Ion Excitation of Stable Isotopes with TAMU Trap

Carlos Marquez[1], Dan Melconian[2], and Praveen D. Shidling[2]

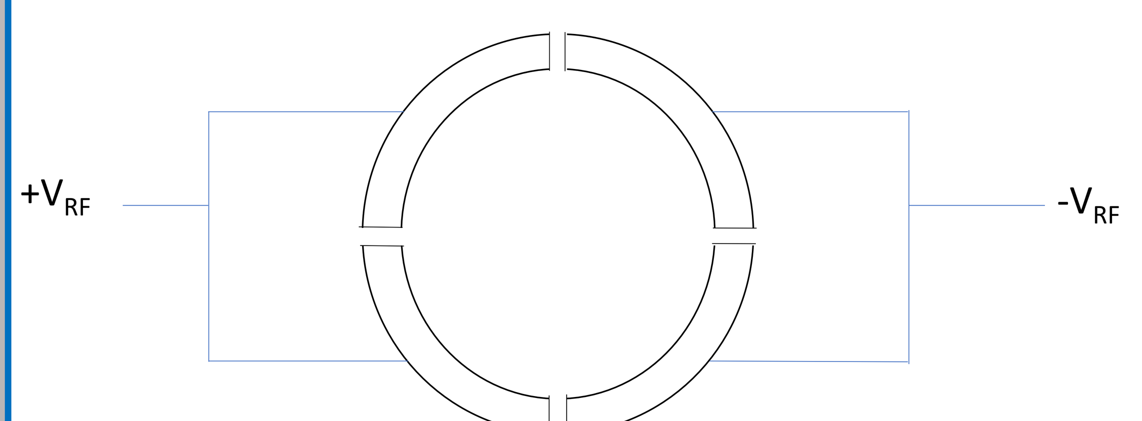
[1]San Diego State University, San Diego, CA

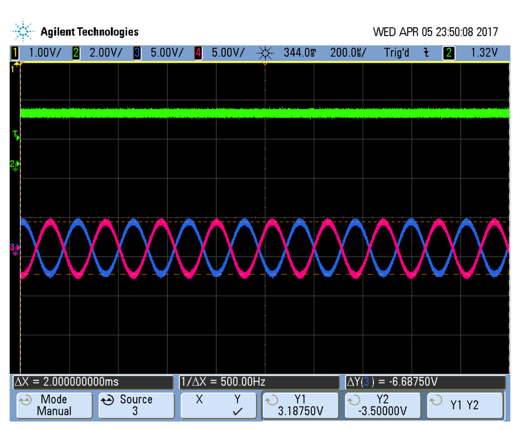
[2]Texas A&M University, College Station, TX

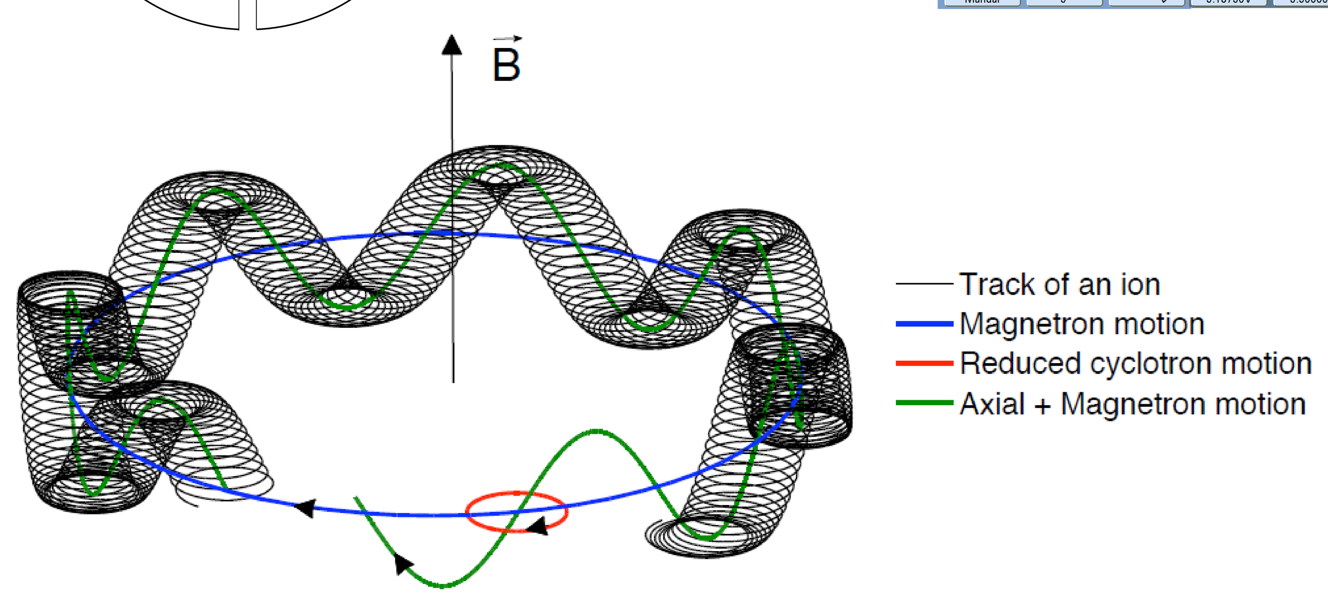
Abstract/Motivation

The Cyclotron Institute at Texas A&M University is commissioning a prototype Penning trap that is capable of executing precise mass spectroscopy. Our goal was to measure the mass of Sodium-23. In order to measure the mass of an ion, we rely on frequency excitations to gain accurate resolutions. Stable ^{23}Na ions were bunched and cooled to a definite energy so that they can be transported into the Penning trap. These ions were then confined until they were excited to a resonance frequency. Finally, we released the ions and measured how long they took to reach a detector. From analyzing the time-of-flight and frequency spectrum, we could conclude the mass of the ions being detected.

Exciting Ions







The ions are excited by alternating radiofrequency voltages on the segmented center ring electrode. At resonance, these equal-magnitude, but 180° out-of-phase, sinusoidal voltages cause the ions to rotate in different motions. Once the ions become excited, they are shot through the end of the trap to a detector.

Frequencies to Excite

Axial Frequency

$$\omega_z = \sqrt{\frac{qU_0}{md^2}}$$

Cyclotron Frequency

$$\omega_- + \omega_+ = \omega_c = \frac{q}{m} * B$$

Magnetron

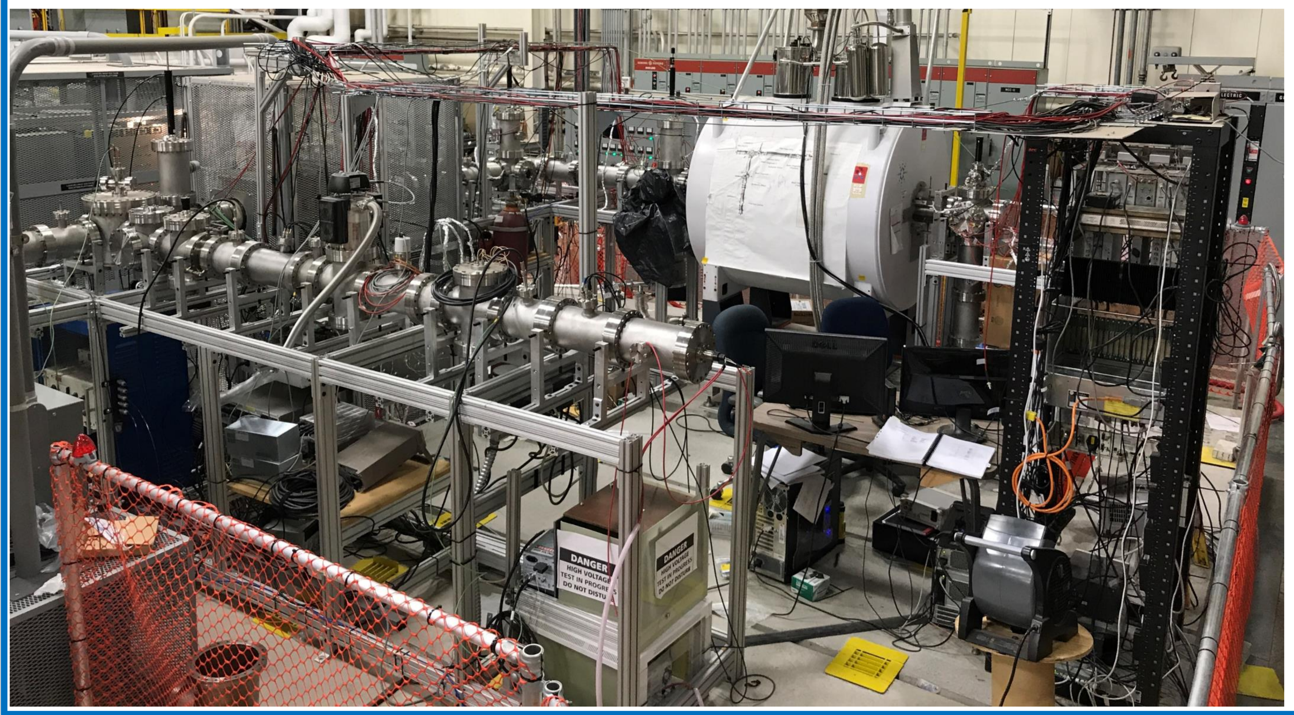
$$\omega_- = \frac{\omega_c}{2} - \frac{1}{2}\sqrt{\omega_c^2 - 2\,\omega_z^2}$$

Reduced Cyclotron

$$\omega_+ = \frac{\omega_c}{2} + \frac{1}{2}\sqrt{\omega_c^2 - 2\,\omega_z^2}$$

The Penning Trap

A steerer and lens have been assembled and implemented into the beamline. Also, a secondary source has been installed to allow for mass measurements after a calibration of the magnetic field has been made. Alignment of the beamline has been checked via an optical transit calibration.

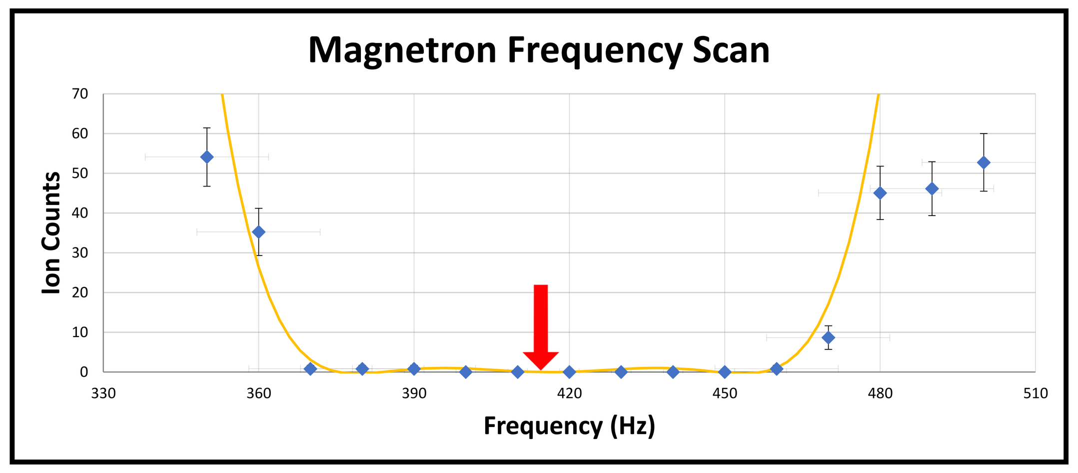


The beamline is a complex set of deflectors, lenses, and steerers in order to control the path the ion takes while traveling to the Penning trap.

Gold-plated Penning Trap with a 6mm extraction point

Data Analysis

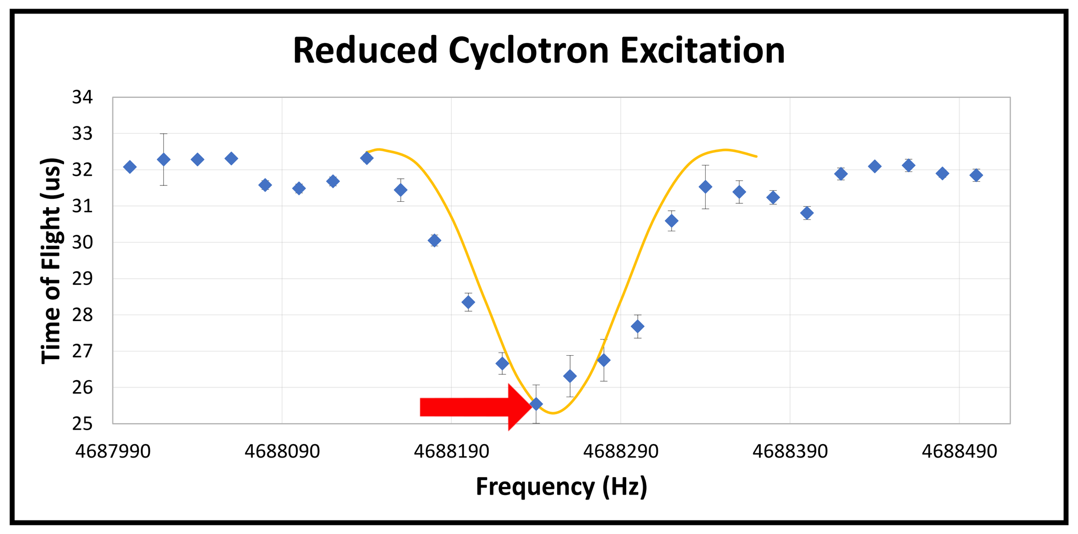
The magnetron frequency scan serves as a first test to confirm that ions are being excited. In order to detect ω_-, we observe a point where mostly all ions have been excited to larger orbits than the diameter of the exit nozzle. In other words, no ions have been detected.



Magnetron Frequency:

416 (9) Hz

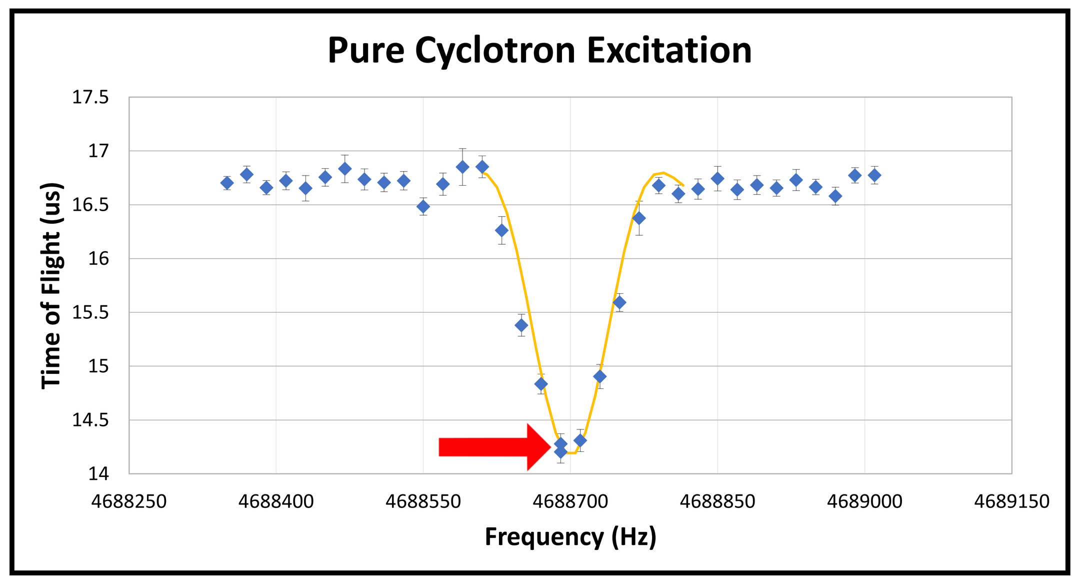
We observe ω_+ by pinpointing the trough of the time-of-flight vs frequency spectra. At resonance, the ions gain more radial energy which is then transformed to axial energy and therefore leads to a shorter time-of-flight.



Reduced Cyclotron Frequency:

4.688250 (7) MHz

Summing the frequencies from ω_- and ω_+ will result in a close approximation of where we should observe the cyclotron motion because ω_c is coupled with the previous two motions. Again, the pure cyclotron motion at the resonance results in a shorter time-of-flight. The mass for the sodium ion can then be determined.



Reduced Cyclotron Frequency:

4.688700 (10) MHz

Conclusion

By knowing the pure cyclotron frequency, we can directly calculate the mass for our ion sample. Having known the charge of the ion (e) and magnetic field strength (7T), we calculate our ^{23}Na mass to be 21.41432 (12) GeV which agrees within 0.00001% of the accepted value.