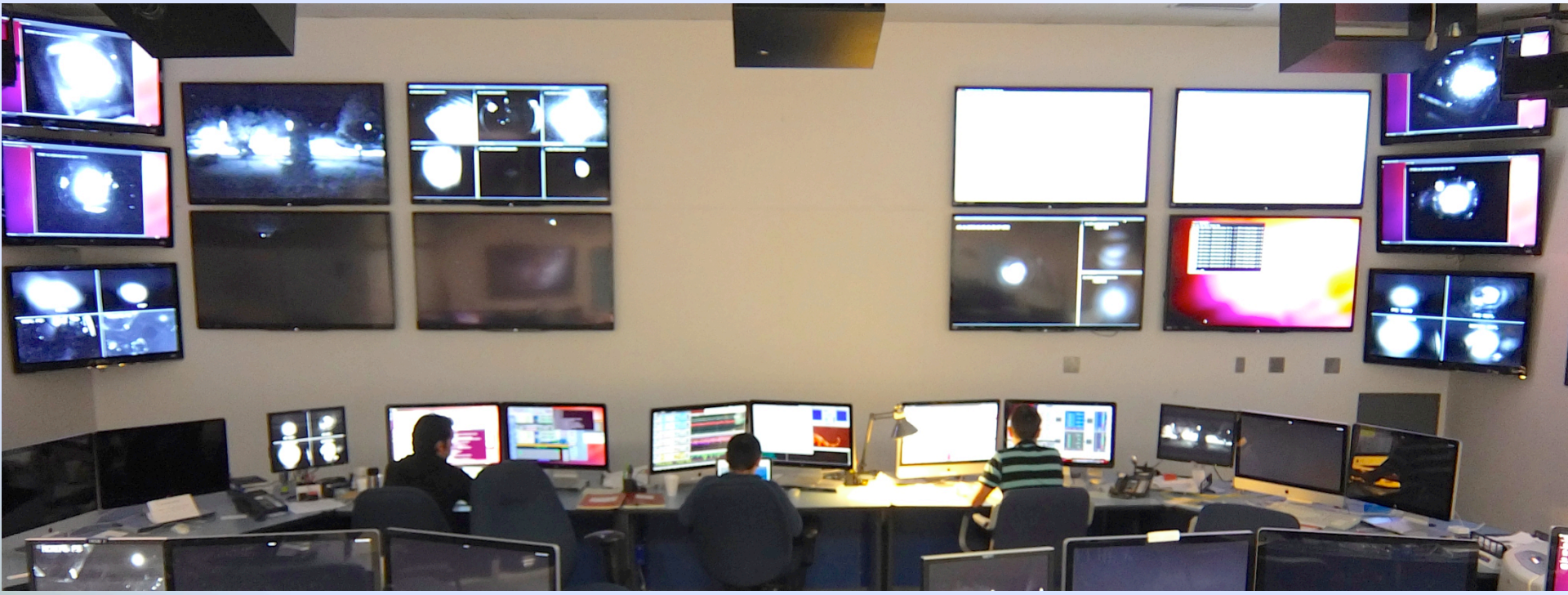
# *Advanced LIGO Commissioning Overview*

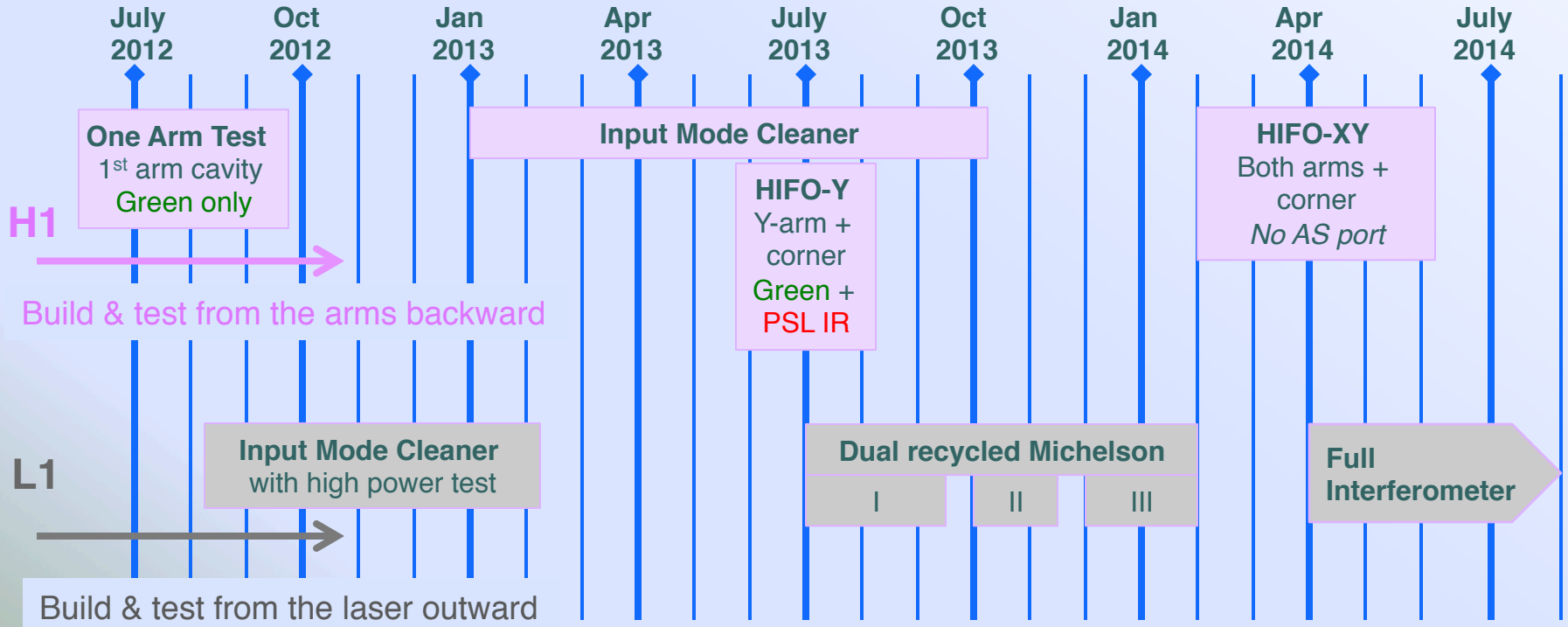


Stanford LVC Meeting, August 27, 2014

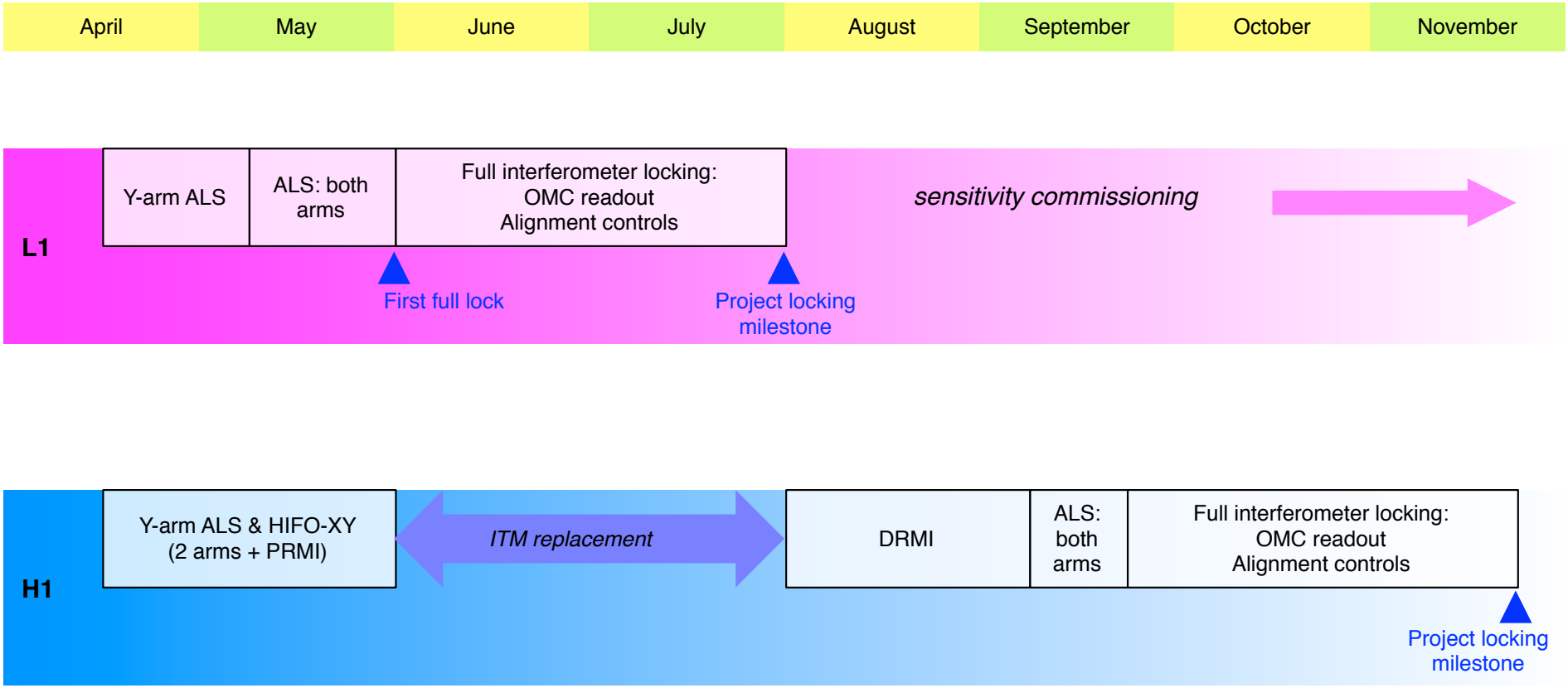
Peter Fritschel

# History of Integrated Testing

- Integrated testing phases interleaved with installation
- Complementary division between LHO and LLO
  - Designed to address biggest areas of risk as soon as possible
  - H1 focused on long arm cavities; L1 worked outward from the vertex

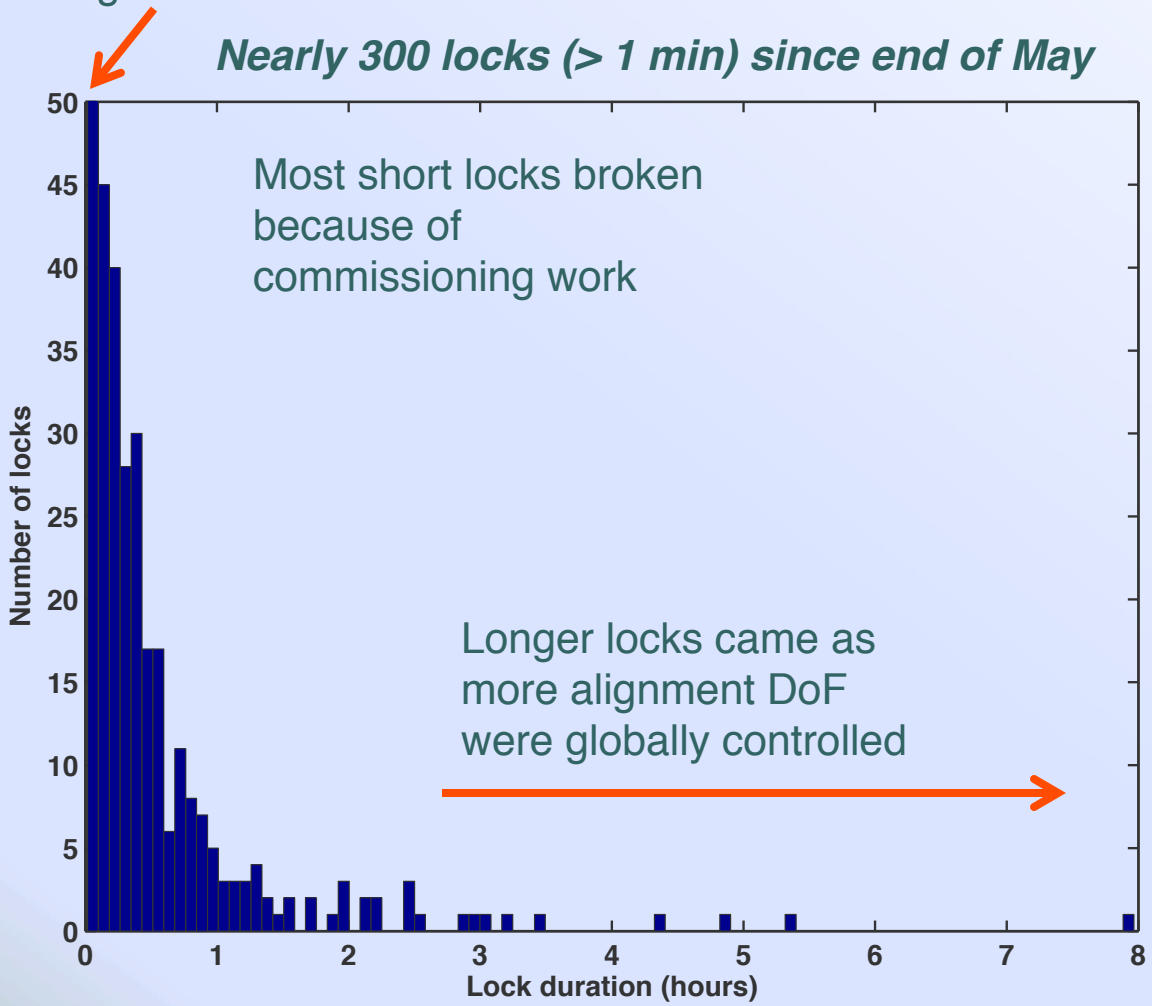


# Current Timeline

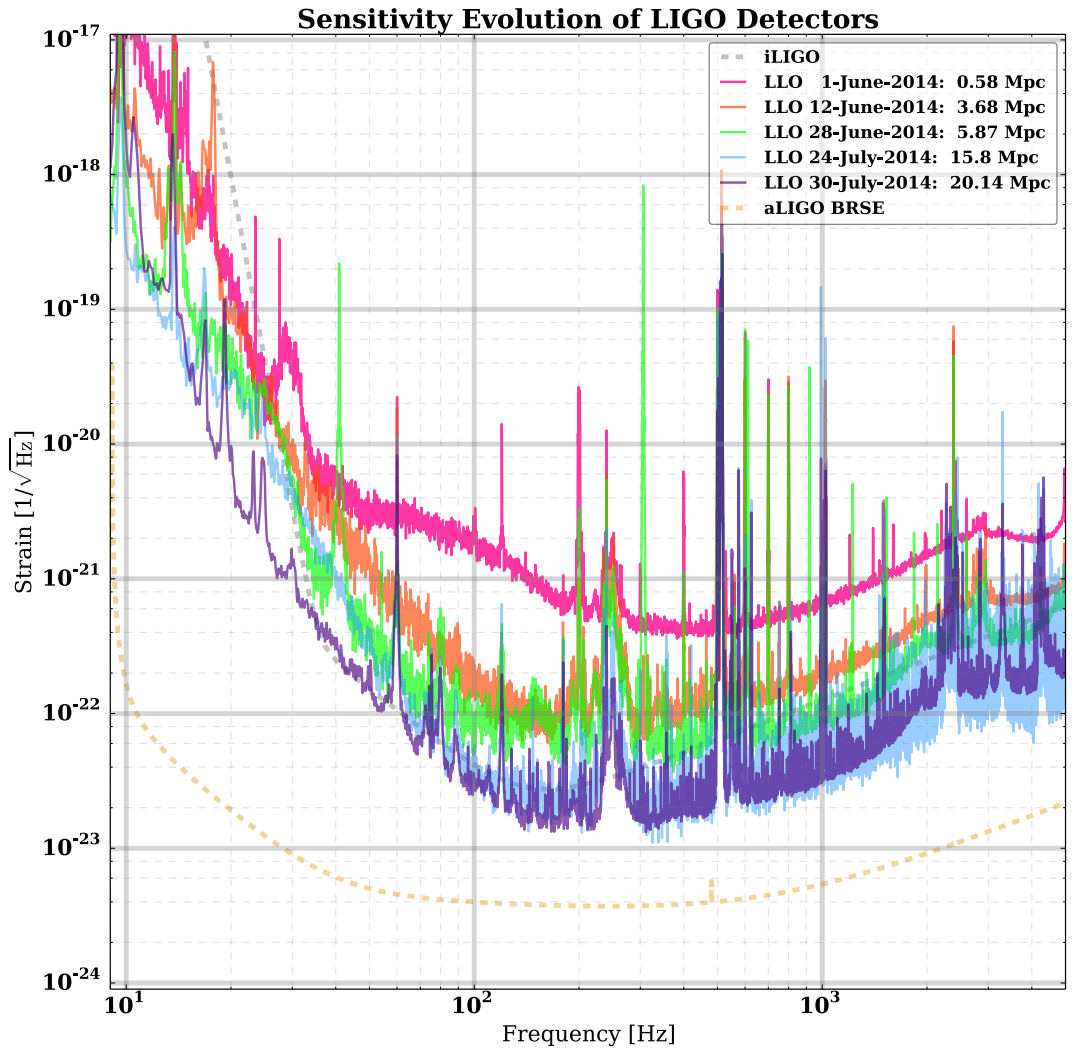


# L1 Locking Statistics

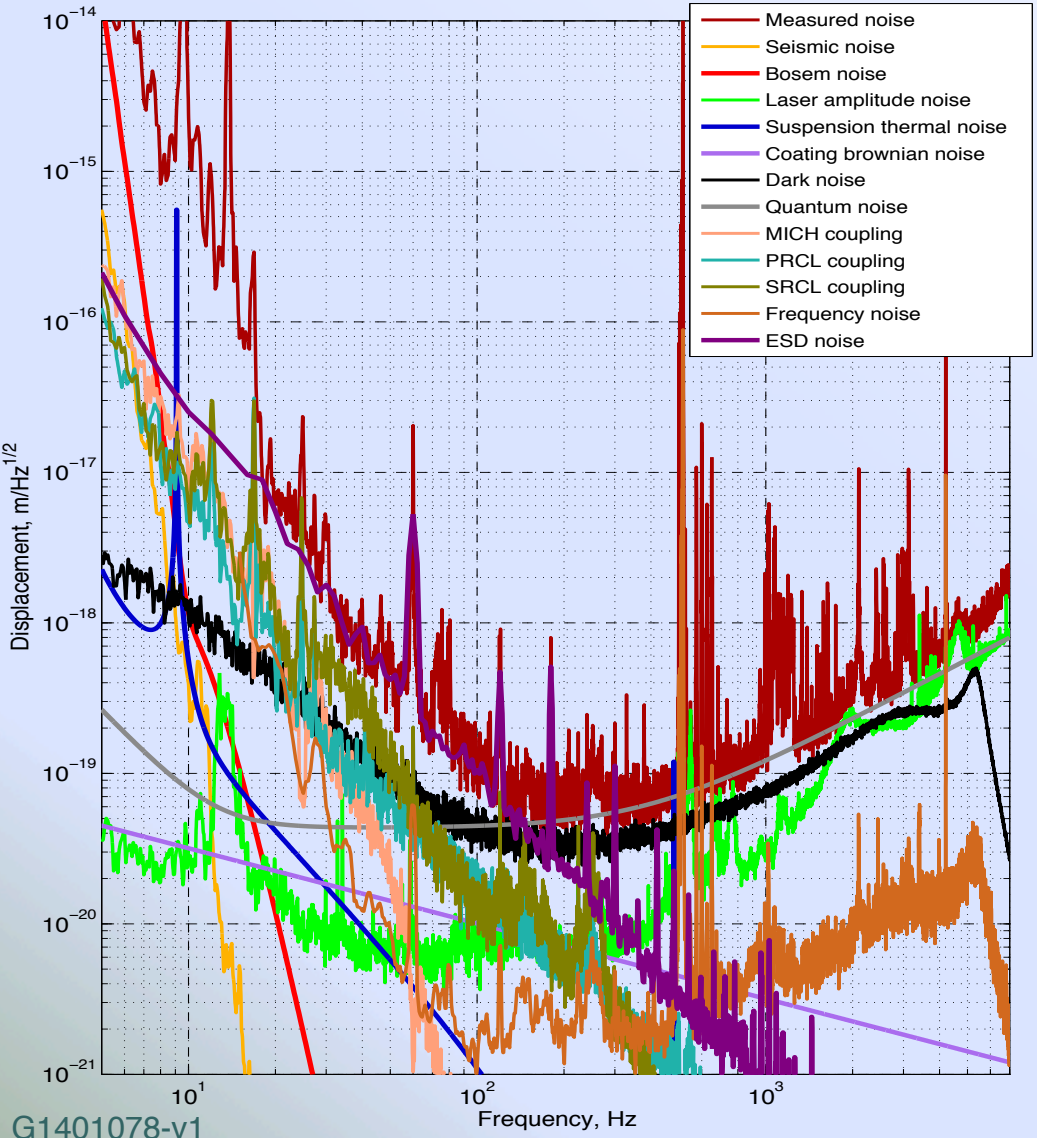
157 locks lasting < 5 min

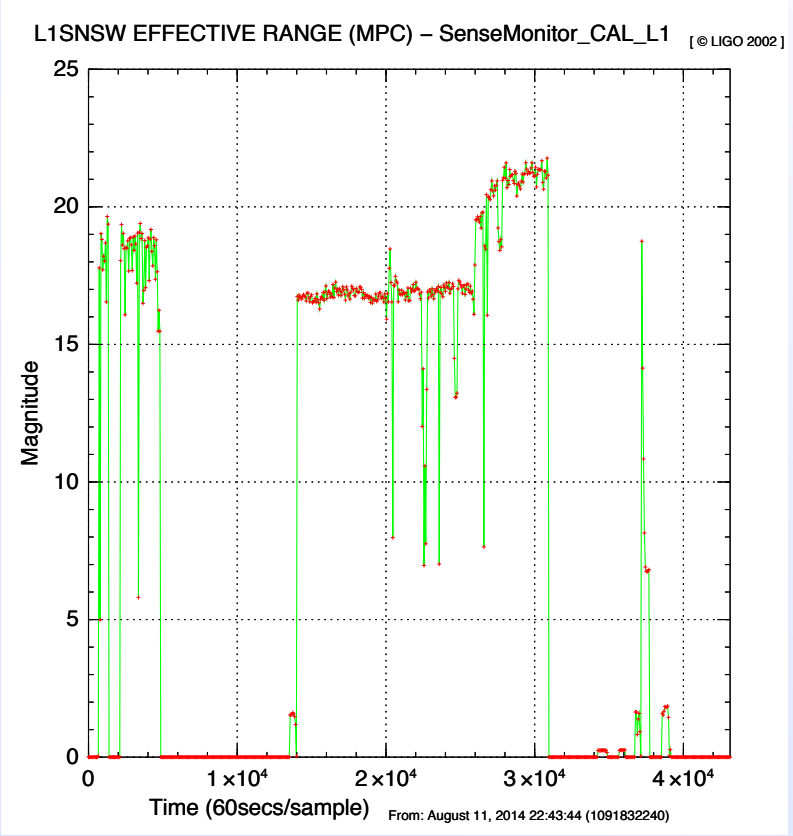


# The First 3 Months



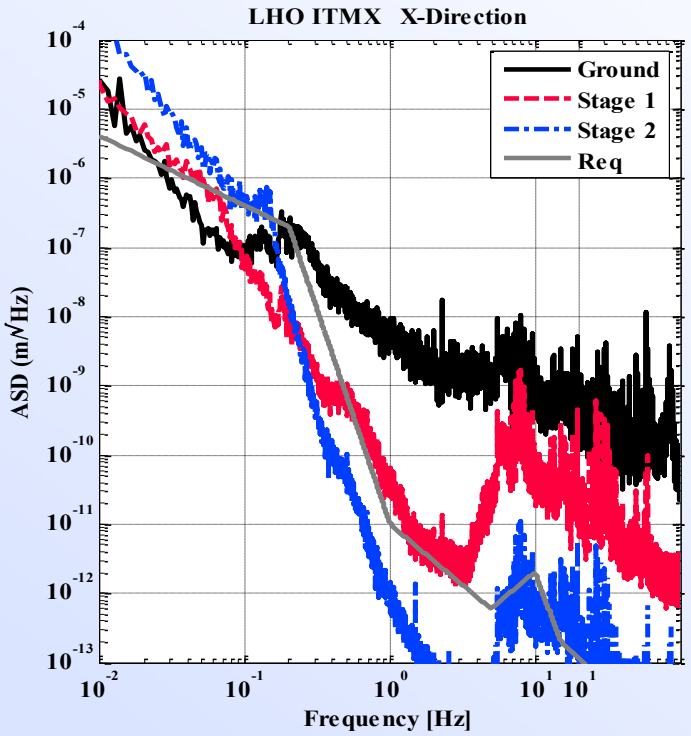
# Latest L1 Noise Budget & Range

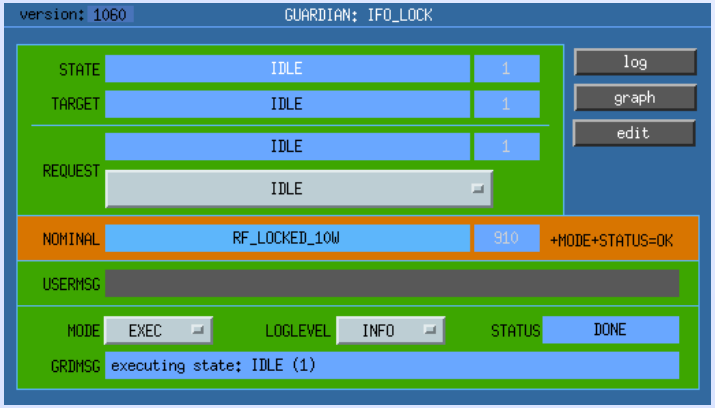


# Subsystem highlights

- Pre-Stabilized Laser (PSL) commissioned
- Input Mode Cleaner (IMC) has been fully commissioned
- All seismic isolators (SEI) work as designed and are fully automated
- All suspensions (SUS) work as designed and are fully automated
- Interferometer locking
  - Following talks by Alexa and Den
- Interferometer Automation
  - Significant progress in implementing the Guardian state control system
  - All subsystems, and full interferometer locking under Guardian control



# Commissioning focus for the first Observational Run

- Target sensitivity
  - Binary neutron star coalescence range of 40-80 Mpc, each detector
  - Important frequency band: 20—300 Hz
  - Input laser power: 25 W
- Nominal duration
  - 3 months
- Run start
  - Some time in 2015, perhaps mid-2015

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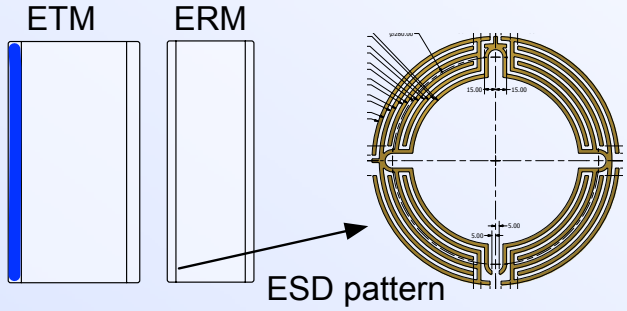
Mysteries, unexpected problems, challenges:

*issues we likely need to address before the first science run*

# Electro-static charging & actuation

- Each End Test Mass has electro-static actuation, via electrodes on the adjacent reaction mass

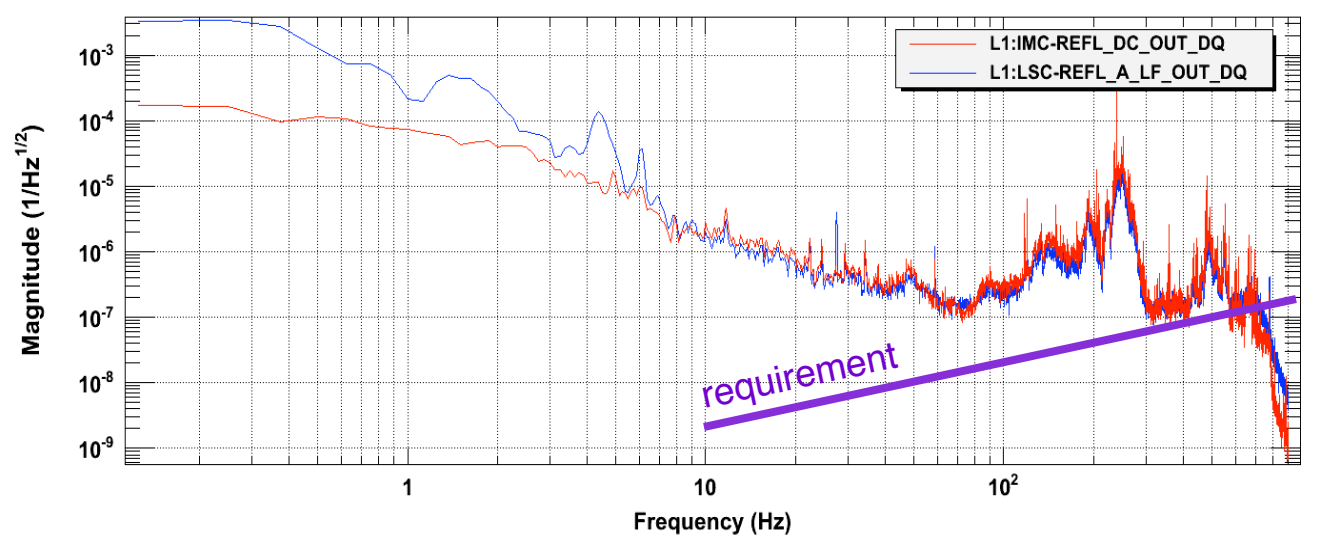
$$Force \propto (V_{bias} - V_{signal})^2$$




- Measurements of force vs bias indicates there is static charge present, equivalent to 10's to several 100's of volts
  - 'static' charge will fluctuate and create noise
  - Charge is not uniform; makes it hard to lower the bias for low noise
- Work in progress: source of charging not clear, nor if it is constant
  - First tests of a 'de-ionizer', connected to ETM chamber
  - Procedure for discharging optic at installation has been vastly improved
- Noise from ESD needs to be reduced: need factor of 3-5x for now
  - Via bias reduction, or lower noise signal path, or both

# Laser intensity noise & coupling

- Laser intensity stabilization is done in 2 stages
  - Second stage detects a sample of the IMC transmitted light in vacuum, to reduce vibration related sensing noise
  - Initial versions of the in-vacuum sensor had several design & assembly problems; essentially non-functional
  - A new version that incorporates several design improvements has been made and installed in H1: testing is imminent

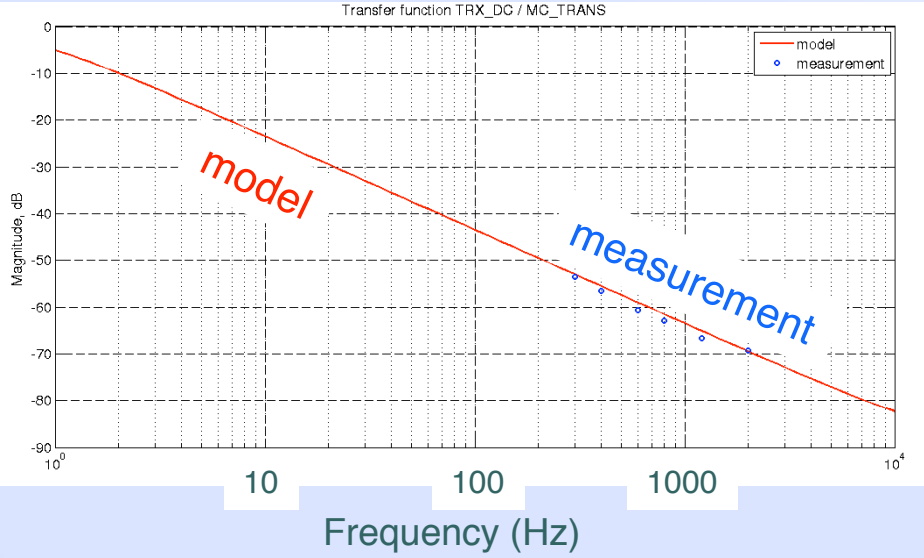



Typical ISS performance on L1, with temporary, in-air 2nd stage detector

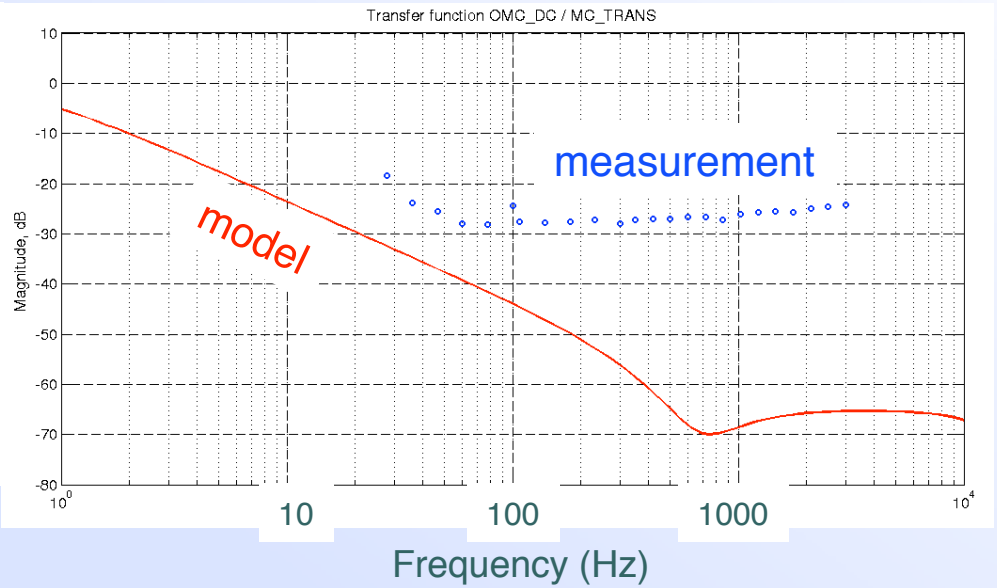
The 250 Hz peak couples through to DARM

# Intensity noise coupling

*Transfer function to arm cavity shows expected filtering:*



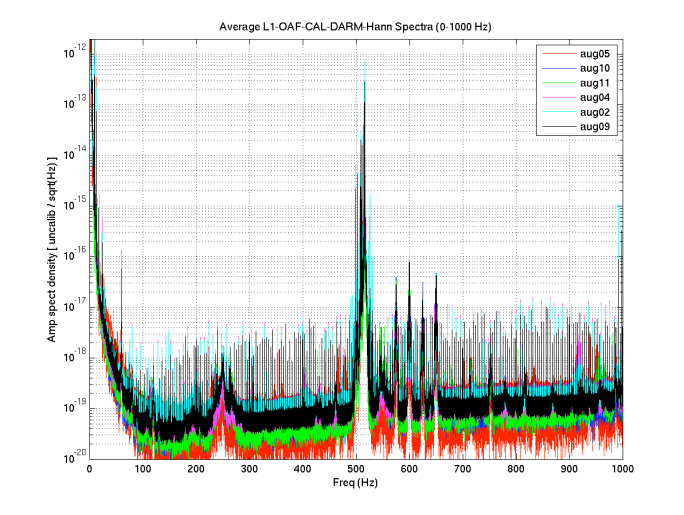

*Transfer function to OMC readout does not …*

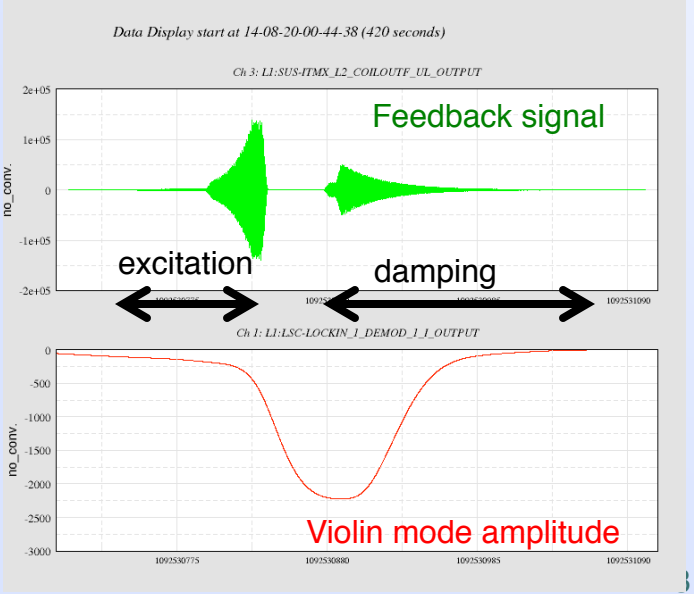



- Work in progress trying to understand this coupling, through measurements and modeling
  - Higher order modes? Offsets? RF sidebands?

# Suspension violin modes

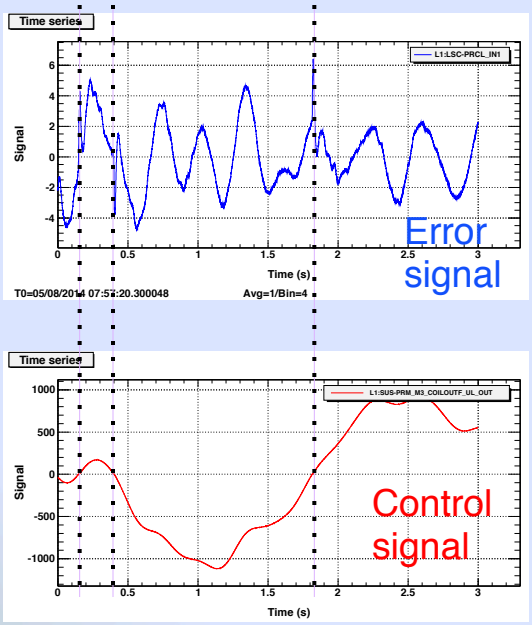
- Test mass suspension violin modes, at 500 Hz, are excited several orders of magnitude above thermal
- We do not understand why they are vibrating so much
- Prevents us from engaging full whitening on the GW readout channels: excess ADC noise
- Need to actively damp the modes, using interferometer signal to feed back to the quad penultimate stages
  - Should be doable, but it is tricky: 16 very high Q modes in a narrow frequency range
  - Some progress recently on L1 with the DRMI



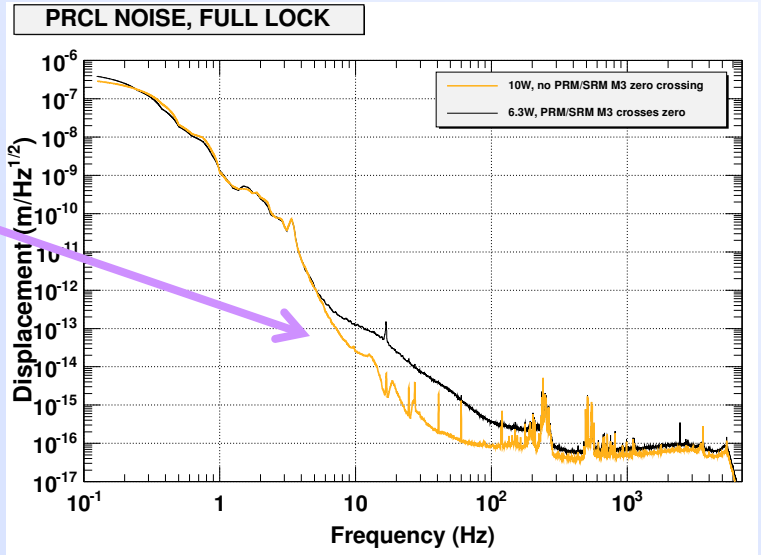
# Glitches from digital-to-analog converters

- DAC transitions are accompanied by a glitch
  - Inevitable in all DACs (12 nV-sec spec for our DACs)
  - Largest at the zero-crossing (all bits flip), next largest at ¼ & ¾ of full scale
- Observed to create low frequency noise in the recycling cavity signals




Noise mechanism not completely clear

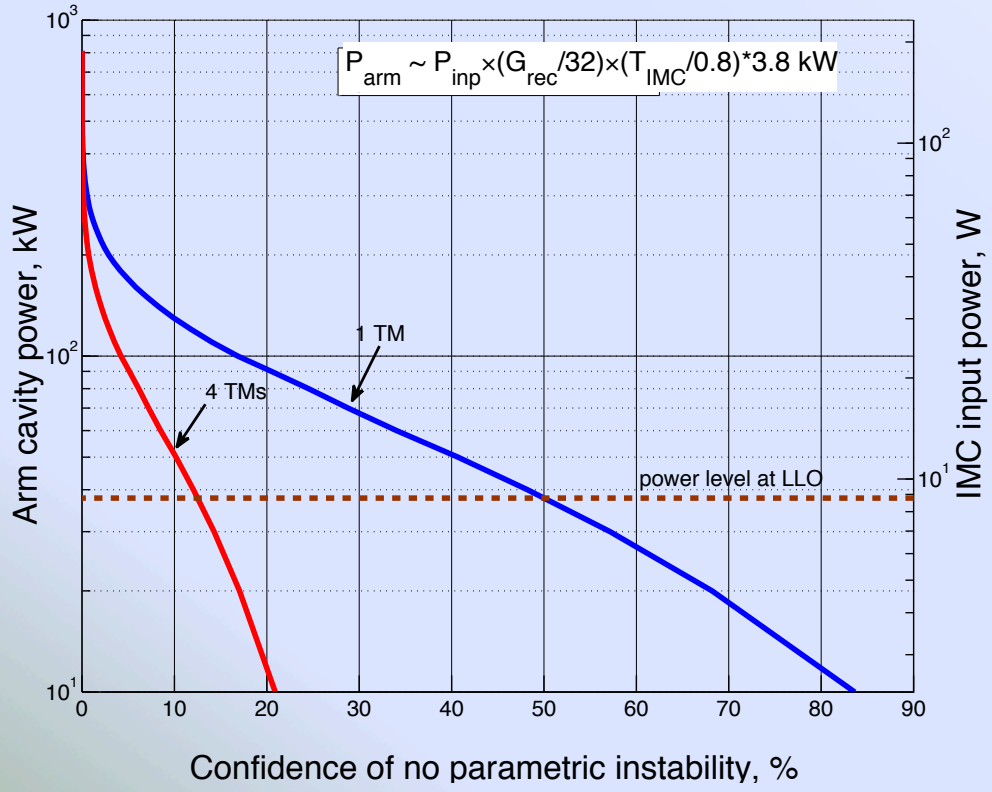
Solutions:
- Offsets on control signals
- Low pass filters after DAC

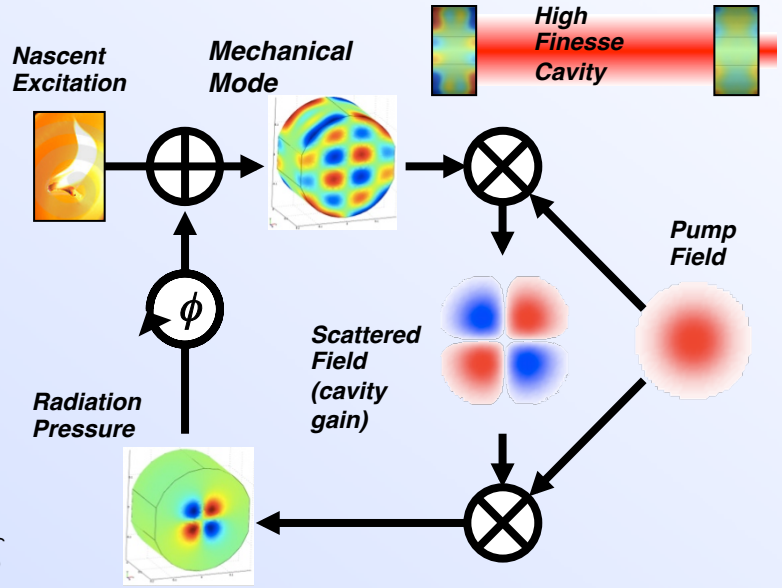



- Also an issue for ESD feedback, at ¾ range transition

# Parametric Instabilities

Combination of high stored optical power and low mechanical loss could cause an instability

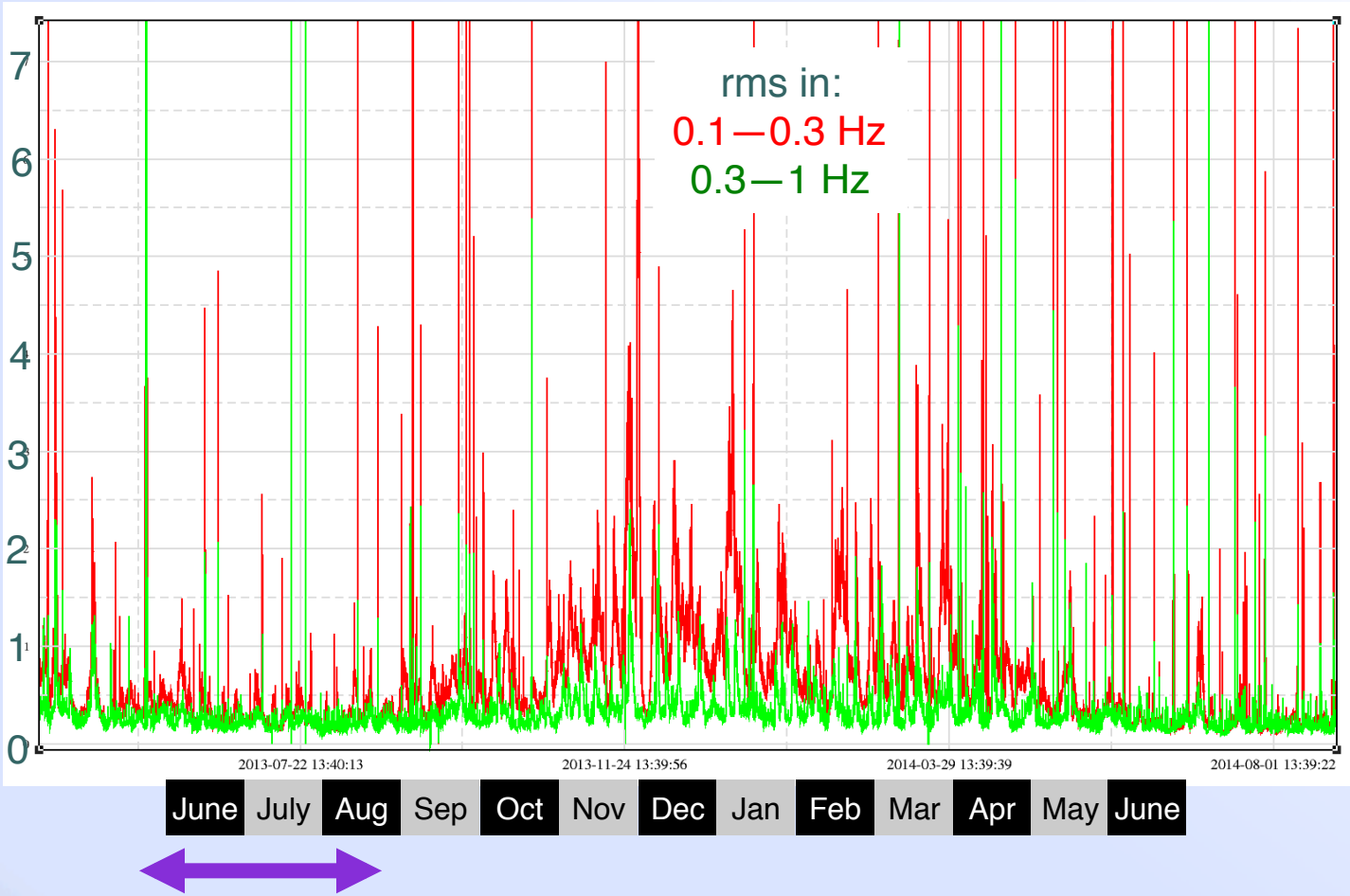



- Latest analysis (S Gras) suggests we are more prone to PI than we thought
  - MC simulation with distribution of RoC's and acoustic mode frequencies of test masses
- Start to look for risky modes even before they become unstable (UWA idea)

# Seasonal variability of ground motion

*LLO ground motion over 500 days*




So far, commissioning has been during periods of low microseism

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# Impact of higher ground motion

- Arm Length Stabilization could suffer
  - Arm cavity finesse at 532 nm is much lower than desired:
    - ETMs have too large a transmission at 532 nm
    - Finesse: 5-10 (actual) vs. 100 (desired)
  - Makes the cavity locking point much more sensitive to alignment and alignment fluctuations
- Replacing the ETMs could be the best solution
  - ETMs now coming out of LMA have the right 532 nm transmission
  - Downside would  be a 2 month hit for replacement

# In Conclusion

- Initial commissioning has progressed quickly
  - The only significant delay was due to the green coating issue.
- Next up: get H1 caught up with L1
  - H1 will test some ideas for improving the locking scheme
  - H1 has the improved second stage detector for the laser intensity stabilization in place
- L1 has reached the aLIGO Project milestone for integration: 2 hour lock
  - As a result, non-LIGO Lab people can now contribute to L1 commissioning, without having to set up a contract with aLIGO