A search for possible anisotropies of cosmic rays at EeV energies in the region of the Galactic Centre

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Motivation

- The GC harbors a super massive black hole associated to the radio emissions from Sagittarius A*;

- Recent measurements by H.E.S.S. of TeV γ-rays close to Sagittarius A*[1] position;

- Previous claims of large excesses at EeV energies from AGASA and SUGAR - None of them confirmed by a later analysis of Auger data;

- Theoretical predictions of neutron sources in the region of the GC;

- The GC lies well within Auger field of view: it passes only 6° away from the observatory zenith.

[1]F. Aharonian et al., Astron. Astrophys. **425** (2004) L13.

Data Set: quality cuts

- Surface Detector (SD) data collected from January 1th, 2004 up to March 31th, 2007;

- Highest trigger level required (level 5) in which the tank with the highest signal has to be surrounded by a complete hexagon of working tanks;

- Events with zenith angle $< 60°$;

- Statistics is twice the size of previous Auger published result (Astropart. Phys. **27** (2007) 244-253).

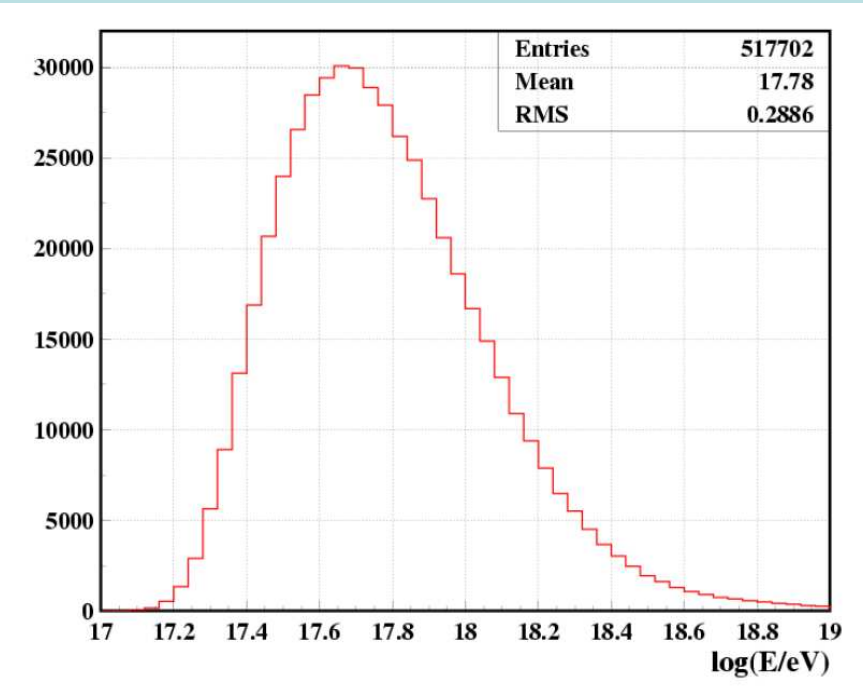
Data Set: final sample

(1 EeV = 10^{18} eV)

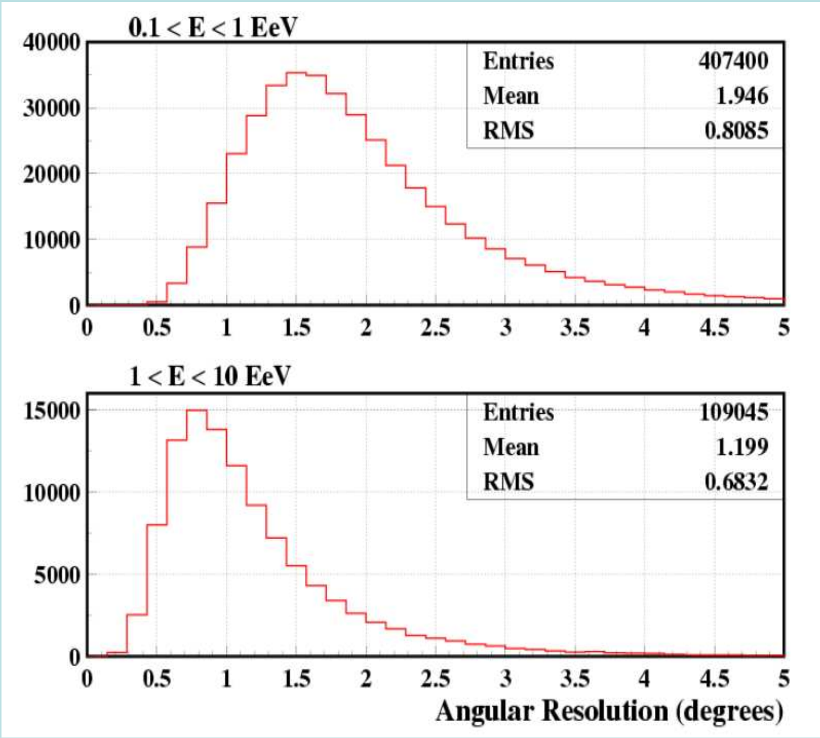
We divided our data set into 2 energy energy bands:

0.1 < *E* < 1 EeV and 1 < *E* < 10 EeV

Energy distribution



Angular Resolution



Pierre Auger Collaboration, 30th ICRC proceedings, 2007, pres. #313 and #297.

Search for Extended Sources

Top Hat windows of 10° and 20° around the GC position .

$0.1 < E < 1$ EeV

window size	n_{obs}/n_{exp}
10°	**5663/5657 = 1.00 ± 0.02(stat) ± 0.01(syst)**
20°	**22274/22440 = 0.99 ± 0.01(stat) ± 0.01(syst)**

$1 < E < 10$ EeV

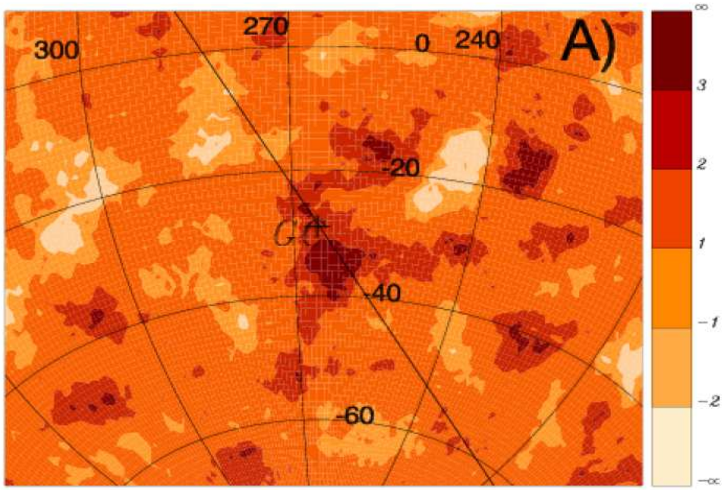
window size	n_{obs}/n_{exp}
10°	**1463/1365 = 1.07 ± 0.04(stat) ± 0.01(syst)**
20°	**5559/5407 = 1.03 ± 0.02(stat) ± 0.01(syst)**

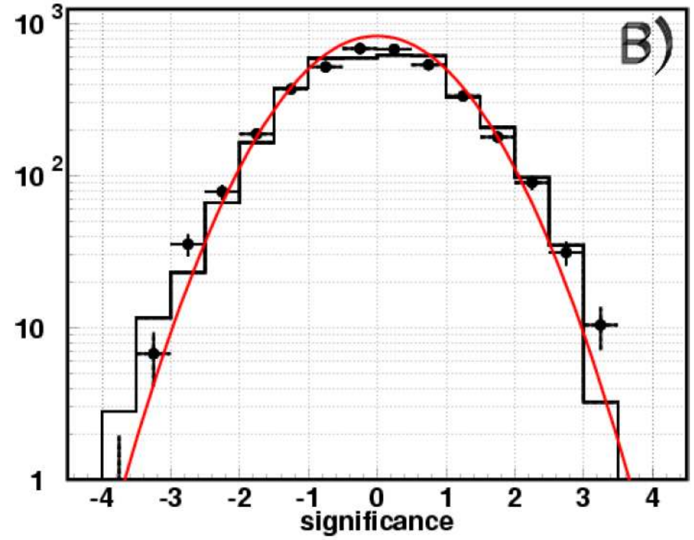
No Excess!

Significance Maps

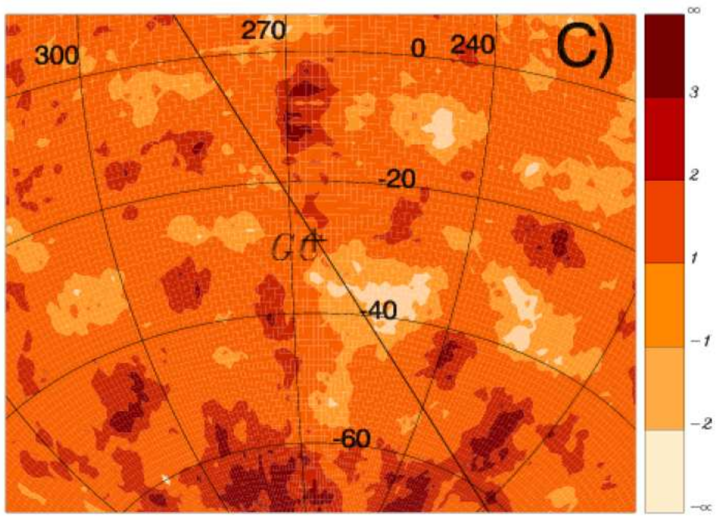
No Excess!

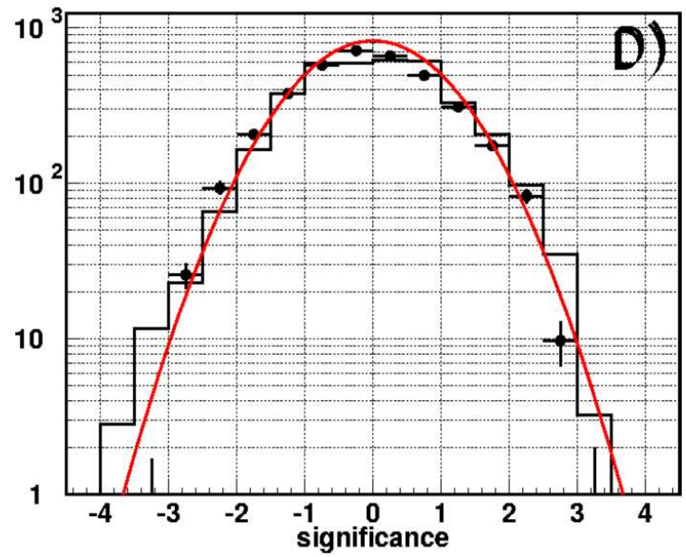
1 < *E* < 10 EeV





E < 1 EeV





Search for Point-like Sources (Neutral Particles)

- Gaussian window maximize signal/noise ratio:

$$W(\beta) = \exp\left(-\frac{\beta^2}{2\sigma^2}\right)$$

σ chosen according to ang. resolution.

- **1 < *E* < 10 EeV:**

$0.8° \rightarrow n_{obs}/n_{exp} = 16.9/17.0 = 0.99 \pm 0.17(\text{stat}) \pm 0.01(\text{syst})$

- **0.1 < *E* < 1 EeV:**

$1.3° \rightarrow n_{obs}/n_{exp} = 192.1/191.2 = 1.00 \pm 0.07(\text{stat}) \pm 0.01(\text{syst})$

No Excess!

Upper limits for Point-like Sources

Number of events (analytic) + Acceptance and spectrum → Flux

- **0.1 < *E* < 1 EeV:**

Neutrons would decay before reaching Earth. Photons would be a candidate at these energies.
Upper limit in the flux cannot be predicted because photon acceptance is still not well known.

- **1 < *E* < 10 EeV:**

$$n_s^{95} = 5.6$$

At these energies neutrons can reach the Earth before decaying.

- Assume Φ_s has the same spectral index as Φ_{CR} and similar source/bulk acceptances:

$$\Phi_{CR} = \kappa 50 \left(\frac{E}{\mathrm{EeV}}\right)^{-3.3} \mathrm{EeV}^{-1}\mathrm{km}^{-2}\mathrm{yr}^{-1}\mathrm{sr}^{-1}$$

κ = 1.2 for HiRes-like norm., κ = 2 for AGASA and κ = 1 for Auger.

- Upper limit for source flux at 95% CL is given by:

$$\Phi_s^{95} = \int_{E_{min}}^{E_{max}} dE\,\Phi_s(E) = \frac{n_s^{95}}{n_{exp}} 4\pi\sigma^2 \int_{E_{min}}^{E_{max}} dE\,\Phi_{CR}(E)$$

$$\Phi_s^{95} = 0.018\kappa \quad \mathrm{km}^{-2}\mathrm{yr}^{-1} \quad (\sigma = 0.8^\circ) \rightarrow$$

Excludes most models predicting neutron sources!

Summary

- We have scanned the GC looking for point-like as well as extended sources;

- Data set from the Auger SD detector twice the size of previous published result was used;

- Data was divided into 2 energy ranges: $E < 1$ EeV and $1 < E < 10$ EeV;

- No significant CR flux excess was found in both energy ranges;

- For $1 < E < 10$ EeV, upper limits on the flux of a hypothetical point-like neutron source in the direction of Sagittarius A* were imposed which excludes most of the models predicting neutrons from the GC;

Background Estimation

- Expected background is estimated using coverage maps;

- Using the data set itself, we scramble the UTC times of the showers into the same bin of zenith;

- Such a procedure keep the original zenith distribution of the data;

- It also takes into account the variations induced by weather, array growth and detector deadtime effects;

Upper limits for Point-like Sources

- Expected background and signal counts are given by:

$$n_{exp} = 2\pi \int_0^{\pi} d\beta \sin\beta W(\beta) \int_{E_{min}}^{E_{max}} dE \mathcal{A}_{CR}(E)\Phi_{CR}(E)$$

$$n_s = 2\pi \int_0^{\pi} d\beta \frac{\sin\beta W^2(\beta)}{\sigma^2} \int_{E_{min}}^{E_{max}} dE \mathcal{A}_s(E)\Phi_s(E)$$

- Therefore, at 95% CL:

$$\int_{E_{min}}^{E_{max}} dE \mathcal{A}_s(E)\Phi_s(E) = \frac{n_s^{95}}{n_{exp}} 4\pi\sigma^2 \int_{E_{min}}^{E_{max}} dE \mathcal{A}_{CR}(E)\Phi_{CR}(E)$$