Fermilab

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# Conventional Facilities Status

Steve Dixon

PIP-II Machine Advisory Committee Meeting

10-12 April 2017

# Outline

- R&D Phase Goals
- Current Status
- Schedule to CD-1
- Risk Status
- Summary

# Charge Questions

1. Is the scope of the facility described in the CDR both feasible and likely to satisfy the requirements outlined in the Mission Need Statement?

2. Is the facility likely to meet the enumerated performance goals incorporated into the Functional Requirements Specification (FRS).

3. Have the risks inherent in the conceptual design been adequately identified and appropriately targeted within the R&D program?

4. Can the conceptual design be characterized as being sufficient to provide the technical basis for CD-1?

# Conventional Facilities Scope of Work

- Conventional Facilities to Support PIP-II:
  - Site Work
    - Utilities (electrical, communication, ICW, DWS, sanitary, chilled water);
    - Site Improvements (roads, parking area, hardstands, tank foundations);
  - Linac
    - Below Grade Enclosure;
    - Linac Service Building;
  - Transport Line
    - Transport Line Enclosure;
    - Beam Dump Enclosure;
    - Connection to existing Booster;
  - Cryo Plant Building
  - Mechanical Plant

# R&D Phase Goals

- Conceptual Design:
  - Conceptual Design Report Text;
  - Conceptual Design Drawings;
- Life Safety Analysis
- Support Analysis of Alternates
- Support NEPA Process
- Prepare for CD-1
  - R&D Phase resource loaded schedule
  - Construction Phase resource loaded schedule
- Prepare for CD-2/3a
  - Advanced Preliminary Design for Site Prep work
  - Advanced Preliminary Design for Cryo Plant Building

# R&D Phase Goals and Status

- Conceptual Design:
  - Conceptual Design Report Text; - Complete
  - Conceptual Design Drawings; - Complete [1]
- Life Safety Analysis - Complete [2]
- Support Analysis of Alternates – Complete
- Support NEPA Process - Ongoing
- Prepare for CD-1 – Ongoing
  - R&D Phase resource loaded schedule - Complete
  - Construction Phase resource loaded schedule – Ongoing
- Prepare for CD-2/3a – Not Started
  - Detailed Design for Site Prep work
  - Detailed Design for Cryo Plant Building

Charge Item: #1

Charge Item: #3

Charge Item: #3

Charge Item: #4

[1] – Conceptual Design Drawings can be found in TeamCenter ED0005473

[2] – Final LSA can be found at PIP-II-doc-120

# Conceptual Design Process

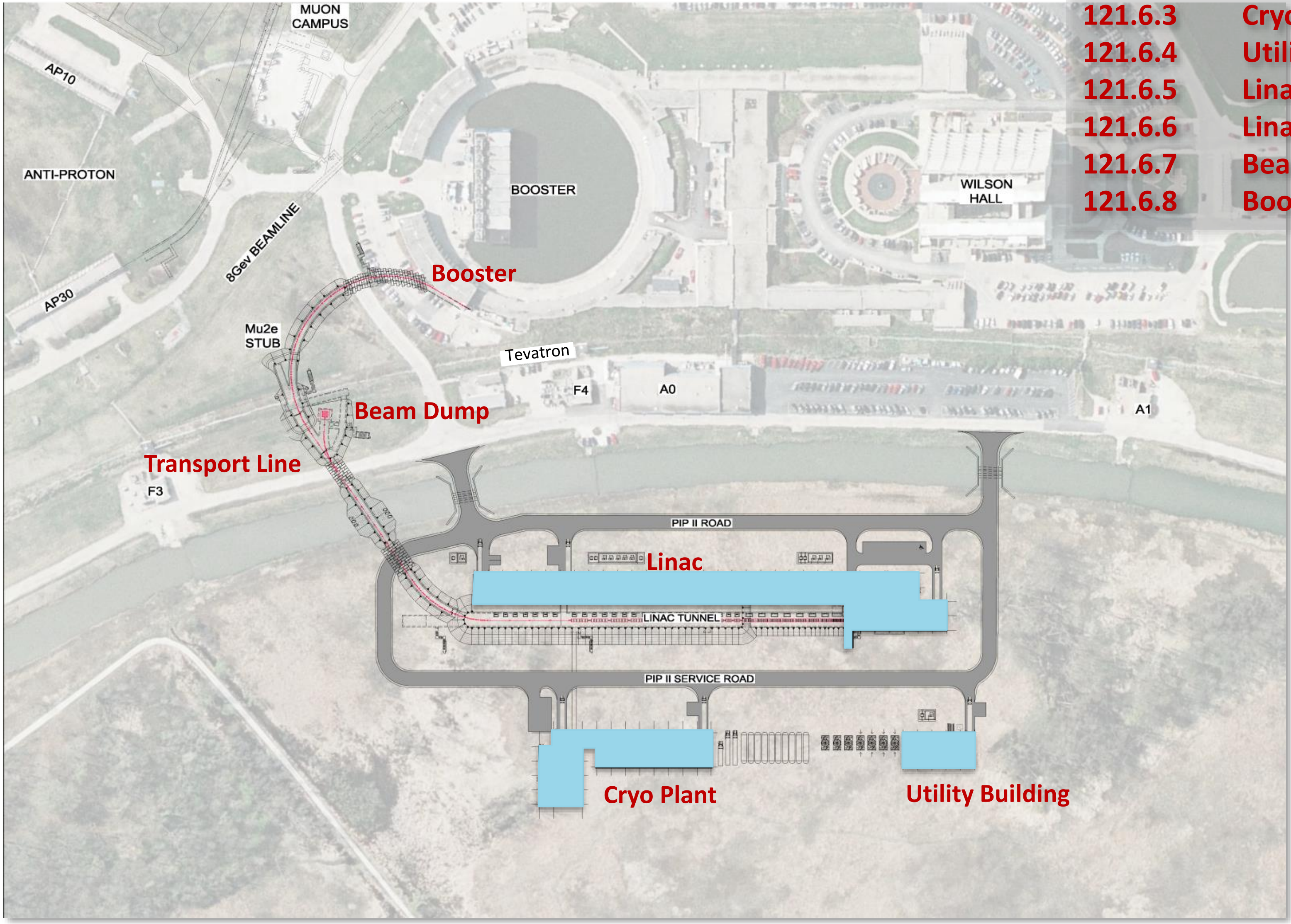
Charge Item: #1

- Meetings with Stakeholders:
  - Goal: Document the spatial and infrastructure requirements for PIP-II facilities; [3]
  - Started in January 2016;
- Results:
  - Product was the Conceptual Design drawings and text that described the sizes/arrangement of spaces and buildings to accommodate the functional requirements;
  - Developed cooling strategies for pulsed mode and continuous wave operation; FRS Section 5: “Full CW RF operational capability”
  - Conventional facilities are similar to typical Fermilab construction;



[3] – Meeting Minutes can be found in PIP-II-doc-70

# Siting Overview

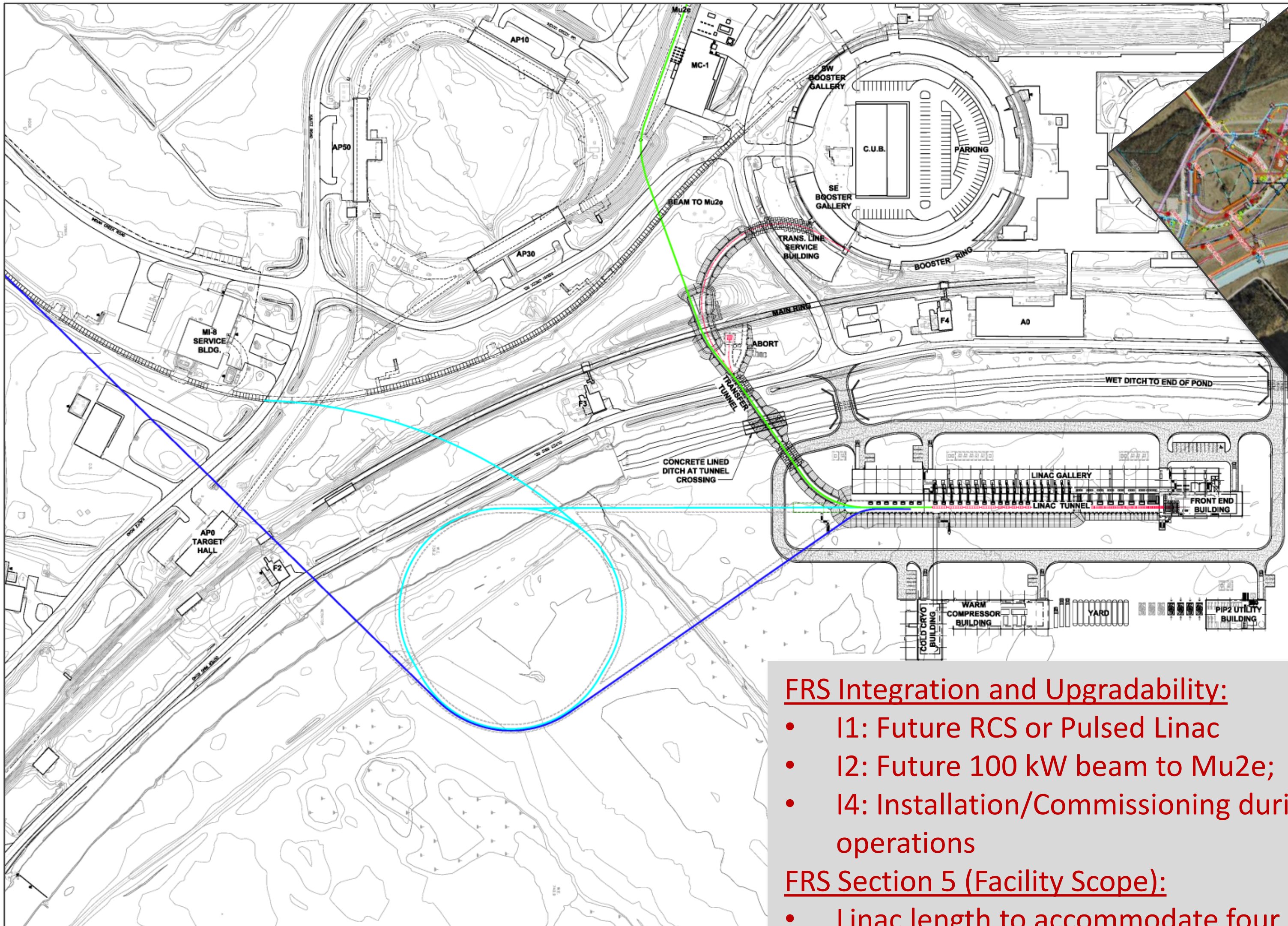


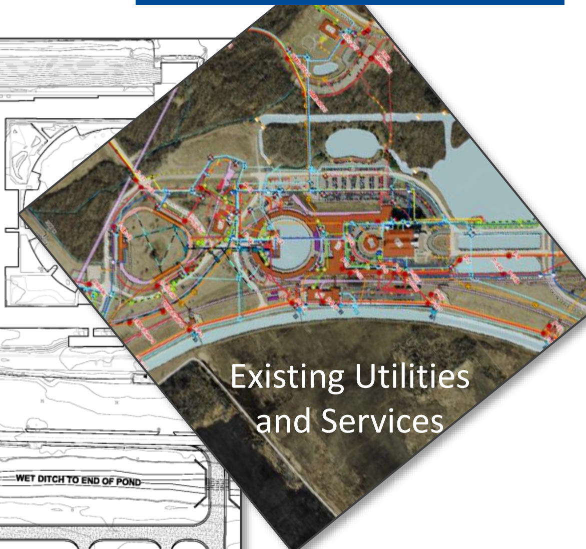

**Construction Packages:**

| | |
|---|---|
| 121.6.2 | Site Preparation |
| 121.6.3 | Cryo Plant Building |
| 121.6.4 | Utility Plant Building |
| 121.6.5 | Linac Tunnel |
| 121.6.6 | Linac Gallery |
| 121.6.7 | Beam Transfer Line |
| 121.6.8 | Booster Connection |

# Siting Considerations

Charge Item: #2




*Site Plan with Possible Future Expansion*

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

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

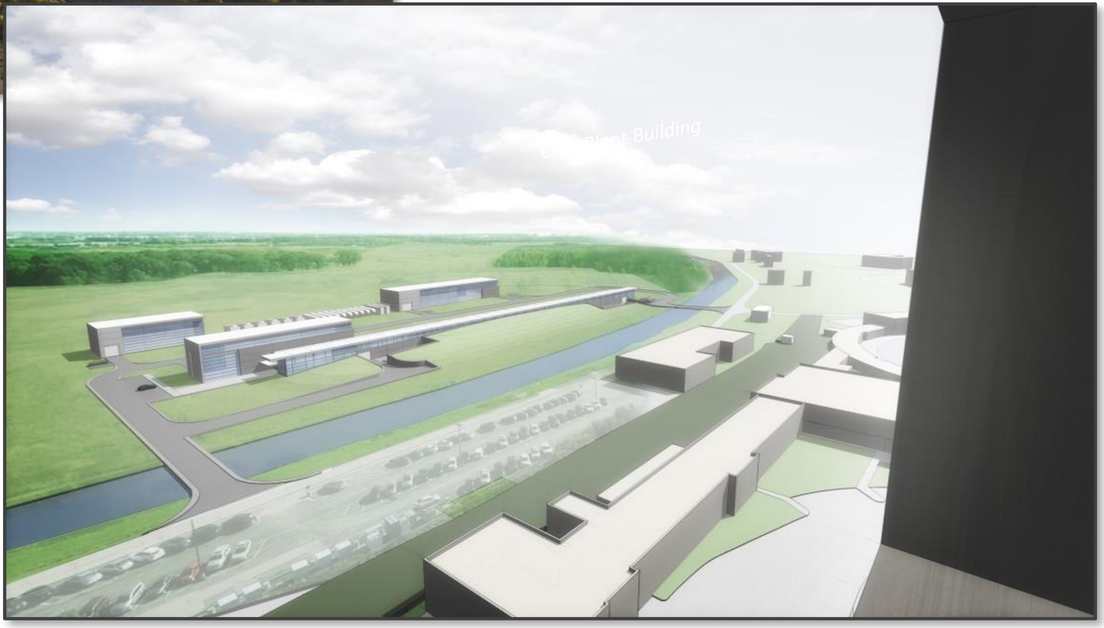
<u>FRS Section 5 (Facility Scope):</u>

- Linac length to accommodate four (4) additional HB650 cryomodules

# Siting Considerations


*Looking Southeast From Wilson Hall*

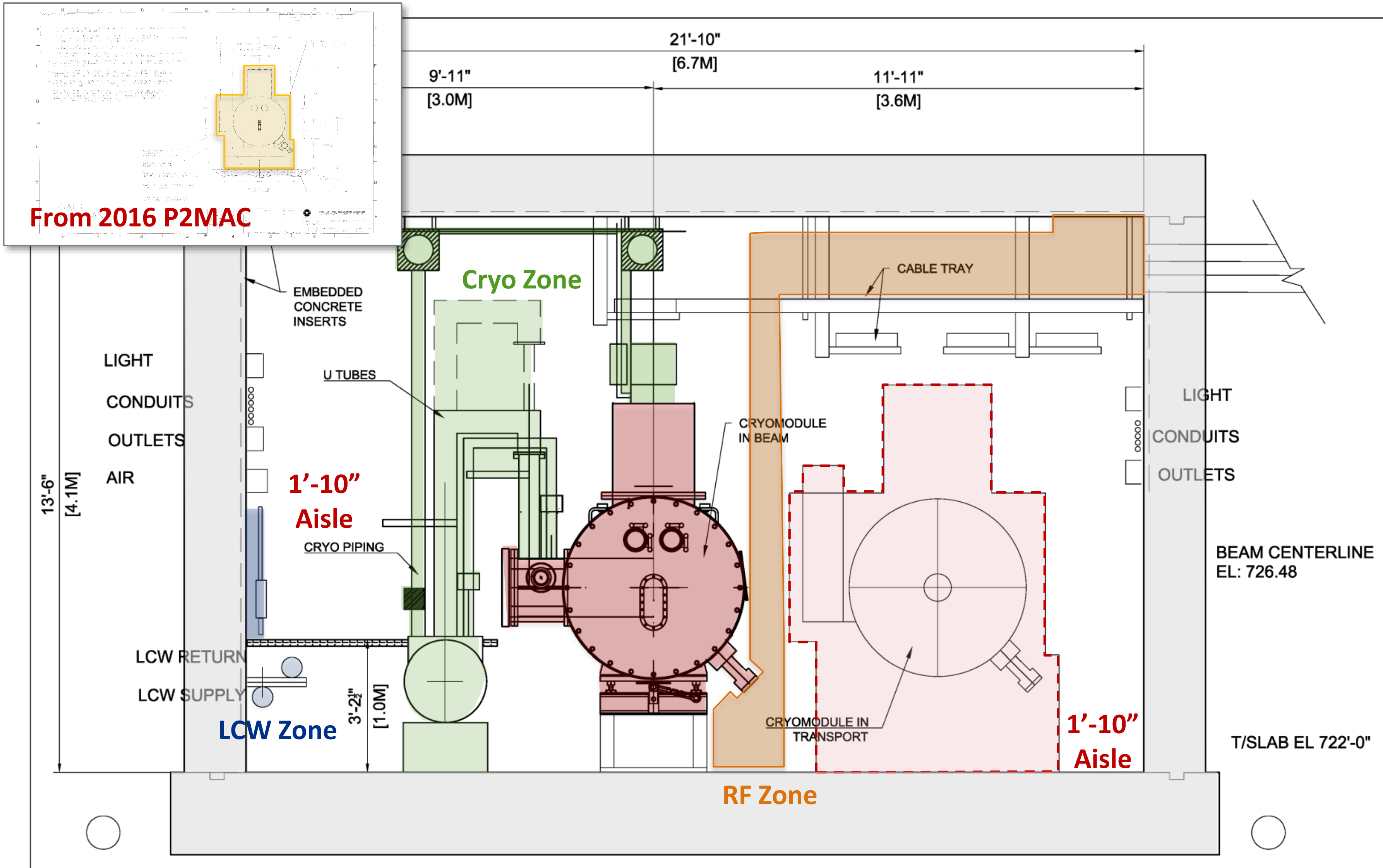

*Looking South Along Beamline*



*View from Wilson Hall*

# Typical Linac Cross Section

Charge Item: #1



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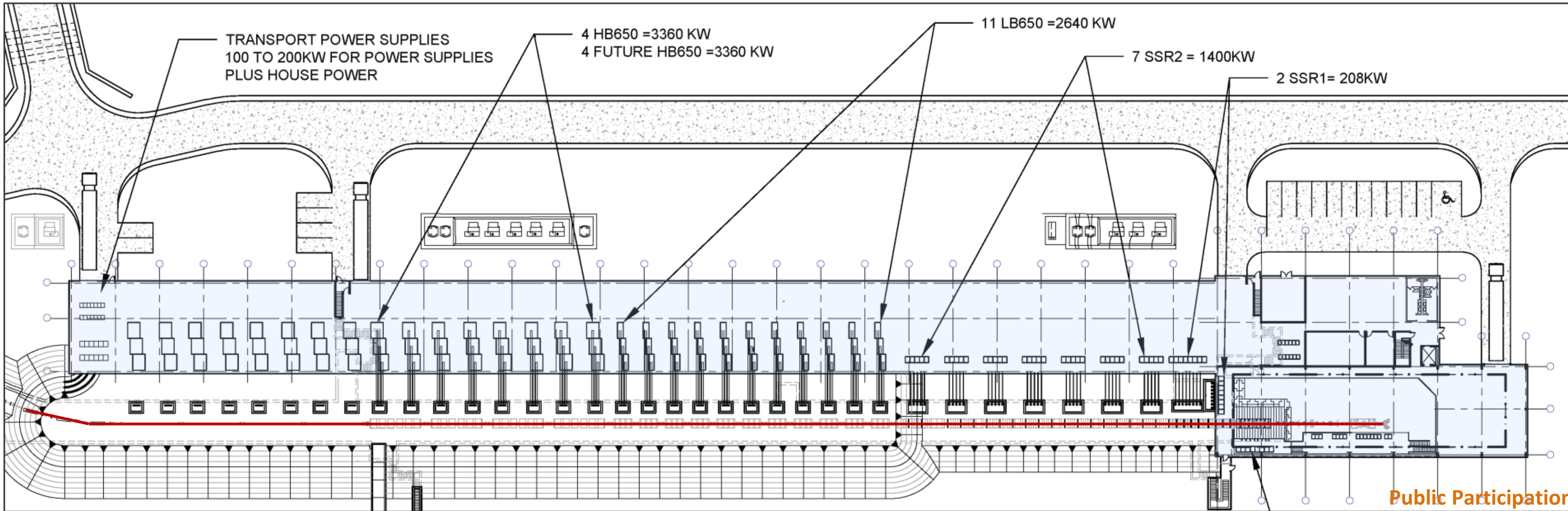
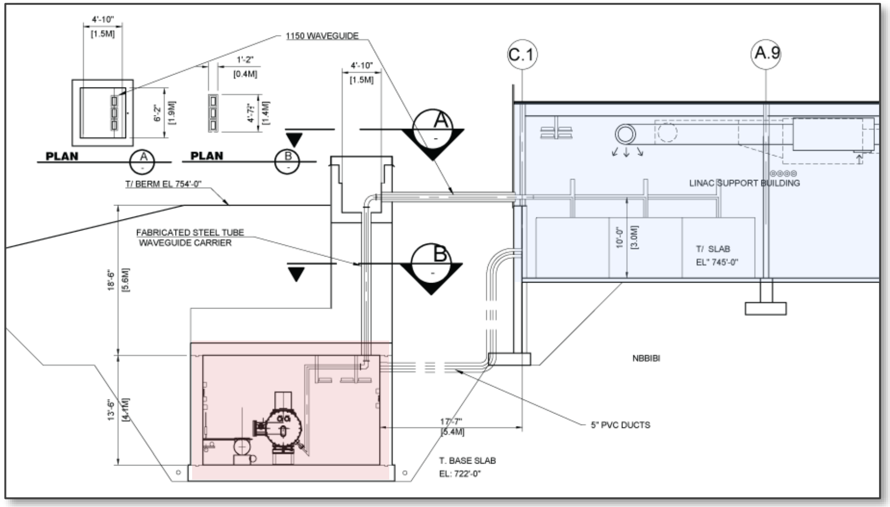
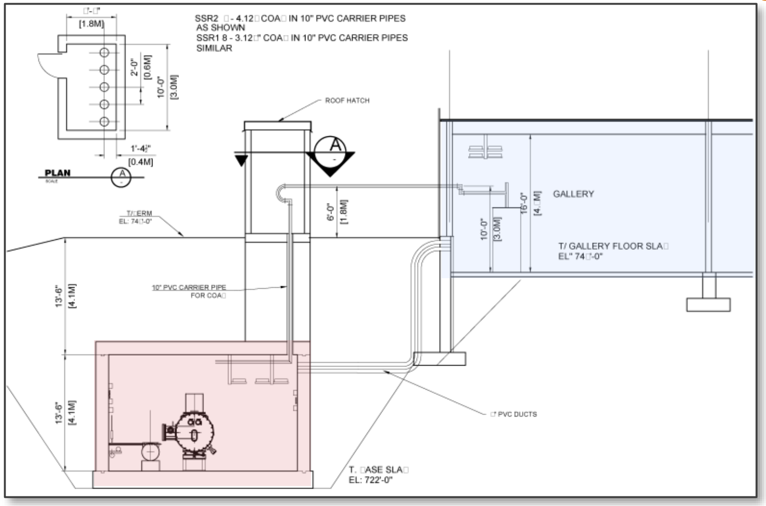
# Linac Plan



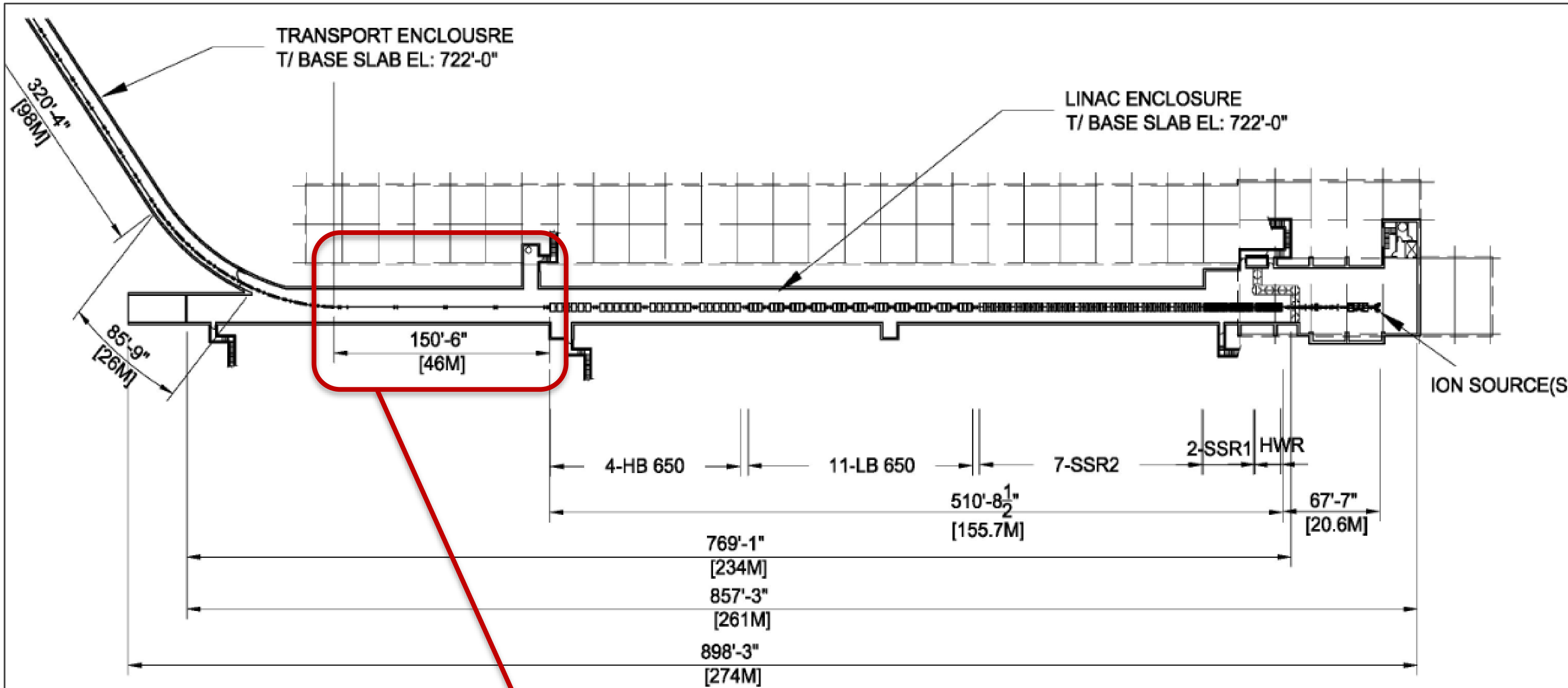




*Cross Section Looking South at Waveguide Penetrations*

*Cross Section Looking South at Coax Penetrations*

# Linac Enclosure Plan

Charge Item: #2




*Plan at Enclosure Level*

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

*The linac enclosure will be constructed with a length to accommodate four HB650 cryomodules beyond the nominal compliment required for 800 MeV*



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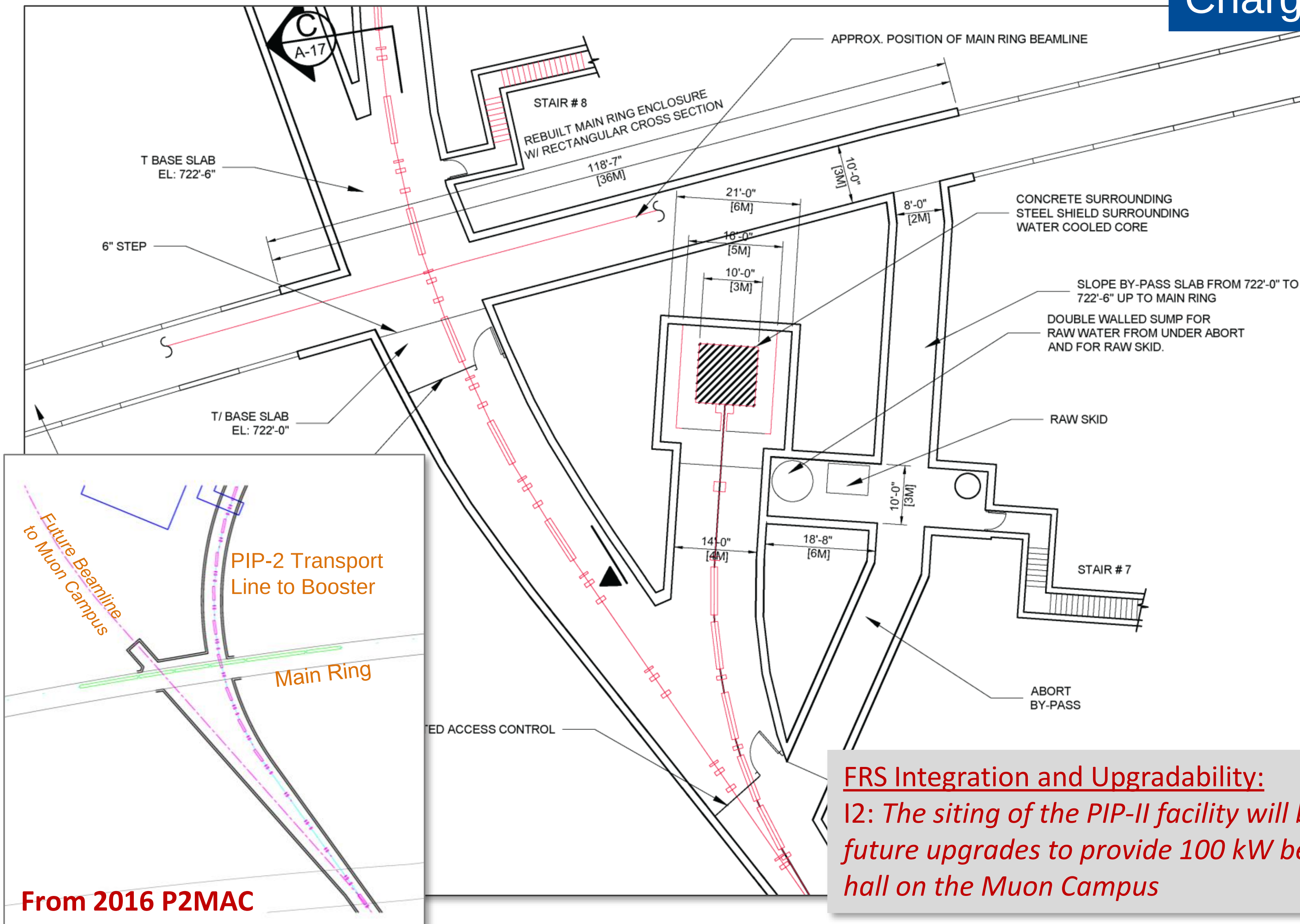
# Main Ring/Transport Line Intersection

Charge Item: #1

Charge Item: #2



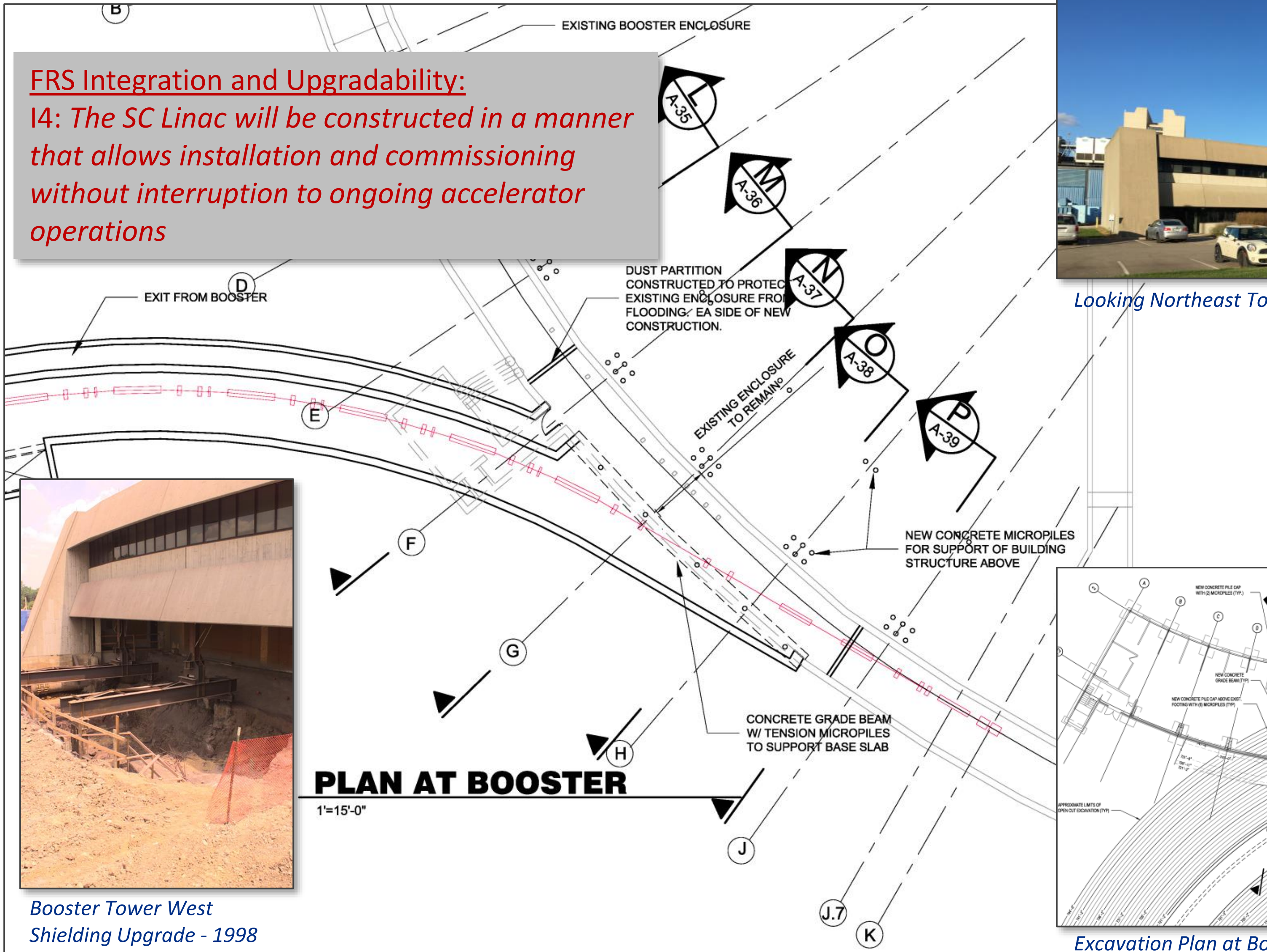

**From 2016 P2MAC**

<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*

# Booster Connection

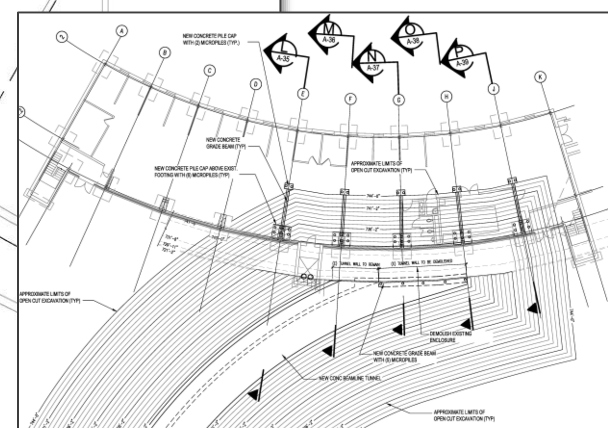
Charge Item: #2




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

*Looking Northeast Towards Booster Tower East*

*Booster Tower West Shielding Upgrade - 1998*



*Excavation Plan at Booster Tower East*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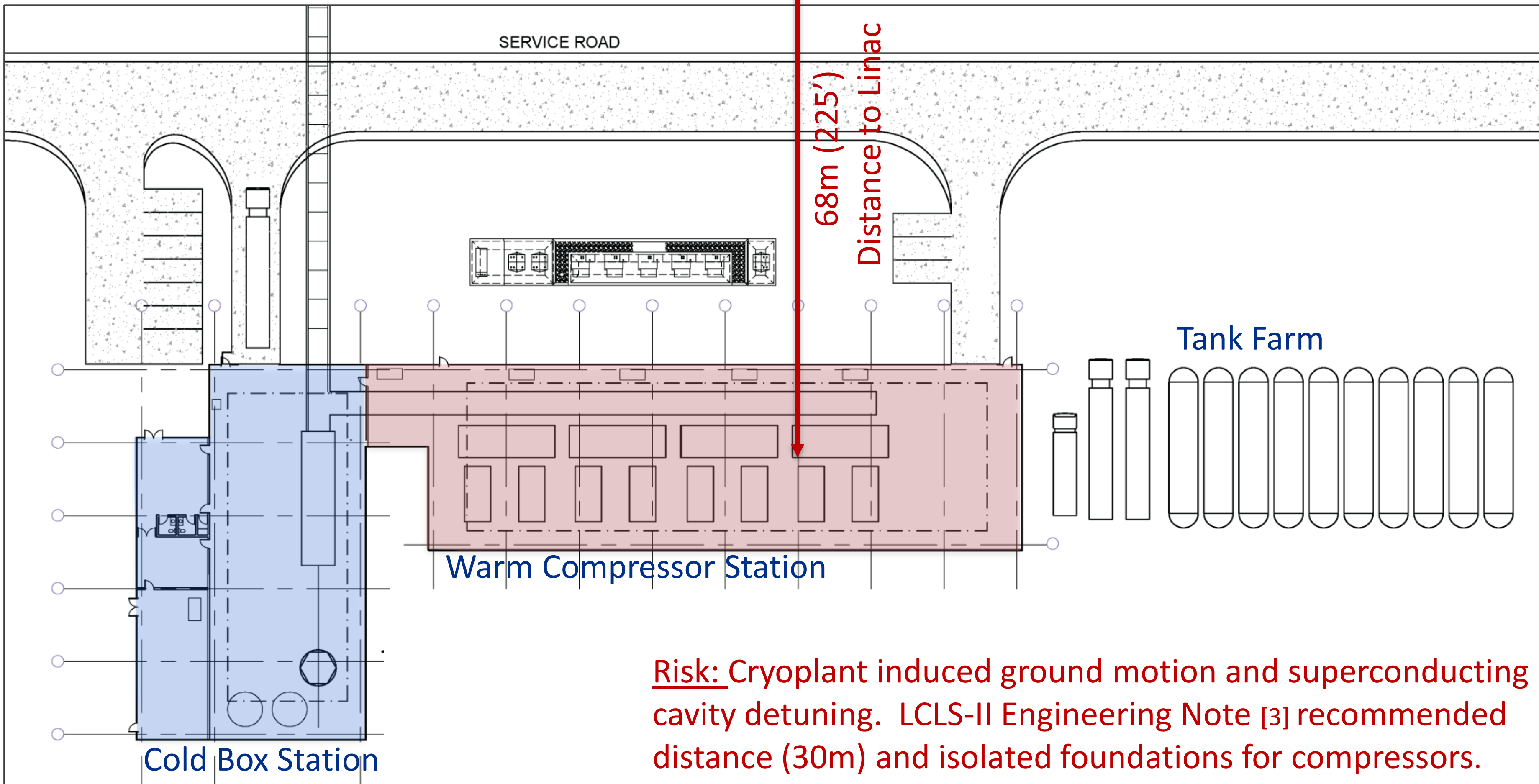
# Cryo Plant Building

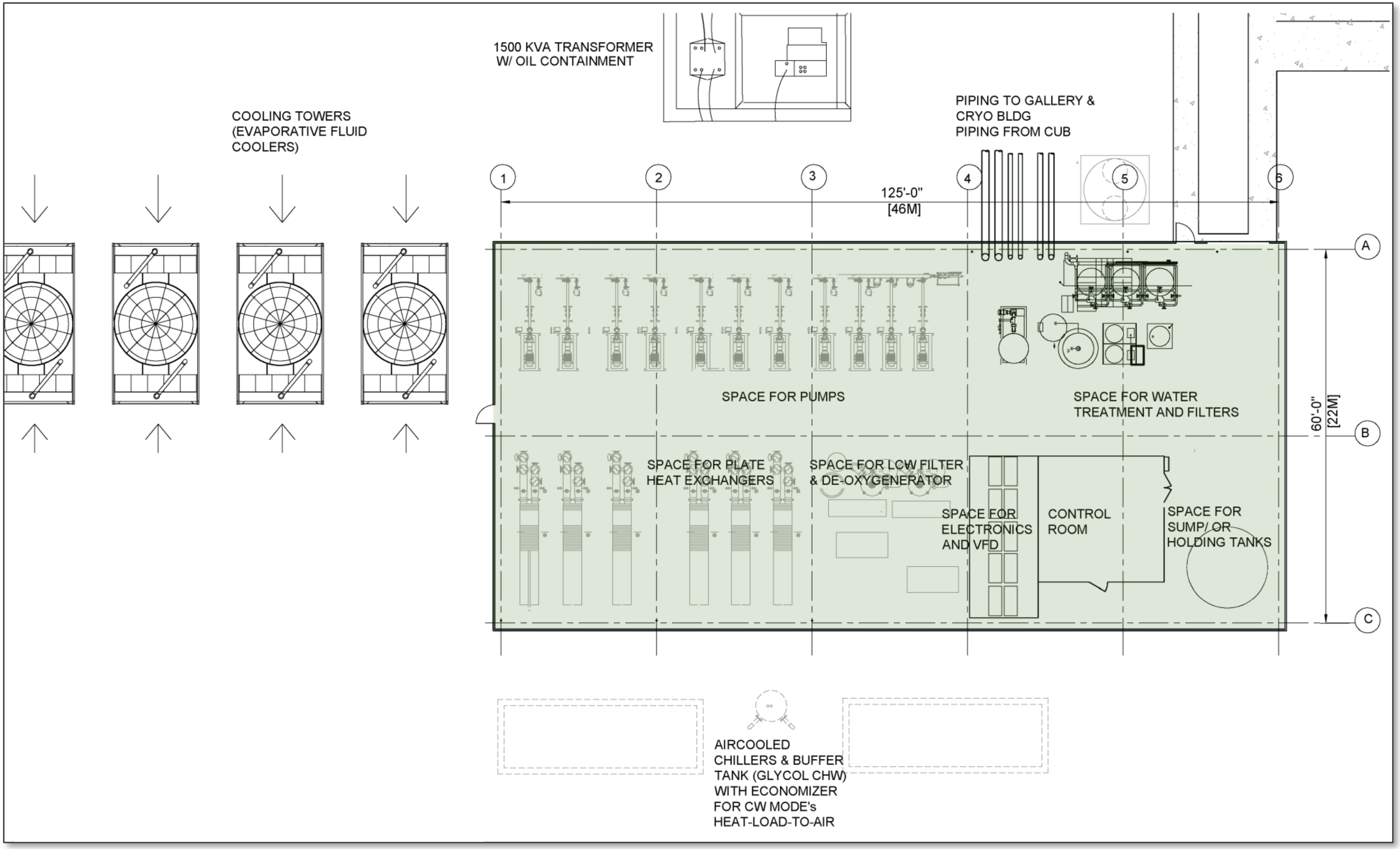
Charge Item: #3



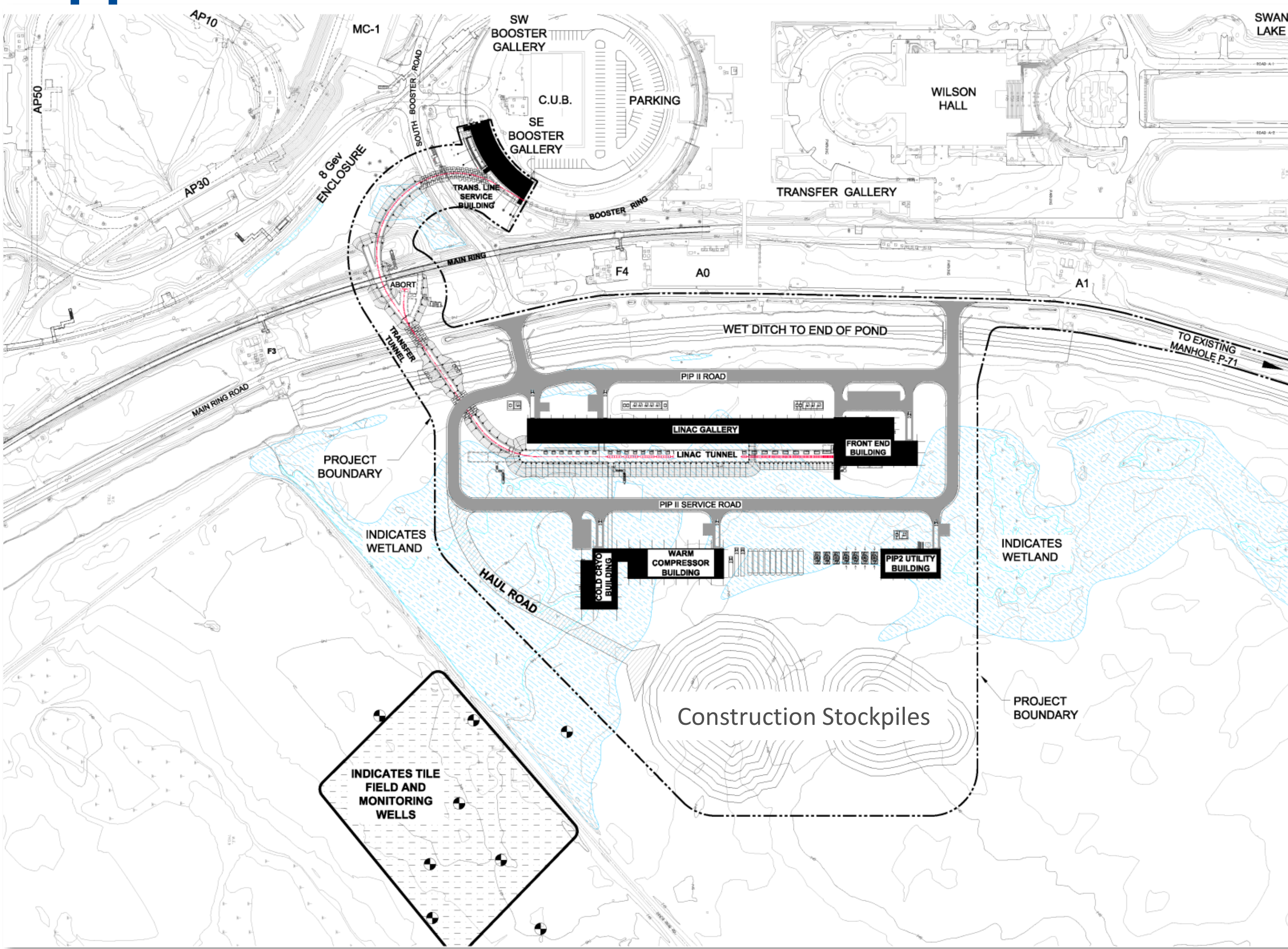

Risk: Cryoplant induced ground motion and superconducting cavity detuning. LCLS-II Engineering Note [3] recommended distance (30m) and isolated foundations for compressors.

[4] – Engineering Note LCLSII-4.8-EN-0326-R0 can be found at PIP-II-doc-122

# Utility Building



# Support NEPA




*Site Plan with 2016 Wetland Delineation*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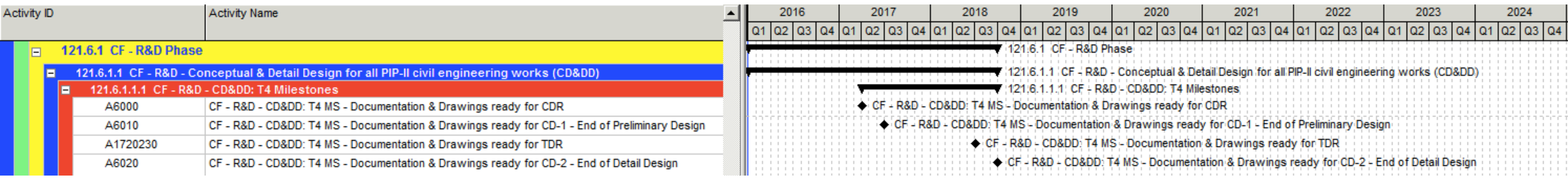
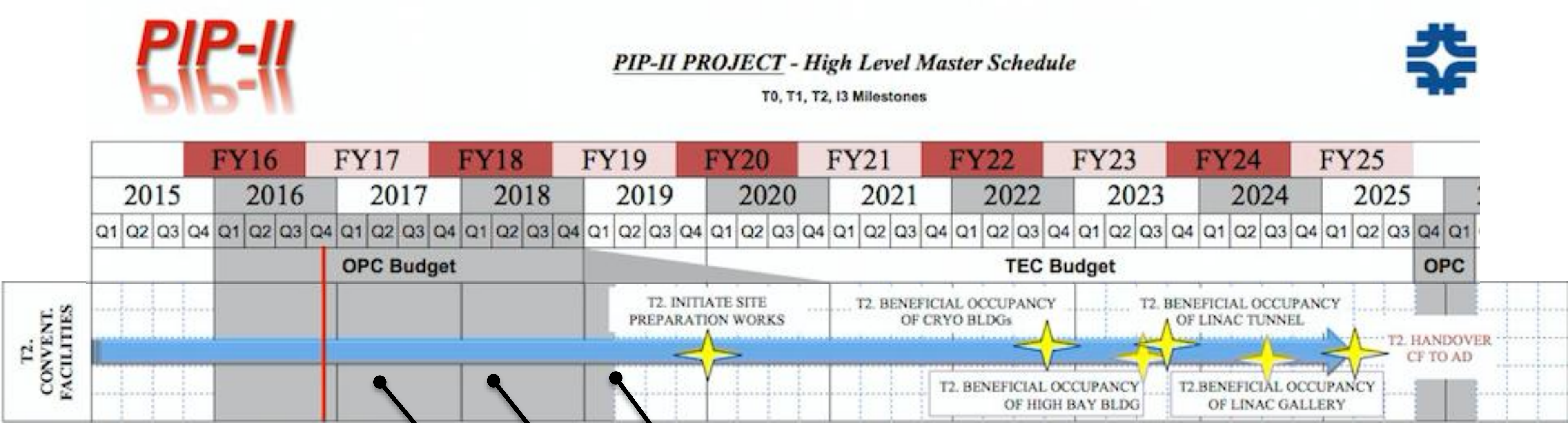
# Schedule to CD-1




FY19 : Final Design begins

FY18:Begin Detail Design for Site Prep, Cryo Plant, Utility Building

FY17:Select an Architect/Engineer - Complete;

- Update the drawings/text - Complete;
- Refine cost estimate/schedule - Underway;



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# Risks

Charge Item: #3

- 9 Opportunities (O)
- 48 Threats (T)

- Largest Opportunities/Threats
  - Wetland Delineation (O)
  - Changes to Subproject Design Requirements (T)
  - Poor Interface Definition Between Subprojects (T)
  - Significant Injury During Construction (T)
  - Accelerator Shutdown Uncertainties (T)

- These are being investigated during the R&D phase

# Summary

- Technical Design of Conventional Facilities is based in iterative discussions and meetings with stakeholders and the conceptual design of the conventional facilities will meet the requirements outlined in the Mission Need Statement;
- The scope of the conceptual design for the conventional facilities is sufficiently well defined to support the development of preliminary cost and schedule estimates currently underway;
- The Conventional Facilities have designed to incorporate and accommodate the performance goals contained in the Functional Requirements Specifications;
- The Conventional Facilities risk (threats/opportunities) review is underway and has identified and targeted keys risks to be addressed within the R&D program;
- The conceptual design is sufficiently developed to provide the technical basis of CD-1;

# Backup Material

# Other FY16/17 Activities:

- Siting Analysis – PIP-II-doc-136
- ICW Water Quality Test Results – PIP-II-doc-155
- Implementation of Guiding Principles – PIP-II-doc-184
- Wetland Assessment Report – PIP-II-doc-159
- Building Renderings – PIP-II-doc-151
- Investigation of One-for-One Building Replacement Requirement - ongoing

# 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 (TeamCenter ED0005473)

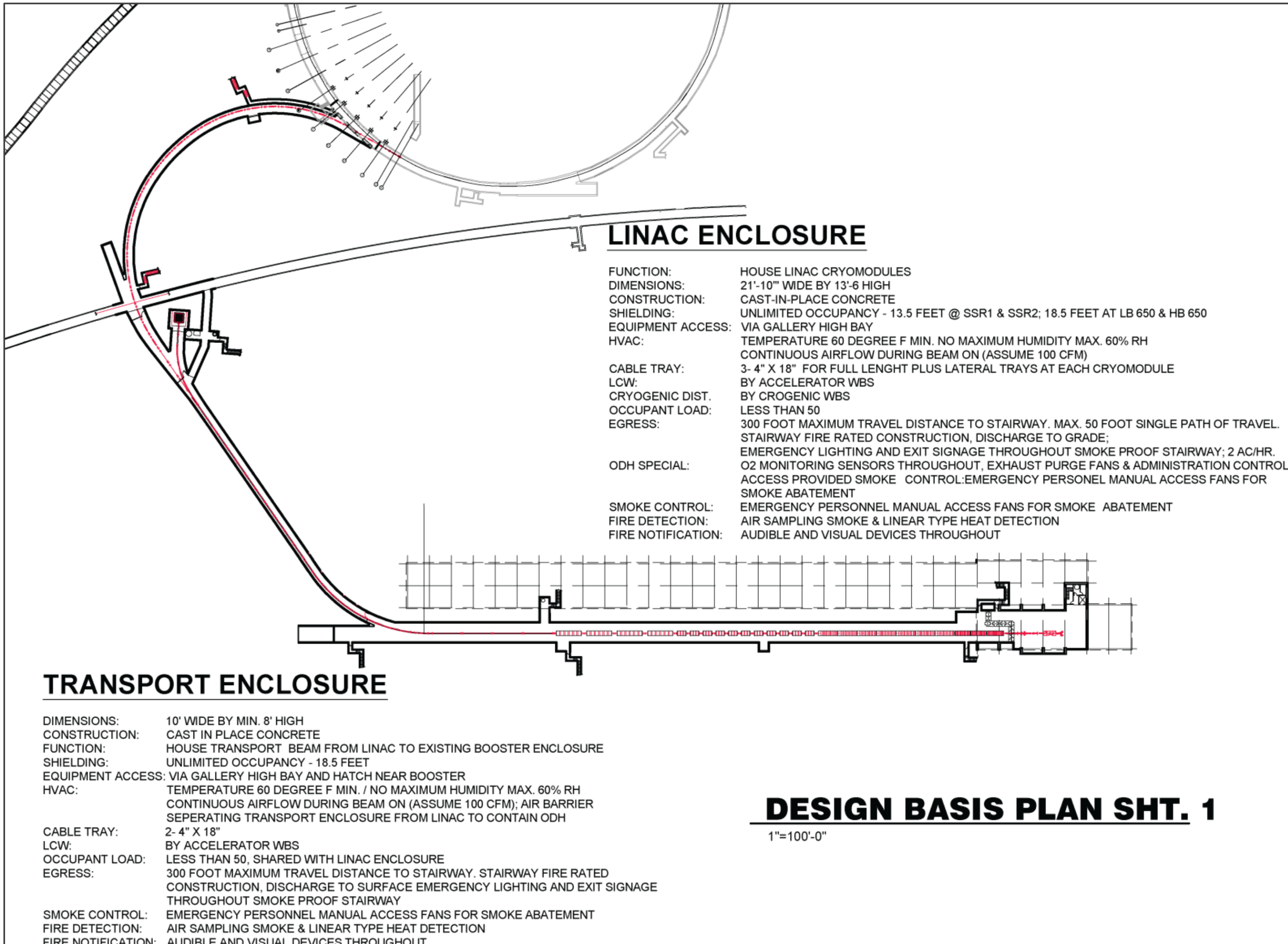
54 Drawings

- One (1) General sheet
- Six (6) Civil sheets
- Forty-Three (43) Architectural sheets
- Three (3) Mechanical sheets
- One (1) Electrical sheet

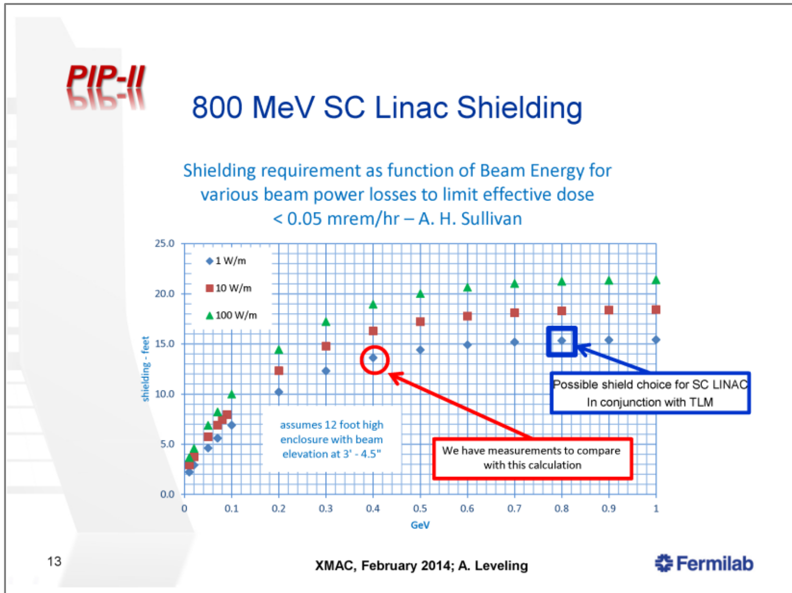
## LIST OF DRAWINGS

| | |
|---|---|
| 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 |
| A-1 | DESIGN BASIS - SHEET 1 |
| A-2 | DESIGN BASIS - SHEET 2 |
| A-3 | DESIGN BASIS - SHEET 3 |
| A-4 | LIFE SAFETY |
| A-5 | ENCLOSURE KEY PLAN |
| A-6 | LINAC ENCLOSURE PLAN - SHEET 1 |
| A-7 | LINAC ENCLOSURE PLAN - SHEET 2 |
| A-8 | LINAC ENCLOSURE PLAN - SHEET 3 |
| A-9 | LINAC ENCLOSURE PLAN - SHEET 4 |
| A-10 | TRANSPORT ENCLOSURE PLAN - SHEET 1 |
| A-11 | TRANSPORT ENCLOSURE PLAN - SHEET 2 |
| A-12 | TRANSPORT ENCLOSURE PLAN - SHEET 3 |
| A-13 | TRANSPORT ENCLOSURE PLAN - SHEET 4 |
| A-14 | TRANSPORT ENCLOSURE PLAN - SHEET 5 |
| A-15 | TYP. LINAC ENCLOSURE SECTION |
| A-16 | TYP. TRANSPORT ENCLOSURE SECTION |
| A-17 | ELEVATION AT MAIN RING CROSSING |
| A-18 | PIP II CAMPUS PLAN |
| A-19 | LINAC SUPPORT BUILDING KEY PLAN |
| A-20 | LINAC SUPPORT BUILDING PLAN - SHEET 1 |
| A-21 | LINAC SUPPORT BUILDING PLAN - SHEET 2 |
| A-22 | LINAC SUPPORT BUILDING PLAN - SHEET 3 |
| A-23 | LINAC SUPPORT BUILDING PLAN - SHEET 4 |
| A-24 | LINAC SUPPORT BUILDING PLAN - SHEET 5 |
| A-25 | SOUTHEAST BOOSTER BUILDING - DEMO PLAN |
| A-26 | SOUTHEAST BOOSTER BLDG. - EXCAVATION PLAN |
| A-27 | SOUTHEAST BOOSTER BUILDING - PLAN |
| A-28 | SECTION THRU RECEIVING |
| A-29 | CROSS SECTION THRU HIGH BAY |
| A-30 | CROSS SECTION @ HWR |
| A-31 | SECTION THRU HIGH BAY |
| A-32 | SECTION @ COAX FOR SSR1, SSR2 |
| A-33 | SECTION @ WAVEGUIDE FOR LB 650, HB 650 |
| A-34 | SECTION AT LINAC ALCOVES |
| A-35 | SECTION SHEET - 1 |
| A-36 | SECTION SHEET - 2 |
| A-37 | SECTION SHEET - 3 |
| A-38 | SECTION SHEET - 4 |
| A-39 | SECTION SHEET - 5 |
| A-40 | CRYOGENIC PLANT |
| A-41 | COLD BOX STATION PLAN |
| A-42 | COMPRESSOR STATION PLAN |
| A-43 | PIP II UTILITY PLANT PLAN |
| 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

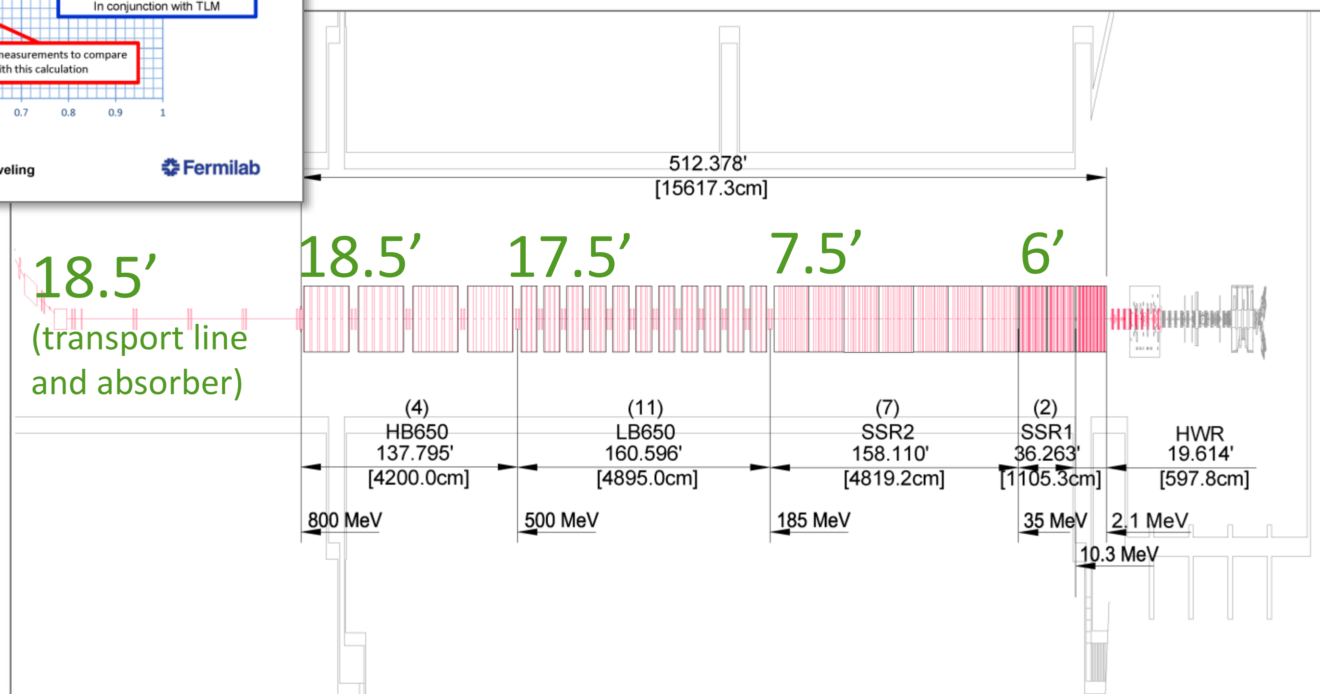


# Preliminary Shielding Considerations



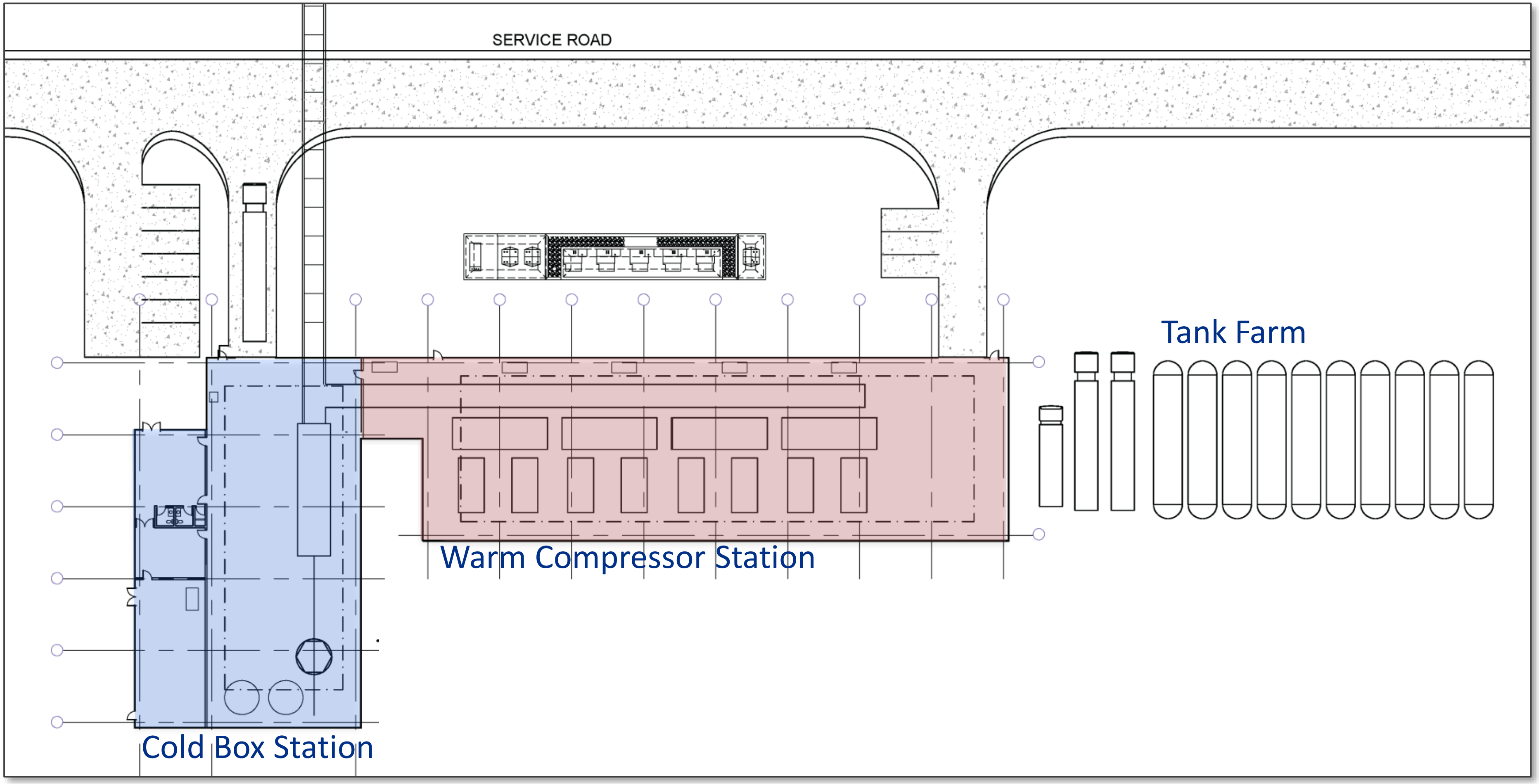

Used the 10W/m curve for the conceptual design

Preliminary Shielding Depths shown below. <u>**Further analysis required**</u>, especially at the Booster.

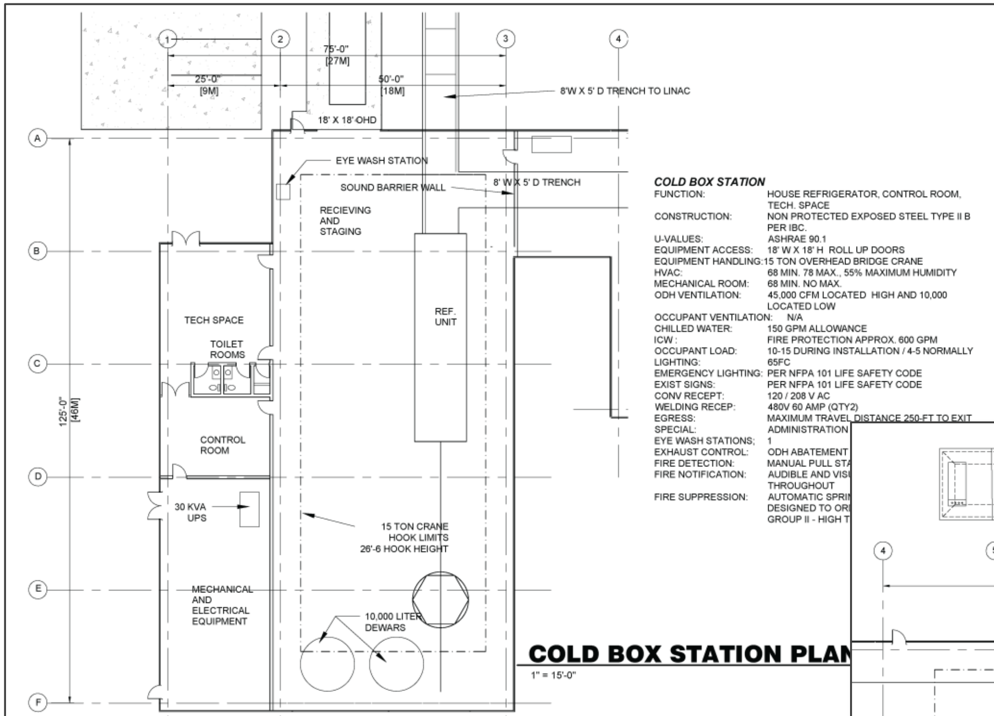


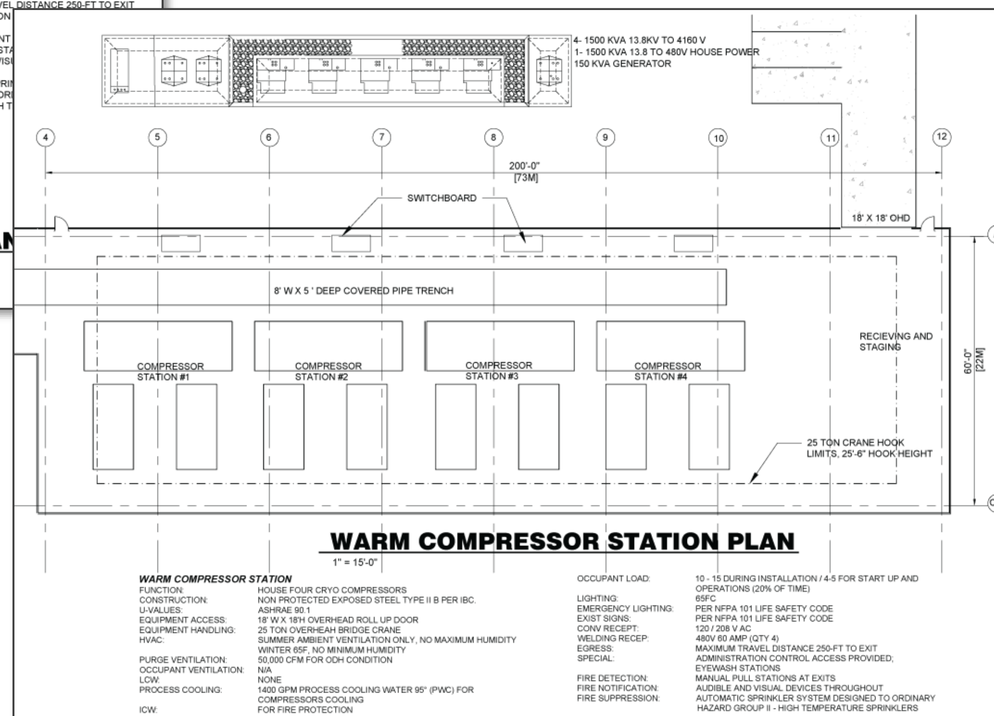

*Thanks to D. Cossairt, T. Leveling and M. Quinn*

# Cryo Plant


SERVICE ROAD
Tank Farm
Warm Compressor Station
Cold Box Station

# Cryo Plant


75'-0"
[27M]
25'-0"
[9M]
50'-0"
[18M]
8'W X 5' D TRENCH TO LINAC
18' X 18' OHD
EYE WASH STATION
SOUND BARRIER WALL
8' W X 5' D TRENCH
RECIEVING
AND
STAGING
TECH SPACE
TOILET
ROOMS
REF.
UNIT
CONTROL
ROOM
30 KVA
UPS
15 TON CRANE
HOOK LIMITS
26'-6 HOOK HEIGHT
MECHANICAL
AND
ELECTRICAL
EQUIPMENT
10,000 LITER
DEWARS
125'-0"
[46M]
COLD BOX STATION
FUNCTION: HOUSE REFRIGERATOR, CONTROL ROOM, TECH. SPACE
CONSTRUCTION: NON PROTECTED EXPOSED STEEL TYPE II B PER IBC.
U-VALUES: ASHRAE 90.1
EQUIPMENT ACCESS: 18' W X 18' H ROLL UP DOORS
EQUIPMENT HANDLING: 15 TON OVERHEAD BRIDGE CRANE
HVAC: 68 MIN. 78 MAX., 55% MAXIMUM HUMIDITY
MECHANICAL ROOM: 68 MIN. NO MAX.
ODH VENTILATION: 45,000 CFM LOCATED HIGH AND 10,000 LOCATED LOW
OCCUPANT VENTILATION: N/A
CHILLED WATER: 150 GPM ALLOWANCE
ICW: FIRE PROTECTION APPROX. 600 GPM
OCCUPANT LOAD: 10-15 DURING INSTALLATION / 4-5 NORMALLY
LIGHTING: 65FC
EMERGENCY LIGHTING: PER NFPA 101 LIFE SAFETY CODE
EXIST SIGNS: PER NFPA 101 LIFE SAFETY CODE
CONV RECEPT: 120 / 208 V AC
WELDING RECEP: 480V 60 AMP (QTY2)
EGRESS: MAXIMUM TRAVEL DISTANCE 250-FT TO EXIT
SPECIAL: ADMINISTRATION
EYE WASH STATIONS: 1
EXHAUST CONTROL: ODH ABATEMENT
FIRE DETECTION: MANUAL PULL STA
FIRE NOTIFICATION: AUDIBLE AND VISU THROUGHOUT
FIRE SUPPRESSION: AUTOMATIC SPRIN DESIGNED TO ORD GROUP II - HIGH T
COLD BOX STATION PLAN
1" = 15'-0"


4- 1500 KVA 13.8KV TO 4160 V
1- 1500 KVA 13.8 TO 480V HOUSE POWER
150 KVA GENERATOR
200'-0"
[73M]
SWITCHBOARD
18' X 18' OHD
8' W X 5 ' DEEP COVERED PIPE TRENCH
RECIEVING AND
STAGING
COMPRESSOR
STATION #1
COMPRESSOR
STATION #2
COMPRESSOR
STATION #3
COMPRESSOR
STATION #4
25 TON CRANE HOOK
LIMITS, 25'-6" HOOK HEIGHT
60'-0"
[22M]
WARM COMPRESSOR STATION PLAN
1" = 15'-0"
WARM COMPRESSOR STATION
FUNCTION: HOUSE FOUR CRYO COMPRESSORS
CONSTRUCTION: NON PROTECTED EXPOSED STEEL TYPE II B PER IBC.
U-VALUES: ASHRAE 90.1
EQUIPMENT ACCESS: 18' W X 18'H OVERHEAD ROLL UP DOOR
EQUIPMENT HANDLING: 25 TON OVERHEAH BRIDGE CRANE
HVAC: SUMMER AMBIENT VENTILATION ONLY, NO MAXIMUM HUMIDITY WINTER 65F, NO MINIMUM HUMIDITY
PURGE VENTILATION: 50,000 CFM FOR ODH CONDITION
OCCUPANT VENTILATION: N/A
LCW: NONE
PROCESS COOLING: 1400 GPM PROCESS COOLING WATER 95° (PWC) FOR COMPRESSORS COOLING
ICW: FOR FIRE PROTECTION
OCCUPANT LOAD: 10 - 15 DURING INSTALLATION / 4-5 FOR START UP AND OPERATIONS (20% OF TIME)
LIGHTING: 65FC
EMERGENCY LIGHTING: PER NFPA 101 LIFE SAFETY CODE
EXIST SIGNS: PER NFPA 101 LIFE SAFETY CODE
CONV RECEPT: 120 / 208 V AC
WELDING RECEP: 480V 60 AMP (QTY 4)
EGRESS: MAXIMUM TRAVEL DISTANCE 250-FT TO EXIT
SPECIAL: ADMINISTRATION CONTROL ACCESS PROVIDED; EYEWASH STATIONS
FIRE DETECTION: MANUAL PULL STATIONS AT EXITS
FIRE NOTIFICATION: AUDIBLE AND VISUAL DEVICES THROUGHOUT
FIRE SUPPRESSION: AUTOMATIC SPRINKLER SYSTEM DESIGNED TO ORDINARY HAZARD GROUP II - HIGH TEMPERATURE SPRINKLERS

# Cryo Plant – Water Quality Requirements

| | | PIP-II Requirements | | Water Analysis Report | | |
|---|---|---|---|---|---|---|
| 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 | |

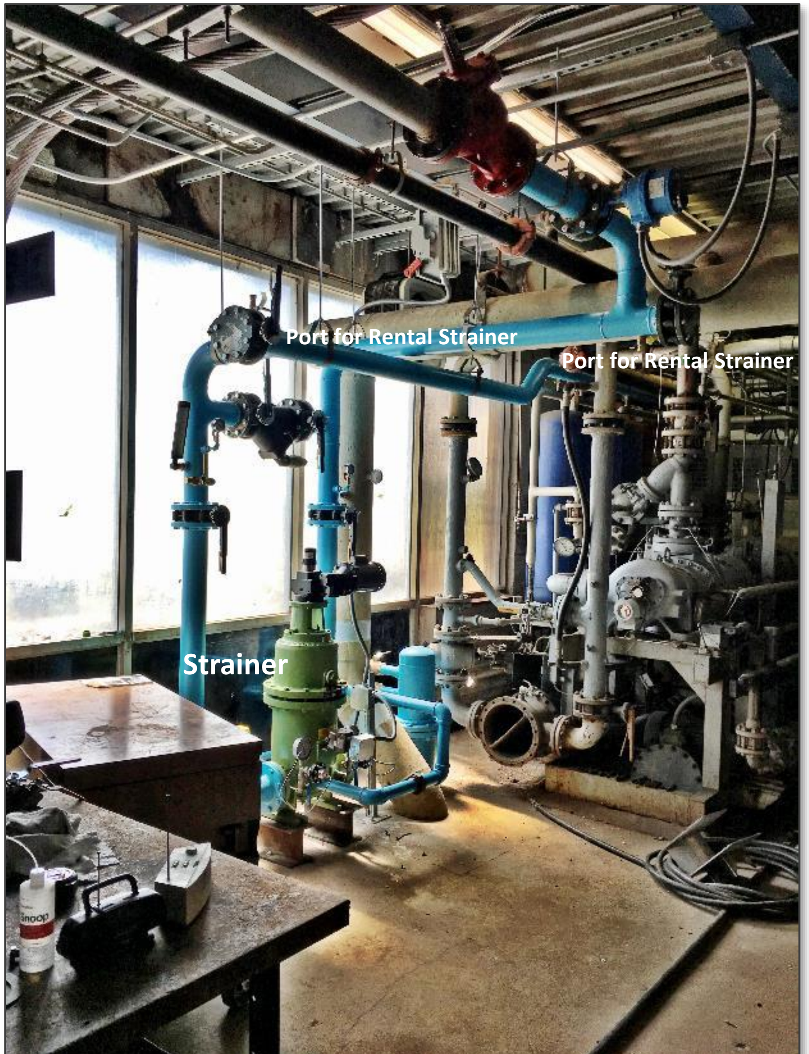
*Thanks to A. Klebaner and A. Chakravarty*

# Cryo Plant Cooling Requirements

- Water Requirements
  - ~2,000 gpm flow
- Pond System
  - Chemical characteristics met by Pond system;
  - Solids content characteristics NOT met by Pond system;
  - No Pond Exists - ~$500-$700k per acre;
- ICW System
  - Testing indicates that ICW meets most requirements (see next slides) [5];
    - Chemical characteristics met by existing ICW system;
    - Solids content characteristics NOT met by ICW system;
  - Only 1,400 gpm available per the ICW model

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

# Cryo Plant – Water Quality Test Stand




- Installed as part of the Mu2e Cryo work for CDF;
- Installed test ports to sample the ICW before and after the strainer;
- Includes a 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;
- Compare strainer options with water quality requirements.

*BZero Compressor Building*

# Cryo Plant – Test Stand Results

*Thanks to G. Gilbert for the help with water sampling/testing*

| | | PIP-II Requirements | | Adam's Strainer (250 micron) | | Adams Strainer (75 micron) | | Lakos Filter (25 micron) | | CUB Cooling Towers | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 21-Oct-16 | | 14-Dec-16 | | 16-Nov-16 | | | |
| **Desription** | **Unit** | **Closed loop** | **Open loop** | Before | After | Before | After | Before | After | 16-Nov-16 | 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:

- Baseline assumes a heat exchanger to isolate the ICW from the cryo compressor side;
- Opportunity to eliminate the heat exchanger/pumps/treatment and have direct ICW cooling with additional testing/convincing;
- Additional testing needed for chloride;
- Algae is likely seasonal, still requires a solution or better definition of requirements;

# PM vs. CW Considerations

- Driven by duty factor of the 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
  - 5.0 mw in pulsed mode;
  - 10.5 mw in continuous wave mode;

# PM vs. CW Considerations - Cooling

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

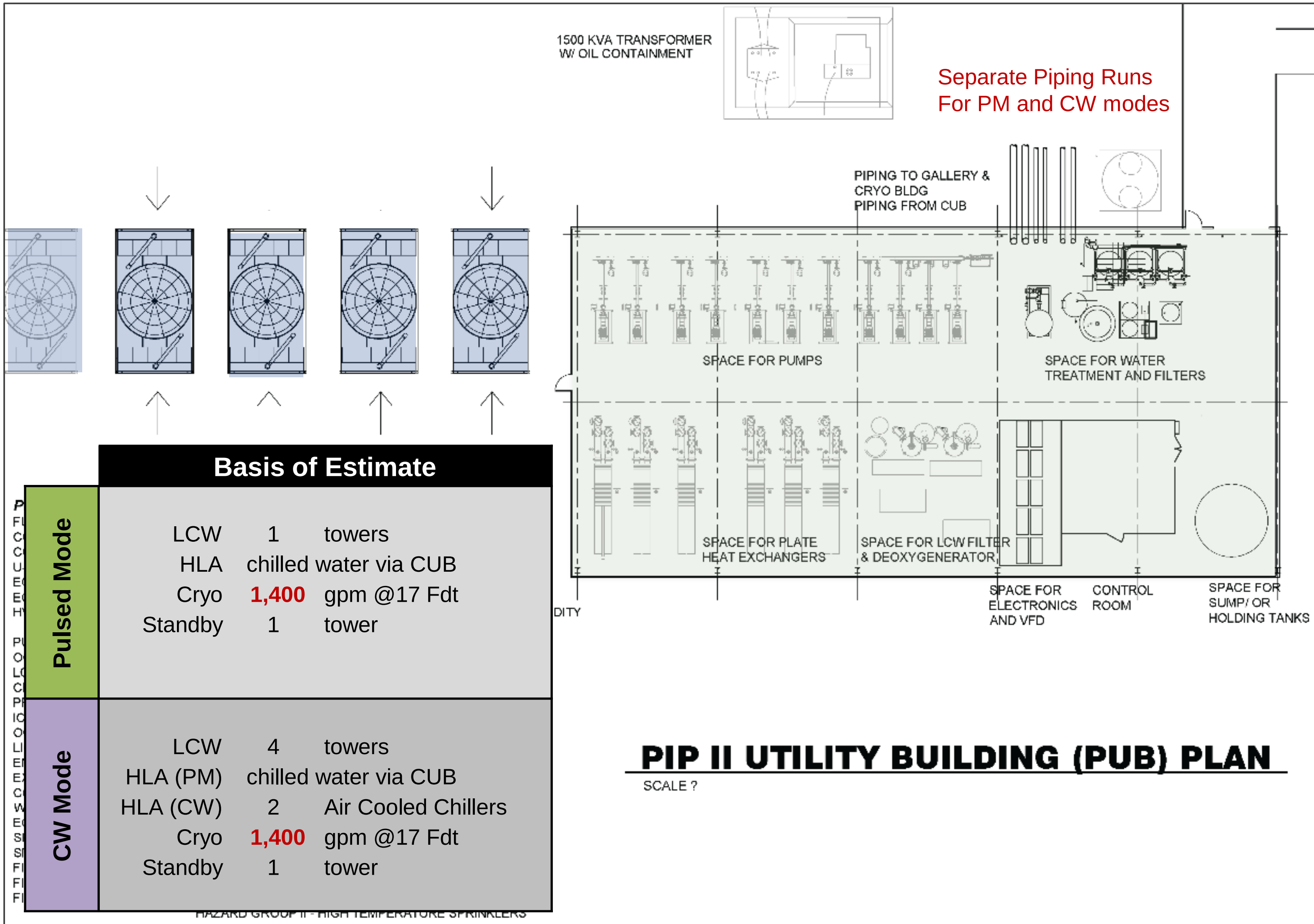
**Note: 1,400 gpm is the highest flow currently available from the existing ICW system**
**2,000 gpm is preferred**

*Thanks to E. Huedem*

# Cooling Design Approach

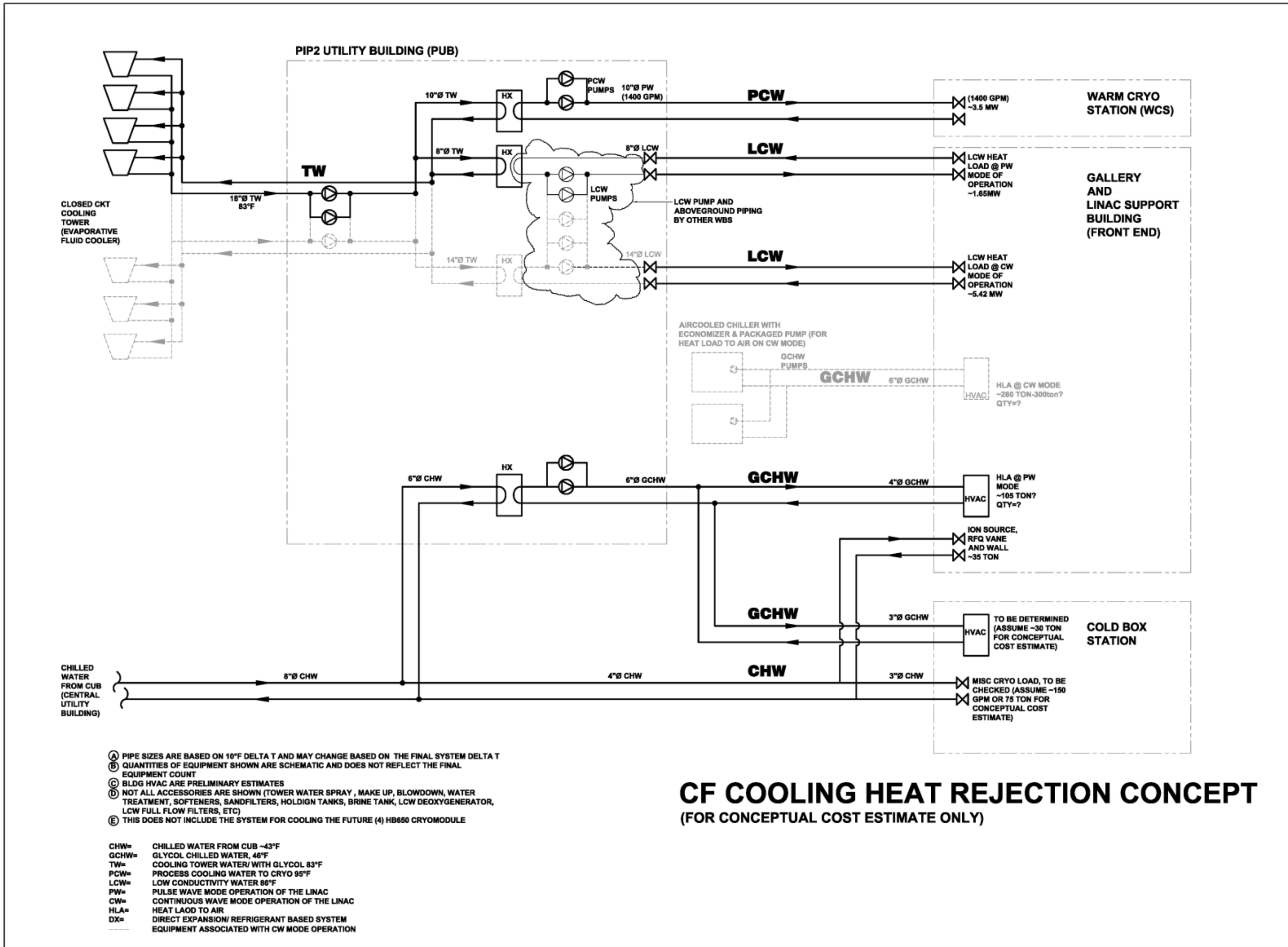
- Goal: Modular approach that allows for efficient operation in both modes;
- CUB Chilled Water Budget: ~250 tons total.  Used for small equipment loads, building loads and RF heat load
- Pulsed Mode
  - Heat Load to Air (HLA): Utilize chilled water from existing CUB for equipment cooling;
  - LCW: (1) Cooling Tower + 1 standby;
  - Cryo: 1,400 gpm of ICW through heat exchanger
- 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 Tower;
  - Cryo: No change

# PIP-II Utility Building

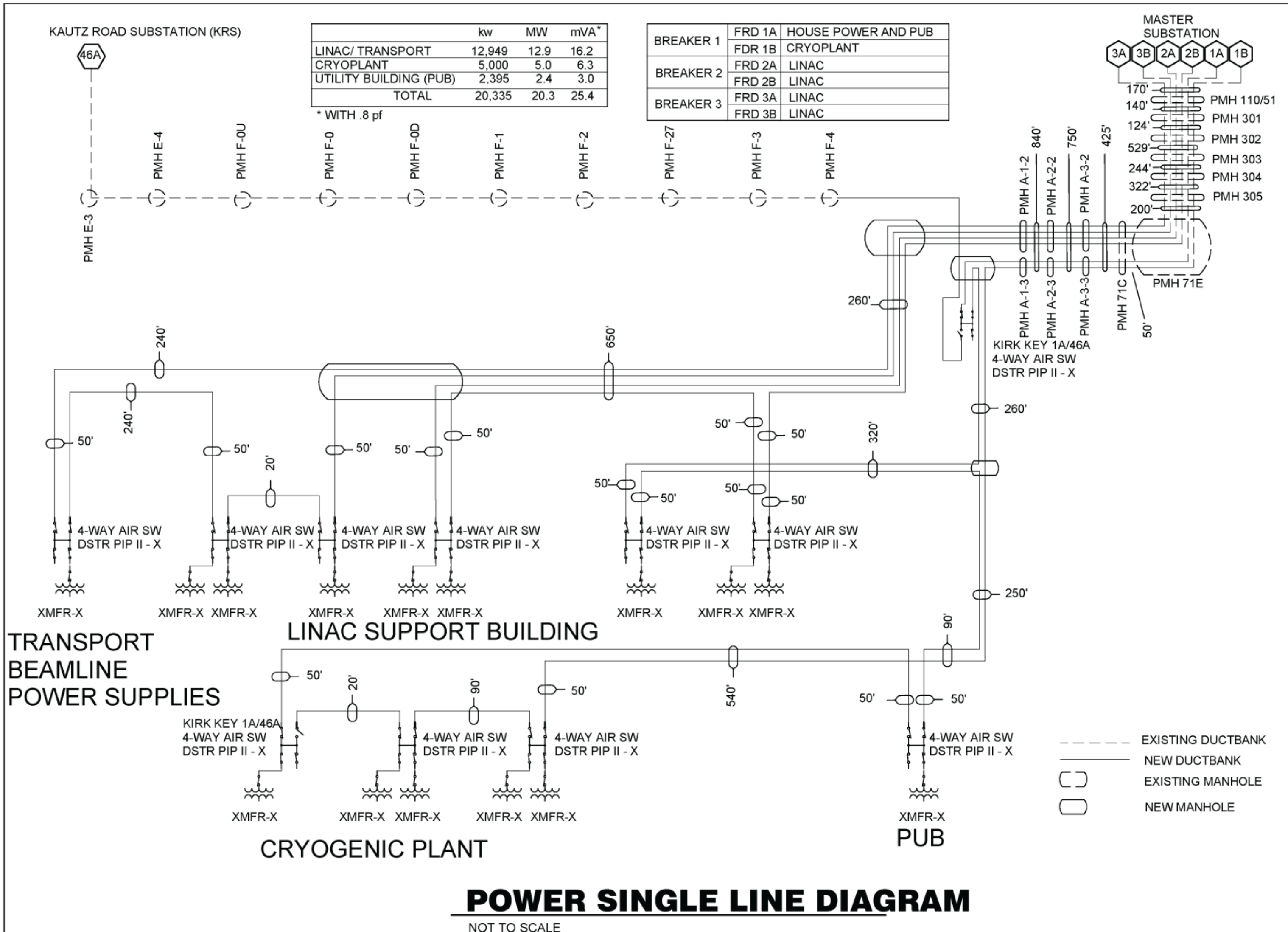



| Basis of Estimate | | | |
|---|---|---|---|
| **Pulsed Mode** | LCW | 1 | towers |
| | HLA | chilled water via CUB | |
| | Cryo | **1,400** | gpm @17 Fdt |
| | Standby | 1 | tower |
| **CW Mode** | LCW | 4 | towers |
| | HLA (PM) | chilled water via CUB | |
| | HLA (CW) | 2 | Air Cooled Chillers |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

# Mechanical Conceptual Design



# MV Electrical Conceptual Design






Fermilab PIP-II