CTA大口径望遠鏡初号機と MAGIC望遠鏡による研究成果

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2023.2.22　令和4年度共同利用研究成果発表会

Cherenkov Telescope Array (CTA)

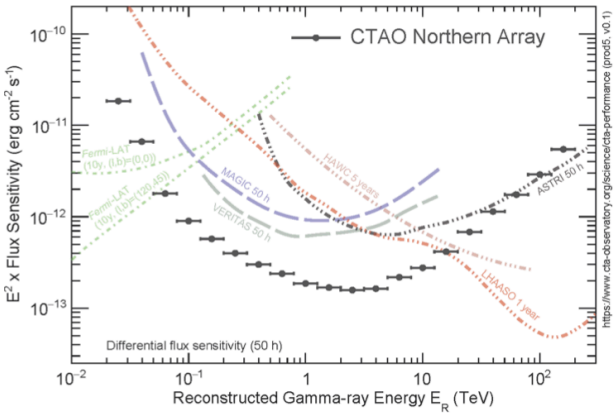
- New gamma-ray observatory under construction
- 4 LSTs will be set at northern site in La Palma, Spain, alongside 9 MSTs.
- Compared to current telescopes,

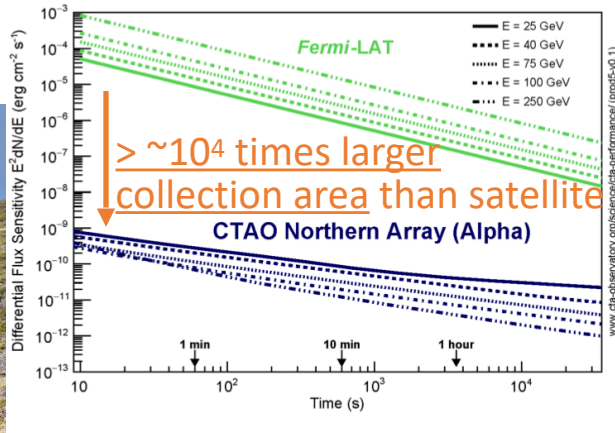
  - 10 times better sensitivity

  - 10 times wider energy range: 20 GeV – 300 TeV

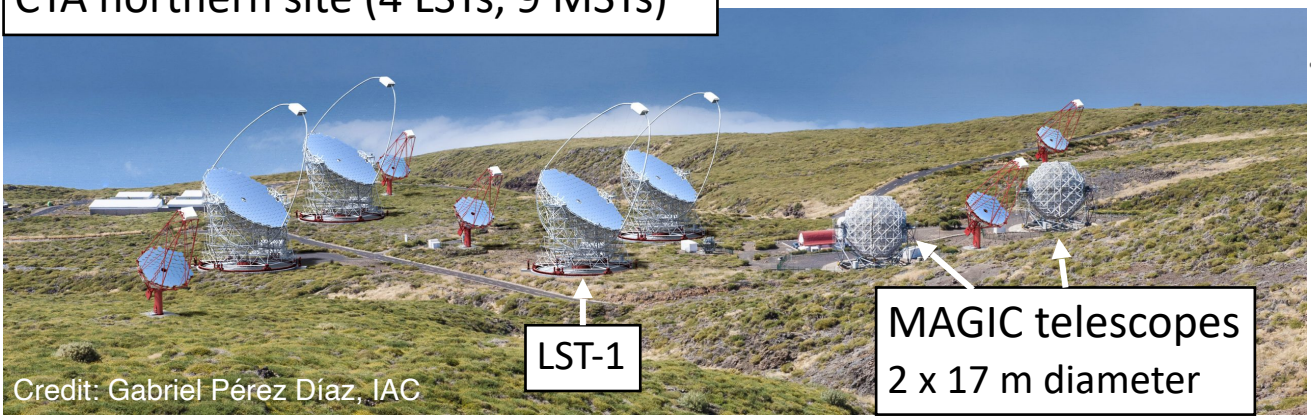
- We started LST-1 operation from 2018.

LST energy range



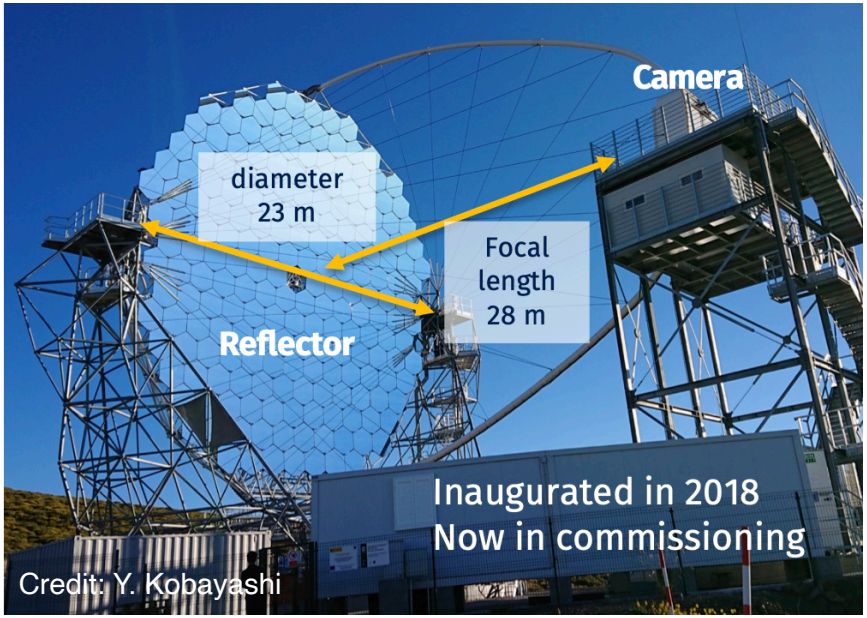


CTA northern site (4 LSTs, 9 MSTs)



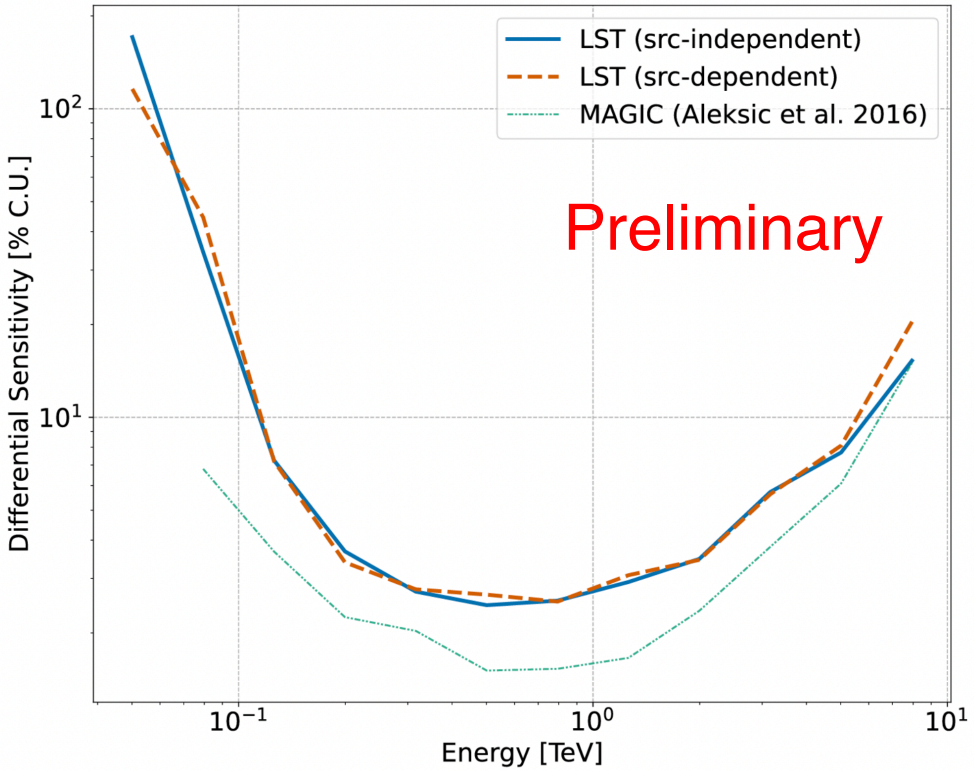
CTA large-sized telescope (LST)

- 23 m diameter: over 400 m^2 mirror area
- Targeting an energy threshold ~20 GeV
- Stereo observations at **lowest energy ever observed from ground**
- Ability to reposition to any point in the sky within 20 seconds
- Ideal for fast transients and soft sources

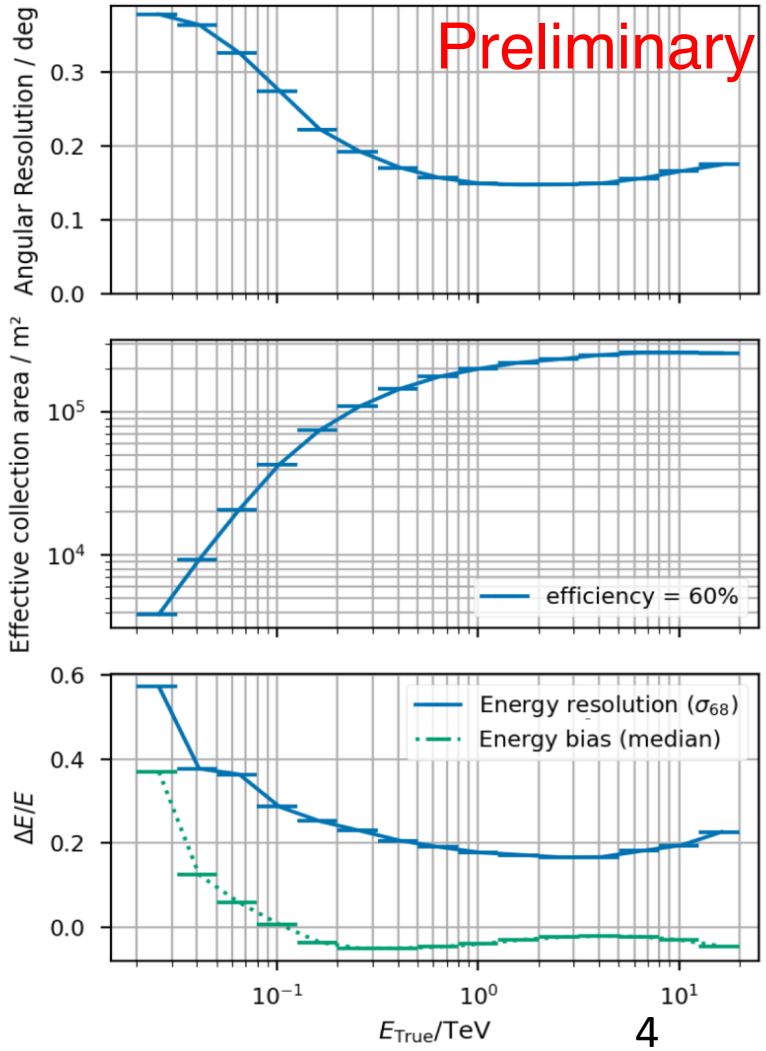


LST-1 performance

- Sensitivity (zenith angle < 35 deg, 50 hours)
- Roughly 1.5 times less sensitive than MAGIC stereoscopic telescopes
- Consistent with single telescope performance vs stereoscopic system because of higher backgrounds



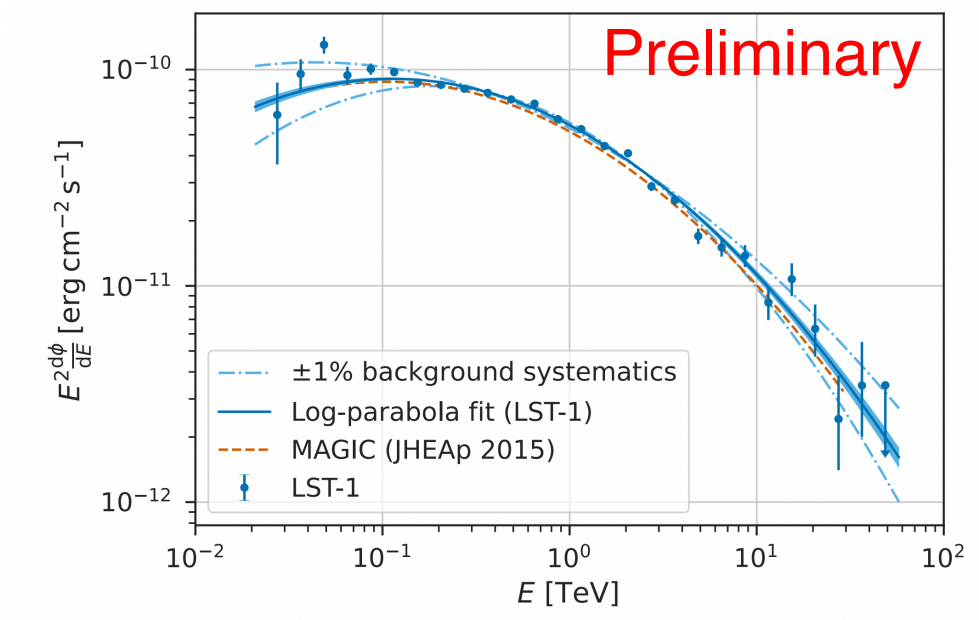
- Effective area, angular and energy resolution (zenith angle = 10 deg)



Crab Nebula and Pulsar

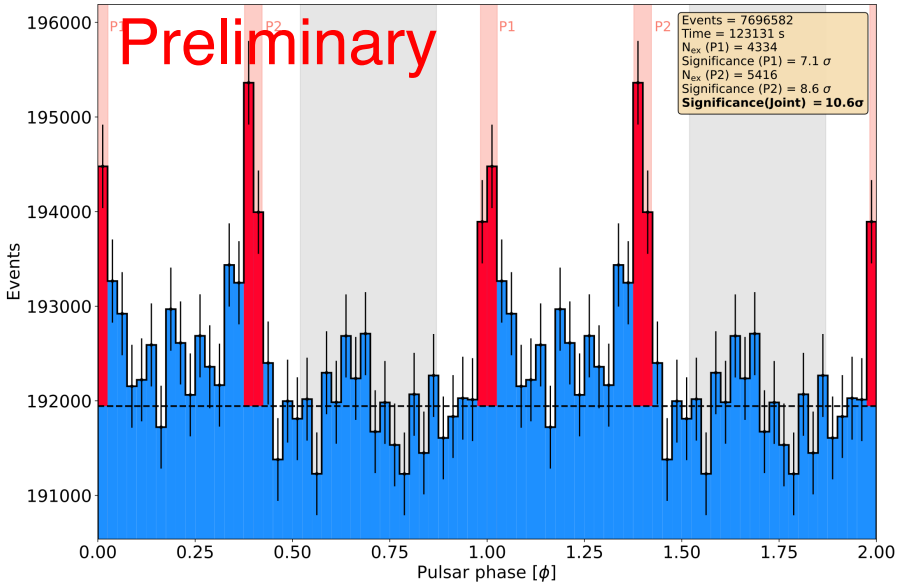
Crab Nebula spectrum

- 34.2 hours of data
- Systematic errors: blue lines correspond to the effect of ±1% background
- Consistent with MAGIC and Fermi-LAT



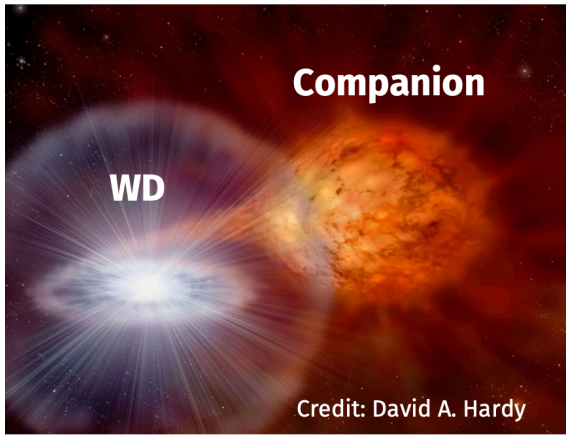
Crab pulsar phaseogram

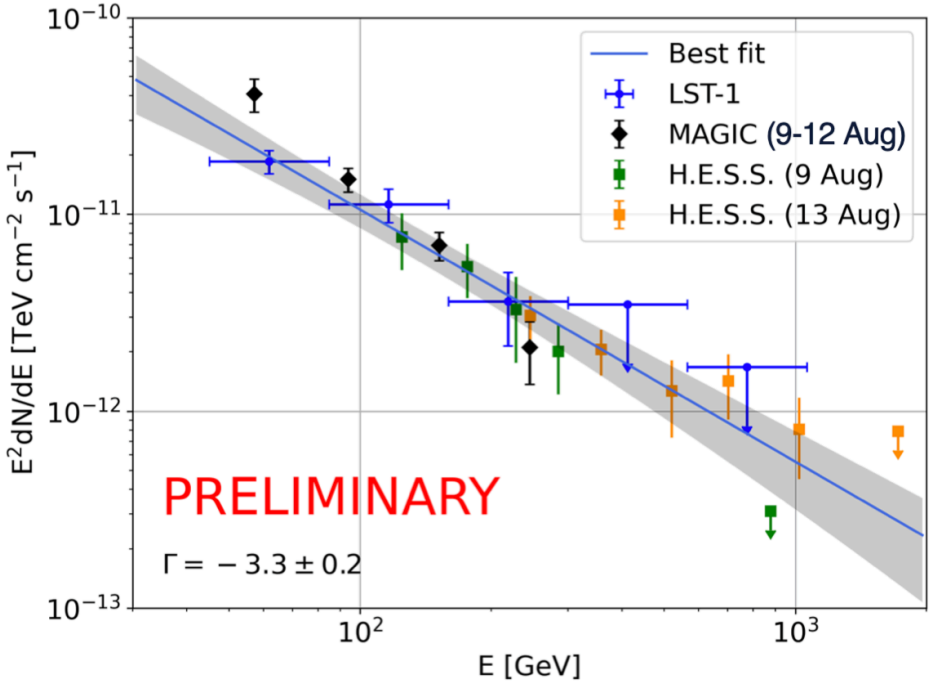
- Data from Nov 2020 - Mar 2022
- Significant detection down to few tens of GeV

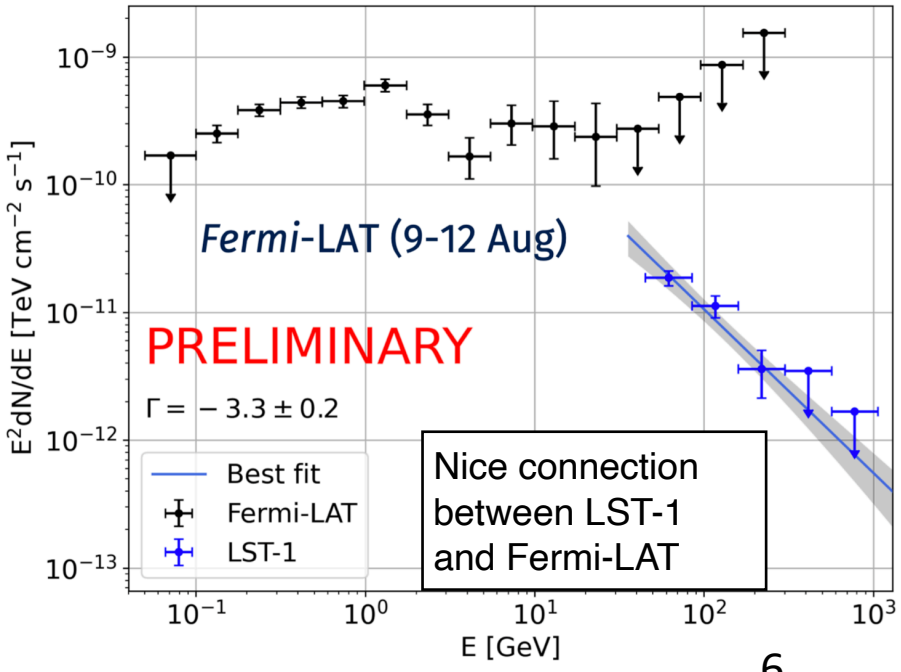


Detection of Nova RS Ophiuchi

- First detected recurrent nova in VHE gamma rays by 2021 outburst (H.E.S.S. and MAGIC)
- LST-1 took part in the first VHE gamma-ray detection with >~6σ in each night
- Consistent SEDs between LST-1, MAGIC, H.E.S.S.

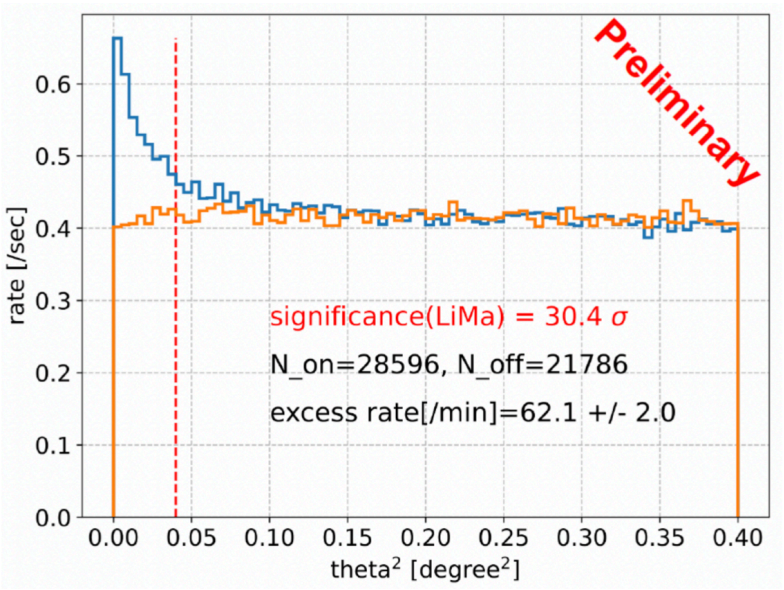


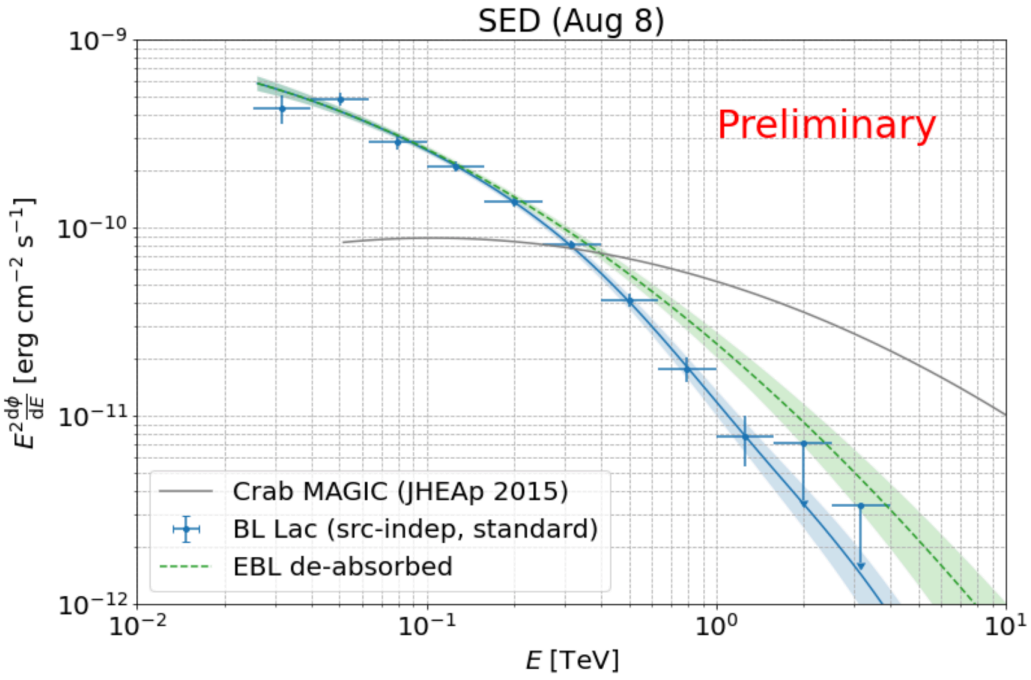




BL Lacertae

- Intermediate frequency peaked BL Lac at z = 0.069
- Flare on 2021 August 8 was detected (ATel #14783).
- ~5x brighter than Crab at 30 GeV
- Extragalactic Background Light de-absorbed spectra still shows curvature.
- Flux variability with ~min scale is observed.
- QG and Relativity tests are ongoing.

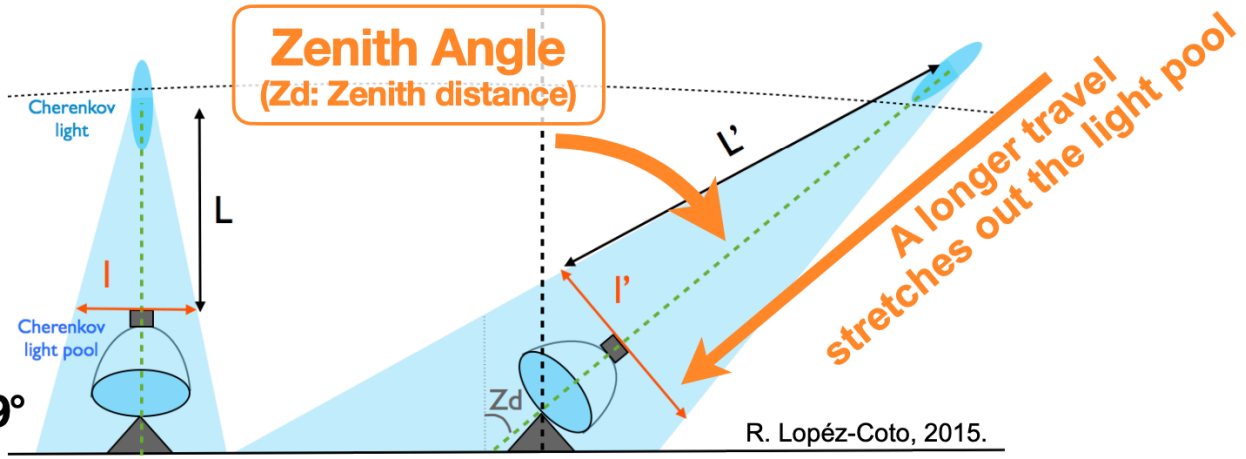


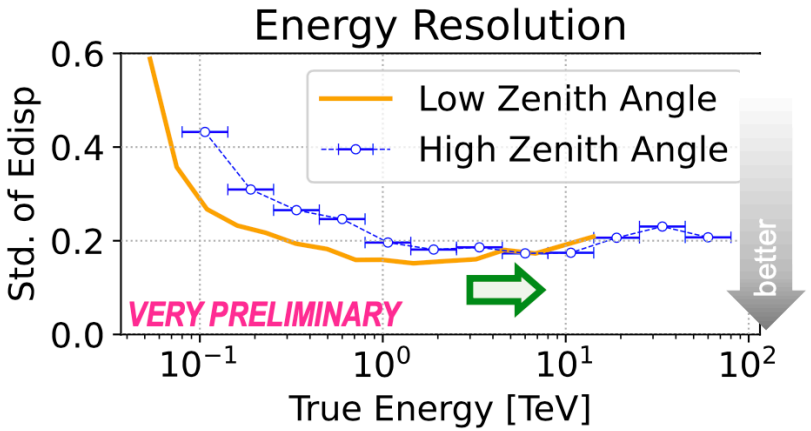


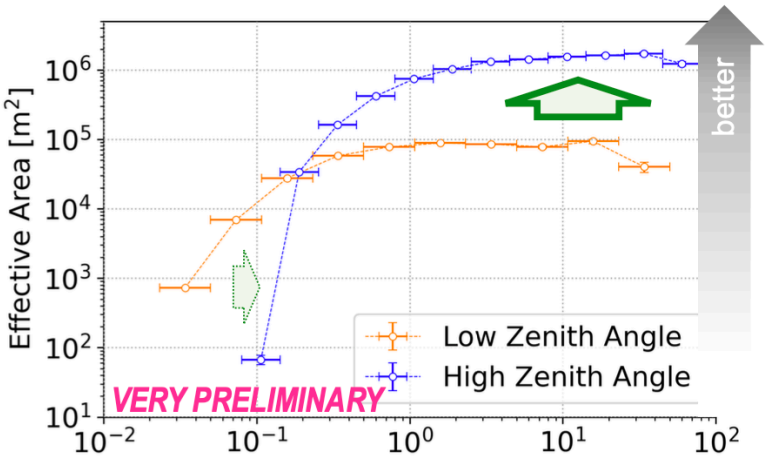
Large-zenith angle observation for Galactic Center

Large-zenith-angle observations (55-70 deg) enlarge the effective area at the high energies.

- **LST-1: 28°N**
- **Gal-Cent: Dec -29°**

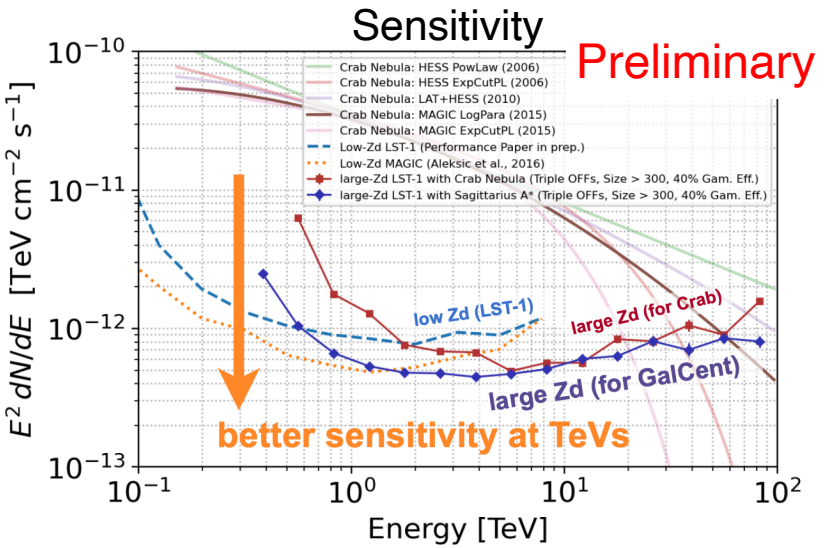


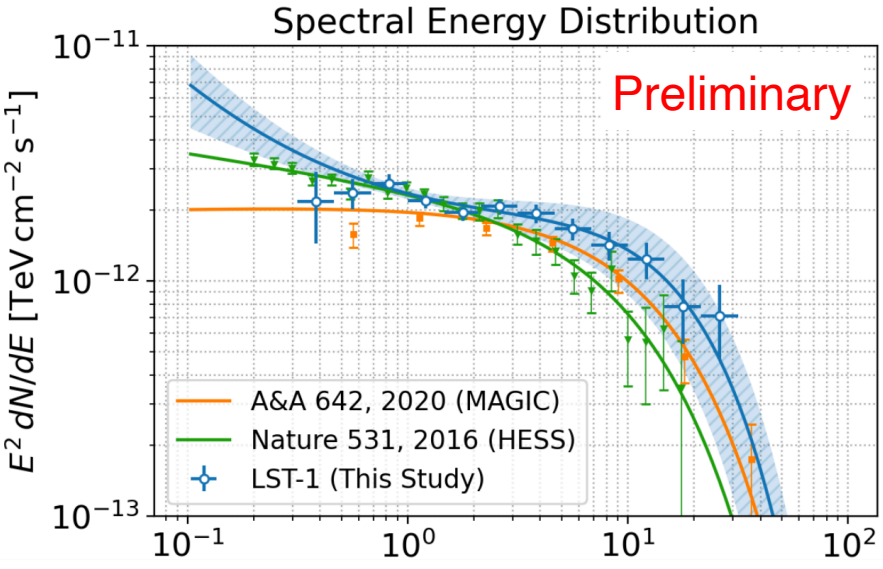


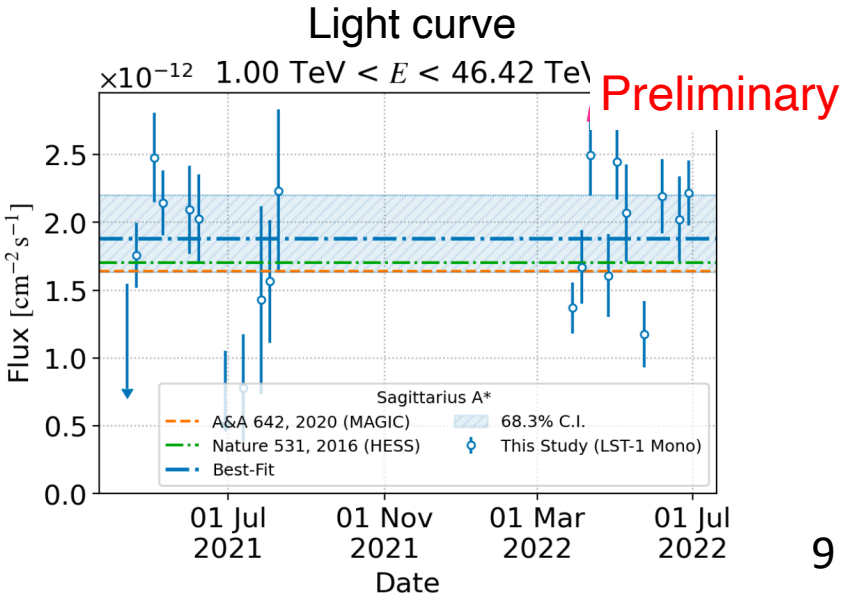


Galactic Center (Sagittarius A*)

- ~40 hours of LST-1 large-zenith angle data
- Spectrum is comparable with H.E.S.S. and MAGIC.
- No significant variability in light curve
- Observation is ongoing.







MAGIC publication in refereed journals (2022)

10 papers:

Search for Gamma-ray Spectral Lines from Dark Matter Annihilation up to 100 TeV towards the Galactic Center with MAGIC
MAGIC Collaboration, Abe *et al.*
Phys. Rev. Lett. **130**, 061002 (2023), accepted in 2022

Long-term multi-wavelength study of 1ES 0647+250
MAGIC Collaboration, Acciari *et al.*
A&A **670**, A49 (2023), accepted in 2022

Gamma-ray observations of MAXI J1820+070 during the 2018 outburst
MAGIC Collaboration, Abe *et al.,* H.E.S.S. Collaboration, Abdalla *et al.,* VERITAS Collaboration, Acharyya *et al., Bosch-Ramon et al.*
MNRAS **517**, 4736-4751 (2022)

MAGIC observations provide compelling evidence of the hadronic multi-TeV emission from the putative PeVatron SNR G106.3+2.7
MAGIC Collaboration, Abe *et al.*
Accepted for A&A in 2022

A lower bound on intergalactic magnetic fields from time variability of 1ES 0229+200 from MAGIC and Fermi/LAT observations
MAGIC Collaboration, Acciari *et al.*
Accepted for A&A in 2022

Multiwavelength Observations of the Blazar VER J0521+211 during an Elevated TeV Gamma-Ray State
VERITAS Collaboration, Adams et al., MAGIC Collaboration, Acciari *et al.,*
ApJ **932**, 2 (2022)

Combined searches for dark matter in dwarf spheroidal galaxies observed with the MAGIC telescopes, including new data from Coma Berenices and Draco
MAGIC collaboration, Acciari *et al.*
Phys. Dark Universe **35** (2022) 100912

Investigating the Blazar TXS 0506+056 through Sharp Multiwavelength Eyes During 2017–2019
MAGIC collaboration, Acciari *et al.*; OVRO collaboration, Hodges *et al.*; Metsähovi collaboration, Lähteenmaäki *et al.*
Astroph. J. **927** (2022) 197

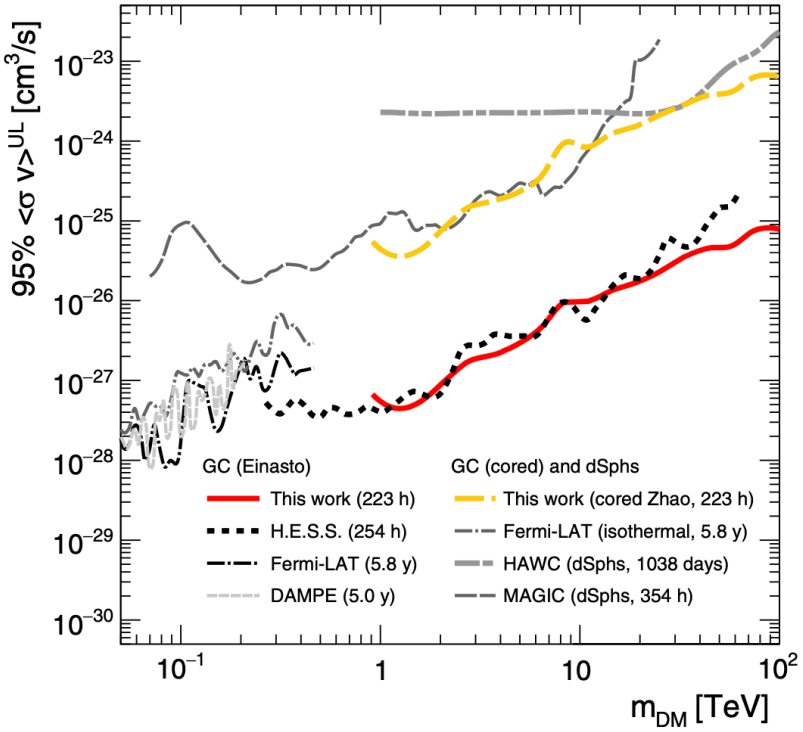
Multiwavelength study of the gravitationally lensed blazar QSO B0218+357 between 2016 and 2020
MAGIC collaboration, Acciari *et al.*
Mon. Non. R. Astron. Soc. **510** (2022) 2344–2362

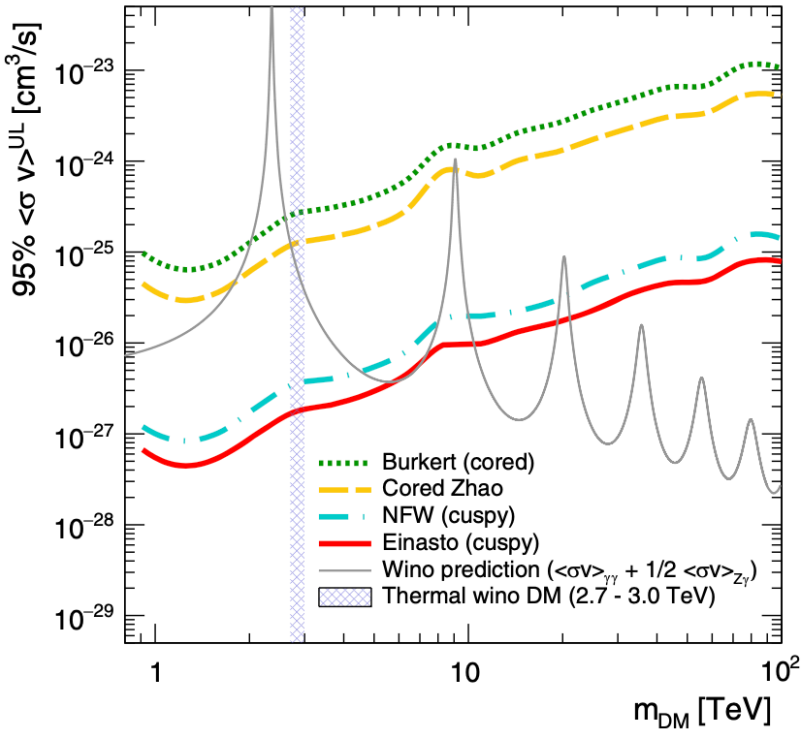
Proton acceleration in thermonuclear nova explosions revealed by gamma rays
MAGIC Collaboration, Acciari *et al.*
Nat. Astron. **6** (2022) 689-697

MAGIC highlights

Search for Gamma-Ray Spectral Lines from Dark Matter

- Search for spectral lines in γ rays from 0.9 TeV to 100 TeV toward the Galactic Center using 223 hours of data
- MAGIC gave the comparable/better upper limit on the cross-section for DM annihilation in the energy range 1 - 100TeV with Large Zenith Angle Technique.
- Physical Review Letters **130**, 061002 (2023)
- ICRR press release on Feb. 4: https://www.icrr.u-tokyo.ac.jp/news/13105/

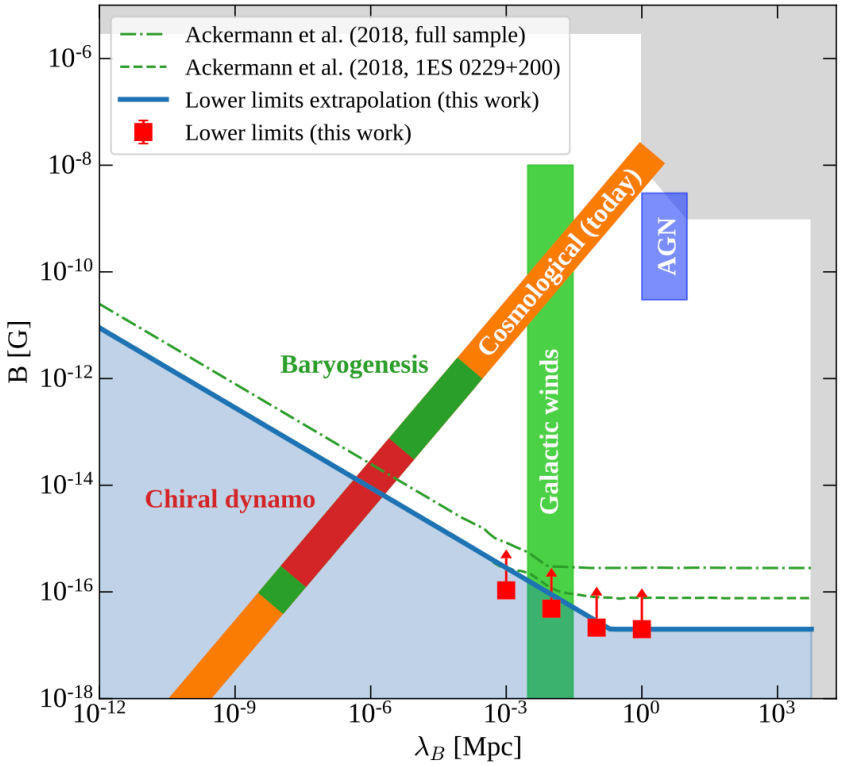




MAGIC highlights

lower bound on intergalactic magnetic fields

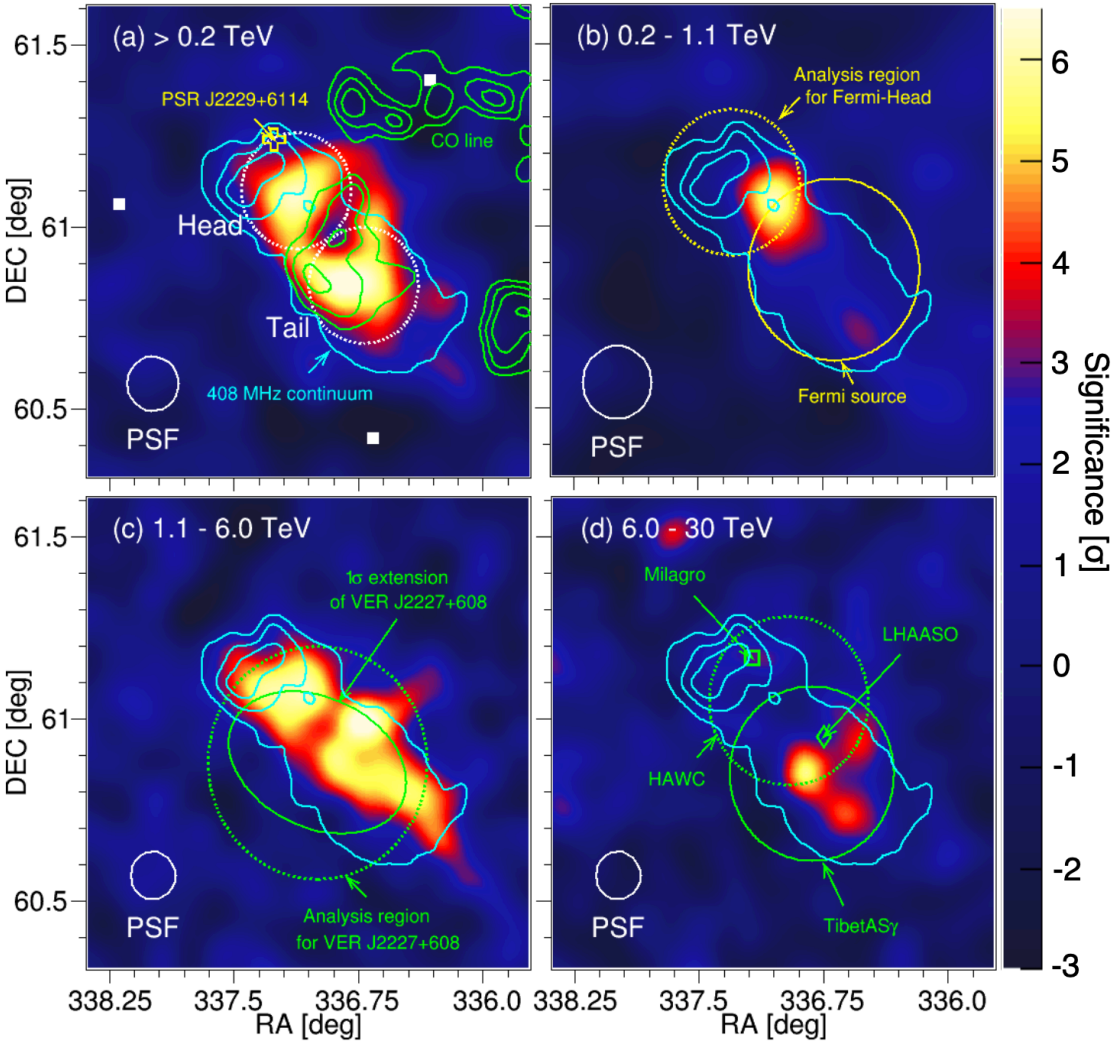
- Search for delayed GeV emission from blazar 1ES 0229+200 to detect or constrain the intergalactic magnetic field (IGMF) dependent secondary flux
- Constrain lower bound on IGMF strength
- Accepted for publication in Astron. Astrophys., 2022



MAGIC highlights

hadronic multi-TeV emission from SNR G106.3+2.7

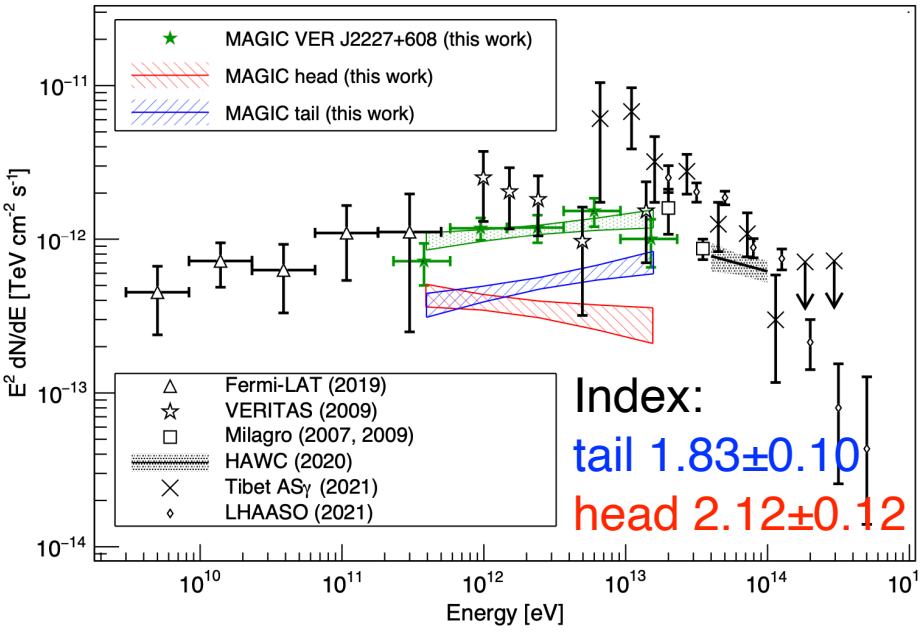
- Observed the SNR G106.3+2.7 for 121.7 hours of data between 2017-2019.
- Detected extended γ-ray emission spatially coincident with the radio continuum emission at the *head* and *tail*
- Detected a significant γ-ray emission with energies above 6.0 TeV from the *tail* region only (distant from pulsar)

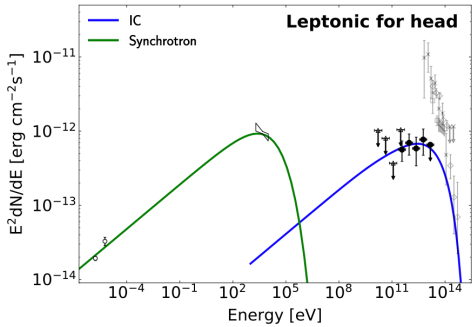


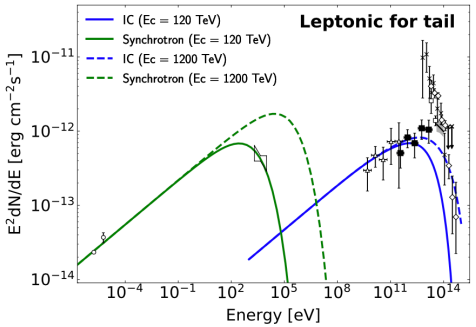
MAGIC highlights

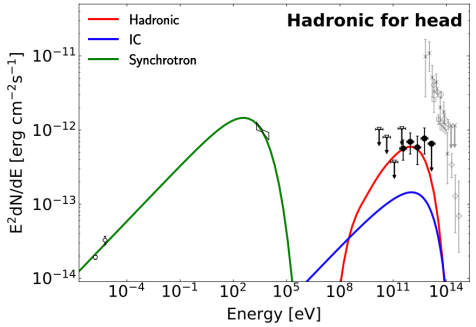
hadronic multi-TeV emission from SNR G106.3+2.7

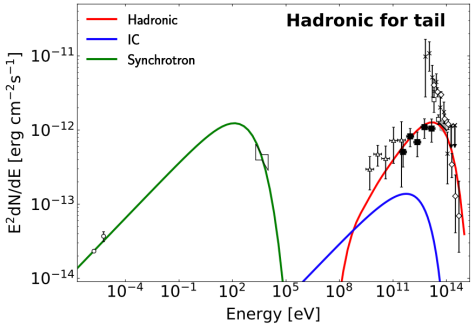
- Different spectral index between *head* and *tail*
- *head* region can be explained with either hadronic or leptonic models, while hadronic model with PeV proton is favored for *tail*.
- Accepted for publication in Astron. Astrophys., 2022











Summary

- LST-1 is continuing observation and performing scientific observation.
- Crab Nebula, pulsar: Significant detection down to few tens of GeV
- Nova RS Ophiuchi: LST-1 took part in the first VHE gamma-ray detection with >~6σ in each night
- Blazar BL Lacertae: Flux variability with ~min scale is observed.
- Galactic center: spectrum detected by large zenith angle method
- Establishing MAGIC+LST method
- Observing Geminga pulsar
- Observing GRB following burst alerts
- Paper projects are ongoing.