Water Cooling in PXIE and PIP-II

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PIP-II Meeting

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U.S. DEPARTMENT OF ENERGY

Fermilab

Outline

- Review of CMTF LCW Design for PXIE
- Review of PIP-II LCW Cooling Needs
- Discussion of LCW Operating Temperature
- PIP-II LCW Layout Scenarios
- Summary

Review of CMTF LCW Design for PXIE

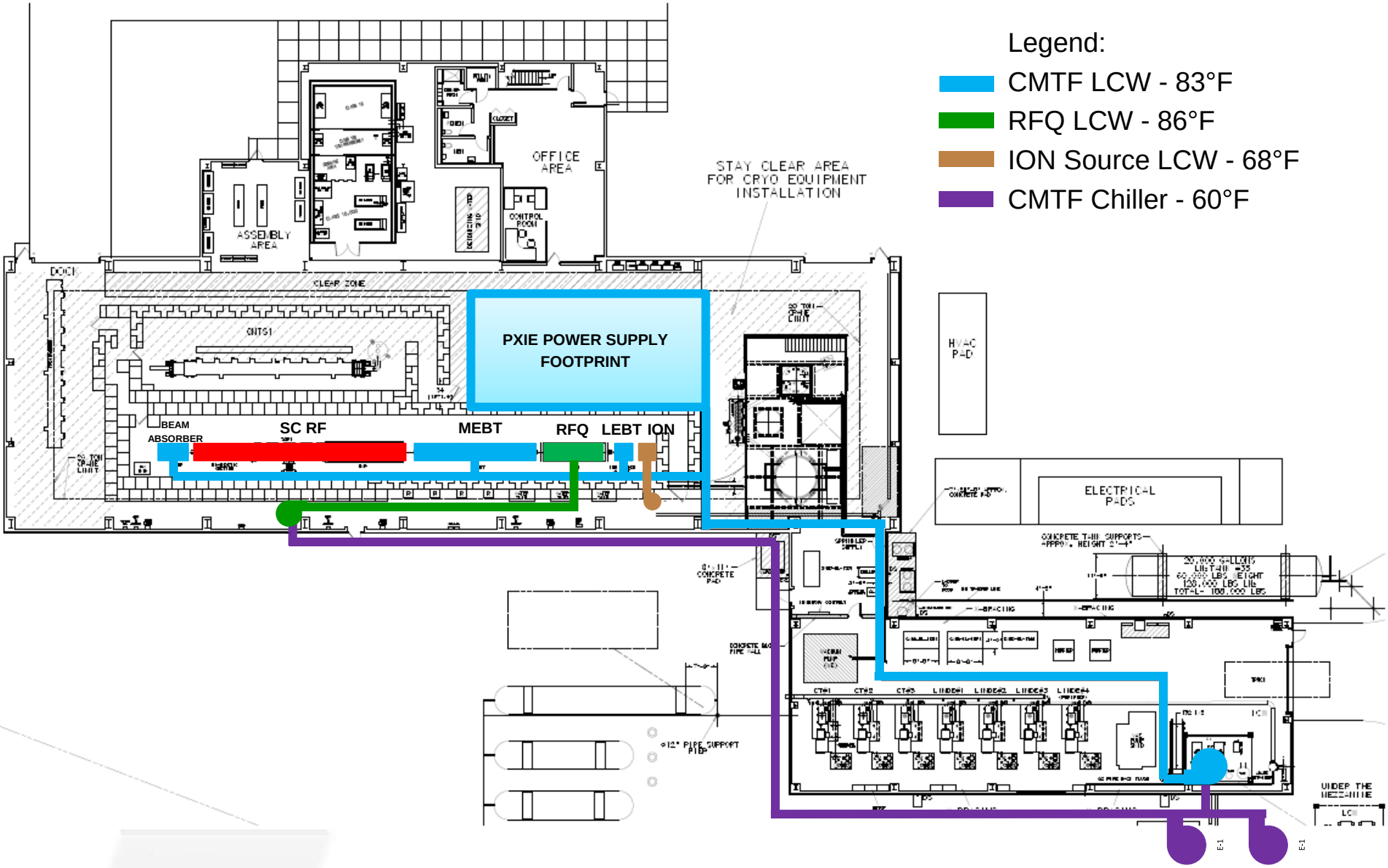
CMTF/PXIE LCW Requirements

PXIE LCW AT CMTF				
Equipment	Required Heat Load (KW)	Flow Rate (GPM)	Inlet T (°F)	
Ion Source[1]	7.4	6.2	68.0	
LEBT	24.9	12.0	83.0	
RFQ[2]	66.0	206.0	86.0	
RF Gallery[3]	569.2	303.0	**83.0**	Historical Default=90.0
MEBT	45.6	38.0	83.0	
Diagnostic Line	37.9	37.0	83.0	
OTHER LCW NEEDS AT CMTF				
CMTS1	125.0	48.0	83.0	

	(KW)	(GPM)	Tons of Refrigeration
PXIE LCW Total[1]	**751.0**	**602.2**	**213.54**
Other LCW Needs Total	**125.0**	**48.0**	**35.54**
Total LCW Cooling Needs at CMTF	**876.0**	**650.2**	**249.09**

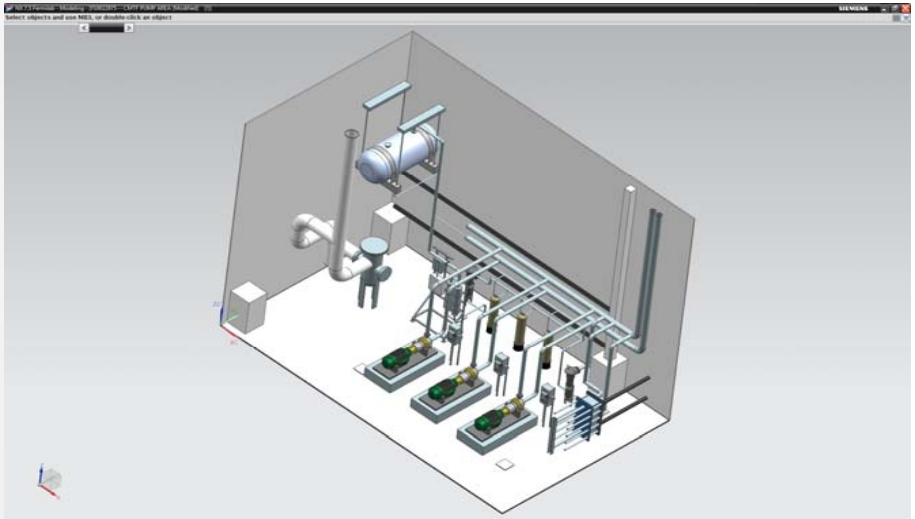
Note:
1. Ion Source uses separate independent chiller skid.
2. RFQ cooling skid connects directly to CMTF chiller.
3. Critical Inlet (Supply) Temperature

PXIE LCW Cooling Layout at CMTF



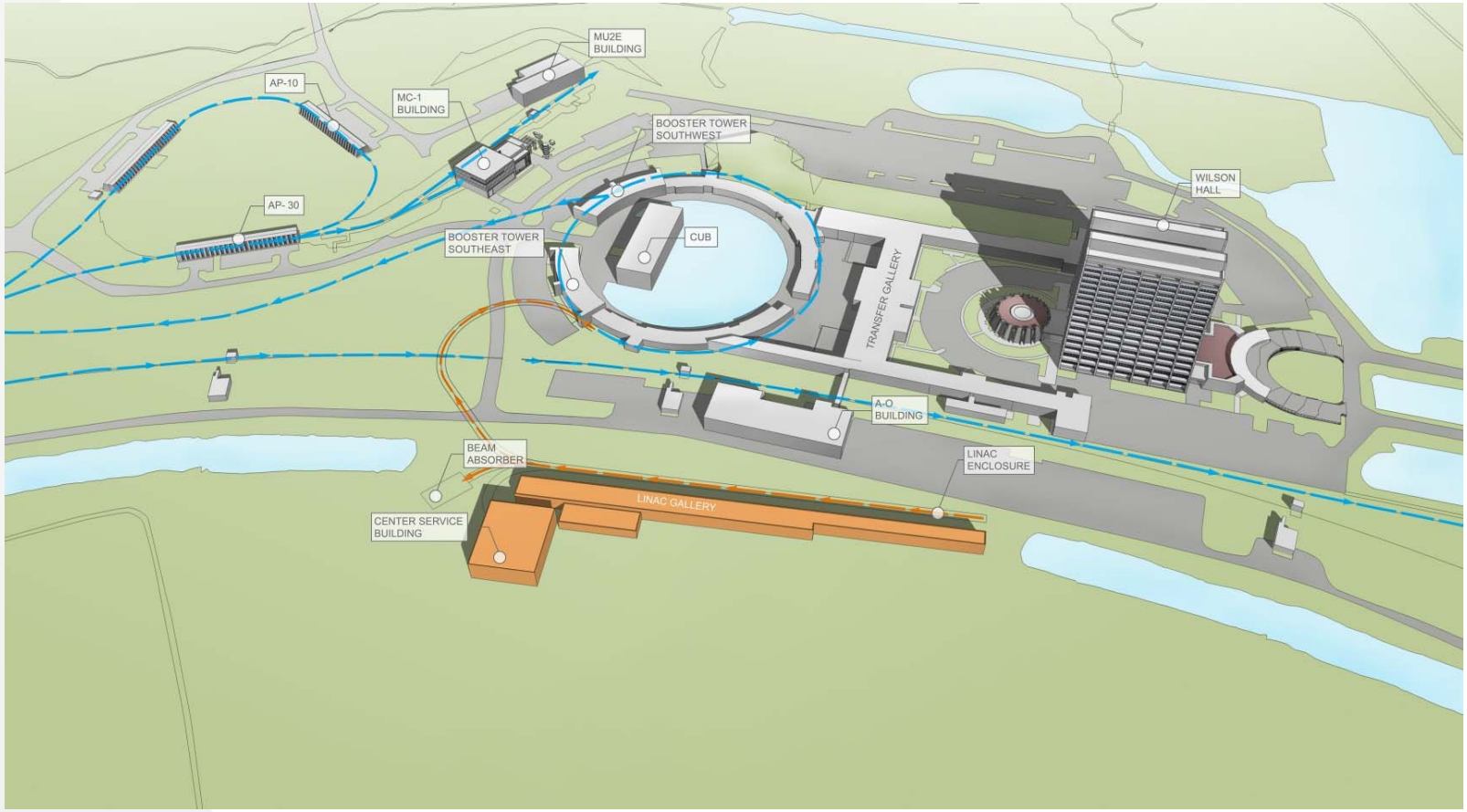
PXIE LCW System Status

- New 315 ton chiller(s) due in December
- Pipefitter installation has begun
- Expected completion by March, 2015

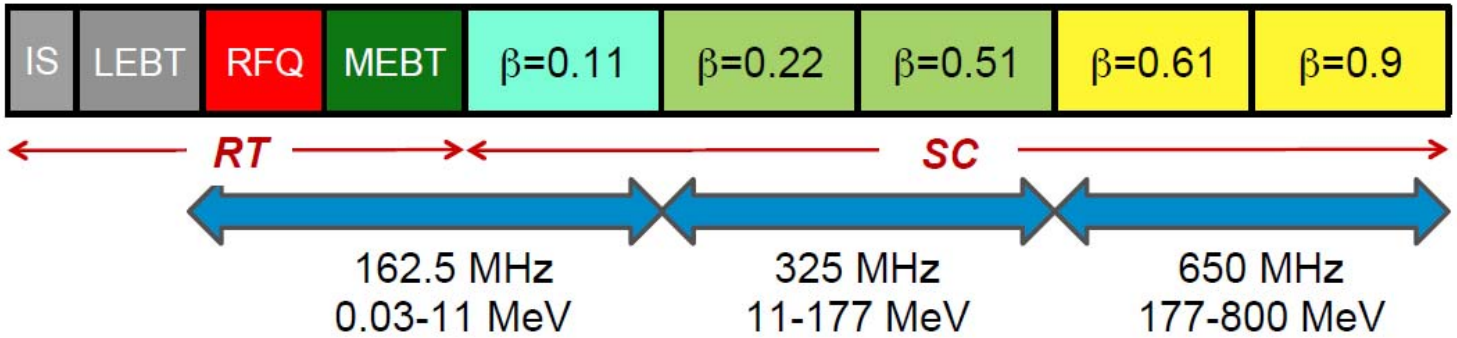


Review of PIP-II LCW Cooling Needs

3-D Overview of PIP-II



PIP-II LINAC Technology Map

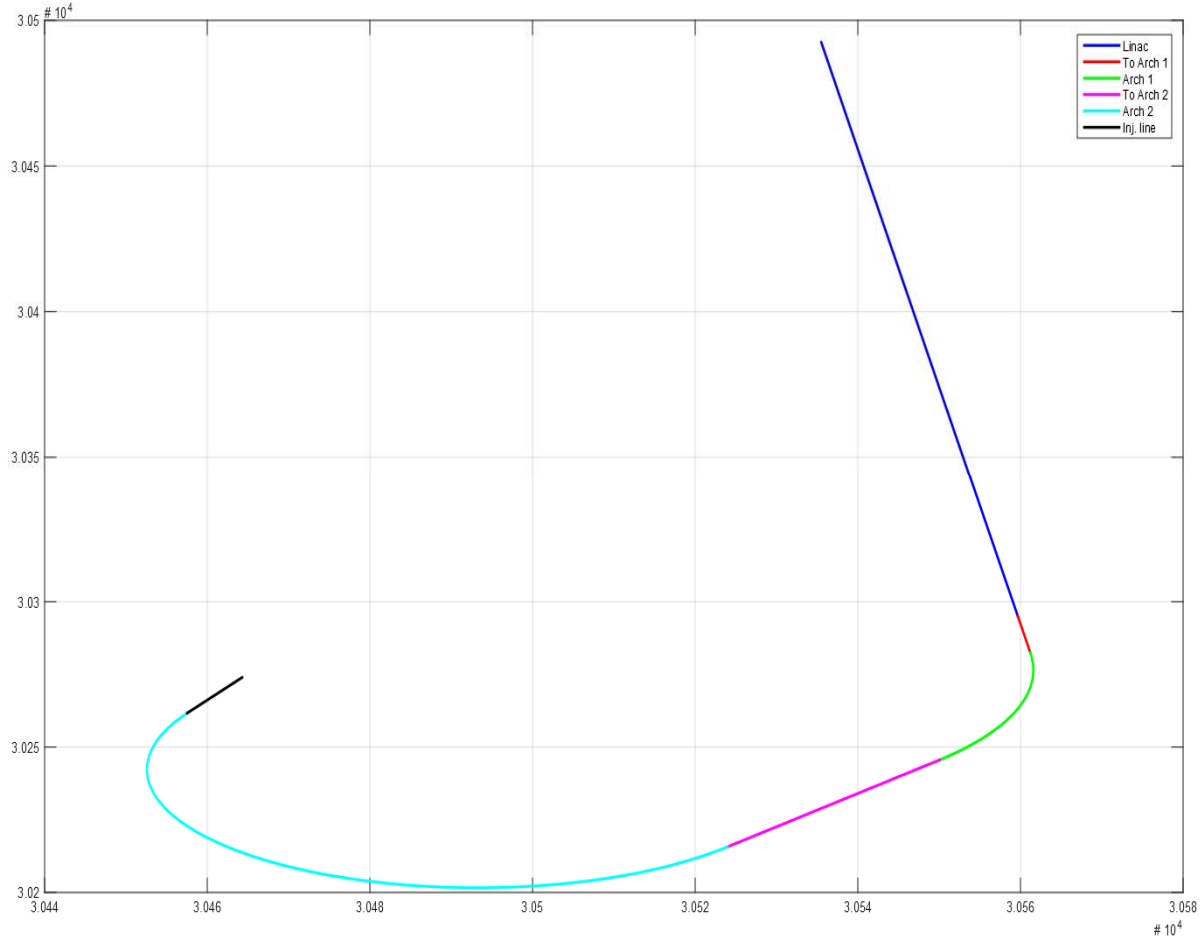


Section	Freq	Energy (MeV)	Cav/mag/CM	Type
RFQ	162.5	0.03-2.1		
HWR (β_{opt}=0.11)	162.5	2.1-11	8/8/1	HWR, solenoid
SSR1 (β_{opt}=0.22)	325	11-38	16/8/ 2	SSR, solenoid
SSR2 (β_{opt}=0.51)	325	38-177	35/21/7	SSR, solenoid
LB 650 (β_G=0.61)	650	177-480	30/20/5	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	480-800	24/10/4	5-cell elliptical, doublet

All components CW-capable ***First HWR cavity recently tested at ANL***

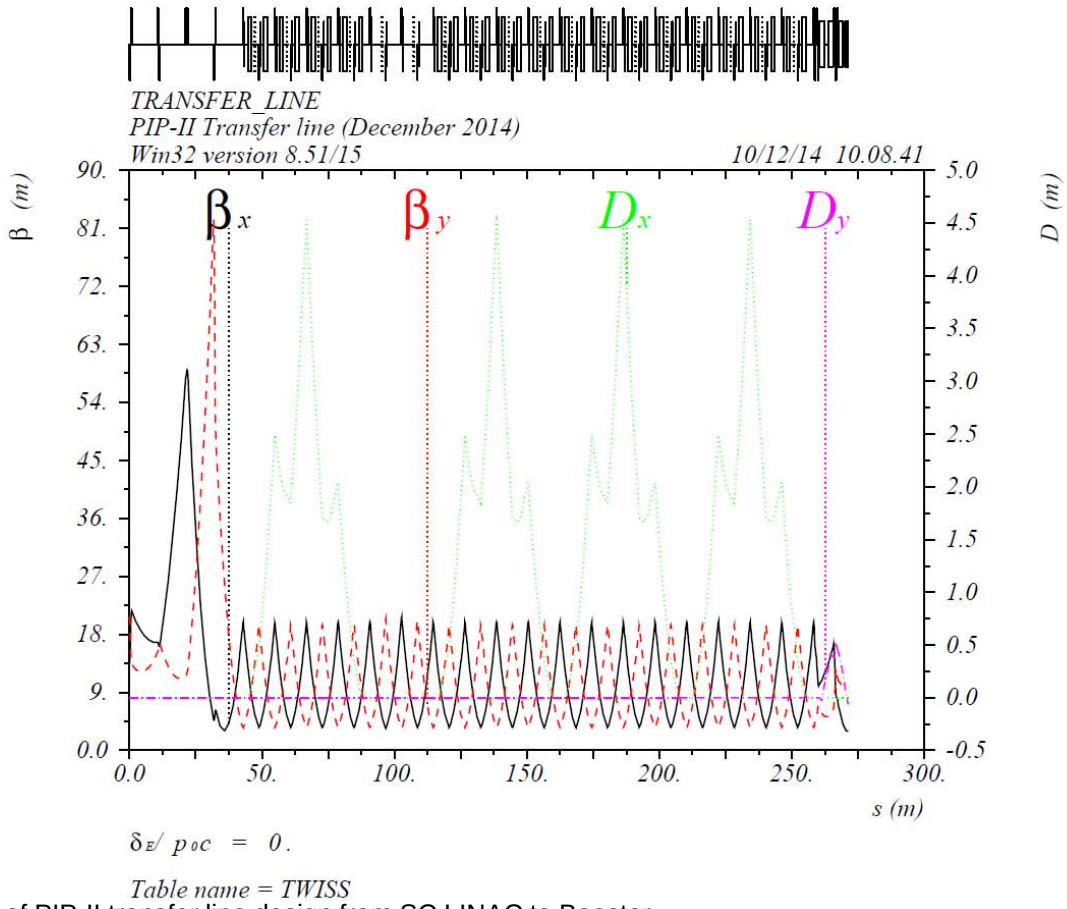
Credit: P. Derwent Neutrino Beams &Instrumentation Workshop Presentation

Transfer Line Survey



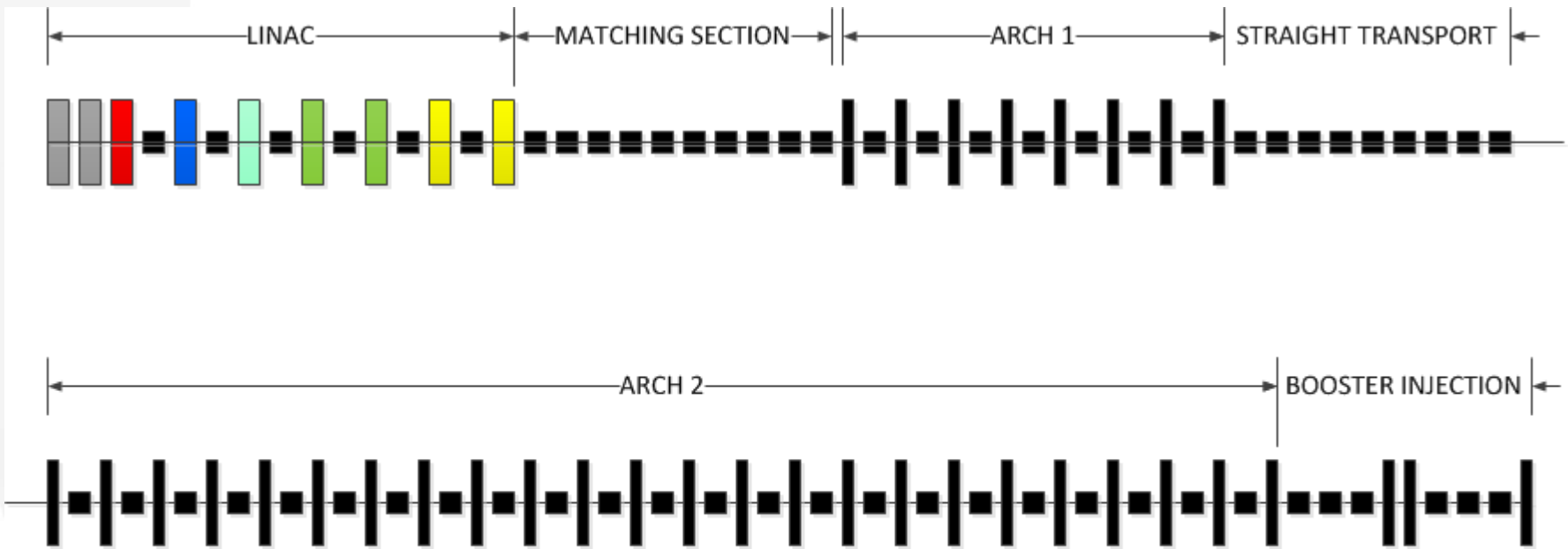
Data Credit: A. Vivoli - Status of PIP-II transfer line design from SC LINAC to Booster

PIP-II Transfer Line Optics



Data Credit: A. Vivoli - Status of PIP-II transfer line design from SC LINAC to Booster

PIP-II Lattice Summary



Assumptions:

- H and V correctors, BPM, vacuum pumps not shown.
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Legend:

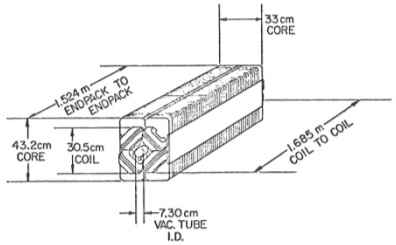
- Quadrupole
- Dipole

Basis Transfer Line LCW Requirements

-12- TM-632 2200.000

3Q60
5 FT. EPB QUADRUPOLE

Design Field Gradient	18.898 T/m
Power (dc)	12 kW
Current	0.104 kA
Voltage	117 V
Transfer Constant	5.38×10^{-3} T/m/kA
Inductance	mH
Gross Weight	1630 kg
Water Flow	340 liters/hr
Pressure Differential	5.78 kg/cm²



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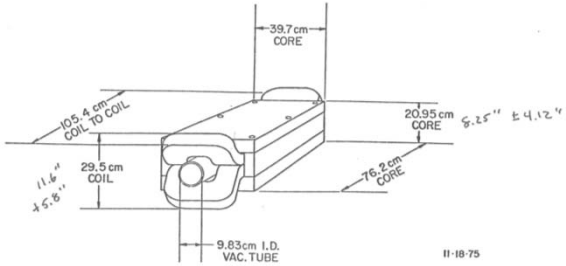
-7- TM-632 2200.000

4-4-30
VERNIER DIPOLE

Design Field	0.4 T
Power (dc)	9 kW
Current	0.18 kA
Voltage	50 V
Transfer Constant	0.4 T/kA
Inductance	mH
Gross Weight	462 kg
Water Flow	1454 liters/hr
Pressure Differential	6.3 kg/cm²



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Note: Drawn double the scale of other data sheet magnets.

PIP-II LCW Requirements

Equipment	Required Heat Load (KW)	Flow Rate (GPM)	Inlet T (°F)
LINAC ENCLOSURE (Front End)[7]			
Ion Source[1]	7.4	6.2	68.0
LEBT	24.9	12.0	83.0
RFQ[2]	66.0	206.0	86.0
MEBT	45.6	38.0	83.0
TRANSFER LINE ENCLOSURE			
Magnets[4,5]	200.0	125.0	95.0
LINAC GALLERY (SC LINAC)[3,7]			
RFQ (162.5 MHz)	310.0	165.0	**83.0**
HWR (162.5 MHz)	181.0	102.0	**83.0**
SSR1 (325 MHz)	168.0	92.0	**83.0**
SSR2 (325 MHz)	350.0	191.0	**83.0**
LOW BETA (LB-650 MHz)	625.0	375.0	**83.0**
HIGH BETA (HB-650 MHz)	504.0	301.0	**83.0**
TRANSFER LINE GALLERY			
Magnet Power Supplies[6]	50.0	40.0	95.0

*Note: 83°F is a critical driving set temperature.

	(KW)	(GPM)	
LINAC Enclosure SubTotal[1]	143.9	262.2	**Tons of Refrigeration**
LINAC Gallery SubTotal	2138.0	1226.0	
LINAC (Enclosure and Gallery) Total	**2281.9**	**1488.2**	**648.85**
TRANSFER LINE (Enclosure and Gallery) Total	**250.0**	**165.0**	**71.09**

Note:
1. Ion Source cooling skid connects directly to facility chill water source (CHW).
2. RFQ cooling skid connects directly to facility chill water source (CHW).
3. Critical Inlet (Supply) Temperature
4. Transfer Line magnet lattice optics data provided by A. Vivoli, V. Lebedev
5. Transfer line magnet flow data assume a 17°F temperature rise.
6. Transfer line magnet power supplies are estimates based on V. Lebedev.
7. LINAC equipment allowable operating temperature rise is limited by absolute flow rate requirements.

LCW Operating Temperature Setpoint Discussion

LCW Operating Temperature Setpoint

- Historical Operating Setpoint Temperature: 90°F and 95°F ideal
  - Main Injector
  - Tevatron
  - Booster
  - Beamlines

LCW Operating Temperature Setpoint Factors

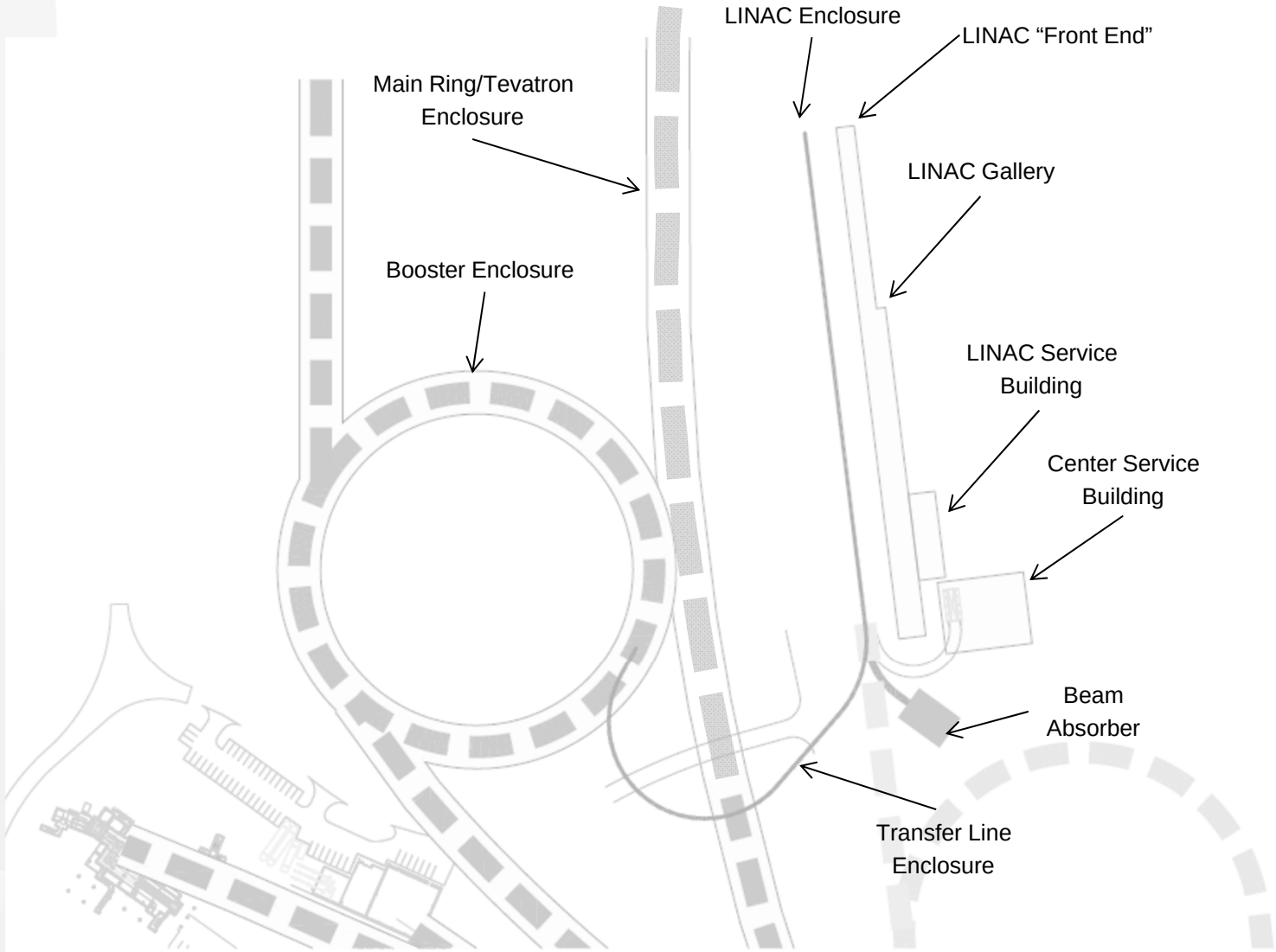
- Factors for chosen optimal LCW temperature setpoint
  - Limitations of cooling media (Ponds, Industrial Cooling Water)
  - Cost to operate, power consumption
  - Mechanical integrity of water cooled equipment (i.e. Magnets, bus, power supplies, some instrumentation)
    - Sudden temperature changes – equipment shock
    - Extreme temperatures - extreme hot/cold
    - Condensation
    - Accelerated equipment aging
      - Reduced life
      - Equipment component breakdown (i.e. failure of epoxies, adhesives, fasteners)
      - Component rust

LCW Operating Temperature Setpoint for PIP-II

- For PIP-II, assuming no limitations of cooling media, a temperature set point within a range of between 80°F and 95°F can be achieved
- Work environment comfort level is a concern for PIP-II front end enclosure area

PIP-II LCW Layout Scenarios

PIP-II General Layout



PIP-II LCW Scenario I

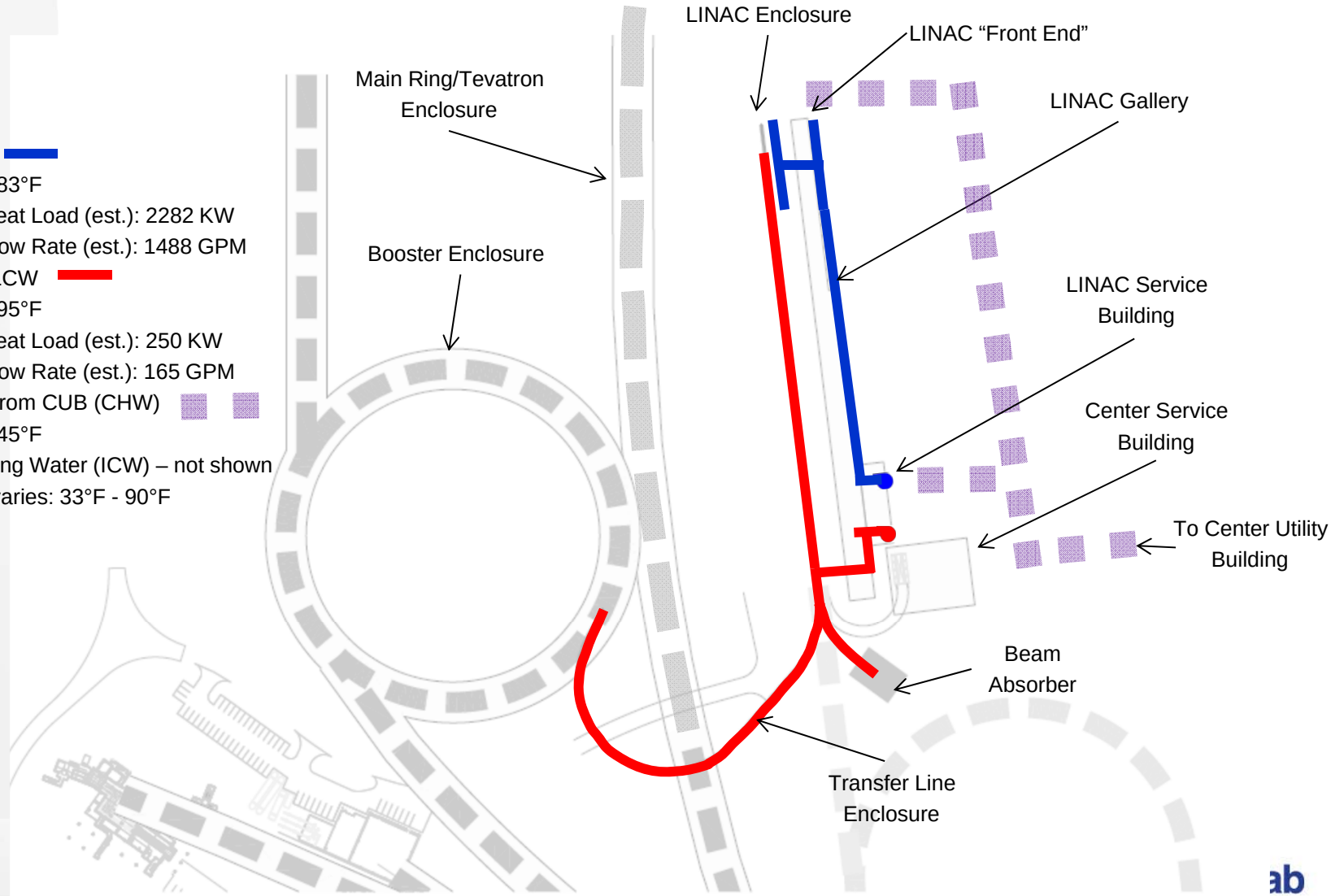
Legend:

LINAC LCW
- Set Inlet T: 83°F
- Required Heat Load (est.): 2282 KW
- Required Flow Rate (est.): 1488 GPM

Transfer Line LCW
- Set Inlet T: 95°F
- Required Heat Load (est.): 250 KW
- Required Flow Rate (est.): 165 GPM

Chilled Water from CUB (CHW)
- Set Inlet T: 45°F

Industrial Cooling Water (ICW) – not shown
- Set Inlet T varies: 33°F - 90°F



PIP-II LCW Scenario II

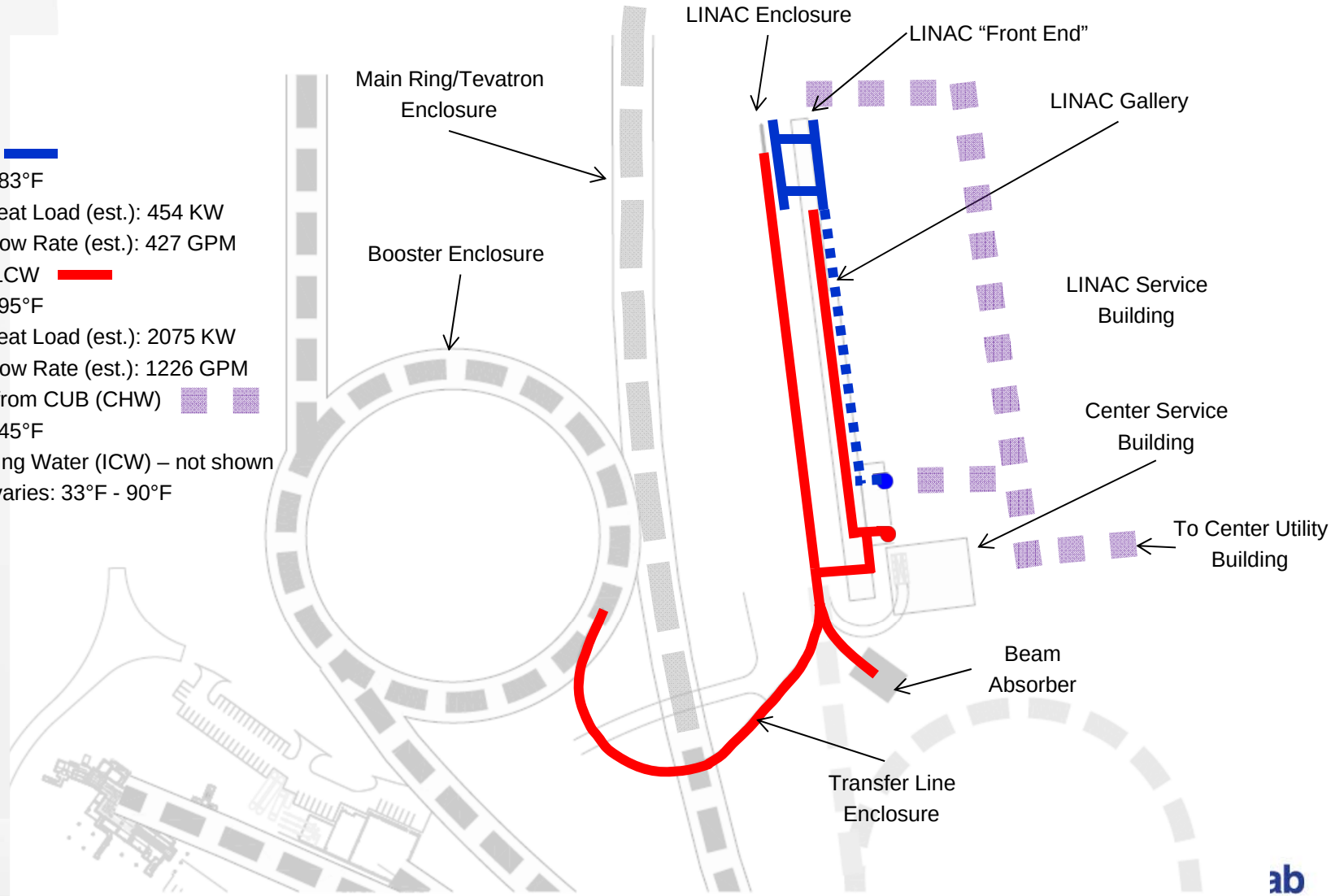
Legend:

LINAC LCW
- Set Inlet T: 83°F
- Required Heat Load (est.): 454 KW
- Required Flow Rate (est.): 427 GPM

Transfer Line LCW
- Set Inlet T: 95°F
- Required Heat Load (est.): 2075 KW
- Required Flow Rate (est.): 1226 GPM

Chilled Water from CUB (CHW)
- Set Inlet T: 45°F

Industrial Cooling Water (ICW) – not shown
- Set Inlet T varies: 33°F - 90°F



PIP-II LCW Scenario III

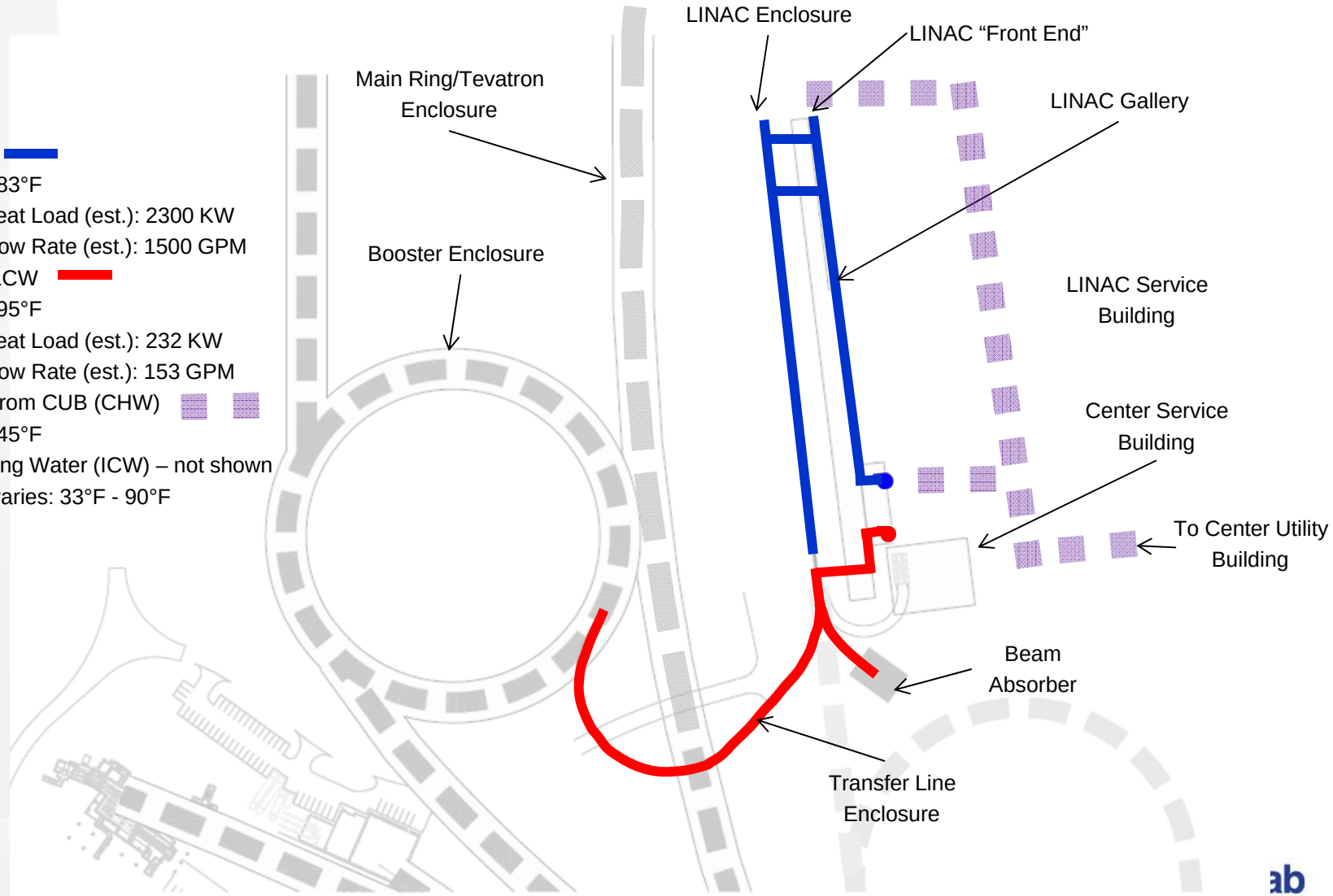
Legend:

LINAC LCW
- Set Inlet T: 83°F
- Required Heat Load (est.): 2300 KW
- Required Flow Rate (est.): 1500 GPM

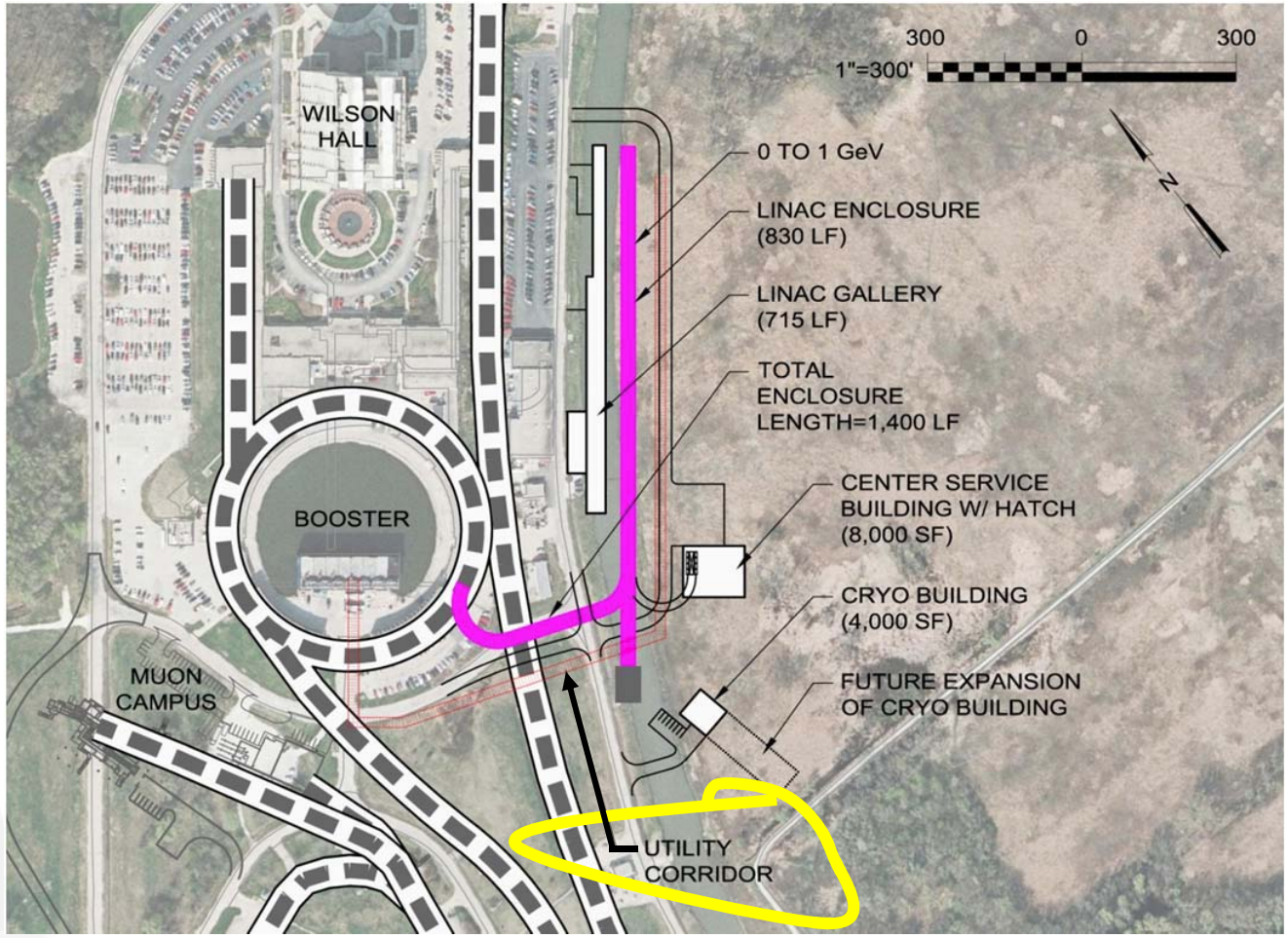
Transfer Line LCW
- Set Inlet T: 95°F
- Required Heat Load (est.): 232 KW
- Required Flow Rate (est.): 153 GPM

Chilled Water from CUB (CHW)
- Set Inlet T: 45°F

Industrial Cooling Water (ICW) – not shown
- Set Inlet T varies: 33°F - 90°F



Utility Corridor



Summary

- Although refining of heat load requirements continues, LCW cooling concept is primarily understood
  - PXIE operations continue
  - Transfer line lattice is being tweaked
- LCW systems with desired temperatures are achievable (i.e. 83°F for PIP-II)
  - LINAC Front End set temperatures can be met
  - Comfortable work environment
- A final design scenario will have to be chosen