

HAWC – GRB sensitivity example



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The HAWC Collaboration



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Outline

Can my favorite source be seen?

-> HAWC Latitude: 20° N.

A very, very, simplified example – not a tutorial!

A benchmark GRB

Effective area

Signal from benchmark GRB

Background rate

Optimization of search circle.

Sensitivity to a GRB

A benchmark GRB

Set the zenith at 20°

Assume a time integrated high-energy spectrum $A \times (E/\text{GeV})^{-2}$

Assume a duration of 2 s – short GRBs are best for HAWC.

A bright GRB in LAT has a fluence of 3×10^{-5} erg/cm² between 100 MeV and 10 GeV. Assume extension to higher energy.

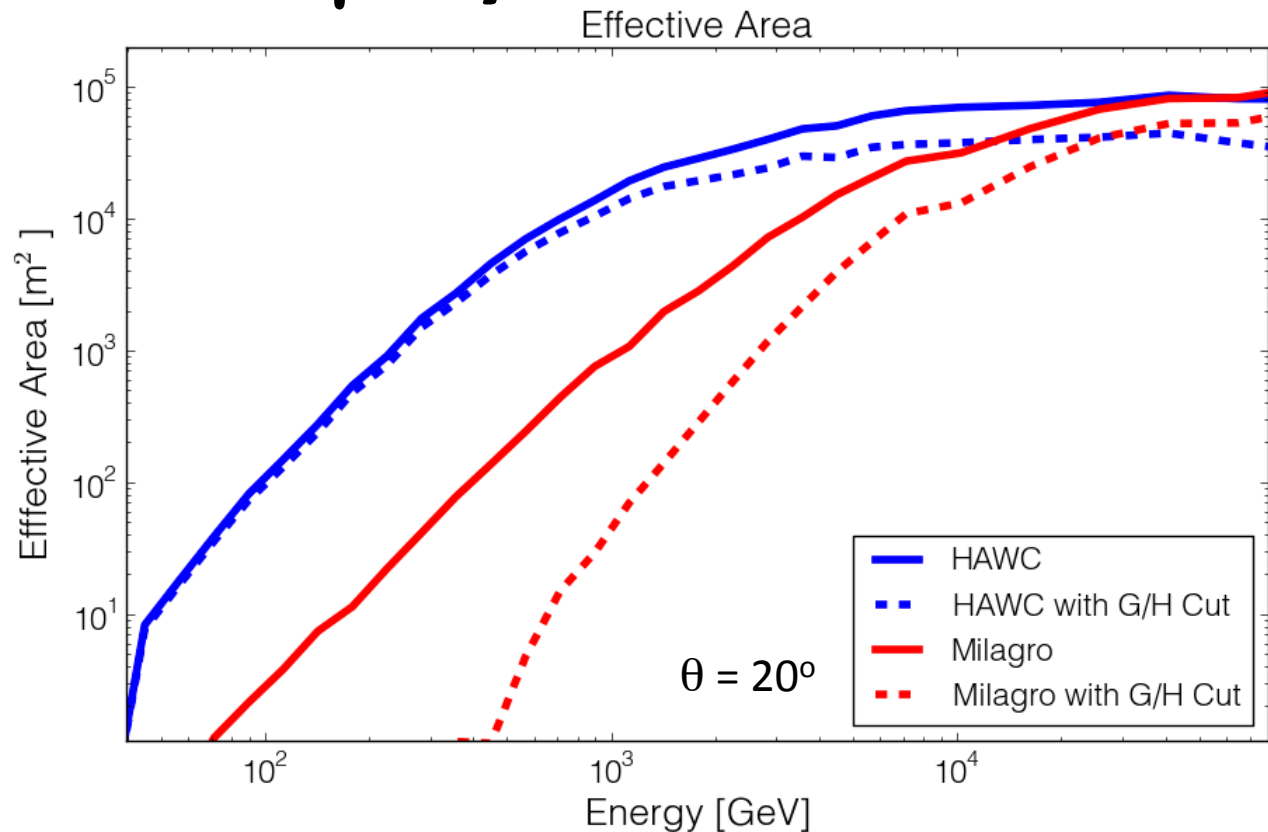
This corresponds to a time integrated spectrum:

$$4.05 \times 10^{-3} \text{ GeV}^{-1} \cdot \text{cm}^{-2} (E/\text{GeV})^{-2}$$

Use an exponential cutoff of 125 GeV

GRB 090510 inspires this benchmark.

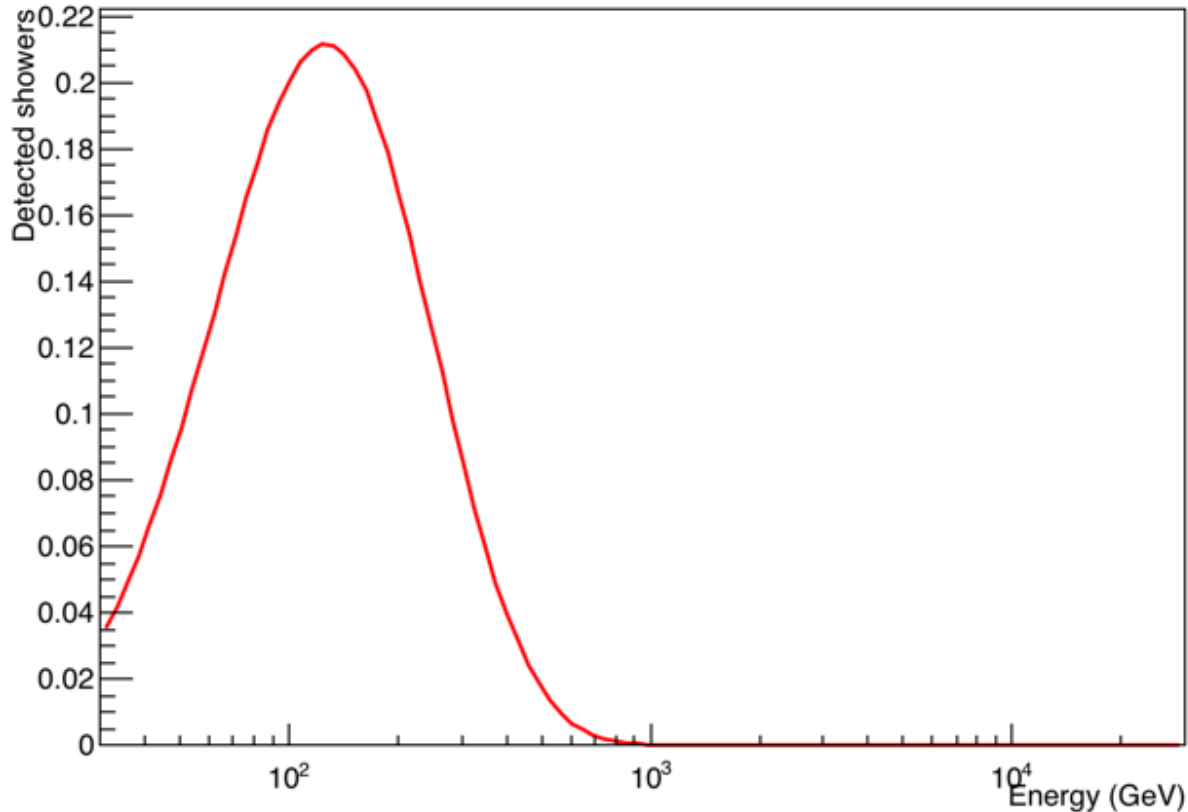
Effective area for γ -rays



$$R = \int_{E_1}^{E_2} \frac{dN}{dE} A_{eff}(E) dE$$

For this example, parameterize effective area (30 GeV – 30 TeV) at trigger level – see root example.

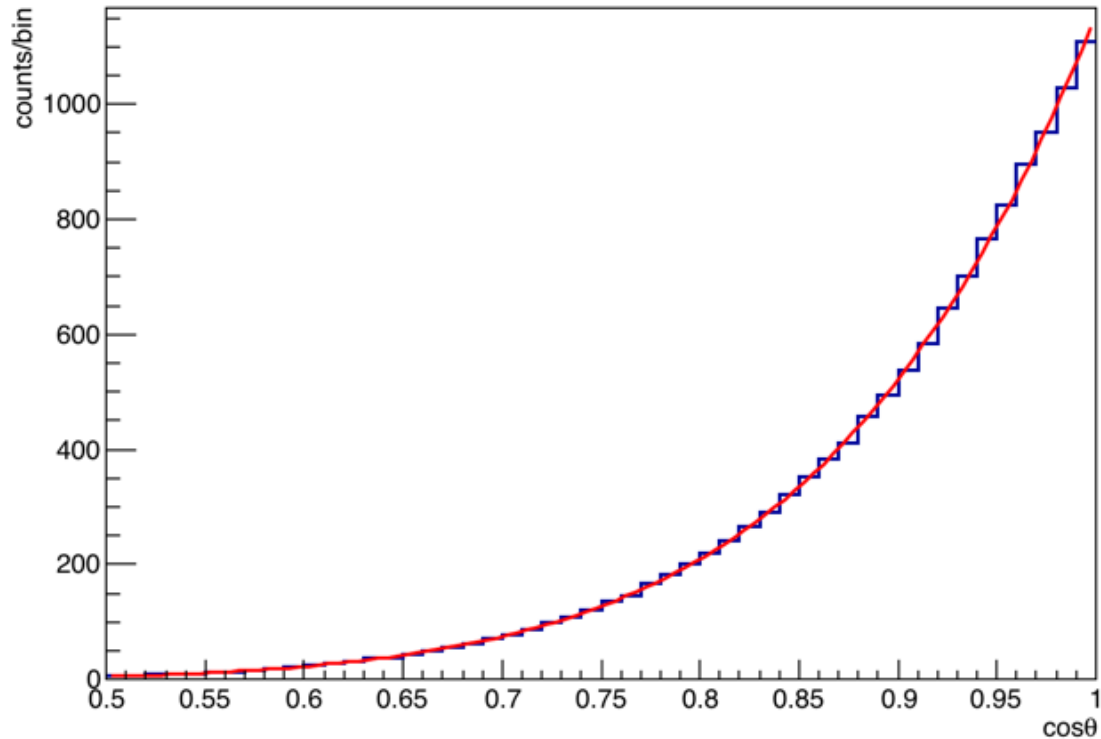
Signal from benchmark GRB



Total signal: 52 events.

Significant number of events above cutoff because of rising effective area

Background



All-sky background rate is 13 kHz.

Parameterize background as a function of $\cos\theta$. See root example.

Point spread function

Assume a Gaussian PSF of 1 degree of angular resolution

$$s(\psi) = N e^{-\psi/2\sigma^2}$$

Here ψ is the angle from the GRB to the reconstructed event.

So the signal within ψ is

$$S = \left(N \frac{\sqrt{2\pi}\sigma}{2} \operatorname{erf}\left(\frac{\psi}{\sqrt{2}\sigma}\right) \right)^2$$

Background – and optimization figure of merit

From the all-sky background fit, the background in a search circle is – valid for a small circle only, in radians, $\theta=20^\circ$.

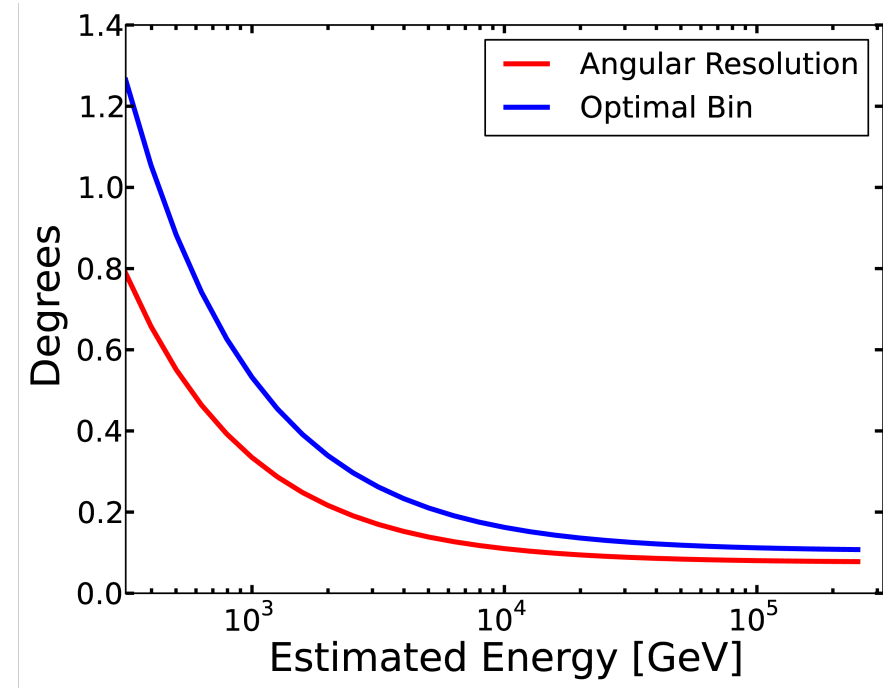
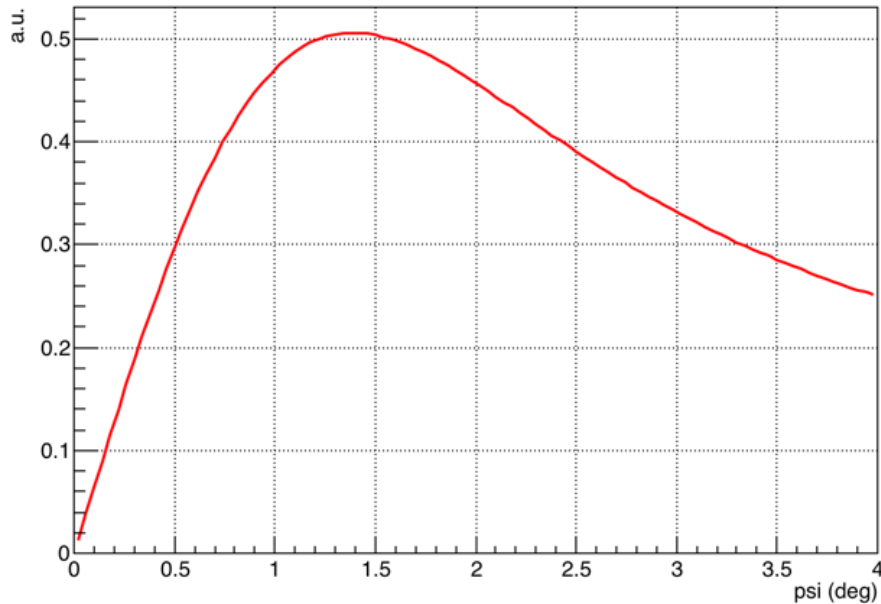
$$B = 1.15 \times 10^4 * \Delta\Omega = 1.15 \times 10^4 * \pi * \psi^2$$

(This corresponds to 11 events/second for a 1 degree circle).

Using S/\sqrt{B} as figure of merit:

$$\frac{S}{\sqrt{B}_{opt}} = \max \left(\frac{(erf(x/\sqrt{2}\sigma))^2}{x} \right)$$

Optimal search bin in this toy model



So optimal search bin for a 1° Gaussian PSF is 1.4°

Toy model final answer

Signal fraction within 1.4° : $\sim 70\%$: 36.5 events.

Background within 1.4° : 43 events (2 second duration)

Significance of benchmark GRB: 5.6 sigma.

How to improve this?

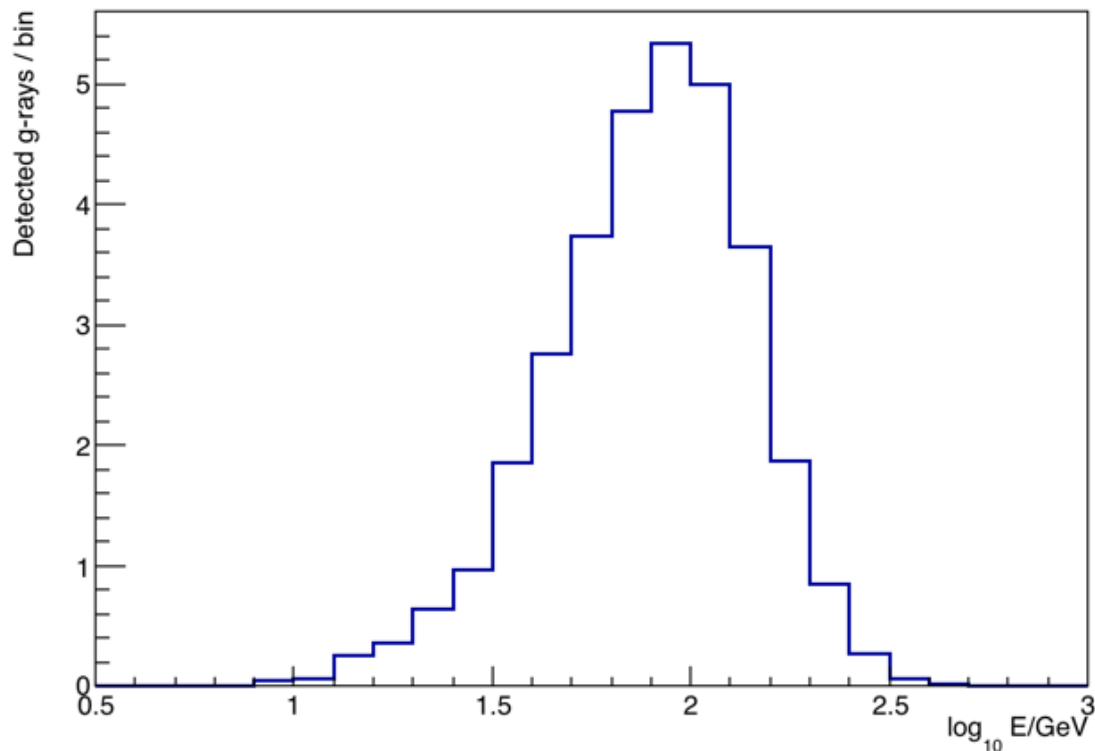
Use MC PSF (not gaussian – verify somehow)

Measure background from data -> Direct integration

Optimize search circle or optimize search circle and g/H cuts simultaneously

Significance from Li & Ma (as appropriate).

Benchmark GRB again



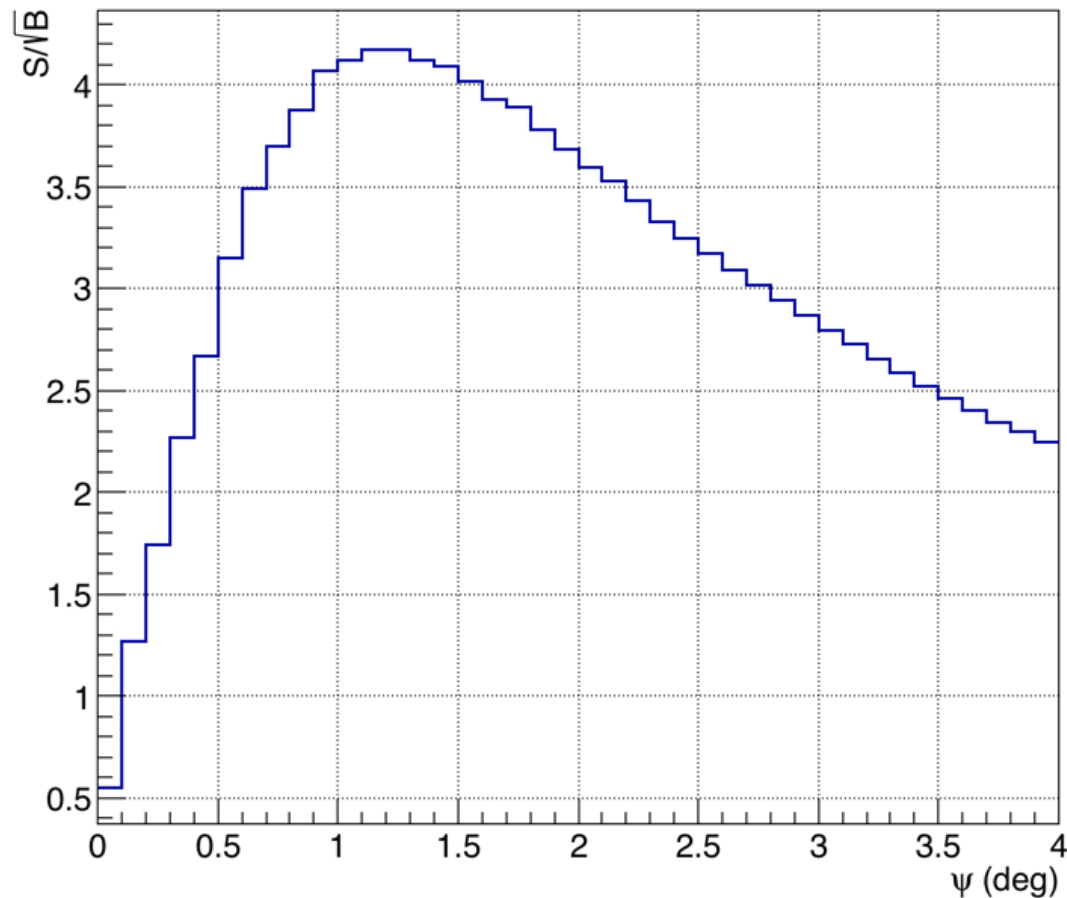
Using HAWC Monte Carlo integration.

Cutoff due to EBL at $z=1$ (Gilmore '13) instead of exponential 125 GeV.

Total signal: 32.5 evt.

Background in 1 degree circle: 11.6 events/s

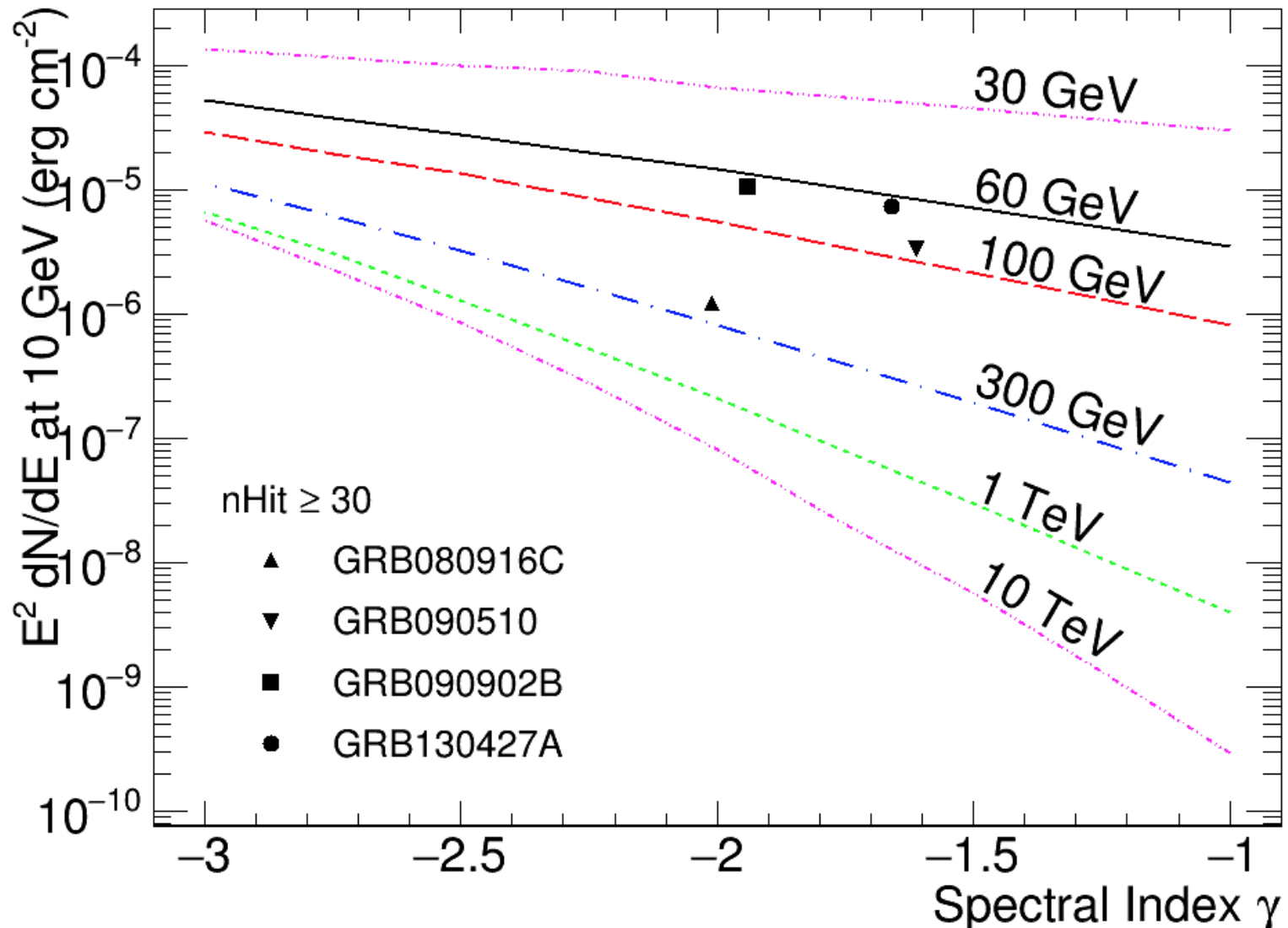
Benchmark GRB again



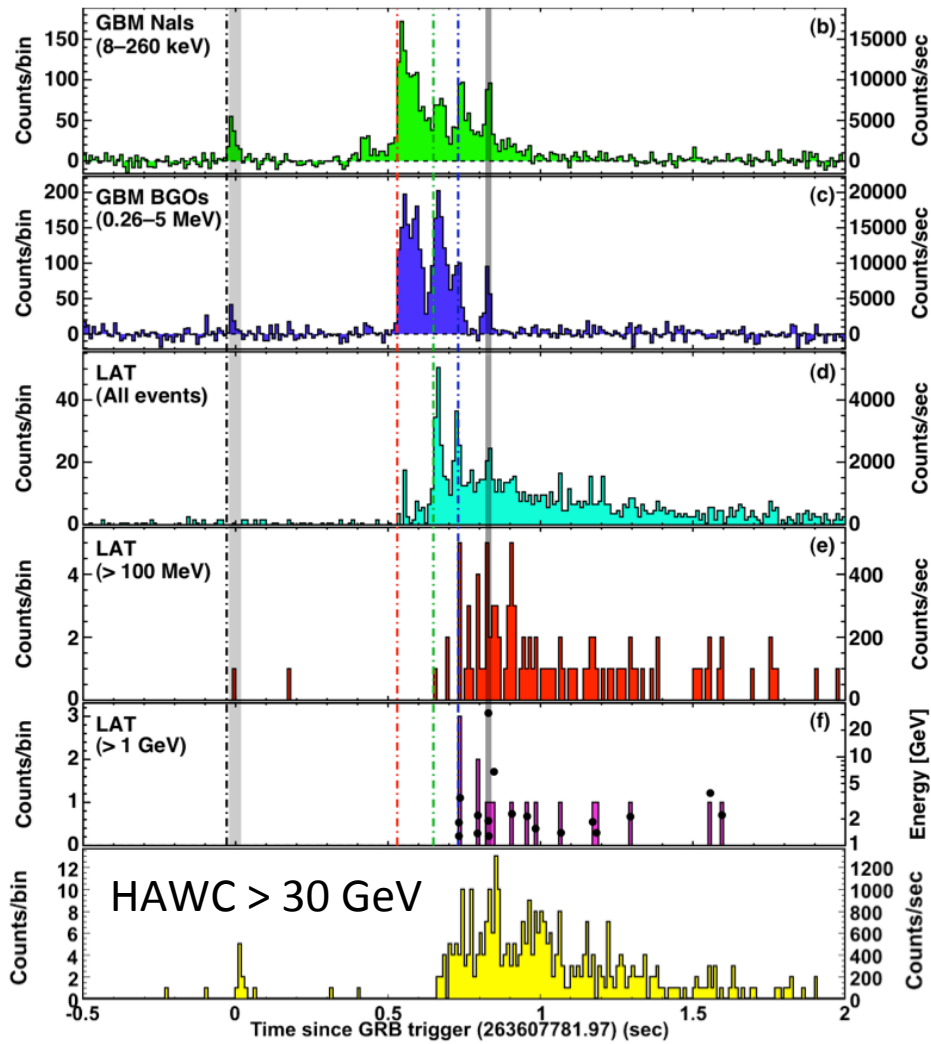
Optimal search bin $\sim 1.2^\circ$

Max significance: ~ 4.2 sigma

GRB sensitivity – with g/H cuts



Fake lightcurve



GRB 090510 spectrum extends to 125 GeV and taking into account EBL:
~200 photons above 30 GeV

