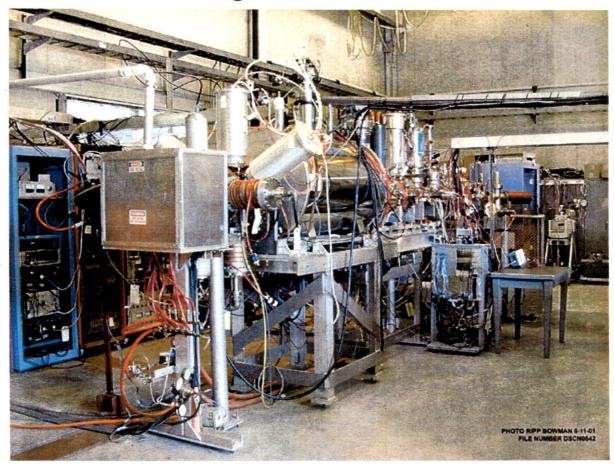


EBIS Pre-CD1 Technical, Cost, Schedule, and Management Review







Department of Energy Review of the Electron Beam Ion Source Project (EBIS)

Brookhaven National Laboratory Brookhaven Center South Room

July 25 – 27, 2005

AGENDA

Monda	ıy, July 25, 2005
10:00	Executive Session - Charge
10:30	Welcome/Introduction
10:45	Project Overview
11:45	Technical Design, Feasibility (EBIS) E. Beebe
12:30	Lunch
13:30	Cost/Schedule/Manpower
14:30	Break
15:00	ESSHE. Lessard
15:15	Management J. Alessi
16:00	Executive Session
18:00	Homework Assignments
19:00	Dinner
Tuesd	ay, July 26, 2005
08:30	Executive Session - Charge
09:00	Assignment Reports
09: 30	Tour and Break
10:45	Accelerator and Transport
11:30	1.1 Structural Components - EBIS, LEBT, External Sources
12:00	1.1 Structural Components – RFQ, Linac, Bunchers
12.15	Lunch

13:15	1.4 Magnet Systems
13:30	1.5 Power Supplies
14:00	1.6 RF Systems
14:15	1.2 Controls
14:30	1.3 Diagnostic Systems
14:45	Break
15:15	1.7 Vacuum Systems
15:30	1.8 Cooling System
15:45	1.9 Facility Modifications
16:00	1.10 Installation and CommissioningL. Snydstrup
16:30	Executive Session
18:00	Homework Assignments
Wedn	esday, July 27, 2005
08:30	Assignment Reports
09:30	Report Writing
14:00	Closeout
14:30	Adjourn

7/21/05 2



Department of Energy

Washington, DC 20585

June 10, 2005

Dr. James Alessi Brookhaven National Laboratory Building 510F Upton, NY 11973

Dear Dr. Alessi:

The Office of Nuclear Physics Facility and Projects Management Division is organizing a Technical, Cost, Schedule, and Management Review of the proposed Electron Beam Ion Source (EBIS) Pre-injector for the Relativistic Heavy Ion Collider (RHIC). As you are aware, this review will take place at Brookhaven National Laboratory on July 25-27, 2005. This review is being organized with input and participation from the DOE Office of Project Assessment.

The purpose of this review is to assess all aspects of the project's conceptual design and associated plans -- technical, cost, schedule, management, and ES&H. The following main topics will be considered at the review:

- a. The significance and merit of this proposed accelerator improvement project;
- b. The status of the technical design, including completeness of technical design and scope, feasibility and merit of technical approach;
- c. The feasibility and completeness of the proposed budget and schedule, including availability of manpower;
- d. The effectiveness of the proposed management structure;
- e. Other issues relating to the EBIS Pre-injector.

In addition to the above, the committee will be asked to evaluate drafts of project documentation that will be considered for Critical Decision 1 (CD-1, Approve Alternative Selection and Cost Range), e.g., Conceptual Design Report, Preliminary Project Execution Plan, Preliminary Hazard Analysis Report, and Preliminary Risk Assessment Report.

The first day will consist of presentations by the laboratory and executive sessions. The second day will include presentations and break-out sessions. The third day will be used for an executive session and preliminary report writing; a brief close-out will end at 2:00 PM. Preliminary findings, comments and recommendations will be presented at the close-out.

The contact within this office for the review is Dr. Blaine Norum at (301) 903-4398, or E-mail: Blaine.Norum@science.doe.gov. The panel members have been instructed to contact Sandy Asselta at BNL at (631)-344-4550 or E-mail: sandylee@bnl.gov regarding any logistics questions. Word processing and secretarial assistance should be made available during the review.

I greatly appreciate your efforts in preparing for this review. It is an important process that allows our office to understand the project and serves as a Readiness Assessment for CD-1 approval. I look forward to a very informative and stimulating visit.

Sincerely,

Jehanne Simon-Gillo Acting Division Director Facility and Project Management Division

Office of Nuclear Physics

cc:

Gene Henry, DOE
Steve Tkaczyk, DOE
Mike Butler, BNL Site Office
Derek Lowenstein, BNL
Sam Aronson, BNL
Frank Sulzman, NASA



EBIS Project Overview

Jim Alessi

July 25-27, 2005





July 25-27, 2005

Outline of Talk



- Review Agenda
- · Scientific/Technical Motivation
- Project History
- Project Performance Objectives
- General layout
- WBS
- Costs & funding
- Schedule
- Deliverables
- Summary





Agenda (day 1)







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Agenda (day 2 & 3)



				ELECTRON BEAM ION
Tuesd	ay, July 26, 2005			
08:30	Executive Session		Wadn	anday Tuly 27 2005
09:00	Assignment Reports		wean	esday, July 27, 2005
09:30	Tour and Break		08:30	Assignment Reports
10:45	Accelerator and Transport		09:30	Report Writing
11:30	1.1 Structural Components – EBIS, LEBT, external sources	. 6	14:00	Closeout
12:00	1.1 Structural Components - RFQ, Linac, Bunchers		14.20	A diagram
12:15	Lunch		14:50	Adjourn
13:15	1.4 Magnet Systems			
13:30	1.5 Power Supplies			
14:00	1.6 RF System			
14:15	1.2 ControlsD. Barton			
14:30	1.3 Diagnostics System			
14:45	Break			
15:15	1.7 Vacuum System			
	1.8 Cooling System	٠.		
	1.9 Facility Modifications			
16:00	1.10 Installation and CommissioningL. Snydstrup			
16:30	Executive Session			
18:00	Homework Assignments	. 4	. •	





Overview



Presently, one or two ~35-year old Tandem Van de Graaff accelerators are used for RHIC pre-injection, but the recent advances in the state of the art in EBIS performance by more than an order of magnitude now make it possible to meet RHIC requirements with a modern linac-based preinjector.

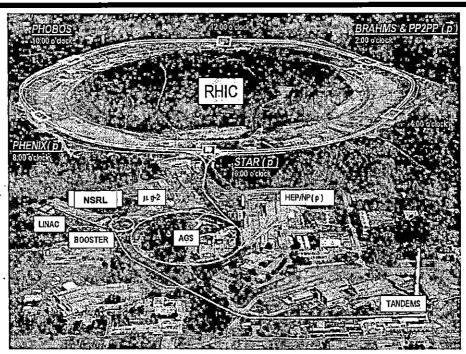
BNL now has DOE CD0 approval for new pre-injector for RHIC based on the Laboratory's development of an advanced Electron Beam Ion Source (EBIS).

The new preinjector would consist of an EBIS high charge state ion source, a Radio Frequency Quadrupole (RFQ) accelerator, and a short linac.



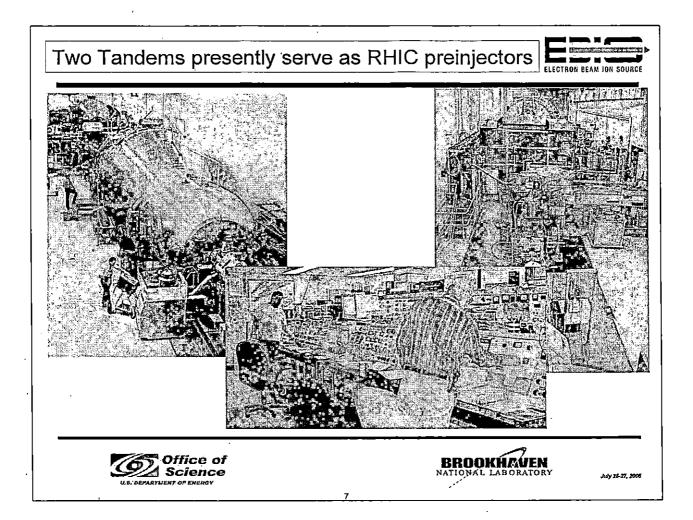


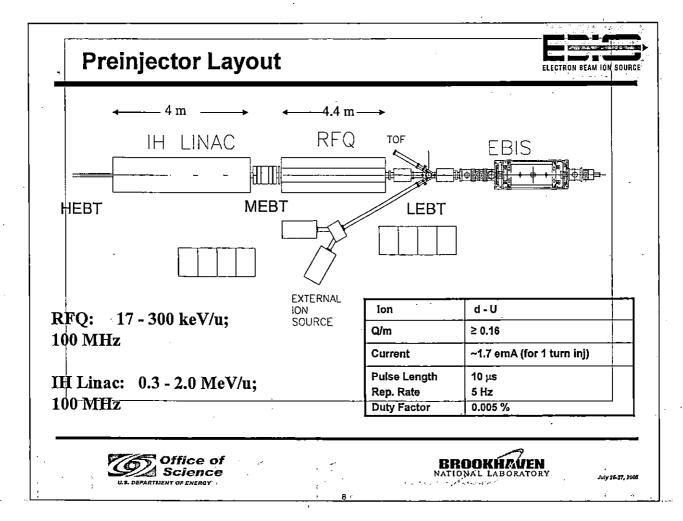












Scientific/Technical Motivation



- Replacement of the two Tandems as the Booster preinjector, resulting in more stable beam intensities
- •Eliminating the need to use the 860-meter long transport line from Tandem to Booster, using instead a much simpler and economic 30-meter long line from EBIS, which will reduce setup time and allow fast switching between beams of different rigidities.
- •Simplification of Booster injection scheme (few turn vs. present 40 turn).
- •Capability to provide ions not presently available for the NASA program, such as noble gas ions (major components of galactic cosmic rays), as well as more massive ions such as uranium, and with additional enhancements, polarized ³He, for the RHIC program.





July 25,77, 3006

Scientific/Technical Motivation (2)



- •Increased flexibility to handle the multiple simultaneous needs of RHIC, NSRL and AGS. Two Tandems are needed for fast beam switching, while the EBIS preinjector will be designed to switch between species in 1 second.
- •Improvements in reliability, setup time and stability should lead to increased integrated luminosity in RHIC and increased productivity for NSRL.
- •Reduced operating costs. The Tandem facility requires a staff of approximately 12 FTEs to support maintenance and a 24-hour shift rotation during operations. The Linac-based pre-injector should be able to run unattended at most times, as with the present proton Linac, and will require only a staff of approximately 3 FTEs.
- •If the new EBIS preinjector is not built, ~9 M\$ in reliability-driven investments in the Tandems will be required.





Project history



- DOE 2003 RHIC Facility review:
 - "The replacement of the Tandems by an EBIS source has merit and the DOE and BNL are encouraged to implement this."
- BNL 2004 Machine Advisory Committee:
 - "The committee strongly recommends launching the project as soon as possible to replace the present Tandem facility by an EBIS source followed by the RFQ and 2 MeV/u LINAC."
- August, 2004: CD0 Approval Mission need
- External technical design review January, 2005.
 - "From the technical point of view the realization of this project is very promising and shows very little risk".
- Internal cost review February, 2005.
- June, 2005 SOW between BNL and NASA contributing 4.5 M\$ to the EBIS project.
- Pre-baseline cost range is 15.6 M\$ 19.3 M\$ (TPC, AY\$).
- Presently 3 year construction, with some NASA-funded long-lead procurements in FY'05, FY'06.

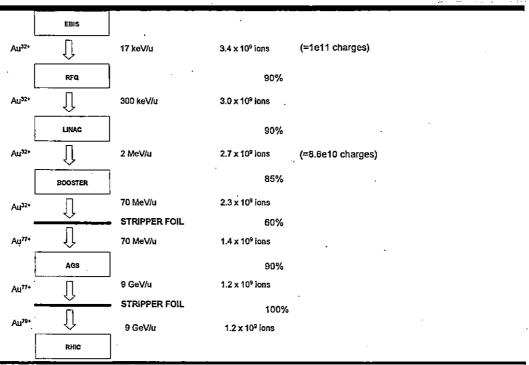




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Example, Au injection









Beams at Booster input



Species	User	Q	Ions/pulse	Charges/pulse
Au	RHIC	32+	2.7×10^9	8.6×10^9
d	RHIC	1+	2.5×10^{11}	2.5×10^{11}
Cu	RHIC	11+	1.0×10^{10}	1.1×10^{11}
C	NSRL	5+	2×10^{10}	1×10^{11}
0	NSRL	8+	6.7×10^9	5.3×10^{10}
Si	NSRL	13+	5×10^9	6.5×10^{10}
Ti	NSRL	18+	1.3×10^9	2.4×10^{10}
Fe	NSRL	20+	1.7×10^9	3.4×10^{10}

These intensities, with the expected 85% efficiency from Booster input to extraction (1-4 turn), will match past runs.





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REQUIREMENTS



It is desirable for the preinjector to be able to switch both species and transport line rigidity in ~1 second, so that there are no restrictions on compatibility between RHIC and NSRL operations.

For example:

Requirement for RHIC : 1.7 emA of Au $^{32+}$, 10 μ s; 5 Hz

plus....NSRL – a second species, 1 second later: He²⁺, C⁵⁺, O⁸⁺, Si¹³⁺, Ti¹⁸⁺, Fe²⁰⁺, Cu²²⁺, at ~2-3 emA, ~ 10 µs

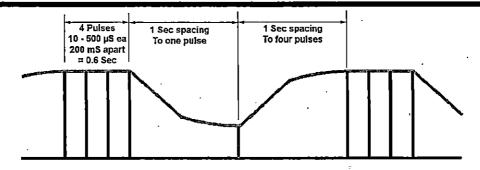
- short pulses
- fast beam changes
- · any species





Species switching requirement





The present control system supports "pulse-to-pulse modulation" The setpoint of any device can be changed pulse-to-pulse, depending on the "user".

So, within 1 second:

the source (EBIS) has to change species, the RFQ and linac have to change gradient (amplitude) transport line elements have to switch to new values





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Source Options - ECR



ECR

Features, advantages

~ the only choice for high current, high Q, dc applications

Reliable; lots of operating ECRs, lots of experience

Technologies

SC magnets; At high freq's, need SC sol and SC hexapole
28 GHz VENUS - 4 T injection field, 2 T hexapole at plasma chamber
RF power source - 28 GHz gyrotron, 10-15 kW; plus sometimes multiple
frequencies

Questions, issues?

Broad charge state distribution, so one has to extract & transport a high total current Performance depends on species, favoring gases and low melting point solids "Memory" effects, slow beam switching times at maximum intensities





Source Options – Laser Ion Source



LIS

Features, advantages

Produces high currents, short pulses

Technologies

High power laser – 100 J, CO_2 , 15-30 ns Optics

Targets – 3 x 10¹³ W/cm² on the target

Questions, issues?

Laser reliability, rep rate

Pulse-to-pulse current fluctuations

Target erosion; coating of optics by target material

Species ~ limited to solid targets; high melting point solids are best





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Advantages of an EBIS (vs. ECR, LIS)



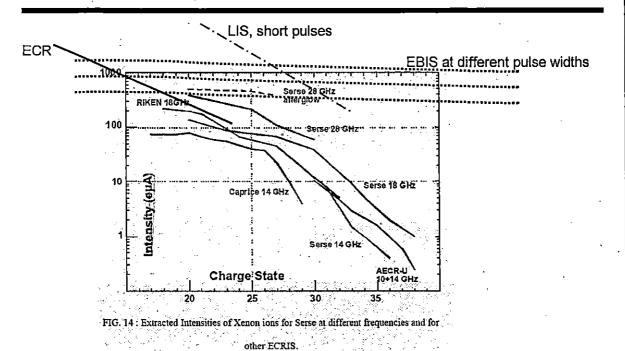
- An EBIS can produce <u>any</u> type ions from gas, metals, etc., and is easy to switch species (pulse-to-pulse!)
- One has control over the charge state produced (easy to get intermediate charge states, such as Au³²⁺ or U⁴⁵⁺)
- One has control over pulse width, extracting a fixed charge can better match to synchrotron requirements
- EBIS produces a narrow charge state distribution (≥ 20% in the desired charge state), so there is less of a space charge problem in the extraction and transport of the total current
- The scaling laws are understood
- The source is reliable, and has excellent pulse-to-pulse stability, long life





Qualitative comparison





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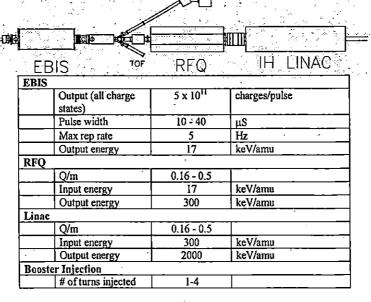


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High-level parameters





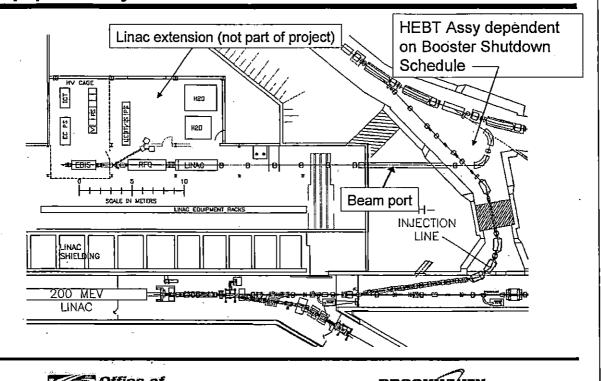
EXTERNAL ION SOURCE





Placement of EBIS Pre-Injector in lower equipment bay of 200 MeV Linac





WBS Description



1.1 Structural Components

Science

- Source components, and accelerators; the EBIS hardware, RFQ, Linac, and bunchers
- 1.2 Control Systems
 - All controls for the project. Networked, front-end interfaces will be connected via Ethernet to control console workstations and central C-AD servers.
- 1.3 Diagnostics
 - Faraday cups, current transformers, and profile monitors in LEBT, MEBT, and HEBT
- 1.4 Magnet Systems
 - EBIS warm solenoids, HEBT dipoles, MEBT and HEBT quads
- 1.5 Power supplies
 - All power supplies for the EBIS, external ion sources, and transport lines.
- 1.6 RF Systems
 - High and low level rf systems for operation of the RFQ, Linac, and bunchers





WBS Descriptions (cont.)



1.7 Vacuum Systems

Vacuum components for EBIS, external ion sources, all transport lines, and accelerators.
 Excludes specialized vacuum chambers on EBIS and LEBT, which are in Structural Components.

1.8 Cooling Systems

 All cooling water systems for EBIS, RFQ, Linac, transport line magnets, and power supplies.

1.9 Facility Modifications

 Relocation of existing power to disconnect switches and then all equipment, plus a port allowing the HEBT line to pass through earth shielding between the Linac and Booster.

1.10 Installation

 Installation in the final location of all structural components, control systems, diagnostic and instrumentation systems, magnets, power supplies, RF systems, vacuum systems, and cooling systems.

1.11 Project Services

 Level of effort tasks associated with the daily management, oversight, and statusing of the project.





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Preliminary Cost Estimate



WBS		Description	AY K\$
%%% \.1.1	Structural	Components:	3,275
	1.1.1	EBIS Hardware	1,300
	1.1.2	LEBT and External ion injection	500
		RF Structures	1,475
港等等1.2	Controls S	ystems	600
1.3	Diagnostic	s/Instrumentation	675
	Magnet Sy		∞ ≪≪600
% % 31.5	Power Sup	ply Systems	251.975
1.6	RF System	St. Andrew Co. Co.	××× 2,325
2222 1.7	Vacuum Sy	ystems	1,450
32 33 1.8	Cooling Sy	rstems	. 300
21.9	Facility Mo	difications	%%% 700
201.10	Installation		1,900
	1.10.1	Structural Components	400
	1.10.2	Control Systems	50
	1.10.3	Diagnostics/Instrumentation	200
	1.10.4	Magnet Systems	25
	1.10.5	Power Supply Systems	500
	1.10.6	RF-Systems	25
	1.10.7	Vacuum Systems	300
	1.10.8	Cooling Systems	400
38 1.11	Project Se	rvices	625
1.12	Commission	oning	
		currently included in above WBSs	
388681.13	R&D	A VICTOR OF THE STATE OF THE ST	1,200
		Conceptual Design Report	200
		Development	1,000
99.7803 MM	28550000000	Subtotal EBIS MIE	15,625
		Contingency	3,675
\$28.43.382	18000	Estimated Total Project Cost	19,300





Preliminary Cost Estimate



		Burdened, AY\$				
WBS		Mat'l	Labor	Cont \$	Total	
1.1	Structural component	2015	1260	890	4165	
1.2	Controls	435	165	135	735	
1.3	Diagnostics	380	295	135	810	
1.4	Magnets	350	250	130	730	
1.5	PS's	1665	310	500	2475	
1.6	RF systems	1670	655	630	2955	
1.7	Vacuum	940	510	290	1740	
1.8	Cooling	240	- 60	60	360	
1.9	Facility mods	475	225	180	880	
1.10	Installation	180	1720	400	2300	
1.11	Project Services	0	625	125	750	
•	R&D	415	585	200	1200	
	CDR		200		200	
	· Totals:	8765	6860	3675	19300	





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DOE and **NASA** funding profiles



. Total (19.3 M\$)	R&D CDR PED/EDIA Cons Pre-Ops TEC TPC	PY 05 0.5 0.2 0.5 0.5	FY 06 0.7 2.0 0.4 2.4 3.1	0.5 0.5 6.0 8.5 6.5	FY 08 8.2 0.3 8.2 8.5	1.2 0.2 2.5 15.1 0.3 17.6 19.3
DOE Contribution (14.8 M\$)	R&D CDR PED/EDIA Cons Pre-Ops TEC TPC	FY 05 0.5 0.2	. FY 06 0.1 - 2.0 - 2.0 2.1	0.5 4.5 5.0 5.0	6.7 7.0	70tal 0.6 0.2 2.5 11.2 0.3 13.7 14.8
NASA Contribution (4.5 M\$)	R&D CDR PED/EDIA Cons Pre-Ops TEC TPC	5Y 05 0.5 0.5	0.4 0.4	1.5 1.5 1.5	FY 08 1.5 1.5	Total 0.6 - - 3.9 - 3.9 4.5





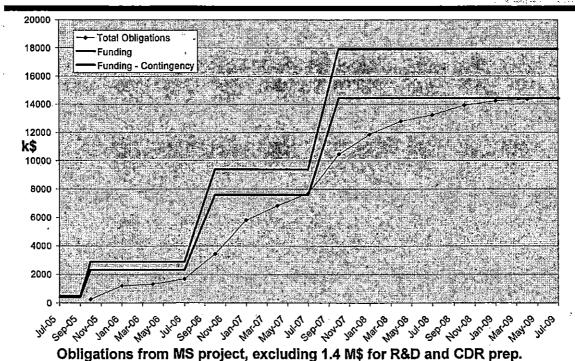




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Funding/Obligation Profile (preliminary)





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Critical Path (preliminary)



The procurement and delivery of the structural components drive installation and testing. Phased funding to the vendors will be needed.

Major procurements

RFQ delivery by 7/07 (18 mo. lead)
Linac delivery by 7/08 (18 mo. lead)
EBIS SC solenoid delivery by 2/07 (14 mo. lead)

- HEBT dipole delivery by 4/08 (12 mo. lead)

Procurements are staged to fit the present funding profile

 Beneficial occupancy of the extension, and beam port completed, by 10/07





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Functional Requirements



Species	d to U (assuming appropriate external ion injection)
Intensity in desired charge state	up to 1.1 x 10 ¹¹ charges/pulse, depending on species
(EBIS beams)	
Charge-to-mass ratio, Q/m	≥ 0.16, depending on ion species
Repetition rate	5 Hz
Pulse width	10 – 40 μs
Switching time between species	1 second
Output energy	2 MeV/amu

Deliverables



As part of the project, the following items will be fabricated or procured:

- a) Electron Beam Ion Source
- b) RFQ accelerator
- c) Linear Accelerator
- d) Beam transport lines for matching the beam from EBIS to RFQ, RFQ to Linac, and Linac to Booster
- e) Power supplies, vacuum systems, diagnostics and controls required for the operation of all elements

CD4 requirements will be met when:

- All items required to meet the functional requirements listed in the previous table are in place and subsystems are tested.
- The EBIS-based pre-injector is commissioned with Au and Fe ion beams and has produced, at Booster input, 3 x 10⁸ Au³²⁺ ions/pulse and 4 x 10⁸ Fe²⁰⁺ ions/pulse (> 10% of design parameters).
- Switching between species has been demonstrated.





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Summary



- The EBIS preinjector is based on a modern technology, which will be simpler to operate and easier to maintain than the Tandems and will have the potential for future performance improvements.
- It will provide a robust and stable preinjector, which is important for the successful operation of the injectors.
- The RHIC EBIS design has been verified by the present EBIS operating at BNL (next talk).
- No significant improvement in EBIS performance is required, other than the straightforward scaling of ion output with an increase in trap length. The RFQ and linac are very similar to devices already operating at other labs.
- With joint funding from DOE and NASA, some long-lead procurements should begin in CY 2005.
- Our present schedule has commissioning of the full preinjector in 2009







Accelerator and Transport

D. Raparia

July 25-27, 2005





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Acknowledgements



Contributors:

J. Alessi, E. Beebe, S. Pikin, A. Kponou, J. Ritter, C. Gardner, S. Y. Zhang, T. Roser B. Schlitt, U. Ratzinger, P.N. Ostroumov



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EBIS Pre-CD1 Technical, Cost, Schedule, and Management Review



- LEBT
- RFQ
- MEBT
- LINAC
- HEBT
- Booster Injection





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Requirements



 The EBIS Preinjector should be able to match the performance for ions species which the Tandem presently provides

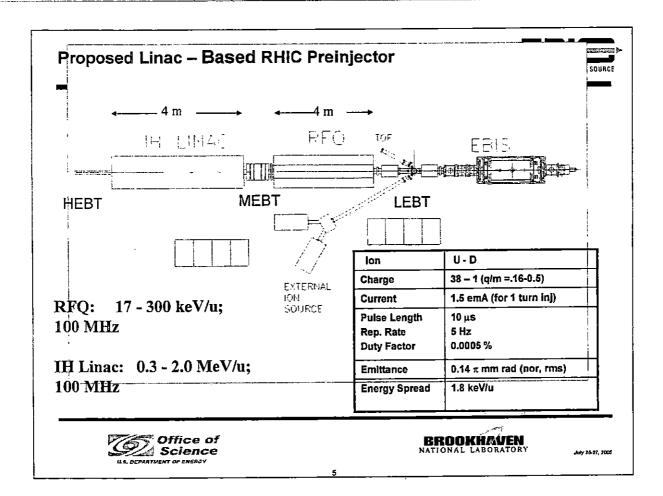
	Z	Α	Q	Q/m	Vext(kV)	1
					(а	ll ch states
He3*	2	3	2	0.67	25.5	10
D	1	2	1	0.50	34.0	6
С	6	12	6	0.50	34.0	10
0	8	16	8	0.50	34.0	10
Si	14	28	12	0.43	39.7	10
Fe	26	56	16	0.29	59.5	10
Au .	79	197	32	0.16	104.7	10

^{*} Out of EBIS Linac scope

Simulations were carried out for two extreme Q/m namely Au⁺³² and ₃He⁺². Only Au³² results will be presented in this talk.



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LEBT Requirements



- -Inject into EBIS
- -HV acceleration
- -Extract from EBIS
- -Diagnostics: Emittance Monitor, Current Monitor(2), TOF
- -Matching into RFQ

Twiss parameters at beginning and end of the LEBT for Au+32

Parameters	Beginning of LEBT (2.6 keV/u)	End of LEBT (17 keV/u)	Units	Energy = 2.6 keV/u
$\alpha_{\acute{\mathbf{x}}}$	0	1.057		β=0.00236 γ=1.0000027
β _x	0.075	0.064	mm/mrad	
ε _{x (rms,N)}	0.035	0.070	π mm mrad	
α_{v}	0	1.057		Energy = 17 keV/u
$\beta_{\rm v}$	0.075	0.064	mm/mrad	β=0.006017 γ=1.000018
ε _{y (rms,N)}	0.035	0.07	π mm mrad	

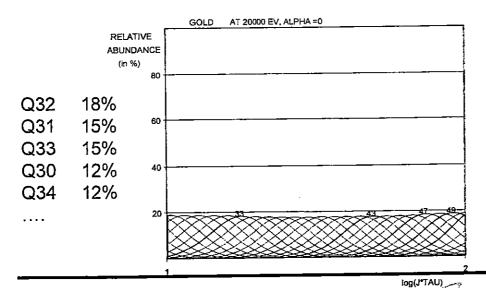




Charge State Distribution



Computer calculations of successive ionization of Au with a 20keV electron beam:





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July 25,77, 2005

Space Charge in LEBT



Curre	ent 10	mΑ			-						
	_ Z	Α	Q	Q/m	Vext	EPS(un)	Perv(gen)	ET	SCT	Ratio	Debye Len
He3	2	3	2	0.67	24.4	326	0.00197	0.0315	0.1314	4.16841	0.002596217
D	1	2	1	0.50	32.5	245	0.001	0.0177	0.0985	5.55788	0.002252987
Si	14	_ 28	12	0.43	37.9	210	0.001	0.0130	0.0845	6.48419	0.002085861
Au	79	197	32	0.16	100.0	79	0.00048	0.0019	0.0320	17.1078	0.001274568

Measurement for 1.7 mA Au $^{+35}$ (n,rms) =0.1 π mm mrad @ 20keV Calculated(n,rms) =0.12 π mm mrad

EPS(n) = $0.16 * r^2 * Bz * (Q/M)$ pi m-rad, R=0.002 m, Bz=4.6 T

Envelope equation
$$R'' + k_0^2 R - \frac{\left(4\varepsilon_{rms}\right)^2}{R^3} - \frac{K}{R} = 0$$

Energy = 17 keV/u β =0.006017 γ =1.000018 R= 15 mm

Gen. Perv. (K)= QI/(2 π ϵ_0 m c³ $\beta^3\gamma^3$) Debey Length(λ_D) = 2 ϵ^2_{rms} /K=(1/8)(R/ λ_D)²



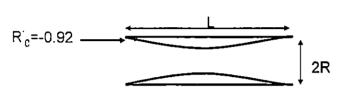
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LEBT Current Limit



- •Distance needed between two lenses for external ion injection (L) ~ 0.67 m.
- Beam radius (R) ~ 3.4 cm, Lenses (solenoid) aperture radius 4.8 cm
- •Maximum beam current for SC dominated drift (L), maximum beam radius (R) and initial slop R'₀=-0.92 given by

$$I_{max}(A)=1.166*(mc^2/30*q)*\beta^3 \gamma^3 (R/L)^2$$



	I _{max} (mA)
₃ He ⁺²	31.0
Au ⁺³²	124.0



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Starting Conditions for LEBT (A.Pikin)



Input parameters are generated using formula below for ion extraction/acceleration for LEBT

$$kT_i\left(\frac{R_i}{R_i}\right)^2 = q.(U(R_i, z_0) - U(0, z_0))$$

Energy = 2.6 keV/u β =0.00236 γ =1.0000027

 R_t = radius of ion beam in the trap, R_i = radius of ion beam kT_i =transverse ion temperature

	E (KeV)	α	β (m)	ε(rms, norm) π mm mrad
Au ⁺³² (10 mA)	512	0	0.075	0.035
₃ He ⁺² (10 mA)	7.875	0	0.047	0.034



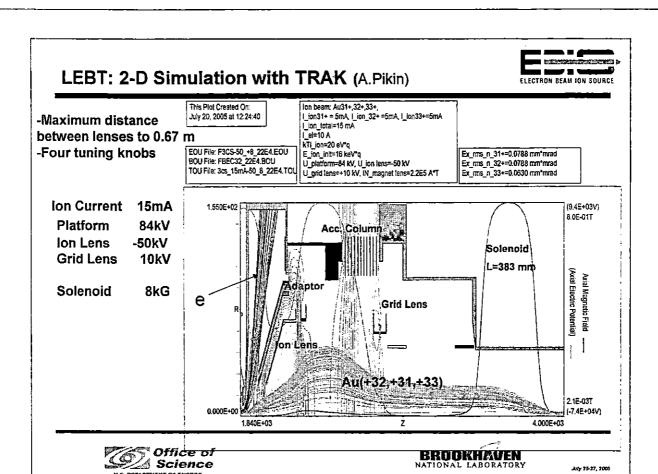
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LEBT Layout (A. Pikin) Cropsus Grace valve Inspectors precipitate Inspecto

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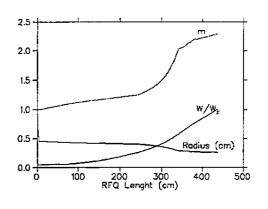


RFQ Parameters



Parameters	BNL	CERN	Units
Туре	4-roci	4-rod	
Q/m	0.16-0.5	0.12	
Energy in	17,0	2.5	keV/amu
Energy out	300	250	keV/amu
Frequency	101.28	101.28	MHz
Max rep rate	5	10	Hz
Length	4.37	2.5	Meters
# of cells	277		
Aperture	0.005	.0045	Meters
Voltage	69	70	kV
E (surface)	20.8	≤23	MV/m
RF Power	< 350	< 350	kW
Acceptance	1.7	> 0.8	π mm mrad (nor)
Input Emit.	0.35		n mm mrad, nor, 90%
Output Emit. (trens)	0.375		я mm mrad, nor, 90%
Output Emit. (longit)	32.5		π MeV deg
Transmission	91	93	%
Bravery factor	1.8	≤2	Kilpatrick

-Could accelerate d- U -q/m =.16-0.5



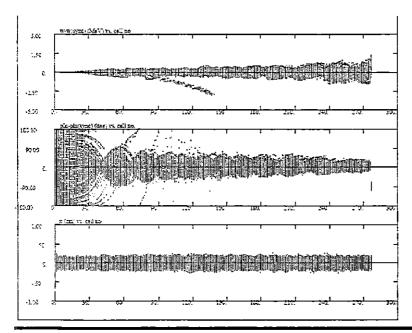




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RFQ Beam Dynamics Design, PARMTEQ





Transmission: Au⁺³² 91% (10 mA) d 91 % (10 mA)

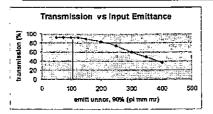
₃He⁺² 88% (2 mA)

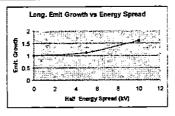
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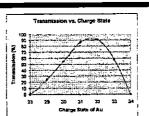
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RFQ Transmission





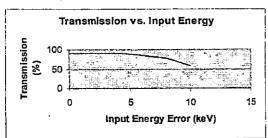


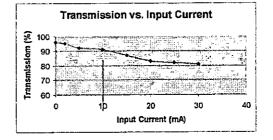


RFQ transmission vs. Input Emittance

Long. Emittance Growth vs. energy spread

RFQ transmission for different charge state of gold





RFQ transmission vs input voltage error (Nominal operating voltage 100 kV)

RFQ Transmission vs. input current



Superconducting Linea



Adv 25-27, 2005

Multi-Component Ion Beam Simulation (ANL Code)

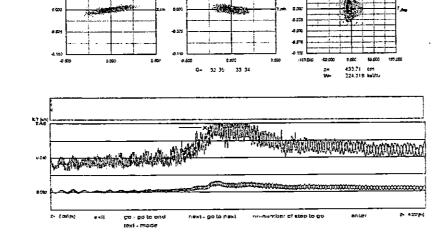
865

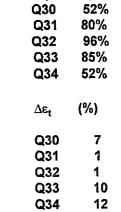
0.125



Transmission:

(10 mA)





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Requirements for MEBT



-Matching from FODO (RFQ) to axial symmetric IH structure with quad triplet -Diagnostics; Current monitors(2), Emittance

Twiss parameters at beginning and end of the MEBT for Au+32

Parameters	End of RFQ	Entrance of IH	Units
αχ	1.8	1.802	
β _X	0.18	1.01	mm/mrad
ε _χ (rms,norm)	0.11	0.11	π mm mrad
αγ	-1.39	0.60	
βγ	0.142	0.59	
ε _γ (rms,norm)	0.11	0.11	π mm mrad
α_z	0.054	0.59	
β _z	0.0203	0.0009	deg/keV
ε _z (rms,norm)	6834	6834	π deg keV



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Adv 25-27, 1005

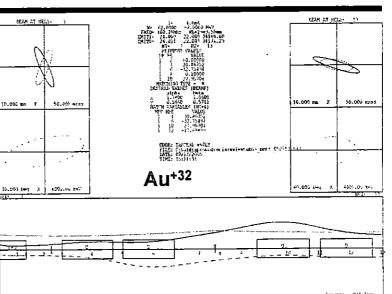
Transport from RFQ to Linac

ELECTRON SEAM ION SOURCE

(4 quads, 1 buncher) RFQ Transition cell

Q2 (EM) 33 T/m Q3 (EM) 38 T/m Q4 (EM) 36 T/m Q5 (EM) 38 T/m B1 150 kV

EM quads same as LANL LEDA quads



Au⁺³² Au⁺³¹ Au⁺³³ Au⁺³⁰ Au⁺²⁹ XI= 1.8*0.9 + 1.5*0.86 + 1.5*0.58* + 1.2*.55 + 0.8*.24=4.6 mA



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The IH Linac is very similar to the first tank of the CERN Pb linac, our baseline:

Main parameters of the IH linac

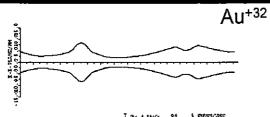
Parameters	BNL	CERN Tank 1	Units
Q/m	0.18-0.5	0.12	
Input energy	0.300	0.250	MeV/amu
Output Energy	2.0	1.87	MeV/amu
Frequency	101.28	101.28	Mhz
Max rep rate	5	10	Hz
length	4.0	3.57	Meters
Input emittamce	0.55		pi mm mrad, norm,90%
Output emittance	0.66		pi mm mrad, norm,90%
Output energy spread	20.0		keV/amu
transmission	100		%



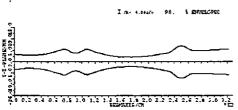
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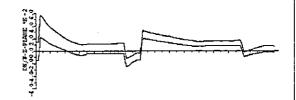
IH linac optics codes LORAS used in the preliminary design





Longitudinal profiles in the IH linac





Transverse profiles in the IH linac

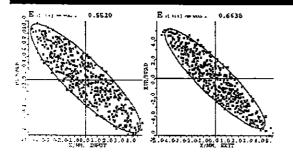
Current = 4.6 mA



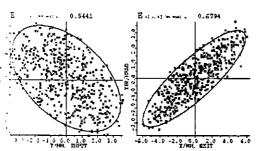
\$\\\ \frac{1}{80} \\ \frac{1}{180} \\ \fra

IH Linac Input and Output Emittances









I=4.6 mA	Input N, rms	Output N, rms	Δε %
X-XP(π mm mrad)	.11	.13	20
Y-YP (π mm mrad)	.11	.13	20
$\phi - \Delta E$ ((π ns/keV/u)	.18	.26	41



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Emittance for Linac

(Au⁺³²)



	Energy (keV/u)	β	Accpt. (N) (π mm mrad)	Transverse ϵ (N, rms) (π mm mrad)		Longitudinal (rms)	
	;			Simulation Input	Simulation Output	ε π MeV deg	ΔE kev/u
EB.S- LEET	2.6-17	0.0060		-	0.125	-	-
먹무산	300	0.025	1.7	0.125	0.125	6.5	1.34
.∺ ∟nac	2000	0.065	4.3	0.125	0.153	7.0	8.9
inflector	2000	0.065	1.9	0.153	0.153	7.0	0.804*

Measurements: 0.1 π mm mrad (n, rms) Au⁺²⁵ (all charge states) 1.7 mA

*Booster requirement 0.89 keV/u

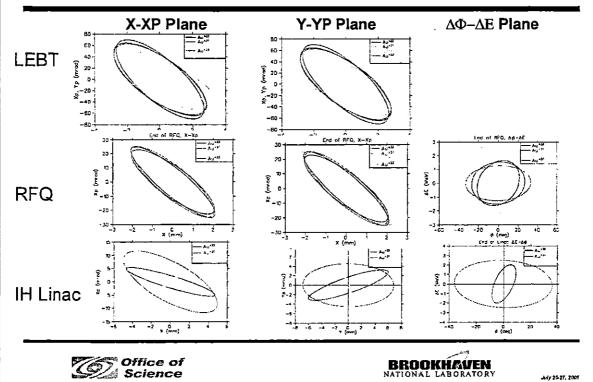
Though simulations show only 22% transverse emittance growth, we have designed for 100% emittance growth from EBIS to Booster.





Phase Space Plots for Different Charge States of Au





Requirements for HEBT



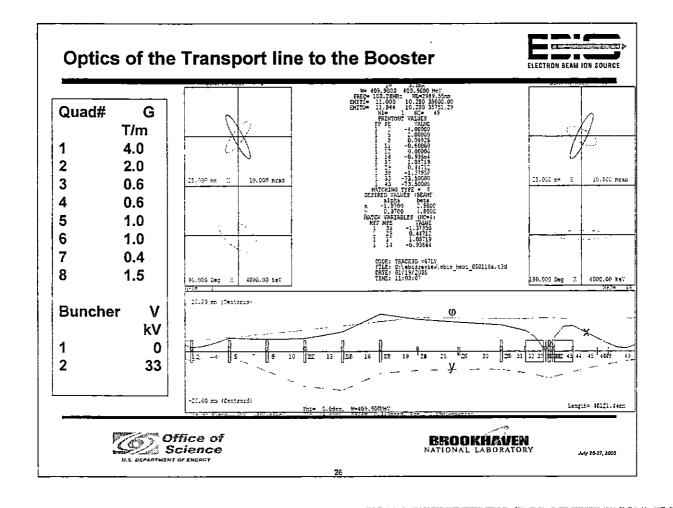
- -Transport beam to Booster
- -Mismatch beam into Booster to avoid scraping at inflector and to reduce Incoherent tune spread in the Booster.
- -Minimize energy spread at the injection, $dp/p = \pm 0.05\%$,
- -Provide ion charge state Discrimination
- -Diagnostics: Current Monitors (2), Multiwire/Faraday cups (3), Fast Faraday cup
 Twiss parameters at beginning and end of the HEBT

Parameters	End of IH Linac	Entrance of Booster	Units
αχ	2.1	-1.87	
β _X	3.0	2.5	mm/mrad
ε _χ (rms,norm)	0.153	0.153	π mm mrad
αγ	-1.59	0.8	
βγ	3.45	4.8	mm/mrad
εγ (rms,norm)	0.153	0.153	π mm mrad
ΔE (rms)	±602	± 162	keV (Au+32)
ΔE (rms)	±16.8	±6.6	keV (₃ He ⁺²)
, ,			





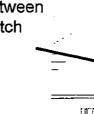
Layout in the Linac Lower Equipment Bay ELECTRON BEAM ION SOURCE Office of Science BROOKHAVEN NATIONAL LABORATORY NATIONAL LABORATORY



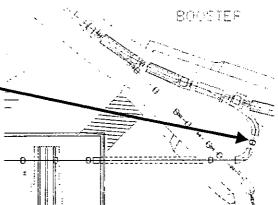
Charge-state separation



 A beam scraper will be placed at the high-dispersion point between the two HEBT dipoles, to catch neighboring charge states.



- · At this location:
 - $-R_{16} = 1.1 \text{ mm}$
 - $-2r_0 = 2.2 \text{ mm}$
 - Resolution = 500 @ 2 MeV/u;310 @ 0.3 MeV/u
 - Efficiency = 100%







....

21

Tuning procedures with Multiple Charge States



We have studied the tuning procedure for the linac. Summary as follows: Set all the quads to calculated values and bunchers off

- •LEBT with TOF maximize beam current for desired charge state
 maximize beam current after RFQ to find the match into RFQ
- •RFQ -since RFQ will be commissioned about 1.5 years earlier than linac, we will set up analyzing magnet to set the correct amplitude (e. g Au⁺³²)
- •IH Linac to set phase and amplitude of IH Linac, maximize the beam current to desired charge state using Booster
- •MEBT maximize current after IH Linac, by tuning quads and buncher
- •HEBT minimize the energy spread by tuning buncher amplitude and look at beam size with profile monitor at high dispersion at the bend
 - verify bend magnet setting with Booster





Booster Injection



Transverse:

-For 1-4 turn injection, the calculated incoherent tune spread is 0.62 to 0.16 without any emittance dilution.

-Present 40 turn injection from tandem results in 6 and 3 π mm mrad or 8 and 4 times larger

-Mismatch or off center (smoke ring) to dilute the emittance

-Booster acceptance (VXH)=70X 225 π mm mrad, 4.5 X15 (Norm)

Longitudinal: -Simulation results show EBIS injected beam will have emittance of 0.05 eVs/u or lower (present 0.05 eVs/u)

-Longitudinal microwave instability: Keil-Schnell criteria requires for trans. emit. of 0.7 π mm mrad and energy of 2 MeV/u should have dp/p >0.0012% which is satisfied by EBIS beam (dp/p = ±0.05%,)



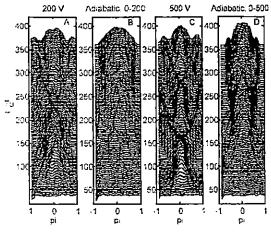


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Booster Injection (S. Y. Zhang, T. Roser)





200 V, 350 tums

0 - 200 V, 350 tums

0 - 200 V, 350 tums

8

0 - 200 V, 350 tums

8

0 - 200 V, 350 tums

Mountain range of 4 EBIS capture schemes

Longitudinal Phase spaces after beam capture for 4 schemes

-Adiabatic capture has low losses and lower emittance

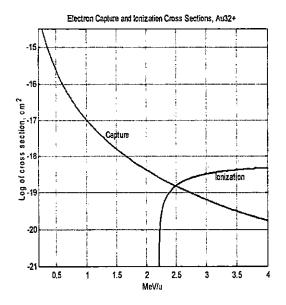


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Electron Capture





At 2 MeV/u, electron capture cross section reduced by factor of 40 relative to tandem.



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Booster Parameters



 $\varepsilon_{\rm N}$ =5 π mm mrad

$$V_{infl} = (G/R)*(Mc^2/Q)*\beta^2$$

$$\Delta v_{inc} = \frac{-3NQr_0}{2\pi AB_f \beta \gamma^2 \varepsilon_N}$$

	Z	Α .	Q	lons/puise (Bstr input)	Charges/pul	d(nu)	Brho EBIS	Inflector V (kV)
He3	2	¹ 3 ¹	2	2.14E+11	4.28E+11	-1.60	0.3073	11.53658
D	1	2	1	2.50E+11	2.50E+11	-0.70	0.4097	15.3821
С	6	12	6	2.00E+10	1.20E+11	-0.34	0.4097	15.3821
0	8	16	8	6.70E+09	5.36E+10	-0.15	0.4097	15.3821
Si	14	28	12	5.00E+09	6.00E+10	-0.14	0.4780	17.94579
Fe	26	56	16	1.70E+09	2.72E+10	-0.04	0.7170	26.91868
Au	79	197	32	2.67E+09	8.55E+10	-0.08	1.2612	47.34803
บ	92	238	45	1.90E+09	8.55E+10	-0.09	1.0835	40.67711

Note – maximum desired Booster emittance ϵ_{N} = 10 π mm mrad



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Emittances



	Vertical π mm mrad (N, 95%)	Horizontal π mm mrad (N, 95%)
Booster*	4.5	10.0
Linac	1.4	1.4
Source	0.7	. 0.7

mismatch injection

Note: Booster acceptance (VXH) 4.5 X 15 π mm mrad (N,95%)



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July 15-27, 2005

3.

Response to January 05 Review



EBIS

- •Requires careful measurement of beam parameters
- -We will measure the beam parameters after raising the EBIS platform to 100 kV (R&D under progress)
- •A more gentle extraction scheme, instead of proposed fast extraction, may result in minimum longitudinal energy spread
- -Within the scope of R&D

Response to January 05 Review (cont...)



LEBT

- Create a 3D computer model of the LEBT
- -Completed 2D model under single code. Work in progress for 3D model in collaboration with ANL
- •Analyze beam dynamics and compare with beam measurement
- -We will measure emittance under several conditions, comparisons work will begin soon using code from ANL (R&D)
- Use model to minimize emittance growth
- -Will do that, once comparison work finishes
- Provide emittance values, energy spread and intensities at RFQ
 -Will do this



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Response to January 05 Review (cont...)



LEBT

A possible alternate design with bend for LEBT: Its benefits are:

- (a) Reduce space charge in LEBT and Linac
- (b) Reduced rf power to compensate beam loading in RFQ and linac
- (c) Beam tuning
- -We have studied the achromatic LEBT for charge separation before RFQ. It could work and have enough dispersion for charge separation
- (a) Simulations show present proposed LEBT and Linac can handle space charge
- (b) rf power to compensate beam loading for additional charge is small in comparison to total rf power
- (c) Studies show that linac can be tuned with multiple charge states

More costly; doesn't seem to be required.



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Response to January 05 Review (cont...)



RFQ and Linac

- •Use simulation codes that include the simultaneous transport and acceleration of multi-component ion beam
- -We have the codes from ANL, we are starting these simulations
- •Use last cells of RFQ to optimize the beam matching with MEBT
- -Done
- •Use electric focusing inside IH linac instead of magnetic triplets. BNL can make a later decision depending on the progress in this field
- -We are looking into electric focusing linacs (ANL, Linac Systems). There are not yet any experimental results.





Conclusions



Will use proven technologies for RFQ and IH structure.

Beam dynamics studies show that the RFQ, LINAC, and matching lines will satisfy all beam requirements.







Management

Jim Alessi

July 25-27, 2005





July 25-27, 2008

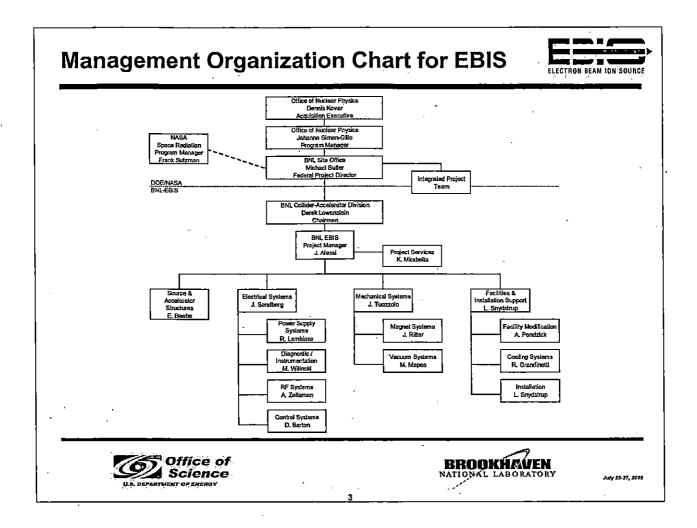
Outline

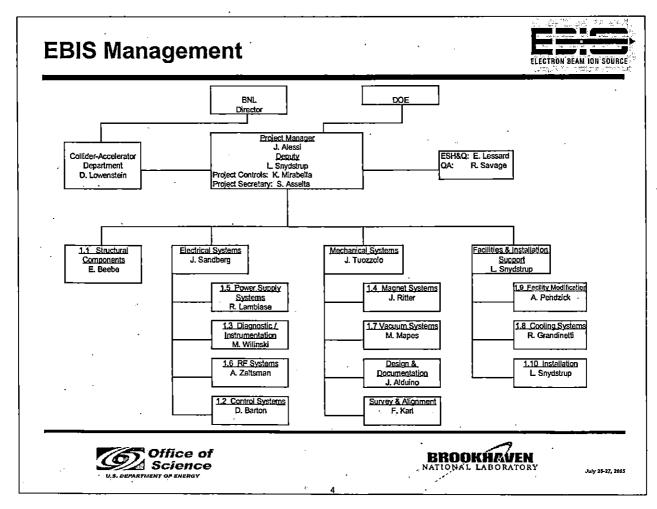


- Organization chart
- Safety
- · Project Execution Plan
- Change control
- Risk assessment
- Communication and reporting plan
- Cost/Funding/Work
- Summary









Large resource pool. Each task supported by an established group. 1.11 1.2 Science Unique Science Unique

Safety



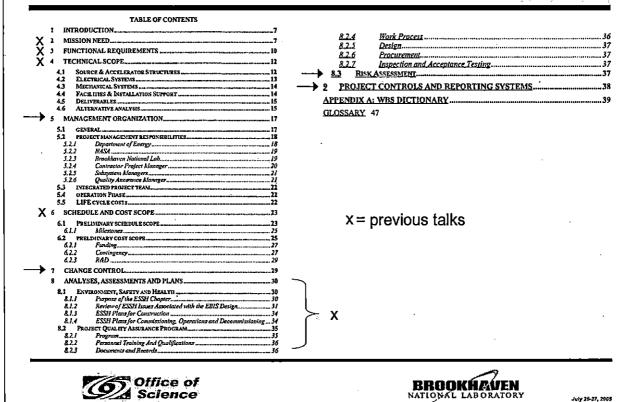
- Lab makes safety a top priority; strong emphasis on working safely. Safety will not be compromised on this project.
- C-AD ESH&Q Group is very experienced and very helpful. They
 work along side those in the field in helping with work planning,
 process reviews, procedure writing, etc. We have all become
 sensitive to what is required to work safely, are accustomed to
 the processes, receive the appropriate training, etc.
- Safety representation on Integrated Project Team
- · We have a high confidence that this project will be done safely.





Project Execution Plan





Project Management Responsibilities



- Within DOE's Office of Science (SC), the Office of Nuclear Physics (NP) has overall DOE responsibility for the EBIS MIE.
- Jehanne Simon-Gillo has been assigned the Federal EBIS Program Manager.
- Michael A. Butler has been assigned as the Federal Project Director at the Brookhaven Site Office (BHSO).
- Frank M. Sulzman, Space Radiation Program Manager, NASA Headquarters will be the NASA representative to the EBIS Project.
- Funding for this project will be directed through BNL's Collider-Accelerator Department. Fiscal and management responsibility for the fabrication of EBIS will reside with the Chairman, Derek Lowenstein.
- The Chairman for the Collider-Accelerator Division, Derek Lowenstein, has appointed James Alessi as the EBIS Contractor Project Manager.





Integrated Project Team



DOE Federal Project Director (Chair)	Michael A. Butler
DOE Program Manager for EBIS	Jehanne Simon-Gillo
NASA Space Radiation Program Manager	Frank Sulzman
BNL Project Manager for EBIS	James Alessi
BNL ESSH Lead	Ed Lessard
C-AD Assistant Chair for Administration	Stephanie LaMontagne





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Summary of Baseline Change Control Thresholds



Level	Cost (Table 6-2)	Schedule (Table 6-1)	Technical Scope (Table 3-2)
DOE-SAE (Deviation Threshold)	25% increase to TEC	6 or more months increase (cumulative) in a project level milestone date	Changes to scope that affect mission need requirement
DOE-SC-26 Program (Level 0)	Any increase in the TEC or cumulative allocation of more than \$500k contingency	3-month or more delay of a Level 1 milestone date	Change of any WBS element that could adversely affect performance specifications (Table 3-2)
DOE-BHSO Federal Project Director (Level 1)	A cumulative increase of more than \$250k in WBS Level 2 or cumulative allocation of more than \$250k contingency	> 1-month delay of a Level 1 milestone date or > 3-month delay of a Level 2 milestone date	Any deviation from technical deliverables that does not affect expected performance specifications
EBIS Contractor Project Manager (Level 2)	Any increase of >\$50k in the WBS Level 2	> 1-month delay of a Level 2 milestone date	Technical design changes that do not impact technical deliverables





Risk Assessment (draft form)



- a) Likelihood of Occurrence
- •Very likely (VL): risk is likely to occur with a probability greater than or equal to 90%
- •Likely (L): risk is likely to occur with a probability greater than or equal to 50%
- •Unlikely (U): There is a less than 50% chance that this event will occur
- b) Consequence

	Marginal (M)	Significant (S)	Critical (C)
Cost Impact on project contingency is:	<\$100K	\$100K - \$500K	>\$500K
Schedule Impact on project schedule is:	None	Impacts milestone dates	Impacts project early finish date
Technical Impact on project performance is:	Minor degradation	Significant degradation	CD-4 will not be met

C) Risk Categorization Matrix

	Consequence								
Likelihood of	Marginal	Significant	Critical						
Occurrence			-						
Very likely	Medium	High	High						
Likely	Low	Medium	High						
Unlikely	Low	Low	Medium						





Anne 76-26 white

Risk Assessment



- Risk of not proceeding with EBIS:
 - significant upgrades to the Tandems will be required
 - some desired beams unavailable to NASA
- Technical risk on EBIS is low due to the successful source development
 - Test EBIS is full electron beam current. Factor of 2 scaling in ion output is well understood.
- Technical risk on RFQ and Linac is low
 - mature technologies, many similar devices in operation at other facilities.





Risk Assessment (cont.)



- Cost risk due to fluctuations in the currency exchange rate on foreign procurements (RFQ and Linac) (medium)
 - Have increased contingency on foreign procurements (30-40%)
 - Planned early procurement of RFQ
 - Try to make contracts in US\$
- Schedule risk due to conflicts with Booster operations schedule (medium)
 - Most work can proceed in parallel with Booster operations
 - Provide plenty of slack in procurement of the Booster-side components.
 - One could reduce time required for installation of Booster-side of HEBT by working 2 shifts if necessary





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Risk Assessment (cont.)



Delays in major procurements

- (low)
- Consider vendor history when awarding contract
- Intermediate vendor milestones
- Frequent communications with vendors
- Vendor visits
- · Delays in funding

(high)

- Try to avoid scheduling large procurements in Q1 of any FY
- Work closely with DOE and NASA
- Possible problems in manufacturing of electron collector (low)
 - Detailed design, followed by engineering review (done)
 - Quality assurance provisions in procurement specification
 - Frequent communication with vendor
 - Early fabrication and testing to allow time for a redesign, if necessary (collector is part of R&D)





Communication and Reporting Plan



- Project Assessment and Reporting System (PARS) will be updated on a monthly basis by the Federal Project Director.
- Contractor Project Manager will lead monthly cost and schedule reviews and report the result to the Federal Project Director.
- Contractor Project Manager will lead quarterly overall cost, schedule and technical performance reviews and report the results to the BHSO-DOE office.
 Federal Project Director will report progress to the DOE Program Manager and NASA on a quarterly basis.
- Federal Project Director and Contractor Project Manager will participate in monthly teleconference calls with the DOE Office of Nuclear Physics.
- Office of Nuclear Physics will conduct annual progress reviews with a committee of experts.
- The standard BNL accounting system will be the basis for collecting cost data.
- Technical performance will be monitored throughout the project to insure conformance to approved functional requirements. Design reviews and performance testing of the completed systems will be used to ensure that the equipment meets the functional requirements.





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Preliminary Cost Range



WBS		Description	AY K\$
¥424431 1	Structural	Components	3,275
	1.1.1	EBIS Hardware	1,300
	1.1.2	LEBT and External ion injection	500
	1.1.3	RF Structures	1,475
		Systems	4 600
		cs/Instrumentation	675
200 21.4	Magnet Sy	/stems	600
3.393.1.5	Power Su	oply Systems	1,975
4.6	RF Systen	ns ystems	2,325
3 3 3 3 T	Vacuum S	ystems	1,450
1.8	Cooling S	ystems	300
2999991:9	Facility M	odifications	700
<u>⊗</u> ‱≆1.10	Installatio	n 6824 Mikaliwa 1334 Mika 140 Mika	1,900
	1.10.1	Structural Components	400
	1.10.2	Control Systems	50
	1.10.3	Diagnostics/Instrumentation	200
	1.10.4	Magnet Systems	25
	1.10.5	Power Supply Systems	500
	1.10.6	RF Systems	25
	1.10.7	Vacuum Systems	300
	1.10.8	Cooling Systems	400
1.11	Project Se	ervices	625
38 ₹1.12	Commiss	loning	\$0.50° 1888 1880 18
		currently included in above WBSs	
33 41.13	R&D		1,200
		Conceptual Design Report	200
		Development	1,000
4200000	38,888 FeV	Subtotal EBIS MIE	15,625
		Contingency	3,675
\$20.50 K		Estimated Total Project Cost	19,300

- ~ 60% materials
- ~ 40% labor

% Materials by WBS

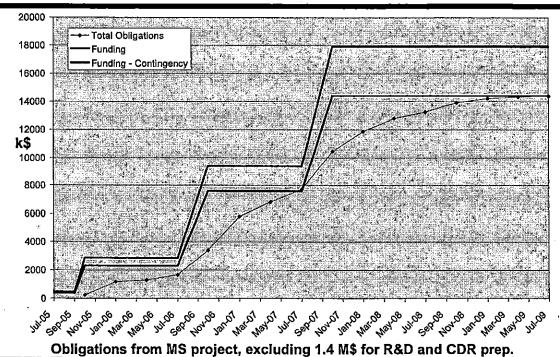
Structural components	62%
Controls	73%
Magnets	58%
Diagnostics	56%
PS's	84%
RF systems	72%
Vacuum	65%
Cooling	80%
Facility mods	68%
Installation	9%
Project Services	. 0%
EBIS, LEBT, external inj	49%
RFQ, Linac, Bunchers	76%





Funding/Obligation Profile (preliminary)





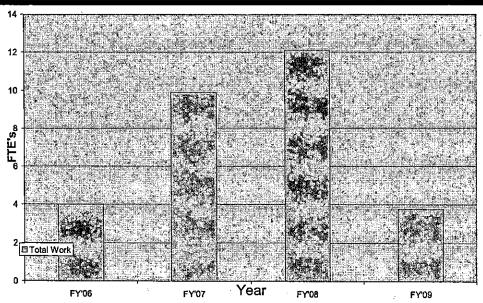
Office of Science



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Work vs. year (preliminary)





First view of resource loading. Still needs to be leveled

Total of ~30 FTE's (does not include ~3 FTE's in R&D)





Comments



- Developing/refining Microsoft Project files becoming an excellent tool (June, 2005 ~ 15 from C-AD took 3-day MS Project class)
- Very experienced subsystem managers on the project. They are used to interacting daily, over the course of many projects. Good communication. Agreements on "handoff" points are almost routine.
- WBS set up so level 2 (subsystem managers) = separate accounts. Easy to track & control spending.
- Signature approvals = Subsystem manager to me to Thomas to Derek (standard procedure in C-AD)
- · Tech notes, design reports, design reviews are standard within C-AD
- At WBS level 2 weekly group meetings are typical already good communication
- Procurement processes, procedure writing, work planning, ESH&Q, etc. all follow standard C-AD and lab procedures.





hito 25.27 2005

<u> 19</u>

Summary



- We feel the design is technically sound
 - The Test EBIS has demonstrated that an EBIS meeting RHIC requirements can be built. The RHIC EBIS design incorporates improvements to make it a more reliable device for routine operations.
 - The RFQ and Linac are straightforward, very similar to existing devices.
- A reasonably advanced cost estimate exists (details in tomorrow's talks). More detailed engineering will improve the estimate. (not yet baselined)
- The project team is very experienced. They know how to build things (Booster, RHIC, NSRL, SNS, ...)







Environment, Safety, Health, & Quality

Ed Lessard

July 25-27, 2005





July 25-27, 2005

Significant Environmental Aspects



- The following Significant Aspects were identified:
 - Sole Source Aquifer
 - Excavation Within Building 930
 - Chemical Storage/Use
 - Liquid Effluent
 - Hazardous Waste
 - Radioactive Waste
 - Radiation Exposures
- National Environmental Policy Act (NEPA)
 - Satisfied by Environmental Assessment, DOE/EA #0909
- An ISO 14001 process assessment will be performed





Safety and Health Hazards



- · Non-ionizing Radiation
- Hazardous or Toxic Materials Radioactive Materials
- Fire
- Electrical Energy
- Oxygen Deficiency
- Kinetic Energy
- Potential Energy
- Thermal Energy
- Cryogenic Temperatures
- Ionizing Radiation





Aug. 15.97 2005

Preliminary Hazards Analysis (PHA)



- Based on PHA, the following hazards require further analysis
 - Ionizing Radiation
 - Fire
 - Electrical Energy
 - Oxygen Deficiency
- · OHSAS 18001 Job/Facility Risk Assessments will be performed
- Hazards analyses will be in C-AD Safety Assessment Document

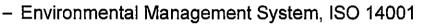


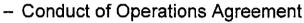


Relevant Requirements



- DOE Orders
 - DOE Order 420.2B, Accelerator Safety
 - DOE Order 420.1A, Facility Safety, §§ 4.2 and 4.4
 - DOE Order 414.1C, Quality Assurance
- BNL Requirements (SBMS)
 - Accelerator Safety
 - Work Planning and Control for Operations
 - Construction Safety
- · C-AD Management Systems
 - OSH Management System, OHSAS 18001





- Self-Assessment Program





July 25-27, 2005

Plan for Construction



- All requests for goods or services will be reviewed to incorporate environmental, safety or health requirements for contractors or vendors
 - C-AD OPM Chapter 13, Quality Assurance
- All work done will meet the DOE ISMS requirements
 - C-AD OPM 1.10, C-AD ESH Policy
 - C-AD OPM 1.12, Training and Qualification
 - C-AD OPM 2.28, Work Planning and Control





Plan for Commissioning



- Safety Assessment Document (SAD)
- Commissioning Accelerator Safety Envelope (CASE)
- · Commissioning Plan
- Accelerator Readiness Review (ARR)
- DOE Approval to Commission





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Plan for Operations



- · C-AD Conduct of Operations Procedures
- Operations Accelerator Safety Envelope (ASE)
- Accelerator Readiness Review (ARR)
- DOE Approval to Operate



Transitioning from Commissioning to Operation



- Target Dates:
 - Q1 2008, ISO 14001 Environmental Process Evaluation 函数



- Q1 2008, Obtain BNL Approval of SAD
- Q2 2008, Obtain DOE Approval of EBIS CASE
- Q2 2008, Complete Commissioning ARR
- Q3 2008, Obtain DOE Approval for Commissioning
- Q4 2008, Obtain DOE Approval of EBIS ASE
- Q1 2009, Complete Operations ARR
- Q2 2009, Obtain DOE Approval for Operations





EBIS Pre-CD1 Technical, Cost, Schedule, and Management Review



Cost, Schedule, Manpower

Kerry Mirabella

July 25-27, 2005





July 25-27, 2005

Outline



- Cost and Schedule Chronology
- Work Breakdown Structure (WBS)
- Preliminary cost methodology
 - Cost Basis
 - Manpower
 - Contingency
 - Rates & Overheads
- · Preliminary cost estimate by WBS
- Procurement Strategy
- Project Controls System
 - Reporting Milestones
- Configuration management system





Cost and Schedule Chronology



- System experts' bottoms up estimates in '05 \$ in Excel.
- · Summary schedule developed.
- Microsoft Project 2003 software adopted as the EBIS cost and scheduling tool.
- 3-day Microsoft Project course held onsite in June.
- · Tasks entered and resources applied.
- · Identification of task dependencies in process.
- · High level milestones included.
- Next:
 - Complete the inter-subsystem logic
 - Iterate schedule to fit funding profile
 - Verify critical path
 - Continue adding milestones





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Work Breakdown Structure



Organized by subsystem, each with its own manager, allowing direct accountability for cost and schedule.

Cost accounts planned at level 2 or lower, as determined by the subsystem managers.

*Commissioning costs are currently estimated within the subsystem WBS's but will be reassigned to WBS 1.12 for baselining.

WBS	Title
1.1	Structural components
1.2	Controls Systems
	Diagnostics/instrumentation
1.4	Magnet Systems
1.5	Power Supply Systems
1.6	RF Systems
	Vacuum systems
1.8	Cooling Systems
1.9	Facility Modifications
	Installation
	Project Services
	Commissioning*
1.13	R&D





Preliminary Cost Methodology



- Tasks defined and estimated by those who will manage/perform the effort, using an agreed-to scope of work
- · Basis of estimate for WBS elements identified

CP - Catalog Price

VQ - Vendor Quote

HC - Historical Cost

EJ - Engineering Judgment





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Cost Basis



CP - Catalog Price VQ - Vendor Budgetary Quote

Definition - A budgetary estimate from a supplier, service supplier (installation, design, consulting, project management, testing, etc.), or other industrial (non-laboratory) source of equipment and/or services. Material, labor, or service costs from vendor catalogs are considered vendor estimates.

Backup material - a fax, catalog page, memorandum of a telephone conversation or other indication of the source of the quote, items included, and the projected cost.

HC - Historical Costs

Definition - Cost based on actual costs from previous projects.

Backup material - an indication of the previous project and the actual cost.

EJ - Engineering Judgment

Definition - Based on techniques such as rules of thumb; taking a percentage of the material, material + installation or other cost base; national cost estimating standards/codes ("Means", square footage of sites, etc.)

Backup material - Identify the rule of thumb, actual cost and its source; percentage, base, standard, or code used; the square footage used and the cost per square foot applied; or other engineering judgment basis.





Manpower



- Total BNL hours estimated at 52K, approximately 30 Full Time Equivalent years (Man-years).
- No resource conflicts are anticipated.
- No new hires are anticipated for the project.
- No impact on RHIC operations.

Category	FTE/yr
Administrator	0.8
Scientist	2.9
Engineer	9.6
Designer	3.1
Technician	9.6
Management	0.5
Building Trades	3.0
Total	29.6





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Contingency



Technical Risk Description	Cost Risk Description	Schedule Risk Description	Contingency Rate		
Direct copy of an existing, working design	Off the shelf hardware or purchased from a catalog	No schedule impact on any other WBS item	10%		
Based on an existing design but requiring extensive modifications	Based on a vendor quote using limited conceptual design sketches	Delays completion of only its own non-critical path subsystem item	20%		
New design different from established designs or existing technology	Estimate for item with little in-house experience	Delays completion of other non-critical path subsystem items	30%		
New design requiring R&D to develop advanced state-of-the-art technology	Top down estimate derived from comparable previous programs	Directly delays completion of critical path subsystem item	40%		

Estimated for each lowest level WBS item/task. An averaged rate was used when risk levels differed across categories.





Rates and overheads



- Departmental Rates and Overheads
 - Labor rates based on C-AD average salary by category
 - Departmental Fixed Costs distributed as a % direct labor Chairman's Office

Administration

ESH&Q

Information Technology

Communications

Space

Building Power

- · Laboratory Rates and Overheads
 - Extraordinary Construction
 - Reduced overheads for high value procurements
- Escalation Rates for DOE Projects (January 2004)





July 15-27, 2005

Preliminary Cost Estimate by WBS



				Direct	05 K\$'s		5			E	Burdened	AY KS	3	
WBS	Title	Mati	Labor	Cost	Cont %	Cont \$	Total cost	Mat	ï	Labor	Cost	Cont %	Cont \$	Total cost
								4			·			
1.1	Structural components	1675	680	2355	28%	665	3020	2	115	1260	3275	27%	B90	4165
1.2	Controls Systems	350	100	450	22%	100	550	,	35	165	600	23%	135	735
1.3	Diagnostics/Instrumentation	290	175	465	20%	95	560		80	295	675	20%	135	810
1.4	Magnet Systems	295	155	450	21%	95	545		50	250	600	22%	130	730
1.5	Power Supply Systems	1350	195	1545	26%	400	1945	1	65	310	1975	25%	500	2475
1.6	RF Systems	1305	375	1680	28%	470	2150	1	70	655	2325	27%	630	2955
1.7	Vacuum systems	761	305	1066	20%	215	1281		40	510	1450	20%	290	1740
1.8	Cooling Systems	195	40	235	21%	50	285		40	60	300	20%	60	360
1.9	Facility Modifications	380	135	515	26%	135	650		75	225	700	26%	180	880
1,10	Installation	145	940	1085	21%	230	1315		80	1720	1900	21%	400	2300
1.11	Project Services	0	370	370	20%	75	445		0	625	625	_ 20%	125	750
1.12	Commissioning*			0			0				0	_		0
1.13	R&D / CDR	345	583	928	16%	145	1073		00	700	1200	17%	200	1400
	Estimated Totals for Project	7091	4053	11144	24%	2675	13819	8	50	6775	15625	24%	3675	19300

Commissioning included in above WBSs





Procurement Strategy



- Subcontract/Purchase Order &
- Basic Ordering Agreement (BOA)
 - Fixed-Price
 - · Incrementally Funded
- · Competitive bids planned vs. sole source
- No Cost-reimbursement/Cost-plus contracts are planned

Major procurements (order >\$100K) will be tracked in Microsoft Project with a minimum of the following planned dates: design package complete, purchase requisition date, purchase order date, delivery date.





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Major Procurements

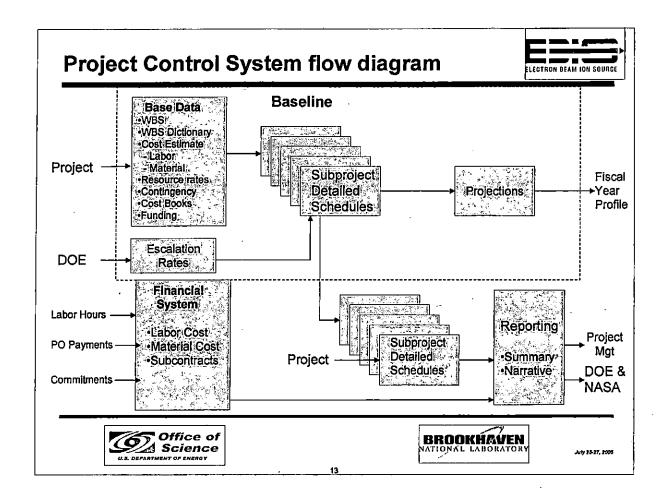


•	Procurements	>	\$100K	(in	FY'05\$)
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, , , , , , , , , , , , , , , , , , , ,	
- RFQ:	\$340k
- Linac:	\$400k
Superconducting Solenoid:	\$328k
- RFQ Power Amp:	\$400k
- Linac Power Amp:	\$400k
- Buncher PA's (3)	\$150k
 Electron Collector PS 	\$200k
 HEBT big bend dipole PS 	\$150k
 HEBT dipole magnets (2) 	\$219k







Milestones



Critical Decision and review dates

Neme	V Start	Finish	100	20	05 🔻	Salir	P(V)	2006	1.3	st . 2	1,41	20	J7 😘	EM.	That'	: 20	XX	(S)	7	58	2003		- 1	Walter State	201
	F 4 74 12 1		Q	Q1	Q2	03 (Д.	Q1: [22	Q3	04	01	, Q	2 0	3 Q4	Q	1 G	22	<u>ග</u> [04	ď:	Q2	Q3.	04	ପା
Critical Decisions and Reviews	Meq 84.44	Tue 18:28.89	₹		et is gen	- 1	Ť	****		1. Y.3	- K	747	52.6		900	7	· Mile	E- 41	in it si	220	28700			* 200	7
CDO Approve Mission Need	Wed 8,4,04	Wed 8/4/04	•				l					l													
CD1 Approve Preliminary Baseline Range	. Wed 9/1 4/05	Wed 9/14/05	M			ļ	*																		
CD2 Approve Performance Baseline	Fri 9.11.06	Fri 9/1/06	H	ļ		1	İ				•	·													l
CD3 Approve Start of Construction	Fri 9/1/06	Fr19/1/06		Τ			T				•	T				T						_			Γ
CD4 Approve Start of Operations	Wed 9/30/09	Wed 9/30/09	ŀ l	1		l	1																	4	ģ.
⊕ Office of Ruclear Physics Annual Review	Wed 419/66	Wed 415.49	1.1			Ì	1		<	>				٥				<)	ĺ			◊		
⊕ Quarterly Cost/Schedule/Technical Reviews	Fr11/13/06	Wed 7/15/19		Ì		ļ	1	◊	\	> (\	þ	٥	٥	◊	þ	◊	((}	> (٥	◊		1
☐ Quarterly Report to BSO	Fi1/1346	Wed 7/15.09	i —	T		7	1	0	• (٧ (٥ -	Þ	◊	◊	◊	Þ	◊	7	(>	> (>	\	◊	H
■ Monthly Cost Schedule Reviews	Mon 10/10/05	Mon 14/12/49	. '			ļ	þ	₩	₩	XX	⅏	ķχ	XX	XX	₩	Ж	XX	XX	⅏	α,	XXX	Ж	⅏	⅏	Þ
Monthly Report to Federal Project Director	Thu 19/20/05	Tue 19/29/99				Ī	k	XXX	¢Χ	XX	¢Χ	bo	000	¢Χ	XXX	dχ	XXX	XX	XXX	XX	⅏	XX	XXX	XX	✡

 Milestones will be added for design reviews, design package completions, purchase requisition dates, purchase order dates, delivery dates, payment dates, testing of major systems, etc.





Configuration Mgmt online system



Project Change Request (PCR)

Cost, Schedule, Technical Assessment (CSTA)

Document Change Notice (DCN)

Track Submitted Documents

PCR Status Report

Approvals

Reports

Risk/Contingency List

Implementation Date/Rev. Number

WBS Descriptors

WBS List

Parameters

Configuration Management Plan







July 25-27, 2006

Summary



- •Scope is defined.
- Costs are understood.
- •EBIS Project Team in place.
- •Integrated Project Team defined.
- •Project Controls systems set up.
- •Ready for Preliminary Baseline Approval.







EBIS Overview

Ed Beebe

July 25-27, 2005





. huhu 26.27 2005

Presentation Overview



- Introduction
- · Test EBIS Results
- R&D Plan
- Status of the RHIC EBIS technical design

Introduction



- Experience with the BNL Test EBIS has shown that an EBIS to supply highly charged ions to the Relativistic Heavy Ion Collider (RHIC) and the NASA Space Radiation Laboratory (NSRL) can be built.
 - Test EBIS operation with 10A electron beams required for RHIC EBIS has been achieved.
 - The ion output scales with length, ion charge state is achieved within design confinement times, and the ion electron system has been shown to be stable for ion trap length up to 107cm.
- The RHIC EBIS design will be very similar to the present Test EBIS operating at BNL.
- No significant improvement in performance is required, other than the straightforward scaling of ion output with an increase in trap length.
- Beyond this, changes to the Test EBIS design, which was a device built to demonstrate feasibility, will make the RHIC EBIS an "operational" device, i.e. simpler to maintain, and more reliable due to increased engineering margins on components.

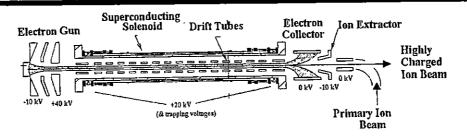


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.ы∾ 25-27, 2005

EBIS principle of operation





Yield of ions in charge state q:

$$N_q = \frac{I_e \times L}{q \times \sqrt{V_e}} \times K_1 \times K_2$$

I_e=electron beam current K₁=neutralization factor

V_e=electron beam voltage K₂=fraction in desired charge state L=trap length

Radial trapping of ions by the space charge of the electron beam.

Axial trapping by applied electrode electrostatic potentials.

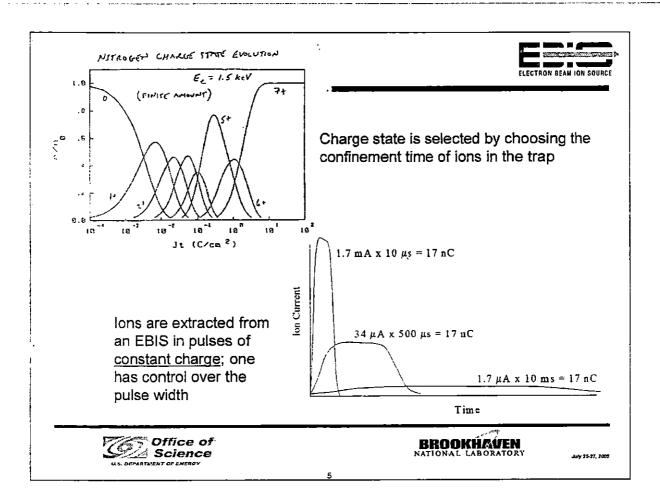
Ion output per pulse is proportional to the trap length and electron current.

Ion charge state increases with increasing confinement time.

Charge per pulse (or electrical current) ~ independent of species or charge state!



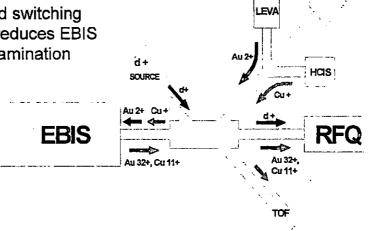
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ELECTRON BEAM ION SOURCE

Injection of "seed ions" from external sources facilitates rapid switching between species and reduces EBIS maintenance and contamination



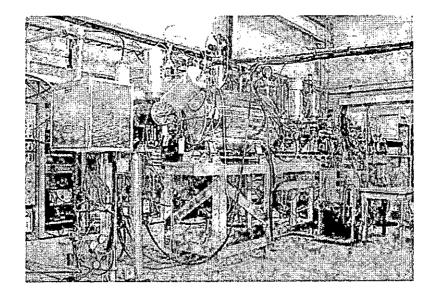
- EBIS Electron Beam Ion Source
- RFQ Radio Frequency Quadrupole Ion Accelerator
- TOF Time-of-Flight Spectrometer
- LEVA Low Energy Metal Vapor Vacuum Arc Ion Source
- HCIS Hollow Cathode Ion Source



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Test EBIS









July 28.27 2005

Test EBIS results and RHIC design parameters



	Achieved	RHIC
Ion	Au ³²⁺	Au ³²⁺
$\mathbf{I_e}$	10 A	10 A (20)
\mathbf{J}_{e}	~575 A/cm ²	575 A/cm ²
$\mathbf{t}_{\mathrm{confinement}}$	35 ms	35 ms
\mathbf{L}_{trap}	0.7 m	1.5 m
Capacity	0.51×10^{12}	1.1×10^{12}
Au neutralization	70%*	50%
% in desired Q	20%	20%
Extracted charge	55 nC	85 nC
Ions/pulse	1.5 x10 ⁹ (Au ³²⁺)*	$3.3 \times 10^9 (Au^{32+})$
Pulse width	10-20 μs	10-40 μs

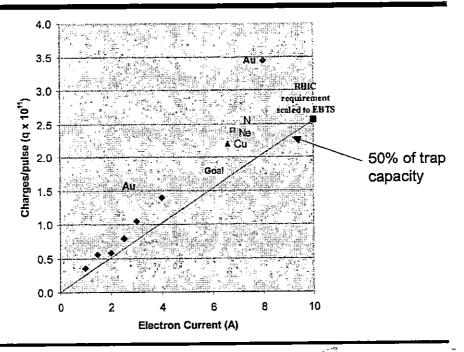
* Estimated result for data with 8A e-beam



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Charge extracted from Test EBIS





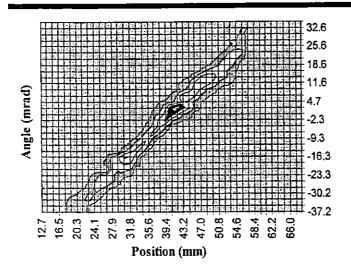


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Measured Emittance for a 1.7mA Gold Beam





Emittance of a 1.7 mA extracted beam from EBIS, with Au injection:

 ϵ (n, rms)= 0.1 π mm mrad.

All charge states, peaked around Au²⁵⁺.

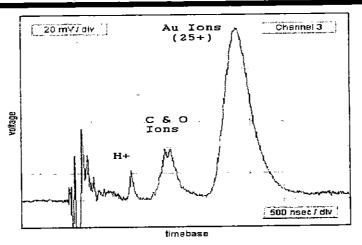
The emittance of light ions from EBIS is expected to be less due to less heating by the electron beam during relatively short confinement times necessary to reach charge states of interest.



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Inline Time-of-Flight showing gold charge fraction





- Full ion beam sampled and collected on Faraday Cup
- I_e= 7A;
- 10 ms confinement
- Au = 83%; C&O = 15%; H = 2%

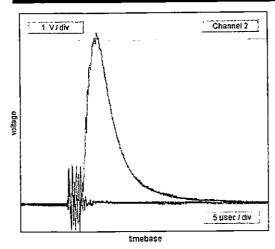


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Adv 25-27, 2005

Test EBIS output after Nitrogen injection from HCIS

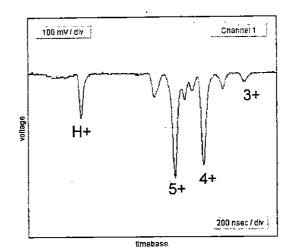




6 mA total current

2.5 x 10¹¹ charges/pulse

 N_2^+ injected from HCIS 3 ms injection, 4 ms confinement I(e) ~ 7A

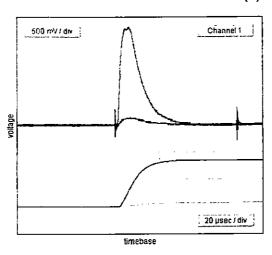


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Test EBIS output after Copper injection from HCIS

ELECTRON BEAM ION SOURCE

I(e) = 6.6 A,



200 mV/div MANUFACTURE PROPERTY. 4.2 ms mental property of the second 17.2 ms 14+ 500 nsec / div timebase

1.8 mA; 2.2x1011 charges/pulse,

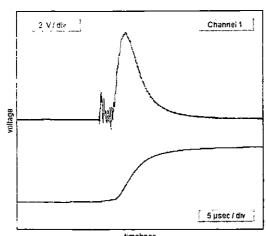
15.3 ms confinement



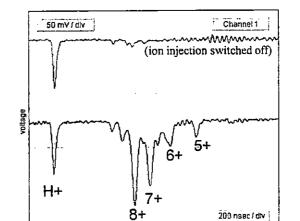
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Test EBIS output after Neon injection from HCIS





6.3 mA peak 2.4 x 10¹¹ charges/pulse 18 ms confinement



 $I(e) \sim 6.8 A$

timebase 14 ms confinement



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R&D



We have defined an R&D plan that will aid us in the design of the Low Energy Beam Transport section and reduce schedule risk during the RHIC EBIS construction. This plan also addresses some recommendations from the January technical review.

R&D using the Test EBIS in FY'05/06:

- Verify Collector design
 - Steps: Build and test RHIC EBIS collector
- · Categorize EBIS emittance at final beam energy
 - Steps: Put EBIS on High voltage platform
- · Verify LEBT design
 - Steps: Build prototype LEBT and measure emittance at RFQ location





July 25-27, 2005

15

R&D



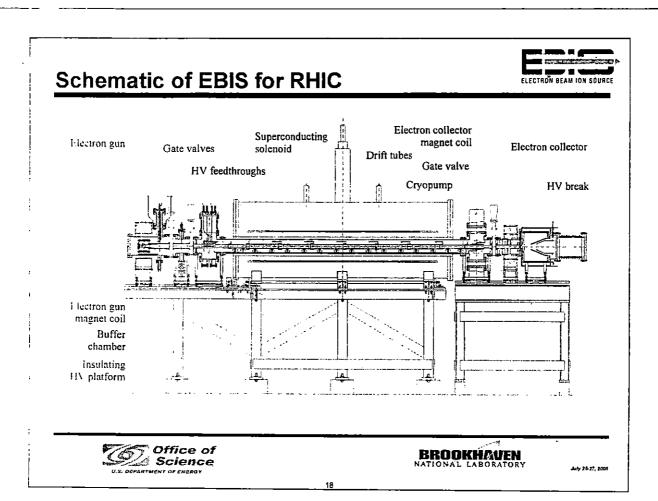
Additional benefits

- Early test of RFQ on Test EBIS
- Use of collector on the RHIC EBIS
- Gain experience with HV pulsing of platform

Through this R&D, designs will be verified ~ 2 years earlier than with RHIC EBIS, giving time to make changes if necessary.



R&D Schedule RECTADE SEAM 109 SOURCE RECTADE



EBIS Source "requirements"



- 1. Intensity for 1 x 10⁹ Au ions/bunch in RHIC: ~3.4 x 10⁹ Au³²⁺ ions/pulse from the source
- 2. No stripping before Booster injection : q/m > 0.16 (Au³²⁺, Si¹⁴⁺, Fe²¹⁺)
- 3. 1-4 turn injection into Booster : pulse width 10-40 μs

(Note - 1 & 3 result in a Au³²⁺ current of 1.6 - 0.4 mA)

- 4. Rep rate: ~ 5 Hz
- 5. Beam species switching: 1 second
- 6. Emittance : $\leq 0.2 \pi$ mm mrad, normalized, rms (for low loss at Booster injection)





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WBS Items



- Superconducting Solenoid
- Electron Gun (up to 20A)
- Electron Collector (300kW peak power)
- · Drift Tube & Chamber Structures
- Stands and Platform Hardware
- LEBT
- External Injection





RHIC EBIS Superconducting Solenoid (SCS)



· Length of the SCS coil:

200 cm

Test EBIS: 100cm

Magnet field:

6 T

Test EBIS: 5T

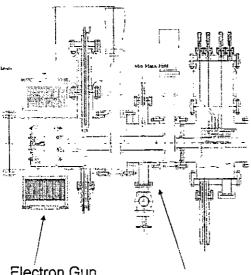
- provides the same magnetic compression of a 20 A electron beam as for 10 A beam
- decreased average power on electron collector
- increased magnet field in transport region outside solenoid
- higher ion charge states if necessary
- Warm bore inner diameter: 204 mm (8") Test EBIS: 155mm (6")
 - 1.7 times increased vacuum conductance
 - more room for HV leads
- This item will be provided by a vendor

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Gun and gun transition regions





- Replaceable electron gun chamber:
 - Minimized vacuum disturbance
 - Pre-conditioned electron gun
 - Fast turn around times
 - Increased EBIS reliability

Electron Gun Chamber with Launching Solenoid

Buffer Chamber with Pump-out port

Gun Transition Chamber

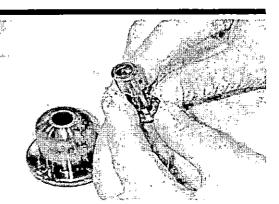


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Electron Gun



- The existing 10 A electron gun with IrCe cathode meets the RHIC EBIS requirements, with an estimated lifetime of >20,000 hours.
- The present cathode is actually capable of operating at 20 A with lifetime of 3000-5000 hours.



In order to have a reserve for a possible future increase of the ion beam intensity, we are building the electron gun electrodes and collector with the capability of operating up to 20 A.





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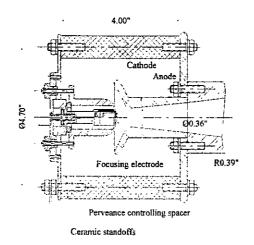
23

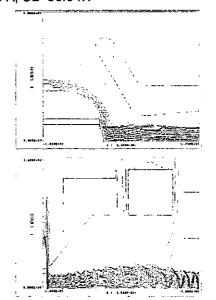
Electron Gun Design



Electron gun

Electron beam transmission from the electron gun. lel=20.5 A, Ua=38.5 kV



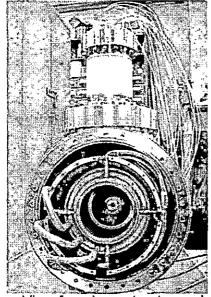


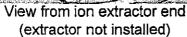
Office of Science

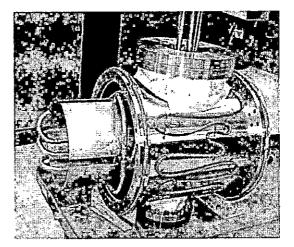
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Test EBIS 50kW Electron Collector









Electron Collector and Vacuum Housing



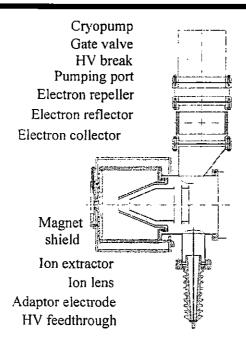


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RHIC EBIS electron collector assembly design





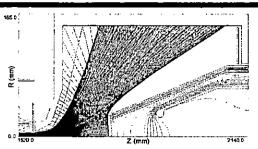
- Designed to dissipate P_{el}= 300 kW peak power
- More uniform distribution of e-beam
- Increased surface area (2300 cm²)
- Calculated max power density on EC surface (for 300 kW): p_{max}= 485 W/cm²
- Outer surface of collector is at atmosphere (no internal cooling lines).



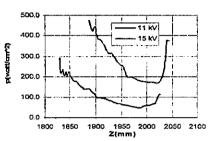
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Simulations for 20A, 15keV electron beam

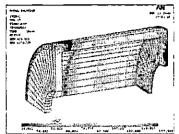




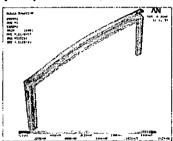
20A electron beam trajectories in EC



Electron beam power density distribution on EC surface



ANSYS simulation of temperature distribution in EC at peak power. 20 A, 15 kV, 50% DC



Von Mises stress distribution at peak power



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2

Electron collector simulation results and status



- RHIC EBIS electron collector was designed and simulated for 300 kW electron beam power.
- After analysis of several EC material we selected Brush Wellman copper-beryllium alloy Hycon-3, because it has the largest margin between the yield stress and the resulting stress.
- ANSYS stress simulations demonstrate, that for 50% duty cycle (50 ms ON, 50 ms OFF) and 15% duty cycle (30 ms ON and 170 ms OFF) the average values of stresses and their amplitudes provide life time before fatigue failure well over 10⁸ cycles.
- The electron collector has had a design review and is expected to be ordered from Brush Wellman in about a month.





Central Drift Tube Structure



Solid thin-walled outer tube

Perforated thin-walled inner tube

NEG strips ST172NP in the gap between tubes

Potential lead (0.25" tube)

Ceramic standoffs

Tube support

Tube support

Similar to existing Test EBIS drift tube structure.

Design in advanced stage, detail for adjustable mounts needs work.



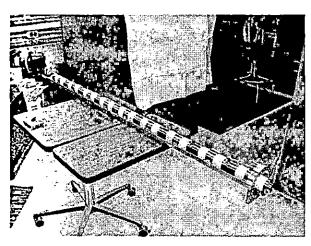
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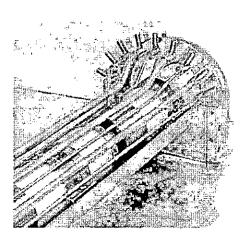
29

Test EBIS Drift Electrode Structure





 Drift electrode structure spans the length of the central vacuum chamber within the Test EBIS Superconducting Solenoid bore



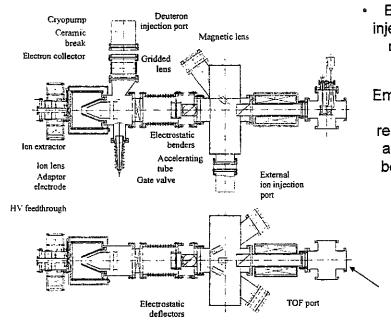
Close-up of electrical leads



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LEBT (hardware view)





 Beam switching in the injection line and LEBT is made in electrostatic bender switchyards

Emittance measurements
will be made in a
removable test chamber
at the end of the LEBT
before the RFQ arrives

Emittance measurement chamber (removable for LEBT attachment to RFQ)

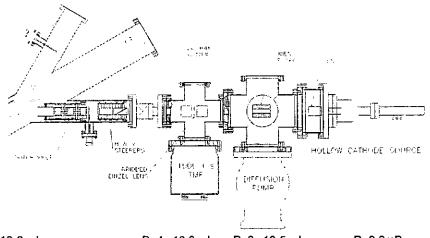


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A.A. 22 27 2001

Hollow cathode source pumping and ion optics





P~4x 10-8 mb

P~4x 10-6 mb P~8x 10-5 mb

P~0.8mB

 P_{EBIS} ~2x10⁻¹⁰ mb for P_{HCIS} ~1mb, 10ms, 1Hz shutter operation

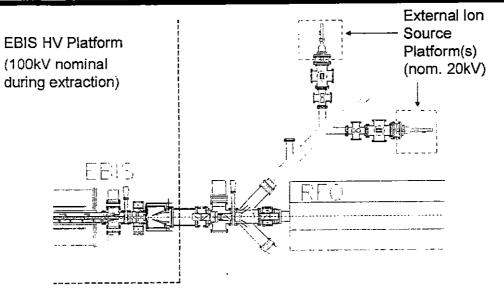
"Seed ions" will be provided from relatively low cost ion sources which have been tested and developed to meet our needs in our laboratory.



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LEBT Layout showing External Ion Injectors and HV Platforms





EBIS Platform: 0V during Ion Injection and confinement; 100kV during ion extraction

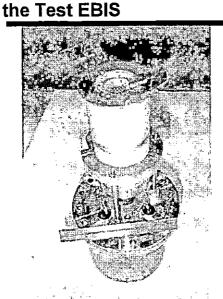


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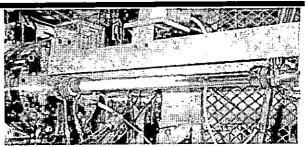
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External sources used for primary ion injection at





Low Energy Vacuum Arc Source (I. Brown); used very successfully for Au injection



Hollow Cathode Ion Source (HCIS), based on design used on Saclay EBIS.

Discharge current = 0.5 - 4 A
Plasma electrode diameter = 1 mm
V(extraction) ~ 15 kV
Source has produced:

45 μA of Cu⁺ 130 μA of Ne⁺ 27 μA of N₂⁺.

These currents are sufficient for seeding the EBIS trap.



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Comments on Schedule



- Components of the RHIC EBIS will be designed, manufactured or procured. Assembly in a temporary location will then start in mid-FY'07.
 - This will allow testing of vacuum and high voltage (no beam testing is planned)
- The EBIS will be moved to its final location as a unit, in Q1, FY'08.





Adv 25.27 2005

3.

Procurements / fabrication (R&D)



- Full power electron collector (later used on the final EBIS)
- High voltage isolation transformer (later used on the final EBIS)
- · High voltage insulating break
- Controls for the EBIS HV platform ps's
- · Platform components
- LEBT chambers, solenoid, components
- Prototype pulsed HV power supply





EBIS R&D costs



Estimated Costs

	Direct FY'05K\$			
Description	Mat'l	Labor	Contingency	Total
R&D	345	383	\$145 (20%)	873

Costs for the EBIS construction and testing will be presented in the detailed talks tomorrow.







WBS 1.1 Structural Components (EBIS, LEBT, External Sources)

Alexander Pikin

July 25-27, 2005





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1. Superconducting solenoid



Will be purchased from the outside vendor, possibly American Magnetics Inc.

Needs to be done at BNL:

- Finalize requirements,
- Final assessing of magnetic field,
- Inspection, installation, safety review.

Procurement: \$328,299

Base for the cost: 2005 Quote from American Magnetic Inc.





2. Electron gun



Provides:

- I el=20 A
- j_emission=35 A/cm²
- Operation in a wide range of current, voltage and magnetic field
- Versatility (variable electron beam profile and perveance)
- Maintainability (robust design, replaceable unit)





Degree of readiness of the electron gun:



Has been done:

- Simulated electron beam extraction and propagation in anode and first drift tubes,
- The mechanical design of the gun is nearly complete

Needs to be done:

- Final simulations with final magnetic field,
- Procurements, manufacturing, testing.

Required resources:

Base for estimate:

Procurements ('05\$): \$53,000

Quote for cathodes from BINP

Manpower:

\$53,899

(Novosibirsk), catalogs.



BROOKHAVEN

3. Drift tube structure



Proposed DT structure:

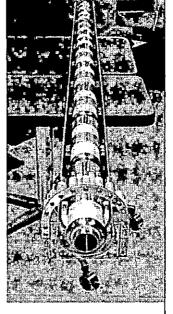
- Larger ID of drift tubes (42 mm instead of existing 31mm),
- Internal pumping capability (NEGs) for better vacuum.
- Design is based on existing design and experience.

We have conceptual design and assembly drawing

Procurements ('05\$): \$80,000

Base for estimate: cost of existing structure

(Historical cost)







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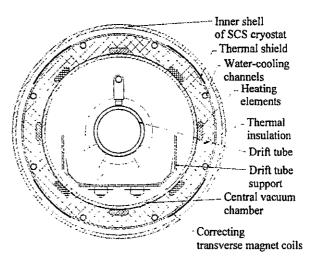
4. Central chamber with its heater



Provides:

- Housing for drift tubes and HV leads,
- Bakeout and magnetic steering of the electron beam

We have: assembly design based on EBTS prototype, technology "know how".



Procurements ('05\$): \$20,000

Base for estimate: catalogs, prototype cost.



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5. Collector-transition chamber



Provides:

- Part of electro- and magneto-optical structure between central chamber and electron collector
- Vacuum separation between electron collector and central chamber
- Vacuum pumping and monitoring
- HV drift tubes connections
- Electron beam loss monitoring

Design is based on using standard elements.

We have: assembly drawing and vacuum separation design, design & technology of magnet coil, prototype "know how".

Procurements ('05\$):

\$15,442

Base for estimate: MDC, ISI catalogs, engineering judgment.



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6. Stands, Platform hardware



Includes:

- Stands,
- Manifolds.
- Fast ion extraction unit,
- Transverse coils.

Provides:

- Support of major EBIS parts,
- HV insulation.
- Cooling water and pressurized air distribution,
- Controlled high speed ion extraction,
- Magnetic control of electron beam propagation







WBS 1.1 Structural Components (EBIS, LEBT, External Sources)

Alexander Pikin

July 25-27, 2005





July 25-27, 2008

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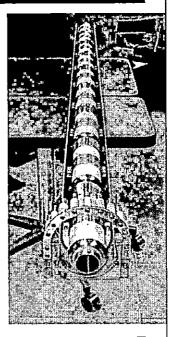
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(Historical cost)







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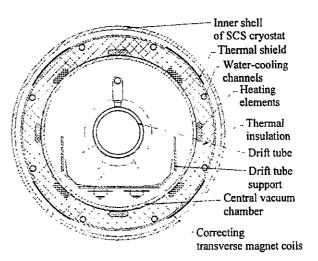
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- Bakeout and magnetic steering of the electron beam

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Base for estimate: catalogs, prototype cost.



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6. Stands, Platform hardware



Includes:

- Stands,
- Manifolds,
- Fast ion extraction unit,
- □ Transverse coils.

Provides:

- Support of major EBIS parts,
- HV insulation,
- Cooling water and pressurized air distribution,
- Controlled high speed ion extraction,
- Magnetic control of electron beam propagation





6. Stands, Platform hardware



We have: EBTS prototype design of supports, and manifolds, prototype of fast extraction unit.

Required resources:

Procurements ('05\$): \$85,000 Manpower: \$103,402

Base for estimate: engineering judgment





July 25-27, 2005

7. LEBT



Provides:

- Transport of the beam of highly charged ions extracted from EBIS to the RFQ
- Transport of the primary ion beam from an auxiliary ion source to EBIS
- Transport of the deuteron beams from additional ion source to the RFQ
- Ion beam diagnostics.







WBS 1.1 Structural Components (EBIS, LEBT, External Sources)

Alexander Pikin

July 25-27, 2005



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- Final simulations with final magnetic field,
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Required resources:

Base for estimate:

Procurements ('05\$): \$53,000

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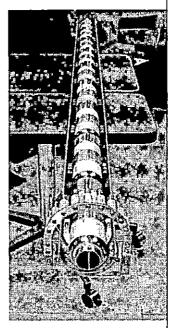
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(Historical cost)









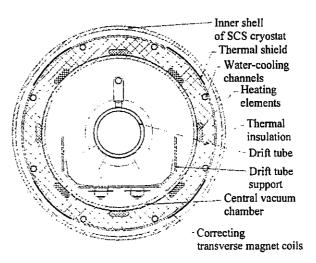
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- Bakeout and magnetic steering of the electron beam

We have: assembly design based on EBTS prototype, technology "know how".



Procurements ('05\$): \$20,000

Base for estimate: catalogs, prototype cost.



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5. Collector-transition chamber



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Procurements ('05\$):

\$15,442

Base for estimate: MDC, ISI catalogs, engineering judgment.



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6. Stands, Platform hardware



Includes:

- Stands.
- Manifolds.
- Fast ion extraction unit.
- Transverse coils.

Provides:

- Support of major EBIS parts,
- HV insulation.
- Cooling water and pressurized air distribution,
- Controlled high speed ion extraction,
- Magnetic control of electron beam propagation





6. Stands, Platform hardware



We have: EBTS prototype design of supports, and manifolds, prototype of fast extraction unit.

Required resources:

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Base for estimate: engineering judgment





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7. <u>LEBT</u>



Provides:

- Transport of the beam of highly charged ions extracted from EBIS to the RFQ
- Transport of the primary ion beam from an auxiliary ion source to EBIS
- Transport of the deuteron beams from additional ion source to the RFQ
- lon beam diagnostics.



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7. <u>LEBT</u>



We have:

■ Preliminary optical simulation of the ion extraction from EBIS and propagation in LEBT structure,

A version of mechanical design with assembly drawing.

Required resources:

Procurements ('05\$): \$82,000 Manpower: \$66,237

Base for estimate: Quote for accelerating tube from BINP (Novosibirsk), catalogs, engineering judgment.

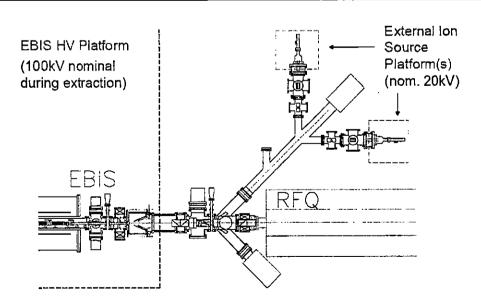


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8. External ion injection







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8. External ion injection



Provides:

- Primary beams of low charged ions for injection into EBIS,
- Transport of primary ions to LEBT,
- Control of used ion source or selection of ion species,
- Vacuum pumping with vacuum separation.

We have:

- Developed versions of hollow cathode ion source and LEVA,
- Developed methods of mass-separation, vacuum separation and pumping.

Required resources:

Procurements ('05\$): \$75,554 Manpower: \$63,802

Base for estimate: catalogs, engineering judgment.





....

9. Electron collector (R&D)



Provides:

- Controlled dissipation of the electron beam,
- Heat removal from electron beam power,
- Ion beam extraction, transport and injection,
- Vacuum pumping.

We have:

- Optical simulations of electron and ion beam transmission,
- Thermal, hydraulic, stress simulations, critical power density and fatigue analysis,
- Mechanical design with design review.

This will be procured/fabricated as part of the R&D, but will later be used on the final EBIS.





Risk assessment



Components	Risk	Mitigations
Electron gun	Low	
Electron collector	Technical (advanced materials and technologies)	Early procurement, test in R&D
Superconducting solenoid	Cost	40% contingency
LEBT	Technical (still in design & simulation stage)	Test in R&D





Ady 25-27, 2005

WBS 1.1 Structural Components



Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'l	Labor	Contingency	Total
1.1	Structural Components	1675	680	\$665 (28%)	3020
	EBIS, LEBT, external inj	770	480	\$320 (26%)	1570
	RFQ, Linac, Bunchers	905	200	\$345 (31%)	1450

Labor hours/equivalents

	EBIS, LEBT, external inj
Resource Category	estimated hours
Scientist	1,760
Engineer	2,255
Designer	5
Technician	2,540
Management	275
Building Trades	50
Total	6885
Full Time Equivalents	3.9





Conclusion



- Design of all components of RHIC EBIS is based on tested design of similar components of the Test EBIS, with improvements in reliability, maintainability, vacuum quality.
- Most of RHIC EBIS components are in an advanced design stage with simulations and calculations mostly done.
- For prototypes of the most critical components (electron collector, LEBT) R&D study is planned in advance of final manufacturing.





LA. 25.27 2008



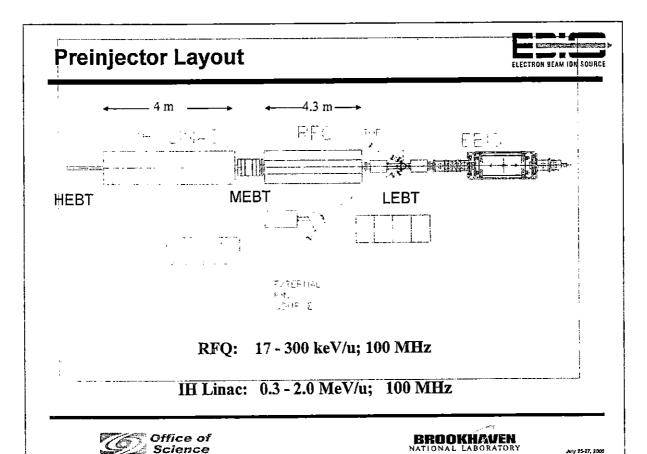
WBS 1.1 Structural Components RFQ, Linac, & Bunchers

Jim Alessi

July 25-27, 2005



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RFQ (vs. CERN Pb RFQ)



Parameters	BNL	CERN	Units
Type	4-rod	4-rod	
Q/m	0.16-0.5	0.12	
Input Energy	16.2	2.5	keV/amu
Output Energy	314.72	250	keV/amu
Frequency	101.28	101.28	MHz
Max rep rate	10	10	Hz
Length	4.37	2.5	meters
Number of cells	277		
Aperture Radius	0.005	.0045	meters
Voltage	69	70	kV
E(surface)	20.8	≤ 23	MV/m
RF Power	< 350	< 350	kW
Acceptance	1,.7	> 0.8	E mm mrad (nor)
Input Emittance	0.35		nt mm mrad, nor, 90%
Output Emittance (trans)	0.375		π mm mrad, nor, 90%
Output Emittance (longit)	33.6		π MeV deg, 90%
Transmission	91	93	%
Bravery factor	1,8	≤2	Kilpatrick





July 15-27, 2005

IH Linac (vs. CERN Pb IH)



Parameters	BNL	CERN Tank 1	Units
Q/m	0.16-0.5	0.12	
Input energy	0.314	0.250	MeV/amu
Output Energy	2.08	1.87	MeV/amu
Frequency	101.28	101.28	MHz
Max rep rate	5	10	Hz
Length	4.0	3.57	Meters
Input emittance	0.55		πmm mrad, norm. 90%
Output emittance	0.61		π mm mrad, norm, 90%
Output energy spread	20.0		keV/amu
Transmission	100		%

Two quadrupole triplets inside for focusing.

The maximum field on the axis will be 13.5 MV/m.

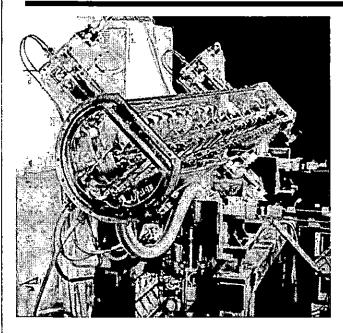
Fixed output velocity, independent of the q/m of the desired beam (cavity gradient is adjusted for different q/m's, to maintain a fixed velocity profile).



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REX-Isolde RFQ





5 keV/u to 300 keV/u 101.28 MHz Q/m= 1/4.5 (1/6.5 possible) L=3m R_s =146 kΩ/m P=30 kW Q=4050

~GSI HLI-Linac and Heidelberg high-current injector

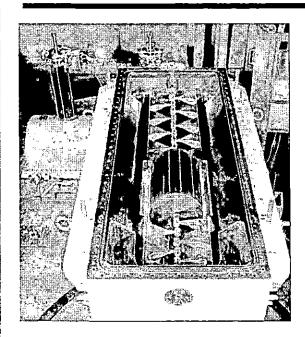


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July 25-27, 2005

REX-Isolde IH Linac





0.3 MeV/u to 1.2 MeV/u 101.28 MHz L=1.5 m Q/m=1/4.5 R_s =330 M Ω /m P=65 kW

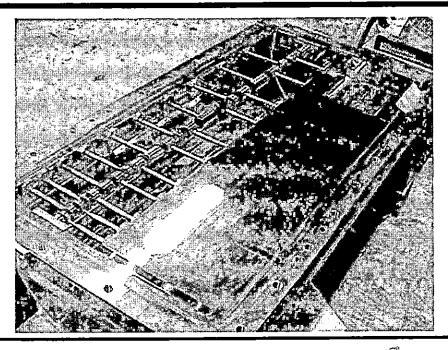
~GSI HLI-IH and CERN Tank1



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RIKEN - Okamura





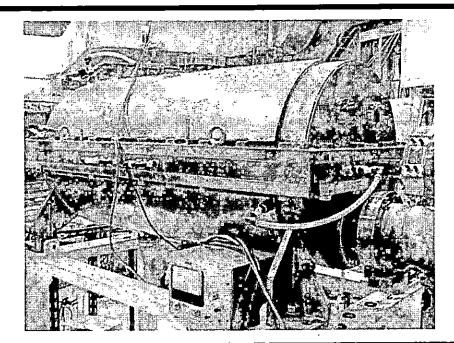


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July 25-27, 2008

RIKEN - Okamura



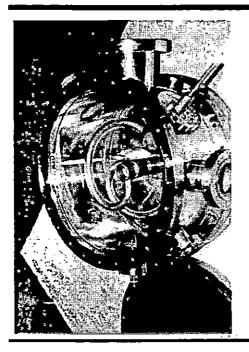




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REX-Isolde Bunchers (split-ring)





Q/m=1/4.5 101.28 MHz L=0.2 m, 3 gaps (70 kV integrated) P= 2 kW

~GSI HLI and CERN Pb linac





Adv 25-27, 2005

SCOPE



Procurement of the following devices:

RFQ:

100 MHz, 4 rod design is conventional. Very similar to GSI, CERN, etc. Will buy RFQ from Frankfurt.

LINAC:

IH structure chosen, very similar to CERN Pb linac. (conventional baseline design).

Will probably get IH from GSI / Frankfurt.

Will still investigate alternatives (electrostatic focusing) in FY'06.

Bunchers – 1 in MEBT, 2 in HEBT (Frankfurt)

Discussions and correspondence with Frankfurt (Schempp, Ratzinger) – they are ready to build the RFQ and Linac for the project.





RFQs and Bunchers supplied by Schempp



11.7.05

Projects: RFQs built for other institutions

GSI: HLI RFQ EZR

HSI * MeVVa,Cordis SCR He+

SCR He+
Spiral Cordis
ESS-prototype Duopi. p
DESY 750keV inj.i Magnetron

Magnetron 18keV inj. 25 mA
Bucket 35keV 50mA
Penning 5%df 35mA ISIS injector

25% df.

27MHz U 2+

Decelerator

HE-Implanters Med.Therapy acc.

20%df

cw-cyclotron injector

DESY 750keV inj.il Bucket
RAL I,II Penning
MISI Stockholm EBIS
Saclay EBIS

Lyon Cluster m=50
Lyon Cluster m=1000

CERN /Orsay p-bar Lear
MPI Heidelberg I,II* EZR, Cordis

LMU München/Rex-Isolde* EZR,Isol
HMI-Berlin I,II EZR
DeBTec volume p,D

Pred-HD EZR p-C

GSI/Heldelberg IKF EZR

Riken Laser-IS 60mA C4+
*=collaboration

Besides RFQs, there were appr. 20 Buncher, Rebuncher, Post acc Cavities "exported" CERN 4, GSI 6, Desy 3, Rex 1, SA 1, MSI, SacI,Pr. 3,IKF 2 resonators,



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Aut 25-27, 2005

WBS 1.1 Structural Components



- Major procurements (direct costs, '05\$):
- RFQ: 340 k\$; 30% contingency
 - Linac: 400 k\$; 40% contingency
 - Bunchers: 3 @ 33 k\$; 30% contingency
- Risks
 - Technical risk is low
 - Schedule risk both are on critical path for the project
 - Cost risk \$/Euro

0.54 alsoriers

0.55 Over past 2 years

0.56 Over past 2 years

0.66 Over past 2 years

0.76 Over past 2 years

0.77 September 1 years

0.77 September 1 years

0.78 Nitro// leaster system over 2 years

0.79 Nitro// leaster system over 2 years



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Schedule



RFQ procurement early in FY'06 with NASA \$ ~ 18 month delivery; test ~ Q3/4 of FY'07 (on Test EBIS)

Linac procurement in FY'07; install in Q4, FY'08. (gives ~ 1 year to investigate alternative linac options)





July 25-27, 2005

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WBS 1.1 Structural Components



Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'l	Labor	Contingency	Total
1.1	Structural Components	1675	680	\$665 (28%)	3020
	EBIS, LEBT, external inj	770	480	\$320 (26%)	1570
	RFQ, Linac, Bunchers	905	200	\$345 (31%)	1450

Labor hours/equivalents

	RFQ, Linac, Bunchers
Resource Category	estimated hours
Scientist	865
Engineer	920
Designer	120
Technician	860
Management	0
Building Trades	0
Total	2765
Full Time Equivalents	1.6







WBS 1.4 Magnet Systems

John Ritter

July 25-27, 2005

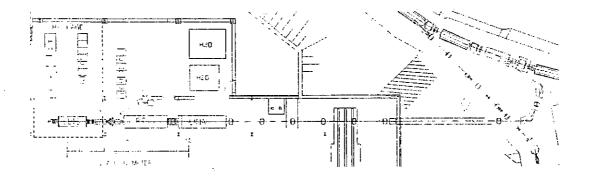


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July 25-27, 2005

WBS 1.4 Magnet Systems





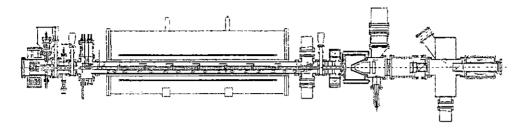
- 1.4.1 EBIS Warm Solenoids
- 1.4.2 MEBT Quadrupoles
- 1.4.3 HEBT Dipoles
- 1.4.4 HEBT Quadrupoles



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WBS 1.4.1 Warm Solenoids





Length Aperture Gradient Field
Electron Gun Solenoid 15.3 cm 25.4 cm 1.4 T/m .22 T
Electron Collector Solenoid 12.7 cm 25.4 cm 1.2 T/m .15 T
EBIS LEBT Solenoid 24.1 cm 10.2 cm 5.2 T/m 1.25 T



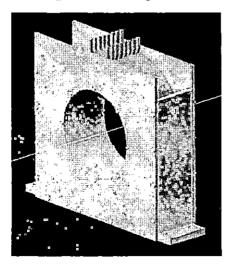


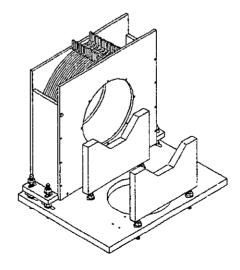
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WBS 1.4.1 Warm Solenoids



Electron Gun Solenoid and Collector Solenoid similar in design to existing solenoids installed on Test EBIS.





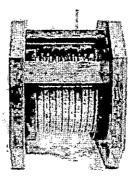


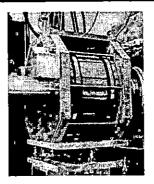


WBS 1.4.1 Warm Solenoids







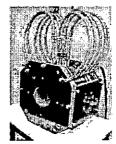


Design of EBIS LEBT Solenoid similar to Existing LEBT Solenoid (H- LINAC) design.

Material/Procurements (Direct '05\$)

Laminations for LEBT Solenoid \$10K Coil Material \$9K Magnet support/mount \$12K Magnet Components \$30K

Estimate based on magnets built for EBIS and LINAC.



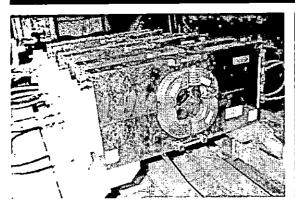


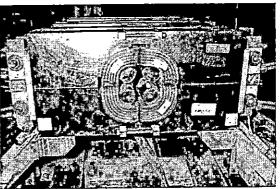


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WBS 1.4.2 MEBT Quadrupoles







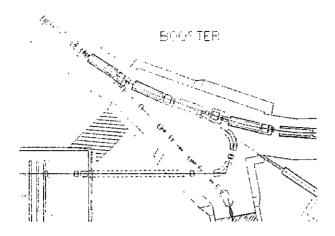
45 mm-long pole LANL Quads are available at BNL. Estimate includes support system of magnets and necessary water manifolds.





WBS 1.4.3 HEBT Dipoles





Bend Angle 73° Gap 12.7 cm Radius 128 cm Field 1.1T Pulse Rate 1 Hz Turns per coil 20 2 coils/magnet Current 2780A @ 1.1T Power 29.6 KW/magnet Voltage 10.65 V **Maximum Current** 3285@1.3T Maximum Power 41.4 KW Maximum Voltage 12.59 V

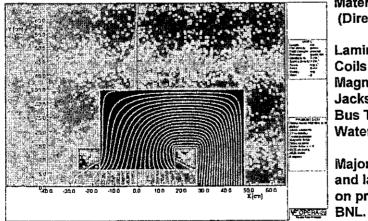


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.HOV 25-27, 2005

WBS 1.4.3 HEBT Dipoles





Material/Procurements (Direct '05\$)

Laminations \$126K
Coils \$57K
Magnet Stands \$20K
Jacks \$3.6K
Bus Terminations \$8K
Water Manifolds \$4K

Major items in estimate are coil and lamination cost. Cost based on prior magnet purchases at BNL.

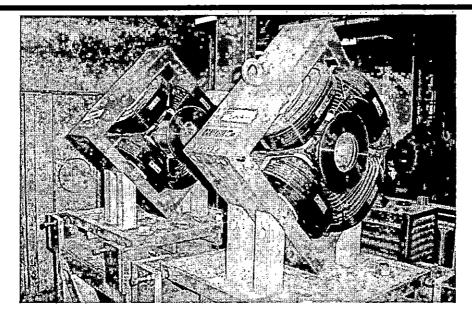
Steel Laminations \$7.98 / lb. Wound Coils \$17.98 / lb.



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WBS 1.4.4 HEBT Quadrupoles





Air-Cooled Quads and magnet stands available at BNL



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. No. 25.37 200

WBS 1.4 Magnet Systems



- Major procurements: (Direct '05 Cost)
 - 1.4.1 Warm Solenoids \$61K
 - 1.4.2 MEBT Quads \$12K
 - 1.4.3 HEBT Dipoles (2) \$219K
 - 1.4.4 HEBT Quads N/A
- Risks:

Increase in foreign currency exchange rates
Drastic increase in price of raw materials
Vendor delays affecting schedule





WBS 1.4 Magnet Systems



Estimated Cost

			Direct FY'05K\$		
WBS	Description	Mat'i	Labor	Contingency	Total
1.4	Magnets	295	155	\$95 (21%)	545

Labor hours/equivalents

Bassuras Catagory	estimated
Resource Category	hours
Scientist	325
Engineer	875
Designer	450
Technician	600
Building Trades	50
Total	2,300
Full Time Equivalents	1.3





Auly 28-27, 2000

Platform Power – Isolation Transformers



Design Considerations

- Provides isolated power to the EBIS, Cathode, and Reflector platforms
- Low inter-winding capacitances minimize current requirements of offset supplies and improves tracking between platforms

Function	Primary	Secondary	Power	Isolation	Cost
Electron Gun Platform	480 VAC, 3φ	480 VAC, 3φ	400 kVA	100 kV	-
EBIS Platform	480 VAC, 3φ	208 VAC, 3φ	20 kVA	20 kV	\$ 15.0 k
Suppressor Platform	480 VAC, 1φ	120 VAC, 1φ	1 kVA	20 kV	\$ 5.0 k





July 25-27, 2005

EBIS Platform - PS Operation / Sequence



- Fill The EBIS platform PS is off. This allows the EBIS to be filled from one of the two external ion sources, which are at ground potential. Having these sources at ground potential makes their maintenance easier.
- HV Pulse The EBIS platform is pulsed to 100kV. As all other platforms are reference to the EBIS platform, they all rise as well. Once at full voltage, the flattop will be maintained for a minimum of 40 µsec.
- Extraction Some of the drift tube power supplies are pulsed by fast solid state switches to extract the ion beam from the EBIS.





Platform Power - Voltage Offset



Design Considerations

- EBIS Platform PS: Provides pulses with two levels of amplitude with flat-tops of 10 – 40 μs widths. Either an tetrode or IGBT design could be used based on detailed design (see next slide).
- Cathode Platform PS: Static offset to the EBIS platform supply
- Reflector Platform: Static offset to the Cathode platform by the electron collector power supply, not a separated offset supply

Function	Voltage	Current	Operation	Cost
EBIS Platform PS	100 kV	0.2 A	Pulsed	\$ 78.7 k
Cathode Platform PS	20 kV	20 mA	DC	\$ 13.4 k

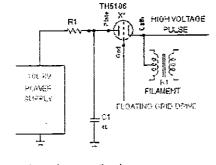


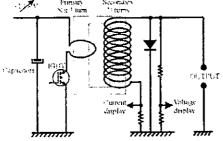


July 25-27, 2008

EBIS Platform PS - Design Trade - Offs







Tetrode

- Continuously variable rise & fall times if needed to control tracking between platforms
- · Modulation by tube in linear operation
- · Integrated at BNL

IGBT

- · Fixed rise and fall time
- Modulation by dual primary windings with independent DC sources - IGBT in switch mode
- · Purchased part



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These supplies are all operated as static power sources, except the cathode heater, which is a ramped, current regulated supply.

Function	Voltage	Current	Power	Qty	Unit Cost
Cathode Heater	20 V	20 A	400 W	1	\$ 9.0 k
Anode	40 kV	20 mA	800 W	1	\$26.8 k
Reflector	1 kV	10 mA	10 W	1	\$ 2.2 k
Repelier	1 kV	10 mA	10 W	1	\$ 2.2 k
Electron Collector	15 kV	15 A	225 kW	1	\$ 200 k
Ion Extractor	10 kV	20 mA	200 W	1	\$ 5.0 k
Gun Solenoid	50 V	200 A	10 kW	2	\$ 9.5 k
Collector Solenoid	60 V	250 A	15 kW	2	\$ 9.5 k
Transverse Magnets	20 V	20 A	400 W	8	\$ 2.5 k





July 25-27, 2005

Platform Power - Drift Tubes



Design Considerations

- The power supplies are operated statically. The output waveform is created by the fast HV switches.
- These waveforms are monitored by the high speed (100 kHz) version of the Power Supply Interface.

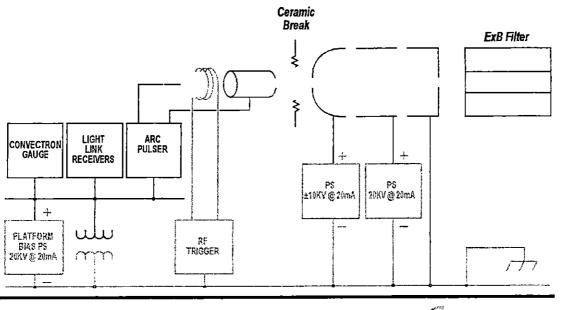
Function	Туре	Ratings	Qty	Unit Cost
Drift Tube PS	Trek 20/20	20 kV, 20 mA	7	\$ 13.4 k
Fast HV Switch	HTS 20103 GSM	20 kV, 30 A	3	\$ 3.5 k





External Ion Injectors & LEBT









July 25-27, 2006

Ion Source Power Elements (Two Units)



- Bias for the Pulser Platform
 - Bias PS: 20 kV @ 20 mA, DC supply (\$ 13.4 k)
 - Isolation Transformer: 120 VAC to supply power to the Arc Pulser and electronics on the platform (\$ 2.5 k)
- Arc Pulser (\$ 15.0 k)
 - Storage Capacitors: Provides pulse energy
 - Variac & Step-Up Tx: Charging supply for the capacitors
 - Heater PS
- RF Trigger Supply (\$ 4.0 k)
 - Initiates discharge





Ion Source Transport Power Elements (Two Units)



- · Static Supplies
 - Extractor PS: 10 kV @ 10 mA (\$ 4.0 k)
 - Lens Supply: 20 kV @ 20 mA (2 units @ \$ 26.8 k ea)
- · Steering
 - Fast Electrostatic Bend: 4 kV @ 1 mA (2 units @ \$ 16.0 k ea)
 - ExB Deflector: +/- 750 V @ 60 mA (\$ 1.2 k)
 - ExB Magnet: 10 V @ 4 A DC (\$ 0.2k)





Arty 23-27, 2005

LEBT Power Elements



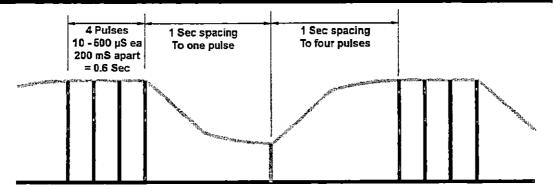
- Steering / Switching
 - Beam Line Steerer: +/- 750 V @ 60 mA (8 units @ \$ 1.2 k ea)
 - Fast Electrostatic Bend: 4 kV @ 1 mA (4 units @ \$ 8.0 k ea)
 - Electrostatic Lens: 30 kV @ 20 mA (2 units @ \$28.0 k ea)
- Matching
 - Pulsed Solenoid: 2,000 A @ 100 V (\$ 75.0 k)
 - Current Wave Period: 2.6 seconds





Pulsed Operation of Magnet Power Supplies





- •The LEBT solenoid, MEBT quads, LINAC quads, HEBT quads, and HEBT dipoles are all pulsed with this wave shape.
- •The L*di/dt requirements of this current wave shape for the magnets require higher voltages on the power supplies, especially the HEBT big bend.



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but 25.27 2005

1.

Sample Pulsed Magnet PS Calculation



This is an example of how the power supply for the big bend dipoles at the end of the HEBT were determined to require 250 V for the pulsed waveform.

- Magnet Parameters: R = 7.6 mΩ, L = 10 mHy, Imax = 3,285 A
- Inductive Voltage: Maximum slew rate of full current in 0.5 seconds. Then, V_L = 10 mHy * 3,285 A / 0.5 sec = 65 V.
- Magnet IR Drop: V_R = 3,285 A * 7.6 mHy = 25 V
- For Two Magnets with 25% overhead:
 V_M = 1.25 * 2 magnets * (65 V + 25V) = 225 V
- Cable Losses: Run from the LINAC to the series connected magnets. Assume round trip losses of 25 V.



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MEBT, IH LINAC, & HEBT



- MEBT
 - Quads: 450 A @ 20 V, Two quadrant in voltage (4 units @ \$ 18.4 k ea)
 - Steerers: 15 A @ 35 V, Four quadrant (4 units @ \$ 4.5 k ea)
- LINAC
 - Quads: 450 A @ 20 V, Two quadrant in voltage (6 units @ \$ 18.4 k ea)
- HEBT
 - Big Bend Dipoles: 3285 A @ 250 V, Two quadrant in voltage (\$ 150.0 k)
 - Quads: 25 A @ 35 V, Two quadrant in voltage (4 units @ \$ 4.5 k ea)
 - Steerers: 15 A @ 35 V, Four quadrant (12 units @ \$ 4.5 k ea)





h.t. PF 57 500

15

WBS 1.5 Power Supplies



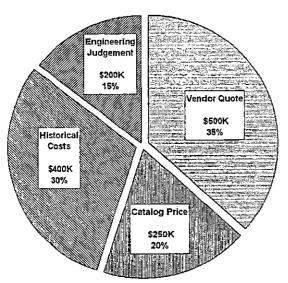
- Major procurements:
 - EBIS Electron Collector PS
 - Pulsed High Current PS: LEBT solenoid & HEBT big bend
- · Deliverables:
 - Everything here except Electron Gun Platform isolation transformer (400kVA).





WBS 1.5 Power Supplies - Cost Summary





Cost Distribution Direct FY'05K\$					
	Material	Labor			
EBIS Platform	\$ 530	\$ 80			
Ext. Injectors & LEBT	\$ 330	\$ 50			
MEBT, IH LINAC & HEBT	\$ 490	\$ 65			
Totals	\$ 1,350	\$ 195			

Basis of Material Costs

Total Cost \$ 1,545K



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WBS 1.5 Power Supplies



Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'l	Labor	Contingency	Total
1.5	Power Supply Systems	1350	195	\$400 (26%)	1945

· Labor hours/equivalents

Resource Category	estimated hours
Engineer	1,475
Designer	975
Total	2,450
Full Time Equivalents	1.4



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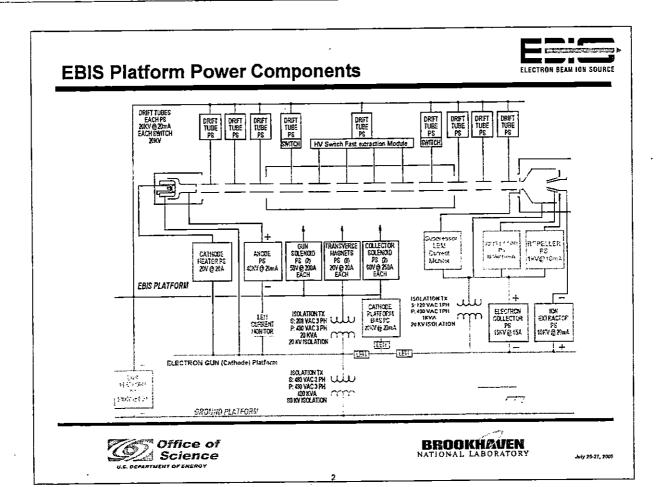
WBS 1.5 Power Supplies

Bob Lambiase

July 25-27, 2005



BROOKHAVEN NATIONAL LABORATORY





WBS 1.6 RF Systems

Alex Zaitsman

July 25-27, 2005





July 25-27, 200

1.6 RF SYSTEM for EBIS



Five RF systems:

- Radio Frequency Quadrupole (RFQ)
- · Inter-digital-H structure (IH) Linac
- Three buncher / debuncher cavities.



EBIS RF SYSTEMS



The RFQ and IH Linac RF systems will be pulsed systems with the pulse width of 1 mS running at 5 Hz, 400 kW peak power. Presently, we are planning to buy commercial type stand-alone FM transmitters. There are at least two companies that have already expressed interest in building them for BNL.

Each of the three bunchers will use a 4kW water-cooled solid state amplifier.

RF systems will be built to accommodate PPM with at least seven independent users, and amplitude and phase controls to compensate for the beam loading; they will not require beam locking or beam chopper.



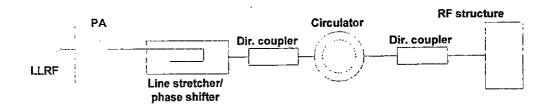


July 23-77, 2003

WBS 1.6.1 High Level RF Systems



EBIS RF SYSTEM







WBS 1.6.1 High Level RF Systems



Bunchers

Frequency 2 MHz
Bandwidth 2 MHz
Average Power 4 kW
R/Q 1.5 k





.....

WBS 1.6.1 High Level RF Systems



RFQ & Linac

Frequency 100 MHz
Bandwidth 2 MHz
Peak power 400 kW

R/Q 108 for RFQ & 30 for Linac

Pulse width 1 mS

Pulse rise time .2 mS max

Duty cycle 1%





WBS 1.6.2 Low Level RF Systems



- EBIS LLRF System Functionality
- Common architecture for all systems, evolving from current RHIC and AGS upgrade efforts.
- Digital IQ fast feedback to maintain RF amplitude and phase as specified. Minimum 50dB dynamic range.
- · Slow feedback for structure resonance control.
- Slow feedback on beam energy if desired.
- All systems phase locked to common external master RF reference.
- System configuration and diagnostics via standard C-AD distributed controls. Rep rate, multiple users, etc. not an issue.





Auto 25.37 2006

WBS 1.6 RF Systems



•	Major proc	curements:	FY'05 direct \$
•	1.6.1.1.2	RFQ Power Amp	-\$400k
•	1.3	Circulator	-\$17,250
•	1.6.1.2.2	Linac Power Amp	-\$400k
•	2.3	Circulator	-\$17,250
•	1.6.1.3.2	Buncher PA's (3ea)	-\$150k
•	3.3	Circulators (3 ea)	-\$15k
•	HL instrum High Level		-\$100k - \$50k -\$1.15M
•	Low Level	RF	-\$135k









Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'l	Labor	Contingency	Total
1.6	RF systems	1305	375	\$470 (28%)	2150

· Labor hours/equivalents

Bassage Cotogoni	estimated
	hours
Engineer	3,200
Designer	450
Technician	2425
Total	6,075
Full Time Equivalents	3.5



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WBS 1.2 Controls

Don Barton

July 25-27, 2005





July 25,27, 2005

WBS 1.2 Controls



System Overview

- · RHIC-generation control system hardware and software
- Ethernet, VME, VxWorks, Linux
- Use existing software for:
 - Device control & archiving (Pulse-to-Pulse Modulation)
 - Data logging, comfort displays, alarms, e-log ...
- Low risk contingency ~20%





WBS 1.2 Controls



1.2.1 Timing & Infrastructure

- Extension of existing f/o for network and standard links
- Standard VME chassis for vacuum system interface
- EBIS event link will support both stand-alone and Booster injection scheduling
- Console workstations, alarms monitor and printer
- SW effort: mainly configuration of existing modules





July 25-27, 2005

WBS 1.2 Controls



1.2.2 EBIS

- PS control for 4 "platforms":
 - Quad Function Generator (QFG) in VME
 - Power Supply Interface (PSI) on platform
 - Function and 2 readbacks at 100kHz, plus Command/Status
 - HV isolation via f/o serial lines between QFGs and PSIs
- Timing via pulsed f/o links
- · Custom console program for coordinated power supply control
 - Specifications based on test stand experience
 - Built with standard RHIC software tools





WBS 1.2 Controls



1.2.3 Accelerators & Beam Transport

- MEBT & HEBT power supply interfaces:
 - Power Supply Controller (PSC) PSI interface for dc magnets
 - QFG-PSI for ramped magnets
 - Standard VME
- Instrumentation interfaces: Like recent projects (TTB and NSRL)
 - Standard VME commercial I/O modules
- RF Controls Infrastructure: VME64X chassis and standard modules
- Software: Minor modifications to existing programs





July 25-27, 2005

WBS 1.2 Controls



- Procurements > \$25K: (FY05\$)
 - PSI modules (\$107K)
 - VME Chassis (\$60K)
 - QFG modules (\$45K)
- Deliverables:
 - VME chassis populated with standard VME interface modules; remote power supply interfaces; f/o links
 - Workstation consoles for commissioning and maintenance
 - Standard network and timing infrastructure elements
 - Custom and (mostly) standard software and database
 - Documentation









Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'i	Labor	Contingency	Total
1.2	Controls	350	100	\$100 (22%)	550
		1			

· Labor hours/equivalents

Resource Category	estimated hours
Engineer	1,050
Technician	275
Management	100
Total	1,425
Full Time Equivalents	0.8







WBS 1.7 Vacuum Systems Mike Mapes

July 25-27, 2005



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WBS 1.7 Vacuum Systems



SCOPE OF WORK

WBS 1.7.1 Beam Pipes and Chambers

Design, fabrication, procurement, assembly and vacuum processing of chambers/beam pipes and vacuum fittings/components. Design and procurement of heating blankets.

WBS 1.7.2 Instrumentation& Controls (I&C)

Design, fabrication, procurement, assembly and testing of a PLC based controls system which monitors and controls pumps, gauges and valves and provide vacuum interlocks.

WBS 1.7.3 Pumps

Design, specification, procurement, assembly and testing of Cryo, Diffusion, Ion, NEG, Titanium and Turbo molecular vacuum pumps.

WBS 1.7.4 Valves

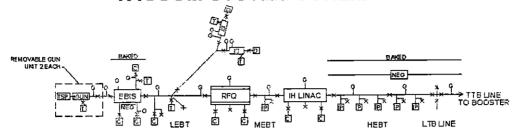
Design, specification, procurement, assembly and testing of vacuum valves.



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VACUUM SYSTEM SCHEMATIC



VACUUM DEVICE LEGEND

(X) - VALVE (G) - CCG/PIRANI GAUGE

C CRYO PUMP

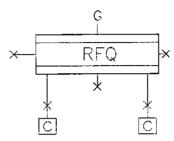
IP - ION PUMP

T TURBO PUMPING STATION

TSP - TITANIUM SUBLIMATION PUMP

NEG - NON-EVAPORABLE GETTER PUMP

D DIFFUSION PUMP



TYPICAL SECTOR

- •GAUGES- ATM.-10-11 TORR
- •PUMPS- CRYO, NEG....
- **•GATE VALVES-**

SECTOR/PUMP ISOLATION



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WBS 1.7 Vacuum Systems



Vacuum Requirements

- •EBIS 10-10 Torr, in situ baked 250°C
- •LEBT, RFQ, MEBT & IH LINAC -Vacuum levels of 10-8 and 10-9 Torr are sufficiently low for the partially stripped low energy ion beams for all these regions due to the single pass nature.
- •HEBT- Vacuum of 10-10 Torr is needed in the last section of HEBT to minimize the diffusion of residual gas into the 10⁻¹¹ to 10⁻¹² Torr Booster ultrahigh vacuum system. In situ baked 150°C

Vacuum Design Parameters

- Only UHV compatible materials used stainless steel and ceramics
- No organic materials allowed
- Stainless steel chambers, Inconel bellows
- Conflat flanges- high reliability low cost
- •All components/chambers cleaned and vacuum fired to UHV standards



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VACUUM SYSTEMS SUMMARY TABLE

SYSTEM	PUMPS	VALVES	GAUGES	PRESSURE	BAKED
EBIS	3 CRYO, NEG 2 TSP, 3 TURBO	7-10°CF, 1-6°CF 1-8°CF	5 CCG 5 PIRANI	10 ⁻¹⁰ Torr	250° C
IS	2 DIFFUSION 2 TURBO	2-10"CF,4-6"CF	4 CCG 4 PIRANI	10 ⁻⁸ -10 ⁻⁹ Torr	No
LEBT	1 CRYO 1 TURBO	3-8°CF,2-10°CF 1-6°CF	2 CCG 2 PIRANI	10 ⁻⁸ -10 ⁻⁹ Torr	No
RFQ	2 CRYO	2-10°CF, 1-6°CF	1 CCG 1 PIRANI	10 ⁻⁸ -10 ⁻⁹ Torr	No
MEBT	1 ION PUMP	1-6"CF	1 CCG 1 PIRANI	10 ⁻⁸ -10 ⁻⁹ Torr	No
LINAC	2 CRYO	2-10"CF,1-6"CF	1 CCG 1 PIRANI	10 ⁻⁸ -10 ⁻⁹ Torr	No
HEBT	5 ION PUMPS NEG	7-6"CF	3 CCG 3 PIRANI	10 ⁻¹⁰ Torr	150° C



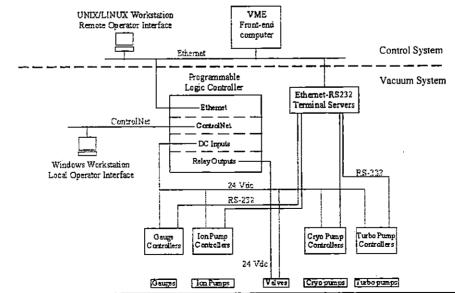


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WBS 1.7 Vacuum Systems



INSTRUMENTATION & CONTROL SCHEMATIC





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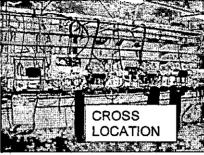


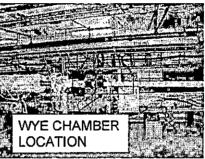




EBIS HEBT VACUUM SECTOR

- **•**CROSSES LTB LINE
- **•**CONNECTS TO TTB LINE
- **•**MODIFICATIONS TO BOTH LINES









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WBS 1.7 Vacuum Systems



- Historical Cost used throughout vacuum systems estimate since it is very similar to other vacuum systems recently installed or upgraded.
- Standardization to Existing Vacuum Systems In C-AD Complex
 - Inverted magnetron CCG and controllers (RHIC)
 - 20 l/s sputter ion pumps (Booster) and controllers (RHIC)
 - NEG cartridge pumps and NEG strip (Booster, NSRL)
 - Turbopump stations with dry backing pumps (RHIC)
 - PLC based vacuum monitoring and control (Booster, AGS, RHIC, NSRL)
 - PLC based bakeout system monitors and controls baked section (RHIC, Booster, NSRL)
 - Gate valves and roughing valves (Booster, RHIC, NSRL)
- Use commercially available vacuum fittings, flanges, seals, etc. wherever possible and avoid custom fabrications.







Major procurements (in FY05 direct dollars):

- Cryopumps with compressors \$112K
- Turbopumps \$144K
- Gate Valves (10",8" and 6") \$104K

Technical Risk Factor:

 LOW RISK – Since designs are based on proven existing vacuum systems designs in C-AD complex





WBS 1.7 Vacuum Systems



Estimated Cost

		Direct FY'05\$			
WBS	Description	Mat'l	Labor	Contingency	Total
1.7	Vacuum Systems	760	305	\$215 (20%)	1280

· Labor hours/equivalents

Passuras Catagory	estimated
Resource Category	hours
Scientist	150
Engineer	1,750
Designer	1,200
Technician	1,500
Building Trades	250
Total	4,850
Full Time Equivalents	2.8







WBS 1.3 Diagnostic Systems

Michelle Wilinski

July 25-27, 2005

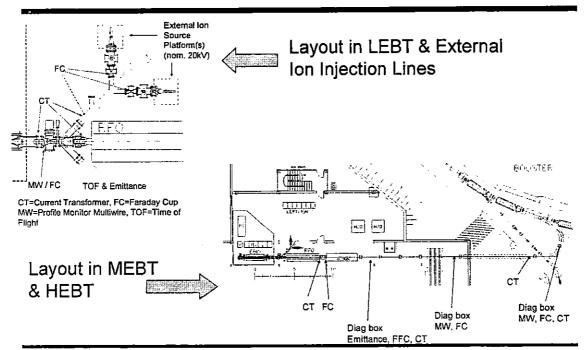


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Specifications



n :			on and			Dun Banas	Resolution	Data Structure	Ref to Similar Device	Comments
Device Current Transformer	<u>- 51</u> 5	FEDI	HEBT	UEDI	Totals	Dyn. Range	Resolution	Data Structure	Ker to agrice persee	Calibrated measurement
Toroid	1	2	2.	2	7	10uA-10mA	0.1uA	Pulse waveform	Similar to TTB	Digitized waveform & avg. current
Faraday Cup Fast Faraday Cup Faraday Cup	2	1	2	1 2				Pulse waveform Pulse waveform	Existing to be reused Similar to TTB	Typical CAD design, plunging Digitized waveform & avg. current 3 combinations with profile monitors
Profile Monitor Multiwire		1		2	3	10-шА-10mA	1mm	Profile	2 from TTB. 1 purchased	Typical CAD design, plunging 32H X 32V wire spacing Gated integrator electronics

- Risk => low as diagnostics for EBIS will be similar to those already installed in TTB (Tandem-to-Booster) line
 - Basic designs exist, modify designs for adaptation into EBIS (physical dimensions, requirements, etc.)





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Current Transformer (CT)



 Ferrite toroid wound with signal wire to measure ion beam current characteristics with respect to time in a non-destructive measurement



- · C-AD made TTB style CTs to be used
- At present one spare TTB CT is on the EBIS test stand





Faraday Cup (FC)/Fast FC (FFC)



- FC: Detector head pneumatically plunged into beam path to collect entire ion beam; captured charge measured as a current in electronics
- Fully destructive measurement can also be used as beamstop
- Provides average current and pulse waveform data with respect to time
- · FFC: Existing coaxial FFC to be reused
- Has bandwidth in GHz, allows observation of 100MHz bunch structure of beam



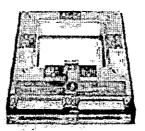


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Profile Monitor – Multiwire (PM)



- Measures transverse beam profiles by plunging 32 x 32 array of wires into beam path
- Installed in combination with FC on a dual feedthrough at 3 locations
- · 2 multiwire heads from TTB will be reused, purchase one new







Major Procurements & Deliverables



- Major procurements (direct '05 \$):
 - FC/PM mechanical parts (feedthroughs and sensor heads)=> ~\$105k
 - 8 Ch. Integrators (PM) => ~\$48k
- Deliverables:
 - 7 Faraday Cup systems, 1 Fast Faraday Cup system
 - 7 Current Transformer systems
 - 3 Profile Monitor systems





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Cost & FTEs



Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'i	Labor	Contingency	Total
1.3	Diagnostics	290	175	\$95 (20%)	560

· Labor hours/equivalents

Resource Category	estimated hours
Scientist	100
Engineer	1,000
Designer	475
Technician	1,050
Management	125
Total	2,750
Full Time Equivalents	1.6





WBS 1.8 - Water Cooling System

Russ Grandinetti

July 25-27, 2005





July 25-27, 200

WBS 1.8 Cooling Systems



- Major procurements: Design and Fabrication
 - Components for 3 Pump Skids
 - EBIS 1-4 Collector & LINAC Quad Magnets
 - EBIS 2-5 High Voltage Platform
 - EBIS 3 RFQ & LINAC System
 - Water Cooling PLC System
 - Cost Basis Similar Items, Engineering Judgment
- · Deliverables:
 - 3 Pump Skids
 - Water Cooling PLC System
- Installation Covered Under WBS 1.10.8





WBS 1.8 Cooling System Requirements



EBIS 1-4 System 30 HP

EBIS 2-5 System 15 HP

EBIS 3 System 5 HP

Electron Collector/Quads	Collector	Linac qua	ds Syst	em	
Flow	40 gpm	20 gpm	60 g	60 gpm	
Supply Pressure	425 psi (note 1)	375 psi	425	psi	
Heat Load	200 kW	1 kW	201	kW	
Inlet Supply Temp	70 F (21C)	85 F (30C) 70 F	(21 C)	
Water Treatment	Di at <10 uS/cm or 0	.1 MegOhms/cm			
Reg'd Floor Area	70 ft ² excluding requ	ired aisle or wall spa	ce for electrical equipr	nent	
High Voltage Platform / RF	emplifiers / Circulators				
	Platform	RF Amplifiers	Circulator	System	
Flow	60 gpm	70 gpm	5 gpm	135 gpm	
Pressure	60 psi (note 2)	80 to 100 psi	80 psi	90 psi	
Heat Load	60 kW	100 kW	5 kW	165 kW	
Inlet Supply Temp	70 F (21C)	85 F (30C)	85 F (30C) +/ -1F	70 F	
Water Treatment	DI at <10 uS/cm or 0	.1 MegOhms/cm			
Reg'd Floor Area	70 ft ² excluding requ	ired aîsle or wall spa	ce for elect rical equ	ripment	
RFQ & Linac					
Flow	20 gpm				
Pressure	100 psi	5 HP estim	ated	•	
Heat Load	7 KW				
Inlet Supply Temp	70 F (21C) +/ - 1F				
Water Treatment	Water additive 4109	iron corresion inhibi	tor		

50ft² excluding requir ed aisle or wall space for electrical equipment



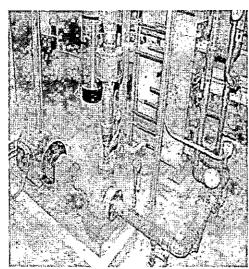
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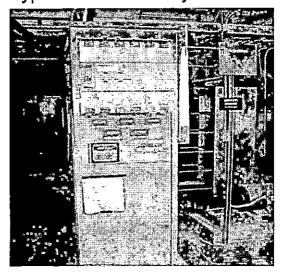
WBS 1.8 Cooling Systems



Typical Pump System



Typical Water PLC System





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WBS 1.8 Cooling Systems



Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'l	Labor	Contingency	Total
1.8	Cooling Systems	195	40	\$50 (21%)	285

Labor hours/equivalents

Resource Category	estimated hours
Engineer	150
Designer	325
Technician	175
Total	650
Full Time Equivalents	0.4







WBS 1.9 Facility Modifications

Al Pendzick

July 25-27, 2005





July 25-27, 2005

WBS 1.9 -- Facility Modifications



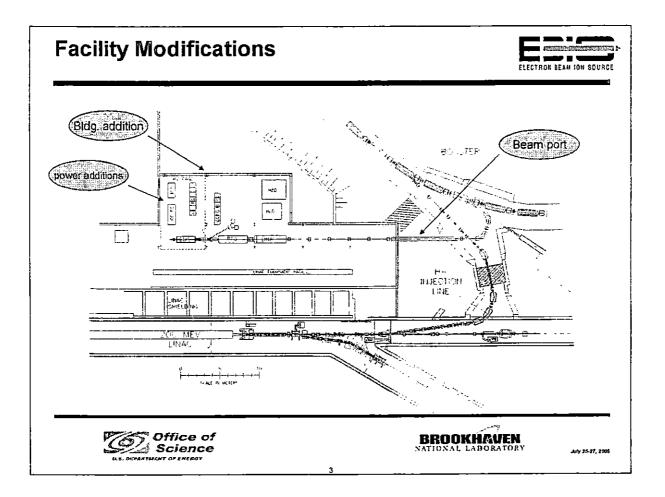
- 1.9.1 Beam access port (L.S. Contract +BNL Labor)
 - Provides an access sleeve for the EBIS beam line between the LINAC building & the Booster injection area.
 - Includes removal & re-installation of existing utilities & equipment in the Booster injection area.

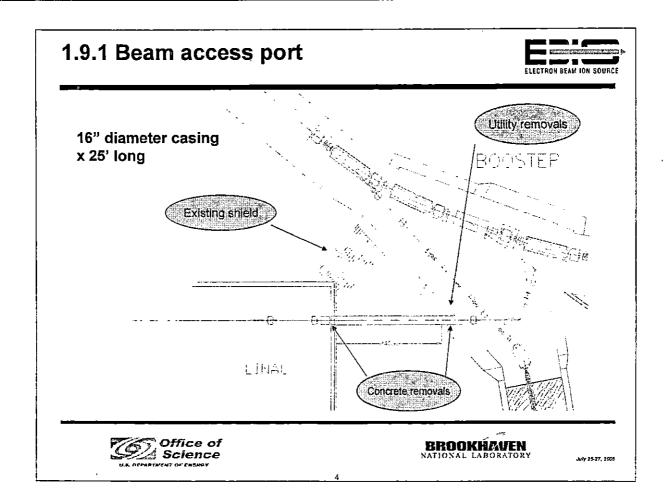
Basis of estimate ----- Similar contracts

- 1.9.2 Power Modifications (L.S. Contract + BNL Labor)
 - Provides AC power from an existing sub-station to disconnect switches in the area and then to all EBIS equipment.
 - Includes all material and labor to accomplish this.
 Basis of estimate ----- "Means" construction estimating guide





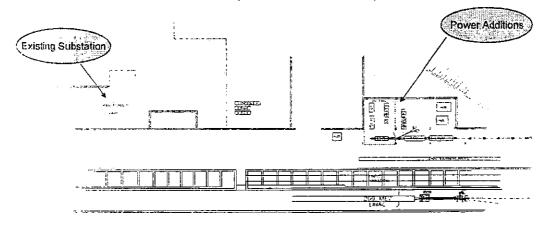




1.9.2 Power Modifications



EBIS Power - ~1.5 MVA (2.5 MVA available)







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WBS 1.9 - Facility Modifications



Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'i	Labor	Contingency	Total
1.9	Facility modifications	380	135	\$135 (26%)	650

· Labor hours/equivalents

Resource Category	estimated hours
Scientist	50
Engineer	425
Designer	500
Technician	100
Building Trades	775
Total	1,850
Full Time Equivalents	1.1







- Scope of Work for WBS 1.10.1 Structural Components
 - Pre-survey of facility site and major components.
 - Installation of anchor bolts for major components and stands and base grouting.
 - Transport of EBIS to the facility site from pre-assembly area.
 - Transport of LEBT components and external ion sources to facility site from pre-assembly area.
 - Linac and RFQ installation.
 - MEBT installation, including stand, quadrupoles (4), buncher, and diagnostic devices.
 - HEBT installation, including stands, debunchers (2), diagnostic devices, and survey and alignment of beam line.
 - HV enclosure.



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WBS 1.10 Installation



- Scope of Work for WBS 1.10.2, Control Systems:
 - Install controls for Timing & Infrastructure, EBIS, and Accelerator & Beam Transport, including:
 - Chassis/cables
 - Integrate/test software
 - Integrate/test hardware
- Scope of Work for WBS 1.10.3, Diagnostics:
 - Install Faraday cups, beam profile monitors, and current transformers, including:
 - Chassis/cables
 - Integrate/test electronics
 - Integrate/test control interface





- Scope of Work for WBS 1.10.4, Magnets:
 - Installation of HEBT dipoles (2) and quadrupoles (8), including rigging/transport of magnets into HEBT line, anchor bolts, and grouting.
- Scope of Work for WBS 1.10.5, Power Supplies:
 - Install PS's and ICT's for all magnets, diagnostic and electrostatic devices, including:
 - Receipt inspection.
 - Cabling/lugs
 - Testing and As-built documentation
 - Power cables from distribution panels or main disconnects to power supplies/power supply racks
 - Material Cost for Cables





July 25-27 7005

WBS 1.10 Installation



- · Scope of Work for WBS 1.10.6, RF Power Supplies:
 - Installation of RFQ and Linac power supplies at EBIS site.
 - Fabrication of circulator support structure.
- Scope of Work for WBS 1.10.7, Vacuum Systems:
 - Install beam pipe sections, vacuum chambers, and beam line support stands.
 - Install vacuum valves and pumps.
 - Install power, instrumentation, and control cables.
 - Install instrumentation and control system.
 - Perform test and checkout of instrument system and vacuum components.
 - Bake out beam line, chambers, and beam components.







- Scope of Work for WBS 1.10.8, Cooling Systems:
 - Assembly labor for closed loop cooling water systems:
 - Sys 1: EBIS Electron collector and Linac quadrupoles.
 - Sys 2: EBIS HV platform components, RFQ and Linac power supplies, and RFQ and Linac circulators.
 - Sys 3: RFQ and Linac.
 - Labor and materials to extend the existing Booster cooling water system to HEBT dipoles.
 - Labor and materials to increase piping size and extend the existing Linac chilled water system.
 - Labor and materials to disconnect and reconnect water cooling lines to existing equipment that must be relocated.
 - PLC instrumentation and control system assembly, installation, test and checkout, including cables installation.





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WBS 1.10 Installation



- Major procurements ('05\$):
 - Most of the procurements will be made in WBS's 1.1 through
 1.9, with the following exceptions:
 - WBS 1.10.1: High Voltage Enclosure \$13,000
 - WBS 1.10.3: Electrical Racks/PS's \$16,300
 - WBS 1.10.5: Cable \$88,490
 - WBS 1.10.8: Piping Materials \$14,000





Schedule



- Installation begins in Q1, FY'08, and is done in stages over ~15 months.
- Procurements will be scheduled so the installation work in the Booster tunnel is done during the FY'08 summer shutdown period.





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1.

WBS 1.10 Installation



Estimated Cost

		Direct FY'05K\$			
WBS	Description	Mat'i	Labor	Contingency	Total
1.10	Installation	145	940	\$230 (21%)	1315

Labor hours/equivalents

Resource Category	estimated hours	
Scientist	125	
Engineer	1,975	
Designer	875	
Management	75	
Technician Supervision	275	
Technician	7,450	
Building Trades	4,200	
Total	14,975	
Full Time Equivalents	8.5	





Commissioning



- •Present estimate for effort is ~1.5 FTEs
- •Cost ~ 300 k\$ (burdened, AY\$)
- •Commissioning is presently included within the various WBS elements, but will be pulled out explicitly for CD2.





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WBS 1.10 Installation (& Commissioning) Lou Snydstrup

July 25-27, 2005





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WBS 1.10 Installation

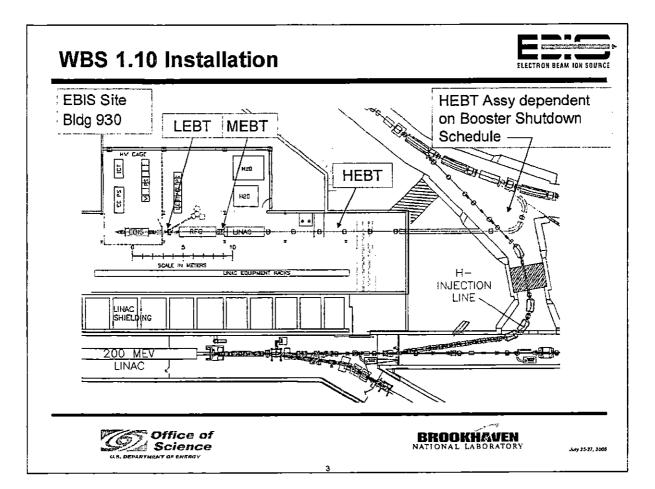


The scope of the installation effort for the individual subsystems is contained in the following WBS sections:

- 1.10.1 Structural Components
- 1.10.2 Control Systems
- 1.10.3 Diagnostics
- 1.10.4 Magnet Systems
- 1.10.5 Power Supply Systems
- 1.10.6 RF Power Supplies
- 1.10.7 Vacuum Systems
- 1.10.8 Cooling Systems









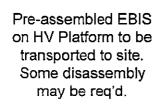
- The Installation effort is based upon the following pre-existing conditions:
 - Power available from installed distribution panels and disconnect switches.
 - For power and electronic systems (e.g., controls, diagnostics, power supplies, and vacuum):
 - Electronic racks are in place (WBS 1.9).
 - Power cable to the electronic racks (WBS 1.9).
 - Cable tray is installed (WBS 1.9).
 - Electron Beam Ion Source pre-assembled and partially tested in building 930 HV Testing Area prior to installation.
 - LEBT pre-assembled prior installation effort, then partially disassembled, moved, reassembled and aligned at the facility site.



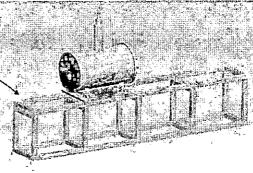
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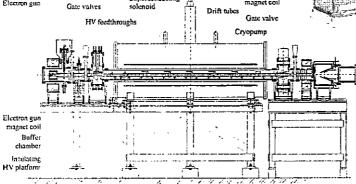
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HV Platform (Conceptual) for Test Stand





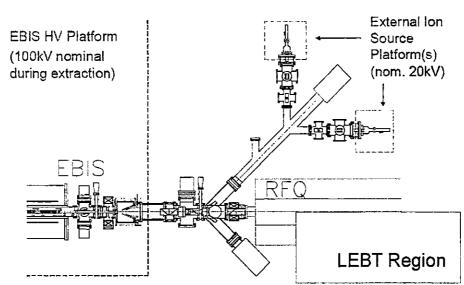




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WBS 1.10 Installation





Partial disassemble, transport, re-assemble, align



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July 25-27, 1005

James Alessi

Project Manager

Dr. James Alessi is Contractor Project Manager for the EBIS Project. He has been the Group Leader of the Preinjector Group in C-AD since 1999. This group is responsible for the operation and maintenance of the 200 MeV H- and polarized H- linac, and the two 16 MV HVEC MP Tandem Van de Graaff accelerators. Prior to that, Dr. Alessi was Linac and Source Development Group Leader since 1986. He was Project Leader for the replacement of the Cockcroft-Walton preinjector by an RFQ at the Linac in 1989. Since joining BNL in 1979, he has worked on development of multi-ampere H- sources for fusion, H- sources for accelerators, polarized H- sources, heavy negative ion sources, high charge state heavy ion sources, RFQ's, linacs, and beam transport. He led the development of BNL's first polarized H- source, along with many other Linac and Tandem upgrades.

Dr. Alessi received his BS in Physics from the University of Buffalo and his PhD in Physics from the University of Pittsburgh. He has served on numerous national and international scientific review committees. He has organized several international conferences, and served as editor of conference proceedings. He has been a member of the Linear Accelerator Conference International Organizing Committee since 1990, and is a member of the International Organizing Committee for the International Conference on Ion Sources.

Donald S. Barton

Subsystem Manager EBIS Controls

Dr. Barton has been appointed the Subsystem manager for Controls in addition to his position as the Head of the Controls Division for the Collider-Accelerator Department. He has been a member of the department scientific staff since 1978. From 1979 to 1982 he was principal physicist in charge of the conversion of the AGS to H- injection. This work entailed development and construction from the H- ion source to the AGS injection area. From 1979 to 1981 he also served as physicist in charge of Operations in the Accelerator Division. From 1983 to 1986 Dr. Barton was in charge of AGS accelerator modifications in the Heavy Ion Transfer Line project to inject heavy ions into the AGS. During the same period, he represented the AGS in conceptual design discussions for RHIC. In 1987, Dr. Barton assumed his current position as head of the Controls Division. From that year through 1991, he also jointly held a project appointment as head of the Booster Project Controls effort. During that time he was the principal architect of pulse-to-pulse modulation in the control system, which permits multiple users and machine studies to "own" their own virtual machines, scheduled by a master supercycle. Since the late '80s, his group has been at the forefront in the development of distributed, networked controls with modern object-oriented software. In 1991 Dr. Barton was assigned to head the RHIC Project Controls effort, which his division successfully brought into being in an effort strongly matrixed with AGS facility support. Since RHIC start-up, the Controls Division has strongly supported the evolving demands of operations and machine development, as well as upgrades of legacy systems at the AGS. Recent planning efforts have supported ERL, RSVP, and EBIS.

Dr. Barton received an AB degree from Harvard College in Engineering and Applied Physics and a Ph.D. from Massachusetts Institute of Technology in Experimental High Energy Physics. He has been a member of the EVA experiment collaboration at the AGS and of the PHOBOS collaboration at RHIC, serving also as Liaison Physicist and Safety Officer for the latter.

Edward Beebe

Subsystem Manager for Structural Components

Dr. Beebe is the Structural Components Subsystem manager for the EBIS project. He is a Physicist in the Preinjector Group in C-AD, reporting to Dr. James Alessi. Since joining BNL in 1994, he has been primarily responsible for development of the high current EBIS for RHIC and NSRL. He has also worked on the EBIS control system, power supply and platform configuration, external ion injection, fast ion extraction, diagnostics and experimental measurements. He obtained, adapted, and developed the LEVA ion source from LBNL and the Hollow Cathode Ion Source from Saclay, France to provide a broad range of primary ion species for injection into the BNL Test EBIS.

Dr. Beebe was co-principle investigator with E.D. Donets (JINR, Dubna, Russia) of two Civilian Research and Development Foundation grants: "High Pulse String Source Of Highly Charged Ions: Studies And First Tests On A Synchrotron" (2000-2001) and "High Intensity Tubular Electron String Source Of Highly Charged Ions: Experimental Proof And Basic Studies" (2002-2003).

Before coming to BNL, Dr. Beebe was a Research Scientist at the Manne Siegbahn (CRYRING) Laboratory in Stockholm, Sweden. He worked primarily on the development of the Stockholm Cryogenic Electron Beam Ion Source, which produces very highly charged ions (up to Xe52+) both for the Stockholm Ion Storage Ring and for atomic physics experiments.

Dr. Beebe received a BS (1980) and M. Eng (1984) in Applied and Engineering Physics and a Ph.D. (1990) in Nuclear Science and Engineering from Cornell University with thesis topic: "An Investigation of Ion Trapping and Heating in the Cornell Electron Beam Ion Source". He is a member of the Advisory Committee of the International Symposium of Electron Beam Ion Sources and Traps and Their Applications. In 2003, Drs. Beebe and Pikin received the "Brightness Award", an Ion Source Prize awarded at the Tenth International Conference on Ion Sources, held in Dubna, for "innovative and significant recent achievements in the fields of ion source physics and technology".

R. A. Grandinetti

Subsystem Manager for Cooling Systems

In addition to his responsibilities on EBIS, Mr. Grandinetti is the Water Systems Group Leader for the C-A Department. Since joining BNL in 1991, Mr. Grandinetti has held various positions in the C-AD department. Initially, in the Magnet Division, he was responsible for the design, installation and operation of the mechanical portion of the testing facility for the RHIC cryogenic magnets. During the RHIC construction effort, he was responsible for the design, fabrication and installation of the DX and Triplet cryostats. Approximately five years ago he assumed responsibility for the C-AD Water Systems Group. The group is responsible for the design and installation of all new C-AD water cooling systems and the maintenance of existing systems. Presently the Water Systems Group has responsibility for 34 cooling towers and 76 different pumping systems. In addition, his responsibilities include the; estimating, design, fabrication and installation of all proposed new C-AD water cooling systems.

Mr. Grandinetti received Bachelor of Science degrees in Civil Engineering in 1962 and Administrative Engineering in 1963, from Tri-State University in Indiana.

Robert Lambiase

Subsystem Manager for Electrical Systems

Mr. Lambiase is a group leader in the Collider - Accelerator Department at BNL, currently working on several projects, including the Energy Recovery Linac and upgrades to the AGS. He was the Power Supply Systems group leader for the SNS Project, and the Magnet Electrical Systems group leader for the RHIC Project. Prior to that work, he designed electrical systems for several other BNL projects, including Laser Resonance Fluorescence experiment, and the Neutral Beam Test Facility.

Prior to his time at BNL, Mr. Lambiase designed radars for search, tracking, and perimeter control (pulse Doppler) applications at AIL Systems (now EDO Corporation).

Mr. Lambiase has a BS and MS in Electrical Engineering from the Polytechnic Institute of Brooklyn (now Polytechnic University). He is also a licensed Professional Engineer. He continues to teach as an Adjunct Professor of Engineering Science and Electrical Technology at Suffolk Community College.

Edward T. Lessard

Environment, Safety, Health and Quality

Mr. Lessard has worked for BNL for the past 28 years and during that period has written over 50 scientific publications and reports in the diverse areas of accelerator safety and internal dosimetry. Currently, he is the Associate Chair for Environment, Safety, Health and Quality for the Collider-Accelerator Department (C-AD), and has been in this role for 17 years. The C-AD operates seven accelerators for the Department of Energy including the Relativistic Heavy Ion Collider (RHIC) and the Alternating Gradient Synchrotron (AGS). Prior to his present position, he was a Health Physicist for the Operations Section, and a Group Leader for the Marshall Islands and Internal Dosimetry Group at BNL's Safety and Environmental Protection Division. He is the Chair of the Spallation Neutron Source (SNS) Accelerator Safety Review Committee at ORNL, and the Team Leader for the Accelerator Readiness Reviews for the SNS. At BNL, he is a member or chair of several BNL and C-AD standing committees including C-AD Radiation Safety Committee, C-AD Experimental Safety Review Committee, C-AD Accelerator Systems Safety Review Committee, C-AD ALARA Committee, BNL Institutional Review Board, BNL Radioactive Drug Research Committee, BNL Environment, Safety and Health Committee (Chairman), BNL Cryogenic Safety Subcommittee (Chairman) and the BNL Radiation Protection Committee. Mr. Lessard has played the lead ESH role in the commissioning of AGS, AtR, RHIC, TTB and NSRL accelerator facilities at BNL.

Mr. Lessard received a Master of Science Degree in Radiological Sciences and Protection from the University of Lowell in May 1977. He is a member of the Health Physics Society and the American Nuclear Society. Among his honors are the Brookhaven Award from Brookhaven National Laboratory (BNL) and the Elda E. Anderson Award from the Health Physics Society.

Michael Mapes

Subsystem Manager for Vacuum Systems

In addition to his assignment on EBIS, Mr. Mapes is the Deputy Vacuum Group Leader for the Collider-Accelerator Department. He has 18 years of experience in design, fabrication, assembly and installation of beam lines and vacuum systems at BNL. He has successfully completed many major vacuum projects including REF, NBTF, AGS Booster, LINAC HEBT, BLIP, NSRL and the SNS Ring and RTBT systems.

Mr. Mapes has been a Professional Engineer since 1993.

Kerry Mirabella

Assistant for Project Controls

Ms. Mirabella is the assistant to Project Manager Jim Alessi for Project Controls (PC). Ms. Mirabella is also the PC Group Leader for the Collider-Accelerator Department at BNL. She has more than 25 years experience in Program Management, Estimating, and Manufacturing and Contracts. Prior to EBIS she spent five years managing the Project Controls and Configuration Management aspects of BNL's involvement in the Spallation Neutron Source. Before joining BNL she spent 12 years in various positions at AIL Systems (now EDO Corporation). Her last position was as Program Manager for Electronic Warfare and Defense, primarily with the ALQ99 EWS, a radar and tactical jamming system employed on the EA-6B aircraft.

Ms. Mirabella is a certified Project Management Professional (PMP) and has both a BBA and an MBA in management and mathematics. She was an adjunct professor in the Arts and Science Department at Dowling College, where she taught undergraduate mathematics.

Alexander Pikin

Lead Physicist for the EBIS, LEBT and External Sources

Dr. Alexander Pikin is a scientist in the EBIS group of C-AD, currently working on RHIC EBIS project. His activities include physical analysis, optical simulations, and design of new units of this ion source (electron gun, electron collector, drift structure, magnetic structure, LEBT). He is also involved in experimental program on an existing Test EBIS and its upgrade.

Prior to BNL he worked at the National Institute of Standards and Technology (Gaithersburg, MD) on ion extraction from EBIT, at the Manne Siegbahn Institute of Physics (Stockholm, Sweden) on the upgrade of CRYSIS electron beam ion source and at the Joint Institute of Nuclear Research (Dubna, Russia) on developing a study of 2 generations of the electron beam ion sources.

Dr. Alexander Pikin graduated from Leningrad Polytechnic Institute with major Experimental Nuclear Physics. He received his PHD on "Cryogenic Electron Beam Source of Highly Charged Ions CRION-1", has over 40 publications and 3 Russian invention certificates. In 2003 he, together with Edward Beebe, received the Ion Source Prize known as the Brightness Award at the Tenth International Conference on Ion Sources, held in Dubna; for innovative and significant recent achievements in the fields of ion source physics and technology.

Al Pendzick

Subsystem Manager for Facility Modifications

In addition to his responsibilities on the EBIS project, Mr. Pendzick is also the Group Leader for Facilities and Experimental Support of the Collider-Accelerator Department. He has 33 years of experience in the construction and operation of Experiments and Accelerator Facilities.

Deepak Raparia

Accelerator Physics Physicist

Dr. Deepak Raparia has been appointed as the lead accelerator physicist for the EBIS project, reporting to Dr. Jim Alessi; in addition to his position BNL Linac group leader. Prior to this project, Dr. Raparia served as the group leader of the SNS/BNL accelerator physics group and as the deputy group leader for the SNS/ORNL accelerator group. Dr. Raparia has 27 years of experience in accelerators and his prior work includes physics designs of the following: superconducting linac injector for the VLBNO project at BNL, the POP H minus laser stripping experiment at 200 MeV BNL Linac, the SNS transfer lines, the POP experiment for BNCT, the 600 MeV linac for 5 MW Spallation neutron source at BNL, the SSC 600 MeV linac; as well as pioneering work on helical electrostatic quadrupoles for low energy beam transport, RFQ physics design for ion implantation, and the charge exchange injection of 20,000 turns into the TRIUMF Kaon factory.

Dr. Raparia received a PhD in accelerator physics from University of Houston, a MS in accelerator physics from University of Manitoba, and a MS in mathematics from Agra University. He has coauthored more than 100 papers, and has given invited talks in several international conferences, participated in numerous seminars and workshops as well as national and international scientific collaborations programs. He is a member of the Linear Accelerator Conference program Committee.

John Ritter

Subsystem Manager for Magnet Systems

Mr. Ritter is a Mechanical Engineer for the EBIS Project. His other responsibilities include Optically Pumped Polarized Ion Source (OPPIS) and LINAC support. He was the project engineer for Experiment 968 Laser Stripping Proof of Principle and was involved with the RHIC Jet Polarimeter.

Prior to joining BNL in 2000, Mr. Ritter designed medical and industrial ultrasonic devices at MISONIX.

Mr. Ritter has a BE and MS in Mechanical Engineering from the State University of New York at Stony Brook. He has coauthored several papers on source development since joining BNL.

Louis Snydstrup

Subsystem Manager for Installation

In addition to Installation responsibilities, Mr. Snydstrup's scope on the EBIS project includes reporting to Project Manager Jim Alessi as the Deputy for Engineering. He has been employed at BNL since 1988 as a project engineer, including one year as the Cryogenic group leader leading up to the consolidation of AGS and RHIC departments. He has been involved in the engineering and design of the Muon g-2 Experiment, Phenix Detector, EBIS Test Stand, NSRL beam line, and is currently supporting Tandem Van De Graaff accelerator operations. He has worked on the mechanical engineering, design, and construction of conventional and superconducting coils, flammable gas systems, beam vacuum chambers, and remotely-operated vacuum components, such as foil strippers, collimators, beam stops, and slits.

Mr. Snydstrup's experience prior to BNL includes 12 years with a DOD engineering contractor as project engineer/manager for DDTE (design, development, test and evaluation) contracts for piping system components and for A/E (architectural/engineering) contracts for special test facilities and construction support.

Mr. Snydstrup has a BE in marine engineering from SUNY Maritime College, MS in mechanical engineering from SUNY at Stony Brook, and holds a PE license in NYS.

Michelle Wilinski

Subsystem Manager for Diagnostics

Michelle Wilinski is a Staff Engineer in the Instrumentation and Beam Components Group in the Collider-Accelerator Department. For the past five years she has been responsible for the upgrade and new design of several systems, specializing in current transformers, dampers, and tune measurement. In addition to instrumentation hardware design, she has developed sophisticated software using LabVIEW for Booster Tune Meter calculations and for sharing control of an oscilloscope among several client applications. Ms. Wilinski was responsible for the design of several diagnostic equipment items for the Spallation Neutron Source accelerator Ring. She is currently providing instrumentation support for the EBIS prototype.

Ms. Wilinski received a B.S. in Electrical Engineering from Hofstra University. She will graduate with an M.S. in Electrical Engineering from SUNY Stony Brook in May 2006.

Alex Zaltsman

Subsystem Manager for RF Systems

In addition to his responsibilities on EBIS, Mr. Zaltsman is the RF group leader in the Collider - Accelerator Department at BNL, currently working on several projects, including the Energy Recovery Linac and operations and upgrades to the AGS and Booster. He was the RF Systems group leader for the Spallation Neutron Source project. Mr. Zaltsman is responsible for operation of RF systems for Booster, AGS and RHIC.

Mr. Zaltsman has a BS in Electrical Engineering from the Polytechnic Institute of Brooklyn (now Polytechnic University). Over the years he has worked in many areas of electrical engineering, including high-voltage and high-current; both pulsed and dc to Controls and diagnostic equipment; and RF, both low level and high power.