GWADW 2023

QUANTUM NOISE REDUCTION FOR ADV+

22-05-2023

LUIS DIEGO BONAVENA
ON BEHALF OF THE VIRGO
COLLABORATION

FIS AND FDS MEASUREMENT

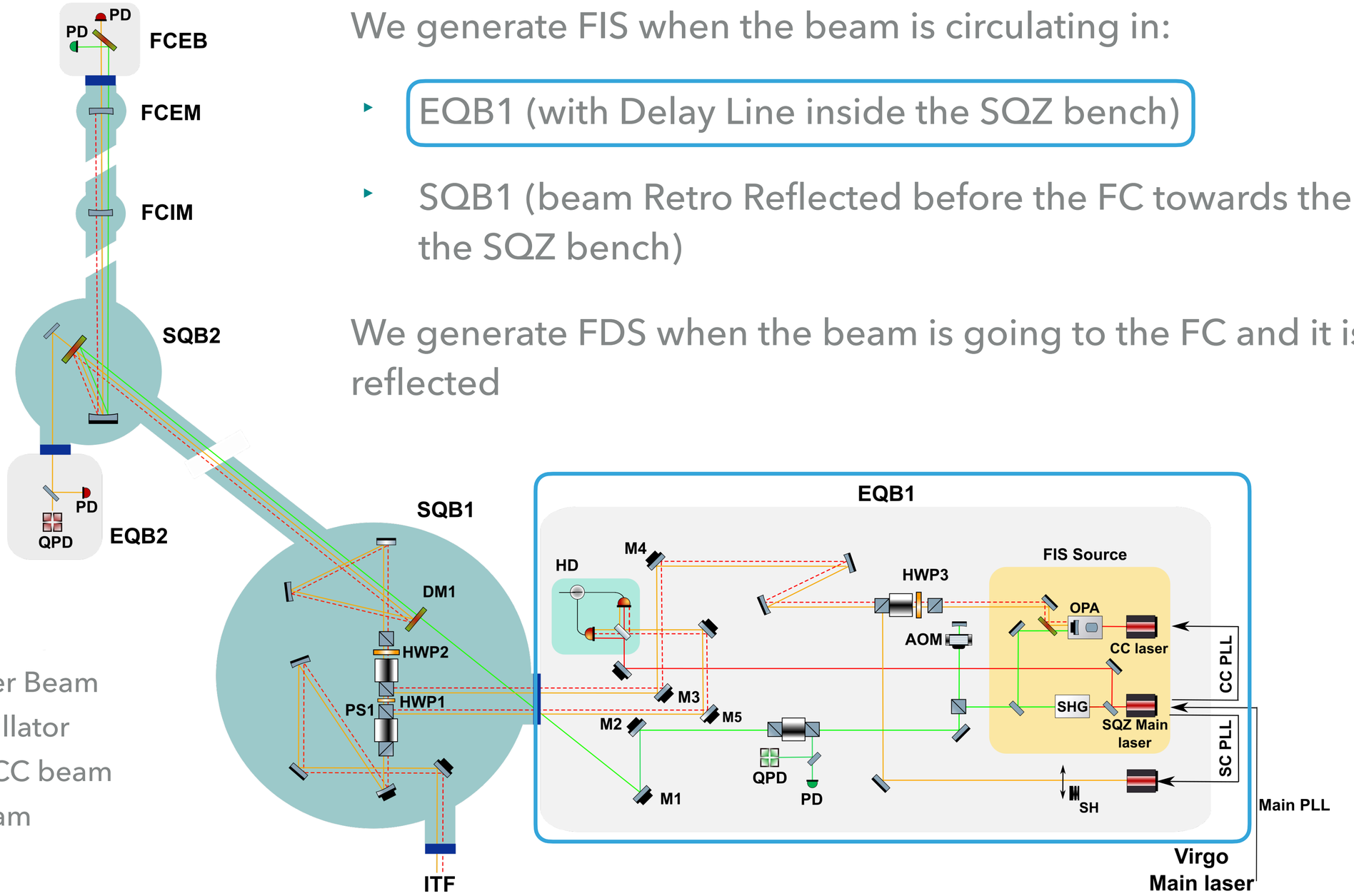
SUSPENDED BENCHES

AIR BENCHES

We generate FIS when the beam is circulating in:

- EQB1 (with Delay Line inside the SQZ bench)
- SQB1 (beam Retro Reflected before the FC towards the ITF or the SQZ bench)

We generate FDS when the beam is going to the FC and it is back reflected



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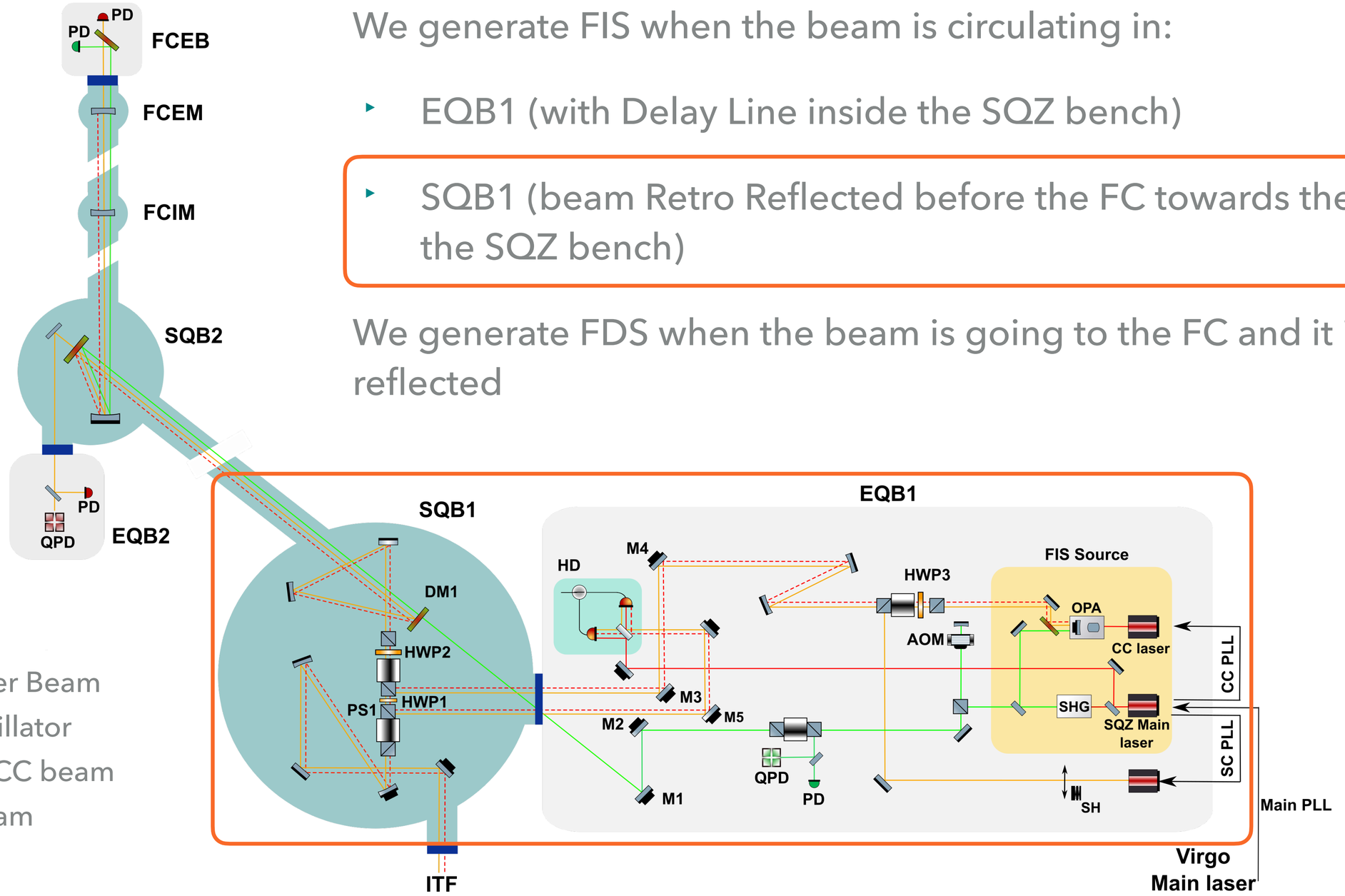

Sub Carrier Beam

Local Oscillator

SQZ and CC beam

Green beam

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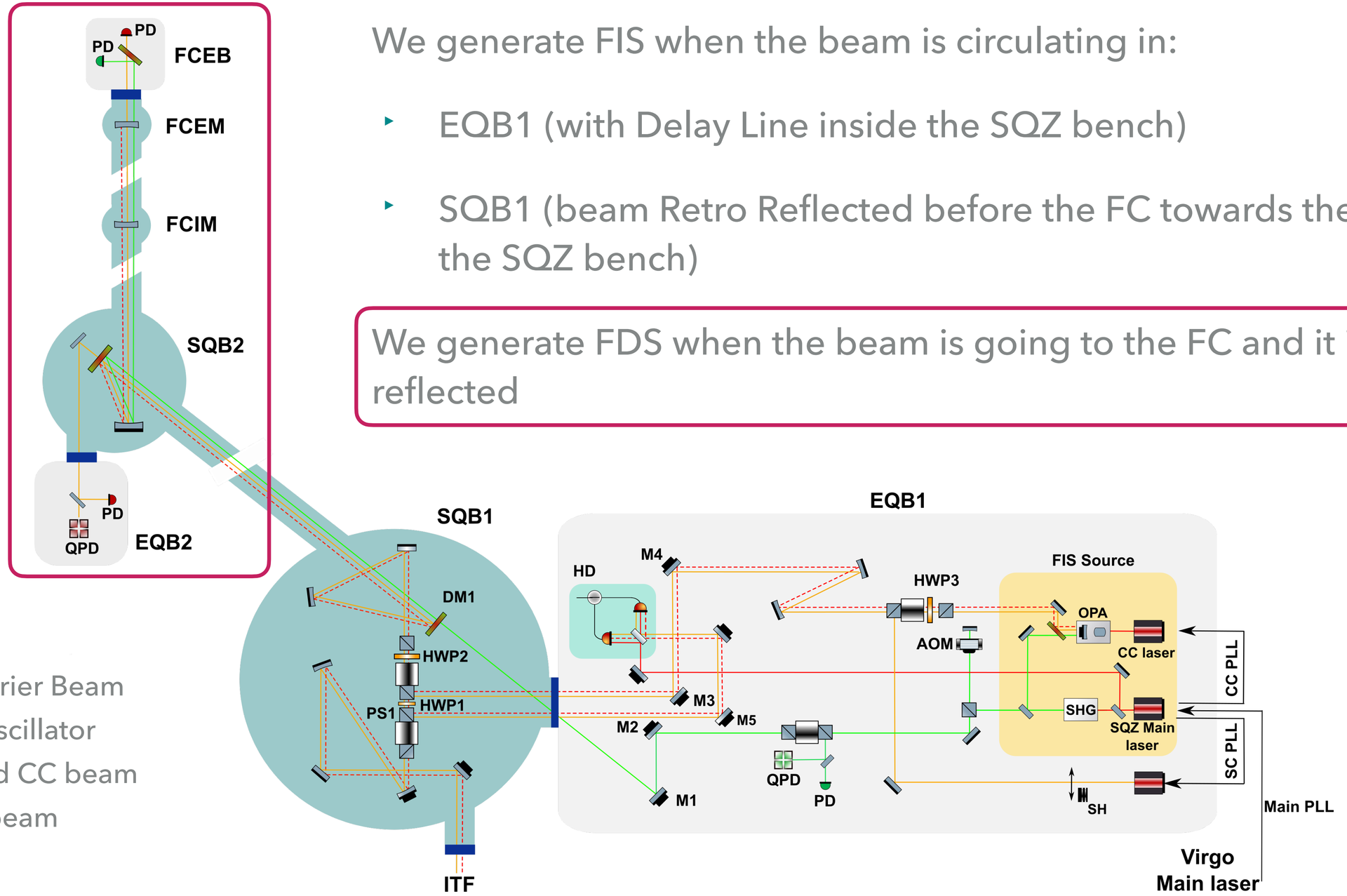


MEASUREMENTS SUMMARY AND LOSS BUDGET

POWER BUDGET

Configuration	Generated SQZ	SQZ	ASQZ
Delay Line	11.5 dB	7.5 dB	10.9 dB
SQB1 Retro Reflector	10.7 dB	6.5 dB	10 dB
Filter cavity	11.8 dB	6.5 dB	11.2 dB

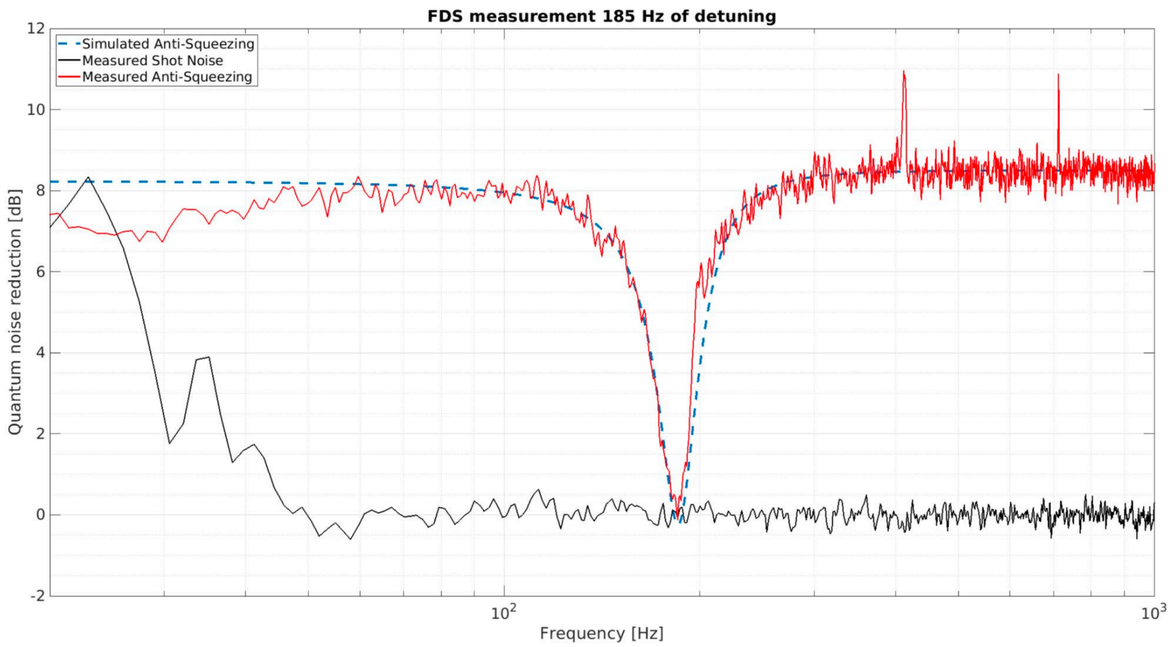
LOSSES

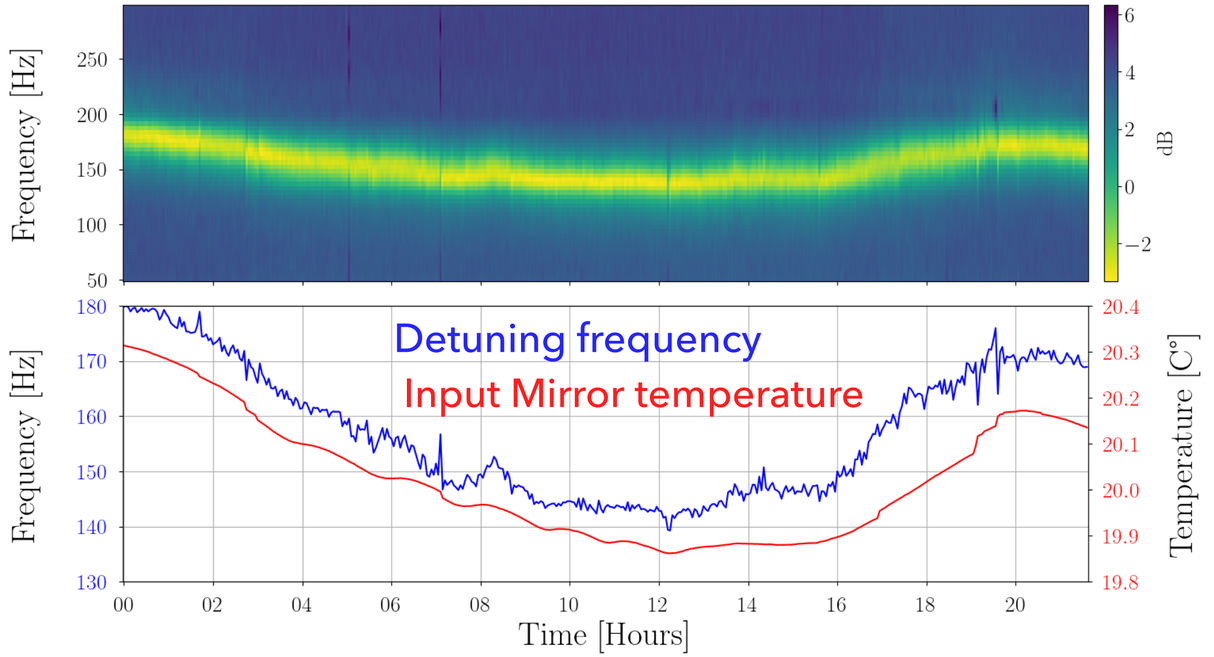
Configuration	Phase noise	Losses	Known/ Unknow
Delay Line	14±12mrad	11±0.4%	8% known 3% unknown
SQB1 Retro Reflector	20±11mrad	14.9±0.4%	10% known 5% unknown
Filter cavity	31±21mrad	17±1%	13% known 4% unknown

KNOWN LOSSES

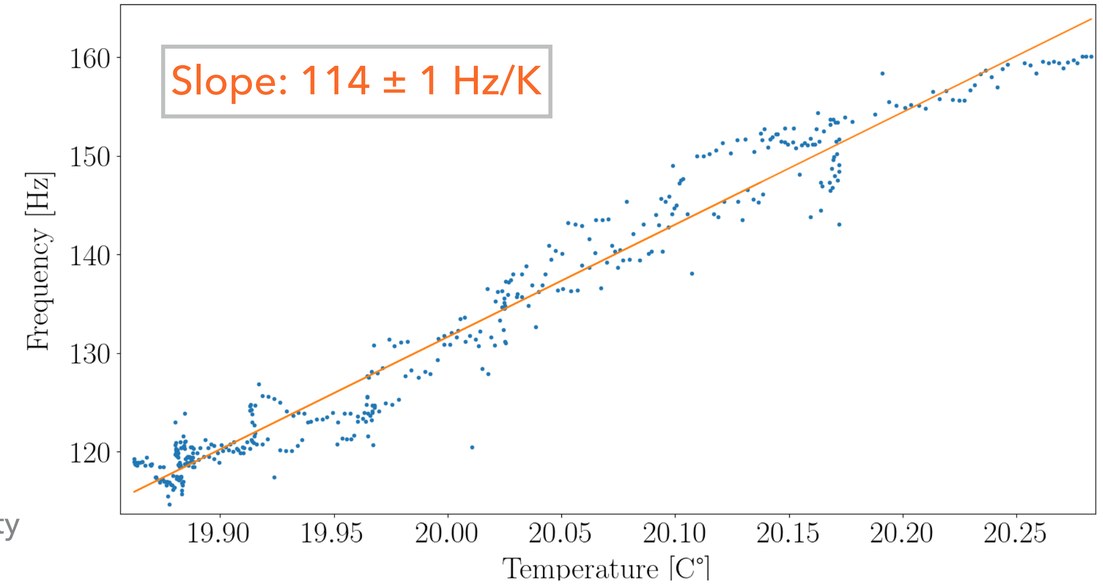
Configuration	Kind of losses	Amount of losses
ALL	OPA escape efficiency	1%
ALL	HD PD quantum efficiency	1%
ALL	HD clearance	1%
ALL	EQB1 FI	1%
DL	VIS 98.4%	4%
RR	VIS 99.2%	2%
FCIM	VIS 98%	5%
RR/FCIM	EQB1-SQB1 propagation losses	4%

21 HOURS OF STABLE FDS



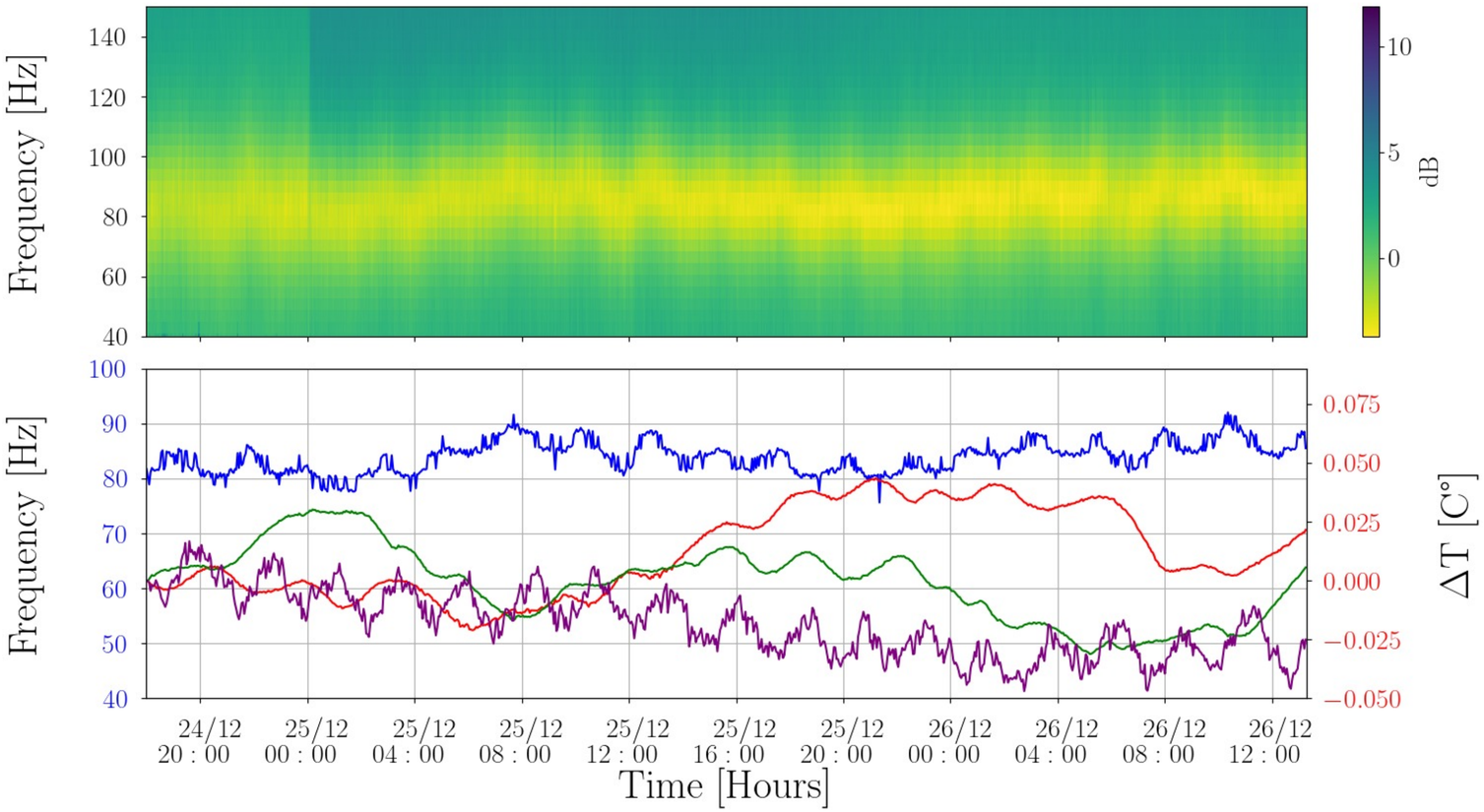


- Automatic engagement of FDS measurement: ASQZ 185 Hz of detuning
- 50 Hz of detuning, correlated with temperature day-night drift (0.5K)
- ~60 minutes of delay between temperature and detuning



Tuesday poster session:
Y. Zhao: Observation and interpretation of bichromatic thermal detuning in Virgo filter cavity

2 DAYS OF STABLE FDS MEASUREMENT



- Two days of continuos FDS measurement with 90 Hz of detuning in ASQZ angle
- Zero unlock of the system
- FDS detuning fluctuations <10Hz peak to peak
- Residual detuning oscillation coherent with the temperature oscillation of the Virgo DET lab (SQZ source)
- PRL accepted

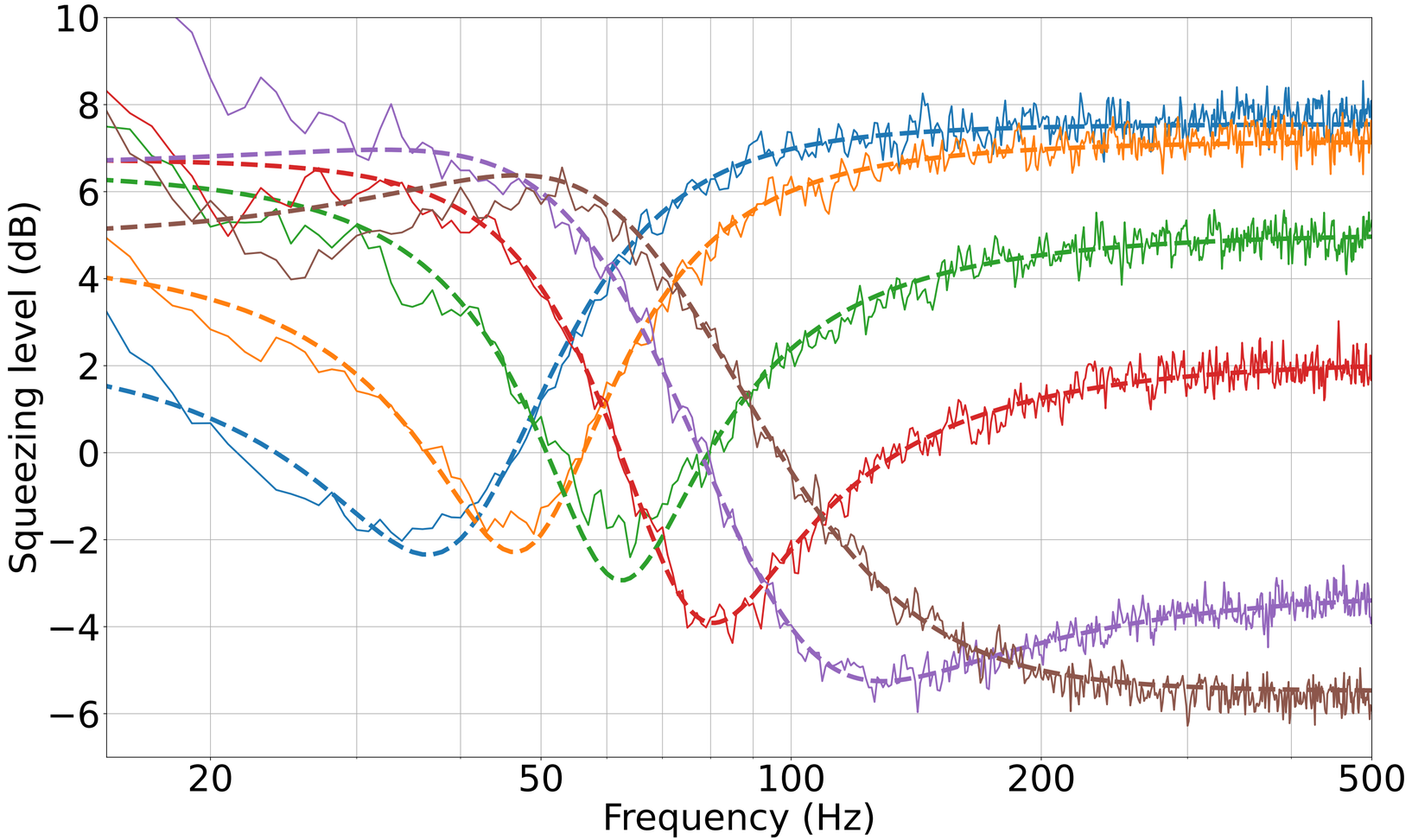
FC detuning frequency
Input mirror temperature
End mirror temperature
Detection LAB temperature

Frequency dependent squeezed vacuum source for the Advanced Virgo gravitational wave detector

F. Acernese *et al.* (the Virgo Collaboration),
H.Vahlbruch, M. Mehmet, H. Lück, and K. Danzmann
Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany

FDS MEASUREMENT (45–55 HZ)

The system is ready for the injection

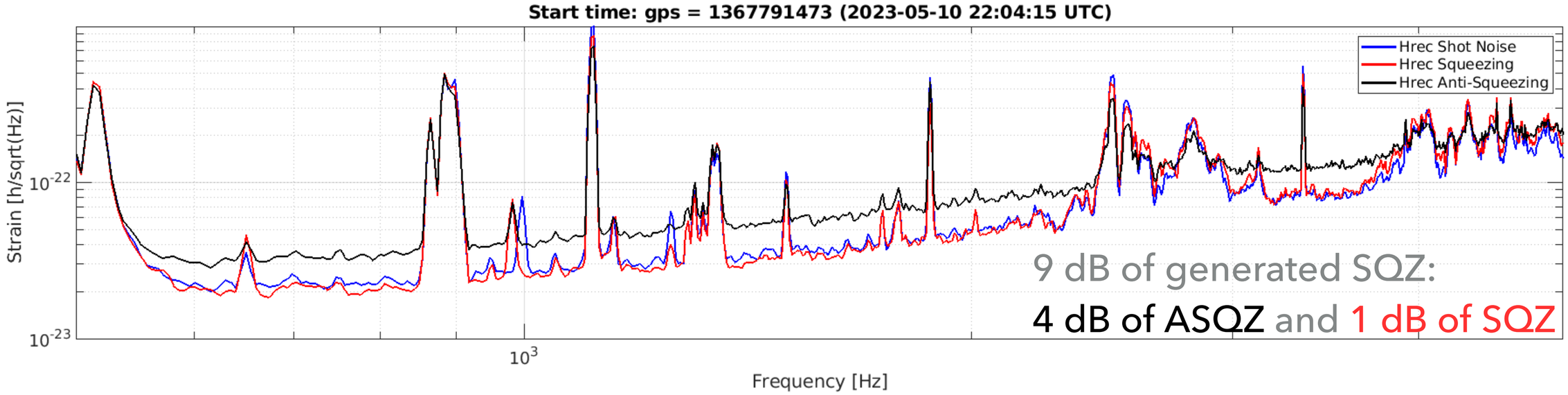


Degradation parameter	O4 design	Measured value
Injection losses [%]	13	10 ± 1
FC round trip Losses [ppm]	60	50 - 90
Mode mismatch SQZ-FC [%]	2	1.5 ± 1
Phase noise - rms [mrad]	40	30 ± 20
FC length Fluctuations - rms[Hz]	1	~1

SQZ AND ASQZ INJECTION

Alignment into the interferometer: CC loop and AA loops closed, 95% of mode matching*

Injection configuration: injection of FIS from RR into the ITF dark port



The injection is currently limited by:

- Frequency noise
- Propagation losses
- OMC
- PDs quantum efficiency
- Signal Recycling (?)
  - Finesse simulations
  - Injection of SC, BAB and vacuum states

SUMMARY AND NEXT STEPS

Summary

- ✓ 3 configurations for SQZ characterization FIS and FDS
- ✓ System automation and stabilization
- ✓ FDS measurement stand alone
- ✓ Alignment into the ITF
- ✓ SQZ injection (FIS) into the ITF

Next steps

- Characterization of the RTL into the SQZ FC
- Characterization of the losses into the ITF (SR cavity)
- Long stable FIS injections (3-4.5 dB)
- FDS injections