An unbiased survey of high-frequency-peaked BL Lac objects by VERITAS

Pazit Rabinowitz
For The VERITAS Collaboration

Washington University in St. Louis

Overview

- Unbiased survey of 36 HBL blazars at TeV energies
  - Looking for unbiased estimates of TeV fluxes of HBLs (often reported only during flares), and new detections of TeV blazars
  - One >5 sigma detection of new TeV source (RBS 1366)
  - NuSTAR observations on 6 sources
- Ultimate goal – luminosity function for HBLs

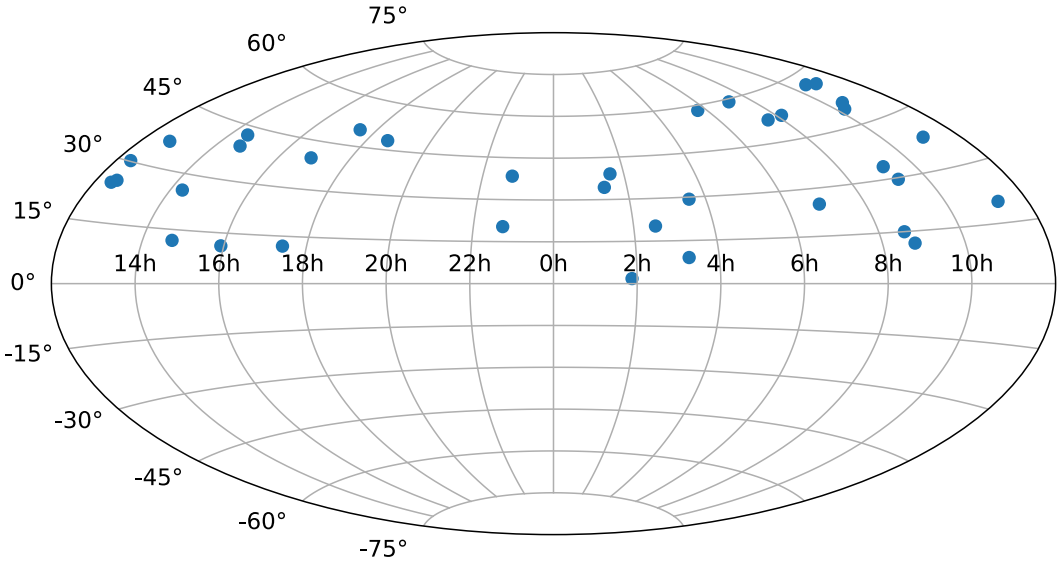
VERITAS (Very Energetic Radiation Imaging Telescope Array System)

- Began full 4-telescope operation in 2007
- Ground-based GeV-TeV gamma-ray observatory in Arizona
- Imaging Atmospheric Cherenkov Telescope (IACT), four 12-meter optical telescopes
- Most sensitive 100 GeV – 10 TeV

VERITAS

VERITAS HBL Sample

- Based on the 3HSP catalog (Chan et al. 2019):
  - Radio and X-ray selected HBLs
  - Contains 2013 sources with synchrotron peak > 10^{15} Hz (UV to X-ray range)
- Additional criteria:
  - Estimated synchrotron peak luminosity > 6.3×10^{-12} erg cm^{-2} s^{-1}
  - Synchrotron peak > 10^{15} Hz
  - Visible with VERITAS: 1.7° ≤ decl. ≤ 61.7°
  - >10 degrees away from galactic plane
- Total of 36 sources (21 previously detected at TeV energies)



The VERITAS HBL sample, in celestial coordinates.

Analysis Strategy

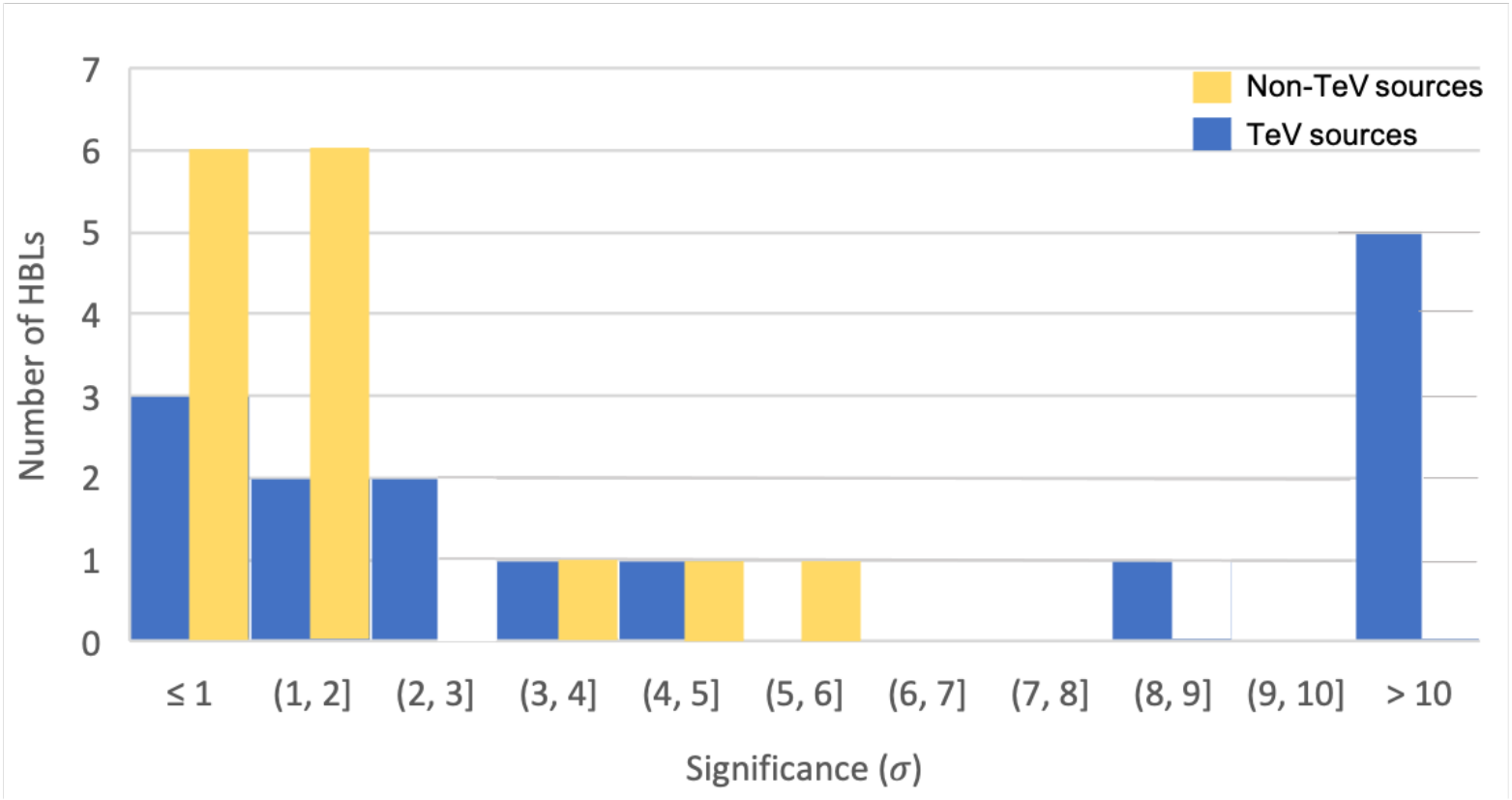
- Remove observational bias
  - HBLs generally observed in flaring states
  - Exclude observations triggered by reported high flux states in TeV or other wavelengths
- Combine archive data with new dedicated observations taken in the last few years
  - >2100 archival hours
  - >160 hours of new observations

Analysis Status

- Completed analysis of 30 of the 36 sources in the HBL sample
  - 15/15 previously non-detected in TeV
  - 15/21 known TeV sources
  - All exposures >7h after quality selection
- 7 sources > 5σ (1 not previously detected)
- 4 sources > 3σ (2 not previously detected)

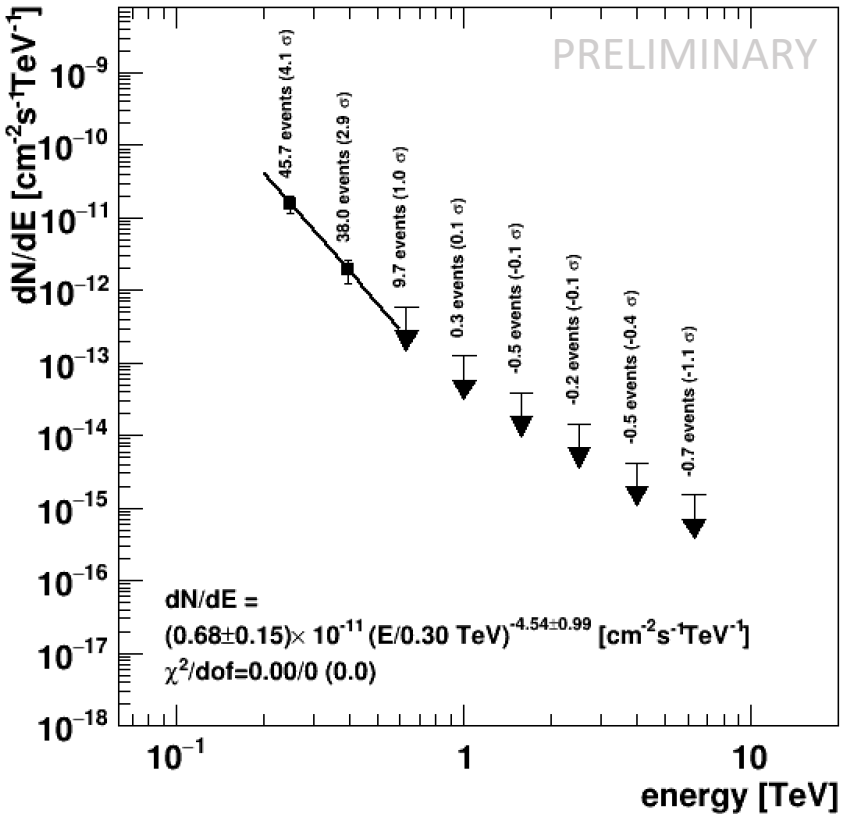
Significance distribution

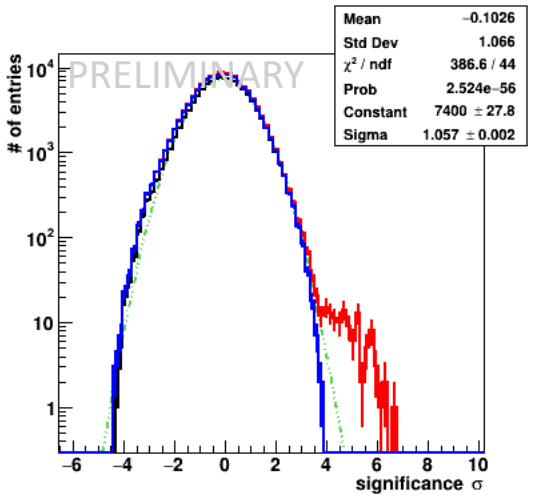
- Histogram of detection significances for known TeV sources (blue) and previously non-detected TeV sources (yellow)

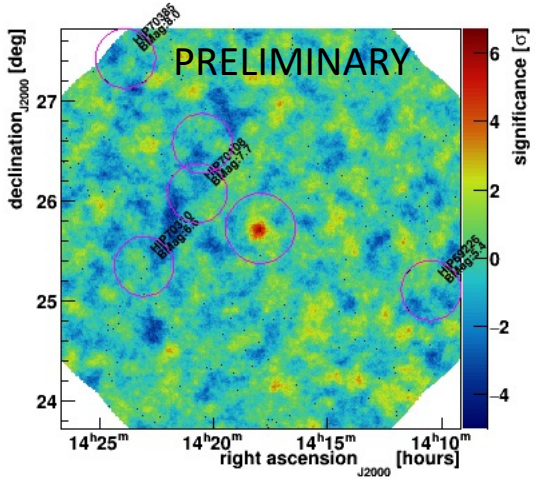


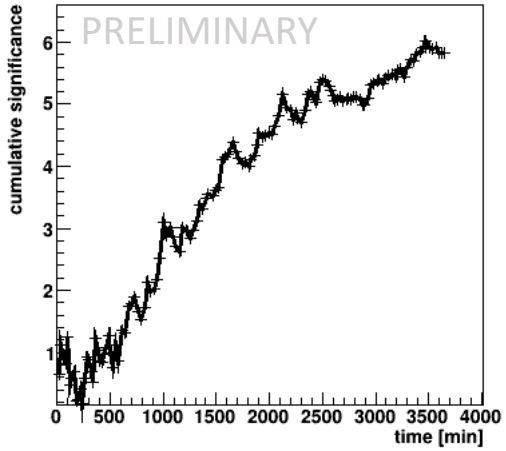
New discovery: RBS 1366

- Detection significance: **5.82σ**
- **61.3** hour dataset
- Flux > 200 GeV: **(1.28 ± 0.24)% Crab**



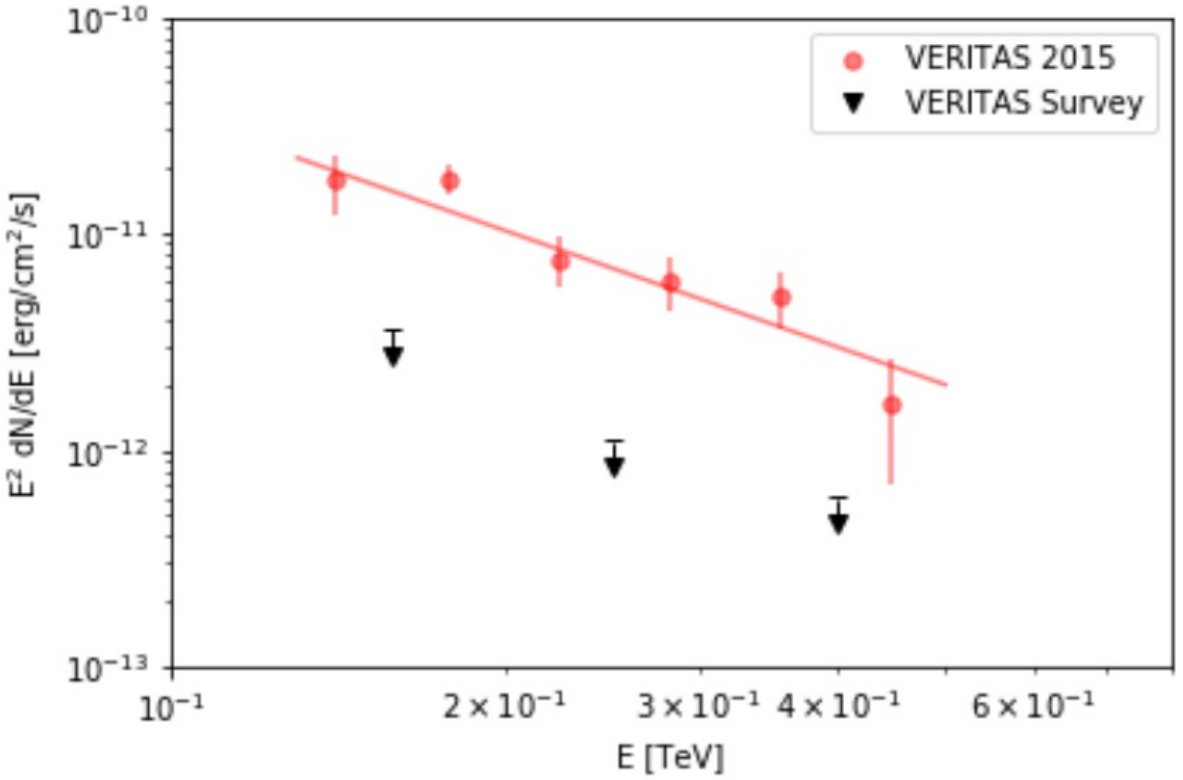






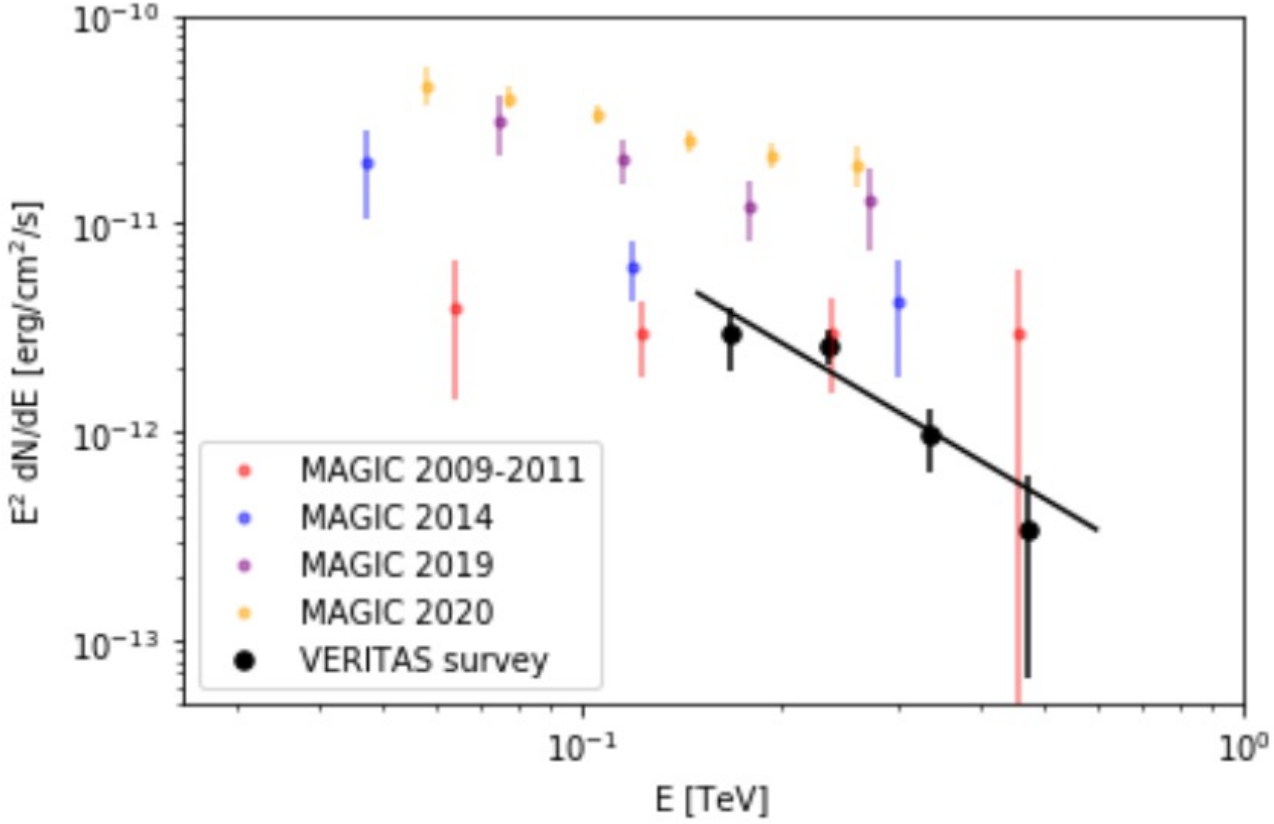
S3 1227+25

- Detection significance: **0.45σ**
- **15.9** hour dataset
- Flux UL > 200 GeV: **1.5% Crab**
- Previously detected by VERITAS during 2015 flaring state (Acharyya et al 2023)

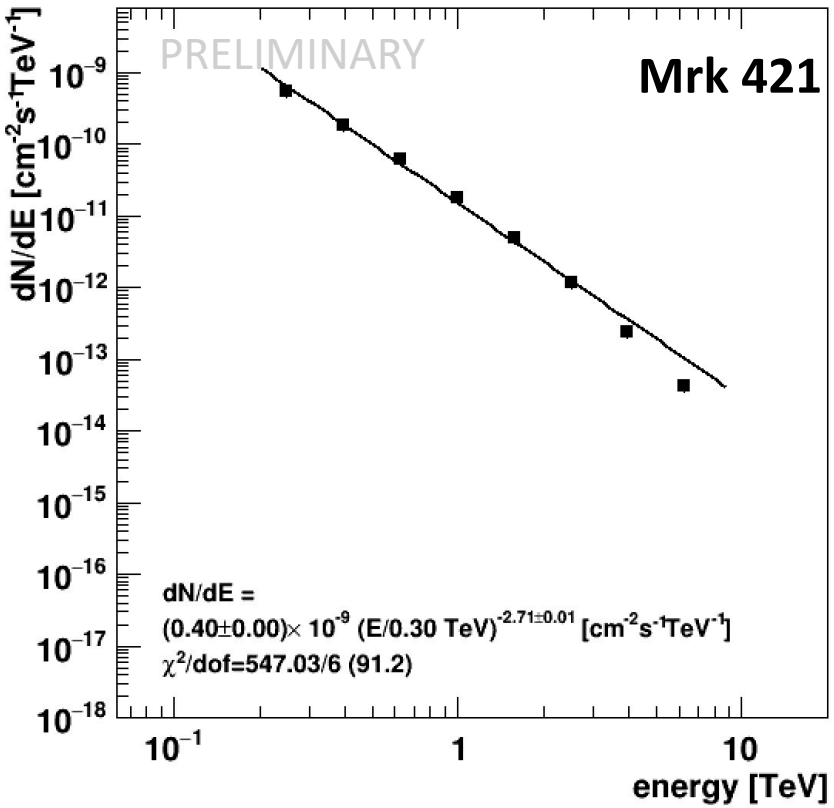


1ES 0647+250

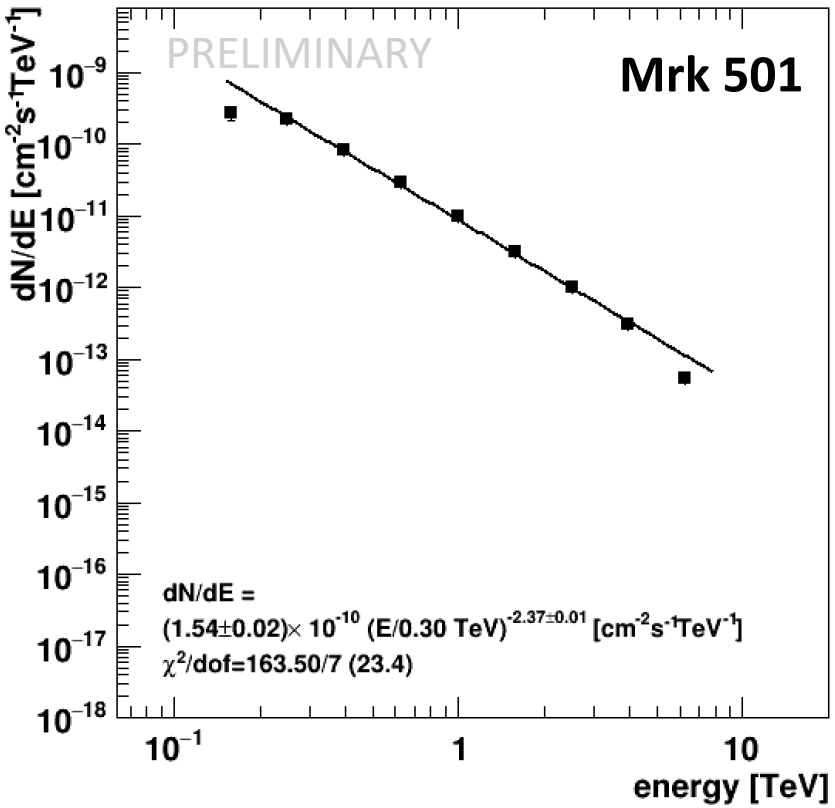
- Previously detected by MAGIC during a low state and three flares (Acciari et al 2023)
- Survey flux found to be higher than TeVCat value (MAGIC low state in 2009-2011)
  - TeVCat flux > 100 GeV: **3% Crab**
  - Unbiased survey flux > 100 GeV: **(5.38 ± 0.68)% Crab**



Mrk 421 & Mrk 501



146.4 hours of data
Obs. from 2010-13, 2017-19, 2020-24
Flux > 200 GeV: (53.3 ± 0.33)% Crab



77.9 hours of data
Obs. from 2008-2009, 2012, 2017-19, 2021-24
Flux > 200 GeV: (23.9 ± 0.27)% Crab

Summary

- VERITAS unbiased survey of 36 high-frequency-peaked BL Lac objects
- Analysis work nearing completion (30/36 sources finished)
- One >5 sigma detection of new TeV source (RBS 1366)
- Revised unbiased flux values/ULs for many others
- Results will lead to first HBL luminosity function at TeV energies