

# PROGRESS TOWARD AN EXPERIMENT TO STUDY THE EFFECT OF RF GROUNDING IN AN INTERNAL ION SOURCE ON AXIAL OSCILLATIONS OF THE BEAM IN A CYCLOTRON

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## Abstract

For practical reasons, the chimney of a cyclotron's internal ion source often has RF grounds at only one end, despite the desire for an axially symmetric electric field throughout the cyclotron. It is generally impractical or impossible to measure the shape of the electric fields around the chimney, but one of the authors (H. Blosser of Michigan State University) has observed that in three cyclotrons of similar design built at the National Superconducting Cyclotron Laboratory, the machine with the least axial oscillation of the beam was the only one designed with median plane symmetry in its RF grounding. Based on this he suggests that RF currents in an asymmetrically grounded chimney give the beam an initial vertical kick which starts a coherent oscillation about the median plane. This hypothesis is being tested in the Ion Beam Applications C235 proton therapy cyclotron which uses an internal hot-cathode PIG ion source that is normally grounded only at the bottom. The test uses an insert which can be temporarily installed in the upper yoke hole of the cyclotron in order to make an RF grounding connection to the top of the chimney. A scintillation probe is then used to study the axial beam position on successive turns with and without the symmetric RF grounding.

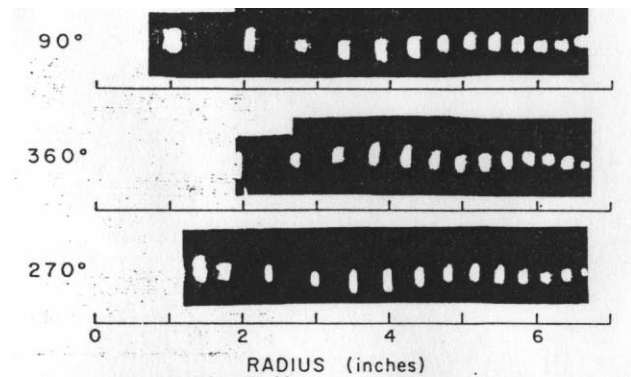
## 1 HYPOTHESIS OF THE EFFECT OF ASYMETRICAL SOURCE GROUNDING

Between 1966 and 1997, researchers at the National Superconducting Cyclotron Laboratory (NSCL) of Michigan State University (MSU) have performed 'foil burning studies' to observe the internal beam cross sections in several different cyclotrons [1,2,3]. A sample of these data is shown in Figure 1. The results from the Harper Medical Cyclotron show the least oscillation of the set, and this is the only machine studied where the ion source chimney has median plane symmetry in its RF grounding.

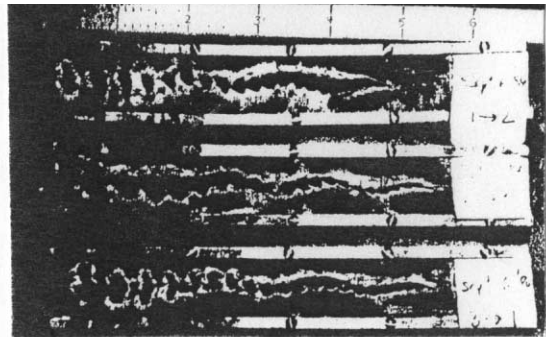
One of the authors, H. Blosser, hypothesises that the coherent vertical oscillations in the earlier machines originate with RF currents flowing in the chimney of the ion source, which would provide an axial kick to the beam as it leaves the chimney.

This kick should be equivalent to using a non-zero axial momentum as an initial condition in an orbit tracking code. Simulations of central region orbits with an initial nonzero axial momentum typically yield vertical oscillations not unlike those of figure 1 [3,4].

MSU K50 CYCLOTRON, 1966



MSU-NSCL K500 CYCLOTRON, 1984



HARPER MEDICAL CYCLOTRON, 1997

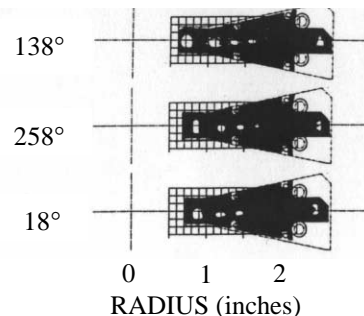


Figure 1: Hole patterns burned in stainless steel screens in three different cyclotrons. Only the Harper Cyclotron has median plane symmetry in its ion source grounding.

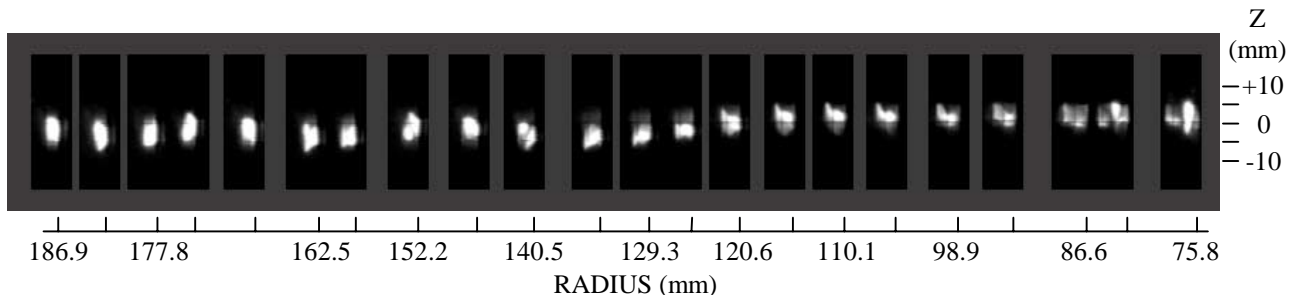


Figure 2: Series of images from the viewer probe showing axial beam oscillations in the C235 cyclotron. Grid marks on the scintillator plate are 5 mm apart in both the horizontal and vertical. The scintillator is set at a 45 degree angle to the camera axis, making the horizontal scale 1.4 times smaller than the vertical. Images are spaced horizontally in rough proportion to the probe radius. (Note that images are scaled smaller than the radius scale. If plotted on commensurate scales, the amplitude of oscillation would be roughly three times greater than it appears in the figure.)

## 2 USE OF THE IBA C235 CYCLOTRON TO TEST THE SOURCE GROUNDING HYPOTHESIS

### 2.1 Features of the C235

The IBA C235 Cyclotron, built for proton beam cancer therapy, provides an excellent opportunity to test our hypothesis. The internal ion source is grounded on the bottom only. The ion source is inserted through an axial hole in the lower yoke. An identical hole in the upper yoke provides sufficient access to install a temporary device for grounding the top of the ion source.

The cyclotron is equipped with a viewer probe that uses a scintillator plate and video camera to observe cross sections of the beam at any desired radius. Studies with this probe (Figure 2) show vertical oscillations with an amplitude of several mm which are similar to the asymmetrically grounded cases shown in figure 1.

We might hope to damp these vertical oscillations by grounding the top of the ion source chimney. Even if the vertical oscillations in the C235 are due in part to other causes, such as magnetic median plane errors or mechanical positioning error of the ion source, we would expect to be able to test our hypothesis by causing a change in the vertical behaviour of the beam when the top of the ion source is grounded.

### 2.2 Effect of source height on internal beam in the C235

Axial beam oscillations can arise from an initial vertical displacement of the beam, or an initial vertical momentum, or a combination of both. If we can observe oscillations in a cyclotron which arise from an initial vertical displacement, then we should be able to use the same machine to observe the effect of a change in the

initial vertical momentum of the beam leaving the ion source.

Figure 3 shows the effect of a 1.3 mm change in the vertical position of the ion source, and therefore a 1.3mm displacement of the initial axial position of the beam. This change is equal to roughly one third of the height of the chimney hole, and thus roughly one third of the initial height of the beam. The fact that such a small change in initial conditions has such a dramatic effect on the beam structure provides confidence that we should be able to detect the influence of a change in initial vertical momentum of the beam when we ground the top of the ion source.

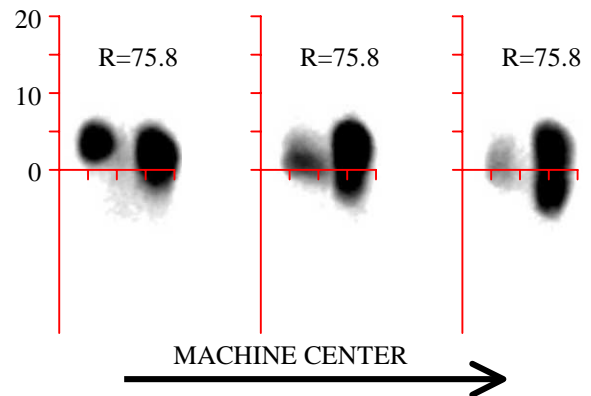


Figure 3: Viewer probe images taken at a fixed probe radius, for three different ion source vertical positions. Left: chimney hole is 0.71 mm below the nominal working position. Middle: chimney hole is at working position. Right: Chimney hole is 0.66 mm above nominal working position. Some blurring of the image is caused by poor camera focus, so the scales of the scintillator plate have been redrawn, and the colors have been reversed. Each horizontal scale defines a region from 75.8 mm to approximately 89.9 mm from the machine center. Axial dimensions are in mm.

### 3 DESIGN OF A SWITCHABLE RF GROUNDING DEVICE

In order to perform a meaningful experiment, it is desirable to be able to rapidly switch the symmetric grounding condition on and off without opening the cyclotron to reconfigure equipment. In addition to saving time, this eliminates the effect of thermal changes in the cyclotron which could influence the turn pattern.

To accomplish easy switching the device is mounted on the end of a long rod, which is fed through a vacuum flange at the top of the cyclotron. The rod can be manually retracted to lift the grounding device off of the ion source, and manually lowered to reattach the device to the ion source.

The grounding device itself is a copper shunt with two sets of RF contact springs. One set of springs contacts the crown of the chimney while the other set touches the nearest grounded structure of the central region.

If the RF current in the ion source is shared equally between the upper (experimental) and lower (permanent) contacts, we expect about 15 A of RF current to flow through the shunt, so it should be sufficient to use a small shunt and to make contact with only a few RF fingers.

### 4 PRELIMINARY RESULTS

Preliminary tests with a hastily designed grounding device yielded a null result. The largest problem with the early trial was the difficulty involved in properly positioning the RF shunt to ensure contact with both the chimney and a reliable RF ground. A new test device is being designed which would allow for more reliable positioning. In addition, the vacuum flange on top of the cyclotron will be remanufactured out of transparent plastic, to allow for visual confirmation of the shunt position.

A more careful comparison will be performed when the improved device is ready.

### 5 ACKNOWLEDGEMENT

The Cyclone 235 cyclotron is installed at the Northeast Proton Therapy Center (NPTC) of Massachusetts General Hospital, in Boston, Massachusetts. This project was performed in co-operation with Dr. J. Flanz and the technical staff of the NPTC.

### REFERENCES

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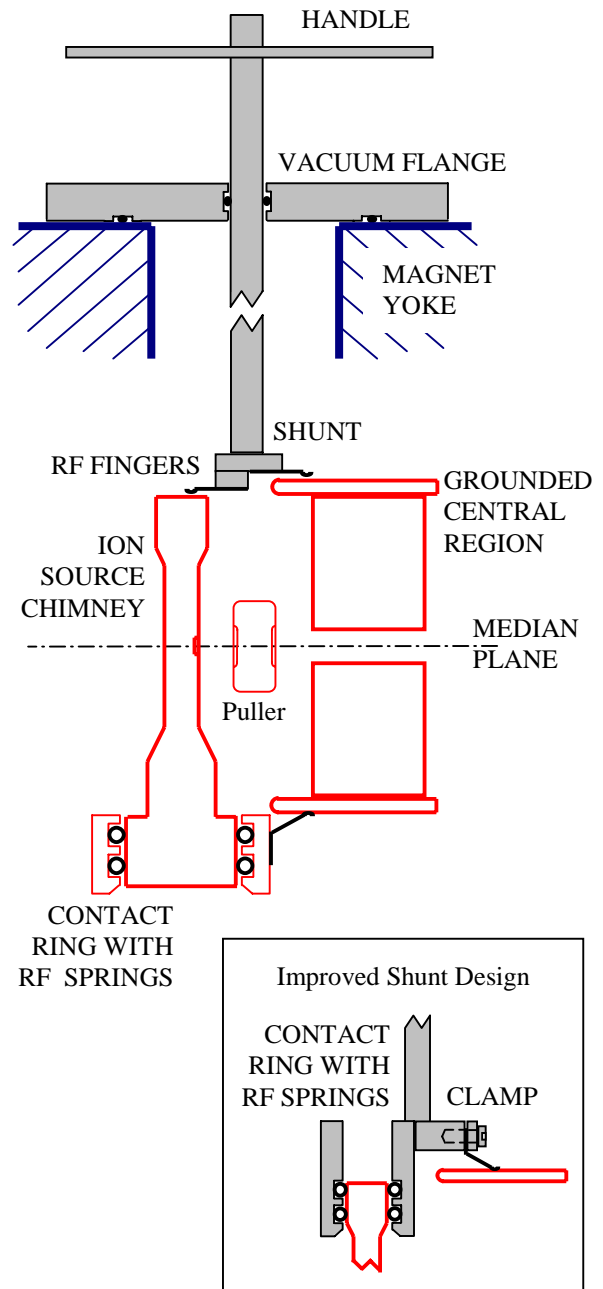


Figure 4: Schematic of a switchable ion source grounding device (shaded structures,) installed in the cyclotron. The device is operated by hand from the top of the cyclotron.