Project Overview & Plan

Steve Peggs

- Technical
- Management
- Cost

Scope

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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 equipment & infrastructure: 32 M$

- 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.

L0E hall evolution

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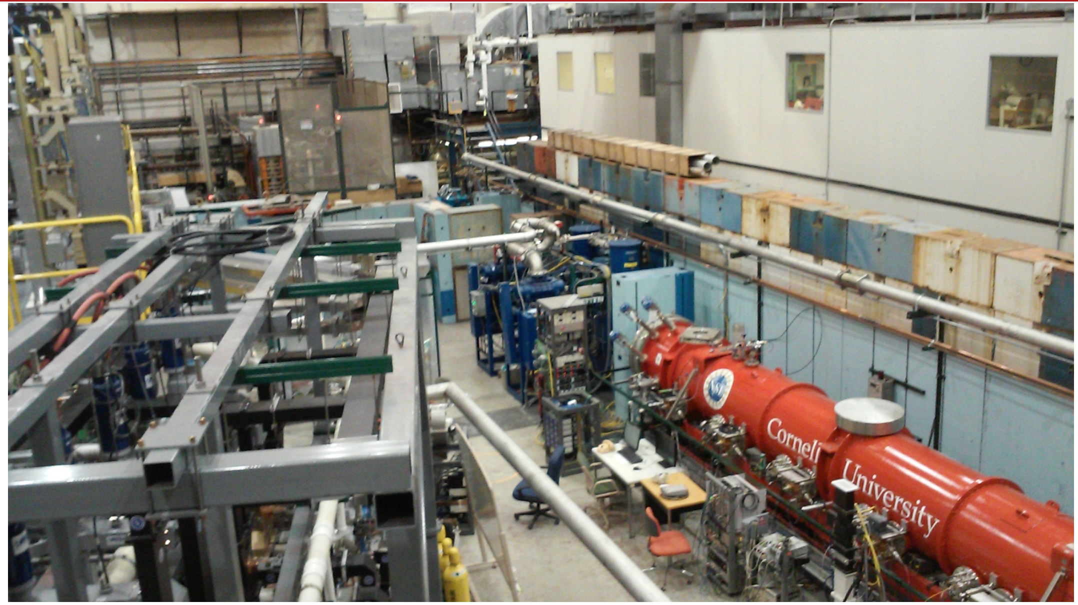
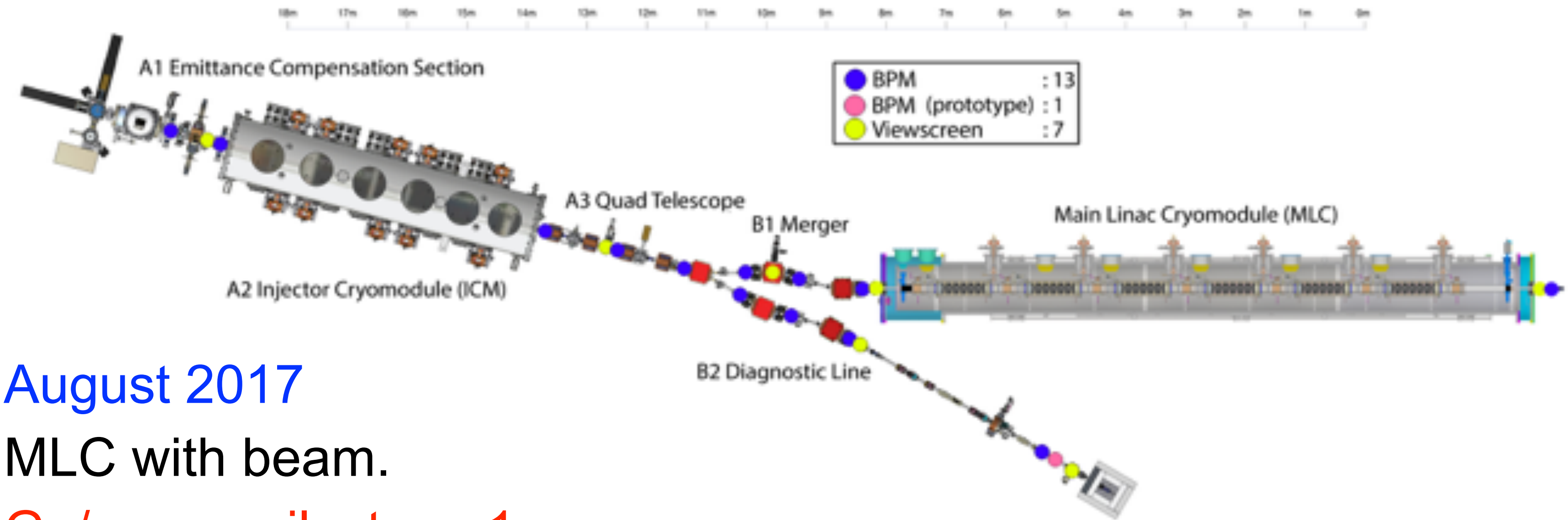
January 2017



2019 - 2020

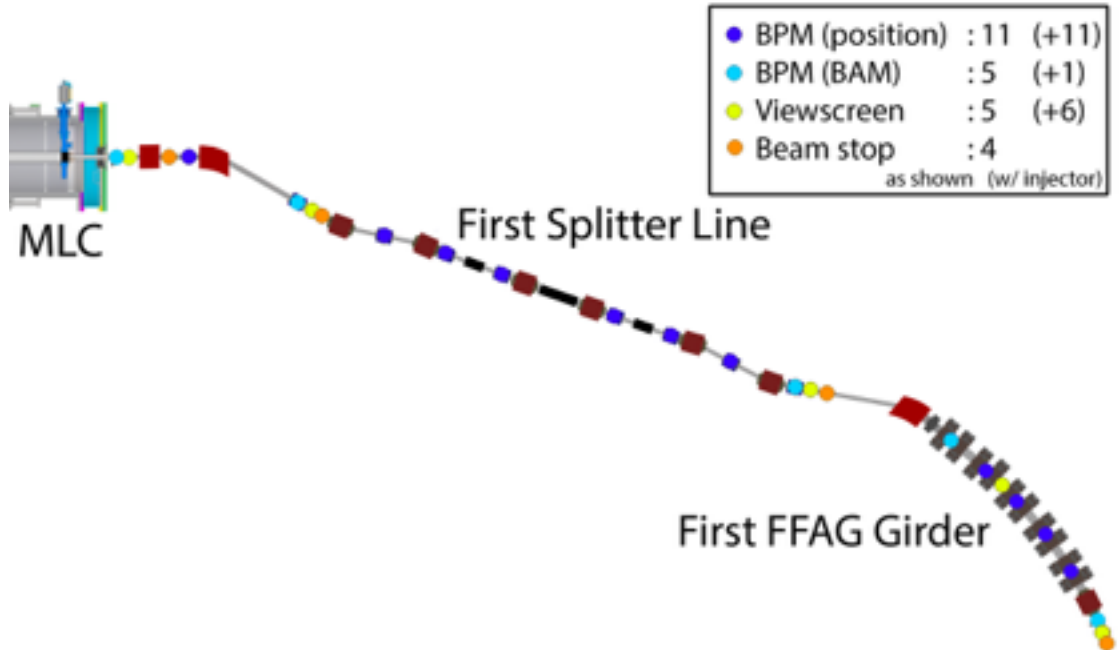
Beam commissioning phases



August 2017

MLC with beam.

Go/no-go milestone 1



April 2018

Fractional Arc Test

Go/no-go milestone 2.

peggs@bnl.gov

Single pass with ER

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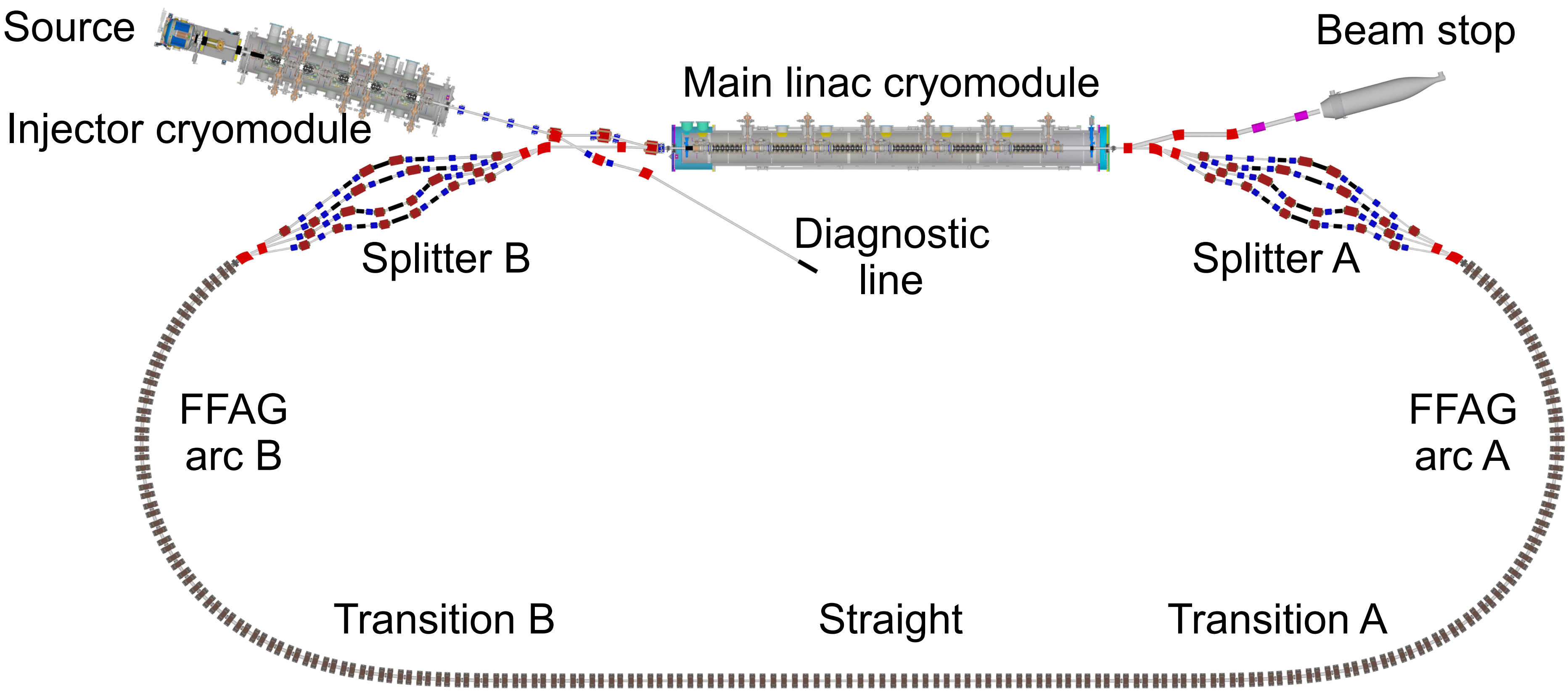

October 2019

Finish meeting the Key Performance Parameters!

NYSERDA contract Table 1

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

- when met, they 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

Baseline Design

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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".

Nonetheless the baseline lattice described in the Design Report needs further fine-tuning for Halbach optimisation.

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

Technical milestones

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		NYSERDA funding start date	31-Oct-16
2017	1	Engineering design documentation complete	31-Jan-17
	2	Prototype girder assembled	30-Apr-17
	3	Magnet production approved	30-Jun-17
	4	**Beam through Main Linac Cryomodule**	**31-Aug-17**
	5	First production hybrid magnet tested	31-Dec-17
2018	**6**	**Fractional Arc Test: beam through MLC & girder**	**30-Apr-18**
	7	Girder production run complete	30-Nov-18
2019	8	Final assembly & pre-beam commissioning complete	28-Feb-19
	9	Single pass beam with factor of 2 energy scan	30-Jun-19
	10	Single pass beam with energy recovery	31-Oct-19
	11	Four pass beam with energy recovery (low current)	31-Dec-19
2020	12	Project complete	30-Apr-20

Four crucial milestones

Jan 31: Engineering design documentation complete

- Last weeks Technical Review — success !

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.

Technical Review close-out

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The Technical Review report will be delivered this week.

32 Comments and 0 Recommendations in the close-out slides, plus 5 summary paragraphs. In their entirety:

"The Committee believes that the baseline design as described in the design report is consistent with both the KPP and the UPP parameter sets."

"The engineering design is sufficiently mature to warrant the start of construction activities. However we believe that further design iterations (e.g. system integration, value engineering) and more detailed engineering specifications will be beneficial in several areas (survey, BPM resolution)."

Close-out paragraphs 3 & 4

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“The design report does contain a series of tables which specify the baseline parameters for both the single and four-turn scenarios. The lattice is well defined as evidenced by the simulation results such as orbit correction and beta-beat evaluation.”

“As previously stated the physics specifications for the four pass ERL are determined. The technical subsystems are sufficiently well defined to proceed on the upcoming procurements to reach the next series of milestones. A more comprehensive set of technical specifications and drawings will be required for many subsystems to proceed through procurement and fabrication to initial operation.”

Close-out paragraph 5

"We note several significant components exist already (Gun, ICM, MLC, dump, diagnostic line). Major components including FFAG magnets, BPM electronics and controls have engineering designs. Girders, splitters, vacuum and other subsystems are still somewhat conceptual in places."

(The color coding is mine.)

Project management

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

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)

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

Project documents

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

Project Management Plan: Revision 1 on Jan 27

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

- Component count is stable enough for C&S accuracy

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

WBS Dictionary: Available at L2 & L3.

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

Baseline parameters

CBETA

Parameters & risks

170204 Baseline parameters
170202 Risk register

Organization

170123 Organization chart
170127 Project Management Plan

Work Breakdown Structure

170123 Structure L2
170204 Structure L3
170204 Dictionary L2
170204 Dictionary L3

Reviews

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

Technical notes

Index	Date	Author(s)	Title
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

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

… e.g. 17 of 83 risks

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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.

When asked for 3 top risks (Oct 2016):

Risk Description	Potential Impact	Score			Mitigation	Comment
		L	I	L×I		
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.

Costs

NYSERDA contract Table 3

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“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

Contingency in the $25.0M TEC is owned by the Project Office.

ESTIMATED BURDENED COSTS (Assumption - Best Case Scenario, Extraordinary Project Rates(EPR)) **Cornell Travel is Burdened

WBS	WBS Name	Total BNL Hours	Total BNL Burdened Labor Cost	Total BNL Burdened Material Cost	Total Cornell Hours	Total Cornell Burdened Labor Cost	Total Cornell Material /Labor	Total Project Burdened Material Cost	Total Project Burdened Labor Cost	Total Hours	Total Project Costs - Burdened
1.01.	Project Management	9,300	$ 1,727,520	$ 72,900	10,840	$ 1,348,126	$ 245,615	$ 318,515	$ 3,075,646	20,140	$ 3,394,161
1.02.	Accelerator Physics	6,160	$ 1,210,144	$ -	21,540	$ 1,034,305	$ 47,075	$ 47,075	$ 2,244,450	27,700	$ 2,291,525
1.03.	DC Gun/Injector	-	$ -	$ -	4,028	$ 270,807	$ 176,264	$ 176,264	$ 270,807	4,028	$ 447,071
1.04.	RF Systems	-	$ -	$ -	12,261	$ 905,710	$ 1,363,348	$ 1,363,348	$ 905,710	12,261	$ 2,269,058
1.05.	FFAG Magnets & Girders	5,964	$ 790,513	$ 2,116,155	-	$ -	$ -	$ 2,116,155	$ 790,513	5,964	$ 2,906,668
1.06.	Splitters	-	$ -	$ -	7,318	$ 393,976	$ 2,497,020	$ 2,497,020	$ 393,976	7,318	$ 2,890,996
1.07.	Power Supplies	-	$ -	$ -	3,818	$ 328,550	$ 890,650	$ 890,650	$ 328,550	3,818	$ 1,219,200
1.08.	Controls	280	$ 45,963	$ -	4,198	$ 254,641	$ 169,000	$ 169,000	$ 300,603	4,478	$ 469,603
1.09.	Instrumentation	2,970	$ 487,531	$ 1,108,350	3,083	$ 335,477	$ 345,606	$ 1,453,956	$ 823,009	6,053	$ 2,276,965
1.10.	Vacuum System & Beam Stop	-	$ -	$ -	6,006	$ 352,675	$ 919,695	$ 919,695	$ 352,675	6,006	$ 1,272,370
1.11.	System Integration	-	$ -	$ -	17,396	$ 1,020,905	$ 2,126,500	$ 2,126,500	$ 1,020,905	17,396	$ 3,147,405
1.12.	Beam Commissioning	-	$ -	$ -	15,120	$ 1,335,752	$ 10,000	$ 10,000	$ 1,335,752	15,120	$ 1,345,752
1.13.	Safety	-	$ -	$ -	3,567	$ 473,840	$ 127,250	$ 127,250	$ 473,840	3,567	$ 601,090
		24,674	**$ 4,261,671**	**$ 3,297,405**	**109,175**	**$ 8,054,766**	**$ 8,918,023**	**$ 12,215,428**	**$ 12,316,437**	133,849	**$ 24,531,865**

Total burdened cost of $24.5M allows a contingency of only 2%.

Although value engineering & C&S optimization will continue, it will not increase contingency to (say) 20%.

Sample of ongoing issues:

Extraordinary Project Rates (EPR): Are assumed in all BNL estimates. Without EPR the estimate increases by about $1M.

- All following presentations assume these rates.

4-pass costs: Included, although 4 passes are not in the KPP. Accomplishing 4 passes will be challenging.

RF maintenance: Has been put into contingency and the Risk Register.

Splitter costs: Appears to offer a real opportunity for value engineering.

More ongoing issues

Girder production: Technical plan for production/assembly/ survey/shipping between multiple vendors, BNL and CU is being re-analyzed and streamlined.

Project Management costs: Relatively high, due to complex collaboration needs, 300 miles apart.

Level of Effort: PM, Accelerator Physics, Commissioning.

BNL/CU purchasing split.

Conclusions

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We are triply constrained:

- Fixed cost: $25M.
- Fixed schedule: 3.5 years.
- Fixed scope: KPP's & 4 pass energy recovery.

These "external" constraints need to be addressed externally, as well as internally.

We seek & value your constructive suggestions.