The cosmic-ray electron spectrum measured with the MAGIC telescopes

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MAGIC

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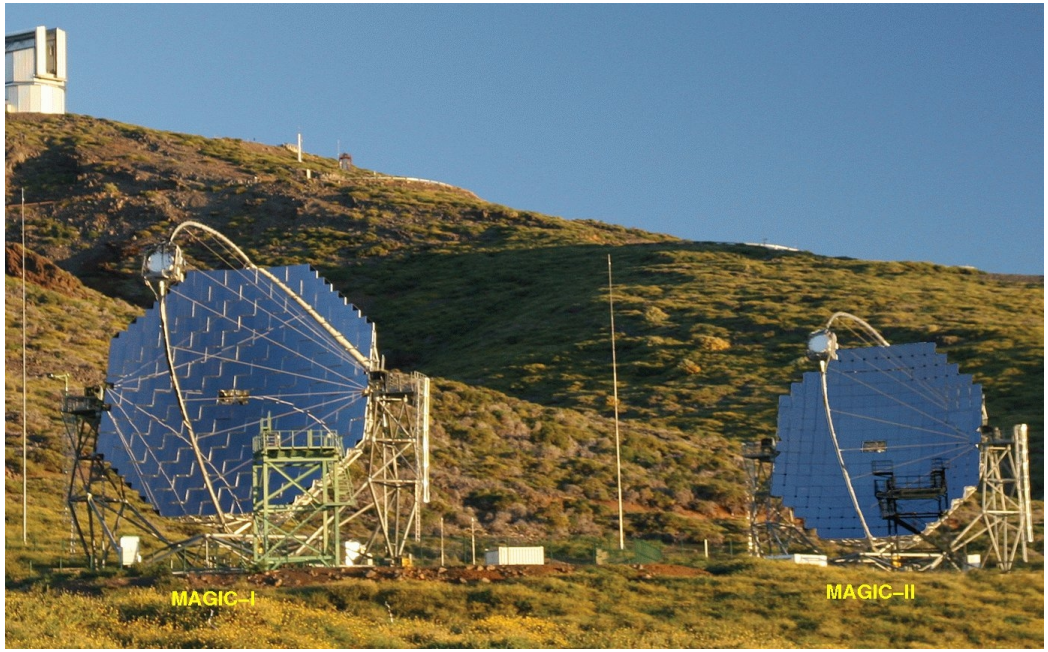
The MAGIC experiment

- **MAGIC consists of two 17 m diameter Cherenkov telescopes**
  - First telescope since 2004
  - Second telescope since 2009
- **Energy range:**
  50 GeV - 50 TeV
- **Field of view of ~3.5°**
- **Designed to detect gamma rays**



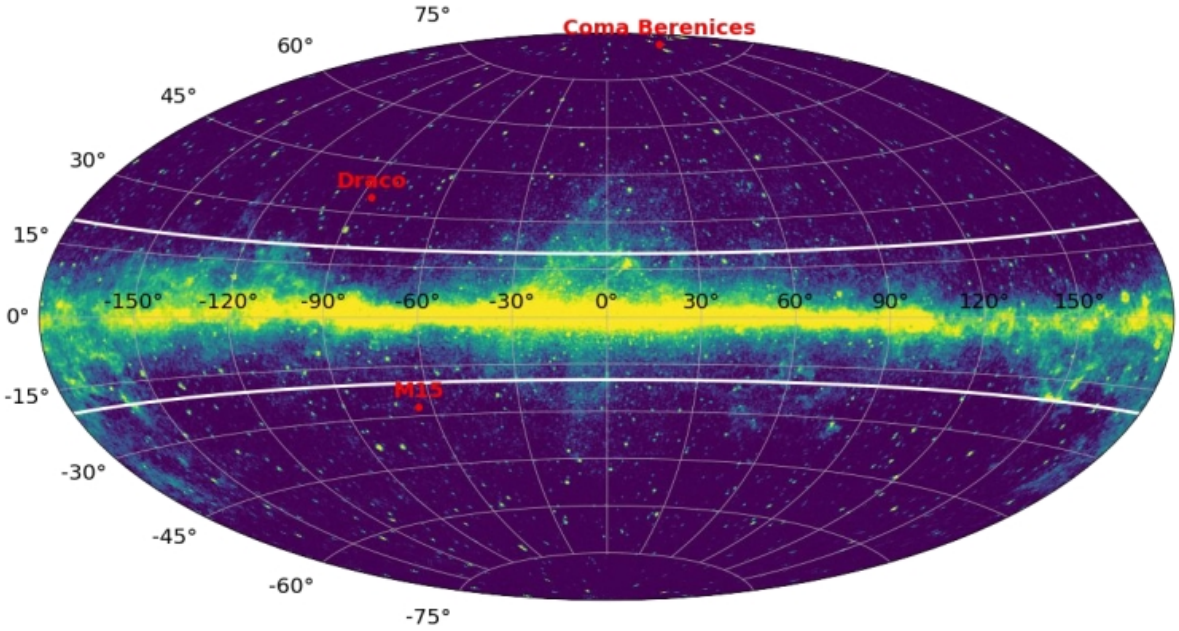
MAGIC: La Palma, Spain, 2200 m

→ Idea is to take advantage that electron induced showers are very similar to gamma-ray induced showers

Data selection

- **In addition to the usual data quality selection, we used the following criteria:**
  - Field of views with no known gamma-ray emission
  - Pointing position 20 degrees or more away from the Galactic plane to avoid Galactic diffuse emission

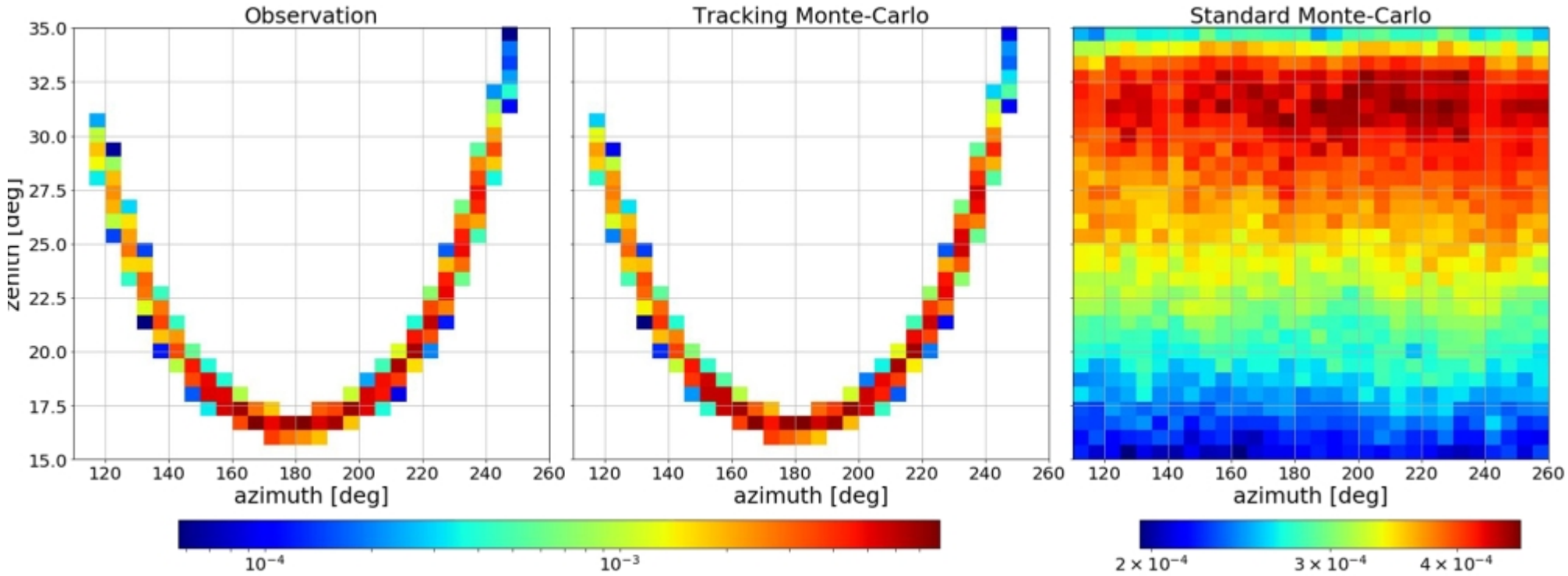
- **In total ~ 220 hours of good quality data were used in this analysis**



Sky map from Fermi-LAT

Dedicated Monte Carlo simulations

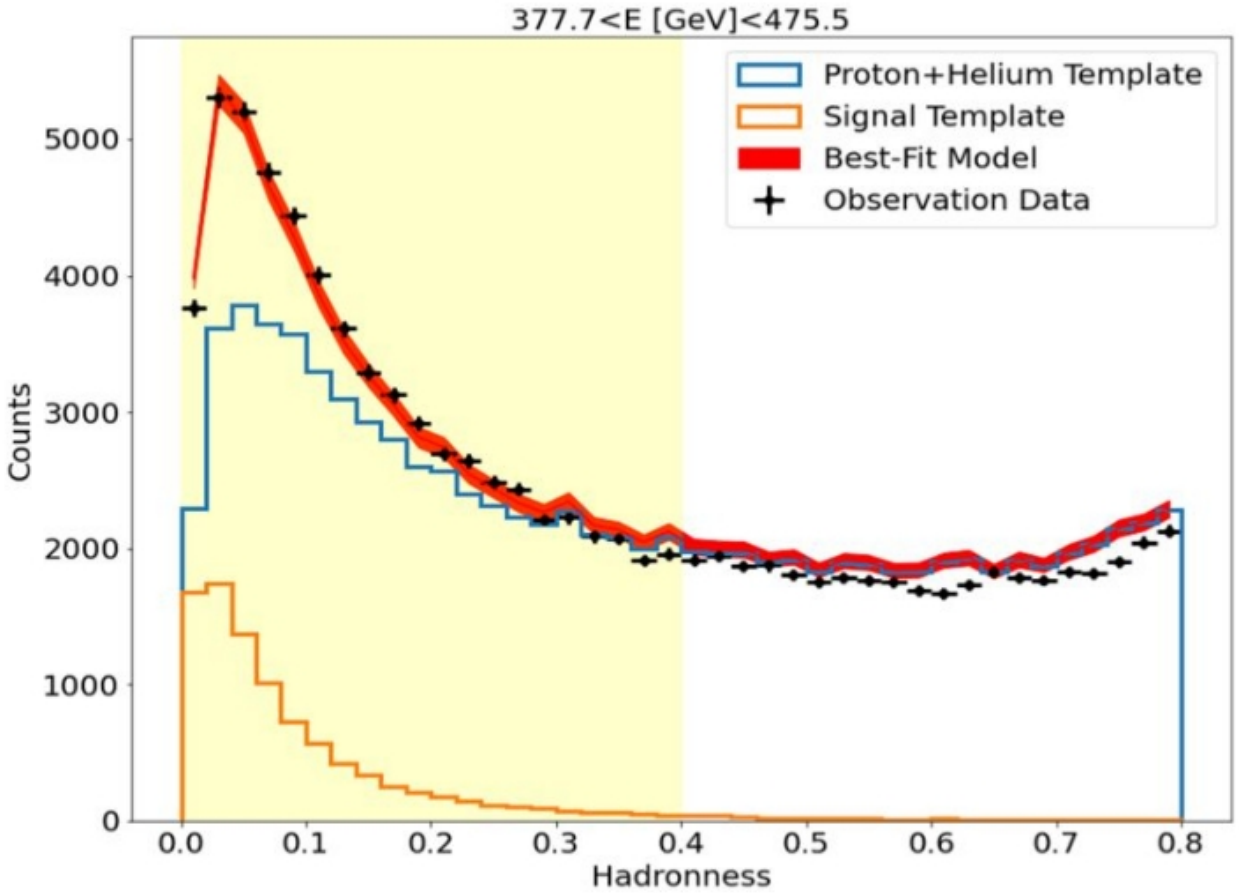
- **Distributions of pointing direction for:**



data **MC for this study** **standard MC**

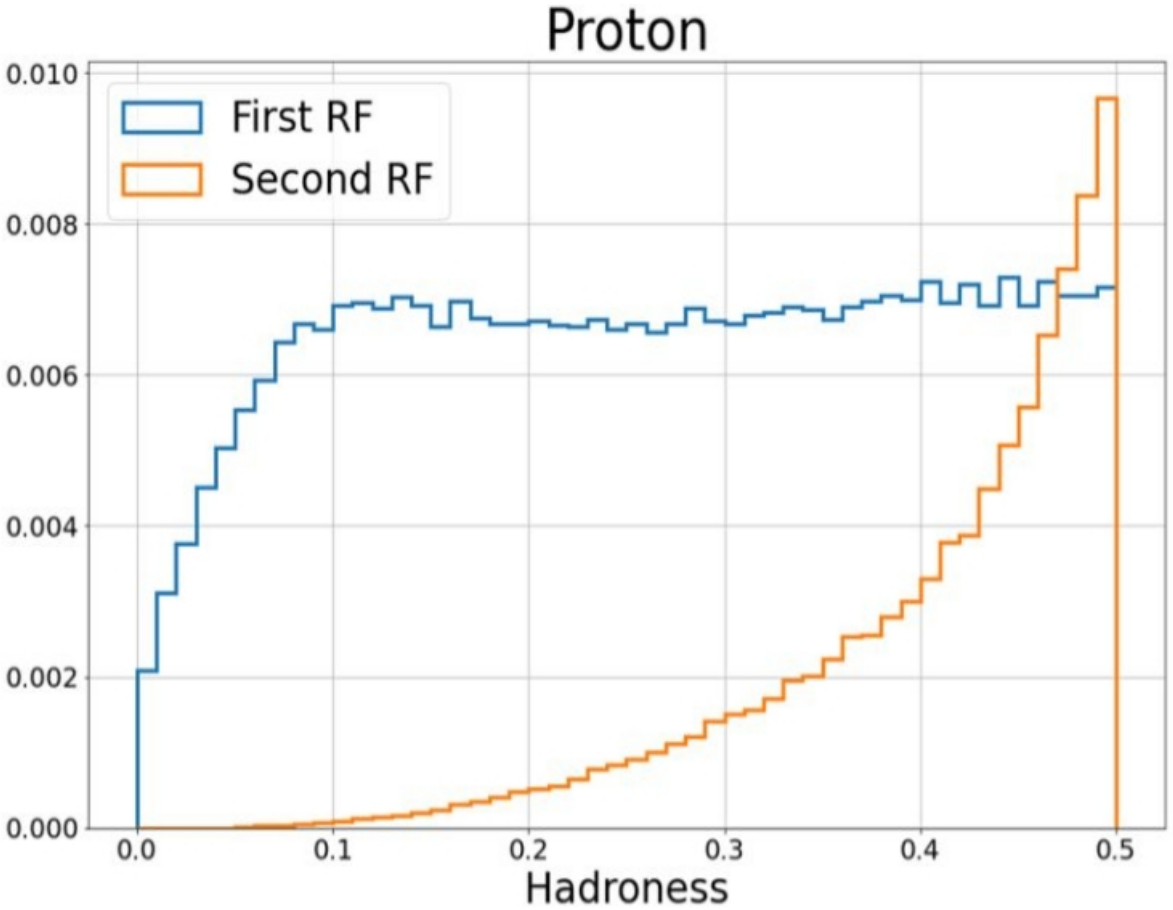
- **Allows to reduce one of the most important source of systematic uncertainty**

Background rejection method I



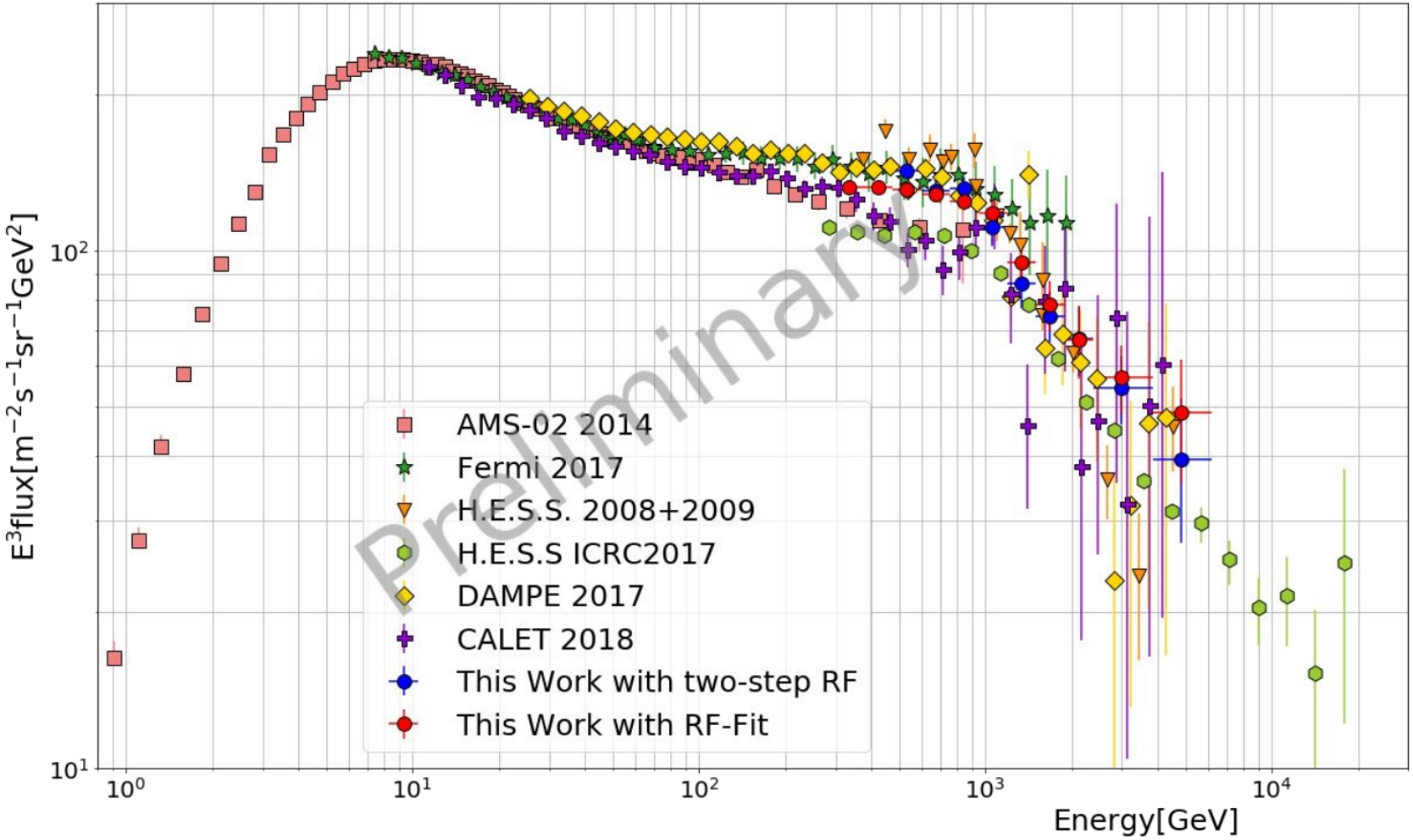
- **Using a Random Forest fit (“RF-Fit”), a “standard” analysis**
- **Signal (electron) template and backgroubd (hadron) template are fitted to the data to estimate the contribution from each**

Background rejection method II



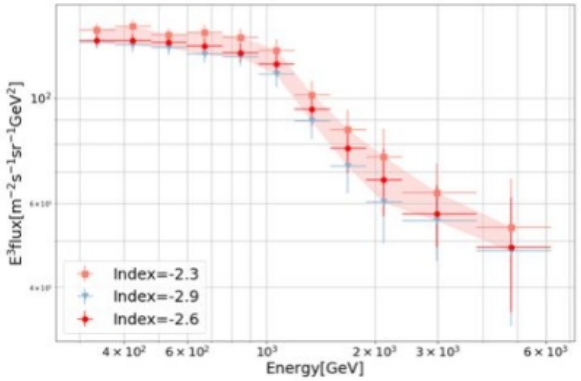
- **Using two Random Forest one after the other to better discriminate between signal events and signal-like background events**
- **The better discrimination allows to apply a tight cut to remove almost all background events (“Two-Step RF with Tight Cut”)**

The electron+positron spectrum

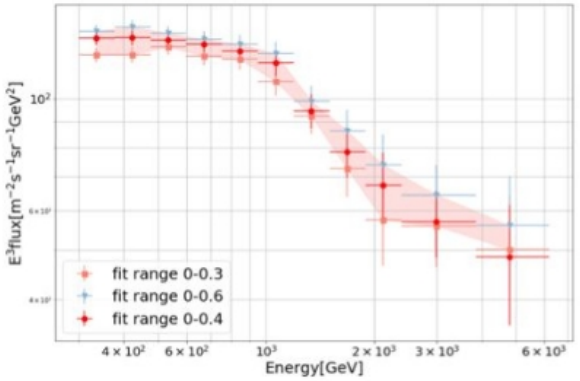


- **Magic spectrum extends from 300 GeV to 6 TeV**
- **Both methods give compatible results**

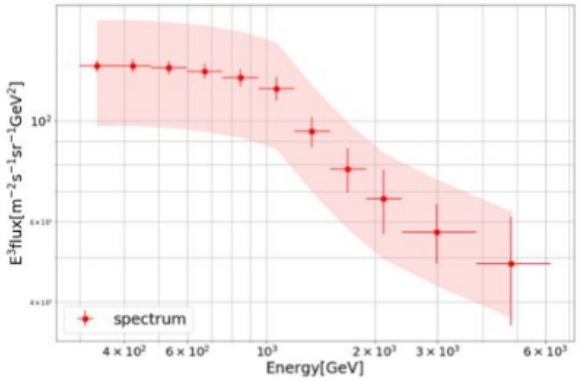
Systematic uncertainties: RF-Fit



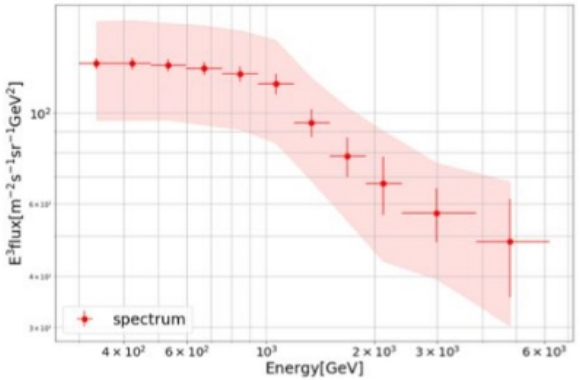
(a) Systematic from Hadron Index



(b) Systematic from Fitting Range



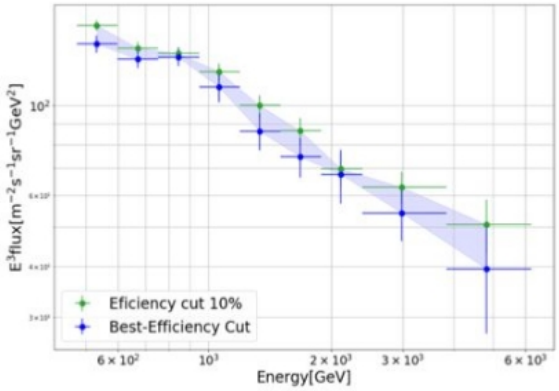
(c) Systematic from Energy Reconstruction



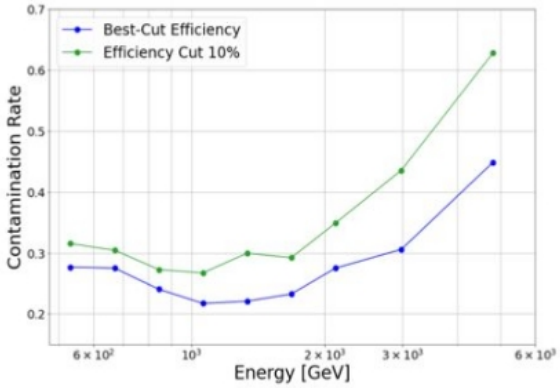
(d) Total Systematic + Statistic

- **Energy scale: ~ 15% uncertainty in energy**
- **Spectral index of MC proton: ±10% from the nominal value -2.6**
- **Varying the fitting range of the hadronness from [0;0.3] to [0;0.6]**

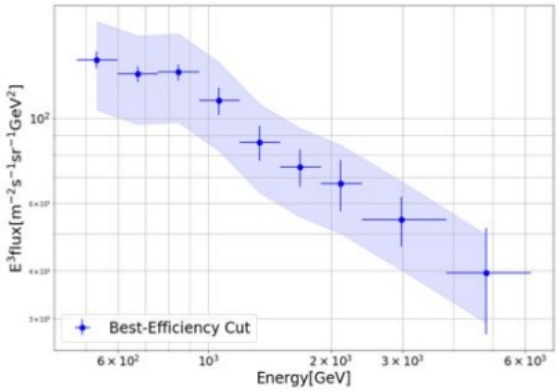
Systematic uncertainties: Two-Step RF with Tight Cut



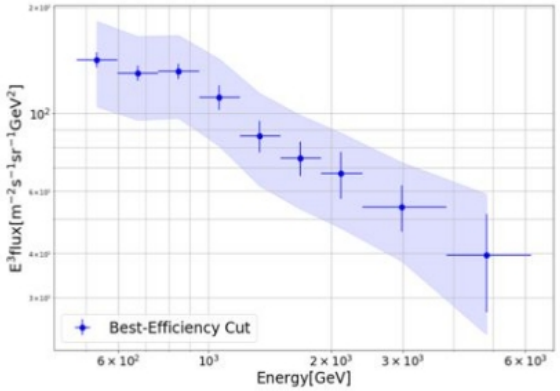
(a) Systematic from Efficiency Cut



(b) Contamination Rates



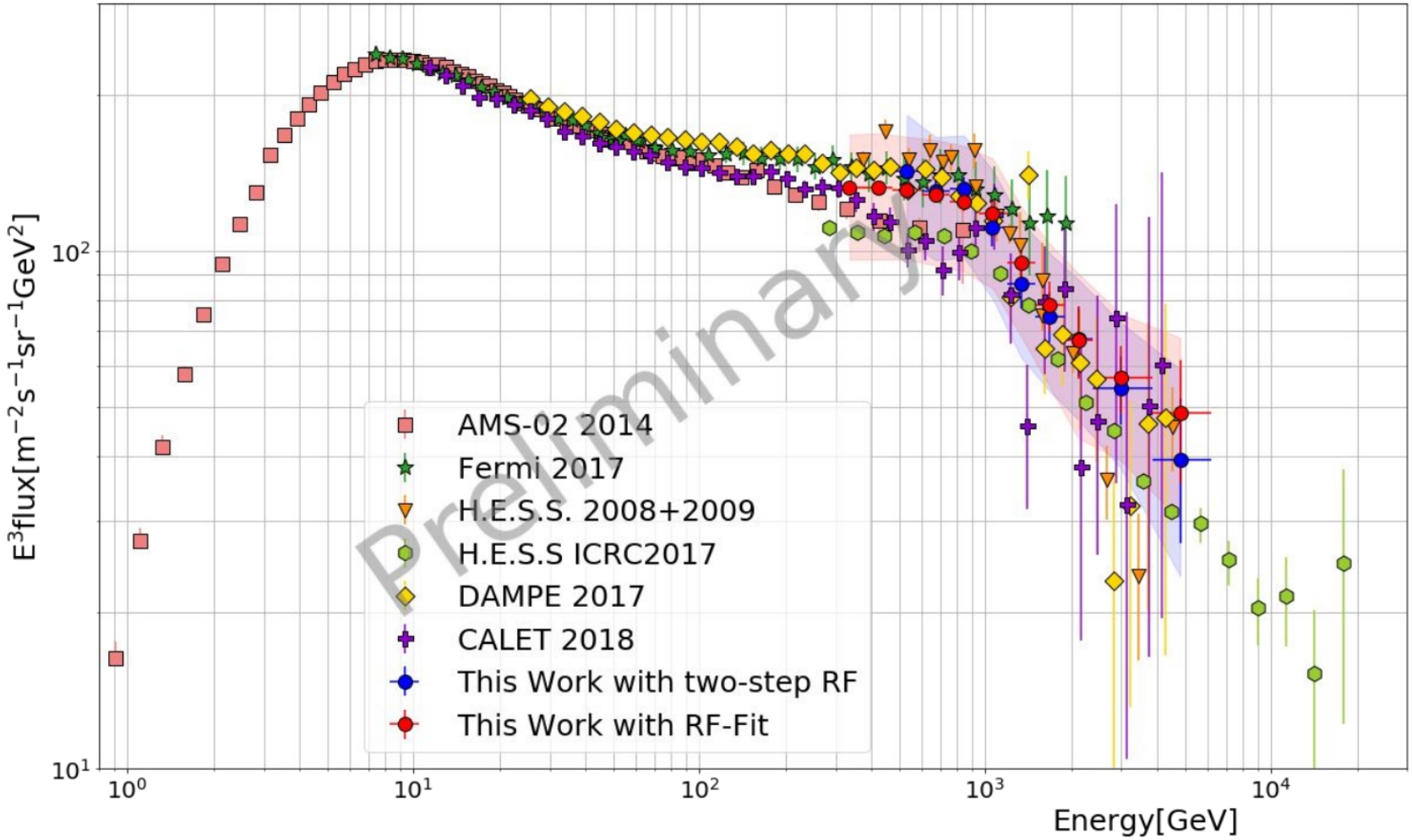
(c) Systematic from Energy Reconstruction



(d) Total Systematic + Statistic

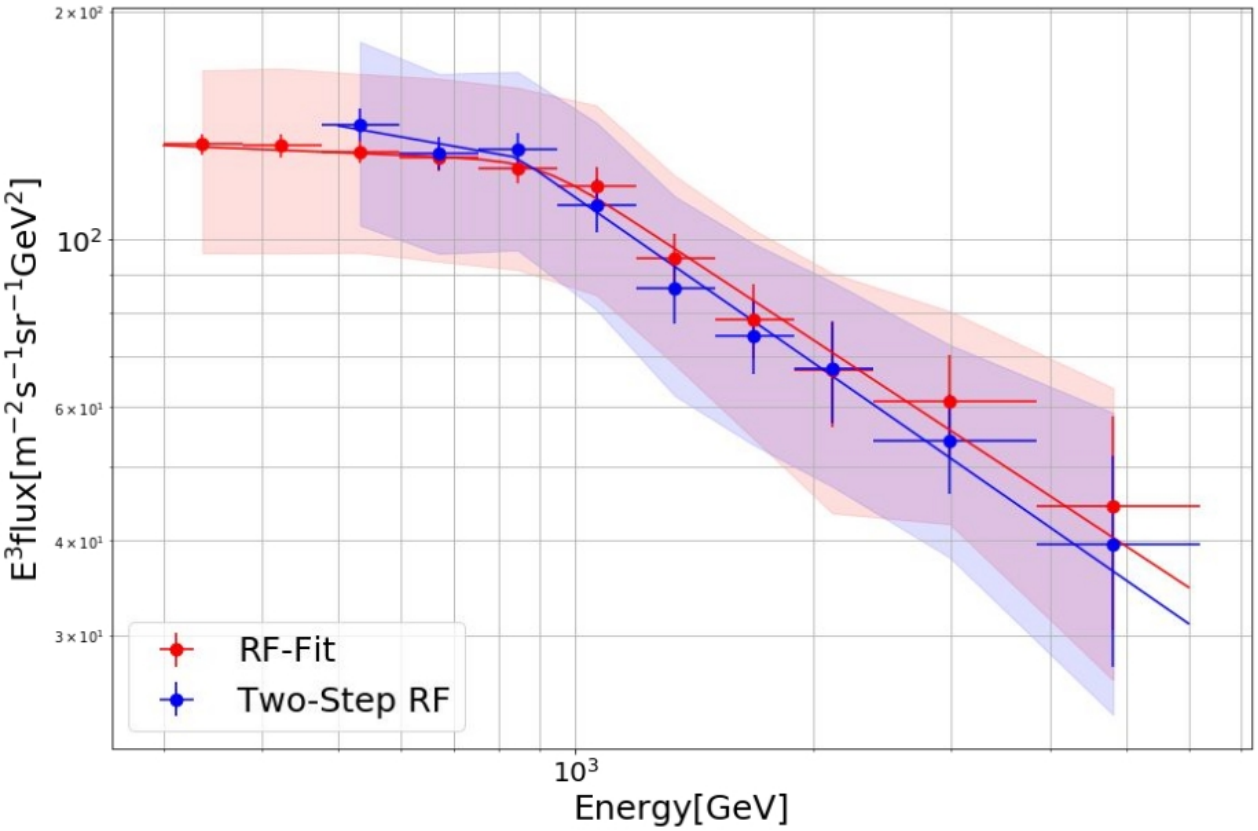
- **Energy scale: ~ 15% uncertainty in energy**
- **Varying the cut position**
- **Extra contamination from helium: tested and found to be negligible**

Spectrum + systematic uncertanties



- **Magic spectrum extends from 300 GeV to 6 TeV**
- **Compatible with all other measurements taking into account systematics**

Fitting the spectrum



RF-Fit
$\Gamma_1 = 3.04 \pm 0.08$
$\Gamma_2 = 3.69 \pm 0.13$
$E_{break} = 905.31 \pm 142.6$
$N_0 = (1.71 \pm 0.90) \times 10^{-7}$
α=0.005
χ^2_R =2.44/6

Two-Step RF
$\Gamma_1 = 3.18 \pm 0.15$
$\Gamma_2 = 3.72 \pm 0.09$
$E_{break} = 845.25 \pm 37.62$
$N_0 = (2.12 \pm 0.34) \times 10^{-7}$
α=0.002
χ^2_R =1.56/4

- **Fitted the spectrum with a smooth broken power law**
  → energy break around 900 GeV

Conclusion

- **The cosmic-ray electron and positron spectrum was reconstructed using ~220 hours of MAGIC data with two different background rejection methods:**
  - The RF-Fit method
  - The Two-Step RF method

  → The spectra reconstructed from the two methods are compatible with each other and with the measurements from other experiments

- **The energy range of the measured spectrum is from 300 GeV to 6 TeV:**
  - with a energy break at ~900 GeV
  - the slope of the spectrum changes from ~3.1 to ~3.7

- **The main source of systematic uncertainty affecting the measurement is the energy scale uncertainly of ~15%**