AN EXTERNAL MONITOR OF BEAM LOSS IN AN H$^-$ CYCLOTRON

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Summary

The TRIUMF cyclotron accelerates H$^-$ ions from 0.3 to 520 MeV. Beam may be lost by dissociation or by collision with mechanical objects in the vacuum tank. To reduce the activation of these components, and to monitor the loss, thin foils have been installed to define the vertical aperture for the beam. The foil's projection toward the median plane is greater than that of any other component; they strip H$^-$ ions with a large vertical amplitude to H$^+$. Their location (R,θ) is such that the H$^+$ ions are energy dispersed along a short region of tank wall. They pass through a thin, 0.8 mm steel, section of wall to enter a thin ion chamber lying between the wall and the surrounding magnet yoke. The chamber is flushed wih Ar/CO_2 gas and the anode-cathode spacing is 6 mm in order to reduce ion recombination. The anode is segmented along the plane of dispersion to yield the region of beam loss. The device is radiation hard, including cabling, and may be removed or installed remotely. It has been calibrated by inducing known amounts of local beam loss and the coefficient scales with stopping power and ion path length as expected.

Introduction

Secondary emission monitors in the vacuum tank detect the beam stripped to H$^+$ by scraper foils. Two pairs of low and high energy monitors on opposite sides of the tank detect this spill, about 3 μA for 140 μA circulating. Thin aluminum SEM foils, with SEM coefficients of about 4.5% at 250 MeV and 3% at 500 MeV per surface, are held at 45° to the beam plane and are biased at -400 V. Signal electrodes above and below collect the electrons. Although the monitors are housed in grounded boxes, rf pickup has been a problem at times. Additional shielding has been added to some monitors.

The stripped beam passes through the tank wall with little scattering allowing monitors to be placed in air between the wall and magnet yoke. Improved energy resolution is possible as the scraped beam locus diverges in azimuth from inside the tank. An external monitor is not subject to rf interference and can be made quite robust. Gas filled ionisation chambers can be used, producing greater signal currents than vacuum devices. Replacement of internal monitors will make more tank space available.

Mechanical Design

A prototype chamber was installed in the location shown in Fig. 1 for preliminary tests. The signal and bias plate arrangement was the same as for the final design but the insulator geometry was different. The signal plate was held directly between two bias plates with 6.4 mm ceramic insulators. The bias plates were attached to the chamber housing with another set of insulators. During one month of high current operation leakage from the bias plates to the signal plate of 4.5 μA at 300 V developed. The chamber had contained air at 1 atm. The leakage disappeared when the air was flushed out with Argon but climbed to 68 μA after 6 months.

The final monitor system design consists of two identical ion chambers, Fig. 2. They can only be accessed when the tank lid is raised. Each chamber houses 4 signal plates with their bias plate pairs. A semi-permanent aluminum frame was installed among the

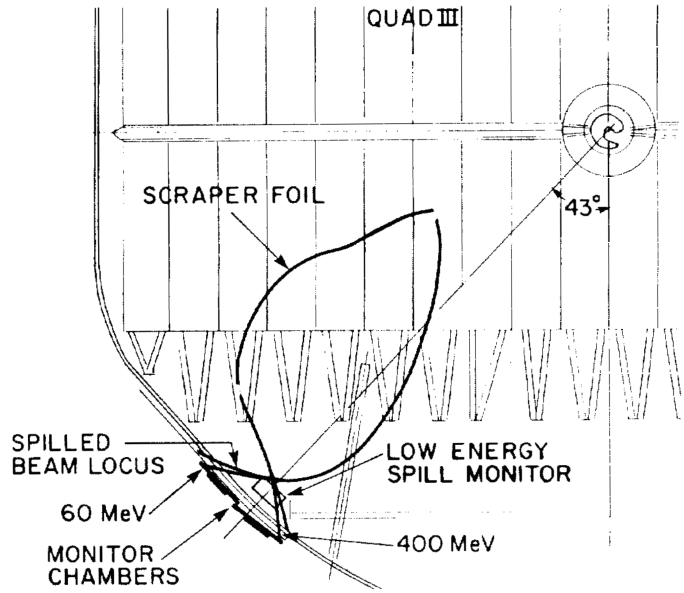

Fig. 1. Monitor location on the vacuum tank wall, showing the beam scrapers and the beam spread coverage.

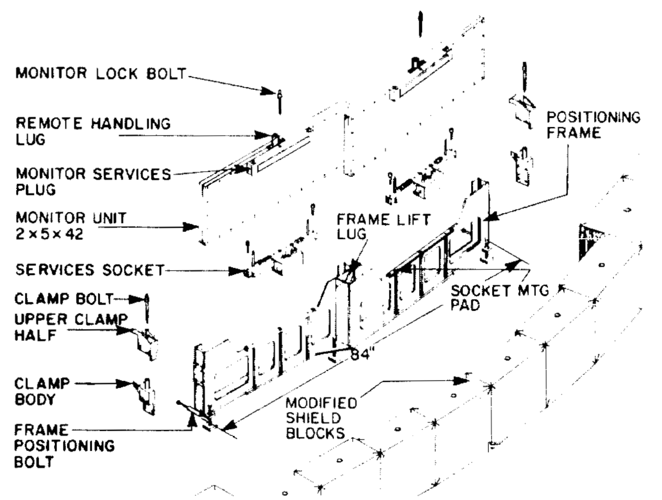

Fig. 2. The mechanical layout of the monitor chambers services connectors, graphite shielding blocks and frame.

carbon shielding blocks immediately outside the cyclotron vacuum tank wall. The frame was built using heavy gauge construction to resist damage from impact by the transfer of heavy shadow shields. It is attached to the cyclotron wall flange with three clamps. All unnecessary material in the beam plane was removed to reduce residual activation. Base support and positioning for the frame is provided by adjustable standoffs.

Both monitor chambers are continuously purged with Ar/CO_2 from a remote gas source to sweep out radiation products that could contaminate the insulators. The plates, Fig. 3, are 0.8 mm aluminum and have small vertical bends to increase rigidity and maintain a constant spacing throughout. Each signal plate has an active area of 2 × 655 cm^2 and is sandwiched between the bias plates with a nominal spacing of 6.4 mm. All plates are held by insulators attached to the grounded chamber housing frame, reducing bias to signal plate leakage. The two chambers overlap to provide continuous energy coverage.

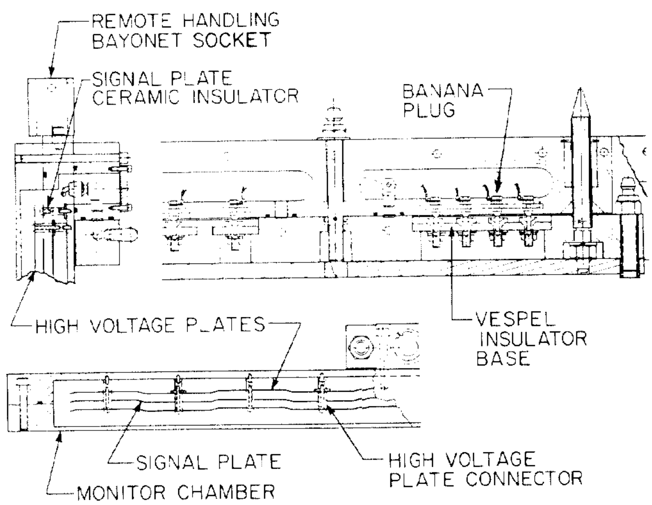

Fig. 3. Monitor chamber assembly showing the signal and HV plates and services connectors. The signal plate insulators pass through holes in the HV plates to the grounded chamber.

The service connections to each chamber, including gas supply, signals, and bias are made by plugs on the chambers and sockets on the frame. The socket housing may be removed from the frame semi-remotely in the event the two alignment pins or other components are accidently damaged. The gas connections are made by Swage-Lok quick connects on the service socket and by face to face contact with viton O-ring seals between the service plug and socket. Long life is expected since this is a static application. The service plug cover plates use a rubber sheet gasket. A grouting of fiber glass resin seals the gap between the vespel plates and the service plug. Two 6.5 mm copper lines bring the gas from the vault basement up to the monitors.

Removal and Installation

There is nominally a 46 cm high × 46 cm wide space between the vacuum tank wall and the main magnet yoke, Fig. 4. It is normally filled with shielding blocks to reduce activation of the yoke near the beam plane. The blocks consist of 38 cm high 5 cm × 5 cm bars of commercial graphite vertically stacked into 0.6 mm wall aluminum boxes lined with a 8 mm thick borax-gypsum compound which absorbes the neutrons given off by the graphite during irradiation. Each block has a remote handling bayonet lifting socket attached on top. To fit the frame into that space, 30% of the graphite was removed. A special boom crane attached to the remote handling man trolley bridge was used to position the frame in the proper location while in situ work took place. The residual activity in the region was 1 to 3 rem/hr. The total dose for installation of frames and block replacement was around 0.6 man-rem. All the service lines and cables were installed at the same time by four technicians to minimize the total dose, about 0.05 man-rem. Removal is a reversal of this operation with about half the expected dose.

The maximum device length accepted by the bridge is about 2 m. Therefore two identical monitor chambers were used to cover the required energy range. They may be removed and installed into the frame completely by remote handling methods. A single tie-down bolt is undone, the standard bayonet lifting lug is latched on and the whole monitor chamber is pulled straight up.

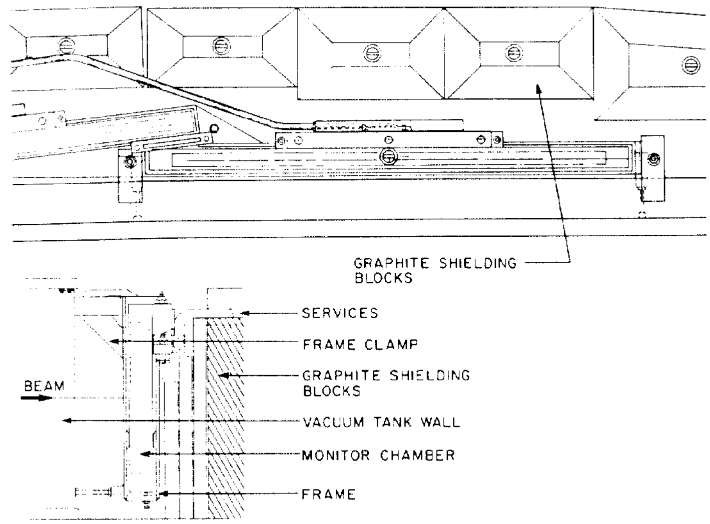

Fig. 4. Installation drawing showing monitor chamber and frame clamped to cyclotron wall and modified graphite shielding blocks.

This detaches the chamber from the frame and automatically disconnects all services. The operation is reversed for installation.

Electrical Design

The radiation resistant wiring inside the chambers consists of ceramic beaded kapton coated copper wire. The cabling to a vault basement junction box is kapton insulated stranded copper inside copper braids. A simple pull off plug connecting to a 9-pin ceramic feed through was used on each monitor service socket. Banana plugs were used between the service plug and socket connection for durability and to take up minor misalignment. The banana plugs and sockets were mounted on vespel plates for electrical isolation from the housing. The plate signals are brought from the junction box to the electronics area by eight 35 m shielded twinax cables. The bias plates in each chamber were wired in series and separate bias lines brought out from the endplates, allowing circuit continuity to be checked at any time. The signals are amplified by a 32 channel 12 bit A/D converter developed at TRIUMF.[1] The unit has autoranging with ranges of 195 nA to 3mA full scale and differential inputs with impedance of 5 KΩ. The amplifier is read using the central control CAMAC system and the currents are displayed on the control room terminals.

Monitor Calibration

Measurements were made by accelerating 0.5 to 1 μA to an energy defined by the radial position of a current measuring probe. Various trim coils were then detuned to produce a local vertical displacement of the beam plane. Thus the scraper foil stripping occurred at a known energy. The amount of beam spilled was taken as the difference of the current measured on the probe before and after detuning. Corrections were made for spill on the opposite side of the tank and for background due to EM and gas stripping. Less than half the circulating current was spilled in order to have a well defined energy.

The bias was initially +70 V and the chambers filled with 1 atm of Ar/CO_2. The response of the individual plates as a function of scraping energy is shown in Fig. 5. In general, the stripped beam was

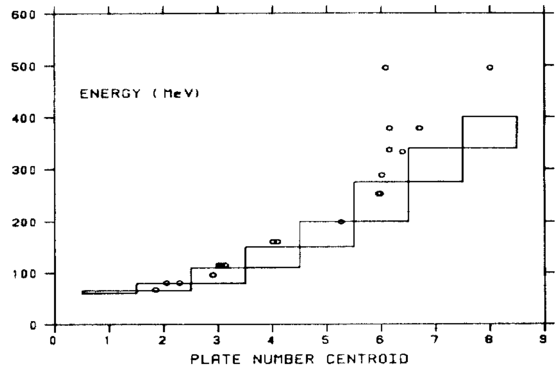

Fig. 5. The boxes indicate the design energy range of each plate. The circles are measured values.

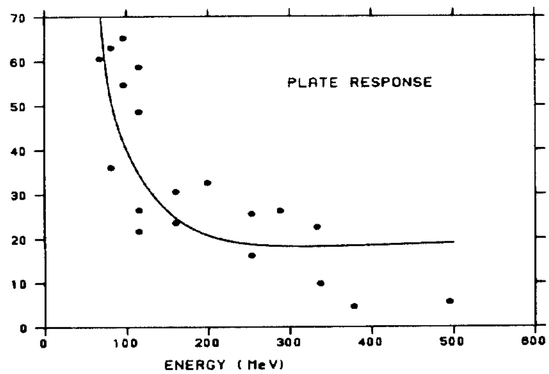

Fig. 6. The response of each plate (signal current/ spilled current) at +70 V bias. The line indicates a function proportional to the stopping power of Argon and path length.

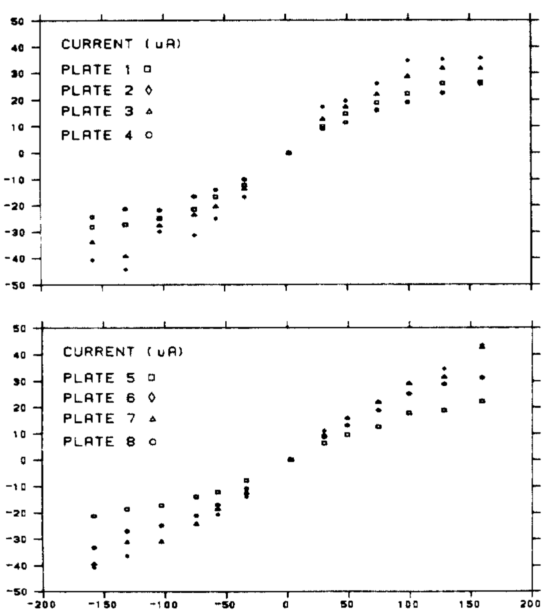

Fig. 7. The effect of bias on the response. The data were taken during regular operation at 144 μA. The distribution of scraped beam varies from plate to plate.

incident on more than one plate so the weighted sum of the plate currents was used to find a centroid. Figure 6 shows that the response of the lowest energy plate is 2.6 times that of the highest. This variation will have to be taken into account in generating trip conditions, although only an unweighted sum is presently used from the internal monitor. The dependence of plate current on bias voltage is shown in Fig. 7. The data was recorded during high current running (144 μA) with a spill of 1.1 μA on the internal tank LESW spill monitor. The signal current varied as power of the bias with an exponent of 0.43 for the lower energy plates to 0.85 for the higher energy plates.

The cyclotron trip level is set at a total loss of about 3 μA which means less than 1 μA per plate so that the linearity shown in Fig. 8 is adaquate for protection. It is not known at the moment whether the knee in the response is due to stripping at several locations as the beam plane was distorted. This will be resolved by future measurements.

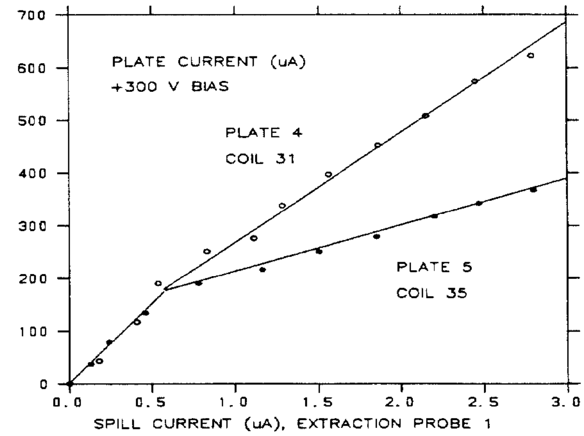

Fig. 8. The linearity of the monitor is difficult to measure as the location of the beam spill is uncertain.

A high energy resolution test was performed by detuning a trim coil to cause spill on two plates and then shadowing with the HE1 probe. As the probe was stepped to greater radius the plate response as a function of energy was recorded. The response of plate 3 fell over an energy range of 115 to 118 MeV while that of plate 4 rose over 117 to 121 MeV, a transition range equivalent to 3 cm radius. This is close to the expected spot size and there is little transfer of charge from plate to plate. Because the beam can cause CO_2 to dissociate to O_2^-, some measurements were made with N_2 gas. Similar results were obtained.

Acknowledgments

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References

1. R. Chan, R. Gebauer, TRAC-32, this conference.