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AP0 Target Station Operational Readiness for Muon g-2 Beam

Yun He

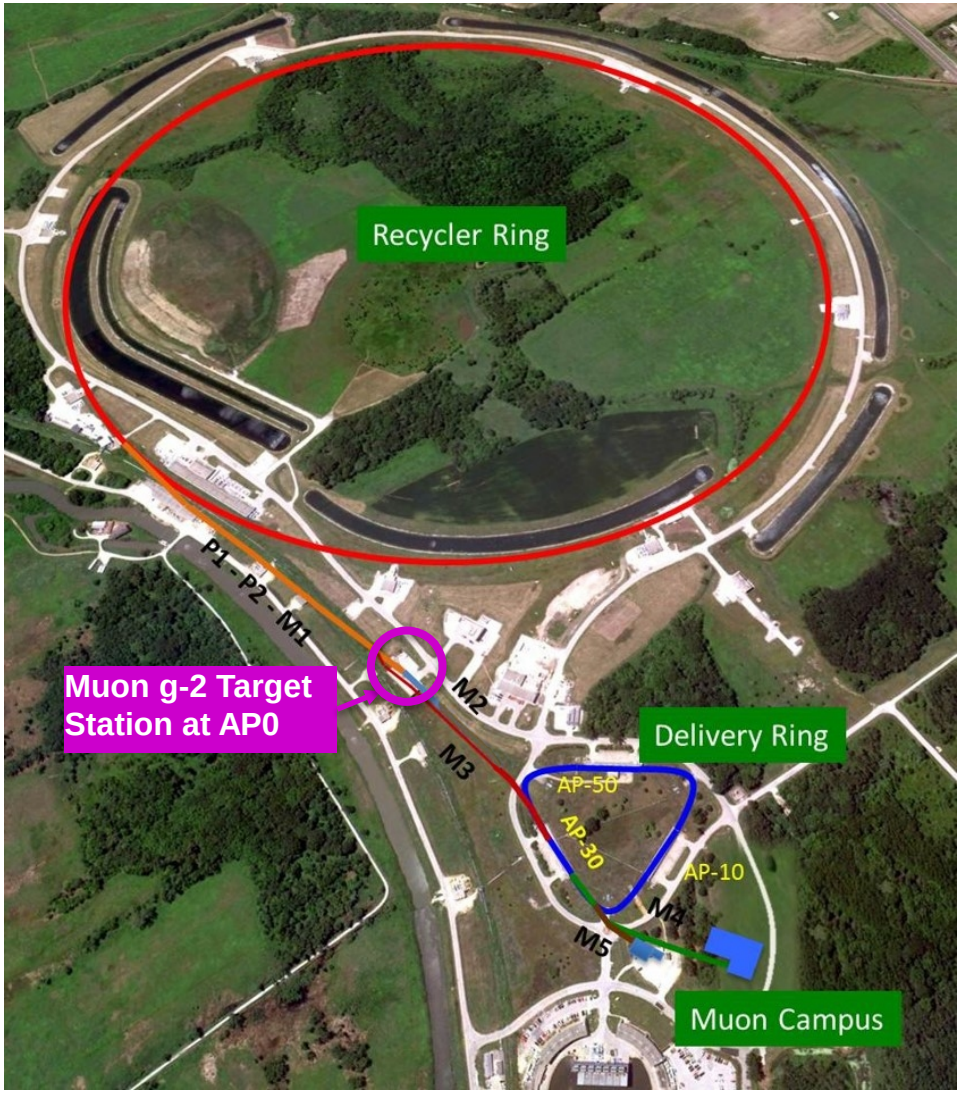
TSD Topical Meeting

13 April 2017

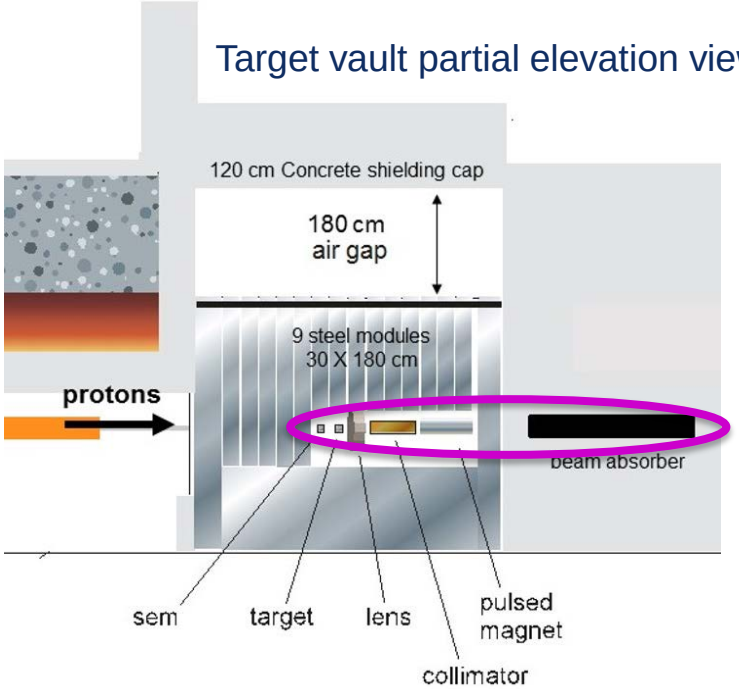
Outline

- Muon g-2 target station
- Conversion from antiproton production to muon beams for g-2
- Target station devices and mechanical support team
- TSD tasks for getting systems ready for g-2 operation (Jan.-April 2017)
  - Three cooling water systems re-startup
  - Target motion control system checkup and updates
  - Target Air cooling system re-startup and target rotation mechanism maintenance
  - Lens dummy load installation
  - Fabrication and installation of new beam absorber
- Description of completed tasks
- Status of on-going tasks
  - SEM repairing (Ion pump, Be window)
  - Beam absorber installation
- Target station SharePoint web site & Elog site
- Muon g-2 beam commissioning schedule

Muon g-2 Target Station



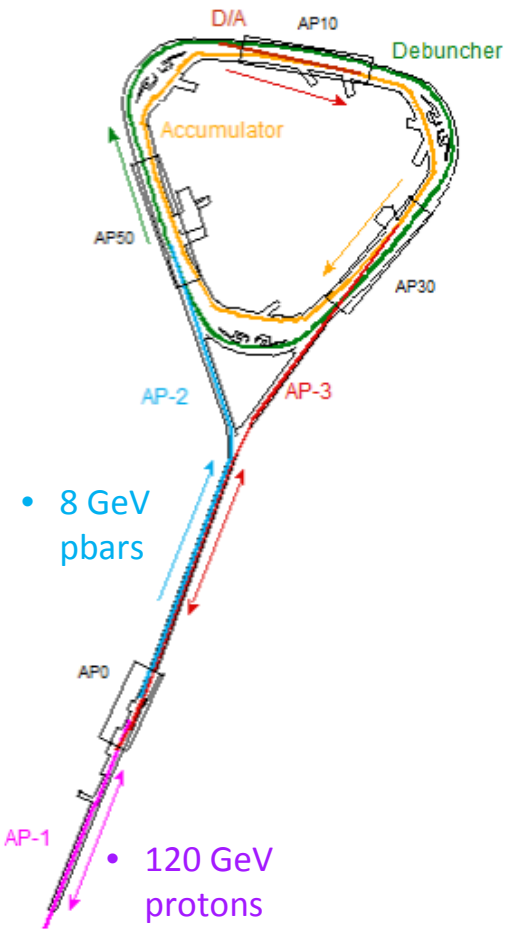
Target vault partial elevation view



This talk covers only the tasks that under TSD responsibilities

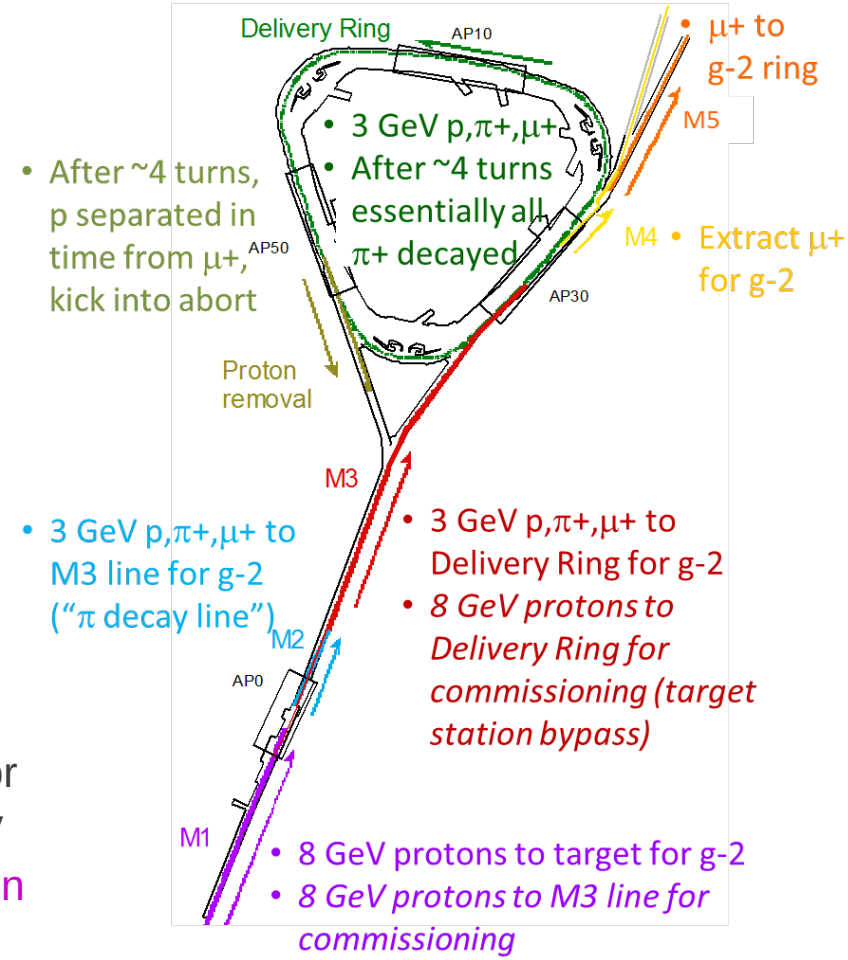
Conversion from Antiproton Source to Muon Beams for g-2

Pbar



- New M4/M5 line to transport beam to g-2 muon ring
- Decommission Accumulator and use magnets for new beamlines
- Delivery Ring largely unchanged from Pbar Debuncher
- Former AP3 line connected to Accumulator – new connection from M3 to Delivery Ring
- Increase number of quads in M2/M3 lines for muon capture efficiency
- Reuse AP0 target station
- Lower beam energy

Muon



Slide copied from Muon Campus Readiness Review March 2017

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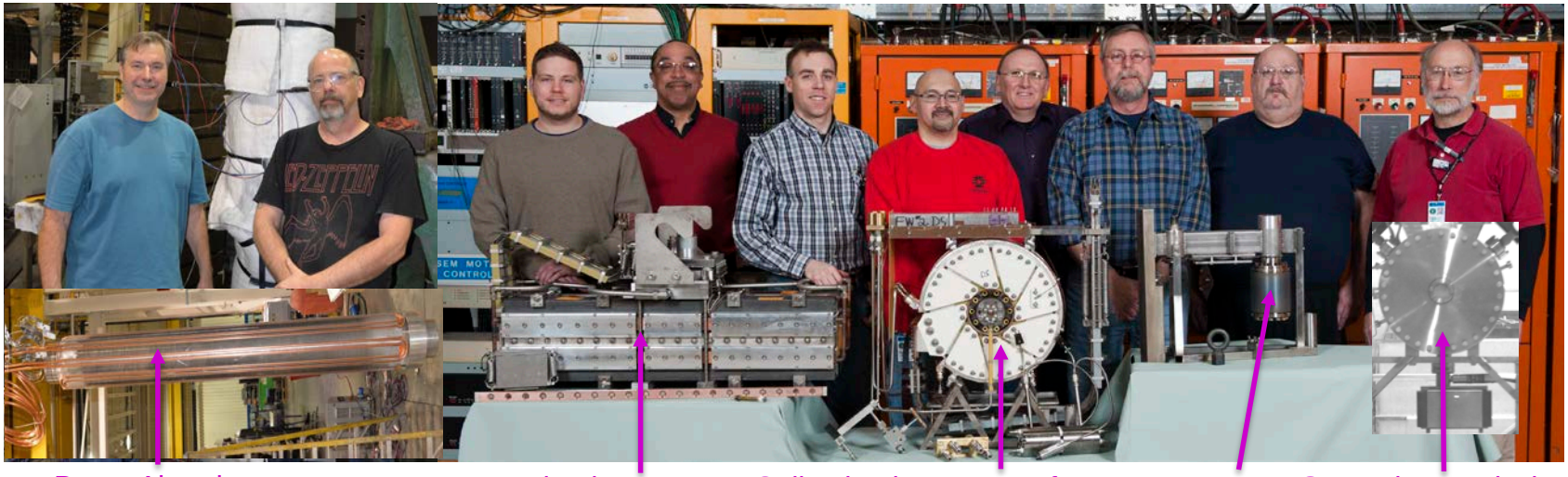
Target Station Devices and Mechanical Support Team



Protons

Beam Absorber | Pulsed magnet | Collection lens & transformer | Target | Secondary Emission Monitor

Collimator, not shown here, still the original one installed in 80's

Team transitions -- two key experts, Ryan Schultz and Tony Leveling, have left or leaving
-- some operational responsibilities are transferred from Muon to TSD

Ron LeBeau
Ralph Ford
Chris Kelly
→ Leading the efforts on getting the systems ready

Yun He
→ Taking partial technical responsibilities from Tony Leveling
- RAW cooling skids/target air cooling operations
- Target motion control (Muon/TSD interfaces yet to be defined)

Kris Anderson
→ Taking care of fabrication of Beam Absorber
- A replacement of leaky beam dump

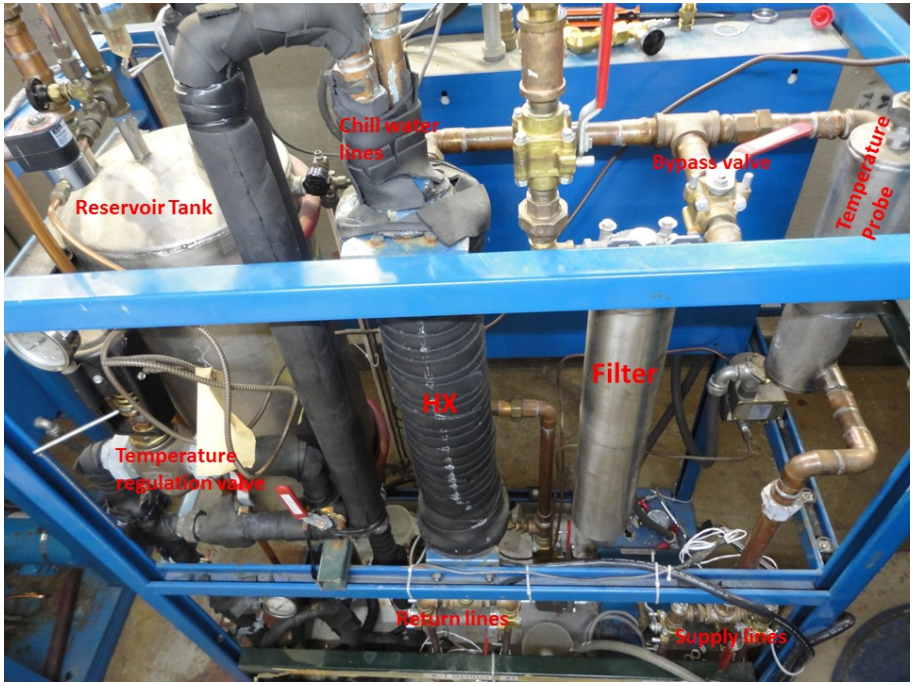
- Closed loop radioactive water cooling systems
- Target air cooling system

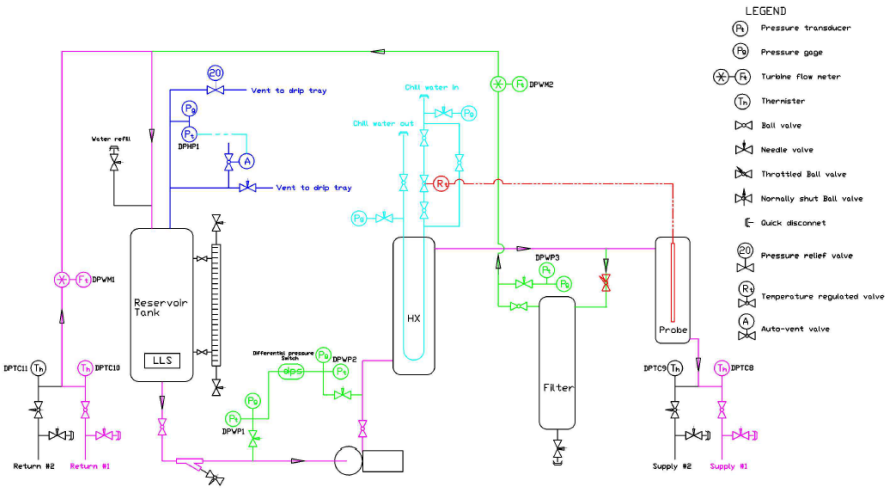
TSD Tasks for Getting Systems Ready for g-2 Operation

Completed work items (January-April, 2017)	
1. Beam absorber water system re-startup	6. Target X, Y, Z and rotation motion control
2. PMag water system re-startup	7. Shift target module 1 inch upstream
3. Collection lens water system re-startup	8. Target rotation mechanism maintenance
4. Lens water conductivity cell testing	9. Target air cooling system re-startup
5. Re-installation of RAW bypassed interlocks	10. Install lens dummy load
Target hall cleanup, SharePoint web site and Target Station Elog site	

Work-to-do list
B1. SEM repairing (Ion pump, Be window)
B2. New beam absorber installation
B3. Replace a few water system components when time permits • Lens water skid heat exchanger • A flow meter in Absorber water skid

1a) Beam Absorber Cooling Water System (BAbsorberWS)





Water skid consists of the following features

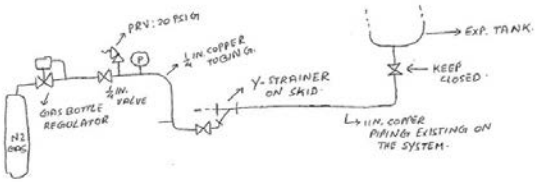
- Auto-vent
- Chill water temperature regulation
- Filter bypass circuit

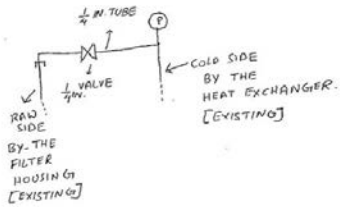
- Basic system maintenance (Drained skid, cleaned strainer, changed filter cartridge, etc.)
- Pressure tested heat exchanger at 100 Psig with nitrogen (bypassed reservoir tank)
- Tested auto-vent sub-system
- Trouble shooting chill water regulation valve
- Balanced the water system operational parameters by adjusting filter bypass circuit flow
- Leak checked penetration lines
- Ran a pair of spare penetration water lines to replace the leaky circuit #2(a backup circuit)

1b) BAbsorberWS Pressure test

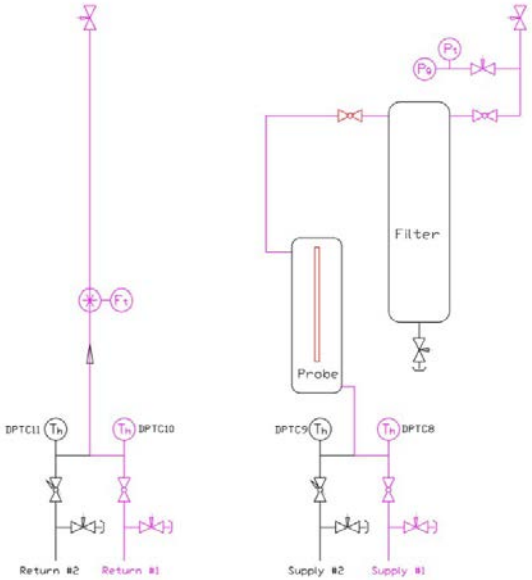
Heat exchanger pressure test at 100 Psig with nitrogen

- bypassed reservoir tank
- under Dez's supervision



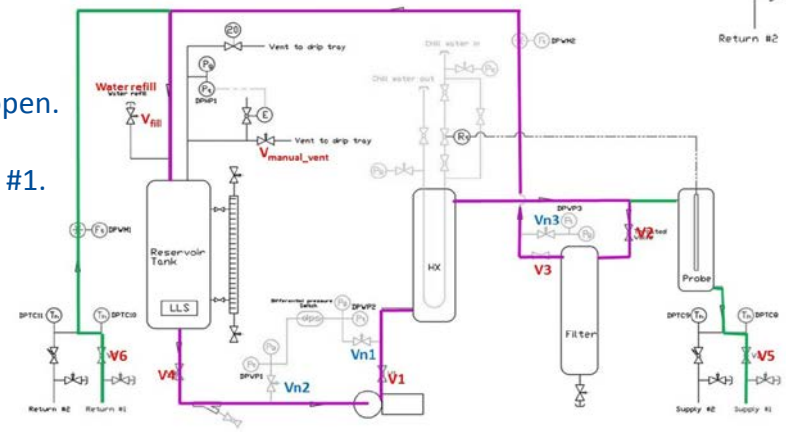


Penetration lines pressure test at 15 Psig with nitrogen



Water skid first test run with water

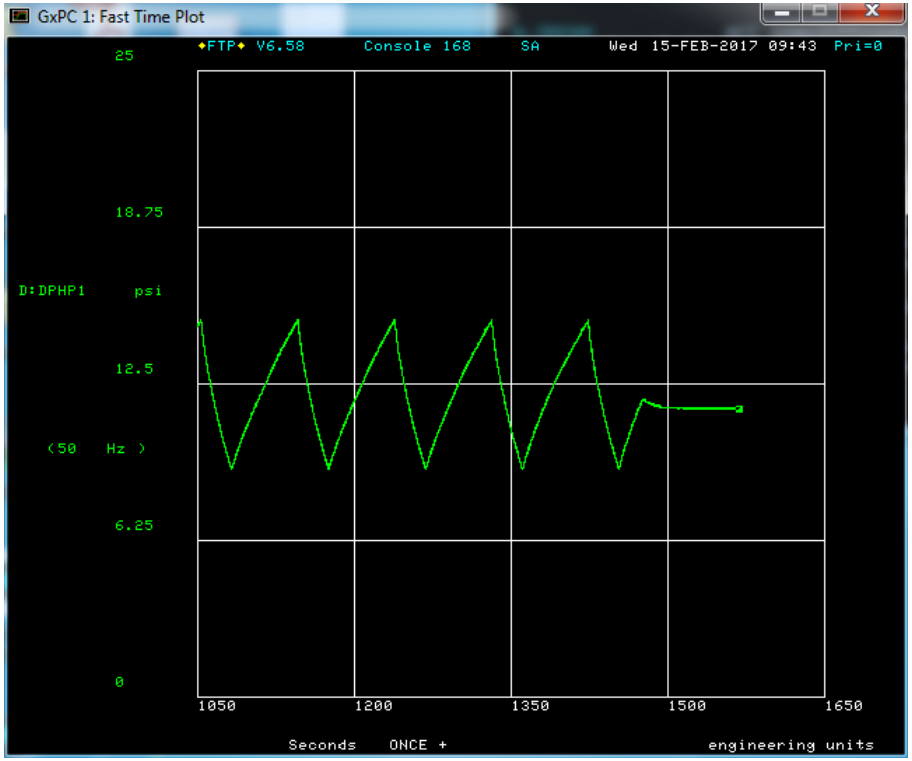
- Loop A, marked in Magenta,
  V5 and V6 closed, and V1, V2, V3, V4 open.
- Added the Green segment
  V5 and V6 open to the penetration line #1.



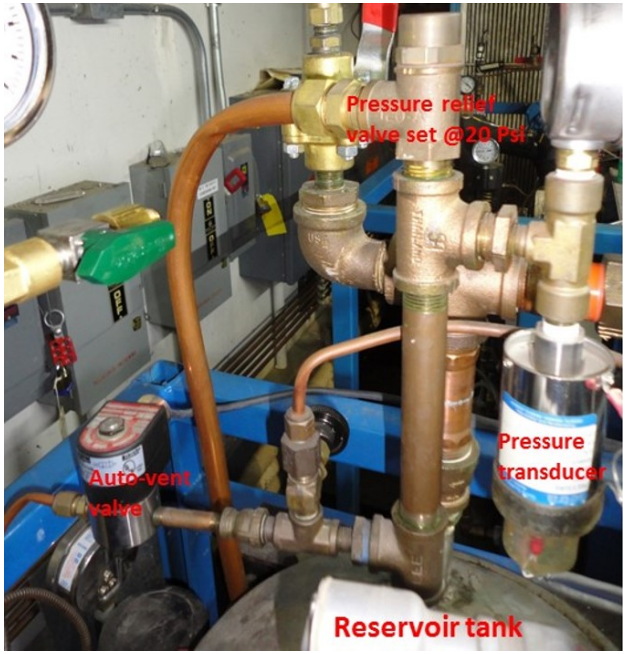
1c) BAbsorberWS Auto-vent Subsystem

Auto-vent valve is opened when the pressure reaches 15 psig, and is closed at 9 psig

- The reservoir tank is not a certified pressure vessel, and the pressure in the tank should be kept below 15 Psig.
- A pressure relief valve is set at 20 Psig.



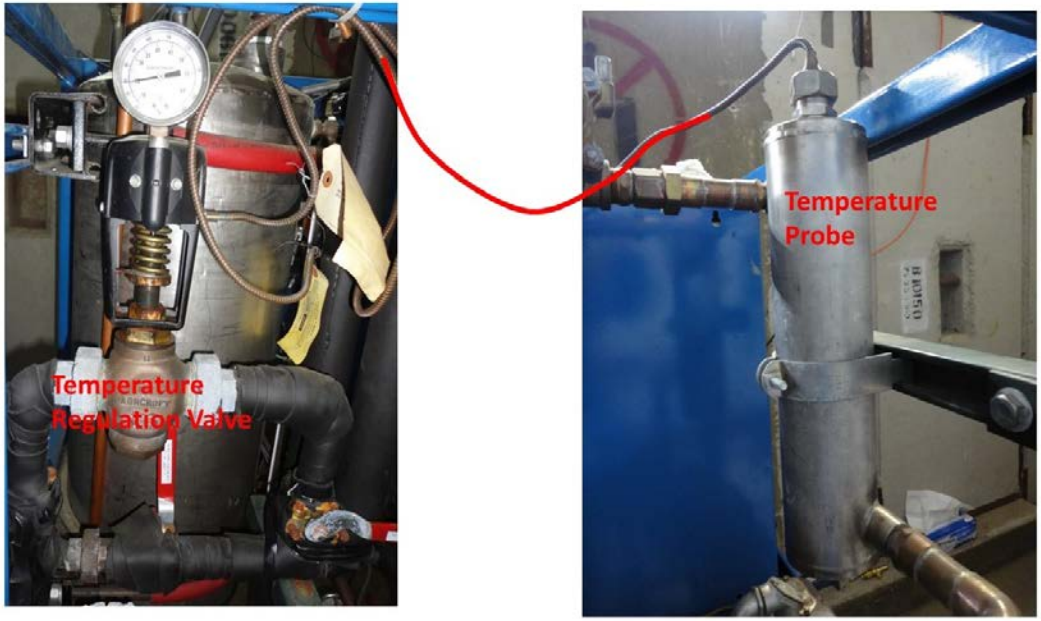
Auto-vent subsystem is in all three water skids



- Radiolytic decomposition of cooling water by the beam shower in the beam devices results in the production of hydrogen gas.
- Hydrogen gas entrained in the cooling water return is recovered in the reservoir tank gas space.
- Since the water system is a closed system, gas system pressure gradually rises proportionally with integrated beam power (kW-hours).
- A pressure transducer used to monitor reservoir tank pressure acts as an input to the Auto-vent circuit, which controls a solenoid actuated vent valve

1d) BAbsorberWS Chill Water Temperature Regulation

- Chill water **temperature regulation**
  - a spring/gas pressure actuated control valve
  - a remotely connected water temperature probe - a pressurized gas tube which is located in a thermal well immersed in the water skid supply line
- Chill Water temperature is the 55° F (13° C)
- A chill water regulation valve is used to limit the supply temperature of the cooling water to a temperature well above the dew point. (25 ° C, ± 5° C)
  - In the absence of temperature regulation, beam device surface temperatures are reduced to near the Chill Water System and well below the dew point of the AP0 service building atmosphere. This results in the formation of condensation on beam device surfaces which is undesirable in the target vault environment.

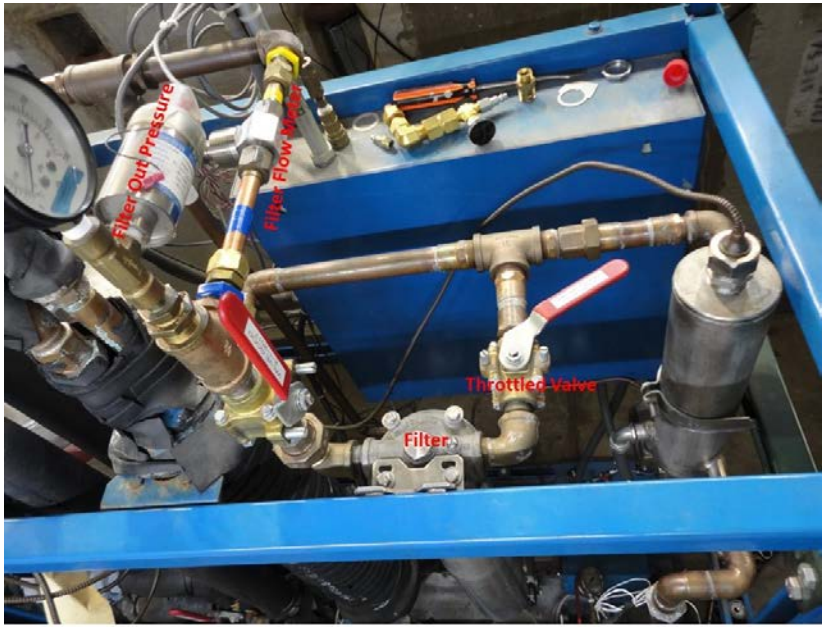


Chill Water temperature regulation subsystem is in all three water skids

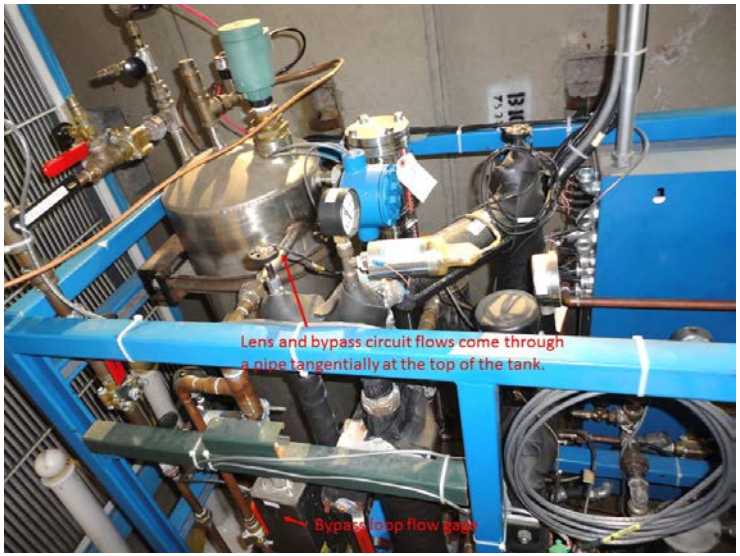
1e) BAbsorberWS Filter Bypass Circuit

- The filter bypass circuit acts to regulate flow through the cooling water circuit and removes entrained corrosion products (primarily copper oxides).
- The activation of corrosion products in water is minimized by the action of a string wound filter cartridge.
  - Corrosion products entrained in the water supply line become radioactive during beam operations.
- The filter circuit runs in parallel with the skid cooling water supply line.
  - The existing pump is capable of supplying water flow which would be excessive for the cooling circuit.

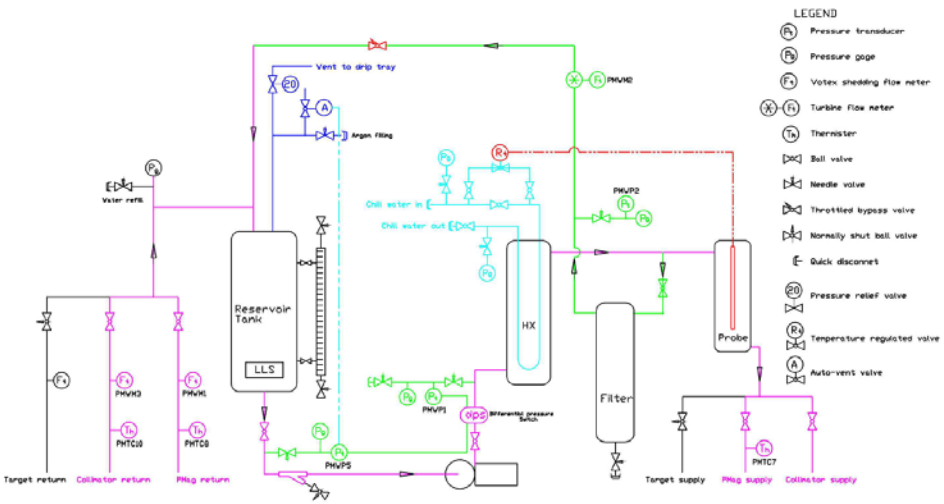
Bypass circuit subsystem is in all three water skids



Bypass circuit plays important role in running LensWS

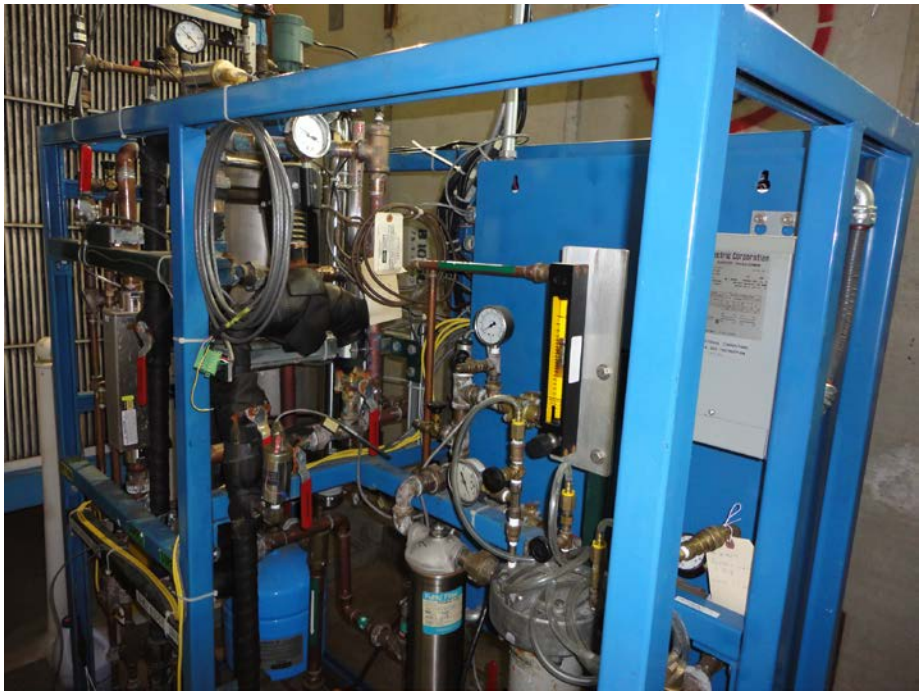


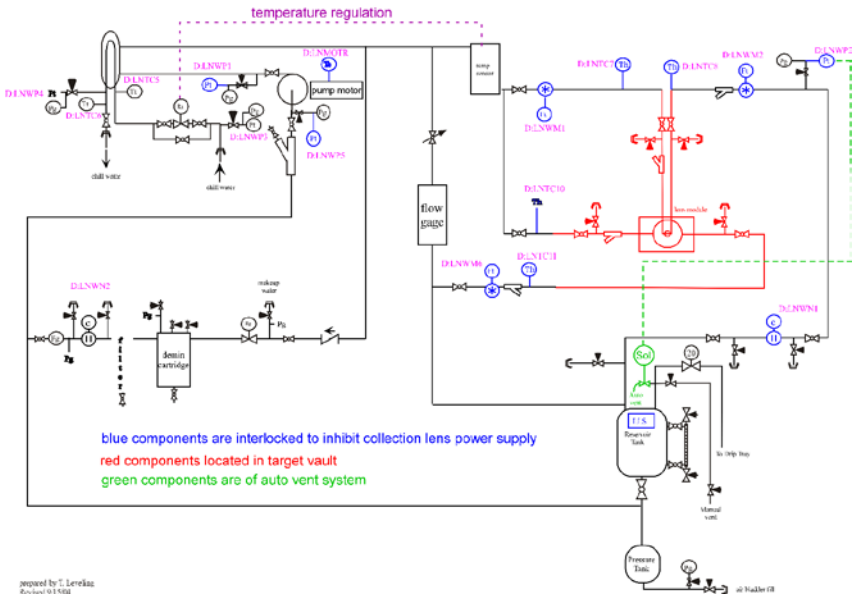
2) Pulsed Magnet / Collimator Cooling Water System



- PMag water skid consists the same features as those in Beam Absorber water skid
  - Auto-vent
  - Chill water temperature regulation
  - Filter bypass circuit
- Performed basic system maintenance
- Tested auto-vent sub-system
- Balanced the water system operational parameters

3) Collection Lens/Transformer Cooling Water System





❖Lens water skid consists of the same features as those in Beam Absorber water skid

- ➢Auto-vent
- ➢Chill water temperature regulation
- ➢Filter bypass circuit

➢ An additional feature: di-ionization

- ❖ Basic system maintenance
- ❖ Trouble shooting auto-vent sub-system, replaced the mal-functioning circuit board
- ❖ Balanced the water system operational parameters
- ❖ Performed conductivity cell testing (knowledge transfer from Tony Leveling)

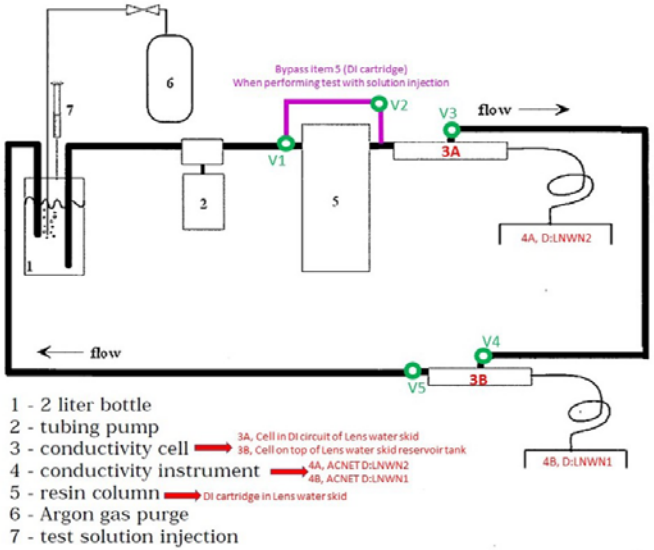
4) Collection Cooling Water Conductivity Cell Testing

Conductivity measurement is used to determine the failure of collection lens.

- High conductivity in the return water is indicative of a septum breach in which water comes into contact with lithium metal which forms lithium hydroxide solution.
- When there is an evidence that the conductivity measurement may be failed, a test needs to be performed.
- Perform test with a solution of known conductivity

Test setup

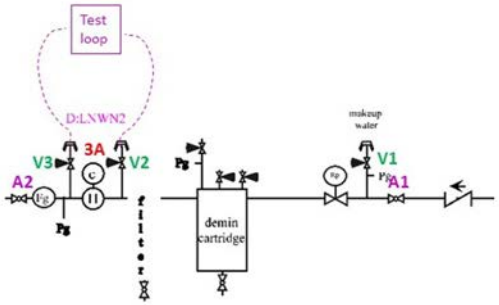
DI water was drawn from a 2 liter bottle by a tubing pump and pumped through two **conductivity cells (3A and 3B)** in the Lens water skid, and then returned to the 2 liter bottle.

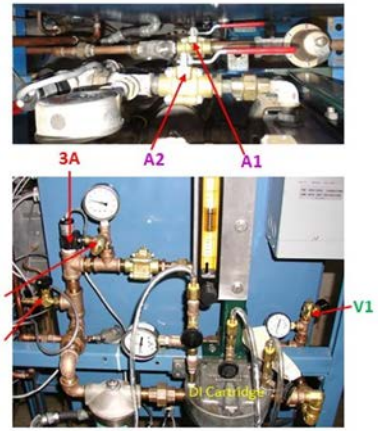


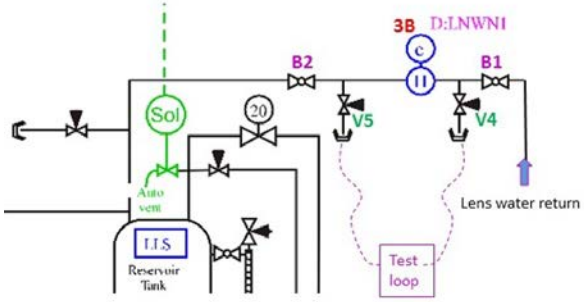
Observe output readings from ACNET devices:

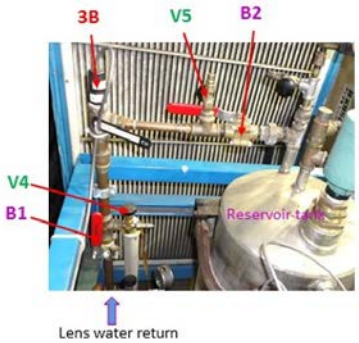
- D: LNWN1
- D: LNWN2

Lens cooling skid consists of some isolation valves so that the conductivity cells could be placed in series in the test loop.





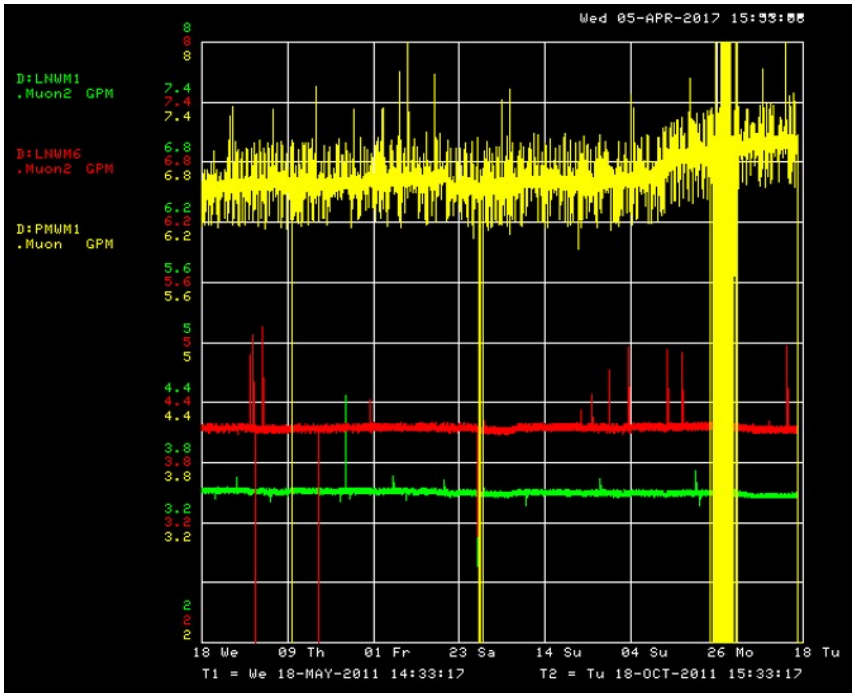




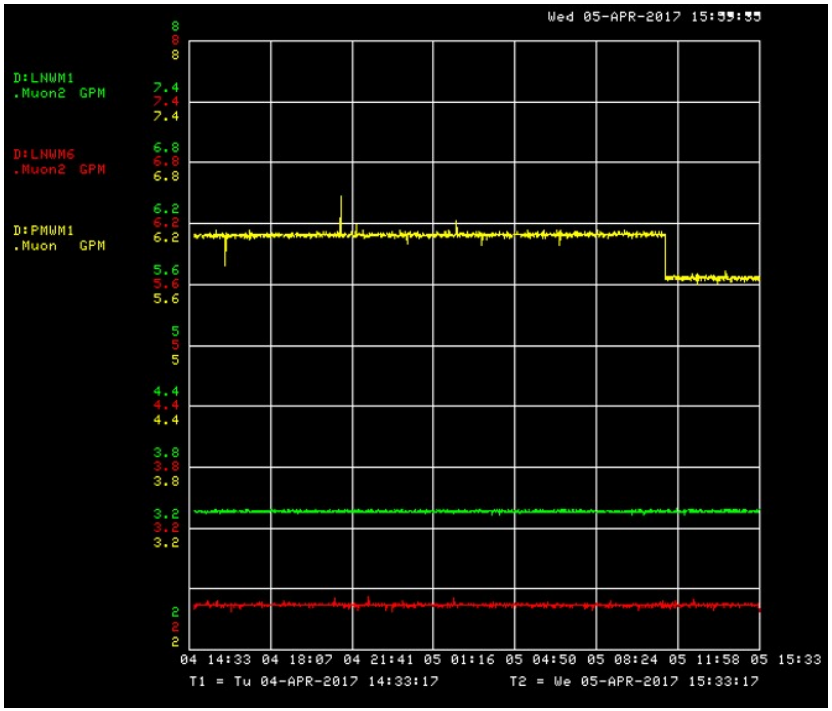
5) Review and Re-installation of Bypassed RAW Interlocks

- During Pbar operations prior 2011 October shutdown, a few alarm card interlocks have been removed from service due to failed instrumentation
- Three cards are reviewed and being re-installed

May-October 2011



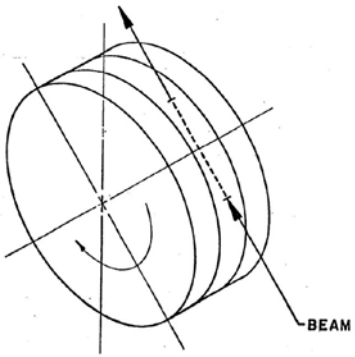
April 2017



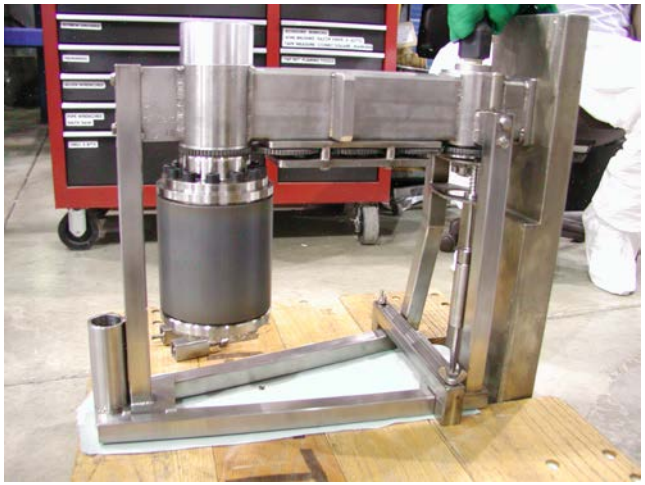
5) Status and Settings of RAW/Target Air Cooling Interlocks

Device	Description	Settings at end of 2009 summer shutdown		Status in March 2017	Status in April 2017	New settings in April 2017	Current reading
		Lower / Upper	LO / HI (Volts)	LO / HI (Volts)			
Collection lens water skid							
D:LNTC7	Lens water supply temp	15 C / 35 C	1.6 V / 2.75 V	1.6 V / 2.8 V			26 C
D:LNTC8	Lens water return temp	15 C /40 C	1.6 V / 3.0 V	1.6 V / 3.0 V			26 C
D:LNTC10	Transform water supply temp	14 C / 35 C	1.5 V / 2.74 V	1.5 V / 2.74 V			26 C
D:LNTC11	Transformer water return temp	14 C / 36 C	1.56 V / 2.8 V	1.56 V / 2.8 V			26 C
D:LNWM1	Lens water supply flow	2.0 gpm / 4 gpm	1.63 V / 2.3 V	Bypassed	Re-installed	1.6 V / 2.6 V	3.4 gpm
D:LNWM2	Lens water return flow	2.0 gpm / 4 gpm	1.63 V / 2.3 V	Bypassed		----	-2.4 gpm
D:LNWM6	Transformer cooling water flow	1 gpm / 5.2 gpm	1.3 V / 2.6 V	Bypassed	Re-installed	1.3 V / 2.63 V	2.4 gpm
D:LNWP1	Lens water supply pressure	60 psig / bypassed	0.6 V / ----	0.2 V / ----			88 psig
D:LNWP2	Lens water return pressure	4 psig / 25 psig	0.4 V / 2.5 V	0.6 V / 4 V			5.5 psig
D:LNWP5	Lens pump inlet pressure	4 psig / 20 psig	0.4 V / 2 V	0.4 V / 4 V			4.7 psig
D:LNWN1	Lens return water conductivity	0 / 0.8 µmho/cm	0 / 4 V	0 / 4 V		1.05 V / 2.6 V	0.055 µm/cm
D:LNWTRL	Lens reservoir tank level	(-8 inch) / 0.7 inch	3.86 V / 5.1 V	3.68 V / 5.1 V			-34.58 inch
D:LNMOTR	Lens pump motor temperature	30 C / 70 C	1.5 V / 3.5 V	1.5 V / 3.5 V			
PMag water skid							
D:PMTC7	PMag-collimator supply temp	10 C / 35 C	1.31 V / 2.74 V	1.3 V / 2.74 V			25 C
D:PMTC8	PMag water return temp	10 C / 35 C	1.3 V / 2.74 V	1.3 V / 2.74 V			25 C
D:PMTC10	Collimator water return temp	N/A	---	---			25 C
D:PMWM1	PMag water return flow	2.0 gpm / 7 gpm	1.63 V / 3.3 V	Bypassed	Re-installed	1.63 V / 4.3 V	6.1 gpm
D:PMWM2	PMag water filter bypass flow	N/A	---	---			12.5 gpm
D:PMWM3	Collimator filter bypass flow	N/A	---	---			-2.5 gpm
D:PMWP1	PMag water supply pressure	50 psig / 150 psig	0.5 V / 1.5 V	0.5 V / 1.5 V			91 psig
D:PMWP2	PMag filter outlet pressure	N/A	---	---			68 psig
D:PMWP5	PMag pump inlet pressure	4.0 psig / 30 psig	0.4 V / 3 V	0.4 V / 3 V			4.2 psig
Beam dump water skid							
D:DPTC8	BDump water supply temp	10 C / 35 C	1.3 V / 2.74 V	1.3 V / 3.1 V			24 C
D:DPTC10	BDump water return temp	10 C / 60 C	1.05 V / 3.8 V				24 C
D:DPWM1	BDump water return flow	2.6 gpm / 8 gpm	0.815 V / 2.5 V	Bypassed	to be re-installed		4.3 gpm
D:DPWM2	BDump water filter bypass flow	1.0 gpm / 5 gpm	Bypassed	Bypassed	to be re-installed		2.4 gpm
D:DPWP1	BDump pump inlet pressure	4.0 psig / 20 psig	0.4 V / 2 V	Bypassed	to be re-installed		10.5 psig
D:DPWP2	BDump water supply pressure	N/A	---	---			50 psig
D:DPWP3	BDump filter outlet pressure	N/A	---	---			8.6 psig
D:DPHP1	BDump reservoir tank pressure	N/A	---	---			8.6 psig
Target air cooling							
D: TARFDP	Target air flow	3 SCFM / 7 SCFM	1.6 V / 2.4 V	1.6 V / 2.4 V			
D: TRMP	Target air pressure pump	6 psig / 15 psig	0.6 V / 1.5 V	0.6 V / 1.5 V			
D: TRMV	Target air pressure vault	3 psig / 10 psig	2.2 V / 5.0 V	2.2 V / 5.0 V			

6) Target X, Y, Z and Rotation Motion Control

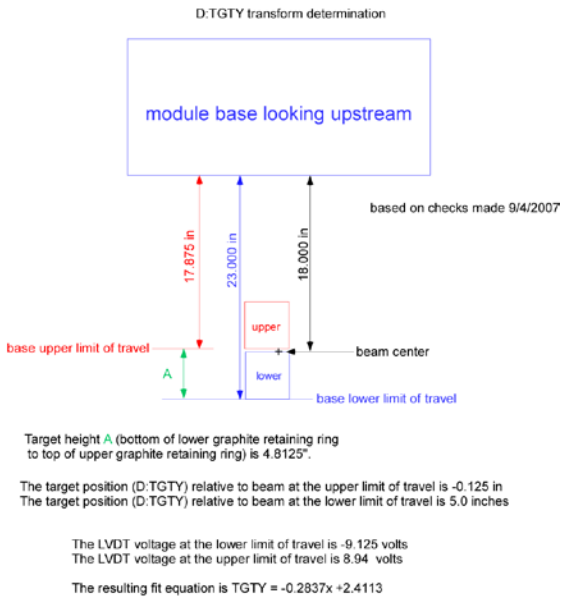


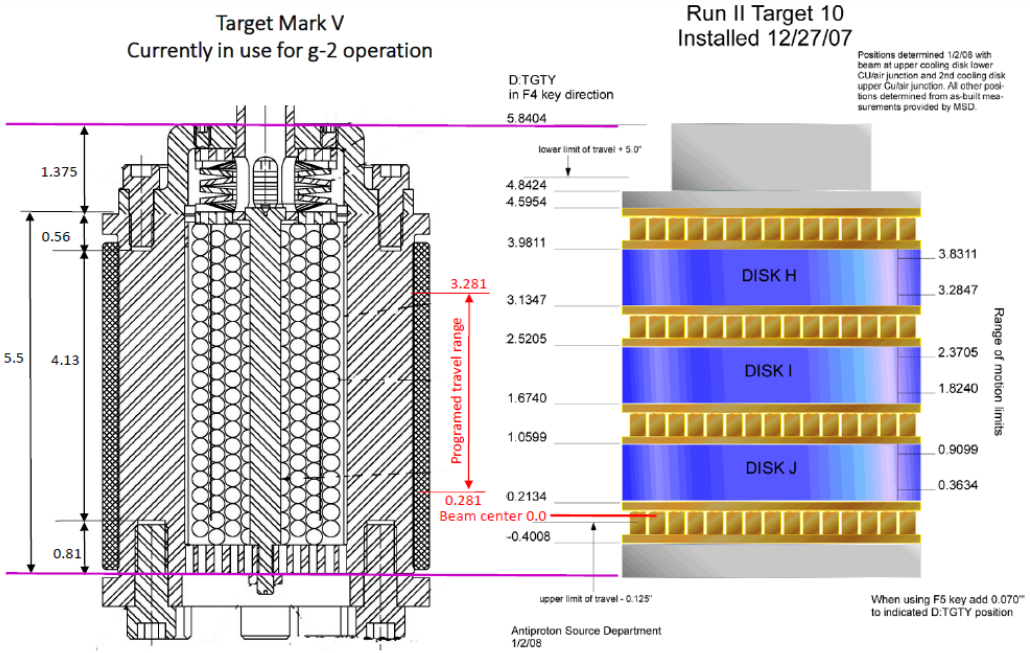
- Target is positioned relative to the proton beam such that the beam subtends a chord of the cylinder
- transverse motion (X) of the cylinder axis perpendicular to the beam allows the effective length of the target to be changed;
- the vertical position (Y) is automatically changed by a Controls System ACL script about 1 mm after every 2E16 protons.
- The target is mounted on a horizontal pivoting arm, which allows target motion of a few centimeters along the beam direction. This allows remote optimization of the target-lens distance (Z).
- Target is continuously rotated (ROT) about its axis with a period of 45 seconds to prevent prolonged energy deposition in any particular location.



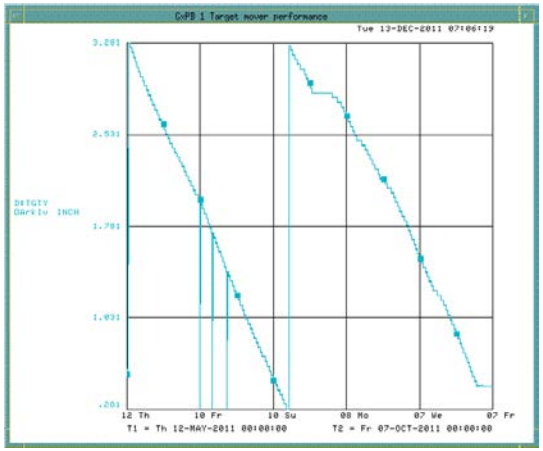
- Stalled target rotation and vertical motion would have led to severe target damage in a short time

6) Target X, Y, Z and Rotation Motion Control (Y-motion)





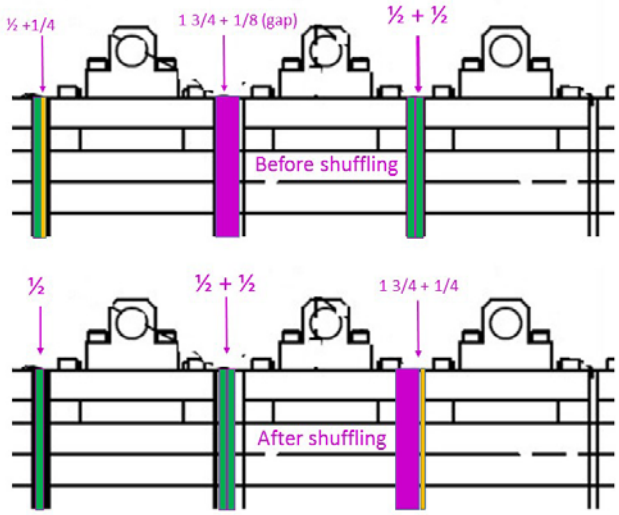
ACL script is updated by Tony Leveling for g-2 operations

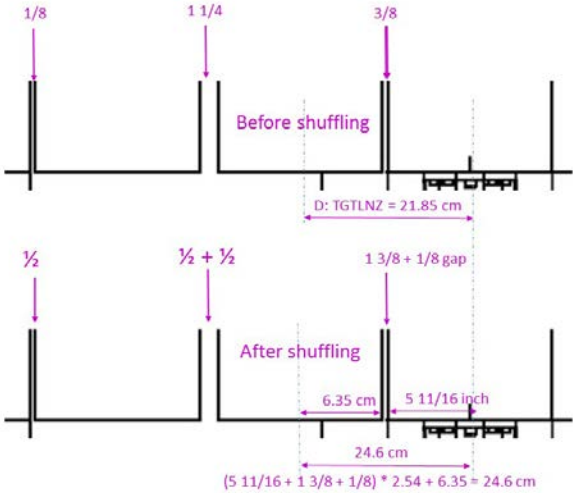


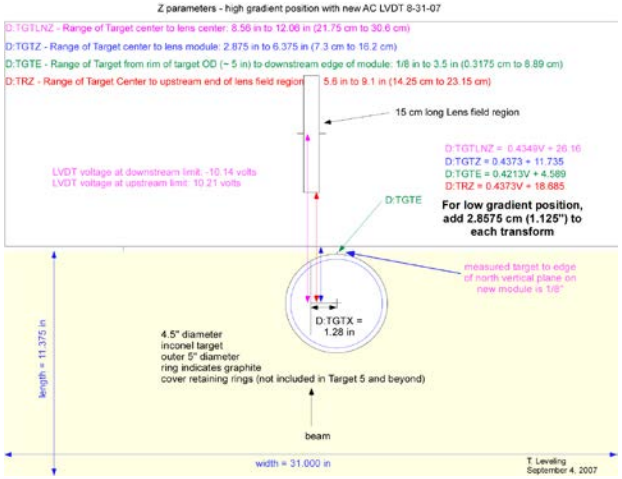
The script will be automatically run every hour as a batch job by AD controls.
The ACL script "pbar_target_mover.acl" is located at cd mecca/services/utility_acl and **is described in <u>Beams doc.db 5357-v1</u>.**

7) Target Z Repositioning

A few module filler plates are repositioned to increase the distance between the target and lens per **low gradient target position**







Tony Leveling has modified the database transforms for the following 4 devices to indicate corrected readback positions following repositioning the thick filler plate

Unit(cm)	D: TGTLNZ	D: TGTZ	D: TGTE	D: TRZ
Before	26.16	11.735	4.589	16.685
After	28.91	14.485	4.589	21 435

8) Target Rotation Mechanism Maintenance

Followed the procedure from ADDP-ME-0700:

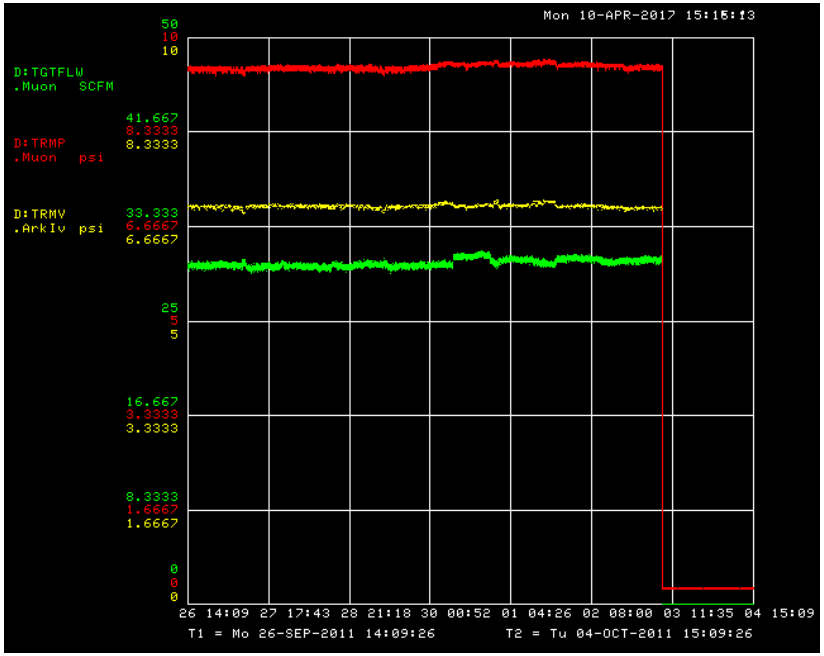
1. Attach the middle shaft clamping fixture.
2. Loosen the four bolts that secure the bearing block
3. Using ACNET controls, lower the Y position such that the weight of the target and/or middle shaft is fully supported by the middle shaft clamping fixture. You will observe the retaining ring being raised above the rotating shaft collar.
4. Once the weight is off of the retaining ring, remove the retaining ring.
5. Loosen the three set screws securing the rotating shaft collar and remove collar.
6. Remove and inspect the thrust bearing. Replace if necessary.
7. Carefully remove the bearing block which includes the Reali-Slim bearing. Inspect the Reali-Slim bearing and replace if necessary.

9) Target Air Cooling System Re-startup

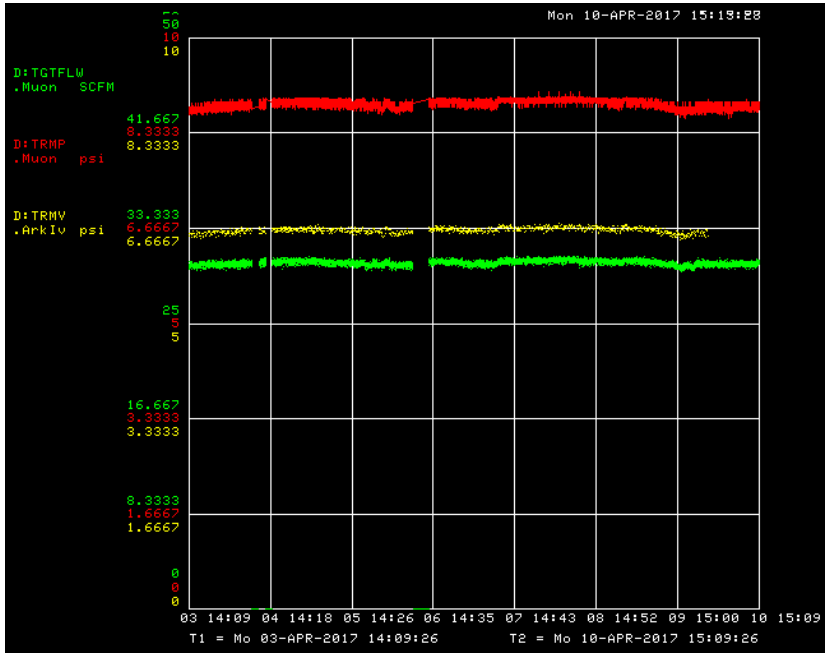
Changed belts, changed oil, greased bearings, replaced air filter and reinstalled sound box

Target Air Cooling parameters are consistent with those in 2011

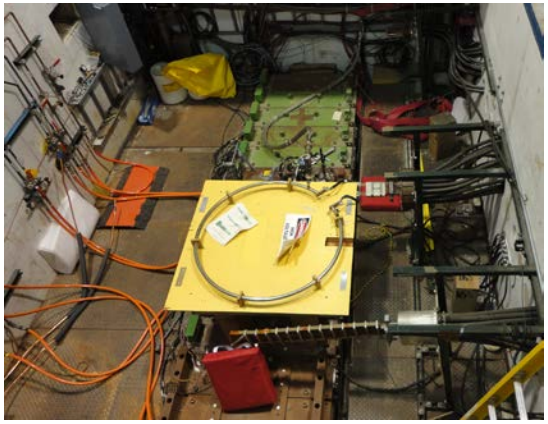
October 2011

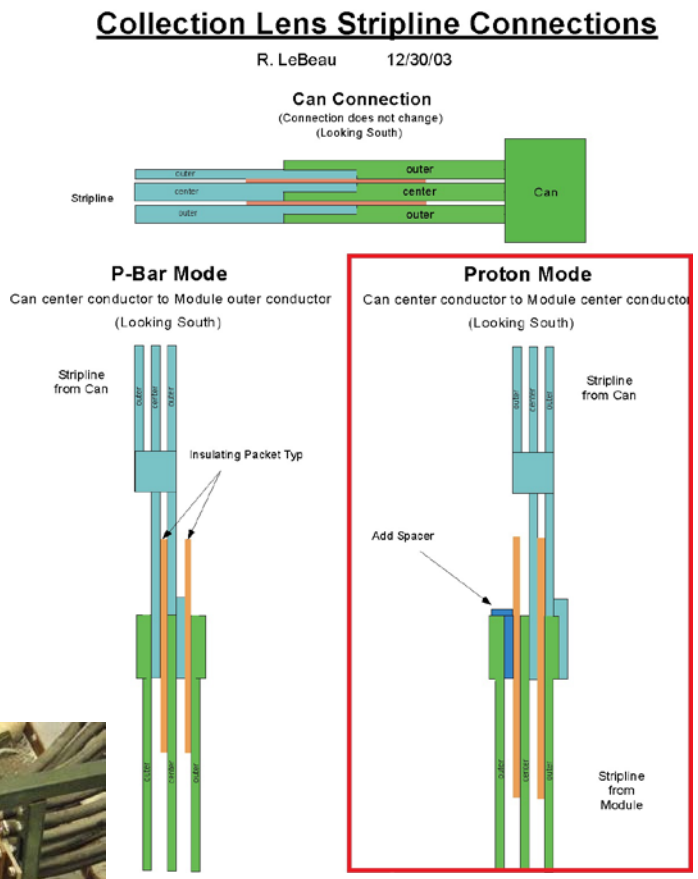


April 2017

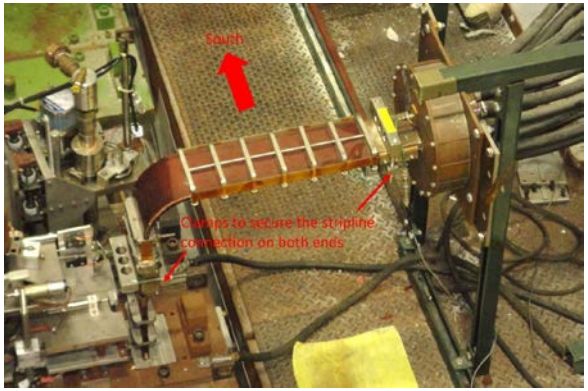


10) Install Lens Dummy Load for New Power Supply Testing





- Dummy load securely anchored to prevent its movement during testing.
- Welding cables lugs used to connect the strip line to the dummy load are mechanically secure at both ends.
- When re-install the real stripline back to the lens after the test is completed, ensure that the stripline connection is using "Proton Mode" configuration



AP0 Target Hall Readiness

Had been deserted for a few years since Tevatron shutdown in Oct. 2011

- Brief occupancy for g-2 test run in 2012-2014
- Dusts and junks everywhere, etc

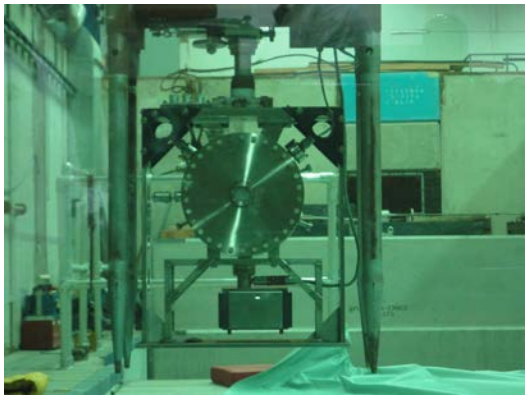
- Hall cleaned up
- Now ready to receive the Beam Absorber

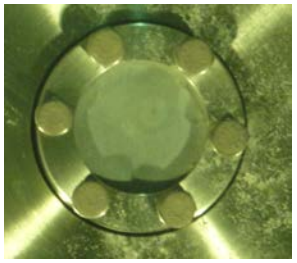
Wi-Fi is installed

- Convenient for reading ACNET parameters while working in water cage
- Access to online documentation
- Write Elog, use laptop, office work, etc.

B1) Secondary Emission Monitor(SEM) Repairing (Ion Pump, Be Window)

- SEM was removed from Vault due to the Ion pump could not get started
- It was verified that the ceramic on HV power feed-thru was broken
- Spent much time and efforts on shielding setup, ion pump removal/re-installation, rough pump hook-up, leak checking, etc. Finally it was discovered that both Be windows have large leaks
- Somehow the historical data of SEM vacuum are not available/or reliable. It is unknown if SEM wires are still in good condition. Now Muon dept. is working on the verification of SEM grid wires condition





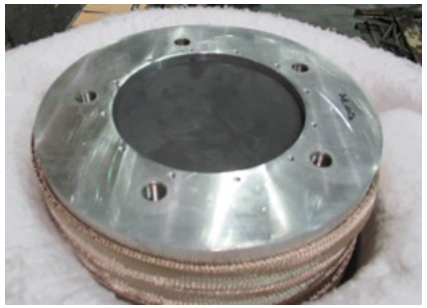
- Ron LeBeau led the effort and prepared ALARA plan

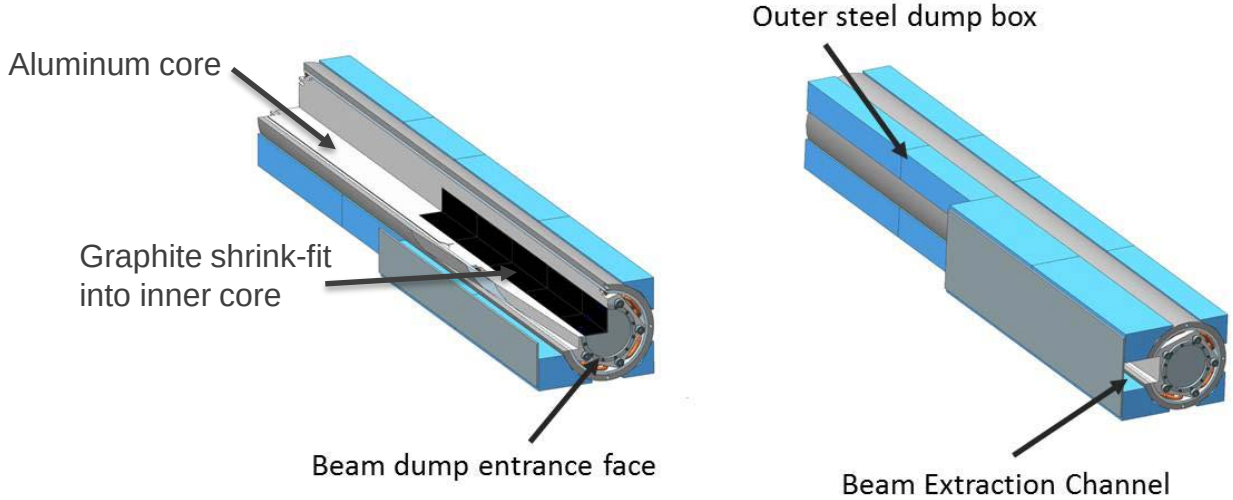
Operation									
1	Disconnect operational high voltage connector from ion pump	1	0.5	Reaching into alcove around side of lead door	1.667	0.83	3.00	15.00	
2	Connect test high voltage connector and cable to ion pump. Run cable outside alcove.	1	0.5	Reaching into alcove around side of lead door	1.667	0.83	1.00	15.00	
3	Attach Hi-Potter to high voltage connector at top of module and test rad hard cable at 10 Kv.	1	5	Platform at top of module	0.033	0.17			
4	Attach ion pump power supply to high voltage connector at top of module and test rad hard HV cable.	1	5	Platform at top of module	0.033	0.17			
5	Attach Hi-Potter to high voltage cable outside of alcove and test SEM ion pump at 5 Kv.	1	5	Vault outside of steel door	0.083	0.42			
6	Attach ion pump power supply to high voltage cable outside of alcove and test SEM ion pump.	1	5	Vault outside of steel door	0.083	0.42			
7	If HV cable, connector and IP tested OK disconnect test HV cable and reconnect operational HV cable to ion pump. If not, disconnect test HV cable and leave operational HV cable disconnected.	1	1	Reaching into alcove around side of lead door	1.667	1.67		30.00	IP ceramic connector found to be cracked! IP must be replaced!
8	Open steel door and rotate SEM Module so that AMV faces south, return module to alcove raised with cribbing, close lead door.	2	2	Platform at top of module	0.167	0.67			One crane operator and one person to rotate module from above with a
9	Open lead door and position radiation shielding that will allow access for ion pump replacement	2	5	vault	1.667	16.67	1.00		
10	Slide steel bridge plate under ion pump and add supports on floor	1	1	Through shielding wall	3.333	3.33	3.00	30.00	Need to measure exposure rate behind temporary shield wall
11	Loosen and remove the six ion pump bolts	1	6	Through shielding wall	3.333	20.00	10.00	180.00	Need to measure exposure rate behind temporary shield wall
12	Remove ion pump and copper seal by sliding out on bridge plate.	1	2	Through shielding wall	3.333	6.67		60.00	Need to measure exposure rate behind temporary shield wall
13	Slide new ion pump and copper seal into position on steel bridge.	1	2	Through shielding wall	3.333	6.67	10.000	60.00	Need to measure exposure rate behind temporary shield wall
14	Insert and tighten the six IP bolts being careful to properly position copper seal.	1	6	Through shielding wall	3.333	20.00	43.00	180.00	Need to measure exposure rate behind temporary shield wall

- Discoloration due to oxidation or degraded due to beam energy deposition?
- Four spare Be window on hands, ordered brazing joint CT scanning

B2) Beam Absorber

- Removed old beam absorber (a.k.a. dump, a.k.a. abort)
  - Had cooling water leaks
- New dump based on previous design (80kW, g-2 =>16kW), Drawing F10015278
  - 2.4 meters long
  - Three shrink-fits of different materials : graphite, aluminum and steel
  - Continuous copper tubing with a MAWP of 120 Psi, requires a 4-hour pressure test at 1.5 MAWP





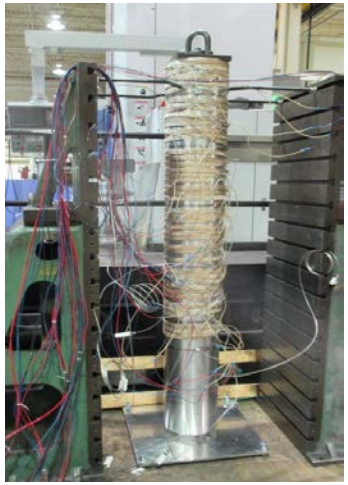
Precision tolerances for the interference fit over the length of the absorber core

Inner	Outer	Diameter	Diamentral Interference Fit
Graphite	Aluminum	6.000”	**0.010”**
Aluminum	Aluminum	ID:9.750” / OD:10.500”	**0.005”**
Aluminum	**Steel**	**12.000”**	**0.003”**

B2) Fabrication of New Beam Absorber

Kris Anderson is leading the effort, making day-trips for vendor visit for each critical step throughout the fabrication process

Water line channels machined



Heating tapes for shrink-fit process

- 5 zones for temperature control
- 3 band heaters per zone
- Each band heater 1.2kW, w/ a total 18 kW heating power
- wrap the whole mess in 2” thick ceramic wool
- First shrink fit at about 160°C, second shrink fit at 180°C +
- Last shrink fit at about 200°C

water lines in place

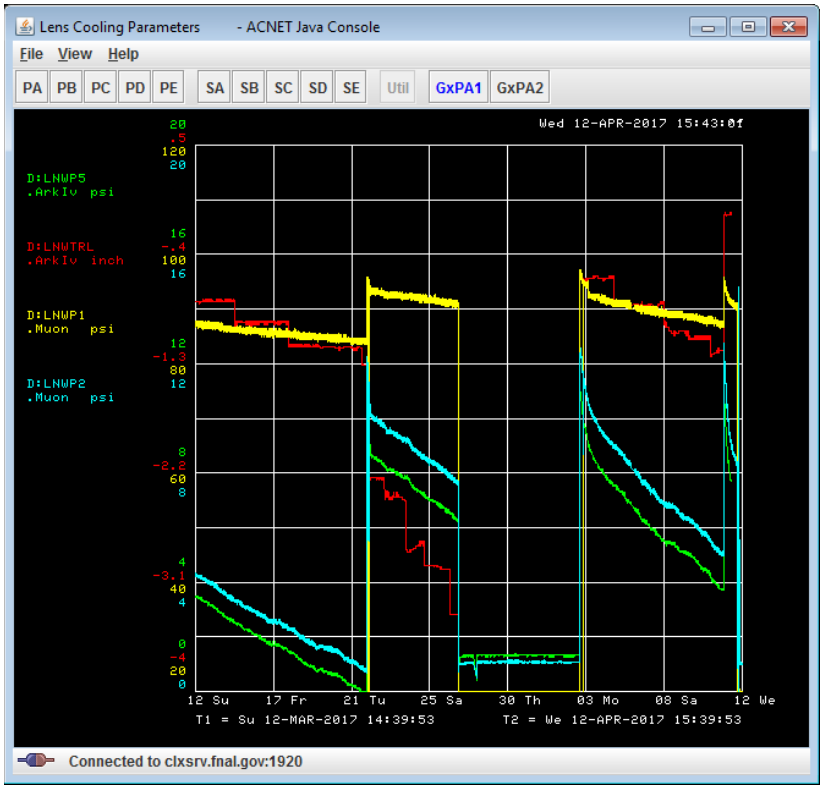
Core shrink-fit into aluminum sleeve

- Shrink-fit into outer steel sleeve – April 18
- Final core angle welding and dowel machining for alignment hanger mounting – April 21
- Delivery – late the week of April 24
- Assemble at Fermilab – one week
- Installation – one week

B3) Replace a Few Water Skid Components

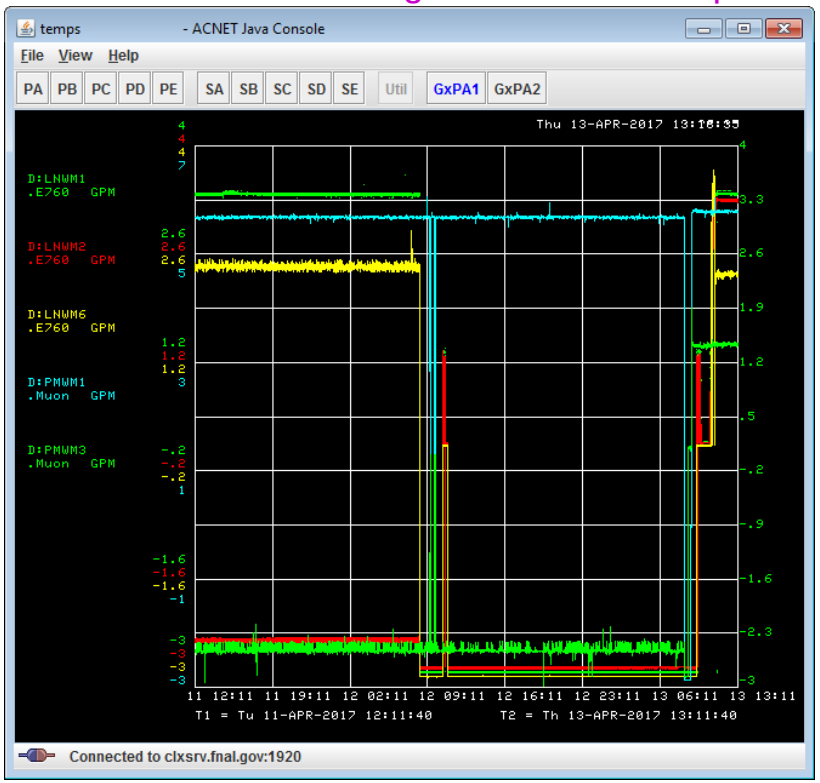
- Lens water skid heat exchanger, to be arrived on April 13 (w/ UPS tracking number)
- One flow meter in Absorber WS
  - Replaced 5 flow meters in PMag and Lens WS, April 12-13 they are now working properly

Water lose in Lens water skid over past month



Water level and pressures are dropping vs. time

5 flow meters in Lens/PMag water skids over past 2 days



Negative readings or with noisy signals are back to normal

SharePoint Web Site

Muon g-2 Target Station | Pbar Target Station | Pbar Target Station elog | Pbar Target Station Procedures | Pbar Target Station References | Target Hall Facilities

Muon g-2 Target Station

- Home
- Target Station to TSD
- SEM
  - SEM Description
  - SEM Drawing 322232 Nov1999
- Target
  - Target Description
  - Target-MK5 Drawing 449255 March2010
  - Target Motion Control
  - Target Rotation Mechanism Maintenace
  - Target #18 Operation Notes
  - Target #18 Installation Notes
- Lens-n-Transfomer
  - Lithium Lens Drawing 413621 Sep2009
  - Lens-n-Transformer 413677 Sep2009
  - H.G. Lens Design PAC03-TPAG010
- Collimator
- Pulsed Magnet and Module
  - Pulsed Magnet MK3 322170 June1994
- Beam Dump

The main page provides information about the water systems that Target Systems Department is maintaining. The recent changes in Target position and motion control and current activities at AP0 target station are also summarized here.

The Side Navigation menu lists information about the current target station devices, while the Top Navigation menu lists information about the Pbar target station.

Beam Dump Cooling Water System	Collection Lens Cooling Water System	PMag Colling Water System
BDump water skid schematic	Lens water skid schematic	PMag water skid schematic
Pictures with description	Pictures with description	Pictures with description
BDump water system re-startup	Lens water system re-startup	PMag water system re-startup
	Water conductivity cell testing	
Common features in all three water skids		
Auto-vent system		
Chill water temperature regulation		
Filter bypass circuit		
Interlocks and current readings of water system devices, procedure for setting alarm card		
Manuals of standard parts		

Target Motion Control
Target motion control
Target Z repositioning per low gradient configuration, (March, 2017)
Target vertical motion-Y ACL script test run (A. Leveling, April 3, 2017)

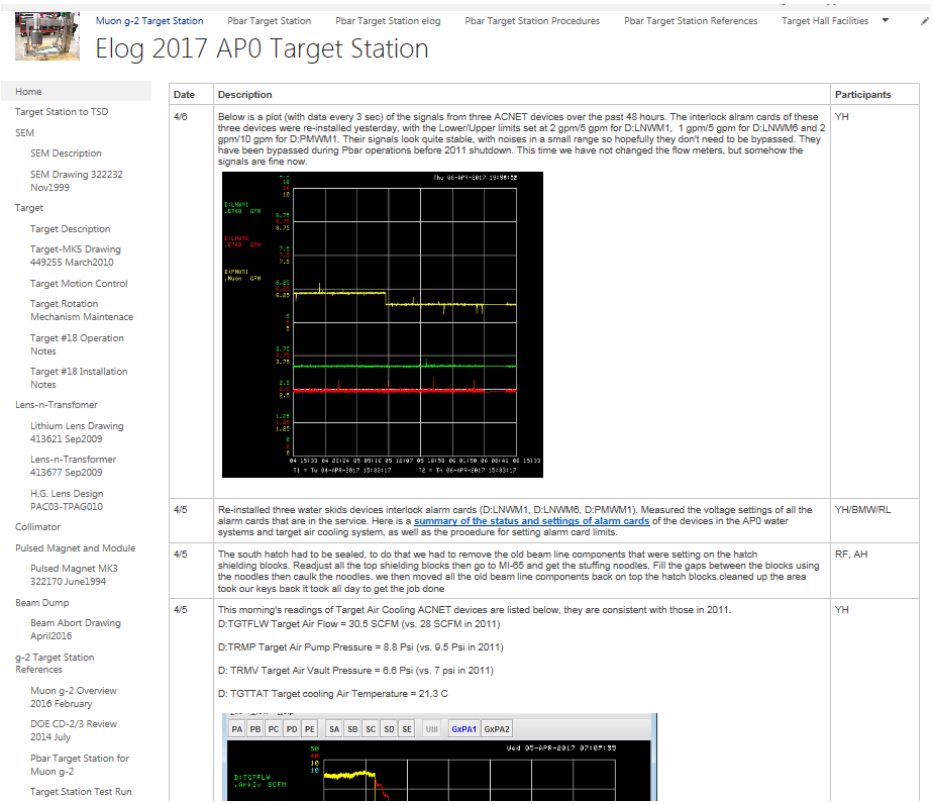
Elog (Jan. 30, 2017 to current)

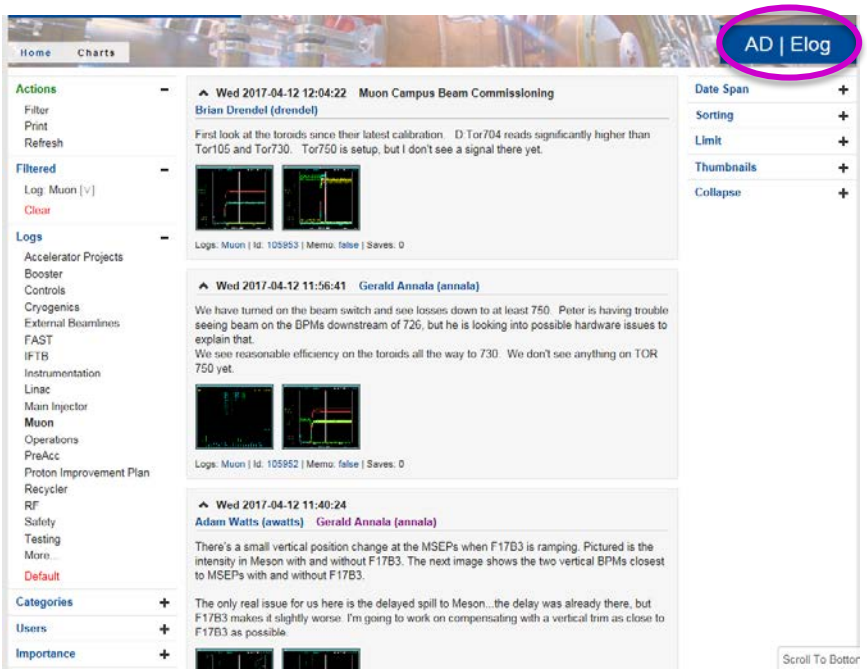
- Communication
- Documentation
- E-log
- User-friendly

Link: https://web.fnal.gov/experiment/MuonG2/g-2_target_hall/SitePages/Home.aspx

Target Station Elog

- We have been using SharePoint site for Elog entries
- As the work is transitioning into operation mode, it is necessary to have Elog migrated into AD/Elog system
- A new Elog filter/tag/category dedicated to “g-2 Target Station” will be created in AD/Elog





Muon g-2 Short-term Beam Commissioning Plans

April: 8 GeV protons bypass target, through shared M4

May: 8 GeV protons to target, 3.1 GeV secondaries to g-2 ring

June 23th: shutdown

Slide copied from Muon Campus Readiness Review March 2017

Acknowledgement

- Thanks Tony Leveling for providing guidance and detailed explanations about the operation issues associated with the cooling water skids and target motion control

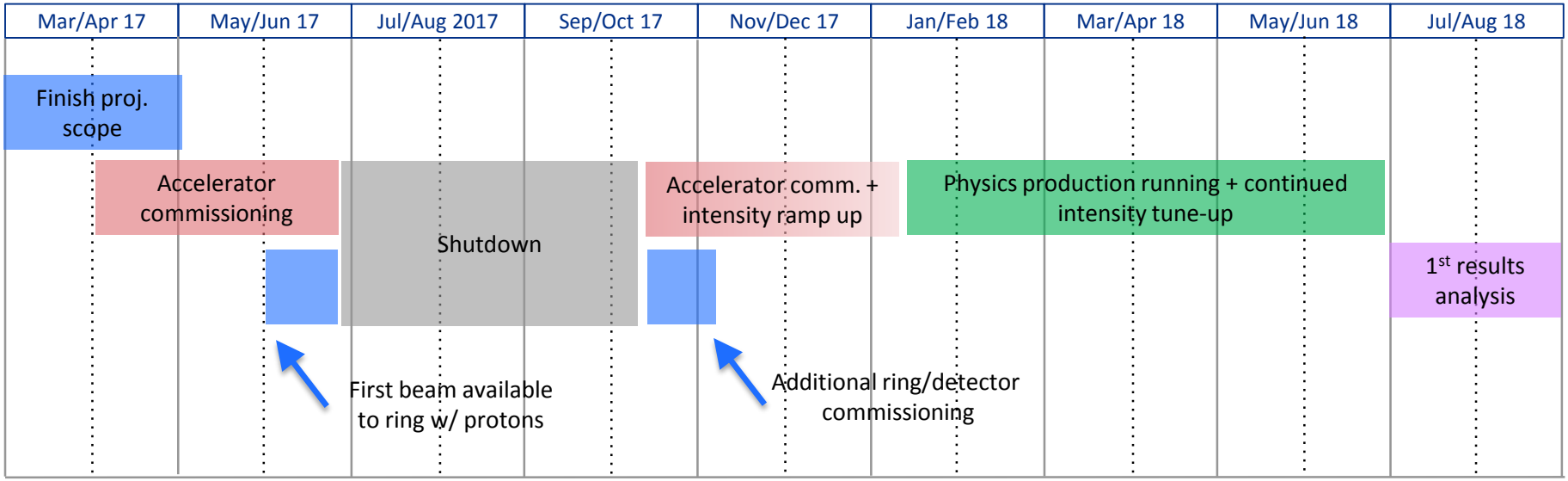
- Thanks Paul Sedory for being available when radiation coverage is needed for access the target vault and water cage

- Abhishek Deshpande provided guidance for the setup of heat exchanger pressure test

- James Zahurones, Amos Horton and other TSD staff have provided assistance

Backup slides, taken from Muon Campus Readiness Review March 2017

Muon g-2 Schedule (Acc. Readiness Review, March 2017)



- Project 6 months to fully commission muons to the storage ring with proton removal operational and at a reasonable intensity with proton removal in the Delivery Ring
- Project 6 weeks (minimum) to commission ring and detectors once muons arrive
- Schedule constraints
  - Need as much data as possible prior to shutdown to effectively use beam off-time to fix any discovered issues
  - Aiming for enough physics production data in 2018 to produce a result with slightly better precision than BNL
- Simulation projects 10 months of running at full intensity to get statistics + 6 months for systematic studies

Beam Commissioning Strategy

- 8 GeV protons through M1
  - BPM's used to steer orbit, existing reference orbit can be used for most of the line
- 8 GeV protons through M3 to Delivery Ring
  - M3 commissioned with 8 GeV protons and BPM's, augmented with SEM's and PWC's
- 8 GeV protons into Delivery Ring
  - BPM's used to steer orbit, existing reference orbit can be used for most of the Ring
- 8 GeV protons into Upstream M4
  - Up to M4/M5 split, M5 can't operate at 8 GeV
  - Upstream M4 commissioned with 8 GeV protons and BPM's, augmented with PWC's
- 8 GeV protons to the target
  - Steer beam to Run II nominal on Target SEM
- 3.1 GeV beam down M2 and M3
  - M3 magnet settings scaled from 8 GeV
  - SEM's, PWC's and Ion Chambers used for tuning
- 3.1 GeV beam straight through Delivery Ring (D30) into M4 and M5
  - M4 magnet settings scaled from 8 GeV
  - PWC's and Ion Chambers used for tuning
- 3.1 GeV beam into g-2 Storage Ring
  - Requires input from Storage Ring experts to define proper trajectory and optics
- 3.1 GeV proton removal in Delivery Ring
  - Commission 3.1 GeV beam in Delivery Ring and proton removal to the Delivery Ring Abort
- 3.1 GeV muons to g-2 Storage Ring
  - Low intensity muon beam in Upstream M4 and M5

More details in GM2-doc-2215

Summary

- The necessary accelerator hardware, beamline controls and monitoring systems are ready for commissioning and operating Muon Campus beam to the g-2 experiment
  - With the following exceptions:
  - Power supply checkout will be complete by April 1
  - We would not run beam to the target until the new target station beam dump (copy of old dump) is installed
  - The proton-removal kicker power supply, of the same design as the injection and extraction kicker power supplies, is not complete; proton removal is not needed for the first 2 stages of commissioning
- We are requesting approval to commission and operate beam to g-2

Still to do

- Target Station
  - Dump will arrive in April
  - Pulsed power supplies capable of pulsing in April
- Kicker Systems
  - Abort Power Supply needs to be installed in the service building
  - Abort Magnets need to be placed in the beam line (no vacuum work needed)
  - Abort kicker cables need to be run from PS to magnets
- Other unfinished system cabling
  - Instrumentation terminations
  - AP-30 shunts
  - Motion control in AP-30
- Power Circuit Verification (30 straight section and M5 line magnets)
- Instrumentation Check out (regular testing is ongoing)