WBS 121.5 – Conventional Facilities

Design and Scope

Steve Dixon

PIP-II DOE Independent Project Review

12-14 December 2017

In partnership with:
- India/DAE
- Italy/INFN
- UK/STFC
- France/CEA/Irfu, CNRS/IN2P3

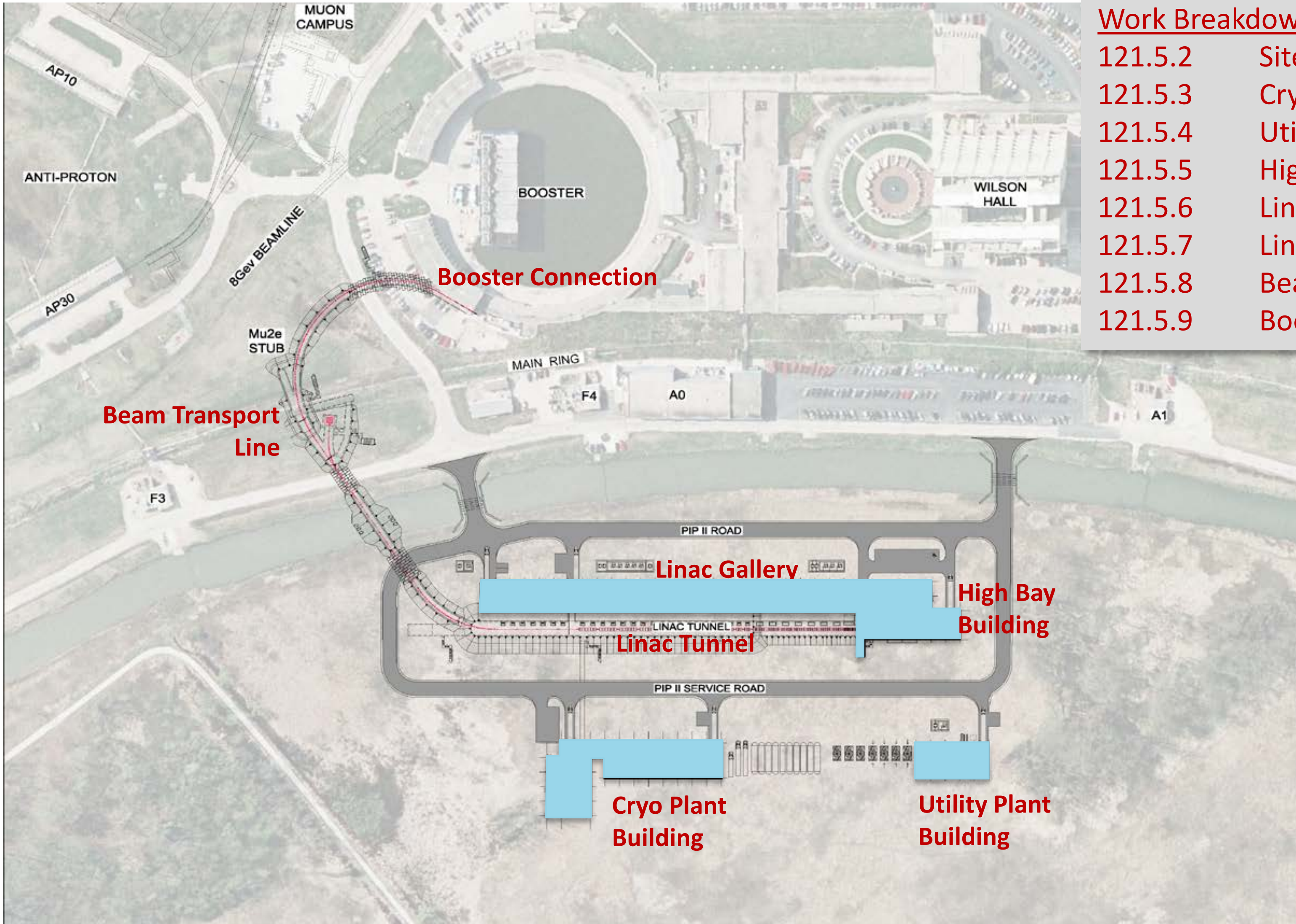
Charge Questions

Charge Question	Presentation
1. Has the project team documented a carefully considered analysis of alternates that supports the preferred alternate?	Plenary and Design and Scope Breakout
2. Does the conceptual design satisfy the perfromance requirements?	Design and Scope Breakout
3. Does the conceptual design report and supporting documentaton adequately justify the stated cost range and project duration?	Cost and Schedule Breakout
4. Does the project team have adequate management experience, design skills, and laboratory support to manage all aspects of this project and produce a credible technical, cost, and schedule baseline?	Management Breakout
5. Are the ES&H aspects of the project being properly addressed and is the ES&H planning currently sufficient for this stage of the project?	Plenary
6. Is the documentation required by DOE O413.b for CD-1 approval complete and in good order?	CD-1 Documentation Breakout
7. Is the allocation of the technical scope that will be contributed by international partners sufficiently understood and documented such that the conceptual design and cost range can be relied on?	Plenary
8. Has the project satisfactorily responded to the recommendations from previous reviews?	Plenary

Agenda

- Conceptual Design Process
- Alternates Investigated
  - Siting
  - ICW Cooling
  - Pulsed Mode vs. Continuous Wave Operation
- Next Steps

Conventional Facilities Overview



Work Breakdown Structure

121.5.2	Site Preparation
121.5.3	Cryo Plant Building
121.5.4	Utility Plant Building
121.5.5	High Bay Building
121.5.6	Linac Tunnel
121.5.7	Linac Gallery
121.5.8	Beam Transfer Line
121.5.9	Booster Connection

Conventional Facilities Overview

Looking Southeast From Wilson Hall

Looking South Along Beamline

View from Wilson Hall

Process

- Functional Requirements Specification (Project Level)
- Functional Requirements Specification (Subproject Level)
- Conceptual Design
  - Drawings [1]
  - Text [2]
  - Estimate Assumptions [3]
- Technical Requirements Specifications
- **Cost/Schedule Estimate** (Separate Breakout Presentation)

[1] – Conceptual Design Drawings can be found in PIP-II-doc-1155
[2] – Conceptual Design Report can be found at PIP-II-doc-113
[3] – Estimate Assumptions can be found at PIP-II-doc-333, Item D

PIP-II Functional Requirements Specifications

- "PIP-II is focused on upgrades to the Fermilab accelerator complex capable of providing proton beam power in excess of 1 MW on target at the initiation of the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE) program, currently anticipated for the mid-2020s"
- TeamCenter document ED0001222, signed in March 2017 (PIP-II-doc-1166)

Integration and Upgradability

Requirement	Description	Value
I1	The siting of the PIP-II facility will be consistent with future replacement of the existing 8-GeV Booster with either an 8 GeV Rapid Cycling Synchrotron or superconducting pulsed linac	
I2	The siting of the PIP-II facility will be consistent with future upgrades to provide 100 kW beams to the Mu2e hall on the Muon Campus	
I3	The SC Linac will be constructed of components capable of operating in CW mode, following modest upgrades	
I4	The SC Linac will be constructed in a manner that allows installation and commissioning without interruption to ongoing accelerator operations	
I5	Residual Activation from Uncontrolled Beam Loss in areas requiring hands-on maintenance.	<20 mrem/hour (average) <100 mrem/hour (peak) @ 1 ft
I6	Scheduled Maintenance Weeks/Year	8
I7	SC Linac Operational Reliability	90%
I8	60-120 GeV Operational Reliability	85%
I9	Facility Lifetime	≥40 years

Conventional Facilities specific requirements

Conventional Facilities FRS and TRS

- Functional Requirements Specification (FRS) define the function of each component (**what**);
- Technical Requirements Specification (TRS) define the critical technical requirements for each components (**how**);
- Support the PIP-II Project FRS;
- Developed for each conventional facilities work package;
- Ensures design meets the requirements;

		Functional Requirements Specification	Technical Requirements Specification
WBS	**Identification**	TeamCenter	TeamCenter
121.5.1	CF Project Management and Coordination		
121.5.2	Site Preparation	ED0006787	ED0006789
121.5.3	Cryo Plant Building	ED0006718	ED0006719
121.5.4	Utility Plant Building	ED0006748	ED0006749
121.5.5	High Bay Building	ED0006756	ED0006757
121.5.6	Linac Tunnel	ED0006790	ED0006791
121.5.7	Linac Gallery	ED0007079	ED0006793
121.5.8	Beam Transfer Line	ED0006785	ED0006786
121.5.9	Booster Connection	ED0006794	ED0006795

Typical FRS

Section 1 – Conventional Facilities Purpose

The PIP-II conventional facilities will house the accelerator components and support equipment required to install and operate the PIP-II linac and transfer line. The PIP-II conventional facilities scope includes the elements of work normally included in conventional construction such as earthwork, utilities, structural concrete, structural steel, architectural cladding, finishes, roofing, plumbing, process piping, heating ventilation and air conditioning (HVAC), fire protection, fire detection, lighting and electrical. This also includes the work required to extend the utilities to the project site, excavation associated with the below grade cast-in-place concrete enclosures, creation of a shielding berm and site restoration.

Section 2 – Key Assumptions

Assumptions related to the Cryogenics Plant Building are contained in the Assumptions Document (TeamCenter ED0001222)

Section 3 – Functional Requirements

The function of the Cryogenics Plant Building is to house the processes required to install, assemble and operate the cryogenic plant and related spaces to support PIP-II accelerator operations.

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Typical TRS Contents

Technical Requirements Specifications

Cryo Plant Building

WBS 121.5.3

Table of Contents

Typical Technical Requirements Specification Table of Contents

Fermilab

Typical TRS

Section 1 – Conventional Facilities Purpose

The PIP-II conventional facilities will house the accelerator components and support equipment require to install and operate the PIP-II linac and transfer line. The PIP-II conventional facilities scope includes the elements of work normally included in conventional construction such as earthwork, utilities, structural concrete, structural steel, architectural cladding, finishes, roofing, plumbing, process piping, heating ventilation and air conditioning (HVAC), fire protection, fire detection, lighting and electrical. This also includes the work required to extend the utilities to the project site, excavation associated wit the below grade cast-in-place concrete enclosures, creation of a shielding berm and site restoration.

Section 2 – Scope

The Cryogenics Plant Building consists of the conventional construction required to install, house and operate the cryogenic plant to support PIP-II accelerator operations. The cryogenics equipment, installation, assembly, testing and commissioning will be accomplished by others.

Section 3 – Requirements

3.1 – Spatial Requirements

The Cryogenics Plant Building will be located at the downstream end of the Linac Enclosure in order to be positioned to allow for future expansion.

The Cryogenics Plant Building contains three (3) primary spaces as described below:

Cold Box Station - The Cold Box Station will contain the equipment to install, operate and maintain the cold box. This includes the following requirements:

- Building Size: 15 m x 40 m (50 feet x 131 feet);
- Overhead door 5 m x 5 m (17 feet x 17 feet);
- Space for five (5) 10,000 liter (2,641 gallons) dewars;
- Coordination Center to house 4-8 people;
- Control Room to accommodate equipment, monitors and related control equipment;
- Control Room and Coordination Center should have an isolated HVAC system that is capable o pressuring the room to reduce the oxygen deficiency hazard of the space;

Warm Compressor Station - The Warm Compressor Station will contain the equipment to install, operate and maintain the compressors and related equipment to support the Cold Box Station. This includes the following requirements:

- Building Size: 20 m x 30 m (66 feet x 100 feet)
- Overhead door 5 m x 5 m (17 feet x 17 feet);
- Space for five (5) 10,000 liter (2,641 gallons) dewars;

Exterior Space - The exterior space for the Cryogenics Plant Building will provide for access to the Cold Box Station and Warm Compressor Station. This includes the following requirements:

- Space for ten (10) 113,000 liter (30,000 gallon) storage tanks and related piping;

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Typical Technical Requirements Specification page

Conceptual Design Process

- Meetings with Stakeholders:
  - Goal: Document the spatial and infrastructure requirements for PIP-II facilities; [4]
  - Started in January 2016;
- Results:
  - Conceptual Design drawings and text that described the sizes/arrangement of spaces and buildings to accommodate the functional requirements; [5]
  - Cost Estimate Assumptions; [6]
  - Life Safety Analysis; [7]
  - Cooling strategies for pulsed mode and continuous wave operation;
  - **Conventional facilities are similar to typical Fermilab construction**;

[4] – Meeting Minutes can be found in PIP-II-doc-70
[5] – Conceptual Design Drawings can be found in PIP-II-doc-1155
[6] – Assumptions can be found at PIP-II-doc-333
[7] – Final LSA can be found at PIP-II-doc-120

Conceptual Design Process

Stakeholders:

Fermilab:

Alessandro Vivoli, Anindya Chakravarty, Anthony F Leveling, Arkadiy L Klebaner

Beau F. Harrison, Curtis M. Baffes, David E Johnson, David W Peterson

Don Cossairt, Donald V Mitchell, Emil Huedem, Jim Niehoff, Fernanda G Garcia

Jerry R Leibfritz, Jerzy Czajkowski, John E Anderson Jr, Luisella Lari

Matthew Quinn, Maurice Ball, Paul Derwent, Ralph J Pasquinelli

Todd M Sullivan, Valeri A Lebedev, William A Pellico

Consultants:

Tom Lackowski, TGRWA

Ron Jedziniak, LG Associates

Rick Glenn, Jensen Hughes

Meeting Minutes (PIP-II-doc-70)

- 01 - Coordination Meeting - 17FEB16 (pdf)
- 02 - Cryogenic Department Meeting 19FEB16 (pdf) – Cryo Meeting
- 03 - Coordination Meeting - 02MAR16 (pdf) – Linac Enclosure
- 04 - Coordination Meeting - 09MAR16 R1 (pdf) – Linac Enclosure and Cooling
- 05 - Coordination Meeting - 24MAR16 R1 (pdf) – Linac Enclosure and Cryo Plant
- 06 - Cryo Coordination Meeting - 01APR16 (pdf) – ICW Cooling and Cryo
- 07 - Coordination Meeting - 14APR16 (pdf) – Penetrations and Cooling Strategy
- 08 - Coordination Meeting - 28APR16 (pdf) – Cooling Strategy
- 09 - Coordination Meeting r1 - 12MAY16 (pdf) – Shielding and Transport Line
- 10 - Coordination Meeting - 09JUN16 (pdf) – Shielding Summary
- 11 - Coordination Meeting - 07JUL16 (pdf) – RF Distribution and LCW Cooling
- 12 - Coordination Meeting - 21JUL16 (pdf) – High Bay Equipment
- 13 - Coordination Meeting - 04AUG16 (pdf) – Cryo Summary and Linac Gallery
- 14 - Coordination Meeting - 15SEP16 (pdf) – Sitewide Electrical Distribution

Drawings (PIP-II-doc-1155)

55 Drawings

- One (1) General sheet
- Seven (7) Civil sheets
- Forty-Three (43) Architectural sheets
- Three (3) Mechanical sheets
- One (1) Electrical sheet

LIST OF DRAWINGS

G-1	TITLE SHEET, LIST OF DRAWINGS
C-1	SITE IMAGE
C-2	FUTURE BEAMLINES SITE PLAN
C-3	WETLANDS SITE PLAN
C-4	SITE PLAN
C-5	ENLARGED PLAN AT ABSORBER
C-6	SITE UTILITY PLAN
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A-2	DESIGN BASIS - SHEET 2
A-3	DESIGN BASIS - SHEET 3
A-4	LIFE SAFETY
A-5	ENCLOSURE KEY PLAN
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A-8	LINAC ENCLOSURE PLAN - SHEET 3
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A-30	CROSS SECTION @ HWR
A-31	SECTION THRU HIGH BAY
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A-33	SECTION @ WAVEGUIDE FOR LB 650, HB 650
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A-42	COMPRESSOR STATION PLAN
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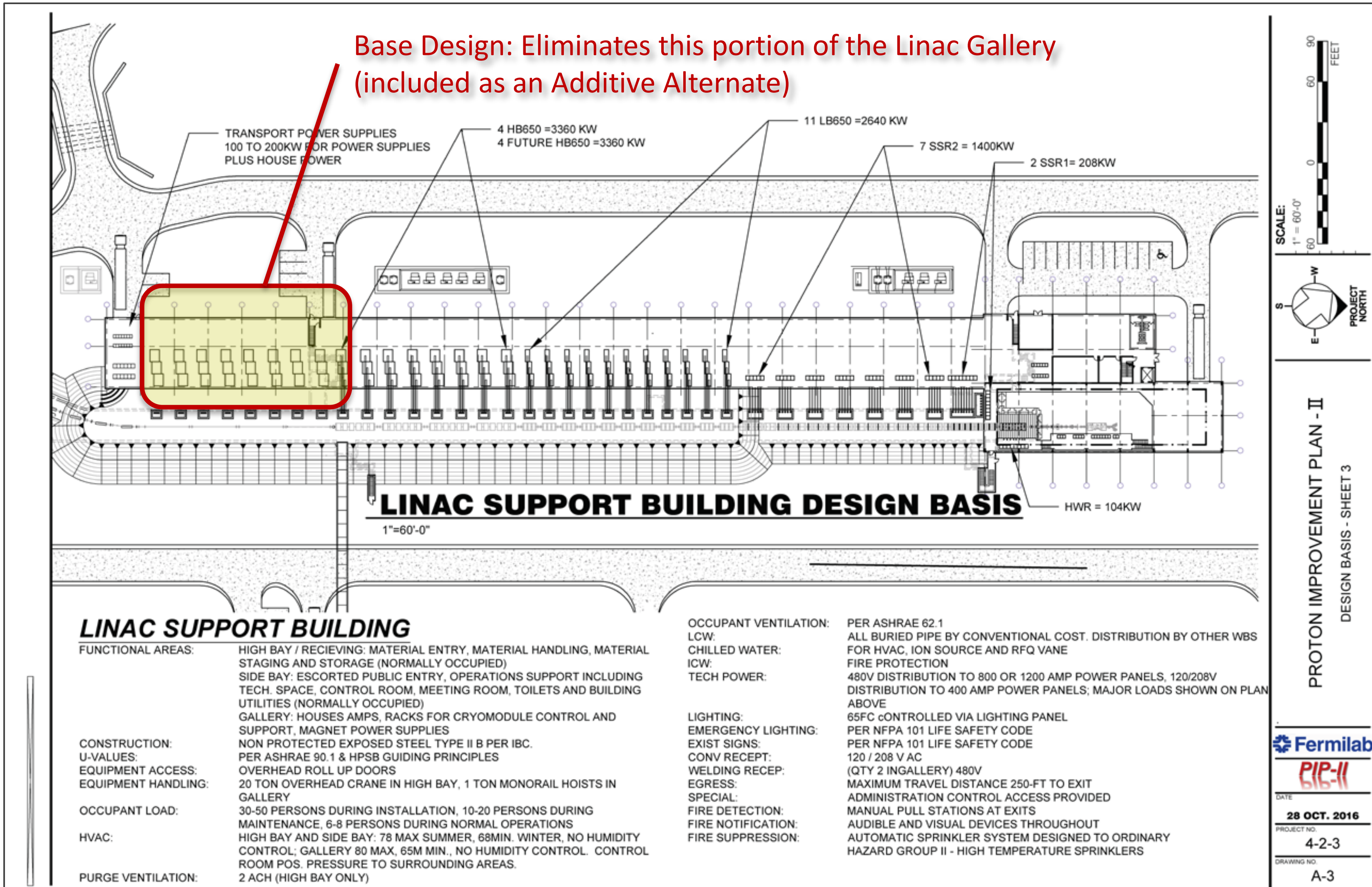
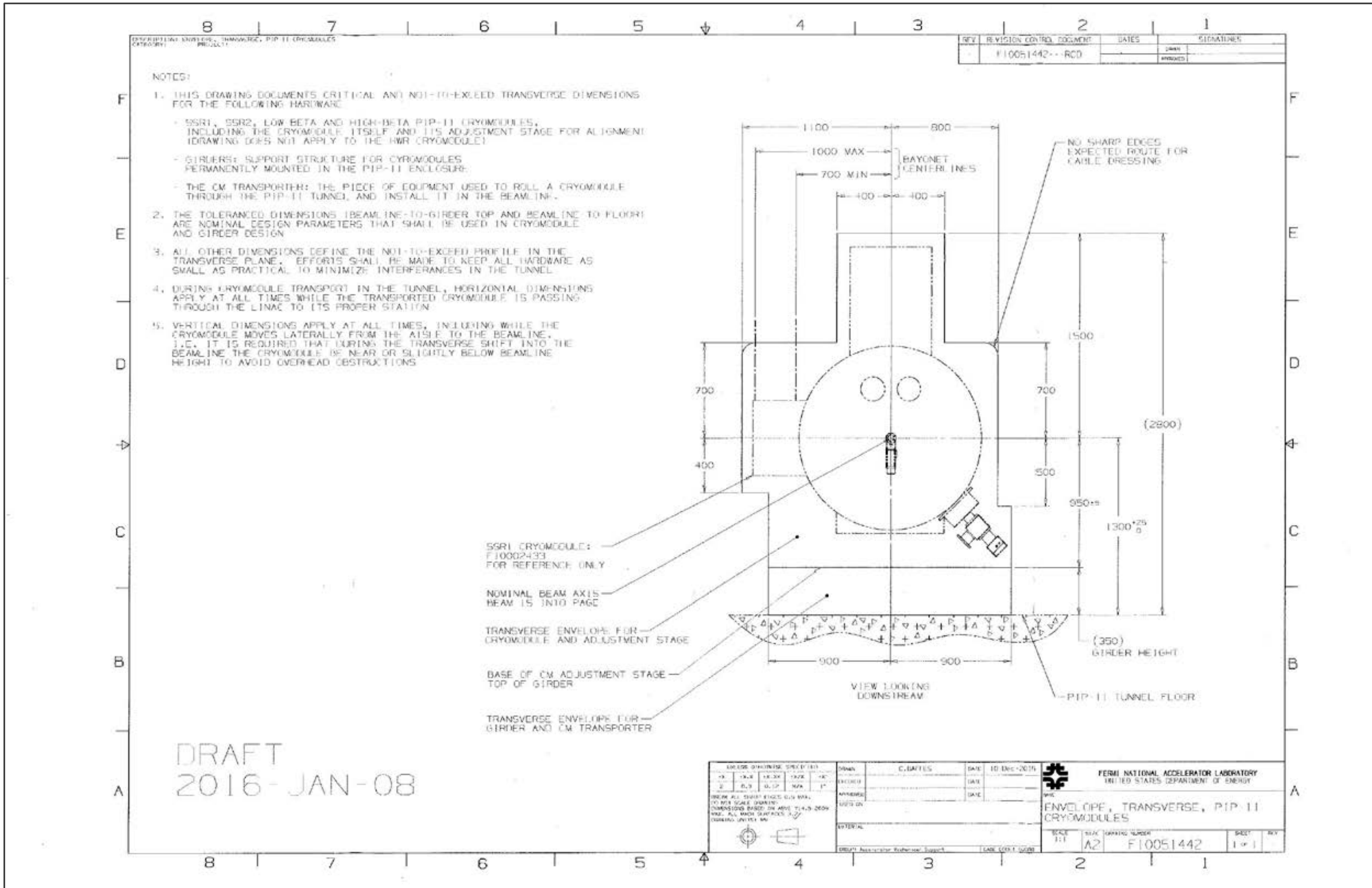
M-1	CONCEPTUAL DESIGN BASIS - SHEET 1
M-2	CONCEPTUAL DESIGN BASIS - SHEET 2
M-3	COOLING HEAT REJECTION CONCEPT
E-1	POWER SINGLE LINE DIAGRAM

Typical Design Basis Sheet

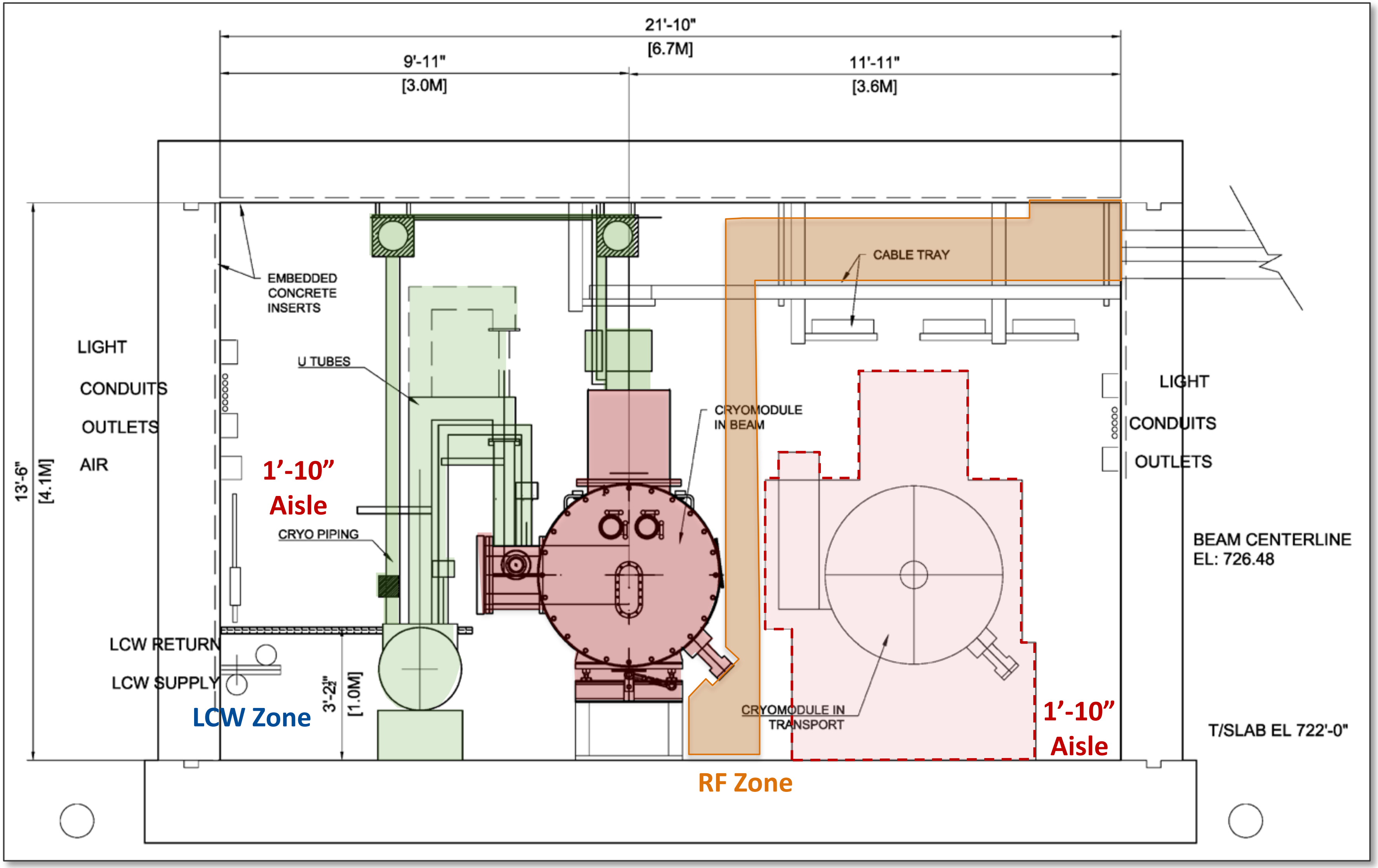


Typical Linac Tunnel Cross Section

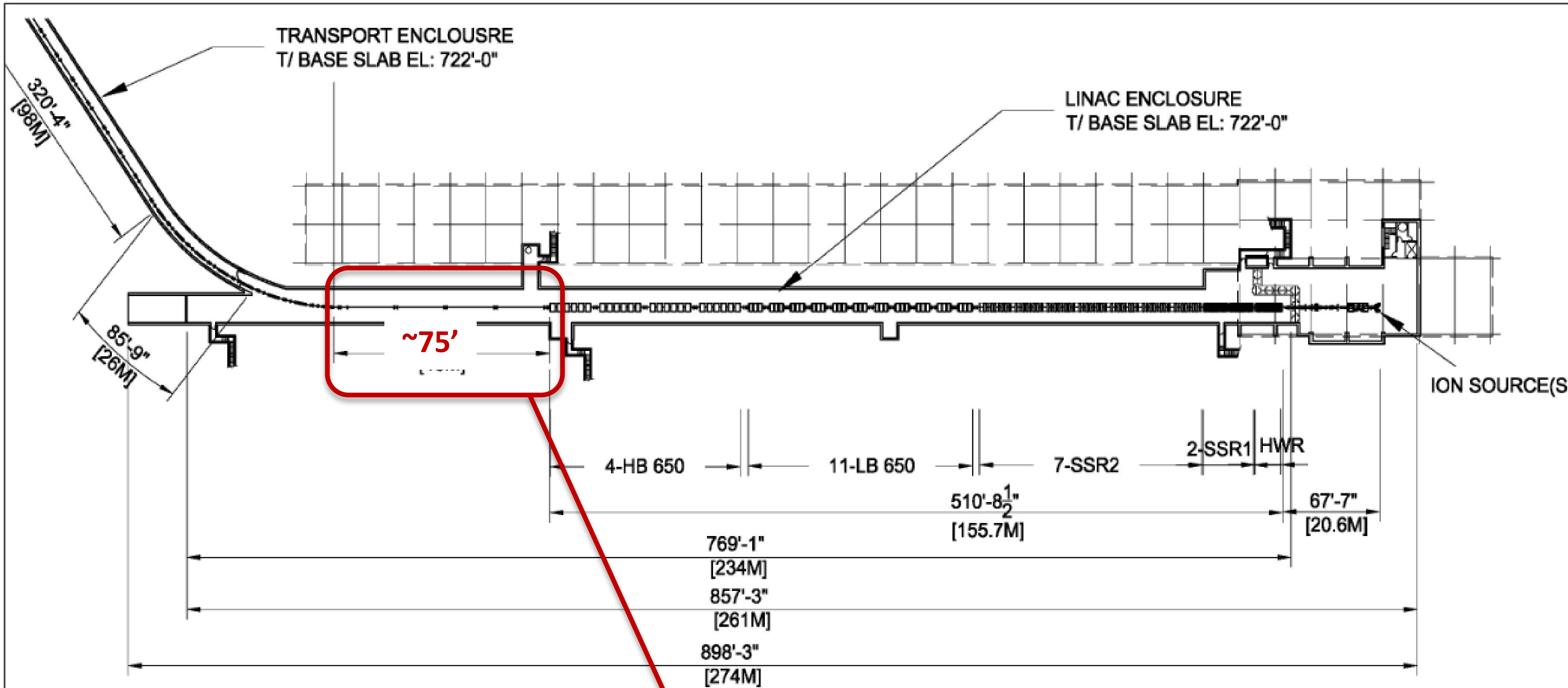


Cryomodule criteria envelope (TeamCenter F10051442)

Typical Linac Tunnel Cross Section



Linac Tunnel Plan (WBS 121.5.6)

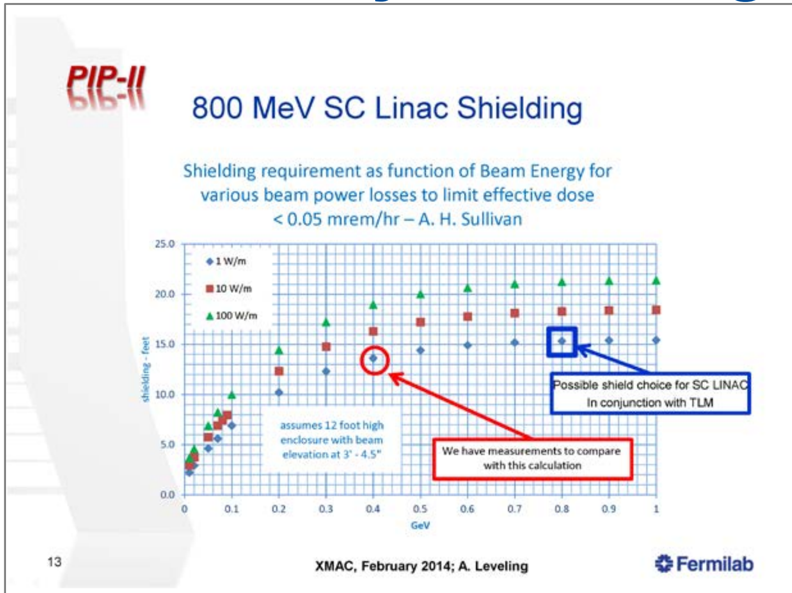


Plan at Enclosure Level

<u>FRS Section 5 (Facility Scope):</u>

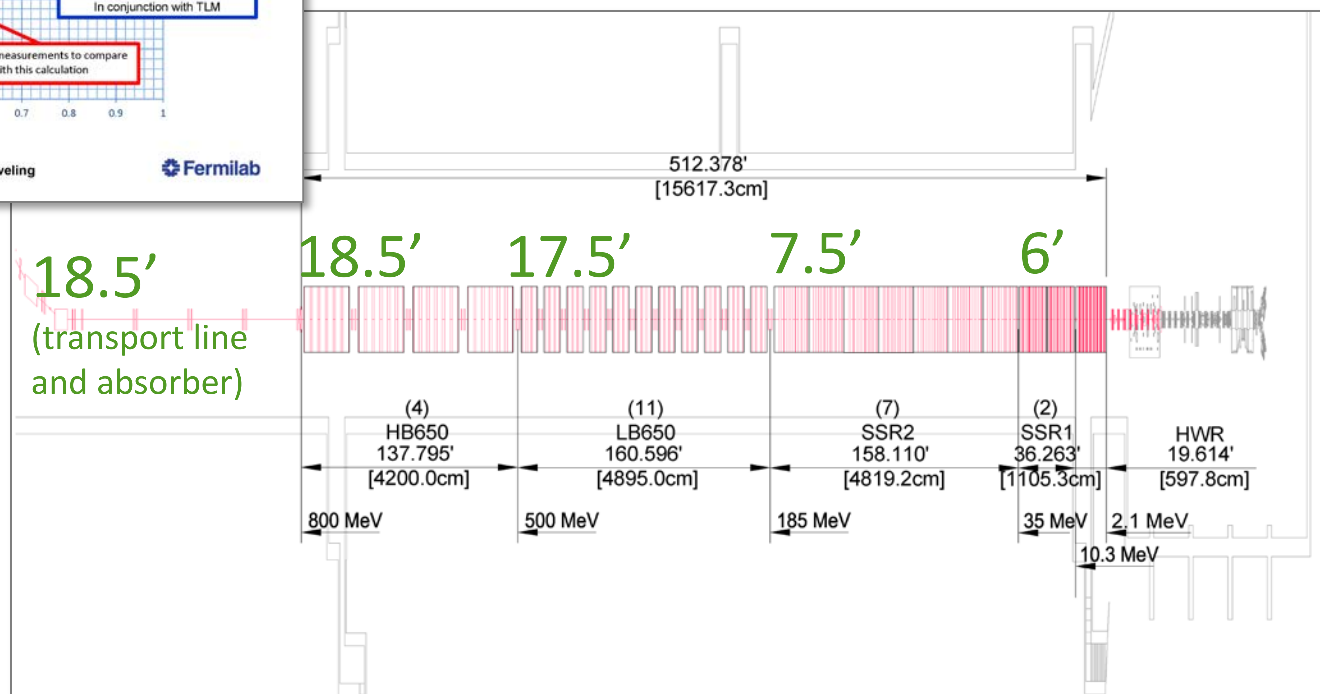
The linac enclosure will be constructed with a length to accommodate two (2) HB650 cryomodules beyond the nominal compliment required for 800 MeV

Preliminary Shielding Considerations



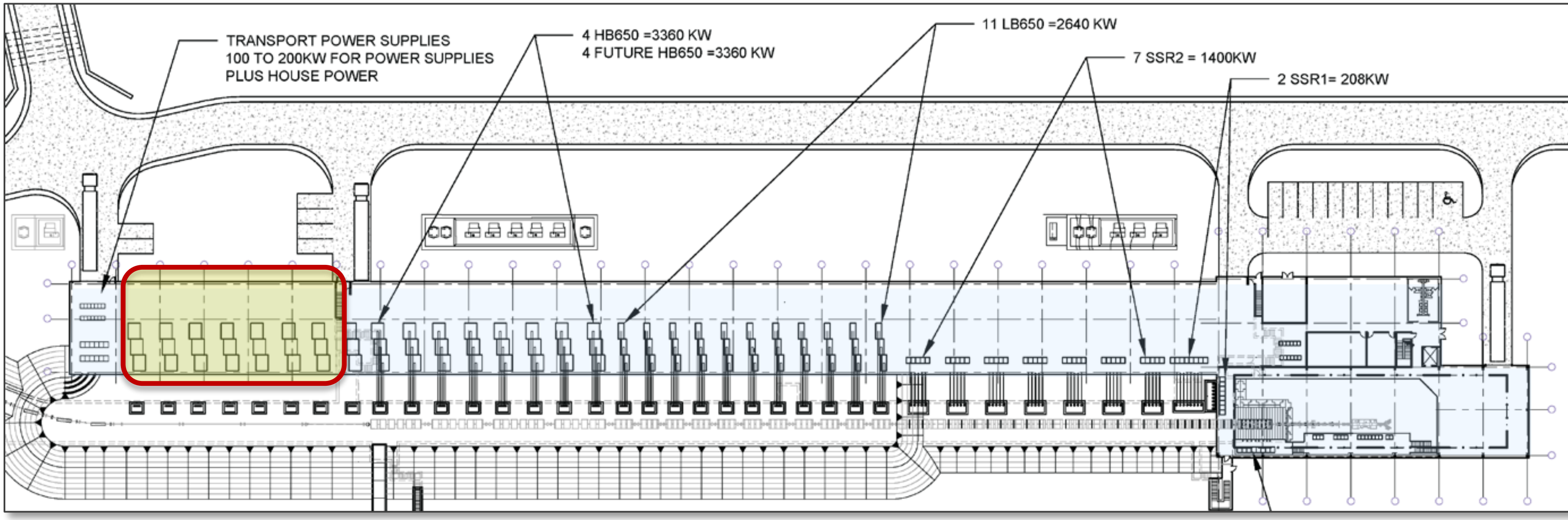
Preliminary Shielding Depths shown below. **Further analysis required**, especially at the Booster.

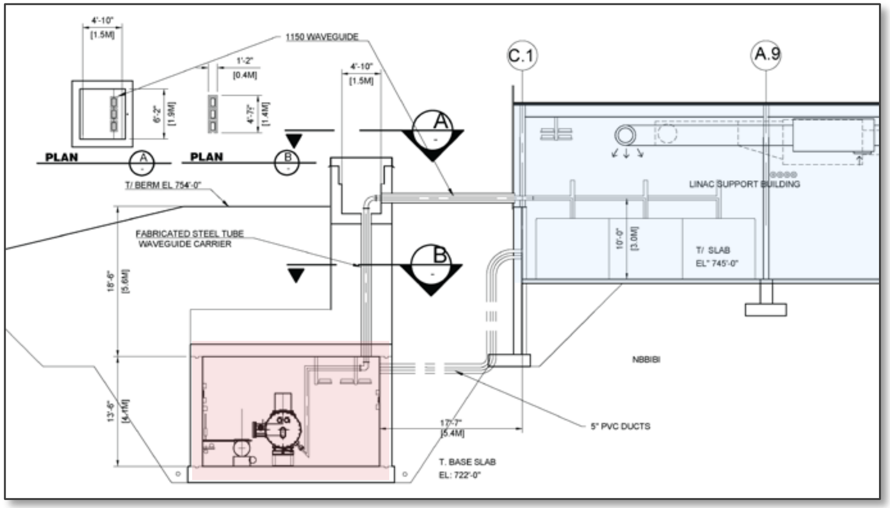
Used the 10W/m curve for the conceptual design



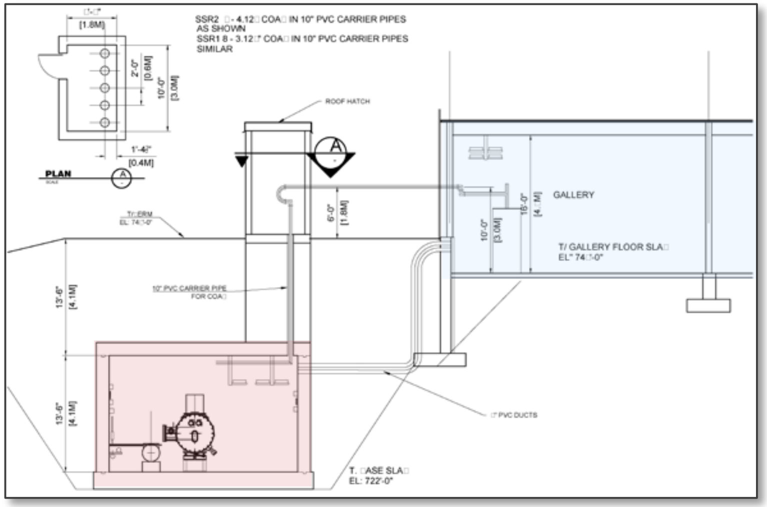
Thanks to Radiation Safety Department (D. Cossairt, T. Leveling and M. Quinn)

Linac Gallery Plan (WBS 121.5.7)





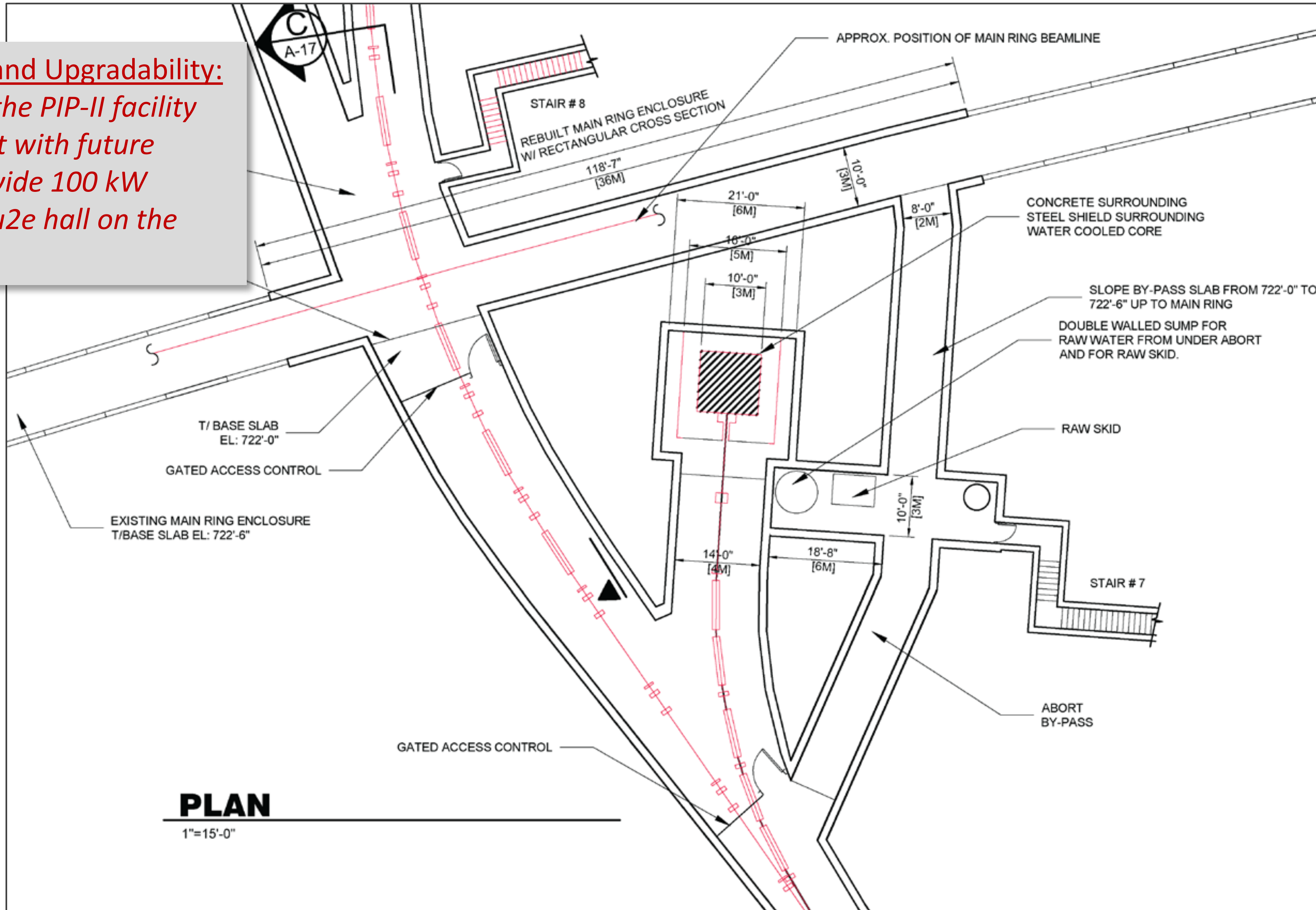
Cross Section Looking South at Waveguide Penetrations



Cross Section Looking South at Coax Penetrations

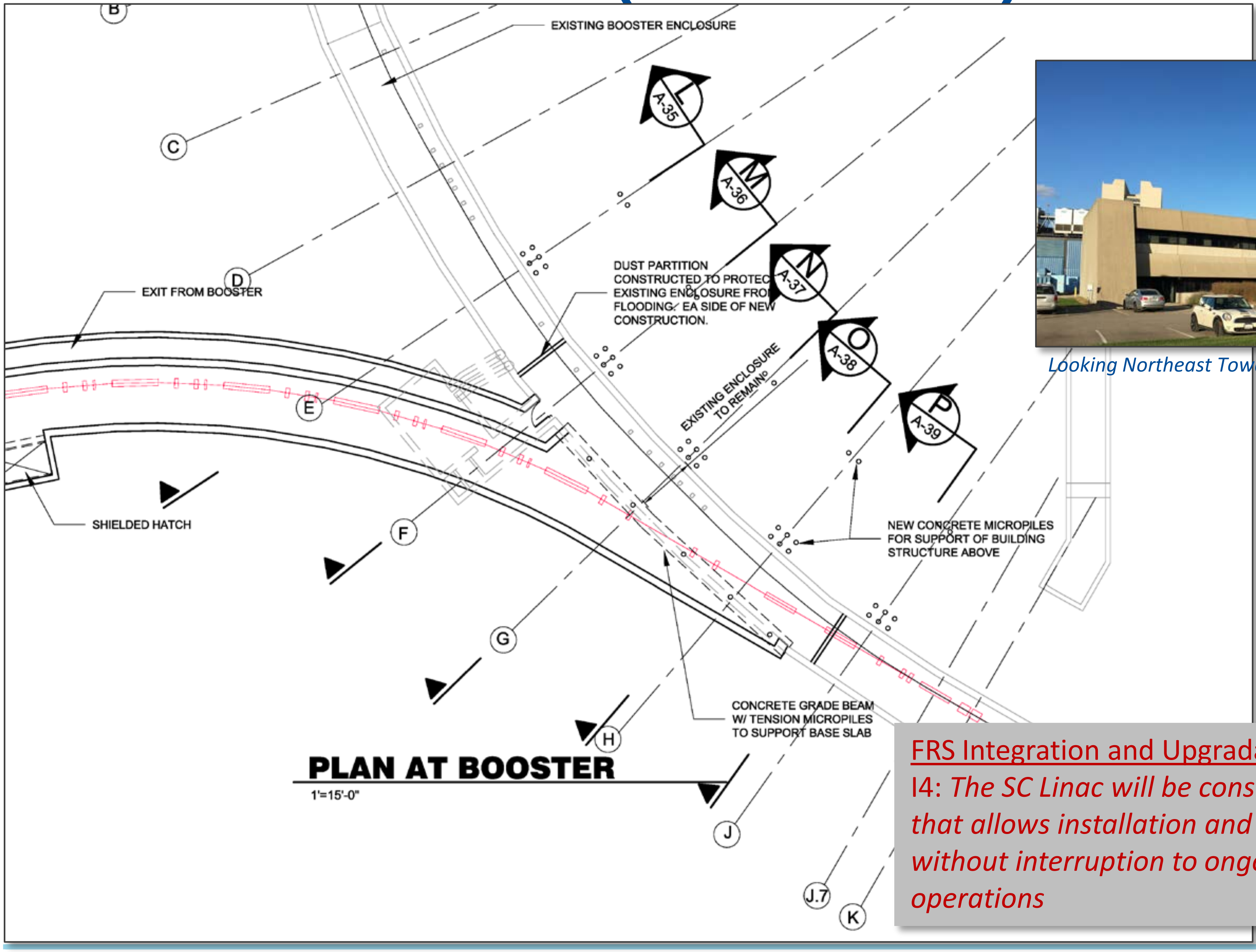
Beam Transfer Line (WBS 121.5.8)

<u>FRS Integration and Upgradability:</u>
I2: *The siting of the PIP-II facility will be consistent with future upgrades to provide 100 kW beams to the Mu2e hall on the Muon Campus*



PIP-II

Booster Connection (WBS 121.5.9)



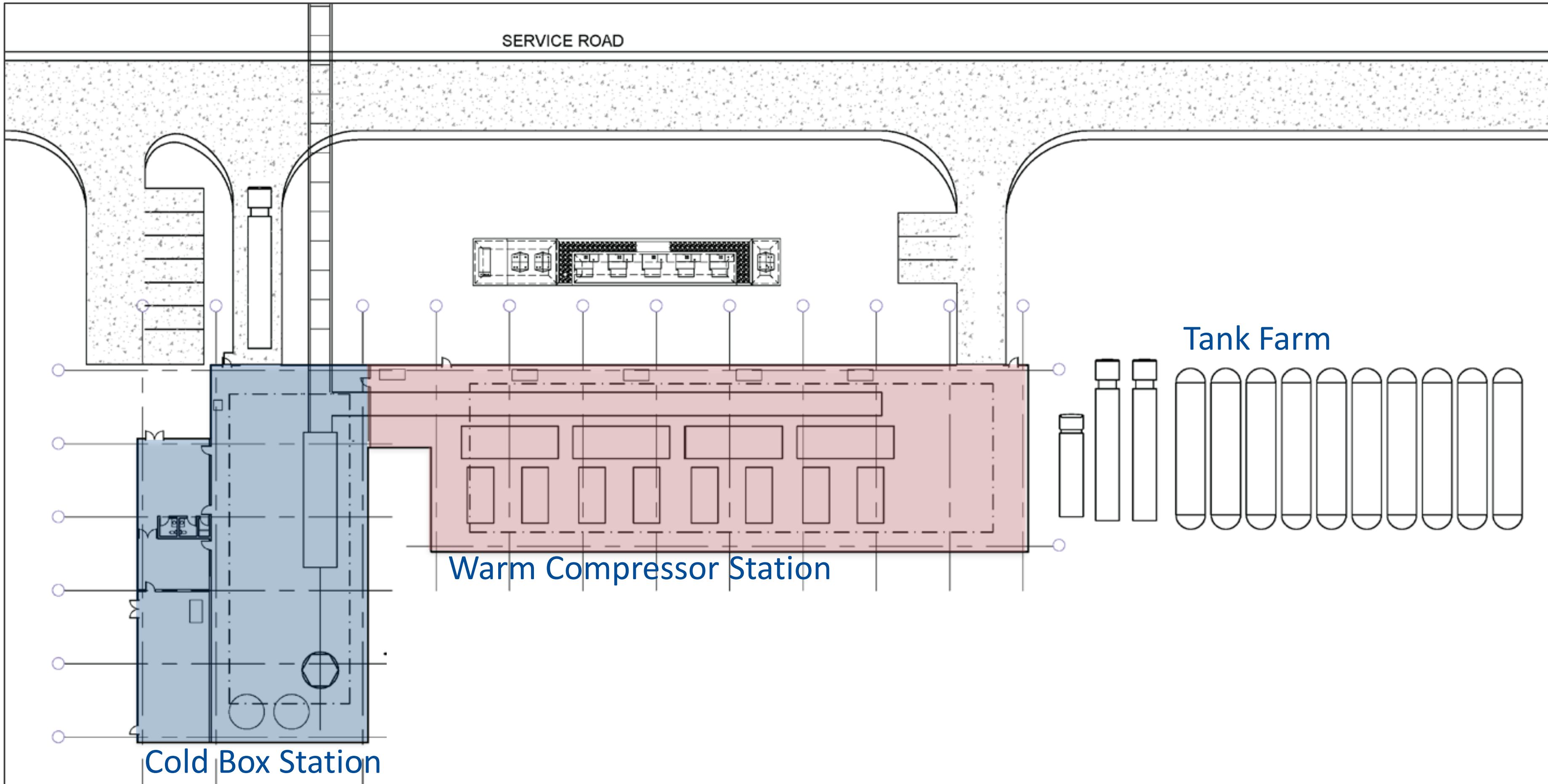
Looking Northeast Towards Booster Tower Southeast

<u>FRS Integration and Upgradability:</u>

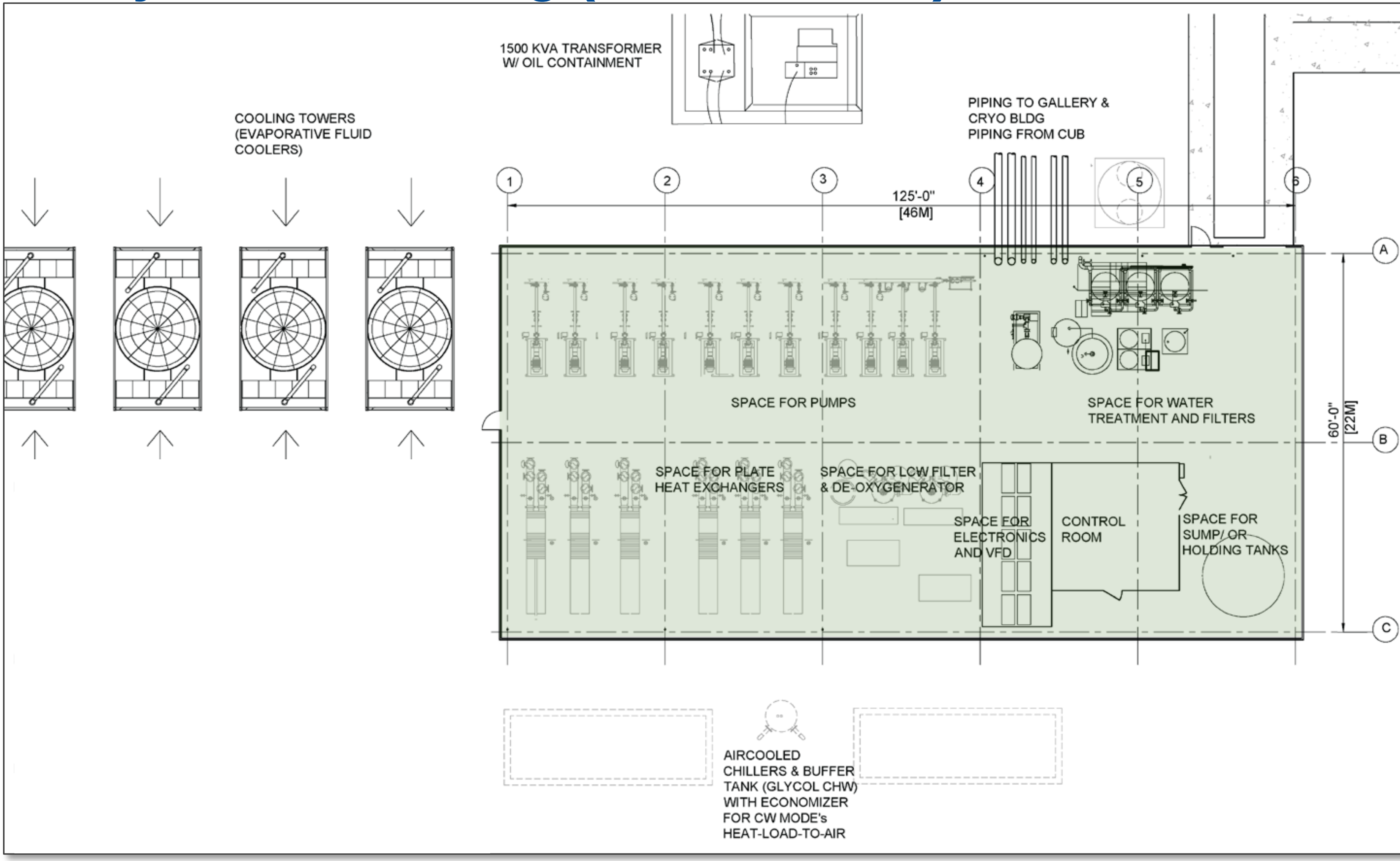
I4: *The SC Linac will be constructed in a manner that allows installation and commissioning without interruption to ongoing accelerator operations*

PIP-II

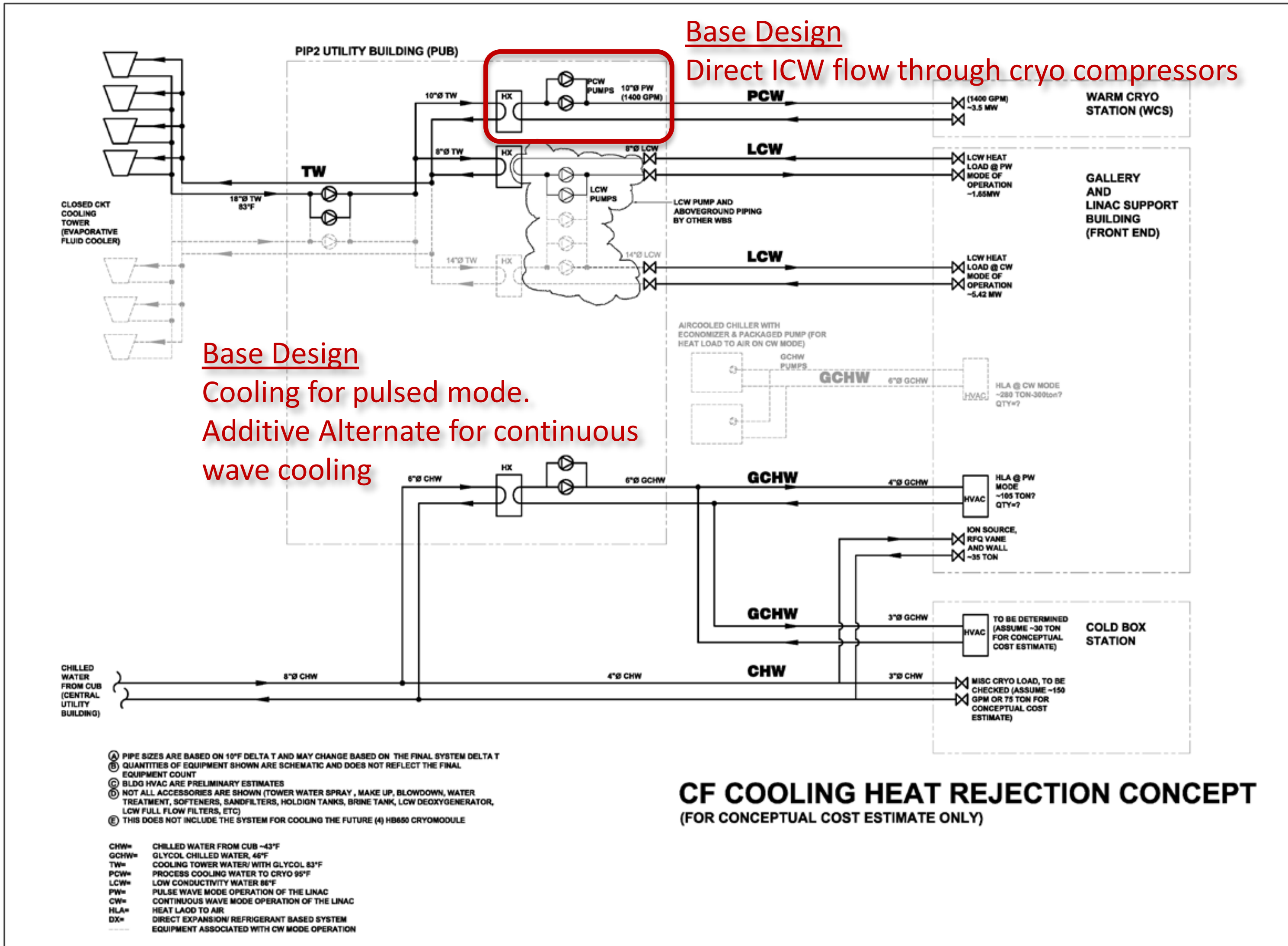
Cryo Plant Building (WBS 121.5.3)



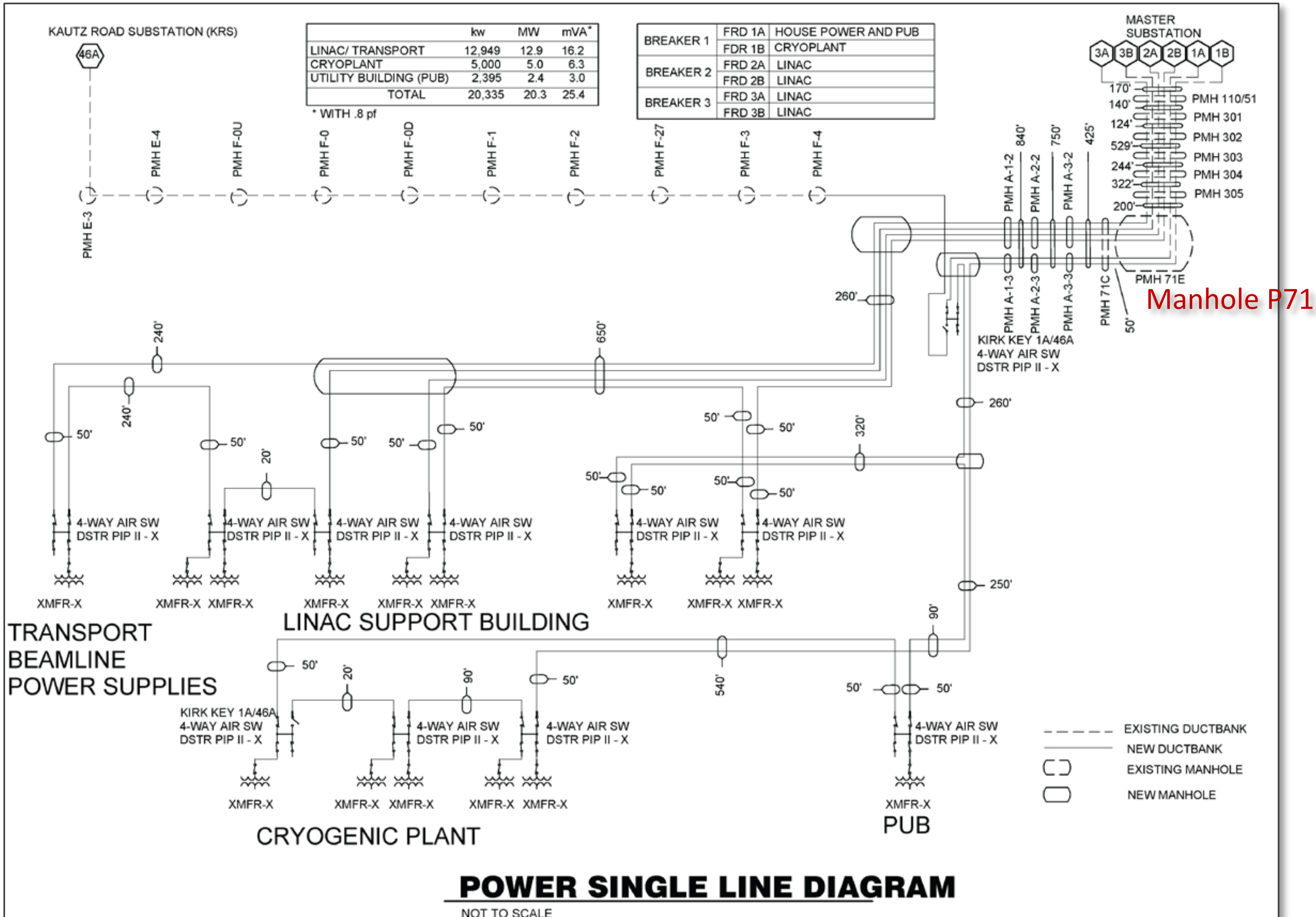
Utility Plant Building (WBS 121.5.4)



Cooling Concept



Electrical Distribution Concept



	kw	MW	mVA*
LINAC/ TRANSPORT	12,949	12.9	16.2
CRYOPLANT	5,000	5.0	6.3
UTILITY BUILDING (PUB)	2,395	2.4	3.0
TOTAL	20,335	20.3	25.4

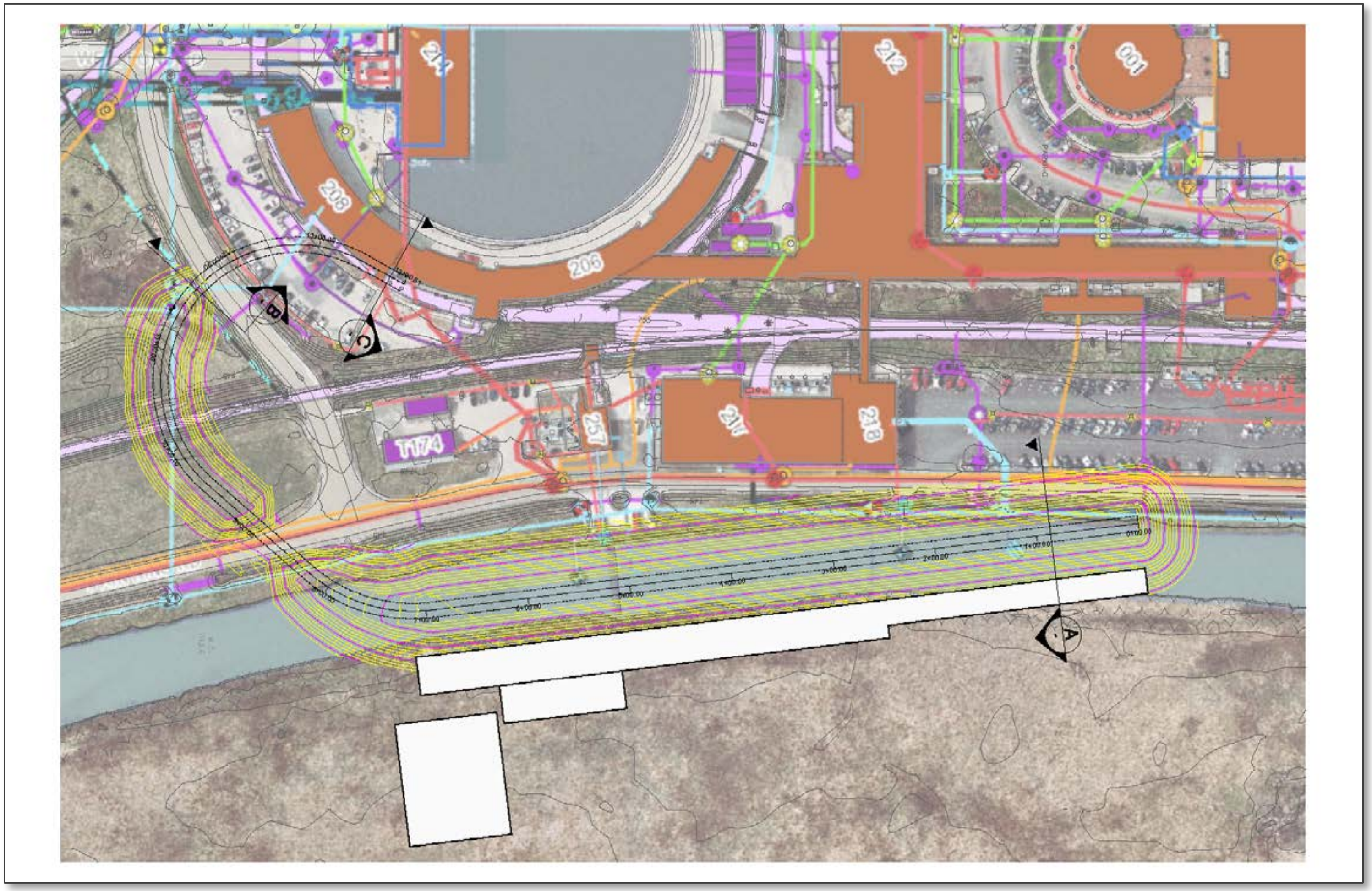
* WITH .8 pf

BREAKER 1	FRD 1A	HOUSE POWER AND PUB
	FDR 1B	CRYOPLANT
BREAKER 2	FRD 2A	LINAC
	FRD 2B	LINAC
BREAKER 3	FRD 3A	LINAC
	FRD 3B	LINAC

Alternates Considered

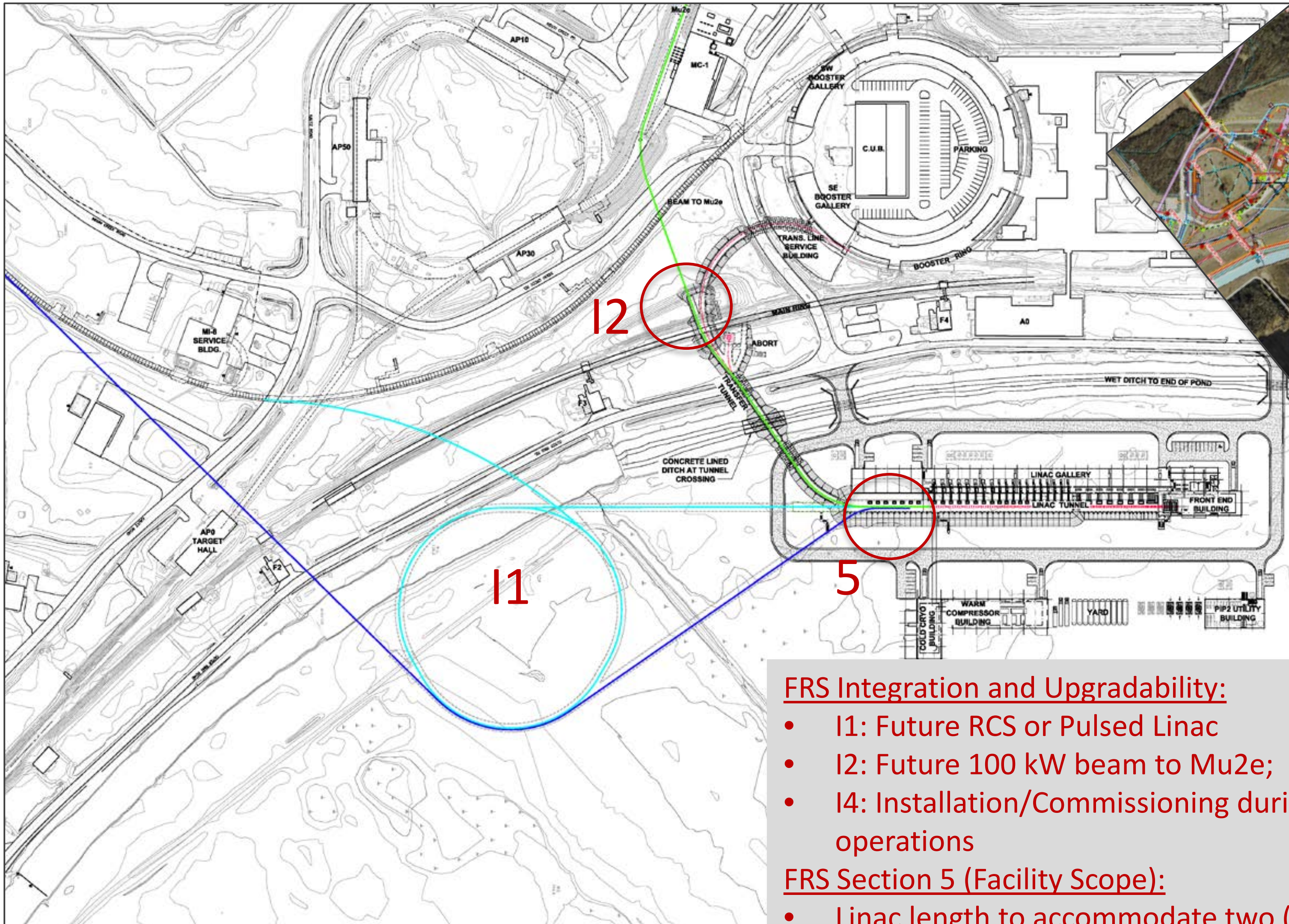
- Siting
- ICW Cooling
- Pulsed Mode vs. Continuous Wave Operation

Preconceptual Location



2014 Location

Siting Considerations



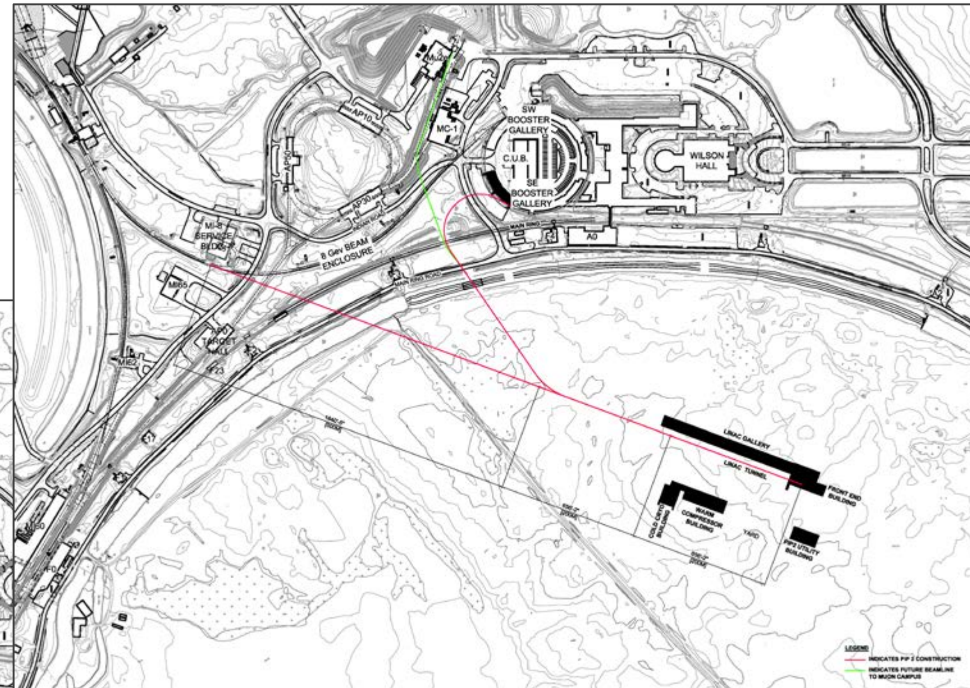
FRS Integration and Upgradability:

- I1: Future RCS or Pulsed Linac
- I2: Future 100 kW beam to Mu2e;
- I4: Installation/Commissioning during ongoing operations

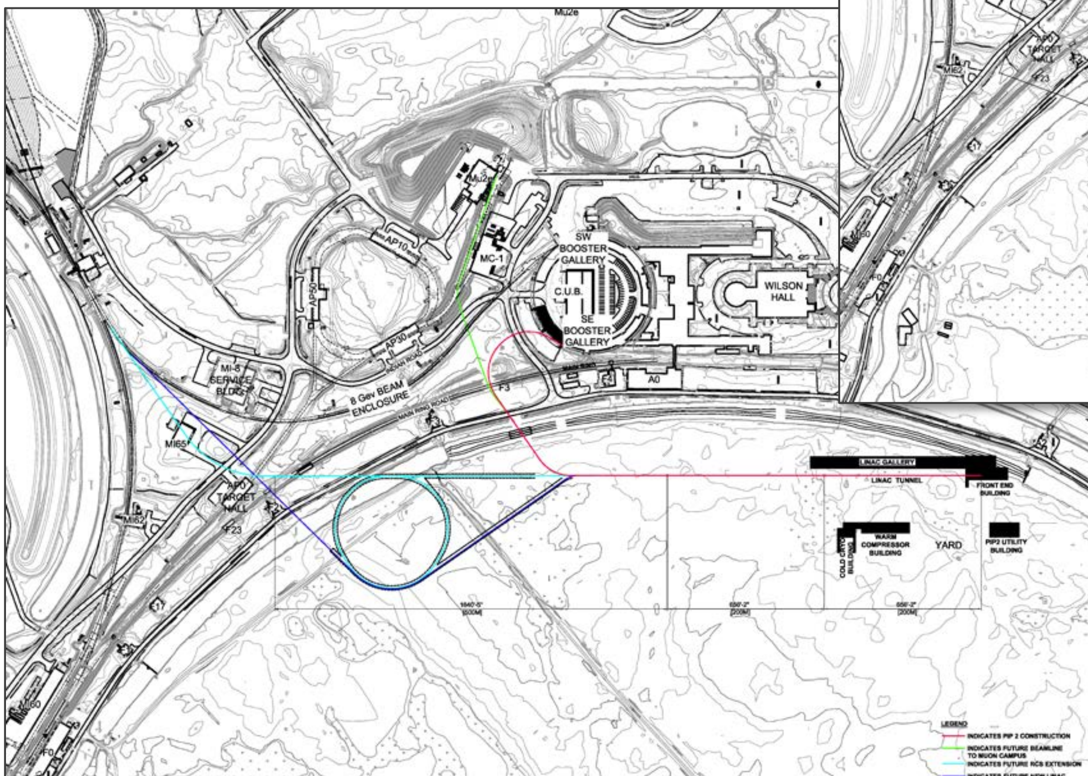
FRS Section 5 (Facility Scope):

- Linac length to accommodate two (2) additional HB650 cryomodules

December 2016 Siting Alternatives Study



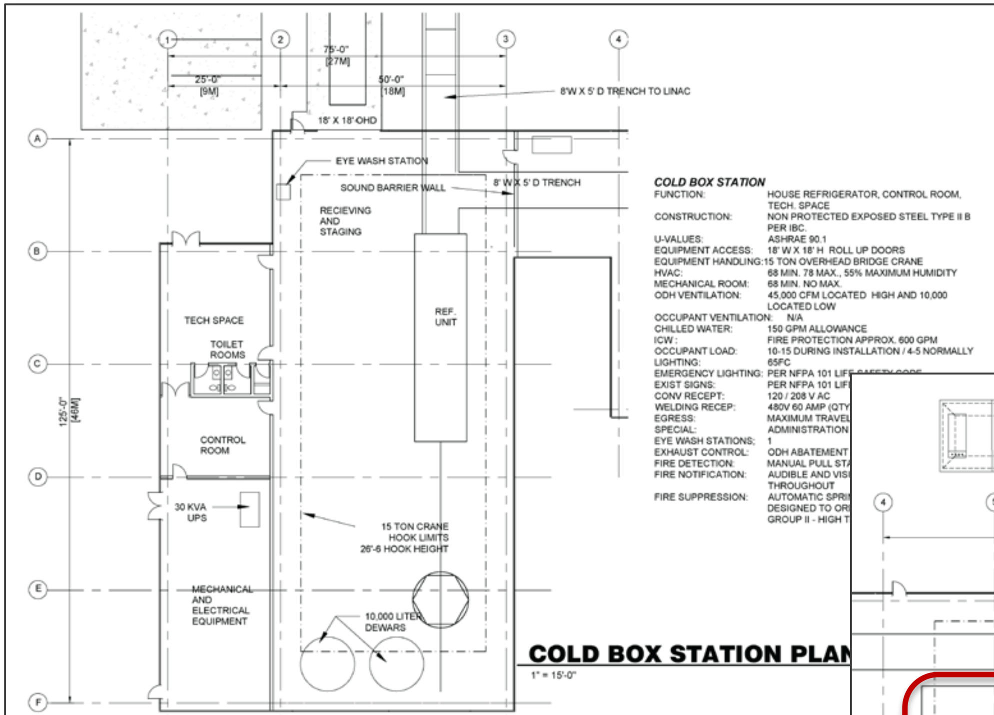
8 GeV Tangent Option

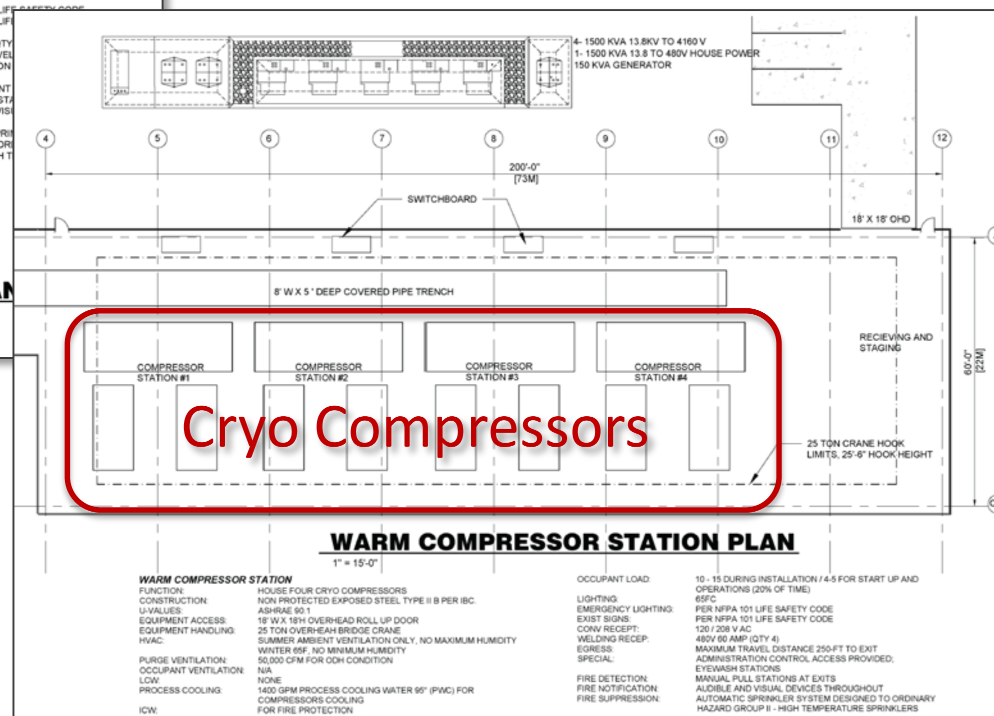


Northward Shift Option

See PIP-II-doc-136 for Siting Alternatives Memo

Cryo Plant Cooling Water





Cryo Plant – Water Quality Requirements

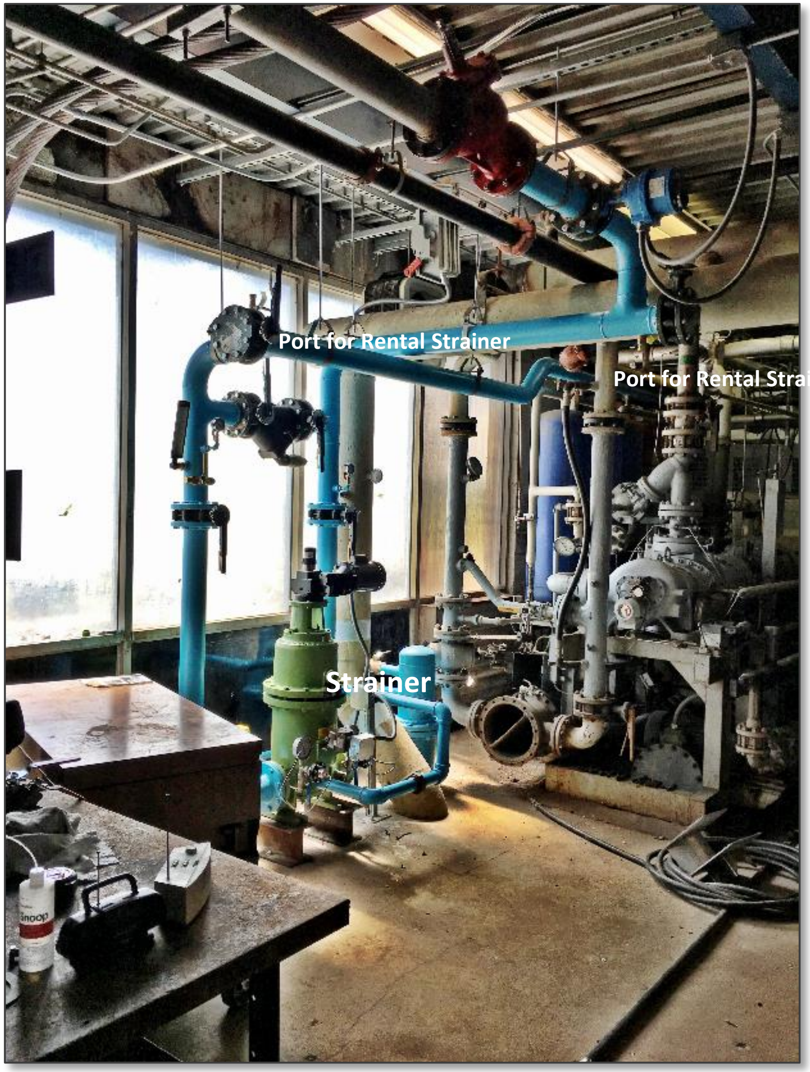
		PIP-II Requirements		Water Analysis Report		Existing Data
Desription	**Unit**	**Closed loop**	**Open loop**	Range	Units	
pH value		7.5 - 9.0	7.5 - 9.0	7.82 - 7.89		
Hardness	[dH]	< 20	< 20	20.79 - 23.02	ppm CaCO3	*1 dH = 17.848 mg CaCO3*
Carbonate hardness	[dH]	< 20	< 4	0.96 - 1.02	Ca/Mg ratio	
Chloride (Cl)	[mg/l]	< 100	< 100	5-15	ppm	
Dissolved iron (Fe)	[mg/l]	< 0.2	< 0.2	0.04 - 0.01	ppm	*1 ppm = 1 milligram/liter*
Sulphate (SO_4)	[mg/l]	< 200	< 200	84.51 - 115.51	ppm	
Sulfide (S_{2-})	[mg/l]	< 0.1	< 0.1			*Future water analysis*
Silicic acid (SiO_2)	[mg/l]	< 200	< 200	10.63 - 11.56	ppm	
HCO_3 / SO_4	-	> 1	> 1			*Future water analysis*
Electrical conductivity	[µS/cm]	10 - 800	10 - 1500			*Future water analysis*
Ammonium (NH_4)	[mg/l]	< 1	< 1			*Future water analysis*
Dissolved manganese (Mn)	[mg/l]	< 0.2	< 0.1	0.00	ppm	
Phosphate (PO_4)	[mg/l]	< 15	< 15			*Future water analysis*
Glycol	[%]	20 - 40	-			*Future water analysis*
Solids (particle size)	[mm]	< 0.1	< 0.1	**?**	**?**	**Requires Further Investigation**
Solids (particle amount)	[mg/l]	< 10	< 10	**?**	**?**	**Requires Further Investigation**
Appearance		clear, colorless	clear, colorless			
Total bacterial count	[CFU/ml]	< 10^4	< 10^4	**?**	**?**	**Requires Further Investigation**
Proportion of non-dissolved solids	[ppm]	< 20	< 20	**?**	**?**	**Requires Further Investigation**
Algae		- not allowed	- not allowed	**?**	**?**	**Requires Further Investigation**
Magnesium				189.46 - 204.43	ppm CaCO3	
Calcium				181.52 - 206.42	ppm CaCO3	
Copper				0.00 - 0.01	ppm	
Total Phosphorus				0.06 - 0.13	ppm	
Zinc				0.0 - 0.01	ppm	
Sodium				23.84 - 34.98	ppm	
Molybdate				0.01 - 0.3	ppm	
Boron				0.55 - 0.65	ppm	
Aluminum				0.02 - 0.03	ppm	

Cryo Plant Cooling – Initial Analysis

- Water Requirements
  - ~**2,000** gpm flow (ideal)
- Pond System
  - Chemical characteristics met by pond water system;
  - Solids content characteristics NOT met by pond water system;
  - No Pond Exists - ~$500-$700k per acre;
- Industrial Cooling Water (ICW) System
  - Testing indicates that ICW meets most requirements [4];
    - Chemical characteristics met by existing ICW system;
    - Solids content characteristics NOT met by ICW system;
  - Only **1,400** gpm available per the ICW computer model;
  - Verified with Cryo that 1,400 gpm at 17 degree F delta T is acceptable

[4] – ICW Water Quality Test Results study can be found at PIP-II-doc-155

Cryo Plant Cooling – Additional Analysis



BZero Compressor Building

Summer/Fall 2016

- Test Station, installed as part of the Mu2e Cryo work for CDF;
- Installed test ports to sample the ICW before and after the strainer;
- Three Options:
  - Adams strainer with 250 micron slot sizes (baseline);
  - Two month rental of a Lakos strainer to reduce the solids with 25 micron filter;
  - Replacement filter elements in Adams strainer with 75 micron slot size;
- Arranged for FESS/O water testing service to increase the testing to include solids;
- Compared strainer options with water quality requirements.

Cryo Plant Cooling - Results

Desription	Unit	PIP-II Requirements: Closed loop	PIP-II Requirements: Open loop	Adam's Strainer (250 micron) 21-Oct-16: Before	Adam's Strainer (250 micron) 21-Oct-16: After	Adams Strainer (75 micron) 14-Dec-16: Before	Adams Strainer (75 micron) 14-Dec-16: After	Lakos Filter (25 micron) 16-Nov-16: Before	Lakos Filter (25 micron) 16-Nov-16: After	CUB Cooling Towers: 16-Nov-16	CUB Cooling Towers: 14-Dec-17
pH value		7.5 - 9.0	7.5 - 9.0	7.51	7.71			8.28	8.23		
Hardness	[dH]	< 20	< 20	12.10	12.03			13.98	14.01		
Carbonate hardness	[dH]	< 20	< 4	1.02	1.01			1.03	1.03		
Chloride (Cl)	[mg/l]	< 100	< 100								
Dissolved iron (Fe)	[mg/l]	< 0.2	< 0.2	0.07	0.07			0.10	0.12		
Sulphate (SO_4)	[mg/l]	< 200	< 200	36.02	34.63			46.16	44.41		
Sulfide (S^{2-})	[mg/l]	< 0.1	< 0.1								
Silicic acid (SiO_2)	[mg/l]	< 200	< 200	5.62	5.56			5.52	5.54		
HCO_3 / SO_4	-	> 1	> 1								
Electrical conductivity	[µS/cm]	10 - 800	10 - 1500	672.00	672.00			698.00	695.00		
Ammonium (NH_4)	[mg/l]	< 1	< 1	0.20	0.20	---	0.30	---	0.22		
Dissolved manganese (Mn)	[mg/l]	< 0.2	< 0.1	0.01	0.01			0.01	0.01		
Phosphate (PO_4)	[mg/l]	< 15	< 15	0.29	0.44			0.07	0.31		
Glycol	[%]	20 - 40	-	0.00	0.00			0.00	0.00		
Solids (particle size)	[mm]	< 0.1	< 0.1	---	0.04	---	0.03	---	0.03		
Solids (particle amount)	[mg/l]	< 10	< 10		*see chart*		*see chart*		*see chart*		
Appearance		clear, colorless	clear, colorless								
Total bacterial count	[CFU/ml]	$< 10^4$	$< 10^4$	1,000	1,000			0	0		
Proportion of non-dissolved solids	[ppm]	< 20	< 20								
Algae	cells/mL	- not allowed	- not allowed	986,751	1,347,557	447	47	23,785	2,144	87	13
Magnesium	ppm			107.12	106.63			122.72	122.87		
Calcium	ppm			108.86	108.13			126.81	127.12		
Copper	ppm			0.00	0.00			0.00	0.00		
Zinc	ppm			0.00	0.01			0.01	0.01		
Sodium	ppm			62.19	61.77			60.21	59.70		
Molybdate	ppm			0.01	0.00			0.00	0.01		
Boron	ppm			107.12	106.63			122.72	122.87		
Aluminum	ppm			0.03	0.03			0.04	0.04		

Results:

- Additional testing (chloride) and discussion with cryo folks;
- Algae is likely seasonal, still requires a solution or better definition of requirements;
- Baseline design will assume direct flow of ICW through cryo compressors;
- Additive Option: heat exchanger to isolate the ICW from the cryo compressor side;

Pulsed Mode vs. Continuous Wave Operation

- Driven by duty factor of the accelerator equipment
  - 15% for Pulsed Mode
  - 100% for Continuous Wave Mode
- Common For Both Modes
  - Physical arrangement of heat producing equipment;
  - Electrical power supply (not usage);
  - Conventional Facilities handles the heat load to air (HLA);
- Difference is Primarily Cooling
  - ~5.4 MW in pulsed mode;
  - ~11.76 MW in continuous wave mode;

Pulsed Mode vs. Continuous Wave Operation

Heat Loads

	Pulsed Mode	Continuous Wave Mode
Low Conductivity Water (LCW)	1.65	7.07
Heat Load to Air (HLA)	0.33	1.29
Cryoplant Cooling (Cryo)	3.4	3.4
Total (MW)	**5.38**	**11.76**

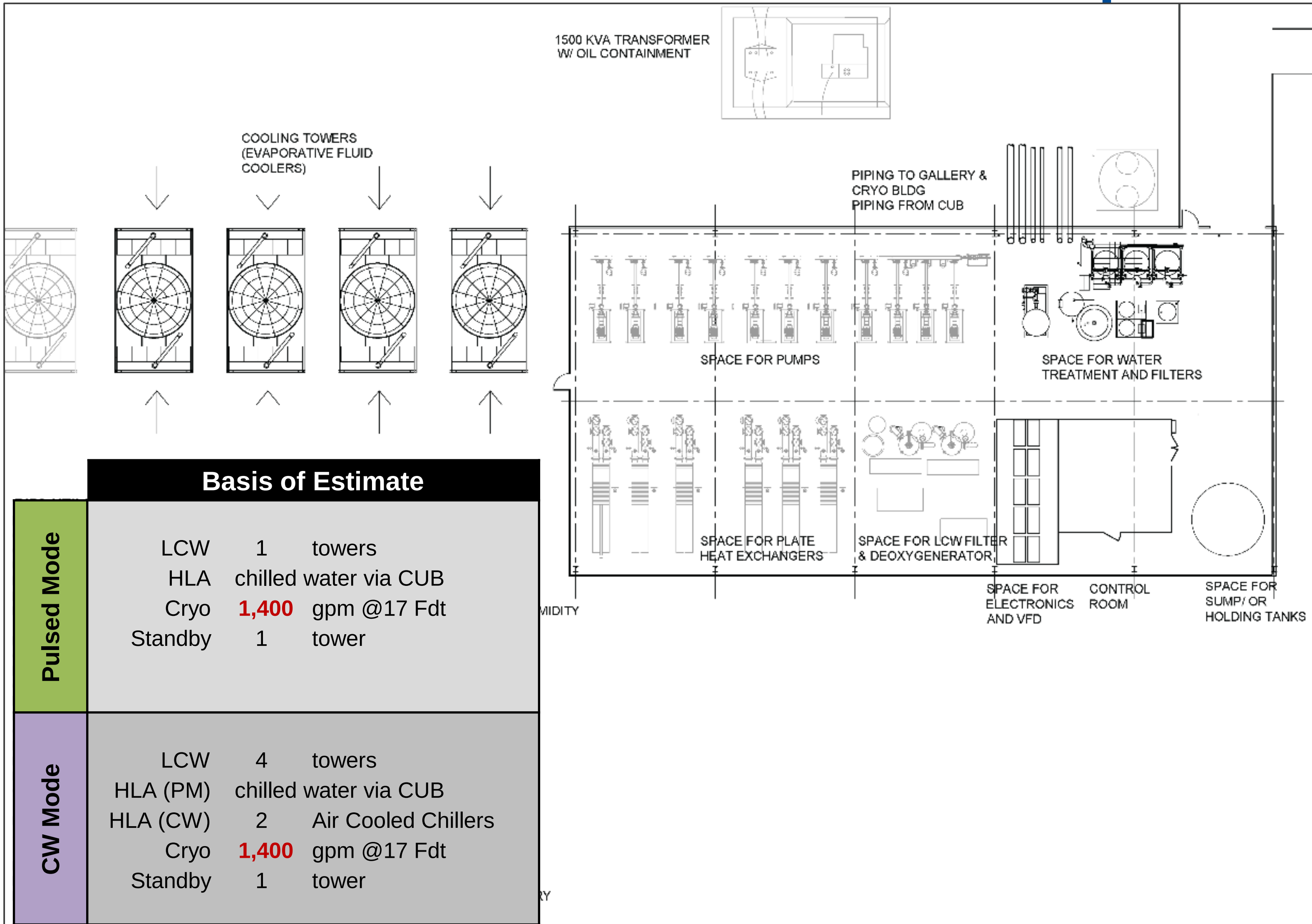
	Industrial Cooling Water (ICW)	Cooling Ponds (PW)	Towers (close)	Towers (open)	Basis of Estimate
Pulsed Mode	*MW to GPM Conversion 682.79* LCW 1,125 gpm HLA 227 gpm Cryo 1,400 gpm @17 Fdt 2,752 gpm	*MW to Acres Conversion 1.2* LCW 1.98 acres HLA 0.50 acres Cryo 4.08 acres 6.56 acres	LCW 1.0 towers HLA towers Cryo 2.0 towers 3.00 towers *excludes standby*	LCW 1.0 towers HLA towers Cryo 1.0 towers 2.00 towers *excludes standby*	LCW 1 towers HLA chilled water via CUB Cryo 1,400 gpm @17 Fdt Standby 1 towers
CW Mode	*MW to GPM Conversion 682.79* LCW 4,827 gpm HLA 881 gpm Cryo 1,400 gpm @17 Fdt 7,108 gpm	*MW to Acres Conversion 1.2* LCW 8.48 acres HLA 1.94 acres Cryo 4.08 acres 14.50 acres	LCW 4.0 towers HLA 2.0 towers Cryo 2.0 towers 8.00 towers *excludes standby*	LCW 2.0 towers HLA 1.0 towers Cryo 1.0 towers 4.00 towers *excludes standby*	LCW 4 towers HLA (PM) chilled water via CUB HLA (CW) 2 air cooled chillers Cryo 1,400 gpm @17 Fdt Standby 1 towers
	Other Considerations *Strainers, Drought Conditions*	*Other Considerations* *Strainers, Heat Exchangers, Treatment* *Drought Conditions*	*Other Considerations* *Heat Exchangers, Treatment, Make Up* *Building Costs*	*Other Considerations* *Heat Exchangers, Treatment, Make Up* *Building Costs*	*Other Considerations* *Heat Exchangers, Treatment, Make Up* *Building Costs*

Note: 1,400 gpm is the highest flow currently available from the existing ICW system
2,000 gpm is preferred

Pulsed Mode vs. Continuous Wave Operation

- Goal: Modular approach that allows for efficient operation in both modes;
- CUB Chilled Water Budget: **~250 tons** total. Used for small equipment loads, building loads and RF heat load to air
- Pulsed Mode
  - Heat Load to Air (HLA): Utilize chilled water from existing CUB for equipment cooling;
  - LCW: (1) Cooling Tower + 1 standby;
  - Cryo: 1,400 gpm of ICW directly through the compressors.
- Continuous Wave Mode
  - Heat Load to Air (HLA): Install a chilled water loop to supplement the pulsed mode system with (2) air cooled chillers;
  - LCW: (3) additional Cooling Towers;
  - Cryo: No change

Pulsed Mode vs. Continuous Wave Operation



	Basis of Estimate		
Pulsed Mode	LCW	1	towers
	HLA	chilled water via CUB	
	Cryo	**1,400**	gpm @17 Fdt
	Standby	1	tower
CW Mode	LCW	4	towers
	HLA (PM)	chilled water via CUB	
	HLA (CW)	2	Air Cooled Chillers
	Cryo	**1,400**	gpm @17 Fdt
	Standby	1	tower

Summary

- Completed:
  - Developed a conceptual design based on technical requirements from stakeholders;
  - Investigated alternate siting locations;
  - Investigated alternate means of cooling cryo compressors;
  - Developed a modular approach to cooling during pulsed mode and continuous wave operation;
  - Approved TRS and FRS
- Next Steps:
  - Radiation Safety Assessment;
  - Refine the design during Detailed Design phase;
  - Value Engineering (purchase order in place);
  - Update the cost/schedule estimate;
  - Constructability Review at ~60%;

Questions