UPGRADE OF THE BEAM PROFILE MONITORING SYSTEM IN THE INJECTION BEAM LINE OF COSY

K. Reimers, C. Böhme, R. Gebel, A. Halama, V. Kamerdzhiev,
Forschungszentrum Jülich, Germany
J.L. Conradie, M.A. Crombie, H.W. Mostert, iThemba LABS, South Africa

Abstract

The cyclotron Julic is used as an injector for the COSY synchrotron and storage ring of 183 m circumference. The 93 m long injection beam line (IBL) transports polarized and unpolarized H^-/D^- ions which are injected into the ring via multi-turn stripping injection. 8 profile monitoring stations are installed in the IBL. Each station contains two harps having 39 wires at 1mm spacing. Each harp is read out by a multichannel pico-amperemeter module designed by iThemba LABS, South Africa, delivering profile data to the COSY control system. The technical details of the upgrade and recent beam profile measurements are presented.

INTRODUCTION

The cooler synchrotron COSY shown in Fig. 1 is operated at the Nuclear Physics Institute at the Forschungszentrum Jülich. It delivers high precision beams of protons and deuterons for experiments in the momentum range of 290 to 3850 MeV/c.

Injection and Beam Cycle

A typical COSY machine cycle consists of injection of particles from the cyclotron into the ring, beam acceleration and storage. Injection momentum is 293 MeV/c for H^- and 538 MeV/c for D^- ions. The shortest cycle at COSY is the test cycle with duration of 2 s. This cycle just contains the injection without acceleration. Injection of particles into the COSY ring is gated by the so called macro-pulse of typically 5-20 ms duration. Only during this time interval beam profiles in the IBL are measurable. The macro-pulse signal therefore is used to trigger the beam profile measurement.

IBL Beam Instrumentation

Figure 2 shows the COSY IBL consisting of 4 bent and 4 straight sections with an overall length of 93 m. Phase probes and harps are installed in the IBL for longitudinal and transverse beam diagnostics. This paper deals with transverse beam diagnostics only. The harps allow the detection of beam shape, beam position and intensity.

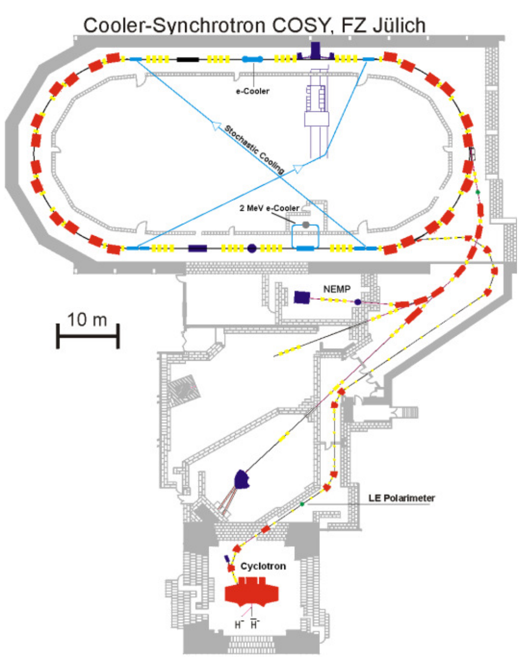

Figure 1: Layout of the COSY accelerator facility. For clarity only a few insertion devices are shown.

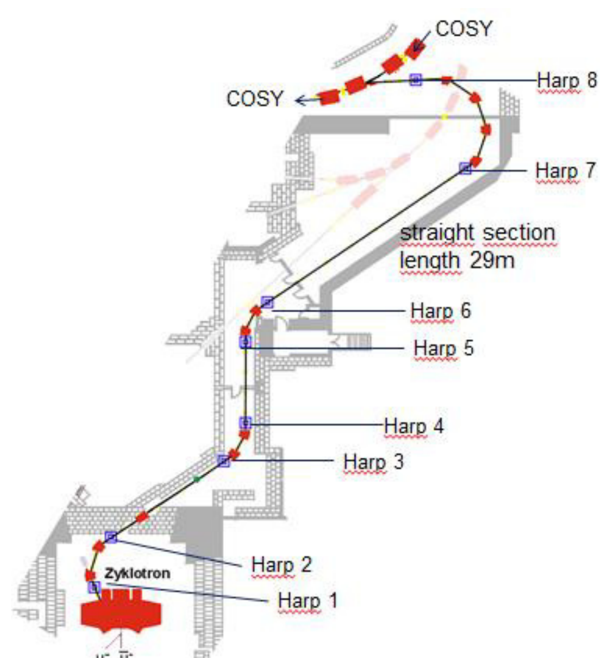

Figure 2: Distribution of harp stations in the IBL.

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Harp Stations

Harps rely on the effect of secondary electron emission. Some particles of ion bunches hit the wires. When fast ions enter a metal surface secondary electrons are emitted [1], which can be detected as electric signal by a sensitive current measurement system [2]. Many wires mounted in parallel allow detecting a transverse charge profile at that position (see Fig. 3).

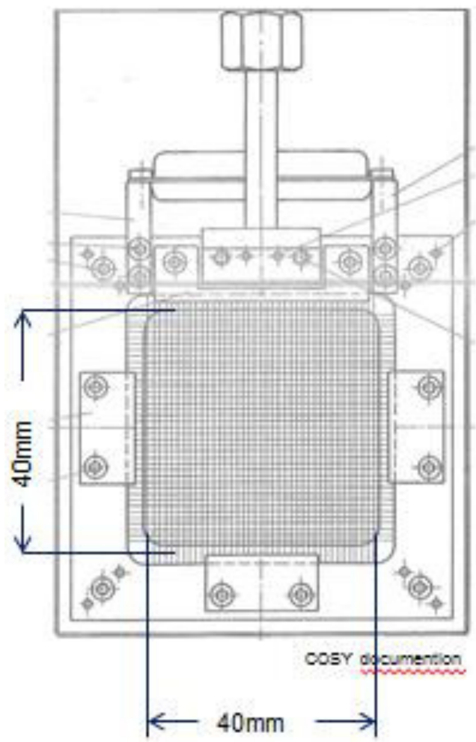

Figure 3: Drawing of a harp installed in the IBL [3].

A harp station is installed at each intersection between straight and bent sections. Each of the 8 profile monitoring stations consists of two harps performing measurement in one transverse plane (see Fig. 4). They have 39 wires with 1mm spacing covering 40mm.

UPGRADE

Motivation

The IBL was commissioned in the early 1990's and has always been in use since then. Originally having been equipped with a harp system as a major means of beam diagnostics the initial readout electronics has reached end of life resulting in time consuming beam setup procedures. The centralized architecture of the readout system allowed only for one profile grid to be used at an instance. The initial harp readout system had an rs232 based communication. There were a multiplexer station for the first group of 4 harp stations and another one for the second group.

Figure 4: Harp station 4 in the IBL contains a vertical and a horizontal harp moved by one pneumatic drive. Two multichannel pico-amperemeters are mounted below the cable tray.

Reliable operation of the beam profile measurement system is crucial for achieving reasonable beam transfer efficiency from the cyclotron to the COSY ring and keeping the IBL setup times short. Furthermore the ability to perform simultaneous profile measurements at all harp stations is regarded as very useful.

Boundary Conditions

Over the years no issues caused by the harp sensors have been reported. The pneumatic drives are considered to be in good working condition. Due to these reasons only the harp read out electronics is replaced. As there were concerns regarding the signal to noise ratio, the read out cables are kept as short as possible, so the read out electronics is placed close to the harps. Radiation effects need to be regarded.

The communication to the controls will be established by use of an EPICS client/server configuration to be integrated into the existing control system.

New Readout Electronics

A multichannel pico-amperemeter current measurement module for harps was designed and manufactured at iThemba LABS. A similar module has already been used for the luminescence profile monitor at COSY [5]. It is based on the charge integrator chip ACF2101 by Burr Brown [6]. The electronics is controlled by a BeagleBone microcontroller board. It controls the integrator chips,

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timing, trigger input and ADC's of the electronics, performs the data acquisition and communicates to the COSY-control system via Ethernet.

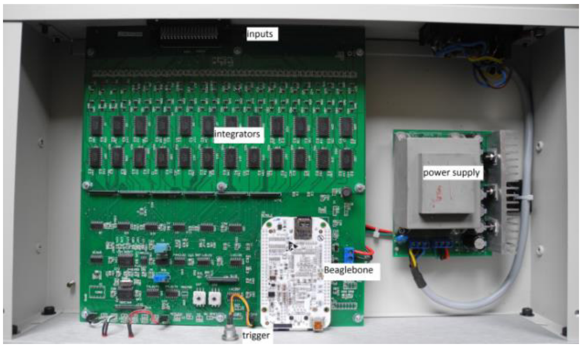

Figure 5: Opened pico-amperemeter current measurement module.

The modules shown in Fig. 5 are capable of measuring currents from 10 pA to 200 µA with 1 pA resolution and use 6 measurement ranges. The module has 48 channels, 39 of them are connected to a harp via a 2 m, 39-wire double shielded coax cable. Free channels are disabled by software. The macro-pulse signal connects to the trigger input by a single coax RG58 cable for synchronization.

Software System

The Experimental Physics and Industrial Control System (EPICS) is an open source architecture hosted by ANL. It has the properties of a client/server and publisher/subscriber systems. It also is capable of real time behavior. EPICS is widely used in the accelerator community. On the BeagleBone microcontroller the EPICS server software runs in an Ubuntu 13 environment. It is distributed on micro-SD cards and can easily be updated.

Control System (GUI)

The existing GUI was adapted to the new protocol. All harps can be read out simultaneously. All beam profiles are shown in one window (see Fig. 6). The profile measurement can be performed in free run mode or in triggered mode, which synchronizes to injection sequence.

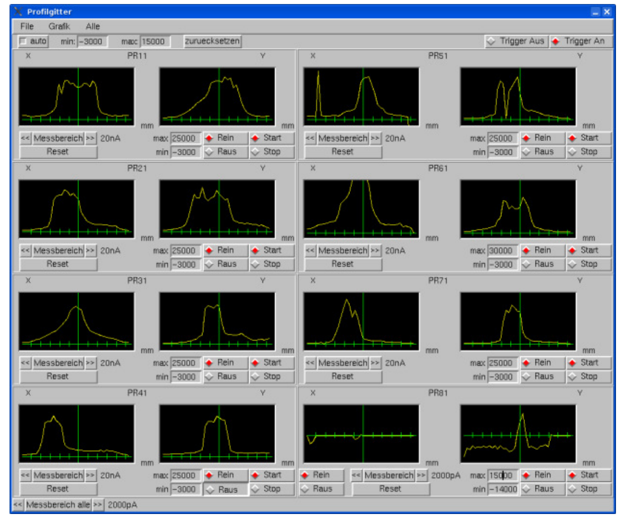

Figure 6: All 16 harps in the beam (H^- at 45MeV) deliver profile data showing a good alignment. At harp station 8 the y-plane covers the x-plane minimising the x-profile.

SUMMARY

The upgrade of the profile monitoring system of the COSY IBL was completed by the beginning of 2015. The system is now in routine operation. The GUI has been modified to work with the new hardware. Occasional hardware resets are required due to radiation and software issues. An upgrade to a better maintained OS-version (Ubuntu 14 LTS) is envisaged.

Outlook

An automatic procedure of determining the beam position, width and intensity based on the harp profile measurements is yet to be implemented. This data will then be used for an automated model-based IBL optimization routine. Long term archiving of the measured data is yet to be implemented as well.

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