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# Lessons Learned from Commissioning of Advanced Detectors

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# Lessons

- Good QA & experience lead to quick progress
- Locking
  - Arm Length Stabilization (ALS) is working
  - Dual Recycled Michelson Locking (DRMI) is working (3f technique)
  - Alignment stability is important with low frequency seismic systems
- Low frequency seismic isolation systems at Virgo
- Squeezing at GEO
- Underground and cryogenic at KAGRA
- Low finesse cavities causes alignment offset problems
- High Q resonances and uncontrolled DOFs
- Thermal adjustments not needed at 20W input
- ESD charging Issues
- Parametric Instabilities

# Progress


aLIGO Commissioning Progress
Inspiral Range, Mpc
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
Days since start of commissioning
LLO
LHO
O1-lower
O1-upper

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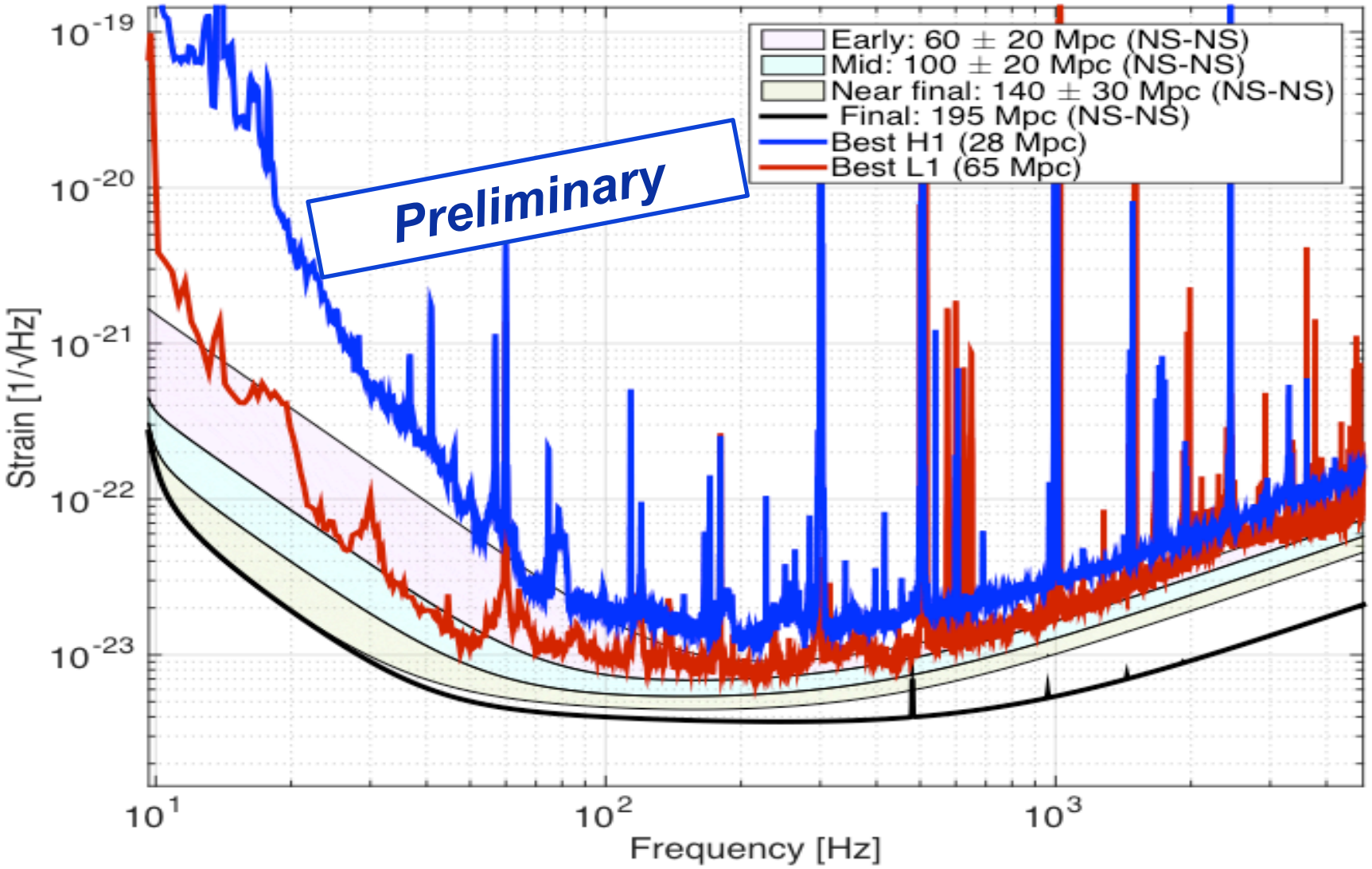
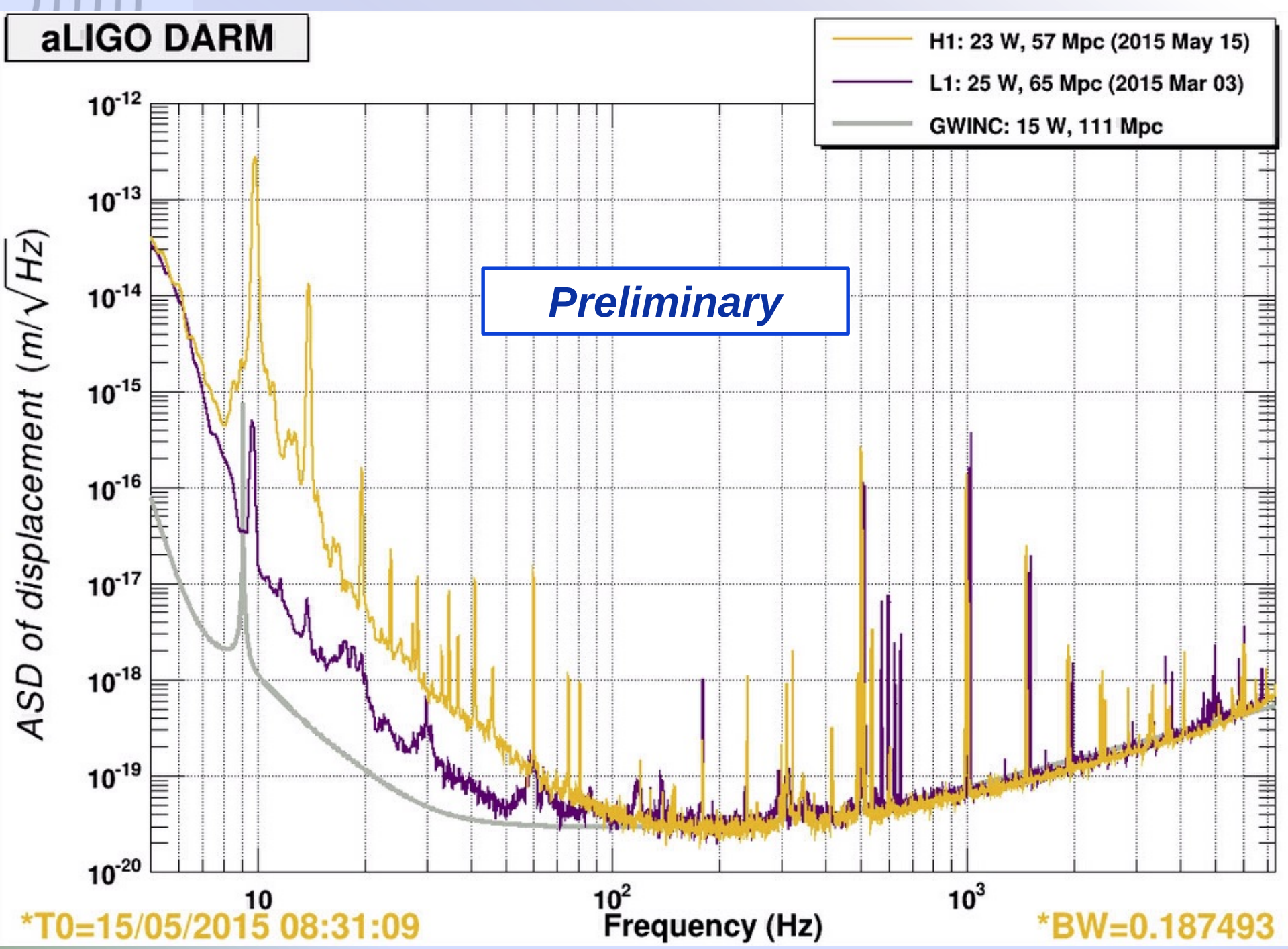
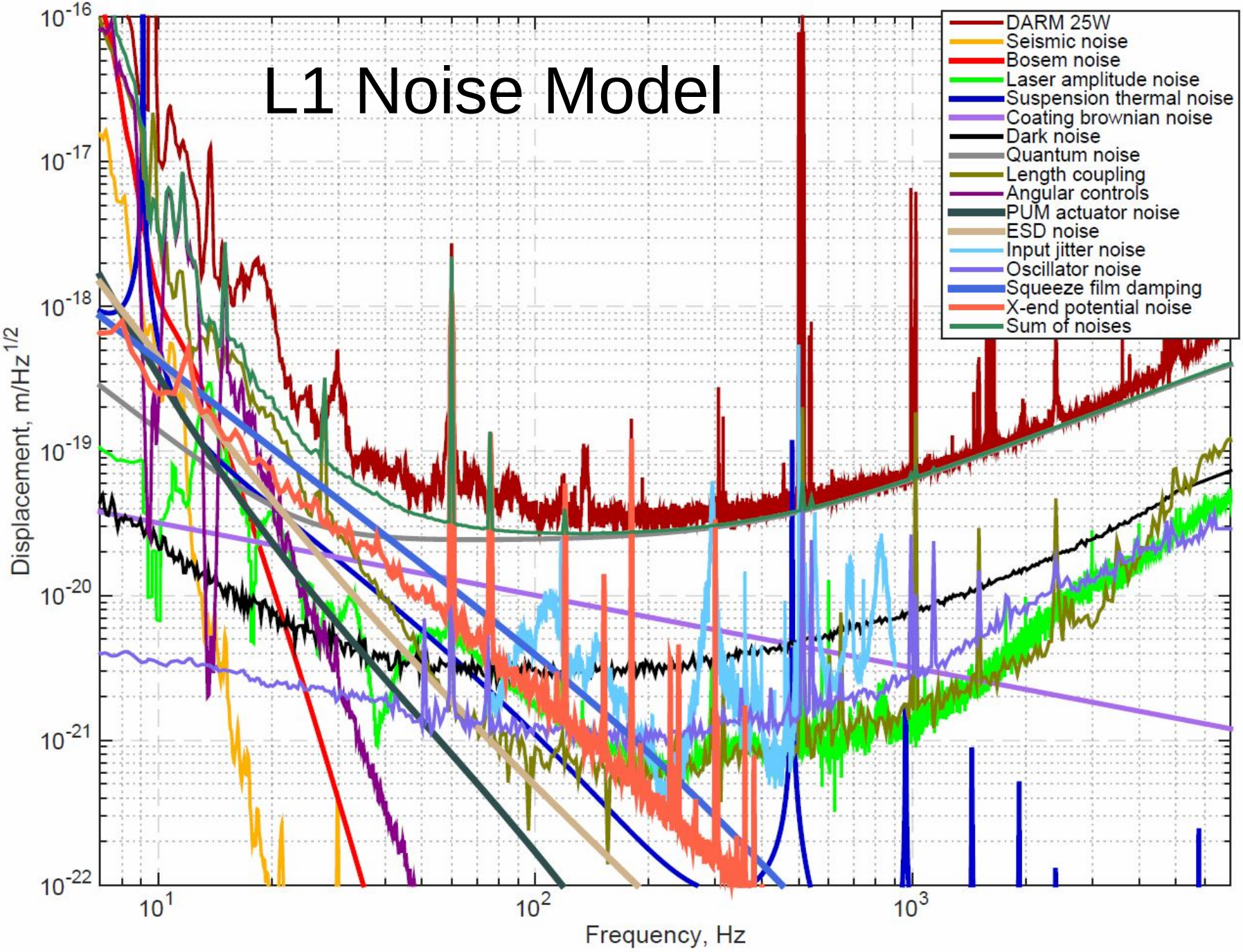
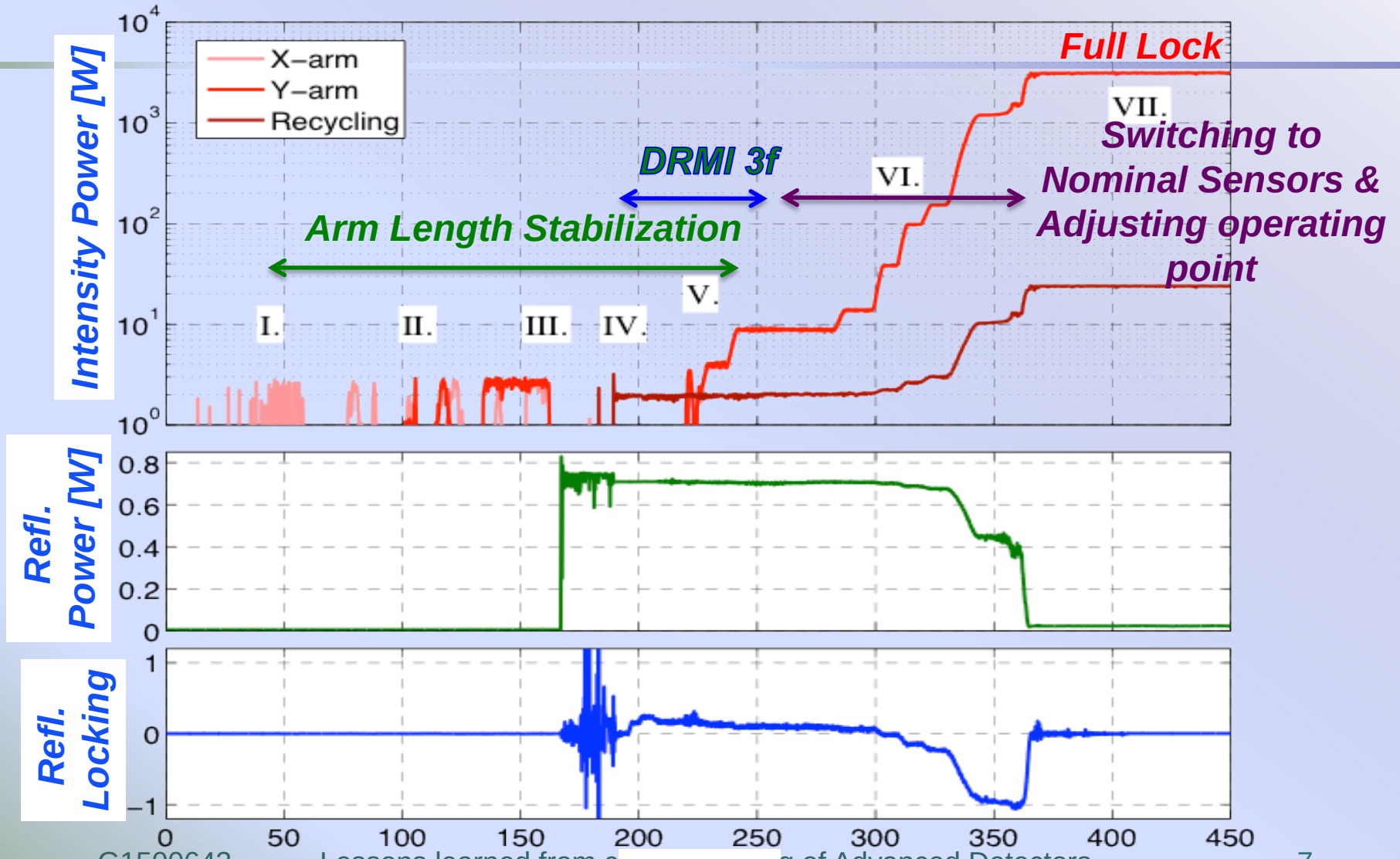
# Sensitivity




aLIGO DARM
H1: 23 W, 57 Mpc (2015 May 15)
L1: 25 W, 65 Mpc (2015 Mar 03)
GWINC: 15 W, 111 Mpc
Preliminary
ASD of displacement (m/√Hz)
10^-12
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20
10
10^2
10^3
Frequency (Hz)
*T0=15/05/2015 08:31:09
*BW=0.187493


L1 Noise Model
DARM 25W
Seismic noise
Bosem noise
Laser amplitude noise
Suspension thermal noise
Coating brownian noise
Dark noise
Quantum noise
Length coupling
Angular controls
PUM actuator noise
ESD noise
Input jitter noise
Oscillator noise
Squeeze film damping
X-end potential noise
Sum of noises
Displacement, m/Hz^1/2
Frequency, Hz
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
10^1
10^2
10^3

# Locking

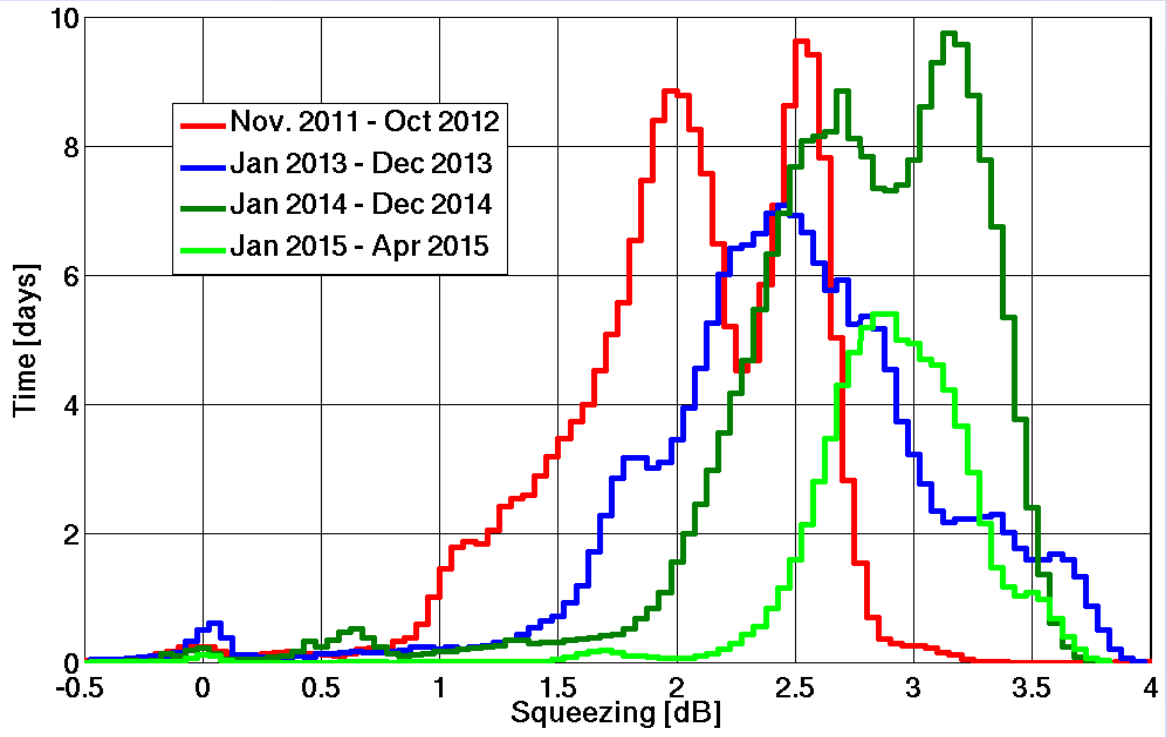




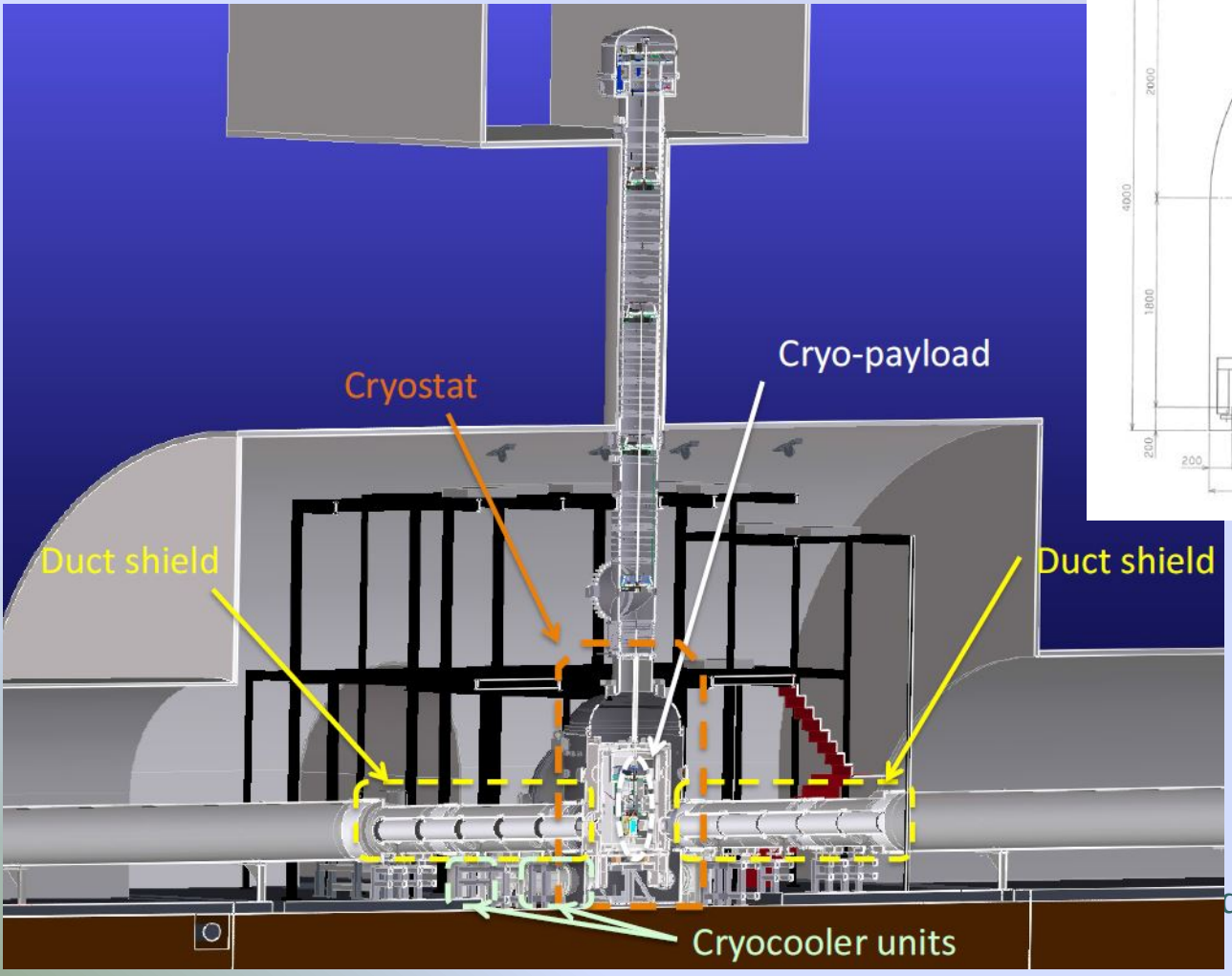

A.Staley et al., Class. Quantum Grav. 31,24 (2014)

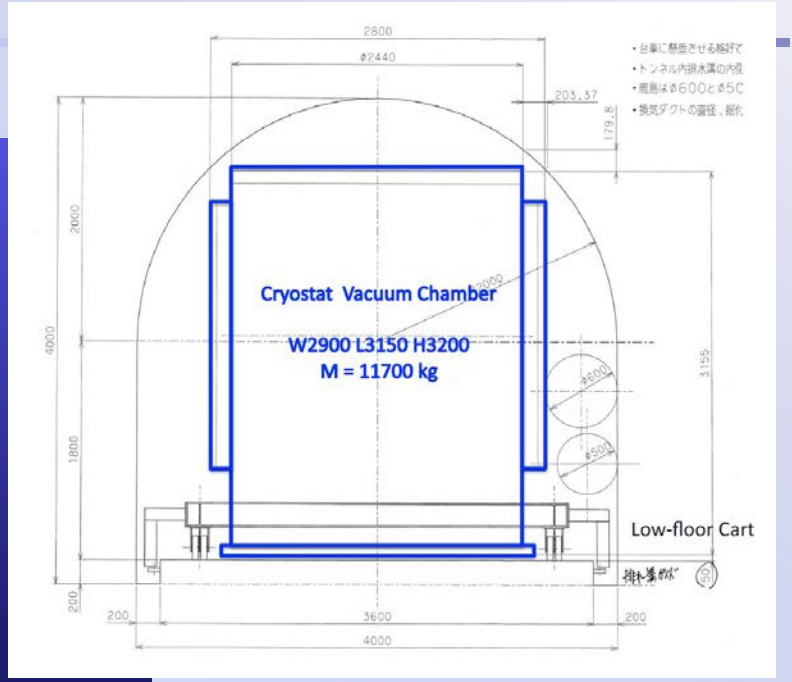
# Squeezing at GEO

- Squeezing long term stable around 3dB
- After researching phase control and auto-alignment now focus on losses
- Data taking runs well, fully automated locking

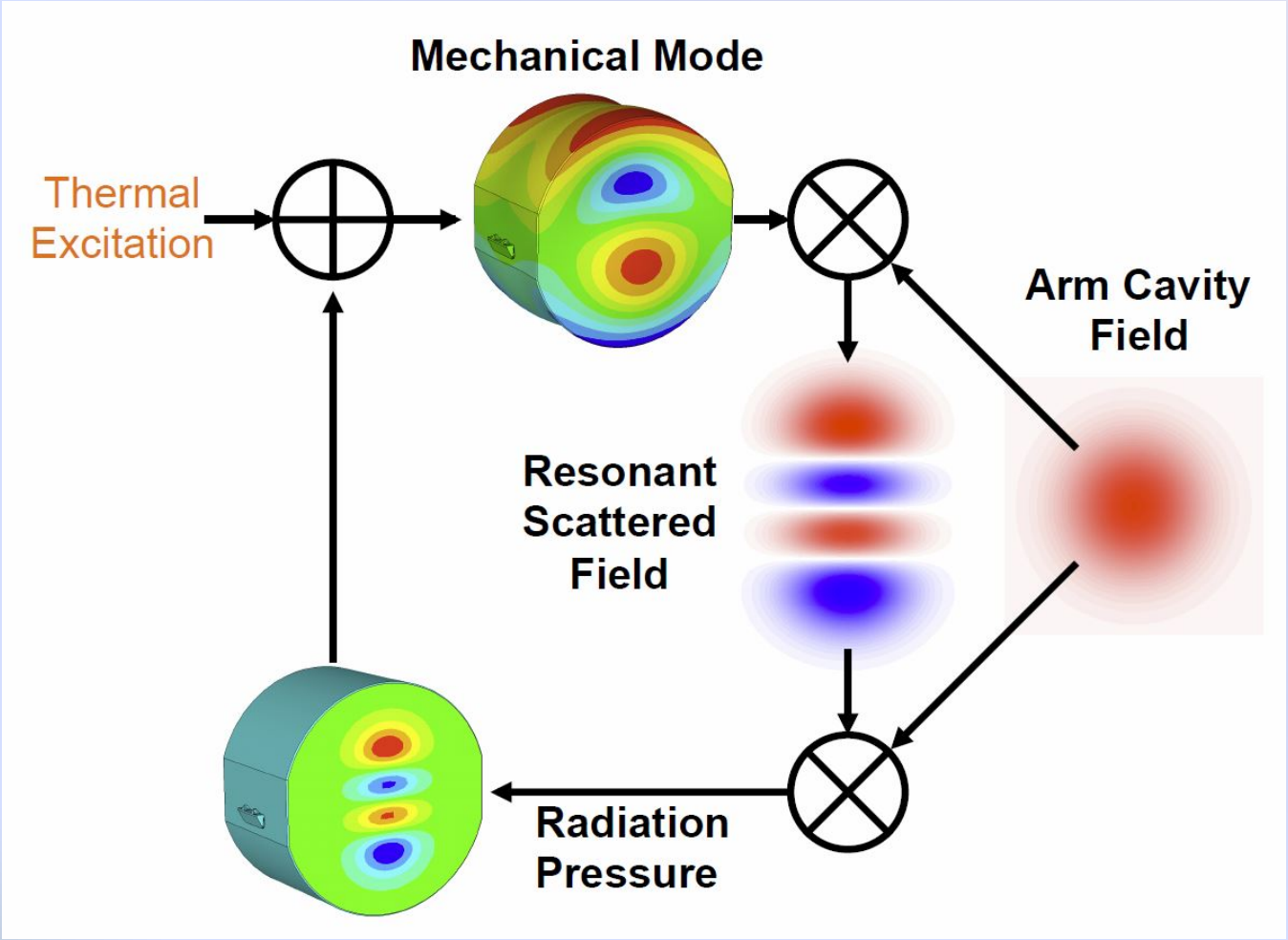


# Underground & Cryogenic at KAGRA



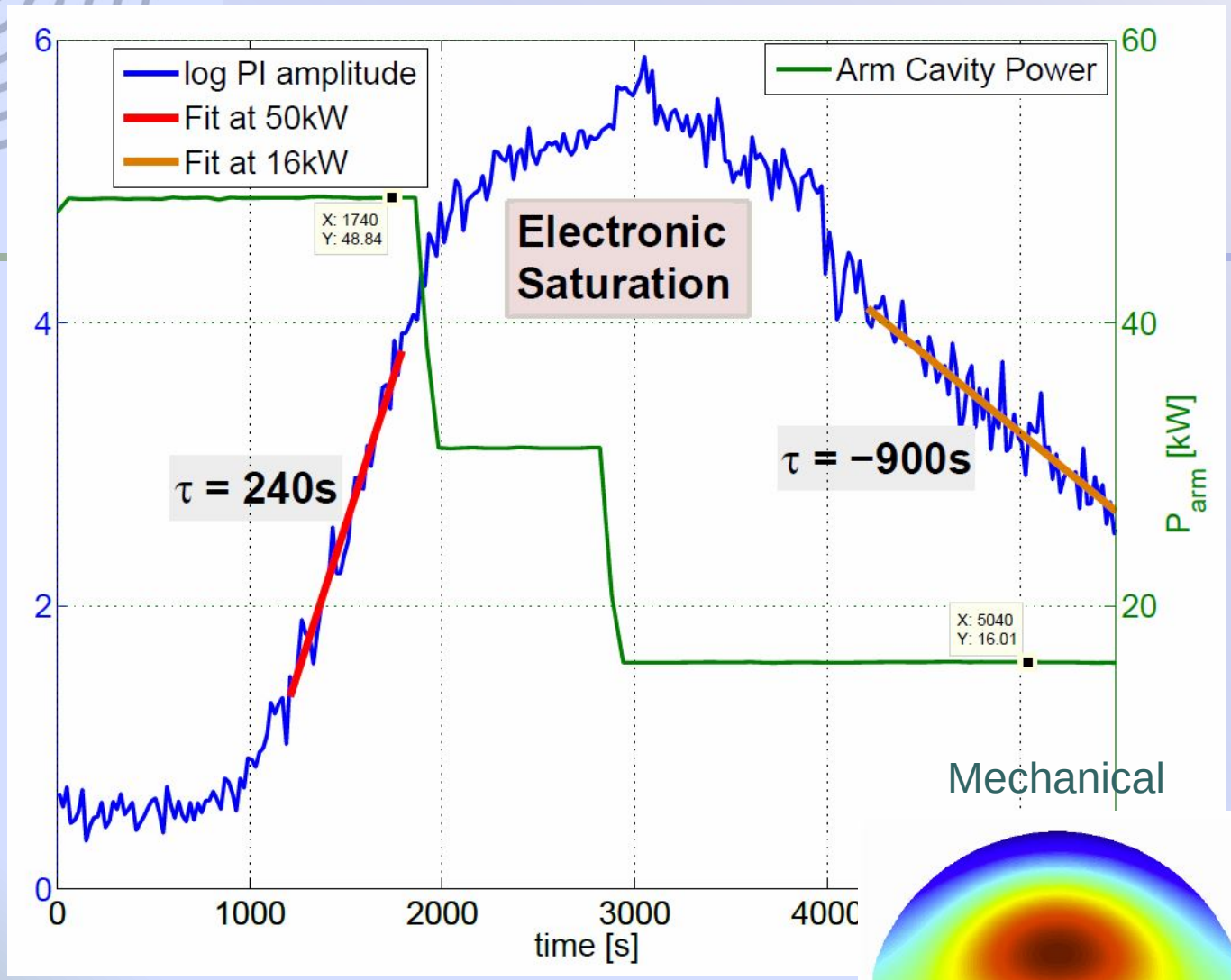
# Parametric Instabilities





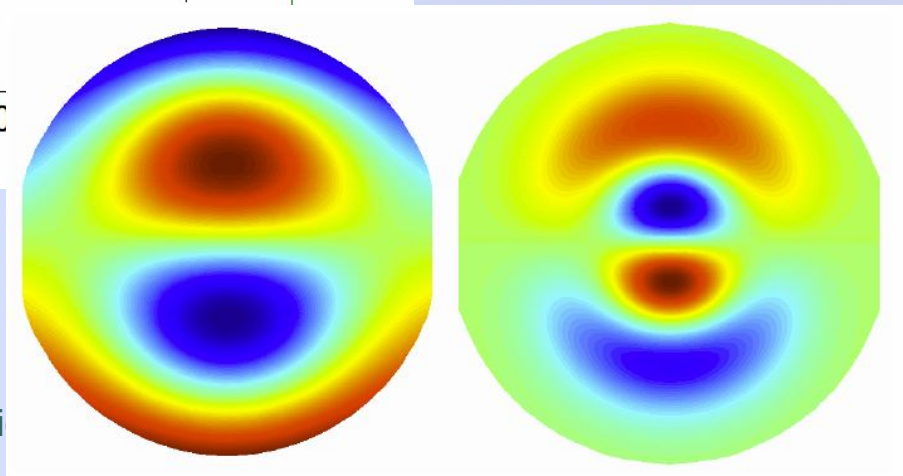

Evans et al., Phys. Rev. Lett. 114, 161102 (2015)

# Parametric Instabilities (3)

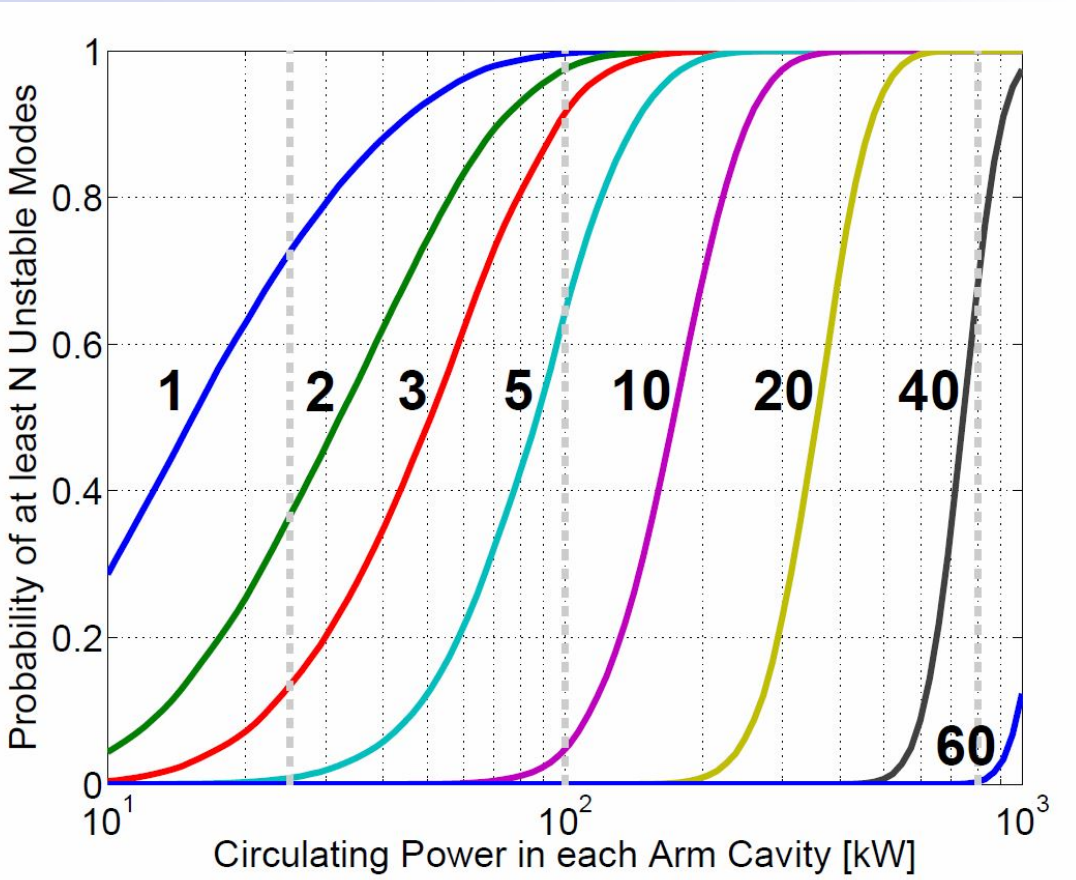


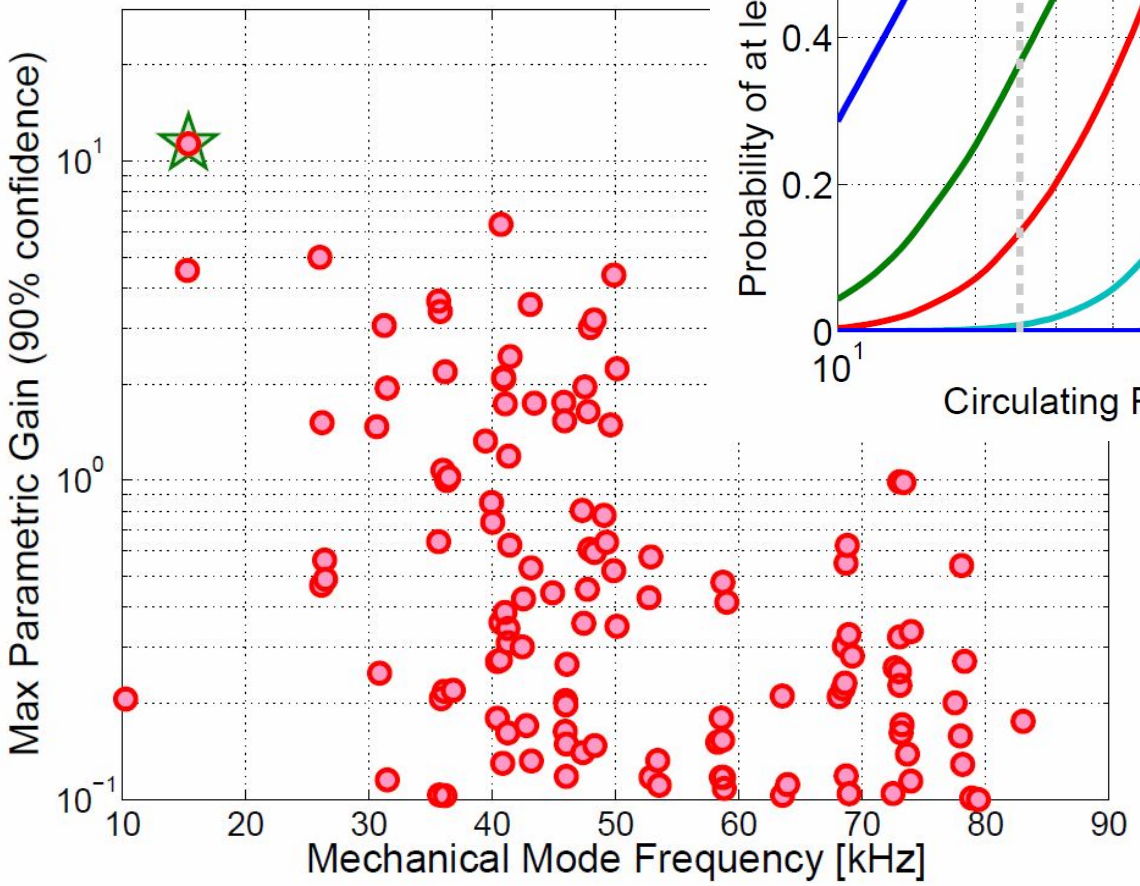

Mechanical

Optical



# Parametric Instabilities (2)

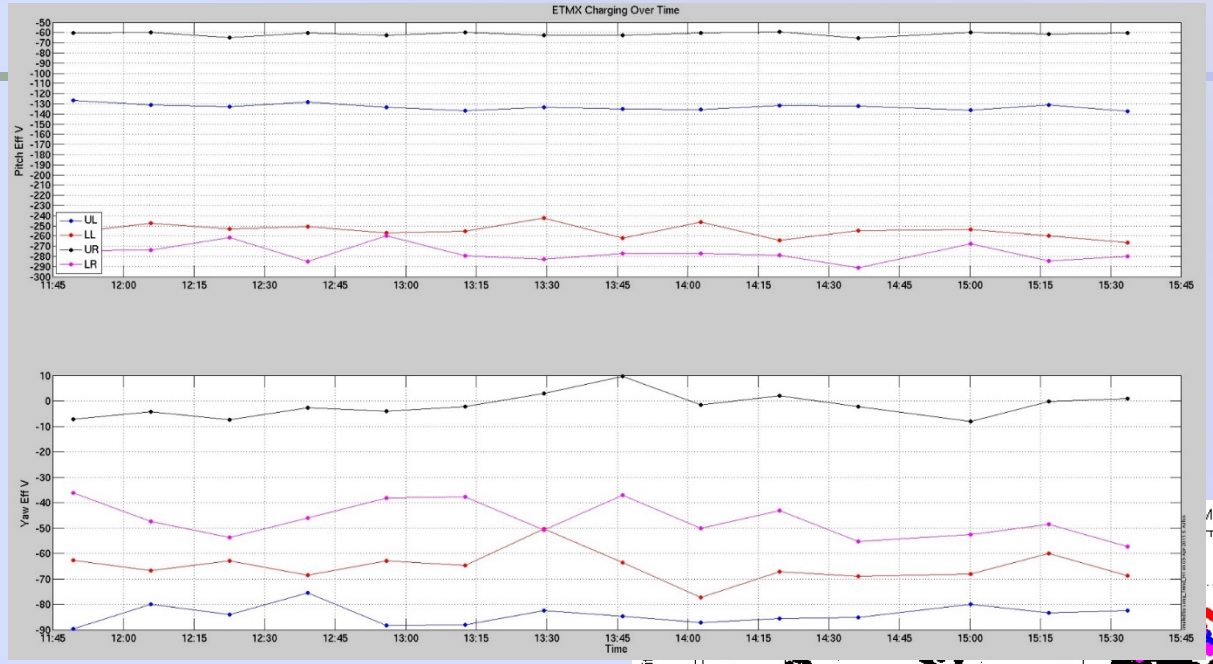



Number of Unstable Modes Depends on ROC

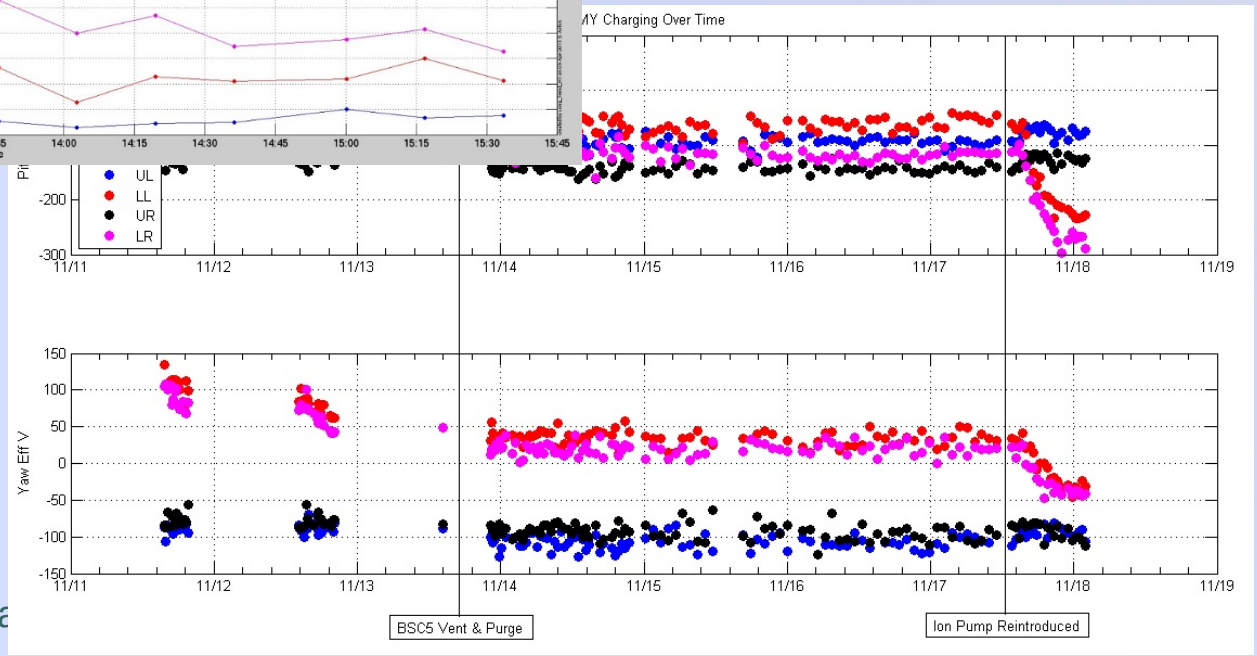
Thermal control of ROC can work for small N

# Electro Static Drive




250V

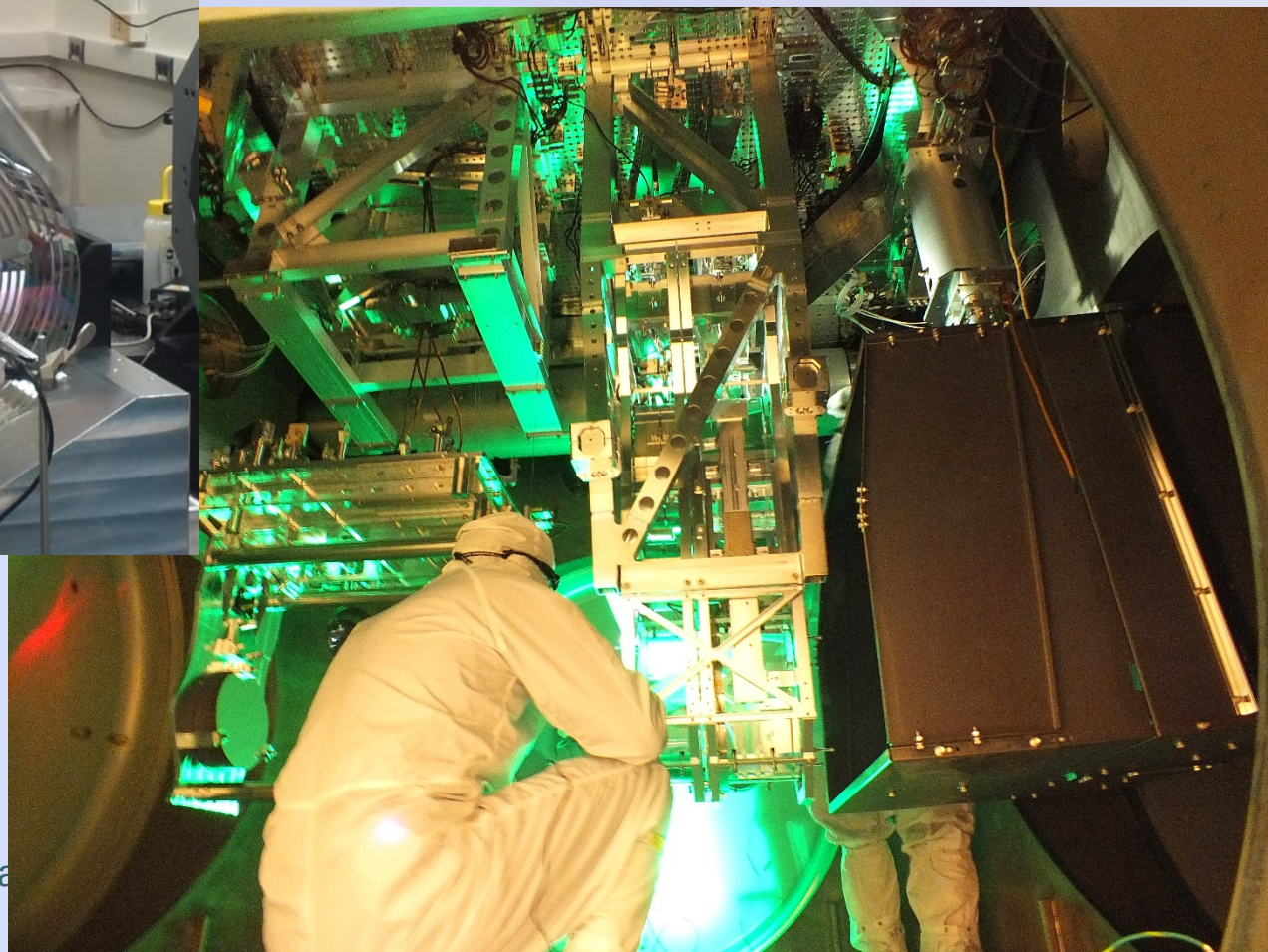
Recharging



# Electro Static Drive (2)

- Charge is a problem, can be 10s (even >100) of Volts
  - First contact leaves a charge behind
  - Field lines must terminate somewhere (e.g. ring heater)
  - Drive strength depends on charge, adds a linear term
  - Charge is not uniform
- Injecting ions into the vacuum did not fix the problem
  - Hard to reach the back surface
- Recharging does occur
  - Ion pump main culprit, needs to be shielded or removed
- Test masses need to be discharged before pumping
  - Seems to stay discharged without an ion pump

# Electro Static Drive (4)



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# Summary

- Sensitivity of initial detectors surpassed quickly
- Robust locking achieved
- Squeezing is now ready and robust (GEO)
- Parametric instabilities are real; need to be dealt with
- Test mass charge is a problem
  - Discharging effort underway
- What's left?
  - High power operations: thermal control, PI, alignment instability
  - Low frequency noise hunting & controls optimization
  - Make the seismic system work during bad weather
  - Damping of high Q modes
  - Backscatter mitigation