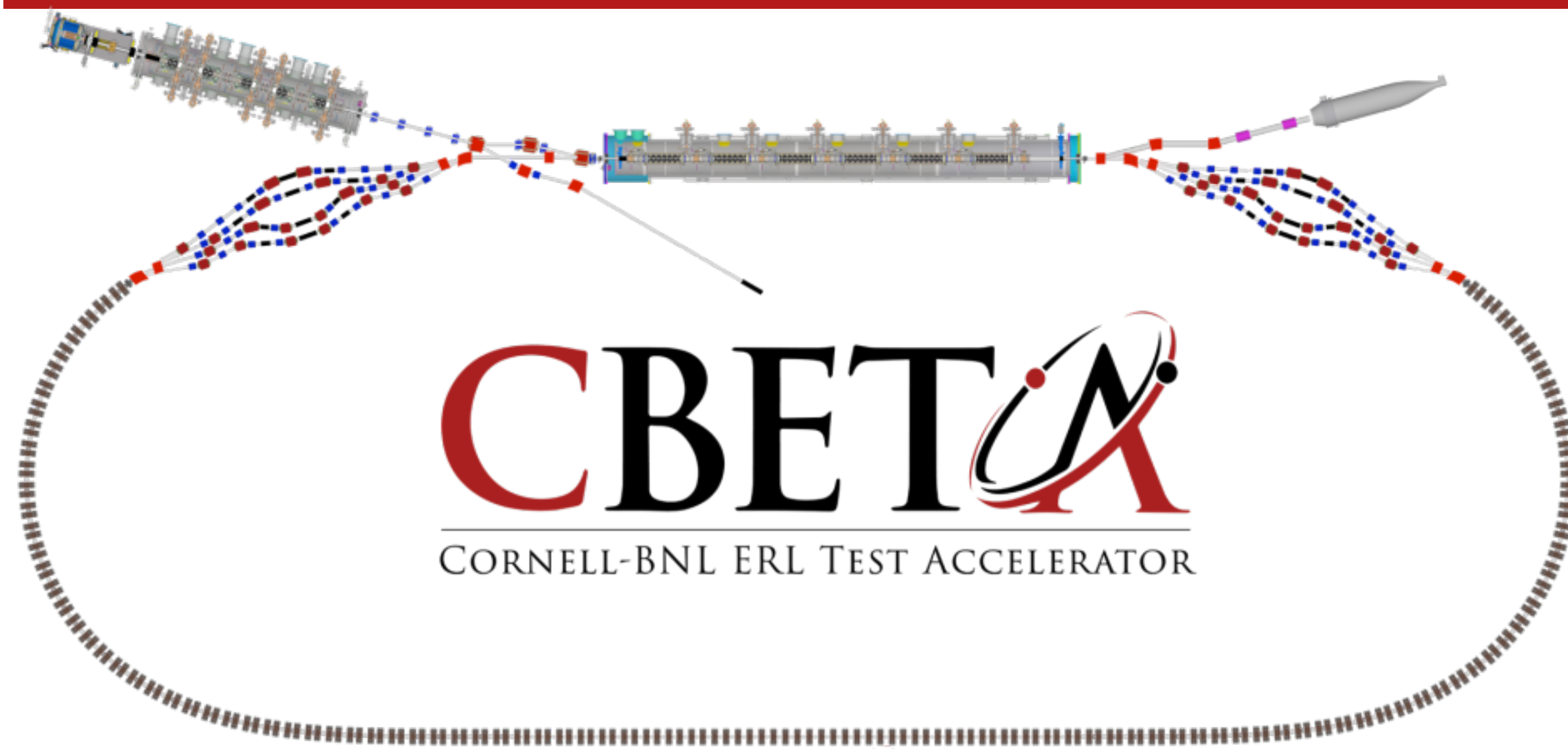
Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

BROOKHAVEN NATIONAL LABORATORY

Accelerator Physics



1.2 Accelerator Physics Outline

- WBS dictionary
- Basis of estimate
- Overview of Cost estimate
  - Labor, materials, burden rates & costs, contingency
- Overview of schedule
  - Design, procurement, construction, pre-beam tests, beam commissioning
- Major Risks
- There are no major procurement items.

Introduction

- Accelerator Physicists are needed to design CBETA, aid in specifying its procurement, and understand it once it is built.
- Major players: Mayes – overall lattice design, Berg – FFAG optics design, analysis, Brooks –simulation and studies.
- The work will continue throughout the entire project, first to design, then to assist in commissioning.
- Such a machine has never been built before. Having a coherent team to solve problems quickly once they arise will help keep us on schedule and avoid making costly mistakes.
- Graduate students are essential to delve deep into special topics (moving towards their dissertations) and to perform ‘mundane’ tasks (easing the burden on the full-time players). *They will be our future designers and operators!*

WBS Dictionary

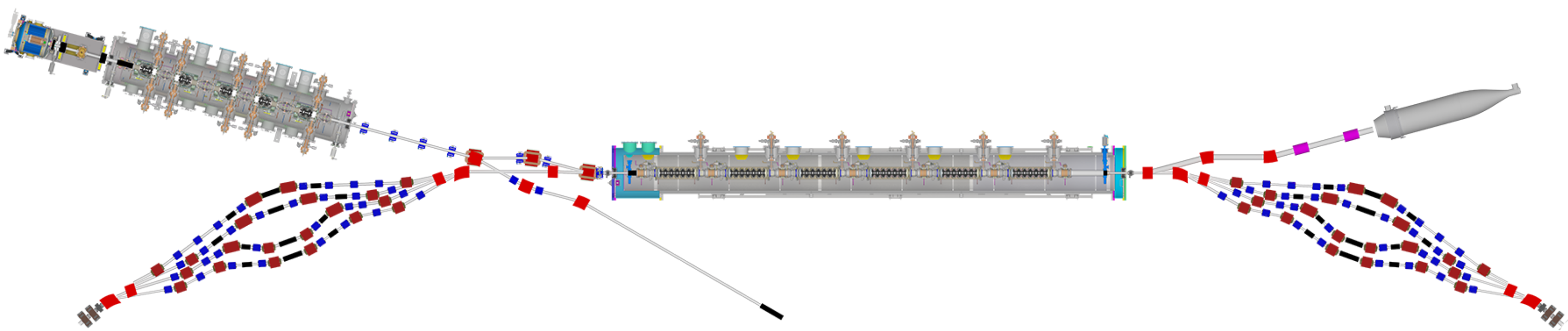
WBS Code	WBS Element				
1.02	*Accelerator Physics*				
Owner		Estimated Start	Estimated Finish	% Total Burdened$	Total % Hours
Mayes				*9%*	*20%*
WBS Element Description					
Responsible for ensuring that the machine design will satisfy the project goals. Conduct and document simulations and modeling, design machine optics, and specify required beam instrumentation. Define machine performance parameters. Provide detailed machine analysis to determine potential beam effects that could prevent achieving the intended machine performance.					
	Labor Hrs	Direct Labor$	Direct Mat'l/Trvl$	Direct Total Cost	Burdened Cost
Cornell	21540	$ 939,522	$ 42,500	$ 982,022	$ 1,081,380
BNL	6160	$ 889,812	$ -	$ 889,812	$ 1,210,144
CBETA Total	**27700**	**$1,829,334**	**$42,500**	**$1,871,834**	**$2,291,525**

WBS Dictionary

WBS	Task Name	Institution	WBS Manager
A1.02	ACCELERATOR DESIGN	Cornell	Mayes
A1.02.01	Baseline Splitter Lattice Design This scope includes the magnetic steering and focusing design and simulation for the Splitter sections (SX, RX), mechanisms for path length adjustment, and error correction analysis.	Cornell	Mayes
A1.02.02	Fractional Arc Lattice Design This scope includes design and simulation for the beam lines from the MLC through the first girder of FFAG magnets.	Cornell	Mayes
A1.02.03	Single Pass Lattice Design This scope includes designing and simulating the one-pass energy recovery mode lattice. It also includes accelerator physics analysis and simulations for this machine, such as error and their correction, beam halo, beam breakup instability, and coherent synchrotron radiation.	Cornell	Mayes
A1.02.04	Four Pass Lattice Design This scope includes the same studies as the single pass design, but for the full four-pass machine.	Cornell	Mayes

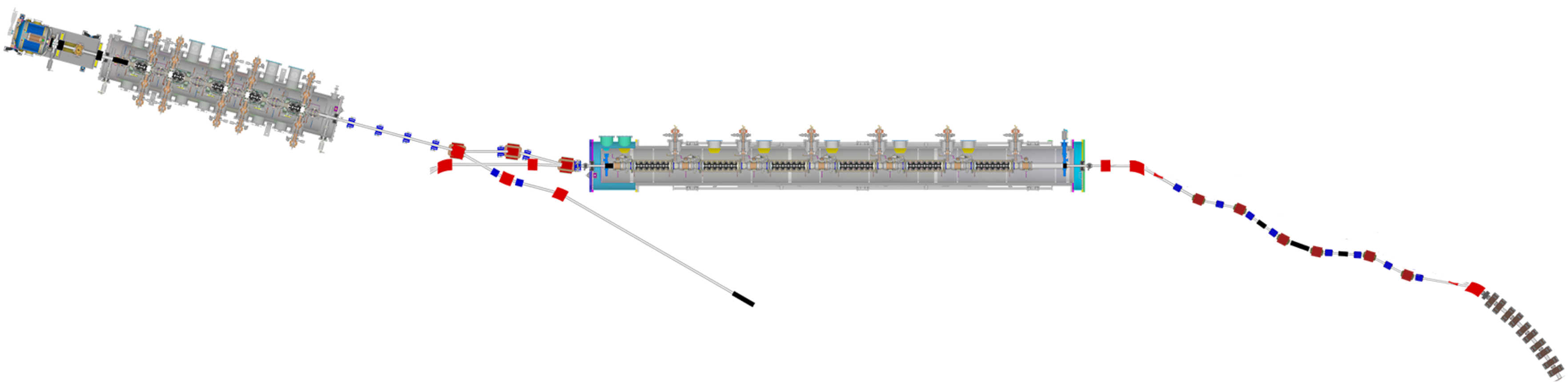
WBS Dictionary: A1.02.01

WBS	Task Name	Institution	WBS Manager
A1.02	ACCELERATOR DESIGN	Cornell	Mayes
A1.02.01	Baseline Splitter Lattice Design	Cornell	Mayes
	This scope includes the magnetic steering and focusing design and simulation for the Splitter sections (SX, RX), mechanisms for path length adjustment, and error correction analysis.		



WBS Dictionary: A1.02.02

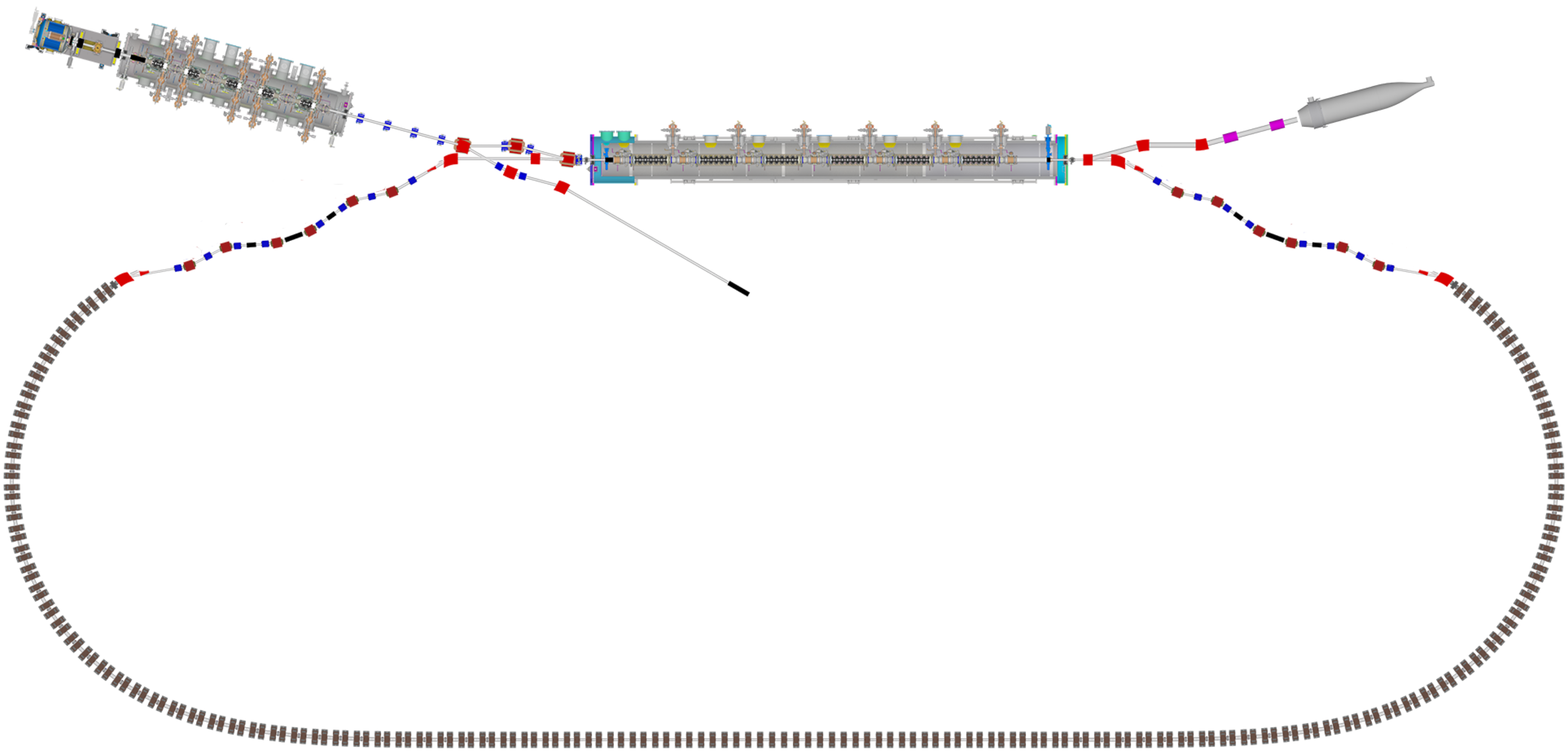
WBS	Task Name	Institution	WBS Manager
A1.02	ACCELERATOR DESIGN	Cornell	Mayes
A1.02.02	Fractional Arc Lattice Design	Cornell	Mayes
	This scope includes design and simulation for the beam lines from the MLC through the first girder of FFAG magnets.		



WBS Dictionary: A1.02.03

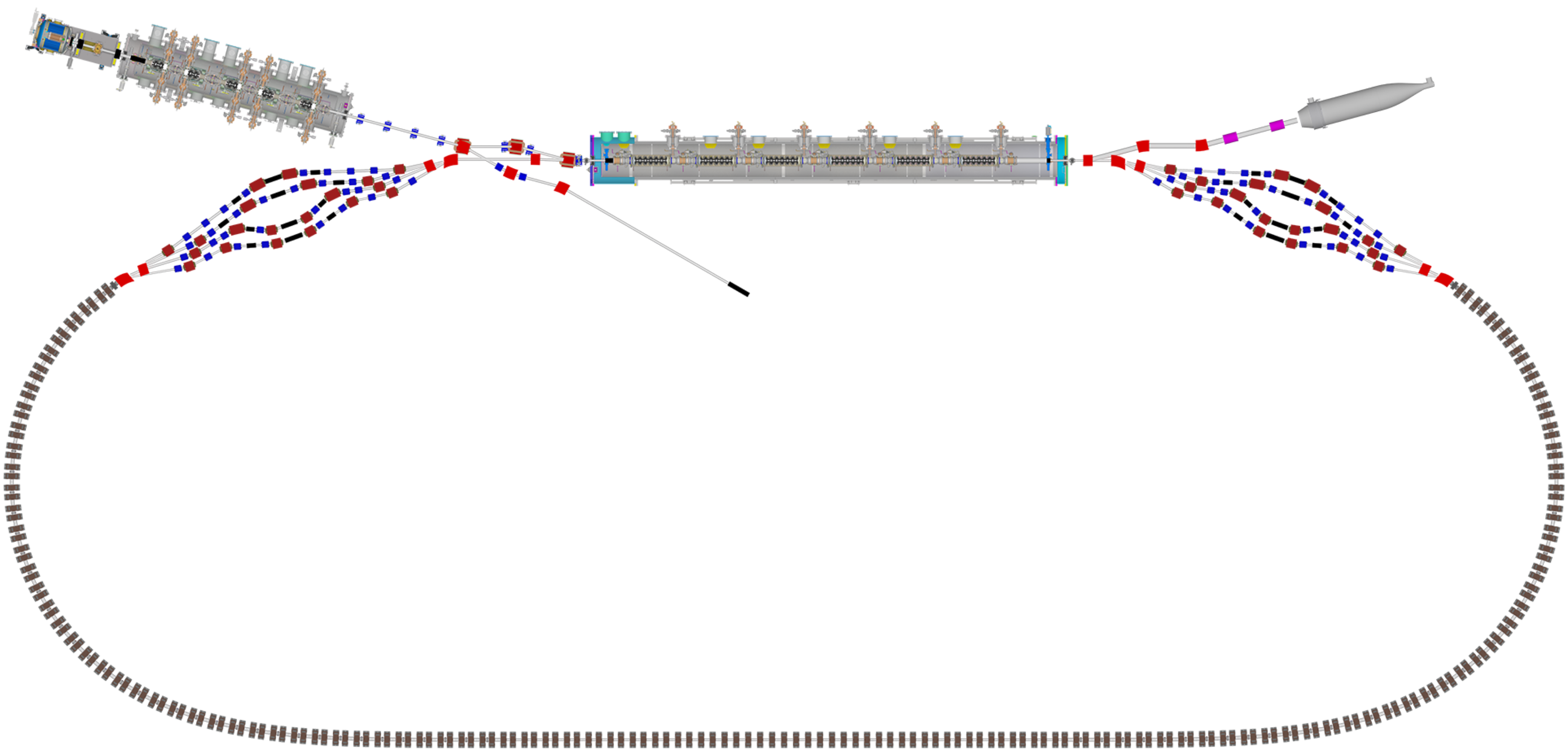
WBS	Task Name	Institution	WBS Manager
A1.02	ACCELERATOR DESIGN	Cornell	Mayes
A1.02.03	Single Pass Lattice Design	Cornell	Mayes

This scope includes designing and simulating the one-pass energy recovery mode lattice. It also includes accelerator physics analysis and simulations for this machine, such as error and their correction, beam halo, beam breakup instability, and coherent synchrotron radiation.



WBS Dictionary: A1.02.04

WBS	Task Name	Institution	WBS Manager
A1.02	ACCELERATOR DESIGN	Cornell	Mayes
A1.02.04	Four Pass Lattice Design	Cornell	Mayes
	This scope includes the same studies as the single pass design, but for the full four-pass machine.		



Basis of Estimate

- All labor based on level of effort.
- Continuous accelerator physics support is expected throughout the lifecycle of the project (i.e. simulations and analysis).
- This will also support commissioning efforts.
- Staff percentages (FTE = 1760 hours/year)

1.02.	**Accelerator Physics**	BNL	Berg	3,080	1.75
			Brooks	1,540	0.88
			Scientist	1,540	0.88
		BNL Total		6,160	3.50
		Cornell	CU - GradStudent	12,320	7.00
			Gulliford	1,520	0.86
			Mayes	6,160	3.50
			Sagan	1,540	0.88
		Cornell Total		21,540	12.24

- Minor other expenses based on past experience (repairs to computer cluster, travel)
- Accelerator Physics travel to BNL / CU / Other specifically for Acc. Physics
- Conference Travel in PM

Cost Estimate Overview

CBETA	Accelerator Physics		
Assumption: EPR Rate	1.02		
	Hours	Burdened Labor Cost	Burdened Material Cost
Building Trades-Riggers	-	$ -	$ -
Central Shops	-	$ -	$ -
Designer	-	$ -	$ -
Engineer	-	$ -	$ -
Scientist	6,160	$ 1,210,144.32	$ -
Technician	-	$ -	$ -
Purchases<$25K	-	$ -	$ -
Purchases>$25K<$2M	-	$ -	$ -
Travel	-	$ -	$ -
BNL Total (Spreadsheets)	*6,160*	*$ 1,210,144.32*	*$ -*
CU - Admin	-	$ 771,805.32	
CU - Scientist	7,680		
CU - Senior Scientist	1,540		
CU - IT (Controls)	-		
CU - Technician	-		
CU - Electronics Technician	-		
CU - Engineer	-		
CU - Machinist	-		
CU - Designer	-		
CU - GradStudent	12,320	$ 262,500.00	
CU - Travel	-		$ 12,075.00
CU - Material	-		$ 35,000.00
CU Total (Spreadsheets)	*21,540*	*$ 1,034,305.32*	*$ 47,075.00*
CU+BNL Burdened Total	***27,700***	***$ 2,244,449.64***	***$ 47,075.00***
Total Burdened Material & Labor			**$ 2,291,524.64**

Major Risks

WBS	ID	Risk Description	Potential Impact	L	I	L×I	S2	S3	Mitigation	Comment
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.	Have provision for 2 mm of magnet shift, which should handle several mm of orbit offsets.
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.	Have provision for 2 mm of magnet shift, can pull beam out of region where systematic effects are significant.
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.	Could better evaluate likelihood and impact with simulation, but complex.
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.	

Major Risks

- Random field errors above levels specified in lattice requirements. If not enough corrector overhead is available, it will prevent operating the machine as an ERL. Magnets may need to be shimmed, or more correction capability installed.

- Corrector strengths unexpectedly low (related to above).

- Current ripple leads to excess emittance growth. Power supplies may need to be replaced, or filtering circuitry added

Procurement Plan

- There are no major procurement items