Initial Results from the LIGO Newtonian Calibrator

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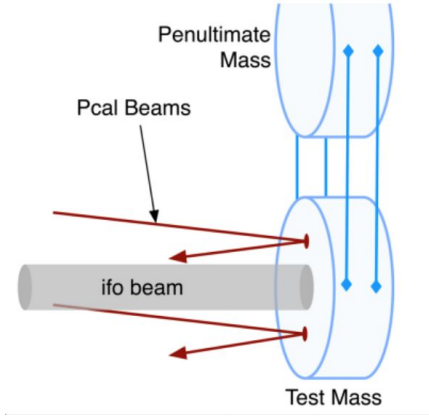
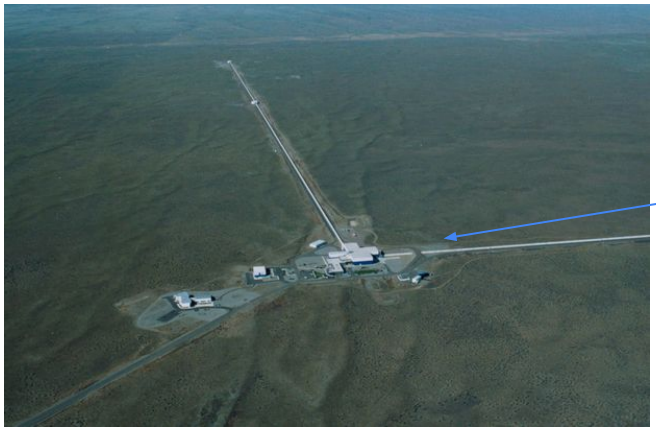
Outline

- Calibration at LIGO
- Introduce the Newtonian Calibrator
- Models
  - Finite Element Simulation
  - Multipole analysis
- Results
- Conclude

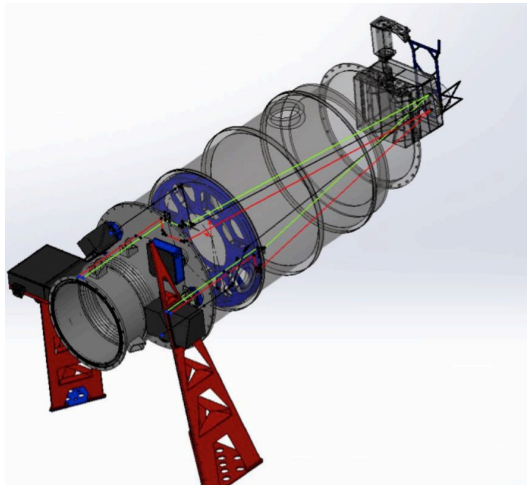
Calibration at LIGO

- Current calibration efforts rely on Photon Calibrator(PCal)
- Utilizes radiation pressure
- Motivate Newtonian Calibrator by having a collection of masses be source of a known force



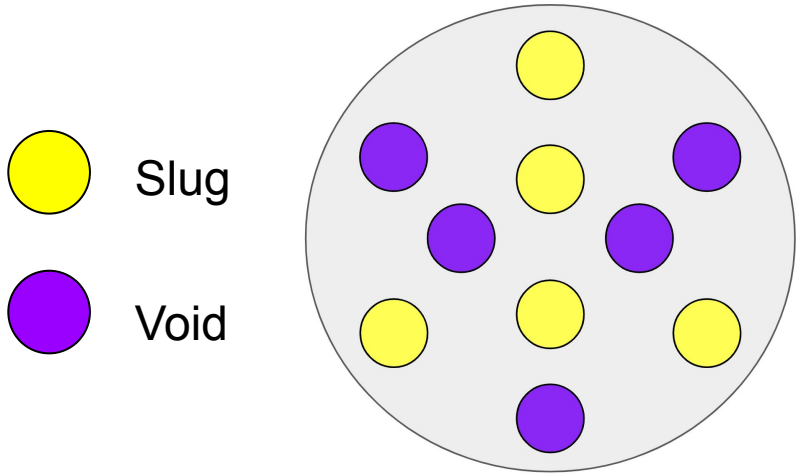


LIGO, Hanford



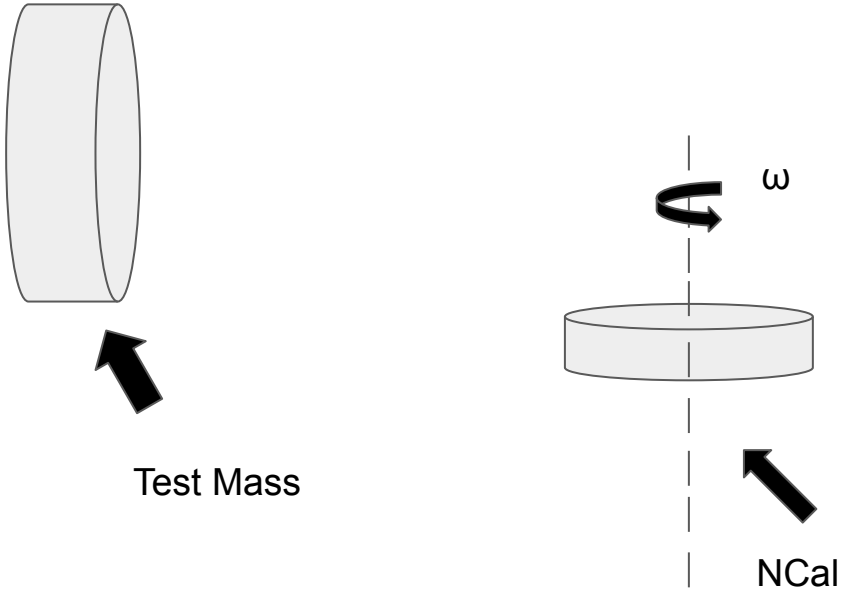
Newtonian Calibrator

- A collection of masses that applies a time-varying force
- Simple geometry allows us to predict force at multiples of rotation frequency
- 4-fold and 6-fold symmetry that have alternating slugs and voids
- More on hardware installation can be found in paper to be published tomorrow(P1900244)

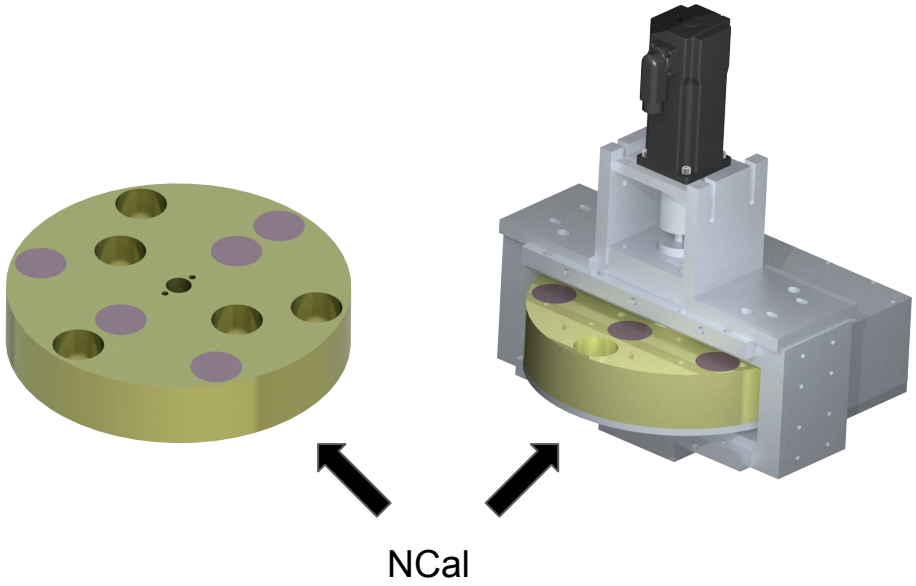


Newtonian Calibrator

Perspective View



Perspective View



Modeling: Finite-Element Simulation

- Within Newtonian limit gravity is linear:

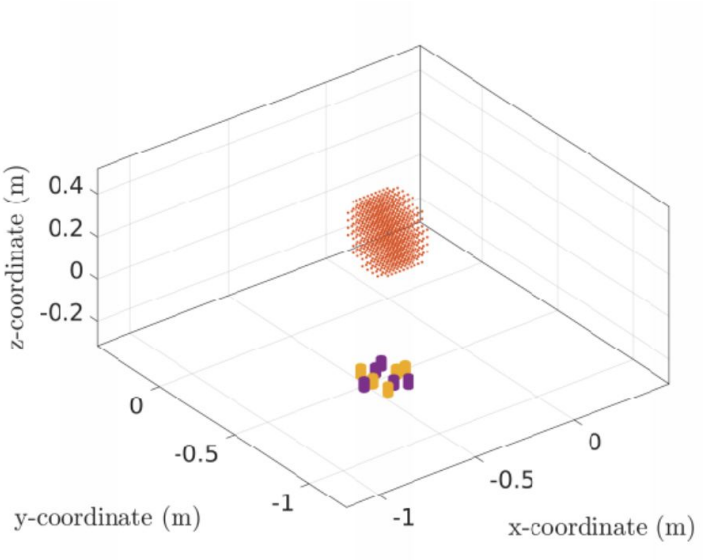
$$F = F^{0f}_{\text{Al Disk}} + F^{2f}_{\text{W Quad.}} + F^{3f}_{\text{W Hex.}} + F^{4f}_{\text{Oct. Holes}} + F^{6f}_{\text{Dodec. Holes}}$$

- We approximate the total force by summing over all the forces between the point masses.

$$F = \sum_i \sum_j \frac{G m_i M_j}{r_{ij}^2} \hat{r}_{ij}$$

Modeling: Finite-Element Simulation

- Code used PointGravity libraries to simulate the geometry of NCal
- Source and test masses have grid points
- Total points are the grid point number cubed
- Rapid convergence with grid point number



Modeling: Multipole Expansion

- Independent Newt code was developed that calculated the multipole moments of the test and source masses from elementary shapes
- The force was calculated using the following summation

$$F = 4\pi G \sum_{l=0}^{\infty} \sum_{m=-l}^{l} \frac{1}{2l+1} Q_{lm} \nabla q_{lm}$$

- Upper limit on l was set to be 11

Results

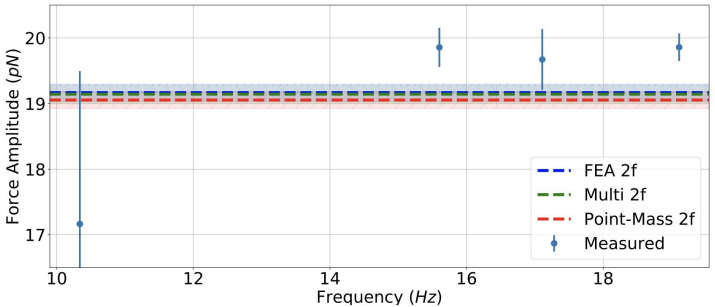
- Both codes produce same force vs. azimuthal angle(of Ncal) plot.
- Least squares fit to find force amplitudes

$$h(t) = a_2 \cos(2\pi\ 2f\ t) + b_2 \sin(2\pi\ 2f\ t) + a_3 \cos(2\pi\ 3f\ t) + b_3 \sin(2\pi\ 3f\ t)$$

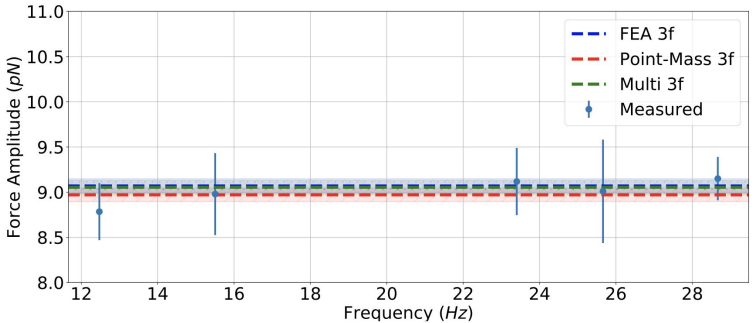
$$h(f_i) = \sqrt{a_i^2 + b_i^2}$$

Model	$F_x^{(2f)}$ (pN)	$F_x^{(3f)}$ (pN)
Finite-element	$19.18^{\pm 0.14}_{(\pm 0.75\%)}$	$9.07^{\pm 0.09}_{(\pm 0.95\%)}$
Multipole	$19.16^{\pm 0.14}_{(\pm 0.74\%)}$	$9.06^{\pm 0.09}_{(\pm 0.94\%)}$
Point-mass	$19.04^{\pm 0.15}_{(\pm 0.76\%)}$	$8.97^{\pm 0.09}_{(\pm 0.95\%)}$

2F



3F



Conclusions and Future Plans

- We have created two independent models that accurately predicts a measured injected force
- We plan to set up future models with simultaneous injections of NCal and PCal
- Uncertainty in current mechanical calibration efforts can be reduced by better distance surveying and installments of more rotors

Thanks And Questions?