CONSTRUCTION OF THE BNL EBIS PREINJECTOR*

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Abstract

A new heavy ion preinjector, consisting of an Electron Beam Ion Source (EBIS), an RFQ, and IH linac, is under construction at Brookhaven National Laboratory. This preinjector will provide ions of any species at an energy of 2 MeV/u, resulting in increased capabilities for the Relativistic Heavy Ion Collider, and the NASA Space Radiation Laboratory programs. The RFQ has been commissioned with beam, and most of the remaining elements are either installed or being assembled.

INTRODUCTION

As shown in Fig. 1, the EBIS-based heavy ion preinjector consists a high current electron beam ion source (EBIS), followed by an RFQ and IH linac. A 37 m long beam transport line follows the linac, connecting to the heavy ion injection point of the Booster Synchrotron. This preinjector will replace two existing Tandem Van de Graaff accelerators and an 800 m transport line, as the heavy ion preinjector for both the Relativistic Heavy Ion Collider (RHIC) and NASA Space Radiation Laboratory (NSRL). It is designed to deliver milliampere currents of any ion species in ~10 µs pulses, to allow single-turn injection into the Booster. Species from EBIS can be changed on a pulse-to-pulse basis, by changing the 1+ ion injected into the EBIS trap from the external ion sources. The switching time for the magnets in the beam transport line following the linac will be 1 second. Table 1 shows high-level parameters for the preinjector. More details on the EBIS source and preinjector can be found in references [1] and [2].

Table 1: Preinjector Parameters

Ions	He – U
Q / m	≥1/6
Current	> 1.5 emA
Pulse length	10 µs (for 1-turn injection)
Rep rate	5 Hz
Final energy	2 MeV / u
Time to switch species	1 second

EBIS SOURCE

The design of the EBIS source is very similar to the prototype Test EBIS at Brookhaven [1]. The source trap length is 1.5 m, compared to 0.7 m on Test EBIS, resulting in approximately twice the output current. The superconducting solenoid length in the RHIC EBIS is increased to 2m to accommodate the longer trap length. The design value of the electron beam current of 10 A is the same as run on the Test EBIS. The source is shown schematically in Fig. 2, and some key parameters are given in Table 2. All EBIS subassemblies have been fabricated, and have either already been tested, or are in the final assembly stages.

Table 2: EBIS Source Parameters

Electron gun current	10 A
Solenoid field	5.5 T
Trap length	1.5 m
Pressure in the trap region	low 10^{-10} Torr
Total extracted charges per pulse	5×10^{11} (80 nC)
Total current per pulse (all charge states)	~8 mA in 10 µs
Output energy	17 keV/u

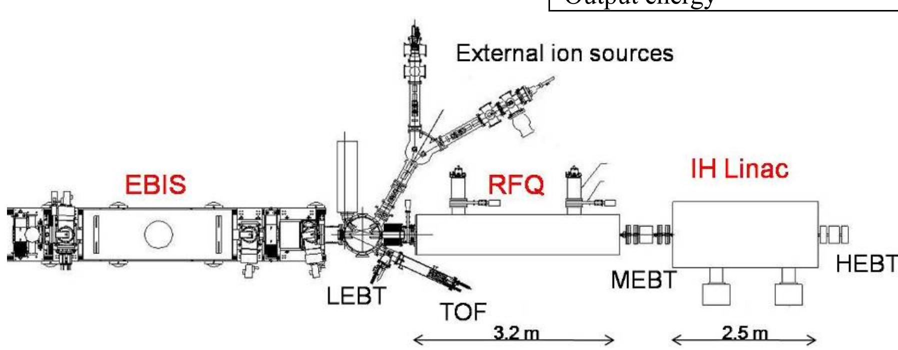

Figure 1: Layout of the EBIS-based heavy ion preinjector.

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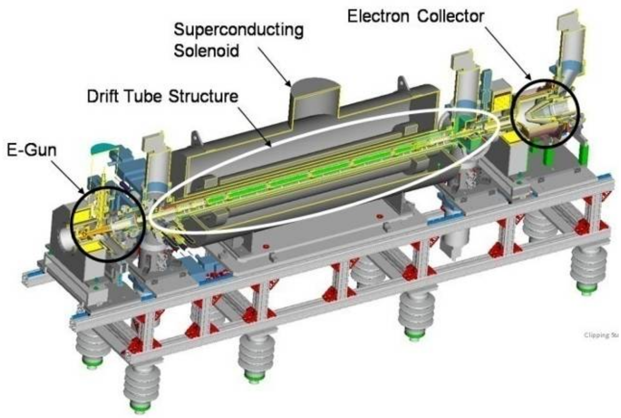

Figure 2: Drawing of the RHIC EBIS.

Electron Gun

The EBIS is planned to operate with a 10 A electron beam, but the electron gun is designed for up to 20 A operation. The cathode is a 9.2 mm diameter IrCe unit, made for BNL by BINP [3]. The final electron gun has been successfully tested to 10 A on the Test EBIS, and has been in routine use there for ~ 6 months.

Electron Collector

The electron collector is designed to handle a nominal electron beam of 20 A, 15 kV dc, i.e. 300 kW, but since ionization times are typically < 50 ms, the electron beam can be pulsed at a duty factor < 25%, for a lower average power. A collector fabricated from a Zr-Cr-Cu alloy is completed and has been in use on the Test EBIS, although the duty factor is low on Test EBIS due to power supply limitations. A second, spare collector has been completed which is identical, except that it is made from a high conductivity Be-Cu (Hycon 3 HP). This should have somewhat better thermal fatigue lifetime.

Superconducting Solenoid

The superconducting solenoid for the EBIS is 2 m long, with a 5.5 T field which is uniform to within ±0.25% over the 1.5 m trap length. The solenoid has a 204 mm diameter warm bore, to allow sufficient space for the vacuum pipe, which also has heating rods and water cooled shield for baking of the central trap region. The solenoid was fabricated by ACCEL Instruments [4], and following a failure during a quench test in 2007, it was repaired and passed factory acceptance testing in January, 2009. It was subsequently found during initial acceptance tests at BNL that it was damaged during shipping. It is now in the process of being repaired by ACCEL at Brookhaven, and is expected to be completed in May.

Central Trap

The central trap region consists of six cylindrical electrodes of ~42 mm diameter. There is also NEG material running the length of the central vacuum pipe to provide extra pumping in this region. This inner trap electrode assembly is complete, and is shown in Fig. 3. Also shown in Fig. 3 is the outer vacuum chamber, with heating elements for baking, an outer cooling jacket, and steering coils. This unit has been successfully tested, reaching a central drift tube temperature in excess of the required 450 deg C, while maintaining the outer skin at room temperature.

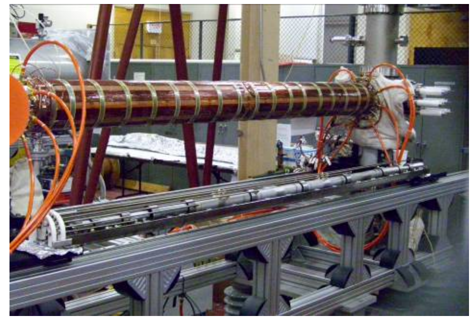

Figure 3: EBIS drift tube structure (below) and central vacuum chamber (above) where it will be inserted.

EXTRACTION AND TRANSPORT TO RFQ

The entire EBIS and its power supplies sits on a voltage isolated platform, and can be pulsed at up to ~ 100 kV to provide 17 keV/u for any ion species at Q/m > 1/6. Matching into the RFQ is via one gridded einzel lens, and one pulsed magnetic solenoid. This matching section has been installed and operated on Test EBIS, to verify the performance of this LEBT. Emittance measurements are complicated by the presence of multiple charge states, but generally are consistent with expectations (rms values of ~0.1 – 0.3 pi mm mrad at the RFQ entrance location, depending on species).

RFQ

The RFQ was built by the Institute of Applied Physics at the University of Frankfurt [5], with most of the fabrication by NTG [6]. Some RFQ parameters are given in Table 3. The RFQ is now at Brookhaven (Fig. 4), and for initial testing, has accelerated beams from the Test EBIS [7]. It conditioned to full power very quickly, and initial measurements of the beam directly out of the RFQ, while complicated by the presence of multiple charge states from EBIS, seem consistent with calculations. We are preparing to measure output energy and emittance of a single charge state, by transporting the beam through a dipole to an analysis line.

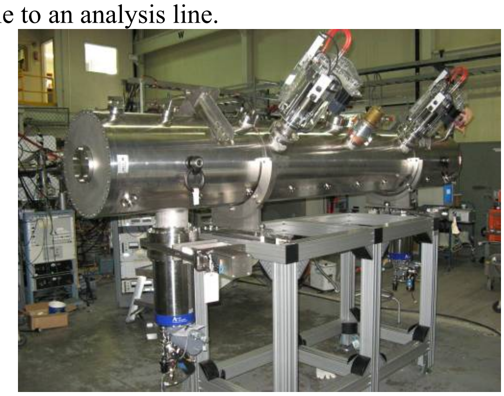

Figure 4: The EBIS RFQ at BNL.

Table 3: Parameters of the RFQ

Input Energy	17 keV/u
Output energy	300 keV/u
Q / m	> 1 / 6
Frequency	100.625 MHz
Length	3.2 m
Power (with beam loading)	~ 200 kW

IH LINAC

The IH Linac is also being built by IAP, Frankfurt. The linac is designed for a beam current of up to 10 mA. Fabrication of the cavity by PINK [8] is complete, and the cavity is now at GSI for copper plating. The internal quadrupole triplet is being built by Bruker [9]. Linac drift tubes are complete, and the structure was assembled (with a dummy drift tube for the internal quadrupole triplet) for low level rf measurements, as shown in Fig. 5. Linac parameters are given in Table 4. The linac is scheduled for delivery in the fall of 2009.

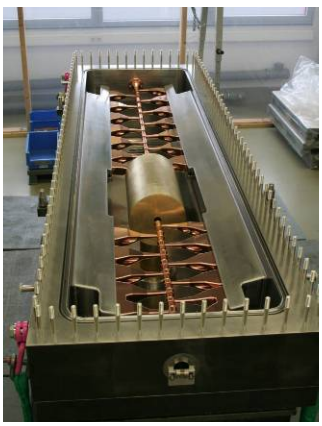

Figure 5: IH linac during initial rf testing.

Table 4: Parameters of the IH Linac

Input energy	300 keV/u
Output energy	2 MeV/u
Q / m	> 1 / 6
Frequency	100.625
Cavity Length	2.46 m
Power (with beam loading)	~ 300 kW

BUNCHER CAVITIES

There are three spiral resonator cavities being built by IAP for the preinjector. A 20 cm long 4-gap rebuncher cavity between the RFQ and linac, is complete and at BNL. In the HEBT line, there are 2 debuncher cavities, to reduce the energy spread of the beam going into the Booster. Delivery of these units is expected this summer.

HEBT

The High Energy Beam Transport (HEBT) line from the linac to Booster injection includes is a ~17 m section in the linac building, transport through a ~8 m thick shield wall, and then inside the Booster tunnel a ~12 m transport, including two dipoles, to inject beam into the Booster at the same location as beam coming from the Tandems. The two identical dipoles, each have a bend angle of 72.5 degrees, a 13.5 cm gap, 1.3m bend radius, and 1T maximum field [10]. These laminated magnets (to allow the required 1 second field changes) were manufactured by Sigmaphi [11]. The final 25 m of beamline from the entrance to the shield wall to the Booster injection, including these dipoles, is installed and under high vacuum (Fig. 6).

Figure 6: Dipoles installed in the Booster tunnel.

SUMMARY

In addition to the items mentioned above, all power supplies for operation of the EBIS and LEBT line are now in hand. EBIS power supplies are installed on the high voltage platform. The rf amplifiers for the RFQ, linac, and three bunchers are now installed in their final location. Hardware for the control system, vacuum, and beam diagnostics has been procured, and installation is in progress. The commissioning of beam into the HEBT and Booster is presently scheduled to start in January, 2010.

REFERENCES

[1] J. Alessi, et.al., “High performance EBIS for RHIC”, PAC 2007, Albequerque, p. 3782 (2007)..

[2] J. Alessi, et.al., “Status of the EBIS project at Brookhaven”, Linac 2006, Knoxville, p. 365 (2006).

[3] G. Kuznetsov, Nuclear Instrum. & Meth. In Physics Res. A 340, 1994, p. 204.

[4] ACCEL Instruments GmbH, Bergisch Gladbach, Germany.

[5] M. Vossberg, et.al., “The new EBIS RFQ for BNL”, Proc. of Linac 2008, Victoria, BC, Canada.

[6] NTG GmbH, Gelnhausen, Germany.

[7] M. Okamura, et.al., “Beam Commissioning of the RFQ for the RHIC-EBIS Project”, these proceedings.

[8] PiNK GmbH, Wertheim, Germany.

[9] Bruker Biospin S.A., Wissenbourg, France.

[10] T. Kanesue, et.al., “Design study of the dipole magnet for the RHIC EBIS high energy transport line”, PAC 2007, Albequerque, p. 3301 (2007).

[11] Sigmaphi, Vannes, France.