LINAC 2014 (Geneva, Switzerland, Sept. 1-5, 2014)

4 K Alignment of Superconducting Quarter-Wave Cavities and 9 T Solenoids in the ATLAS Intensity Upgrade Cryomodule*

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September 2, 2014

* This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under contract number DE-AC02-06CH11357. This research used resources of ANL's ATLAS facility, which is a DOE Office of Science User Facility.

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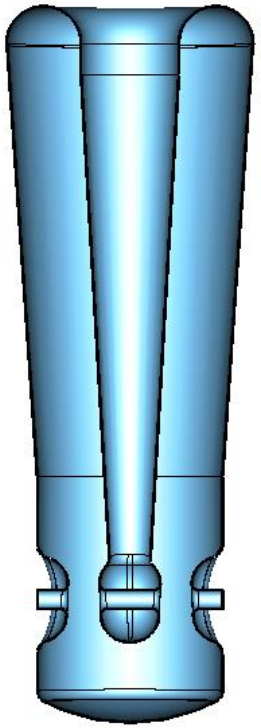
Alignment of Superconducting Cavities and Magnets

- Why Align?
  - To suppress emittance growth due to misalignments.
  - Reduce beam loss to prevent the activation of accelerator components in high-intensity accelerators.
- ATLAS Intensity Upgrade Cryomodule:
  - 7 SRF quarter-wave cavities of 72 MHz, β=0.077 and 4 SC solenoids of 9 T.
  - The cavities and solenoids are assembled at room temperature so that they are aligned to the beam at 4.5 K.
- Hardware:
  - Kelvin type kinematic coupling used in the cavity and solenoid mount
- Alignment Accuracy Goal:

Coordinate	ATLAS Intensity Upgrade Cryomodule
x/y	±0.25 mm
z	±1 mm
Pitch/Yaw/Roll	±0.1°

Cavity Alignment During Fabrication

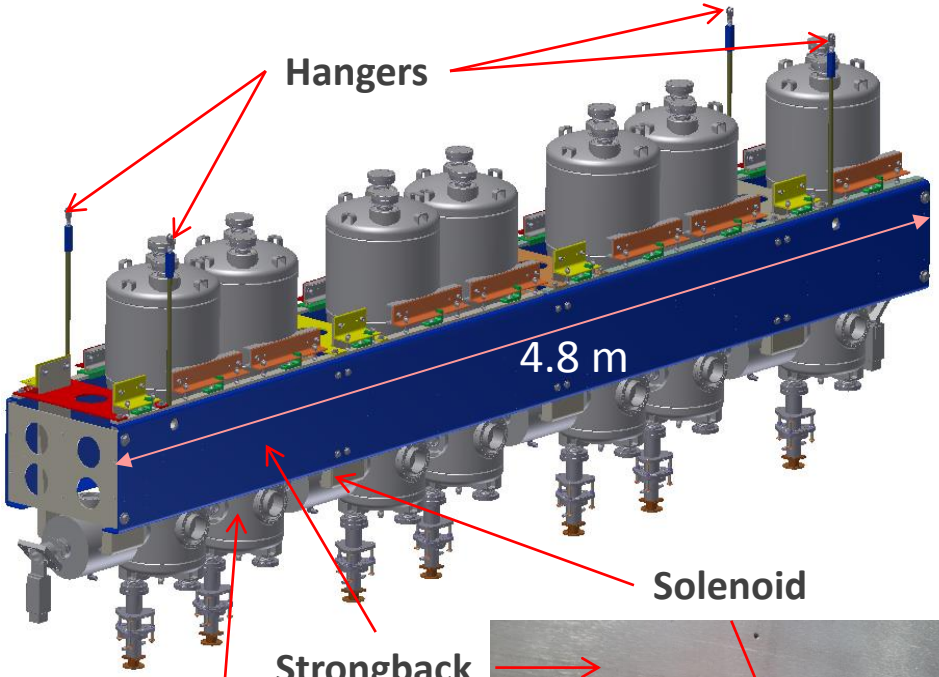
- Alignment of the apertures in the re-entrant noses and central conductor
  - Build with slightly smaller aperture
  - Apply wire EDM through 3 apertures after completion of Nb welding except the bottom dome
  - Create aperture with design dimensions of 30 mm in diameter

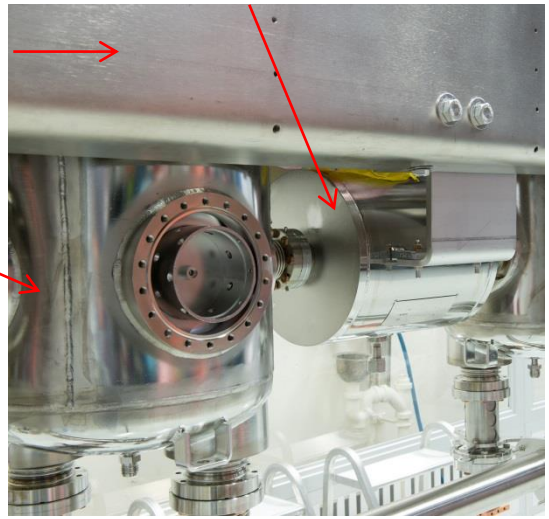


Wire EDM

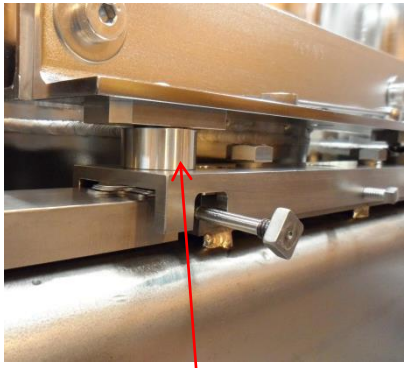
QWR cleaning after wire EDM of apertures

Kinematic-Alignment Hardware

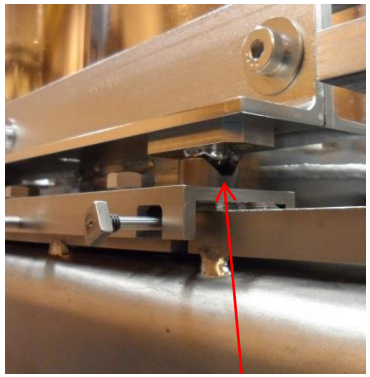




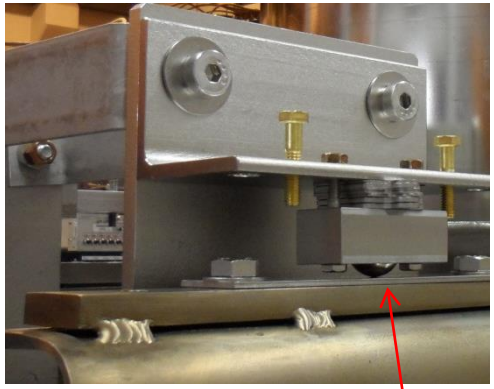
Kelvin Type Kinematic Coupling for Solenoid/Cavity Mount



Ball in Ring



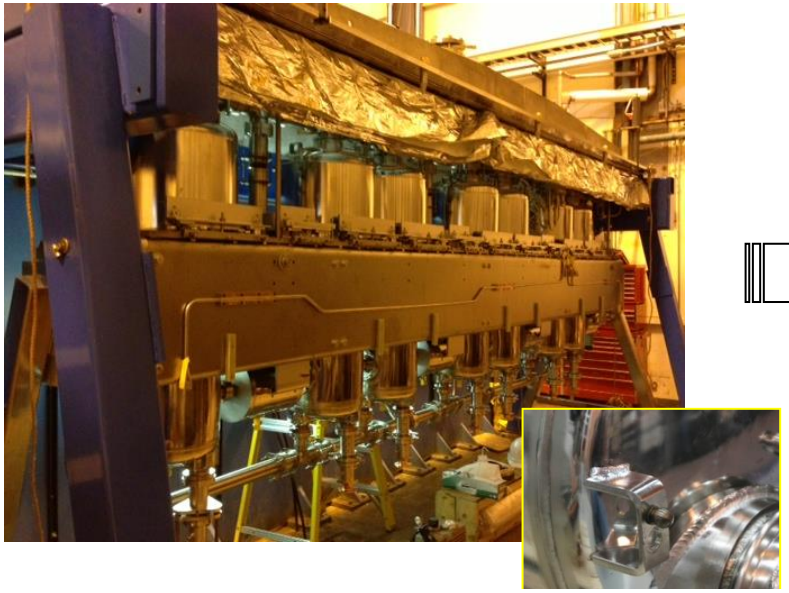
Ball on Vee



Ball on Flat Surface

Alignment Results

Room Temperature Fine Alignment



Fiducials on Cavity

Measurements of Shifts on Cooldown

Crosshair Targets

Alignment Results in Cryomodule at 4.5 K

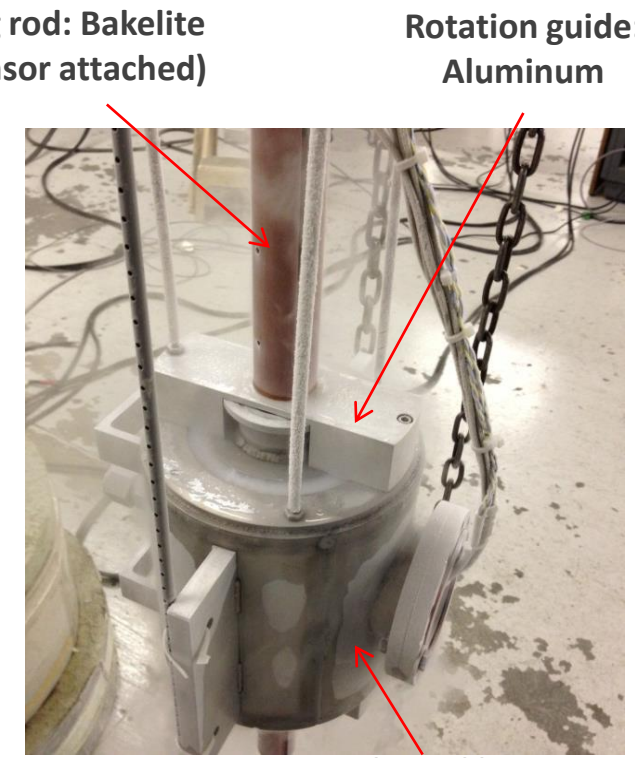
(RMS deviations from the fitted beam axis)

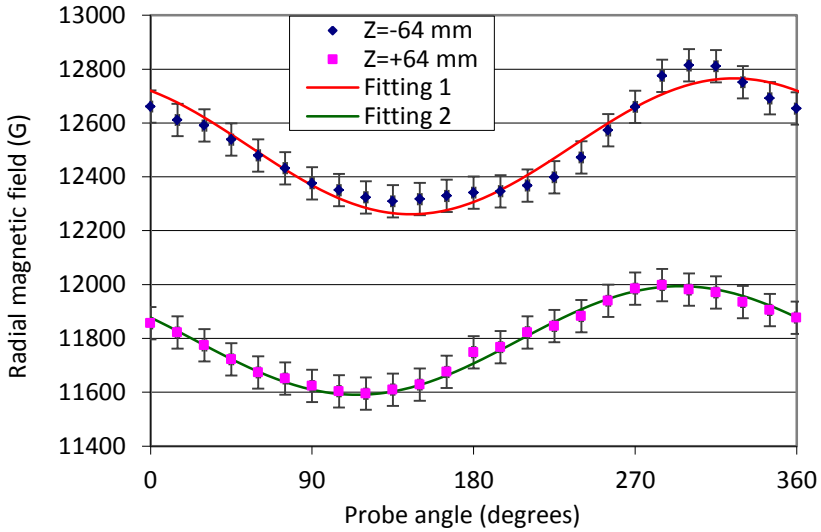
	Solenoids	Cavities*
Horizontal	0.12 mm	0.50 mm
Vertical	0.18 mm	0.28 mm

* Notice that the cavity has almost 4 times looser tolerances than the solenoid.

Improved Solenoid Alignment in Future Cryomodules

- Measure magnetic axis of the solenoid after installation of helium vessel





Magnetic centers at flanges (unit: mm)		
	x	y
Flange 1	-0.30 ± 0.07	0.17 ± 0.04
Flange 2	-0.08 ± 0.02	0.26 ± 0.07

Summary

- We used a kelvin type kinematic mount for the positioning of 7 superconducting quarter-wave cavities and 4 superconducting solenoids.
- We achieved <0.2 mm RMS alignment error at 4.5 K in the ATLAS Intensity Upgrade Cryomodule.