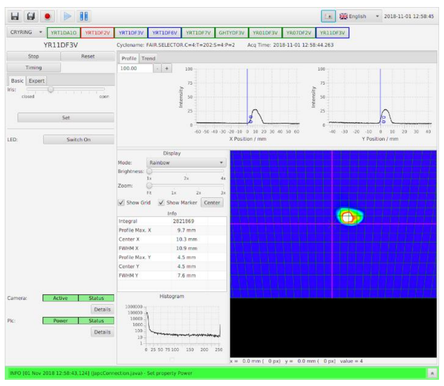


Figure 9: Screenshot of a beam spot on a scintillating screen with data evaluation like projections, FWHM, centre of mass etc.

- GigE cameras:
  - ➢ Ueye UI-5240SE
  - ➢ MegaRAD3 (Thermo Fisher) radhard analog with Pleora framegrabber
- Vadatech AMC217 Switch
- FTRN-AMC
- triggered or free running

Figure 10: Scintillating screen DAQ system

5. Particle Counter Expert System

- High performance multi-channel DAQ for spill micro-structure analysis with plastic scintillators at slow extracted ion beam.
- SIS8800 Multiscaler with SIS8980 LE Discriminator µRTM
- Continuous readout, untriggered
- Readout in multi-channel scaler mode (MCS) into DMA
- Complete record of all timing messages in parallel
- High efficiency and performance achieved by pipelined concept
- 10MHz@128channels
- Next: Spill duty factor evaluation, FFT, Spectrogram

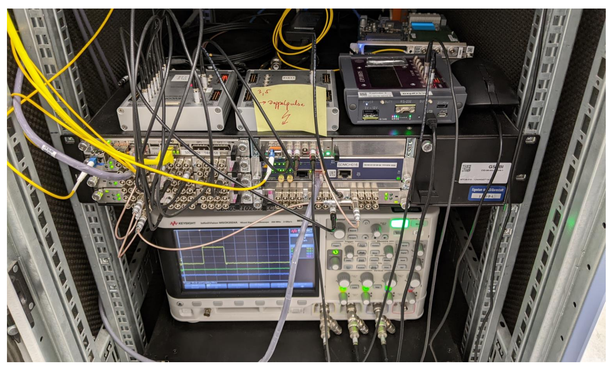


Figure 11: Setup of LASSIE Expert prototype system using four SIS8800 scalers in parallel.

Fair Timing Receiver (FTRN-AMC) in MicroTCA form-factor

- ➢ White Rabbit
- ➢ Single width, mid size AMC
- ➢ Open hardware (see ohwr.org/project/tr-amc/
- ➢ Bi-directional I/Os
- ➢ Trigger over backplane (M-LVDS)
- ➢ Clock and time / time-stamping
- ➢ Generate digital pulses and clock signals
- ➢ Generate specified interrupts at given times
- ➢ Custom functionality via LM32 cores

Advanced FMC Carrier (AFC)

- ➢ Open hardware (see https://ohwr.org/project/afc)
- ➢ Developed by Warsaw University of Technology (WUT) and LNLS, Brazil
- ➢ Xilinx Artix-7 200T FFG1156 FPGA
- ➢ Dual slot HPC FMC carrier w/wo RTM on demand

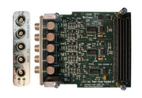
FMC and AMC Modules

OHWR FMC ADC 100M 14B 4CHA (Image Source: ohwr.org)

OHWR FMC ADC 250M 16B 4CHA (Image Source: ohwr.org)

Struck FMC 2500M 14B 2CHA DC on SIS8160 FMC Carrier (Image Source: struck.de)

IOXOS FMC ADC_3117 5M 16B 20CHA (Image Source: ioxos.ch)



OHWR FMC 5-channel Digital I/O (Image Source: ohwr.org)

Struck SIS8800 MTCA.4 32CHA multiscaler (Image Source: struck.de)

Struck SIS8980 MTCA.4 16CHA Leading Edge Discriminator (Image Source: struck.de)

Struck SIS8864 MTCA 64CHA digital I/O board (Image Source: struck.de)

Vadatech AMC217 8CHA LAN Switch (Image Source: vadatech.com

OUTLOOK

New intensity-, transmission-, and beam-loss monitoring system at the UNILAC
- Sampling of 64 AC transformers in parallel
- 50 Hz Unilac repetition rate
- >40 timing domains
- Digitizer: 5 x TEWS TAMC532 32-channel ADCs at 50MSPS/16Bit plis µRTM, reduced to 10MSPS
- Digitisation of analog transformer signal and its correlated frame pulse

Digitizer:
- ➢ TEWS TAMC532 + RTM
- ➢ 32 Ch. via RTM with 8xRJ45
- ➢ 75/50 MSPS 12/14 Bit
- ➢ triggered readout at 50Hz (Unilac)

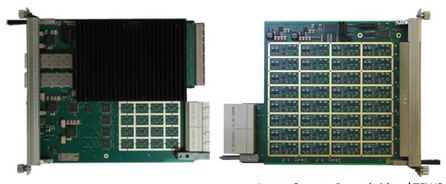


Image Source: Powerbridge / TEWS

ACKNOWLEDGEMENTS

The authors would like to thank the colleagues from CERN BE-CCS for many years of inspiration in software and hardware concepts. In particular, we would like to acknowledge the introduction of the CERN Open Hardware License. Furthermore, we would like to thank DESY for the valuable workshops, tutorials and support around MicroTCA. Big thanks also go to the many supporting industry partners such as Struck (SIS), Powerbridge, Tews, Emcomo, NAT, Wiener and Schroff. Finally we would like to thank Piotr Miedzik for major contributions in settling FPGA and OHL technology within the BEA-DAT team at GSI.