LBNF Absorber Radio-Activated Water (RAW) Cooling System Preliminary Design Review

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Overview

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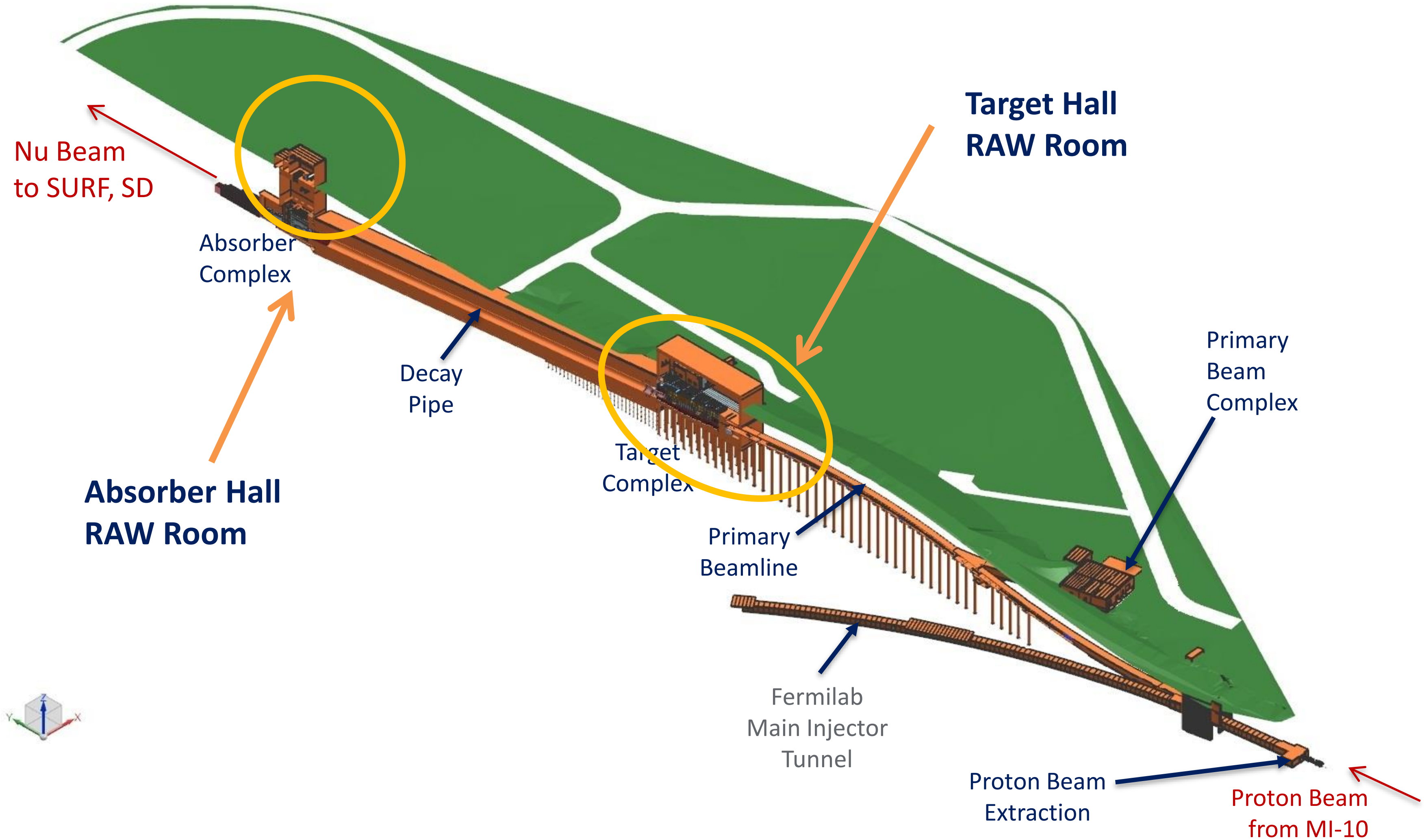
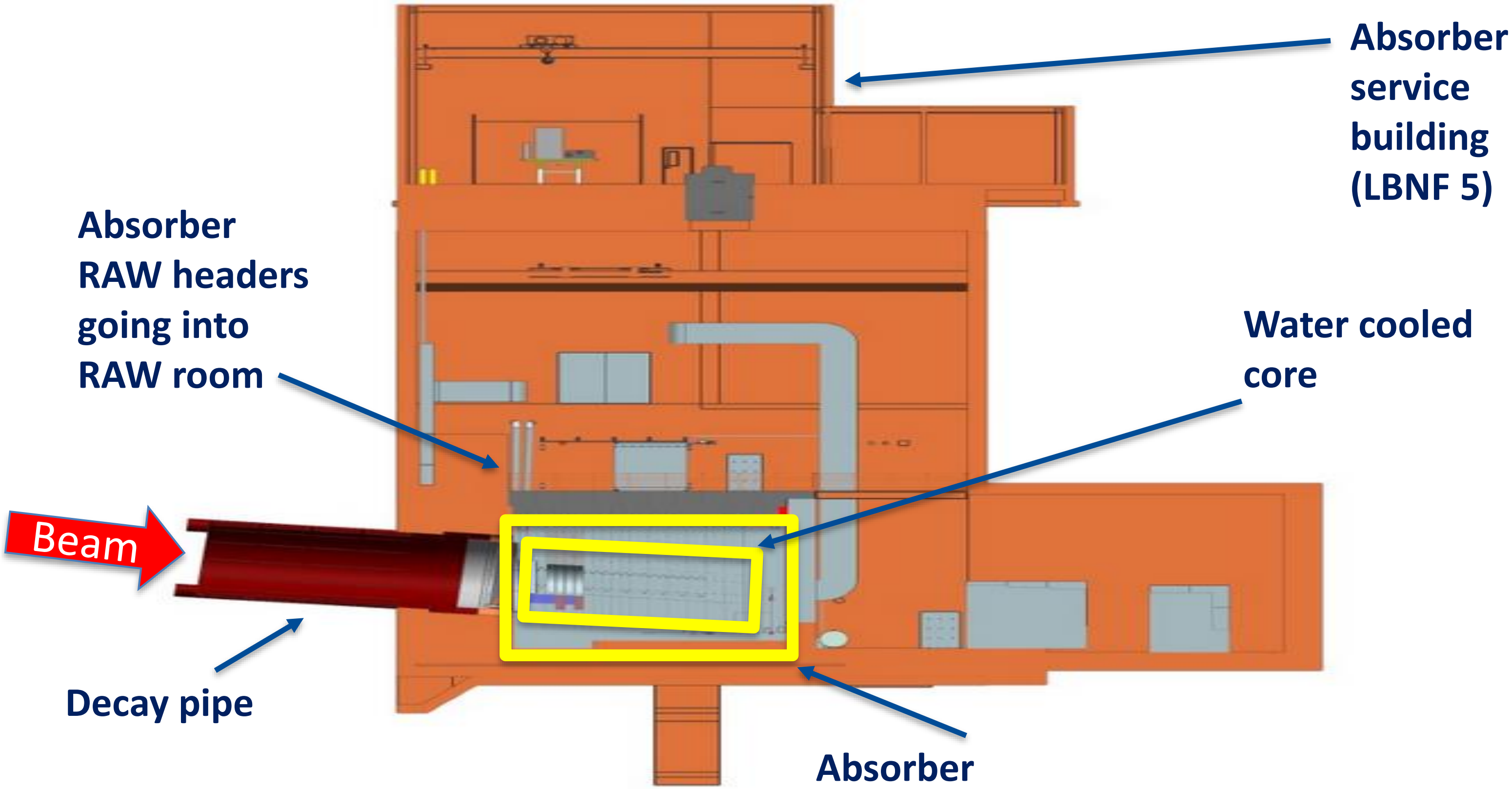
Introduction



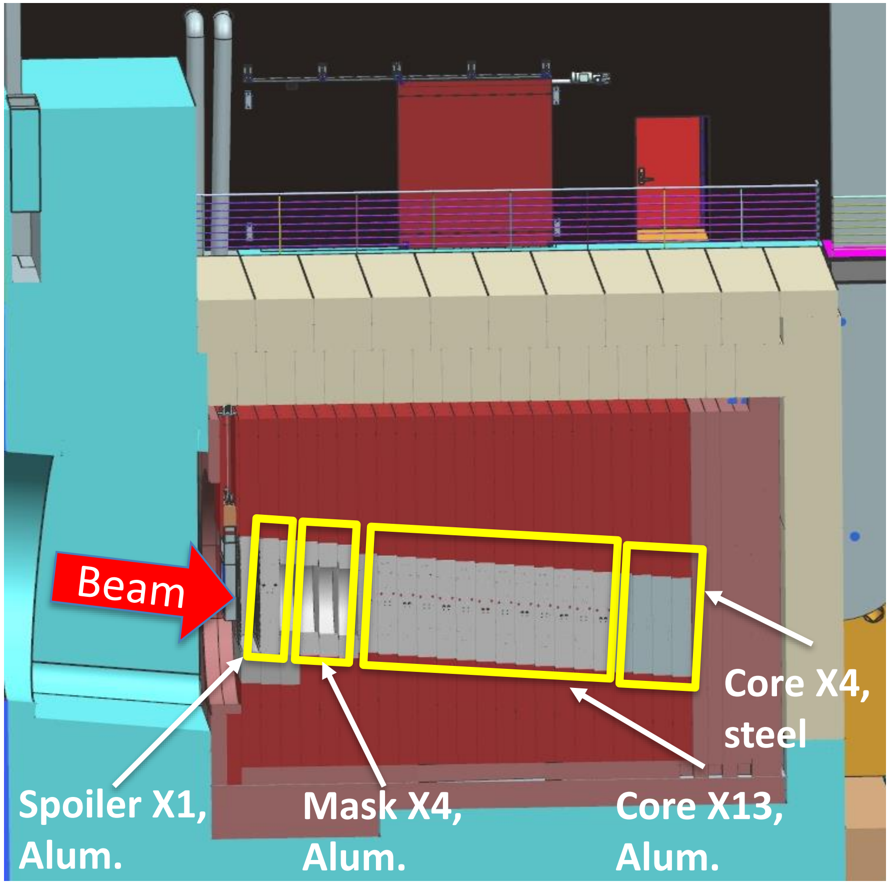
Introduction

- Absorber is located downstream of the decay pipe. It consists of actively water-cooled aluminum (6061-T6) and steel (A36) blocks surrounded by steel and concrete shielding
- It absorbs the residual particles exiting the decay pipe.
- Majority of the heat load is deposited in the water-cooled core.
- The surrounding steel shielding is air-cooled.

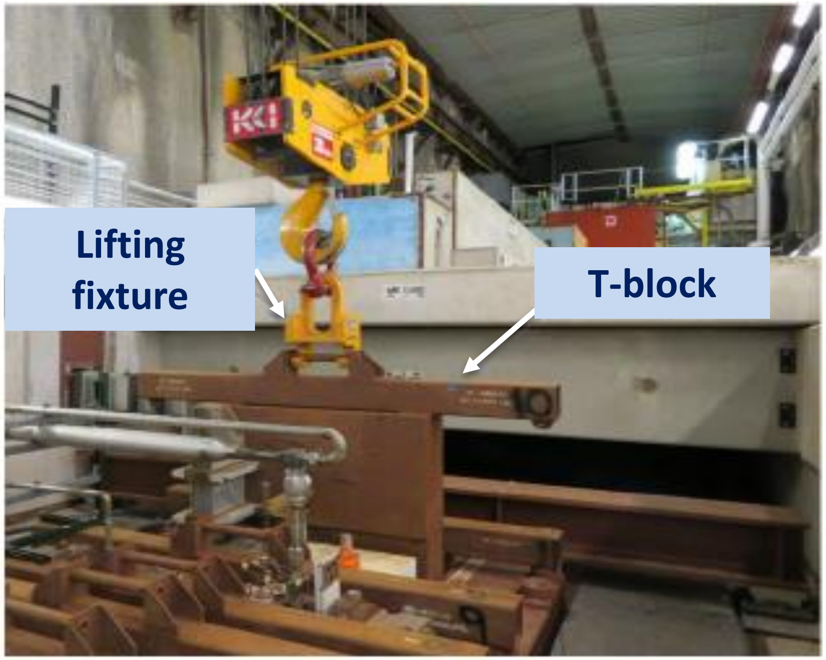


Absorber details

- Absorber is designed for 2.4 MW beam operations with a 1.5 m target (located in the Target Hall).
- The design requirement calls for a 30-year operational life with replaceable water-cooled (yellow boxes) components.



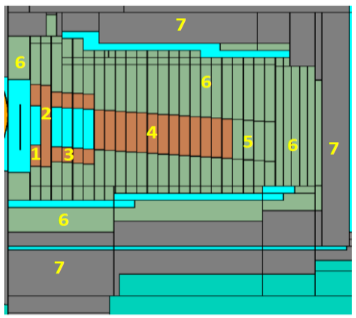
Absorber core blocks modeled after NuMI's removable T-block design (below)



Heat load

- Heat load into the water cooled components from MARS analysis for 2.2 m target is 280 kW.
- For the 1.5 m target (current design), the multiplier is 1.53, thus the heat load into water cooled components is ~430 kW

EDEP in Uniform Hadron Absorber Components (OD)



No	Component	kW
1	Mask 1	34.6
2	Spoiler	57.3
3	Masks 2-5	79.5
4	Aluminum core	105.9
5	Steel core blocks 1-4	3.3
6	Steel shielding	114.5
7	Concrete	2.7
8	Miscellaneous	4.6
9	**Total**	**402.4**

18 06/09/2017 N. Mokhov | LBNF MARS Modeling: Status & Plans DUNE-doc-3896 LBNF

2.4-MW LBNF EDEP (kW) in OD *vs* RD and OD-RAL 1.5m vs 2.2m

System	RD	OD	OD/RD	1.5m/2.2m
Target Station	951.5	1,237.7	1.30	< 1
Decay Channel	452.1	542.2	1.20	1
Hadron Absorber	786.0	400	0.51	1.53
4-π Neutrino power	66	69	1.05	~1
Misc: infrastructure, binding energy & sub-threshold ptcls	144.4	151.1	1.05	~1
Total	**2400**	**2400**		

14 July 25, 2019 N. Mokhov: target system details impact on other components LBNF/DUNE

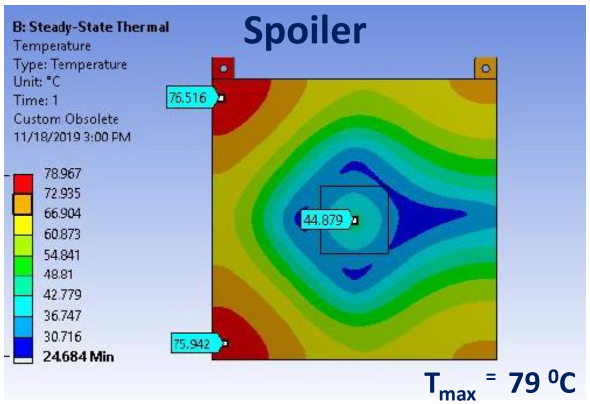
N. Mokhov Dune doc 3896

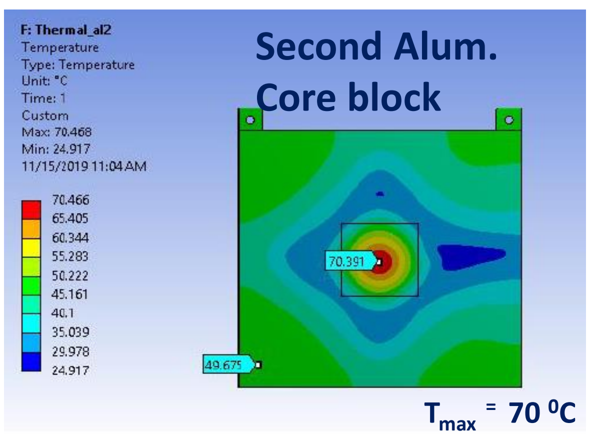
Component	Heat load (2.2 m Target), kW	Heat load (1.5 m Target), kW
Alum. Spoiler	57	88
Alum. Mask blocks	114	175
Alum. Core blocks	106	162
Steel. Core blocks	3	5
Total heat load, kW	281	429

***Scaling applied (conservative assumption)**

Design limits for absorber components

- The design limit for the 6061-T6 absorber blocks is 100 ^{0}C.
- The flow requirements are specified to keep the temperature of the aluminum blocks below this value to prevent creep.





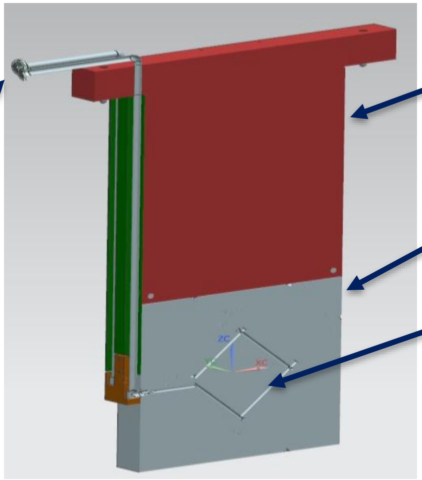
Source: Ang Lee, Dune Doc 17082

Type of block	Qty.	Number of loops per component	Flow per channel	Flow per component , Gpm	Total flow, Gpm
Aluminum spoiler	1	4	20	80	80
Aluminum mask block	4	2	15	30	120
Aluminum core block	13	4	20	80	1040
Steel core block	4	2	15	30	150
Minimum flow required for cooling @ 80 F inlet water temperature--->					1390

*Aluminum cooling blocks have gun-drilled channels

*Above flow/channel guarantees 6-7 ft/s velocity

2" supply and return lines. Lines are 6061-T6 Alum.



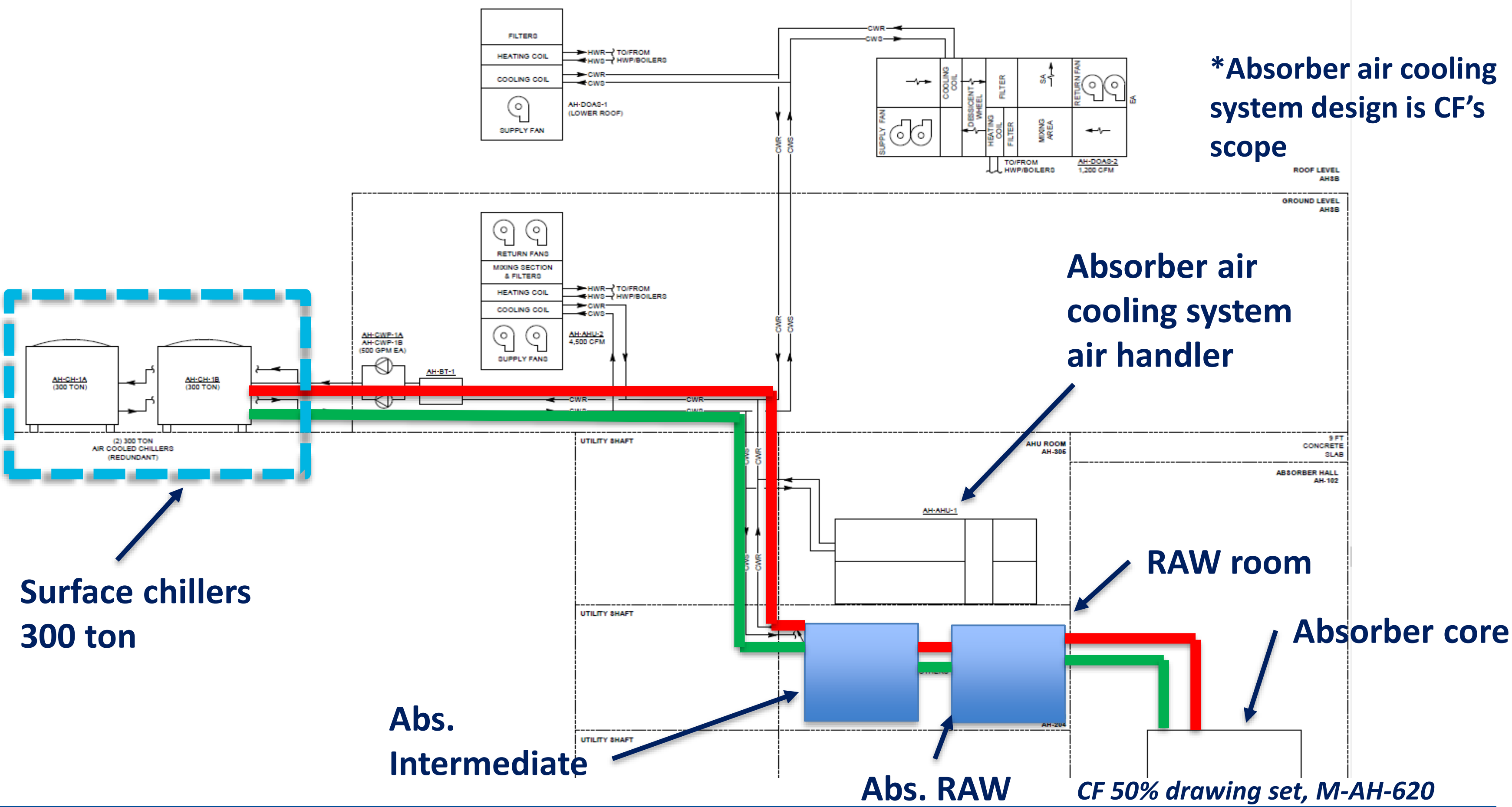
Steel T-block

Alum. core block 67"X67"

1" ID gun-drilled channels

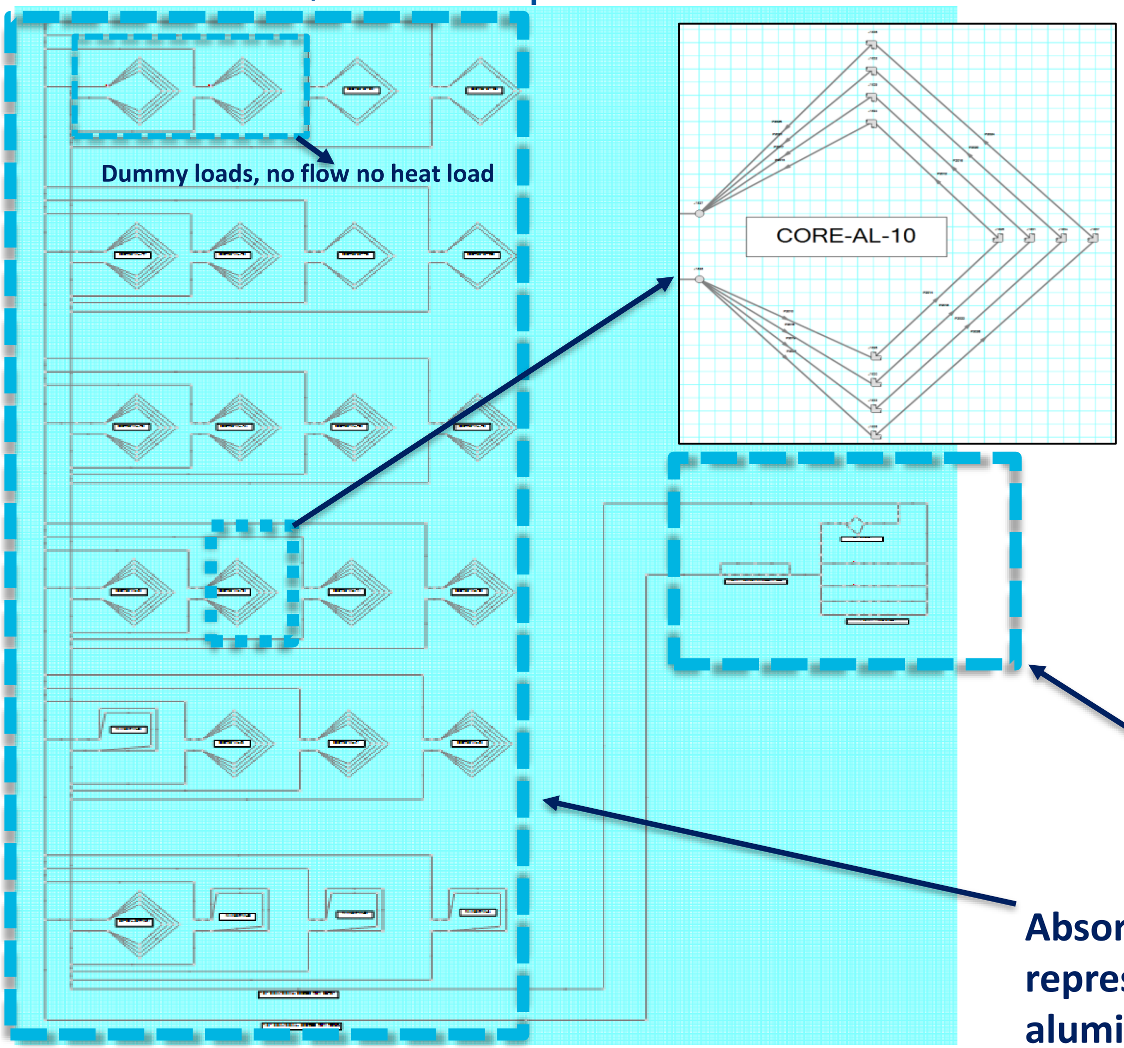
Absorber RAW Cooling System: Design

- Modeled after the NuMI Absorber RAW system.
- Heat from RAW system goes into Absorber Intermediate system.
- The heat from the Absorber Intermediate system goes to the surface chillers.



Absorber RAW Cooling System: Simulation/analysis

- Cooling system simulated in AFT Fathom to generate flow, pressure, heat transfer, and temperature values.



Absorber component IDs

SPOILER-AL-1
MASK-AL-2
MASK-AL-3
MASK-AL-4
MASK-AL-5
CORE-AL-9
CORE-AL-6
CORE-AL-7
CORE-AL-8
CORE-AL-10
CORE-AL-11
CORE-AL-12
CORE-AL-13
CORE-AL-14
CORE-AL-15
CORE-AL-16
CORE-AL-17
CORE-AL-18
CORE-ST-19
CORE-ST-19
CORE-ST-21
CORE-ST-22

AL-> Aluminum
ST->Steel

RAW room with pumping, HX, DI and filtration loop, and expansion tanks

Absorber core components. Model representing gun-drilled channels in aluminum blocks

Absorber RAW Cooling System: Selected components

- A Tranter welded HX and an RS Corcoran pump/motor selected. We have used the same company components on our NuMI Absorber RAW system. They have been in operation since 2007.

Cust. Reference: Item No.:

Technician: SLM

Model: GCP-026-L-5-NR-36 Units Required: 1

Intended End Use: Heat exchanger to cool Water 10 °F using 65 °F Water with pressure drop at or below 10 psi on hot side and at or below 10 psi on cold side.

		Hot Side		*Cold Side*		
Fluid Name		Water		Water		
OPERATING DATA		***Inlet***	***Outlet***	***Inlet***	***Outlet***	
Total Liquid flow	GPM	400.00	400.00	650.00	650.00	GPM
Operating Temperature	°F	90.00	80.00	65.00	71.14	°F
Pressure drop (allowed / calc.)	psi	10.00 / 4.22		10.00 / 9.99		psi
Operating Pressure	psi(g)	150.00	145.78	150.00	140.01	psi(g)

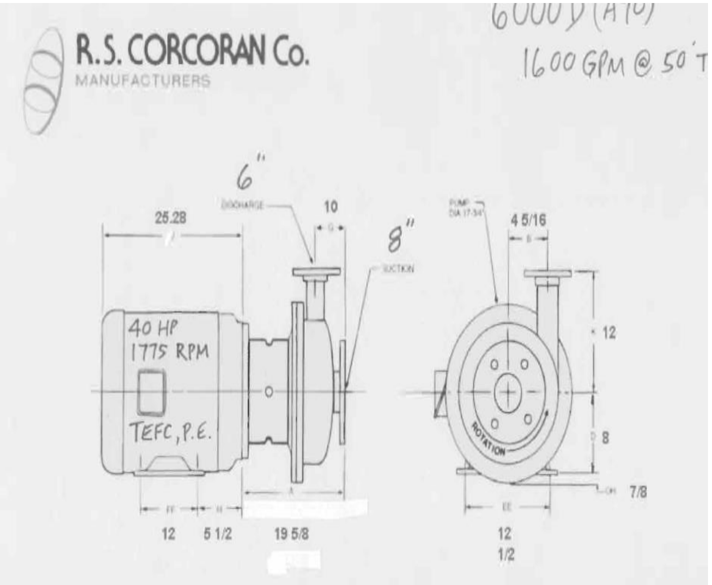
Total Heat Exchanged	Btu/h	1,990,473
U-Service	Btu/(h·ft²·°F)	1,241
Total Heat Transfer Area	ft²	95.15
LMTD	°F	16.86

FLUID PROPERTIES		***Inlet***	***Outlet***	***Inlet***	***Outlet***
Specific Gravity	-	1.00	1.00	1.00	1.00
Specific Heat	Btu/(lb·°F)	1.00	1.00	1.00	1.00
Thermal Conductivity	Btu/(h·ft·°F)	0.36	0.35	0.34	0.35
Viscosity (avg.)	cP	0.76	0.85	1.04	0.96

CONNECTIONS

Position	S4	S3	S2	S1
Type	STUDDED	STUDDED	STUDDED	STUDDED
Liner	welded	welded	welded	welded
Size	4"	4"	4"	4"
Rating	ANSI 16.5 150#	ANSI 16.5 150#	ANSI 16.5 150#	ANSI 16.5 150#
Material	316L SS		316L SS	

Tranter GCP-026-L-5-NR-36

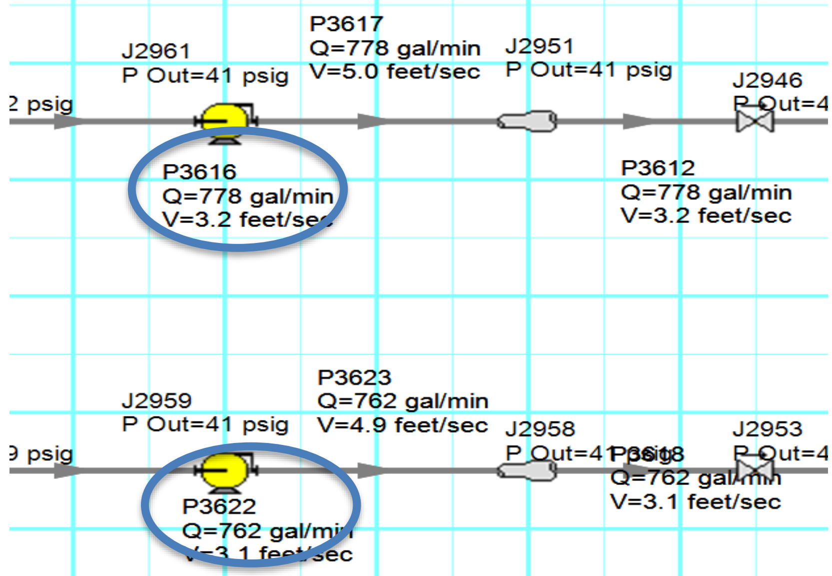


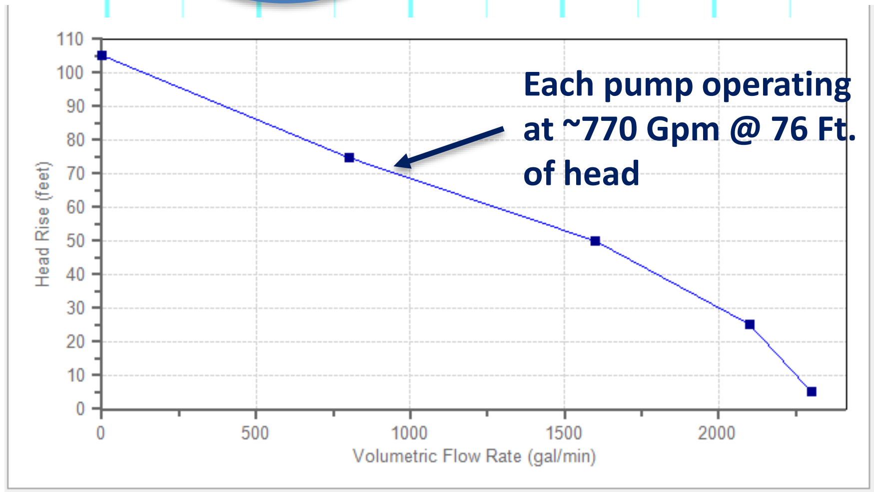
RS Corcoran 40 HP. 6000D A90 6" X 8" X 10.875"

Absorber RAW Cooling System: Requirements met

- System simulation/analysis shows that temperature, heat load, flow rate, and velocity criteria, in gun drilled channels, has been met:

Jct	Name	Vol. Flow (gal/min)	T Inlet (deg. F)	T Outlet (deg. F)	T 2nd Inlet (deg. F)	T 2nd Outlet (deg. F)	Heat Rate In (kW)
2935	TRANTER WELDED HX GCP-026-L-5-NR-36	343.98	82.30	72.24	62.00	66.44	-504.768
3020	SPOILER-AL-1	91.97	80.10	86.66	N/A	N/A	88.000
3021	MASK-AL-2	31.95	80.09	89.48	N/A	N/A	43.750
3022	MASK-AL-3	31.98	80.08	89.47	N/A	N/A	43.750
3023	MASK-AL-4	32.11	80.06	89.41	N/A	N/A	43.750
3024	MASK-AL-5	31.80	80.14	89.58	N/A	N/A	43.750
3025	CORE-AL-9	110.43	80.19	80.96	N/A	N/A	12.460
3026	CORE-AL-6	90.74	80.14	81.08	N/A	N/A	12.460
3027	CORE-AL-7	82.56	80.12	81.15	N/A	N/A	12.460
3028	CORE-AL-8	82.69	80.11	81.15	N/A	N/A	12.460
3029	CORE-AL-10	99.42	80.17	81.03	N/A	N/A	12.460
3030	CORE-AL-11	99.72	80.17	81.03	N/A	N/A	12.460
3031	CORE-AL-12	99.88	80.15	81.01	N/A	N/A	12.460
3032	CORE-AL-13	84.48	80.23	81.25	N/A	N/A	12.460
3033	CORE-AL-14	79.18	80.23	81.31	N/A	N/A	12.460
3034	CORE-AL-15	79.33	80.21	81.29	N/A	N/A	12.460
3035	CORE-AL-16	79.38	80.20	81.28	N/A	N/A	12.460
3036	CORE-AL-17	84.20	80.28	81.30	N/A	N/A	12.460
3037	CORE-AL-18	81.16	80.26	81.32	N/A	N/A	12.460
3038	CORE-ST-19	29.82	80.26	80.55	N/A	N/A	1.250
3040	CORE-ST-19	29.83	80.24	80.53	N/A	N/A	1.250
3041	CORE-ST-21	29.81	80.29	80.58	N/A	N/A	1.250
3042	CORE-ST-22	29.81	80.29	80.58	N/A	N/A	1.250

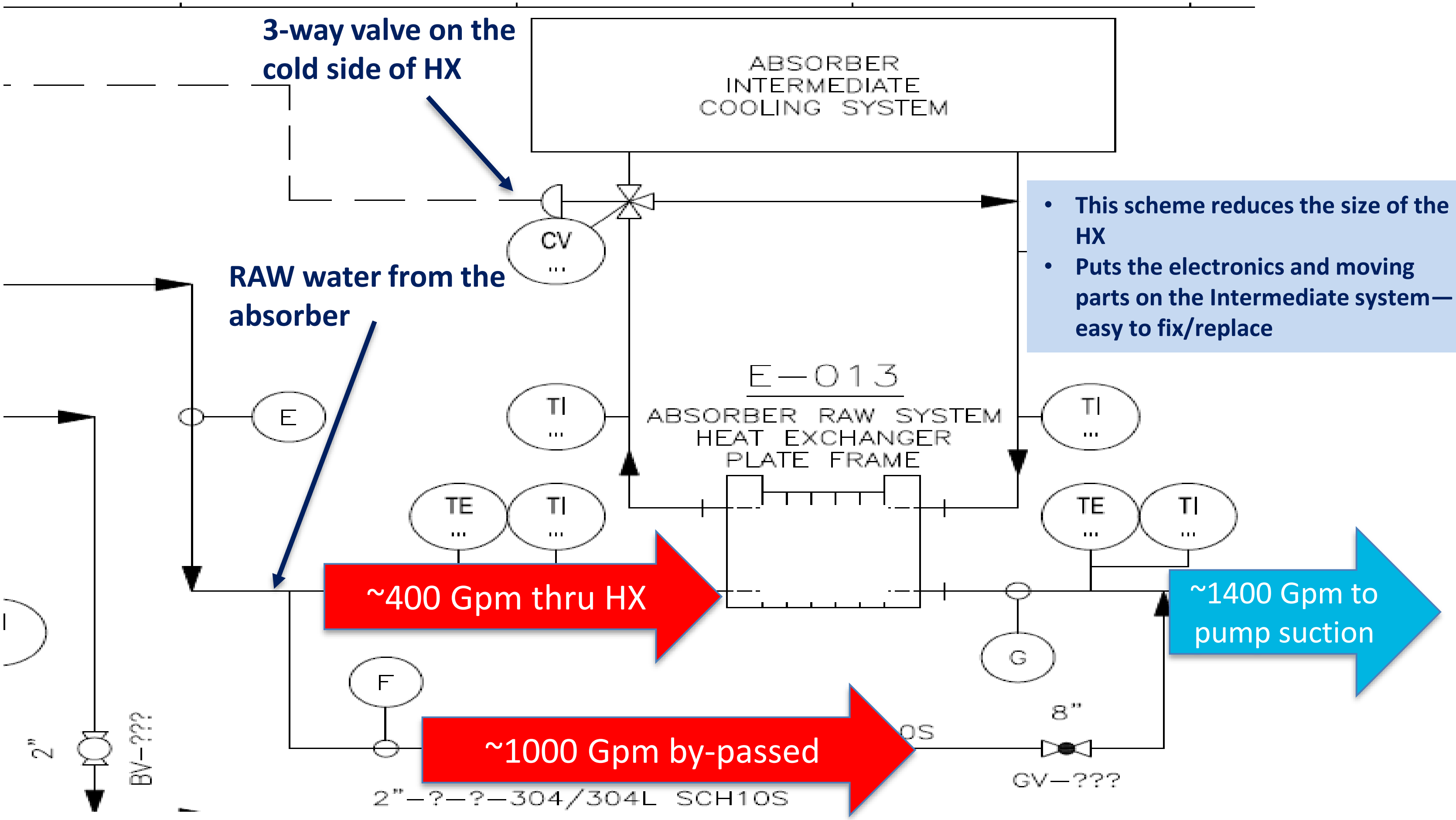




*Satisfied flow, velocity, and temperature criteria for each component

Absorber RAW Cooling System: Temperature control scheme

- Temperature control loop is similar to other NuMI RAW systems (Horn 1,Horn 2, and Absorber). In that, the temperature control valve is on the cold side (non-RAW/Intermediate) of the HX



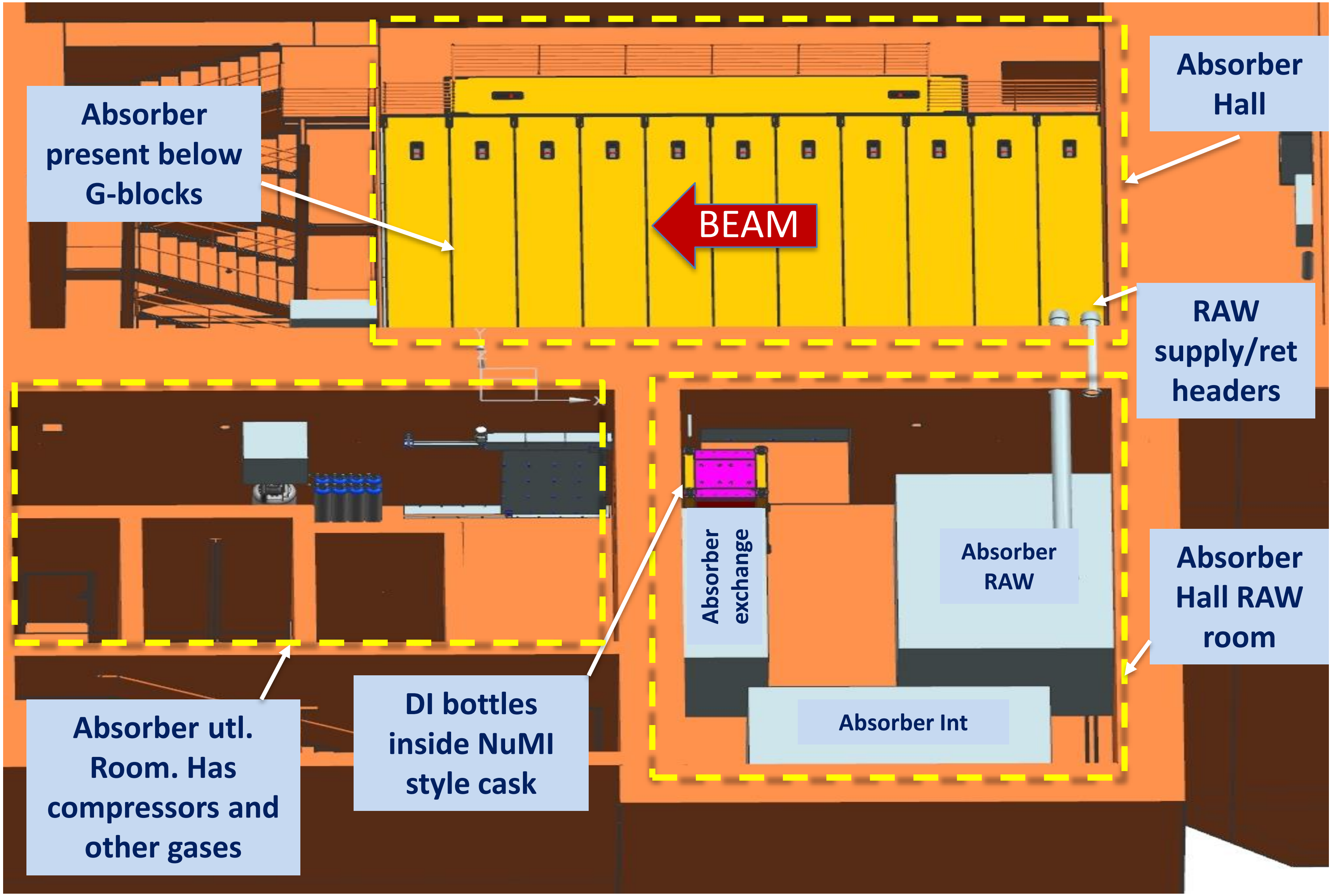
- This scheme reduces the size of the HX
- Puts the electronics and moving parts on the Intermediate system—easy to fix/replace

Absorber RAW Cooling System: Design

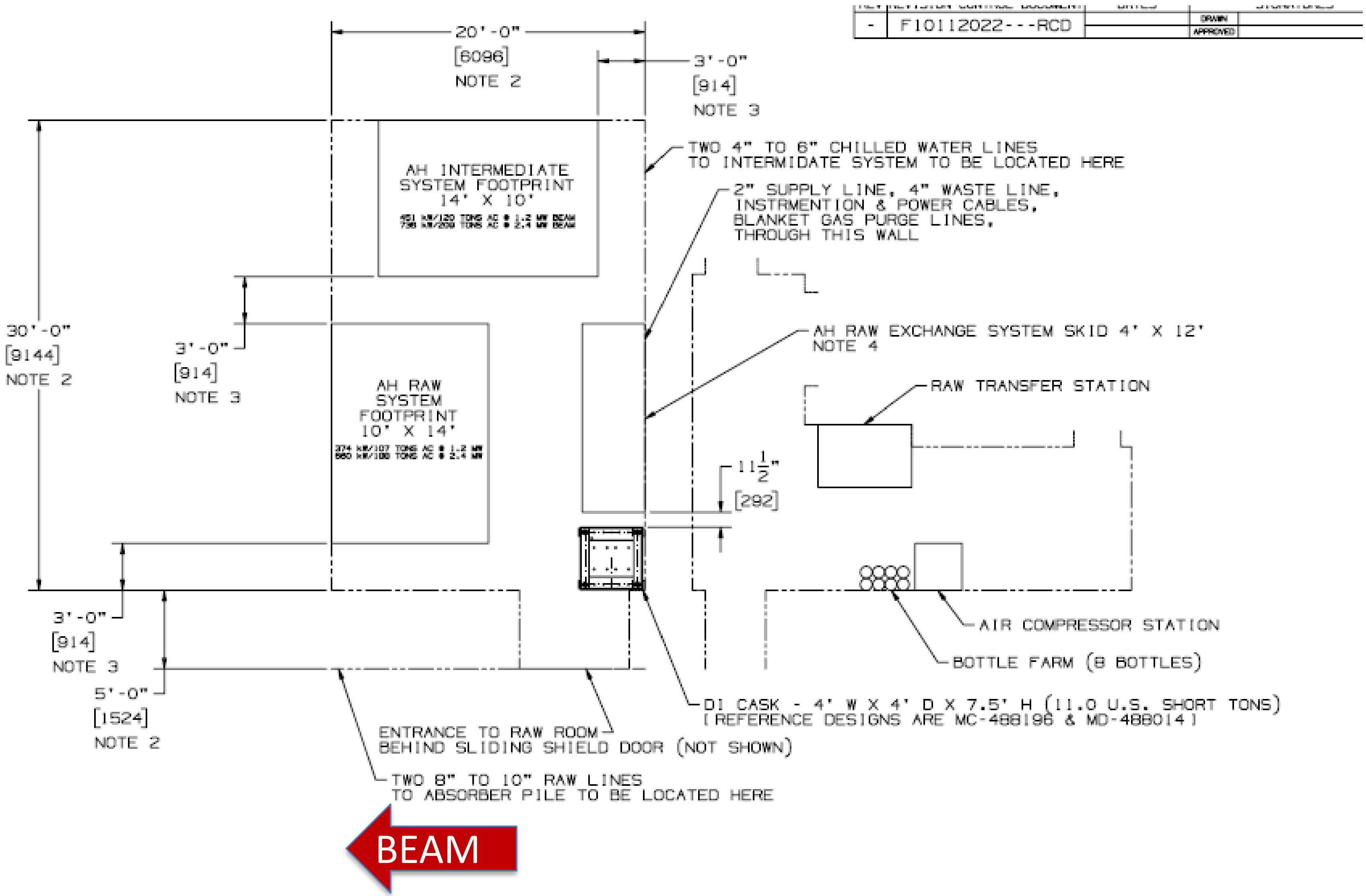
- After an iterative simulation and design process, following are the design parameters for the LBNF Absorber RAW system for the 2.4 MW operations

Parameter	Value	Units	Remarks
System volume	~1500	Gal.	
System design temperature	130	F	
System operating temperature	80	F	
Maximum allowable working pressure	75	Psig	
System operating pressure	45	Psig	
Expansion tank operating Ar. Pressure	5	Psig	
System pump design horse power	40	Hp	2 pumps running, 1 stand-by spare
System design flow	1540	Gpm	
Design flow through the DI loop	48	Gpm	Includes side-stream filteration. 5 micron pre-DI and 20 micron post-DI
Design system resistivity low	3	MOhm-cm	
Design system resistivity high	5	MOhm-cm	
Tritium concentration	<1E6	pCi/ml	Absorber exchange system, periodic feed/bleed
Design flow through water cooled components	1492	Gpm	Spoiler, mask, Al-core, Steel- core
Design flow through (RAW side) the heat exchanger	405	Gpm	
Design flow (cold side) through heat exchanger	650	Gpm	Cold side means Absorber Intermediate system
Design temperature difference (RAW side)	10	F	
Design temperature difference (cold side)	6.2	F	
Design heat capacity	590	kW	
Design heat transfer surface area	95	Ft^2	

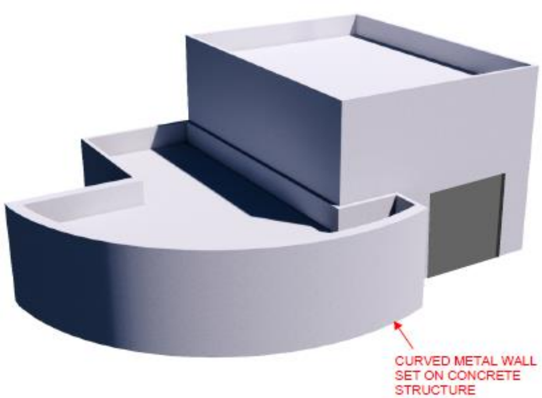
Absorber RAW Cooling System: Layout

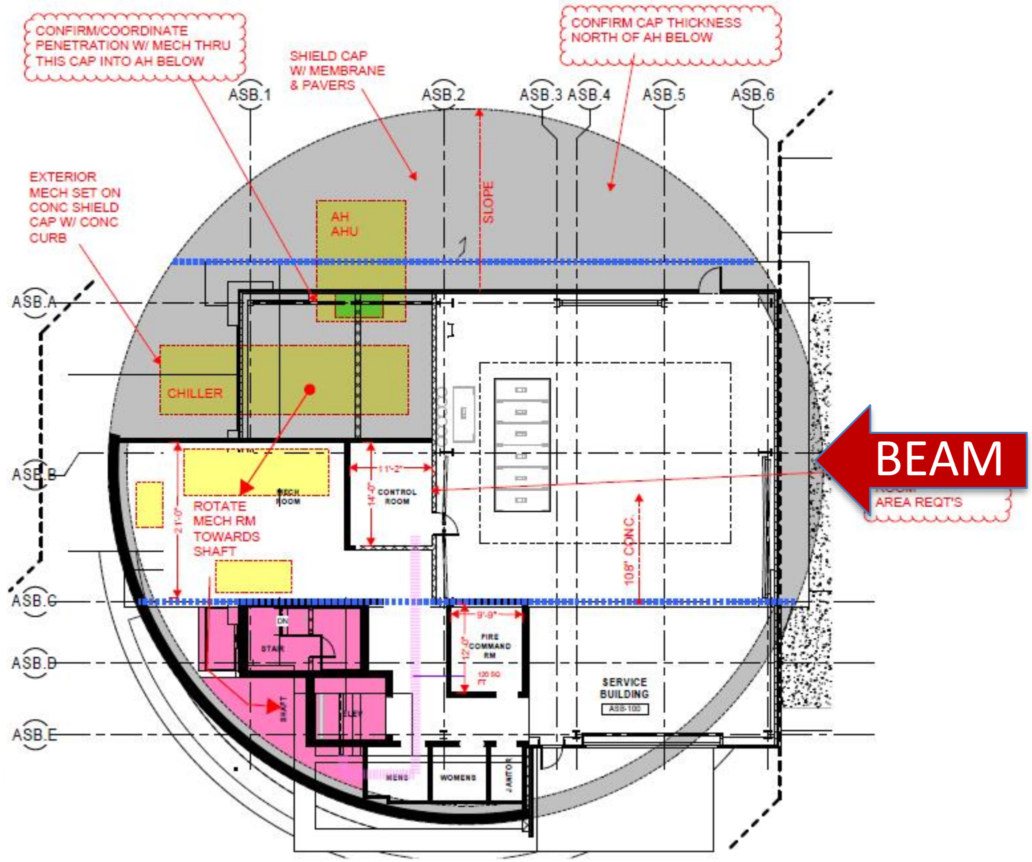


Absorber RAW Cooling System: Layout

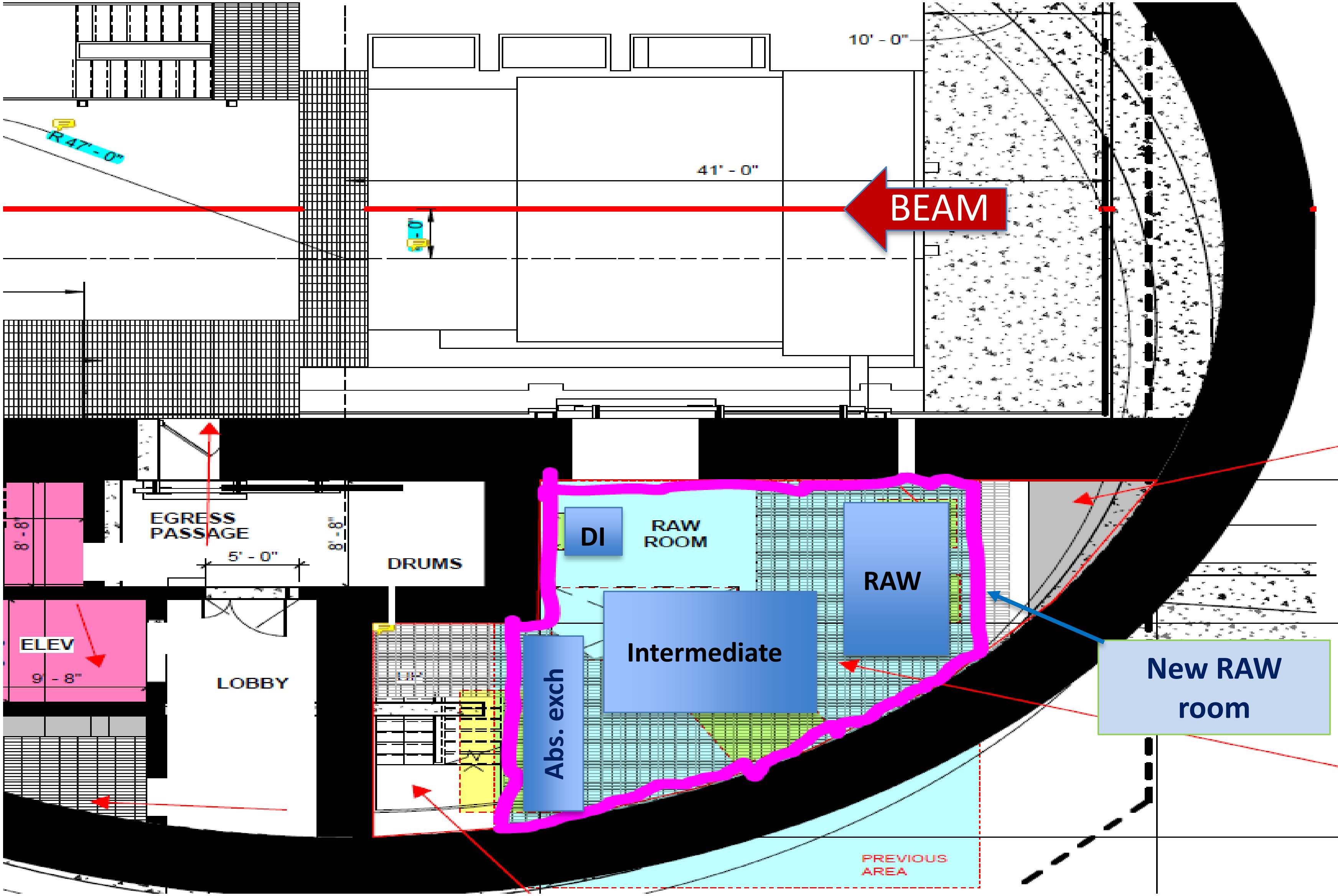


Absorber RAW Cooling System: Layout, Building Design Change

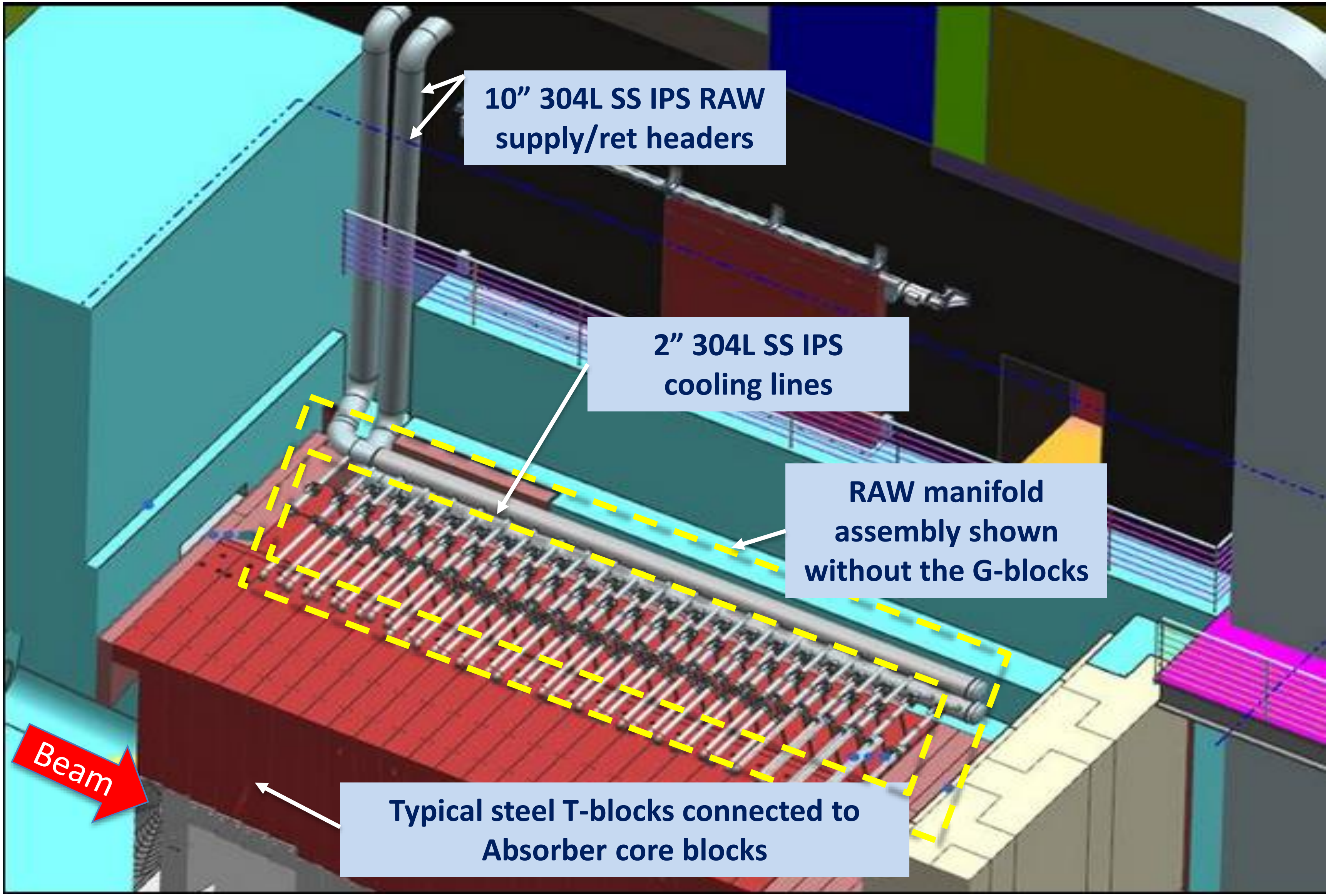




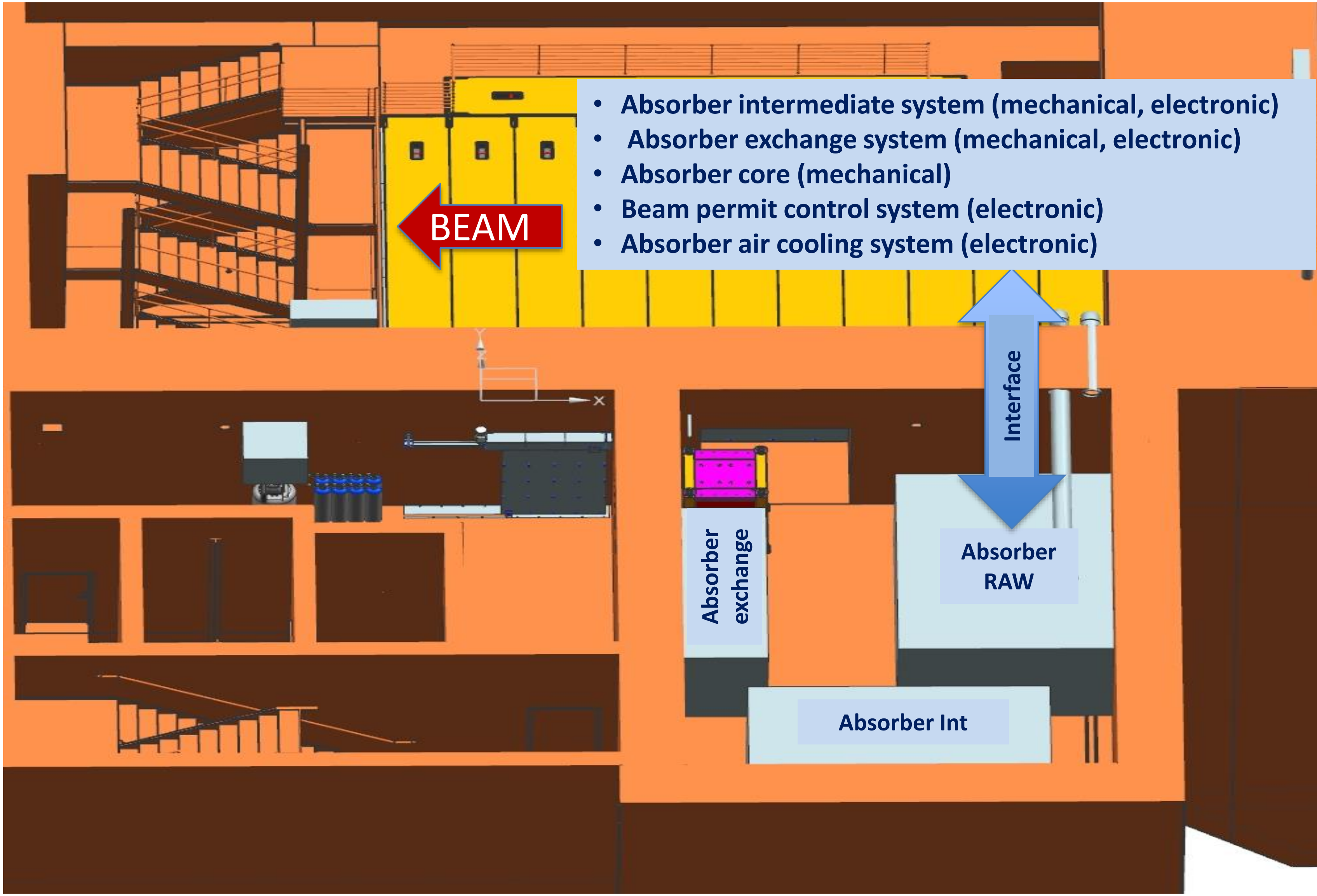
Absorber RAW Cooling System: Layout, New AH concept



Absorber RAW Cooling System: Layout, Absorber Hall Proper



Absorber RAW Cooling System: Interfaces



- Absorber intermediate system (mechanical, electronic)
- Absorber exchange system (mechanical, electronic)
- Absorber core (mechanical)
- Beam permit control system (electronic)
- Absorber air cooling system (electronic)

Experience from NuMI and MiniBooNE design/operations

- Specify corrosion resistant and rad-resistant materials.
- Specify instrumentation that is rad-hard and has remote signal processing capabilities.
- Using equipment manufacturers that have worked well for us in NuMI and MiniBooNE.
- Maintain low DI values in cooling systems not connected to electrical components.
- Maintain a constant argon blanket in the system expansion tank
- Sufficiently size the secondary containment.
- Sufficiently size the expansion tanks to prevent rapid level rise/fall owing to temperature swings.
- Strict adherence to ASME codes for fabrication.
- System start-up/commissioning done as per approved written safety/operational procedures under supervision of design engineer.
- Soft-starts for high HP pump/motor assemblies.
- Filter cartridge maintenance program to prolong the life of DI bottles.

Conclusion

- We understand the heat load, flow, temperature, and velocity requirements well.

- Incorporated experience from NuMI and MiniBooNE RAW during the design process.

- The H2 production in the Absorber RAW system needs to be understood more—MARS simulations are on-going.

- The steel components operate at temperatures that are much lower than steel’s allowable limits in the current scenario—there is room for value-engineering in the future—could reduce the size of the system.

- The cost and schedule for the system seem reasonable at this time.

Thank you!
Questions and discussion