

# IMPROVEMENTS TO LCLS-II CRYOMODULE TRANSPORTATION

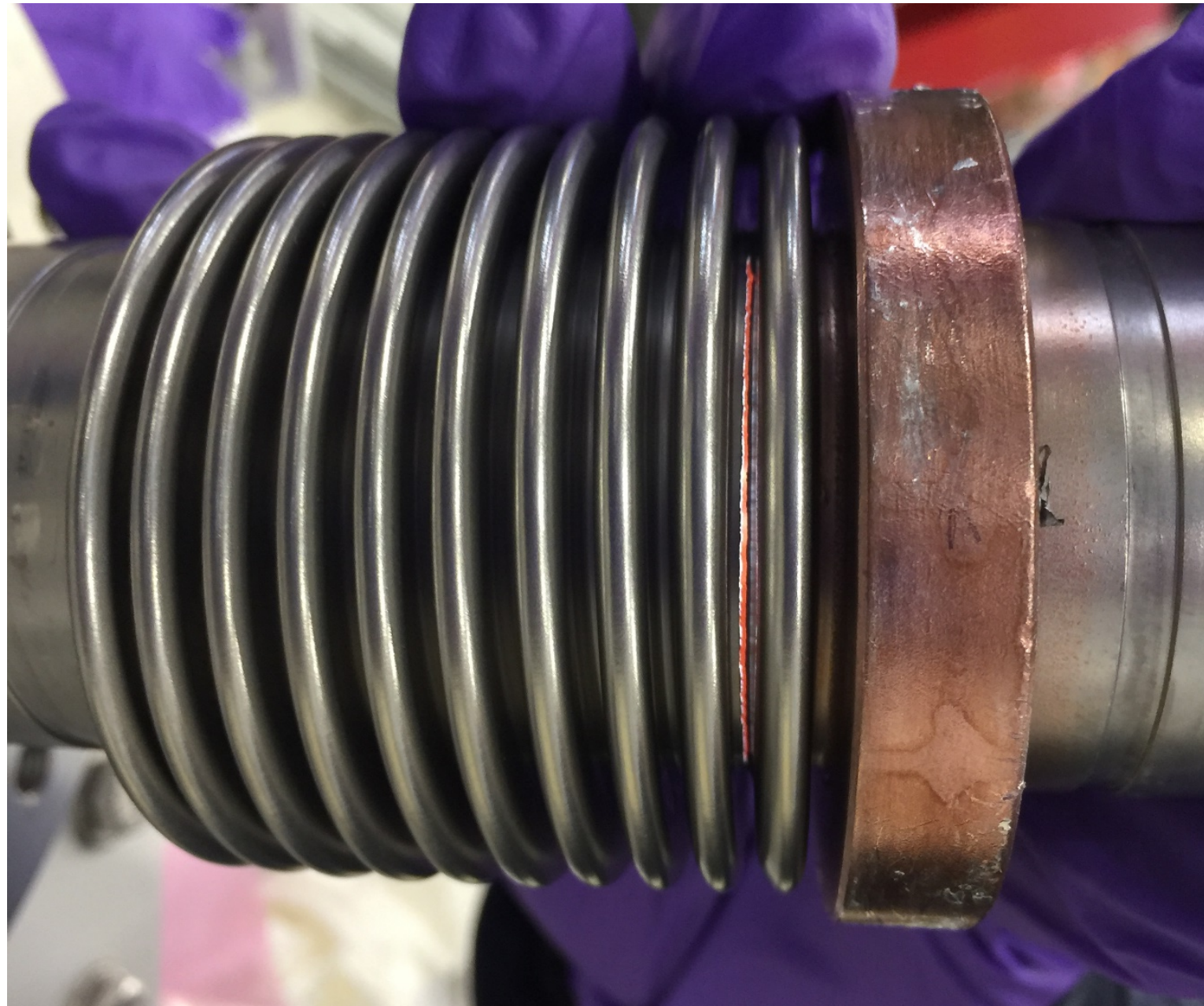
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## INTRODUCTION

- LCLS-II Cryomodules are shipped from JLab (VA, USA) and FNAL (IL, USA) to SLAC (CA, USA)
- Early shipments had failed FPC bellows, venting the beamlines
- A restraint system was proposed to limit bellows motion
- The spring configuration on the shipping fixture was also changed to lower shocks

## FAILURE MODE

- Bellows resonant frequency of 15 Hz excited by road transport
- Excessive motion ( $\pm 3.0$  mm) found in the beamline (longitudinal) direction
- Fracture of bellows due to cyclic fatigue



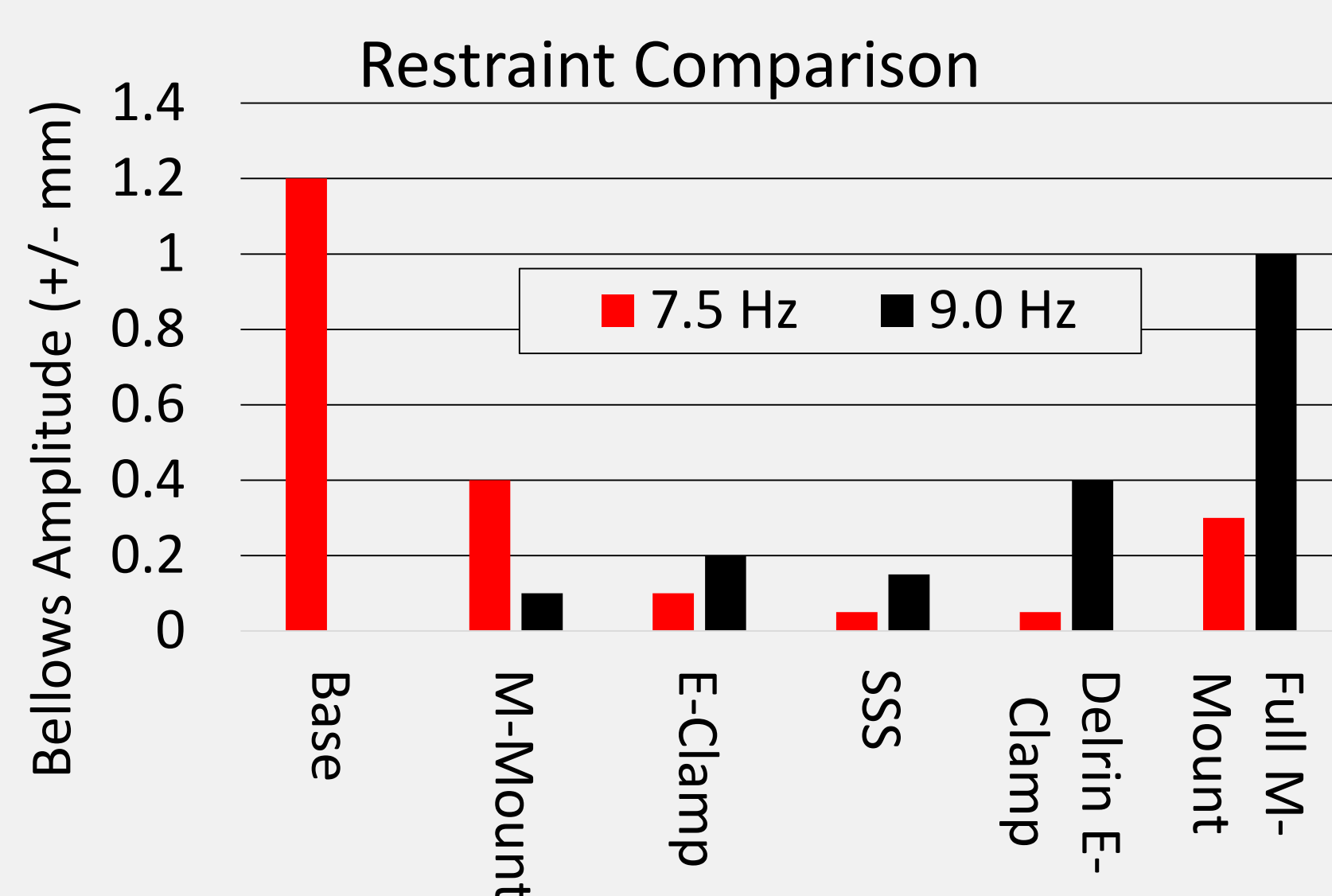
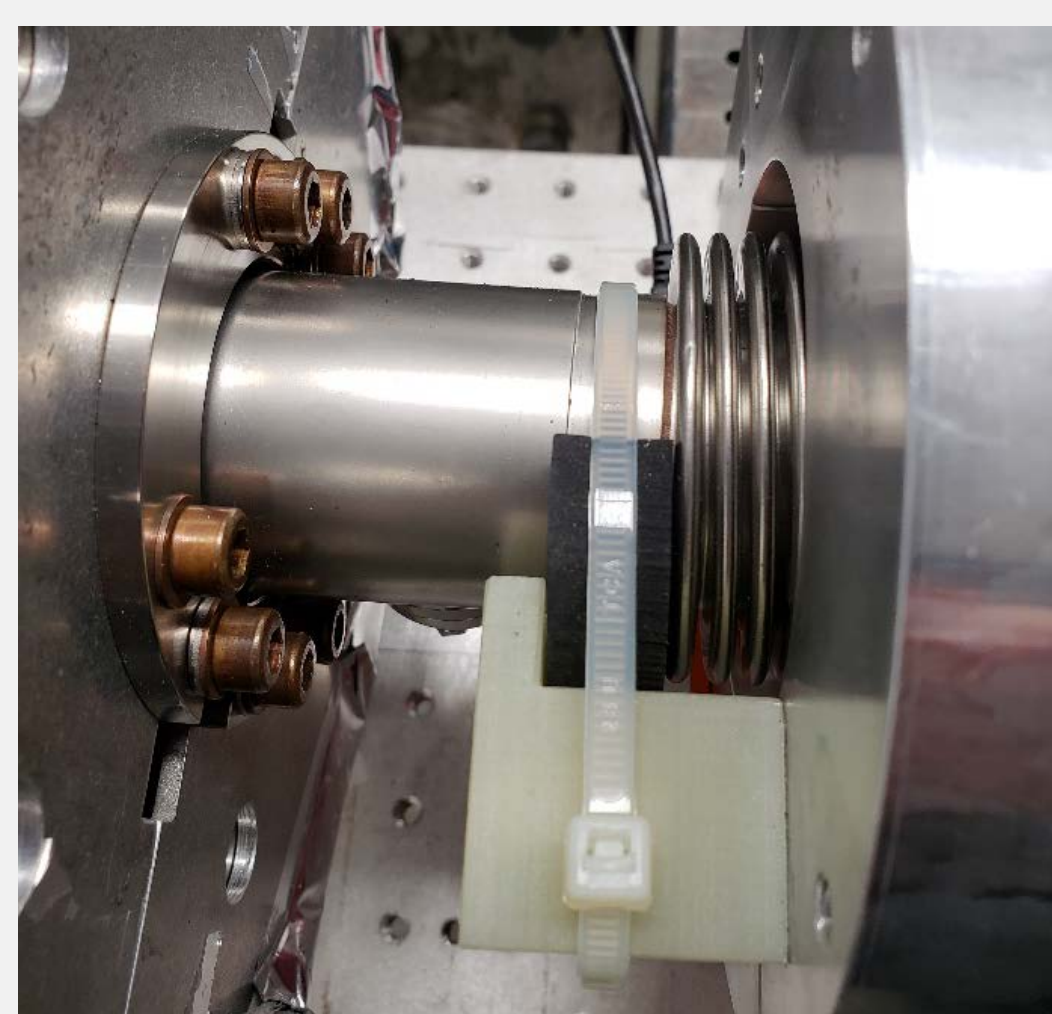
## RESTRAINT DEVELOPMENT

### Requirements

- Restrict motion to less than  $\pm 2.0$  mm
- Increase the natural frequency of the bellows assembly significantly higher than 15 Hz
- Install through tuner ports on completed CMs
- Removable after shipping

### Development and Testing

- Shortlisted restraint installed on FPC on shaker table
- Shaker table was run at  $\pm 2.0$  mm at 7.5 Hz and 9.0 Hz
- E-Clamp and M-Mount chosen for CM testing**



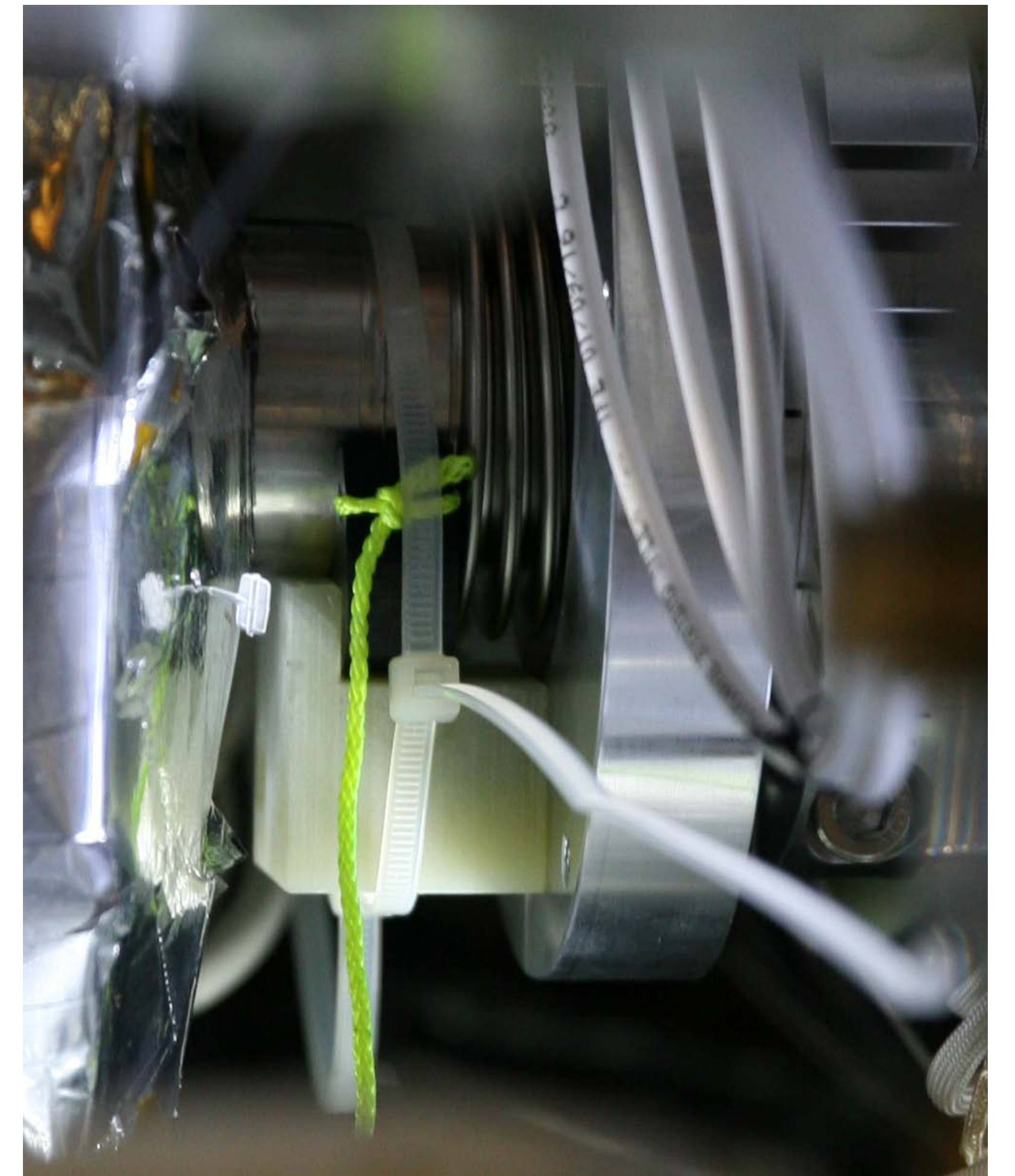
## CRYOMODULE TESTING

- E-Clamp and M-Mount tested on F1.3-05 (beamline previously vented)
- Tested on two 3,000 mile road trips
- New 8-spring configuration used
- Beamline vacuum intact
- Shocks within spec
- Bellows motion below  $\pm 2.0$  mm and resonant frequency above 15 Hz
- M-Mount chosen for shipments**

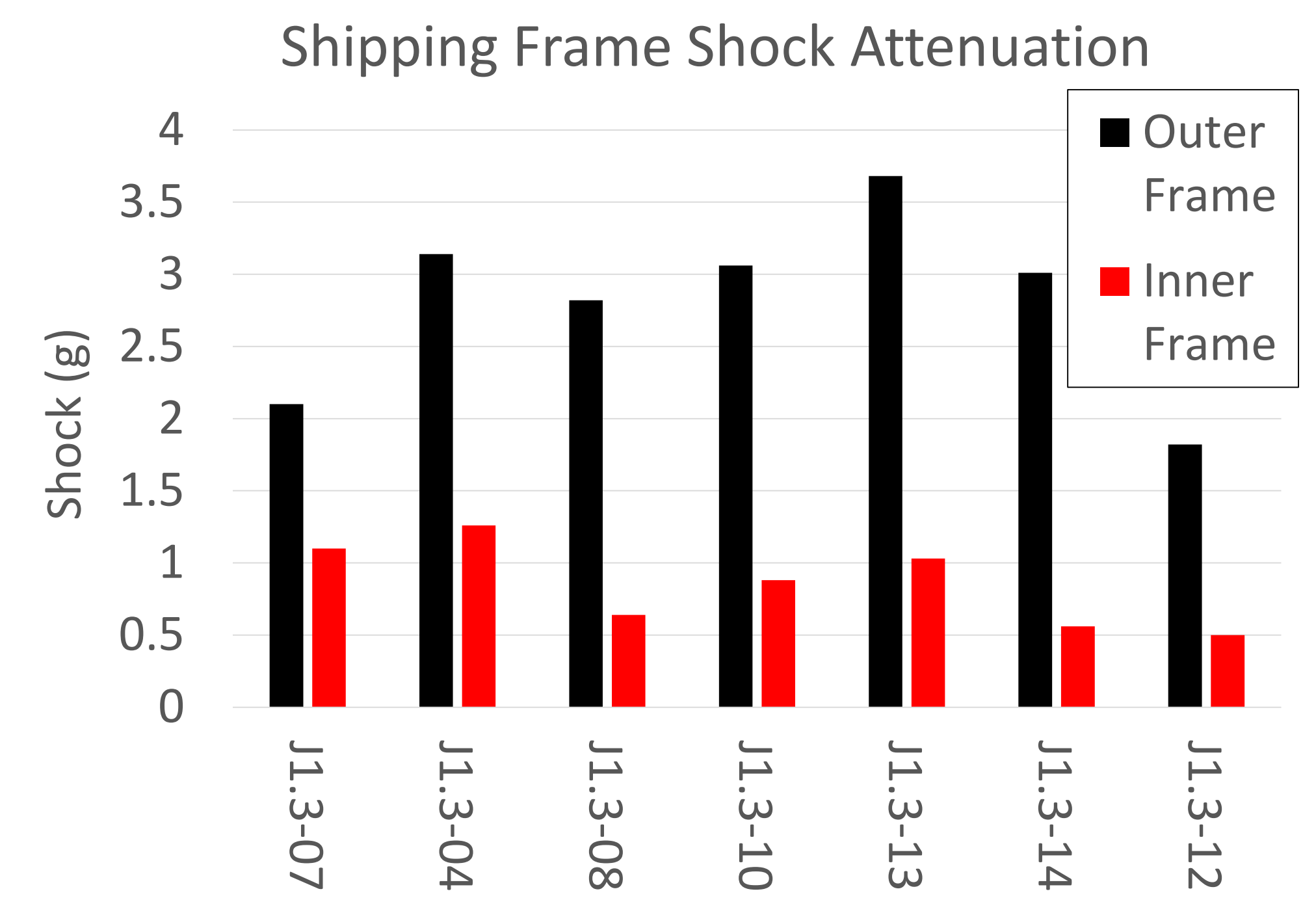
Cavity	Motion (+/- mm)	Freq. (Hz)
1 (E-Clamp)	0.60	33.0
2 (E-Clamp)	0.70	-
3 (E-Clamp)	1.05	40.0
4 (E-Clamp)	1.25	-
5 (M-Mount)	-	-
6 (M-Mount)	0.85	30.0
7 (M-Mount)	0.35	40.0
8 (M-Mount)	0.55	37.0

## CURRENT SHIPPING RESULTS

- Cryomodule shipments have been on-going at JLab and FNAL
- All FPC bellows are fitted with the M-Mount (right image)
- The Shipping Frames use the 8-spring configuration
- Measured bellows motion is below the spec of  $\pm 2.0$  mm (table below)
- Shocks on the cryomodules are below the specified thresholds (graph below)
- No failures from 16 shipments

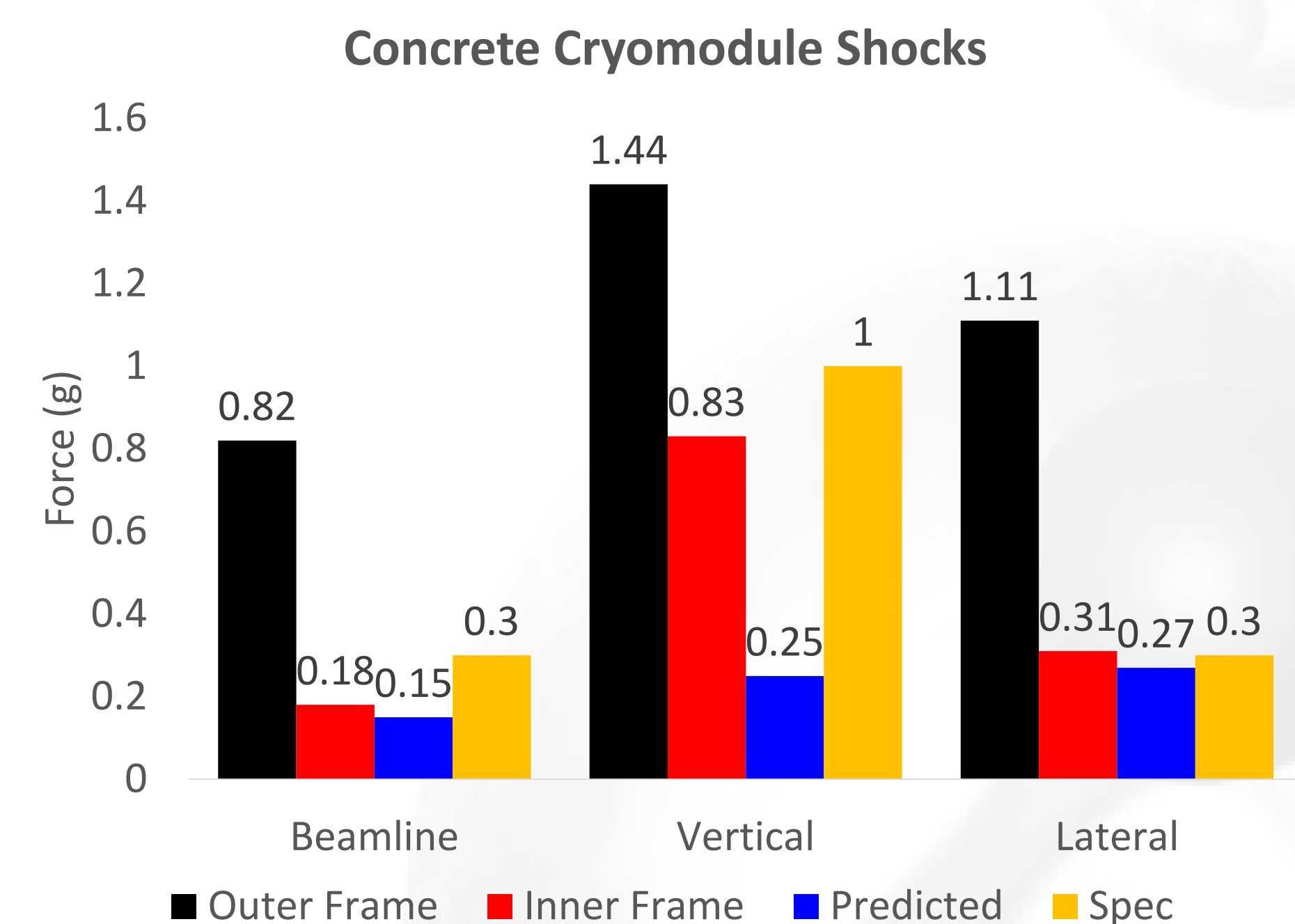


Cryomodule (Cavity)	Bellows Motion (+/- mm)
F1.3-05 (C1)	0.95
F1.3-05 (C6)	1.4
J1.3-10 (C6)	0.95
J1.3-12 (C1)	0.60
J1.3-12 (C6)	0.70
J1.3-14 (C1)	0.85
J1.3-14 (C6)	0.95



## FRAME SPRING RECONFIGURATION

- Original shipping frame spring configuration found to be too stiff
- The number of springs was decreased from 32 to 8
- Acceptable shock criteria target revised to 0.3g, 1.0g and 0.3g in X, Y, and Z respectively
- New configuration met specifications on testing with concrete CM**



## SUMMARY

- The shipping system for LCLS-II was modified to avoid the beamline failures of early shipments.
- A retrofitted bellows restraint limited shipping motion to below  $\pm 2.0$  mm
- Reducing the number of springs on the shipping frame reduced shocks
- Cryomodule shipping to SLAC has been on-going, with 16 CMs delivered

### Acknowledgements

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