Status of Beam Thermalization and Preliminary Experimental Results

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New Momentum Compression Lines

ANL gas catcher initial operation & Improvements

- Commissioning runs with ^{76}Ga
- Recommissioning of LEBIT with ^{63}Co
- Laser Spectroscopy & Initial Reacceleration with ^{37}K
- Reacceleration of ^{76}Ga and ^{37}K

Progress on Cyclotron Stopper construction

FRIB Ground Breaking

D.J. Morrissey

NSCL & Dept. of Chemistry
Michigan State Univ.

Original GasCell/LEBIT System

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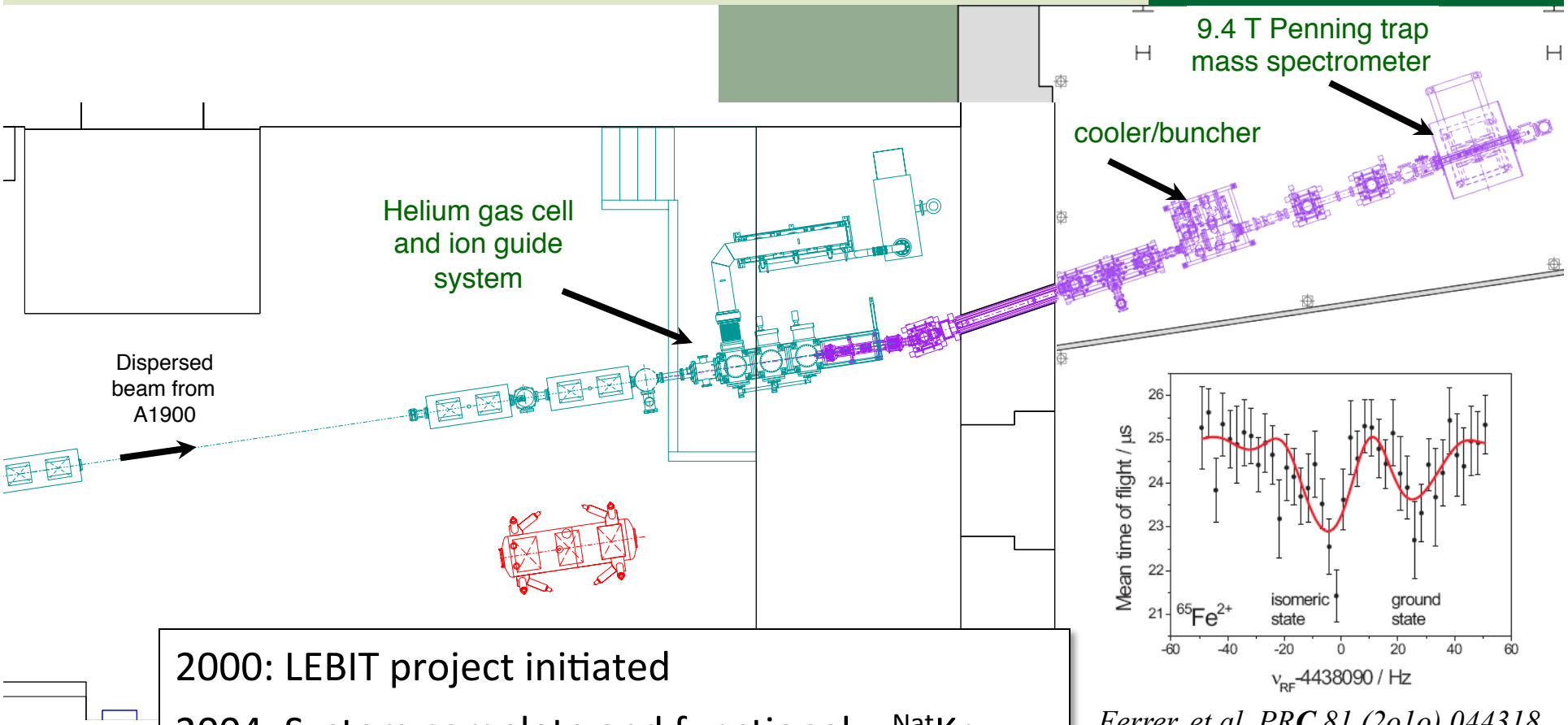

Ferrer, et al. PRC 81 (2o1o) 044318

2000: LEBIT project initiated

2004: System complete and functional – ^{Nat}Kr

2005: First radioactive mass measurement – ^{38}Ca

2009: Final mass measurement – ^{66}As

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Transition to New Capabilities

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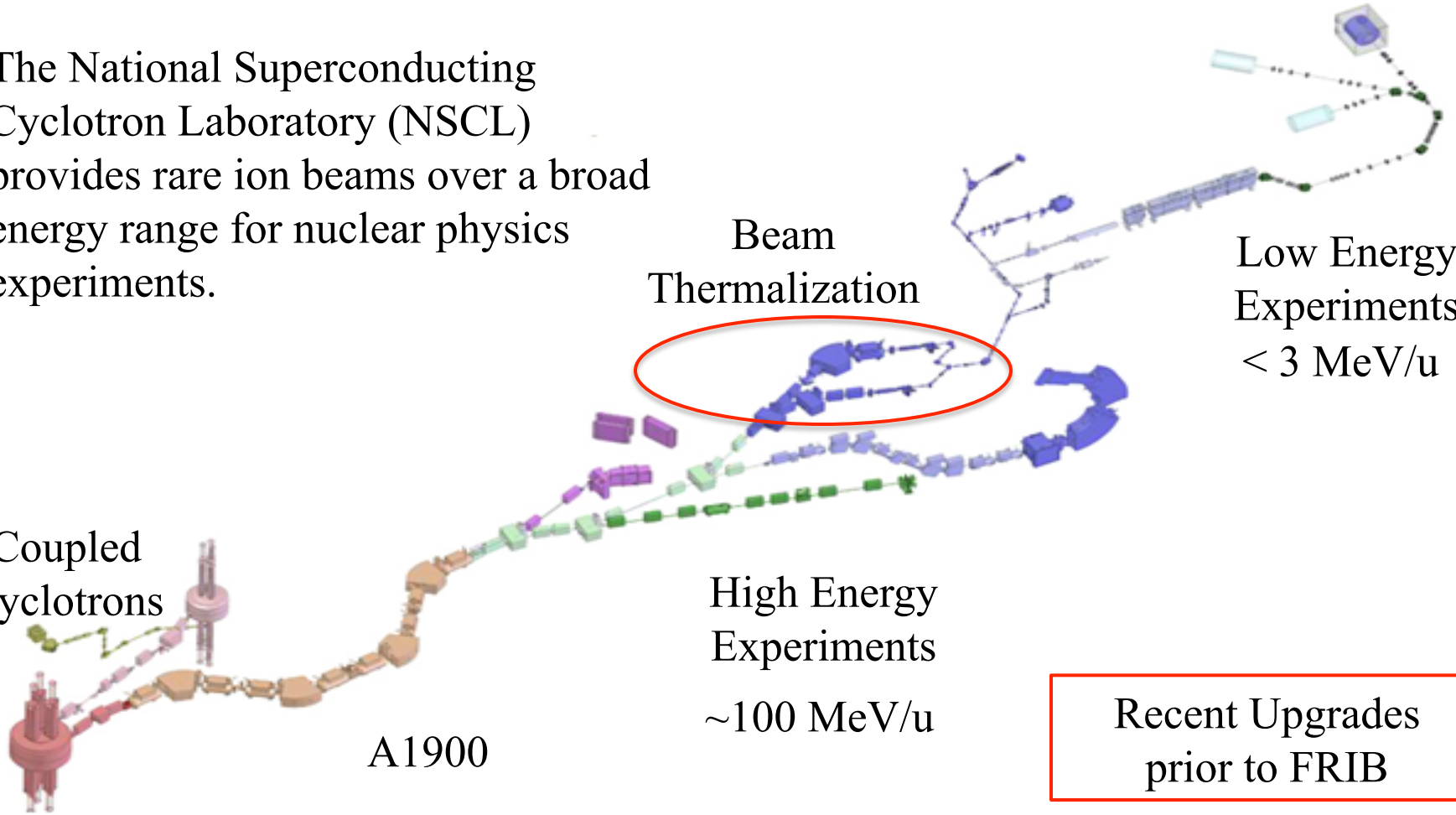
The National Superconducting Cyclotron Laboratory (NSCL) provides rare ion beams over a broad energy range for nuclear physics experiments.



Recent Upgrades prior to FRIB

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Future ‘N4’ Vault

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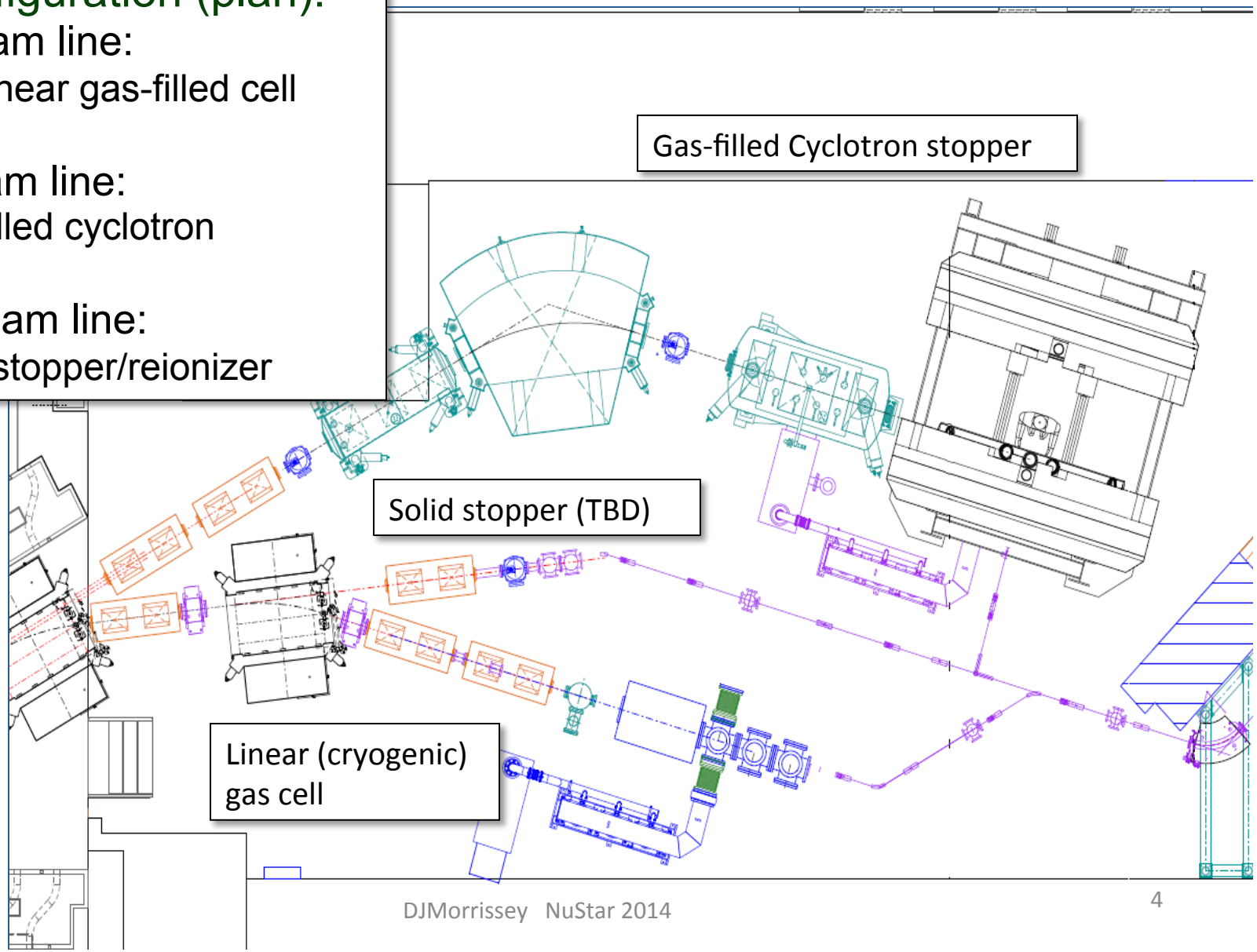
- FRIB Configuration (plan):
  - South beam line:
    - One linear gas-filled cell
  - North beam line:
    - Gas-filled cyclotron
  - Middle beam line:
    - Solid-stopper/reionizer



Present 'N4' Vault

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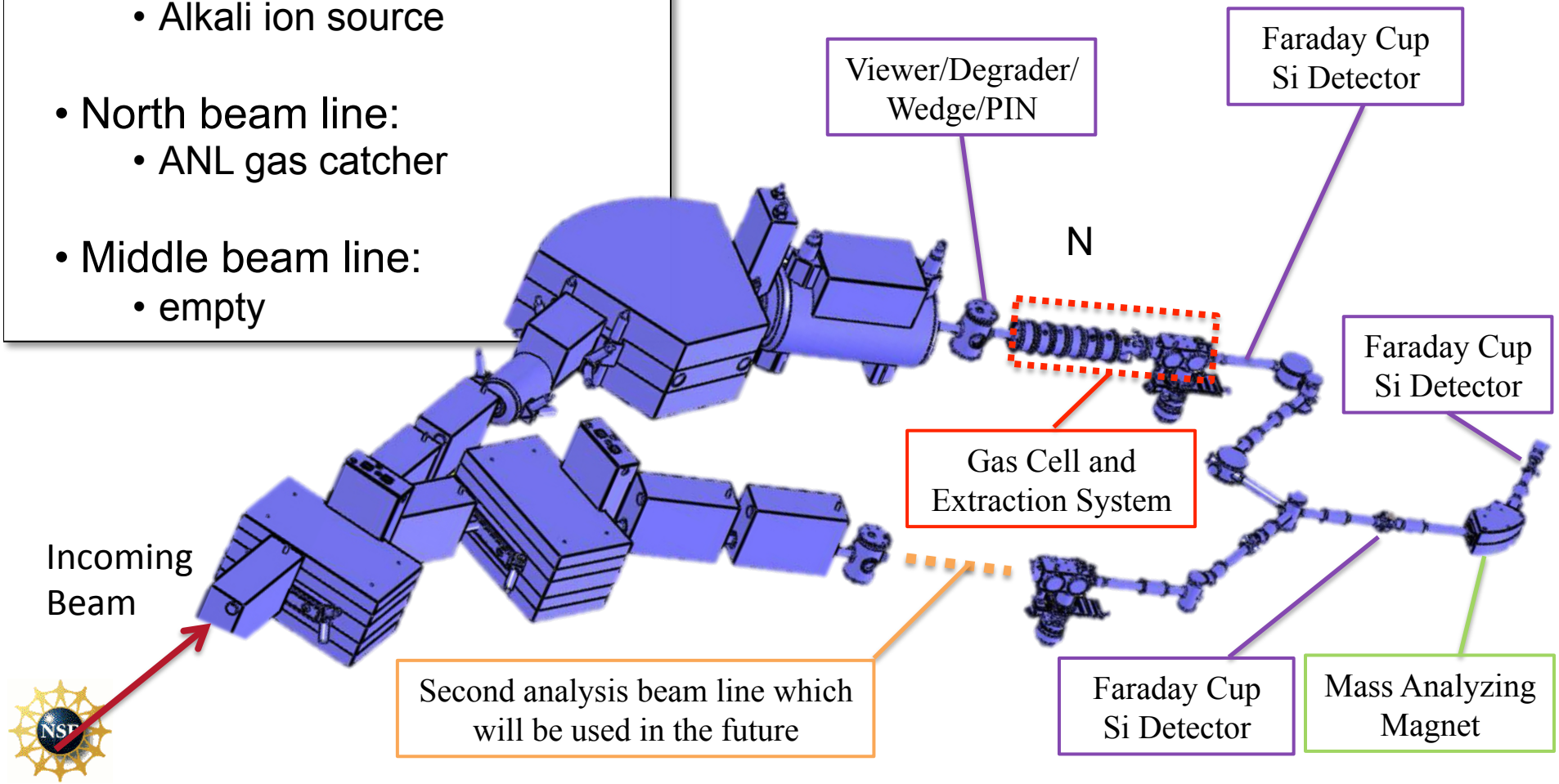
- NSCL Configuration (now):
  - South beam line:
    - Alkali ion source
  - North beam line:
    - ANL gas catcher
  - Middle beam line:
    - empty



N4 Vault

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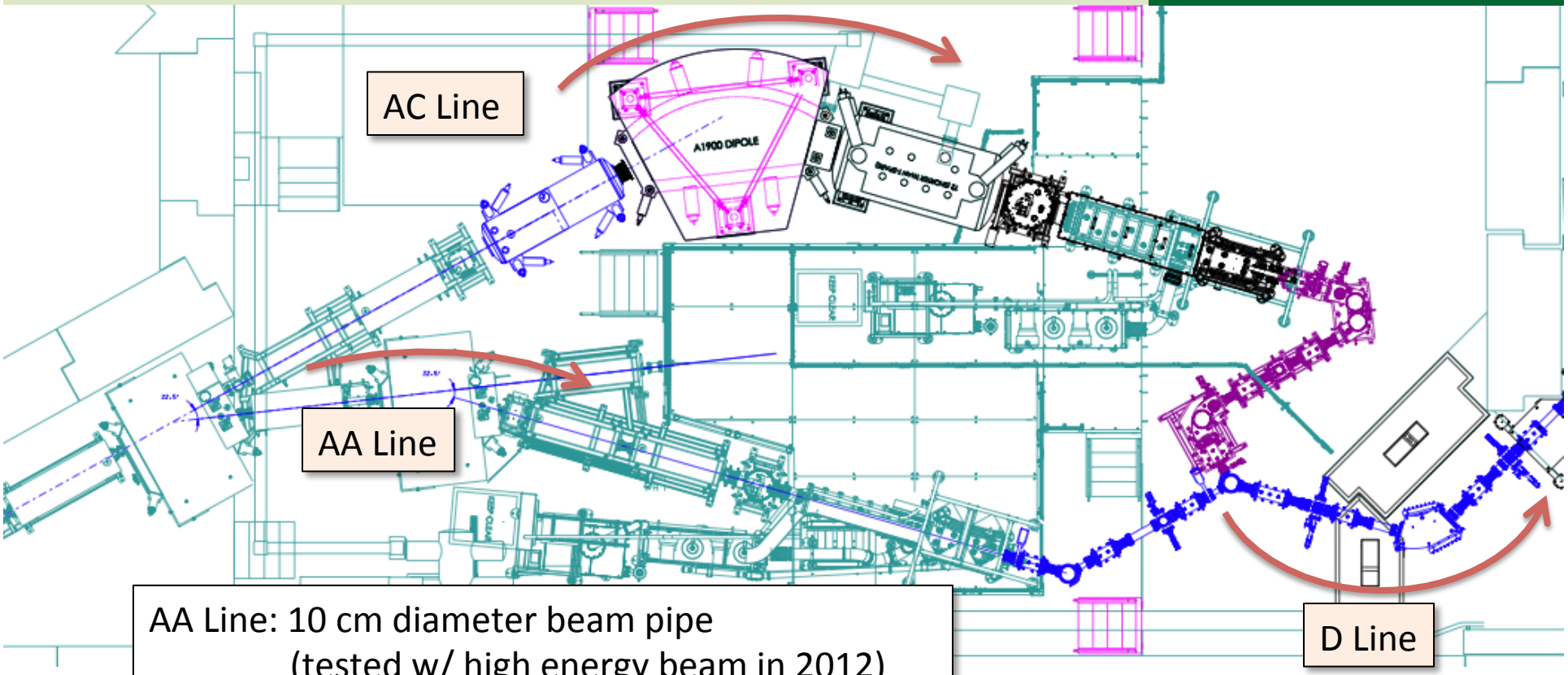

AA Line: 10 cm diameter beam pipe
(tested w/ high energy beam in 2012)

AA gas Cell: design proposed to NSF
presently alkali ion-source

AC Line: 20 cm dia. beam pipe, operational

AC gas Cell: ANL gas catcher (<120 mbar)

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ANL Gas Cather

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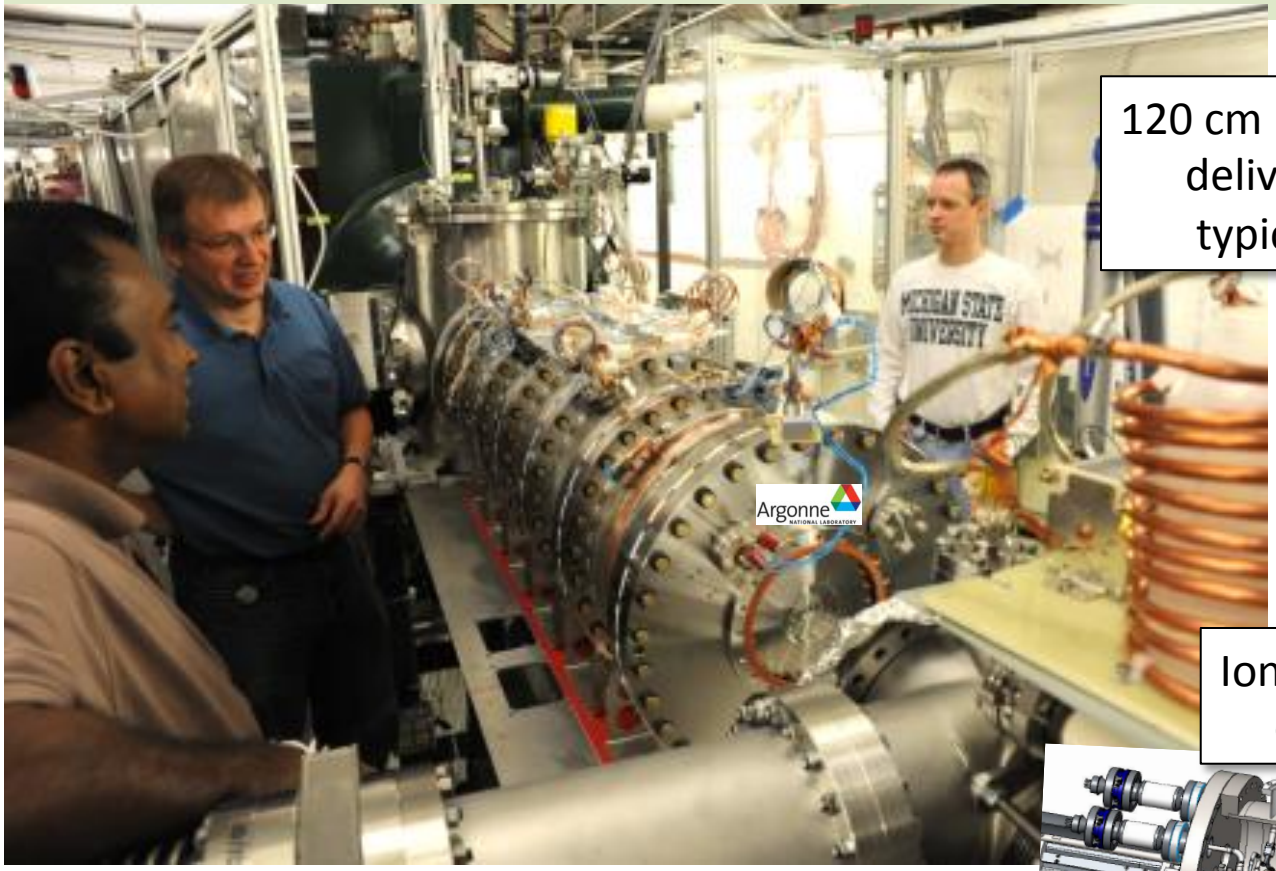
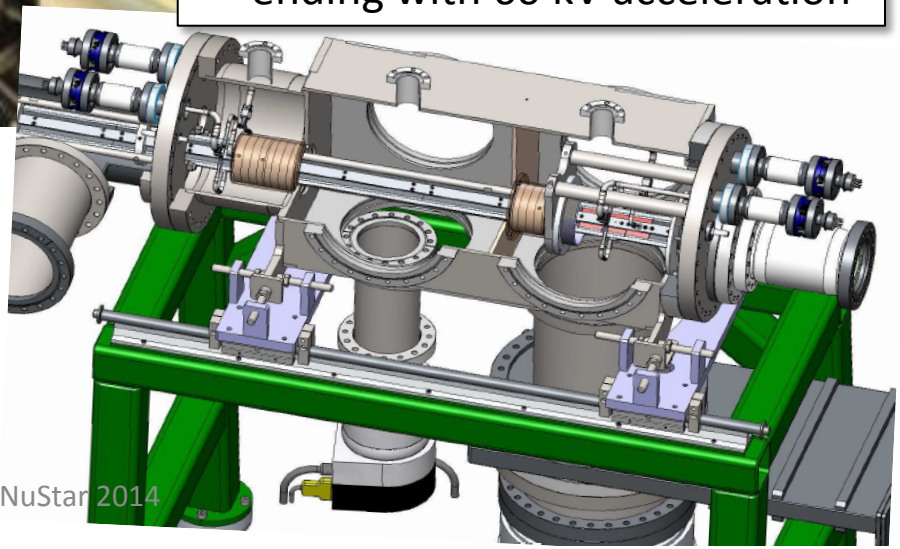


120 cm long Cas Catcher,
delivered Summer, 2012
typically ~100 mbar, 0°C

Ion Guide w/ differential pumping
ending with 60 kV acceleration



Beam

^{76}Ga Distribution at Gas Catcher

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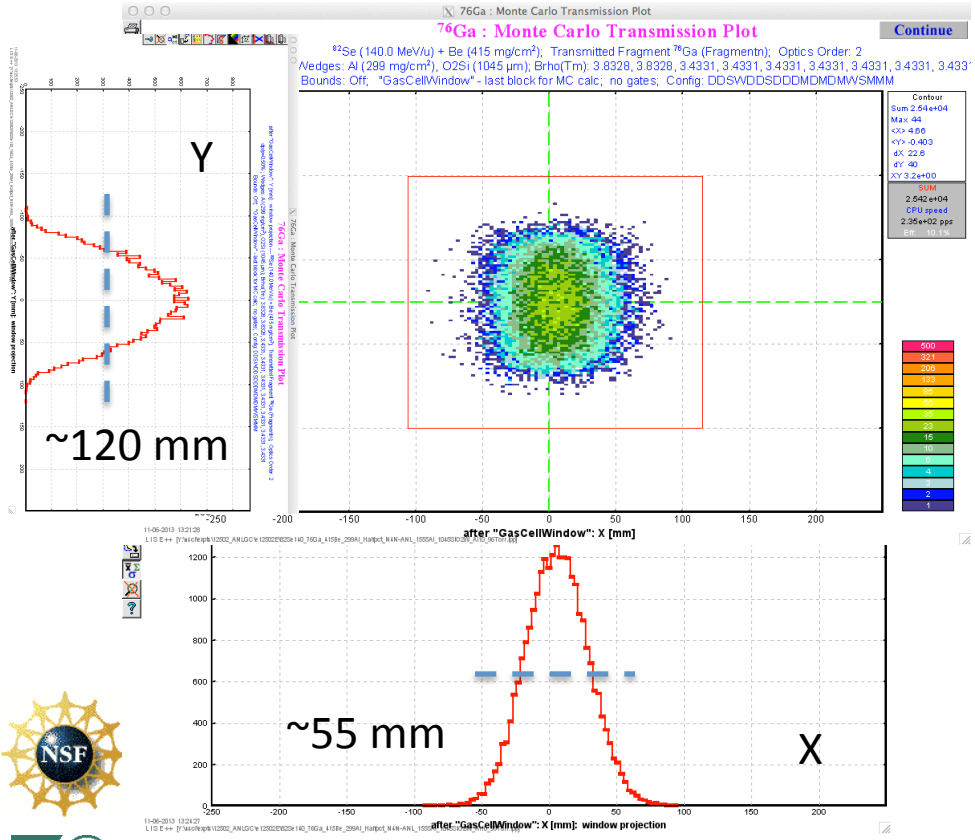
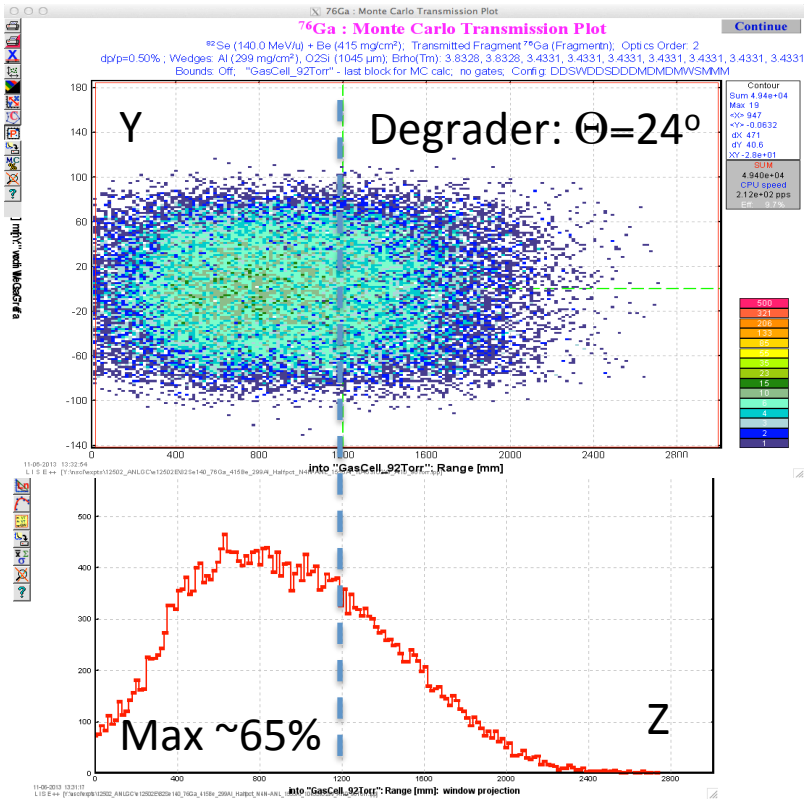
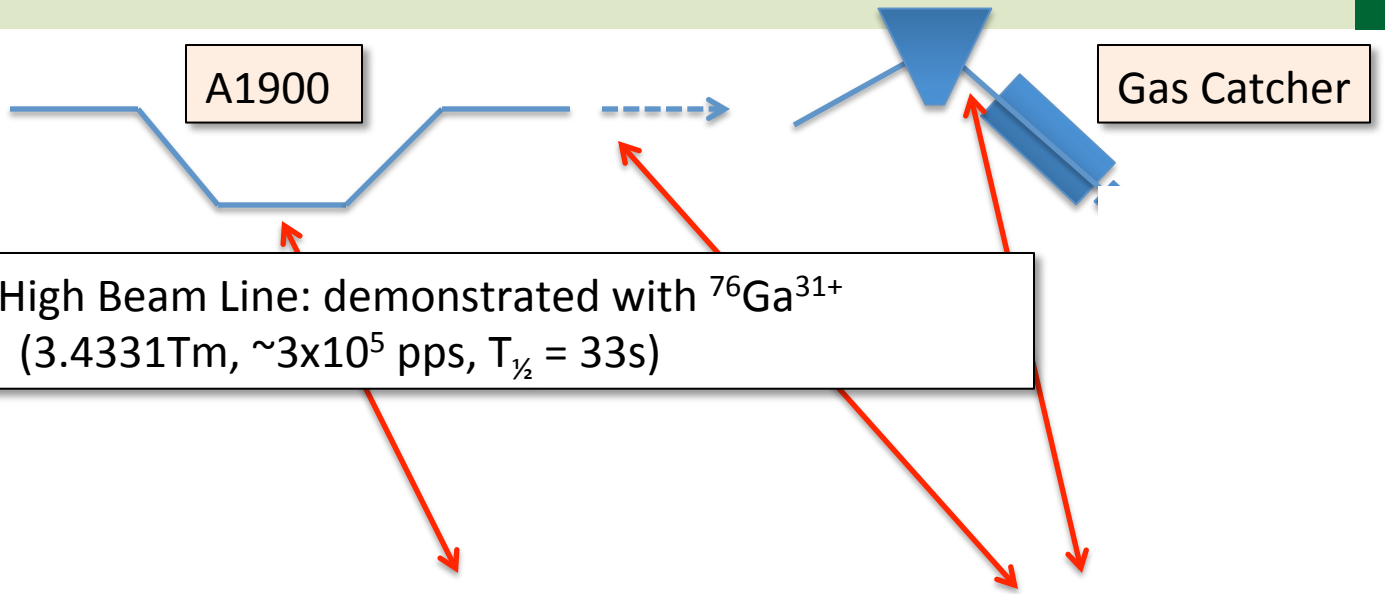
- Commissioning Runs
- ^{82}Se (140MeV/u, Be415, Al299) → ^{76}Ga, Bρ = 3.4331Tm, Δp/p=0.5%
- 1555 μm Al degrader, 1045 μm SiO_2 wedge → LISE^{++} predictions

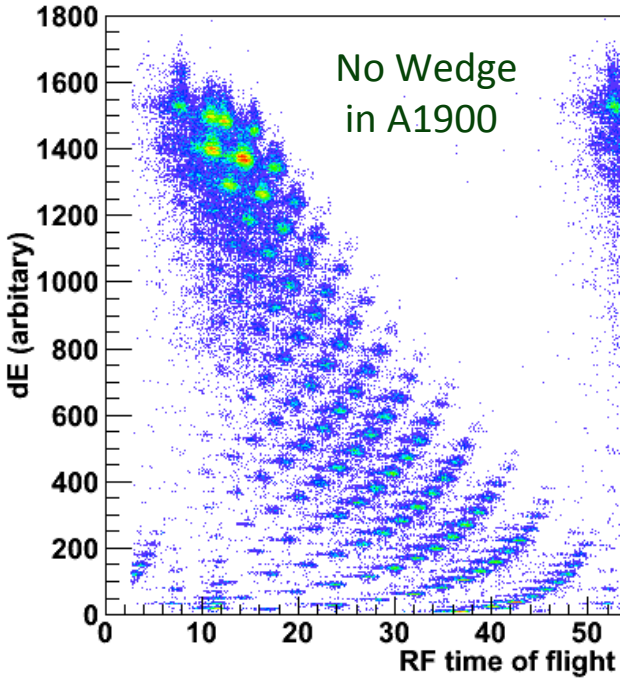


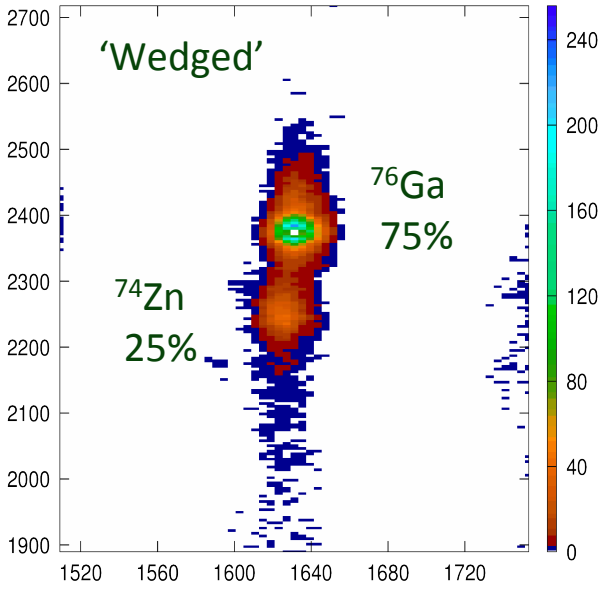


^{76}Ga Distribution at Gas Catcher



High Beam Line: demonstrated with $^{76}Ga^{31+}$
(3.4331Tm, ~3x10^5 pps, $T_{½}$ = 33s)





^{76}Ga Distribution at Gas Catcher

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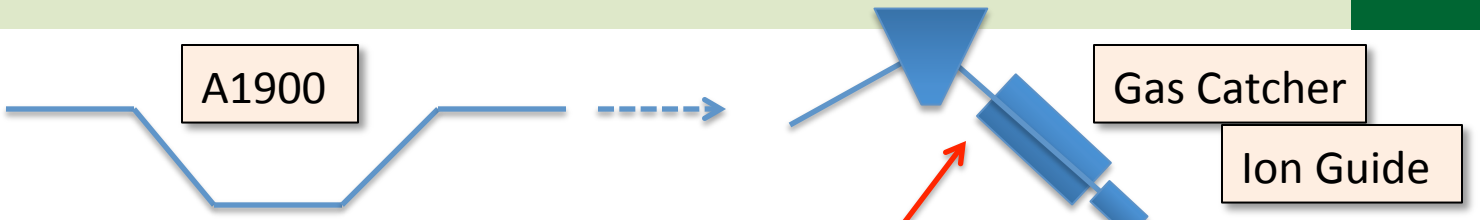
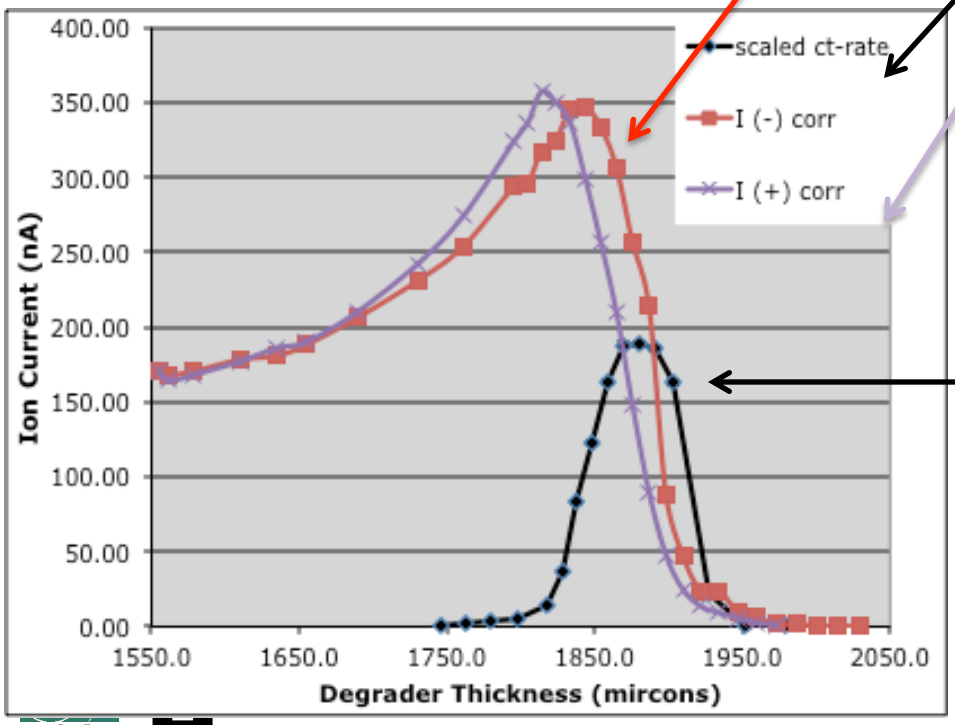
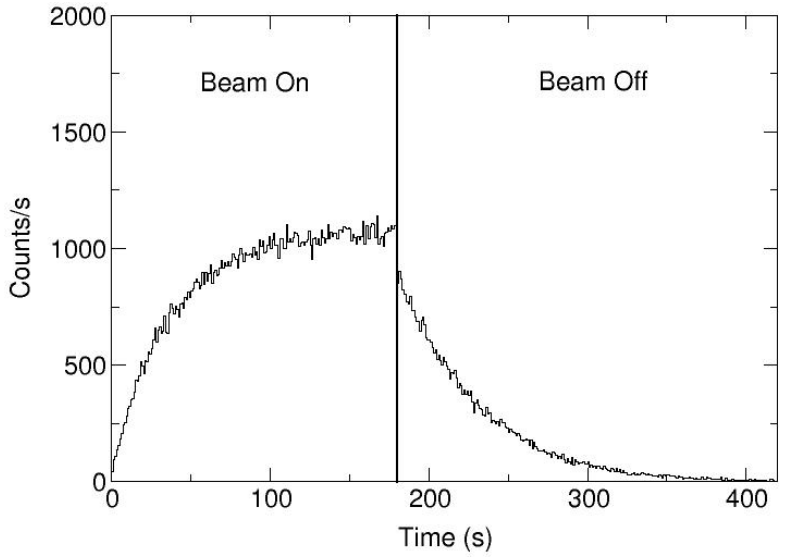


High Beam Line: demonstrated with $^{76}Ga^{31+}$
(3.4331Tm, ~3x10^5 pps, $T_{½}$ = 33s)
Range distribution from + , - ions (Bragg Curves)
Range distribution for Total Activity ($\varepsilon_{\text{total ext.}}$ ~10%)





^{76}Ga Distribution at Gas Catcher

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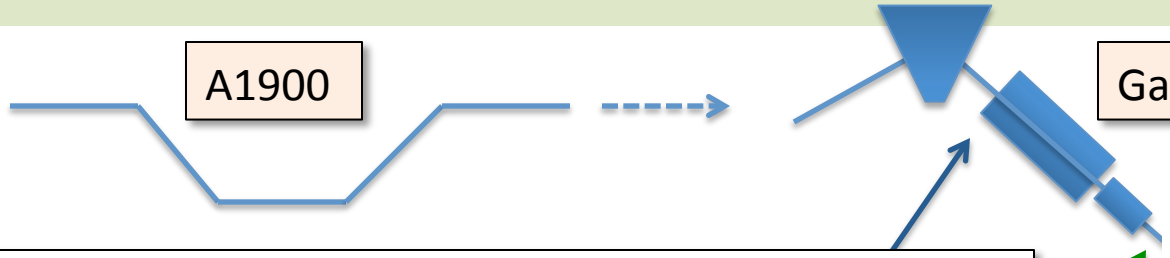
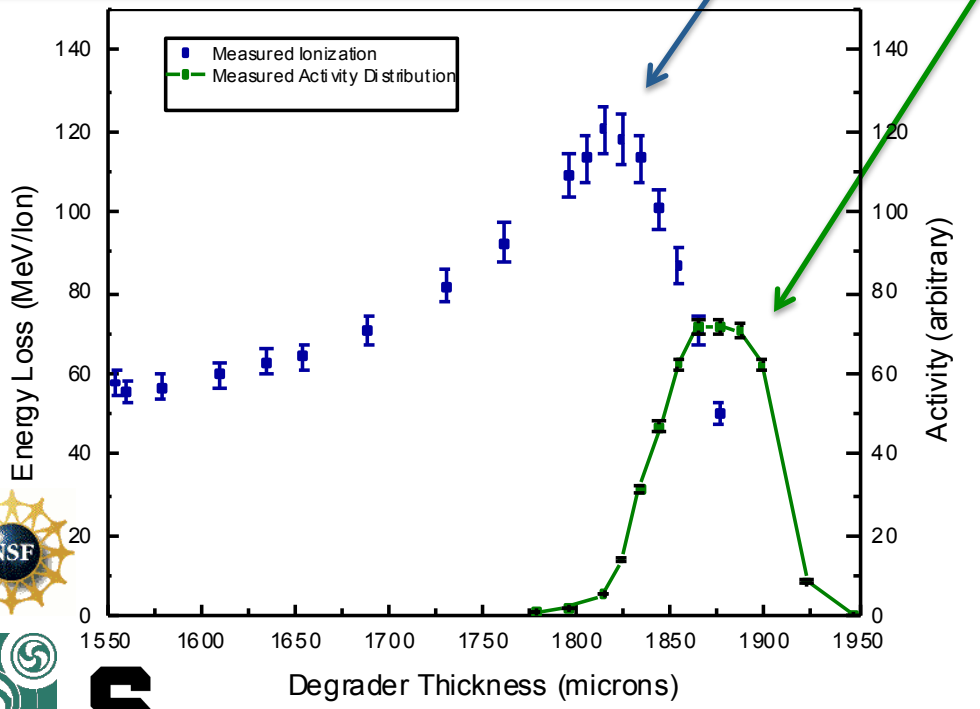
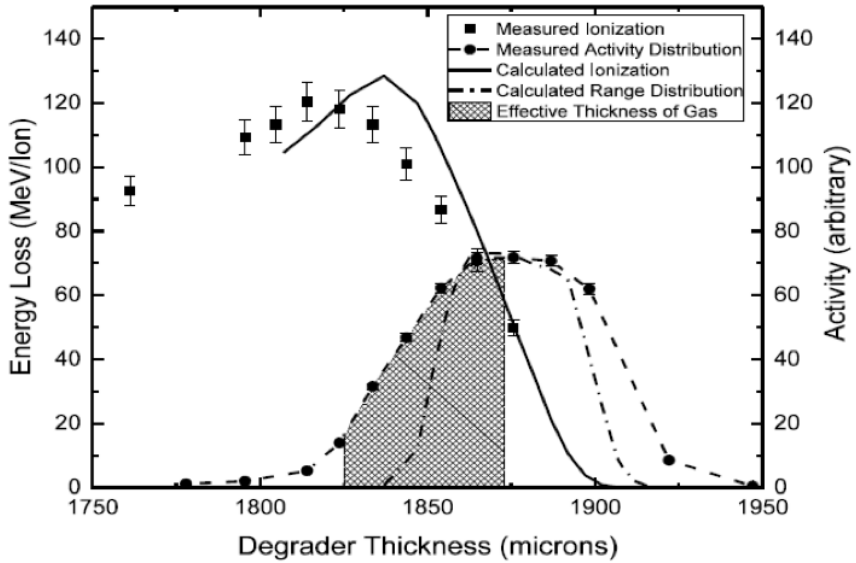


High Beam Line: demonstrated with $^{76}Ga^{31+}$
(3.4331Tm, ~3x10^5 pps, $T_{½}$ = 33s)
Range distribution from + , - ions (Bragg Curves)
Range distribution for Total Activity ($\varepsilon_{\text{total ext.}}$ ~10%)

SRIM Calculation (δR~165μm)
+/- 0.25 % $\Delta p/p$





^{76}Ga Distribution at Gas Catcher

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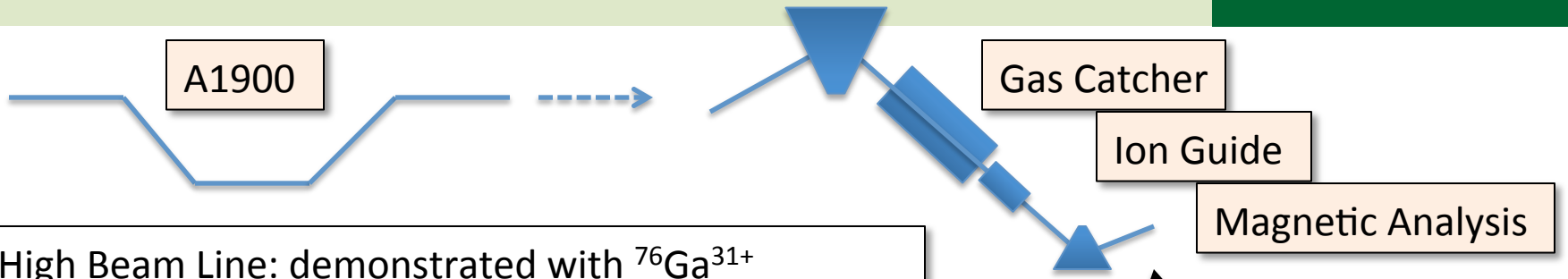

High Beam Line: demonstrated with $^{76}Ga^{31+}$
(3.4331Tm, ~3x10^5 pps, $T_{½}$ = 33s)
Range distribution from + , - ions (Bragg Curves)
Range distribution for Total Activity ($\varepsilon_{\text{total ext.}}$ ~10%)
Mass Analysis of (+) ion current

MCP/CCD image of (stable) ion current

N.B. not “upright” – optics issue

^{76}Ga Distribution at Gas Catcher

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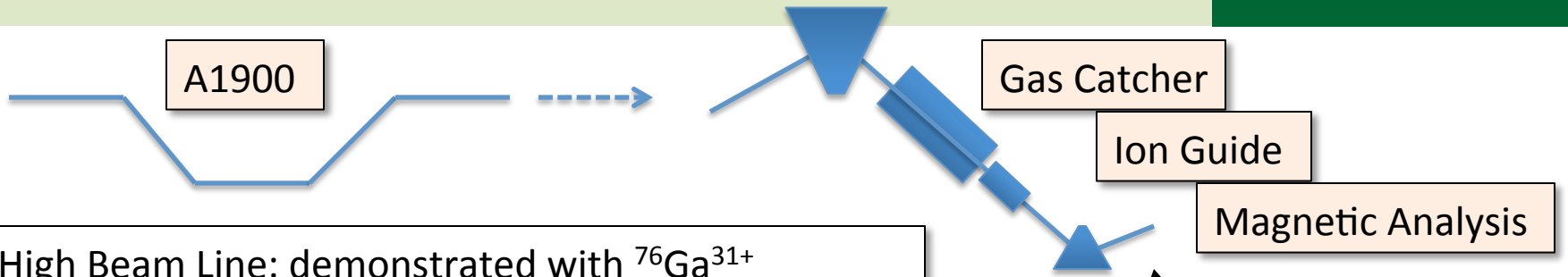
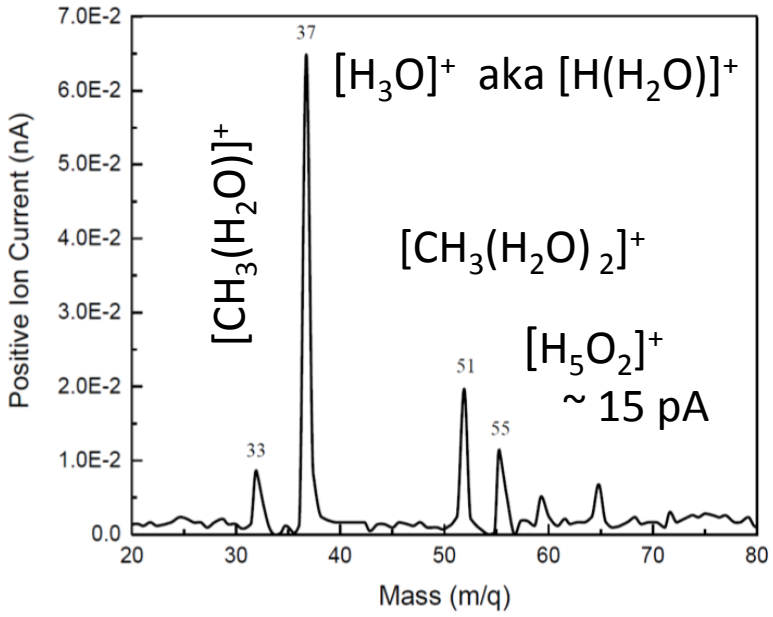
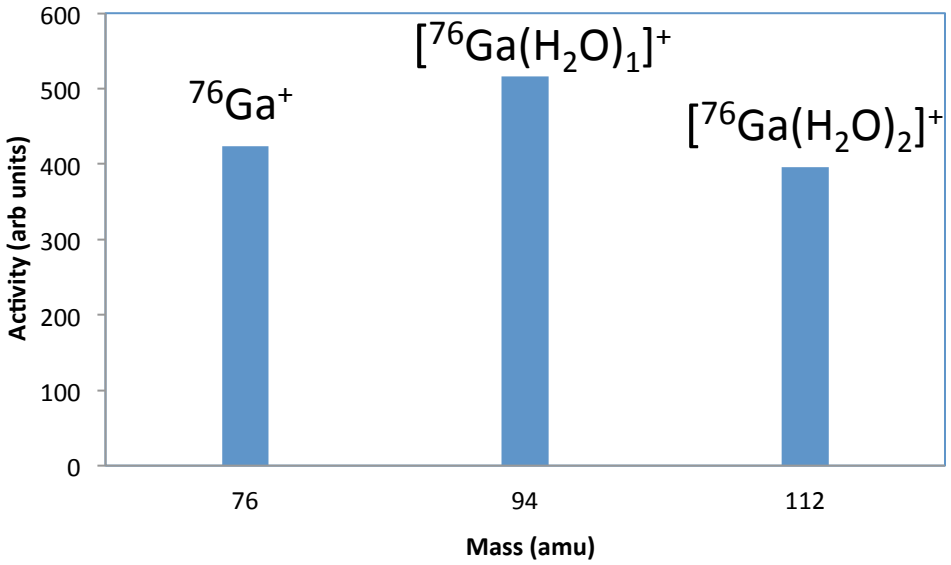


High Beam Line: demonstrated with $^{76}Ga^{31+}$
(3.4331Tm, ~3x10^5 pps, $T_{½}$ = 33s)
Range distribution from + , - ions (Bragg Curves)
Range distribution for Total Activity ($\varepsilon_{\text{total ext.}}$ ~10%)
Mass Analysis of (+) ion current ($\varepsilon_{\text{tot. ext. 1 mass}}$ ~3%)

Mass Scan: Stable Ions



Mass Scan: Radioactive Ions



ANL Gas Cell Improvements

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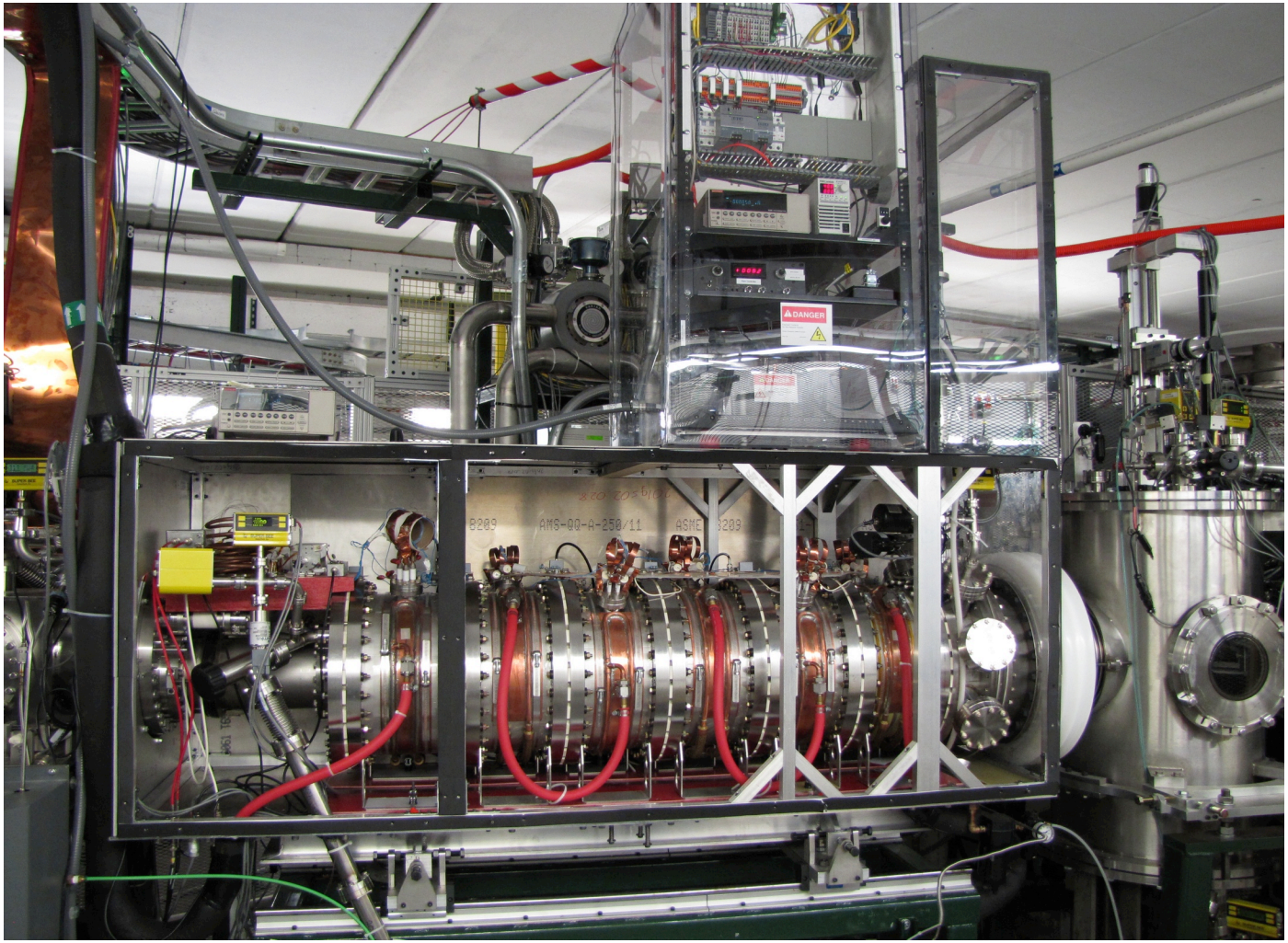
Significant improvements for operation just completed (Feb/2014):
Add TMP pumping to gas cell volume
Add Internal stable ion source(s) to gas cell (multiple ports)
Add stronger upstream window (presently Δp < ~200mbar)

Next:
Develop new metal seals



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ANL Gas Cell Operation

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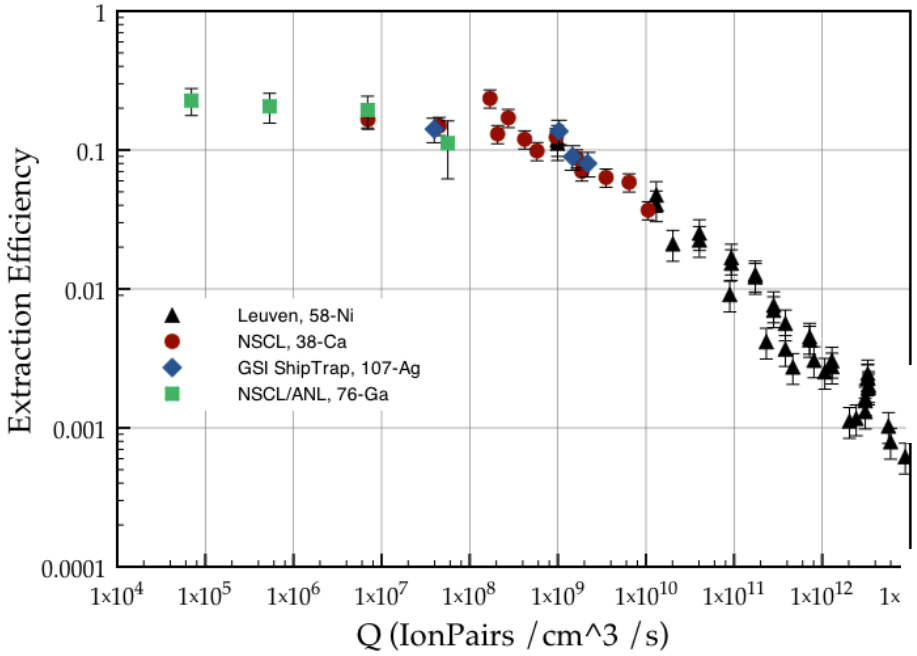
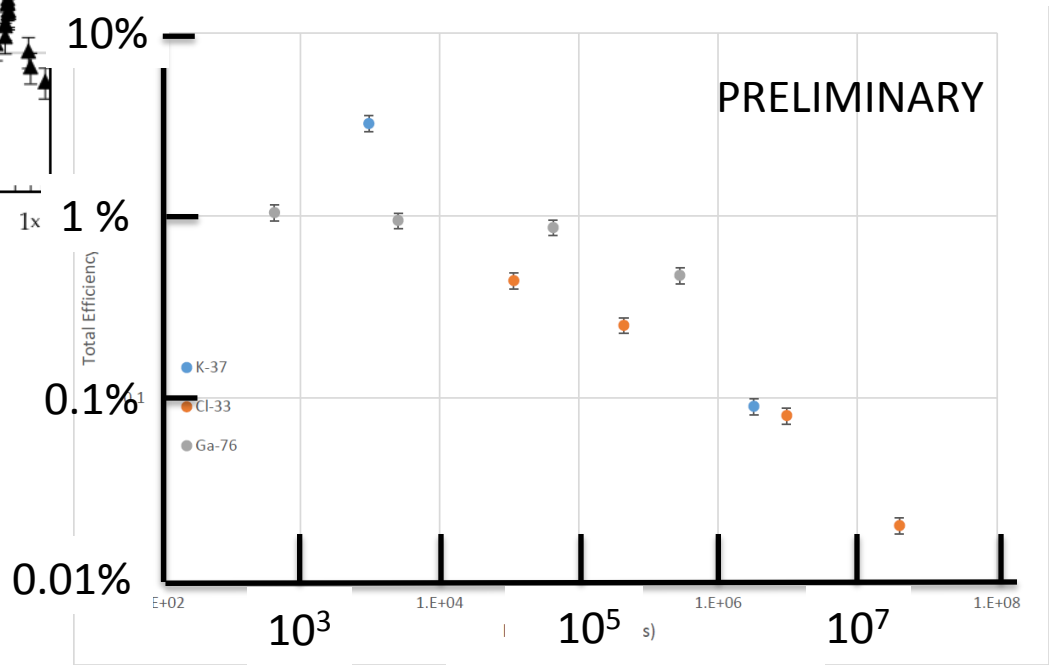
"Extraction Efficiency" is in general agreement with previous work
DJM, EPJ Special Topics 150 (2007) 365



"Total Efficiency" is more interesting to this audience … includes stopping, collection, and extraction



Overall Floor Plan, Spring/2o13

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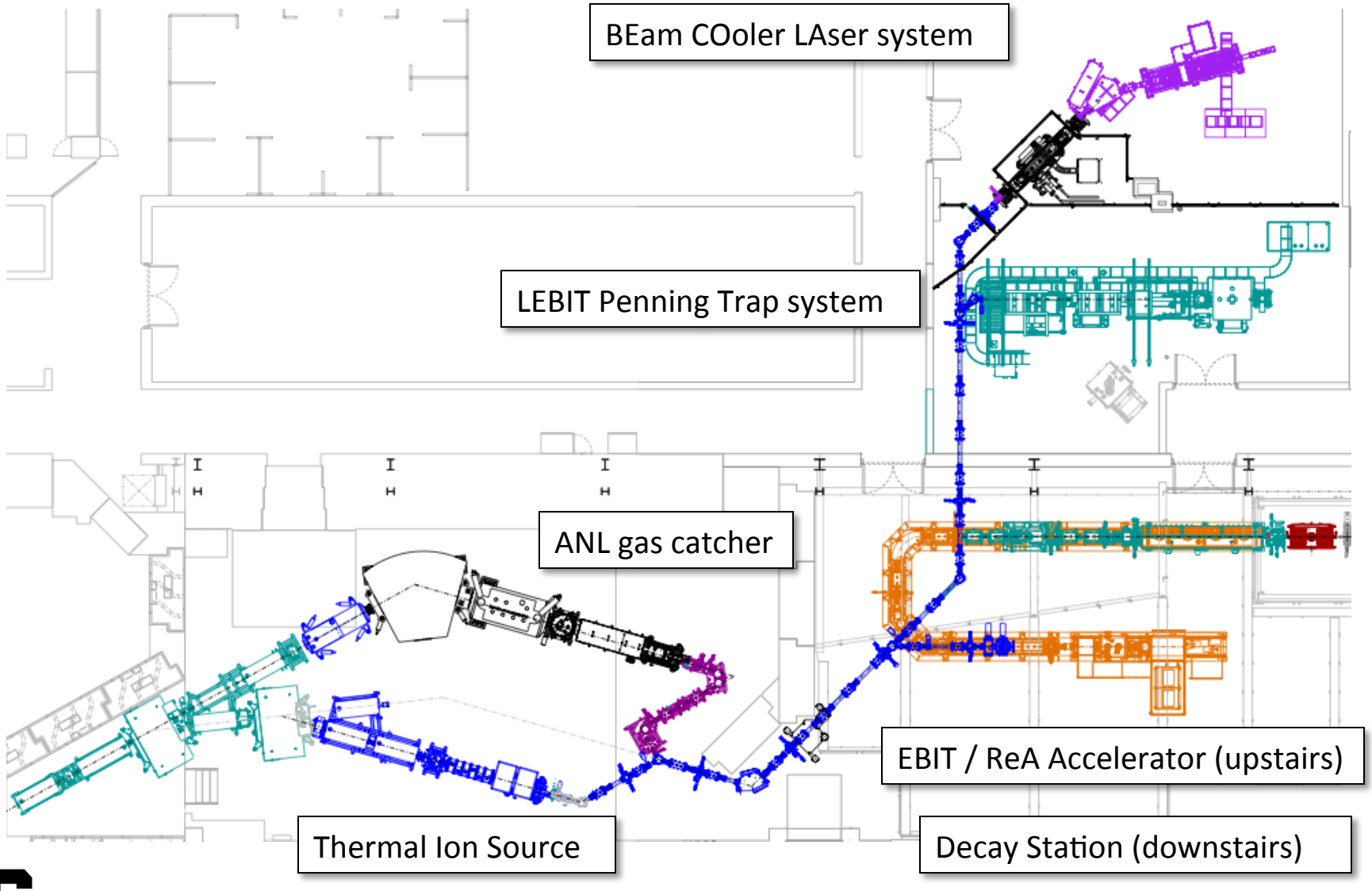

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LEBIT – Phase II

Back to Life after Move

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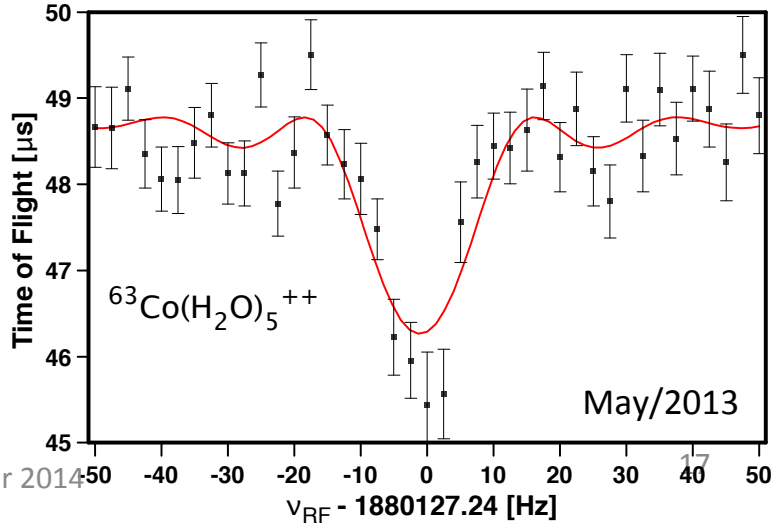
- LEBIT re-commissioned
  - First rare isotope measurement in new configuration – ^{63}Co in May, 2013
  - High-precision off-line mass measurements ongoing
- New **Single Ion Penning Trap** (SIPT) for highest sensitive far from stability under construction
- **Minitrap** magnetometer for permanent field monitoring developed
- **Laser ablation source** for carbon cluster ions for absolute field calibration routine operation
- **SWIFT technique** for fast, efficient in-trap beam purification developed

G.Bollen, R.Ringle, S.Schwarz



Collinear Laser Spectroscopy with BECOLA

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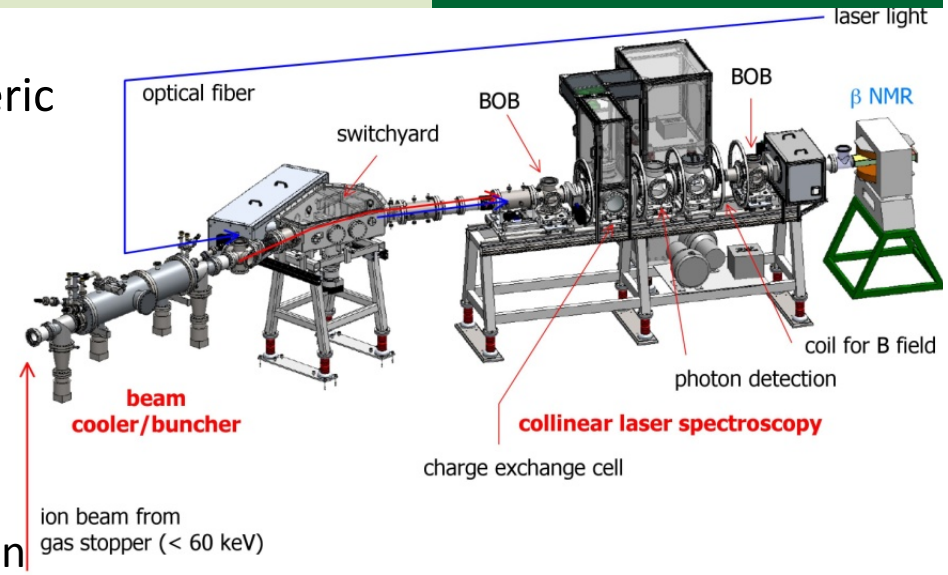
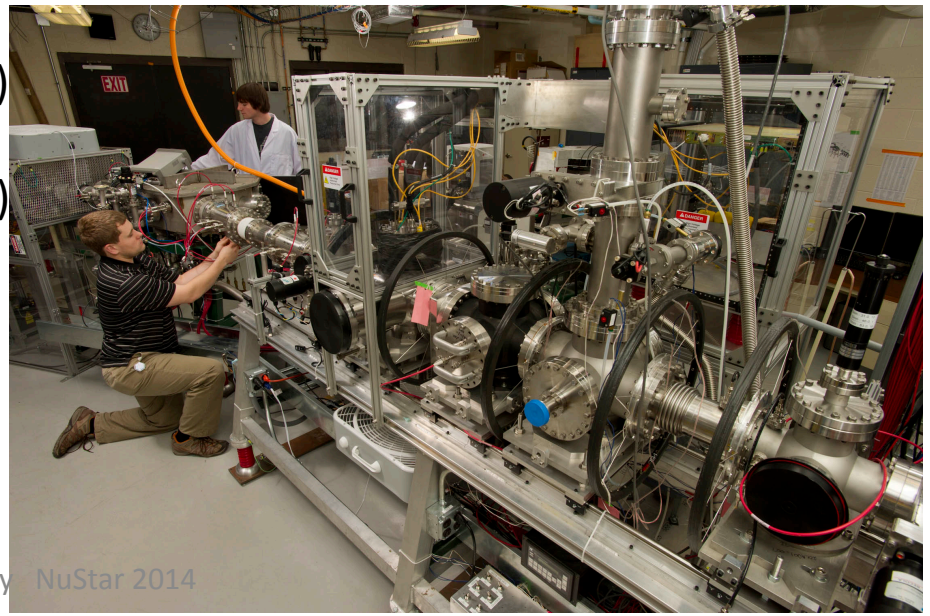
Laser probing techniques to determine static properties of nuclear in their ground or isomeric states

- Nuclear spins (I)
- Nuclear moments (Q, μ)
- Mean square chare radii ($<r^2>$)



Accomplishments

- Laser system operating since Summer 2009
- Vertical charge exchange cell commissioned in Summer 2011 at Mainz
- Collinear beam line completed in Fall 2011
- First on-line resonance (D1 transition in $^{40}Ca^{+}$) observed in Winter 2011
- Hyperfine structure of ^{55}Mn (transition metal) obtained
- Commissioned with ^{37}K in July, 2013



P. Mantica, K. Minamasono

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TAS Measurements (A. Spyrou)

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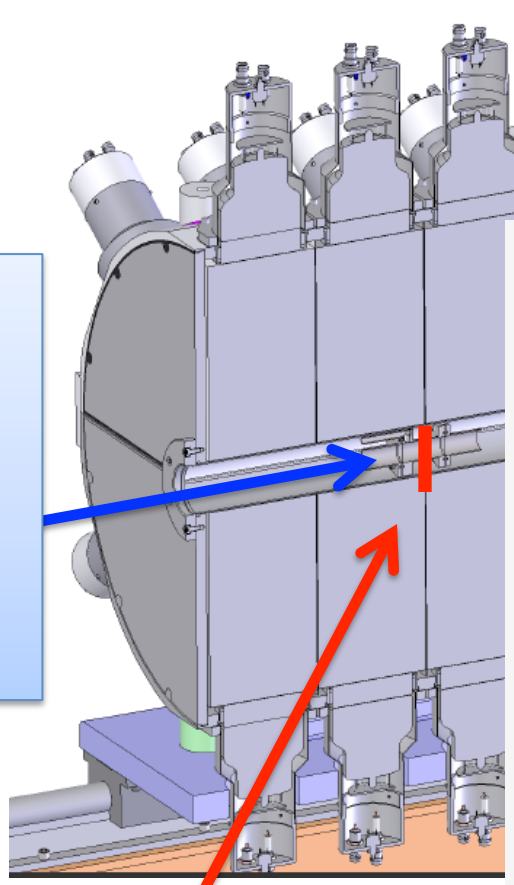
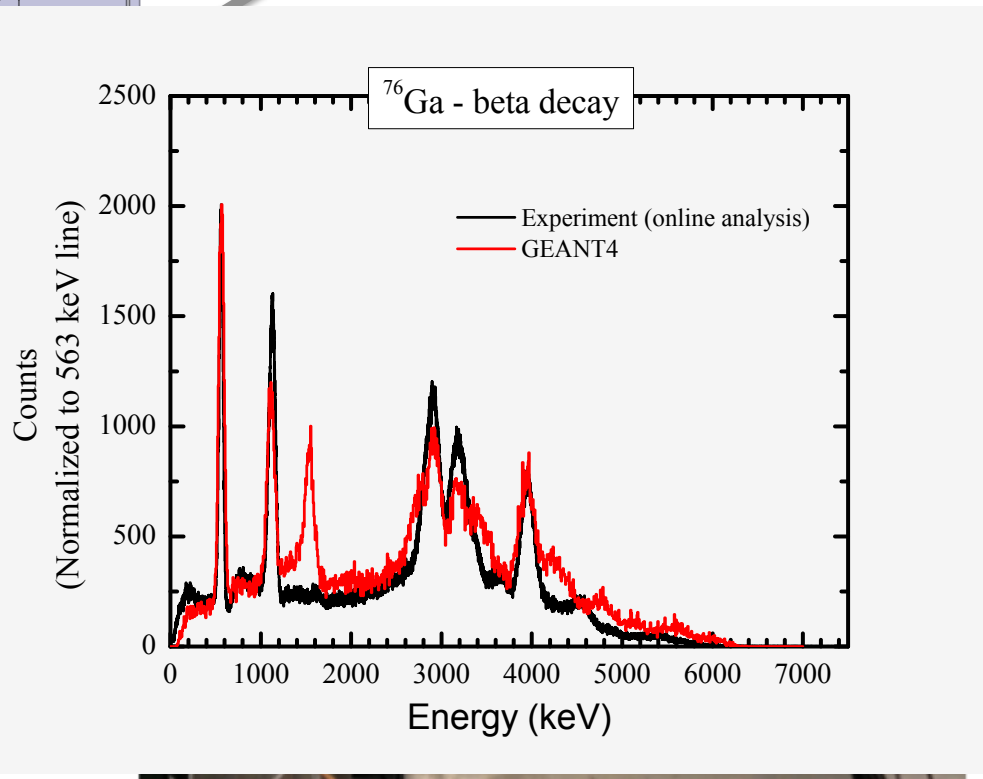
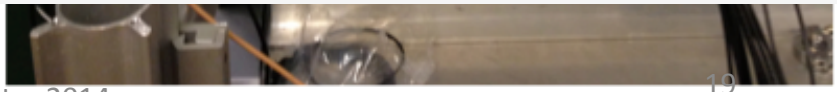
Detector
15” x 15” NaI(Tl)

Beam
^{76}Ga @ 45 keV
~ 500 pps
“No beam contaminants observed.”



Silicon Implantation detector





EBIT Charge Breeding/Analysis

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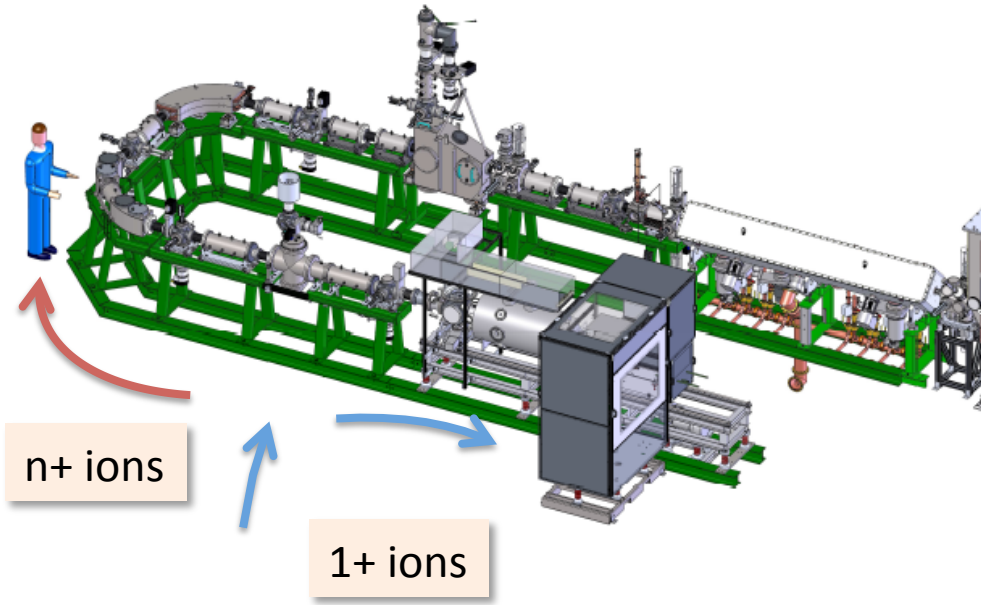

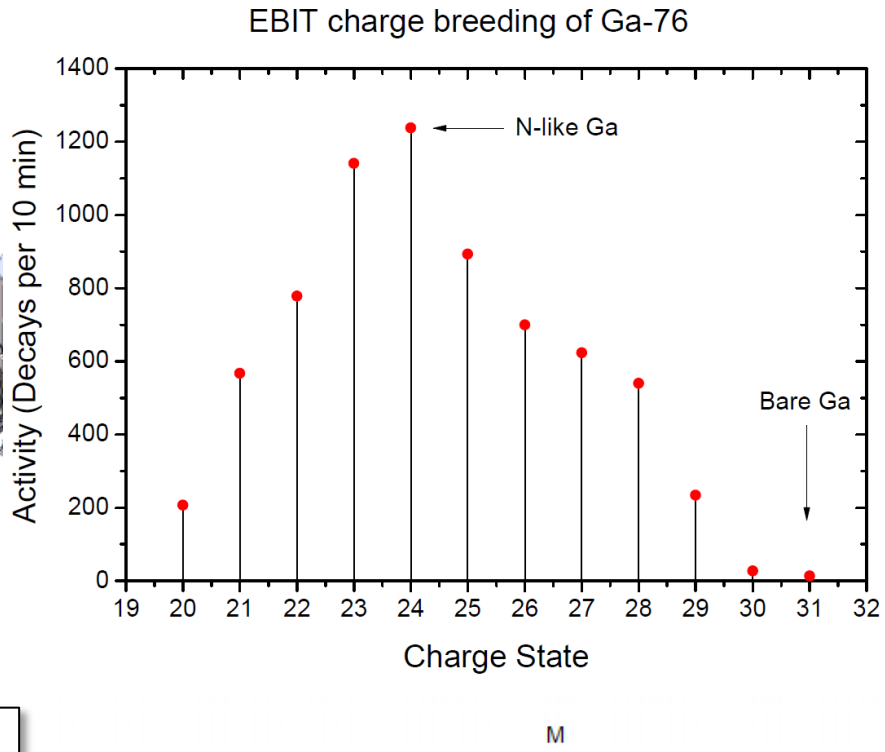

M

Extensive EBIT Studies / Development
A.Lapierre, S.Schwarz, K.Kittimanapun (G.S.)

e.g., Residual Gas Ionization (meas. current)
stable Rb^{1+} ions from N4 (Mar/13)
^{76}Ga from A1900/N4 (meas. Decay, Apr/13)
ANASEN (active target device) ^{37}K Jul/13

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Cyclotron Stopper Project

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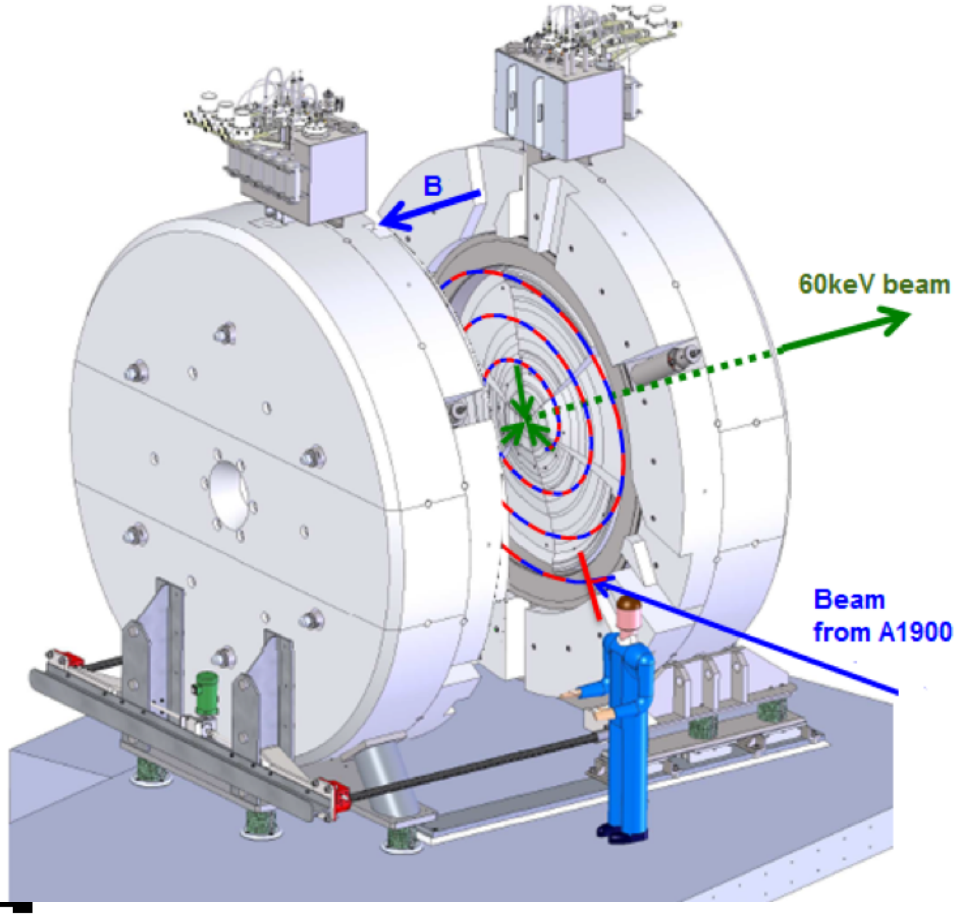
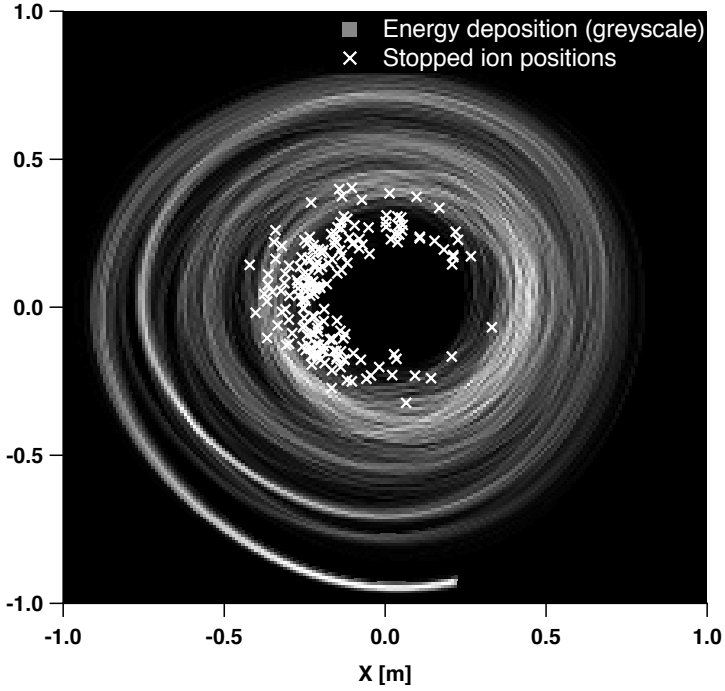
- Bollen, et al., NIM A50 (2005) 27
- Chohan, et al., IEEE Trans Appl Supercon 23 (2013) 4101805
- Schwarz, et al. NIM B317 (2013) 463 [EMIS 2012]





^{79}Br Bρ=1.6 Tm, 180 mbar

Construction of Cyclotron Stopper

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- Yoke delivered Nov/2012 and Assembled in ReA6 High Bay
- Coils in helium vessels Mar/2013

S.Chouhan, et al., IEEE Trans Applied Superconductivity, **23** (2013) 4101805

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Construction of Cyclotron Stopper

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- Yoke delivered Nov/2012 and Assembled in ReA6 High Bay
- Coils in helium vessels Mar/2013
- Completed cryostats installed in yoke Sept/2013
- Cool-down tests now
- Magnetic Field mapping next

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Construction of Cyclotron Stopper

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- Yoke delivered Nov/2012 and Assembled in ReA6 High Bay
- Coils in helium vessels Mar/2013
- Completed cryostats installed in yoke Sept/2013
- Fabrication of inner chamber essentially complete, out for B mapping

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Construction of Cyclotron Stopper

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Development of large RF carpet system – done

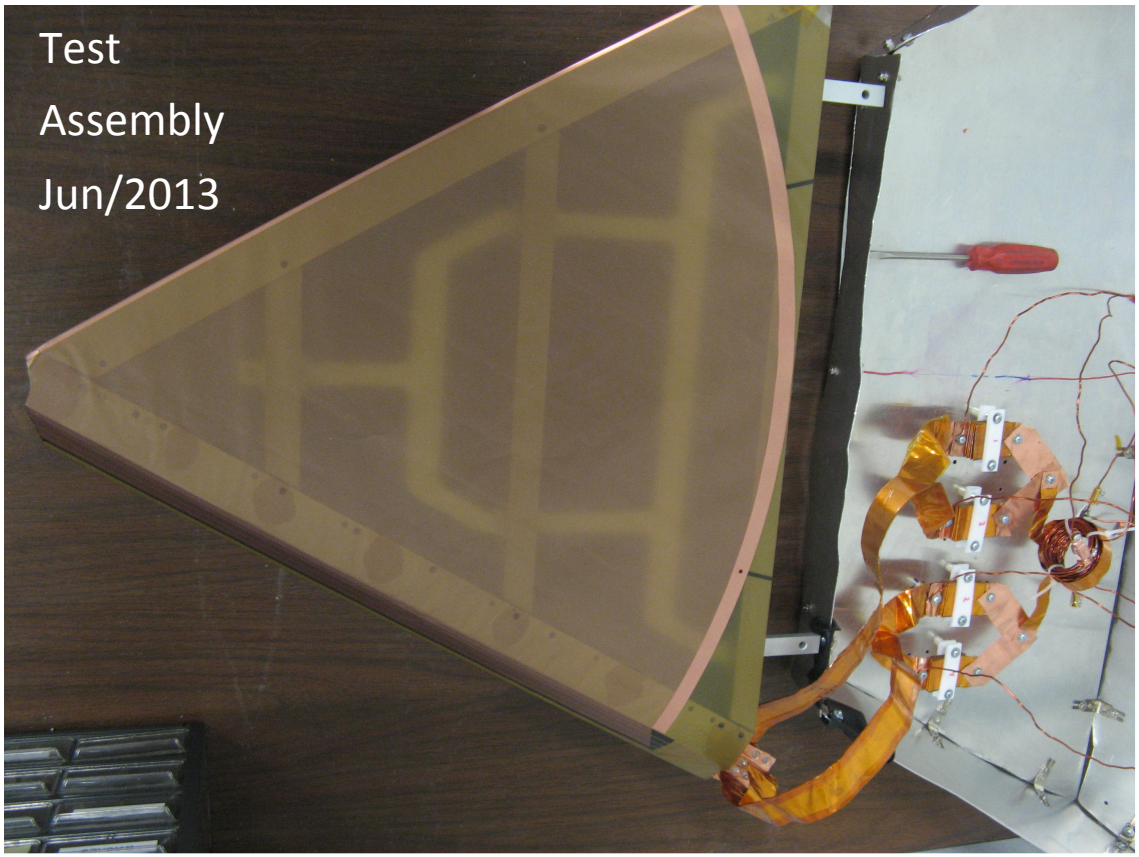
- Detailed simulations of ion motion under various conditions
- Large DC gradient carpets

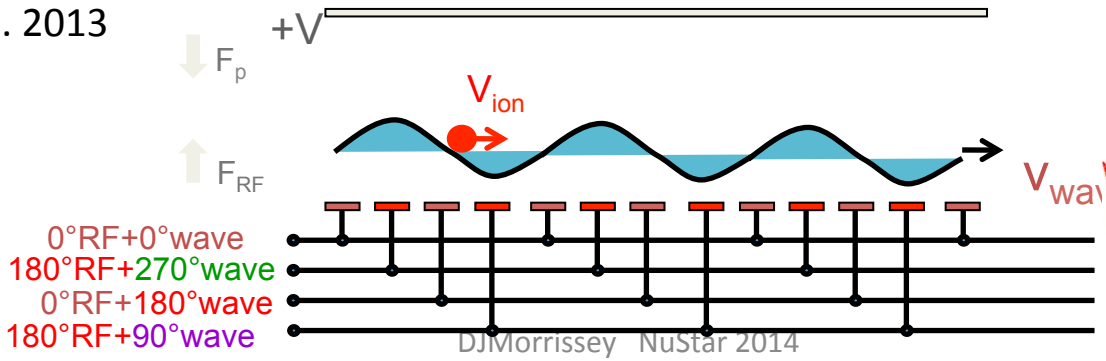
  G. Pang, Ph.D. 2011
- Test of new RF carpet concepts RF and DC decoupling, traveling wave "surfing" transport

  G. Bollen, IJMS 299 (2011) 131

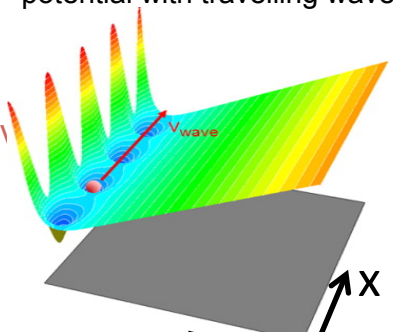
  M. Brodeur, IJMS 336 (2013) 53
- Test ion transport as a function of pressure, RF parameters and carpet design

  M. Gehring, Ph.D. 2013





Snapshot of the pseudo-potential with travelling wave



Construction of Cyclotron Stopper

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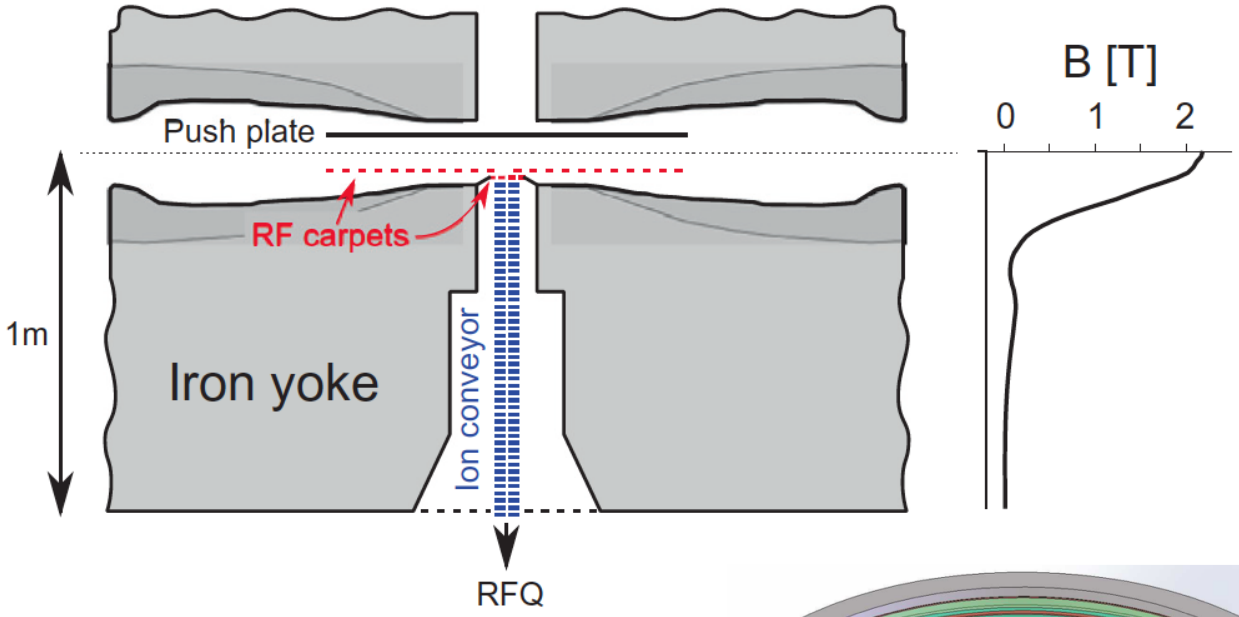
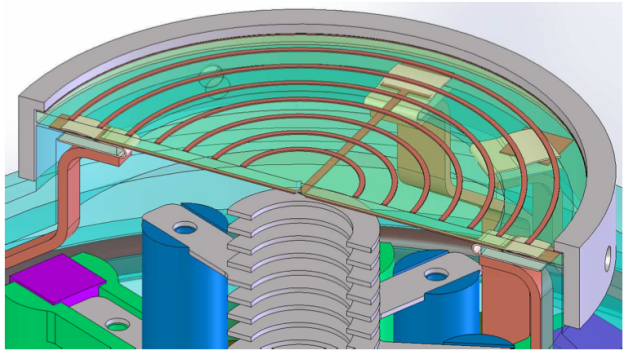
Development of Surf Tube Extraction System (Traveling Wave Ion Mobility device)

- Ion collection from large carpets to central axis with small surf carpet
- Ion transport through the axial (falling) magnetic field with "surf tube" system



S. Schwarz, et al., NIM B317(2013) 463
M. Brodeur, et al., NIM B317 (2013) 468



FRIB Ground Breaking, March 17th

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- FY14 DOE Line Item 55M$ for construction this year
  - DOE “authorizes” construction Jan/2014
- Ground Breaking March 17, 2014
- CD3b Review in June, 2014

Summary

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- New Momentum Compression Lines in operation
- ANL gas catcher initial operation
  - Commissioning runs with ^{76}Ga
  - Recommissioning of LEBIT with ^{63}Co
  - First Decay Study with "purified" projectile fragment beam
  - Colinear laser spectroscopy commissioning with ^{37}K
  - Charge Breeding & Reacceleration of ^{76}Ga, ^{37}K
    - First test experiment with ^{37}K in August, 2013
- Cyclotron Stopper construction nearing completion
  - Test magnet
  - Install RF carpets and extraction system
  - Use thermal ion sources in ReA6 hall (2014)
  - Move to high-energy beam line …
- FRIB Ground Breaking in <2 weeks

NSF

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