

# Search for TeV- $\gamma$ Ray Emission from the Star Cluster Berkeley 87



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**Abstract:** Observations of the nearby young open star cluster Berkeley 87 (distance = 0.9 kpc) have been carried out in the TeV energy range with the System of Imaging Air Cherenkov Telescopes of the HEGRA Collaboration. Berkeley 87, with its dense interstellar medium, many young stars and especially the Wolf-Rayet Star WR-142 producing stellar winds of approximately 5000 km/s, is the most promising candidate among the known open clusters for the acceleration of cosmic rays. The EGRET source 2EG J2019+3719 has been associated with Berkeley 87, thus giving further motivation for VHE observations of this source with the HEGRA telescopes. No evidence for the emission of TeV gamma rays has been found. The derived upper limit on the integral flux allows one to exclude all models of cosmic ray acceleration based upon the acceleration of hadrons in the shockfront of the stellar wind. Furthermore, the upper limit rules out any theories claiming open clusters as the main sources of charged galactic cosmic rays.

## Berkeley 87

One possible class of accelerators of cosmic rays are the open star clusters. Berkeley 87 is a star cluster with about 100 stars, and presents the following characteristics, which make it **one of the most promising candidates** for the acceleration of cosmic rays among the class of open star clusters.

- Proximity: 0.9 kpc (3000 Lightyears)
- Many young stars with strong stellar winds
- Probably part of a star forming region
- Wolf-Rayet star with stellar winds of  $\sim 5200$  km/s in the center of the cluster
- Dense interstellar medium
- Molecular clouds

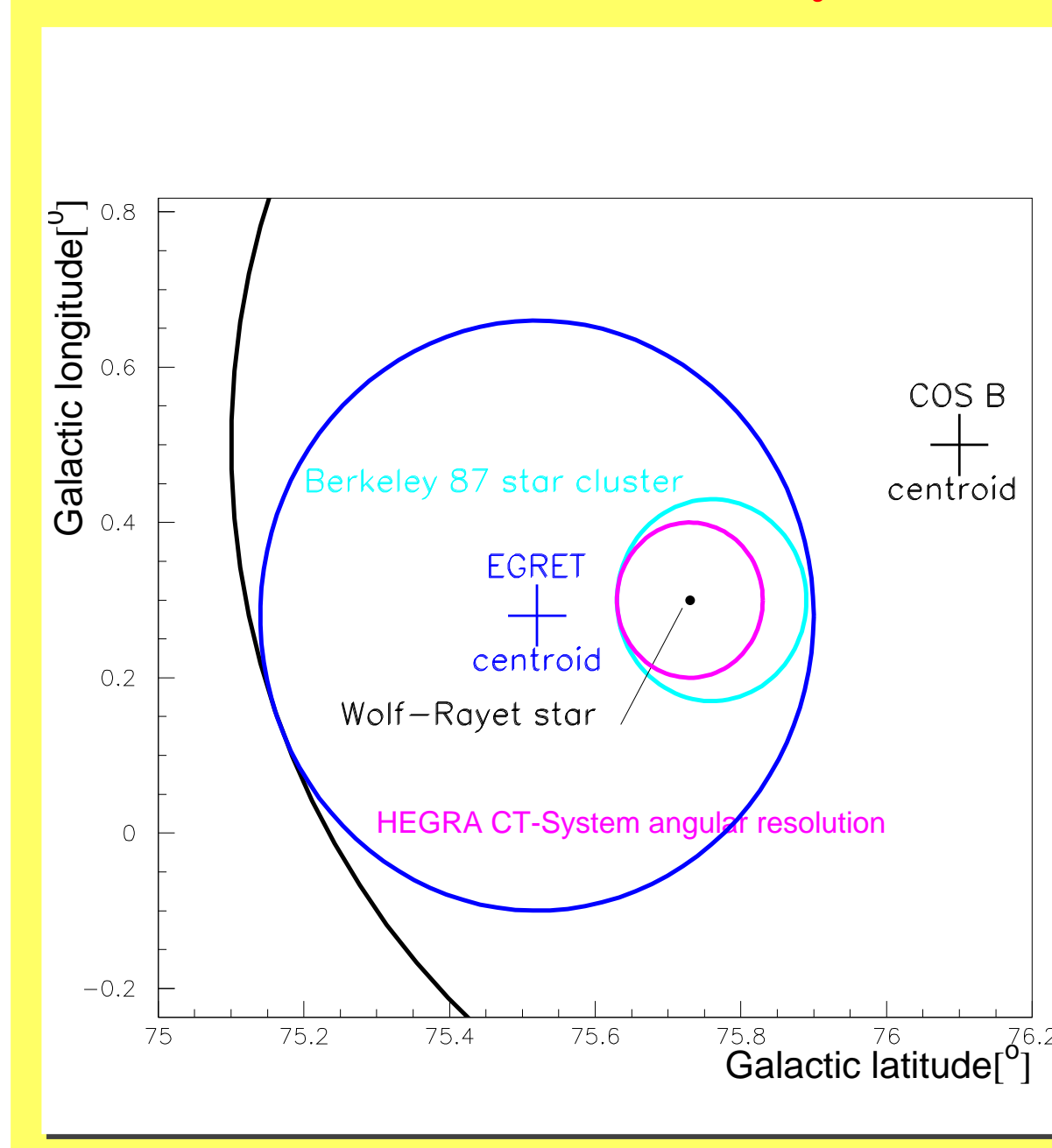
Possible  $\gamma$ -production via decaying  $\pi_0$  from proton proton collisions [1,2].

## Satellite Observations: $E > 100\text{MeV}$

COS B source 2CG 075+00

EGRET source 2EG J2019 +3719

Association with Berkeley 87 [1]



## The HEGRA IACT System

A Cherenkov Telescope detects the Cherenkov light emitted by air showers induced in the atmosphere by cosmic rays. The system of imaging air Cherenkov telescopes (IACT) of the HEGRA collaboration is located at the Canary island La Palma, on the site of the Observatorio del Roque de los Muchachos (2200 m a.s.l. at  $28.75^\circ$  N) of the Instituto de Astrofísica de Canarias.

- $8.5 \text{ m}^2$  mirror area per system telescope
- 271 PMT (pixels) per camera
- Field of view  $4.3^\circ$



The HEGRA Collaboration operates 6 Cherenkov Telescopes. One telescope operates in a stand alone mode while 5 build up a **stereoscopic system**.

## Predictions

Giovanelli et al. [2] have given predictions for the flux of Berkeley 87 in the TeV energy regime based upon an extrapolation of the observed EGRET flux to higher energies, assuming different cutoff energies of the proton energy spectrum at the source.

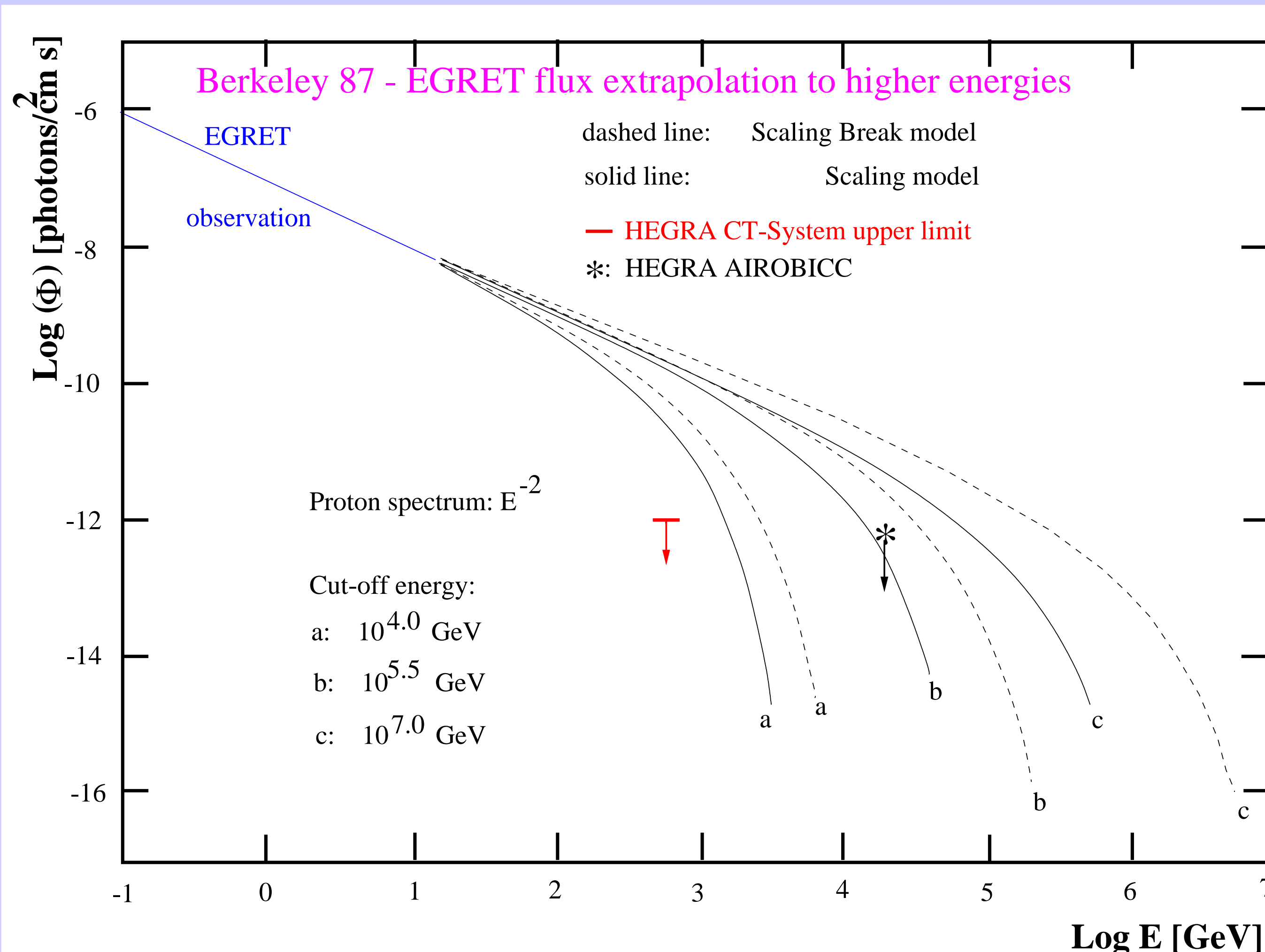


Figure 1. EGRET extrapolated flux ( $\Phi$ ) predictions. The upper limit on the integral flux derived in this work is indicated as a red arrow.

Source: Giovanelli et al. [2]

**Stereoscopic observations** consist in the observation of the air shower from different viewing angles, thus allowing the complete geometrical reconstruction of the air shower. The image of the shower is reconstructed in each camera and the single images are overlaid in the camera plane, where the Cherenkov light of the shower forms an elliptical image. The main axis of each ellipse points to the impact point of the shower core in camera coordinates (direction).

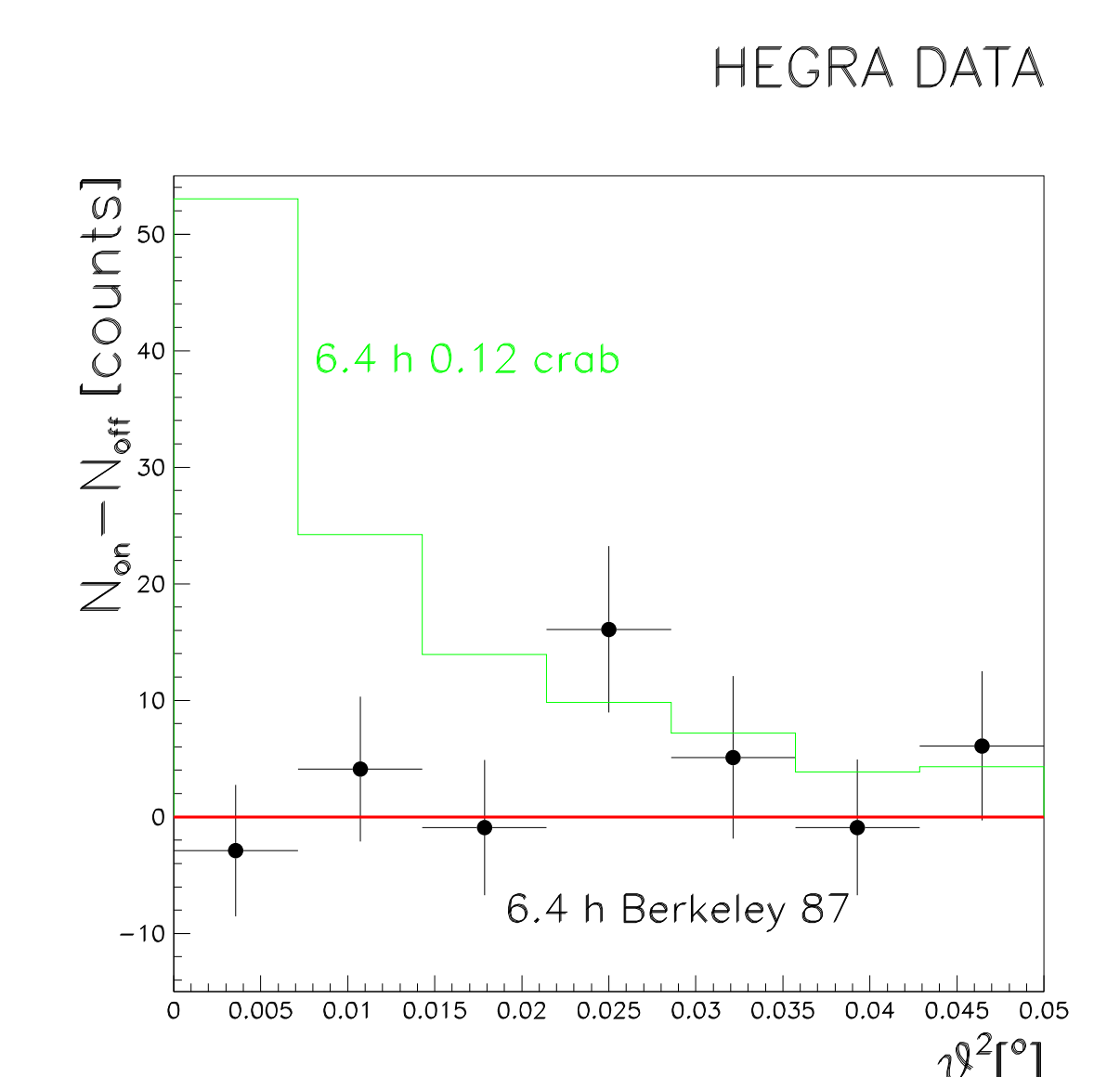
- Energy threshold:  $E > 0.5 \text{ TeV}$
- Angular resolution  $0.1^\circ$
- Energy resolution  $\Delta E/E = 20\%$
- Mean scaled width parameter (MSCW) for hadron rejection (up to  $10^2$ )

271-pixel camera, overlay of elliptical images and telescope system view.

## Data sample and analysis

- data period August 1999
- average zenith angle of  $15^\circ$
- Energy threshold: 0.8 TeV
- 6.4 hours of data (after quality cuts)
- MSCW  $< 1.2$  ( $\gamma$ -hadron separation)
- Angular distance to object:  $\theta^2 < 0.05$

- Crab data sample for upper limit calculation: October 1999
- Gamma efficiency  $\epsilon_\gamma = 0.68$
- Hadron efficiency  $\epsilon_h = 0.12$



The analyzed data sample shows no significant TeV- $\gamma$  ray excess. The derived upper limit on the integral flux (indicated as red arrow in Figure 1) has been found to be [3]:

$$\phi_{90\%}(E > 0.8\text{TeV}) < 0.12 \text{ Crab} < 2.9 \times 10^{-12} \text{ cm}^{-2} \text{ s}^{-1}$$

exclusion of proposed models

## References

- [1] Polcaro, V.F. et al., in *Astron. and Astroph.* 252 (1991) 590-596
- [2] Giovanelli F., Bednarek W., Karakula S. in *J. Phys G Part Phys.* 22 (1996) 1223-1228
- [3] Helene, O., 1983

## Conclusion and outlook

Provided the model assumptions of Giovanelli et al hold true, one can conclude from the derived upper limit that the contribution of young open clusters to the acceleration of cosmic rays is negligible. However the association of the EGRET source with Berkeley 87 may be doubted. Therefore in a next step a scan of the data in the field of view of the HEGRA telescopes will be performed in order to search for a TeV counterpart of the EGRET source 2EG J2019+3719.