Virgo NCal update
LVK March 2021 meeting

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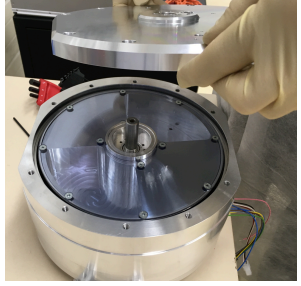
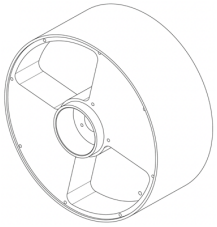
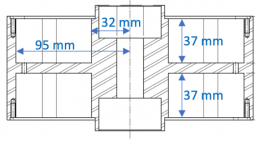
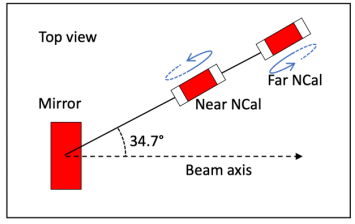
VIRGO

O3 setup

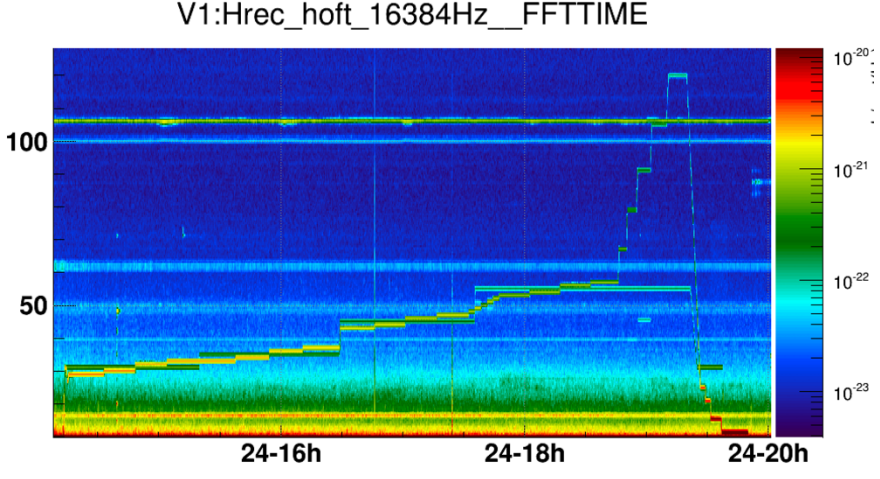


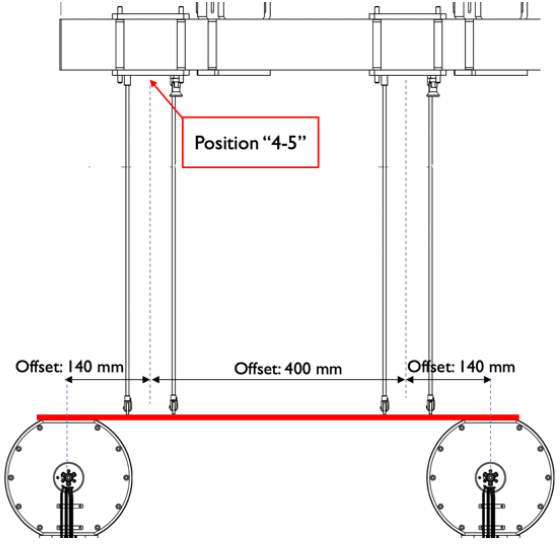






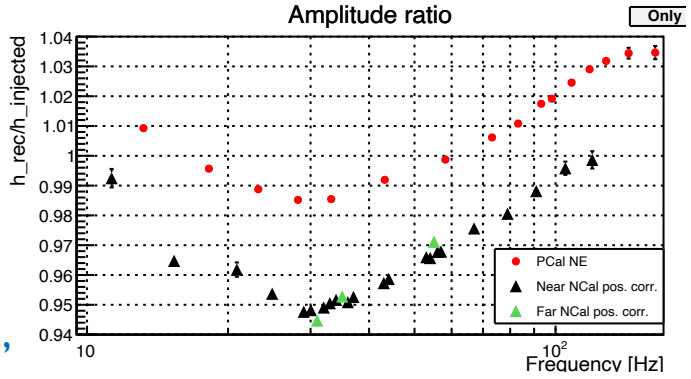
- Two NCals tested during O3
  - At 1.27 and 1.95 m from the mirror
- Most useful data set:
  - 6 hours on March 24, 2020

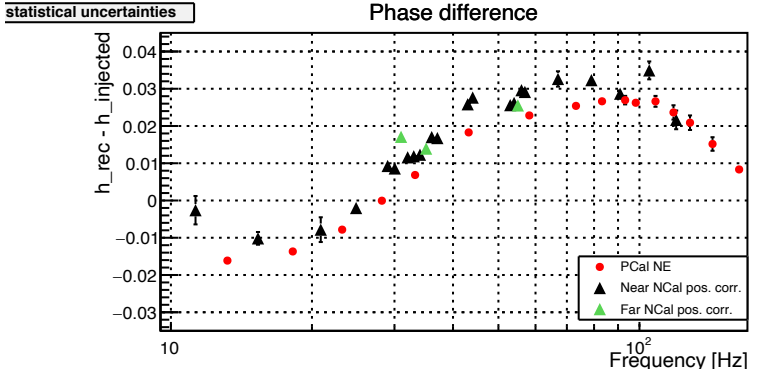




O3 results

- Accurate FEM simulation
- Results published: CQG **38**, 075012
  - "Newtonian calibrator tests during the Virgo O3 data taking"
- Probing h(t) up to 120 Hz (rotor @ 60 Hz)
- Same shape as PCal
- 3% amplitude offset between PCal and NCal
- Systematic uncertainties
  - At the level of the PCal uncertainties
  - Dominated by NCal-mirror distance

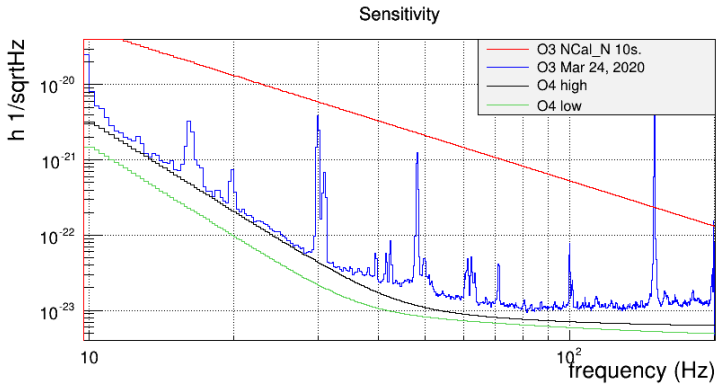




Parameter	uncertainty	formula	h_{rec}/h_{inj} near [%]	h_{rec}/h_{inj} far [%]
NCal to mirror distance d	6.4 mm	$4\delta d/d$	2.02	1.31
NCal to mirror angle Φ	5.0/3.3 mrad	$\delta\Phi \sin\Phi$	0.28	0.19
NCal vertical position z	1.3 mm	$5/2(z/d)^2$	0.03	0.01
Rotor geometry	see table 1		0.53	0.53
Modeling method	see end of section 4		0.018	0.017
Mirror torque from NCal	see end of section 4		0.05	0.03
Total	quadratic sum		2.1	1.4

O4 foreseen NCal operations

- O4 goals
  - Validate h(t) within 1% in the 10-200 Hz frequency range
  - Add a permanent NCal monitoring line
- NCal foreseen operations during O4
  - Dedicated commissioning shifts to:
    - Compare NCals strength by swapping NCals,
    - Extract mirror-NCal relative position by comparing NCal amplitudes
    - Check vertical position by moving the NCal along the vertical axis
    - Search for induced NCal noises, …
  - Weekly, calibration period:
    - Frequency scan and check of the mirror-NCal position
    - Should not take too much time (less than half an hour) → NCal signal should be large enough
  - Permanent line(s) for h(t) monitoring
    - Strong enough to get a meaningful result
    - Not to strong to avoid sidebands
- → build more and better NCals and improve there position survey

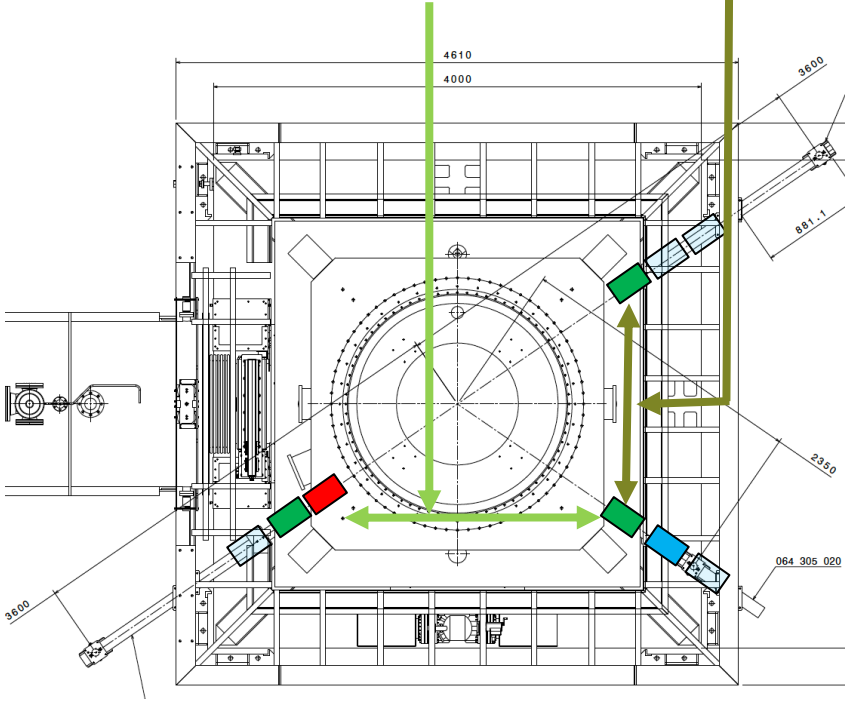


Tentative layout for O4

- 1 close NCal (red) for high frequency check
  - At 1.3 m from the mirror
    - Same distance as O3 NCal_N
- 3 NCals (green) for mirror position control
  - Same mirror distance to reduce model uncertainties
  - At 1.7 m from the mirror
    - Attenuation factor vs O3 NCal_N: 2.9
- 1 Far NCal (blue) for permanent line
  - At 2.1 or 2.5 m from the mirror
    - Attenuation factor vs O3 NCal_N: 6.8/13.7
  - Could be installed on any side;
  - Around 30 Hz (in h(t)) ?

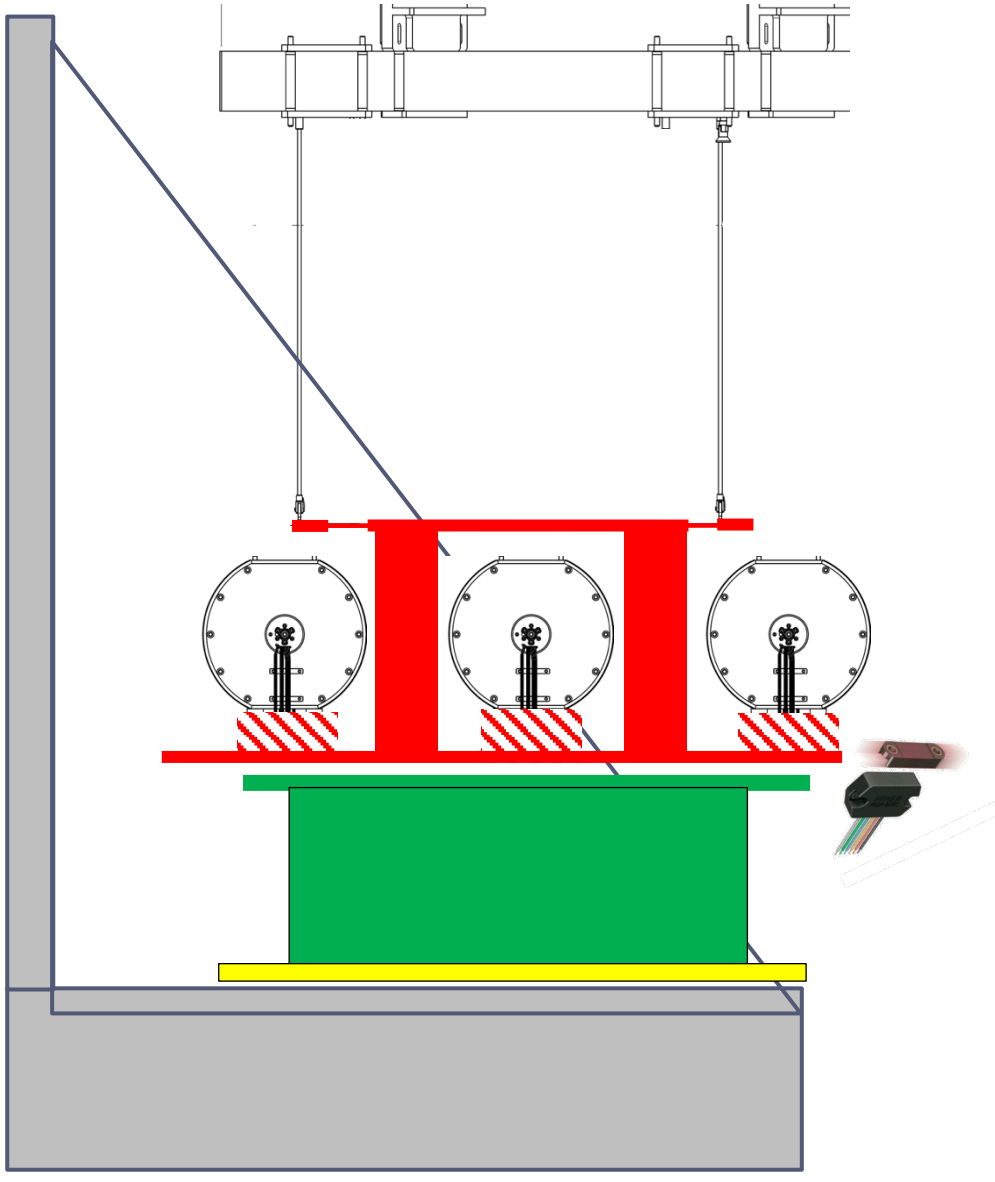
- → Build 5+1 new NCals + positioning system

Expect to know the relative positions of
North NCals within 0.1- 0.2 mm
South NCals within 1-2 mm

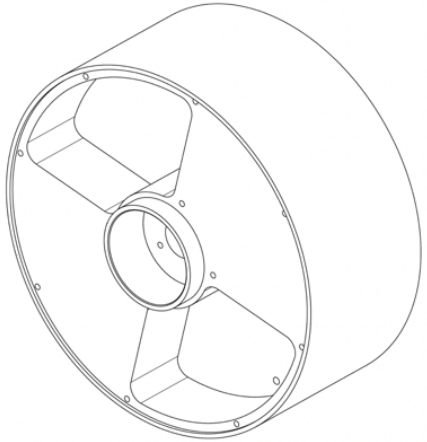


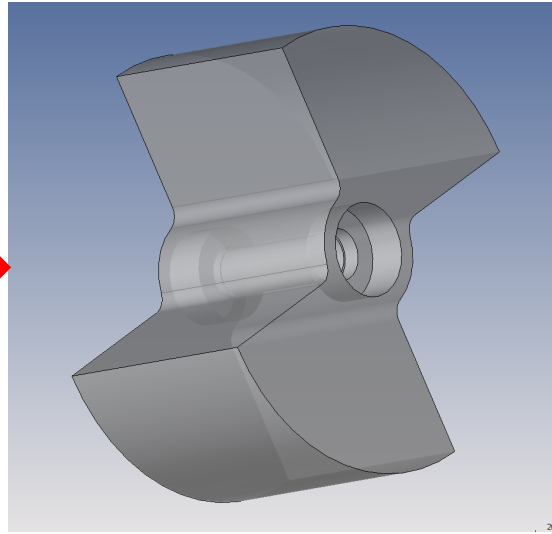
New NCal supports

- 3 NCal slots
  - Only one or two slots used
- Simple soft suspension
  - Coarse filtering of NCal vibrations
- Bottom reference
  - Fixed to the vacuum chamber base
  - Relative position measurement
- Design in progress

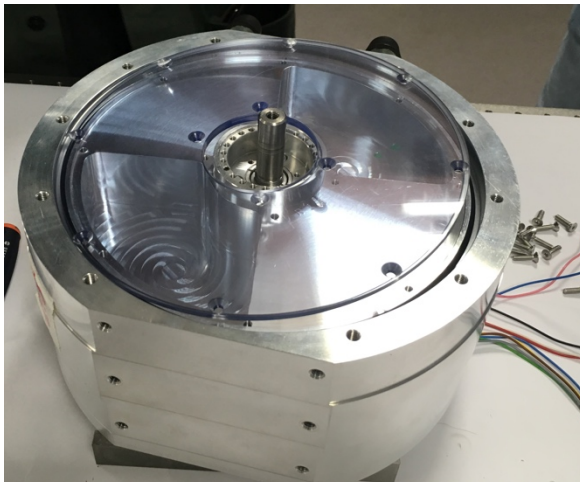


Improving the NCal rotor





- Remove:
  - the external ring
  - the central disk
- Make it thicker
- Benefit
  - Force x 2
  - Simpler geometry: better metrology and prediction
- Drawbacks:
  - Air motion → limited rotation frequency
    - unless going under vacuum (not foreseen for O4)
  - Expect to reach close to 50 Hz (rotor speed)
    - Current test: 70 Hz achieved without the plexiglass cover but with the external ring
- Rotor to be used for the absolute calibration, mirror position control & permanent line



Other rotor improvements

- Change motor
  - 50 W motor replaced by a 70W motor
  - → able to run the O3 NCal (with cover) up to 100 Hz (200 Hz for h(t))
    - Rotor be used for the high frequency check
- Reliability
  - Ongoing work to find the right bearings for
    - Noise reduction
    - Long lifetime for the periodic calibration and the permanent line
  - Rotor balancing
- Rotor speed control to be improved
  - Must slave the NCal rotation on the GPS

Summary

- There should be more and better Virgo Ncals for O4
- The NCal systematic uncertainties might be smaller than for Pcal

… but planning is tight and we are late (COVID doesn't help…)