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Pulsar observations at Very High Energies with MAGIC

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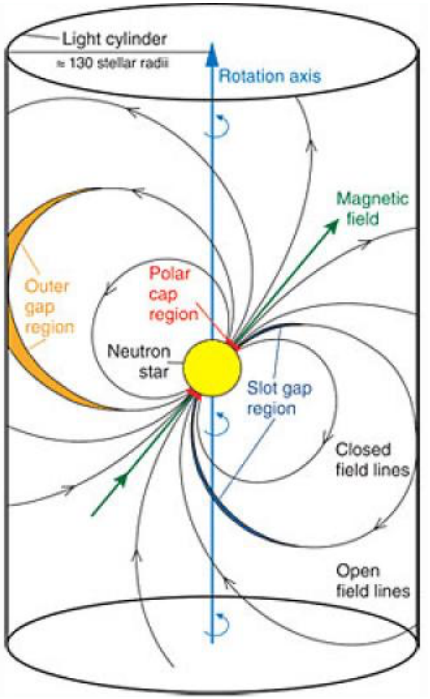
Abstract

MAGIC has contributed to pulsar astronomy with the discovery of the first pulsar emitting VHE γ-rays. With the detection of the Crab pulsar up to hundreds of GeV, MAGIC have shown that pulsar spectra can extend beyond what was previously expected. To understand the emission mechanism of γ-ray pulsars, MAGIC continues with further observations and technical improvements.

MAGIC and Pulsars

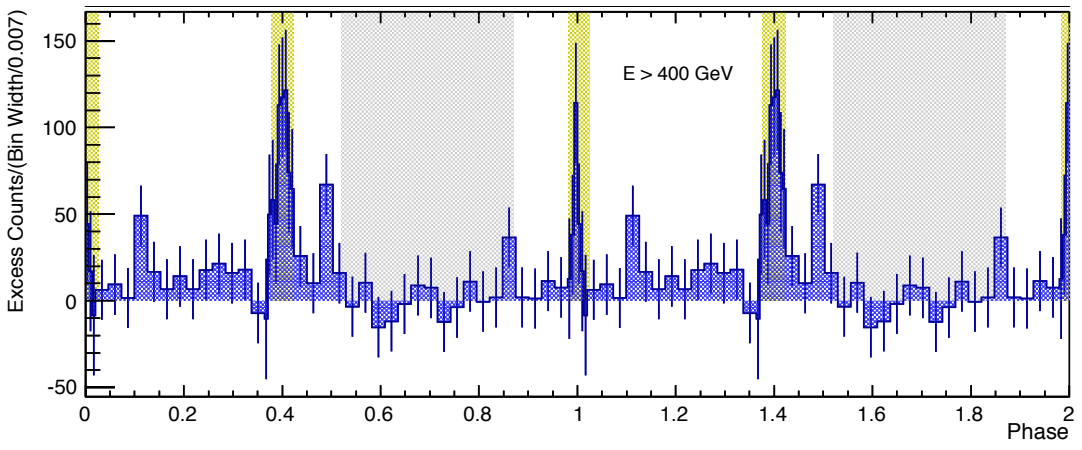
- The MAGIC telescopes are two 17 m Cherenkov Telescopes located on La Palma island (Spain), designed to detect VHE γ-rays from tens of GeV to tens of TeV [1].
- Pulsars γ-ray emission originate from synchro--curvature radiation by $e^{-/+}$ pairs accelerated close to the neutron star surface or at higher altitudes close to the light cylinder.
- The MAGIC Crab pulsar detection above 25 GeV [2] ruled out low altitude models, since they predict a sharp cut-off at few GeV.
- High altitude models are now the preferred ones, since they reproduce the spectral cut-offs seen in the majority of Fermi-LAT pulsars. However, they can not explain the Crab VHE tail seen by MAGIC, for which new mechanisms were suggested, as IC scattering in the vicinity of the light cylinder [3] or in the wind zone [4].



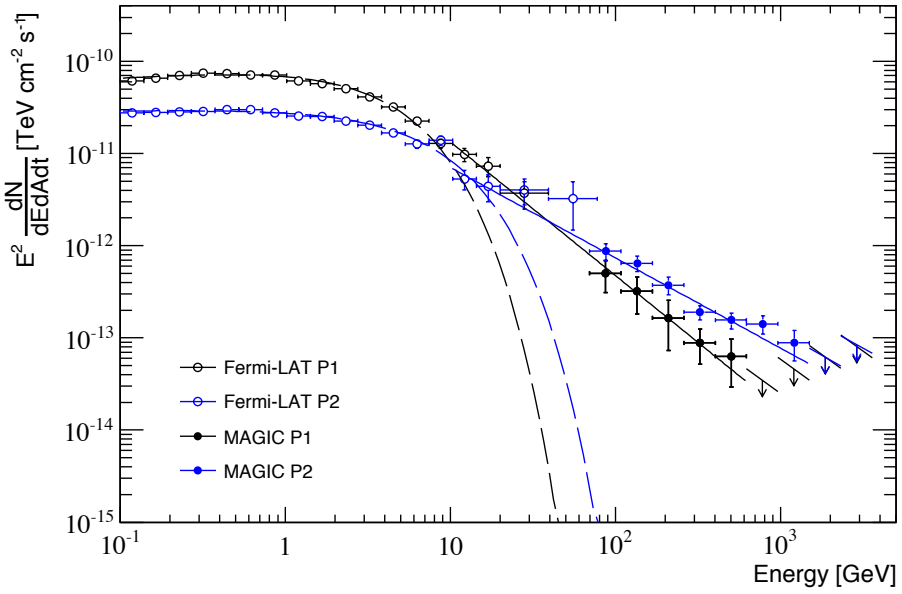
- To shed light on VHE emission in pulsars, MAGIC have continued studying Crab and observing other pulsars like Geminga.

Crab

- To investigate the maximum energy at which the Crab pulsation is still visible, 320 h of data recorded by MAGIC between 2007 and 2014 were reanalysed [5]. Pulsar rotational phases were calculated with Tempo2 [6] using the Monthly Ephemerides provided by the Jodrell Bank Observatory [7].
- The Crab pulsation is clearly detected above 400 GeV. The emission comes mainly from the interpulse, P2. The main pulse, P1, is only marginally seen.
- Both peaks follow a power-law like spectrum: from 90 GeV up to 500 GeV in the case of P1, and up to 1.2 TeV for P2. A joint Fermi-MAGIC fit reveals a softer spectrum for P1 (Γ=3.5±0.1) compared to P2 (Γ=3.0±0.1).

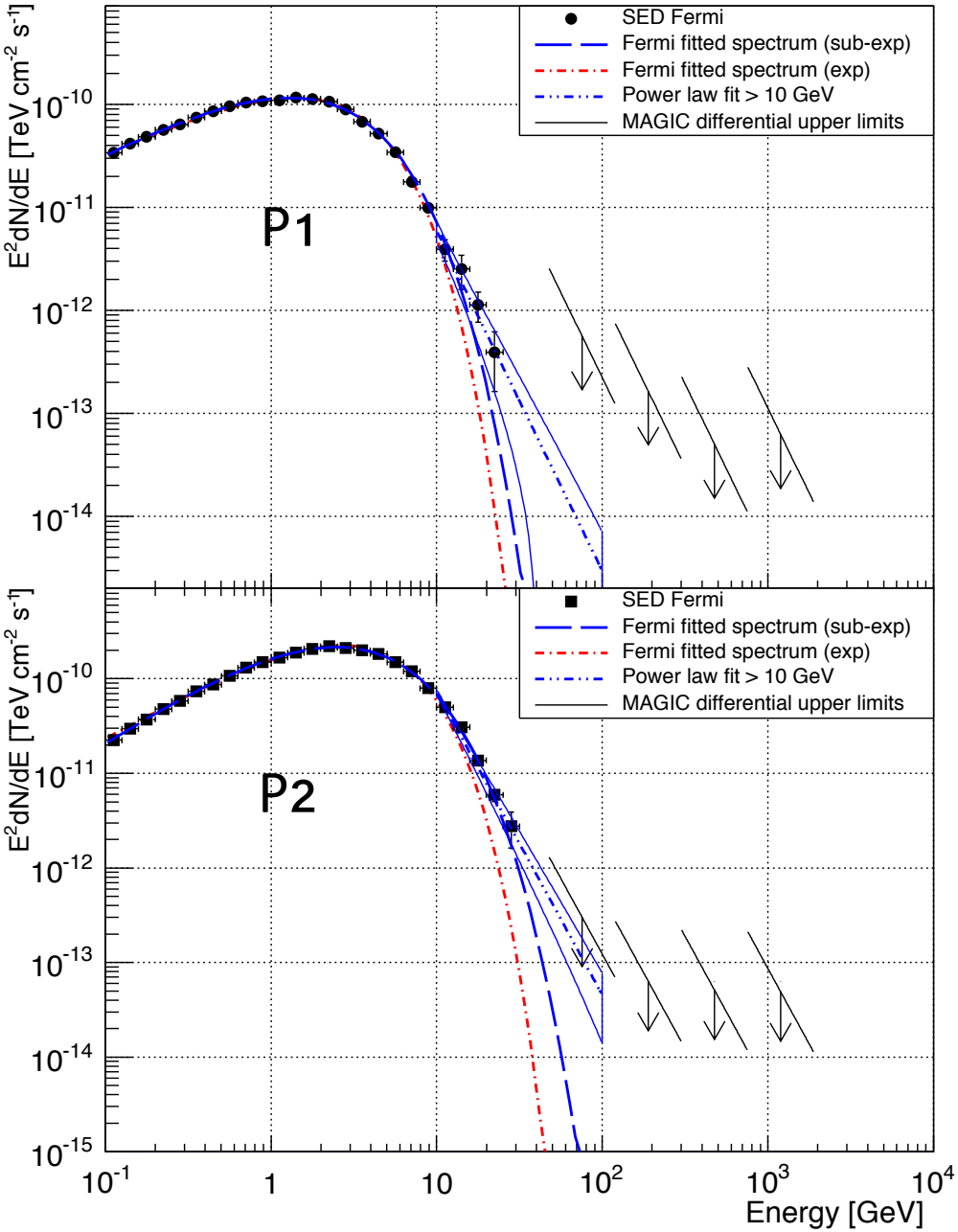


Ahnen et al., A&A 582,133 (2016)



Geminga

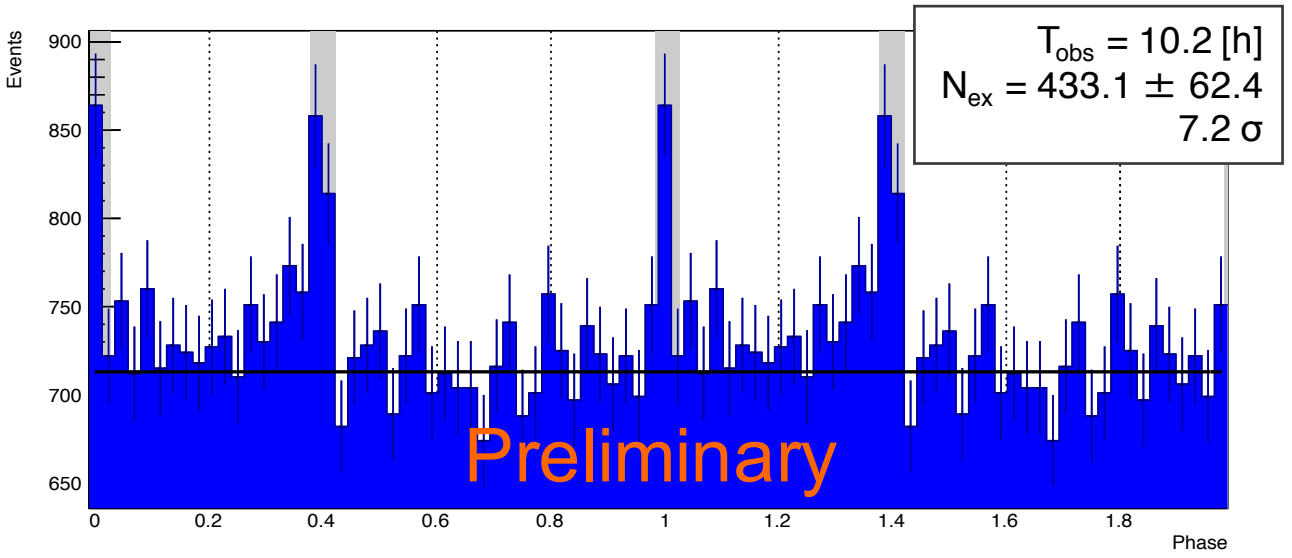
- Geminga is the prototype of the radio-quiet pulsar population and one of the best candidates to be detected at VHE.
- The deviation from the exponential cutoff seen in Fermi-LAT data above 10 GeV [8] motivated MAGIC observations
- 63 h of good quality data were collected in Winter 2012/13 [9]. The event phases were calculated using ephemeris provided by the LAT collaboration [10].
- Search for pulsations was performed between 50 and 200 GeV. No signal was found.
- The upper limits for each emission peak (P1 and P2) do not allow to rule out the existence of a VHE power-law tail.



Ahnen et al., A&A 591 A138 (2016)

Current observations

- A new trigger system, dubbed Sum-Trigger-II, has been installed in both MAGIC telescopes, aiming to reduce the energy threshold and to improve the performance at low energies for pulsar observations [11].
- The current Crab pulsar data shows that the new trigger system outperforms the standard one.



- This should allow MAGIC to detect a second VHE pulsar in the Northern Sky.

Summary

- The latest MAGIC results from the Crab pulsar have releveled emission up to 1 TeV, mainly arising from P2. The spectrum can be described by a simple power-law from 10 GeV to 1 TeV, which suggests a single mechanism being responsible for the VHE emission. Synchro-curvature radiation is unable to explain this spectrum, which could be due to inverse Compton scattering.
- With the aim of detecting another VHE pulsar MAGIC, observed Geminga for more than 60 h. No significant signal was found above 50 GeV.
- The MAGIC telescopes have been updated with a novel trigger system. Preliminary results show its potential for the study of pulsars at VHE.

References

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[11] J. Rodriguez, EWASS 2016