THE ISAC-II CURRENT MONITOR SYSTEM

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Abstract

The post acceleration section of the ISAC-I radioactive ion beam (RIB) facility is composed of two room temperature machines: a radio frequency quadrupole (RFQ) followed by a drift tube linac (DTL). They serve a medium energy experimental area up to 1.8 MeV/u. These accelerators act also as injector for the ISAC-II superconducting linac (SCLINAC) that serves a high energy experimental area. This SCLINAC, composed of forty quarter wave resonators housed in eight cryomodules, is capable of a total accelerating voltage of circa 40 MV. Since each cavity is phased independently at the maximum operational voltage, the final energy depends on the mass to charge ratio of the accelerated species. In order to deliver energies higher than 5 MeV/u we need to monitor the beam current as mandated by our operating license. The current monitor system (CMS) is composed of two non intercepting and one partially intercepting monitor. The signals from these three monitors are processed in a single control system that provides a go signal to the Safety system enabling beam delivery. The CMS system allows to exploit the SCLINAC to its full potential. In this paper we will present both hardware configuration and software control of the CMS.

INTRODUCTION

The ISAC facility at TRIUMF (see Fig. 1) is a world class laboratory for production and post acceleration of rare isotope beams (RIB) [1]. The post accelerators deliver ion beams to a medium (ISAC-I) and a high energy (ISAC-II) experimental area.

In the medium energy area the deliverable beam energies range between 120 KeV/u and 1.8 MeV/u for $2 \leq A/Q \leq 6$. These energies are achieved by means of an RFQ followed by a DTL. When used as injector for ISAC-II the DTL is tuned for a final energy of 1.5 MeV/u.

In the high energy area the ion beams are boosted using a superconducting linac. The initial installation of twenty accelerating cavities (quarter wave resonators) has been upgraded by adding twenty more cavities for a total accelerating voltage of 40 MV. Each cavity powered and phased independently is always run at the highest gradient possible for stable operation with a maximum cryogenic power consumption of 7 W. The final energy of the beam depends on the mass to charge ratio of the accelerated ions. The ISAC superconducting linac upgrade is commissioned and operational [2].

In order to exploit this machine at its full potential the operating license requires the monitoring of the beam current during delivery in the ISAC-II experimental hall for energies higher than 5 MeV/u. The current limits stated in the license are a function of the beam energy. These limits are present for personnel safety reasons. The beam current is monitored using the current monitor system (CMS).

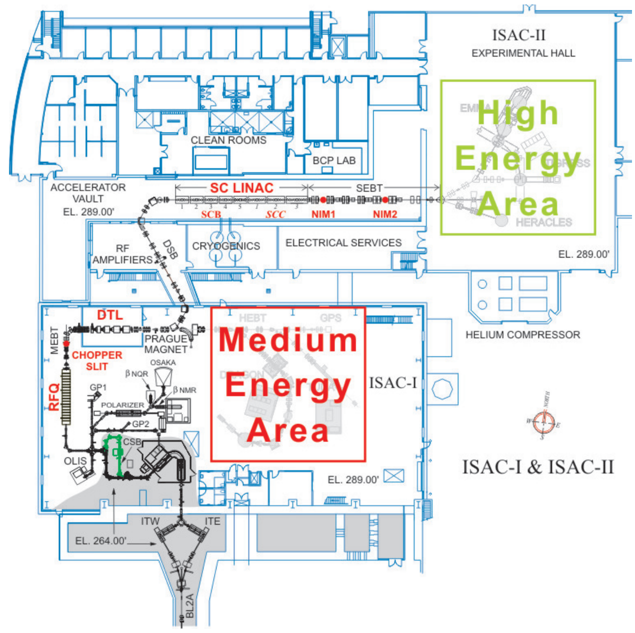

Figure 1: Overview of the ISAC-I and ISAC-II facilities at TRIUMF.

THE CURRENT MONITOR SYSTEM

The current monitor system consists of three devices: a partially intercepting beam monitor and two non-intercepting beam monitors (NIMs). The CMS sends a ”go” signal to the Safety system as long as the monitored current stays below the license limit. Upon removal of the ”go” signal the Safety system triggers the source Faraday cups and a beam stopper (beam blocker) inside the accelerator vault hence preventing the beam from going into the ISAC-II experimental hall.

The Partially Intercepting Monitor

The partially intercepting monitor is an upgrade of the existing chopper slit [3]. This slit is part of the chopper system [4] installed in the medium energy beam transport (MEBT) line (see Fig. 1).

The continuous beam coming from the source is pre-bunched before being injected into the RFQ. The pre-buncher [5] operates at 11.78 MHz while the RFQ resonates at 35.36 MHz. This implies that we mainly feed one out of three RF buckets in the RFQ while the tails of the beam fall in the side buckets. This acceleration scheme produces a time structure at the exit of the RFQ with one main peak every 86 ns and two satellite peaks 28 ns apart (see Fig. 2).

The chopper is needed to clean the time structure of the beam coming out of the RFQ. It can be operated in two modes using the single 11.78 MHz frequency or by adding the second 5.89 MHz. In the first mode the chopper deflects the satellites sideways with respect to the main peak. In the second mode the chopper also deflects one out of two main peaks in order to increase the time separation between them. The satellites (and the main peak if the chopper is used in the second mode) are then intercepted by the downstream chopper slit while the non deflected main peaks goes through a 2 mm slot in the slit plate.

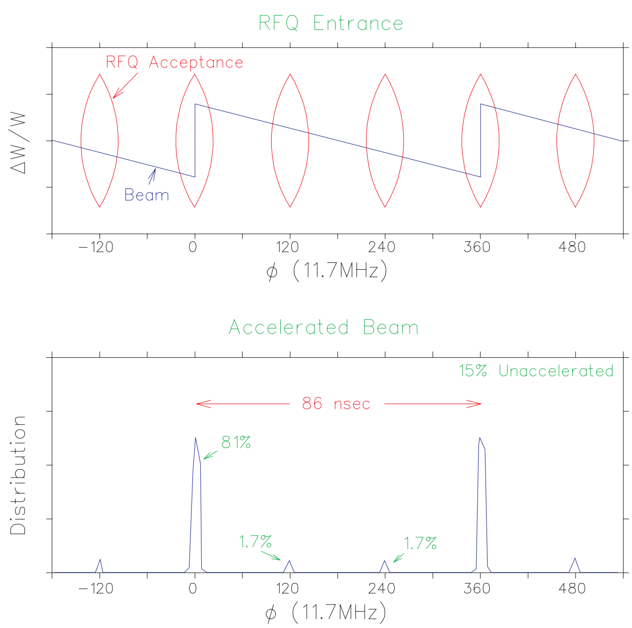

Figure 2: Time structure of the beam at the exit of the RFQ. The main peak frequency is 11.78 MHz. The satellites are a result of the 35.36 MHz RF.

The upgrade consists of installing a pick up plate on the chopper slit that intercepts the satellite peaks (see Fig. 3).

The signal produced by the satellites is linearly proportional to the current of the main peak (see Fig. 4).

The open geometry of the pickup doesn't allow the absolute current to be read even though a bias is present. The bias can indeed be used in reverse mode (positive bias) to increase the signal (see Fig. 5). Here a theoretical fit to the data has been constructed by symbolical integration of equation 1 [6].

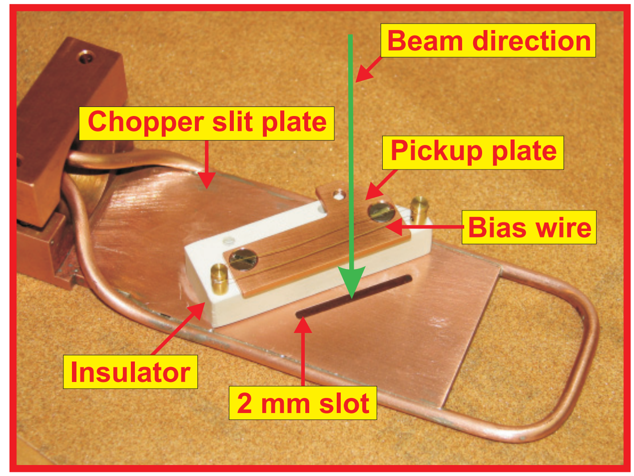

Figure 3: The upgraded chopper slit.The main bunch goes through the 2 mm slot while the satellites land on the pick up plate.

$$Q(\mu_1) = \int_{\mu_0}^{\infty} (\mu - \mu_0)(\mu^2 - 1)^{-2} d\mu \qquad (1)$$

The fit was made using the Fermi Energy for copper of 7.0 eV. The work function for copper is 4.7 eV but the best fit was obtained using half this value, possibly due to surface conditions. Measurements demonstrate that the pickup is sensitivity to a beam current as low as few hundreds of electrical pA.

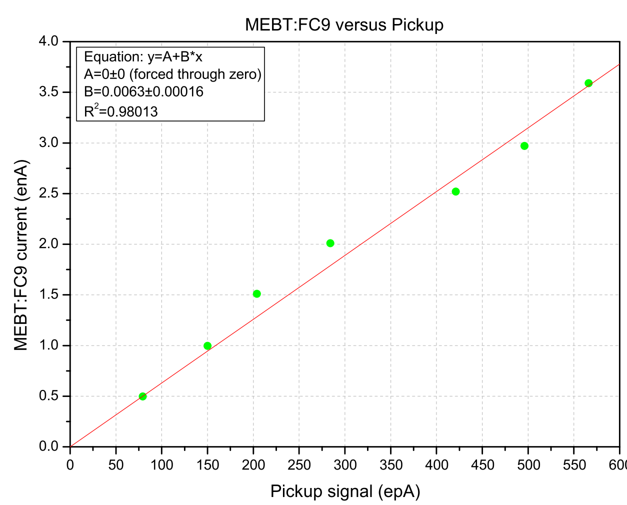

Figure 4: A test of the linearity of the chopper slit pickup.

The Non-intercepting Monitors

The two non intercepting monitors (NIMs) are resonant capacitive pickups. This device is described in details in previous papers [7].

The NIMs are installed in the SEBT beam line downstream of the superconducting linac (see Fig. 1). The two

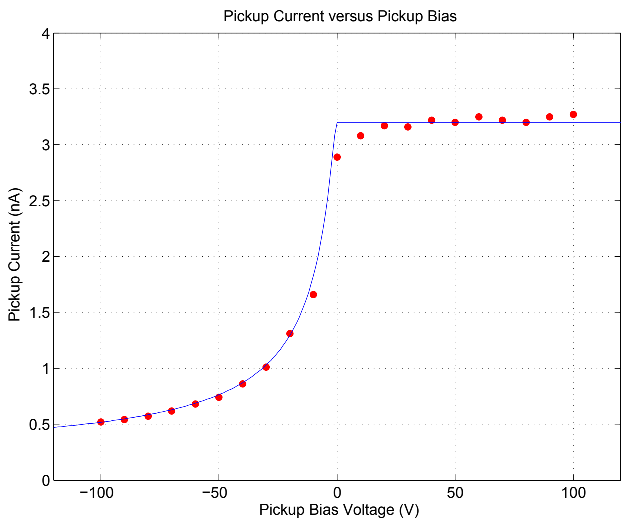

Figure 5: The effect on the signal of the bias voltage.

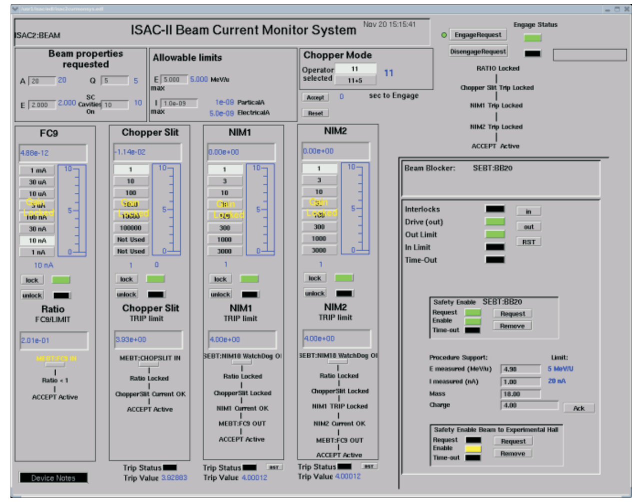

Figure 6: The EPICS CMS interface displays beam parameters (top left), license allowable limit, chopper operational mode, monitor read backs and trip limits.

identical monitors are required for redundancy. Like the chopper slit, the NIMs don't read absolute currents.

THE CONTROL SYSTEM

Each monitor has a dedicated interlock control box the output of which is directly connected to the Safety system. The NIM interlock boxes monitor the beam currents, watchdogs and gain control signals from the front end electronics for the two devices. The chopper slit interlock box monitors the beam current, bias voltage and gain control signals from the front end electronics. In this case it also monitors the status of the chopper amplifiers (5MHz and 11MHz operational mode) and the position (in or out) of the chopper slit. The beam currents are compared to thresholds set by ISAC operators based on the beam characteristics and license limits. Complex programmable logic devices are used to drive relays to give contact closures ("go" signal) to the ISAC Safety System when the defined signal conditions are met.

The threshold (trip limit) for each monitor is automatically calculated by calibrating the monitor signal against a Faraday cup. The Faraday cup reads an absolute electrical current that is compared directly to the license current limits.

The current monitor system is controlled via an EPICS graphic user interface (see Fig. 6). The input beam mass and energy parameters are necessary to determine the current limit specified in the operating license. The charge state is necessary to convert the license current limit from particle to electrical. The operator also has to choose the chopper mode of operation. Once this is selected the parameters must be locked (accept button) in order to proceed with the monitor calibrations. The monitor signals and relative trip limits are displayed as well as the current read back from the calibrating Faraday cup. After the monitor calibration is completed the system can be engaged (engage button).

The engage action enables the interlock control boxes to send the "go" signal to the Safety system if all conditions are satisfied. If the system is disengaged (disengage button) the control boxes remove the "go" signal. None of the parameters nor the monitor calibrations can be changed if the system is engaged.

CONCLUSION

The partially intercepting monitor is a fairly inexpensive solution that satisfies the license requirement. The current monitor system has been operational for more than one year. It has been proven reliable and effective in detecting over current.

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