Status of the 88-Inch Cyclotron High-Voltage upgrade project

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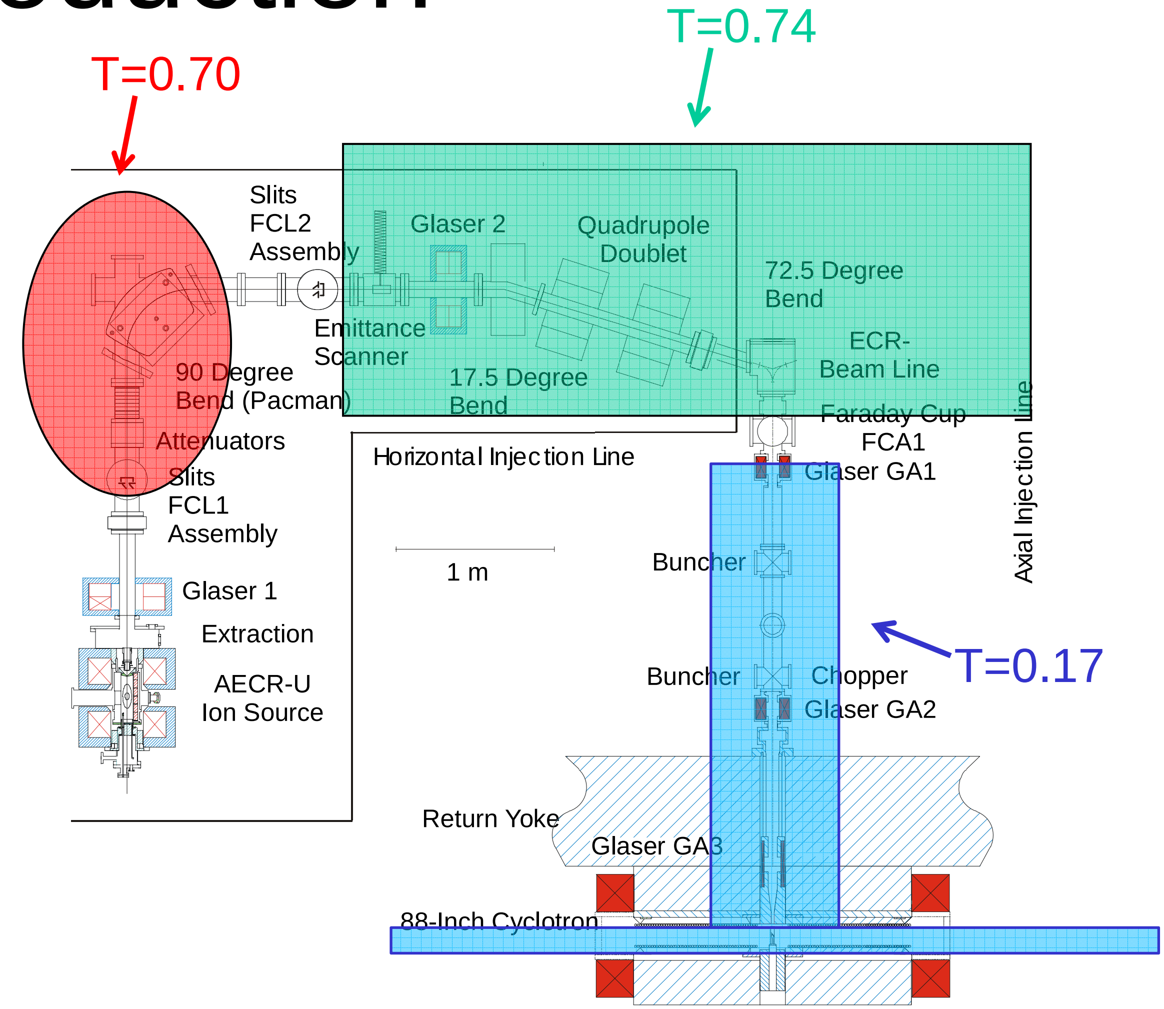
Introduction

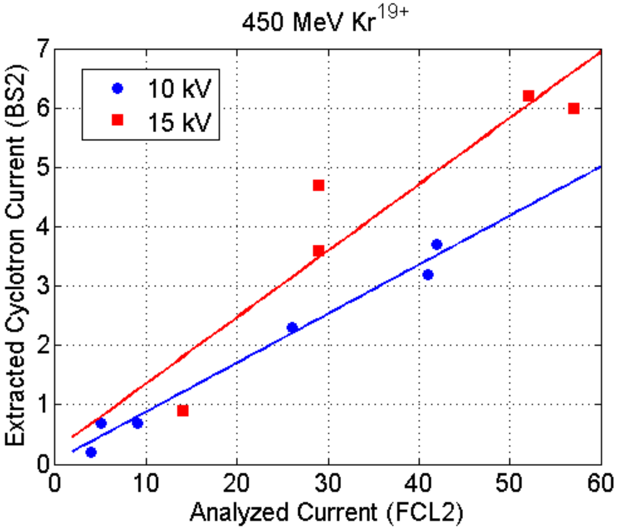
- Cyclotron beam intensity…
  - critical for some users (e.g. super-heavy element studies)
  - for others not really important (e.g. chip testing)... but they often want switch beam quickly
- Limited by injection beam line transmission between ion sources and cyclotron
  - E.g. $^{40}Ar^{9+}$, V_{source}=12.5 kV, 150 μ A at FCL2



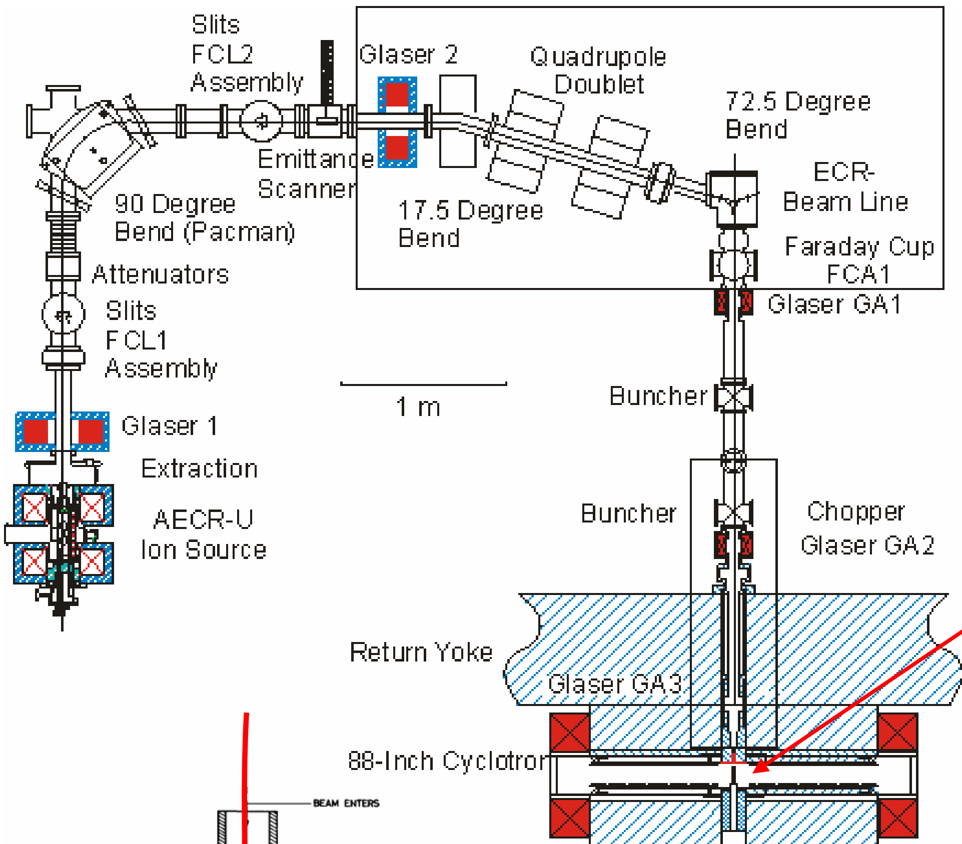
- Total transmission T= 0.70 x 0.74 x 0.17 = 9%
- Gets worse at higher beam currents….

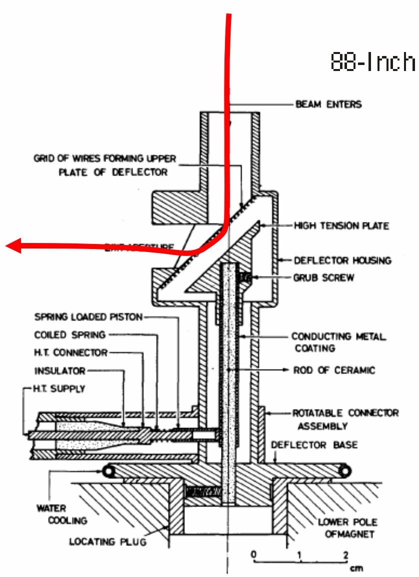
Goal of HV-upgrade

- Transport efficiency limited by space-charge effects
  - It helps to extract at higher voltage from ion source.
- Goal of HV-upgrade is to increase injection energy of key ion beams in the mid-range (20<A<136), in particular for ^{48}Ca and ^{50}Ti...
  - … without impacting performance for other cases.
- Target injection voltage is 25 kV (if feasible up to 30 kV) which should provide user with an improvement >2.



So what is stopping us?





Electrostatic mirror inflector

- Major culprit in achieving HV injection.
- Purpose is to deflect the beam 90° .
- Consists of 47° grid and electrode.

Mirror inflector pros and cons

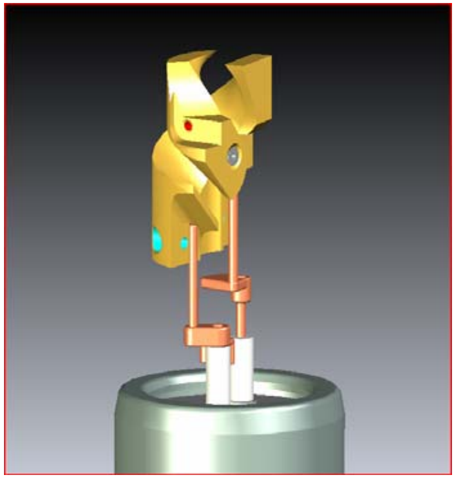
Pros

- Versatile
- Straightforward
- Easy to model

Cons

- Needs high voltage but current one does not go up to more than ~15 kV
- Output beam center of curvature too far from cyclotron center at high energies
- Grid degradation (sputtering)

Use spiral inflector for high-intensity runs



Pros

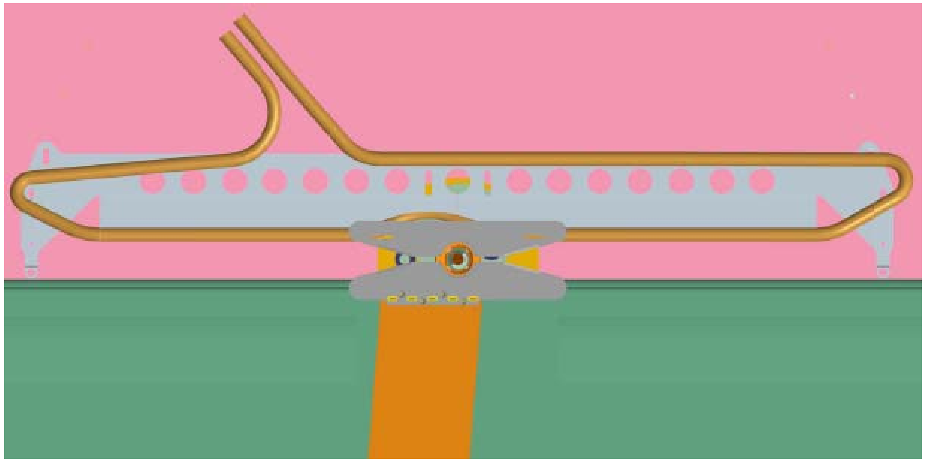
- 100 % transmission
- Lower voltage → Can do HV injection
- Injected beam more centered

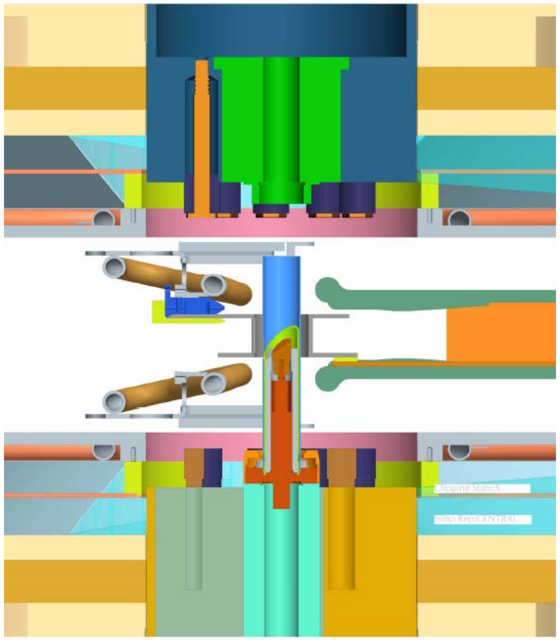
Cons

- Narrow operational range
- Causes emittance growth due to fringe field effects
- Difficult to manufacture
- Difficult to model

Preliminary Design of Spiral Inflector and Cyclotron Center Region Electrodes

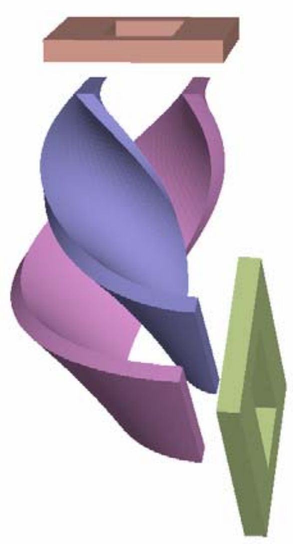
- Based on extensive 3D FEA modeling
  - Iterative process
- Major challenges are
  - Geometrical constraints
  - High injection energy
  - Compatibility with mirror mode operation

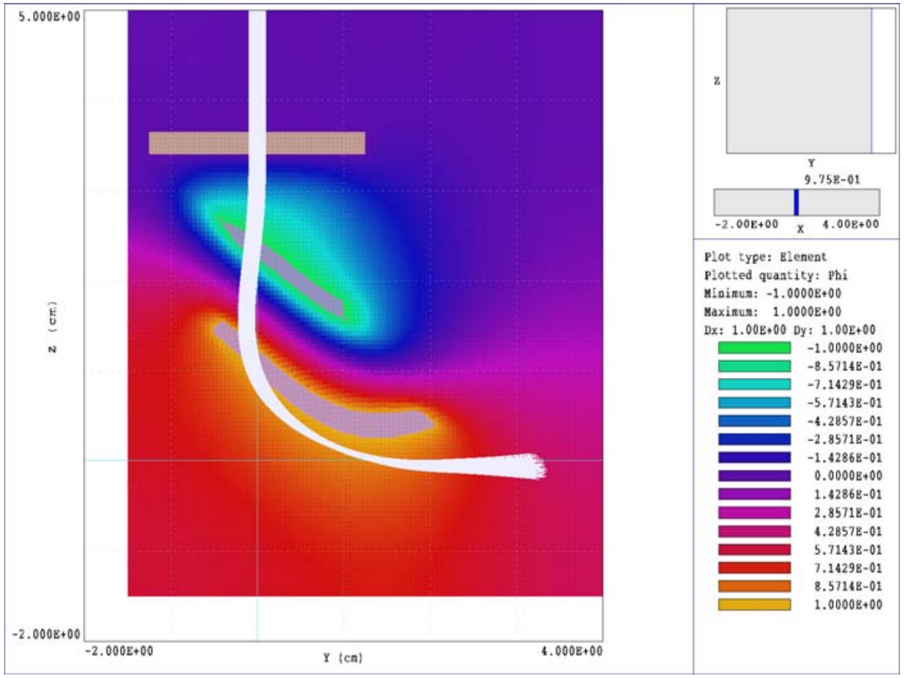




Spiral inflector modeling procedure

1. Create FEA 3D model of a general spiral inflector based on an analytical single particle model.
2. Define potentials applied to all bodies and calculate electric fields in 3D.
3. Track beam through electric fields with a superimposed magnetic field.

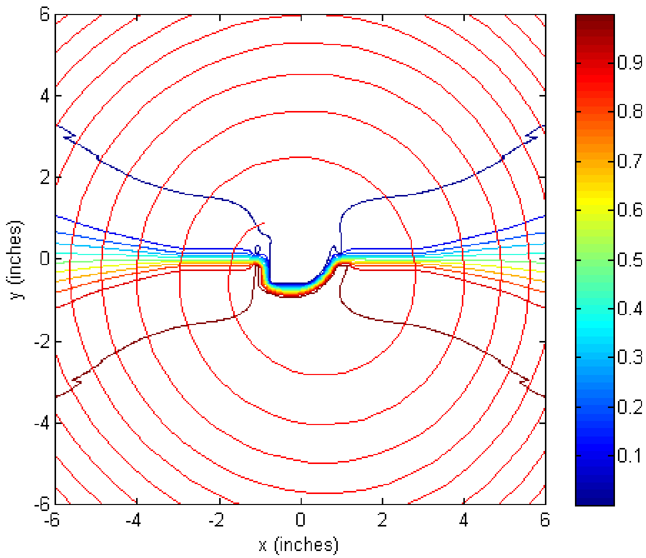


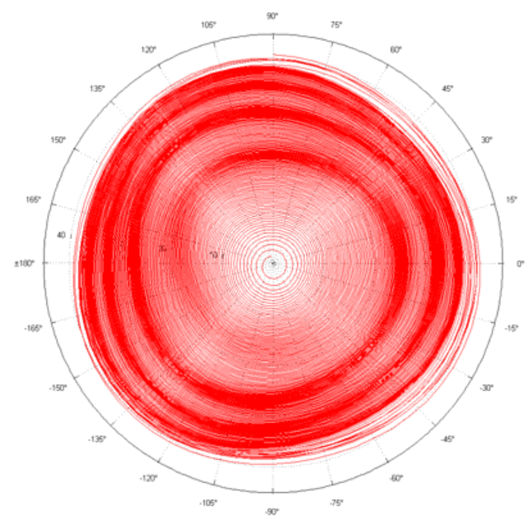


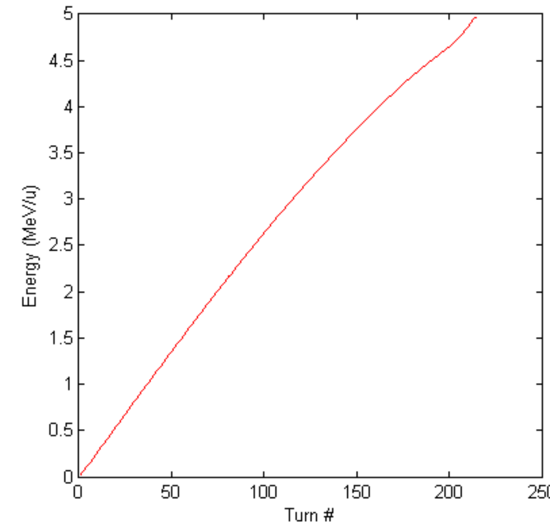
Cyclotron modeling procedure

1. Use a code from MSU (Z3CYCLONE) to track the beam from the center region all the way out to extraction.

2. Calculate the performance of each design in terms of transmission and energy.

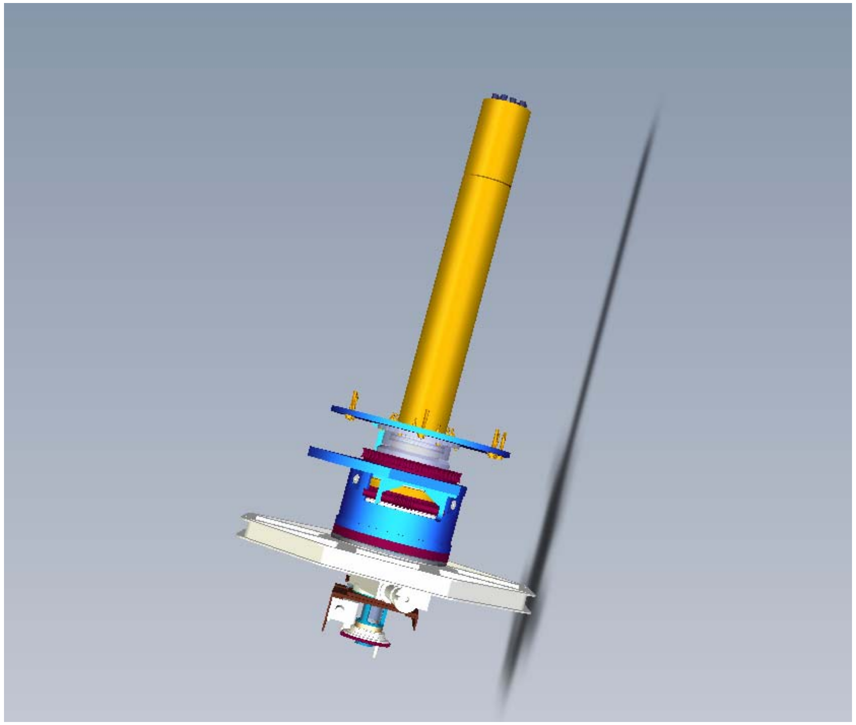


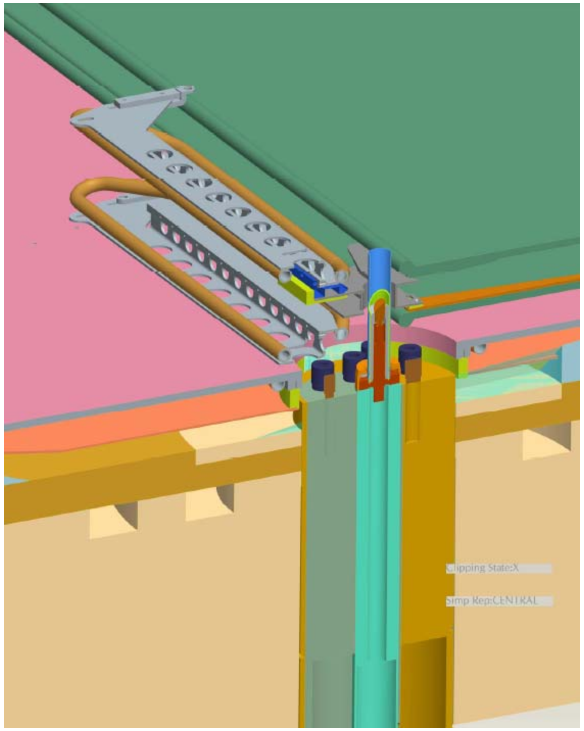




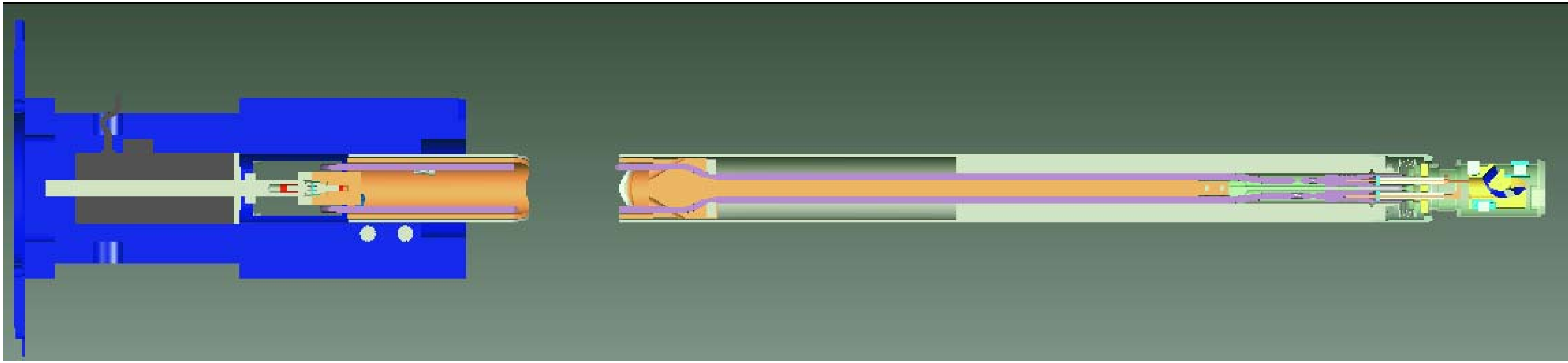
Center Region Positional Mechanism Modeling and Testing

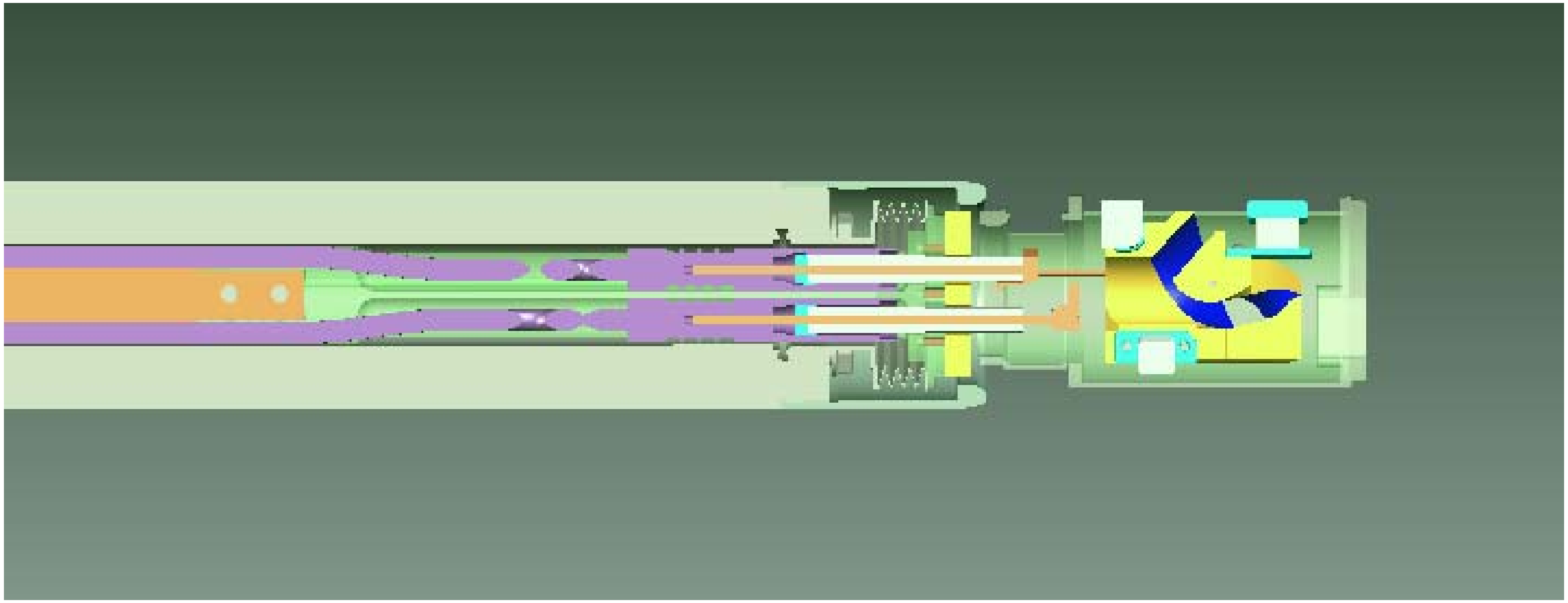
- The platform supporting the spiral inflector needs to be positioned differently than for the mirror inflector.
  - Requirement is to swap within two hours between systems
- Will use existing mechanism which is presently being tested during a five week shutdown.
  - Has not been used for many years.





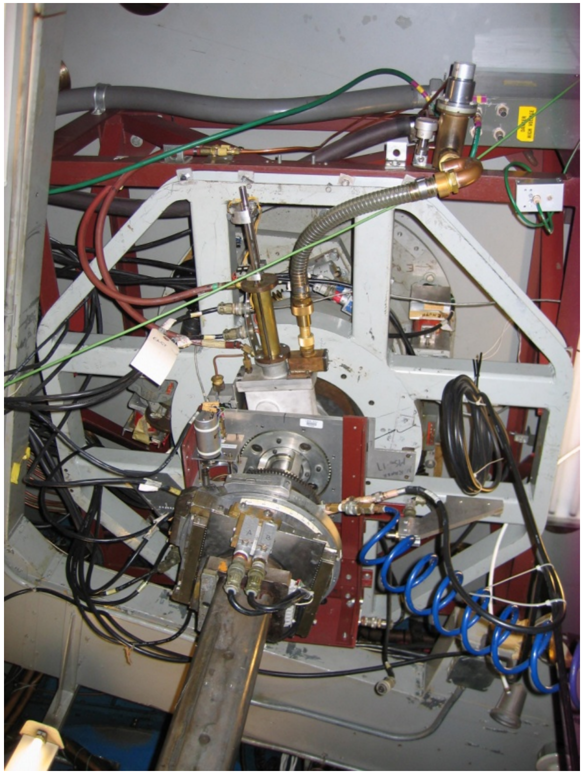
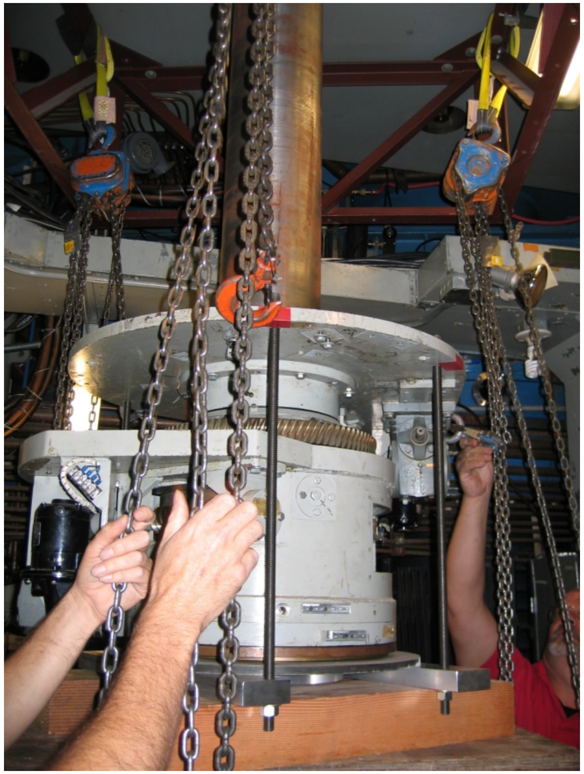
Shaft design





Work in progress…

- Mechanism was tested before removal.
- Changing gaskets and servicing gears.
- Cyclotron back on-line September 21.


Project Schedule

Phase	Description	Start	Finish	DOE Milestones	Comments
1	Requirement Analysis	Aug 2009	Sep 2009	Sep 2009	Done
2	Preliminary Design	Sep 2009	Jun 2010	Dec 2010	In progress. Exit review required.
3	Design	Apr 2010	Nov 2010	May 2011	Exit review required.
4	Manufacturing	Nov 2010	Mar 2011	May 2012	
5	Installation	Mar 2011	May 2011	Jul 2013	In parallel with Ops
6	Testing	May 2011	Jan 2012	Sep 2013	During shutdowns
7	Operation	Jan 2012			

Conclusion

- HV injection upgrade project is on track.
- Design close to being finished.
- Test and service of mechanism for positioning of new inflector close to being finished.
- Initial Operation targeted for early 2012.