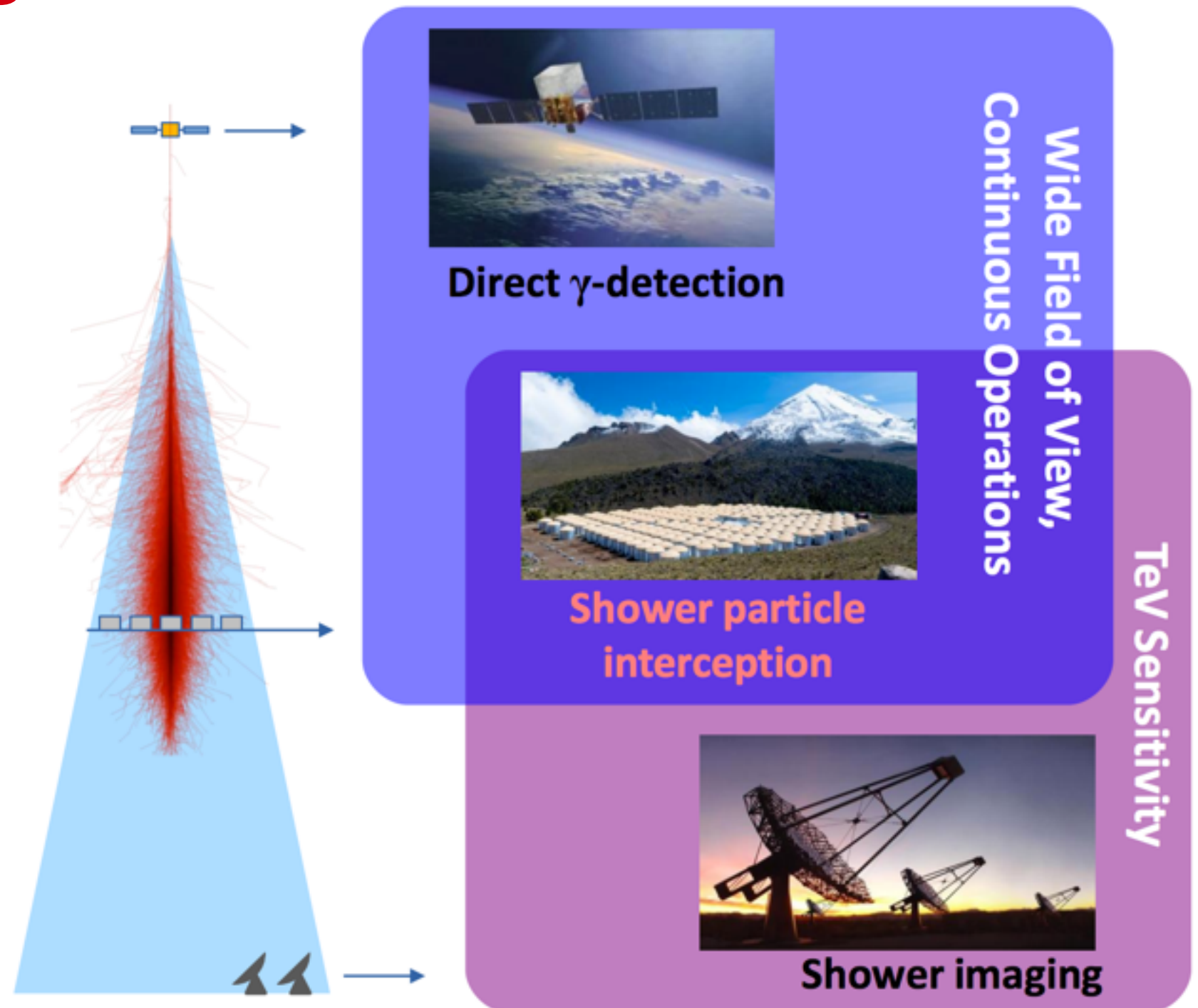


Alerts to and from HE/VHE gamma-ray observatories



Transient events: monitoring instruments



Fermi-LAT



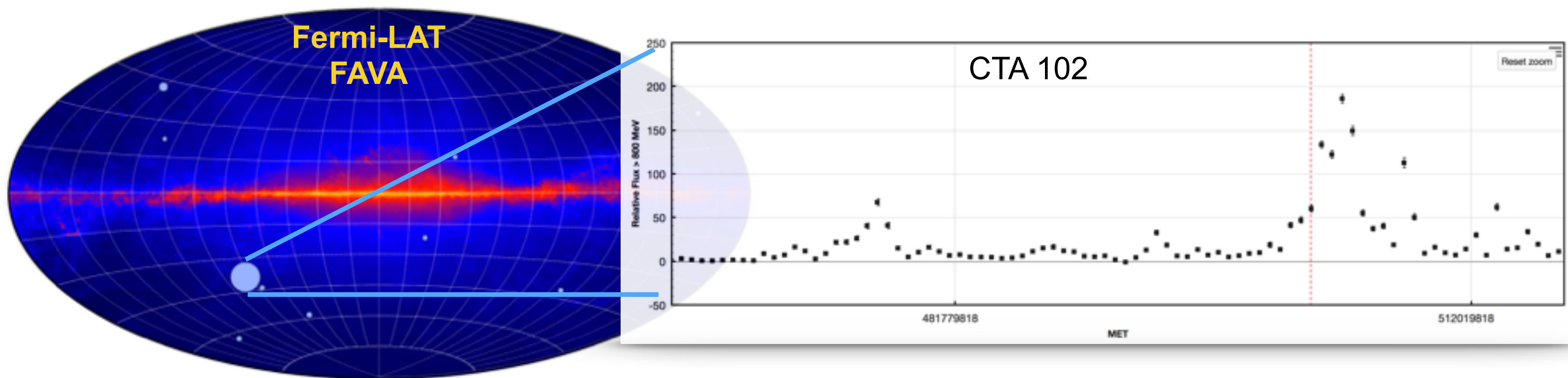
FACT

- long-term light curves
- trigger MWL follow-ups
- archival data for follow-up analyses

HAWC + LHAASO + SGSO

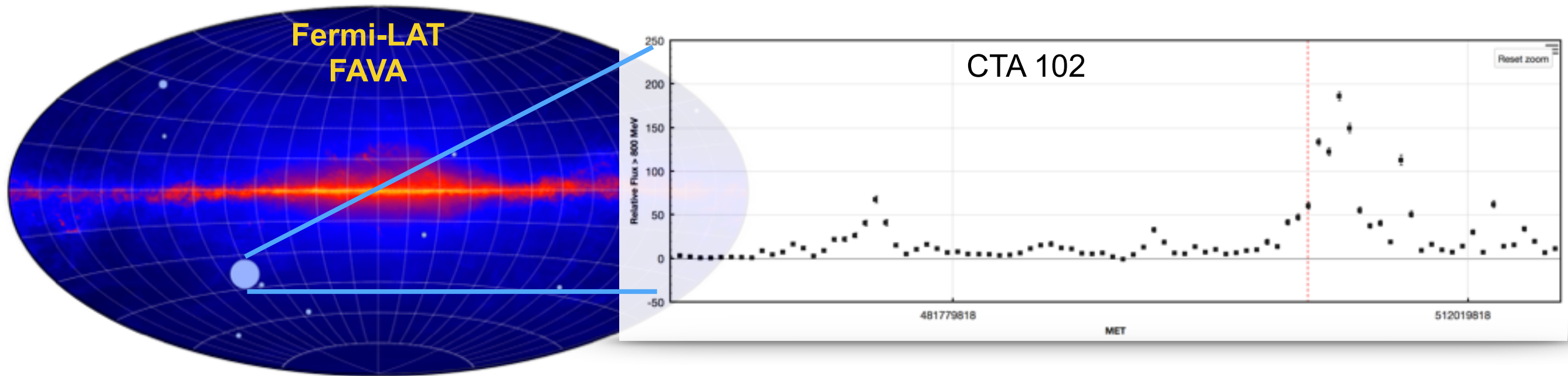


Monitoring observatories: current status



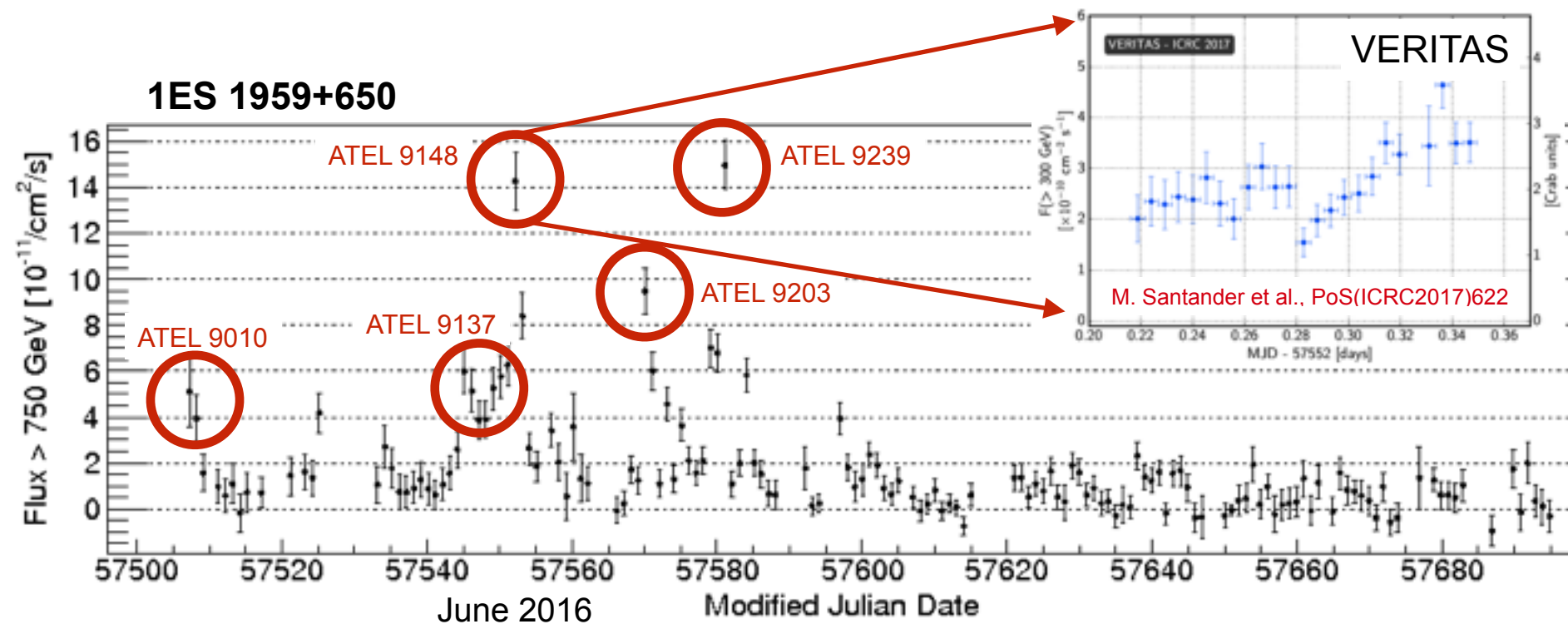
- best current example: **Fermi-LAT**
 - all-sky monitoring at GeV energies, important input to many ToO programs

Monitoring observatories: current status



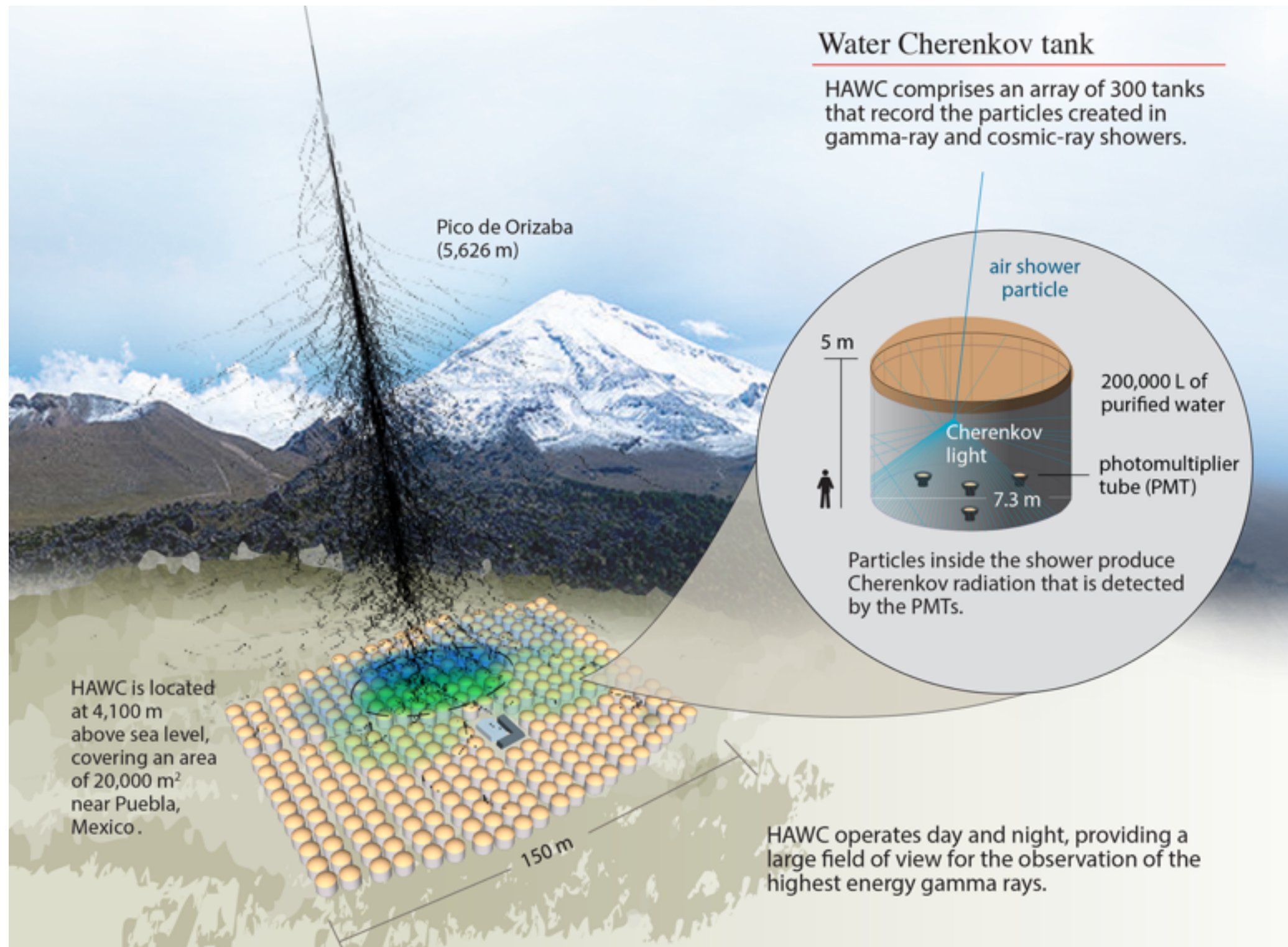
- best current example: **Fermi-LAT**
 - all-sky monitoring at GeV energies, important input to many ToO programs

- dedicated IACTs: **FACT**
 - monitoring of AGNs
 - gaps (only) due to weather and moon-light



D. Dorner et al., PoS(ICRC2017)608

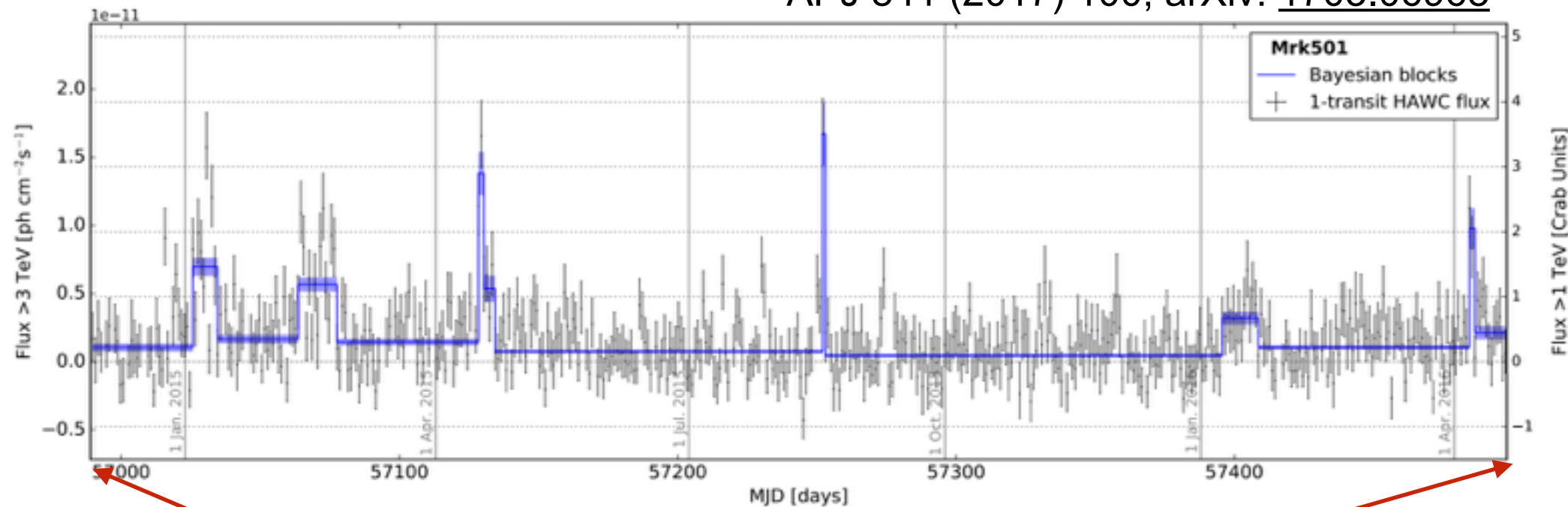
High Altitude Water Cherenkov Observatory (HAWC)



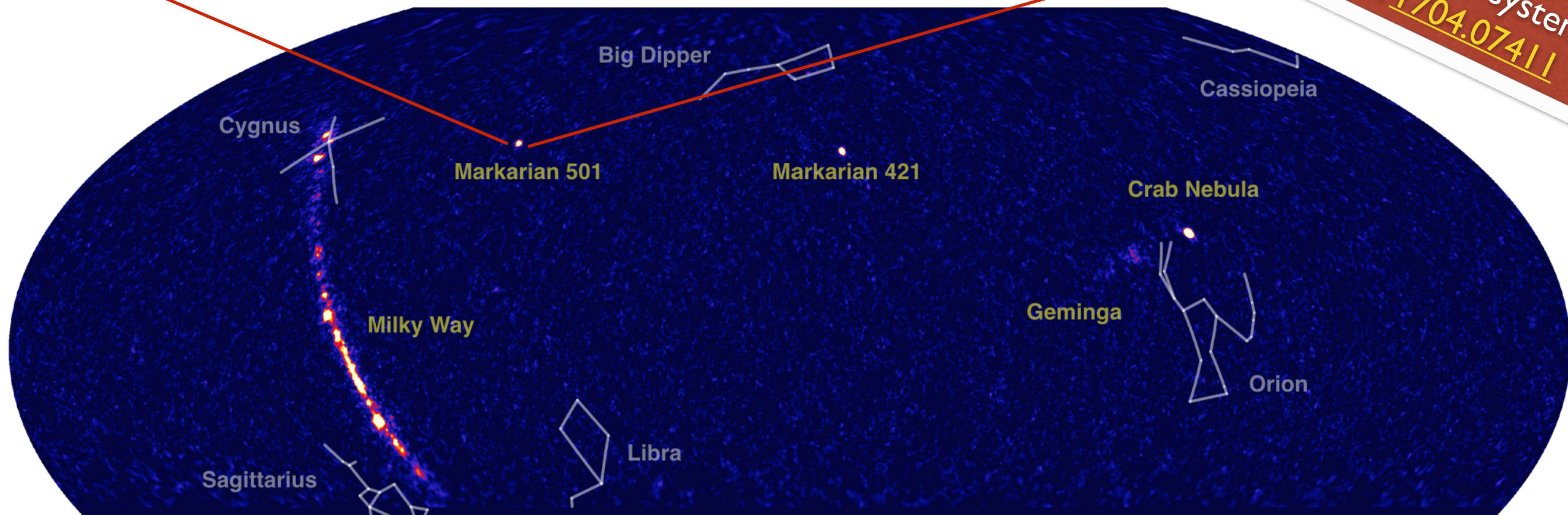
HAWC: monitoring the (Northern) TeV sky



APJ 841 (2017) 100, arXiv: [1703.06968](#)

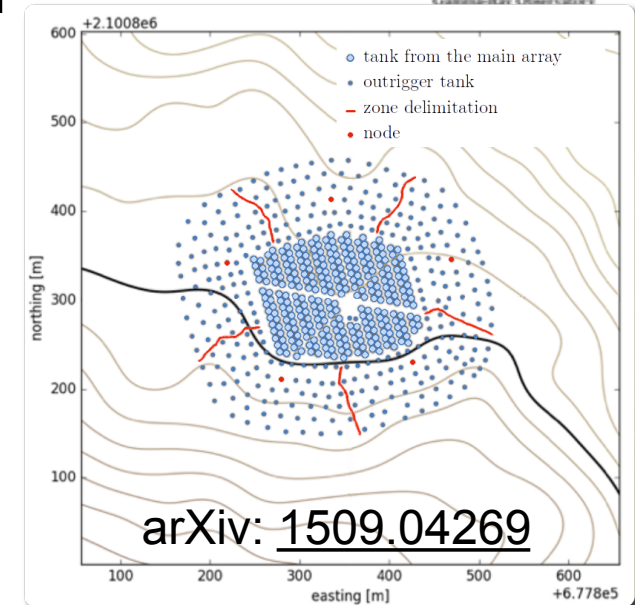


Online alert system
arXiv: [1704.07411](#)

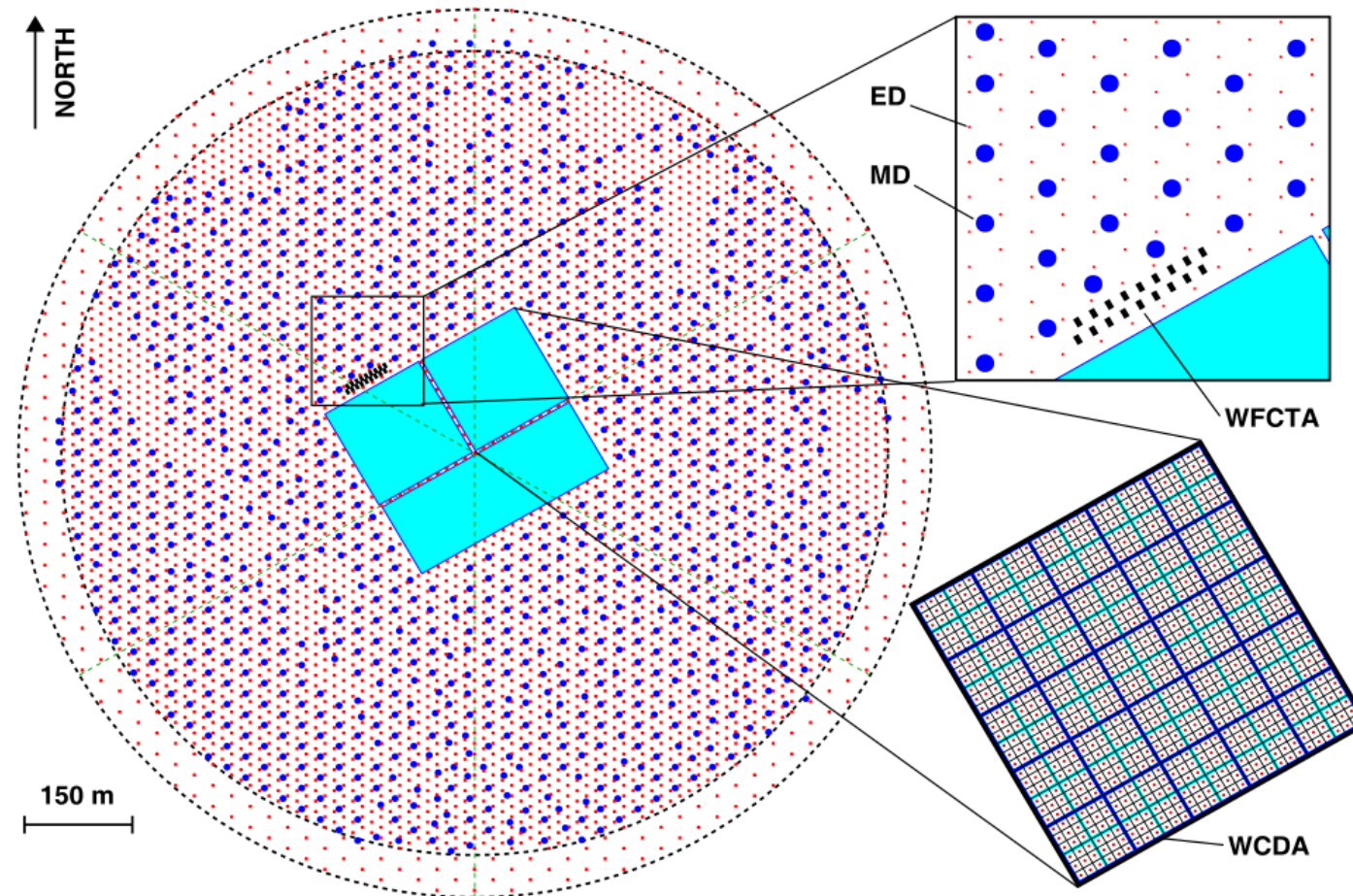


HAWC: upgrade and future

- installation of 300 outrigger stations around the main detector
- improved angular resolution + gamma/hadron separation
 - factor 3-4 increased sensitivity above 10TeV
 - important improvements also at lower energies
- use of CTA electronics (FlashCam@MPIK/Germany)
- DOE: end of operations 12/2019 => extension to 12/2020 (?)

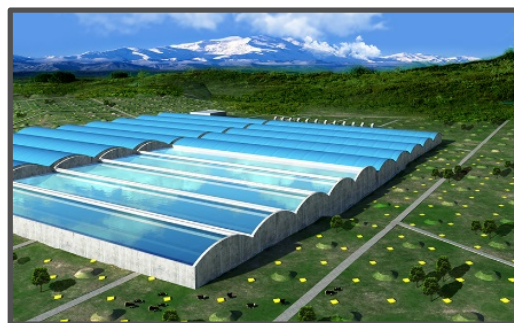


LHAASO



Y. Liu, et al. The Astrophysical Journal (2016)

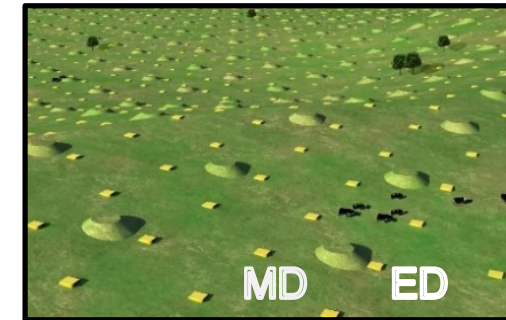
WCDA



Water Cherenkov Detector Array

3000 detector units
 $5 \times 5 \text{ m}^2$ for each unit
 Total effective area of 78000 m^2

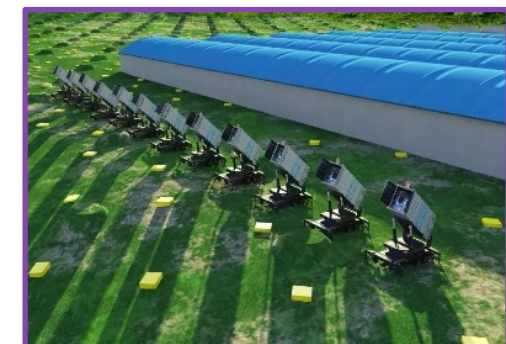
KM2A



1 km² array

5195 electromagnetic particle detectors (ED)
 1171 muon detectors (MD)

WFCTA



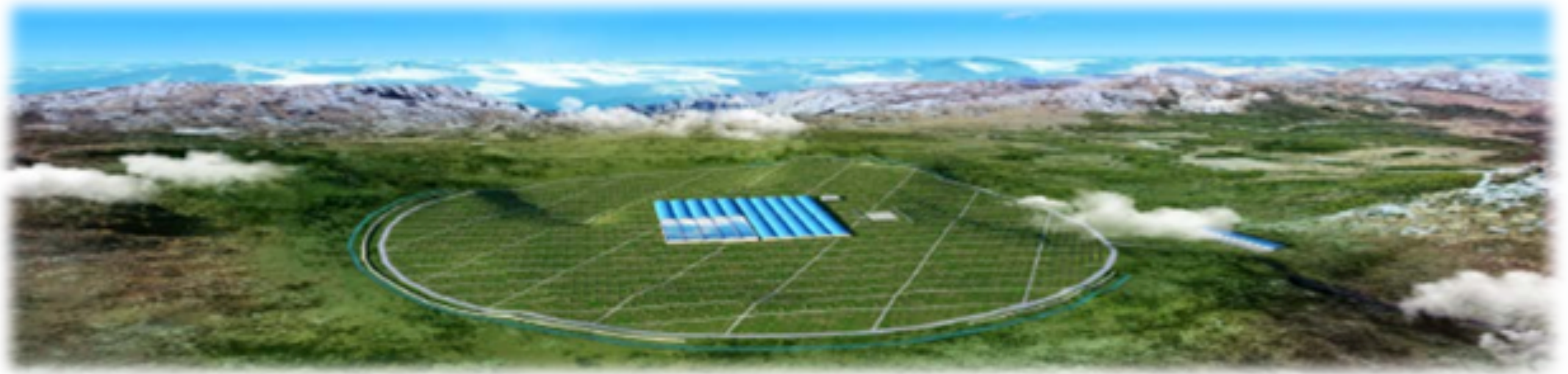
Wide field-of-view (FoV)

Cherenkov Telescope

Array 12 telescopes
 $16 \times 14^\circ$ FoV
 1024 pixels in each camera

LHAASO

LHAASO site, Sichuan province China, 4410m a.s.l.



The LHAASO project is currently under construction.
Infrastructures will be finished in 2017.
One fourth of the Observatory to be finished end of **2018**.
The whole observatory to be completed by the end of **2021**.



Zizhao Zong (LHAASO)

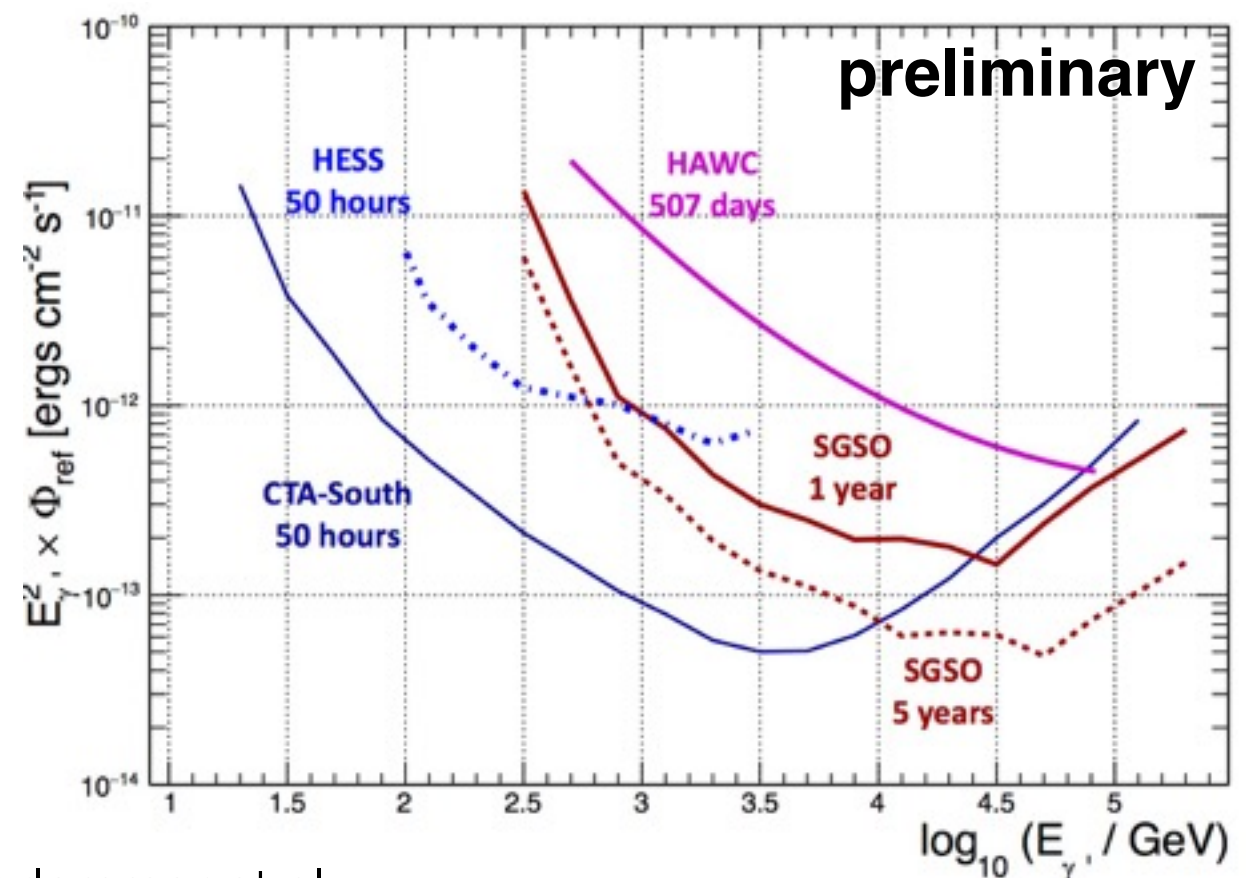
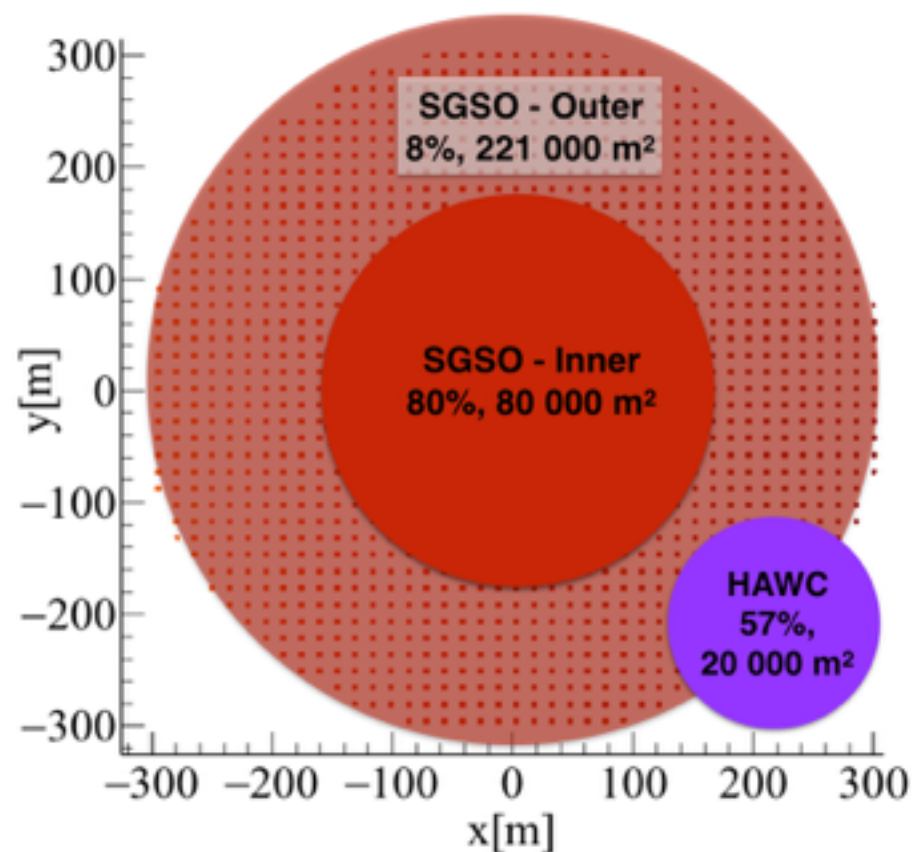
Southern Gamma Survey Observatory (SGSO)

- community getting organized: SGSO Alliance
 - several workshops (Puebla 2016, Rochester+Buenos Aires 2017, Heidelberg 2018)
 - sgso-alliance.org
- White paper on Science Case in preparation (input for US Decadal Survey)
 - “Studying Galactic Particle Accelerators”
 - “*Monitoring the Transient Sky*”
 - “Probing Physics Beyond the Standard Model”
- various designs and sites under discussion (e.g. ALTO prototype in Värxjö)



Southern Gamma Survey Observatory (SGSO)

- current straw man design:
 - altitude 5000m
 - 4m x 4m units (threshold of 50MeV)
 - dense array of 4000 units covering 80.000m² with a fill-factor of 80%
 - sparse array with 1000 units covering 221.000m² with a fill-factor of 8%
- baseline design: water Cherenkov
 - potentially scintillator and/or resistive plate chambers to increase γ -hadron separation



H. Schoorlemmer et al.

High-energy monitoring in 2020

- global network of FACT like telescopes (?)
 - limited list of monitored sources
- HAWC
 - taking data since 2015
 - upgrade/extension in commissioning
- LHAASO
 - construction started
 - increased sensitivity over HAWC
- Southern Gamma Survey Observatory (?)
 - preparing Science Case White Paper



Imaging Air Cherenkov Telescopes

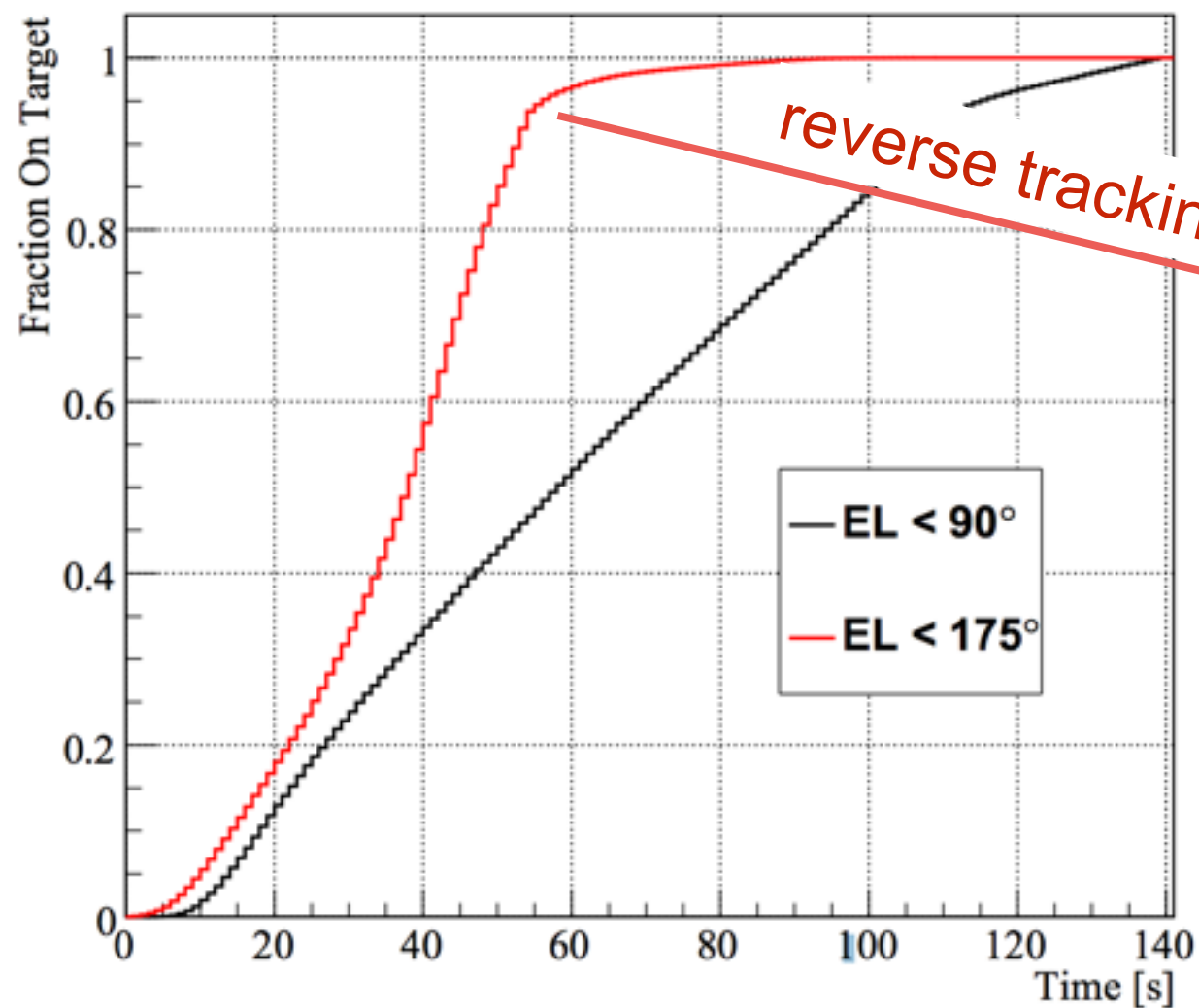
- currently mainly follow-up of ToOs and incoming alerts
 - manual ToOs: AGN flares, Galactic binaries/novae/etc., FRBs, etc.
 - H.E.S.S.: automatic reaction to GRBs, GWs, neutrinos
 - manual exchange of information with partners + ATELs
- CTA: extensive automatisatisation + emission of alerts



extension of current instruments
under discussion+preparation

H.E.S.S. II: ToO follow-up performance

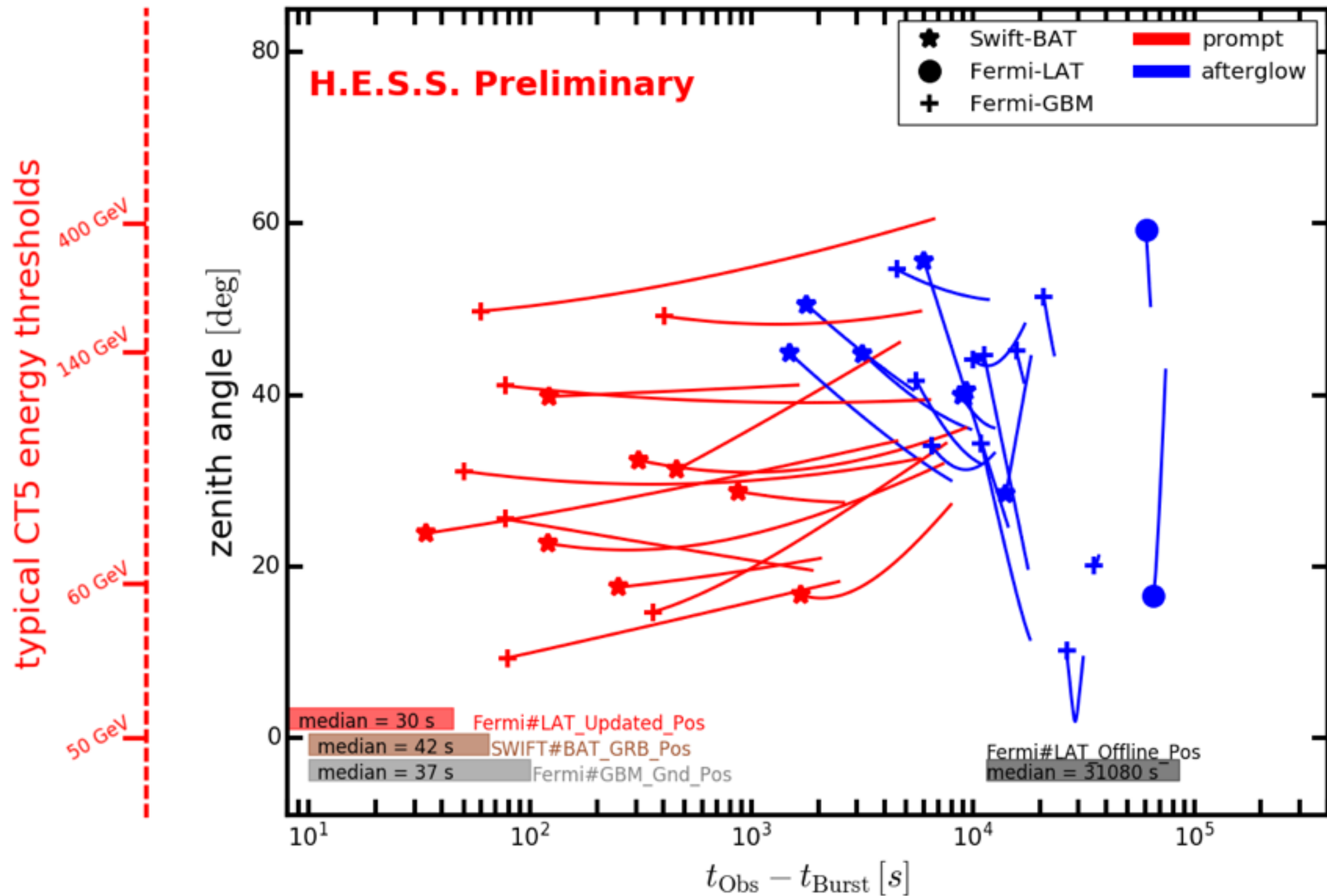
- main design principles of the H.E.S.S. 28m telescope
 - large photon collection area → 614 m² mirror area (largest IACT worldwide)
 - rapid response time



Hofverberg et al., ICRC 2013



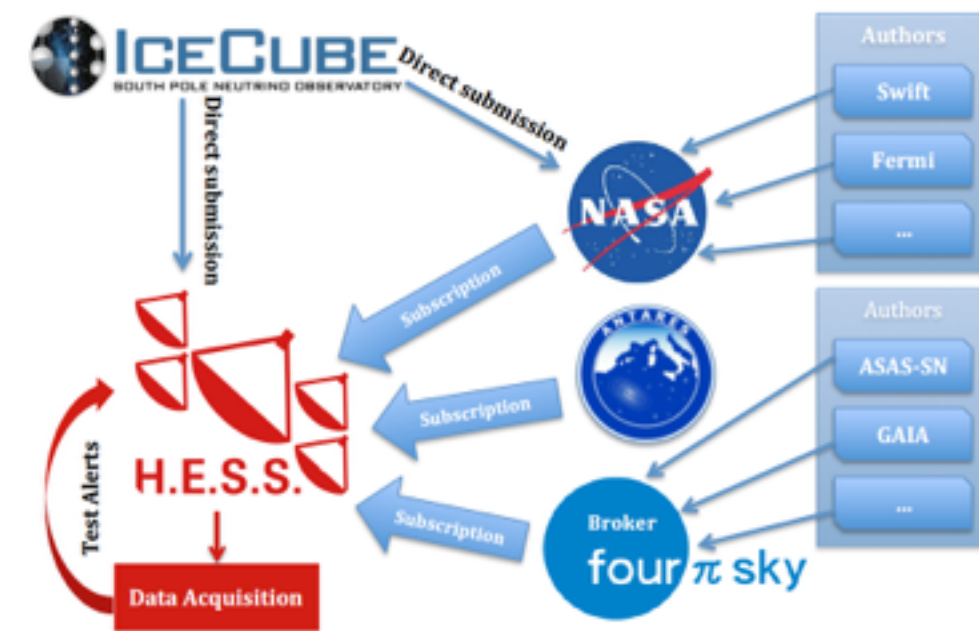
Gamma Ray Burst follow-up with H.E.S.S.



C. Hoischen et al., PoS(ICRC2017)636

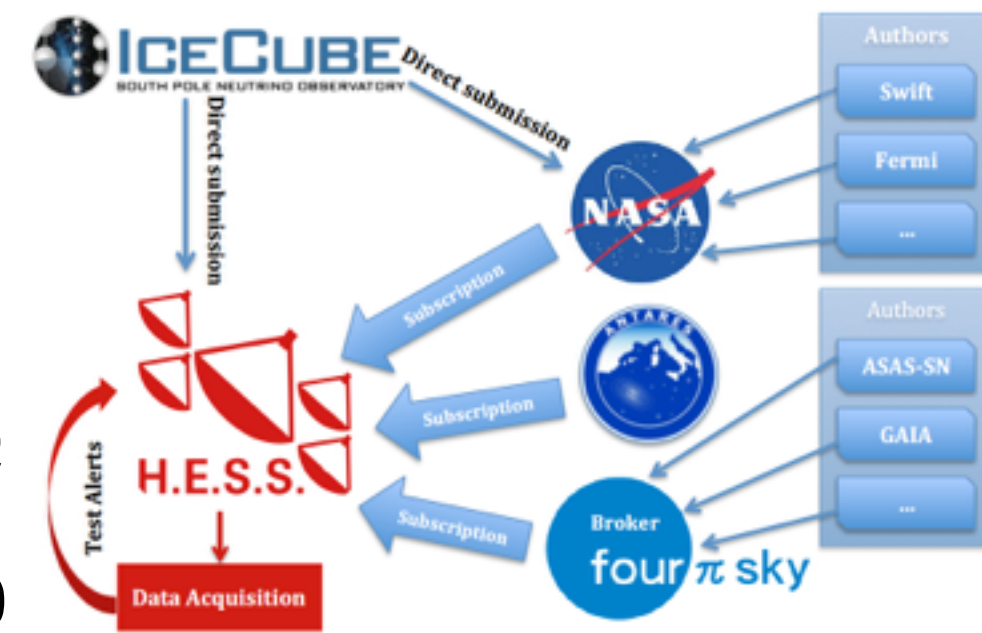
MWL and MM alerts with H.E.S.S.

- fully automatic and flexible alert handling system
 - VoEvents + Python
 - analysis + filtering, scheduling + connection to the DAQ

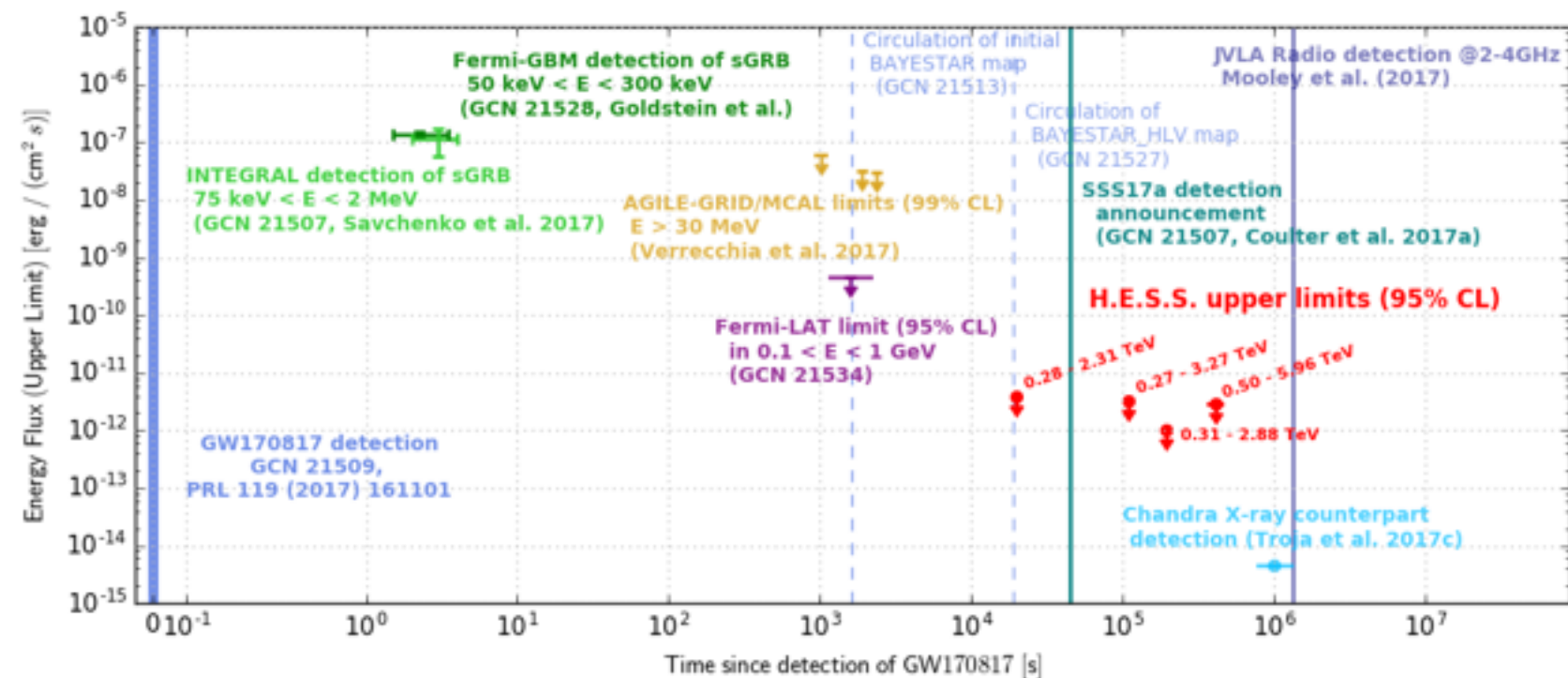
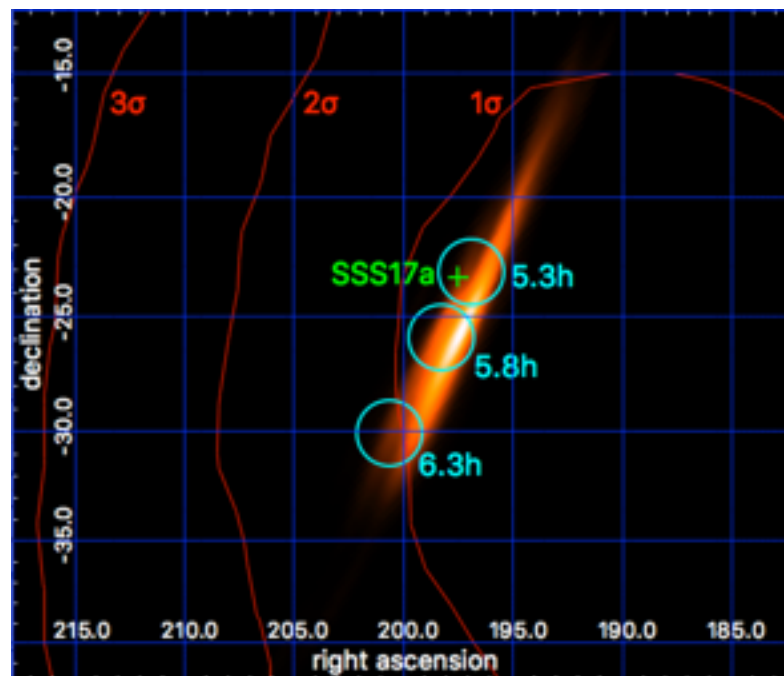


MWL and MM alerts with H.E.S.S.

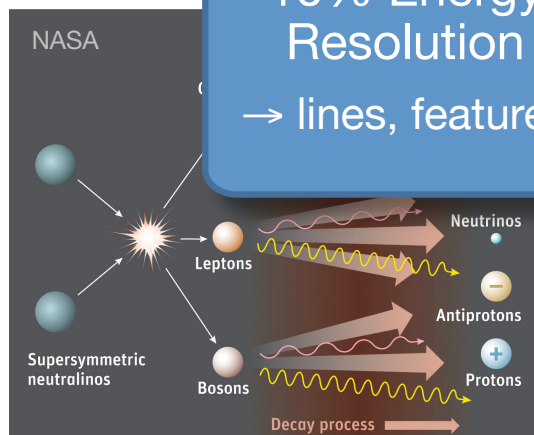
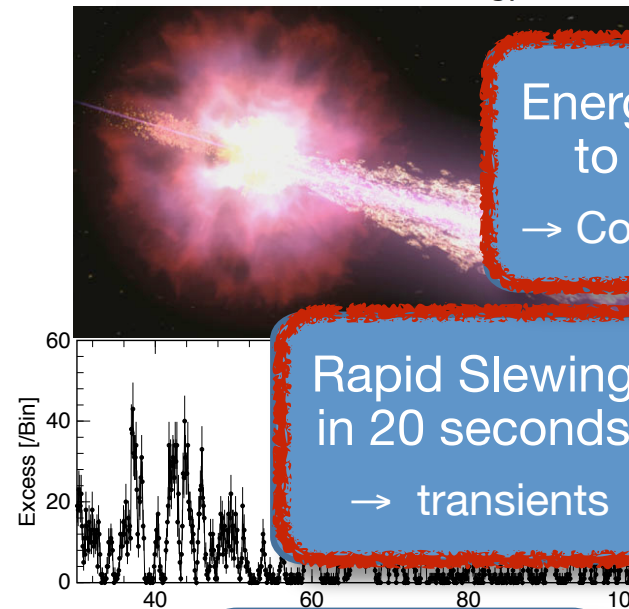
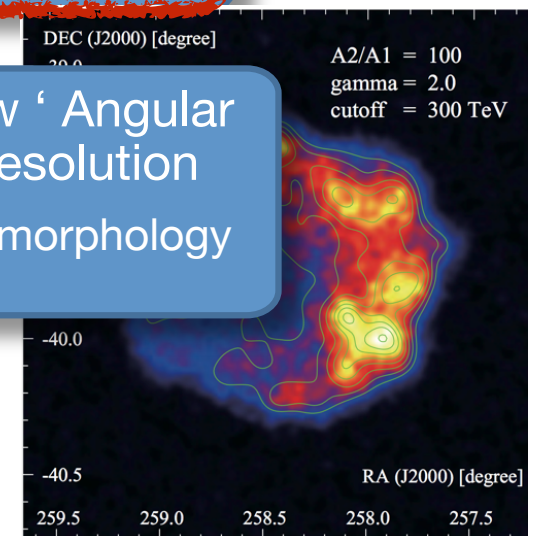
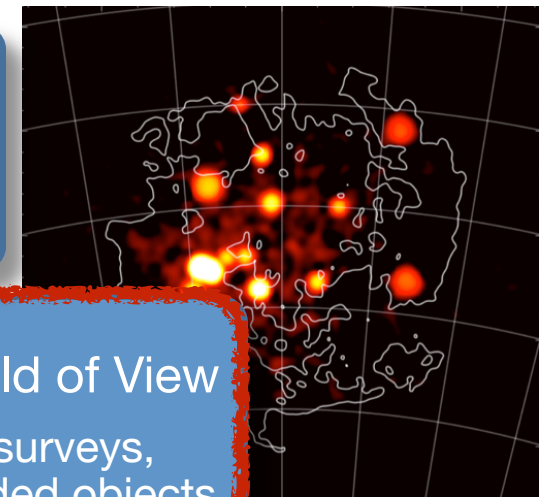
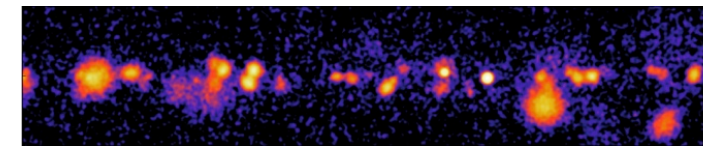
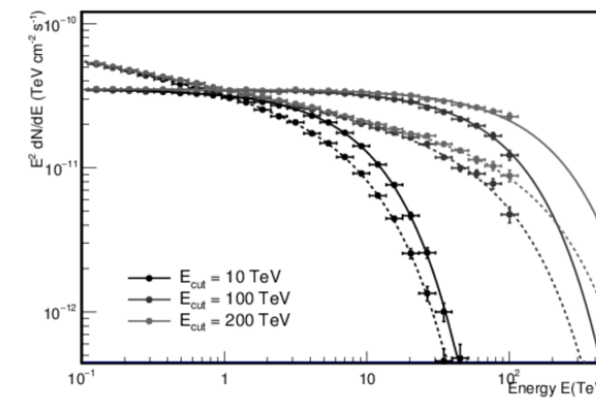
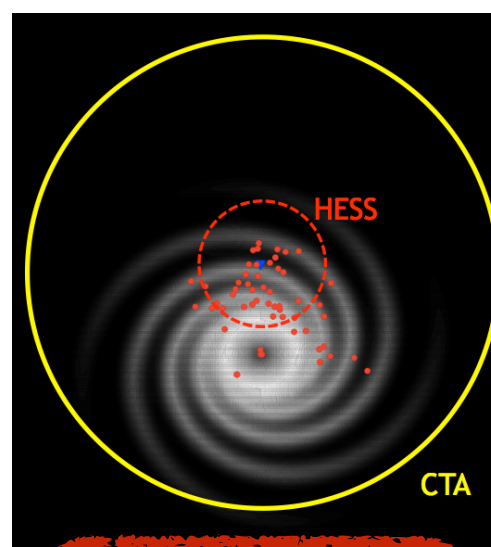
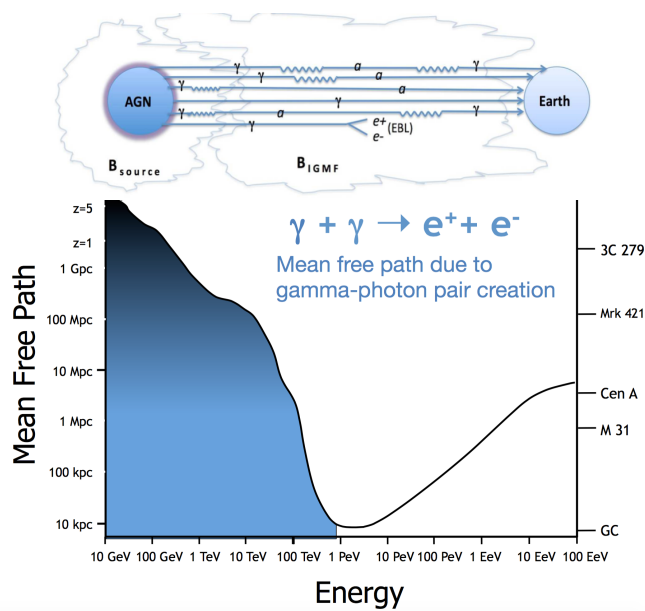
- fully automatic and flexible alert handling system
 - VoEvents + Python
 - analysis + filtering, scheduling + connection to the DAQ
- high-energy neutrino seen by Antares 2017-01-30
 - automatic alert emission by ANTARES/TAToO + automatic reaction of H.E.S.S.
 - time delay between neutrino interaction and start of gamma-ray observations: **32 seconds**
- GW170817
 - observations starting ~5min after publication of first LIGO + VIRGO map



FS et al., PoS(ICRC2017)653



H. Abdalla et al. (H.E.S.S. Collaboration), ApJL 855:L22 (2017)



Energies down to 20 GeV
→ Cosmology++

10 x Sensitivity,
Large Collection Area
→ all topics

Energies up to 300 TeV
→ Pevatrons

Rapid Slewing
in 20 seconds
→ transients

10% Energy Resolution
→ lines, features

8° Field of View
→ surveys,
extended objects

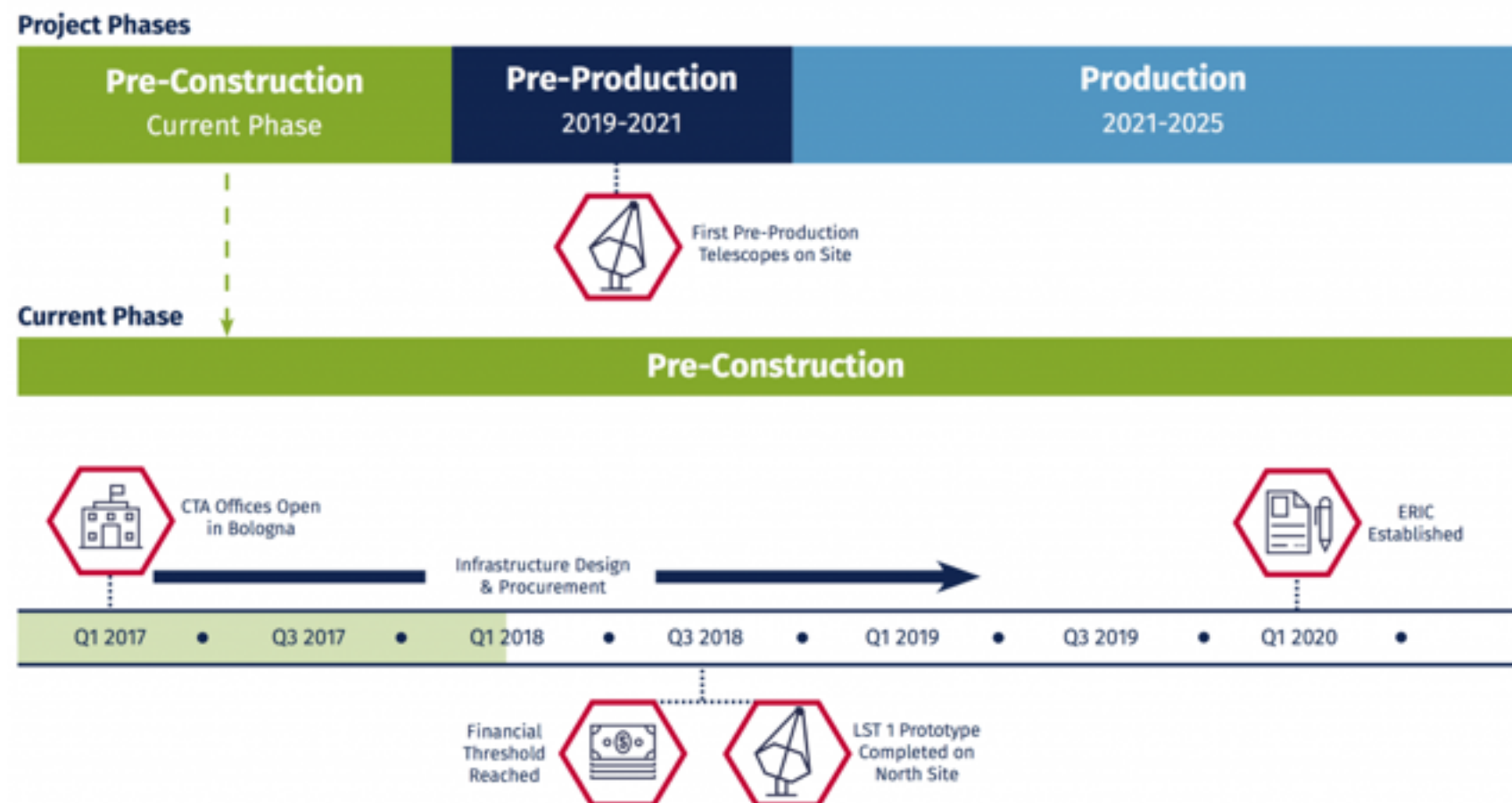
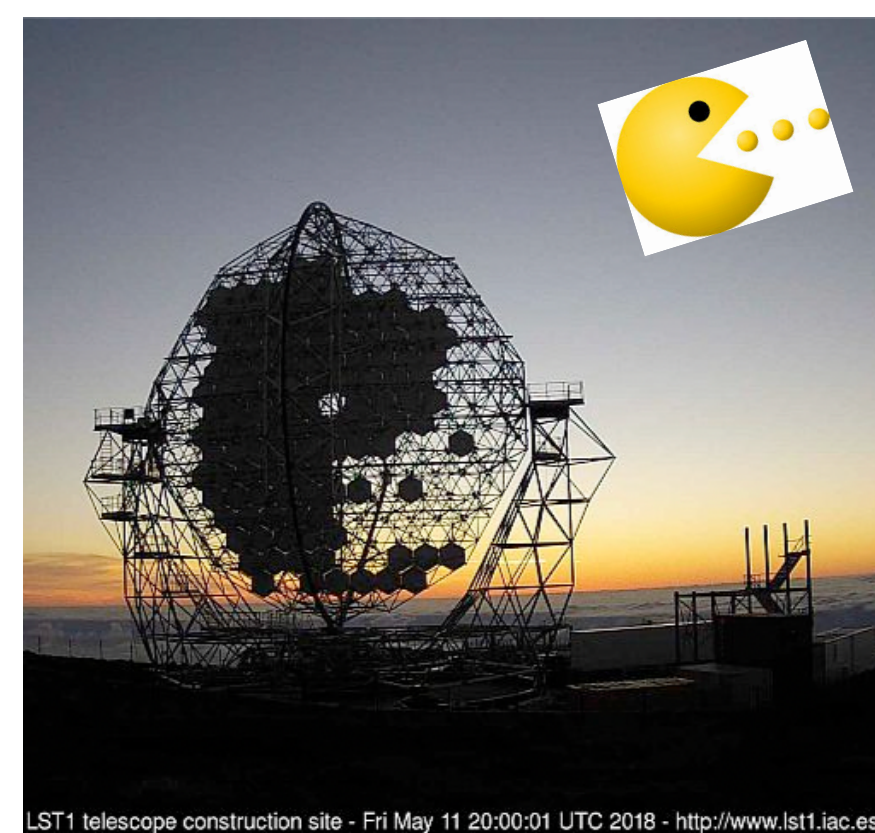
Few ' Angular Resolution
→ morphology



For details see
"Science with CTA"

CTA status

- Construction of first prototypes progressing
 - Large Size Telescope on La Palma end 2018
 - Mid Size Telescope in Berlin since 2012
 - Schwarzschild-Couder in Arizona in 2018
 - First (Cherenkov) light of Small Size Telescopes
- Site agreement with Chile in 2018
- Observatory operations starting in 2022 (completion in 2025)

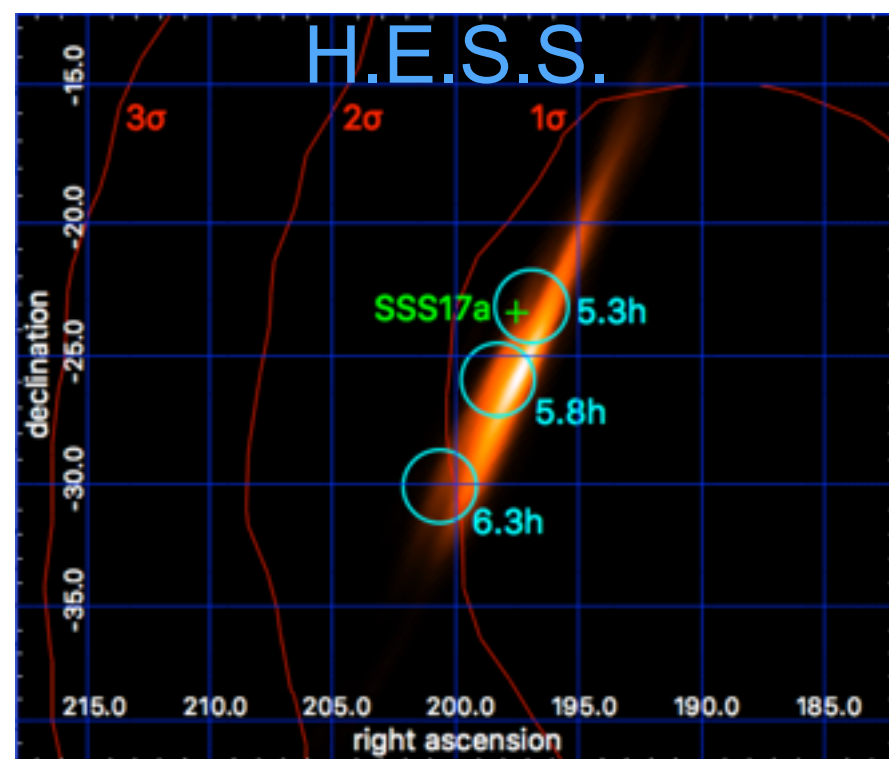


The CTA Transient program

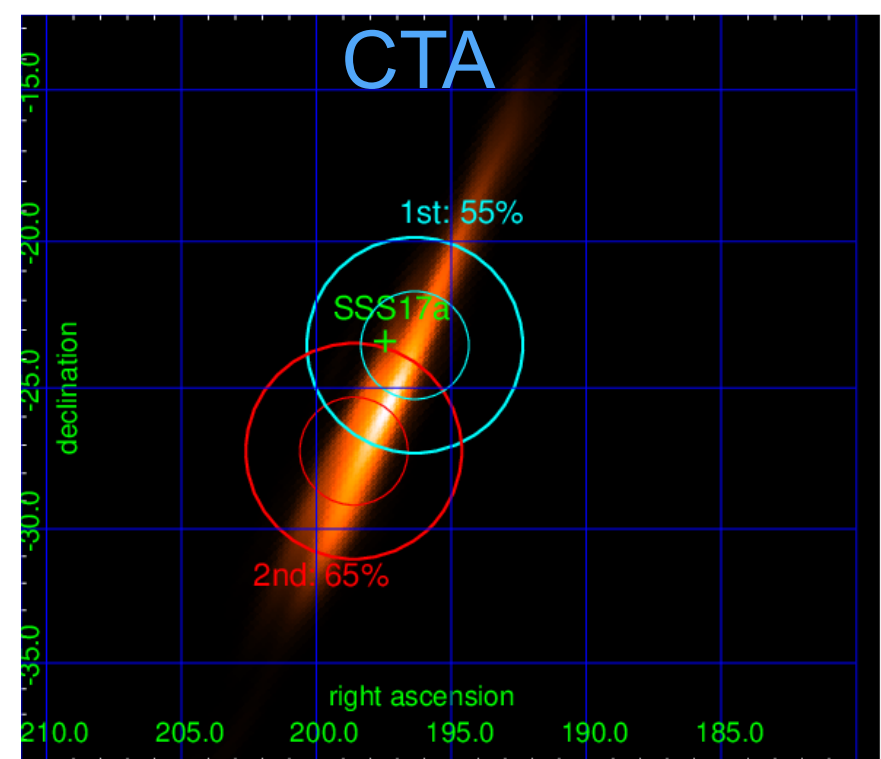
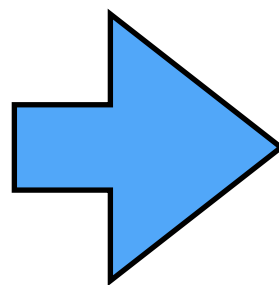
- Transients are integral part of the "Key Science Projects"
 - Observation time allocated to the CTA consortium
- dedicated Science Working Group "Transients and MWL"
 - Led by Daniela Hadasch and FS
 - Preparation of the first observations (reaction to ToOs, observation program, etc.)
 - Setup of multi-wavelength/messenger connections
 - Main topics: gamma-ray bursts, gravitational waves, high-energy neutrinos, FRBs, Galactic transients (e.g. microquasars, novae, magnetars, etc.)
 - Real-time analysis of the data => emission of notifications/alerts (internal + external)
- Also: AGN monitoring program + survey of the extragalactic sky + ...



GW170817 @ Cherenkov Telescope Array



H. Abdalla et al. (H.E.S.S.), ApJL 855:L22 (2017)



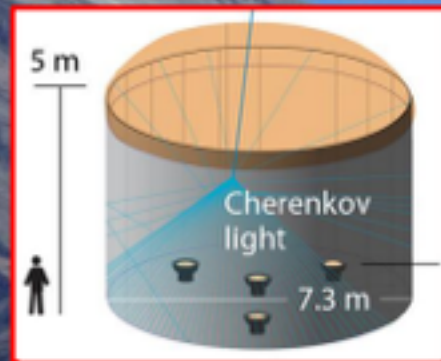
FS (CTA consortium), preliminary

Summary

- HE/VHE monitoring + sensitive follow-up observatories crucial for a large range of transients
 - monitoring with large FoV observatories
 - "finder scopes" emitting alerts in real-time
 - archival data for delayed incoming alerts ("go back in time and check for signal from a given direction") + long-term light-curves
 - follow-up instruments:
 - detailed observations: (short-term) light-curves + spectra
- currently a large variety of instruments are monitoring + observing the HE+VHE sky
 - Fermi-LAT (+ Swift-BAT, etc.), FACT, HAWC + H.E.S.S. / MAGIC / VERITAS
- Transient Sky in 2020
 - uncertain: Fermi-LAT / H.E.S.S. / MAGIC / VERITAS
 - FACT (+ MATE ?)
 - HAWC
 - CTA
 - LHAASO
 - SGSO (?)

High Altitude Water Cherenkov Observatory (HAWC)

Citlaltepetl
Pico de Orizaba
5610m a.s.l.



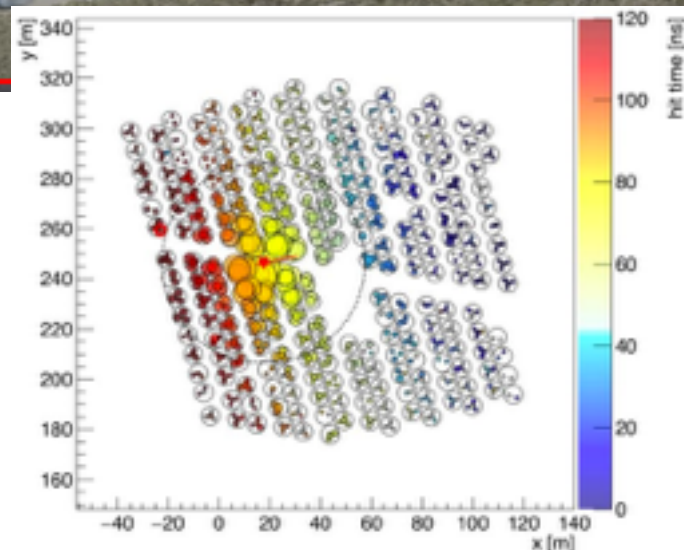
- 22,000 m² air shower array
- 300 Water Cherenkov detectors (WCD)
- 180,000 liters of purified water **per WCD**
- 4 PMTs per WCD (3x 8" from Milagro + 1x 10" high QE)
- **Completed March 2015**

Large
Millimeter
Telescope
Alfonso Serrano

Tliltepetl
Sierra Negra
4582m a.s.l.

HAWC
4100 m a.s.l.

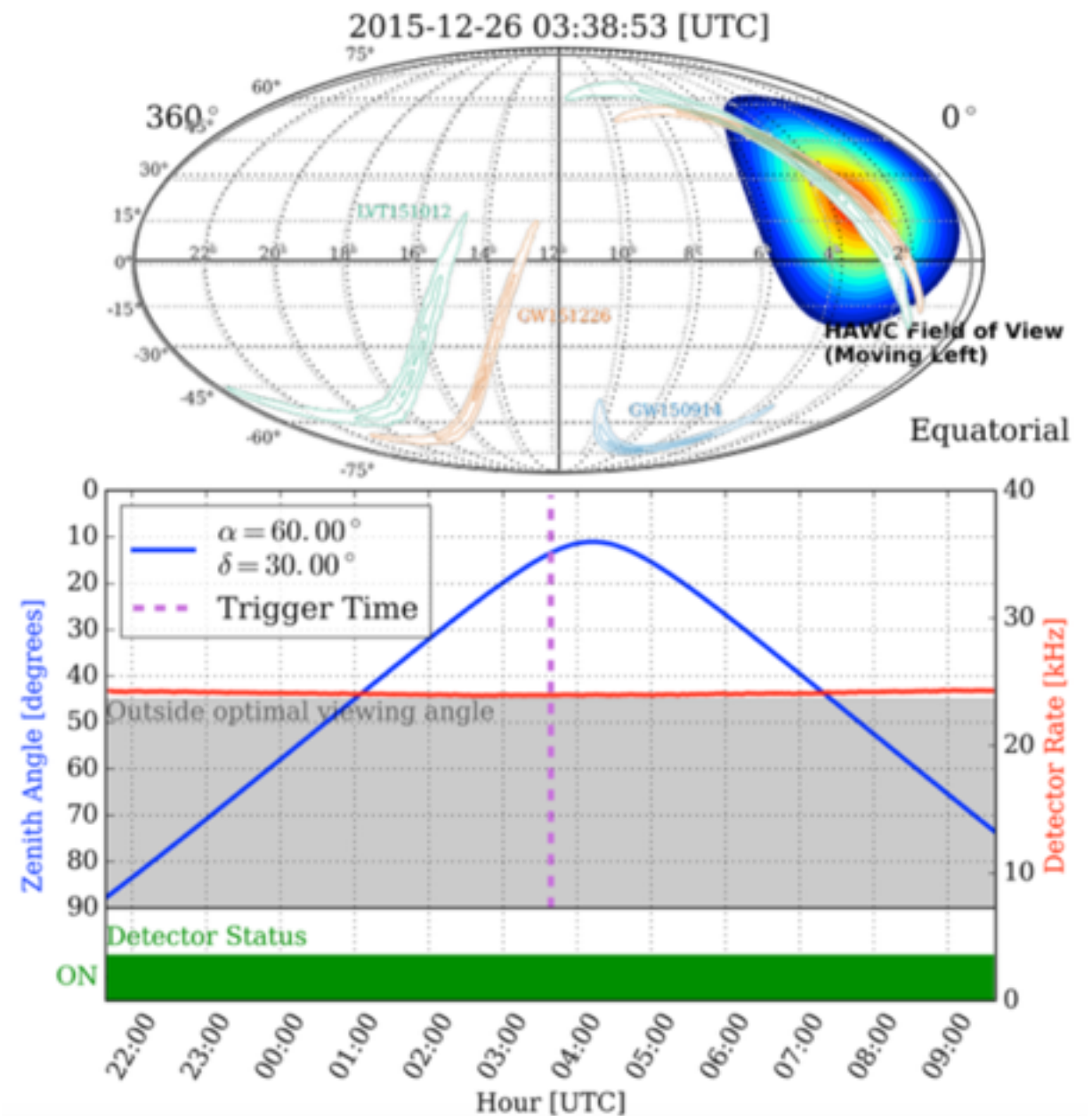
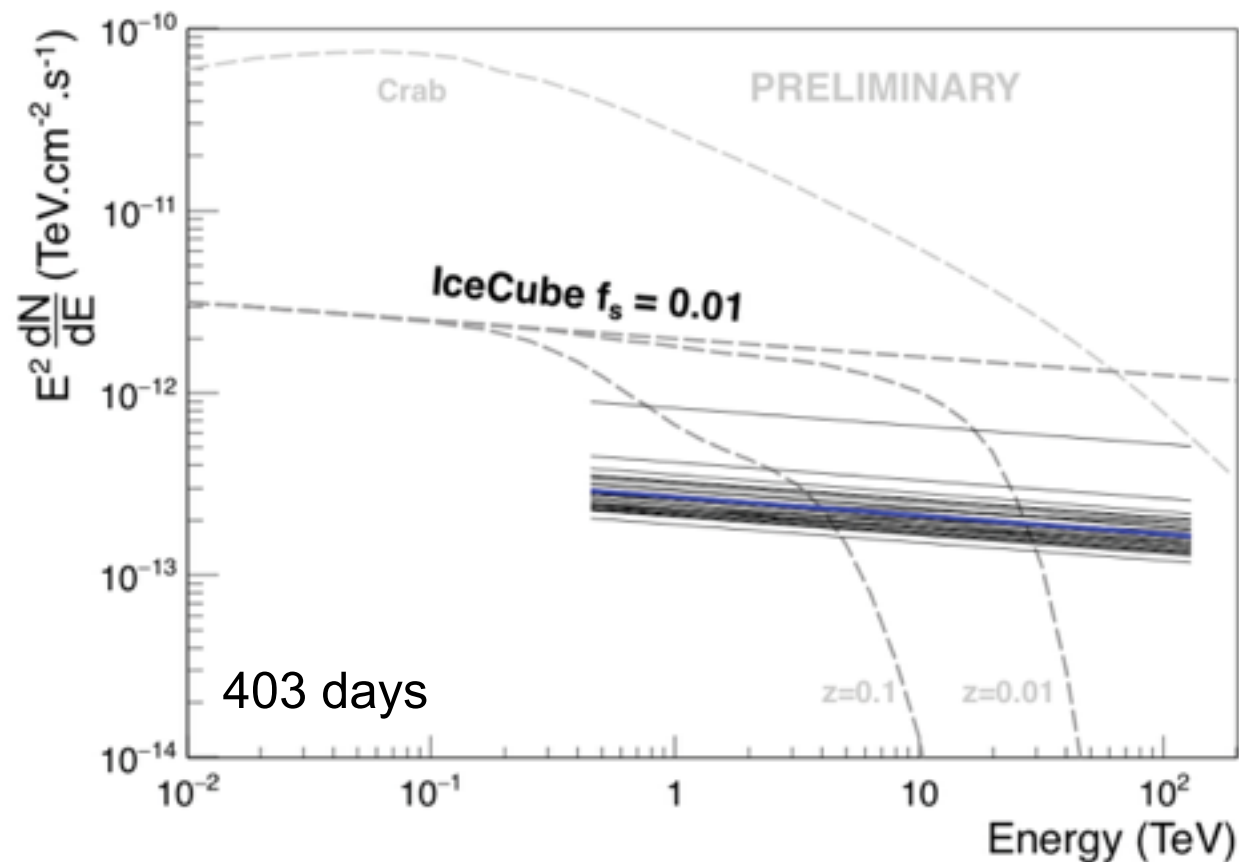
R. Lauer (HAWC)



HAWC: multi-messenger transients



- full-sky monitoring allows for efficient multi-messenger searches
 - high-energy neutrinos, e.g. IC-HESE tracks ($\sim 1\text{deg}^2$) + cascades $\sim 200\text{deg}^2$)
 - gravitational waves ($\sim 1000\text{deg}^2$)



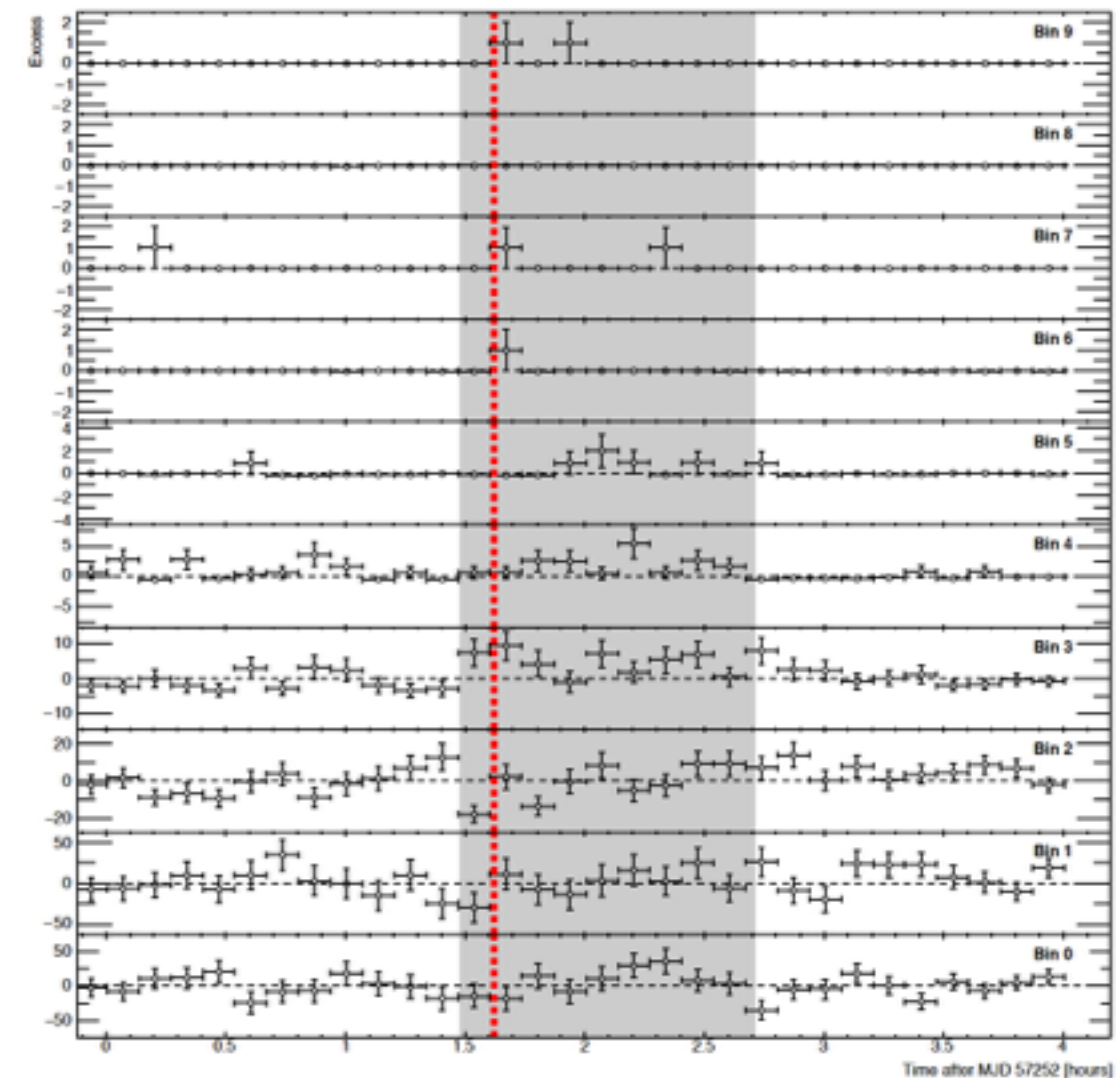
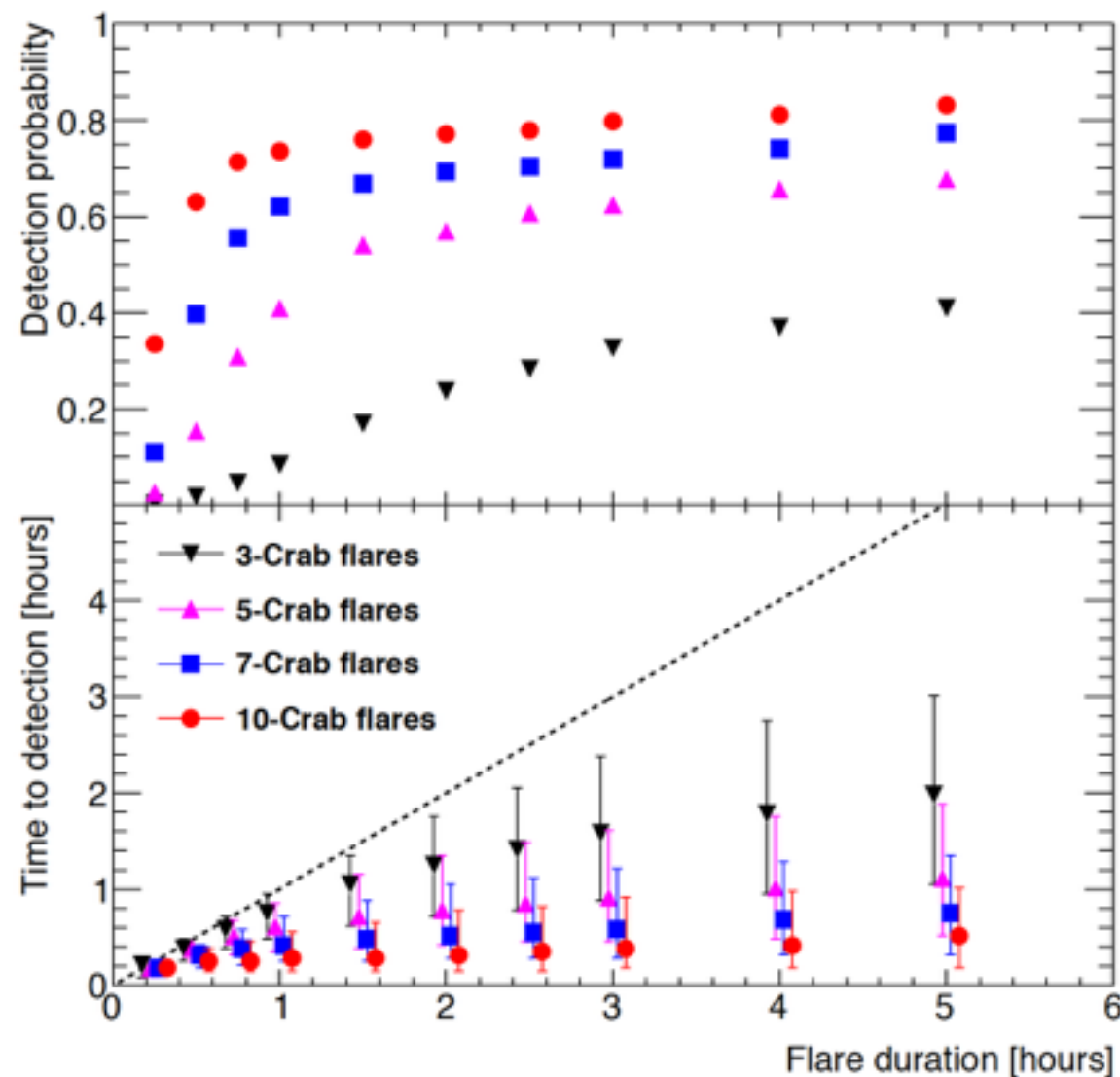
A. Sandoval, Gamma 2016

HAWC: online flare monitoring



- online monitoring of sources across the visible sky ($\sim 2\text{sr}$ instantaneous FoV)
- flares between 2min and 2days
- alert emission to MoU partners since 01/2017

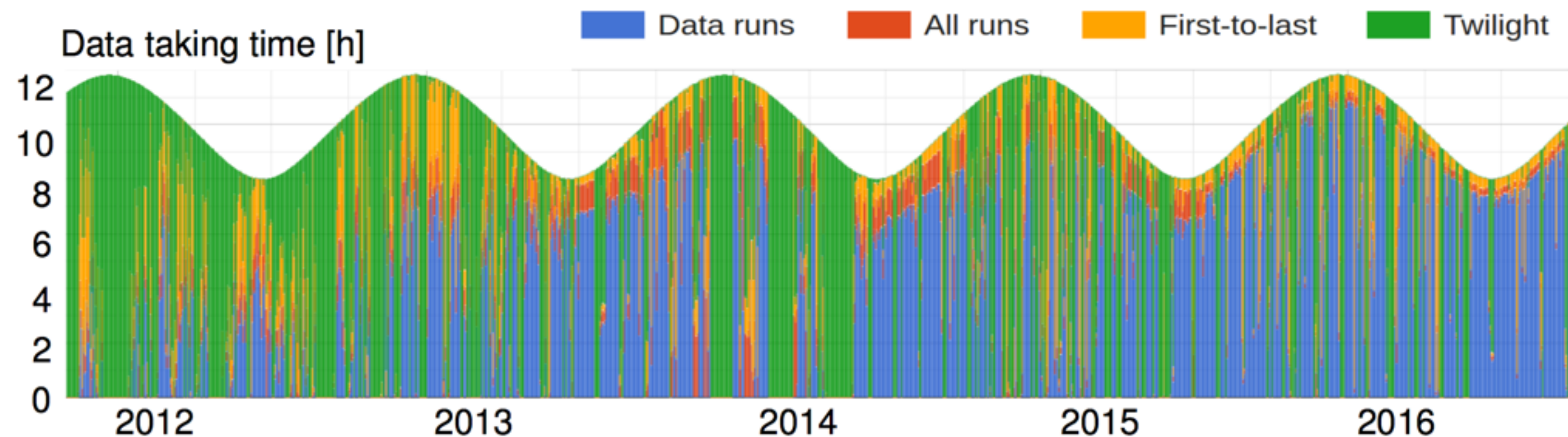
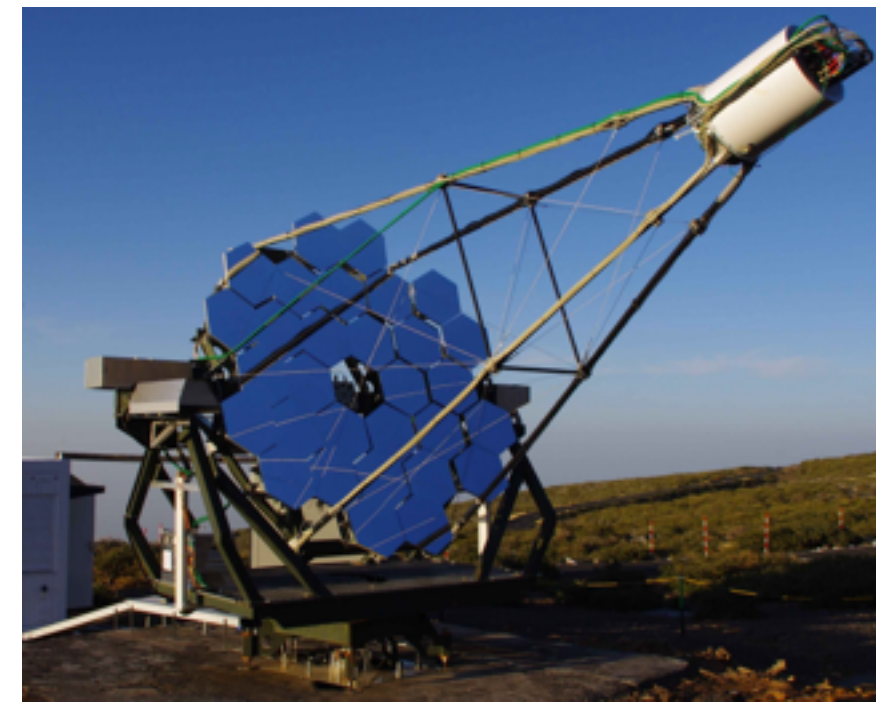
Mrk 501 (August 18, 2015)



T. Weisgarber (HAWC), arXiv: [1704.07411](https://arxiv.org/abs/1704.07411)

FACT

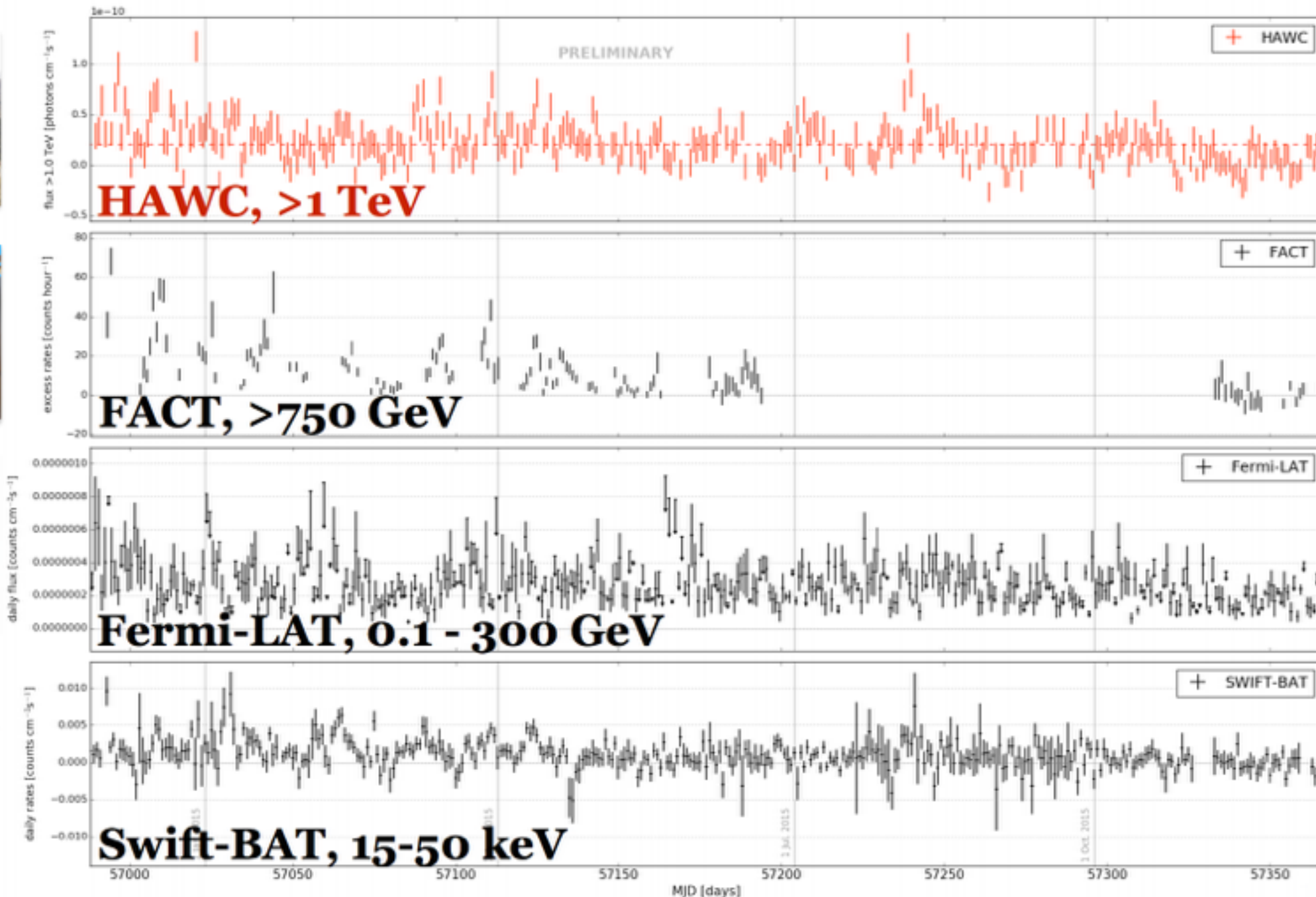
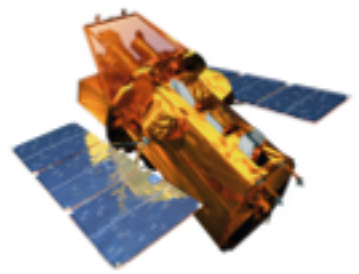
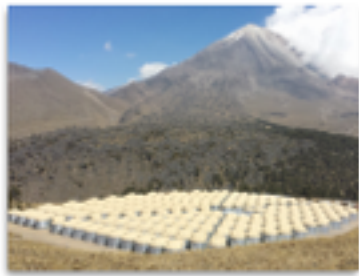
- HEGRA telescope mount
- SiPM camera (operation during moon-light possible)
- largely automatized + remote monitoring



D. Dorner et al.

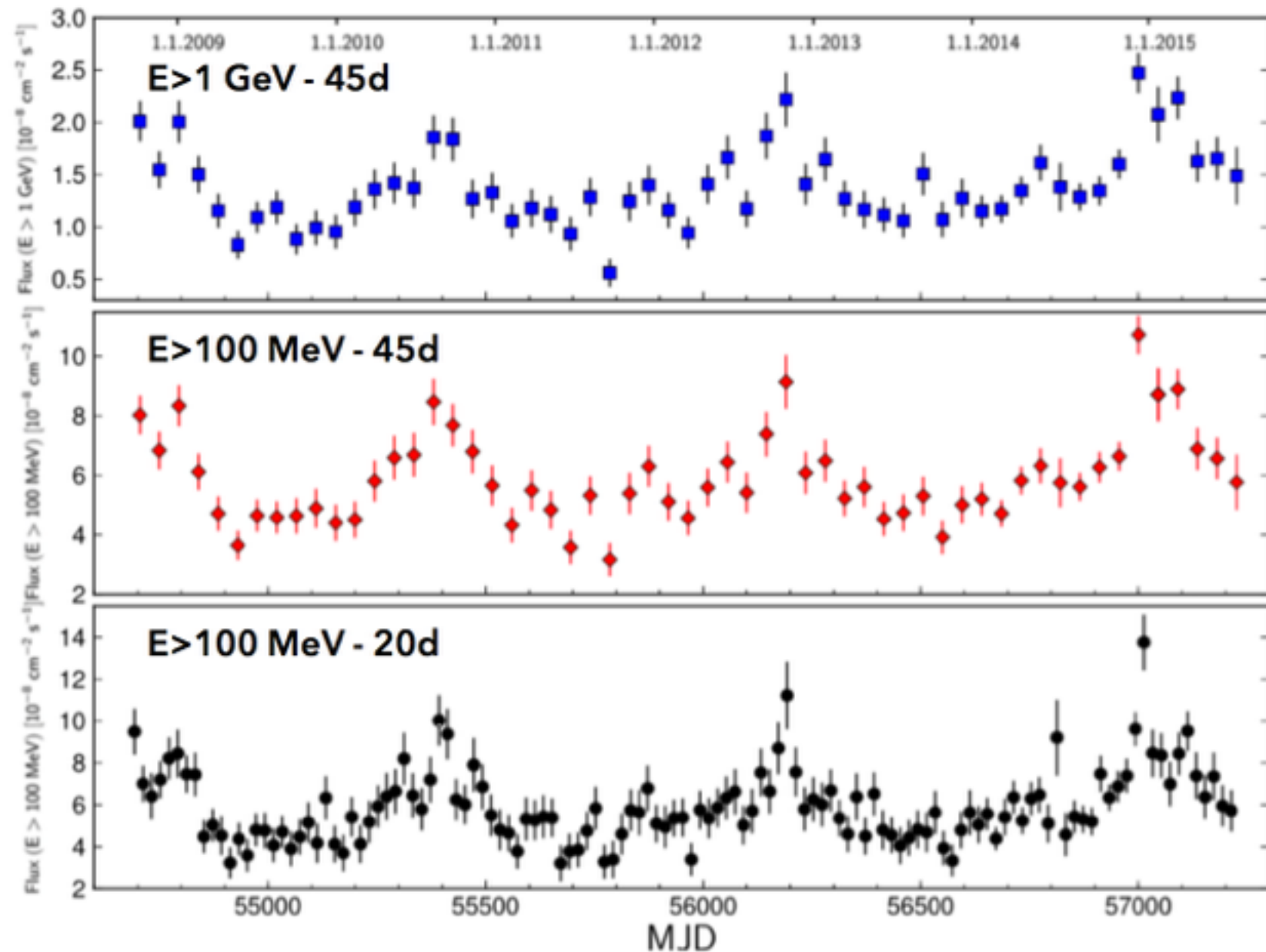
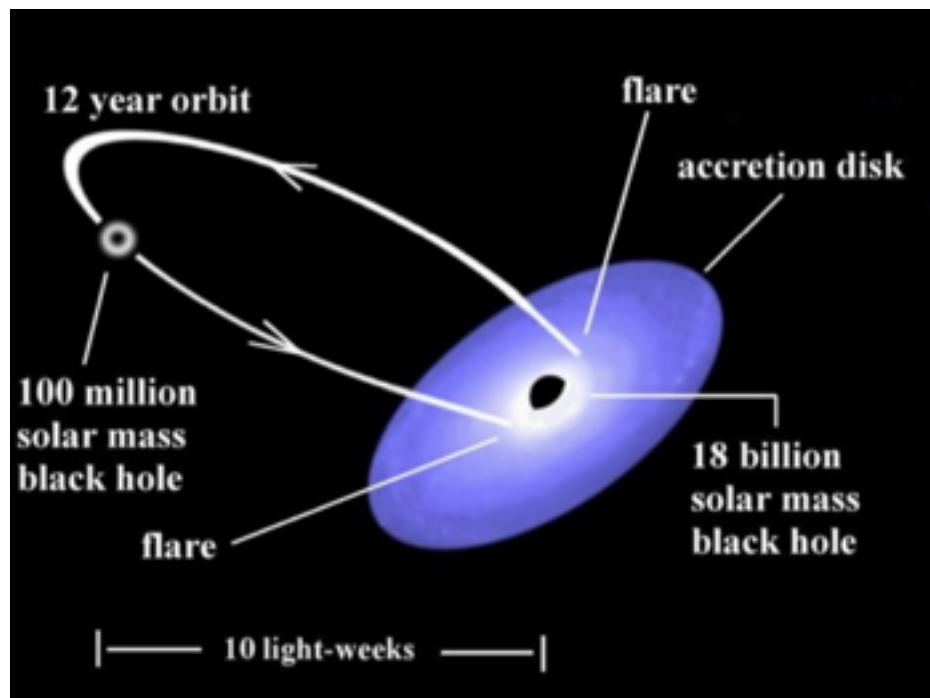
Long-term light-curves across the EM spectrum

- currently: various wide FoV instruments monitoring the sky
- extremely valuable for long-term MWL studies



Quasi-periodic modulations in PG1553+113

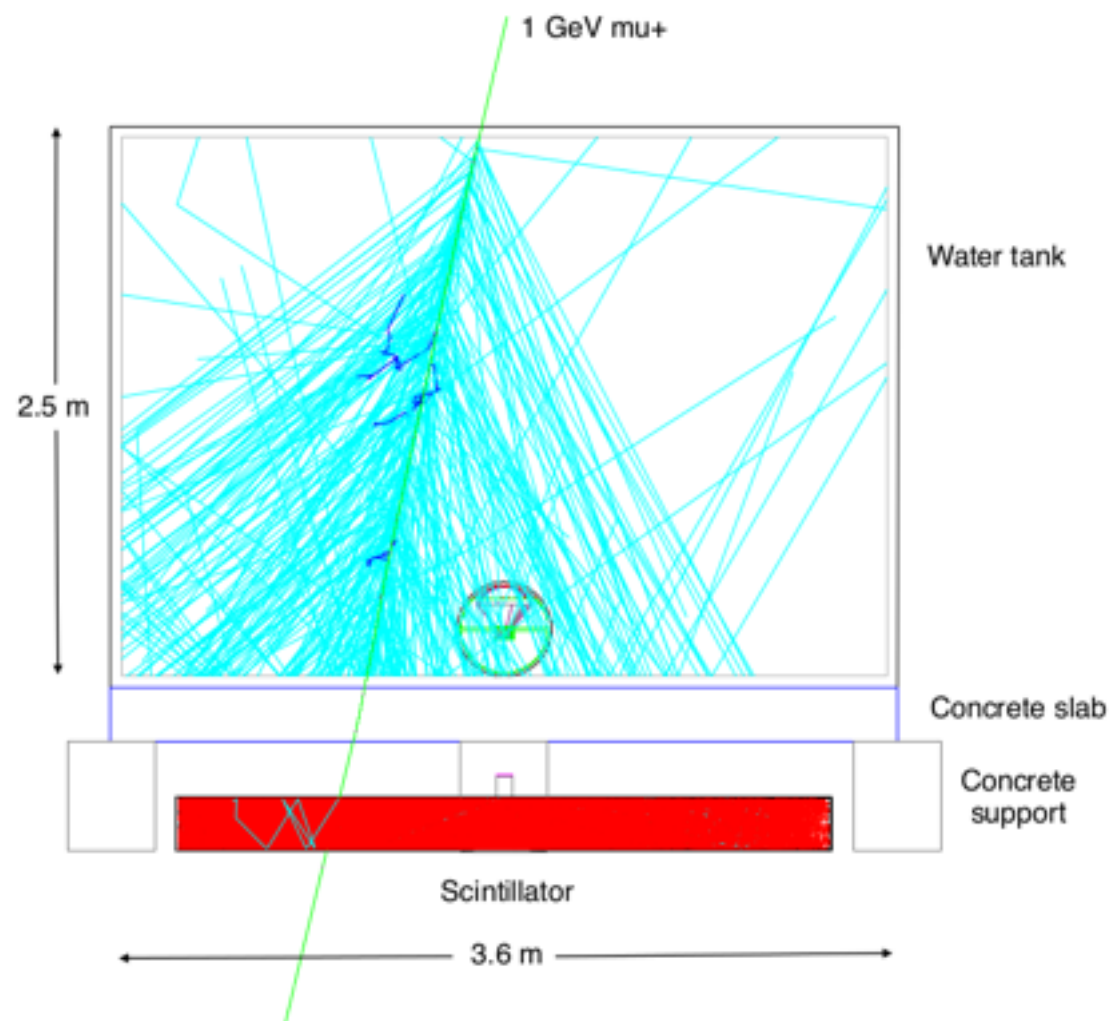
- $z \sim 0.5$
- Fermi-LAT
- period ~ 2 years
- super-massive binary black hole?



Ackermann et al. (Fermi-LAT), 2015

ALTO

- Design and prototyping driven by Linnaeus University (Växjö, Sweden)
- French participation via M. Punch and J.P. Ernenwein



<https://alto-gamma-ray-observatory.org/>