Online all-sky burst searches during the joint S6/VSR2 LIGO-Virgo science run

Igor Yakushin
LIGO Livingston Observatory, Caltech

For the LIGO Scientific Collaboration and Virgo Collaboration

S6/VSR2 Science run

- In July 2009 LIGO 6th / Virgo 2nd Science run (S6/VSR2) will start and continue for about two years with some breaks for commissioning.
- During S6/VSR2 we plan to do low latency all-sky search for gravitational wave bursts using LIGO-Virgo network of three detectors (H1L1V1) that would produce preliminary gravitational wave candidate triggers within a few minutes from the moment the data is collected. These triggers will be:
  - sent to external observatories for follow-up studies;
  - used for rapid detector characterization and feedback to the control room.
- The real-time low latency analysis will be followed up by:
  - background and sensitivity study - a few hours behind real-time;
  - final offline analysis - a few weeks or months later once we have final calibration and data quality information.

Science goals of low latency search

- Rapid identification of triggers from GW detectors for prompt follow-up with other instruments
  - GW event can be accompanied by
    - EM radiation (optical, UV, x-ray)
    - Neutrinos
  - EM observatories are not searching all the time the entire sky, but the GW detectors are
  - The prompt follow-up by external collaborations may allow us:
    - increase significance of the GW observation if it is accompanied by EM or/and neutrinos counterpart
    - obtain additional informations about GW sources: host galaxy, more accurate sky coordinates, distance, etc.

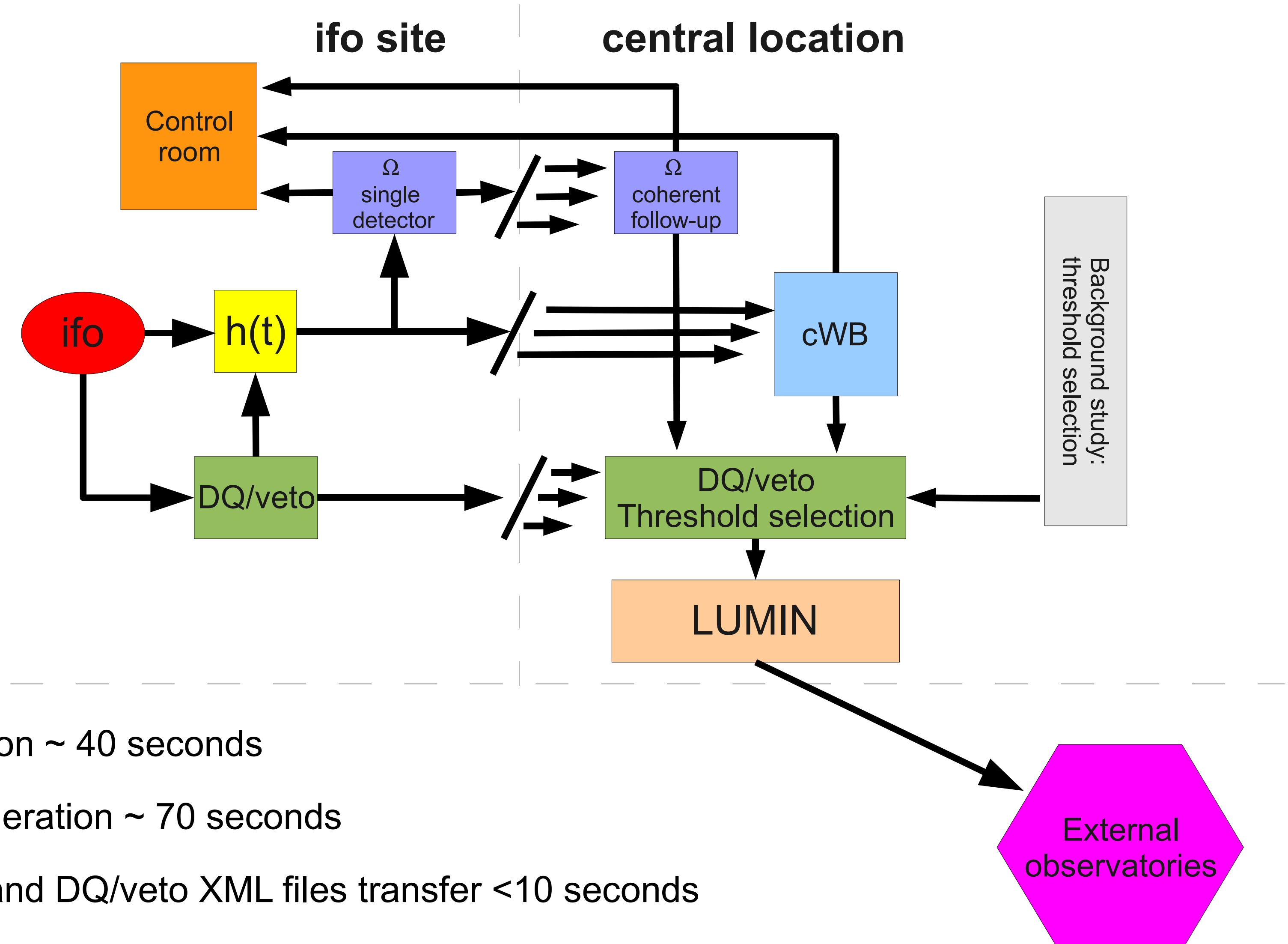
Potential external collaborators

- Swift (approved): multi-wavelength (optical, UV, X-ray) satellite telescope
- Wide-field optical telescopes: ROTSE, TAROT, SkyMapper
- Narrow-field optical telescopes: ESO, Liverpool robotic telescope
- Radio telescopes: LOFAR
- Neutrino detectors: Antares, IceCube, LVD, Borexino, Super-Kamiokande

Search pipeline overview

- Online burst search will use two independent analysis pipelines in parallel:
  - Coherent WaveBurst (cWB):
    - Fully coherent algorithm that generates triggers on combined data streams reconstructing signal waveforms and sky coordinates (talks by M. Drago and S. Klimenko)
  - Omega Pipeline (Ω):
    - Hierarchical approach
      - Single-detector triggers are generated at the detector sites: template based search for sine-gaussians
      - Time-frequency coincidence and coherent Bayesian follow-up is done at the central location (talk by A. Searle)

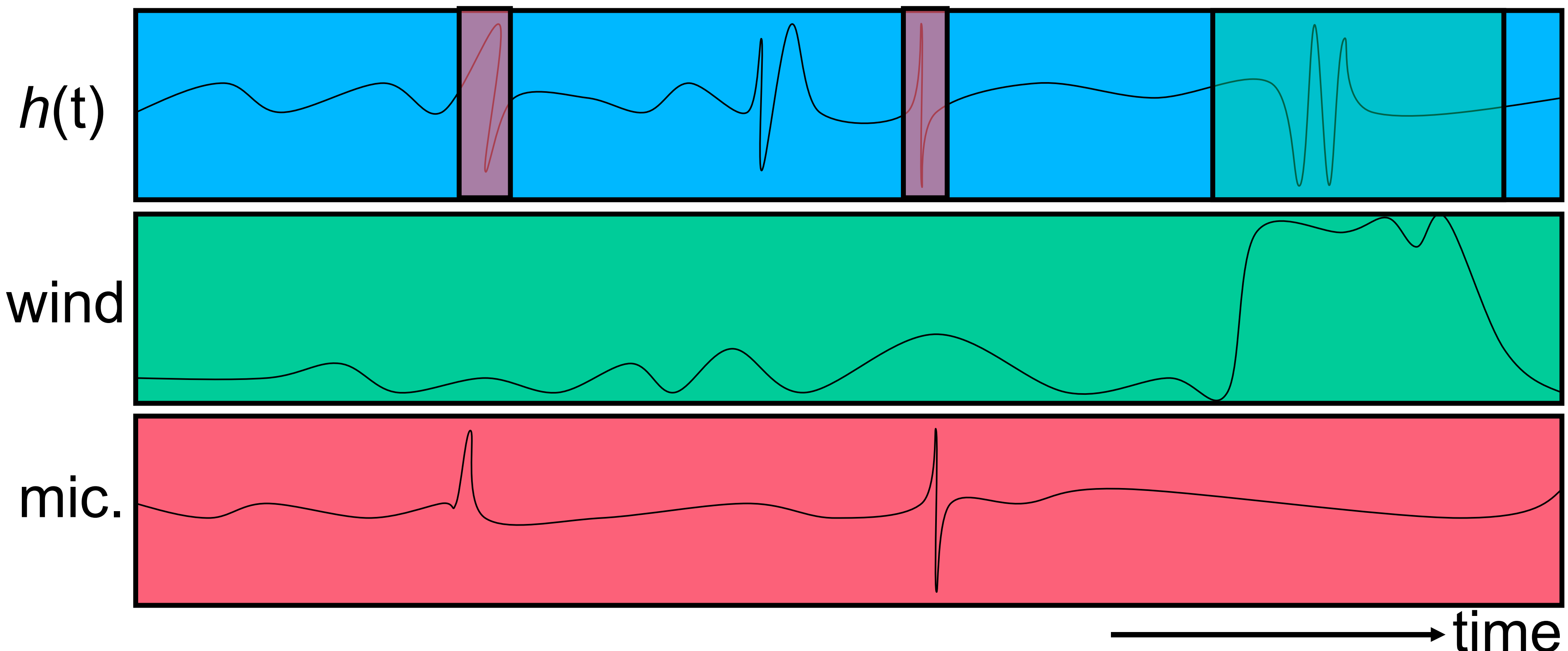
Search pipeline overview



- h(t) generation ~ 40 seconds
- DQ/veto generation ~ 70 seconds
- h(t) frames and DQ/veto XML files transfer <10 seconds
- Trigger generation ~ 2-5 minutes
- LUMIN ~ 1-2 minutes (once in autopilot mode; at the beginning there will be human making final decision)

Data Quality and Vetoes

- Data quality (DQ) flags cut out N-second time intervals when we have reason to believe the detector is behaving badly
- Event-by-event vetoes cut out 100ms-1s time intervals based on auxiliary channel triggers that have been shown to have a safe and significant relationship with h(t) triggers

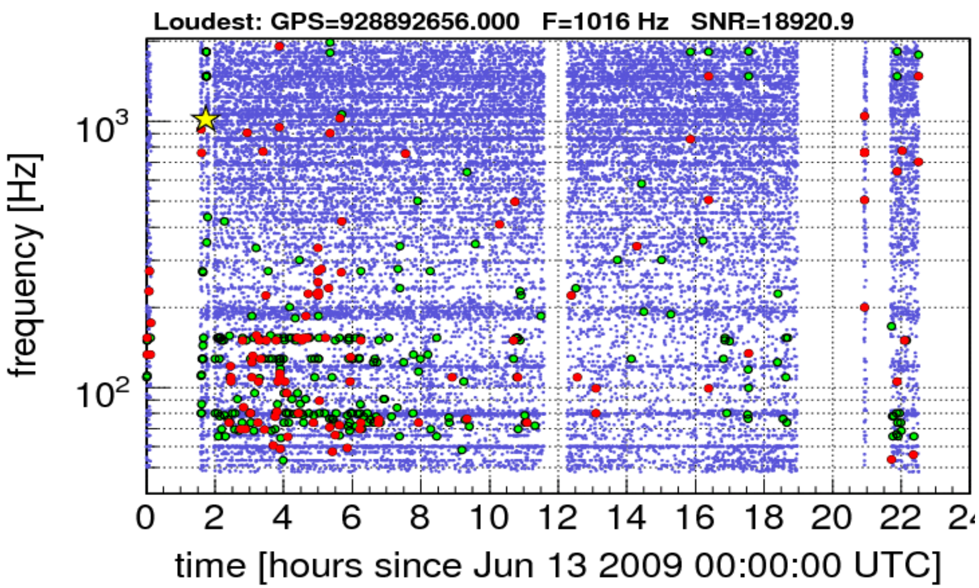


Data Quality and Vetoes

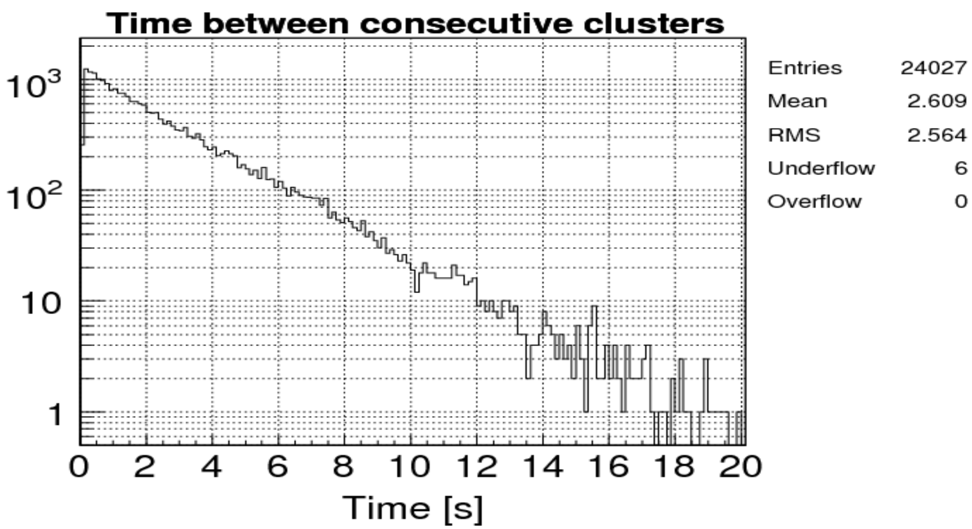
- To support online analysis
  - Tens of DQs are produced with ~1 minute latency
  - Online KleineWelle algorithm runs on H1L1V1 (~150 channels per site) identifying transients and event-by-event vetoes with ~1 minute latency
- DQ/vetoes are grouped by categories 1-5. For online analysis we shall apply categories 1-4 before sending triggers to external collaborations
- The results are available in the form of XML files and database entries that can be queried with the provided tools.

Ω single detector triggers

- First step in Ω pipeline
- Also used for on-site detector characterization and generation of data quality figures of merit in the control room:



- Blue: SNR>5 Green: SNR>10 Red: SNR>20

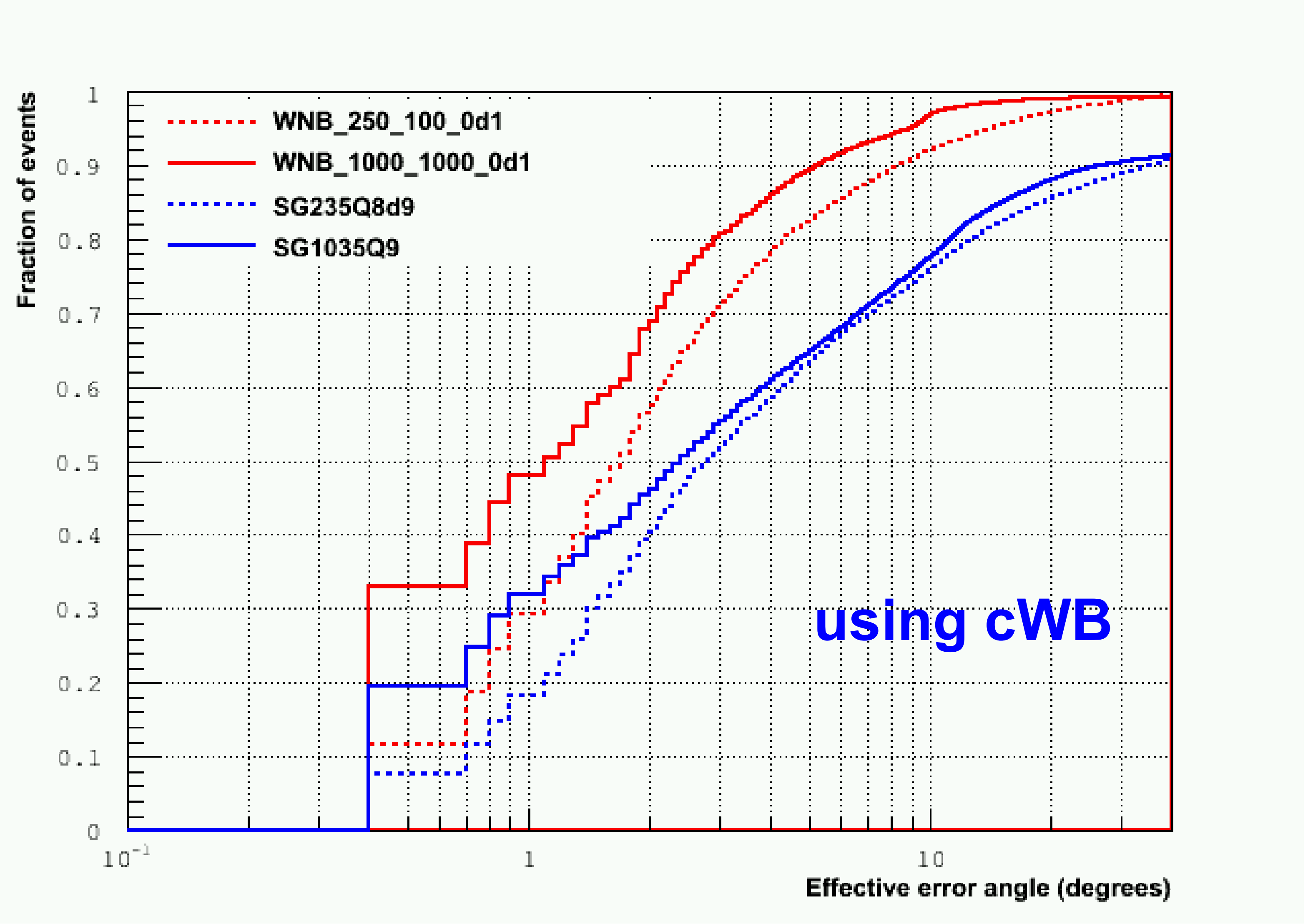


Multi-site coherent network analysis

- Both Ω and cWB:
  - Low latency coherent network analysis
    - Ω: Bayesian analysis
      - [Searle et al, CQG 25.114038,2008]
      - Talk by A. Searl
    - cWB: maximum likelihood analysis
      - [Klimenko et al, CQG 25.114029,2008]
      - Talk by S. Klimenko
  - High latency offline follow-up:
    - Ω–scan of other IFO channels
    - Coherent event display (based on cWB)
    - Time shift analyses to assess background
    - Search sensitivity study with software injections

Position reconstruction

- On simulated detector noise with S5 sensitivities
- H1L1V1
- log(SNR) of simulated signals is uniformly distributed with SNR<1000
- Source coordinates can be reconstructed with a precision of a few degrees



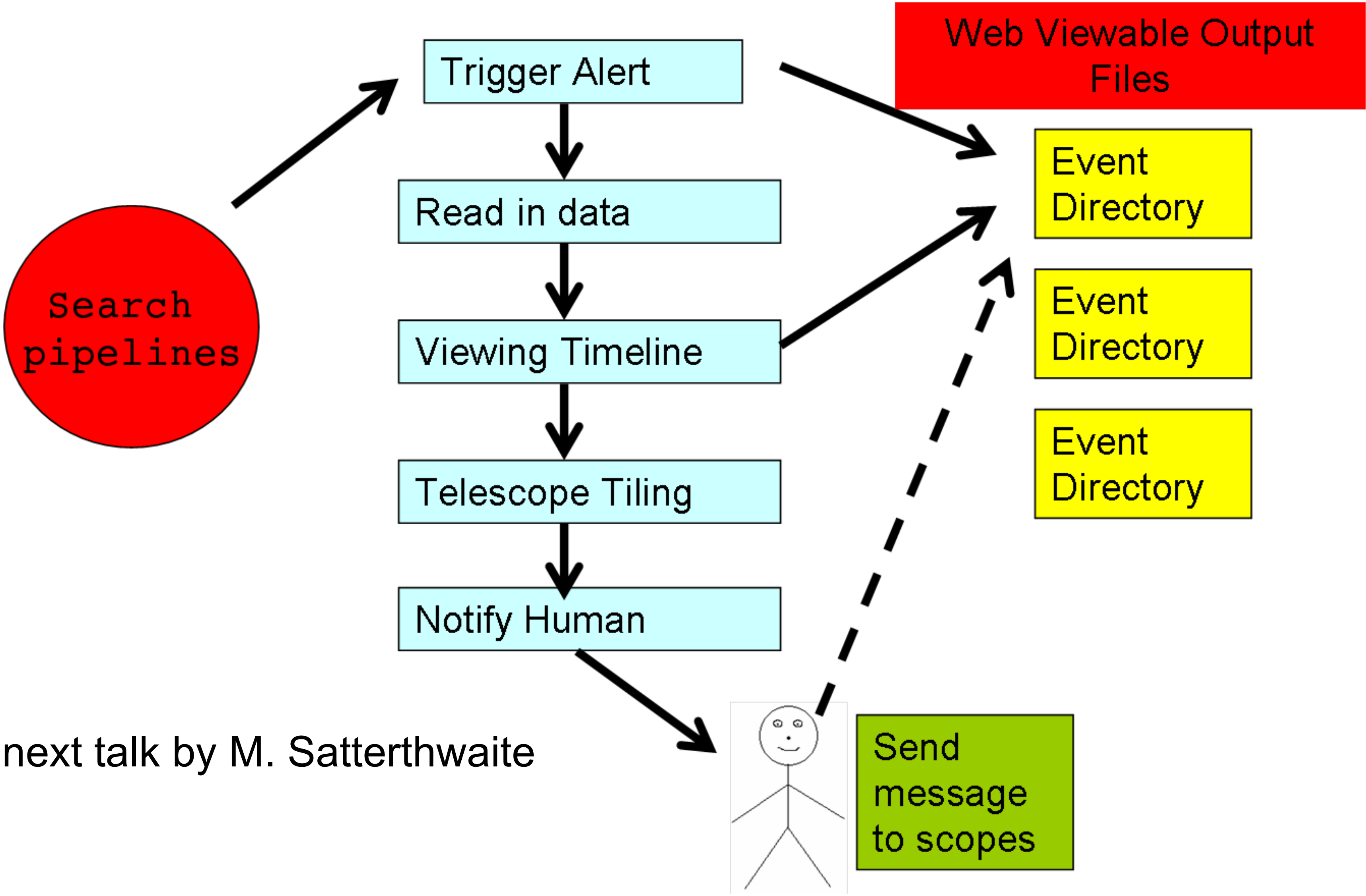
Error regions

- LUMIN gets sky coordinate information from the pipelines in the form of error regions:
  - A set of pixels sorted by probability
  - Not necessarily connected:
    - It is often impossible to distinguish the source and its mirror image
  - One can choose to report either a certain fixed number of pixels or as many pixels as necessary to achieve a certain probability that a true coordinates are inside the error region

counter	skyID	theta	DEC	step	phi	R.A	step	probability	cumulative
1	31785	52.0	38.0	0.50	227.0	214.3	0.63	1.243656e-01	1.243656e-01
2	32354	52.5	37.5	0.50	226.7	214.0	0.63	9.579223e-02	2.201578e-01
3	31219	51.5	38.5	0.50	226.7	214.0	0.64	9.455111e-02	3.147089e-01
4	31786	52.0	38.0	0.50	227.6	215.0	0.63	9.103733e-02	4.057462e-01
5	137509	132.0	-42.0	0.50	45.4	32.8	0.67	6.553371e-02	4.712799e-01
6	135882	130.5	-40.5	0.50	45.7	33.1	0.66	5.504128e-02	5.263212e-01
7	137508	132.0	-42.0	0.50	44.7	32.1	0.67	5.223054e-02	5.785517e-01

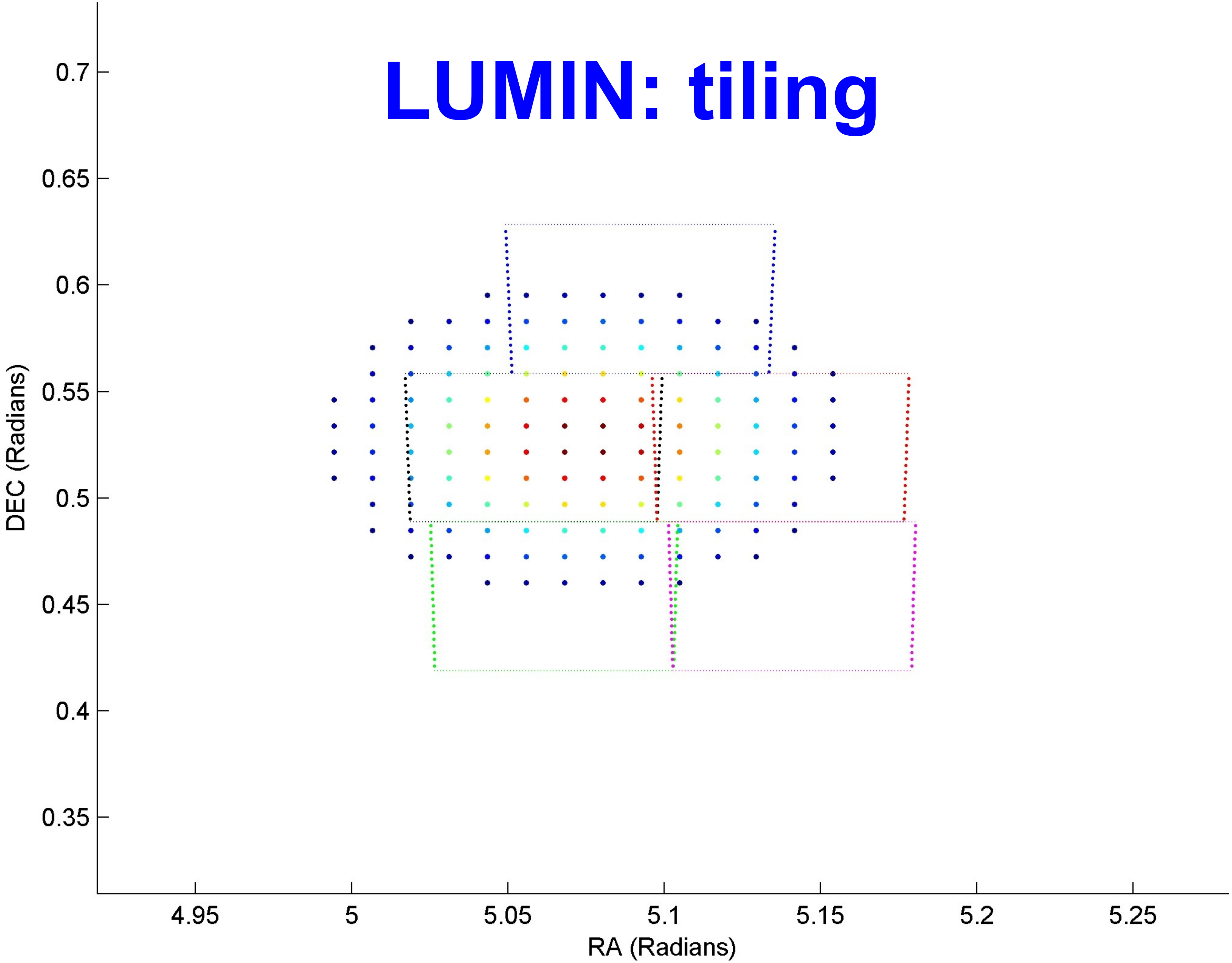
LUMIN

- LoocUp Management & INterface



- See also the next talk by M. Satterthwaite

LUMIN: tiling



Tests

- Various parts of the online burst search were tested during recent six months in engineering and mini runs: M9, M10, E13, E14.
- We also extensively tested the search using simulated frames based on a day from S5.
- The current plan is to use the first few weeks of S6/VSR2 as a testbed for online analysis before we start submitting triggers to external collaborations.

Conclusion

- For the first time LIGO and Virgo will produce close to final results of the GW search analysis almost in real time and follow up candidate triggers with electromagnetic observations!