Neutrinos from the gamma-ray source eHWC J1825-134

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Introduction

- The observed energy spectrum of *cosmic rays* is described by a power law with spectral index of about 2.7 up to energies of a few PeV, where the spectrum gets steeper and a feature called the "knee" originates.
- The knee is believed to mark the maximum energy for cosmic rays accelerated by *Galactic sources* [1], or the energy above which the effectiveness of the confinement within the Galaxy is reduced.
- The characteristic gamma-ray feature of a *PeVatron* include an hadronic, hard spectrum that extends until at least several tens of TeV.
- A *multi-messenger* search is mandatory for the identification of the sources of cosmic neutrinos. In particular, a gamma-ray experiment with sensitivity up to about 100 TeV is of fundamental importance.

⇒ The eHWC J1825-134 source is located in the southern sky and has been recently detected by the HAWC observatory.

⇒ Amongst the HAWC sources, it is the most luminous in the multi-TeV domain and therefore is one of the first that should be searched for with a neutrino telescope in the northern hemisphere.

The eHWC J1825-134 source

We will use for the analysis the spectrum reported in [2], where a power-law with exponential cut-off fit was considered:

$$\frac{dN_\gamma}{dE_\gamma} = \phi_0 \left(\frac{E_\gamma}{10\ \text{TeV}}\right)^{-\alpha_\gamma} \exp\left(-\frac{E_\gamma}{E_{cut,\gamma}}\right),$$

with $E_{cut,\gamma}$ being the cut-off energy of the gamma-ray spectrum, α_γ the spectral index and ϕ_0 the flux normalization:

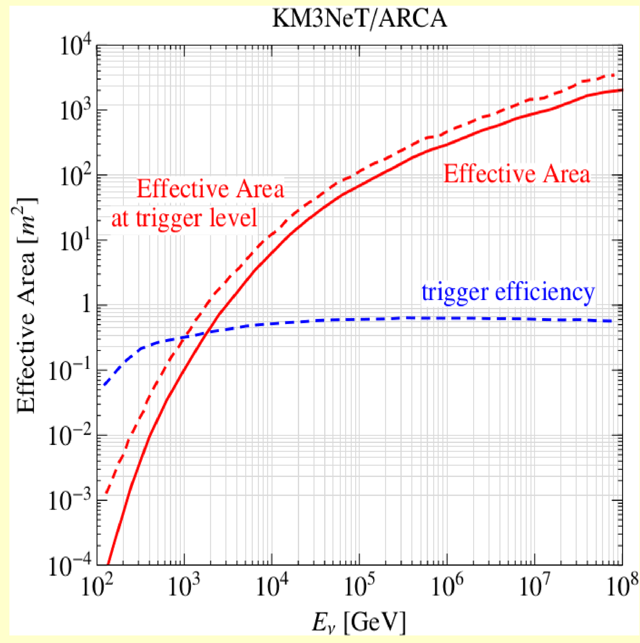
$$E_{cut,\gamma} = (61 \pm 12)\ \text{TeV}, \qquad \phi_0 = (2.12 \pm 0.15) \times 10^{-13}\ \text{TeV}^{-1}\ \text{cm}^{-2}\ \text{s}^{-1},$$
$$\alpha_\gamma = 2.12 \pm 0.06, \qquad \sigma_{\text{ext}} = 0.53^\circ \pm 0.02^\circ,$$

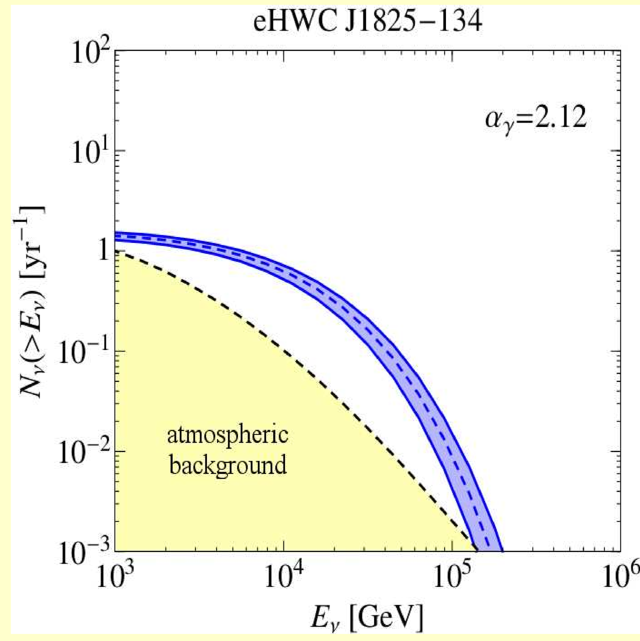
where σ_{ext} is the extension of the source.

⇒ The sensitivity of HAWC to the high energy tail of the spectrum is of fundamental importance for the correct prediction of the neutrino flux.

⇒ The eHWC J1825-134 overlaps with two HESS sources: the very bright HESS J1825-137 and the much weaker HESS J1826-130.

The KM3NeT/ARCA effective area and the neutrino events





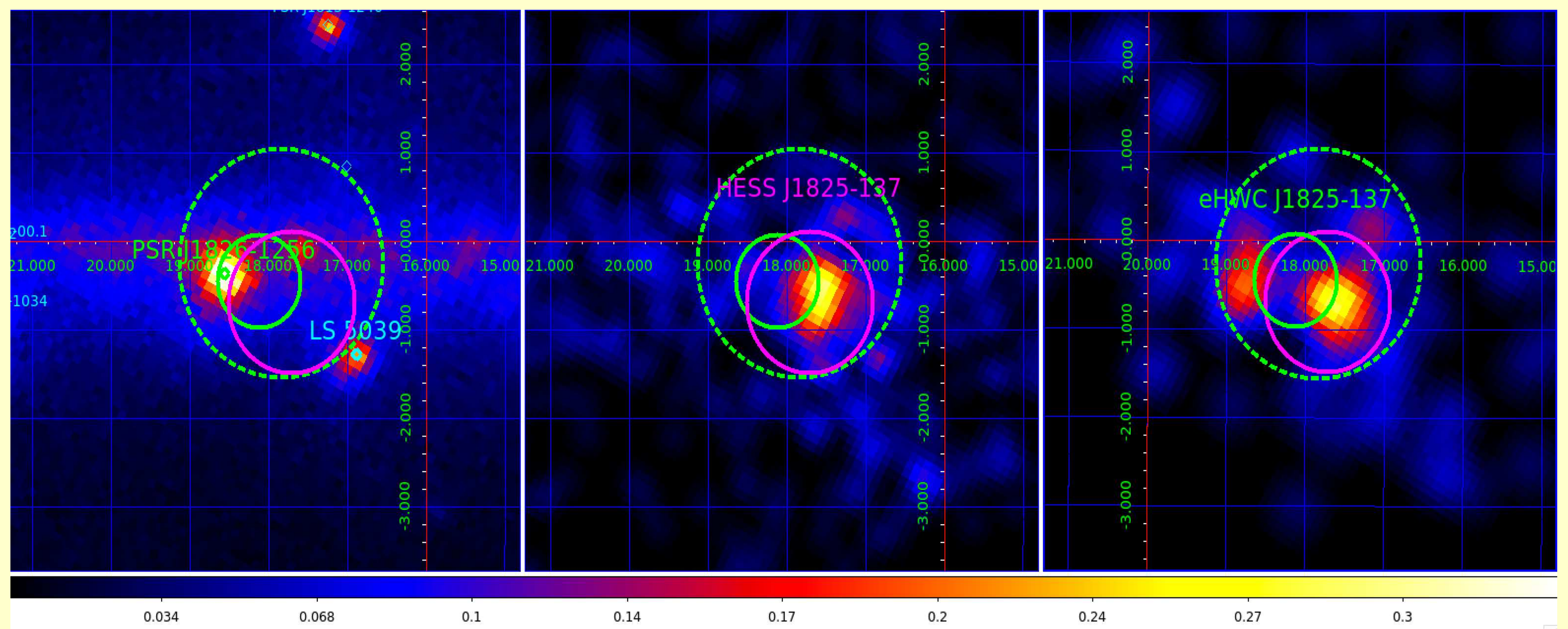
The event rate at the detector can be obtained by the following expression:

$$N_{\text{ev}} = \epsilon_\theta\, \epsilon_v\, t \int_{E_\nu^{\text{th}}} dE_\nu \frac{dN_\nu(E_\nu)}{dE_\nu} \times A_\nu^{\text{eff}}.$$

The parameter $\epsilon_v = 0.57$ is the visibility of the source, while $\epsilon_\theta = 0.72$ is a reduction factor due to the fact that only a fraction of the signal will be detected if the source morphology is assumed to be a Gaussian and the signal is extracted within a circular region of radius $\sigma_{\text{eff}} = 1.6\sqrt{\sigma_{\text{ext}}^2 + \sigma_{\text{res}}^2}$. Here, $\sigma_{\text{res}} \sim 0.1^\circ$ is the angular resolution of KM3NeT/ARCA, while A_ν^{eff} is the effective area [3].

Fermi/LAT observations

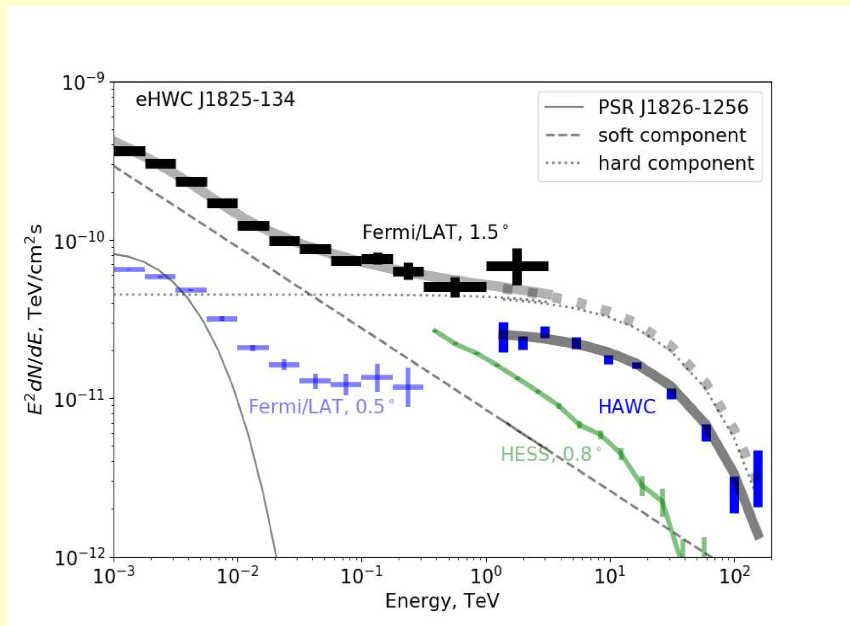
Analysis of the region using Fermi/LAT data [4]:

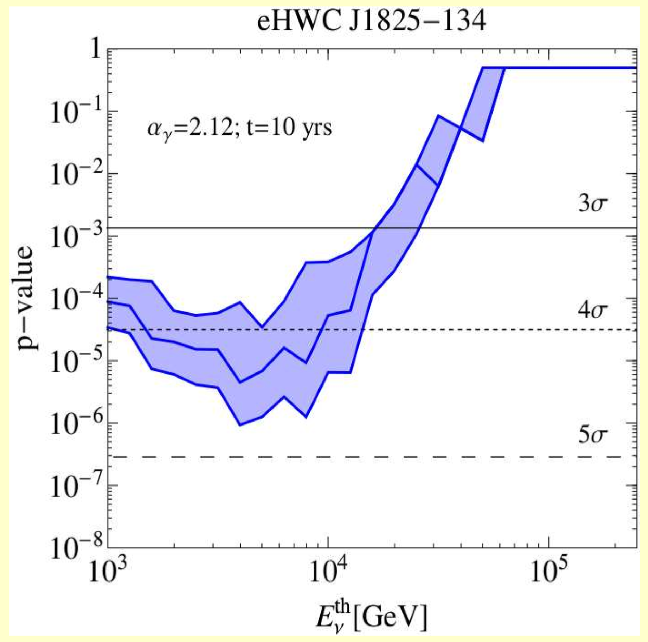


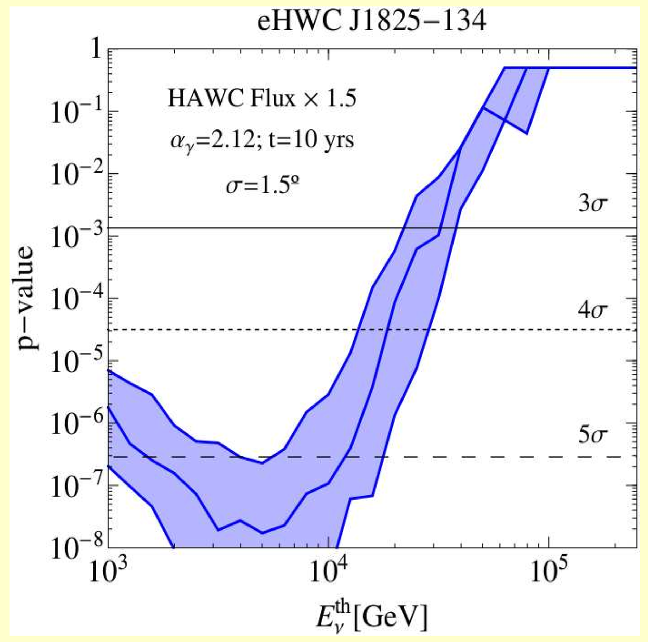
Left panel: 1-10 GeV map smoothed with 0.3 degree Gaussian. The dominant source in the region is the pulsar PSR J1826-1256. The HAWC source (green solid circle) is immediately adjacent to the pulsar location.
Middle panel: energy range above 100 GeV. The centroid of the source is at the position of the extended source HESS J1825-137 [5], identified as a pulsar wind nebula.
Right panel: energy range above 300 TeV. The Fermi source consists of two components and the position of the HAWC source is in between them.

⇒ complicated source morphology; it is not possible to find an exact match between the HAWC extended source and different source components observed by Fermi/LAT.

Spectrum of the eHWC J1825-134 region and statistical significance







The black data points show the source spectrum extracted from the region which encompasses the ~ 1 TeV emission as observed by Fermi/LAT (the green dashed circle of radius 1.5°). We find that the flux level measured by Fermi/LAT in the TeV range is 1.5 higher than that of HAWC.

Note that the HAWC analysis assumes a Gaussian source morphology convolved with the HAWC point spread function, which does not match the complex morphology seen by Fermi/LAT.

The eHWC J1825-134 source: we have estimated the statistical significance at the KM3NeT detector.

We can see that for an energy threshold of the order of $E_\nu^{\text{thr}} \lesssim 10$ TeV we have a minimum in the p-value.

In 10 years of running of KM3NeT the significance is well above 3σ independently of the specific value of $E_{cut,\gamma}$, as long as the energy threshold is less than about 10 TeV.

The eHWC J1825-134 extended region: considering $\sigma_{\text{eff}} = 1.5^\circ$, $\epsilon_\theta = 1$ (i.e. we do not assume a Gaussian morphology), and the Fermi/LAT flux as reference, the statistical significance reaches 5σ in 10 years running time and for an energy threshold of the order of about 10 TeV.

The BAIKAL-GVD detector [6] in Baikal Lake will have the discovery potential for this source similar to the KM3NeT detector.

The cascade channels [7] represent the most promising way to discover this source at the IceCube detector.

References

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