LVK strategy on Multimessenger Science

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Discussion on multimessenger science and supporting computing infrastructure at the 2nd annual Einstein Telescope meeting (**November 15 from 14:10 - 15:55**)

The Goals

- Disseminate **public alerts** of transient GW (and MMA involving GW) detections.

- Enable the discovery of **EM and neutrino counterparts** to GWs (and vice versa) and assist the (common) source characterisation.

- Provide **feedback to the instrument** teams by facilitating the diagnosing of detector problems via real-time analysis.

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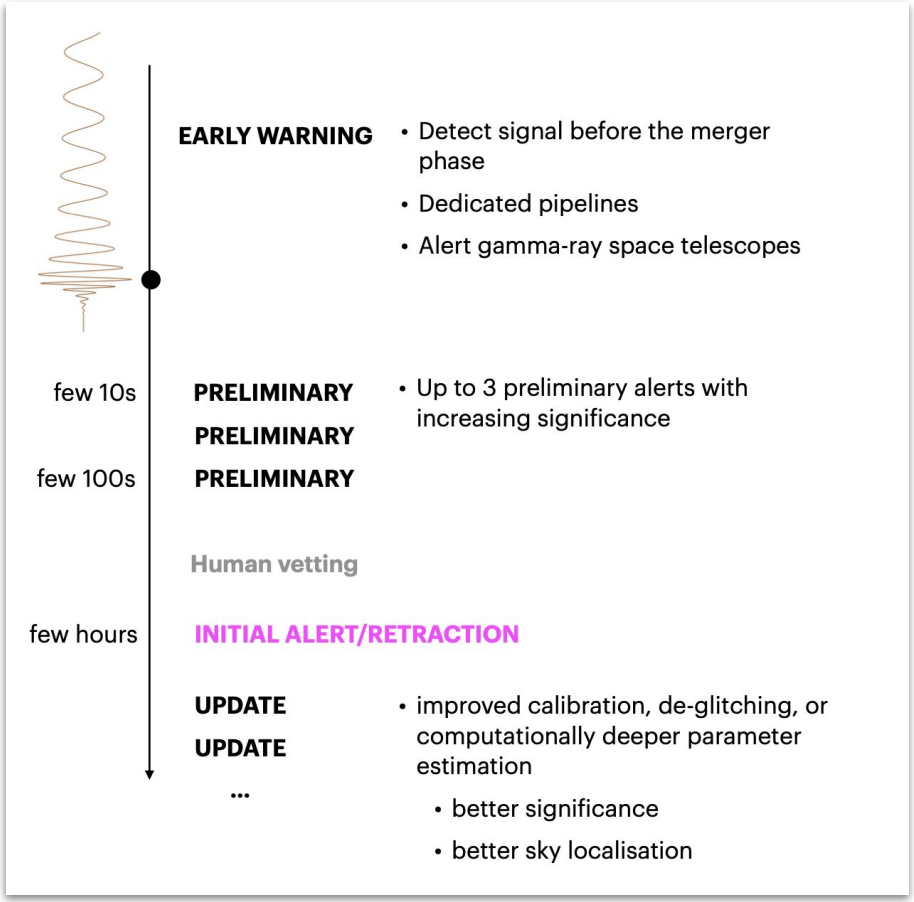
The O4 system - alerts timeline and thresholds



- The **False Alarm Rate (FAR)** threshold for public alerts is **2/day**.
- **Significant** gravitational-wave alerts:
  - FAR < 1/month for CBC searches
  - FAR < 1/year for Bursts searches
  - pass automated and **manual verification tests**.
- All other alerts have low-significance.
- The FAR of the alerts threshold for the single pipeline computed FAR is determined by dividing the declared FAR by a *trial factor* that considers the number of active pipelines per search type (CBC or Burst).

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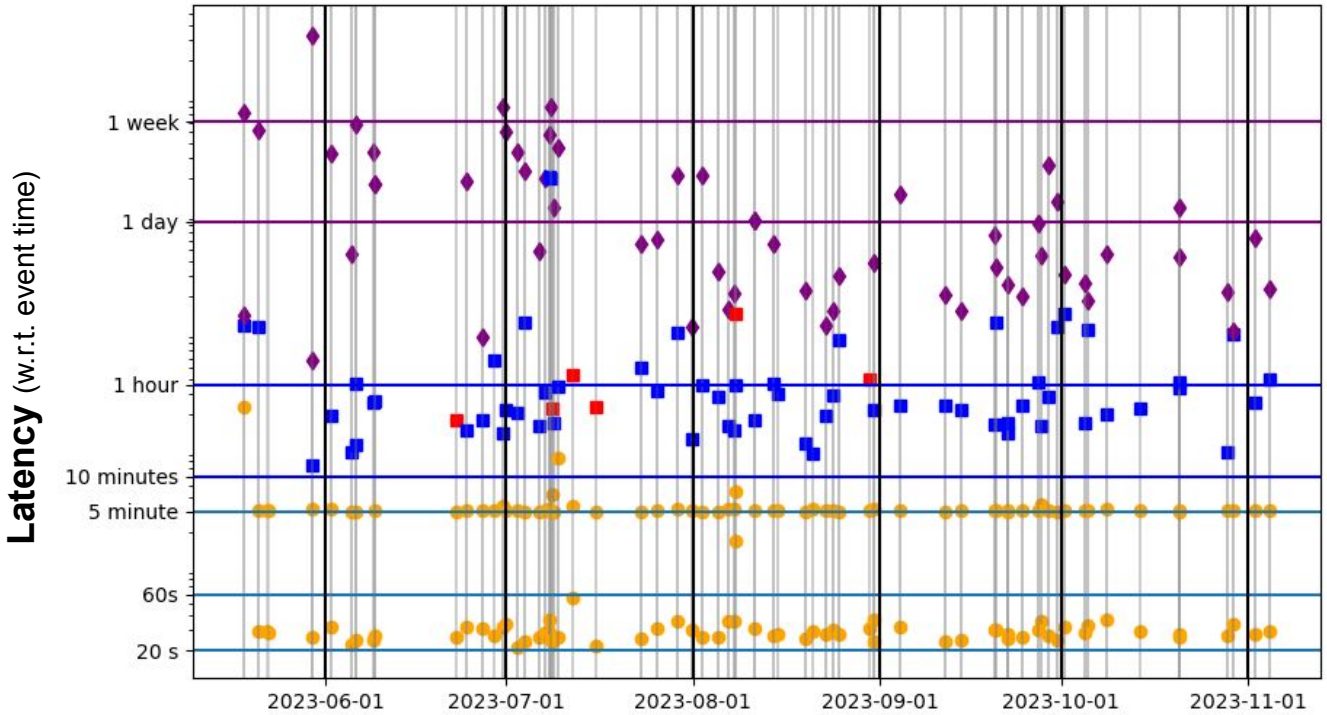
The O4 system - alerts latency



orange = preliminary, blu = initial, red=retraction, purple = update (after first rapid PE)

Updates
from few hours to 1 week, mostly within 1 day.

Initial or retraction
within 1 hour
(most of the time).

Second preliminary
in about 5 minutes .

First preliminary
in 20s to 60s.

The O4 system - duty factor and alert rates

Network duty factor

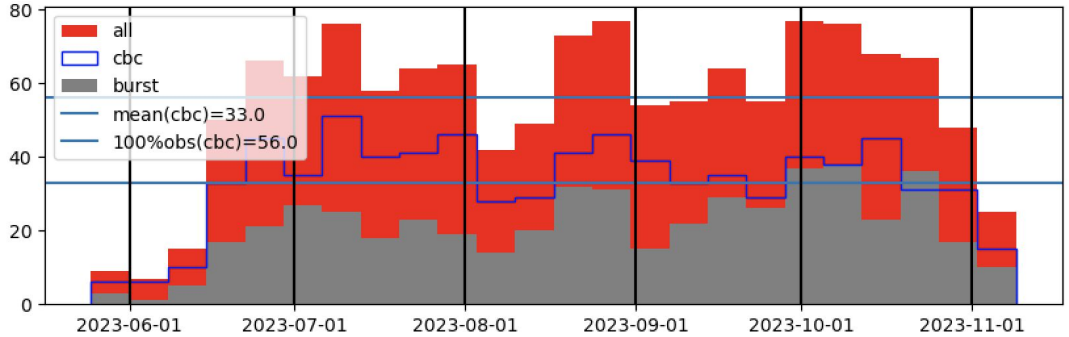
Since the beginning of O4.

[BLUE] Double interferometer 59%

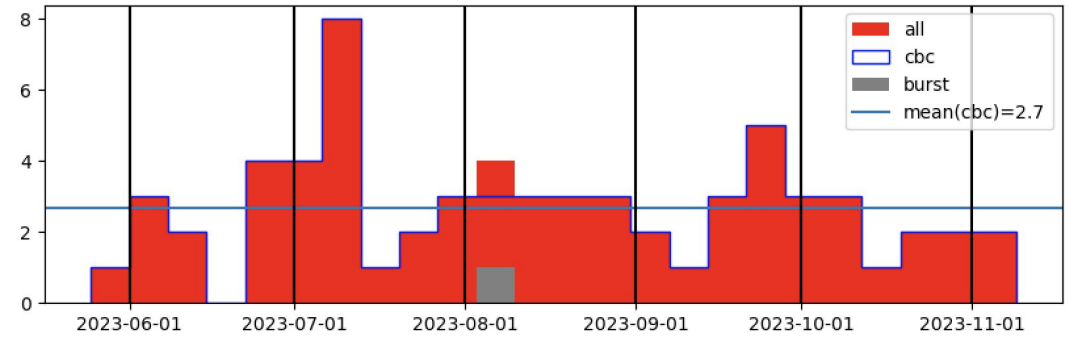
[Orange] Single Interferometer 28%

[Grey] No interferometer 13%

Number of alerts per week of operation



Number of **significant** alerts per week of operation

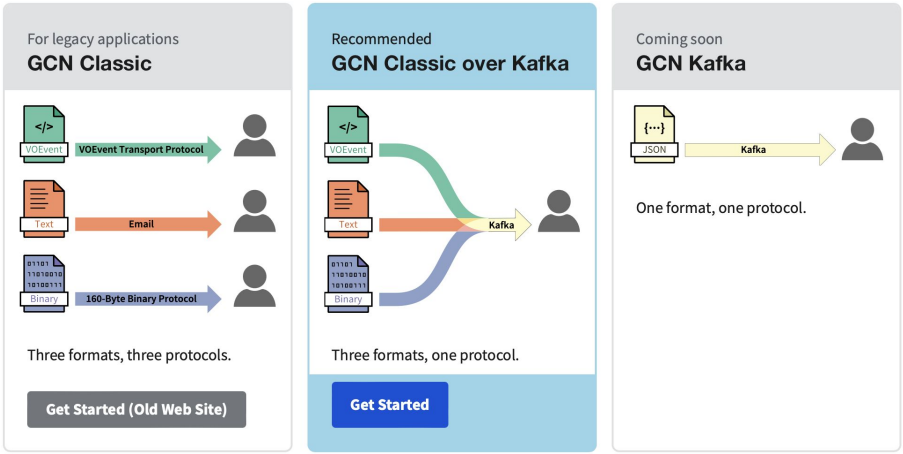


Significant alerts are of CBC type → 2.7 per week (the burst one was retracted)

LVK strategy - distribute using GCN and SCiMMA

NASA's Time-Domain and Multimessenger Alert System

https://gcn.nasa.gov/



SCiMMA

https://scimma.org/

HOPSKOTCH

Scalable Cyberinfrastructure to support Multi-Messenger Astrophysics

We use the Hop.SCIMMA production instance they provide based on HOPSKOTCH Software and a server that provides a scalable, high-throughput, low-latency platform for handling real-time data streams for MMA applications, which:

- provides a cloud-based instance of Kafka data streams to support MMA applications via a publish-subscribe paradigm
- allows for “at least once” delivery semantics
- allows catchup if a client is unavailable or needs to reprocess recent alerts
- offers extensive identity and access management controls and fine-grained Kafka topic permission configuration to respect data rights as documented online with the HOPSKOTCH authenticator

Data products and localization

EVENT 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
- values are **updated** (as well as the localization) after **parameter estimations (PE)** but still have the assumption that the signal is a CBC one.

EVENT CLASSIFICATION (for CBC events)

- provided by the pipeline and based on injection campaigns with Astrophysical rates
- tailored to the characteristics of the pipeline and its sensibility to the detector noise
- not (usually) updated because it depends on the real-time pipeline used to generate the localization skymap
- for CBC alerts is **updated** (within few hourw and possibly with the initial alert) by rapid PE tasks**.**

DURATION and **CENTRAL FREQUENCY** (for Burst events)

- frequency position of the signal and the detected signal's duration (signal over the noise).

SKYMAP (for CBC events)

- the case of CBC signal, the localization information also includes distance information
- not available for burst events.

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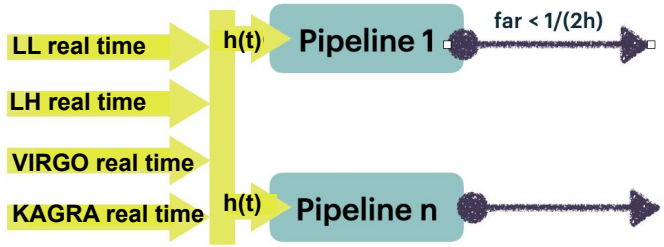
The Low Latency Alert Generation Infrastructure (LLAI)

Multiple components come into play:

- **Data acquisition** and production of h(t) data
- **Transfer of data** to compute centers for real-time data analysis
- Trigger production by **online transient-search** (CBC and Burst) search pipelines
- **Recording** of transient triggers into the event DataBase (graceDB)
- This is where the Low Latency Alert Pipeline (GWCelery) commences to process events under multiple tasks:
    - **Event aggregation** resulting from multiple search pipelines but due to the same physical event in the detectors
    - **Enrichment** of the events with source classification, other properties, sky localization, as well as detector characterization information
    - **Distribution of the alert** to the transient astronomy community via multiple event brokers/formats (these are what we refer as Public Alerts)

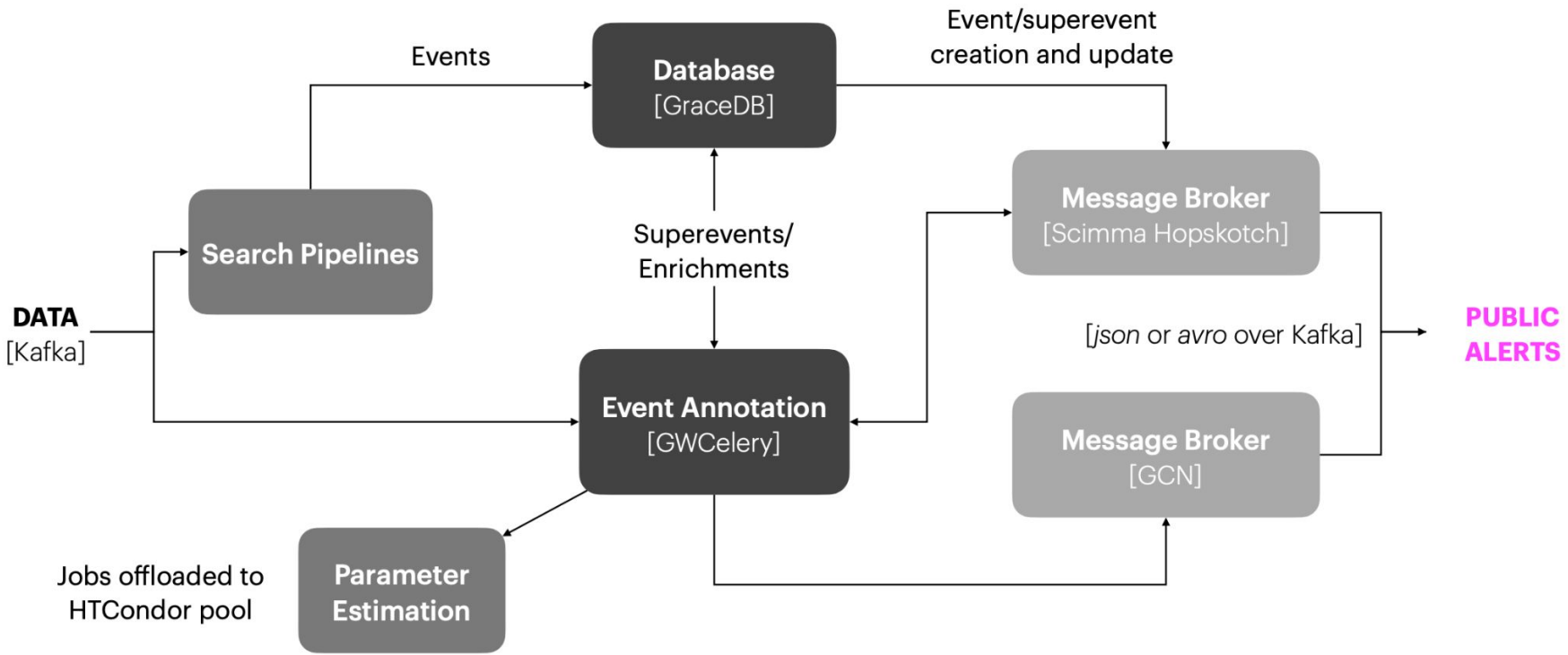


CBC pipelines	Burst pipelines
MBTA	cWB
GstLAL	oLIB
SPIIR	
PyCBC	

GraceDB

amazon web services

The Low Latency Alert Generation Infrastructure (LLAI)



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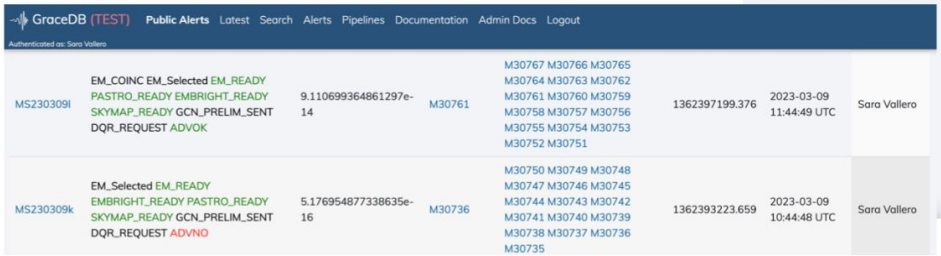
GraceDB - the event database

- Different deployments (tiers):
  - **Production**
  - **Playground:** designed for users to develop and test their own applications. It mimics the production instance, but events and associated data are not preserved indefinitely. Used in Mock Data Challenges
  - **Test:** designed for Quality Assurance (QA) testing and validation for GraceDB and electromagnetic follow-up developers. Software should meet QA milestones on the test instance before being moved to Playground or Production.

- **Web application:**
  - provides long-term storage for its inputs, outputs and by-products
  - accessible via GUI or API
  - relational database and local storage for persistence
  - deployed in replica 3 (each tier)



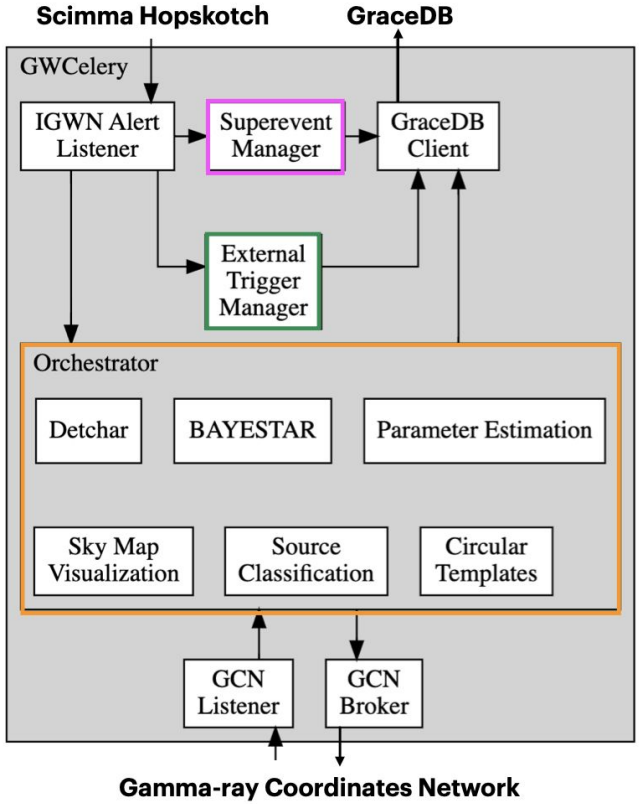
GWCelery - the event annotation service

Superevent Manager: clusters and merges related candidates into *superevents*

External Trigger Manager: correlates gravitational-wave events with GRB, neutrino, and supernova events

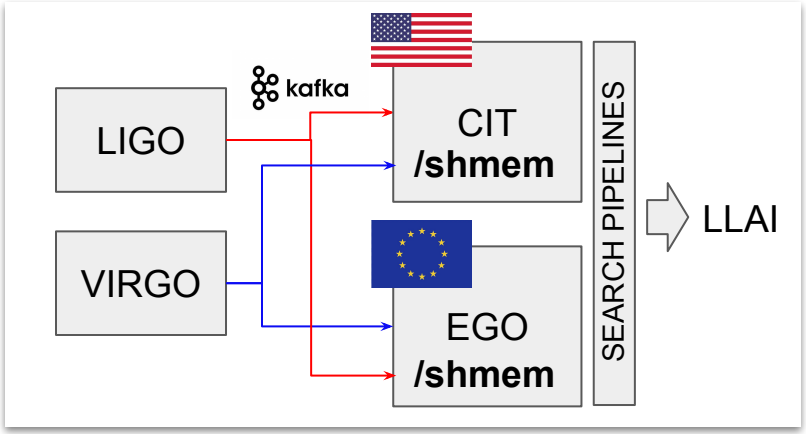
Orchestrator: executes the per-event annotation workflow

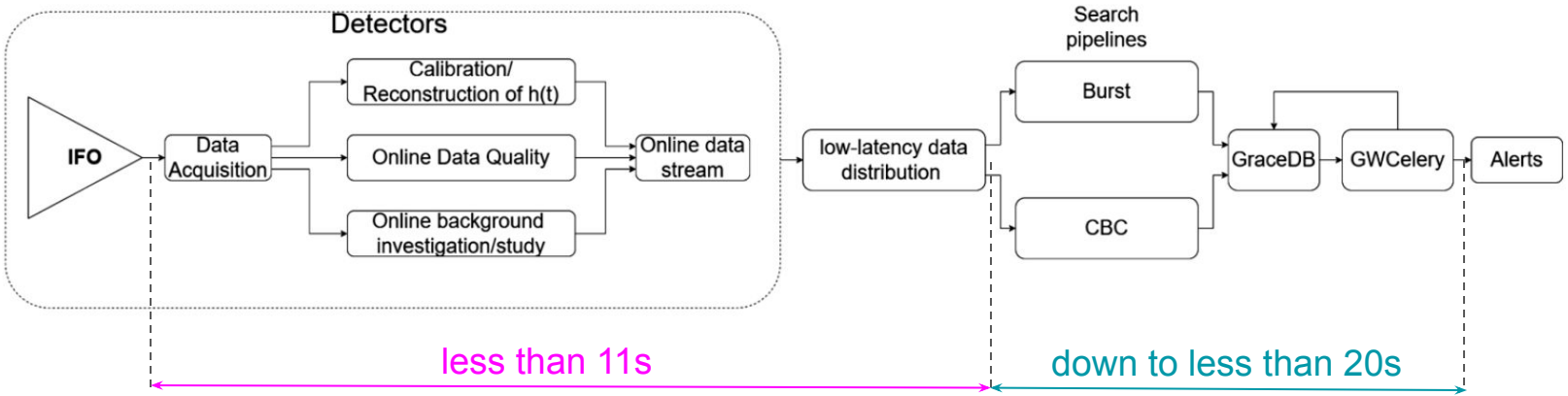
- these functional components are roughly mapped to Celery workers
- 1 Celery worker has been configured to accept only computationally intensive tasks that use OpenMP parallelism (HTCondor cluster)



Low-latency data distribution

- h(t) data are ready to be analyzed online in **less than 11 seconds** from the acquisition by the detectors.
- This makes **pre-merger alerts** (with negative latency) **possible.**
- The **first Preliminary** alert is available **in less than a minute**.





Conclusions

- No major change is expected for the rest of O4.
- It is based on the **gwcelery** annotation services.
- Relying on external services for the alerts dissemination (SciMMA/GCN-TACH).
- Delocalized computational infrastructure for search/pipeline computation (multiple computing centers involved). The central event database (GraceDB) on AWS.
- We are focused on generating alerts with minimum latency (~30s) and continuous effort to reduce latency and uptime.

- Improving and maintaining the public database (GraceDB) of triggers and alerts.
- Improve resilience of the system against single points of failure.
- Start working on planning for O5

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EXTRA SLIDES

Low Latency Architecture