Pulsar Prospects for the Cherenkov Telescope Array

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Abstract. In the last few years, the *Fermi*-LAT telescope has discovered over a 100 pulsars at energies above 100 MeV, increasing the number of known gamma-ray pulsars by an order of magnitude. In parallel, imaging Cherenkov telescopes, such as MAGIC and VERITAS, have detected for the first time VHE pulsed gamma-rays from the Crab pulsar. Such detections have revealed that the Crab VHE spectrum follows a power-law up to at least 400 GeV, challenging most theoretical models, and opening wide possibilities of detecting more pulsars from the ground with the future Cherenkov Telescope Array (CTA). In this contribution, we study the capabilities of CTA for detecting *Fermi* pulsars. For this, we extrapolate their spectra with "Crab-like" power-law tails in the VHE range, as suggested by the latest MAGIC and VERITAS results.

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INTRODUCTION

The detection of neutron stars through gamma-ray pulsations is a key science goal for the future Cherenkov Telescope Array (CTA) [1]. Gamma-ray pulsar observations at high energies (over a few tens of GeV) could help to understand the region where pulsed emission takes place by comparing the measured spectra with predictions by theoretical models. The *Fermi* mission has revolutionized the study of gamma-ray pulsars detecting 117 sources in the MeV-GeV energy range, which are reasonably fitted with sharp exponential cutoff values between 0.7 to 7.7 GeV [2].

Nonetheless, the detection of the Crab pulsar above 25 GeV with IACTs [3, 4, 5] has reframed the exponential cutoff observed by *Fermi* in favor of a broken power-law shape that extends the pulsed emission up to 400 GeV. This recent discovery motivates the need for further pulsar studies in the VHE regime.

To place this in context, Fig. 1 shows the spectral fits (power-law with exponential cutoff) for 46 *Fermi* pulsars taken from [2], in comparison with the standard CTA diferential sensitivity curve for configuration B (configuration with 5 LSTs [1]) in 50 h . The fits of Vela, Crab and Geminga pulsars are indicated explicitly, while the shaded area contains the fits for the remaining 43 pulsars.

In order to estimate Cherenkov Telescope Array (CTA) potential, we generate a full simulated spectrum for a 50 h observation of the Crab pulsar [6]. We also explore

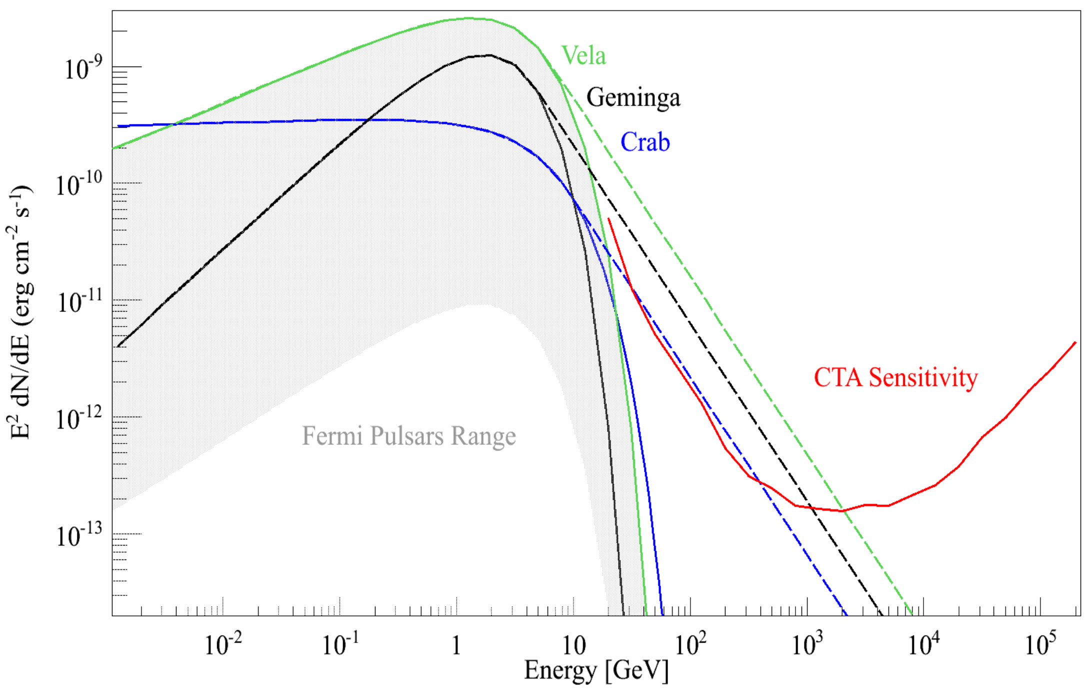

FIGURE 1. Fermi-LAT pulsars general profile (grey area) with standard CTA sensitivity curve for configuration B in 50h. Vela, Geminga and Crab extrapolated SEDs (dashed lines).

the detectability of Fermi pulsars presuming a "Crab-like" power-law tail, as the latest observations suggest.

PROCEDURE

Initially, we generate a 50 h simulated observation of the Crab pulsar using *CTA-macrosv6*. Total emission (P1 + P2) and both P1 and P2 peaks were simulated using the MAGIC power-law fits given in [5]. CTA configuration B, E and C [1] were tested.

To explore the detectability of *Fermi* pulsars, we extend their spectra above the cutoff energy with a power-law tail that assumes the same spectral index (β) as the one found for the Crab, when a broken power-law is applied to fit both *Fermi* LAT and VERITAS detections, i.e $\beta = 3.52$ [4]. In Fig. 1 we show some examples of the extrapolation performed in dashed lines.

We consider a 90% background reduction assuming a pulsed duty cycle of 10% (reduced to 5% for the Crab pulsar independent peaks), systematic errors of 5% and standard detection conditions (detection over 5σ in 50 hours of observation time). No gamma-ray emission from a pulsar wind nebula was considered.

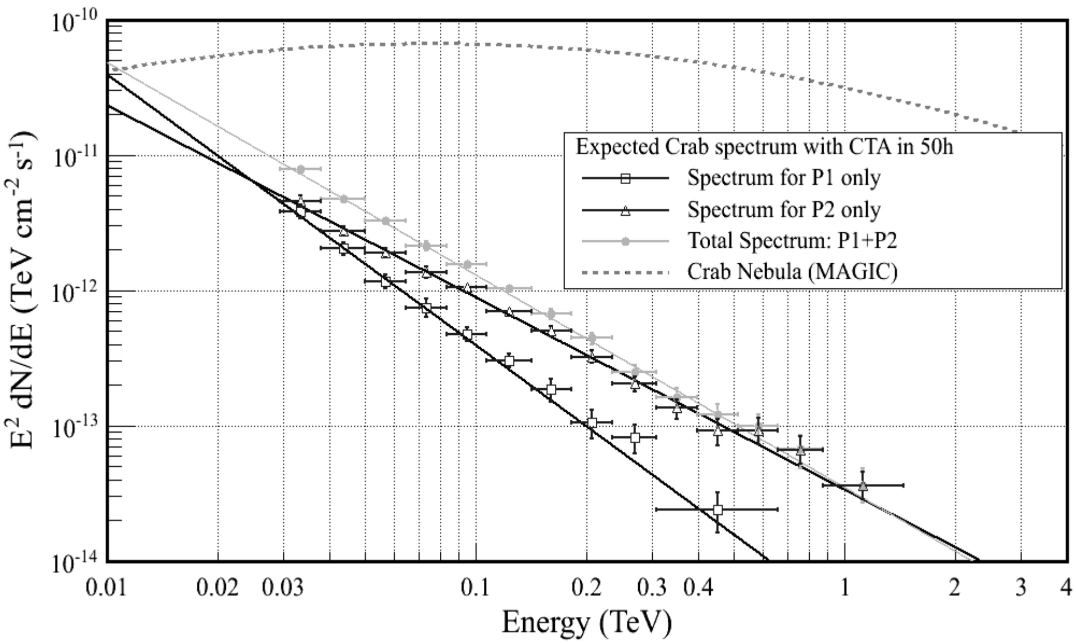

FIGURE 2. Simulated spectra of each of the two Crab phase peaks for 50 h with CTA configuration B and total spectrum using MAGIC power-law fits given in [5].

RESULTS

In Fig. 2 we show the simulated 50 h observation of CTA array B of the Crab pulsar. One can see how both total signal and resolved peaks are well characterized up to 1 TeV.

Presuming the previous hypothesis of “Crab-like“ emission, we found that 20 pulsars would be detectable by CTA with configurations B and E. Figure 3 shows how the detectability with configuration B depends on the exponential cutoff energy value (as determined by *Fermi* LAT) and the photon flux density at this energy.

CONCLUSIONS

CTA potential for pulsar detection seems encouraging, as it will be able to reveal the extent of the Crab pulsed emission up to at least 1 TeV. In fact, the bare detection of the pulsations would take less than one hour.

Under the hypothesis that the existence of VHE-tails is a universal feature in pulsars, we conclude that 20 pulsars would be detectable by CTA. This represents a large fraction (up to 40%) of the brightest *Fermi* pulsars. We can also affirm that CTA configurations with more Large Size Telescopes (LST) are preferred, as pulsar detection falls in the low energy range (50 to 200 GeV).

Needless to say, there is no assurance that gamma-ray pulsars will cooperate in the way described above. However, some theoretical models of young and energetic pulsars

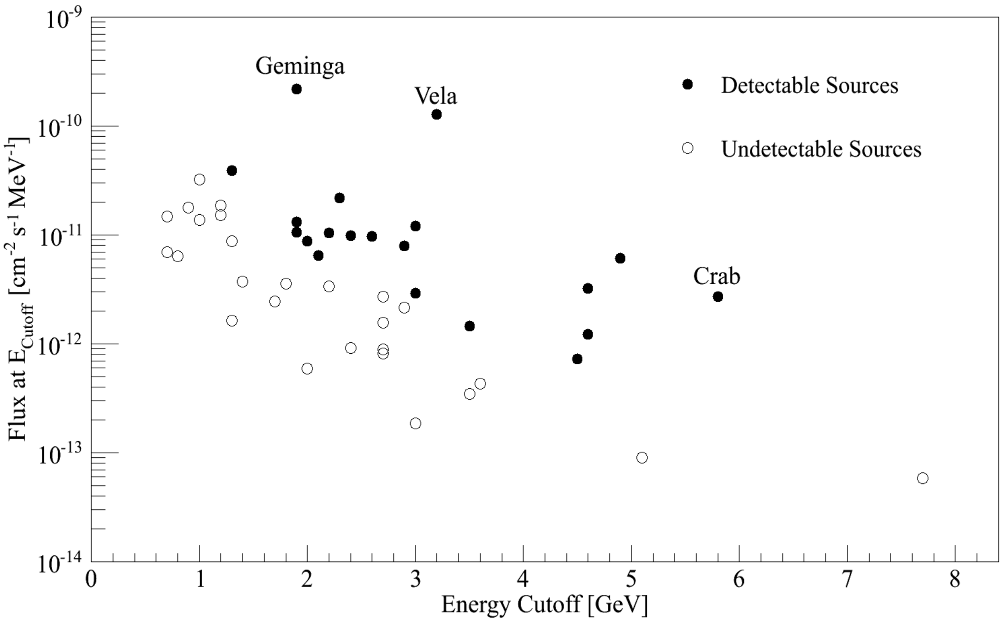

FIGURE 3. Detectable pulsars extrapolated with Crab pulsar power-law index (Γ=3.57, from [3]) by the future CTA array B in 50h.

as well as old millisecond pulsars speak in favor of pulsed spectral components located in the VHE domain [7]. CTA will be the only facility in near future capable of solving this problem.

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