Ando Lab Seminar

Sep 7, 2018

Visitare Virgo 2018 Estate

Yuta Michimura

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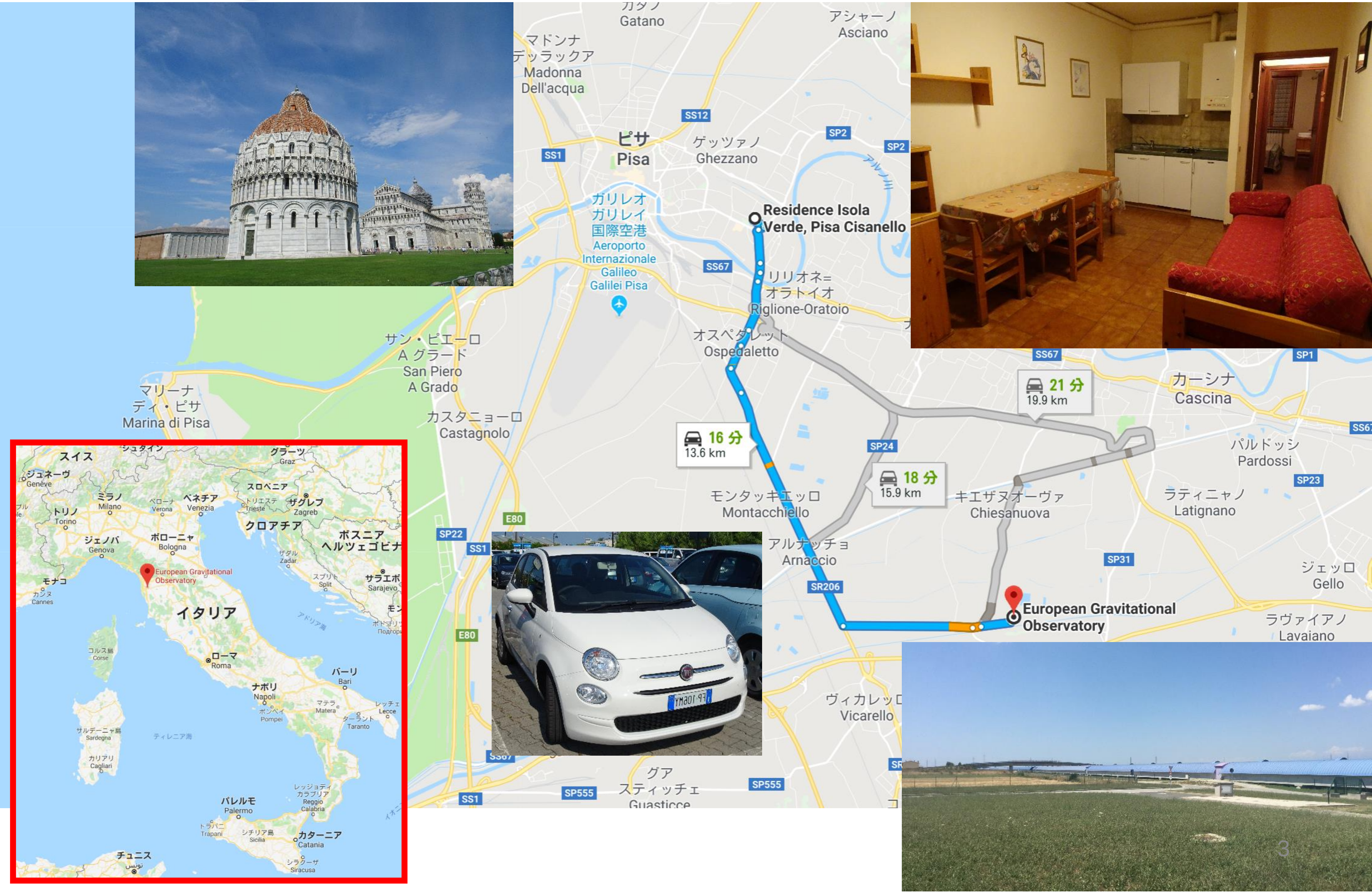
About

- Host: Alessio Rocchi
- Period:
  June 5 – 26 @ Virgo
  June 28 – 29 @ KIW4 Seoul
  July 2 – 7 @ MG15 Rome
  July 9 – Aug 11 @ Virgo
- Supported by
  東京大学 若手研究者の国際展開事業 (国際研鑽事業)
  Young Researcher's International Deployment Program

- My first visit to Virgo

Virgo is Located Close to Pisa



People Worked With

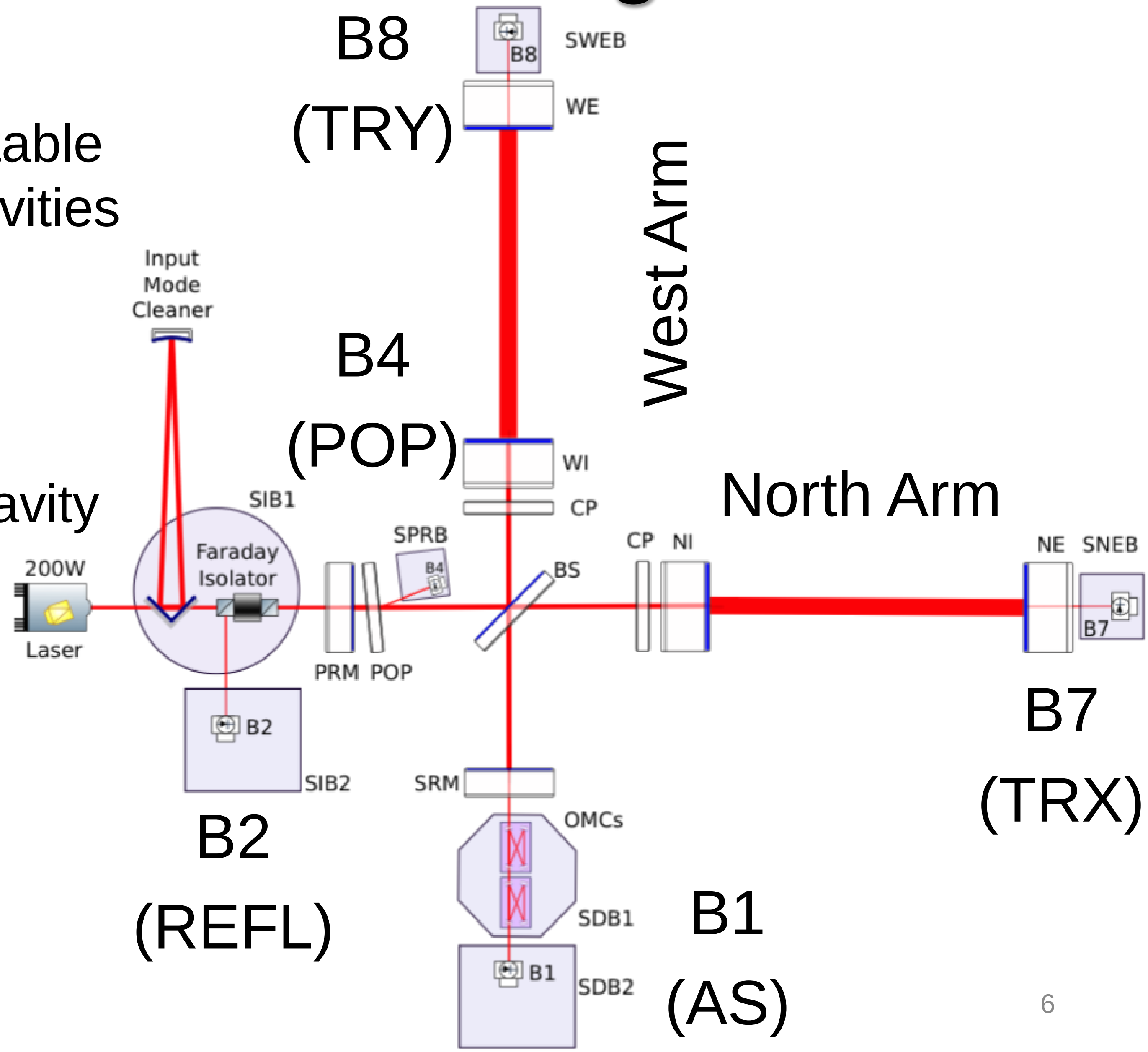
ISC etc.: Diego Bersanetti, Julia Casanueva, Franco Carbognani, Bas Swinkels (NIKHEF), Michal Was (LAPP), Terra Hardwick (LSU)
Optical Characterization: Annalisa Allocca, Antonino Chiummo, Jerome Degallaix (LMA)
Environmental Monitoring: Federico Paoletti, Irene Fiori
Injection System: Eric Genin, Camilla De Rossi, Gabriel Pillant
Suspensions: Paolo Ruggi, Valerio Boschi …… and many more

Contents

- **Advanced Virgo status**
  - interferometer configuration
  - sensitivity
  - lock sequence
  - locking issues
- **Selected commissioning topics**
- **Working environment**
- **Summary**

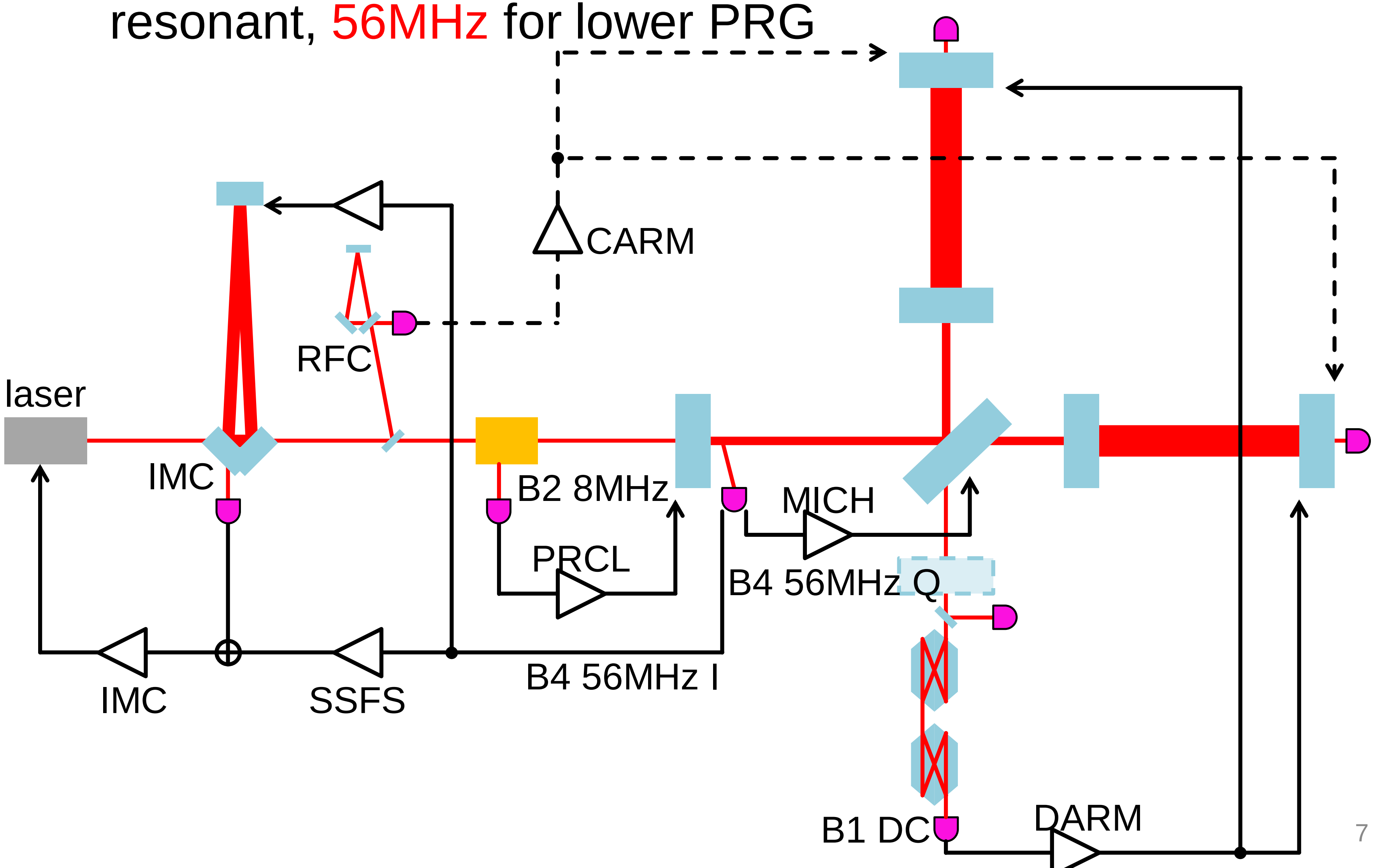
Interferometer Configuration

- 3 km arms
- Marginally stable recycling cavities
- No SRM yet (blank SRM)
- Two OMCs
- Reference cavity after IMC



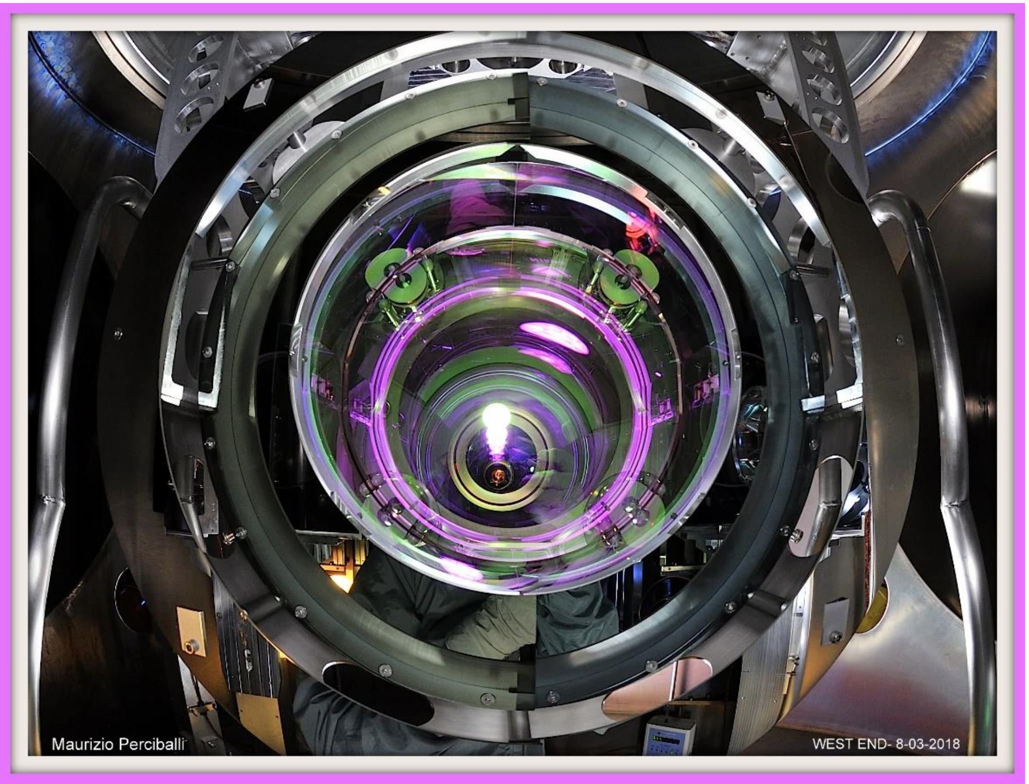
Full Lock Topology

- Sidebands: 6MHz only lock acquisition, 8MHz for non-resonant, 56MHz for lower PRG



Status

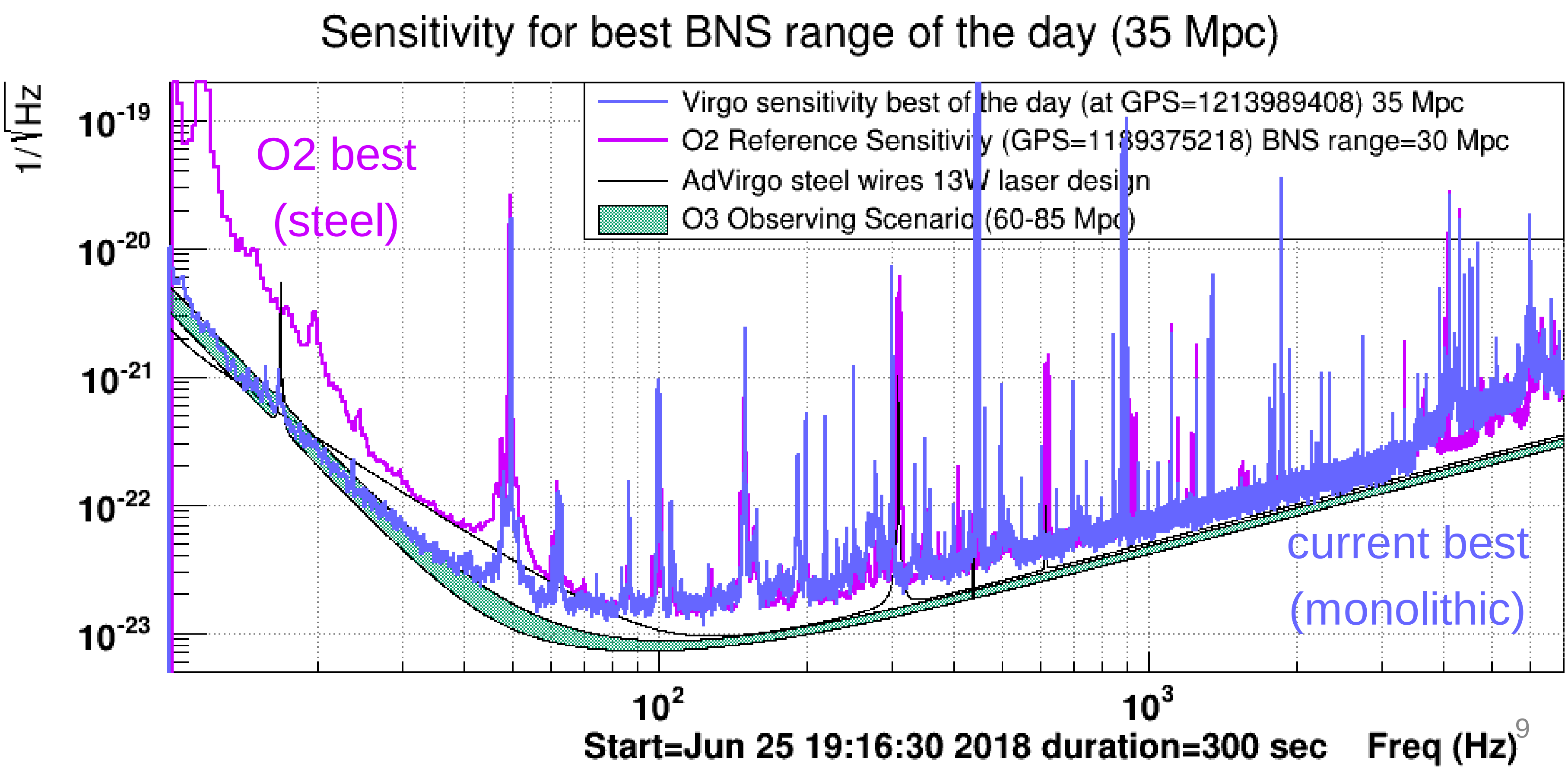
- See JGW-G1808906 by Raffaele Flaminio for clear summary of the status
- Monolithic suspension installation done in March
- Reached the best BNS range of 35 Mpc on June 25
- Increased the input power from 13 W to 25 W on June 26



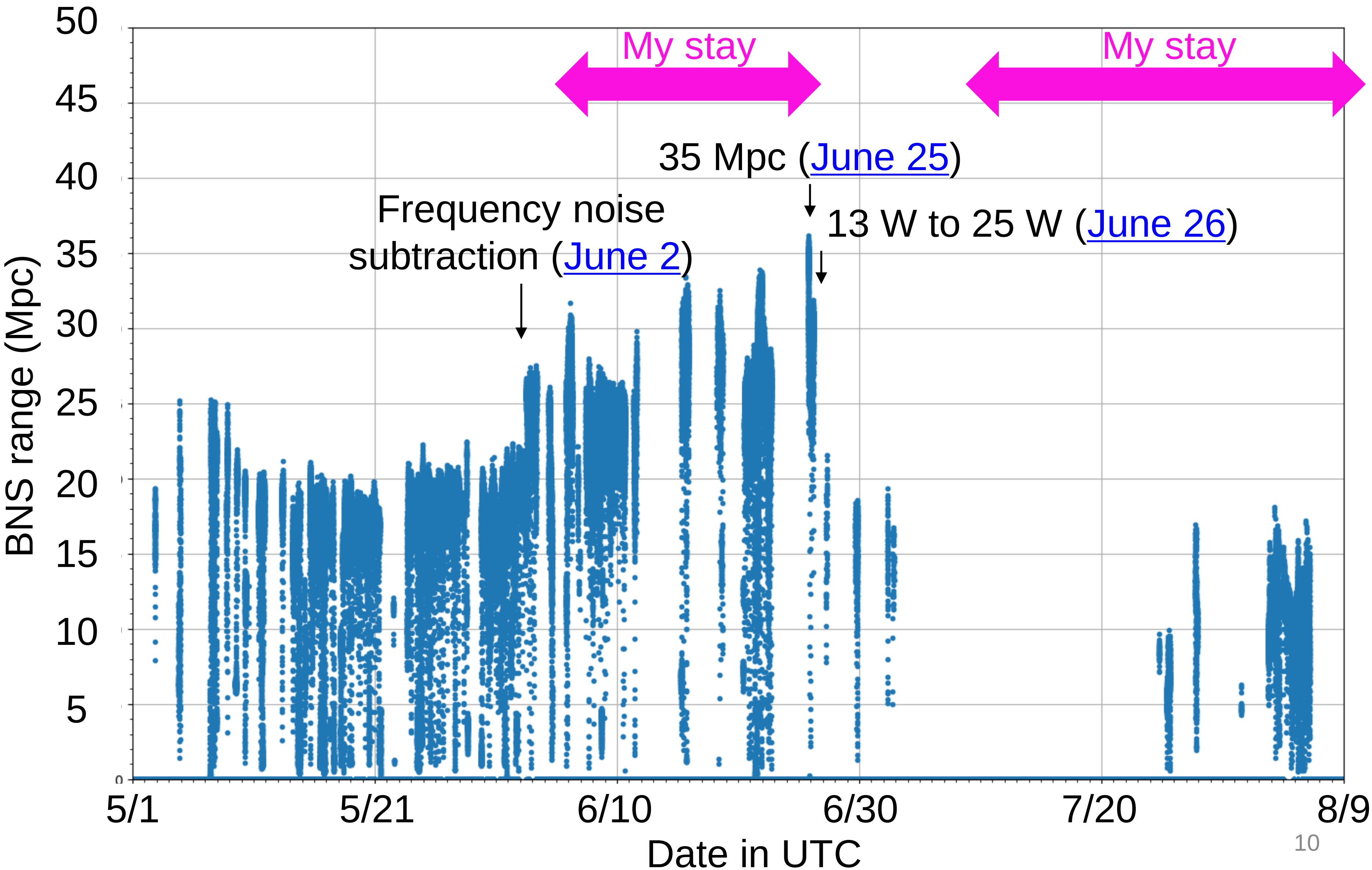
#40754, #40715

Best Sensitivity So Far

- BNS range of 35 Mpc achieved on June 25
- Low frequency sensitivity compliant with O3 goal, and better than thermal noise from steel wires

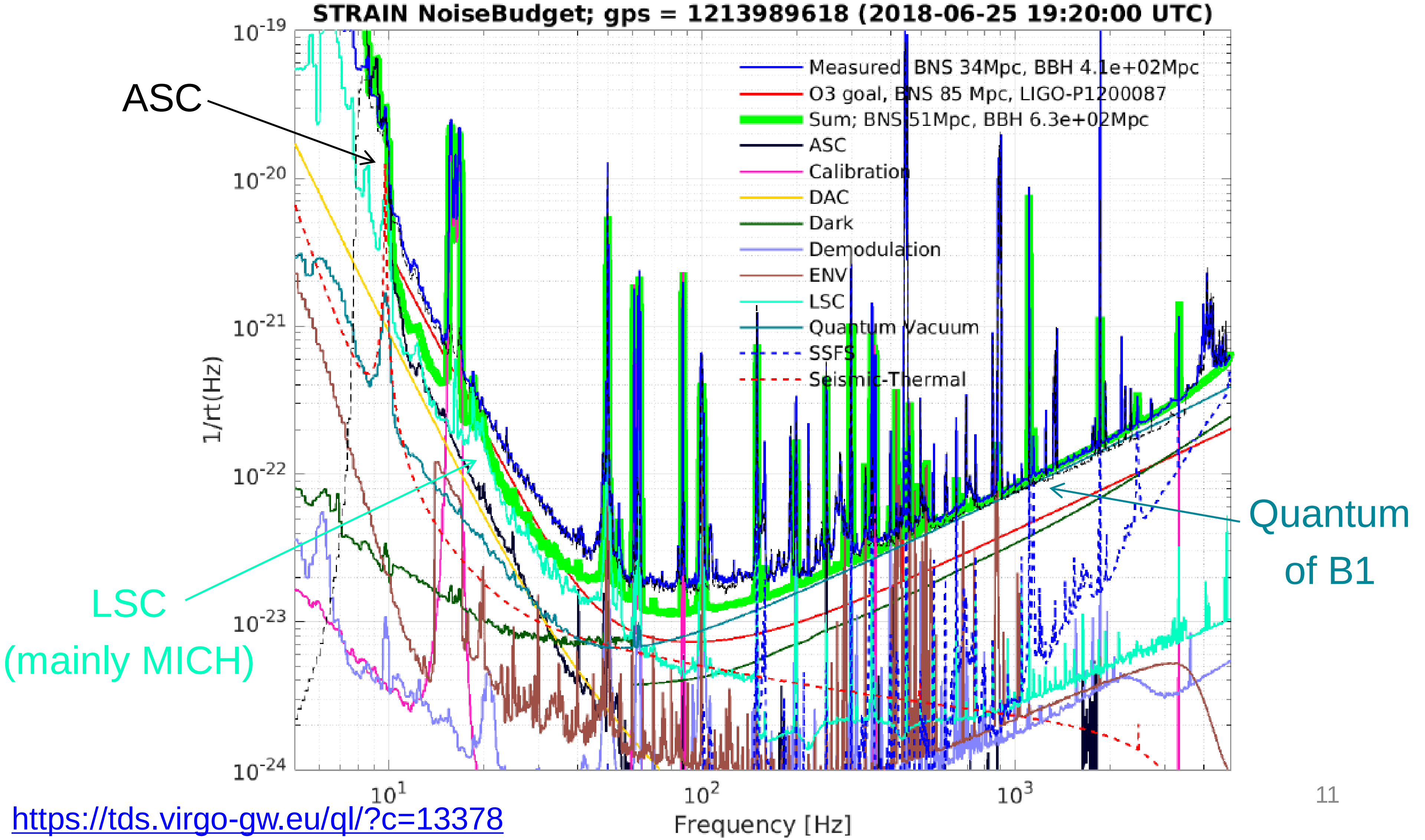


BNS Inspiral Range Evolution



Noise Budget at 13 W

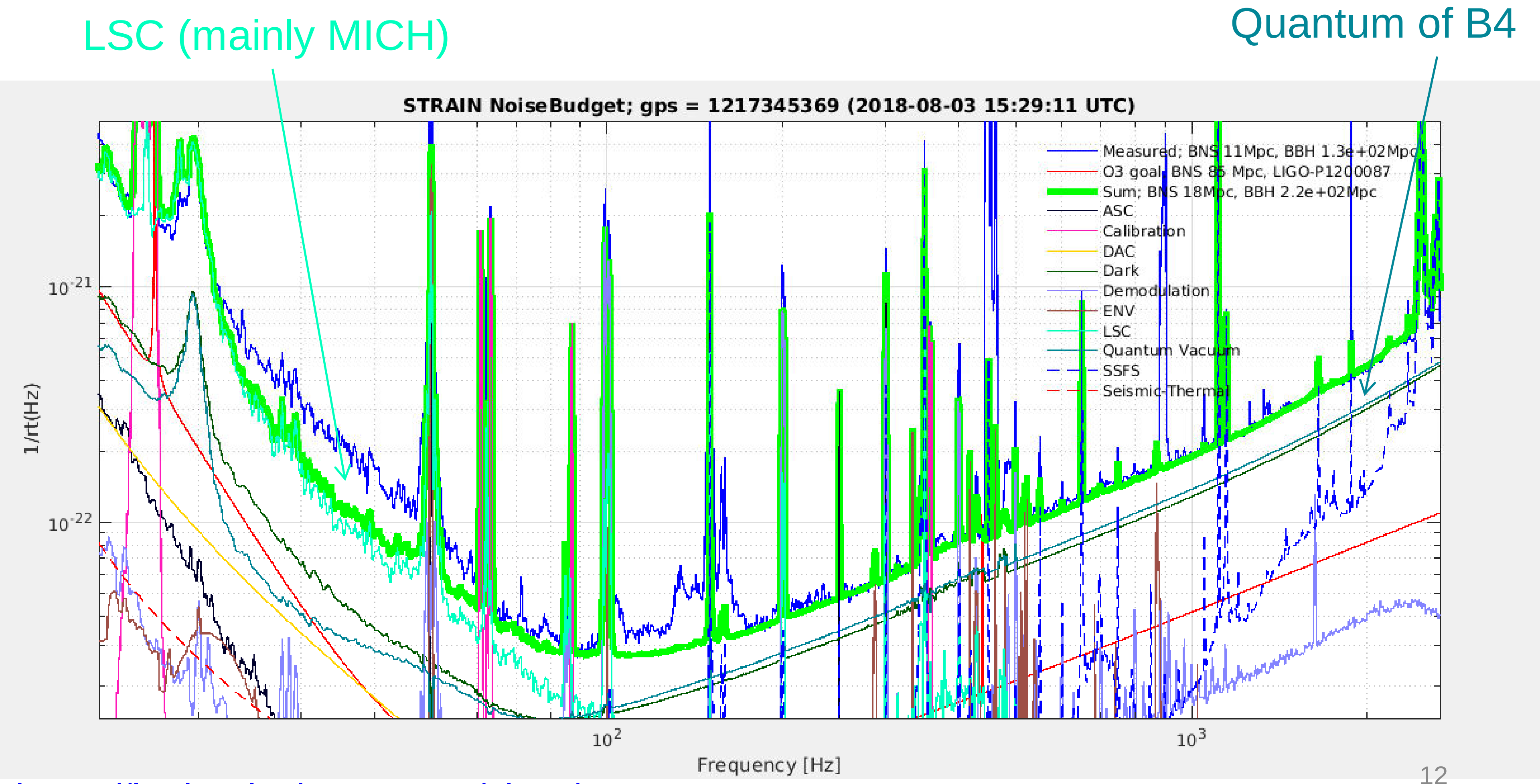
- shot noise above 600 Hz, unexplained noise at bucket



https://tds.virgo-gw.eu/ql/?c=13378

Noise Budget at 25 W

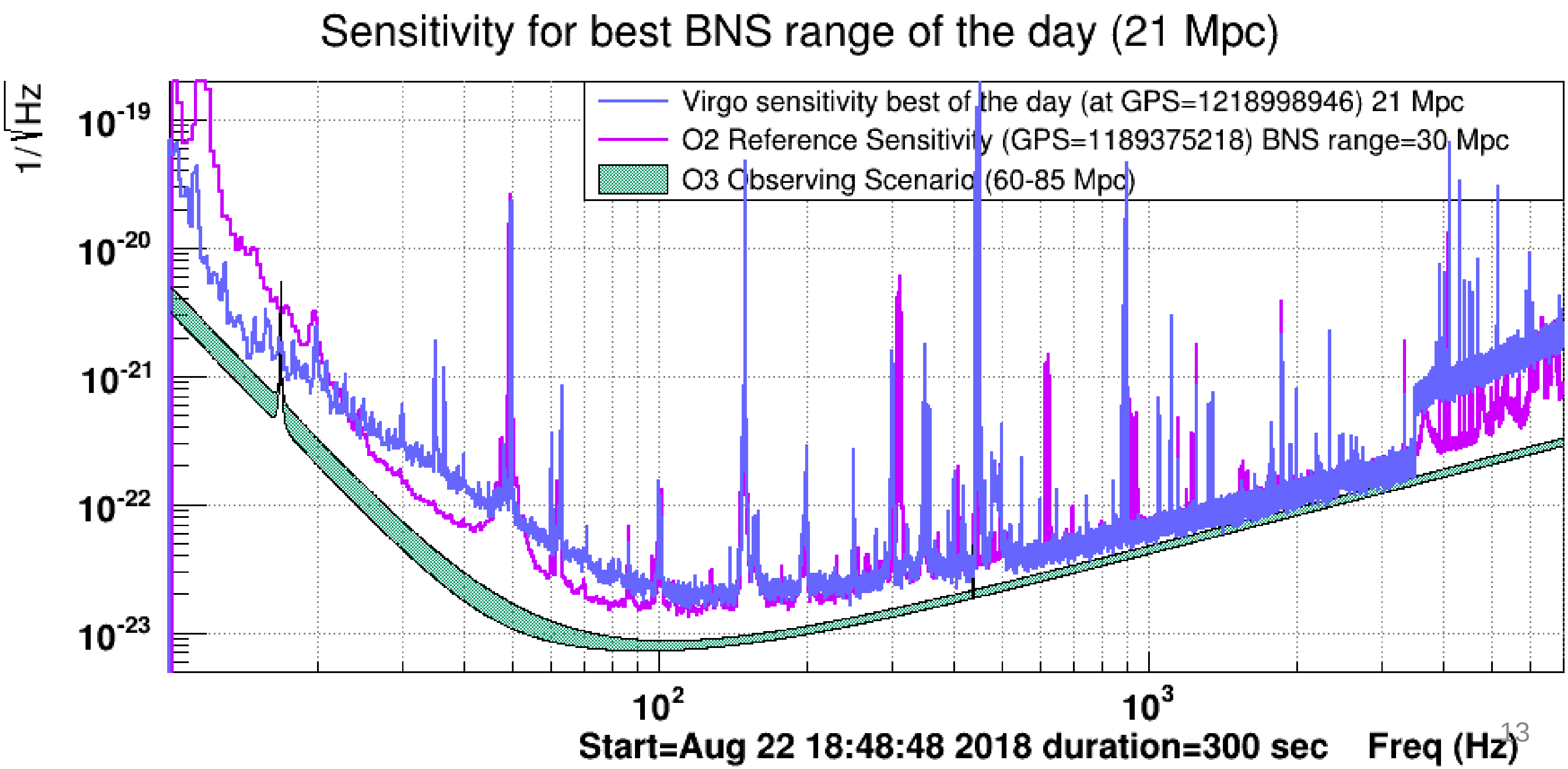
- Shot noise from B4 for MICH and SSFS (56MHz in PRC is half compared with 13W), couples as frequency noise



https://logbook.virgo-gw.eu/virgo/?r=42323

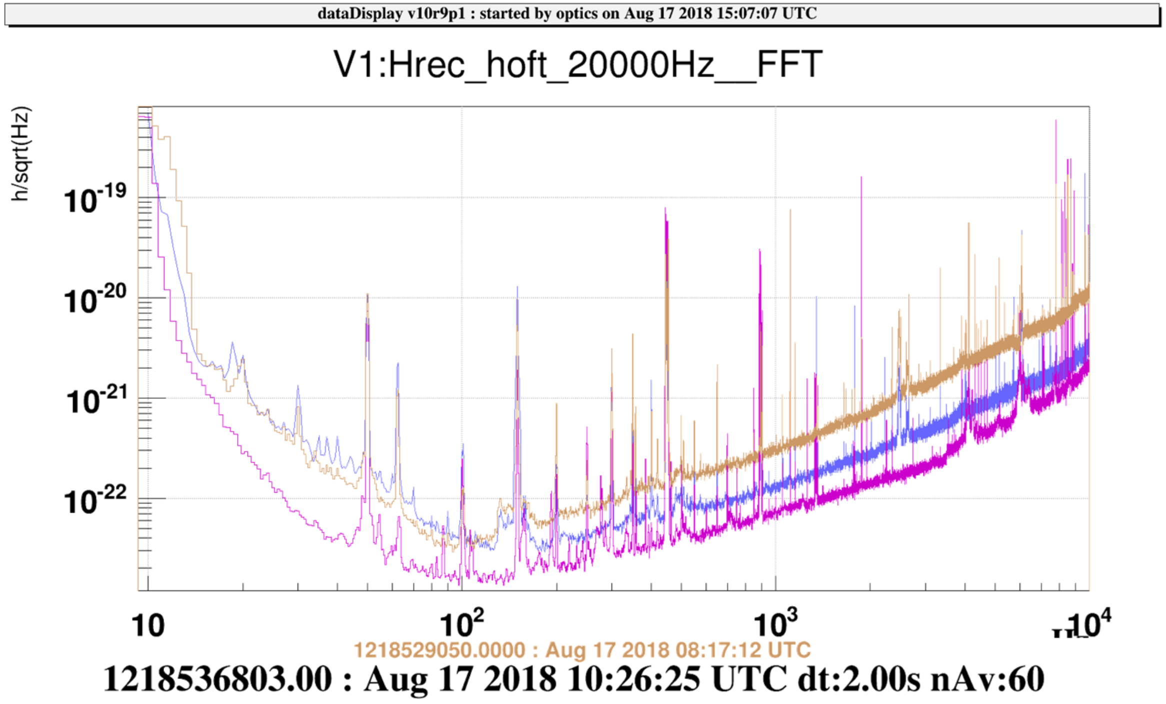
Frequency Noise Subtraction

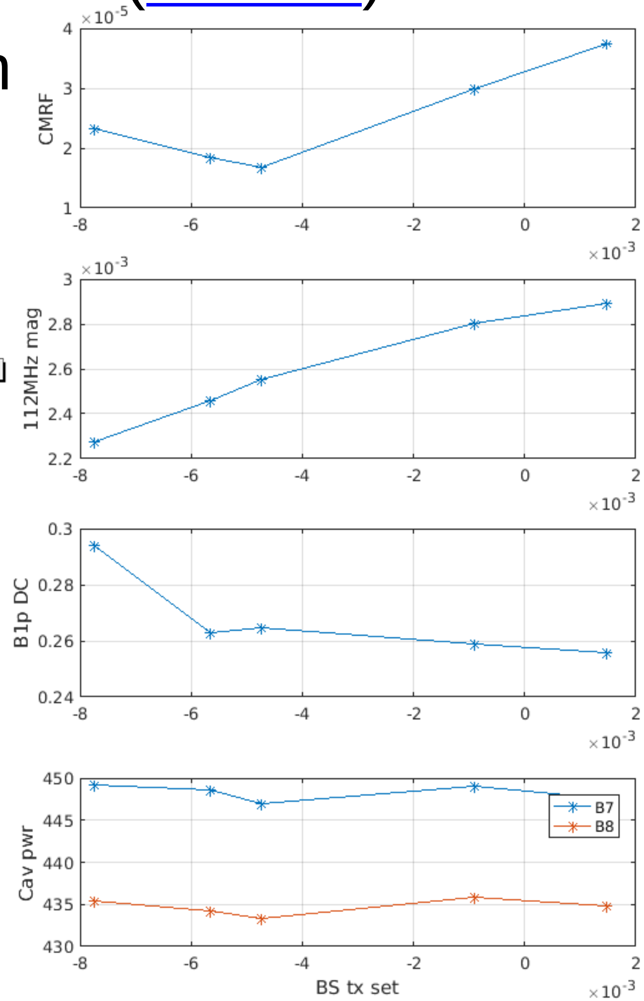
- Reactivated on Aug 20 (#42483) after I left
- B2 8MHz I (PRCL) is used for frequency noise sensor (VIR-0396A-18)



CMRF Investigations

- Common mode rejection factor (CMRF) and thus the sensitivity depends on the BS alignment (#42469)
- But good working point do not match with 56MHz sideband build-up
- Under investigation…



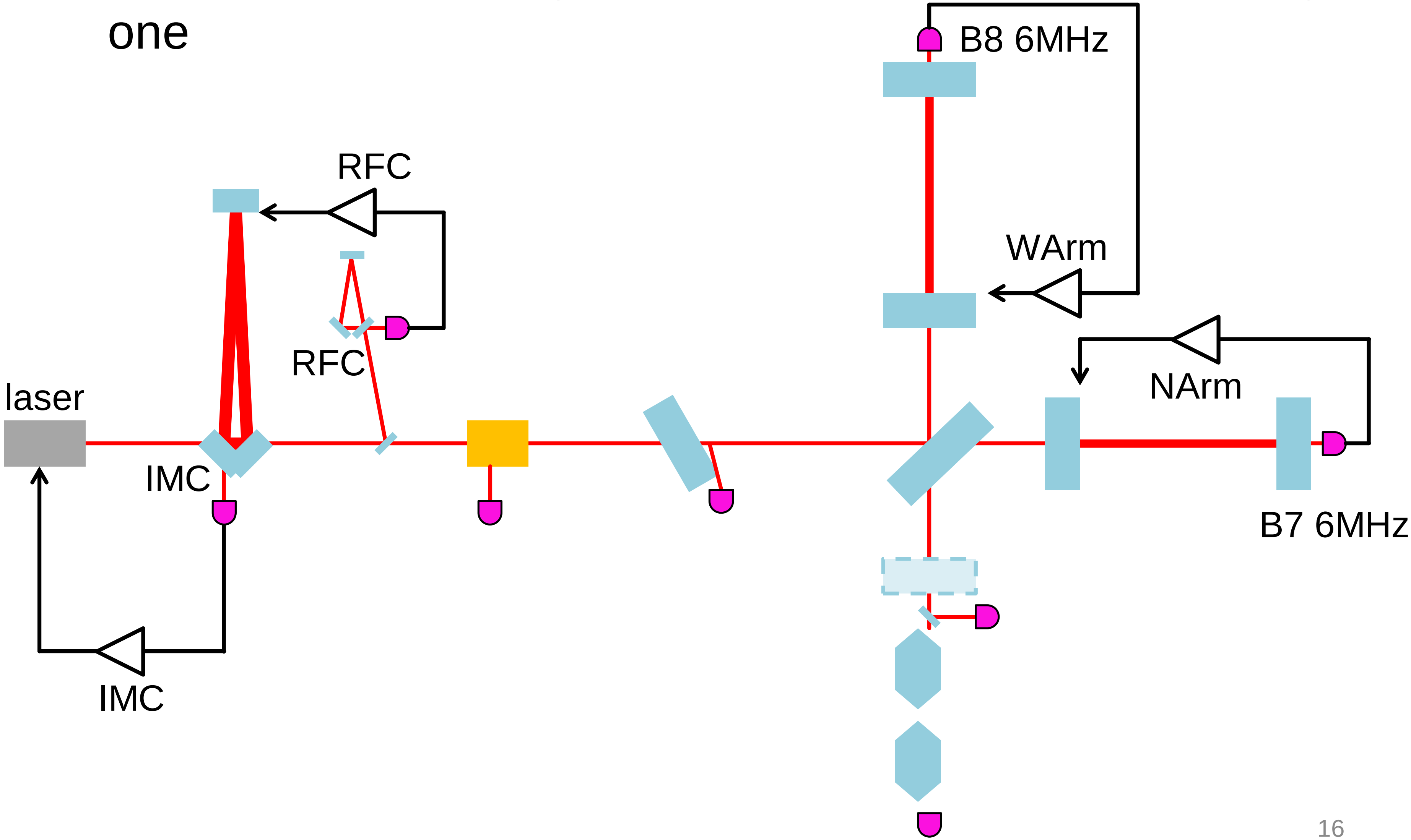


Locking Issues at 25 W

- Took a month to recover the full lock stably after increasing the power from 13 W to 25 W (#42188)
- Photodiode DC/RF saturations
  - power changes by an order of magnitude during variable finesse
  - broadband PD for all the ports (digital demodulation)
  - locking with high power (LIGO locks at lower power and increases the power after the full lock)
  - (tentatively) solved by reducing the modulation depths and reducing the power on PDs
- Thermal compensation
  - stable lock was not possible without activating the TCS by compensation plates

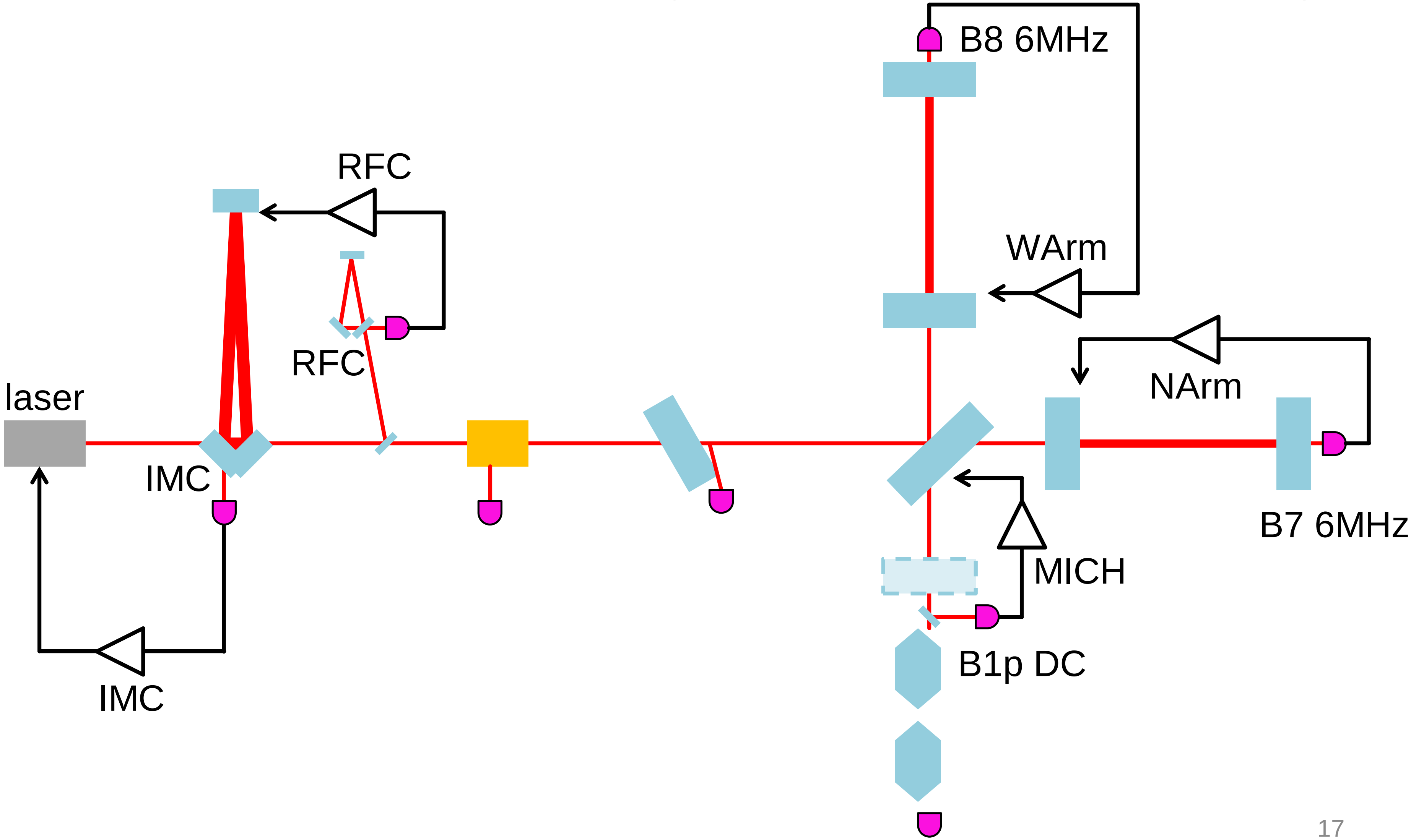
Lock Sequence 1: Lock Arms

- Lock both arms using arm transmission at 6MHz, one by one



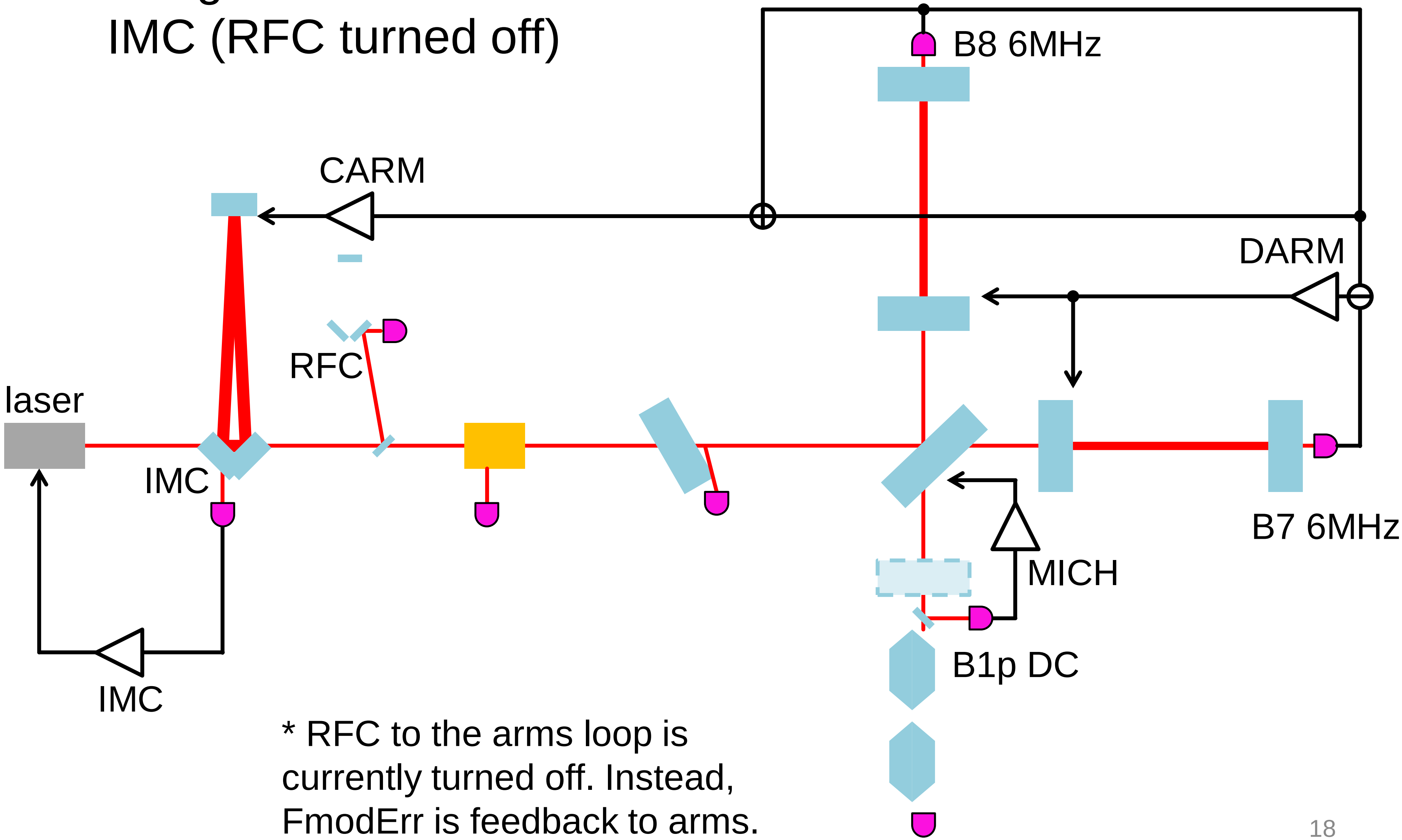
Lock Sequence 2: Recombined

- Lock MICH to form a Fabry-Perot Michelson at half fringe



Lock Sequence 3: CARM to MC

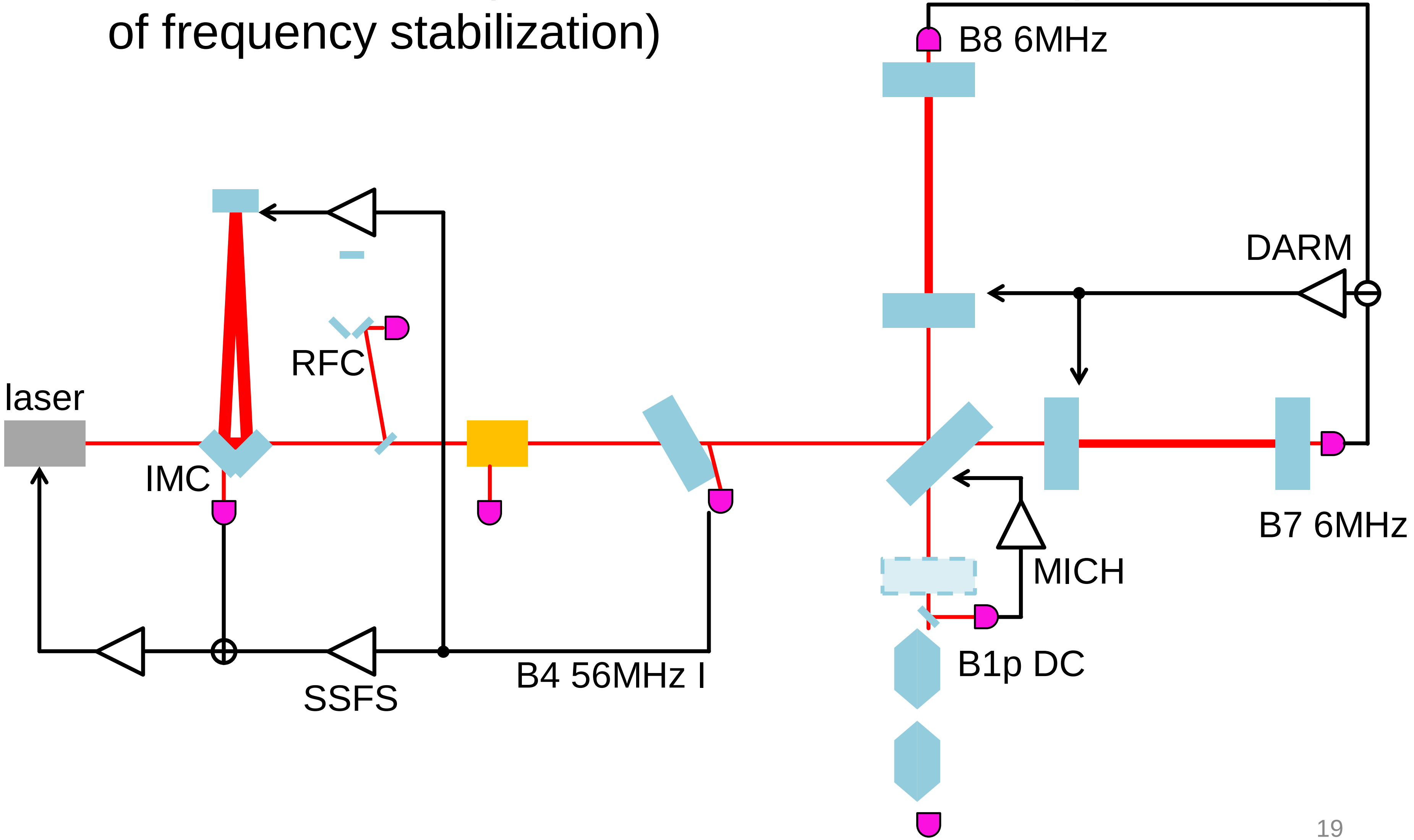
- Chage the basis to DARM/CARM and feedback CARM to IMC (RFC turned off)



* RFC to the arms loop is currently turned off. Instead, FmodErr is feedback to arms.

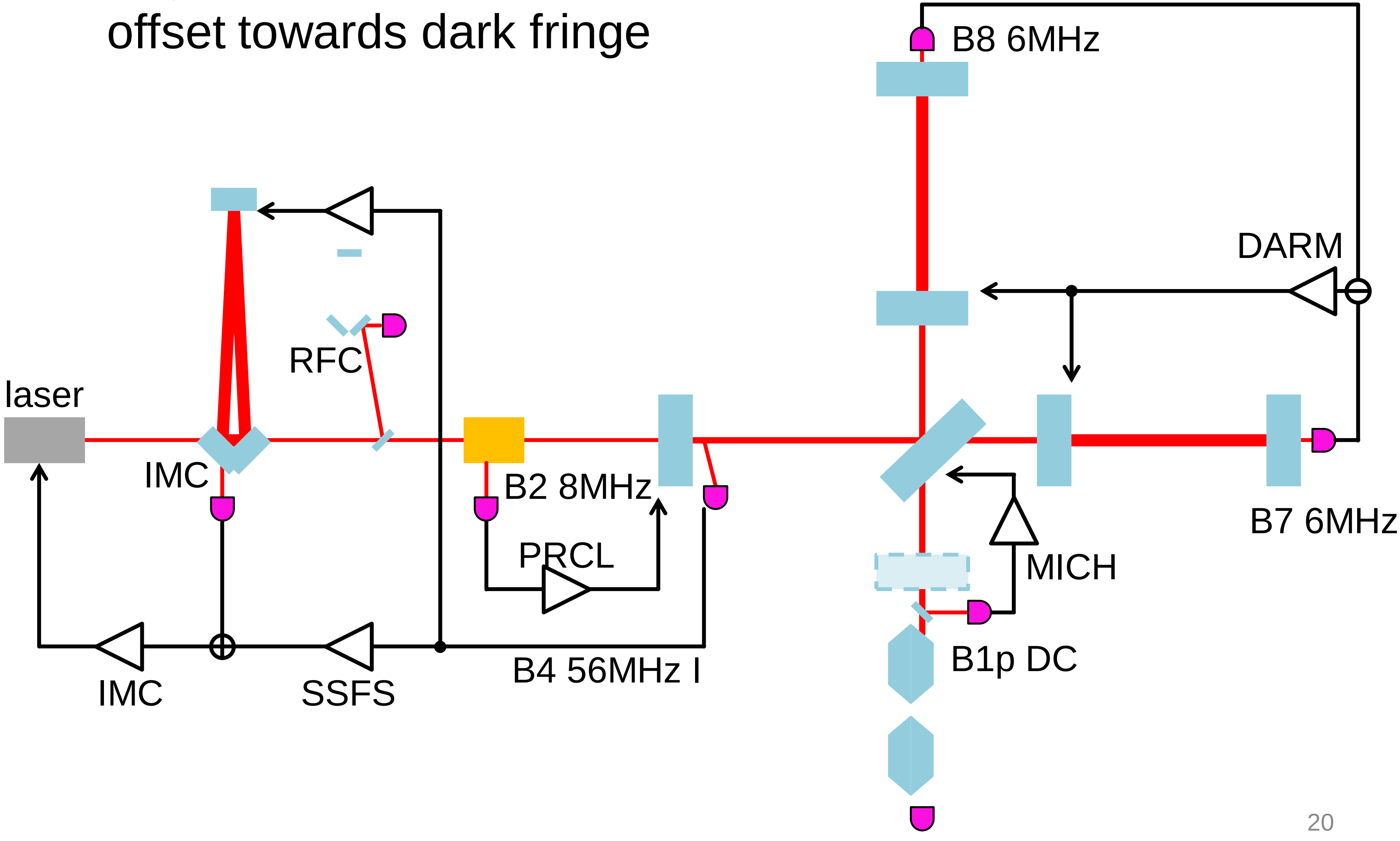
Lock Sequence 4: Lock SSFS

- Switch CARM loop to B4 56MHz I for SSFS (second stage of frequency stabilization)



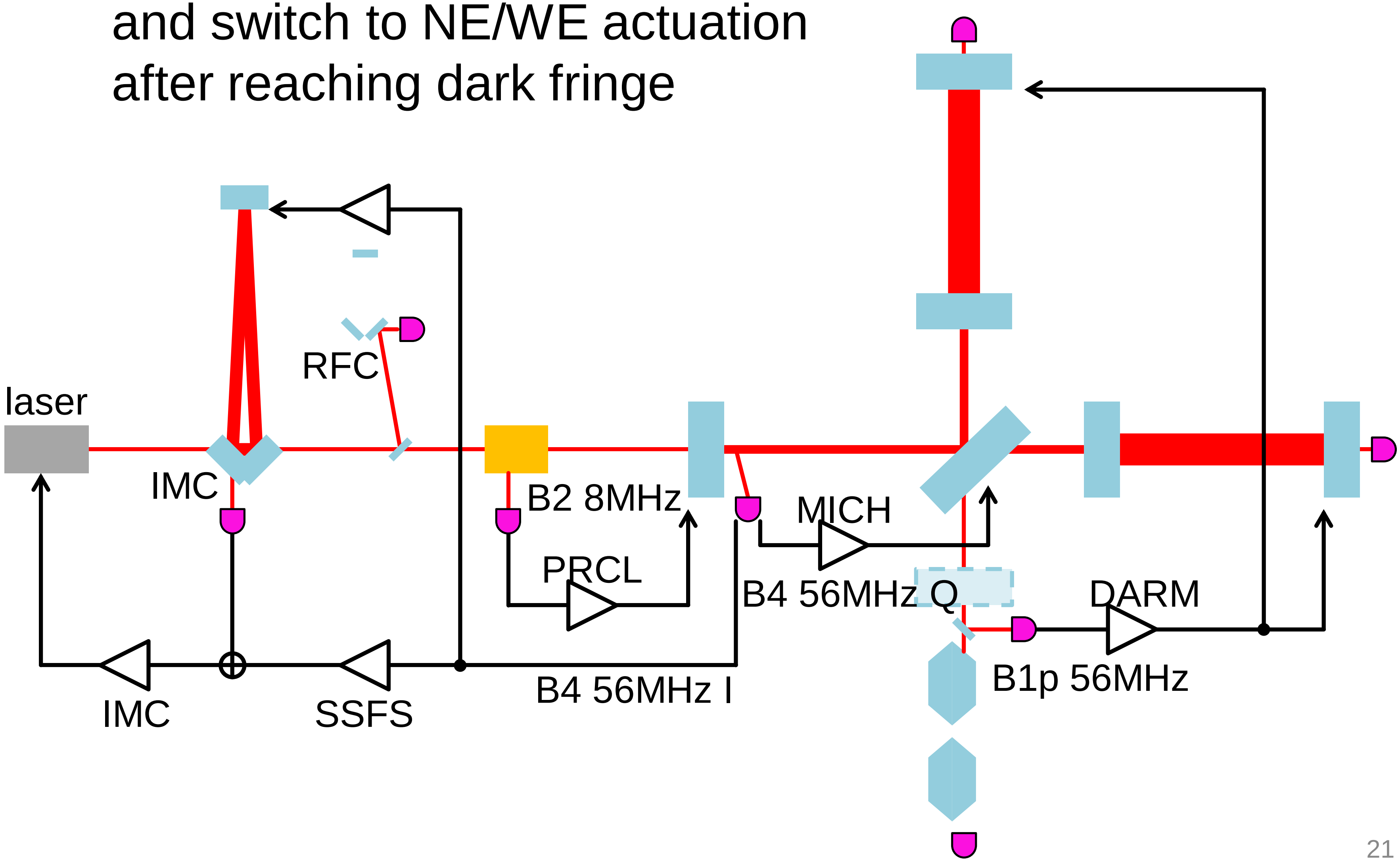
Lock Sequence 5: Variable Finesse

- Align PRM, lock PRCL at MICH offset 0.7 and reduce MICH offset towards dark fringe



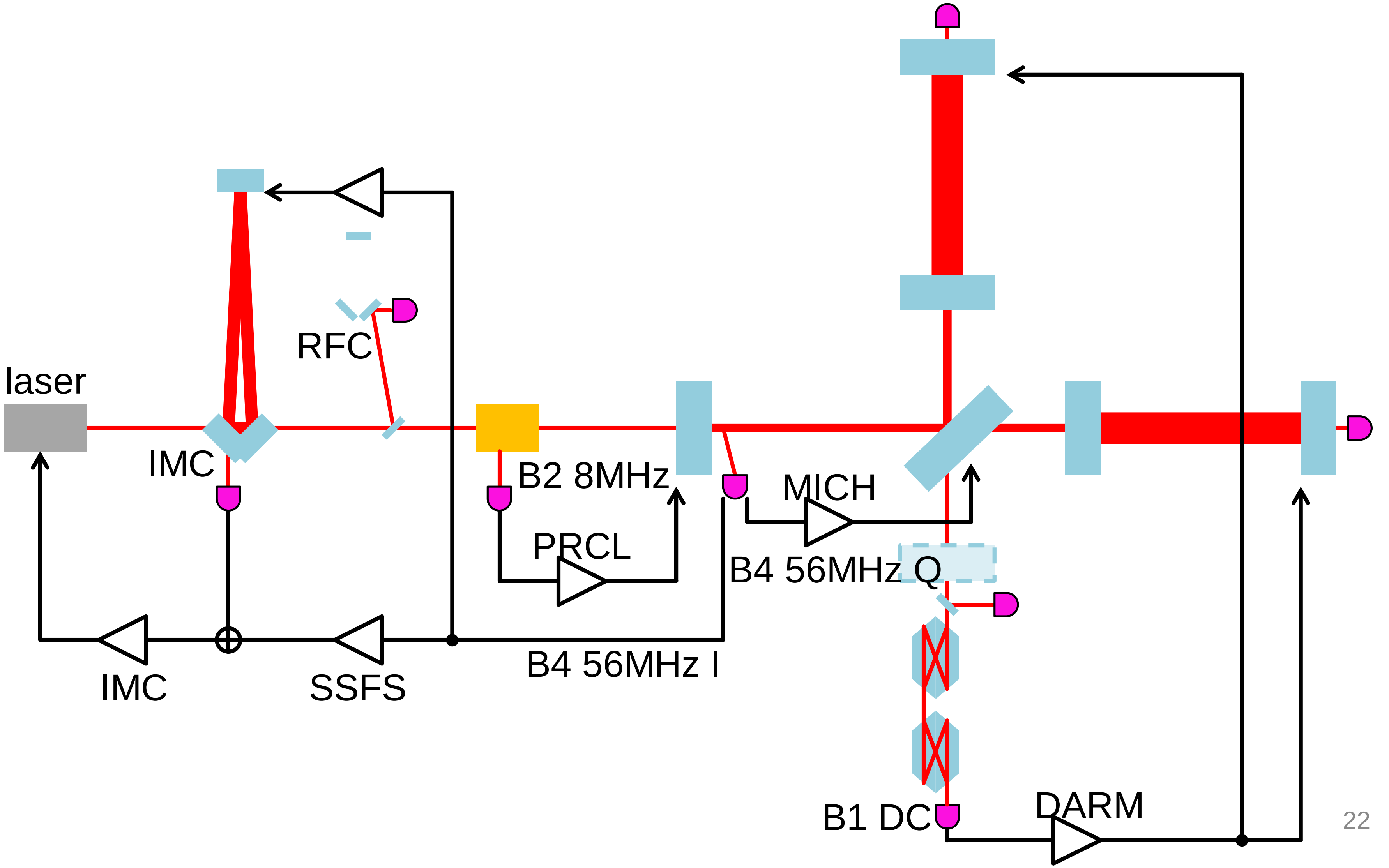
Lock Sequence 6: Dark Fringe

- Switch to MICH to RF, DARM to dark port (turn 6MHz off), and switch to NE/WE actuation after reaching dark fringe



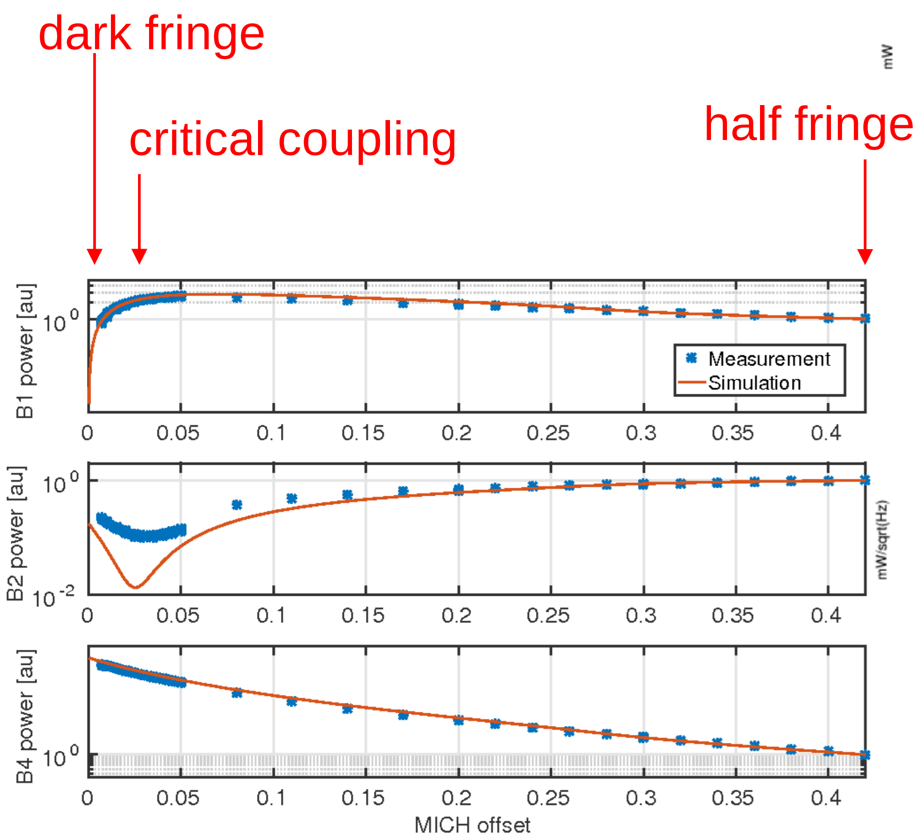
Lock Sequence 7: DC Readout

- Lock two OMCs and reach DC readout

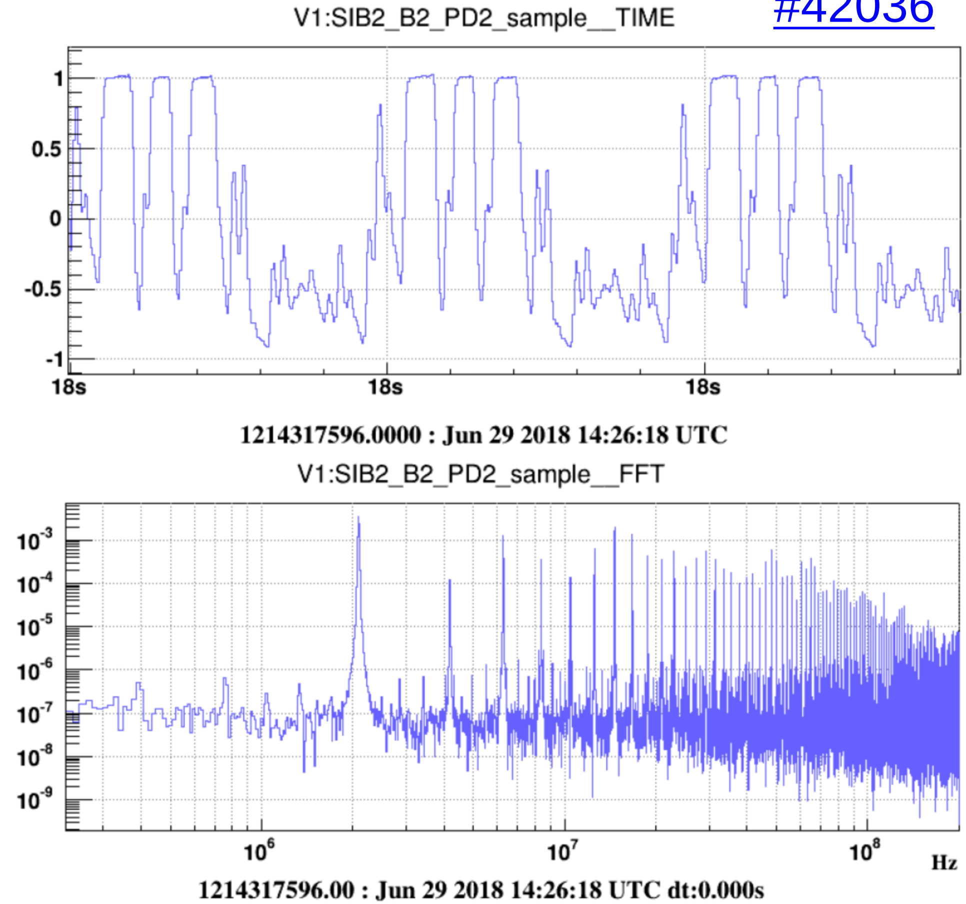


Photodiode Saturations

- DC and RF saturations prevented from reaching dark fringe reliably



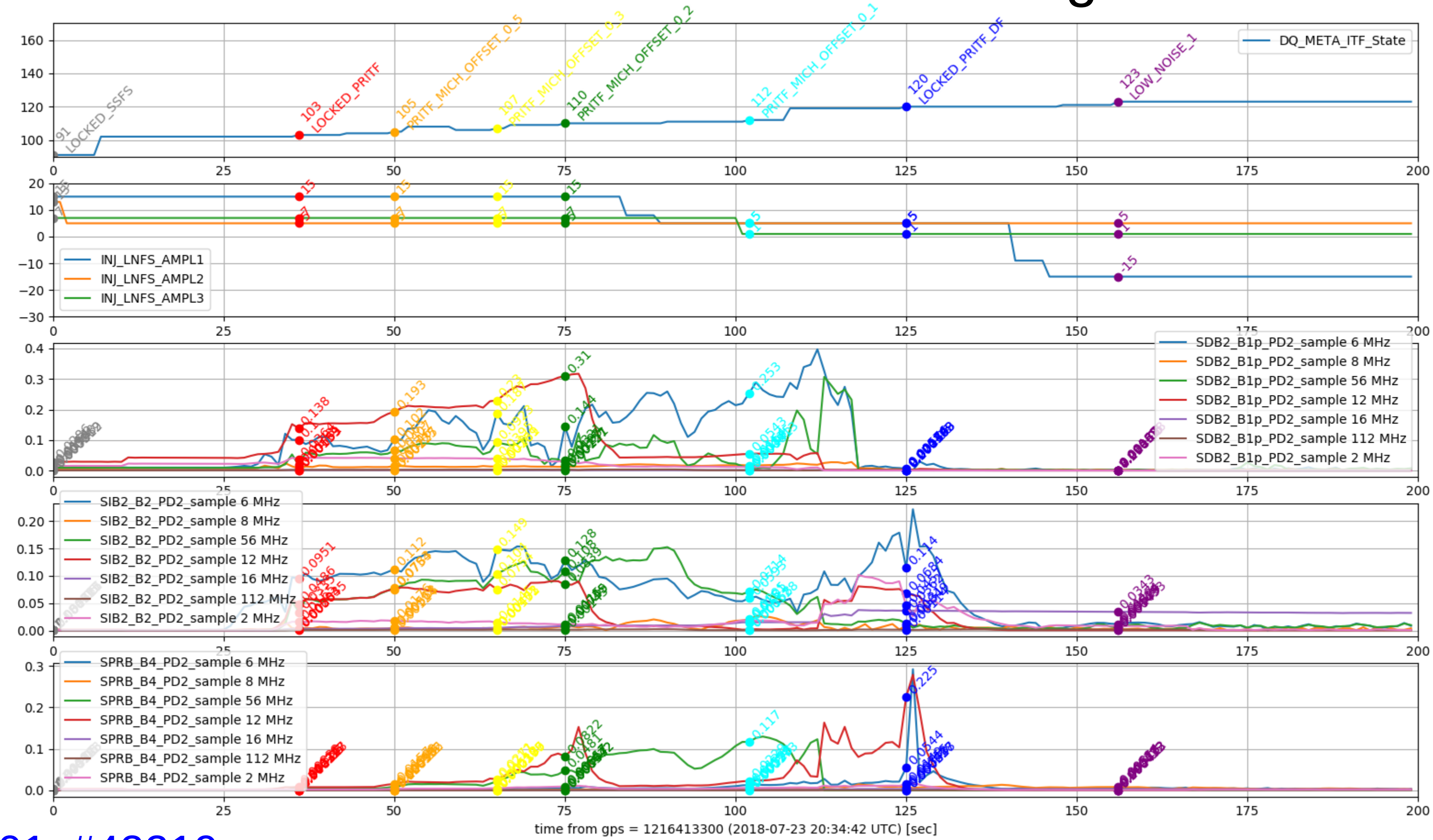
[#42036]



[VIR-0116A-18]

Photodiode Saturations

- (tentatively) solved by reducing the modulation depths and reducing the power on PDs
- notches to be installed to have more margins

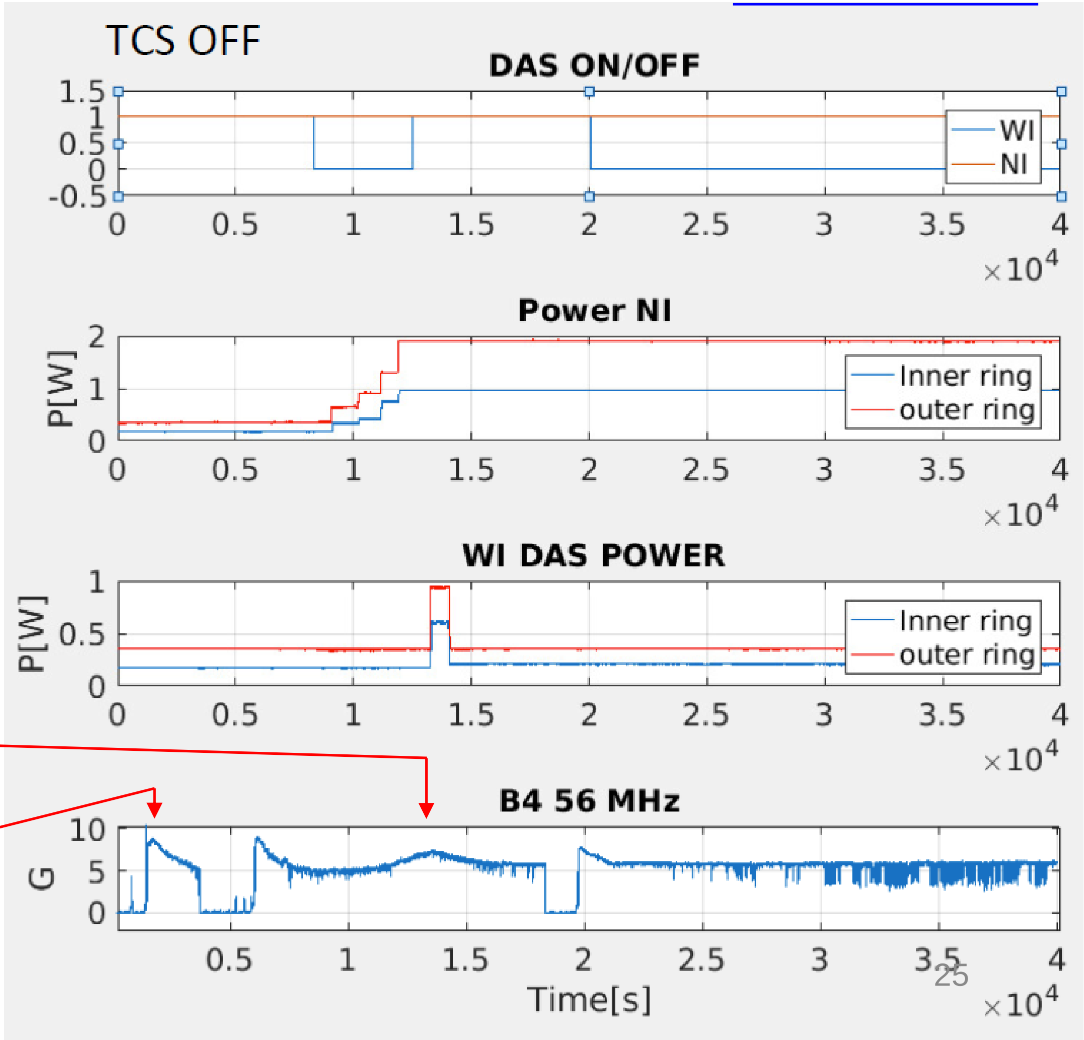


[#42201](), [#42219]()

Thermal Compensation (TCS)

- NI CO_2 laser helps recovering 56MHz sideband build-up
- WI CO_2 laser have little effect (misaligned?)
- NI CO_2 laser turned always on for stable lock
- Activities in progress…

[VIR-0566A-18]



56MHz recovers with TCS

56MHz decays (~1000 sec) without TCS

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Thermal Compensation System

- Double axicon system (DAS)

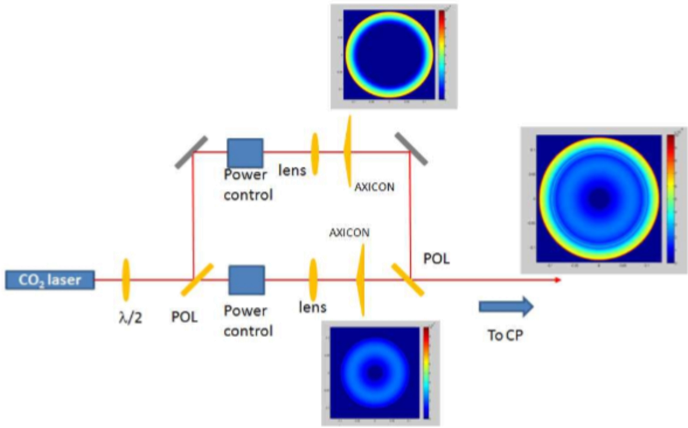
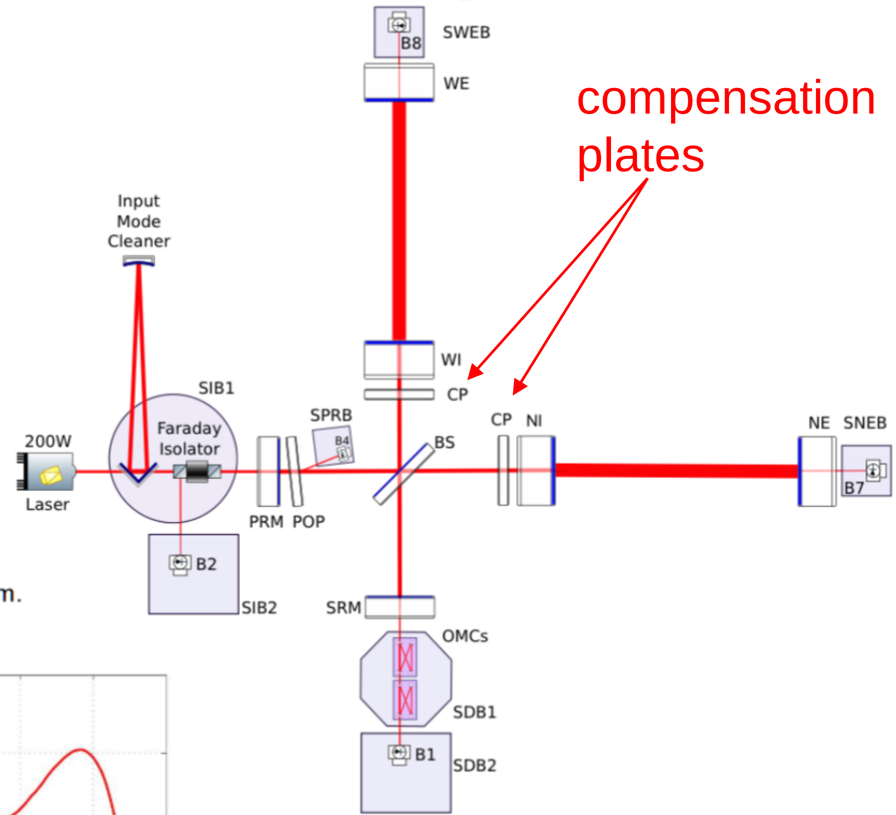


Figure 6.19: Conceptual design of a double axicon compensation system.



compensation plates

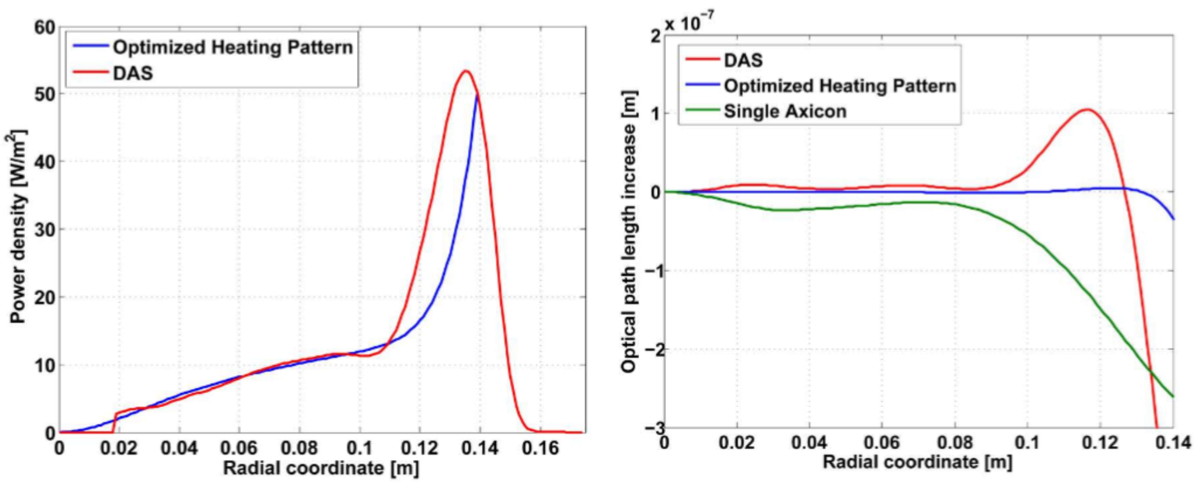
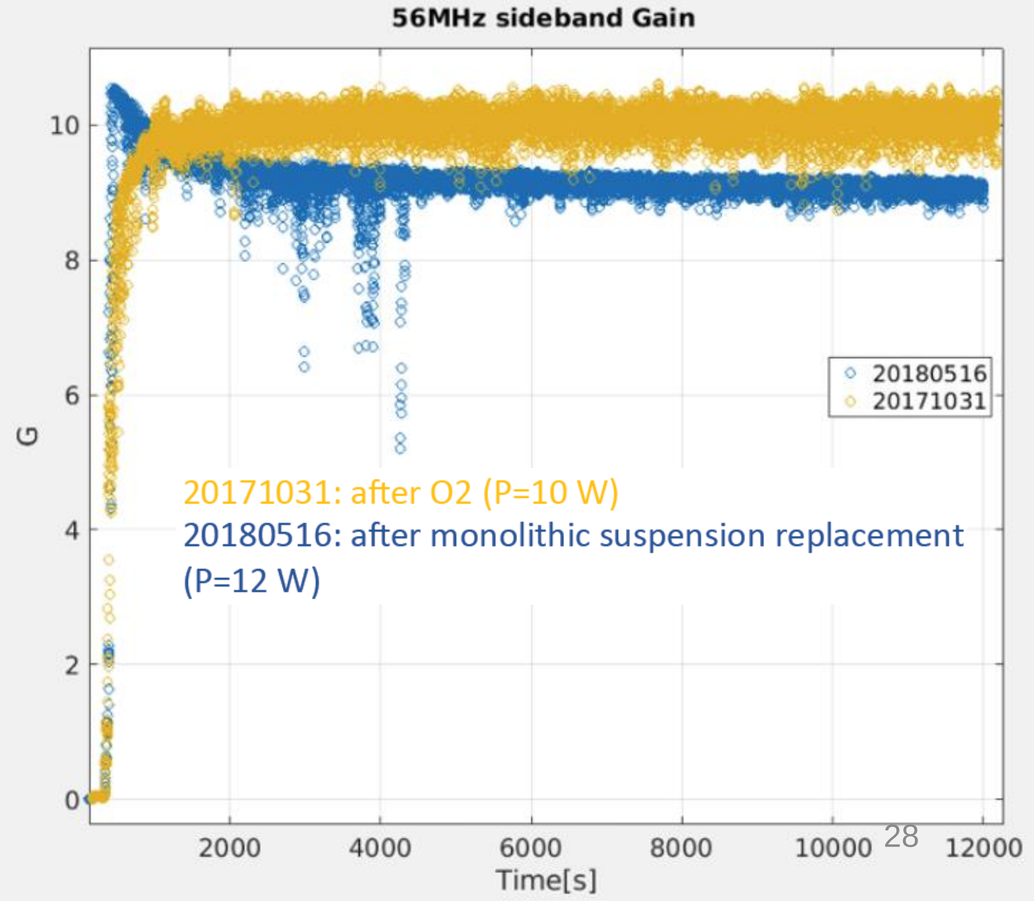


Figure 6.20: Left: the double axicon heating pattern (red) compared to the optimized heating pattern (blue). Right: corresponding optical path length increase (optimized heating pattern is in blue and the DAS is in red). Also the OPL given from a single axicon system (green) is reported for comparison.

[Advanced Virgo Technical Design Report]

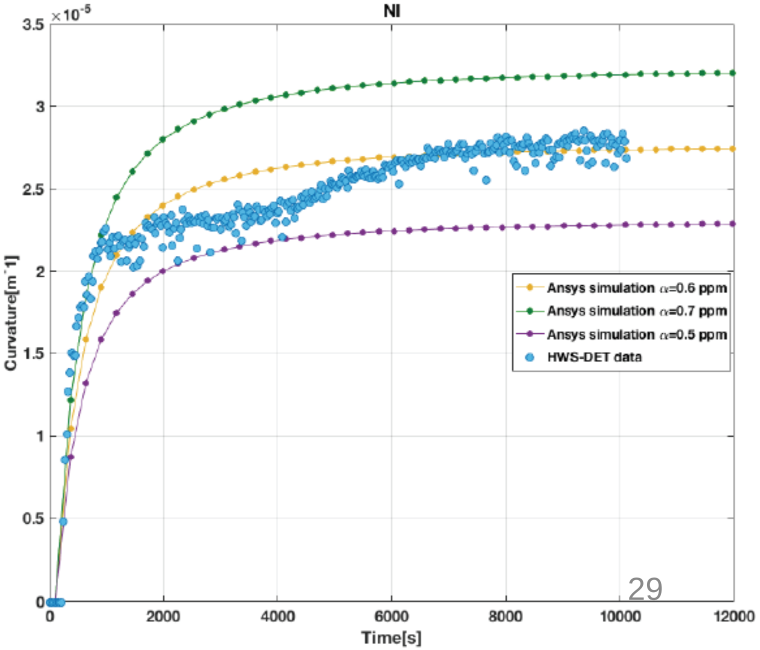
56MHz Recycling Gain

- Overshoots after the monolithic suspension replacement
- Decay at time constant of ~1000 sec (#41817)
  - thermal lensing time constant
  - shorter than mirror bulk heating time constant (~ few days)
- Overshoot could be due to power increase and/or absorption increase (according to study by TCS team)



Absorption Measurements

- Done by RoC measurements using Hartmann Wavefront Sensor (HWS)
- WI
  before monolithic: 0.39 +/- 0.06 ppm
  after monolithic: 0.36 +/- 0.07 ppm
- NI
  before monolithic: no measurement (0.19 ppm by LMA)
  after monolithic: 0.6 +/- 0.1 ppm

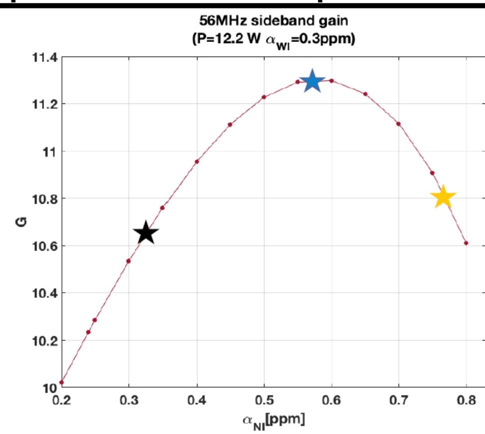


Overshoot and Absorption

- If we fix input power and WI absorption, there is an optimum NI absorption in terms of 56MHz recycling gain
- Overshoot happens if NI absorption is higher than optimal (reaches maximum when NI and WI RoC become equal, but degrades afterwards; never reaches equal if NI absorption is smaller than optimal)

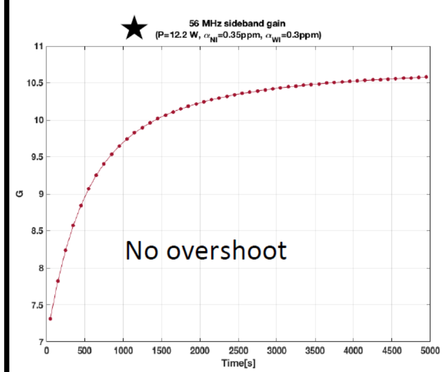
OSCAR simulations

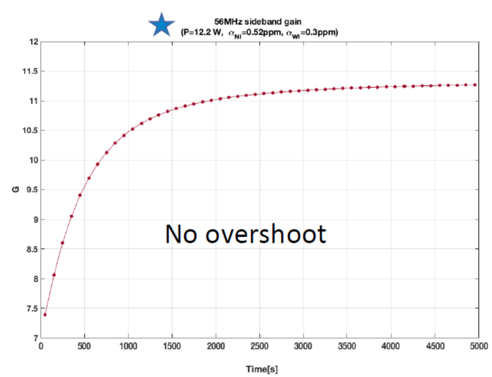
- examples of SB behavior with YAG at different powers (no TCS)

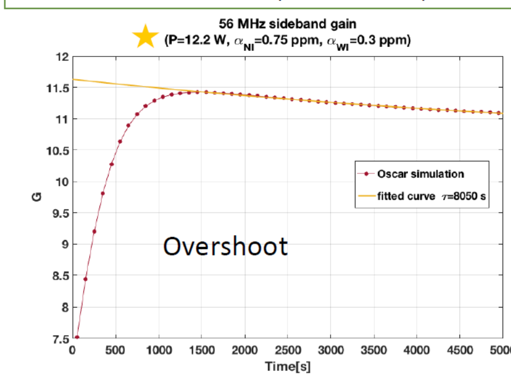


The presence of overshoot at @P=12 W is expected from simulations

Overshoot time constant depends on absorption budget



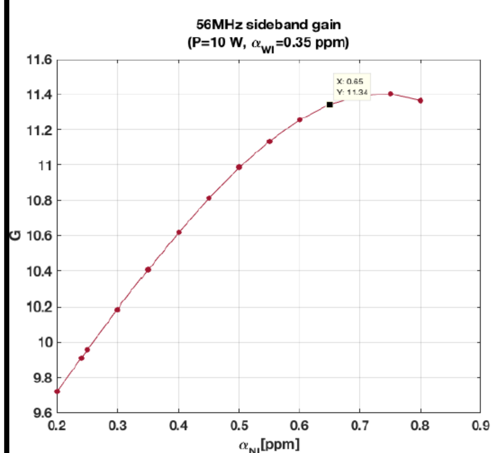


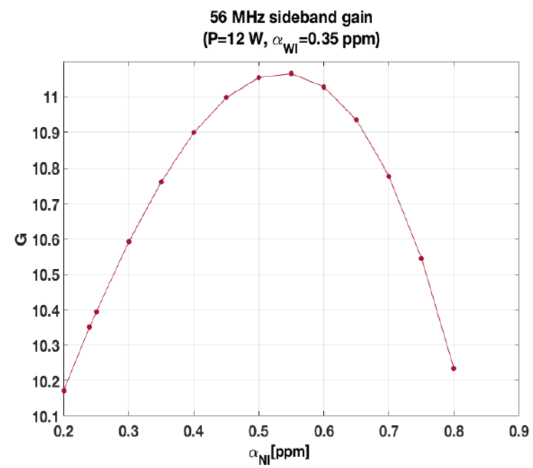


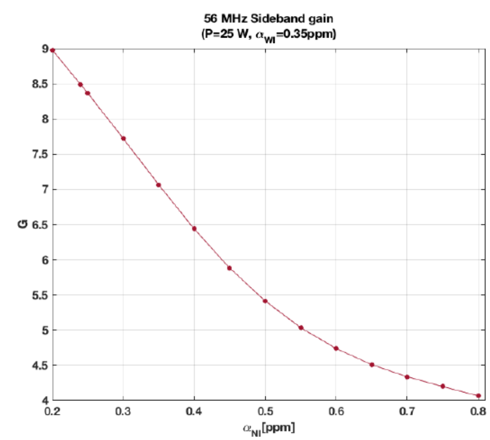
Overshoot and Absorption

- NI optimum absorption changes with input power
- Overshoot could be from input power increase and/or NI absorption increase

OSCAR simulations

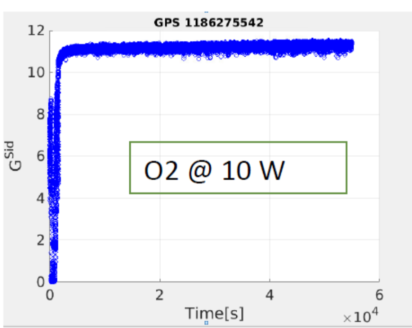






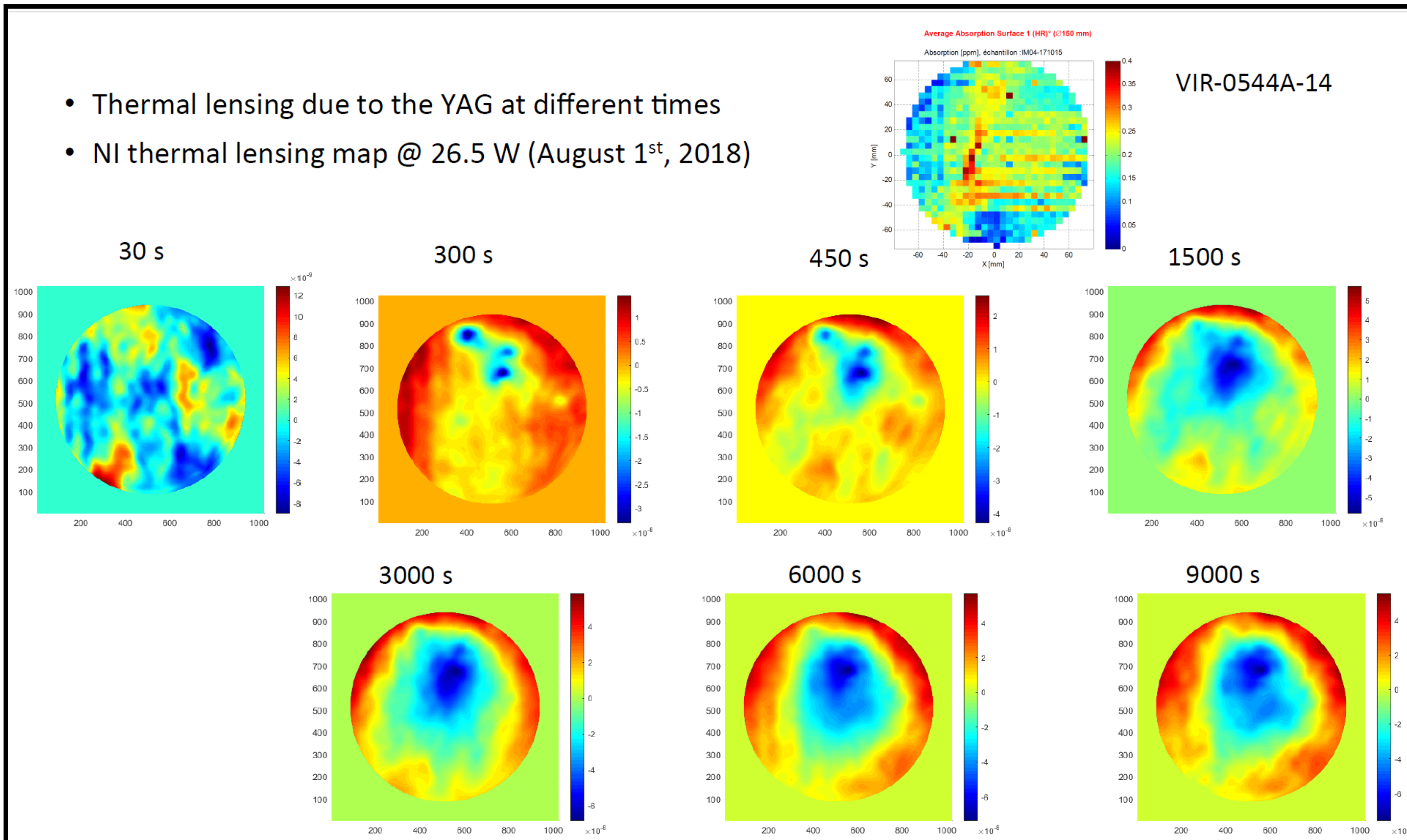
Coherent with O2 Gain (about 11.3) → 0.5 ppm<NI absorption <0.8 ppm

Coherent with May 2018 Gain → 0.6 ppm<NI absorption <0.8 ppm



Point Absorber Investigation

- NI absorption increase might be from monolithic suspension installation
- Point absorber investigation by Hartmann wavefront sensors



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  - **- thermal compensation (TCS)**
  - **- line noises and line tracking**
  - **- violin mode damping**
  - **- graphical user interfaces**
  - **- power drop issue**
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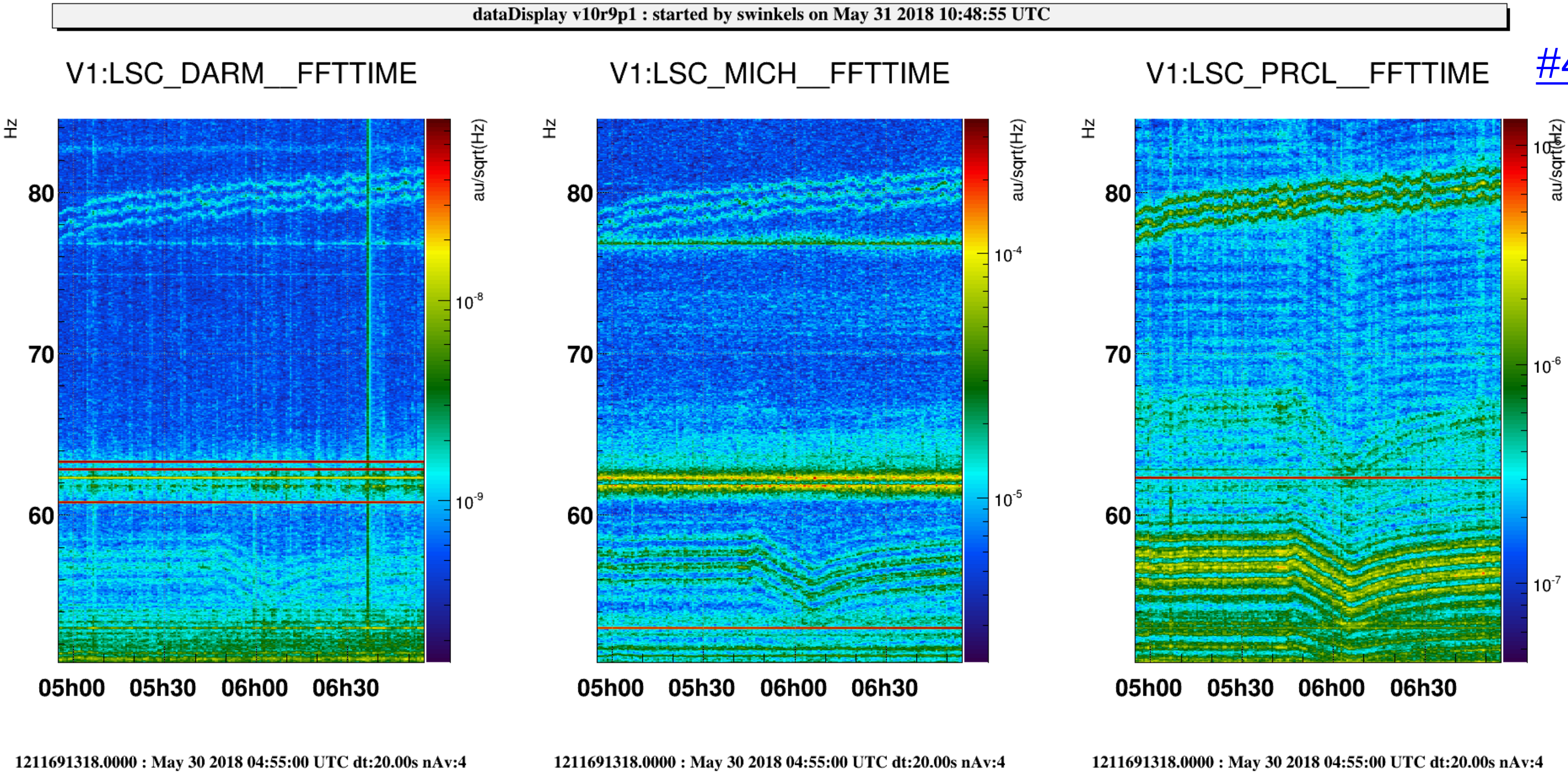
Line Noises

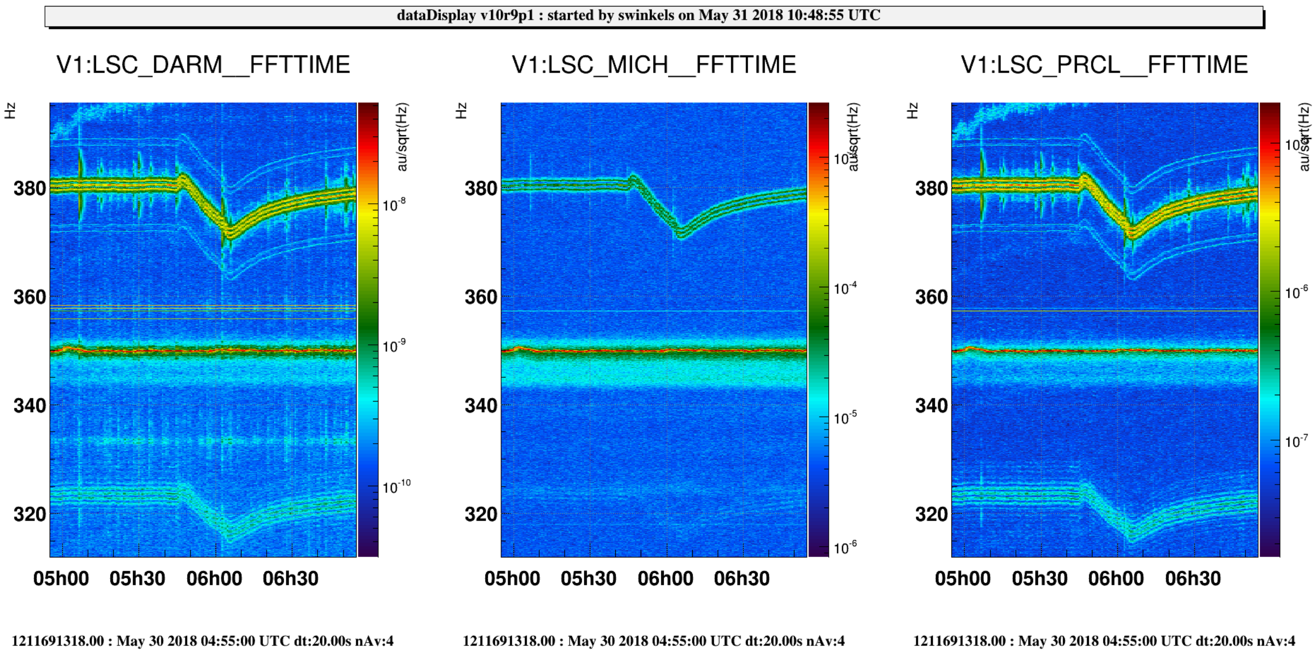
- There are so many lines
- Some identified by tracking the line frequency offline
- Online tracking also useful for monitoring mirror temperature, parametric instability investigations etc.

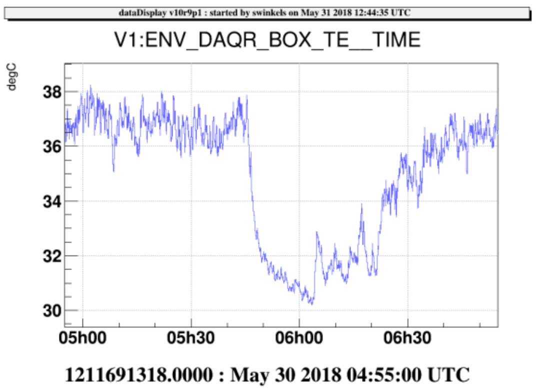


#41624

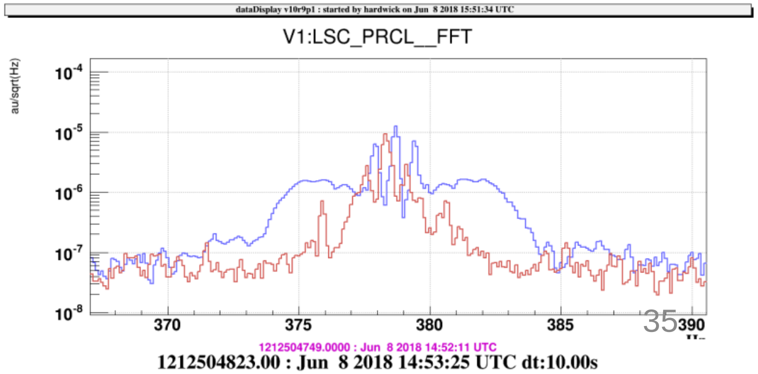
Moving Lines around 380 Hz etc.

- Correlated with DAQ room temperature change ([#41624](#41624))



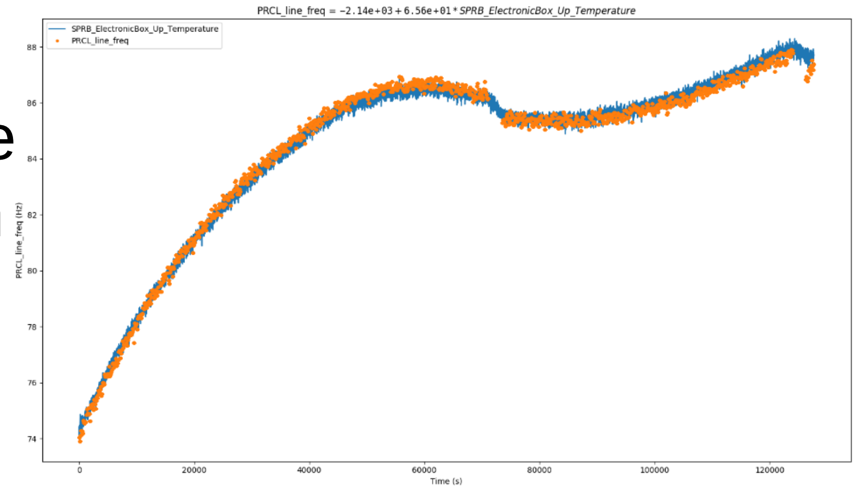


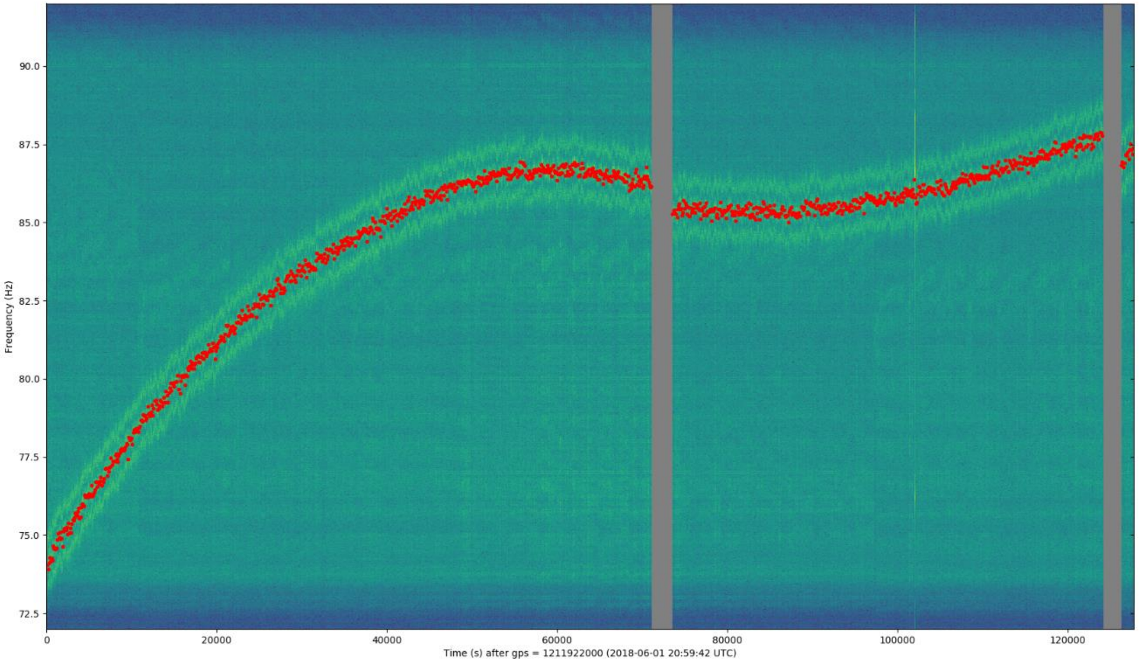
- Identified to be timing noise by tapping GPS synchronized 10 MHz timing box in DAQ room ([#41763](#41763))



Moving Lines around 80Hz

- Correlation with SPRB electronics box temperature found by brute force search (#41819)
- Another timing noise! (#41821)



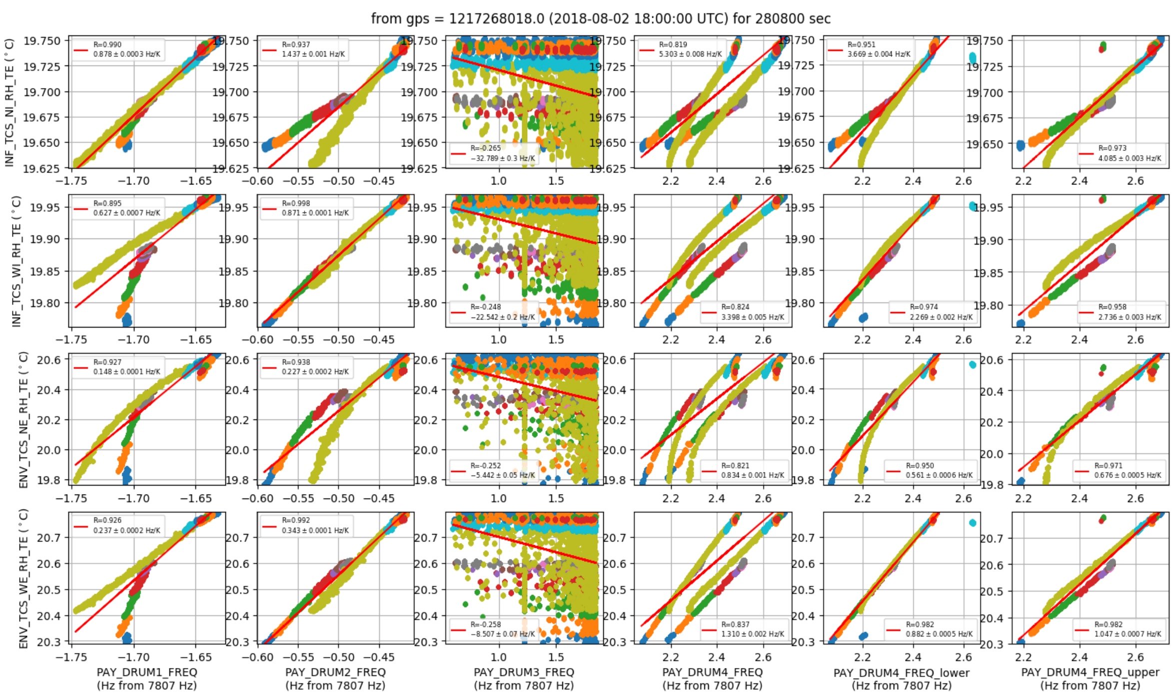


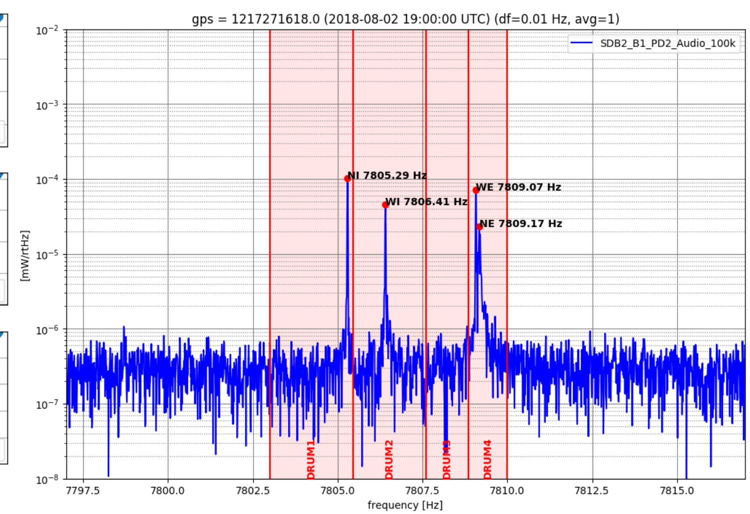
Very cool tool

Bas Swinkels,
Brute force correlation of drifting lines
VIR-0420A-18

Online Line Freq & Ampl Tracking

- Can be used to monitor the mirror temperature (and parametric instability damping in the future)
- Mirror identification possible by correlating with ring heater temperature (and some by kicking each mirror)
- Super useful FFT code by Bas (#38844), modified to track multiple modes (#41883)





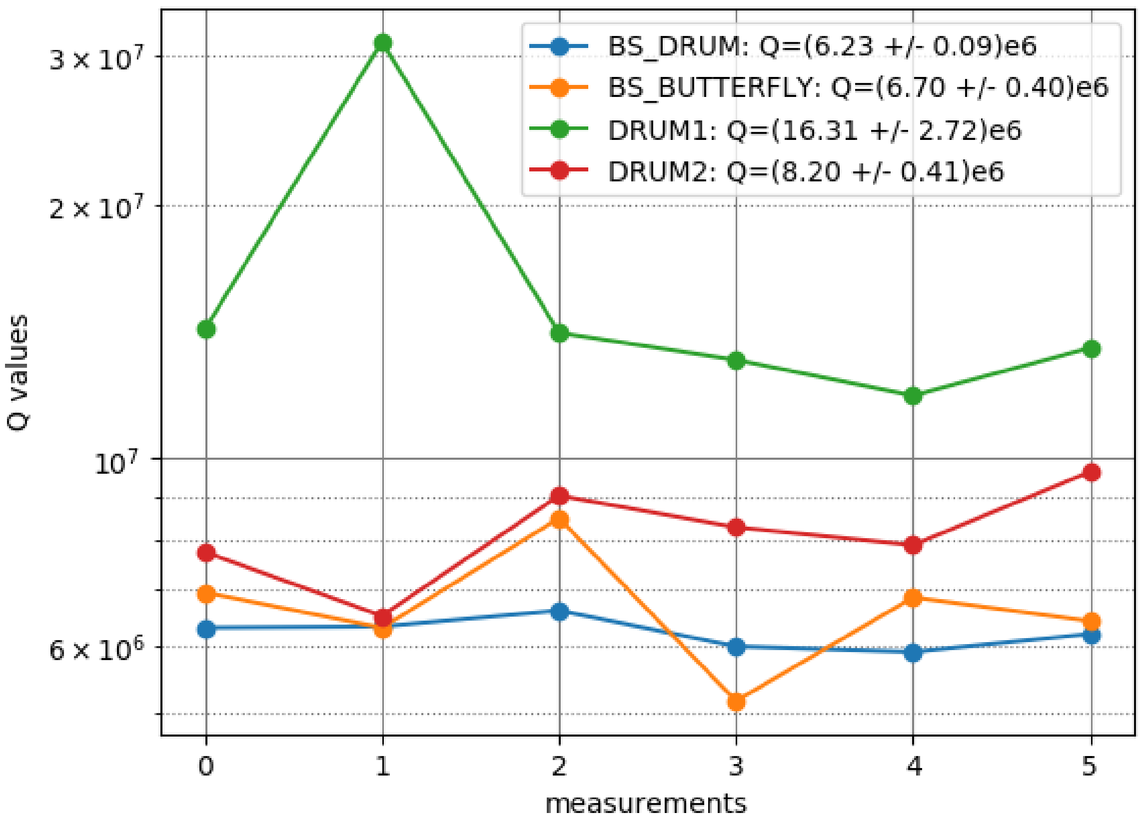
#42370 etc

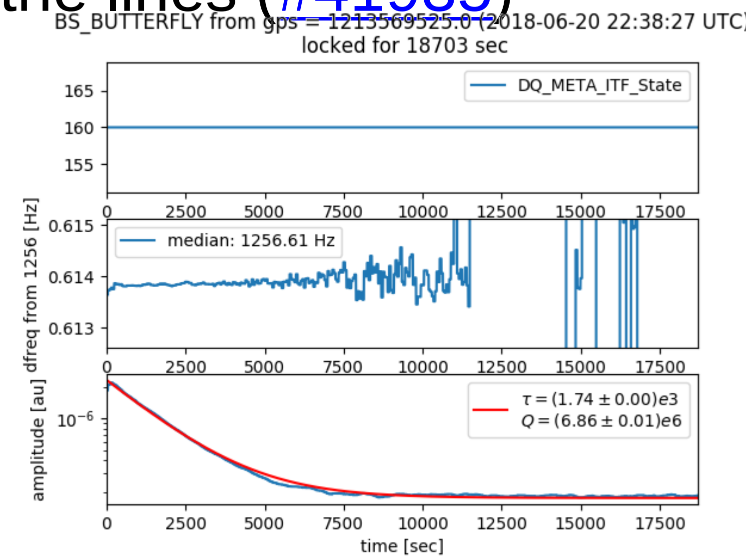
In Virgo, you can also save the processed data as DAQ channels!

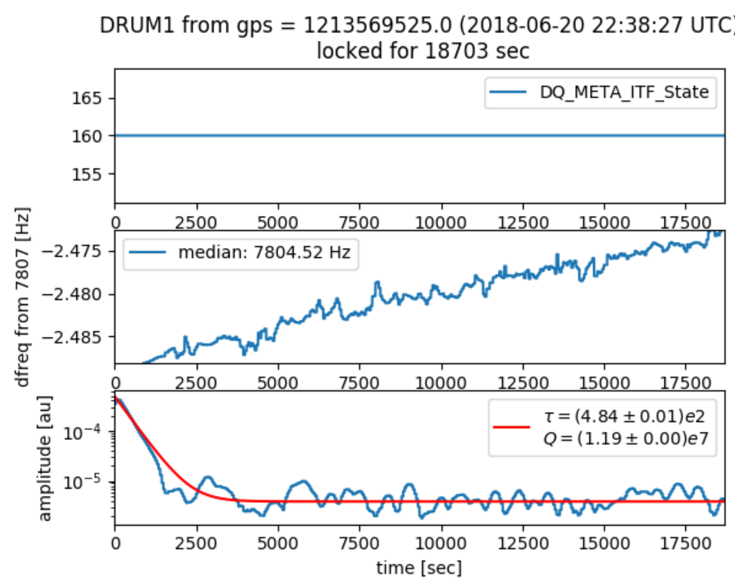
Q-Value Measurement

- Done by tracking the amplitude of the lines ([#41935](#41935))

BS DRUM (1875.5 Hz): (6.2 +/- 0.1)e6
BS BUTTERFLY (1256.5 Hz): (6.7 +/- 0.4)e6
NI DRUM (7804.5 Hz): (1.6 +/- 0.3)e7
WI DRUM (7807.5 Hz): (8.2 +/- 0.4)e6



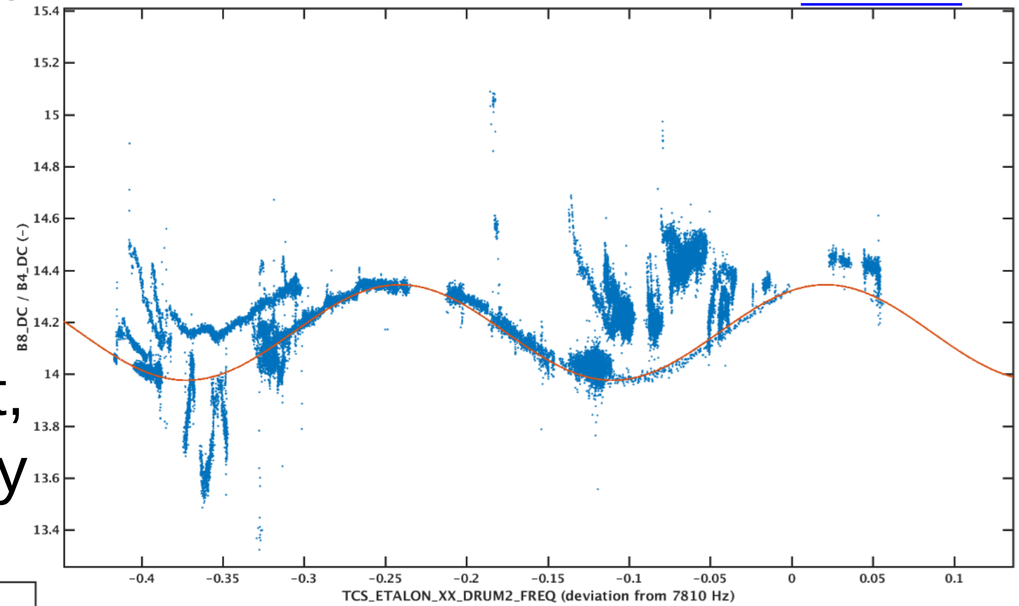




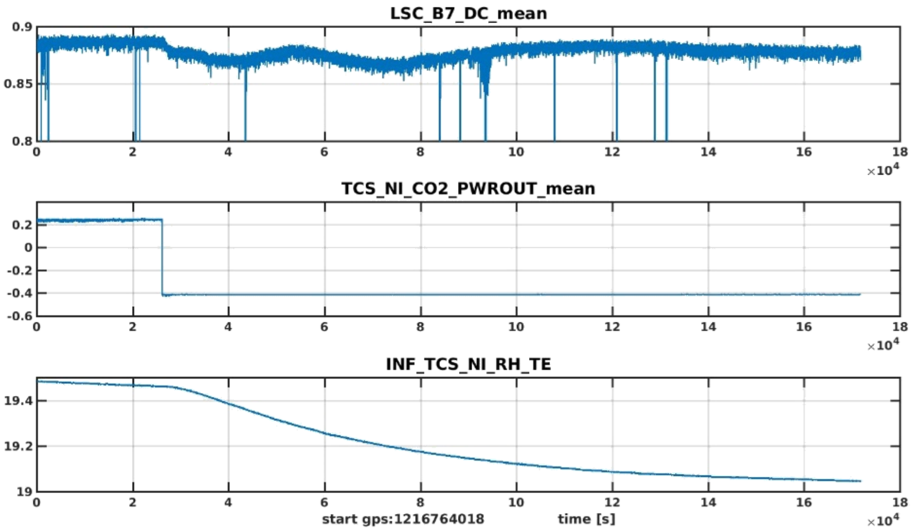
Input Mirror Etalon Effect

- NI/WI are non-wedged so that the reflectivity can be tuned by tuning the temperature

#39767



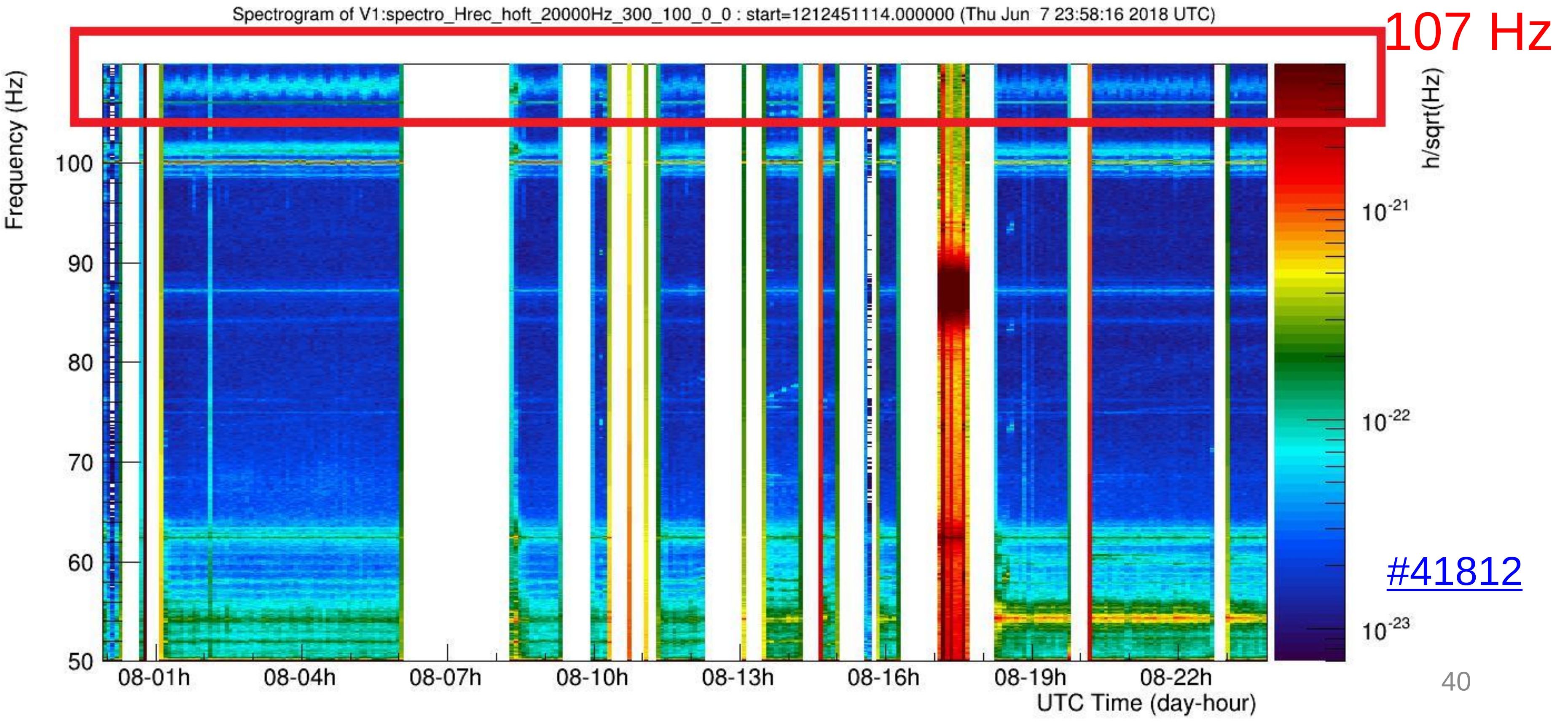
- Arm finesse can be tuned by
  - Warm ~3%
  - Narm ~2%
- Very interesting and neat, but adds more complexity



TCS DAS turning off reduces ring heater temperature (mirror temperature) from radiative coupling, which leads to modulation of the arm transmission via etalon effect.
#42318

Frequency Modulated Lines

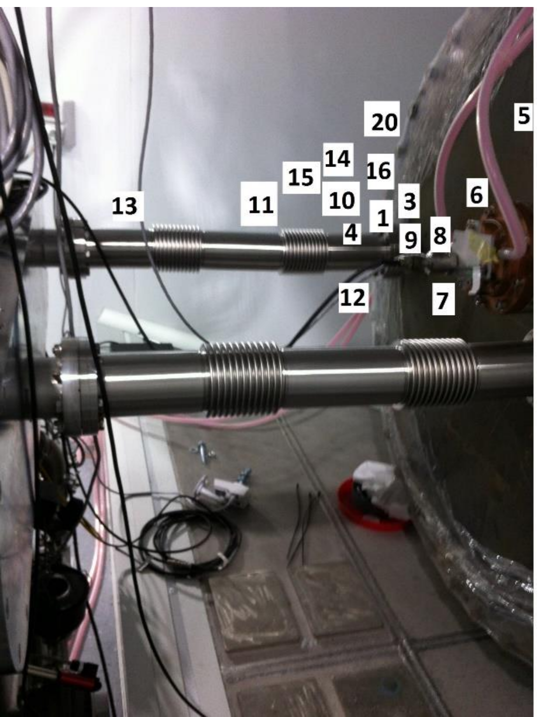
- Some lines are modulated, with time-varying period
- Resembles arm transmission with etalon
- Size of the etalon object can be estimated by counting number of fringes (etalino; see also #27328, #27648)

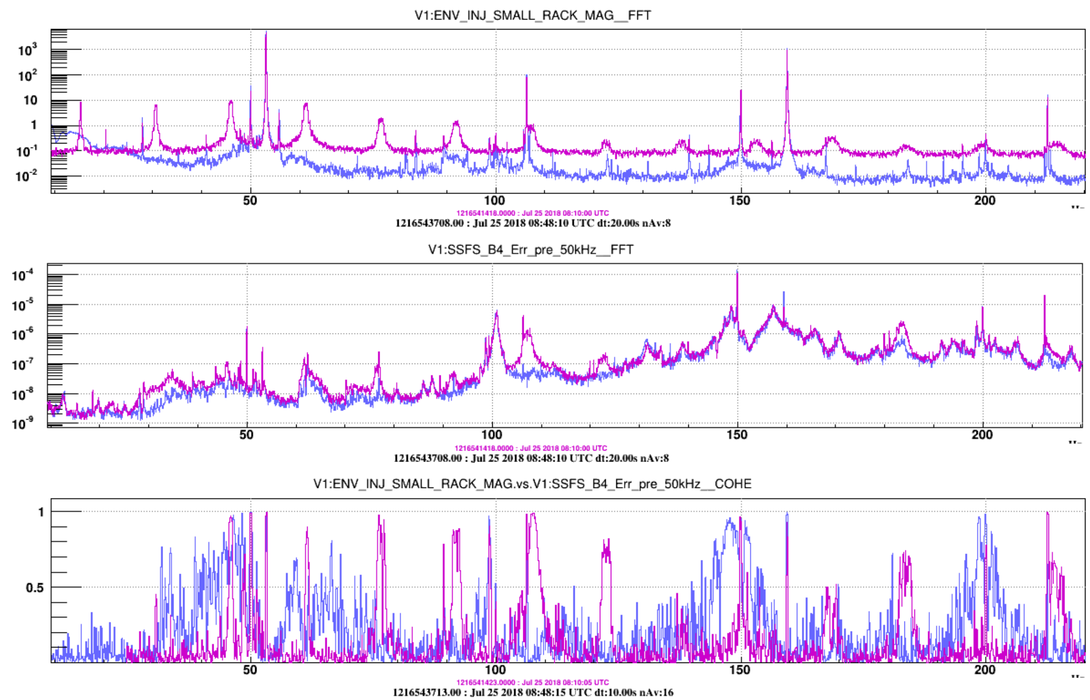


#41812

107Hz Noise Story

- Found in May 2017 (#37744)
- Coherence with reference cavity (RFC) error found (#41824)
- Tapping tests at RFC (#41947)
  → scattered light? for some lines → beam dump installed
- Finally identified to be magnetic noise (15.3 Hz and harmonics) from picomotor driver on July 25, 2018 (#42212)





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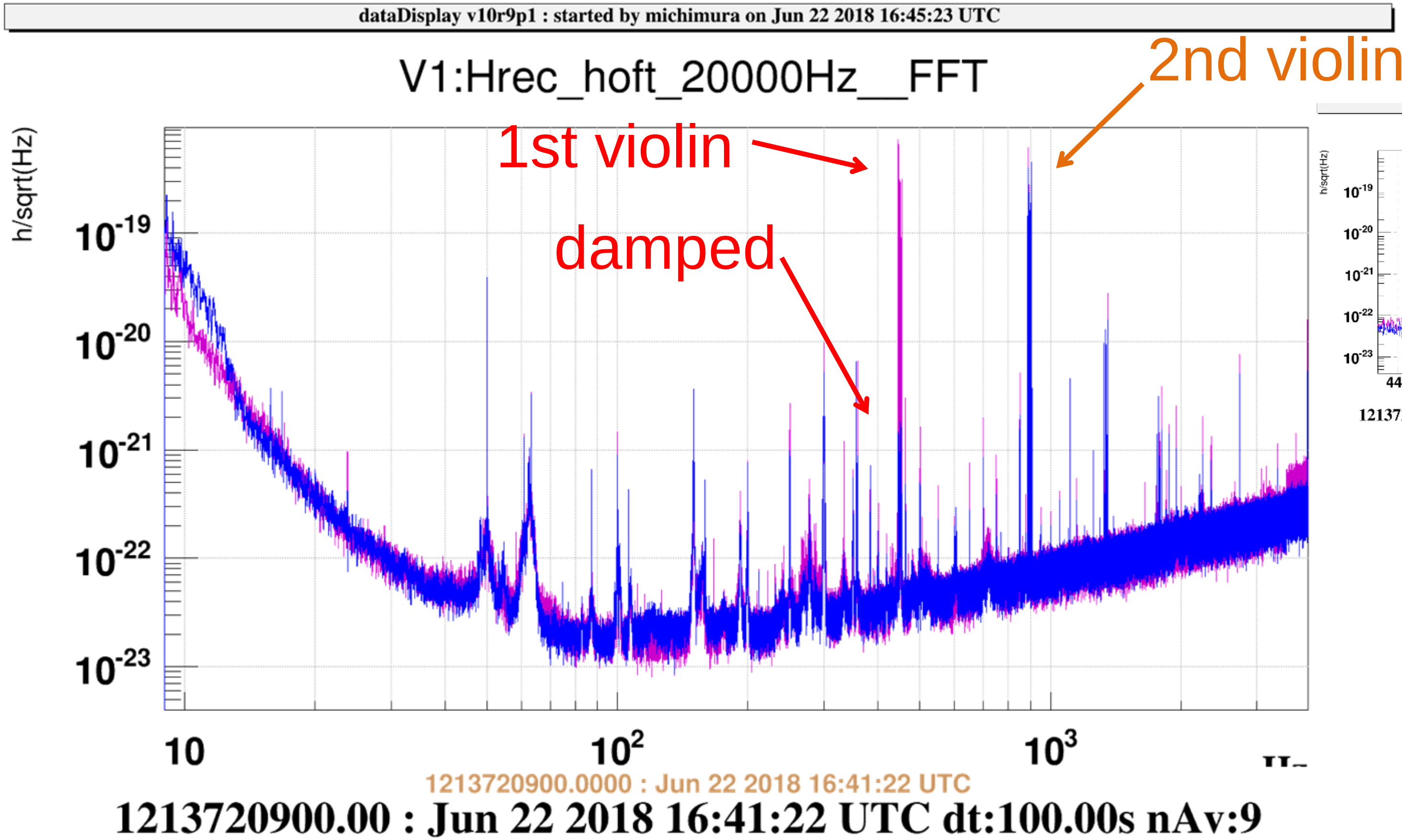
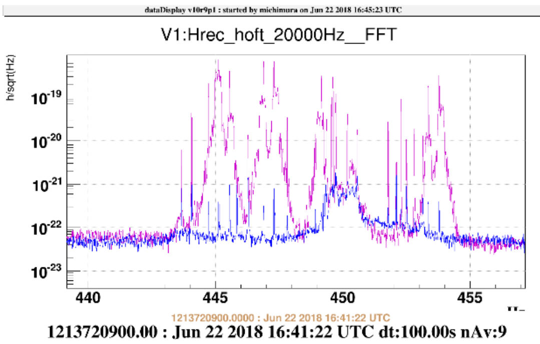
  - **- power drop issue**
- **Working environment**
- **Summary**

Violin Mode Damping

- Looks ugly, contributes to actuation range, takes time to damp (Q~2e7 #41728)
- So, we damped by actively feeding back to marionette (#41949)

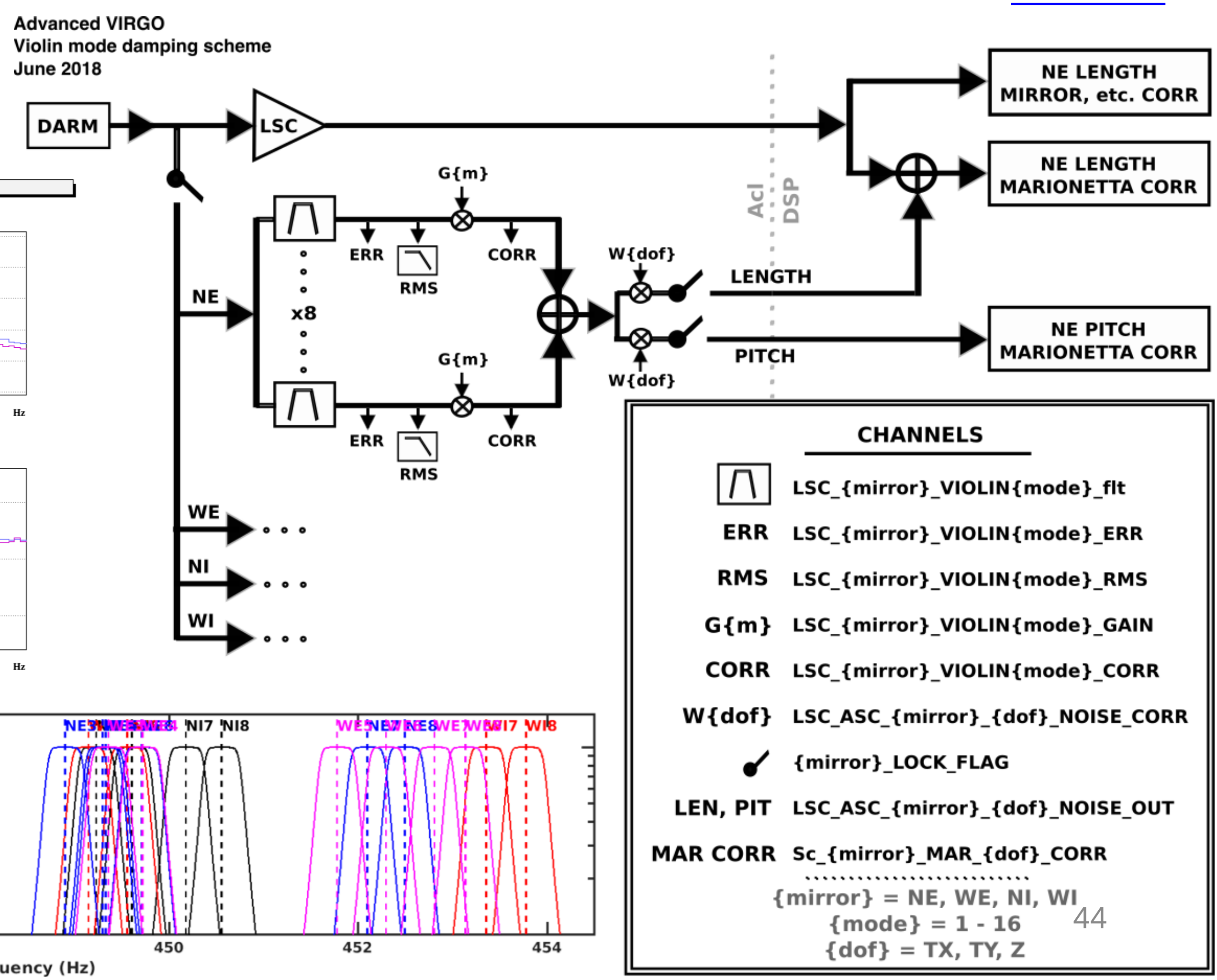


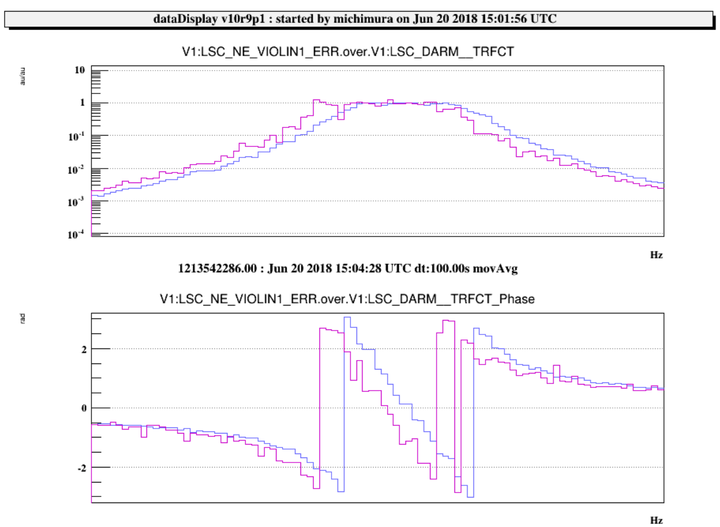


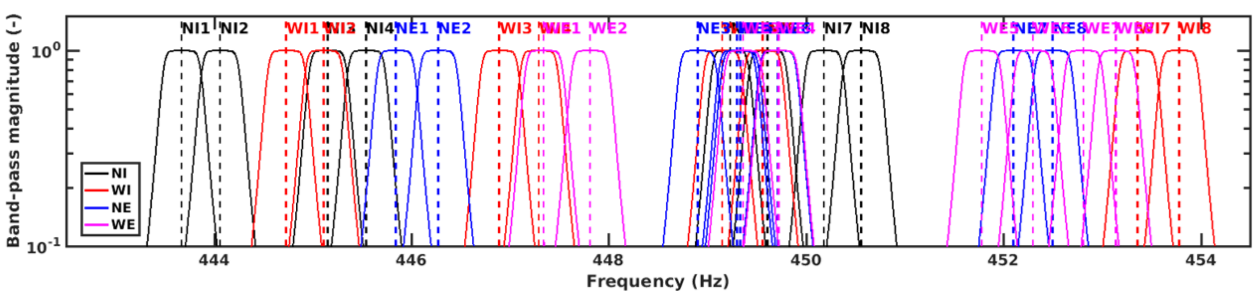
Damping Scheme

- 4th order Butterworth bandpass filter, 0.2 Hz wide
- Select between two BPF to shift phase (~60deg)

#41922



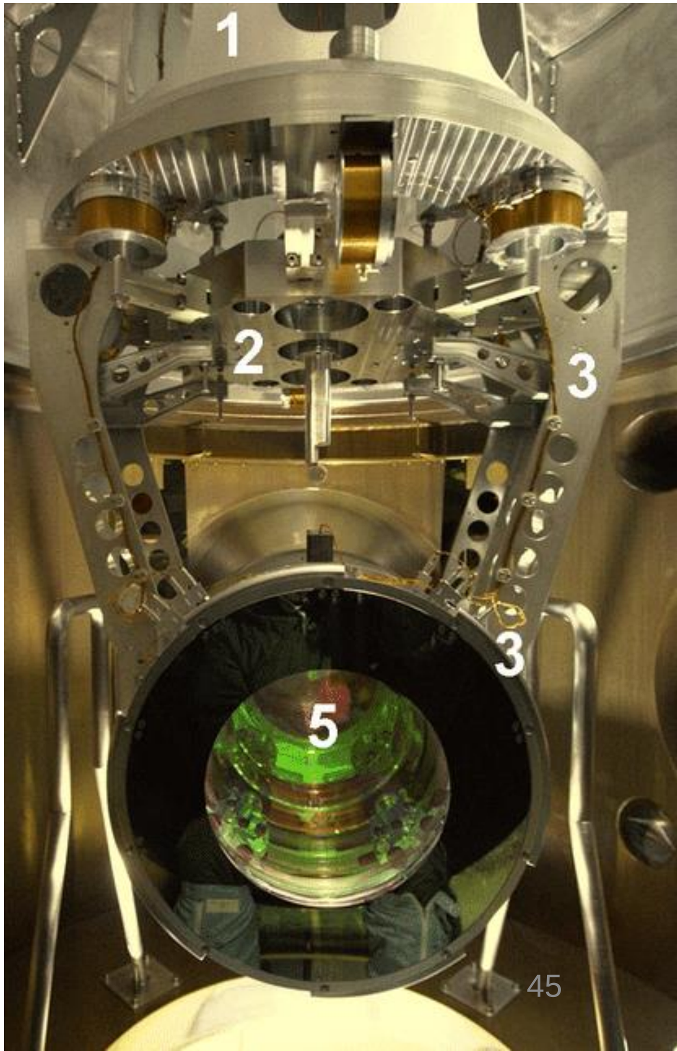




Next Step

- Include to automated locking procedures (Metatron)
  - Currently only manually turned on (and probably never turned on by Virgo people so far…)
- Damp 2nd mode

- It was a nice little project to grasp control system and commissioning coordination (shift scheme) in Virgo



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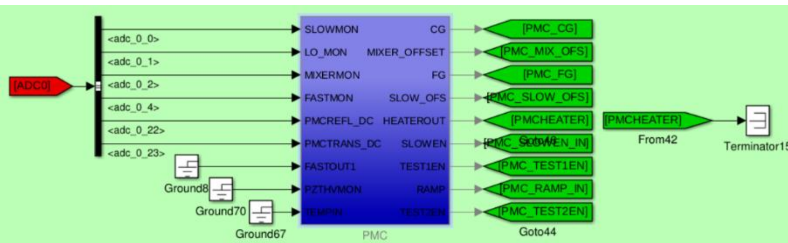
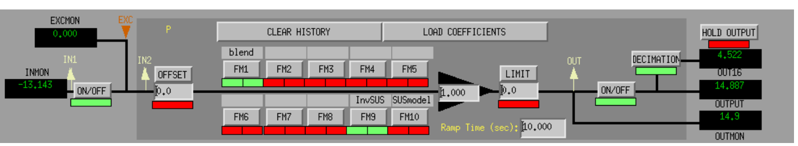
Virgo has Less GUIs

- Hard to see and check what's happening (harder for visitors)

Simulink



MEDM

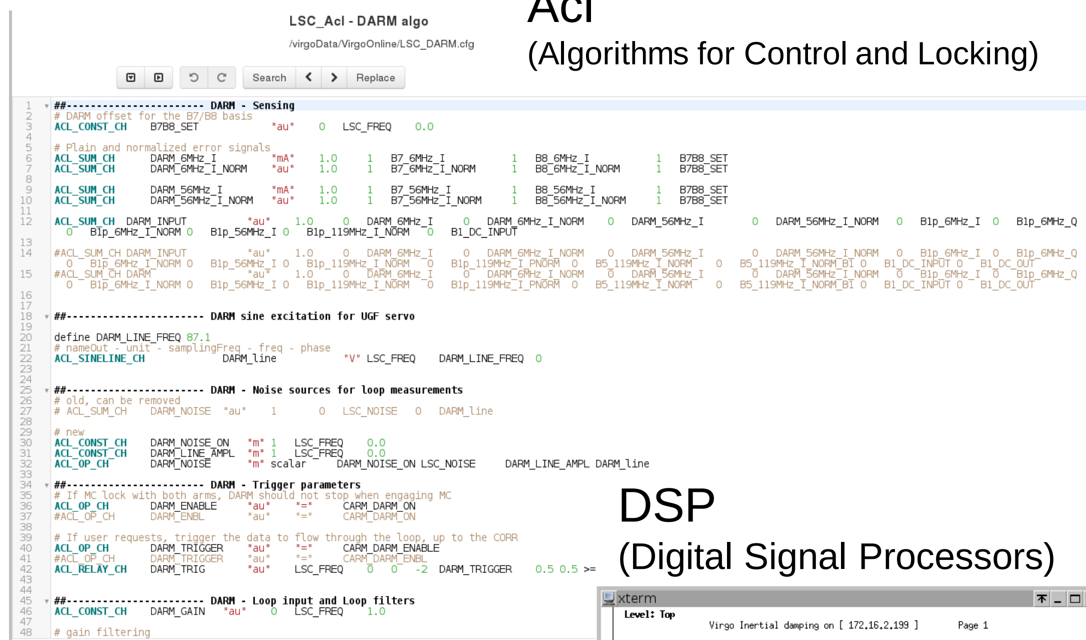


LIGO / KAGRA

Virgo

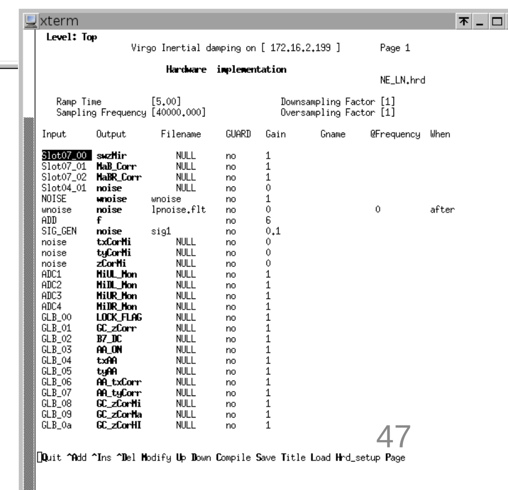
Acl

(Algorithms for Control and Locking)



DSP

(Digital Signal Processors)

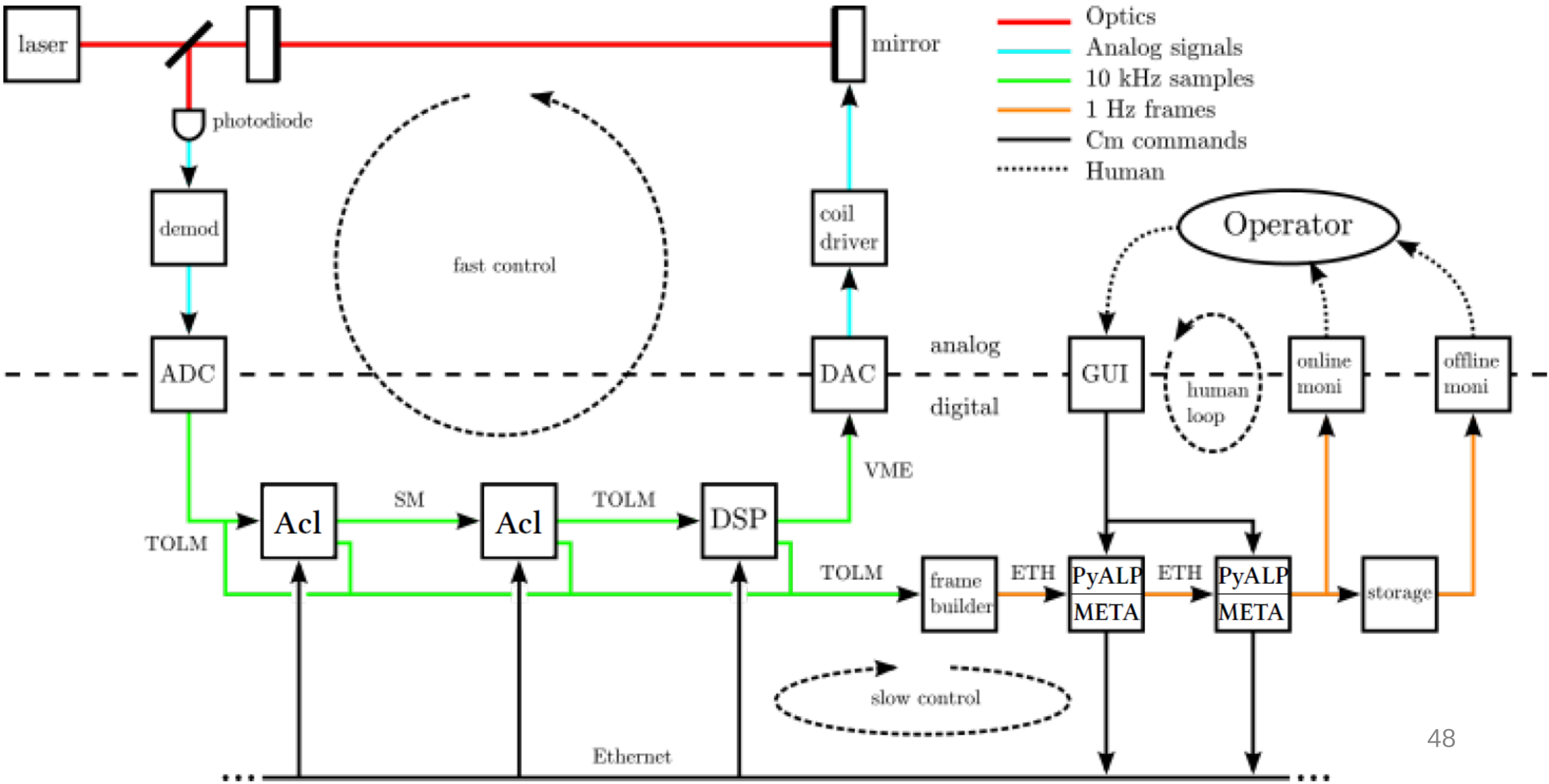


Acl command to change a gain

```
cm_send('LSC_Acl','AcConstChSet',MICH_GAIN, 300, 10)
```

Acl and DSP

- Developed by different institutes, completely different language
- I concentrated basically only on Acl during the visit

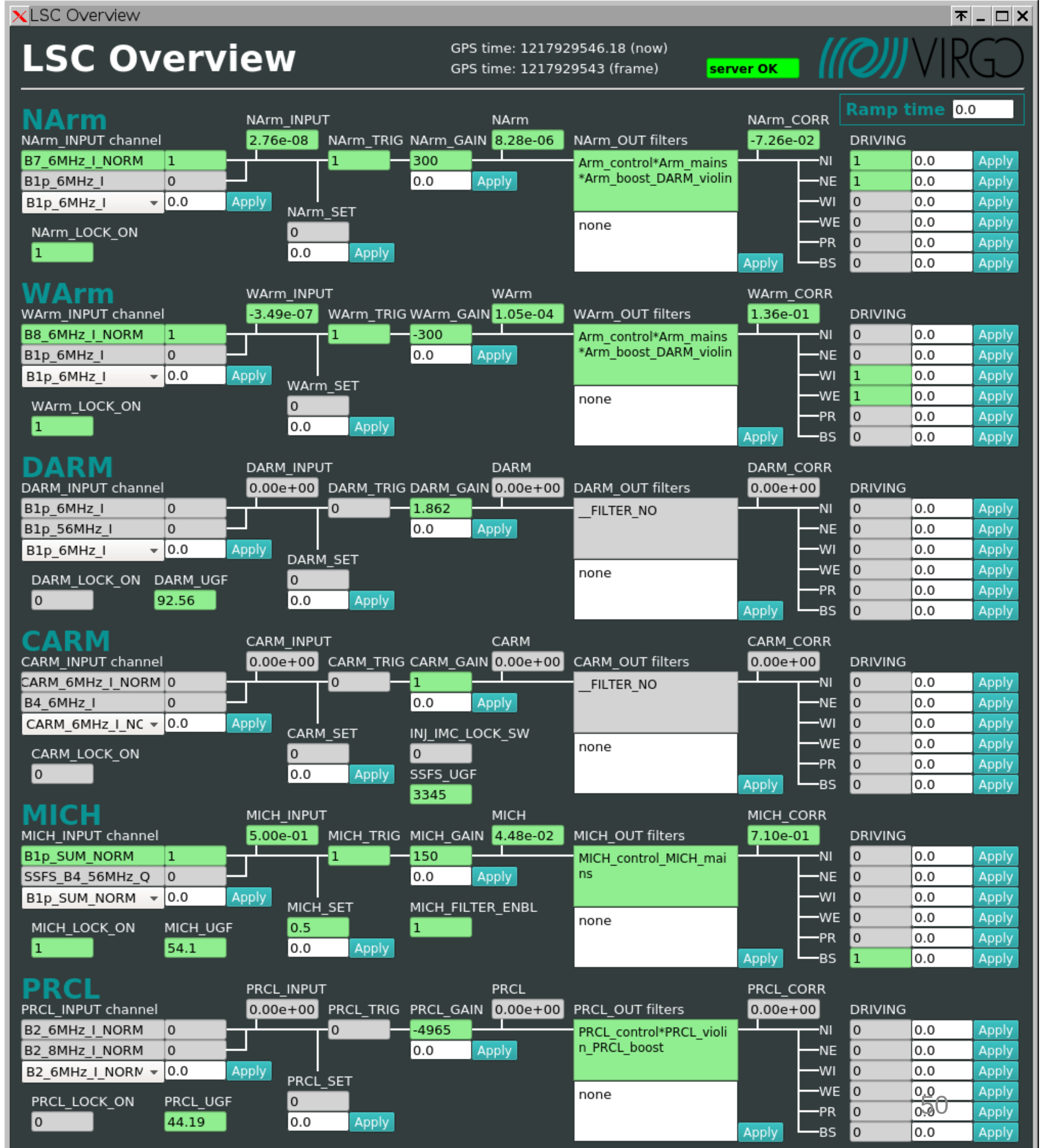


Motivations for Making GUIs

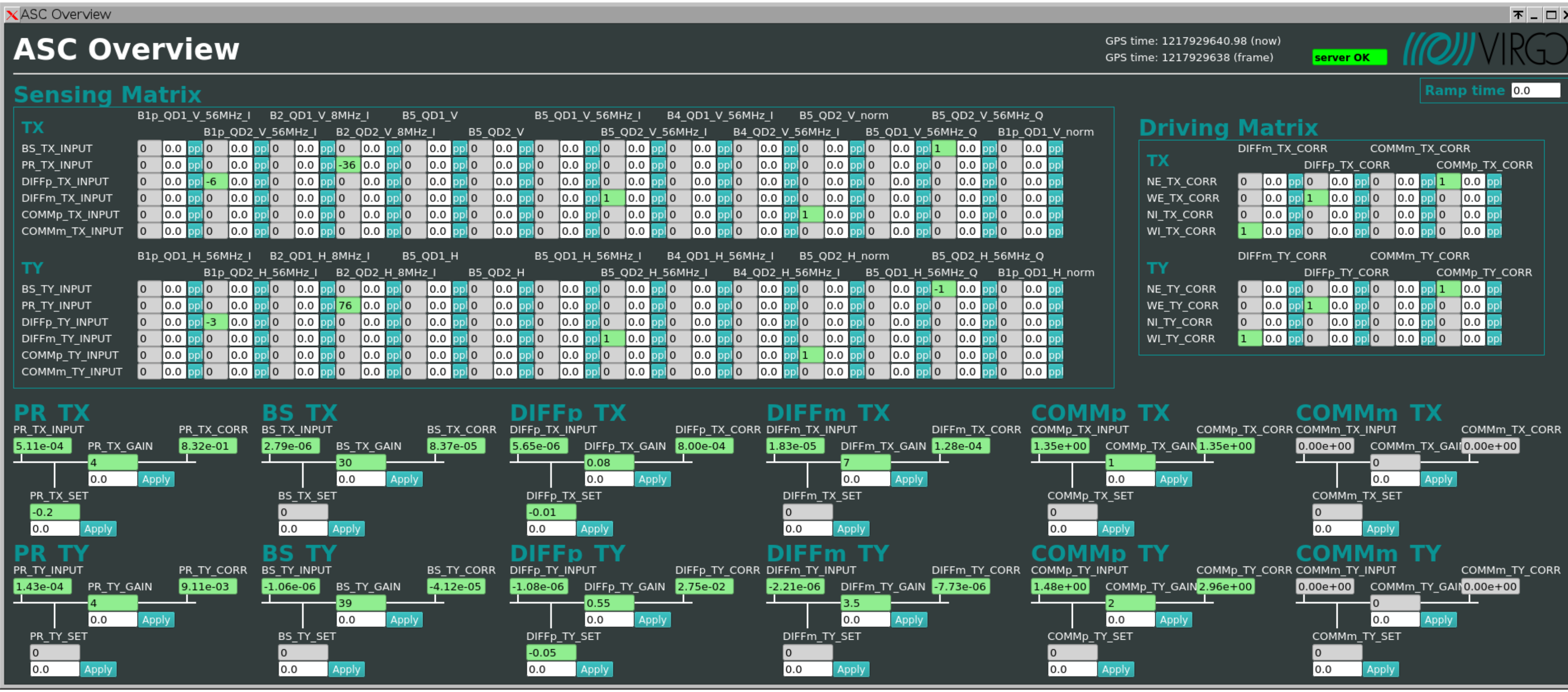
- GUIs help understand the diagram of the signal flow
- You can quickly change the parameters with GUIs
- People can work together easier with GUIs

- I thought we can increase the number of people who can involve into commissioning with GUIs
- This time, I made some GUIs equivalent to MEDMs
(but Simulink equivalent is also definitely necessary)

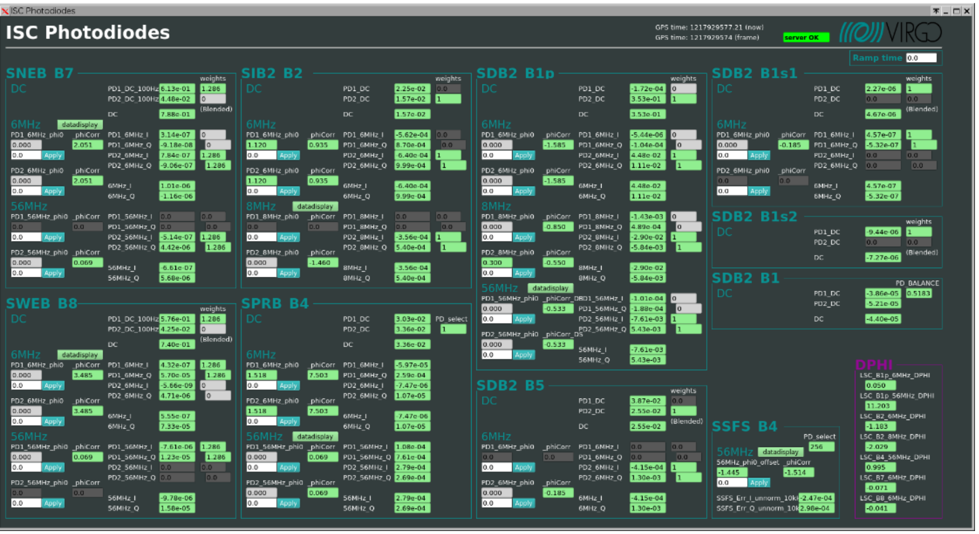
LSC Overview

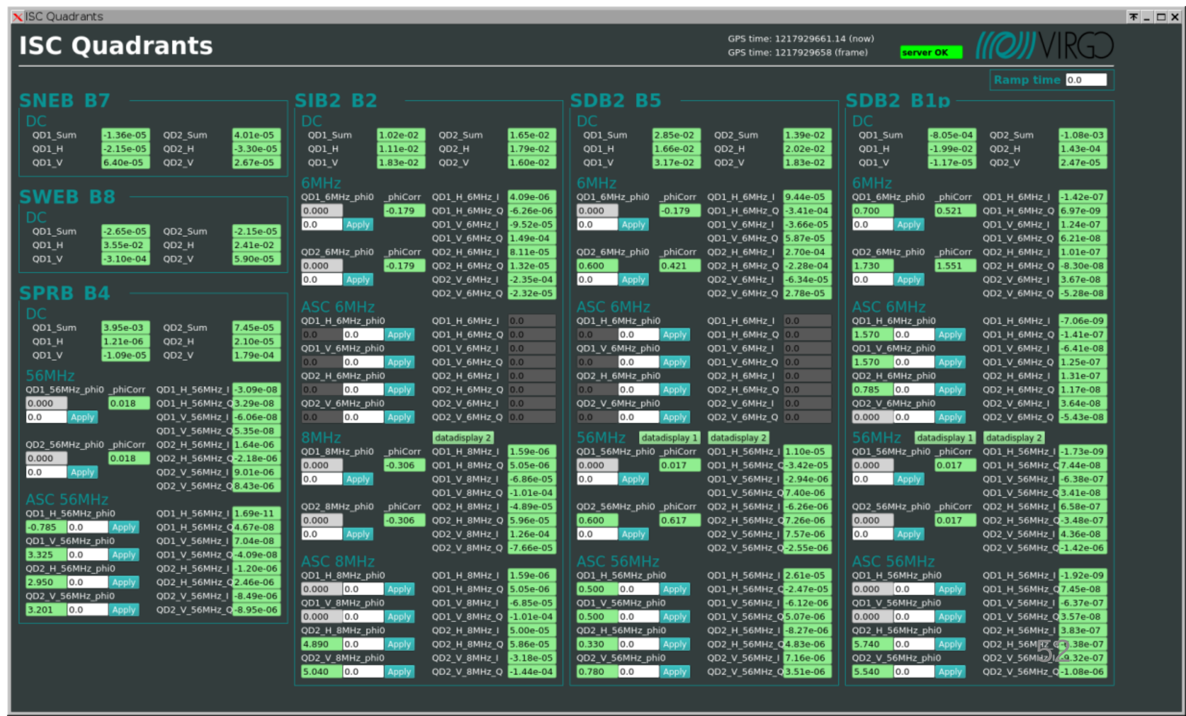


ASC Overview

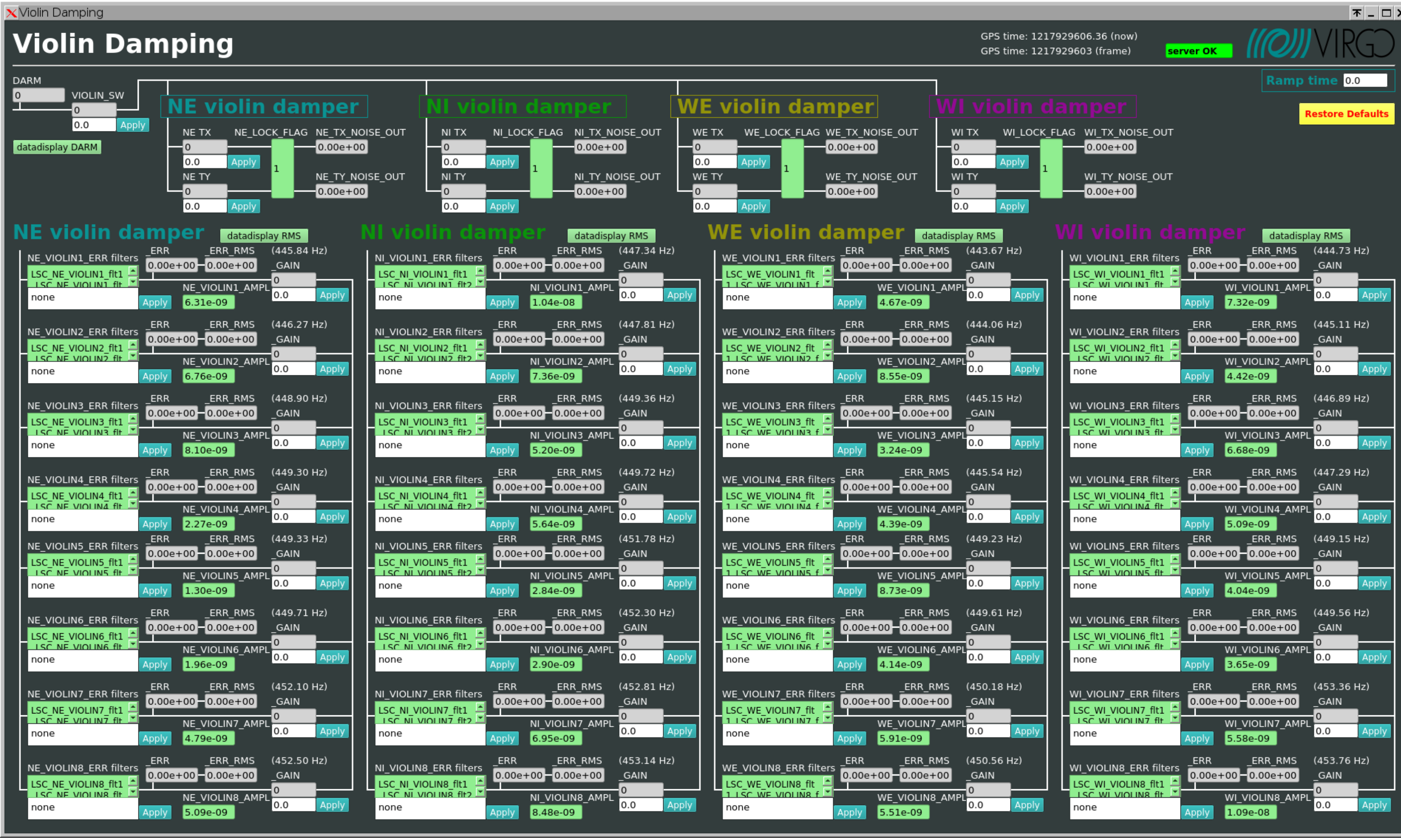


ISC Photodiodes and Quadrants

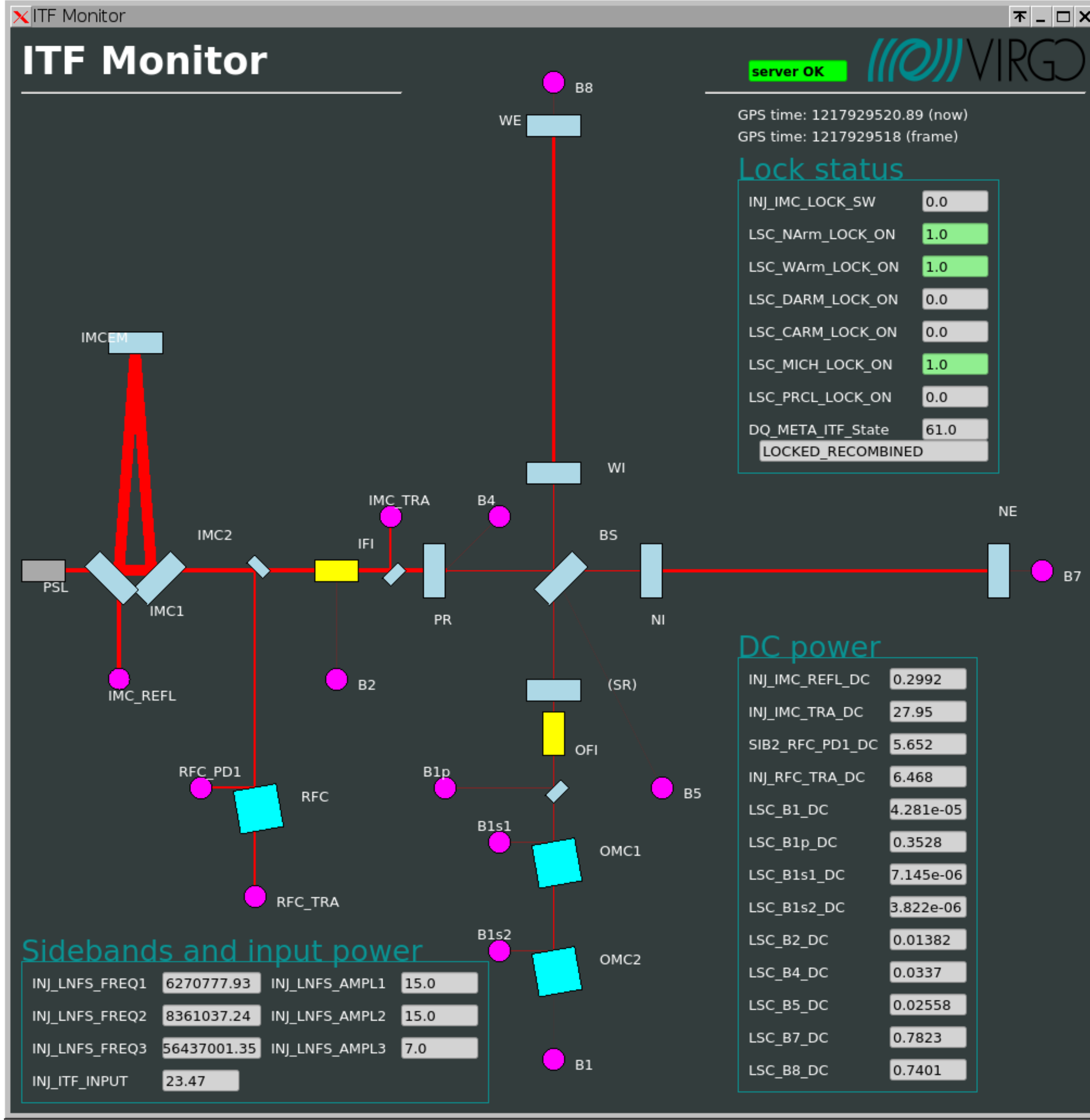




Violin Damping

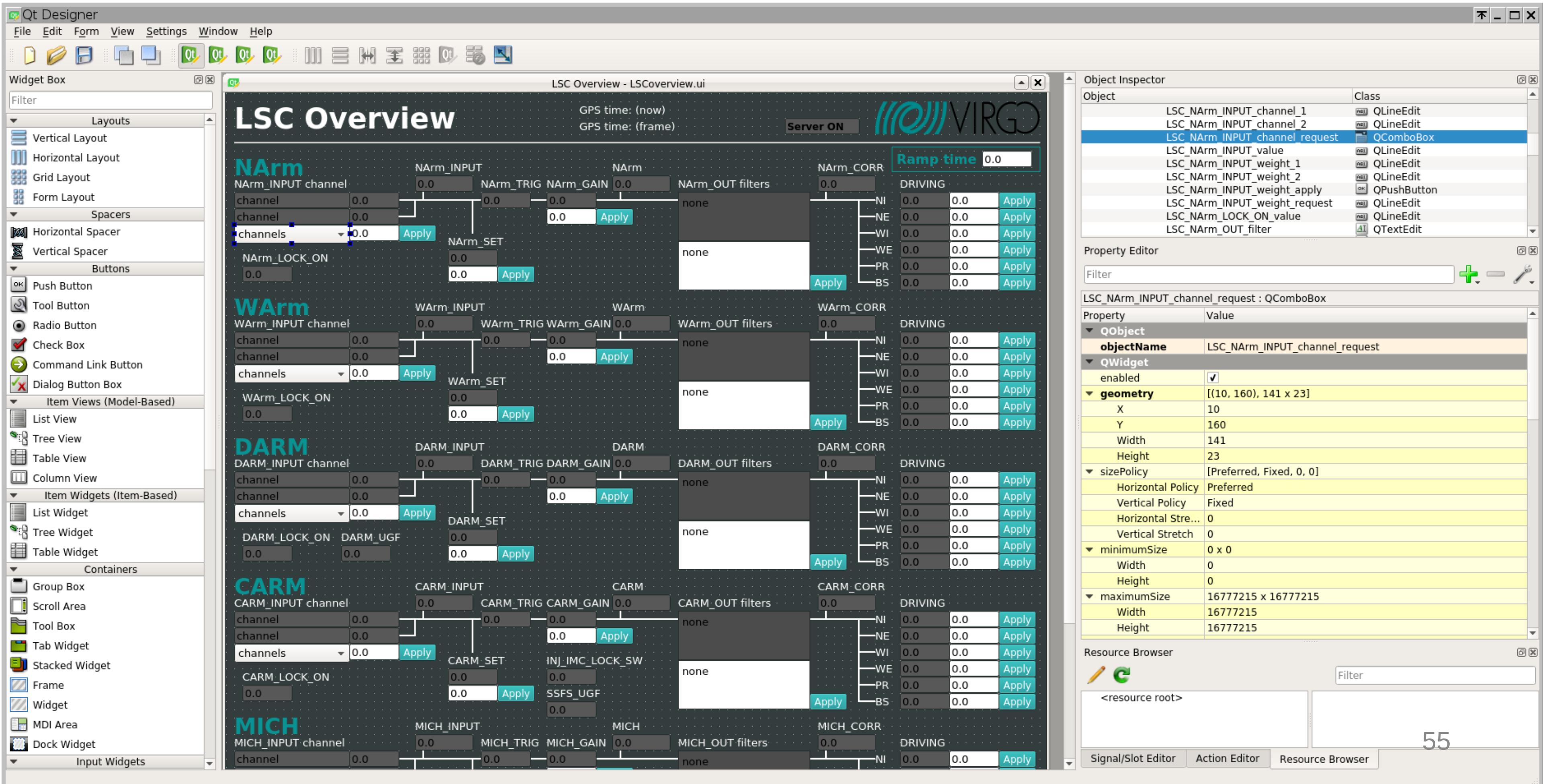


ITF Monitor


ITF Monitor
ITF Monitor
server OK
VIRGO
GPS time: 1217929520.89 (now)
GPS time: 1217929518 (frame)
Lock status
INJ_IMC_LOCK_SW 0.0
LSC_NArm_LOCK_ON 1.0
LSC_WArm_LOCK_ON 1.0
LSC_DARM_LOCK_ON 0.0
LSC_CARM_LOCK_ON 0.0
LSC_MICH_LOCK_ON 1.0
LSC_PRCL_LOCK_ON 0.0
DQ_META_ITF_State 61.0
LOCKED_RECOMBINED
B8
WE
WI
IMCEM
IMC_TRA
B4
NE
IMC2
IFI
BS
B7
PSL
IMC1
PR
NI
IMC_REFL
B2
(SR)
OFI
RFC_PD1
RFC
B1p
B5
B1s1
OMC1
RFC_TRA
B1s2
OMC2
B1
DC power
INJ_IMC_REFL_DC 0.2992
INJ_IMC_TRA_DC 27.95
SIB2_RFC_PD1_DC 5.652
INJ_RFC_TRA_DC 6.468
LSC_B1_DC 4.281e-05
LSC_B1p_DC 0.3528
LSC_B1s1_DC 7.145e-06
LSC_B1s2_DC 3.822e-06
LSC_B2_DC 0.01382
LSC_B4_DC 0.0337
LSC_B5_DC 0.02558
LSC_B7_DC 0.7823
LSC_B8_DC 0.7401
Sidebands and input power
INJ_LNFS_FREQ1 6270777.93
INJ_LNFS_AMPL1 15.0
INJ_LNFS_FREQ2 8361037.24
INJ_LNFS_AMPL2 15.0
INJ_LNFS_FREQ3 56437001.35
INJ_LNFS_AMPL3 7.0
INJ_ITF_INPUT 23.47

PyQt and Qt Designer

- GUIs are made by Python package PyQt4
- GUI design made with Qt Designer
  (easier to design than MEDM editor)



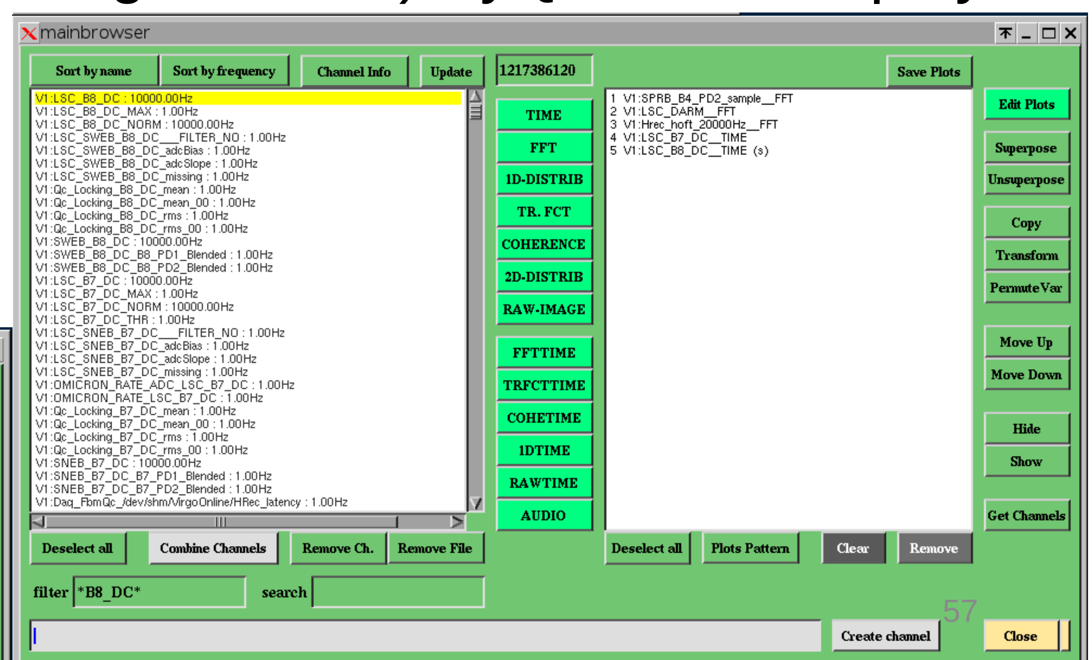
Some Headaches

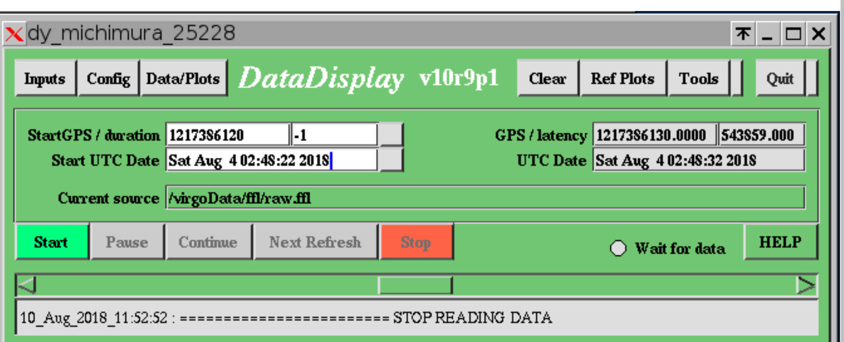
- In Virgo, getting current value of a parameter is more difficult than pushing a new value
  - You have to access to frames to get it (~3 sec latency)
  - Not all channels (even 1Hz ones) are saved unless configured so
  - Frames store data in multiple ways, and how to access to frames depends on how it is stored. You cannot tell how to access from the channel name
- Pushing is also tricky since the command depends on what kind of parameter you want to push (constant value, matrix element, weight of sum channel or filter name)

- So, making GUIs also needs some expertize…
- Maintaining existing GUIs would be tough

For 3G

- Virgo system is better in the sense, for example, that
  - it recompiles fast
    (new DAQ channel immediately available)
  - number of filters can be arbitrarily set, and you can
    use same filters to different loops
- I think something like
  Simulink + Foton + (auto generated) PyQt + dataDisplay
  is the best





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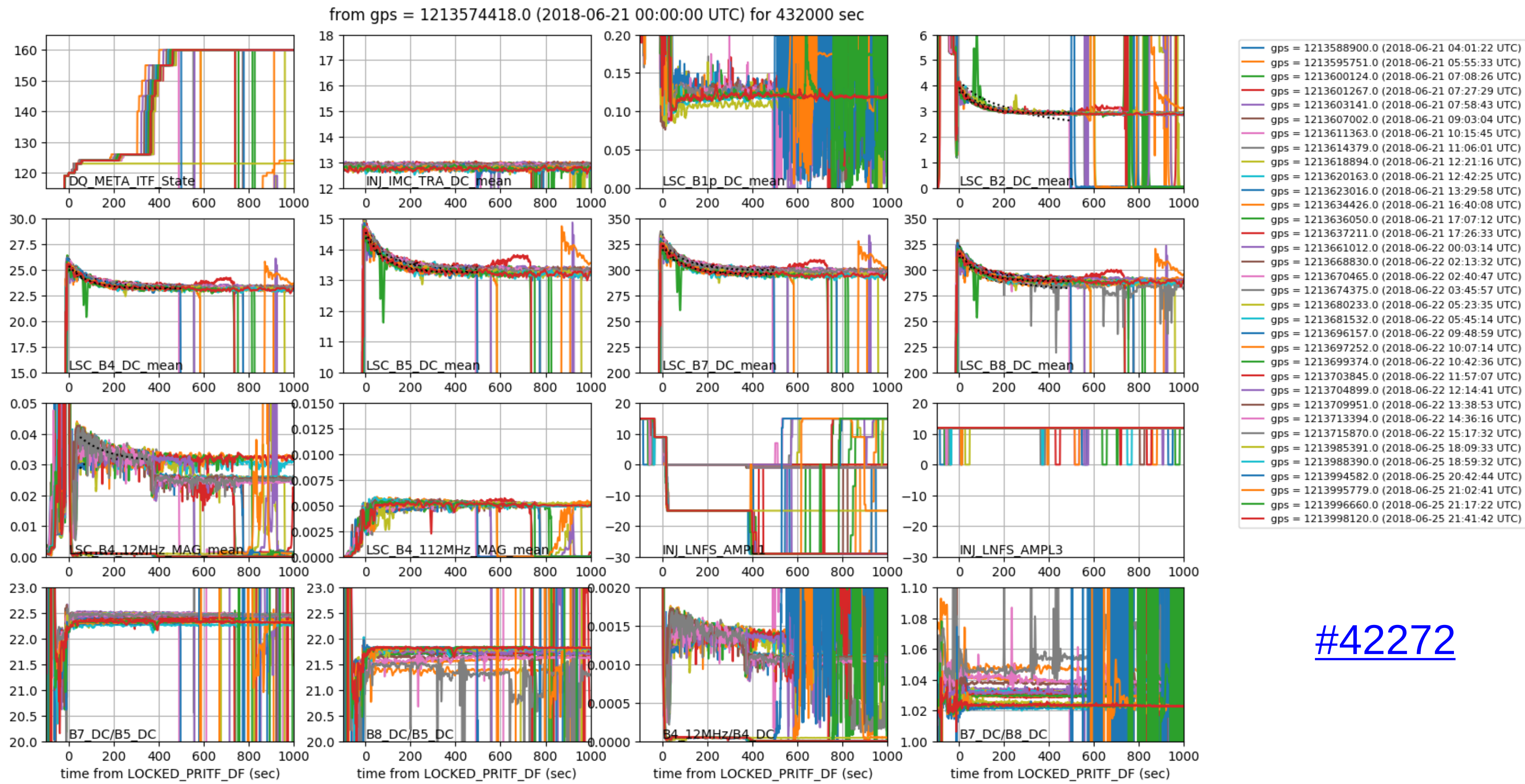
Power Drops at Dark Fringe

- After reaching dark fringe, arm transmission drops quickly @ ~100 sec, and B1p increases quickly ([#42058]())
- Can be explained by power recycling gain decay, but the reason is unclear

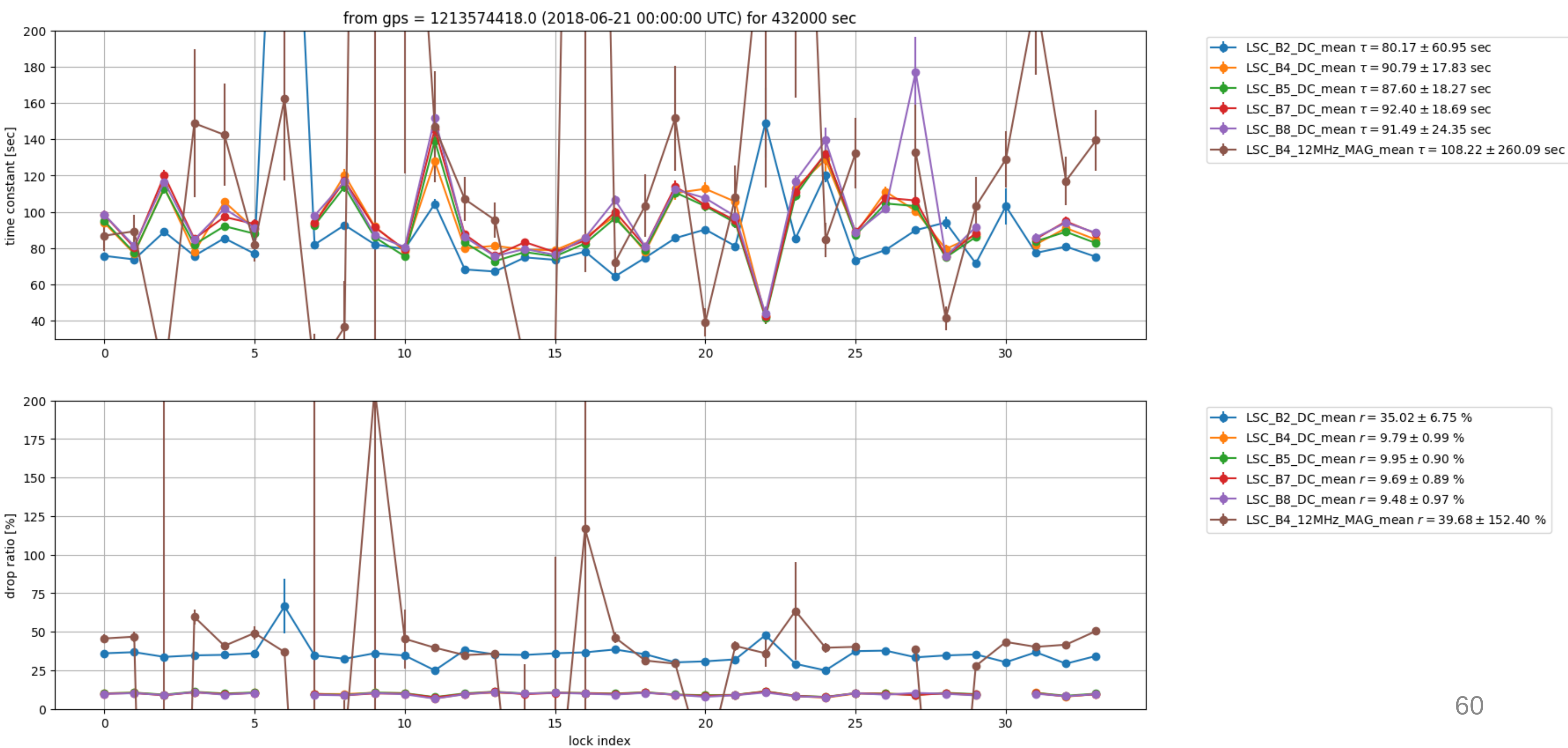


#42272

Time Constant

- Time constant of the decay changed after power increase
  ~90 sec in June 21 @ 13W
  ~50 sec in July 23 @ 25W

#42272



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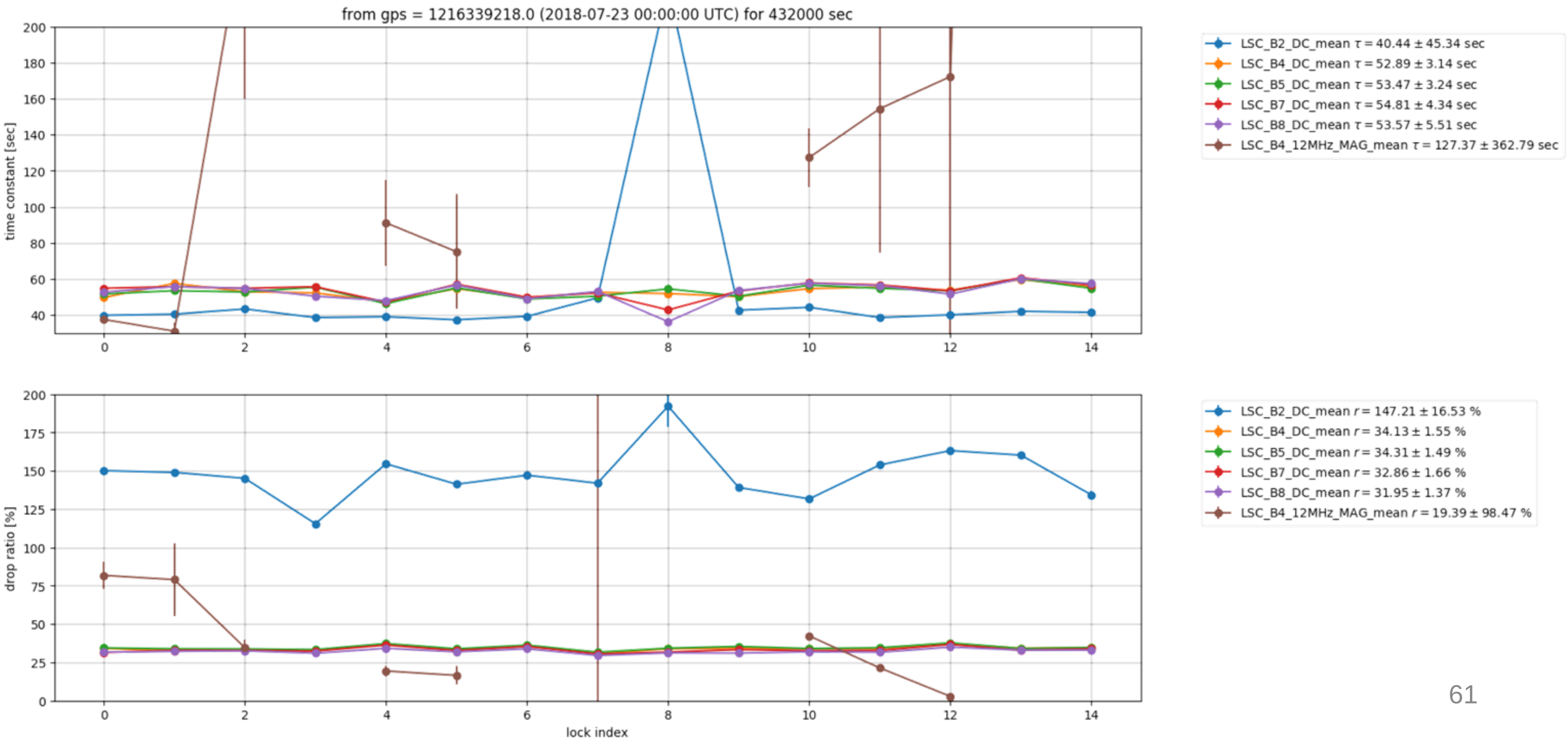
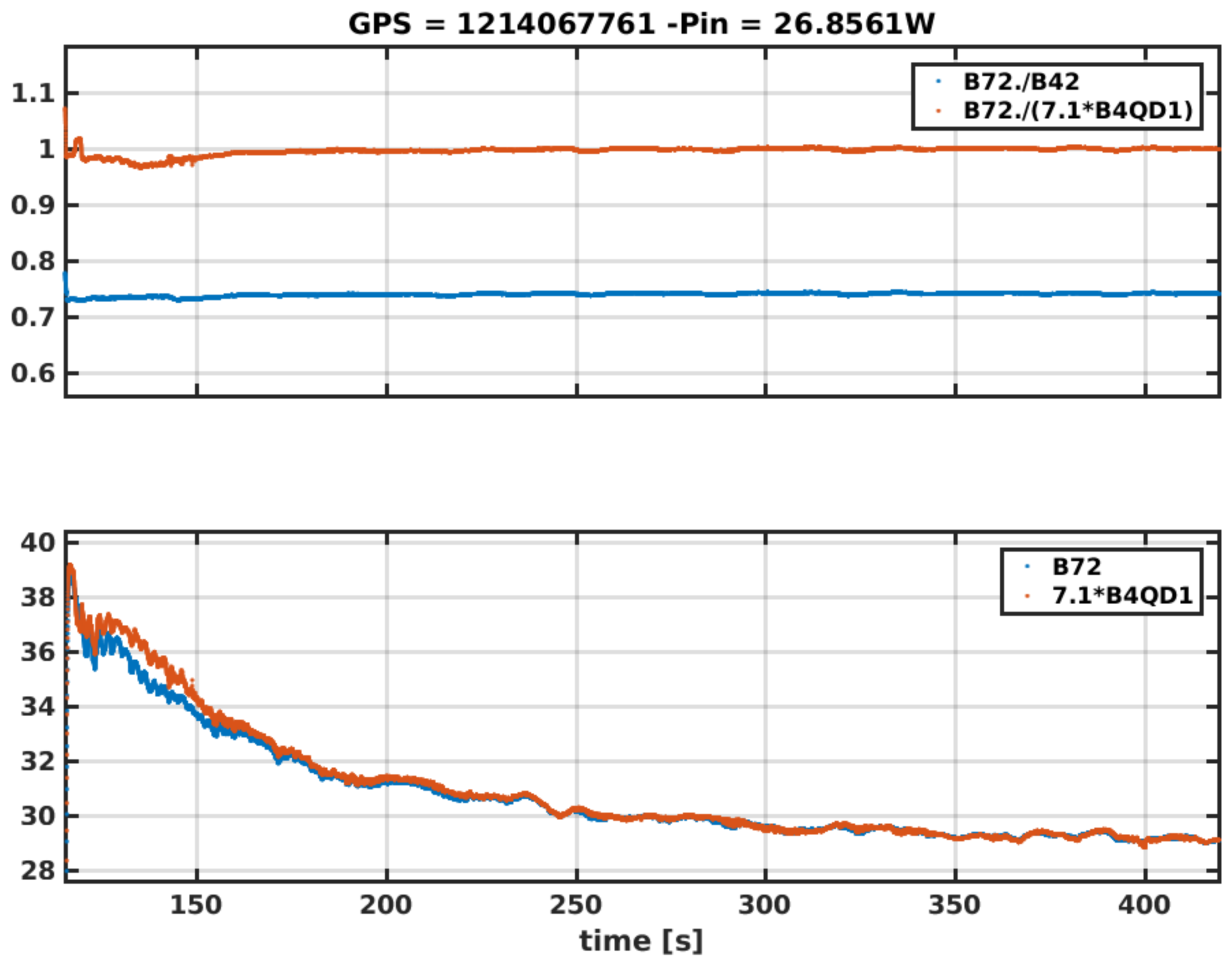
#42272



Comparison between PD & QPD

- Photodiodes and quadrants have similar time constants
- Probably not due to photodiode heating



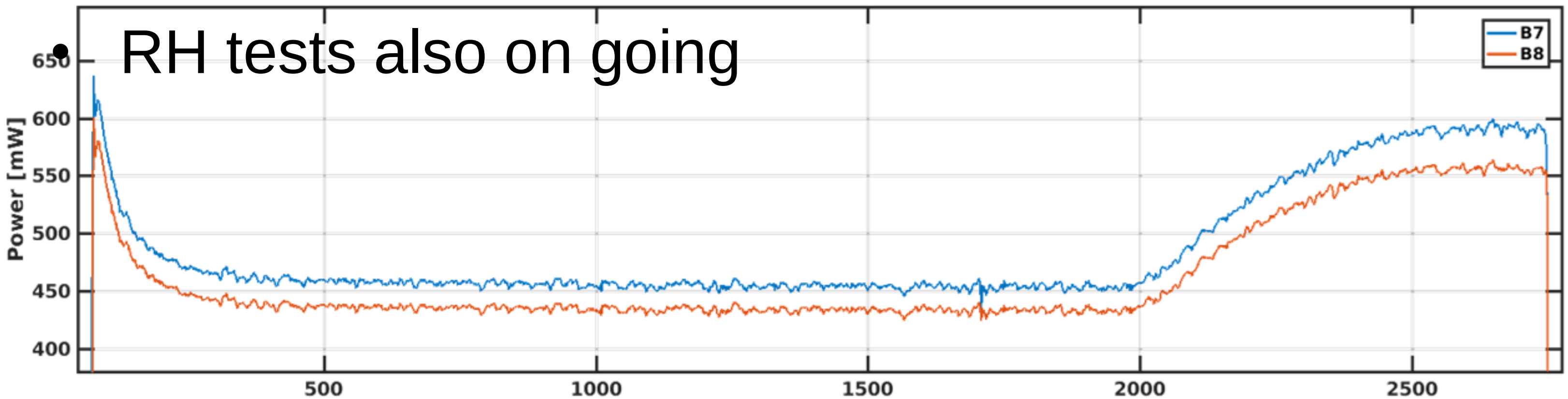
#42240

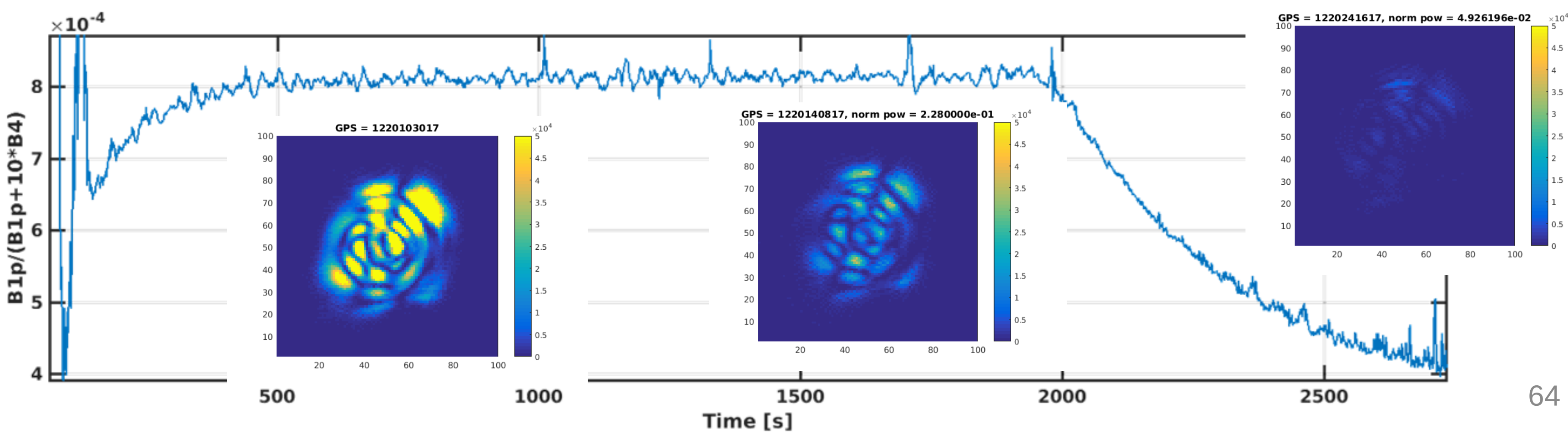
Mystery

- Too quick compared with
  - thermal lensing of input mirrors (~1000 sec)
  - bulk heating of input mirrors (~ few days)
- Point absorber??
- Power recycling gain comparison between 6 MHz and 56 MHz might indicate something
  - 6 MHz is more sensitive to alignment and aberration

Recent News from This Week

- Changing beam spot on ETM recovers the power drop of arm transmission and increase of B1p, but B1p mode content stays the same (#42639)
- RH tests also on going





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  - **- commissioning coordination**
  - **- control room**
  - **- random impressions**
- **Summary**

Commissioning Coordination

- Shift based (08:00-16:00, 15:00-23:00, 23:00-07:00)
  also shift for remote
- Wiki for coordinating the shift
- Daily meeting 15:30- (~0.5 h)
  between morning and afternoon shifts
  active remote participation (~15 at site, ~8 from remote)
- Weekly commissioning meeting on Tue 11:00- (~1.5 h)
  during maintenance
- Weekly coordinator (from remote)
  (assigned based on the number of authors in the institute)
- Well organized, very subsystem-oriented.
  - You have to coordinate before you work (e.g. You cannot just turn on XXX yourself. You have to convince XXX team to turn it on by themselves).

Shift Table Example

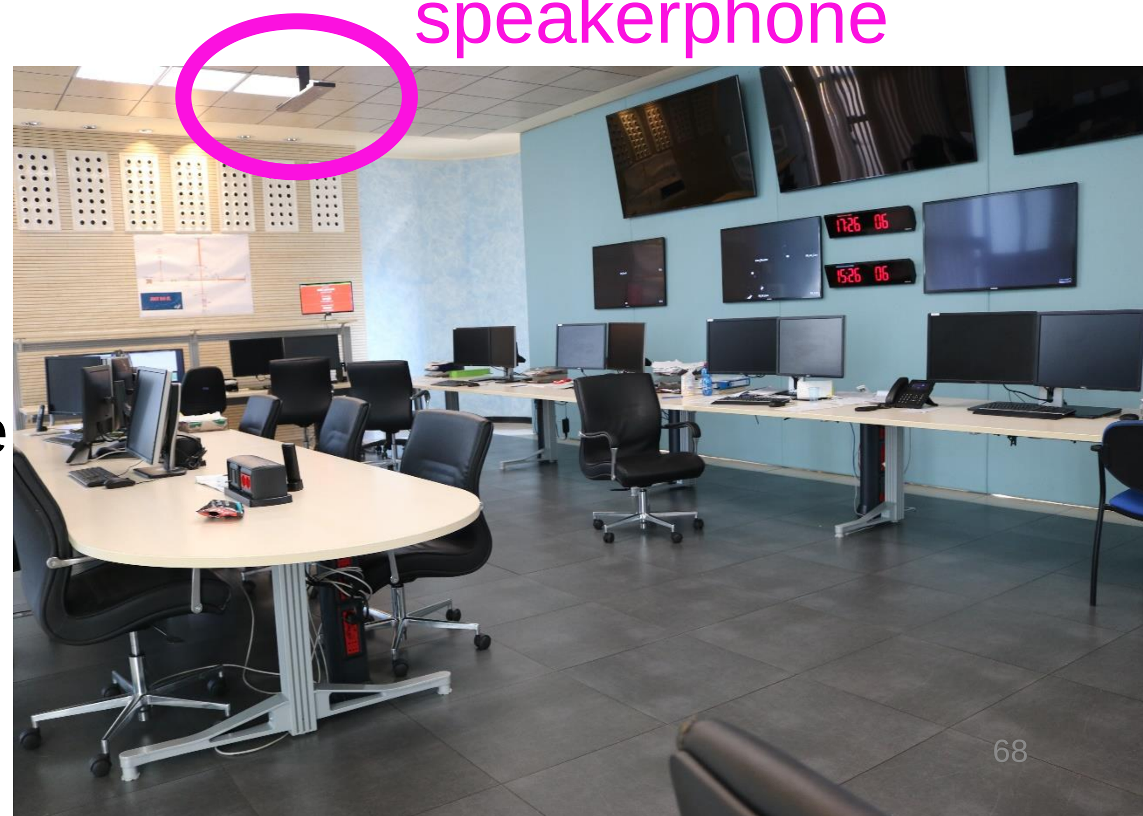
- You have to propose ahead to get a shift
- I think it is good that you can plan ahead and prepare for it

June 18 – 24

MON	TUE	WED	THU	FRI	SAT	SUN
ISC – LSC 7Hz damping - tuning BS alignment loop in full bandwidth (Ruggi, ...)	Maintenance Relocking (Casanueva late morning?, Chiummo)	ISC - tuning ITF alignment loops in full bandwidth (Ruggi, Chiummo, Mantovani)	ISC – Casanueva, Mantovani, Cohen: CMRF and related	ENV - tapping tests B1 pipe, 50Hz magnetic noise in sensitive locations around TMs and TMs electronics (Fiori, Paoletti, Boschi, Hardwick, Michimura) (until lunch-time)		
ISC – Casanueva, Masserot: SSFS hand-off to B2	ISC – Bersanetti, Michimura, Hardwick, Ruggi: violin modes active damping	ISC – Bersanetti Carbognani, Swinkels: FmodErr	ISC – tuning ITF alignment loops in full bandwidth: (Ruggi, Allocca, Chiummo)	DET - noise injections on benches and/or OMC (half shift after lunch time to 17h00) ISC – Carbognani Casanueva: tuning phases automation		
			Automation – Carbognani: cleaning metatron			

Control Room

- Nice system to talk to people off-site and people working at experiment area
- Many measurements done off-site (NoiseBudget, cavity scan, transfer functions etc.)
  - people in the control room help (and vise versa)
- Remote desktop (ThinLink) to control machines to work
  - same working condition for on-site and off-site



Random Impressions

- Many people are at the site, but basically only two who can take care of ISC
- Many site people also do not understand what's happening in the control room now
  - Maybe partially because some work is done with people remote
- Many people responsible for the hardware is not at the site
- Sectionalism
  - Pros: clear who is responsible
    (and people actually take responsibility)
  - Cons: we cannot touch their system on our own
    sometimes their data is not open
    mixed-up system (e.g. Acl and DSP)

- We can learn many things from Virgo

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  - **- Lessons Learned**
  - **- Visiting Around**
  - **- Summary**

Lessons Learned

- Understand the current configuration as much as possible before changing the configuration (but do not waste too much time on intermediate configurations)
  - May be do not take intermediate steps unless necessary
  - Recovering the interferometer after some changes is always time consuming
- Take your time to increase the number of people who can do what you do
  - It's not good if you are the only person who can do some specific work (e.g. locking, suspension tuning etc.)
- You can detect gravitational waves even if you don't follow LIGO designs
  - Be creative and be brave to design your own scheme
- DetChar tools (VIM, line tracker etc.) are extremely useful

Visiting Around

Summary

- Commissioning is fun

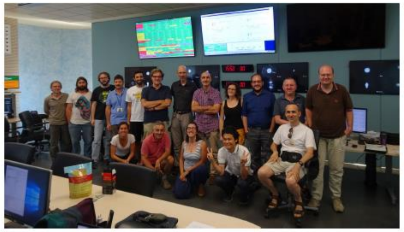
KAGRA Scientific Congress Newsletter No. 2 2018/08/01

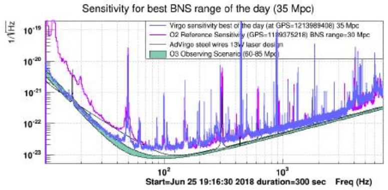
Site Report

Advanced Virgo: the best summer destination for commissioners

Yuta Michimura

I am now visiting Virgo site for 2 months from June 5. Advanced Virgo commissioning is now in a critical phase to reach the O3 sensitivity goal of 60-85 Mpc in the binary neutron star (BNS) range. The installation of a full monolithic suspension was done in March, and on June 25 we reached the best best BNS range up to now of 35 Mpc. The sensitivity improvement is mainly due to frequency noise subtraction at high frequencies and a tuning of the suspension controls. Amazingly, the sensitivity below 40 Hz is already compliant with the O3 goal! On June 26, we doubled the input power from 13 W to 25 W, to reduce shot noise at high frequencies. After the power increase, we were suffering from new issues. On July 23, we finally recovered the full lock of the interferometer, but the sensitivity is still at around 15 Mpc. Work towards more stable locking and investigations on some new noise sources is ongoing with great efforts.





The best sensitivity was achieved on June 25 (plot from Virgo Interferometer Monitor, VIM).

Virgo site has a superb canteen, which offers a different menu every day. Buonissimo!

Beautiful sunflowers along the west arm.

I have been to LIGO for several times, but this is my first visit to Virgo. The working environment at Virgo is very nice: friendly people, beautiful weather, excellent facilities, and delicious food. I realized that working environment is crucial for physics research. Interferometer commissioning is fun, but it can be even more fun with a better environment.

From my perspective, the KAGRA collaboration resembles more to Virgo than LIGO in which subgroups are led by different institutes. Virgo is suffering from the lack of manpower especially for the interferometer commissioning at the site, and therefore participation of remote people is very active compared with KAGRA and LIGO. I think many issues Virgo is now facing will be our own issues in the near future. I hope my experience from the Virgo visit will be useful not only for KAGRA commissioning, but also for a better collaboration in KAGRA.

This visit is supported by the Young Researchers International Deployment Program at the University of Tokyo. Visiting abroad for this long period not be possible without this program and the support from my colleagues in the Ando group and KAGRA. Thank you very much.

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KSC NewsLetter 201808