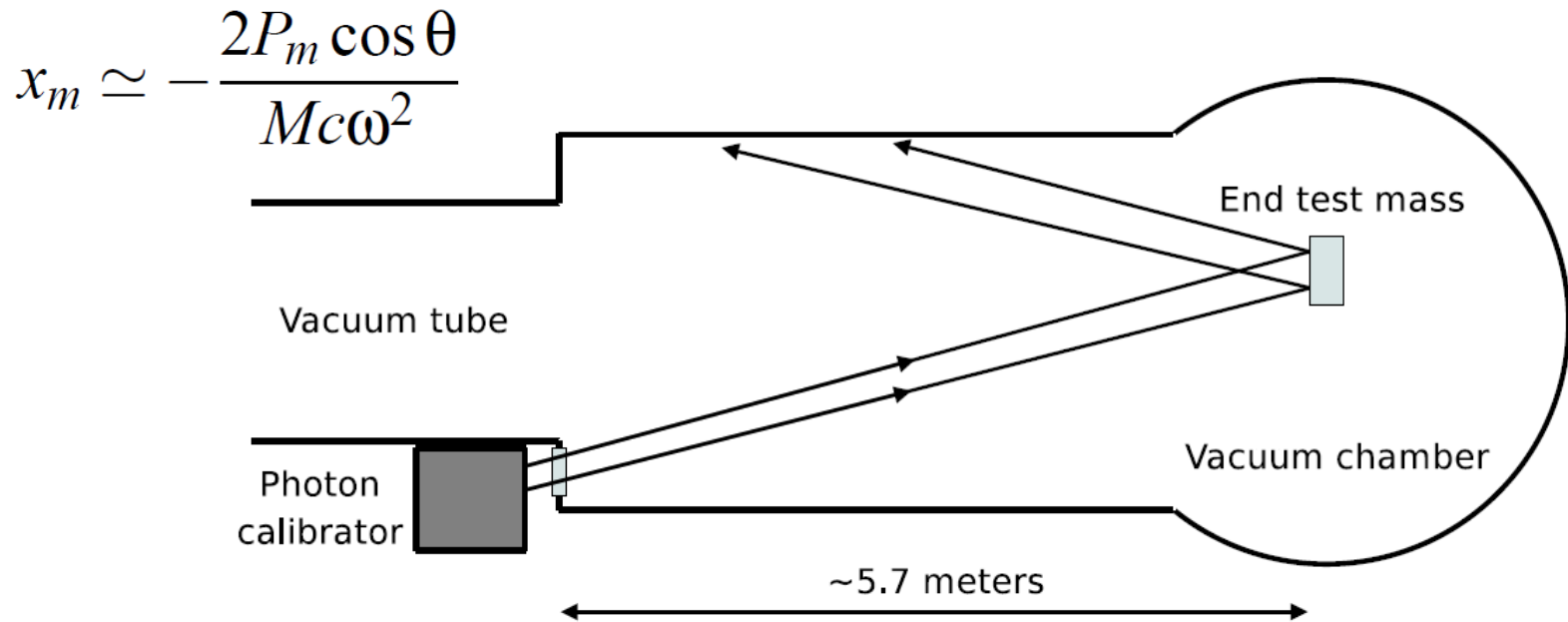

*eLigo Photon Calibrator investigation:
long-term stability of DARM actuation*

Rick Savage

*Jonathan Berliner, Pablo Daveloza, Roberto Grosso,
Greg Mendell, Michael Sakosky, Ryan DeRosa, Matt West*

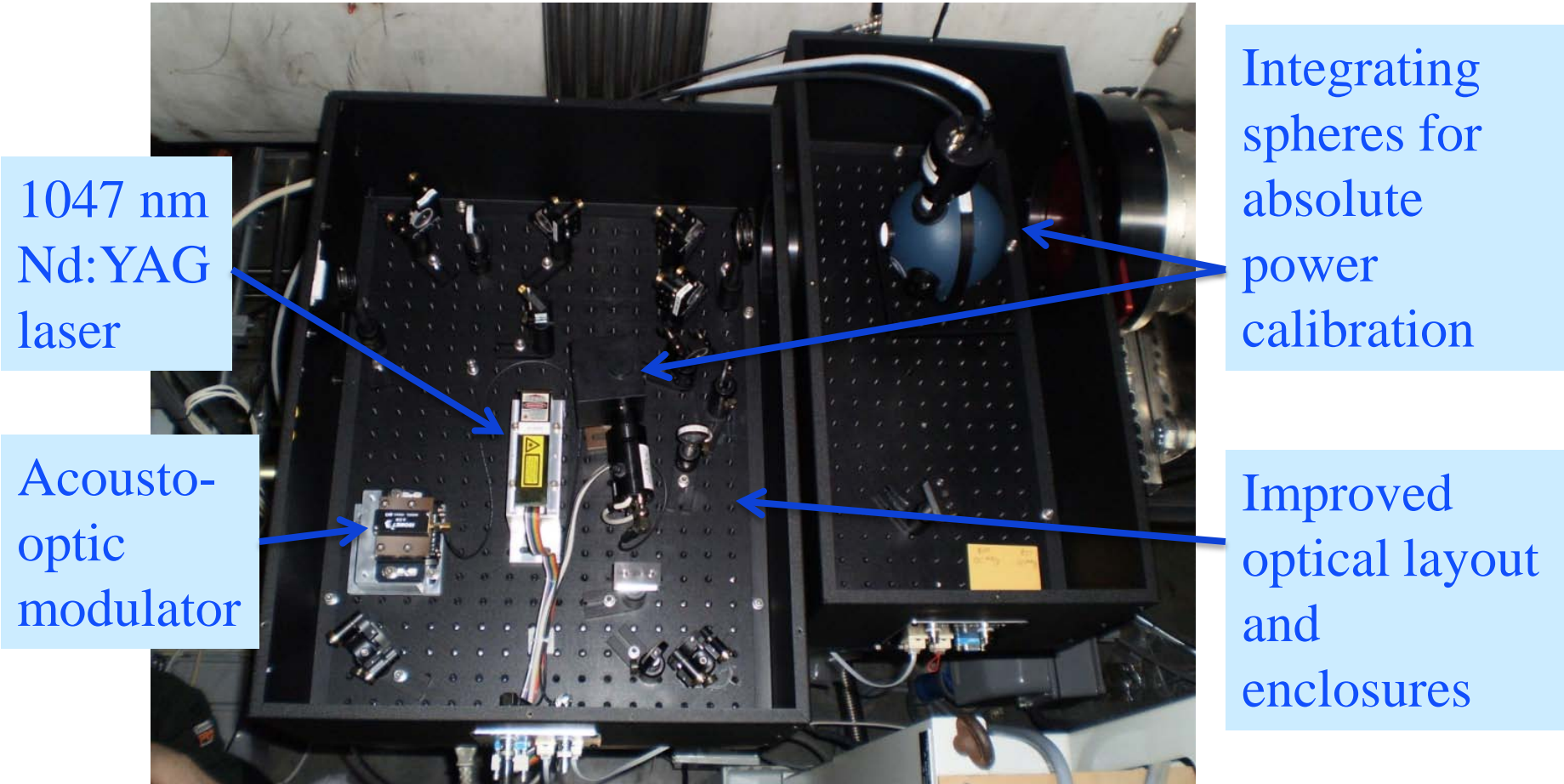
Photon Calibrator method

- Power-modulated auxiliary laser to displace the mass via the recoil of the photons (in “Science mode” configuration). E. Goetz, et al. *Class. Quantum Grav.* **26** (2009)



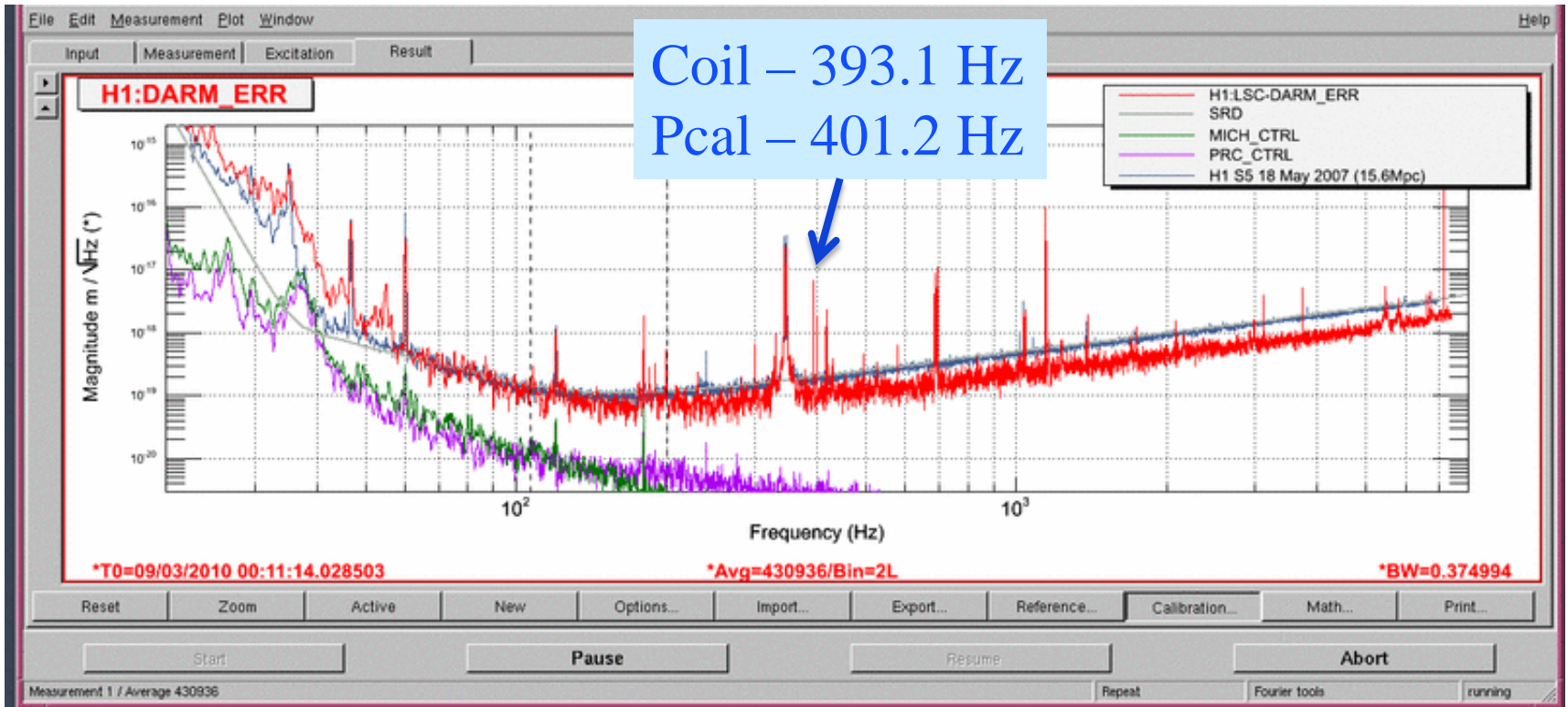
eLigo Pcal upgrades

- Upgraded Pcal installed for S6. H1 and L1 X-arm end test masses (Matt West, Ryan DeRosa, Michael Sakosky)



Calibrating DARM_CTRL_EXC with Pcal

- Simultaneously drive ETM position with both **Pcal** and **voice coil** actuators with sinusoidal excitations separated by 7.1 Hz

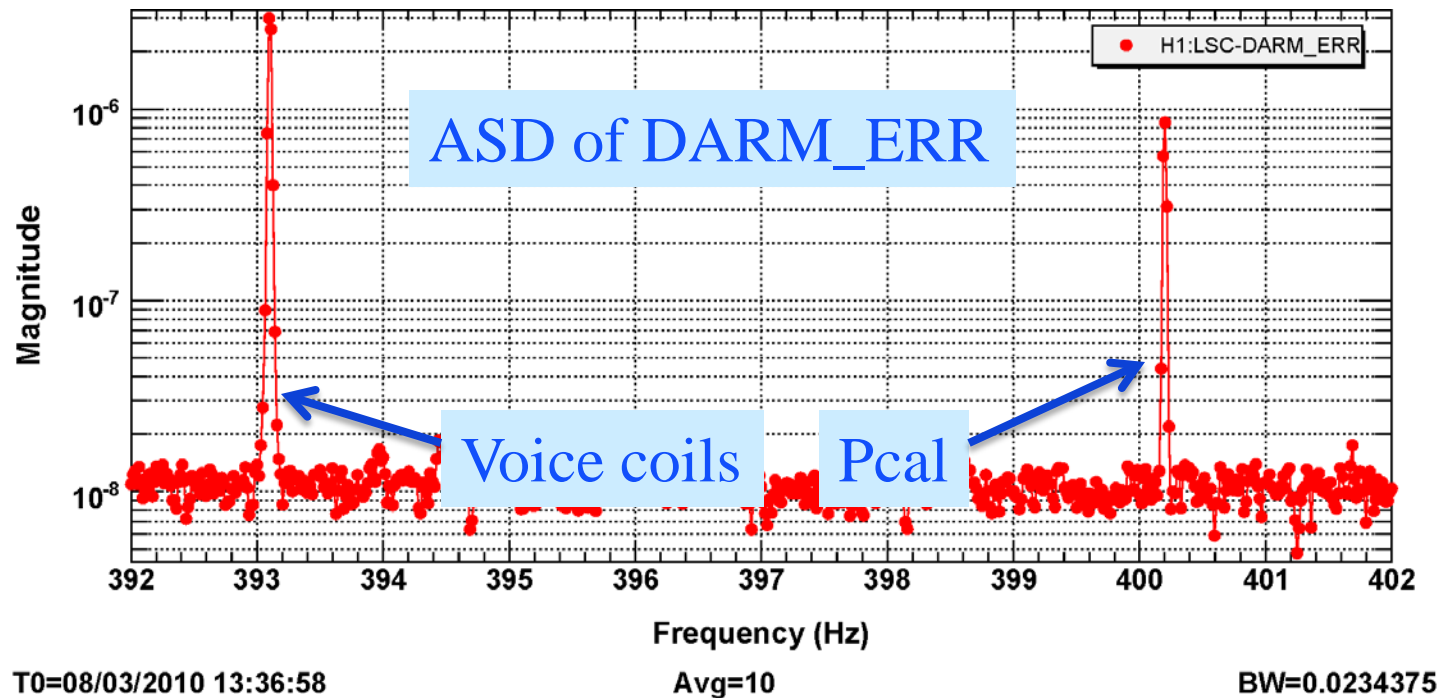


- Ratio of peaks together with Pcal absolute power calibration yields on-line, continuous calibration of DARM_ERR

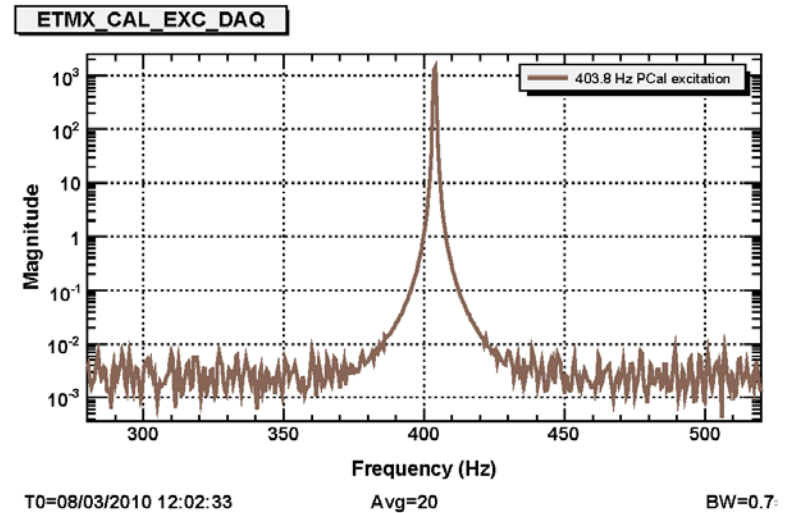
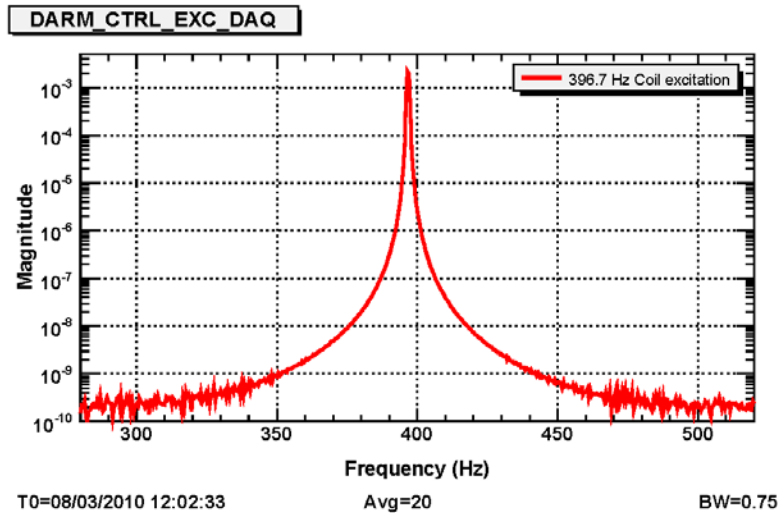
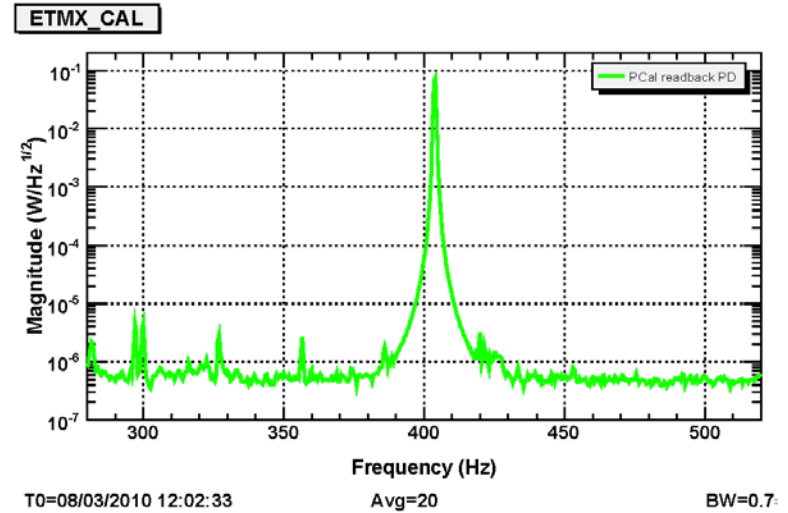
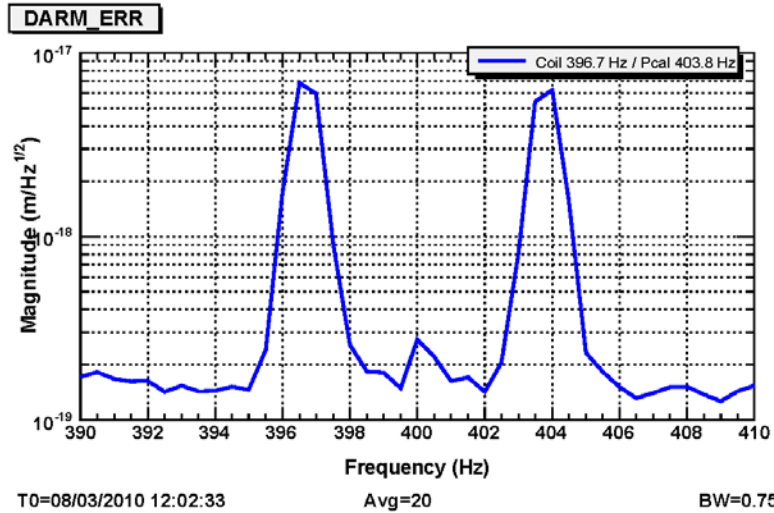
DARM_ERR lines with ~ 60-sec FFTs

Excitation frequencies: H1: coils – 393.1 Hz; Pcal – 400.2 Hz

L1 : coils – 396.7 Hz; Pcal – 403.8 Hz

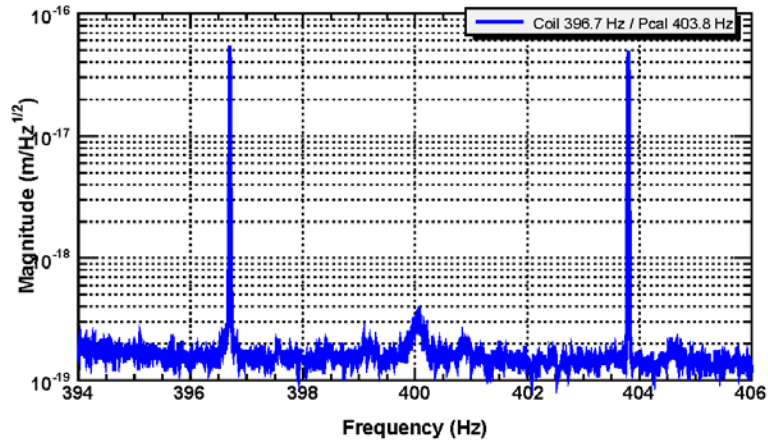


Relevant LLO Pcal peaks – high BW



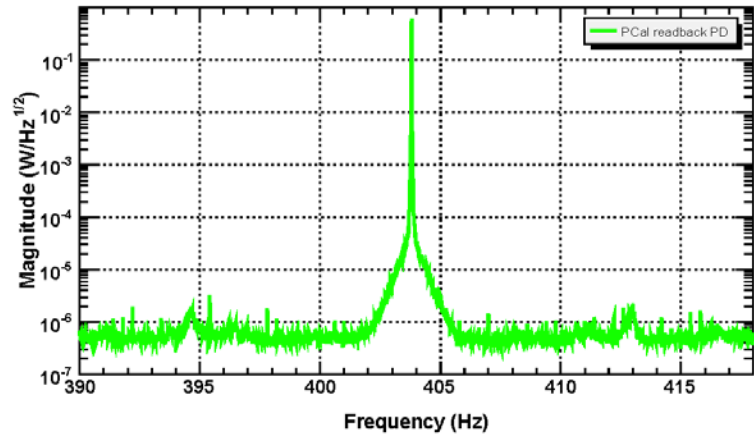
Relevant LLO Pcal peaks – Low BW

DARM_ERR



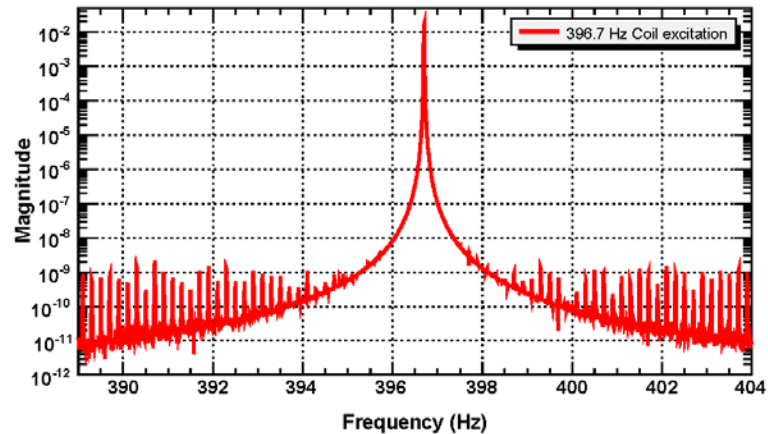
T0=09/03/2010 00:44:33 Avg=20 BW=0.0117178

ETMX_CAL



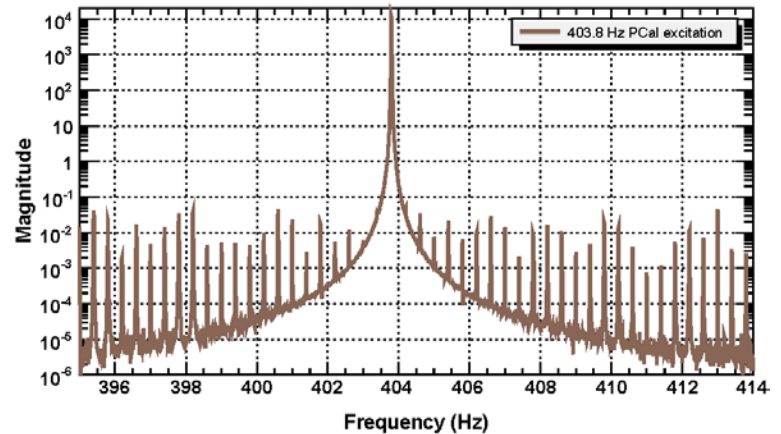
T0=09/03/2010 00:44:33 Avg=20 BW=0.011717

DARM_CTRL_EXC_DAQ



T0=09/03/2010 00:44:33 Avg=20 BW=0.0117178

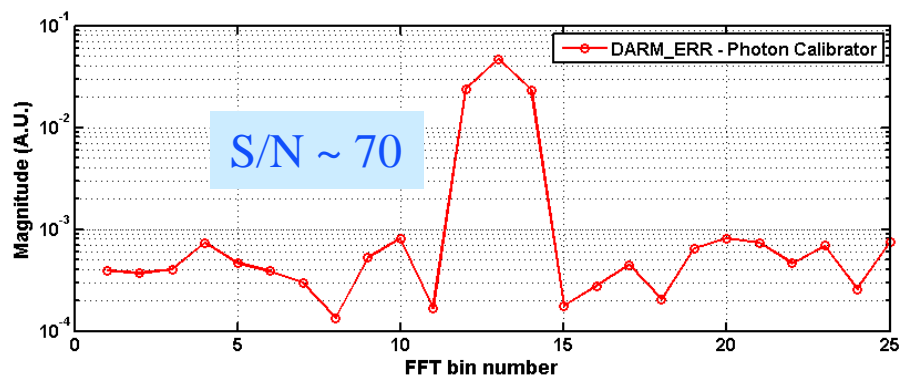
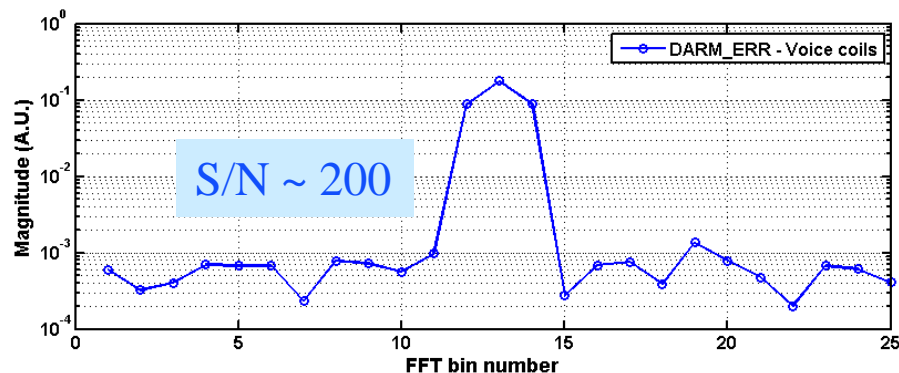
ETMX_CAL_EXC_DAQ



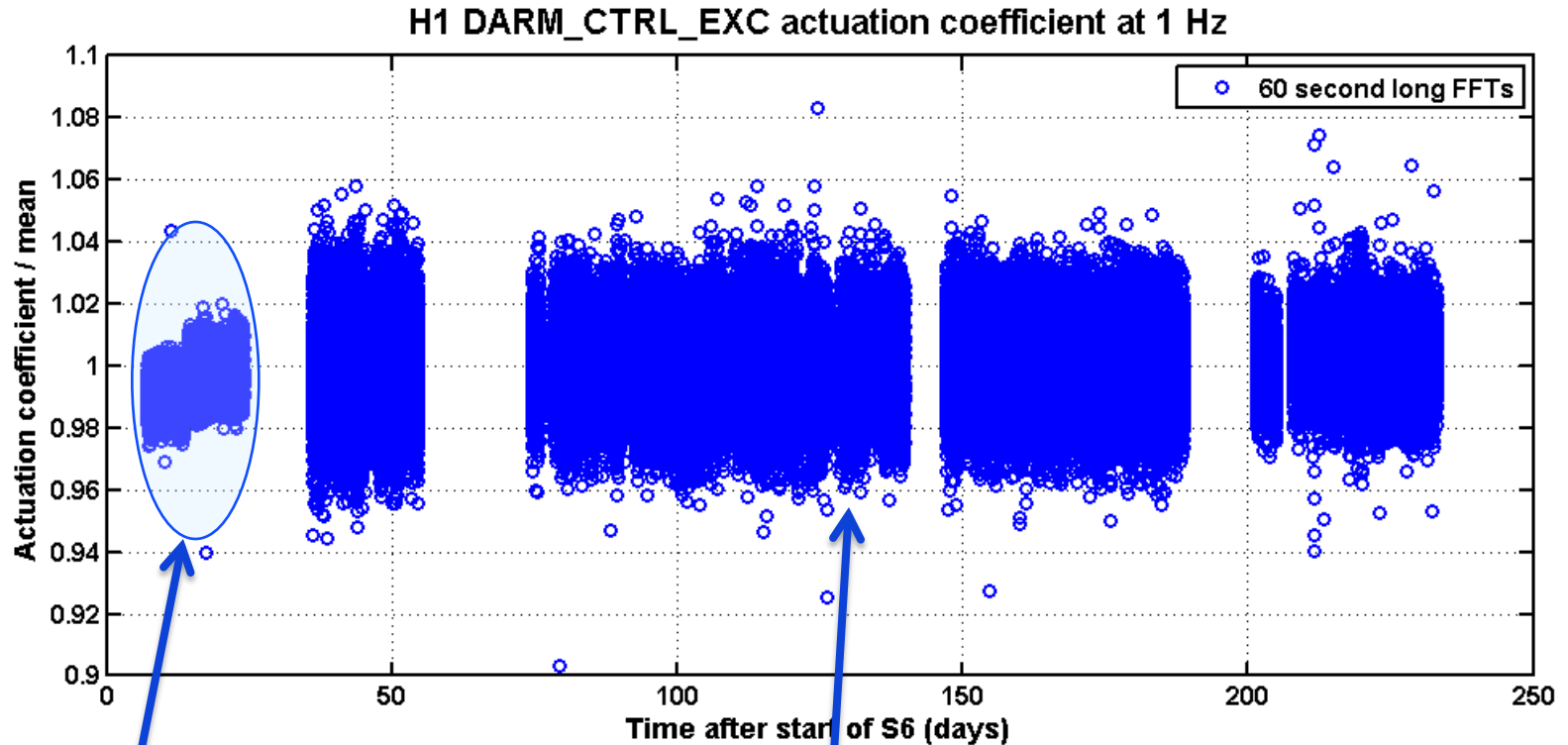
T0=09/03/2010 00:44:33 Avg=20 BW=0.011717

DARM actuation long-term trend investigation

- C++ code running on cluster at Caltech (LHO or LLO)
 - level 1 RDS frames
 - one S6 day per core
- 60 sec. data segments for three channels
 - DARM_ERR
 - 2 excitation readback channels
- Hann window data
 - all lines bin-centered
- FFT using FFTW3
- Write
 - GPS time at start of data segment
 - minimum state vector value during segment
 - complex amplitude for four lines
 - 2 DARM_ERR
 - 2 excitation readbacks



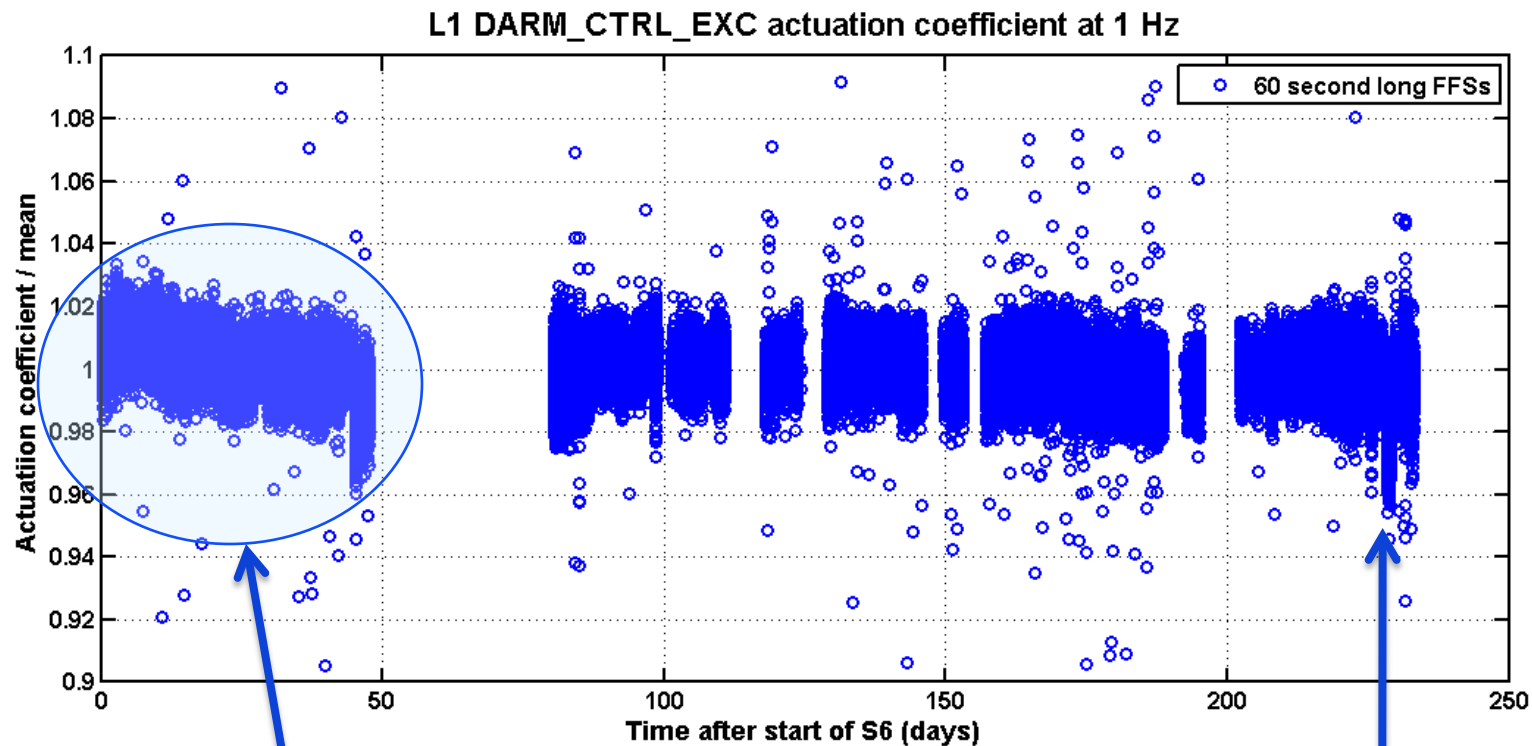
60-sec FFT Science Mode data: H1



Higher S/N
Pcal beam spot
locations changed

Violin notches removed -
response function change

60-sec FFT Science Mode data: L1

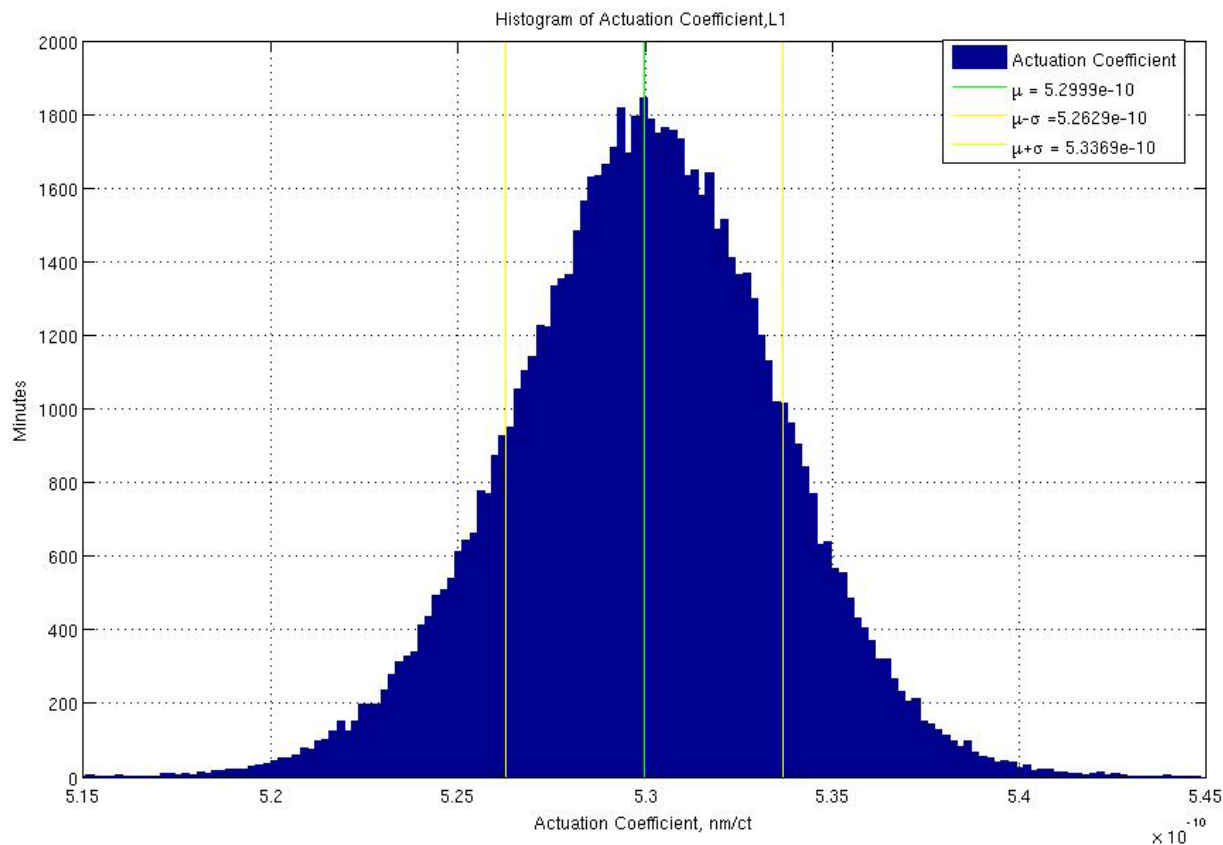


Shorted wire in
Pcal internal
power sensor

Swap of coil
driver

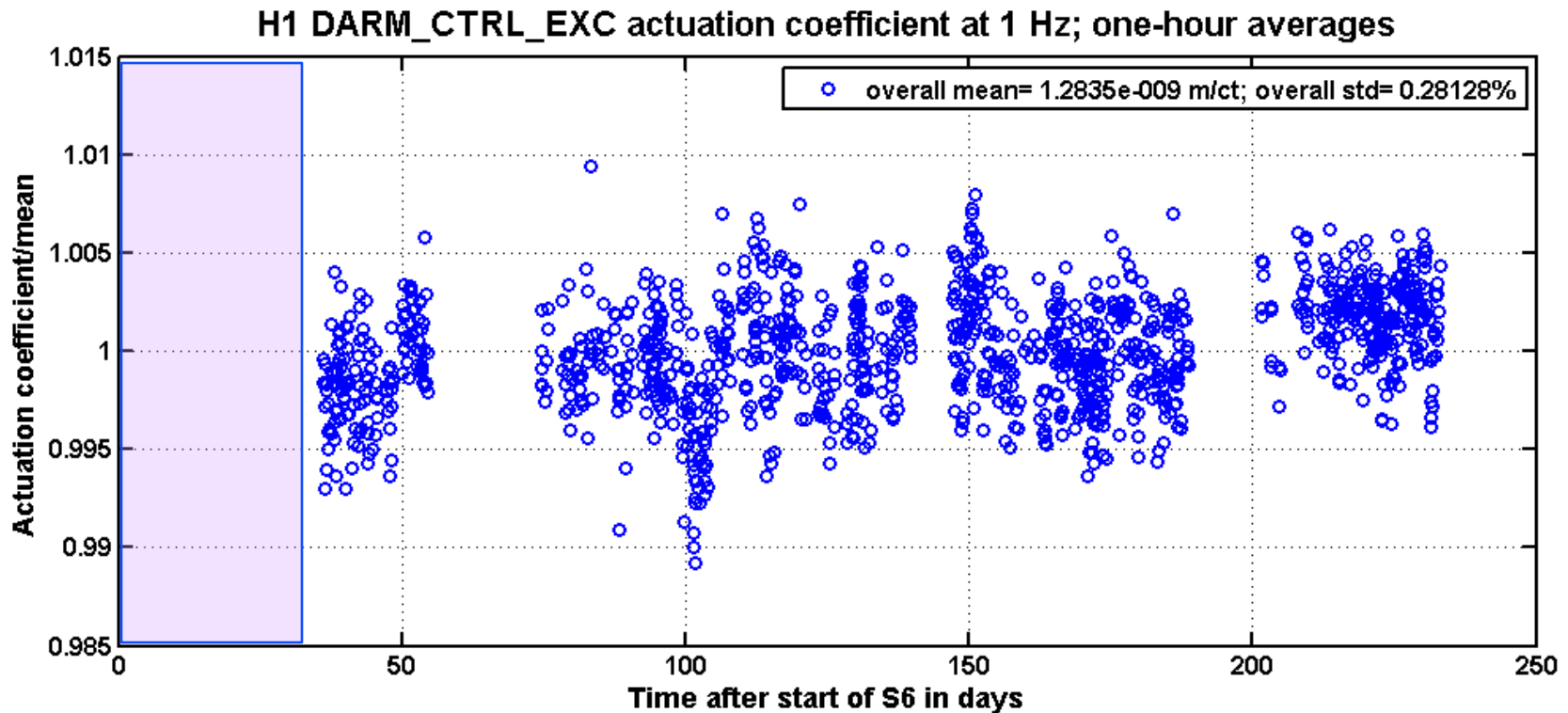
Characterization of data

- Outliers
 - » Glitches
 - » Data errors
- Distribution
 - » Correlated noise due to laser speckle
 - » etc., etc.
- Focus on goal of assessing long-term stability of DARM acutation



One-hour averages – Science Mode: H1

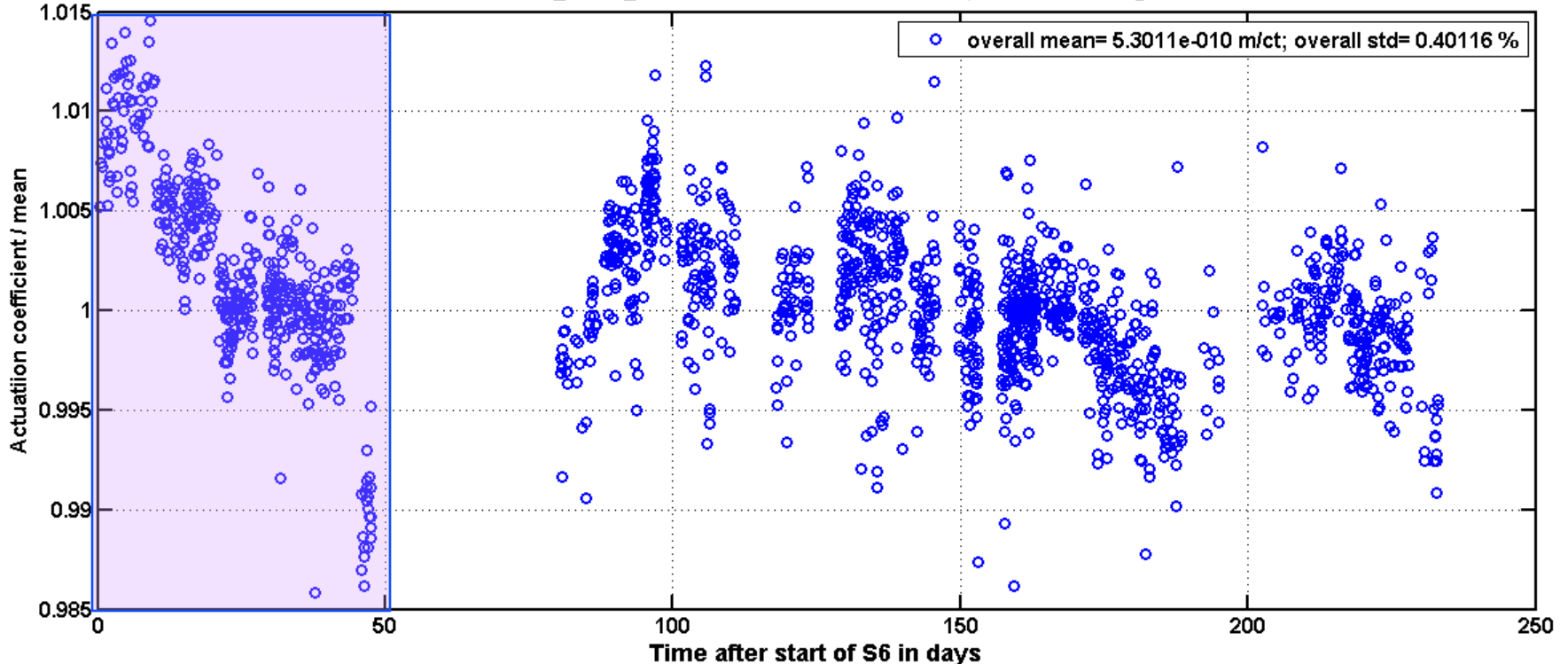
- DARM_CTRL_EXC calibration (> 8 mos of S6)
 - » Mean **1.28 nm/ ct** ; standard deviation **0.28%**



One-hour averages – Science Mode: L1

- DARM_CTRL_EXC calibration (> 8 mos of S6)
 - » Mean **0.53 nm/ ct** ; standard deviation **0.40%**

L1 DARM_CTRL_EXC actuation coefficient at 1 Hz; one-hour averages



Conclusions – Future work

- Long-term stability of actuation
 - » Photon calibrator calibration **and** DARM actuation (coil driver and voice coils) stable within fraction of a percent over ~ 8 months
 - » Continue to monitor during remainder of S6
- Future work:
 - » Use relative phase between DARM_ERR and Pcal readback peaks to investigate phase jumps due to computer reboots, etc.
 - » Generate Pcal data using DMT monitor (R. Grosso)
 - » Drive Pcal with GPS-synched aLIGO timing module for absolute phase reference (with I. Bartos, et al.)
 - » Investigate source of outliers
 - » Investigate if laser speckle is fundamental limit to Pcal precision using integrating spheres (J. Berliner)