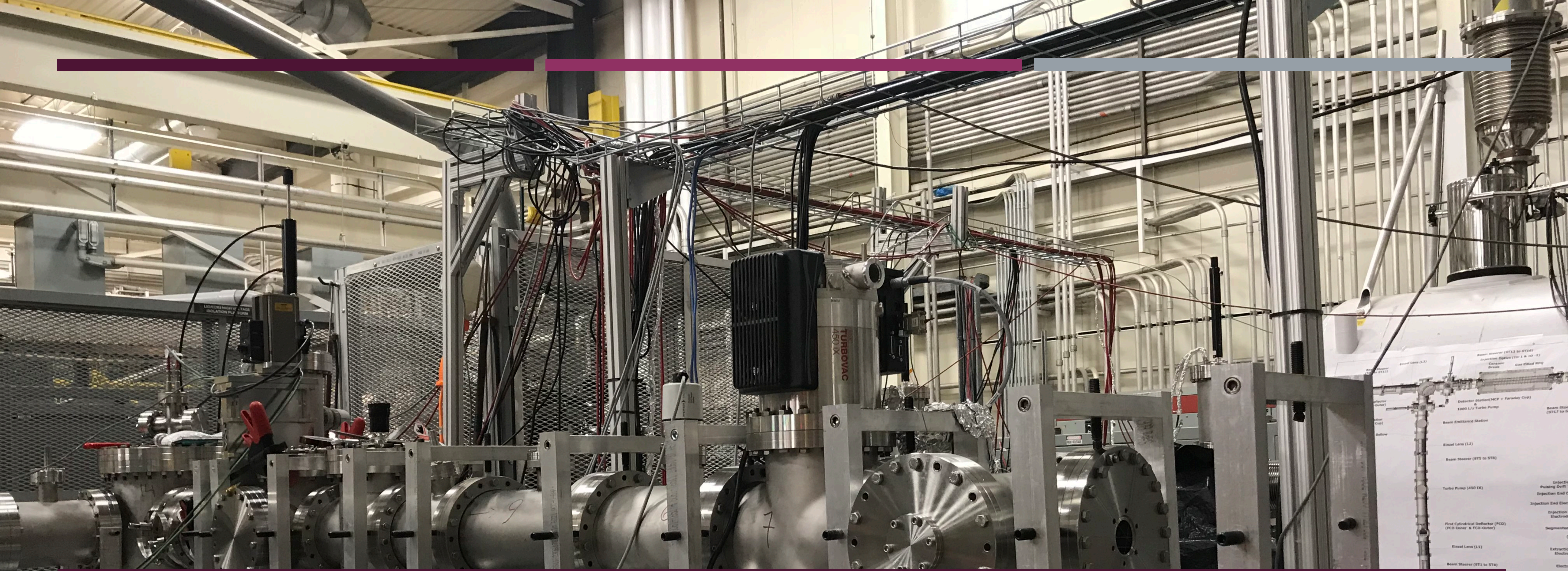



# UPGRADES TO TAMUTRAP FACILITY AND MASS MEASUREMENTS OF $^{23}$NA

GUADALUPE DURAN, BRANDEIS UNIVERSITY, WALTHAM, MA

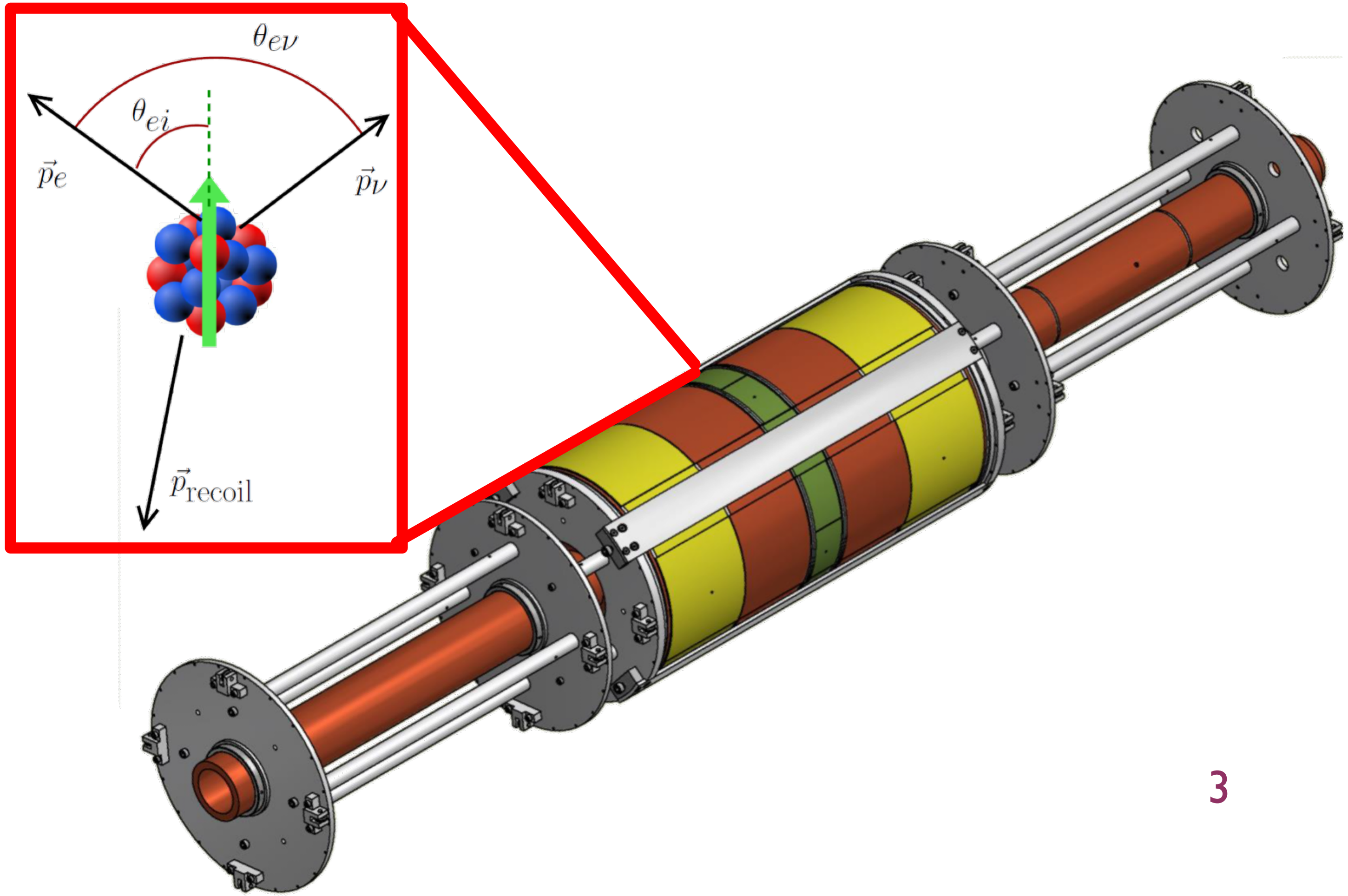
ADVISOR: DR. DAN MELCONIAN, TEXAS A&M UNIVERSITY, COLLEGE STATION, TX

# OUTLINE

- Background
- Spherical Deflector & Beam Steerer
- Beamline Alignment
- The Penning Trap
- Mass Measurements
- Conclusions and Future Work
- Acknowledgments
- References

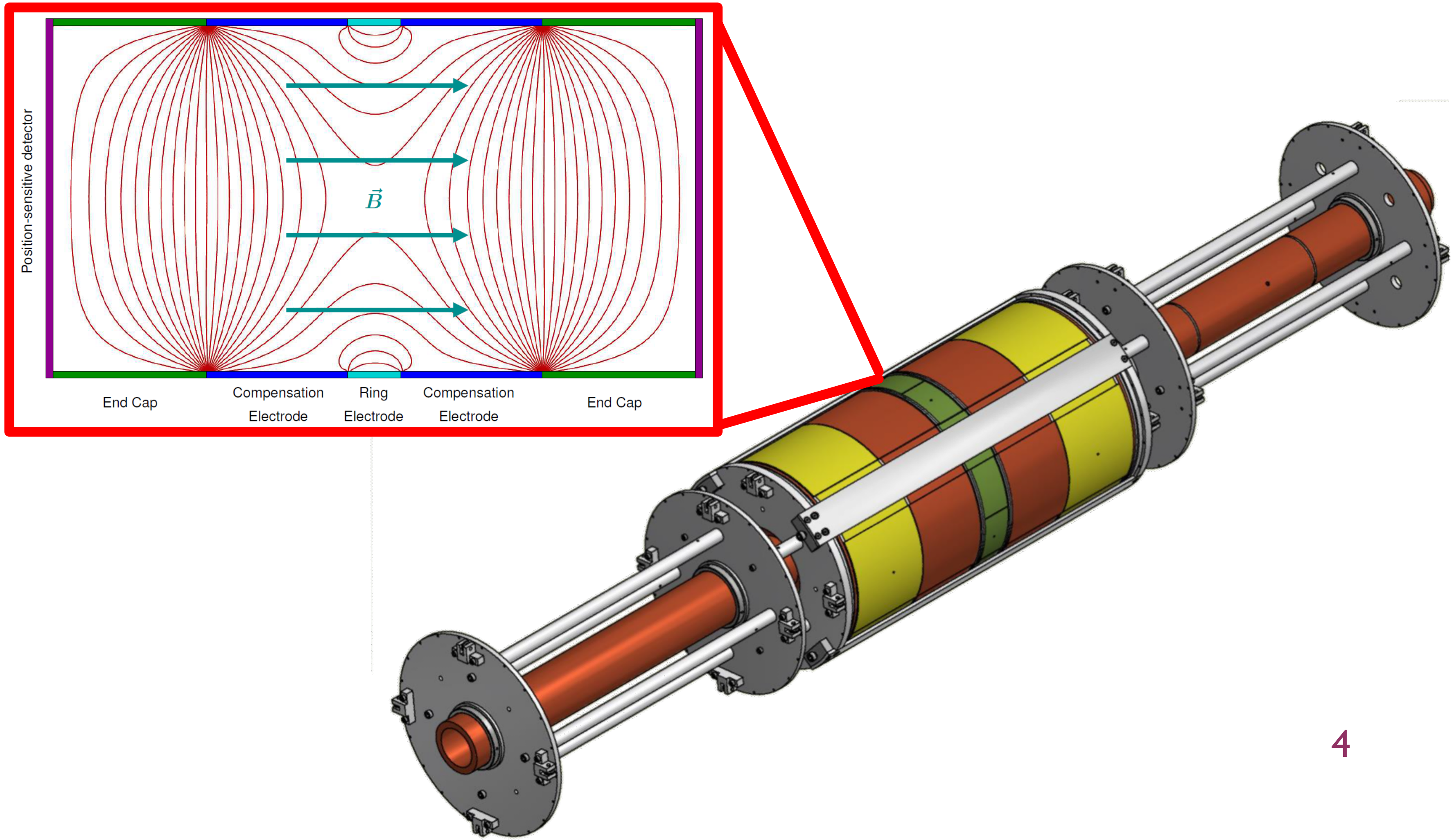
# BACKGROUND: BETA DECAY

- The Standard Model predicts that the β-ν angular correlation parameter, $a_{\beta\nu} = 1$
- However, if anything other than a $W^+$ boson is exchanged, $a_{\beta\nu} < 1$. This will be indications of physics beyond the Standard Model.
- TAMUTRAP will study $a_{\beta\nu}$ for isospin T=2, 0+→0+ superallowed beta delayed proton emitters such as 32Ar

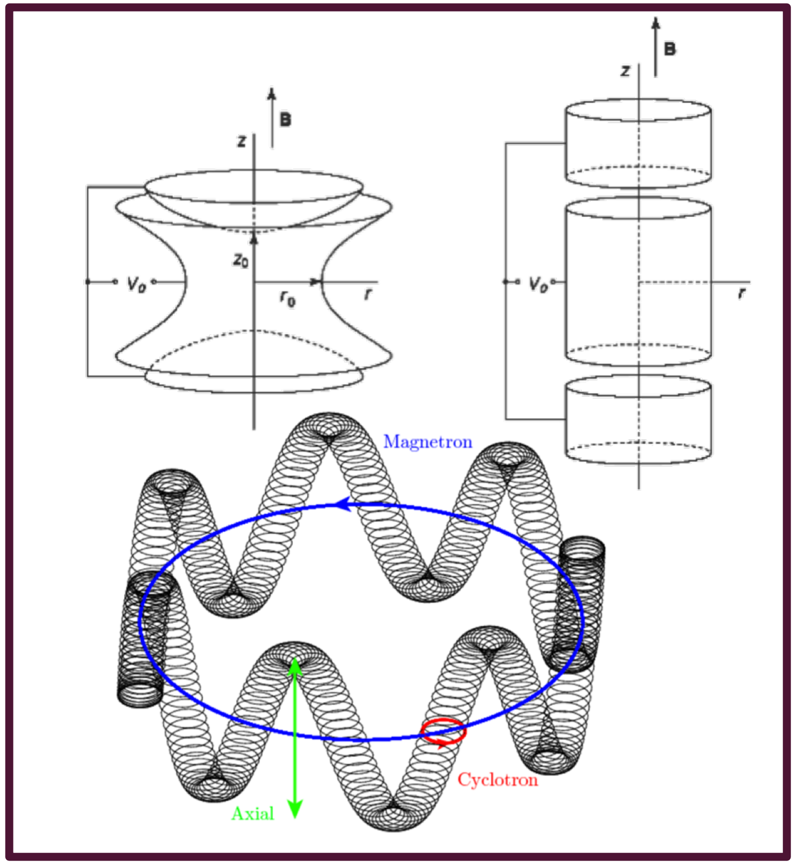


# BACKGROUND: PENNING TRAP

- Ions in a Penning trap are confined to a small area using a static electric field  and a linear magnetic field
- TAMUTRAP uses a 7T magnet



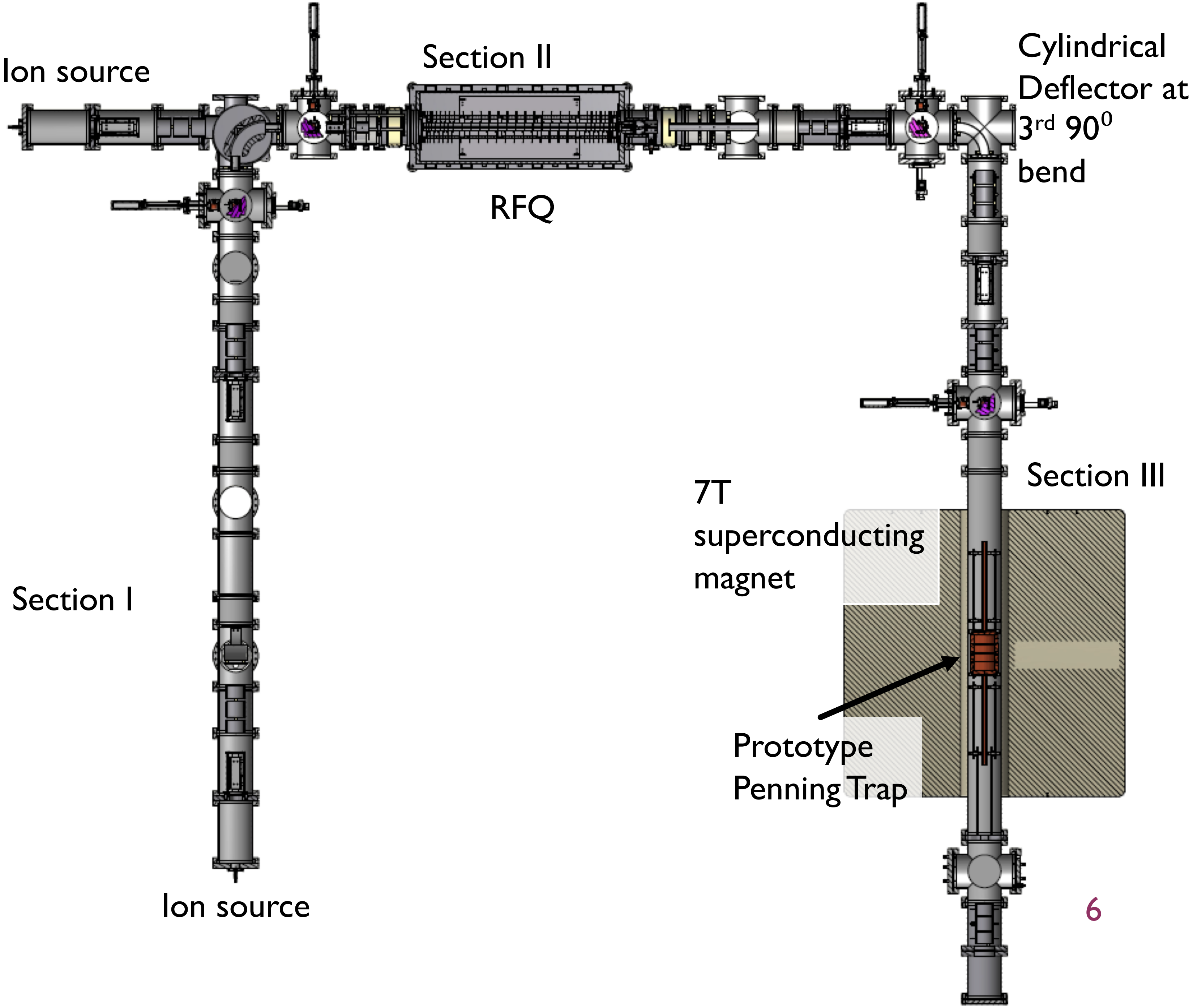
# BACKGROUND: MOTION IN A PENNING TRAP




- Trapped ions undergo a combination of three eigen motions, axial($\omega_z$), magnetron($\omega_-$) and reduced cyclotron($\omega_+$ ).
- Since $\omega_+ + \omega_- = \omega_c$, we can couple the frequencies by applying an oscillating field.
- The cyclotron frequency can then be used to find the mass of the particle.

$$\omega_c = \frac{QB_0}{M}$$

# TAMUTRAP

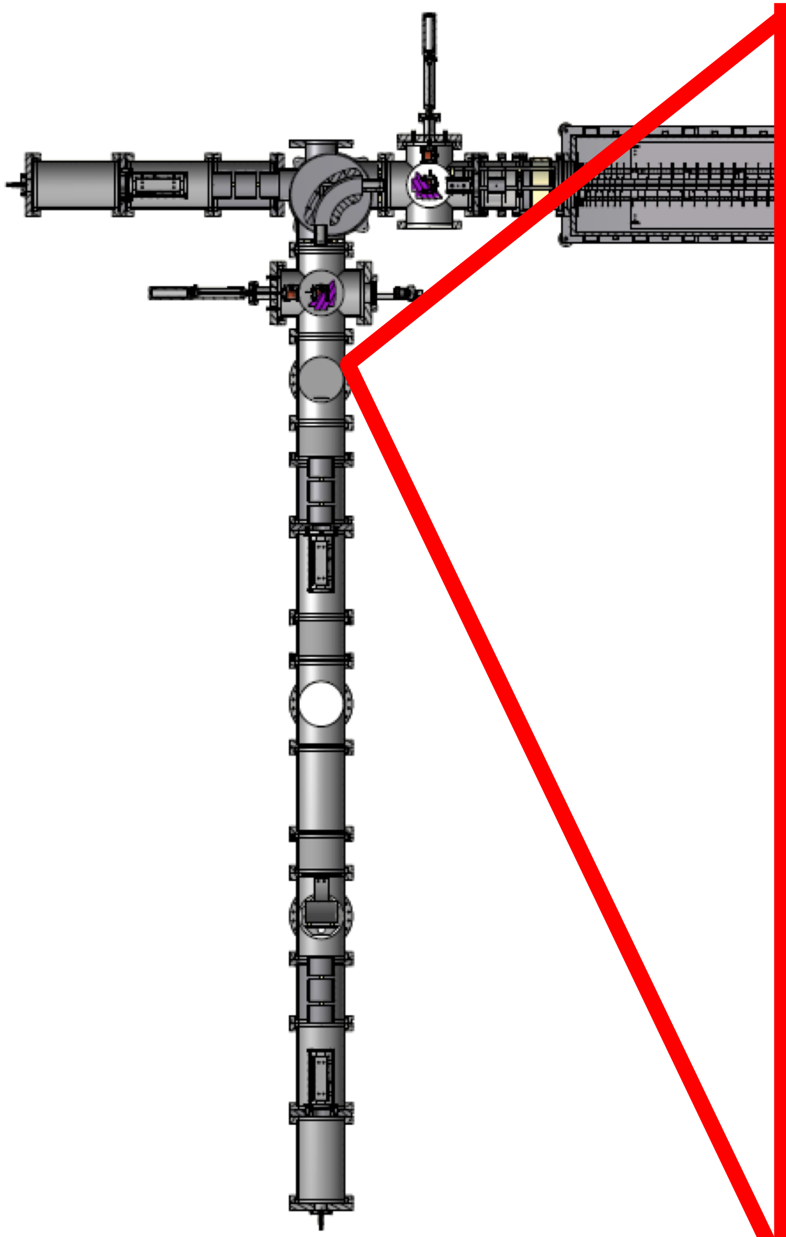


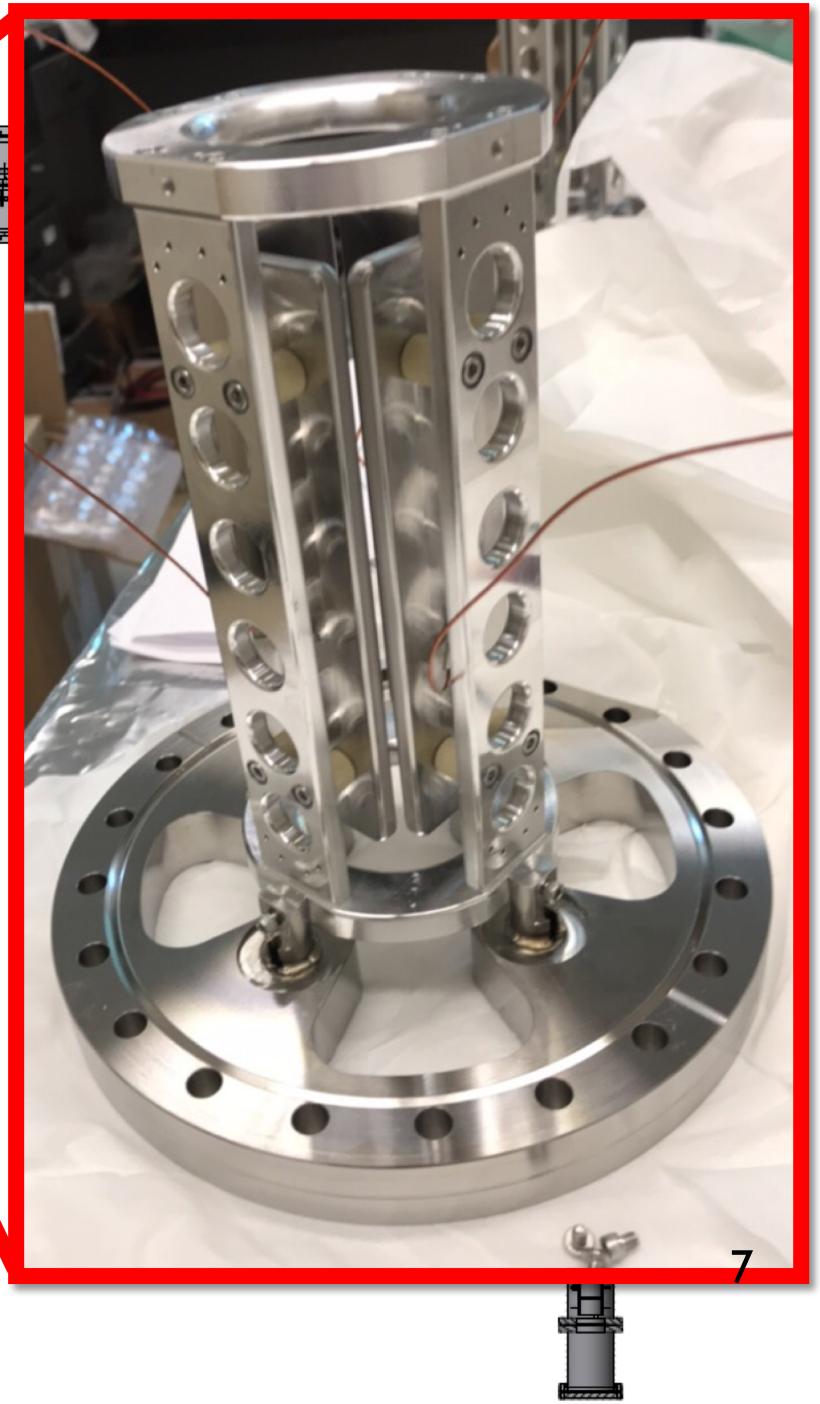
Ion source
Section II
Cylindrical Deflector at 3rd 90⁰ bend
RFQ
Section III
7T superconducting magnet
Section I
Prototype Penning Trap
Ion source

# TAMUTRAP

## Beam Steerer

- Beam Steerer installed with a gate valve into section I of the beamline

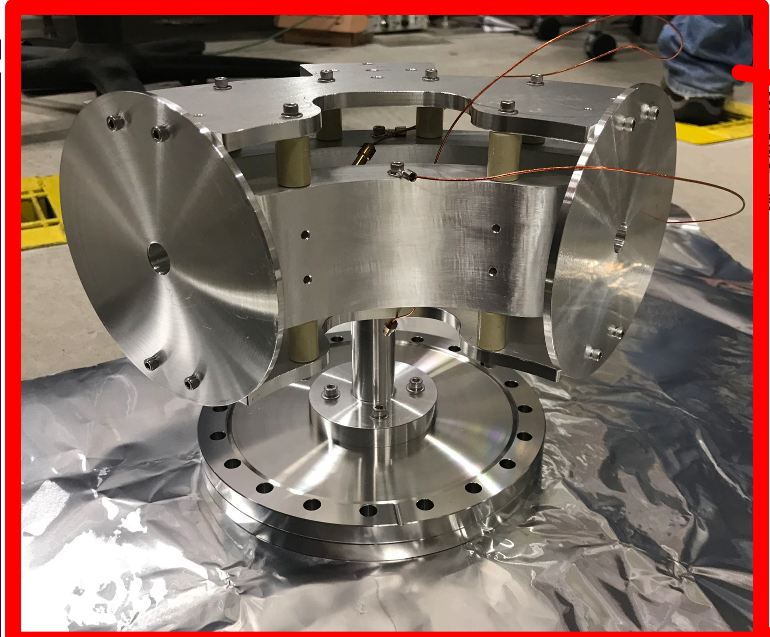


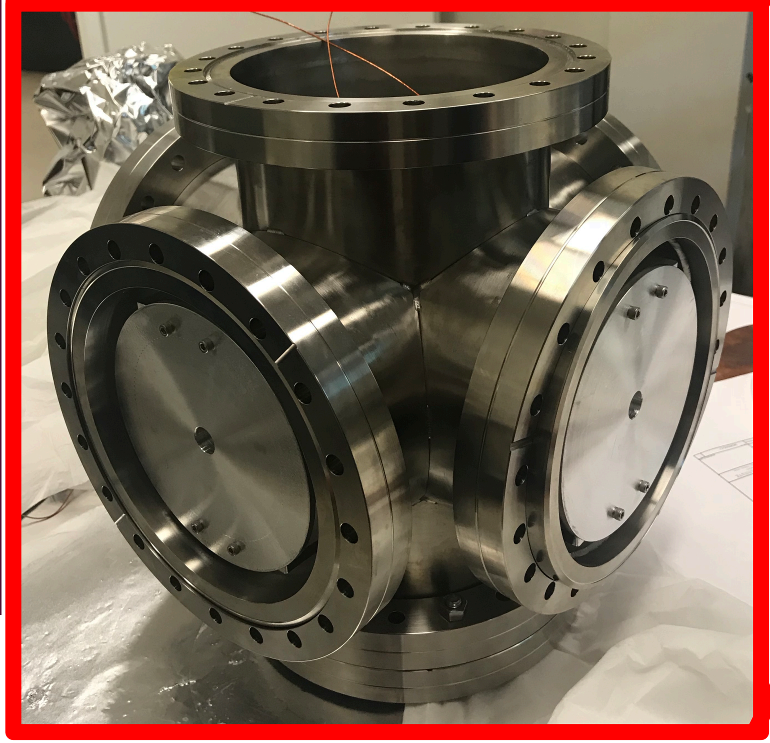


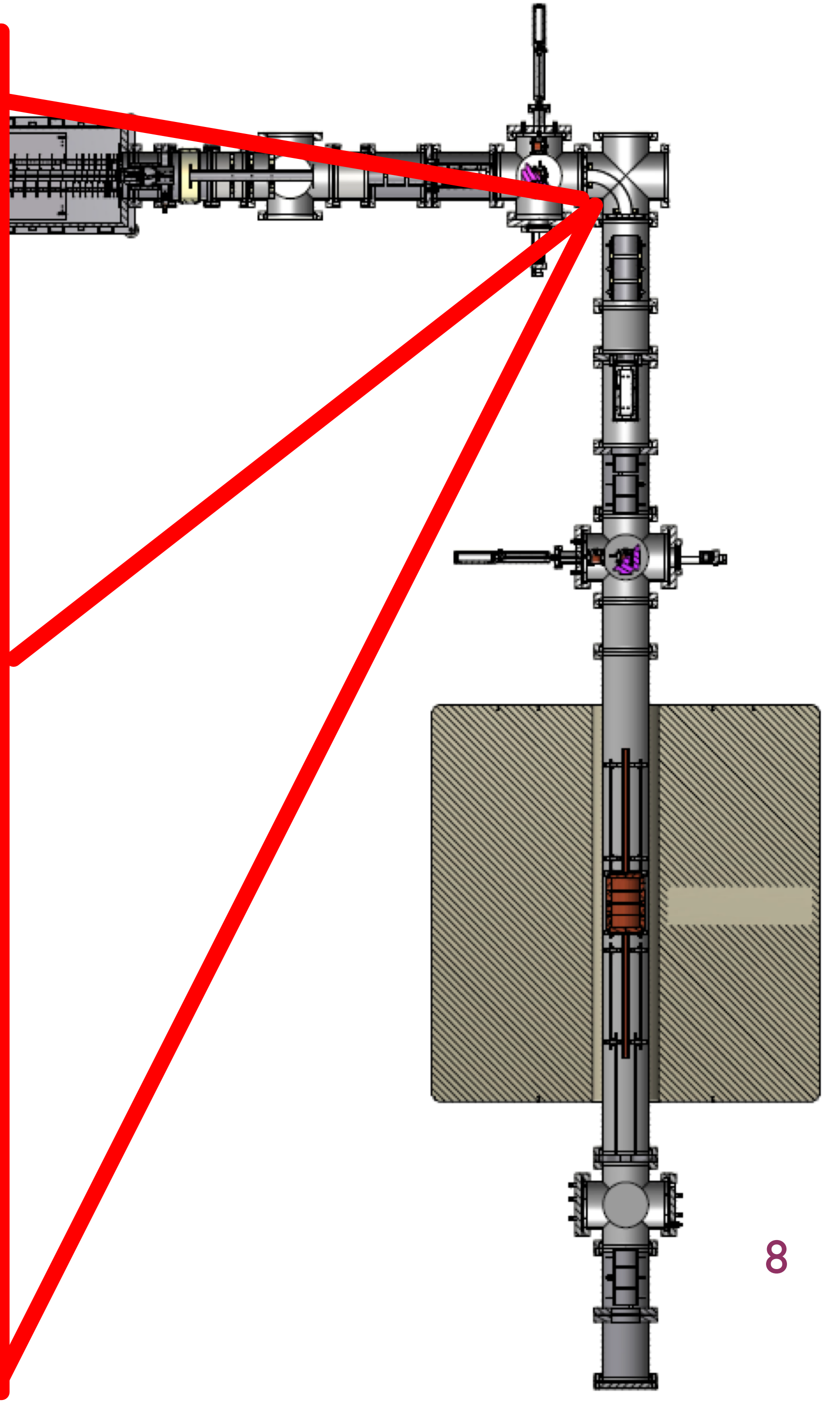
# TAMUTRAP

## Spherical Deflector

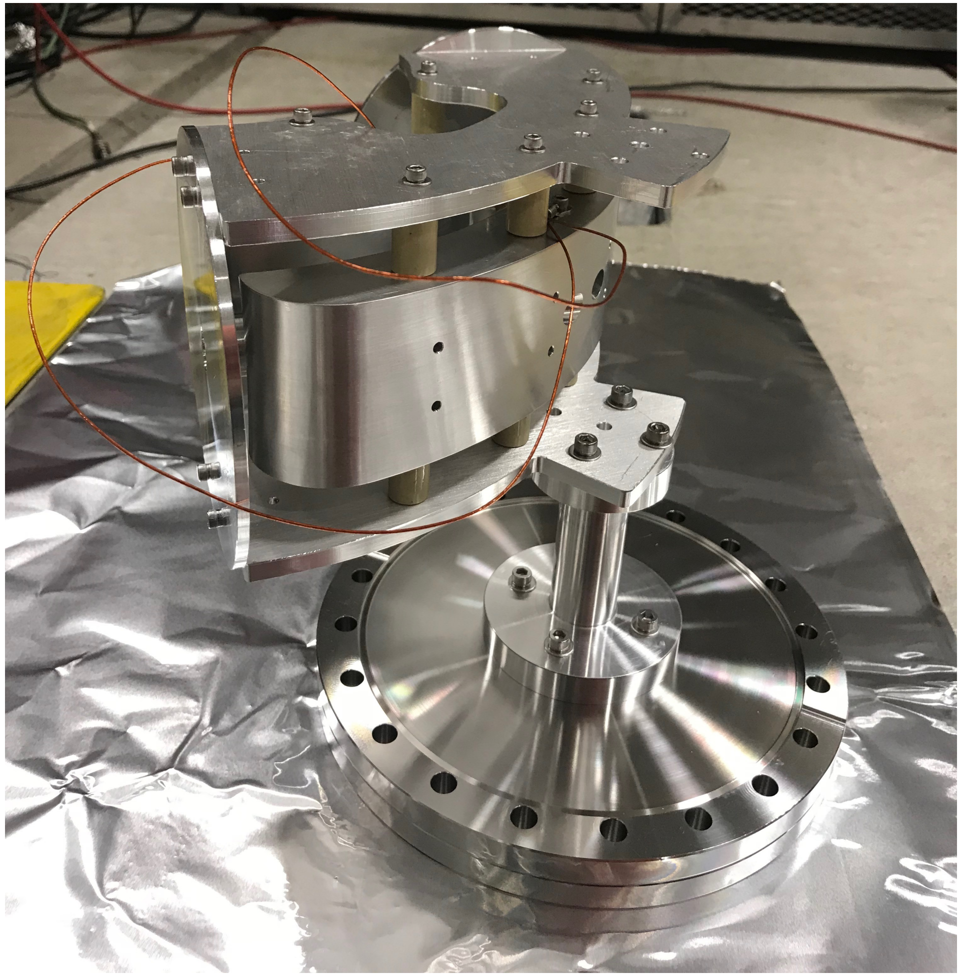
- Replaced cylindrical deflector at 3rd 90 degree turn of the beamline

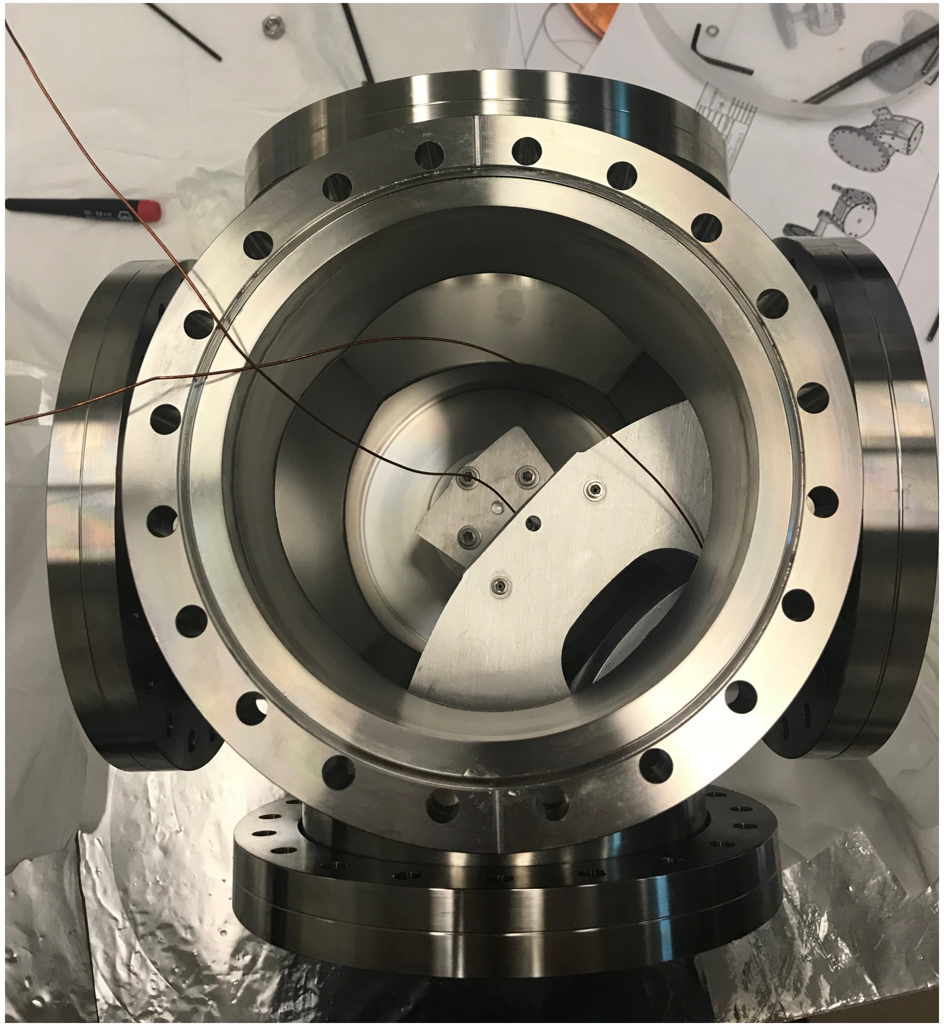






# SPHERICAL DEFLECTOR



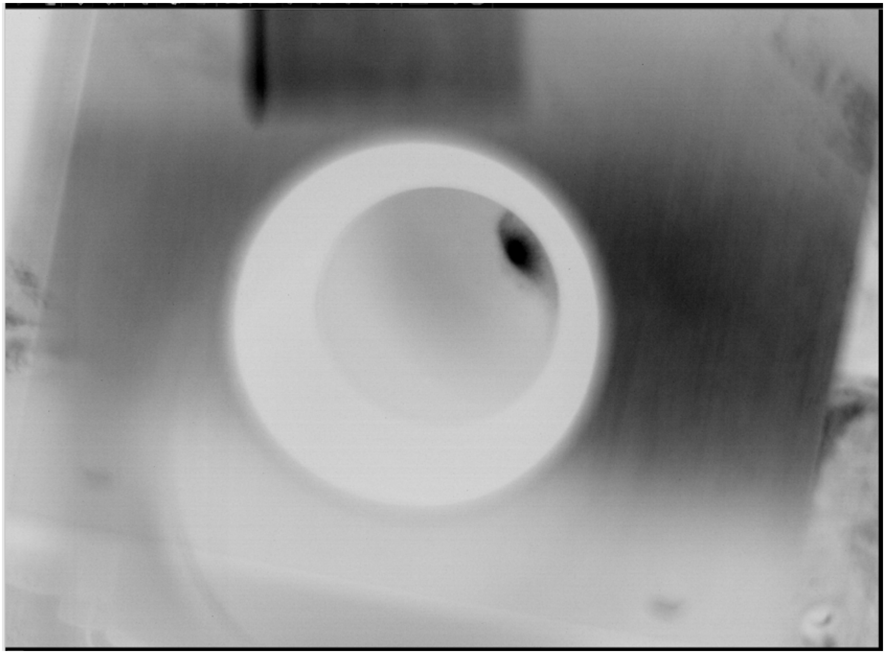


# TESTING THE SPHERICAL DEFLECTOR: BEAM SPOTS

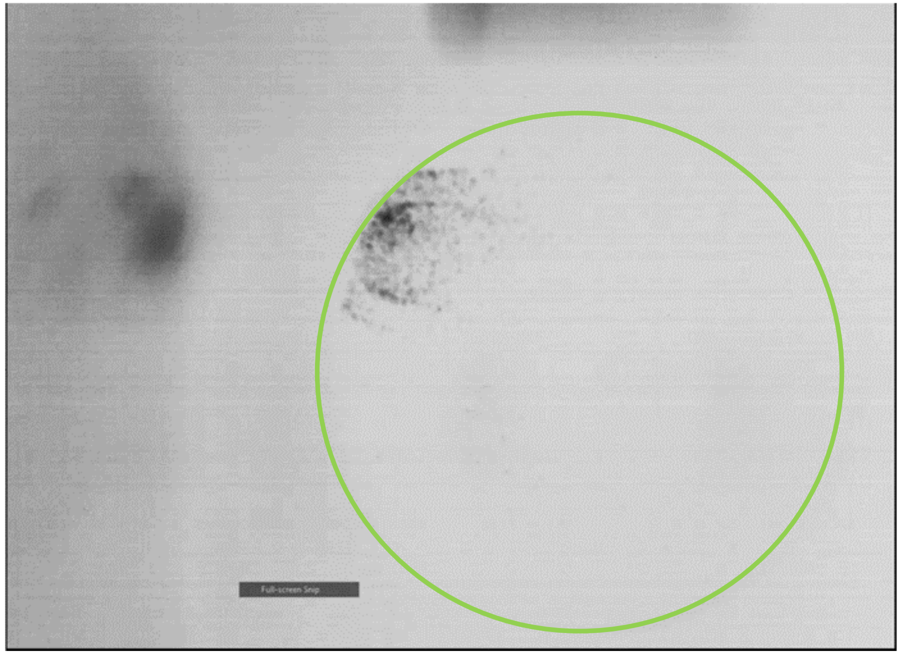
## Cylindrical Deflector

- To test the spherical deflector, compared the beam spots from before and after its installment

Before Deflector



After Deflector



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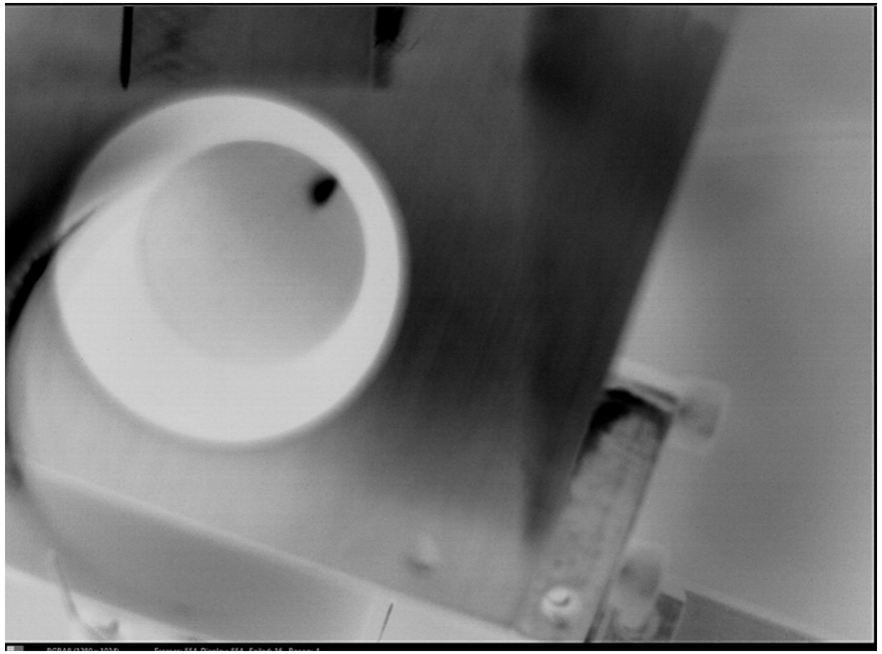
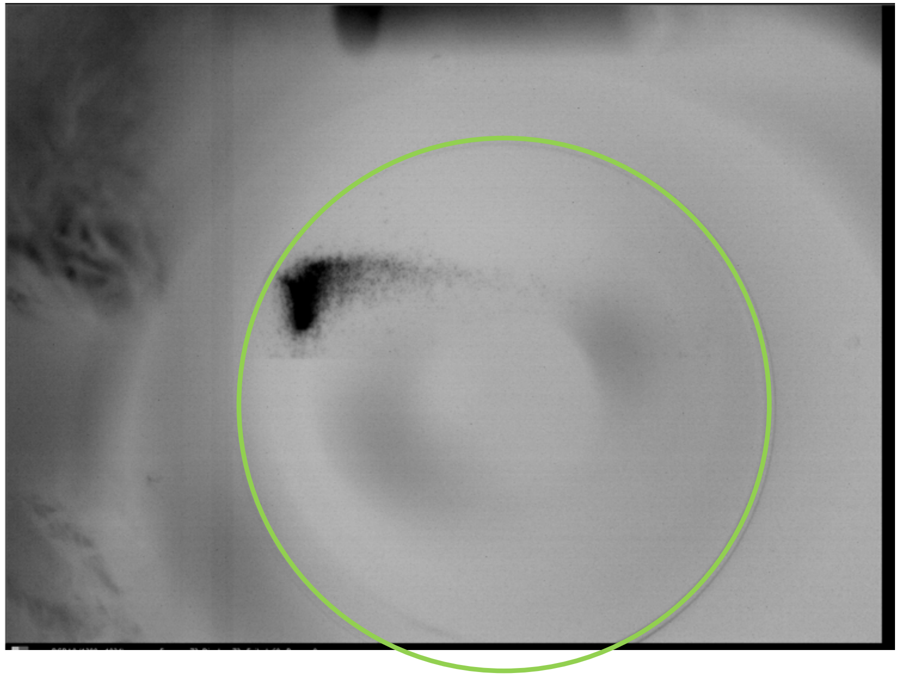
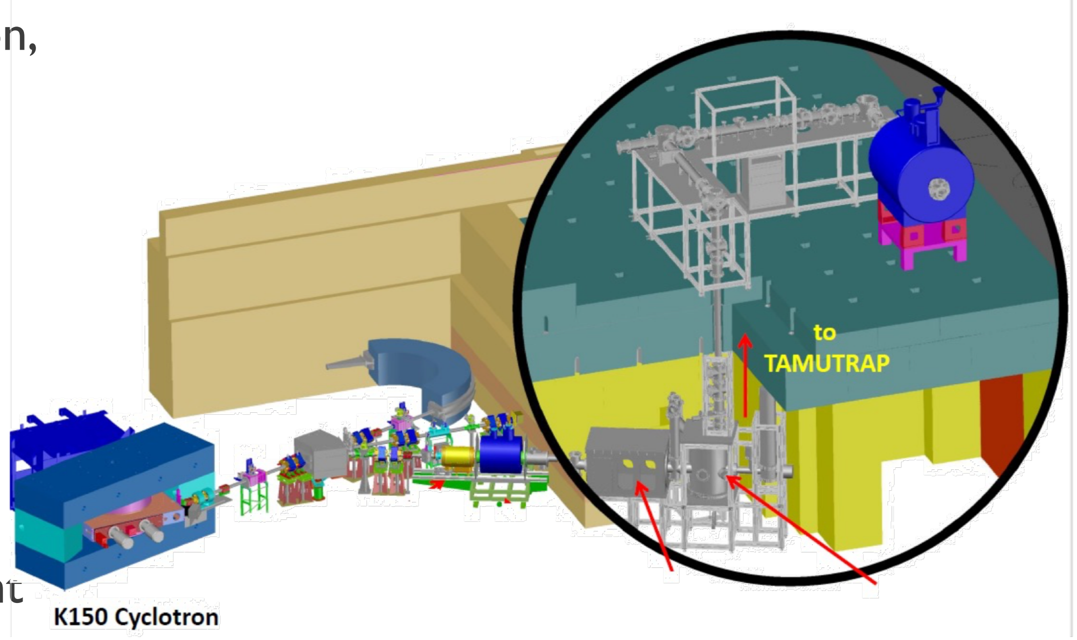


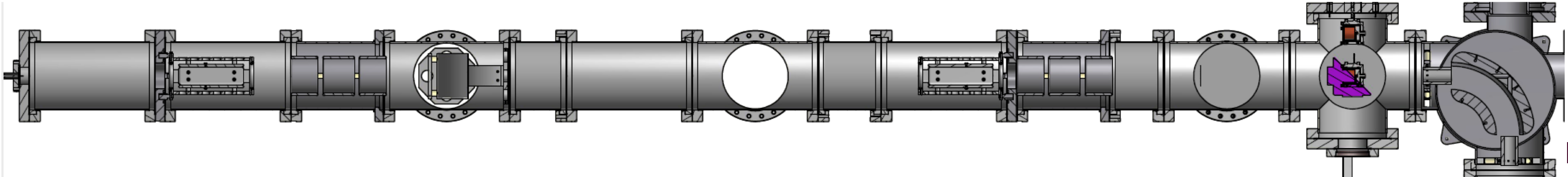
After Deflector



# BEAMLINE ALIGNMENT

- In order to receive radioactive beam from K150 cyclotron, must realign section I of the beamline with T-REX
- Dis-assembled the beamline
- Cleaned each component
- Aligned the optical transit
- Installed new beam supports
- Re-installed components → coupled new components
- 1in off between bellow and 1$^{st}$ spherical deflector → cant couple them and keep a vacuum
- Will realign both section I and II of the beamline in the fall



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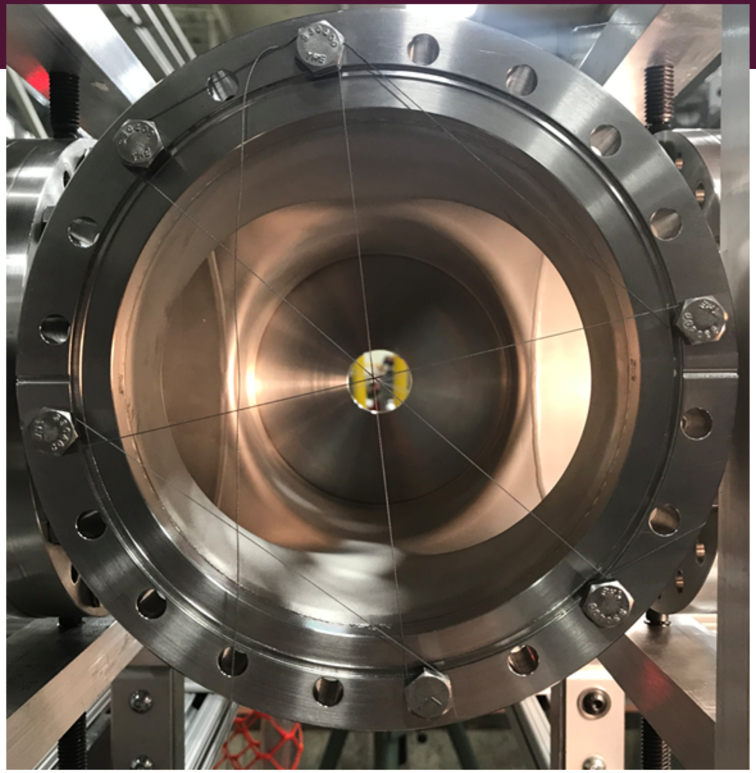

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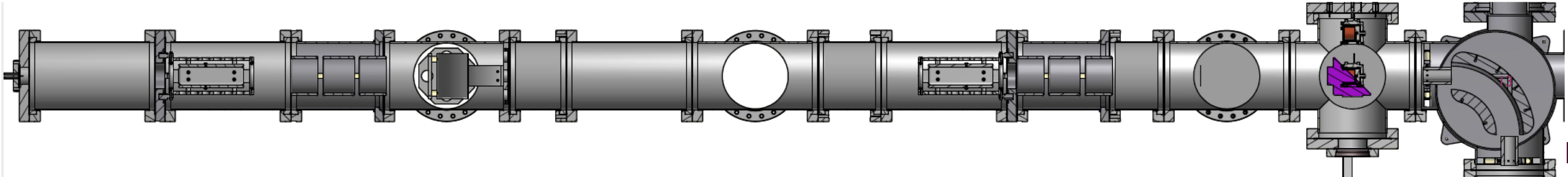

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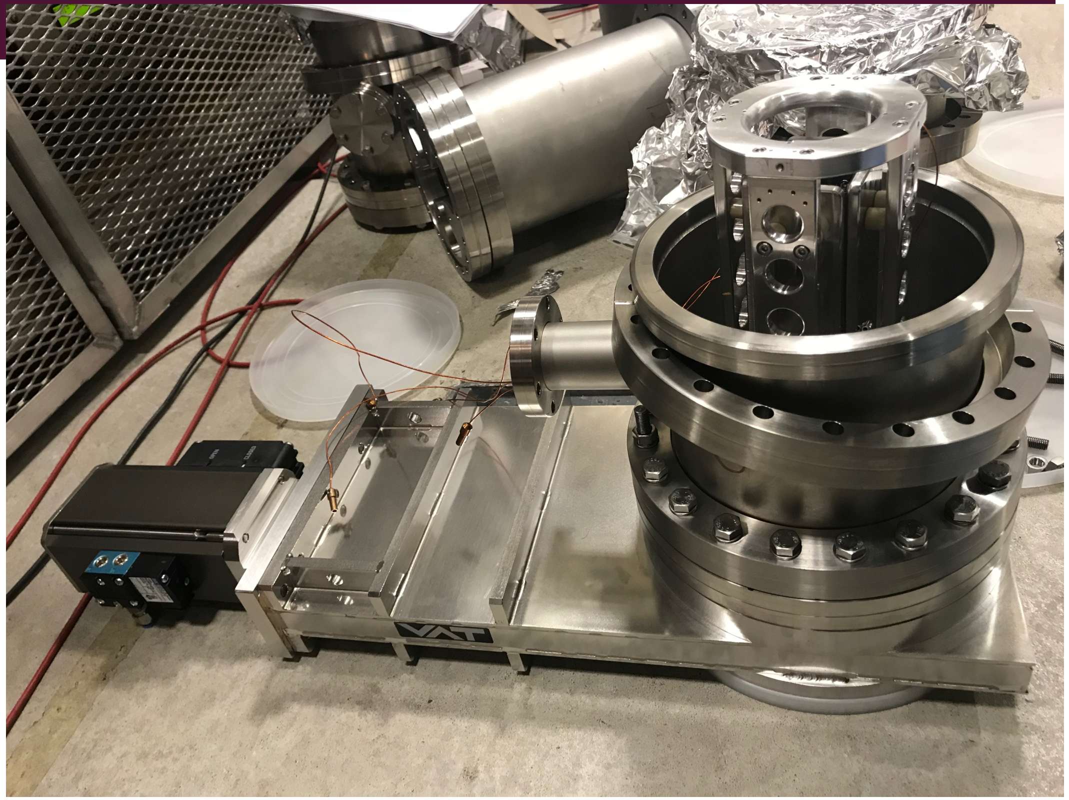


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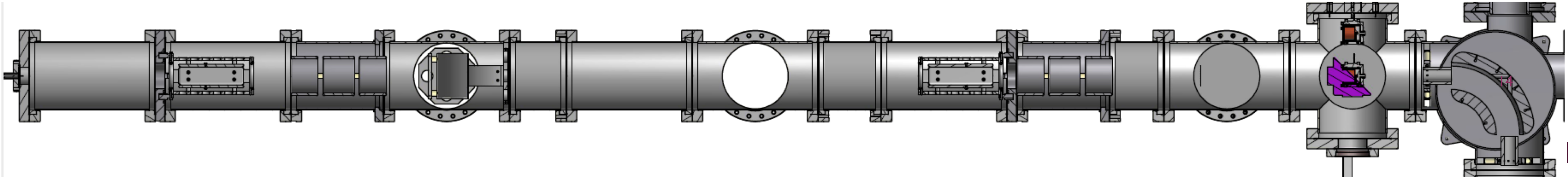

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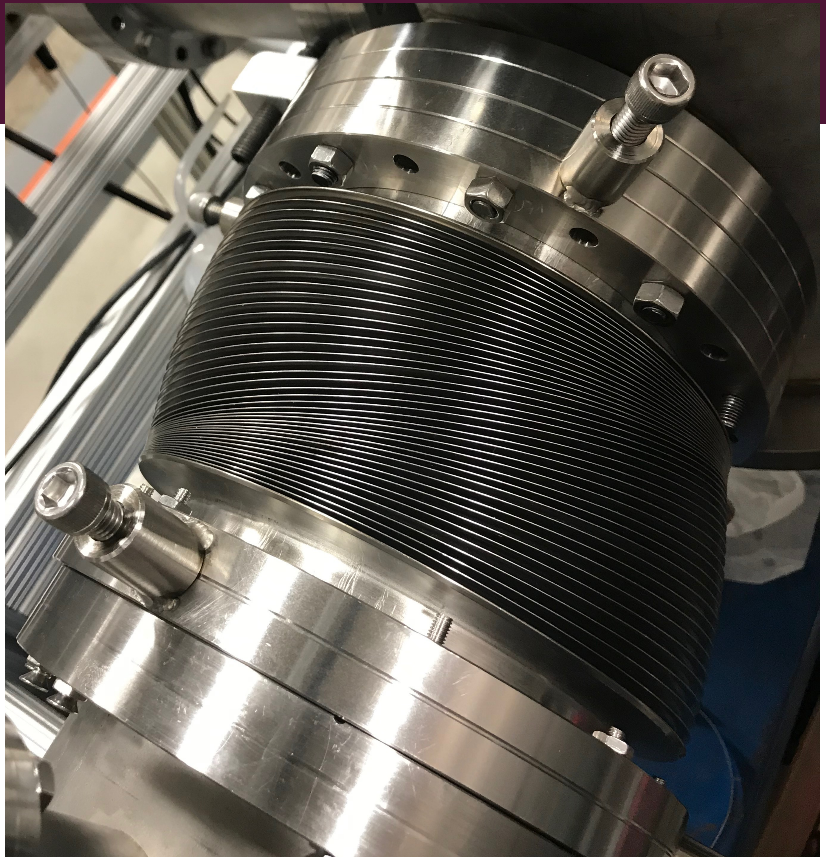

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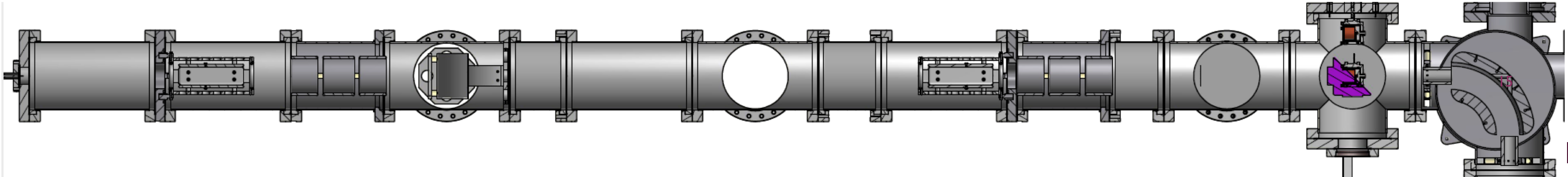
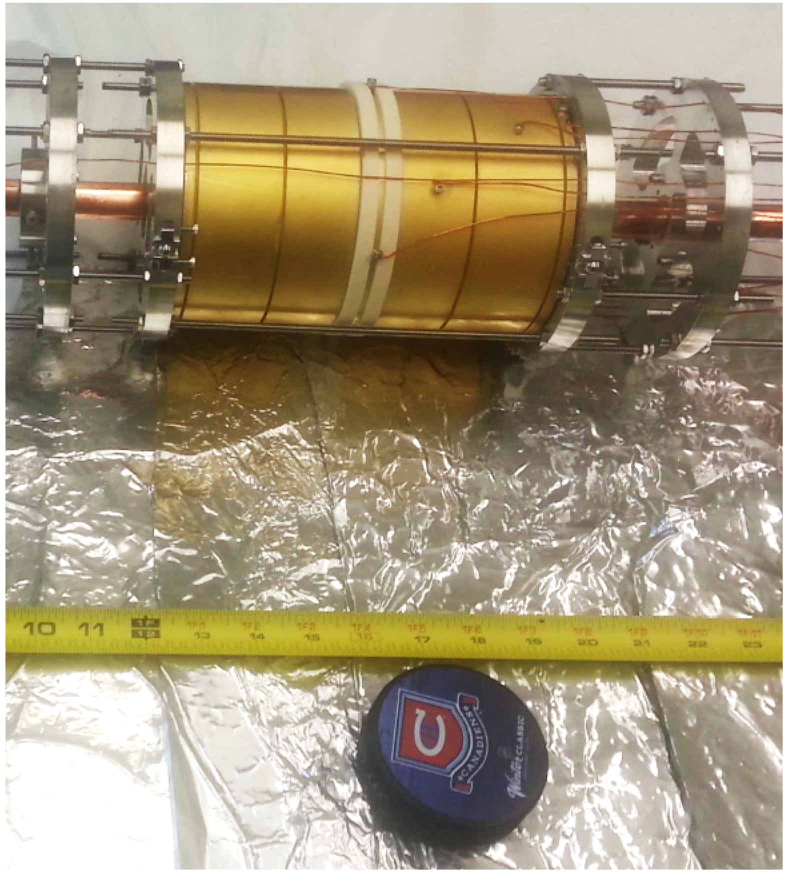


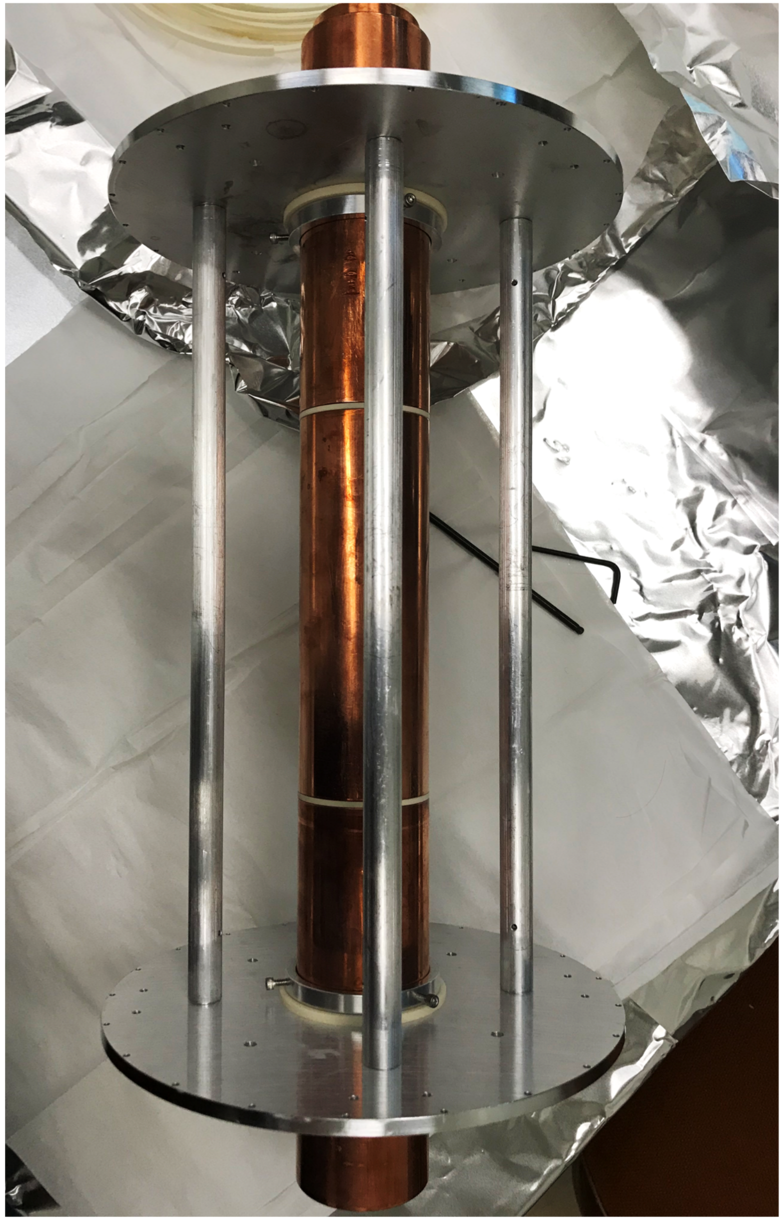
# THE PENNING TRAP

- New Trap Dimensions:
  - Inner radius = 90 mm
  - Length = 335 mm
  - $l/r_0$ = 3.72, much smaller than other traps such as ISOLTRAP, where $l/r_0$ = 11.75
- Large inner radi will allow us to study the decay of ions whose protons have even a large Larmor radi, up to 42.7mm in the case of $^{20}Mg$



Prototype Penning Trap

Full Size Penning Trap



# THE PENNING TRAP

Extraction Tube

- New design for the extraction tube has three segmented cooper tubes instead of only one solid tube
- Will allow us to re-accelerate particles as they leave the penning trap → hopefully lead to a decrease in beam loss.

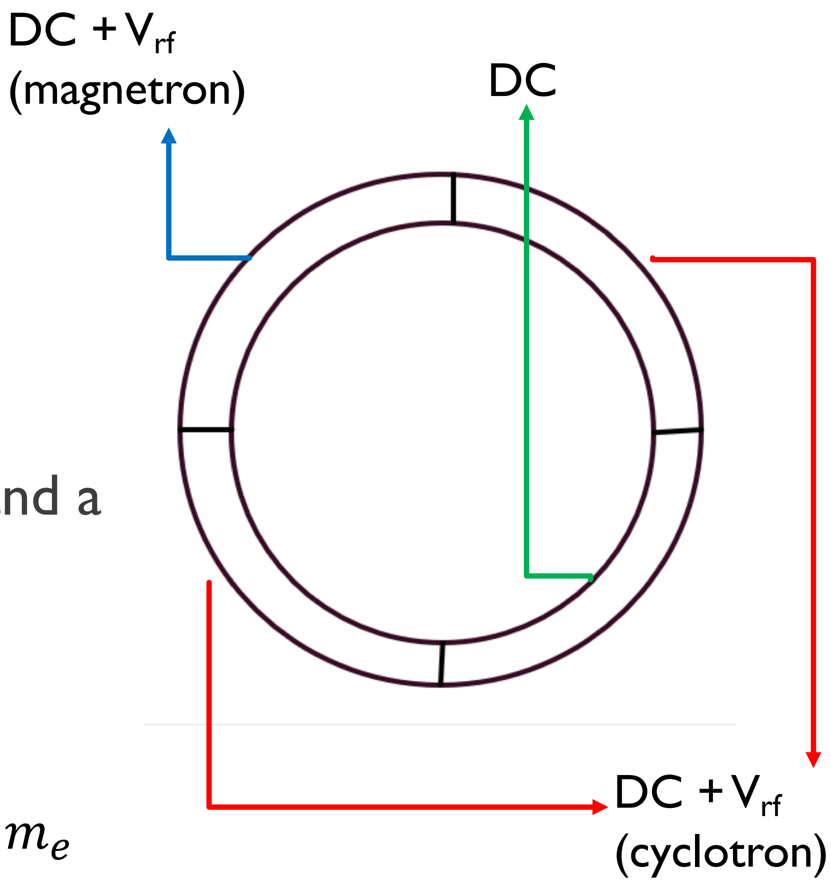
# MASS MEASUREMENTS

Time-of-flight cyclotron resonance technique

- Apply an RF at $\omega_-$, → increase in magnetron radius
- Apply excitation near $\omega_c$ → increase in radial energy and coupling of radial motions
- Ions are ejected along magnetic field lines → radial energy is converted to axial energy
- When rf is at resonance, ions will have greater axial energy and a shorter time of flight
- Run scans for two ions, and use one as a reference mass to negate need to know the magnetic field

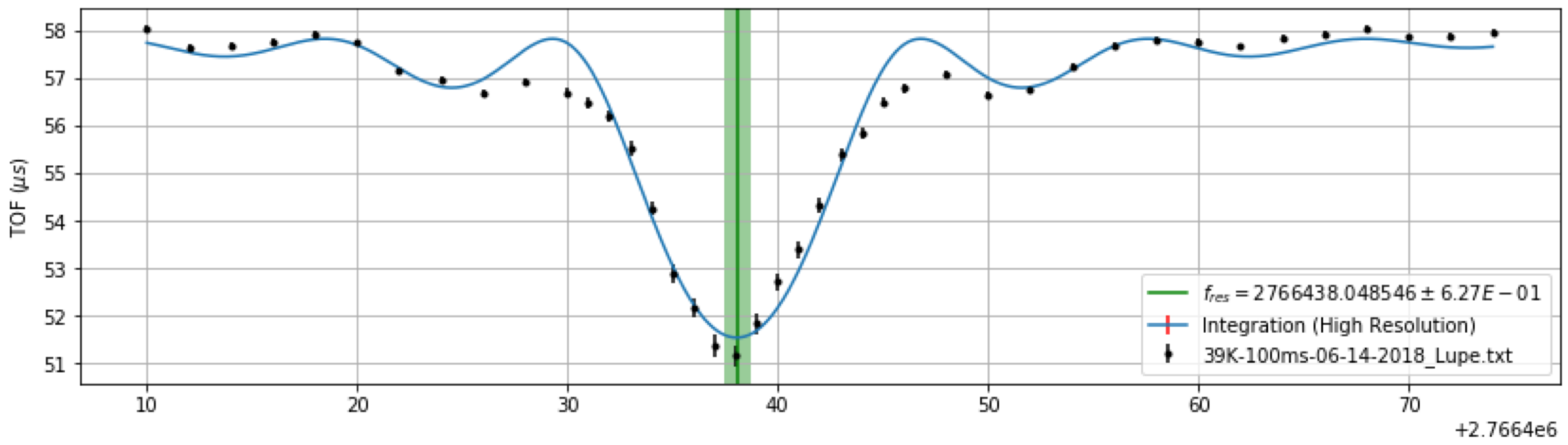
$$\omega_c = \frac{QB_0}{M}$$

$$m_{23Na} = \frac{f_{39K}}{f_{23Na}}(m_{39K} - m_e) + m_e$$

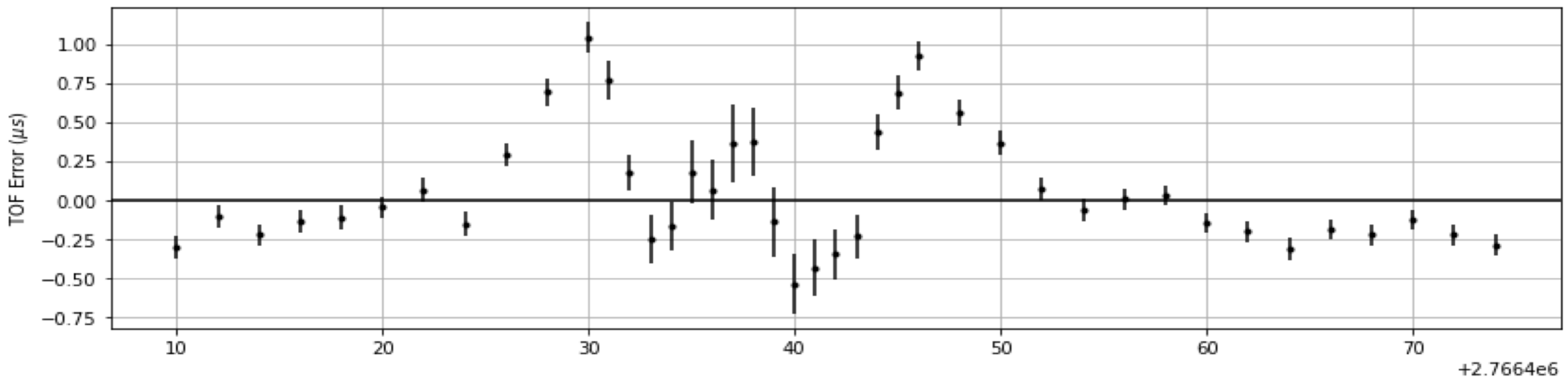


# MASS MEASUREMENTS

Resonance Frequency for 39K




Residual for 39K fit

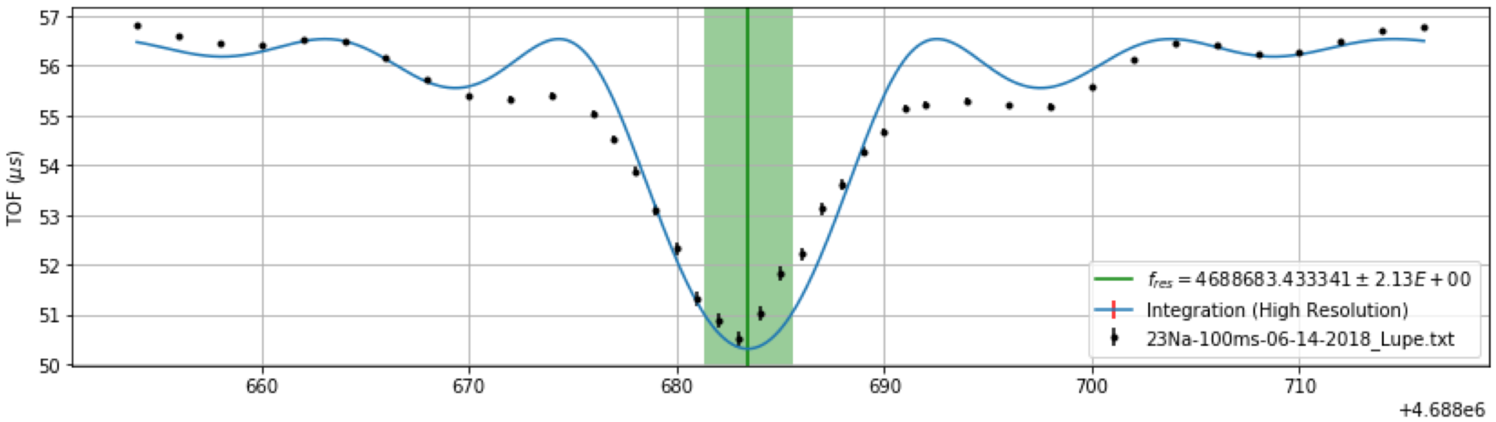



39 K

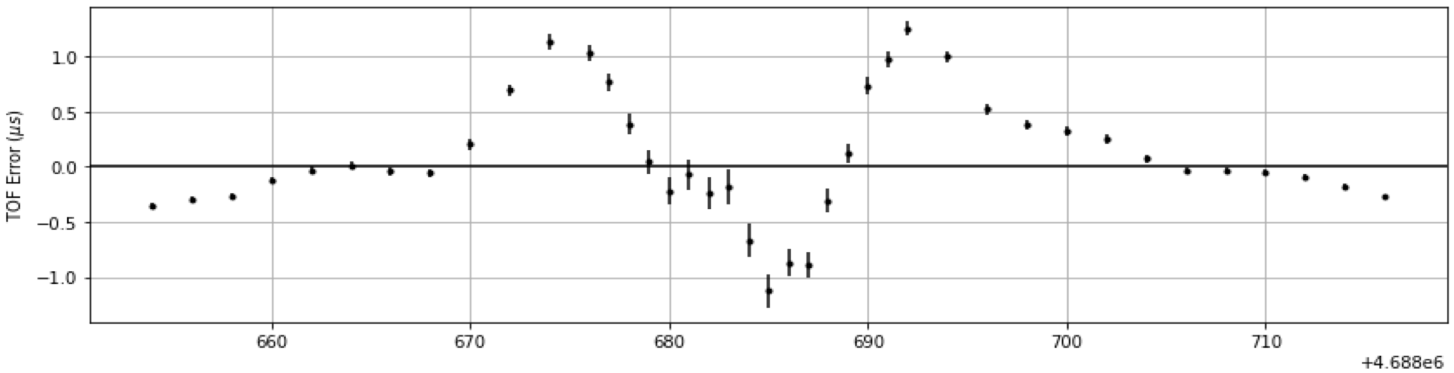
- Potassium was used as our reference mass
- Resonance frequency: 2766438.05(63) Hz
- Trapped Ion Energy: 115 eV
- Excitation time: 100ms

# MASS MEASUREMENTS

Resonance Frequency for 23Na




Residual for 23Na fit

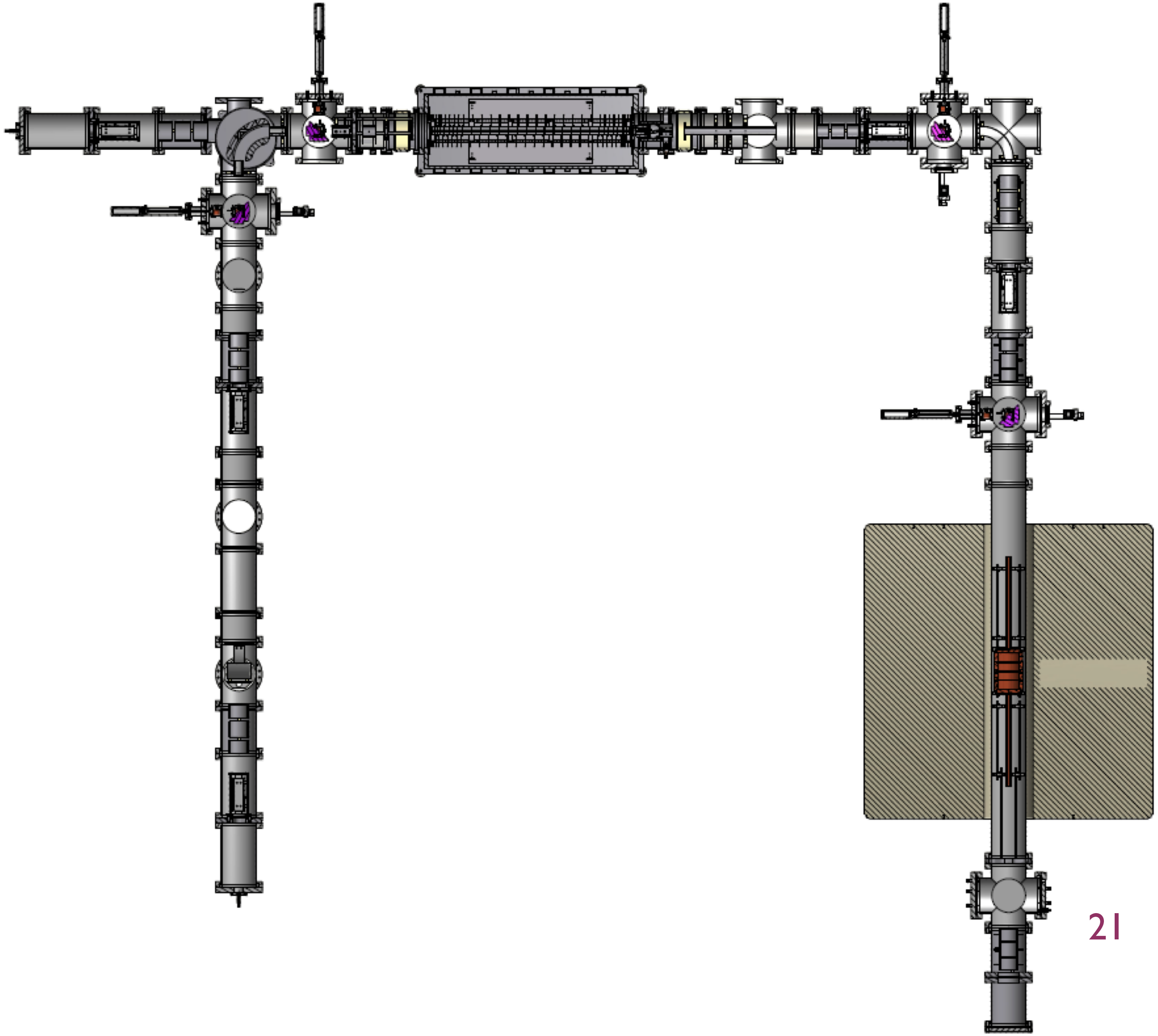



23 Na

- 23 Sodium is our subject ion
- Resonance frequency: 4688683.43(213) Hz
- Trapped Ion energy: 115eV
- Excitation time: 100ms

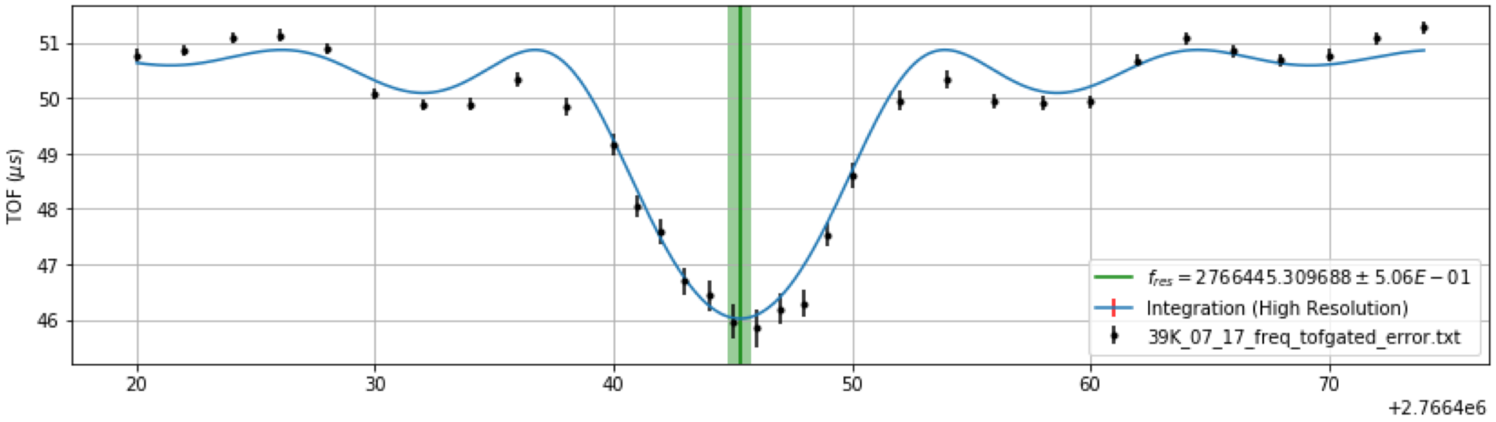
- Calculated mass: 22.98976593 (18)u
- Agrees with literature value to a precision of 1.5x$10^{-7}$

# TAMUTRAP

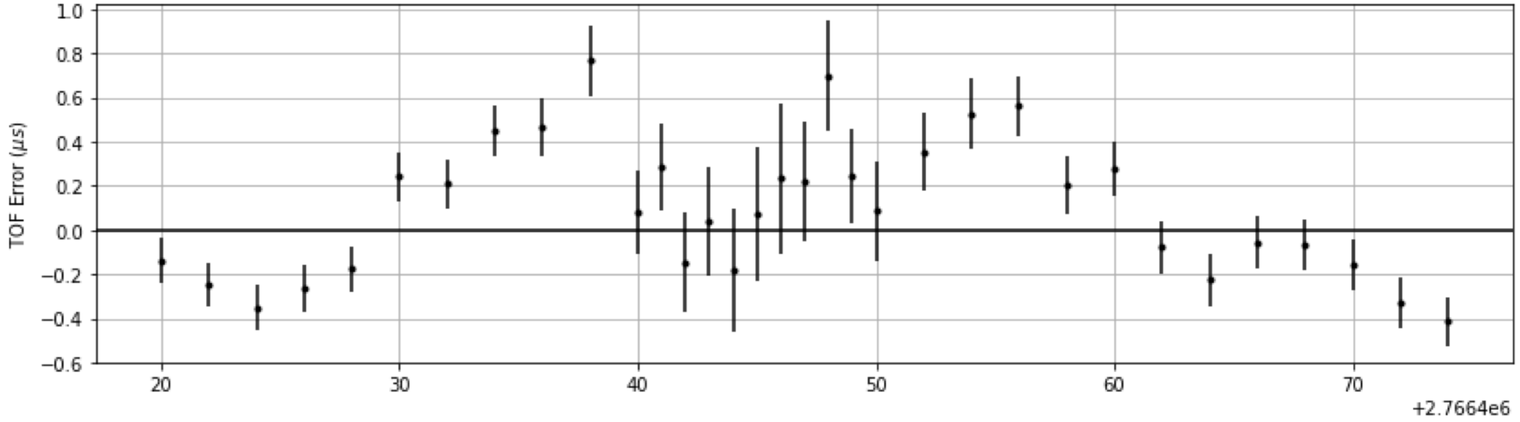


# TESTING OF SPHERICAL DEFLECTOR

Resonance Frequency for 39K




Residual for 39K fit




39 K

- Demonstrate spherical deflector works
- Resonance frequency: 2766445.33(18) Hz
- Trapped Ion Energy: 90 eV
- Excitation time: 100ms

# CONCLUSIONS & FUTURE WORK

- We have the capabilities to measure the mass of ions to very high precisions
- These high precision mass measurements allow us to characterize the facility and perform better measurements in the future.
- Hardware upgrades will facilitate the use of radioactive beam at TAMUTRAP

- Gold plating of Penning trap & installation
- Realignment of Section I & II of the beamline + RFQ

# ACKNOWLEDGMENTS


- Special thanks to: Praveen Shidling,  for helping direct my work; Veli Kolhinen, Ben Schroeder, Morgan Nasser, for writing the code to automate the data acquisition and fitting the data; Asim Ozmetin, Cristhan Gonzalez Ortiz, for helping with the beamline alignment; and everyone at the Machine shop

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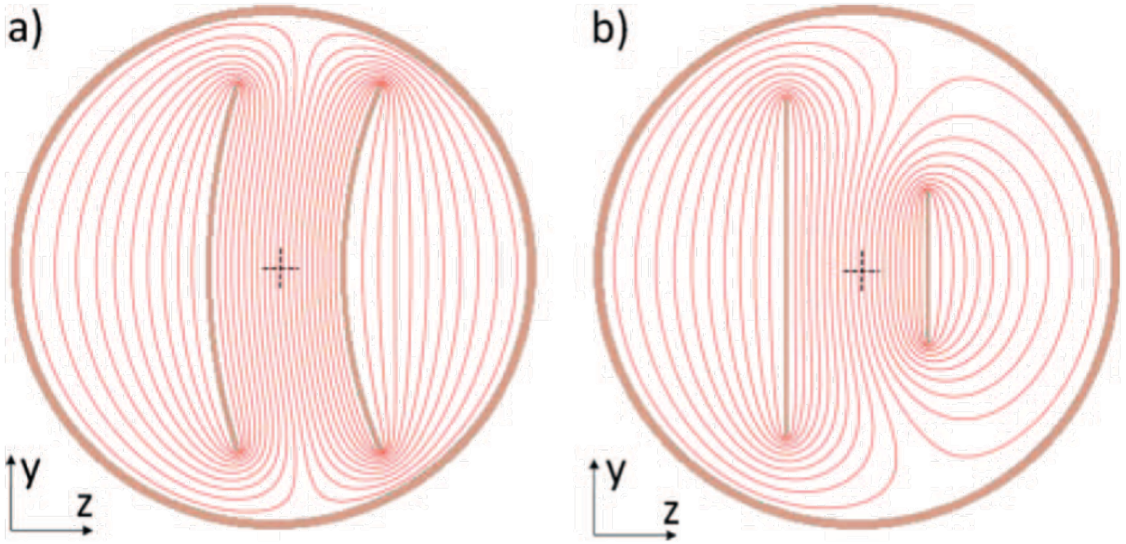
# CYLINDRICAL DEFLECTOR




# ASSEMBLY & CLEANING

Pre-Assembly

Cleaning in Ultrasonic Cleaner & with Alcohol

Final Assembly of Hardware

Attachment of guide wires and conductivity testing

# SPHERICAL DEFLECTOR & BEAM STEERER

- Spherical deflector replaced cylindrical deflector at 3rd 90 degree turn of the beamline
- Beam Steerer installed with a gate valve into section I of the beamline