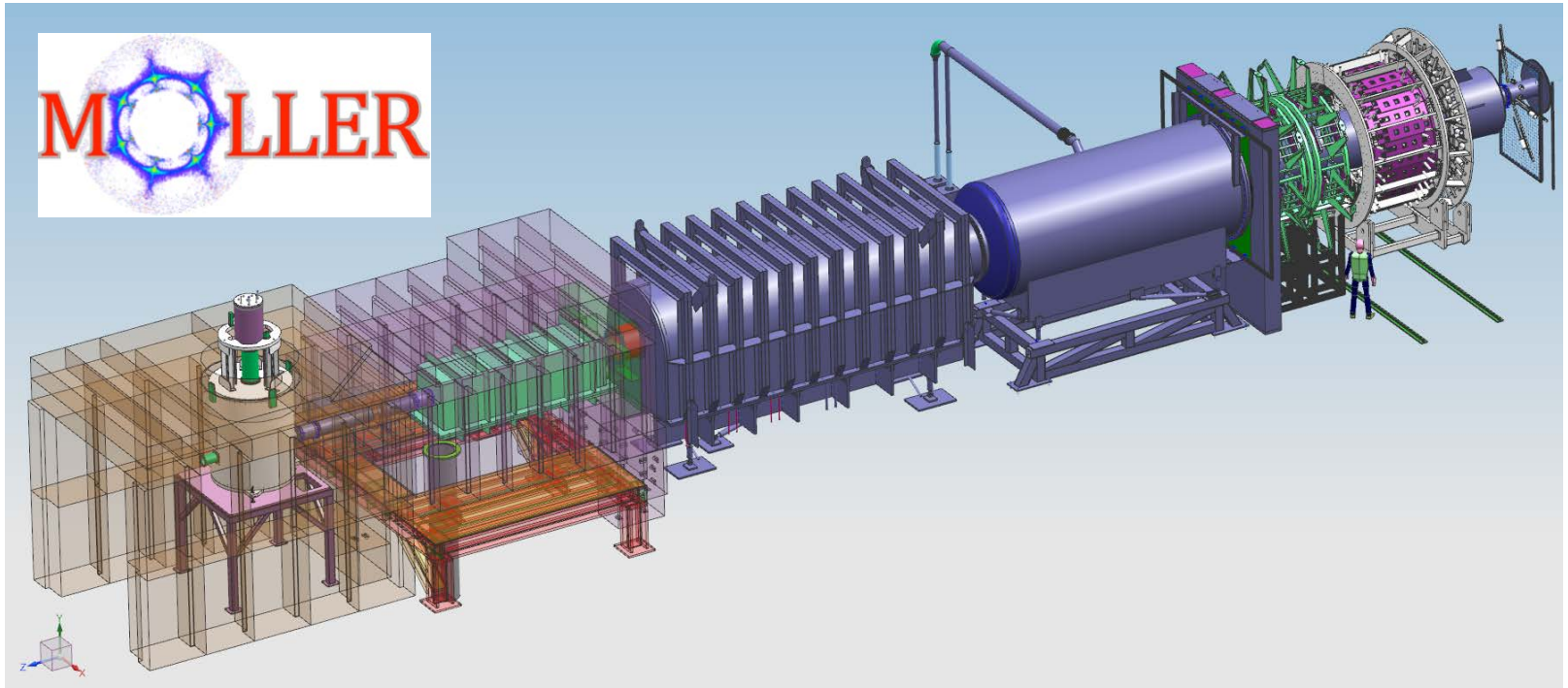
MOLLER Spectrometer – WBS 1.03

MOLLER Collaboration Meeting

June 21-22, 2022

Prototype Coil Test, MPS, I&C and Mapping



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Team - Magnet Group/ENP/Engineering

Jefferson Lab

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Outline

- **Prototype Coil Test**
  - ❑ Engineering requirements
  - ❑ Coil Fabrication
    - QA&QC checks
    - Measurements and factory test
  - ❑ JLAB Coil Acceptance Tests
    - Prototype coil test facility
    - Prototype coil test setup
  - ❑ MPS and I&C
    - Layout
    - Protection system layout
- **Magnet Mapping requirements**
- **SUMMARY**

Prototype Coil test

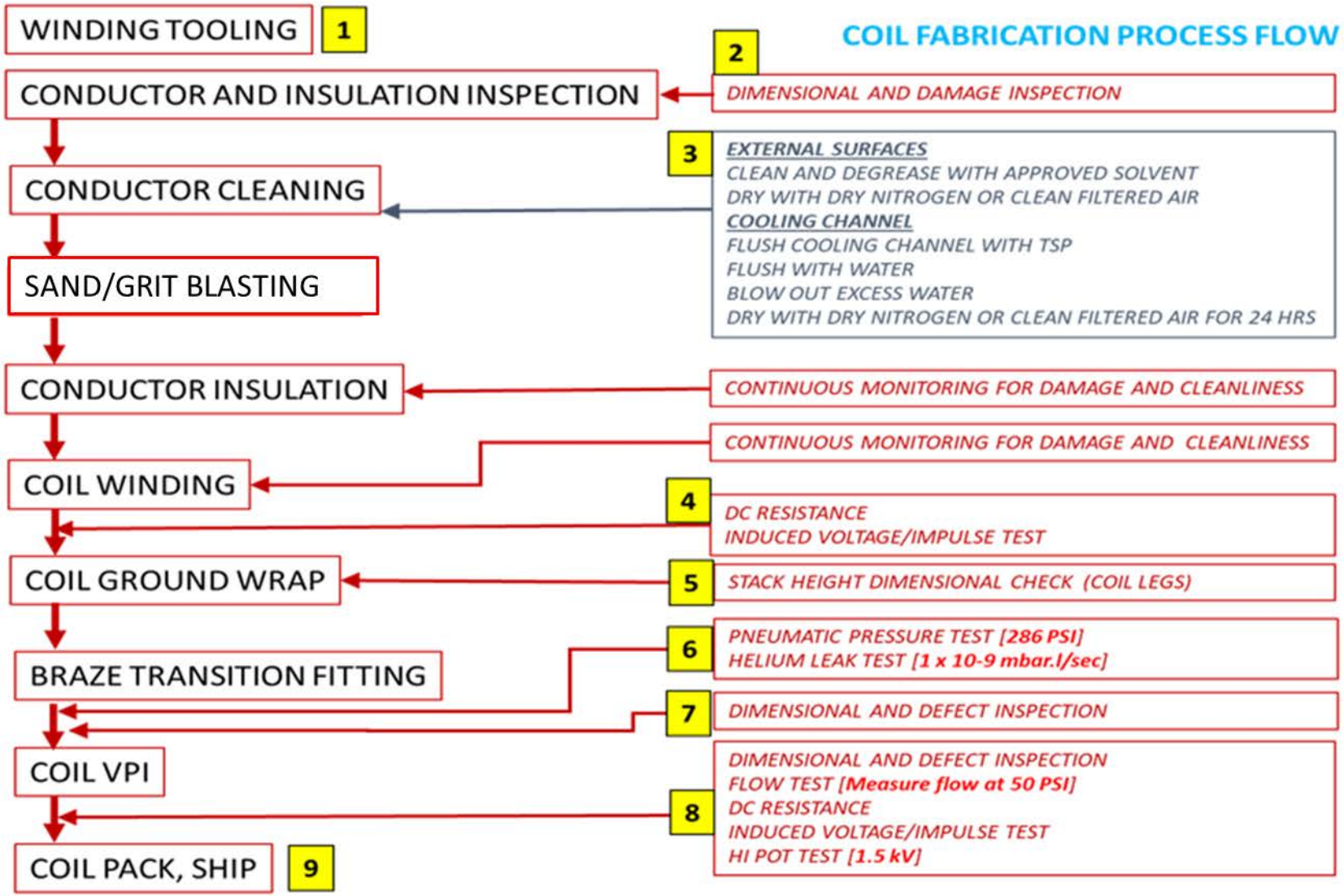
- The key component of the prototype coil is the **fabrication and testing of a full size pre-production** coil (i.e. four sub-coils)
- **Physics Requirements translated into Engineering Requirements**

  Reference –

  1. *PMAG0000-0100-A0007 MOLLER - Upstream and Downstream Coil Functional Requirements*
  2. *PMAG0000-0100-A0008 MOLLER - Spectrometer Functional Requirements*

- **Measurements and tests planned as part coil fabrication**
  - **Vendor fabrication of coils** – *individual coils*
    - *Visual inspection*
    - *Dimensional checks*
    - *Leak test (pressure & He)*
    - *Coil Hi-pot*
    - *Resistance and Inductance check*
  - **Testing of coils on receipt at JLAB – *individual coils* (*low current* and high current)**
    - The prototype coil allows us to verify and validate: our design and the vendor's manufacturing process
    - Flow, temperature gradient, pressure drop - validate JLAB design

Vendor Coil Fabrication - *individual coils*



COIL FABRICATION PROCESS FLOW SUMMARY WITH HOLD POINTS

	MILESTONE	DELIVERABLE
1	P1, C1	REPORT
2	P2, C2	REPORT
3	P3, C3A-G	REPORT
4	P4, C4A-G	REPORT
5	P5, C5A-G	REPORT
6	P6, C6A-G	WITNESS, REPORT
7	P7, C7A-G	REPORT
8	P8, C8A-G	WITNESS, REPORT
9	P9, C9A-G	WITNESS

For details refer the supporting documents 'PMAG0000-0100-A0005 MOLLER Downstream Torus Magnet Segmented Coil Statement of Work'

JLAB Coil Acceptance Tests - Prototype Coil Test Facility

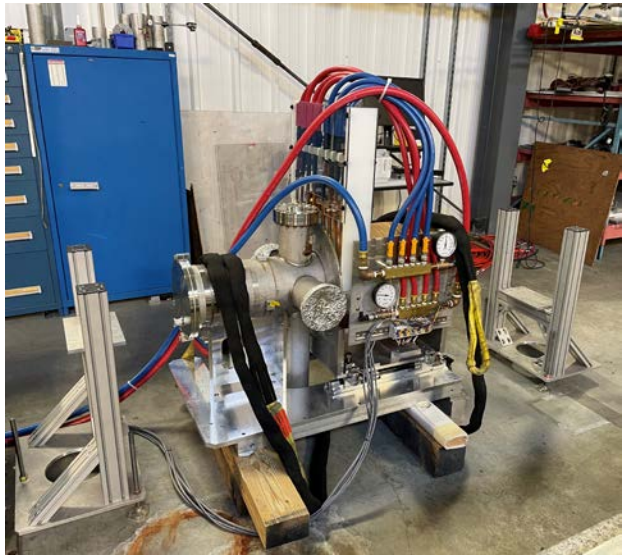
Moller at Magnet Measurement Facility

Existing OCEM – MPS

- ❑ 166 kW PS, Vmax = 200V, Imax = 830A, connected to EPICS controls
- ❑ DC Power is currently performing maintenance and certification testing on the PS in progress….

Facility

- ❑ 10T Overhead Crane
- ❑ Surface plate up to 5m length
- ❑ LCW connections (ΔP = 73 psi, Psupply = 110 psi, Tin = 35 deg C)
- ❑ Safety beacons (Entrance Doors/Power Supply's) and red-white electrical Limited Approach Boundary
- ❑ OSP's available for testing



Test of Prototype coil in test lab (USING the basic control hardware from Dump solenoid in UITF)

- ❑ Primary Control using *PLC Based: Allen Bradley CompactLogix*
- ❑ Local Control only, network access only for archiving to JLAB OPS
- ❑ Direct Interlock capability 5 or 24 VDC (e.g. voltage, temperature, field, flow, etc.)
- ❑ Magnet is used to pretest the set up for the prototype coil inspection (HDIce Dump solenoid 320A)
- ❑ All I&C and control and read back to EPICS with the MPS in the Magnet Measurement Lab
- ❑ Address the operating parameters and requirements for testing - Flow, temperature, pressure, current, and voltage (available from operating manual max I=320A)

Acceptance Tests and Status of activities

Coil Testing - Mechanical & electrical inspections, and tests shall be performed on each (all individual coils)

- ❑ Dimensional inspection - made to verify conformance to drawing and specification requirements.
- ❑ Pressure leak check and helium leak check
- ❑ DC Resistance and inductance measurement
- ❑ DC Hi-pot tests (Line to GND) - establish an intimate Ground plane each circuit at 1.5 kV, *e.g. at the clamping location(s)*.
- ❑ Water Circuit Test – Flow, pressure drop and temperature tests (low current test @800 A)
  - establish and evaluate mechanical and thermal stability of the coil with reduced flow (per flow path)

Status of activities

- ❑ Power Supplies Functional requirements - PMAG0000-0100-S0015 MOLLER (COMPLETE)
- ❑ Physics and Engineering Requirements for Magnet Power Supplies (COMPLETE)
- ❑ Magnet Power Supplies Specification Document both US & DS - PMAG0000-0100-A0014 (COMPLETE)
- ❑ **Prototype MPS (DS Torus3) – ORDER PLACED with OCEM, Italy.**
- ❑ Hall A – Location of PSUs and Lead Routing (COMPLETE)
- ❑ Water-Cooled Leads, Air-Cooled Jumpers - Design (COMPLETE) and Interfaces (IN PROGRESS)
- ❑ Control, Instrumentation (IN PROGRESS, ALONG WITH P&ID)
- ❑ Environment Safety and Health (IDENTIFIED AND INCORPORATED AS REQUIRED)
- ❑ Test Lab set-up and plan for the prototype coil (In Measurement Lab)
  - ➢ Challenges with MPS for test (Low current test and high current test)

The total number of power converters with their respective ratings are listed in the following **Table 2**. The ratings listed here includes the 120% of voltage margin stated in §1.0 and 120% of peak current capability stated in §4.2.1.iii. of the reference document [a]

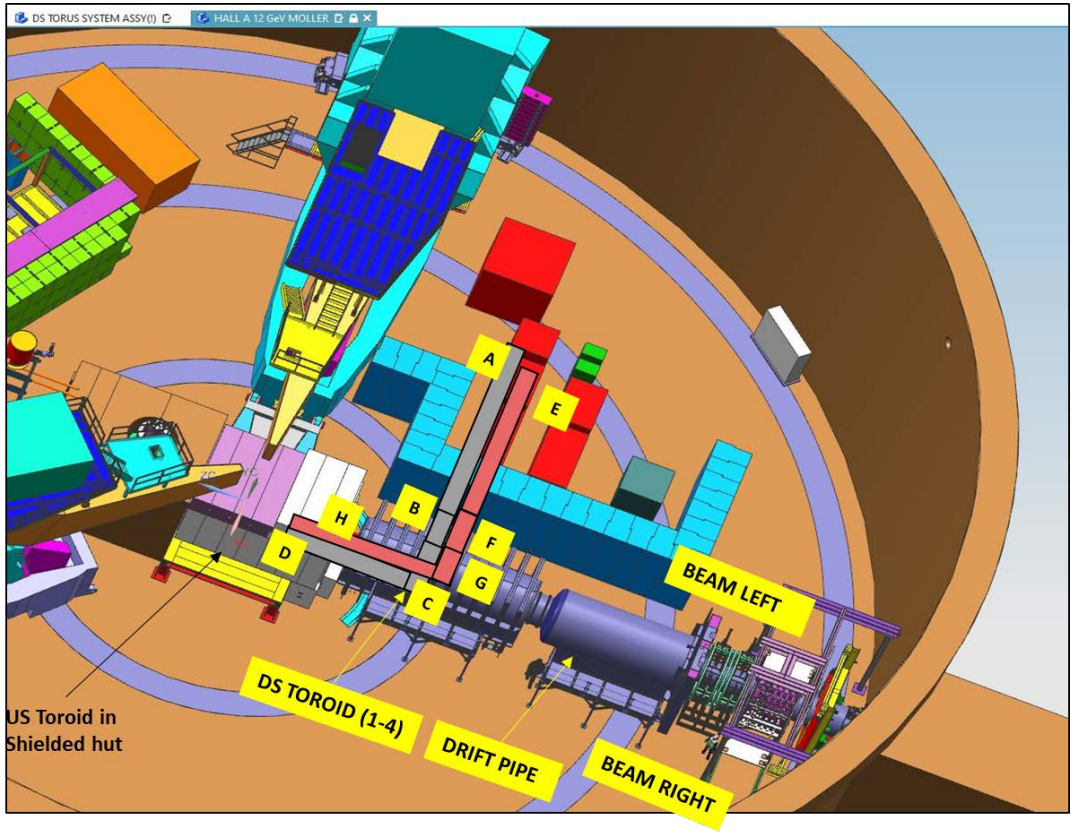
Magnet Type/Name	Q.ty of Power Converters	Type	Peak Current [A]	Max. Voltage [V]	Rated Power [kW]
US Torus	1	Monopolar	1290	93	84
DS Torus - 1	1	Monopolar	2676	48	90
DS Torus - 2	1	Monopolar	2928	50.4	103
DS Torus - 3	1	Monopolar	3882	68.4	185
DS Torus - 4	1	Monopolar	4020	269	751

Table 2 – Power converters required

Magnet Power Supplies, I&C: Routing from MPS bunker to enclosure

ID	Route	Height above hall floor (m)	Length (m)
	DS TOROID CURRENT LEAD ROUTING		
A	From top of magnet power supplies to exit at top of bunker (just below bunker roof), at outside wall of bunker	3.4	15.0
B	90° vertical drop to hall floor	3.4 to 0	3.4
C	From outside of bunker wall to underside of DS toroid	0	4.0
	TOTAL FOR DS TORUS (no margin)		**22.4**
	DS TOROID INSTRUMENTATION LEAD ROUTING		
E	From top of instrumentation racks to exit at top of bunker (just below bunker roof), at outside wall of bunker	3.4	15.0
F	90° vertical drop to hall floor	3.4 to 0	3.4
G	From outside of bunker wall to underside of DS toroid	0	4.0
H	Along floor and up to feedthroughs on underside of DS toroid	0 to 1.29	3.7 + 1.29
	TOTAL FOR DS TORUS (no margin)		**27.4**

ID	Route	Height above hall floor (m)	Length (m)
	US TOROID CURRENT LEAD ROUTING		
A	From top of magnet power supplies to exit at top of bunker (just below bunker roof), at outside wall of bunker	3.4	15.0
B	90° vertical drop to hall floor	3.4 to 0	3.4
C	From outside of bunker wall to underside of DS toroid	0	4.0
D	Along floor to underside of US toroid	0	5.6
	TOTAL FOR US TORUS (no margin)		**28.0**
	US TOROID INSTRUMENTATION LEAD ROUTING		
E	From top of instrumentation racks to exit at top of bunker (just below bunker roof), at outside wall of bunker	3.4	15.0
F	90° vertical drop to hall floor	3.4 to 0	3.4
G	From outside of bunker wall to underside of DS toroid	0	4.0
H	Along floor and to center of DS toroid	0	3.7
I	From center of DS toroid, along floor and up to feedthroughs on US toroid	0 to 1.29	5.6 + 1.29
	TOTAL FOR US TORUS (no margin)		**32.99**



1. The water cooled leads/bus design and specification - COMPLETE
2. At the **PSU** end - Flexible copper air-cooled jumpers connect the PSU bus bars to the water-cooled leads, bolted connection (1 jumper per GO and RETURN lead is required). - COMPLETE
3. At the **MAGNET** end - Flexible copper air-cooled jumpers connect the magnet feedthroughs to the water-cooled leads (Multiple jumpers per GO and RETURN lead are required). - COMPLETE
4. Conductor sizes **per** GO or RETURN lead - COMPLETE
5. Voltages and kW values for **both** GO and RETURN leads and all jumpers – COMPLETE
6. MOLLER Spectrometer - Spec and RFQ US_DS Magnet WCL & Jumper leads PMAG0000-0100-S0017 (Draft completed)

Magnet Power Supplies, I&C: Routing from MPS bunker to enclosure

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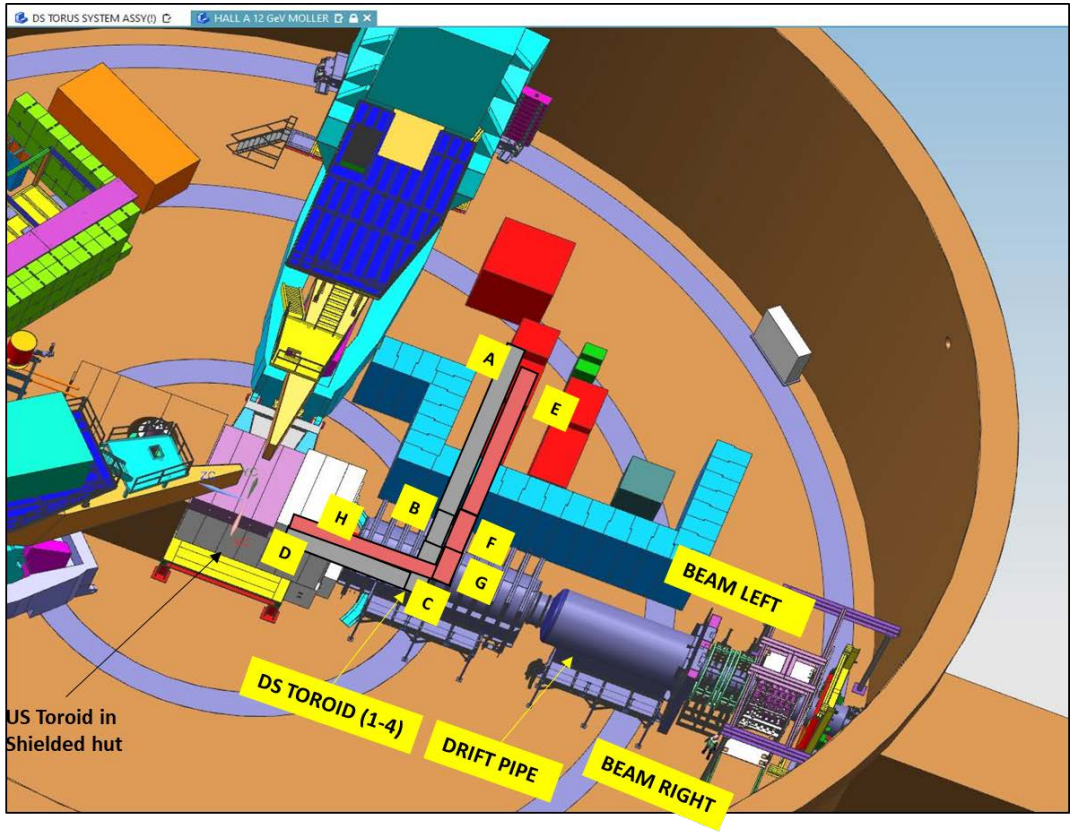
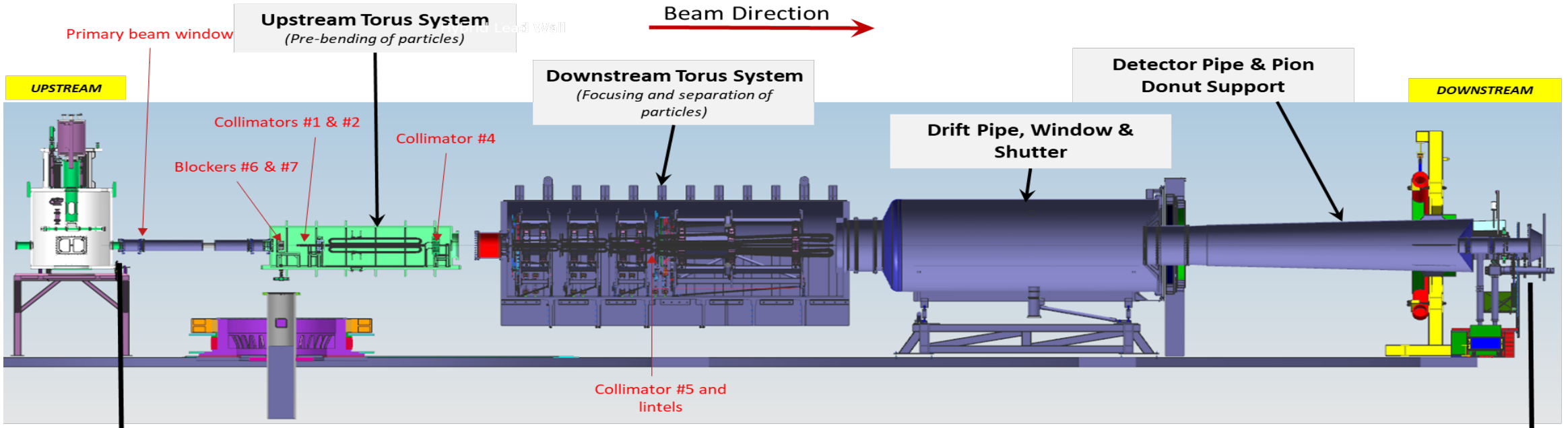
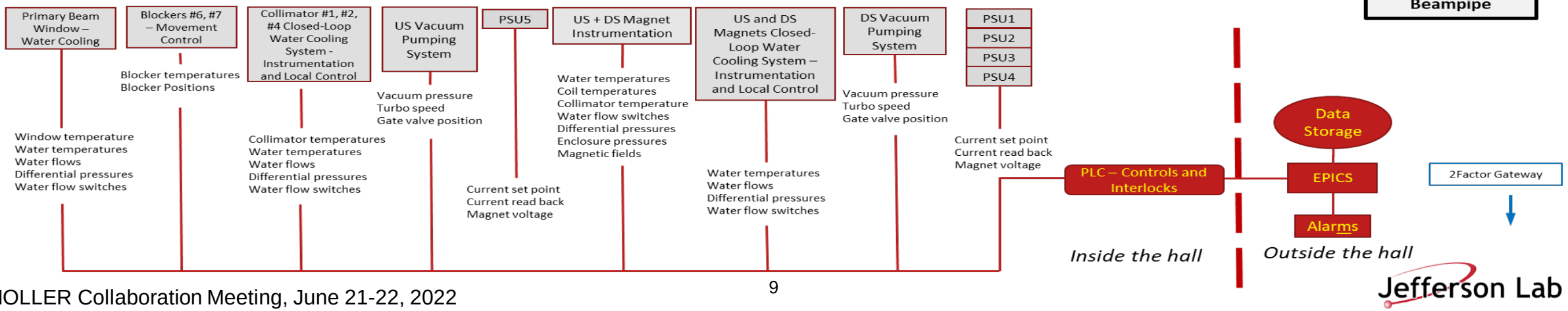


1. The water cooled leads/bus design and specification - COMPLETE
2. Both **PSU and Magnet** end - Flexible copper air-cooled/in vacuum jumpers - COMPLETE
3. MOLLER Spectrometer - Spec and RFQ US_DS Magnet WCL & Jumper leads PMAG0000-0100-S0017 (Draft completed)

Engineering – Basic layout (Instrumentation and Control)

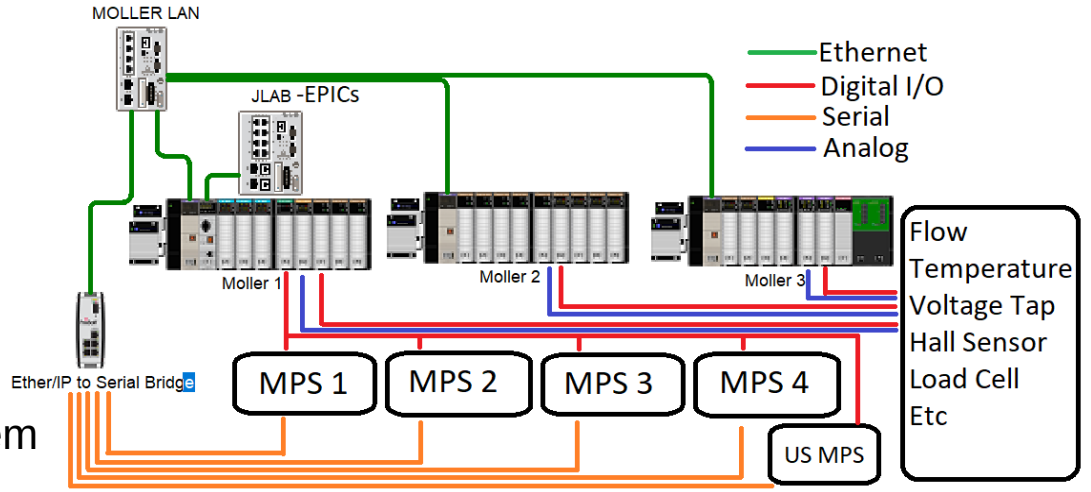


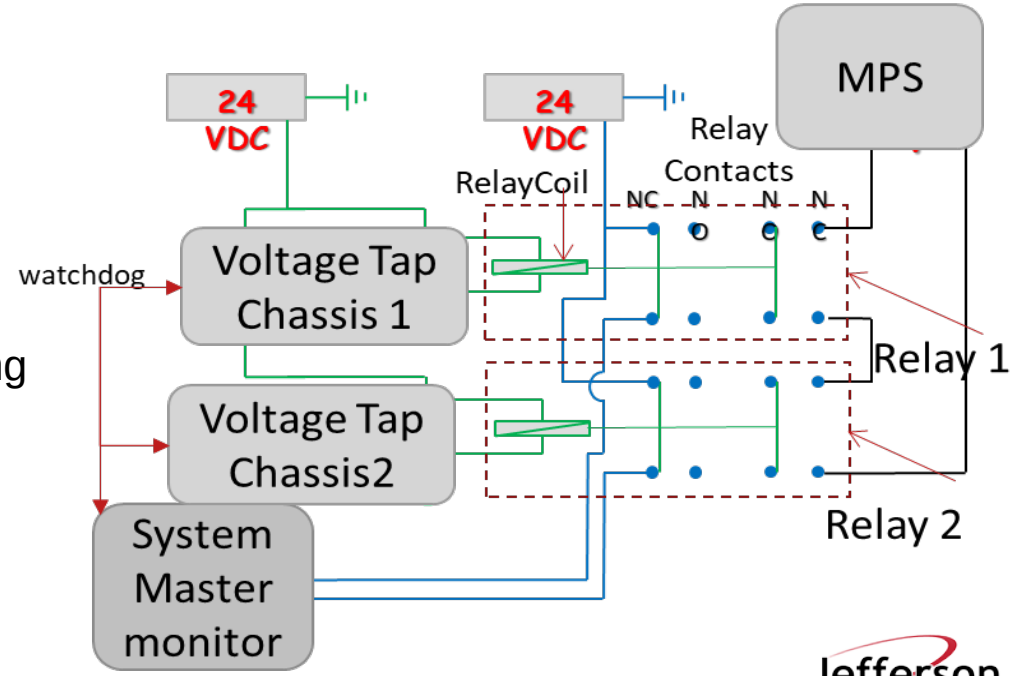


Magnet Power Supplies, I&C : Protection System layout

Sensor Node based controls

- Primary Control provided by master processor with 1g/b Ethernet Interface
- Dual Ethernet Interface
  - 1 for JLAB: IOC/EPICS, remote programming, remote diagnostic
  - 2 for Private Local Network for critical instruments
- Direct Interlock capability 5 or 24 VDC (e.g. voltage, temperature, field, flow, etc.), each Chassis can independently safe out the system
- **Primary protection** is accomplished using one hardwired multi-channel voltage tap readout chassis
- A second multi-channel voltage tap readout runs through a PLC
- Each chassis reads the same voltage taps and performs the comparator function in parallel
- Chassis is JLAB designed FPGA system and targeting 100hz to 2.7khz sample rate. All hardwire interlocks shared with system master digital input for monitoring and diagnostics
- Heartbeat messages are sent across nodes via Ethernet allowing automated response during communication outages
- Secondary protection is on outlet temperature of each coil





MOLLER – Mapping REQUIREMENTS

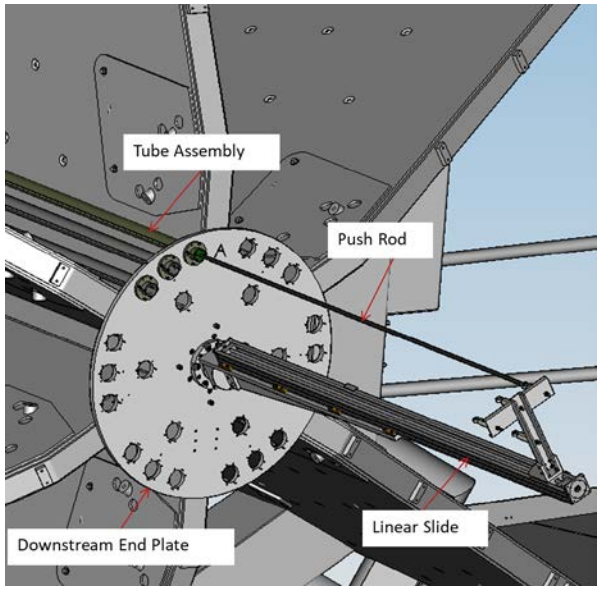
Mapping specification - definition wrt the accuracy and location requirements.

- Mapping design tool for mapping all sector (TBD) plus the central bore.
- Uncertainty in variation of field from sector to sector Things beyond measuring
- modification(s) to match the coil geometry to produce field map…

Complete Magnet – after assembly of magnet

- BMOD measurements (radially focusing component of field, BMOD) along Z in an open sector at r = 135 mm (TBR)
- Determination of magnetic center, measurement of any dipole moment in the bore
- Stray field measurements (location of 5 Gauss line)

Individual Coils - during fabrication and on receipt at JLab**,** Quality Assurance/Quality Check for each coil - Gauss/Amp, Polarity

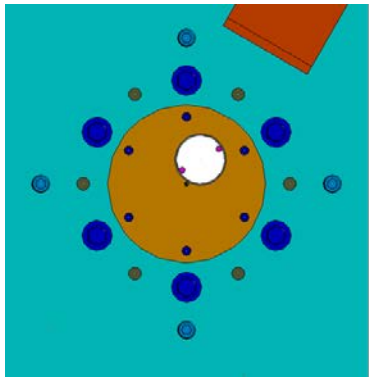


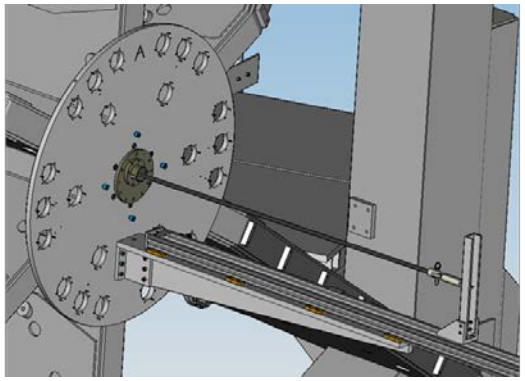
Mapping Tool used in HALL B Torus/Solenoid

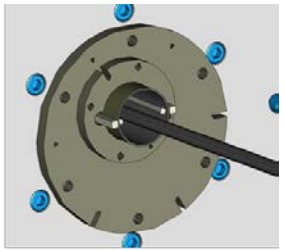
- Precisely machined upstream and downstream plates
- The plates will be surveyed prior to install to know hole locations
- Precise pins locate and orient the carbon fiber tubes
- Pins assure locating/repeatability of carbon fiber tubes to 0.05mm
- Linear slide/motor/controller accurate to 0.010mm

Mapping Tool Operation-Mapping the Bore

- The bore has a total of seven locations mapped
- The center tube is offset from the collar center to take the 2.5cm radius measurement
- The assembly is rotated for each angle while maintaining the required local coordinate system orientation







Summary

- **Engineering test requirements are defined**
  - Conductor design → Coil design → Test requirements (Low current test)
- **Quality Assurance and Quality Control (QA/QC) process requirements at vendor and JLab**
  - Verification and validation of the specifications (defined)
  - Vendor fabrication of coils and tests (defined)
  - OSP's in place for the test in the Magnet Measurement Lab
  - Acceptance testing of coils on receipt at JLAB (defined)
  - Performance testing to evaluate JLAB Coil Acceptance for *individual coils*
- **MPS – Order in place for the prototype MPS (DS Torus-3)**
- **The WCL and jumpers draft specifications are complete**
- **P&ID's are in place and list of instrumentation is been populated**
- **Instrumentation and control philosophy is defined**
- **Magnet Protection/Interlocks logics are defined**
- **Hardware and software development required for the system are identified and the work is in progress**
- **Moller mapping requirements are worked upon**
  - Intent to use concept and tooling used in 12 GeV Hall B torus and solenoid mapping