
Investigation of discrepancies
between *Photon calibrator*, *VCO* and
Official (coil) calibration techniques

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with

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Peter Kalmus, Jeff Kissel, Mike Landry, Brian
O'Reilly, et. al.

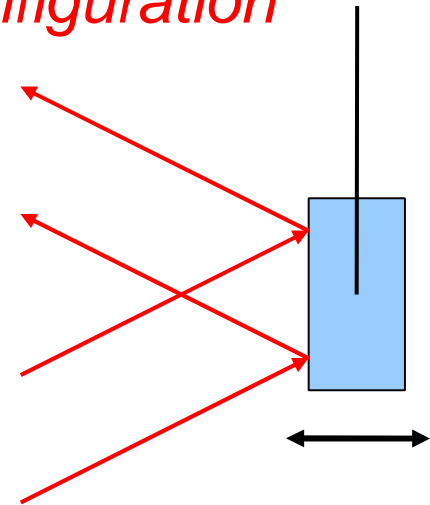
March 2008 LSC-VIRGO meeting
Detector characterization session

Progress since July LSC

- Extensive Post-S5 measurements utilizing all calibration techniques
- Photon calibrator accuracy improved to $\sim\pm 3$ percent (2-sigma)
 - » Absolute power calibration – temperature controlled PDs on integrating spheres – calibration at NIST
 - » In-chamber optical efficiency measurements (H2 only, so far)
 - » Relief of beam clipping on baffle supports (H1)
 - » Confirmation of elastic deformation of the TM (Hild, et. al.) -- two-beam configuration
- Voltage Controlled Oscillator (VCO) measurements in both *Science configuration* and *Calibration configuration*
- Discovery of $\sim 10\%$ discrepancy between *Science configuration* and *Calibration configuration* electronics

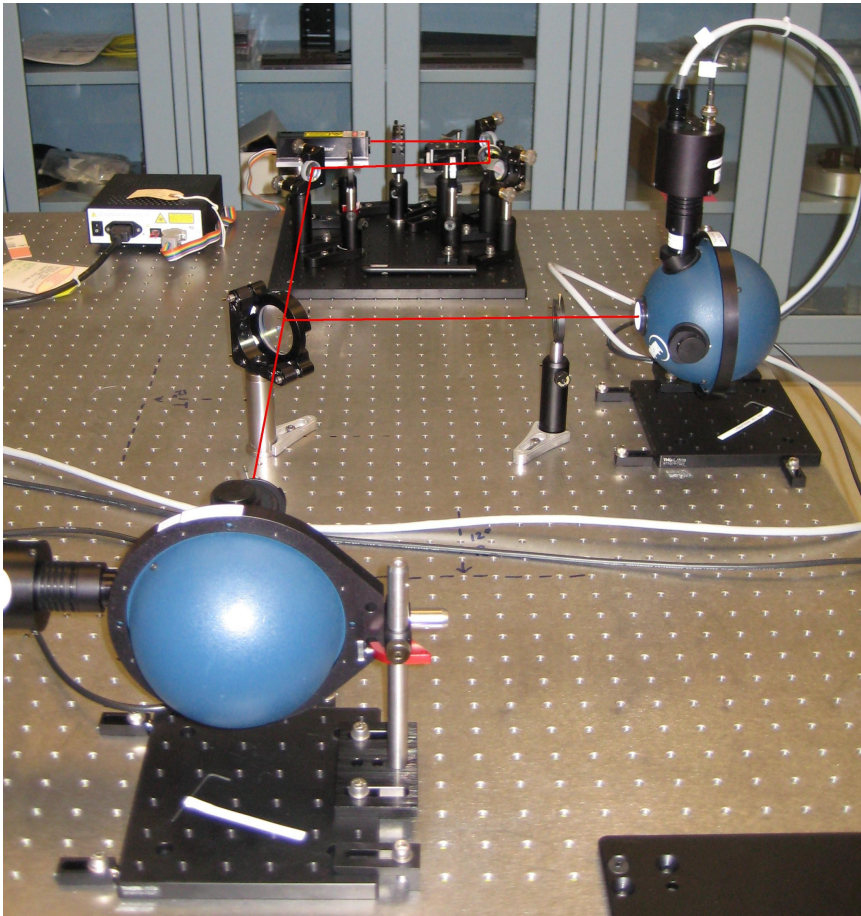
Post-S5 photon calibrator measurements

- Photon calibrator uses power-modulated auxiliary laser to push the ETM in the full *Science configuration*
- Increased instrument availability enabled significant improvement of photon calibrator accuracy
 - » Absolute power calibration
 - » Photon calibrator and interferometer beam positions on ETMs (Thanks to: A. Effler)
 - » Angle of incidence from beam position measurements and mechanical drawings
 - » Improved technique for assessing (and relieving) clipping on ETM baffle supports
 - » Increased number of averages to reduce statistical errors
 - » In-chamber measurements of optical efficiency (H2 so far)



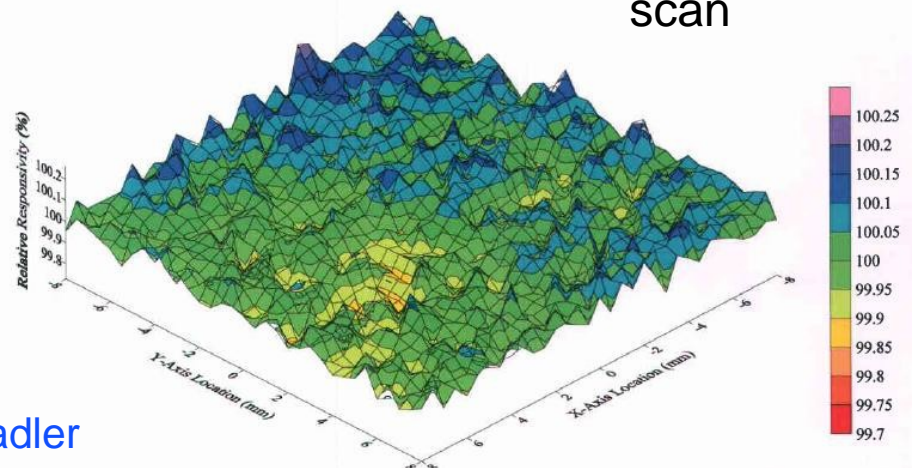
Absolute power calibration

- Temperature controlled InGaAs PDs on integrating spheres
 - » Gold standard for lab calibration and working standard for field work
 - » Gold standard calibrated at NIST using spare pcal laser
 - System accuracy 0.88% (2 sigma)



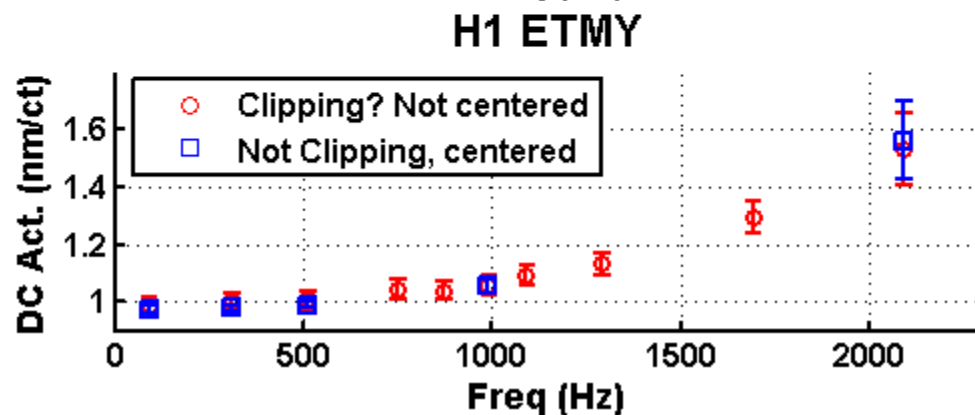
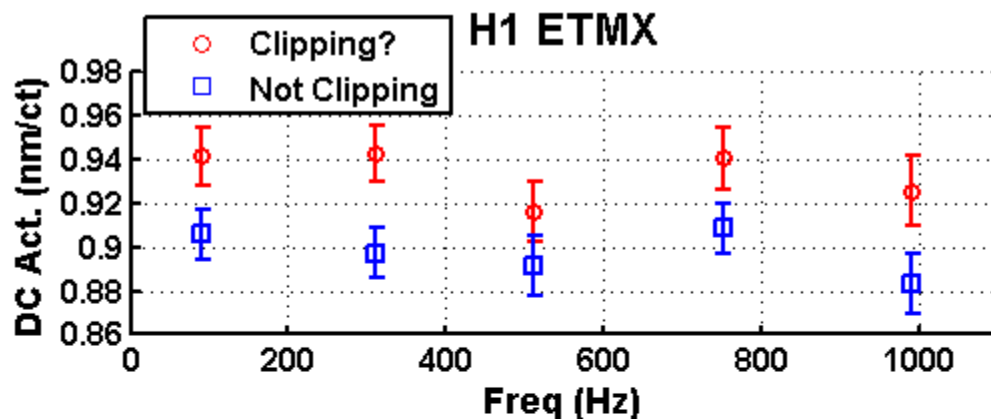
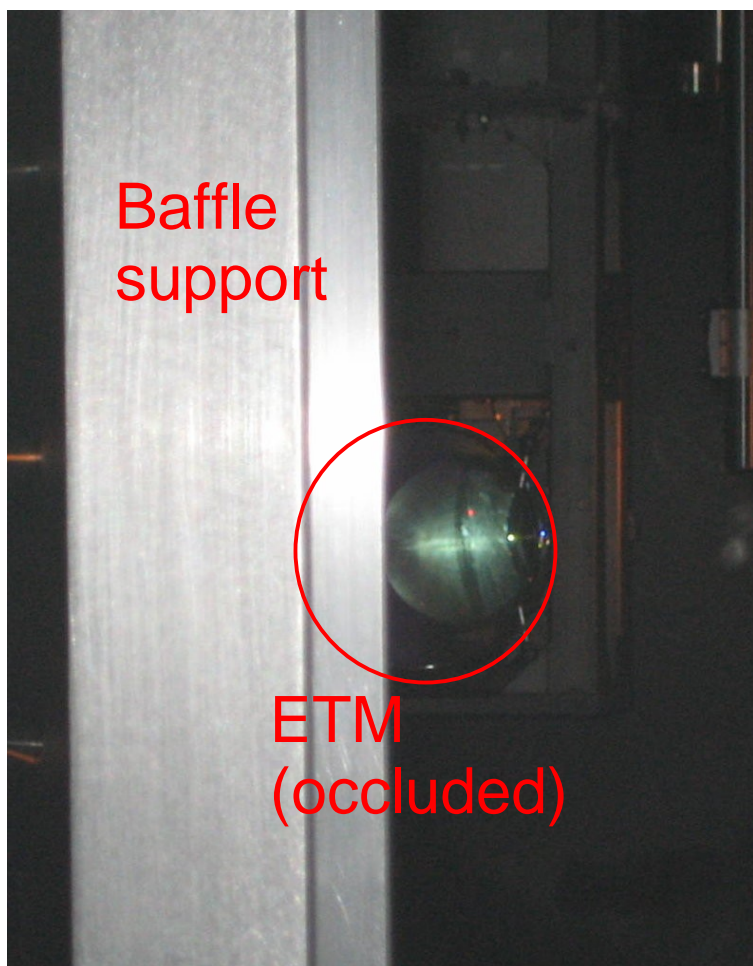
LASER POWER METER
 Labsphere Model: 3P-LPM-040-SL, S/N 05076191
 with Keithley Current Amplifier Model: 428, S/N 1154940

Aperture
 uniformity
 scan



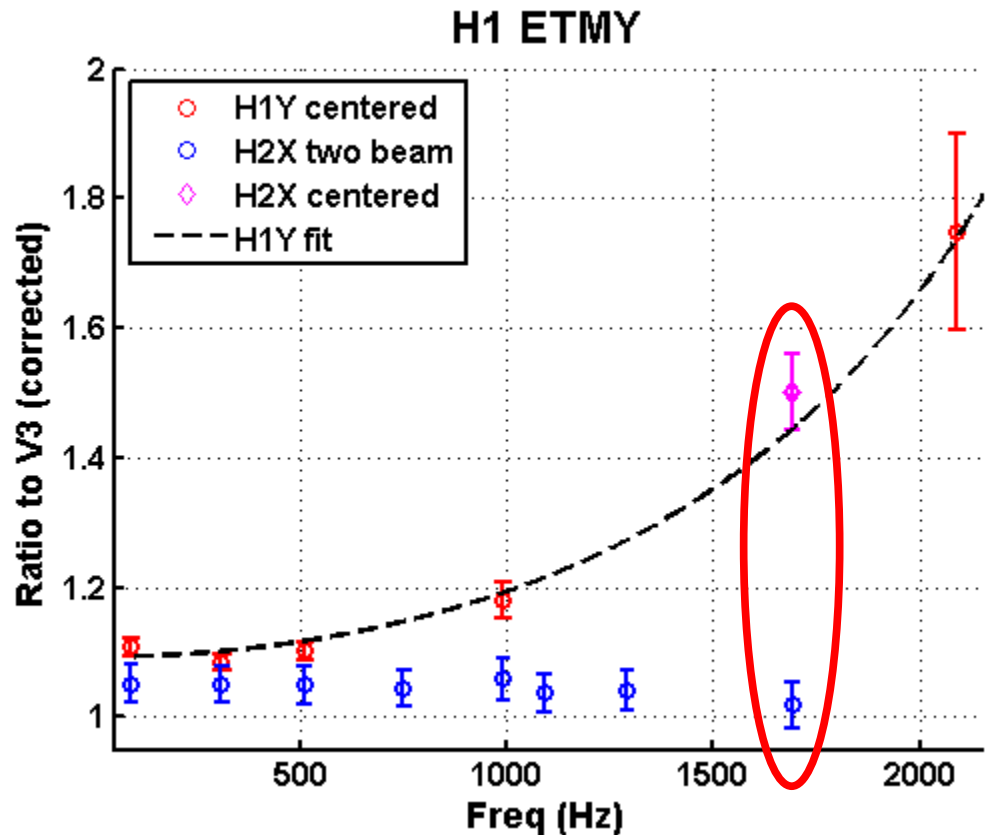
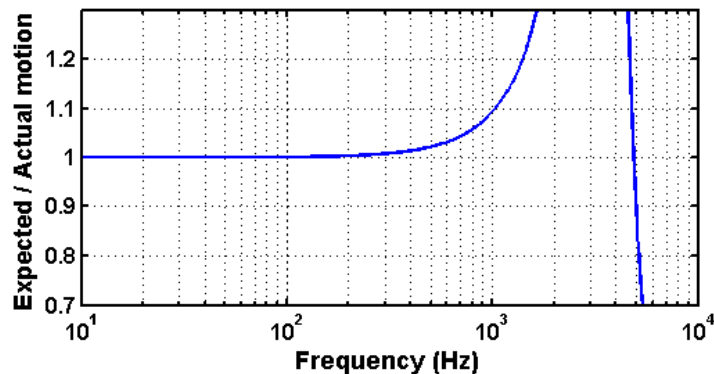
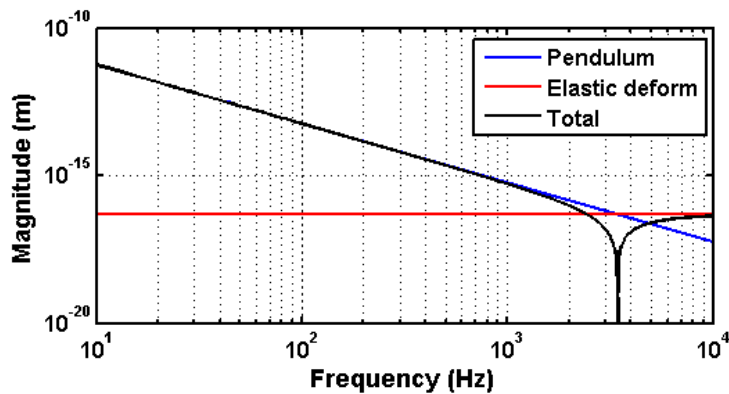
H1 beam clipping -- relieved

- Occlusion of view of ETM by unused baffle supports makes centering difficult, clipping can happen



Elastic deformation

- Pcal beam elastically deforms the mass where it reflects from the ETM (S. Hild et al 2007 Class. Quantum Grav. 24 5681-5688)



In-chamber measurements

- H2 ETM EQ swap allowed for access to measure optical efficiency
 - » Used pcal working standard
 - » Calibration of Pcal PD to power incident and power reflected from ETM
- ETM reflectivity $> 99.5\%$ (as expected)
- $\sim 2\%$ unexplained loss of Pcal light at both H2X and H2Y
 - » Absorption/scattering in vacuum window?
 - » Pcal beam propagation loss?
 - » Consistent with optical efficiency measurement on H2X during S5
- H1 vent for magnet swap (3/24/08) will enable similar measurements for H1 ETMs
- L1 measurements during their ETMs magnet swap work

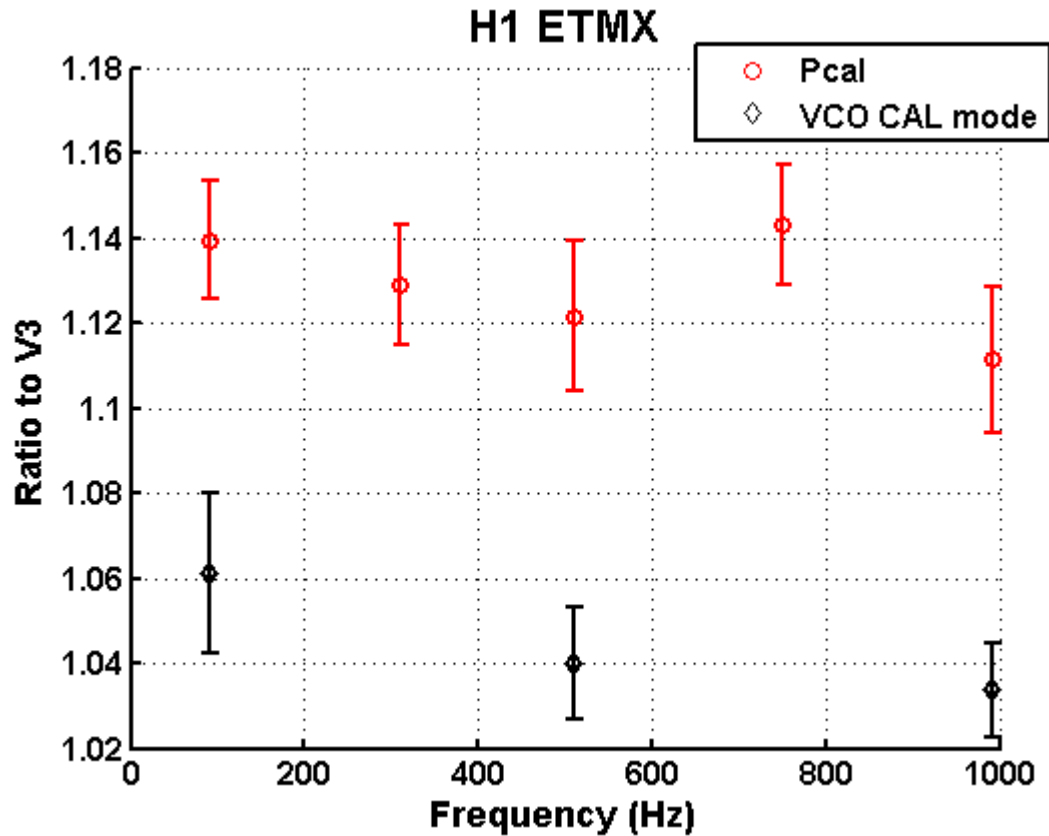


Photon calibrator errors

- Systematic errors
 - » Absolute power calibration
 - » ETM pcal and IFO spot position
 - » Photon calibrator power balancing of two beams

 - » Viewport transmission
 - » Photon calibrator angle
 - » ETM mass
 - » Response function (for 0.1 Hz separation)
 - » ETM reflection
- Statistical errors
 - » Measurement in DTT

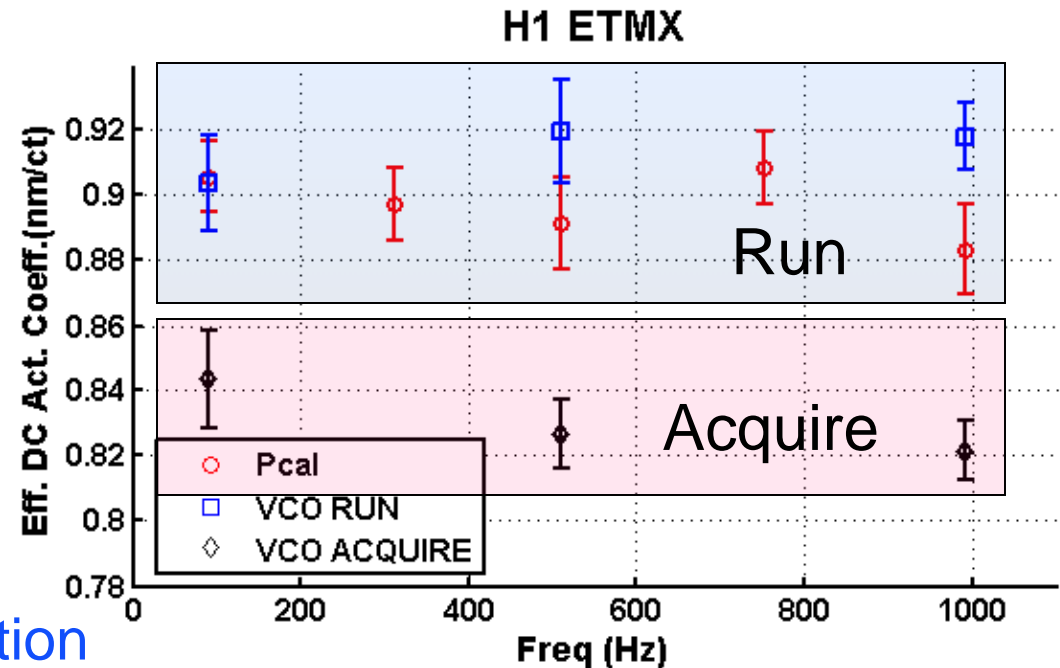
The leftover discrepancy...



VCO measurements

- Frequency modulation of the laser light via the PSL Voltage Controlled Oscillator (VCO) using single-arm locks
- Measurements performed in *Calibration configuration* indicated a ~10% discrepancy with Pcal meas. performed in *Science configuration*
- Repeated VCO meas. In *Science Config.* to investigate role of run/acquire compensation

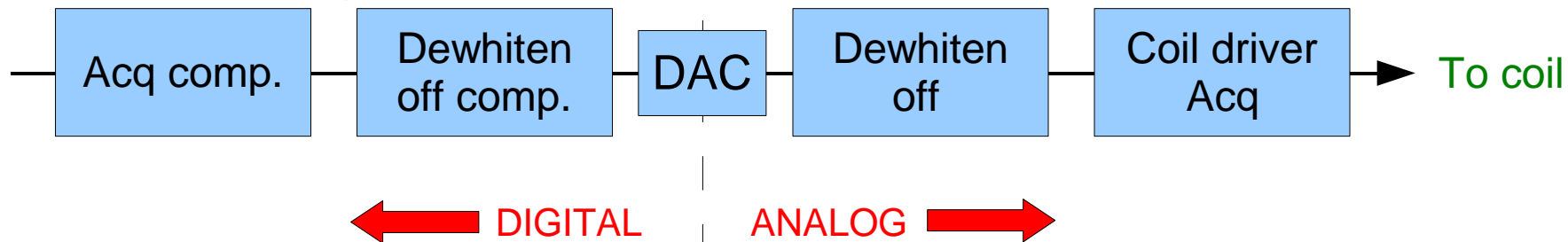
$$\frac{\Delta L}{L} = \frac{\Delta v}{v}$$



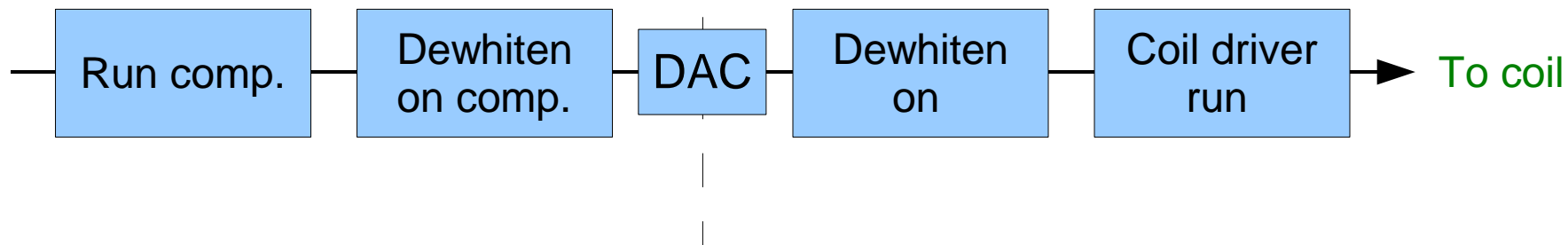
Actuation electronics

- Official calibration technique traditionally measures with the ETMs in “Acquire” mode, dewatering off
- We expect the transfer function remain unchanged in going to *Science configuration*

Calibration configuration:

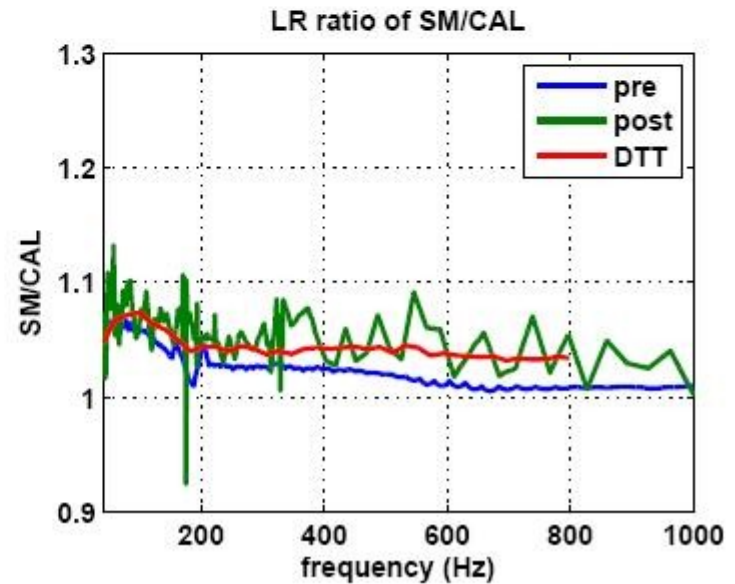
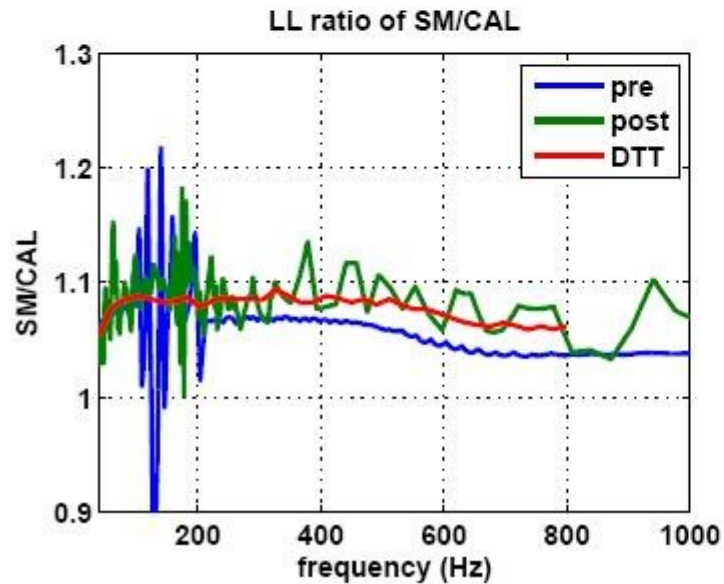
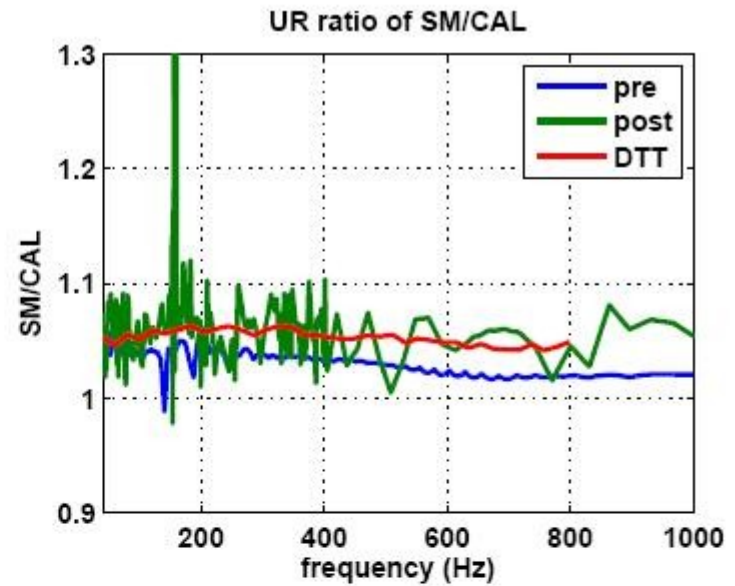
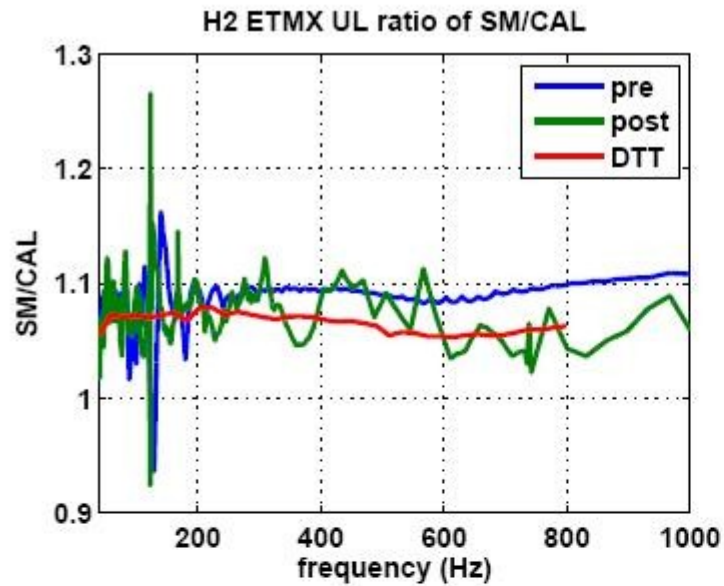


Science configuration:



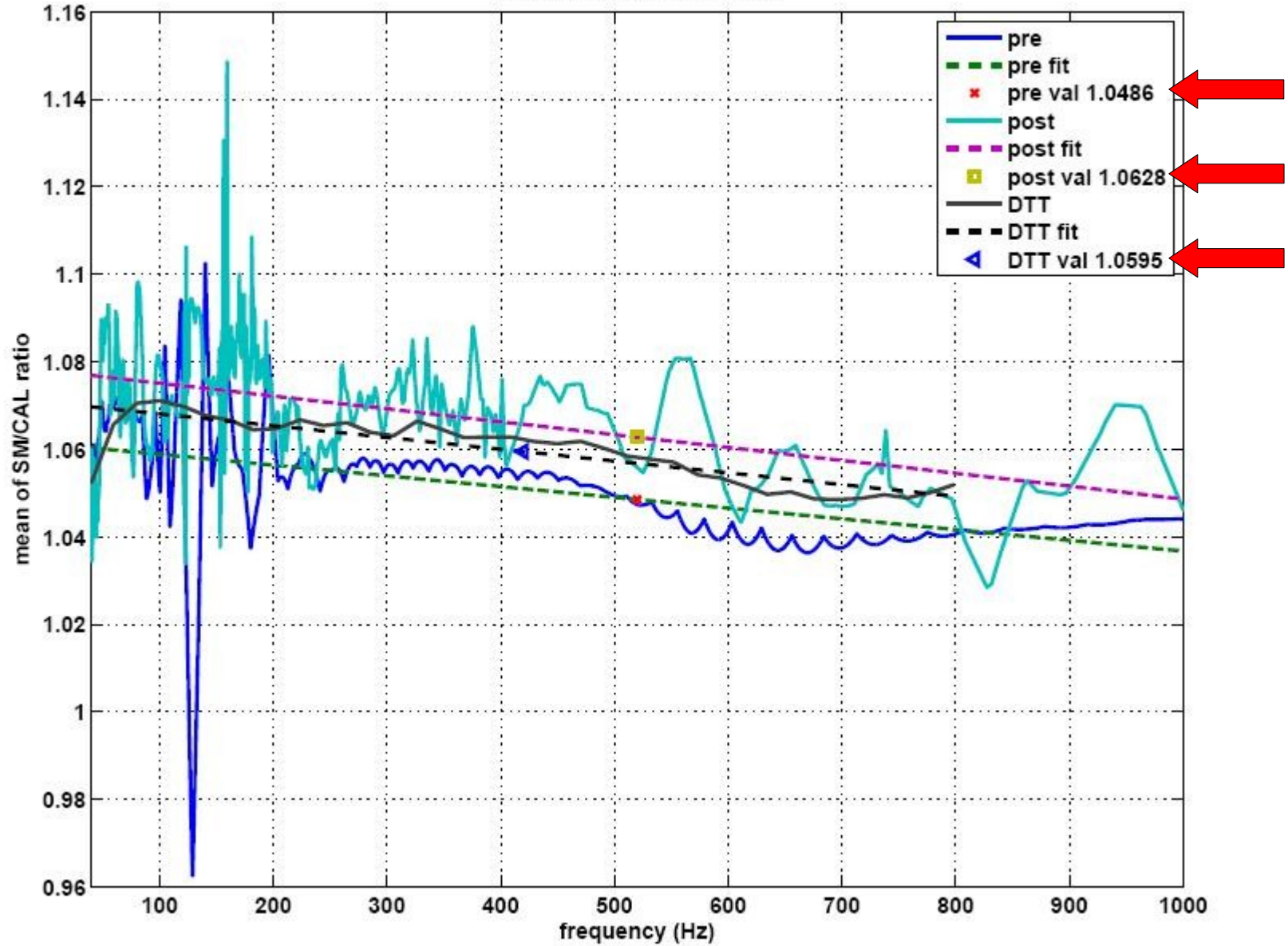
Measurement of electronics

- Measured transfer function of electronics 2 ways:
 - » Using dynamic signal analyzer during Pre- and Post-S5 measurement period to measure components individually and use Matlab to create the digital filters from the analog data
 - » Full path using Control Room tools during Post-S5 measurement period using low drive levels and many averages to reduce statistical errors
- Measure the coil transfer function in the two configurations, take complex ratio and mean to find the correction factor
- H1 and H2 need correction, L1 appears to be fine (so far)
- L1 is either okay by yet undetermined reason
 - » Same compensation code used
 - » Measurement variation between people? devices? sites?



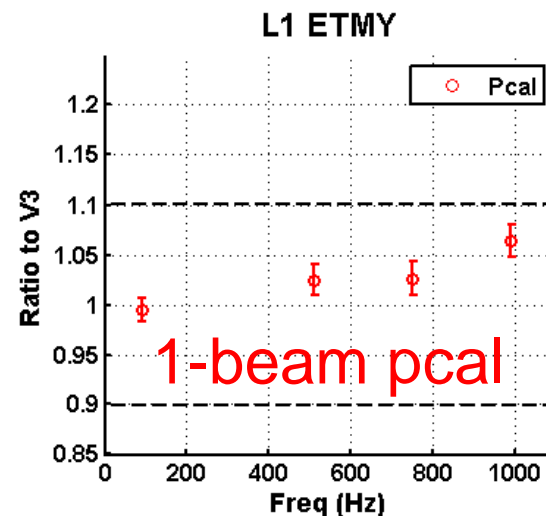
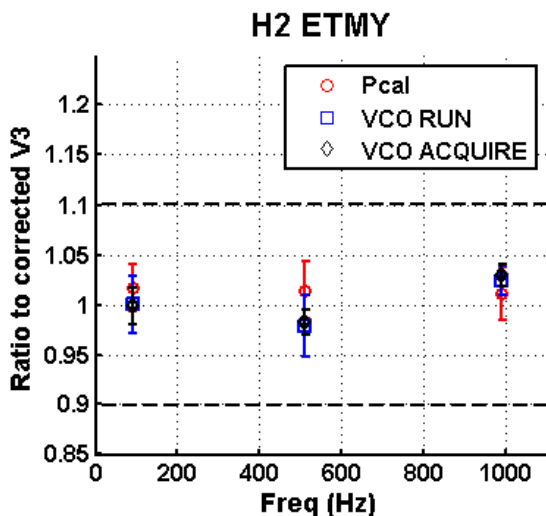
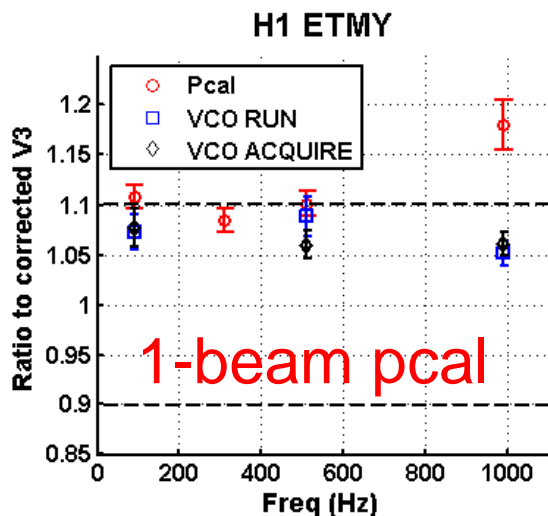
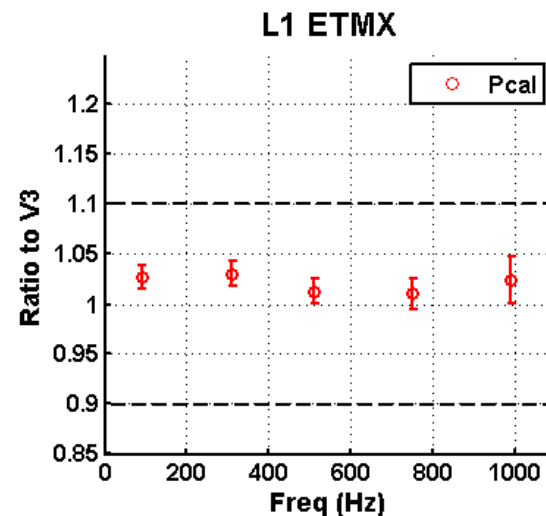
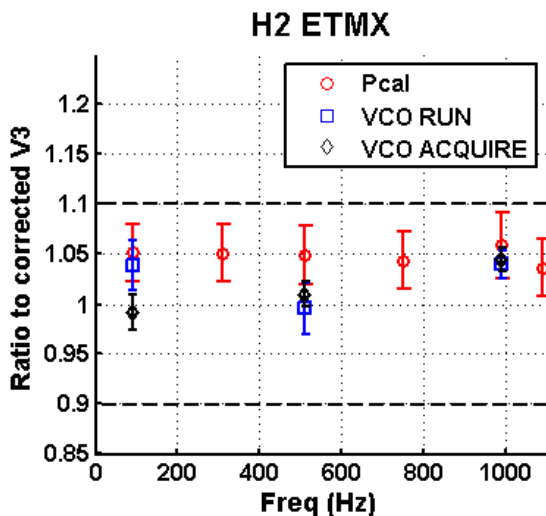
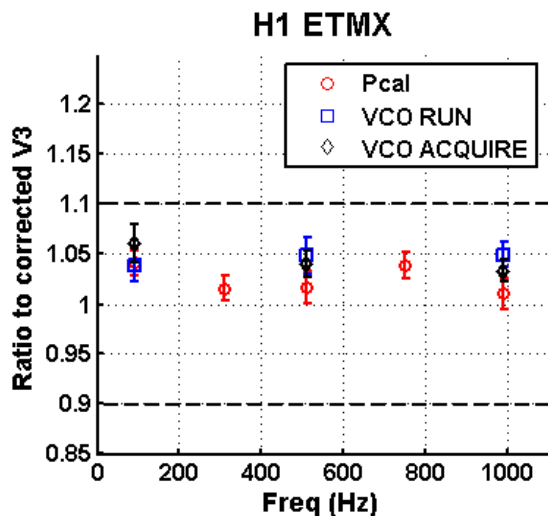
Plot by Justin Garofoli

H2 ETMX
mean of ratios of each coil



Plot by Justin Garofoli

Calibration comparison with correction for Sci/Cal config.



LIGO

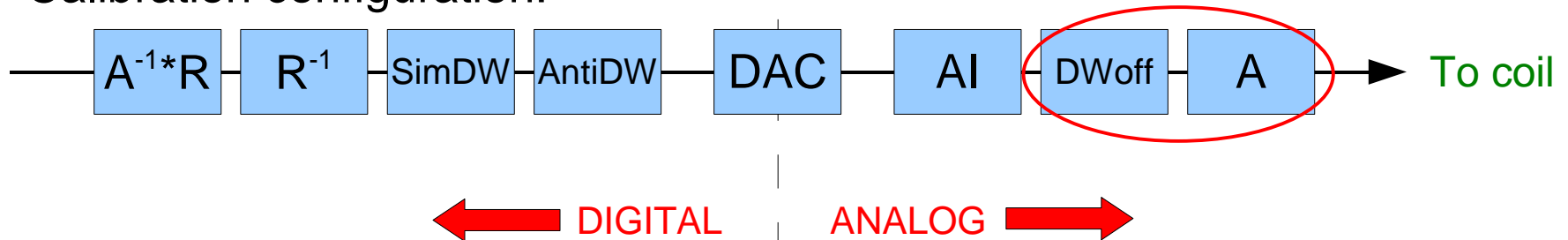
Thank you!



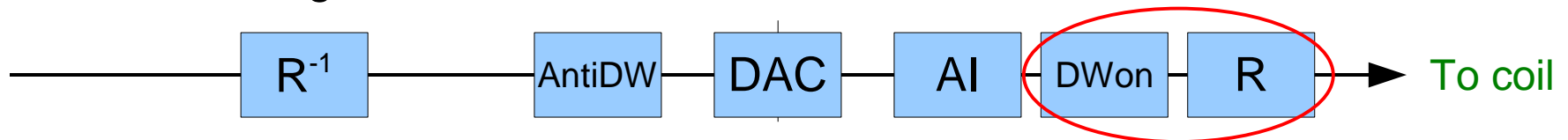
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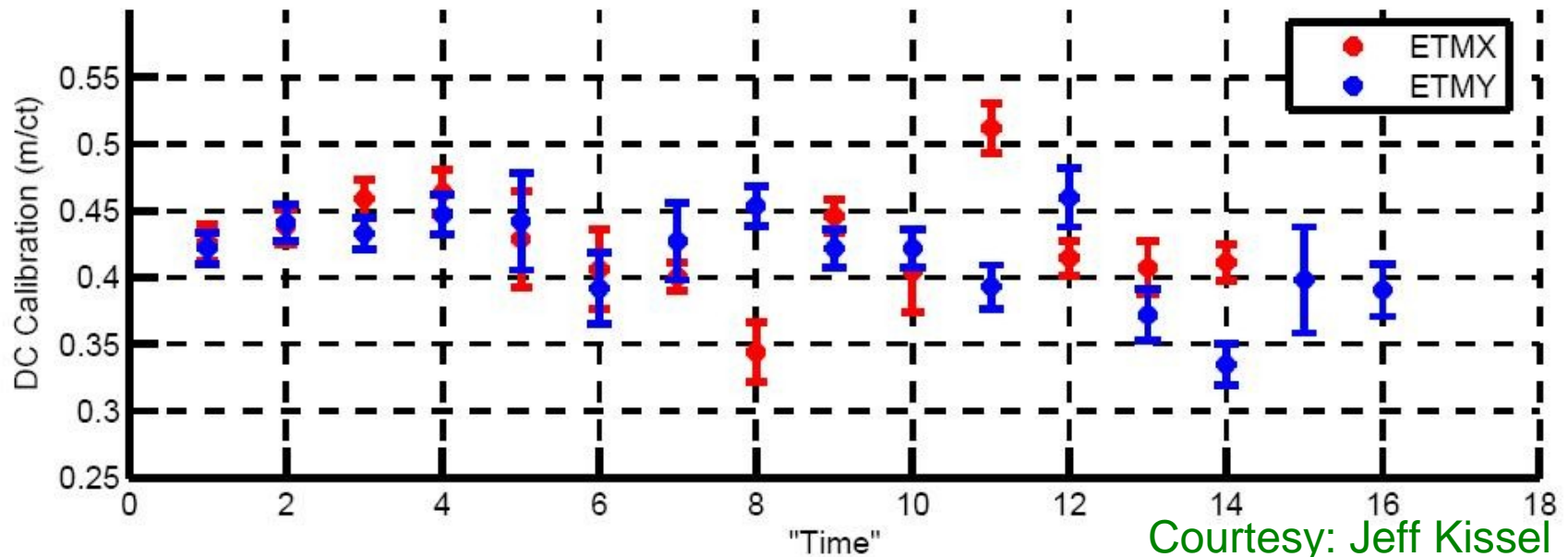


Science configuration:



Post S5 standard calibration

L1 Summary of DC Calibrations for S5



- Utilizes the wavelength of laser light as the standard of length
- Other techniques utilized in the past also tested:
 - » Fringe fitting, Sign toggling, Asymmetric Michelson
- Serves as validation of the technique used during S5