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Commissioning and Characterization of the Advanced LIGO instruments

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A04/05 Joint Camp

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G1400128-v2

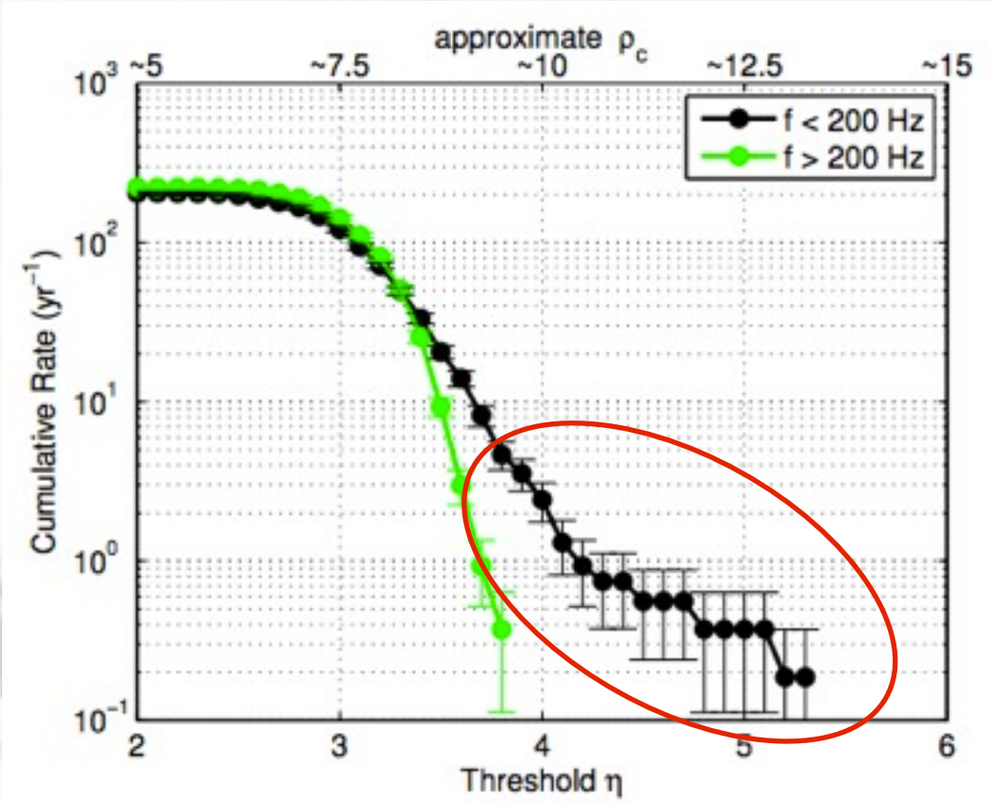
Purpose of Detector Characterization

- Detector Characterization is crucial to the instruments' science output — earlier science runs (S5/S6) saw impacts on searches from both ***non-stationary noise*** and ***transient effects***:

  - ***Detection Confidence***: Families of loud transients / non-stationary noise can ***mimic*** a GW signal and reduce our ability to distinguish them from an astrophysical source

- ***Parameter Estimation***: Transients ***obscure*** our ability to estimate the source parameters of a putative detection

- ***Multi-messenger Astronomy***: Rapid data quality information is necessary to alert electromagnetic observatories of ***real*** events while minimizing the number of ***false alarms***



Tail of background events mimicking a GW signal from a generic all sky search for transient GW signals

arxiv.org 1304.0670

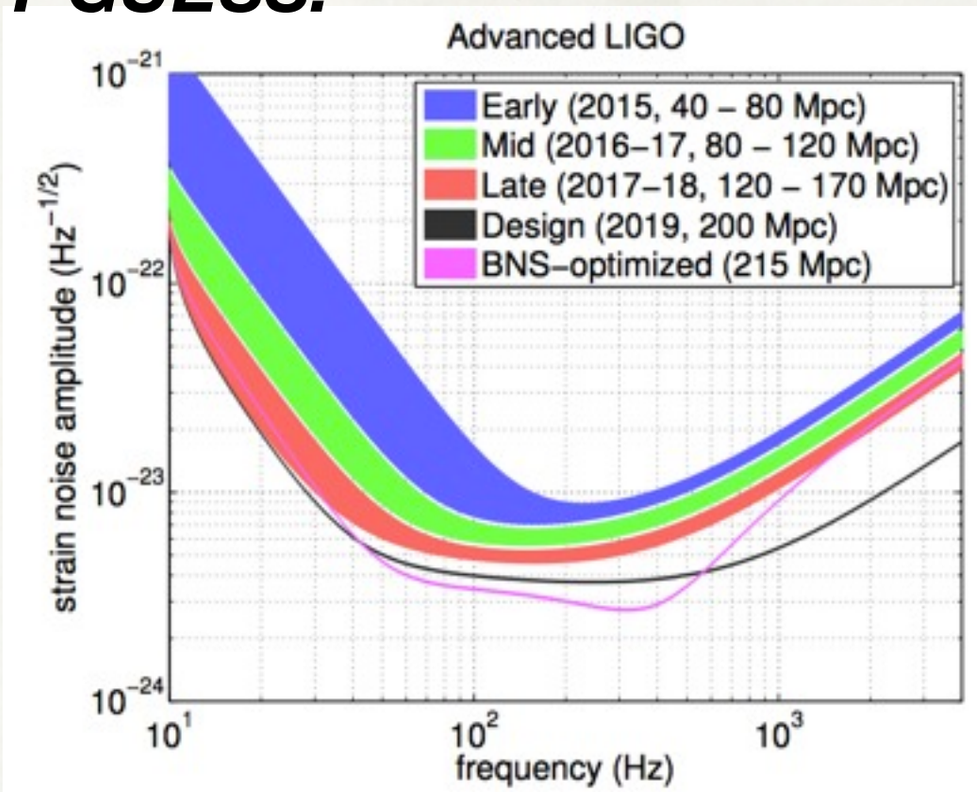
Current Status of aLIGO

arxiv.org 1304.0670

ALL DATES AND EVENTS ARE MY GUESS!

- **Speculative**: Instrument acceptance expected to come late this year or early next year with a ramp up to the blue sensitivity region (right) later in 2015

- Short commissioning breaks thereafter towards increasing sensitivity (green, red)



Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc) LIGO	Virgo	BNS Range (Mpc) LIGO	Virgo	Number of BNS Detections	% BNS Localized within 5 deg^2	20 deg^2
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

Current Status of aLIGO

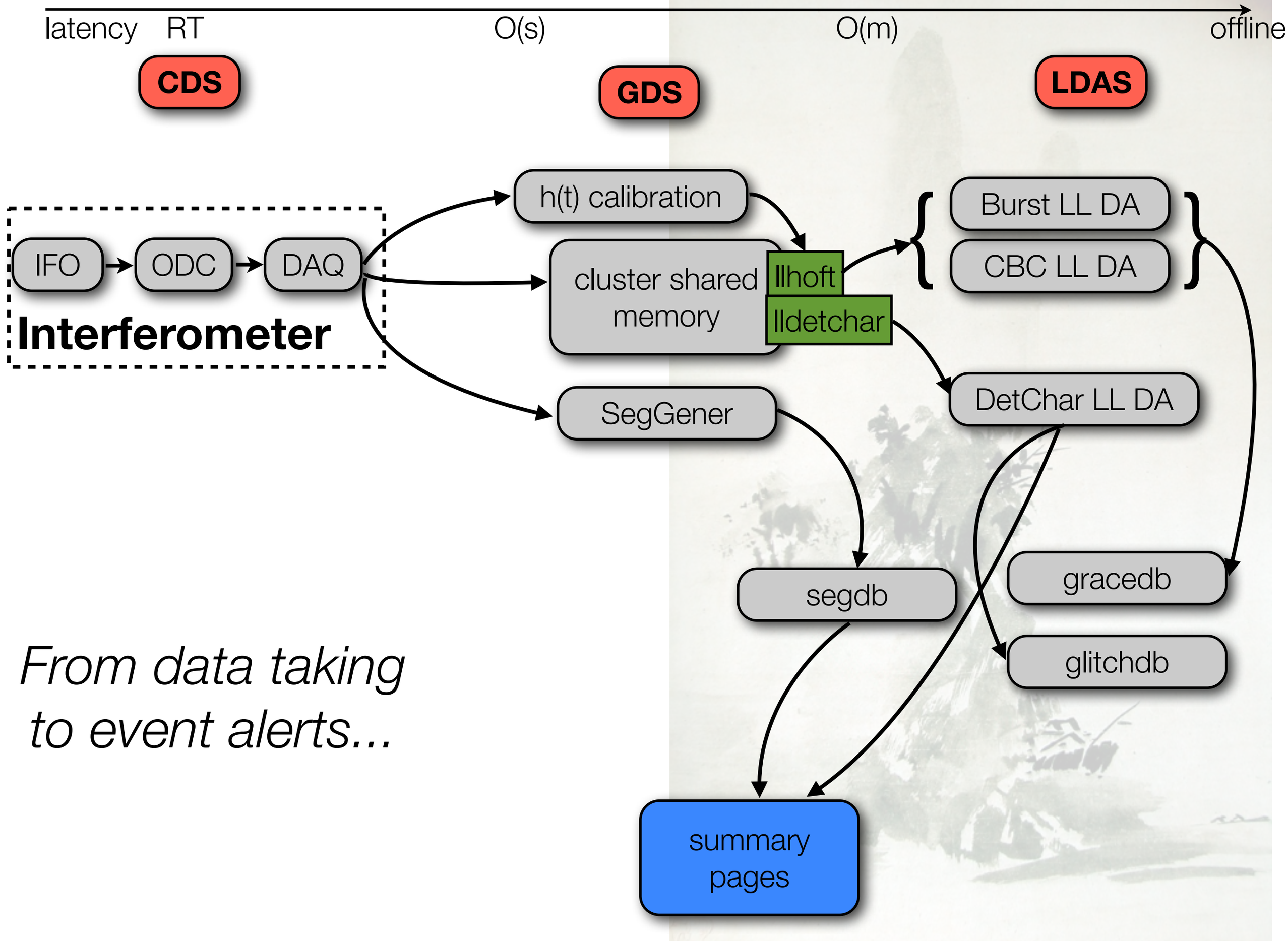
- Currently in the fifth Engineering Run (ER5) — runs are intended to be "practice" for the upcoming advanced instrument observational runs

  - Commissioning: **P***ower*/**D***ual Recycling* **M***ichaelson* **I***nteferometer* --- tests of the inner Michaelson interferometer without the long arms but using the power (laser side) and signal (output side) recycling mirrors along with the new aLIGO laser and stabilization systems

- Commissioning: **H***alf*-**I***nter***F***er***O***meter* **X**/**Y** — tests of locking one ***long*** arm of the interferometer (includes light storage cavities)

- Observing: Data analysis pipelines analyzing in near real time, sending out alerts of possible GW candidates in ***O(min)***

From data taking to event alerts...



Commissioning Overview

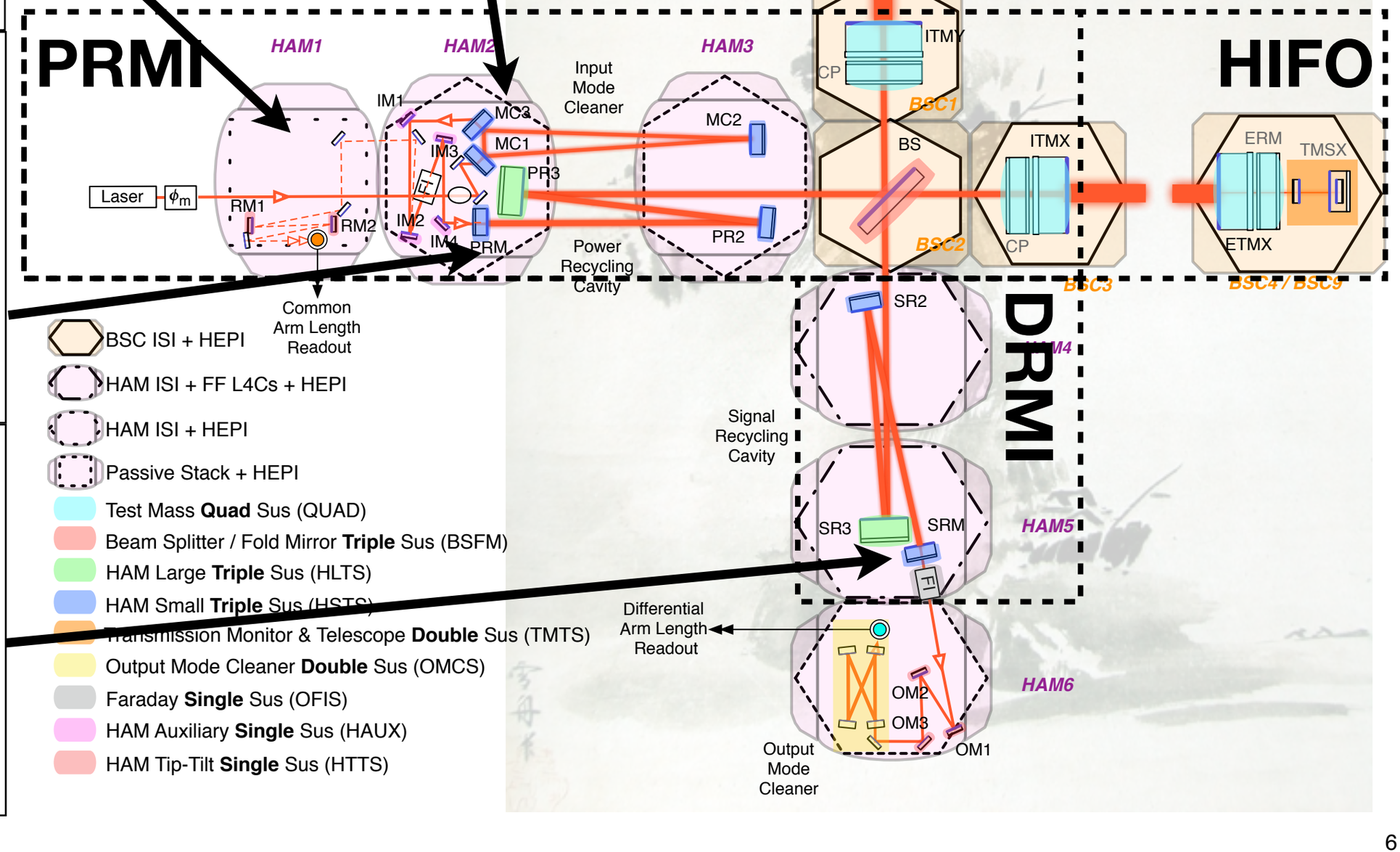
LIGO-G1200071

(**1**) Pre-stabilized Laser (PSL)

(**2**) Input Mode Cleaner (IMC)

(**3**) Power recycling mirror (PRM)

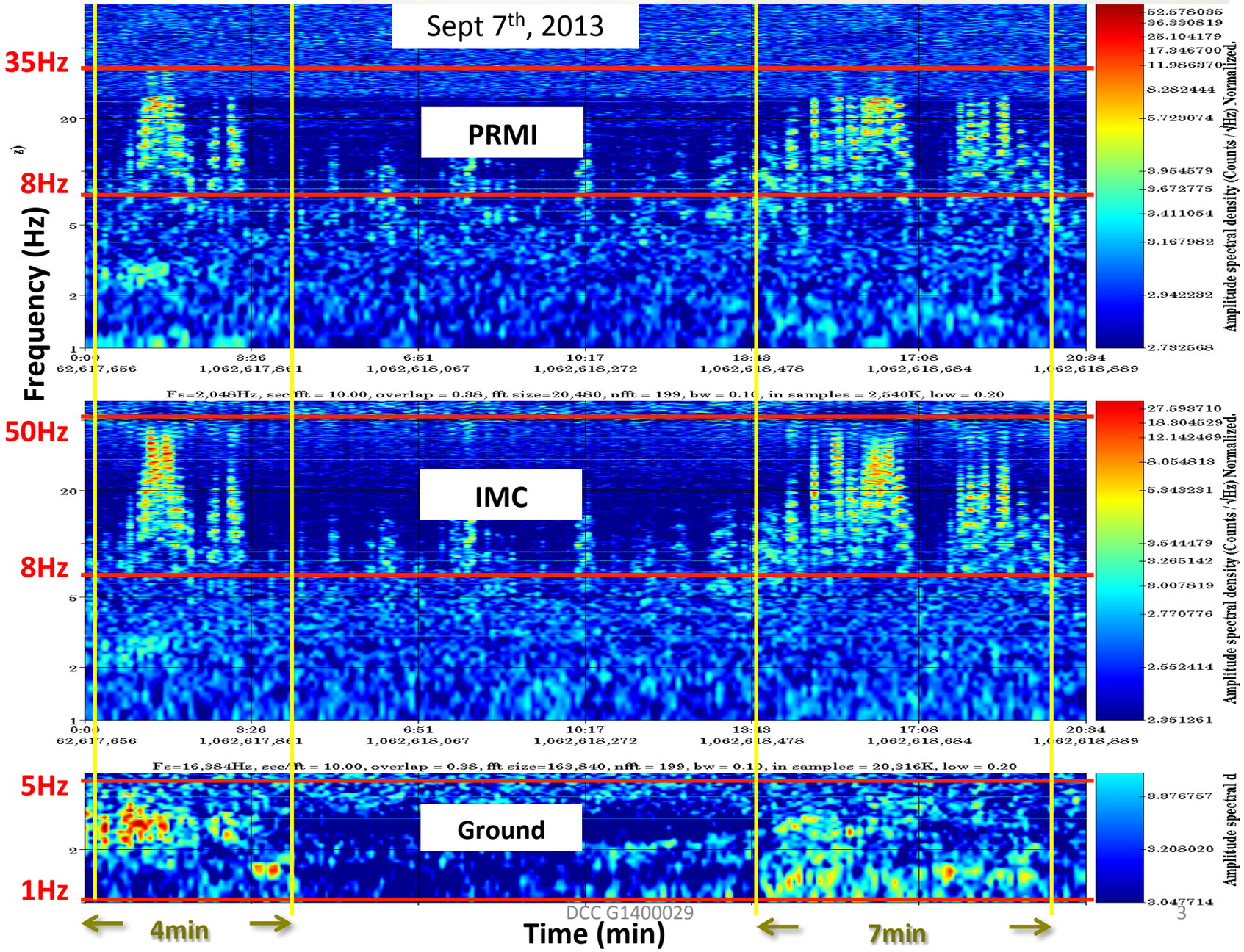
(**4**) Signal recycling mirror (SRM)



Commissioning (SUS/SEI/IMC)

- Commissioning new active seismic isolation systems — many of the interferometer chambers on triple/ quadruple suspensions (***passive isolation***) with active feedback loops

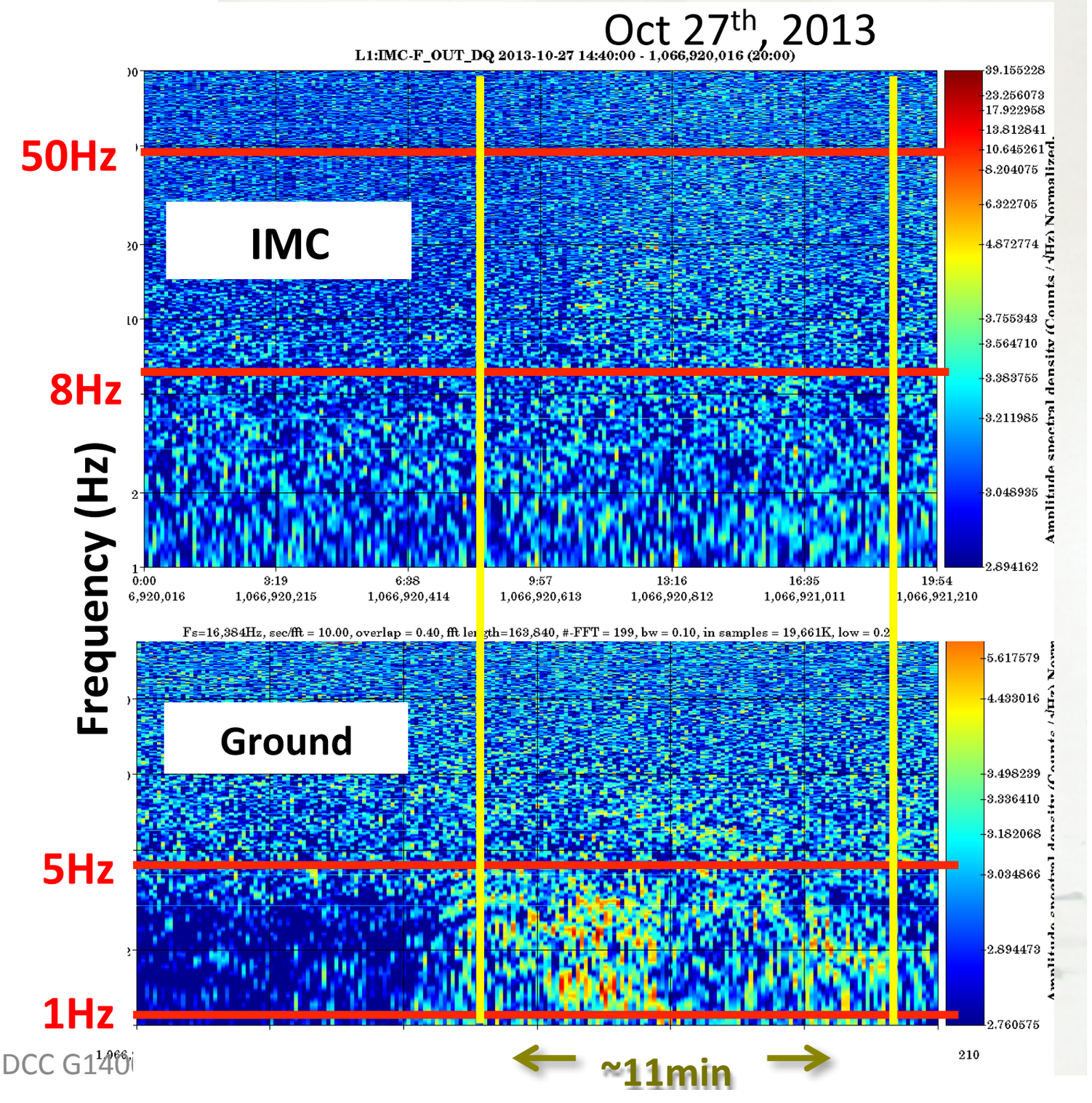
- Some concern about low frequency noise (trains) manifesting at higher frequencies within the chamber readout channels (***upconversion***)

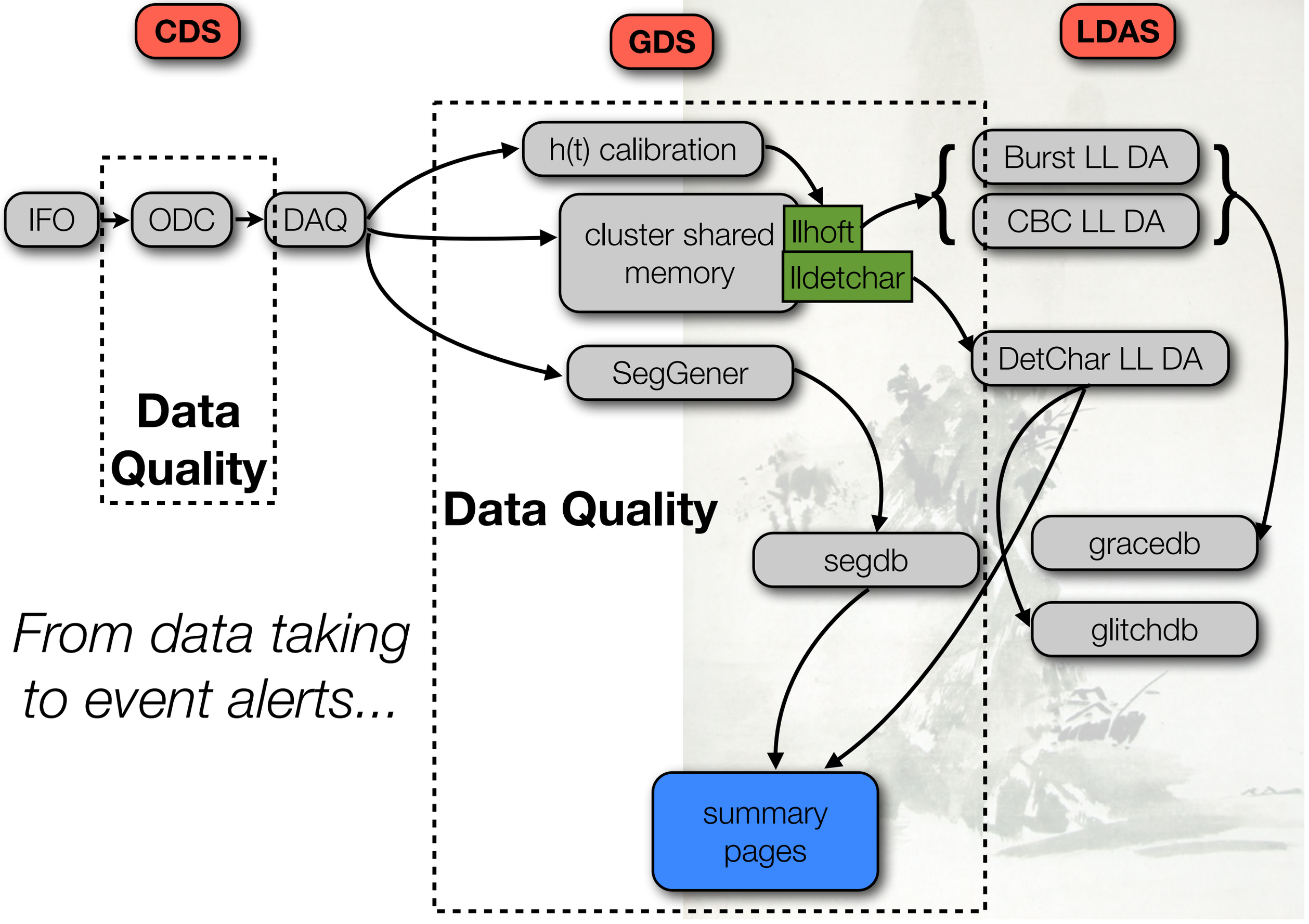


Commissioning (SUS/SEI/IMC)

- The problem was reported by DetChar to the seismic experts, who tuned the active isolation feedback loops to target the excess 1-3Hz motion induced by the train

- After this change excess ground motion upconversion into the IMC was diminished

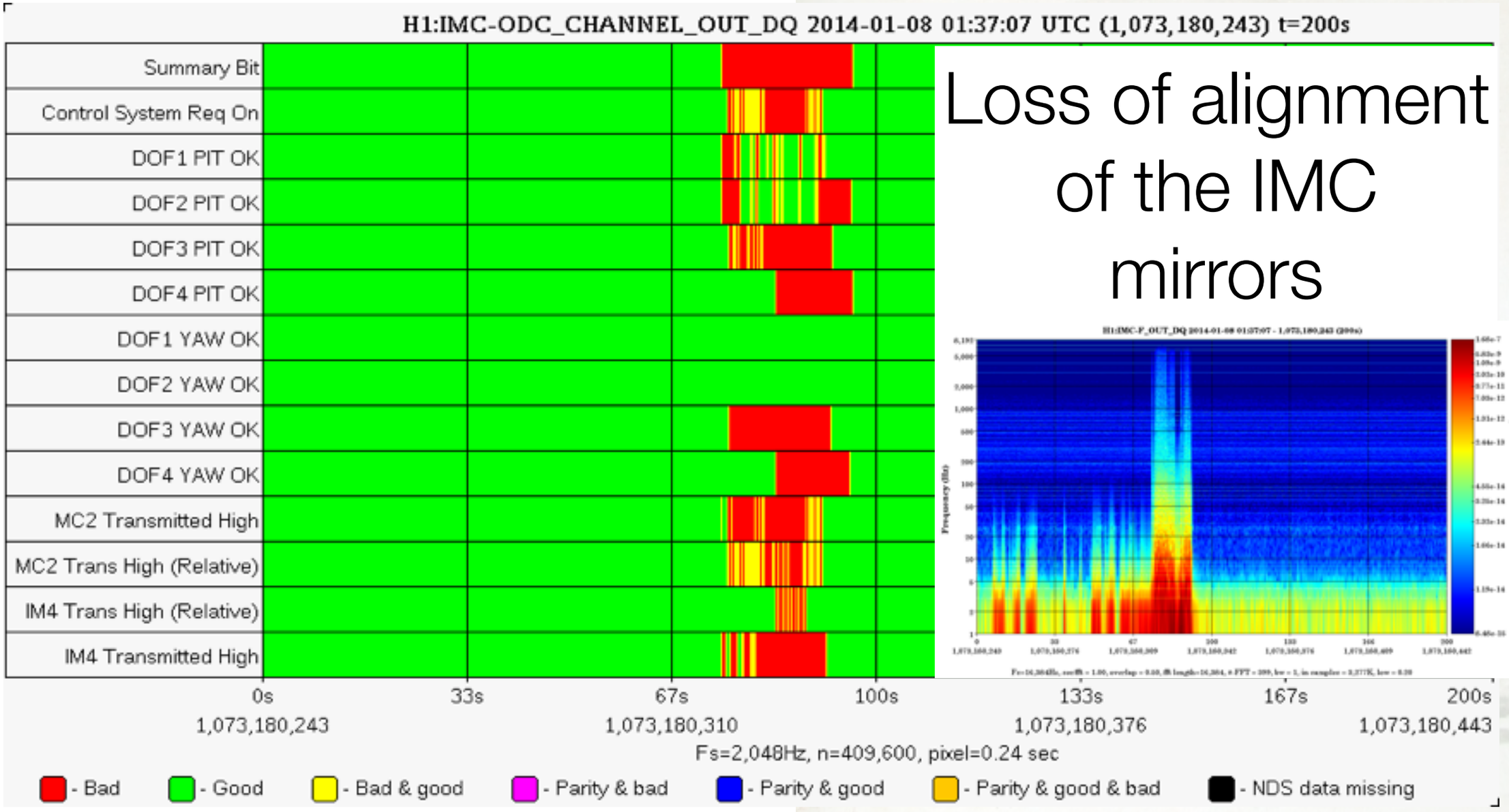




From data taking to event alerts...

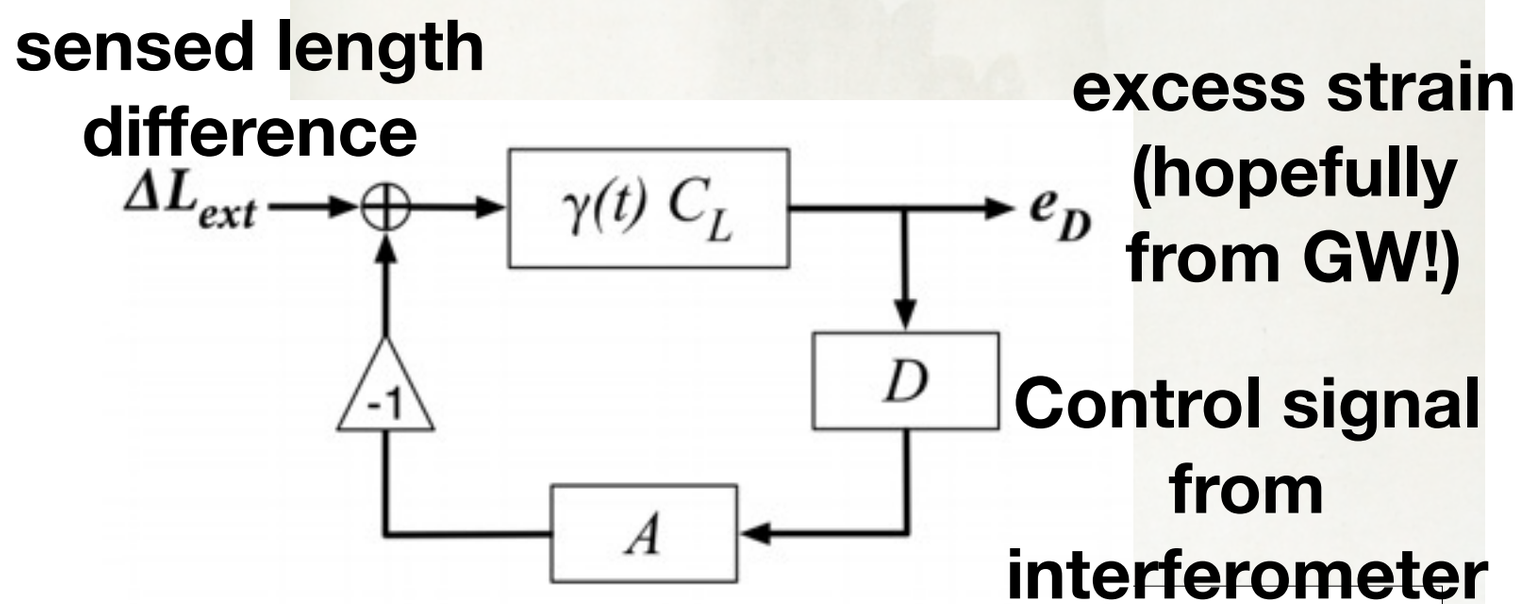
Online Detector Characterization (ODC) and Interferometer State

- Subsystem (e.g. IMC) status at a glance; used to inform the lowest order information about interferometer state

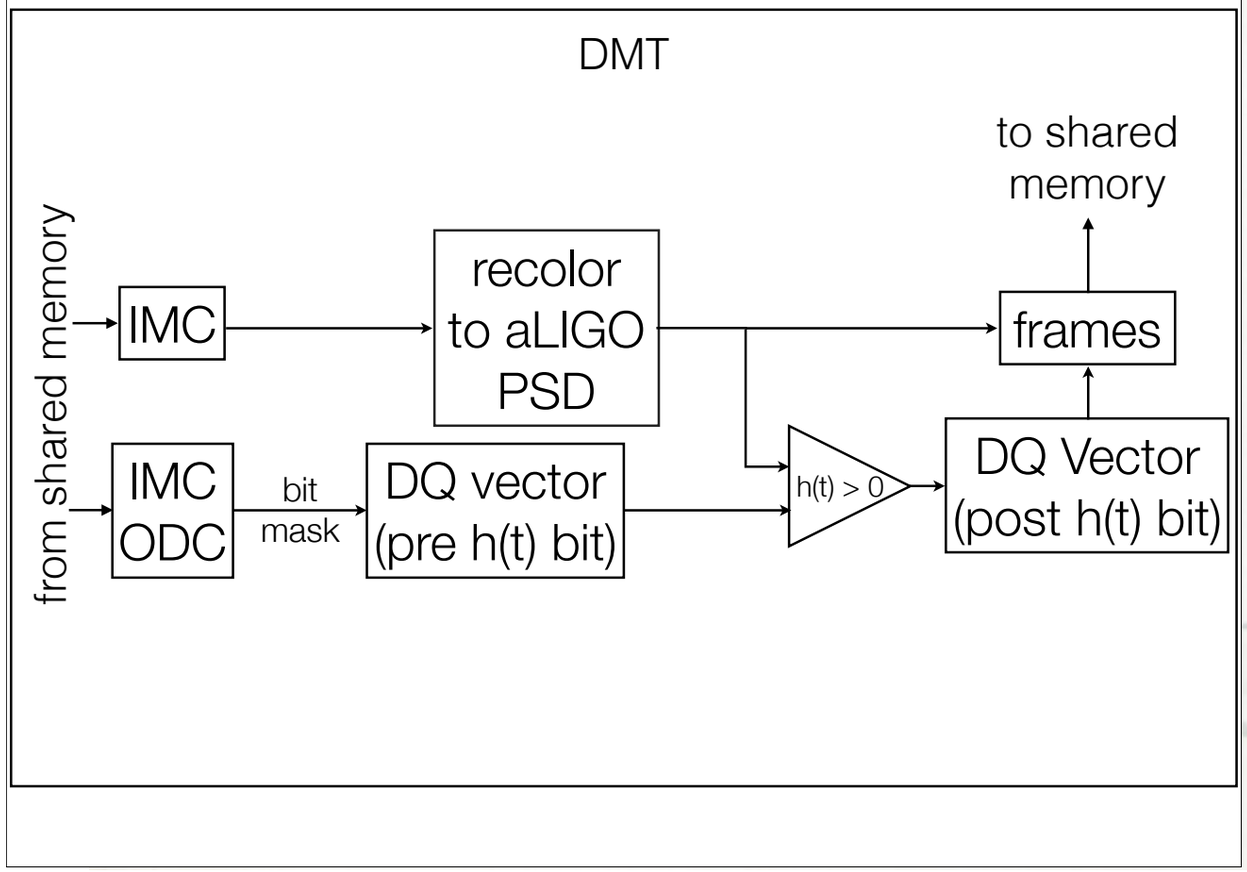


Strain Calibration

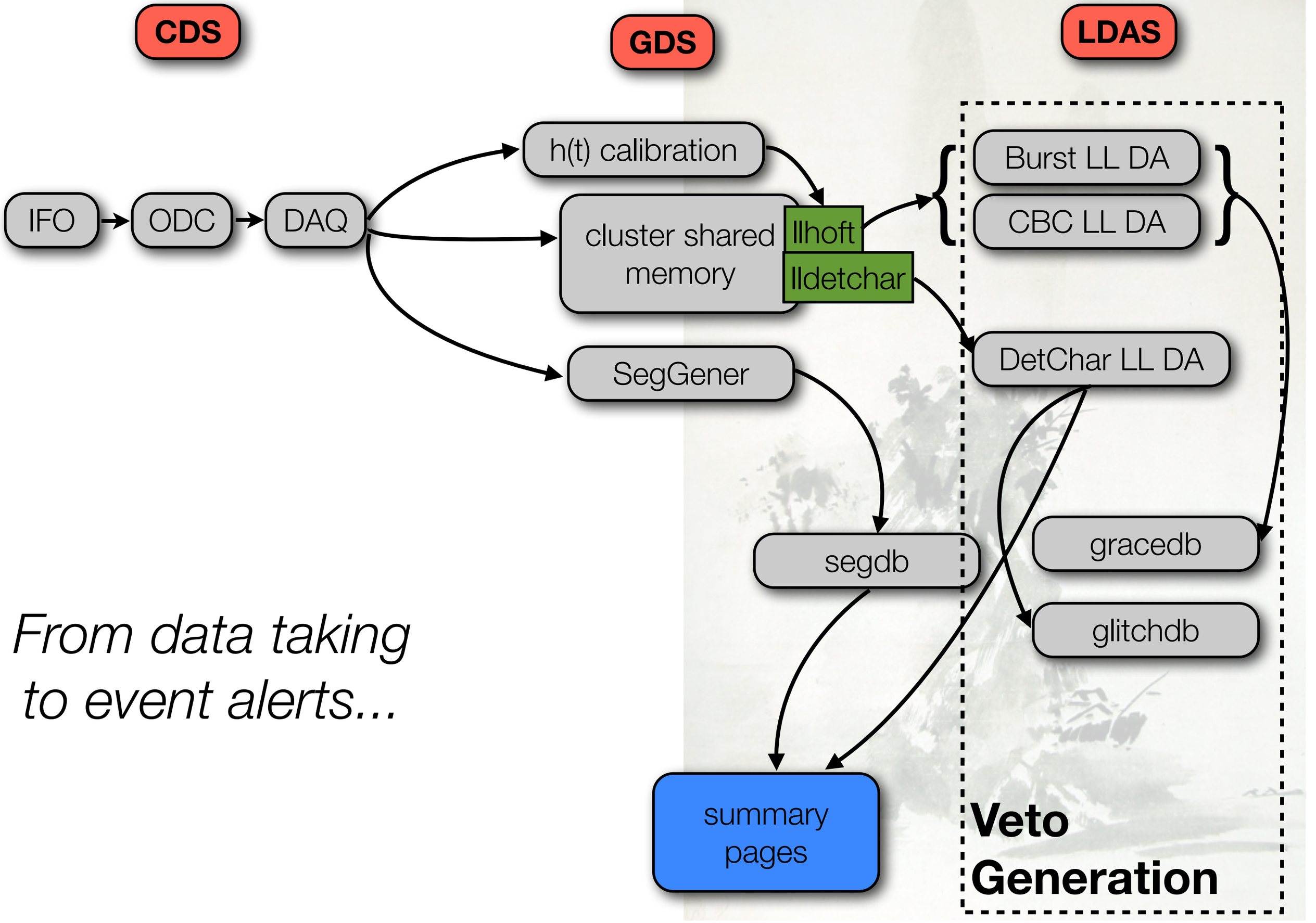
- Calibration pipeline being prototyped; calibrated data being produced within seconds of acquisition



- Current test setup uses different filters to “transform” IMC spectral data into GW strain data to distribute to low latency GW analyses

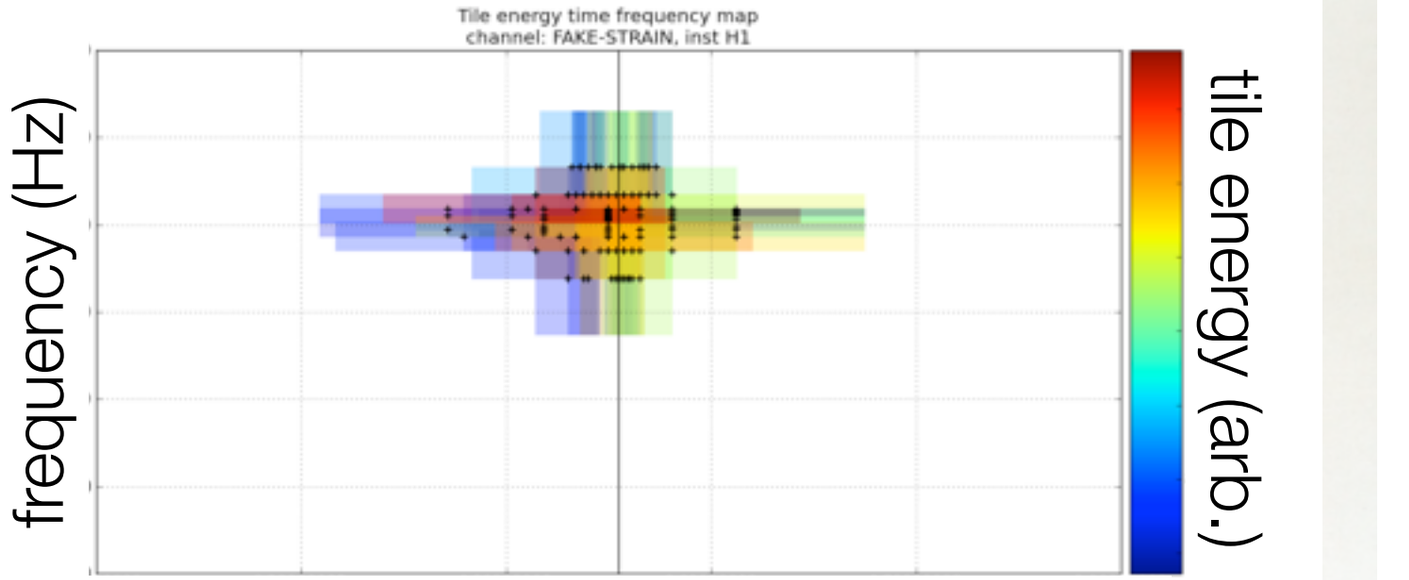


From data taking to event alerts...



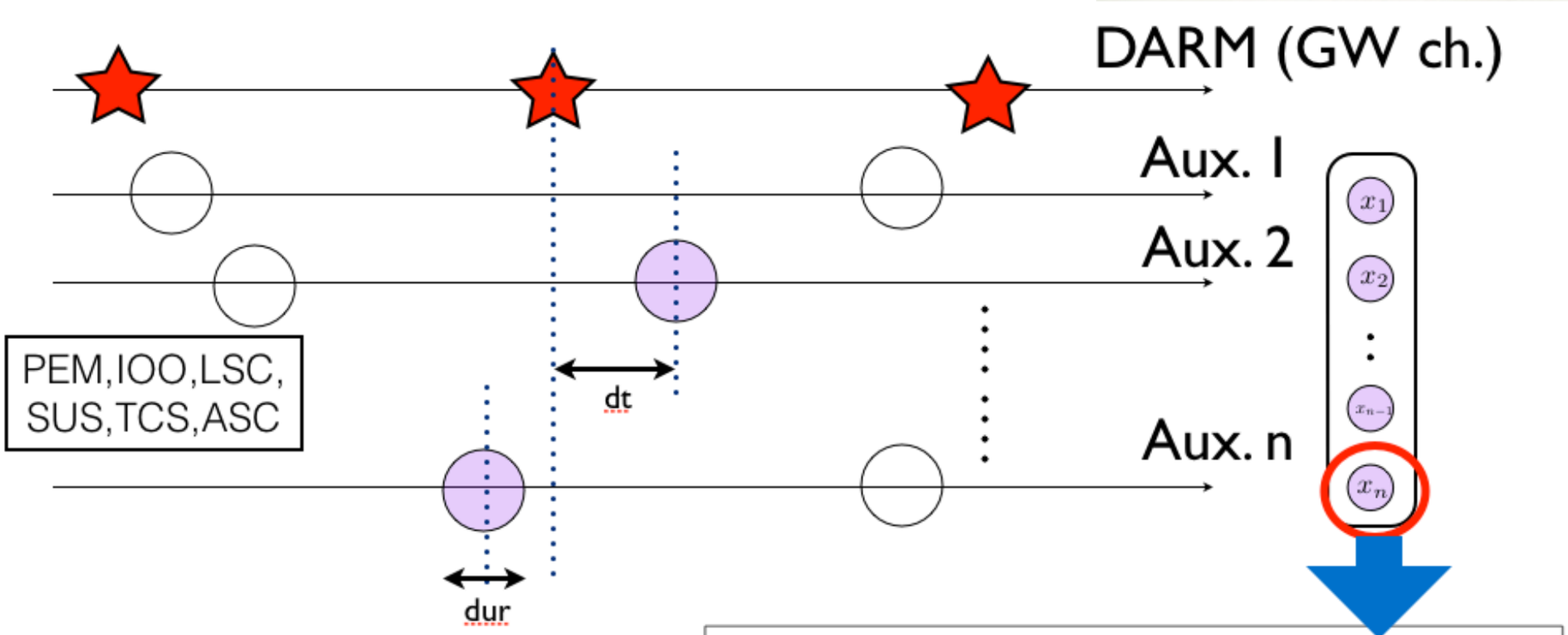
Trigger / Veto Generators

- Trigger generators running for detector characterization purposes
  - `Omicron` — O(1000) of channels, ~1-2 hours
  - `gstlal_excesspower` — O(100) of channels, ~few minutes
- Veto generation: hierarchical optimization of trigger rejection using auxiliary data



iDQ: low-latency glitch classification / vetoes

- Data from hundreds of instrumental channels are analyzed in low-latency (~minutes)
- Combining time-series analysis with multi-variate classifiers to recognize glitches in GW data



(a) cluster significance of loudest trigger within +/-100ms, or significance of nearest trigger if none exists (significance is related to the SNR)
(b) dt between DARM trigger and AUX trigger in (a)
(c) duration of AUX trigger in (a)
(d) frequency of AUX trigger in (a)
(e) npts (cluster size) of AUX trigger in (a)

Impact on Multimessenger Astronomy

- Candidate event database (***gracedb***) is the clearing house for GW event information, including follow up from data quality checks and basic detector characterization feedback

- GW event candidates will be sent out within a few minutes of identification

    - Some data quality information already available: basic interferometer operational status, known environmental disturbances

    - Additional auxiliary vetoes generated within a few minutes up to a day

- Send follow up alerts down-ranking candidates based on data quality

Basic Info

UID	Labels	Group	Type	Instruments	GPS Time Event Time	FAR (Hz)	Links	UTC Submitted
T73979	DQV	Test	LowMass	H1,L1,V1	1045019974	8.053e-11	Data	2013-07-18 22:07:01 UTC

Submitter	Comment
GDB Processor	Data quality check completed H1L1V1-DATA_QUALITY-1045019964-20.xml.gz
Brian Moe	Tagged message 9: data_quality
Chris Pankow	H1L1V1-DATA_QUALITY-1045019964-20.xml.gz