A NEW ECRIS INSTALLATION AT THE ARGONNE TANDEM LINAC ACCELERATOR SYSTEM*

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Abstract

An existing all permanent magnet ECRIS, the BIE100 [1], will be installed at ATLAS to recover operational flexibility by providing ATLAS with a second ECR ion source for stable beams. For years ATLAS has operated with two ECR ion sources, ECR2 and the ECR charge breeder as well as a tandem electrostatic injector. The tandem was retired in 2013 and in mid-2015 the ECR charge breeder was decommissioned to make room for a new Electron Beam Ion Source exclusively for charge breeding radioactive ion beams. This left the facility with a single ECR source for virtually all stable ion beam production. Design, installation plans and anticipated operational parameters are discussed.

ATLAS MULTI-SOURCE HISTORY

The Argonne Tandem-Linac Accelerator System (ATLAS) has mostly relied on the use of multiple ion sources since inception in 1985. This has allowed for enhanced operational flexibility and time to develop new beams and improve ion source performance. One source can be prepared, maintained and conditioned while another is in use for the experimental program. If there is a major failure of an ion source system another one can be called into duty to continue accelerator operations and reduce overall downtime.

Early on two negative ion source injector platforms (east and north) were used to feed the Tandem Vandegraff Accelerator, stripping to positive ion beams and subsequently feeding the Booster and Atlas superconducting linac sections (see Fig. 1). In 1992 the Electron Cyclotron Resonance Ion Source (ECRIS) ECR1 and Positive Ion Injector (PII) linac were commissioned to also feed into Booster, while the east injector was retired. Through the years, and a variety of upgrades, ATLAS has maintained multiple ion sources for the production of stable beams as can be seen in Fig. 2. Recently the ECRCB (charge breeding upgrade of ECR1) was only used for stable beams that did not affect the low background essential for effective charge-bred radioactive beam delivery. In the summer of 2013, the tandem injector was retired and in June of 2015 the ECRCB was retired from part time stable beam operation to be dismantled a few months later and replaced with an Electron Beam Ion Source (EBIS) dedicated solely to radioactive beam charge breeding.

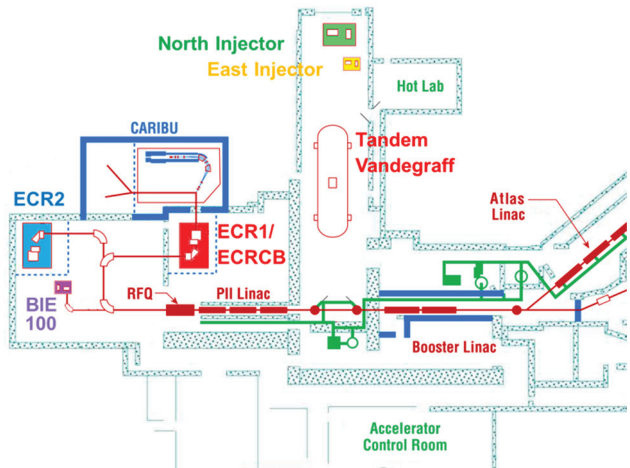

Figure 1: Layout of ATLAS accelerator section.

PRESENT SOURCE OPERATIONS

Since ECRCB removal, ATLAS has been left with a single source, ECR2, for all stable beam production. This source limitation has been very taxing for ATLAS operations. ATLAS essentially follows a 24 hour 7 day/week operational schedule. Typical experiments last 3-7 days with a very quick turnaround time expected of less than 24hrs for a new ion species to be tuned on target. Scheduling of beam time has become more complicated with more consideration needed for outside user schedules in relation to ion source preparation demands. Some of the scheduling burden will be lifted from ECR2 when the EBIS is brought online in late 2016 for breeding CARIBU radioactive ions, but there will still be no alternate ion source for stable beam production.

Carbon-14 Beams

Carbon-14 ion beam production ended at ATLAS with the retirement of the tandem in 2013. The demand for this beam has not diminished, and experiments delivering ^{14}C have been approved by the ATLAS program advisory committee. Until now, resumption of ^{14}C beam production in ECR2 has been avoided, mostly due to time prohibitive radioactive contamination procedures that would make maintenance and operation very difficult. Based on experience with the tandem ion sources, ^{14}C contamination also continues into the beamline past the ion source for quite some distance.

* Work supported by U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357.
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ISBN 978-3-95450-186-1

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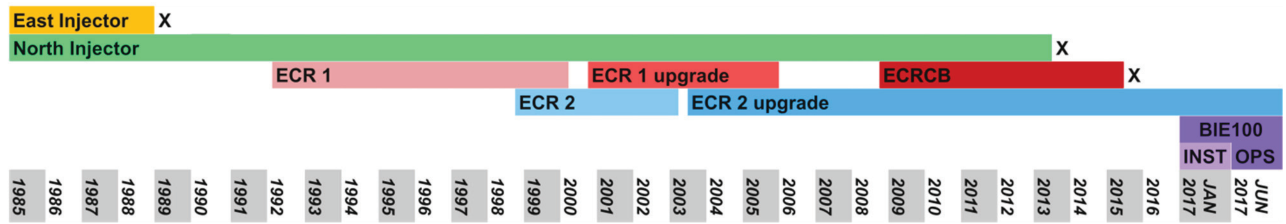

Figure 2: Timeline of stable beam production from ion sources for the ATLAS facility experimental program.

BIE100 PROJECT

The need for ion source flexibility and the need to return to ^{14}C production are the performance goals which drive a project to install the BIE100 [1] ECRIS as a second 'stable' beam source for ATLAS. It is an all permanent magnet (NdFeB) design that was developed for a DOE small business innovation research (SBIR) project from 1999 thru 2002 [2] by Dan Xie at Berkeley Ion Equipment, Inc. The BIE100 was most recently used within the Argonne Physics Division for demonstration of a multi-charge state low energy beam transport (LEBT) system. The simple plasma chamber design and the compact nature (47 cm Ø, 32 cm L) of this ion source are suited for ^{14}C contamination clean-up when needed (see Fig. 3).

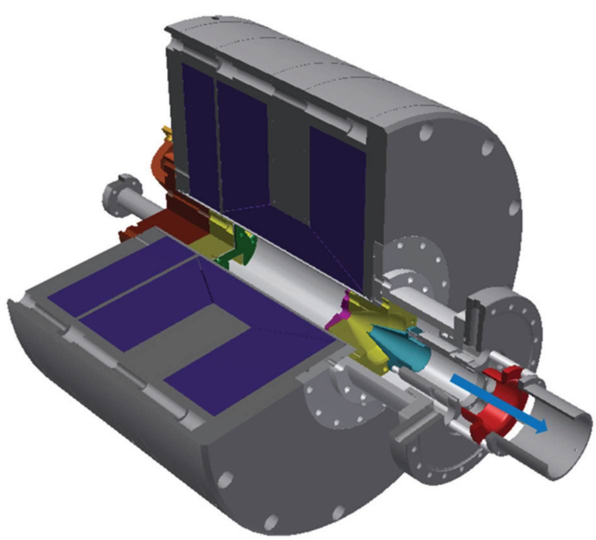

Figure 3: BIE100 ECRIS sectioned perspective view, the blue arrow denotes ion beam extracted from source.

Operations

The BIE100 has measured injection, extraction and radial magnetic fields of 12.7, 6.5 and 10 kG respectively. It typically ran with RF power ≤1.3 kW at 2 frequencies: 12.7 and 13.5 GHz during development, but will run at a single frequency between 11-13 GHz at up to 350 W for current ATLAS needs. The purchase of another TWTA, that would provide a second frequency of plasma heating, can be delayed if needed. This source will operate at 15-25 kV source potential with 1-10 mA of drain current. The HV platform will operate as high as 175 kV to meet the energy required for injection into the first accelerating section. The maximum mass to charge ratio is currently limited to ~6.5.

When the source becomes operational, it will not only produce the highly desired ^{14}C beam from $^{14}CH_4$, but can also be tasked for beams from all of the elemental gases, other molecular gases, and materials with a high vapor pressure. Usage of this source is expected mostly for lighter beams ($Z \leq 18$). As a benchmark, the BIE100 has produced 200 eμA or more for Argon charge states up to 8+ with 330 W single frequency RF power [2]. For reference, approximately 50% of the experimental runs from FY2016 could have been produced using the BIE100 at the requested beam current, all without venting the ion source.

Installation

The preliminary beamline design from the source into the existing ATLAS LEBT is shown in Fig. 4. The small size of the BIE100 will allow it to fit next to ECR2 (see Fig. 1) requiring no new building construction. A number of items from ECRCB that will be reused include a travelling wave tube amplifier (TWTA), gas leak valves/controllers, vacuum pumps, waveguides, power supplies, a small high voltage (HV) platform and insulators as well as existing beamline elements such as dipole magnets and accelerator tubes. A major beam optics difference compared to existing and previous sources at ATLAS is that the mass analysing magnet will be moved off of the HV platform resulting in full beam loading of the HV power supply and accelerator tubes. Electrostatic beam focusing elements are important to keep the beam loading small. A new vacuum chamber for the convergence of the new beamline with the PII LEBT at a 90 degree dipole magnet has already been constructed. It has new beam entrance and optical alignment ports for the intersection point.

Timeline

Plans have already begun for the installation of the BIE100 ECRIS at ATLAS. Items for reuse have been identified and placed into an initial design layout. Beam optics were calculated using TRACK beam dynamics code [3]. The timing of many of the activities will be somewhat fluid with availability of personnel and needs of ATLAS. The next step shall be a finalization of layout of ion source and HV platform placement, which should be completed by end of September 2016. After a safety review is performed, placement of beamline stands, HV platform, vacuum and optics components will follow

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without interruption to ATLAS beam delivery. The new intersecting 90 degree vacuum chamber will be installed during a scheduled downtime period over December 2016 or January 2017. Electrical, vacuum control, safety interlocks, fencing, and control system hardware will be installed in early 2017. It is anticipated that beam tests can begin April-May followed by experiments at ATLAS using the BIE100 in June 2017.

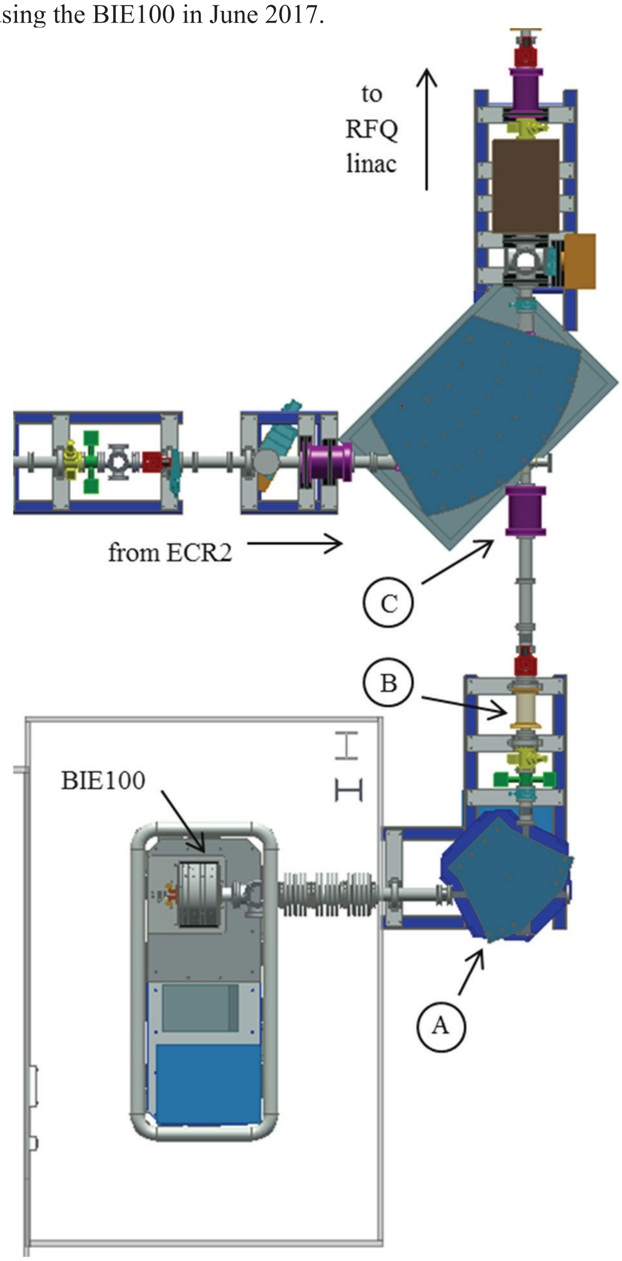

Figure 4: Planned BIE100 at ATLAS. Note the initial mass analysis off the HV platform (A), followed by a simple beamline design with steerer (B) and electrostatic quadrupole triplet (C) to match into existing LEBT.

CONCLUSION

A new ion source for ATLAS will be installed and made operational in the next year using an existing permanent magnet source. The source must provide both ^{14}C beams and added flexibility to stable beam operations. The BIE100 ECR ion source has been identified as a solution for the accelerator's current and near future needs. Layout design is underway and installation is to follow. Operations are currently slated for mid-2017.

REFERENCES

[1] D. Z. Xie, "The BIE100 ECR ion source," *Rev. Sci. Inst.*, vol. 73, no. 2, pp. 531-533, Feb. 2002.

[2] D. Z. Xie, "A high efficiency electron cyclotron resonance ion source system for the production of radioactive ion beams," Rep. DOE00 SBIR Phase II Project (Grant No: DE-FG-99ER82750) Nov. 2002

[3] B. Mustapha, V. N. Aseev, P. N. Ostroumov, and E. S. Lessner, "TRACK: the new beam dynamics code," in *Proc. PAC'05*, pp. 2053-55.

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