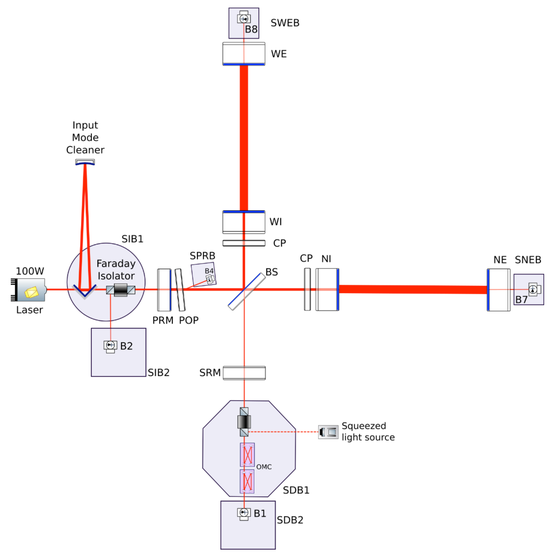
Study of the control losses of the Virgo gravitational-wave (GW) detector in data-taking mode during the O3 run (2019/04 – 2020/03)

Active control required for a detector like Virgo to be sensitive to the passing of GWs



- 4 longitudinal degrees of freedom
  - Michelson interferometer on the dark fringe
  - Resonant power-recycling cavity
  - Resonant kilometric Fabry-Perot cavities
- Alignment
- Laser frequency stabilization

Nominal working point

→ Working point needs to be acquired – "Locking"
- Sequence median duration: 25 minutes

→ Each control loss – "lock loss" – leads to a decrease of the Virgo detector duty cycle
- Defined as the fraction of time spent taking good quality physics data – "Science mode"

→ It is important to study the lock losses and understand their origin
- 601 such lock losses in Science mode during O3

O3 Science mode lock losses investigation strategy

① Estimate accurately the time of each lock loss

→ Three reference channels: use the one that latches first
- Monitoring of the Fabry-Perot cavities (arms) stored power
  - Goes down abruptly when working point is lost
- Fast dark-fringe photodiode shutter
  - Closes quickly when detected power increases to protect hardware
- Slow (1 Hz) global detector status provided by the automation system
  - Used to steer the detector
  - Can trigger a lock loss if non-nominal conditions detected

Arm power	Dark fringe shutter	Automation status	Total
14	559	28	601

② Test several hypothesis in parallel for the root cause of each lock loss
- Binary output for each check
  → Data around lock loss compatible or not with that particular scenario
- Improvement foreseen for O4: adapt the Data Quality Report framework used during O3 to vet the quality of the data around a public alert
  - GW trigger ↔ Lock loss
  - Data quality check ↔ Lock loss hypothesis check

③ Classify test outputs
- "Sure" lock loss causes

Human error	Manual lock loss	Hardware problem	Control software	Parametric instability	Earthquakes	Total
2	10	92	7	2	30	143 (24%)

- "Other" lock loss causes
  → Human assessment to select the most likely cause for each lock loss

Laser injection	Actuation saturation	Control inaccuracy	Issue with control signals	Arm power asymetry	Likely missing data	Automation decision	Others	Total
173	85	77	22	4	10	23	64 (11%)	458 (76%)

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Nicolas ARNAUD (nicolas.arnaud@ijclab.in2p3.fr) IJCLab & EGO
Laboratoire de Physique des 2 Infinis Irène Joliot-Curie (Université Paris-Saclay & CNRS/IN2P3)
European Gravitational Observatory