

# Detector Characterization Report

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European Gravitational Observatory (Consortium, CNRS & INFN)

On behalf of the **Virgo DetChar** group

**ILANCE workshop – April 15, 2022**

*Development of innovative tools for new collaborations*

*within gravitational wave detection experiments*

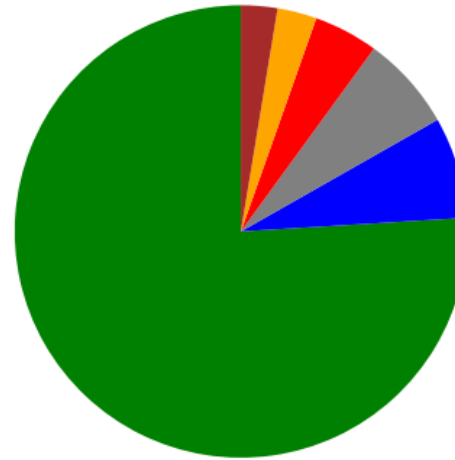
<https://indico.in2p3.fr/event/26414>

**VIR-0420A-22**



# Outline

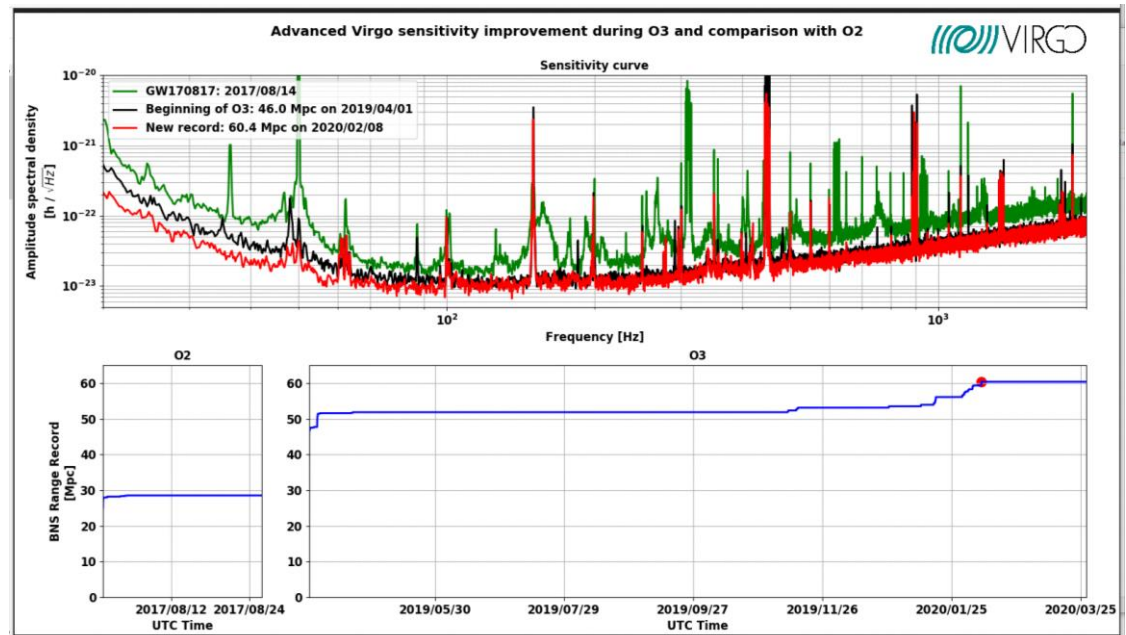
- Virgo DetChar in a nutshell
- Looking back at O3
  - Dataflow
  - Some key tools
  - Focus: Data Quality Reports



- 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 10:30 **CE(S)T** – late afternoon in Asia
  - **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) – **No need to be registered to post**: never hesitate!
  - **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 and internal webpages
- **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>

# About Virgo DetChar

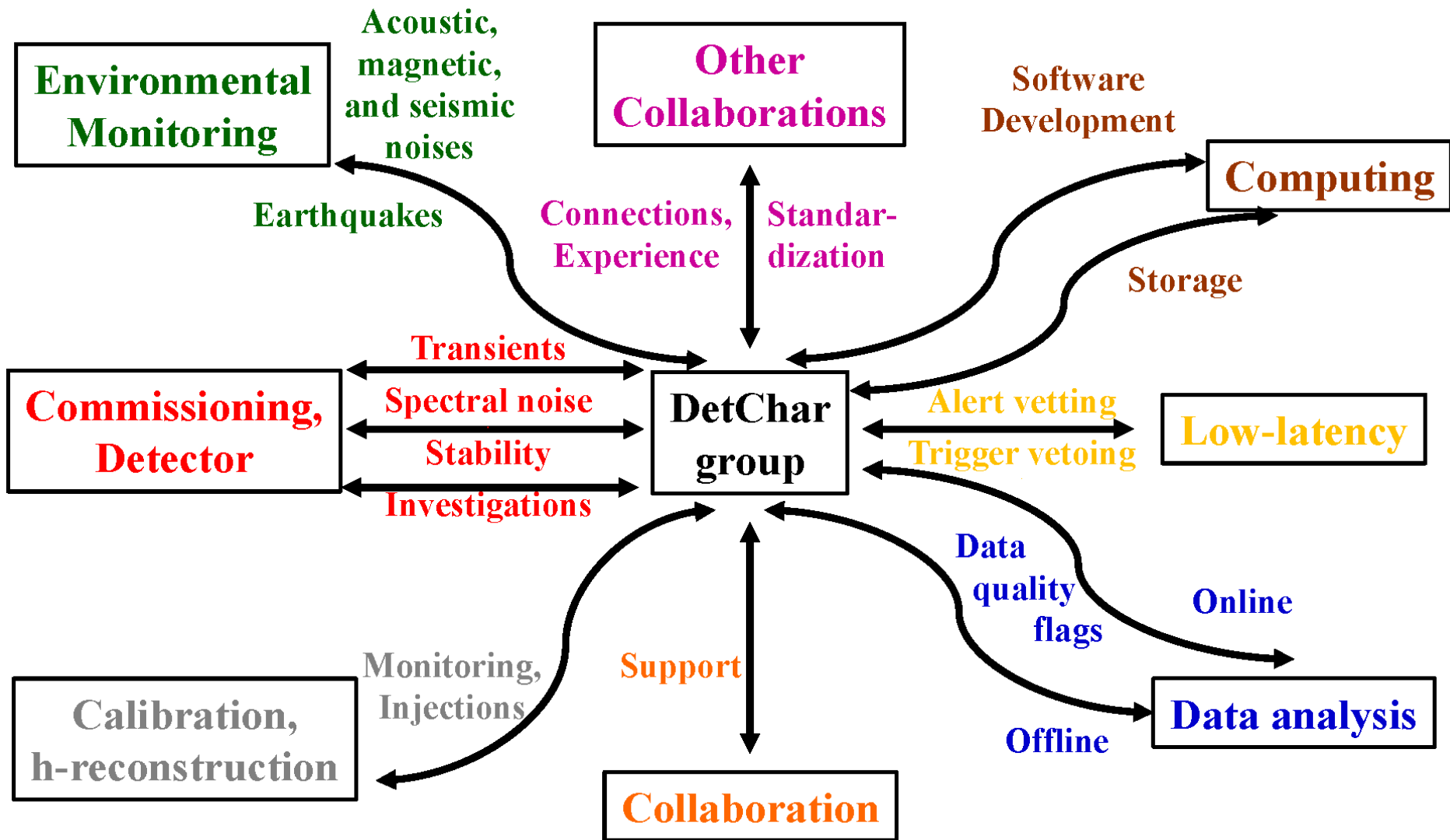
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  - **Subscription:** <http://mail.ego-gw.it/mailman/listinfo/detchar>
- Getting **Virgo accounts:**  
[https://wiki.virgo-gw.eu/InformationSystem/Cascina\\_EGO-Virgo\\_Accounts](https://wiki.virgo-gw.eu/InformationSystem/Cascina_EGO-Virgo_Accounts)
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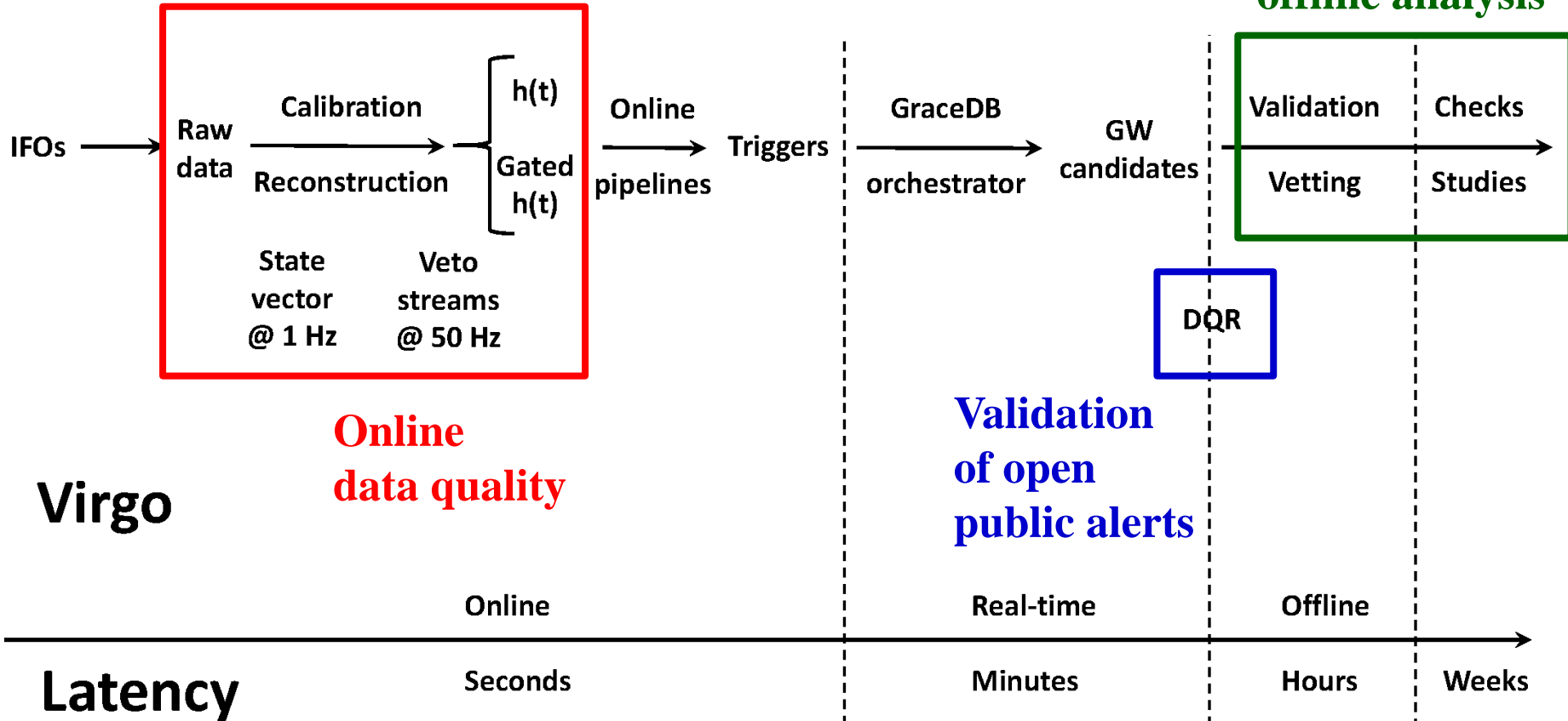
- O3 DetChar summary:
  - <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/DetCharO3Summary>
- O4 preparation
  - Roadmap: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/O4RoadMap>
  - Projects: <https://wiki.virgo-gw.eu/DataAnalysis/DetChar/O4Projects>

# Virgo DetChar within Virgo & LVK

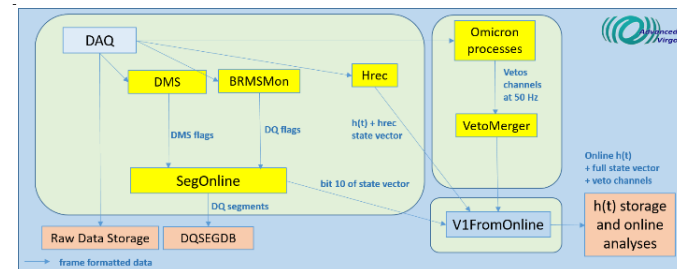


# A look back at O3

- **Workflow: three main pillars**



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

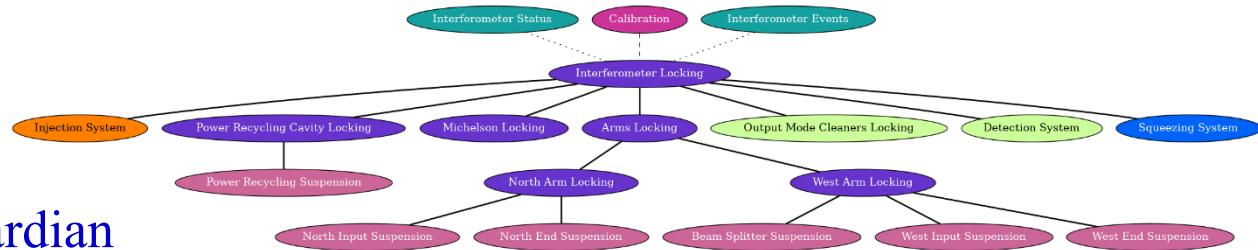


# Some examples of key tools

- Automation

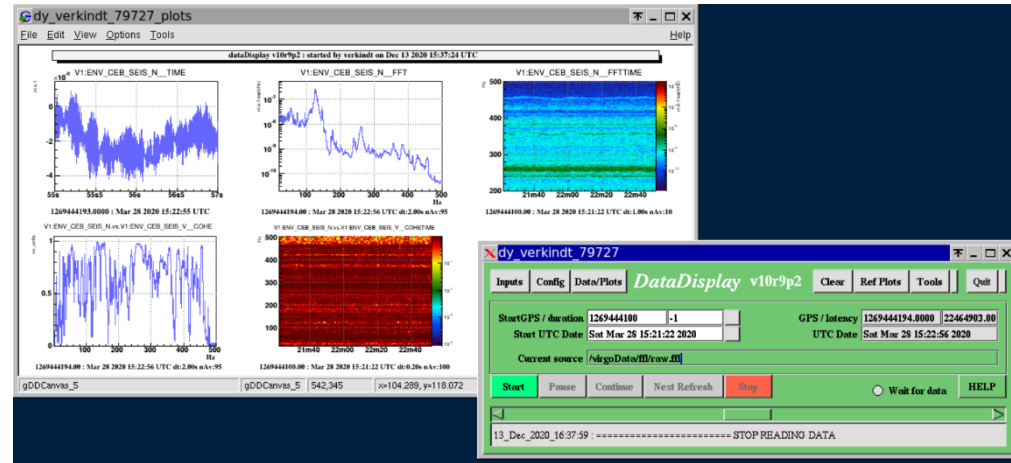
- Metatron

- Based on LIGO's Guardian



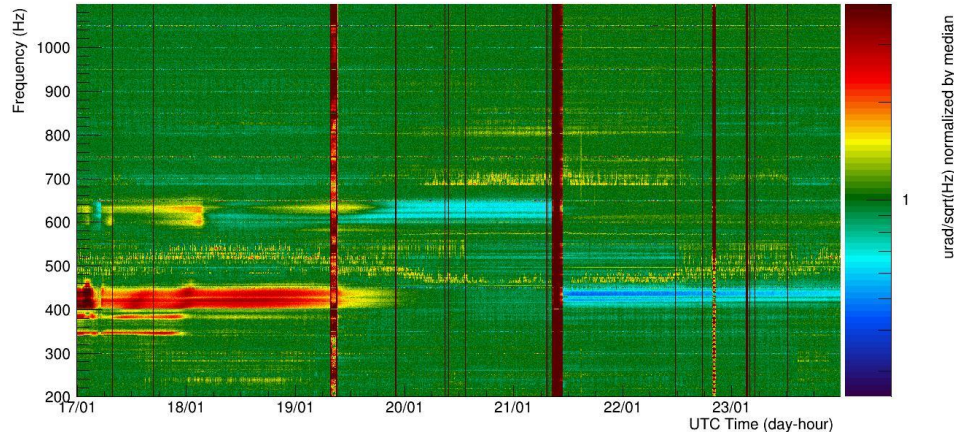
- dataDisplay

- 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)**

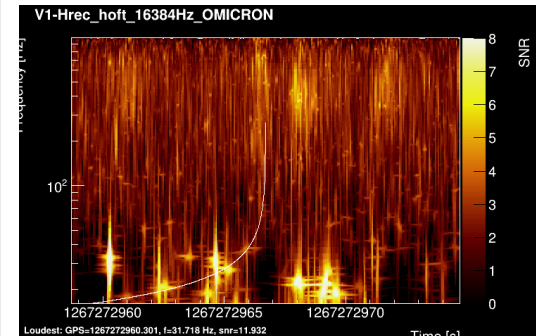
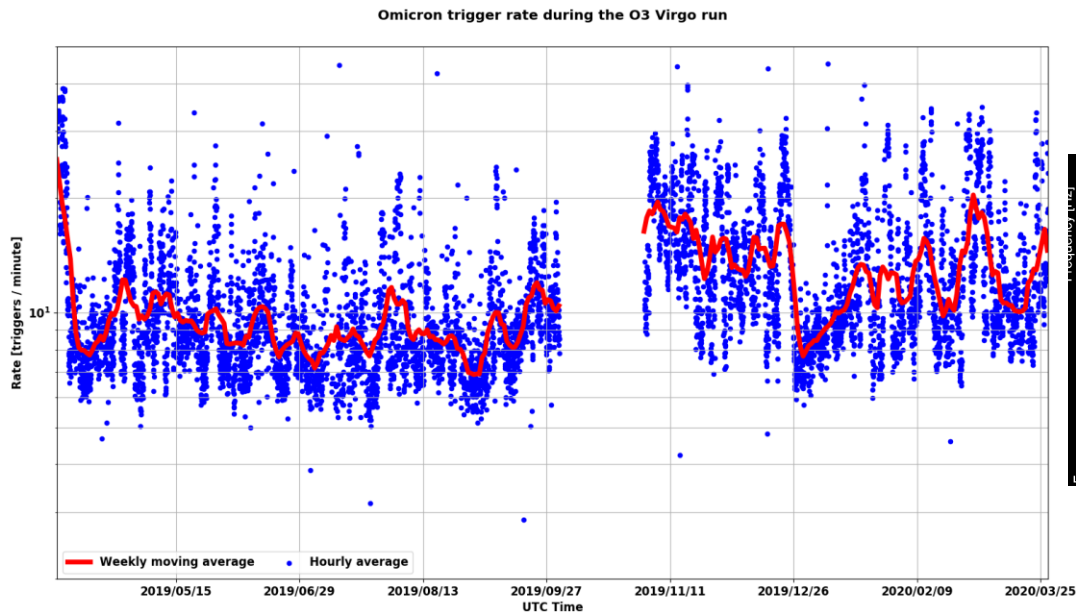
- Detailed detector status
- Information about online servers

ITF Mode: Science	ITF State: LOW_NOISE_3_SQZ	UTC: 2019-04-12 05:30:48						
<b>Injection</b>	SIB1_IP, MC_IP, Laser, MC_Power	SIB1_BENCH, MC_PAY, LaserAmpl, FSTAB	SIB1_BR, MC_BR, LaserChiller, IMC_AA	SIB1_Vert, MC_Vert, SL_TempController, IMC_AA_GALVIO	SIB1_TE, MC_TE, RFC, MC_FD_x	SIB1_Guard, MC_Guard, LMS, BPC	SIB1_Electr, MC_Electr, PC, BPC_Electr	
<b>Detection</b>	PD, SDB1_IP	QPD_B1p, SDB1_LC	QPD_B2, SDB1_BR	QPD_B5, SDB1_Vert	OMC, SDB1_IP	PicoDisable, SDB1_Guard	Shutter, SDB1_Electr	
<b>ISC</b>	B2_BMHz_DPHE, B4_1129Hz_MAG	B4_S094Z_DPHE, DARM_UGF	UNLOCK, SDFS_UGF	FFedErr, GIPC				
<b>Suspensions</b>	BS_IP, NL_IP, NE_IP, PR_IP, SR_IP, WL_IP, WE_IP	BS_F7, NL_F7, NE_F7, PR_F7, SR_F7, WL_F7, WE_F7	BS_PAY, NL_PAY, NE_PAY, PR_PAY, SR_PAY, WL_PAY, WE_PAY	BS_BR, NL_BR, NE_BR, PR_BR, SR_BR, WL_BR, WE_BR	BS_Vert, NL_Vert, NE_Vert, PR_Vert, SR_Vert, WL_Vert, WE_Vert	BS_TE, NL_TE, NE_TE, PR_TE, SR_TE, WL_TE, WE_TE	BS_Guard, NL_Guard, NE_Guard, PR_Guard, SR_Guard, WL_Guard, WE_Guard	BS_Electr, NL_Electr, NE_Electr, PR_Electr, SR_Electr, WL_Electr, WE_Electr
<b>Environment</b>	INJ_Area, CB_Hall	DET_Area, MC_Hall	SE_Room, TCS_zones	DAQ_Room, NE_Hall	External, WE_Hall	DeadChannel, WindActivity	Lights, Season	SeaActivity, BRMSMon
<b>Infrastructures</b>	ACS_CB_Hall, UPS_TB	ACS_TB, UPS_CB	ACS_DAO_Room, UPS_MC	ACS_EE_Room, UPS_NE	ACS_MC, UPS_WE	ACS_INJ, ACS_DET	ACS_NE, ACS_CB_OK	ACS_WAB, ACS_COB
<b>SRE</b>	EIB_SRE, SDB2_SRE	SDB2_SRE, SDB2_LC	SNEB_SRE, SNEB_LC	SWEB_SRE, SWEB_LC	SPRB_SRE, SPRB_LC			
<b>TCS</b>	NE_RH	WE_RH	NI_CO2_Laser, WL_CO2_Laser	SQZ_Shutter, SQZ_Inj	Cahe_CTRL, SQZ_Inj			Chillers, RaDp_TE
<b>SQZ</b>	PLL	Squeezer	STQZ_AA, SQZ_Shutter	Cahe_CTRL, SQZ_Inj				
<b>Vacuum</b>	LargeValves, Pressure	Clean_Air, CompressedAir	TubeStations, TowerServers	TubePumps, TowerPumps	MiniTowers, CryoRap	TurboLinks, O2_Sensors	RemDryPHP, Vacuum	VAC_SERVOS, Tank
<b>VPH</b>	DetectorEnvironment	ControlRoom	Minotowers	ISC	Injection	TCS	Suspension	Vacuum
<b>DAQ Computing</b>	Latency, DMS_machines	Disk, DetOp_machines	Timing, observers	Timing_rpc, rtpcs	Timing_dsp, CoilSwitchBoxes	Fast_DAC, INF_devices	ADCS_TE, ENV_devices	Daq_Boxes_TE, VAC_devices
<b>Calib_Hrec</b>	CalRE, CalIB	CalWE, CalBU	observers, CalBS	CalPR, PCalRE	PCalWE, HOFT	NCAL		NoiseInjection
<b>ITF OeCall</b>	SoftwareM	TemperatureM	InjectionM	UPS	GeneratorM	TcalM		
<b>DetChar</b>	Hrec_RANGE_BNS			Bag_AlertGracdB		STATE_VECTOR		

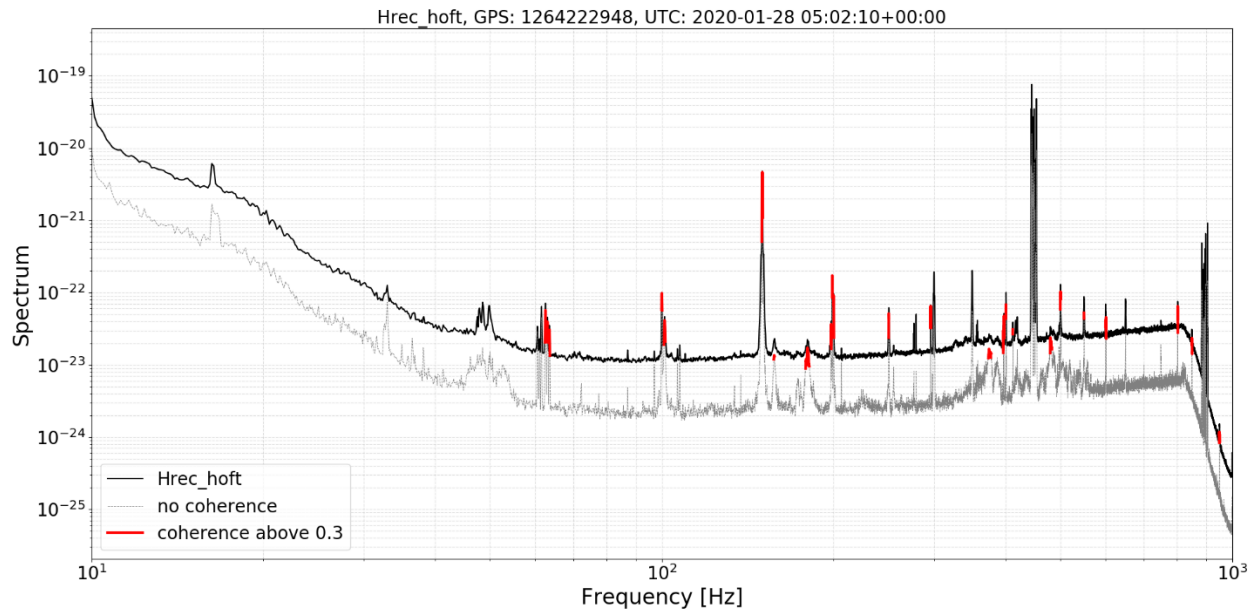


# Some examples of key tools

- Omicron
  - Glitches

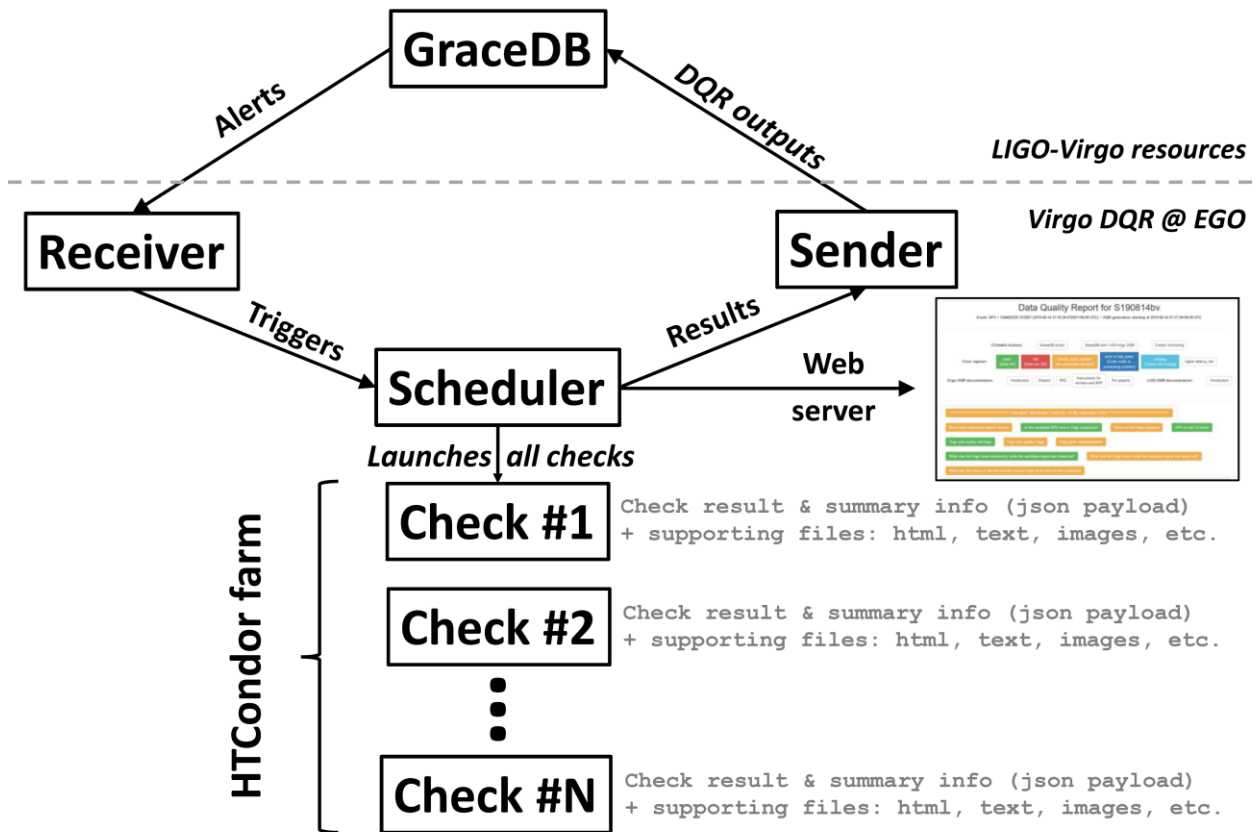


- Bruco
  - Spectral lines



# 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**

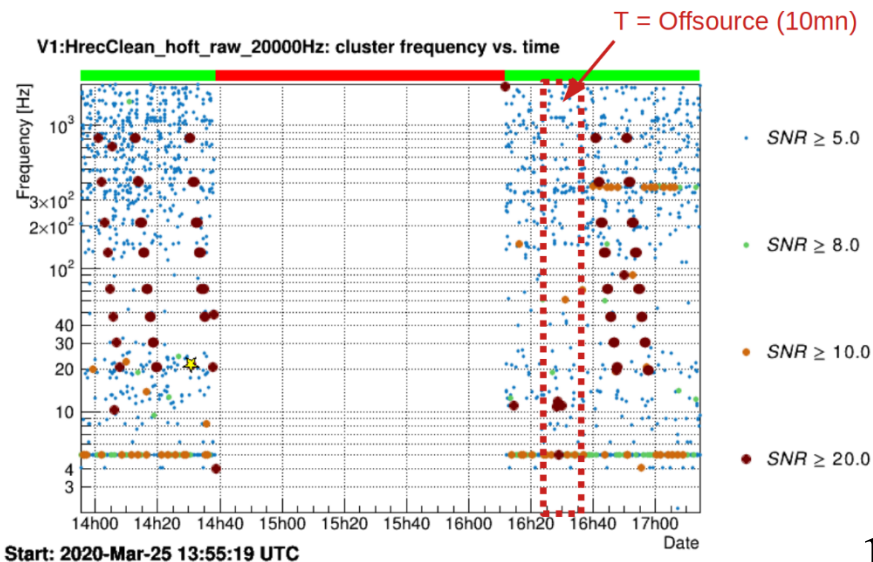
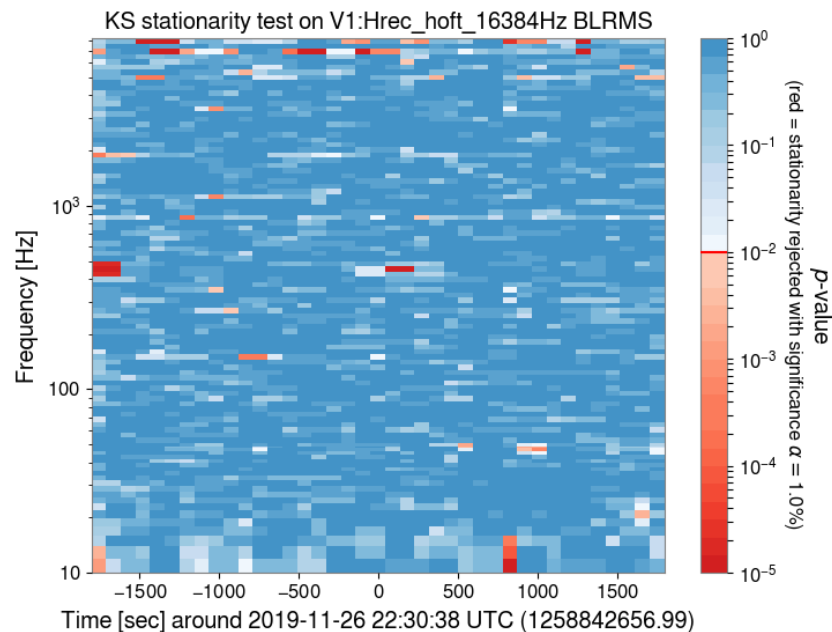
Number of unsuccessful checks	0	1	2
Percentage of O3b automatically processed DQRs	85%	13%	2%

- ◆ **Solidify O3 performance**
- ◆ **Improve code structure and quality** + **fix bottlenecks and weak parts**
- ◆ **Review all existing checks** + **code modularity** to ease addition of new checks
- ◆ **Hunt down latencies**
- ◆ Possibility to **run elsewhere** than on the **EGO Condor farm**
- **Joint LIGO-Virgo-KAGRA developments** for **O4 DQR infrastructure** + **alert system**
  - ◆ **Avoid duplication of work**
  - ◆ **But need to adapt to existing design**

After O4: **assessment of how well that worked**

# 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
- Had to develop **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 the mandatory definition of the datasets
  - **Everyone at all levels now aware of that**
    - ◆ Yet, no clear path forward to escape from this unfortunate 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
  - The “Engineering run” (ER14) was 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 them 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
  - **Centralized management of the (many) lists of Virgo channels**
    - **Inputs from systems and working groups**
    - **Main consumers: tools** – Omicron, Bruco, etc.
- Dedicated **GitLab package**

In progress

# 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**
- In the meantime: **convert group investment and experience into publications**
  - **O2-O3 DetChar**: <https://git.ligo.org/virgo/detchar/o3-paper> [Review almost over]
  - **Impact of external env. noise**: <https://arxiv.org/abs/2203.04014> [+ CQG]

→ **These took two years after the end of O3**

  - But **vicious circle (finally) broken**: no time/person ↔ no publication

# Outlook

- Long and challenging O3 run
  - Unvaluable experience gathered during 11 months data-taking + offline analysis
- Transitioning from final O3 analysis to O4 preparation
  - Almost completed: now focus on O4
- Manifold improvements targeted
  - Group organization and support from collaboration
  - Mostly existing O3 frameworks
  - Not many new projects
- Tight constraints from limited personpower
  - Not solved despite growing collaboration
- Benefiting from joint LVK activities
  - An asset to make progress
  - Happy to help KAGRA time- and resource-permitting