H.E.S.S. multi-messenger and real-time follow-up observations

Fabian Schüssler (Irfu/CEA-Saclay)
on behalf of the H.E.S.S. collaboration

TevPA 2015, Kashiwa

The H.E.S.S. multi-messenger and GRB team

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Overview

- The H.E.S.S. instrument
  - H.E.S.S.-II
- Multi-Messenger program
  - Neutrinos
    - ANTARES hotspot
    - IceCube HESE events
  - ToO/alert follow-up
    - ToO follow-up performance
    - GRBs
    - FRBs
    - Gravitational waves
    - Neutrinos

The H.E.S.S. experiment

H.E.S.S. phase I
- four 12m telescopes
- FoV 5deg
- energy threshold ~100GeV
- angular resolution <0.1deg

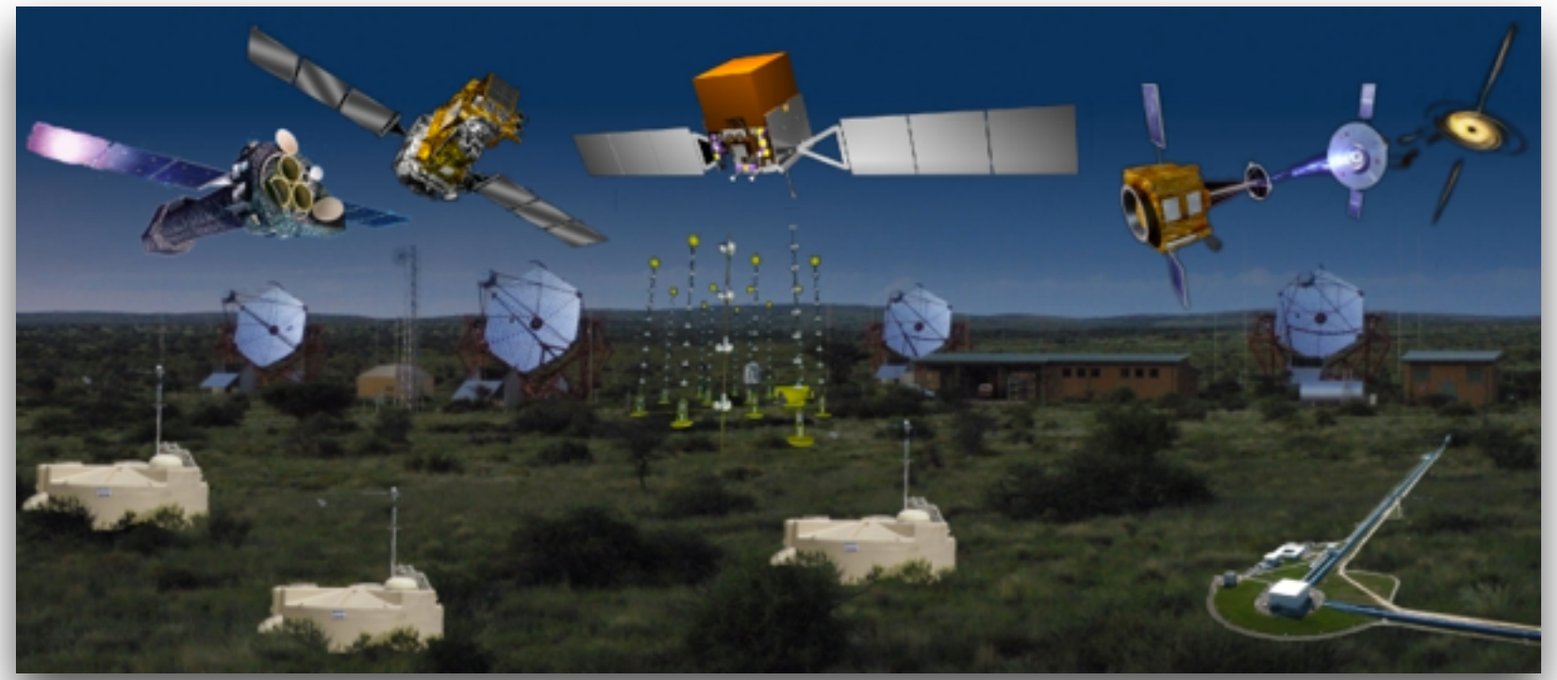
H.E.S.S. phase II
- four 12m telescopes
- one 28m telescope (FoV 3.5deg)
- energy threshold ~30GeV
- angular resolution from 0.4 to less than 0.1deg

2012

H.E.S.S. phase I → H.E.S.S. phase II

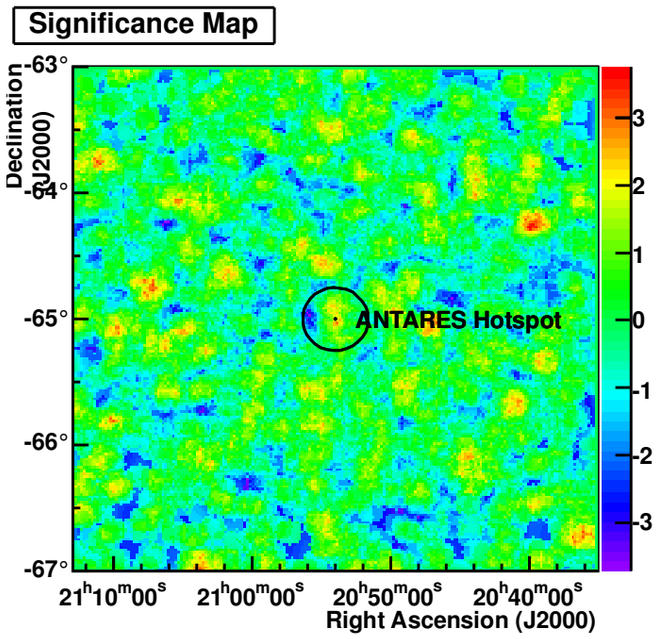
Multi-messenger program

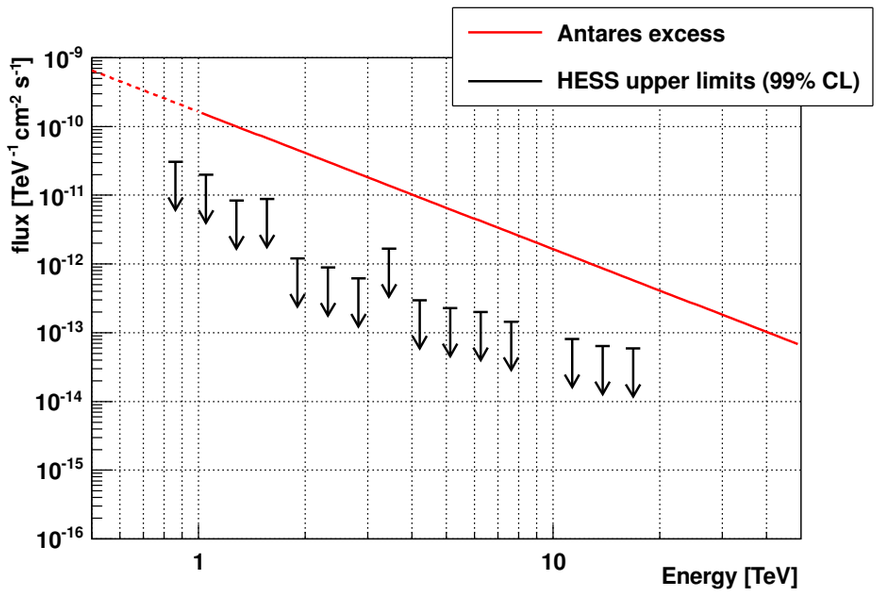
- Cosmic rays
  - no time correlation (except neutrons): waiting for a small-scale excess ;-)
- Gravitational waves
  - increasing interest (Advanced Virgo/Ligo)
  - H.E.S.S. takes part in the Virgo/Ligo EM follow-up effort
  - follow-up difficult due to large localization uncertainties
    - important input from additional EM detection
- **Neutrinos**
  - ROIs
    - neutrino hotspots
    - IceCube HESE events
  - ToOs

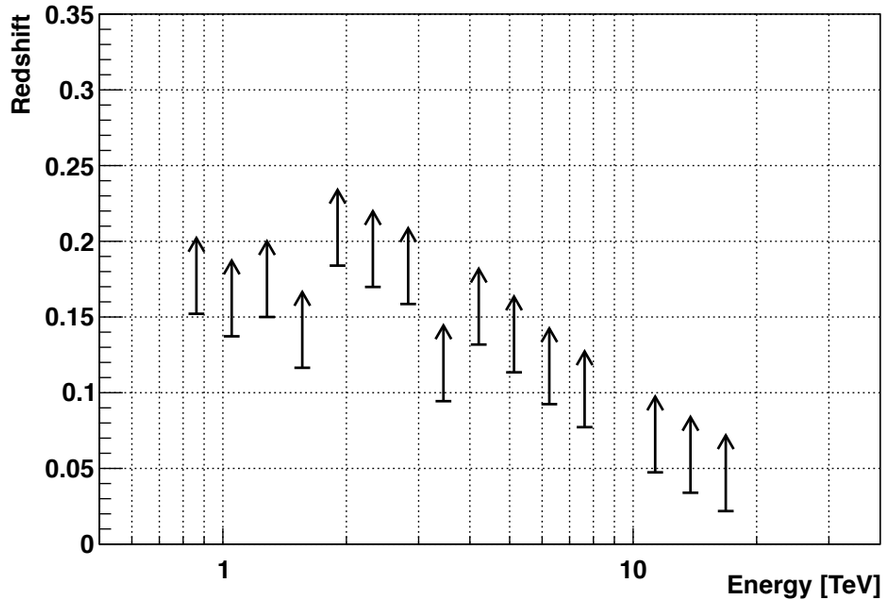


Multi-messenger program: Neutrino hotspots

- Antares hotspot
  - 2.2σ excess (Adrian-Martinez et al., APJ 760 (2012) 53)
  - 2h of H.E.S.S. observations in 2013 ruling out close-by source





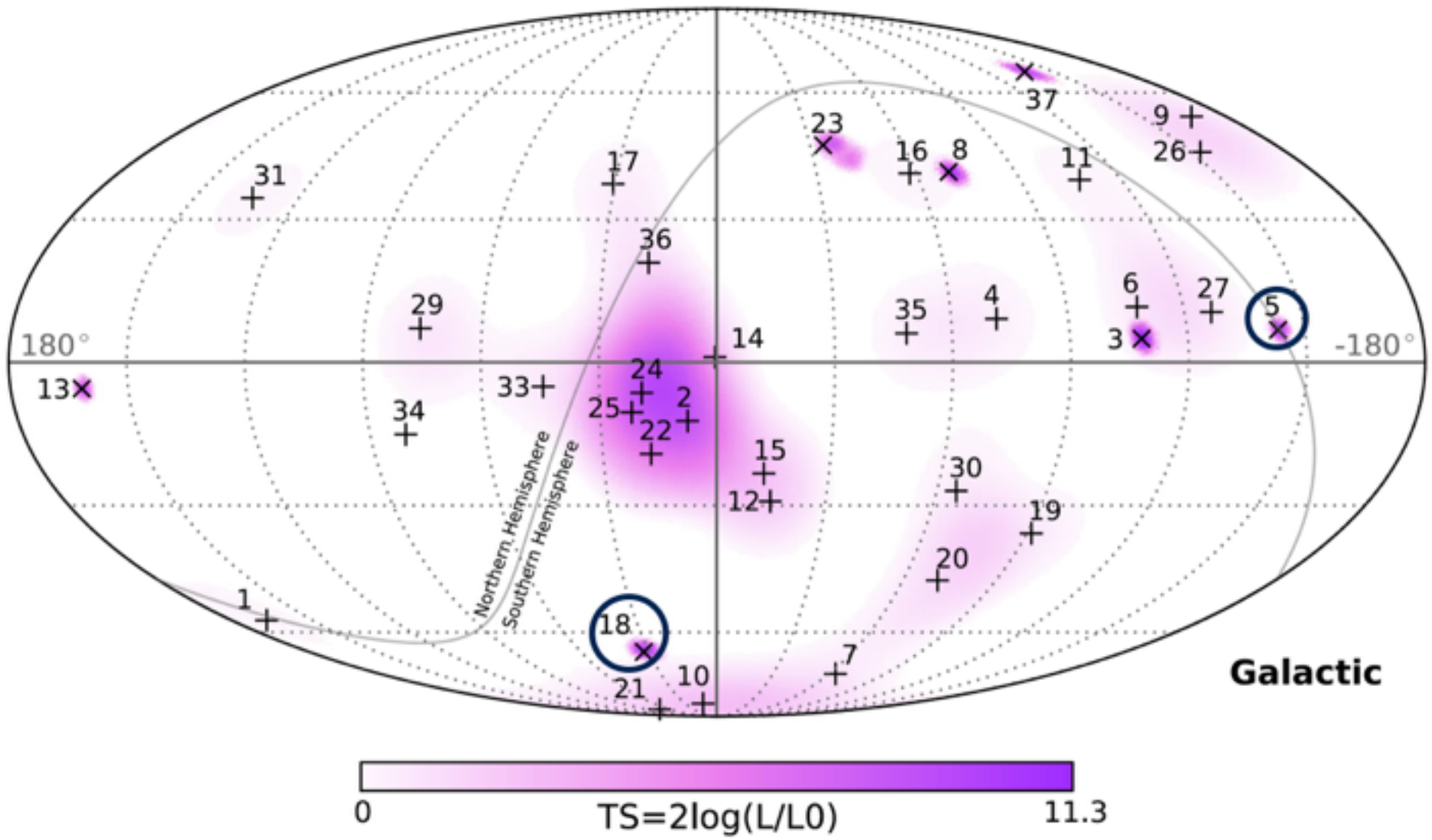


FS et al., ICRC 2013, arXiv:1307.6074

Multi-messenger program: IceCube HESE tracks

- H.E.S.S. observations of IceCube High Energy Starting Events
  - track like events (angular uncertainty)
  - H.E.S.S. visibility + constrains by other observations
  - high energy, etc.

M.G. Aartsen et al. (IceCube), PRL 113 (2014) 101101

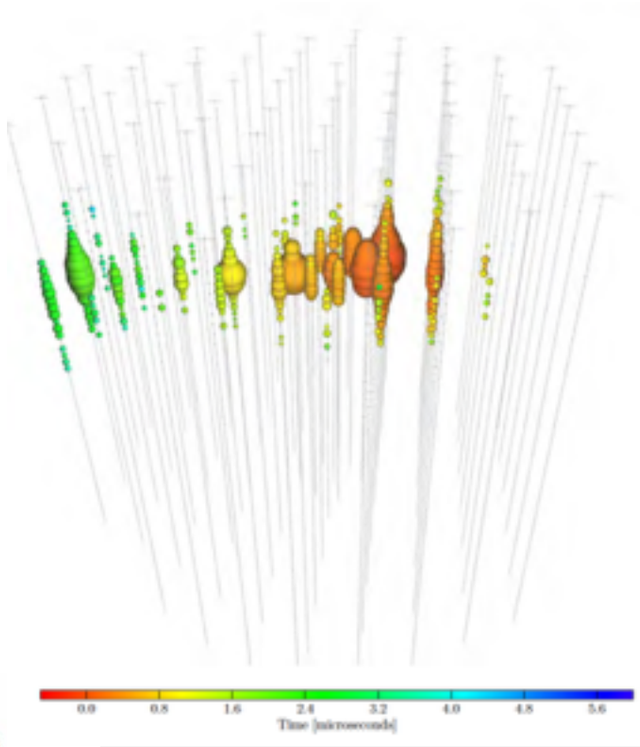


Dr. Strangepork

IceCube Event 5

- deposited energy: 71.4^{+9}_{-9} TeV
- Ra=110.6deg / Dec=-0.4deg

- H.E.S.S. observations
  - HESS-II 28m monoscopic mode
  - 0.9h effective livetime (acceptance corrected)

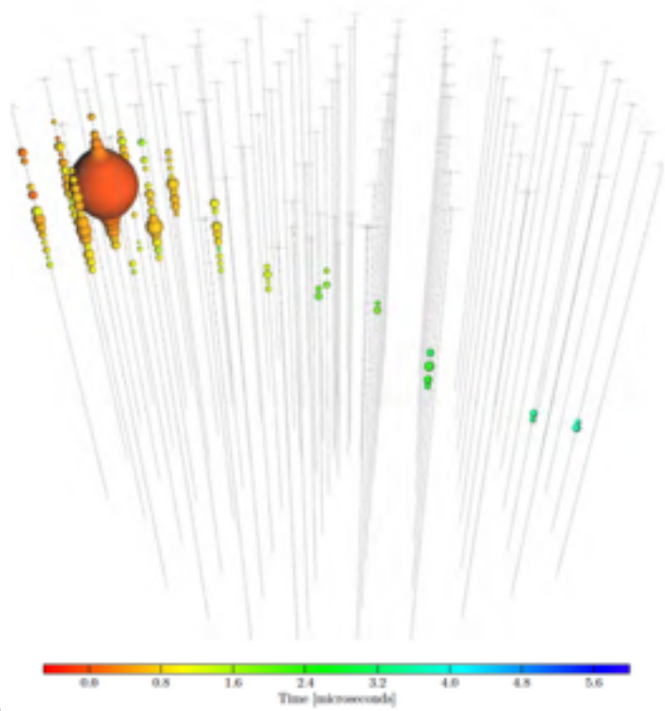


Zoot

IceCube Event 18

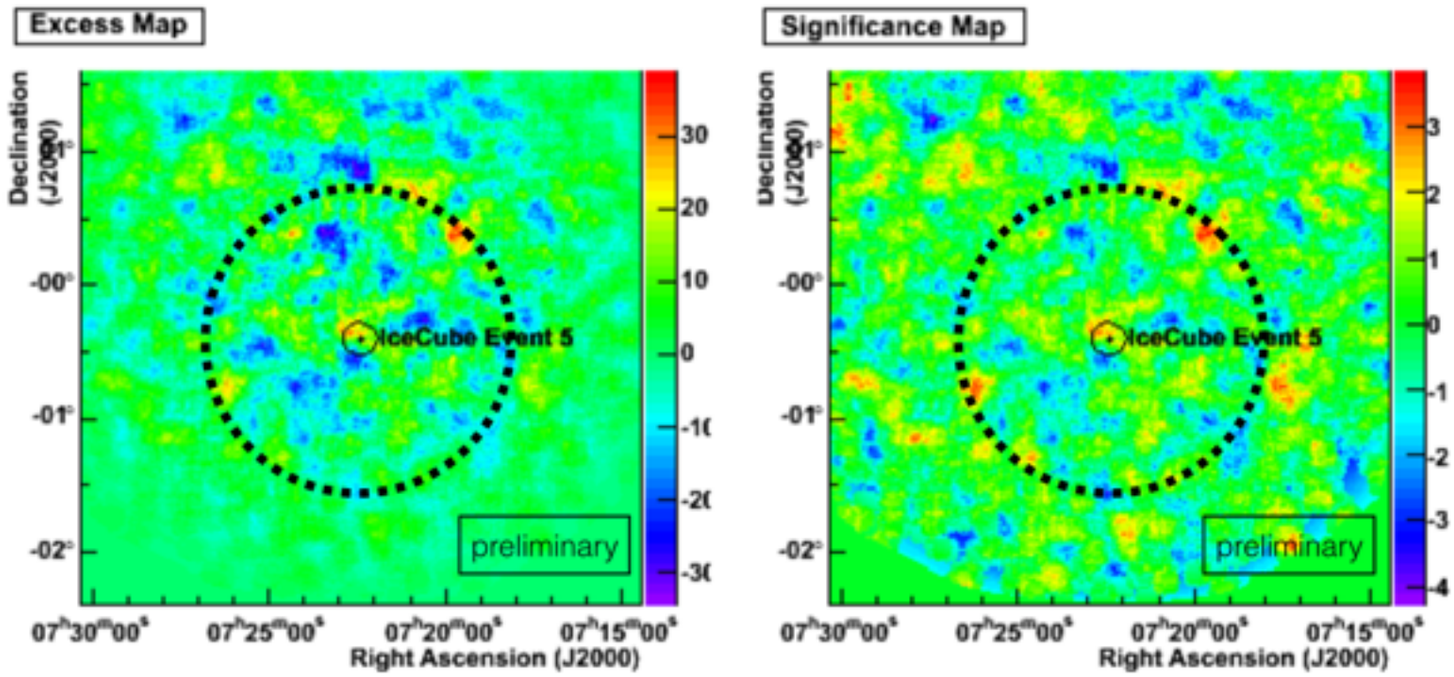
- deposited energy: $31.5^{+4.6}_{-3.3}$ TeV
- Ra=345.6deg / Dec=-24.8deg

- H.E.S.S. observations:
  - HESS-II observations with full 5-telescope array
  - 9.5h effective lifetime (acceptance corrected)

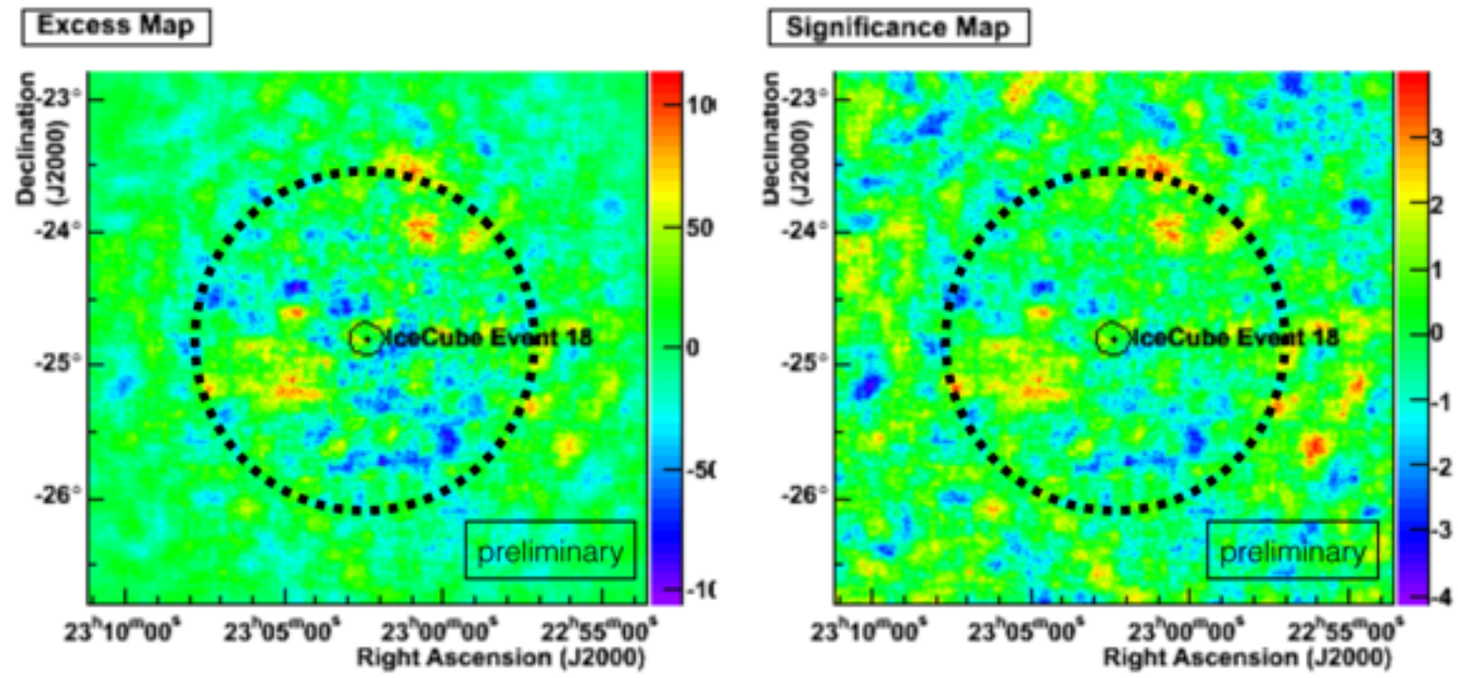


IceCube HESE tracks: results

- IceCube 5



- IceCube 18

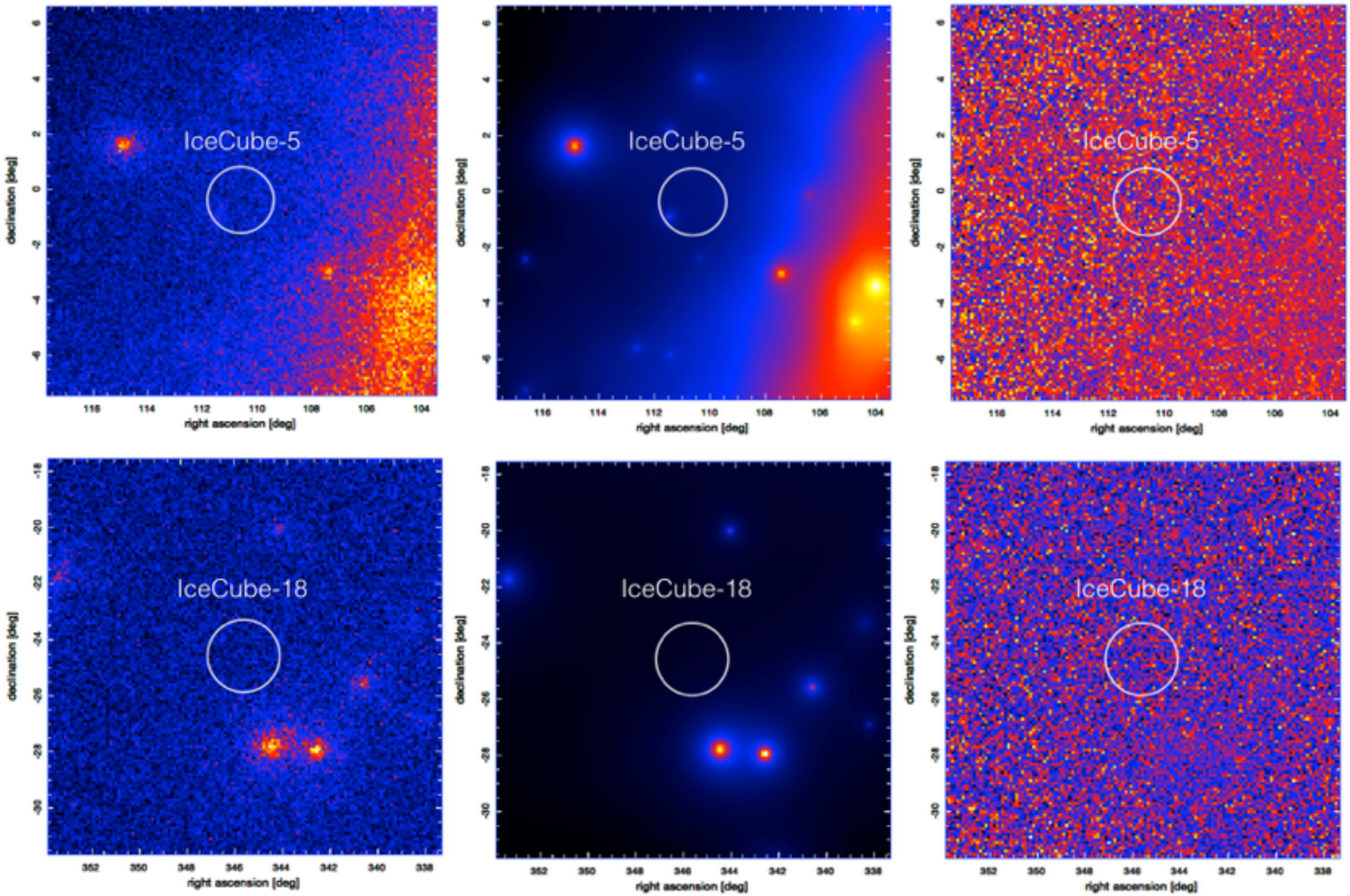


FS et al., ICRC 2015, arXiv:1509.03035

IceCube HESE tracks: Fermi-LAT analysis

- 08/2008-05/2015; P7Rep, 100MeV-300GeV

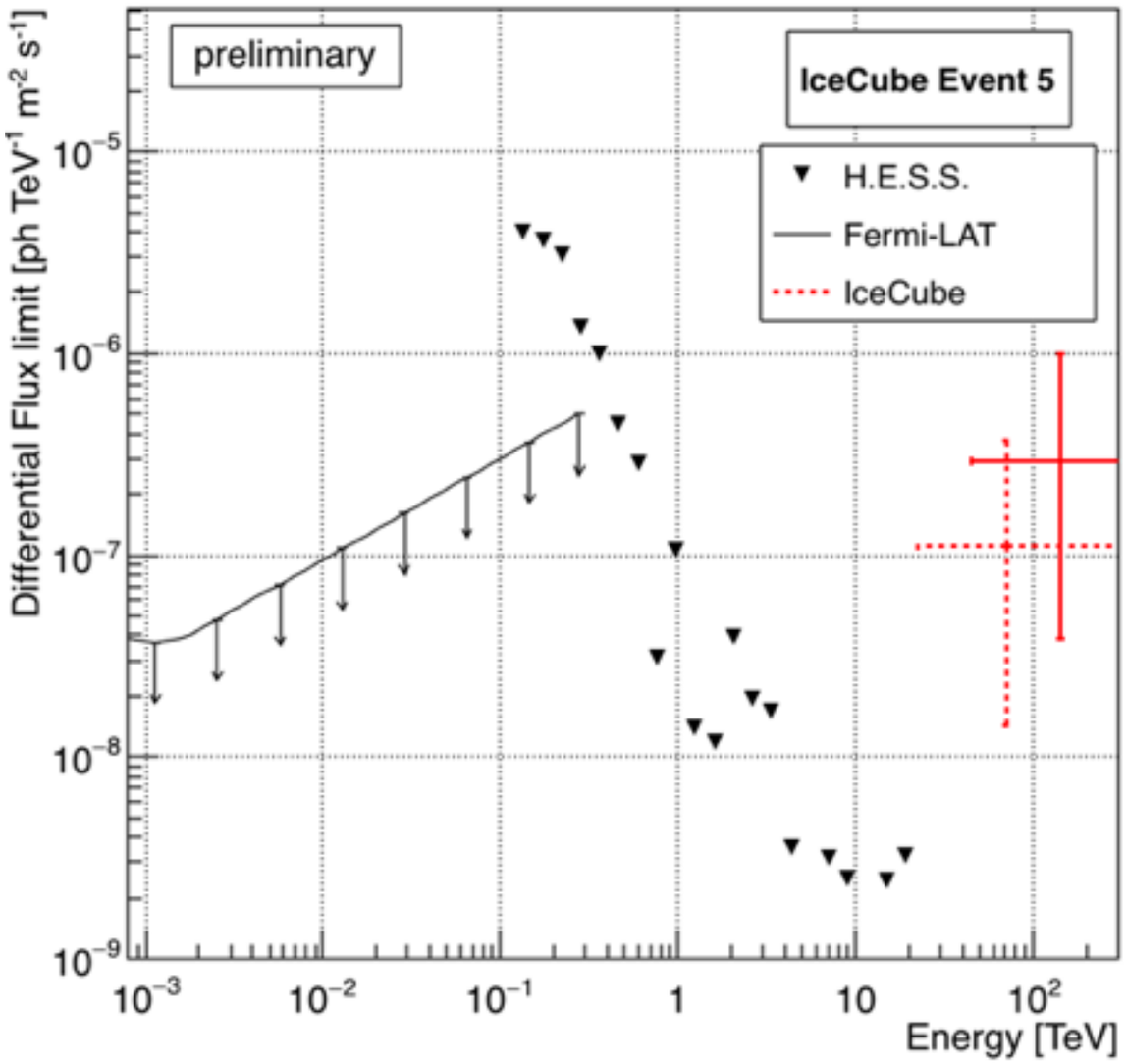
counts **model** **residuals**



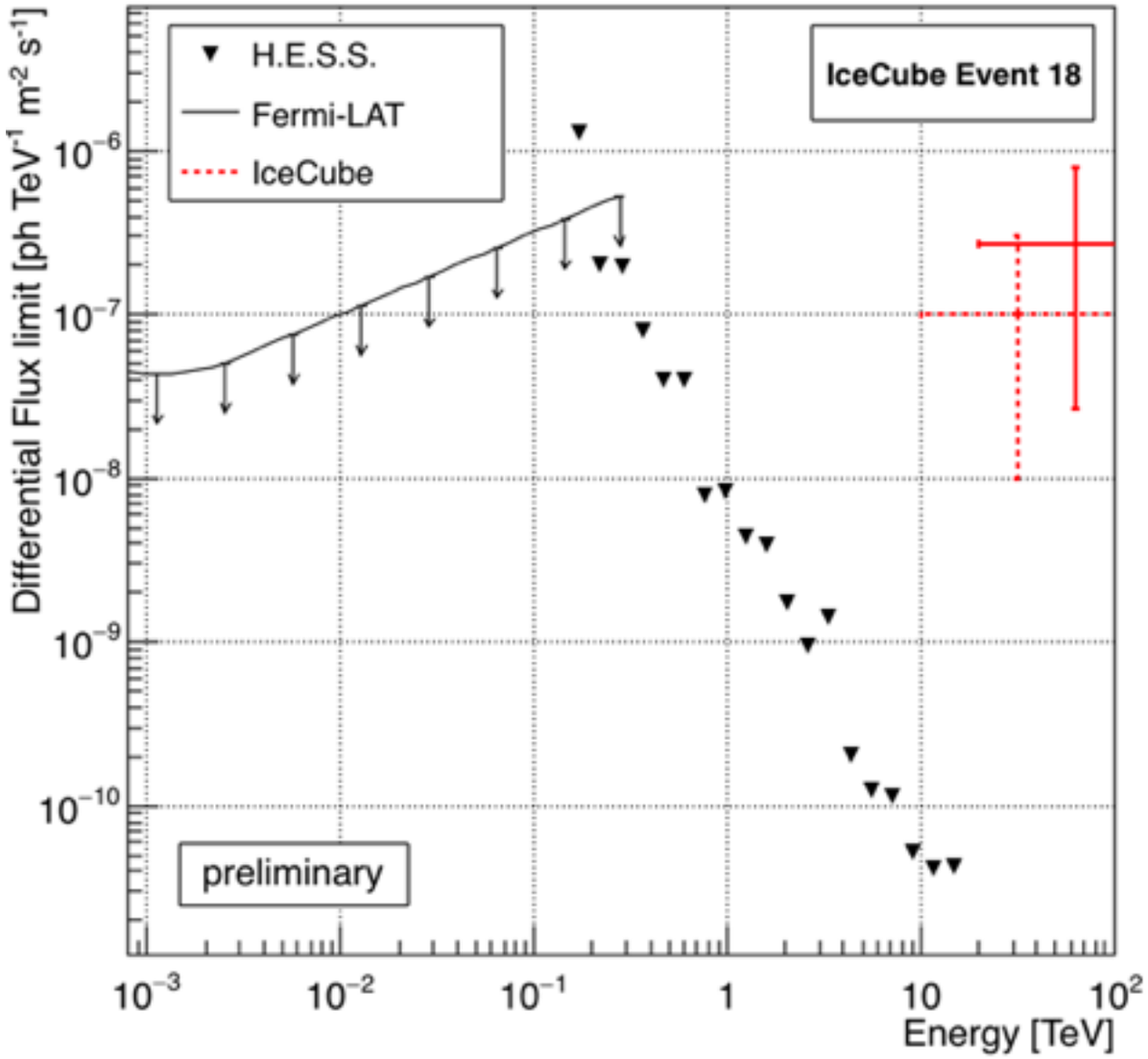
FS et al., ICRC 2015, arXiv:1509.03035

IceCube HESE tracks: limits

IceCube 5



IceCube 18



- caveat: EBL absorption of gamma rays

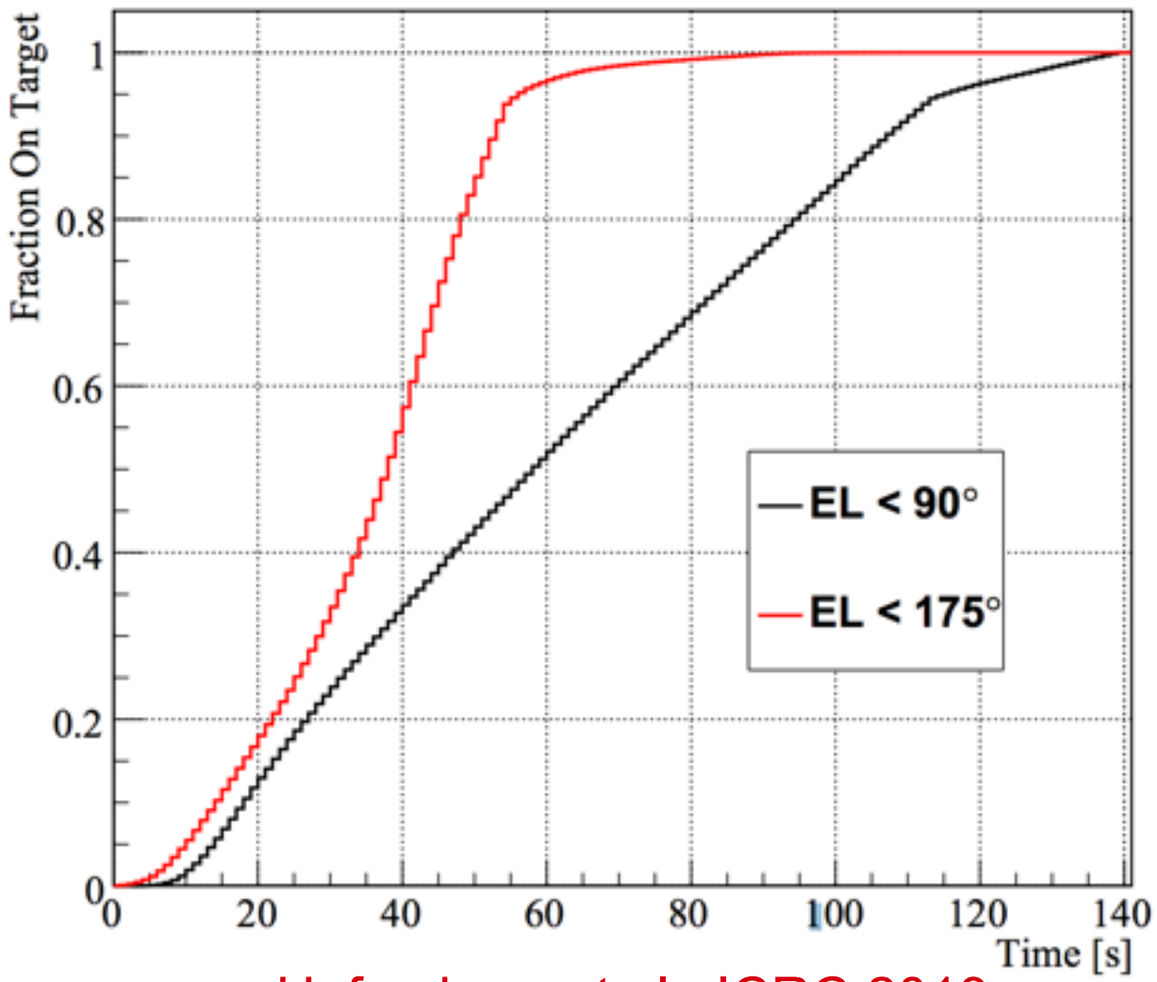
Future of the H.E.S.S. neutrino program: alerts and ToOs

- Interpretation of potential gamma-ray source within the neutrino error box difficult (has to rely on basic energetics and follow-up observations)
- Space and time correlations would provide ”smoking gun” signal for joint emission processes => CR interaction/acceleration

- IceCube
  - real-time alerts on HE/HESE events in preparation
  - expected delays O(10min)
- ANTARES
  - online reconstruction and rapid alert emission: TAToO (Ageron et al., APP 35 (2012) 530)
  - delays O(10s)

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

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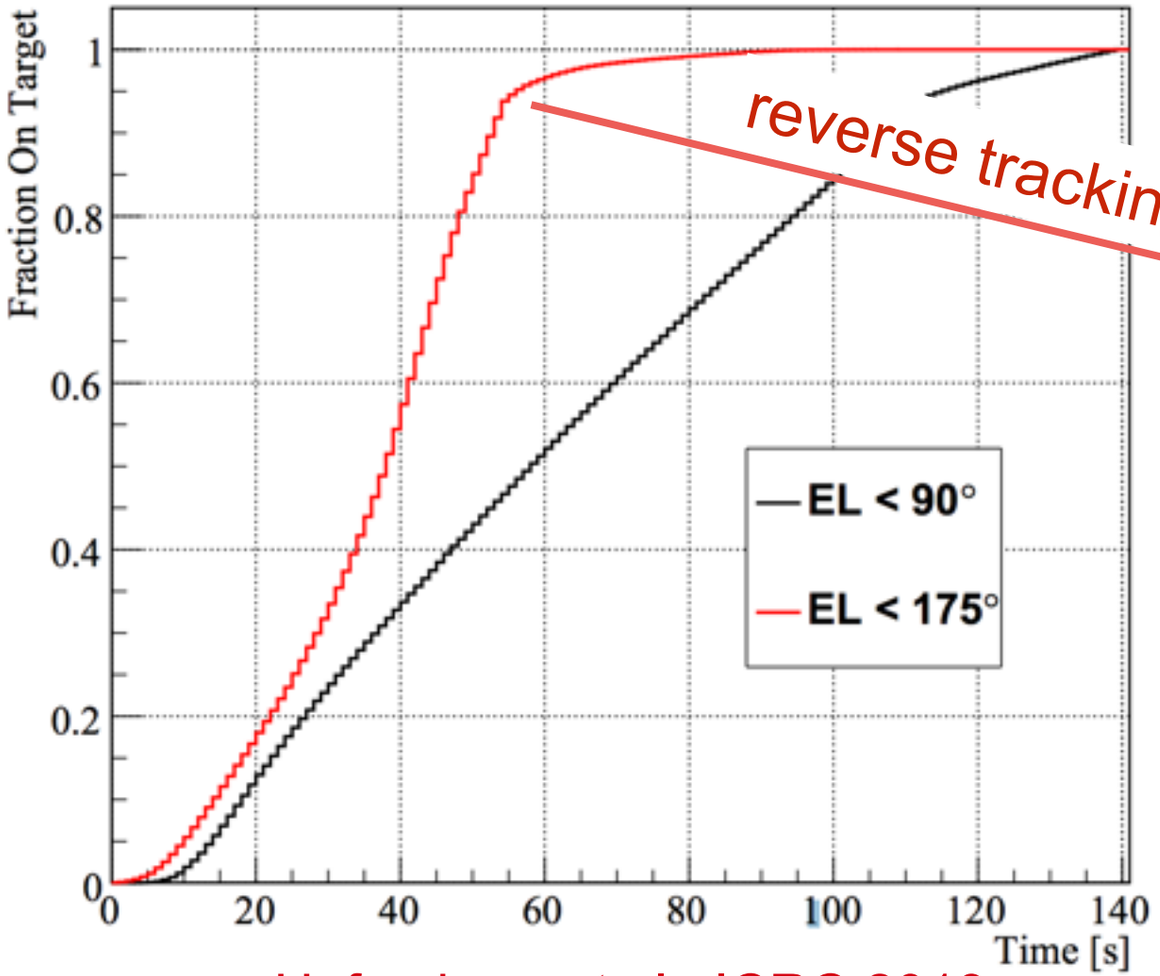

Hofverberg et al., ICRC 2013

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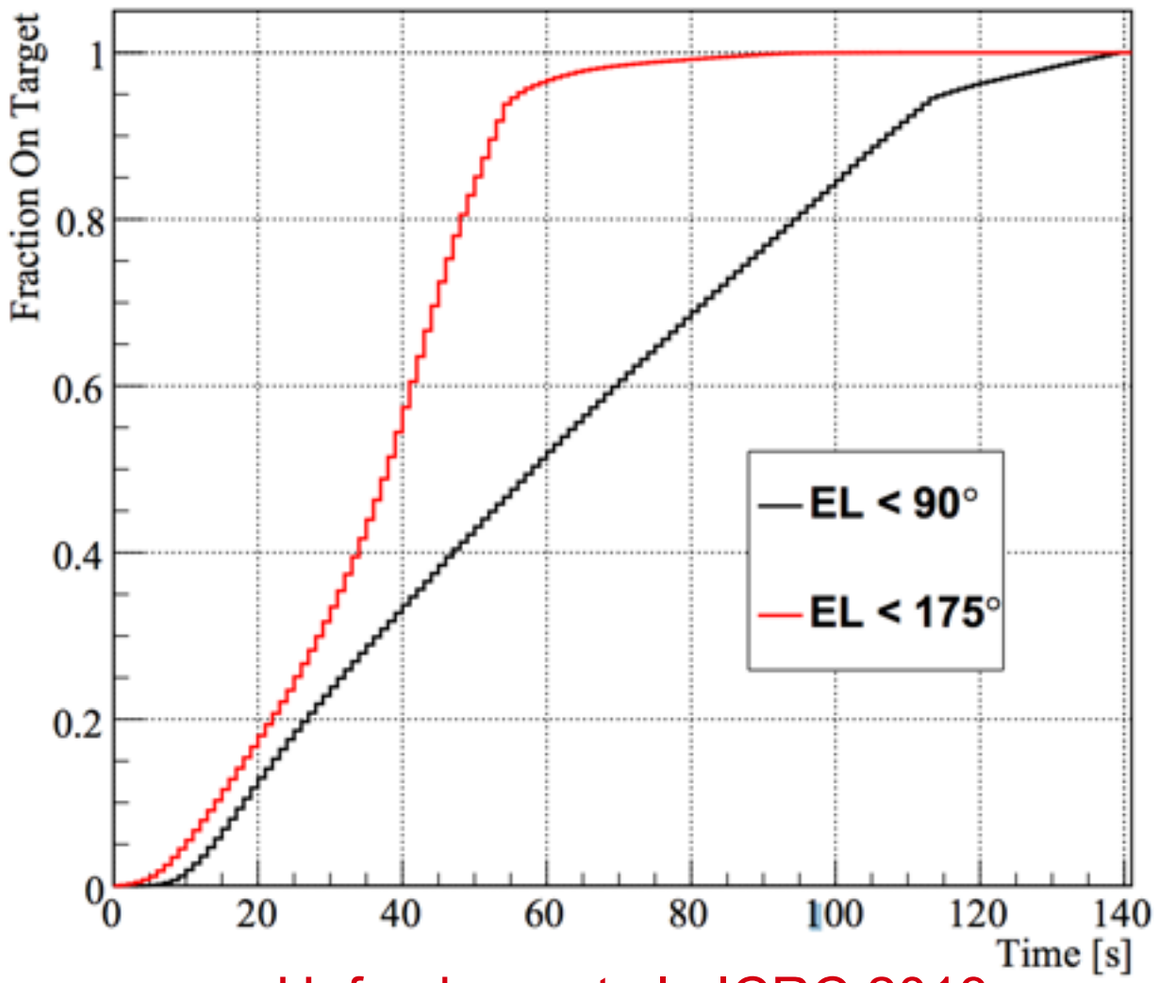


Hofverberg et al., ICRC 2013

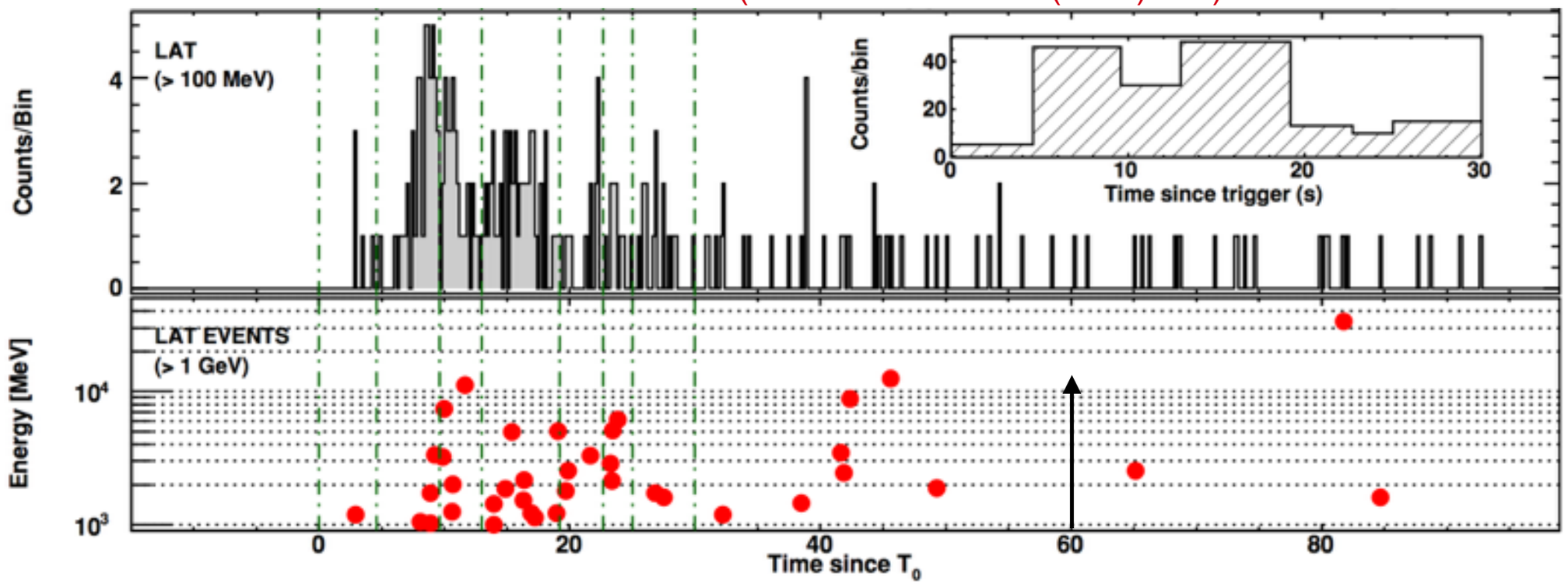
- ToO+DAQ re-organization in 2014/2015
  - significant reducing overhead
    - software overhead now: O(s)
    - CTA requirement: <10s
- response time only limited by hardware
  - slewing: O(60s)
  - HV ramping: O(s)
  - Camera configuration: O(s)

VoEvent alert system
in preparation

GRB follow-up with H.E.S.S.

- extensive follow-up program during H.E.S.S. phase I (e.g. A&A 495, 505-512 (2009))
- follow-up rapidity increased with H.E.S.S. II
  - rapid slewing speed
  - dedicated operation mode (e.g. data taking starts as soon as *source* enters the FoV)
  - fully automatic repositioning after the reception of a GCN alert
  - GRBs have highest ToO priority (following all accessible alerts)
  - dedicated data blinding scheme in place

GRB 090902B (Abdo et al. APJ 706 (2009) 138)

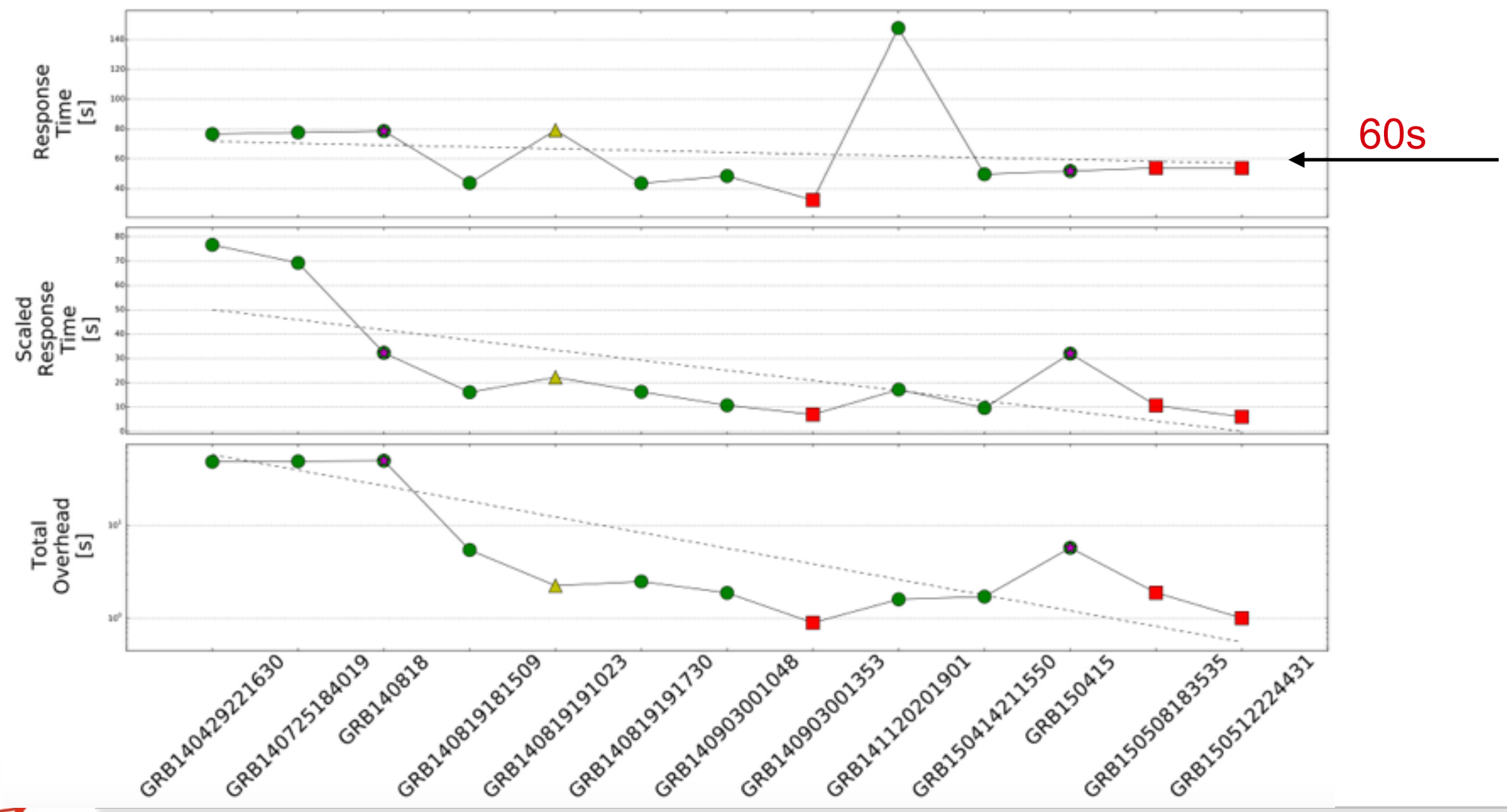


A. Balzer et al., CHEP2015

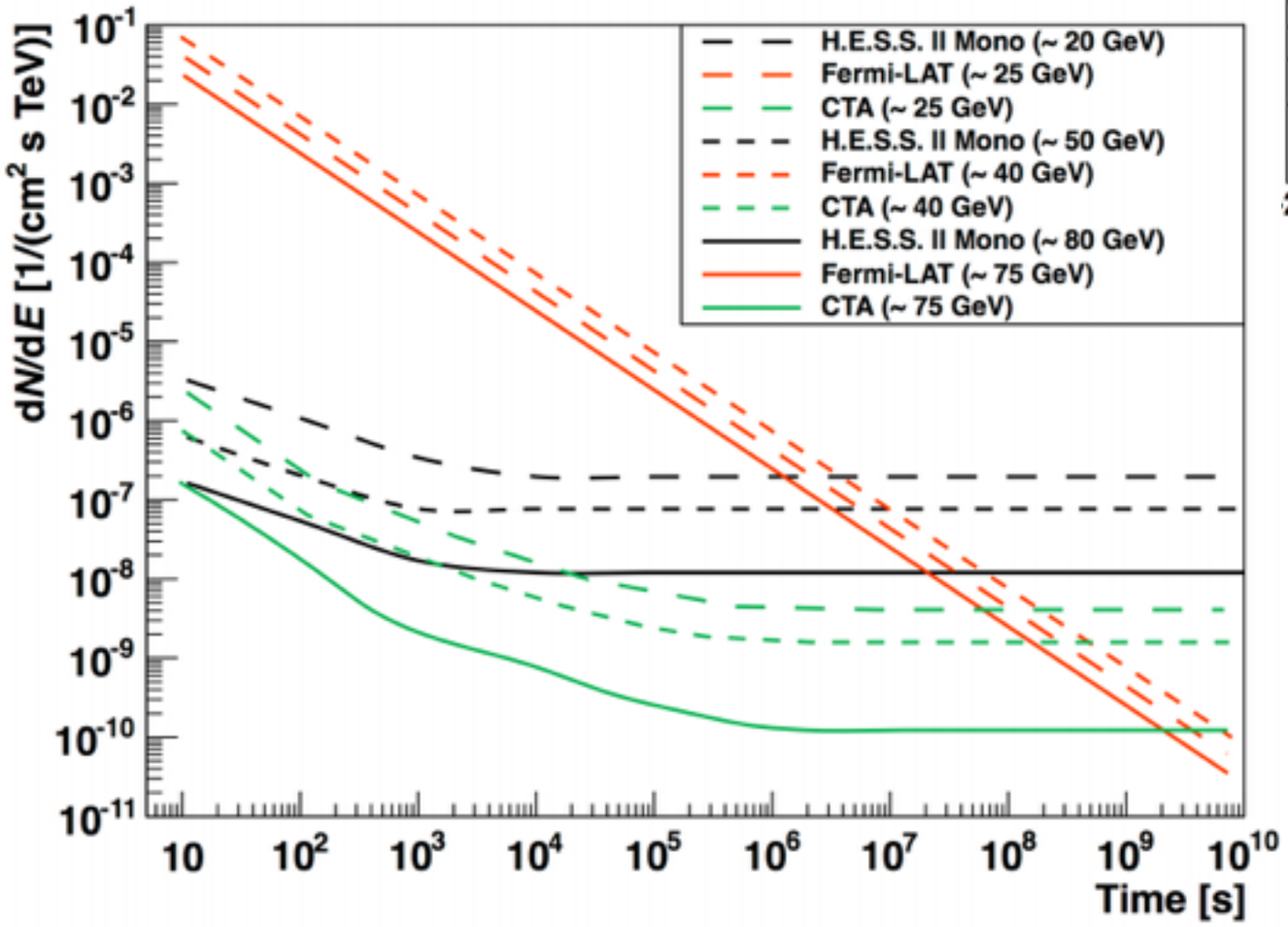
D. Parsons et al., ICRC 2015, arXiv: 1509.05191

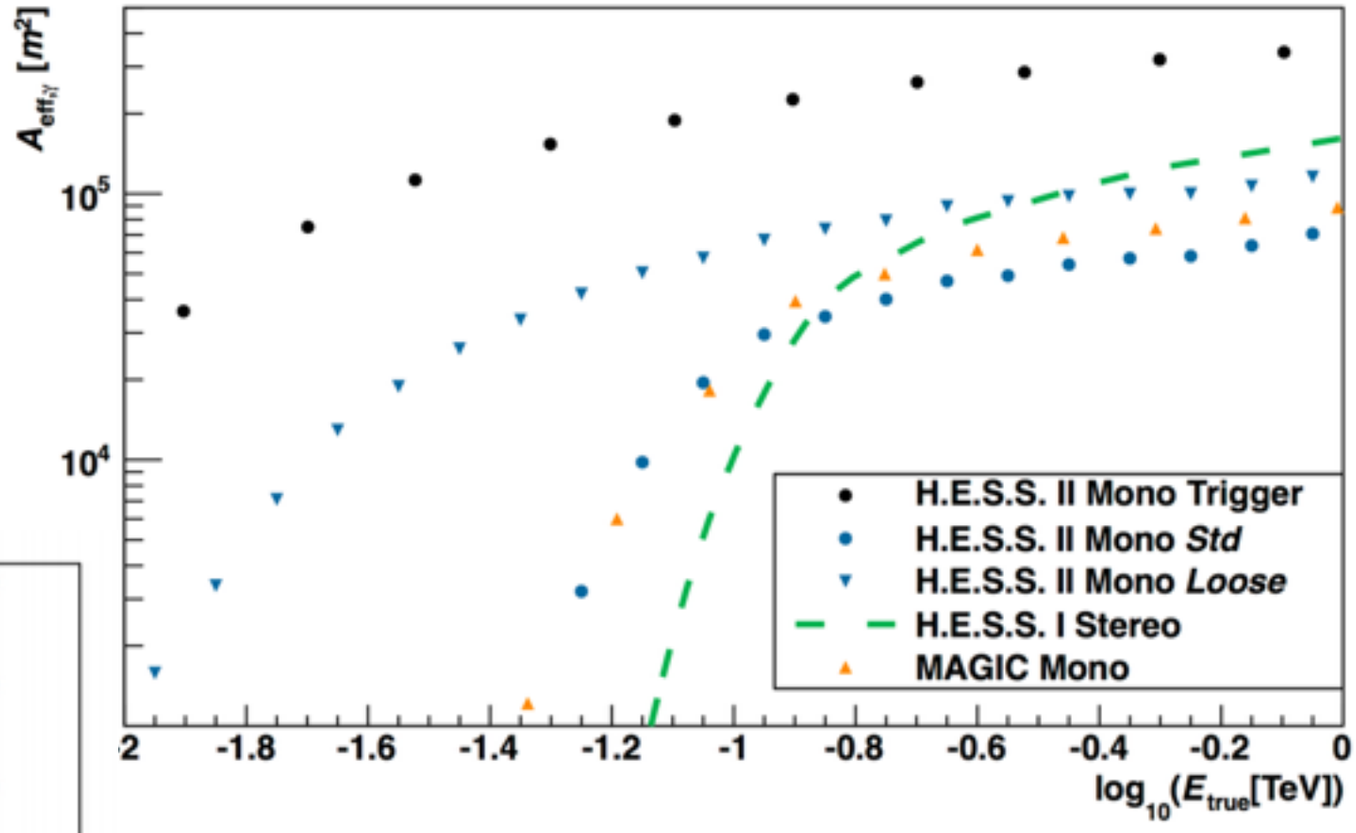
GRB follow-up: performance

- DAQ re-organisation led to significant improvement of the response time
- continuous monitoring via ”fake GRBs”: end-to-end tests of the full chain



GRB follow-up: sensitivity



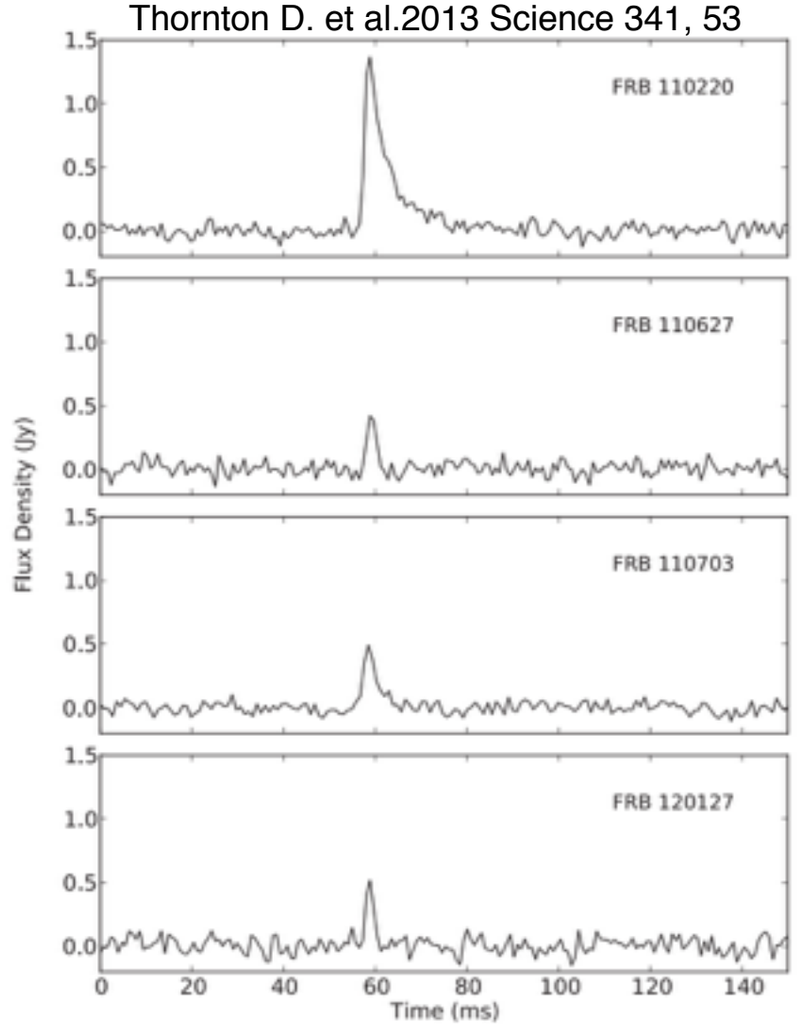


- rapid response + best sensitivity
- waiting for the first detection ;-)

Fast Radio Bursts

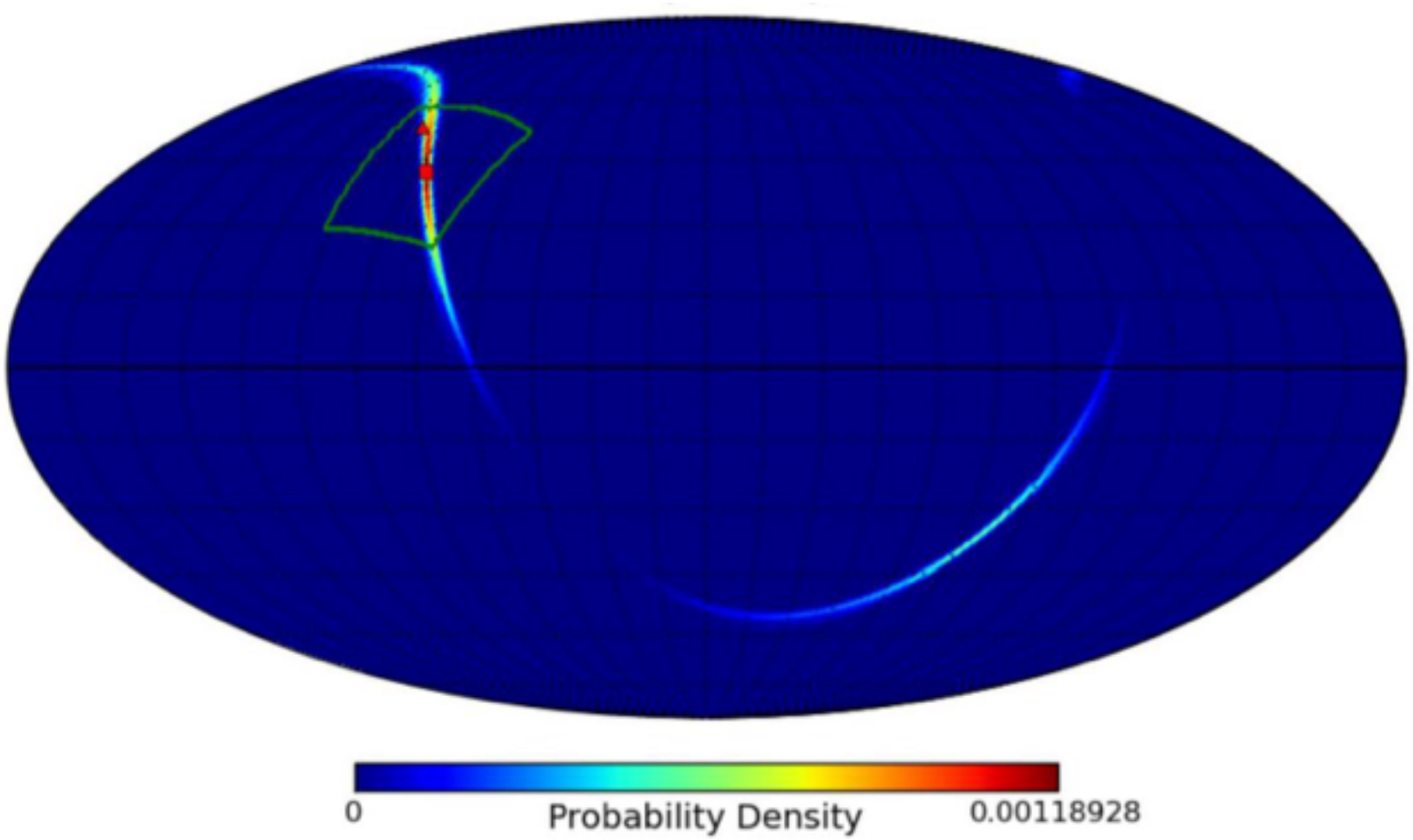
- strong, millisecond radio burst of possibly extragalactic origin
- H.E.S.S. takes part in the SUPERB project @ Parkes
- first follow-up observations in 2015
- analysis in progress

Thornton D. et al.2013 Science 341, 53



Gravitational Waves

- Advanced LIGO taking first physics data
- H.E.S.S. takes part in the extensive EM follow-up program
- localization typically poor O(100 deg^2)
- follow-up decision on case-by-case basis



I. Bartos, AMON 2014

Summary

- H.E.S.S. phase II: lower energy threshold and rapid response
- Multi-messenger program
  - Neutrinos
    - hotspot + HESE source searches
    - ToO programs starting
- Follow-up of alerts and ToOs
  - GRBs
    - improved performance: average response time <60s
    - highest priority
  - Fast Radio Bursts
  - Gravitational Waves