Jefferson Lab
MAGNET GROUP

03rd March 2020

v1.00

Ruben Fair

on behalf of

Probir Ghoshal, Sandesh Gopinath, David Kashy, Renuka Rajput-Ghoshal, Eric Sun, Randy Wilson, Dan Young

Outline

- **Contribution to Physics Division and Project Involvement**
  - **Hall A**
  - **Hall B**
  - **Hall C**
  - **EIC**
  - **Cryo**
  - **HD Ice**
  - **MOLLER**
  - **Other Work**
- **Publications**
- **Support for DOE reviews**
- **Involvement with the external community**
- **Team Strategic View**

Cryogenic Control Reservoir for Hall A SC Solenoid Magnet - (SOLID)

- Existing CCR (Cryogenic Control Reservoir) was designed per ASME 2007 Section VIII, Division 2.
- CCR for Hall A SC Solenoid Magnet was rechecked to ensure it satisfied the rules of ASME 2019 Section VIII, Division 1.
- The change expands the potential vendor pools from two to seven.
- Existing calculations and drawings are being updated to reflect the requirements of ASME 2019 Section VIII, Division 1.

2007 VIII

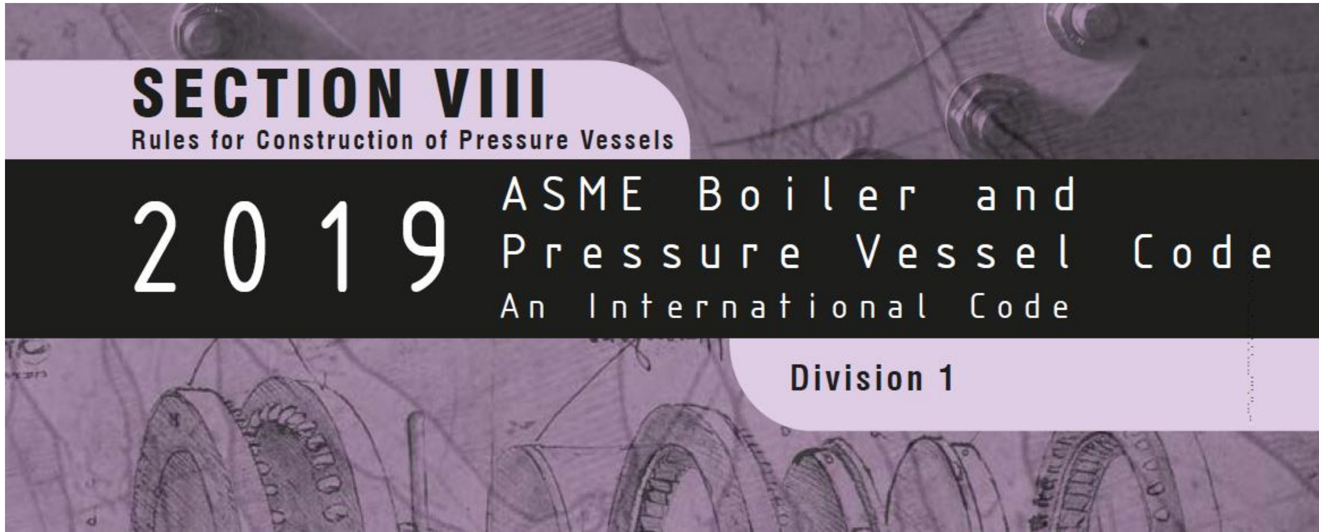
Division 2

Alternative Rules

RULES FOR CONSTRUCTION OF PRESSURE VESSELS

Existing CCR

CCR for SC Solenoid Magnet



SECTION VIII

Rules for Construction of Pressure Vessels

2019 ASME Boiler and Pressure Vessel Code

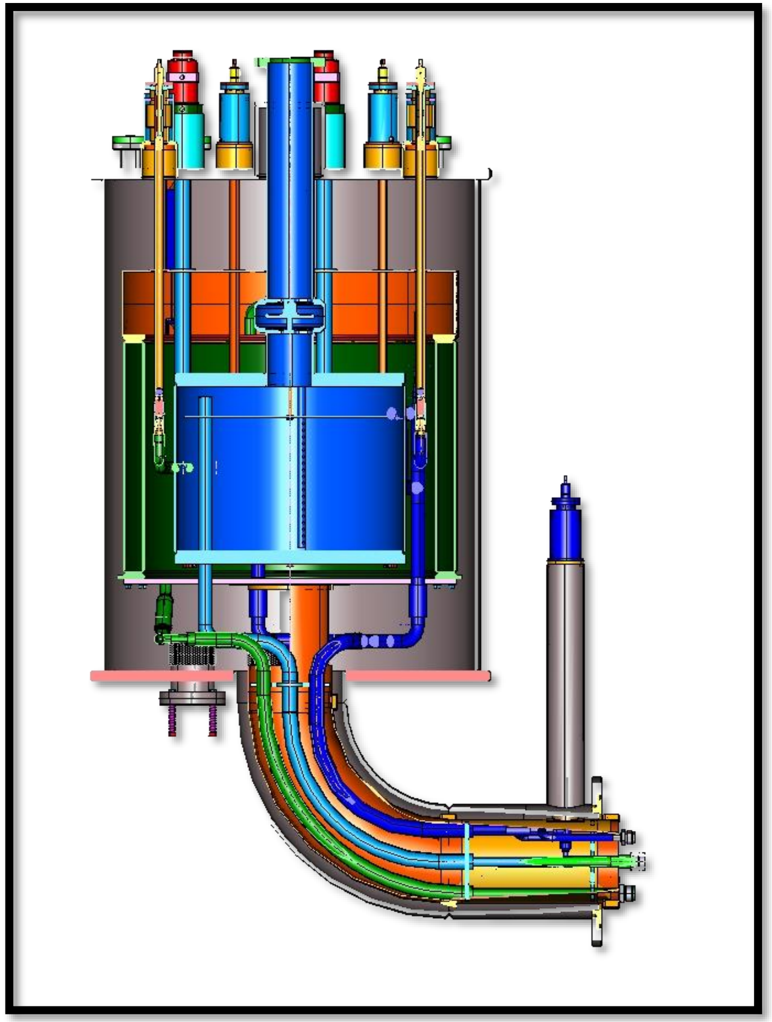
An International Code

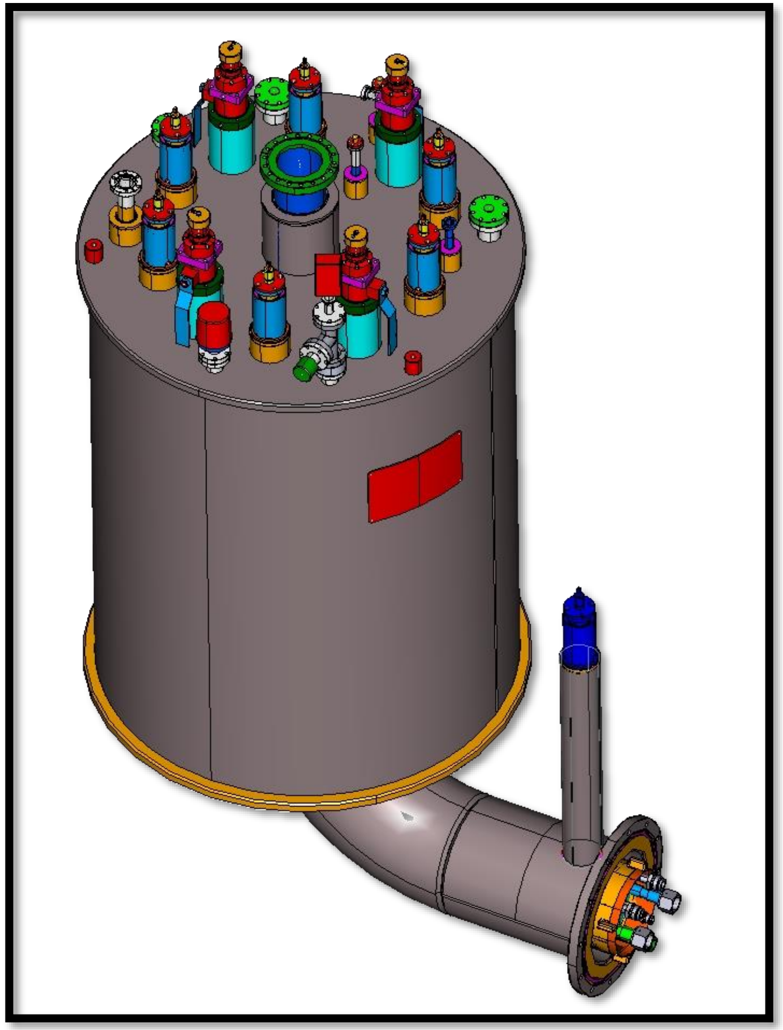
Division 1

Dan Young

Cryogenic Control Reservoir for Hall A SC Solenoid Magnet - (SOLID)

Rework of existing Hall C Cryobox design and details for new interface with the Hall A “SC Solenoid Magnet" (CLEO II) - SOLID





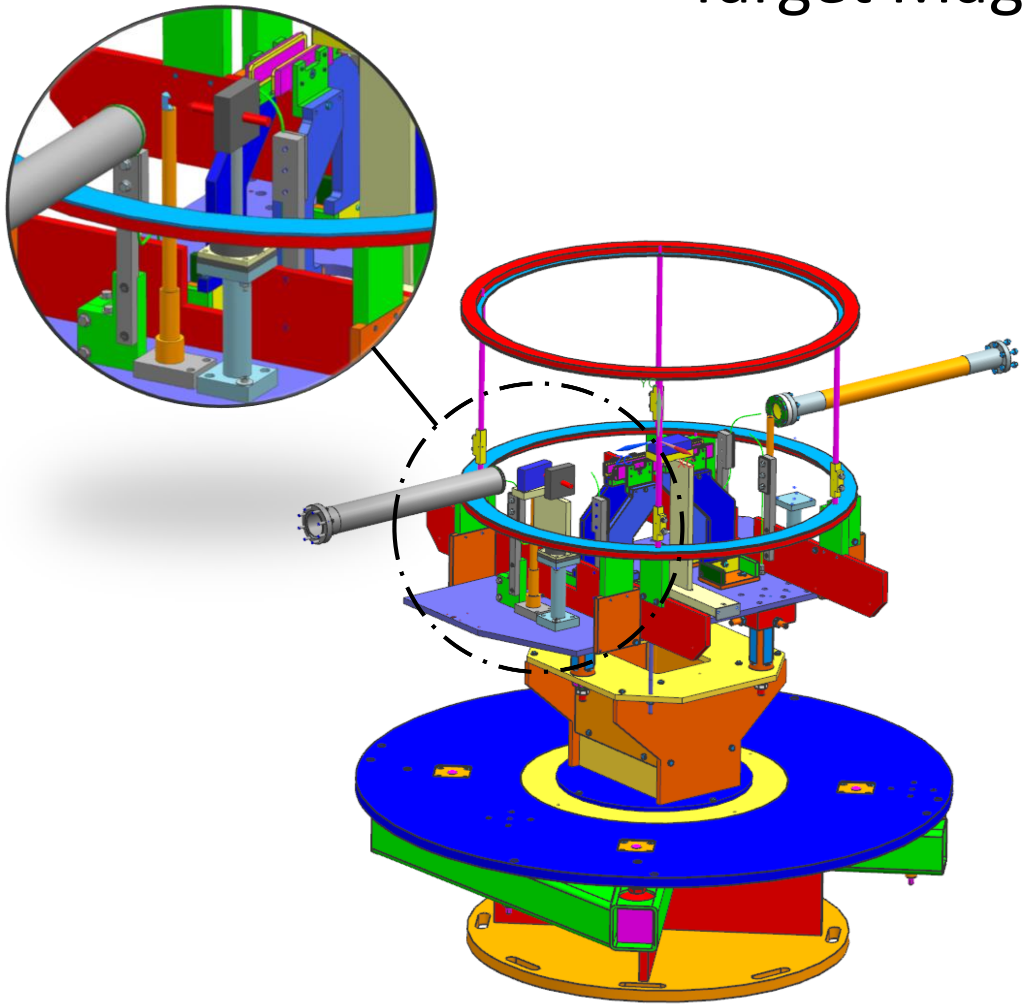
HALL A

Dan Young

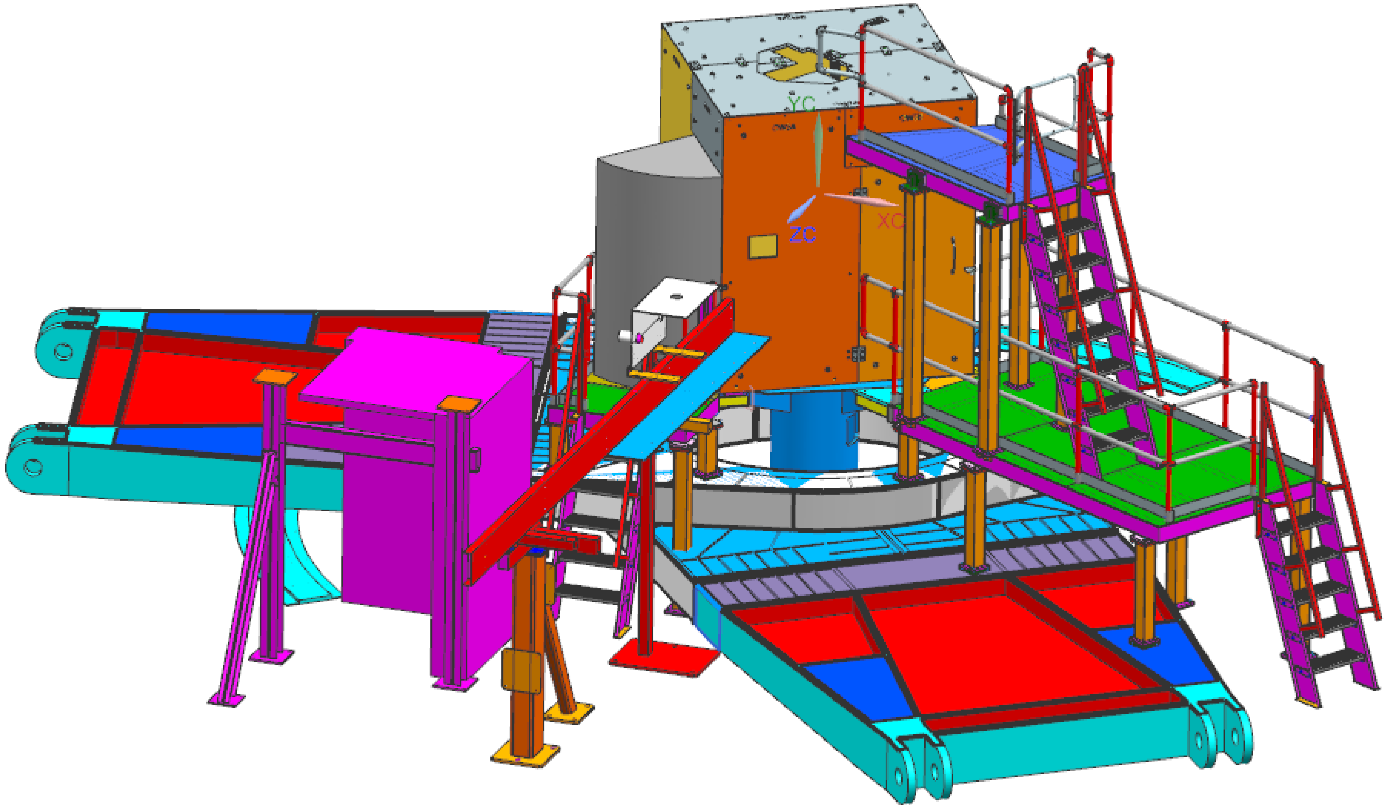
SBS GEn

Super BigBite Spectrometer

Target Magnetic Field Shielding



Design and detail of target laser alignment components



Hardware design revisions to accommodate the installation of experiment power supplies, electronics and shielding bunkers.

Probir Ghoshal
Sandesh Gopinath

Torus – Modeling of the magnetic field

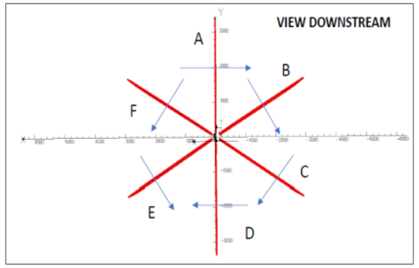
- ❑ **Modeling the actual conductor layout for the torus magnet in Hall B to improve matching with the measured field data**
- ❑ **Engineering and physics working closely to minimize the mismatch (better than 150 G) between measured and model**
  - ➢ **Upon a few iterations (over 16 so far), US end near hub, use an S-bend to simulate the conductor using surveyed data and expected shape of the conductor**
  - ➢ **average model from all coils.**
  - ➢ **All 6 coils relocated /moved in r, ɸ, ϴ translated to x, y, z as shown.**
  - ➢ **Results shows significant improvement with the last iteration (week ending 2/23/2020)**
  - ➢ **Physics now required to define the points in space for magnetic field for engineering to generate B(x,y,z) map.**

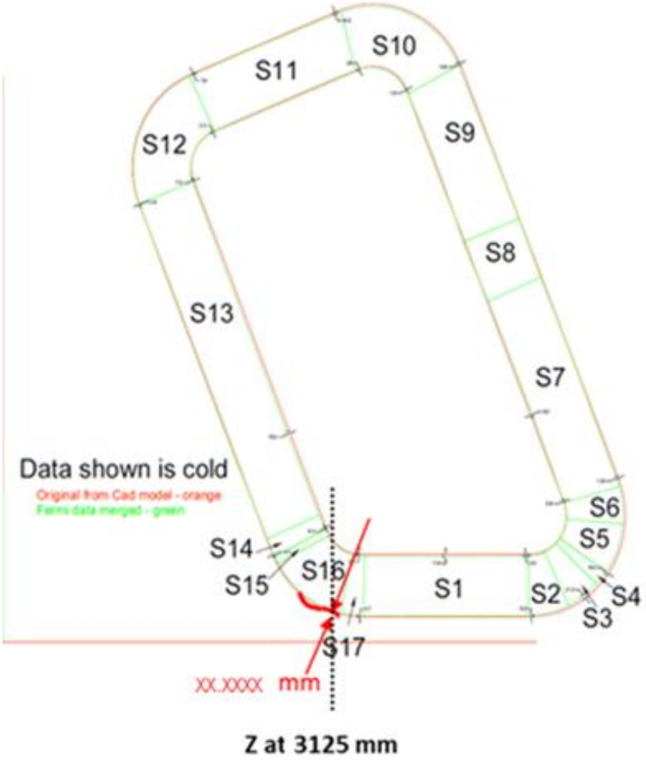
Coil A moves radially in by 0.431708 mm (towards bore/hub)
Coil B moves radially out by 0.286486 mm (away from bore/hub)
Coil C moves radially out by 1.3984 mm (away from bore/hub)
Coil D moves radially out by 3.80696 mm (away from bore/hub)
Coil E moves radially out by 2.41042 mm (away from bore/hub)
Coil F moves radially in by 0.758226 mm (towards from bore/hub)

Coil A moves upstream by 1.01172 mm
Coil B moves downstream by 1.76846 mm
Coil C moves downstream by 0.837393 mm
Coil D moves upstream by 0.518406 mm
Coil E moves upstream by 0.775945 mm
Coil F moves downstream by 0.827278 mm

Coil A moves in azimuth by 0.609696 mm (see diagram)
Coil B moves in azimuth by 1.59645 mm (see diagram)
Coil C moves in azimuth by 2.04734 mm (see diagram)
Coil D moves in azimuth by 0.876729 mm (see diagram)
Coil E moves in azimuth by 1.72266 mm (see diagram)
Coil F moves in azimuth by 1.10946 mm (see diagram)

Coil A shape change magnitude (s-wave at Z = 3125 mm) is 8.71688 mm
Coil B shape change magnitude (s-wave at Z = 3125 mm) is 9.52377 mm
Coil C shape change magnitude (s-wave at Z = 3125 mm) is 8.26433 mm
Coil D shape change magnitude (s-wave at Z = 3125 mm) is 5.99812 mm
Coil E shape change magnitude (s-wave at Z = 3125 mm) is 5.83982 mm
Coil F shape change magnitude (s-wave at Z = 3125 mm) is 10.7929 mm

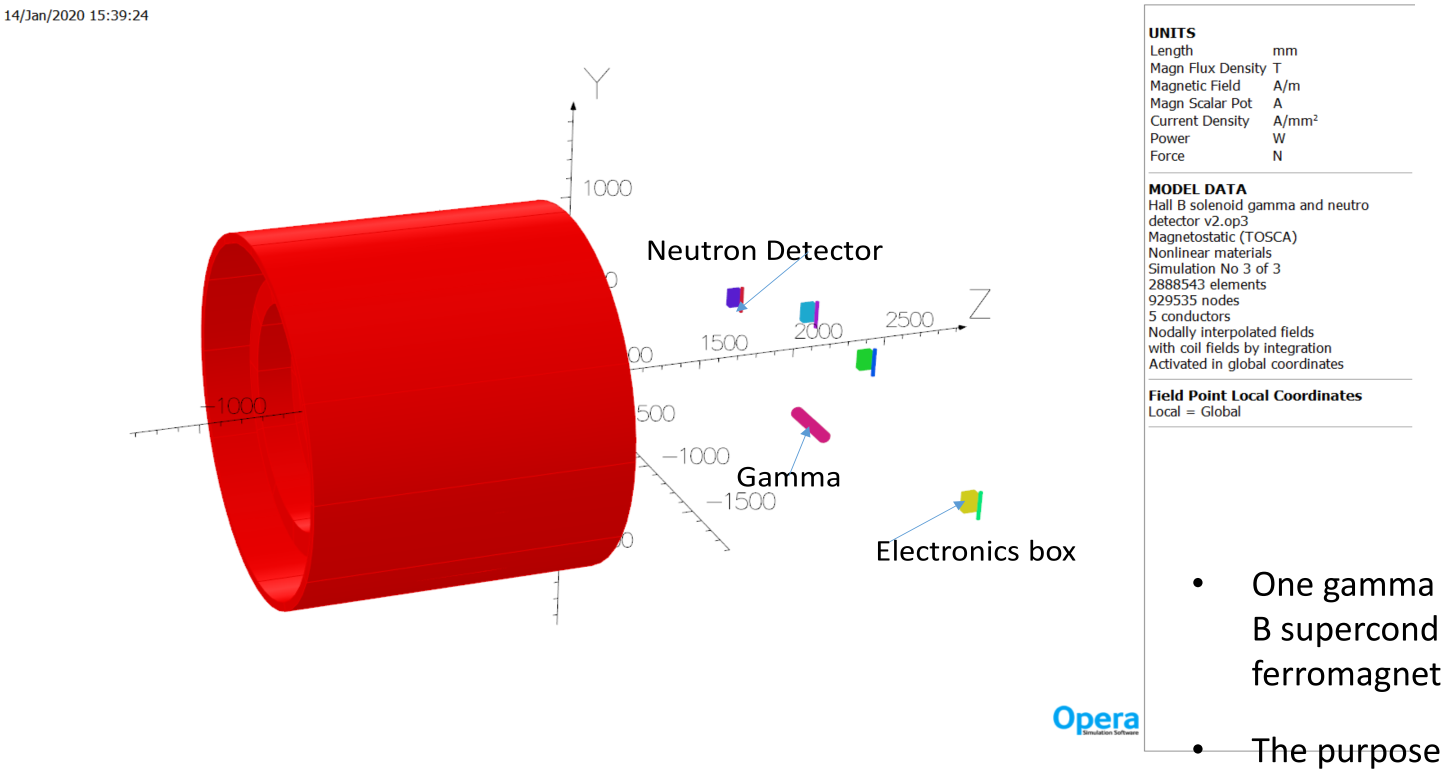




Data shown is cold
Original from Cad model - orange
Fermi data merged - green

Z at 3125 mm

Force Analysis for Neutron and Gamma Ray Detectors for use with Solenoid



UNITS

Length	mm
Magn Flux Density	T
Magnetic Field	A/m
Magn Scalar Pot	A
Current Density	A/mm²
Power	W
Force	N

MODEL DATA
Hall B solenoid gamma and neutro detector v2.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 3 of 3
2888543 elements
929535 nodes
5 conductors
Nodally interpolated fields with coil fields by integration
Activated in global coordinates

Field Point Local Coordinates
Local = Global

- One gamma ray detector and 4 neutron monitors will be installed close to the Hall B superconducting solenoid magnet. These detectors will have some ferromagnetic components.
- The purpose of this technical report is to analyze the forces on these detectors due to the stray magnetic field of the Hall B solenoid.
- These forces are considered to be negligible. Although the field in that region is only of the order of about 300G, no loose magnetic material should be allowed to be in close proximity to the magnet.

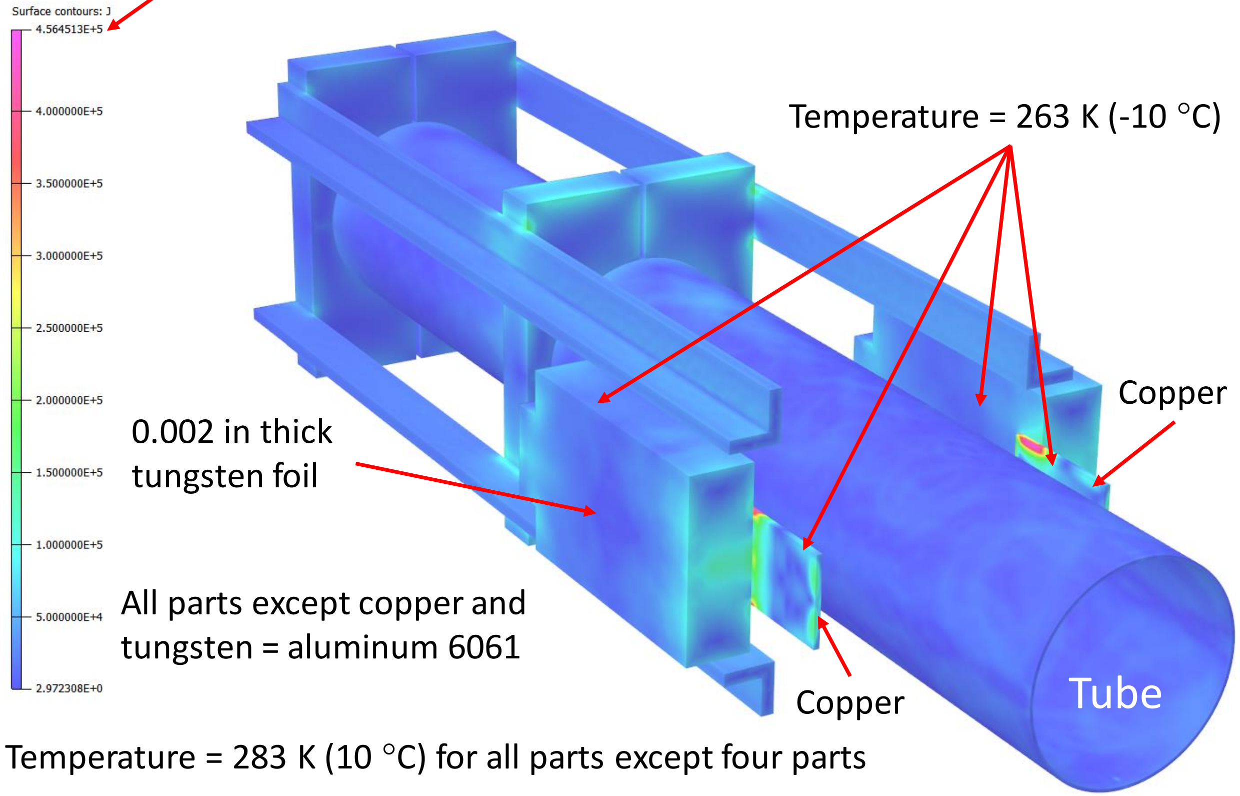
→ Tech report B000000400-A028

HALL B

Eric Sun
Renuka Rajput-Ghoshal

Eddy Current Analyses of Detectors for use with Solenoid

Hall B CLAS12



Max eddy current = 4.565E5 A/m^2

Temperature = 263 K (-10 °C)

Copper

0.002 in thick tungsten foil

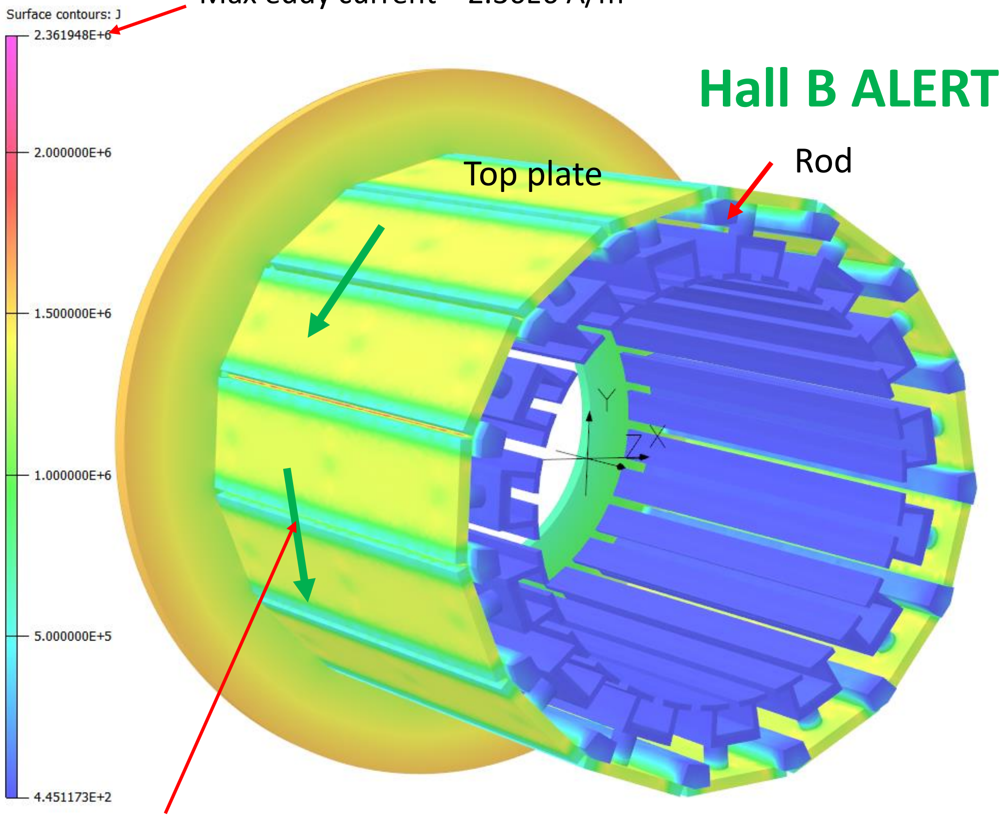
All parts except copper and tungsten = aluminum 6061

Copper

Temperature = 283 K (10 °C) for all parts except four parts

- ☐ Maximum current is 2416 A; maximum decay rate = 281 A/s.
- ☐ Negligible Lorentz forces on the aluminum, copper, and tungsten.
- ☐ Internal bursting force of the tube = 104 N. No concern.

Hall B ALERT



Max eddy current = 2.36E6 A/m^2

Top plate

Rod

Eddy current direction

All parts = aluminum 6061, 293 K

- ☐ Maximum current is 2416 A; maximum decay rate = 281 A/s.
- ☐ Internal bursting force of the flange = 1932 N, producing an average stress of 0.68 MPa. No concern.
- ☐ Large Lorentz force in top plate. Recommend insulation layers between top plates and rods to suppress eddy current.

Tests of SHMS Magnet Dump Resistors

- 7.5 mΩ and 25 mΩ dump resistors, manufactured by Switzerland’s Widcap AG, were tested at Jefferson Lab.
- Fig. 1 shows that no quench-back of Q2/Q3 magnets was observed with 7.5 mΩ dump resistor. Fig. 2 illustrates the quench-back phenomenon with a 75 mΩ dump resistor.
- Fig. 3 shows that no quench-back of Dipole magnets was observed with 25 mΩ dump resistor. Fig. 4 illustrates the quench-back phenomenon with a 75 mΩ dump resistor.

→ MT26 Paper: Test Results of Fast Decaying Current-Induced AC Losses in SHMS Superconducting Magnets at Jefferson Lab

  - Published in Feb 2020

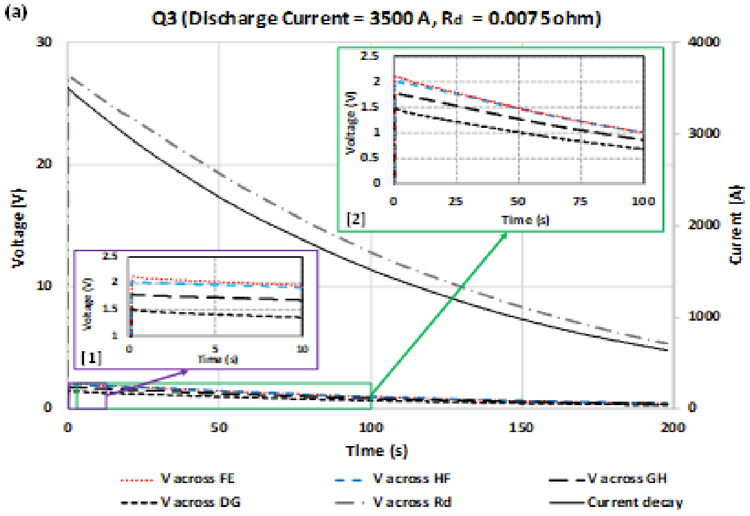


Fig. 1

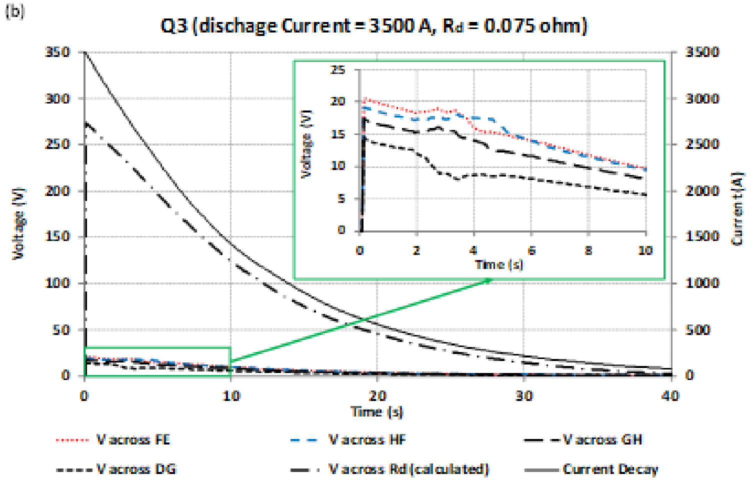


Fig. 2

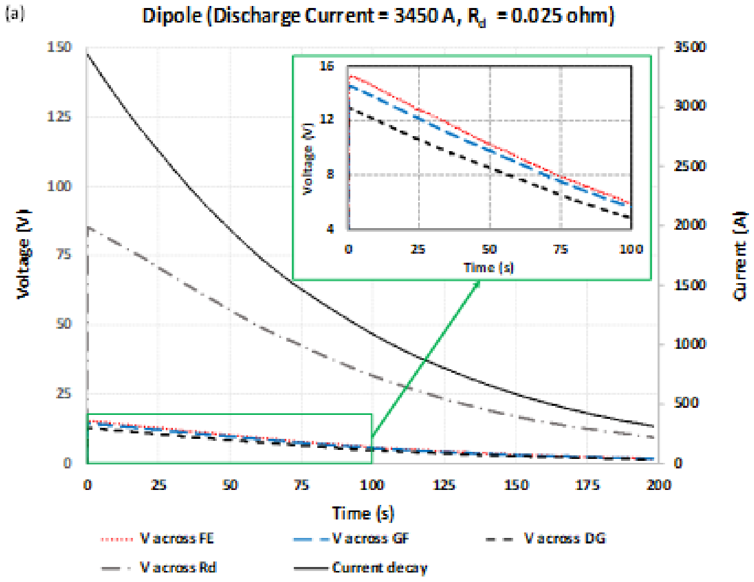


Fig. 3

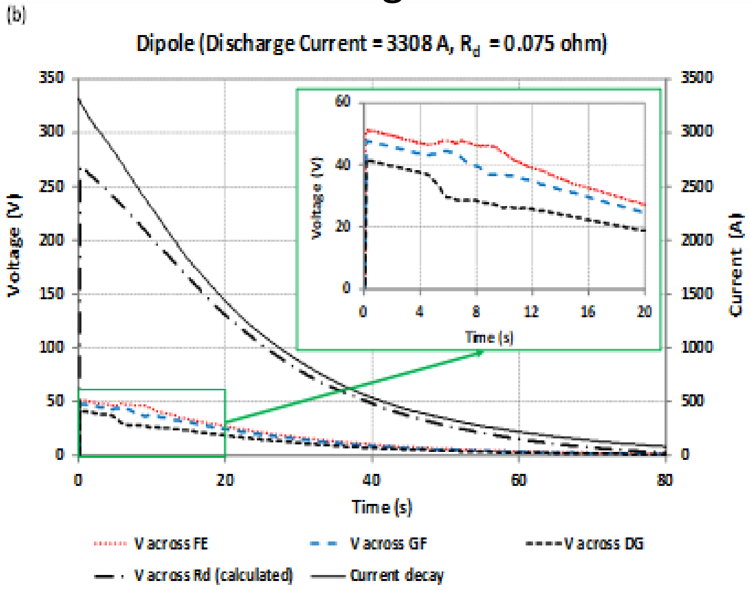


Fig. 4

Potential Magnet Design work (with BNL)

The goal is to establish Task Forces to support specific design/analysis/research activities. They are described below.

- EIC Task Force on Compensation of Detector Solenoid Effects
- Mechanical analysis of the IR magnets and to make sure that physically we have allocated enough space (with end volumes and end plates, power feedthroughs etc.). This has been started here with our Magnet Division, but there is a lot left to be done.
- BNL has not worked on including correctors into the IR (we only recently came up with a first shot at a correction scheme)
- BNL has not looked at multipole errors at different energies, so this is also something which could be interesting.
- There are spin rotator solenoids (7T, 3m long) which could do with more design effort.
- Magnets which have so far received very little attention are the additional magnets required to match into the RHIC ring (80T/m quads and 5-6T dipole magnets). Each of these requires a magnetic design as well as a first pass on engineering.
- Another potential topic for a magnet Task Force is fast ramping magnets for the RCS (rapid cycling synchrotron).

→ ***We have the skill sets in house. We need more information on the level of detail required/desired and in what time frame prior to committing to this work. This work is desirable and we should take it on if we have the staff to get it done. It requires support from both the Physics Magnet Group and the ME Group. Staff from the ME Group may also be used to support SRF design work and the EIC Task Force on Hadron Storage Ring Vacuum Chamber Upgrade.***

CRYO – Coordination

Dave Kashy

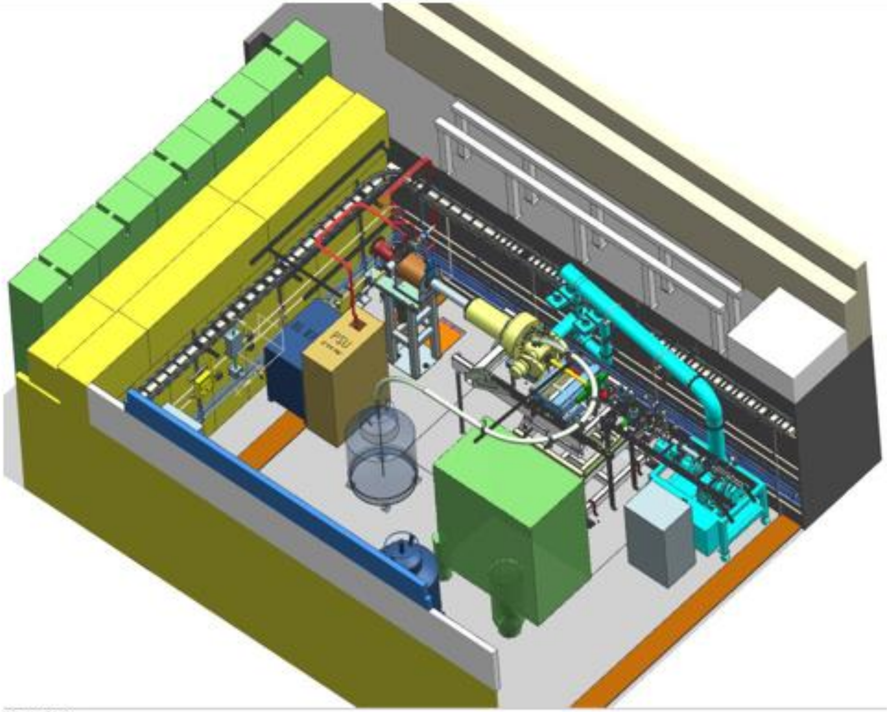
- Hall A SAD Plan review with Cryo
- Reinforce use of esr-users@jlab.org to both Hall Techs and ESR operators
- Lots of design consultation with Cryo engineers
- Trouble shooting of instability in Hall B system (U-tube vacuum)
- Distributed design guidance to target group for Moller target (Temperature/Pressure/Flow)

HDIce

Dave Kashy
Probir Ghoshal
Randy Wilson
Ruben Fair

HD Ice Dump Solenoid (UITF)

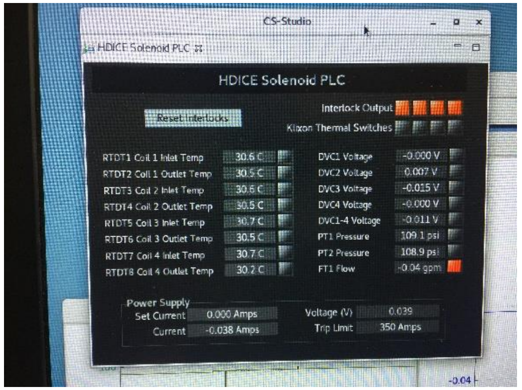
Magnetic Field at the magnet center, B(0,0,0) in T	0.25 (Nominal)
Maximum length (mm)	< 500 (Nominal)
Clear bore diameter (inches)	9.5
Integral B.dL (T.m)	0.125 (start of solenoid to HARP 630 mm downstream (~ - ve 250 mm to + ve 380 mm)
Operating current (A)	318.2 (Nominal), (Allowed up to 350A max.)
Operating voltage (V)	47 (Nominal)
Maximum supply voltage (V)	< 80 (MPS)



lick an object

Figure 1 – The UITF Enclosure showing the location of the HD-Ice experiment and the PSU connected to the solenoid at the top of the picture. The solenoid can be seen on the top of its stand.

HD Ice Dump Solenoid (UITF) - Solenoid Test Results

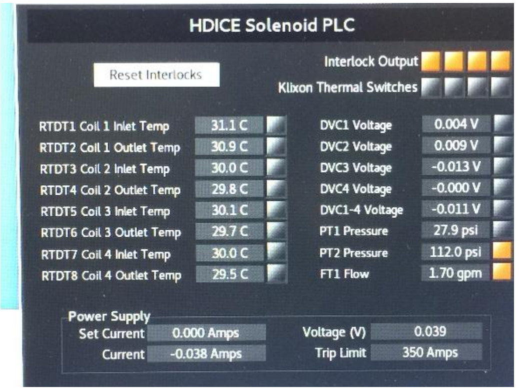


HDICE Solenoid PLC

RTDT1 Coil 1 Inlet Temp 30.6 C
RTDT2 Coil 1 Outlet Temp 30.5 C
RTDT3 Coil 2 Inlet Temp 30.6 C
RTDT4 Coil 2 Outlet Temp 30.5 C
RTDT5 Coil 3 Inlet Temp 30.7 C
RTDT6 Coil 3 Outlet Temp 30.5 C
RTDT7 Coil 4 Inlet Temp 30.7 C
RTDT8 Coil 4 Outlet Temp 30.2 C
DVC1 Voltage -0.000 V
DVC2 Voltage 0.007 V
DVC3 Voltage -0.015 V
DVC4 Voltage -0.000 V
DVC1-4 Voltage -0.011 V
PT1 Pressure 109.1 psi
PT2 Pressure 108.9 psi
FT1 Flow -0.04 gpm

Power Supply
Set Current 0.000 Amps
Current -0.038 Amps
Voltage (V) 0.039
Trip Limit 350 Amps

PT cross check (0.23psi full range)



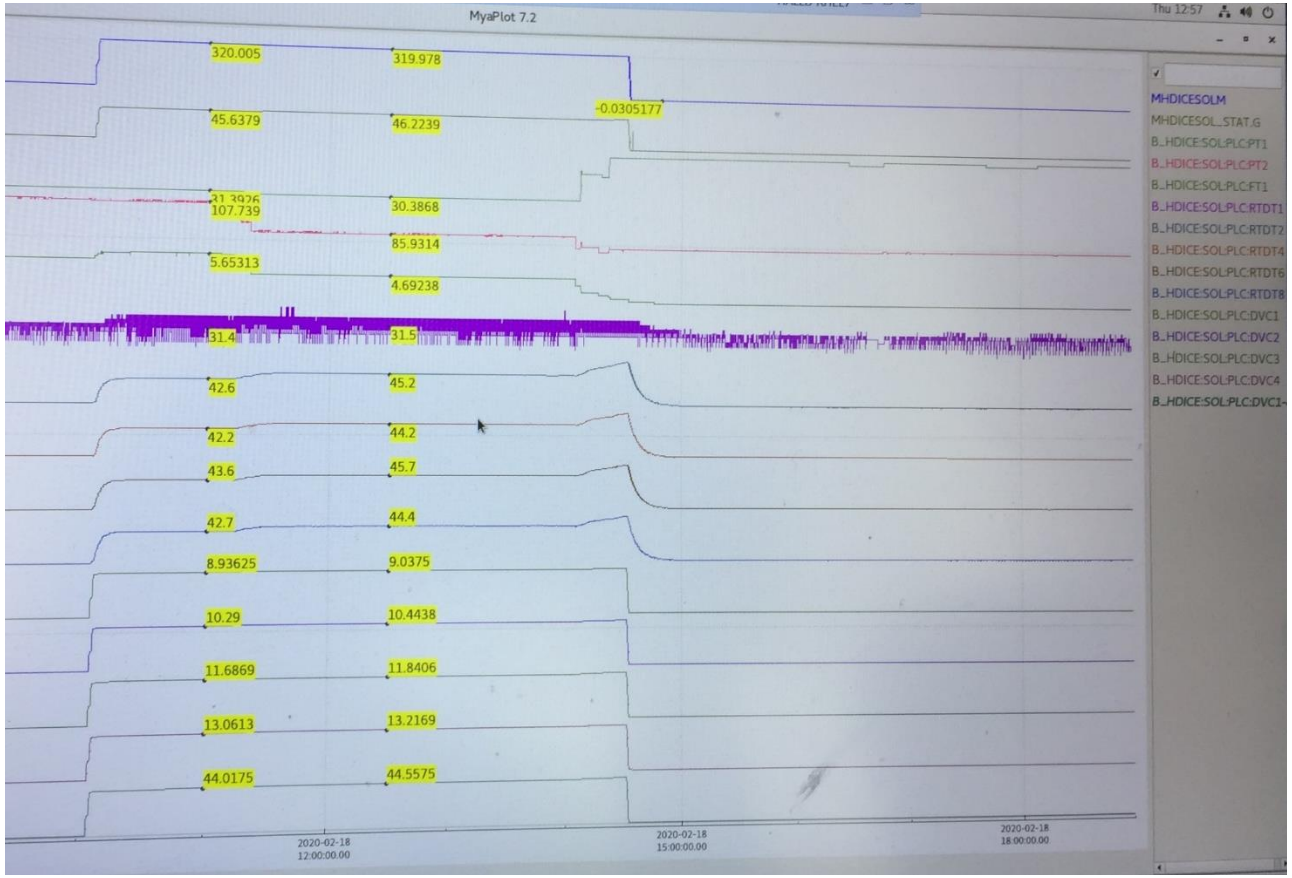
HDICE Solenoid PLC

RTDT1 Coil 1 Inlet Temp 31.1 C
RTDT2 Coil 1 Outlet Temp 30.9 C
RTDT3 Coil 2 Inlet Temp 30.0 C
RTDT4 Coil 2 Outlet Temp 29.8 C
RTDT5 Coil 3 Inlet Temp 30.1 C
RTDT6 Coil 3 Outlet Temp 29.7 C
RTDT7 Coil 4 Inlet Temp 30.0 C
RTDT8 Coil 4 Outlet Temp 29.5 C
DVC1 Voltage 0.004 V
DVC2 Voltage 0.009 V
DVC3 Voltage -0.013 V
DVC4 Voltage -0.000 V
DVC1-4 Voltage -0.011 V
PT1 Pressure 27.9 psi
PT2 Pressure 112.0 psi
FT1 Flow 1.70 gpm

Power Supply
Set Current 0.000 Amps
Current -0.038 Amps
Voltage (V) 0.039
Trip Limit 350 Amps

Flow through each coil measured

- LCW Pressure available is higher with Test Lab system improved and tuned
  - Prior to adjustment <50psid
  - Now 76psid at full flow
- Magnet flow is higher than originally analyzed
  - Original Calc 3.2gpm at 70 psid P=13.3kW
  - Actual 5.6gpm at 76psid P= 14.0kW
- Power calculation quite close (resistivity of copper not specified)
- Flow analysis quite conservative
- Data will be used to improve flow calculations



Magnet run at two flow rates (5.6 and 4.7 gpm)

Spectrometer CD0 to CD1 Action Plan

TASKS COMPLETED

- ☐ Helium v Vacuum down select → Vacuum selected
- ☐ Basis of Estimate

REVIEWS COMPLETED

Independent Cost Review – Nov 2019

Design Review – Dec 2019

Director's Review – Jan 2019

TASKS IN PROGRESS

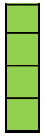
- ☐ Risk Register update *(RF)*
- ☐ Re-sequencing of P6 tasks *(RF)*
- ☐ Working with Procurement Dept to agree on timescales for procurement-related activities *(RF)*
- ☐ Improving 'drill-down' of Basis of Estimates for costs, for reviews *(RF)*
- ☐ Updating of Hall A CAD model *(DK/RW)*
- ☐ Beam pipe conceptual design *(DK)*
- ☐ Coil support design (strong backs and frame) *(SG/DK)*
- ☐ Field mapping specification and conceptual design of mapping fixture *(RRG)*
- ☐ Coil unbalanced forces for misalignment and fault scenarios *(ES/RRG/SG)*
- ☐ Re-design of upstream torus *(DK)*
- ☐ Assessment of particle-tracking capability within TOSCA *(PG/RRG)*
- ☐ Update of downstream coil designs for GEANT modeling *(DK/SG/RW/PG)*
- ☐ Down select of DS Hybrid v Segmented coil design *(RF, team, Collaboration)*

Hall A - MOLLER

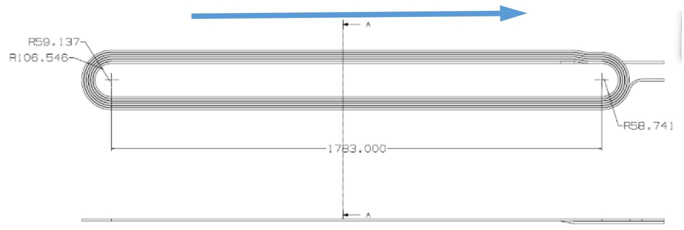
Dave Kashy / Randy Wilson / Sandesh Gopinath / Probir Ghoshal

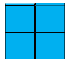
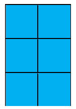
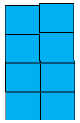
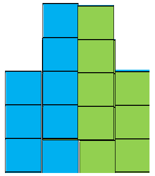
Magnet Coil Designs

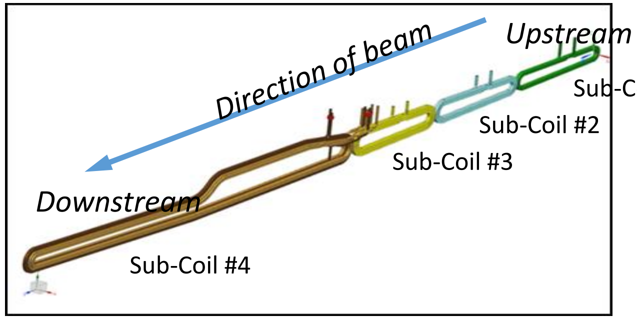
- New Blocky models produced for collaboration analysis

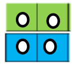
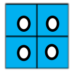
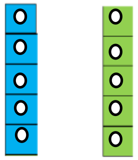
Upstream (larger conductor fewer turns)			
Upstream Torus Feb 26, 2020			US Torus (single pancake)
LUVATA Conductor #			6862
Conductor width	W	mm	9.0
Conductor width	H	mm	9.0
Concuctor hole dia	d	mm	6.5
Insulated Coil Clearance to envelope	C	mm	1.7
Current Density	Rhoi	A/mm2	28.5
Temperature rise	DT	C	21.7
Water velocity	V	ft/sec	13.6
Water Pressure Drop	DP	psi	102.3
Subcoil String flow rate	F	gpm	15.3
Voltage Subcoil String (PS voltage)	V	V	62.4
Current Subcoil String (PS current)	I	A	1339.4
Power Subcoil String (PS power)	P	kW	83.6
Total Magnet Power	PT	kW	83.6
Total Magnet Flow rate	Fm	gpm	15.3
Average temperature rise	DT avg	C	21.7
Pump DP	H	psi	102.3

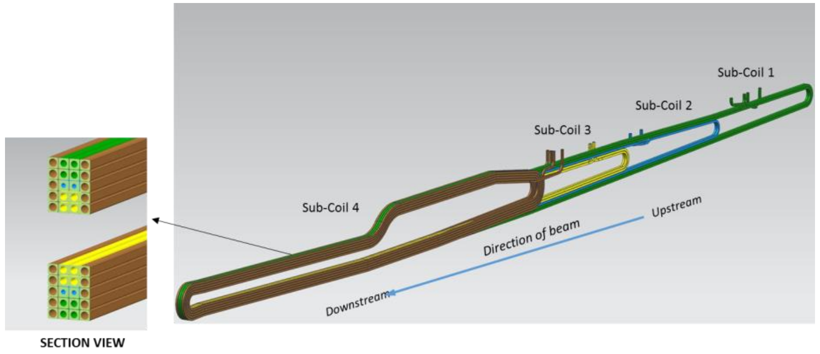
Direction of beam



DS Segmented (re-arrange conductors and fewer turns in SC3)						
Segemented Torus Jan 24, 2020			DS segmented Sub coil 1	DS segmented Sub coil 2	DS segmented Sub coil 3	DS segmented Sub coil 4
LUVATA Conductor #			7034	8426	8151	8193
Conductor width	W	mm	12.7	14	15	16
Conductor width	H	mm	12.7	14	15	16
Concuctor hole dia	d	mm	4.5	6	7	12
Insulated Coil Clearance to envelope	C	mm	4.1	14.8	23.6	
Current Density	Rhoi	A/mm2	15.4	12.2	13.1	14.7
Temperature rise	DT	C	23.2	14.6	20.0	28.1
Water velocity	V	ft/sec	13.9	13.2	12.2	9.5
Water Pressure Drop	DP	psi	98.9	99.1	98.9	100.4
Subcoil String flow rate	F	gpm	7.5	12.6	15.8	72.6
Voltage Subcoil String (PS voltage)	V	V	19.7	22.9	33.1	246.1
Current Subcoil String (PS current)	I	A	2228.7	2032.1	2423.9	2095.9
Power Subcoil String (PS power)	P	kW	43.8	46.6	80.3	515.8
Total Magnet Power	PT	kW	686.5			
Total Magnet Flow rate	Fm	gpm	108.5			
Average temperature rise	DT avg	C	25.0			
Pump DP	H	psi	99.3			



DS Hybrid (minor tweak in shape)						
Hybrid Torus March 6,2019			DS hybrid Sub coil 1	DS hybrid Sub coil 2	DS hybrid Sub coil 3	DS hybrid Sub coil 4
LUVATA Conductor #			10000	8449	8185	6819
Conductor width	W	mm	13.0	13.0	13.0	13.0
Conductor width	H	mm	13.0	13.0	13.0	13.0
Concuctor hole dia	d	mm	8.5	6.0	9.0	10.0
Insulated Coil Clearance to envelope	C	mm	4.5	15.8	25.9	5.7
Current Density	Rhoi	A/mm2	17.4	10.2	15.0	13.9
Temperature rise	DT	C	19.2	16.3	20.4	11.7
Water velocity	V	ft/sec	12.8	11.1	10.7	11.0
Water Pressure Drop	DP	psi	99.4	99.4	99.5	99.8
Subcoil String flow rate	F	gpm	49.1	10.6	23.0	58.4
Voltage Subcoil String (PS voltage)	V	V	123.3	30.8	75.9	140.5
Current Subcoil String (PS current)	I	A	1938.0	1425.0	1565.0	1230.0
Power Subcoil String (PS power)	P	kW	239.0	43.9	118.8	172.9
Total Magnet Power	PT	kW	574.5			
Total Magnet Flow rate	Fm	gpm	141.1			
Average temperature rise	DT avg	C	16.1			
Pump DP	H	psi	99.5			

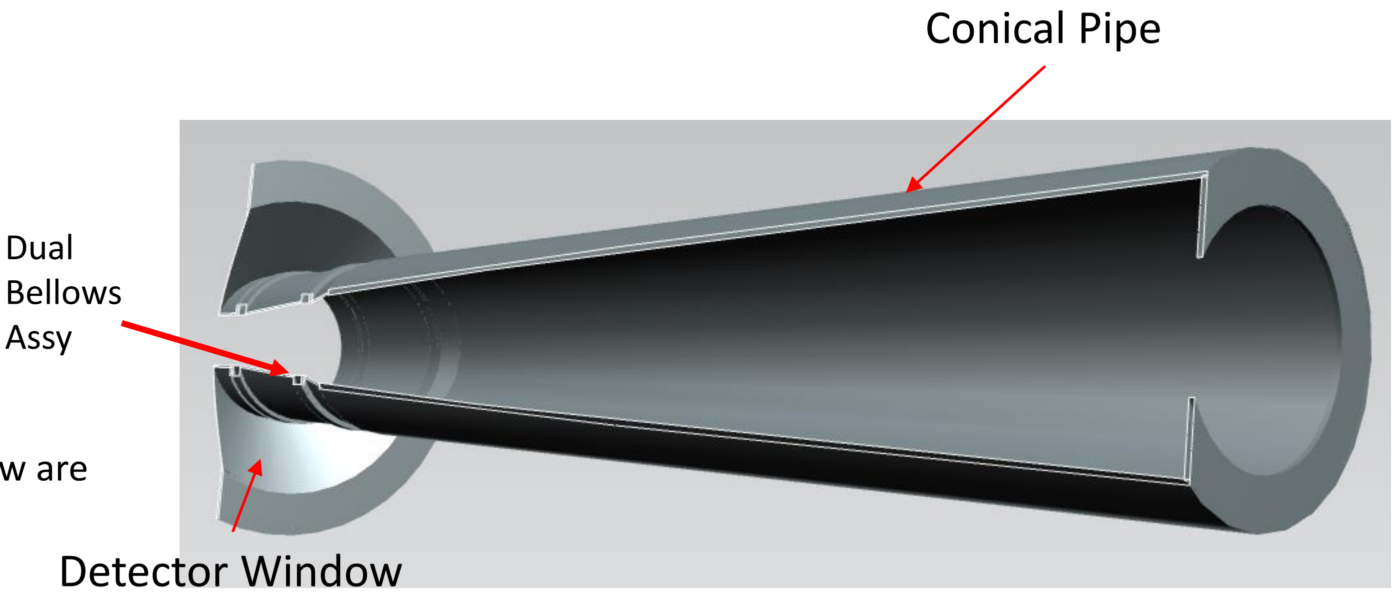


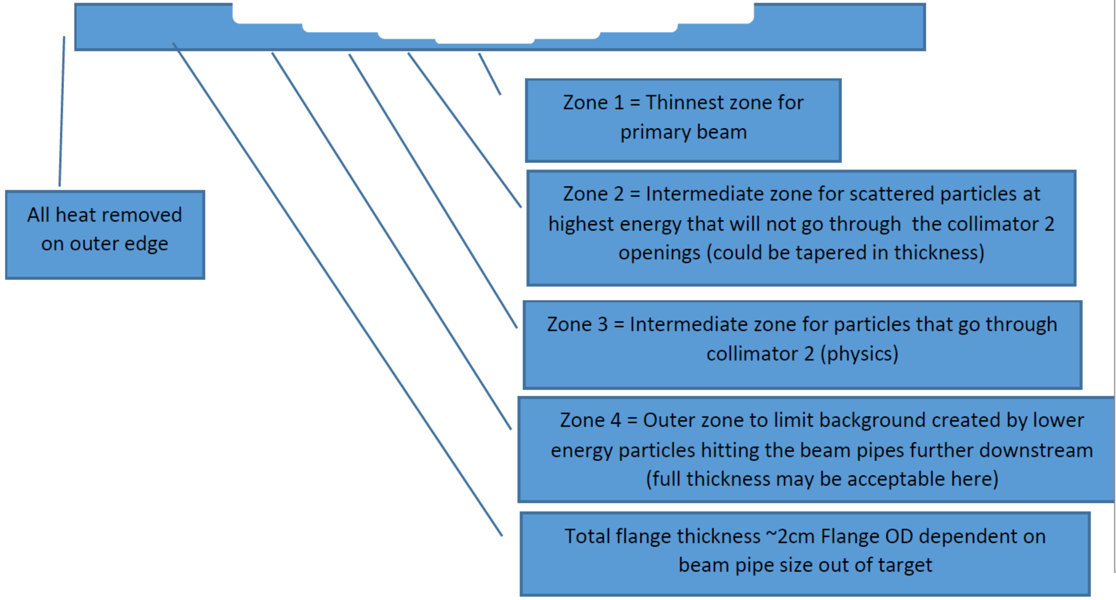
Hall A - MOLLER

Dave Kashy / Randy Wilson

Beam Pipes and Windows

- Conceptual design of Detector Beam Pipe started
  - Working to get rough budgetary estimate drawings
- Have contacted potential vendors for
  - Window forming
  - Bellows Manufacture
  - Conical aluminum pipe
- Preliminary calculations on primary beam window are encouraging
  - Staggered thickness 0.1, 0.2, 0.3mm
  - Peak temp 120C





All heat removed on outer edge

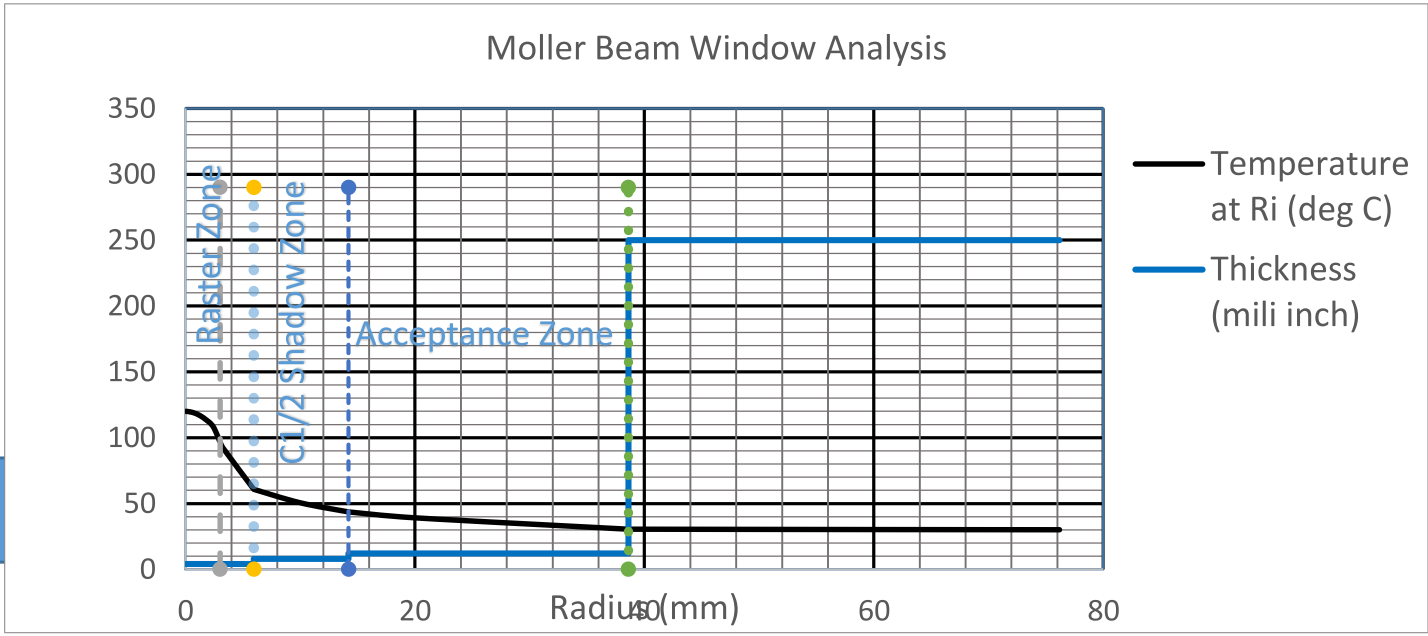
Zone 1 = Thinnest zone for primary beam

Zone 2 = Intermediate zone for scattered particles at highest energy that will not go through the collimator 2 openings (could be tapered in thickness)

Zone 3 = Intermediate zone for particles that go through collimator 2 (physics)

Zone 4 = Outer zone to limit background created by lower energy particles hitting the beam pipes further downstream (full thickness may be acceptable here)

Total flange thickness ~2cm Flange OD dependent on beam pipe size out of target



DS Torus coil support design & analysis

- **Objectives**: To compare different conceptual designs to support the DS torus

- Evaluate conceptual coil support structures based on coil deflections and stresses.
- Compare hybrid and segmented coil designs for same support structure concepts.

What's in store:

- Study design options to allow for thermal motion. (with DK)
- Interface with physics to study radiation dose distribution and select materials.
- Develop new support concept based on above studies.

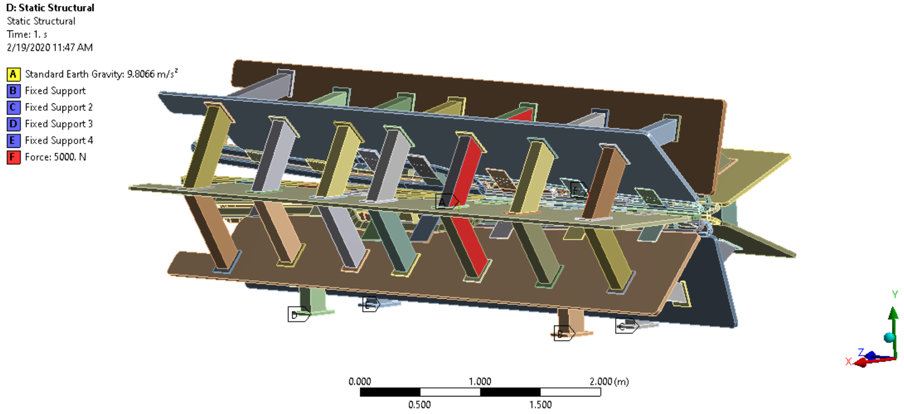


Fig 7. CASE 1 geometry with boundary conditions

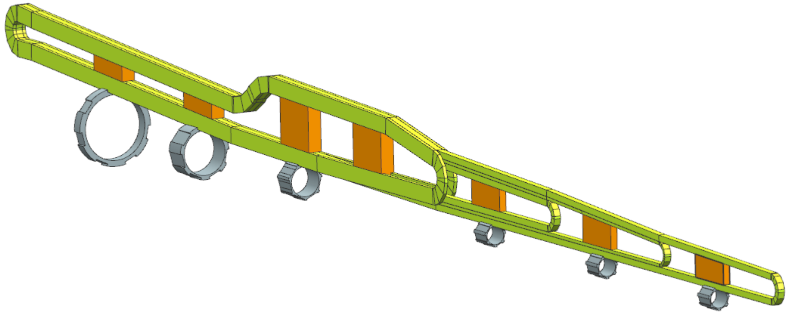


Fig 20. CASE 6 Figure showing COIL 1 with 6 support rings in the bore.

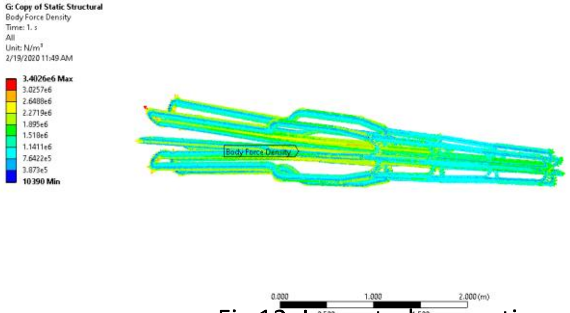


Fig 12. Imported magnetic load from MAXWELL

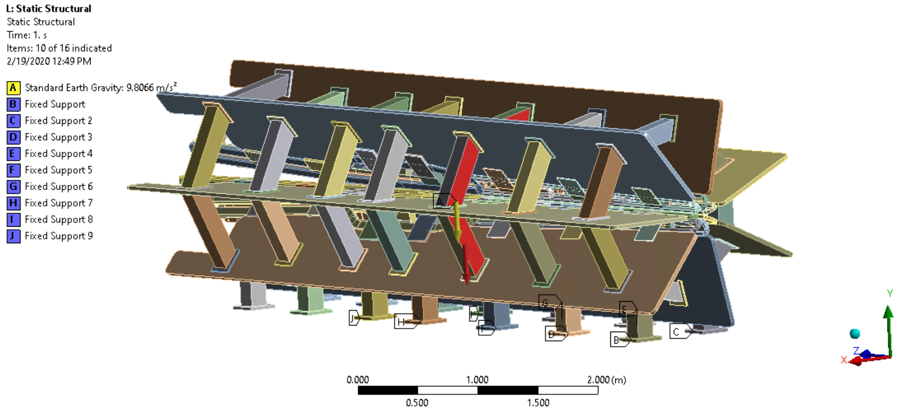


Fig 17. CASE 5 geometry with boundary conditions

Hall A - MOLLER

Sandesh Gopinath

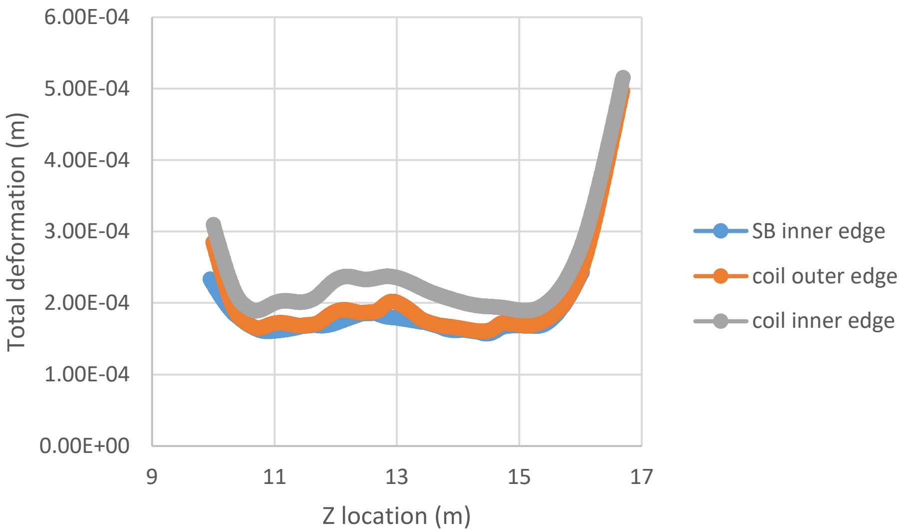


Fig 10. CASE 1 Deflection plot of COIL1 vs Z location

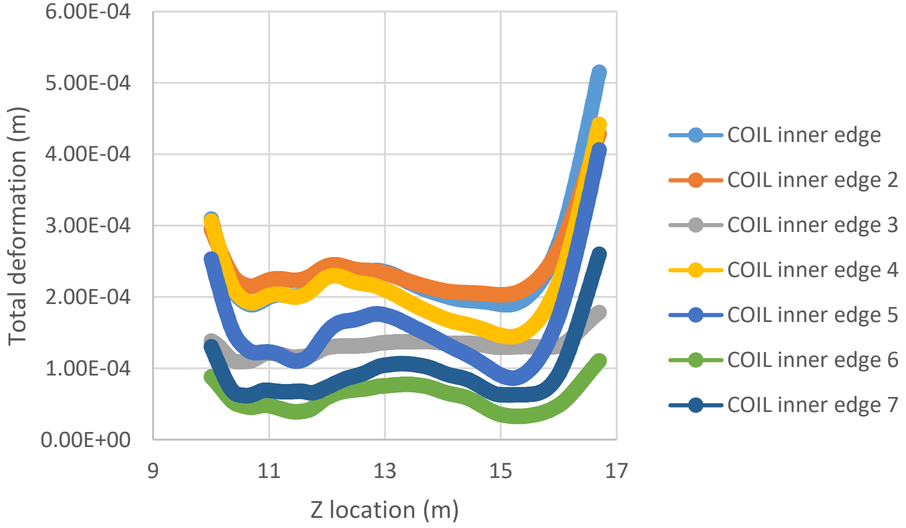


Fig 11. CASE 1 Plot comparing deflections of inner edge of all coils with COIL 1 & 2 showing the highest overall movement

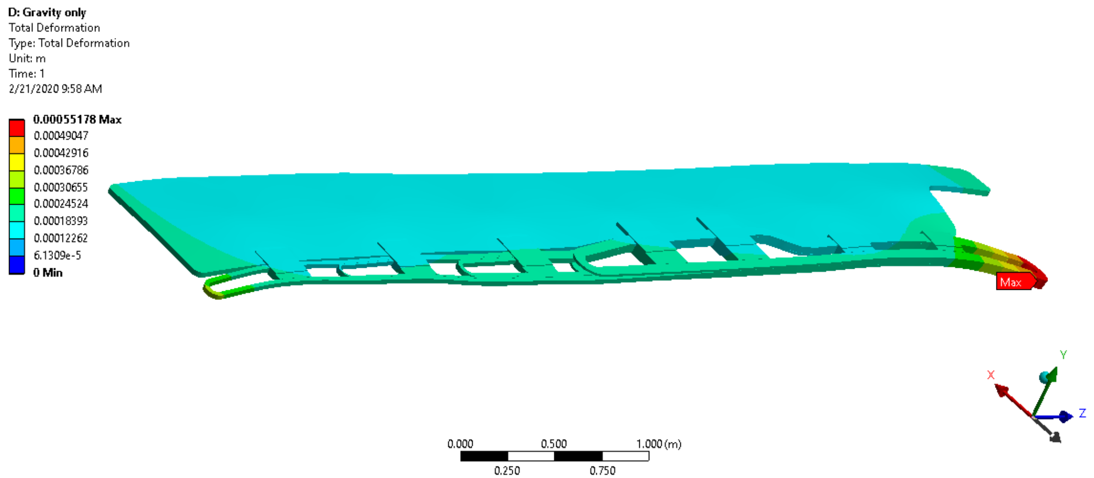
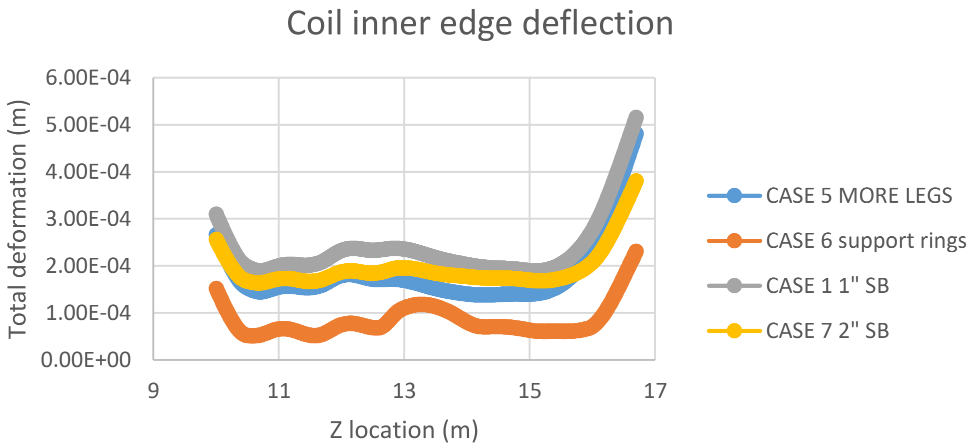


Fig 8. Total deformation of COIL1 and SB1 when subjected to only gravity.



	Max Stress (MPa)	Location & Safety factor	Max deflection (mm)	Location
Aluminum	22	Rear support legs SF = 4.18	0.242	SB1 tail
Copper	8.3	Coil block @ Z = 10.5 m SF = 5.3	0.548	COIL1 tail

CASE 1 output summary

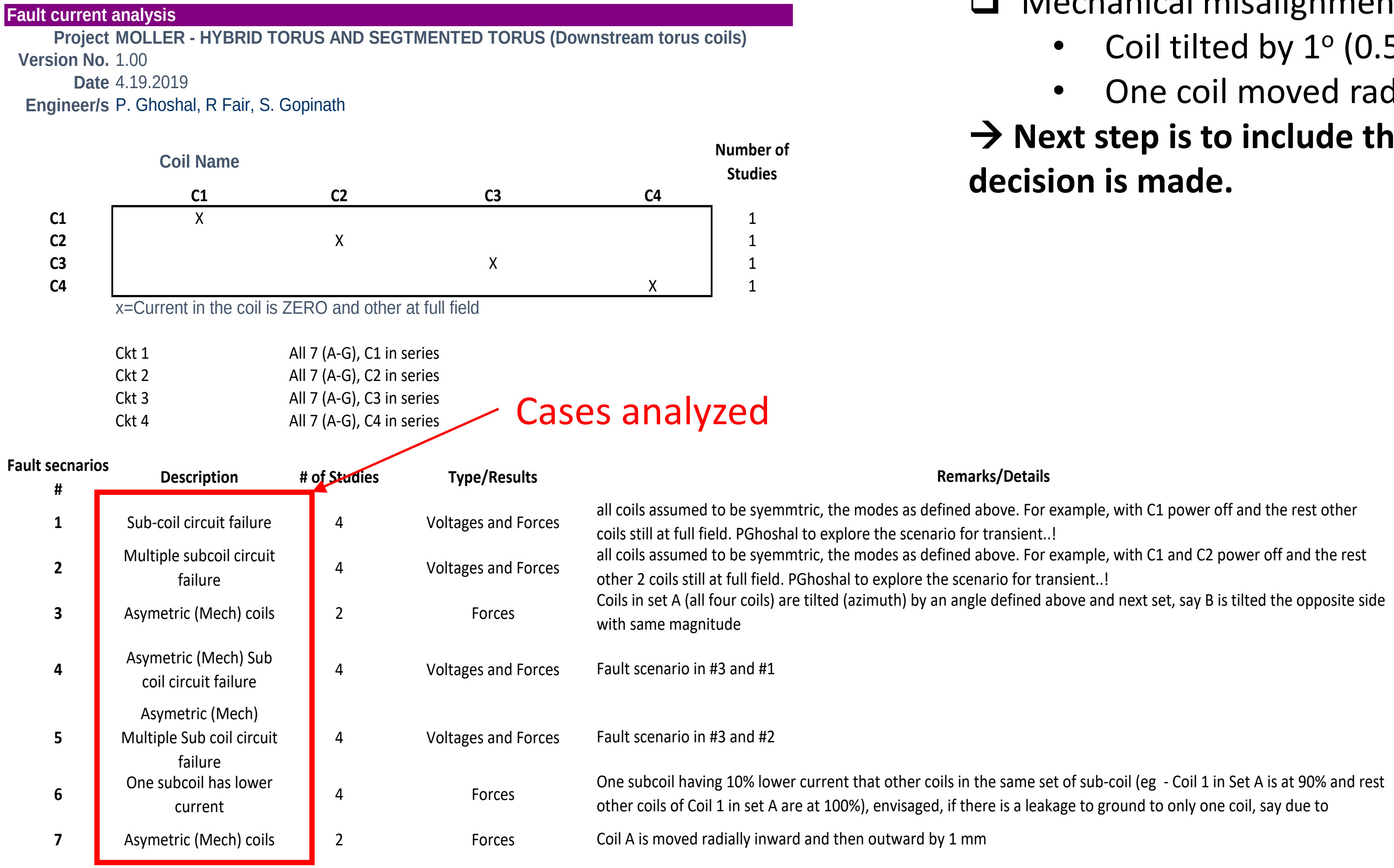
Probir Ghoshal
Eric Sun
Ruben Fair
R Rajput-Ghoshal

Moller Magnet Fault Analysis Matrix

Coil force studies carried out to date include:

- ❑ Electrical fault conditions (Complete - Probir and Ruben)
- ❑ Mechanical misalignment (Complete - Eric/Probir/Ruben)
  - Coil tilted by 1^{o} (0.5^{o} either side – both away and closer to the next coil)
  - One coil moved radially outwards by 3 mm (e.g. Coil A - all 4 sub-coils)

→ Next step is to include the coil supports and calculate stresses before a final decision is made.



Fault current analysis

Project MOLLER - HYBRID TORUS AND SEGTMENTED TORUS (Downstream torus coils)
Version No. 1.00
Date 4.19.2019
Engineer/s P. Ghoshal, R Fair, S. Gopinath

Coil Name

	C1	C2	C3	C4	Number of Studies
C1	X				1
C2		X			1
C3			X		1
C4				X	1

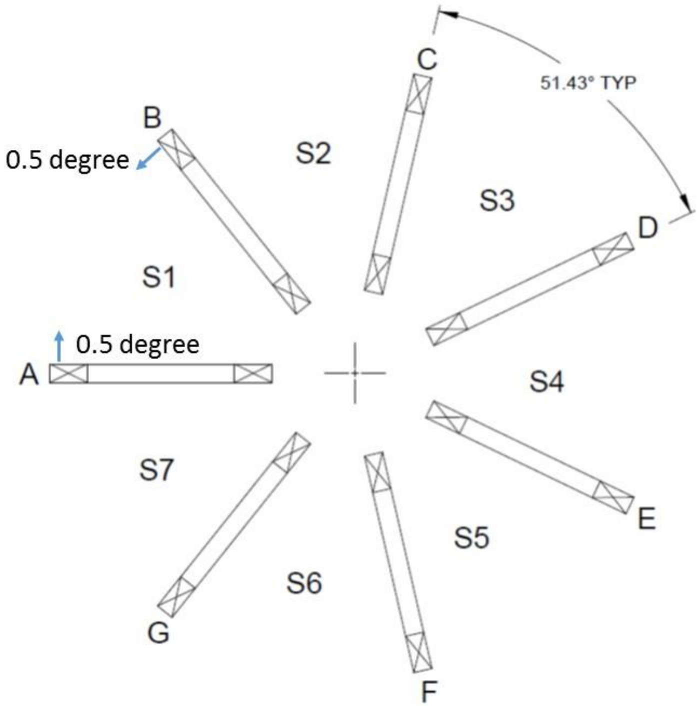
x=Current in the coil is ZERO and other at full field

Ckt 1	All 7 (A-G), C1 in series
Ckt 2	All 7 (A-G), C2 in series
Ckt 3	All 7 (A-G), C3 in series
Ckt 4	All 7 (A-G), C4 in series

Cases analyzed

Fault secnarios #	Description	# of Studies	Type/Results	Remarks/Details
1	Sub-coil circuit failure	4	Voltages and Forces	all coils assumed to be syemmtric, the modes as defined above. For example, with C1 power off and the rest other coils still at full field. PGhoshal to explore the scenario for transient..!
2	Multiple subcoil circuit failure	4	Voltages and Forces	all coils assumed to be syemmtric, the modes as defined above. For example, with C1 and C2 power off and the rest other 2 coils still at full field. PGhoshal to explore the scenario for transient..!
3	Asymetric (Mech) coils	2	Forces	Coils in set A (all four coils) are tilted (azimuth) by an angle defined above and next set, say B is tilted the opposite side with same magnitude
4	Asymetric (Mech) Sub coil circuit failure	4	Voltages and Forces	Fault scenario in #3 and #1
5	Asymetric (Mech) Multiple Sub coil circuit failure	4	Voltages and Forces	Fault scenario in #3 and #2
6	One subcoil has lower current	4	Forces	One subcoil having 10% lower current that other coils in the same set of sub-coil (eg - Coil 1 in Set A is at 90% and rest other coils of Coil 1 in set A are at 100%), envisaged, if there is a leakage to ground to only one coil, say due to
7	Asymetric (Mech) coils	2	Forces	Coil A is moved radially inward and then outward by 1 mm

Study 1 – A and B gets close by 1.0 degree

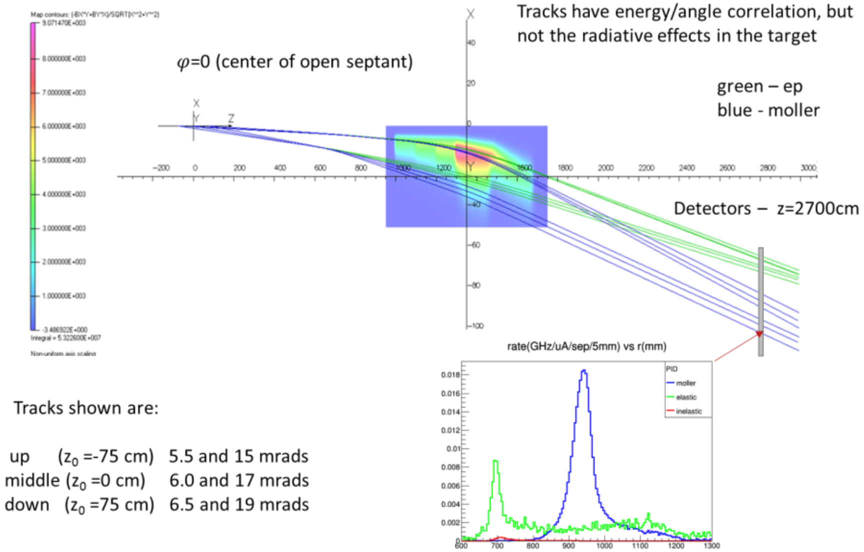


Hall A - Moller

Probir Ghoshal
R Rajput-Ghoshal

Moller Particle (ee and ep) tracking

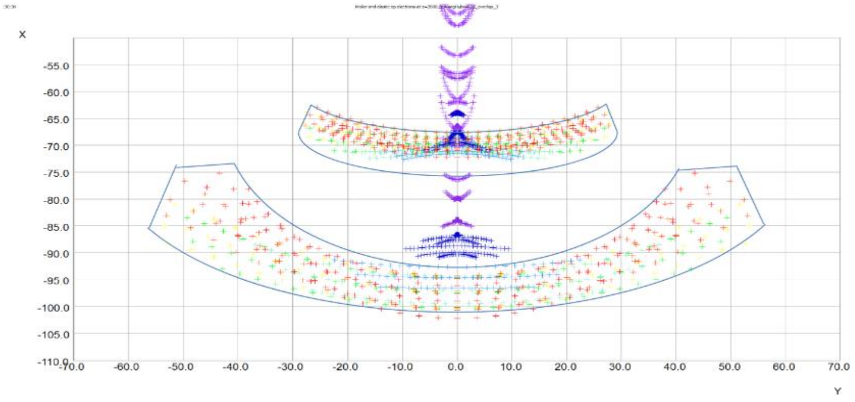
JM - Director's Review of Moller, April 2019

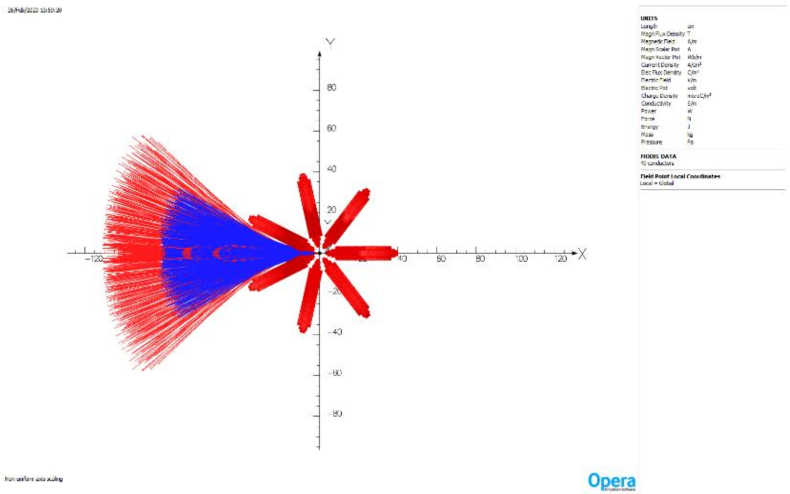


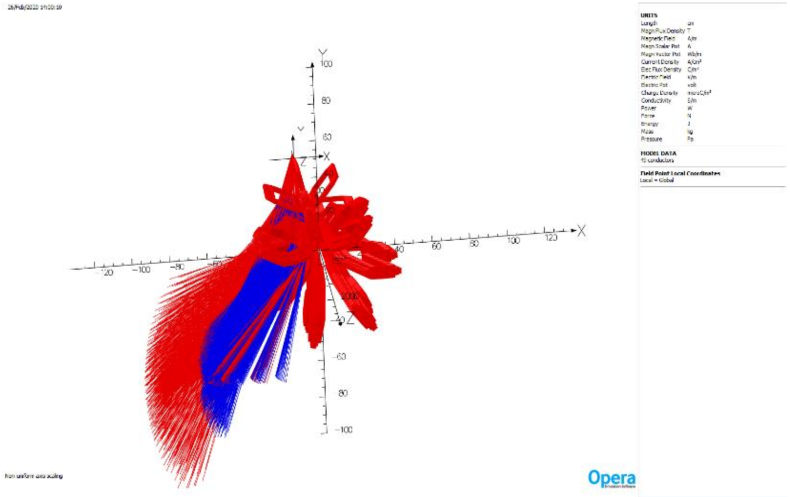
Tracks shown are:

up	(z_0 =-75 cm)	5.5 and 15 mrads
middle	(z_0 =0 cm)	6.0 and 17 mrads
down	(z_0 =75 cm)	6.5 and 19 mrads

JM – ee and ep print from 2018 (ee and ep)

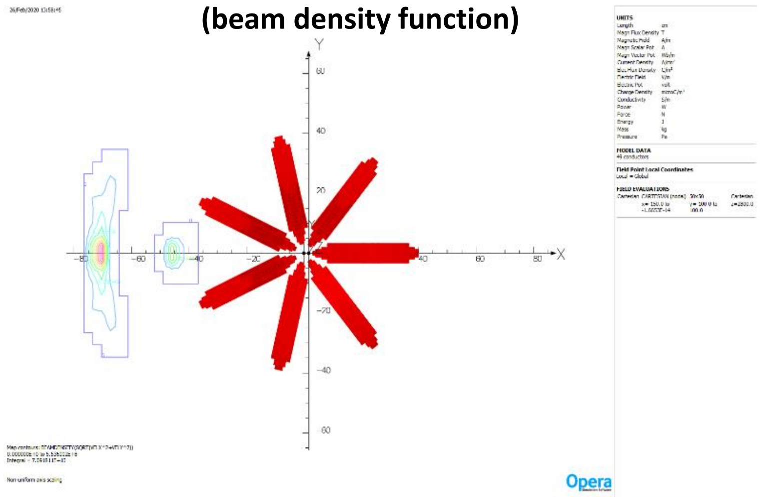






ee and ep tracks – BLUE ep and RED ee

ep track on 2800 cm XY plane
(beam density function)



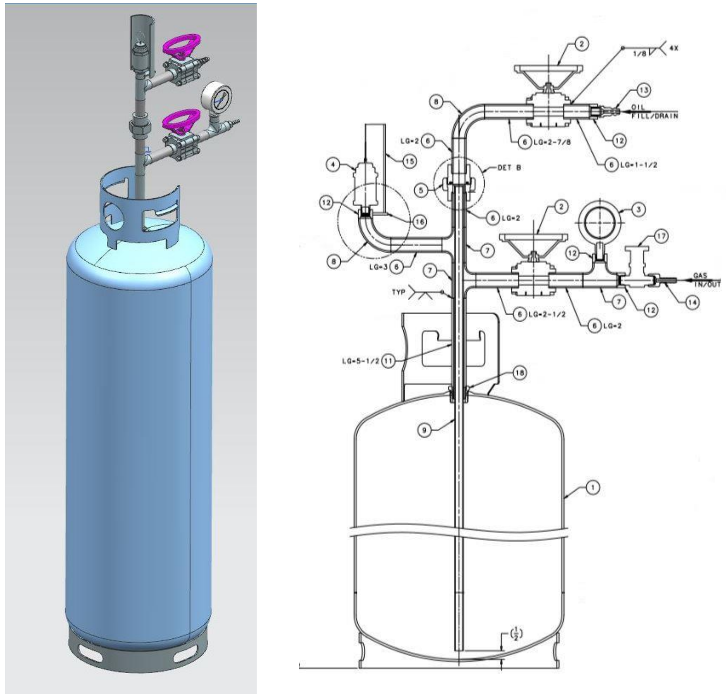
JLab Model files

- All tracks can be plotted in Opera if the function is defined…we used velocity as energy function – beam density function
- Directly define the function to extract the information. Model to have all ee & ep (at predefined phi and theta).
- All ee tracks and ep are in individual independent track file (all tracks in one file).
- No need to plot individual tracks and extract from *.lp file for data.

CHL + Test Lab

Randy Wilson

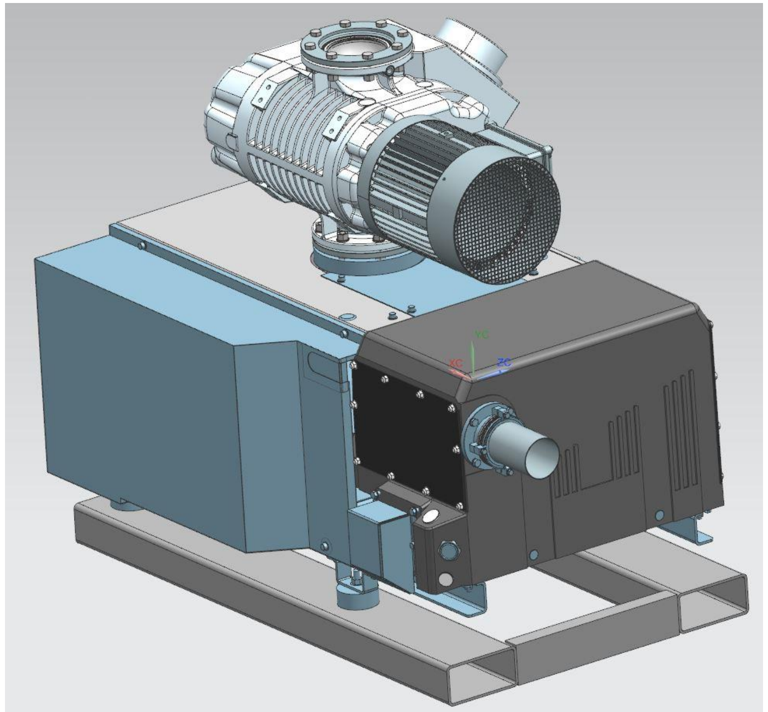
A design task for J-Lab CHL was an Oil Removal cylinder with attached piping and components. Fabricated at Jefferson Lab.



Model & Dwg

Finished Oil Cylinder

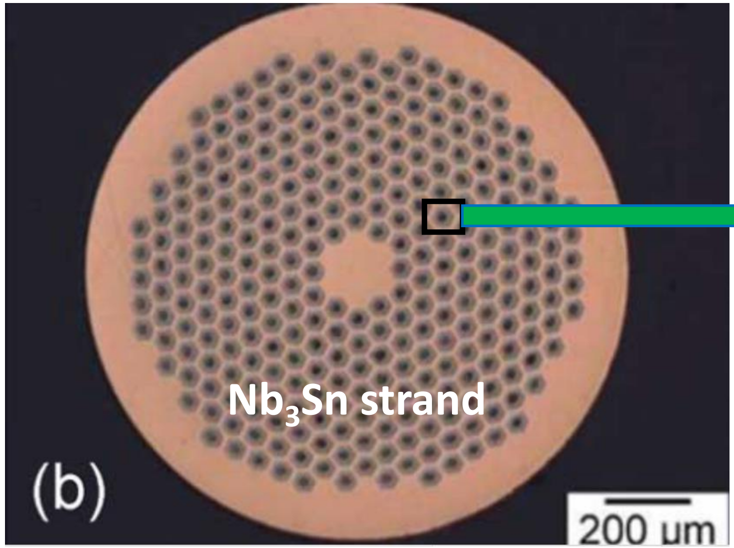
Developing model to install Pair Pump for Vertical Test Area.

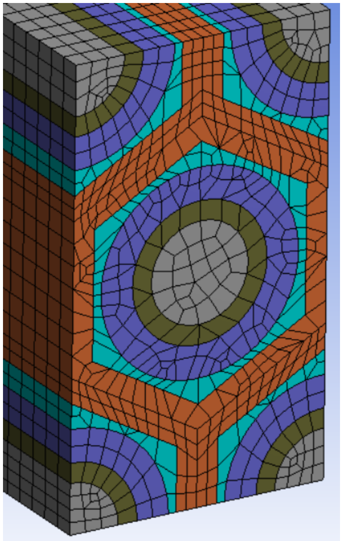


Product model

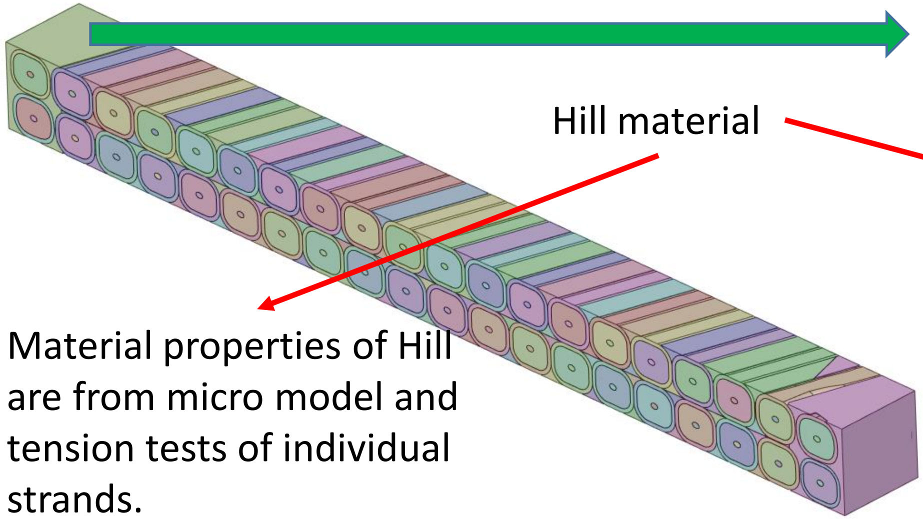
Mechanical Analysis of Coil

Novel Gasket-based Nonlinear Analysis of Superconducting Magnets



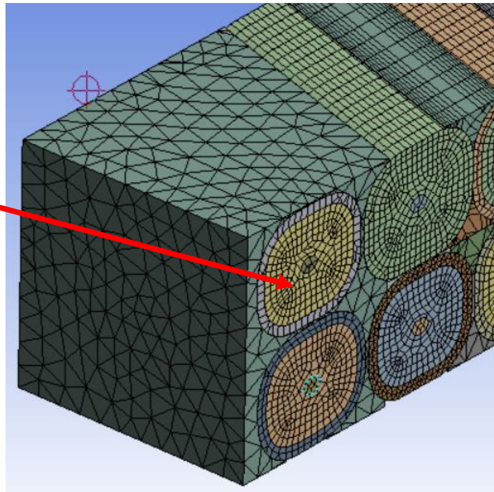


Micro model – **Nb_3Sn strand**

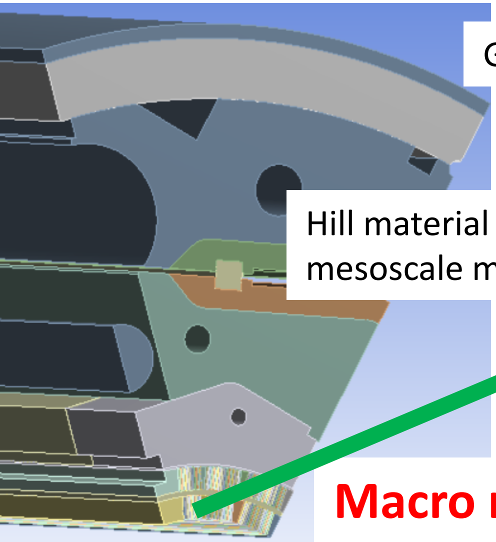


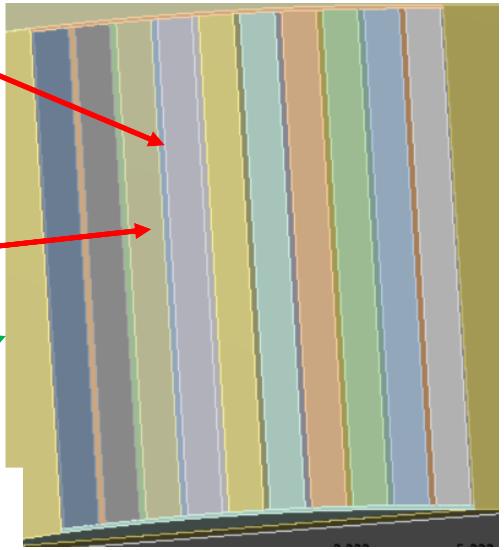
Hill material

Material properties of Hill are from micro model and tension tests of individual strands.



Mesoscale model – **resin-impregnated Nb_3Sn cable**





Gasket

Hill material from mesoscale model

Macro model

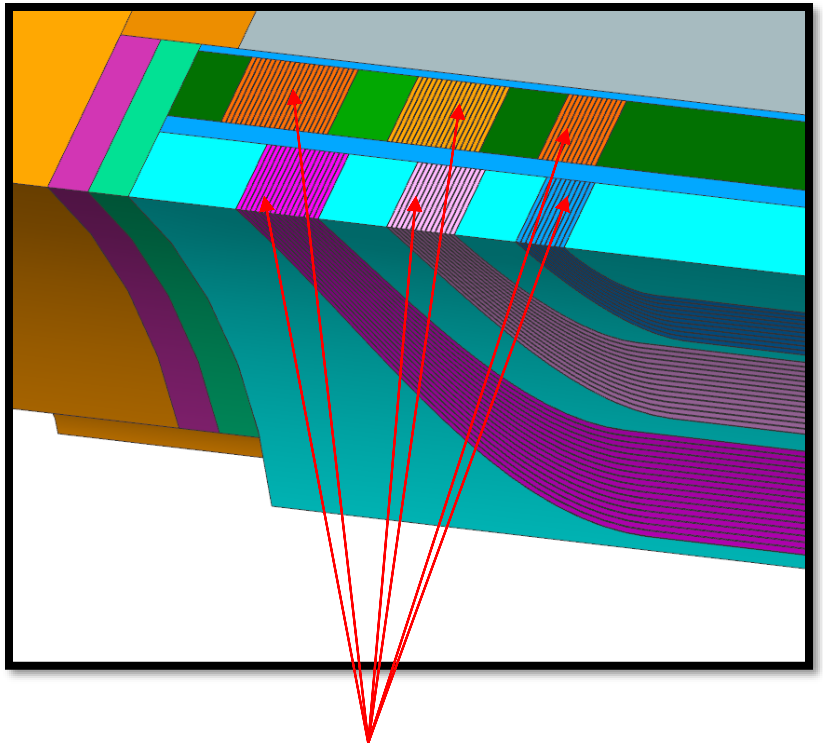
- ☐ To better predict the overall stress/strain of a coil, a more accurate analysis method is needed.
- ☐ Present analysis methods assume the coil as either linear isotropic or linear orthotropic, which is far from reality.
- ☐ Gasket-based nonlinear analysis is the first of its kind to use the stress-strain curve of a 10-stack Nb_3Sn coil sample as an input to the nonlinear analysis.
- ☐ Nonlinear Hill model is the first of its kind to link the micro model and tests to the macro model of the magnet
- ☐ The new method can improve the accuracy of the analysis by up to 45 times depending on the layer granularity of the model.
- ☐ This type of analysis could prove to be crucial for designing high field magnets employing Nb_3Sn and **NbTi** superconductor (EIC, Hi-Lumi, FCC……..)

Other Work

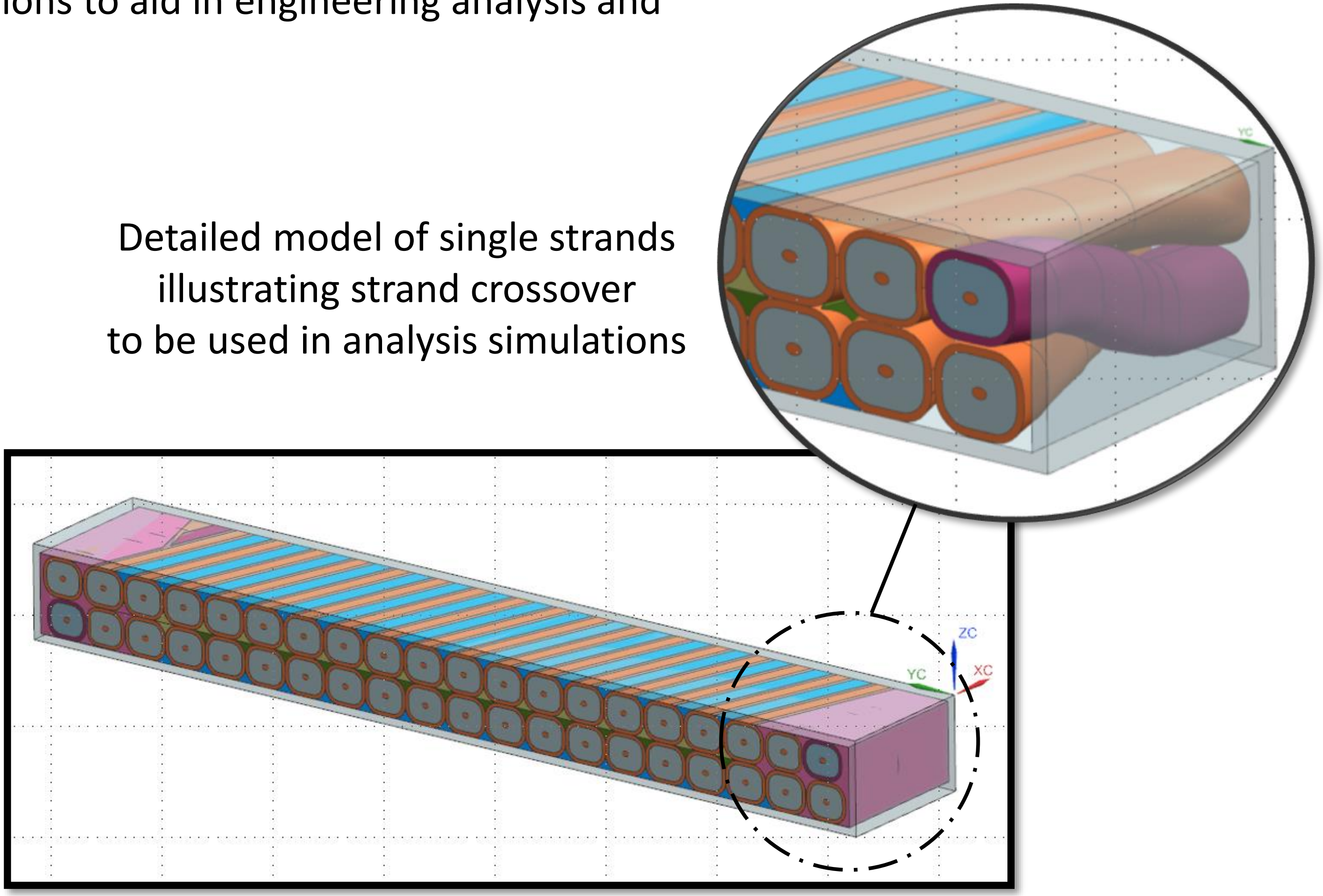
Dan Young
Eric Sun

Coil Structure Modeling

Modeled and modified coil components to reflect a variety of iterations to aid in engineering analysis and simulations



Coil (SC cables + insulation)



Detailed model of single strands illustrating strand crossover to be used in analysis simulations

Detailed model of conductor cable section

Publications / Conferences

Manuscripts Published and under review/accepted

- **P. K. Ghoshal,** R. Bachimanchi, P. Bonneau, P. Campero Rojas, B. J. Eng , **R. J. Fair,** T. Lemon , and N. R. Sandoval, “Development of FPGA-based multi-sensor excitation low voltage (MSELV) chassis at Jefferson Lab”, Rev. Sci. Instrum., 90(12), 124701, Dec 2019, **DOI: 10.1063/1.5127460**
- **P. K. Ghoshal,** D. Chavez, R. Fair, **S. Gopinath, D. Kashy**, P. McIntyre, T. Michalski, **R. Rajput-Ghoshal,** A. Sattarov, “Preliminary Design Study of a Fast-Ramping magnet for Pre-concept Design of an Electron-Ion Collider at Jefferson Lab”, *IEEE Trans on Appl. Superconductivity ,* V30(1), January 2020, **DOI: 10.1109/TASC.2019.2929495**
- **E Sun, P K Ghoshal, R Fair,** S Lassiter, P Brindza, “Quench-back Management for Fast Decaying Currents in SHMS Superconducting Magnets at Jefferson Lab”, *IEEE Trans on Appl. Superconductivity, IEEE Trans on Appl. Superconductivity ,* V30(3), April 2020, **DOI: 10.1109/TASC.2019.2931978**
- R. Rajput-Ghoshal, R. Fair, P. K. Ghoshal, “Optimization of the Interaction Region Quadrupole Magnet for Future Electron-Ion Collider at Jefferson Lab, *IEEE Trans on Appl. Superconductivity, (**Preprint**)* **DOI: 10.1109/TASC.2020.2972217**
- **E Sun,** P Brindza, **R Fair, P K Ghoshal**, S Lassiter, “Test Results of Quench-back Management Due to Fast Decaying Current and AC Losses in SHMS Superconducting Magnet at Jefferson Lab”, **Accepted POSTER Presentation**, *IEEE Trans on Appl. Superconductivity, (**Preprint**)* **DOI: 10.1109/TASC.2020.2974850**
- **D. Kashy, R. Fair, P. K. Ghoshal, R. Rajput-Ghoshal,** “An Investigation of the Electromagnetic Interactions between the CLAS12 Torus & Solenoid Superconducting Magnets at JLab”, *IEEE Trans on Appl. Superconductivity* **(Under review)**

Publications / Conferences

Manuscripts Published and under review/accepted (Cont'd)

- B.R.P. Gamagey, V.S. Morozov, F. Lin, T. Michalski, **R. Rajput-Ghoshal,** M. Wiseman, , Y. Cai, Y. Nosochkov, M. Sullivan, G.-L. Sabbi, "MULTIPOLE EFFECTS ON DYNAMIC APERTURE IN JLEIC ION COLLIDER RING", Proceedings of NAPAC2019, Lansing, MI, USA
- **Renuka Rajput-Ghoshal,** Chuck Hutton, Fanglei Lin, Tim Michalski, Vasiliy Morozov and Mark Wiseman, "INTERACTION REGION MAGNETS FOR FUTURE ELECTRON-ION COLLIDER AT JEFFERSON LAB", Proceedings of NAPAC2019, Lansing, MI, USA
- G. L. Sabbi†, B.R. Gamage, T.J. Michalski, V.S. Morozov, **R. Rajput-Ghoshal,** M. Wiseman, Y.M. Nosochkov, M.K. Sullivan, "FIELD QUALITY ANALYSIS OF INTERACTION REGION QUADRUPOLES FOR JLEIC" Proceedings of NAPAC2019, Lansing, MI, USA
- "Full Acceptance Interaction Region Design of JLEIC", V.S. Morozov, R. Ent, Y. Furletova, F. Lin, T. Michalski, **R. Rajput-Ghoshal**, M. Wiseman,R. Yoshida, Y. Zhang, Y. Cai, Y. Nosochkov, M. Sullivan, G.-L. Sabbi, 10th Int. Particle Accelerator Conf.IPAC2019, Melbourne, Australia JACoW Publishing, **DOI :10.18429/JACoW-IPAC2019-WEPGW123**
- V. D. Burkert, et al., "The CLAS12 Spectrometer at Jefferson Laboratory", Nuclear Inst. and Methods in Physics Research, A 959 (2020) 163419, **DOI: 10.1016/j.nima.2020.163419.**
- M. Ungaro, et al., "The CLAS12 Geant4 Simulation", Nuclear Inst. and Methods in Physics Research, A 959 (2020) 163422, **DOI: 10.1016/j.nima.2020.163422**
- R. Fair, R. Rajput-Ghoshal, D. Kashy, P. K. Ghoshal, et al, "Superconducting Magnets for CLAS12" – **Accepted by NIM (Dec 2019)** , With the NIM typesetters (Feb/Mar 2020)

2. Preparation in Progress for Submission

- P. K. Ghoshal, R. J. Fair, S. Gopinath, D. Kashy, R. Rajput-Ghoshal, et al., "Risk management with Accelerator and Detector magnets at JLab: Failure Mode and Effect Analysis", *IEEE Trans on Appl. Superconductivity*
- J. Mammei, et al, "A Novel Resistive Toroidal Spectrometer for the MOLLER Experiment", NIM (Elsevier)
- **2 papers Withdrawn from Applied Superconductivity (on EIC)**

Support for External DOE Reviews

- **FRIB – Facility for Rare Isotope Beams (MSU) – SC magnet design –** *R. Fair, P. Ghoshal*
- **NSTX-U – National Spherical Torus Experiment – Upgrade (PPPL) – Resistive coil design –** *R. Rajput-Ghoshal*
- **Mu2e – Muon to Electron Conversion Experiment (FNAL) – SC magnet design –** *R. Fair, R. Rajput-Ghoshal*
- **MPEX – Material Plasma Exposure Experiment (ORNL)** – **SC magnet design** - *R. Fair*
- **Hi-Lumi LHC – High Luminosity Large Hadron Collider (FNAL)** – **SC magnet design -** *R. Fair, P. Ghoshal*
- **US-ITER – US Contributions to the ITER Project – SC Magnet design –** *R. Fair*
- **FRIB- High Rigidity Spectrometer – SC Magnet design –** *R. Rajput-Ghoshal*

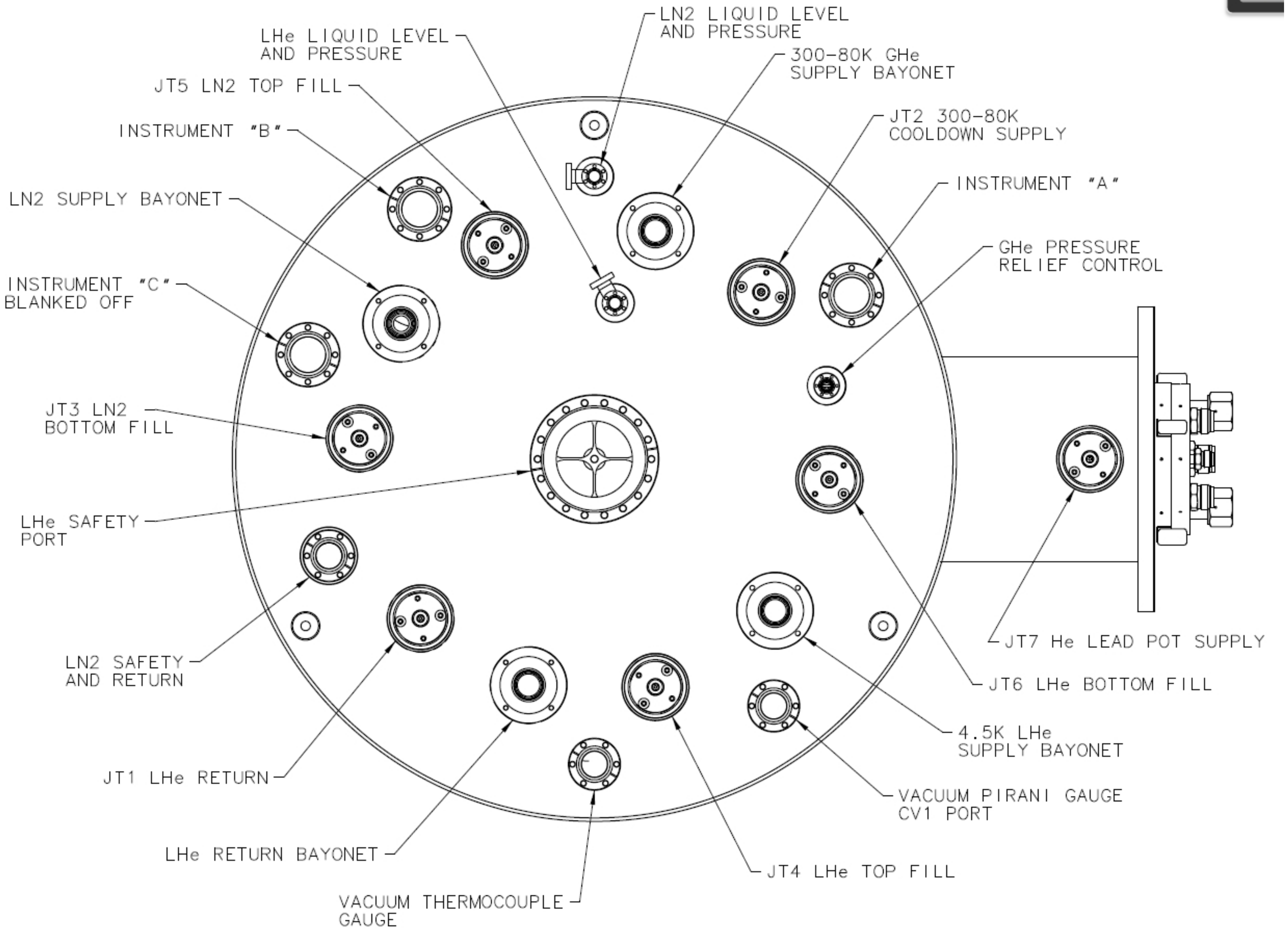
Involvement with the external community

- BEAMS (Being Enthusiastic about Math and Science) – *Renuka, Ruben*
- Science Bowl - *Renuka*
- Women in Science and Engineering - *Renuka*
- Career Café – *Renuka, Dan, Ruben*
- Engineering Career Day – *Renuka, Ruben*
- DOE SBIR/STTR Phase I and II proposals – *Ruben, Renuka, Probir*

Team Medium – Long term Strategic View

1. **MOLLER–Related**
   1. Development of tool to translate information from NX CAD models to OPERA (*Sandesh, Randy, Probir*)
   2. Training on using MAXWELL and ANSYS for structural analysis (*Sandesh*)
   3. Beam Power Analysis – Methodology and Design Tool (*Dave*)
2. **General**
   1. Development of design tools to support magnet design iterations (*Ruben, Probir, Renuka, Sandesh, Dave*)
   2. Development of modelling techniques for coil structures (*Eric, Dan*)
   3. Mentoring of engineers – internal and external to our group (*Dave*)
   4. Database of Magnet-Related Design Tools (*Probir*)
   5. Identification (development?) of local shops for ‘simple’ magnet fabrication projects (*Dave*)
   6. Involve new Engineering Division Magnet Engineer (Seetha Lakshmi Lalitha) – to share and problem-solve issues

Backup


LHe LIQUID LEVEL AND PRESSURE
LN2 LIQUID LEVEL AND PRESSURE
300-80K GHe SUPPLY BAYONET
JT5 LN2 TOP FILL
JT2 300-80K COOLDOWN SUPPLY
INSTRUMENT "B"
INSTRUMENT "A"
LN2 SUPPLY BAYONET
GHe PRESSURE RELIEF CONTROL
INSTRUMENT "C" BLANKED OFF
JT3 LN2 BOTTOM FILL
LHe SAFETY PORT
JT7 He LEAD POT SUPPLY
LN2 SAFETY AND RETURN
JT6 LHe BOTTOM FILL
4.5K LHe SUPPLY BAYONET
JT1 LHe RETURN
VACUUM PIRANI GAUGE CV1 PORT
LHe RETURN BAYONET
JT4 LHe TOP FILL
VACUUM THERMOCOUPLE GAUGE