Commissioning of the ARRA-funded AIP project for ATLAS entitled "Replacement of First Booster Cryostat Module & Liquid Helium Upgrade"

The Physics Division at Argonne National Laboratory has successfully initiated the commissioning with beam of a new cryomodule for the Argonne Tandem Linac Accelerator System (ATLAS) funded under the American Recovery and Reinvestment Act (ARRA). This new cryomodule of high-performance, superconducting (SC) quarter-wave resonators (QWR's) replaces three modules of split-ring resonators in operation at ATLAS since the early 1980s. A number of technology improvements are implemented in the new cryomodule. Most importantly, an improved radio-frequency (RF) design, based on conical-shaped inner and outer conductors provides the maximum possible accelerating gradient with both a large acceptance and minimal beam losses. In addition, fabrication methods, unique to ANL, include the capability to electropolish complete quarter-wave cavities, the use of wire electron discharge machining (EDM), and lower heat 'keyhole' welding. The new cryomodule of seven QWRs also includes four 9-Tesla SC solenoids with a design that incorporates return coils and does not require any magnetic shielding. The assembly (see Fig. 1) followed by off-line testing of the cryomodule was completed in the early summer of 2013.

The cryomodule was installed in the ATLAS tunnel in December 2013 (Fig. 2) as part of a major reconfiguration of the accelerator. It has since been prepared for beam commissioning. On February 18, 2014 tuning of a $^{20}Ne^{6+}$ beam from the Positive Ion Injector (PII) of ATLAS through the new cryomodule was performed. The PII provided a 29.4-MeV $^{20}Ne^{6+}$ beam to the entrance of the cryomodule. The seven resonators were phase locked and prepared for the tuning procedure where RF field phases are set for optimal beam acceleration. Beam energy spectra were measured with a silicon barrier detector following acceleration by each successive cavity. The $^{20}Ne^{6+}$ ions were accelerated to total kinetic energy of 104.9 MeV as can be seen in Fig. 3. The transmission through the entire Booster section of ATLAS that includes the new cryomodule together with an older one of split-ring resonators and new beam line was nearly 100%. At this point in time, it is noteworthy that all the demonstrated parameters for the accelerated beam (Table 1) already significantly exceed the "Project Completion Performance Requirements" as defined in the Project Management Plan (PMP) approved by DOE's Office of Nuclear Physics.

Figure 1: Left: seven 72 MHz SC cavities after final clean room assembly. Right: completed cryomodule string with cavities, couplers, tuners, alignment and cryogenics systems.

Figure 2: The reconfigured ATLAS Booster area with the new cryomodule (rectangular structure) coupled to a cryomodule of the previous generation (white, circular structure).

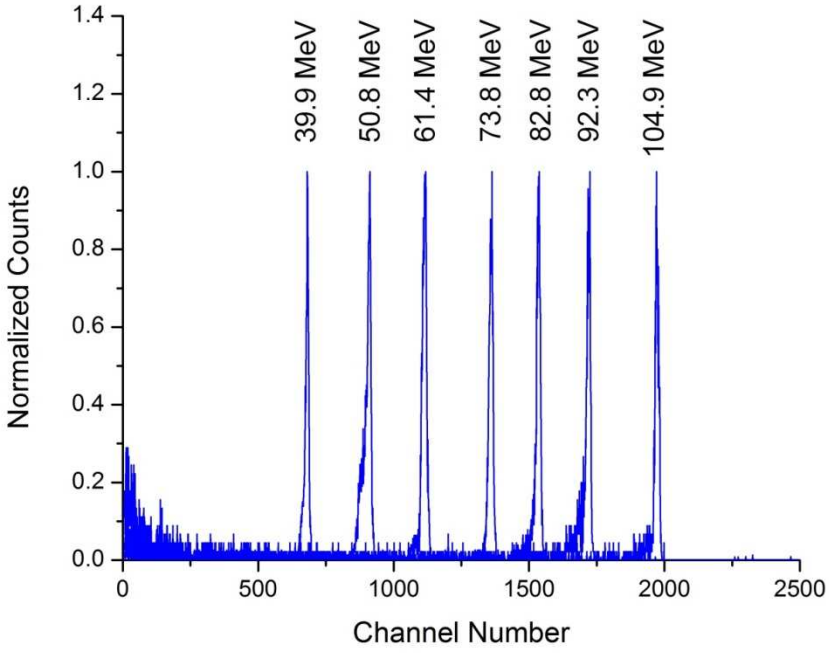

Figure 3. Energy spectrum for $^{20}Ne^{6+}$ ions following the sequential tuning of each of the seven SC resonators. The injection energy was 29.4 MeV.

It should be noted that, for the first phase of this commissioning, the total accelerating voltage was conservatively set to14.0 MV. Earlier RF testing of individual cavities has demonstrated that every cavity can provide about 3 MV in accelerating voltage. Commissioning will proceed further during the coming days, including first beam delivery to experimental systems.

The successful completion of the ARRA-funded cryostat construction project also demonstrates major strides toward completion of the associated Booster upgrade project which includes the installation of additional shielding to enable significant increases in the beam intensities from ATLAS, the reconfiguration of the transport and beam preparation systems into and out of the new cryostat, and the major redesign of the cryogenics system supporting these improvements. All major elements of these projects are now in place and commissioning of the remaining components are rapidly moving forward.

This first acceleration by the new cryostat represents a major milestone in the commissioning of the upgraded ATLAS facility. The development of the cryostat is the result of several years of dedicated work by the Accelerator R&D group. Its successful installation at the facility exemplifies the outstanding collaborative efforts over many months of this group and the ATLAS Operations staff.

Table 1: Project Completion Performance Requirements from PMP and Demonstrated Parameters

Parameter	Required Value	Demonstrated value
All cavities are phase-locked to the MO and provide accelerating voltage	≥ 1.0 MV per cavity	**≥ 1.82 MV per cavity**
Output energy of a test ion beam with input energy 1.8 MeV/u and Q/A=1/4	≥3.3 MeV/u	**5.25 MeV/u**
Transmission through the cryomodule	≥ 90%	**~100%**