HEAVY ION ACCELERATION IN THE BNL AGS*

DONALD S. BARTON
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK, U.S.A.

Brookhaven National Laboratory has embarked on a program of heavy ion research with the completion of runs with oxygen and silicon beams at energies of 14.6 GeV per nucleon. The acceleration of oxygen occurred in October, 1986, two years after groundbreaking for the beam transfer line connecting the Tandem Van de Graaff facility and the AGS. With the acceleration of silicon beam, which occurred in March, 1987, the AGS has achieved the highest energy beam of masses above oxygen. The previous high energy had been achieved at the Synchrophasotron, Dubna (USSR).

Beam from a high intensity pulsed negative ion source system was accelerated in one of two available upgraded Model MP Van de Graaff accelerators to deliver fully stripped 7 MeV/nucleon oxygen ions for further acceleration in the AGS. Oxygen ion currents of up to 90 μA were delivered to the AGS for better than 90% of the time during the October-November, 1986, run. To obtain fully stripped ions heavier than oxygen, the pulsed sputter ion source was installed in the terminal of the second MP Tandem which operated at negative high voltage as a pre-injector for the other Tandem. During typical silicon running conditions, an output of 50 μA of Si^- at the output of the first Tandem yielded a beam current of fully stripped Si^{14+} of about 15 μA

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delivered to the AGS. A conventional beam transport system joining the Tandem and the AGS was installed in a new 640-meter long tunnel. Standard positive ion multi-turn injection with a d.c. electrostatic septum was used to stack, nominally, 12 turns of the 2-3 π-mm-mr O^{8+} or Si^{14+} beam from the transfer line into the AGS with an overall efficiency of approximately 40-50%.

Normal proton acceleration at the AGS is accomplished using a ten cavity rf system which sweeps from 2.5 MHz to 4.5 MHz. The time variation of the frequency is obtained from the accelerating bunches ("bootstrap"). Phase and radial control also is derived from beam signals. To accommodate the wider frequency swing and lower intensities associated with light ion acceleration, both a new low level and a high level rf system were built. The basic frequency program for this new system was derived solely from a measure of the ramping AGS magnetic field. A single rf cavity covered the early acceleration from 500 kHz to 2.5 MHz at which point, "handoff", the cavities of the normal proton system took over. The peak voltage available to a circulating particle increased drastically at handoff, from two gaps of 7 kV each to 40 gaps of 3 kV each over about 1 ms. Handoff efficiency was close to 100%, and from this point lossless acceleration to full field occurred with the standard rf manipulations for transition passage and extraction debunching. Normal resonant extraction at a horizontal tune of eight and two-thirds completed the cycle.

The experimental program comprised experiments with intensity requirements ranging from 10^9 ions/spill to 10^4 ions/ spill with the majority of experiments at the lower intensity range. The average extracted intensity of 5×10^8 oxygen ions and 5×10^7 silicon ions per cycle therefore required providing 0.01-0.1% of the beam to a typical experiment while maintaining reasonable beam purity. The heavy ion beam was delivered to the experiments using the proton transport system. The AGS switchyard incorporated a series of electrostatic splitters and thin-septum magnets enabling the delivery of beam to four primary beam lines simultaneously. Substantial collimation was used to reduce the beam intensity, followed by momentum selection to eliminate projectile fragments. The measured beam contamination was found to be less than 1% during the oxygen run and less than 3% during the silicon run. Tests of sulfur acceleration are planned for fall, 1987.

REFERENCES

H. Foelsche, D.S. Barton, and P. Thieberger, Light Ion Program at BNL, Proc. 13 International Conference on High Energy Accelerators, Novosibirsk, USSR (August, 1986).