The High-Energy End of the Cosmic-Ray Electron Spectrum

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***now at IFAE-BIST**

H.E.S.S.

The H.E.S.S. experiment

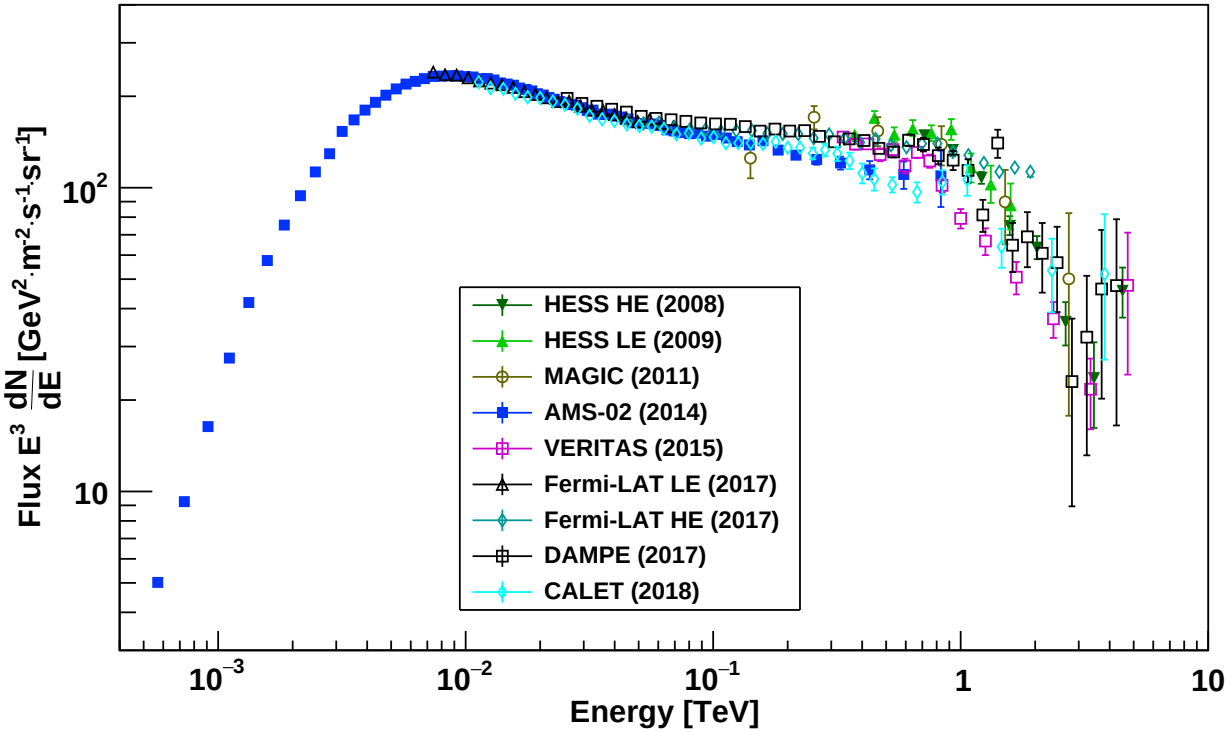
H.E.S.S. phase I

- 4 telescopes since 2003
- 960 PMT/camera
- Field of view: 5°
- Stereoscopic reconstruction

H.E.S.S. phase II

- 5th telescope in 2012
- 2048 PMT
- Field of view: 3.5°

Cosmic-ray electron spectrum measurements status



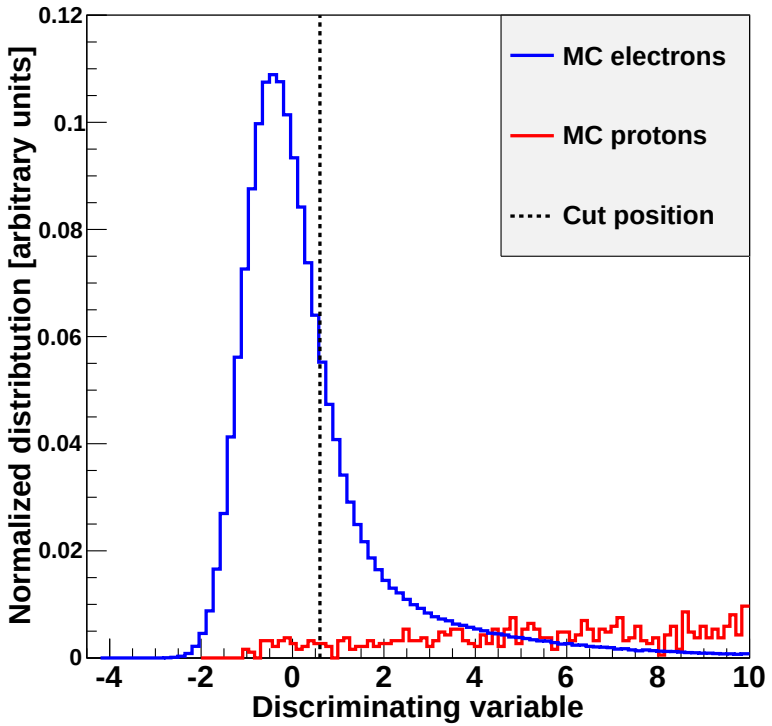
- 2008/2009 H.E.S.S. results with multivariate analysis.
- Now: up to 15 years of observations with H.E.S.S.

F. Aharonian *et al.*, A&A 508 (2009), 561
F. Aharonian *et al.*, Phys. Rev. Lett. 101 (2008), 261104

H.E.S.S. standard data analysis method

The **Model Analysis**:

- Log-likelihood comparison between recorded images and pre-calculated templates including Night Sky Background
- Widely used for H.E.S.S. analysis
- Improved discrimination based on the goodness of fit compared to previous analysis



M. de Naurois & L. Rolland, Astropart. Phys., 32 (2009), 231-252

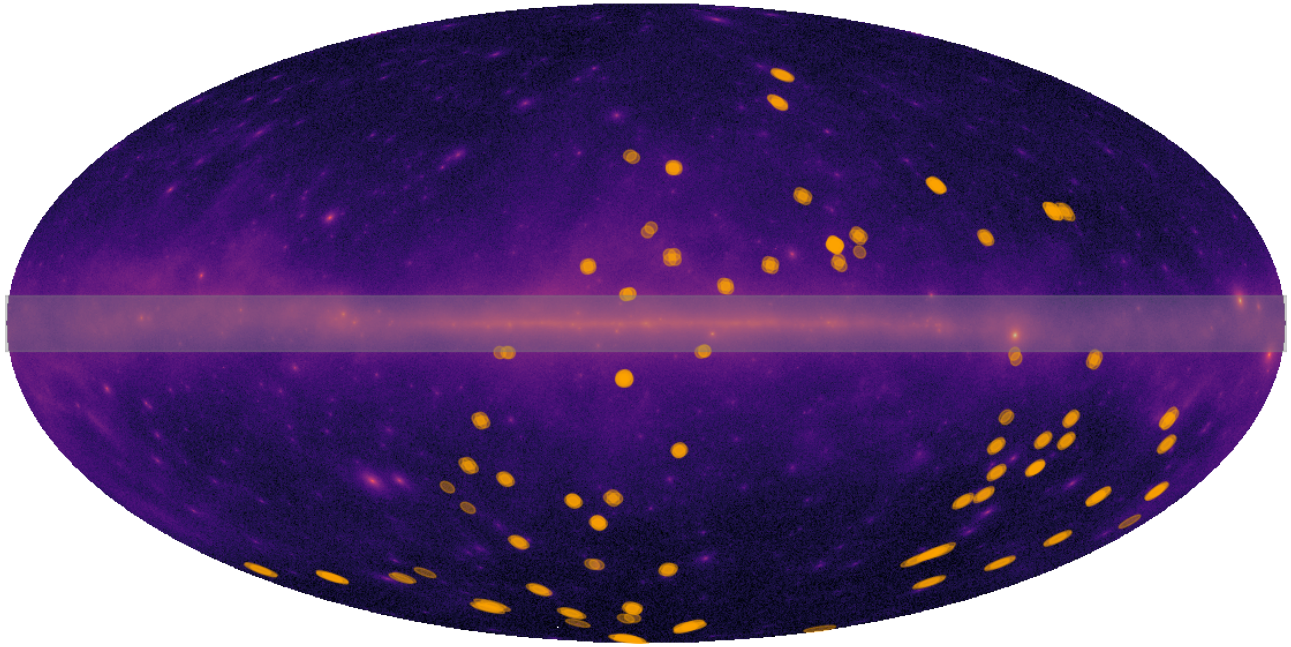
Dataset for the electron analysis

In addition to the standard data quality selection, we used the following criteria:

- Pointing position is **more than 7 degrees** away from the Galactic plane
- H.E.S.S. I runs with **4 telescopes** operational
- Zenith angle is **< 28°**

Excluded regions: 0.4° around any known γ-ray source.

Dataset for the electron analysis



Final dataset consists in 2742 runs for a total livetime of $\sim$ **1186 hours**.

–> about 4 times more data than for the previous analysis

Estimated background contamination

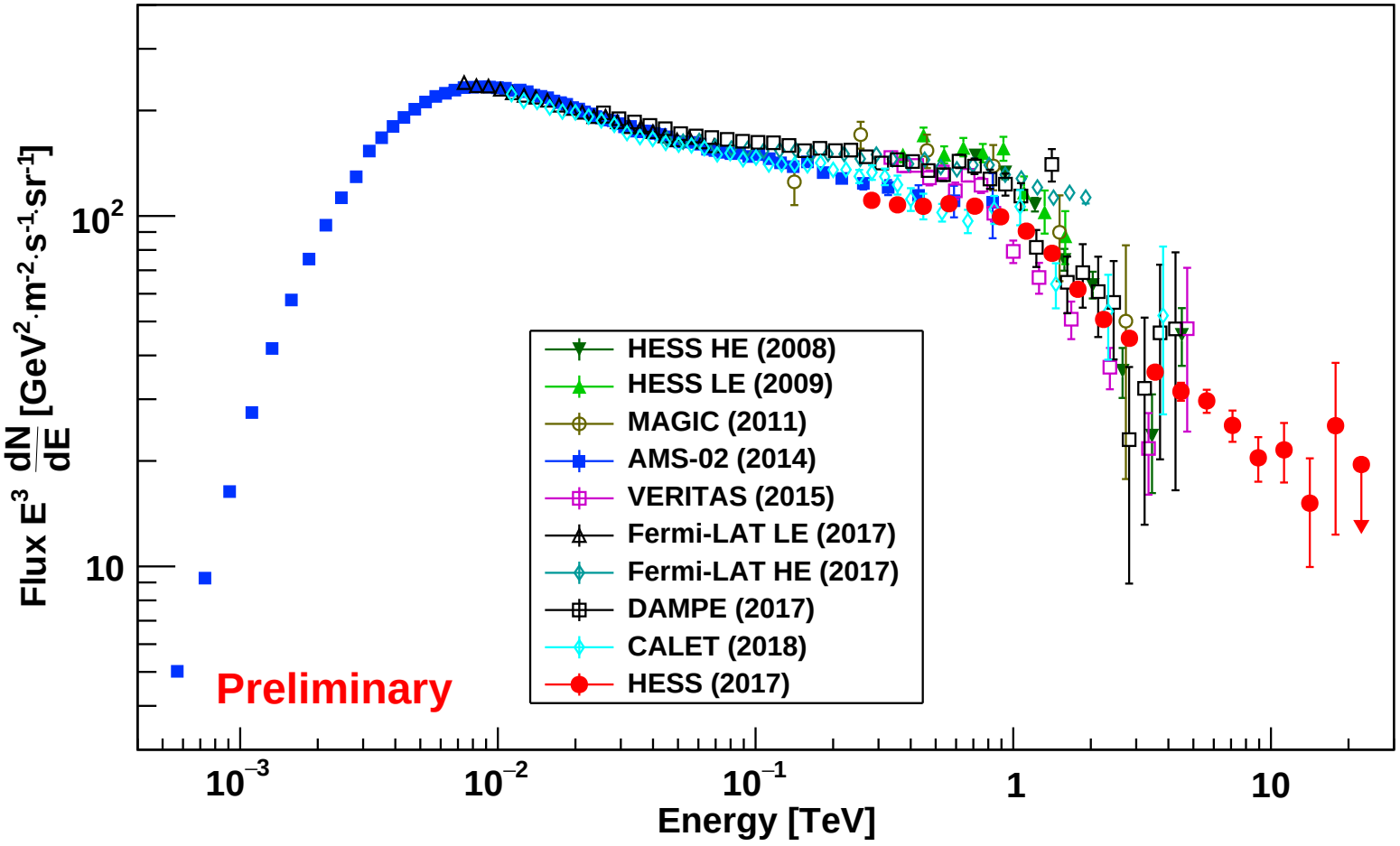
Preliminary estimation of proton contamination with MC simulations (knowing the actual measured fluxes of electrons and protons):

Energy	Expected contamination from protons
1 TeV	$\sim 15\%$
2 TeV	$\sim 7\%$
> 5 TeV	$< 10\%$

Energy range of the analysis : **[0.25 TeV; 25 TeV]**

Total number of electron-like detected events : **480 739**

New H.E.S.S. cosmic-ray electron spectrum



Background issue

Contamination from protons is the main issue for an electron analysis!

Because electron spectrum is steeper than proton spectrum, misidentified protons could induce an artificial **hardening** in the electron spectrum even if only a small fraction of protons is misidentified as electrons.

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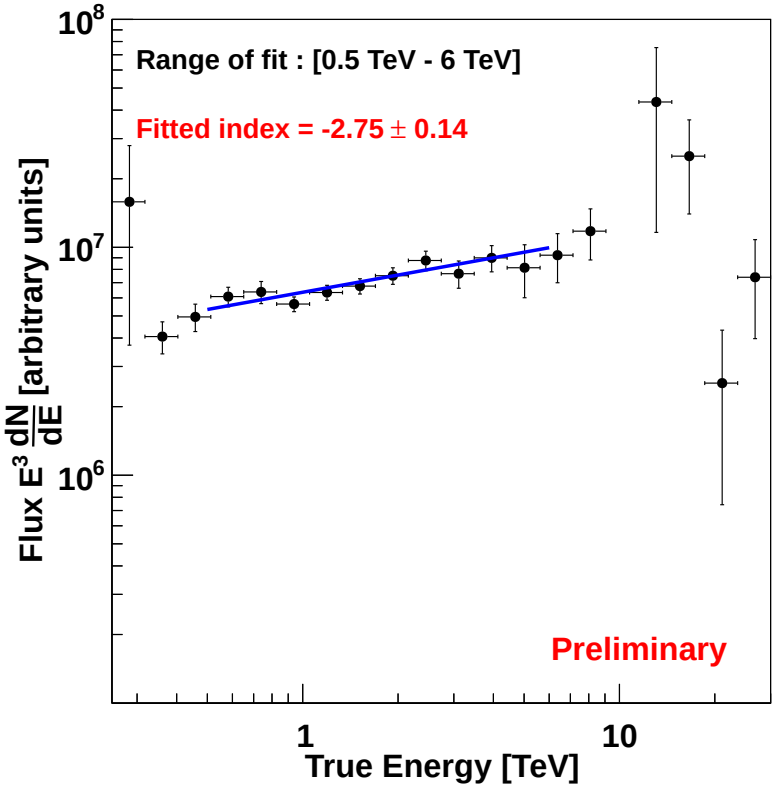

Injection of **MC protons** with simulated spectral index of **-2.8** reconstructed using **protons** acceptance.

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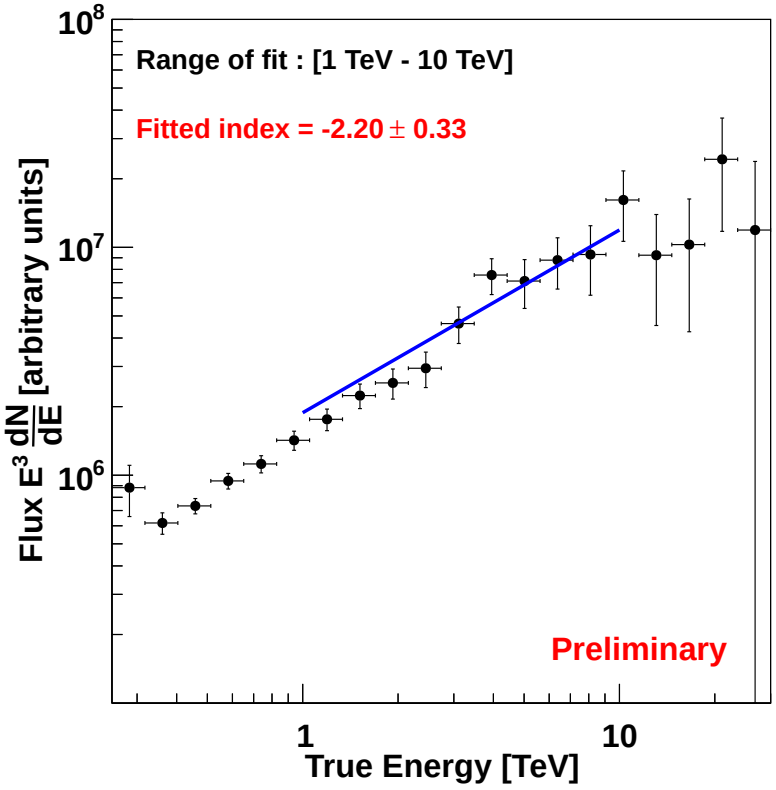

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Fitting of the spectrum

Fit function is a smooth broken power law:

$$E^3 \frac{\mathrm{d}N}{\mathrm{d}E} = N_0 \left(\frac{E}{(1\ \mathrm{TeV})}\right)^{3-\Gamma_1} \left(1+\left(\frac{E}{E_b}\right)^{\frac{1}{\alpha}}\right)^{-(\Gamma_2-\Gamma_1)\alpha}$$

Result of the fit:

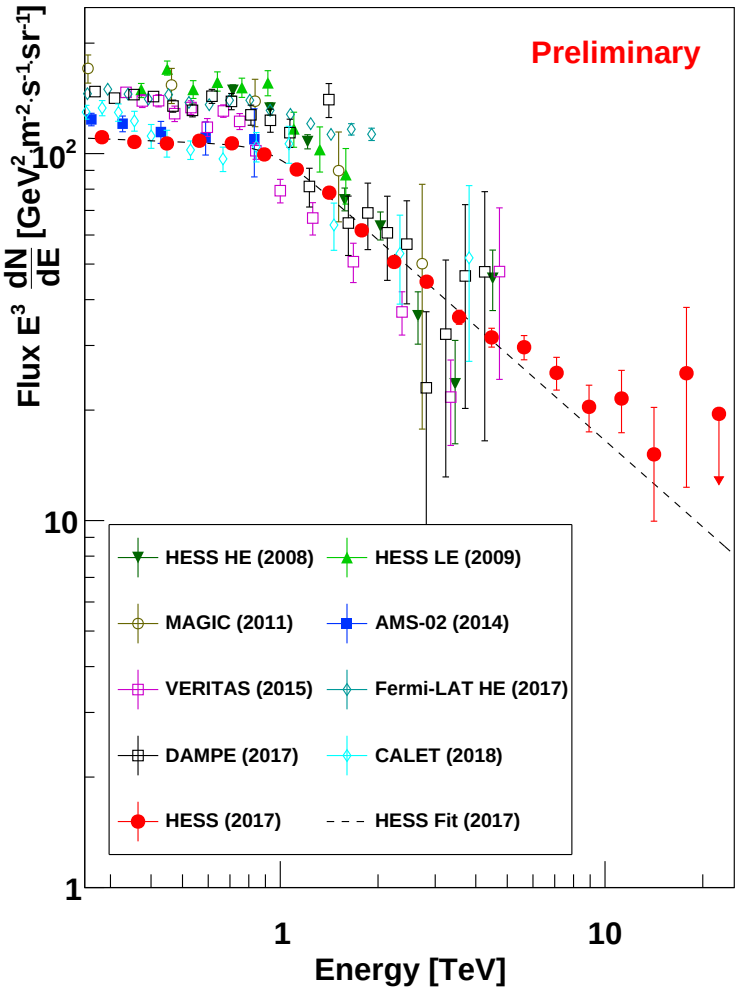
$\Gamma_1 = 3.04 \pm 0.01$ (stat)

$\Gamma_2 = 3.78 \pm 0.02$ (stat)

$E_b = 0.94 \pm 0.02$ (stat) TeV

$N_0 = 105 \pm 1$ (stat) $\mathrm{GeV}^2 \cdot \mathrm{m}^{-2} \cdot \mathrm{sr}^{-1} \cdot \mathrm{s}^{-1}$

$\alpha = 0.12 \pm 0.01$ (stat)



Systematics uncertanties

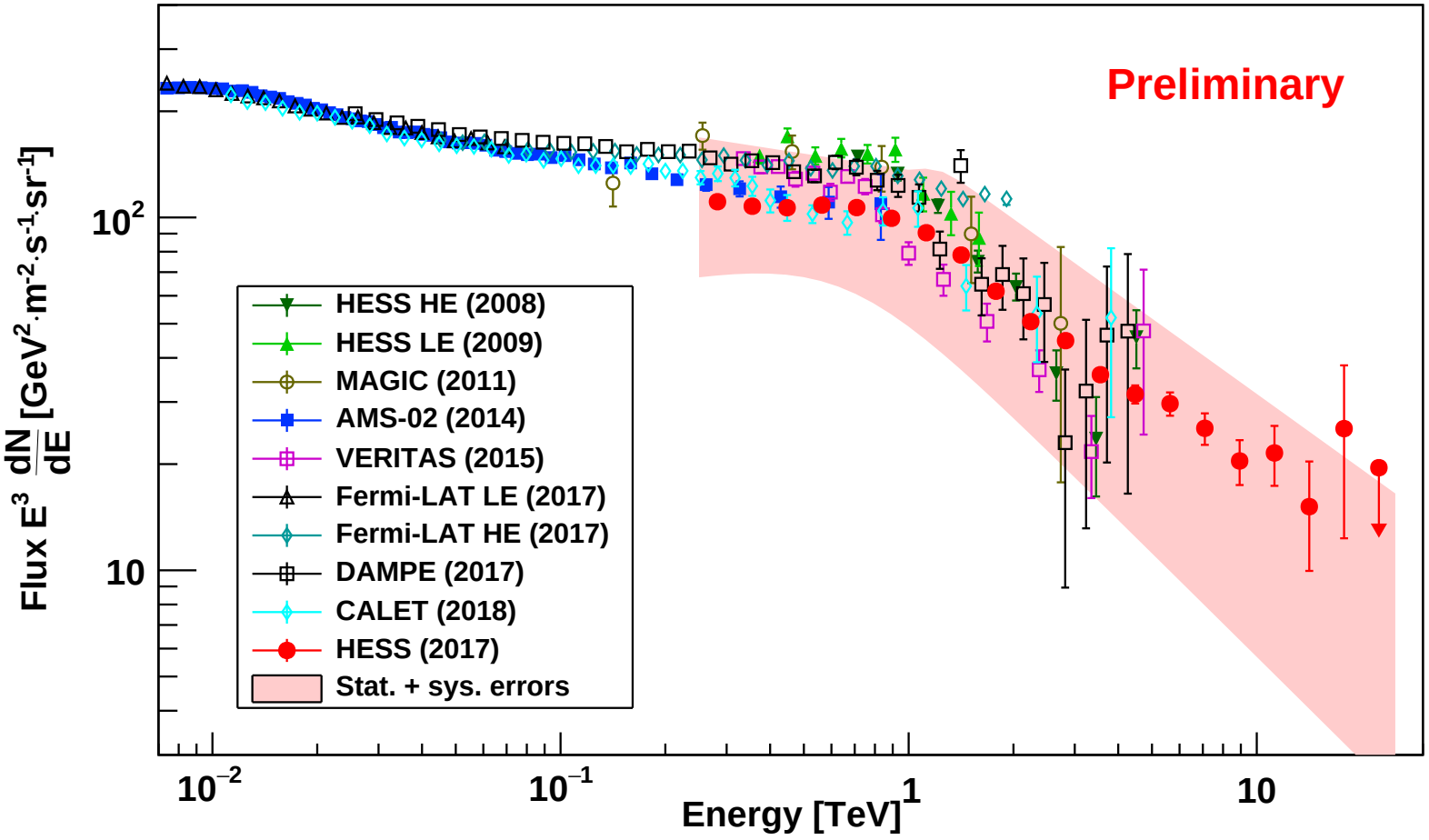
The systematics studies included:

- Test on all event selection cuts involved in the analysis
- Dependency on the zenithal angle
- Dependency over the years
- Dependency on atmospheric conditions

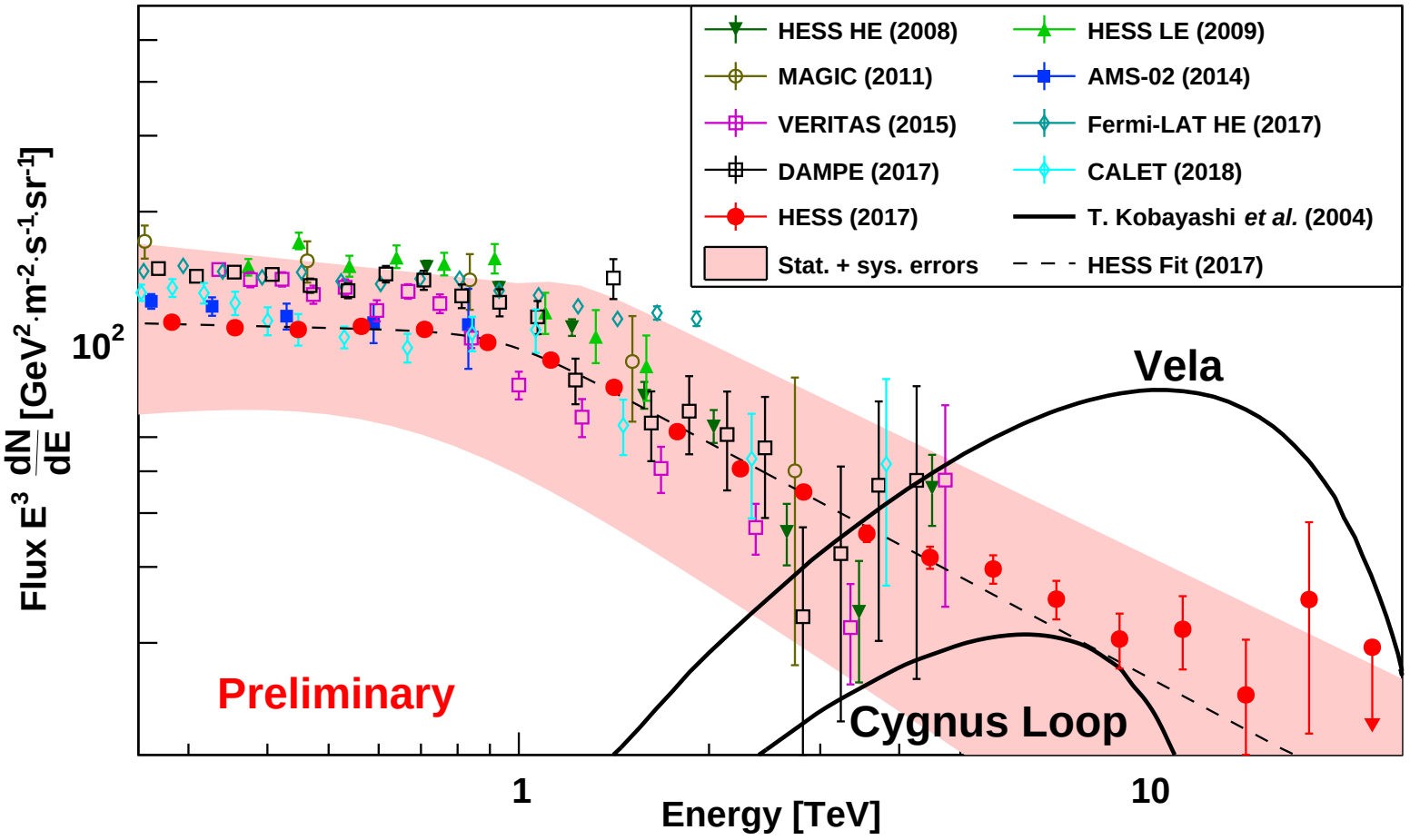
Total systematic errors: quadratic sum of each tests.

$$
\begin{aligned}
\Gamma_1 &= 3.04 \pm 0.01\,(\text{stat}) \; {}^{+0.10}_{-0.18}\,(\text{sys}) \\
\Gamma_2 &= 3.78 \pm 0.02\,(\text{stat}) \; {}^{+0.17}_{-0.06}\,(\text{sys}) \\
E_b &= 0.94 \pm 0.02\,(\text{stat}) \; {}^{+0.29}_{-0.26}\,(\text{sys})\ \text{TeV} \\
N_0 &= 104 \pm 1\,(\text{stat}) \; {}^{+27}_{-16}\,(\text{sys})\ \text{GeV}^2\cdot\text{m}^{-2}\cdot\text{sr}^{-1}\cdot\text{s}^{-1} \\
\alpha &= 0.12 \pm 0.01\,(\text{stat}) \; {}^{+0.19}_{-0.05}\,(\text{sys})
\end{aligned}
$$

Electron spectrum with systematic uncertanties



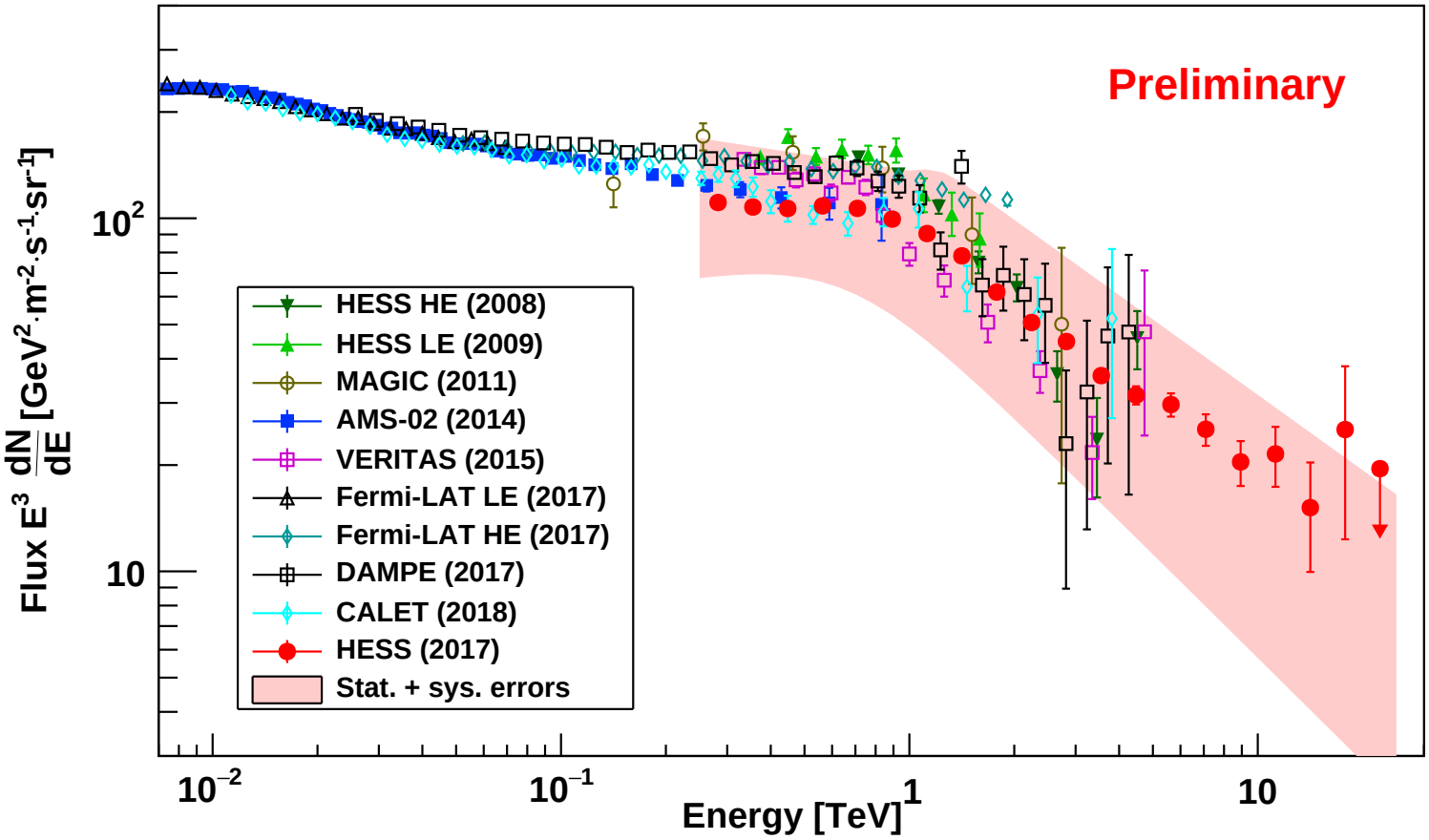
Featureless spectrum up to the highest energies



T. Kobayashi *et al.*, ApJ, 601:340-351 (2004)

Summary

- Electron spectrum measured with standard analysis allowing excellent background rejection.
- Detection of 480 739 electron-like events from 250 GeV up to $\sim$ 20 TeV.
- Electron spectrum fitted with a smooth broken power law:
  - low energy index $\Gamma_1 = 3.04 \pm 0.01$ (stat) $^{+0.10}_{-0.18}$ (sys)
  - high energy index $\Gamma_2 = 3.78 \pm 0.02$ (stat) $^{+0.17}_{-0.06}$ (sys)
  - break at $E_b = 0.94 \pm 0.02$ (stat) $^{+0.29}_{-0.26}$ (sys) TeV
  - flux at 1 TeV $\Phi(1\ \mathrm{TeV}) = 96 \pm 1$ (stat) ± 17 (sys) GeV^2.m^{-2}.sr^{-1}.s^{-1}
- No features is seen in the electron spectrum up to the highest energies which allow us to exclude models that describe prominent features from nearby sources such as Vela.
- Please refer to the forthcoming paper from the H.E.S.S. Collaboration!



Thank you for your attention!