Very-high-energy gamma-ray emission from GRB 201216C detected by MAGIC

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37th ICRC (2021)

Very-high-energy gamma rays from GRBs

- So far 3 GRBs have been detected at very high energy (**VHE, > 50 GeV**) gamma rays.

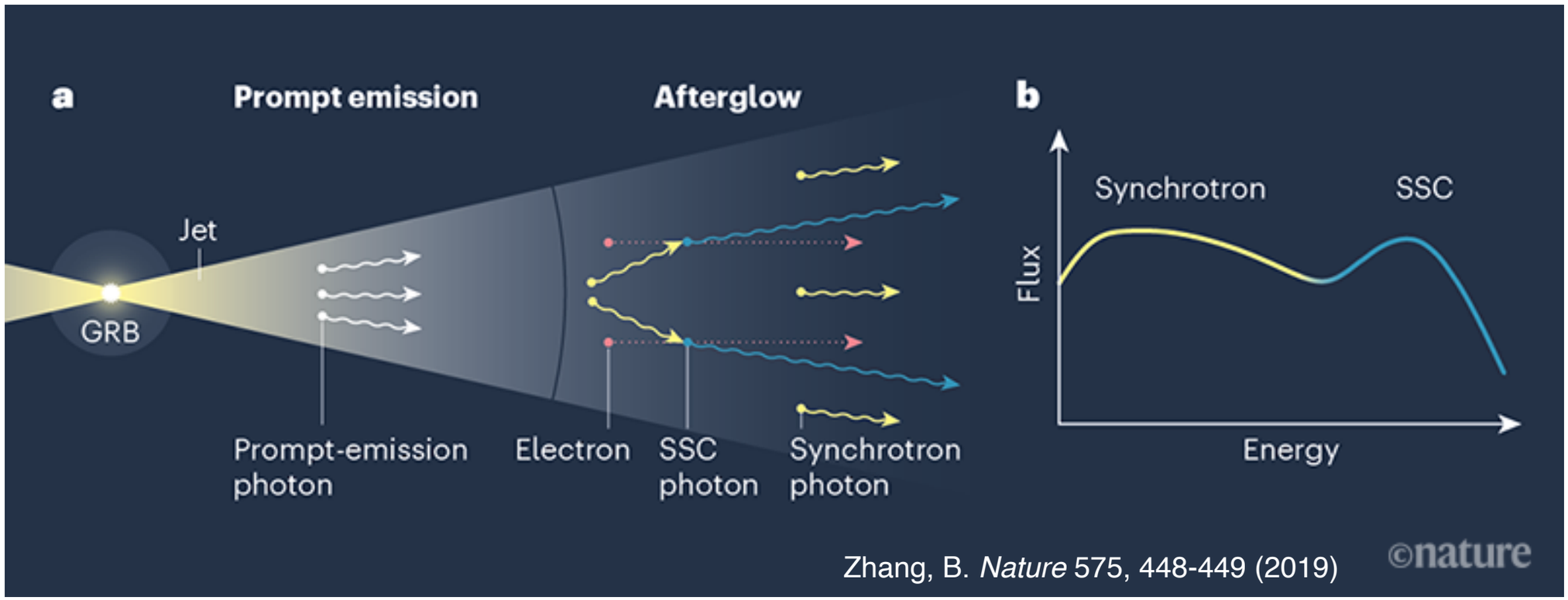
  - **GRB 180720B** (H.E.S.S.) : a long GRB (z 0.65, E_{iso} $6*10^{53}$ erg @ 50-300 keV)

  - **GRB 190114C** (MAGIC) : a long GRB (z 0.42, E_{iso} $3*10^{53}$ erg @ 1-10^{4} keV)

  - **GRB 190829A** (H.E.S.S.) : a low-luminousity GRB (z 0.078, E_{iso} $2*10^{50}$ erg @ 10-1000 keV)

- Synchrotron Self-Compton (SSC) by relativistic electrons can explain the VHE emission for at least the first 2 GRBs.

- Is SSC a common emission mechanism of VHE GRBs? Still we need more GRBs…



Zhang, B. *Nature* 575, 448-449 (2019)

GRB 201216C

a bright long GRB triggered by Swift BAT (on 23:07:31 UT on Dec 16th, 2020 : T_0)

- T_{90} (Swift BAT, 15-350 keV) : 48+-16 s

- late-time X-ray observation (by Swift XRT) from T_0+3ks

- late-time UV observation (by UVOT) from T_0+3ks, GeV observation (by Fermi LAT) from T_0+3.5ks

    - no detection by UVOT or Fermi-LAT

- a few optical observations

    - VLT detected with r' 21.8 mag at T_0+2.19 h : redshift *z* : 1.1

    - Liverpool Telescope detected with r' 18.4 mag at T_0+177 s

    - FRAM-ORM detected after T_0+31.6 s

- E_{iso} (Fermi GBM, 10-1000 keV): $4.7*10^{53}$ erg

- no detection > 100 TeV by HAWC, no neutrino detection by IceCube

See https://gcn.gsfc.nasa.gov/other/201216C.gcn3 in detail

MAGIC telescopes

MAGIC (Major Atmospheric Gamma Imaging Cherenkov telescope)

- **location** : La Palma, Canary Islands, Spain (28°N, 18°W)

- **systems** : 17-m parabolic primary mirror, photomultiplier focal plane × 2

- **performance** :

  - <u>energy range</u> : **50 GeV - 30 TeV**

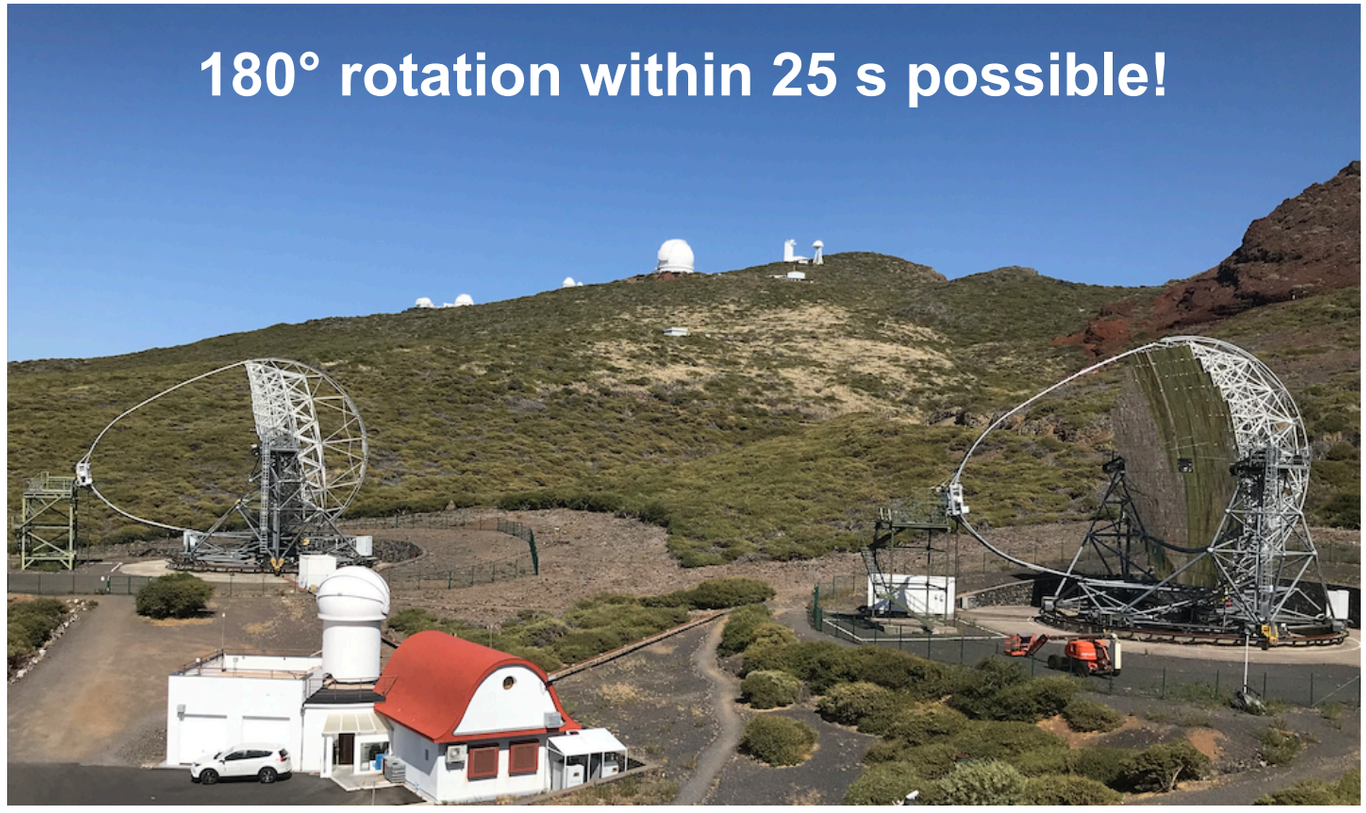
  - <u>field of view</u> : 3.5° (0.1° for 1 pixel)

  - <u>energy resolution</u> :
    ~20% @100 GeV, 15% @1 TeV

  - <u>angular resolution</u> :
    ~5 arcminutes @100 GeV,
    ~3 arcminutes @1 TeV

  - <u>effective area</u> :
    ~10^4 m^2 @100 GeV, **~10^5 m^2** @1 TeV

  - <u>integral sensitivity</u> :
    ~0.6% crab unit > 220 GeV



MAGIC observation of GRB 201216C

- observation for **2.2 h** soon after T_0

  - automatic fast repositioning immediately after receiving the alert at T_0+22 s

  - stable observation with data taking started from T_0+56 s

- moonless dark night - good weather through all the observation

- zenith angle from 37 deg to 68 deg : moderate energy threshold

Atel #14275

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GRB 201216C: MAGIC detection in very high energy gamma rays

ATel #14275; *Oscar Blanch (IFAE-BIST) on behalf of the MAGIC Collaboration*
on 17 Dec 2020; 17:23 UT
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Subjects: Gamma Ray, >GeV, TeV, VHE, Gamma-Ray Burst

Referred to by ATel #: 14277

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On December 16, 2020, the MAGIC telescopes observed GRB 201216C following the trigger by Swift-BAT and Fermi-GBM (Beardmore et al., GCN 29061, Fermi/GBM team GCN 29063). MAGIC started observations under good conditions about 57 seconds after the GRB onset. The preliminary off-line analyses show an excess above 5 sigma, compatible with the GRB position reported by the Swift and Fermi teams. Refined off-line analyses of the data are ongoing.

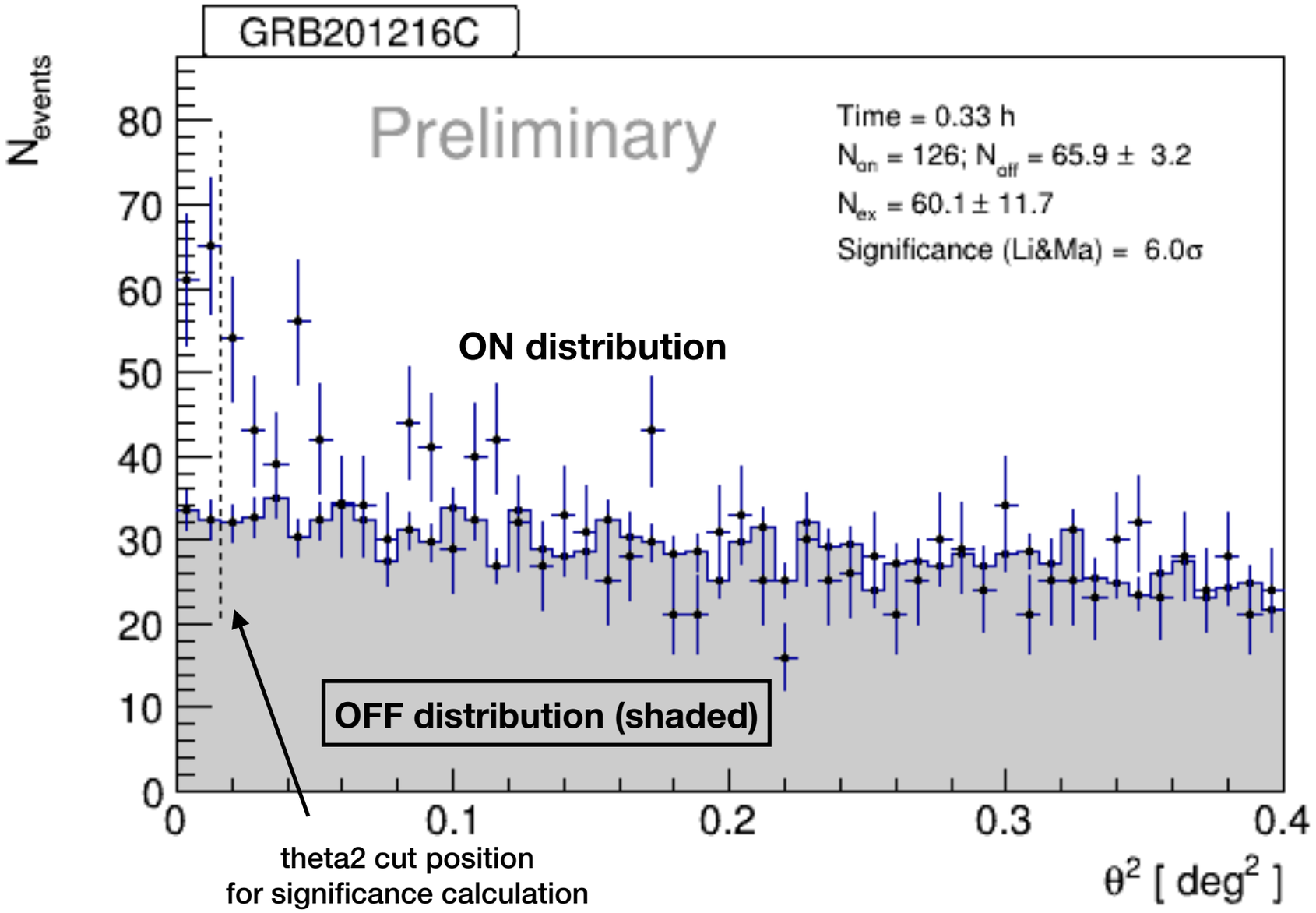
detection by offline analysis

theta2 plot

theta2: squared angular distances to the GRB position for ON/OFF regions

- **6 sigma significance** around the GRB position for the first 20 min with optimized cuts

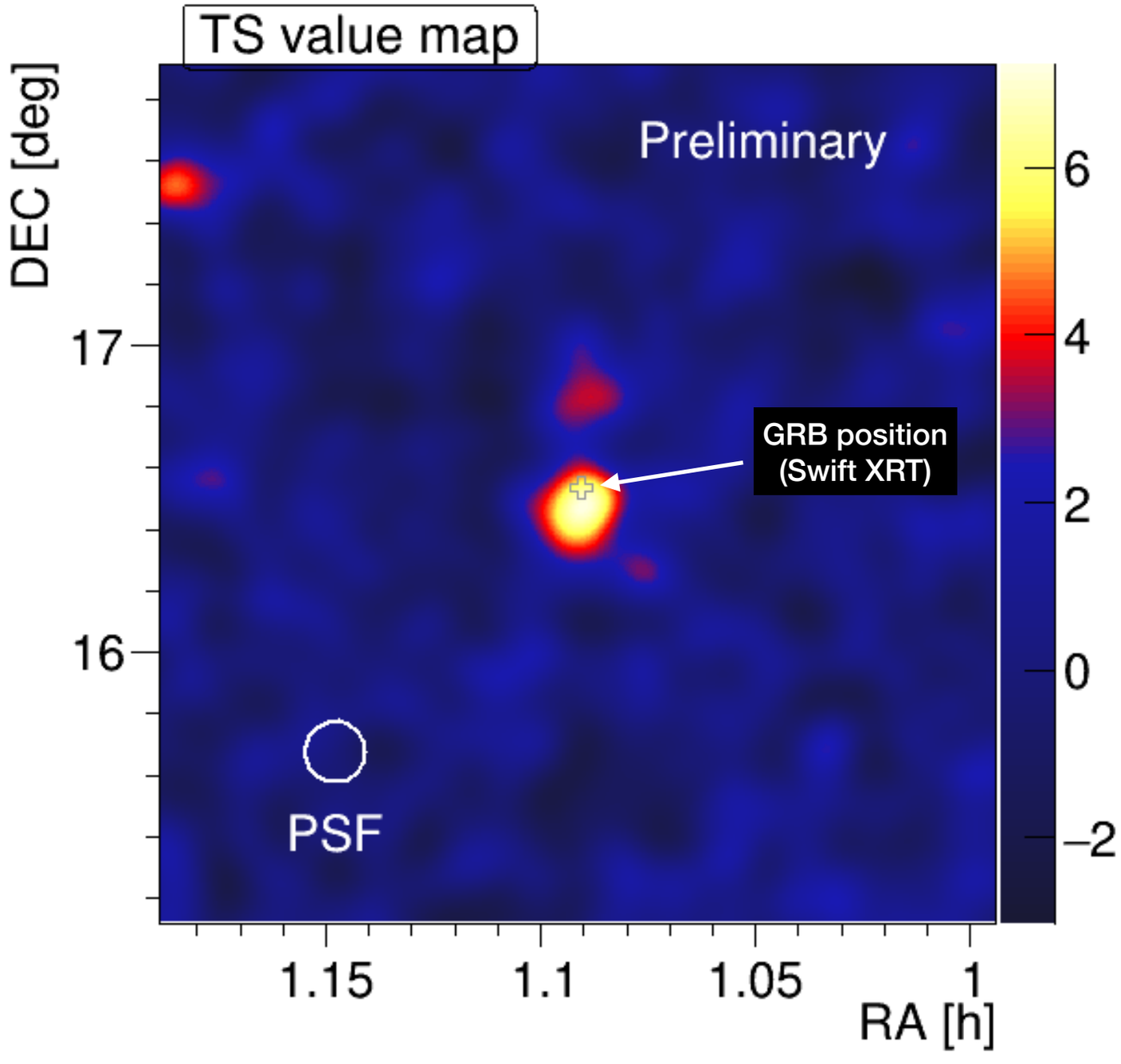
  - post-trial significance of **5.9 sigma** (2 periods analyzed : 20 min, 2.2 h)



skymap

Significance sky map around the GRB position for the first 40 min

- **6 sigma significance** around the GRB position with optimized cuts

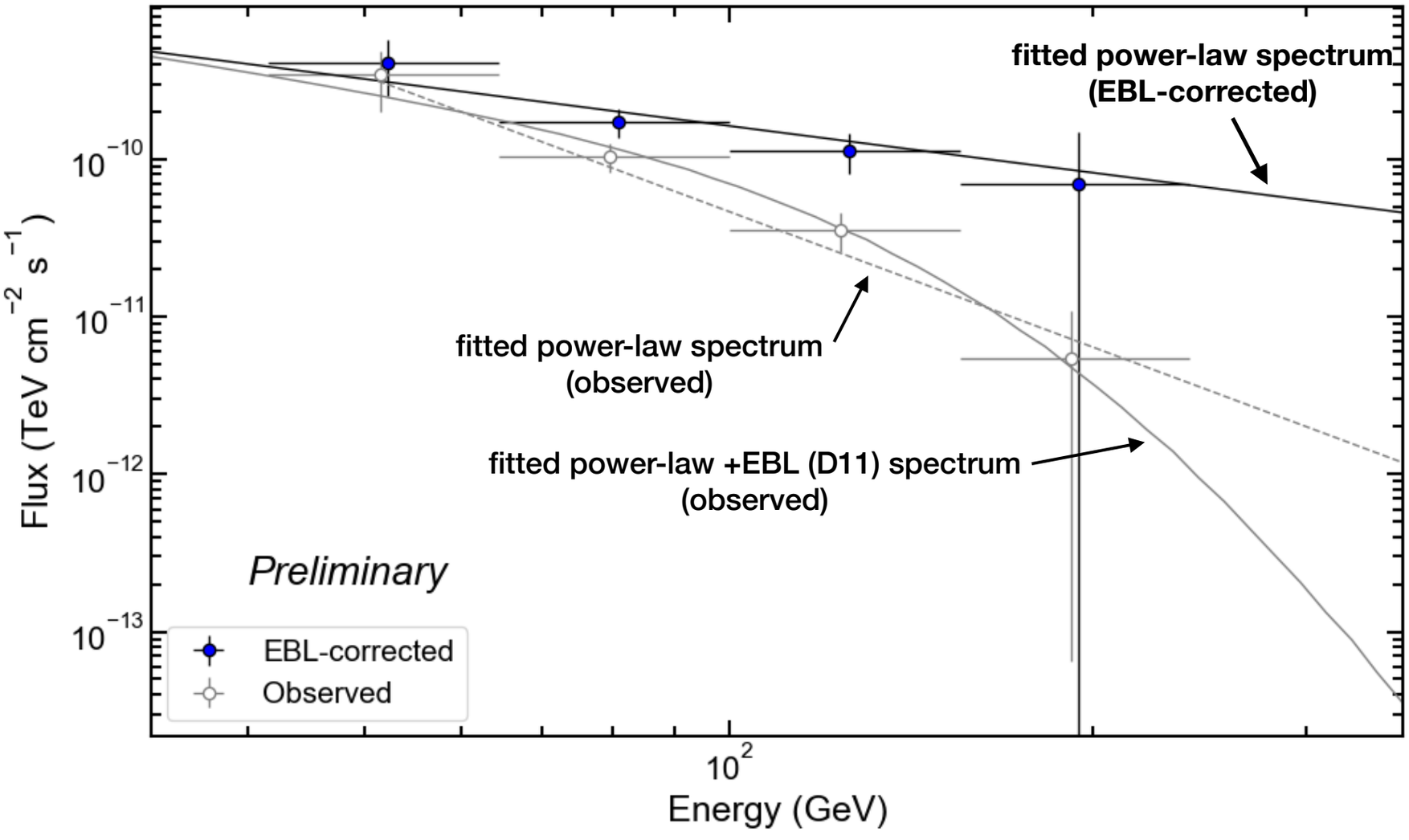


unfolded spectra

unfolded spectrum (points) and forward folded spectrum (fitted line) for the first 20 min

- observed spectrum (open circle and gray dashed/solid lines) shows a steep slope due to strong attenuation by EBL at z~1.1

- EBL-corrected spectrum by Dominguez 2011 (filled circle and solid line) shows a much flatter shape and is consistent with a power-law

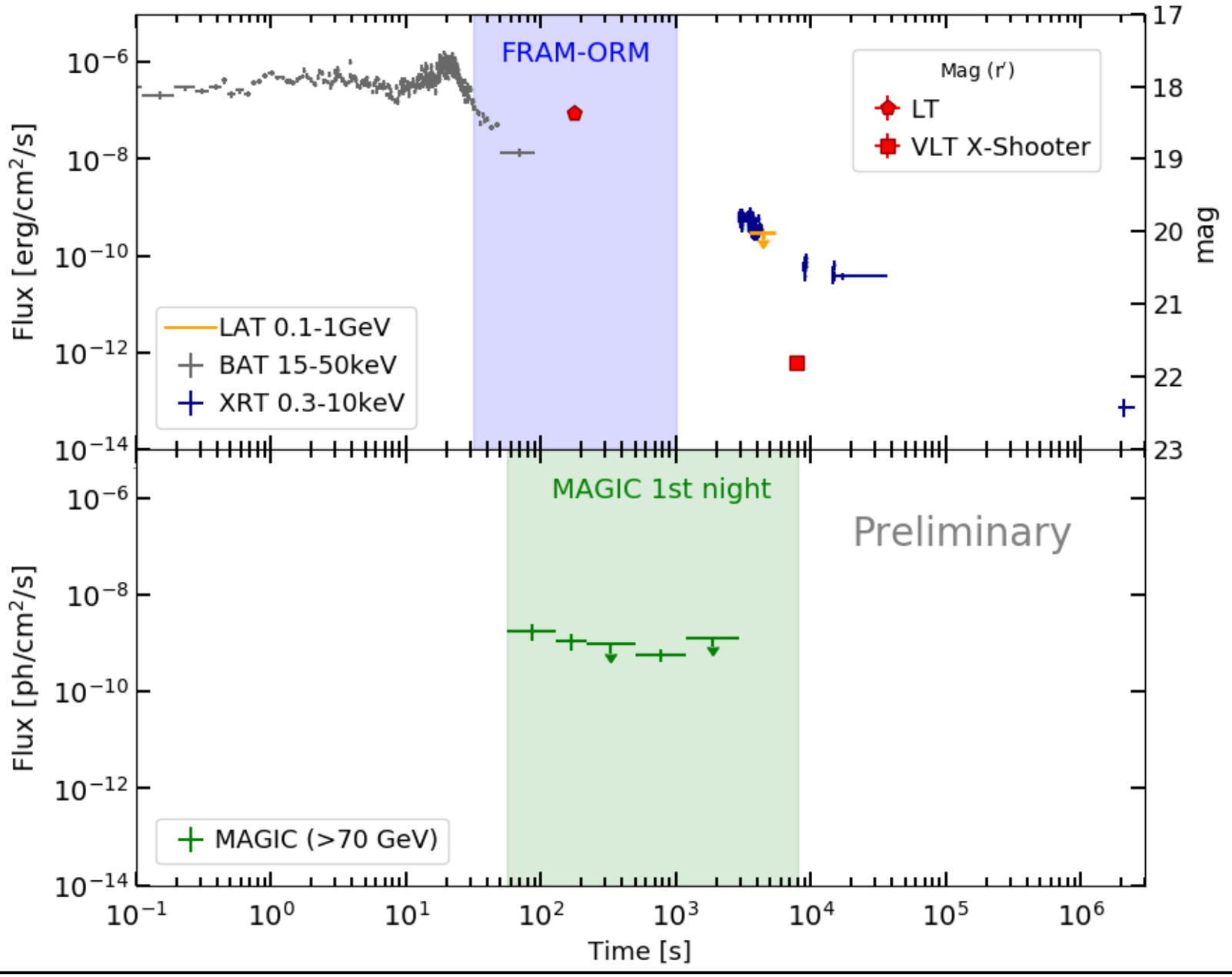


photon flux light curve

MAGIC photon light curve above 70 GeV together with multiwavelength light curves

- MAGIC photon flux decays monotonically with time from the beginning (T_0+56 sec)

- Only upper limits are obtained after T_0+20 min



Discussion

- MAGIC observation is possibly in the afterglow phase from the beginning of the light curve.

- Different temporal index between X-ray and VHE gamma rays

  - suggesting different process of VHE emission from that of X-ray emission

  - SSC would be one of the possible models (like GRB 190114C)

Detailed modeling will be provided in the upcoming paper.

- similarity with GRB 190114C, or other typical long GRBs:

  - monotonic decay in the light curves of MAGIC from T_0+~60 s

  - T_{90} : order of 10-100 s

  - main peak of the prompt emission finished at ~T_0+10-20 s

  - E_{iso} : order of 10^{53} erg

→ VHE emission might be common in long GRBs.

Summary

- MAGIC observed GRB 201216C from T_0+56 s, and detected VHE gamma rays above 5 sigma around the GRB position.

- The offline analysis shows 6 sigma for the first 20 min observation.

- The observed spectrum has a very steep spectral index. The EBL-corrected spectrum is much flatter and consistent with a power-law.

- The photon light curve shows a monotonic decay at least up to T_0+20 min.

- The VHE emission could be already in the afterglow phase, and might not be explained by the synchrotron emission. The modeling results will be shown in the upcoming paper.

- Future VHE observations and detections on GRBs will provide a deeper insight on the emission processes and physical conditions. Stay tuned!

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