

# A New Beam Intensity Monitoring System with Wide Dynamic Range for the Holifield Radioactive Ion Beam Facility

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## I. ABSTRACT

A new beam intensity monitoring system with a wide dynamic range has been designed, fabricated and tested for use at the Holifield Radioactive Ion Beam Facility (HRIBF). Radioactive ion beams produced with this first generation facility will have intensities much lower than those of stable ions previously injected into the 25URC tandem accelerator and the existing beam current monitoring systems, which have a lower limit of approximately 100 pA, will not be adequate to tune the injection line or accelerator. This paper describes a new system which combines a Faraday cup and a continuous dynode electron multiplier (CDEM) to yield a dynamic range from a few particles per second to greater than a microampere. The CDEM can be biased to count either secondary electrons or Rutherford backscattered ions.

## II. INTRODUCTION

The expected low intensities of radioactive ion beams require a new type of diagnostic for use as a tuning aid. Diagnostics presently available in the tandem accelerator and in the experimental beam lines are limited to Faraday cups, beam profile monitors and beam viewers. The logarithmic amplifiers used with the present Faraday cups have a lower limit of about 100 picoamperes while the beam profile monitors may be used with intensities a factor of ten lower. Various phosphors used with the beam viewers have problems with certain beam energies and with producing adequate light for typical cameras. Therefore, the concept for a new beam diagnostic system was developed. The essential design goals were: 1. One universal design to be used throughout the RIB injector, beam lines and tandem accelerator. 2. Primary use as a tuning aid rather than an absolute measure of beam intensity. 3. Beam current measurement range from a few particles per second to at least one microampere.

## III. SYSTEM DESCRIPTION

The new diagnostic system uses a Faraday cup for currents greater than one picoampere. The present logarithmic amplifiers will be replaced with Keithley logarithmic amplifiers with a dynamic range of  $10^{-12}$  to  $10^{-4}$  amperes. Another feature of the new system is the ability to amplify the current reading by using the "bad" Faraday cup mode. In this mode, the polarity of the electron suppresser power supply is made positive so that secondary electrons are attracted to the suppresser and the Faraday cup current reading is amplified. The amount of amplification is dependent on the ion beam being measured (species and energy) and the backing material in the Faraday cup. Preliminary tests have used both Cu and Al as backing materials with the highest amplification being observed with Al. Beams of 50 and 300 keV  $^{58}\text{Ni}$  and  $^{16}\text{O}$  were used with the higher energies yielding the highest amplification. The lowest factor was 5.3 for 50 keV  $^{16}\text{O}$  and the highest factor was 12.9 for 300 keV  $^{58}\text{Ni}$ . These beams were negative ions, but ion beams of both polarities will be amplified using this method. For either polarity of beam, however, the Faraday cup current measured will be positive.

Beam currents less than one picoampere will be measured by counting either ions or secondary electrons with a CDEM. A metal target will be placed in the beam and the CDEM will count either electrons or Rutherford backscattered ions depending on the intensity of the beam. For ion beam currents less than  $10^5$  ions per second (16 femtoamperes), the CDEM will be configured so that it will count secondary electrons. The entrance bias in this configuration is a few hundred volts positive which will attract secondary electrons. The total bias for the CDEM is always positive and its value is kept the same in either mode. When the entrance bias is negative by a few hundred volts, electrons, but not Rutherford backscattered ions, are repelled from the entrance. This configuration allows counting in the range  $10^4$  to  $10^7$  (1.6 picoamperes) ions per second.

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The combination of the CDEM in both modes and the Faraday cup allows measurement in the full range of interest for either stable ions or RIBs. Since the intent of these devices is as a tuning aid, exact calibrations for each ion will usually not be performed. The operator will be able to read a rate meter or Faraday cup current to determine the effect of tuning on beam intensity. Other devices will be used to determine the exact intensity of specific radioactive ions.

Figure 1 shows a capacitively coupled CDEM configured for pulse counting. This is the configuration wherever the CDEM is used. For those unfamiliar with CDEMs, a good general description is found in reference 1.

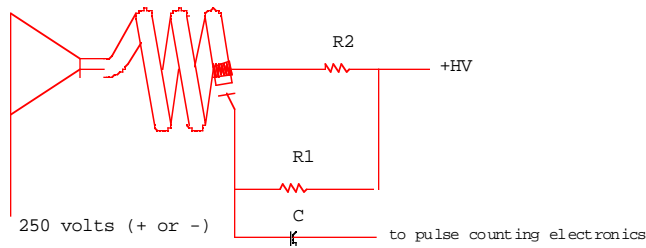


Figure 1. CDEM showing electrical connections for pulse counting.[1]

#### IV. PROTOTYPE TEST RESULTS

The system description given above provides for an entrance bias on the CDEM for counting either electrons or ions. It should be noted that the same effects can be achieved by biasing the metal target that the beam strikes. It is obvious, however, that the polarity of the target bias would be opposite from the entrance bias for each mode. Since biasing the target can be simpler, this configuration was used for the initial tests. Stable beams from the 25 URC Tandem accelerator injector were used for the tests. Both  $^{58}\text{Ni}$  and  $^{16}\text{O}$  beams, accelerated to 50 and 300 keV, were used. An example of a measurement of the CDEM count rate as a function of target bias is shown in figure 2. In this measurement, the CDEM bias voltage was maintained at 2500 volts and the intensity of the impinging beam was kept constant for this test. As can be seen, counting in the ion mode reduces the sensitivity of the detector by a factor of approximately  $10^3$ , which effectively allows an extension of the usable range for the CDEM. It is expected that the change in modes may be accomplished through the control system by operator choice.

The range for the ion-counting mode actually extends into the range for the Faraday cup which allows a calibration for the CDEM counts. Figure 3 shows the ion mode calibration for 300 keV  $^{16}\text{O}$ . As can be seen, the count rate is a linear function of the beam intensity until the CDEM saturates.

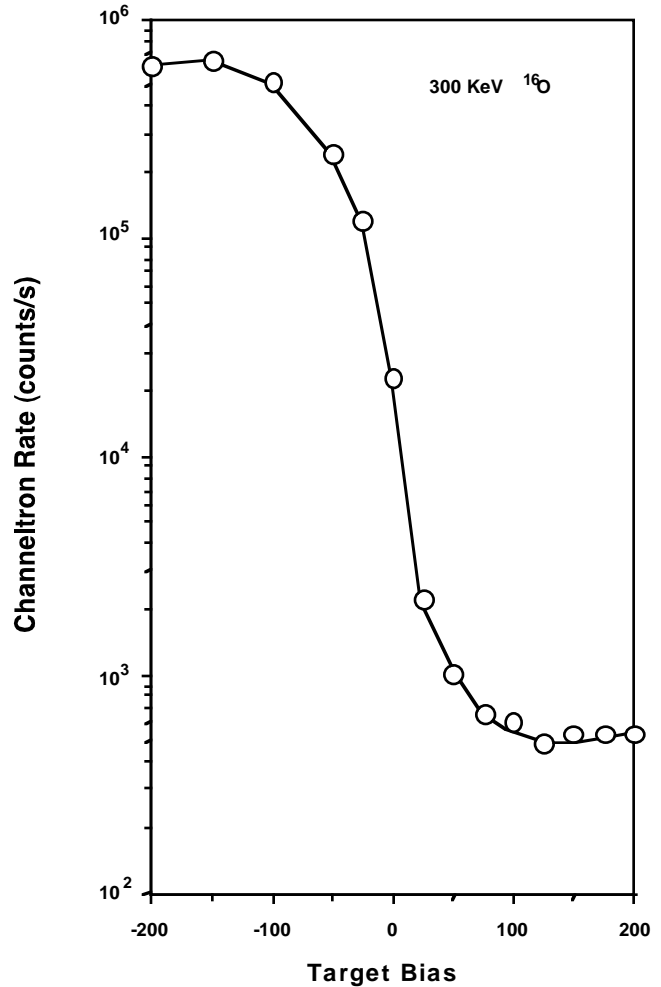


Figure 2. CDEM count rates versus target bias for constant beam.[2]

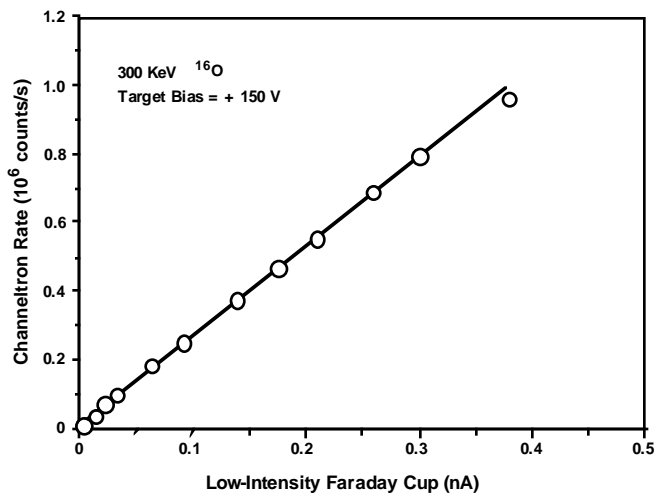


Figure 3. Ion mode calibration for 300 keV  $^{16}\text{O}$ . [2]

The efficiency of the detector is dependent on several factors, including ion species, ion energy, and mechanical alignment. For the beam tests depicted in figures 2 and 3, the electron mode efficiency is 50%. That is for every count, an average of two ions have hit the target. In the ion-counting mode, the efficiency is 0.04%. Tests with different species, energies, and alignment show a variation in efficiency from a high of 79% down to a low of 22% for the electron-counting mode, while the ion-counting mode efficiencies range from 0.04% to 0.2%.

Later tests which used a grounded target and a bias on the entrance of the CDEM showed comparable results. The need to bias the entrance of the CDEM rather than the target arose from the requirement to measure radioactive beams. Many radioactive ions are beta emitters and as they are deposited on the target, the betas could confuse the measurement. Therefore a movable target, which is more difficult to bias, was necessary. A movable-belt target system was designed, fabricated, and tested. Figure 4 shows a simplified drawing of this system.

## V. Summary and Conclusions

The combination of more sensitive Faraday cups and the CDEM system should allow tuning very low intensity radioactive ions from the RIB injector through the tandem accelerator and on to the user's target. Even though testing has only been done for low energy beams from the stable-ion injector, no significant problems are expected from ion beams at higher energies. A test at higher energies is planned before installation of the new diagnostics throughout the tandem accelerator system

The new Faraday cup configurations have been installed on the RIB platform and the new stub beam line transporting beams off the platform. Low intensity assemblies for use inside the tandem accelerator will require modification to withstand the SF<sub>6</sub> gas pressure and to fit in the very limited space available. These assemblies will be designed, fabricated, and installed before accelerating RIBs through the tandem accelerator in August 1995.

## VI. REFERENCES

[1] Kurz, Edward A., "Channel Electron Multipliers", American Laboratory, March 1979.

[2] Channeltron is a registered trademark of the Galileo Electro-Optics Corporation.

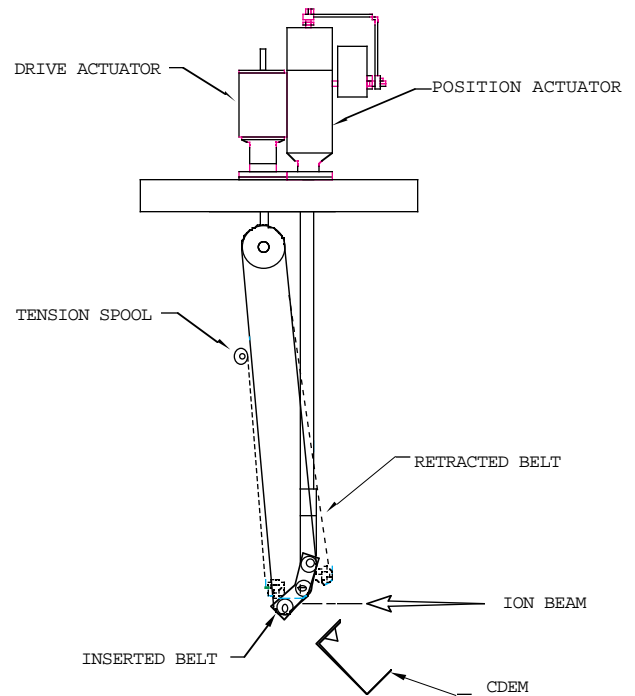


Figure 4. Simplified drawing of the moveable-belt target system.