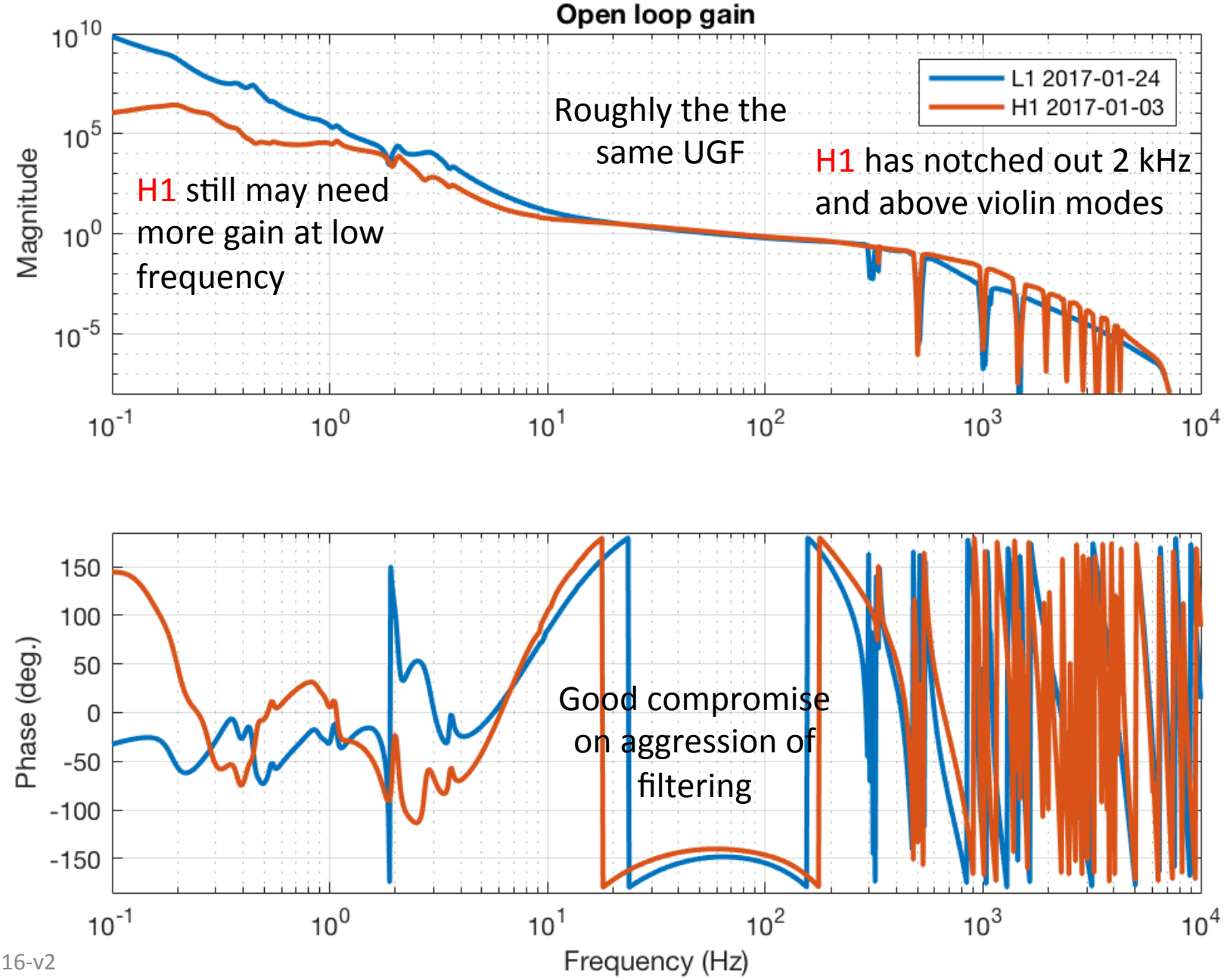
O2 DARM Loop Design Comparisons and Critiques

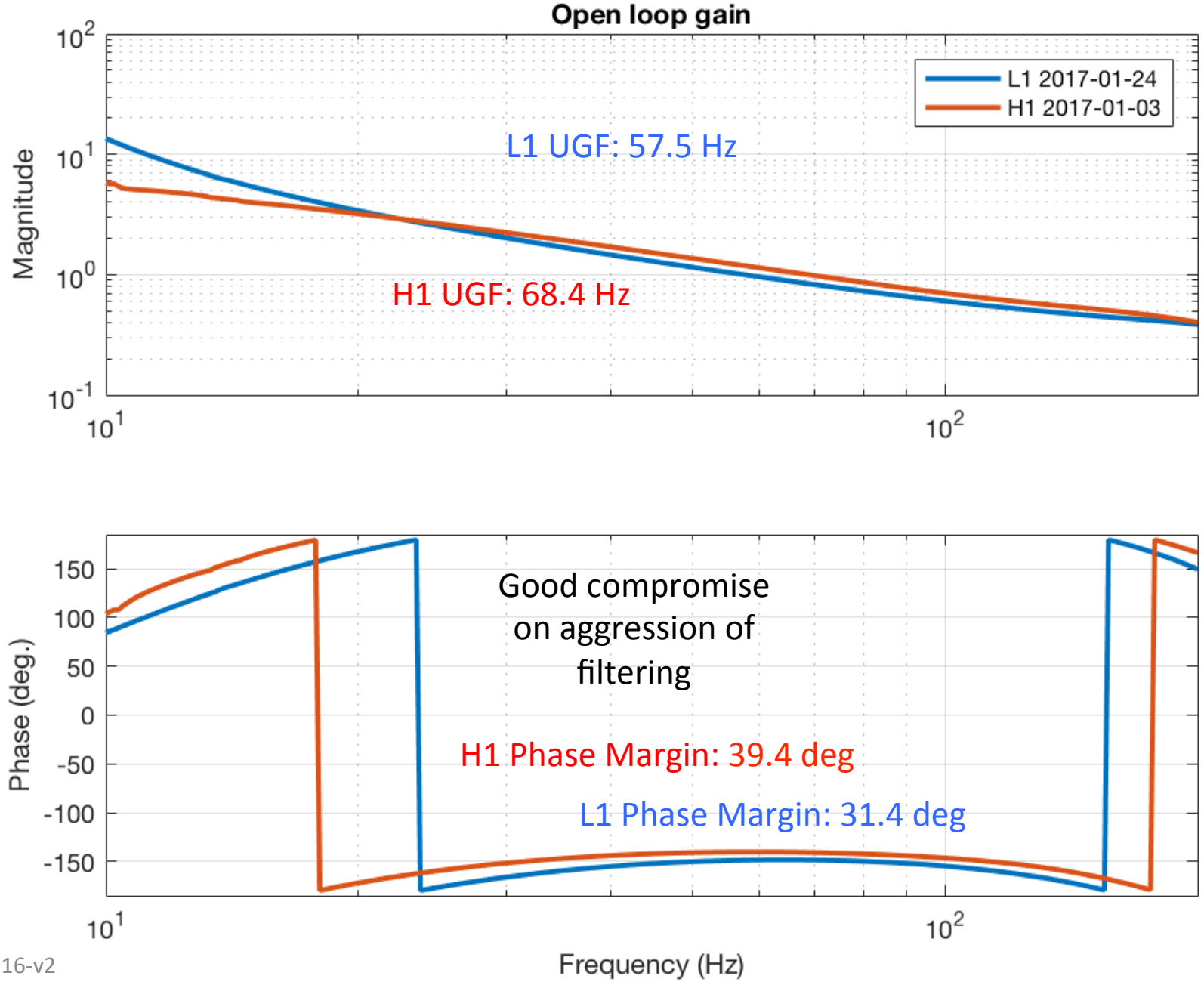
E. Goetz, J. Kissel, for the Calibration Team

For similar O1 critique, see LIGO-G1501372

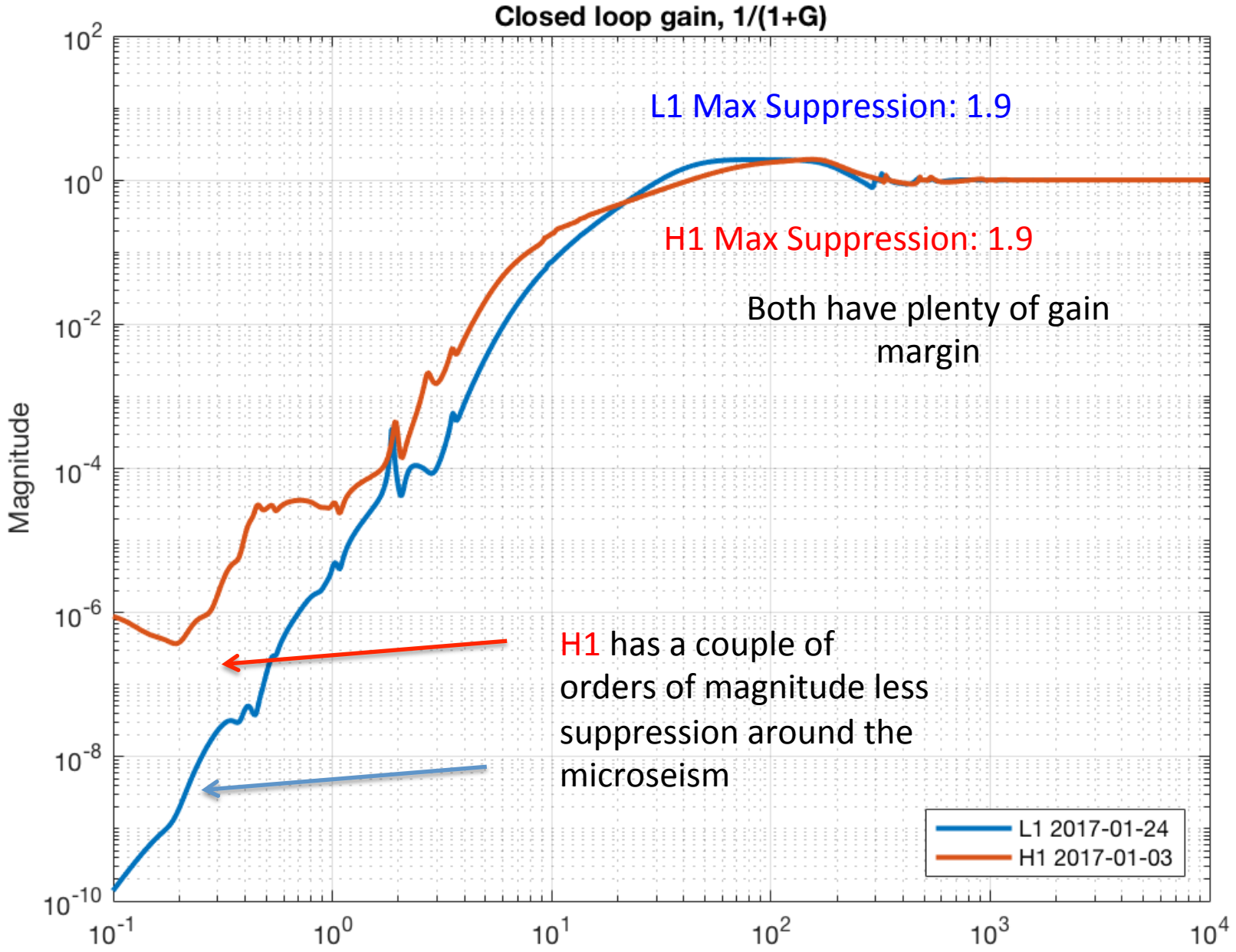
DARM Open Loop Gain TF (Big Picture)



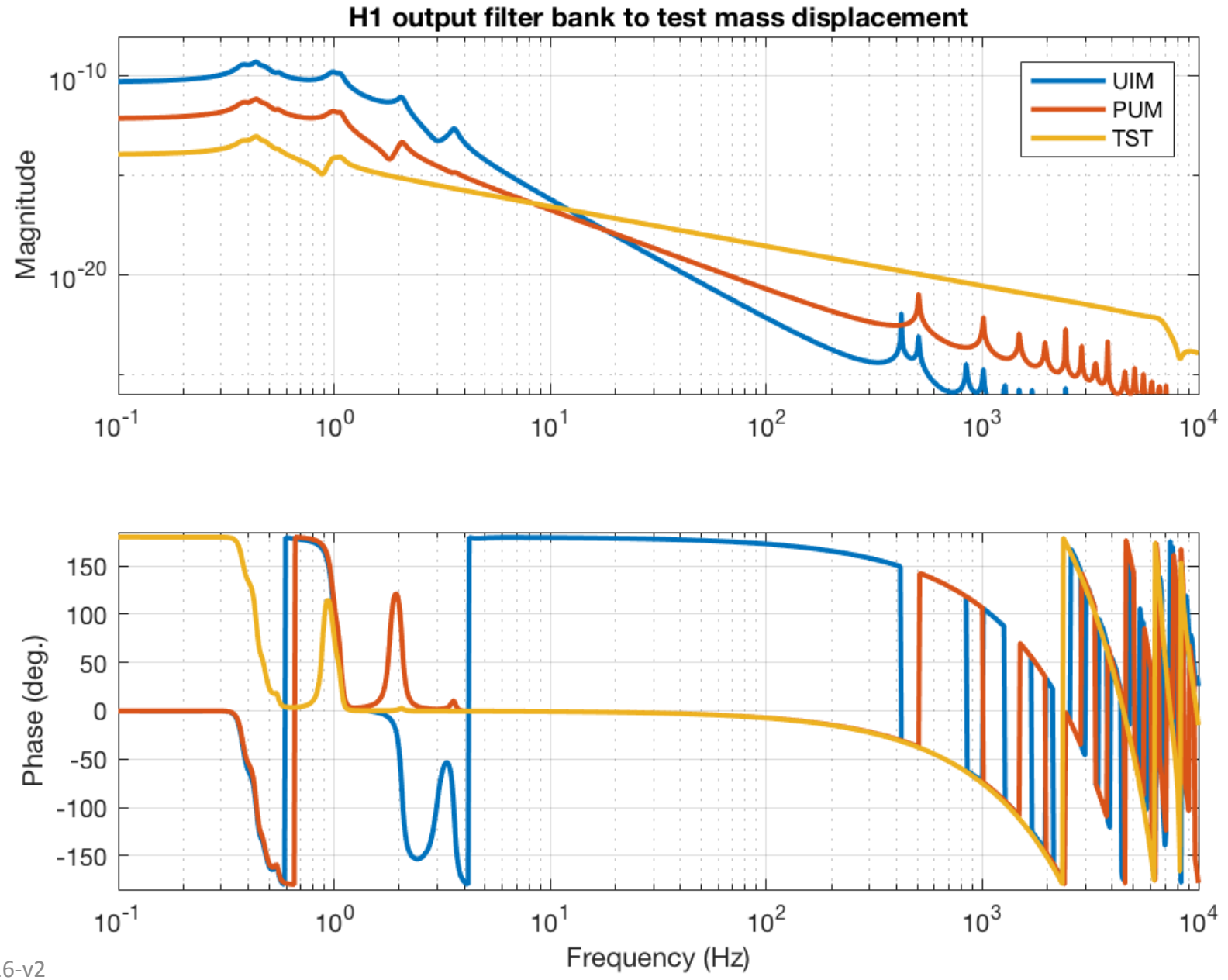
DARM OLGTF (UGF Zoom)



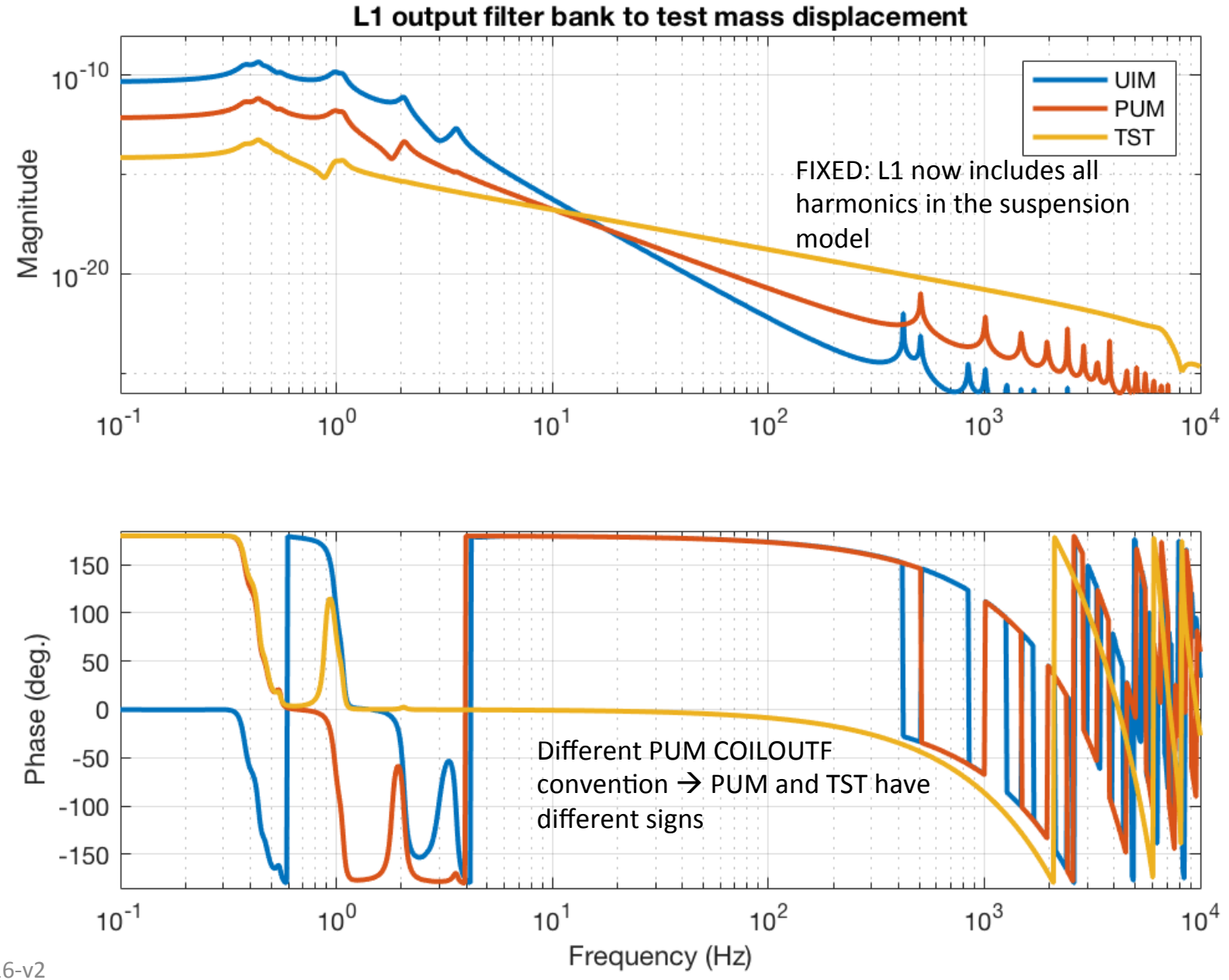
DARM Open Loop Gain TF



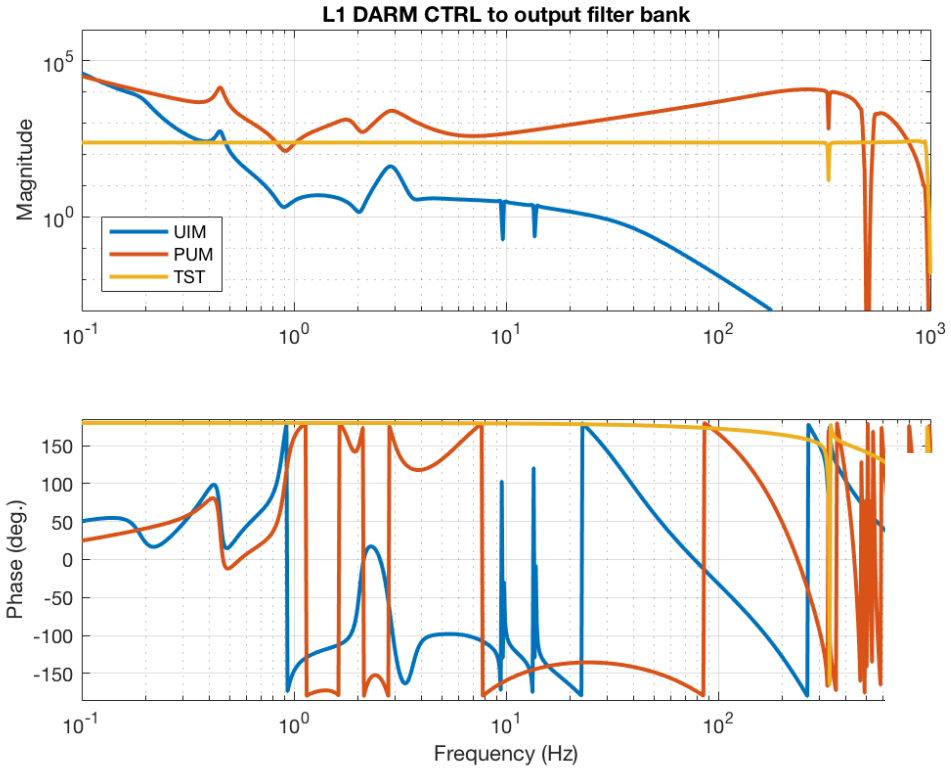
Actuator Strength Comparison



Actuator Strength Comparison

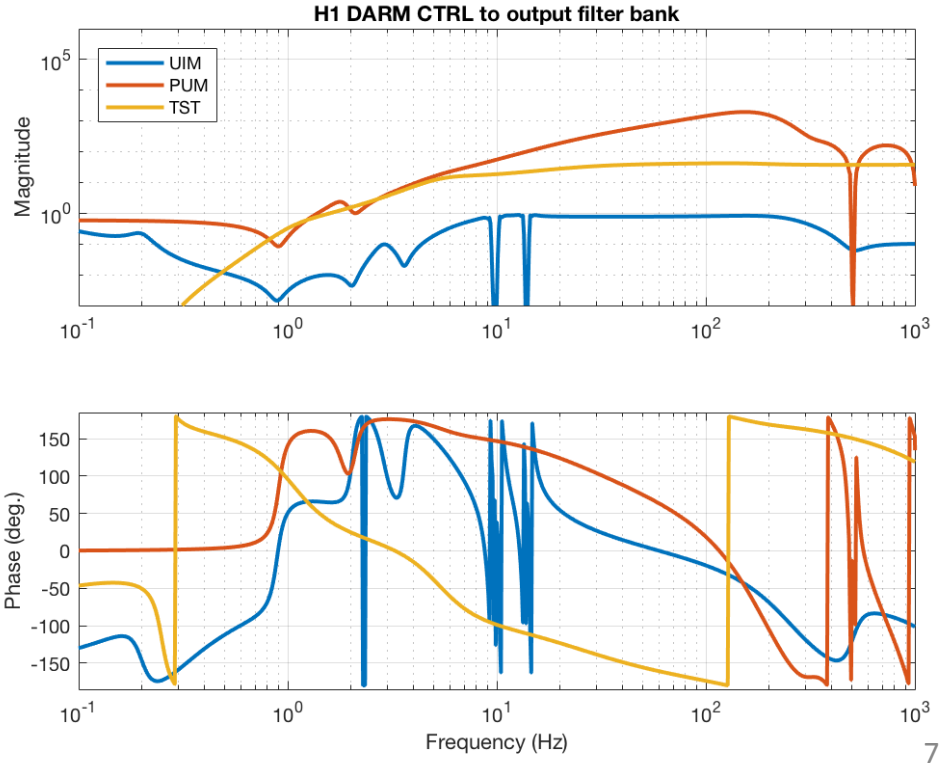


Actuator Comparison (Hierarchy Filters)



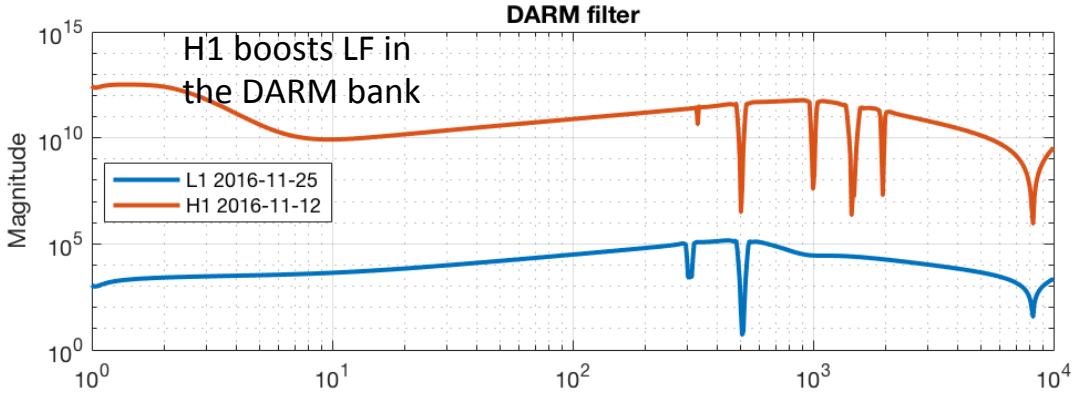
Both sites have a mish-mash of "offloaded" vs. "distributed" hierarchy filters due to staggered design

L1 does more loop shaping in the DARM bank (because of all the notching done at H1)

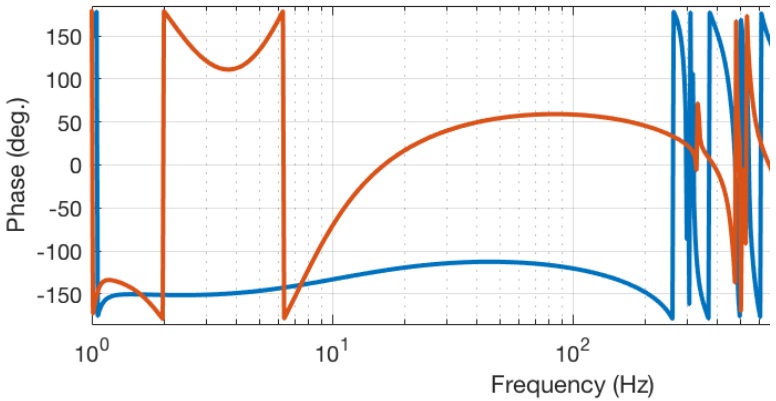


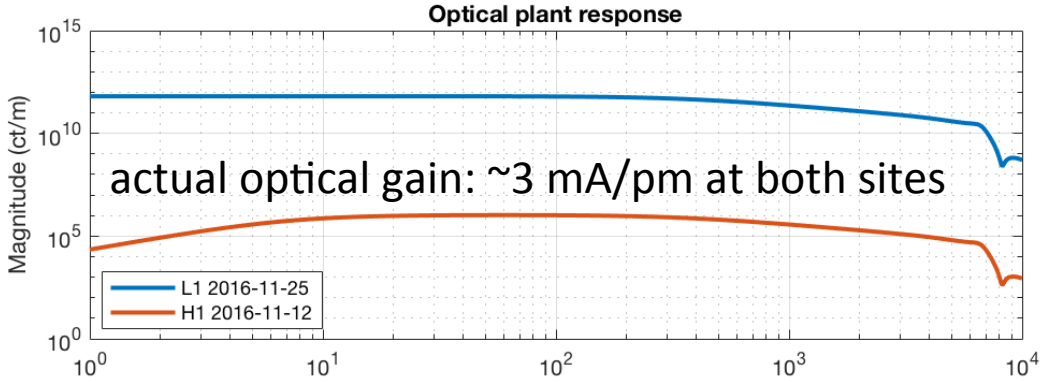
Note the difference in HF cut-off filter for all stages…

The DARM Filter and Sensing Function

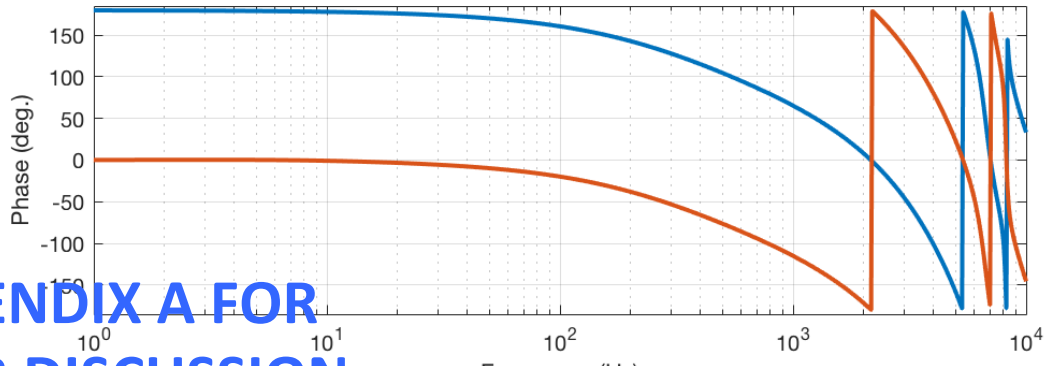


Digital gains (and a sign) are distributed differently on the sensing side, so DARM filter gain and sign compensate, otherwise pretty similar…



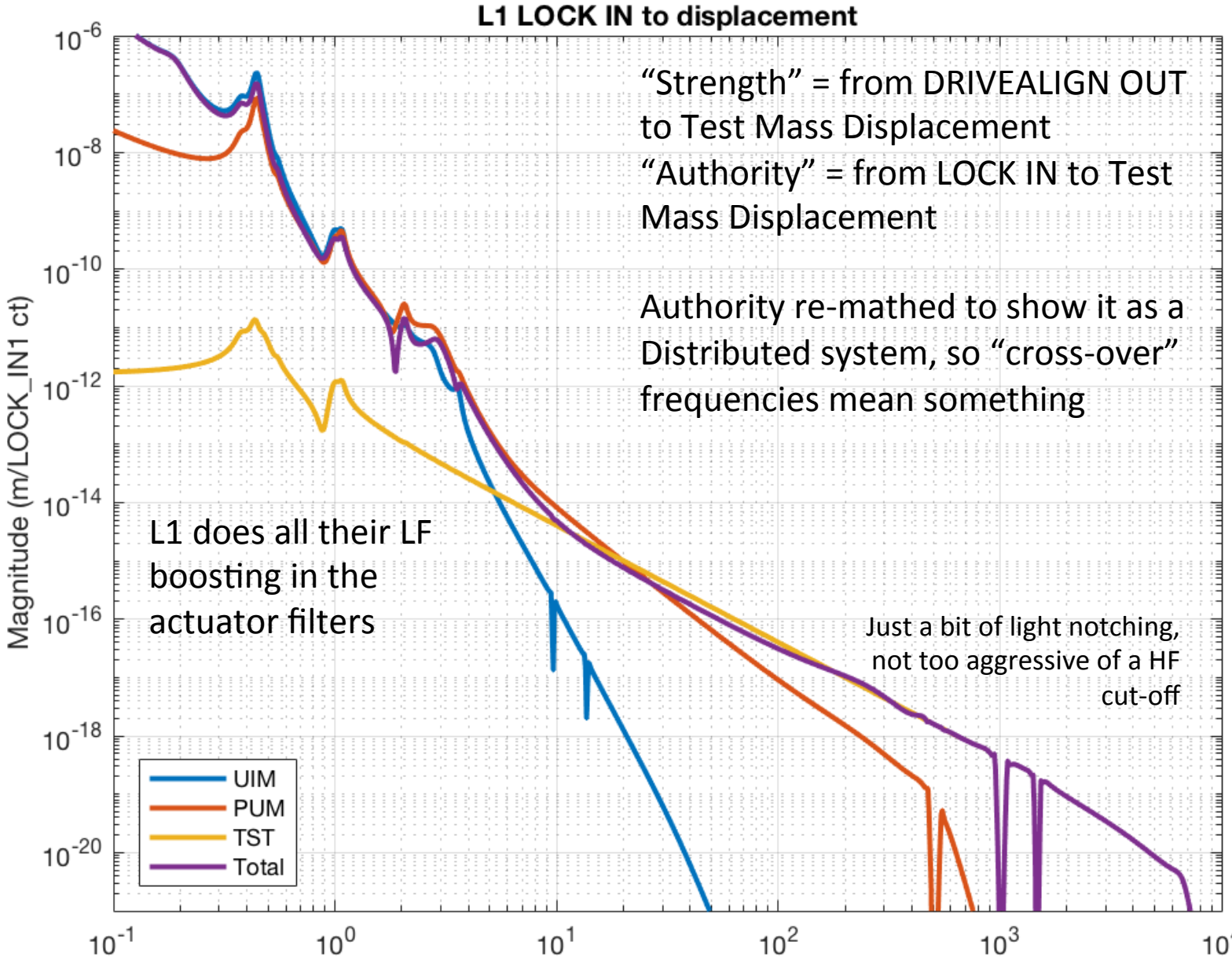


But because of the **different design choices**, with frequency response and gains all over the place, **tough to get a feel for the loop shaping from just one filter or plot**

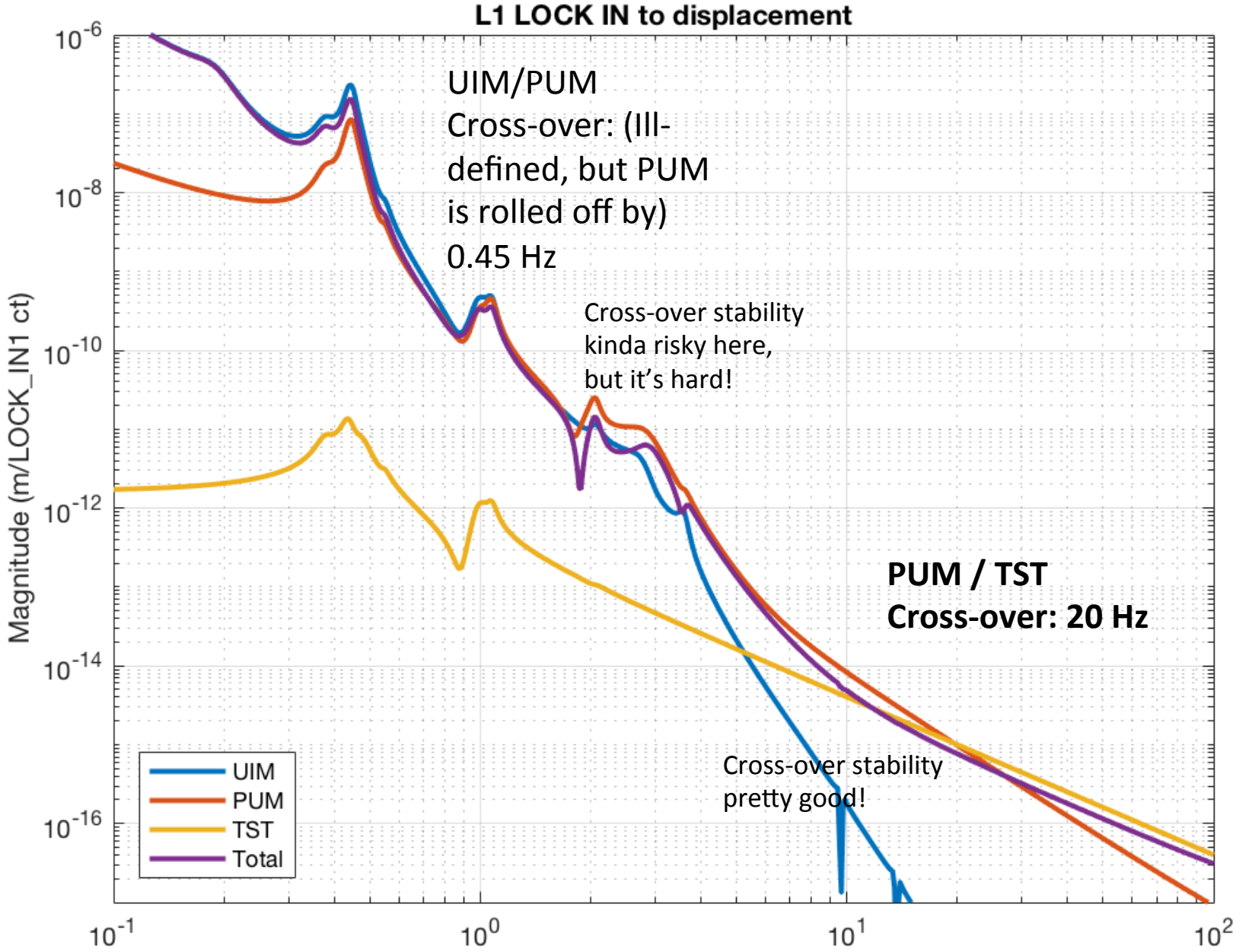


SEE APPENDIX A FOR FURTHER DISCUSSION

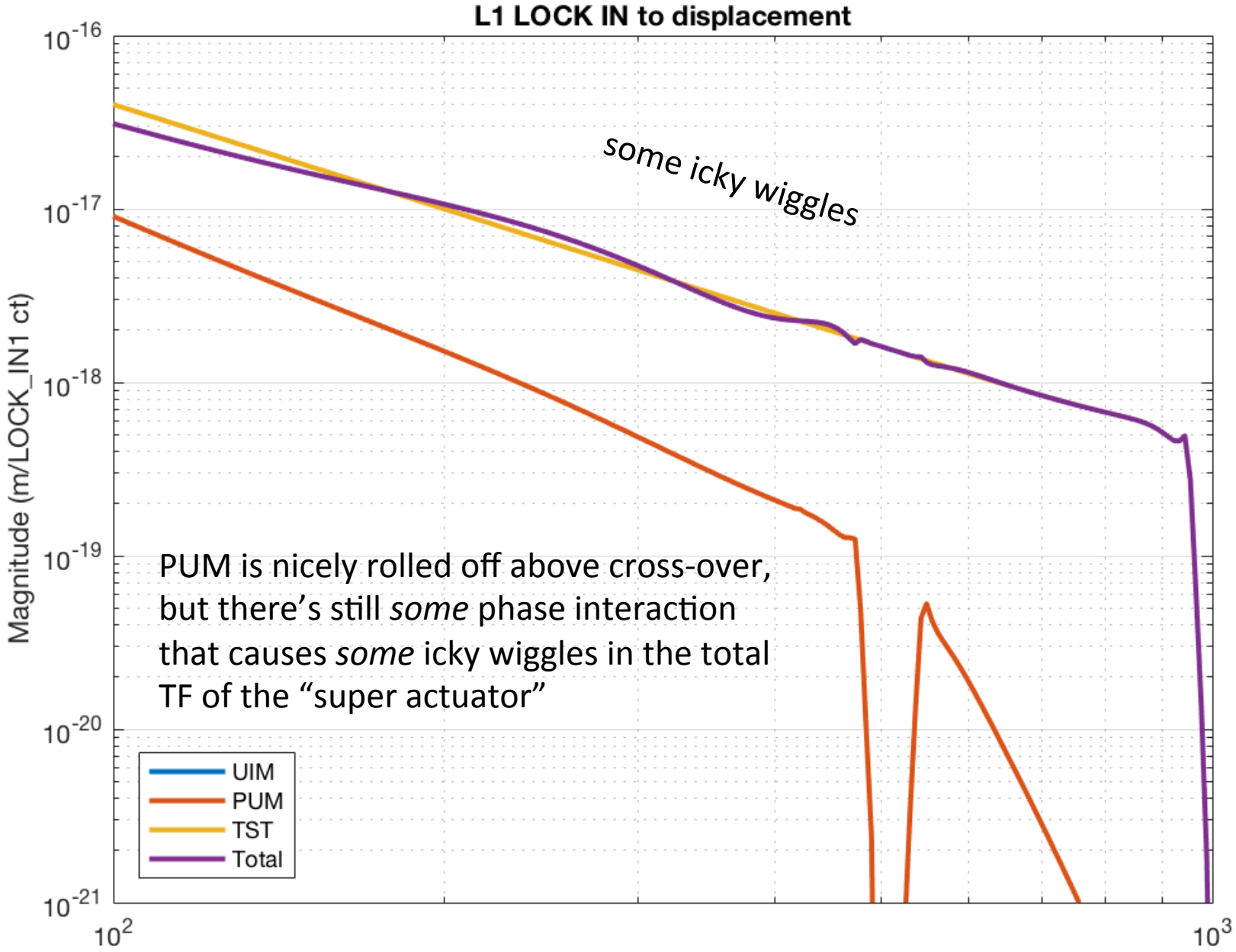
L1 Actuator Authority (Big Picture)



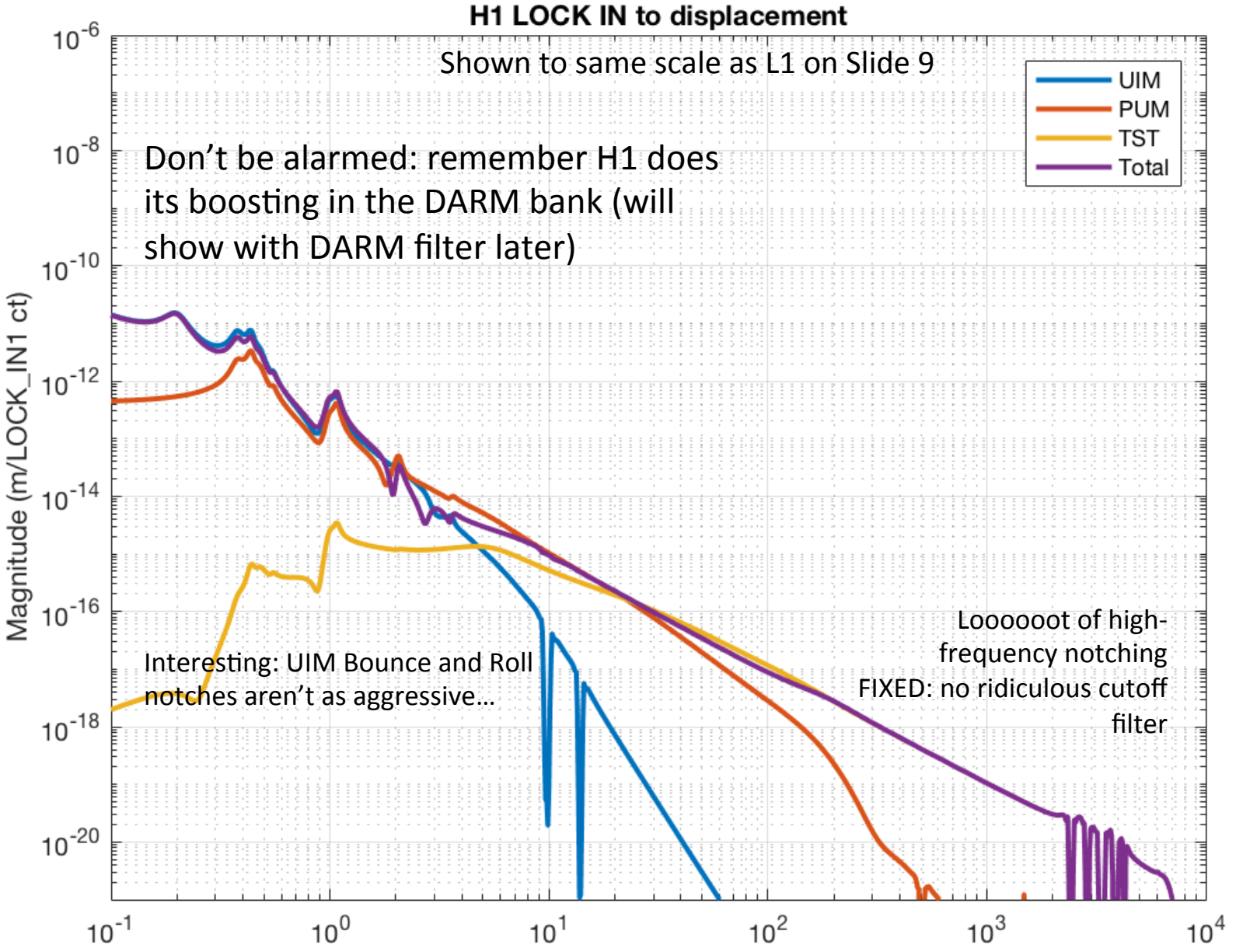
L1 Actuator Authority (X-over Zoom)



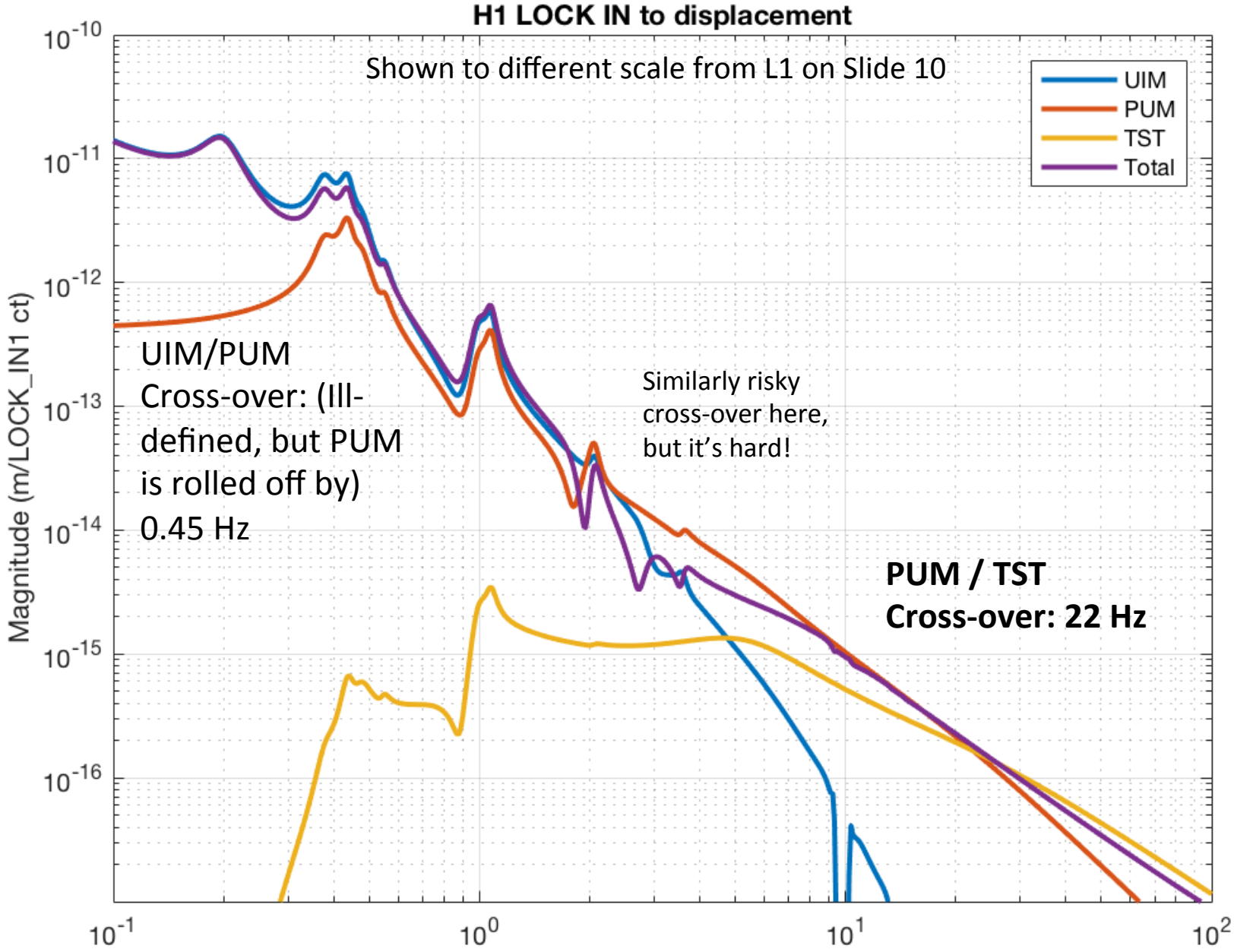
L1 Actuator Authority (HF Roll-off Zoom)



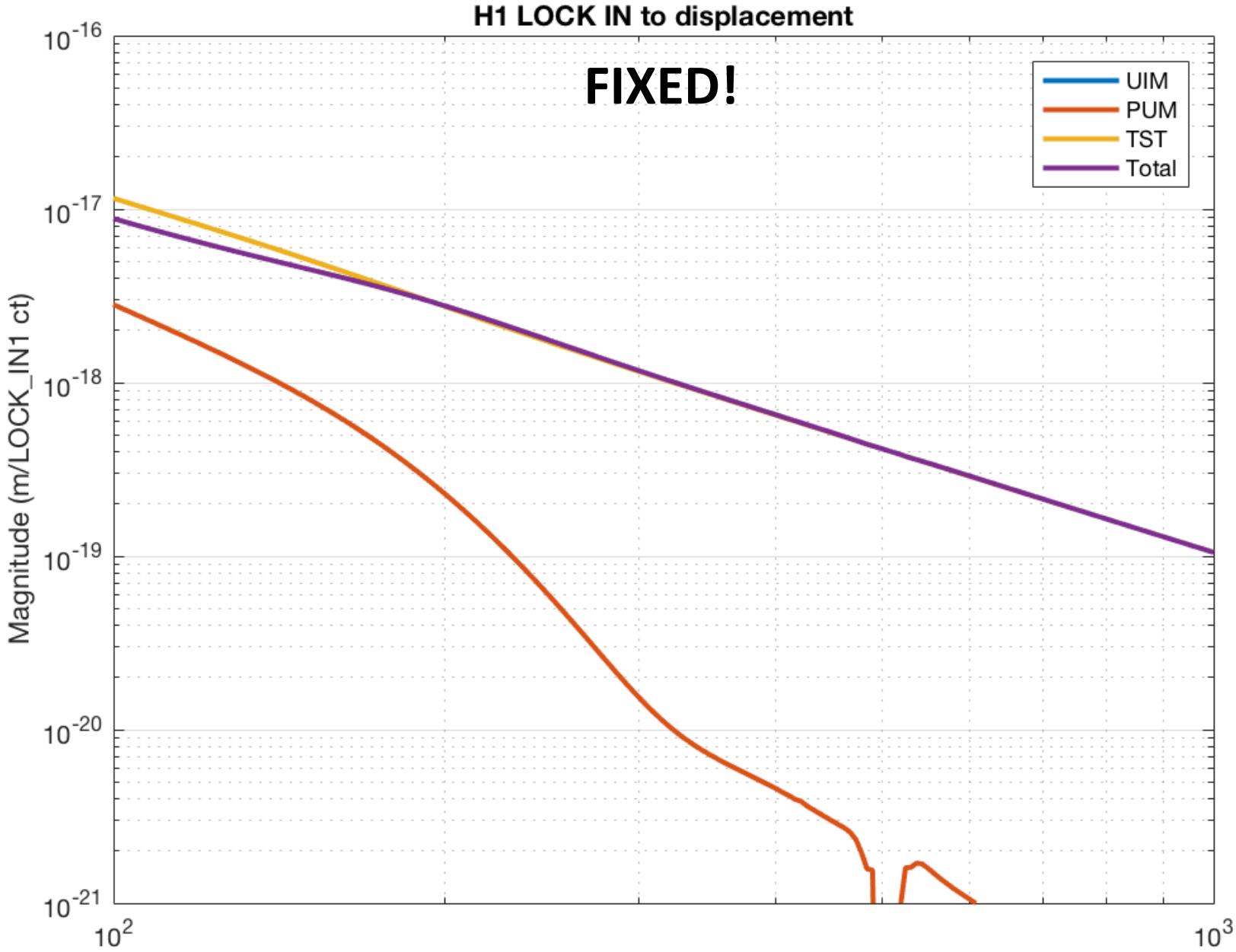
H1 Actuator Authority (Big Picture)



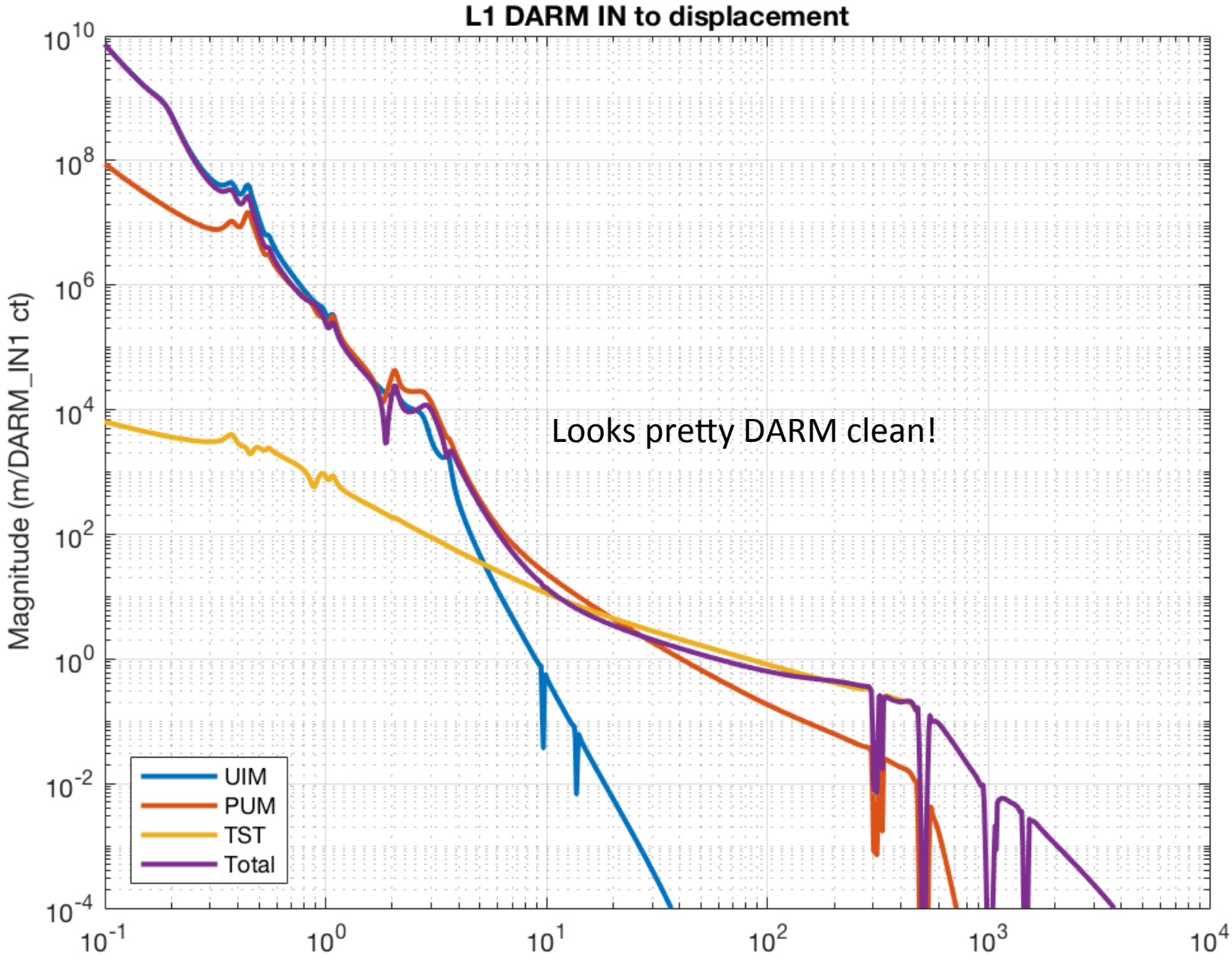
H1 Actuator Authority (X-over Zoom)



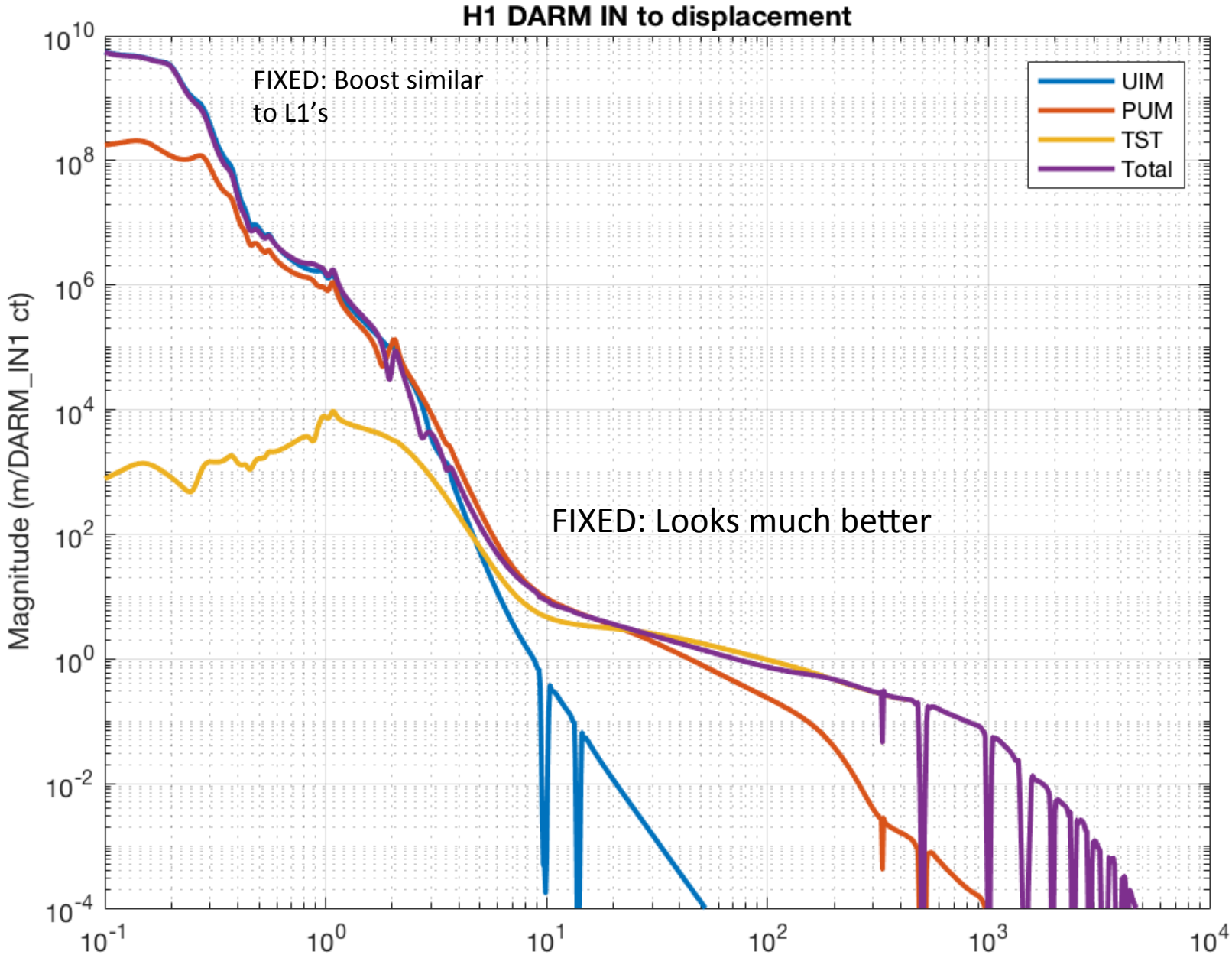
H1 Actuator Authority (HF Roll-off Zoom)



Authority Including DARM Filter (scaled by optical gain)



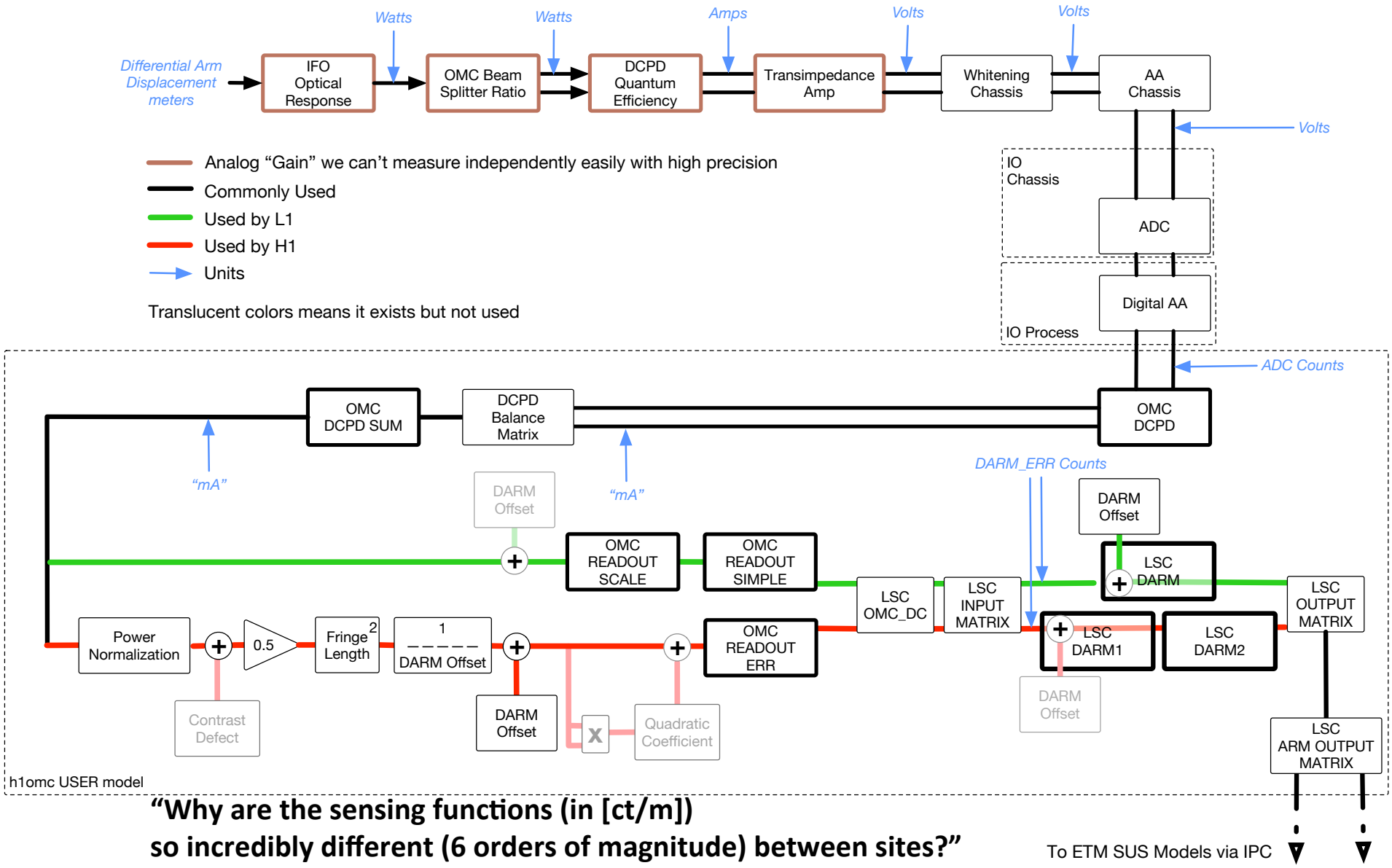
Authority Including DARM Filter (scaled by optical gain)



Conclusions

- H1 DARM Loop has been cleaned up since O1
  - FIXED: More boosting at low-frequency
  - FIXED: Better / simpler distribution filters
  - Less notching?
- Frequency response is splayed out everywhere at both sites, evident that "design" was staggered and piecemeal
  - Both sites should consider consolidating, for easier analysis of performance

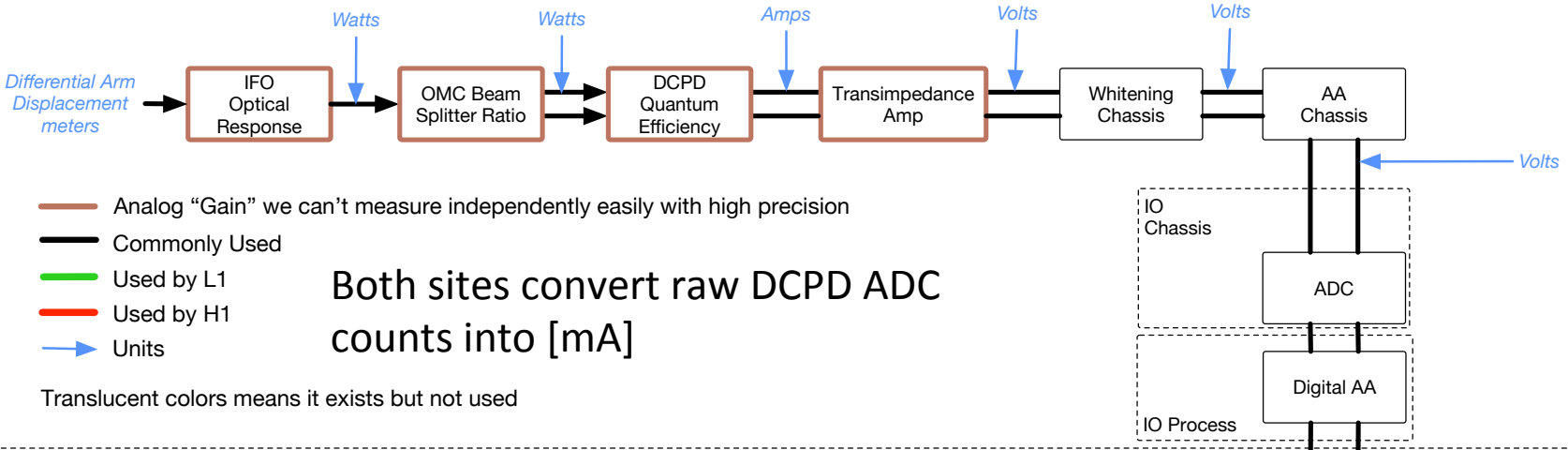
APPENDIX A: Sensing Function Units

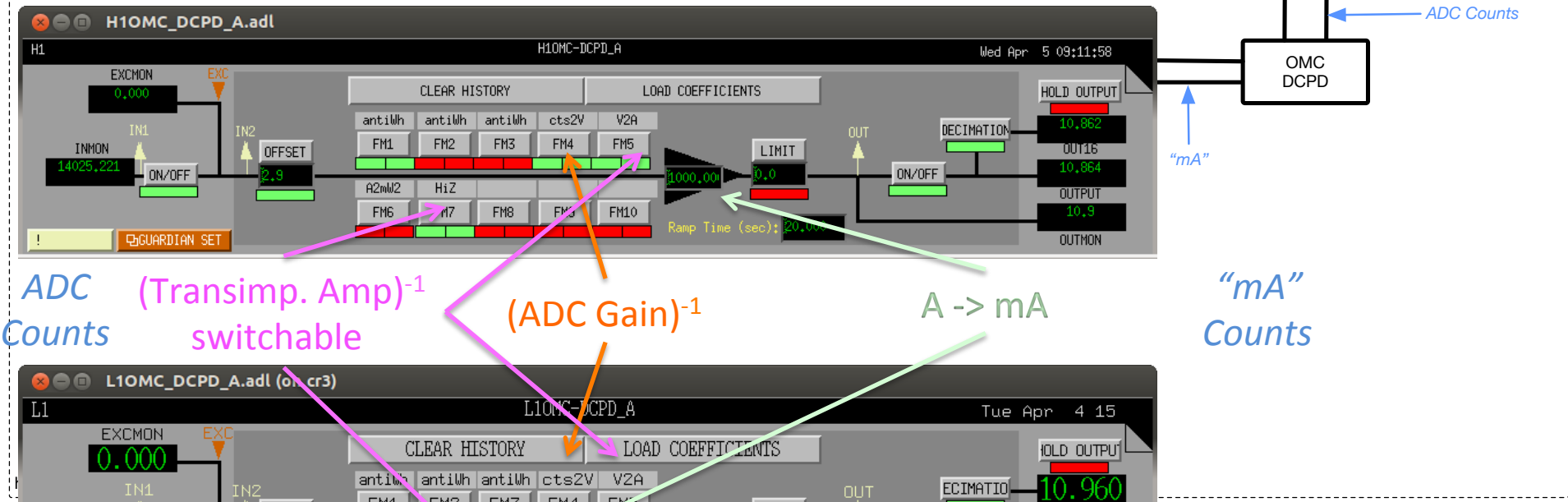


"Why are the sensing functions (in [ct/m]) so incredibly different (6 orders of magnitude) between sites?"

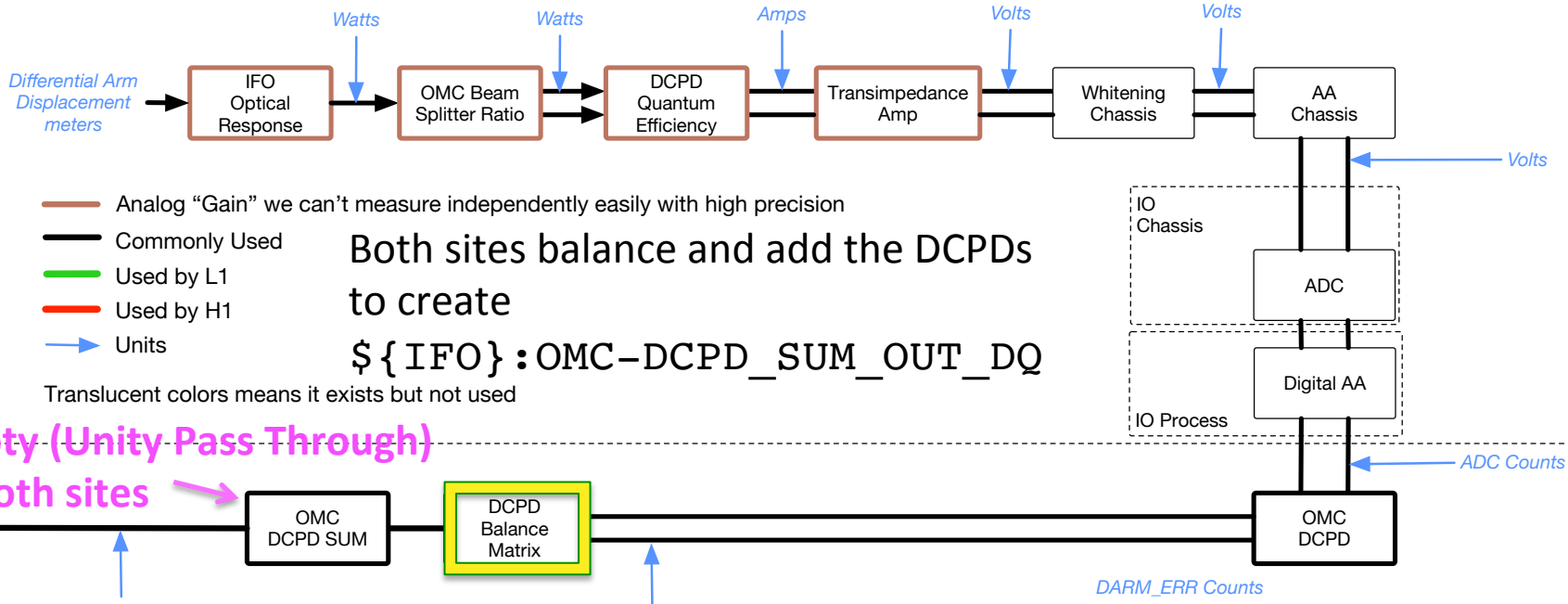
This has entirely and only to do with a different choice of digital allocation of gains.

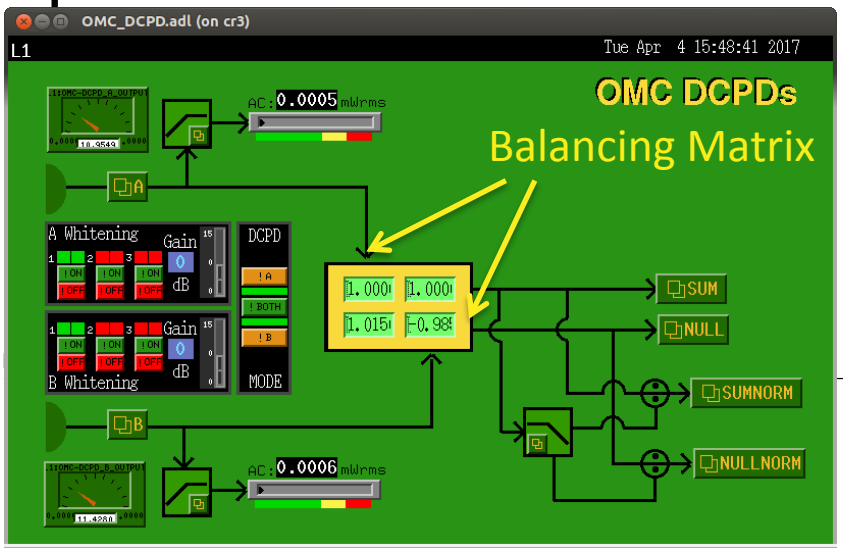
APPENDIX A: Sensing Function Units

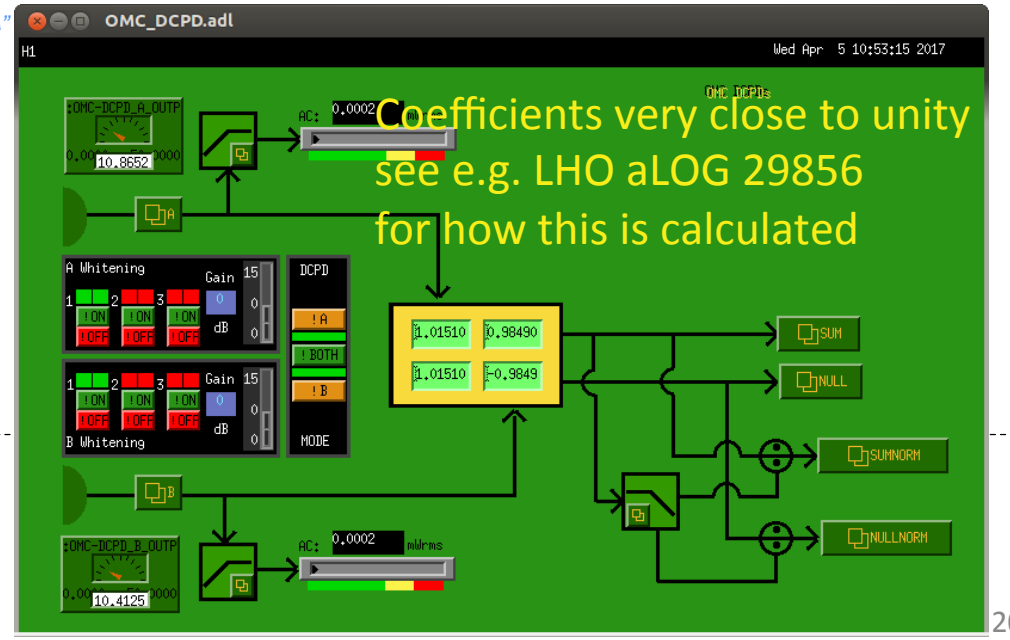




APPENDIX A: Sensing Function Units

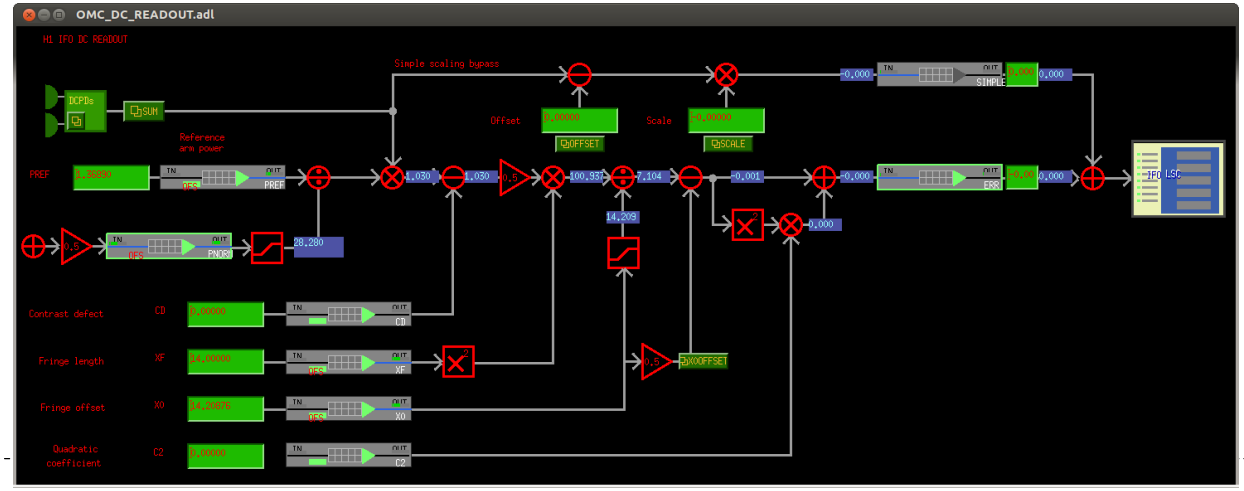


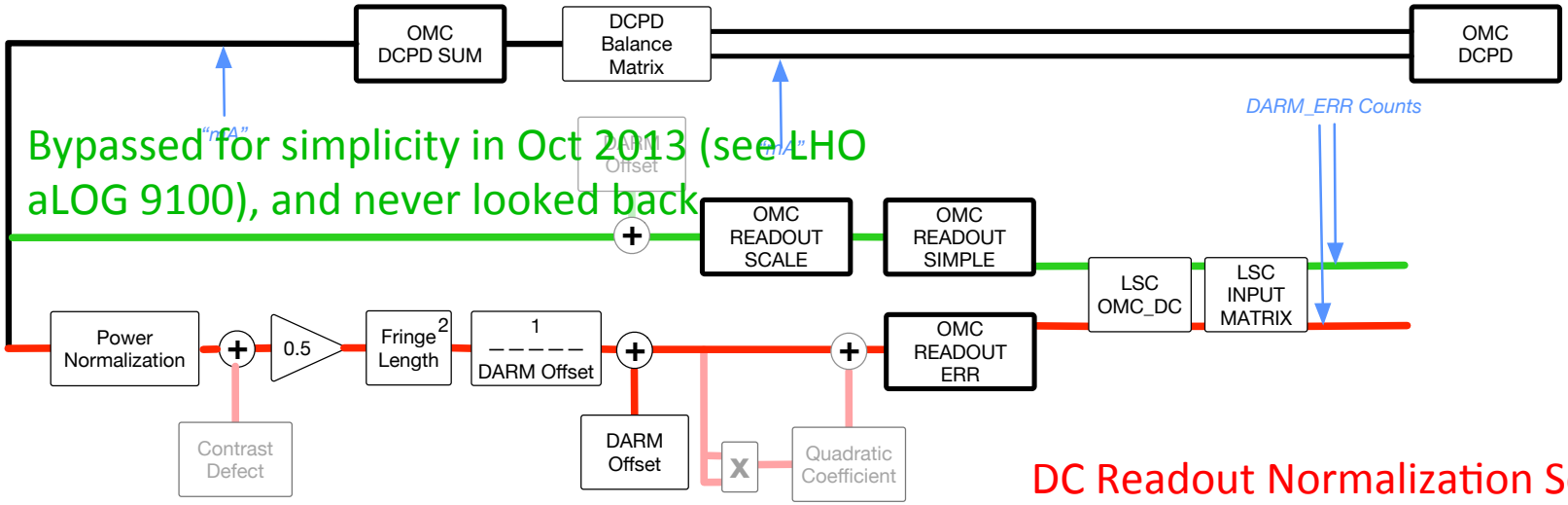




APPENDIX A: Sensing Function Units

But from here, they depart from each other soley due to how, historically, the sites were commissioned in parallel…





DC Readout Normalization Scheme developed in eLIGO, T0900023

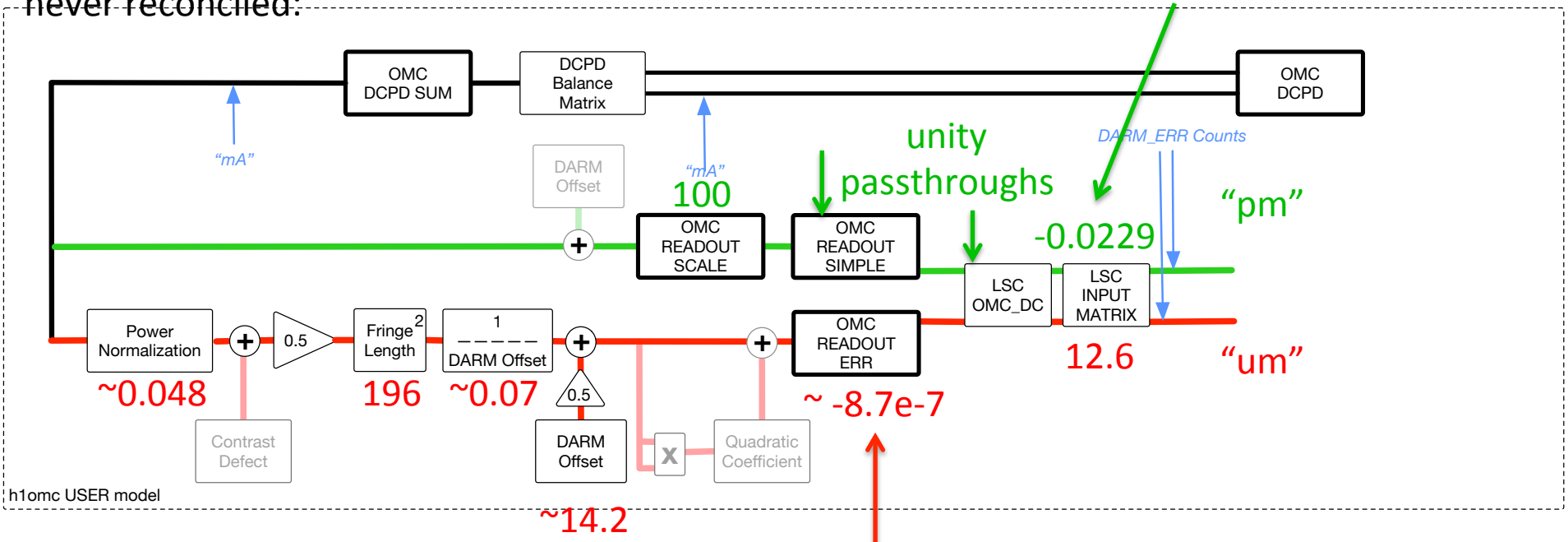
(re)commissioned for aLIGO in May-July 2015 (see e.g. LHO aLOG 19233, 18470)

APPENDIX A: Sensing Function Units

While there were efforts to calibrate DARM_ERR into displacement units, it all boils down to whether DARM ERR needed to originally be in “pm” or “um” and was never reconciled:

The scale factors are geared such that DARM_ERR is in “pm” so the OFFSET in the DARM bank can be the DARM OFFSET in physical units.

Collectively it’s about 1/ (4.5 [mA/pm]) ~ 0.2

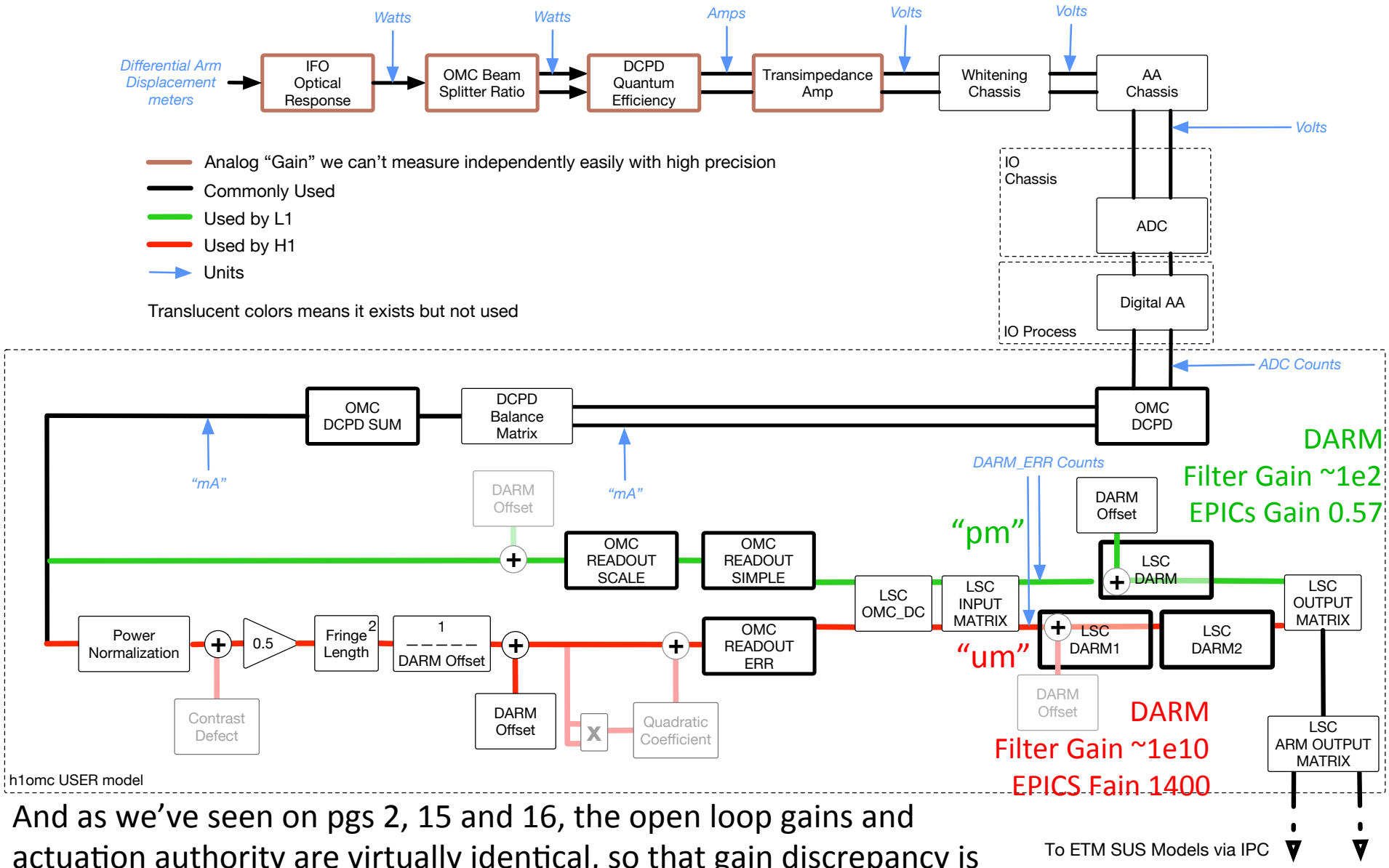


This gain factor is such that the OMC DCPD error signal matches the AS AIR, and AS AIR error is matched to ALS DIFF, which was originally (roughly) calibrated in “um”

Scale factor collectively works out to about 1e-6 [um/pm] / (2.7 [mA/pm]) ~ 3.6e-7

In other words, both sites are normalizing their DARM loop gain to some reference time with the optical gain was ~ 4.5 / 2.7 [mA/pm]

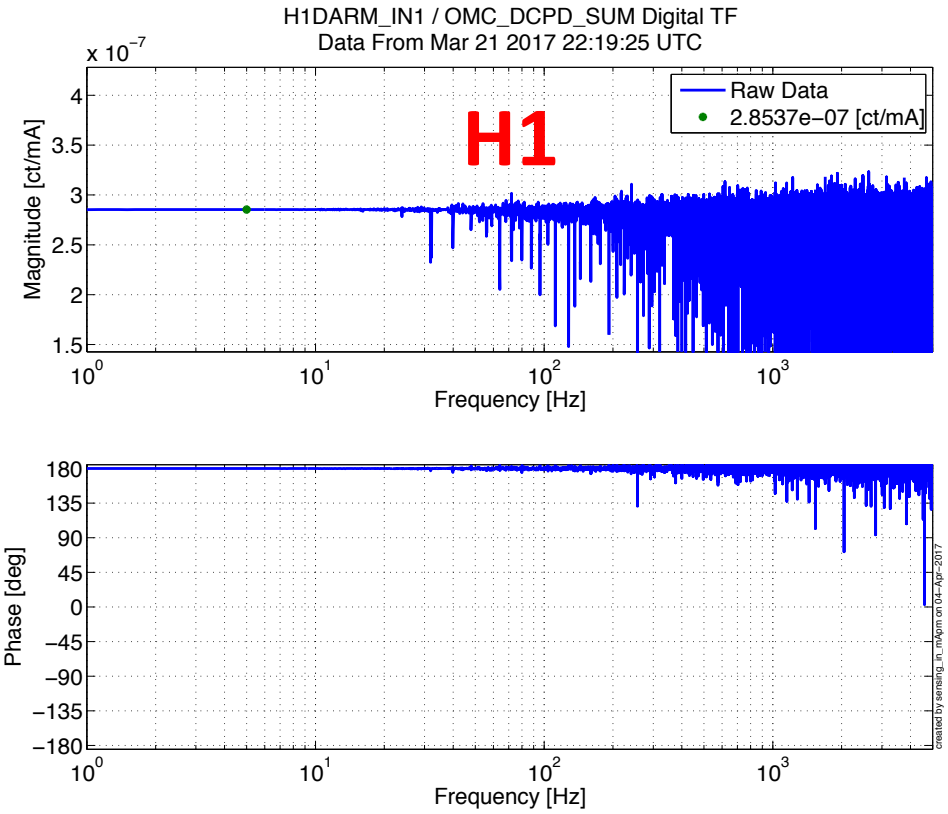
APPENDIX A: Sensing Function Units



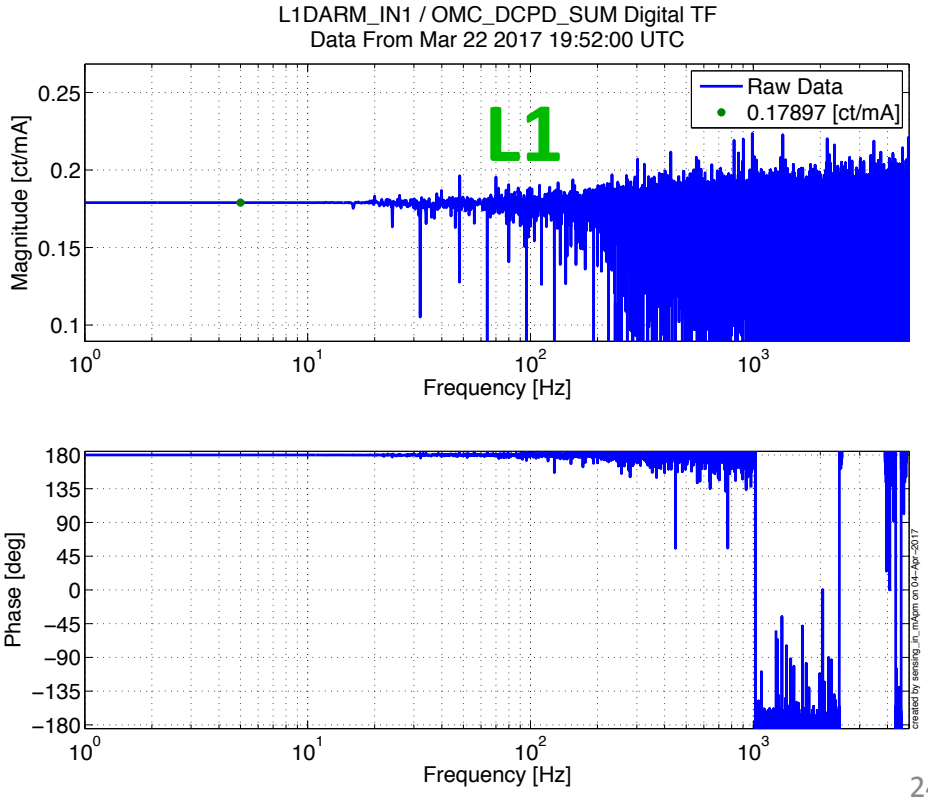
And as we've seen on pgs 2, 15 and 16, the open loop gains and actuation authority are virtually identical, so that gain discrepancy is made up for in the DARM banks.

Side note: as of O2, L1 still hasn't split their DARM bank into two, and that's shown here

APPENDIX A: Sensing Function Units

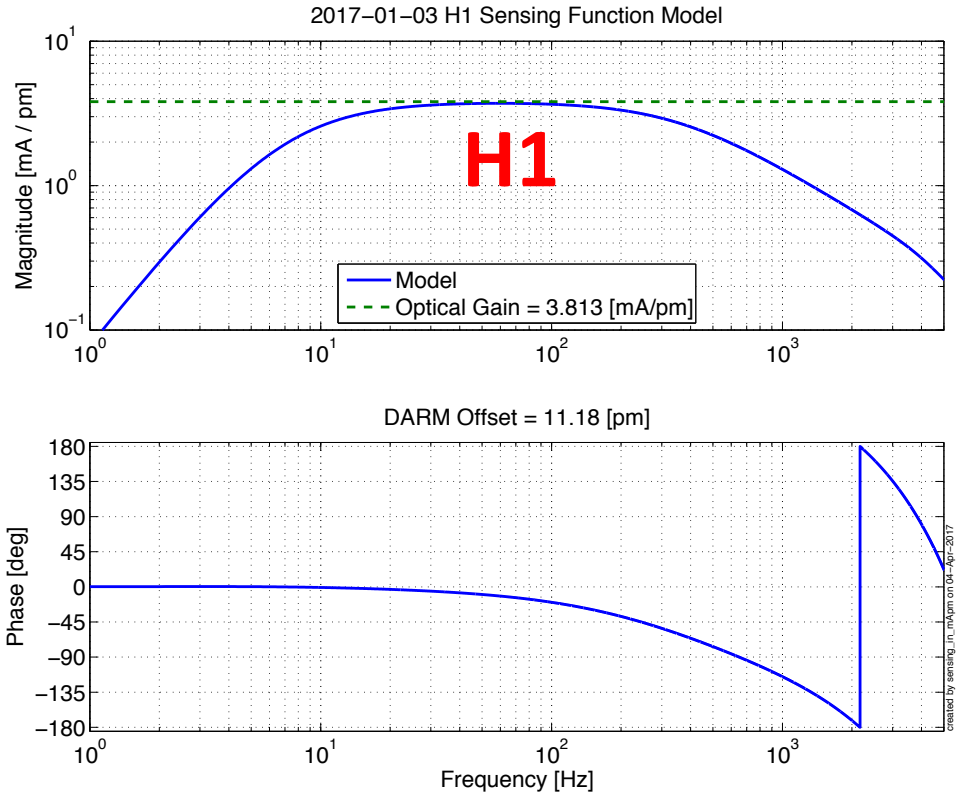


This explains the difference between the site's transfer function between the OMC DCPD SUMM (in [mA]) and DARM_IN1 (i..e DARM_ERR in [ct])



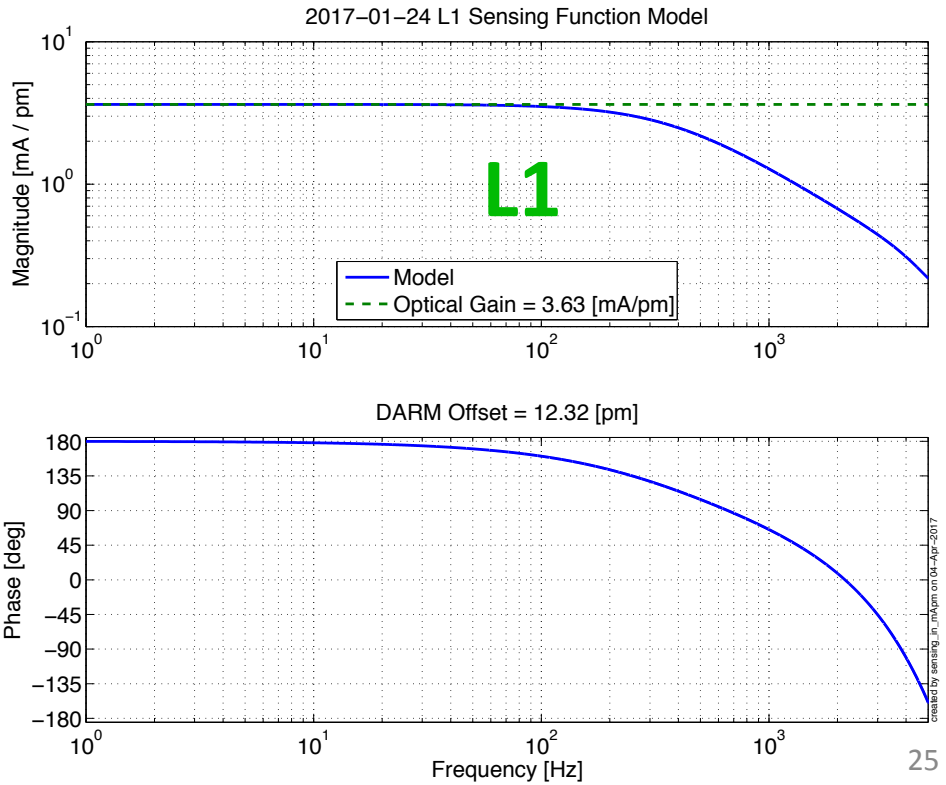
So, if we use this entirely digital transfer function to "correct" (namely, undo) the sensing function from DARM_ERR counts to mA on the DCPDs, we get….

APPENDIX A: Sensing Function Units



The modeled optical gain is about ~3.7 [mA / pm] for both observatories (and remember, measurement matches our model very well).

BUT, that "mA" is an function of how well commissioners filled out the DCPD banks – namely the "V2A" and "HiZ" filter modules in the OMC DCPD Banks



Side notes:

- the sites also chose different sides the the quadratic for the DARM offset, so the phase is 180 different at low frequency.
- Remember L1 doesn't include any SRC detuning, because they hadn't been able to measure it before O2 (now they have, see LLO aLOG 32495)

APPENDIX A: Sensing Function Units

Conclusions

- On a loglog plot, the two sites have virtually identical sensing function optical gains in physical units, as expected.
- The sensing function's optical gain in the DARM loop model is necessarily in unphysical units and very different in scale in order to cover the choices in digital gain distribution.
- For the purposes of a paper, the sensing function can be scaled from the model's unphysical units to physical units using the transfer function between

  `LSC-DARM_IN1_DQ / OMC-DCPD_SUM_OUT_DQ`

- But, if we want traceable accuracy and precision, we should be sure to understand how the digital filters in the DCPD banks were populated.