



# Acceleration of $H^-$ ions for the Cyclotron Institute Upgrade Project

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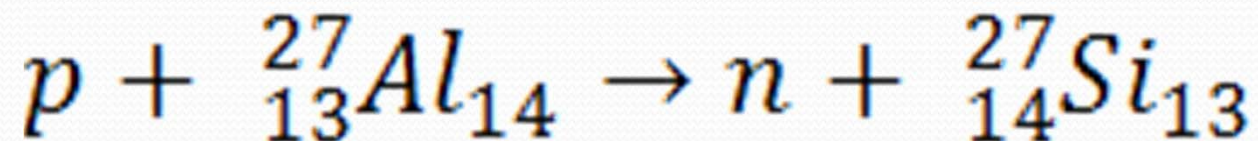
# Outline

- Why we need the K150 Cyclotron
- Original plans for proton ( $H^+$ ) beam via ECR<sub>2</sub>
- Problems with proton extraction using ECR<sub>2</sub>
- Enter the  $H^-$  Source
- Other upgrades done to K150 Cyclotron
- Future work
- Acknowledgments
- References



# Why K150 is Needed

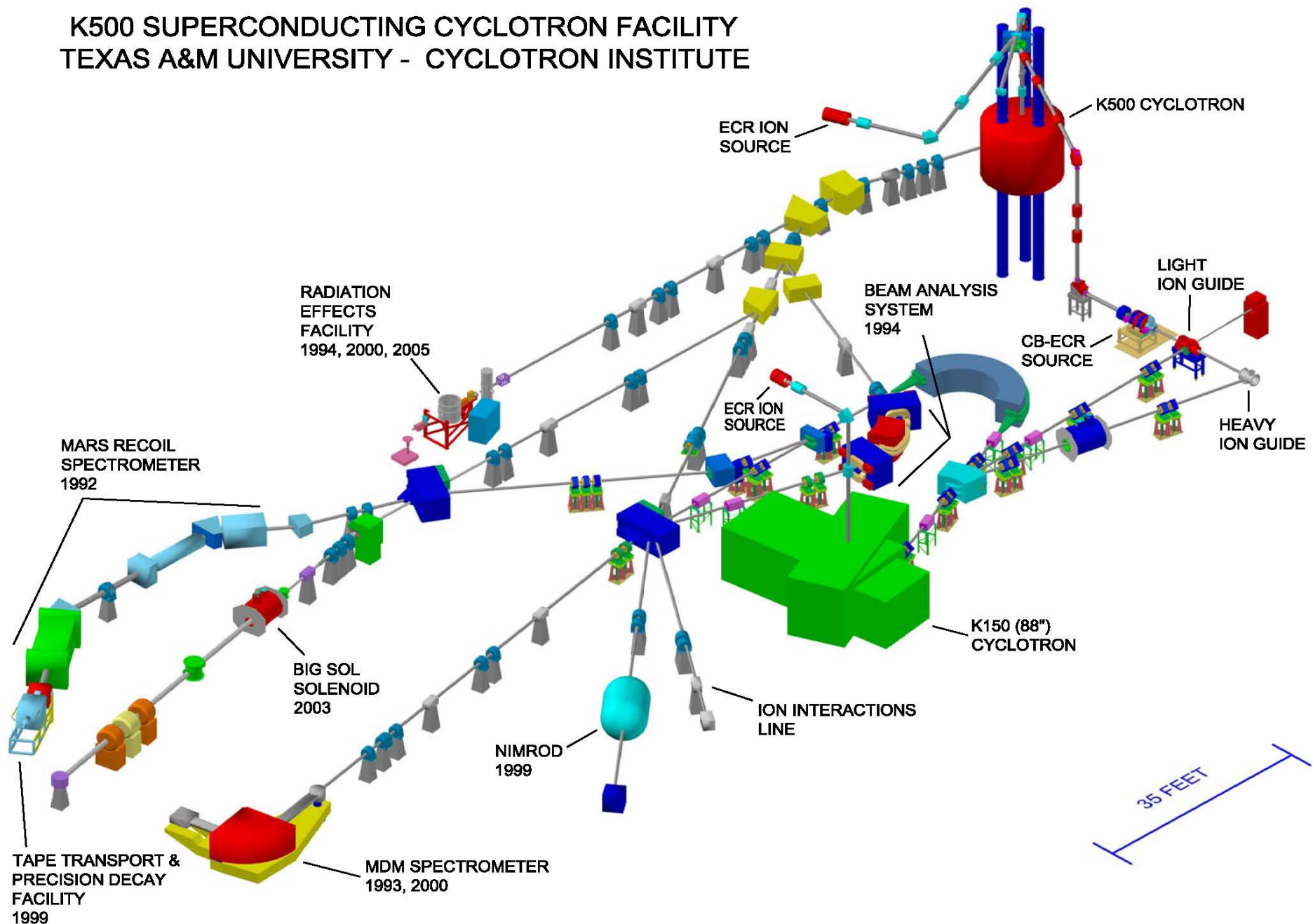
- New concept using Rare Isotope Accelerator (RIA)
- First proposed experiment:

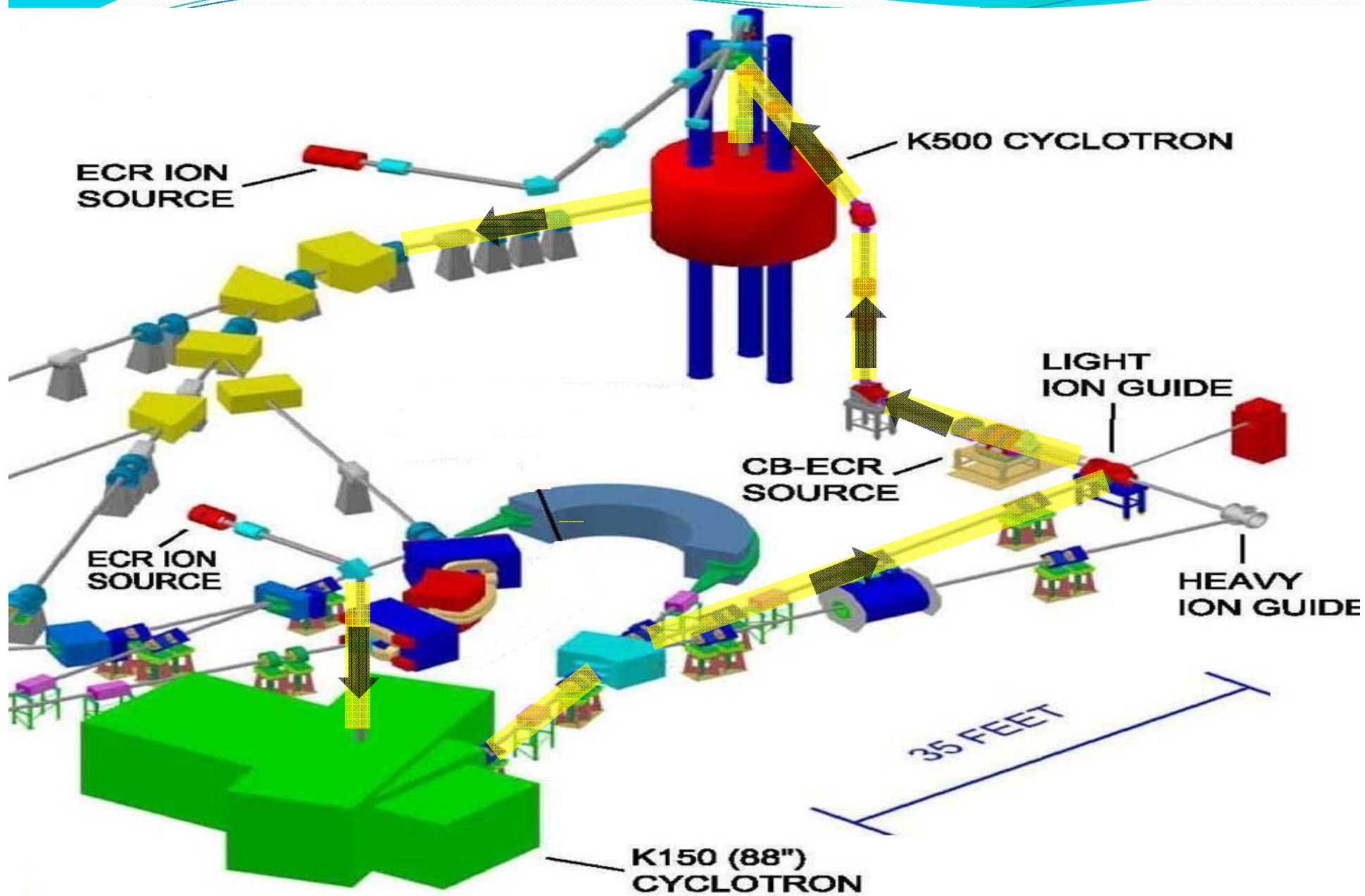


- Requirements for this reaction:
  - Proton current of 14μA at extraction
  - Proton current of 10μA on target
  - Proton beam energy of 30MeV on Al target



# K500 SUPERCONDUCTING CYCLOTRON FACILITY TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE







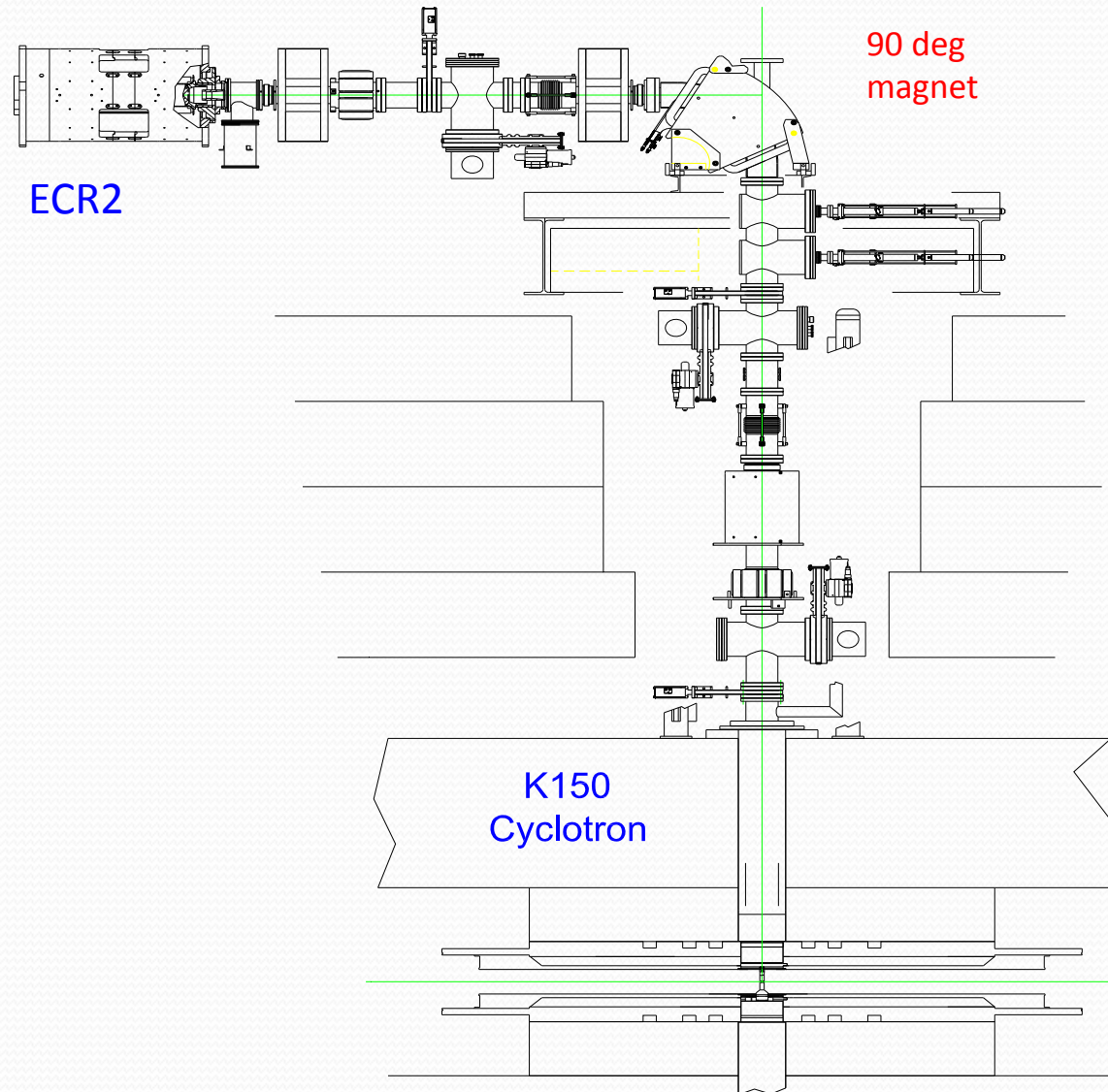
# Initial Plan for Proton Production

- Original plan called for use of the Electron Cyclotron Resonance (ECR<sub>2</sub>) source
- ECR<sub>2</sub> source removes electrons, produces H<sup>+</sup> Ions (protons) before injection into cyclotron
- H<sup>+</sup> are injected into the cyclotron and accelerated





# K150 Injection Line





# Extraction Problems

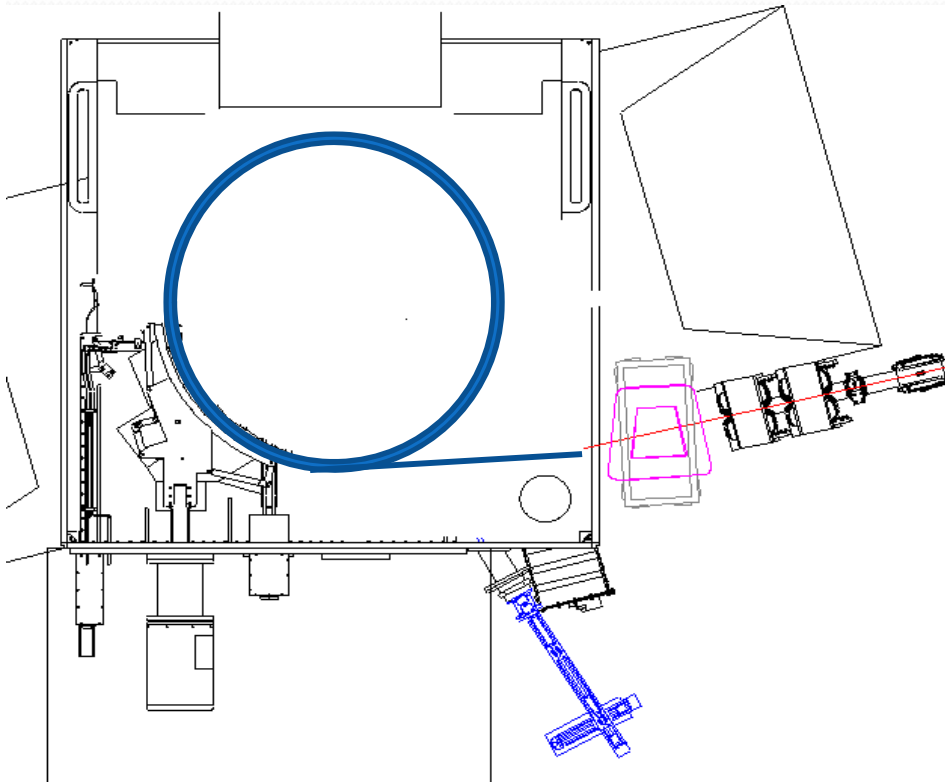
- Activation of deflector
  - Loss of run time
  - Safety hazard – secondary radiation
- Extraction efficiency of deflector
  - Approximately 50% loss of beam at best



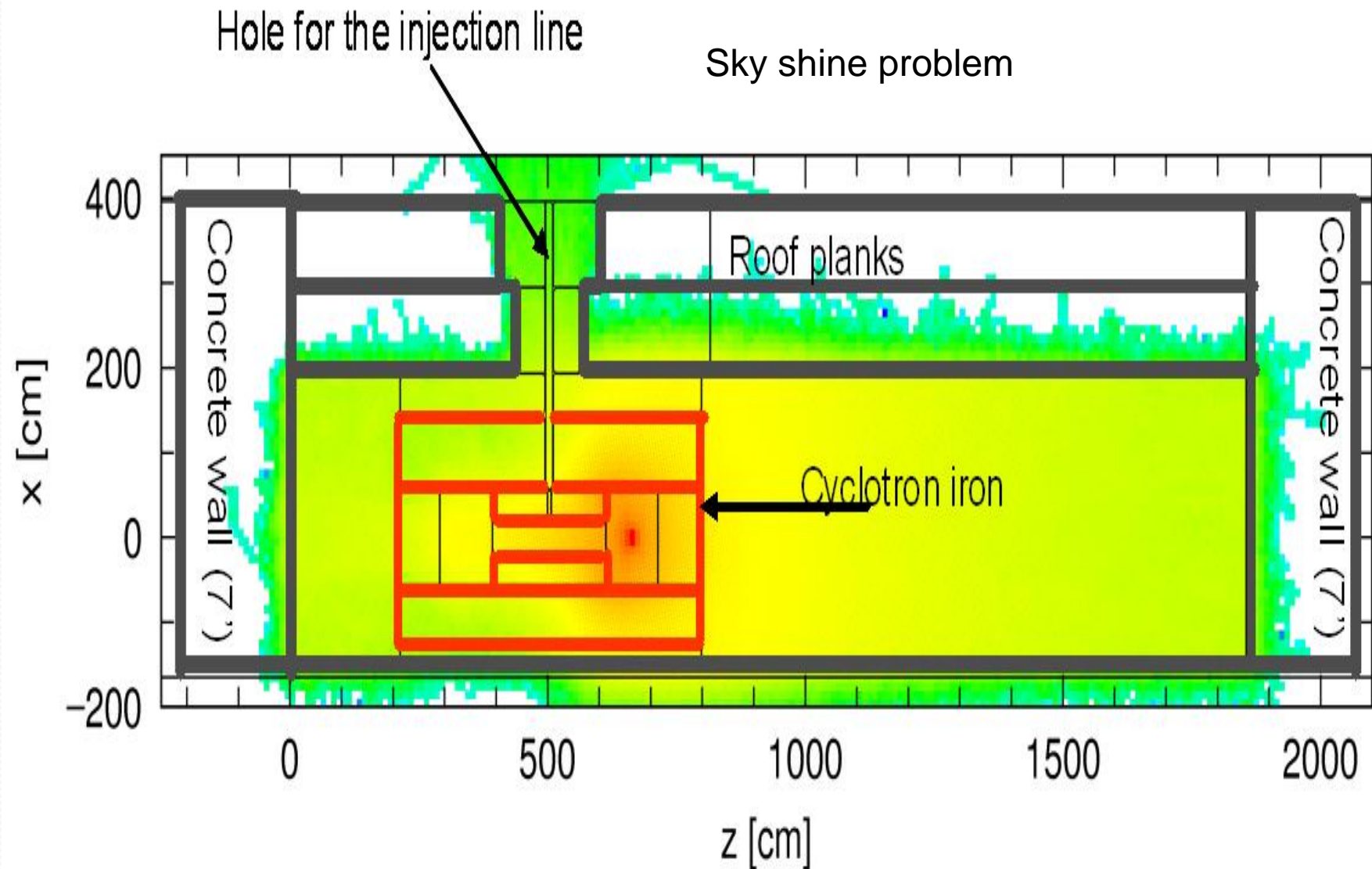


# Activation of Deflector

Time	Activity(mCi)	Dose Rate(mRem/hr)
10 min	1168.108	52144.3
1 hour	1028.649	45918.9
1 day	686.216	30632.7
3 days	390.27	17421.7
5 days	265.811	11865.8
Na-22 gamma source	0.1	4.5
Rad worker limit: 5000mRem/year		
Distance: .5 meters		



# Activation of Deflector





# Solutions

- Build a special deflector for protons
  - Need one for each proton energy, ideally
  - Approximately 80KV bias needed – HV danger
  - HV Sparking – degrades surface, less deflection
- Build deflector from pure Aluminum
  - Excessive heat – complicates maintenance
- Make ions via an  $H^-$  source
  - Best option

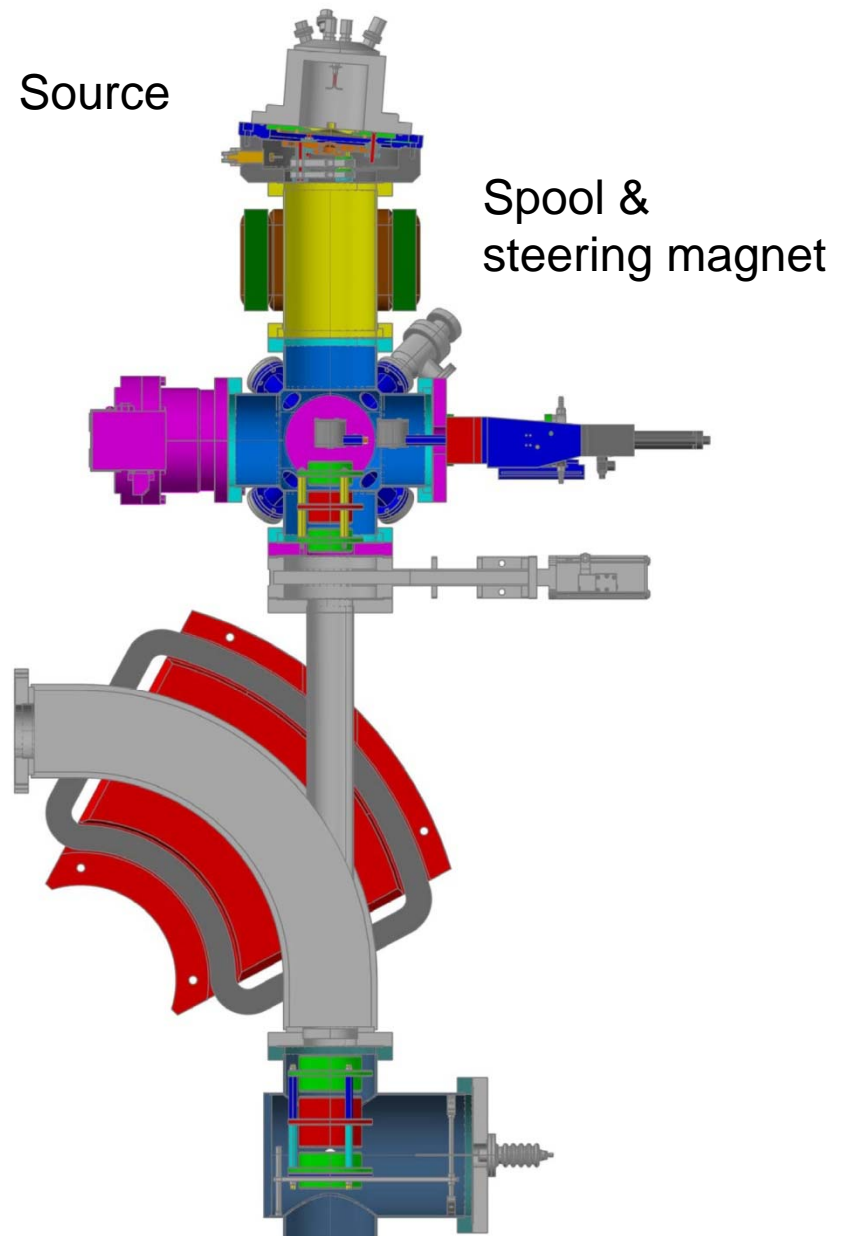
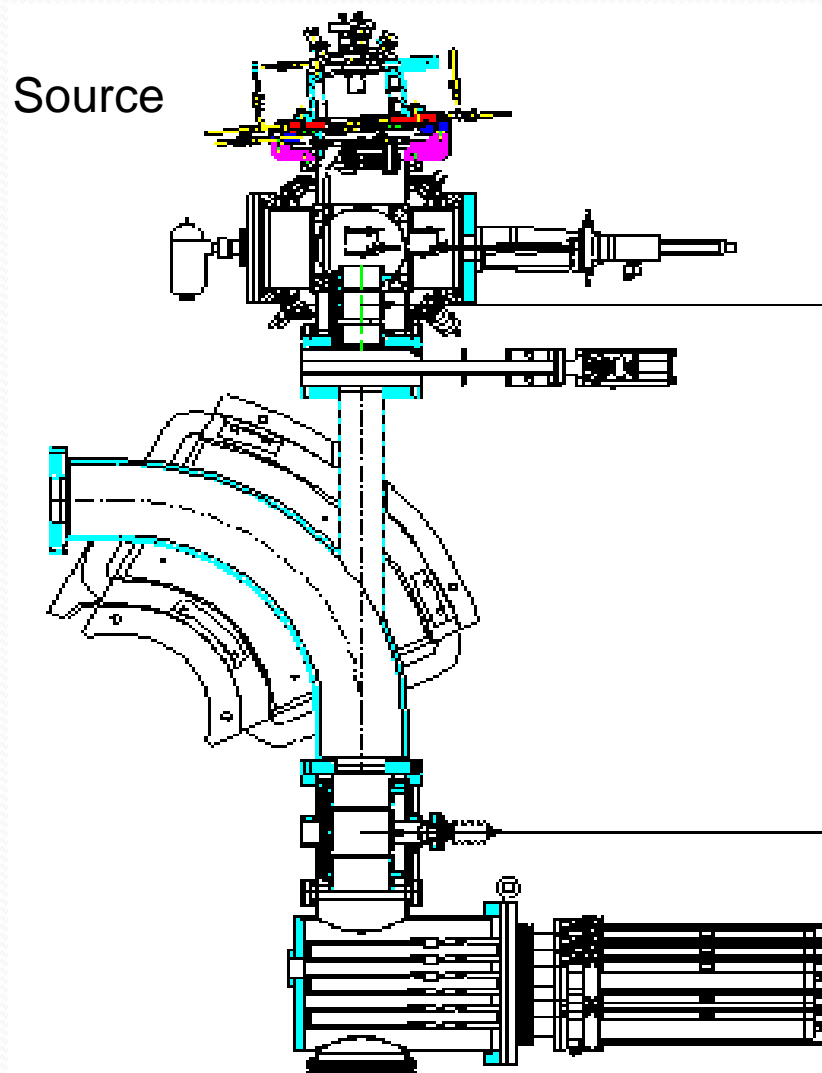




# Enter the H<sup>-</sup> Source

- 100% extraction efficiency from cyclotron
- No need for deflector - reduces secondary radiation
- No danger of HV – no sparking, less maintenance
- Allows production of high intensity proton and deuteron beams

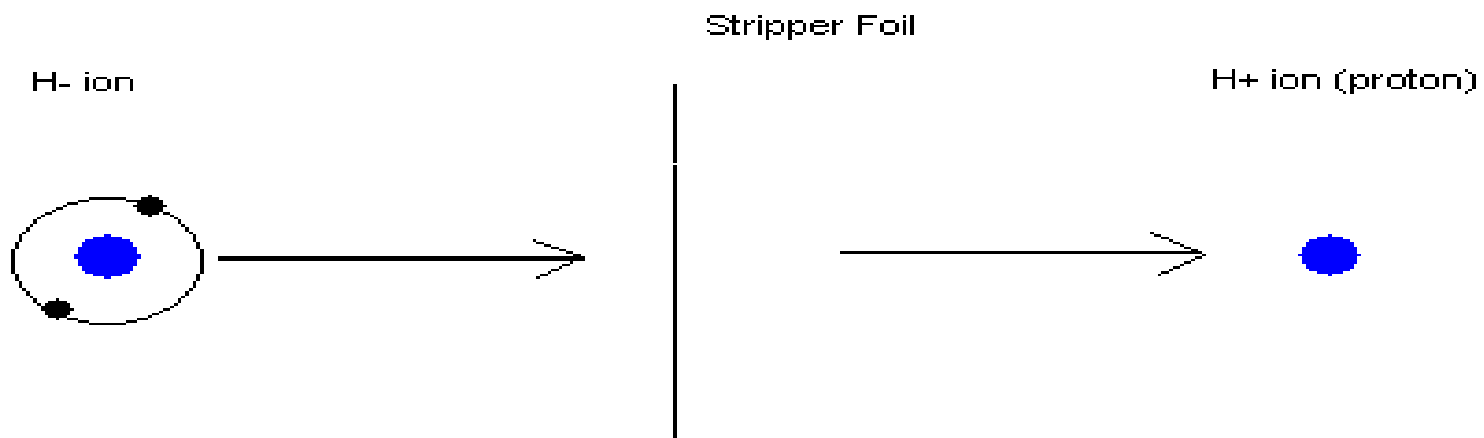
# H-Source Placement





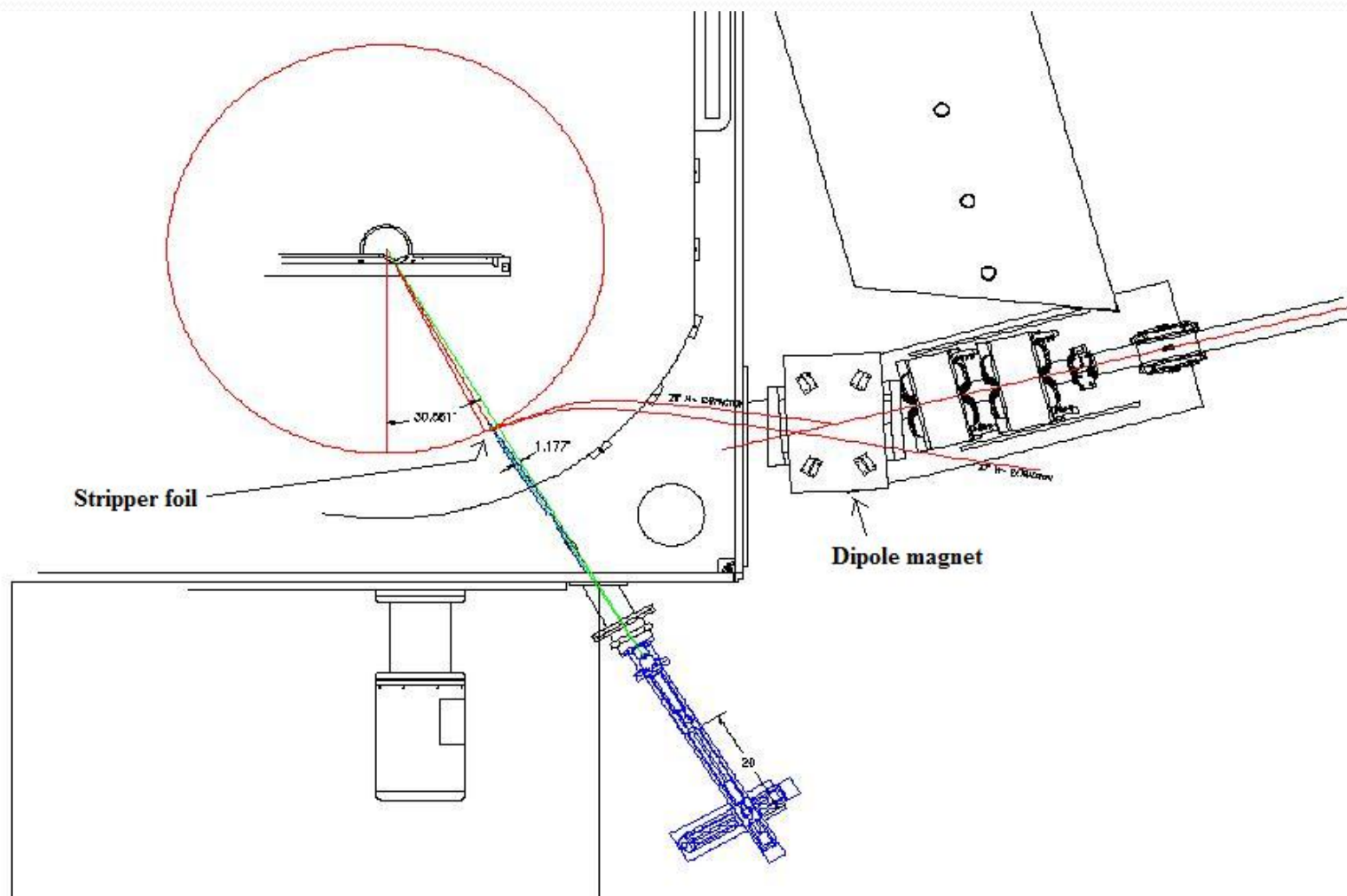
# Proton ( $H^+$ ) Production

- $H^-$  ion collides with Carbon foil 2 microns thick
- Electrons are stripped away
- Proton ( $H^+$ ) emerges from collision

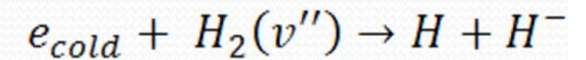
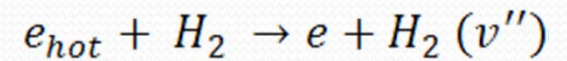
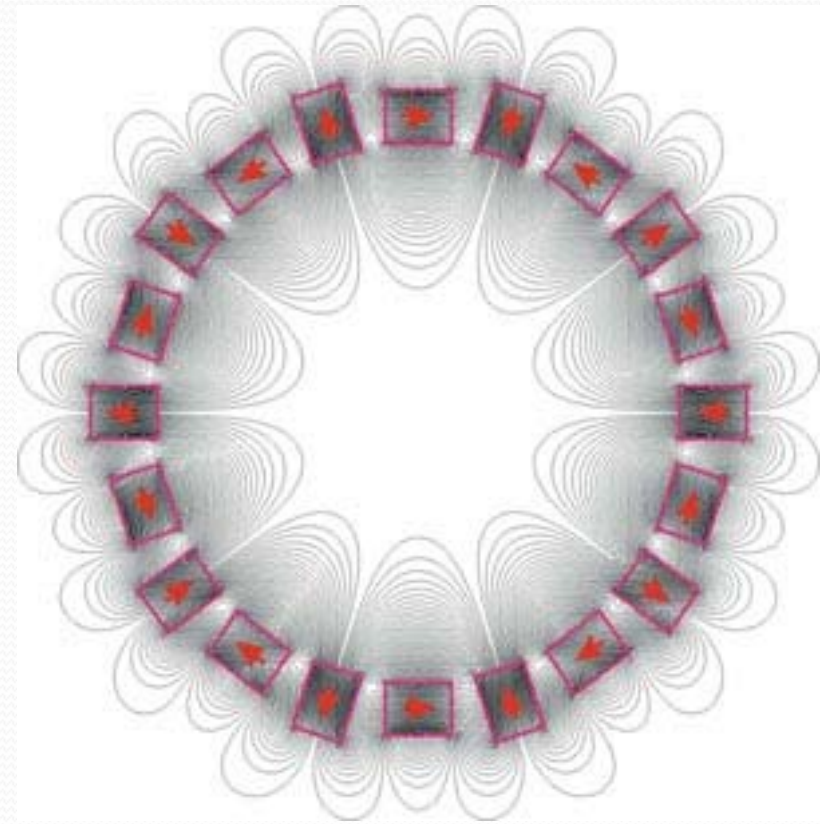
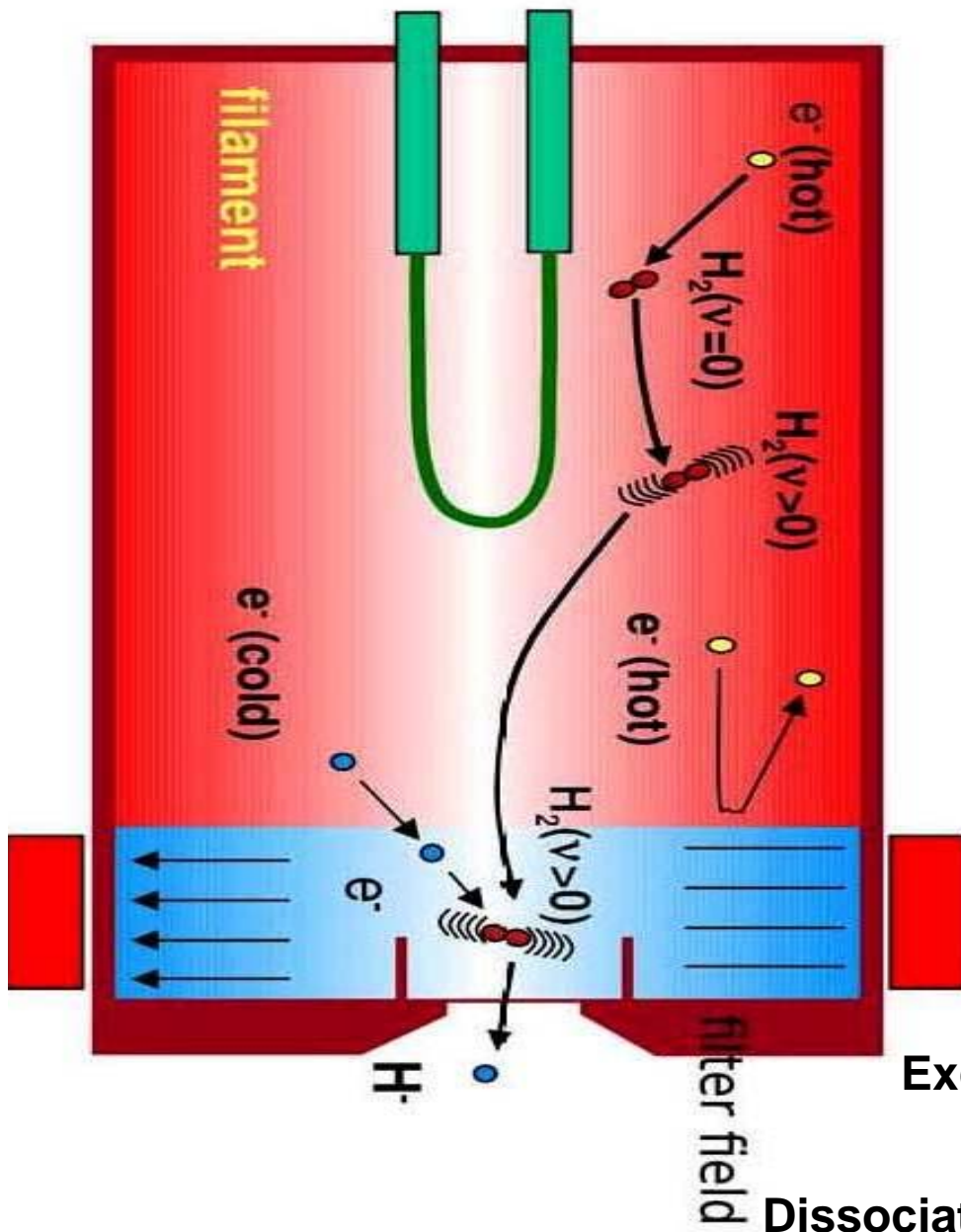




# Extraction of Protons



# But How to Get $H^-$ Ions?







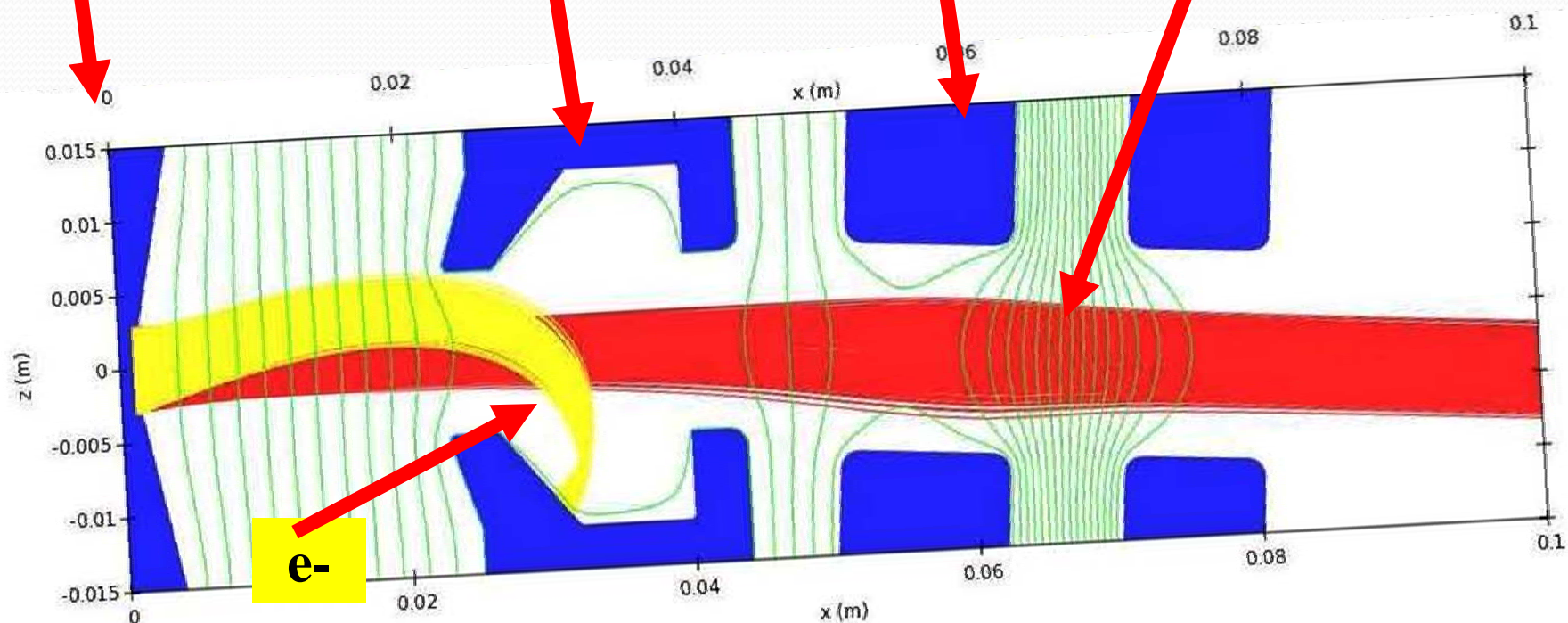
## Source “Tilt” suggested by Olli Tarvainen, JYFL

Plasma  
Electrode

Puller with  
 $e^-$  Dump  
Magnets

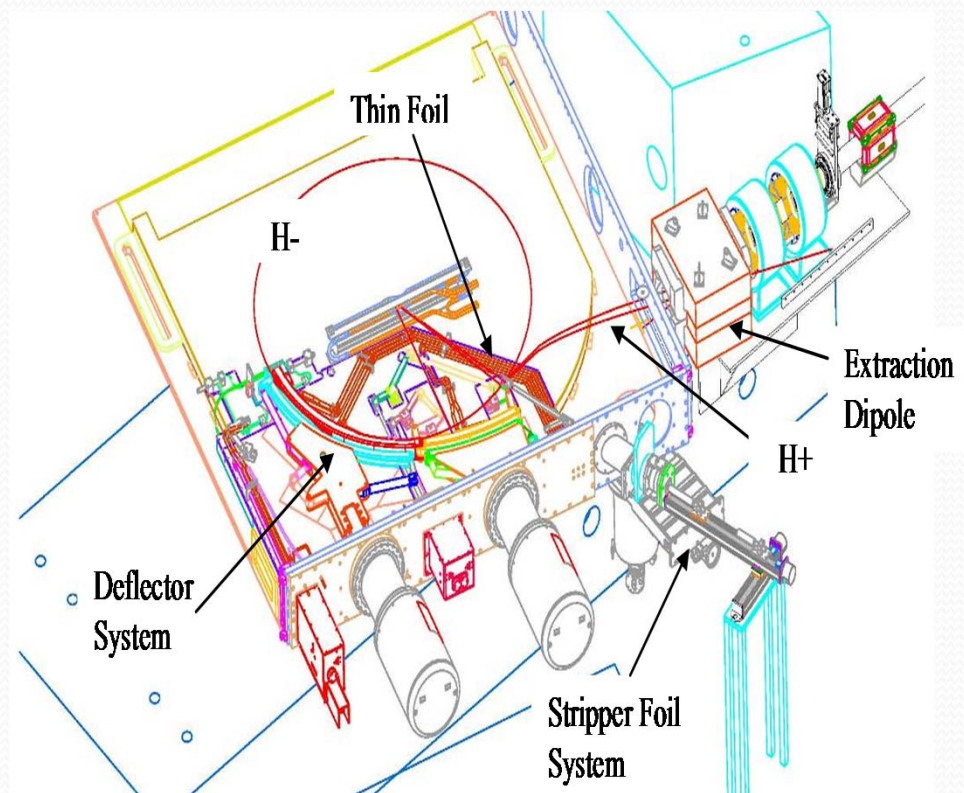
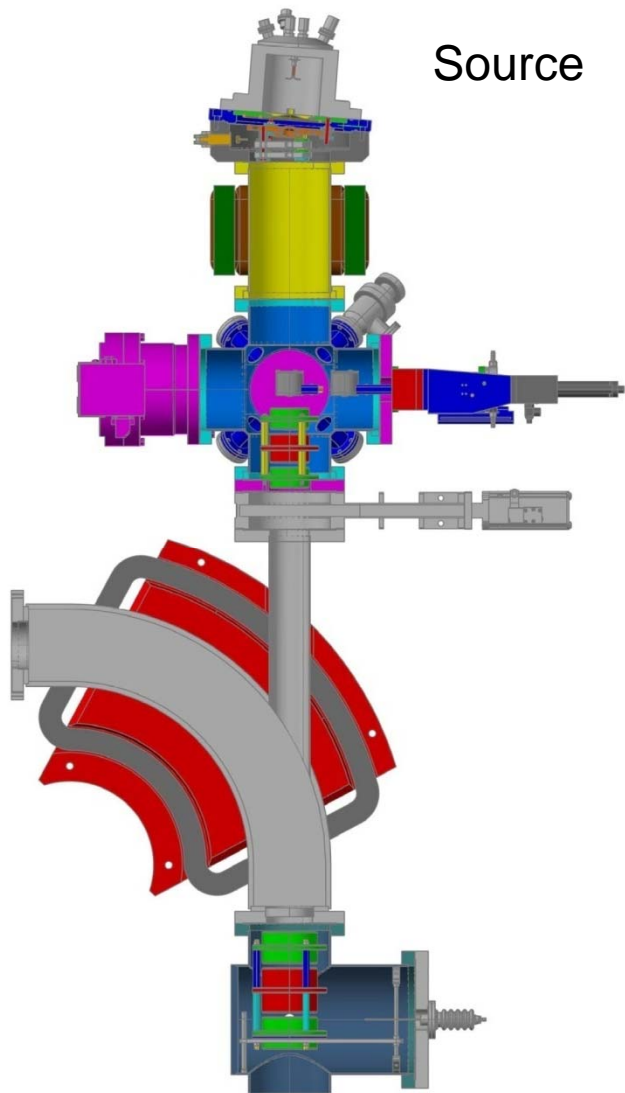
Einzel  
Lens

$H^-$   
ions





# Quick Recap





# Results From First Test

- 24.5 $\mu$ A at extraction for a brief moment
- 10 $\mu$ A at extraction, sustained – vacuum problems
- 60+ hours of filament use without failure



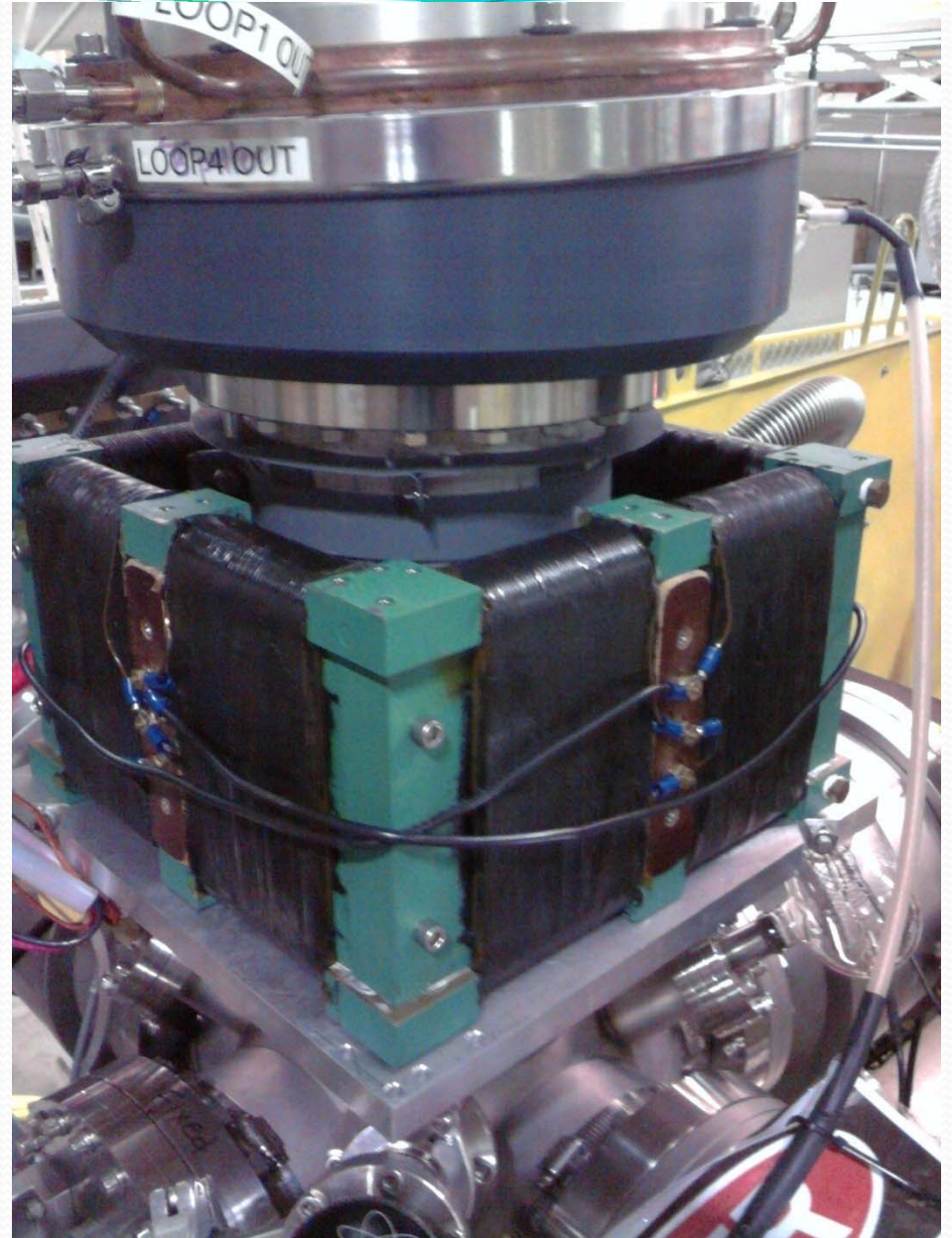




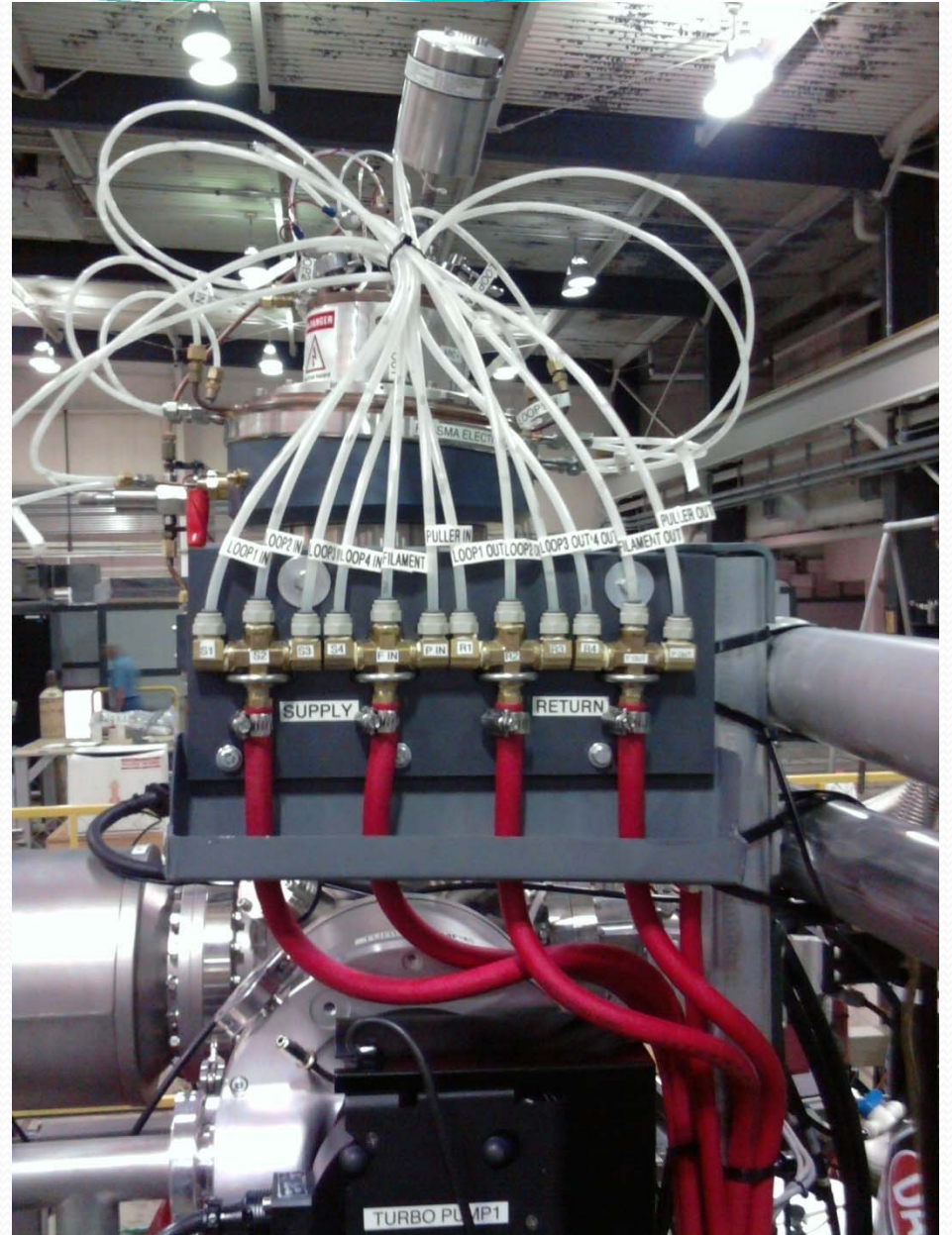
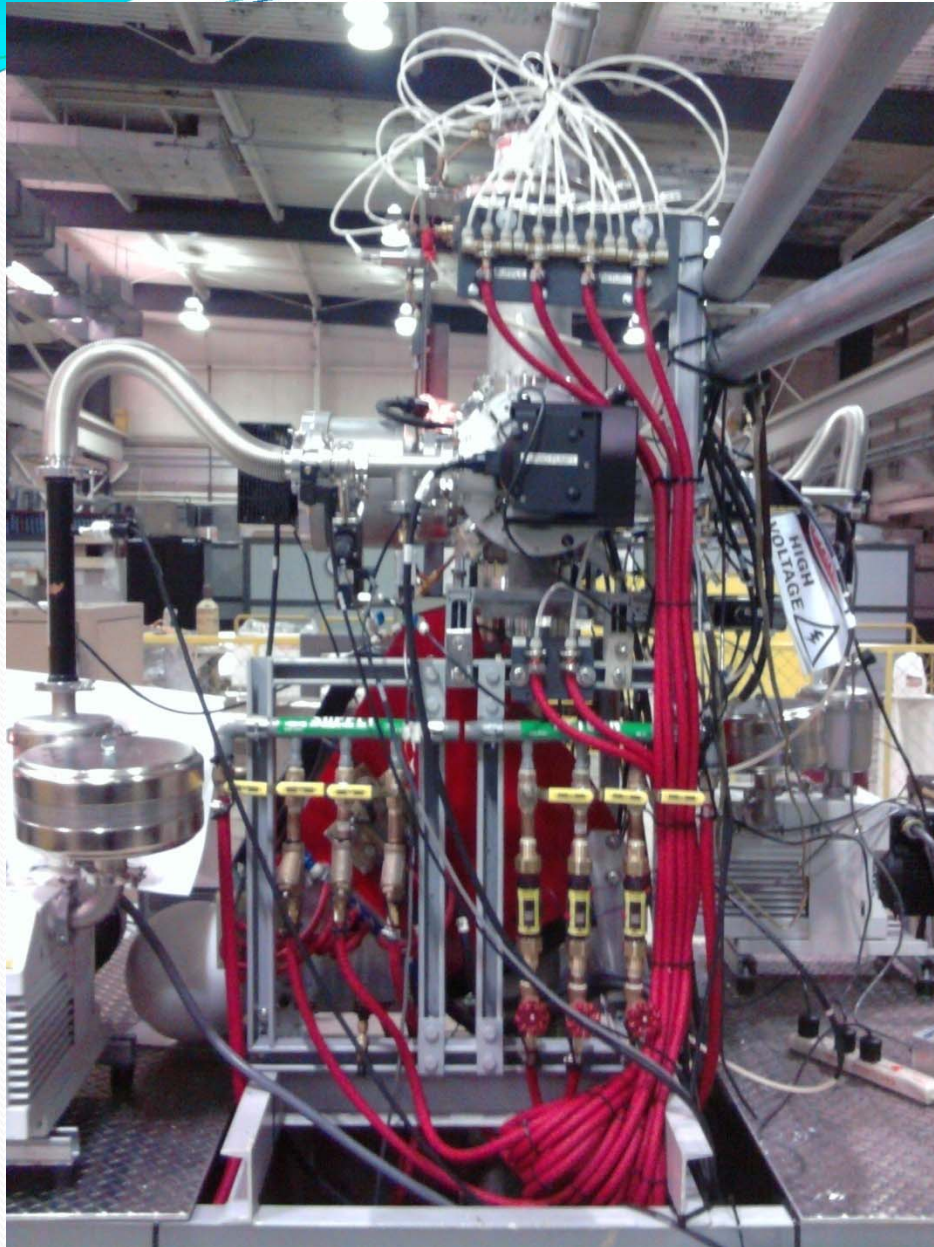
# Other Upgrades to the K150

- Installed spool, steering magnet, and platform
- Raised water cooling system – reduced clutter
- Installed door switches in HV cage – safety precaution
- Installed safety cage to isolate HV near source
- Installed gas lines, air lines, electrode covers, helped wire some interlock lines

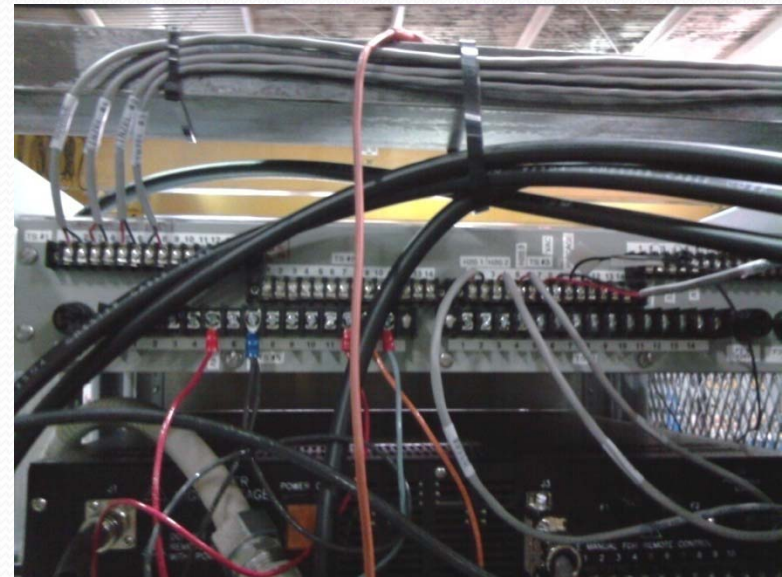
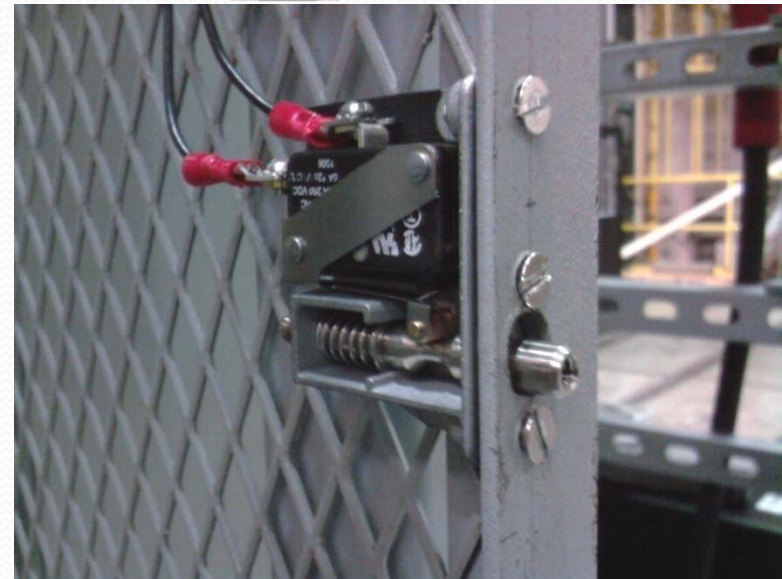




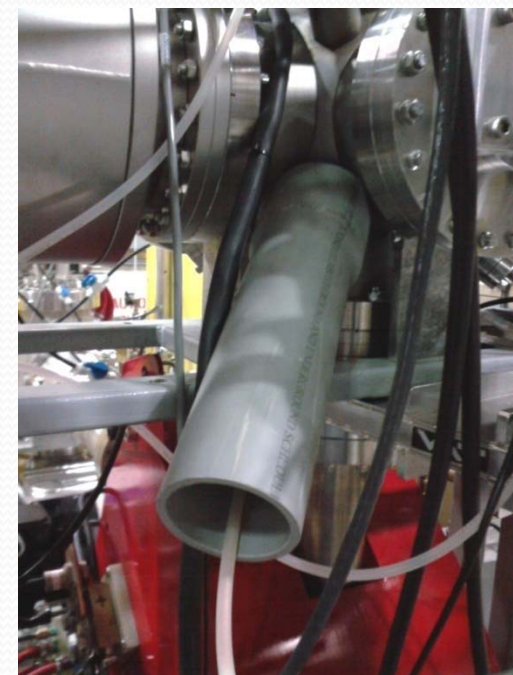
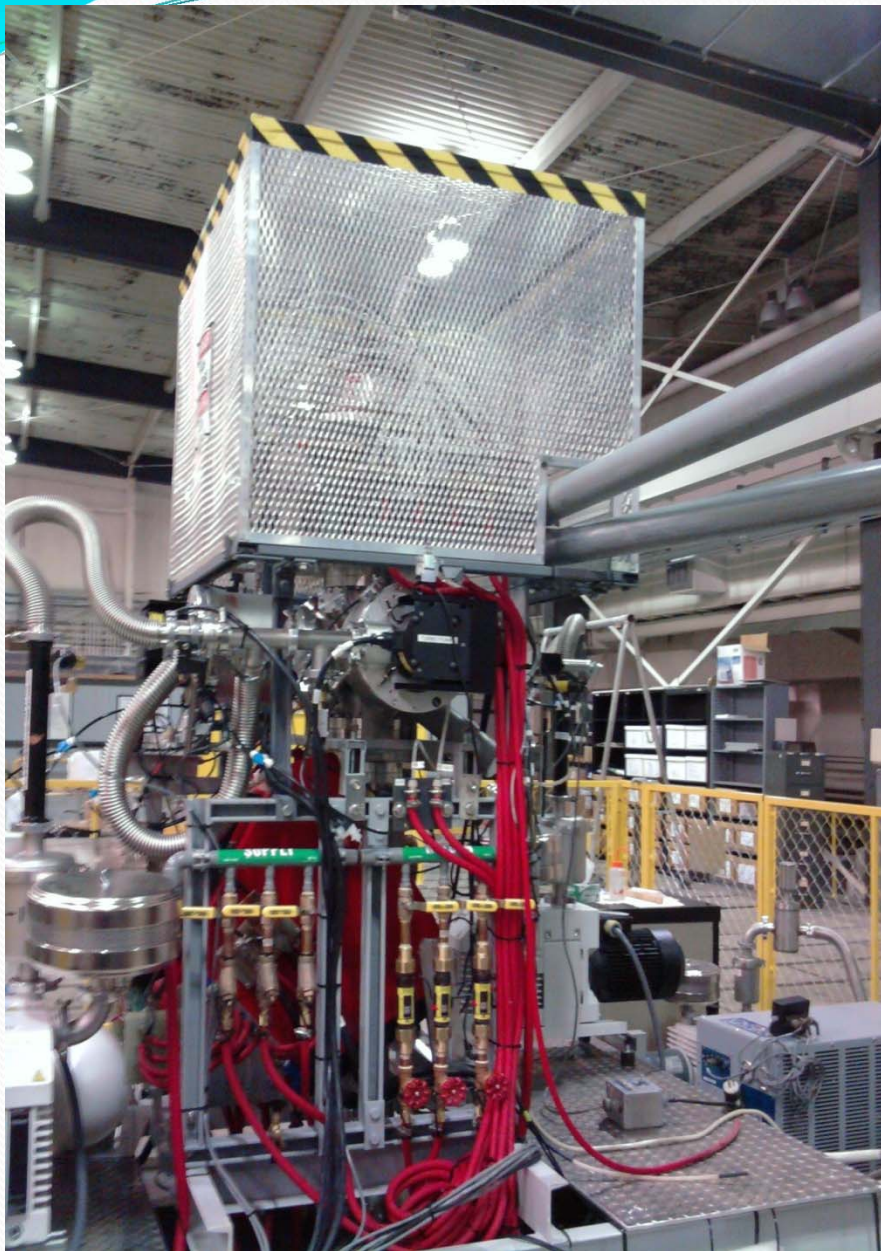
















# Future Work

- Test beam focusing, throughput down the beam line
- Joe Brinkley will develop program to optimize beam from source
- Improve ion source – filament is limiting factor
  - Inductively coupled rf-discharge
    - Eliminates filament
  - Inductively heated thermionic emission cathode
    - Extends the lifetime of the filament – further development needed



# Acknowledgments

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# Acknowledgments

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Questions?