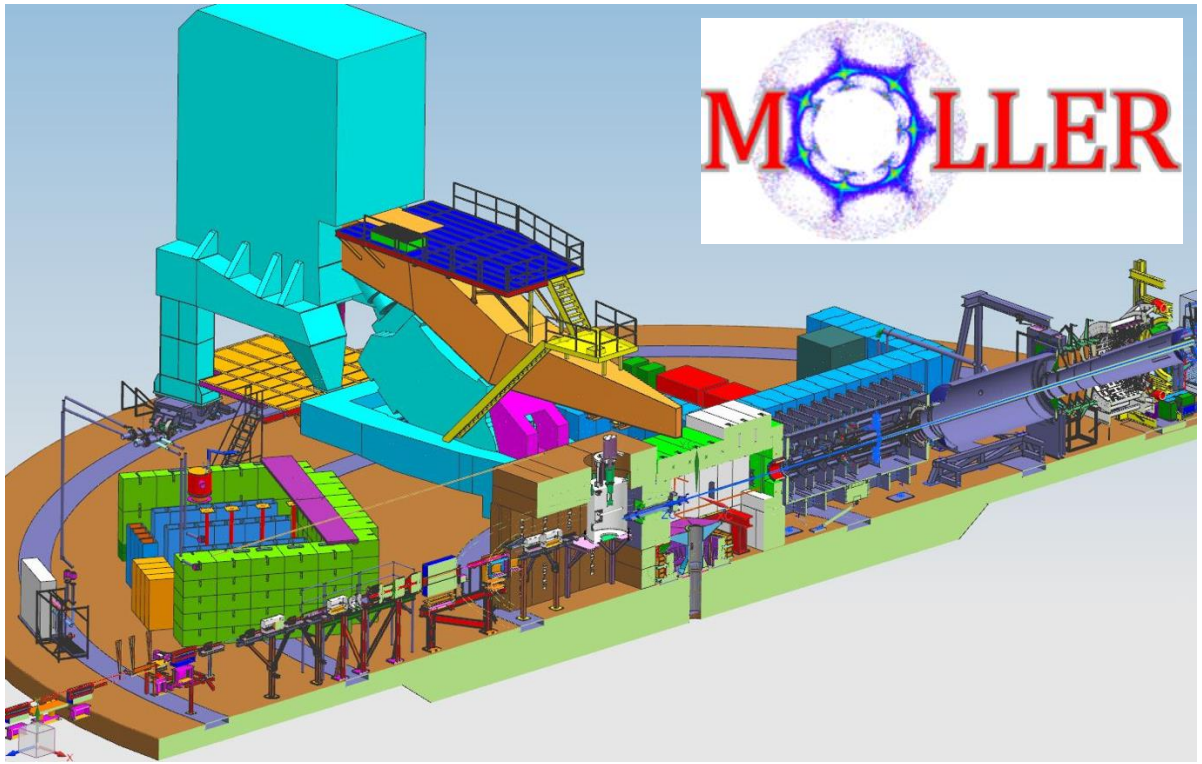
MOLLER ERR2 - Spectrometer

Spectrometer overview and integration



Michael Dion – CAM

July 28th, 2025

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Charge - Summary

The committee is requested to assess if the design, fabrication, installation, protection systems, and operational procedures of the MOLLER Spectrometer satisfactorily support safe and efficient operation of the magnet within performance specifications. The MOLLER Magnets (5 individual magnets) will be operated for the first time during test in the High Bay test lab (Bldg. 58). The magnets will be energized in the test lab prior to moving into Hall A after successful completion of this review. The following points will summarize the magnet status and test plans to the committee:

- Summary and results of the major magnet analyses done.
- Summary and results of major components to be assembled in the test lab/hall (e.g. bellows, window, etc.).
- High-level commissioning and running plans.
- “What if” scenario if performance specifications are not met.

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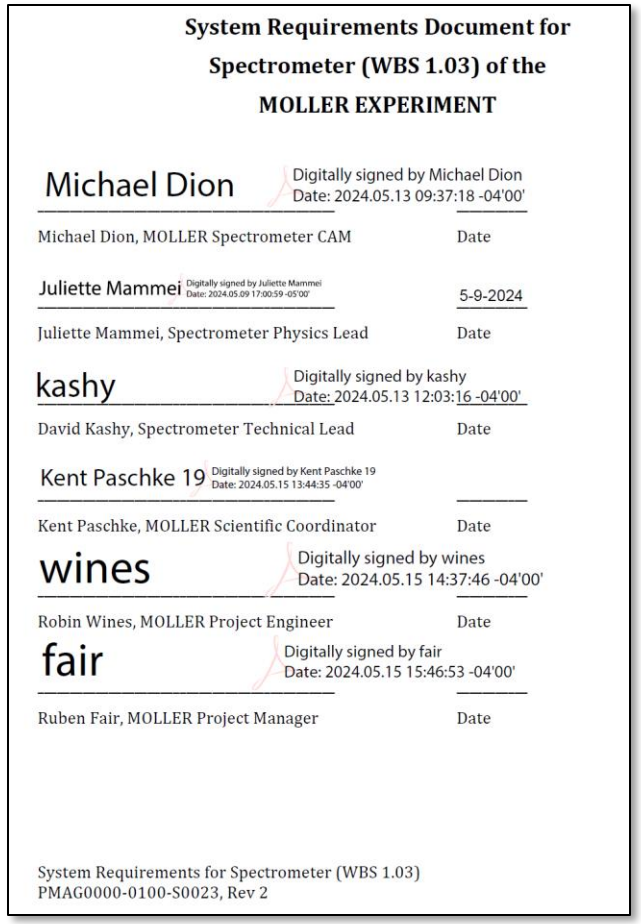
Summary and results of the major magnet analyses done

- Requirements flow down→"System Requirements Document for MOLLER Spectrometer (WBS 1.03) of the MOLLER EXPERIMENT" (PMAG0000-0100-S0023, Rev 2)
  - **Materials:** Defines prohibited and allowed; ferromagnetic limits[1], long half life activation, compatible epoxies, etc.
  - **Magnets:** Current and temp stability, power deposition, coil current and B-field vector definitions[2,3,4]
  - **Enclosures:** Nominal 1 X 10^{-2} Torr
  - **Collimators, Blockers, Shield Elements:** Machining, location, positioning accuracy, power deposition (cooling needs)
  - **Beam Pipe, Windows, Bellows:** Accuracy of detector window thickness and concentricity, beam pipe and drift pipe positioning, bellows spec[5] and gasketing for each.
  - **Field Measurements:** Preliminary specs to be finalized now that prototyping complete.
  - **Instrumentation:** Wire and location definitions for radiation mitigation.



System Requirements Document for Spectrometer (WBS 1.03) of the MOLLER EXPERIMENT

Michael Dion — Digitally signed by Michael Dion Date: 2024.05.13 09:37:18 -04'00'
Michael Dion, MOLLER Spectrometer CAM — Date

Juliette Mammei — Digitally signed by Juliette Mammei Date: 2024.05.09 17:00:59 -05'00'
5-9-2024
Juliette Mammei, Spectrometer Physics Lead — Date

kashy — Digitally signed by kashy Date: 2024.05.13 12:03:16 -04'00'
David Kashy, Spectrometer Technical Lead — Date

Kent Paschke 19 — Digitally signed by Kent Paschke 19 Date: 2024.05.15 13:44:35 -04'00'
Kent Paschke, MOLLER Scientific Coordinator — Date

wines — Digitally signed by wines Date: 2024.05.15 14:37:46 -04'00'
Robin Wines, MOLLER Project Engineer — Date

fair — Digitally signed by fair Date: 2024.05.15 15:46:53 -04'00'
Ruben Fair, MOLLER Project Manager — Date

System Requirements for Spectrometer (WBS 1.03)
PMAG0000-0100-S0023, Rev 2

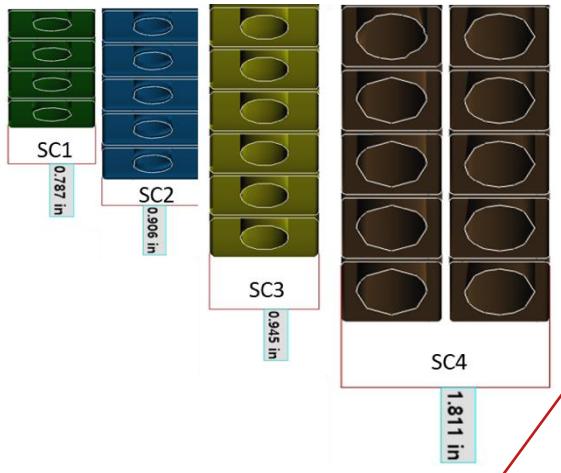
1. PMAG0000-0100-S0022 - MOLLER Materials List (Inside Enclosure)
2. PMAG0000-0100-A0007 MOLLER – Upstream and Downstream Coil Functional Requirements
3. PMAG0000-0100-A0009 MOLLER – Upstream and Downstream Coil Design Specification
4. PMAG0000-0100-S0014 - Moller - Magnet Power Supply specification (Upstream and Downstream)
5. PMAG0000-0100-S0016 - MOLLER Specifications of Bellows

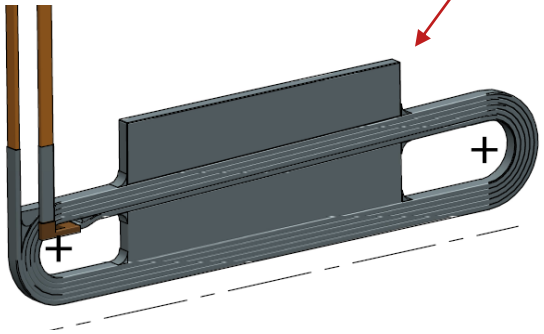
Summary and results of the major magnet analyses done (cont.)

- **Magnets→Design Review & Approval**

Physics requirements translated into a complete set of Engineering requirements and scope.

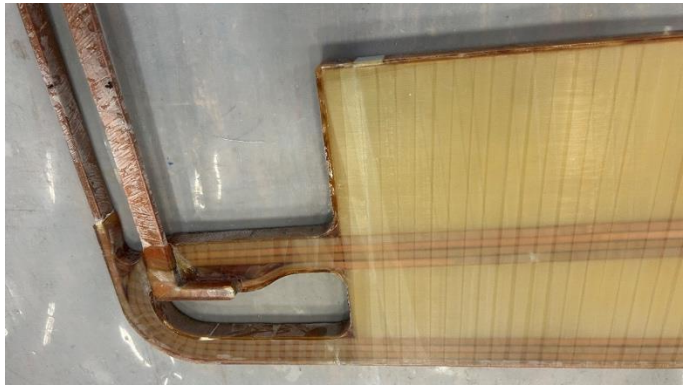
- **All parameters considered: conductor geometry, cooling (T rise), water flow rate, current density, etc.**



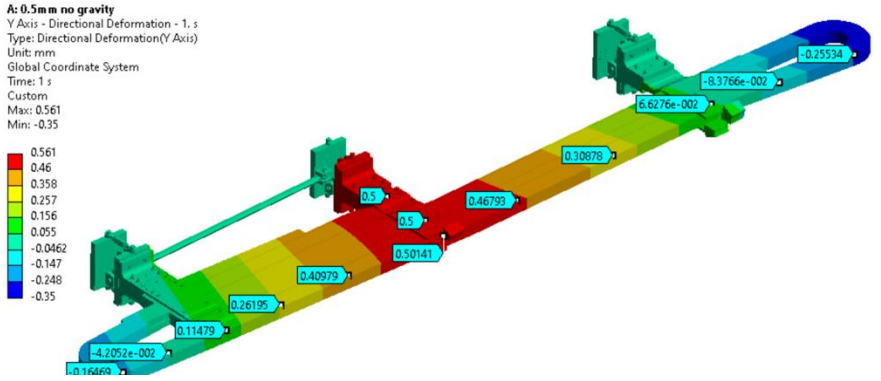


- Operation Current 100% value needed to achieve the physics; Design Current is defined as 110% of Operational
- (DS) Coils designed with G10 inserts providing stiffness and coil supports (Clamp Plates)
- Analyzed and confirmed stress during coil potting was acceptable

Magnet	Operational NI	Design NI	110% Current (amp) – N turns
US	5357	5893	1179 – 5
DS1	8915	9806	2451 – 4
DS2	12192	13412	2682 – 5
DS3	19391	21330	3555 – 6
DS4	33534	36887	3689 - 10



Production coil w/ G10



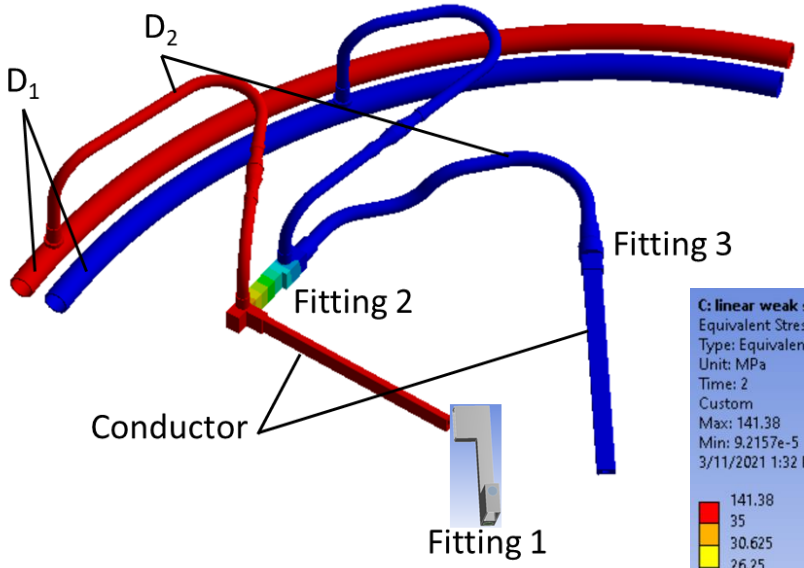
Investigate forces on coils: FEA shows low forces required to remove 0.5mm of bow to coil

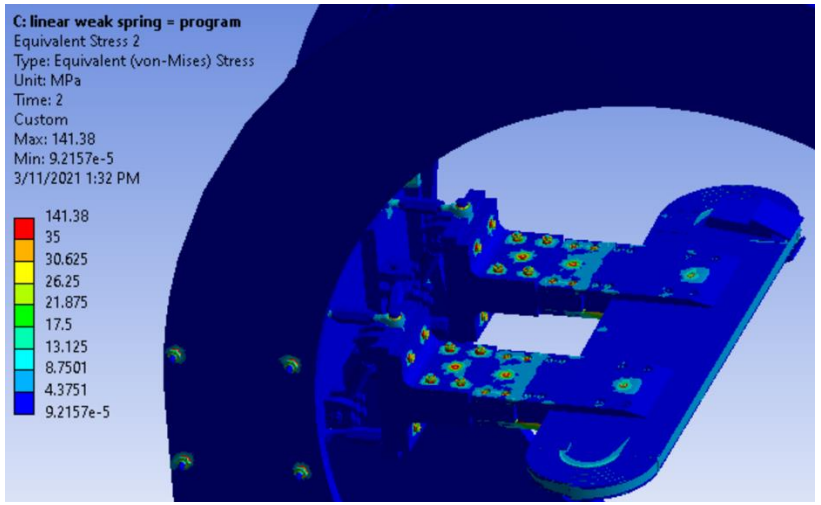
Summary and results of the major magnet analyses done (cont.)

- **Magnets→Design Review & Approval**

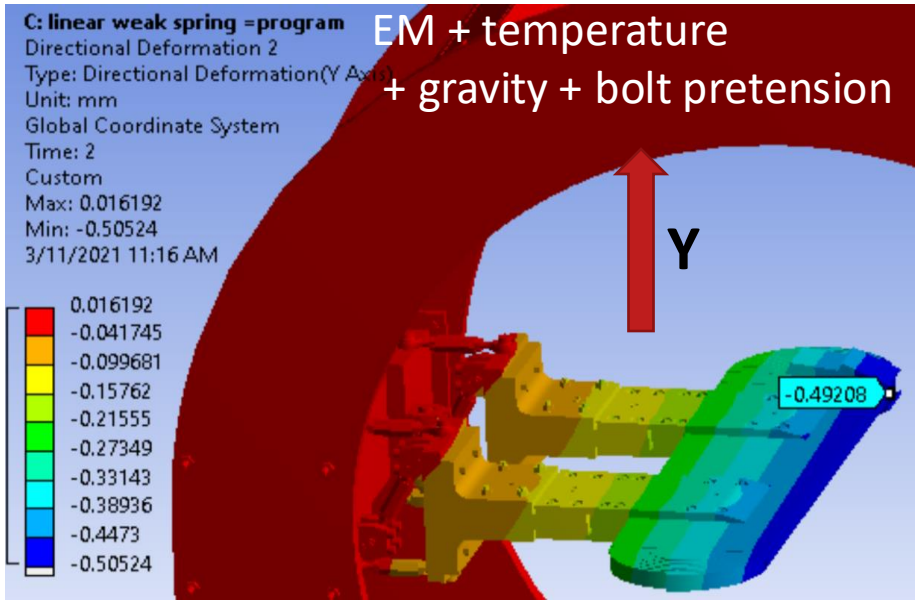
DS Spectrometer

- Extensive analyses of forces and impact on coil alignment
- Piping analyses, B31.3 code compliance





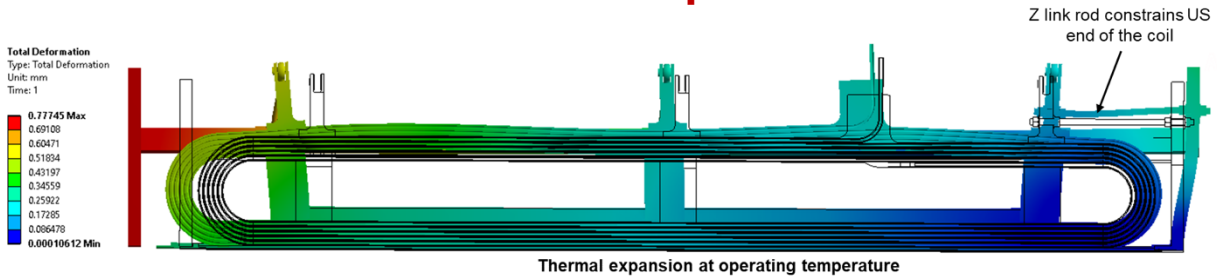
All stresses acceptable



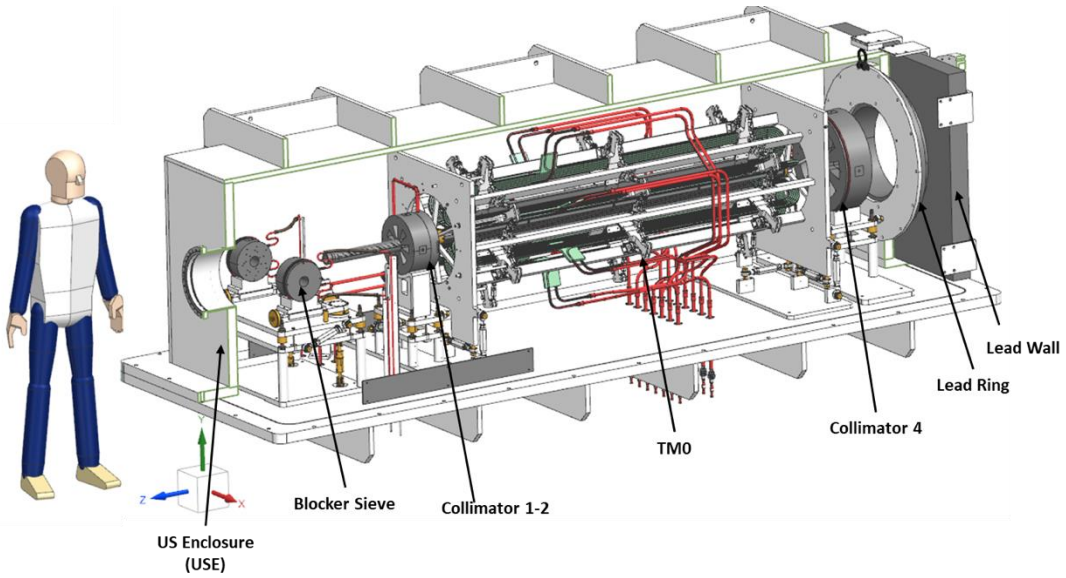
SC1, 2, 3 ~0.36 mm “sag”, 0.14 mm T influence

Summary and results of the major magnet analyses done (cont.)

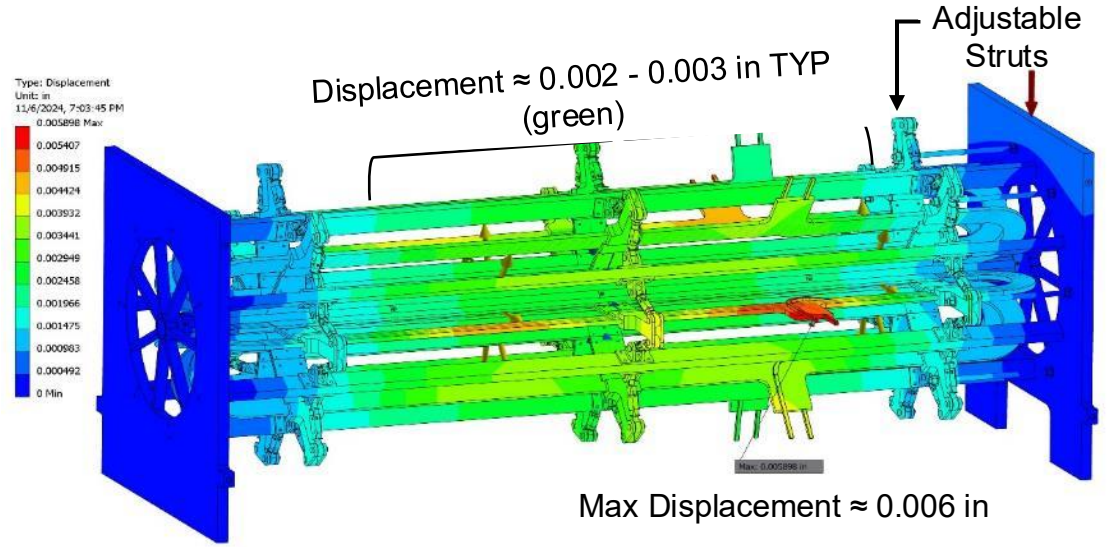
- **Magnets→Design Review & Approval**
  - **US Spectrometer:**
    - **Displacement, stress, thermal analysis are allowable/acceptable**



Thermal expansion at operating temperature



Loads: EM Forces + Gravity (-Y)
Contour Plot: Total Displacement, Auto Scale
Constraints: Bonded coil-to-2BS contacts, all struts connected



Max Displacement ≈ 0.006 in

Part Description (MTL)	Allowable Stress (ksi)	Max Stress (ksi)	Safety Factor
Coil Shear (Insulation)	7	0.2	35
Coil (Cu)	6	0.2	30
2BS (W)	98.4	0.7	141
Side Shield (W)	98.4	3.0	33
Magnet Frame (Al)	21	0.5	42

Summary and results of the major magnet analyses done (cont.)

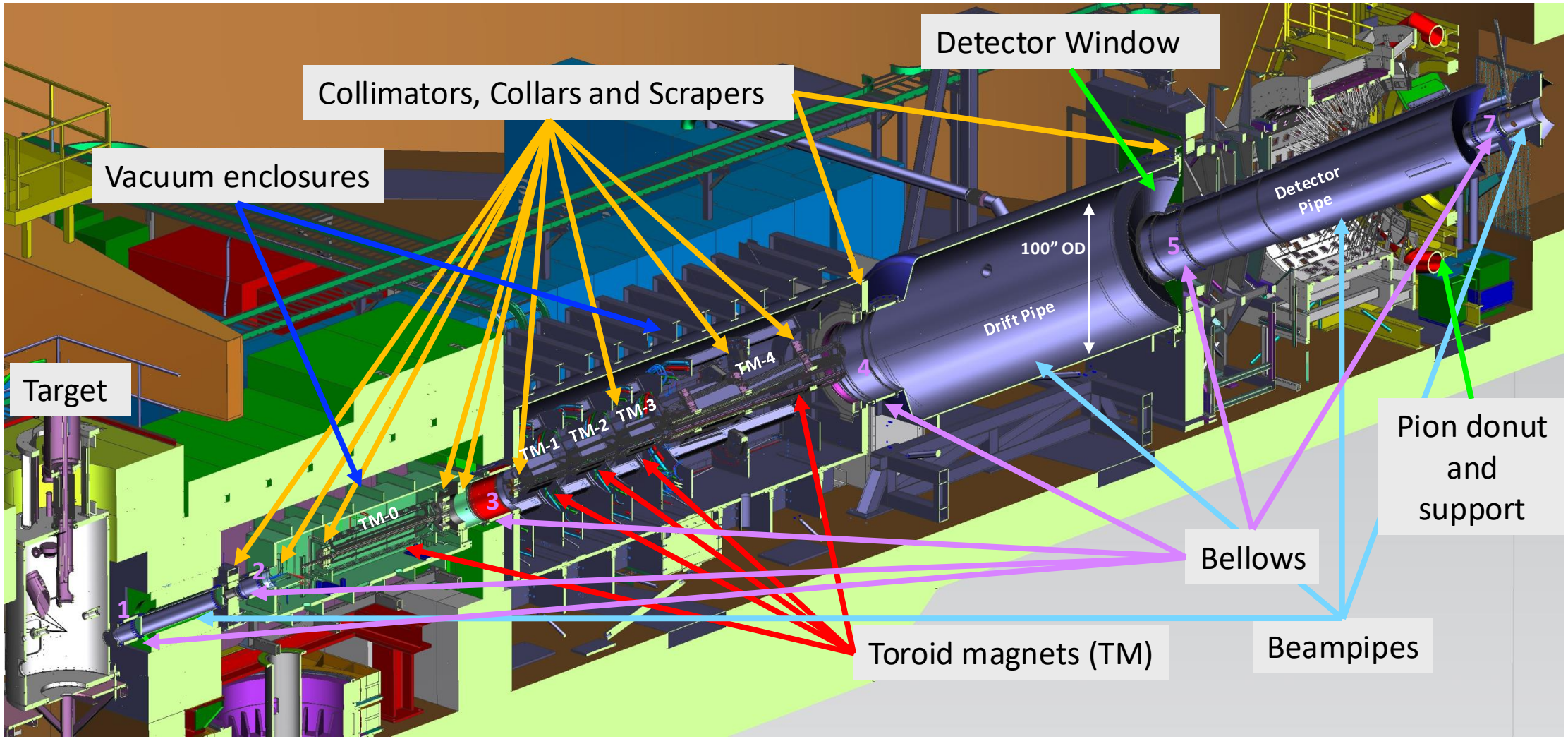
- **Coils:**
  - Worked with single vendor so lessons learned could be applied across production lines, and set/maintain expectations
  - Vendor sent data/test travelers for all coils (~13 pages/each)
    - Additional confirmatory testing at JLab
      - Hi-pot, coil insulation thickness, dimensional check, etc.
- **Magnets:**
  - Assembly, survey and alignment (more survey)
  - Braze and solder qualifications
  - Vacuum leak check all connections – water headers, etc.
  - Instrumentation installed and checked
  - Hi-pot and electrical tests
  - Hydrostatic tests

		JLab Downstream Torus Magnet SC1	
		Document # 53257-602-SC1 Revision # 0	
Work Order Number	18073	Coil Serial Number	SC1-02

Record all specified data from the JLab Downstream Torus Magnet SC1 MPO, Document # 53257-601-SC1.
All traveler users must fill out the user table at the end of this document.

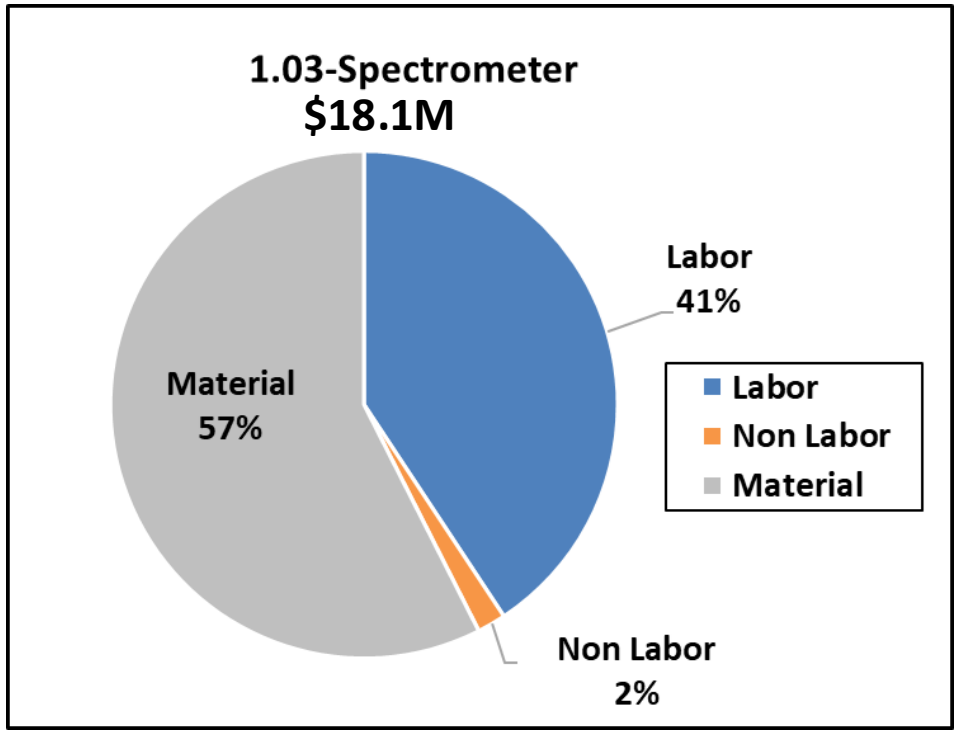
MPO	Task Description
4.1.1	Conductor meets the description in Section 4.1 of Document # 53257-601-SC1 Initials: BS Date: 5/23/23
5.1.5	SC1 coil winding complete Initials: BS Date: 5/23/23
6.1.1	Record dimensions of the SC1 conductor offset braze joints below Asset #: 00760 Due Date: 8/24 Inside Lead: 0.278" x 0.783" Inside Slot: 0.280" x 0.785" Outside Lead: 0.278" x 0.780" Outside Slot: 0.281" x 0.785" Initials: MS Date: 11/8/23
6.1.9	SC1 conductor offset braze joint complete Initials: BS Date: 11/10/23

Summary and results of major components to be assembled in the test lab/hall



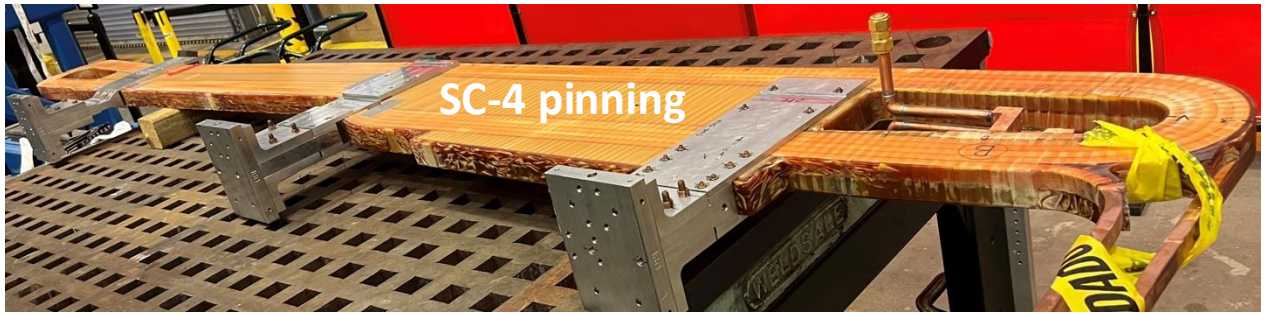
Summary and results of major components to be assembled in the test lab/hall

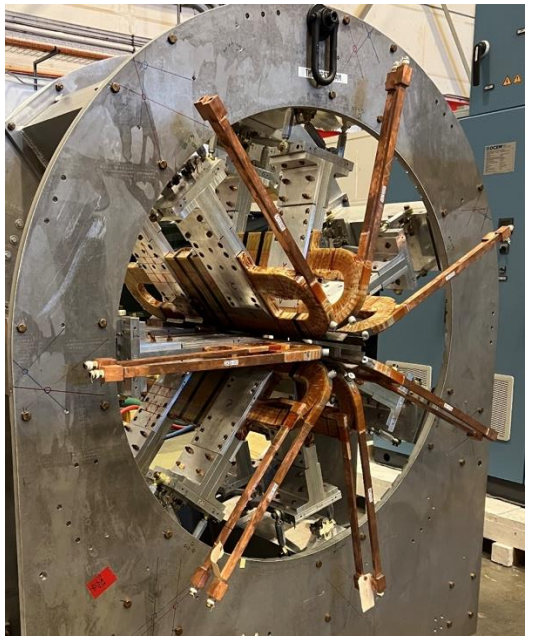
- Spectrometer Scope & Deliverables (**MOLLER Project**)
  - Five, 7-fold symmetry toroidal magnets (TM0-TM4)
  - Lead and tungsten collars, collimators, lintels, etc.
  - Beam pipes, bellows and toroid vacuum enclosures from *target exit window* to beam dump entrance pipe
  - Support stands with 6-D adjustments
  - Five magnet power supplies, leads and jumpers
  - Closed-loop cooling systems for collimators
  - Instrumentation and control software



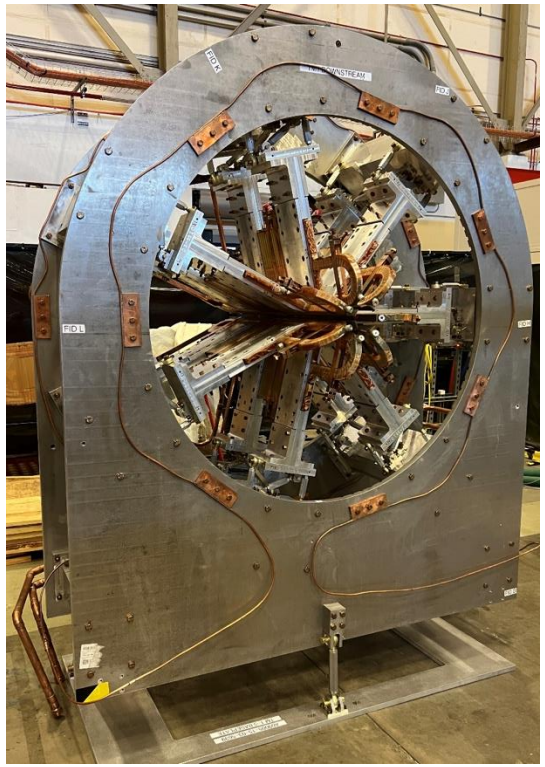
Summary and results of major components to be assembled in the test lab/hall

- Spectrometer Scope & Deliverables
  - Five, 7-fold symmetry toroidal magnets (TM0-TM4)
    - **All** coils fabricated, received and inspected
    - TM1, 2, 3 are assembled, including hi-pot and leak tests
    - SC-4 coils being assembled.





TM-3



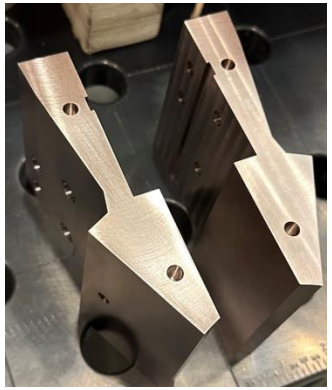
TM-1

TM-2

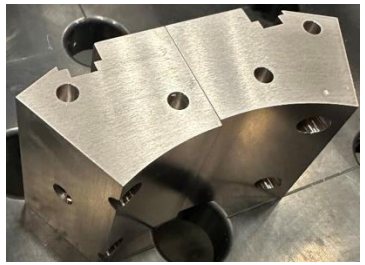
Summary and results of major components to be assembled in the test lab/hall

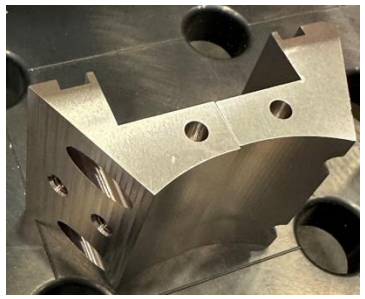
- Spectrometer Scope & Deliverables
  - Lead and tungsten collars, collimators, lintels, etc.
    - **Components received:** Collars 0 & 1, lintels, Coll 5 and 6, photon scraper, 2 bounce shield, Coll 4, Blocker & Sieve, Pion Donut
    - **Components in design, award, or fabrication:** Coll 1-2; brazing of cooling loops on Blocker, Sieve, and Coll 4; W shielding for US Enclosure o-ring; US lead mini wall

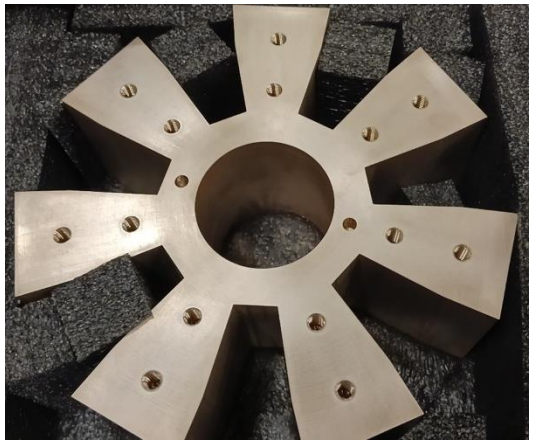
Collar 0



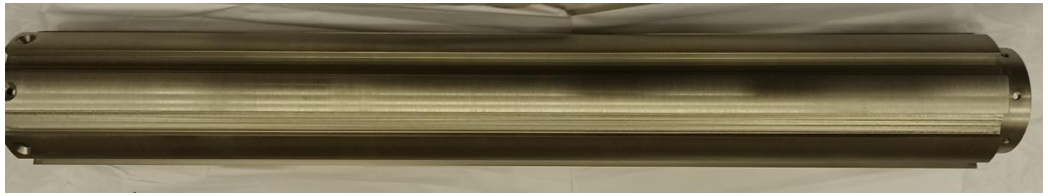
Coll 5 & 6



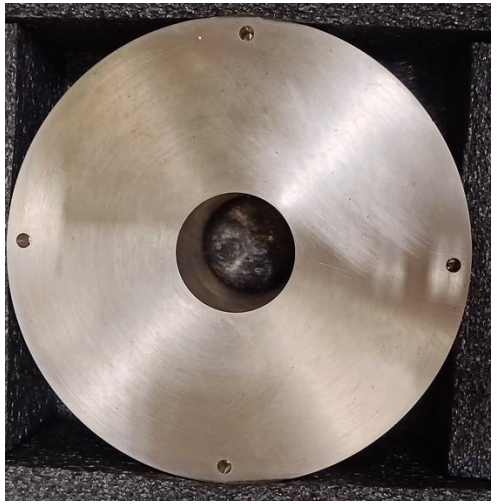




Photon Scraper



2BS section

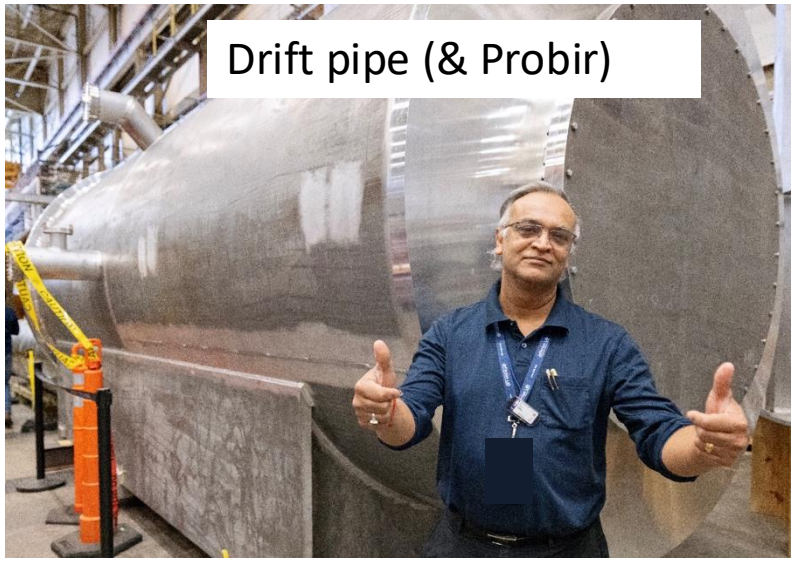


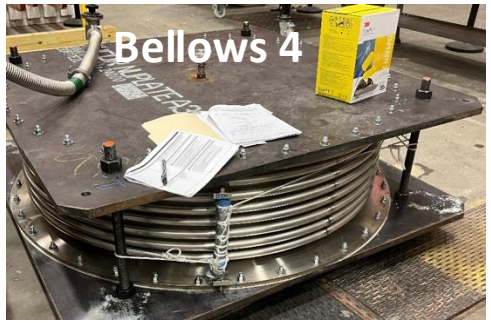
Blocker

Sieve

Summary and results of major components to be assembled in the test lab/hall

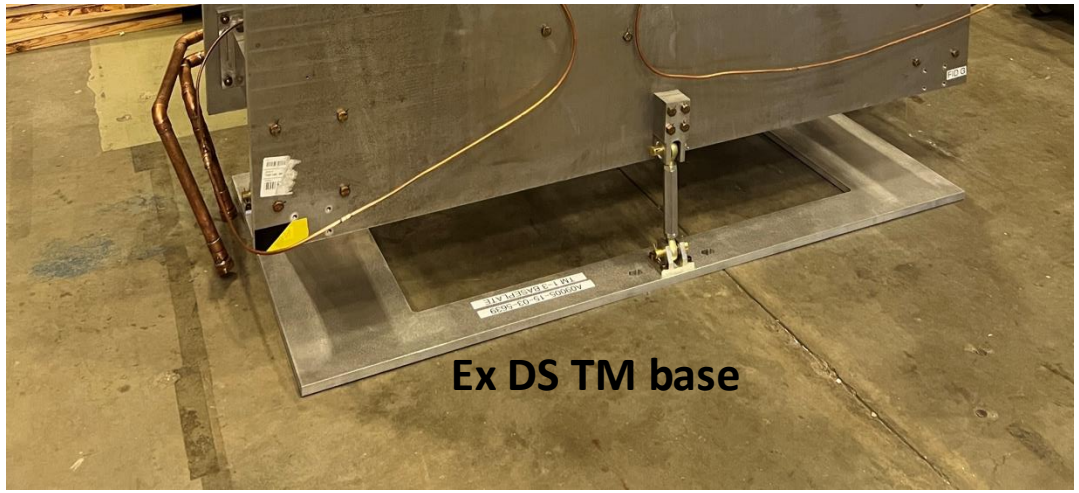
- Spectrometer Scope & Deliverables
  - Beam pipes, bellows and toroid vacuum enclosures from target exit window to beam dump entrance pipe
    - **Pending:** DS and US Toroid Enclosures

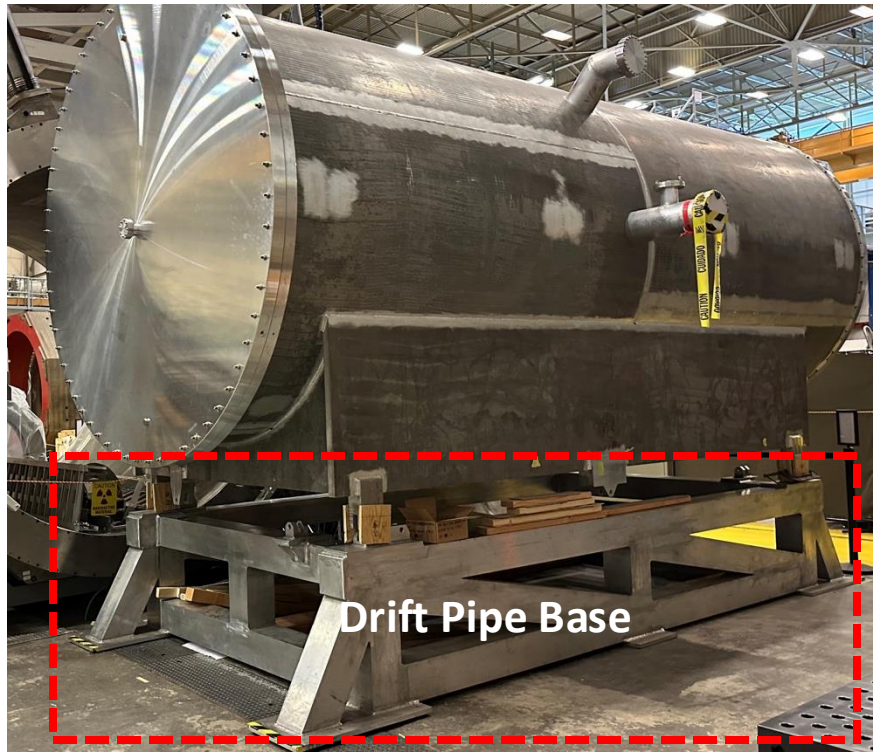


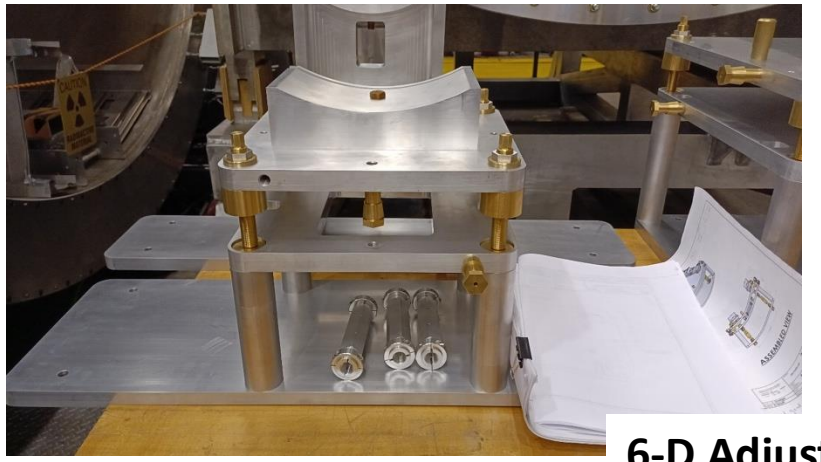


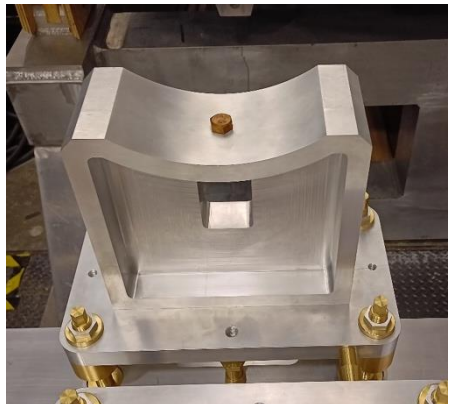
Summary and results of major components to be assembled in the test lab/hall

- Spectrometer Scope & Deliverables
  - **Support stands with 6-D adjustments**









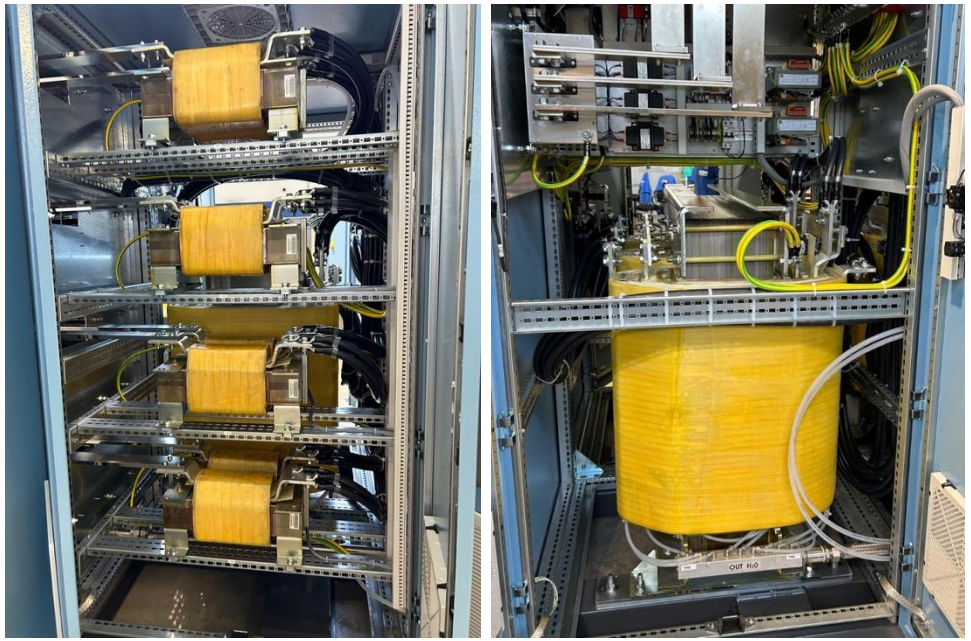
6-D Adjustable Bases for US Collimators

Summary and results of major components to be assembled in the test lab/hall

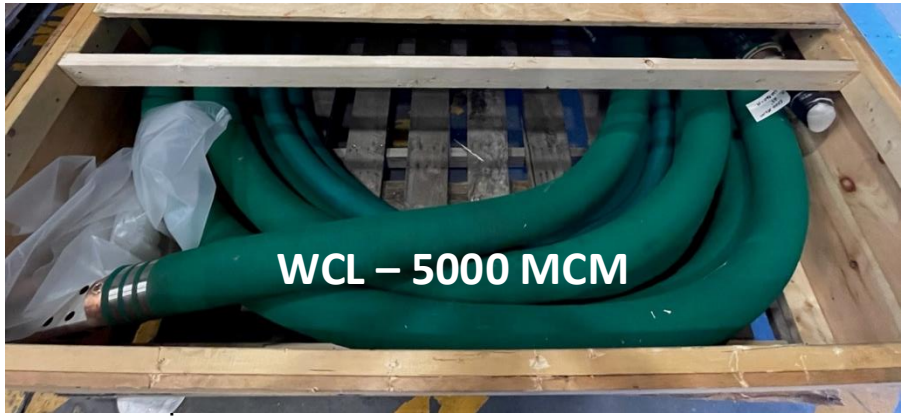
- Spectrometer Scope & Deliverables
  - **Five magnet power supplies, leads and jumpers**

TM-0, 1, 2 in Physics Storage

TM-3 installed TL

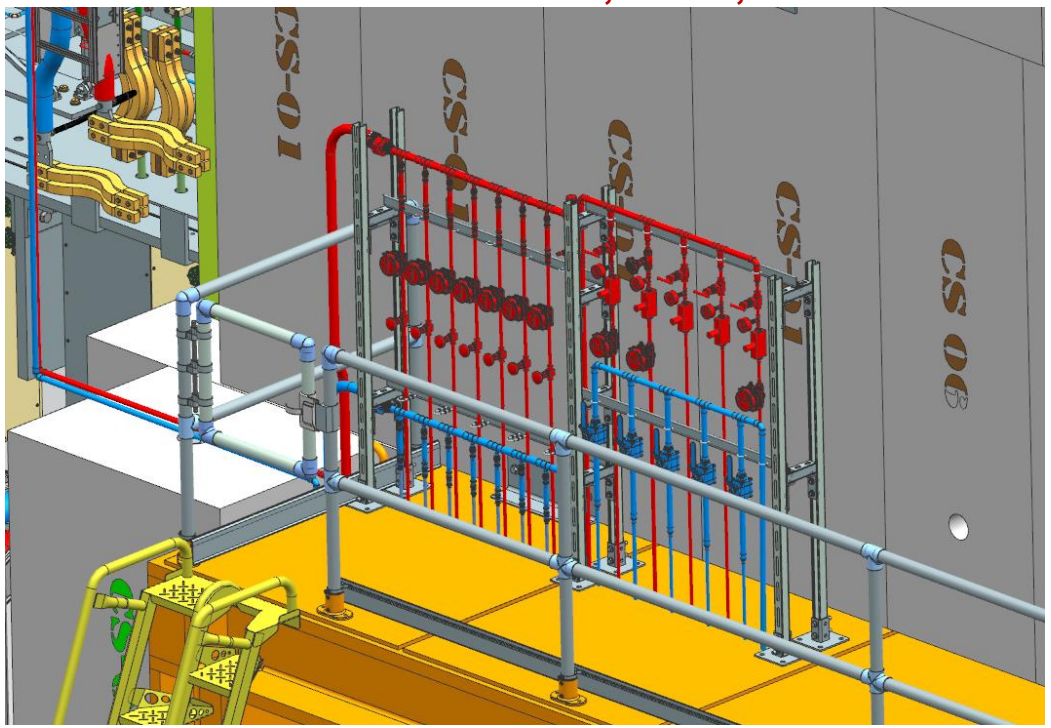


TM-4 (virtual) FAT 7/24/25

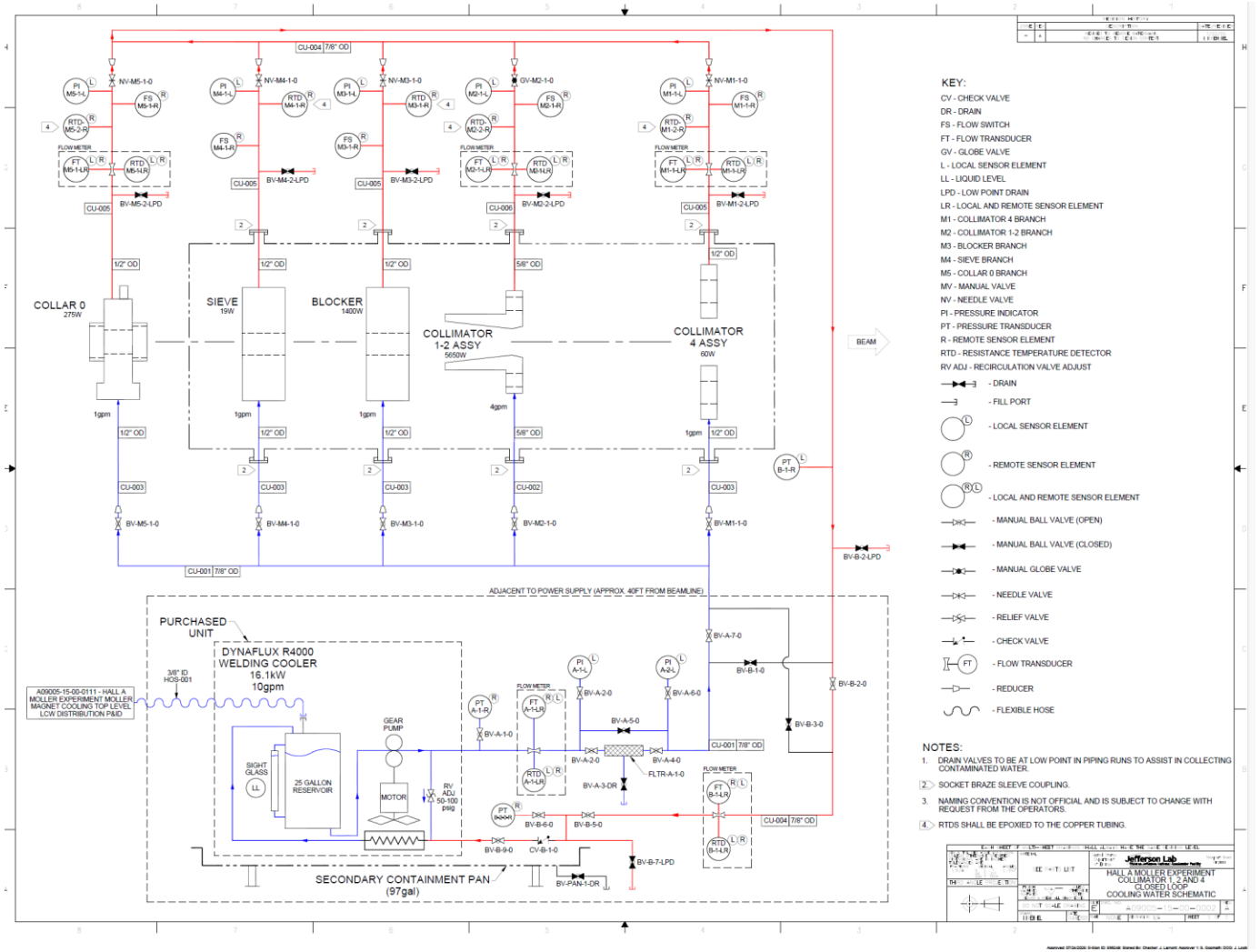


Summary and results of major components to be assembled in the test lab/hall

- Spectrometer Scope & Deliverables
  - **Closed-loop cooling systems for collimators**
    - **Total heat load ~6 kW beam on: Collar 0, Sieve, Blocker, Coll 1-2, and Coll 4**
    - **COTS welding chiller**
    - **Remote flow and temp w/ redundant sensors on Col 1-2, Coll 4, and Collar 0**



US Valve/Sensor Panel Design

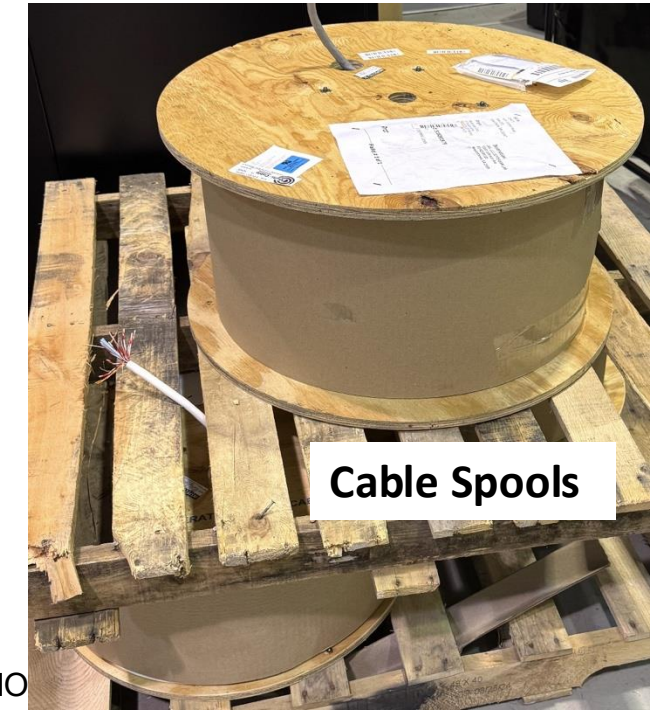


P&ID Complete

Jefferson Lab

Summary and results of major components to be assembled in the test lab/hall

- Spectrometer Scope & Deliverables
  - **Instrumentation and control software (more details in Probir's presentation)**
    - **All procurements complete including PLC modules and racks, TM cables and connectors, I&C PC, current transducers, RTD, ISO amps, sensors, etc.**



“What if” scenario if performance specifications are not met.

- **R3.12**
  - IF - Delay on MPS; THEN – Coil powering delayed
  - Impacts schedule
  - Vendor is currently holding production schedule for on time delivery
- **R3.13, 3.14**
  - IF - Mistake in fabrication (.13 measurement rig fabrication, .14 Collimator Supports); THEN –will need repair
  - Impacts schedule
  - Evaluate in test lab
- **R3.16, 3.17**
  - IF – Fabrication mistakes (beam pipes, bellows, windows); THEN – special order or retrofit
  - Impacts schedule and cost
  - Prototyping Bellows 7 reduces risk of Bellows 5. TR visits to vendors to oversee work.
- **R3.18/.19**
  - IF- Magnet needs to be assembled more times; THEN- Assembly would take longer.
  - Impacts schedule and labor cost
  - Mitigation w/ prototyping efforts
- **R3.29**
  - IF- vendor has issues with a proprietary process; THEN – magnet assembly will be delayed.
  - Impacts schedule and (potentially) cost
  - Mitigation work closely with vendor to mitigate delays.
- **R3.30**
  - IF- simulations used deviate from actual conditions; THEN- fabrication will be incorrect and would need re-design
  - Impacts schedule and cost
  - Mitigation by verification through peer review

- Project Risk Register maintained and updated:

		Impact				
	Rating	Very Low	Low	Medium	High	Very High
Probability	Very High					
	High					
	Medium		R3.22a. R3.22b, R3.23	R3.12, R3.13, R3.14b, R3.16a, R3.17, R3.18a, R3.18b, R3.19, R3.29, R3.30		
	Low		R3.03b, R3.04b, R3.08a, R3.08b, R3.11b, R3.21a, R3.21b			
	Very Low					

Summary

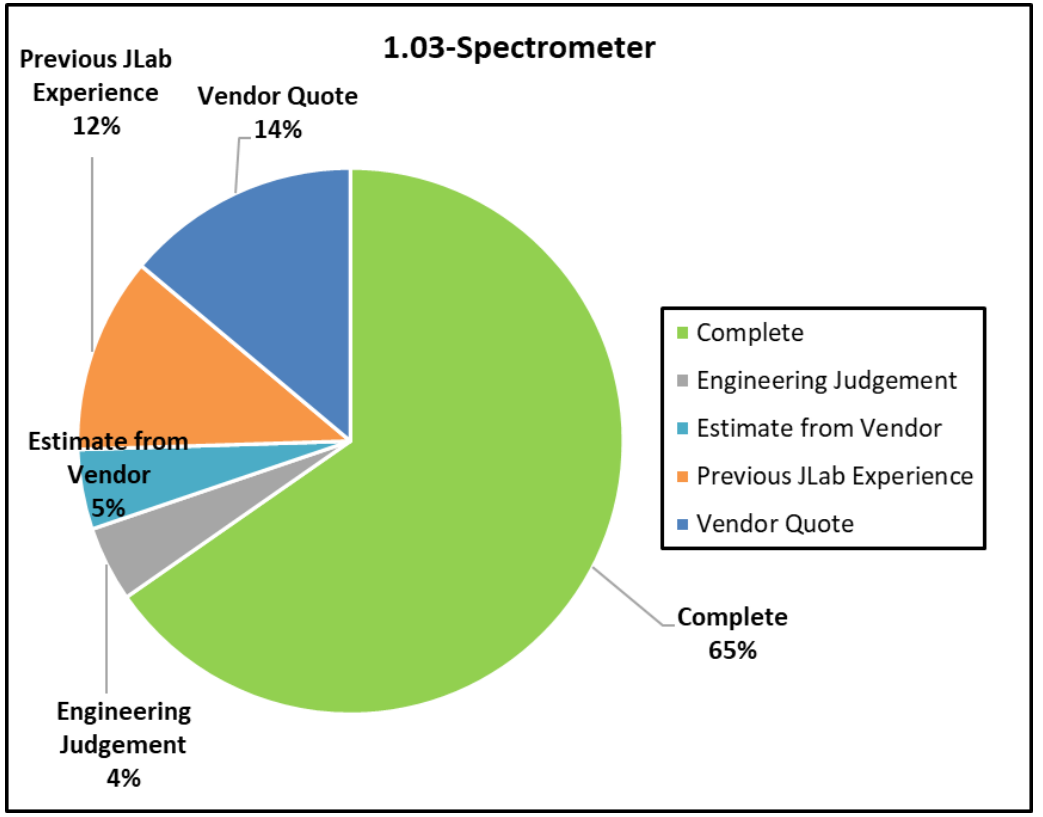
- ALL CD-3A scope Awarded, In-process, or Received.
- CD-2/CD-3 assembly activities proceeding, material receipts, and processing remaining procurements.
- US Spectrometer technical, design, and manufacturing drawings are progressing well.
- Working with numerous vendors to alleviate risks, and remain on delivery schedule.
- Risk register revisited and retired/closed several mitigated risks.
- Additional staff added to the project to assist in assembly efforts in the TL and to expedite work on the upstream toroid

QUESTIONS?

Cost Estimate Basis

Level 2 WBS	Level 3 WBS	Name	Element of Cost	Hours	Direct $K	AY$K	25-003 Baseline Start	25-003 Baseline Finish
1.03		Spectrometer		51,962	12,645	18,056	12/16/2020	2/17/2027
			Labor	51,962	2,821	7,349		
			Non Labor	0	225	330		
			Material	0	9,599	10,376		
	1.03.01	Spectrometer Management		4,635	377	991	1/19/2021	2/17/2027
			Labor	4,635	375	986		
			Non Labor		6	8		
			Material		-4	-4		
	1.03.02	Downstream Toroid		19,339	4,627	6,559	12/16/2020	7/25/2025
			Labor	19,339	997	2,593		
			Non Labor		104	174		
			Material		3,526	3,792		
	1.03.03	Upstream Toroid		2,982	2,519	3,025	12/16/2020	10/14/2025
			Labor	2,982	166	434		
			Non Labor		27	39		
			Material		2,326	2,552		
	1.03.04	Magnet Power Supplies, Cooling and Controls		8,025	2,433	3,272	3/8/2021	6/24/2025
			Labor	8,025	432	1,127		
			Non Labor		37	43		
			Material		1,964	2,103		
	1.03.05	Beam Pipes and Windows		9,541	2,226	3,138	12/16/2020	3/14/2025
			Labor	9,541	487	1,251		
			Non Labor		10	18		
			Material		1,728	1,870		
	1.03.06	Spectrometer Assembly		7,440	463	1,070	5/3/2022	11/26/2025
			Labor	7,440	364	958		
			Non Labor		41	49		
			Material		58	63		

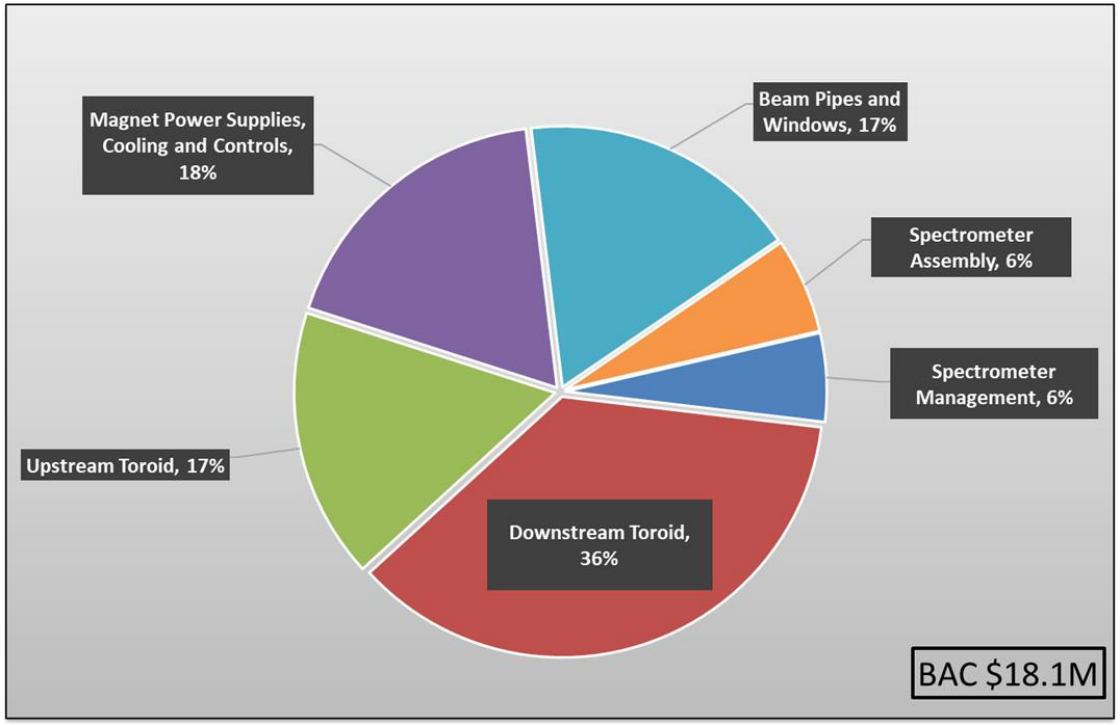
Basis of Estimate

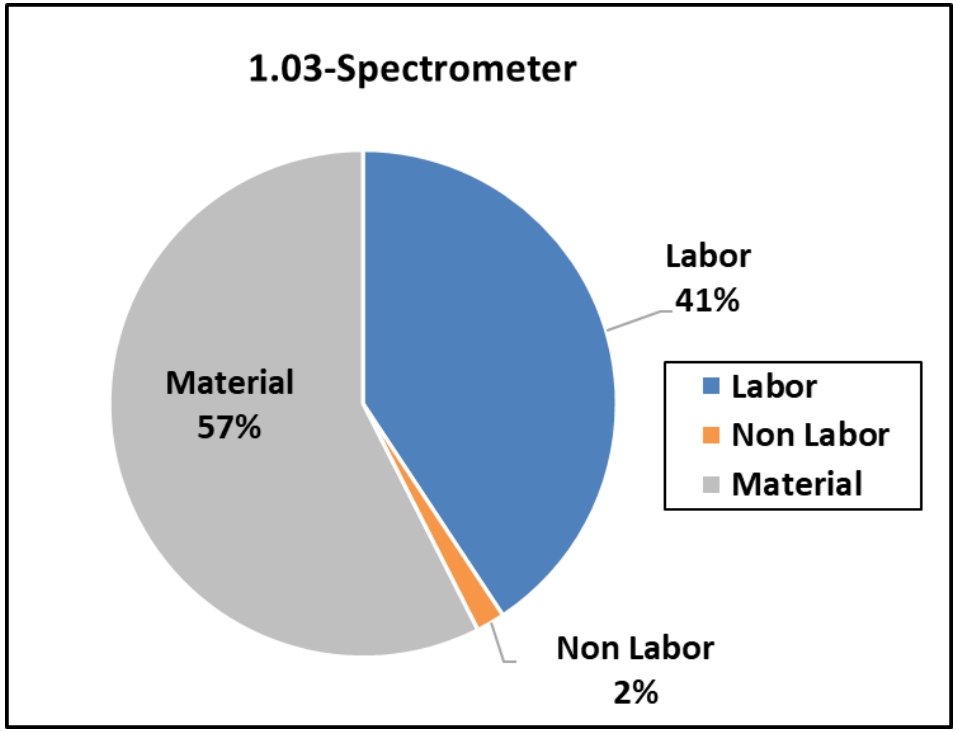


- Hour labor units
- Direct costs (unburdened, AY$K)
- AY$K (burdened Direct costs)

Burdened and Escalated Costs for 1.03

Fiscal Year (Burdened and Escalated)										
WBS - Title	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26		Total Budget
1.03.01-Spectrometer Management	$0	$0	$80	$172	$138	$294	$186	$100	$20	$991
1.03.02-Downstream Toroid	$0	$0	$660	$1,025	$921	$3,052	$901			$6,559
1.03.03-Upstream Toroid	$0	$0	$184	$477	$475	$792	$1,093	$5		$3,025
1.03.04-Magnet Power Supplies, Cooling an	$0	$0	$116	$533	$674	$765	$1,184			$3,272
1.03.05-Beam Pipes and Windows	$0	$0	$104	$266	$1,004	$790	$974			$3,138
1.03.06 Spectrometer Assembly	$0	$0			$122	$38	$778	$131		$1,070
1.03-Spectrometer Total	$0	$0	$1,144	$2,473	$3,335	$5,733	$5,115	$236	$20	$18,056





Risk Management

- **R3.12**
  - IF - Delay on MPS; THEN – Coil powering delayed
  - Impacts schedule
  - Vendor is currently holding production schedule for on time delivery
- **R3.13, 3.14**
  - IF - Mistake in fabrication (.13 measurement rig fabrication, .14 Collimator Supports); THEN –will need repair
  - Impacts schedule
  - Evaluate in test lab
- **R3.16, 3.17**
  - IF – Fabrication mistakes (beam pipes, bellows, windows); THEN – special order or retrofit
  - Impacts schedule and cost
  - Prototyping Bellows 7 reduces risk of Bellows 5. TR visits to vendors to oversee work.
- **R3.18/.19**
  - IF- Magnet needs to be assembled more times; THEN- Assembly would take longer.
  - Impacts schedule and labor cost
  - Mitigation w/ prototyping efforts
- **R3.29**
  - IF- vendor has issues with a proprietary process; THEN – magnet assembly will be delayed.
  - Impacts schedule and (potentially) cost
  - Mitigation work closely with vendor to mitigate delays.
- **R3.30**
  - IF- simulations used deviate from actual conditions; THEN- fabrication will be incorrect and would need re-design
  - Impacts schedule and cost
  - Mitigation by verification through peer review

		Impact				
	Rating	Very Low	Low	Medium	High	Very High
Probability	Very High					
	High					
	Medium		R3.22a. R3.22b, R3.23	R3.12, R3.13, R3.14b, R3.16a, R3.17, R3.18a, R3.18b, R3.19, R3.29, R3.30		
	Low		R3.03b, R3.04b, R3.08a, R3.08b, R3.11b, R3.21a, R3.21b			
	Very Low					

Procurements - Completed

WBS	Activity ID	PHASE	Activity Name	Start	Finish	Base Project Finish	Budgeted Cost[1]
1.03 Spectrometer				**05-06-21 A**	**12-18-24 A**	**1/3/2025**	
1.03.02 Downstream Toroid				**05-06-21 A**	**12-18-24 A**	**12/3/2024**	
1.03.02.01 Downstream Toroid Coils				**05-06-21 A**	**07-01-24 A**	**6/11/2024**	
1.03.02.01	1030201030		AWARD: Downstream Toroid Coil Prototype	09-27-21 A	09-27-21 A	8/2/2021	$ 232,107
1.03.02.01	10302011473A		AWARD: Downstream Toroid Coils (7) (AWARD)	05-22-23 A	05-22-23 A	5/3/2023	$ 521,221
1.03.02.01	10302011483A		AWARD: Additional SC4 Coil Winding	09-27-23 A	09-27-23 A	9/5/2023	$ 11,449
1.03.02.01	10302013033A		AWARD: Downstream Toroid Coil Clamps (Award)	01-04-24 A	01-04-24 A	1/3/2024	$ 298,058
1.03.02.01	10302013283A		AWARD: Downstream Toroid Coil Support Frames (Award)	02-02-24 A	02-02-24 A	2/2/2024	$ 307,378
1.03.02.01	10302013533A		AWARD: Downstream Toroid Adjustable Rod Linkage Bodies and Clevises (Award)	11-03-23 A	11-03-23 A	11/2/2023	$ 33,246
1.03.02.01	10302013753A		AWARD: Downstream Toroid Integration and Interconnections Hardware	03-01-24 A	03-08-24 A	9/7/2023	$ 25,758
1.03.02.01	10302013973A		AWARD: Fabricate the Water Headers and Feeders - Bulkhead Cooling Plates	01-04-24 A	01-04-24 A	1/3/2024	$ 5,701
1.03.02.01	1030201420		AWARD: Coil Sample Irradiation Studies (Sample Fabrication and Final Analysis)	05-06-21 A	11-01-21 A	6/7/2021	$ 40,919
1.03.02.01	1030201460		AWARD: Coil Sample Irradiation Studies (Sample Encapsulation)	06-22-21 A	06-22-21 A	6/8/2021	$ 5,846
1.03.02.01	1030201485		AWARD: Coil Sample Irradiation Studies (Reactor Irradiation)	10-11-21 A	10-11-21 A	6/9/2021	$ 24,084
1.03.02.01	1030201515		AWARD: Downstream Toroid Coils Conductor	06-14-21 A	06-14-21 A	6/9/2021	$ 98,207
1.03.02.01	1030201667		AWARD: Downstream Toroid Prototype Coil Supports (Jigs and Fixtures) (AWARD)	07-06-22 A	07-06-22 A	7/6/2022	$ 61,674
1.03.02.01	1030201685		AWARD: Downstream Toroid Prototype Coil Copper Water Cooled Leads	06-06-22 A	06-06-22 A	2/3/2022	$ 18,665
1.03.02.01	103020170223A		AWARD: DS Coil Tungsten Belly Plates (AWARD)	11-27-23 A	11-27-23 A	11/2/2023	$ 23,405
1.03.02.01	10302018483A		AWARD: Downstream Toroid Assembly and Alignment Hardware Rod Ends (Award)	01-04-24 A	01-04-24 A	1/3/2024	$ 250,829
1.03.02.01	10302018803A		AWARD: Downstream Toroid Coil Alignment Gauge	11-08-23 A	11-08-23 A	11/9/2023	$ 2,903
1.03.02.01	10302019253A		AWARD: Downstream Toroid Coil Support Frame Refurbishment of Frame TM3	01-04-24 A	01-04-24 A	1/10/2024	$ 16,002
1.03.02.01	1030201965		AWARD: Coil Drilling Jig	07-01-24 A	07-01-24 A	6/11/2024	$ 20,174
1.03.02.02 Downstream Toroid Enclosure				**12-01-23 A**	**12-18-24 A**	**12/3/2024**	
1.03.02.02	10302020803A		AWARD: Downstream Toroid Enclosure Electrical power penetrations	01-08-24 A	01-08-24 A	7/14/2023	$ 25,758
1.03.02.02	10302021053A		AWARD: Downstream Toroid Enclosure Water penetrations	12-01-23 A	12-01-23 A	7/17/2023	$ 4,644
1.03.02.02	1030202132		AWARD: Downstream Toroid Vacuum Pumping System (AWARD)	12-18-24 A	12-18-24 A	12/3/2024	$ 68,379
1.03.02.02	10302021923A		AWARD: Downstream Toroid Enclosure (AWARD)	01-03-24 A	01-03-24 A	1/3/2024	$ 1,250,566
1.03.02.03 Downstream Toroid Collimator				**08-02-23 A**	**08-15-24 A**	**8/15/2024**	
1.03.02.03	10302030333A		AWARD: Collimator 5 (Award)	01-04-24 A	01-04-24 A	1/3/2024	$ 22,762
1.03.02.03	10302030983A		AWARD: Collimator 6A and 6B (Award)	01-04-24 A	01-04-24 A	1/3/2024	$ 40,158
1.03.02.03	10302031223A		AWARD: Photon Scraper (Award)	11-03-23 A	11-03-23 A	11/2/2023	$ 43,326
1.03.02.03	10302031523A		AWARD: Photon Scraper Supports (Award)	11-03-23 A	11-03-23 A	11/2/2023	$ 13,617
1.03.02.03	1030203180		AWARD: Collar 1	08-15-24 A	08-15-24 A	8/15/2024	$ 89,216
1.03.02.03	10302032123A		AWARD: Lintels (AWARD)	09-01-23 A	09-01-23 A	9/5/2023	$ 72,846
1.03.02.03	10302034253A		AWARD: Thermal Straps for Photon Scraper	11-01-23 A	11-01-23 A	9/13/2023	$ 8,455
1.03.03 Upstream Toroid				**08-13-21 A**	**12-11-24 A**	**1/3/2025**	
1.03.03.01 Upstream Toroid Coils				**08-13-21 A**	**07-03-24 A**	**7/3/2024**	
1.03.03.01	10303011323A		AWARD: US Toroid Coils (Award)	07-03-24 A	07-03-24 A	7/3/2024	$ 148,192
1.03.03.01	1030301260		AWARD: US Toroid Design Contract	08-13-21 A	08-13-21 A	7/1/2021	$ 542,706
1.03.03.01	1030301295		AWARD: US Toroid Design Extension	07-05-23 A	07-05-23 A	3/28/2023	$ 54,467
1.03.03.01	10303014323A		AWARD: US Toroid Coils Conductor (AWARD)	05-03-23 A	05-03-23 A	4/4/2023	$ 9,945
1.03.03.01	1030301457		AWARD: US Toroid Support (Award)	11-06-23 A	11-06-23 A	11/2/2023	$ 77,887

Procurements – Completed (cont.)

WBS	Activity ID	PHASE	Activity Name	Start	Finish	Base Project Finish	Budgeted Cost[1]
1.03 Spectrometer				**05-06-21 A**	**12-18-24 A**	**1/3/2025**	
1.03.03 Upstream Toroid				**08-13-21 A**	**12-11-24 A**	**1/3/2025**	
1.03.03.02 Upstream Toroid Enclosure				**04-08-24 A**	**10-15-24 A**	**11/14/2024**	
1.03.03.02	10303022723A		AWARD: US Toroid 2 bounce shield segments (AWARD)	04-10-24 A	04-10-24 A	4/10/2024	$ 40,619
1.03.03.02	1030302486		AWARD: Phase I Effort (Award)	09-04-24 A	09-04-24 A	9/4/2024	$ 6,536
1.03.03.02	1030302505		AWARD: MOLLER US Engineering Part II - Bartoszek	10-15-24 A	10-15-24 A	11/14/2024	$ 56,932
1.03.03.03 Upstream Toroid Collimators				**03-01-24 A**	**12-11-24 A**	**1/3/2025**	
1.03.03.03	10303031373A		AWARD: Collimator #4 (AWARD)	04-10-24 A	04-10-24 A	4/10/2024	$ 100,447
1.03.03.03	10303032173A		AWARD: Collimator A - Blocker	03-05-24 A	03-05-24 A	3/5/2024	$ 16,128
1.03.03.03	10303032183A		AWARD: Collimator B - Sieve	03-05-24 A	03-05-24 A	3/5/2024	$ 17,710
1.03.03.03	103030690		AWARD: US Toroid Contract for MIT Design Extension Effort	06-05-24 A	06-05-24 A	6/11/2024	$ 71,944
1.03.03.03	1030307203A		AWARD: MIT Activity L	09-04-24 A	09-04-24 A	9/4/2024	$ 121,142
1.03.03.03	103030745		AWARD: MIT Completion of US Engineering - MOD 3 Line 4	10-01-24 A	10-01-24 A	10/23/2024	$ 32,680
1.03.03.03	103030765		AWARD: MIT Completion of US Engineering - MOD 5	11-12-24 A	11-12-24 A	1/3/2025	$ 54,044
1.03.03.03	1030307803A		AWARD: US Support Stands	12-09-24 A	12-09-24 A	12/2/2024	$ 49,842
1.03.04 Magnet Power Supplies, Cooling and Controls				**11-01-21 A**	**12-16-24 A**	**12/4/2024**	
1.03.04.01 Magnet Power Supplies				**11-01-21 A**	**12-16-24 A**	**12/4/2024**	
1.03.04.01.01 Toroid Magnet Power Supplies				**11-01-21 A**	**12-16-24 A**	**12/4/2024**	
1.03.04.01.01	103040101042		AWARD: Toroid Magnets Electrical isolation boxes (AWARD)	09-04-24 A	09-04-24 A	9/4/2024	$ 16,585
1.03.04.01.01	103040101067	3A	AWARD: Magnet Power Supplies (AWARD)	09-06-23 A	09-06-23 A	9/5/2023	$ 1,050,923
1.03.04.01.01	103040101095	3A	AWARD: Toroid ceramic breaks (or hoses)	07-05-23 A	07-05-23 A	9/8/2023	$ 22,167
1.03.04.01.01	103040101123	3A	AWARD: MPS Distribution Panel (AWARD)	05-09-23 A	05-09-23 A	5/3/2023	$ 90,503
1.03.04.01.01	103040101420		AWARD: Downstream Toroid Prototype Power Supply	02-15-22 A	02-15-22 A	3/3/2022	$ 320,239
1.03.04.01.01	103040101445		AWARD: Downstream Toroid Prototype Power Supply I&C Hardware	11-02-22 A	11-02-22 A	4/6/2022	$ 22,040
1.03.04.01.01	103040101521		AWARD: Magnet Leads and Jumpers (AWARD)	12-16-24 A	12-16-24 A	12/4/2024	$ 165,841
1.03.04.02 Magnets Intrumentation and Controls				**06-01-24 A**	**09-04-24 A**	**10/16/2024**	
1.03.04.02.01 Toroid Magnet I&C				**06-01-24 A**	**09-04-24 A**	**10/16/2024**	
1.03.04.02.01	103040201052		AWARD: Toroid Magnets I&C Computer (award)	09-04-24 A	09-04-24 A	9/4/2024	$ 2,556
1.03.04.02.01	103040201080		AWARD: Toroid Magnets I&C Current Transducers	07-09-24 A	07-09-24 A	8/14/2024	$ 9,967
1.03.04.02.01	103040201140		AWARD: TM instrumentation sensors and readback electronics ISO Amps	07-09-24 A	07-09-24 A	7/8/2024	$ 20,490
1.03.04.02.01	103040201165		AWARD: Toroid Magnets PLC modules and software programming license	09-02-24 A	09-02-24 A	10/16/2024	$ 60,455
1.03.04.02.01	103040201205		AWARD: TM inst.sensors and readback electronics - Resistance Temp Detector	08-30-24 A	08-30-24 A	9/3/2024	$ 25,243
1.03.04.04 Field Measurement System				**06-01-24 A**	**11-04-24 A**	**11/4/2024**	
1.03.04.04	1030404017		AWARD: Field Measurement probes and electronics - Field Mapping Elec (AWARD)	11-04-24 A	11-04-24 A	11/4/2024	$ 788
1.03.05 Beam Pipes and Windows				**06-01-22 A**	**09-05-24 A**	**9/5/2024**	
1.03.05	10305046		AWARD: Collar 0 Pipe (including lead) (AWARD)	09-04-24 A	09-04-24 A	9/4/2024	$ 106,525
1.03.05	103050823A		AWARD: Bellows 3 and 4 (AWARD)	09-01-23 A	09-01-23 A	9/5/2023	$ 151,807
1.03.05	103050863A		AWARD: Bellows 3 and 4 Shipping (AWARD)	07-09-24 A	07-09-24 A	7/9/2024	$ 419
1.03.05	103051053A		AWARD: Drift Pipe	11-06-23 A	11-06-23 A	4/28/2023	$ 393,976
1.03.05	103051113A		AWARD: Detector and Neckdown Pipe (AWARD)	09-05-23 A	09-05-23 A	9/5/2023	$ 195,451
1.03.05	10305114		AWARD: SAM Pipe (to dump)	07-17-24 A	07-17-24 A	7/16/2024	$ 68,083
1.03.05	10305130		AWARD: Beam Pipes - Target to US Toroid	07-22-24 A	07-22-24 A	7/15/2024	$ 19,191
1.03.05	10305155		AWARD: Spectrometer Detector Window Machining	07-03-24 A	07-03-24 A	7/25/2024	$ 24,837
1.03.05	10305167		AWARD: Spectrometer Detector Window Hardware	07-01-24 A	07-01-24 A	7/25/2024	$ 1,566
1.03.05	10305172SRR		AWARD: Spectrometer Detector Window Annular Flange (AWARD)	09-04-24 A	09-04-24 A	9/4/2024	$ 66,188

Procurements – Completed (cont.)

WBS	Activity ID	PHASE	Activity Name	Start	Finish	Base Project Finish	Budgeted Cost[1]
1.03 Spectrometer				**05-06-21 A**	**12-18-24 A**	**1/3/2025**	
1.03.05 Beam Pipes and Windows				**06-01-22 A**	**09-05-24 A**	**9/5/2024**	
1.03.05		10305442	AWARD: Prototype Window and Test Fixture Components (AWARD)	07-05-22 A	07-05-22 A	7/5/2022	$ 34,091
1.03.05		103054923A	AWARD: Pion Lead Donut AL Can (AWARD)	11-03-23 A	11-03-23 A	11/2/2023	$ 57,081
1.03.05		103055493A	AWARD: Pion Lead Donut/Detector Pipe Support Stand (Award)	03-04-24 A	03-04-24 A	3/4/2024	$ 138,069
1.03.05		10305583	AWARD: Prototype Bellows 7 (award)	11-10-22 A	11-10-22 A	11/2/2022	$ 66,189
1.03.05		10305615	AWARD: Window Shutter System	07-23-24 A	07-23-24 A	7/25/2024	$ 16,830
1.03.05		103056873A	AWARD: Beam Dump Support (AWARD)	09-05-23 A	09-05-23 A	9/5/2023	$ 18,873
1.03.05		103057153A	AWARD: Bellows 1 and 2 (AWARD)	09-01-23 A	09-01-23 A	9/1/2023	$ 28,183
1.03.05		103057403A	AWARD: Bellows 5 (AWARD)	09-06-23 A	09-06-23 A	9/1/2023	$ 161,899
1.03.05		103057903A	AWARD: Metal Seal for Beam Dump Pipe Support	11-03-23 A	11-03-23 A	11/27/2023	$ 6,634
1.03.05		10305825	AWARD: Drift Pipe Stand	07-01-24 A	07-01-24 A	7/17/2024	$ 60,890
1.03.05		10305860	AWARD: Spectrometer Detector Window Pipe Nipple (AWARD)	09-05-24 A	09-05-24 A	9/5/2024	$ 43,464
1.03.06 Spectrometer Assembly				**02-08-23 A**	**11-18-24 A**	**11/4/2024**	
1.03.06		10306515	AWARD: Toroid Assembly Tables	02-08-23 A	02-08-23 A	2/20/2023	$ 31,007
1.03.06	10306673S		AWARD: Construct Jig for Pion Donut Frame (AWARD)	11-18-24 A	11-18-24 A	11/4/2024	$ 28,030

Procurements - Remaining

WBS Path	Activity ID	PHASE	Activity Name	Start	Finish	Base Project Finish	Original Duration	Total Float	Budgeted Cost
MOLLER-12-24Forecast.1.03 Spectrometer				**12-02-24 A**	**7/18/25**	**7/2/25**	**138**	**97**	
MOLLER-12-24Forecast.1.03.02 Downstream Toroid				**1/6/25**	**2/11/25**	**2/19/25**	**26**	**95**	
MOLLER-12-24Forecast.1.03.02.02 Downstream Toroid Enclosure				**01/06/25**	**02/11/25**	**02/19/25**	26	95	
1.03.02.02	1030202155		AWARD: Downstream Toroid Enclosure Racks, Electronics, Electrical boards and Circuit Breakers	02/11/25	02/11/25	08/08/24	1	95	$ 86,206
1.03.02.02	1030202440		AWARD: Spectrometer Vacuum Pump Line	01/06/25	01/06/25	02/19/25	1	78	$ 42,034
1.03.02.02	1030202475		AWARD: Spectrometer Vacuum Pump Hardware	01/06/25	01/06/25	02/19/25	1	88	$ 33,627
MOLLER-12-24Forecast.1.03.03 Upstream Toroid				**1/8/25**	**7/18/25**	**7/2/25**	**134**	**97**	
MOLLER-12-24Forecast.1.03.03.01 Upstream Toroid Coils				**03/12/25**	**07/18/25**	**07/02/25**	90	92	
1.03.03.01	1030301080		AWARD: US Toroid Assembly and Alignment Hardware	07/07/25	07/07/25	03/19/25	1	98	$ 6,762
1.03.03.01	1030301105		AWARD: US Toroid Integration and Interconnections Hardware	07/10/25	07/10/25	07/02/25	1	98	$ 2,714
1.03.03.01	1030301160		AWARD: US Toroid Coil Clamps and Support Links	03/12/25	03/12/25	10/18/24	1	86	$ 40,557
1.03.03.01	10303011720		AWARD: US Coil Tungsten Side Plates	03/12/25	03/12/25	10/18/24	1	140	$ 13,211
1.03.03.01	1030301185		AWARD: US Toroid Frame (TM0)	04/16/25	04/16/25	02/12/25	1	77	$ 20,285
1.03.03.01	1030301210		AWARD: US Toroid Water Headers and Feeders (TM0)	06/06/25	06/06/25	01/28/25	1	109	$ 5,416
1.03.03.01	1030301235		AWARD: US Toroid Electrical Busbars (TM0)	07/18/25	07/18/25	03/07/25	1	81	$ 16,225
MOLLER-12-24Forecast.1.03.03.02 Upstream Toroid Enclosure				**03/13/25**	**07/09/25**	**06/02/25**	82	98	
1.03.03.02	1030302080		AWARD: US Toroid Enclosure supports	04/17/25	04/17/25	03/18/25	1	100	$ 40,557
1.03.03.02	1030302105		AWARD: US Toroid Enclosure Electrical power penetrations	07/08/25	07/08/25	04/25/25	1	98	$ 4,059
1.03.03.02	1030302130		AWARD: US Toroid Enclosure Water penetrations	07/09/25	07/09/25	06/02/25	1	98	$ 3,255
1.03.03.02	1030302155		AWARD: US Toroid Enclosure	03/13/25	03/13/25	02/11/25	1	95	$ 289,076
MOLLER-12-24Forecast.1.03.03.03 Upstream Toroid Collimators				**01/08/25**	**03/24/25**	**10/18/24**	53	178	
1.03.03.03	10303030753A		AWARD: Collimators #1 and #2	01/08/25	01/08/25	07/14/23	1	23	$ 760,646
1.03.03.03	1030303510		AWARD: Lead Mini Wall	03/24/25	03/24/25	10/18/24	1	178	$ 27,046
1.03.03.03	1030303535		AWARD: Shielding for O'ring	02/26/25	02/26/25	10/04/24	1	196	$ 2,030
MOLLER-12-24Forecast.1.03.04 Magnet Power Supplies, Cooling and Controls				**12-02-24 A**	**2/25/25**	**1/23/25**	**38**	**107**	
MOLLER-12-24Forecast.1.03.04.02 Magnets Intrumentation and Controls				**12-02-24 A**	**02/25/25**	**09/04/24**	38	107	
MOLLER-12-24Forecast.1.03.04.02.01 Toroid Magnet I&C				**12-02-24 A**	**02/25/25**	**09/04/24**	**38**	**107**	
1.03.04.02.01	1.0304E+11		AWARD: Toroid Magnets Racks, Cables and Connectors	12-02-24 A	02/25/25	07/25/24	1	85	$ 31,081
1.03.04.02.01	1.0304E+11		AWARD: Remaining TM inst.sensors and readback electronics	01/02/25	01/02/25	09/04/24	1	144	$ 39,260
MOLLER-12-24Forecast.1.03.04.03 Magnet Cooling System				**02/04/25**	**02/04/25**	**09/26/24**	1	49	
1.03.04.03	1030403030		AWARD: TM LCW Flow Control System	02/04/25	02/04/25	09/26/24	1	49	$ 120,098
MOLLER-12-24Forecast.1.03.04.04 Field Measurement System				**01/21/25**	**02/06/25**	**01/23/25**	13	7	
1.03.04.04	1030404050		AWARD: Field measurement probes and mech components	01/21/25	01/21/25	01/06/25	1	7	$ 50,259
1.03.04.04	10304075		AWARD: Field measurement Cabling and Data Acq	02/06/25	02/06/25	01/23/25	1	7	$ 50,259
MOLLER-12-24Forecast.1.03.05 Beam Pipes and Windows				**2/17/25**	**2/17/25**	**7/25/24**	**1**	**7**	
1.03.05	10305515		AWARD: Pion Lead Donut - Lead Pour	02/17/25	02/17/25	07/25/24	1	7	$ 55,966

$1.7M remaining