Project Status

Steve Peggs

Scope

In collaboration with Cornell University, test & develop a multi-turn Energy Recovery Linac using a single FFAG return loop with an energy acceptance factor of up to 4, at Cornell

Relocate Cornell's existing:

- Gun with its laser system
- Injector Cryo-Module & Main Linac Cryomodule (MLC)
- Merger system
- High-power beam stop

Move the associated RF-power system, cryogenic system, & electrical controls.

Install a single FFAG return loop for multi-turns with separator & combiner sections that connect the arc to the MLC.

Commission & operate with 1 mA, increasing towards 40 mA.

Existing & new equipment

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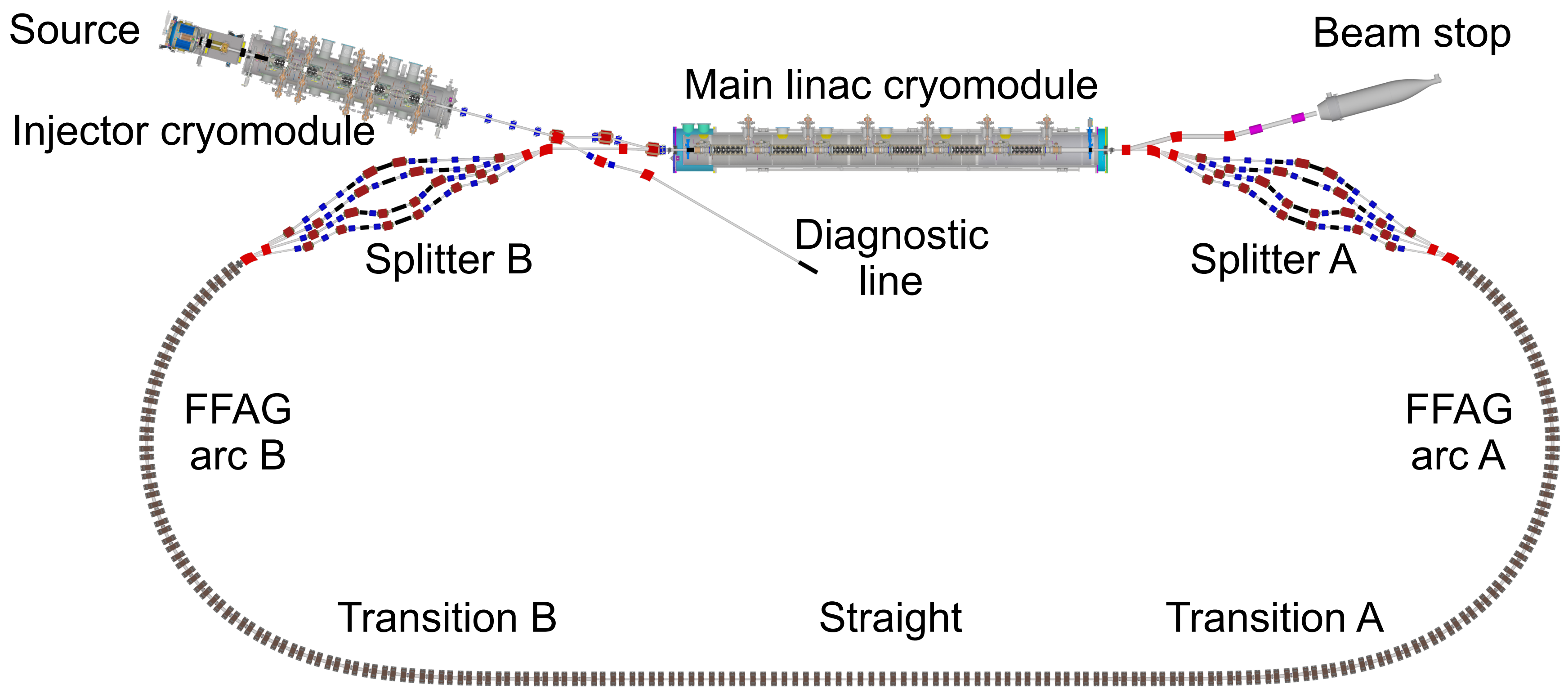


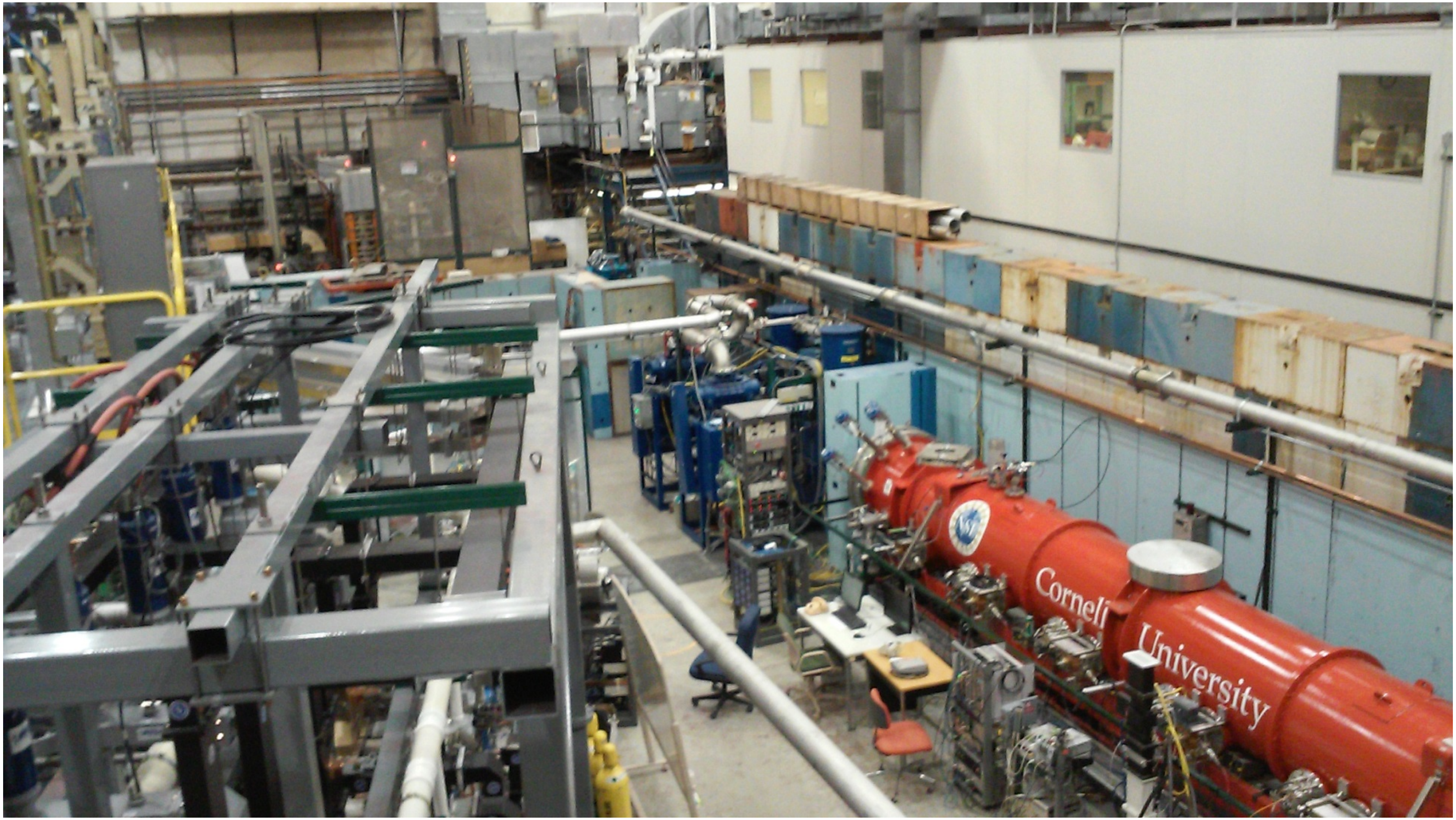
Much equipment & infrastructure exists — 32 M$

Major new equipment:

- 2 splitters (electromagnets & tables)
- FFAG arc permanent magnets
- Diagnostics, power supplies etc.

L0E hall — Jan 2017

CBETA



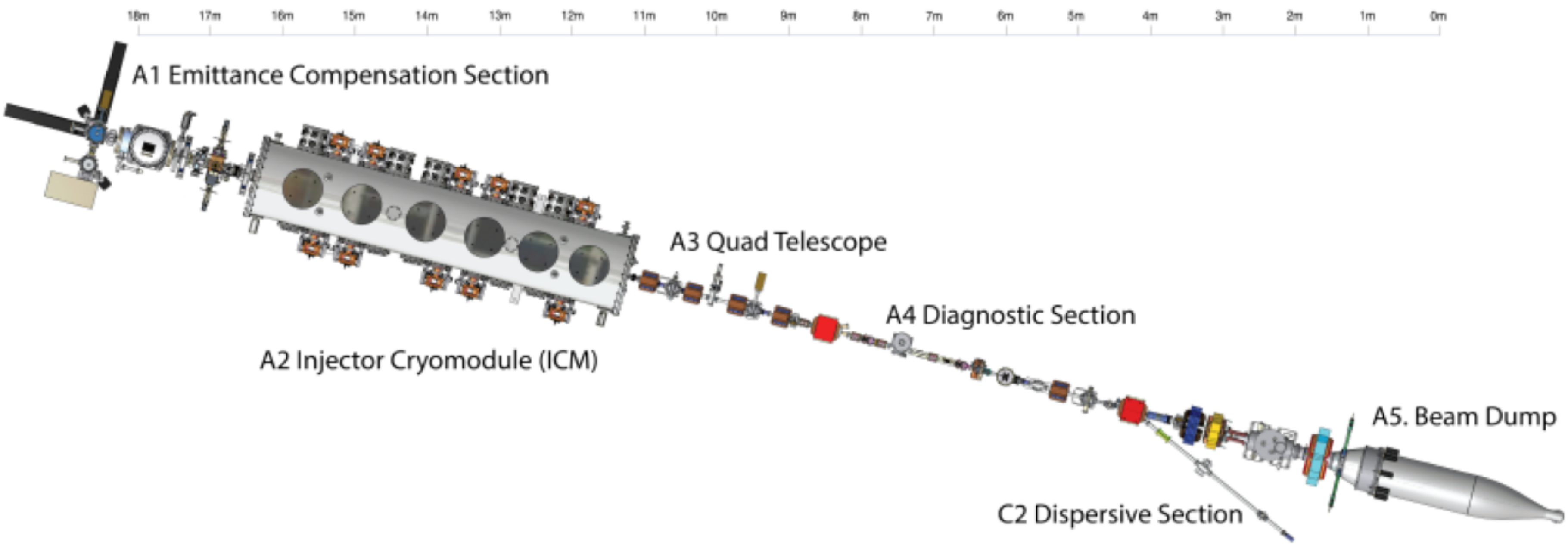
(Rich Gallagher)

Shielding layout — 2019

(Brian Heltsley)

Beam commissioning phases

Dec 2016



(Colwyn Gulliford)

Installed in LOE experimental hall

All subsystems tested

Initial beam recommissioning already performed

Main Linac Cryomodule

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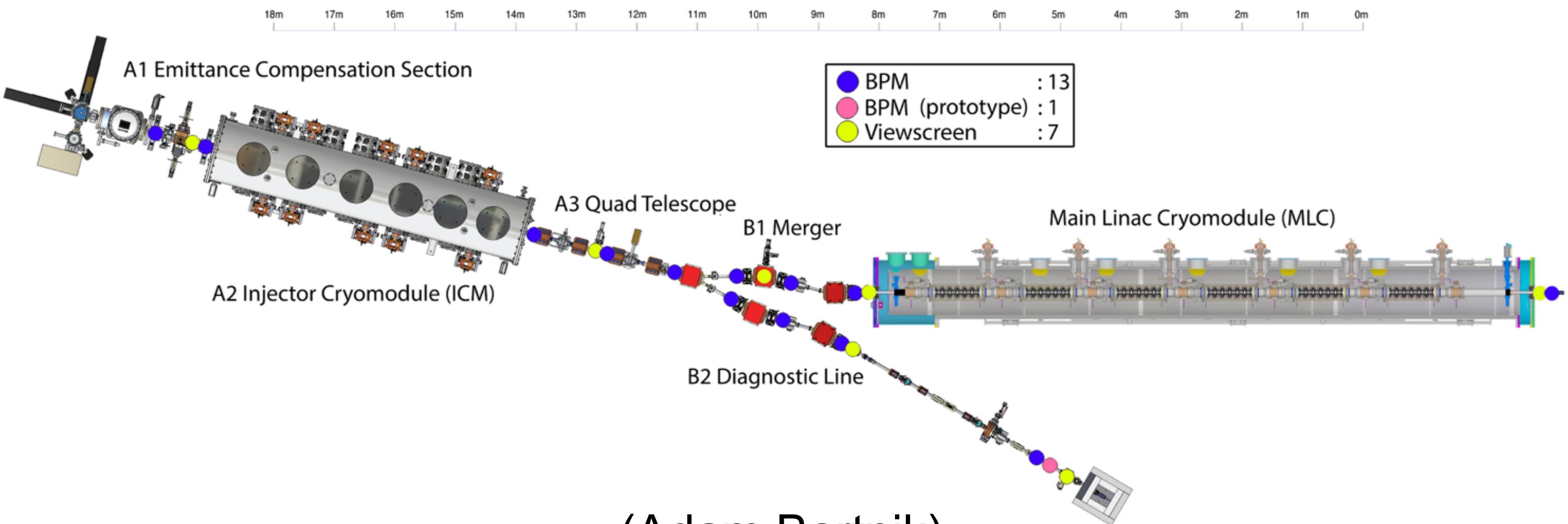
August 2017



(Adam Bartnik)

MLC cavities have been individually power tested, without beam.

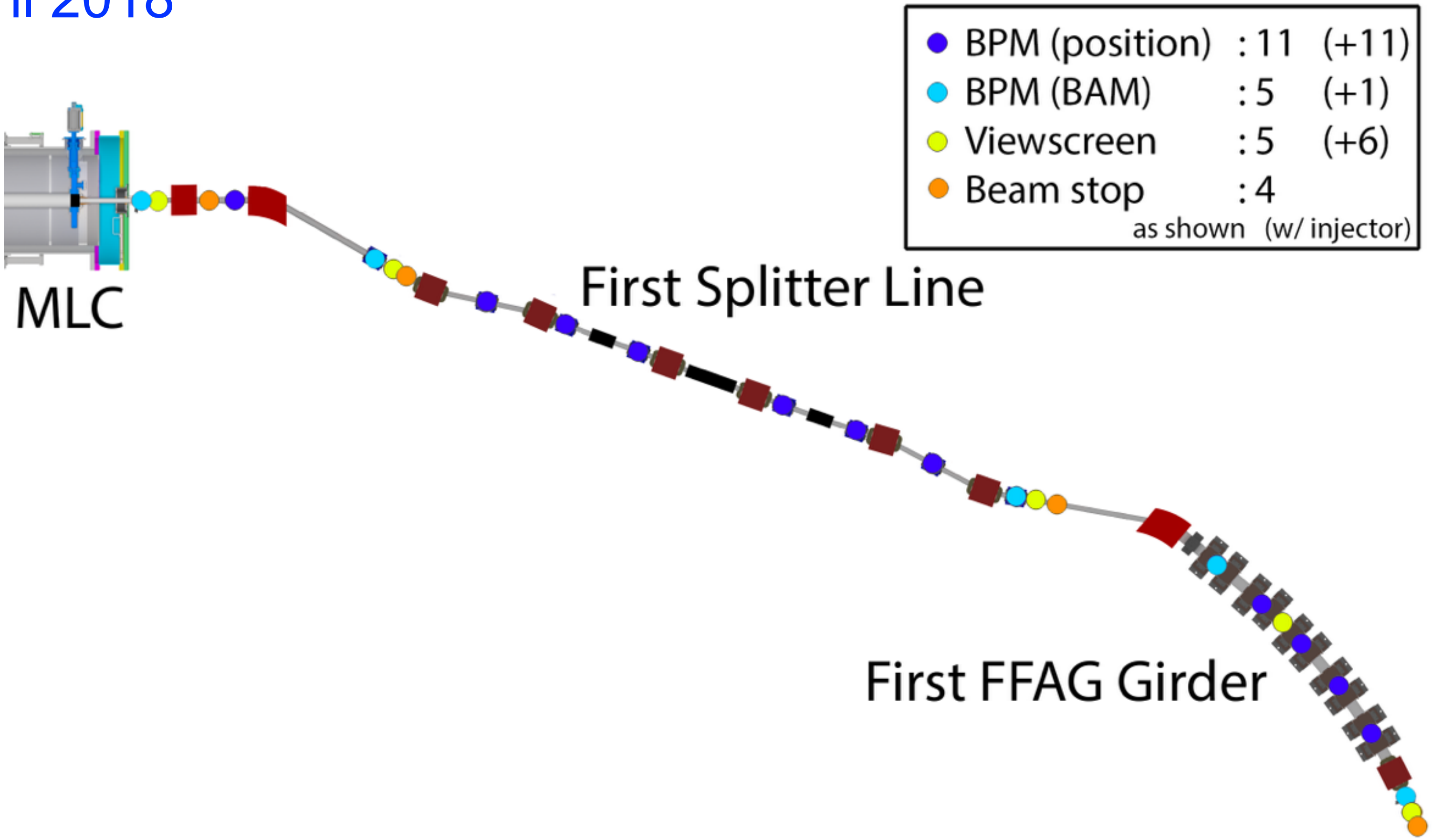
Solid state amplifiers (6) being procured.

Beam commissioning will meet "go/no-go" milestone 1.

Fractional Arc Test

CBETA

April 2018



Will address several “first article” issues.

Commissioning will meet “go/no-go” milestone 2.

Single pass with ER

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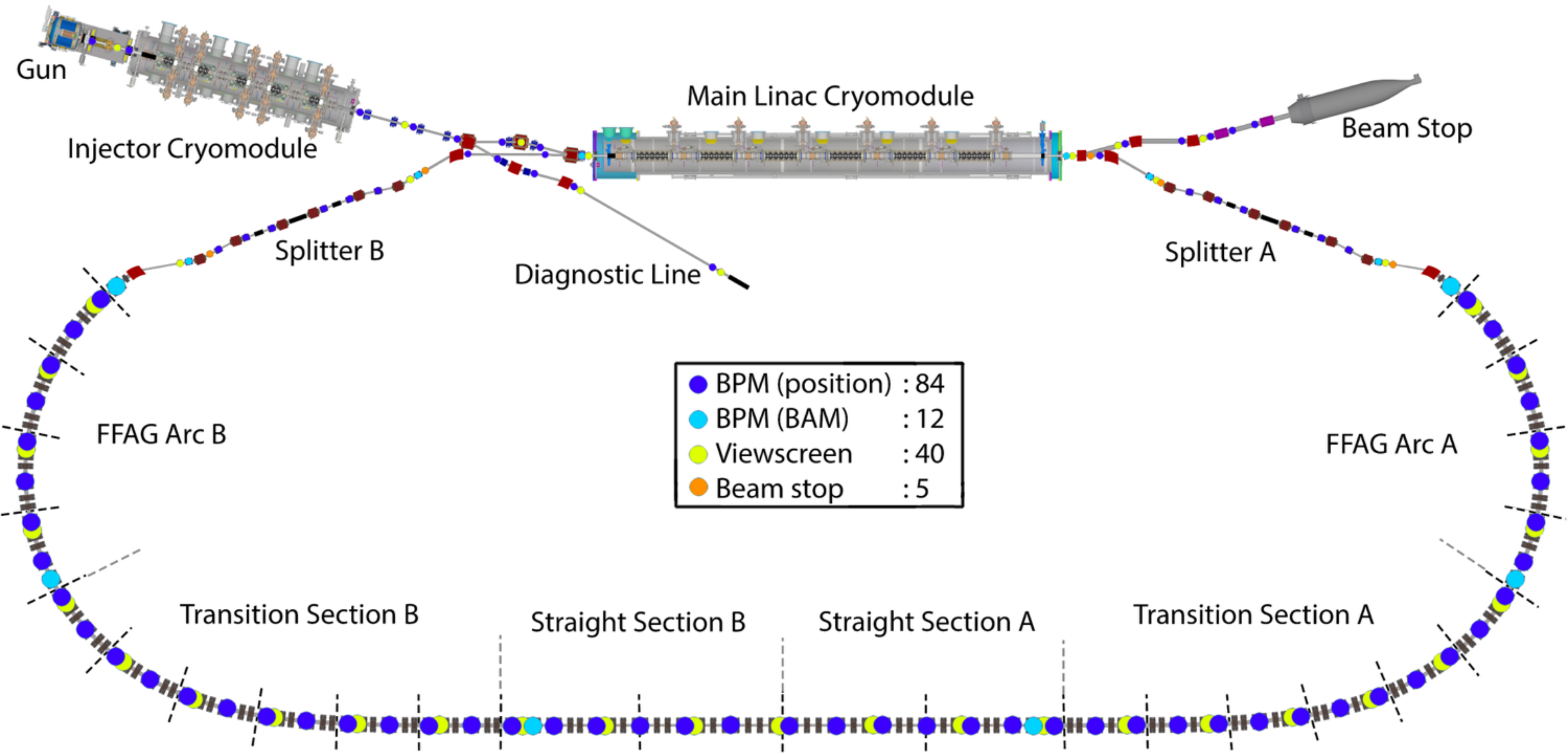
October 2019



Meet beam KPPs.

Technical milestones

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The 42-month timeline of milestones includes 2 "go/no-go" milestones requested by NYSERDA: 4 & 6

#	NYSERDA milestone	Baseline	Actual	Forecast
	NYSERDA funding start date		31-Oct-16	
1	Engineering design documentation complete	31-Jan-17		31-Jan-17
2	Prototype girder assembled	30-Apr-17		30-Apr-17
3	Magnet production approved	30-Jun-17		30-Jun-17
4	**Beam through Main Linac Cryomodule**	**31-Aug-17**		**31-Aug-17**
5	First production hybrid magnet tested	31-Dec-17		31-Dec-17
6	**Fractional Arc Test: beam through MLC & girder**	**30-Apr-18**		**30-Apr-18**
7	Girder production run complete	30-Nov-18		30-Nov-18
8	Final assembly & pre-beam commissioning complete	28-Feb-19		28-Feb-19
9	Single pass beam with factor of 2 energy scan	30-Jun-18		30-Jun-18
10	Single pass beam with energy recovery	31-Oct-19		31-Oct-19
11	Four pass beam with energy recovery (low current)	31-Dec-19		31-Dec-19
12	Project complete	30-Apr-20		30-Apr-20

Four crucial milestones

Jan 31: Engineering design documentation complete

- This Review

Apr 30: Prototype girder assembled

- 8 permanent magnets on a single 1.7 m girder
- Positively impacted by the technology switch to Halbach magnets

Aug 31: Go/no-go 1: Accelerate beam through the MLC.

The MLC will be moved into its final location for beam testing that will be completed in summer 2017.

Apr 30, 2018: Go/no-go 2: FAT: Beam through MLC and 1 girder

Initial configuration of 1 splitter line & 1 prototype girder.

NYSERDA Task 1

“Engineering design documentation complete”

As presented in the charge:

> “The Committee is asked to review whether the design of the project will be able to support the design performance and whether the engineering design of the project, including all technical subsystems, is sufficiently complete to proceed to detailed designs and start of construction.”

Thus, the project interprets this Advisory Committee meeting as the equivalent of a DOE “CD-2” review.

Achieving this first milestone on time is crucial to maintaining & developing good relations, especially financial, with NYSERDA.

NYSERDA contract Table 1

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Key Performance Parameters, are single turn (with 4-turn capability installed.

- when met, enable a “CD4” success

Design parameters are the stretch goals — how far is the stretch?

Parameter	Unit	KPP	Design
Electron beam energy	MeV		150
Electron bunch charge	pC		123
Gun current	mA	1	40
Bunch repetition rate (gun)	MHz		325
RF frequency	MHz	1300	1300
Injector energy	MeV		6
RF operation mode			CW
Number of ERL turns		1	4
Energy aperture of arc		2	4

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Documentation

Stable documentation

Design Report: Released Jan 27, describing baseline lattice "161117".

Risk Register: Mature, but with continuing maintenance & development.

Baseline parameters: Spreadsheet-based "database" is under configuration control, but easy to use.

- Component count stability is crucial for C&S

Project Management Plan: Revision 1 on Jan 27: e.g. PD, PM, DPM ….

Technical notes: Past & future technical documentation is being consolidated.

Design Report

CBETA

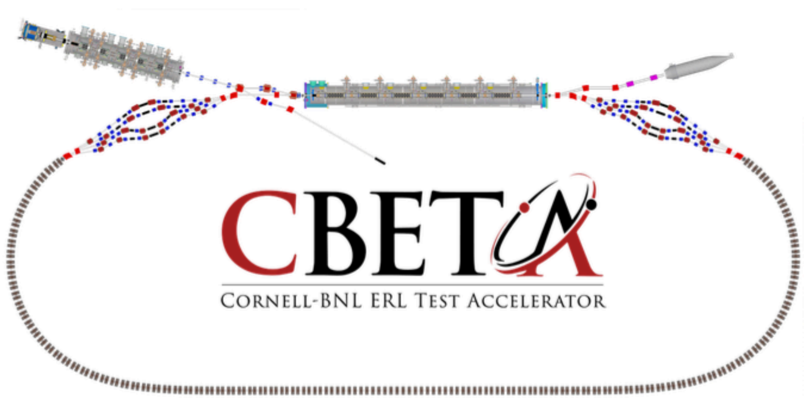
CBETA Design Report

Cornell-Brookhaven ERL Test Accelerator

Principal Investigators: G. Hoffstaetter and D. Trbojevic

Editor: C. Mayes

Contributors: J. Barley, I. Bazarov, A. Bartnik, I. Ben-Zvi, J. S. Berg, M. Blaskiewicz, S. Brooks, D. Burke, J. Crittenden, J. Dobbins, D. Douglas, B. Dunham, R. Eichhorn, F. Furuta, C. Franck, R. Gallagher, C. Gulliford, B. Heltsley, G. Hoffstaetter, V. Kostroun, Y. Li, M. Liepe, W. Lou, G. Mahler, C. Mayes, W. Meng, F. Méot, R. Michnoff, M. Minty, S. Panuganti, R. Patterson, S. Peggs, V. Ptitsyn, T. Roser, D. Sabol, E. Smith, K. Smolenski, P. Thieberger, J. Tuozzolo, D. Trbojevic, N. Tsoupas, G. Wang, H. Witte, W. Xu



January 27, 2017

(Editor: Chris Mayes)

Baseline lattice 161127 was optimized for hybrid (iron) magnets in the arcs.

Since then Halbach magnets have been adopted for use in the FFAG arcs.

To first order the baseline lattice is unchanged — "swap out, swap in".

Lattice fine-tuning

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Nonetheless the baseline lattice needs further fine-tuning for Halbach optimisation.

Minor lattice evolution will continue in the future, under configuration control.

- e.g. through the parameter lists and the Baseline Control Board.
- magnet moves at the level of < 10 mm

Baseline parameters

CBETA

Parameters & risks

170128	Baseline parameters
170123	Risk register

Organization

170123	WBS chart
170123	Organization chart
170127	Project Management Plan

Work Breakdown Structure

Dictionary 161019 Under development

Reviews

161220	Magnet Buildability Review
170130	Advisory Committee Technical Review
170206	Directors Review - Cost & Schedule

Technical notes

Index	Date	Author(s)	Title	Comment
0000	141216	Bazarov, Ben-Zvi et al	A whitepaper: The Cornell-BNL FFAG-ERL Test Accelerator	
0001	161229	Brooks	Magnet & lattice specifications for the CBETA first girder	
0002	161215	Brooks	Halbach magnets risks & challenges	
0003	161028	Brooks, Trbojevic, Tsoupas, Mahler	Halbach magnets outline construction method	
0004	170112	Karl, Trbojevic	Survey procedure	
	170124	Ed. Mayes, et al	CBETA Design Report	96 Mbyte

Parameters & risks are under administrative control & maintenance at the CBETA home page:

www.classe.cornell.edu/CBETA_PM

Parameters: an XLS file with one sheet per L2 plus other sheets …

… e.g. component counts:

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COMPONENT COUNTS 27-Jan-17

WBS 1.2 Accelerator Physics	170128		**Component count by sector**											
Component	**Name/description**	**TOTAL**	**Sector: IN**	**LA**	**SX**	**FA**	**TA**	**ZA**	**ZB**	**TB**	**FB**	**RX**	**DU**	**DI**
1.5 MAGNETS														
Conventional dipole		44	3		18							18	3	2
Conventional quadrupole		76	4	1	32							32	3	4
FFAG type QF		108			1	16	24	13	13	24	16	1		
FFAG type QD		107			1	16	24	13	12	24	16	1		
Common dipole		4			2							2		
Septum dipole		8			4							4		
1.9 INSTRUMENTATION														
LLRF DAQ/Controllers		12	6	6										
Beam Position Monitor (BPM) pickups (MLC test)	13 existing, one new style w/ transition pipe	14	7	2										5
Beam Position Monitor (BPM) pickups (final)		191	7	5	32	16	24	13	13	24	16	32	5	4
BPM electronics (MLC test)	9 existing w/ switches for 13, 1 V301	14	7	2									5	
BPM electronics: DAQ/Controllers (final)		138	7	5	32	8	12	7	6	12	8	32	5	4
View-screen DAQ/Controllers (1 pass)	7 existing, IN, LA, DI	40	2	2	2	4	6	4	3	6	4	2	2	3
View-screen DAQ/Controllers (multi pass)	7 existing, IN, LA, DI	40	2	2	8	2	3	3	2	3	2	8	2	3
Beam Loss Monitors (BLM)		48	8	6	4	4	6	3	3	6	4	4		
Bunch Arrival Monitors (BAM) (final)		16			8							8		
Bunch Arrival Monitor (1 pass)		12		2	2	2		1	1		2	2		
Beam Current Monitor		2	1										1	
Emittance Measurement		1												1
Beam stops	Pneumatic control	17		1	8							8		
1.10 VACUUM	Do these counts include splitters and FFAG?													
Instrumentation ports		52												
Gate valves		11												
NexTorr pumps		28												
CapaciTorr pumps		34												
Ion pumps		2												
Ion & Pirani gauges		8												

WBS 1.3 DC gun/injector	170115		
Component	**Name/description**	**Count**	**Comment**
SF6 tank		6	
New laser oscillator		1	
Stands (mirror merger installation)			80/20
Magnets (mirror merger)		4	
Vacuum - gate valve	DM40		VAT
Vacuum pump	NT200	1	
Vacuum pump	CT 200	2	
Vacuum - ion gauge			
Girder			80/20

17 of 82 risks (by WBS)

CBETA

WBS	ID	Risk Description	Potential Impact	L	I	LxI	S2	S3	Mitigation
1.1	1	Loss of key personnel	somewhat likely, and high impact	2	3	6	2.4	3.2	identify possible replacements, encourage commitment to project and high morale
1.1	2	Missing Key Milestone leads to funding delays or increased scrutiny	very possible, delays to schedule, possible funding delays recovering from problems.	3	4	12	3.5	4.6	Careful focus on meeting go/no-go milestones
1.1	3	Lack of qualified personnel leads to slow down in overall project schedule	highly likely, schedule slips leading to additional costs	5	2	10	3.2	5.1	diversify suppliers / shops / technicians / etc.
1.1	4	Insufficient human resource availability, especially engineers and technicians, due to conflict with other activities, eg CHESS-U at Cornell, or RHIC operations at BNL.	Schedule overruns, and standing army knock-on effects.	3	3	9	3.0	3.8	Identify the most critical deficiencies as soon as possible, especially with regard to magnet design protoyping and procurement (hybrid and conventional). Develop a Resource Loaded Schedule that includes (at a high level) conflicts with other projects. Increase the relative priority of C-Beta relative to other BNL and CLASSE activities. Hire additional personnel.
1.1	5	Funding Delays or Cuts from NYSERDA	Fund not available for project to move forward	1	5	5	2.2	5.0	Unless other funding sources are identified, there may be no way for the project to proceed.
1.2	1	Random field errors above levels specified in lattice requirements	Beam cannot be steered acceptably for operation with existing correctors.	2	4	8	2.8	4.2	Re-engineering of magnets. Re-design correctors with increased strength. Or run temporarily with worse emittance.
1.2	2	Magnetisation of blocks systematically lower or higher than specified range	Forced to lower or higher energy	2	2	4	2.0	2.4	Lower or higher linac energy by a few percent.
1.2	3	Systematic difference in fields, from crosstalk or single-magnet effects, small impact	Orbit differences below 1 mm, dynamically unimportant changes in tune range	2	1	2	1.4	2.0	Tweak linac energy to adjust tune and orbit range if desired, but probably just ignore.
1.2	4	Systematic difference in fields, from crosstalk or single-magnet effects, resulting in larger orbit differences	Orbit differences above 1 mm, dynamically unimportant changes in tune range	1	2	2	1.4	2.0	Systematically offset arc and transition magnets.Tweak linac energy.
1.2	5	Systematic difference in fields, from crosstalk or single-magnet effects, resulting in unacceptably large tune	Operating tune range will not allow a factor of 4 in energy	1	3	3	1.7	3.0	Adjust linac energy to allow factor of 4 in energy. Systematic quadrupole offset. Downgrade one quadrupole class with shunts to adjust tune range.
1.2	6	Non-uniformity of correctors or coupling of correctors to each other leads to different correction response than expected.	Correction algorithm not as effective as expected. Design corrector strength not as effective as expected.	2	3	6	2.4	3.2	Rewrite correction algorithm. Minor re-design of correctors.
1.2	7	Corrector strengths unexpectedly low.	Beam cannot be steered acceptably for operation with existing correctors.	1	4	4	2.0	4.0	Re-design correctors with increased strength.
1.2	8	Current ripple leads to excess emittance growth.	Beam loss impairs energy recovery. Radiation beyond permitted bounds.	2	4	8	2.8	4.2	Replace power supplies. Add filtering circuitry. Improve response of corrector systems.
1.3	1	gun failure / insulator punchthough / problem with HVPS	Months and months (6 months)	2	4	8	2.8	4.2	have backup gun, but BNL has backup HVPS in RHIC, Have a 2mA 500KV Glassman PS
1.3	2	Buncher IOT Tube	a week to fix,	2	2	4	2.0	2.4	$$$ to repair
1.3	3	Vacuum / diagnostic failure	fairly likely, but minor impact	2	2	4	2.0	2.4	
1.3	4	Cathode preparation issues (FE problems recently)	many minor delays	4	1	4	2.0	4.0	Multiple cathode growth systems / more trained experts in cathode growth. Better growth system diagnostics and testing.

(Scott Berg)

When asked for 3 top risks (Oct 2016):

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Risk Description	Potential Impact	Score L	Score I	Score L×I	Mitigation	Comment
Main Linac Cryomodule acquires an internal problem, such as a vacuum leak, that requires extensive dismantling, repair and reconstruction.	The MLC would take many months to repair, and would absorb a significant amount of labor.	2	4	**8**	Almost none, except for prevention: exercising great care during the relocation and beam-testing required for go/no-go milestone 1.	The MLC is a complex cryogenic with high power RF and high-vacuum sub-systems. It has mostly been tested, although not yet at full power, nor with beam.
Hybrid girder integration issues, mainly from magnet vendor performance and potential slow procurement, but also from protoype girder assembly schedule, production testing, and parts flow choreography.	Schedule impact leading to cost overruns. Vendor cost overruns.	3	3	9	Support the hybrid magnet design team with adequate technical personnel. Prepare and review the procurement plan, and the parts flow choreography, as comprehensively and as early as possible. Assemble and construct the 8-magnet prototype girder in-house at BNL. Monitor a geographically close magnet vendor carefully, offering technical assistance as necessary.	Prototype testing of the relatively simple but somewhat unusual magnet has gone slower than desired. BNL procurement process can be slow. Vendor may be geographically distant, in Europe or Asia.
Insufficient human resource availaibility, especially engineers and technicians, due to conflict with other activities, eg CHESS-U at Cornell, or RHIC operations at BNL.	Schedule overruns, and standing army knock-on effects.	3	3	9	Identify the most critical deficiencies as soon as possible, especially with regard to magnet design protoyping and procurement (hybrid and conventional). Develop a Resource Loaded Schedule that includes (at a high level) conflicts with other projects. Increase the relative priority of C-Beta relative to other BNL and CLASSE activities. Hire additional personnel.	The 4 mitigation strategies can be very effective. Two of them would require support from laboratory management.

Project management

Project Management Plan

CBETA

Table of Contents

Revision: 1/27/17

Closely follows the contents of the legal contract between BNL & the New York State Energy Research & Development Agency

NYSERDA

New York State Energy Research and Development

Laboratory Director: Doon Gibbs

Advisory Committee
Chair: Mike Harrison.
Sergey Belomestnykh, Oliver Bruning,
Wolfram Fischer, Shinji Machida,
Dave Rubin

You are here!

Oversight Board
Chair: Berndt Mueller (BNL), Robert Buhrman (CU),
Ritchie Patterson (CU), Thomas Roser (BNL)

Project Office
Project Director: Steve Peggs (BNL),
Project Manager: Rob Michnoff (BNL), **Deputy PM:** Karl Smolenski (CU)
Principal Investigators: Georg Hoffstaetter (CU), Dejan Trbojevic (BNL)
Resource Manager: Stephanie LaMontagne (BNL)
Financial Services: Katie Jacoby (CU), Ann Lamberti (BNL), Chris Manalo (BNL)

Baseline Control Board
Chair: Ivan Bazarov (CU),
Georg Hoffstaetter (CU),
Rob Michnoff (BNL),
Steve Peggs (BNL),
Vadim Ptitsyn (BNL),
Karl Smolenski (CU),
Dejan Trbojevic (BNL)

Work Breakdown Structure (Level 2)

1.1	**Project management**	Rob Michnoff (BNL)
1.2	**Accelerator physics**	Chris Mayes (CU)
1.3	**DC gun/injector**	Colwyn Gulliford(CU)
1.4	**RF systems**	Fumio Furuta (CU)
1.5	**FFAG magnets & girders**	Joe Tuozzolo (BNL)
1.6	**Splitters**	David Burke (CU)
1.7	**Power supplies**	John Barley (CU)
1.8	**Controls**	John Dobbins (CU)
1.9	**Instrumentation**	John Dobbins (CU)
1.10	**Vacuum system & beam stop**	Yulin Li (CU)
1.11	**System integration**	Rich Gallagher (CU)
1.12	**Beam commissioning**	Adam Bartnik (CU)
1.13	**Safety**	Dwight Widger (CU)

Org chart boxes

Oversight Board: Two BNL & two Cornell members, chaired by BNL.

Advisory Committee: A standing committee that can be asked for advice by both the OB & the Project Office.

Baseline Control Board: Chair from CU + 6 others.

- Decisions by consensus whenever possible.

Project Office: 1 Director, 1 Manager, 1 Deputy Manager, 2 PI's, 1 Resource Manager, financial services support.

- Coordinates CLASSE & C-AD activities.

Baseline Control Board

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E.g, recent harmonic number & FFAG magnet changes:

Baseline Control Board 1/19/2017 (Summary)

The Baseline Control Board (BCB) has reviewed the following two changes to the CBETA project:

1) The harmonic number change, in which the circumference length of the recirculation has changed from h = 333 to h = 343 as measured in RF periods (1.3 GHz RF frequency).
2) The adoption of Halbach instead of hybrid magnets for the project.

The details of the changes can be found at the end of the document as Appendices 1 and 2. Note: the decision to recommend the Halbach option for magnets was preceded by a separate CBETA Magnet Buildability Review in Dec 2016 chaired by T. Tanabe / consultation with the Oversight Board.

Outcome

The BCB members: I. Bazarov (chair), V. Ptitsin, G. Hoffstaetter, D. Trbojevic, S. Peggs, K. Smolenski

Result: The BCB has voted unanimously to adopt the proposed changes to the new baseline (h = 343 and using Halbach magnets).

Change control

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Level	Cost	Schedule and Risk	Technical Scope
Oversight Board	Costs needs that surpass the total project cost	Project Milestones, Review Milestones, review scopes	Changes of Key Performance Parameters and design parameters
Management Board	Contingency allocations	L2 subsystem completion dates and risks	Baseline changes, after consultation with the Baseline Control Board
Project Manager & Deputy Project Manager	Allocations at L2 larger than $10k, without contingency	Milestone changes that do not affect L2 completion dates or risks	Changes that do not affect the baseline
Cost Account Managers	Allocations at L3 less than $10k, without contingency	Changes that do not affect L3 milestones	Changes that do not affect technical deliverables

NYSERDA contract Table 3

"Expected quarterly cash flow [from NYSERDA] is subject to change on a monthly basis as the project is implemented."

Invoices submitted monthly will vary according to the precise timing of equipment purchases.

Year	Q1 ($M)	Q2 ($M)	Q3 ($M)	Q4 ($M)	Sub-total ($M)
1	1.7	1.9	2.1	2.3	8.0
2	2.3	2.3	2.3	2.0	8.9
3	1.7	1.3	1.3	1.3	5.6
4	1.3	1.2			2.5
Total					25.0

Cost baseline by WBS

The Total Estimated Cost of $25.0M includes contingency, which is owned by the Project Office.

Cost estimates will soon be discussed in detail.

- C&S Directors Review, Feb 6 & 7, at BNL.

Value engineering & C&S optimization will continue.

Concerns

Concerns

CBETA

Cost: Developing & distributing an adequate contingency at a fixed TEC while improving depth & accuracy.

Schedule: Achieving early NYSERDA milestones (especially prototype girder) while generating a project schedule consistent with cost sheet structure.

Technical: Understanding the detailed implications of the Halbach decision.

Ensuring design & specification consistency — configuration control — while applying value engineering.

Management: Enhancing efficient collaboration & communication between two cultures, 300 miles apart.