Low Latency Alerts Update

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PIPELINES ACTIVE in O4

Generating Early Warning Alerts

- 4 Early warning pipelines (**gstlal/MBTA/pycbc/spiir**)

Generating Preliminary Alerts (4+1=5 CBC alerts and **3+1=4)**

- **4 CBC** (template bank based) **allsky** search pipelines (**gstlal/MBTA/pycbc/spiir**)
- **3 Burst** (un-modelled) searches: **olib-allsky**, **cWB-allsky**, **cWB-BBH**
- **1 RAVEN**: coincidence search trigger with GRB alerts.

Threshold for alerts.

- Alerts are send for all trigger with a reported False Alarm Rate (FAR) of less than **2/day.**

Since we do have **7 active** (four **CBC** and three **burst**) the effective FAR for alerts is **14/day**.

We do mark as **"Significant"** all alerts that will be followed by the collaboration. The alert threshold for significant gravitational-wave alerts aims to reach a purity (association to gravitational signal) of greater than 90% and it is set to have a FAR for alerts marked as significant to be **one per month** for **CBC** target searches and of **one per years** for unmodeled burst searches. Since we have **four CBC** searches, **three** searches for **burst** (including a CBC target one: cWB-BBH), and an external coincidence search **RAVEN** that looks at results from **CBC** and **burst** searches.

- Alerts corresponding to **CBC** trigger are marked **"Significant"** if they are associate to, at least one, trigger with a reported False Alarm Rate (FAR) of less than **1/(five months)**. (trial factor 5=**4**+**1**)
- Alerts corresponding to **burst** trigger are marked **"Significant"** if they are associate to, at least one, trigger with a reported False Alarm Rate (FAR) of less than **1/(four years)**. (trial factor 4=**3**+**1**)

We do not perform any further analysis following gravitational-wave **Preliminary** alerts that are not marked as **"Significant"** or **EarlyWarning** alerts that are not followed by a **"Significant"** **Preliminary** alert. That means that human veto will be performed only for trigger associated **"Significant"** **Preliminary** alert that will be followed by **Initial** or **Retraction**, and **Update** alerts-

The O4 system - per pipeline threshold (2/day)

We will provide public alerts:	- GCN classic - Avro over kafka (SCIMMA) - GCN kafka

- **EarlyWarning** — **Associated to EW pipeline**

— Trigger time —

- **Preliminary (1)** — **median latency ~30s**
- **Preliminary (1a)** — **in case of new significance**
- **Preliminary (2)** — **final in ~320s**

— Rapid Response team decision —

- **Initial/Retraction Alert**
- **Update (1)**
- **….**
- **Update (n)**

The false alarm rate threshold for public alerts is **2/day** (on the FAR reported by the pipeline).

Significant gravitational-wave alerts with false alarm rate less than 1/month for CBC and 1/year for bursts that pass automated and **manual verification tests**. All other alerts have low-significance.

The thresholds on the reported pipeline FAR are indeed:

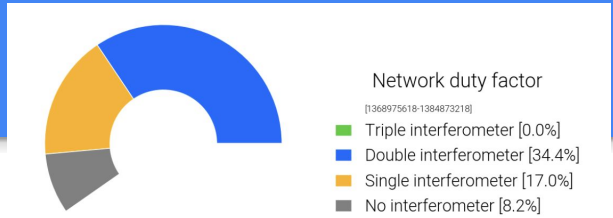
CBC **1/(5 months)** – trial factor five

BURST **1/(4 years)** - trial factor four

The pipeline FAR based thresholds may change if we change the active pipelines.

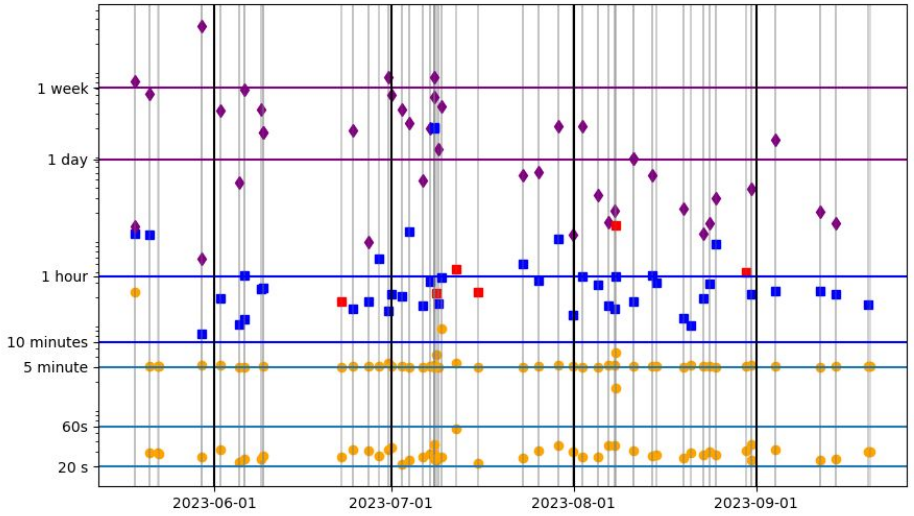
Preliminary (1a) for
- S230831e 23.9s – 36.9s – 314.9s

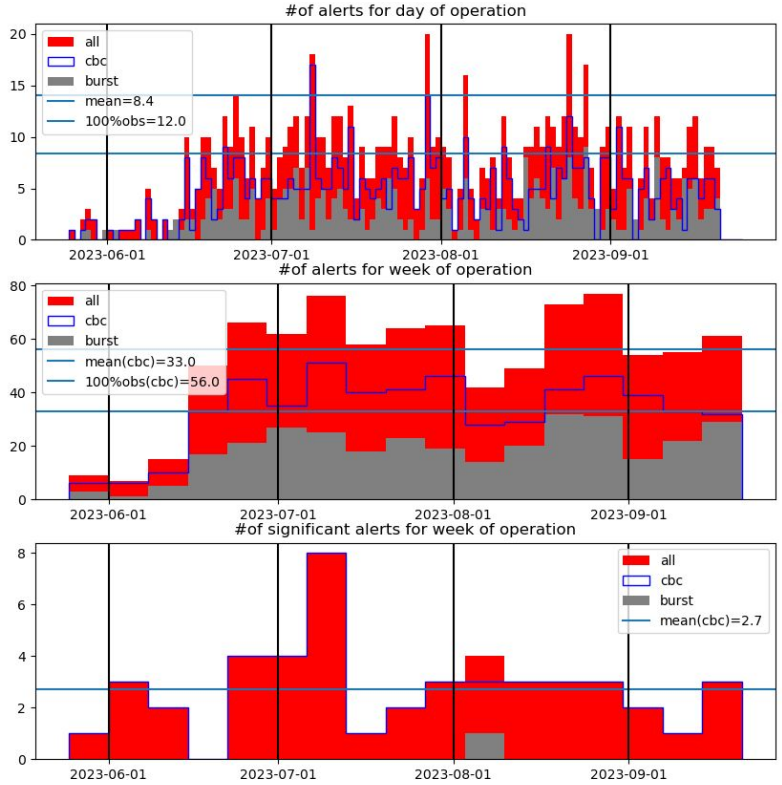
ALERT LATENCY and RATE



- First preliminary in 20s to 60s latency
- Second preliminary latency at about 5 minutes with respect to event time.
- Initial of retraction within 1 hour (most of the time)

- Duty factor are (1IFO) ~86% (2IFO) ~58%





Analized interval of DATA: from 2023-05-18T06:08:40.045 to 2023-09-20T08:09:24.513

ALERTS STATISTICS

MULTI-PIPELINE vs SINGLE-PIPELINE

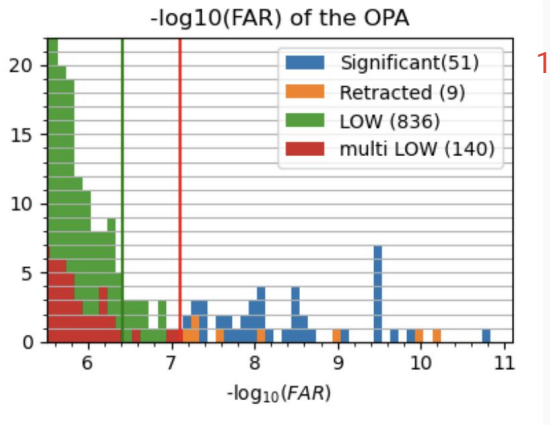
	Alerts	#multi	#single			
•	SIGNIFICANT	**40(1)**	11(5)	tot	51	**RETRACED(6)**
•	not-SIGNIFICANT	**140**	696	tot	836	
•	EARLYWARNING	0	3(3)	tot	3	**RETRACTED(3)**
•	ALL alerts	180(1)	710(8)	tot	890	**RETRACED (9)**

RETRACTIONs are not based on the number of pipeline involved by on the veto on the noise present in the IFO

Retracted	S230622ba	#1 FAR=5.18e-08	MBTA
Retracted	S230708bi	#1 FAR=1.11e-09	gstlal
Retracted	S230712a	#1 FAR=3.27e-15	gstlal
Retracted	S230715bw	#1 FAR=7.84e-09	spiir
Retracted	S230808i	#1 FAR=6.85e-11	CWB
Retracted	S230830b	#2 FAR=1.15e-10	spiir,CWB-AllSKy

EARLY WARNING (We do issue RETRACTIONs if not followed by a Preliminary)

Retracted	S230524x	#1 FAR=7.22e-08	pycbc-EW (received back -6.8s)
Retracted	S230810af	#1 FAR= 2.9e-08	spiir-EW (received back -4.6s)
Retracted	S230918aq	#1 FAR= 5.4e-08	pycbc-EW (received back -3.2s)



1/(5 months)=7.71e-8

SEVEN SINGLE DETECTOR (out of 43) SIGNIFICANT TRIGGERS

- **1** by (**gstlal** and **pycbc**) S230529ay
- **6** by (**gstlal**) S230522a,S230522n,S230726a,S230802aq, S230814ah,S230911ae

Consistent with the single IFO multiple IFO duty factors.

https://ldas-jobs.ligo.caltech.edu/~detchar/summary/O4a/

DATA PRODUCT (S30706ah)


```
{ "alert_type": "INITIAL",
  "time_created": "2023-07-06T11:10:08Z",
  "superevent_id": "S230706ah", "urls": {"gracedb": "https://gracedb.ligo.org/superevents/S230706ah/view/" },
   "event": {
      "significant": true,
      "time": "2023-07-06T10:43:33.157Z",
      "far": 4.261355826314869e-08,
      "instruments": ["H1", "L1"],
      "group": "CBC", "pipeline": "gstlal", "search": "AllSky",
      "properties": {"HasNS": 0.0, "HasRemnant": 0.0, "HasMassGap": 0.03551048951048951},
      "classification": {"BBH": 0.97333, "BNS": 4.4208e-18, "NSBH": 2.78285e-16, "Terrestrial": 0.02666},
      "duration": null,
      "central_frequency": null,
      "skymap": "U0lNUExFICA9ICAgICAgICAgICAgICAgICAgICBUIC8gY..."
         },
    "external_coinc": null }
```


Hourly MDC events on the production have the new schema

Three kind of data products plus localization

Properties (for CBC events) based on the assumption that the event is of astrophysical origin and corresponds to a CBC event. Meaningful only in the case of astrophysical events. These values are **updated** (as well as localization) after **bilby-fast-parameter estimations** but still have the assumption that the signal is a CBC one.

Classification (for CBC events) that is provided by the pipeline and based on injection campaigns with Astrophysical rates. Tailored to the characteristic of the pipeline and its sensibility to the detector noise. This one is not (usually) updated because it depends on the real-time pipeline used to generate the “bayestar” localization skymap. For CBC alerts will be (to go online soon) **update** (within few hour and possibly with the initial alert) by **rift/rapidPE.**

Duration and **central_frequency** (for burst events) provided the frequency position of the signal and the duration (signal over the noise) of the detected signal.

SKYMAP: In the case of CBC signal, the localization information also includes distance information. That information is not available for burst events.

Conclusion

- We provide public alerts for:
  * Compact binary coalescences (CBC) and gravitational wave burst events
  * pre-merger (negative time) **early warning** alerts for CBC events.
  * alerts based on a **coincident external public trigger**.
- **You are providing: should expect public alerts with a rate of:**
  - order three per week (Significant gravitational-wave alerts)
  - up to fourteen per day (Low Significance gravitational-wave alerts).
- Data produced **should be trusted only for real** CBC GW-signal and that correspond to **significant** alerts and **classification - terrestrial** (probability not of CBC astrophysical origin) less than 0.5.
- For CBC events, the BAYESTAR localization include distance information and provide extra information on the properties of the source and how well the signal matches the template that originated the trigger.
- For **significant** alerts the GCN-circular contains the list of pipelines that contributed to the alert.