

# Detector Characterization Report

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On behalf of the **Virgo DetChar** group

**8<sup>th</sup> KAGRA Workshop**

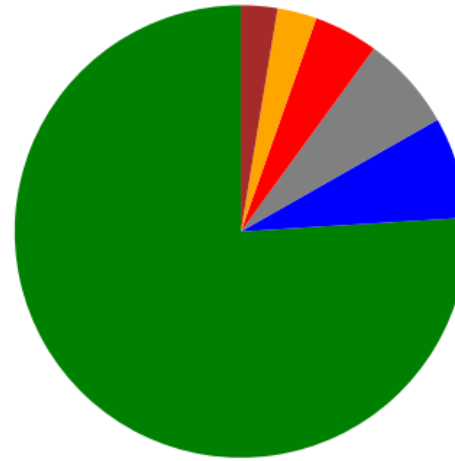
**Remote conference, July 09, 2021**

**VIR-0745A-21**



# Outline

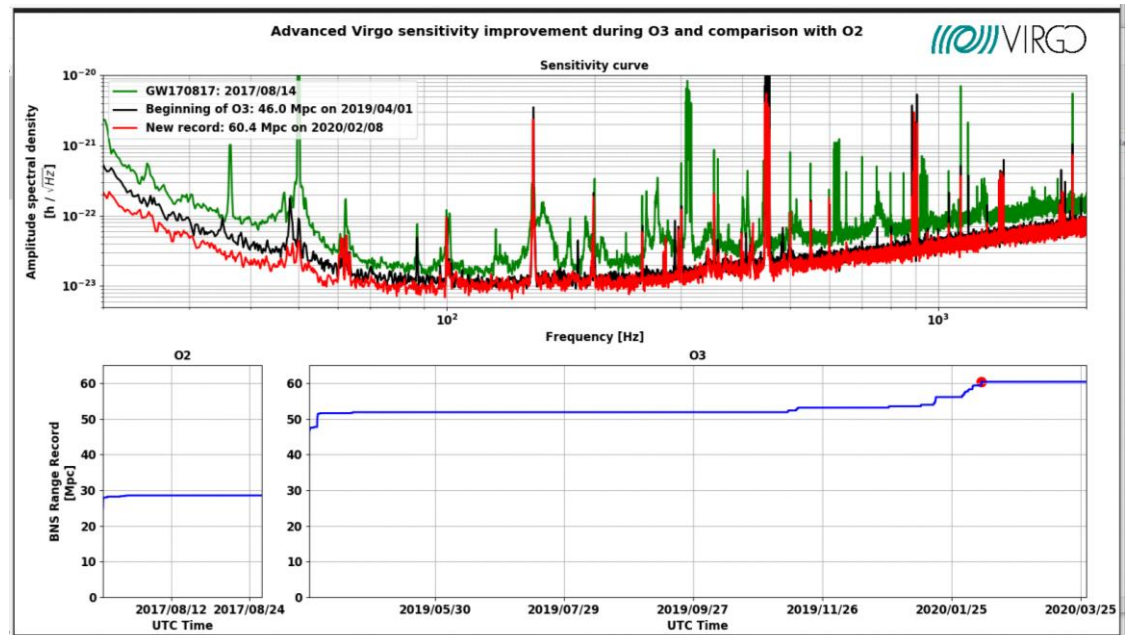
- Virgo DetChar in a nutshell
- Looking back at O3
  - Dataflow
  - Some key tools
  - Focus: Data Quality Reports



- Virgo DetChar and the first long Advanced Virgo run
  - Improvements during and following O3
  - What worked / did not work so well
  - Experience and lessons learned

- O4 preparation
  - Group organization
  - Software frameworks
  - DQ checks

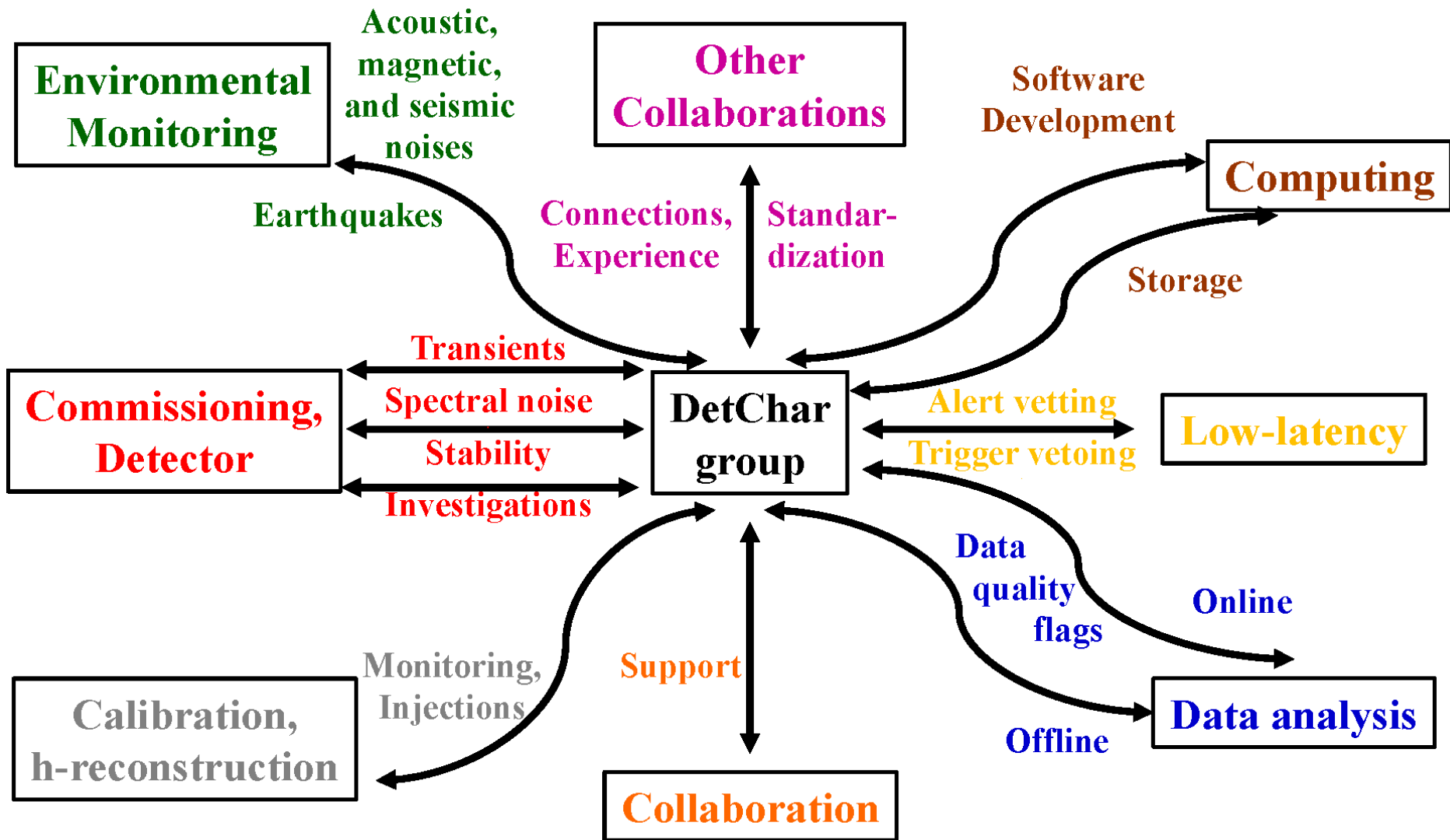
- Outlook



# About Virgo DetChar

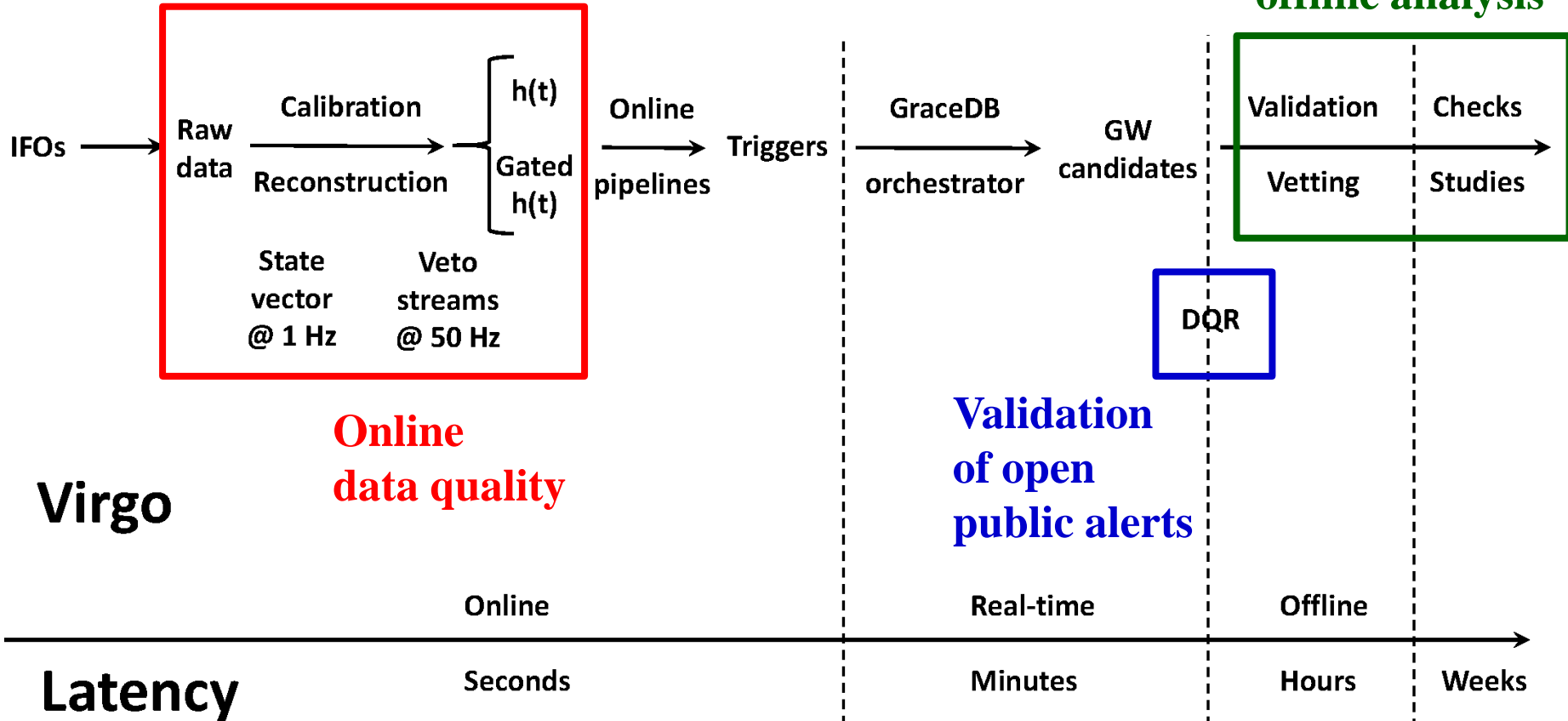
- Virgo **WikiArea**: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/WebHome>
  - **Newcomers**: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/DetCharNewComers>
  - **Help**: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/DetCharHelp>
  - **Trainings**: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/DetCharShifts#Training>
- **Meetings**
  - **When?** Every (other) Friday at 11:00 CE(S)T
  - **Where?** On the **EGO TeamSpeak Server**, **DetChar channel**:  
<https://wiki.virgo-gw.eu/InformationSystem/TeamSpeak>
- **Mailing list**: [detchar@ego-gw.it](mailto:detchar@ego-gw.it)
  - **Subscription**: <http://mail.ego-gw.it/mailman/listinfo/detchar>
- Getting **Virgo accounts**:  
[https://wiki.virgo-gw.eu/InformationSystem/Cascina\\_EGO-Virgo\\_Accounts](https://wiki.virgo-gw.eu/InformationSystem/Cascina_EGO-Virgo_Accounts)
  - **EGO Active directory account** required to **access** Virgo Wiki
- **O3 DetChar summary**:
  - <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/DetCharO3Summary>
- **O4 preparation**
  - **Roadmap**: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/O4RoadMap>
  - **Projects**: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/O4Projects>

# Virgo DetChar within Virgo & LVK



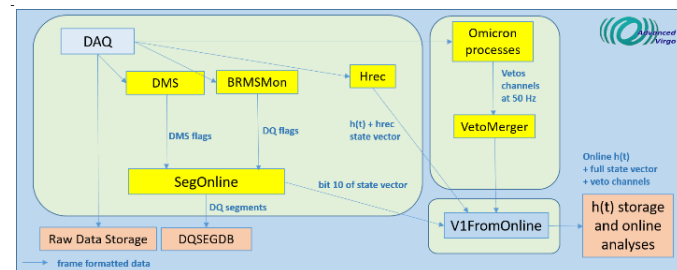
# A look back at O3

- **Workflow:** three main pillars



- **Monitoring**

- Detector & servers
- Environmental impact
- Online & offline DetChar products

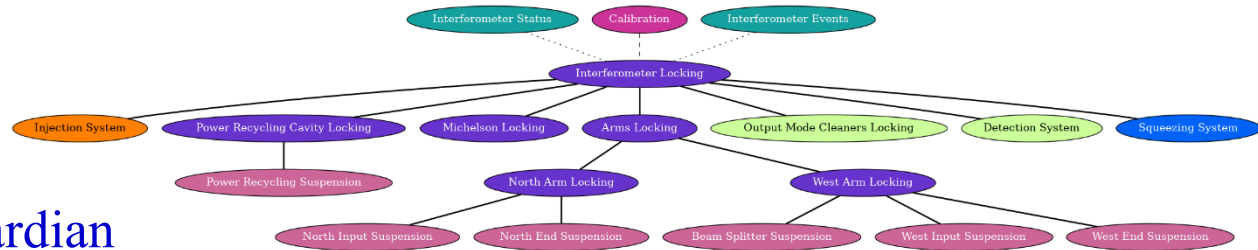


# Some examples of key tools

- Automation

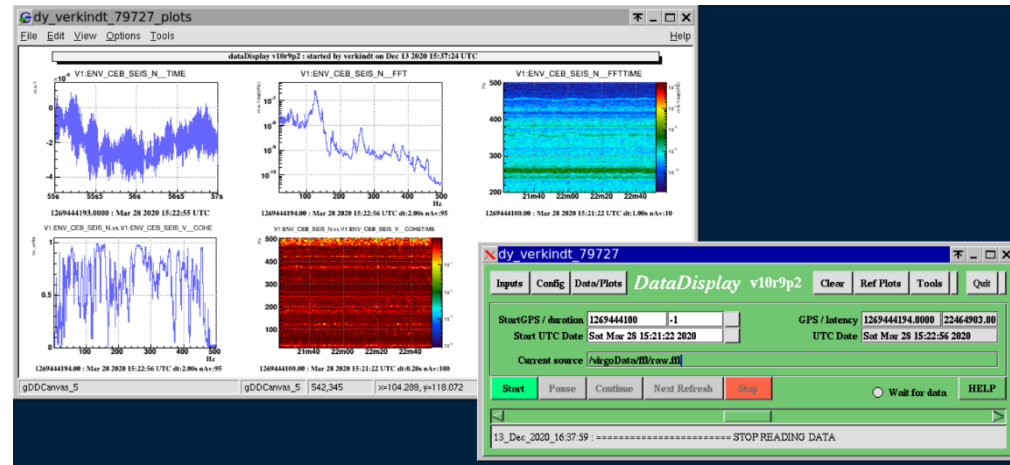
- Metatron

- Based on LIGO's Guardian



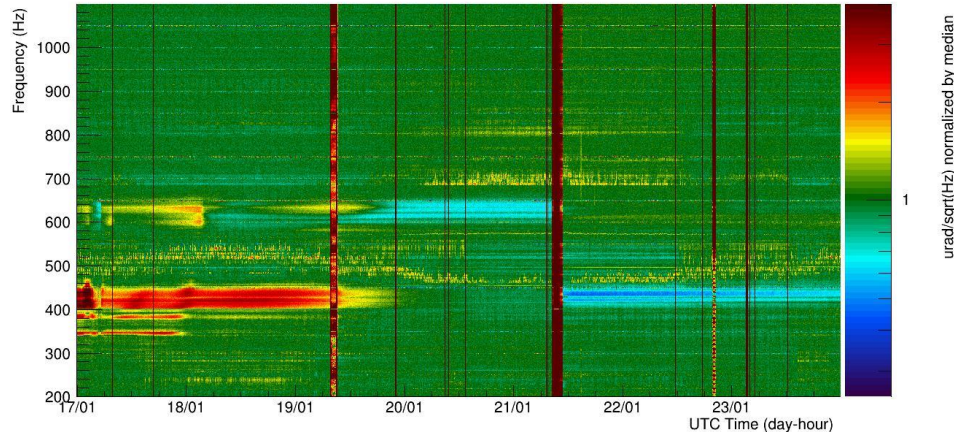
- dataDisplay

- Interactive signal processing



Spectrogram of V1:spectro\_BsX\_TX\_300\_100\_0\_0 : start=1263254339.000000 (Thu Jan 16 23:58:41 2020 UTC)

- Spectrograms



# Some examples of key tools

- **Virgo Interferometer Monitor (VIM)**

- In-time and archived plots from all subsystems



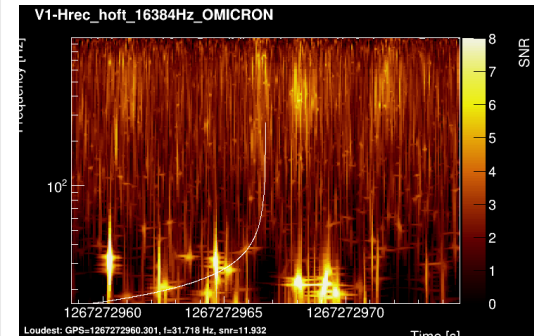
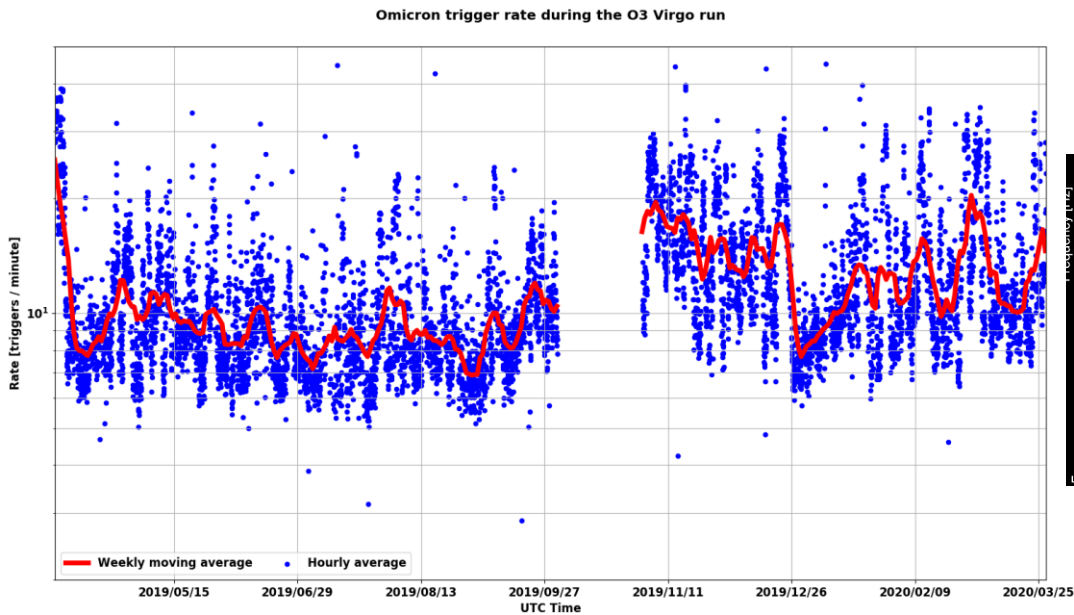
- **Detector Monitoring System (DMS)**

- Detailed detector status
- Information about online servers

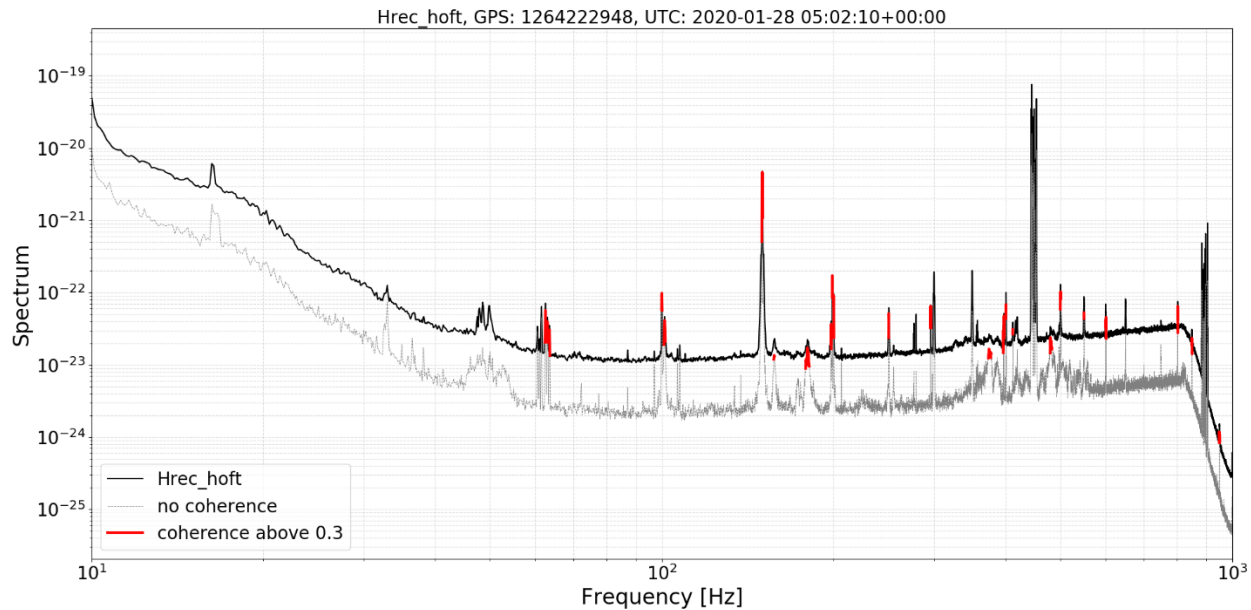
|               | ITF Mode: Science (on 21 Jan 20) |                |               |                   |              |             |              |              |              |                    | ITF State: LOW_NOISE_3_SQZ (on 21 Jan 20) |                | UTC: 2019-04-12 05:30:48 |              |              |             |          |            |         |
|---------------|----------------------------------|----------------|---------------|-------------------|--------------|-------------|--------------|--------------|--------------|--------------------|---|----------------|--------------------------|--------------|--------------|-------------|----------|------------|---------|
| Injection     | SIB1_IP                          | SIB1_BENCH     | SIB1_BR       | SIB1_Vert         | SIB1_TE      | SIB1_Guard  | SIB1_Electr  | MC_IP        | MC_PAY       | MC_BR              | MC_Vert                                   | MC_TE          | MC_Guard                 | MC_Electr    |              |             |          |            |         |
|               | Laser                            | LaserAmp       | LaserChiller  | SL_TempController | RFC          | LMS         | PC           | MC_Power     | FSTAB        | IMC_AA             | IMC_AA_GALV0                              | MC_FD_x        | BPC                      | BPC_Electr   |              |             |          |            |         |
|               | PD                               | QPD_B1p        | QPD_B2        | QPD_B5            | OMC          | PicoDisable | Shutter      | SD01_IP      | SD01_LC      | SD01_BR            | SD01_Vert                                 | SD01_TE        | SD01_Guard               | SD01_Electr  |              |             |          |            |         |
|               | ISC                              | B2_BMHz_DPHE   | B4_S0MHz_DPHE | DARM_UGF          | UNLOCK       | SGFS_UGF    | FeedErr      | GIPC         | B1p_DC       | B4_112MHz_MAG      | B7_DC                                     | B8_DC          | LSC_rms                  | ASC_rms      |              |             |          |            |         |
| Suspensions   | BS_IP                            | BS_F7          | BS_PAY        | BS_BR             | BS_Vert      | BS_TE       | BS_Guard     | BS_Electr    | NL_IP        | NL_F7              | NL_PAY                                    | NL_BR          | NL_Vert                  | NL_TE        | NL_Guard     | NL_Electr   |          |            |         |
|               | NE_IP                            | NE_F7          | NE_PAY        | NE_BR             | NE_Vert      | NE_TE       | NE_Guard     | NE_Electr    | PR_IP        | PR_F7              | PR_PAY                                    | PR_BR          | PR_Vert                  | PR_TE        | PR_Guard     | PR_Electr   |          |            |         |
|               | SR_IP                            | SR_F7          | SR_PAY        | SR_BR             | SR_Vert      | SR_TE       | SR_Guard     | SR_Electr    | WL_IP        | WL_F7              | WL_PAY                                    | WL_BR          | WL_Vert                  | WL_TE        | WL_Guard     | WL_Electr   |          |            |         |
|               | WE_IP                            | WE_F7          | WE_PAY        | WE_BR             | WE_Vert      | WE_TE       | WE_Guard     | WE_Electr    | CB_Hall      | MC_Hall            | TCS_zones                                 | NE_Hall        | WE_Hall                  | WindActivity | Season       | BRMSMon     |          |            |         |
|               | Environment                      | INJ_Area       | DET_Area      | EE_Room           | DAQ_Room     | External    | DeadChannel  | Lights       | SeaActivity  | WAB                | ACS_CB_Hall                               | ACS_TB         | ACS_DAO_Room             | ACS_EE_Room  | ACS_MC       | ACS_INJ     | ACS_DET  | ACS_NE     | ACS_WAB |
|               | Infrastructures                  | UPS_TB         | UPS_CB        | UPS_MC            | UPS_NE       | UPS_WE      | FatChannel   | ExitChannel  | ACS_WE       | ACS_CB_OK          | ACS_COB                                   | EIB_SRE        | SD02_SRE                 | SD02_LC      | SNEB_SRE     | SNEB_LC     | SWEB_SRE | SPRB_SRE   | SPRB_LC |
| SRE           | NE_RH                            |                | WE_RH         |                   | NE_CO2_Laser |             | WL_CO2_Laser |              | Chillers     | PLL                | Squeezer                                  | SQZ_AA         | SQZ_Shutter              | Cohe_CTRL    | SQZ_Inj      | Radr_TE     |          |            |         |
| SQZ           | LargeValves                      | Clean_Air      | TubeStations  | TubePumps         | MiniTowers   | TurboLinks  | RemDryPHP    | VAC_SERVOS   | Pressure     | CompressedAir      | TowerServers                              | TowerPumps     | CryoRap                  | O2_Sensors   | Tank         |             |          |            |         |
| Vacuum        | DetectorEnvironment              | ControlRoom    | Minotowers    | ISC               | Injection    | TCS         | Suspension   | Vacuum       | Metatron     | DetectorMonitoring | DataCollection                            | Storage        | DataAccess               | Automation   | DetChar      |             |          |            |         |
| VPH           | Latency                          | Disk           | Timing        | Timing_rpc        | Timing_dsp   | Fast_DAC    | ADCS_TE      | Daq_Boxes_TE | DMS_machines | DetOp_machines     | observers                                 | rtics          | CoilSwitchBoxes          | INF_devices  | ENV_devices  | VAC_devices |          |            |         |
| DAQ_Computing | Calib_Hrec                       | CalRE          | CalWE         | CalBU             | observers    | CalBS       | CalPR        | PCalRE       | PCalWE       | HQFT               | NCAL                                      | NoiseInjection | ITF_OeCall               | SoftwareA    | TemperatureA | InjectionA  | UPS_A    | GeneratorA | TcalA   |
| ITF_OeCall    | ITF_Char                         | Hrec_RANGE_BNS |               |                   |              |             |              |              |              |                    |   |                |                          |              |              |             |          |            |         |
| ITF_Char      |                                  |                |               |                   |              |             |              |              |              |                    |   |                |                          |              |              |             |          |            |         |

# Some examples of key tools

- **Omicron**
  - Glitches



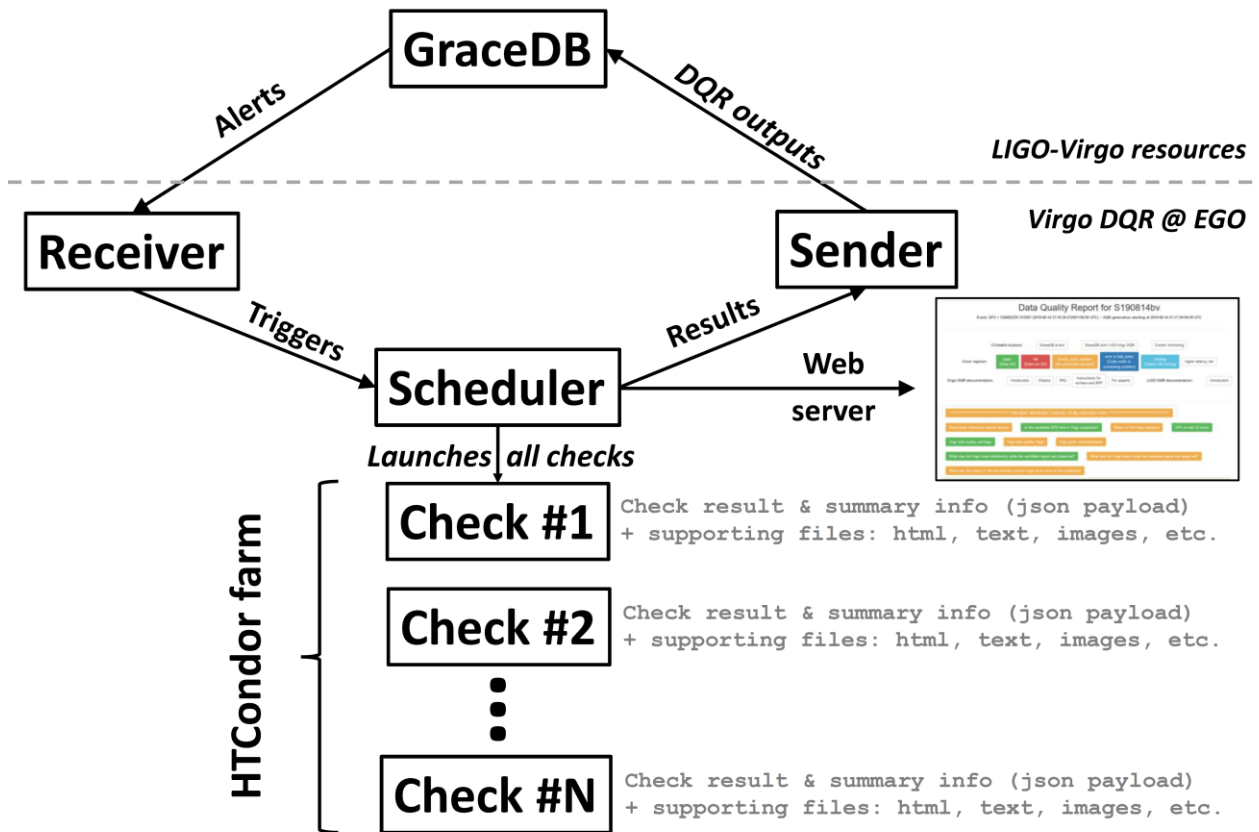
- **Bruco**
  - Spectral lines





# Data Quality Reports

- **Virgo DQR** framework
  - Triggered by GraceDB
  - Full running at EGO
  - Results directly and immediately available through EGO web server  
→ Uploaded back to GraceDB



# Data Quality Reports

- Design choices

- High-reliability framework
- Robust and proven checks

- ◆ Major reuse of already existing codes: DQ flags, Omicron, noise stationarity...
- ◆ Dedicated developments as well

→ Good performance overall

|   | Duration [s] | Median | Mean | 95th percentile |
|---|--------------|--------|------|-----------------|
| Quick key checks                              |              | 374    | 383  | 619             |
| Adding Omicron trigger distributions          |              | 868    | 816  | 935             |
| Adding full Omicron scans                     |              | 1740   | 2159 | 4690            |
| Complete DAG duration (adding longest checks) |              | 5185   | 4954 | 6330            |

- DQR 2.0

- A key development for O4

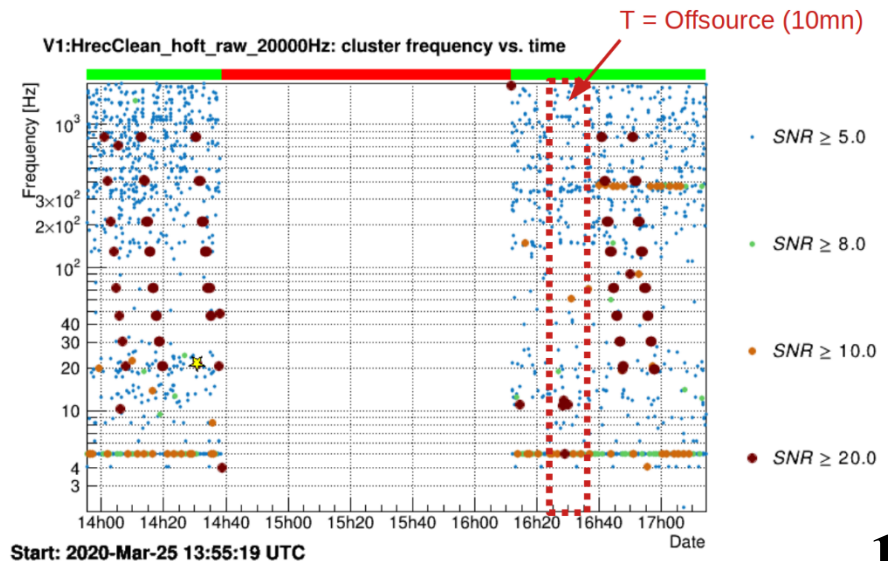
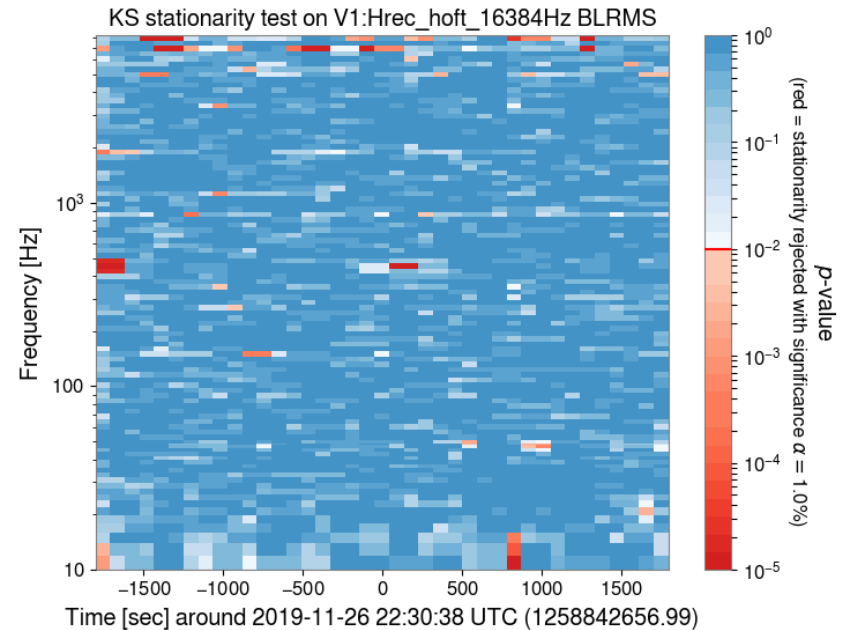
→ Manifold goals

|  | Number of unsuccessful checks | 0   | 1   | 2  |
|--|-------------------------------|-----|-----|----|
| Percentage of O3b automatically processed DQRs |                               | 85% | 13% | 2% |

- ◆ Solidify O3 performance
- ◆ Improve code structure and quality
- ◆ Fix bottlenecks and weak parts
  - e.g. lvalert receiving
- ◆ Review all existing checks
- ◆ Code modularity to ease the addition of new checks
- ◆ Hunt down latencies
- ◆ Possibility to run elsewhere than on the EGO Condor farm

# Improvements during and following O3

- **Noise stationarity and Gaussianity**
  - BRISTOL framework and related libraries
- **Channel safety study**
  - Analysis of hardware injections using LIGO's PointyPoisson framework
- **Data quality improvements**
  - Extending existing checks
  - Developing new ones to cope with newly identified issues
- Developing **dedicated framework to access raw data from computing centers** when no more available at EGO
  - Needed to vet latecomer events  
→ 1.5+ year after data were taken



# What worked well during O3

- First long run for Advanced Virgo
  - Virgo DetChar held on over 6+5 months
    - ◆ No significant failure/delay, major milestones achieved
  - A lot of experience gained for O4 preparation and data taking
    - ◆ Weak and strong points are clear
- Virgo flavour of the DQR
  - The DetChar group priority for O3: a new, key, development
    - ◆ Significant resource dedicated to it, well ahead of time
      - A real arbitration given the global personpower shortage
- Partial but efficient internal feedback mechanism to review and improve tasks
  - Between O3a and O3b, using the 1-month commissioning break
  - But also during sub-runs as well
- Connection with the LIGO DetChar group
  - Already well-established for years!
- Virgo DetChar visibility
  - Within the Virgo collaboration and also more broadly within LVK

# What did not work so well during O3

- **Personpower**: the **biggest, more limiting, issue** for Virgo DetChar
  - **Direct impacts** on DetChar: **limitations**
    - ◆ Improvements & new developments in between runs
    - ◆ Activities during runs, on-call/on-duty commitments
  - **Indirect – but real – impacts** on the rest of the Collaboration / the LVK
    - ◆ **Detector**: investigations, monitoring
    - ◆ **Analysis**: low-latency, products beyond SCIENCE segments + CAT1 vetoes
  - **Everyone at all levels now aware of that**
    - ◆ Yet, no clear path forward to escape from this bad situation
- **DetChar shifts**
  - **Too broad in scope** and audience
    - ◆ To be included in a **broader framework** of service tasks
    - ◆ **Less people in total, but more committed**: longer shifts and/or more per shifter
- **Beginning of O3**: planning should be updated based on actual situation
  - ER14 still an active development phase,  
the first few weeks of O3a were the real engineering run!

# Experience and lessons learned

- 1+ year of data taking is an endurance test
  - Preserve strength and energy – and, above all, DetChar people
  - Identify and focus on what really matters for the run
    - ◆ Limited personpower ↔ impossible to do everything: priorities
    - ◆ Learn and be prepared to answer « no » to some requests
    - ◆ Seek internal (at the collaboration level) recognition
  - Be proactive about interfaces – both instrument and data analysis
    - ◆ Define, improve and practice them before the run starts
- And keep in mind that the end of the run is just a step!
  - There will be events to vet for a long time
  - Final DetChar products to be generated, both for offline analysis and GWOSC
- Document your activities and have your colleagues do so as well
  - Consistent and complete logbook entries are a pre-requisite
  - Otherwise, potentially important things will be forgotten / missed
- Tedious and repetitive, but time-saving (and neuron-saver) on the long term
- A light review is better than no review at all
  - DQR and flags during O3

# Experience and lessons learned

- Try to **keep an eye on what the other DetChar groups are doing**
  - Not necessarily to start new projects – time and resource permitting
  - But very useful for **brainstorming**: **new ideas**, **different viewpoints** on a topic
    - Potentially leading to straightforward improvements to some frameworks
- Examples of **existing (and fruitful) LVK collaborations**
  - **Common coherence tool: bruco**
  - **DQR**
    - ◆ **Common framework** developed and agreed on **before O3**
    - ◆ **Joint group to prepare O4**
  - **Seismon framework** for earthquake early warnings
    - ◆ **First setup for O2**; extensively used during **O3**; will use **latest version for O4**
    - ◆ Test possibility to use warnings from Italian geophysics institute (**INGV**)
  - Investigating the **possibility to run iDQ for Virgo during O4**
    - ◆ **Offline** first – and **possibly online** as well
      - **Focus on technical issues**: **environment**, **configuration**, **software**
  - **Virgo representative** included to the **O3 data mitigation team**
  - Use of **LIGO framework** for improved **channel safety study**

# O4 preparation

- **Virgo DetChar group reorganization**
  - Bottom-up approach
  - Addressing long-standing personpower issue
  - Define operational interfaces and core team for O4

→ **Mixed success** (so far)

  - ◆ Clear improvements on the DetChar/DAC side
  - ◆ Waiting for the interferometer to be back before (hopefully) moving forward on the DetChar/instrument side
  - ◆ No significant progress on personpower, nor on the group reorganization
- **Improve existing frameworks**
  - Code improvements
  - More automation
    - ◆ Keeping humans in the loop though
  - Extend diagnosis and monitoring tools
  - Reduce latency
    - ◆ Software running more frequently
    - ◆ People looking more regularly at outputs

→ **Catching issues quickly and fixing them is better than workarounds offline**



# O4 preparation

- **Spectral line analysis**
  - **List of lines** for offline analysis and GWOSC
    - ◆ **Document procedures**
  - **Goal: to monitor more frequently and in more details lines** during future runs
    - ◆ **Additional coherence runs on environmental channels**
- **End-to-end O3 data replay: use this playground to test future code versions**
  - **Online dataflow and associated servers**
  - **Online data quality + interplay with Hrec/calibration**
  - **DQR 2.0**
- Explore the possibility to **reuse existing tools** to address other questions
  - Adapt the (O3) **DQR** to create a **lock loss monitor**
    - ◆ S-event ↔ Lock loss
    - ◆ Checks ↔ Tests to find the root of the lock loss

} To be developed  
this Summer,  
resources permitting
- **Centralized management of the (many) lists of Virgo channels**
  - **Inputs from systems and working groups**
  - **Main consumers: tools – Omicron, Bruco, etc.**

→ Dedicated **GitLab package**

# O4 preparation

- Deal with the reorganization of storage areas at EGO
  - Online / Production / Development / Web / Archive
- Improve/extend EGO software environment
  - Merge (recent) LIGO packages and Virgo-specific ones
  - IGWN framework
- Collaboration with EU projects
  - Find synergies, identify spin-offs that would benefit directly to Virgo DetChar
- Strengthening all interfaces
  - DetChar / Instrument + commissioning
  - DetChar / data analysis
  - Among DetChar groups
- Trying to convert group investment and experience into publications
  - O2-O3 DetChar: <https://git.ligo.org/virgo/detchar/o3-paper>
  - Impact of external env noise: <https://git.ligo.org/virgo/detchar/o3-extenvnoise>
  - Mature drafts but review / fine-tuning phases still to come

# Outlook

- Long and challenging O3 run
  - Unvaluable experience gathered during 11 months data-taking + offline analysis
- Transitioning from final O3 analysis to O4 preparation
  - Ramping up expected after Summer break
- Manifold improvements targeted
  - Group organization and support from collaboration
  - Mostly existing O3 frameworks
  - Not many new projects
- Tight constraints from limited personpower
- Benefiting from joint LVK activities
  - An asset to make progress
  - Happy to help KAGRA time- and resource-permitting

