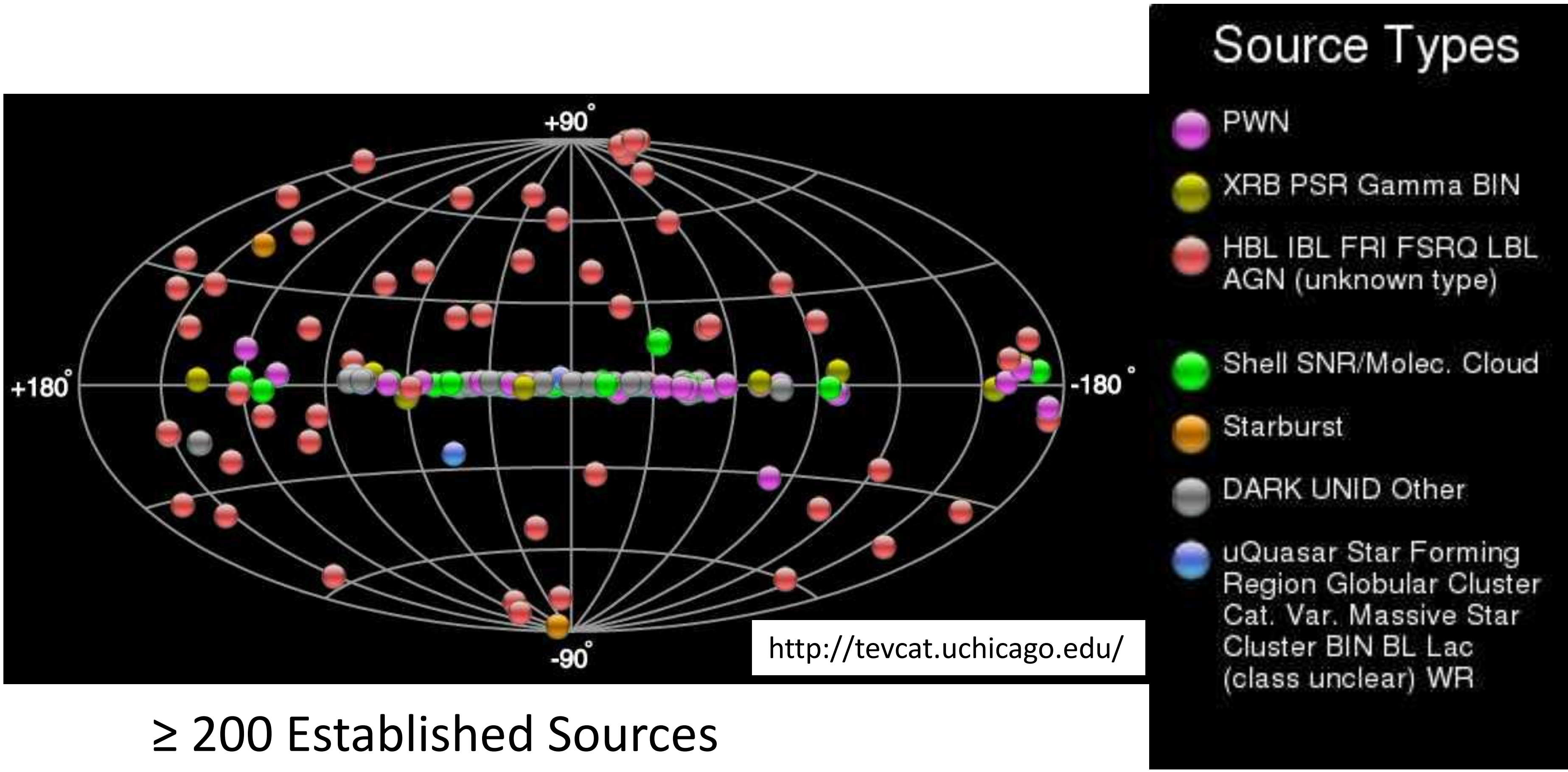
On the Recent Discoveries of GRBs at TeraelectronVolt Energies

Razmik Mirzoyan
Max-Planck-Institute for Physics
Munich, Germany
&
SINP at LMSU
Moscow, Russia

Today‘s VHE γ–ray Sources in the Sky



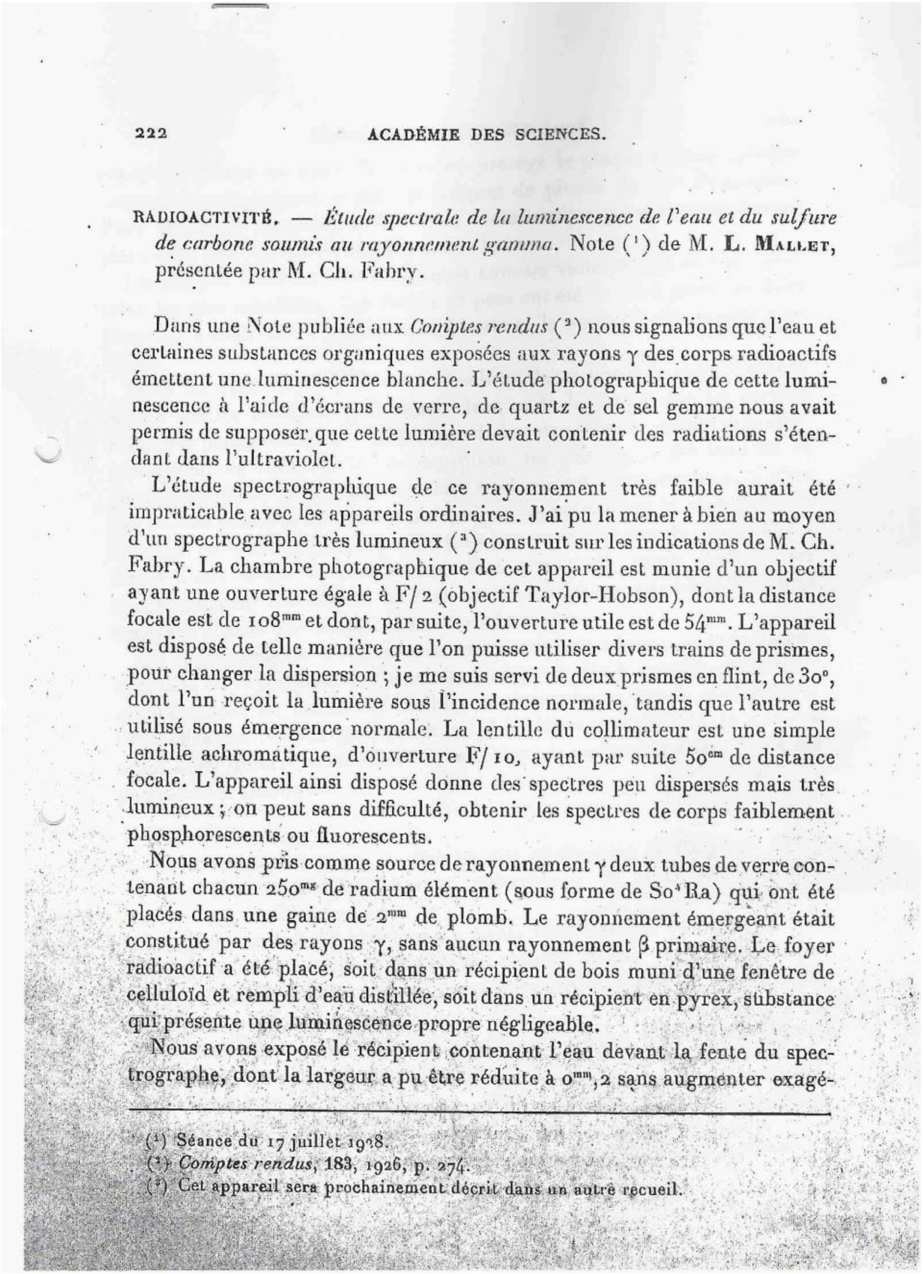
≥ 200 Established Sources

Cherenkov light: the beginnings

- In a series of publications Oliver Heaviside has calculated and predicted the main features of a special emission when an e- movs in a transparent medium with a speed higher than that of light.
- The work of the genius, who advanced his time by half a century, was not appreciated by contemporary scientists and was forgotten. In 1912 he calculated the geometry and the angle of emission relative to the axis of movement of the charge (1888, 1889, 1892, 1899, 1912a,b)
- Please note that during the end of 19th century scientists believed the space was feeled-in with Ether.

Cherenkov light: the beginnings

- It took almost 50 years until the effect was experimentally discovered and later on got the name Cherenkov
- Also Sommerfeld studied the problem of a charge moving in vacuum with a speed v > c (1904). The relativistic principles prohibit such a motion in vacuum but in a medium with given *n* then his equations give valid solution („sonic boom“).
- First observation of ghostly bluish glow of bottles in the dark cellar, containing radium salts dissolved in distilled water, by Marie Curie in 1910 (E. Curie, 1937). It was thought to be a type of fluorescence.



RADIOACTIVITÉ. — *Étude spectrale de la luminescence de l'eau et du sulfure de carbone soumis au rayonnement gamma.* Note (1) de M. L. MALLET, présentée par M. Ch. Fabry.

Dans une Note publiée aux *Comptes rendus* (2) nous signalions que l'eau et certaines substances organiques exposées aux rayons γ des corps radioactifs émettent une luminescence blanche. L'étude photographique de cette luminescence à l'aide d'écrans de verre, de quartz et de sel gemme nous avait permis de supposer que cette lumière devait contenir des radiations s'étendant dans l'ultraviolet.

L'étude spectrographique de ce rayonnement très faible aurait été impraticable avec les appareils ordinaires. J'ai pu la mener à bien au moyen d'un spectrographe très lumineux (3) construit sur les indications de M. Ch. Fabry. La chambre photographique de cet appareil est munie d'un objectif ayant une ouverture égale à F/2 (objectif Taylor-Hobson), dont la distance focale est de 108^{mm} et dont, par suite, l'ouverture utile est de 54^{mm}. L'appareil est disposé de telle manière que l'on puisse utiliser divers trains de prismes, pour changer la dispersion ; je me suis servi de deux prismes en flint, de 30°, dont l'un reçoit la lumière sous l'incidence normale, tandis que l'autre est utilisé sous émergence normale. La lentille du collimateur est une simple lentille achromatique, d'ouverture F/10, ayant par suite 50^{cm} de distance focale. L'appareil ainsi disposé donne des spectres peu dispersés mais très lumineux ; on peut sans difficulté, obtenir les spectres de corps faiblement phosphorescents ou fluorescents.

Nous avons pris comme source de rayonnement γ deux tubes de verre contenant chacun 250^{mg} de radium élément (sous forme de So^4Ra) qui ont été placés dans une gaine de 2^{mm} de plomb. Le rayonnement émergeant était constitué par des rayons γ, sans aucun rayonnement β primaire. Le foyer radioactif a été placé, soit dans un récipient de bois muni d'une fenêtre de celluloïd et rempli d'eau distillée, soit dans un récipient en pyrex, substance qui présente une luminescence propre négligeable.

Nous avons exposé le récipient contenant l'eau devant la fente du spectrographe, dont la largeur a pu être réduite à $0^{mm},2$ sans augmenter exagé-

(1) Séance du 17 juillet 1928.
(2) *Comptes rendus*, 183, 1926, p. 274.
(3) Cet appareil sera prochainement décrit dans un autre recueil.

• French scientists M.L. Mallet published 3 articles on the bluish glow in transparent liquids (1926-1929).
• On the left one can see a scan of one of those papers (1926)
• Mallet recongnised the continuous spectrum of emission that was contradicting the fluorescence theory, but failed to offer any deep explanation

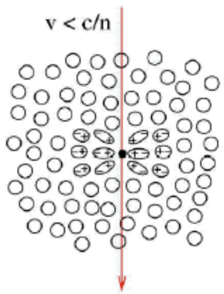
Cherenkov light: the beginnings

- Pavel Cherenkov: born July 28th 1904 in a poor peasant family in village Novaya Chigla, Voronezh province.
- 1924-1928 studying in Voronezh sate university.
- 1930: postgraduate student of Sergej Vavilov at the Institute of Physics of Soviet Academy of Sciences in Sankt-Petersburg (later on FIAN).
- Had to find the fluorescence nature of solvents of uranium salts, emitting bluish light
- Big was his surprise that also pure solvents and even water were emitting the annoying background light

Cherenkov, Tamm and Frank awarded Nobel Prize in 1958

- S. I. Vavilov has passed away in 1951 (after ~10 heart attackes).
- Nobel prize is awarded only to scientists who are alive

Cherenkov Effect

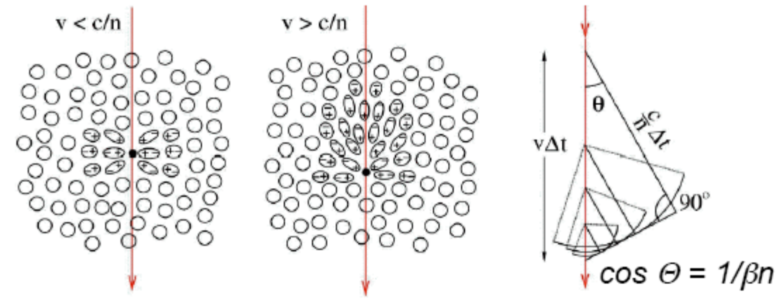


Medium, refractive index n

Charged particle with v < c/n traverses medium
==> local, shorttime
polarization of medium

Reorientation of electric dipoles results in (very faint) isotropic radiation

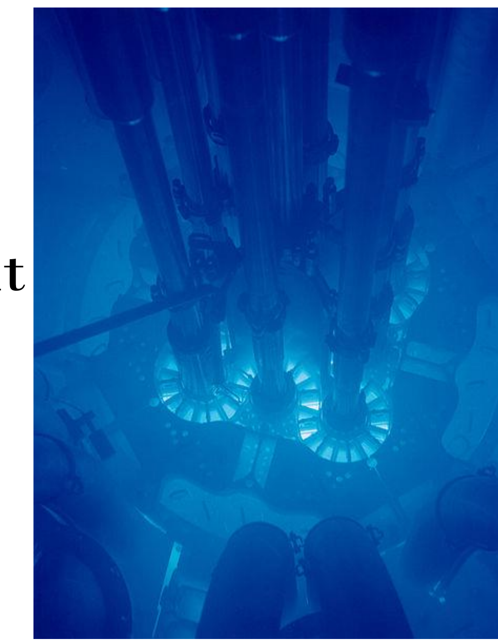
Cherenkov Effect



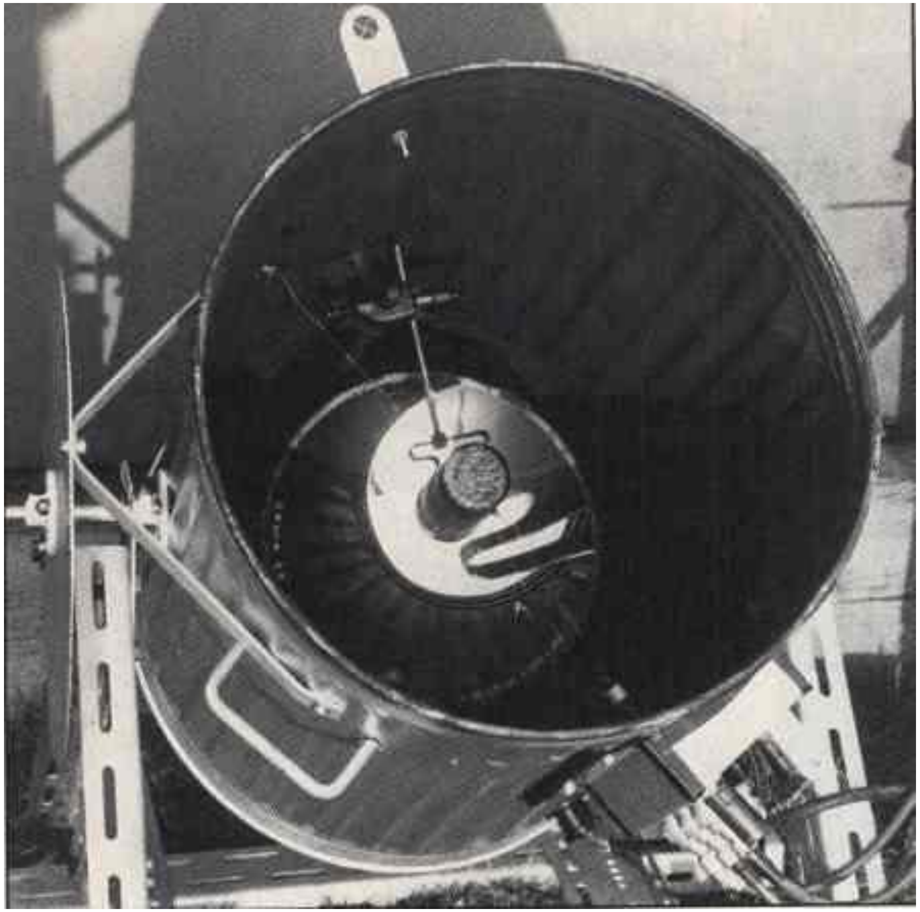
Similar to sonic boom if $v > c_{acoustic}$

v > c/n
==> radiation from different points along the trajectory arrive in phase within narrow light-cone at the observer ==> bright light

- Initially complaning about his boss: he had to spend >1-1,5 hours in a dark, cold cellar, for accomodating his eyes
- He noticed that the emission is not chaotic, but is related to the track of moving particle.
- 1934-1938 conducting a series of brilliant expeirments.
- Obtained doctorate in 1940



The Experimental Beginning



1953
By using a garbage can,
a 60 cm diameter mirror
in it and a PMT in its focus
Galbraith and Jelly had
discovered the
Cherenkov light pulses
from the extensive air
showers.

Gamma-ray Astronomy, the beginning

Seminal paper by Phillip Morrison, 1958

AN AIR SHOWER TELESCOPE

AND THE DETECTION OF 10^{12} eV PHOTON SOURCES

Giuseppe Cocconi *

CERN - Geneva.

1) This paper discusses the possibility of detecting high energy photons produced by discrete astronomical objects. Sources of charged particles are not considered as the smearing produced by the magnetized plasmas filling the interstellar spaces probably obliterates the original directions of movement.

2). Here are some numerical estimates.

The Crab Nebula: Visual magnitude of polarized light m = 9.

Magnetic field in the gas shell $H \simeq 10^{-4}$ gauss.

Therefore: $U_\gamma = 10^{12}$ eV and $R(10^{12} eV) \approx 10^{-3.2}\ m^{-2} s^{-1}$.

The signal is thus about 10^3 times larger than the background (2). Probably in the Crab Nebula the electrons are not in equilibrium with the trapped cosmic rays, and our estimate is over-optimistic. However, this source can probably be detected even if its efficiency in producing high energy photons is substantially smaller than postulated above.

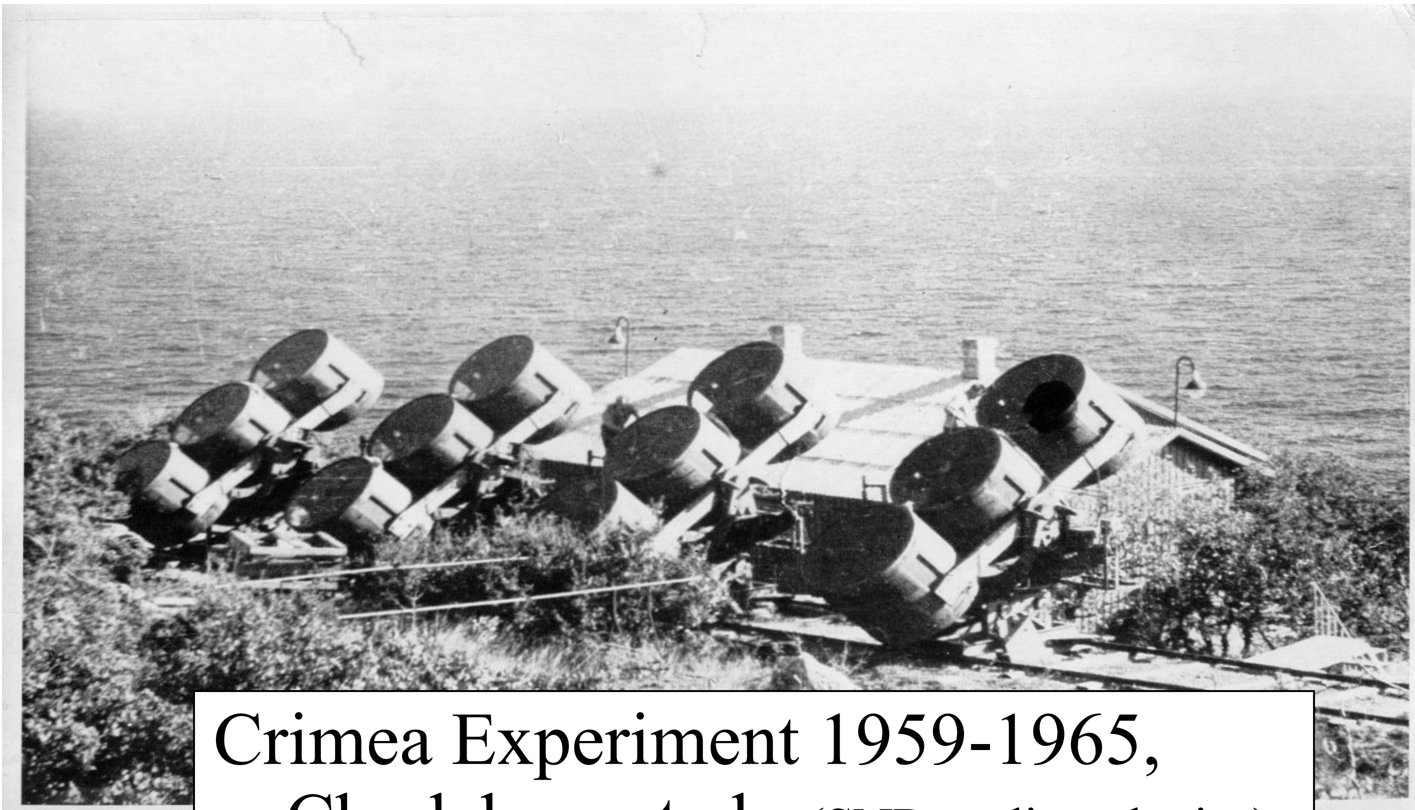
M87, the Jet Nebula: m = 13.5 $H \simeq 10^{-4}$ gauss.

$R(10^{12} eV) \simeq 10^{-5} m^{-2} s^{-1}$, still well above the background (2). For this object our evaluation is probably not fundamentally wrong.

Also proposed at higher energies independently by Giuseppe Cocconi, 1959

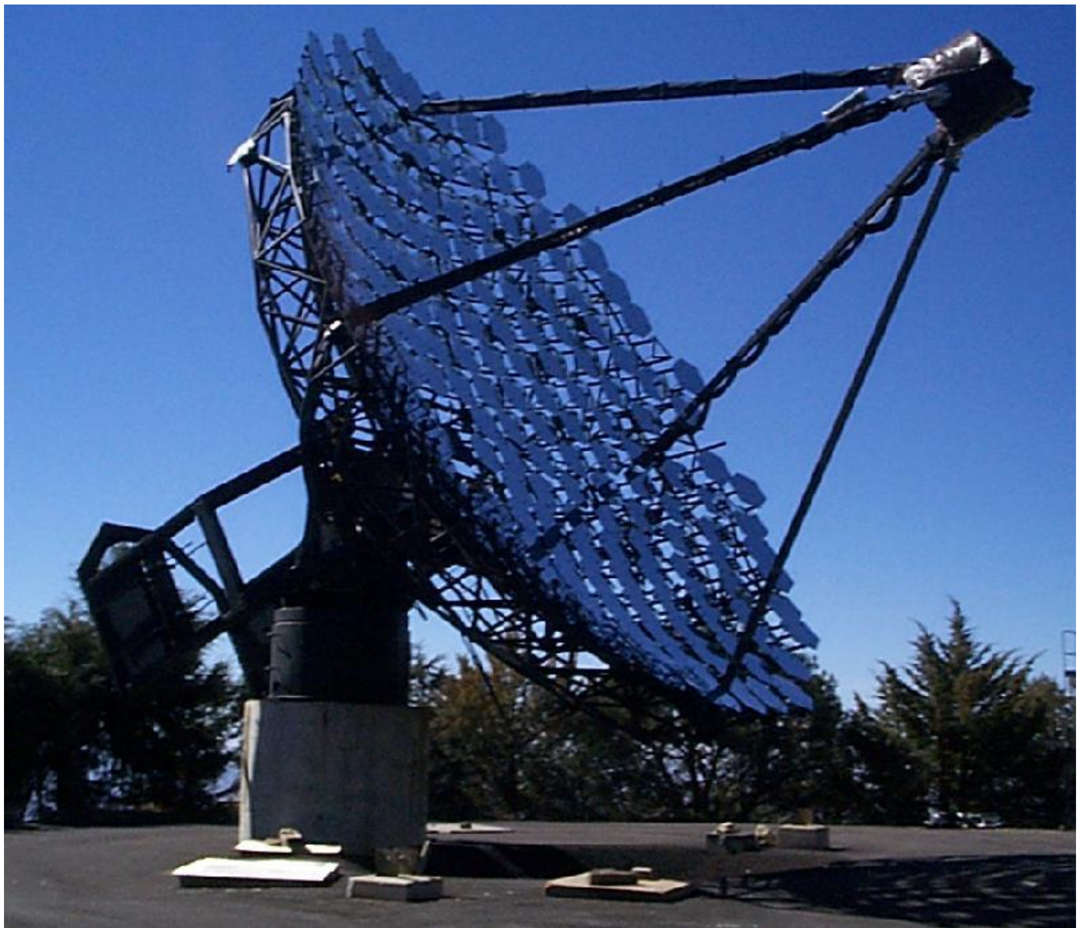
1921-2001

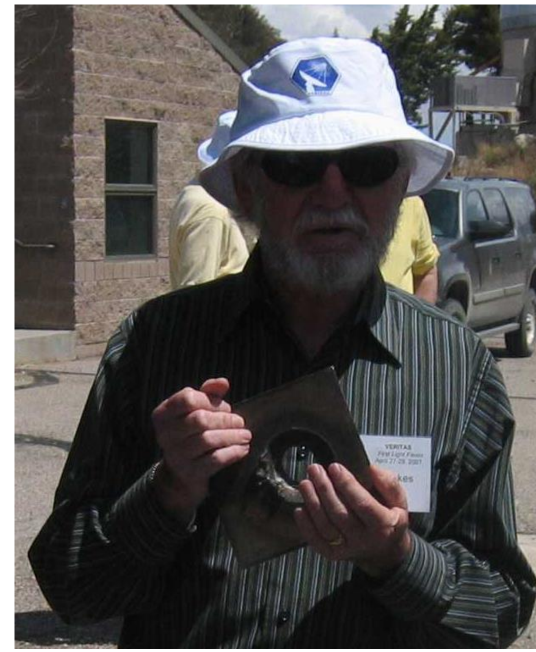
Alexander Chudakov and the Cherenkov Technique for Gamma Ray Astronomy



Crimea Experiment 1959-1965,
Chudakov, et al., (SNR, radio galaxies)

The Pioneer Trevor Weekes and his 10m Ø Whipple telescope gave birth to γ-ray astrophysics: 9σ from Crab Nebula in 1988 !





„If a telescope can within a few s evaporate a solid piece of steel, it can also measure gamma rays“ ;-)

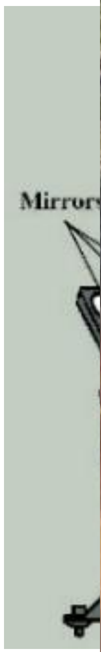
Last year we celebrated the 30 year jubilee of ground-based VHE γ-ray astronomy

- The first 9σ detection of the Crab Nebula marked the birth of the VHE γ-ray astronomy as an independent branch of astronomy

- This detection was reported by the 10m diameter Whipple IACT team in Arizona, lead by the pioneer of VHE γ-ray astronomy Trevor Weekes, in 1989

- With the detection of the first gigantic signal from the GRB190114C (in the first 30 s the gamma-ray rate was x 130 Crab!) one year ago we celebrated the 30 years jubilee of VHE γ-ray astronomy !

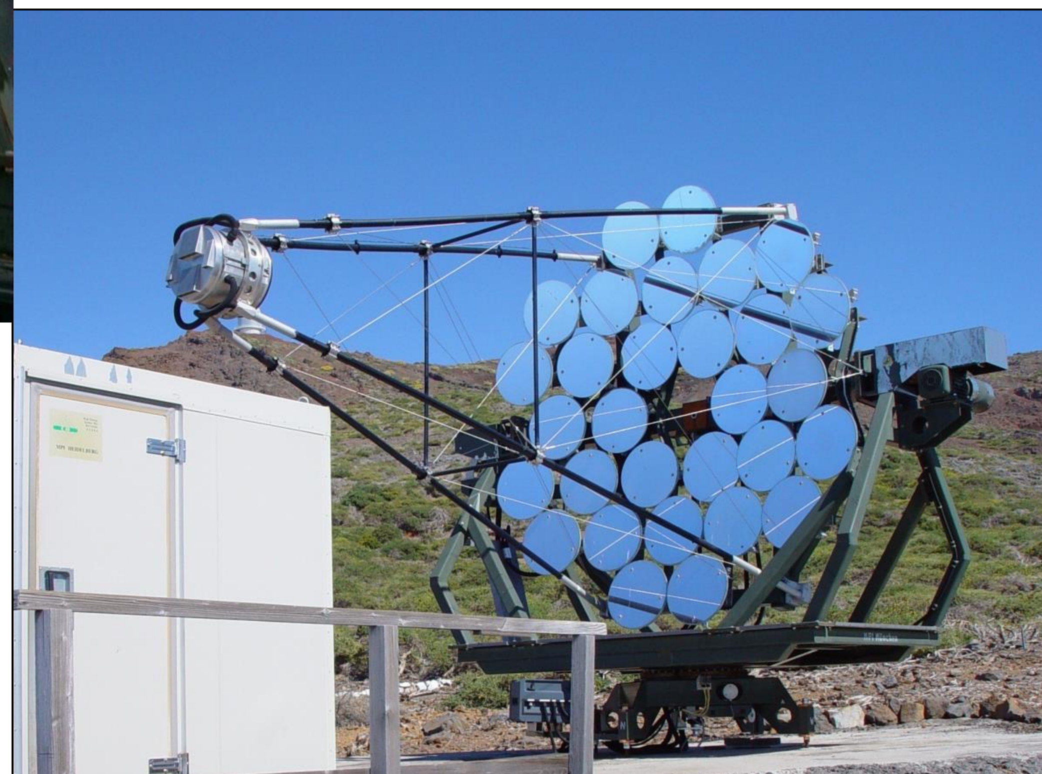
Arnold Stepanian's pioneering imaging "stereo "telescopes: GT-48 in Crimea



The 1st telescope (of 5 planned) we´ve built: 1989

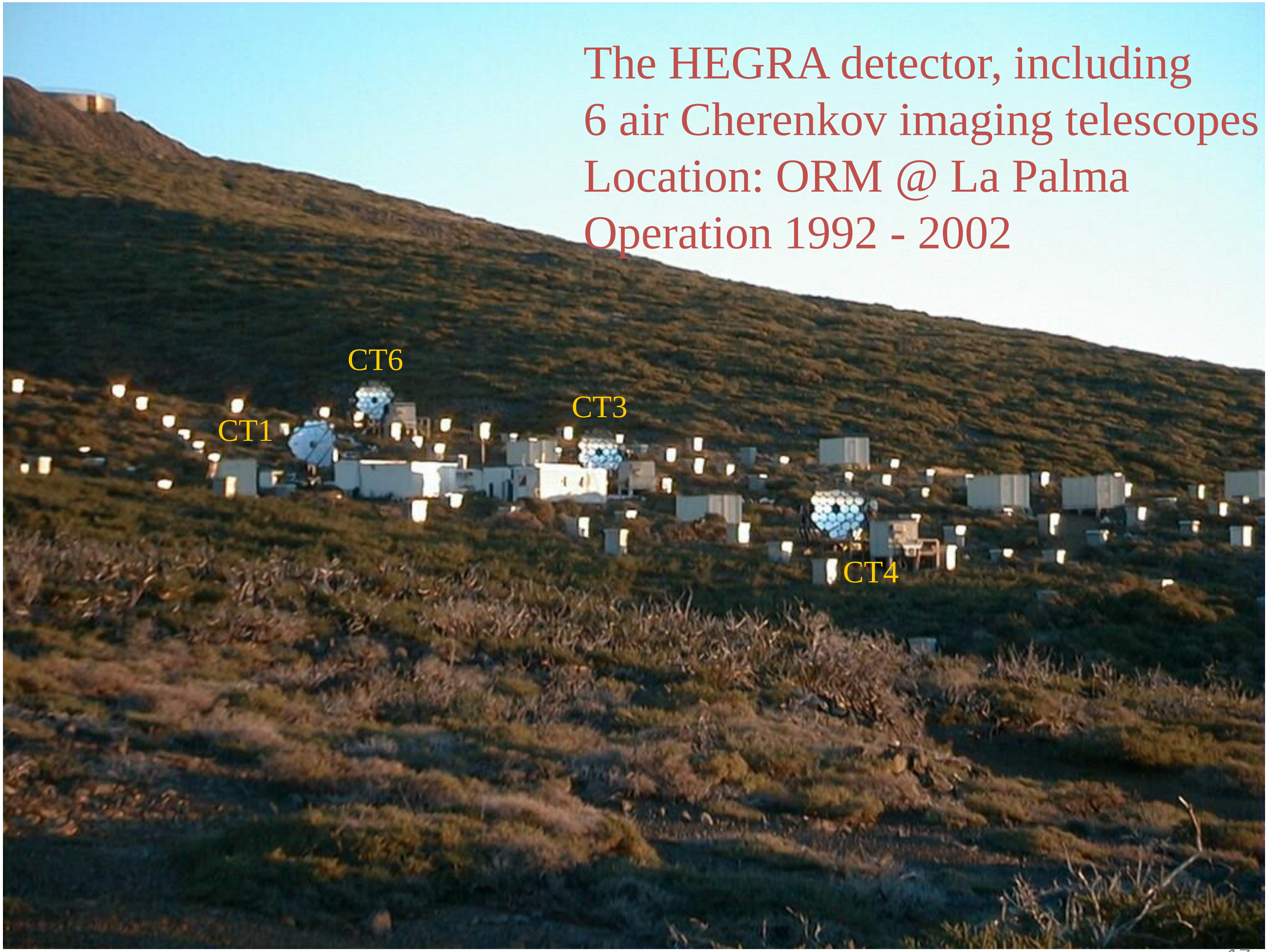
CT1 started to collect data in summer 1992
The 1st signal from Crab Nebula fall 1992

CT2 – CT6: 5 more telescopes were built until 1997.

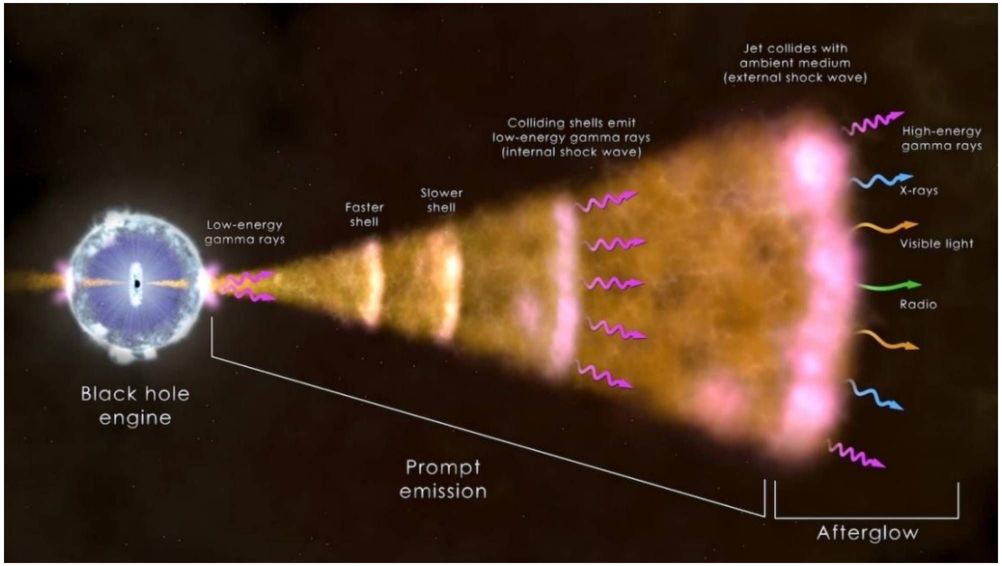


The 1st telescope of HEGRA, the CT1 (installed spring 1992)

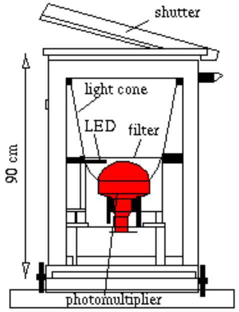
The HEGRA detector, including
6 air Cherenkov imaging telescopes
Location: ORM @ La Palma
Operation 1992 - 2002



Gamma Ray Bursts



- Most powerful, violent, distant explosions in the Universe
- 2 different populations, short and long bursts
- Long GRBs: T > ~ 2s; massive star collapse > ultra-relativistic jet
- Recent detection of a gravitational wave signal consistent with a binary neutron star merger and associated to a short GRB
- Until recently Both long and short GRBs have been detected at E < 100 GeV
- No strict division in time between prompt and afterglow



Past Hint from a GRB @ E ≥ 20 TeV AIROBICC & GRB 920925c

- AIROBICC in 1990's was an open air Cherenkov integrating array of 7x7 PMT-based stations (40cm Ø light guide) of ≥ 0.032 km^2
- From GRB 920925c one expected 0.93 events while 11 were observed.
- But the "signal" preceded the WATCH trigger by < 1 minute and was ~9° away from its location.
- Evidence ~2.7 σ (post-trial) from AIROBICC above 20 TeV from GRB 920925c was reported

Padilla et al., 1998

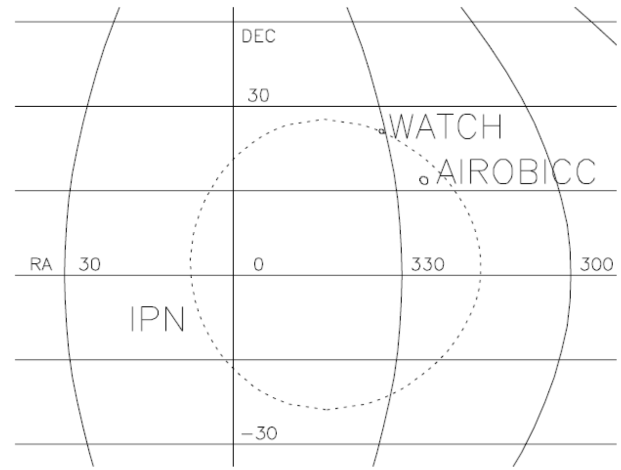
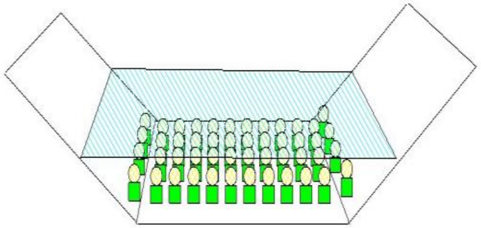


Fig. 6. Map with the situation of the WATCH GRB 920925c and the IPN ring as calculated from the WATCH and ULYSSES observations. The location of the excess detected by AIROBICC nearly coincident in time with WATCH is also shown.

Keeping in mind the unknown redshift and the possible EBL absorption, this should be a spurious event

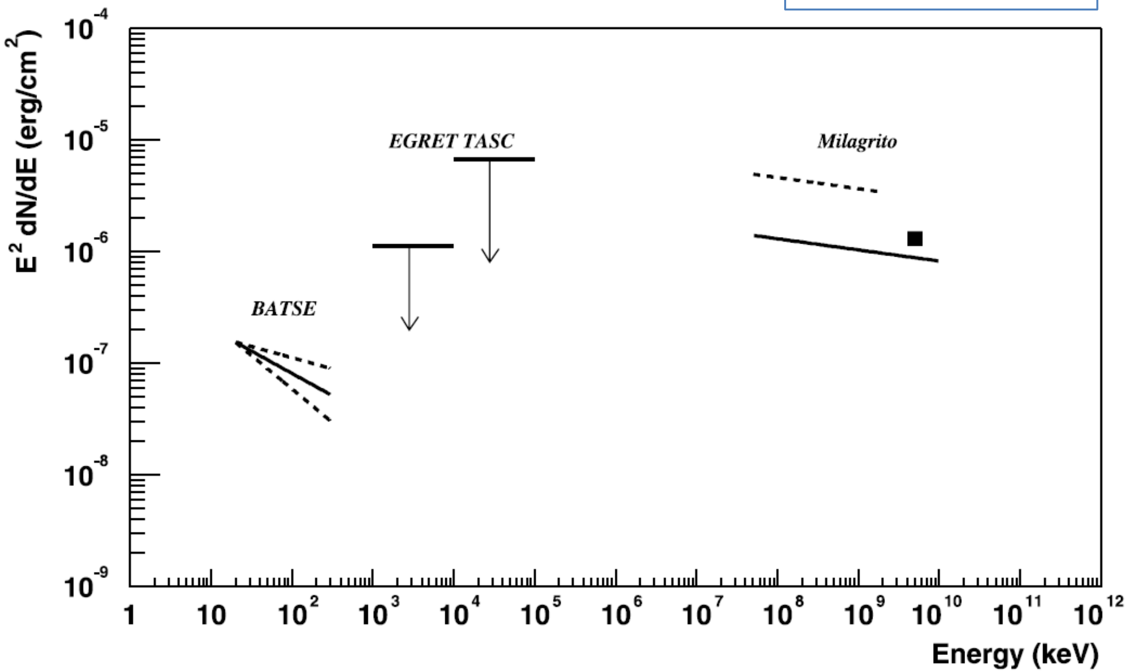


Past Hints from GRBs @ sub-TeV Milagrito & GRB 970417a

- GRB 970417a was a weak, soft GRB as observed by BATSE. The fluence in the 50–300 keV range was 1.5 x 10^{-7} ergs cm^{-2} and the T90 period was 7.9 s.
- Milagrito, a prototype of Milagro, consisted of a planar array of 228 PMTs of 8'' size submerged in a light-tight water reservoir with a size of ~ 42 x 42 m^2. Milagrito reported evidence for emission above 650 GeV from GRB 970417a, with a (posttrials) probability of 1.5 x 10^{-3} of being a background fluctuation (Atkins et al. 2000; Atkins et al. 2003)

MILAGRITO and GRB 970417a

Atkins et al., 2003

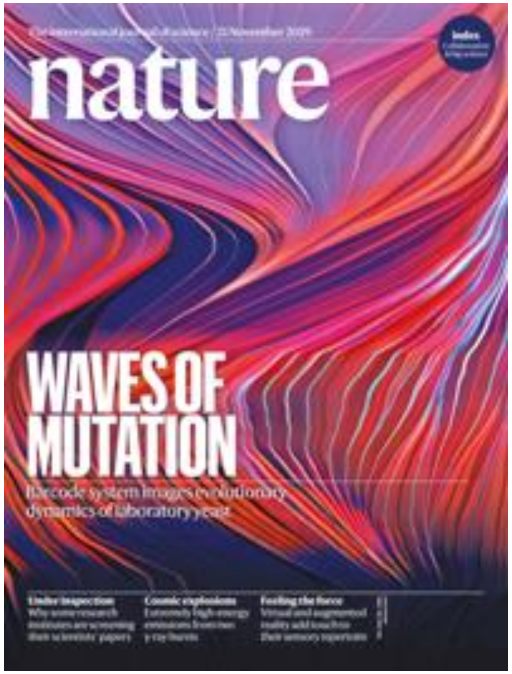


- The VHE fluence must be at least an order of magnitude greater than sub-MeV fluence measured by BATSE
- A way out: if the actual peak of the SED may lie below the energy range of BATSE ?

Fig. 9.—Spectral energy distribution for GRB 970417a, showing a single power-law fit to the BATSE data, upper limits at 1 and 10 MeV from the EGRET TASC detector, and three possible spectral forms consistent with the Milagrito observations.

Observing Transients with TeV Instruments

- All the major TeV instruments like **Veritas, H.E.S.S., HAWC, MAGIC, LHASSO,…** are pursuing intense programs for following transient alerts: GRBs, Gravitational wave sources, Neutrino ToO, Fast Radio Bursts, Novae, etc.
- While for a wide angle detector like HAWC the transient just needs to happen in their field of view, the narrow field of view IACTs need to possibly fast slew and track the alerted position
- All the IACTs optimized their operation for possibly fast sluing to the alerted position and starting observations
- Despite the really large number of followed GRBs by the above collaborations over many years, until recently only upper limits were reported



4 publications appeared in Nature in November 21st 2019 issue

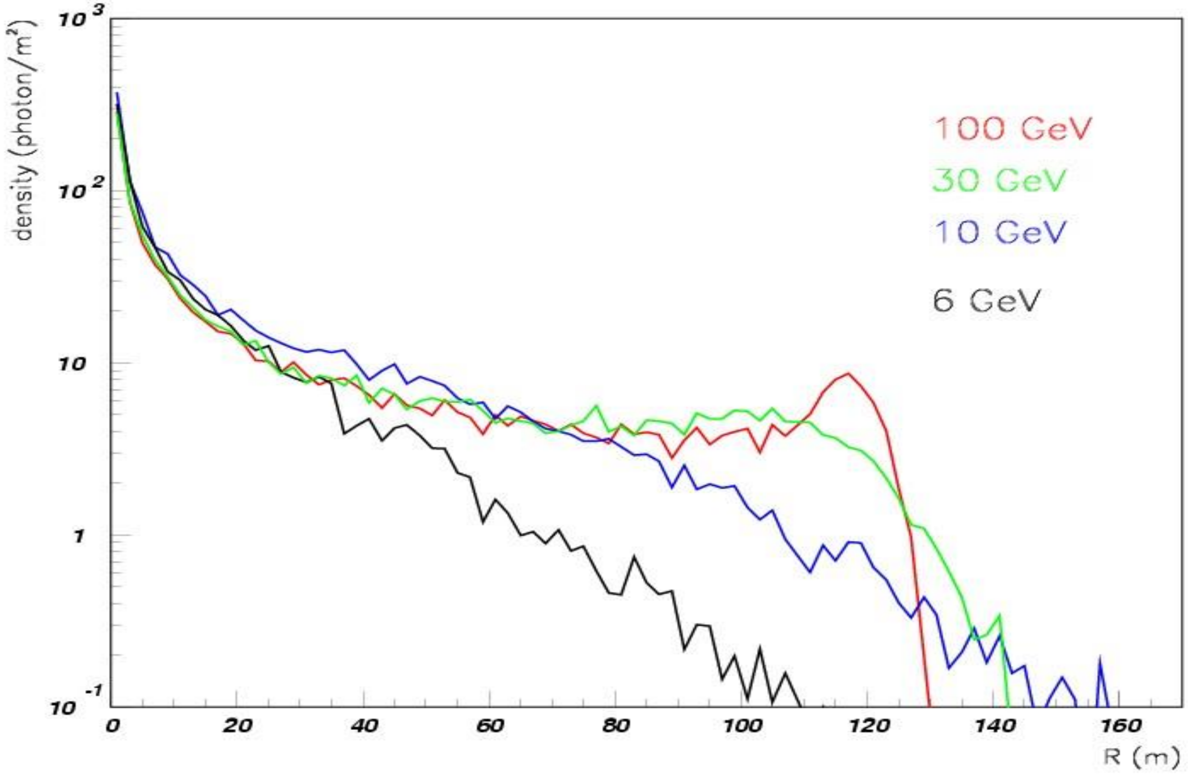
Teraelectronvolt emission from the γ-ray burst GRB 190114C
Acciari, et al., MAGIC Collaboration
Observations of teraelectronvolt-energy γ-rays starting about one minute after the γ-ray burst GRB 190114C reveal a distinct component of the afterglow emission with power comparable to the synchrotron emission.

Observation of inverse Compton emission from a long γ-ray burst
MAGIC Collaboration, et al.,
A multi-frequency observing campaign of the γ-ray burst GRB 190114C reveals a broadband double-peaked spectral energy distribution, and the teraelectronvolt emission could be attributed to inverse Compton scattering.

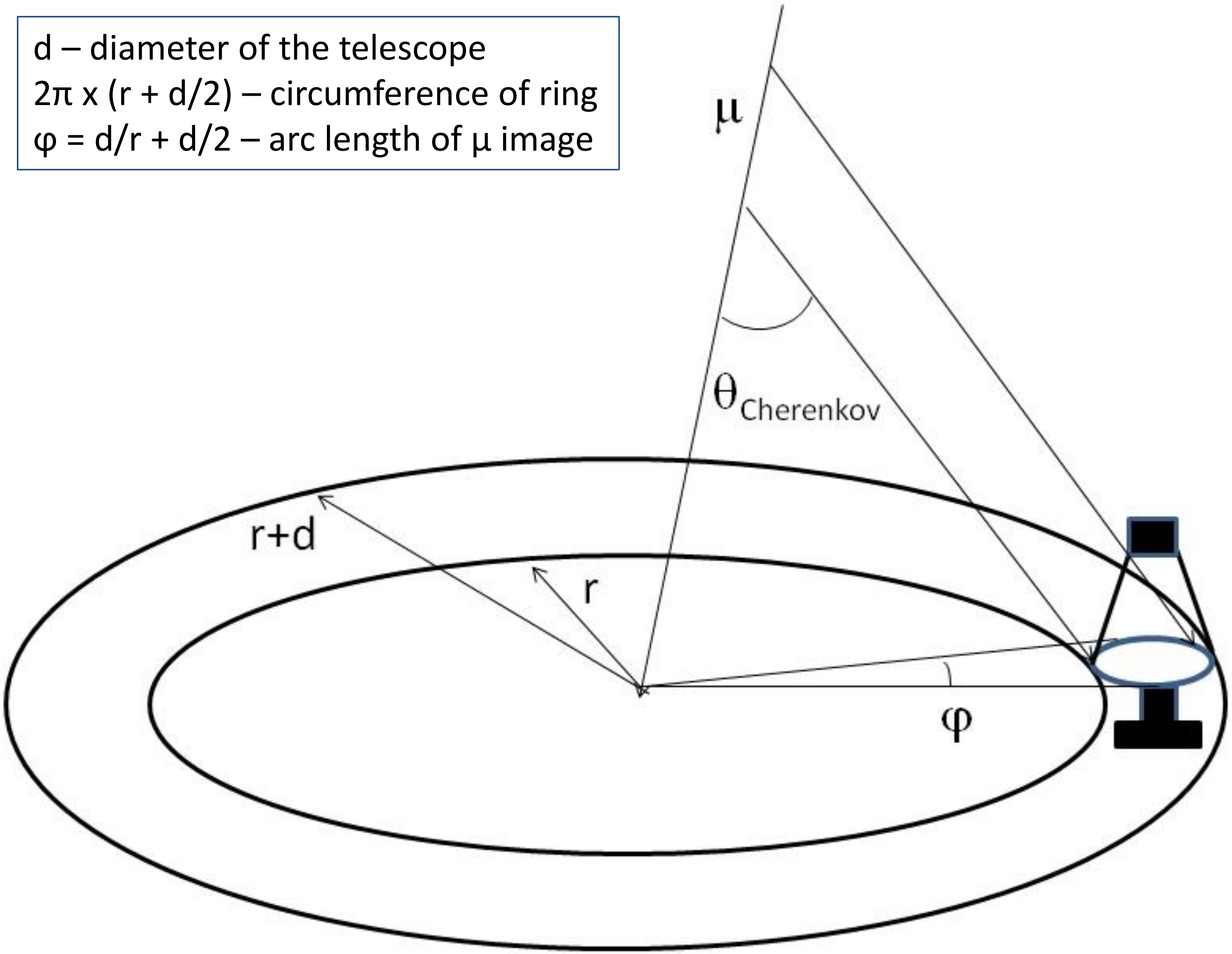
A very-high-energy component deep in the γ-ray burst afterglow
Abdalla, et al., H.E.S.S. Collaboration
Very-high-energy γ-rays observed ten hours after the prompt emission of the γ-ray burst 180720B can be attributed to either an inverse Compton or an extreme synchrotron process.

News & Views | 20 November 2019
Bing Zhang
Extreme emission seen from γ-ray bursts

Lateral distribution of light from a single μ

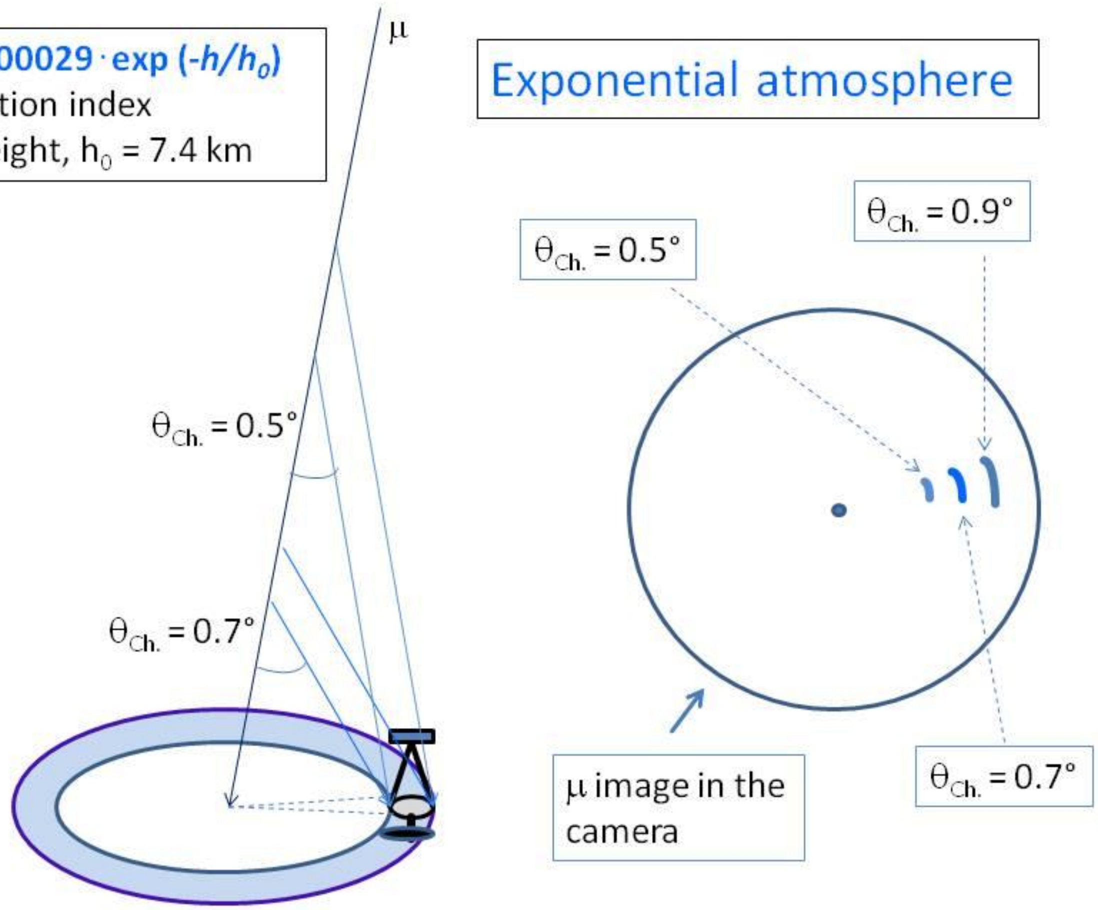


d – diameter of the telescope
2π x (r + d/2) – circumference of ring
φ = d/r + d/2 – arc length of μ image



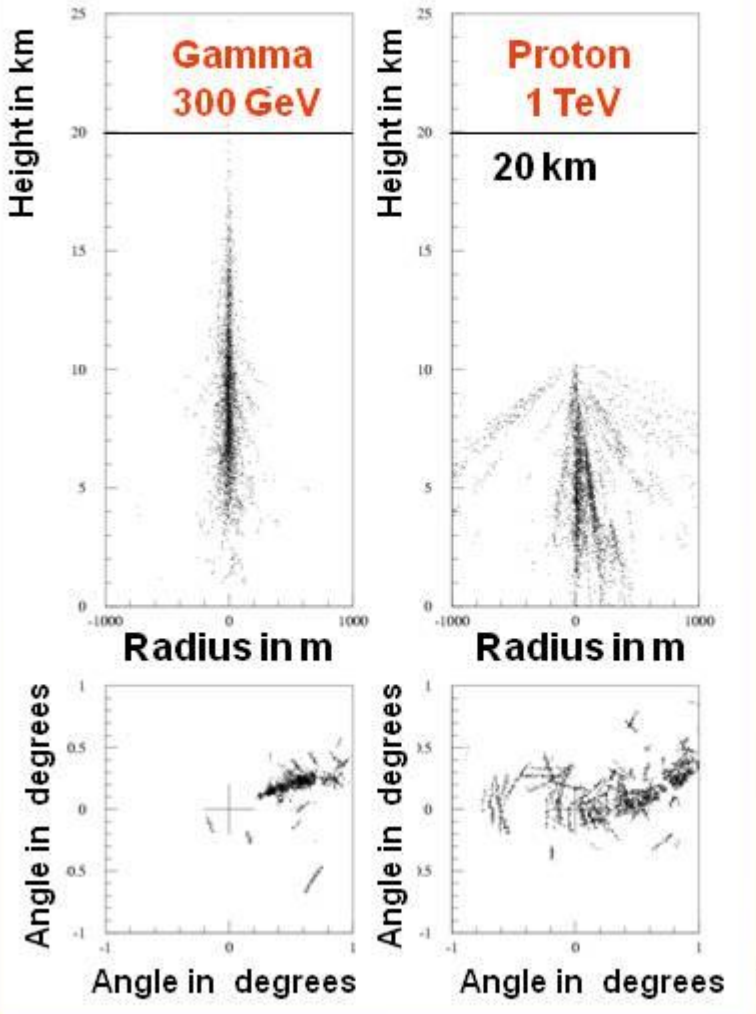
VHE γ-astrophysics with IACTs is possible thanks to exponential atmosphere

$n(h) = 1 + 0.00029 \cdot \exp(-h/h_0)$
n(h) – refraction index
h_0 – scale height, h_0 = 7.4 km

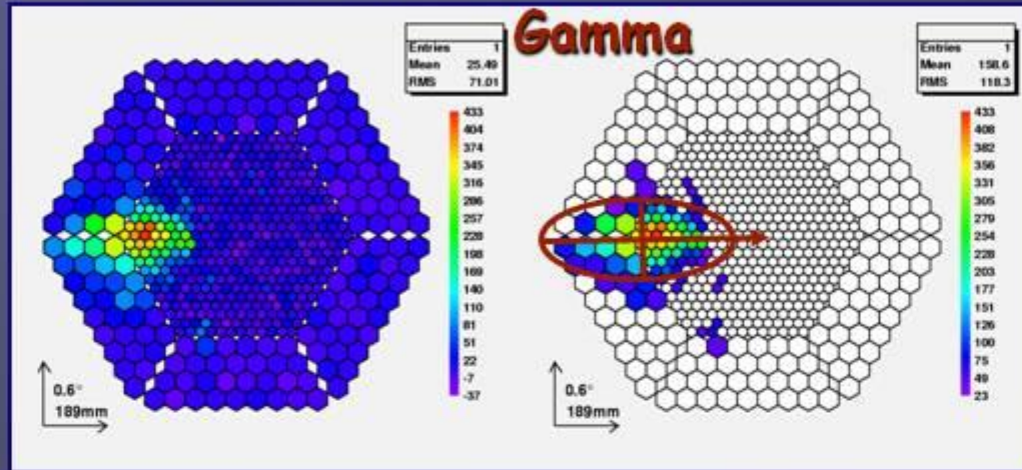


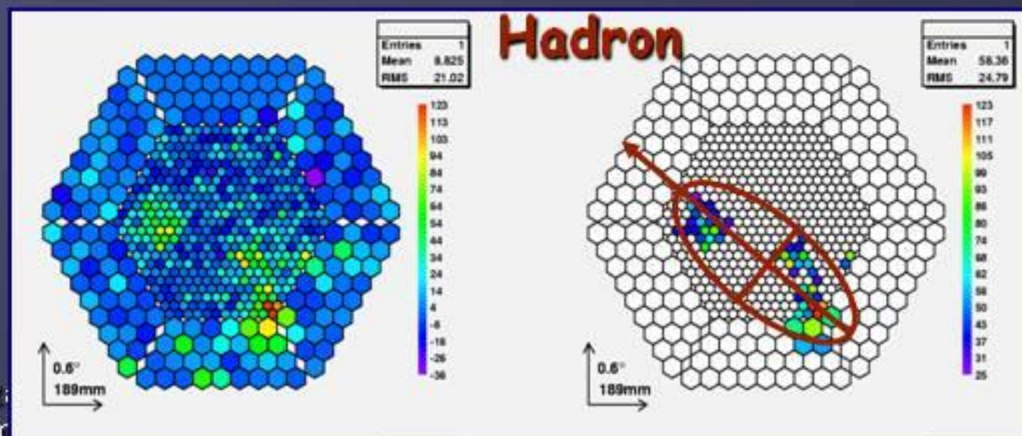
Gamma/Hadron separation

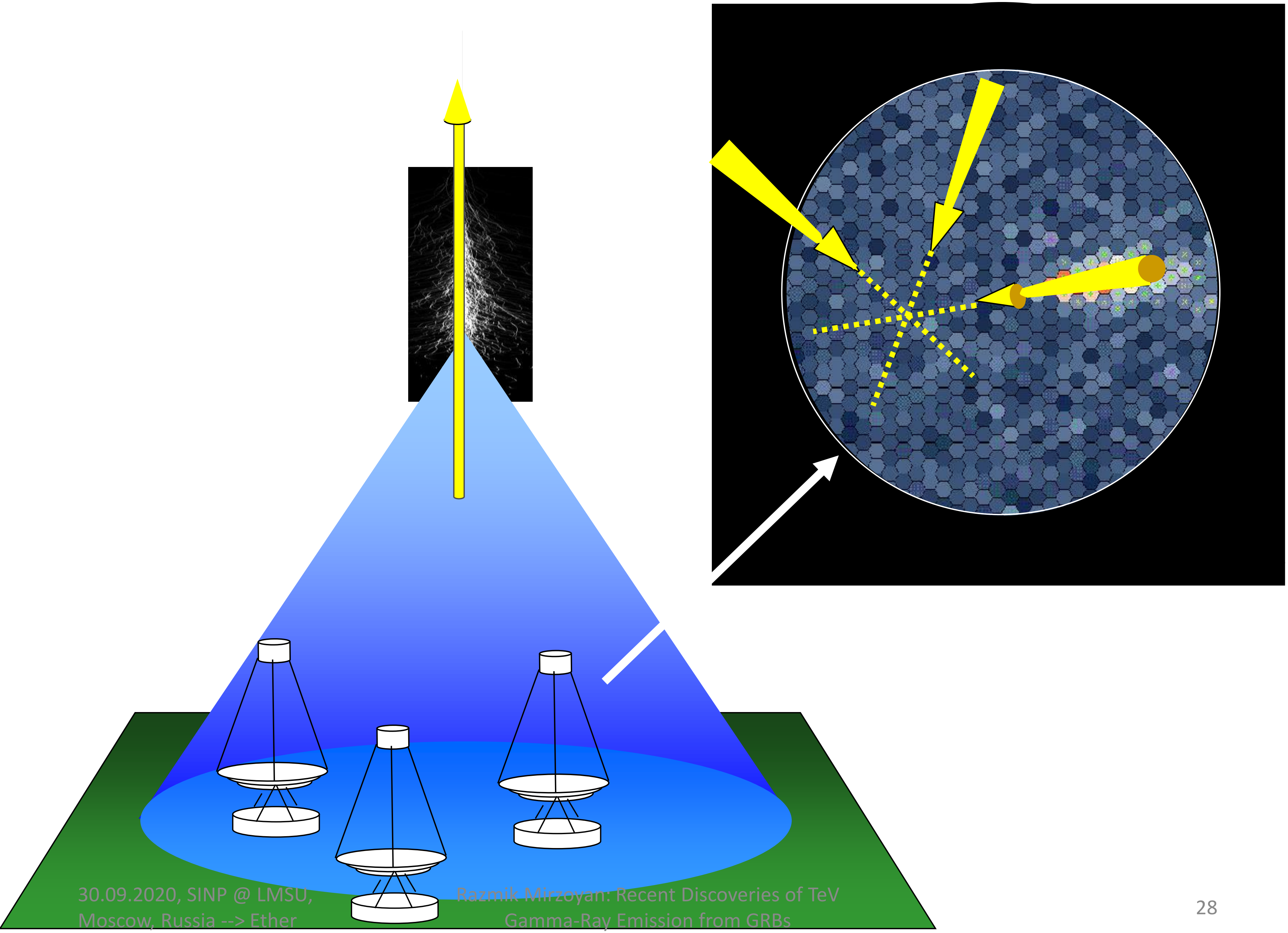
MC Simulation of Shower



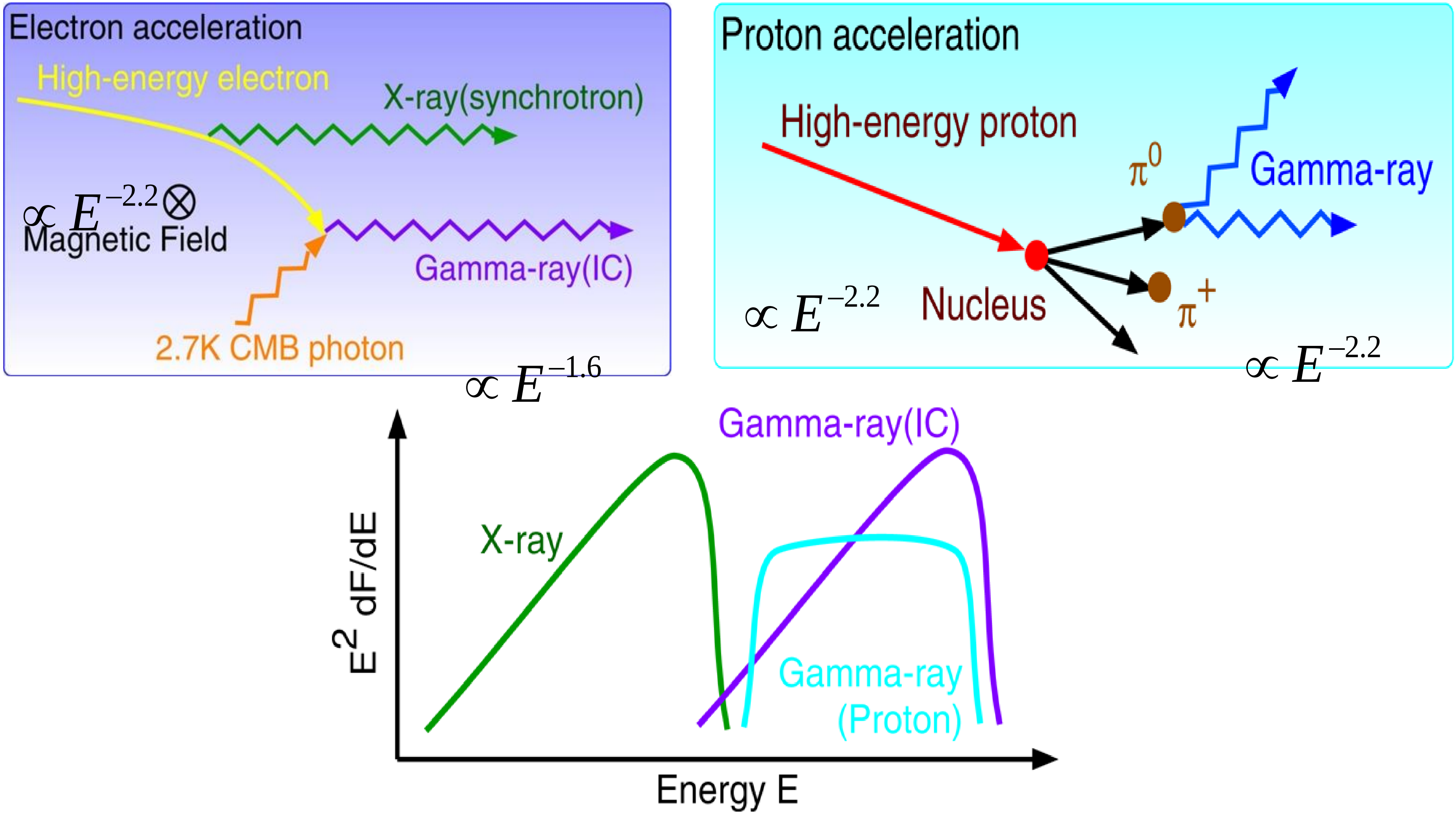
Hadron Rejection by Image Shape + Orientation ~ 99.9 %



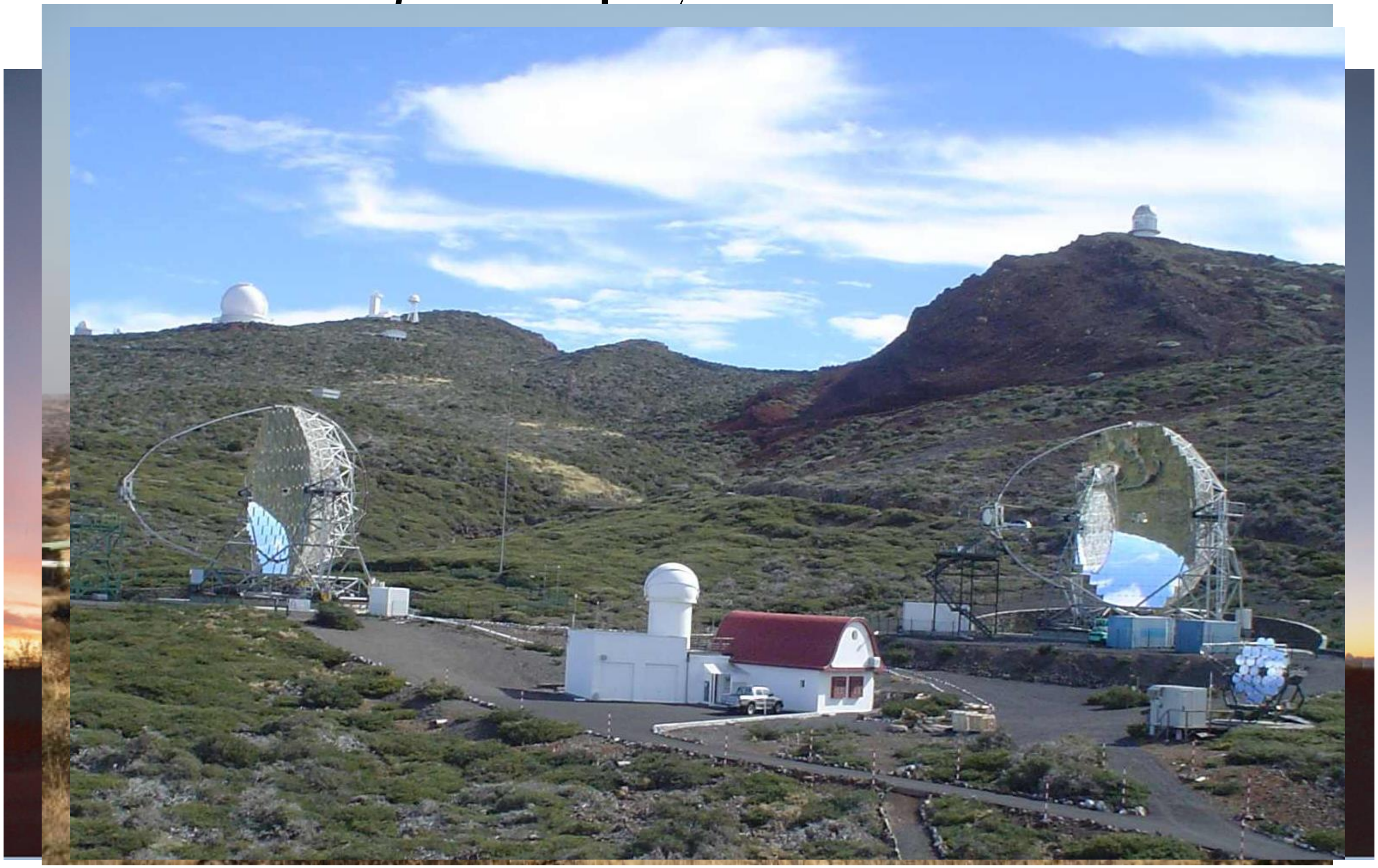




Gamma-Ray Emission Processes
Astrophysical process



VERITAS, H.E.S.S. & MAGIC: pushing the VHE γ-astro-physics to its limits



The 17m Ø MAGIC IACT project for VHE γ astrophysics at E ~ 30 GeV - 100 TeV

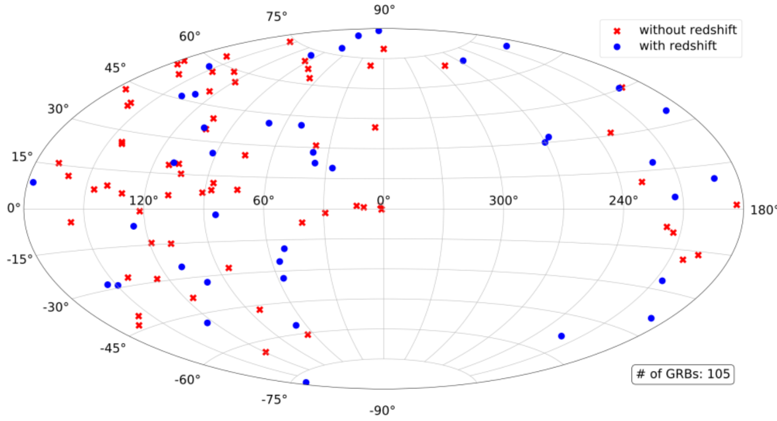
Fast Motion of the MAGIC Telescopes

Fully-Automatic System for Following the Transient Alerts with MAGIC

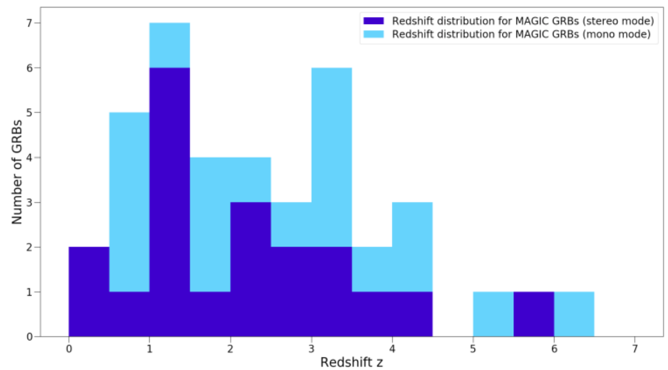
- When obtaining an alert the software checks several criteria if the alert should be followed
- If yes, the telescopes start fast rotation and within ≤ 25 s slue to any given position in the sky and start tracking it
- While the telescopes are in fast motion, the software closes data-taking files of the previous observation, downloads the look-up tables for the aimed for elevation angle and by using the AMC system re-adjusts the individual mirror positions, adjusts the discriminator thresholds to the estimated brightness of the position
- We used to issue fake alerts once per observational shift for debugging the system

GRB follow-ups

- Since 2005 we observed 105 GRBs
- On average 8-10 GRB/year
- Afterglow observations since 2013
- 24 with < 100 s delay & stereo, 4 out of which with z < 1.5

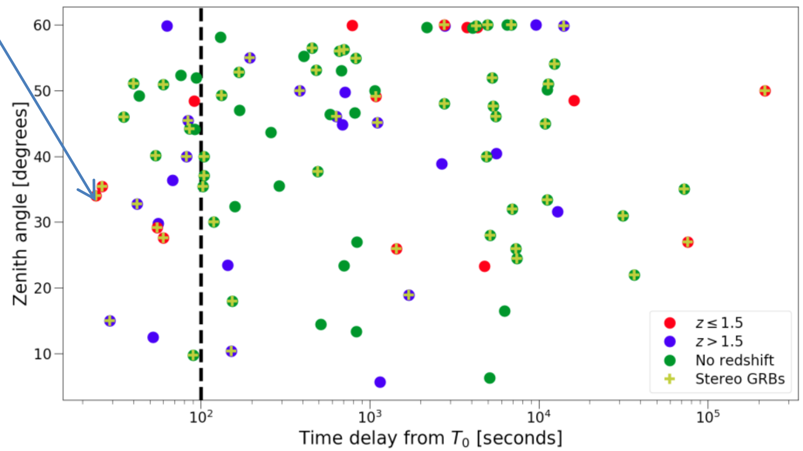


Red-shift distribution



GRB 160821B

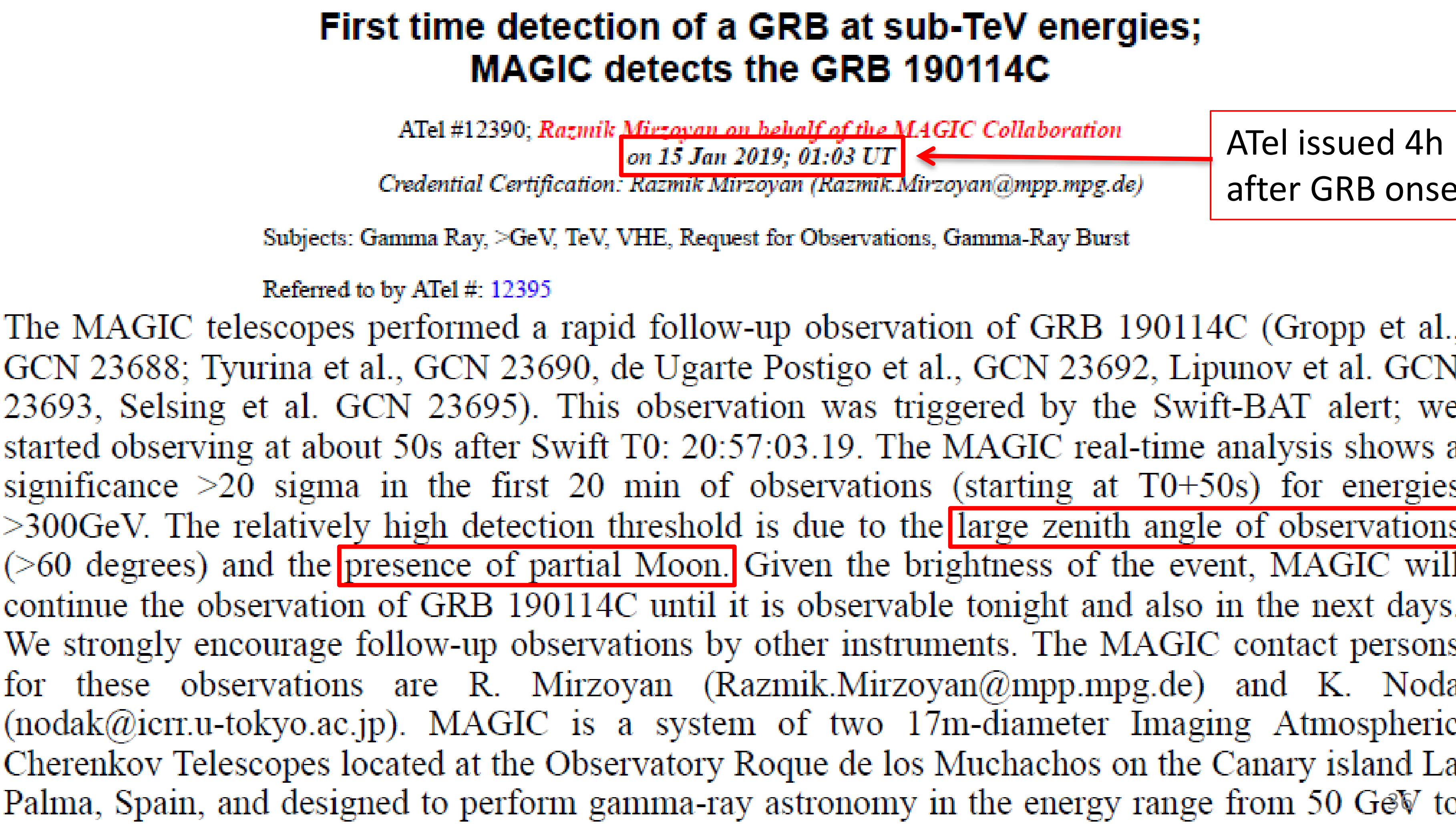
Delay versus observation angle



List of MAGIC GRBs observed under good technical and weather conditions with $z < 1$ and $T_{delay} < 1$ h

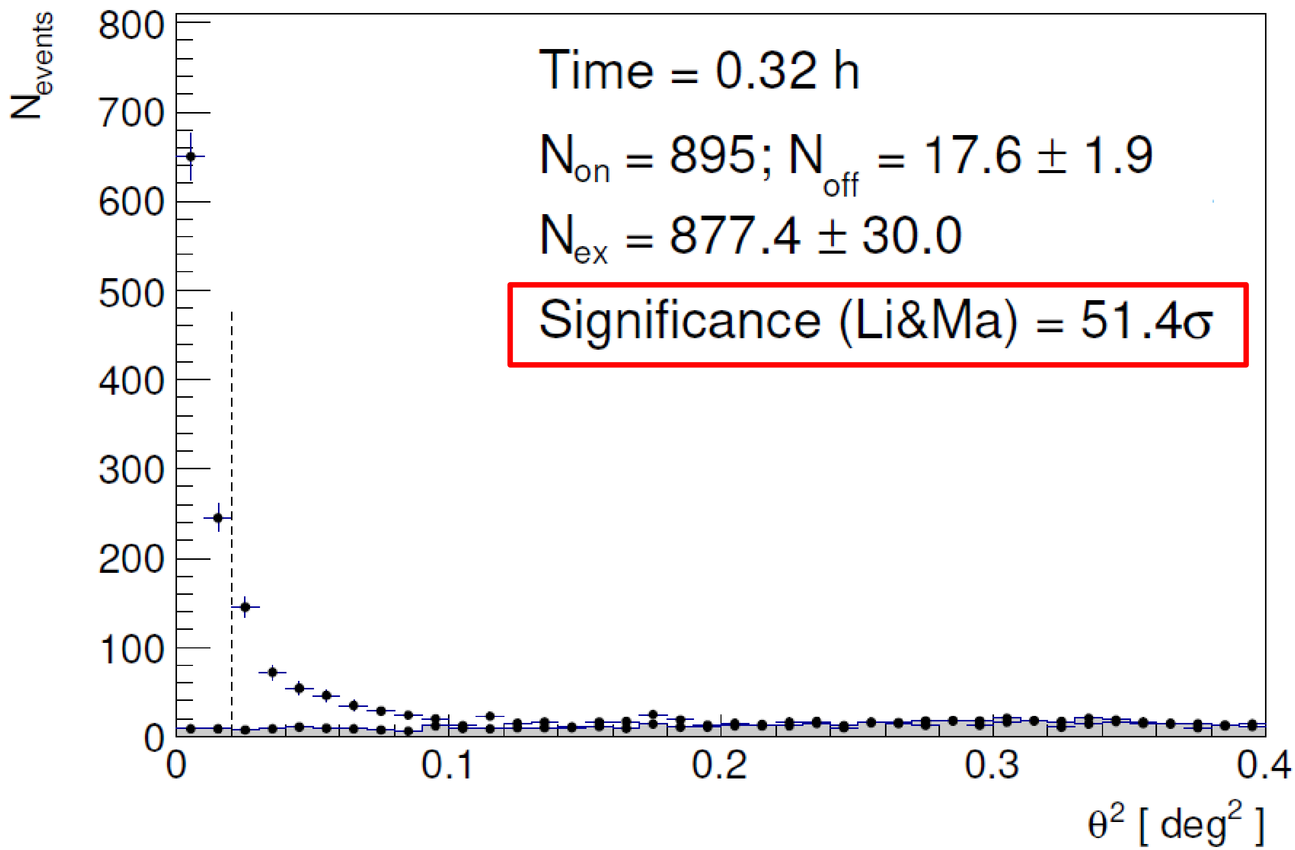
Event	redshift	T_{delay} (s)	Zenith angle (deg)	
GRB 061217	0.83	786.0	59.9	short
GRB 100816A	0.80	1439.0	26.0	short
GRB 160821B	0.16	24.0	34.0	short
GRB 190114C	0.42	58.0	55.8	long

MAGIC capability to observe at the presence of **partial Moon** and at **large zenith angles** were of key importance for this detection



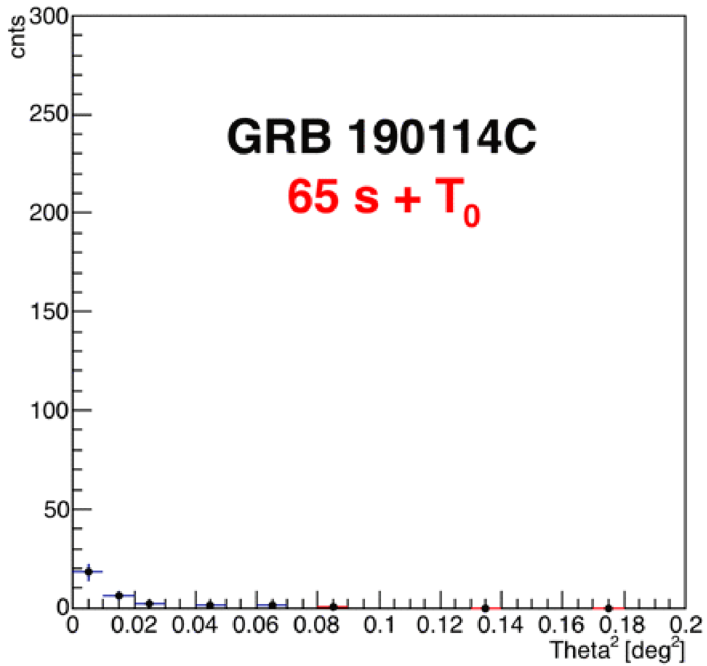
ATel issued 4h after GRB onset

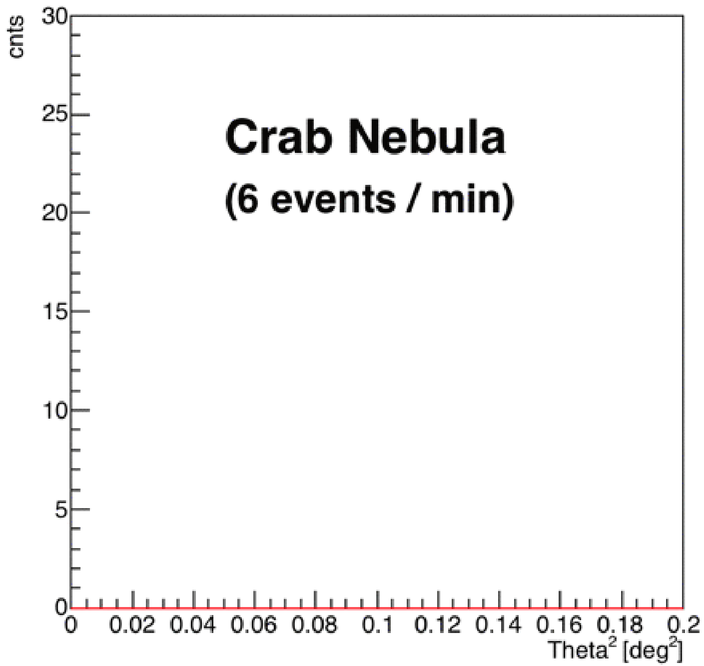
The most intense, purest signal in VHE γ-ray astrophysics: GRB190114C detection by MAGIC at E ≥ 200 GeV



γ-rate from GRB190114C & Crab Nebula by MAGIC for the first ~100 s of data taking; during the first 30s the VHE γ rate is ~ 130 x Crab

Please note the Y-axes scale difference of x 10 for the GRB190114C



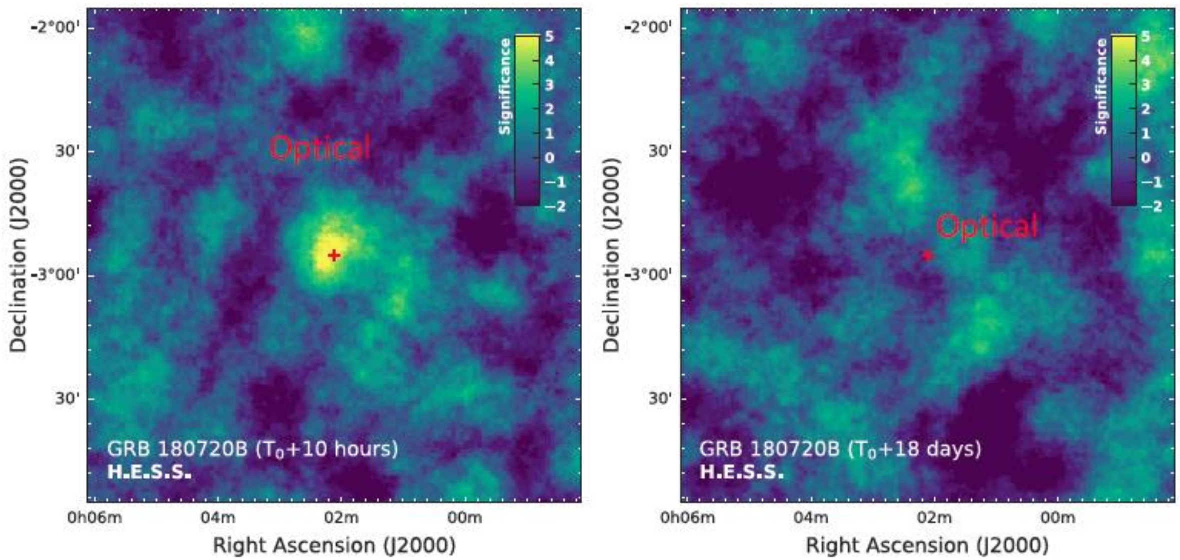


@ CTA symposium in Bologna in May 2019 H.E.S.S. reported on GRB 180721B

The GRB180720B detection

- 10 hours after the Swift trigger
- Redshift z = 0.653 (ESO-VLT/X-shooter)

Details in Gal10a by Quentin Piel



2 hours taken between 25° and 40° zenith angle

Between 18 days and 25 days after the burst

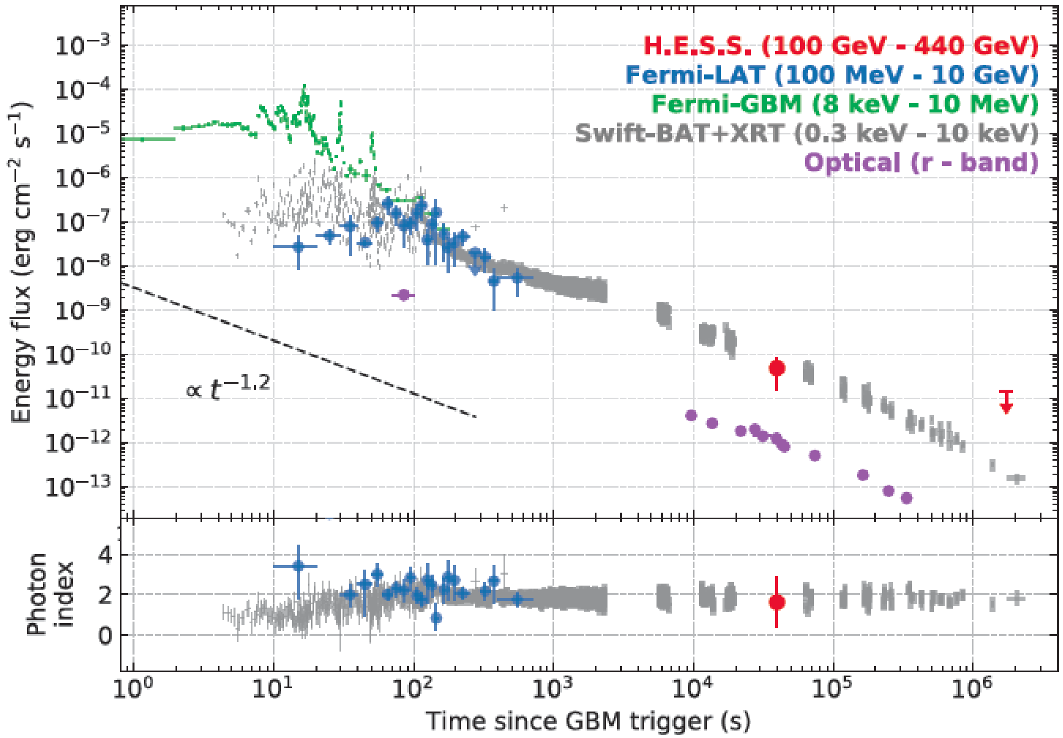
H.E.S.S.

Piel - Gamma-Ray Burst observations at Very High Energy with H.E.S.S. - ICRC 2019 9

H.E.S.S. Detection of Afterglow From GRB180720B

The GRB180720B detection

- Fermi-LAT detection up to 700 s after trigger wit a photon index close to -2.0.
- Coincident optical and X-ray temporal decay
- H.E.S.S. detection until 440 GeV and same level as X-ray domain



Piel - Gamma-Ray Burst observations at Very High Energy with H.E.S.S. - ICRC 2019 10

H.E.S.S.

The Original Goals of the MAGIC Project: Measure GRBs, Pulsars, Distant AGN above the threshold energy 10 GeV

MAGIC Design Study, 1998

MAGIC is a pioneering IACT paving the road down to a few 10's of GeV energies

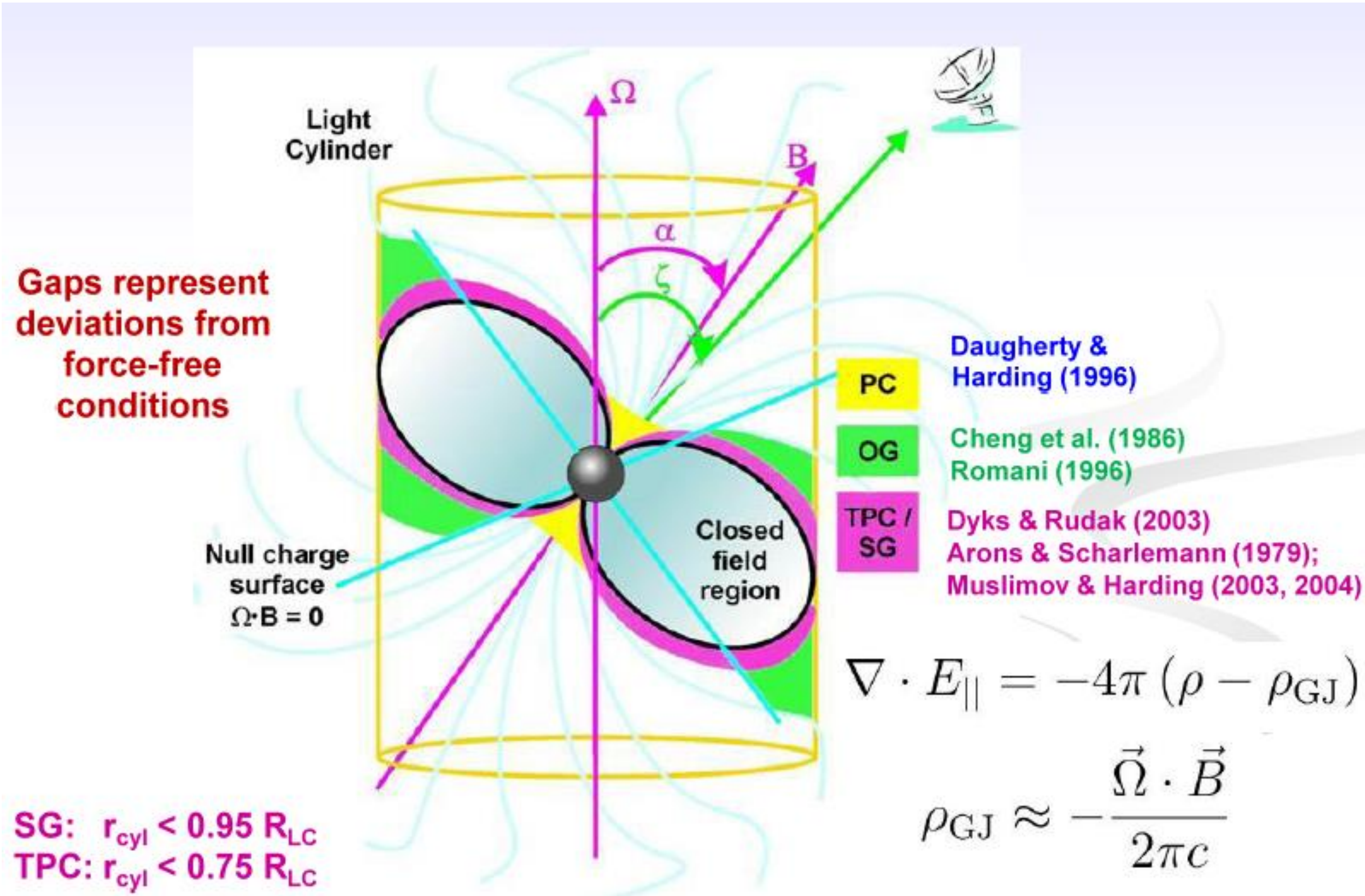
Introduced multiple novel techniques & technologies into the field

- Fast slew for transients
- Active Mirror Control
- T° controlled camera
- Analog signal via optic fibers, ~2ns fast signals
- Carbon-fiber structure,…

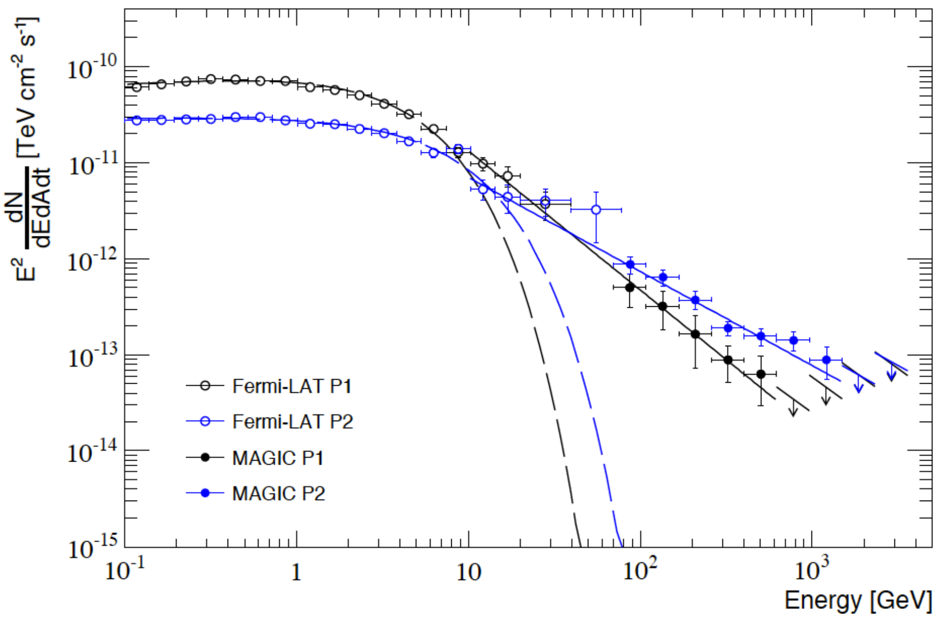
After 15 years of successful operation of MAGIC we thought we are ready to measure the next best GRB above the lowest threshold

- With time we improved the performance of the MAGIC telescopes and learnt to measure γ-ray signals from sources at E ≥ 20-30 GeV; (*G. Ceribella, "Crab Pulsar & Nebula"* 36th ICRC ; Acciari et al, *and* M. López, "Detection of the *Geminga pulsar*", accepted for publication in A&A Letters)
- We succeeded to measure the spectrum of a remote *FSRQ PKS1441* (z=0.939) at E ≥ 40 GeV *(Ahnen, et al, ApJL 2015)*
- So we were preparing and training ourselves to measure γ-rays at lowest energies ≥ 20-30 GeV from the next best GRB

Cartoon of a pulsar



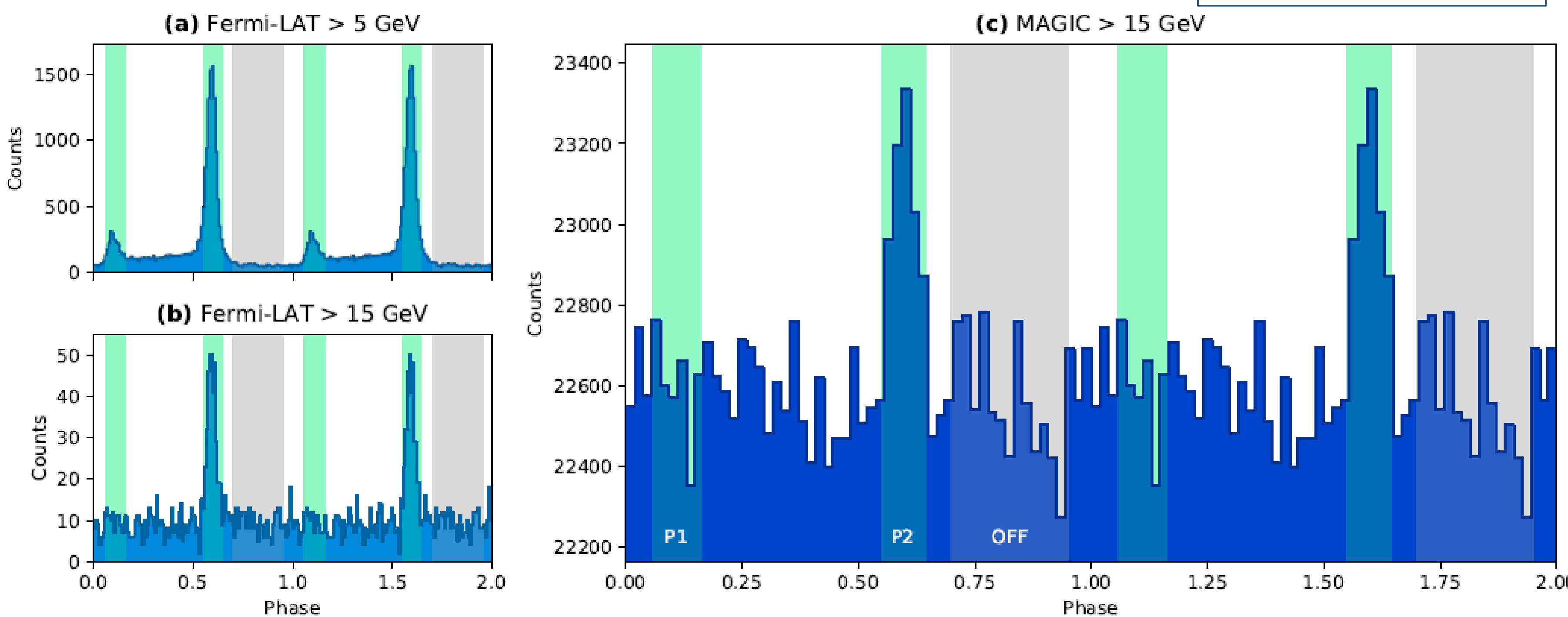
MAGIC established the Crab pulsar as the most compact accelerator of TeV γ rays



- Discovered pulsed emission from Crab, spectrum extending ≥ 1.2 TeV
- Challenging the emission models
- MAGIC-Fermi fit shows IC emission from ~10 GeV to ≥ 1 TeV
- Emission from the neighborhood of Light Cylinder (r ~1600km)
- TeV pulsation is used to put quadratic limits for Lorentz Invariance Violation (LIV): EQG2 > 4.4 x 10^{10} GeV: this is only factor 3 below current best limit from Fermi

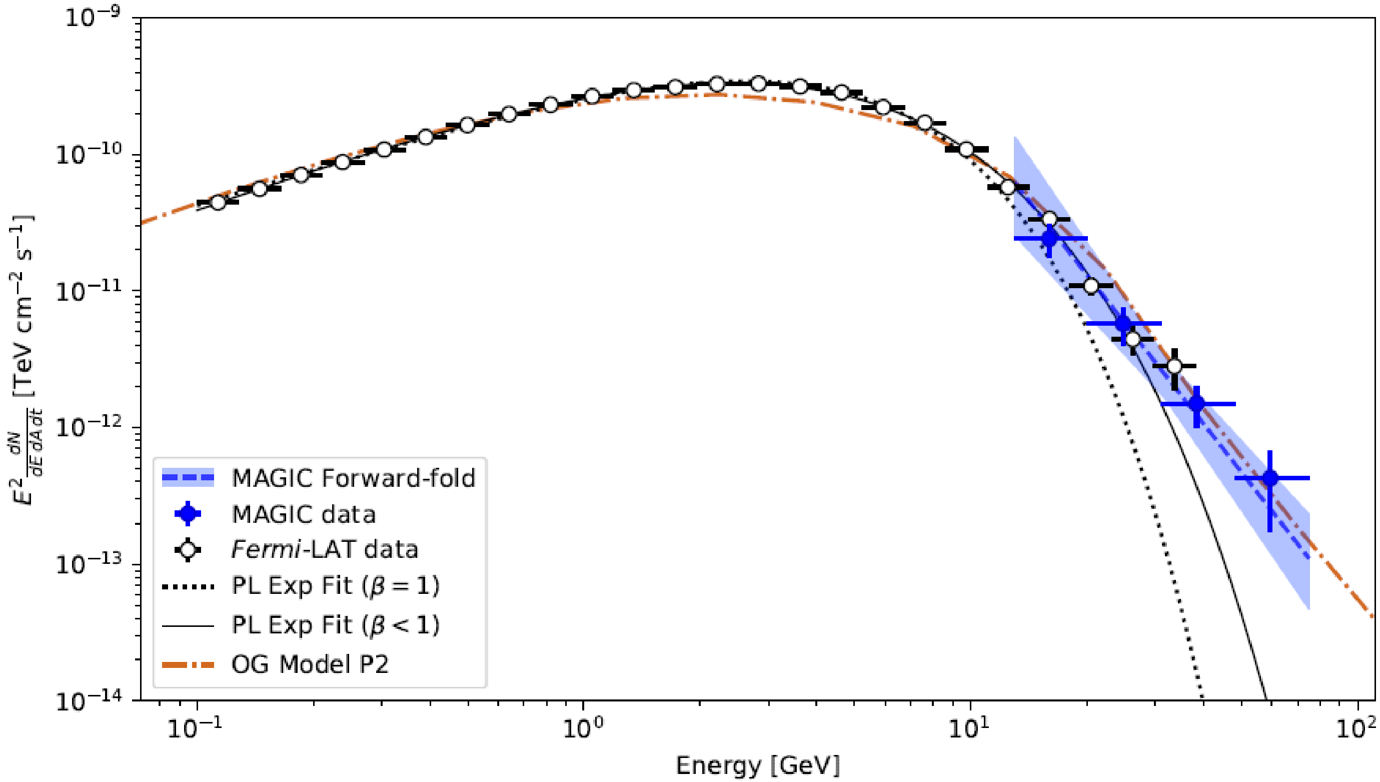
Measured by MAGIC pulsed signal from the Geminga pulsar at E ≥ 15 GeV

Acciari et al, A&A, 2020



MAGIC data hints on power law behaviour of the Geminga spectrum

Acciari et al, A&A, 2020



The Surprise with the GRB 190114C

- But the reality looked quite different
- The burst of GRB 190114C happened at a **large zenith angle of ~60°** and moreover, **the Moon was up**
- Both effects together increased the threshold energy to ~200-300 GeV
- Why GRB happened at high zenith angle ? Because the observation chance is proportional to the solid angle
- Why at the time when the Moon was up ? Because the partial Moon observations seriously increase the duty cycle of IACTs
- Despite the high threshold we were surprised to measure in a shortest time a truly gigantic signal, the most intense signal in the 30 years history of VHE gamma astronomy

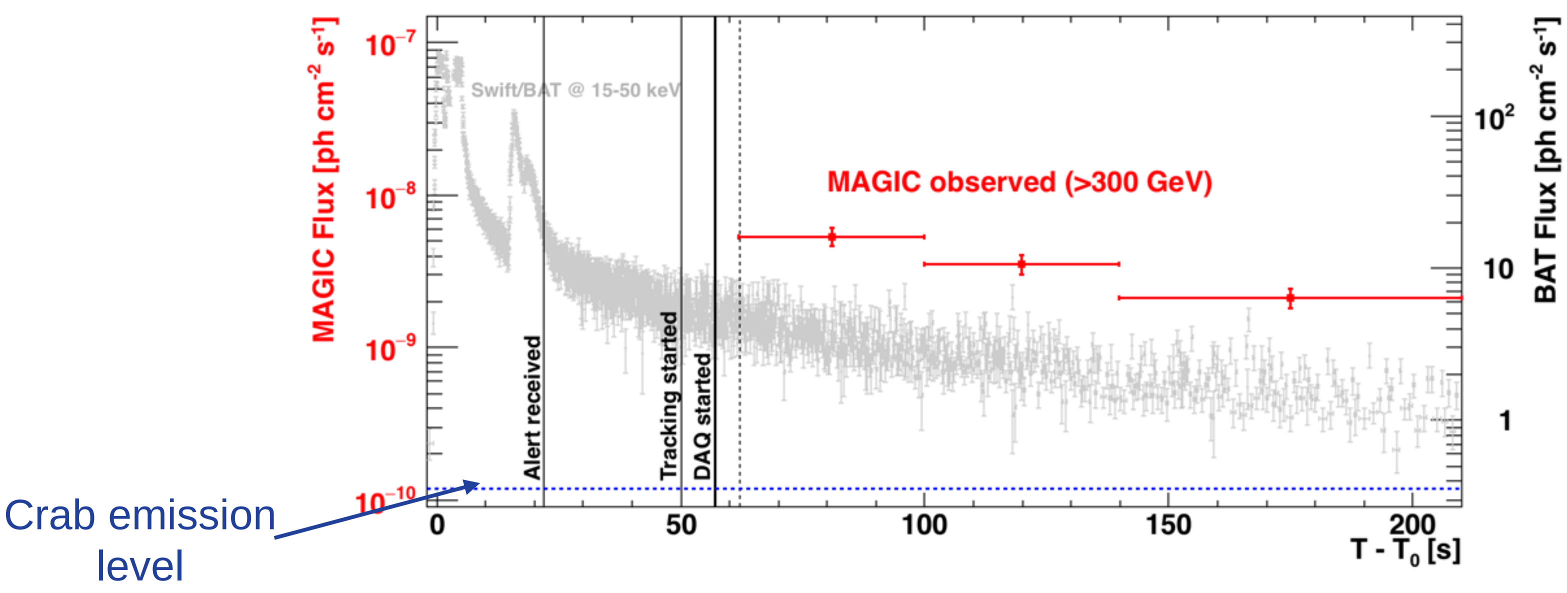
MAGIC Partial Moon Observations Were Crucial for Discovering the GRB 190114C

- Hence from the beginning of the project MAGIC is regularly observing at the presence of partial Moon, at Dusk and Dawn
- These provide significantly longer observations, albeit at somewhat higher threshold energy
- The Moon observations were inherited already from the HEGRA CT1 operation; back in 1997 we observed Mrk-501 for 244 h dark time and 134 h at partial moonlight. The latter was crucial for finding quasi-periodic γ-ray emission from

  Mrk-501, see *Kranich et al., 1999*
- MAGIC & Moon observ.: *Albert et al (2007); Ahnen et al (2017)*
- During the GRB 190114C observations the partial Moon increased the anode currents of PMTs by 6-8 times – fully O.k.

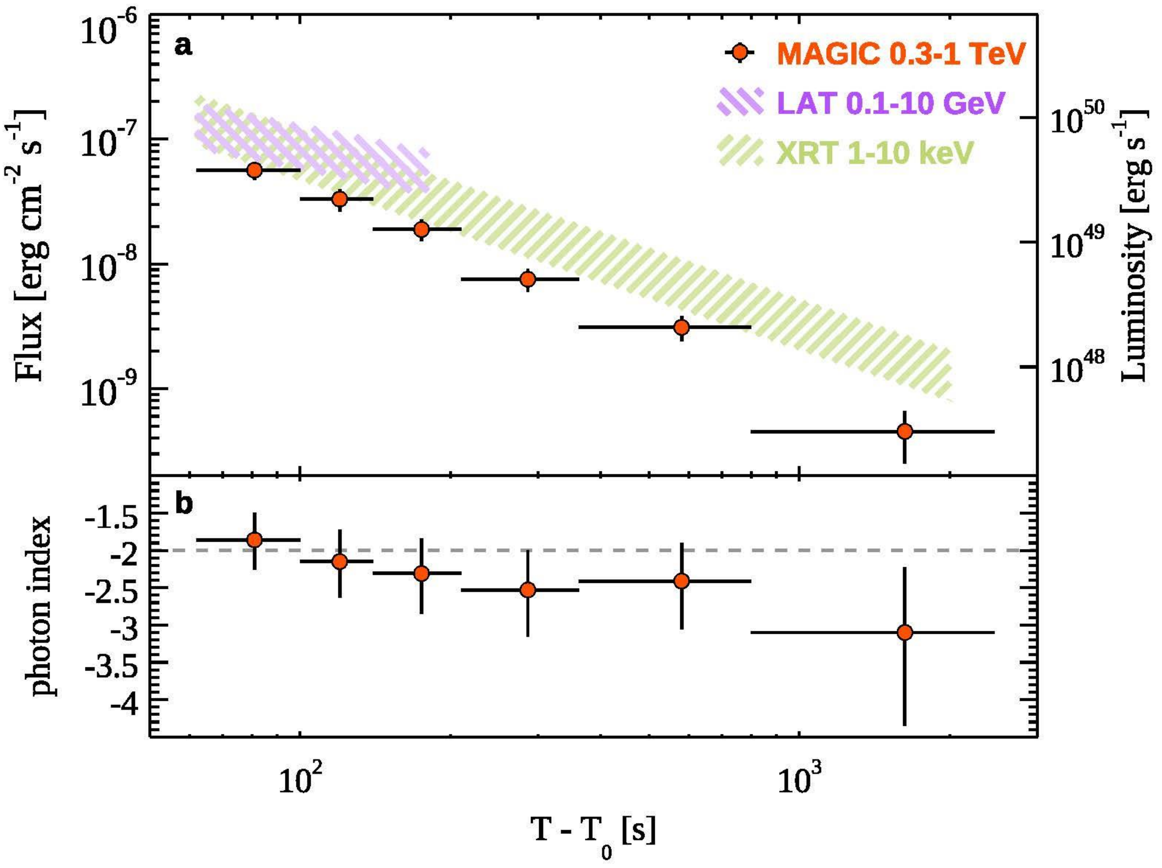
GRB 190114C signal footprint

- Very strong signal, almost background-free
- Signal detected up to ~40 minutes
- Energy flux emitted @ sub-TeV comparable within factor of two to the one emitted in X-rays (between 60-2000s)

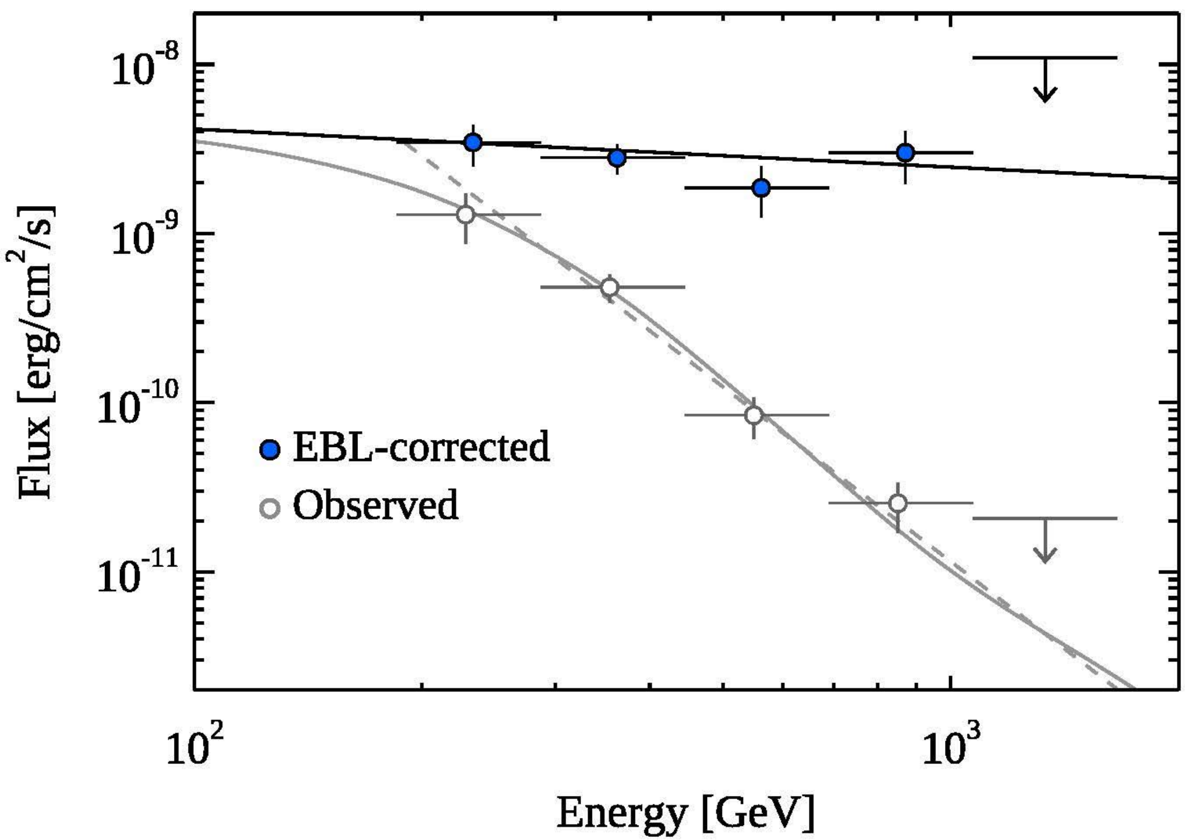


GRB 190114C light curves in the keV, GeV and TeV bands

MAGIC detected the afterglow phase of the GRB

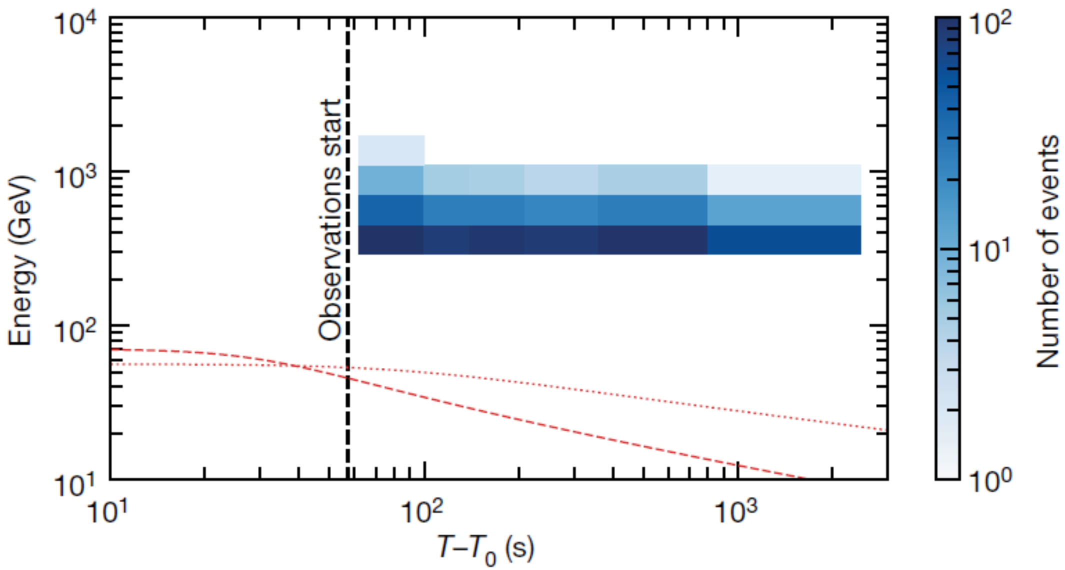


Spectrum above 0.2 TeV averaged over the period between *T*0 + 62 s & *T*0 + 2454 s for GRB 190114C



Distribution of TeV-band γ rays in energy versus time for GRB 190114C

MAGIC detected an energetic component not yet seen in GRBs, different from synchrotron



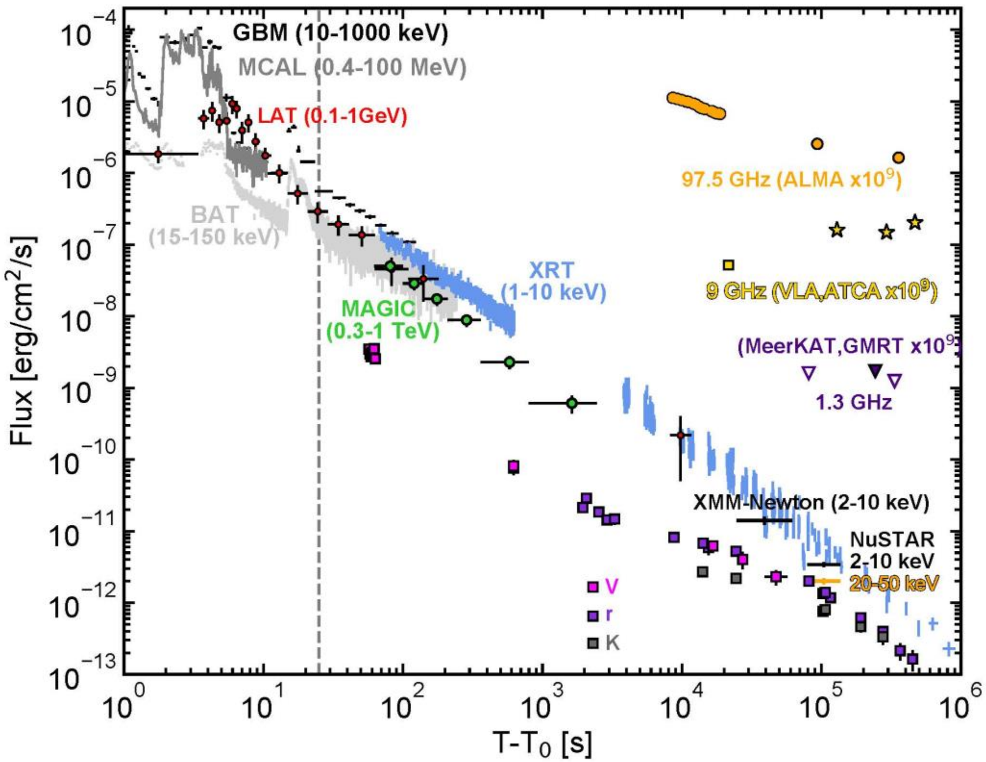
Bottom curves show the expected max. photon energy $\varepsilon_{syn,max}$ of electron synchrotron radiation in the standard afterglow theory, for two extreme cases; isotropic-equivalent blast wave kinetic energy $E_{k,aft} = 3 \cdot 10^{55}$ erg

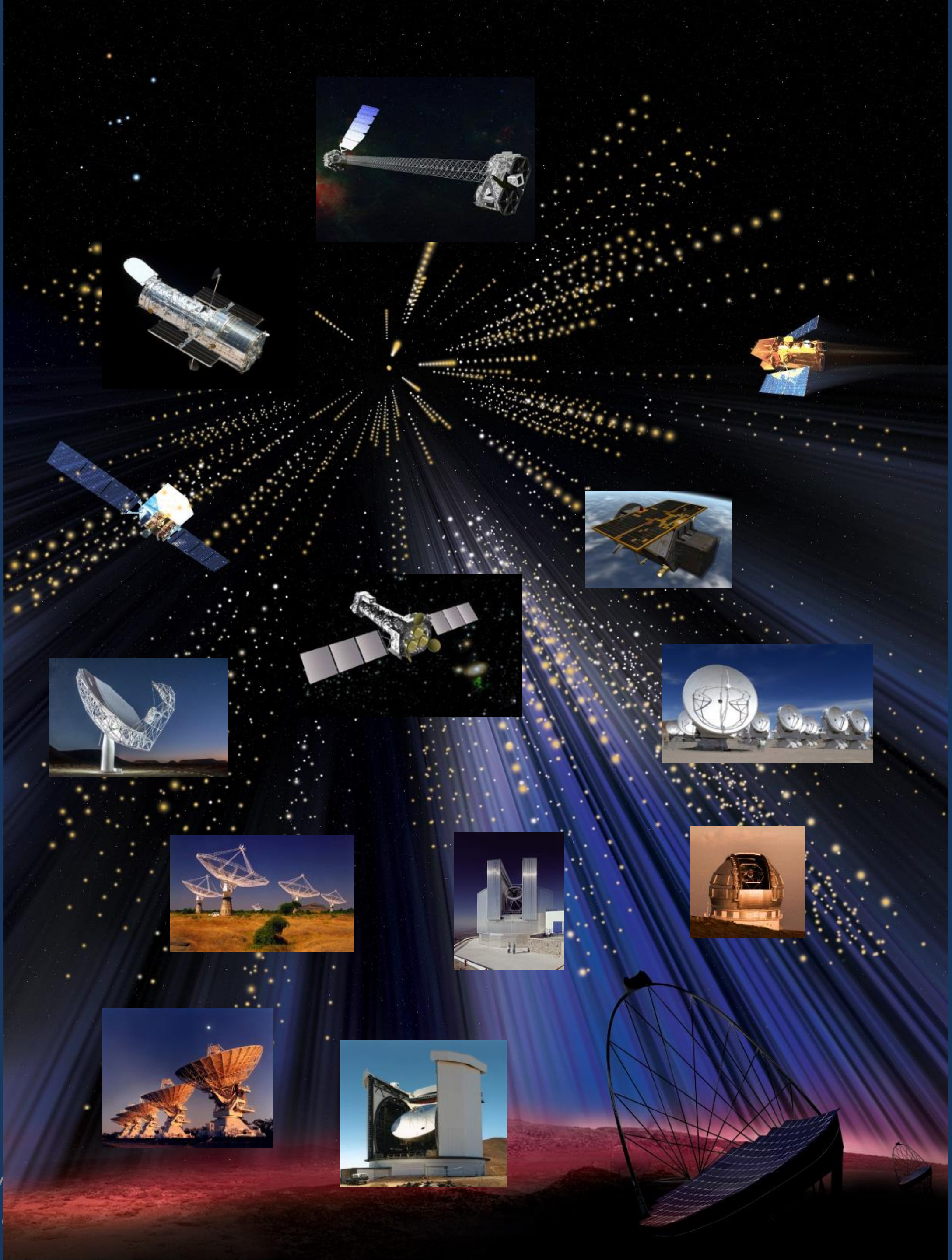
dotted – n = const.

dashed – n ~ $1/R^2$

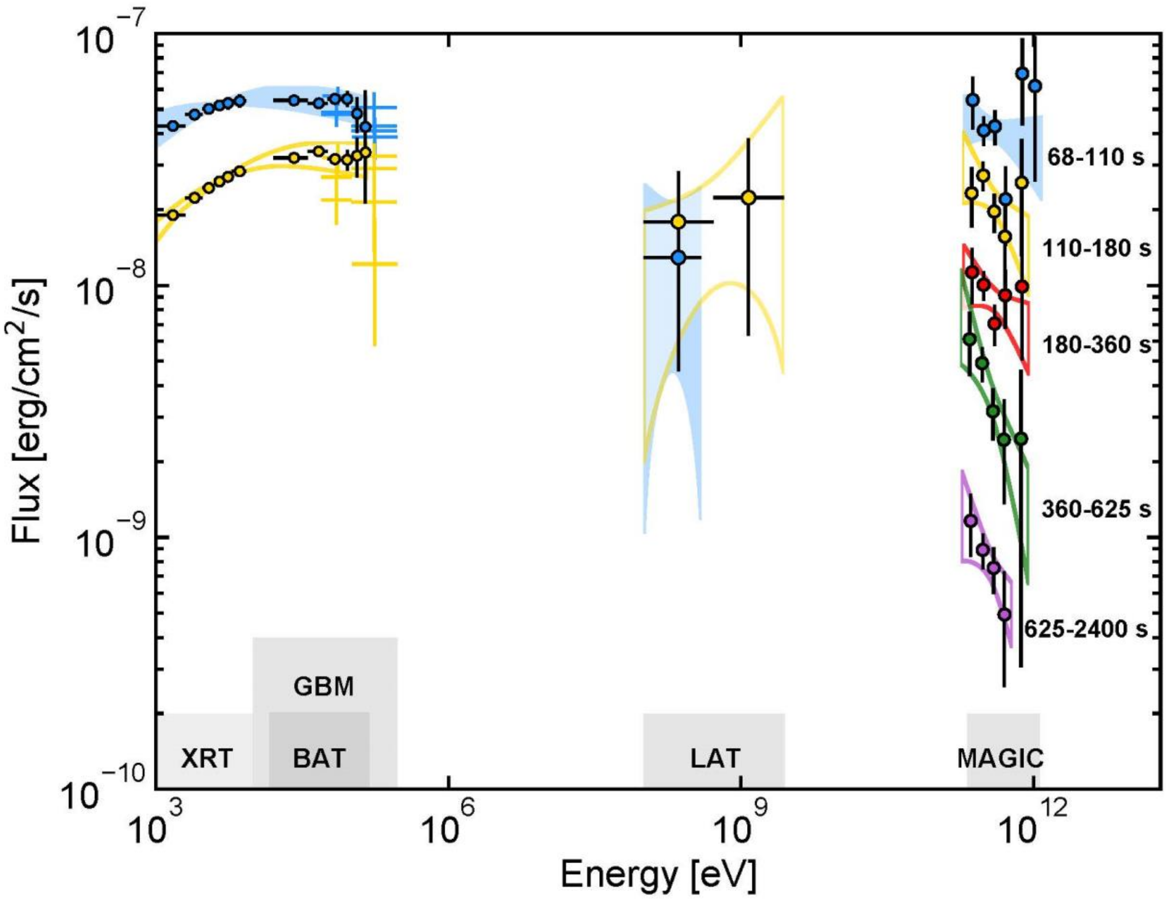
Multi-wavelength light curves of GRB190114C measured > 20 space-born and ground-based instruments

- MAGIC detected the afterglow phase of the GRB
- A significant share of GRB energy is emitted in the TeV energy range





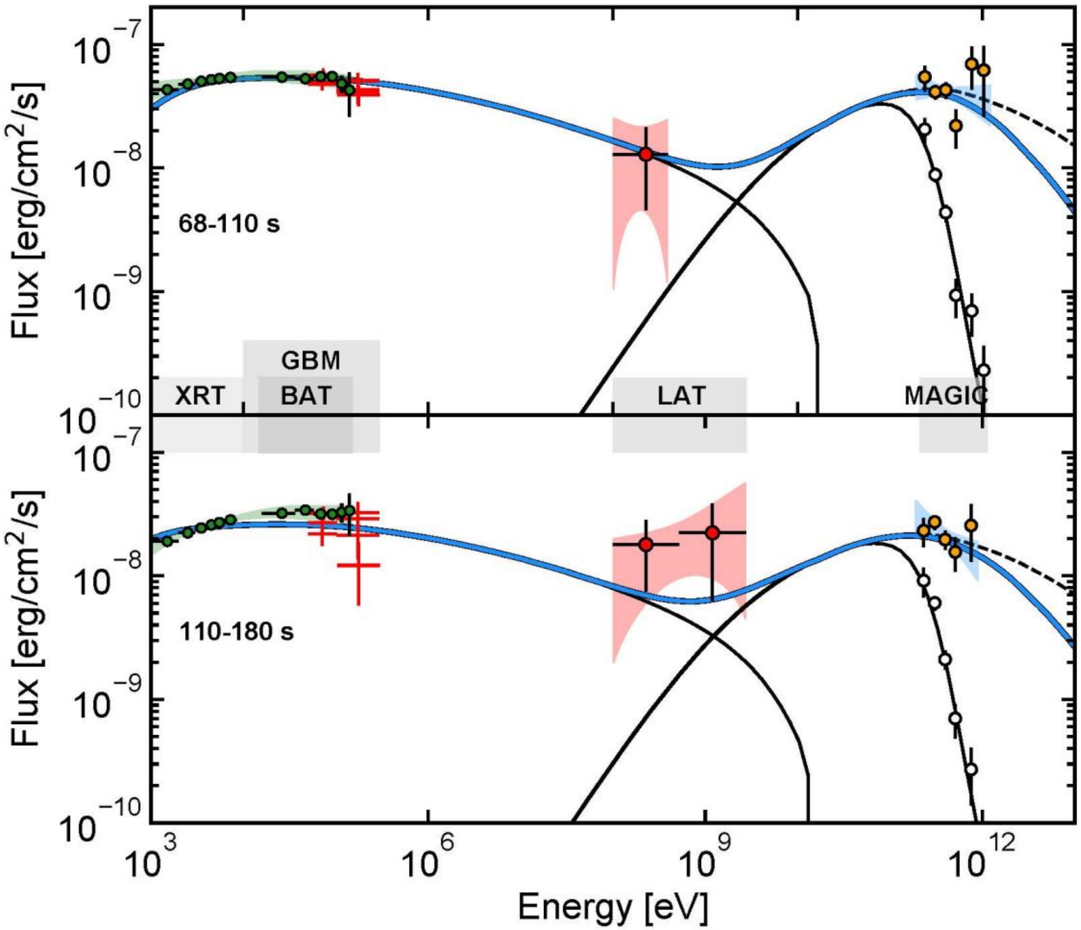
Dynamics of multi-wavelength spectra of GRB 190114C



A really unique event; the spectra have been measured during the

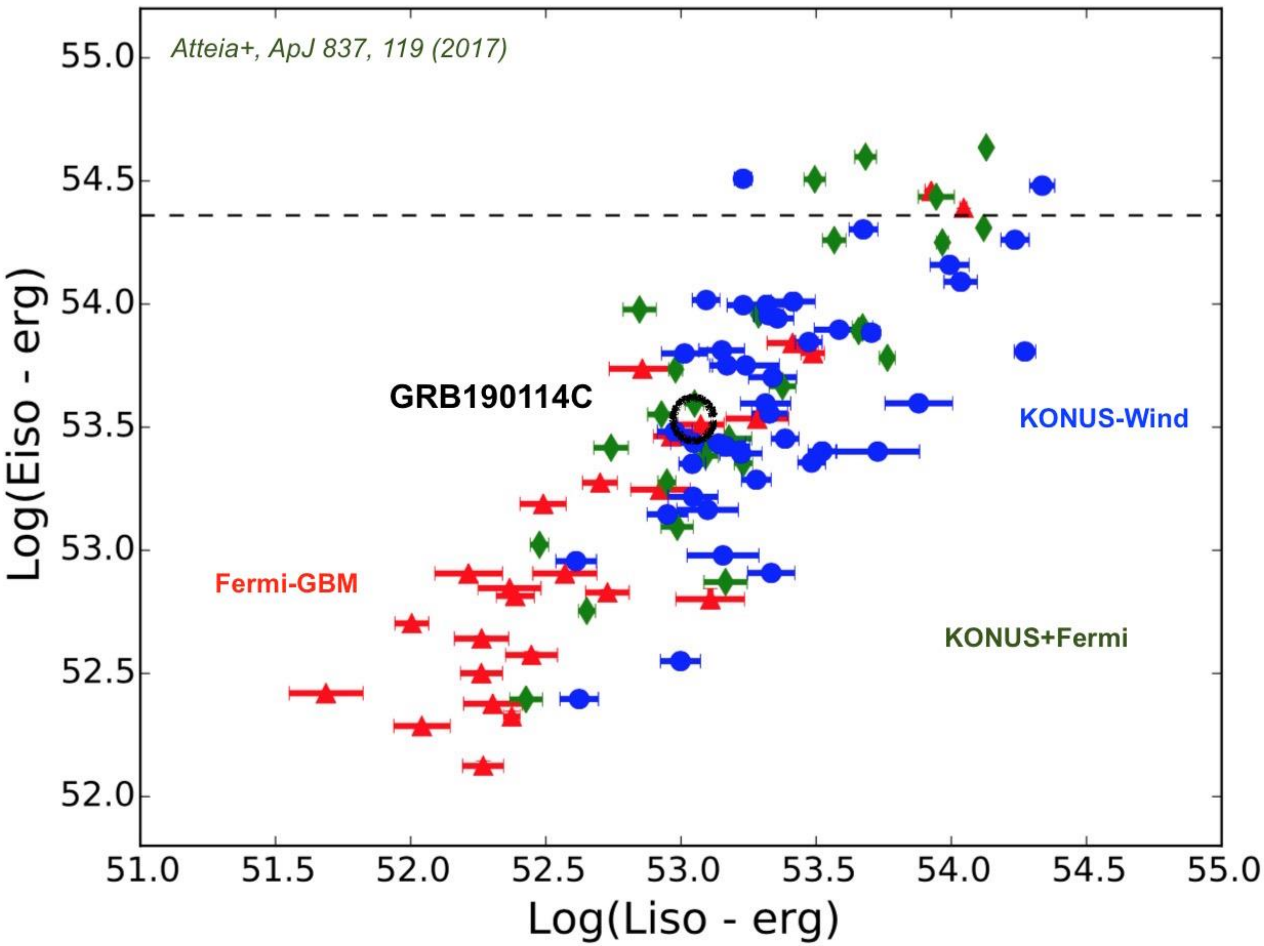
- 1st time bin for only 42 s,
- 2nd time bin for 70 s
- 3rd time bin 180 s

IC Emission from GRB 190114C



- Note the double-peak structure, resembling the well-known pattern from blazars SED
- The energy in the SSC peak is comparable to the energy in synchrotron

Luminosity of GRB 190114C as compared to other long GRBs: it is not too special



Study on Lorentz Invariance Violation by Using MAGIC GRB190114C Data

Amelino-Camelia, et al, Nature, 1998

- One assumes that the Quantum theory and the gravity could merge at around the Planck energy ($E_{Pl} \approx 1.22 \times 10^{19}$ GeV) into a joint, yet unknown theory of quantum gravity (QG)
- Some candidate theories predict a violation or deformation of the Lorentz symmetry, also known as Lorentz invariance violation (LIV)
- One of the manifestations of LIV can be parametrized as energy-dependent corrections to the *in vacuo* photon dispersion relation;

$$E^2 \simeq p^2 \times \left[1 - \sum_{n=1}^{\infty} s \left(\frac{E}{E_{\mathrm{QG,n}}}\right)^n\right]$$

E and *p* are the energy and momentum of the photon, $E_{QG,n}$ is the QG energy scale, and *s* is a theory-dependent factor (+1 or −1)

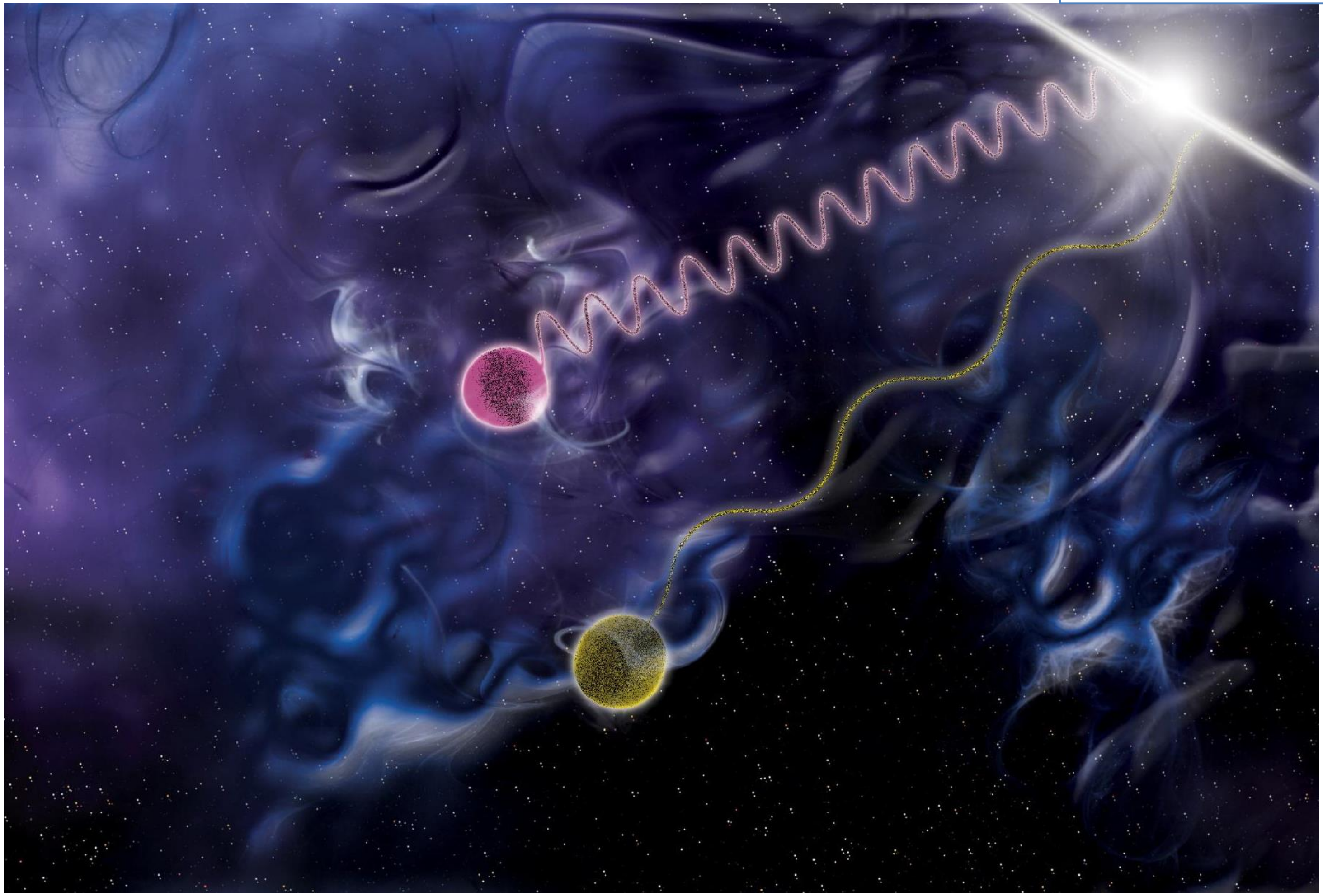
The time delay between the photons of energy difference ΔE is

$$\Delta t = s\frac{n+1}{2} D_n(z) \left(\frac{\Delta E}{E_{\mathrm{QG,n}}}\right)^n$$

$D_n(z)$ includes the information on the source-detector co-moving distance

LIV; the higher E particles are slower than the lower E ones

picture credit Ma, 2011



LIV Measurements – Time of Flight

Acciari, et al., Phys. Rev., 2020

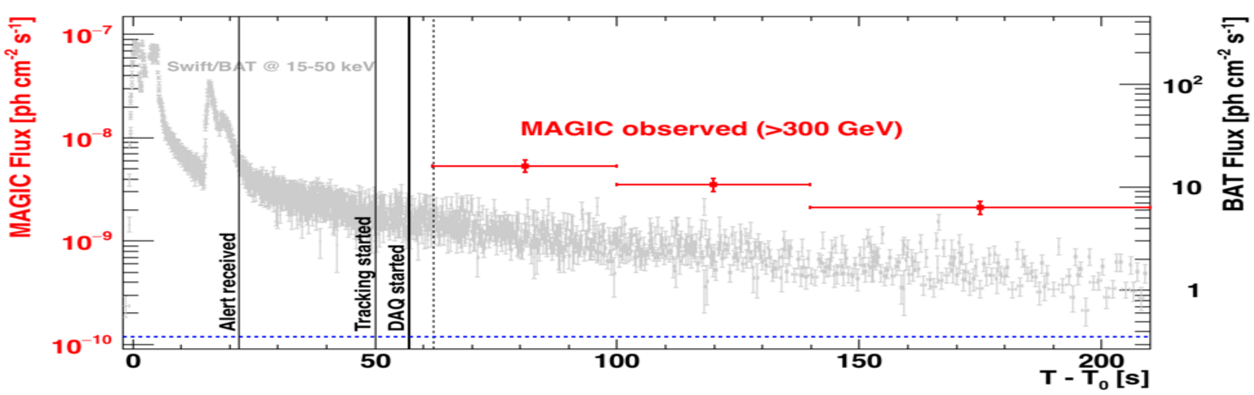
Source	Source type	Redshift	$E_{QG,1}$ [10^{19} GeV]	$E_{QG,2}$ [10^{10} GeV]	Instrument
GRB 090510	GRB	0.9	2.2	4.0	*Fermi*-LAT[1]
GRB 140119C_{Min}	GRB	0.42	0.28	7.3	MAGIC[6]
GRB 140119C_{Th}	GRB	0.42	0.58	6.3	MAGIC[6]
PKS 2155-304	AGN	0.116	0.21	6.4	H.E.S.S.[2]
Mrk 501	AGN	0.034	0.036	8.5	H.E.S.S.[3]
Mrk 501	AGN	0.034	0.021	2.6	MAGIC[4]
Mrk 421	AGN	0.031	pending	pending	MAGIC
Crab Pulsar	Pulsar	2.0 kpc	0.055	5.9	MAGIC[5]

[1] Vasileiou, et al (2013)
[2] Abramowski, et al (2011)
[3] Abdalla, et al (2019)
[4] Albert, et al (2008)
[5] Ahnen, et al (2017)
[6] Acciari, et al (2020)

	GRB 090510	Mrk 501	GRB 190114C
E_{max}	31 GeV	$\sim$ 20 TeV	1.955 TeV
Redshift	0.9	0.034	0.4245
Variability	$\sim$ 1 sec	$\sim$ 600 sec	$\sim$ 100 sec (∞)
$E_{QG,1}[10^{19}]$ GeV	2.2	0.036	0.58
$E_{QG,2}[10^{10}]$ GeV	4.0	8.5	6.3

IACT Technique Sensitivity to LIV with GRBs

- It is worth noting that MAGIC observed a smooth, featureless afterglow signal from the GRB190114C
- Obviously this has limited the sensitivity of our LIV analysis.
- We are looking forward to VHE observations of a GRB in its prompt phase; the structured signal would enhance the analysis sensitivity to the LIV effects



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

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/

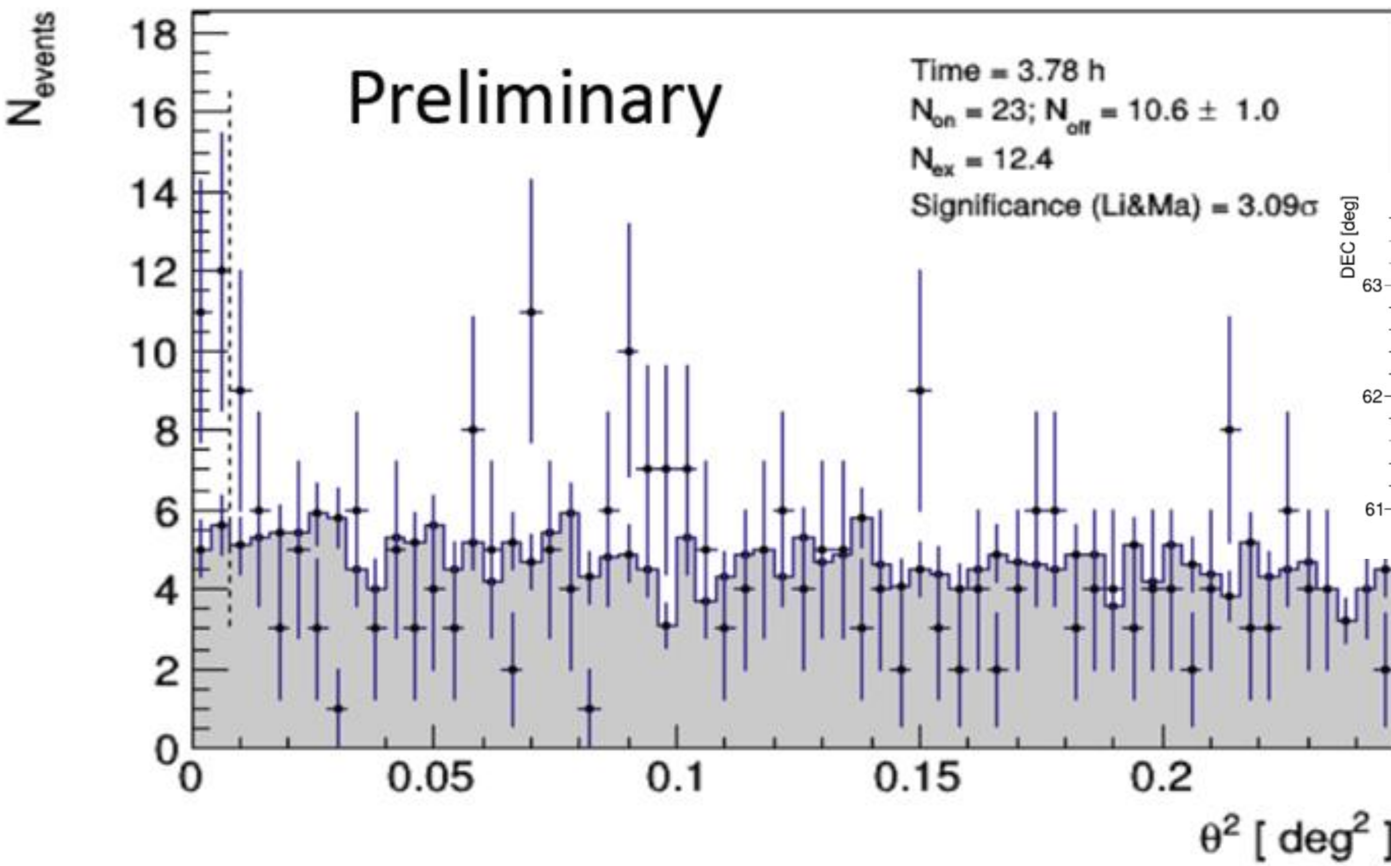
GRB 160821B with MAGIC

- Short GRBs in high-energy gamma rays are still poorly constrained, with only ~20 events detected in the GeV band, and none in the TeV band.
- Of the 186 GRBs detected by Fermi-LAT from August 2008
  until August 2018, only 17 are short GRBs
- GRB 160821B is one of the nearest short GRBs known at
  z = 0.162

GRB 160821B with MAGIC

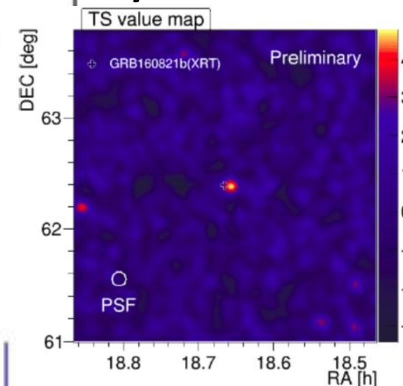
- Its afterglow emission was followed up by several telescopes, resulting in detections in the radio, optical-infrared, and soft X-ray bands.
- Upper limits from Fermi-LAT in the GeV energy range were also derived.
- Optical-infrared observations clearly revealed the presence of a kilonova, dominating the emission at about 1 day.
- After the burst trigger, it took 13 seconds for satellites to generate the alert and send it to the community. It took only 11 seconds to slew the MAGIC telescopes, and configure them to start the data acquisition.

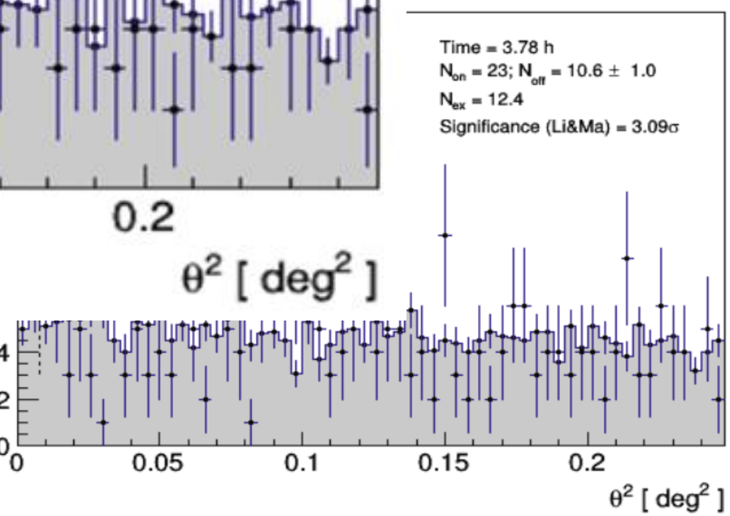
Hint From GRB 160821B with MAGIC



…wift-BAT

…ay, t < 30 ks





This result is produced by using the standard analysis technique

Take away messages on the detection of GRBs @ TeV

- MAGIC discovered a novel, TeV energetic component in GRBs, a 2nd bump
- A very strong signal has been detected in the afterglow phase (T_0 > 60s) of the GRB 190114C residing at redshift z=0.42
- The new spectral component extends till ~2 TeV
- This is the brightest source ever detected by IACTs, the peak rate of gamma-rays ~ 130 x Crab
- The flux observed at T0+80 s corresponds to apparent isotropic-equivalent luminosity $L_{iso} \sim 3 \times 10^{49}$ erg/s at E ≥ 0.3 TeV, making this the most luminous source known at these energies

Take away messages on the detection of GRBs @ TeV

- Most GRBs may possibly possess TeV emission components similar to GRB 190114C, which may be detectable as long as redshift is low and the observing conditions are acceptable
- H.E.S.S. reports on γ-ray emission of up to 400 GeV from GRB 180720B at z=0.653 10h after the burst – afterglow
- H.E.S.S. detected GRB 190829A 4 h after the burst
- Also MAGIC detected a small signal from GRB 190829A
- MAGIC has measured a 3σ hint from the *short* GRB 160821B with the standard analysis; an improved analysis shows higher level of signal (under preparation)
- This is just the beginning of the GRB era with IACTs