Concepts for the Cryomodule Design: 2K Operation, Alignment System, Solenoids, BPMs, vacuum/cryogenic/pressure safety

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on behalf of the ANL Linac Development Group

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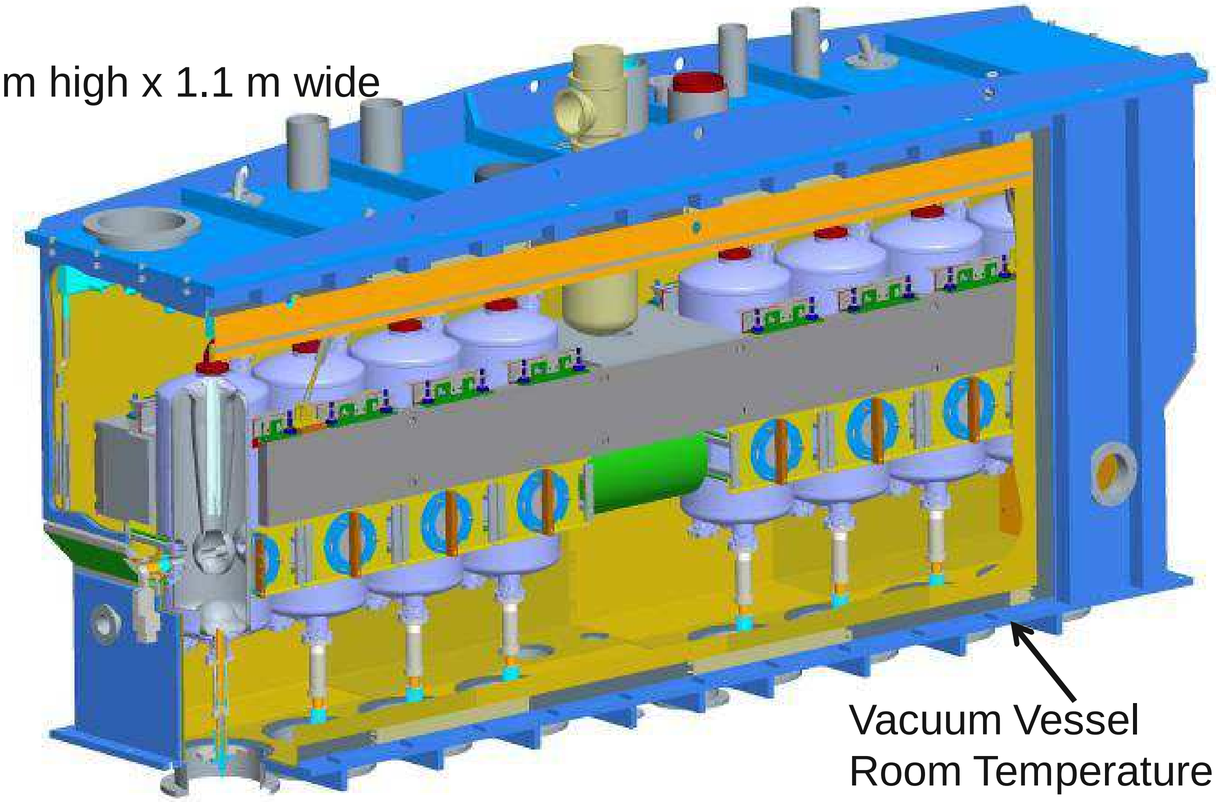
Outline

- Recent Experience: ANL ATLAS Upgrade Cryomodules
- Design Parameters
- Conceptual Cryomodule Layout
- Future Work

ANL ATLAS Energy Upgrade Cryomodule

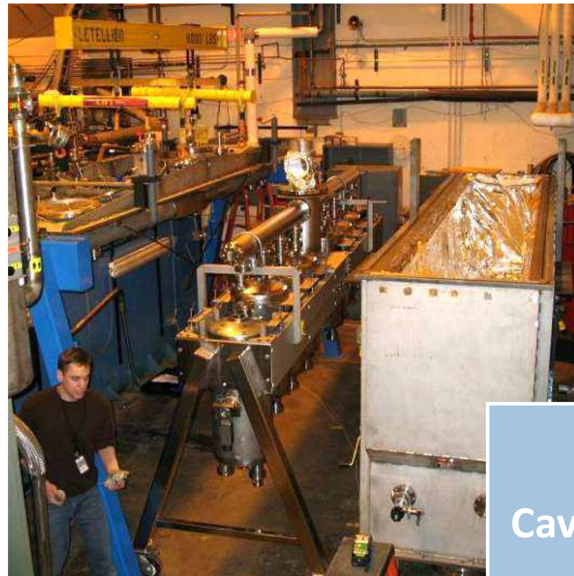
4.6 m long x 2.6 m high x 1.1 m wide



Vacuum Vessel
Room Temperature Magnetic Shield
Aluminum Heat Shield
(MLI not shown)

- 7 $\beta = 0.15$ 109 MHz SC quarter-wave cavities and 1 SC solenoid
- 14.5 MV gain in 4.5 m, limited by VCX fast tuners, 21.1 MV would be limit if VCX did not limit cavities
- Very similar to the high-beta 109MHz cryomodule for SARAF Phase-II.
  – Phase II will need ~7 SC QWR and 4 SC solenoids

ANL ATLAS Energy Upgrade Cryomodule

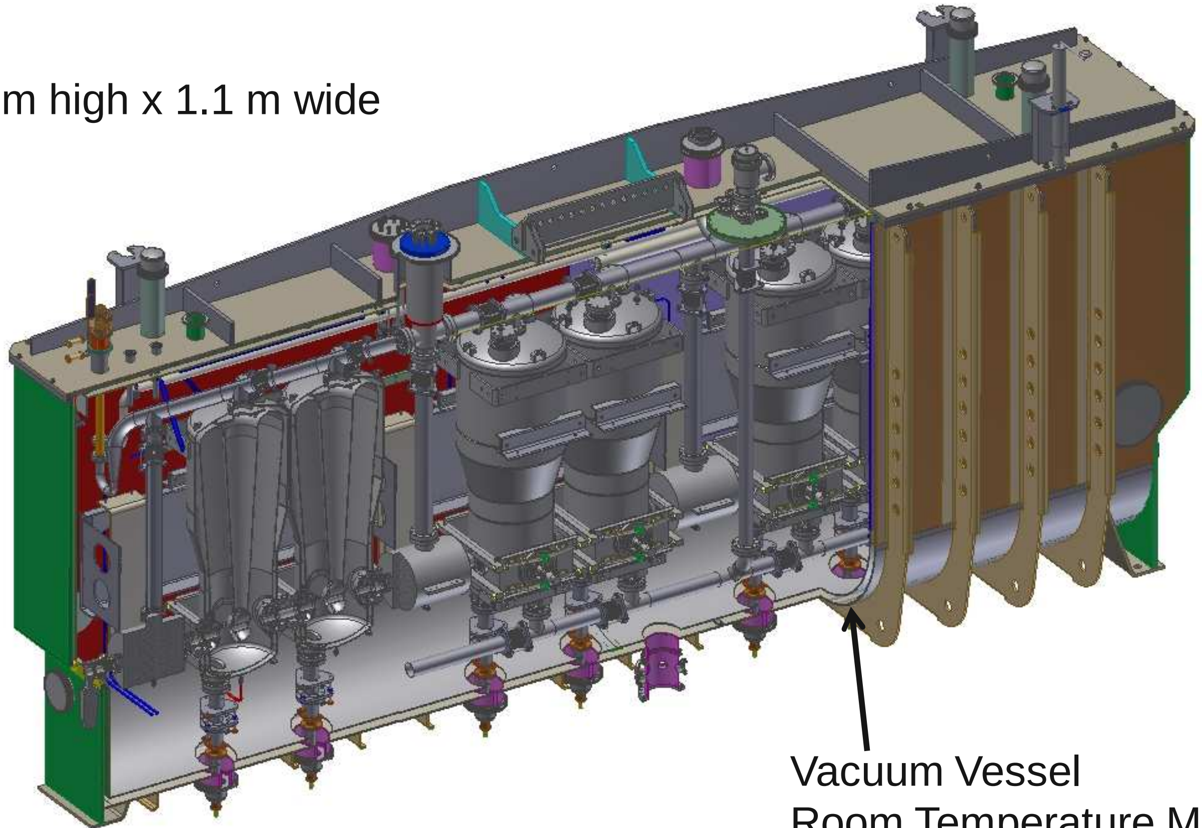


World record gradients for β = 0.15

Cavity	Operating Voltage (MV)	Max. Achievable Voltage (MV)
1	1.96	2.88
2	1.89	2.75
3	2.13	3.75
4	2.29	3.13
5	2.12	2.75
6	1.92	2.08
7	2.24	3.75
Total	14.5	21.1

ANL ATLAS Intensity Upgrade Cryomodule

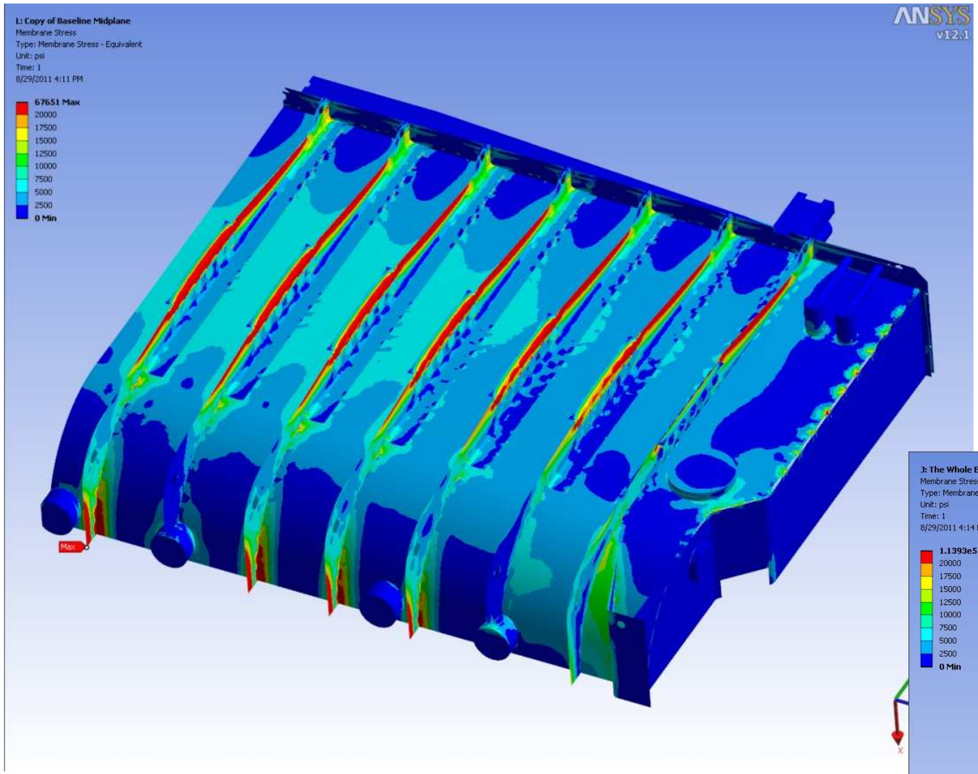
5.2 m long x 2.9 m high x 1.1 m wide



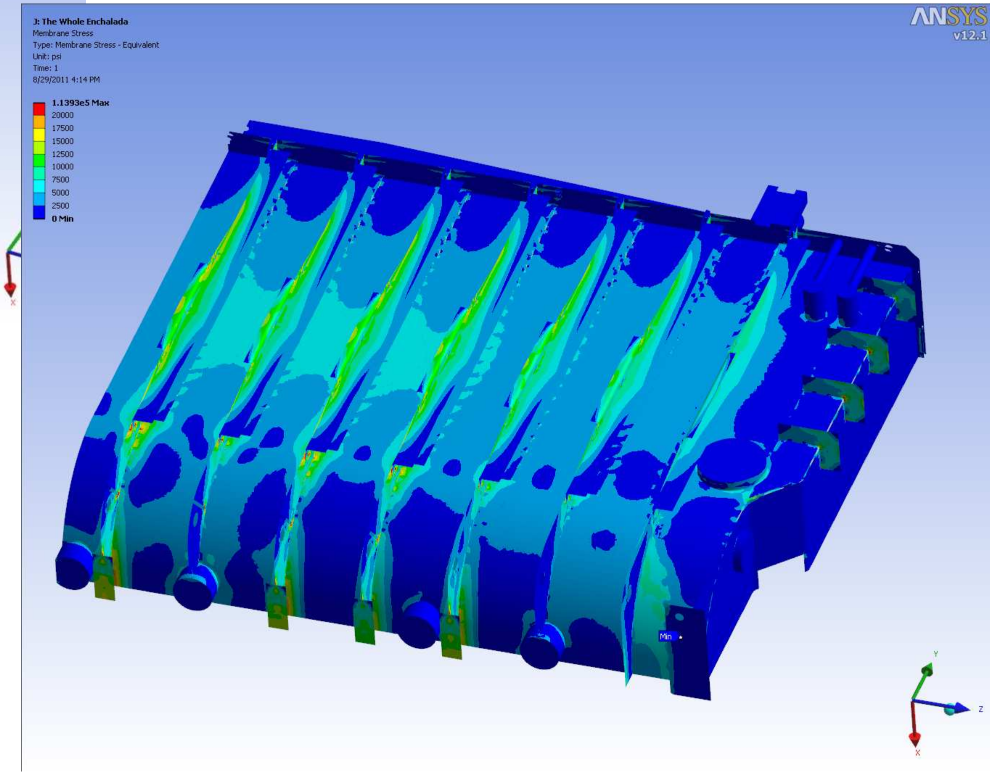
Vacuum Vessel
Room Temperature Magnetic Shield
Aluminum Heat Shield
(MLI not shown)

- 4 superconducting solenoids
- 7 β = 0.075 72.75 MHz quarter-wave cavities
- Work will be complete in 2012

ANL ATLAS Intensity Upgrade Cryomodule



- ARRA Intensity Upgrade was designed to satisfy the DOE Vac. Vessel Consensus Guidelines
- These models are of the primary membrane stresses



- Everything in red is above 20 ksi
- 20 ksi is the maximum allowable stress for 304/304L which meets SA-240
- Similar modeling is performed for secondary stresses

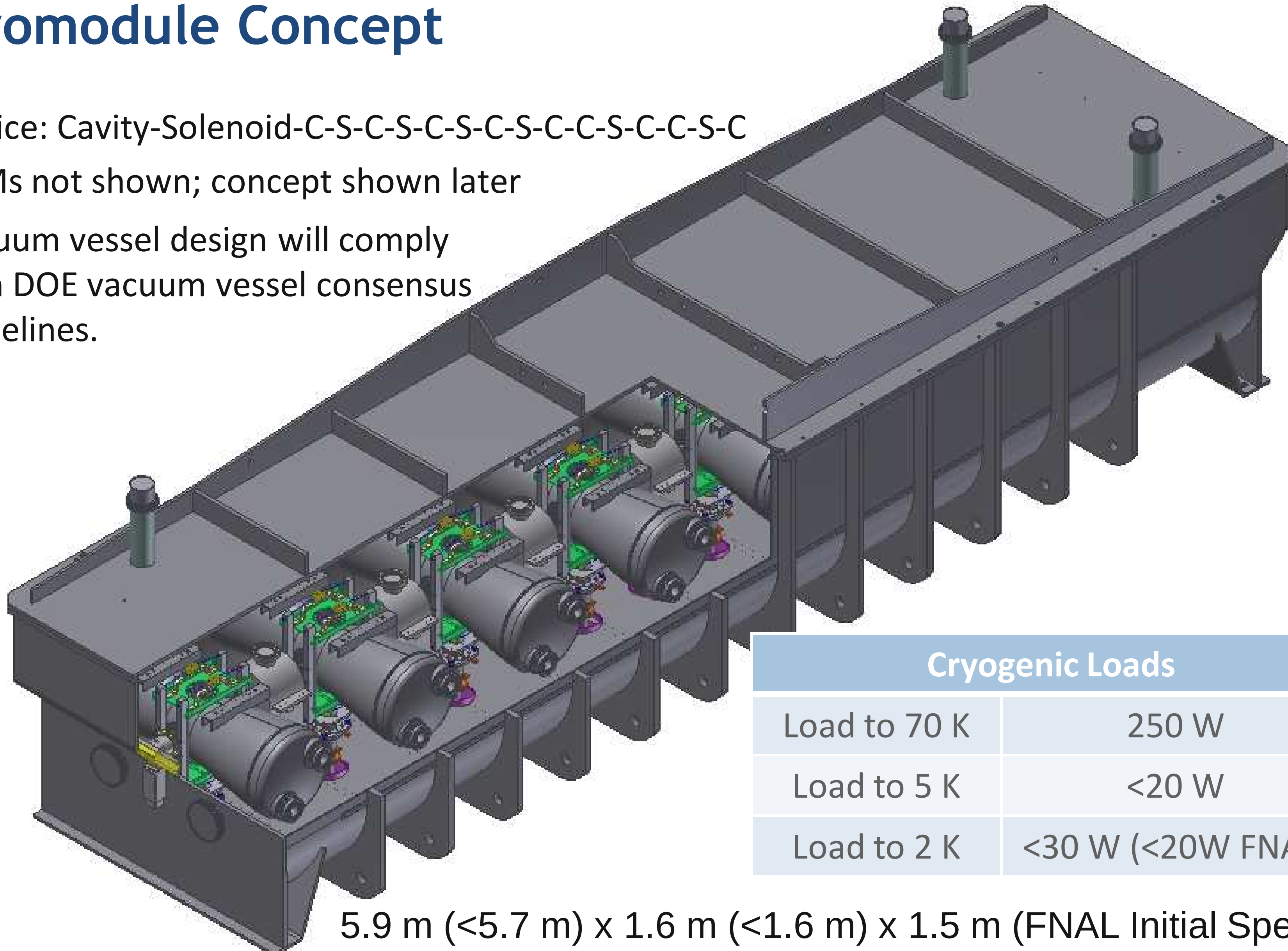
FNAL PXIE HWR Cryomodule Design Parameters

Material	Young's Modulus (KSI)	Poisson's Ratio	Density (lbs/in^3)	Maximum Allowable Stress (KSI)
Niobium	15,200	0.395	0.3096	4.4
304 Stainless Steel	29,000	0.270	0.286	20.0
Titanium, Grade 2	16,600	0.300	0.164	27.0

- We will design the cavity helium space to equivalent levels of safety per the ASME B&PV code and TD-09-005
- The helium plumbing in the cryomodule will also be design to the ASME B&PV code equivalent levels of safety
- 304 S.S. maximum allowable stress come from the ASME B&PV code Table 5B – Section VIII, Division 2, Maximum Allowable Stress Values for Ferrous Materials.
- The Titanium, Grade 2, maximum allowable stress value is 0.8 of the 0.2% yield strength, per FNAL TD-09-005.
- We need someone who can speak for FNAL safety to interface with us early in the design of the cryomodule.

Cryomodule Concept

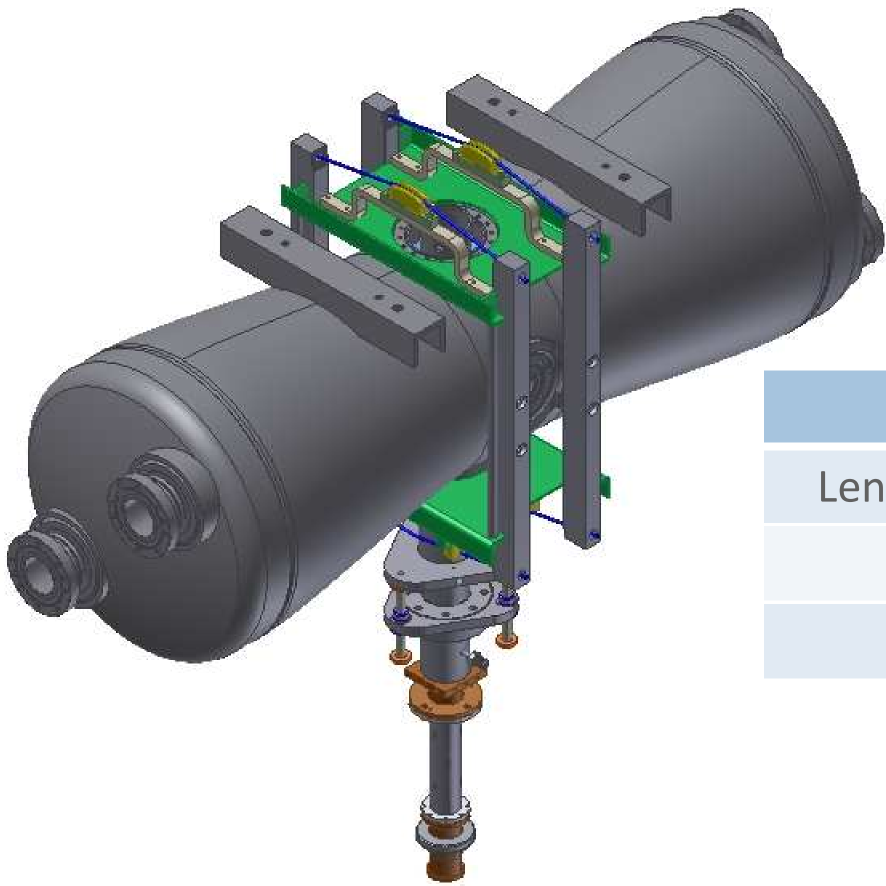
- Lattice: Cavity-Solenoid-C-S-C-S-C-S-C-S-C-C-S-C-C-S-C
- BPMs not shown; concept shown later
- Vacuum vessel design will comply with DOE vacuum vessel consensus guidelines.



Cryogenic Loads	
Load to 70 K	250 W
Load to 5 K	<20 W
Load to 2 K	<30 W (<20W FNAL)

5.9 m (<5.7 m) x 1.6 m (<1.6 m) x 1.5 m (FNAL Initial Spec)
With the beam height = 1.3 m the top of the lid will be at 2.0 m (<2.00 m) from the floor

Cavity Dimensions

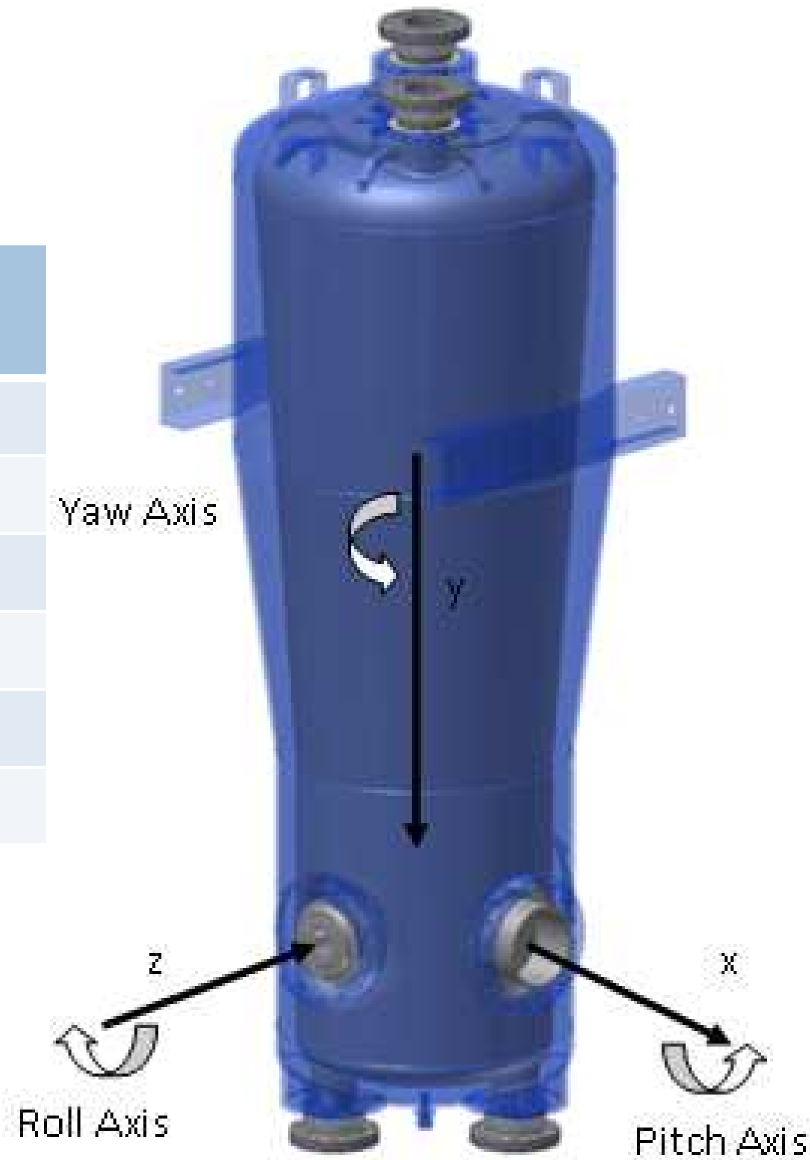


Concept Cavity Dimensions	
Length (Along Beam Line)	0.28 m
Large OD	0.39
Width	1.22 m

Cavity and Solenoid Alignment

Beam-Line Alignment Tolerances

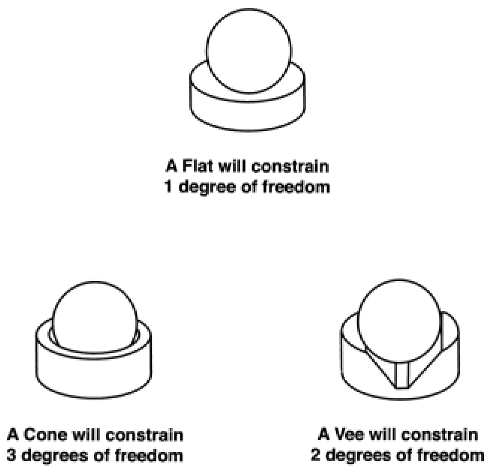
Dimension	ATLAS	Energy Upgrade	Intensity Upgrade	FNAL
x (mm)	±1	±0.25	±0.25	±0.25
y (mm)	±1	±0.25	±0.25	±0.25
z (mm)	±1	±1	±1	±1
Pitch	$\pm 0.5^0$	$\pm 0.1^0$	$\pm 0.1^0$	$\pm 0.1^0$
Yaw	$\pm 0.5^0$	$\pm 0.1^0$	$\pm 0.1^0$	$\pm 0.1^0$
Roll	$\pm 0.5^0$	$\pm 0.5^0$	$\pm 0.1^0$	$\pm 0.1^0$



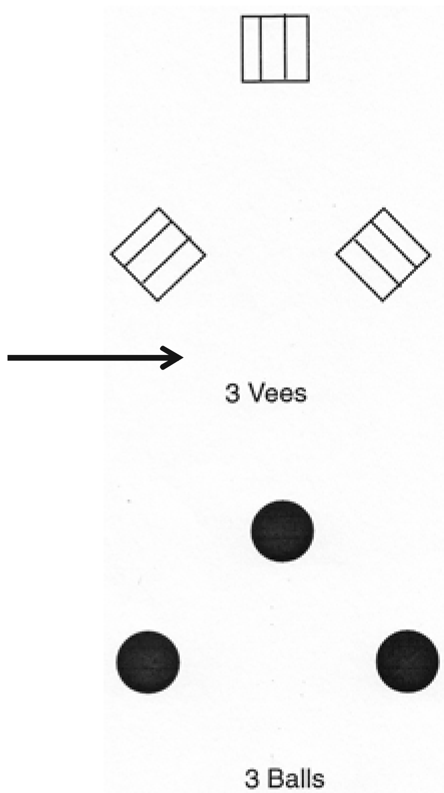
Alignment Coordinate System

Alignment Hardware

Kelvin



Maxwell



Alignment Hardware Examples

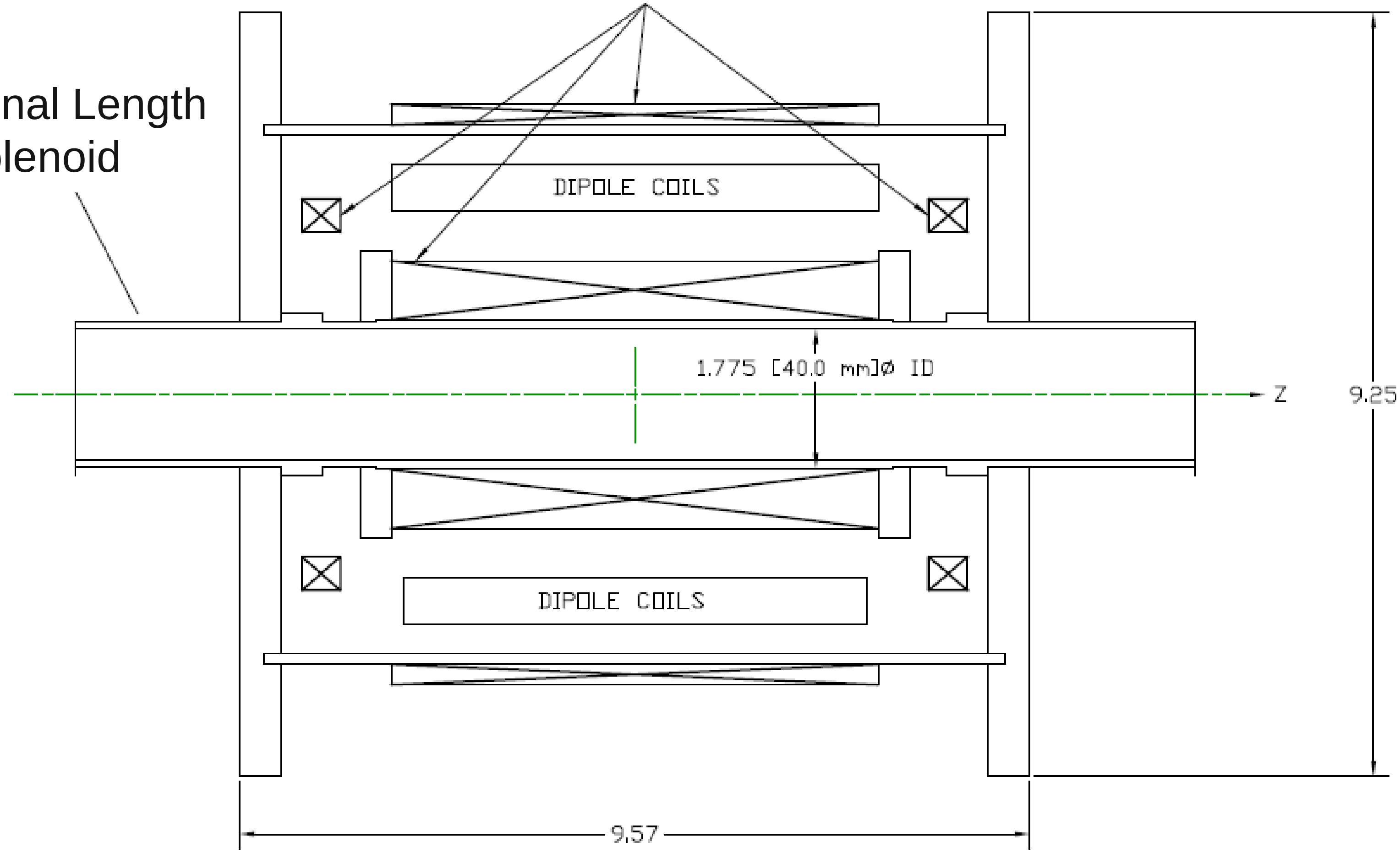
- The Maxwell kinematic alignment arrangement is thermally stable since all three supports expand/contract in unison. It is used for high precision accelerator magnet positioning.
- We currently use the Kelvin arrangement which shifts the device being suport (left-right) during cooldown/warm-up.

Solenoids and BPMs

9 T, 2 K Solenoid Concept

9T Superconducting Magnet

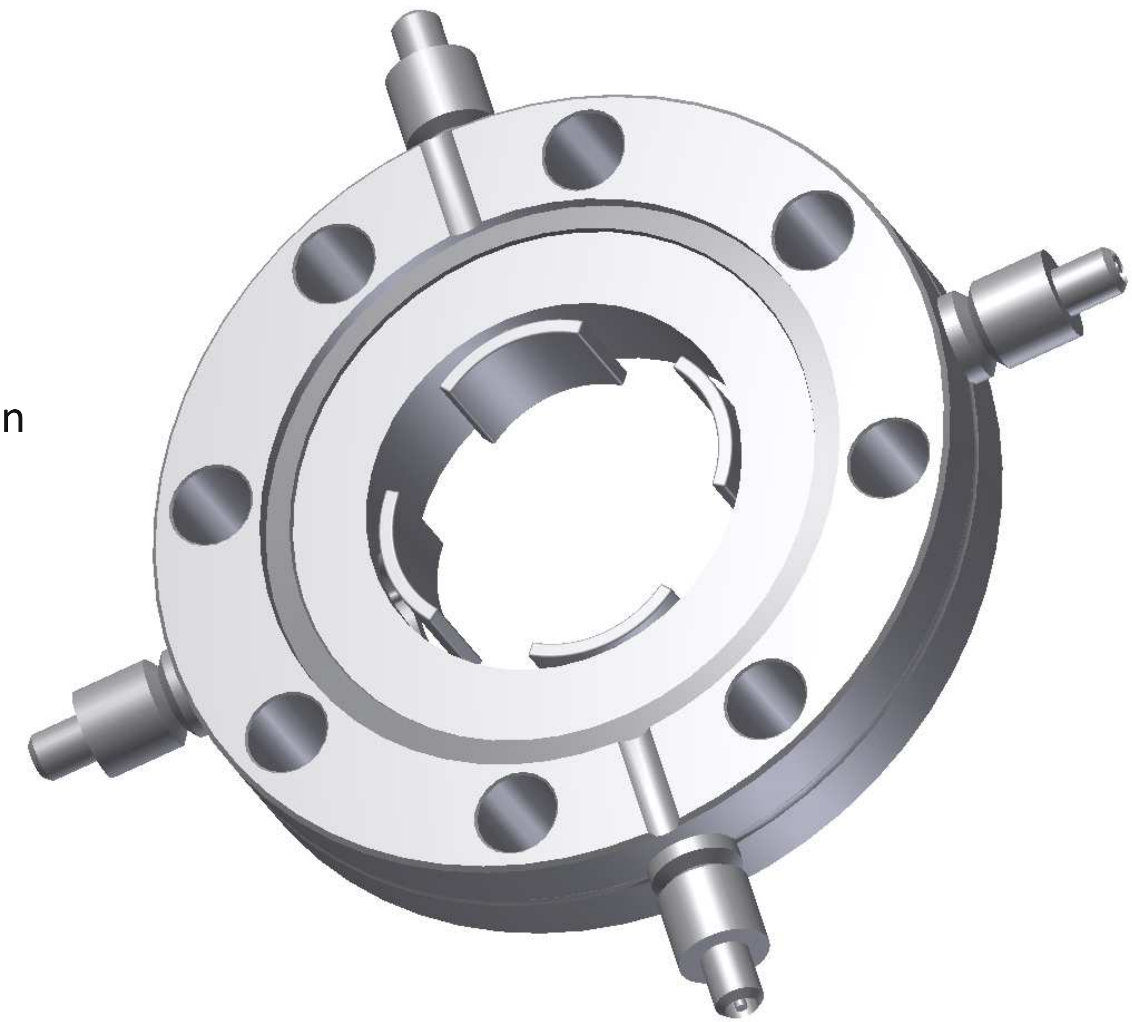
9.75" = Final Length of Solenoid



We are still in discussions with vendors. This geometry is not final.

Compact BPM

- Small Compact BPM
- A device to test different electrodes is under construction
- Must be:
  - Compact
  - Cleanable
  - Couple to the beam for a useful SNR



Future Work

- Continue to develop the cryomodule as major subcomponent designs are complete:
  - 162.5 MHz β = 0.11 halfwave cavities
  - BPMs
  - Superconducting solenoids (however will not be longer than 9.75” along beam line)

- The ANL model of cryomodule design (would like to do this with FNAL safety):
  - Start project
  - Start talking to ANL pressure/vacuum safety representatives

- Have already constructively interacted with A. Klebaner with cryogenic supply/return issues and looking forward to other/future interactions

- Things look good. The path forward is clear.