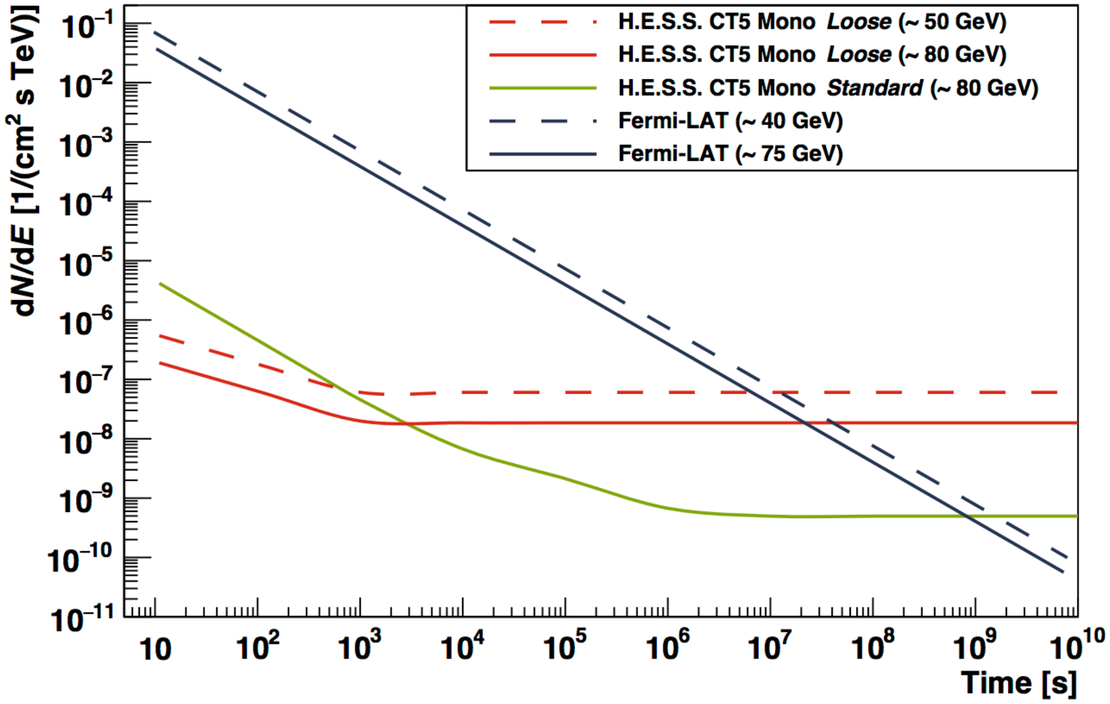
# The H.E.S.S. Transients Follow-up System

Clemens Hoischen (Potsdam University),
Kathrin Egberts (Potsdam University)  Matthias Füßling (CTAO), Stefan Ohm(DESY)

Bundesministerium
für Bildung
und Forschung

# Transients and IACTs (Follow-up Instruments)

- Not that many known transient phenomena in the IACT energy range:
  - AGN flares & GRBs (since this year!)
  - Main objective: **Discoveries!**



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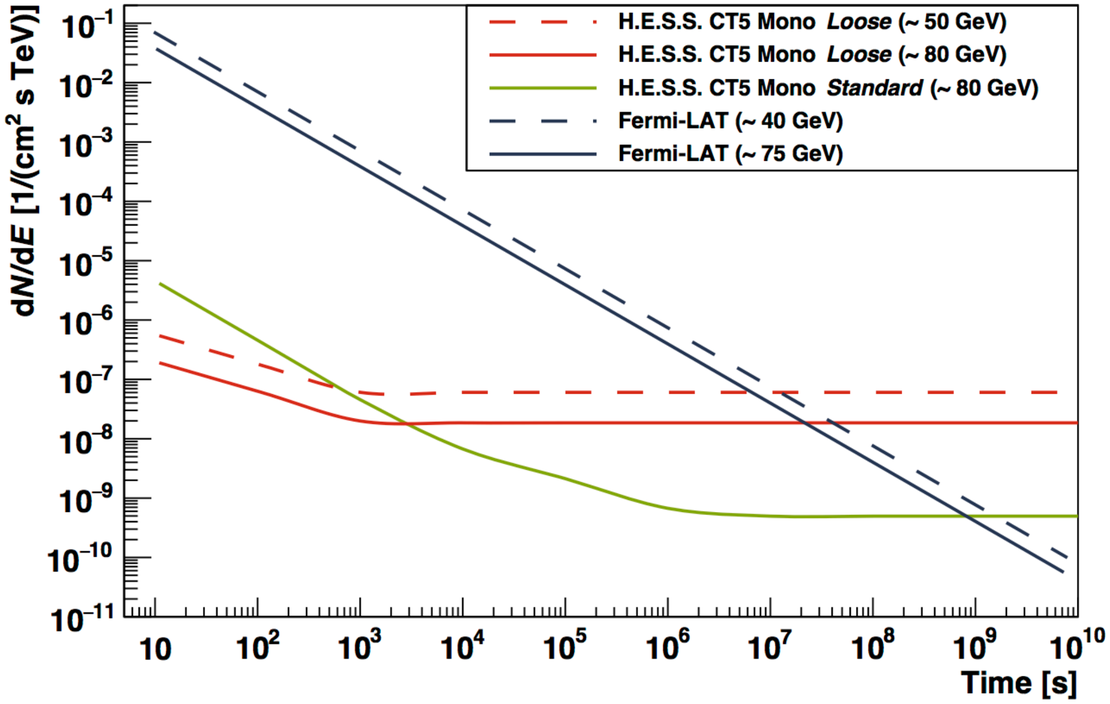
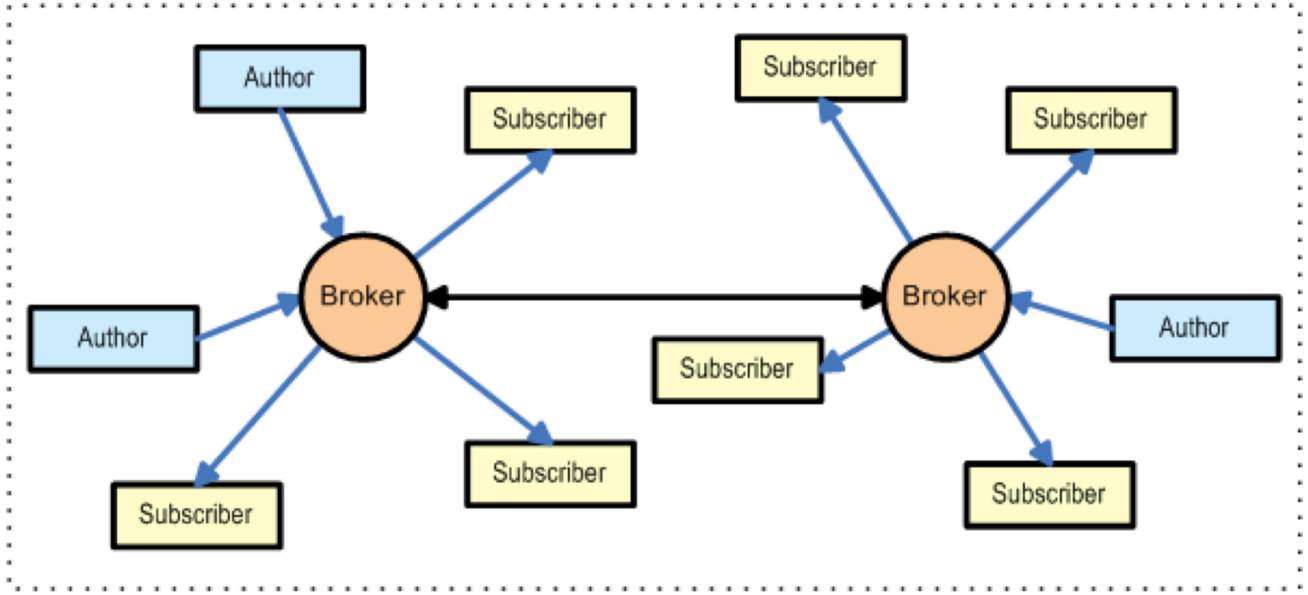



- Largely dependent on external triggers

**IVOA standards:**
- VoEvent (alerts)
- VoEvent Transport Protocol (communication of alerts)




from VoEvent Transport Protocol v1.1 (2009)

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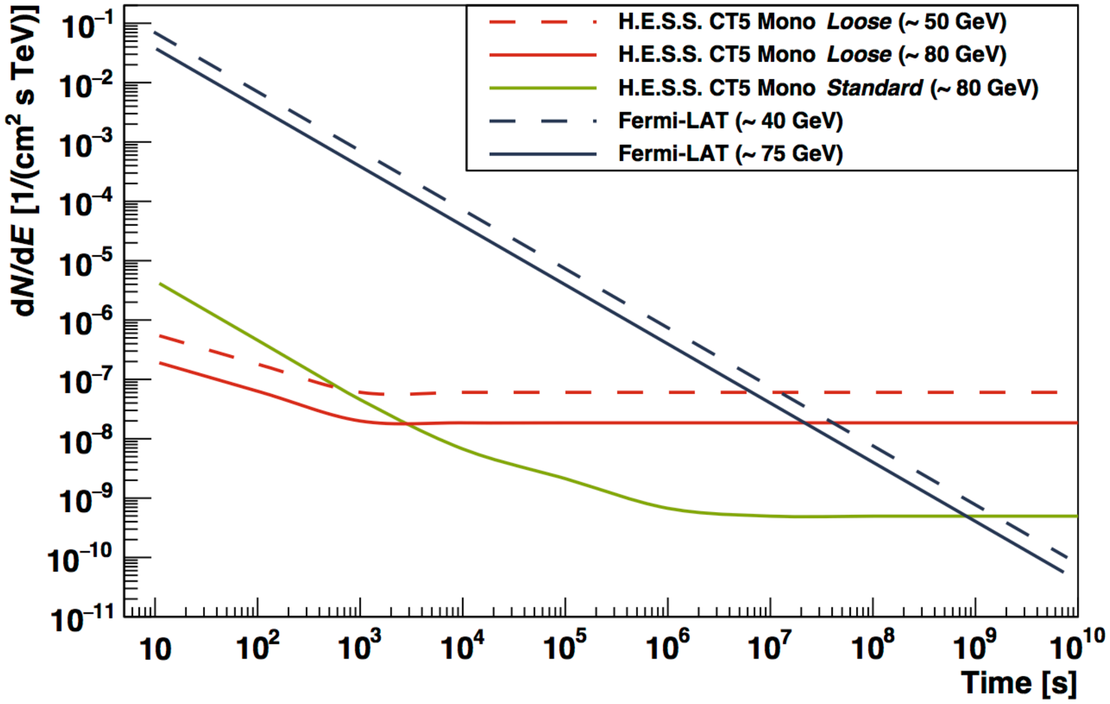


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  - Historically driven by GRB science
  - React as fast as possible
  - Solid decision making needed
  - Clear reaction schemes needed
  - Need to know about results as soon as possible

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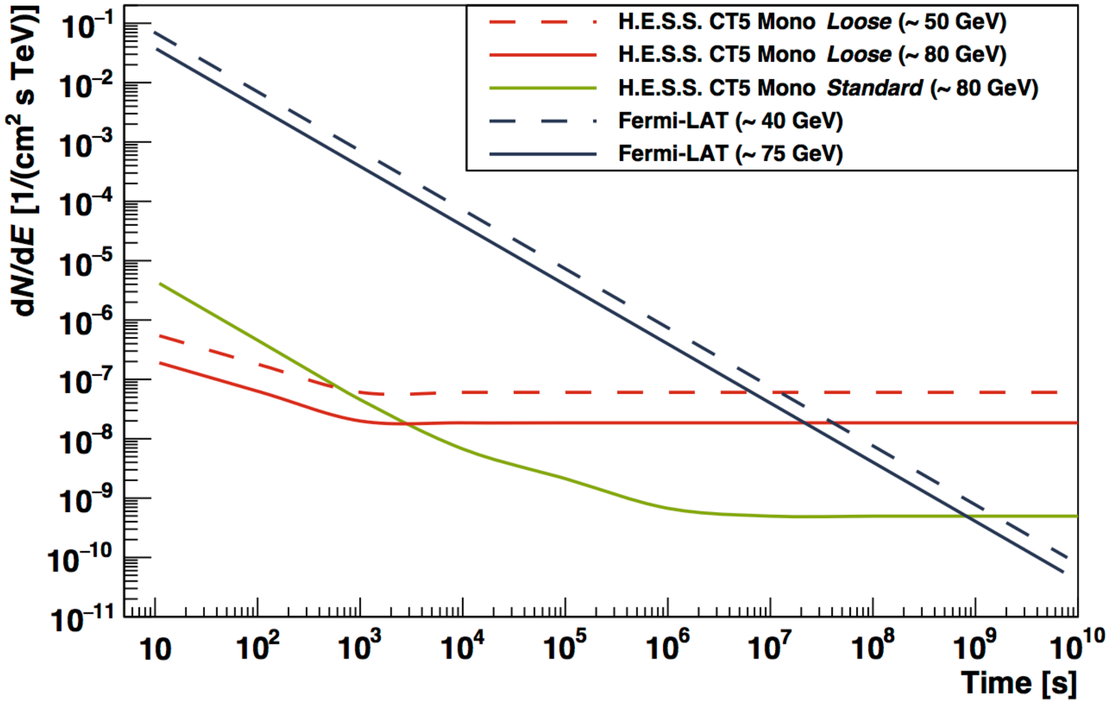


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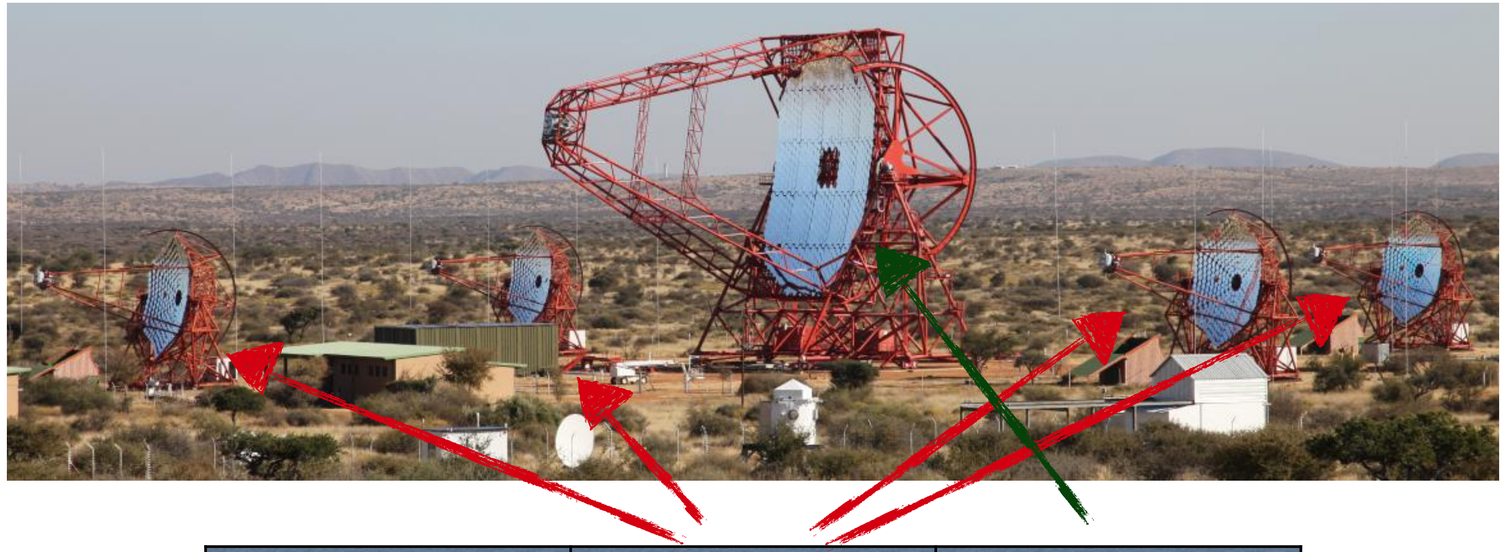
**First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C**

ATel #12390; *Razmik Mirzoyan on behalf of the MAGIC Collaboration*
*on 15 Jan 2019; 01:03 UT*
*Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)*

# High Energy Stereoscopic System
# - an Array of Imaging Air Cherenkov Telescopes



| | CT1-4 | CT5 |
|---|---|---|
| # Telescopes | 4 | 1 |
| Mirror Area | 107 $m^2$ | 614 $m^2$ |
| PMTs | 960 | 2048 |
| Field of View | 5 deg | 3.2 deg |
| **Rotation speed** | **100 deg/min** | **200 (100) deg/min** |
| **Energy threshold** | **~ 150 GeV** | **~ 50 GeV** |
| Year of construction | 2003 | 2012 |

# Main Objectives of the System

- Receive and process high-level astrophysical alerts
  - standardised format (VoEvent)
  - matching to H.E.S.S. science cases
  - decision making (can include complex algorithms and scanning patterns)
- Initiation of the follow-up observations
  - controls array of telescopes as fast as possible
  - reaction details dependant on the science case and it’s time-scale
  - changing the nominal observation schedule
- Provide Feedback
  - analysis results in real-time
  - decide between prolongation or abortion of the observations
  - alert experts, PIs and the community

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Expert:
Clemens Hoischen
(Potsdam University)

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***ToO Alert System***

Expert:
Matthias Füßling
(CTAO)

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***Central Control & Data Acquisition***

Expert:
Stefan Ohm
(DESY)

- Provide Feedback
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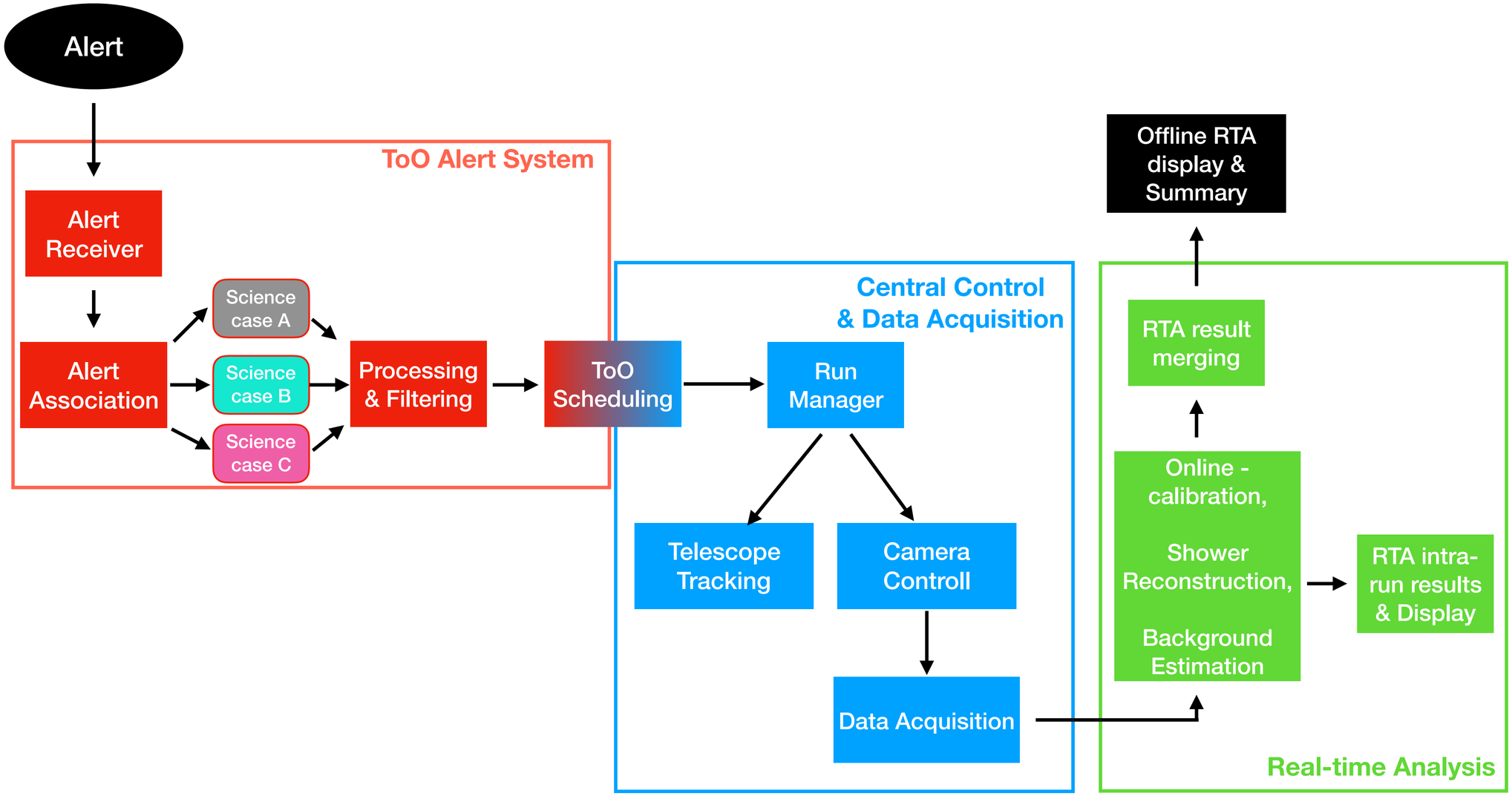
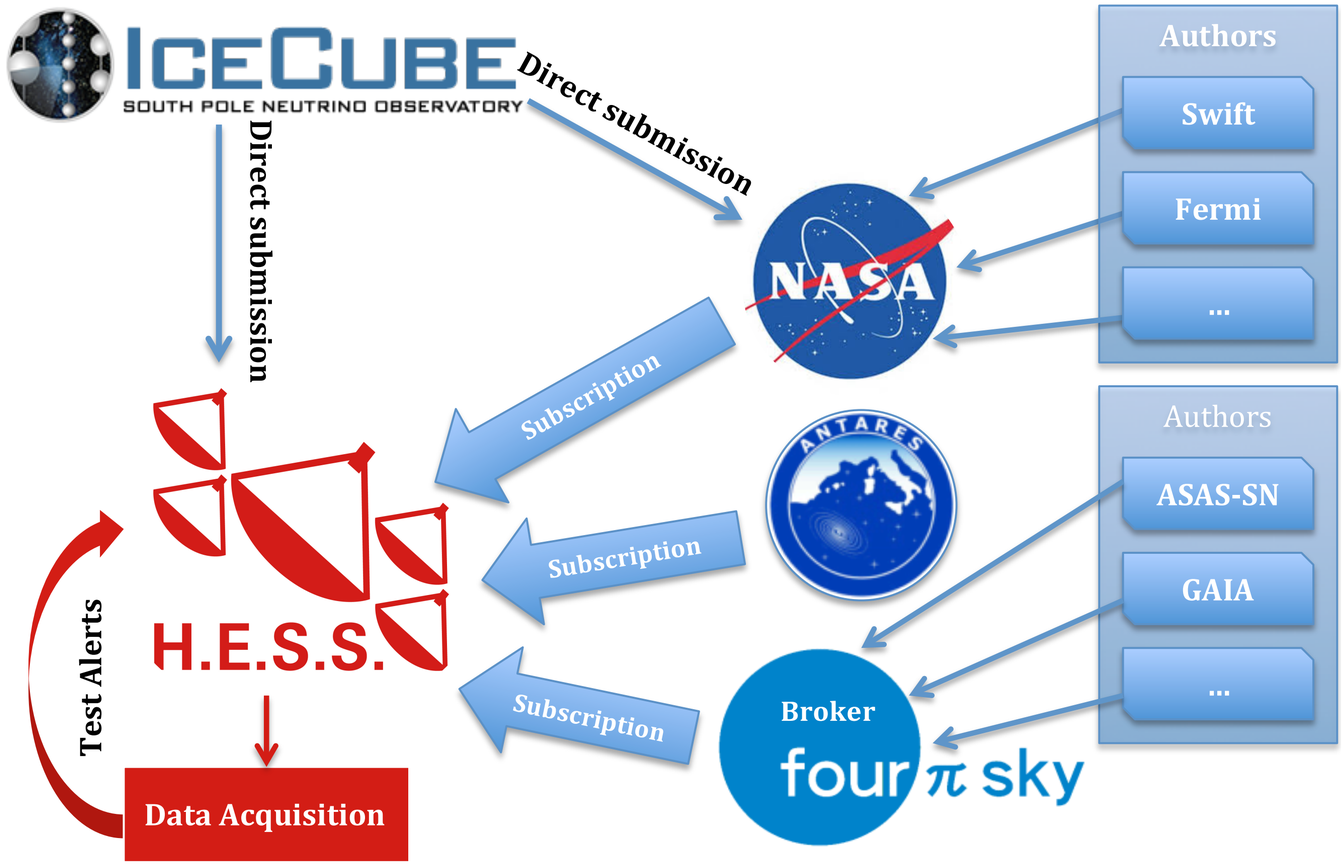
***Real-time Analysis***

# The H.E.S.S. Transients Follow-up System - Overview



# Receiving Alerts

- Based on *comet*[1] broker - implementation of VoEvent Transport Protocol with many helpful features
- Subscribed to GCN, 4piSky, Antares and whitelisted IceCube IPs for direct submission of alerts
- Broker is monitored with *monit*[2] to guarantee uptime of the receiver.




**Alert statistics per month**

- Receives ~ 50k alerts
- Stores ~18k
- 1.5 k non-test alerts
- ~ 50 alerts of interest for H.E.S.S.

[1] see comet.readthedocs.io/
[2] monit is a watchdog which automatically restarts a process if it crashes.

# Matching Alerts to Science Cases

- Initial parsing of alerts
  - identifying the experiment, alert type, …
    done with voevent-parse[1].
  - identification of the alert type is driven by the IVORN (unique alert identifier)

- A single incoming alert will be matched with all science case configurations which are related to this alert.
  - Processed in prioritised order
    (proposal grade & urgency of timely follow-up)
  - Each science case has its own configuration file
  - Easy to register additional science cases with a new configuration

| Alert Type | Matched Science Cases |
|---|---|
| LAT_Updated_Pos | GRB_prompt, GRB_afterglow |
| LAT_Pos_Gnd | GRB_prompt |
| LAT_Offline_Pos | GRB_afterglow |
| BAT_GRB_Pos | GRB_prompt, SGRAXP_prompt, GRB_afterglow, GRB... |
| gwnet_LVC_#S_Preliminary | GravitationalWave |
| gwnet_LVC_#S_Initial | GravitationalWave |
| gwnet_LVC_#S_Update | GravitationalWave, GravitationalWave |
| GBM_Gnd_Pos | GRB_prompt, GRB_afterglow_long, GRB_afterglow |
| GBM_Fin_Pos | GRB_prompt, GRB_afterglow |
| IceCube_HESE# | Neutrino_prompt, Neutrino_afterglow |
| ICECUBE_EHE_AMON | Neutrino_prompt, Neutrino_afterglow |
| IceCube_GFU | Neutrino_GFU_Prompt, Neutrino_GFU_Afterglow, |
| gwnet_LVC_#MS_Preliminary | GravitationalWave_Test, GravitationalWave_Test |
| gwnet_LVC_#MS_Initial | GravitationalWave_Test, GravitationalWave_Test |
| MAXI_Unknown | Flaring_Star_All, Flaring_Star_Prompt, Flarin... |
| MAXI_Known | Flaring_Star_Afterglow, Flaring_Star_Prompt, ... |
| HESS_FireDrill | FireDrill |

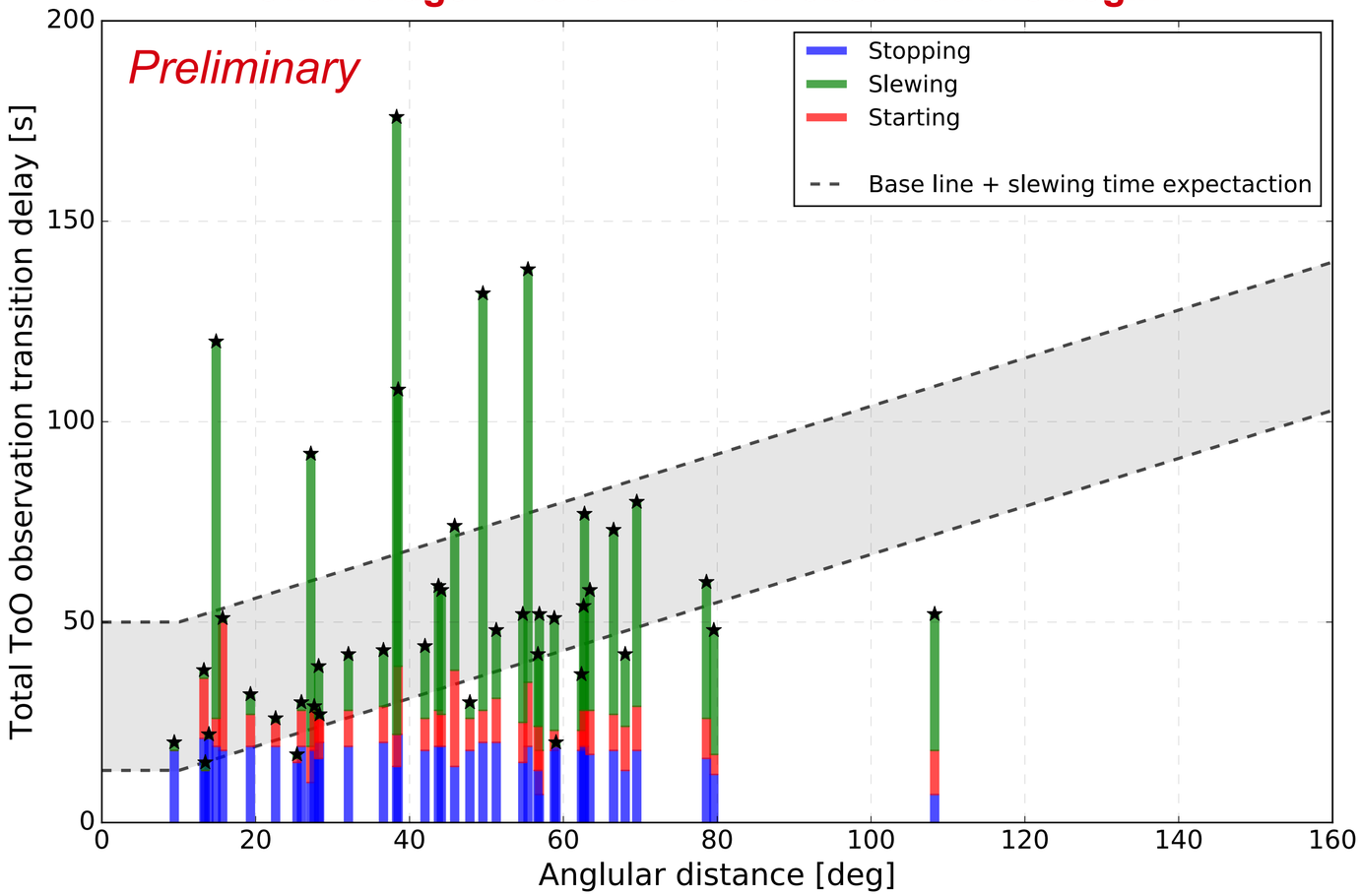
[1] see https://voevent-parse.readthedocs.io/en/stable/#

# Scheduling ToO Observations

- Two main modes:
  - **Prompt:** if the position of the ToO is visible within the next 10 minutes.
    - Fully automatic reaction
    - Always takes precedence over nominal schedule
    - transition between observations with a **special ToO mode**
    - Shifters are alerted by sound, pop-ups and email (including instructions)
    - Experts and PIs are alerted by email.

**Also handle corner cases:**
- Coordinate updates
- new alerts with higher priority
- alert position is within the current FoV

**On average: < 60 s until new observations begin**



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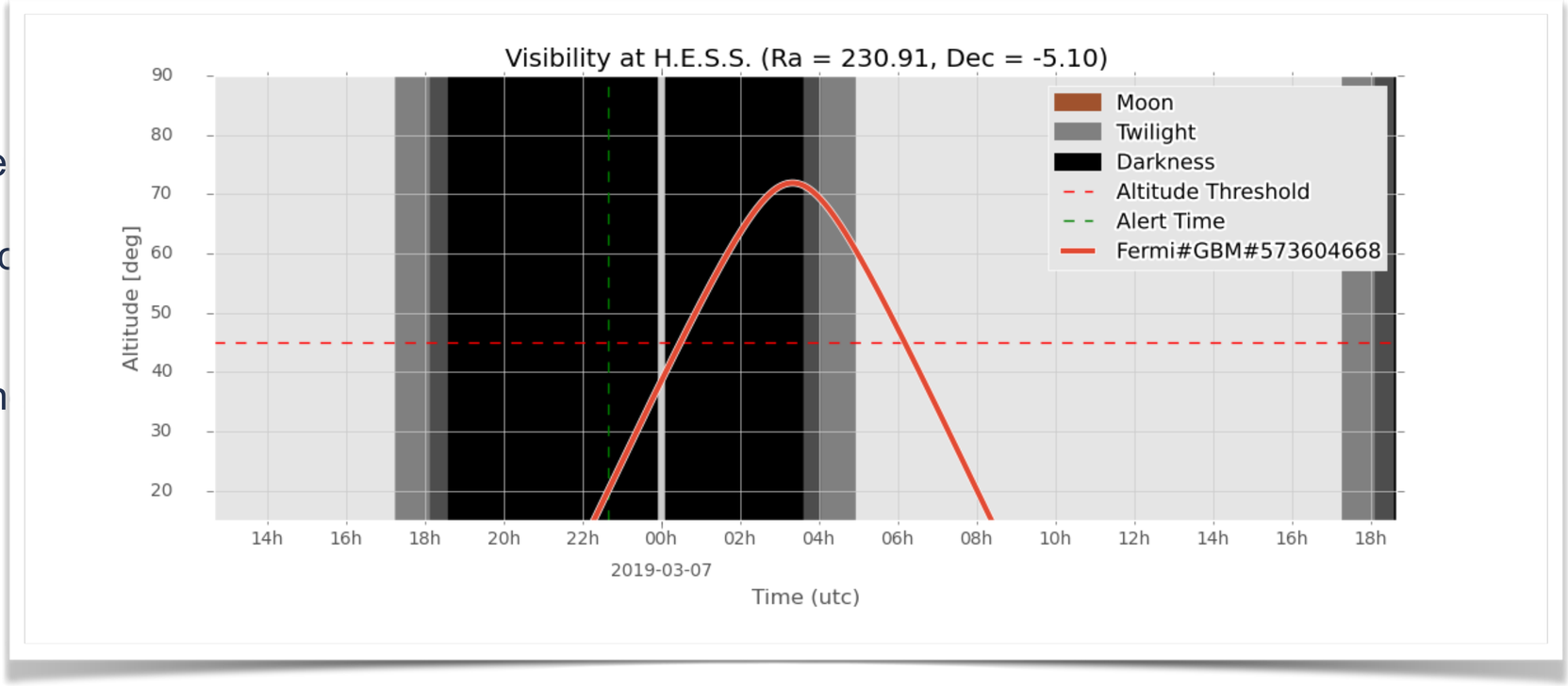
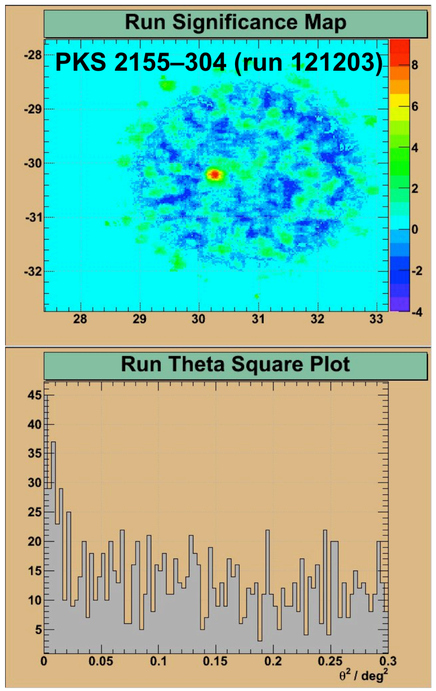
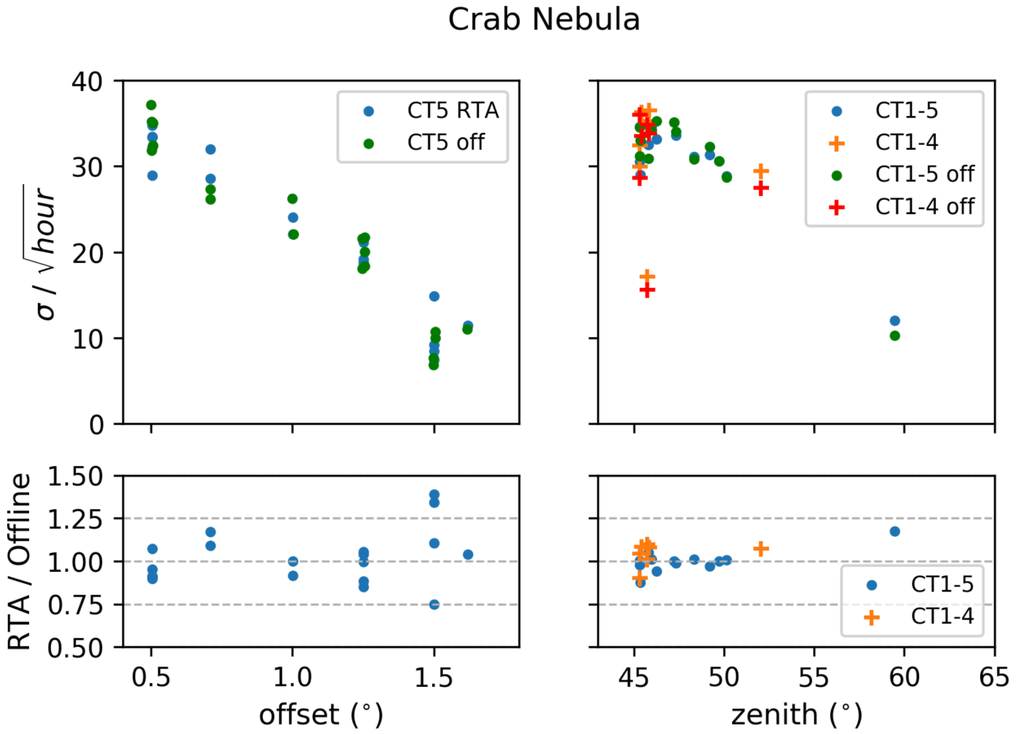



  - **Afterglow:** observation starts later than 10 minutes after the event
    - Shifters are alerted by pop-ups, sound and emails (including instructions)
    - Experts and PIs are alerted by email.
    - Observations are initiated with the help of scripts (given in the instructions) by the shifters.
    - Allows to Consult PIs and Experts on-call by phone.
    - Also applies to alerts during the day.

# Real Time Analysis

- Simplified live-calibration scheme
- Image reconstruction in different operation modes (mono and stereo)
- Background subtraction
- Shows live:
  - Theta$^2$ histograms
  - Sky maps
- Merging of consecutive observations
- Entered in a database
  - allows to review results from the last night(s)
- Used to decide if observations should be prolonged
  - during the same night (e.g. AGN monitoring)
  - for the next night(s)
- Used to inform the community quickly (currently via ATels)



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**H.E.S.S. detection of a strong VHE activity from the blazar 3C 279**

ATel #11239; ***Mathieu de Naurois for the H. E.S. S. collaboration***
*on **28 Jan 2018; 15:00 UT***
*Credential Certification: Jean-Philippe Lenain (jlenain@in2p3.fr)*

Subjects: Gamma Ray, VHE, Request for Observations, AGN, Blazar, Quasar

Referred to by ATel #: 11246, 11464, 11680

**H.E.S.S. and ATOM detection of renewed activity of the FSRQ 3C 279**

ATel #11680; ***Mathieu de Naurois for the H. E.S. S. Collaboration***
*on **4 Jun 2018; 14:05 UT***
*Credential Certification: Michael Zacharias (m.zacharias@lsw.uni-heidelberg.de)*

Subjects: Optical, Gamma Ray, >GeV, VHE, Request for Observations, AGN, Black Hole, Blazar, Quasar

Referred to by ATel #: 11687

**H.E.S.S. follow-up of IceCube-170922A**

ATel #10787; ***Mathieu de Naurois for the H. E.S. S. collaboration***
*on **27 Sep 2017; 14:33 UT***
*Credential Certification: Fabian SchÃÂ¼ssler (fabian.schussler@cea.fr)*

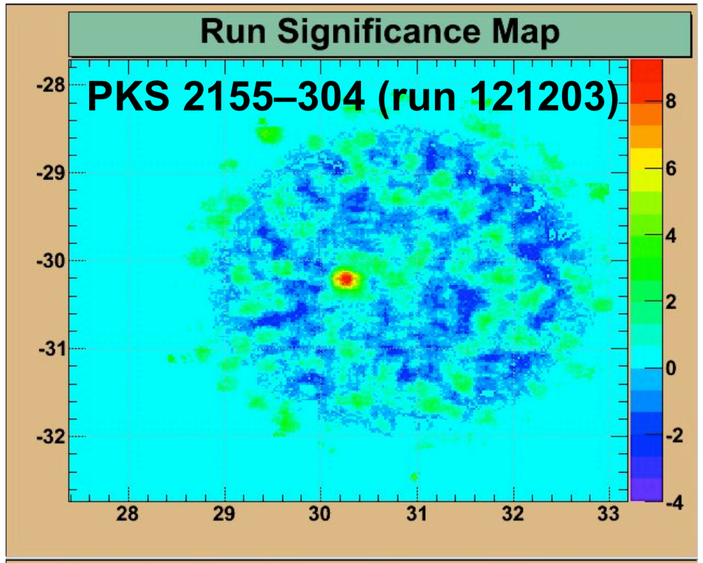
Subjects: VHE, Neutrinos

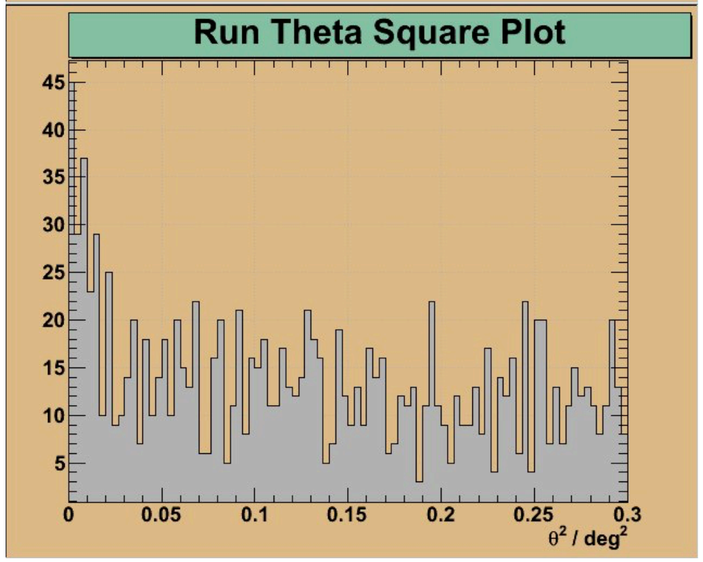
Referred to by ATel #: 10799, 10817, 10830, 10833, 10844, 11419

# Link between Transients Alert System and Real Time Analysis

- **Currently**:
  - manually via the shifters monitoring the significance plots
  - Thresholds defined by PIs based on Flux estimates

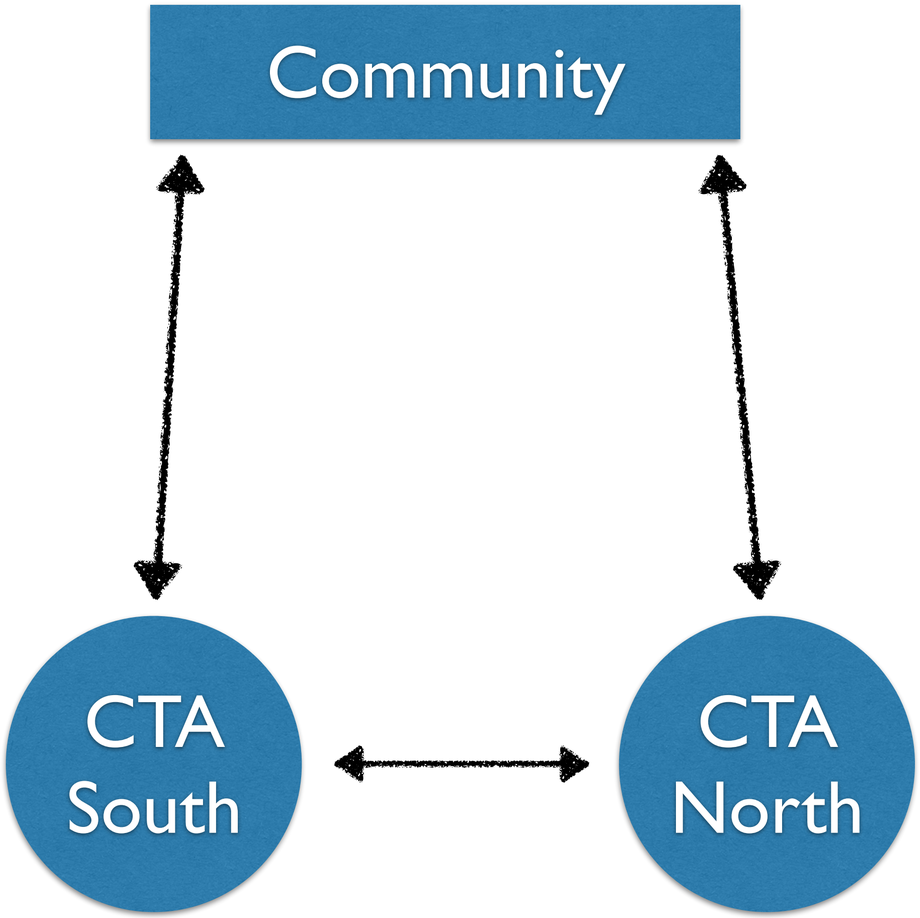
- **Anticipated**
  - Generate VOEvent for each observation run
  - Inject it into the Transients Alert System
  - Decide on follow-up observations depending on criteria for known and unknown sources



# Differences in light of CTA (my view)

- Observation-wise
  - Up to 8 sub-arrays (at the same time)
  - Two sites which (in some cases) need coordination



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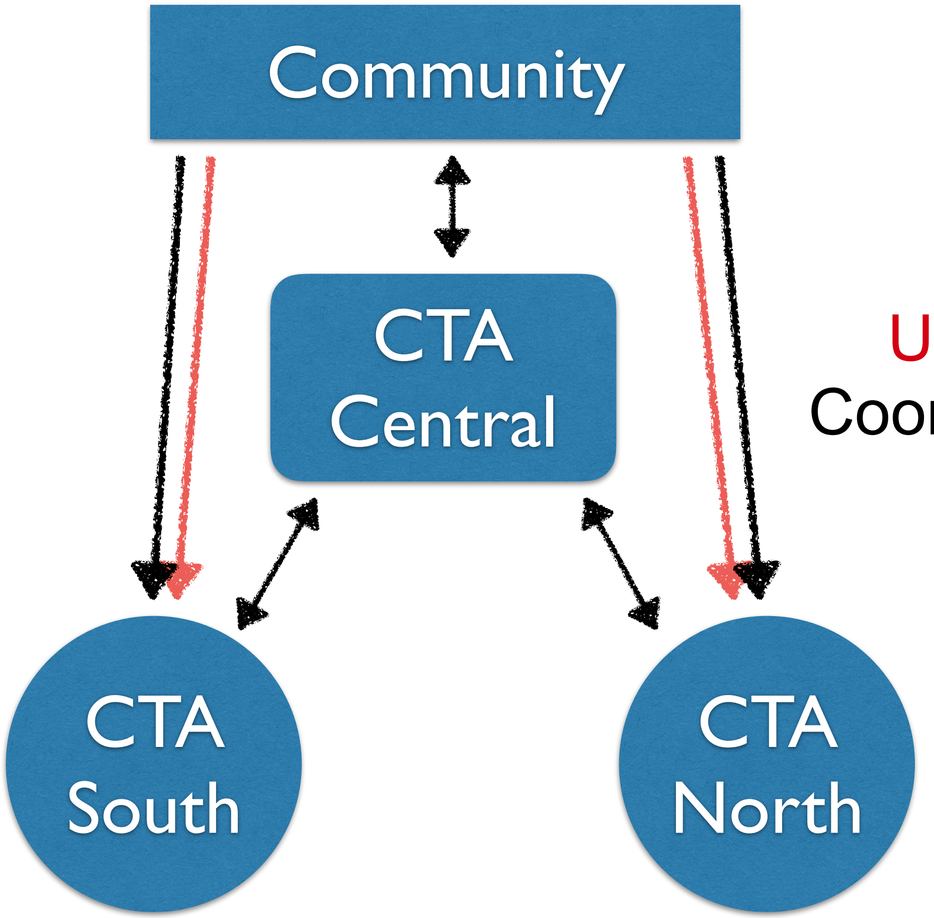


Urgent
Coordinated

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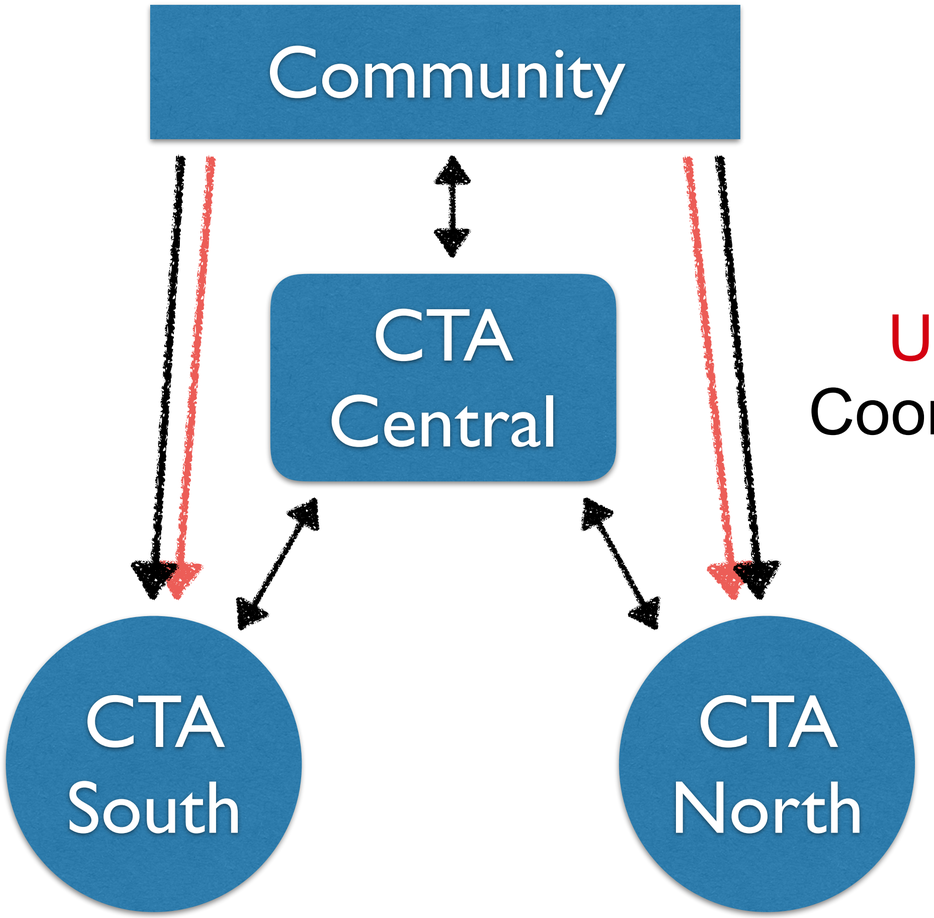
  - Up to 8 sub-arrays (at the same time)
  - Two sites which (in some cases) need coordination
- Observatory-wise
  - Open Proposals
  - Data Access/Policy
  - Schedule Policies (open or not)
  - Configurability for a TAC
- Realtime Analysis
  - Currently going for discrete alerts
  - Also affected by Data Policies
- Correlation of data streams
  - Difficult to imagine inside of CTA
  - Clearly interesting as external service
  - Currently not anticipated by the RTA team (afaik)
  - Depends on Data policies

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