The cosmic-ray electron spectrum measured with H.E.S.S.

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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°

Designed for $\gamma$-ray detection.
Cosmic-ray electron spectrum measurements status

- 2008/2009 H.E.S.S. results with multivariate analysis.
- In 2017: up to 14 years of observations with H.E.S.S.
  -> Standard analysis relying on cut on very discriminating variable.

F. Aharonian et al., A&A 508 (2009), 561
Standard 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
- Very powerful discrimination based on goodness of fit

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.

Final dataset consists in 2742 runs for a total livetime of ~ 1186 hours.
Estimated background contamination

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

<table>
<thead>
<tr>
<th>Energy</th>
<th>Expected contamination from protons</th>
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<tbody>
<tr>
<td>1 TeV</td>
<td>$\sim 15%$</td>
</tr>
<tr>
<td>2 TeV</td>
<td>$\sim 7%$</td>
</tr>
<tr>
<td>$&gt; 5$ TeV</td>
<td>$&lt; 10%$</td>
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</tbody>
</table>

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

Energy [TeV]

Flux $E^3 \frac{dN}{dE}$ [GeV$^2$ m$^{-2}$ s$^{-1}$ sr$^{-1}$]

Energy [TeV]

HESS HE (2008)
HESS LE (2009)
MAGIC (2011)
AMS-02 (2014)
VERITAS (2015)
Fermi-LAT LE (2017)
Fermi-LAT HE (2017)
HESS (2017)
Preliminary
Background issue

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

Because electron spectrum is steeper than proton spectrum, protons induce **an hardening** in the electron spectrum even if only a small number is mis-identified 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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Injection of **MC protons** with simulated spectral index of **-2.8** reconstructed using **electrons** acceptance.
Fitting of the spectrum

Fit function is a smooth broken power law:

\[ E^3 \frac{dN}{dE} = N_0 \left( \frac{E}{1 \text{ TeV}} \right)^{3-\Gamma_1} \left( 1 + \left( \frac{E}{E_b} \right)^{\frac{1}{\alpha}} \right)^{-(\Gamma_1-\Gamma_2)\alpha} \]

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) GeV\(^2\)·m\(^{-2}\)·sr\(^{-1}\)·s\(^{-1}\)
- \( \alpha = 0.12 \pm 0.01 \) (stat)
Systematics uncertainties

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.

\[ \Gamma_1 = 3.04 \pm 0.01 \text{ (stat)} \pm^{0.10}_{-0.18} \text{ (sys)} \]
\[ \Gamma_2 = 3.78 \pm 0.02 \text{ (stat)} \pm^{0.17}_{-0.06} \text{ (sys)} \]
\[ E_b = 0.94 \pm 0.02 \text{ (stat)} \pm^{0.29}_{-0.26} \text{ (sys) TeV} \]
\[ N_0 = 104 \pm 1 \text{ (stat)} \pm^{27}_{-16} \text{ (sys) GeV}^2 \cdot \text{m}^{-2} \cdot \text{sr}^{-1} \cdot \text{s}^{-1} \]
\[ \alpha = 0.12 \pm 0.01 \text{ (stat)} \pm^{0.19}_{-0.05} \text{ (sys)} \]
Electron spectrum with systematic uncertainties

![Graph showing electron spectrum with systematic uncertainties](image)

Featureless spectrum up to the highest energies


H.E.S.S.

Daniel Kerszberg . The cosmic-ray electron spectrum measured with H.E.S.S. - ICRC 2017 - 19 July 2017 . 14/16
Summary

- Electron spectrum measured with standard analysis allowing excellent background rejection.
- Detection of 480,739 electron-like events from 250 GeV up to \( \sim 20 \text{ TeV} \).
- Electron spectrum fitted with a smooth broken power law:
  - low energy index \( \Gamma_1 = 3.04 \pm 0.01 \text{ (stat)} \pm^{0.10}_{0.18} \text{ (sys)} \)
  - high energy index \( \Gamma_2 = 3.78 \pm 0.02 \text{ (stat)} \pm^{0.17}_{0.06} \text{ (sys)} \)
  - break at \( E_b = 0.94 \pm 0.02 \text{ (stat)} \pm^{0.29}_{0.26} \text{ (sys)} \text{ TeV} \)
  - flux at 1 TeV \( \Phi(1 \text{ TeV}) = 96 \pm 1 \text{ (stat)} \pm^{17}_{26} \text{ (sys)} \text{ GeV}^2 \text{.m}^{-2} \text{.sr}^{-1} \text{.s}^{-1} \)
- 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!