FARADAY CUP SELECTOR FOR DC-280 CYCLOTRON

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Abstract

New isochronous cyclotron DC-280, the basic facility of Super Heavy Element (SHE) Factory was put into operation in the FLNR JINR on March 25, 2019. Key role in beam diagnostics for lossless transportation is played by Faraday cups. Five elements were installed along the two injection lines and 14 elements on the five transport channels to the experimental facilities. The software was developed to automatically select the active Faraday cup depending on its location and track the current on a single indicator. This paper describes basic principles and algorithm of the Faraday cup Selector module which is a part of the DC-280 cyclotron control system.

INTRODUCTION

The DC-280 cyclotron has been created and put into operation in the new experimental building of the FLNR. The main goals of Super Heavy Element factory [1] are:

- Synthesis of SHE and studying of their properties.
- Search for new reactions for SHE synthesis.
- Chemistry of new elements.

The SHE will increase the present rate of super heavy nuclei production by one-two orders of magnitude. This will enable studies of nuclear/atomic structures of heaviest atoms and open the door to the discoveries of the new elements above Z=118 and of isotopes closer to the predicted shell closure at N=184.

The main purpose of beam transport is lossless and high-quality delivery of accelerated particles to a target in a physical setup. By affecting the particles by the magnetic field of the correction magnetic elements (coils, solenoids, lenses, etc.), the operator focuses and holds the beam in the pipe. The result is measured by means of a variety of devices: current probes, Faraday cups, stoppers, luminophores and so on. Most of these elements are opaque for the beam and interrupt it on the way. Therefore, the only beam current measured on a device that was inserted first along the beam is significant. Eight multichannel meters are used to measure current from 21 diagnostic devices. During beam transportation operator has to switch his attention among multiple displays of current meters. For the convenience of the operator it was decided to create a program that automatically determines the actual diagnostic device and toggles its measurement to one common monitor.

HARDWARE

The beam transport system consists of two lines from different ECR ion sources on HV platforms (DECRIS-PM 14 GHz and Superconducting ECR), a common injection line into the accelerator, extraction line and 5 beam lines

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to the physical setups (see Fig. 1). To measure the ion currents and to determine the beam transverse position total 5 diagnostics units were installed in the injection system, 2 units in common extraction line and 12 units in five beam lines to the physical setups. Each diagnostic unit may contain Faraday cup together with ionization beam profile monitor, luminophore. Depending on the acceleration mode, ions pass from one of two ECR sources through the accelerator to one of five physical facilities.
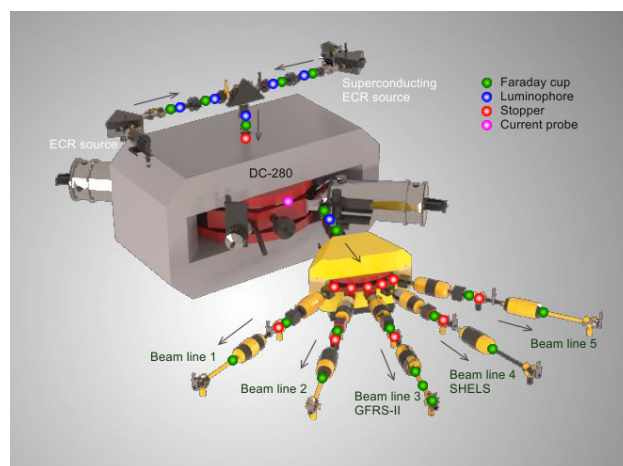

Figure 1: Beam diagnostics layout.

Key role in beam diagnostics for lossless transportation is played by Faraday cup. It was designed and manufactured in INR&NE department of the Bulgarian Academy of Sciences (Sofia, Bulgaria). Its design is shown in Fig. 2. Instruments for beam diagnostics are mechanically placed in the ion guide using a pneumatic drive mechanism.
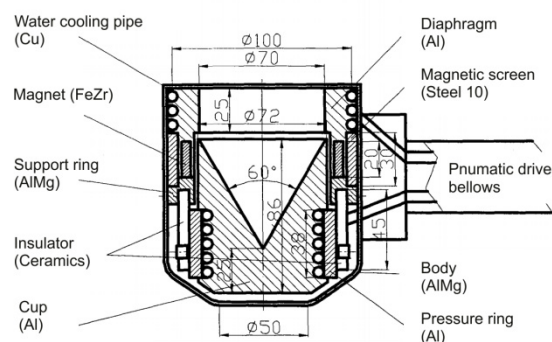

Figure 2: Faraday cup.

To measure the beam current, a specially developed module MI08-01 is used. It was designed and manufactured in FLNR JINR and meets SMARTBOX-6 system specifications [2]. The module has 8 input channels for connecting analog signals multiplexed to one measuring

channel. Measuring ranges are: ±1 mA, ±100 µA, ±10 µA and ±1 µA. Type of ADC is sigma-delta with a resolution of 16 bits. The measurement time is 133 ms. Common mode attenuation: 50, 60 Hz - 120 dB.

SOFTWARE

The control system software of DC-280 is based on NI LabVIEW platform with the Datalogging and Supervisory Control (DSC) module [3]. The control system is distributed over a network. Based on our experience, we decided to consider 3 projects (subsystems) for control system software: Injection (ECR source, axial injector), Accelerator (cyclotron, extraction, transport, water cooling) and Low level RF. Its essence (all signals) is described by means of shared variables which are deployed on the dedicated hosts [4]. Each subsystem includes its own vacuum control and beam transportation with diagnostics. Diagnostic equipment is presented in all subsystems and installed along the beam transport lines.
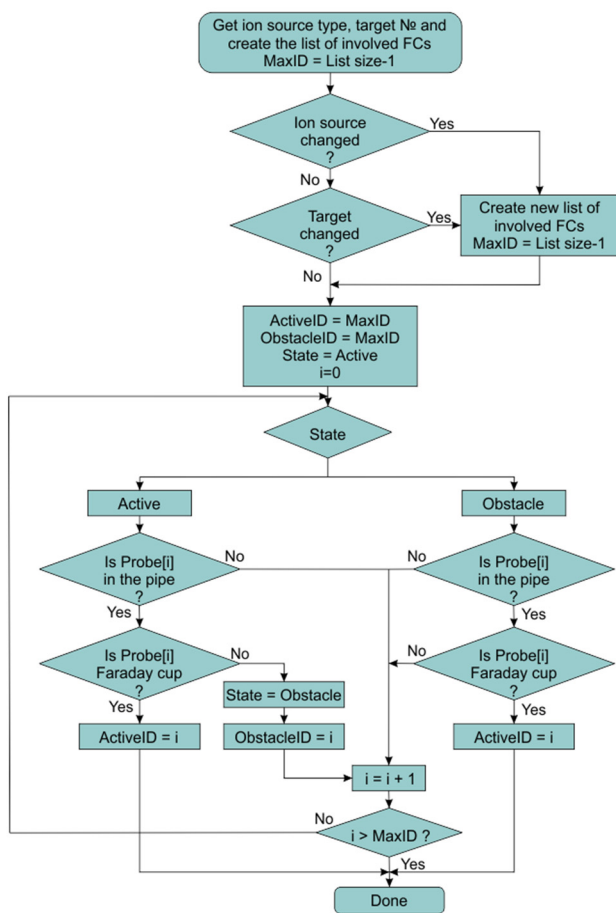

Figure 3: Algorithm for calculating the active FC and obstacle.

The software of the control system consists of a number of program modules that perform corresponding tasks: device drivers, alarms monitor, beam diagnostics, user interfacing, etc. To control or monitor any device in the control system, the program gains access to the corresponding shared variables. The FC selector is a standalone application and operates with diagnostic de-

vices and current meters by means of shared variables too.

In this article saying Faraday cup, it also means other types of diagnostic devices for measuring current, such as a stopper or current probe. At first step program builds a list of involved FCs in order of increasing distance from the ion source (see Fig. 3). It is based on the current ECR ion source and line number for the actual target. Then passing through the elements of the array, the pro-gram analyses the state of each and calculates the index of the first active element and the index of the obstacle if one exists. Based on the results obtained, the program marks corresponding elements in user interface (see Fig. 4).
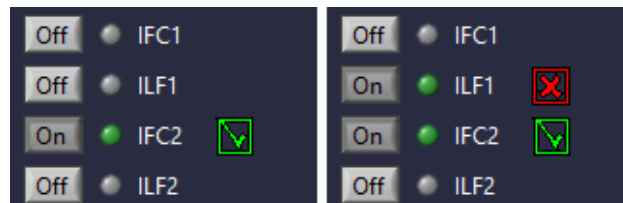

Figure 4: Marks of the active FC and obstacle.

The program commutes active FC to the designated meter and displays its readings on a single display. The user interface screen is divided into several areas with different purposes (see Fig. 5):

- Menu with settings button and current meter controls.
- List of involved diagnostic devices.
- Active FC name (black text) or obstacle name (red text).
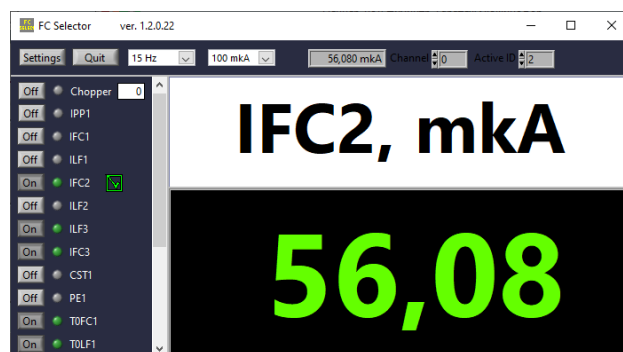- Current value.

Figure 5: Faraday cup selector User Interface.

Front panel controls and indicators are connected to the process variables by means of Data Binding technic [5]. Therefore, the program allows the operator to monitor and control diagnostic devices and corresponding current meters along with the user interface application of the project. The operator can change the size of the front panel elements as necessary.

CONCLUSION

The first beam of $^{84}Kr^{14+}$ ions was accelerated in the DC-280 on December 26, 2018 and extracted to the ion transport channel on January 17, 2019. In March 2019, beams of accelerated $^{84}Kr^{14+}$ ions with intensity of

1.36 pμA and $^{12}C^{2+}$ ions with and intensity of 10 pμA were extracted from the DC-280 to the beam transport channel with energy about 5.8 MeV/nucleon. The DC-280 cyclotron has been functioning successfully for six months. Operating experience requires us to develop programs such as a FC selector. This simple utility gives operator great convenience when using a variety of measuring instruments to monitor the beam.

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