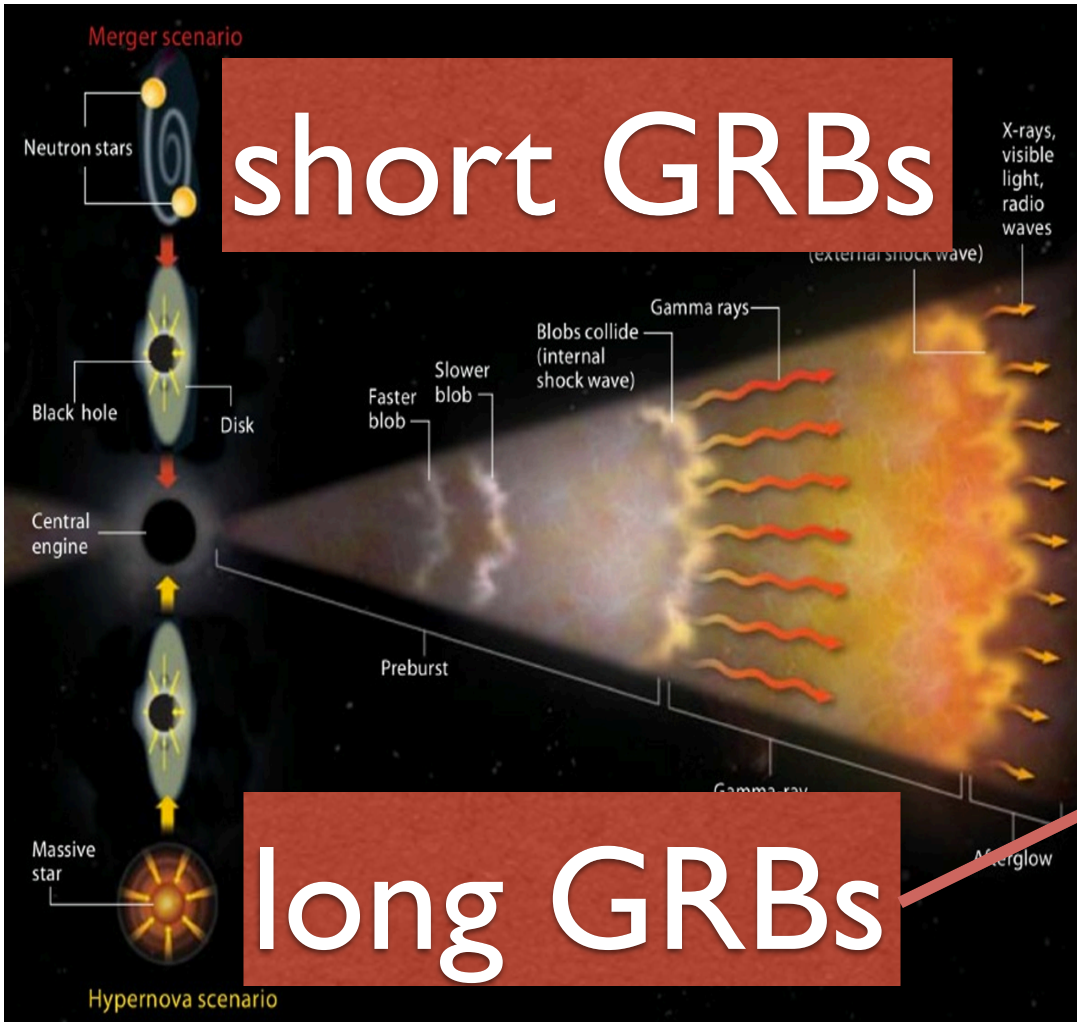
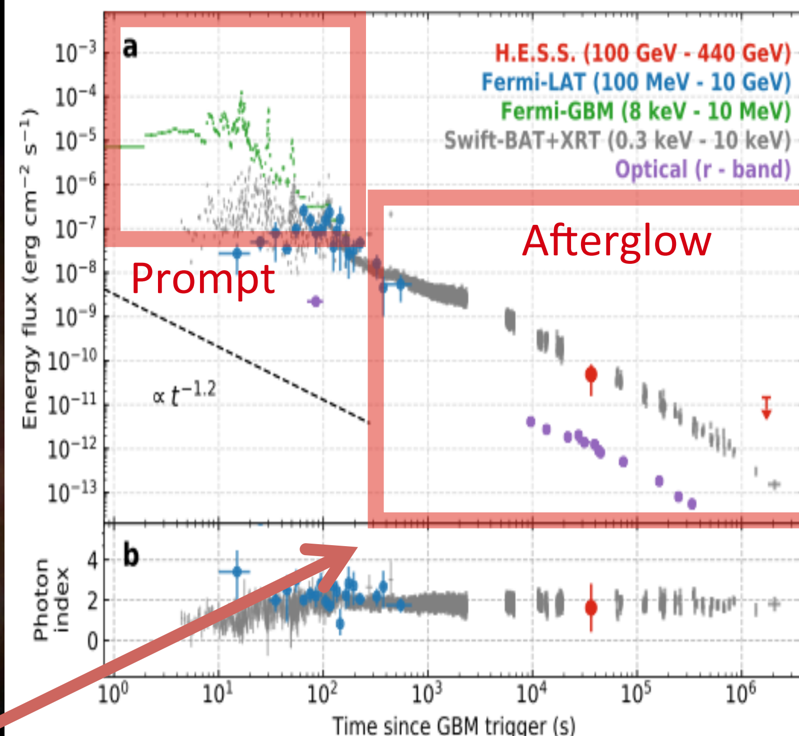
HESS Observations of GRBs





Nature **575,** 464–467 (2019)

DESY.

Credit: NASA

H.E.S.S.

Indications of Gamma-Ray Bursts at VHE by Fermi-LAT

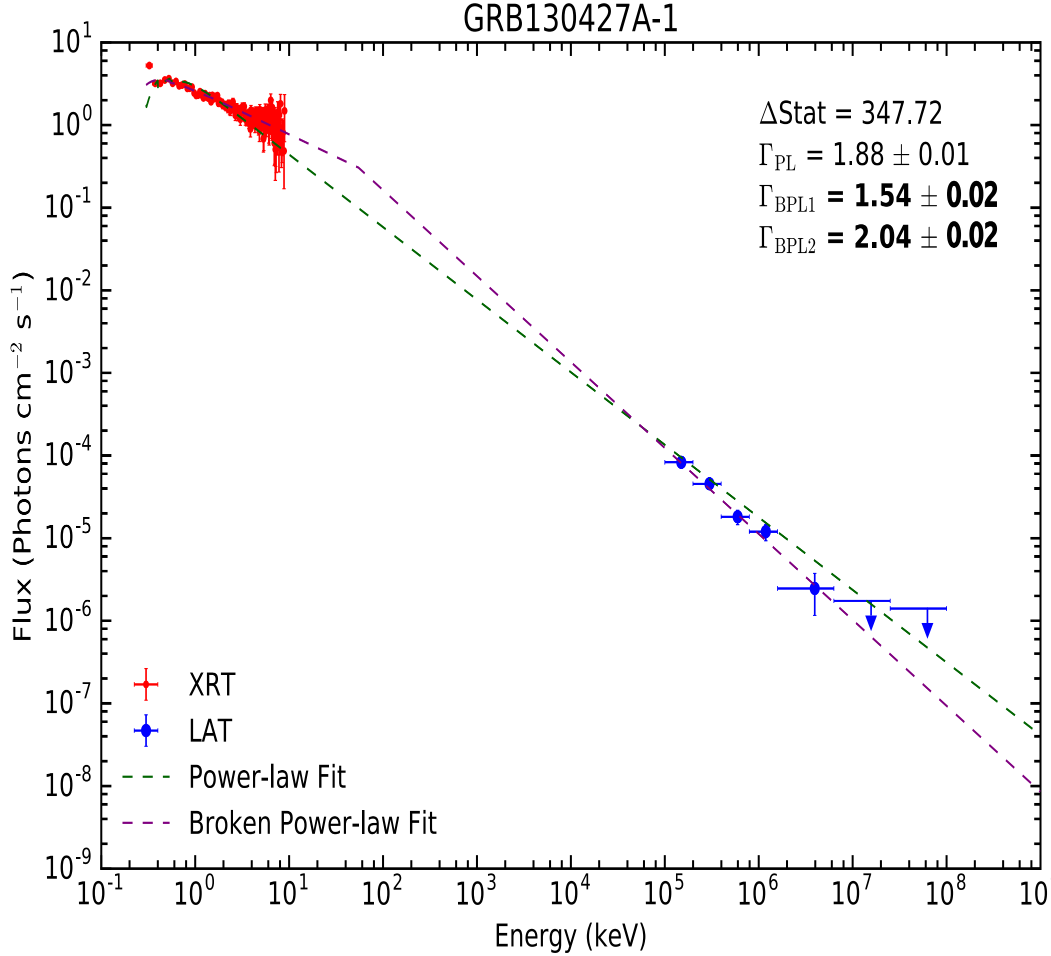
- GRBs at HE and VHE:
  ~12 GRBs per year Fermi-LAT

  - However, most science learnt from brightest event-GRB130427A: 94 GeV max energy photon.

VHE emission has been a decades-long mystery

t^{GBM}_{90} ~ 140 s, t^{BAT}_{90} ~ 160 s
z = 0.34

Ajello+, ApJ 863 138 (2018)



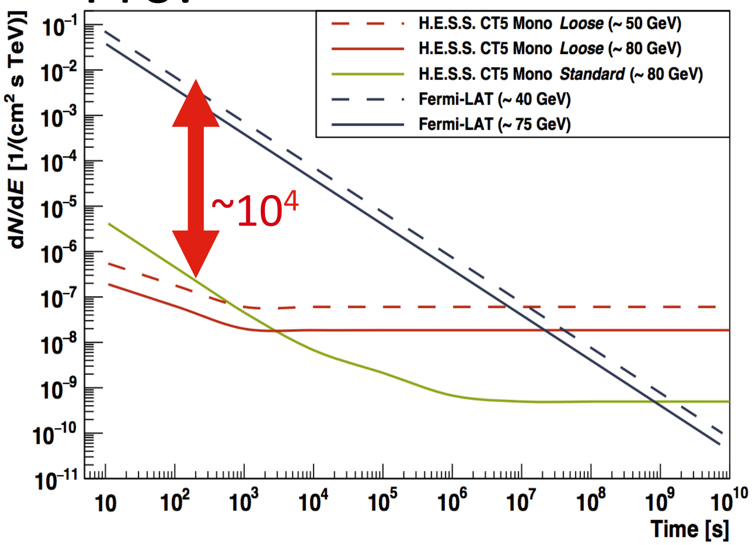
DESY. Fermi Gamma-ray Space Telescope H.E.S.S.

H.E.S.S. GRB follow-up observations: 2012 to 2017

H.E.S.S. telescopes:

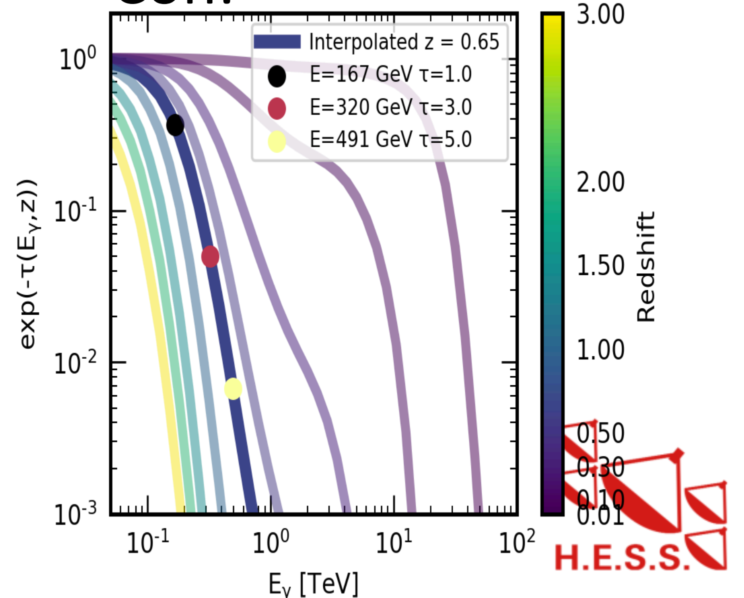
- Five Cherenkov telescopes (CT1-4 + CT5)

Pro:



HESS Collaboration(ICRC 2015)

Con:

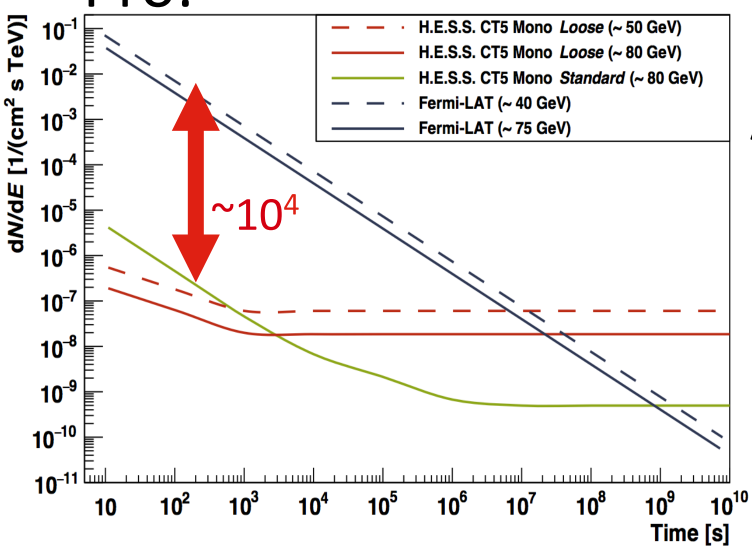


H.E.S.S. GRB follow-up observations: 2012 to 2017

H.E.S.S. telescopes:

- Five Cherenkov telescopes (CT1-4 + CT5)

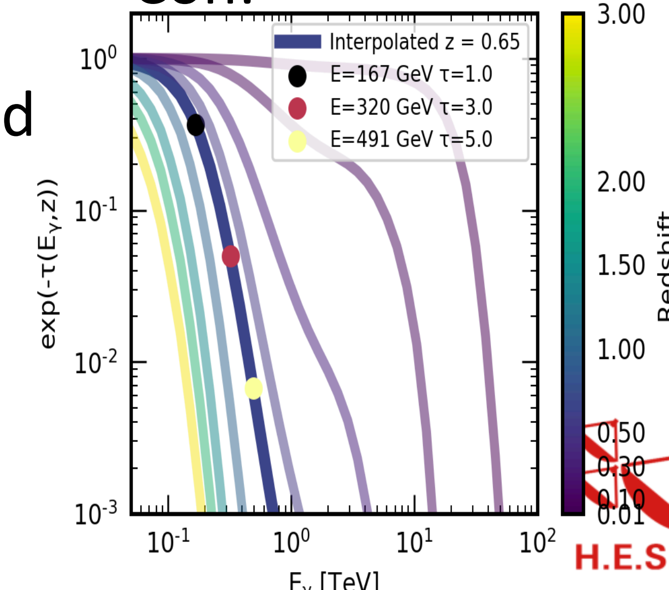
Pro:



HESS Collaboration(ICRC 2015)

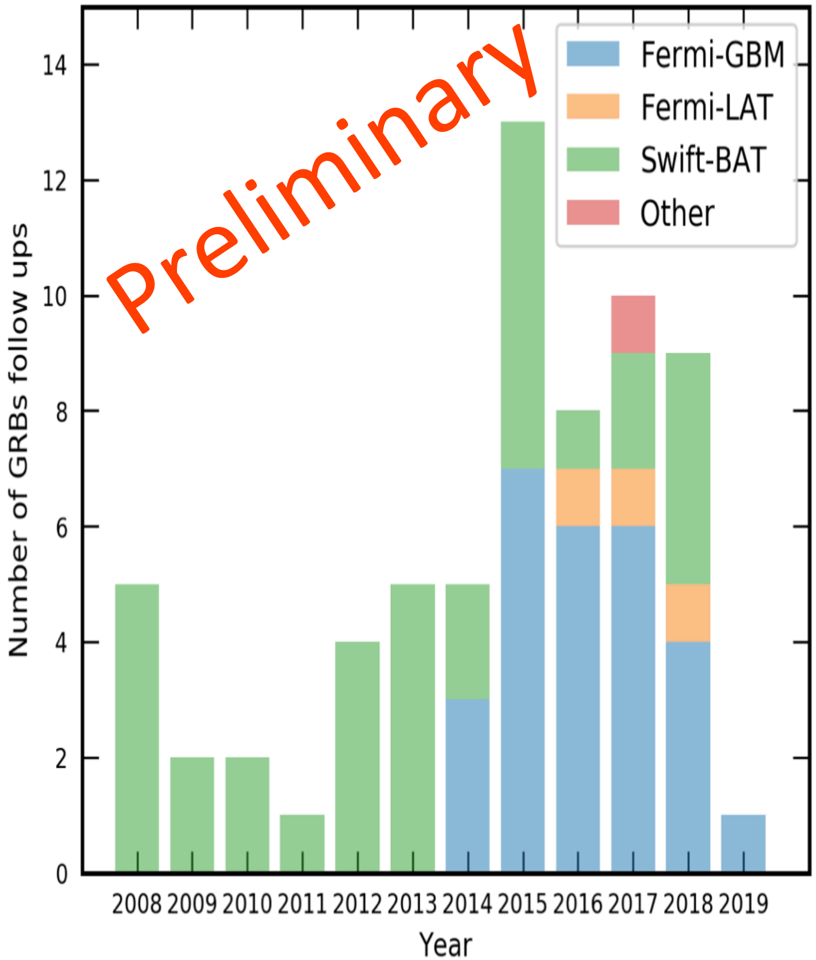
A low threshold energy is everything!

Con:



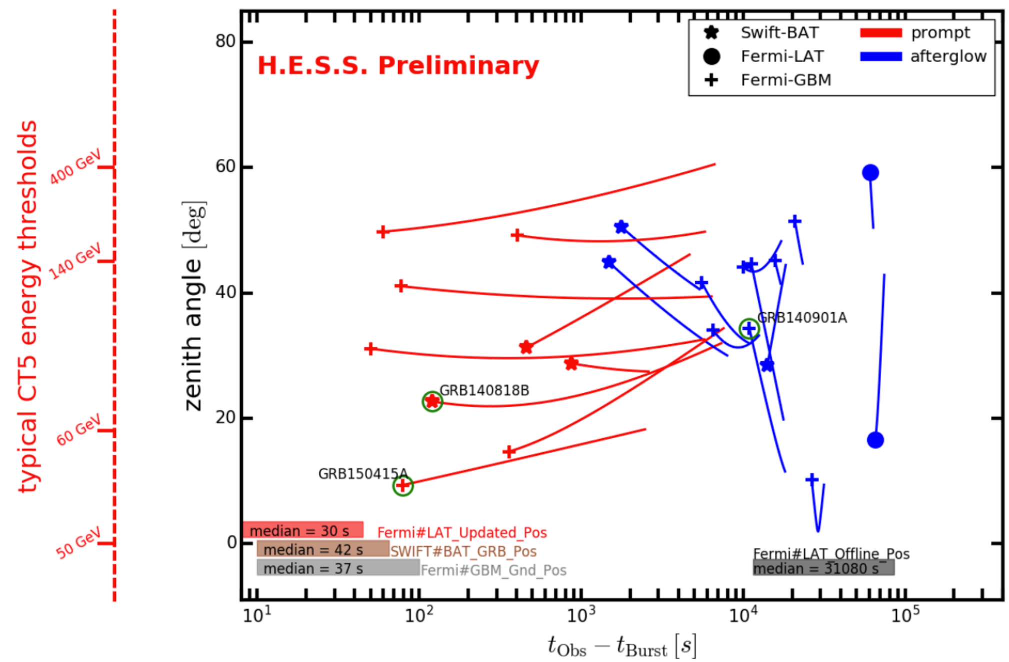
H.E.S.S.

H.E.S.S. GRB follow-up observations: 2012 to 2017



(note- plot made early 2019)

- ~10 Fermi-GBM GRBs/yr
- ~1 Fermi-LAT GRB/yr



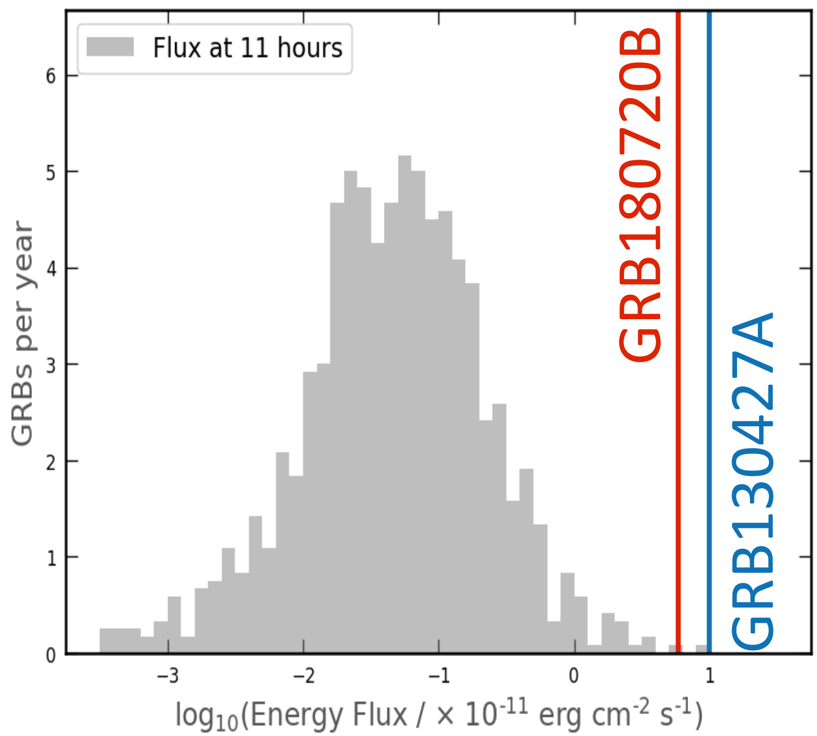
HESS Collaboration (ICRC 2017)

DESY.

H.E.S.S.

GRB 180720B X-ray 11 hr Energy Flux in Comparison to Other Bright Bursts

Swift-XRT GRBs
energy flux distribution at 11 hours



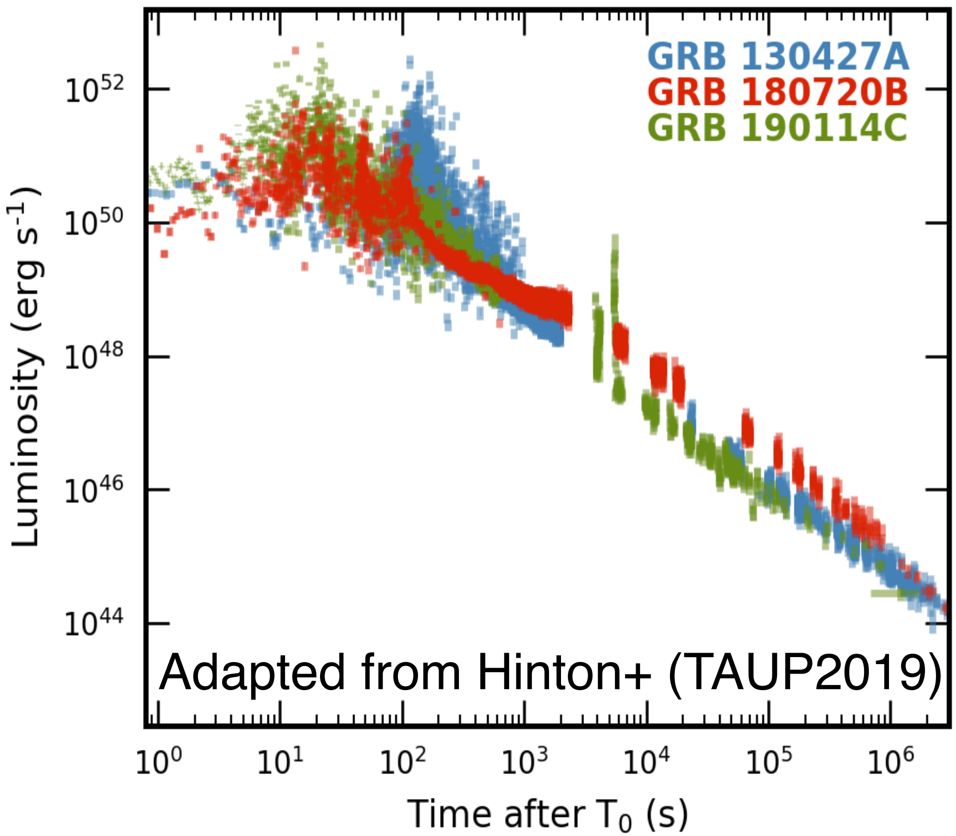
Ruiz-Velasco+ (1st CTA symposium)

- Triggered Fermi-GBM and Swift-BAT (5 s later).
- Fermi-LAT detection from T_0 to T_0+700 s (max. energy photon 5 GeV).
- Extremely bright burst:
  - 2nd brightest afterglow measured by Swift-XRT.
  - 7th brightest prompt emission detected by Fermi-GBM.
- Very similar x-ray light curve to GRB130427A and GRB190114C.

DESY.

H.E.S.S.

GRB 180720B X-ray Lightcurve in Comparison to Other Bright Bursts



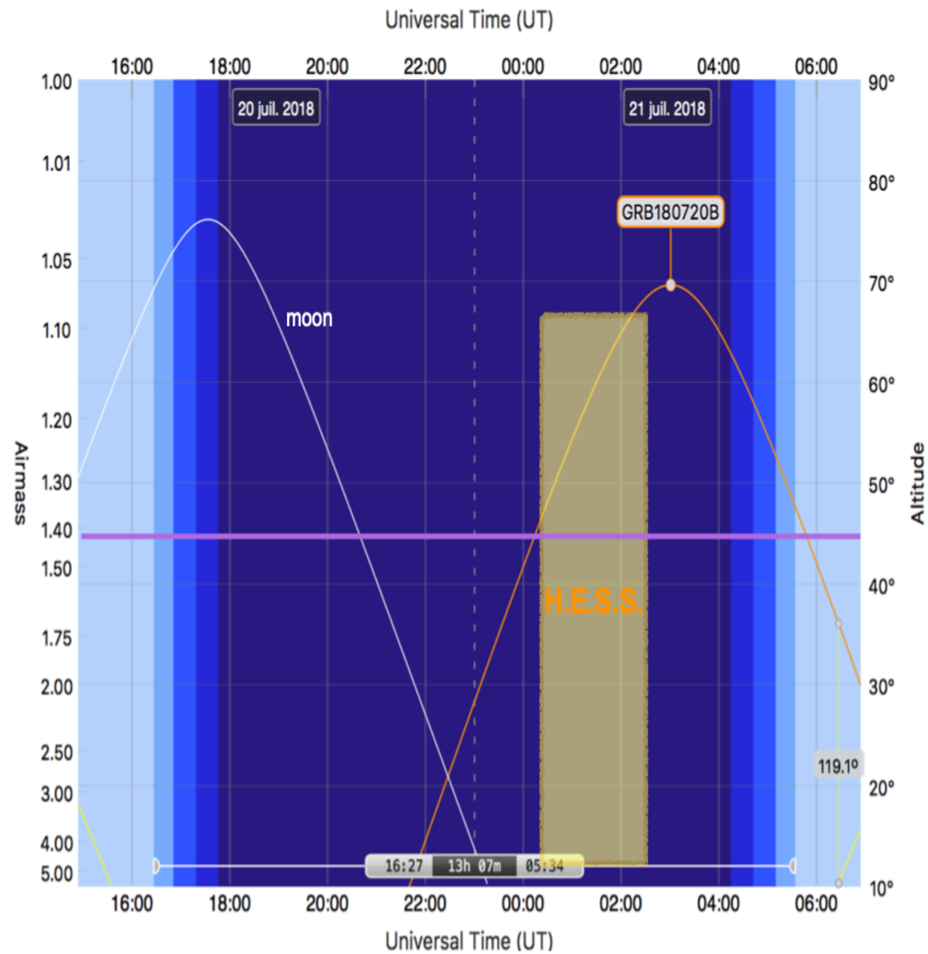
- Triggered Fermi-GBM and Swift-BAT (5 s later).
- Fermi-LAT detection from T_0 to T_0+700 s (max. energy photon 5 GeV).
- Extremely bright burst:
  - 2nd brightest afterglow measured by Swift-XRT.
  - 7th brightest prompt emission detected by Fermi-GBM.
- Very similar x-ray light curve to GRB130427A and GRB190114C.

t^{GBM}_{90} ~ 50 s, t^{BAT}_{90} ~ 100 s
z = 0.653

(ie. long GRB)

H.E.S.S. Observations of GRB 180720B

- Observation started ~10 hours after the burst.
- Such GRB observations were exceptionally late time for HESS to carry out (motivated by late-time brightness of afterglow in X-ray)
- Follow-up performed for ~2 consecutive hours (zenith 40º to 25º)
- Moderate presence of clouds at the beginning not affecting the observations.

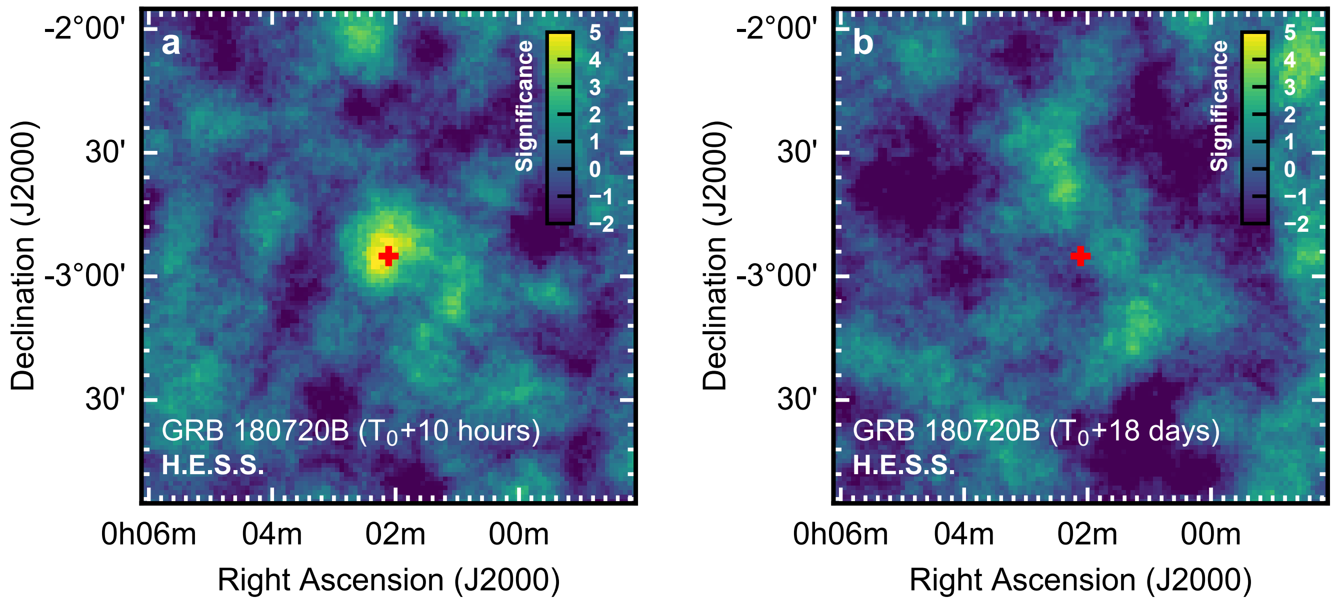


GRB 180720B H.E.S.S. Detection

- Observation started ~10 hours after the burst.
- Follow-up performed for ~2 consecutive hours (zenith 40º to 25º)

H.E.S.S. detection: ~5.3σ pre-trial, 5.0σ post-trial (5 similar searches).

- Gone in re-observation 18 days after T_0.
- Cross-check analysis (totally independent calibration and analysis chain), influence weather conditions and other systematics



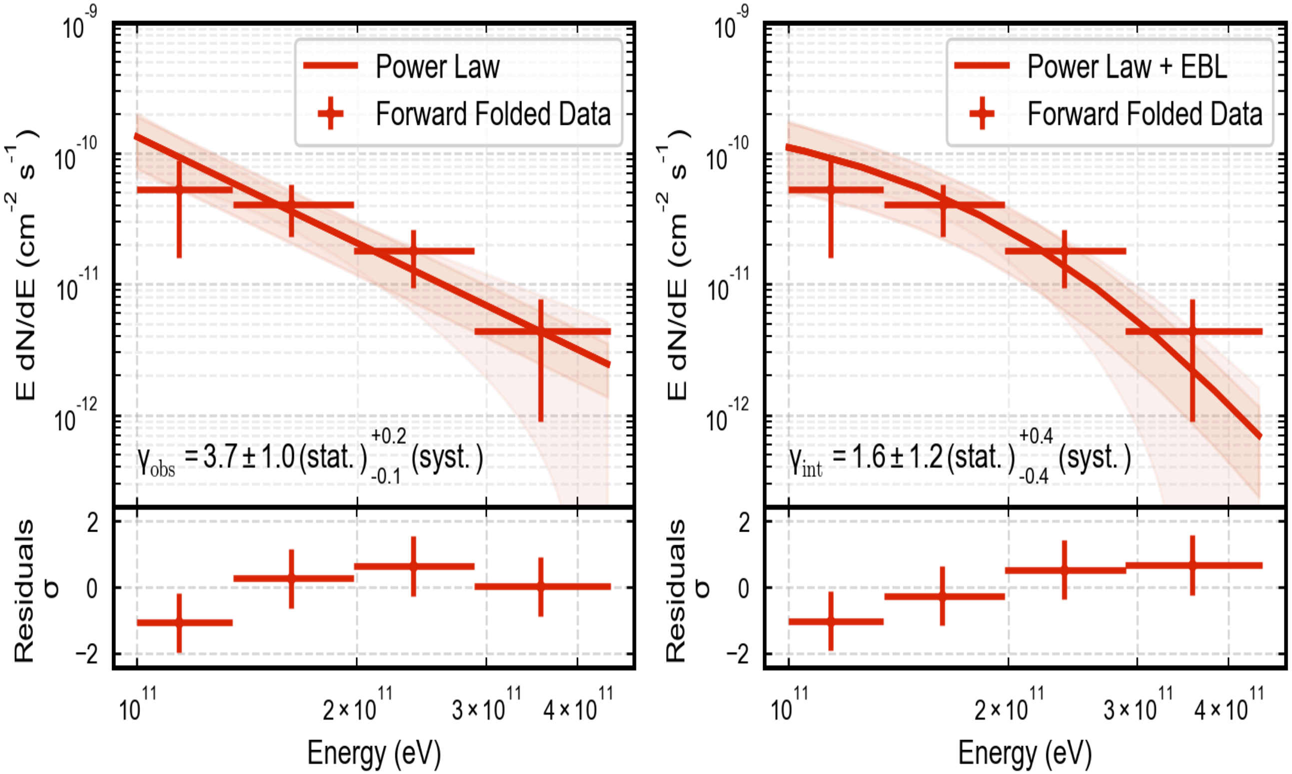
HESS Collaboration *Nature* **575**, 464–467 (2019)

DESY. H.E.S.S.

GRB 180720B H.E.S.S. Detection

$$\frac{dN}{dE} = \Phi_0 \left(\frac{E}{E_0}\right)^{-\gamma_{int}} \times exp(-\tau(E,z))$$

Steep spectrum from 100 GeV to 440 GeV

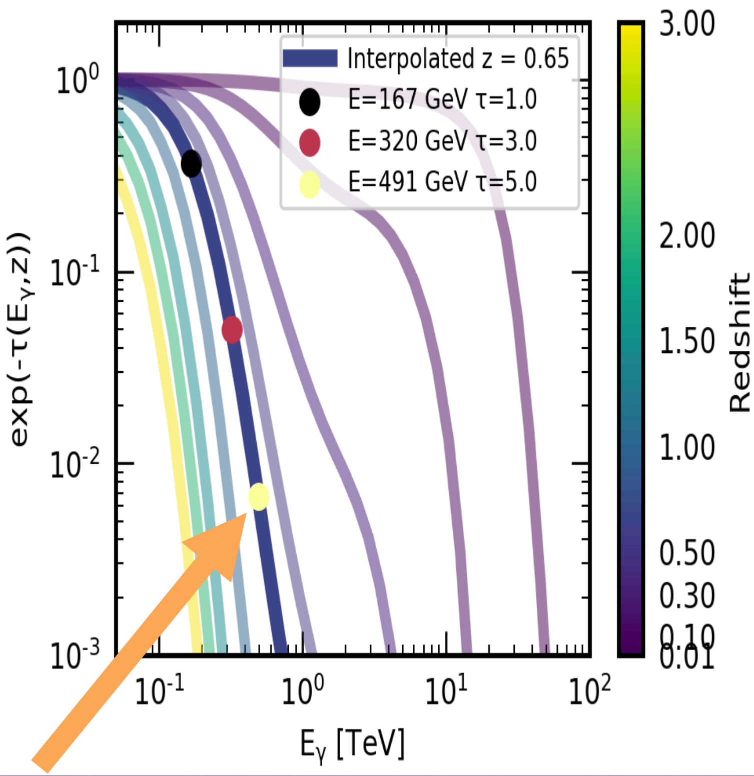


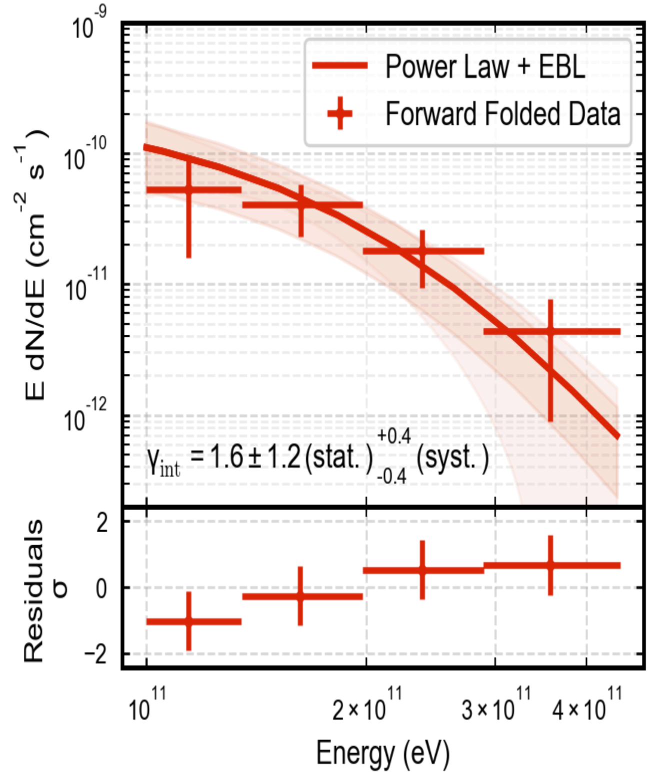
HESS Collaboration *Nature* **575,** 464–467 (2019)

GRB 180720B H.E.S.S. Detection

Very hard intrinsic spectrum (EBL de-absorbed), $\frac{dN}{dE} = \Phi_0 \left(\frac{E}{E_0}\right)^{-\gamma_{int}} \times exp(-\tau(E,z))$

redshift 0.65 (most distant GRB from the 3 detected at VHE)





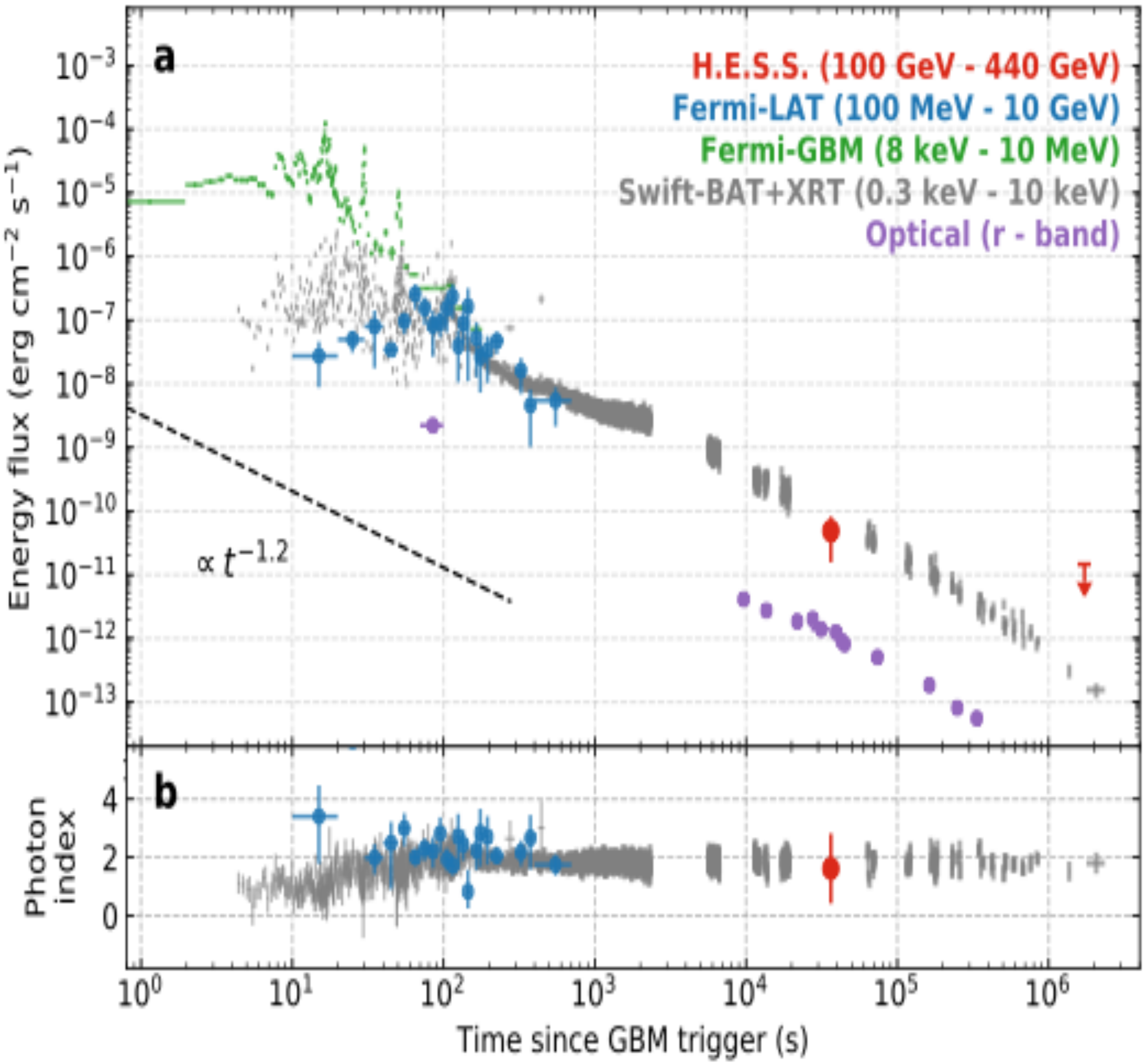
98% absorption at ~500 GeV due to EBL

DESY.

HESS Collaboration *Nature* **575,** 464–467 (2019)

H.E.S.S.

GRB 180720B Multi-Wavelength Light Curve



- H.E.S.S. flux (100 - 440 GeV). Photon index consistent with -2.0.
- Fermi-LAT (detection < 700 s). Photon index -2.0.
- XRT Photon index is -2.0.
- X-ray, HE + VHE Gamma-ray energy fluxes all sit at a consistent level.
- Afterglow falling at same rate in all high energy wavelengths.

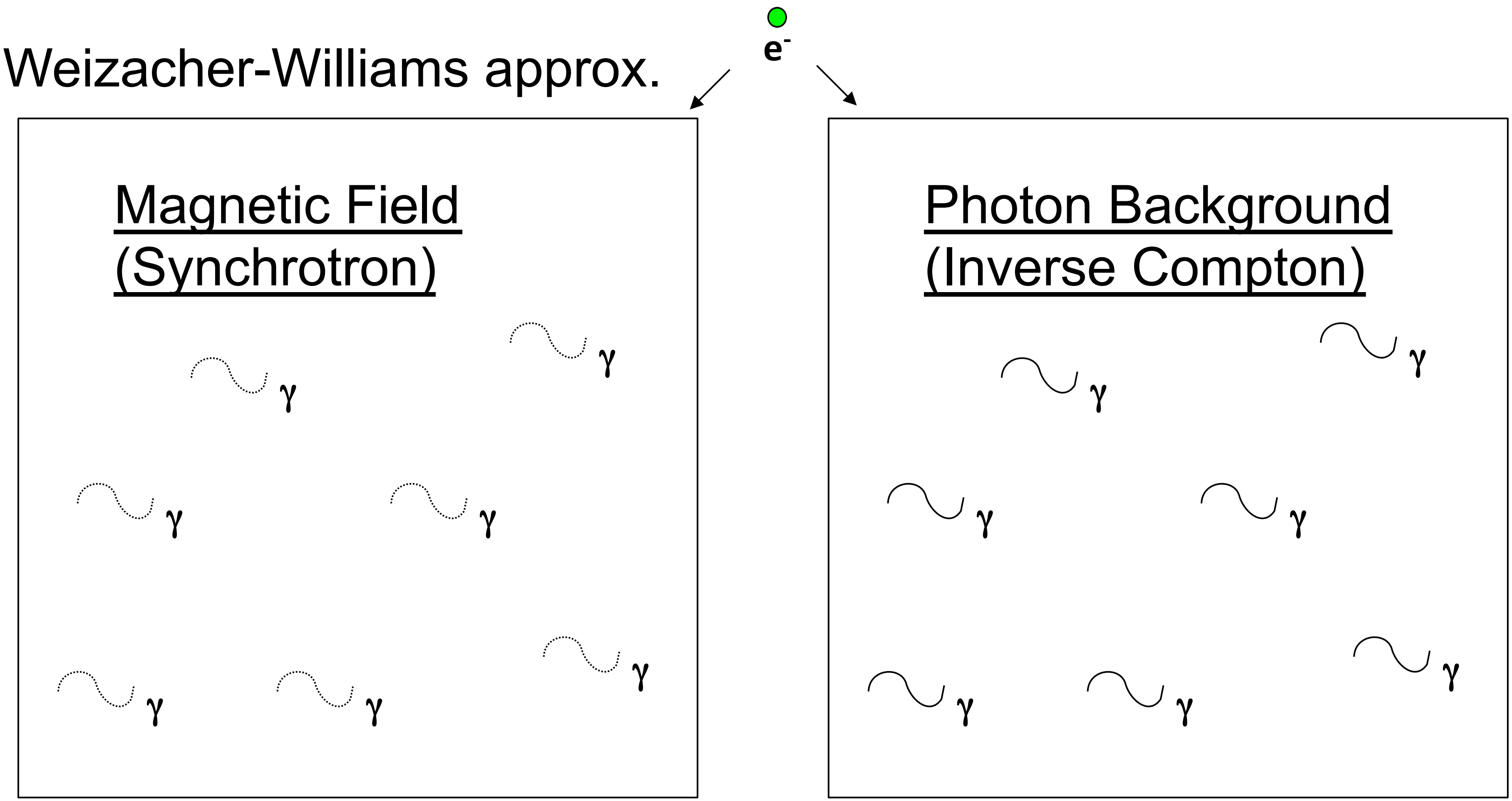
HESS Collaboration *Nature* **575,** 464–467 (2019)

DESY.

H.E.S.S.

Possible VHE Emission Processes

Weizacher-Williams approx.



Virtual Photons

$$\mathbf{E_\gamma^{target}} = \left(\frac{\mathbf{B}}{\mathbf{B_{crit}}}\right)\mathbf{m_e c^2}$$

Real Photons

$$\mathbf{E_\gamma^{target}}$$

Efficiency of Synchrotron Emission

$$\mathbf{E_\gamma^{sync} \approx \frac{b}{3} E_e}$$

$$\mathbf{b} = \frac{\mathbf{4E_e E_\gamma^{\mathrm{target}}}}{\mathbf{(m_e c^2)^2}}$$

$$\mathbf{E_\gamma^{target}} = \left(\frac{\mathbf{B}}{\mathbf{B_{crit}}}\right) \mathbf{m_e c^2}$$

$$(\mathbf{B}_{\mathrm{crit}} = \mathbf{4} \times \mathbf{10^{13}}\ \mathrm{G})$$

$$\mathbf{E}_\gamma^{\mathrm{sync}} = \frac{\mathbf{400}\ \mathrm{GeV}}{\mathbf{\Gamma}}$$

$$\mathbf{B} = \mathbf{0.1}\ \mathrm{G} \qquad \mathbf{\Gamma} = \mathbf{20}$$

Requires: $\mathbf{E_e > PeV}$

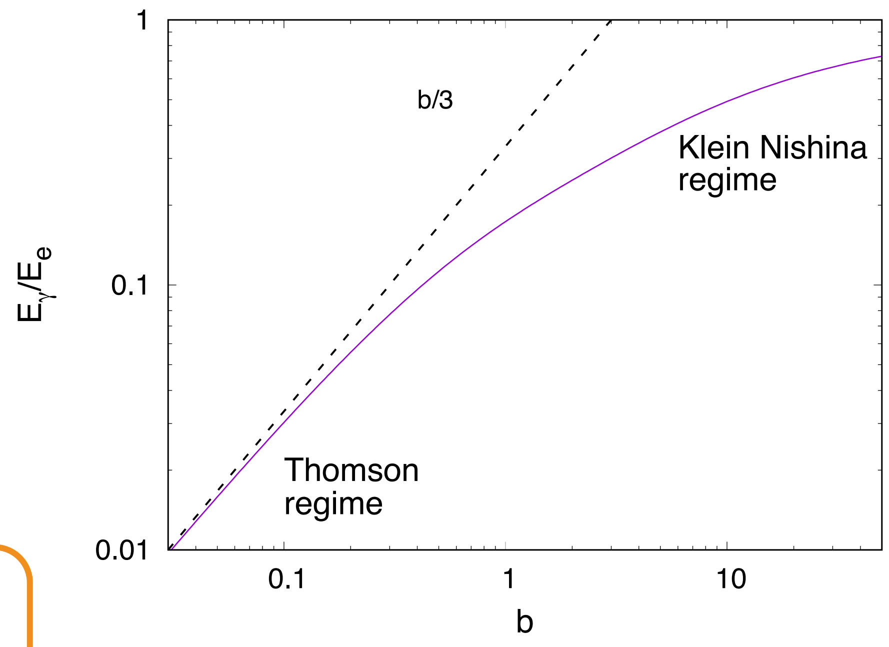
DESY. H.E.S.S.

Efficiency of Inverse Compton Emission

$$\mathbf{E}_\gamma^{\mathbf{IC}} \approx \left(\frac{\mathbf{b}}{\mathbf{1+b}}\right)\mathbf{E_e}$$

$$\mathbf{b} = \frac{\mathbf{4E_eE_\gamma^{target}}}{\mathbf{(m_ec^2)^2}}$$

$$\mathbf{E}_\gamma^{\mathbf{target}} = \frac{\mathbf{1}\ \mathrm{keV}}{\mathbf{\Gamma}} \qquad \mathbf{\Gamma = 20}$$



$$\mathbf{b} \approx \mathbf{1}$$

Requires: $\mathbf{E_e} > \mathbf{400}\ \mathrm{GeV}$

DESY.

H.E.S.S.

Electron Acceleration to PeV Energies Taking into Account Cooling?

$$\mathbf{t_{acc}} = \eta \frac{\mathbf{R_{lar}}}{\mathbf{c}\beta^{\mathbf{2}}}$$

$$\mathbf{t_{cool}} = \frac{\mathbf{9}}{\mathbf{8}\pi\alpha} \left(\frac{\mathbf{U_{Bcrit}}}{\mathbf{U_B}}\right) \left(\frac{\mathbf{h}}{\mathbf{E_e}}\right)$$

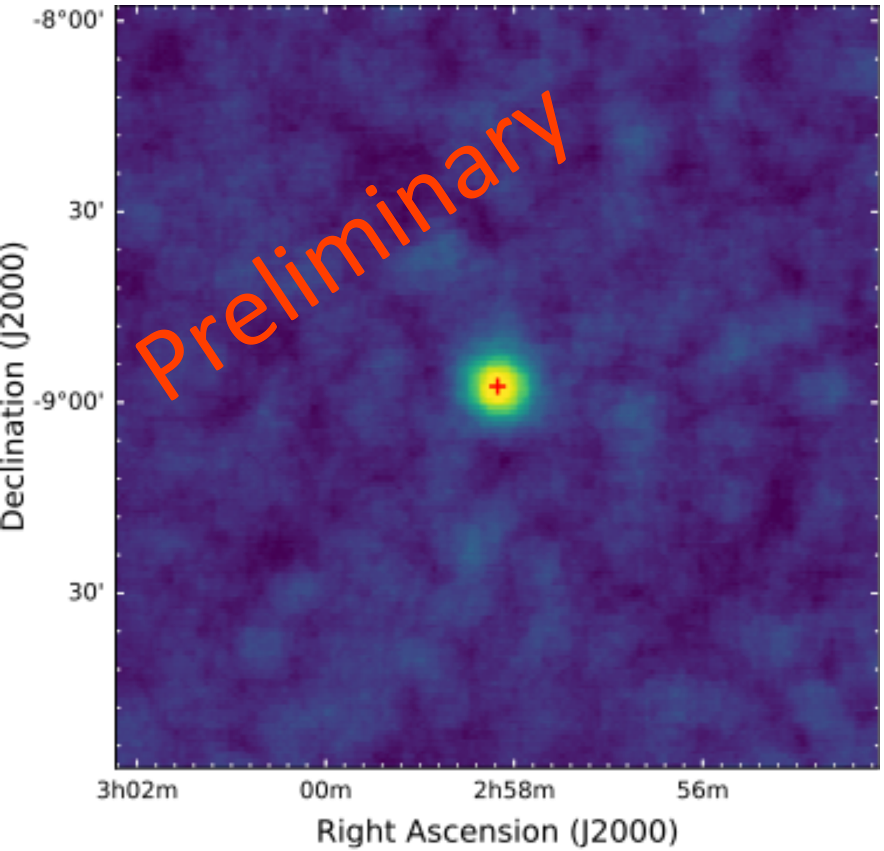
$$\mathbf{E_e^{max}} = \left(\frac{\eta^{-\mathbf{1/2}}}{\alpha^{\mathbf{1/2}}(\mathbf{B/B_{crit}})^{\mathbf{1/2}}}\right) \mathbf{m_e c^2}$$

$$= \mathbf{3}\ \eta^{-\mathbf{1/2}} \left(\frac{\mathbf{B}}{\mathbf{100}\mu\mathbf{G}}\right)^{-\mathbf{1/2}} \mathbf{PeV}$$

ie. would require weak B-fields in acceleration region

HESS Detection of GRB 190829A

$t^{GBM}_{90} \sim 60$ s, $t^{BAT}_{90} \sim 60$ s
$z = 0.078$



[Previous | Next | ADS]

GRB190829A: Detection of VHE gamma-ray emission with H.E.S.S.

ATel #13052; *M. de Naurois (H. E. S. S. Collaboration)*
on 30 Aug 2019; 07:12 UT
Credential Certification: Fabian SchÃ   Â¼ssler (fabian.schussler@cea.fr)

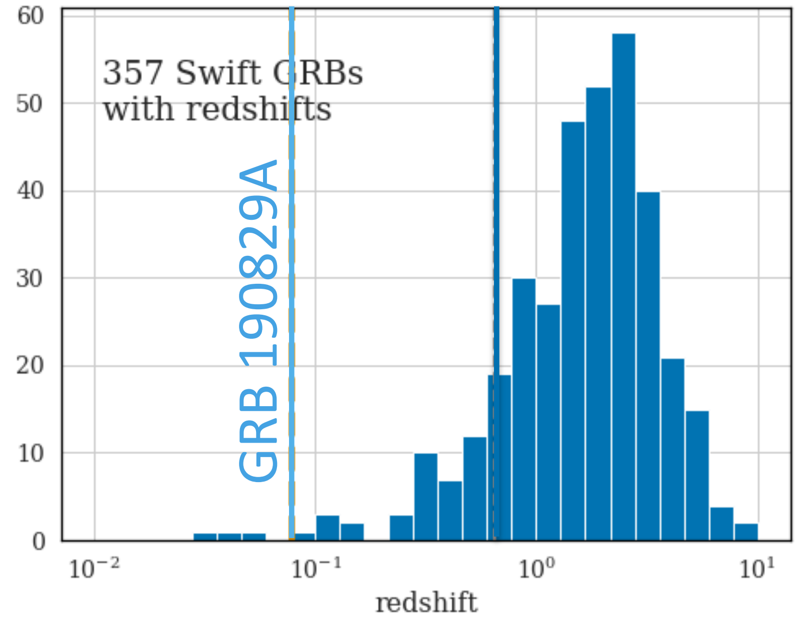
Subjects: Gamma Ray, >GeV, TeV, VHE, Gamma-Ray Burst

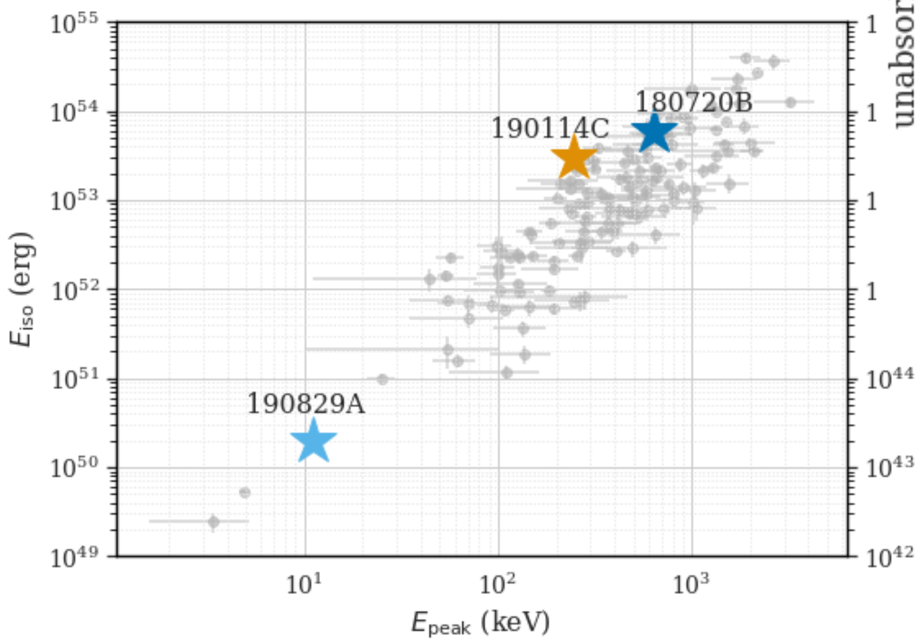
The detection of VHE emission in the deep afterglow of GRB 180720B

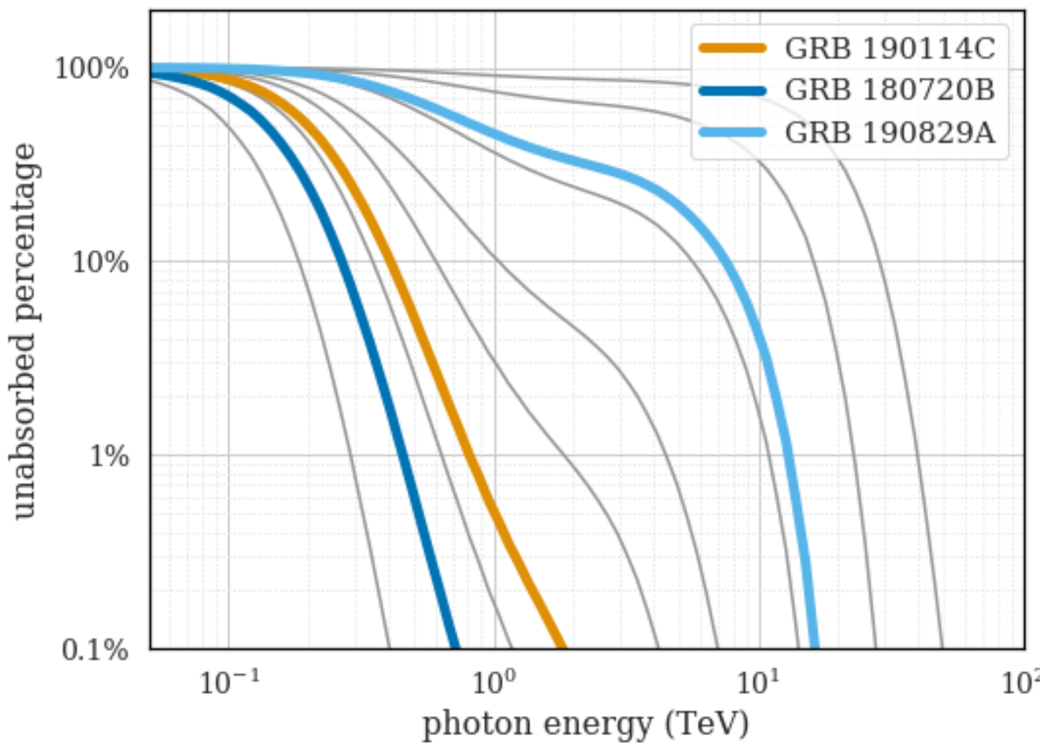
Tweet

The H.E.S.S. array of imaging atmospheric Cherenkov telescopes was used to carry out follow-up observations of the afterglow of GRB 190829A (Dichiara et al., GCN 25552). At a redshift of z = 0.0785 +/- 0.005 (A.F. Valeev et al., GCN 25565) this is one of the nearest GRBs detected to date. H.E.S.S. Observations started July 30 at 00:16 UTC (i.e. T0 + 4h20), lasted until 3h50 UTC and were taken under good conditions. A preliminary onsite analysis of the obtained data shows a >5sigma gamma-ray excess compatible with the direction of GRB190829A. Further analyses of the data are on-going and further H.E.S.S. observations are planned. We strongly encourage follow-up at all wavelengths. H.E.S.S. is an array of five imaging atmospheric Cherenkov telescopes for the detection of very-high-energy gamma-ray sources and is located in the Khomas Highlands in Namibia. It was constructed and is operated by researchers from Armenia, Australia, Austria, France, Germany, Ireland, Japan, the Netherlands, Poland, South Africa, Sweden, UK, and the host country, Namibia. For more details see https://www.mpi-hd.mpg.de/hfm/HESS/

HESS Detection of GRB 190829A





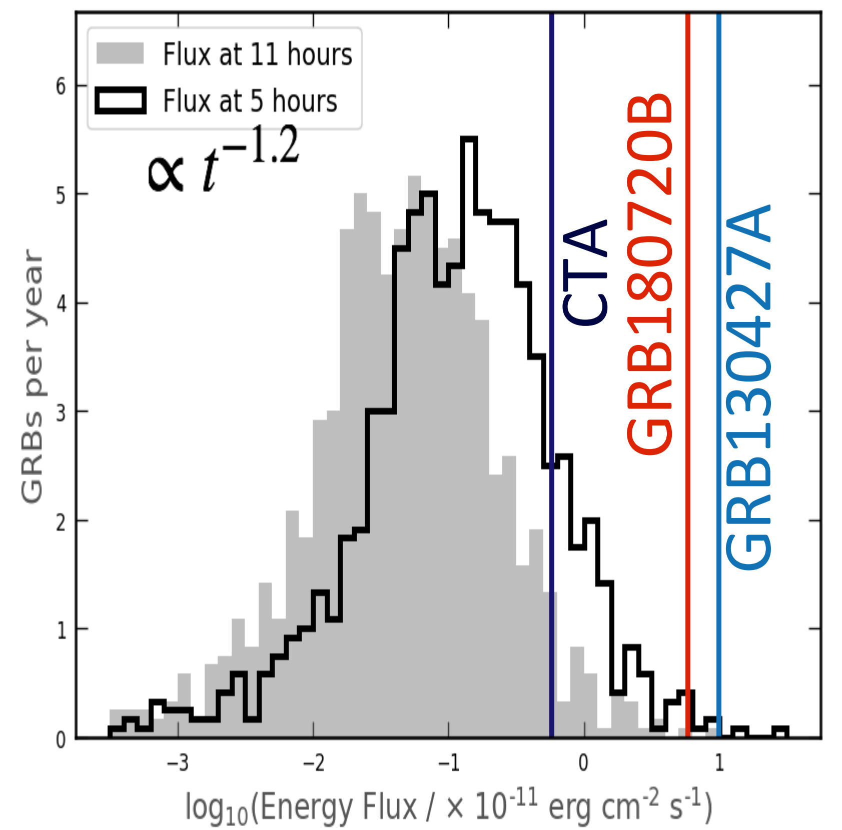


H.E.S.S.

Prospects for Future Observatories

- CTA to have ~10 times better sensitivity than H.E.S.S.
- Will be able to detect flux over many decades in time with detailed spectra information.
- Boost the detection of GRBs at VHE.
  - ~ 3 GRBs per year at 11 hours after burst.
  - ~ 11 GRBs per year at 5 hours after burst

Swift-XRT GRBs energy flux distribution



Ruiz-Velasco+ (1st CTA symposium)
HESS Collaboration *Nature* **575,** 464–467 (2019)

Conclusions

- HESS efforts to observe GRB over the last two decades have finally paid off
- GRB 180720B was detected more than 10 hours after the GBM trigger
- Looking for a signal deep in the afterglow have proven to be very effective, leading to the HESS detection of a second GRB, GRB 190829A
- It is premature to conclusively state that the VHE emission is SSC in origin. However, a synchrotron origin would require additional physics to be feasible.

DESY.

H.E.S.S.