ATLAS

Guy Savard

Scientific Director of ATLAS

Argonne National Laboratory
&
University of Chicago

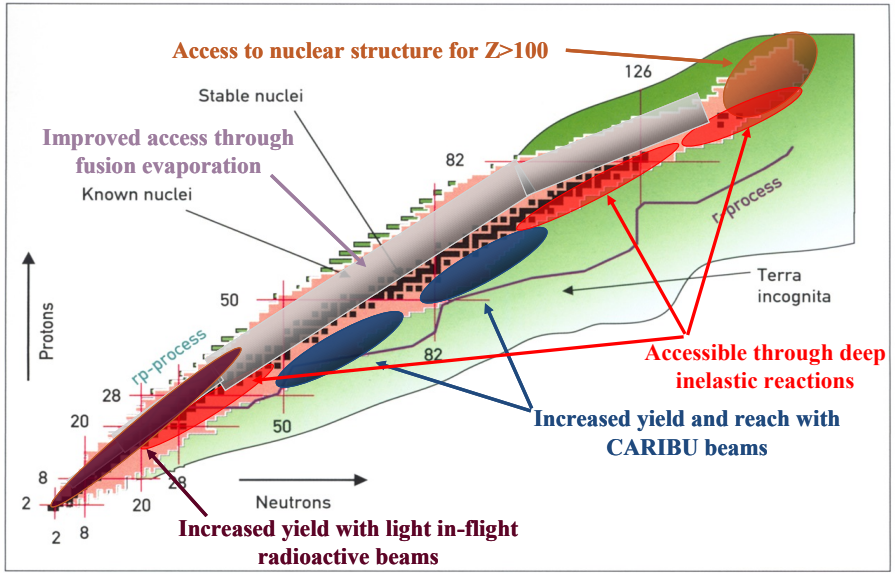
Presentation to the Low Energy Nuclear Physics Town Meeting
College Station, August 21-23, 2014

ATLAS Role and Goals

- ***ATLAS is the DOE low-energy nuclear physics national user facility***
- It provide beams and facilities enabling world leading research at around Coulomb barrier energy, answering key questions in the fields of:
  - nuclear structure
  - low-energy tests of the Standard Model
  - nuclear astrophysics
  - applications of low-energy nuclear physics

Research goals are guided by the Nuclear Science Long-Range plan, the relevant DOE performance milestones and the ATLAS Strategic plan.

- This is done through:
  - providing beamtime for research programs
    - Any stable beam from proton to uranium
    - some in-flight radioactive beams
    - Low-energy and reaccelerated CARIBU beams
  - developing new capabilities to address evolving needs of the field
    - new experimental equipment
    - new accelerator capabilities (accelerator R&D group)

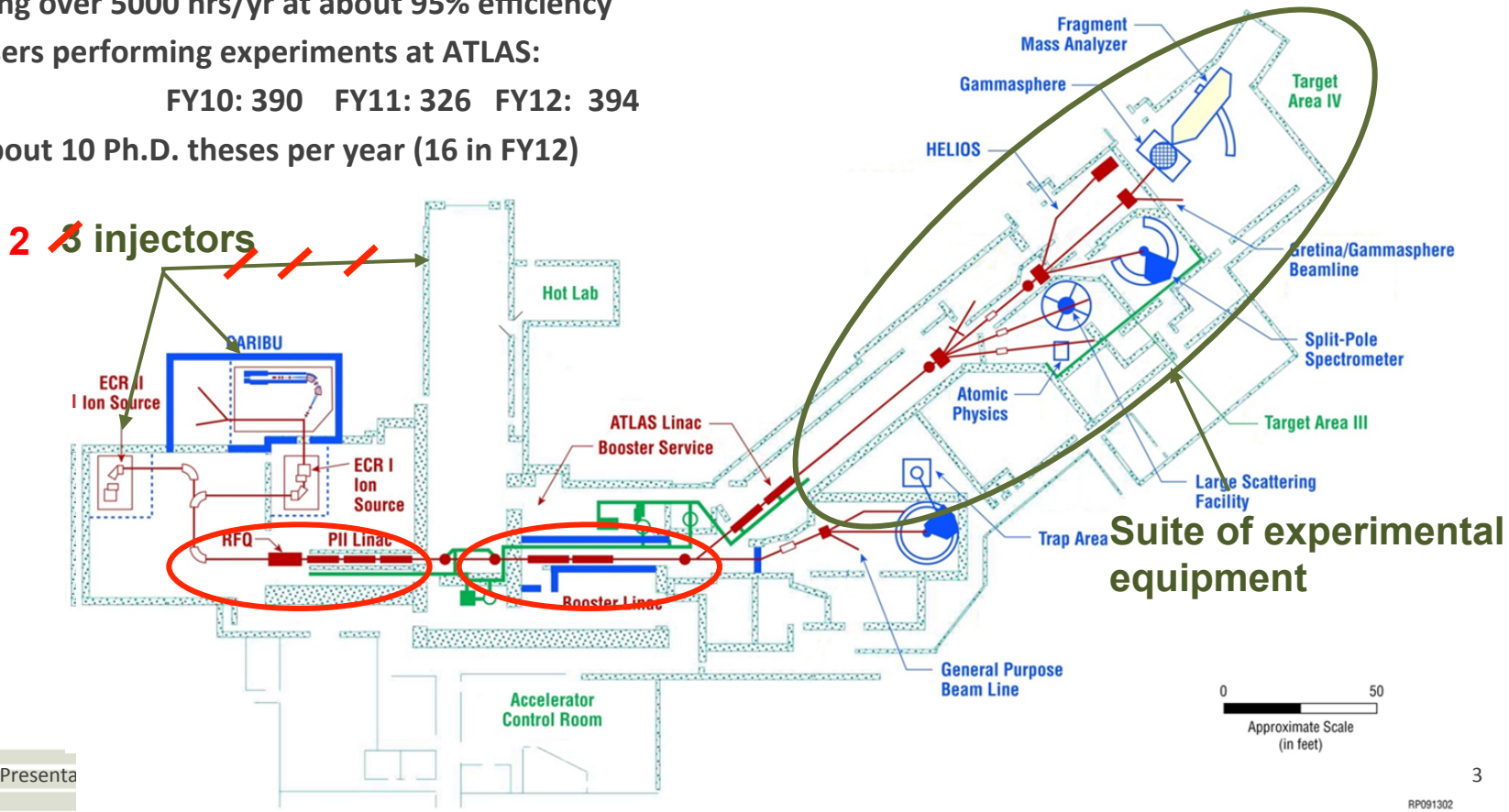


- ATLAS is interacting with the community to ensure that it fulfills the needs of its users and evolves to continue doing so in the future. This includes developing capabilities and expertise that will be important for the physics program (focused mainly on reaccelerated beams) at FRIB and positioning ATLAS for its expected role as the high-intensity stable beam facility in the FRIB era.

ATLAS facility

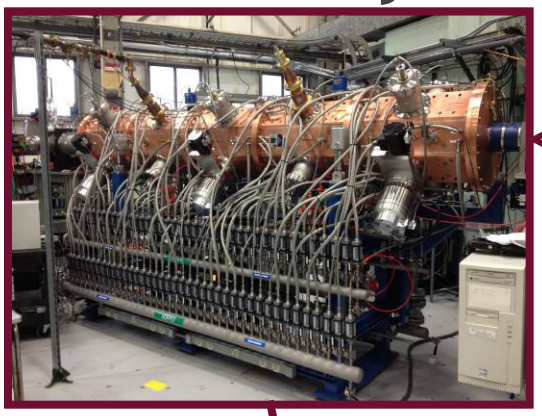
- Stable beams at high intensity and energy up to 10-20 MeV/u
- Light in-flight radioactive beams
  - *light beams, no chemical limitations, close to stability, acceptable beam properties*
- CARIBU beams
  - *heavy n-rich from Cf fission, no chemical limitations, low intensity, ATLAS beam quality, energies up to 15 MeV/u*
- State-of-the-art instrumentation for Coulomb barrier and low-energy experiments
- Operating over 5000 hrs/yr at about 95% efficiency
  - Users performing experiments at ATLAS:

    FY10: 390 FY11: 326 FY12: 394
  - About 10 Ph.D. theses per year (16 in FY12)



RP091302

ATLAS layout with completed and ongoing upgrades



Novel highly-efficient design from Accelerator R&D group

Improved instrumentation

New low-energy experimental hall

High-Intensity ECR

EBIS

CARIBU

cryomodule and rebuncher rearranged

New in-flight separator (AIRIS)

MHB RFQ

new cryomodule

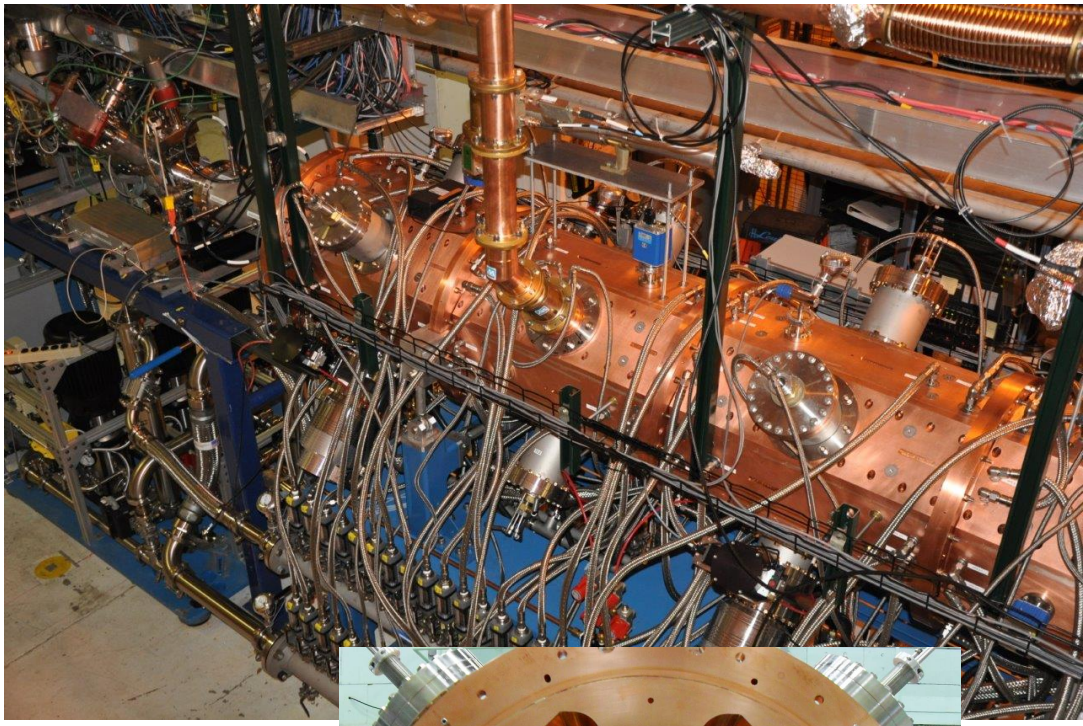
World record performance

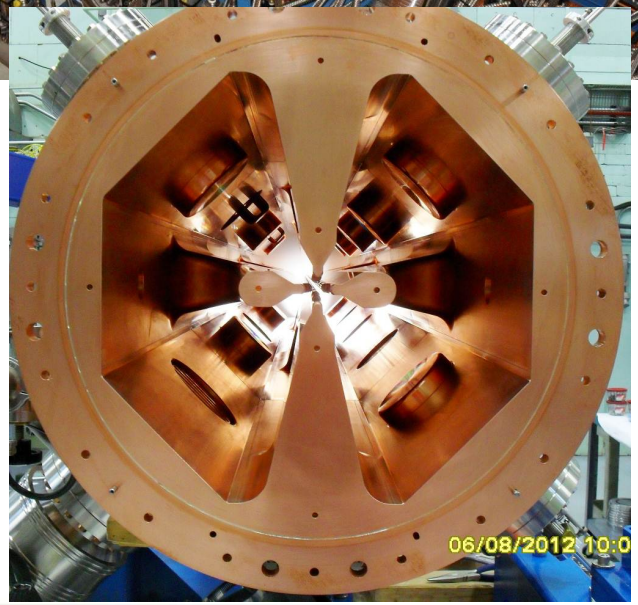
ATLAS Efficiency & Intensity Upgrade: New RFQ Accelerator

Project: RFQ Construction & installation, beam line reconfiguration, & cryomodule reconfiguration

Performance:

1. RFQ WORKS – CW!!
2. Excellent transmission
   a) 40%-60% → 80% through PII
   b) Up to 100% PII → Target
3. Operation at ~95% of full power
   → m/q ~7 acceleration achieved





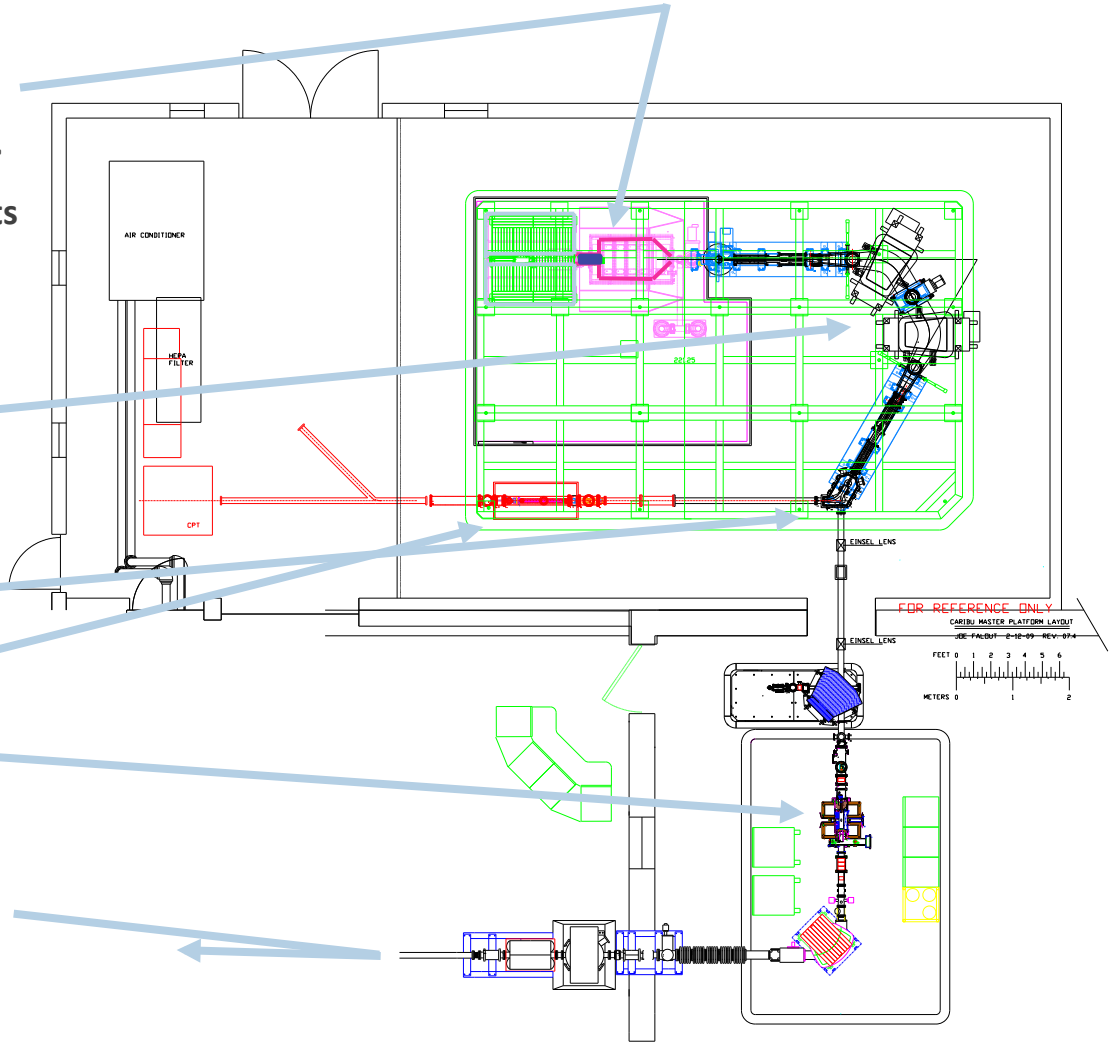
RFQ has been in routine operation since January, 2013.

ATLAS Efficiency & Intensity Upgrade: Replacement of First Booster Cryostat Module & Liquid Helium Upgrade

Neutron-rich beam source for ATLAS: CARIBU "front end" layout …. a compact "ISOL" facility

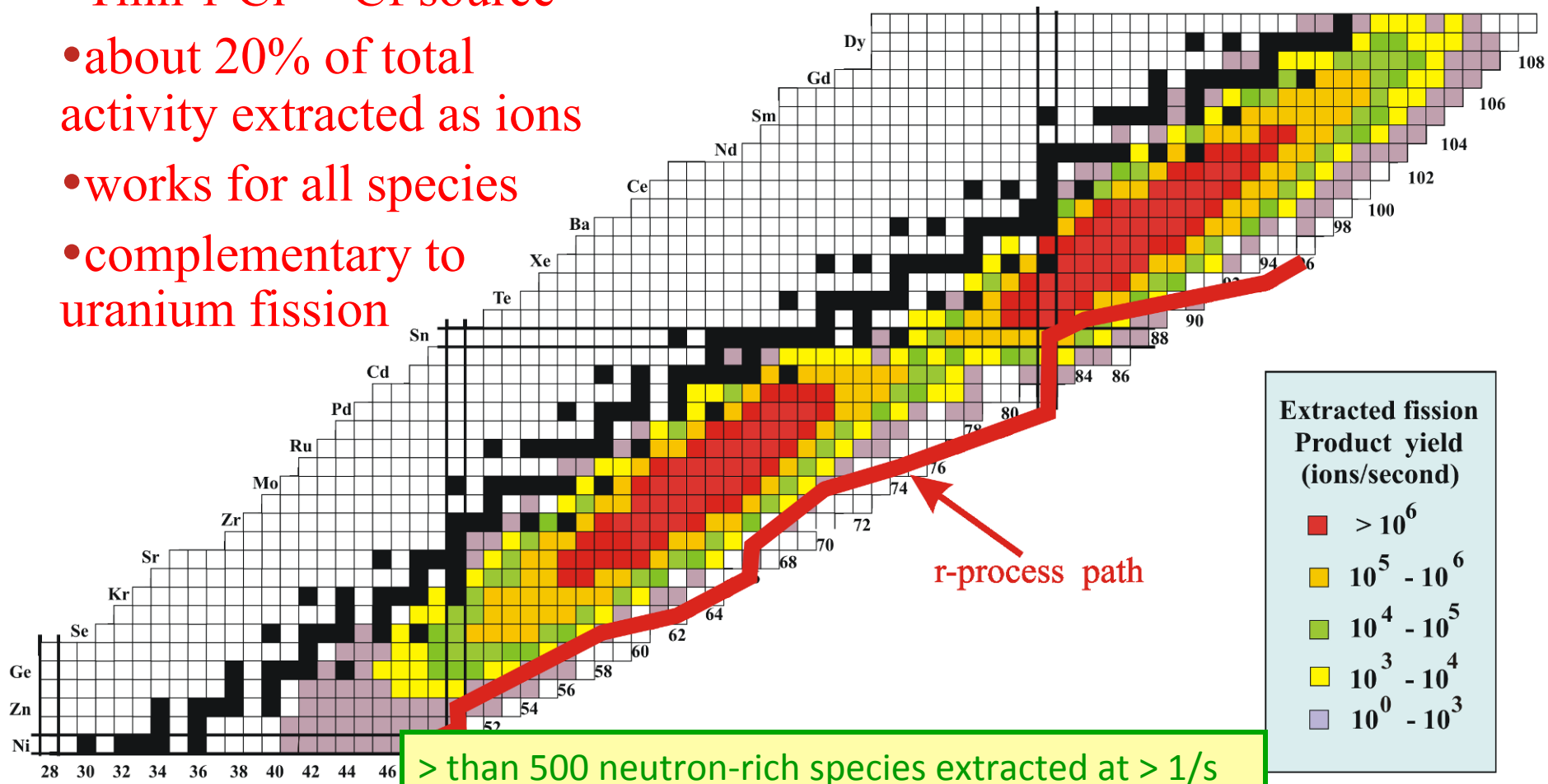
Main components of CARIBU

- **PRODUCTION**: "ion source" is ^{252}Cf source inside gas catcher
  - Thermalizes fission fragments
  - Extracts all species quickly
  - Forms low emittance beam
- **SELECTION**: Isobar separator
  - Purifies beam
- **DELIVERY**: beamlines and preparation
  - Switchyard
  - Low-energy buncher and beamlines
  - Charge breeder to Increase charge state for post-acceleration
  - Post-accelerator ATLAS and weak-beam diagnostics



Extracted isotope yield at low energy (50 keV)

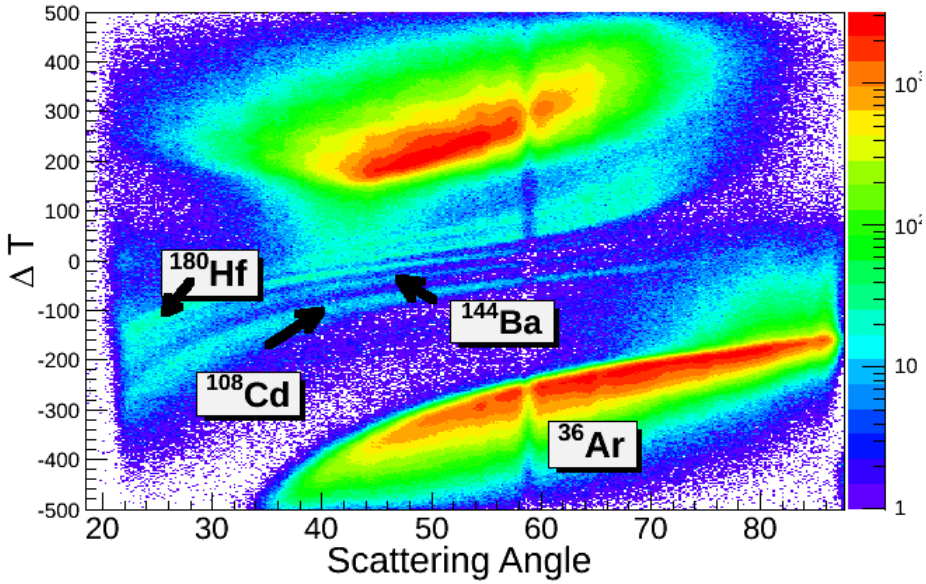
- Thin 1 Ci ^{252}Cf source
- about 20% of total activity extracted as ions
- works for all species
- complementary to uranium fission

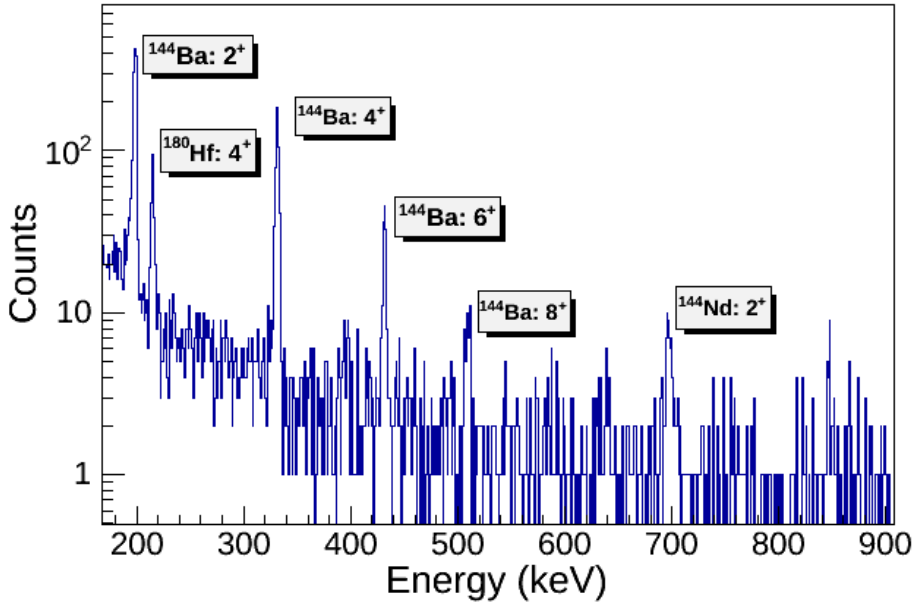


> than 500 neutron-rich species extracted at > 1/s

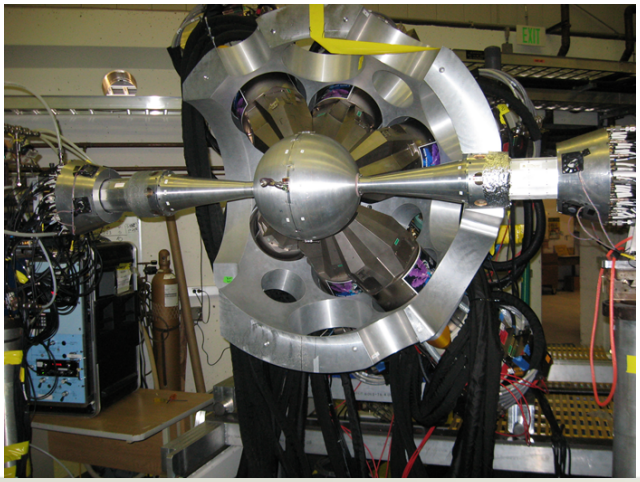
> 150 whose mass has never been measured

Coulomb excitation of ^{144}Ba from CARIBU with GRETINA/CHICO2





650-MeV ^{144}Ba + ^{208}Pb (1mg/cm^2) GRETINA + CHICO2 + CARIBU/ATLAS expt.



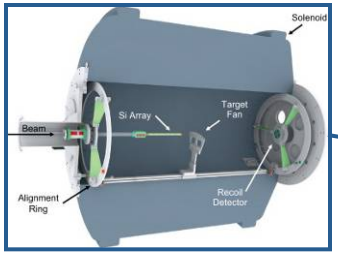
Charge breeder + upgraded ATLAS provides post-acceleration with ~10% total efficiency and exquisite beam properties

Main tools enabling the physics: ATLAS suite of experimental equipment

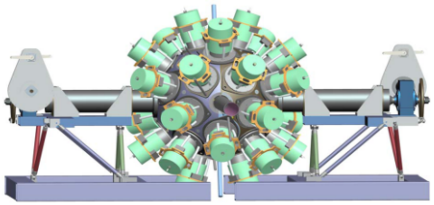
CPT mass spectrometer

X-array

HELIOS spectrometer

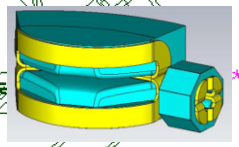


GRETINA

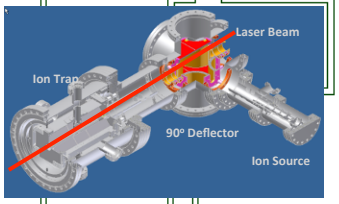


FMA

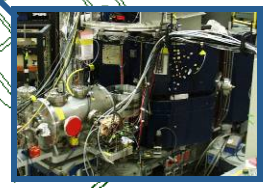
AGFA



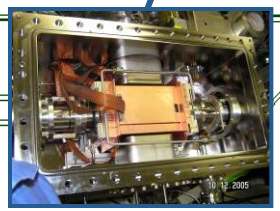
Laser Lab



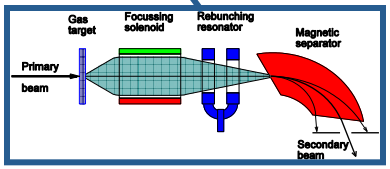
CARIBU



Si-array (Ludwig) and Enge spectrometer



Beta decay Paul trap



In-flight RIBs production

+ outside instruments: CHICO-II, HERCULES, GODDESS, VANDLE, …

ATLAS Users meeting

- Changing landscape and the needs/opportunities for ATLAS and its User community created the need to update the ATLAS strategic plan.

- ATLAS management and its Users Executive Committee organized a dedicated ATLAS Users Meeting (as opposed to the joint low-energy meetings of the last few years) to address this specific need

    - Two day meeting: May 15-16 2014
    - Mix of
        - presentations on ATLAS/CARIBU new capabilities and possible upgrades
        - presentations on experimental equipment (existing and new initiatives)
        - five physics working group sessions
        - Strategic plan discussion
    - 100 attendees

Major Scientific Goals

Discussed in 5 working group sessions:

I. Understanding the stability and structure of nuclei as many-body systems built of protons and neutrons bound by the strong force;

II. Exploring the origin of the chemical elements and their role in shaping the reactions that occur in the high-temperature and explosive events of the cosmos;

III. Understanding the dynamics governing interactions between nuclei at energies in the vicinity of the Coulomb barrier;

IV. Testing with high accuracy the fundamental symmetries of nature by taking advantage of nuclei with specific properties;

V. Nuclear physics applications at ATLAS and CARIBU;

Summary of discussion groups available at
http://www.phy.anl.gov/atlas/workshop14/index.html .

Current push forward for ATLAS

- Increasing efficiency with which programs are run
  - Pushing back beam limitations
    - Stable beams → higher intensity
    - In-flight radioactive beams → higher intensity, purity, and accessible to more experimental areas
    - CARIBU beams → higher intensity, purity
  - Pushing back rate limitations for essentially all experiments, including Gammasphere
  - Gaining higher efficiency for weak channels
  - Gaining access to other regions of the nuclear chart
  - Providing more beam hours

- Recent/current/possible upgrades addressing main limitations
  - ARRA funded intensity and efficiency upgrade of ATLAS (X10 in intensity) (FY13-14)
  - Digital Gammasphere (X4-12 in rate capabilities) (FY13-14)
  - EBIS charge breeder and larger low-energy experimental area for CARIBU (X 3 in intensity and higher purity) (FY14-15)
  - AGFA (X10 in acceptance for superheavies) (FY14-16)
  - AIRIS: New recoil separator for in-flight program (>100 in intensity and higher purity) (FY15-17)
  - Multi-user upgrade (FY16-20)

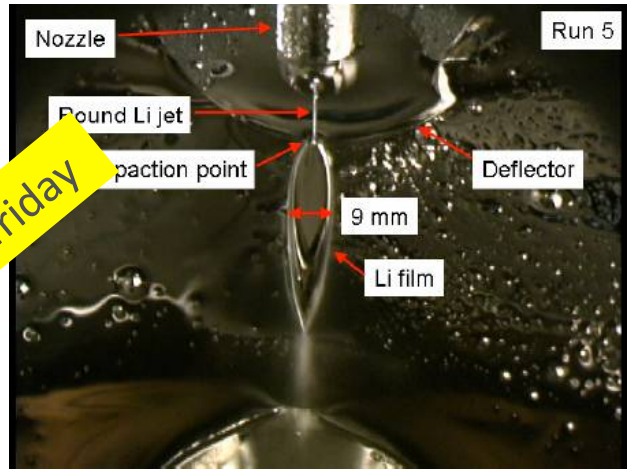
Two orders of magnitude intensity gain on in-flight beams with AIRIS

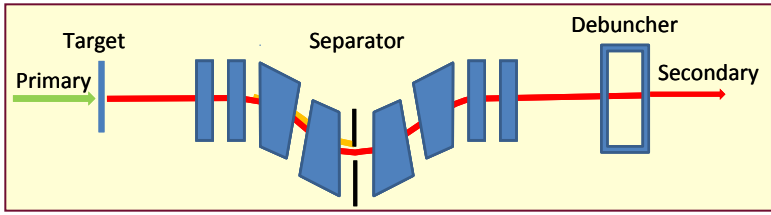
- Existing system limited by
  - Production → Q-value, primary beam intensity and targets
  - Poor transmission (measured transmission for ^{17}F was 0.3%)
  - Limited selectivity

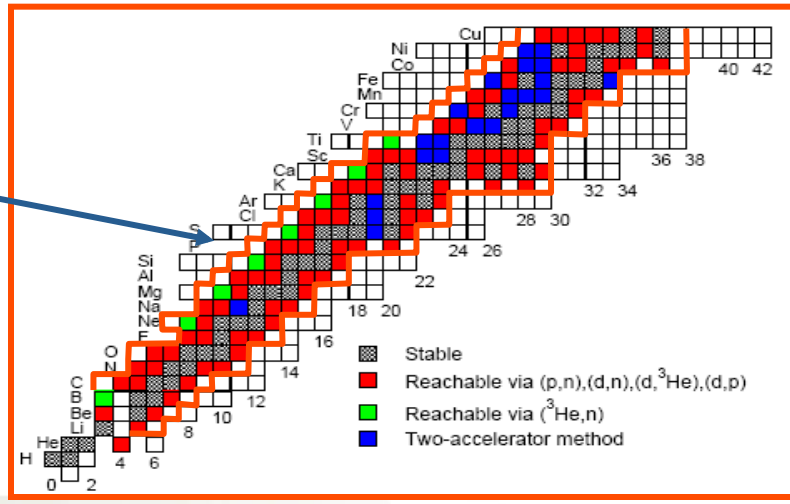
- Upgraded separator (AIRIS) will provide
  - > X10 in primary beam for H and d targets
    - High power target based on liquid lithium str… velopment at ANL
  - ~ X100 in transmission with better selec…
    - Transmission of ~50% versus ~0.3%
  - Access to nuclei produced with n… gative Q values
  - Production of higher energy … eams

- Enables
  - Better experim… th existing beams
  - Experimen… beams one (or few) neutron further away fro… bility
    - These beams were too weak (or Q value too negative e.g.: ^{12}N, ^{20}Na, …) with the present system, with the upgrade, they become usable
  - Experiments with radioactive beams of higher energy
  - Beam can be delivered to all experimental areas

Talk by Ben Kay in Facilities and Instrumentation session friday







AGFA: Argonne Gas-Filled Analyzer

Purpose:

- High efficiency separation
  - Gammasphere at target position
  - Evaporation residues
    - Super-heavy nuclei
    - ~^{100}Sn region
    - Spectroscopy at the p drip line
  - Deep-inelastic products
    - N-rich nuclei e.g. N~126
  - General purpose use

Status:

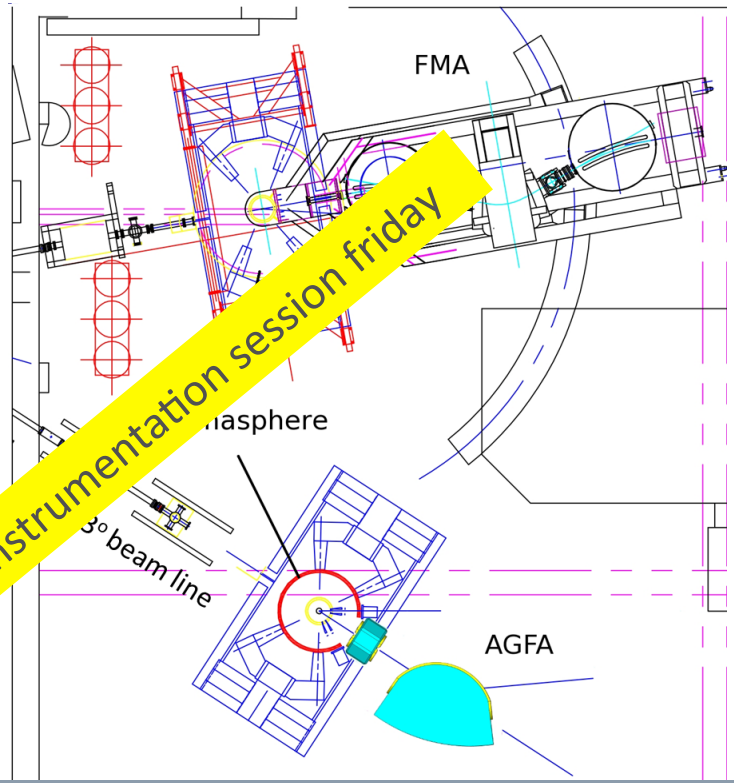
- DOE go ahead July 2013
- Management plan submitted Sept 2013
- ***First project review yesterday***
- Planned completion Q2 FY2016

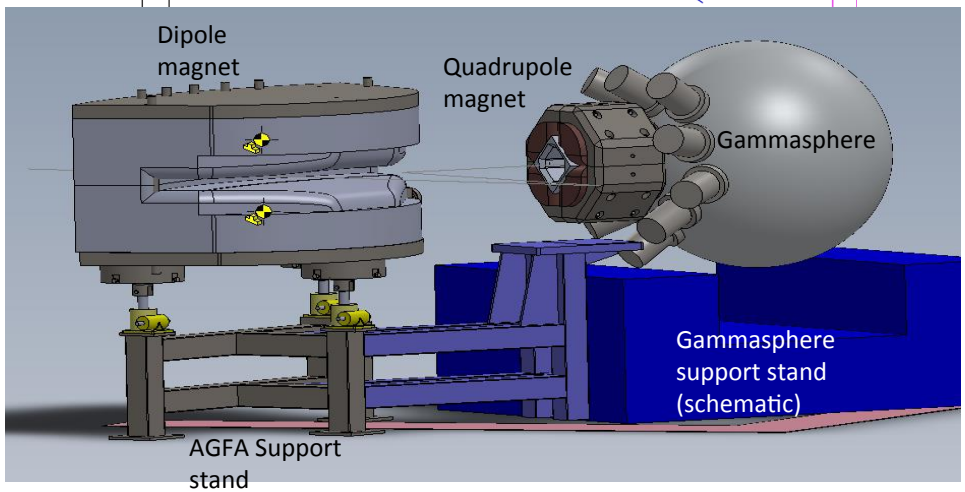
Cost: $1755k (incl. conti cy)

AGFA: 50-95% Effi cy

FMA: Less efficiency, m/q measurement

Talk by Darek Seweryniak in Facilities and Instrumentation session friday

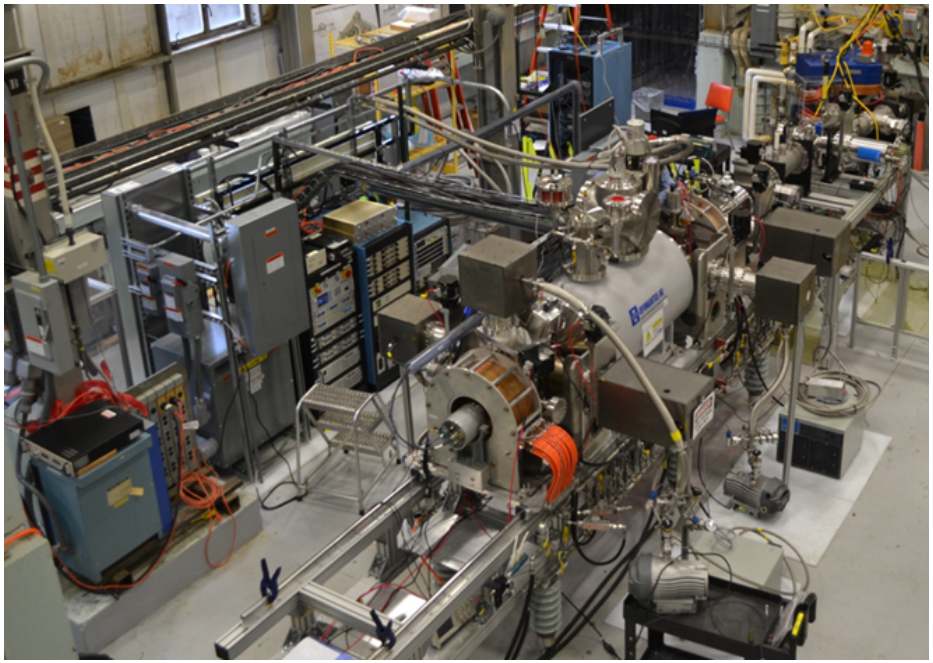




EBIS charge breeder upgrade

- Removing stable beam contamination of reaccelerated beams from ECR charge breeder
  - Concept developed and demonstrated by accelerator R&D group
  - Provides two important gains versus ECR charge breeding at CARIBU
    - Higher charge breeding efficiency demonstrated for pulse injection operation (ANL tests at BNL EBIS … and now operating off-line at ANL)
    - UHV system leads to stable beam background suppression

Factor 2 gain in intensity and large suppression of stable beam contaminants for reaccelerated CARIBU beams



ATLAS multi-user upgrade … filling the gap

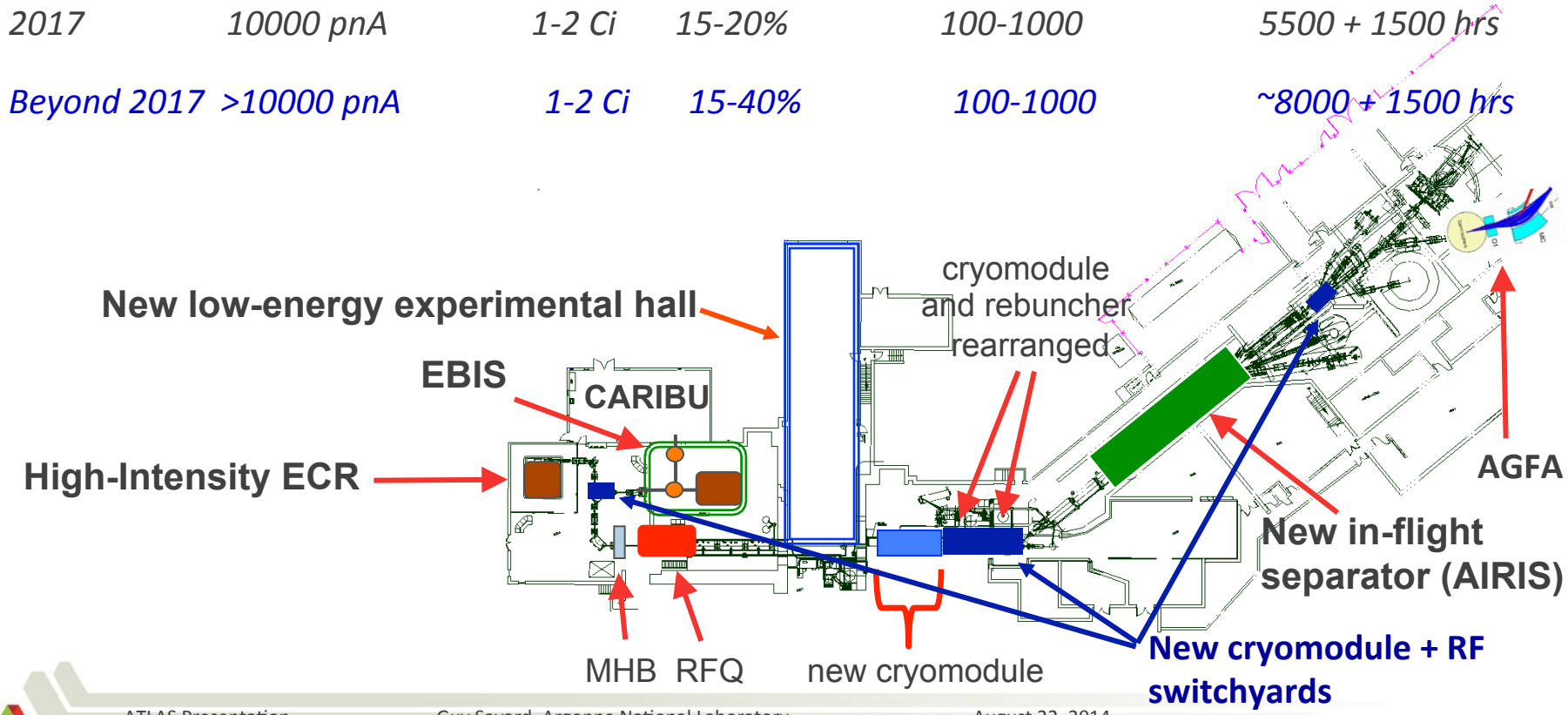
- Beamtime availability for low-energy community is under increasing pressure
  - In last few years, the low-energy community lost HRIBF and Yale (~ 4000-6000 hrs/yr)
  - Facilities outside the US (GSI, GANIL, RIKEN, ISAC, ISOLDE) also have limited capabilities in coming years
- Further pressure on available beamtime to users from
  - Move to longer experiments with weak beams or low cross-section channels
- Specific characteristics of ATLAS and CARIBU can provide a cost efficient way to remedy this situation
  - With the EBIS breeder, the full CARIBU reaccelerated beam will be pulsed with a duty cycle of ~ 1%, leaving the accelerator "idle" for ~99% of the time.
  - The ATLAS linac can accelerate simultaneously ions of charge-to-mass ratio over a range of 10% or so as shown in the multiple-charge-state acceleration performed at ANL to demonstrate the original RIA/FRIB accelerator concept

ATLAS could be modified to simultaneously accelerate two beams … providing full fledged multi user capability (2 simultaneous users)

- **One full intensity CARIBU beam using 10-100 μs 30 times per second**
  - **Could accelerate 2 charge states to essentially double available intensity**
- **One ATLAS stable beam utilizing the remaining ~99% of the time**
  - **Available at the full intensity provided by the source**

ATLAS layout: 2012 -> fall 2013 -> 2015 ->2017 -> 2020

	Stable beam	CARIBU		in-flight beams	beam hrs
	I_{max}	*source*	*reacc. eff.*	*relative yield*	*ATLAS+CARIBU low-E hrs*
2012	*200-500 pnA*	*0.3 Ci*	*3%*	*1*	*5500 + 1500 hrs*
Fall 2013	*10000 pnA*	*1 Ci*	*8%*	*10*	*5500 + 1500 hrs*
2015	*10000 pnA*	*1-2 Ci*	*15-20%*	*10*	*5500 + 1500 hrs*
2017	*10000 pnA*	*1-2 Ci*	*15-20%*	*100-1000*	*5500 + 1500 hrs*
Beyond 2017	*>10000 pnA*	*1-2 Ci*	*15-40%*	*100-1000*	*~8000 + 1500 hrs*



ATLAS role in 2020

- Two main users facility needed to accommodate low-energy nuclear physics community in the US after 2020
  - FRIB: single user radioactive beam facility with the furthest reach from stability
  - ATLAS: high-intensity stable beam facility for low cross section and high precision experiments closer to stability

- ATLAS high-intensity stable beam facility main capabilities
  - Highest intensity stable beam (> 10 pμA) facility at the Coulomb barrier energy
    - Suite of experimental equipment capable of using this highest intensity
    - Large amount of beamtime to perform experiments with lowest cross-section
  - Limited capabilities for radioactive beams close to stability
    - Perform important niche radioactive beam experiments close to stability that
      - Can be performed effectively without the full FRIB reach/capabilities
      - Require more beamtime than will be available at FRIB
  - Development and testing of new equipment for low-energy and reaccelerated beams
  - Applications

Resolutions from the May 2014 meeting of the ATLAS Users

- The Users strongly support the development of accelerator- and equipment-related initiatives that will enhance the scientific reach and efficient utilization of the ATLAS facility. These initiatives include the upgrade of ATLAS to provide multi-user capabilities and the timely development of the AGFA and AIRIS instruments

- The Users strongly support the establishment of a Center for Accelerator Target Science (CATS) and urge the timely consideration of the CATS proposal submitted to the U. S. Department of Energy

- The Users strongly urge that sufficient support be provided for operations and staffing levels in order to efficiently utilize the ATLAS facility

- The Users strongly endorse the vision expressed in the draft ATLAS Strategic Plan for the future of the ATLAS facility

Status

- ATLAS is the DOE low-energy nuclear physics national user facility
  - Running reliably and logging in a large number of operating hours
  - Doing great science
  - Adding new capabilities
    - CARIBU
    - Intensity upgrade
  - Improving its suite of experimental equipment
    - HELIOS, digital Gammasphere and DSSD, X-array
    - AGFA, AIRIS, N=126 factory, laser lab, beta-delayed neutron trap

- Providing unique capabilities to a broad user community
  - unique experiments with stable beams
  - exploring the path and bridging the gap to the reaccelerated beam program at FRIB

- Evolving to keep up with (and anticipate) the needs of the community and keep its central role in low-energy nuclear physics