Initial Results from HAWC on Gamma-Ray Bursts

Joshua Wood
for the HAWC Collaboration

HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

UNIVERSITY OF MARYLAND
18 56

6th Fermi Symposium
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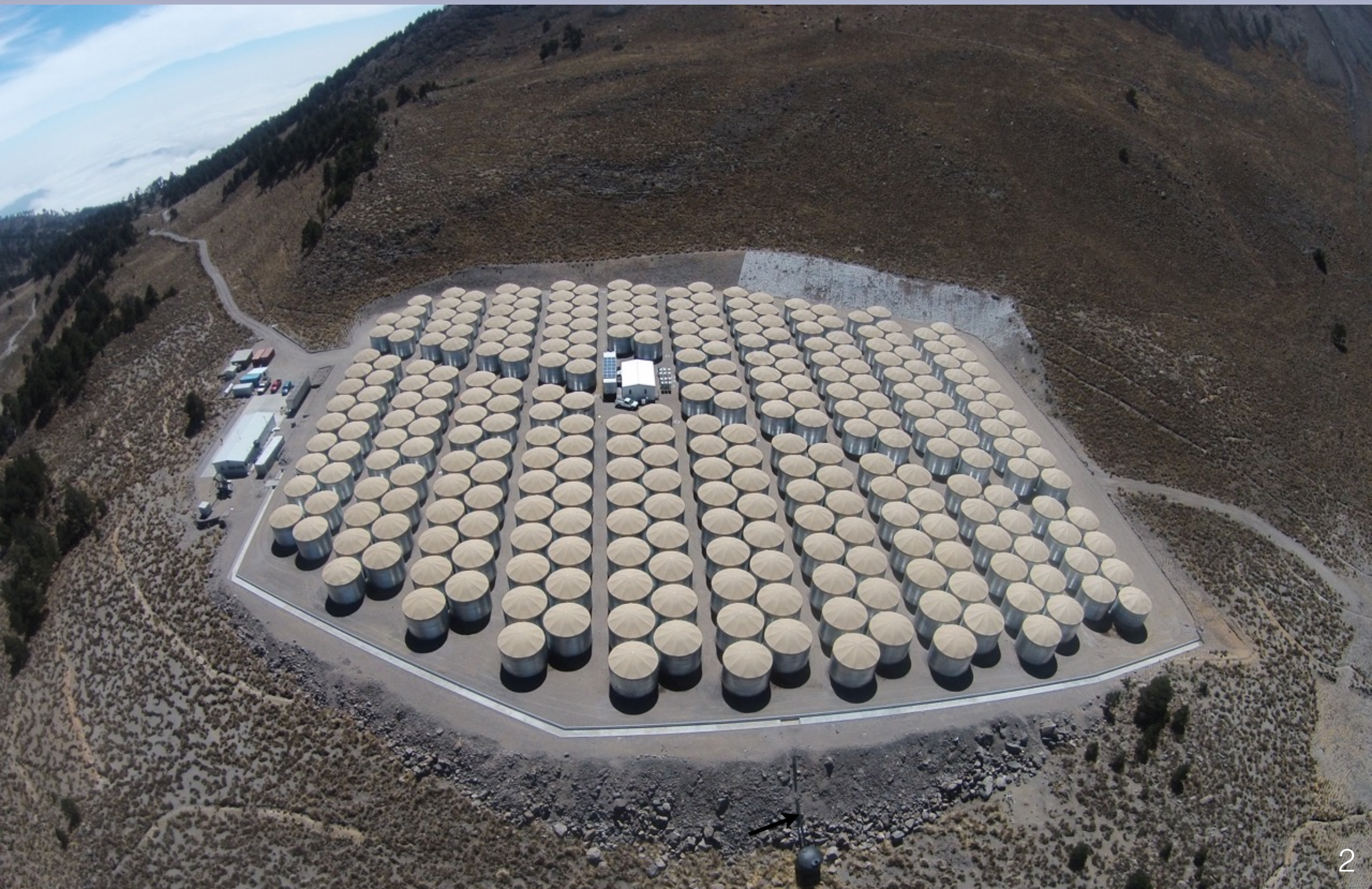
Outline

- What is the HAWC Observatory?
- What can it contribute to GRB Science?
- Initial Results on Gamma-Ray Bursts
- Current real-time searches

HAWC Overview



HAWC Overview

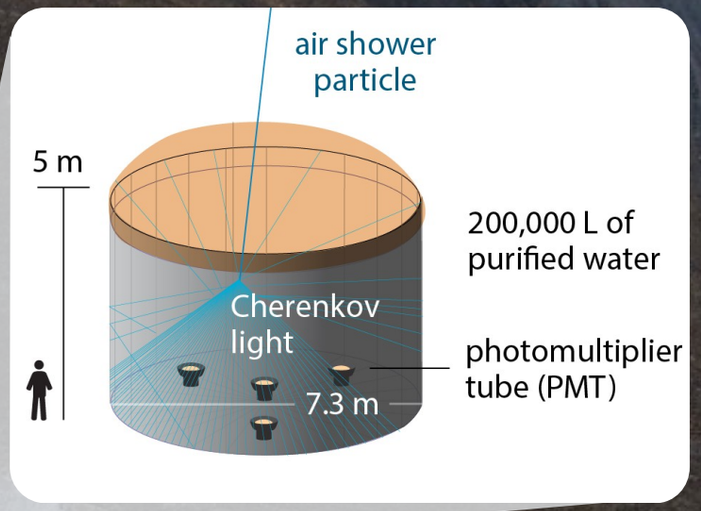
- High Altitude Water Cherenkov Observatory

- Inaugurated in March, 2015

- In central Mexico at an altitude of 4100 m

- Comprised of 300 water tanks instrumented with 4 upward facing photomultiplier tubes

- Detects secondary air shower particles at ground level from both gamma- and cosmic-ray primaries



HAWC Overview

- continuous readout of air shower events @ 24 kHz trigger rate

- for each event we reconstruct its angle & energy and determine type (γ or CR)

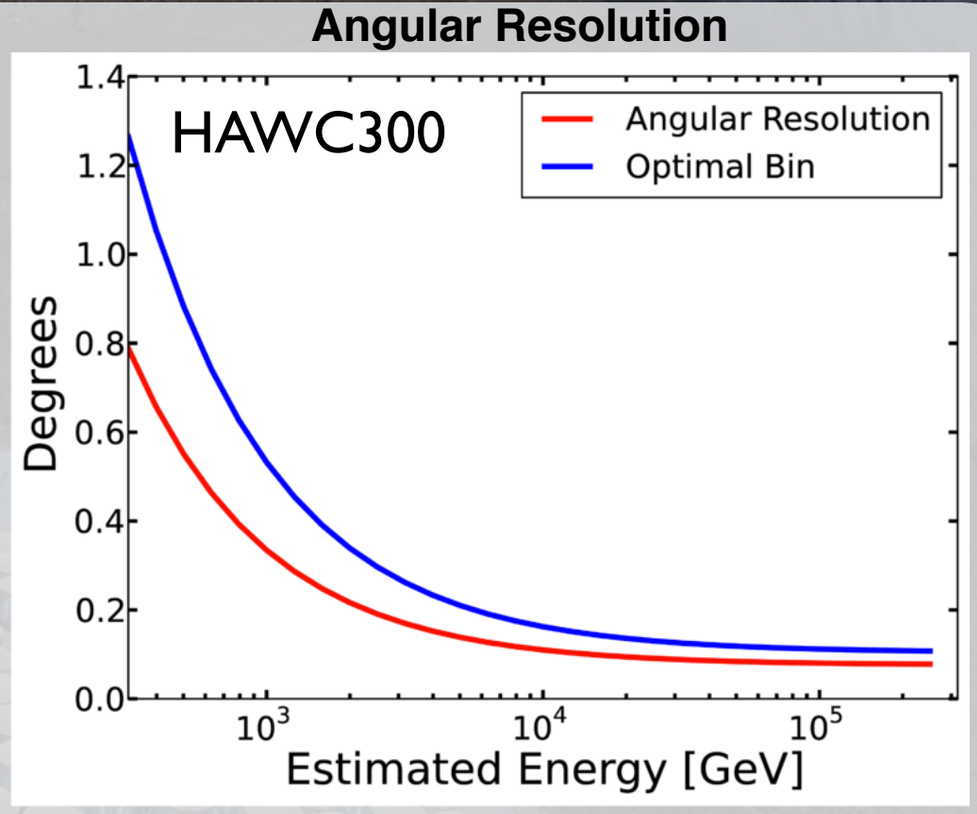
- ~100 GeV threshold near zenith

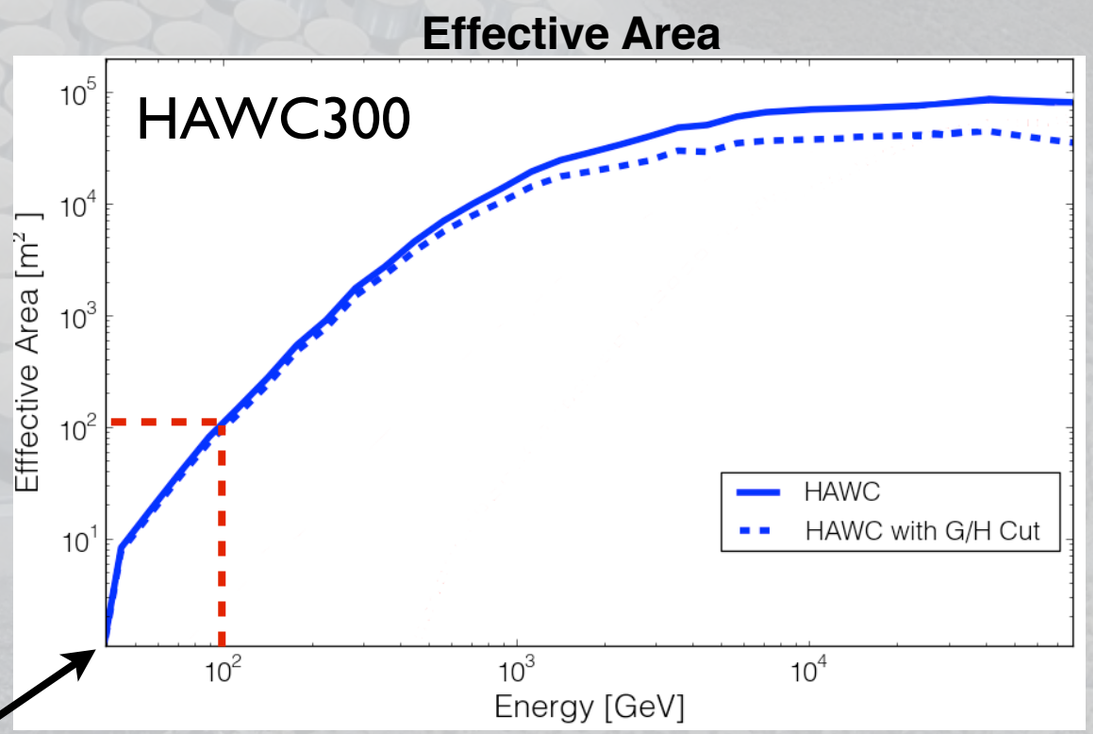
- angular resolution < 1.0°

- near 100% duty cycle

- 2 sr FoV (no need for pointing)

- 100 times size of FERMI @ 100 GeV

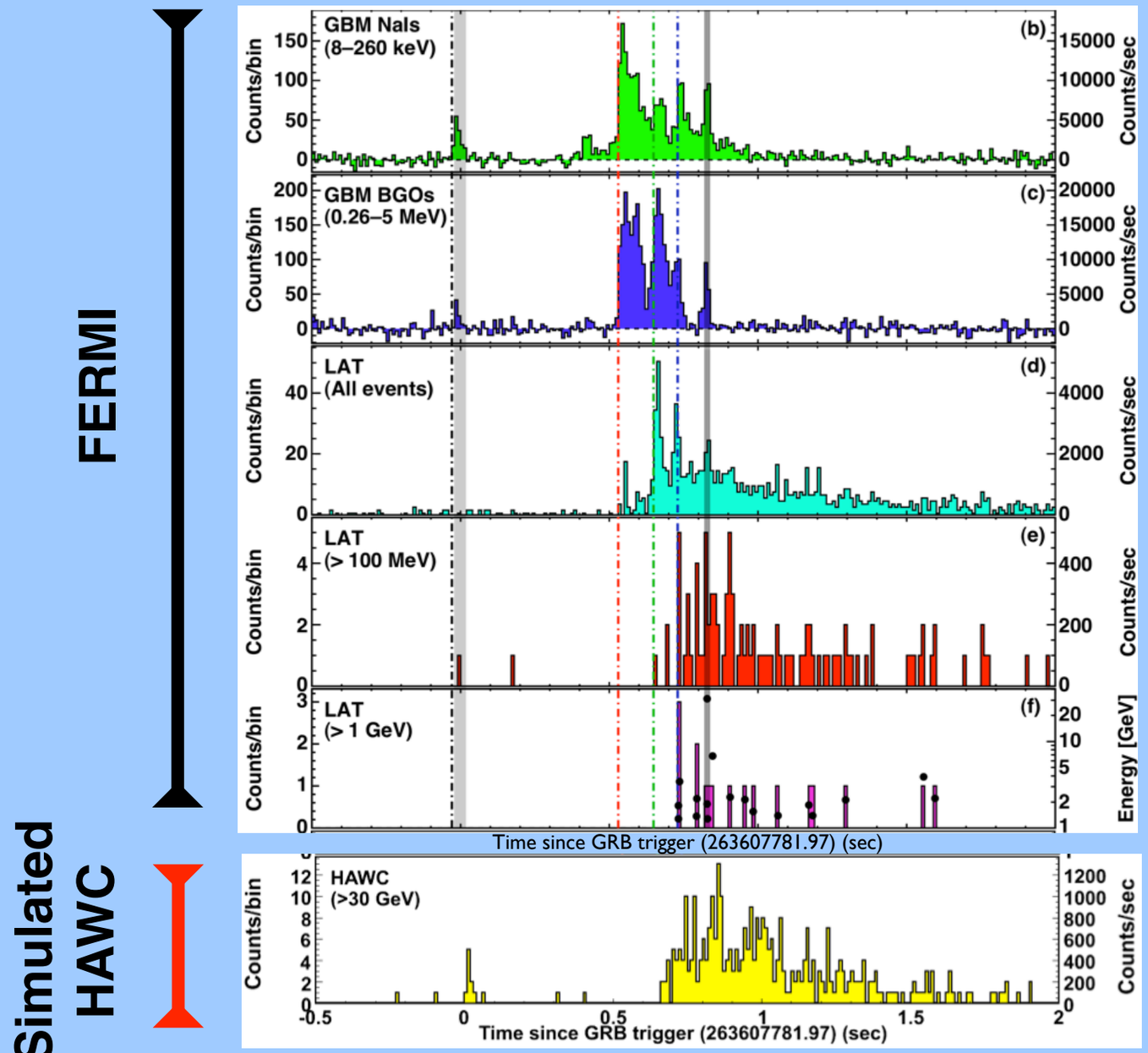




FERMI-LAT ~1m^2

HAWC and GRBs

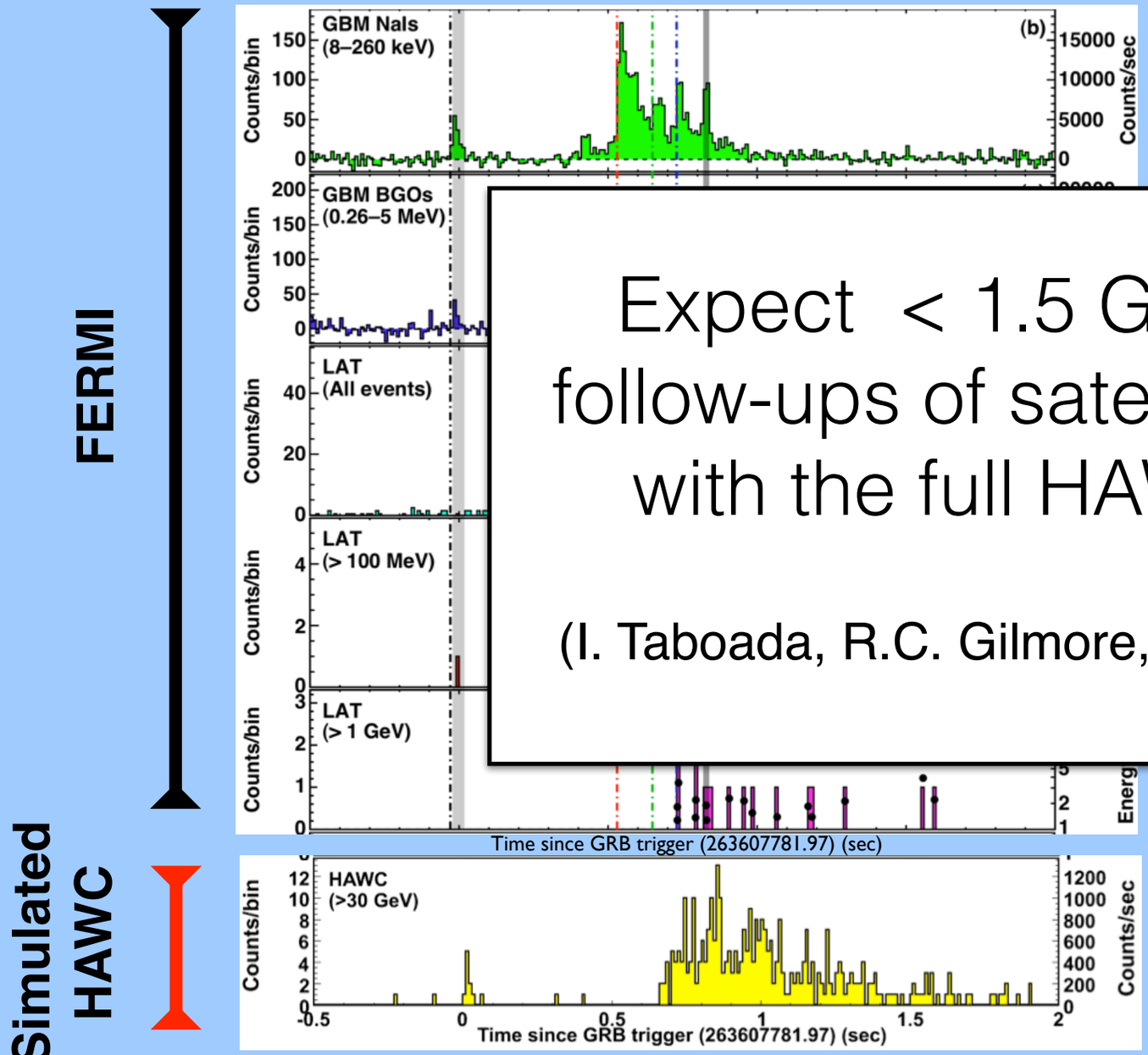
Simulated response to GRB090510



- Simulate response to GRB090510
  - extrapolate FERMI SED with abrupt 125 GeV cutoff
  - z = 1
  - cos(Θ) = 0.9
  - 200 signal photons
- HAWC can see full high energy time structure before, during & after a GRB

HAWC and GRBs

Simulated response to GRB090510



- Simulate response to GRB090510

ED
cutoff

Expect < 1.5 GRB per year from follow-ups of satellite reported GRBs with the full HAWC-300 detector

(I. Taboada, R.C. Gilmore, NIM A 742 (2014), 276-277)

- HAWC can see full high energy time structure before, during & after a GRB

Initial Results

- Follow-up observations of reported GRBs

Time Period

August 2, 2013 - July 8, 2014 (HAWC-111)

Partial detector, 83% uptime due to construction

GRB Selection

GRBs within 51˚ of zenith reported from:

LAT: 1 (GRB 130907A), but during downtime
GBM: ~40 (6 without data, only 1 since October 2013)
***Swift*:** 22 (4 without data)

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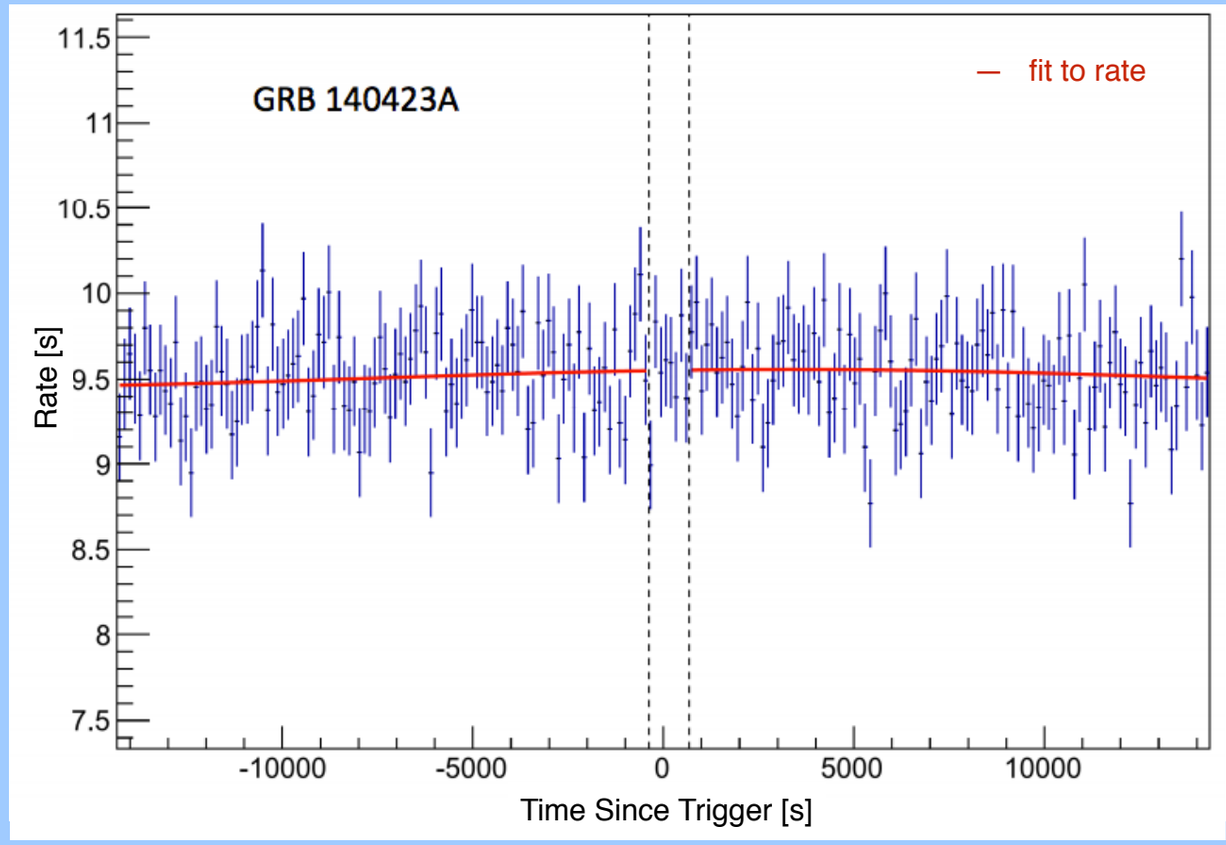
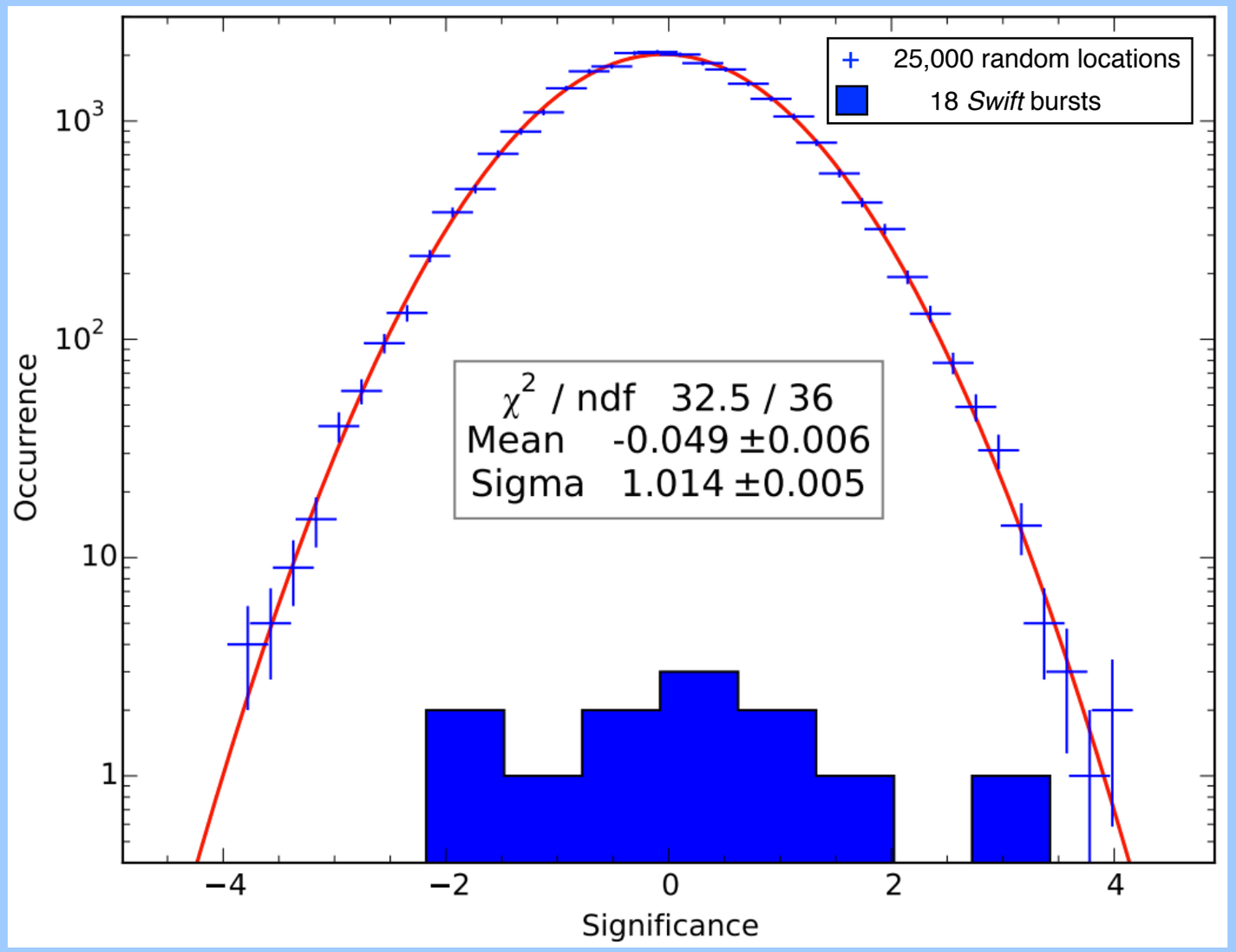
Analyzed 18 well localized bursts from *Swift*

Follow-up Method

- Define a 3° radius spatial bin (optimized for GRB gamma-rays seen by HAWC-111) around the reported *Swift* location.
- Count the number of air showers arriving in this bin during T90
- Compare to expected counts from rate at that location in local coordinates ⟶
- Obtain p-value from Poisson statistics and convert to σ



Follow-up Results

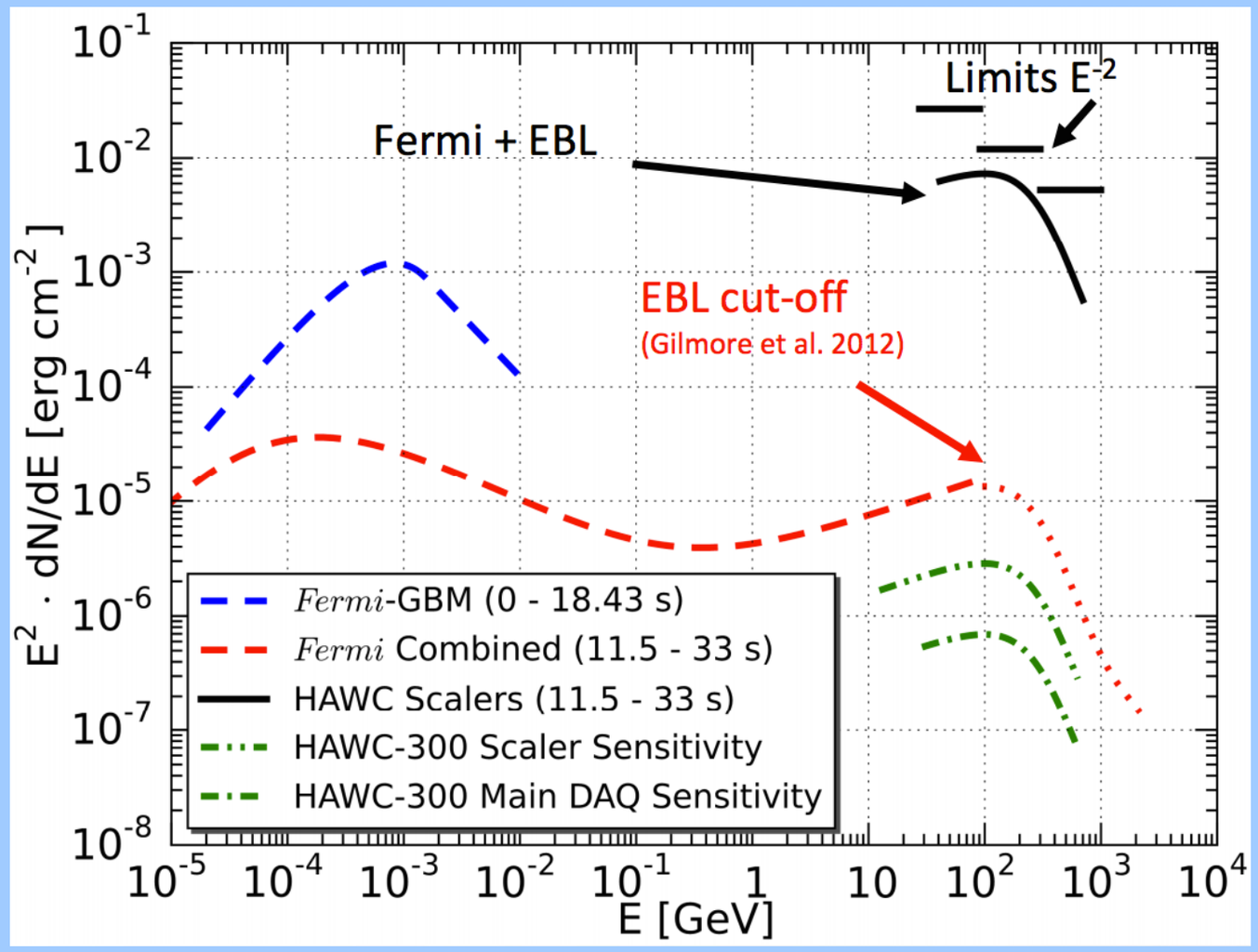


- No >5σ detections
- Most significant result is GRB140607A 3.4σ pre-trials, 2.5σ post-trials
- Performing the follow-up method on 25,000 random locations across the sky throughout HAWC-111 period yields μ = 0, σ = 1

Full list of analyzed GRBs: D. Lennarz, I. Taboada. Proceedings of the 34th ICRC http://arxiv.org/abs/1508.07325

GRB130427A

- Most powerful ever detected z < 0.5. Longest high energy emission.
- Main data acquisition system (DAQ) was OFF at the time
- Less sensitive scaler DAQ was ON. No direction, just overall PMT rates. Provides limits on high energy emission.
- Easily detectable now with HAWC-300!



HAWC collaboration, ApJ 800 (2015) 78

Real-Time GRB Searches

- HAWC triggers and reconstructs showers in real-time (~ 4 sec), all day, every day

- Currently running two search methods on real-time data:

Method 1: Follow-ups of *Swift* triggers with ~2 min latency (same as presented here, but with full HAWC300)

Method 2: Untriggered search of the full overhead sky on 4 timescales (0.1, 1, 10, 100 sec) with ~4 sec latency

Idea is roughly the same as method 1 (tile sky with optimal bins, analyze poisson distributed counts within fixed window) but you search the full sky continuously in time.
Lots of trials!

Full details: J. Wood. Proceedings of the 34th ICRC
http://arxiv.org/abs/1508.04120

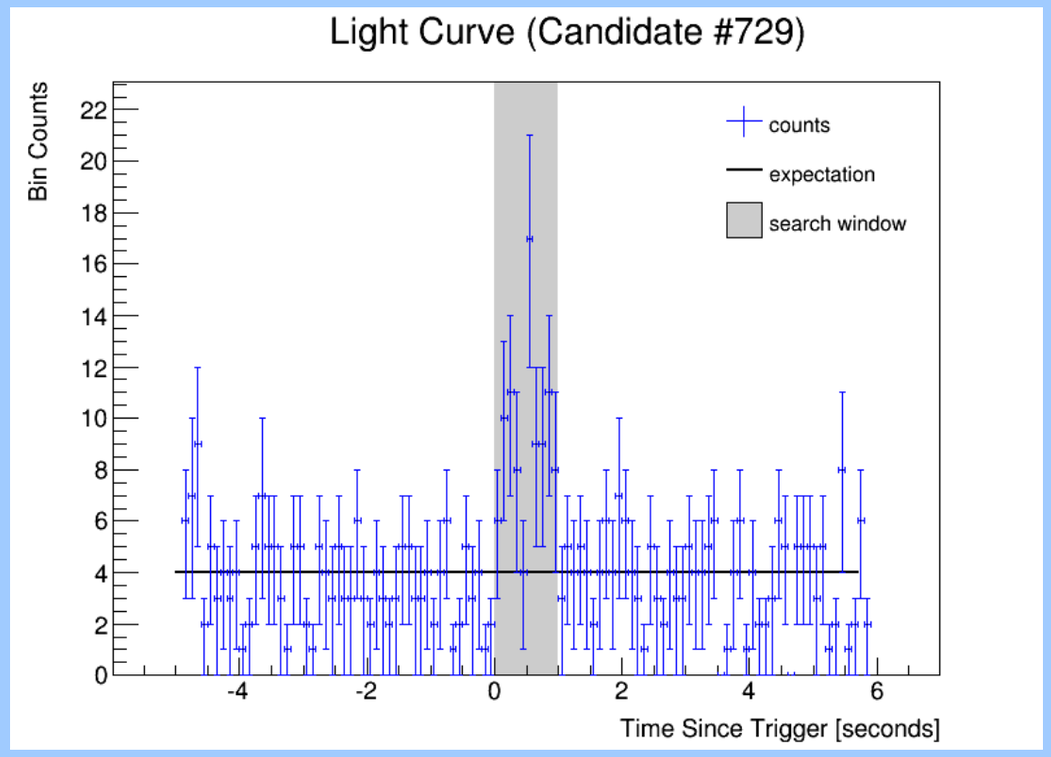
Untriggered, All-Sky Search

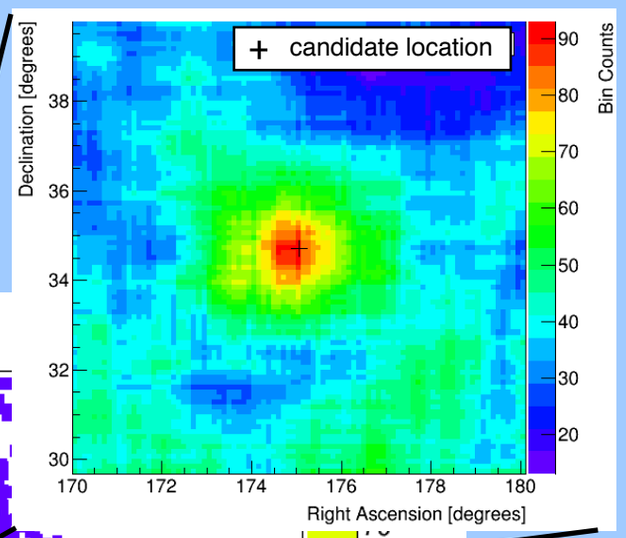
- 1 second duration, shifted by 10% over the course of a full day with spatial bins shifted by 10% over the full sky yields ~10^{12} trials

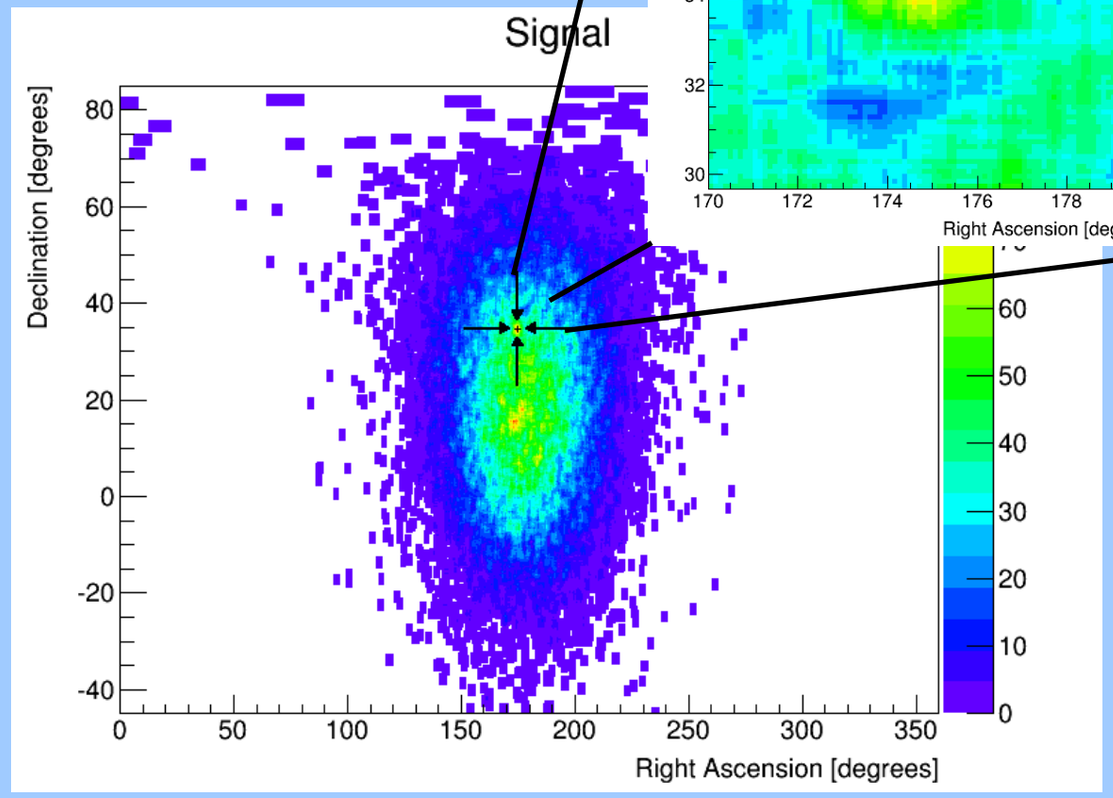
- Only requires 2x flux increase over triggered search, opens up sky where satellites are not overhead

- Let's you see really cool background fluctuations!

$P_{pre} = 6 \times 10^{-13}$, $P_{post} = 4 \times 10^{-2}$







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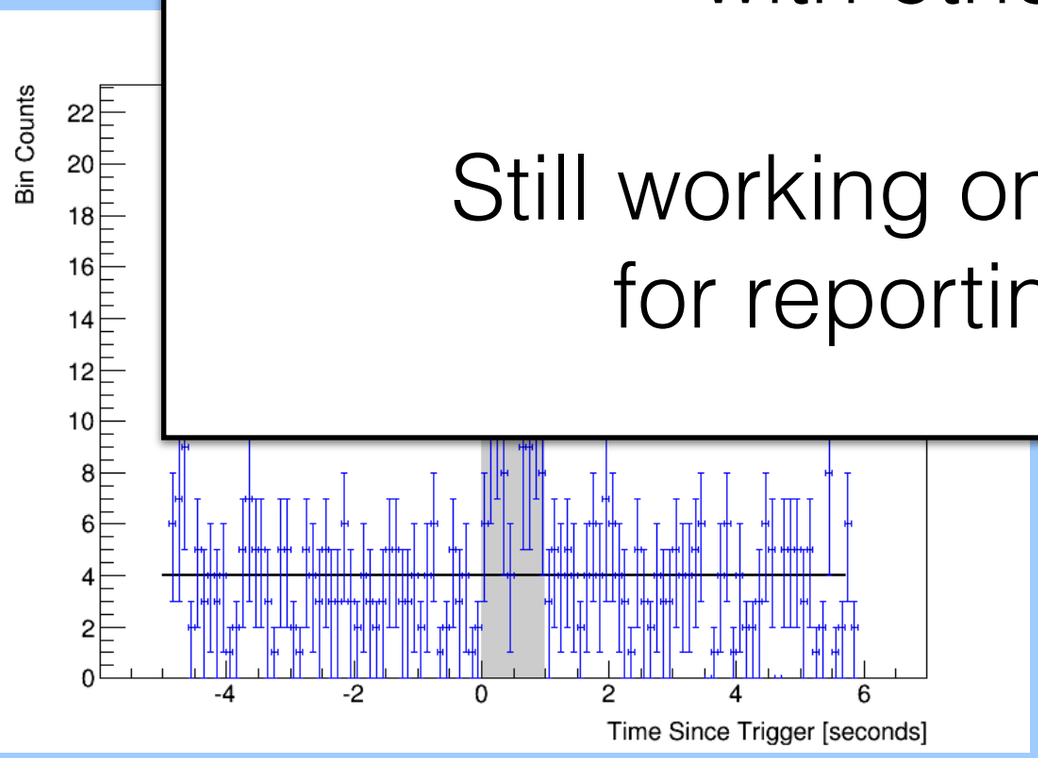
- 1 second duration, shifted by 10% over the course of a full day with spatial bins shifted by 10% over the full sky yields ~10^{12} trials
- O… …ky wh…
- Le…

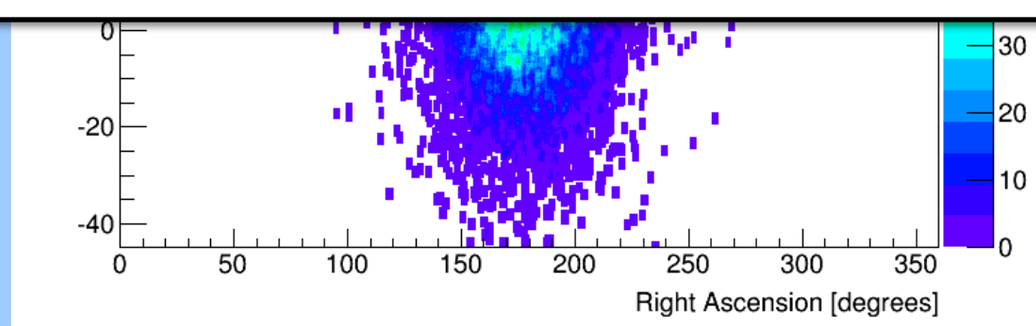
P…

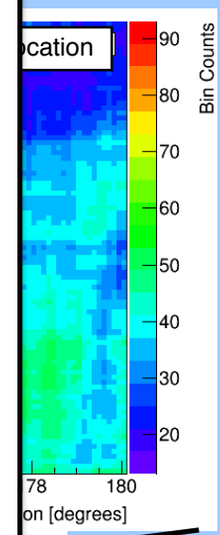
No significant detections yet.

AMON is working on adding our sub-threshold events to their database for correlation with other experiments.

Still working on getting a framework for reporting results to GCN.







Summary

- HAWC should be able to detect ~1 GRB per year, providing temporal and spectral information at ~100 GeV
- Sensitive enough to detect several historical bursts (GRB090510, GRB130427A)
- Running both triggered and untriggered GRB searches in real-time
- No significant detections yet, but the future is bright!

Backup

18 *Swift*-detected GRBs

GRB	Trigger Number	Time UTC	RA J2000	DEC J2000	Zenith Angle deg	BAT T90 s	Significance σ
140628A	602803	13:35:37	02h42m39.88s	-0d23m05.7s	26.0	10.5	-0.74
140622A	602278	09:36:04	21h08m41.56s	-14d25m09.5s	33.4	0.13	-0.93
140607A	601051	17:13:31	05h45m29.52s	18d54m14.4s	27.9	109.9	3.42
140518A	599287	09:17:46	15h09m00.60s	42d25m05.6s	48.6	60.5	-0.61
140430A	597722	20:33:36	06h51m44.61s	23d01m25.2s	31.3	173.6	-1.75
140423A	596901	08:31:53	13h09m08.54s	49d50m29.4s	46.9	134	0.21
140419A	596426	04:06:51	08h27m57.56s	46d14m25.3s	45.3	94.7	1.35
140414A	GA	06:06:29	13h01m14.40s	56d54m07.2s	37.8	0.7	-0.18
140408A	595141	13:15:54	19h22m51.83s	-12d35m42.5s	32.4	4.00	-0.02
140331A	594081	05:49:48	08h59m27.46s	02d43m02.3s	45.7	209	-2.18
140215A	586680	04:07:10	06h56m35.81s	41d47m11.7s	23.2	84.2	0.30
140206A	585834	07:17:20	09h41m20.26s	66d45m38.6s	47.7	93.6	-1.86
140129A	585128	03:23:59	02h31m33.78s	-01d35m43.4s	47.8	2.99	1.65
140114A	583861	11:57:40	12h34m05.16s	27d57m02.6s	11.1	139.7	0.29
131229A	582374	06:39:24	05h40m55.61s	-04d23m46.7s	27.7	13.86	1.23
131227A	582184	04:44:51	04h29m30.78s	28d52m58.9s	10.1	18.0	-0.48
131117A	577968	00:34:04	22h09m19.36s	-31d45m44.3s	50.9	11.00	0.27
131001A	GA	05:37:24	00h33m12.96s	25d33m25.2s	12.4	4.9	0.96