Argonne NATIONAL LABORATORY

… for a brighter future

U.S. Department of Energy

UChicago ▶ Argonne LLC

Office of Science U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

Accelerator Developments in the Physics Division

Robert V. F. Janssens

Scientific Director of the ATLAS Facility

Division Director

2009 DOE-ONP Science & Technology Review of ATLAS, May 18-19.

ATLAS TODAY

- ATLAS is the National User Facility for Physics with stable beams in the vicinity of the Coulomb Barrier

- The facility has also developed capabilities for physics with exotic beams using two methods:

  - two-accelerator method

  - in-flight method

  The program is complementary to HRIBF and other facilities, i.e., only runs experiments that cannot be run at other facilities

- A new opportunity has arisen because of development of gas stopping technology: CARIBU

- ATLAS provides in excess of 5000 h/year of beam for research to a community of 300-500 Users

FY2009: A Year of Major Change for ATLAS

- New opportunities envisioned by the 2006 Strategic Plan are coming to fruition:
  - **CARIBU** (**CA**lifornium **R**are **I**on **B**reeder **U**pgrade) will turn on
  - **ATLAS Energy Upgrade** (New Cryostat, New resonators, 10-12 MeV/u A~150 beams) is being completed
  - The **instrumentation plan** has been partially realized (HELIOS, X-array, CPT move, ..)
- This positions ATLAS well to continue to serve the low-energy community by providing:

  (1) high-quality stable beams

  (2) unique exotic beams

  at the energies and with the instruments required to do the science.

- BUT, the vision expressed in the strategic plan is only partially fulfilled as:
  - equipment budgets have been less than needed to fully execute the instrumentation plan
  - the ultimate goal of the strategic plan was for ATLAS to be the world class post-accelerator for FRIB

FY2009: A Year of Major Change for ATLAS

- For more than a decade, we have been fully committed to FRIB and planning for ATLAS and R&D activities always had FRIB as focus and end goal.

- The decision to locate FRIB at the NSCL, makes the need to re-think ATLAS and its future obvious.

  - The Argonne Tandem Linac Accelerator System (ATLAS) Facility at ANL is the world's premier stable ion beam facility for studies of nuclear structure and astrophysics.
    - The ATLAS facility and staff are a critical part of the NP mission, now and in the foreseeable future.
    - NP is looking forward to working with ATLAS staff to develop plans that will ensure a compelling and vital future for the ATLAS facility.
    - NP wants to assure ANL that the staff currently dedicated to FRIB activities will be supported and are not in jeopardy of a reduction-in-force (RIF).

- We remain 100% committed to making FRIB a success (science & technology).
- We have been encouraged by ONP to "think big" in terms of the future of ATLAS

  → *we have done so, following consultations within and outside ANL (the Executive Committee of the User Group has been associated to the activities)*

  → ***we had to rush because of the ARRA opportunity***

ATLAS: a User Facility for Physics at the Coulomb Barrier

World's First Superconducting Accelerator for Ions

Capabilities:

- **beams of all masses** ***(H to ^{238}U, and exotic beams)***
- **energies comparable to internal energies of the nucleus**

  (16 MeV/A for light ions, 7 MeV/A for heaviest ions, upgrade to 10 MeV/A on-going)
- **high beam intensities** ***(particle micro-amps)***
- **exceptional beam quality** ***(spot sizes of 1mm diameter or less)***

  (emmitances: transverse ~ 0.2 π mm - mrad

  longitudinal ~ 20 keV – ns)

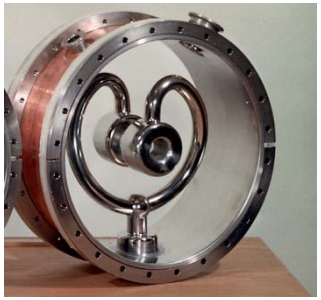
  (resolutions: energy ~ 10^{-3} or better,

  time as low as 100 ps, 200 – 400 ps typical)
- **great flexibility and reliability** ***(energy changes in minutes, > 95%reliability)***
- ***and more (duty cycle, micro-pulsing…)***

The ATLAS Facility – The world's first superconducting ion accelerator

One of four DOE-ONP National User Facilities
RHIC
CEBAF
HRIBF
ATLAS

- ✓ Unique and powerful accelerator
- ✓ Unique experimental equipment
- ✓ Great user community



The immediate future at ATLAS:

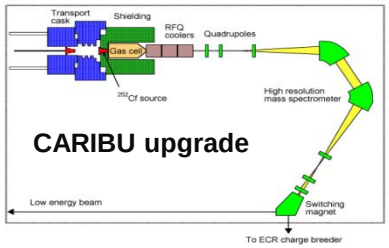
CARIBU

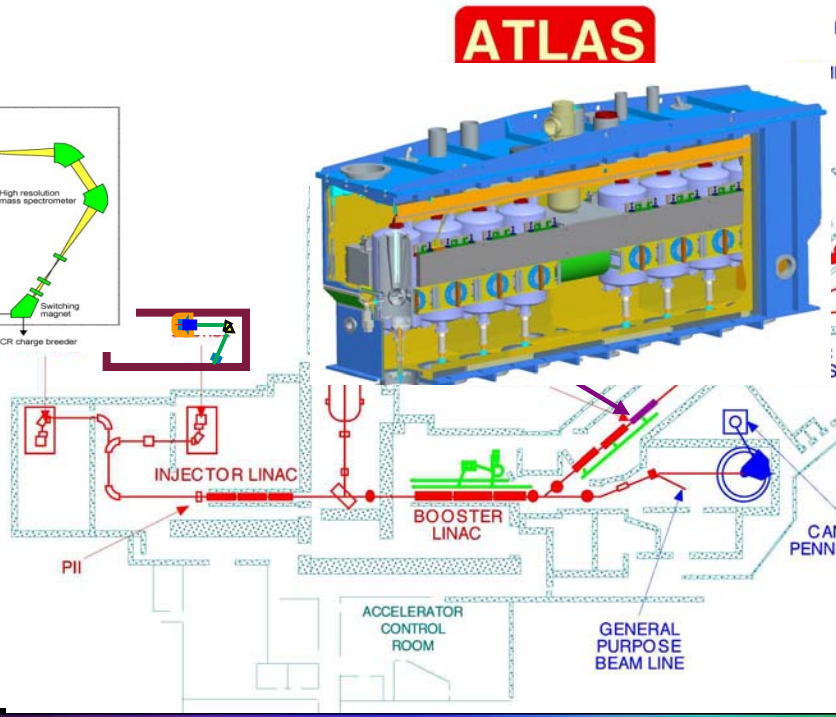
Energy Upgrade

HELIOS

ATLAS Tomorrow: CARIBU & Energy Upgrade & HELIOS: Unique Synergy

- CARIBU gives access to exotic beams not available elsewhere.
- Physics with beams from CARIBU (1 & 2 nucleon transfer reactions) needs the new energy regime opened by the Energy Upgrade (12 MeV/u) .
- Solenoid Spectrometer greatly expands the effectiveness of both the fission fragment beams and the existing in-flight RIB program at these higher energies.
- These three projects combine to form a truly unique facility which complements the capabilities of other world facilities in the era leading to FRIB





CARIBU: Commissioning & First Experiments

2.5 mCi source: summer 2009 → *debug CARIBU components, ID fragments, 1st charge breeding, beam studies, start stopped beam program, provide realistic yields to Users* ***5% ATLAS beam time***

80 mCi source: fall 2009 → *1st acceleration through full system, 1st demo expts, commission facility, start physics program* ***up to 20% ATLAS beam time***

***1 Ci source**: depends on isotope program (early 2010?) → full research program*
up to 50% ATLAS beam time

Isotope	Half-life (s)	Low-Energy Beam Yield (s^{-1})	Accelerated Beam Yield (s^{-1})
^{104}Zr	1.2	1.5×10^{3} / 4.8×10^{4} / 6.0×10^{5}	5.3×10^{1} / 1.7×10^{3} / 2.1×10^{4}
^{143}Ba	14.3	3.0×10^{4} / 9.6×10^{5} / 1.2×10^{7}	1.1×10^{3} / 3.4×10^{4} / 4.3×10^{5}
^{145}Ba	4.0	1.4×10^{4} / 4.4×10^{5} / 5.5×10^{6}	5.0×10^{2} / 1.6×10^{4} / 2.0×10^{5}
^{130}Sn	222.	2.5×10^{3} / 7.8×10^{4} / 9.8×10^{5}	9.0×10^{1} / 2.9×10^{3} / 3.6×10^{4}
^{132}Sn	40.	9.3×10^{2} / 3.0×10^{4} / 3.7×10^{5}	3.5×10^{1} / 1.1×10^{3} / 1.4×10^{4}
^{138}Xe	846.	2.5×10^{4} / 7.8×10^{5} / 9.8×10^{6}	1.8×10^{3} / 5.8×10^{4} / 7.2×10^{5}
^{110}Mo	2.8	1.6×10^{2} / 5.0×10^{3} / 6.2×10^{4}	5.8×10^{0} / 1.8×10^{2} / 2.3×10^{3}
^{111}Mo	0.5	8.3×10^{0} / 2.6×10^{2} / 3.3×10^{3}	0.3×10^{0} / 9.6×10^{0} / 1.2×10^{2}

ATLAS: Medium-Term Future

Efficiency and Intensity Upgrade

ATLAS: Upgrade goals

- Present ATLAS intensity limitations for stable beams due to: (A) space charge effects, transverse emittance issues & longitudinal capture in the PII affecting transmission, (B) stray beam heating SC solenoids in the booster linac
- Present CARIBU intensity limitations: charge breeding efficiency of ECR source & transmission

→ → **Path Forward:**

- Deliver 6 MeV/u ion beams with intensities of ~100 μA (electrical) or 5-10 pμA, maintain capability to do 12 MeV/u, at today's intensities

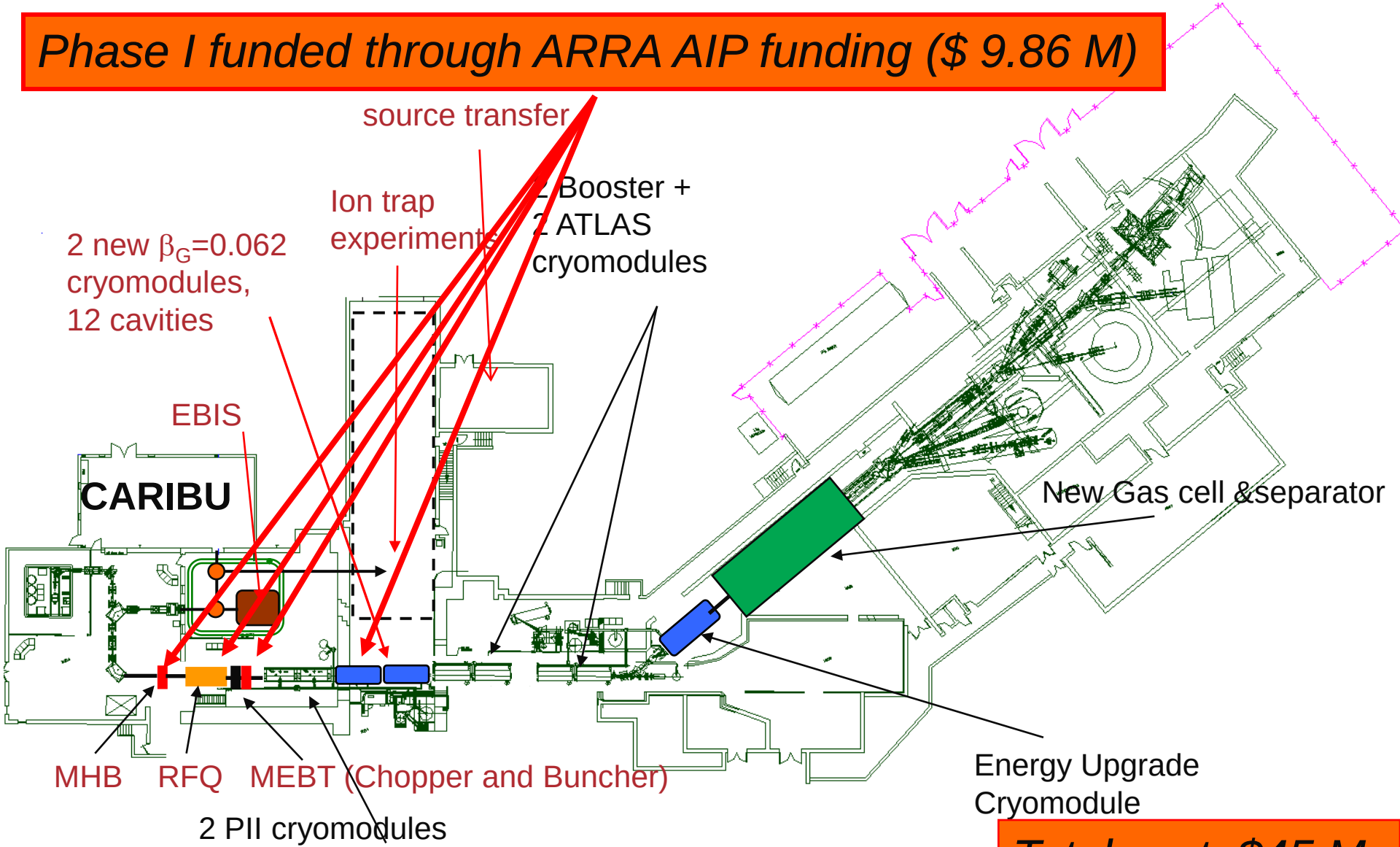
- Increase overall transmission of any ion beam including CARIBU radioactive beams to 80% as compared to the intensity of DC beam from the ion source or breeder

- Increase efficiency of charge breeding by using EBIS

  For low intensity CARIBU beams (≤10^7 ions/sec) the efficiency can be ~20-30% at least for A/Q ~ 7

ATLAS Upgrade Layout

Phase I funded through ARRA AIP funding ($ 9.86 M)



Total cost: $45 M

ATLAS upgrade: Broader Prospective

- The proposed upgrade positions ATLAS to be:
  - *- capable of the higher stable beam intensities required for nuclear astrophysics (reaction rates for small cross sections with stable and in-flight RIB beams), for nuclear structure (heavy elements), fundamental interactions*
  - *- ready to be the test bed for accelerator & instrumentation techniques for FRIB*
- The proposed upgrade provides the Users with the beams required to meet the objectives of the Long Range Plan.
- The upgrade is a means to have the ATLAS users well positioned for the FRIB science program.
- The proposed full upgrade can be a first step towards a future upgrade to even higher beam intensities (i.e., VENUS-type ECR source & possibly more new cryostats).
- The proposed upgrade can be used with an ISOL facility if the Advanced Accelerator-Based Concept to Produce Isotopes for Medicine and Physics materializes.

- Next steps: further community involvement (ATLAS User workshop) & evaluation (S&T review is one step).

ATLAS & FRIB

- ANL is 100% committed to making FRIB a success (science & technology).
- For more than a decade, we have been fully committed to FRIB and planning for ATLAS and Accelerator R&D activities always had FRIB as focus and end goal.
- ANL has developed most, if not all, the technologies required to make FRIB the most powerful rare isotope accelerator in the world such as:
  - Multi-charge state acceleration, injection into the linac, new fabrication methods for SRF and high-performance cavities, beam dynamics, liquid Li targets & strippers, gas catcher, RFQ, etc..
- ANL has kept its “FRIB team” intact and ready to collaborate with MSU, discussions are ongoing (Liquid Li, RFQ, Gas catcher, ..)
- CARIBU & our in-flight beams are an excellent test bed for developing the instrumentation for FRIB
- *We did host the first FRIB User Meeting on May 30-31*

ATLAS: Longer Term Future

An Advanced Accelerator-Based Concept to Produce Isotopes for Physics and Medicine

Addressing the Nation's Needs for Isotopes

- Advanced accelerator technology has been developed by the RIA/FRIB R&D program; it is utilized in the present concept for optimized isotope production
  - A superconducting linac with 20 times the power of a modern cyclotron (*Cost per watt of beam power ~25% of cyclotrons*)
  - 2 MW beam power shared by multiple production stations
  - 200 MeV p, 200 MeV d, 400 MeV 3He, 400 MeV 4He
- Advanced target technology enables effective production of both neutron-rich "reactor isotopes" and proton-rich "accelerator" isotopes, e.g.
  - ^{99}Mo is produced in a sub-critical array of Argonne LEU target capsules
  - ^{225}Ac/^{213}Bi are produced via spallation of ^{232}Th
- A public-private partnership (PPP) can be a cost-effective solution to two areas of high national importance:
  - A medical isotope production capability for both neutron-rich and proton-rich isotopes
  - A nuclear physics research capability in the fields of fundamental symmetries, nuclear astrophysics, and superheavy elements
- Argonne has developed the technology, and has the team in place to proceed quickly with the implementation of this concept

Facility Block Diagram

- A compact superconducting linac for light ions, 80-m long
- Independent ion sources for medical isotopes and nuclear physics
  - Beams merged into RFQ injector
- Multiple target stations, ~100-250 kW each