

BRIAN ROEDER

9 / 23 / 2026

OPERATIONAL
EXPERIENCE
WITH A
POSITIVE /
NEGATIVE
FILAMENT ION
SOURCE



OVERVIEW

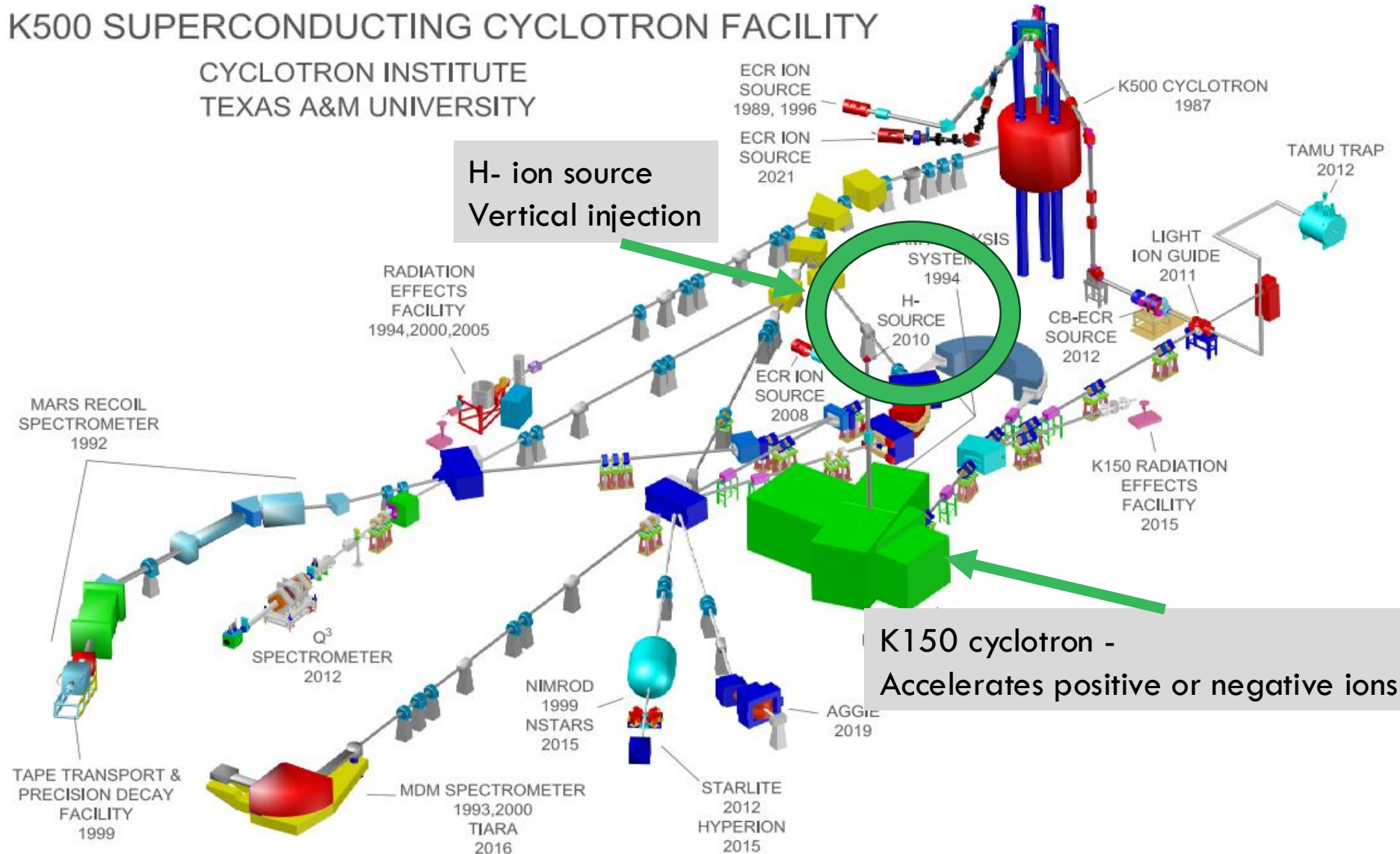
- Overview of the Cyclotron Institute at Texas A&M University
- Applications of the positive/negative filament ion source
- K150 cyclotron and foil extraction of accelerated negative ions
- The “old” ion source
- The D-pac +/- filament ion source
- Extraction studies
- Intensity studies
- Summary



OUR LAB

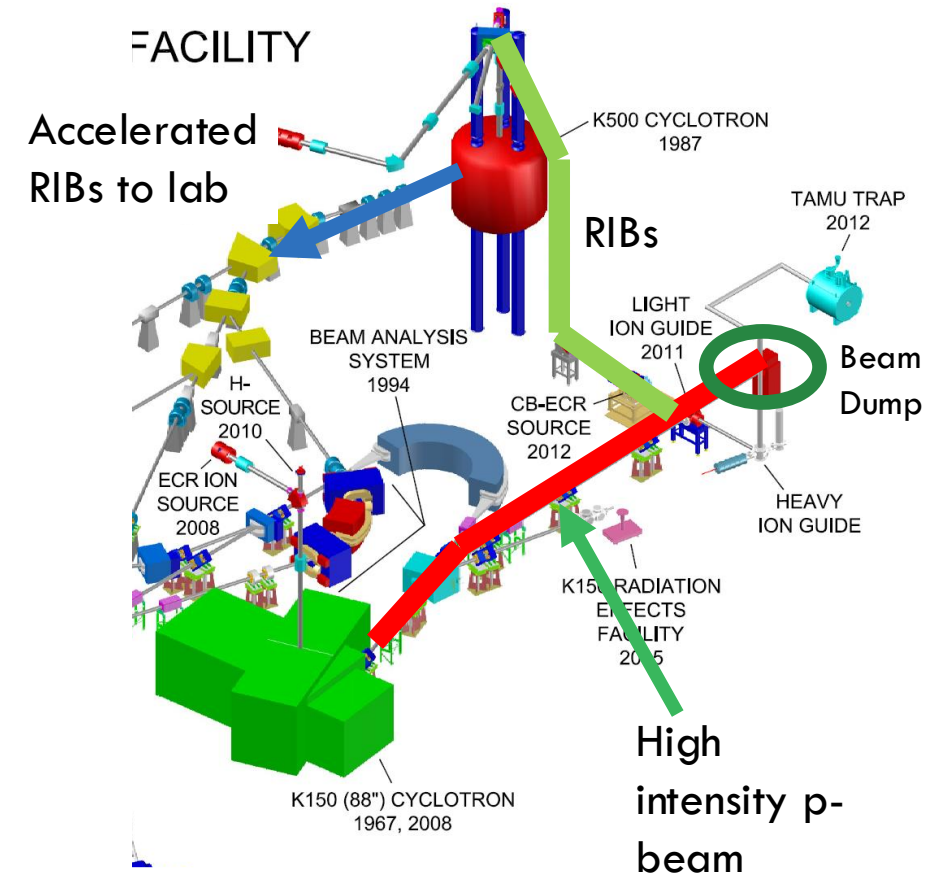
K500 SUPERCONDUCTING CYCLOTRON FACILITY

CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY



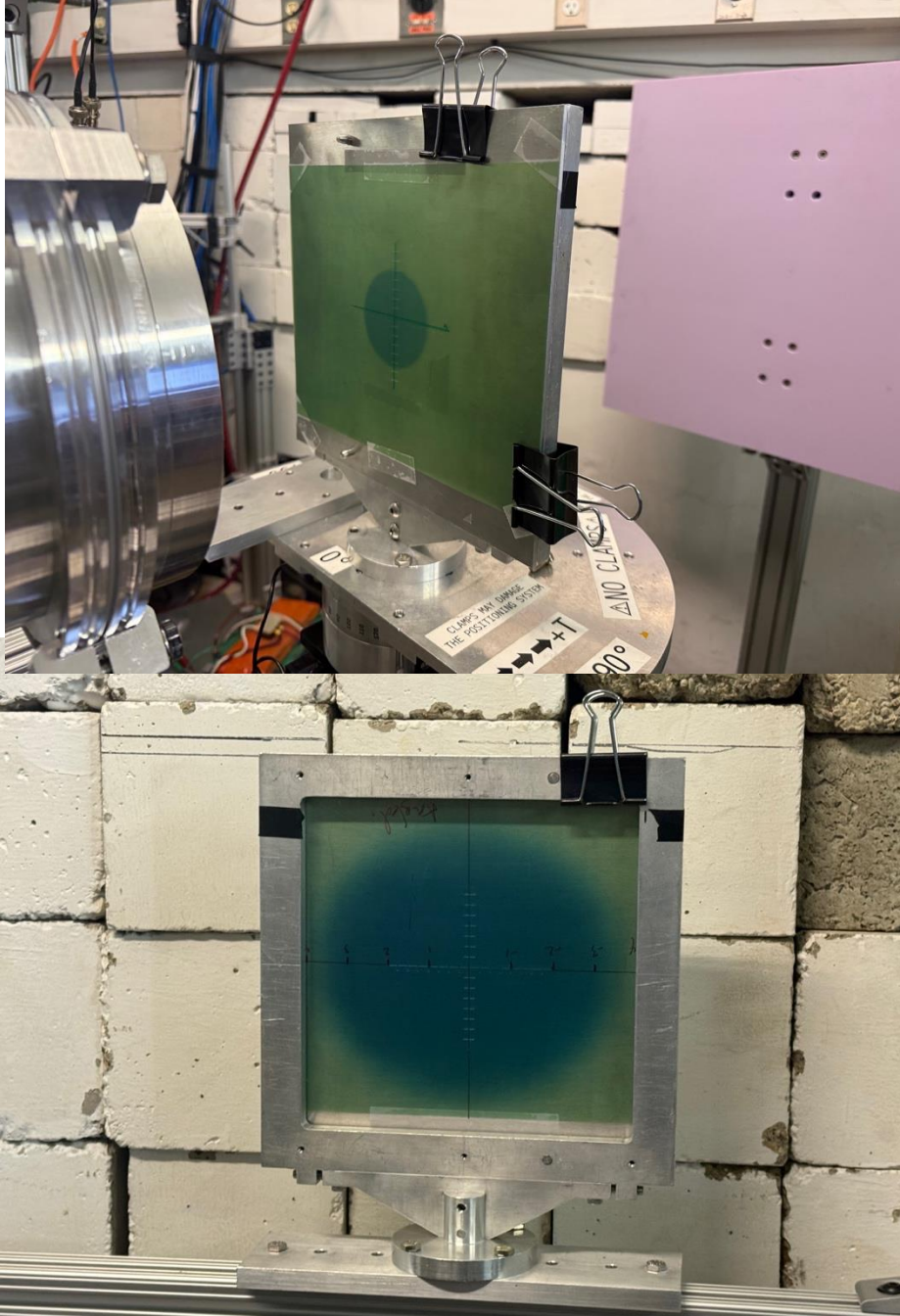
RE-ACCELERATED RADIOACTIVE BEAM

- Original need was for high-intensity proton beams for re-accelerated beam project.
- High intensity proton and deuteron beams up to 50 MeV and 20 μ A needed to produce exotic nuclei.
- $1+$ ions transported with a sextupole ion guide
- Ions charge bred with a CB-ECR source
- Ions accelerated from 10-30 MeV/u with K500 cyclotron.
- To date, ^{112}In , ^{105}In and ^{89}Nb beams have been made for experiments.

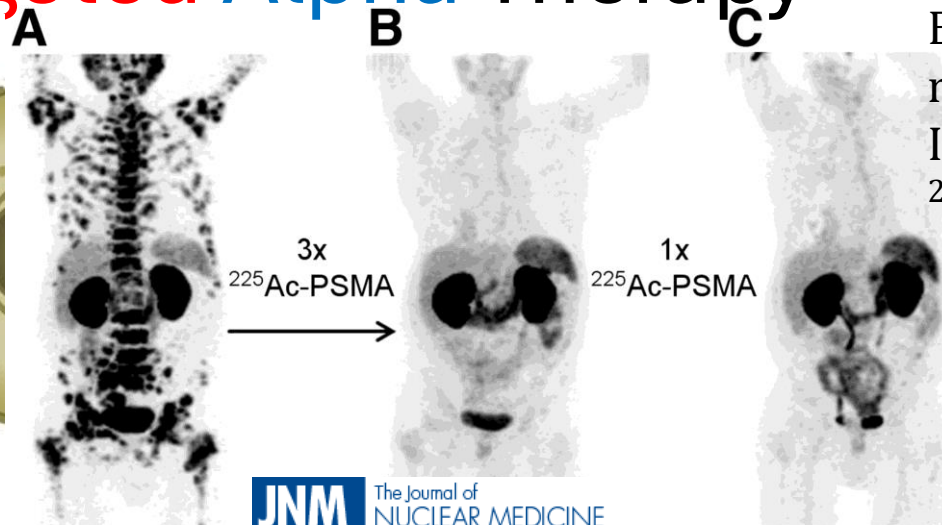
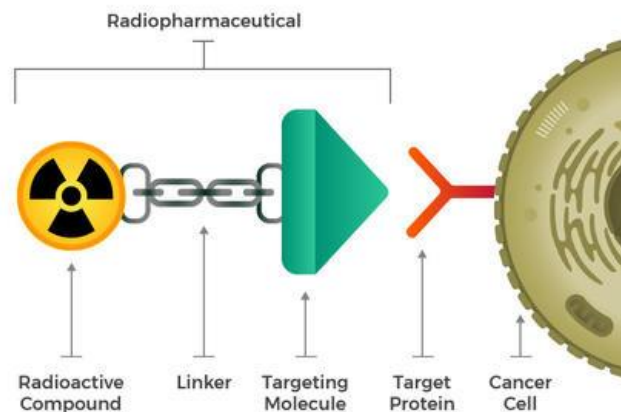


TESTING OF ELECTRONICS

- Radiation Effects Testing with protons or deuterons with energies from 3 to 50 MeV and fluxes up to 10^{10} particles/sec/cm².
- Particle dosimetry and flux measured with back-scatter technique.
- Flux is more limited by the detection system than the beam available.
- Large-area beams available to study system-wide effects.



At-211 for Targeted Alpha Therapy



12/2014
PSA = 2,923 ng/mL

7/2015
PSA = 0.26 ng/mL

9/2015
PSA < 0.1 ng/mL

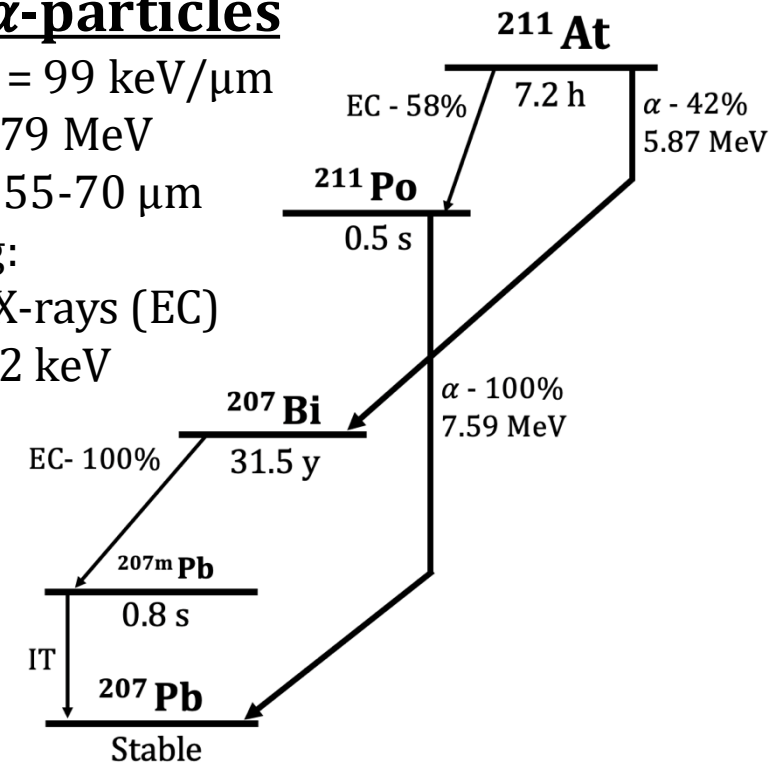
^{68}Ga -PSMA-11 PET/CT scans of patient A. Pretherapeutic tumor spread (A), restaging 2 mo after third cycle of ^{225}Ac -PSMA-617 (B), and restaging 2 mo after one additional consolidation therapy (C). Clemens Kratochwil et al. J Nucl Med 2016;57:1941-1944

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^{211}At at α -particles

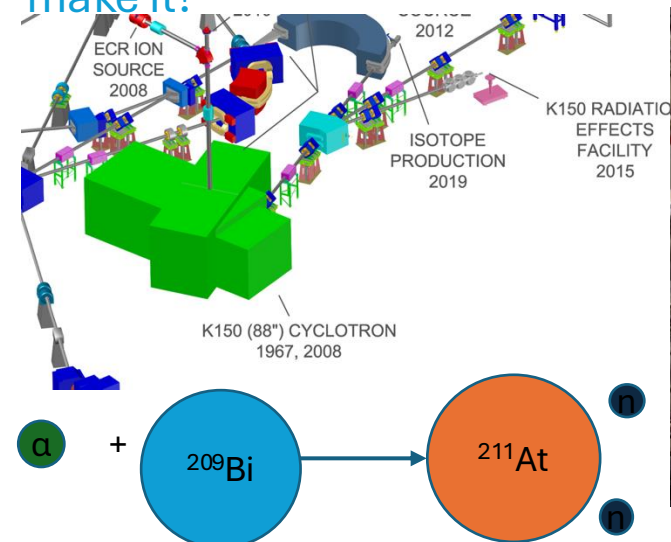
$\text{LET}_{\text{mean}} = 99 \text{ keV}/\mu\text{m}$
 $E_{\text{avg}} = 6.79 \text{ MeV}$
range = 55-70 μm

Imaging:
 ^{211}At K X-rays (EC)
76-92 keV

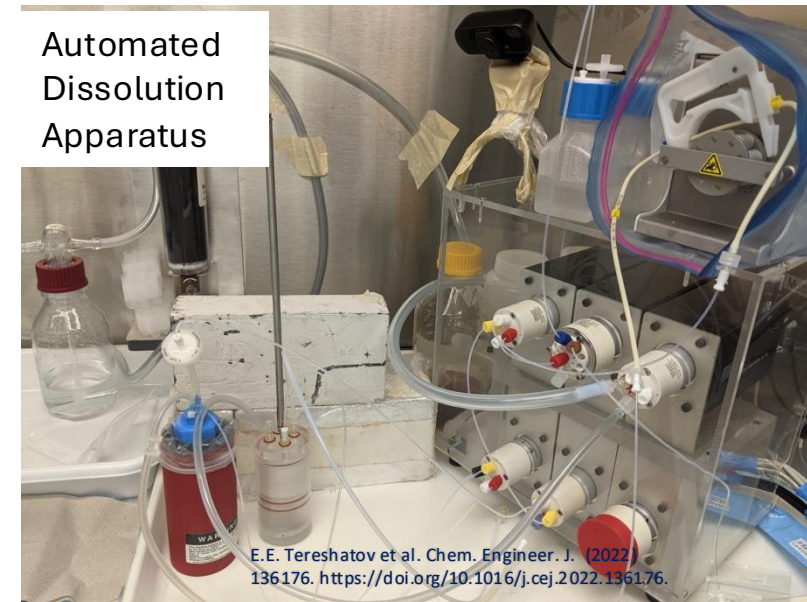


Adapted from Zalutsky, M. and Pruszyński M. Curr. Radiopharm. 2008, 1, 177-196.

At-211 is very rare in nature. In order to use or study, we have to make it!

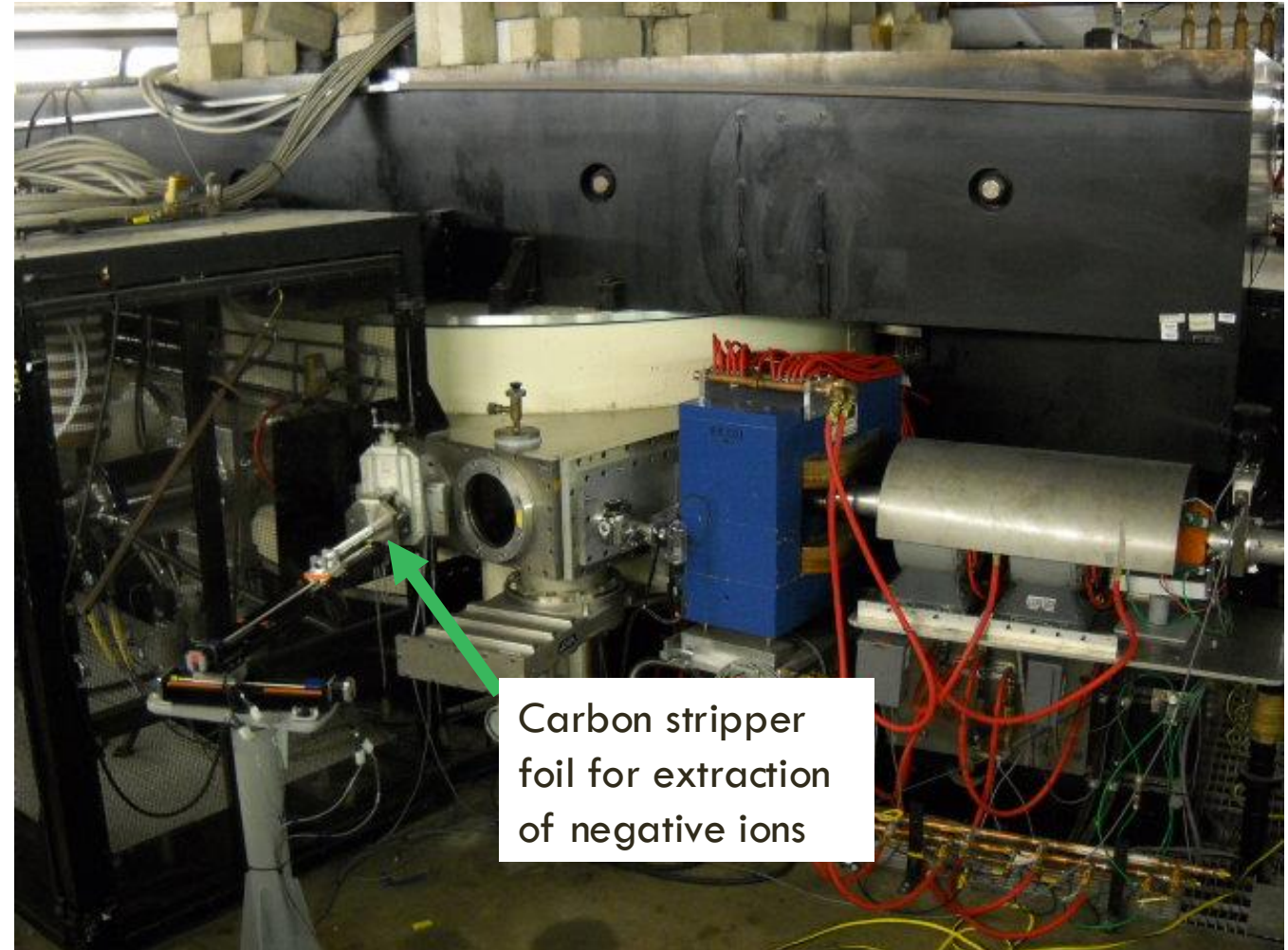


Automated Dissolution Apparatus

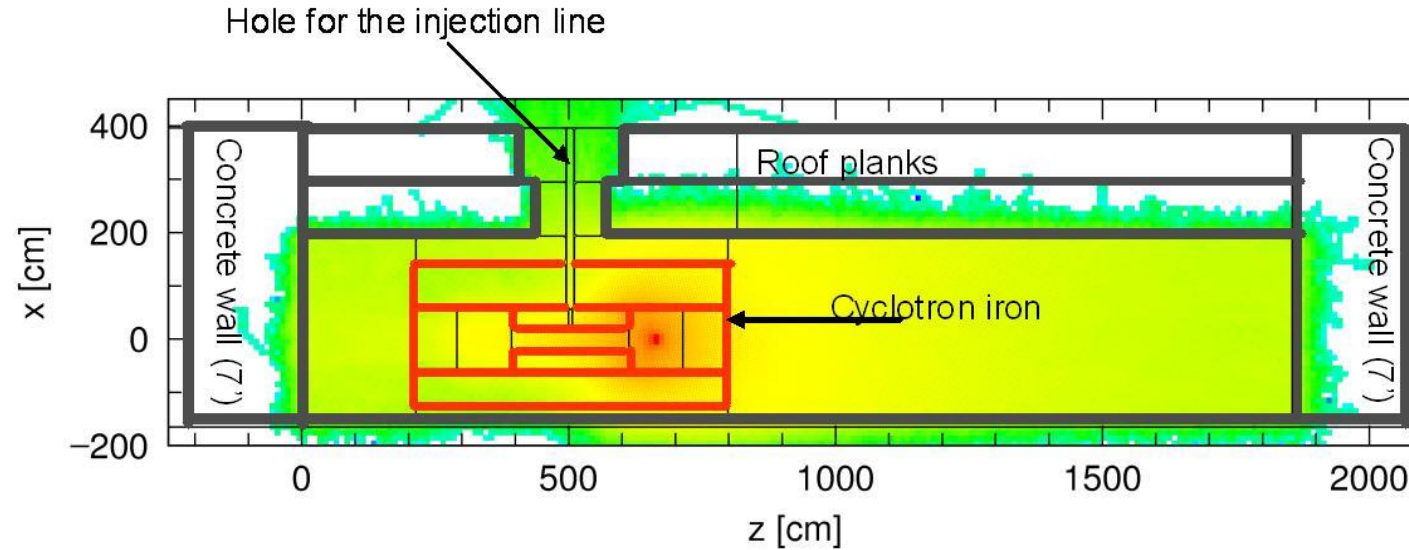


K150 Cyclotron

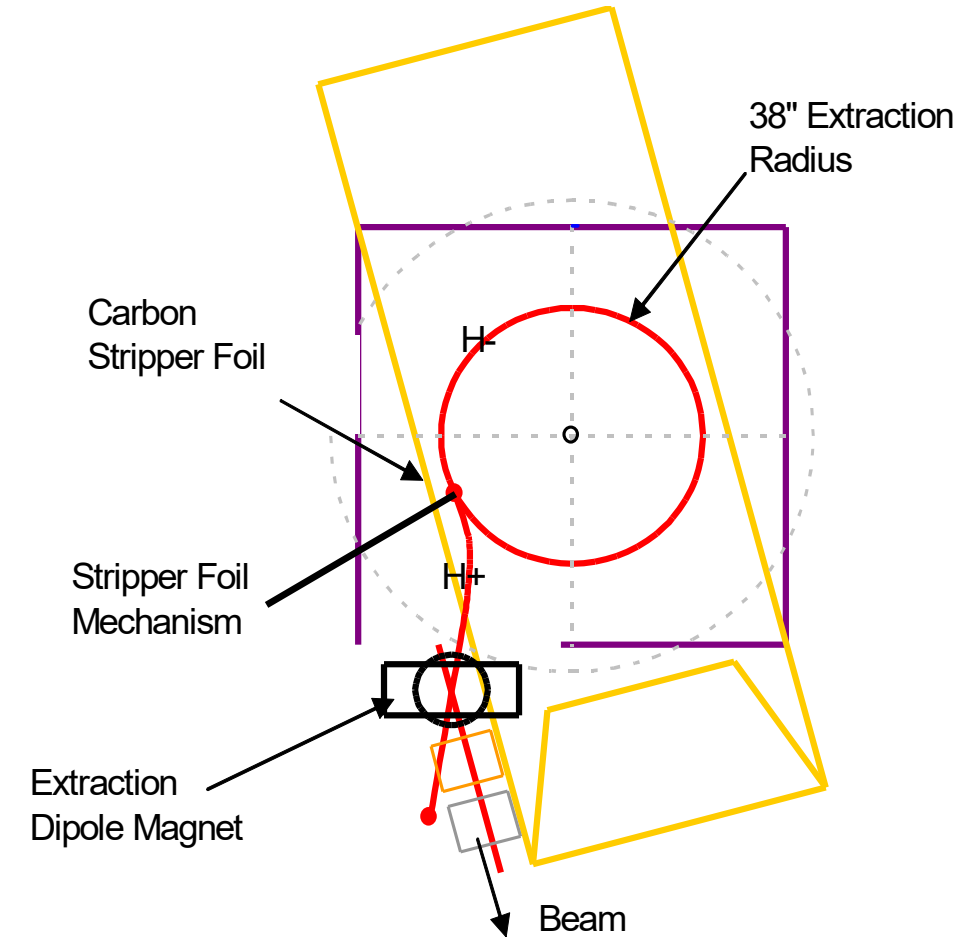
- Conventional, water-cooled magnet with fields up to ~ 1.5 Tesla.
- Magnet radius 44 inches (“88 inch cyclotron”).
- Radiofrequency ~ 5.2 MHz up to 16 MHz for acceleration.
- Allows for up to 50 MeV protons (H^-), extracted with a carbon foil.
- D^- and He^{2+} up to ~ 25 MeV/u
- Heavy Ions to Argon up to ~ 19 MeV/u, extracted with electrostatic deflector plates (ECR ion source).



K150 Cyclotron – negative beam extraction



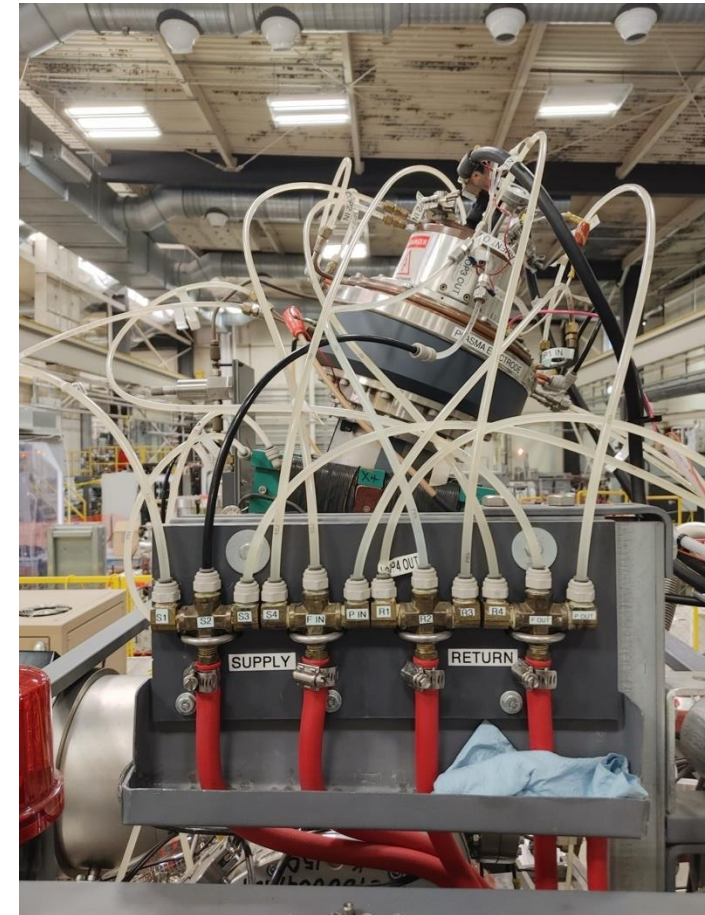
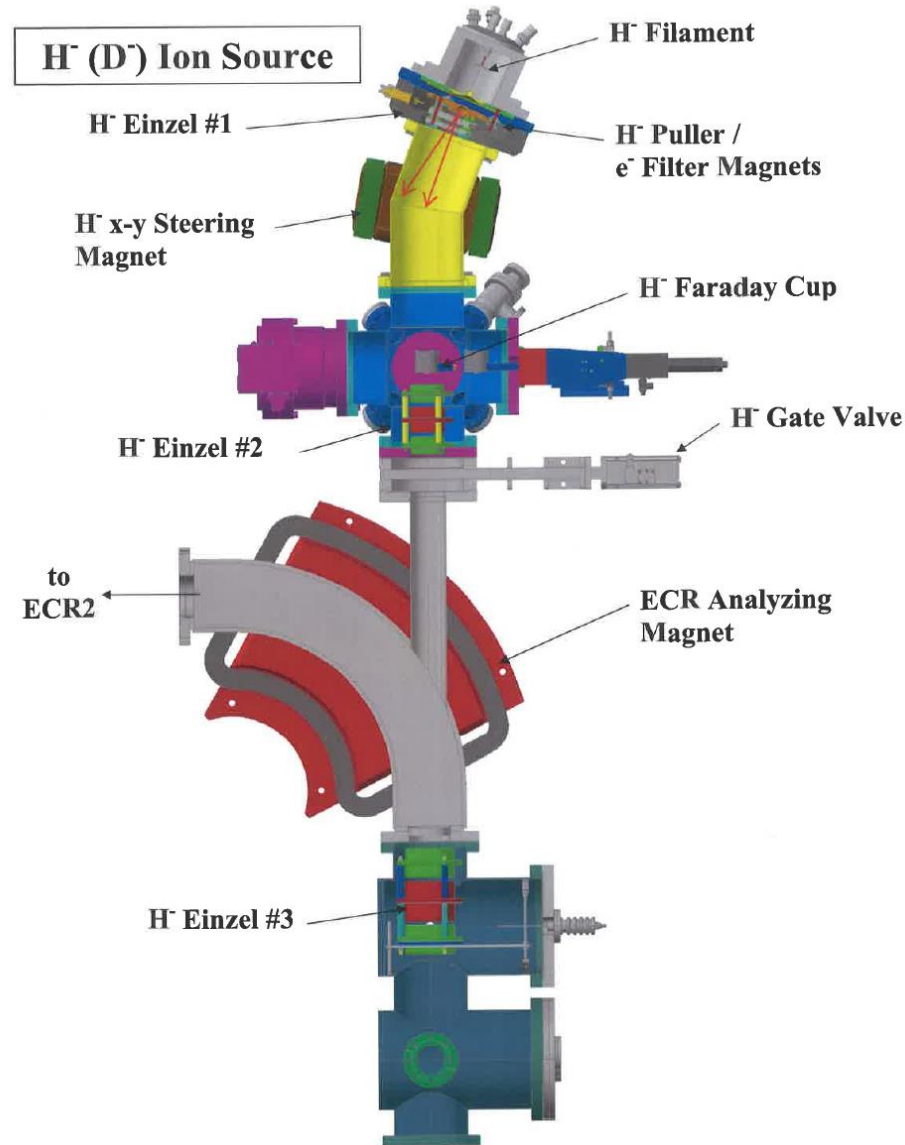
Carbon
stripper foil



- Acceleration of negative ions allows for better extraction efficiency (up to 100%)
- Extraction with stripper foil lowers radiation levels inside the accelerator vault.

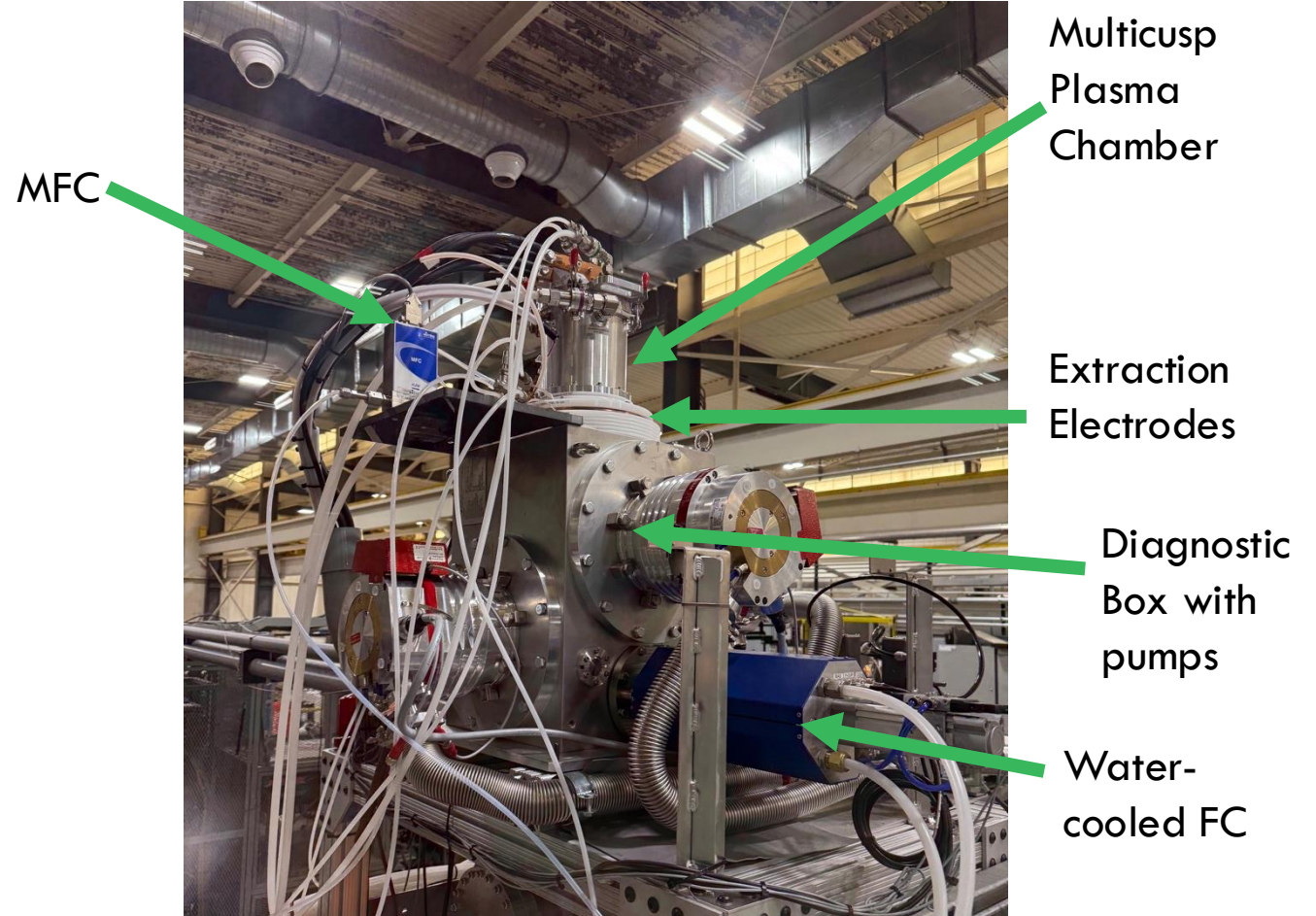
First TAMU/JYFL H- source

- Operated from 2009-2023
- Produced H⁻ and D⁻ ions
- 15 deg tilt introduced to reduce debris from filament falling into the injection line.
- Produced low-emittance beams with high transmission ratios through the accelerator.
- Positive and negative ions extracted with different trajectories. Required internal modifications to the ion source to re-configure.



INSTALLATION OF THE $\pm$ FILAMENT ION SOURCE FROM D-PACE (2024-2026)

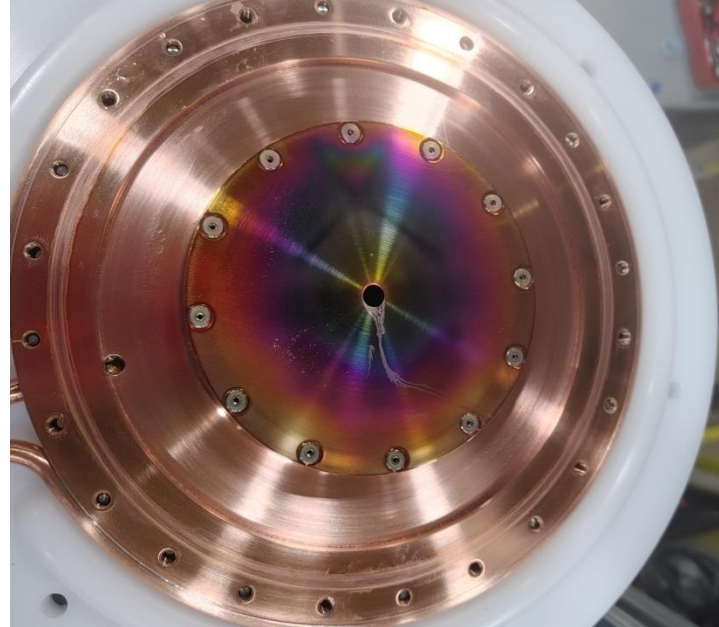
- Installation of the $\pm$ filament ion source from D-Pace occurred Jan-April 2024.
- Allows for easy, external switching between $+$ and $-$ ions (voltage on e-suppression electrode).
- Up to 2 mA of He^+ beam extracted.
- Up to 1 mA H^- beam extracted.
- Also can make D^- and 3He^+ (to be developed).
- More beam available, but need to get it into the cyclotron.



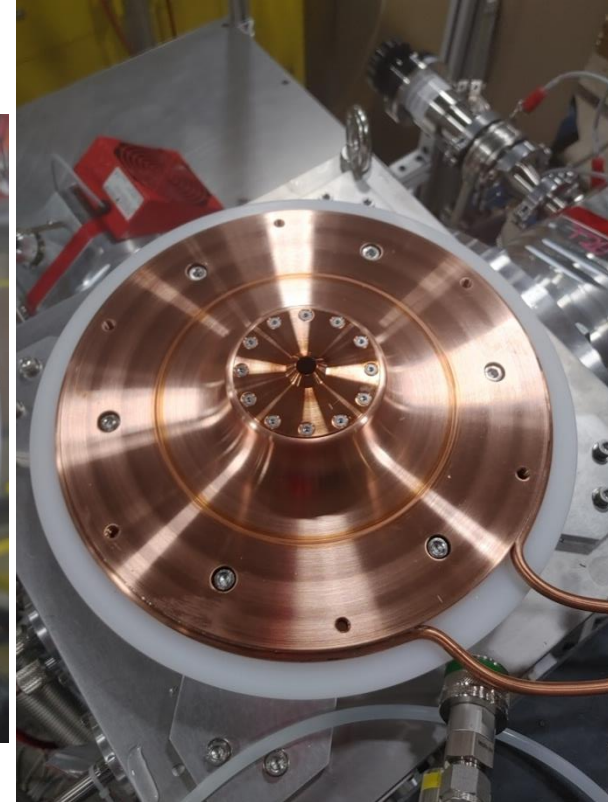
INSIDE THE ION SOURCE



1. Tantalum Filament heats the gas



2. Plasma Electrode confines electrons in plasma. Defines size of the extracted beam.



3. Extraction Electrode pulls and accelerates ion beam away from the plasma (opposite polarity of beam and potential).



4. Magnets filter electrons and allow for H^- production via charge-exchange. Voltage applied to electrode to transport + beam (if needed).

CHANGING FROM POSITIVE TO NEGATIVE IONS



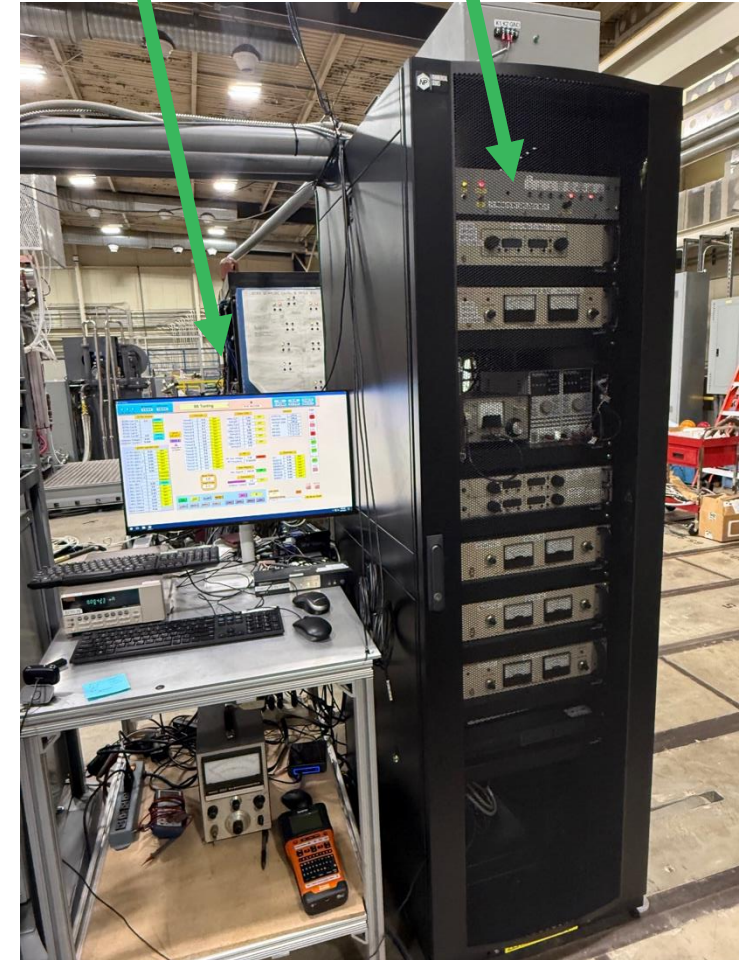
Filament
and
Extraction
(at HV)

+/- switch

- H^- beams extracted with dedicated negative power supplies.
- He^+ beams extracted with dedicated positive powers.
- Switching requires a simple switch flip, changing gas and turning on the -1.7kV electrode in the extraction.

Control Station

HV Supplies



GETTING THE BEAM INTO THE CYCLOTRON

1/4"

Mirror

Electrode

Mirror Inflector Tower

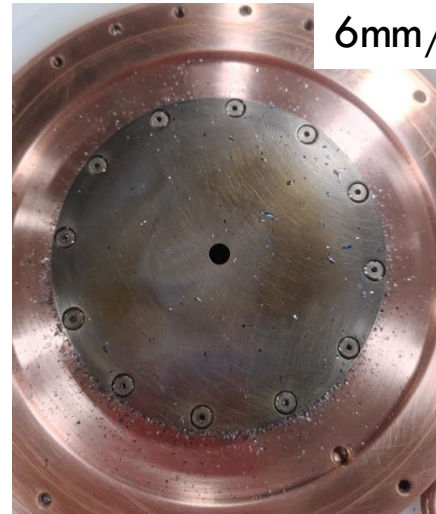


Screen

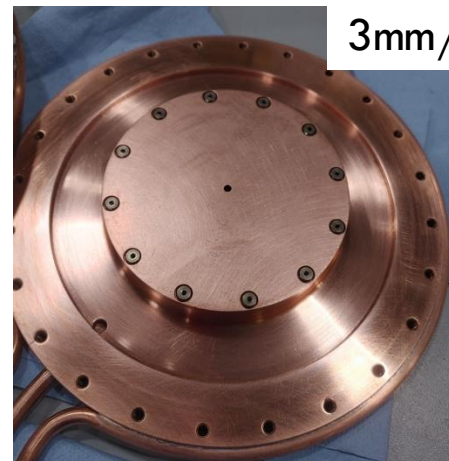
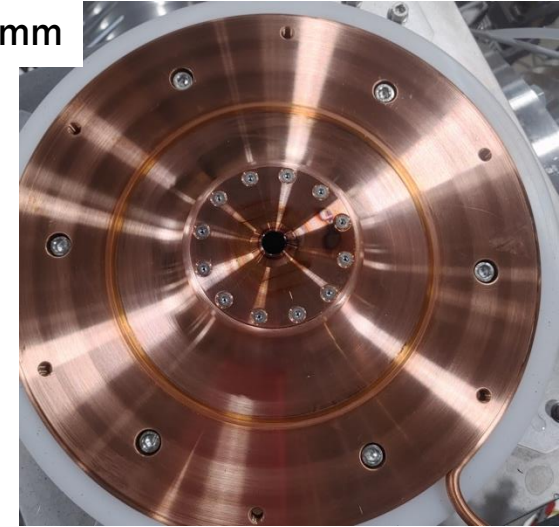
- The ions need to be bent 90° from the vertical injection line into the horizontal plane of the cyclotron.
- The electrostatic inflector can operate up to about 12 kV. Limits the extraction voltage of the ion source.
- The beam is bent by the 1/4" mirror electrode.
- Better emittance from the ion source allows better transmission through inflector

EXTRACTION APERTURE TESTS

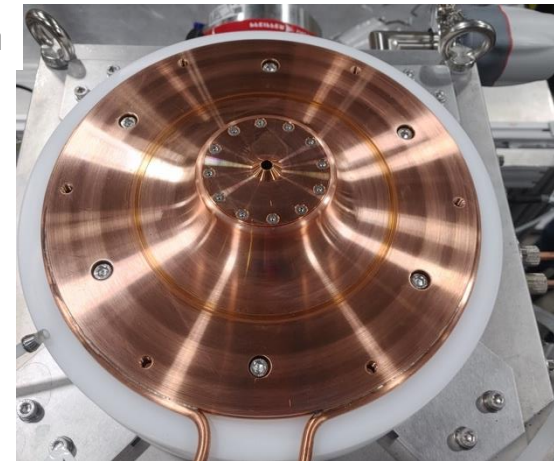
- Tested 6mm vs. 3mm extraction aperture.
- Also changed Puller aperture from 14 mm to 6mm.
- Total source output was reduced by approximately 4x, but transmission % into cyclotron improved. Less loss on downstream Einzel Lenses.



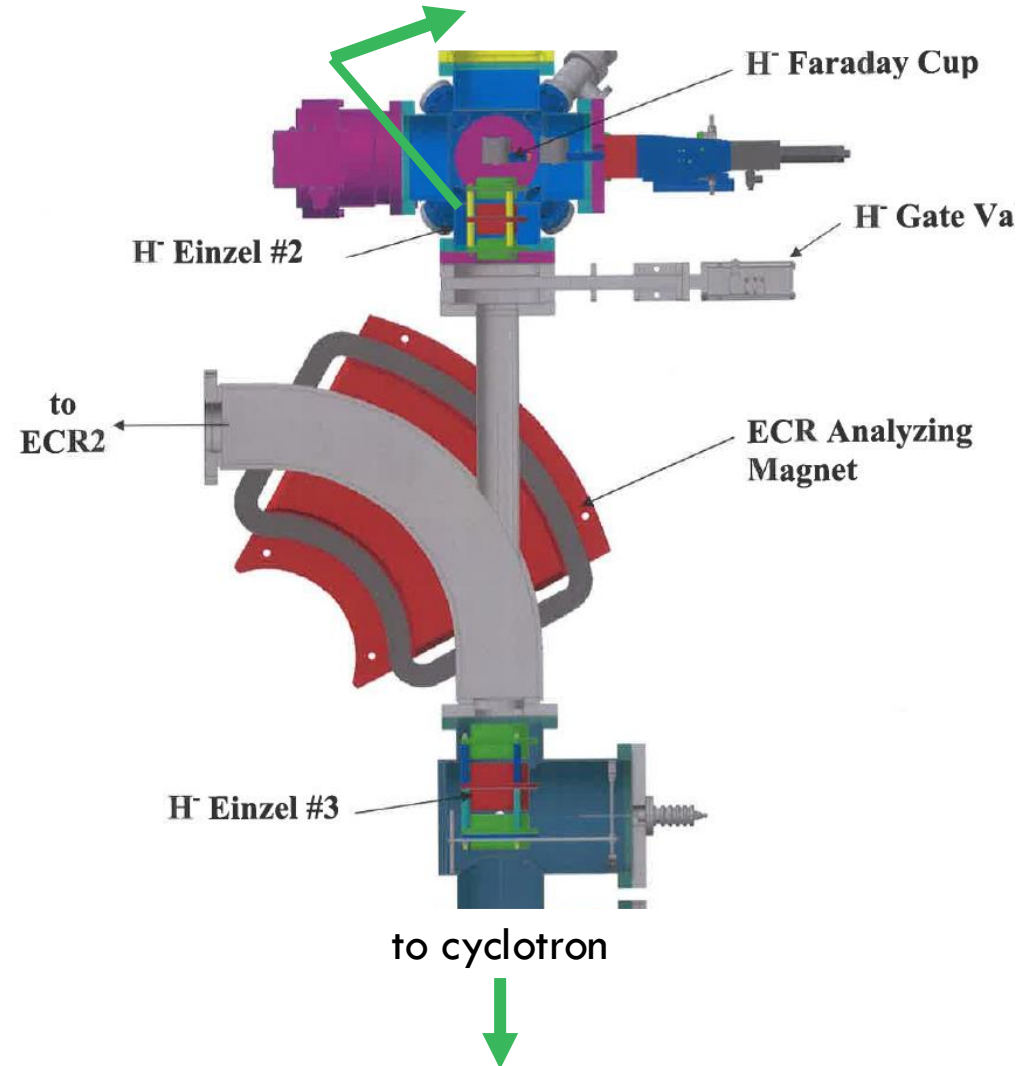
6mm/14mm



3mm/6mm



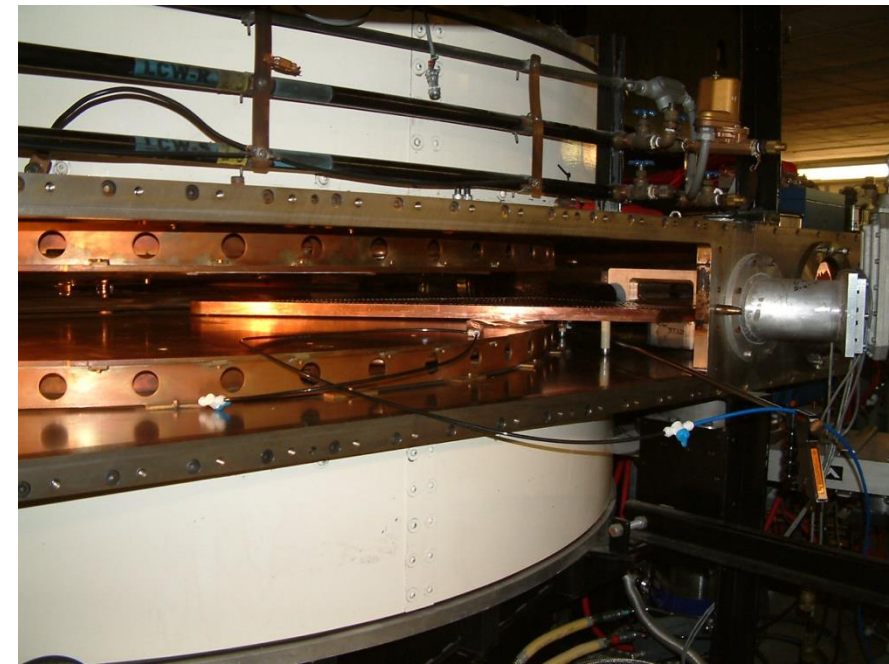
EINZEL LENS



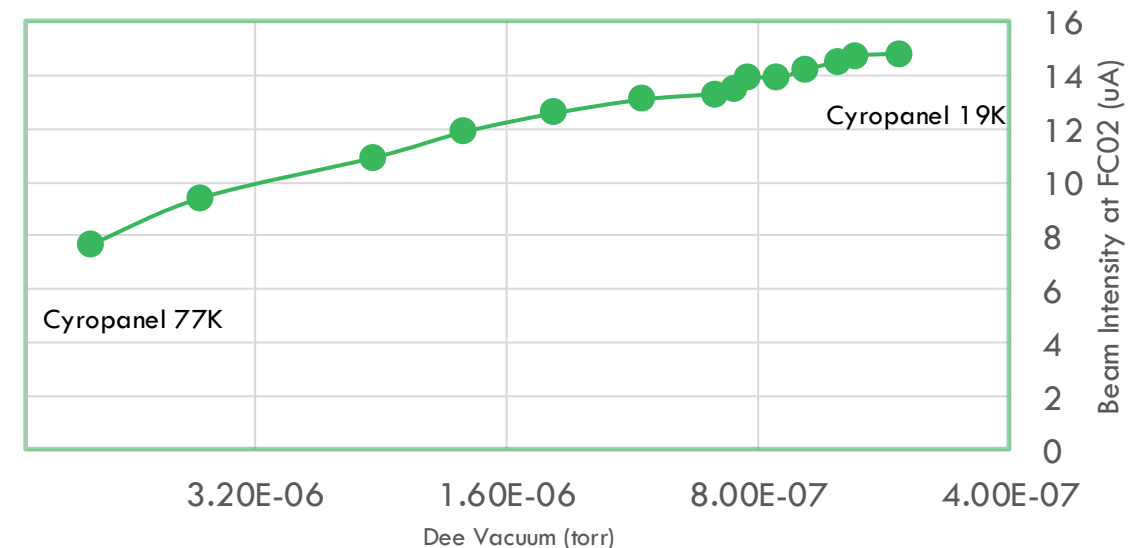
- Below the diagnostic box, the beam passes through a bottle neck region above the vertical injection line.
- In an attempt to improve transmission, Einzel Len #2 moved about 20cm closer to ion source.
- Beam transmission improved, but only with the lens grounded.
- Need further simulations of extraction and optics to determine better placement of this lens.

INTENSITY STUDIES

- The filament ion source is ideal for cyclotron tuning studies due to its stability (relative to the ECR ion sources).
- Have achieved up to 20 μA of protons (H^+) extracted from K150 cyclotron at a variety of beam energies.
- Have achieved up to 15 μA of He^+ extracted from K150 (through the deflector).
- Transmission is affected by the beam injection, as well the condition of the cyclotron.
- Best results have been observed with the improved vacuum in the cyclotron from the recently commissioned He cryopanel.



4He beam intensity vs. dee chamber vacuum

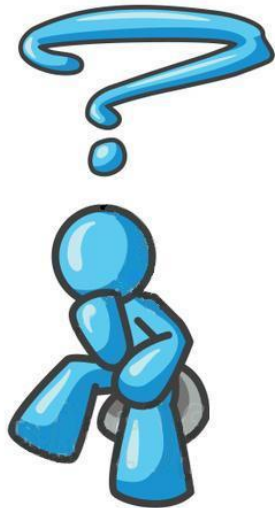


SUMMARY

- Intense, stable, light ion beams from filament-driven ion sources have a broad range of applications.
- At the Texas A&M University Cyclotron Institute, we have been operating an H^- ion source since 2010. It was replaced with the positive/negative ion source from D-pace in 2024.
- The existing source, made by D-Pace, provides up to 1 mA of H^- and up to 3 mA of He^+ for injection into the K150 cyclotron.
- Beam transmission is limited by details of the injection of the beam into the cyclotron and the condition of the cyclotron.
- Studies of the external optics after the source are ongoing to improve the beam injection into the cyclotron.
- Development of D^- and $^3He^+$ beams are planned in the near future.

THANKS

- Collaborators:
- TAMU - Gabriel Tabacaru, Hyo-in Park, George Kim, and TAMU Cyclotron Institute staff
- D-Pace Inc. – Stephane Melancon, Anand George



QUESTIONS?

