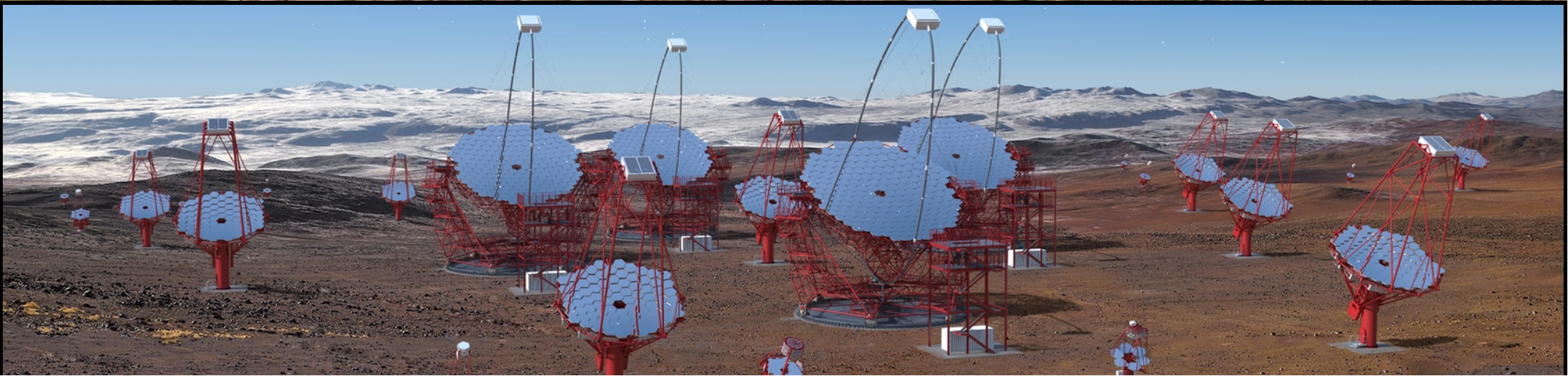
The CTA Project
Status of CTA-LST

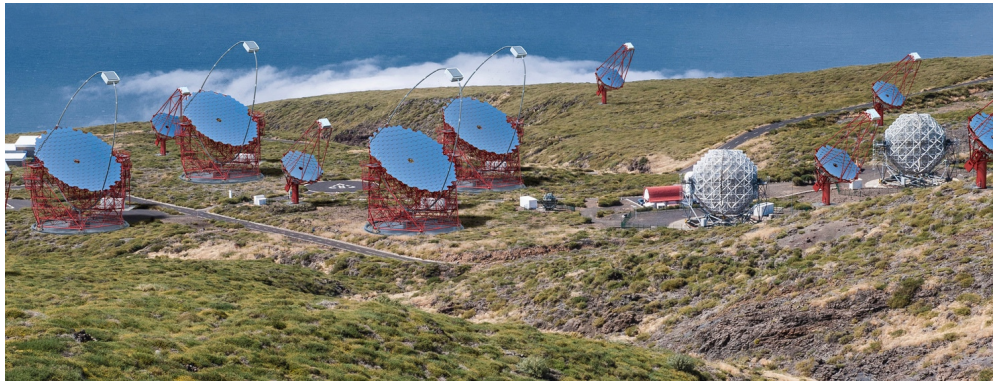
Masahiro Teshima

ICRR, The University of Tokyo
Max Planck Institute for Physics

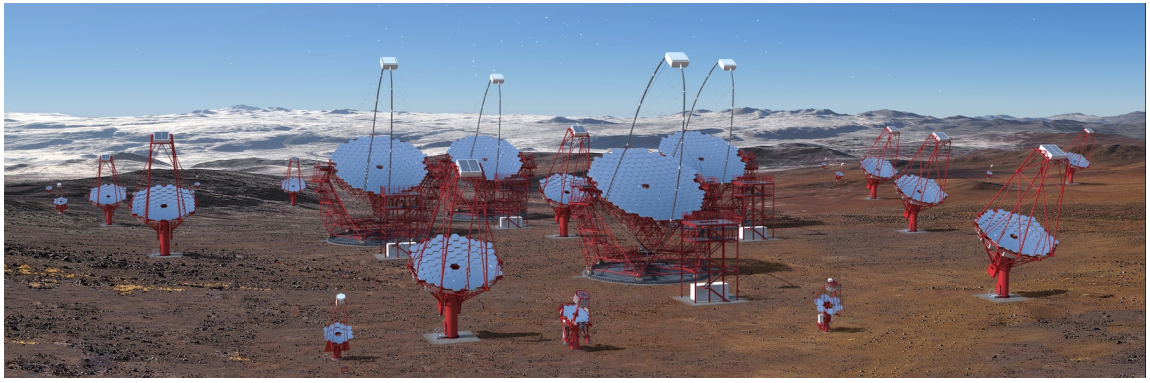


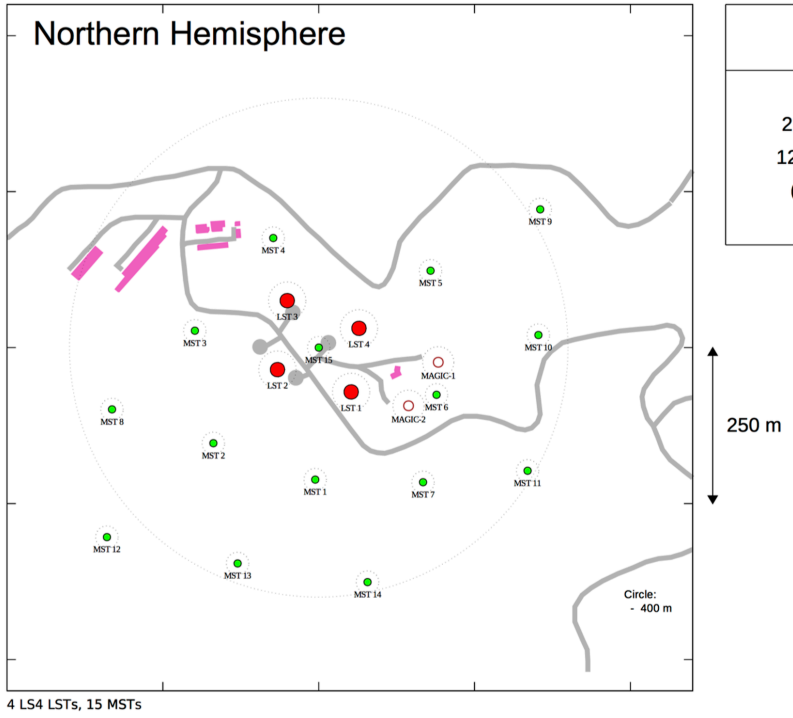
Two sites for all sky observatory

Roque de los Muchachos Observatory
La Palma, Spain

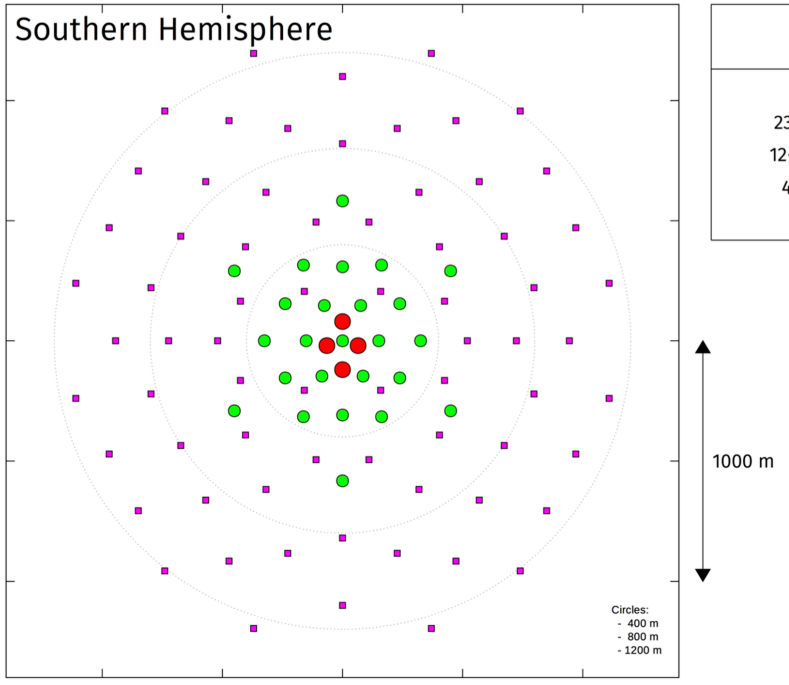


Paranal, Chile



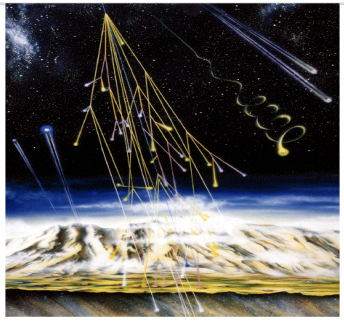


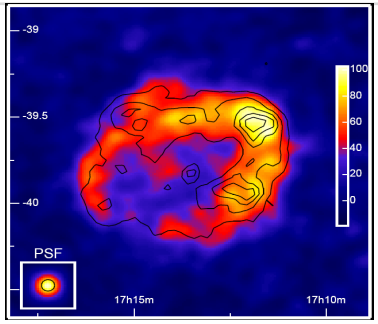
4 LS4 LSTs, 15 MSTs



4 LSTs, 25 MSTs, 70 SSTs

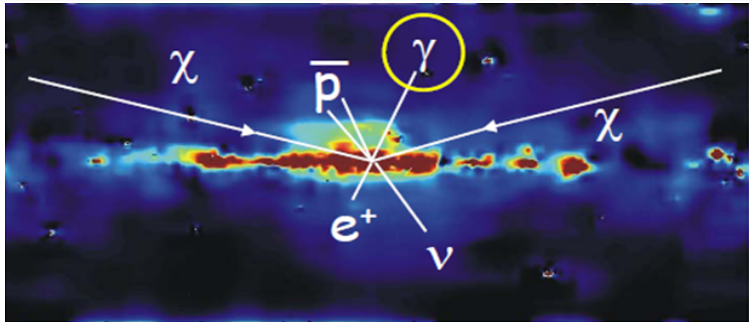
Science of HE Gamma-Ray astronomy is very wide
Energy Frontier in Astrophysics





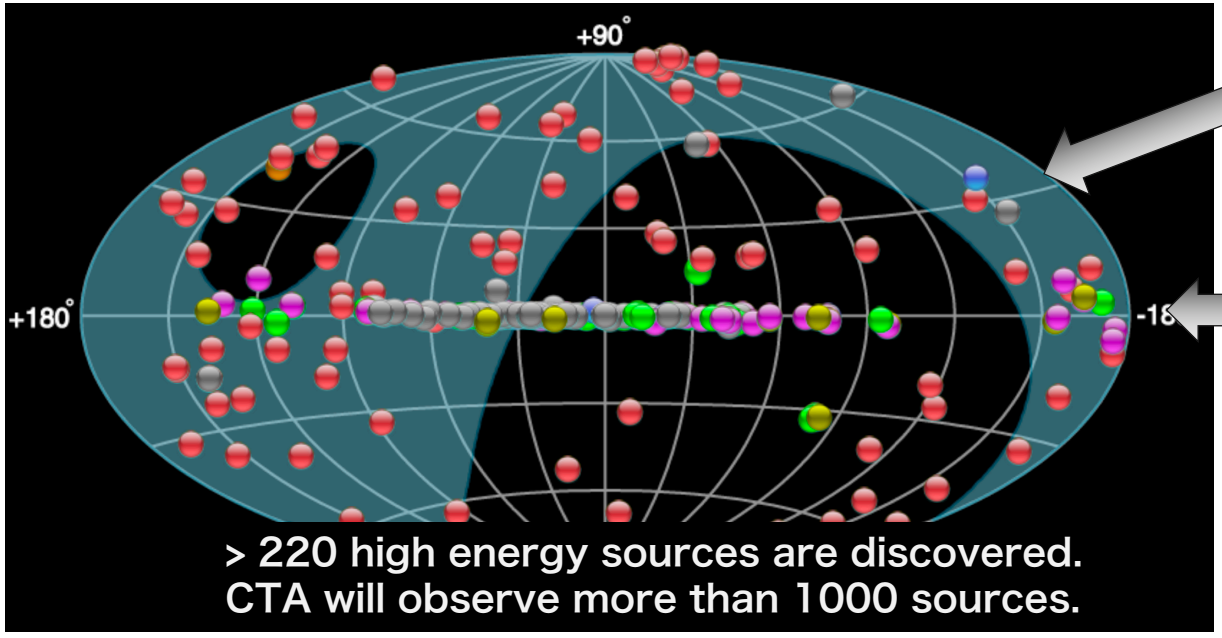
Cosmic Ray Origin

Super Massive Black Holes



Dark Matter Search (Discovery)

- Origin of Cosmic Rays (Big accelerators)
- Black Hole and S.M.B.H.
- Dark Matter Search

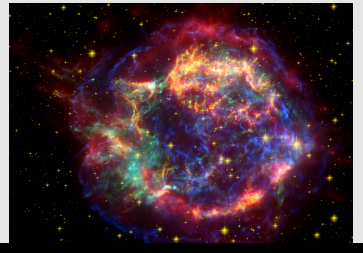


Extragalactic Sources

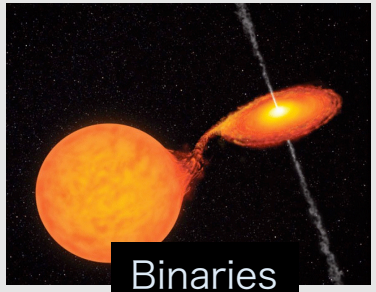
Active Galactic Nuclei

Gamma Ray Bursts

Galactic Sources

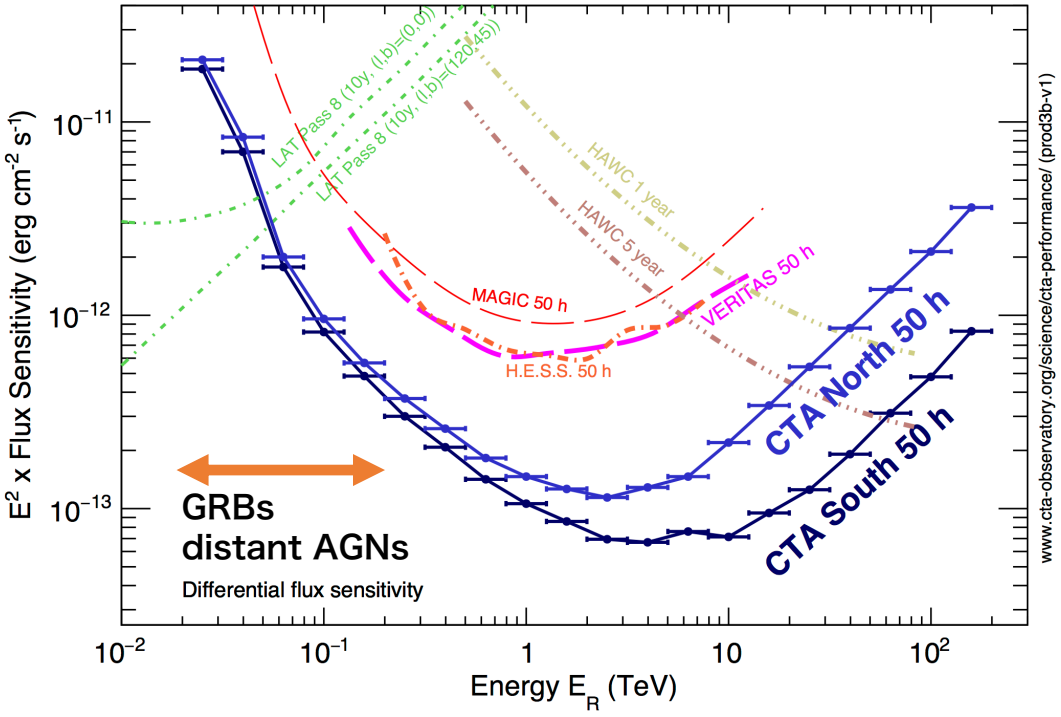


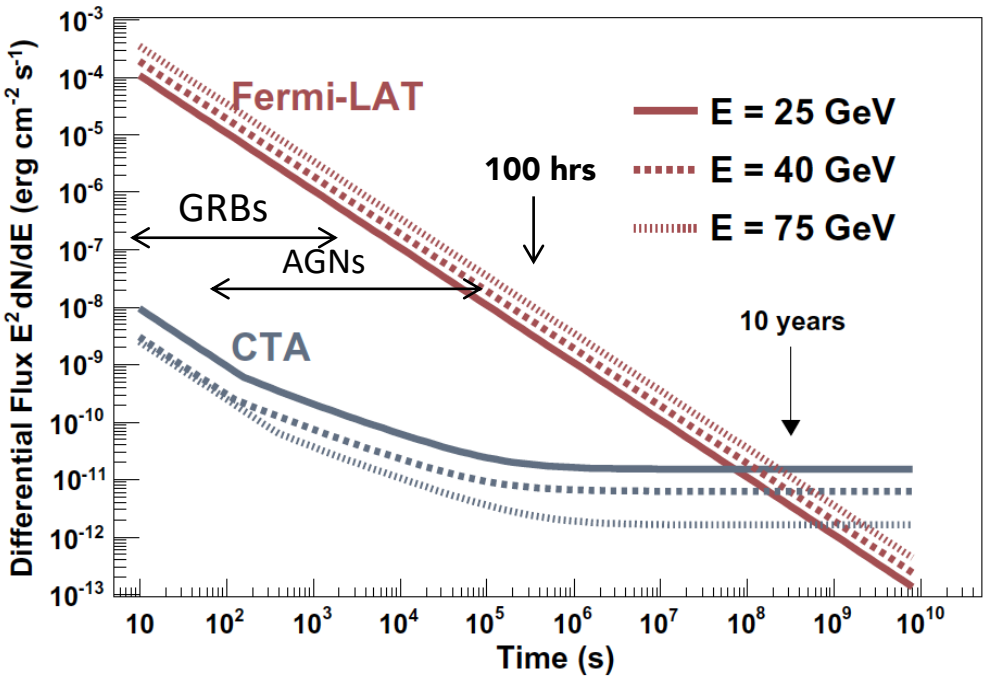
Super Nova Remnants



Binaries

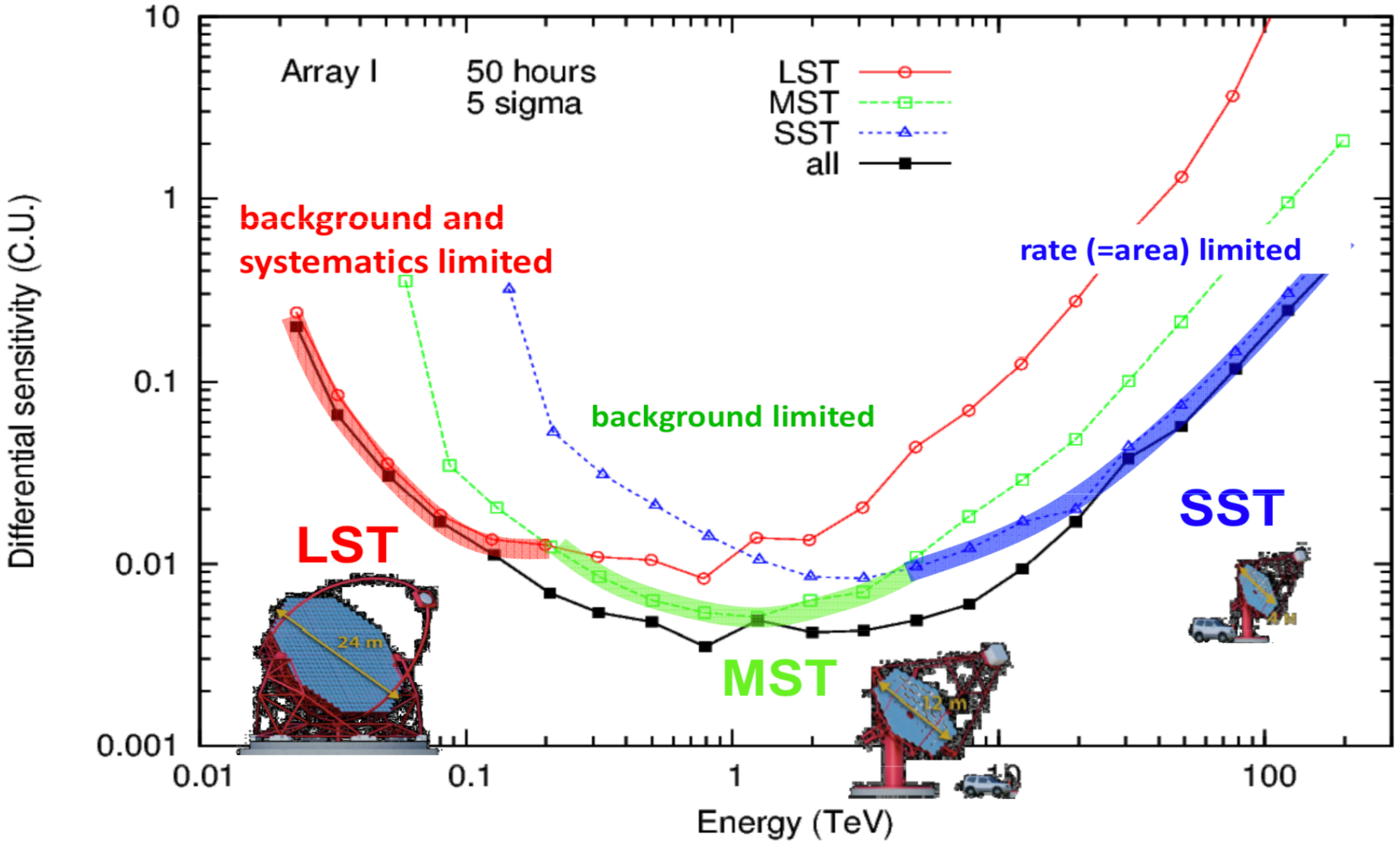
Sensitivity x10, Angular Resolution x2 Energy Range 20GeV~200TeV





- CTA-LST array contributes to the sensitivity in low energies >20GeV
- Distant AGNs are observable up to z=2, and GRBs up to z=3
- X10000 sensitivity for GRBs and AGN flares than Fermi
- GRB Prompt emission, and evolution of afterglow with the fast rotation (20 sec)

Differential Flux Sensitivity



cherenkov telescope array

LST1 at CTA-North

Large Size Telescope

Mirrors: JP
Interface plates: JP, DE, BR
Actuators: JP, CH
CMOS: JP

Tension cables: IT

Camera Support Structure: FR

calibration: IT, HR, IN, DE

Camera electronics: JP, IT, ES, CH
Camera mechanics: ES
Camera safety: FR

Telescope structure: DE

Rail: DE

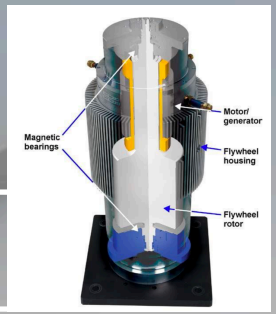
Camera Access Tower: DE

Bogies: ES

Foundation: ES

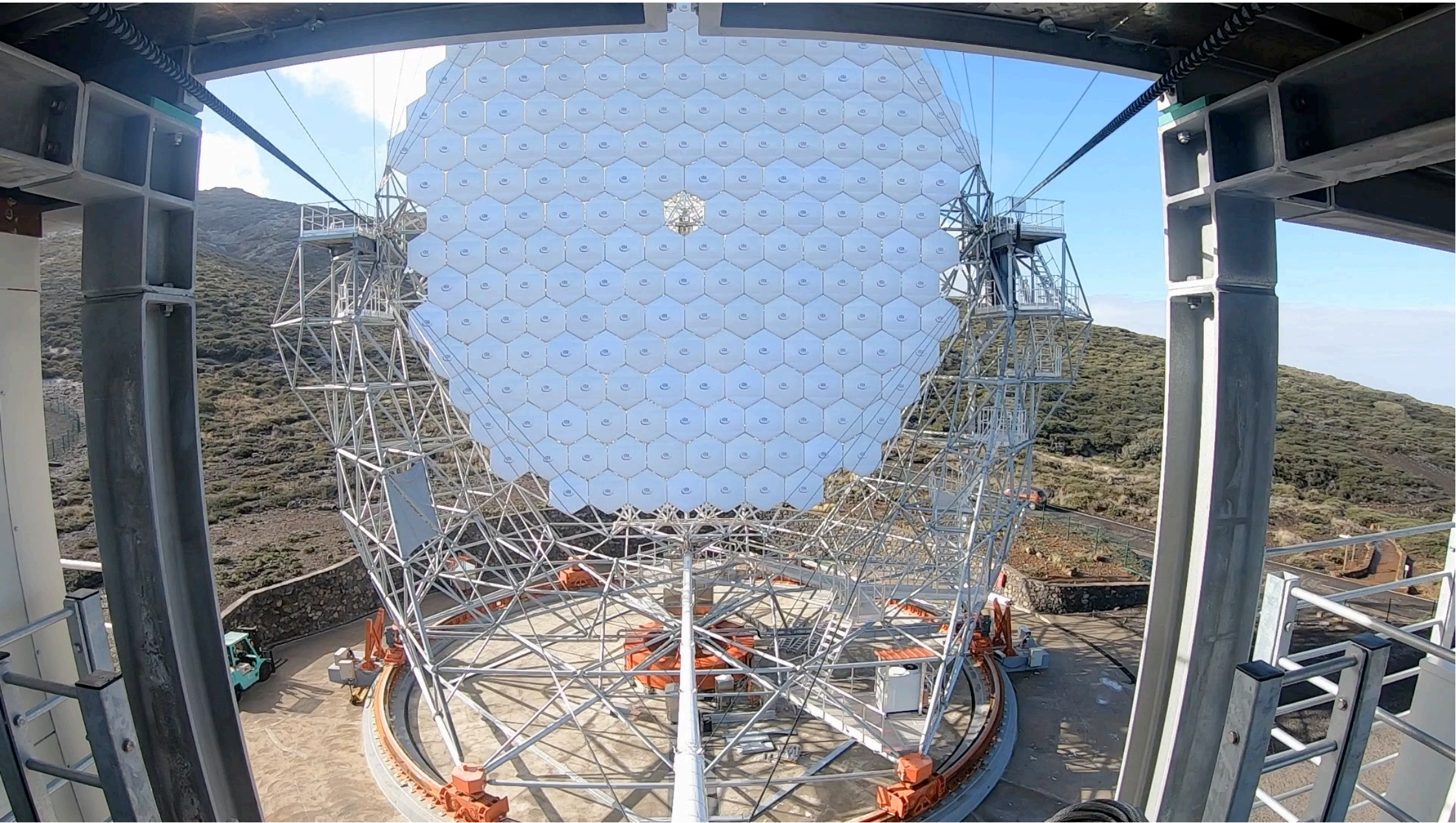
Drive and main el. cabinet: FR

FlyWheels (2x300kW) energy storage and UPS: JP



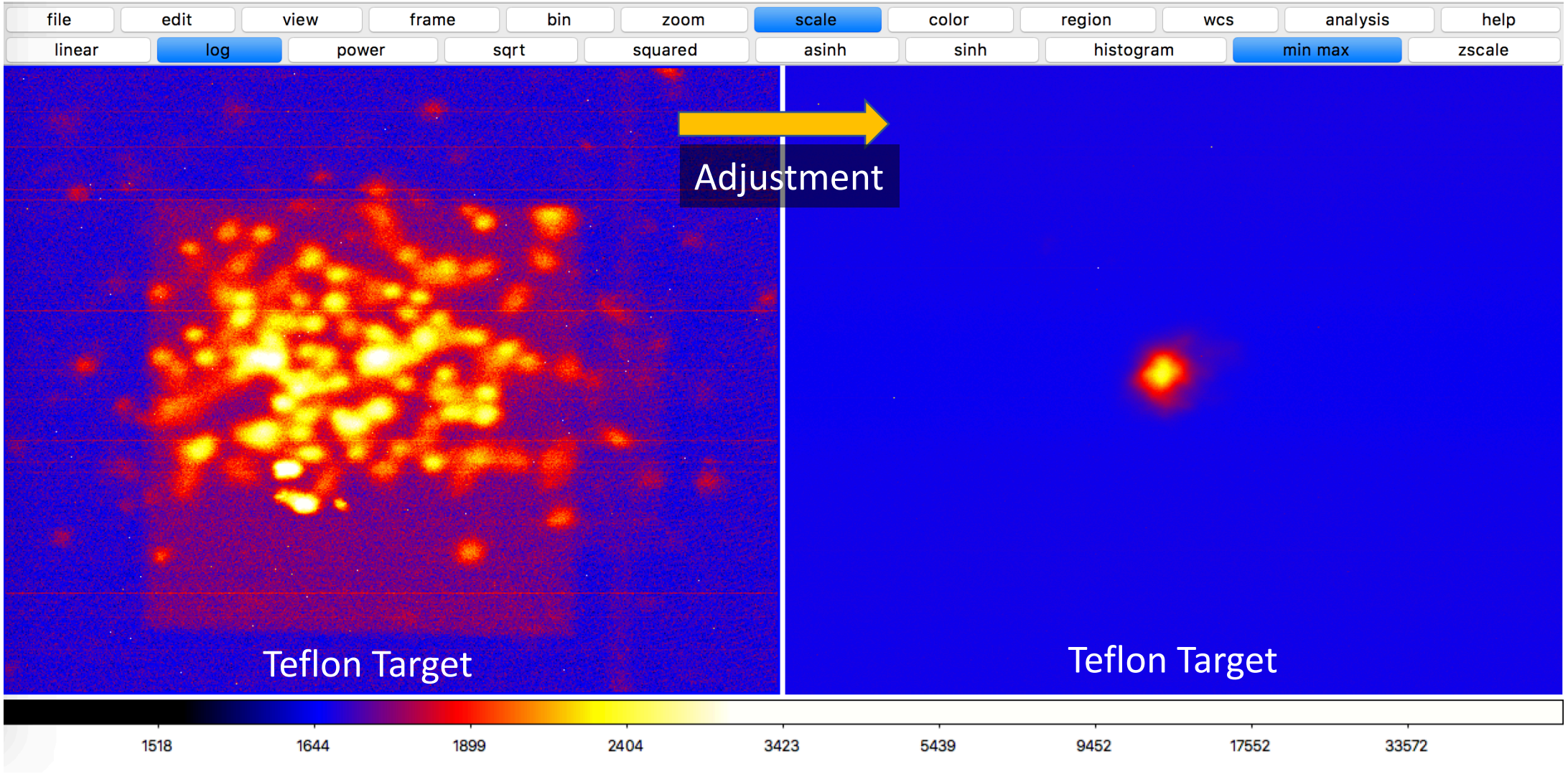
cherenkov telescope array

Fast Rotation of LST1 for GRB observations (April 2019)

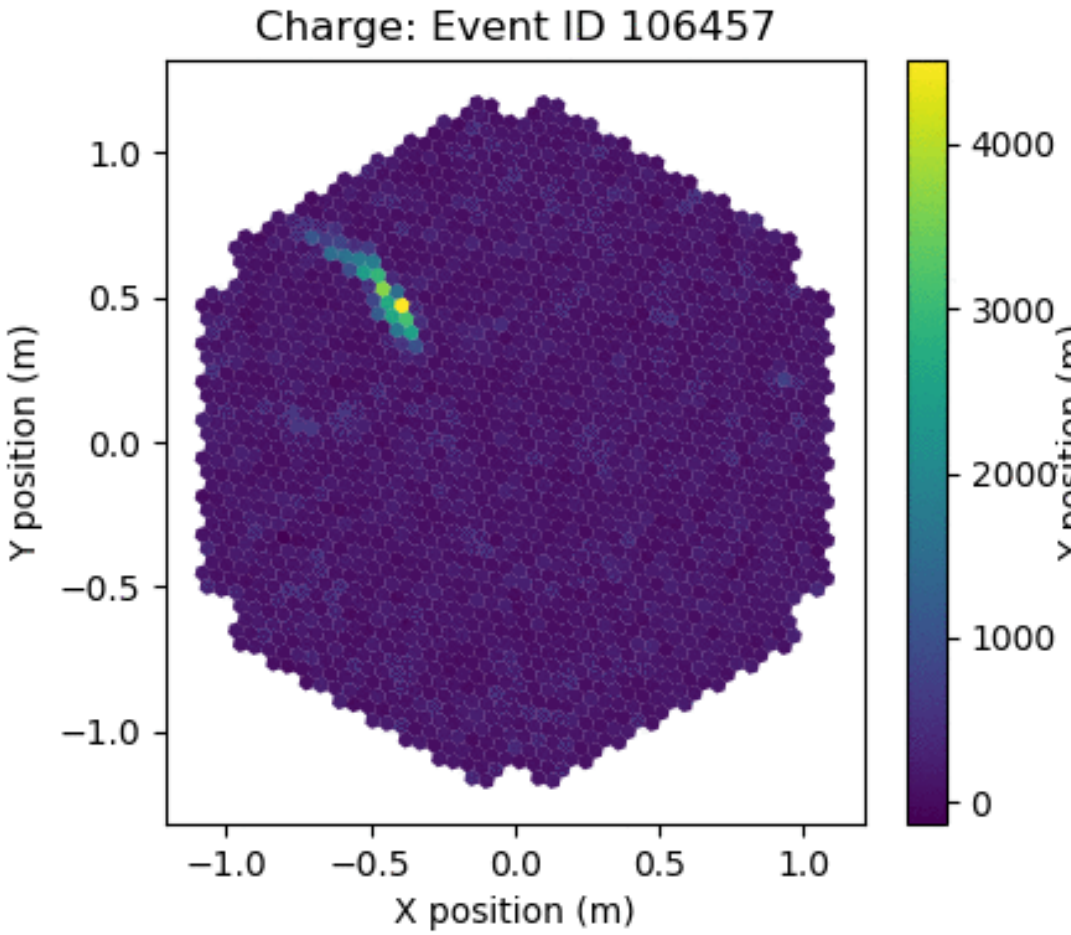


Active Mirror Control and PSF (Image of Arcturus) May 2019

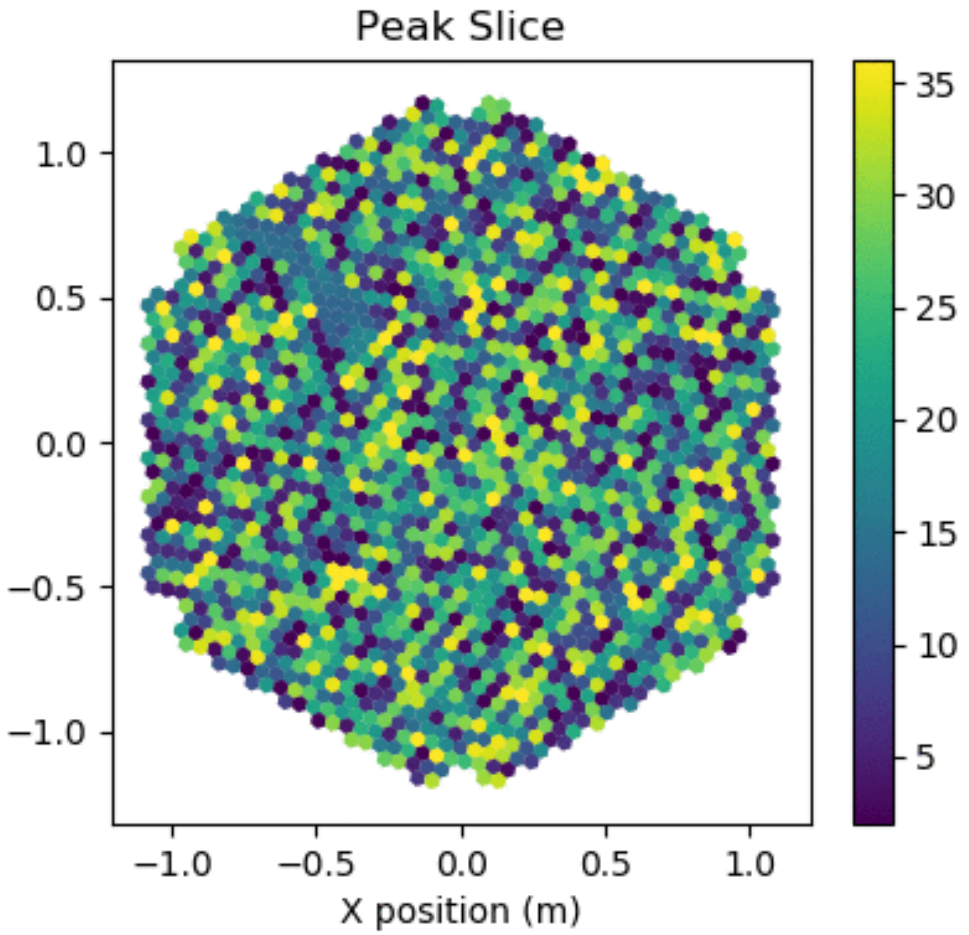
PSF < 0.1 degrees in diameter ➔ D80 =0.05 degrees reached



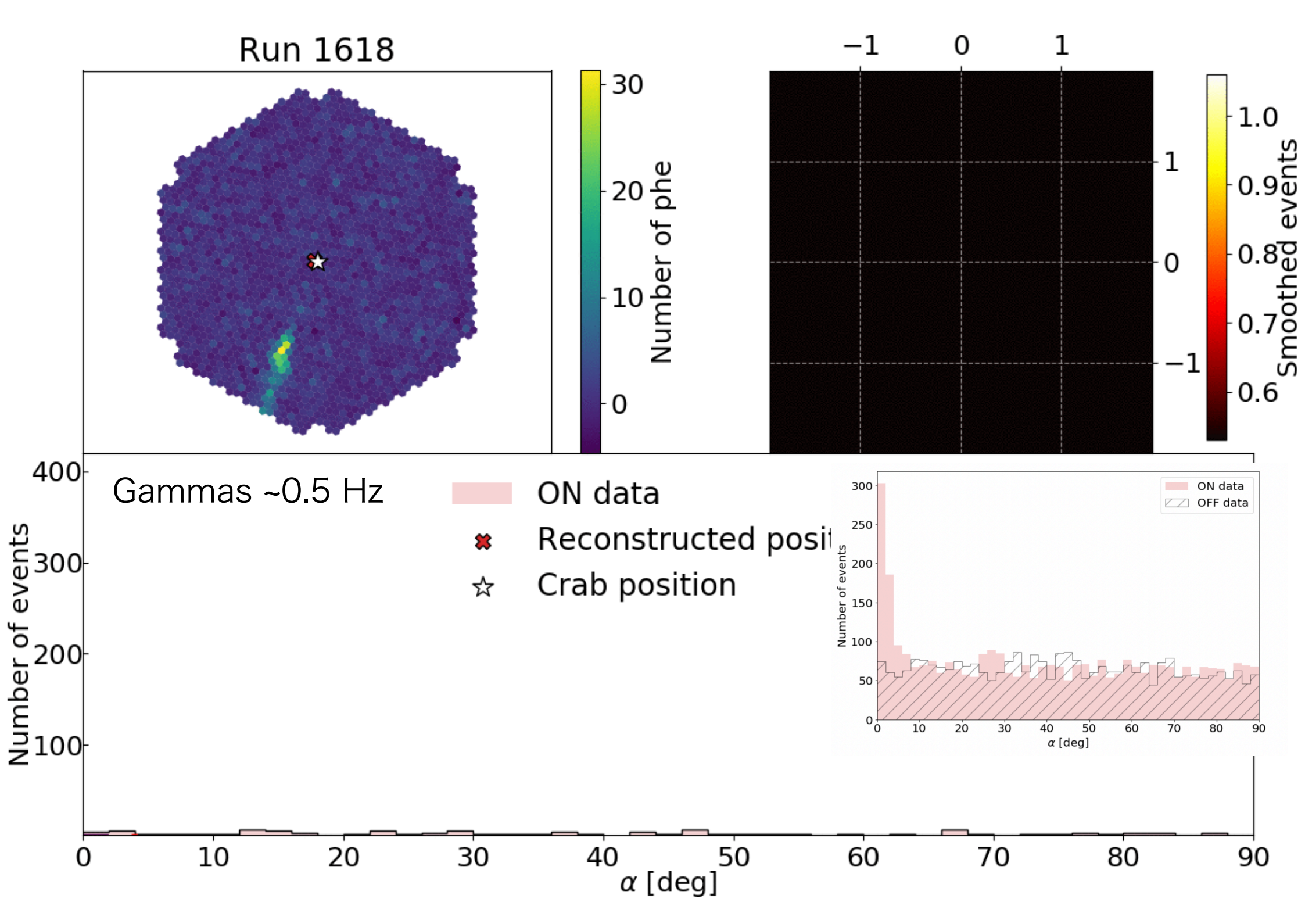
Test Observation August 2019
Trigger is not optimized yet



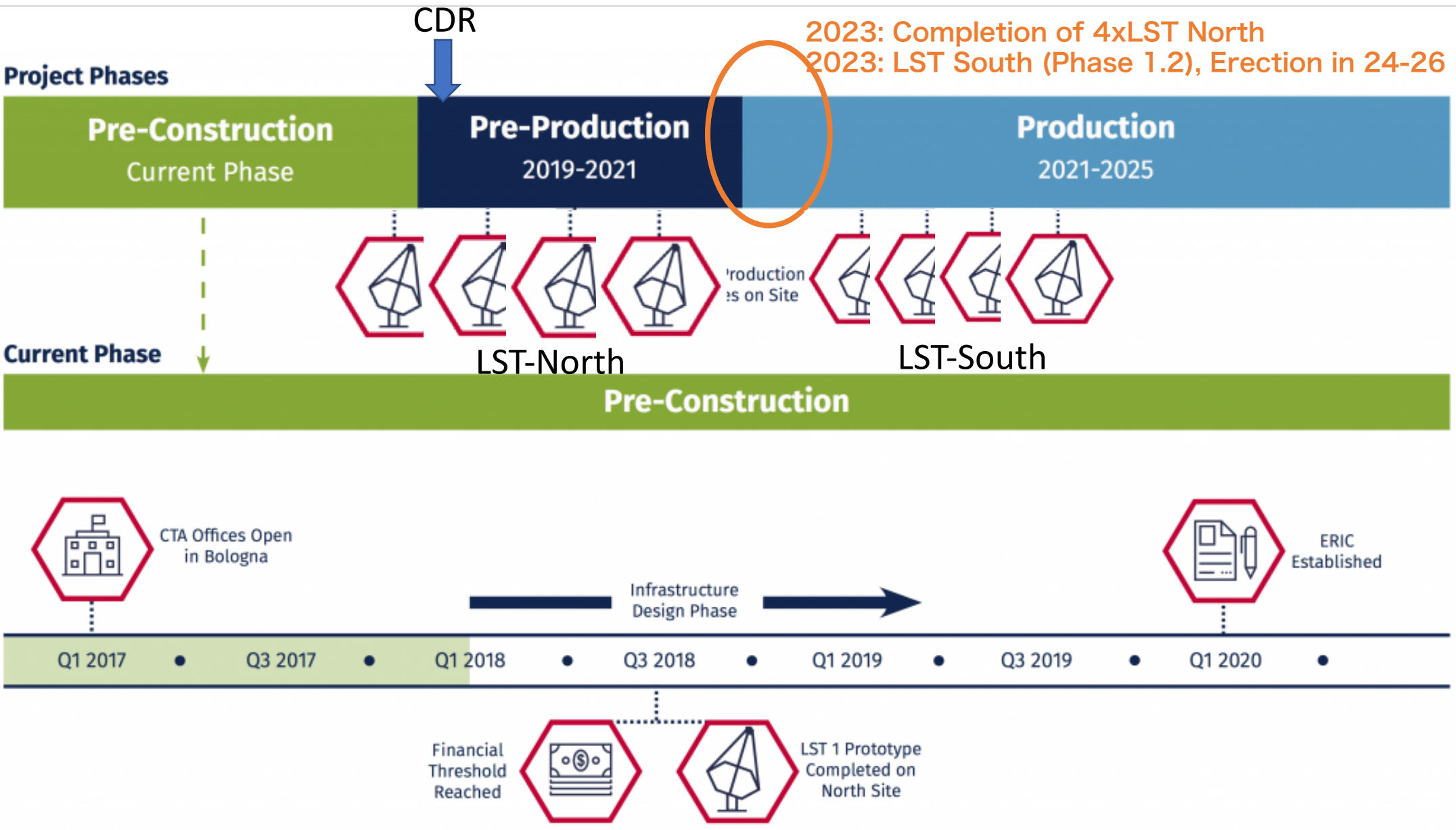
Charge



Timing


Run 1618
Number of phe
Smoothed events
Gammas ~0.5 Hz
ON data
Reconstructed posi
Crab position
Number of events
α [deg]
OFF data

Time line for CTA and CTA-LSTs



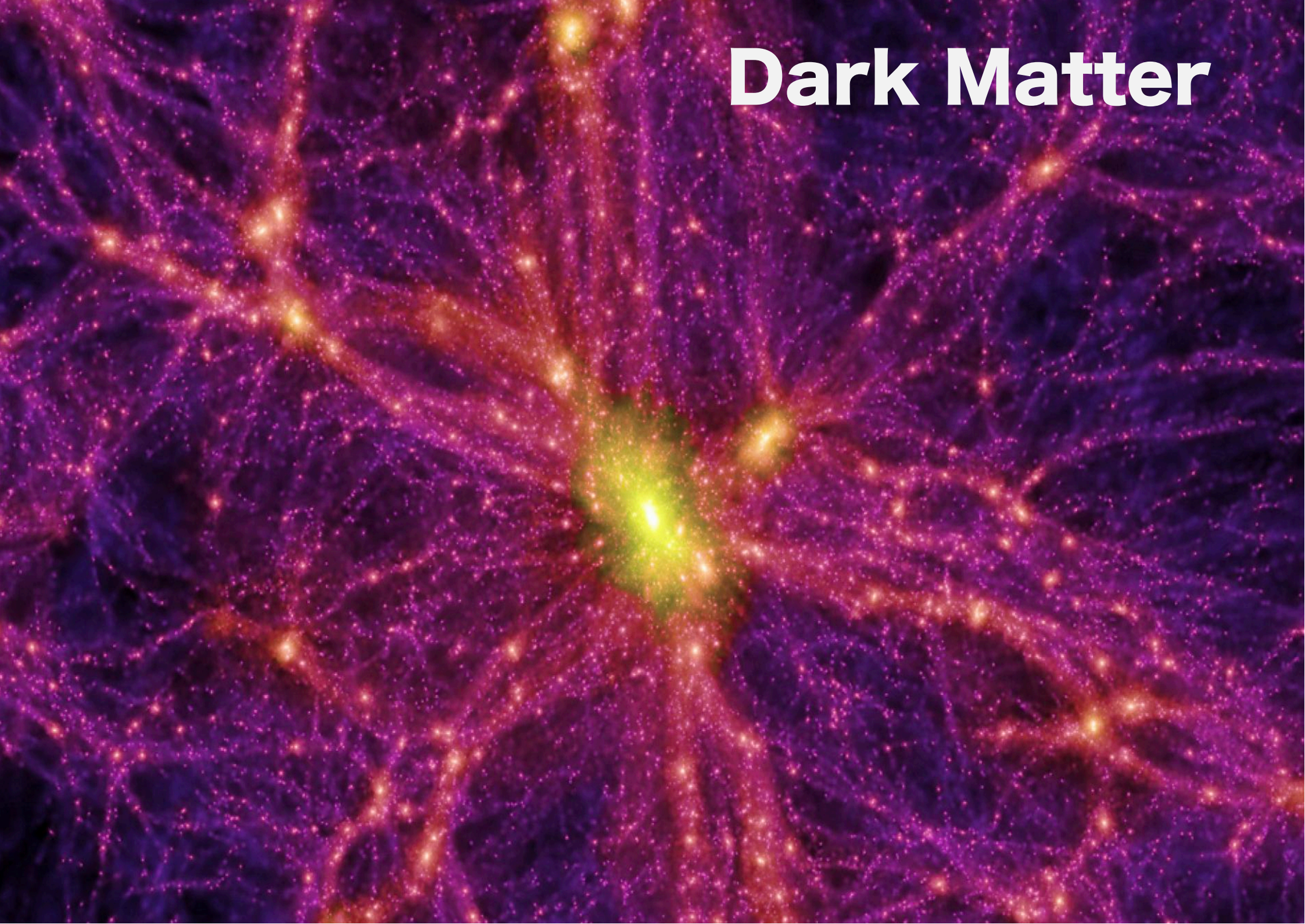
Why do we need CTA South / LST South?

- Increase Number of sources/detections
  - Doubling Sky and deep Universe (AGNs z<2, GRBs z<4)
  - AGNs / AGN Flares, **GRBs**
  - Detailed study of galactic objects
    - Pulsars, PWNe, SNRs, Detailed study of Specific SNRs
    - Dwarf Spheroidal Galaxies for D.M. indirect search

- New Quality and New Findings
  - G.C. and G.C. Halo
  - Our G.C. is the closest S.M.B.H.
    - Should be studied in detail, Spectrum, Time variation, Flares etc.
  - Dark Matter Halo
    - LST+MST array in South, and L.Z.A. observation from North
  - Fermi-bubble

Why do we need CTA South / LST South?

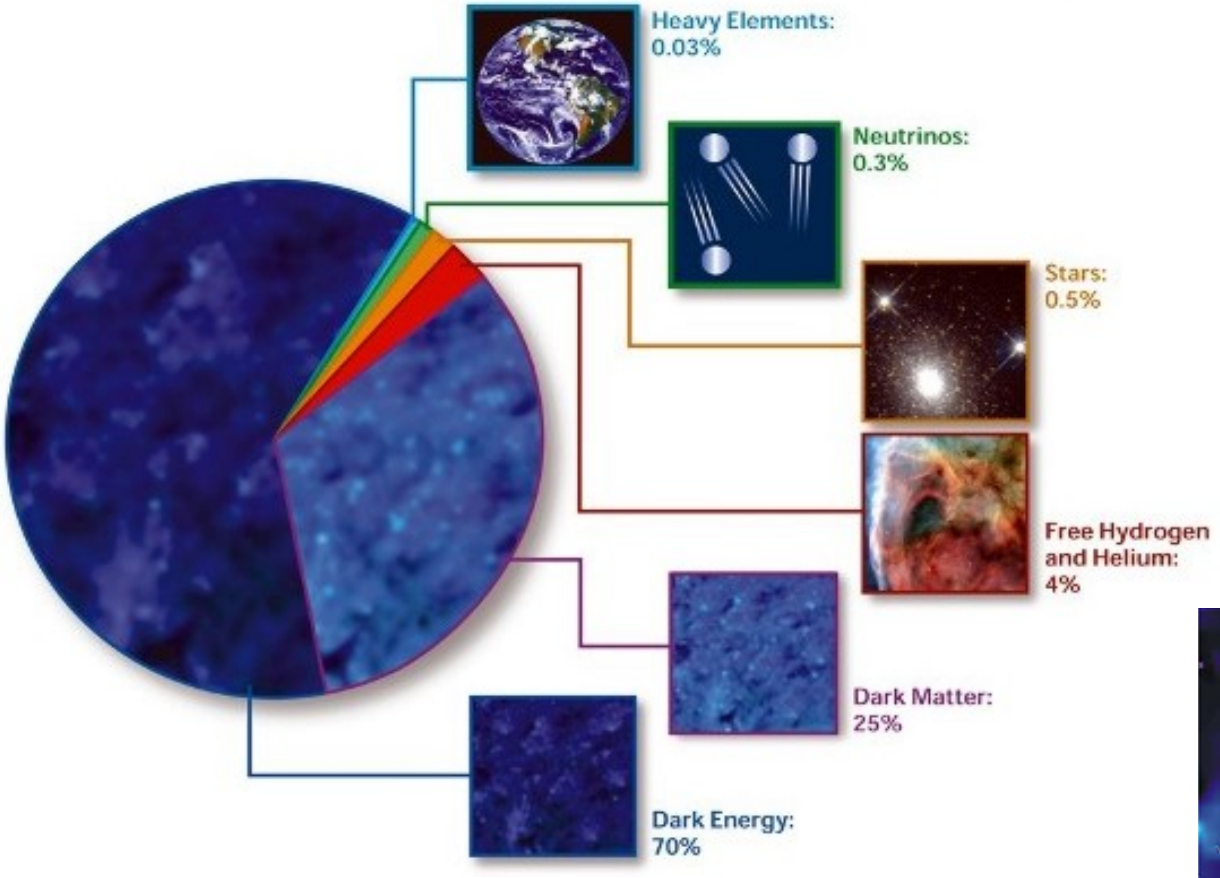
- Multi Messenger Astronomy with PeV neutrinos from the deep Universe
  - Ice Cube Source, high z (TXS 0506; z=0.336)
  - ➔ Low threshold is essential for better coincidence rate with IceCube Neutrinos
  - ➔ increase latitude coverage and time coverage
- Multi Messenger Astronomy with Gravitational Wave detectors
  - Short GRBs
  - H.E. Gamma Ray emission from remnants?
  - ➔ low threshold is essential
- Specific nearby sources in South
  - Cen A, (M87) --- Hadronic source? UHECRs, Jets
  - Fermi Bubble
- LST South will give a high potential for new discoveries!!


Dark Matter

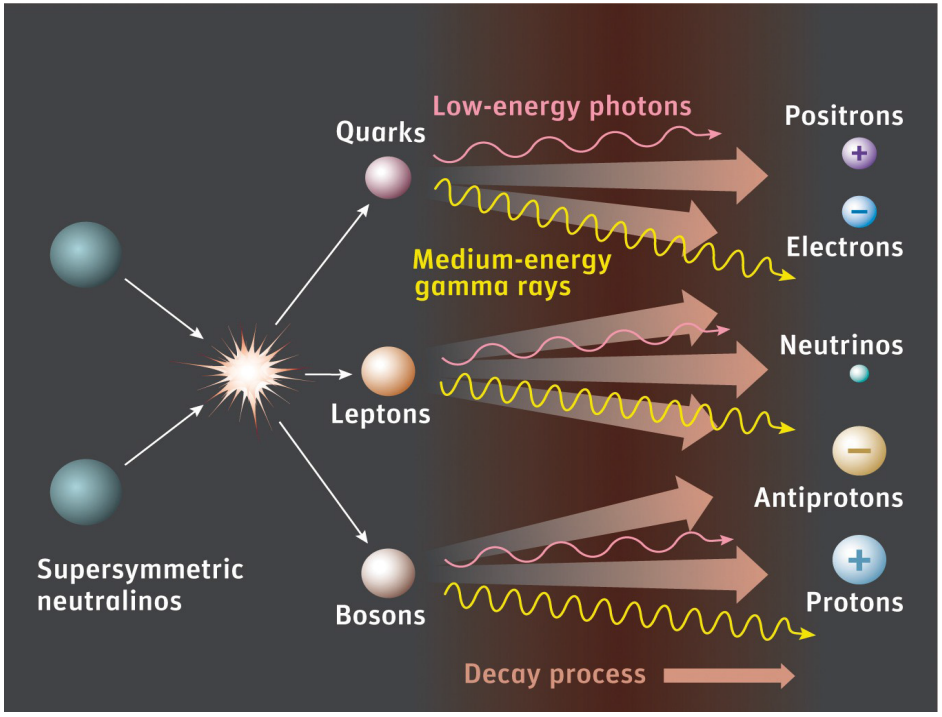
Dark Matter Search

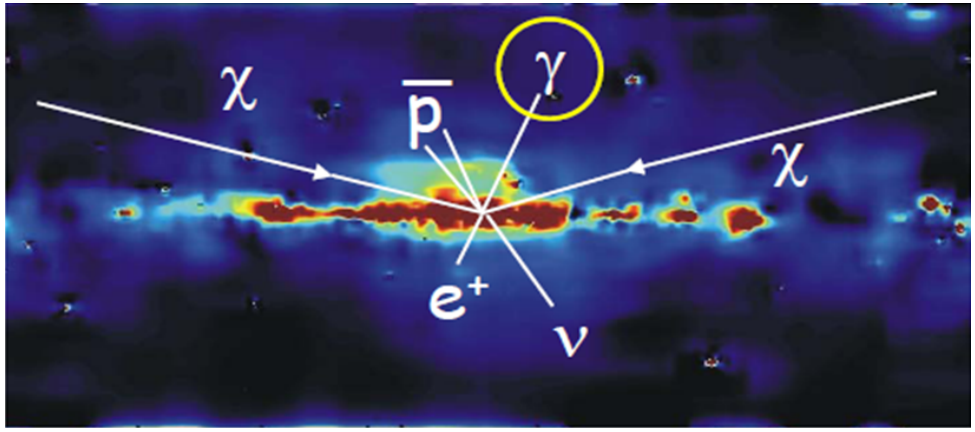
Mass Scale M_χ: 100GeV - 10TeV

Surprisingly Physicists, Astronomers and Professors do not know well the Universe!!



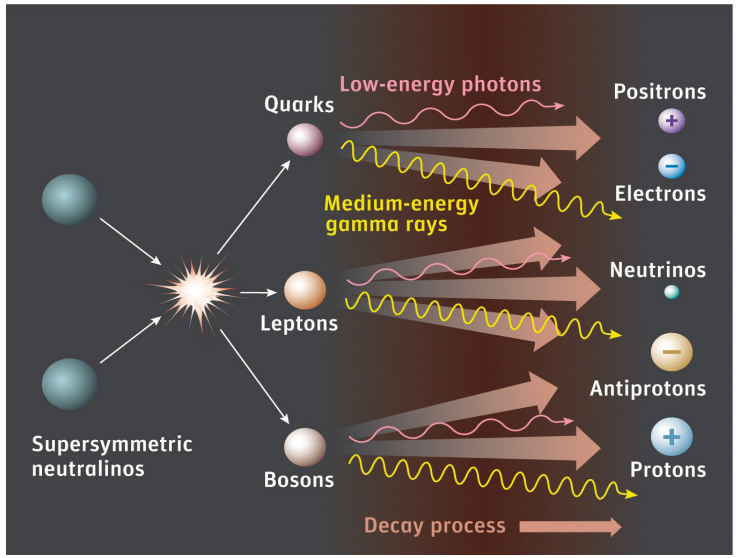
Known Matter	~ 5%
Dark Matter	~25%
Dark Energy	~70%





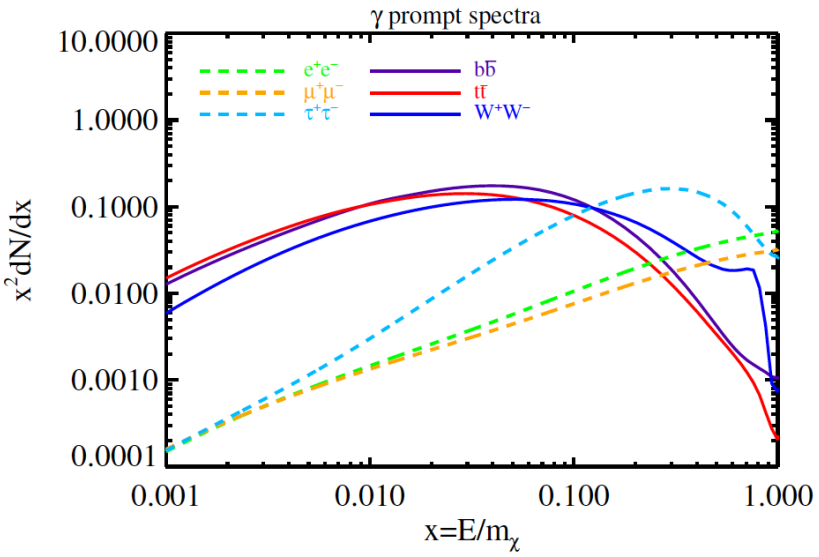
Dark Matter Search

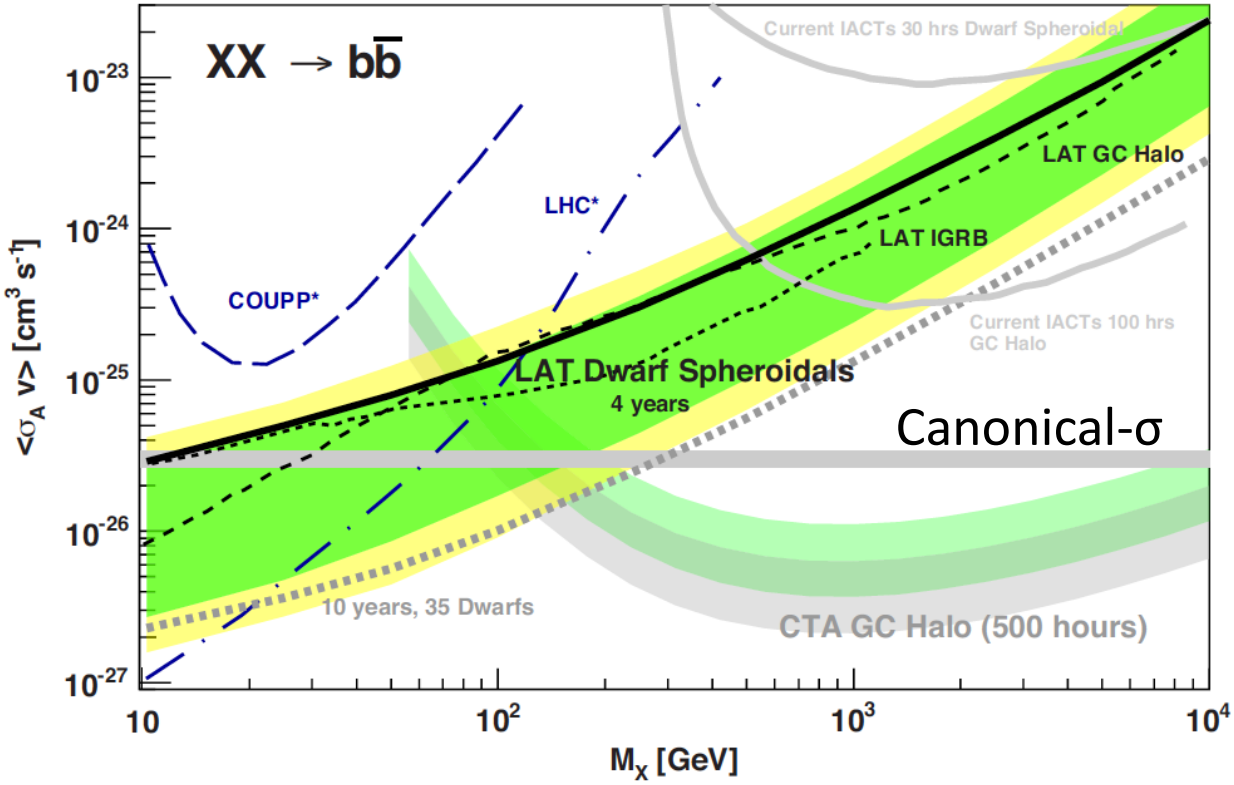
Sensitive M_χ: 200GeV - 10TeV



$$\frac{d\Phi_\gamma}{dE_\gamma} = \frac{1}{4\pi} \underbrace{\frac{<\sigma_{ann} v>}{2m^2_{WIMP}} \sum_f \frac{dN^f_\gamma}{dE_\gamma} B_f}_{\text{'Particle Physics'}} \times \underbrace{\int_{\Delta\Omega} d\Omega' \int_{los} \rho^2 dl(r,\theta')}_{\text{'Astrophysics' or } J(E)}$$

Particle Physics Astrophysics



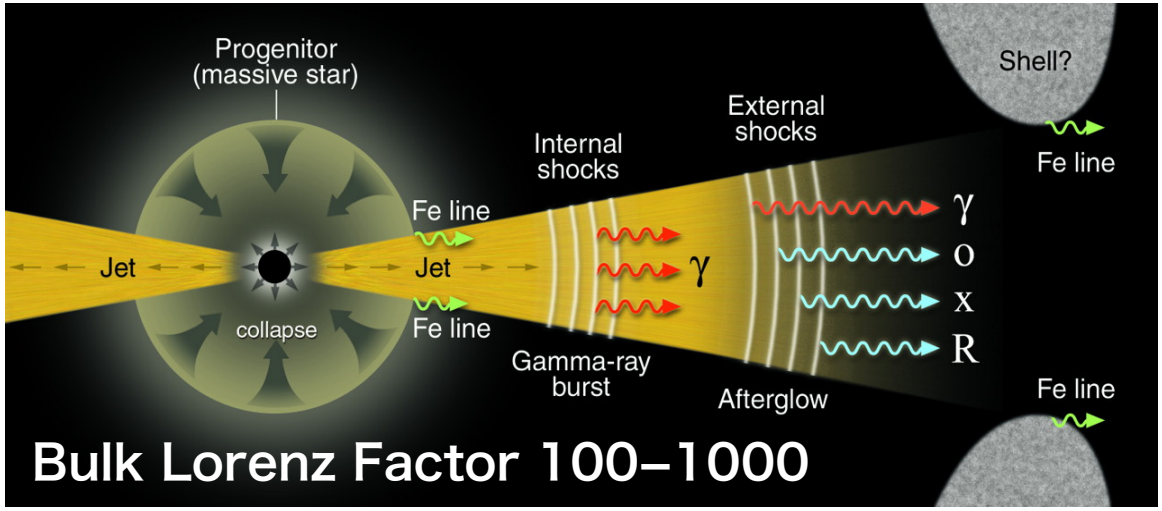


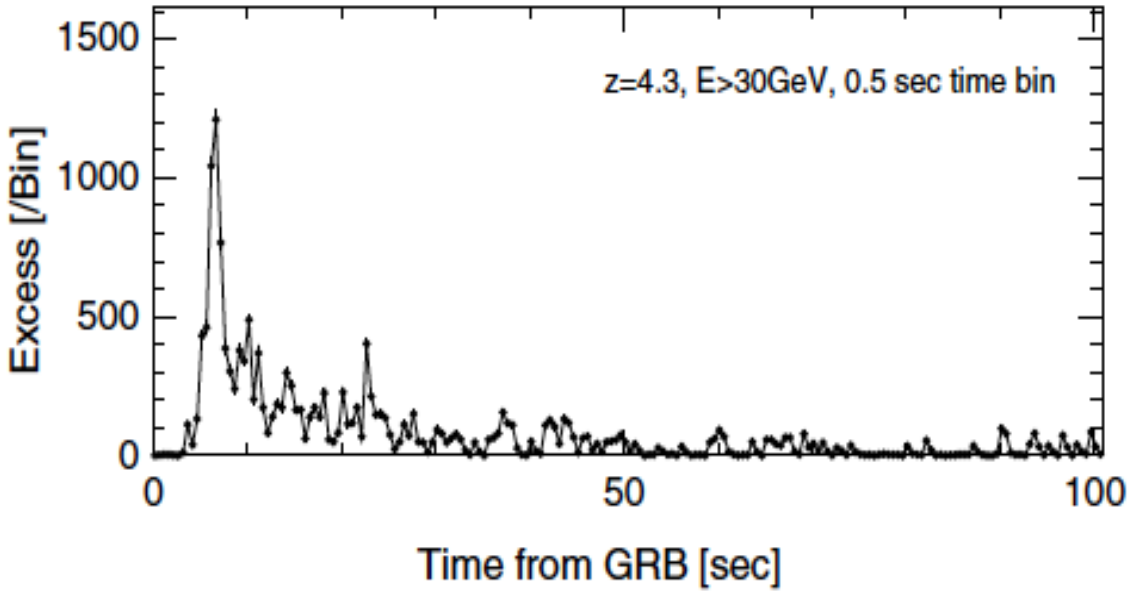
Gamma rays from Annihilation produce the bump around 1/10 -1/20 Mχ ➔ 20GeV-1TeV domain

CTA gives the stringent upper limit.
Stefan Funk 2015

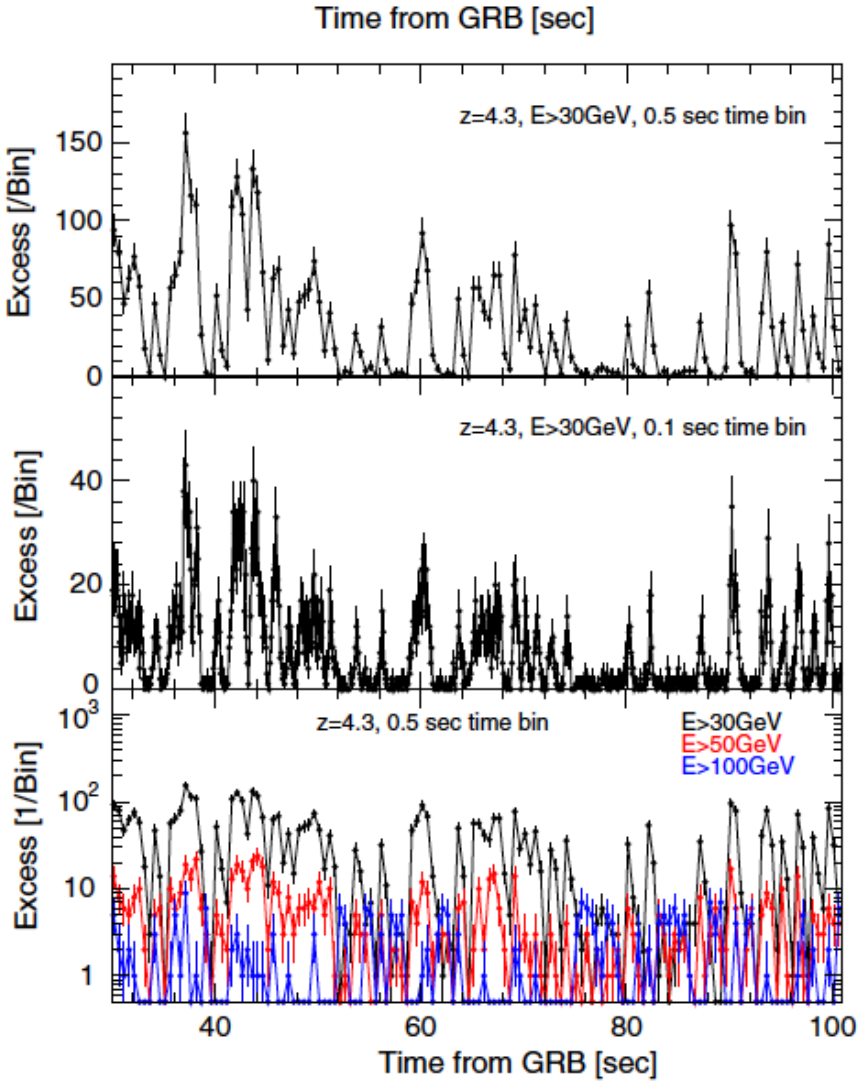

Gamma Ray Bursts

GRBs: good targets for CTA-LSTs
Study the newborn baby black holes





CTA Simulation
(Template GRB080916C)



MAGIC observed TeV-GRB190114C with >50 sigma above 300GeV, distance z = 0.42

[Previous | Next]

First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

ATel #12390; *Razmik Mirzoyan on behalf of the MAGIC Collaboration*
on 15 Jan 2019; 01:03 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

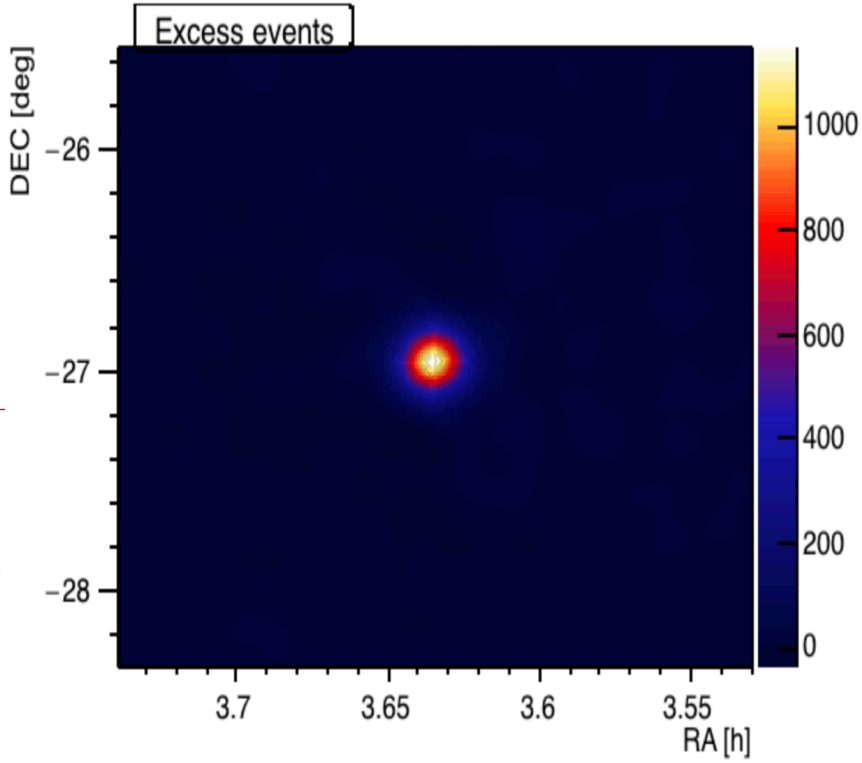
Related
12395 GRB 190114C: Search for high-energy neutrinos with IceCube
12390 First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, Gamma-Ray Burst

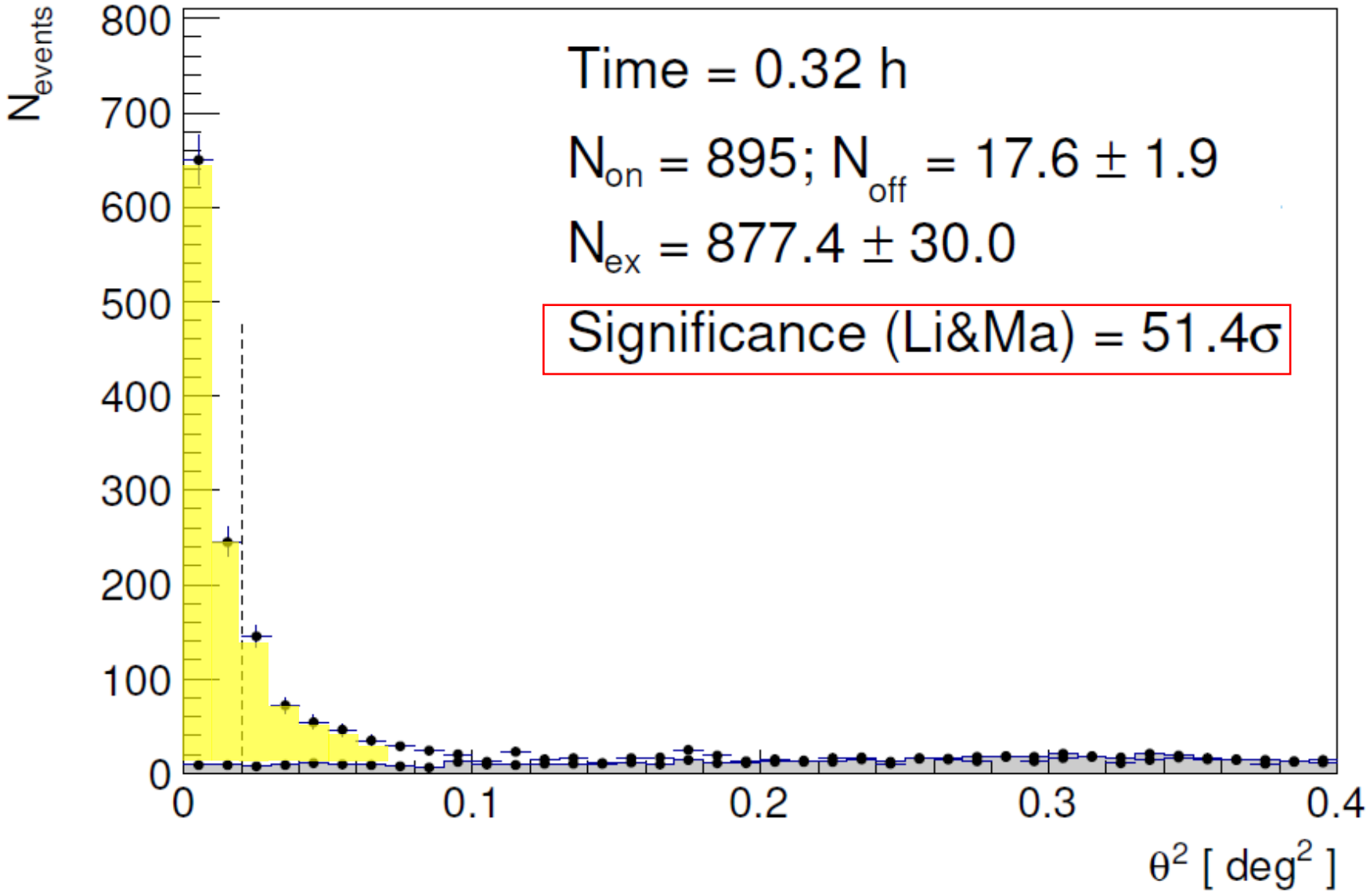
Referred to by ATel #: 12395

Tweet

The MAGIC telescopes performed a rapid follow-up observation of GRB 190114C (Gropp et al., GCN 23688; Tyurina et al., GCN 23690, de Ugarte Postigo et al., GCN 23692, Lipunov et al. GCN 23693, Selsing et al. GCN 23695). This observation was triggered by the Swift-BAT alert; we started observing at about 50s after Swift T0: 20:57:03.19. The MAGIC real-time analysis shows a significance >20 sigma in the first 20 min of observations (starting at T0+50s) for energies >300GeV. The relatively high detection threshold is due to the large zenith angle of observations (>60 degrees) and the presence of partial Moon. Given the brightness of the event, MAGIC will continue the observation of GRB 190114C until it is observable tonight and also in the next days. We strongly encourage follow-up observations by other instruments. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) and K. Noda (nodak@icrr.u-tokyo.ac.jp). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

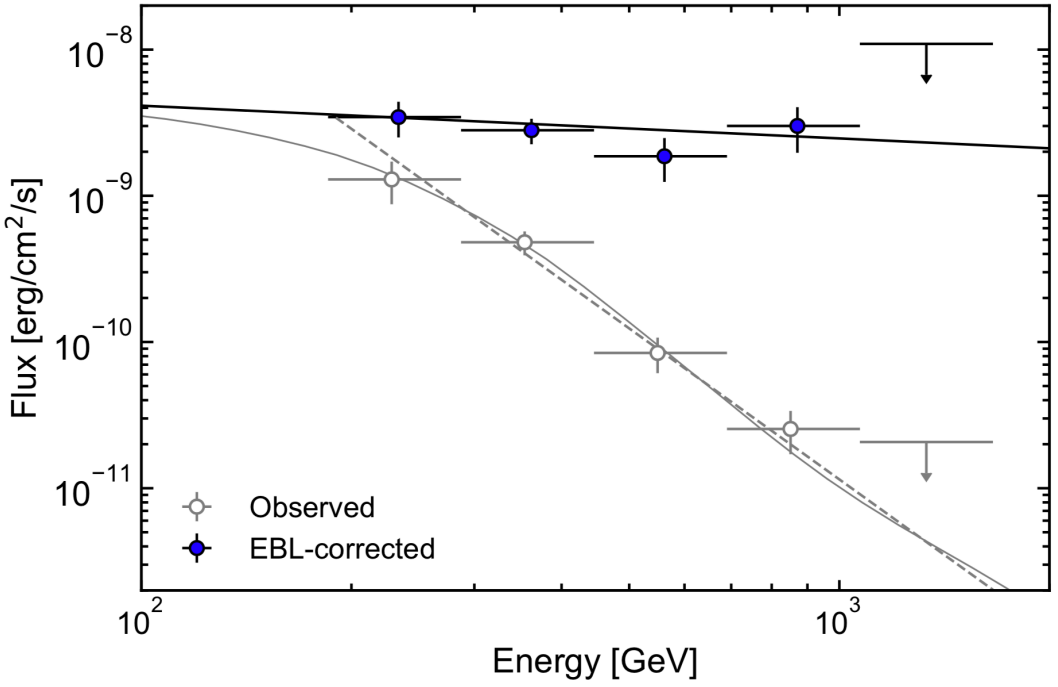


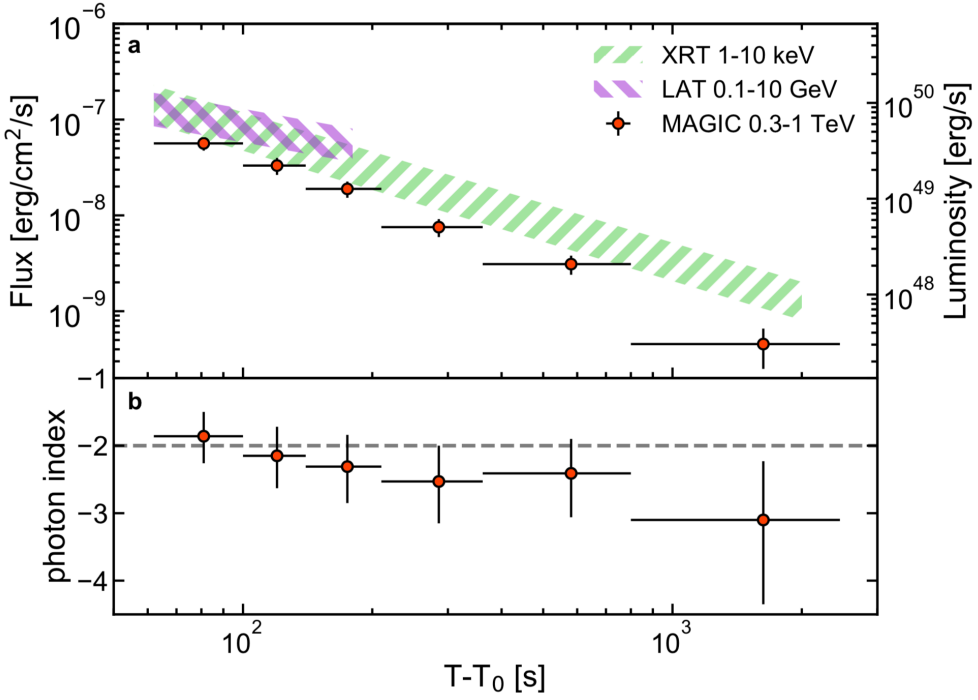
The most intense, purest signal in VHE gamma-ray astrophysics: GRB190114C detection by MAGIC at E ≥ 200 GeV

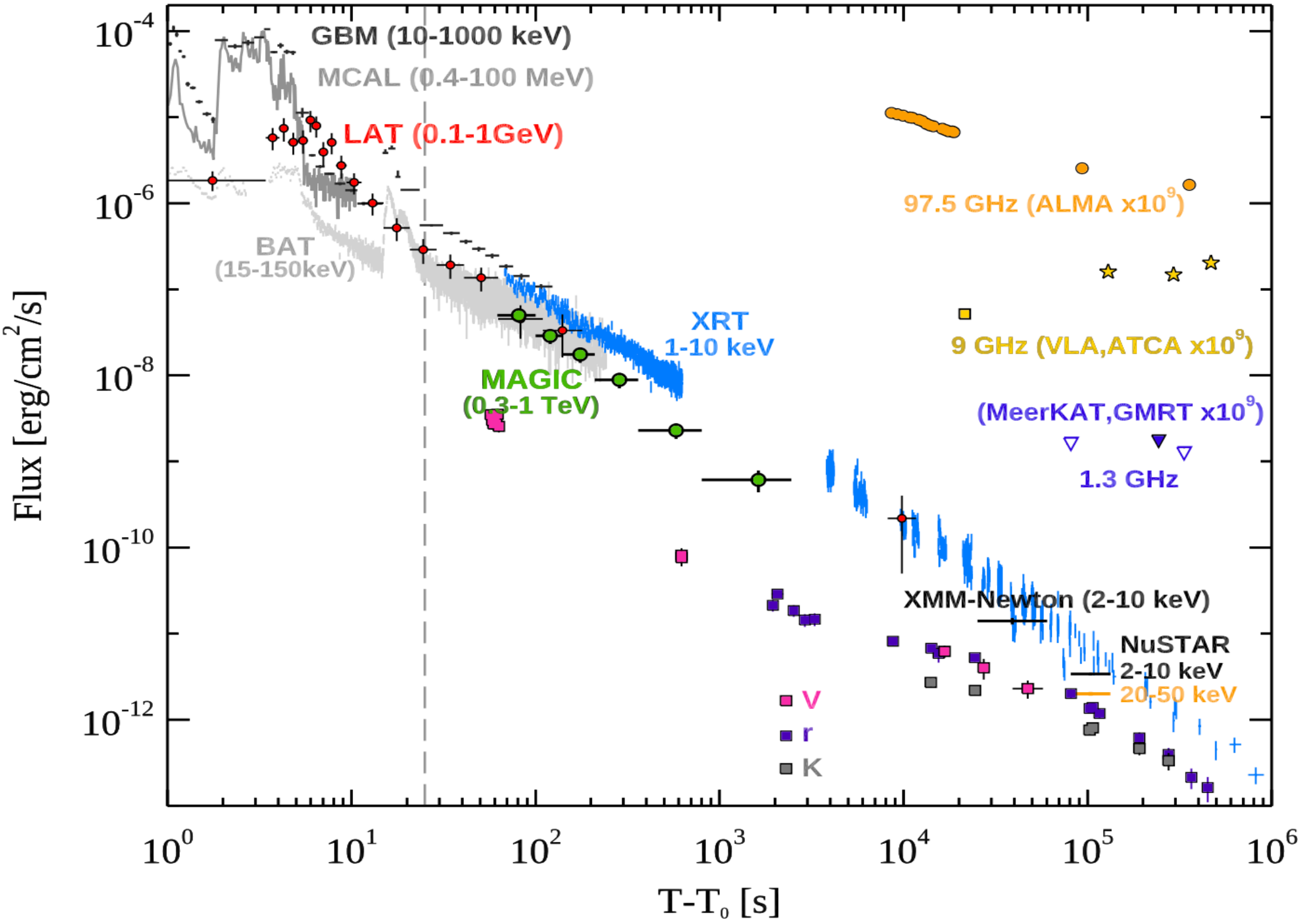


GRB 20190114C

- Gamma ray spectrum is extending to 1TeV
- De-absorbed spectrum shows $\propto E^{-2.0}$
- Light curve shows the long tail and almost parallel with X-Ray afterglow. $\propto T^{-1.6}$






GBM (10-1000 keV)
MCAL (0.4-100 MeV)
LAT (0.1-1GeV)
BAT
(15-150keV)
XRT
1-10 keV
MAGIC
(0.3-1 TeV)
97.5 GHz (ALMA x10^9)
9 GHz (VLA,ATCA x10^9)
(MeerKAT,GMRT x10^9)
1.3 GHz
XMM-Newton (2-10 keV)
NuSTAR
2-10 keV
20-50 keV
V
r
K
Flux [erg/cm^2/s]
T-T0 [s]

Giulia Stratta's slide yesterday we can expand z ~ 0.5 → z ~ 2.0

GRB detection with MAGIC and H.E.S.S.

2018

First hint of VHE from the short GRB 160821B@z=0.16 (Berti+2018, 15° Marcel Grossman meeting 2018)

- MAGIC follow-up of started at T0+24 s
- **Hints of gamma-ray signal at >500 GeV are found few hours after the burst**

Jan 2019

First strong evidence from long GRB 190114C@z=0.42 (Mirzoyan et al. 2019, Atel#12390)

- MAGIC follow-up of started at T0+50 s
- **>20 sigma in the first 20 min for energies >300 GeV** > 50 sigma

May 2019

Long GRB 180720B@0.654 (Ruiz-Velasco, CTA Symposium 2019)

- H.E.S.S. follow-up started ~10hr after the burst trigger

Aug 2019

Long GRB 190829A@z=0.0785 (de Naurois et al. 2019, GCN 25566)

- H.E.S.S. follow-up started at T0+4h20 and lasted 3.5h
- **>5 sigma gamma-ray excess compatible with the direction of GRB190829A**

Learned from these GRBs

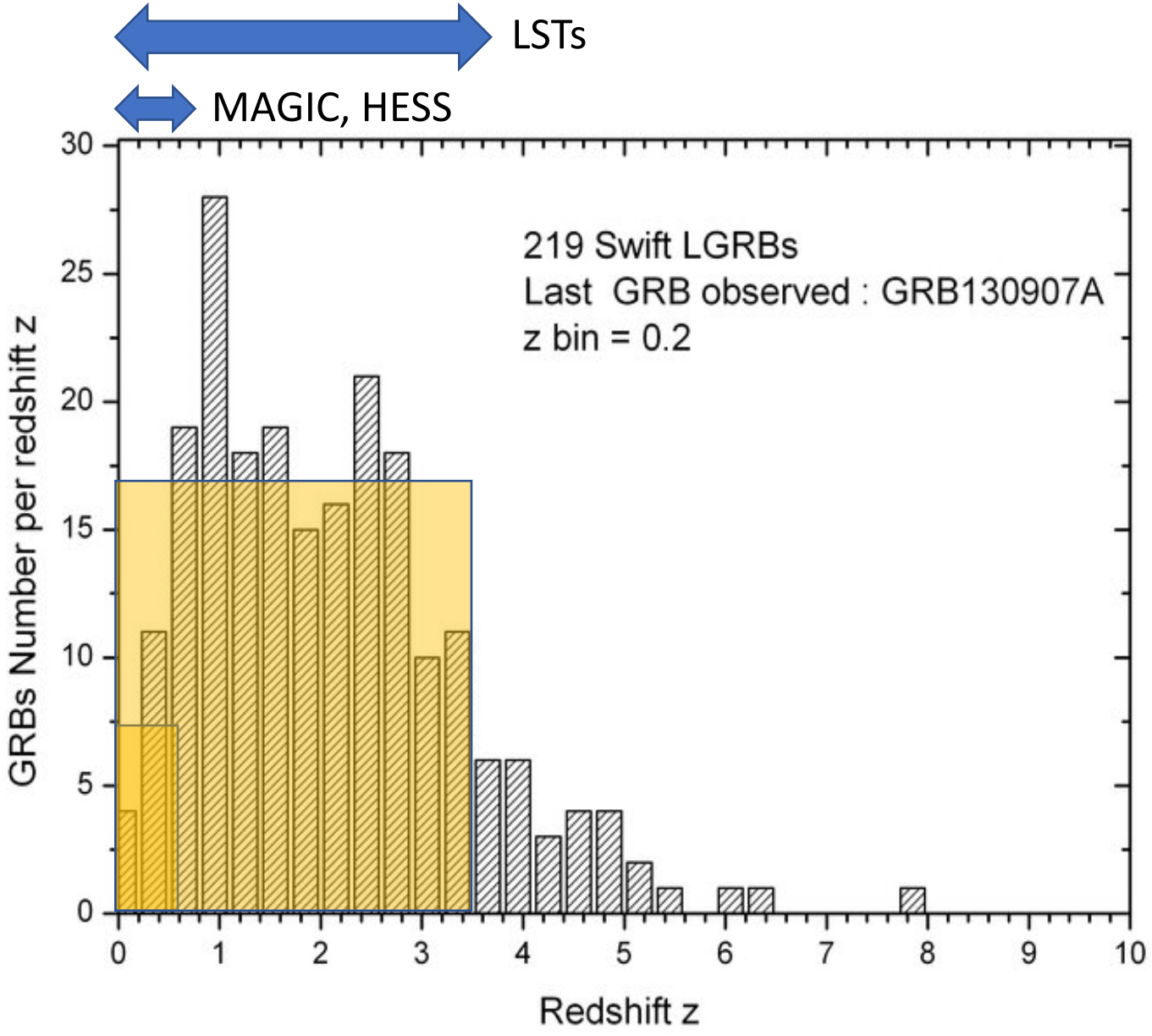
- There are high energy emission up to TeV and even no cut off feature
- dF/dE ~E^{-2}, EBL absorption
- Afterglow light curve shows long tale dF/dT ~ $T^{-1.5}$ and almost parallel with X-Ray afterglow

➔➔➔

- Observation with low threshold energy to overcome EBL absorption
  - Increase the observable volume, gaining factor ~ x 10
- We shall continue to observe even 12 hrs or a day
  - Increase observational time window, gaining factor ~ x ~3
- Fast rotation of LSTs
  - delivers us dynamical part of GRBs
  - Prompt emission or rising part of afterglow and Short GRBs
  - Close watch of newly born BH/Central Engine

Redshift Distribution from SWIFT GRBs

W. J. Azzam et al. 2014



15 GRBs in z < 0.5
112 GRBs in z < 2.0
164 GRBs in z < 3.0

LST North and LHAASO

Cooperation for Transients, GRBs and AGN flares

Eth ~ 20GeV, 28.75 N, 17.9 E

Eth ~ 50GeV, 29 N, 100 E

~118 degrees (~8hrs / 16hrs)

Summary

- Young scientists are hungry on the data and science, we shall construct CTA-LSTs in CTA-N and CTA-S as soon as possible.

- LST-1 is in commissioning phase
  - LST-1 will be in the regular engineering run in January 2020
  - LST-1 – MAGIC cross calibration now starts

- LST south (LST 5-8) program should be launched around 2022-23
  - Strong impacts to Dark Matter and GRB physics

- Scientific cooperation between LHAASO and LST-N

TeV-GRB190114c Observation with MAGIC


cta
cherenkov
telescope
array

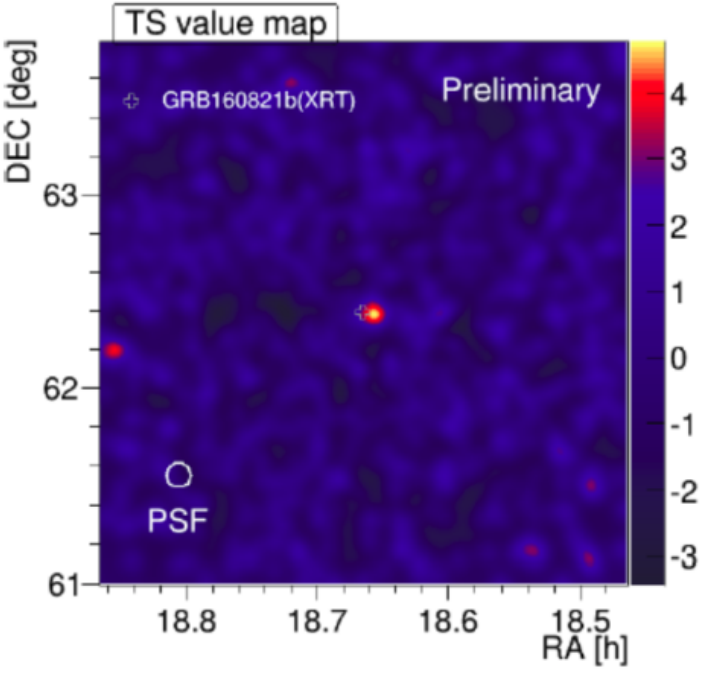
MAGIC Hint From GRB 160821B at ICRC2017

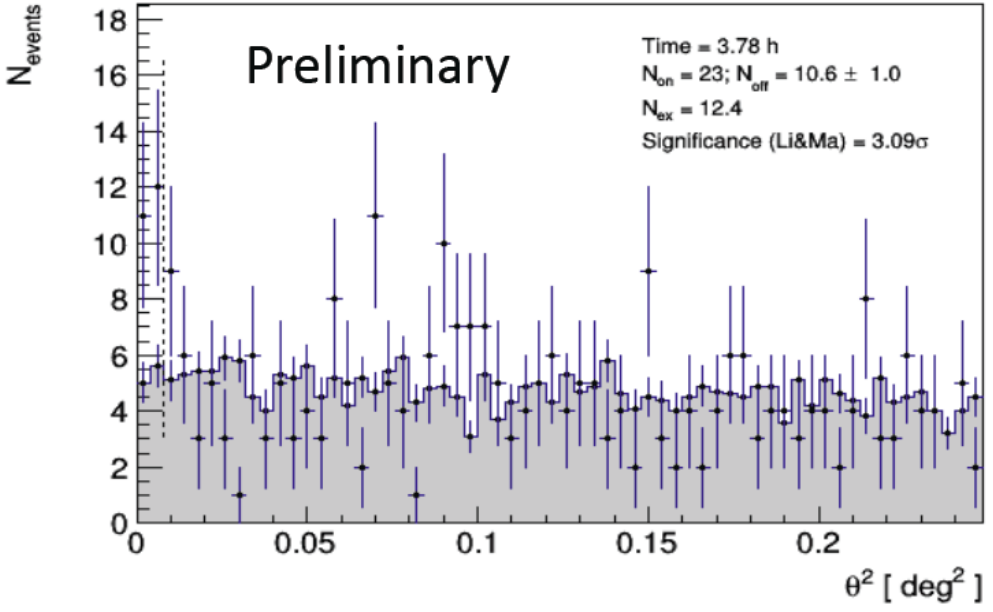
MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

- **Short GRB** (T90 ~= 0.5 s) at **z = 0.16**, triggered by Swift-BAT
- Swift-XRT: t < 300 s extended emission + steep decay, t < 30 ks plateau?
- No LAT detection. HST: **hint of a kilonova?**
- **MAGIC: 24 s - 4 hr**. Bright moon

  (3-9 x dark LoNS)
- **3.1 sigma (post-trial)**

  hint at E ≥ 600-800 GeV



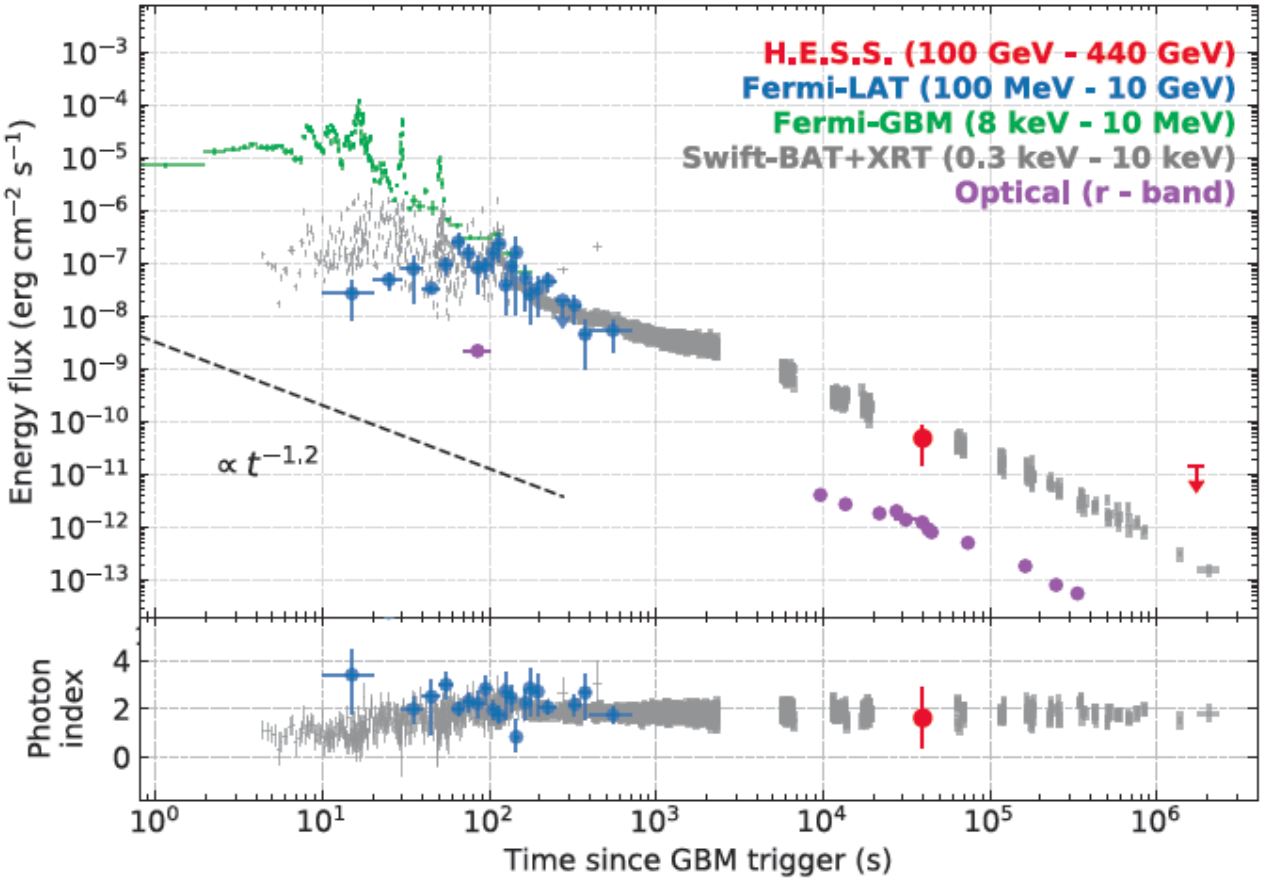


The first TeV-GRB observed by MAGIC
GRB 190114C

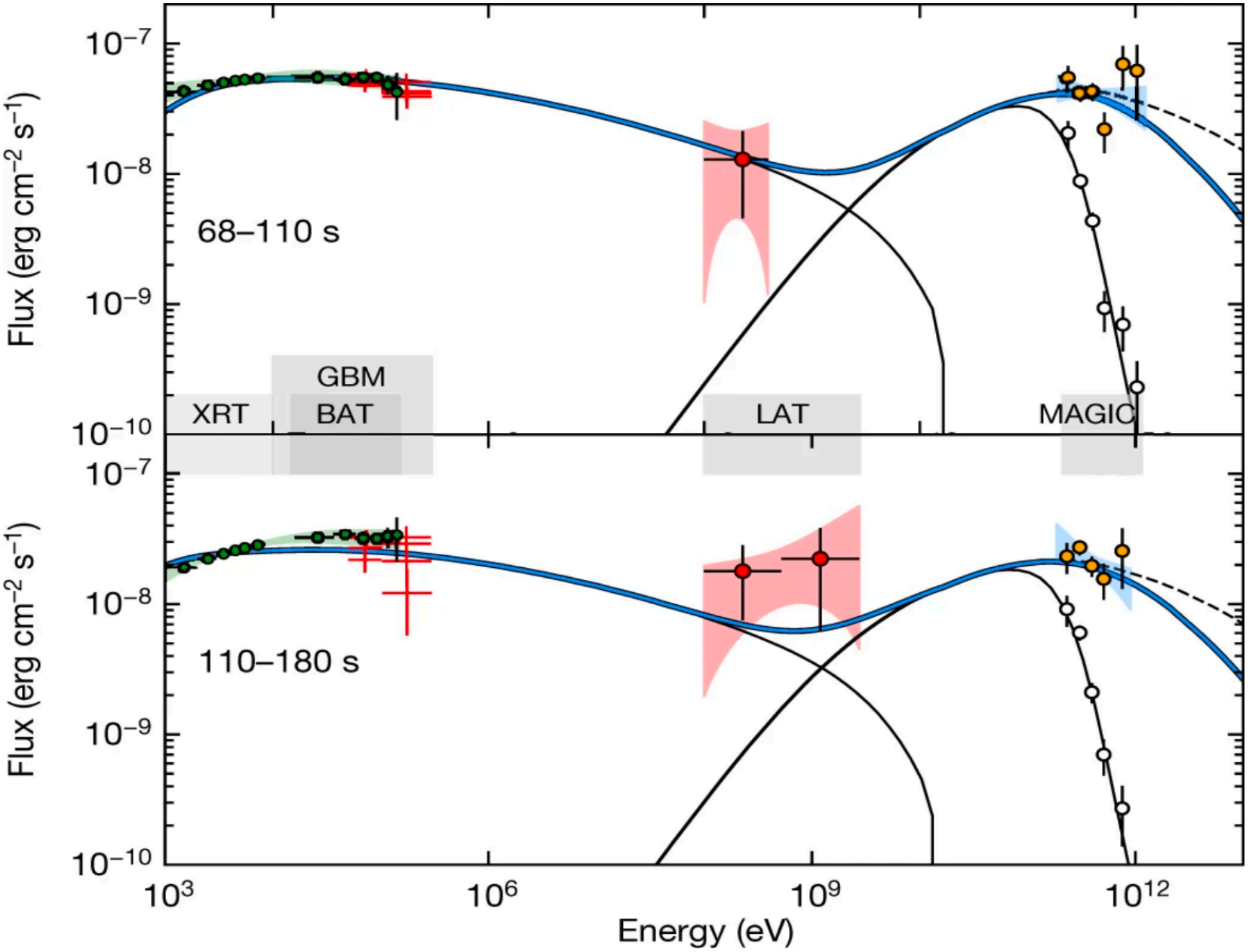
H.E.S.S. Detection of Afterglow From GRB180720B

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



MWL interpretation

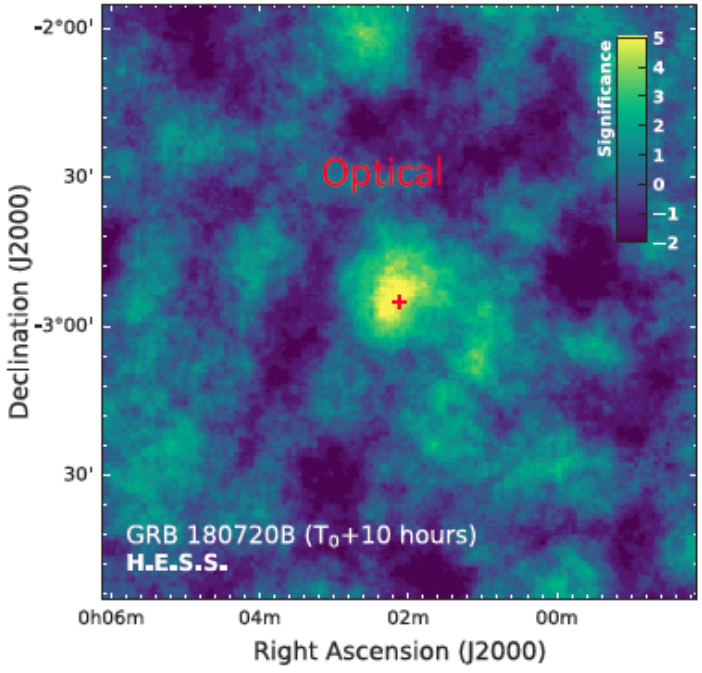


~5 months after MAGIC GRB Detection
At CTA Symposium in Bologna on 8th of May 2019
H.E.S.S. Reported on GRB 180721B

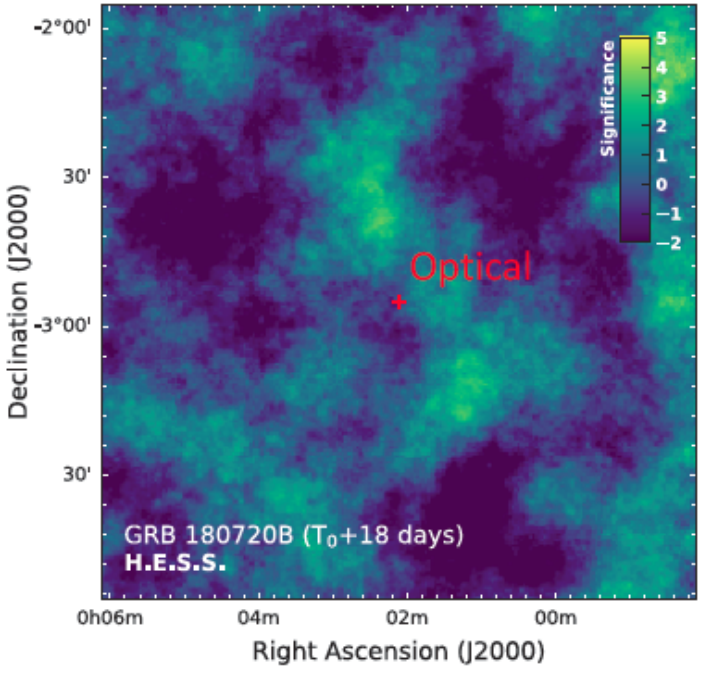
The GRB180720B detection

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

Quentin Piel ICRC2019



2 hours taken between 25° and 40° zenith angle



Between 18 days and 25 days after the burst

Evolution of the spectrum