LASER ABLATION ACCELERATOR MASS SPECTROMETRY OF ACTINIDES WITH AN ECRIS AND LINEAR ACCELERATION For the MANTRA Project

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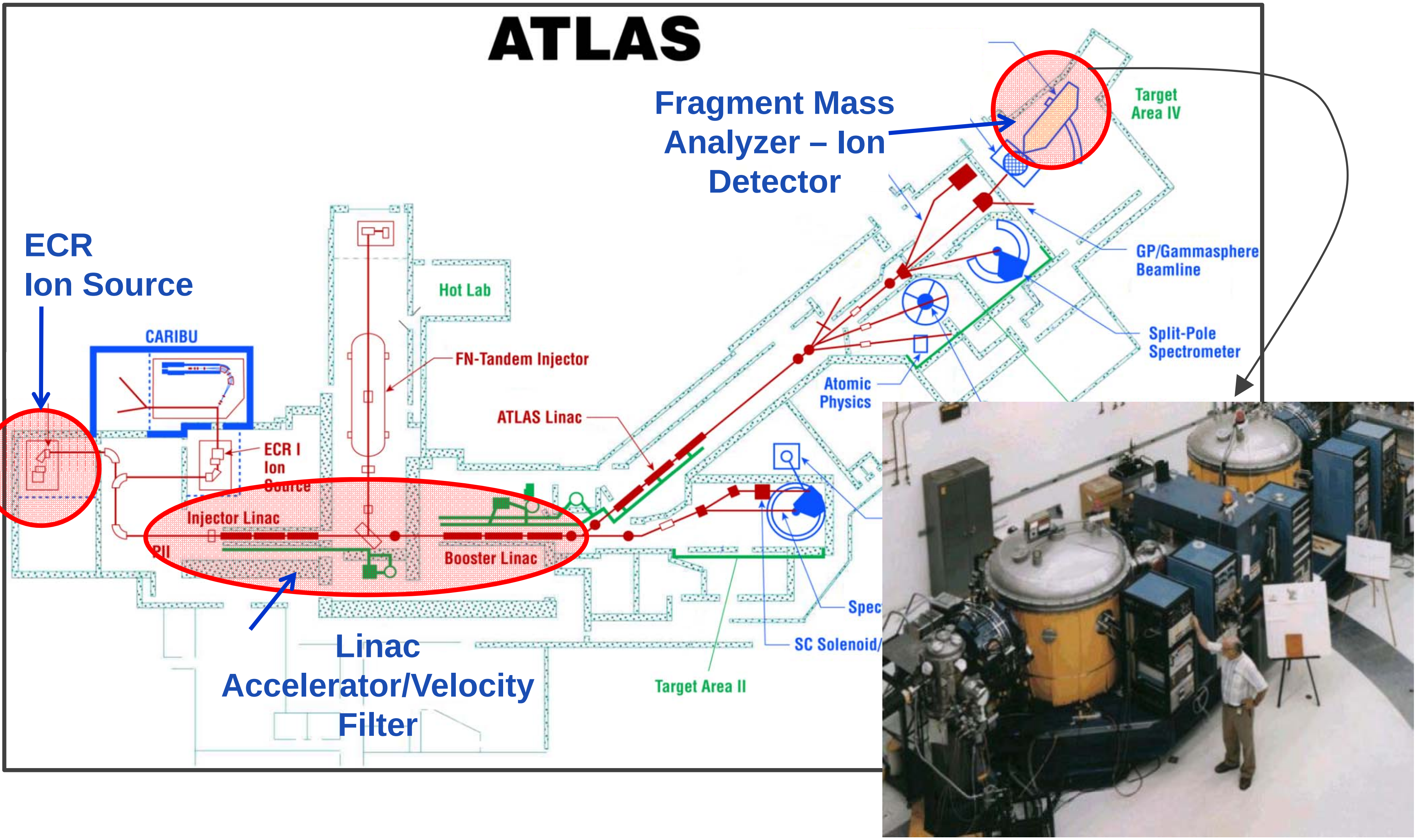
Actinide AMS at ATLAS



Actinide AMS at ATLAS

- Electron Cyclotron Resonance (ECR) Ion Source
  - No molecules
  - High charge states ($^{238}U^{31+}$)
  - Quartz liner to reduce backgrounds
- Superconducting Linear Accelerator
  - Beam energy of 1.1 MeV/u limited by FMA detector
  - Velocity filter (Use in Acel-Decel mode.)
  - Accelerates ions to same E/A
  - Filters ions that differ in m/q from reference by >1:500
- Fragment Mass Analyzer Detector
  - Electric & Magnetic fields
  - Focal plane dispersion in m/q
  - Limited to E/q ~7 MV and Bρ ~1.1 T*m
  - Strip at entrance to FMA to allow higher ion energy
  - Sophisticated focal plane detector provides
  - Position, Energy, dE, & Time information

AMS Challenges for MANTRA include:

- Large number of samples:
  - o 13 high purity target materials
  - o 3 different neutron energy spectra
  - o 2-3 samples for each case.
  - o Un-irradiated material
  - o Blanks
- Desired accuracy of results: ~2%
  - o No cross-talk between samples
  - o Stable, repeatable transmission between source and ion detector
- Small sample size (few mg total, actinide component <1mg)
  - o Reduce radiological problems with samples
  - o Reduce sample consumption/improve efficiency
- Limited “Z” element resolution in detectors

Improved Configuration for AMS

Major Changes to ATLAS to address high precision AMS

1) Laser ablation of material into ECR Source.
2) Automated multi-sample changer for source.
3) Fully automated experiment, much as in ^{14}C AMS.
   - Automated switching of accelerator between (m/q) configurations.
   - Automated sample changing
   - Integrated data acquisition
4) Improved detector electronics to improve sensitivity, reduced background and increase “Z” resolution.

Controlled Laser Ablation

We will use laser ablation at relatively low power levels to efficiently introduce solid materials into plasma.

Benefits of laser ablation expected are:

a) Efficient use of solid materials for AMS and enriched isotopes.

b) Less sensitive to material chemical composition.

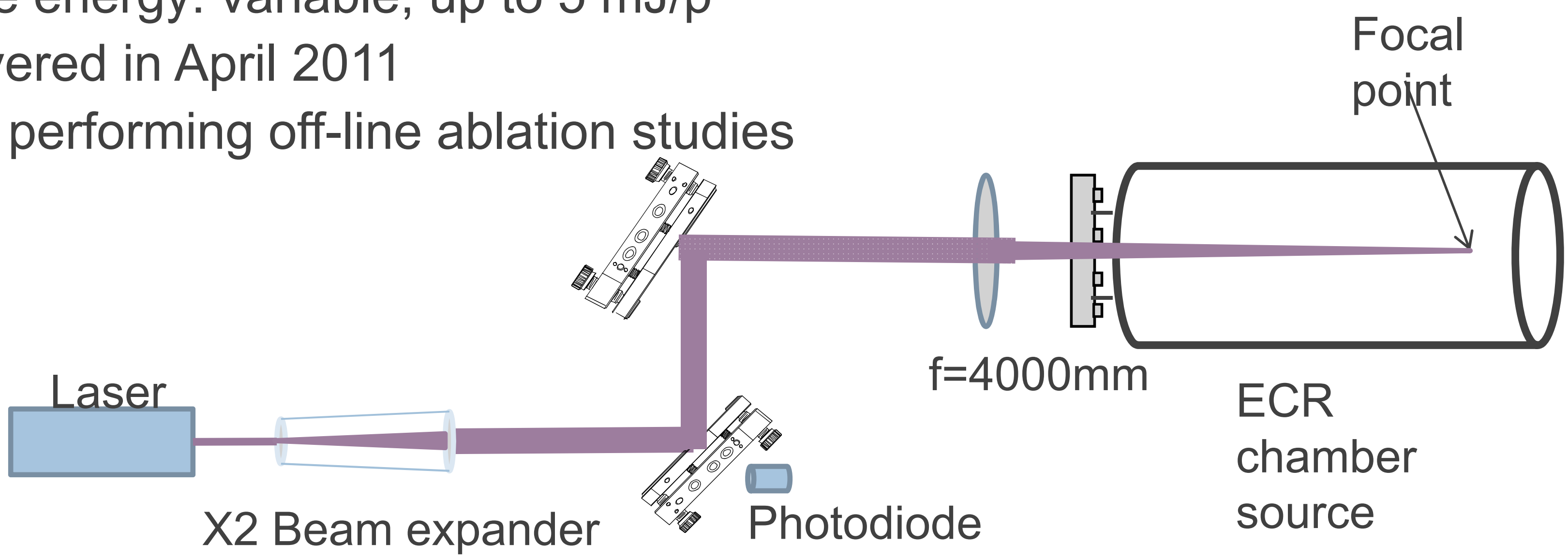
c) Cleaner source operation (yet to be proven).

d) Decouples source operation from material insertion.

Laser for ablation

A Passat Diode-Pumped Solid-State HELPP 1064 Laser

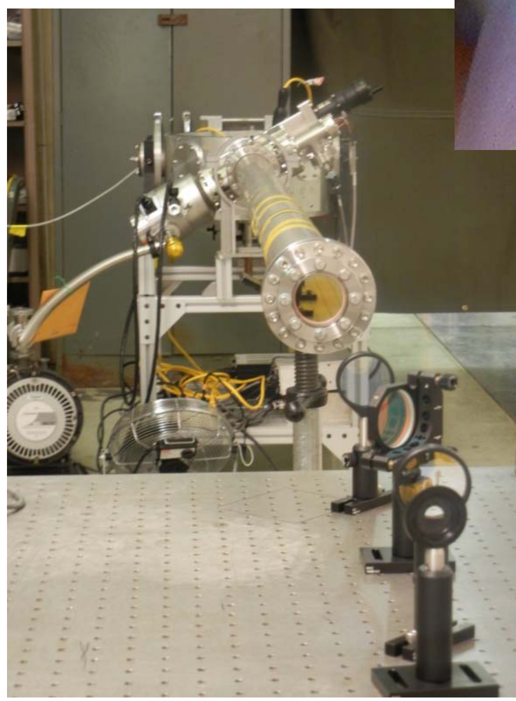
- λ =1064 nm
- ≤10^{11} W/cm^2
- 8 ps pulse width (to reduce splatter and improve efficiency)
- Rep Rate up to 400 Hz
- Laser beam size ~7 mm maximum
- Less than 1 mm diameter spot on sample
- Pulse energy: variable, up to 5 mJ/p
- Delivered in April 2011
- Now performing off-line ablation studies

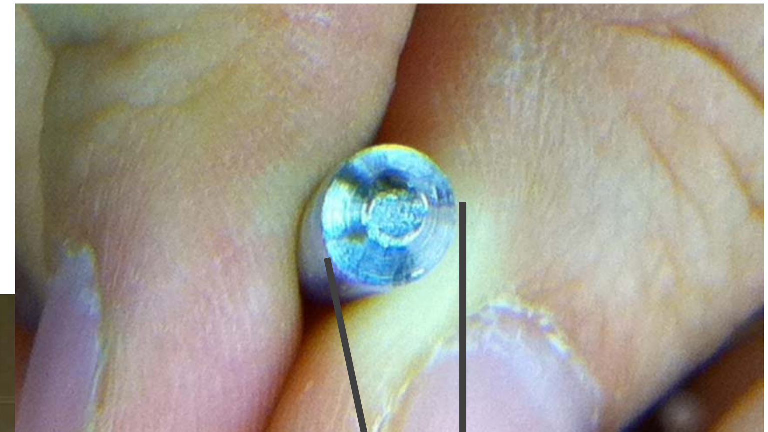


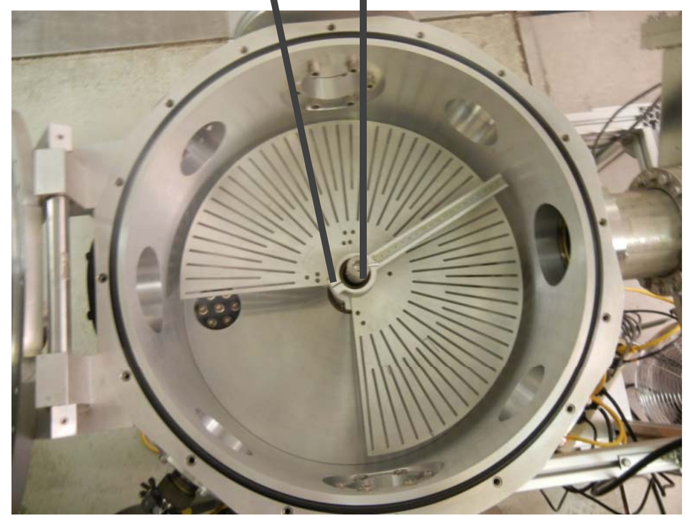
Off line laser ablation test facility

First measurements on stable targets made in last two weeks.

- Ablation rates appear more than adequate
- angular distribution of ablated material very sharply peaked at the normal.







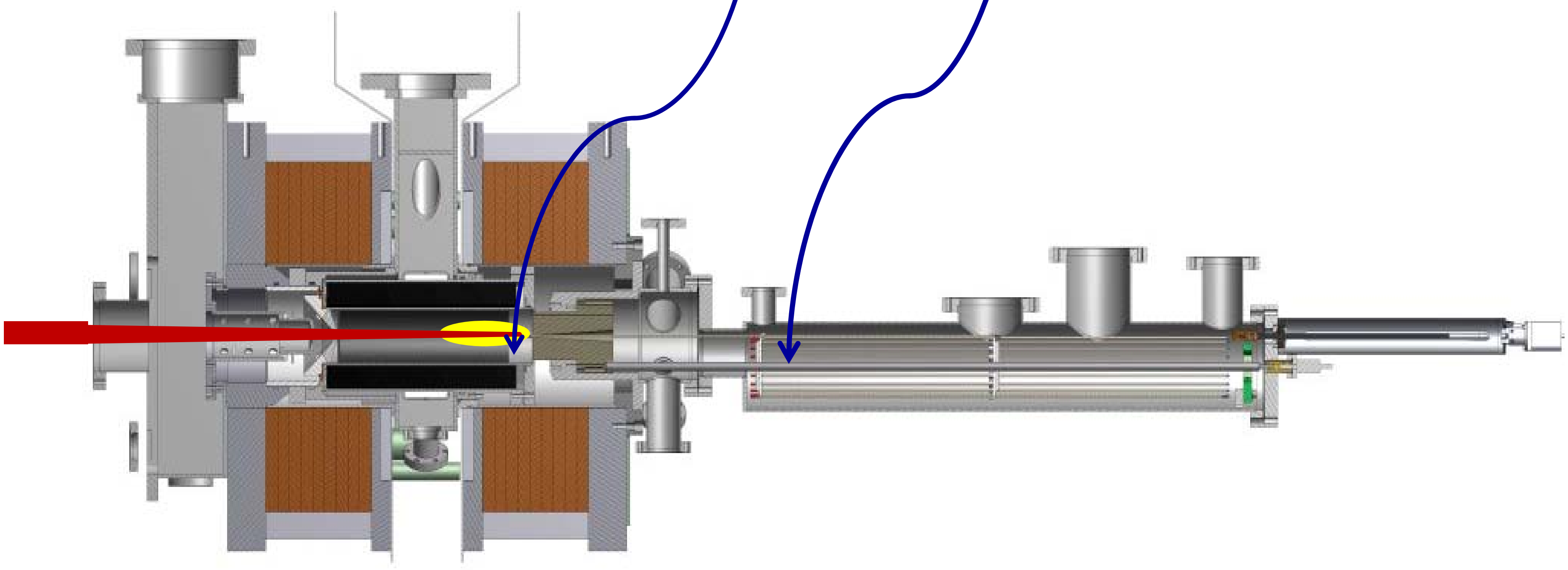
Complete off-line tests by October 2011.

ECR Source Modifications

Required to address needed precision and accuracy

- 20 Sample holder system
  - Samples retracted far from plasma for storage
  - Rapid switching between samples
- On- axis laser ablation target
  - Reduced surface contamination

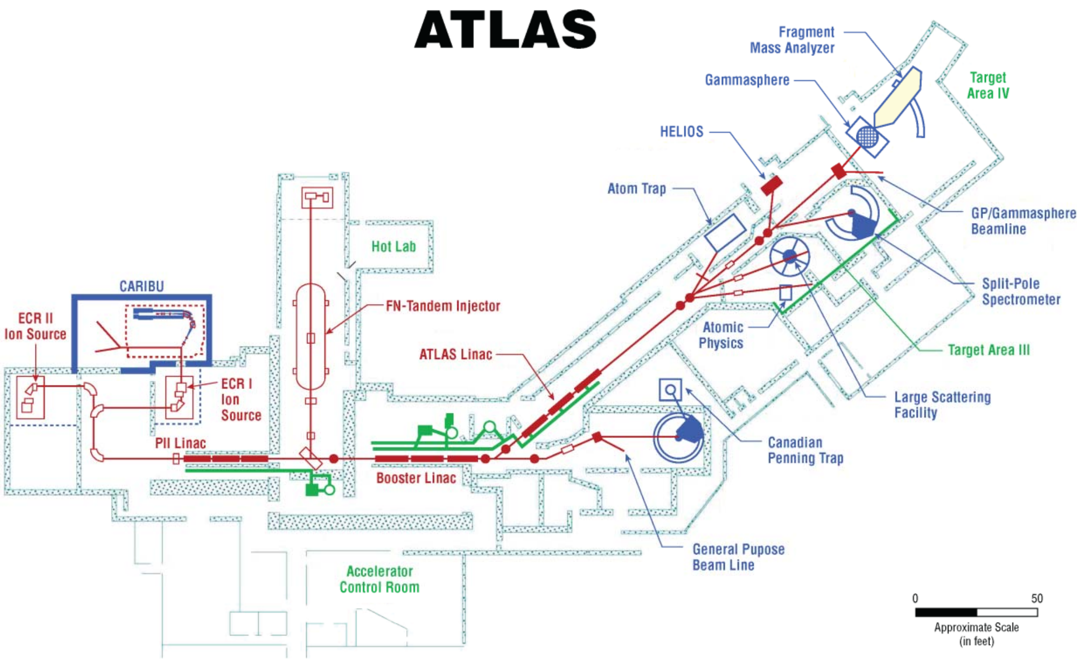
Status: Components ordered or underconstruction



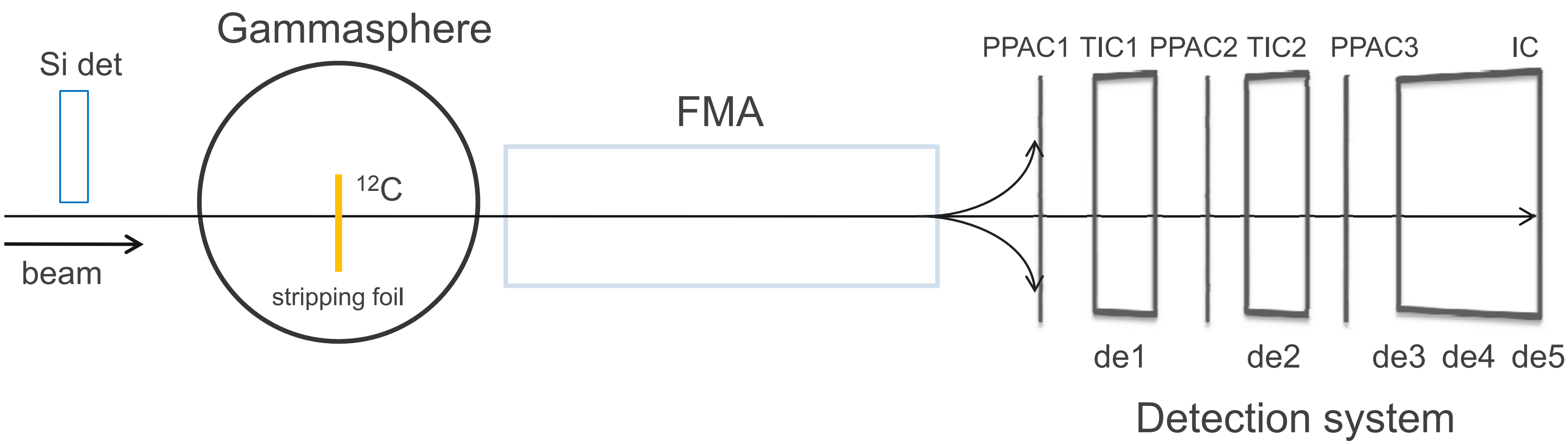
Accelerator Modifications

Required to improve reproducibility of transmission

- Computer controlled accelerator switching between species
- Stored configurations with rapid loading ability
- Automatic setting of dipoles to exact field
  - Continuously monitored
- All parameters continuously monitored and alarmed for deviations
- Data acquisition and accelerator control directly linked.
- Master clock to synchronize accelerator/ion source/data acquisition



Fragment Mass Analyzer and Detector System

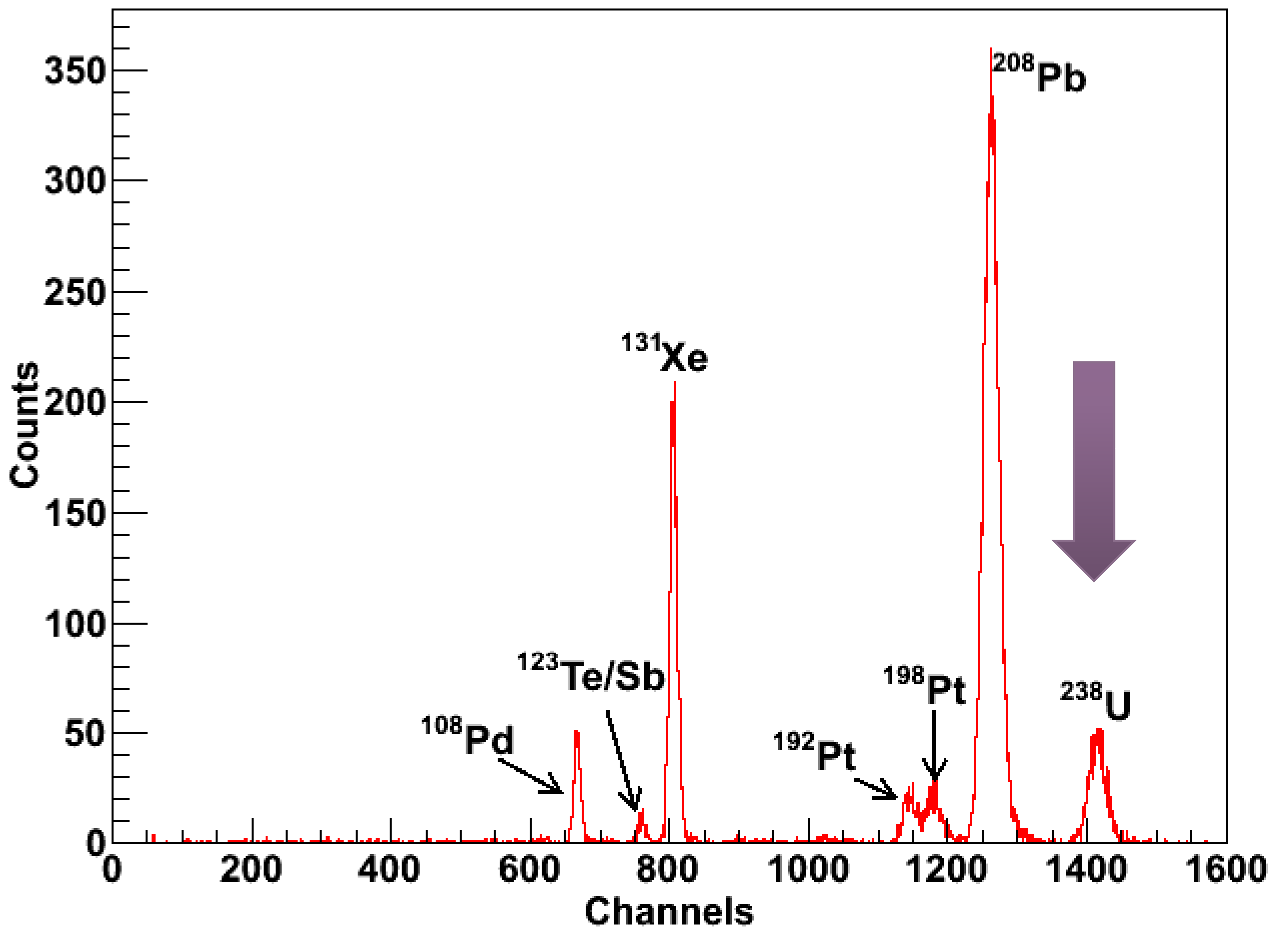


- Si detector used for energy monitoring: first hand particle identification
- FMA limits: Electrostatic rigidity E/q: 7 MV and Magnetic rigidity Bp: 1.1 Tm
- For ^{238}U with 200 MeV, for the ECR charge states 28-32,
  E/q = 6.25 to 7.14 (at the limit), Bρ = 1.05 to 1.22 (above limit)
- Stripping foil changes charge state of incident beam: With a 40 μg/cm^2 ^{12}C stripping foil, 28+->36+,E/q = 5.5 (within limit), Bp = 0.87 (within limit)

MANTRA Initial test run: December 2010

$^{238}U^{31+}$, Sample #12, 0.5 μg

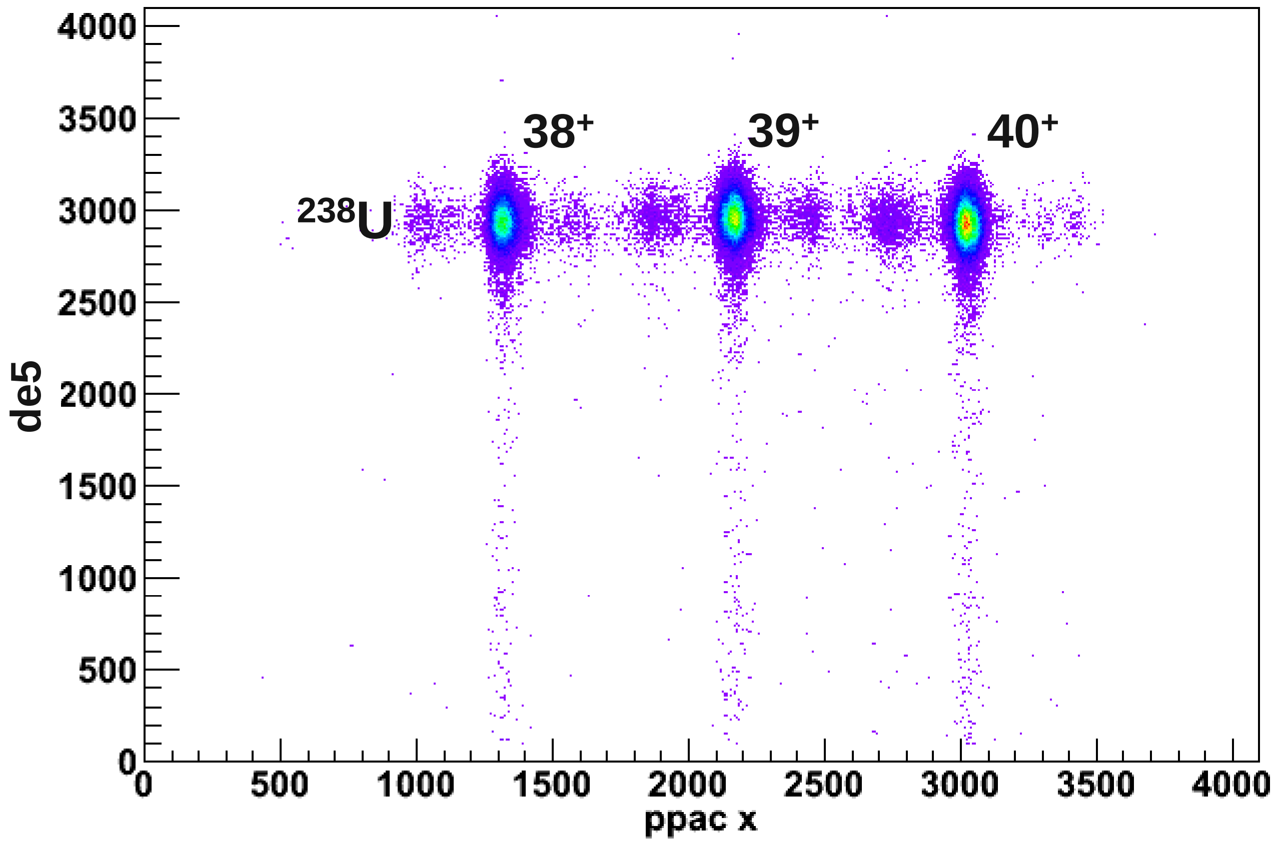
Accelerated beam seen at entrance to FMA



MANTRA Initial test run: December 2010

^{238}U: FMA set for $^{238}U^{39+}$

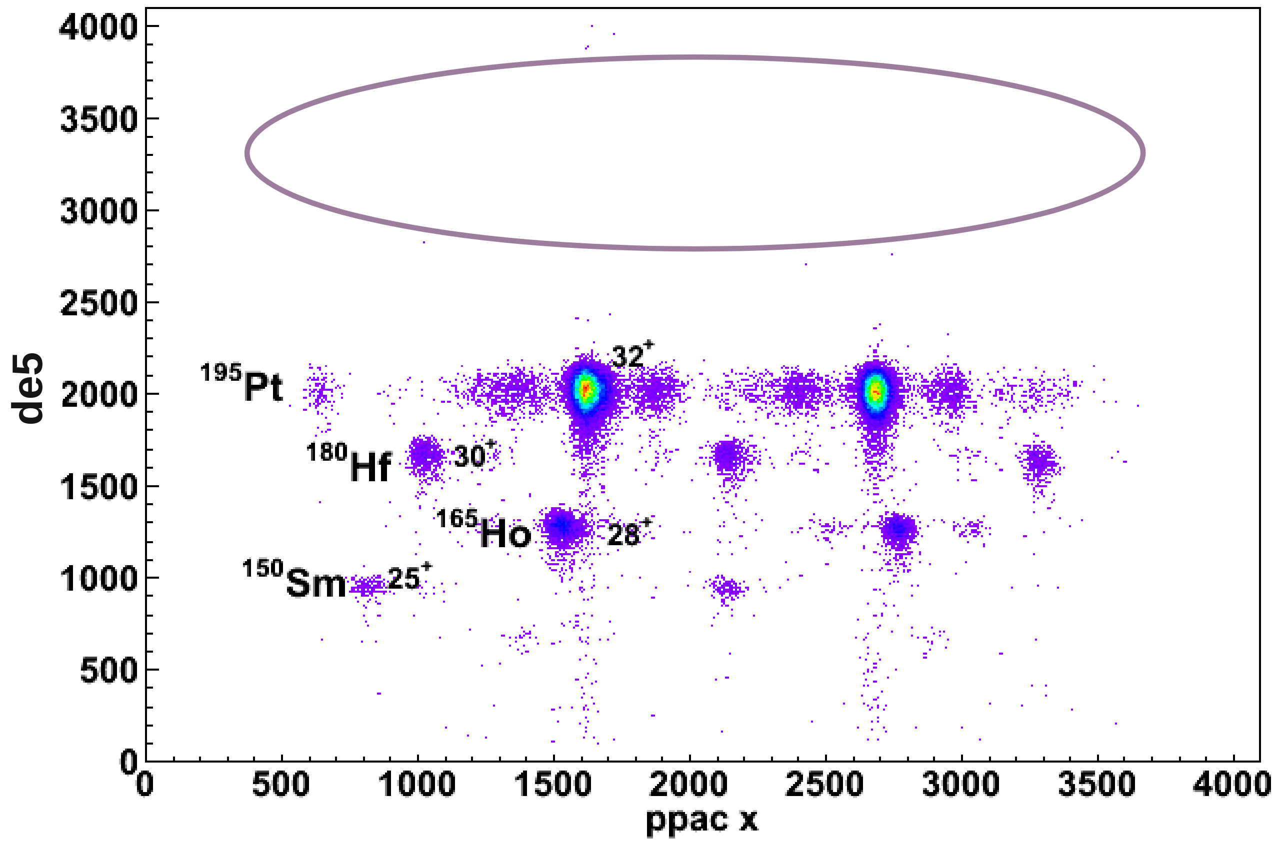
Corresponding spectrum at FMA focal plane detector



MANTRA Initial test run: December 2010

$^{240}U^{32+}$: scaled for $^{240}U^{39+}$

Corresponding spectrum at FMA focal plane detector



Next Steps

- At Argonne
  - Off- line laser ablation studies completed by October
    - ablation rates
    - angular distribution
    - ‘splatter’ effects studies
  - Move laser to ECR source in late Fall, 2011
    - Repeat subset of off-line tests
    - Measure source performance with laser
      - Charge-state distribution
      - Efficiency
      - Sample cross-talk
  - Install multi-sample changer in December
    - Test function
  - Full accelerator test of new system in March 2012.
- First actual measurements of samples: Summer/Fall 2012.
- Complete sample measurements: 2013.
- Budget: $960k, $547k spent. All categories within budget.
- Milestones: FY2010 completed, FY2011 approximately 3 months behind schedule.