STATUS AND OPERATION OF THE ATLAS SUPERCONDUCTING ACCELERATOR*

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Abstract

ATLAS (the Argonne Tandem Linac Accelerator System) is a super conducting heavy ion accelerator which can accelerate nearly all stable, and some unstable, isotopes between protons and uranium with a charge to mass range of 1/1 to 1/7. The maximum energy ranges of these accelerated ions are 7-17 MeV per nucleon with intensities ranging from a few thousand ions/second to microampere currents. On average ATLAS delivers a different ion species and energy each week to one of six target areas. ATLAS currently operates 24 hours a day, 7 days per week, and at least 40 weeks per year. Topics discussed will be how we handle day to day operation of the facility including start up, reusing old accelerator configurations for new experiments (scaling), tuning for in-flight produced radioactive beams, troubleshooting problems, and maintenance.

THE ATLAS FACILITY

ATLAS is the worlds' first superconducting heavy ion accelerator [1]. From its origins in 1978 until now it has consistently pushed new boundaries for stable low energy ion beam production. Located at Argonne National Laboratory outside of Chicago, Illinois in the United States, ATLAS has been delivering beams consisting of stable isotopes between protons through uranium for 37 years. The facility (Fig. 1) has two ion sources, an ECR source for multipurpose use and a charge breeding source coupled to the CARIBU radioactive ion source [2]. Once ions are produced they are accelerated through a maximum of 50 superconducting RF resonators which can give beam energies of 10-20 MeV/A depending on the atomic mass of the ion. Typical beam currents of 5-500 electrical nanoamps to target are common. However, the facility has demonstrated 35 electrical micoamps through the first linear accelerating section. While the facility can accelerate ions in a mass range between protons and uranium, in 2014 the facility accelerated 29 unique ions species. Of those 29 species, 5 species delivered to target were radioactive ion beams (RIB). Two of the 5 species were from CARIBU, and 3 were produced in-flight from accelerated stable beam.

Staffing and Operations

The facility operates 24 hours a day, 7 days a week. Relying on a total staff of 21 full time employees, divided into the following specialities and full time employees: physicists (2), operations (8), ion source (2), control system (2), cryogenic (2), mechanical (2), and electronic (3).

New experiments are scheduled, on average, once a week and involve reconfiguring all elements of the accelerator. Two methods exist for this reconfiguration, either using an old saved configuration from a previous experiment, or by establishing a new configuration. The largest advantage to using an old saved configured is the amount of time saved versus establishing a new accelerator configuration. Even though a new configuration takes more time to create, it typically achieves the best beam quality. Depending on requirements for different experiments, it may take 8-24 hours to establish the accelerator and be delivering the requested ion species, energy, and intensity to target.

Accelerator configurations are saved via an offline computer. These saved configurations create a library of configurations which can be leveraged in future experiments. These configurations are scaled when applicable to future experiments. Resonators are scaled by the mass to charge ratio, but limited to approximately ±15% of the saved configuration's mass to charge ratio. This limit is driven by the lack of linearity when setting resonator phase and amplitude beyond this percentage. Magnetic devices are scaled based on the magnetic rigidity. The ability to scale accelerator configurations is critical for setup and delivering CARIBU beams, as well as for performing accelerator mass spectroscopy.

Facility Upgrades

The accelerator has undergone several improvements in the past 6 years, which have greatly benefited its operation and performance. In 2009 the last cryostat of the accelerator containing 1978 era RF resonators was replaced with a new cryostat containing, at that time, state of the art quarter wave resonators (QWR) [3]. These QWR had more than twice the voltage potential, a world record at the time, than the previous resonators. This cryostat had additional improvements as well, such as separating the cavity and cryostat vacuum spaces. Separating the vacuum spaces is motivated by the desire to keep the QWR RF surfaces as clean as possible. This cleanliness is import to maintaining cavity performance and is also a challenge to preserve. Since introduction there has been no degradation of quality or potential gradients for the QWR.

In 2011 a room temperature radio frequency quadrouple (RFQ) [4] was installed at the beginning of the accelerator. Since an RFQ maintains beam emittance, beam transmission through the first accelerating section, the PII Linac, improved to over 80%, instead of 60%, as was achievable under the previous configuration.

The most recent upgrade to the facility was a reconfiguration of the BOOSTER linac, including the

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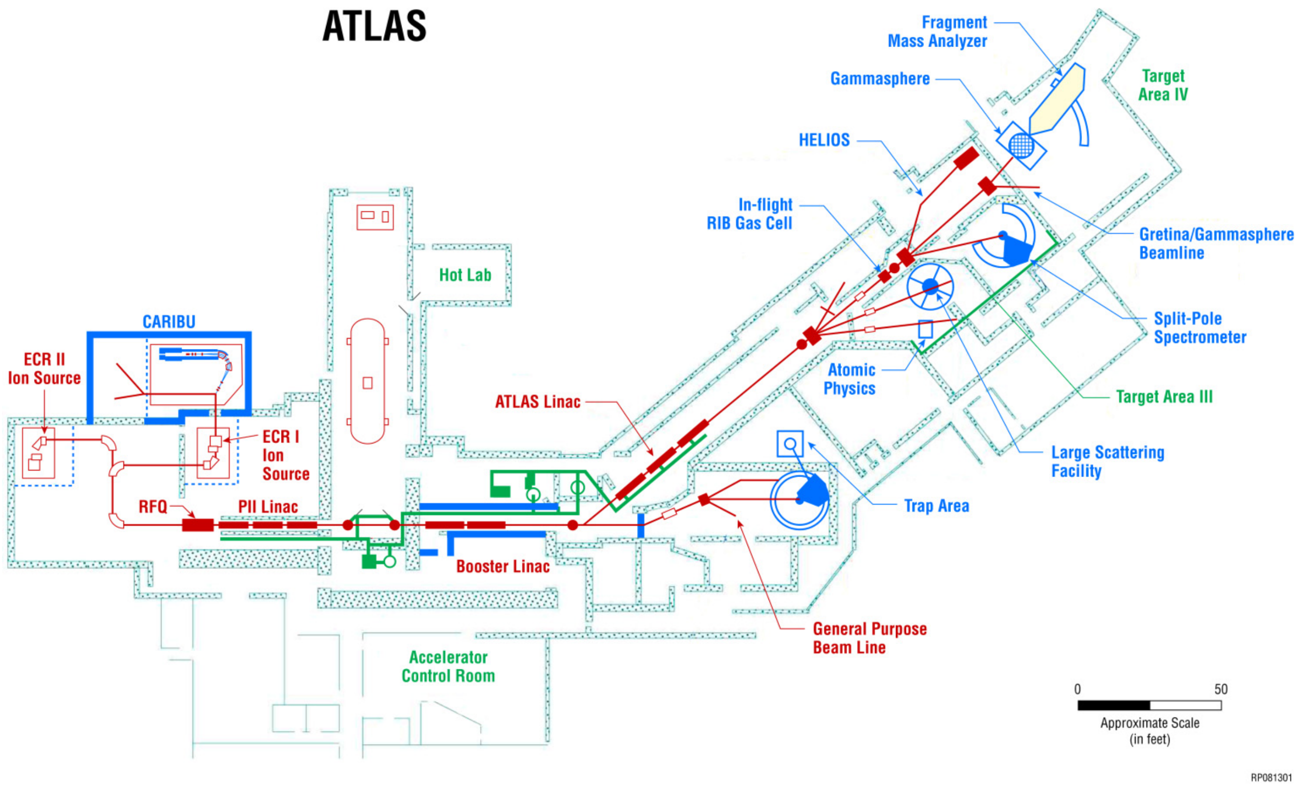

Figure 1: Overview of the ATLAS facility.

exchanging of three 1978 era cryostats, for a single new QWR cryostat [5]. Similar in implementation to the cryostat installed in 2009, it houses 7 QWR cavities, and achieves an average world record 2.5MV per resonator, while only contributing 45W of power into the 4.5K liquid helium system.

The existing ECR charge breeder ion source, currently coupled with CARIBU, will be replaced with an Electron Beam Ion Source (EBIS) early in 2016 [6]. This approximately doubles the charge breeding efficiency versus the ECR charge breeder. Additionally, EBIS will provide very clean background in the A/q range of CARIBU ion beams.

Before 2017 the facility plans to install the Argonne In-flight Radioactive Ion Separator (AIRIS). This new upgrade has many improvements versus the existing method of in-flight production. It will provide new regions of RIB, with a higher mass and further from stability, while improving the transmission. Its location will be moved upstream from the existing position which offers RIB to more target areas in the facility.

RIB Tuning

Tuning of radioactive ion beams is complicated versus stable ion beams. ATLAS as two different ways of producing radioactive beams, either from charge breeding the daughter products from a decaying ^{252}Cf source, or producing them in-flight from accelerated stable beam interacting with a gas cell or beryllium foil.

The process for delivering the in-flight produced RIBs, is as follows. First stable beam is delivered to the experimenter's detector area, where they may or may not use that beam for calibration of their detector. Next the gas target or beryllium foil is inserted into the beamline, and an energy degraded stable beam is then tuned to the detector area again. Finally to deliver RIB all beamline devices between the gas target or beryllium foil and the detector are scaled based on the expected rigidity of the RIB of interest. Additional tools are available to try and optimize the RIB, those include a superconducting solenoid after the gas cell or beryllium foil. Two different rebunching superconducting resonators, for time focusing both the stable and radioactive ion beams, are also configured. Finally, a RIB "sweeper" in some cases allows for the removal of undesired beam with similar rigidity but different timing.

RIB from CARIBU are tuned and delivered to target in a different way than in-flight beams. First a "guide beam" of similar A/q as the desired RIB is delivered to the detector area. The entire accelerator is then scaled by that A/q ratio difference between the "guide beam" and the desired RIB. Beams from CARIBU have an intensity of less than 10^5 particles/second, therefore special detectors are need throughout the accelerator are needed. These detectors rely on counting beta radiation emitted from the RIB once in implanted on an aluminium foil. Eight of these detectors are strategically placed in the accelerator and are used to optimize the CARIBU RIB transmission

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after the scaling from the stable beam has been completed.

Maintenance and Troubleshooting

ATLAS has one planned maintenance period per year, which typically is 4 weeks long, and scheduled to occur in January. This period is used to address annual safety tests and inspections. Additional time is used to perform major repairs that are outstanding such as, cryostat repairs or cryogenic system repairs for example.

Aside from this planned maintenance period, the facility operates under the philosophy of run to failure. That means that ATLAS delivers beam to a target area unless there is a critical failure that requires maintenance. This attitude towards maintenance has given ATLAS an average reliability of nearly 92% over the past 6 years. The recent upgrades to the accelerator have improved reliability; however the upgrades and their operation require more diverse expertise to achieve.

Nearly all problems at ATLAS are first handled by the operators. The expectation is that the operator can troubleshoot and correct simple problems, and if they are not resolved by them, then the operator will contact the system expert for the affected subsystem experiencing difficulty. System experts are continually on call for troubleshooting problems.

SUMMARY

The ATLAS accelerator is versatile machine capable of delivering stable and radioactive beams to a wide variety of target areas. Recent upgrades have improved performance and reliability, while future upgrades will focus on improving the increasing the diversity of radioactive ion beams available to target. Tuning the accelerator for radioactive beams is well understood and becoming standardized.

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REFERENCES

[1] L.M. Bollinger et al., “ATLAS: A Proposal for a Precision Heavy Ion Accelerator at Argonne National Laboratory”, Argonne National Laboratory, 1978, ANL-78-XX-68.

[2] R.C. Pardo et al., “Neutron-Rich Beams from 252Cf Fission at ATLAS – The CARIBU Project,” MO3GRI02, PAC proceedings, PAC’09, Vancouver, Canada (2009).

[3] M.P. Kelly et al., “Superconducting Quarter-Wave Resonators for the ATLAS Energy Upgrade,” THP025, LINAC proceedings, LINAC’08, Victoria, Canada (2008).

[4] P.N. Ostroumov et al., “Efficiency and Intensity Upgrade of the ATLAS Facility,” MOP045, LINAC proceedings, LINAC’10, Tsukuba, Japan (2010).

[5] P.N. Ostroumov et al., “Completion of Efficiency and Intensity Upgrade of the ATLAS Facility,” TUPP005, LINAC proceedings, LINAC’14, Geneva, Switzerland (2014).

[6] S. Kondrashev et al., “Commissioning of CARIBU EBIS Charge Breeder Sub-systems,” WEB02, HIAT proceedings, HIAT’12, Chicago, USA (2012).

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