EBIS Status and Improvements

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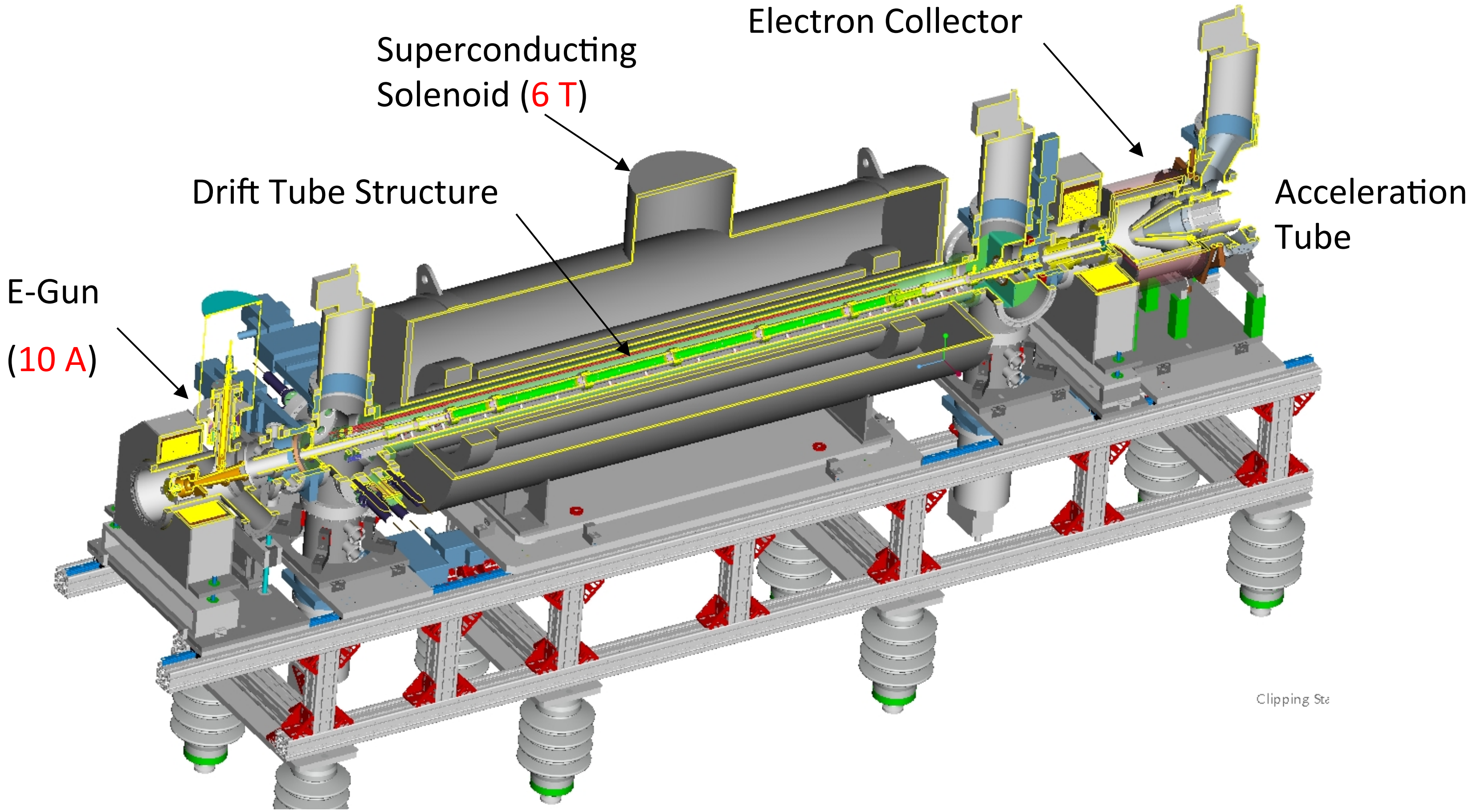
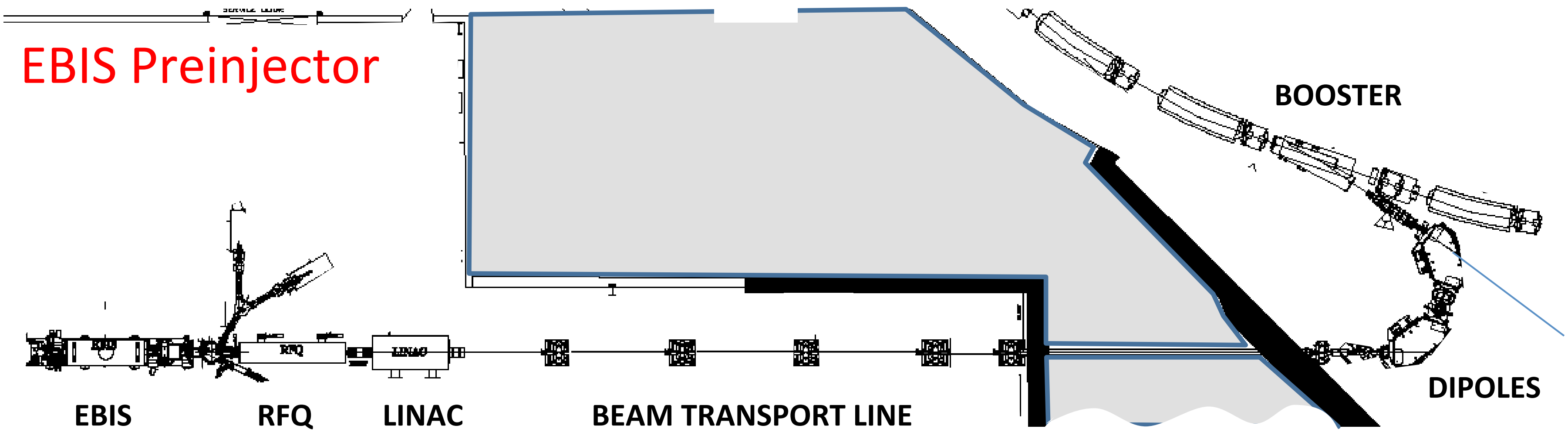
EBIS running for NSRL
Status of intensity, improvements
Laser source; Polarized He-3 activities
RHIC (Au-D or Au-He3)

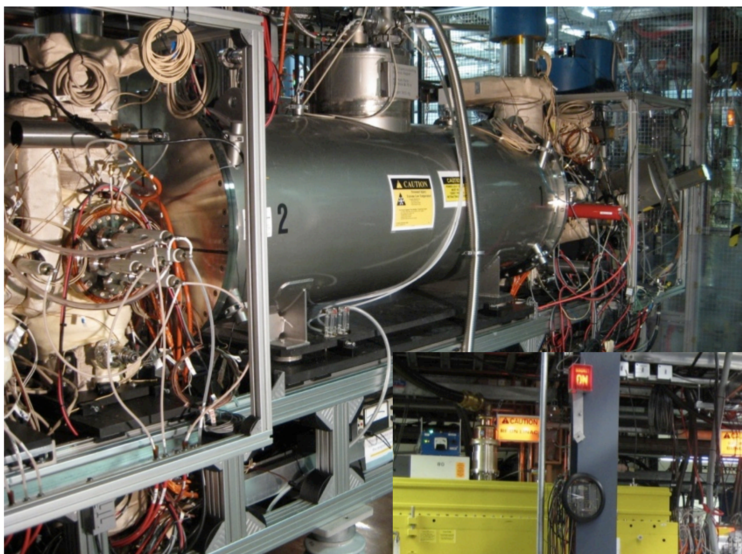
Electron Beam Ion Source (EBIS) – produces high charge state heavy ions

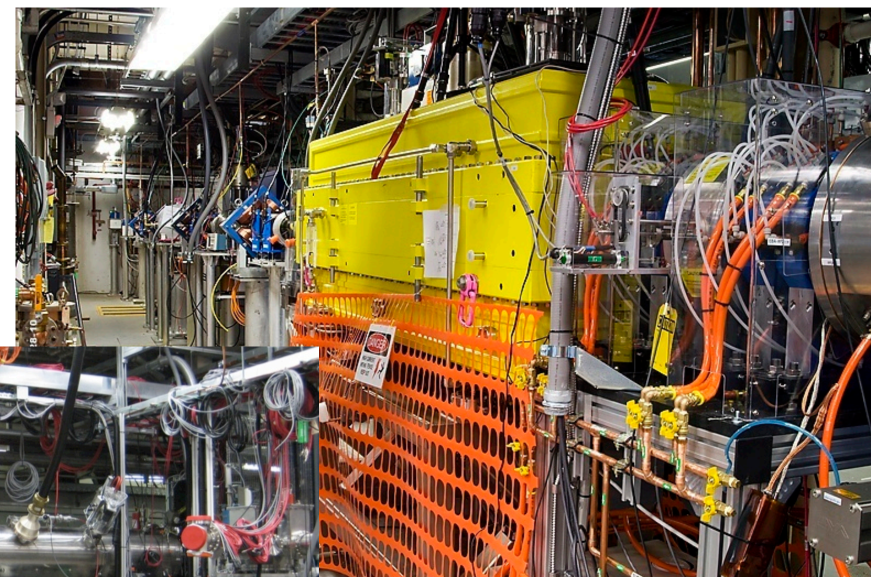


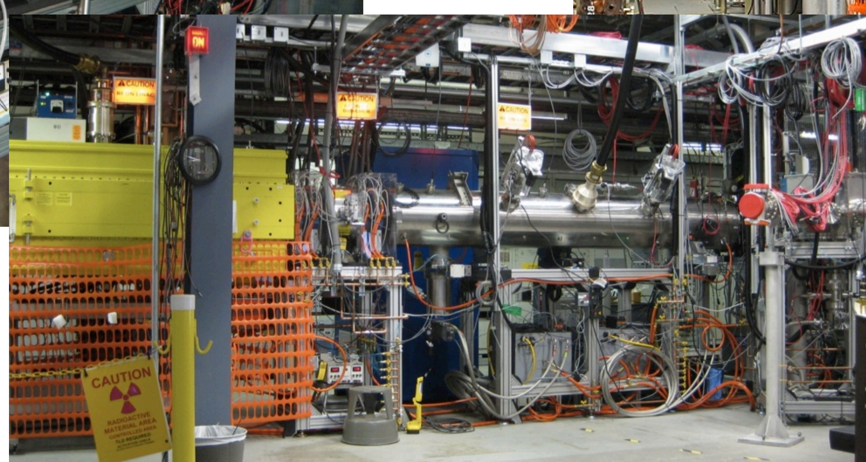
Provided U-U and Au-Cu for 2012 RHIC run
Some ions for NSRL starting in 2011; all NSRL ions in 2013

EBIS Preinjector









Acceleration to 2 MeV/u for injection into Booster

2012/2013 NSRL Running

NSRL 12C:

21 days; Fe, C, Ti, O

Only Si came from Tandem

NRO:

11 days; Ta, Fe, Kr, Xe, Au (all from EBIS)

NSRL 13A:

34 days; Ti, Fe, Si, C, O, Au, He (all from EBIS)

NSRL 13B:

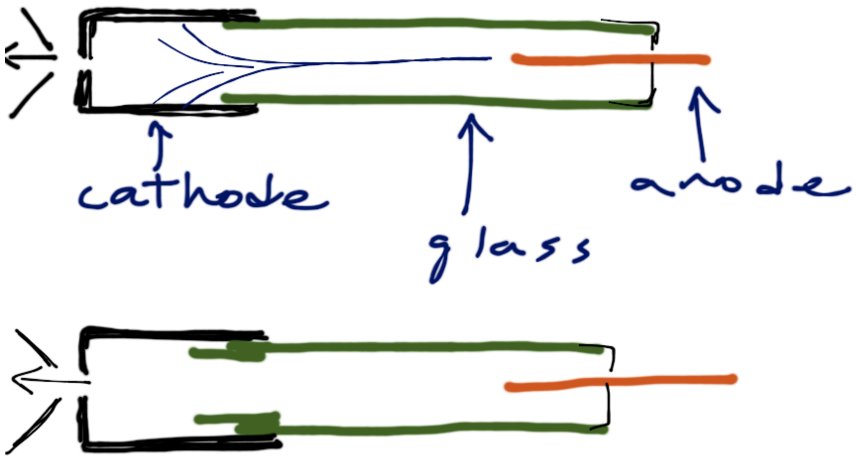
19 days; Fe, Ti, Si (all from EBIS)

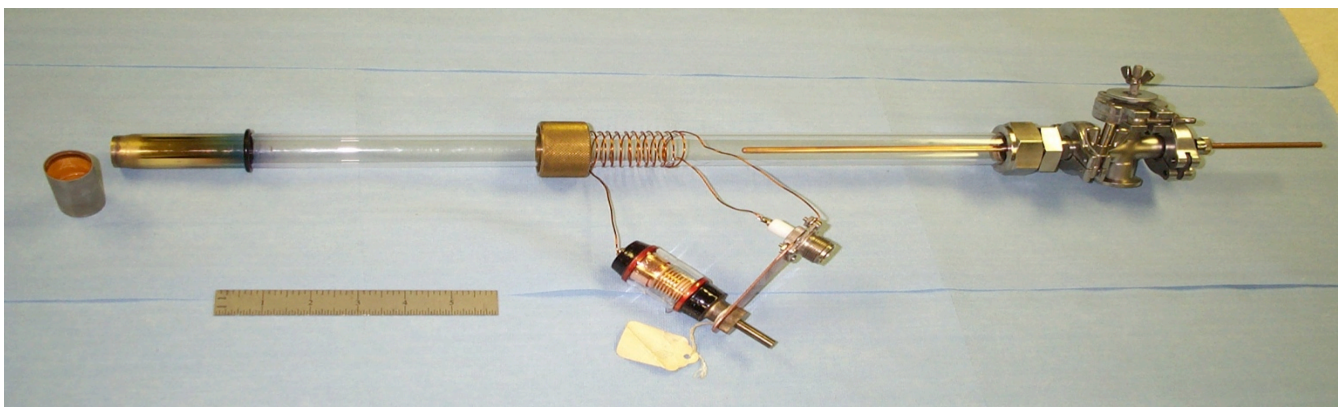
Total 85 days, 10 different species

(also did He-3 for AGS between 13A and 13B)

- Downtime was minimal during the NSRL running
  - RF amplifier trips a few times/week
  - Sometimes beam pulse-to-pulse stability problems
  - LEBT Solenoid pulser trips (near the end; loose wire into PLC)
- The electron gun cathode had to be changed between 13A and 13B
  - Cathode had been in since July, 2011. Developing partial short, intermittent
  - May 10 – opened and changed. May 11-13 – bakeout May 14 – ramp up magnet and run He-3 to Booster by end of day.
- C and Si were new EBIS beams this year

Hollow cathode ion sources used to produce 1+ ions

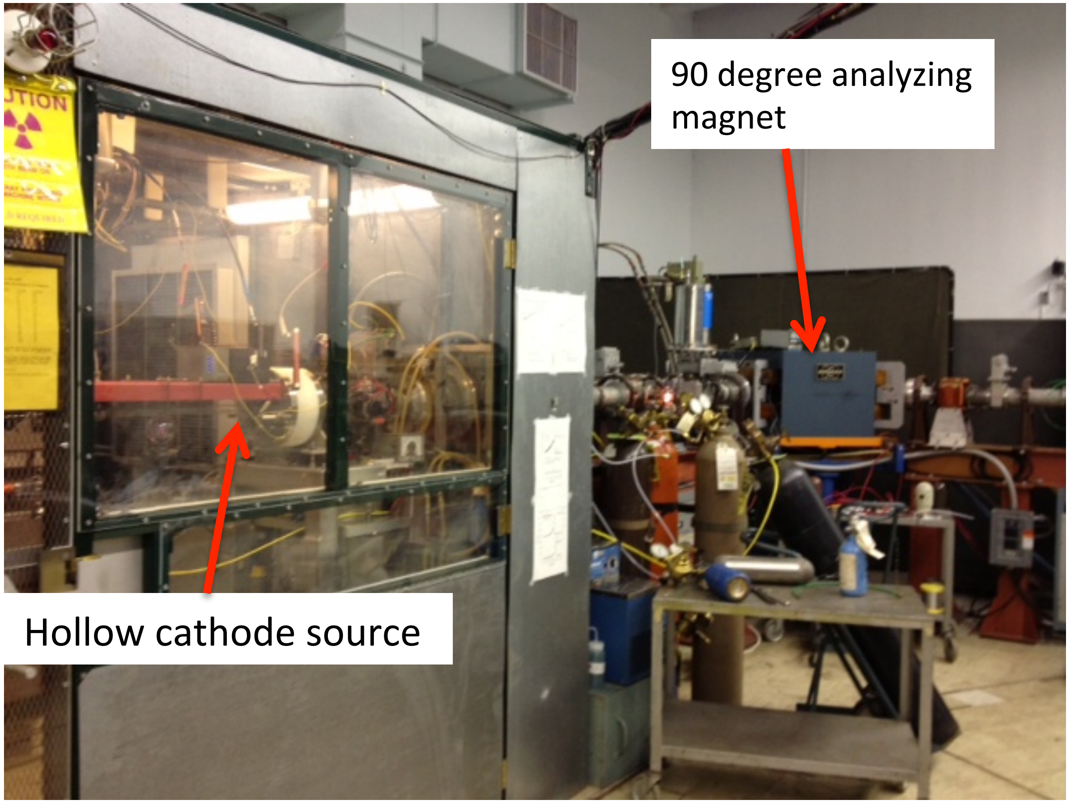




- Discharge of neon, argon, etc. working gas
- 1+ ions produced either from the working gas, or sputtering of the cathode : Au (foil), solid U, Fe, C, etc.

Finding the best way to to produce Si 1+ in the hollow cathode ion source was a challenge this year (ions produced by cathode sputtering vs. Si is an insulator).

An ion source test stand at the Tandem was modified so a spare EBIS 1+ source (hollow cathode ion source) could be run there (C. Carlson, et.al.).
90-degree dipole allowed precise analysis of the content of the extracted ion beam.

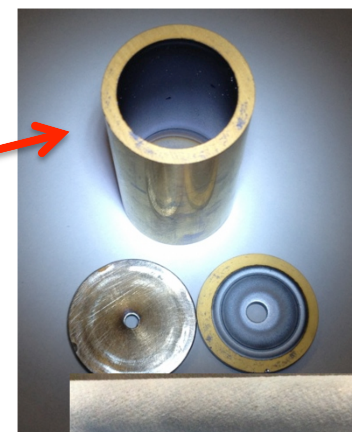


Both at Tandem test stand, and on EBIS, we have tested:

- Silicon
- Boron-doped Si
  - (with and without Au coating)
- Si (14%)/Fe(86%) alloy
- Hexamethyldisilane **$(CH_3)_3SiSi(CH_3)_3$**
  - (vapor is added to the working gas)

Cathodes were tested with He, Ne, Ar, and Kr as the working gases for the discharg.

First 5-day Si for NSRL – used Au coated Si
Second 5-day run – Hexamethyldisilane
Third 5-day run – Si/Fe alloy



All were ok, but none were “perfect”.
We’ve just begun testing of the Si(80%)/Cu(20%), and it looks promising.

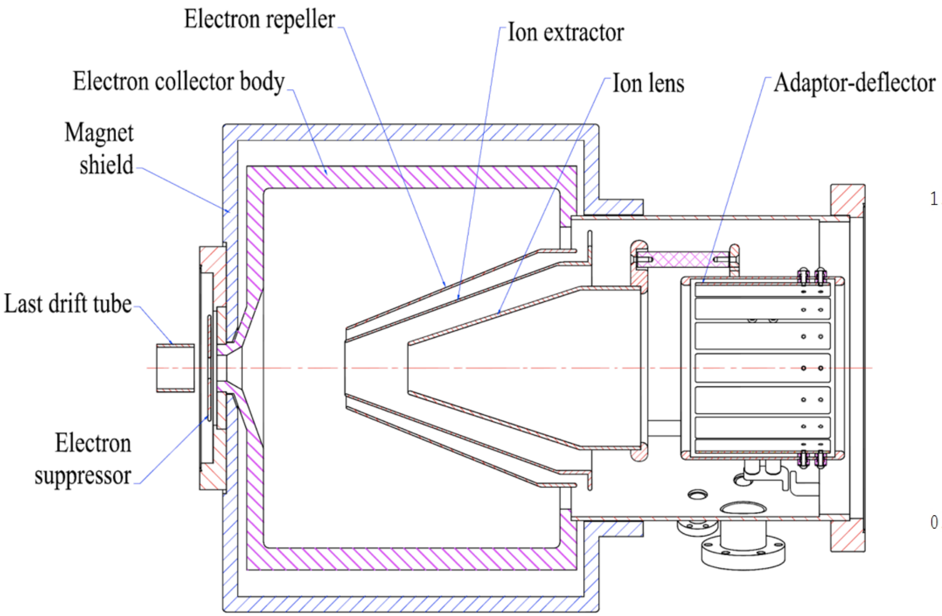
Fifteen EBIS beams have been used to date

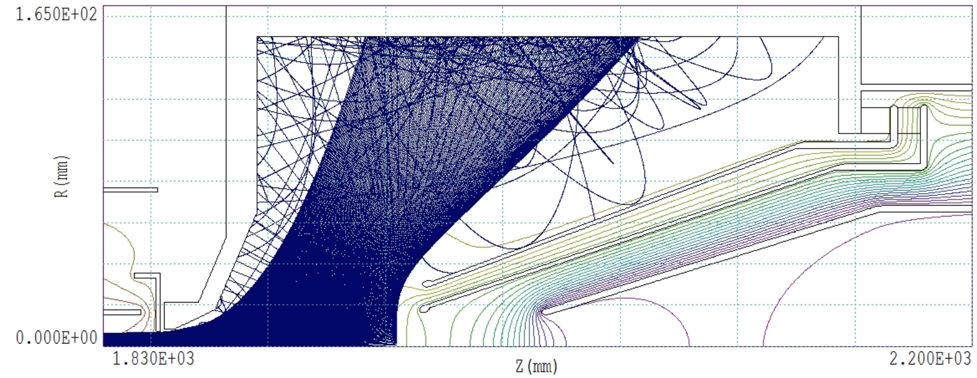
- **He-3 2+ AGS**
- **He-4 1+, 2+ NSRL**
- **C 5+ NSRL**
- **O 6+ NSRL**
- **Ne 5+ NSRL**
- **Si 11+ NSRL**
- **Ar 11+ NRSL**
- **Ti 18+ NSRL**
- **Fe 20+ NSRL**
- **Cu 11+ RHIC**
- **Kr 18+ NSRL**
- **Xe 27+ NSRL**
- **Ta 38+ NSRL**
- **Au 32+ RHIC & NSRL**
- **U 39+ RHIC**

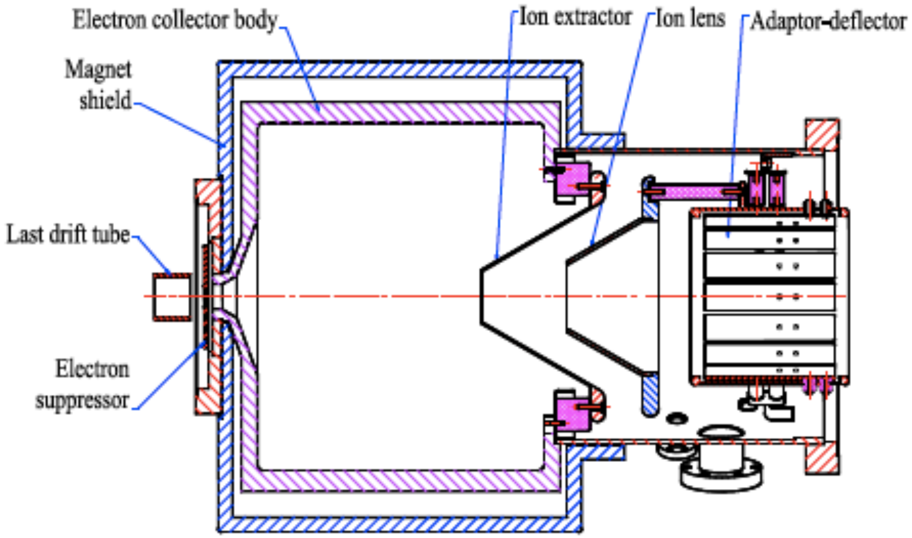
EBIS work – summer 2012

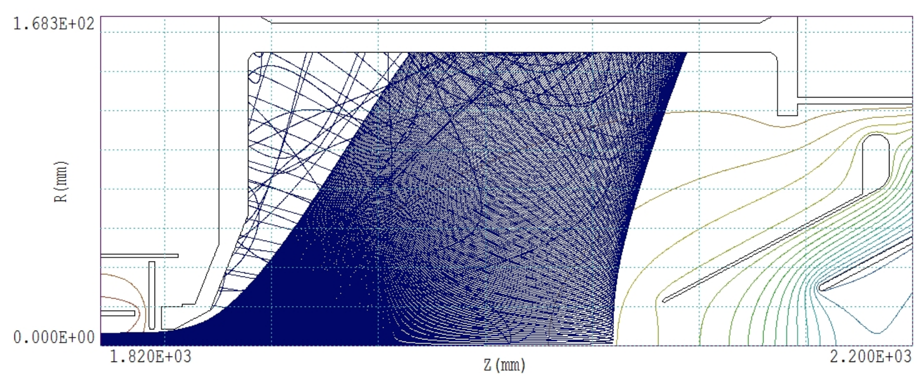
- Vacuum
  - Fixed shorted NEG in EBIS trap bore, and activated
  - Fixed leaky cryo valves. Replaced cryos (faulty charcoal arrays).
  - Replaced cracked feedthrough
  - Baked the source
  - Electron collector electrode modification to reduce gas load
- Diagnostics
  - Profile monitor added in LEBT
  - Faraday cup added directly after the RFQ

Electrodes in collector modified to reduce heat load (problem arising from backscattered electrons).



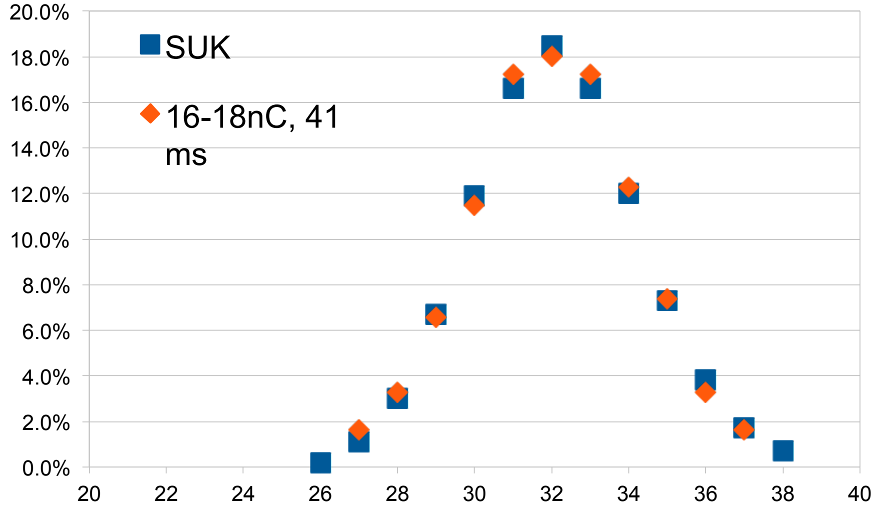






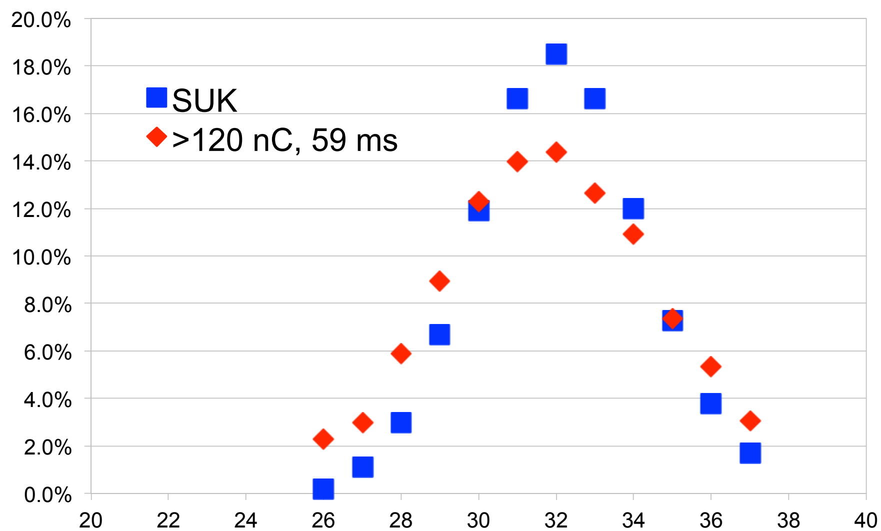
Bottom line…

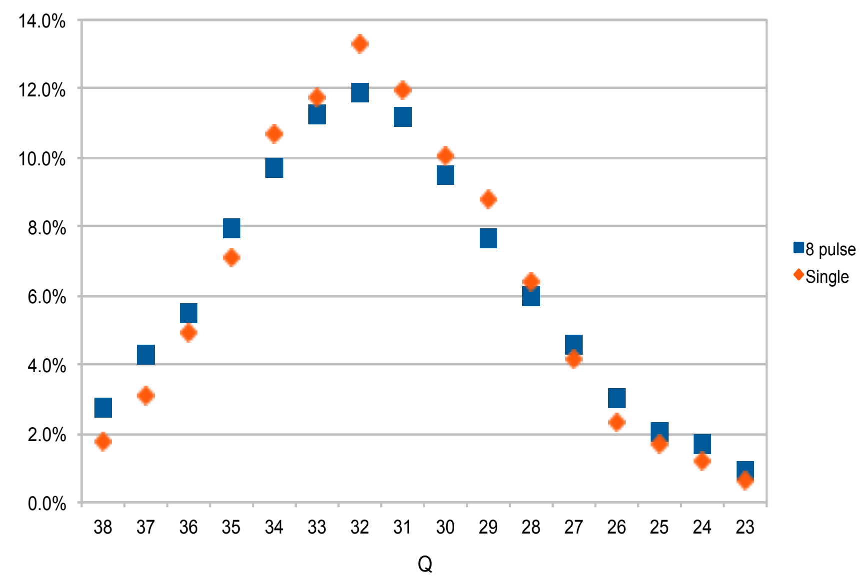
- There has not been any gain in intensity since the last RHIC run
  - Collector electrode change/vacuum work last summer – helped vacuum, but not bottom line.
- Charge state distribution – compared 1 pulse vs. 8 pulse - not too different....
- Added another FC in MEBT – more reliable reading, but consistent with previous measurements
- Added multiwire in MEBT – beam looked ok



Au ions - measured charge state distributions (orange), vs. calculated (blue, R. Becker code), which assumes 100% overlap of ions with electron beam

Test at reduced charge - measured distribution matches calculated





Normal running at >50% of capacity gives ~14% in desired charge state vs. 18.5% calculated.

1 pulse/5 seconds vs. 8 pulse, 5 Hz burst every 5 seconds – Au^{32+} reduced to ~12%

12% vs. 18.5% = 65% of design

Recent He-3 Performance estimates

- EBIS to RFQ input: 66-90% of expected value (for measured 1+/2+ ratio)
- RFQ transmission: 50-60% (expect 70-80%)
- MEBT/Linac transmission: 65-70% (expect 90-100%)
- ETB transmission: 95-100% (expect 100%)

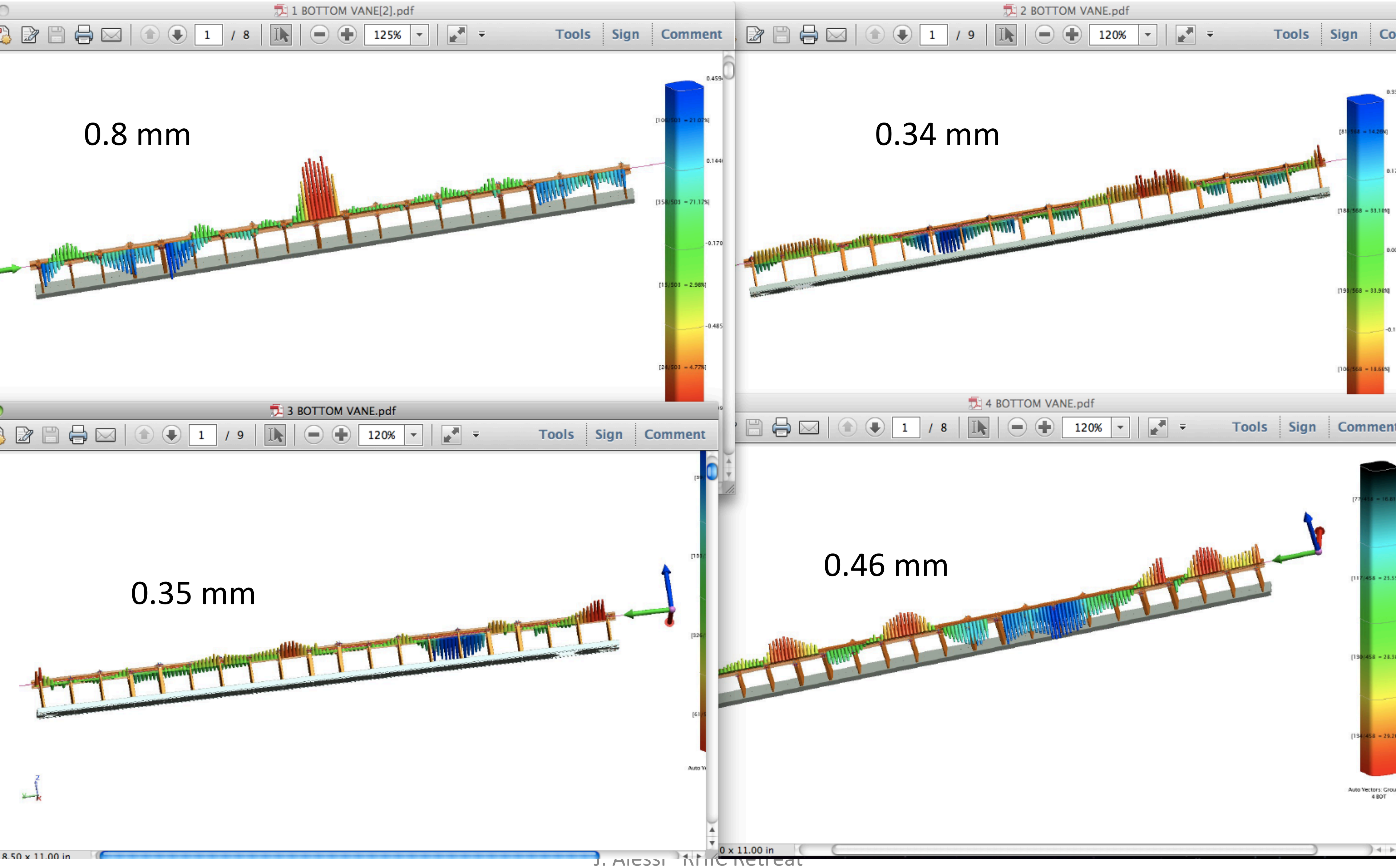
Summer 2013 (in the 4th week since NSRL ended)

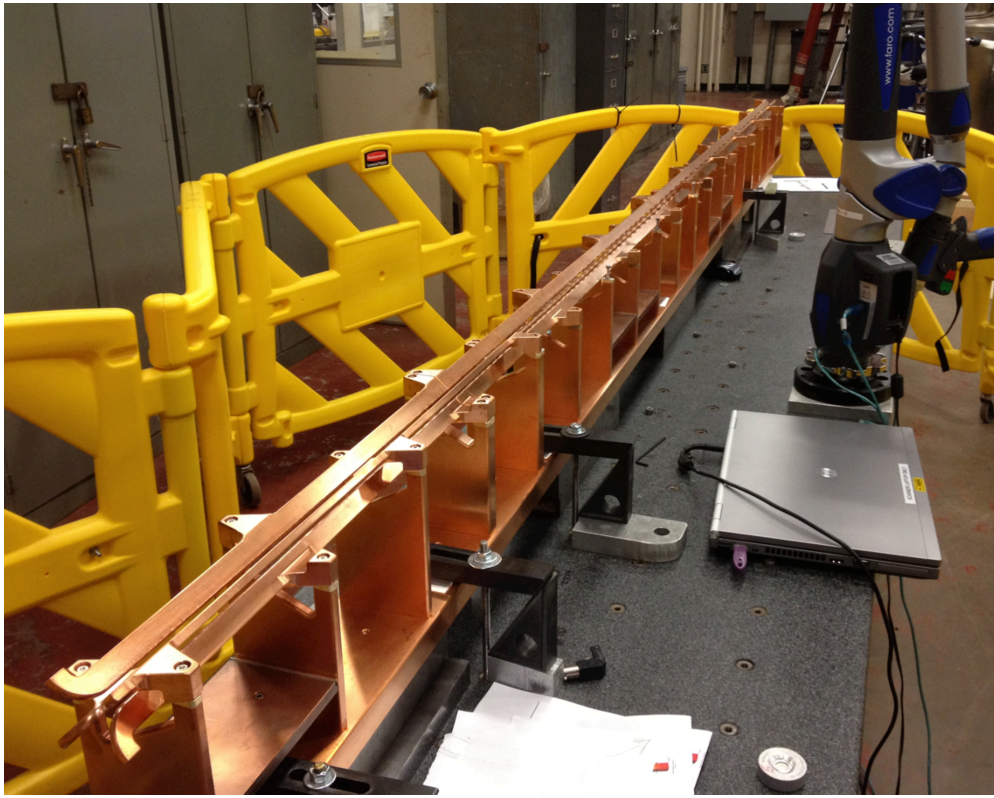
- RFQ has been moved off axis, vanes removed from cavity
- RFQ vane assembly is being measured and realigned
- While RFQ is out, putting an emittance head at the RFQ entrance location to measure EBIS emittances
- While RFQ is out, Animesh, et.al. have put a vibrating wire measurement system in place to find magnetic centers of MEBT, linac, and triplet after linac (10 magnets), and they will then be realigned based on these measurements.
- Once lifting fixture is completed, the linac cover will be opened and Survey Group will measure position of drift tubes (also look for areas where there is sparking)

Great cooperation from Survey Group, Magnet Division, help from Tandem, Don Von Lintig, etc.

First vane measurements:

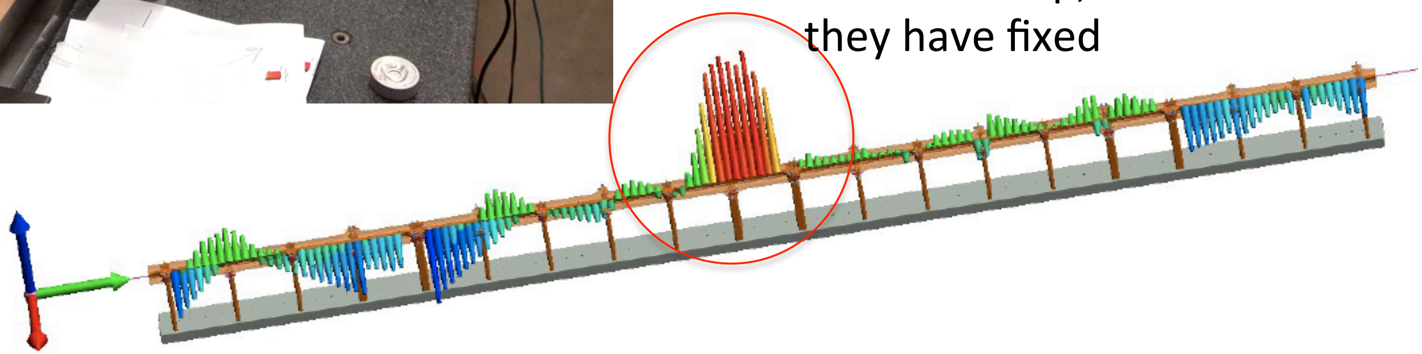
largest offsets from best line fit – each picture is one of the 4 vanes



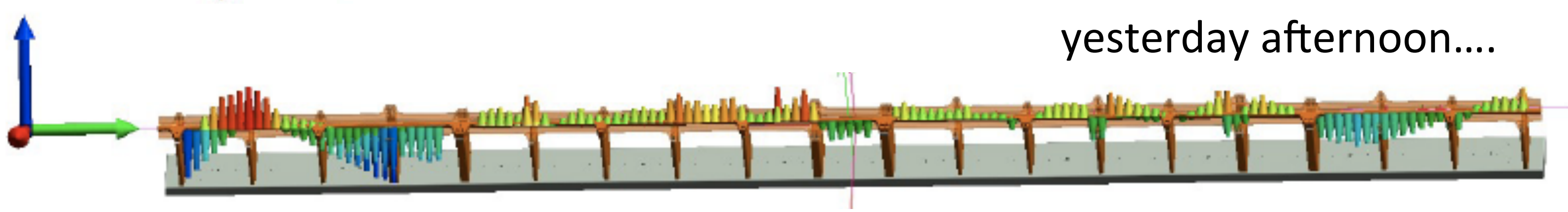


Frank Karl, Matt Iiardo,
Ming Ke, Don Von Lintig

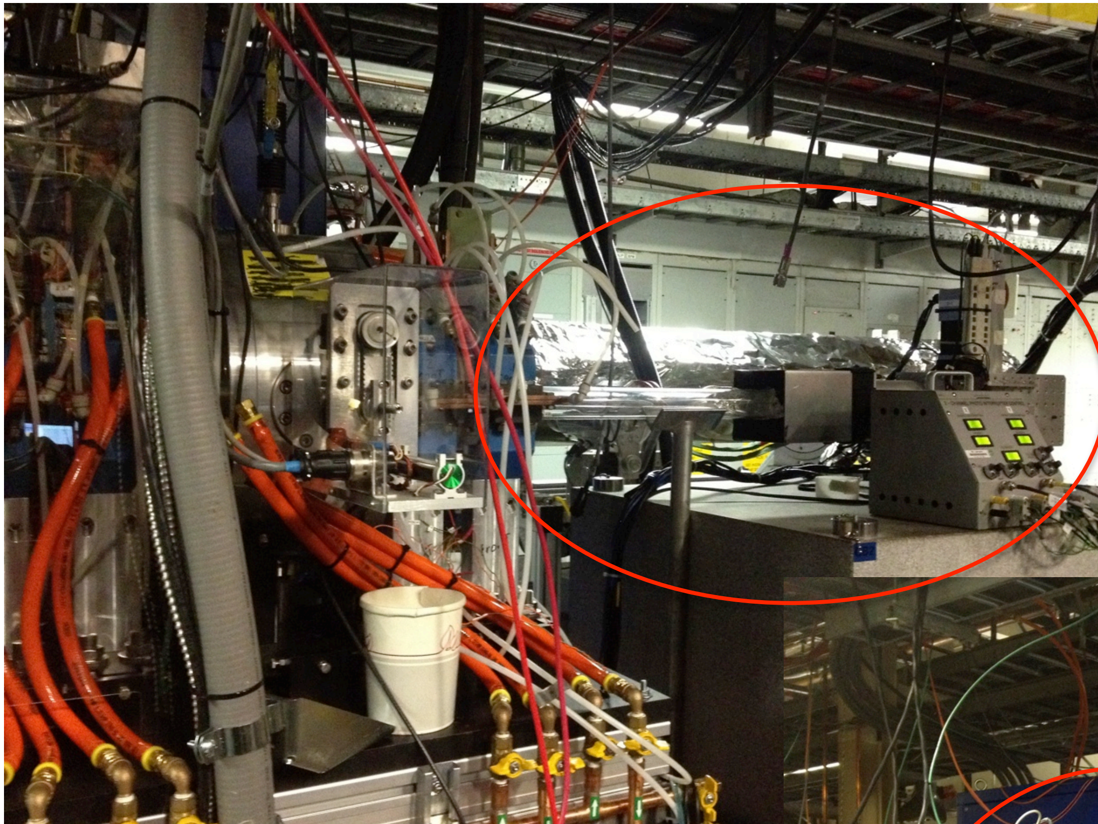
0.8 mm bump, first one
they have fixed

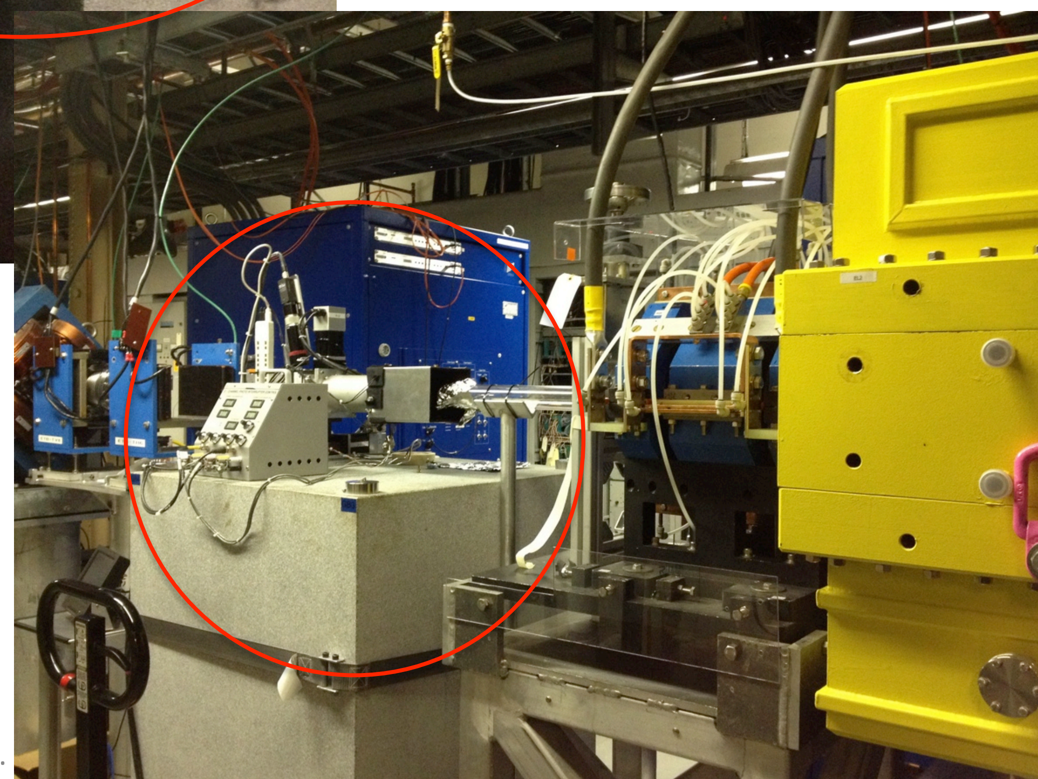


yesterday afternoon....



Vibrating wire setup – Animesh Jain and Magnet Division





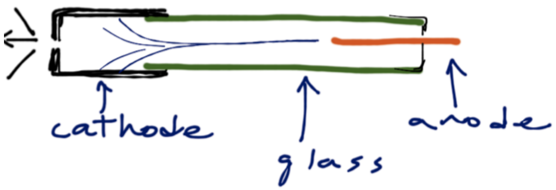
In addition to the alignment work…

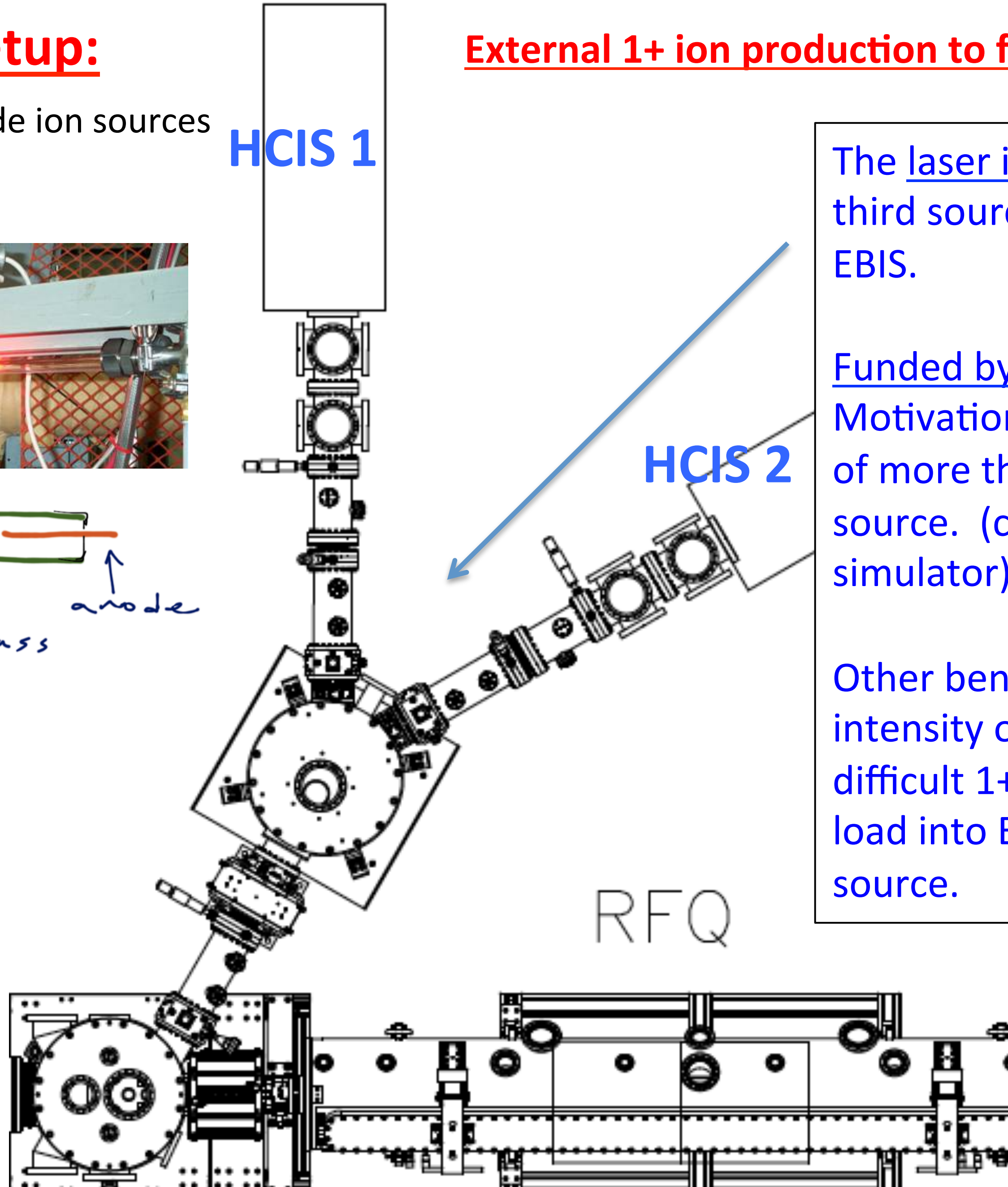
- LLRF upgrade (was already outdated!)
- Emittance at RFQ entrance point…
- Laser Ion Source installation

Present setup:

External 1+ ion production to feed the EBIS trap

Two hollow cathode ion sources (HCIS)





The laser ion source will be a third source of 1+ ions for EBIS.

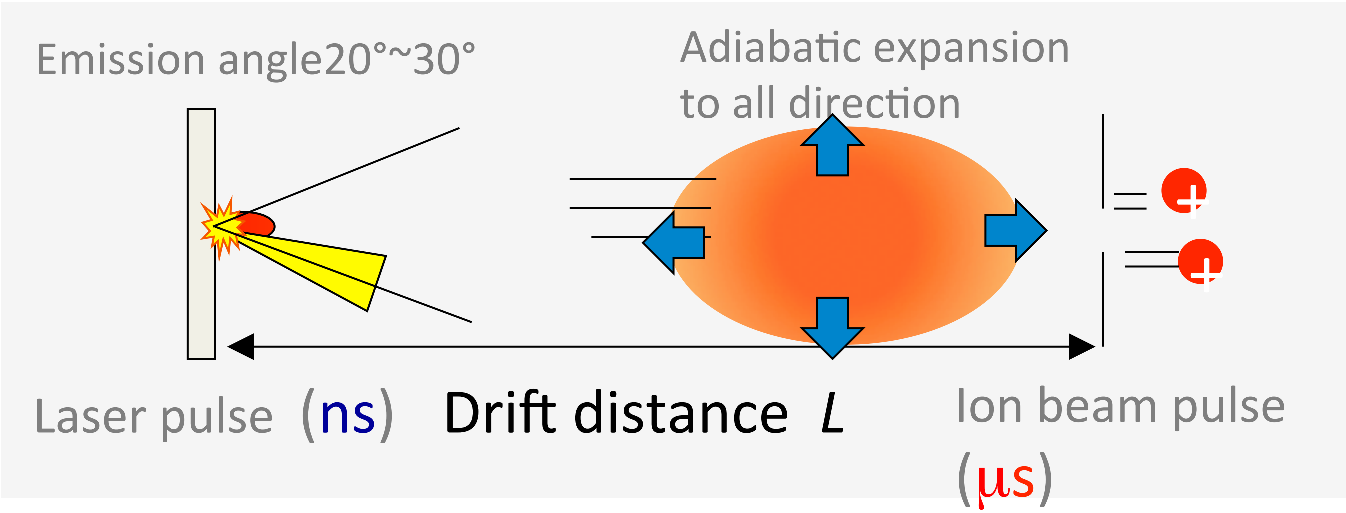
Funded by NASA. Motivation is faster switching of more than 1-2 species per source. (cosmic ray simulator)

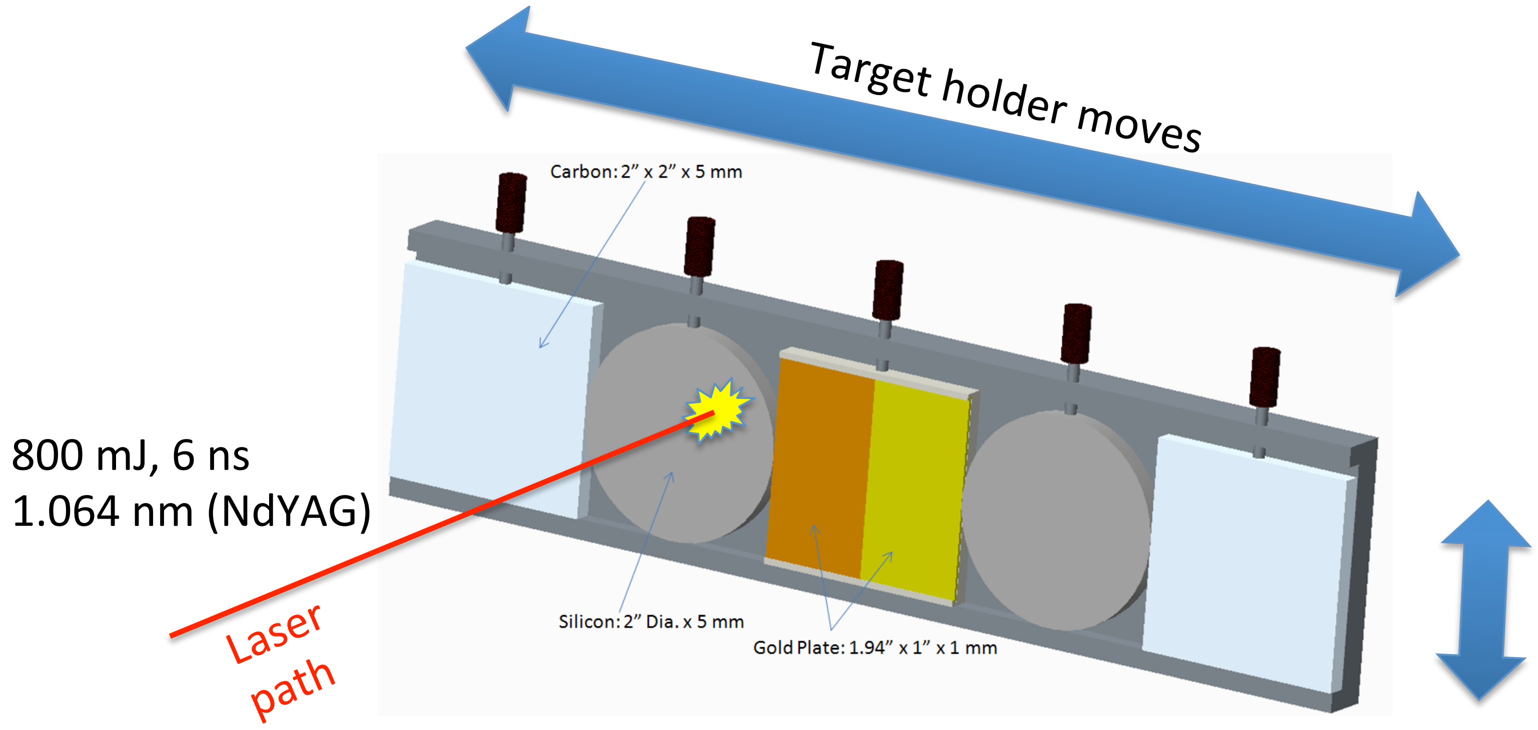
Other benefits could be more intensity on some of the difficult 1+ beams, low gas load into EBIS from the 1+ source.

EBIS is a “charge breeder” of the injected 1+ ions

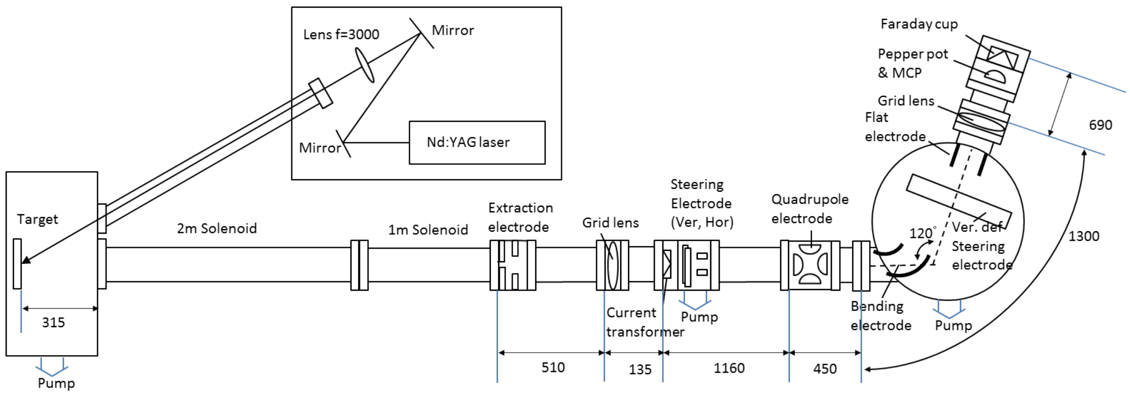
1+ Ions into EBIS ←

What is a laser ion source?

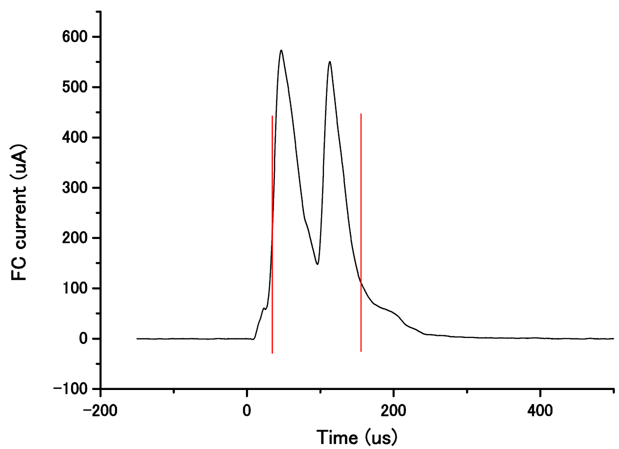




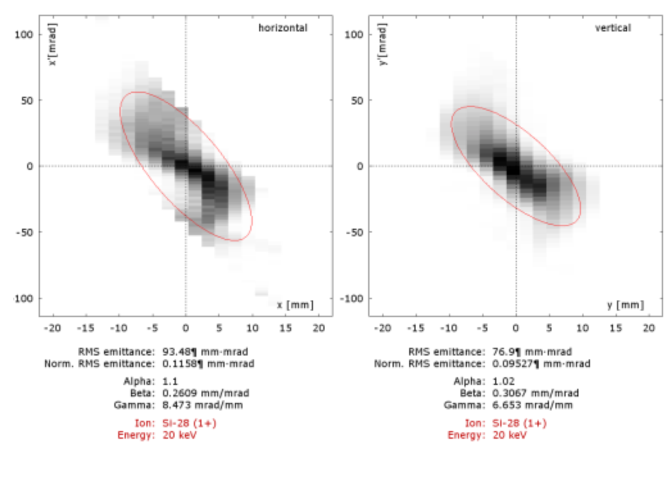
Laser Ion Source test bench



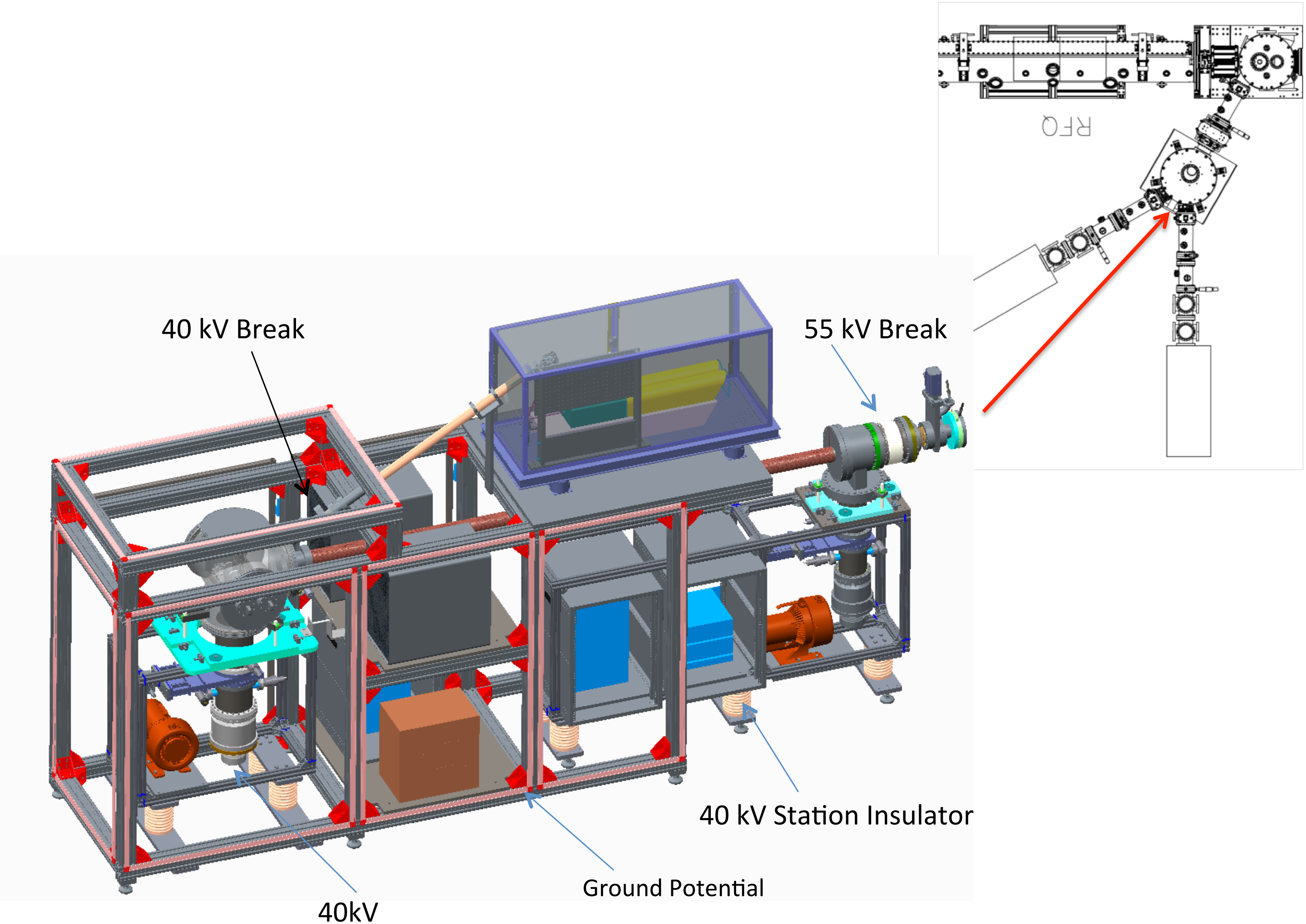
Targets tested: C, Al, Si, Cr, Fe, Cu, Ag, Ta, Au (total: 9 species)



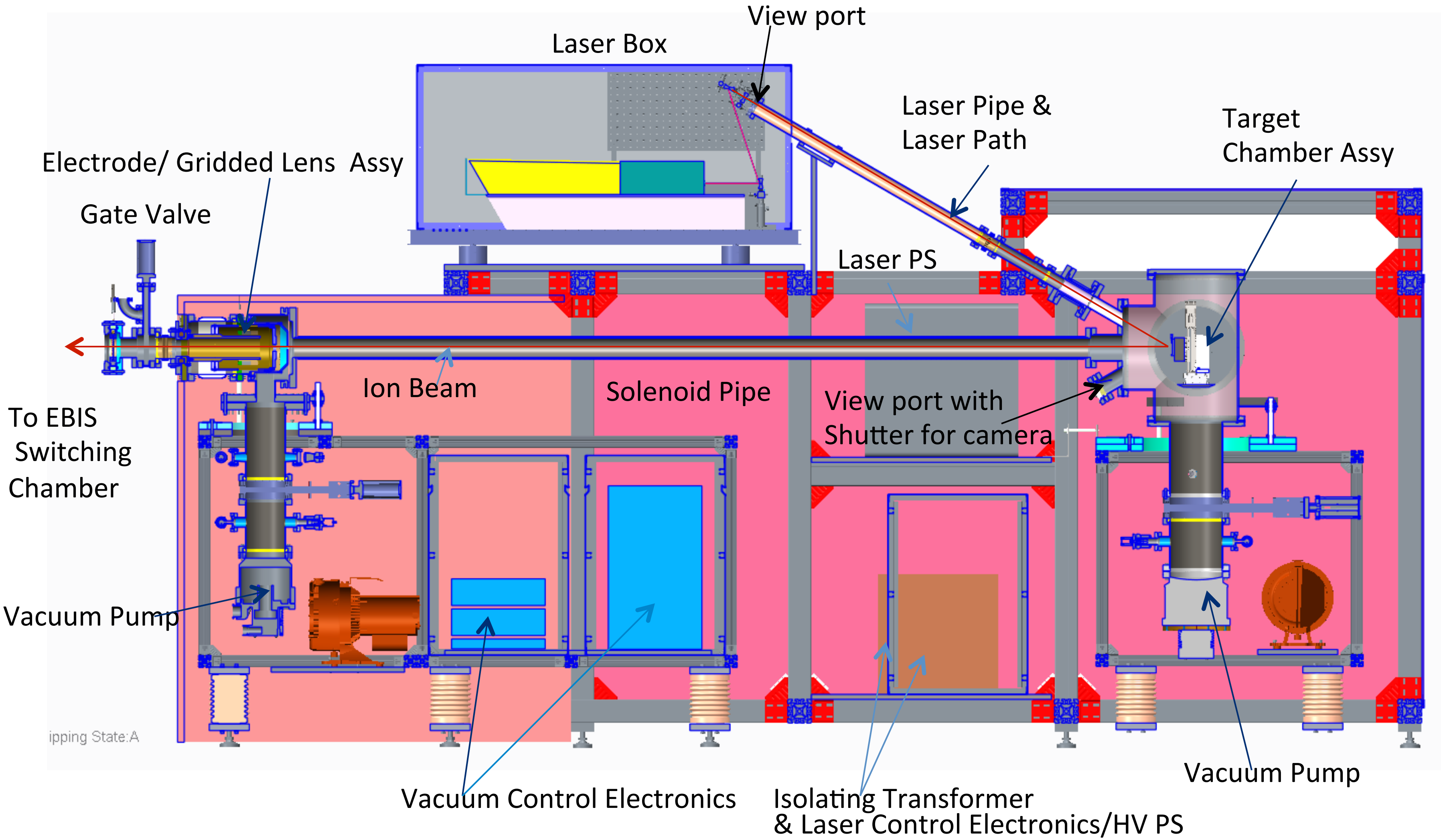
Si beam



Si beam emittance


40 kV Break
55 kV Break
40 kV Station Insulator
Ground Potential
40kV

Final Laser Ion Source



EBIS ionizer for polarized ^{3}He gas (collaboration with MIT)

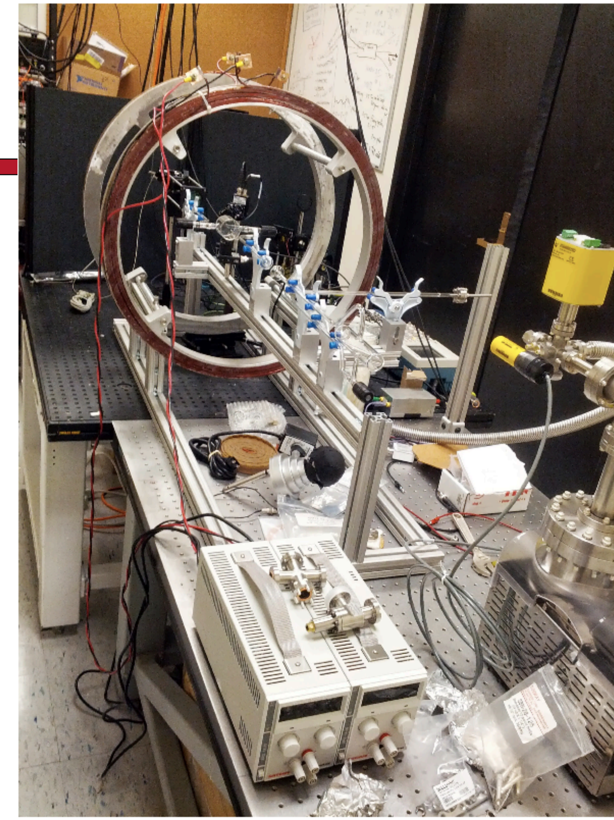
- Polarized ^{3}He gas is produced by a "metastability exchange" technique.
- This polarized ^{3}He gas is injected in the EBIS ionizer.
- The ionization in EBIS is produced in a 50 kG field.

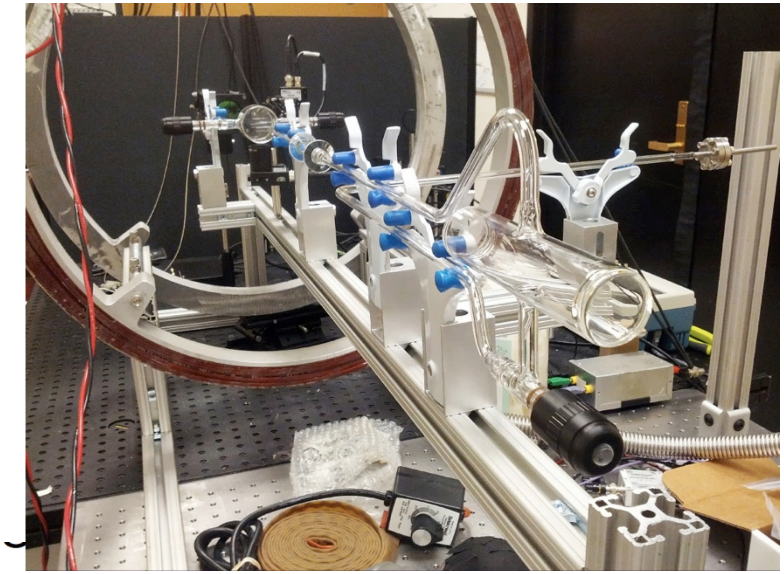
Polarized ^{3}He gas can be transported without depolarization in glass tubes, but there is a limitation on the magnetic field gradient in the gas transport path. Calculations show that there should be minimal depolarization with the real magnetic field of the EBIS superconducting solenoid.

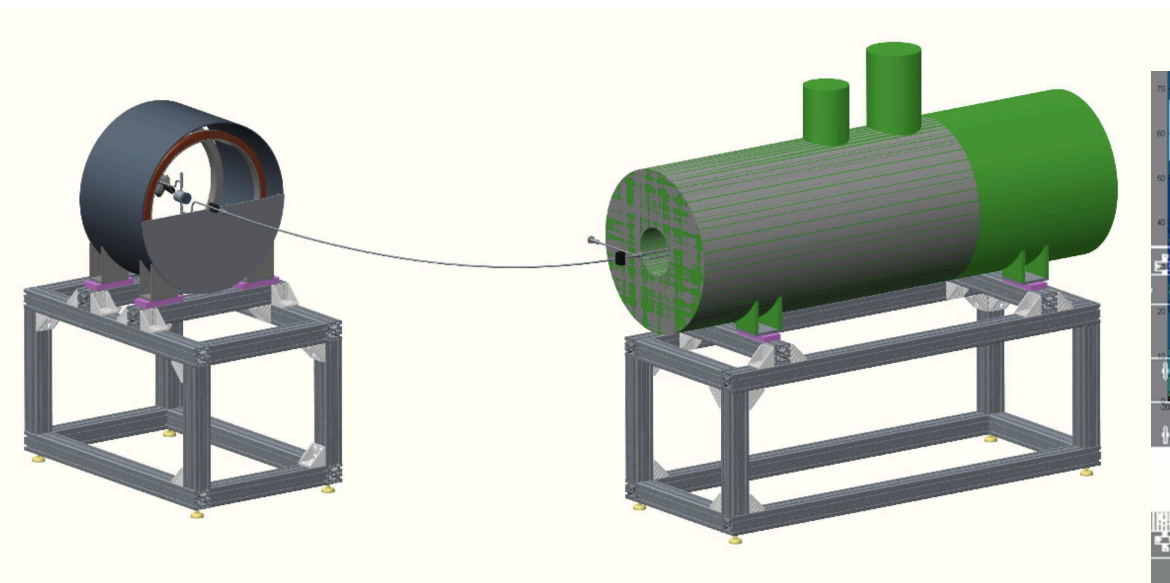
Experiments to show feasibility:

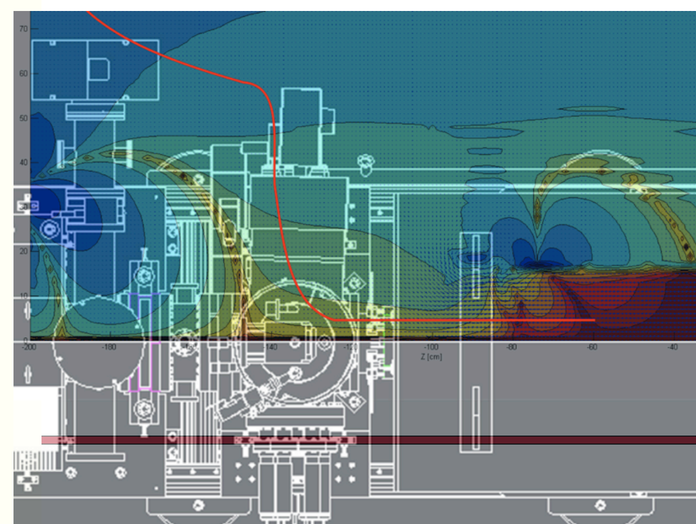
1. Will He-3 stay polarized going into EBIS? (use EBIS spare solenoid for test this fall)
2. Will it remain polarized during ionization?
    - Put system on RHIC EBIS
    - Install 21.5 degree dipole after linac, and measure polarization at 6 MeV

Preparations at MIT (R. Milner, J. Maxwell, C. Epstein)
Will be brought to BNL this fall and tested with spare solenoid

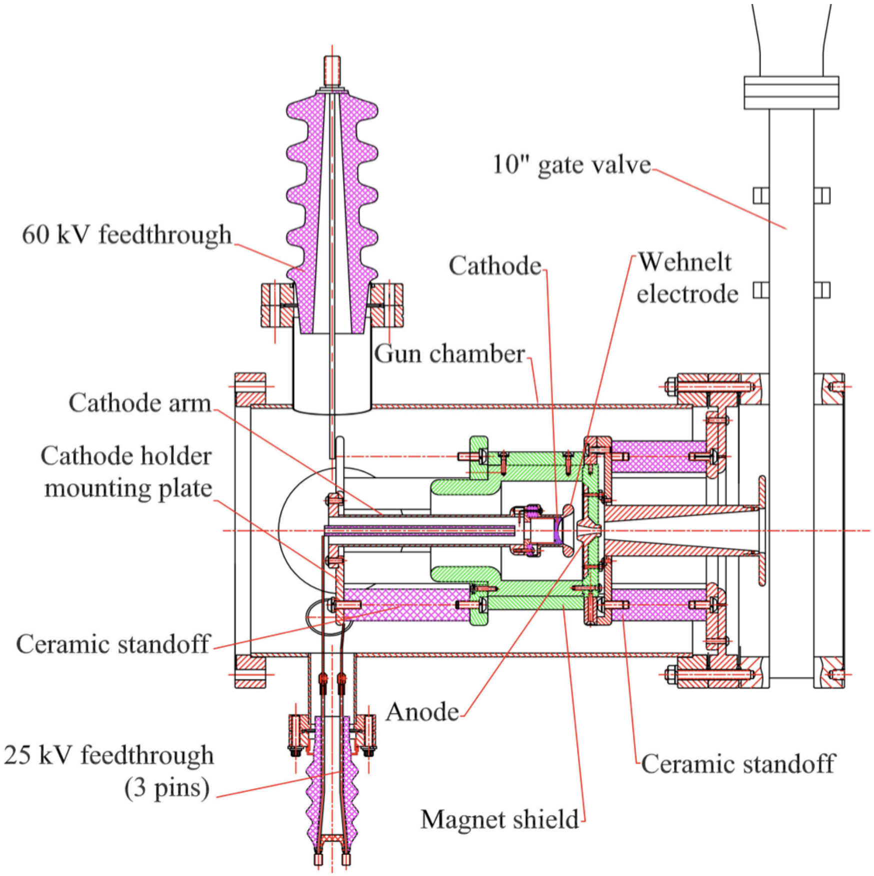








Brillouin gun - S. Pikin design; was built in collaboration with CERN, and is now being prepared for testing on BNL Test EBIS



- Electron beam is launched in a weak magnetic field and electrostatically focused before compression in the trap magnetic field.
- Current density in the trap can be >5000A/cm^2, compared to <500A/cm^2 with the present gun. This results in 10-times shorter confinement times (and therefore shorter electron beam pulses), leading to improved vacuum.
- Could give a better charge state distribution, lower impurities, and smaller emittance of the extracted ion beam.

Potential issues – instabilities in the electron beam and small acceptance for injected ions

Next RHIC run…

- Au-Au – will realignment help?
- Au-D – haven't tried D, but it would be done similar to He-3
  - Pulse D gas directly into the trap
  - Could expect intensity ~2 x He-3 since Q=1 vs. 2
  - Need radiation safety studies (fault studies) – n's from beamstop, etc. could require change in postings
- Au-He-3
  - Pulse He-3 directly into EBIS trap

- For either Au-D or Au-He-3, might take ~ 1 minute to switch species (rather than pulse-to-pulse as we did for Au-Cu). Time needed for He or D gas to pump away before we would get good Au beam.

  (injecting Au first could be quicker and better)

Summary

- Many species, good running for NSRL
- No jump in intensity, but we haven't given up hope
- LIS coming this year for at least some beams
- Polarized He-3 and advanced electron gun R&D in progress