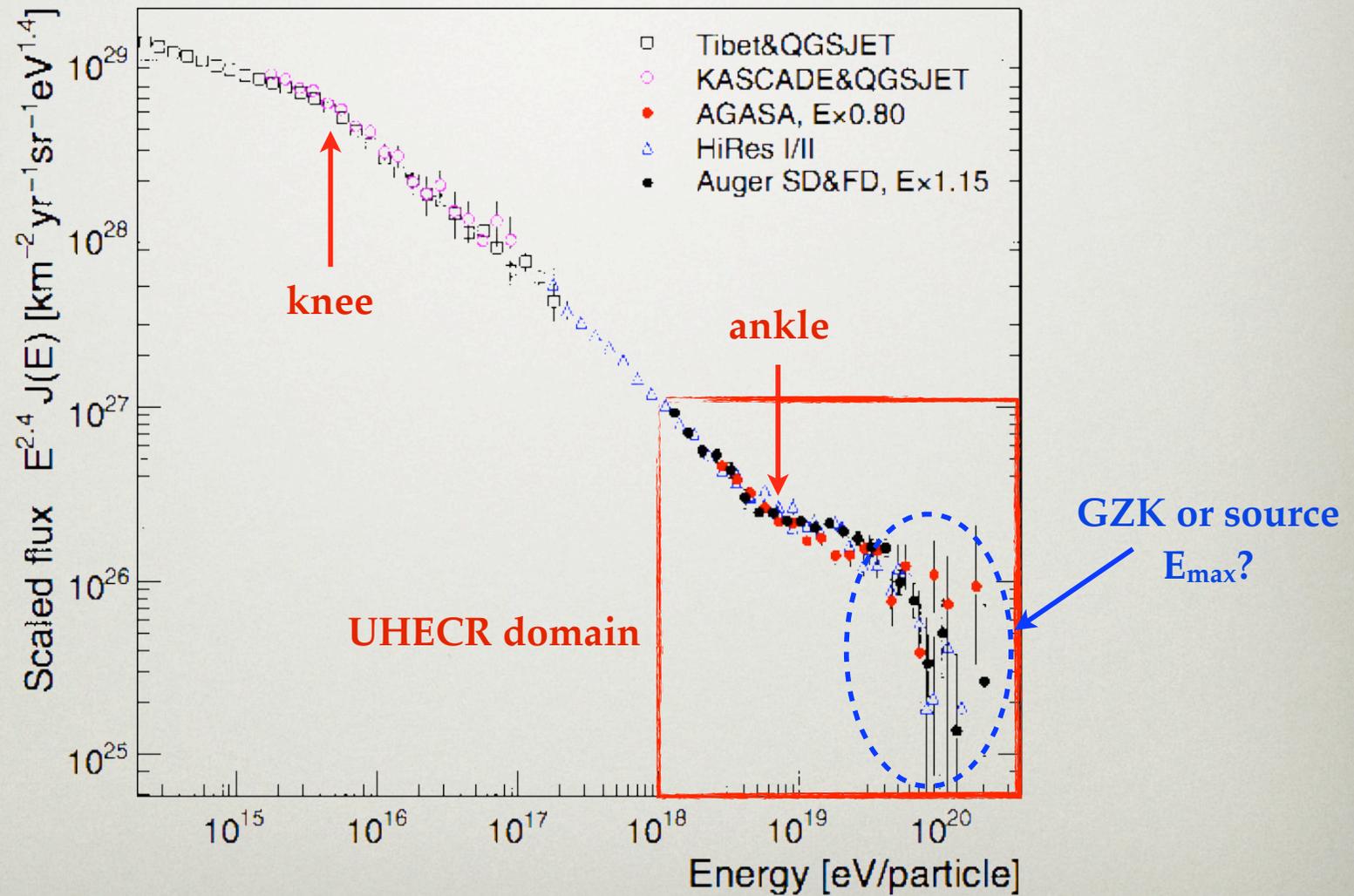


ULTRA-HIGH ENERGY COSMIC RAYS PHYSICS WITH THE AUGER OBSERVATORY

E. M. SANTOS
UNIVERSIDADE FEDERAL DO RIO DE JANEIRO

CTA-LINK MEETING, 19-21 Nov. 2012,
BUENOS AIRES

THE UHECR SPECTRUM



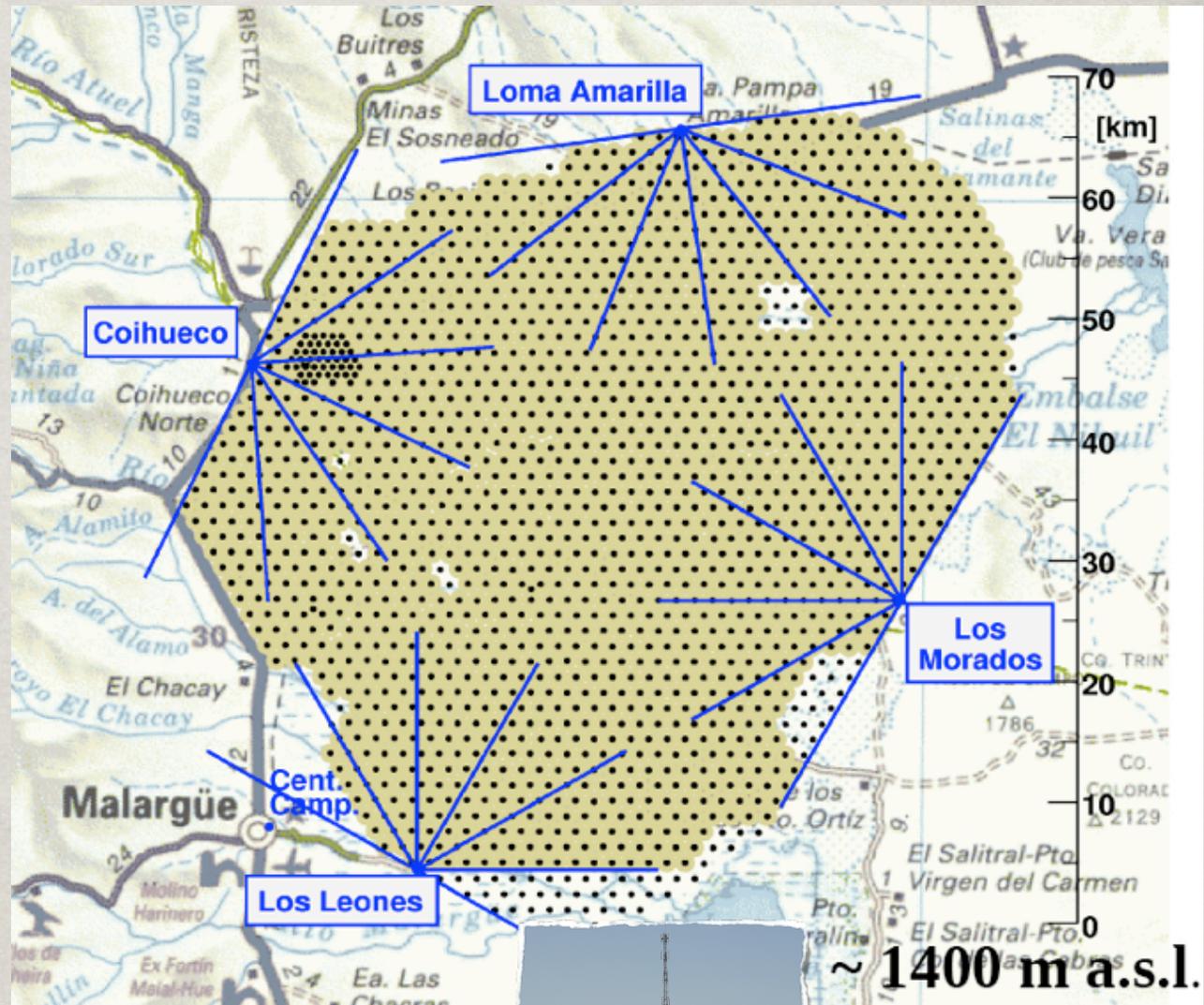
THE OBSERVATORY

1660 water Cherenkov detectors

1.5 km regular triangular grid covering 3000 km²

0.75 km infill-grid

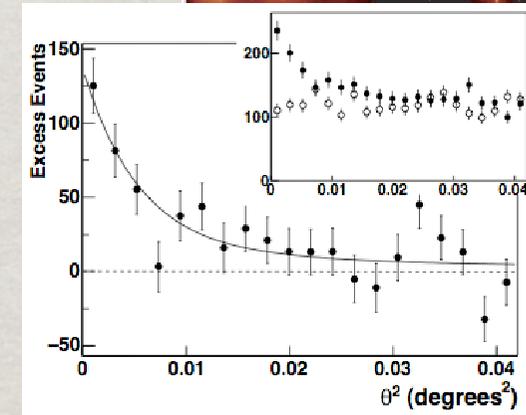
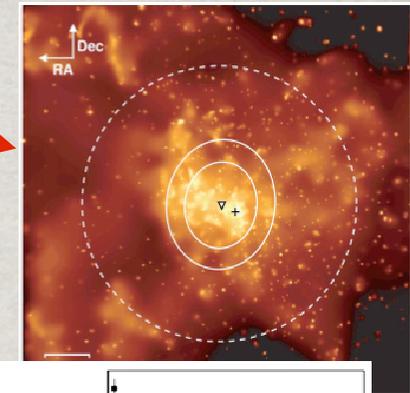
27 fluorescence telescopes



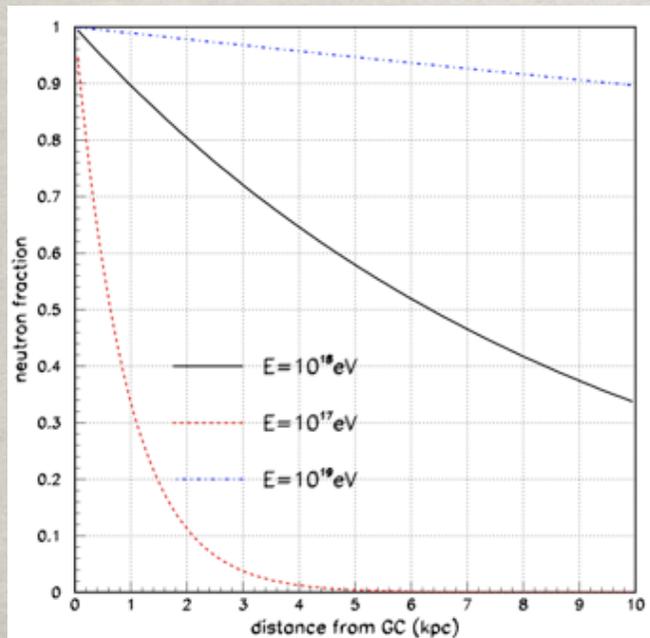
RECENT RESULTS

GALACTIC CENTER

- Strong TeV gamma-ray emissions measured by HESS
- Evidences through stellar orbits of the presence of a supermassive blackhole (Sgr A*)
- Large UHECRs excess claims from SUGAR and AGASA.
- Auger has excellent exposure in the direction of the GC



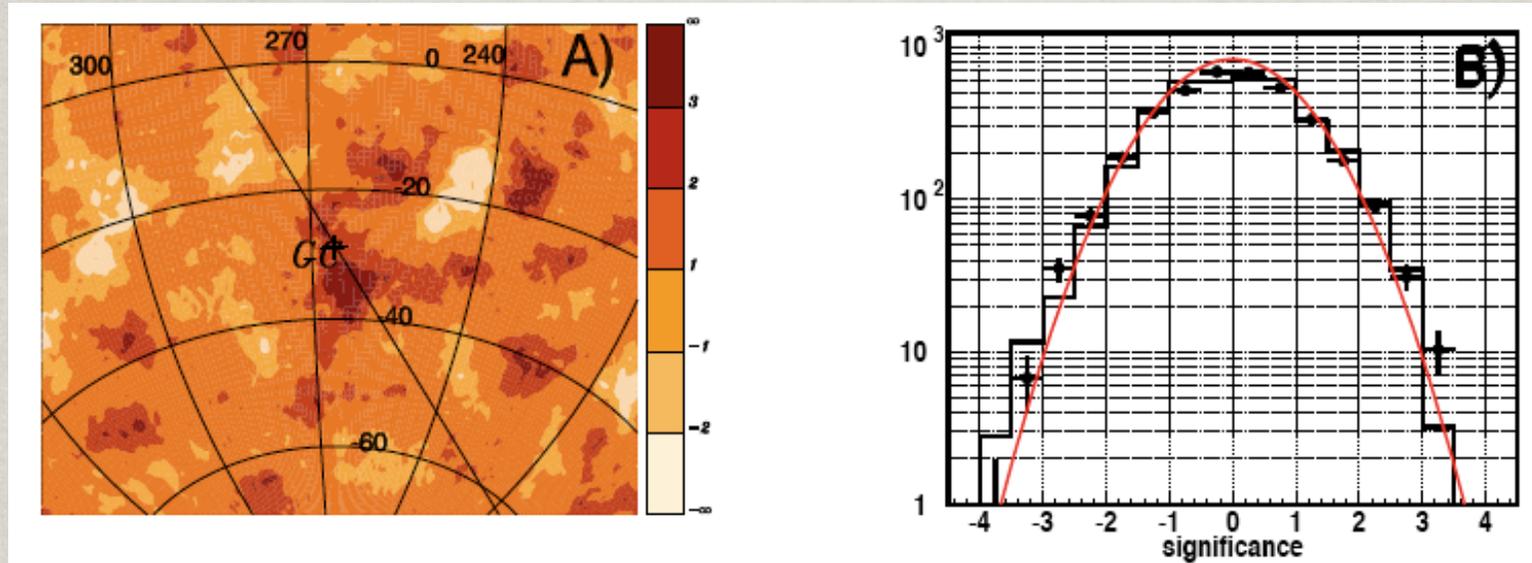
(F. Aharonian et. al Astron. and Astrophys. 425 L13)



At EeV energies, neutrons from the GC could reach Earth!

SEARCHES FOR GC UHECRS EXCESSES

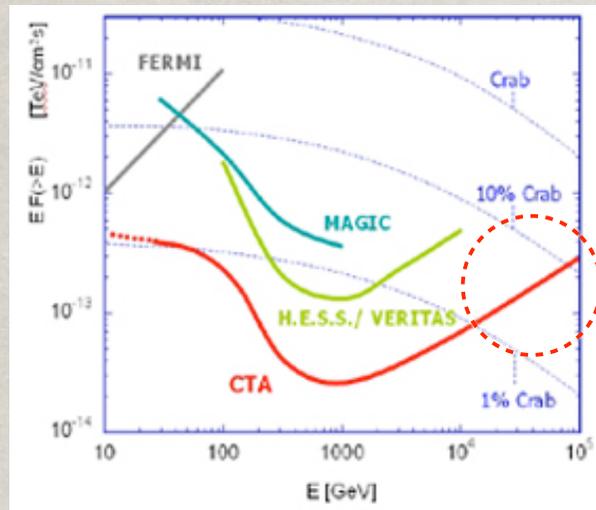
No significant excess found in the GC at EeV energies



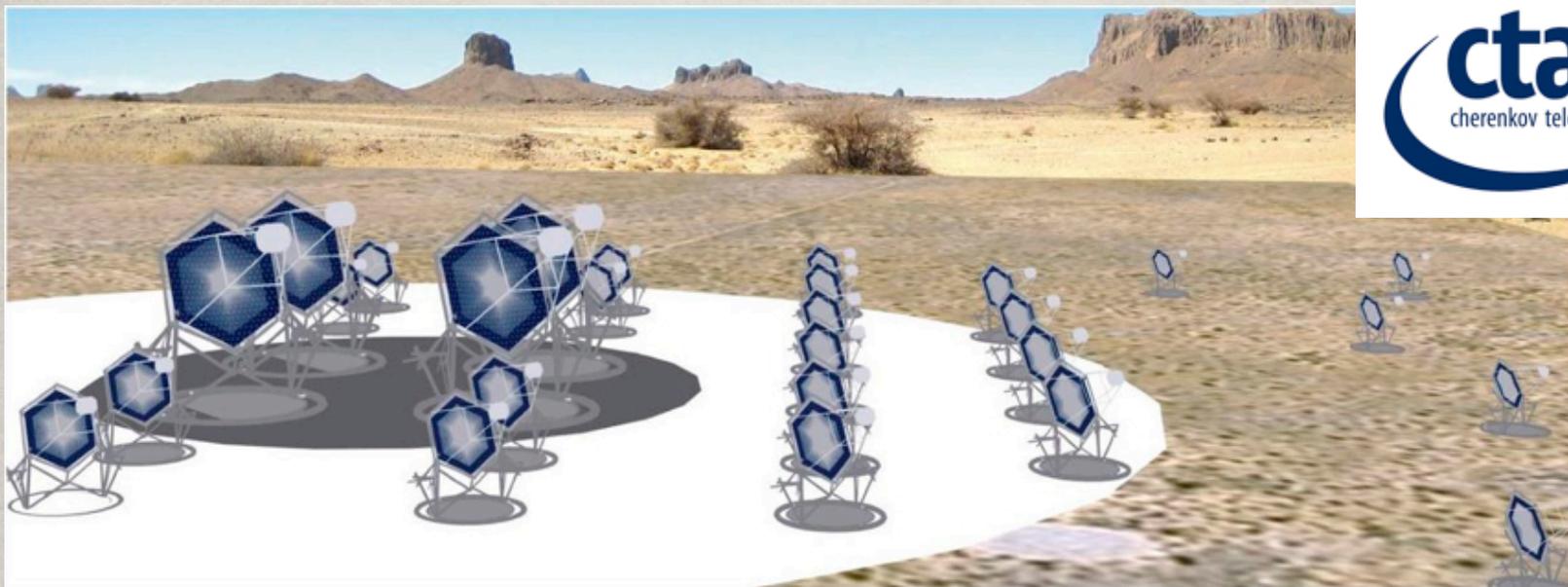
Careful study of systematic effects in the Observatory coverage: weather, detector size & trigger

search	window size	n_{obs}/n_{exp}	n_s^{95}	Φ_s^{95} ($\text{km}^{-2} \text{yr}^{-1}$)
extended	10° (TH)	$1463/1365 = 1.07 \pm 0.04(\text{stat}) \pm 0.01(\text{syst})$		
	20° (TH)	$5559/5407 = 1.03 \pm 0.02(\text{stat}) \pm 0.01(\text{syst})$		
point-like	0.8° (G)	$16.9/17.0 = 0.99 \pm 0.17(\text{stat}) \pm 0.01(\text{syst})$	5.6	0.018κ

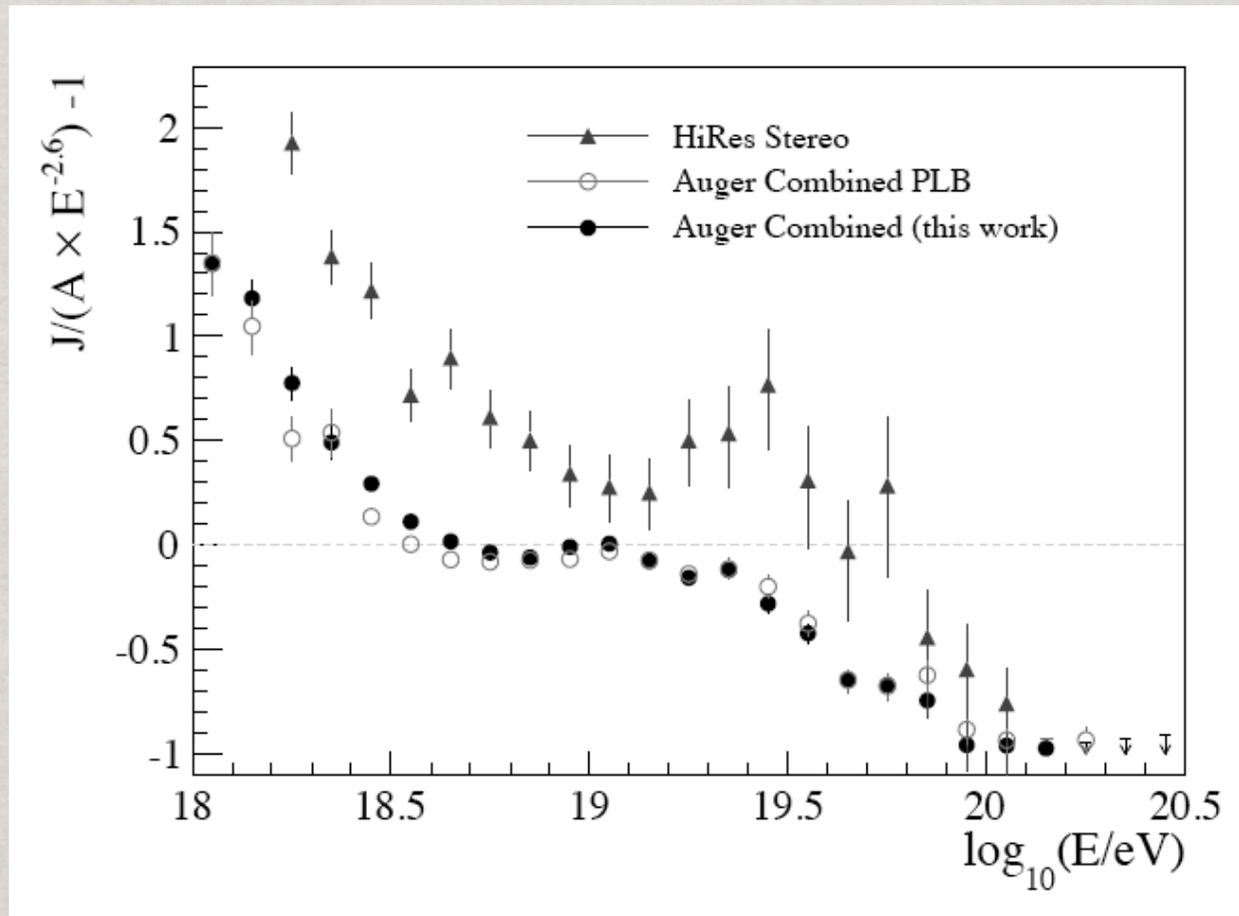
CTA CAN HELP US!



With enhanced sensitivity and angular resolution at high energies ($\sim 10^{14}$ eV), CTA can look deeper into the GC looking for gamma-ray emissions.

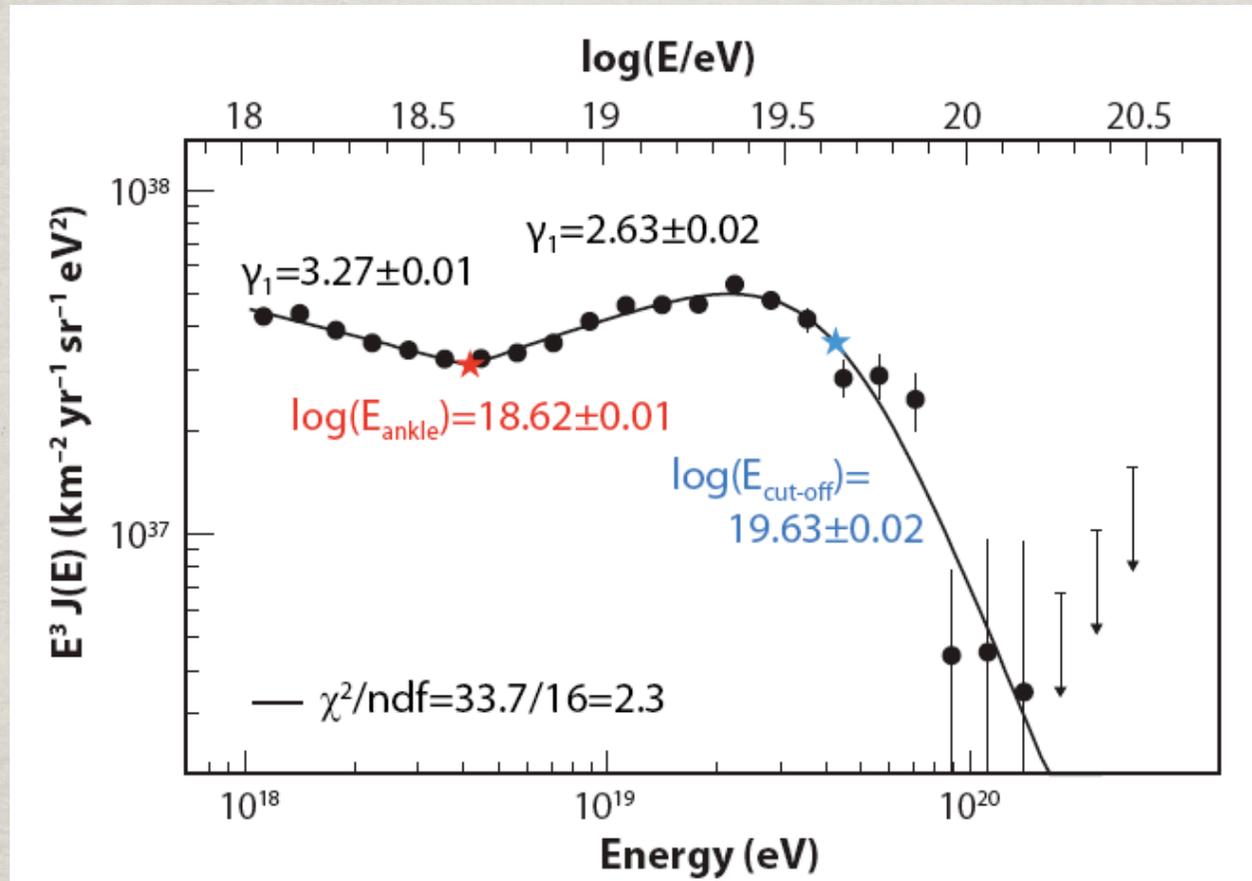


SPECTRUM



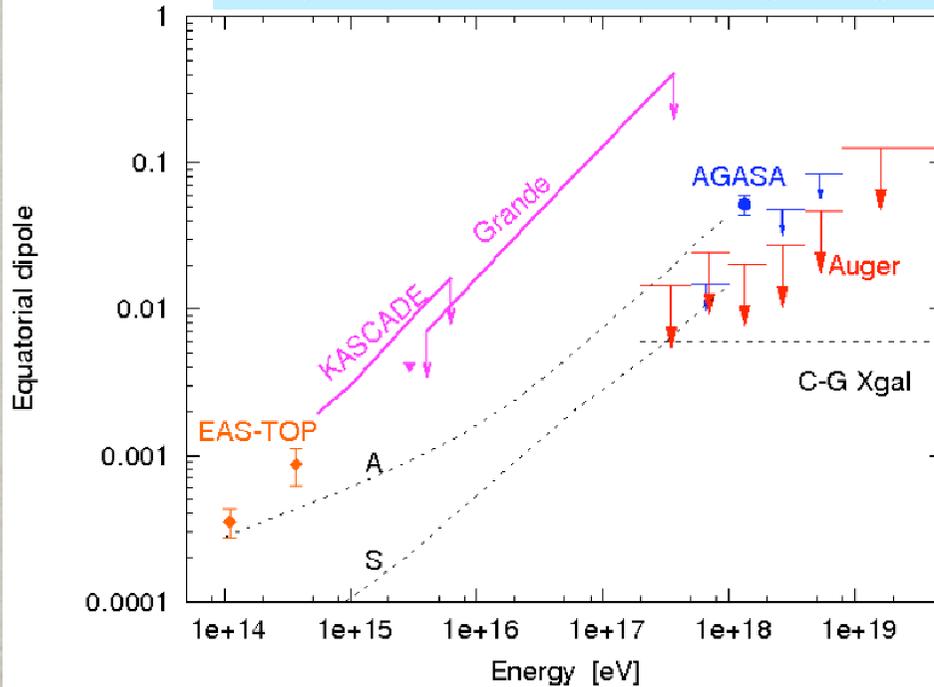
Ankle and flux suppression at highest energies clearly seem
22% of systematic uncertainty in the energy scale

SPECTRUM



LARGE SCALE ANISOTROPIES

No significant effect observed in the dipole amplitude



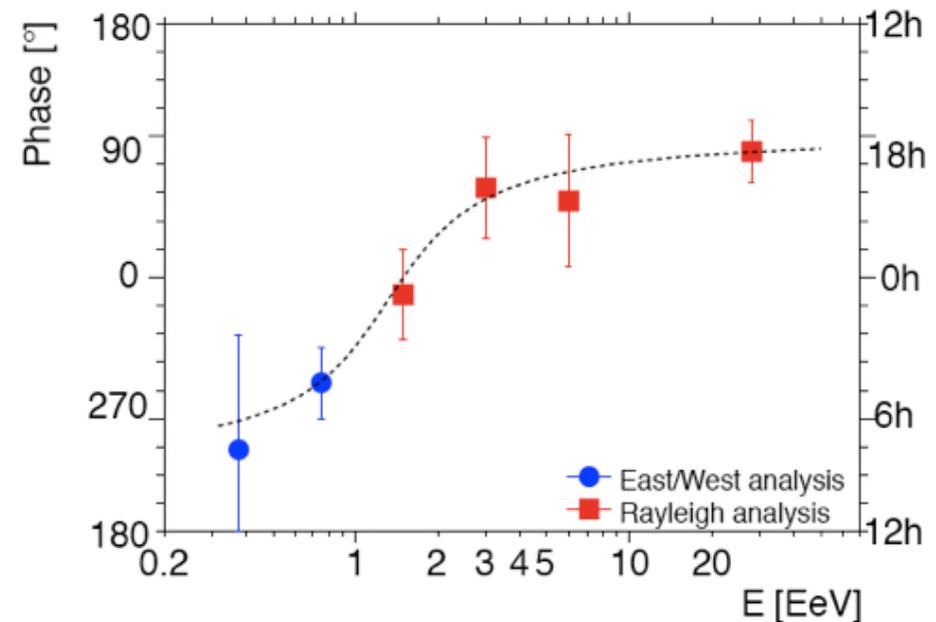
Generalized Rayleigh analysis

$$a = \frac{2}{\mathcal{N}} \sum_{i=1}^{\mathcal{N}} w_i \cos \alpha_i, \quad b = \frac{2}{\mathcal{N}} \sum_{i=1}^{\mathcal{N}} w_i \sin \alpha_i,$$

Amplitude and phase:

$$r = \sqrt{a^2 + b^2}, \quad \varphi = \arctan \frac{b}{a}.$$

phase flips from galactic to anti-galactic center

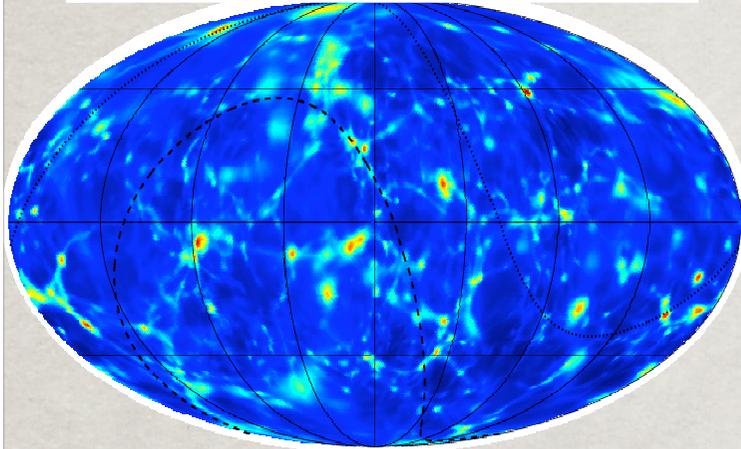


Weather and exposure corrections applied

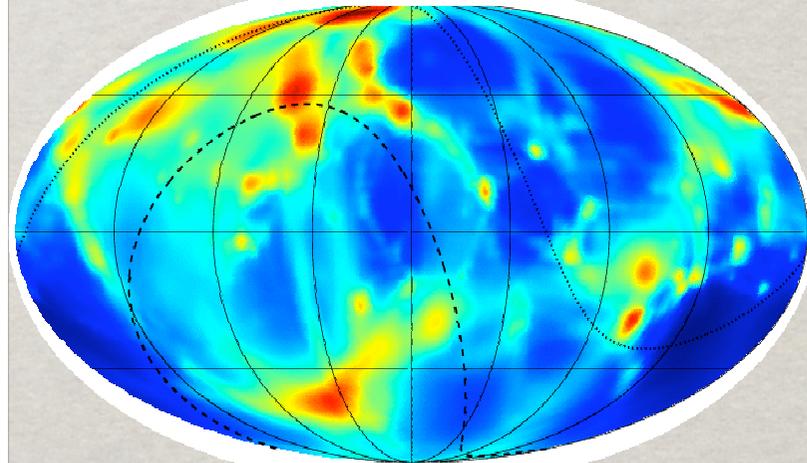
Different methods applied in order to take into account trigger inefficiencies at low energies ($E < 1$ EeV)

IF THE GZK MECHANISM IS IN PLACE...

Universe's low energy portrait

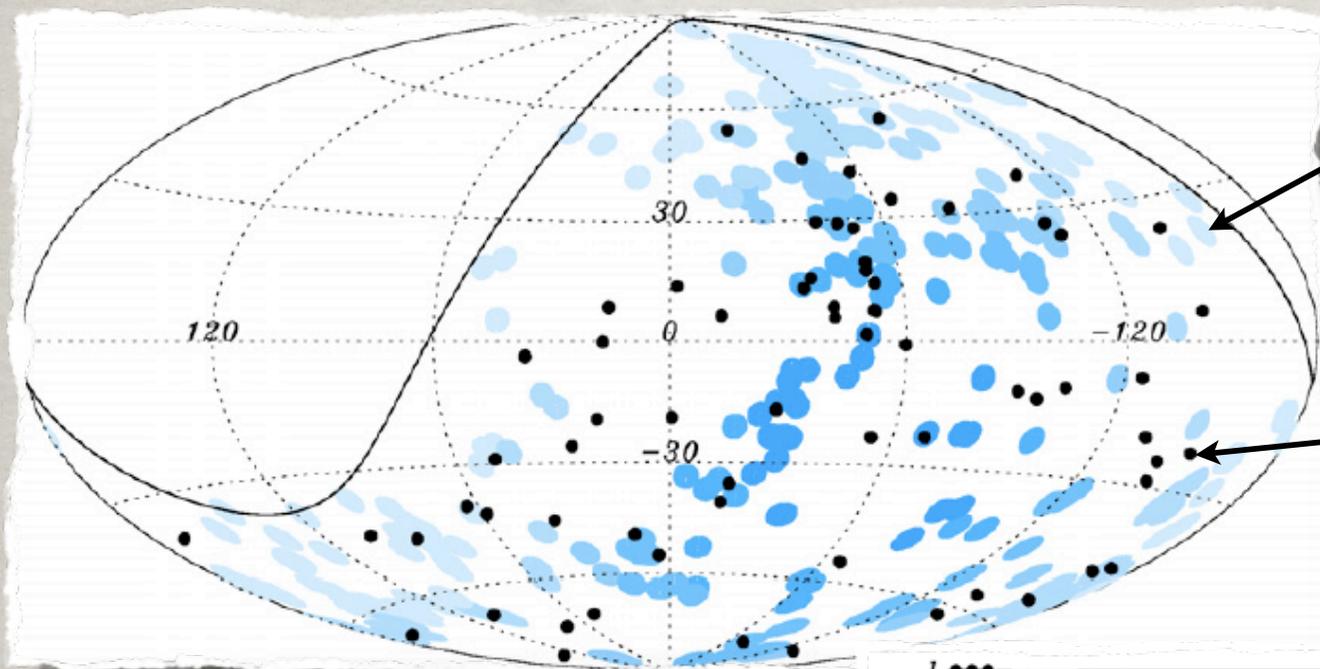


Universe's high energy portrait



E. Armengaud

CORRELATIONS WITH EXTRAGALACTIC SOURCES



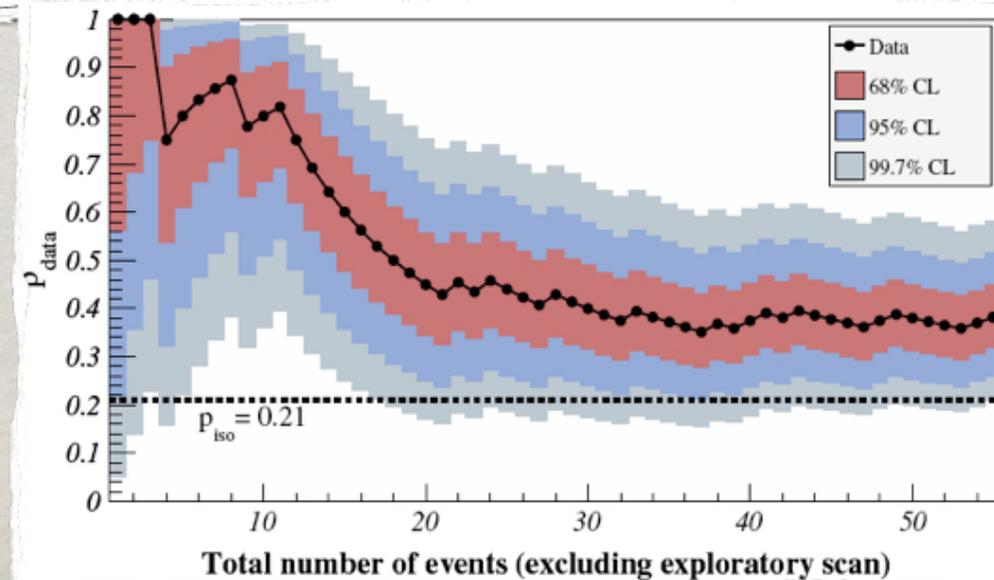
3.1° window
around AGNs up
to 75 Mpc

Auger events above
55 EeV

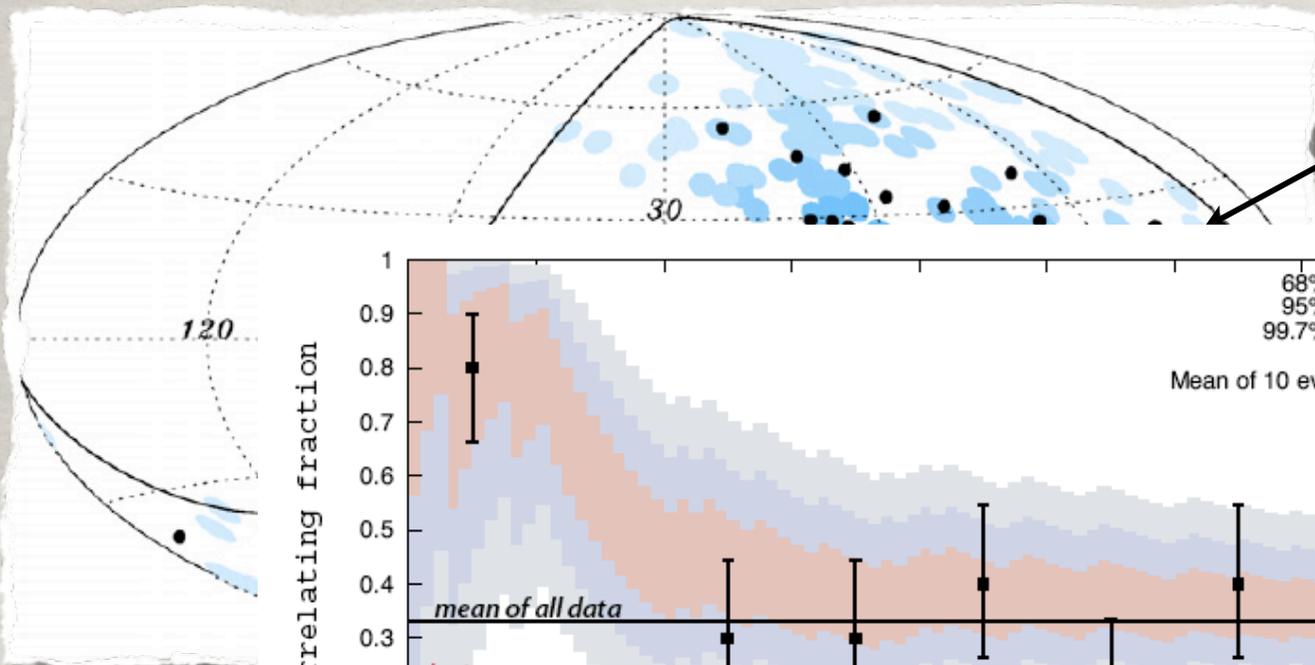
Correlation parameters defined a priori

Correlation signal became stable...

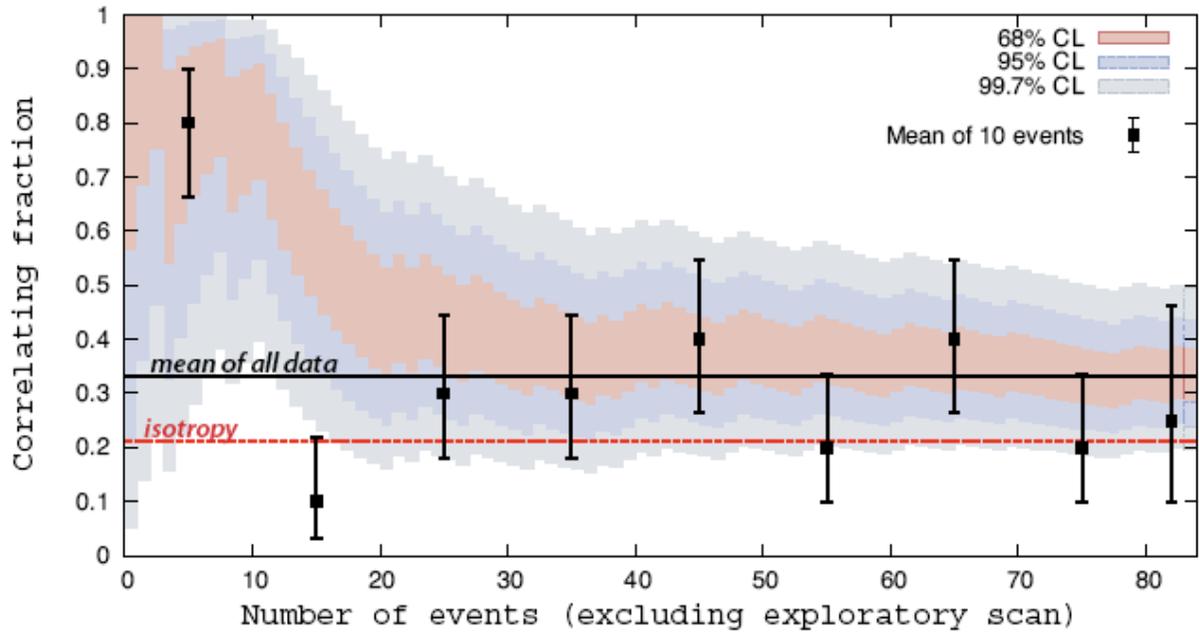
...and arrival directions above 55 EeV are **not consistent** with an isotropic sky.



CORRELATIONS WITH EXTRAGALACTIC SOURCES



3.1° window around AGNs up to 75 Mpc

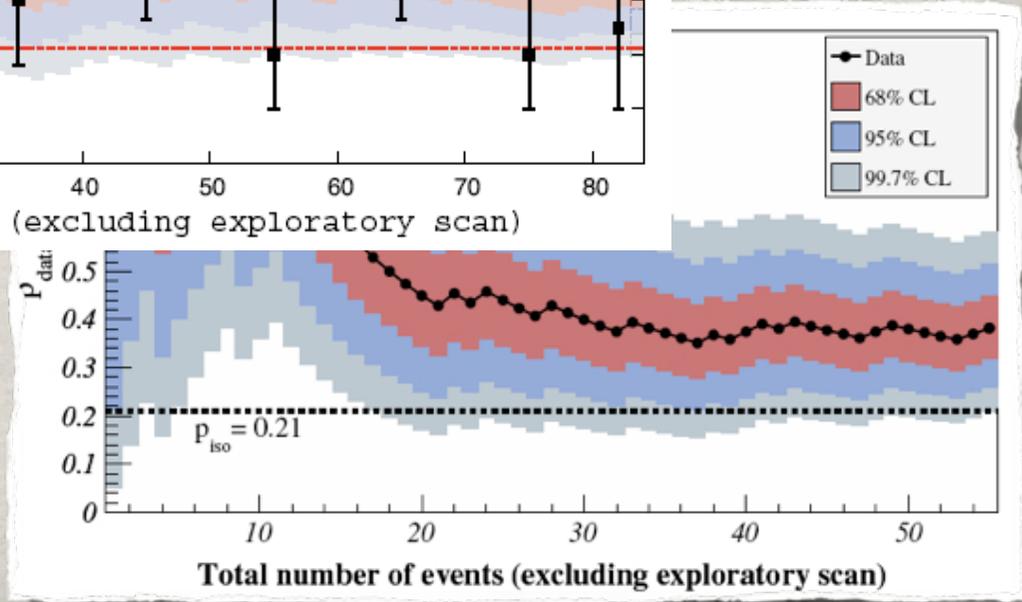


events above 55 EeV

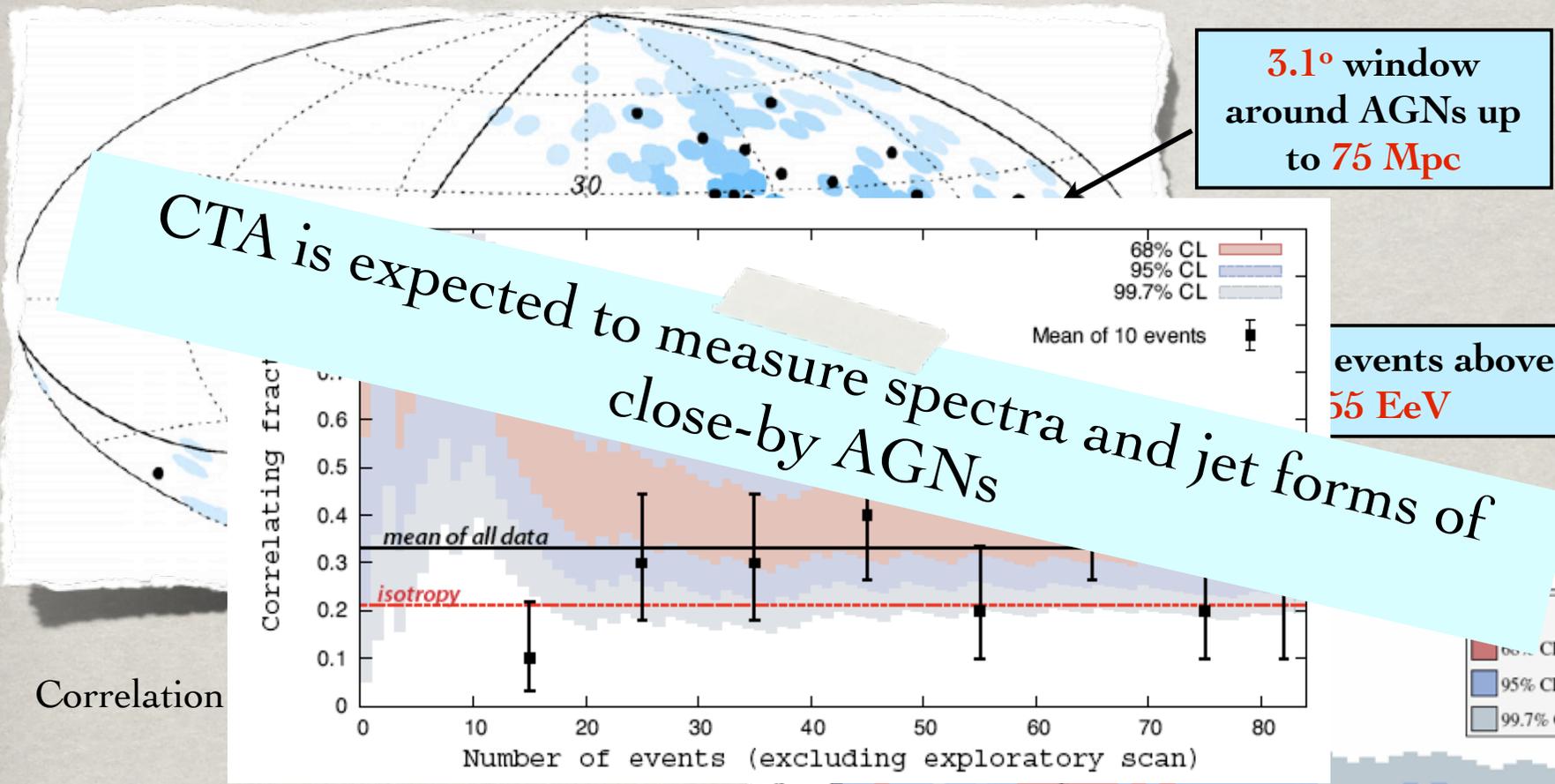
Correlation

Correlation signal became stable...

...and arrival directions above 55 EeV are not consistent with an isotropic sky.



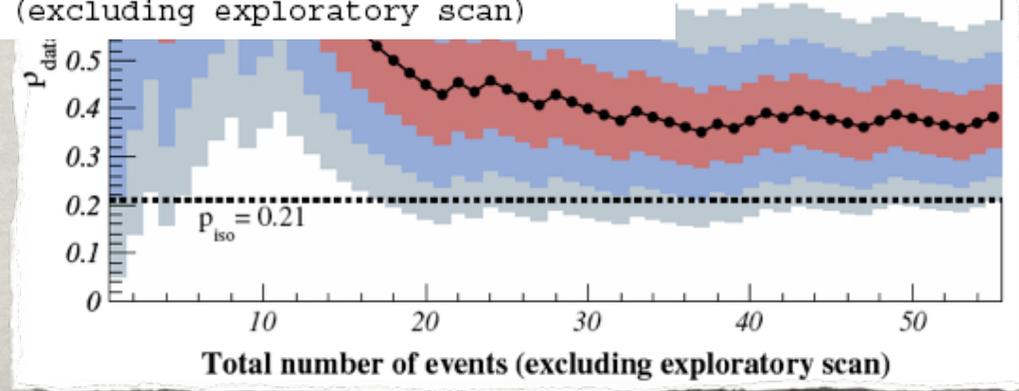
CORRELATIONS WITH EXTRAGALACTIC SOURCES



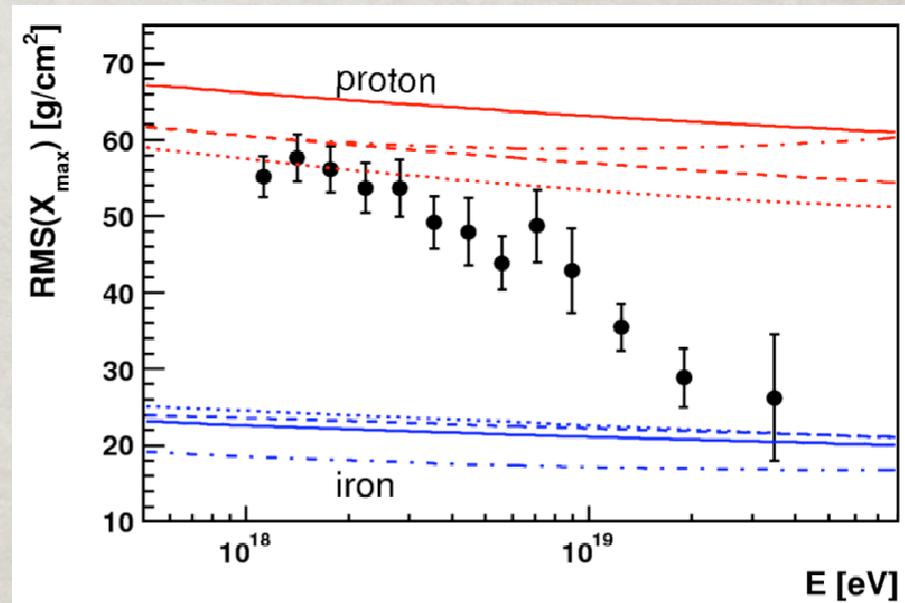
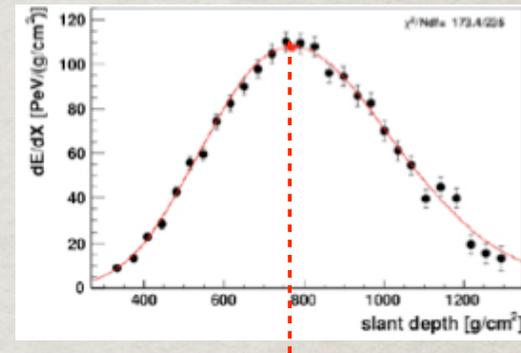
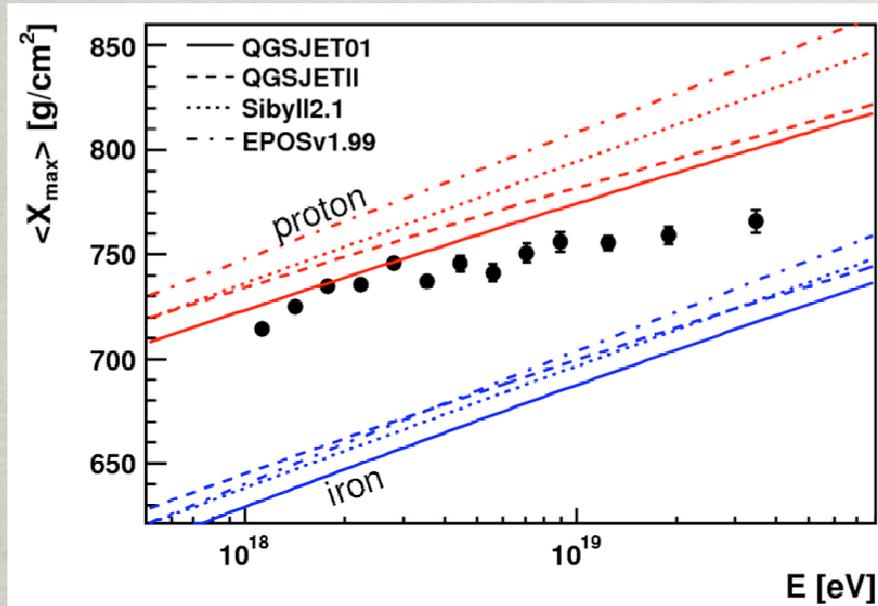
Correlation

Correlation signal became stable...

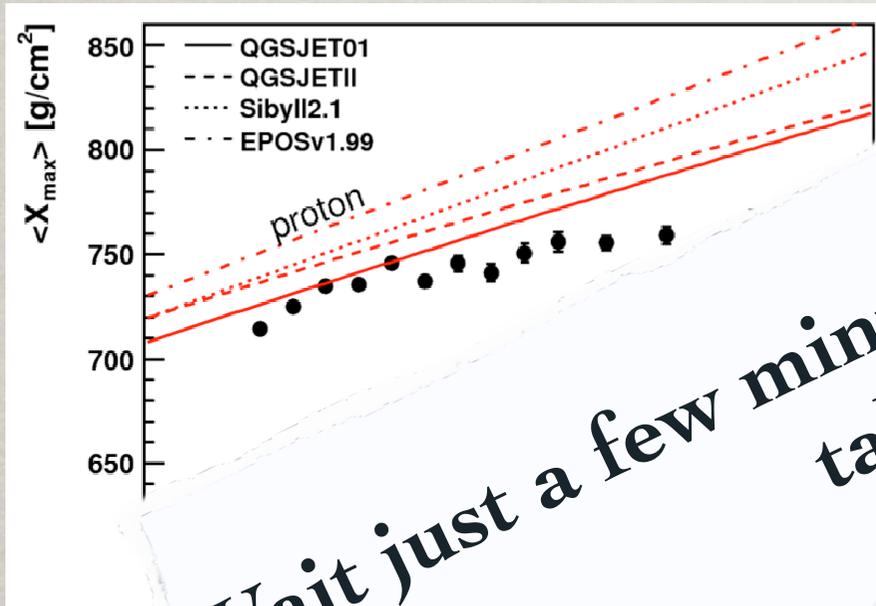
...and arrival directions above 55 EeV are not consistent with an isotropic sky.



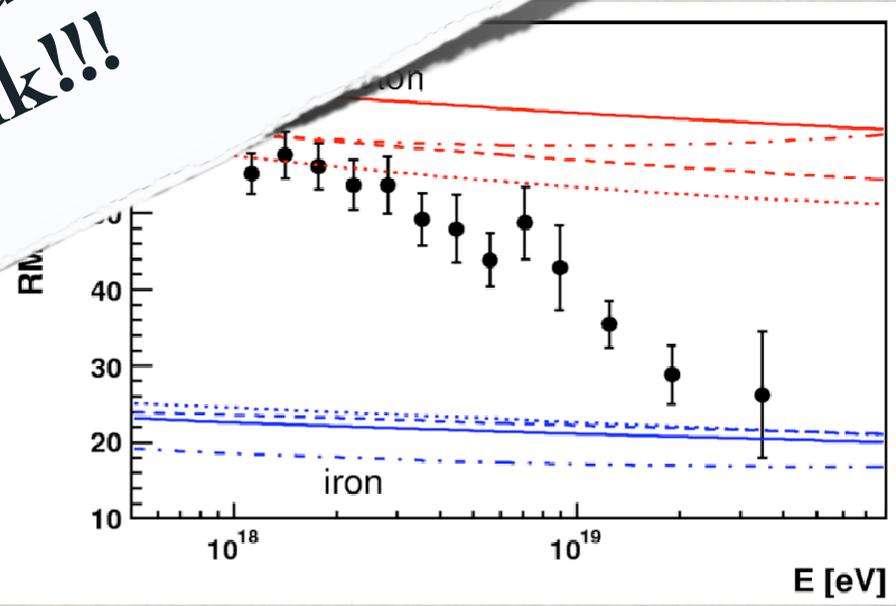
CHEMICAL COMPOSITION



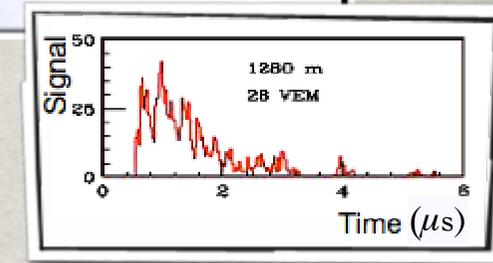
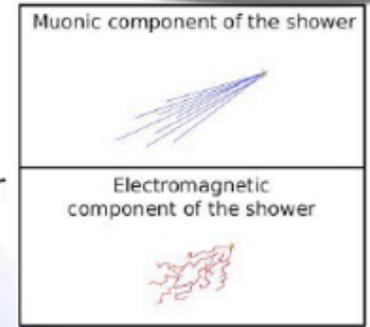
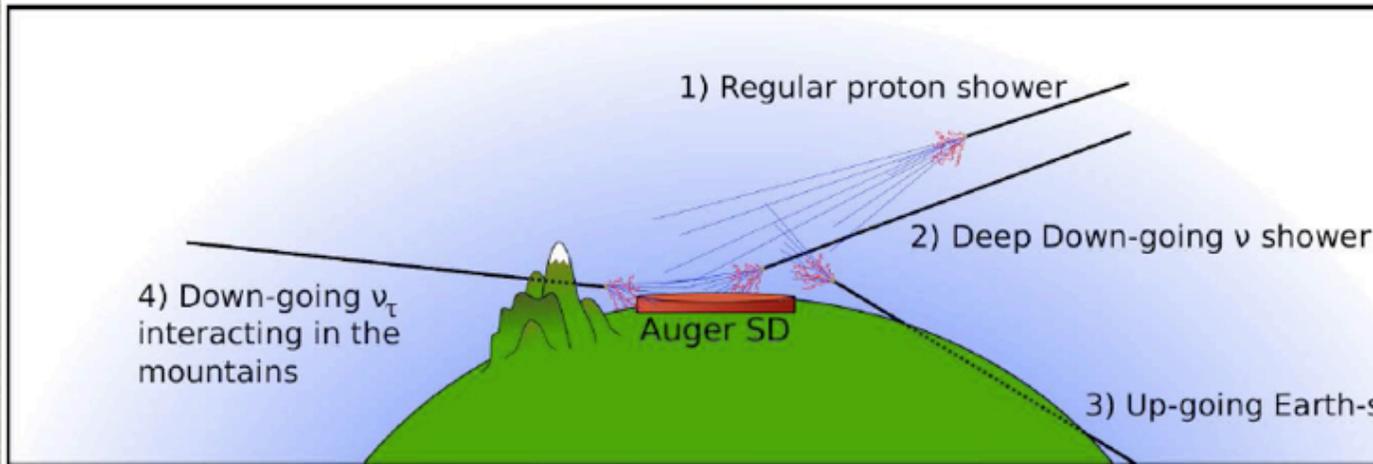
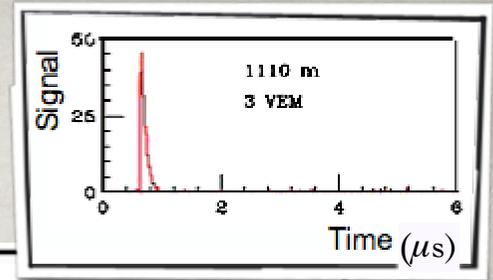
CHEMICAL COMPOSITION



Wait just a few minutes for M. Unger's talk!!!



NEUTRINOS

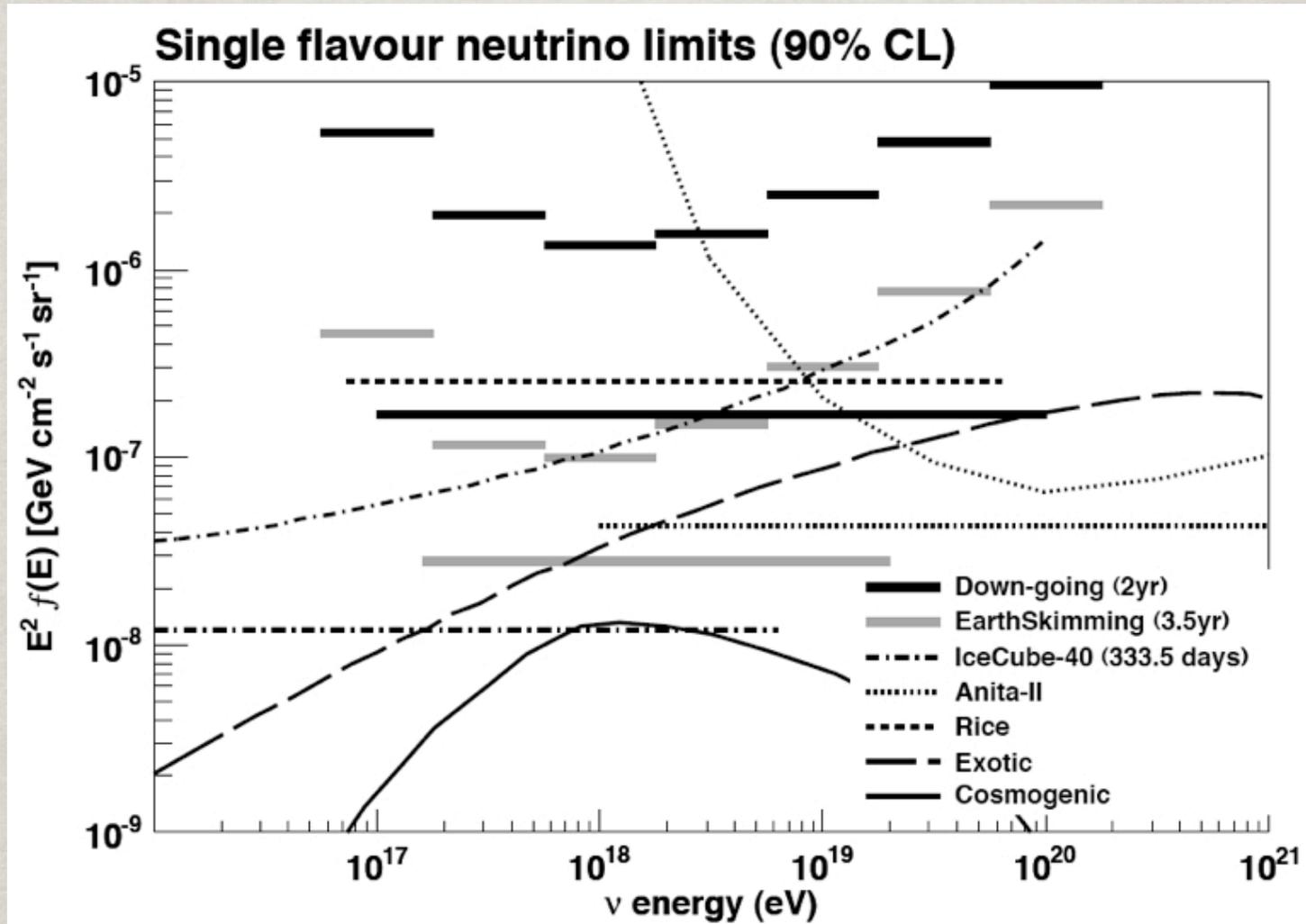


25ns time resolution of FADC traces allow for a distinction between electromagnetic and muonic shower fronts

	Earth-skimming	Down-going
Inclined Showers	$N^\circ \text{ of Stations} \geq 3$ $L/W > 5$ $0.29 \frac{m}{ns} < V < 0.31 \frac{m}{ns}$ $RMS(V) < 0.08 \frac{m}{ns}$ -	$N^\circ \text{ of Stations} \geq 4$ $L/W > 3$ $V < 0.313 \frac{m}{ns}$ $\frac{RMS(V)}{V} < 0.08$ $\theta_{rec} > 75^\circ$
Young Showers	ToT fraction > 0.6	Fisher discriminator based on AoP

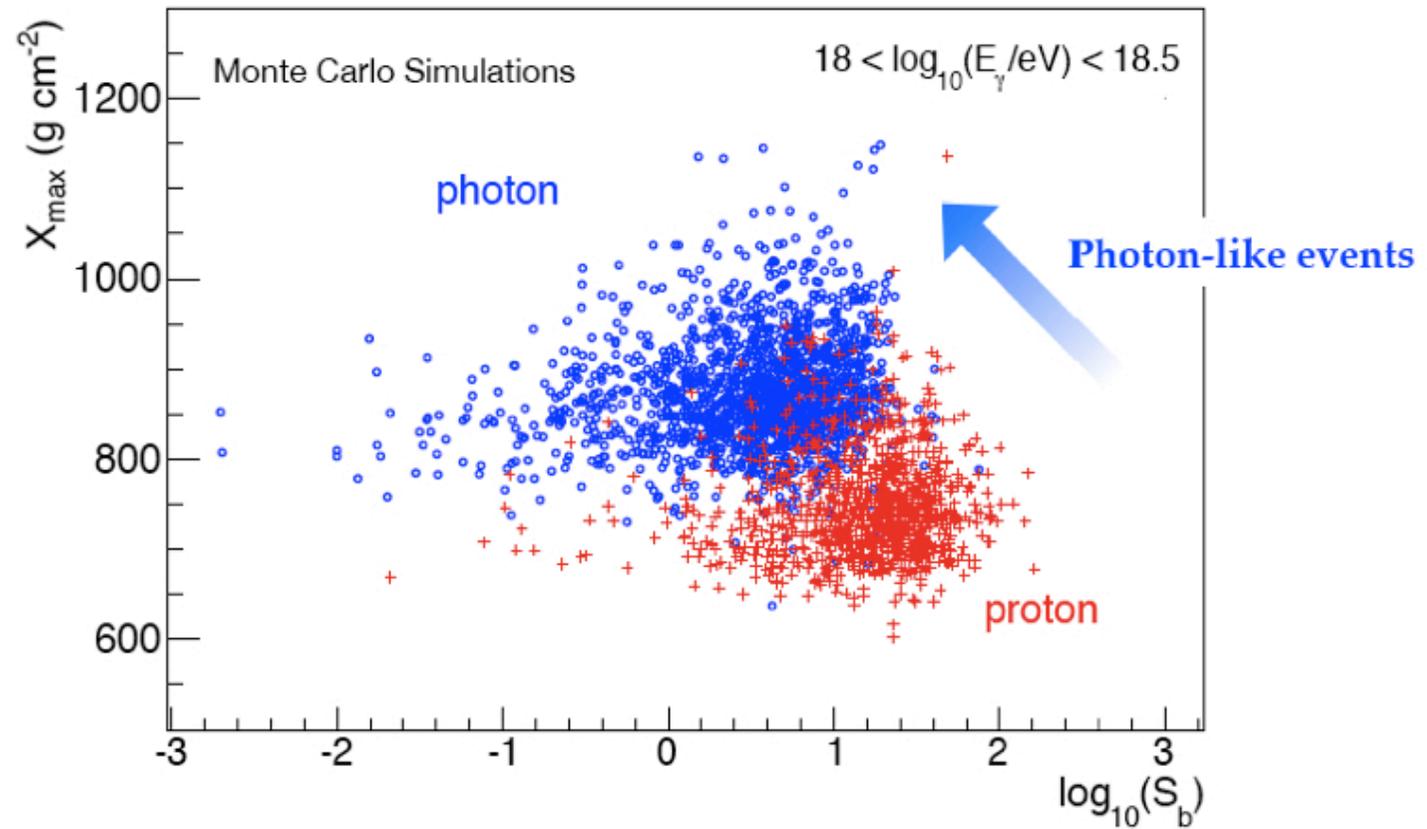
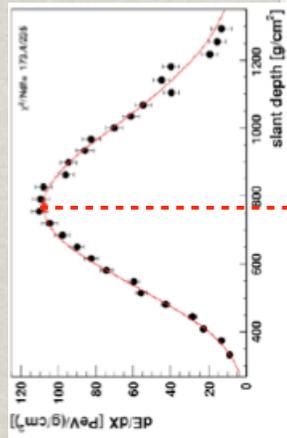
No neutrino candidates found!

NEUTRINOS



PHOTONS

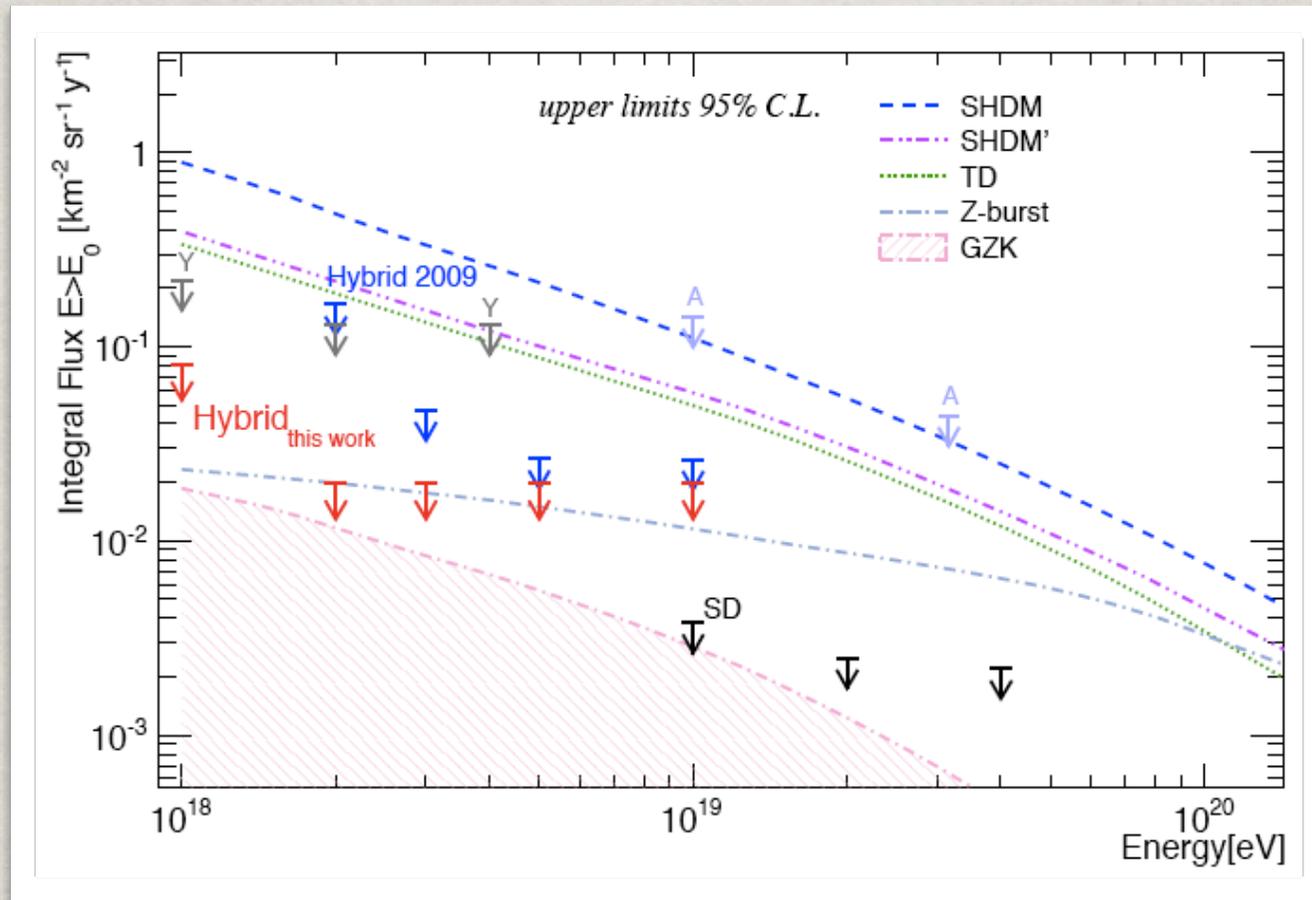
photon showers develop deeper in the atmosphere
have smaller number of secondary muons
smaller footprint on ground



powerful combination of FD and SD observables

$$S_b = \sum_i S_i \left(\frac{R_i}{1000} \right)^4$$

PHOTONS



No photon candidates identified above 10^{18} eV

SUMMARY

- ✿ The Auger Observatory has been continuously taking data.
- ✿ Spectrum above 10^{18} eV measured both with SD and in hybrid mode. Ankle and high energy suppression identified.
- ✿ No significant excess observed from the Galactic Center at EeV energies.
- ✿ Large scale anisotropy studies show interesting behavior of the equatorial dipole phase.
- ✿ Stringent limits on both photons and neutrinos above 10^{18} eV were imposed, excluding many top-down models. Approaching the flux regions for cosmogenic photons and neutrinos.
- ✿ With VHE photon measurements, CTA can bring valuable information on sources and production mechanism of UHECRs.

See also:

M. Unger talk on UHECRs chemical composition

T. Suomijärvi talk on Auger performance and enhancements