EBIS Project

Annual Progress Report

Collider-Accelerator Department
Brookhaven National Laboratory

June 1, 2006 through August 31, 2007

EBIS Project Annual Report

I. Summary of Project Status

Early in this reporting period, effort went in to completing almost all project engineering and design (PED), finalizing all project documents required for the DOE Independent Project Review, and then obtaining DOE CD-2 and CD-3 approval. Prior to the receipt of DOE construction funding, activities in several areas, and orders for several major items, progressed with NASA funding. A Continuing Resolution in FY'07 delayed the start of DOE construction funds by 6 months, and reduced the FY'07 funds received by $2.4 M. This led to a 4 month slip in scheduled project completion, and an increase in cost of $140 k, which was taken from project contingency.

As discussed in detail in the following sections, the following activities were accomplished during this reporting period:

1. CD-2 and CD-3 approved.
2. Operation of the Test EBIS at 100 kV, including emittance measurements.
3. RFQ procurement placed, design reviews held, and fabrication is in progress.
4. Linac procurement placed, physics design and preliminary mechanical design completed, and detailed mechanical design started.
5. RF amplifier procurement placed, design review held, and fabrication is in progress.
6. LEBT chamber designed, fabricated, tested (including internal deflectors, ESQ's, …)
7. Prototypes of the LEBT solenoid magnet and MEBT quadrupole magnet were designed, fabricated, and tested
8. Beam port installed, chamber installed in Booster, and NEG pipe placed through the wall.
9. Dipole magnetic calculations were completed, and we are in the evaluation process of the vendor proposals for fabrication.
10. The Beneficial Occupancy Readiness Evaluation for the building extension, funded by the Empire State Development Corporation (NYS), which will house many of the EBIS power supplies is scheduled for mid-September.
11. Many orders were placed for power supplies, vacuum components, and controls hardware.
12. Safety reviews were conducted addressing operation of the Test EBIS at high voltage, cryogenic safety of the superconducting solenoid, and an overview of safety of the entire EBIS preinjector.

Also discussed in more detail later, the following problems were encountered:

1. Electron collector delivery has been delayed due to difficulties encountered by the vendor during fabrication. A second collector is being fabricated in the BNL shops using an alternate material to reduce schedule risk.
2. The superconducting solenoid delivery has been delayed due to a failure following a forced quench as part of the factory acceptance testing.

Good progress continues to be made in all major areas. Presently, our main concerns relate to the effects of future Continuing Resolutions, and possible schedule delays due to delays in delivery of the superconducting solenoid and the Linac.

A total of six Project Milestones (Levels 0, 1, and 2) were scheduled to be met during this period, and all of those have been achieved.

The project costs remain within the baseline budget, with $821 k of contingency used, and the contingency on remaining work at 25%. Almost all major procurements have been placed. We estimate the project to be 40% complete.

II. Detailed Report

<u>Test EBIS Experiments and Prototype Testing:</u>

The main goals on the Test EBIS for this past year were met:

Operation of the Test EBIS on a 100 kV ion extraction platform

- Gain experience in HV platform pulsing
- Test the extraction optics and compare to calculations
- Measure emittances at full energy

Test the prototype LEBT ion injection optics

Due to difficulties described in a later section, the only goal not met was the testing of the prototype electron collector.

Early in the reporting period, the EBIS and its power supplies were mounted on 100 kV isolation platforms, with the EBIS operating at ground potential until the isolation transformer was delivered. In preparation for high voltage operation, controls were added to allow remote control of the EBIS. Following design and safety reviews, the pulsed extraction platform power supply was fabricated at BNL and successfully tested up to 100 kV.

A BNL electrical engineer went to the transformer vendor (Stangenes) for the acceptance test of EBIS platform 100 kV isolation transformer. Following a few minor changes, the transformer was received on schedule in August 2006, and installed soon after. The high voltage enclosure for the Test EBIS was assembled; high voltage interlocks for personnel protection were implemented, operating procedures written, and a final Department safety review held. Full high voltage was then successfully applied to the Test EBIS and all the EBIS power supplies. The pulsed 80 kV extraction platform power supply operated very successfully. During this effort, $100 k of contingency funds was required to complete the electrical power distribution work and high voltage platform preparation.

The original plan for the high voltage insulating vacuum break was for fabrication at the Budker Institute, in Novosibirsk. Although they had built similar units in the past, their attempt to build the vacuum break for EBIS was unsuccessful, so we have now placed an order with Kyocera for this break. Fortunately, we had an existing break that could be installed on the Test EBIS, so high voltage operation has not been impacted.

With the EBIS high voltage platform fully operational, results of the pulsing of the platform voltage were very successful. The prototype high voltage pulser has performed very well, and the demonstrated platform voltage risetime of ~200 µs exceeds the 1 ms requirement. This pulsing had no adverse effects on the EBIS operation. Emittance measurements with high voltage extraction up the required 80 kV were performed, and were in good agreement with expectations.

The prototype multi-port LEBT chamber beam switchyard was fabricated in the BNL shops. All internal deflectors and lenses were fabricated and installed. The Hollow Cathode Ion Source was mounted on the chamber. An adjustable aperture, a Faraday cup and an emittance head were installed before the four quadrupole lenses and LEBT chamber bend, and two emittance heads and a Faraday cup were installed after the LEBT bend. The beam optical performance of this prototype was studied, and performance was in good agreement with simulations. Cu^{1+} ions were transported through the LEBT chamber with > 90% efficiency for current intensities of interest (~10 µA), and currents in excess of 50 µA have been measured at the injection point into the EBIS. Emittances had the desired symmetry in horizontal and vertical planes. The new LEBT has now been mounted on the Test EBIS for ion injection studies, and in initial tests Ne^{1+} ions have been injected into EBIS and ions extracted.

<u>**RHIC EBIS Hardware**</u>

Electron Collector

The first of two planned electron collectors was funded through R&D, due to the risk of possible difficulties during the manufacturing process. Unfortunately, this concern proved to be warranted, and the delivery of this electron collector by Brush-Wellman – Custom Engineered Products has been delayed by about 1 year from the vendor's original expected delivery date due to vacuum leakage problems in the Be-Cu cylinder welds. So far, all attempts to repair the vacuum leaks have failed. The back disk has been removed from the cylinder due to a poor weld that could not be fixed. Now a vacuum leak has been found in the front disk. The Custom Engineered Products Division has been in contact with the BW Elmore, Ohio division (Engineered Materials) for support and they are working out a plan for repair and joining of the front and back disks at Acceleron (electron beam welding company).

This delay in the collector has had only minimal impact to our R&D experimental program, but in order to minimize the risk of not having an EC ready for the final EBIS assembly we have now started a parallel effort to build a second collector ourselves of the same design, but using a Zr-Cr-Cu alloy rather than the Be-Cu. This eliminates the safety concerns of machining and handling of Be-Cu and allows fabrication to be done at BNL, speeding up the fabrication/leak checking steps. Since having a second electron collector was one of the suggestions at the May 2006 DOE EBIS Project review (to keep the Test EBIS operational), starting on this second collector seemed appropriate, even if the vendor is able to satisfactorily repair the first unit.

The parallel effort to build the second collector has progressed nicely. Several test welds were performed successfully on samples of the material. The BNL shops have now begun fabrication of the full collector. The new cylinder was rough machined and sent out for gun drilling of the cooling passages. The cylinder is now back at BNL for further machining. The goal is to have this backup collector fabricated by the end of October.

A linear strip detector was designed and parts fabricated to measure linear distribution of the electron beam current inside the electron collector on the gun-collector test bench, once the collector arrives.

Superconducting Solenoid

Delivery of the EBIS superconducting solenoid is behind schedule, although to date it has not affected the overall project schedule. In June, 2006 two engineers from ACCEL came to BNL for a detailed design review of the superconducting solenoid and a review by the Laboratory Cryogenic Safety Review Committee. Subsequently, manufacturing was delayed due to late receipt of subcontracted materials (specifically the superconducting wire and power supply), a vacuum leak in the turret area, required rework of the heat shield, and an out-of-tolerance condition on the helium vessel end plates affecting the alignment of the magnet bore. Finally, in early July, 2007, prior to factory acceptance testing, the superconducting solenoid had been operating at ACCEL at 5% over the design field of 6 T. The helium evaporation rate was slightly high, but in an acceptable range, and the measured field decay rate was satisfactory. The magnet had successfully quenched at 99% of full field during training without damage. The crash button (inducing a quench) was tested successfully at half field.

In mid-July, 2007 two BNL representatives (Pikin and Snydstrup) went to ACCEL and participated in the factory testing. As part of the factory acceptance testing with BNL witnessing, the magnet underwent a forced “crash button” quench at full field (6T). After this quench, the magnet was not able to achieve full field, and subsequently quenched repeatedly at 3.6 to 3.9T. While investigating the cause of the problem ACCEL found damaged contacts on the removable current leads. The leads were repaired. During a subsequent cool down, the magnet quenched 3 times at ~4.4 T. Further testing is in process to diagnose the problem.

This delay in the solenoid delivery, while not impacting the overall finish date, will soon start to reduce the time we will have to operate the EBIS source in the final location while other systems are being installed.

Electron Gun

Fabrication of the first of two electron guns for the RHIC EBIS is complete and the gun has been mounted on the Test EBIS for testing.

EBIS drift tubes, chambers, stands

Detailed calculations were carried out related to the baking and cooling of the drift tube section, and heat transfer to the thermal shield on the central vacuum chamber.

Fabrication of the EBIS drift tube components in the BNL shops is in progress. All parts for the stand for the RHIC EBIS were fabricated or procured, and the stand has been assembled. The wheeled and cushioned frame, which will be used to transport the assembled EBIS ~ 600 feet down the Linac tunnel to its final location, was also assembled, and the stand was rolled down the tunnel as a test.

External Ion Injection

The design of the external ion injection lines is similar to the existing injection on Test EBIS. The spherical deflectors and electrostatic quadrupoles to be used in this beam line are essentially the same as those used in the LEBT chamber tests.

The hollow cathode ion source, low energy vacuum vapor arc source, and liquid metal ion source, have all been used for injection of external ions into the Test EBIS. An interesting new development this past year is the possibility of using a laser ion source for the production of 1+ ions for injection in to EBIS. This idea, recently described in a paper at the ICIS Conference, is the result of work at BNL by Okamura, Kanesue, and Tamura. A simple laser and an array of solid targets could be used to produce 1+ ions of almost any species, with pulse-to-pulse switching of species by steering of the laser onto the appropriate sample in the array. Further testing of this idea is planned as the Master's Thesis work of Kanesue.

RFQ

The RFQ procurement was placed with the University of Frankfurt. They are the world's experts in the design and fabrication of heavy ion RFQs like that required for the EBIS. This fixed-price contract turned out to be very close to our original cost estimate. A design review was held in October, 2006 with Dr. Alwin Schempp, from IAP, Frankfurt presenting the detailed physics and mechanical design. Following the review, some design changes were made, primarily vacuum-related aspects, to better meet our requirements. Detailed physics calculations were performed to verify the RFQ performance under varying conditions (input emittance, input current, input energy, charge state, etc.) and the final physics design met or exceeded all our requirements. Fabrication of the cavity is completed, and the cavity is at GSI awaiting copper plating, scheduled for September, 2007. Internal components of the RFQ are being fabricated. Delivery is presently scheduled for January 2008.

Linac

Dr. U. Ratzinger of IAP Frankfurt is the world's expert on IH-Linac structures like that to be used in the EBIS preinjector, and with his experience in the fabrication of these structures, his cooperation on this project has been very important. Throughout the linac design stage, we have had a close collaboration with Dr. Ratzinger. Deepak Raparia spent one week at IAP, Frankfurt in October, 2006, in order to finalize the main aspects of the physics design of the linac. The Specification and Statement of Work for the linac were completed and the fixed-price procurement contract awarded to IAP in December, 2006, with a delivery date 21 months ARO. Since then, work has concentrated on completing the physics design and preliminary mechanical design of the linac. Careful attention was paid to the matching of the RFQ output beam in to the

IH Linac, and to obtaining the required energy spread out of the linac. An alternative MEBT design was suggested for consideration by Dr. Ratzinger (one triplet for matching, versus the two-doublet design favored by BNL). After detailed comparisons of the two designs, the original BNL design was retained. A design report for the Linac has been received from IAP, and they are now in the process of selecting a vendor to produce final drawings and then do the fabrication of the linac. Based on discussions with Ratzinger, we are now estimating that the linac delivery may be delayed until March, 2009 (6 months later than originally planned). While ways to reduce this slip are being discussed, this delay has put the linac back onto the critical path for the project.

Physics Design

Simulations have been done on a method to improve the efficiency of continuous ion injection into the EBIS trap using a “slanted” trap ion potential barrier, first using the 2-D program TRAK. The dependence of injection efficiency on the ion energy, angle of the mirror and potentials on the trap electrodes was studied. 3-D models were then made for simulations of ion injection with this slanted mirror, using the KOBRA program. Theoretical results are promising, so we have installed electrodes for a test of this idea on the Test EBIS.

Detailed beam optics design work was done on the low energy beam transport (LEBT) line.

Calculations were made on the ion extraction optics at the exit of the collector.

Design and simulations of an axially compact ion beam deflector for the collector exit were completed. Effective deflectors are essential for steering of the relatively modest injector ion beams into the EBIS; however, the deflectors must also provide a low emittance growth steering solution for large diameter, high space charge ion beams extracted from EBIS. We have investigated different types electrostatic deflecting structures for the EBIS low energy transport including parallel plate, split tubes, 8 segment and 16 segment deflecting structures which can deflect in the both x and y planes, using 3D code KOBRA. Study indicates that the 16 segment cylindrical deflector has the minimum emittance distortions. This multipole deflector is capable of arbitrary deflection angle direction perpendicular to the beam propagation axis. We have now developed the basic hardware and software to test this deflector on Test EBIS.

Using KOBRA we have simulated the electrostatic quadrupole triplet which will be used in the injection lines to EBIS. We found that emittance distortion is minimal and required voltage and focal length is as calculated by formula.

End-to-end simulations of the beam from the EBIS to the Booster, including the effect of errors, were essentially completed. In order to perform error studies in the IH linac, modification of the LORAS code is required. This is being addressed by both BNL and IAP, Frankfurt.

The effect of reducing the EBIS ion extractor aperture on the reflected electron current in the EBIS electron collector was analyzed by computer simulation of alternative geometries.

To understand how the EBIS emittance depends on mass to charge ratio, modeling of the physics of the EBIS trap is in progress. We have used the 2D code TRAC and full 3D code KOBRA. The initial particle distributions are generated in the trap such that ions at a given radius satisfy the transverse velocity due to the space charge potential of electrons and ions, and azimuthal velocity due to the solenoidal field of EBIS. We have done simulations for various degrees of neutralization of ions in the EBIS trap.

Controls

Detailed specifications for controls requirements for the project were developed, including power supply interface requirements, timing trigger signals, signal distribution, data acquisition, fiber optic infrastructure, network distribution, etc. Most procurements have been placed for the controls hardware for the EBIS. The few remaining off-the-shelf items will be procured in early FY08. Incoming inspection and first article tests have begun on electronic parts and subassemblies.

Diagnostics

Most diagnostics construction activity is funded in FY08. A prototype current transformer is currently being fabricated. Prototype circuit boards were made for the current transformer and Faraday cup amplifiers.

Improvements were made to the pepperpot emittance device, primarily in the software development. EBIS emittances can now be displayed on a pulse-to-pulse basis, and the accuracy and stability of the analysis routine has been improved.

Magnets

The major constraints on the design of the two large dipoles for the final bending of the beam in to the Booster are 1) minimize variation of the effective length for various Q/M beams (since there is an analyzing slit between the two magnets) and 2) minimize the volume of the magnet with evenly distributed field flux in the iron, including consideration of lamination stacking direction. In addition, the design needs to minimize multipoles, and the effect of including a 4" hole in the magnet core to allow the Tandem line to pass through the dipole had to be investigated. Because of the in-house expertise at C-AD on magnet design, and the challenges these constraint presented, it was decided to complete the detailed magnetic design of the large dipoles, then go out for bids on the mechanical design and fabrication of the dipoles. Detailed magnetic field calculations for the two large dipoles were finished during this period, while considering information from discussions with possible vendors on their likely fabrication techniques. The dipole specification was sent out to vendors for bids, with four vendors submitting proposals. Vendor selection is scheduled for mid-September, and magnet delivery scheduled for next spring.

Fabrication of the prototype MEBT quadrupole magnet was completed, and tests of this pulsed magnet at full field and duty factor were very successful. Following these tests, further magnetic field calculations were made, and some minor design changes are planned to make the magnet easier to fabricate, and to reduce saturation in the laminated core.

The prototype LEBT solenoid was designed, parts fabricated in the BNL shops, coils wound at BNL, and the assembled magnet tested. Performance of this laminated core magnet meets our requirements, and this solenoid will be installed on the prototype LEBT/Test EBIS, and used for beam matching into the RFQ when it is delivered. In addition, this solenoid will serve as the spare for the one on the final beamline.

Power Supplies

Power supply platform diagrams, parameter lists, and database have been developed and continually updated.

An EBIS platform 100 kV pulsing supply was designed and built, and has been operating successfully on the Test EBIS, where we now operate routinely at HV. Originally we had planned to find a commercial vendor to build the final HV pulser. However, because this supply has performed so well, the same design will be used for the RHIC EBIS pulser which will be built by BNL technicians.

Many power supply procurements either have been placed or are in process. The electron collector power supply procurement has been placed. This supply was purchased from the vendor who made a nearly identical 10 kV, 30A anode power supply for an RF system in the C-A Department. All TREK 10/10 power supplies are ordered, and the 20 kV TREK units and fast Behlke switches are in procurement. Orders have been placed for the low current HV power supplies for electrostatic lenses, etc., and the electron gun and collector solenoid supplies have been ordered.

Following the successful operation of the first 100 kV isolation transformer on the Test EBIS, a second transformer from Stangenes for the RHIC EBIS has been ordered.

RF Systems

Bids were received from five vendors for the procurement of the pulsed 350 kW RF amplifiers for the RFQ and Linac in July, 2006. Once the formal selection process was completed, the procurement had to await the availability of DOE construction funds. Fortunately, the selected vendor, Continental Electronics, extended the expiration date for the bid, and as soon as the 2007 Continuing Resolution ended in April, the procurement was placed for the amplifiers. In June, two BNL engineers went to Continental Electronics for a design review. The amplifiers are now being fabricated, with delivery scheduled for January, 2008.

Procurements for circulators, coax, power splitters, etc. have been placed.

Detailed requirements for the low level RF system are being finalized, with input coming from IAP Frankfurt on the characteristics of the RFQ, Linac, and bunchers.

Vacuum

The ~28 foot vacuum pipe that penetrates through the shield wall was fabricated and the NEG pumping strip was installed in the pipe. The chamber for the crossing of the 200 MeV H- beamline with the EBIS beamline was fabricated. Following the drilling of the beam port through the shield wall in July, 2006, the beam pipe and crossing chamber were installed in August, 2006.

All valves for the EBIS and LEBT have arrived, as well as vacuum gauging and some of the PLC vacuum controls. Orders for the turbo pumps and cryopumps required for EBIS and LEBT are in process.

Facilities

The 10 inch diameter beam port for the transport line through the shielding wall between the Linac building and the Booster tunnel was completed in early September, 2006, including installation of the beam vacuum pipe through the penetration. Radiation fault studies were carried out at this beam port penetration into the Booster. Proton beam from the 200 MeV Linac was dumped near the port location, and no radiation levels were measured outside the shield wall from this loss. This important result means that the beamline from the EBIS in to the Booster tunnel can be straight, and avoids the complication of having to add a “dog leg” in the beamline for additional radiation shielding.

New York State funding, administered by the Empire State Development Corporation, arrived in October, 2006, for the construction of the extension building on the 200 MeV Linac, which will house some of the EBIS hardware. The construction contract was awarded in November, 2006, and work started in April, 2007. The building is scheduled to be completed in September, 2007, and the Beneficial Operational Readiness Evaluation walkthrough is scheduled for mid-September, 2007. This meets our original baseline schedule date.

Procurements for long-lead items have been placed, in preparation for power distribution work to be done this fall.

Installation

The installation of the EBIS facility will start after the addition to Building 930 has been completed and the Beneficial Occupancy Readiness Evaluation is done. The floor plan for EBIS systems and equipment has evolved as the design has matured and the actual sizes of the components have become known. Away from the beam line most of these components are power supplies, transformers, and electronic racks. In the beam line the actual sizes of the RFQ and IH-Linac are now final. The plan for the installation effort has centered on placing the EBIS stand and associated support equipment (racks and vacuum components) in the final site by August 2008. This has determined the order of procurements and fabrications by the various subsystems. Most of these purchases and construction efforts are now in process.

Project Services

Following the DOE Annual review in May, 2006, actions were taken on all recommendations; and documents were updated in preparation for a DOE Independent Project Review (IPR) prior to CD2. An Independent Project Review team was assigned, and additional documentation in support of the review was uploaded to the EBIS website. Requests for additional information and documentation were made and responded to via email, and a teleconference was held between the IPR team, the EBIS Project Office, and the Federal Project Director to clarify additional items. Work on the preparation of all documents required for CD-2 and CD-3 continued, and the Federal Project Director presented the status of the EBIS project to the ESAAB-equivalent board on September 29th. Dennis Kovar signed off on the Approval Letter granting both Critical Decision 2 and Critical Decision 3 for the Project.

The Continuing Resolution delayed the start of all DOE-funded project construction. In April $5.0M of the $7.4M in FY07 Construction funds were received. The funding reduction and delay has impacted both cost and schedule. A Project Change Request to change the CD-4 date from 2nd to 4th qtr FY10 was approved. A PCR reassigning the funding source for some equipment (DOE-NASA) plus $140 k contingency to cover the LOE for the additional months has been approved.

An EBIS Status Review was held at the DOE Site Office in June, 2007.

The EBIS Project continued to have quarterly teleconference reports with DOE, monthly teleconference reports with the Federal Program Manager Jehanne Simon-Gillo, bi-weekly progress meetings with Collider-Accelerator Department management and the Federal Project Director Mike Butler, bi-weekly meetings with subsystem managers and other key project personnel, as well as various weekly meetings at the group level.

Safety

The design of the superconducting solenoid was reviewed by the Cryogenic Safety Review Committee. Representatives from ACCEL, who is fabricating the magnet, participated in the review.

A Radiation Safety Committee review of EBIS beamline was held, addressing issues related to the linac building addition which will house some of the EBIS equipment, and estimates of radiation levels coming through the beam port under various Booster and H- Linac fault conditions. The early completion of the beam port allowed radiation fault studies to be carried out at an early stage. Beam port fault studies were evaluated by the Radiation Safety Committee (no dog leg will be required).

An Accelerator Systems Safety Review Committee meeting was held where an overview of the ESS&H issues of the EBIS project was presented. There will be a series of meetings addressing subsystems at the appropriate times. Also held were safety reviews of emergency egress from Booster after installation of the new dipoles, the high voltage pulser prior to start of construction of the unit, the Test EBIS prior to operation at high voltage, and an ES&H review of the beam port construction.

Publications and Presentations at Conferences

2006 Linear Accelerator Conference, Knoxville, TN, August 21-25, 2006:

- "***Status of the BNL EBIS Project at Brookhaven***", J. Alessi, D. Barton, E. Beebe, S. Bellavia, O. Gould, A. Kponou, R. Lambiase, E. Lessard, R.Lockey, V. LoDestro, M. Mapes, D. McCafferty, T. Nehring, A. Pendzick, A. Pikin, D. Raparia, J.Ritter, J. Scaduto, L. Snydstrup, C. Theisen, M. Wilinski, A. Zaltsman,

2007 Particle Accelerator Conference, in Albuquerque, NM

- "***High Performance EBIS for RHIC***" (invited talk), J. Alessi, E. Beebe, O. Gould, A. Kponou, R. Lockey, A. Pikin, D. Raparia, J. Ritter, L. Snydstrup,
- "***Design and Performance of the Matching Beamline Between the BNL EBIS and an RFQ***", J. Alessi, E.Beebe, J.Brodowski, A.Kponou, M.Okamura, A.Pikin, D.Raparia, J.Ritter, L.Snydstrup, V.Zajic,
- "***End-to-End Simulation for the EBIS Preinjector***", D. Raparia, J.Alessi, A.Kponou, A.Pikin, J.Ritter, BNL, and S.Minaev, U.Ratzinger, A.Schempp, R.Tiede, IAP. University of Frankfurt/Main.
- "***RFQ and IH Accelerators for the new EBIS Injector at BNL***", A. Schempp, U. Ratzinger, R. Tiede, C. Zhang; IAP, Univ. Frankfurt; J. Alessi, D. Raparia, L. Snydstrup; BNL.
- "***Design Study of the Dipole Magnet for the RHIC EBIS High Energy Transport Line***" Takeshi Kanesue, Kyushu University; Deepak Raparia, John Ritter, Masahiro Okamura, BNL; Jun Tamura, Tokyo Institute of Technology.

X International Symposium on the Physics and Applications of Electron Beam Ion Sources and Traps (EBIS/T 2007), Heidelberg, Germany, August 1-4, 2007:

- "***Model Simulations of Ion Injection into EBIS Trap with Slanted Electrostatic Mirror***", A.Pikin, A.Kponou, J.G.Alessi, E.N.Beebe, K.Prelec, D.Raparia.
- "***A Summary of Results Obtained on the BNL Test EBIS***", E.Beebe, J.Alessi, O.Gould, A.Kponou, R.Lockey, R.Lambiase, A.Pikin, K.Prelec, D.Raparia, J.Ritter, L.Snydstrup, V.Zajic.

12th International Conference on Ion Sources, Jeju, Korea, August 26-31, 2007:

- "***Status of the New BNL EBIS for RHIC***", <u>J.G. Alessi</u>, E. Beebe, S. Bellavia, O. Gould, A. Kponou, R. Lambiase, R. Lockey, A. Pikin, J. Ritter, L. Snydstrup.
- "***BNL Test EBIS Operation on a 100 kV Platform***", E.N. Beebe, J.G. Alessi, O. Gould, A. Kponou, R. Lockey, R. Lambiase, A. Pikin, K. Prelec, J. Ritter, and V. Zajic
- "***Development of Ion Injection into the BNL Test EBIS using a Prototype LEBT Switchyard and a Hollow Cathode Ion Source***", E.N.Beebe, J.G.Alessi, A.Kponou, C.Meitzler, A.Pikin, K.Prelec, D.Raparia, J.Ritter, V.Zajic.
- "***Model Simulations of Continuous Ion Injection into EBIS Trap with Slanted Electrostatic Mirror***", A.Pikin, A.Kponou, J.G.Alessi, E.N.Beebe, K.Prelec, D.Raparia.
- "***LIS for Primary Ion Injection Into EBIS***", Takeshi Kanesue (Kyushu Univ., Japan), Jun Tamura (Tokyo Institute of Technology, Japan), Masahiro Okamura (Brookhaven National Laboratory,USA).

III. Review of Project Milestone Status and Overall Project Schedule

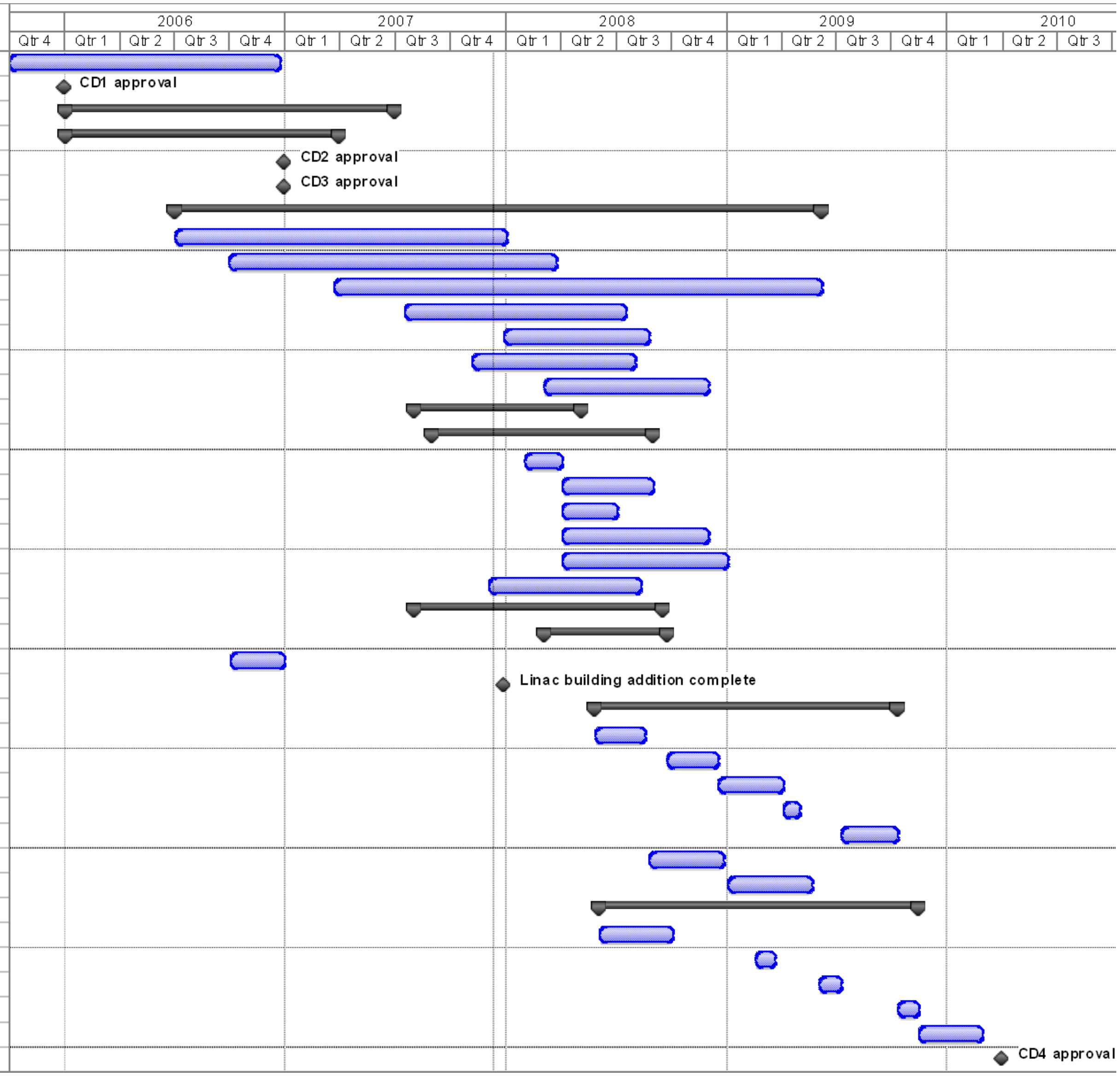
Milestones achieved during reporting period	Baseline	Actual
L0 - CD-2 – Approve Performance Baseline	4QFY06	9/06
L0 - CD-3 – Start of Construction	1QFY07	9/06
L1 - RFQ Procurement placed (NASA funded)	4QFY06	6/06
L1 - Beam Port Complete	4QFY07	9/06
L1 - Linac Procurement Placed	2QFY07	12/06
L2 - R&D High Voltage Beam Tests Begin	3QFY07	12/06

Project Milestones:

Project Milestones Level 0	Baseline	Actual Dates + PCR changes
Critical Decision 0 (CD-0)	Q4,04	Q4,04 (A)
Critical Decision 1 (CD-1)	Q4,05	Q4,05 (A)
Critical Decision 2 (CD-2)	Q4,06	Q4,06 (A)
Critical Decision 3 (CD-3)	Q1, 07	Q4,06 (A)
Critical Decision 4 (CD-4)	Q2,10	Q4,10
Project Milestones Level 1		
RFQ procurement placed	Q4, 06	Q3,06 (A)
Linac Procurement placed	Q2, 07	Q1,07 (A)
Beam port complete	Q4, 07	Q4,06 (A)
SC solenoid factory/acceptance test	Q1, 08	Q1,08
Building addition approved for occupancy	Q3, 08	Q3,08
EBIS Safety Assessment Document complete	Q4, 08	Q4,08
CASE for EBIS approved by DOE	Q4, 08	Q2,09
BHSO letter approving commissioning	Q3, 09	Q4,09
Beam out of EBIS	Q3, 09	Q1,10
HEBT dipole installation complete	Q4, 09	Q4,09
Beam out of RFQ	Q4, 09	Q2,10
Beam out of linac	Q1, 10	Q2,10
Beam through HEBT	Q2. 10	Q3,10
Project Milestones Level 2		
R&D EBIS installed on HV platform	Q1, 06 (A)	Q1,06 (A)
Electron collector procurement placed	Q1, 06(A)	Q1,06 (A)
Superconducting solenoid procurement placed	Q2, 06 (A)	Q2,06 (A)
R&D High Voltage beam tests begin	Q3, 07	Q1,07 (A)
Electron collector pressure/vacuum tested	Q1, 08	Q1,08
EBIS Drift tube structure complete	Q3, 08	Q4,08
EBIS preassembly complete	Q4, 08	Q1,09
Electron collector ps acceptance tested	Q2, 09	Q2,09
ARR review team for EBIS appointed	Q2, 09	Q2,09
RF amplifiers acceptance tested	Q2, 09	Q3,09
Accelerator Readiness Review	Q3, 09	Q4,09
EBIS installation complete	Q3, 09	Q4,09
RFQ tested to full power	Q3, 09	Q3,09
RFQ installation complete	Q4, 09	Q1,10
Linac tested to full power	Q1, 10	Q1,10
Linac installation complete	Q1, 10	Q2,10
HEBT beamline installation complete	Q1, 10	Q2,10
HEBT dipole ps acceptance tested	Q1, 10	Q1,10

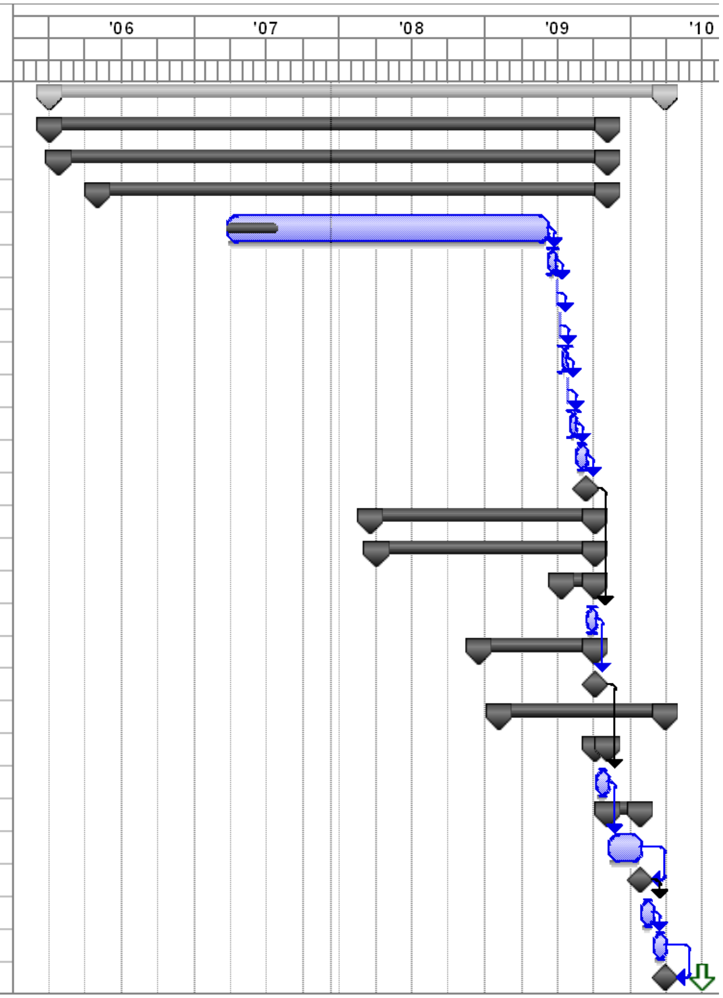
Current high level schedule:

ID	Task Name	Start	Finish
1	**R&D**	7/1/05	9/21/06
2	**CD1 approval**	9/30/05	9/30/05
3	**Engineering & Design**	**10/3/05**	**3/30/07**
9	**Specifications**	**10/3/05**	**12/29/06**
14	**CD2 approval**	9/29/06	9/29/06
15	**CD3 approval**	9/29/06	9/29/06
16	**Procurement**	**3/31/06**	**3/4/09**
17	Superconducting solenoid	3/31/06	10/1/07
18	RFQ	6/29/06	12/21/07
19	Linac, Bunchers	12/20/06	3/4/09
20	RF amplifiers	4/16/07	4/14/08
21	HEBT Dipole magnet	9/28/07	5/25/08
22	Electron collector ps	8/6/07	4/30/08
23	HEBT Dipole ps	12/3/07	8/29/08
24	**Other EBIS procurements**	**5/1/07**	**1/31/08**
28	**LEBT procurements**	**6/1/07**	**5/30/08**
31	RFQ vacuum	11/1/07	12/31/07
32	Controls (excluding EBIS)	1/1/08	5/30/08
33	Vacuum (MEBT-to-HEBT)	1/1/08	3/31/08
34	Power supplies (MEBT-HEBT)	1/1/08	8/29/08
35	Diagnostics	1/1/08	9/30/08
36	RF coax, LLRF, circulators	9/3/07	5/9/08
37	**Manufacturing**	**5/1/07**	**6/16/08**
45	**Pre-assembly**	**12/3/07**	**6/23/08**
48	Beam access port	7/1/06	9/29/06
49	Linac building addition complete	9/28/07	9/28/07
50	**Installation**	**2/25/08**	**7/8/09**
51	EBIS, platform	2/25/08	5/16/08
52	LEBT	6/24/08	9/15/08
53	RFQ	9/16/08	12/30/08
54	MEBT	12/31/08	1/27/09
55	Linac	4/6/09	7/8/09
56	HEBT (Booster side)	5/25/08	9/25/08
57	HEBT (Linac side)	10/1/08	2/17/09
58	**Beam Testing**	**3/3/08**	**8/11/09**
59	RFQ with Test EBIS	3/3/08	6/30/08
60	RHIC EBIS / LEBT	11/17/08	12/18/08
61	EBIS & RFQ	3/2/09	4/6/09
62	EBIS/RFQ/Linac	7/9/09	8/11/09
63	**Commissioning (final)**	8/12/09	11/25/09
64	**CD4 approval**	12/29/09	12/29/09



Current Critical Path:

ID	WBS	Task Name	Start	Finish
0	**1.**	**Project Summary**	**10/3/05**	**12/29/09**
1	**1.1**	**Structural Components**	**10/3/05**	**8/3/09**
146	**1.1.8**	**RF Structures**	**10/24/05**	**8/3/09**
165	**1.1.8.2**	**Linac**	**2/1/06**	**8/3/09**
169	1.1.8.2.4	Linac Procurement 14397	12/20/06	3/4/09
177	1.1.8.2.12	Linac Shipping to BNL 14397	3/4/09	3/25/09
178	1.1.8.2.13	Linac Incoming Inspection 14397	3/25/09	4/1/09
183	1.1.8.2.18	Linac Mount on Stand 71175	4/1/09	4/8/09
184	1.1.8.2.19	Linac Assist Vacuum and Leak Checking 7117	4/8/09	4/22/09
185	1.1.8.2.20	Linac Assist Water Connections 71175	4/22/09	4/29/09
186	1.1.8.2.21	Linac Assist RF Hookup 71175	4/29/09	5/13/09
187	1.1.8.2.22	Linac Low/High Power Tests 71175	5/13/09	6/11/09
188	1.1.8.2.23	Linac Ready for Beam 71175	6/11/09	6/11/09
775	**1.10**	**EBIS Installation E**	**12/19/07**	**7/6/09**
777	**1.10.2**	**Structural components**	**1/2/08**	**7/6/09**
791	**1.10.2.5**	**LINAC**	**4/8/09**	**7/6/09**
793	1.10.2.5.2	Linac Mech Install 71275	6/11/09	7/6/09
965	**1.10.11**	**Installation Completion Milestones**	**9/16/08**	**7/6/09**
969	1.10.11.4	LINAC Install Complete	7/6/09	7/6/09
1050	**1.12**	**Commissioning**	**11/6/08**	**12/29/09**
1059	**1.12.3**	**Linac**	**7/6/09**	**8/3/09**
1060	1.12.3.1	Linac Test with Beam	7/6/09	8/3/09
1062	**1.12.4**	**HEBT**	**8/3/09**	**10/27/09**
1063	1.12.4.1	HEBT Test with Beam	8/3/09	10/27/09
1065	1.12.4.3	HEBT Test with Beam Complete	10/27/09	10/27/09
1066	1.12.5	Performance Validation & Document Development	10/27/09	11/25/09
1067	1.12.6	CD4 Presentation & Approval	11/25/09	12/29/09
1068	1.12.7	CD4 Complete	12/29/09	12/29/09



IV. Review of Project Cost Status

Present funding profile:

Total Funding

	FY 05	FY 06	FY 07	FY 08	Total
R&D	0.5	0.7	-	-	1.2
CDR	0.2	-	-	-	0.2
PED/EDIA	-	1.98	0.12	-	2.1
Cons	0.5	2.4	6.0	6.6	15.5
Pre-Ops	-	-	-	0.3	0.3
TEC	0.5	4.38	6.12	6.6	17.6
TPC	1.2	5.08	6.12	6.9	19.3

DOE Funding

	FY 05	FY 06	FY 07	FY 08	Total
R&D	0.5	0.1			0.6
CDR	0.2				0.2
PED/EDIA		1.98	0.12		2.1
Cons			5.0	6.6	11.6
Pre-Ops				0.3	0.3
TEC		1.98	5.12	6.6	13.7
TPC	0.7	2.08	5.12	6.9	14.8

NASA Funding

	FY 05	FY 06	FY 07	FY 08	Total
R&D		0.6			0.6
CDR					-
PED/EDIA					-
Cons	0.5	2.4	1.0		3.9
Pre-Ops					-
TEC	0.5	2.4	1.0	-	3.9
TPC	0.5	3.0	1.0	-	4.5

Contingency used to date:

			Burdened K$
Contingency from 9/06 Baseline			3000
PCR number	**Date Approved**	**Title**	
PCR-EB-07-002	Jan-07	HV Platform + power for Test EBIS	(100)
PCR-EB-07-003	Jun-07	Impact of Continuing Resolution	(140)
PCR-EB-07-004	May-07	Linac vendor price exceeds baseline estimate	(324)
PCR-EB-07-005	May-07	RF Amps vendor price exceeds baseline estimate	(157)
PCR-EB-07-006	Jul-07	Change in CD-4 Date	0
PCR-EB-07-007	a/w FPD approval	Use of NASA R&D Contingency	(100)
PCR-EB-07-008	a/w FPD, FPM approvals	Milestone change due to CD-4 date change	0
Contingency Allocated by PCR			(821)
Remaining Contingency			2179

Risk list:

	WBS	Description	Type of Risk	Consequence	Likeli-hood	Cost Impact (burdened $K)	Risk Expiration
High Risk	1.0	Delays in DOE Project Funding	Cost/Schedule	Level 1	V	TBD	FY08
	1.1	Solenoid needs rework to meet performance specification	Schedule	Level 1	L	---	1QFY08
	1.1	Manufacturing of Electron Collector	Cost/Schedule	Level 2	V	70K-85K	1QFY08
	1.5	Power Supply scope/vendor pricing exceeds baseline	Cost	Level 2	V	280K-320K	2QFY08
Medium Risk	1.1	Delay in Linac delivery	Schedule	Level 1	U	---	3QFY09
	1.4	Dipole magnet vendor price exceeds baseline	Cost	Level 3	V	125K	4QFY07
Low Risk	1.1	Delay in RFQ delivery	Schedule	Level 3	U	---	2QFY08
	1.6	RF Systems - added scope - splitter, cable	Cost	Level 3	L	50K	4QFY07

Possible Risk Mitigation:

	WBS	Description	Mitigation Plan
High Risk	1.0	Delays in DOE Project Funding	Avoid procurements in 1st qtr, work closely with DOE,procurement.
	1.1	Solenoid needs rework to meet performance specification	Change assy sequence for the EBIS to minimize schedule impact
	1.1	Manufacturing of Electron Collector	Start parallel effort with alternate material
	1.5	Power Supply scope/vendor pricing exceeds baseline	Contingency will be used on this item
Medium Risk	1.1	Delay in Linac delivery	Vendor history, frequent communication, vendor visits.
	1.4	Dipole magnet vendor price exceeds baseline	Contingency will be used on this item
Low Risk	1.1	Delay in RFQ delivery	Vendor history, frequent communication, visits
	1.6	RF Systems - added scope - splitter, cable	Contingency will be used on this item

Costs and Commitments to date:

EBIS Project		Burdened k$					
WBS	Title	FY07 to date	Project to date (PTD) costs*	Commit-ments		Budget at Comple-tion	
1.1	Structural components	267	1066	1540		3533	
1.2	Controls	107	148	307		776	
1.3	Diagnostics/instrumentation	79	177	2		677	
1.4	Magnet Systems	0	46	261		658	
1.5	Power Supply Systems	60	222	673		2031	
1.6	RF Systems	1213	1296	680		2970	
1.7	Vacuum systems	167	392	207		1502	
1.8	Cooling Systems	3	23	0		251	
1.9	Facility Modifications	47	214	23		541	
1.10	Installation	0	0	0		1429	
1.11	Project Services	192	463	51		1175	
1.12	Commissioning	0	0	0		177	
1.13	R&D/CDR	125	1268	101		1400	
	Contingency					2179	
	Total	2260	5315	3845		19300	
* costs through August 2007							