BEAM INSTRUMENTATION AND DATA ACQUISITION FOR CRYRING@ESR

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Abstract

At FAIR the re-assembly of the well-known CRYRING accelerator, formerly hosted by Manne Siegbahn Laboratory (MSL) Stockholm, is currently in progress. This compact low energy heavy ion synchrotron and experimental storage ring will be a testing platform for all control system (CS) concepts decided on for FAIR. The CRYRING CS will be based on the system originally developed by CERN which combines the JAVA based application level LSA (LHC Software Architecture), the data acquisition level FESA (Front-End Software Architecture) and the White Rabbit based timing system. All parts have been enhanced with GSI specific functionality. In preparation for the commissioning of CRYRING later in 2015 all required beam instrumentation (BI) equipment including the software is now under development. We present the data acquisition (DAQ) concepts for the various instruments with emphasis on the seamless integration into the overall CS. For standard BI systems, such as digital video imaging, profile and intensity measurement, VME and IndustryPC based DAQ systems are used. For beam position monitoring a new hardware strategy which combines the microTCA and FMC (FPGA mezzanine card) form factors is under evaluation.

INTRODUCTION

The modernized CRYRING accelerator is presently being assembled in Experiment Cave B on the GSI Campus [1]. A schematic overview over site and accelerator design is given in Fig. 1. The accelerator consists of a 108 MHz 300 keV/u RFQ linac with a 50 kV MINIS ion source platform, the ESR injection transfer

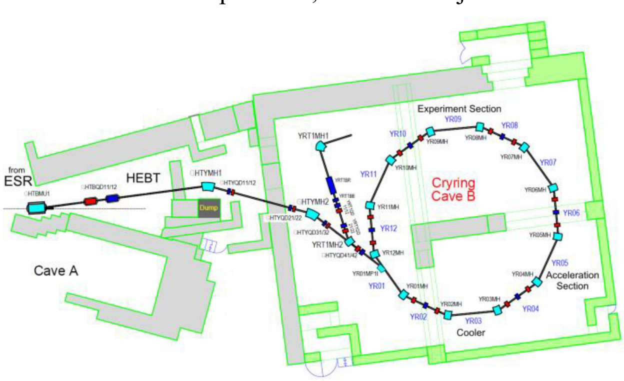

Figure 1: Scheme of CRYRING installation in Cave B.

line and a synchrotron storage ring of 54.18 m circumference including an electron cooler and experiment section. Different singly charged ions in bunched or coasting beam will be provided by the linac. Later, the GSI experimental storage ring (ESR) will inject cooled, highly-charged heavy ions via fast extraction which can be accelerated up to 14.8 MeV/u in case of U^{92+} or 96 MeV/u protons. All accelerator parts are equipped with original beam instrumentation systems designed at MSL as well as new FAIR type solutions. The original MSL detectors and specialised pre-amps were preserved, but all DAQ systems have to be replaced.

The main intention in operating this accelerator, besides the physics aspects, is to provide a test platform with ion beams for many FAIR relevant systems in both hard- and software. Commissioning of the ion source has already started. The RFQ is ready for operation. The linac and the ring will be commissioned next year.

CONTROL SYSTEM

The control- and data acquisition system for CRYRING operation is based on a three tier architecture with FESA as the front-end level, the ZeroMQ based middleware and the top JAVA application level supported by JAPC (Java API for parameter control) and the LSA settings management [2]. CRYRING will be operated and synchronized with White Rabbit (WR) timing [3]. All BI DAQ systems need to be equipped with dedicated WR timing receivers in stand-alone, VME and PCIe form-factors. All those receivers were developed at GSI.

BEAM INSTRUMENTATION

CRYRING is equipped with a variety of beam instrumentation systems. For all of them new DAQ software has to be provided, which is also suitable for further use at FAIR. Presently the following BI systems are under development:

Intensity

A beam intensity measurement, mainly in the linac part, was realized by using Faraday-cups. The signals are digitized in a VME system by a SIS3302, 8-channel, 100 MSa/s, 16 bit ADC. The current amplifier copes with AC and DC beam and the DAQ calculates the total charge plus mean and maximum currents.

For AC beams automatic determination of the signal's baseline for every bunch is supported. For DC operation, the baseline may be measured on user request when no beam is hitting the cup. In both cases predefined values may be used in case of problems with the online measurement.

The region-of-interest to determine the mean current and total charge can be taken from two dedicated WR machine events indicating "beam on" and "beam off" or via user-defined markers. For offline analysis the raw

ISBN 978-3-95450-148-9

data can be stored. Fig. 2 shows a chopped 500 μs D^+ beam pulse and the correlated intensity in units of Ampere at the linac injector.

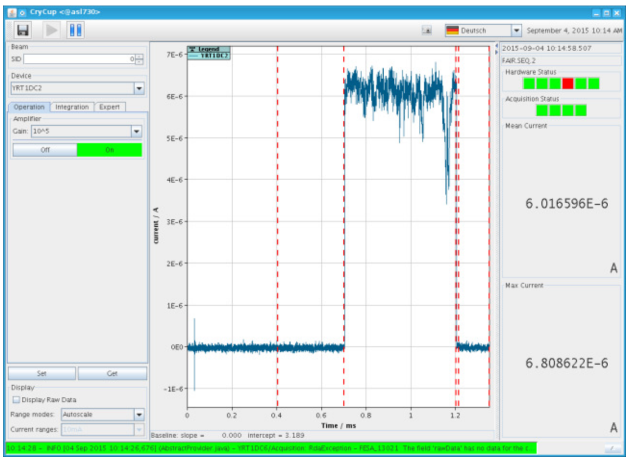

Figure 2: Intensity measurement of a chopped 500 μs D^+ beam pulse with a Faraday-cup.

For absolute beam intensity measurements in the ring both the Bergoz Integrating Current Transformer (ICT) and Bergoz Parametric Current Transformer (PCT) are used. For relative intensity measurements the IPM count rate is registered. As the bandwidth of the analogue outputs of those devices is below 1 MHz, the signals can be converted by a voltage-to-frequency converter (VFC) and sampled by the VME based GSI LASSIE [4] system, which is based on SIS3820 32 Bit / 32 Ch. multi scalers.

As CRYRING is bakeable to achieve an appropriate vacuum pressure, the transformers need to be protected against overheating. Hence temperature data derived from PT100 sensors is logged in LASSIE. The PT100 measurement is also required for temperature-drift compensation of the PCT. In the same setup Hall sensors are sampled to subtract magnetic field perturbations induced by dipoles and quadrupoles nearby. In addition, all other signals, which can be converted to frequencies such as Hall sensors, and BPM sum signals are fed into LASSIE. They are sampled and displayed on the same time basis for easy correlation.

Linac Energy

Phase and energy determination is realized with 3 capacitive ring pickups by time-of-flight measurements. The DAQ consists of a LeCroy Waverunner 6100A oscilloscope (1 GHz, 5 GSa/s) with 4 channels. As there are 5 signal sources (3 pickups, RF signal, debuncher signal), a Keithley switching matrix (Type 2701/7712 with 2x Dual 1x4, LXI) is used to select four signals for a given measurement. The oscilloscope is read out via LAN by a dedicated FESA class using the LXI protocol. The data is sampled over one thousand and more RF cycles. This allows for efficient noise reduction of the signal and oversampling, thus increasing the time resolution to approx. 5ps [5]. The time-of-flight between two pickups is determined by cross-correlation of the signals and yields with the known distance the beam energy.

Position and Orbit

CRYRING is equipped in total with 18 either horizontal or vertical oriented Beam Position Monitors (BPM), which will be controlled and read out by a high data bandwidth μTCA system. As μTCA, especially PICMG MTCA.4 [6], is an emerging form factor within the physics community, this DAQ system shall contribute in gaining experience on this platform as μTCA was defined besides VME and IPC as a standard form factor for FAIR beam instrumentation DAQ systems. The DAQ consists of a 12-slot MTCA.4 chassis hosting five AMC Dual FMC Carriers (AFC). Those are equipped with 250 MSa/s, 16 bit, 4 ch. ADC FMC boards. Both AFC and ADC were developed and produced by the Polish company Creotech under the Open Hardware License [7]. Furthermore the system contains a digital I/O FMC board as trigger input and remote control interface of the BPM preamplifiers.

After some incompatibilities and instabilities between different vendors of the main carrier hub (MCH), the module management controller (MMC) firmware of the AFCs is under revision. The setup will be prepared for usage in a Vadatech VT812 chassis with UTC002 MCH and also in a Schroff chassis with NAT MCH. The heart of the BPM DAQ is the trajectory measurement system (TMS), which was developed for measurements at CERN PS [8]. In a first step the system will operate as an oscilloscope type tracker at 125 MSa/s. Later on the system will be enhanced by full CS implementation with closed orbit, tune and bunch tracking features.

The Base Band Tune (Q) measurement system (BBQ) [9], which was invented at CERN and adapted for SIS18 at GSI, will be additionally installed at CRYRING to validate the TMS results. At CRYRING the DAQ is realized in VME also using the SIS3302. The pick-up used for the BBQ can be optionally used for Schottky analysis. This requires an LXI based network analyser (NWA) to investigate longitudinal and transversal beam parameter, such as tune, emittance and chromaticity.

Profile and Imaging

For the beam profile measurements the CUPID [10] system is used, which is already operational at the GSI

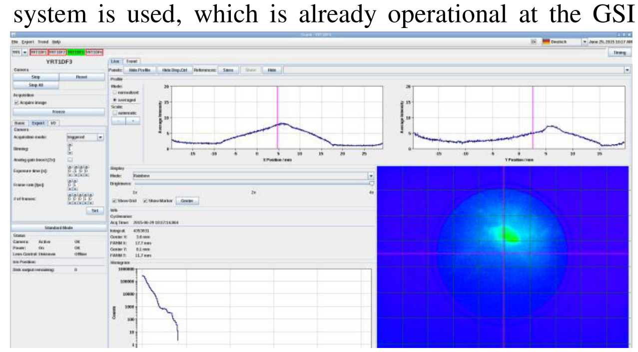

Figure 3: Profile of deuterium beam in the low energy beam transfer (LEBT) during injector commissioning.

ISBN 978-3-95450-148-9

transfer lines and fully compliant with the FAIR standards. In total eight fluorescent phosphor screens are observed by GbE µEye CMOS cameras, which are concentrated on one 10 GbE HP switch and a 10 GbE uplink to an evaluating Kontron KISS front-end IndustryPC. An additional identical camera provides a direct view into the ion source. The typical presentation of profiles and live view is shown in Fig. 3.

Essential for beam cooling operation within the CRYRING are the non-destructive profile measurements using one horizontal and one vertical ionisation profile monitor (IPM) [11]. Ions produced by ionization of the residual gas are accelerated towards a micro-channel plate (MCP) detector with a position sensitive resistive anode. The time and position pulses of each ion hitting the MCP are amplified and shaped in a CAEN N586 spectroscopy amplifier, which are remote controlled via LAN. A peak-sensing multi-event CAEN ADC V785N digitizes the pulse heights. The interaction vertex of the ion can be reconstructed from the 4 signal amplitudes. The FESA class periodically reads the events stored in the ADC, calculates the position and performs the histogramming of the pulse height and position. It also sends periodically or on request the obtained spectra to interested clients. Insofar the handling of the IPM strongly deviates from the typical, machine event driven arm-trigger-readout cycle of other beam instrumentation like the faraday cups.

High Voltage and Fieldbus

High voltage power supplies (HV) are required for Faraday cups, IPMs, MCPs in front of scintillating screens and electrostatic devices at the RFQ injector beam line. Both commercially available modular HV power supply systems from CAEN and Wiener/ISEG will be used. Fesa classes for the CAEN SY5527 and the Wiener MPOD system have been developed. Special care has been taken to present a unified interface to clients regardless of the differences in the hardware. This allowed us to write a generic GUI for HV control which hides the underlying hardware from the user. However, the unified interface does not prevent future hardware specific extensions should they become necessary.

At CRYRING, the newly developed FAIR standard pneumatic actuators and some other slow-control devices will be operated by Siemens Programmable Logic Controllers (PLC). In order to keep the automation system modular a distributed and decentralized Profinet IO remote system is used. This allows safe hardware control in two different ways: decentralized from the CS and locally, while the machine is in maintenance or shutdown mode. The PLC communicates with the CS through a dedicated Siemens communication processor (CP) and by a FESA class, glued together with a CERN made SILECS (formerly called IEPLC [12]) interfacing software.

The system is accessible via the CS, one mobile and two stationary HMIs, an Android tablet and a PC based visualization running an additional webserver with the capability to archive signal, warning and error messages. For the purpose of wireless visualization, the Profinet infrastructure has been extended with two iWLAN Access Points operating at 5 GHz.

OUTLOOK

The installation of CRYRING is well on the way. The injector is already under commissioning and first beam instrumentation devices such as screens or Faraday-cups demonstrate very good performance within the new FESA DAQ concepts. It has shown that LXI based systems are a good choice. The LXI protocol can be used from simple function generator and lab oscilloscope readout up to high performance instrumentation such as Schottky NWA readout and linac energy measurements. Learning LXI paves the way to the full digital control room providing reliable remote control and data readout.

The ring itself is being assembled right now and installations are planned to be finalized in 2016. Next steps are setup of the PROFINET field bus infrastructure and improvement of the BPM system.

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ISBN 978-3-95450-148-9