LECM2025
Texas A&M, College Station, Texas
August 13-15, 2025

ATLAS UPDATE



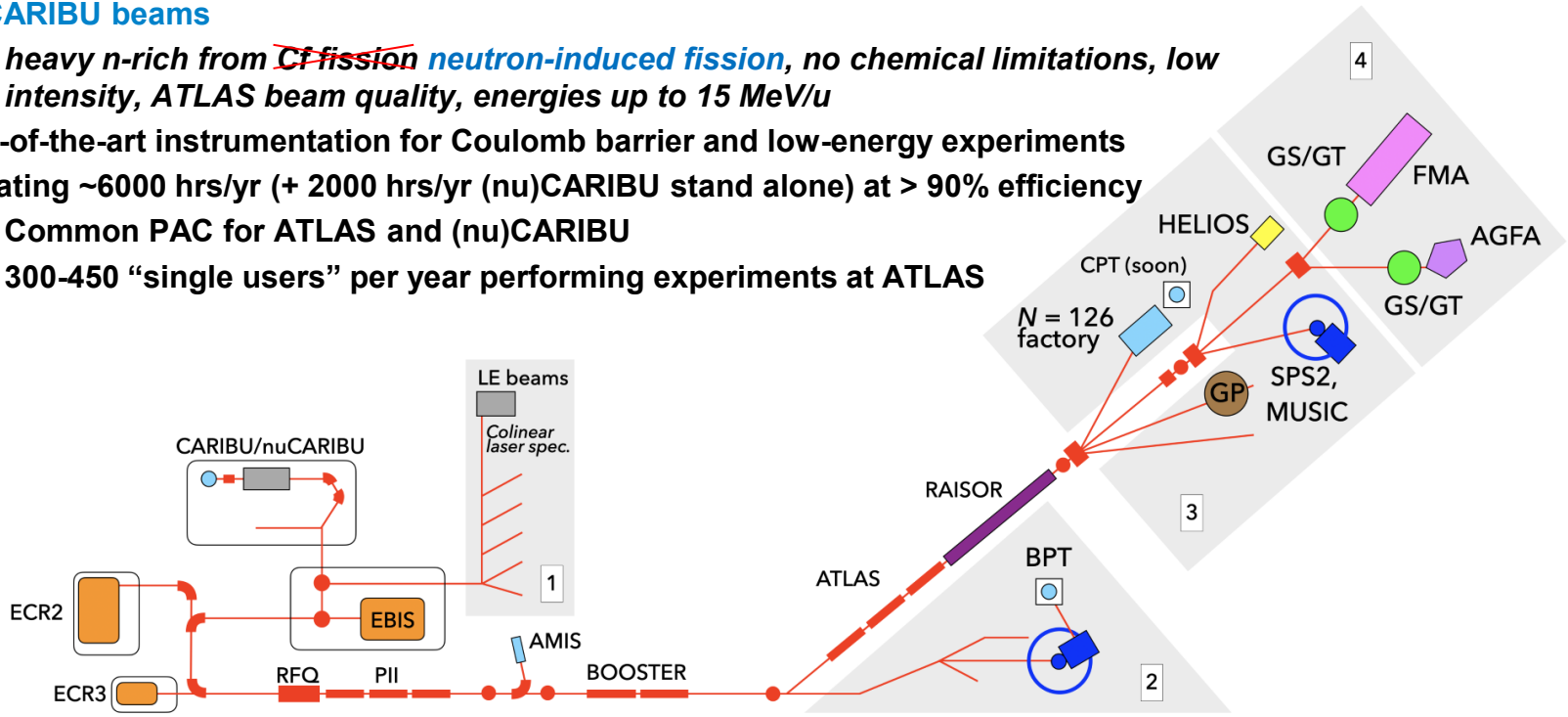
GUY SAVARD
ATLAS Scientific Director

U.S. DEPARTMENT of ENERGY
Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

Argonne NATIONAL LABORATORY
Argonne Tandem Linac Accelerator System

ATLAS/CARIBU FACILITY

- Stable beams at high intensity and energy up to 10-20 MeV/u
- Light in-flight radioactive beams with RAISOR
  - *light beams, no chemical limitations, close to stability, acceptable beam properties*
- (nu)CARIBU beams
  - *heavy n-rich from ~~Cf fission~~ neutron-induced 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 ~6000 hrs/yr (+ 2000 hrs/yr (nu)CARIBU stand alone) at > 90% efficiency
  - Common PAC for ATLAS and (nu)CARIBU
  - 300-450 “single users” per year performing experiments at ATLAS



ATLAS STABLE AND LONG-LIVED BEAMS

- **Wide variety of "primary" beams**
  - Stable beams from protons to Uranium
  - some long-lived beams (^{14}C, ^{85}Kr, ^{223}Ra, …)

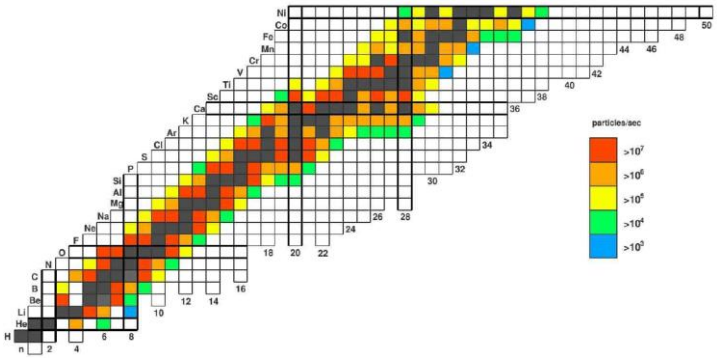
- **Intensity up to a few pμA, limited by ion source performance and radiation safety**

- **Excellent timing properties**
  - Pulse separation of 82 ns or n X 82 ns with n=1, 2, 3, …
  - Pulse timing down to ~100 ps depending on beam and target location

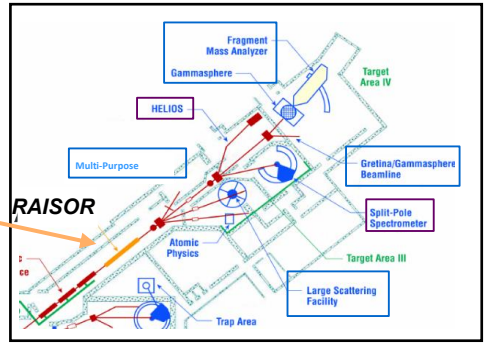
- **Energy range from ~ 0.5 MeV/u up to 10-20 MeV/u depending on mass**

- **Recent expansion of safety envelope with new SAD and ASE**
  - Maximum allowed proton beam energy raised to 25 MeV
  - Deuterium and tritium beams now available
  - Maximum allowed radiation potential increased

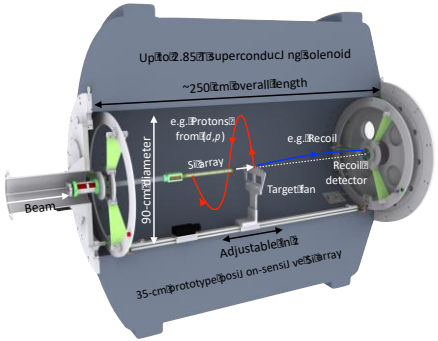
RAISOR: Light In-Flight Radioactive Beams

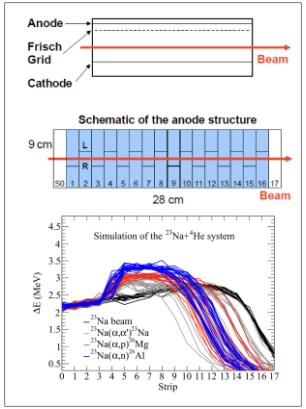






- Ideal energies for direct reaction studies (5-15 MeV/u), including negative *Q*-value reactions
- RIB production is close to instrumentation making very short-lived beams (few 100 ns) available for reaction studies (including isomers).
- Major programs are direct-reaction studies with HELIOS (inc. AT-TPC) and reactions relevant to nuclear astrophysics with MUSIC

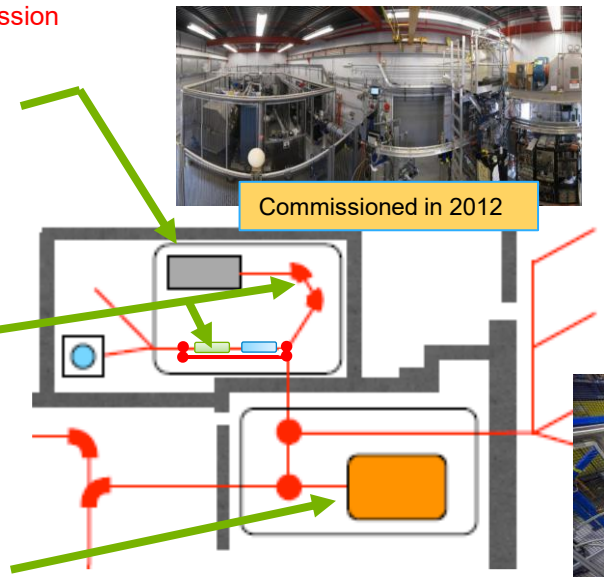




Neutron-rich beam source for ATLAS: nuCARIBU “front end” layout

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 and MR-TOF
  - Purifies beam
- **DELIVERY**: beamlines and preparation
  - Low-energy buncher and beamlines
  - Charge breeder to Increase charge state for post-acceleration
  - Post-accelerator ATLAS and weak-beam diagnostics

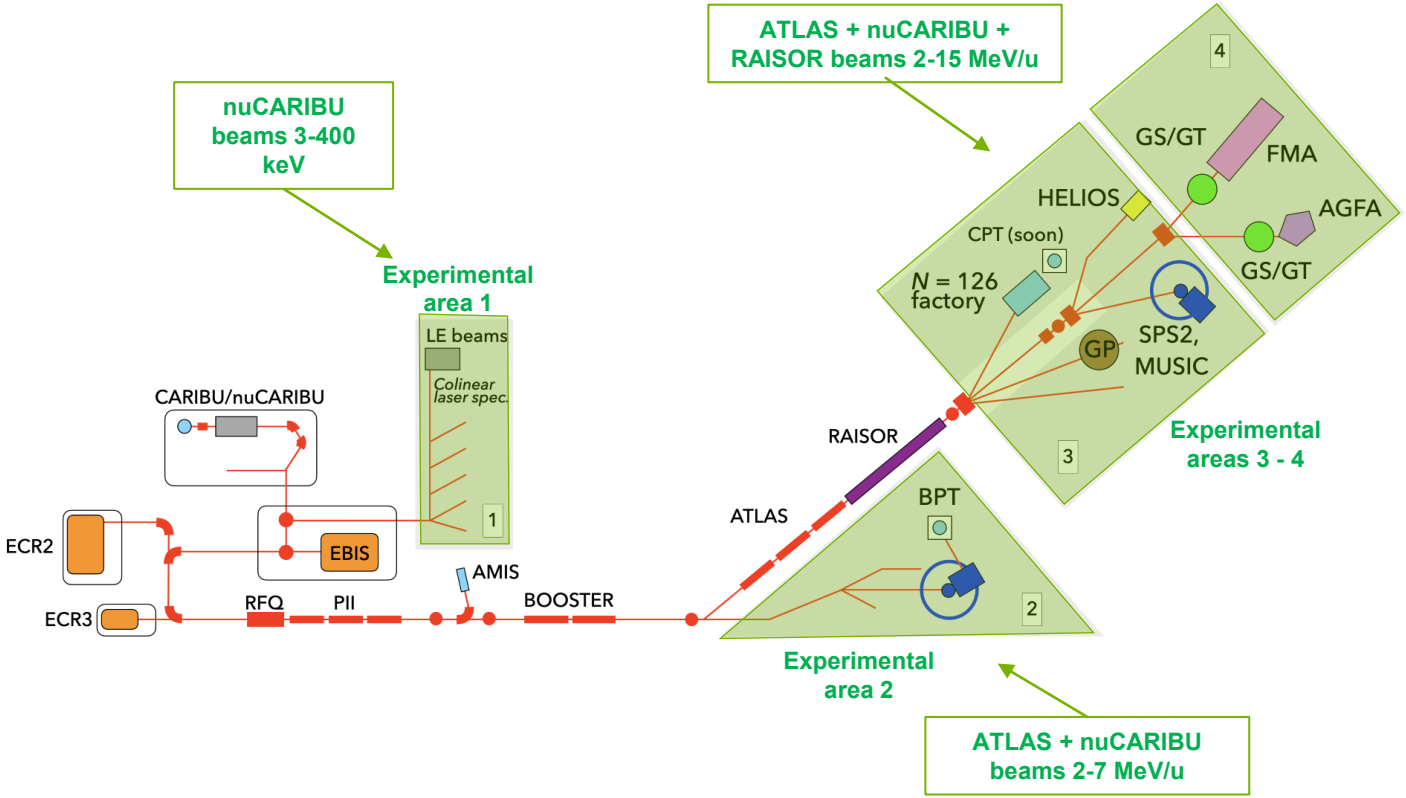


Commissioned in 2012

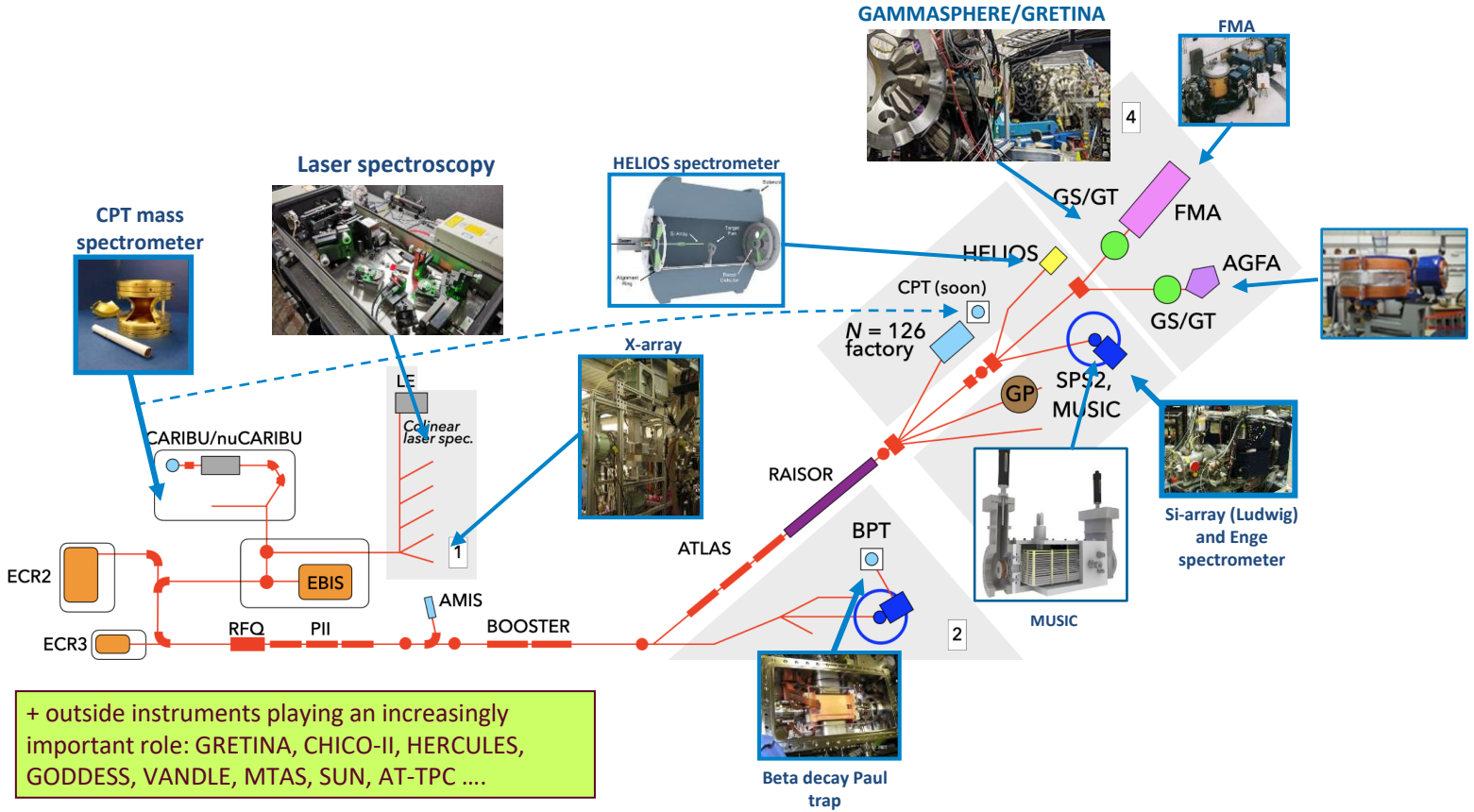

Commissioned in 2020


Commissioned in 2017

LAYOUT OF ATLAS FACILITY

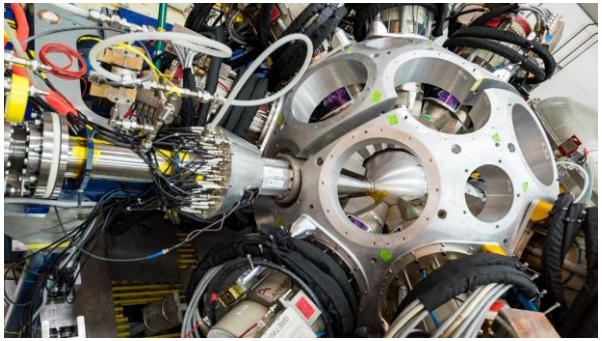


DISTRIBUTION OF EXPERIMENTAL EQUIPMENT



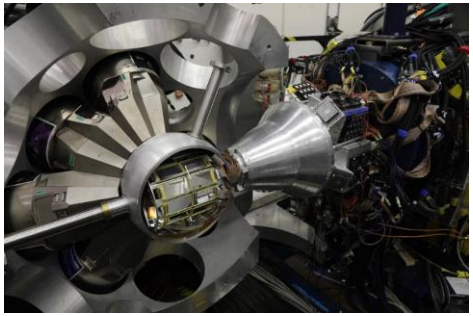
NEW AND IMPROVED EQUIPMENT CAPABILITIES

Significant impact of community devices

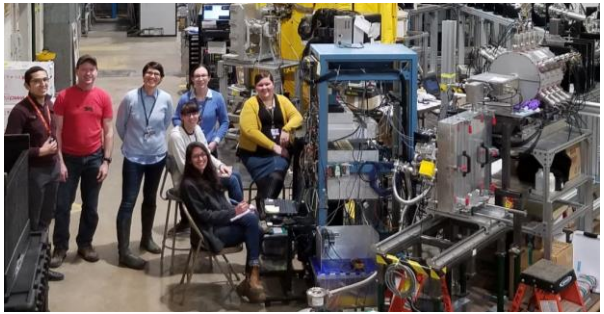


CHICO2 + GRETINA

- Local equipment continually improved for higher efficiency and rate capability
- Extended stays by state-of-the-art community devices for focused physics campaigns
- Versatile DAQ infrastructure to merge signals from visiting devices with local equipment



ORRUBA/GODDESS + GRETINA



SUN



AT-TPC
+
HELIOS



MTAS

ATLAS FACILITY PERFORMANCE

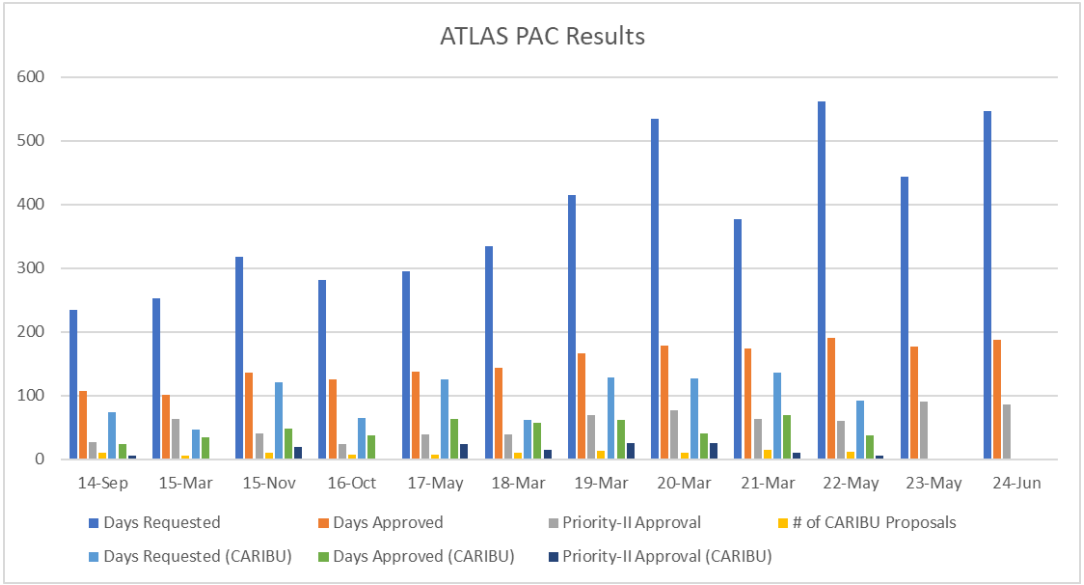
Operating Statistics

Machine Operation ATLAS	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025 (proj)
Research Hours (on Target)	4953	4318	4497	5377	3640	4071	4808	3887	4851	4800
Beam Study Hours	352	310	255	296	203	394	643	1145	217	350
Tuning/Restore	855	840	995	1100	685	1018	975	737	1086	750
Total Delivered Hours	**6160**	**5468**	**5747**	**6773**	**4528**	**5483**	**6426**	**5769**	**6154**	**5900**
Unscheduled failure hours	433	452	612	594	206	675	363	913	291	450
Total Scheduled Hours	6593	5920	6359	7367	4734	6158	6789	6682	6445	6350
Availability (%)	94.4	92.4	90.4	91.9	95.6	89.0	94.7	86.3	95.5	92.9
CARIBU										
Research Hours	2820	2260	652	1068	862	1328	2264	1971	1072	500
Beam Study Hours	464	204	240	296	138	264	232	148	124	500
Total Delivered Hours	3284	2464	892	1332	1000	1592	2496	2119	1196	1000

ATLAS+CARIBU delivered	**9444**	**6932**	**6639**	**8105**	**5528**	**7075**	**8922**	**7888**	**7350**	**6900**	**hours**

- FY20: operating hours reduced due to COVID shutdown for 3 months followed by restart at 5 days/wk without outside users
- FY21: targeted 5350 hours for ATLAS due to budget reduction and to allow removal of 109 MHz cryostat
- FY22: targeted 5800 hours for ATLAS due to reduced budget and to allow reinstallation of 109 MHz cryostat
- FY23: targeted 5950 hours for ATLAS but reduced hours delivered due to power failure event in summer 2023
- FY24: targeted 5803 hours for ATLAS due to reduced budget
- FY25 – FY27 : target 5900 hours for ATLAS in FY25 and ~6000 hours per year beyond, subject to adequate funding

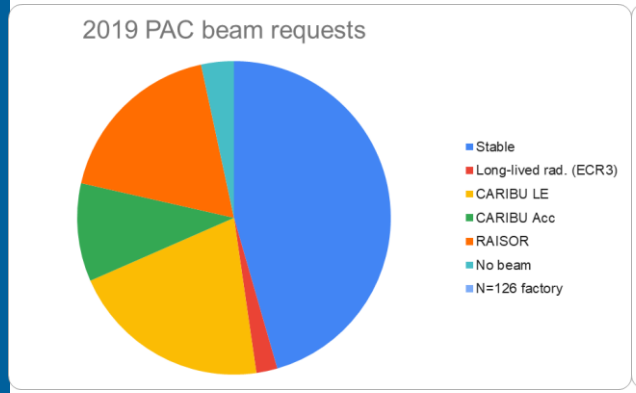
BEAM TIME REQUEST CONTINUES GROWING

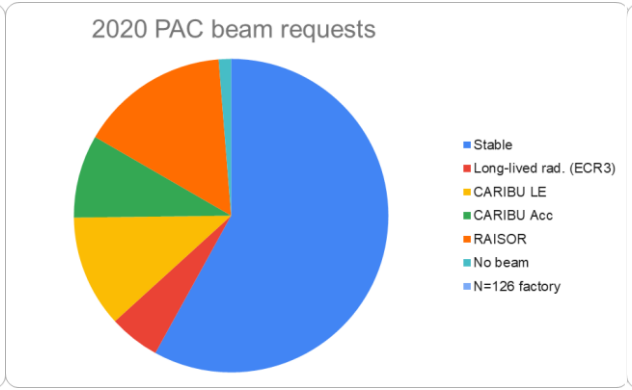


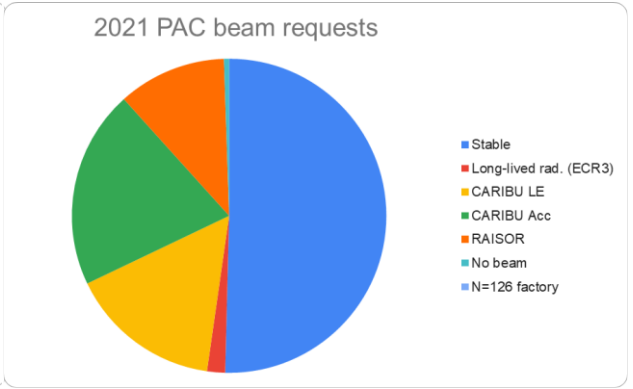
PAC Statistics:

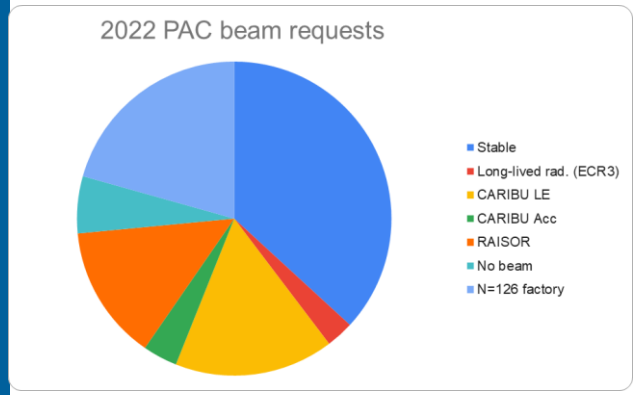
- Trends persist, i.e., high number of proposals & oversubscription by a factor of ~3
- Continue to operate with priority I & II modes to optimize efficiency of program
- Keep enough backlog to allow additional needed flexibility in scheduling
- For the last PAC meeting, record number of proposals and 546 days requested
- Call for next PAC is out, proposal submission deadline is Sept. 22/2025

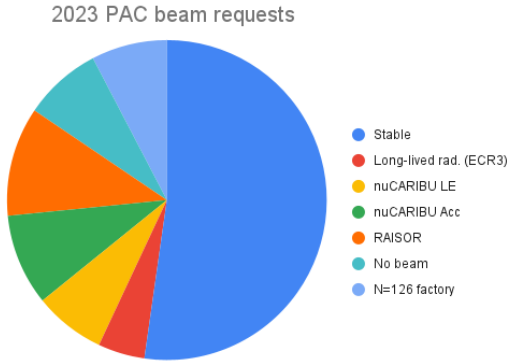
TYPE OF BEAMS REQUESTED BY USERS

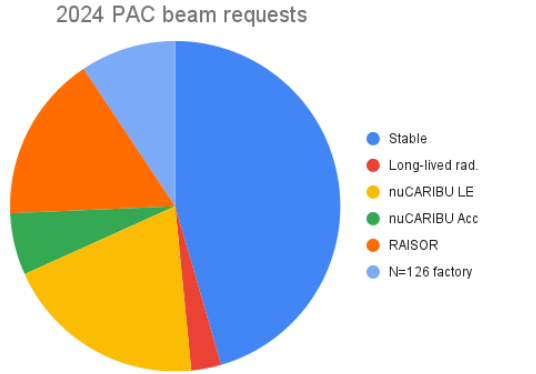




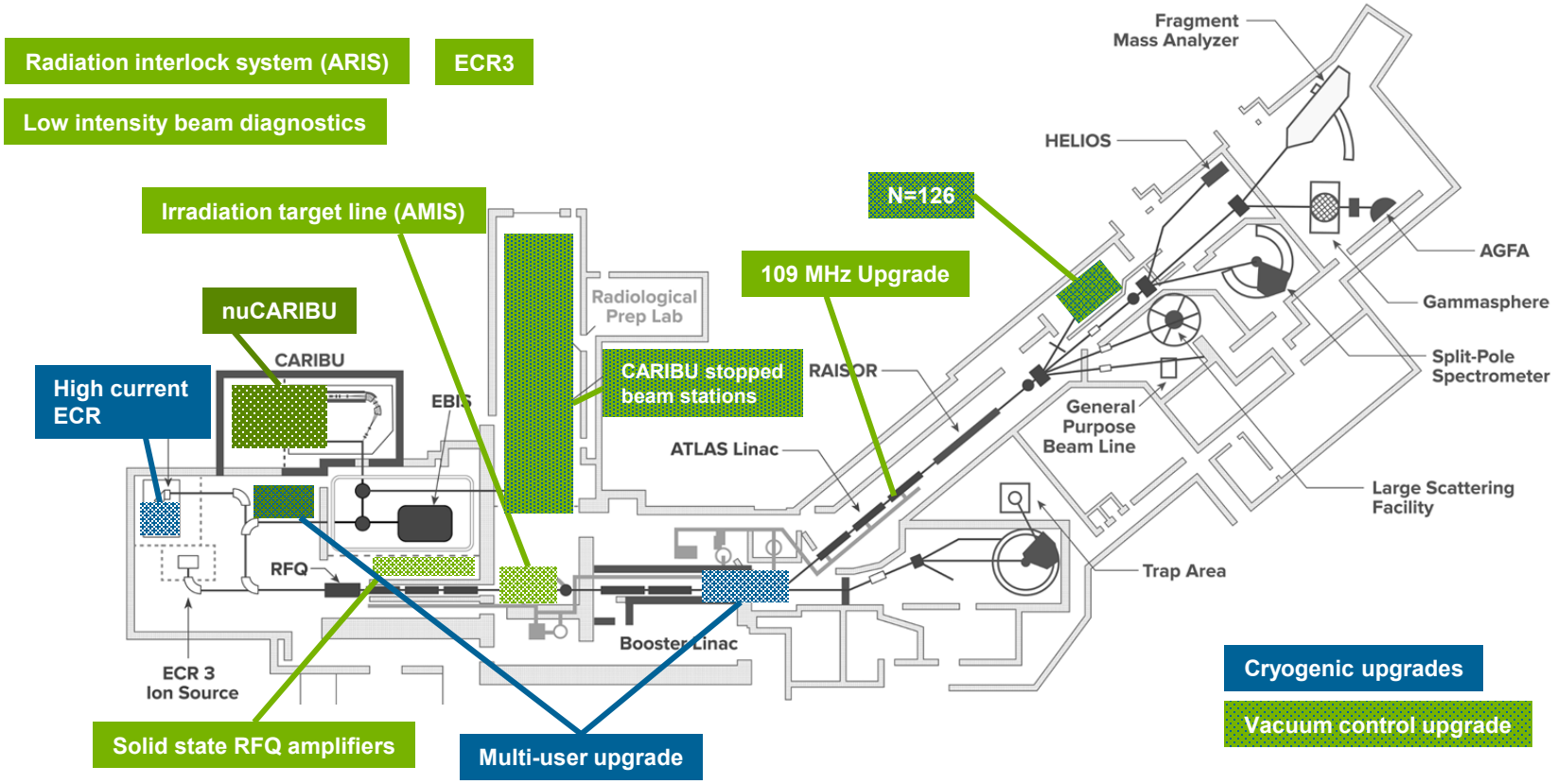








ATLAS is constantly being upgraded/improved



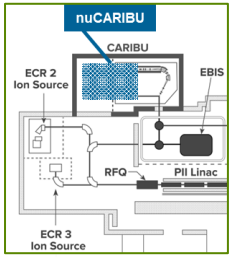
nuCARIBU (neutron-induced fission)

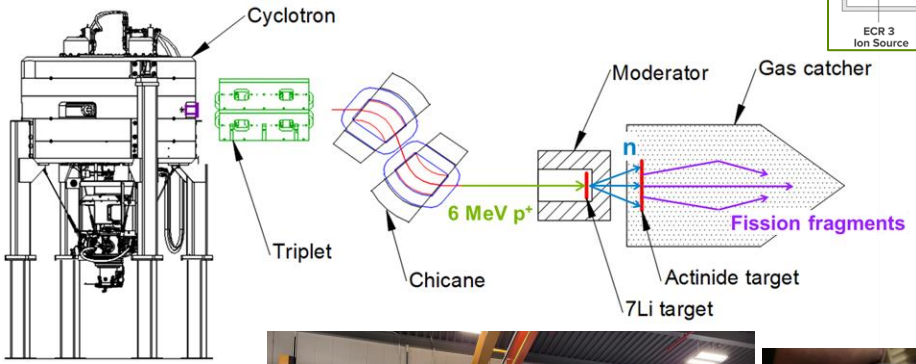
- Move from spontaneous fission of ^{252}Cf to neutron-induced fission of actinides (starting with ^{235}U)
  - Higher yield
  - Easier to maintain and operate (neutron source based on p-^{7}Li reaction)

- Serving all areas of ATLAS
  - seven low-energy beam lines in area 1
  - ~6 MeV/u beams in area 2
  - up to ~10 MeV/u beams in areas 3 & 4

- Major programs for reaccelerated beams in Coulomb excitation (GS and GRETINA and in the future Clarion), with MUSIC for r/i-process, and with the AT-TPC and HELIOS for direct reaction studies and resonant elastic scattering

- Major programs for low-energy beams in mass measurements, decay and laser spectroscopy

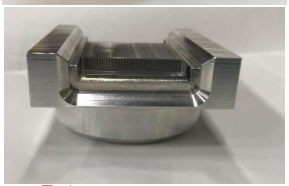


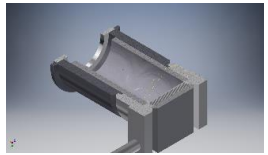












nuCARIBU Status

A shift towards much higher radiation potential for ATLAS

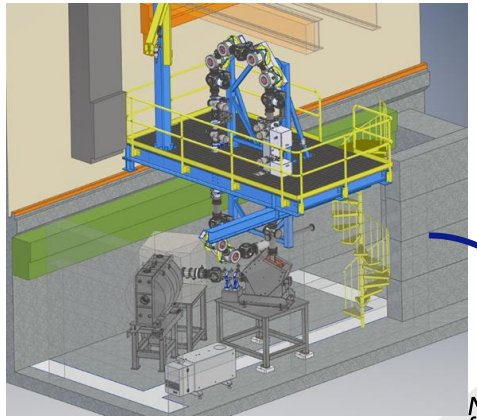
- Technical work on project, including demonstration of proton beam up to location of Li target (without target), completed in January 2025
- Final authorization to commission (at up to 75 uA) received on April 30 2025
- Enriched uranium foil installed mid-May 2025
- Shielding verification with beam on Li target (May 30 – June 3 2025)
- First extracted nuCARIBU radioactive beam on June 30 2025
- Proton beam intensity increased from 10 uA to 50 uA over next few weeks
  - Yield is as predicted and scales properly with power
- First highly-charged nuCARIBU radioactive beam injected into ATLAS July 17 2025
- Water leak in neutron generator target July 18 2025 … busy fixing that right now!

N = 126 Factory (multi-nucleon transfer beams)

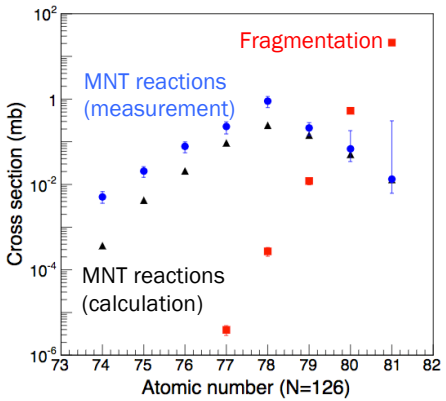
Adapt universality of CARIBU concept to a different reaction mechanism

Novel powerful yet very compact RIB facility

- *production (MNT reactions)*
- *Cooling (gas catcher)*
- *Pre separation (magnetic)*
- *Bunching (RFQ buncher)*
- *Final separation (MRTOF)*
- *Beam delivery*



NEW CAPABILITY ENABLED BY GAS CATCHERS: N=126 FACTORY … MULTI-NUCLEON TRANSFER TO PRODUCE NEUTRON-RICH HEAVY ISOTOPES

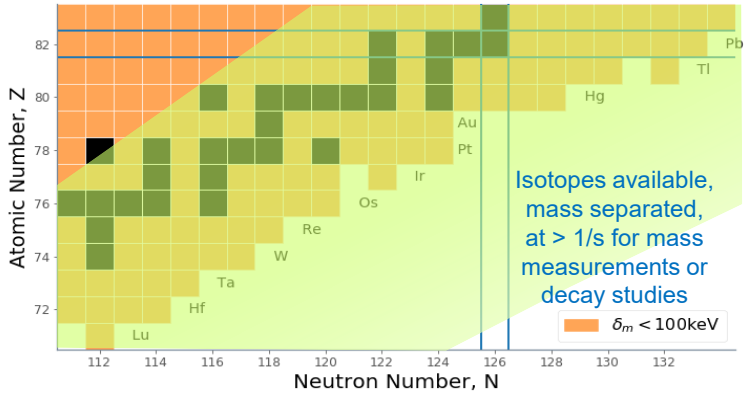


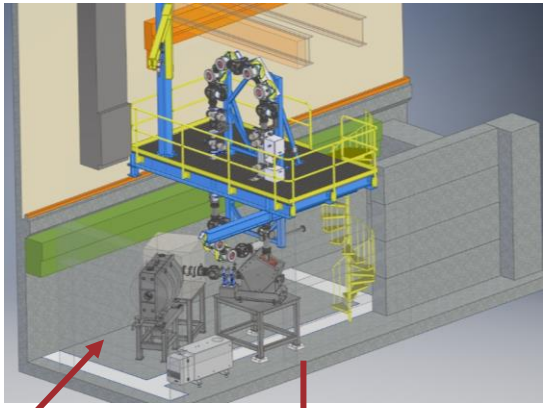
Hirayama *et al.*, EPJ Web Conferences **109,** 08001 (2016)

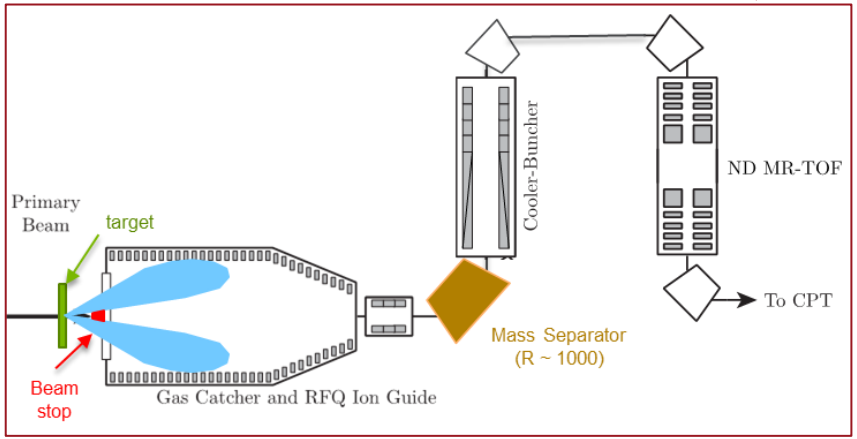
^{208}Pb + ^{9}Be at 1 GeV/u (best fragmentation reaction cross-sections for N = 126)

versus

^{136}Xe + ^{198}Pt at 10 MeV/u (best multi-nucleon transfer (MNT) reaction)

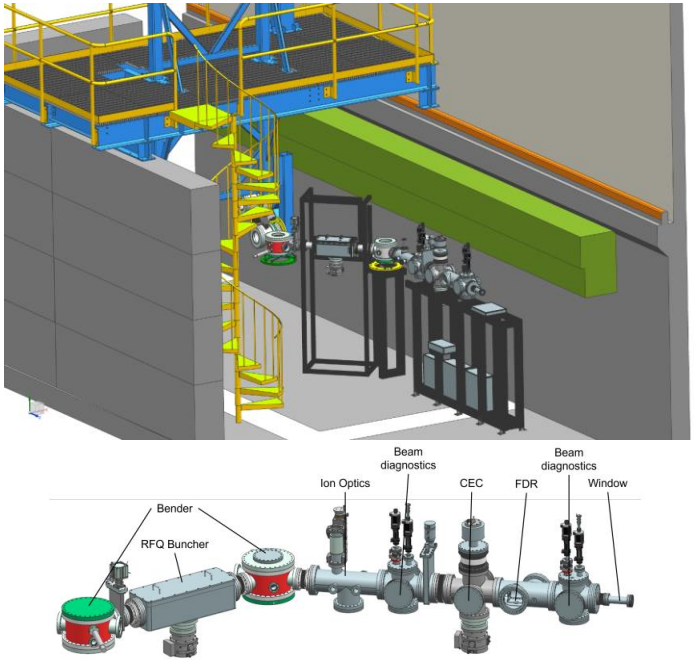




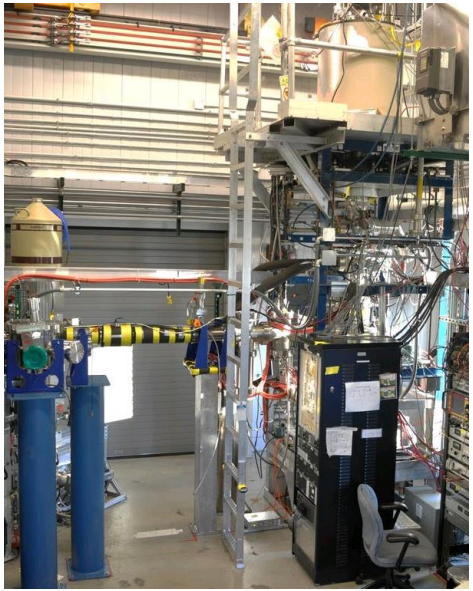




EXPERIMENTAL EQUIPMENT FOR N=126



Laser spectroscopy



CPT mass spectrometer

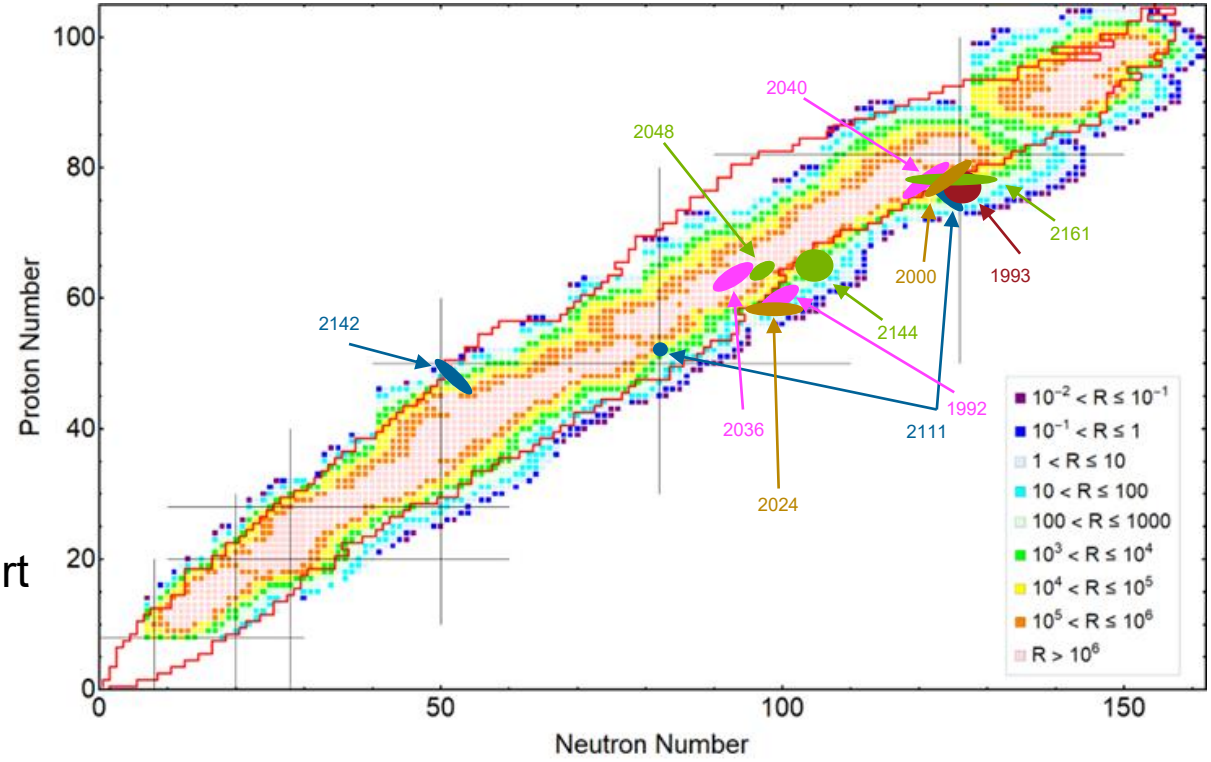


X-array

+ SuN, LACES, ….

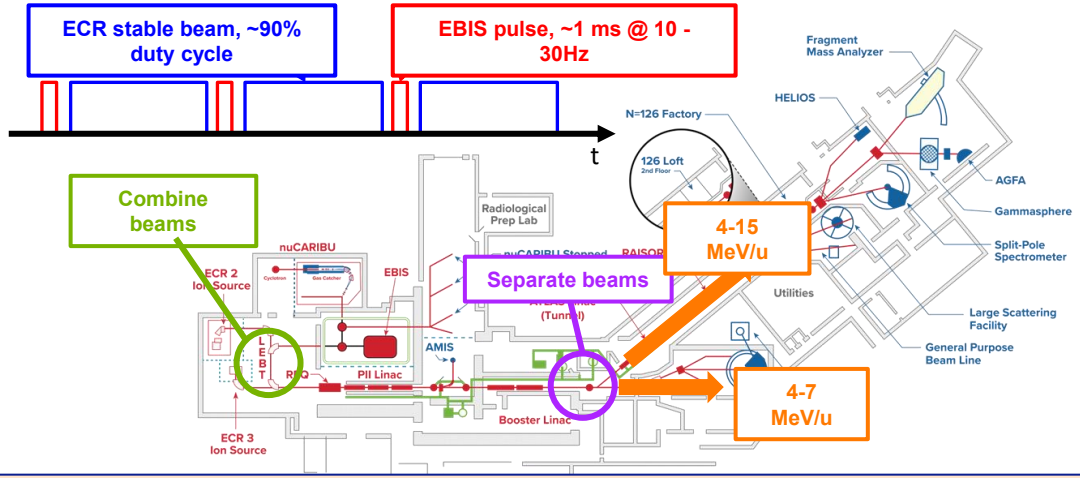
The ‘Everything’ Factory

- Initially targeting the N=126 region below Pb, this technique promises extraordinary reach via specific choices of beams and targets
- Early focus of approved experiments on mass measurements, decay spectroscopy, and laser spectroscopy
- Future ambitions to transport to area 1 and potentially consider re-acceleration



INCREASING THE NUMBER OF DELIVERED BEAM HOURS: MULTI-USER UPGRADE

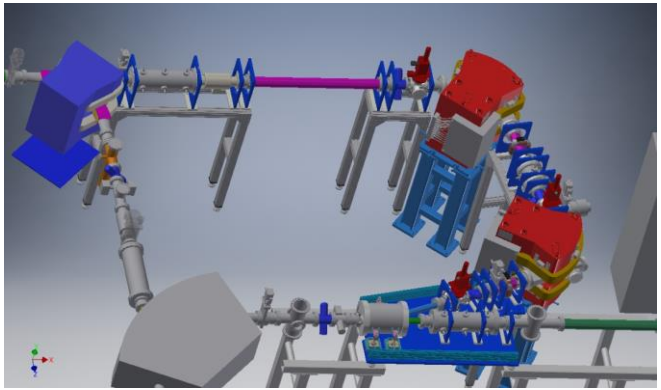
- EBIS beams represents 1-3% duty factor
- Combine pulsed EBIS beam with stable ECR beam
  - Address high demand on facility
  - Enable long duration experiments
  - Maximize efficient accelerator usage

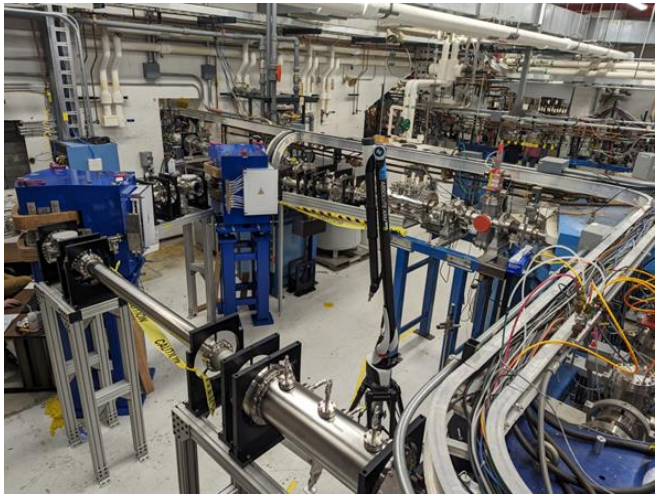


Great flexibility (2 different beams at different energies) to increase beam hour delivered by ~3000 hours per year … main constraint is that one of the beams has to be a nuCARIBU beam!

PII LEBT – STATUS

- All equipment installed and aligned, under vacuum
- Connecting power supplies and controls
- Preparing for commissioning with beam … trying to minimize ATLAS beam schedule impact

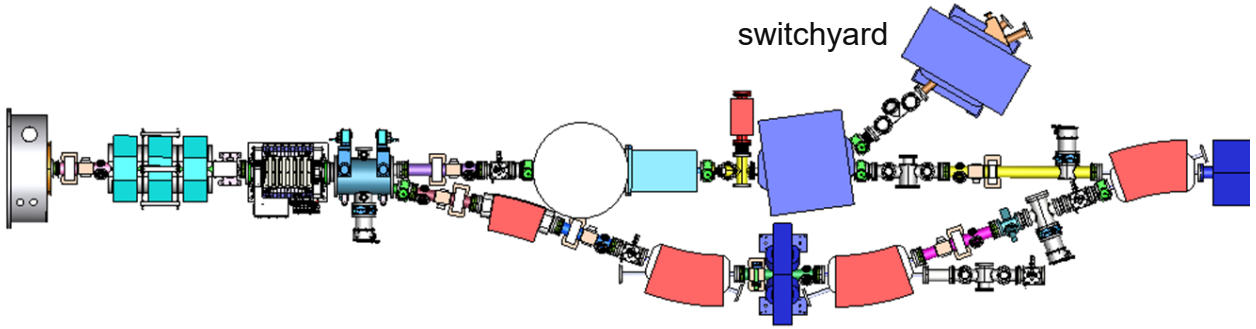




ATLAS MULTI-USER UPGRADE – HIGH ENERGY PART

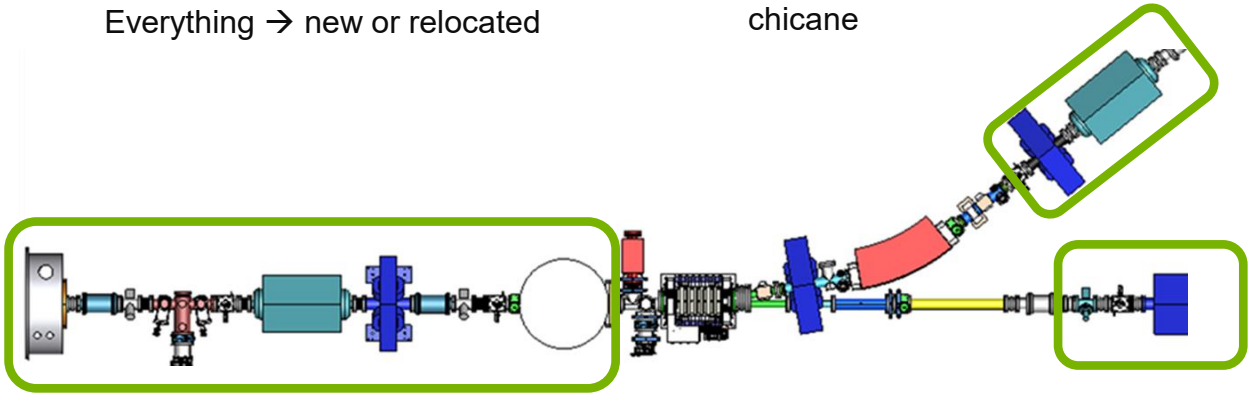
A technical redesign in 2024-25 simplifies reconfiguration in the ATLAS Booster

- **Initial design:** added a new chicane to preserve the existing switchyard



Everything → new or relocated

- **Redesign:** Requires reconfiguration of the switchyard but greatly reduces overall effort and requires few procurements



Equipment in green boxes stays put

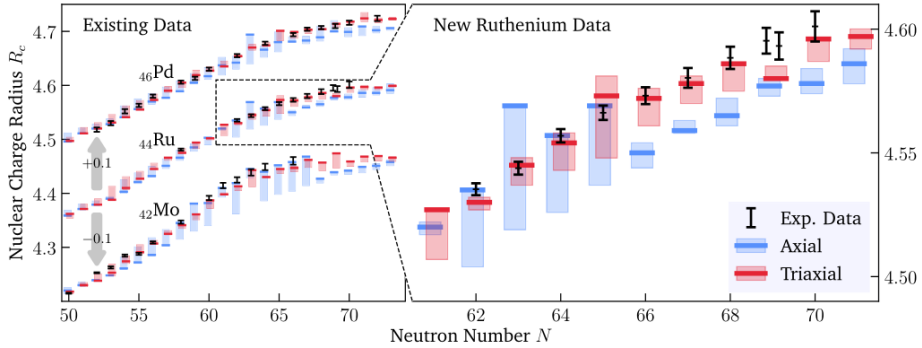
Final installation planned for Jan. 27 shutdown

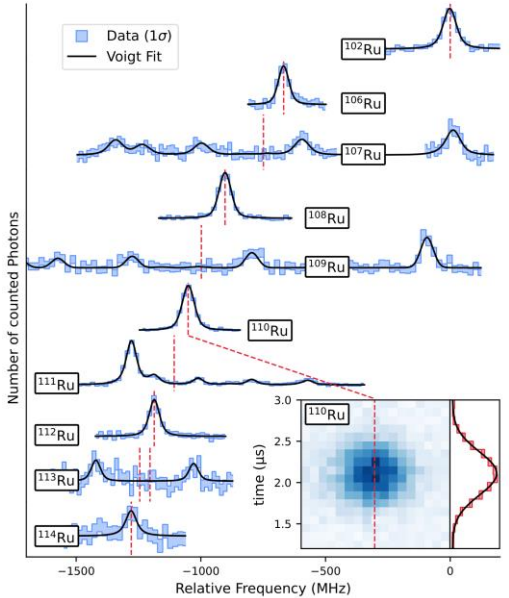
LASER SPECTROSCOPY AT ATLAS



ATLANTIS at CARIBU

- Nuclear charge radii of ruthenium, submitted to PRL (arXiv.2503.07841)
- Excellent agreement with Skyrme EDF including triaxial degree of freedom





4th GRETINA CAMPAIGN

Equipment was delivered from FRIB last summer

Installation and commissioning took two months

GRETINA running since then





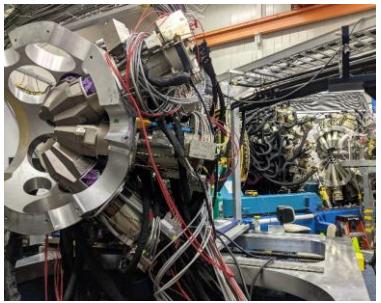








4th GRETINA CAMPAIGN IN NUMBERS



4th GRETINA campaign at ATLAS

- Installation of the array in June-July
- Experimental campaign started right after

74 requests submitted during the last PAC:

over the 32 projects devoted to γ-ray spectroscopy,

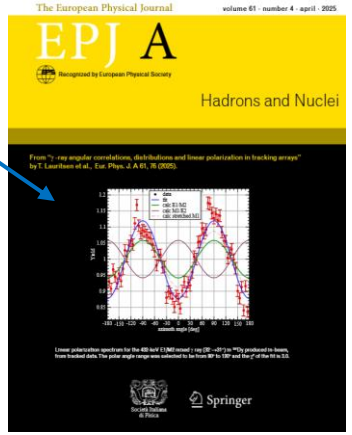
18 proposals required GRETINA

11 proposals approved for a total for a total of **81 days**
+ **additional 91 days** from previous PACs
= more than **170 days/year**

THE “RETURN” OF GRETA

GRETA was built for a broad physics program and a large part is best matched to ATLAS energy

- GRETA was proposed initially as a high-spin physics device
  - high efficiency, high throughput, excellent Doppler correction, exquisite polarization measurement capability, total calorimetry at high resolution
  - Makes it an ideal instrument for many physics programs covering various energy regimes



- Possible programs at ATLAS … just a few examples:
  - Hyperdeformation, decay out of superdeformed bands, weak bands, … all the high-profile high-spin physics that could not be completed because the limit of sensitivity of previous arrays was reached
  - Coulomb excitation of deformed/octupole/triaxial nuCARIBU beams
  - Identification and spin/parity of states of interest for nuclear astrophysics
    - e.g. proton unbound states in ^{38}K, ^{31}S (and mirror ^{31}P), ^{52}Fe, ^{56}Ni, ^{46}Ti, and unique isomer beams such as $^{34m/g}$Cl with RAISOR
  - Entry distribution and quasi-continuum γ-rays measured with germanium resolution
  - Pushing towards heavier systems when coupled to AGFA

ATLAS has been a great host for GRETINA over 4 campaigns, enabling a broad physics program with a lot of beamtime and support for the community. It is looking forward to enabling an even more impactful program with GRETA, one that will fully exploit all the capabilities of this new device.

OUTLOOK

- ATLAS is the DOE nuclear physics stable beam national user facility
  - Running reliably and logging in a large number of operating hours
  - Accomplishing its current science goals
  - Demand for beamtime remains high and is increasing

- Lots of new capabilities coming online and becoming available to the community

ATLAS Call for Proposals

Proposal submission deadline: Monday September 22, 2025

all stable/long-lived + deuterium + tritium beams,
nuCARIBU beams at increased intensity, RAISOR beams



U.S. DEPARTMENT OF ENERGY
Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

Argonne NATIONAL LABORATORY