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NuMI-AIP Target Systems Updates

Yun He

TSD Topical Meeting

April 18, 2019

Outline

Project Plan approved Dec. 18, 2018

12 tasks, managed mostly within TSD

- Introduction
  - Project scope, issues to be addressed, and schedule
  - Prior to & after funds approval
- Project implementation
  - Project organization chart and WBS
  - Project schedule and phased installation
  - SharePoint site for documentation and communication
- Project technical details and status
  - 2019 summer shutdown tasks and job schedule
  - Rest tasks not tied to 2019 summer shutdown
- Summary

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Project Scope, Issues to be Addressed, and Schedule

Beam Power	1 MW	700 kW	Rate of change
Proton beam energy	120 GeV		----
Protons per spill	6.5E13	4.9E13	32.7%
Main injector cycle time	1.2 sec	1.33 sec	10.8%
Beam pulse width	10 microsec		----
Horn current/pulse width	200 kA / 2.3 msec		----

- Beam acceptance capabilities
  - maximum beam power to target of **1 MW**
- Reliability
  - maintain 85% availability for HEP at full proton delivery
- Lifetime
  - minimally through 2025

Temperatures and stresses due to beam heating	Increased radio-activation	An aging infrastructure in radiative environment
1. MARS simulation 2. Pre-target beam window 3. Target core and baffle 4. Horn 1 stripline cooling 5. Radioactive water (RAW) systems 6. Target chase air handling, chiller 7. Hadron absorber temperature monitoring	8. Additional shielding to target chase 9. Tritium mitigation upgrade 10. New radiation-hard hadron Monitors	11. Decay pipe window repair plan 12. Target/horn 1 module positioning drives

12 upgrade tasks were identified
Starts – Dec. 2018
Ends – April 2021

Prior to & After Funds Approval

FY19 Q1
Prior to funds approval
System assessment & preliminary design with TSD Operations funds
Cory Crowley / Katsuya Yonehara

FY19 Q2
Funds received Dec. 2018
Project implementation
Yun He / Marty Murphy

Tasks identified	Status prior to re-start	Current status
MARS simulations	Preliminary simulations	Re-run for new changes
Pre-target window	Installation	Spare fabrication
Target baffle & core	Preliminary design and FEA	Final design and FEA, fabrication
Horn 1	Preliminary design and FEA	Final design and FEA, fabrication
Stripline air diverter T-block	Scope defined	Design
Target and horn 1 module drives	Preliminary design	Final design, fabrication
RAW skids	Design	Procurement
Target hall chiller/air handling	Scope defined	Procurement
Target chase shielding	Design	Fabrication
Tritium mitigation	Scope defined	Re-define scope
Decay pipe window	Preliminary design and FEA	Final design and FEA, test welding
Hadron beam monitor & absorber	Scope defined	Design

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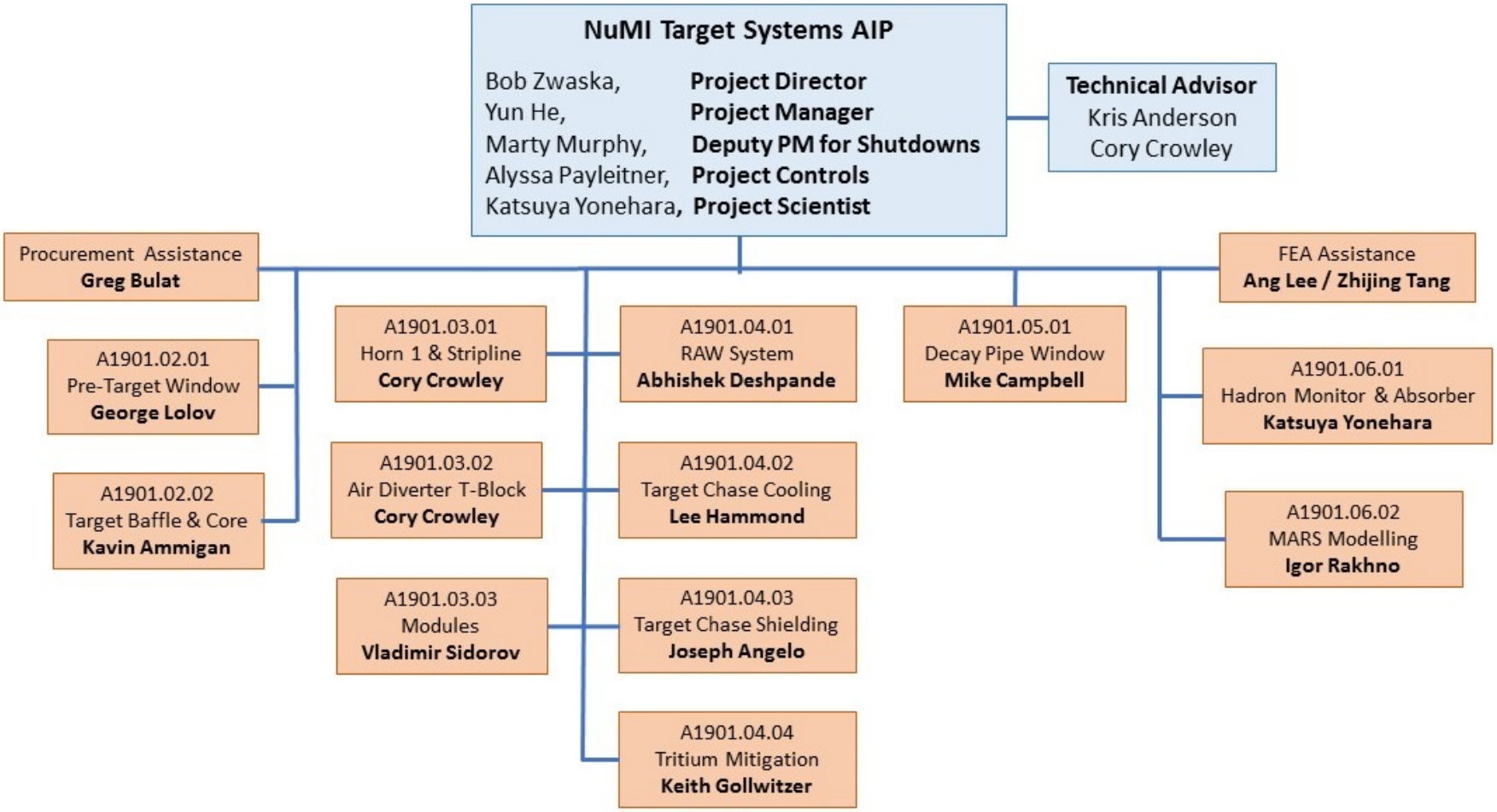
Project Organization Chart and WBS

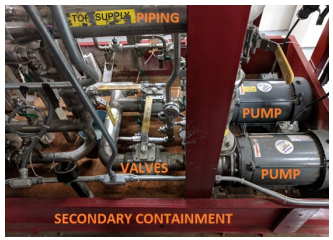


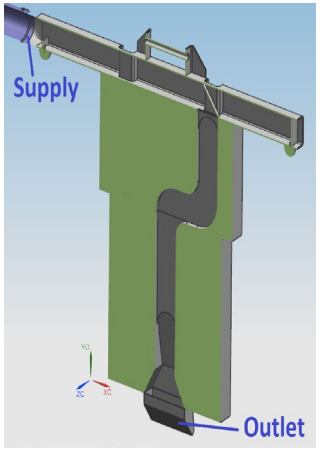
12 Control accounts

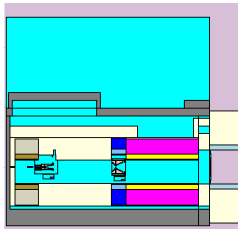
The work presented here are team work led by people in this org chart

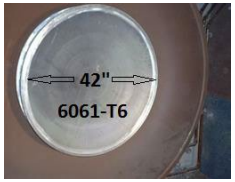
Project Schedule and Phased Installation

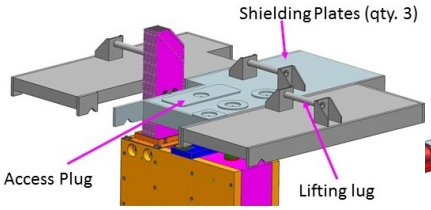
2019 summer shutdown	2020 summer shutdown	Tasks not involving summer shutdowns
1 MW target installation	1 MW horn 1 installation	MARS simulations
Target & Horn 1 RAW upgrade	Stripline air diverter T-block	Pre-target vacuum pipes
Target chase cooling / air unit upgrade	Target and horn 1 module drives	Decay pipe window
Target chase supplemental shielding	Hadron beam monitor	Tritium mitigation

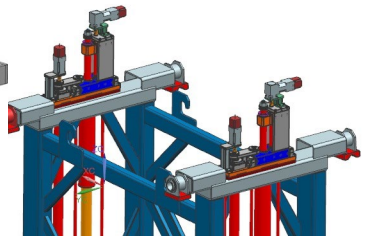


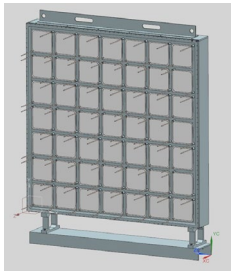


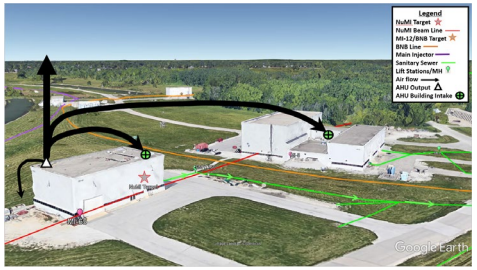












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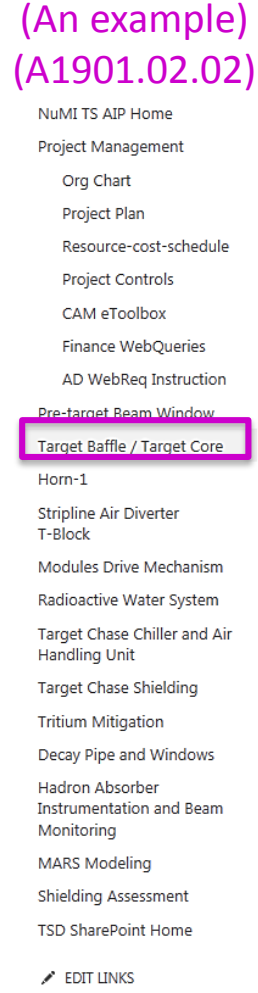
SharePoint for Documentation and Communication

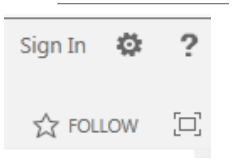
https://web.fnal.gov/project/TargetSystems/NuMI-AIP/

(An example)
(A1901.02.02)



Target Baffle and Target Core

With your Fermilab Service account password



A190.02.02, Task Scope

- Redesign the core and baffle to accommodate larger fins for the larger beam spot size (**Completed**).
- Fabricate and install new target core and baffle.

Status /Schedule

Drawing in TeamCenter

Analysis report in Beams DocDB

Design review comments

Budgeted resource

Tasks for target baffle	Resources (Hours)	Schedule	References
FEA of preliminary design		**Completed**	Dwg. No. **F10041831**, Mar. 30, 2018
Final design / drawing package		**Completed**	**Baffle analysis**, Beams-DocDB-6147, Kavin Ammigan, Feb. 27, 2018
Design review		**Completed**	**Target Baffle Design Review Comments / Recommendations**, Beams-DocDB-225, Mar. 19, 2018
Procurement and fabrication	Engineer / Physicist / Techs / Fab. specialist (40 /8 /80 /40)	Jan. 2 - June 27, 19	50K ← Budgeted M&S cost Order placed with Magna Machine to produce spare 1MW baffles TET-05. Spare baffles ordered for MET-06,07, 08 and 09

Break-down activities

Tasks for target core	Resources	Schedule	References
FEA of preliminary design		**Completed**	**Target core preliminary analysis**, Beams-DocDB-6835, Kavin Ammigan, Nov. 7, 2018
Final design	Engineer / Physicist / Designer (200 /32 /200)	Jan. 2 -May 22, 19	F10115609 (Winged fins at US, **final version**) • Fin width increase to 9.0mm from 7.4mm. • 4 winged fins added. • Information has provided for MARS modeling Winged Fin Position Desision Briefing, TSD-Briefing-2019-002, Cory Crowley, Jan. 22, 2019 F10109309 (Winged fins at DS, **Obsolete**)
Design review	Engineer / Physicist (16 /24)	May 23 -29, 19	**Review comments & recommendations**, Dec. 10, 2018
Procurement and fabrication	Engineer / Physicist / Techs / Fab. specialist (40 /8 /120 /8)	Jan. 2 - June 27, 19	60K Req#293190 / PO#653400, **Target Rail Support / Brackets**, Qty. 4, Jan. 29, 2019, $3368.79, Delivery date Feb. 06, 2019 WebReq#29990, **Target Graphite Fins**, approved Feb. 5, 2019, Village Machine Shop, for Qty. 6, with the 1st set MET-05 delivered by Mar. 29, 2019, 92.7K

Procurement Req# / PO#, Delivery date

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2019 Shutdown NuMI-AIP Job Schedule (Marty Murphy)

4 Tasks

Cool down time before target chase can be opened

Job/Week	1	2	3	4	5	6	7	8	9	10	11	12
Tar/H1 RAW skid work - Des												
Horn-1 Target Pile RAW Fitters. - Des												
Mez fitting work. Lee Hammond												
Mez Chiller HX Clean Lee Hammond												
Mez Chiller PM - Prism Lee Hammond												
Chase Cooling HVAC/Fitting Lee Hammond												
Transfer MET-02 to C0												
Install MET-05 Crowley & Lolov					MET-03 to Morgue							Install MET-05
Replace Stipline Hardware												

Pipefitter T&M Contractor teams have worked on similar NuMI jobs in the past

Target installation

Next 4 slides will cover these 4 tasks with more technical details and status

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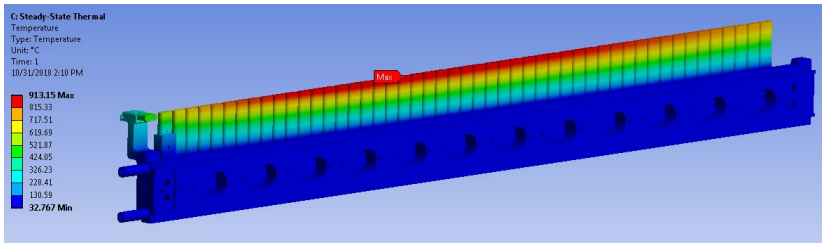
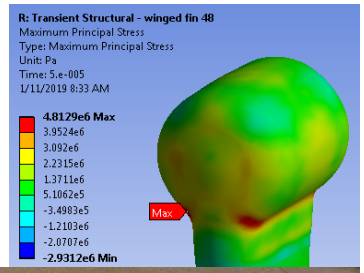
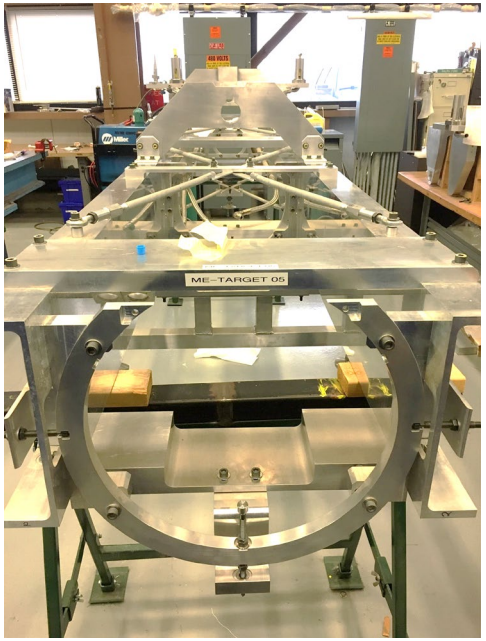
1a). 1 MW Target (A1901.02.02 / Kavin Ammigan)

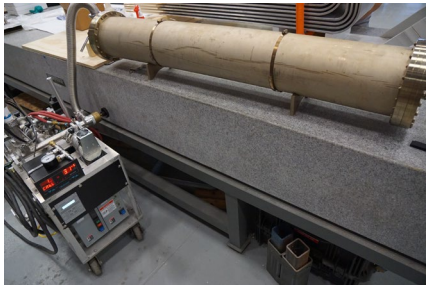
Redesigned the target core fins and baffle per increased beam spot size

Design & FEA completed	Fabrication status	Plans for next quarter
• Addition of U.S. winged fins provide protection per mis-steered beam • Extensive FEA performed • Additional cooling to DS Be window (next slide)	• Target canister and carrier are ready • Baffle on hand • Bake graphite fins in vacuum oven	• Inspect baffle straightness • Start assembling process in late April









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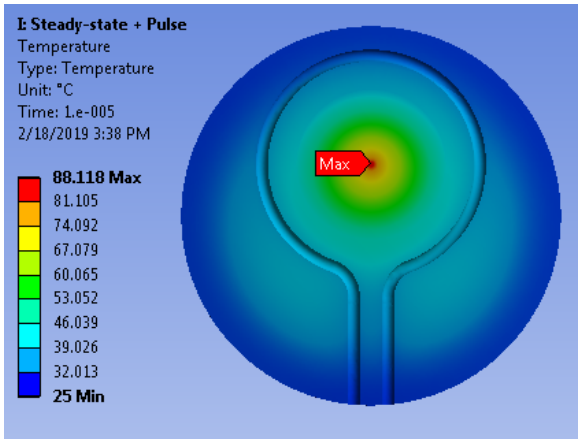
1b). Target DS Beryllium Window (A1901.02.02 / Kavin Ammigan & Cory Crowley)

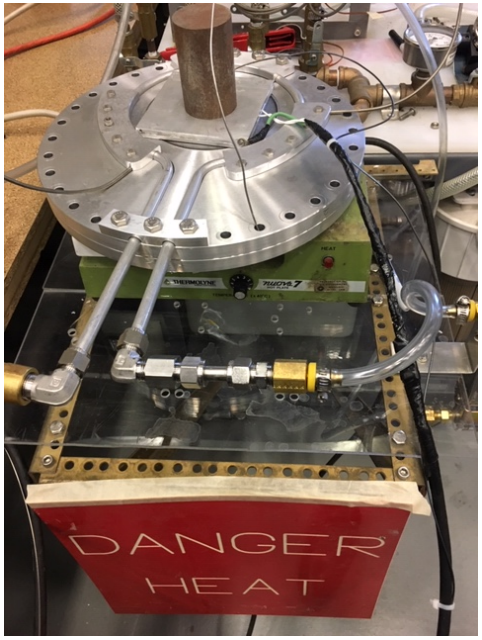
FEA results indicated D.S Be window temperatures and stresses were higher than originally envisioned and were marginal to the material allowable strength

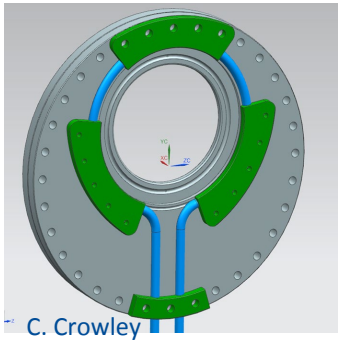
- Additional cooling loop was designed and tested.

With cooling loop:

Internal pressure (psig)	T_{max} (°C)	Internal surf. $\sigma_{equiv,\ max}$ (MPa)	External surf. $\sigma_{equiv,\ max}$ (MPa)
5	88	164	132
10	88	197	192







- Fabrication is not an issue, Loop fitment is good
- Temperature measurements, average heat transfer coefficient from 3 tests: **2550 W/m².C**

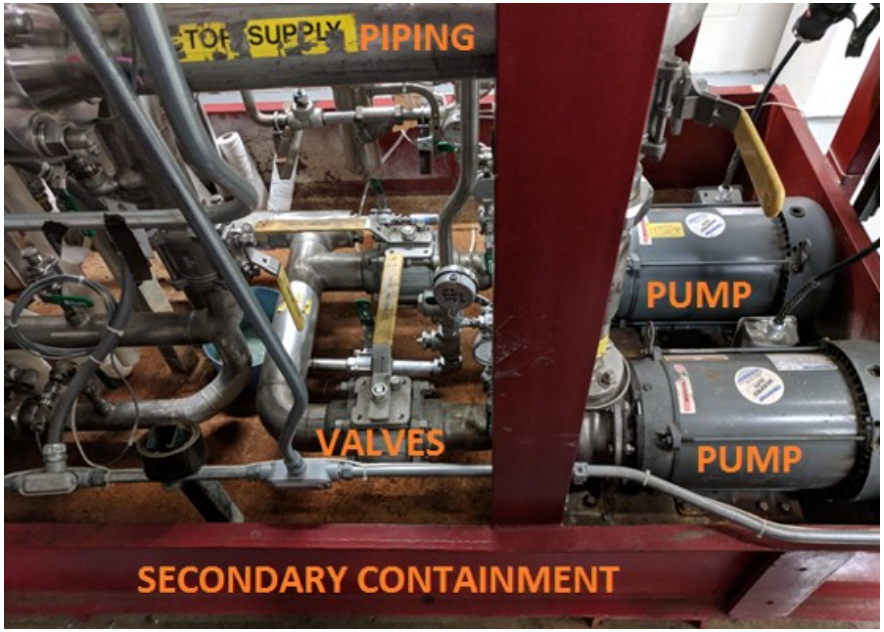
- Cooling loop does not require additional target RAW skid revisions.
- Effectively reduces maximum window temperature and stresses to within acceptable limits.
- Modification to real window and water line revisions to Target assembly started
- Can be accommodated in overall target schedule

2). Target & Horn 1 RAW System Upgrade (A1901.04.01 / Dez)

Upgrade RAW pumps, heat exchangers, piping and instrumentation, to handle extra cooling required

- Heat exchangers, centrifugal pumps, valves and instrumentation parts are on hands
- PO for Horn 1 RAW ejector pump and piping are complete
- Pipefitter T&M requisitions were approved – two jobs

Modifications in RAW room

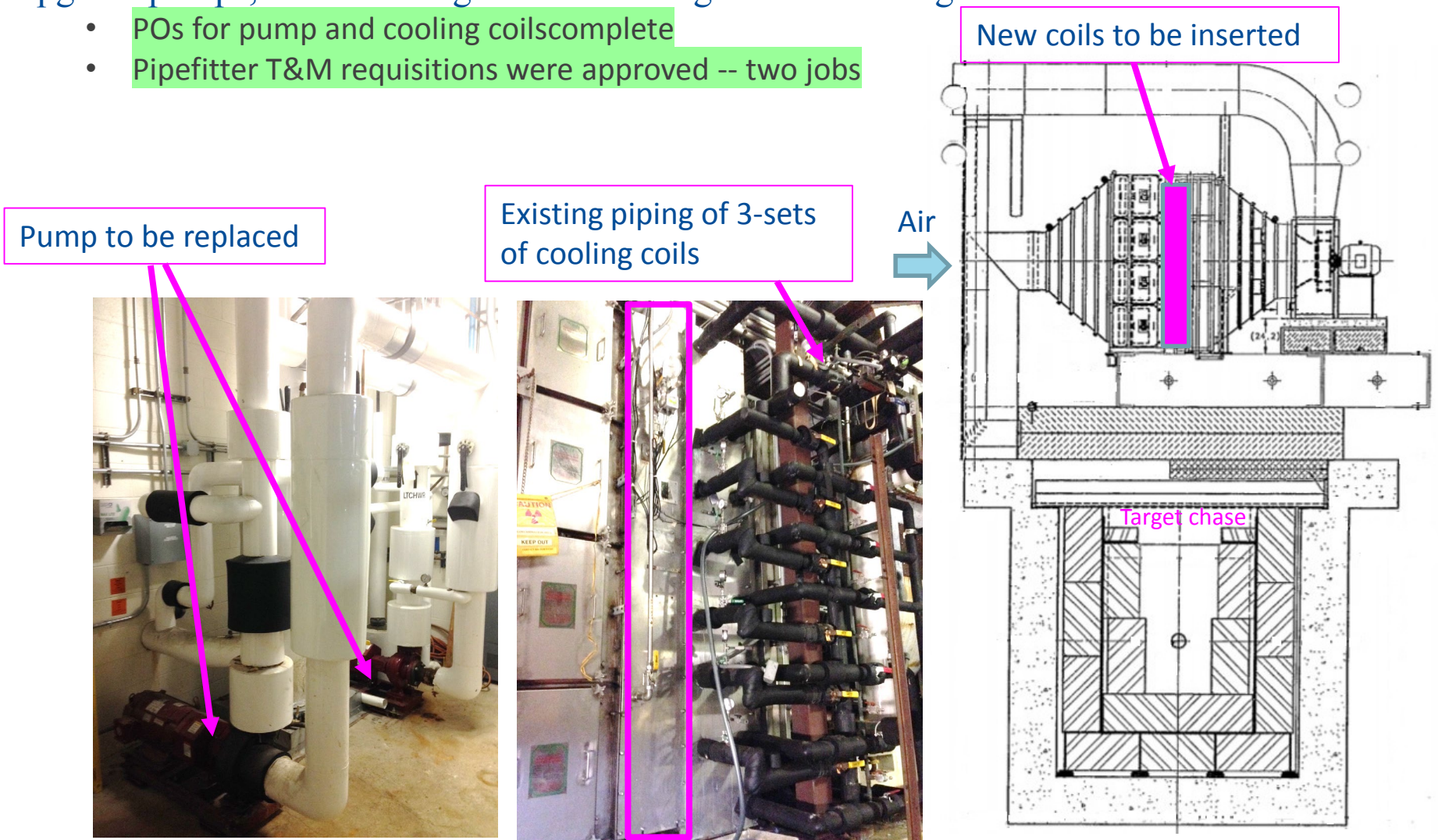


Piping modifications in Target Hall

3). Target Chase Cooling & Air (A1901.04.02 /Lee Hammond & Cory Crowley)

Upgrade pumps, add 3 cooling coils to the target chase cooling circuit

- POs for pump and cooling coilscomplete
- Pipefitter T&M requisitions were approved -- two jobs

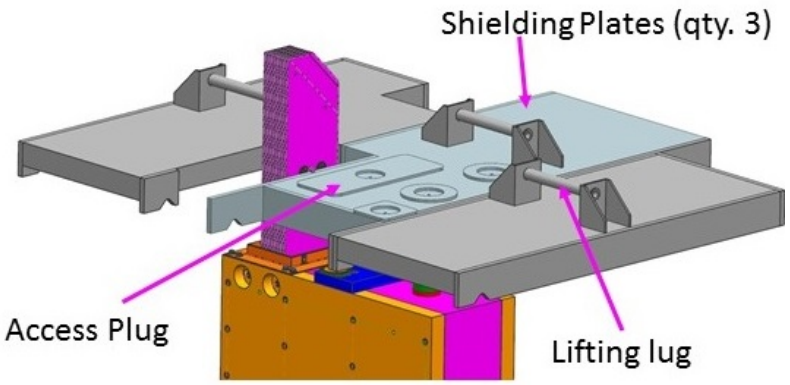


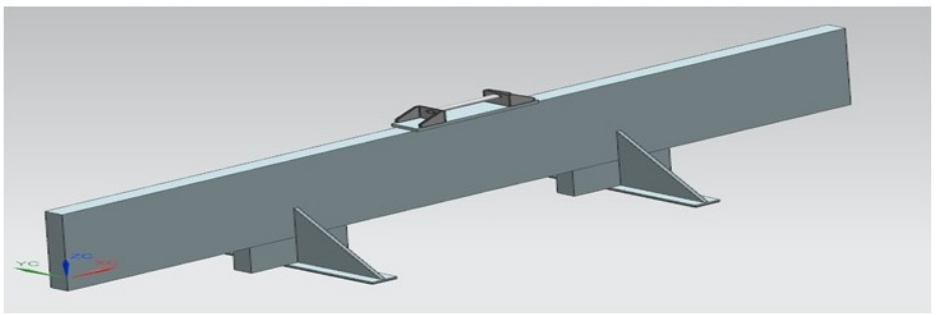
4). Target Chase Supplemental Shielding (A1901.04.03 / Joe Angelo)

Increases in residual radiation due to higher beam power will significantly increase the cool-down time needed before maintenance or changeout activities can start

- Supplemental shielding for Horn 2 stripline block
- Shield curtain between the steel shield pile and the concrete cap downstream of Horn 1

Procurement complete, delivery date May 1st





Status of Rest Tasks (not Tied to 2019 Summer Shutdown)

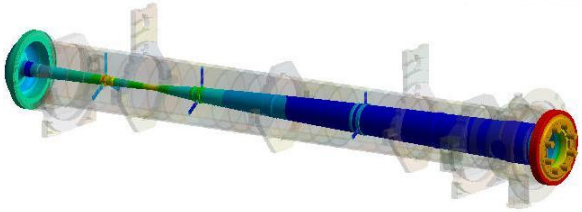
Major activities: review preliminary design, finalize design and generate drawing package

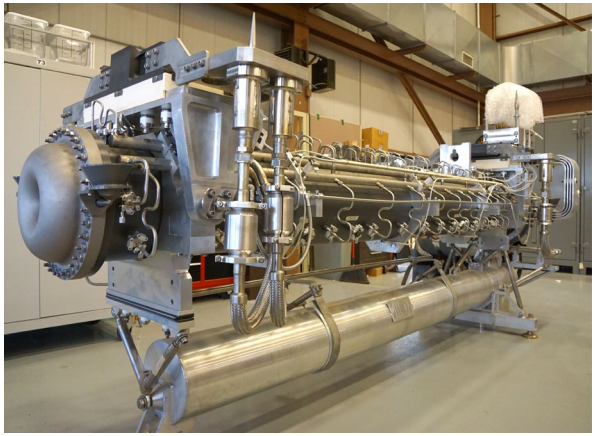
#	Tasks	Activities	Complete %
5	1 MW horn 1 5a) Horn 1 conductors PH1-05 ready and tested 5b) Horn 1 stripline	Wind tunnel test	100%
		FEA of conductors & stripline	100%
		Stripline fabrication	60%
		Air diverter fabrication	90%
6	Stripline air diverter T-block	Design and drawing package	60%
7	Target & Horn 1 module drive mechanism	Design and drawing package	50%
8	Hadron beam monitor & absorber	R&D, prototyping	70%
		Design	30%
9	MARS modelling	Additional information provided, re-run	
10	Pre-target window	Spare fabrication	40%
11	Decay pipe window	Test welding gets started	
12	Tritium mitigation	Redefine scope due to recent new findings	

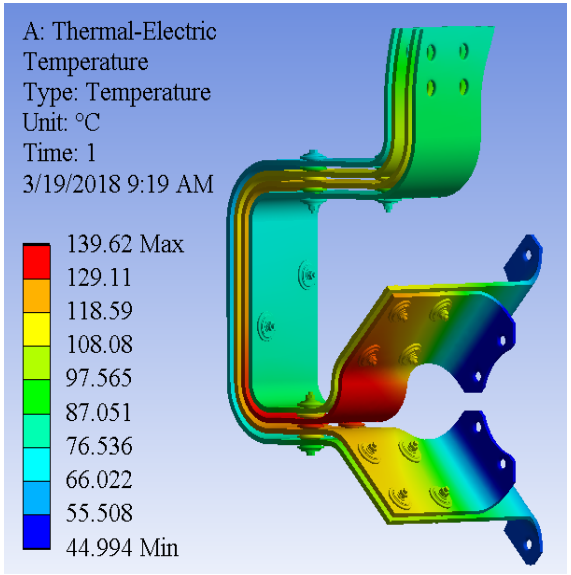
Next a few slides will cover these tasks with more technical details

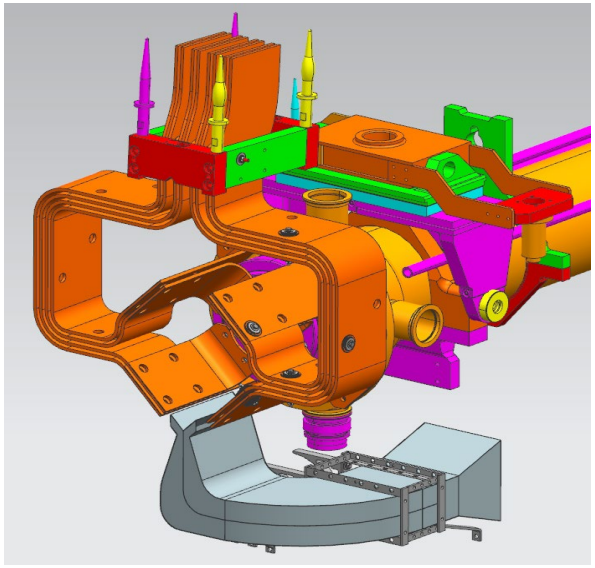
5). Horn 1 Conductors & Stripline (A1901.03.01 / Cory Crowley)

Design & FEA completed	Fabrication status	Plans for next quarter
• Cooling improvement to Horn 1 inner conductor (RAW upgrade) • Design improvements to stripline (w/ air diverter) • Wind tunnel test • Extensive FEA	• PH1-05 ready and tested • Stripline fabrication 50% • Air diverter fabrication 90%	• Continue stripline fabrication • Test air diverter with Horn 1





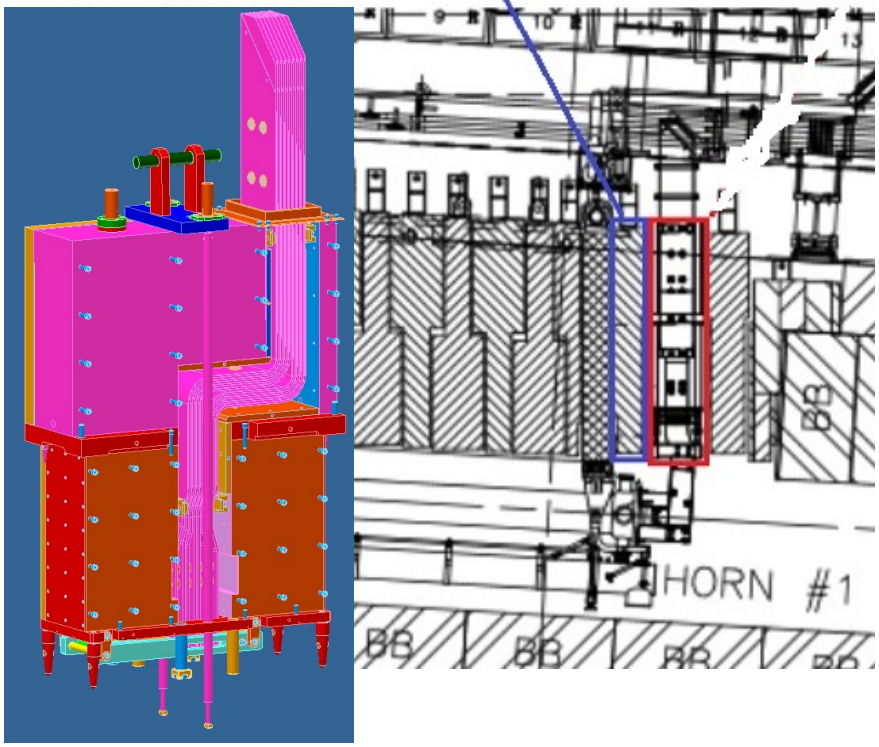


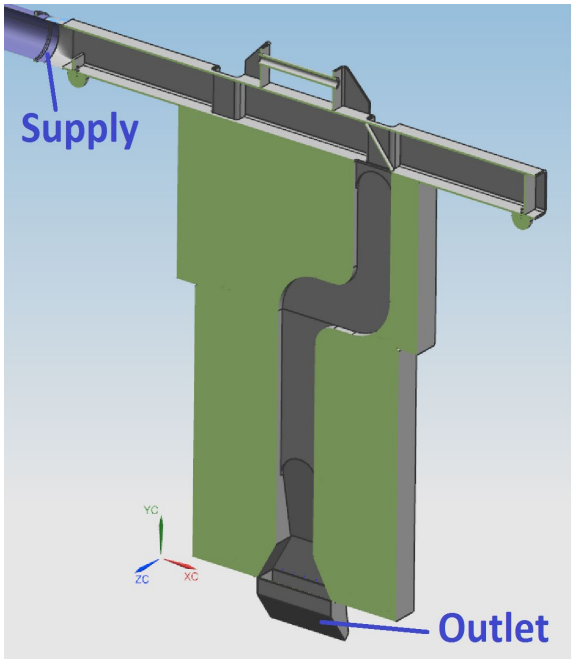


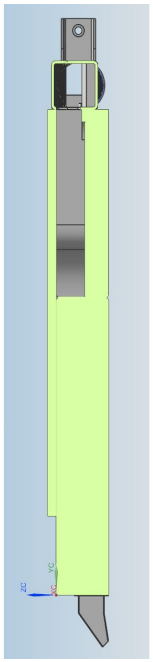
6). Stripline Air Diverter T-block (A1901.03.02 / Cory Crowley)

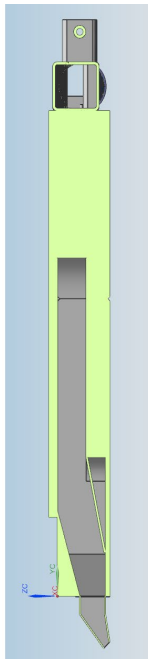
Dedicated air cooling to upper end of Horn 1 electrical bus stripline

- through an adjacent shielding block with new air supply installation through battlement
- Design and drawing package 60%









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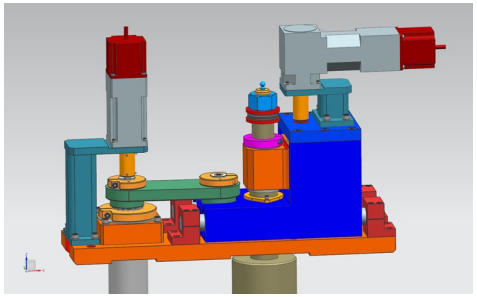
7). Target & Horn 1 Module Drive Mechanism (A1901.03.03 /Vladimir Sidorov)

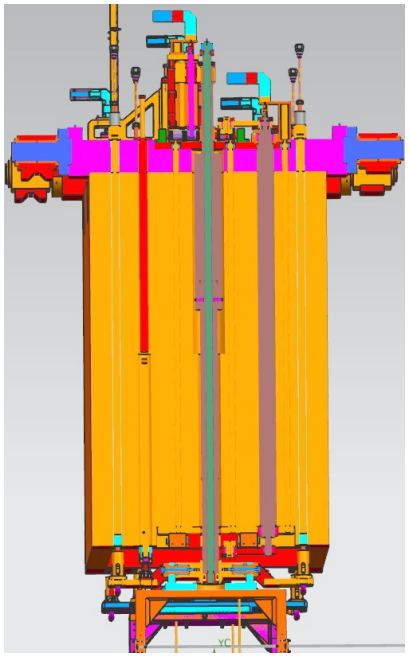
Module are corroded, motion control on Target & Horn 1 is failing

- Target horizontal motion is frozen
- Redesigned drives and linkages with corrosion resistant materials SS

Target module	Horn 1 module	Mock-up frame
Released in 2018 Under review	Design, simpler	Fabrication at MAB



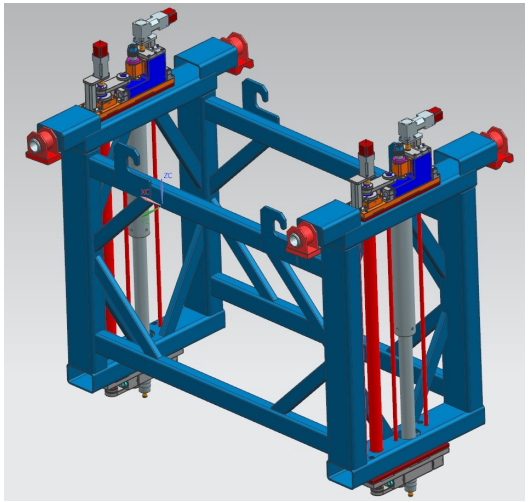
Upper drive sub-asm



Lower drive sub-asm

Modifications:

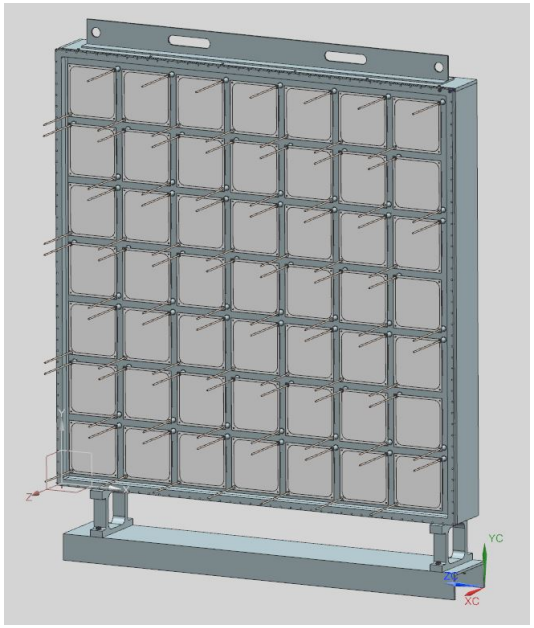
- Graphalloy bushings and washers
- More powerful motors with stainless steel gear box
- Al anodized bushings in lower linear block
- Transverse link shaft design
- Vertical shaft support block

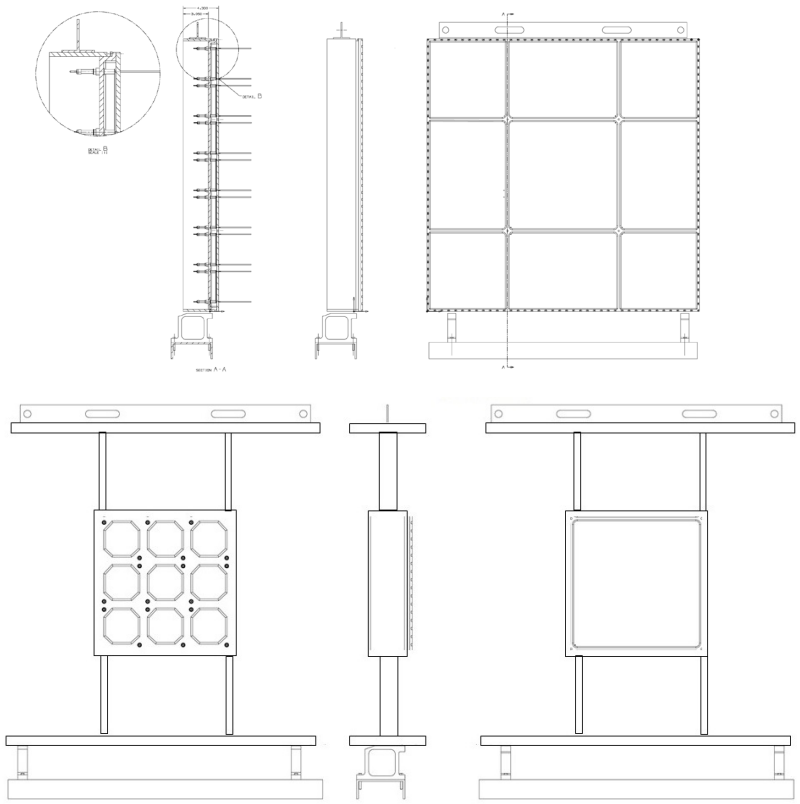


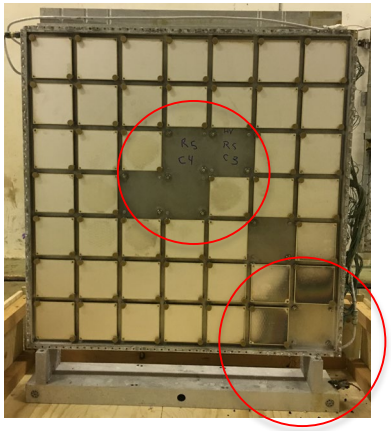
Modules	Vertical motion	Horizontal motion
Target	+8 mm to -200 mm	+/- 8mm
Horn 1	+/- 3 mm	+/- 3 mm

8) Hadron Beam Monitor (A1901.06.01 / Katsuya Yonehara)

- Experiencing pixel failure from radiation damage
- Inspected 1st and 2nd retired hadron beam monitors
  - Performed dimensional measurements and reproduce drawings
- Design simplified robust hadron monitor (3x3 array) with radiation hard materials
  - Seeking collaboration with U. of Texas
- R&D alternative detectors
  - RF detector
  - SEM

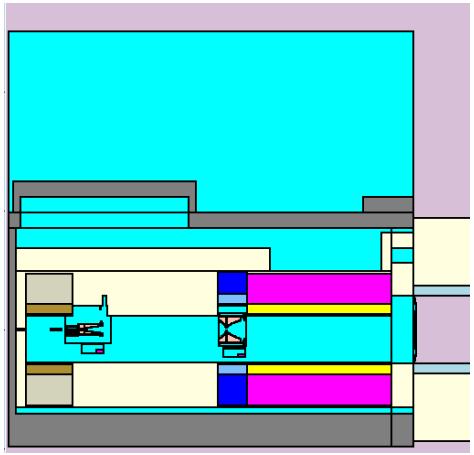






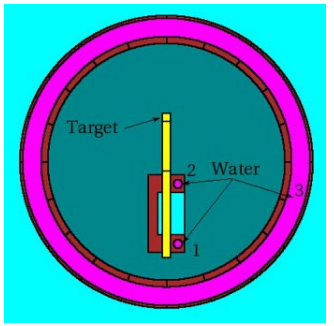
Fermilab

9). MARS Simulations (A1901.06.02 / Igor Rakhno)

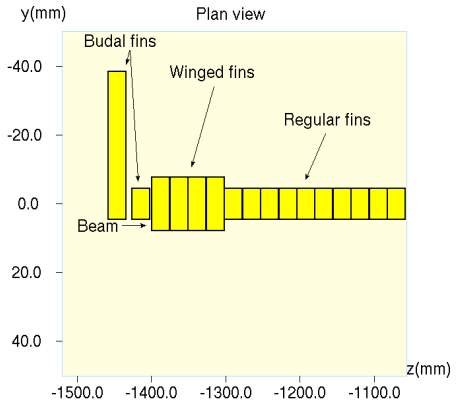


Calculated distributions of star density, hadron flux, prompt and residual dose, and energy deposition for:

- Target chase
- Decay pipe
- Absorber Hall and Muon Alcoves



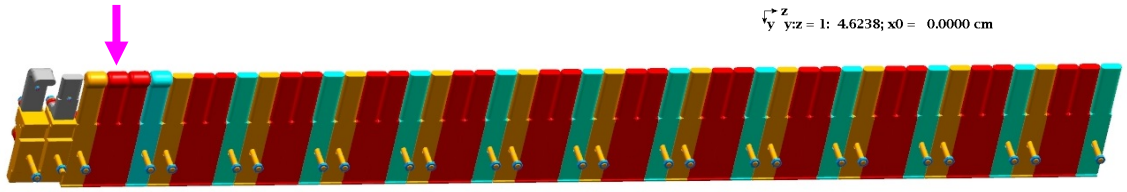
- ➢ Shielding and environmental assessments
- ➢ Preliminary FEA thermal and structural analysis



The following information were provided for MARS model updates:

- New target core changes with winged fins placed upstream
- Target DS window cooling loop
- Decay pipe repair patch

Winged fins



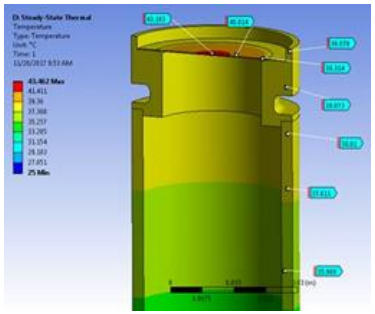
MARS re-run for:

- Target DS Be window
- Decay pipe window
- Hadron absorber
- Normal operation, and accident condition with a 6mm beam offset.

10) Pre-target Vacuum Pipe (A1901.02.01 / George Lolov)

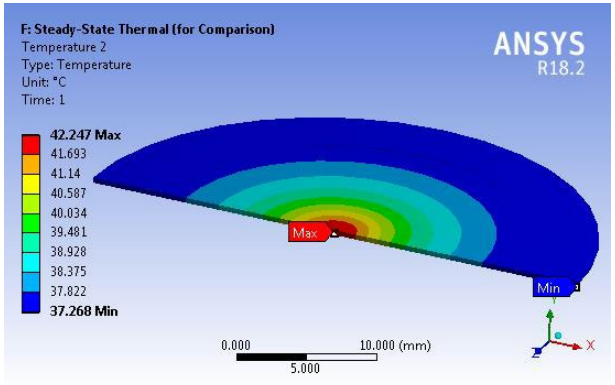
Pre-target vacuum pipe with improved Beryllium window was installed in summer 2018

- Pre-target Be window
  - Slightly domed and thicker
  - Improved brazing joint design
  - Thermal-structural analysis



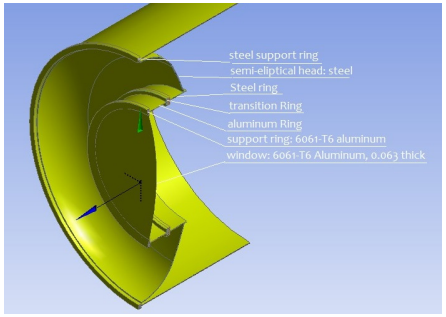
Fabrication of pre-target vacuum pipe spares (qty. 3)

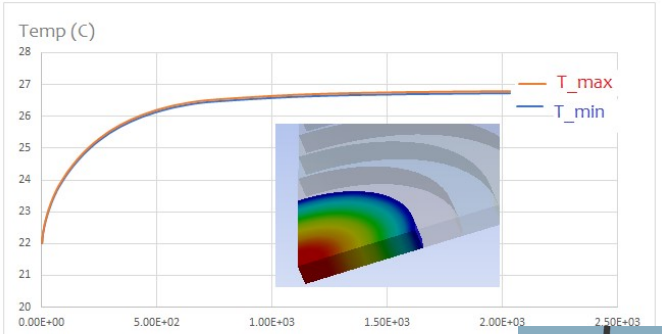
- 80% parts on hand
- EB-welding
- Assembly welding

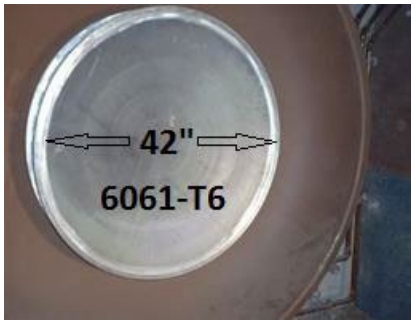


11) Decay Pipe Window (A1901.05.01 / Mike Campbell)

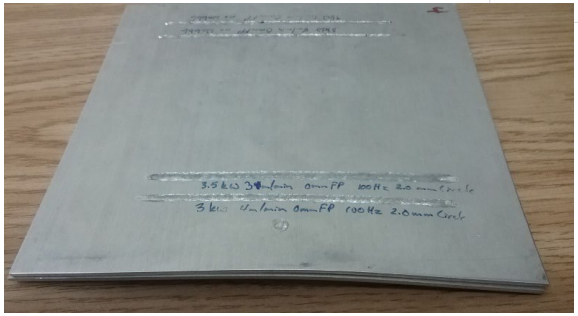
- Evaluation and possible solutions in event window needs to be replaced
  - Preliminary FEA analysis
  - Weld repair patch (Al 5086 or 5052) over failed section (Al 6061)
  - Repair mechanism concept developed

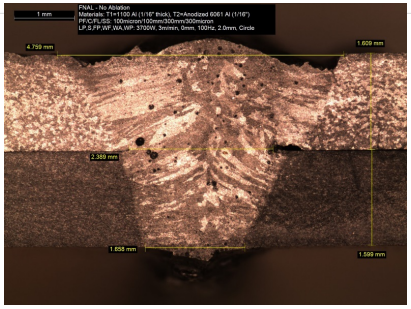


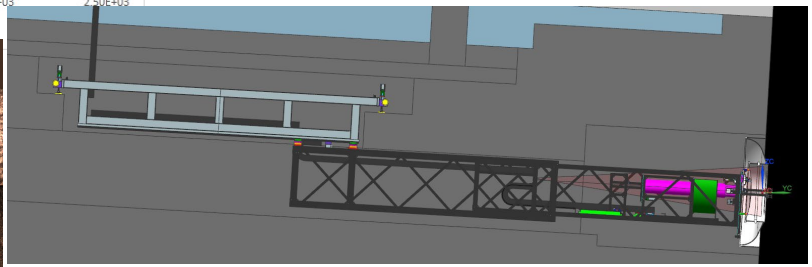


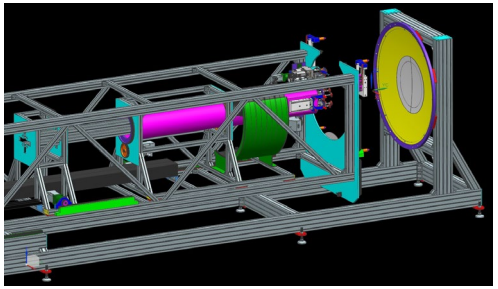


Suspected corrosion was found on the window at beam spot center in 2007 (heat or corrosion?)









- Weld testing (Robot laser ablation welding)
  - Material selection (Al 5052, Al 5086, with Al 6061)
  - Samples, welding, testing & characterize properties
- MARS and FEA with new parameters and beam accident conditions

12) Tritium Mitigation (A1901.04.04 / Keith Gollwitzer)

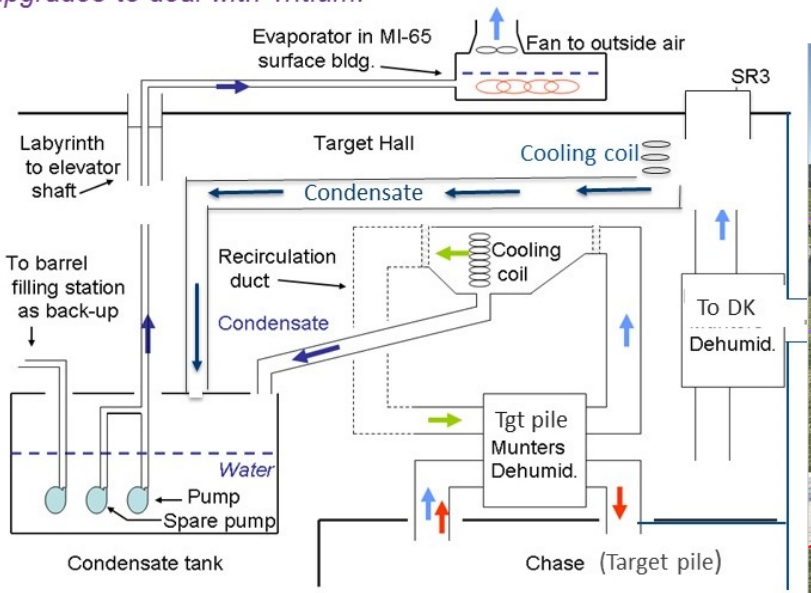
Tritium is nearly all produced by spallation in the shielding, increases exponentially with beam power

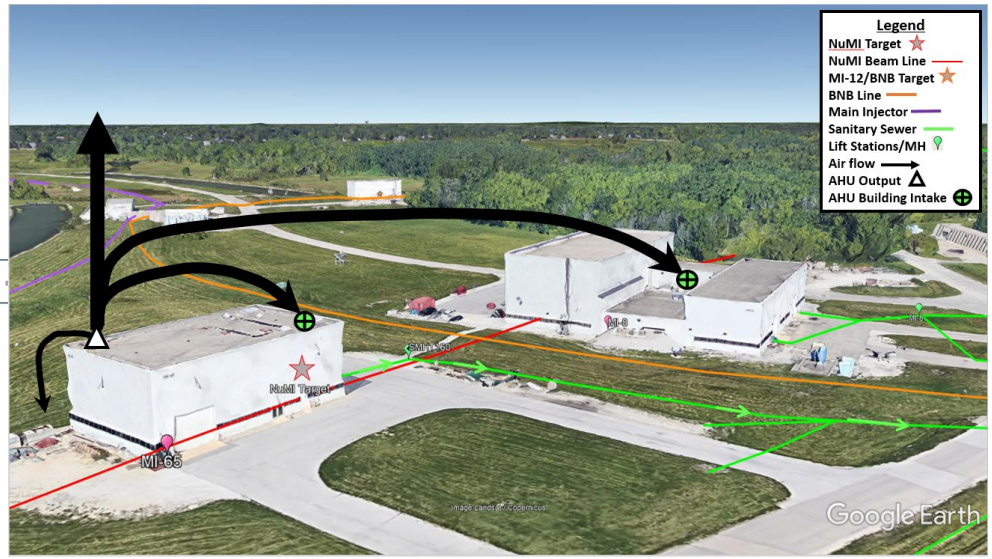
- Baseline scope: extend chimney stack for an improved evaporative disbursement
- Recent measurements:
  - spikes in sewer higher than expected after rain
  - under investigation
- Intend to redefine the task scope in collaboration with Tritium Task Force

Schematic of main NuMI Tritium release path

Takes target hall HTO humidity, condenses it, then evaporates it from roof

All of this dehumidification and evaporation equipment was added to NuMI as upgrades to deal with Tritium.





Summary

- Most tasks are on schedule
  - 1 MW target fabrication, requires alignments during shutdown time, but it is scheduled to be installed in the last week of summer shutdown.

  Schedule & quality control (George Lolov):

  https://web.fnal.gov/project/TargetSystems/Devices/MET-05/

  - DS Be window additional cooling is an extra activity In Target Core A1901.02.02, it is addressed and on schedule
- Next quarter will be busy – preparing for summer shutdown