# **First results from HAWC on GRBs**

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3<sup>rd</sup> of August 2015







### Gamma-Ray Bursts (GRBs)

- Central engine (e.g., the core-collapse of a rapidly rotating star, merger of two compact stellar remnants)
- Collimated relativistic outflow (fireball)
- Internal and external shocks
- Prompt keV– MeV emission  $(10^{-2} 10^3 s)$
- Multiwavelength afterglow emission



Artist impression of a GRB. Credit: NASA/Dana Berry, SkyWorks Digital

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# **GRBs at Higher Energies**

#### Fermi-LAT

- High energy (HE, > 100 MeV) emission delayed
- HE emission temporally extended
- GRBs produce photons at very high energies (VHE, >100 GeV)

Acceleration mechanisms?

#### **VHE Observation of GRBs**

- Acceleration mechanisms (e.g. VHE photons challenge synchrotron emission scenarios)
- Probe the extragalactic background light (EBL)
- Search for Lorentz invariance violation



Artist impression of a GRB. Credit: NASA/Dana Berry, SkyWorks Digital

# > 10 GeV Gamma-Ray Observatories

# Wide Field of View

### **Continuous Operation**



Artist impression of Fermi. Credit: Fermi collaboration

Fermi

AGILE EGRET



**TeV Sensitivity** 

HAWC

Milagro

ARGO

Tibet AS- $\gamma$ 



H.E.S.S. VERITAS MAGIC



34th International Cosmic Ray Conference

- Sierra Negra volcano near Puebla, Mexico
- High altitude: 4,100m
- 20,000 m<sup>2</sup> covered with 300 water Cherenkov detectors (WCD)
- 200,000 litres of purified water per WCD
- 1,200 PMTs
- Completed in March 2015







# HAWC Limits on GRB 130427A

- Most powerful burst ever detected z < 0.5
- Longest lasting HE emission ever detected

- Low in the sky for HAWC
- 10% of final detector
  - **Upper limits**
  - Easily detectable for the final detector at low zenith!



## HAWC GRB Observations

- Science operations started August 2, 2013
- HAWC-111: data until July 8, 2014
- Uptime fraction 83% (includes time for construction)

#### **GRB** selection

- Using LAT, GBM, *Swift* online tables
- Considering GRBs down to a zenith angle of 51°
- LAT: 1 (GRB 130907A), but during downtime
- GBM: ~40 (6 without data, only 1 since October 2013)
- Swift: 22 (4 without data)

Analyse the 18 well localized Swift bursts



### **Analysis Method**



- Define angular bin (search bin) around GRB position
- Estimate number of background events in search bin
- Significance of excess from Poisson distribution

#### Optimal search bin size

- GRB with E<sup>-2</sup> spectrum
  - Optimise signal (S) over square root of background (B)
    - Depends on burst redshift z
      - Conservatively chose 3°



### **Detector Rate**



Search duration: T<sub>90</sub>

Rate is constant with 12 h sinusoidal oscillation on top (~0.5%)



### **Search Bin Rate**



- ON/OFF method (at T=0 follow GRB for  $T_{90}$ , otherwise offset search bin by multiples of  $T_{90}$  in right ascension)
  - Red line: scaled detector rate to match summed counts in search bin



### Results

GRB	Trigger	Time	RA J2000	DEC J2000	Zenith Angle	BAT T90	Significance
	Number	UTC			deg	S	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



### Results



- 25,188 fake GRB positions in HAWC 111 data, at zenith angles between
  0 and 60°
- Well fitted by a Gaussian, background understood to the 4σ level



### **GRB 140607A**

- Only burst above 3σ
- Accounting for trials:  $2.5\sigma$
- Detected by the BAT only, *Swift* couldn't slew (Sun observing constraint)
- No other observations were reported for this GRB



# **Online Analysis**

#### **Triggered GRB analysis**

- Connected to GCN
- Apply analysis to online reconstructed data
- Results for 1s, 20s, 300s within < 2 hours

#### Untriggered GRB analysis

- Near real time
- Low latency seach of overhead sky (within 60° of zenith)
- Searching 0.1, 1, 10s
- Sensitivity cost compared to triggered search due to trials

#### Poster #68, J. Wood

The All-Sky Sensitivity of HAWC to Gamma-Ray Bursts



## Outlook

- Search other time windows than T<sub>90</sub>
- Optimised angular bin size for next stage of HAWC
- Exploring application of gamma-hadron separation cuts
- HAWC is sensitive enough to detect several historical (like GRB 090510, 090902B, 130427A)
  HAWC collaboration, Astropart. Phys. 35 (2012) 641
- In addition to exceptional bursts, HAWC might detect other GRBs with a rate as high as 1–2 GRBs per year
   Taboada & Gilmore, NIM A 742 (2014) 276
- Even the absence of detections will be useful in constraining the highest energy of GRB spectra

