

Results from the Pierre Auger Observatory

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PIERRE
AUGER
OBSERVATORY



MU Days, November 2021



Photo credit: Steven Saffi

Hybrid Observatory

Fluorescence Detector

27 telescopes in 4 locations

Measures the fluorescence light produced by extensive air showers



3000 km²

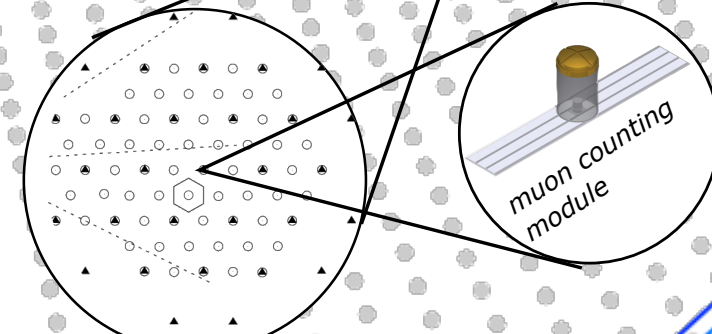
Surface Detector

1660 water-Cherenkov detectors

Measures the footprint of extensive air showers reaching Earth's surface

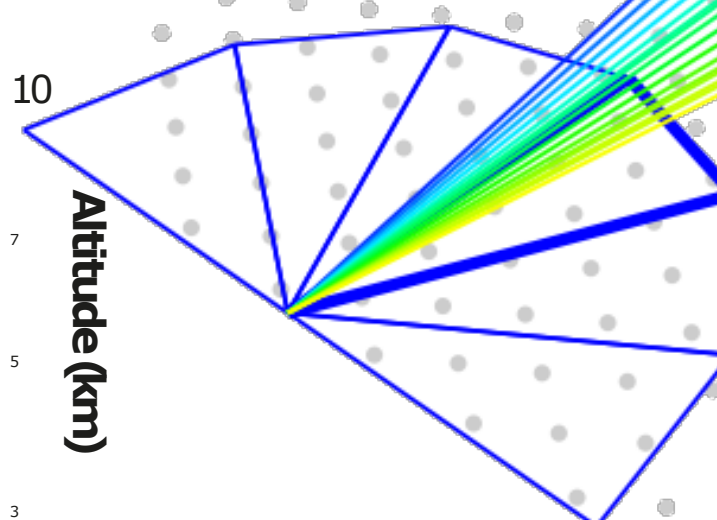


Underground Muon Detector



Denser arrays

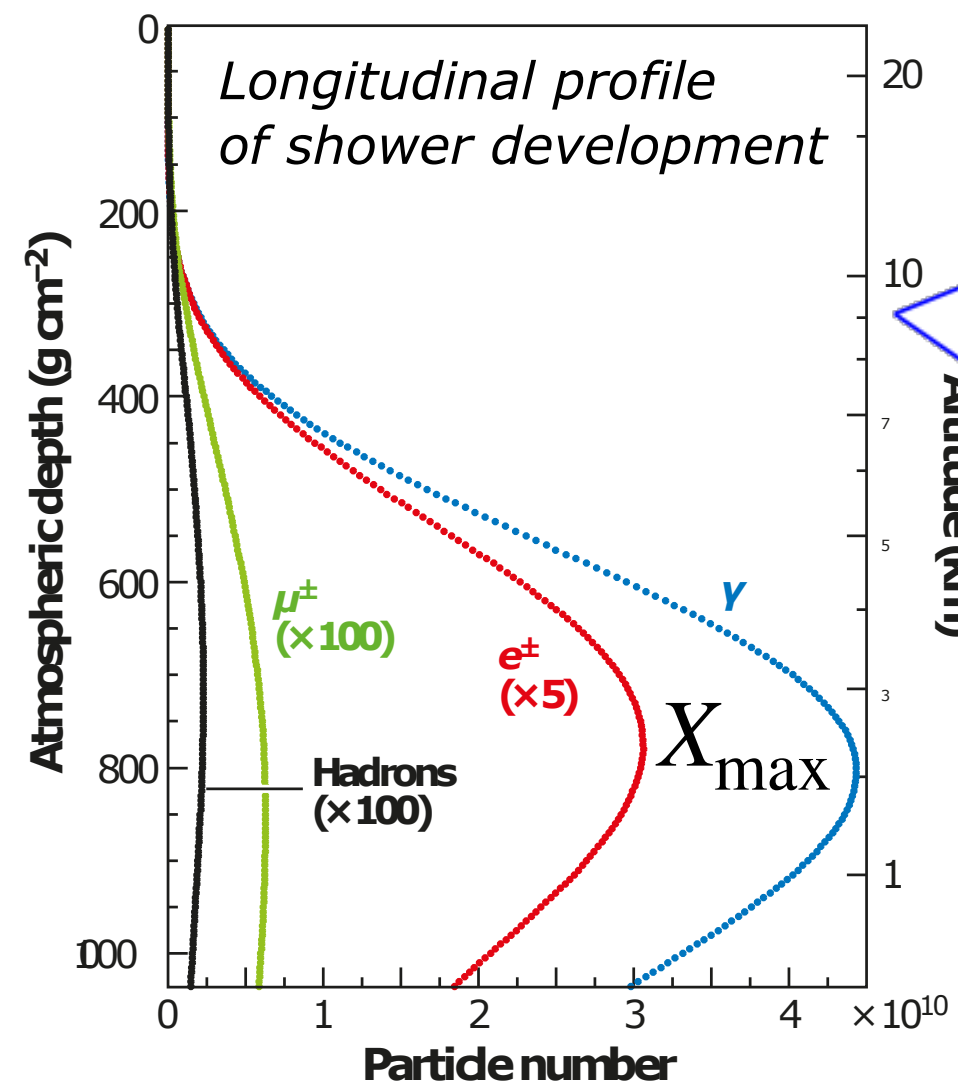
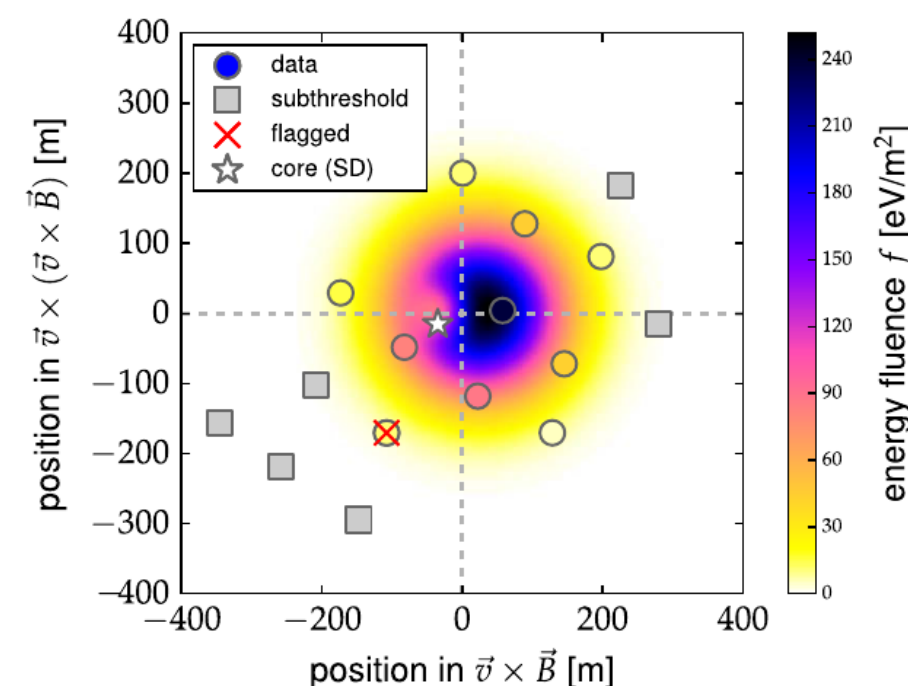
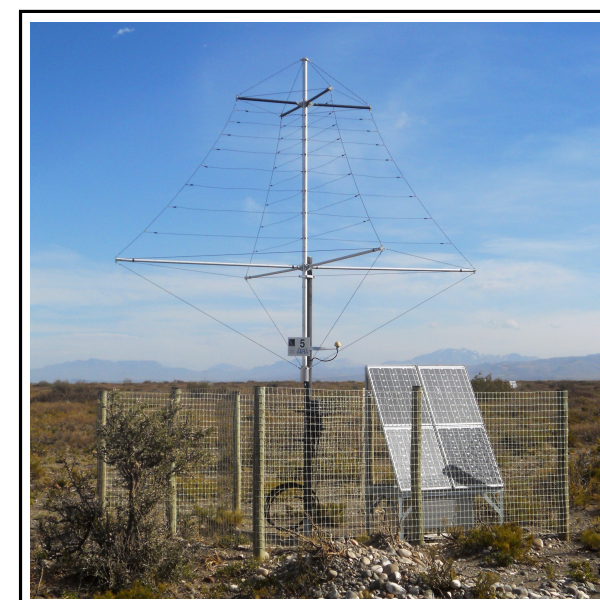
750 m, 433 m spacing



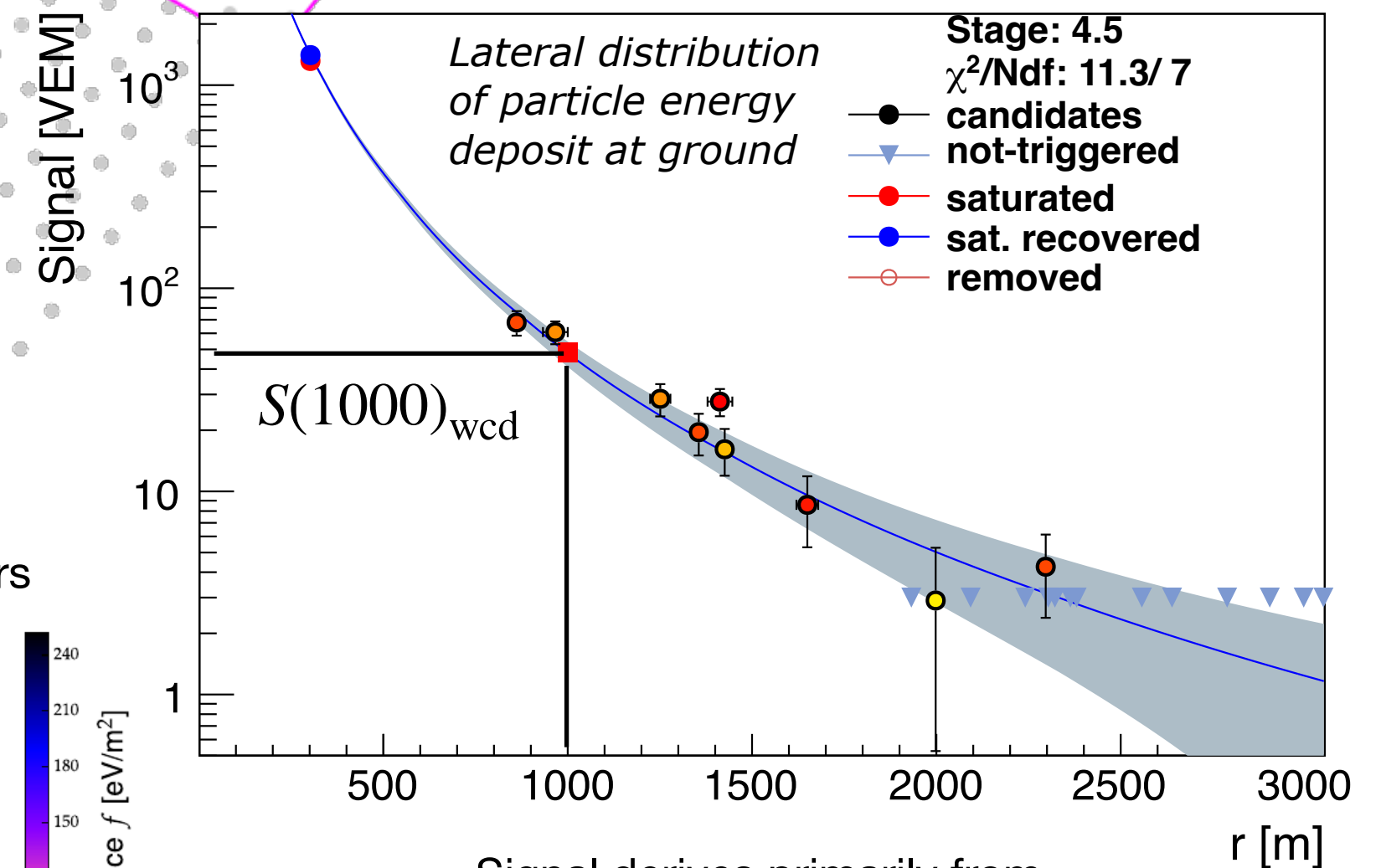
Radio Detector

153 autonomous radio stations on a 17 km² grid

Measures the radiation energy released by the electromagnetic cascade of extensive air showers



$$E_{\text{cal}} = \int_0^{\infty} \left(\frac{dE}{dX} \right)_{\text{obs}} dX$$



Signal derives primarily from electrons, photons, and muons

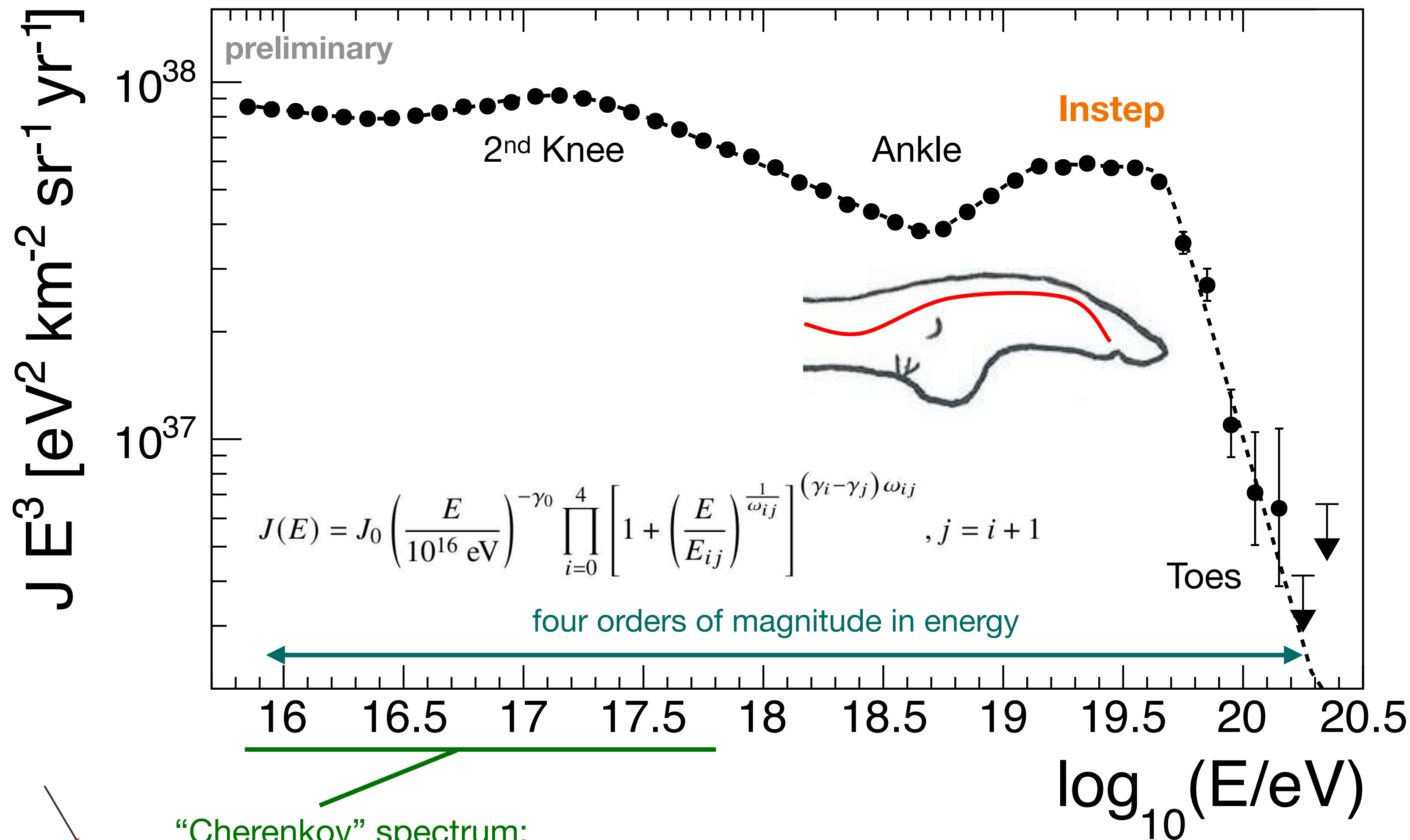
$$E_{\text{rec}} = f(S_{1000}, \theta)$$

Energy spectrum

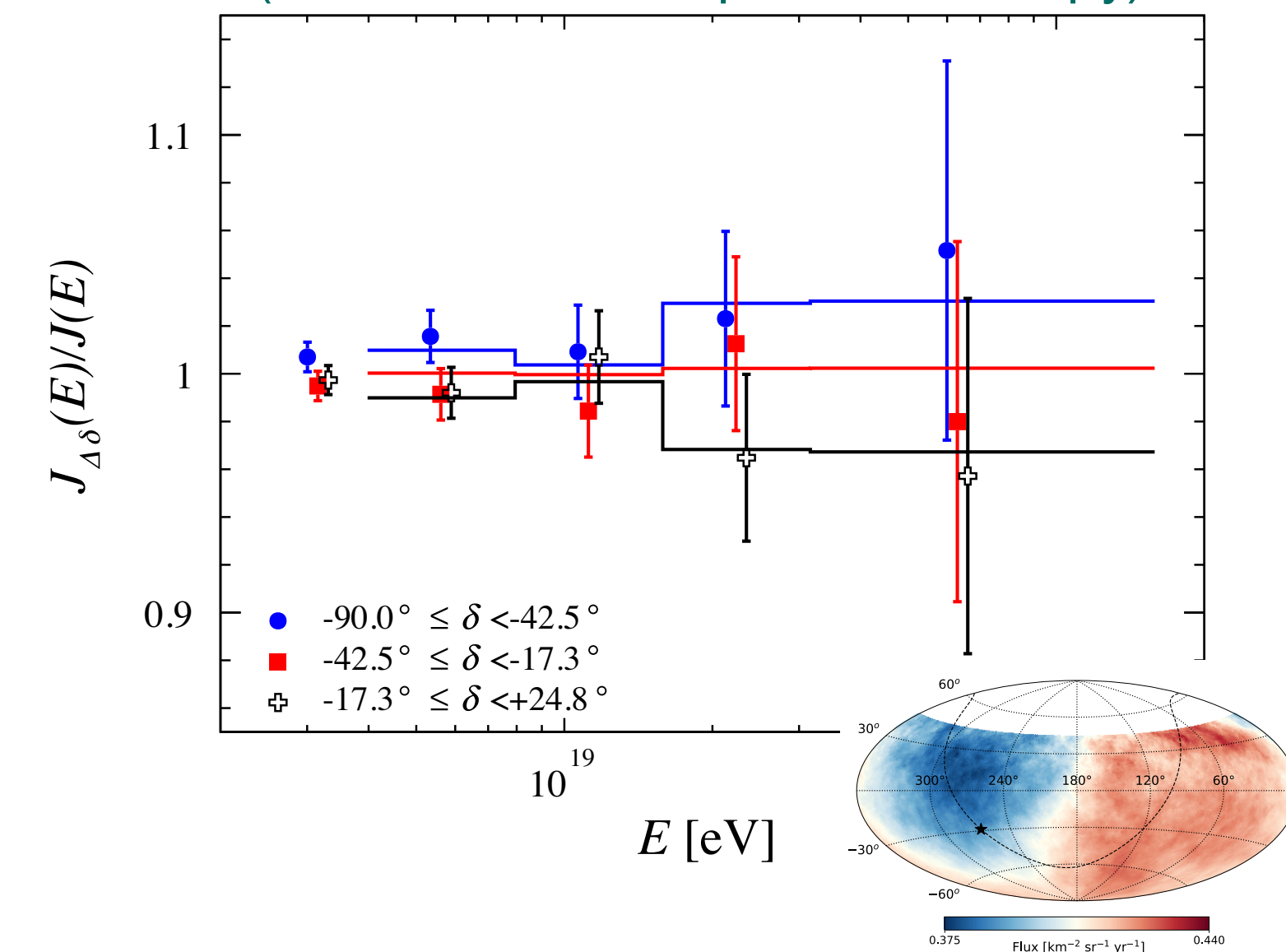
Phys. Rev. Lett. 125 121106 (2020)

Phys. Rev. D102 062005 (2020)

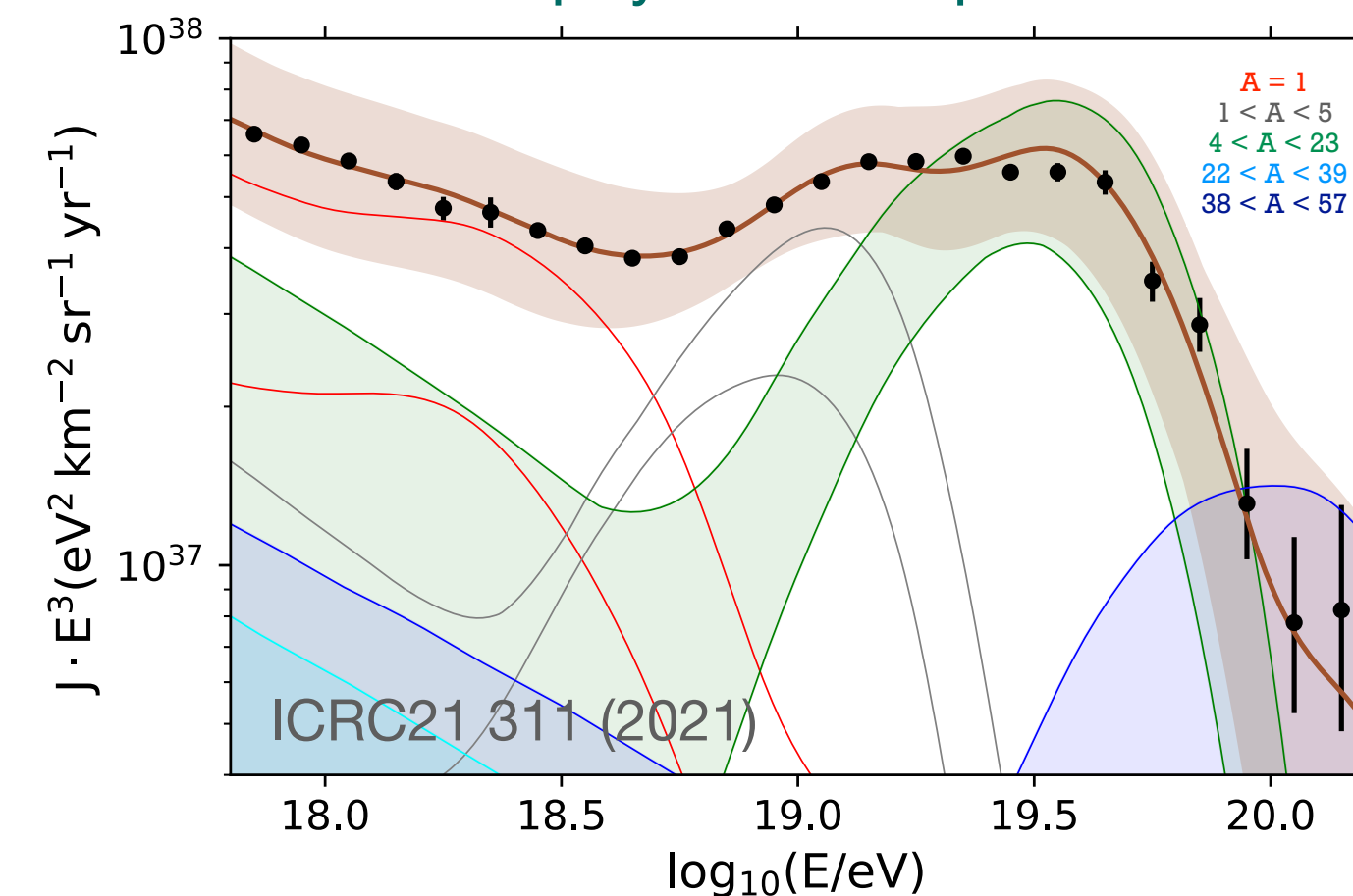
ICRC21 324 (2021)



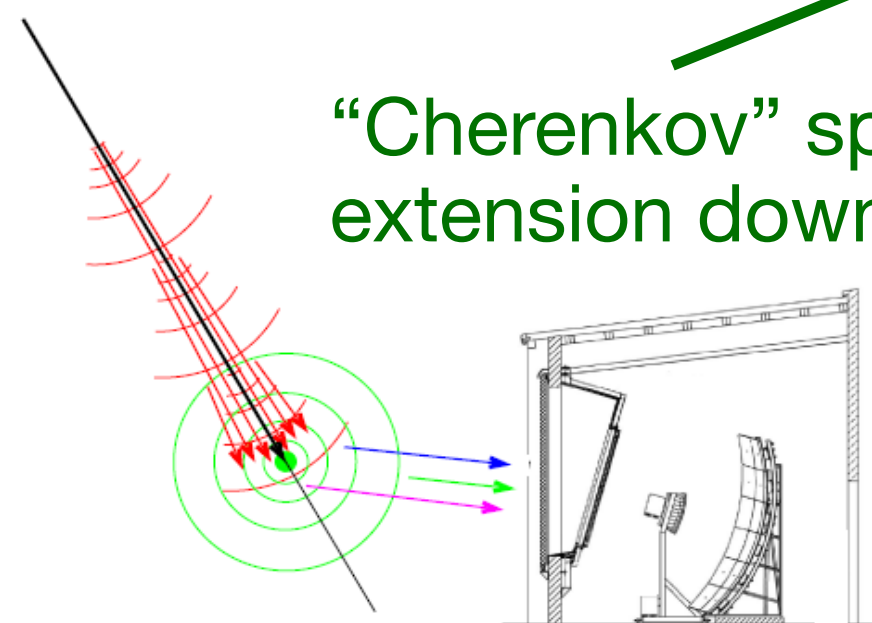
Slight declination dependence
(consistent with dipolar anisotropy)



Astrophysical interpretation

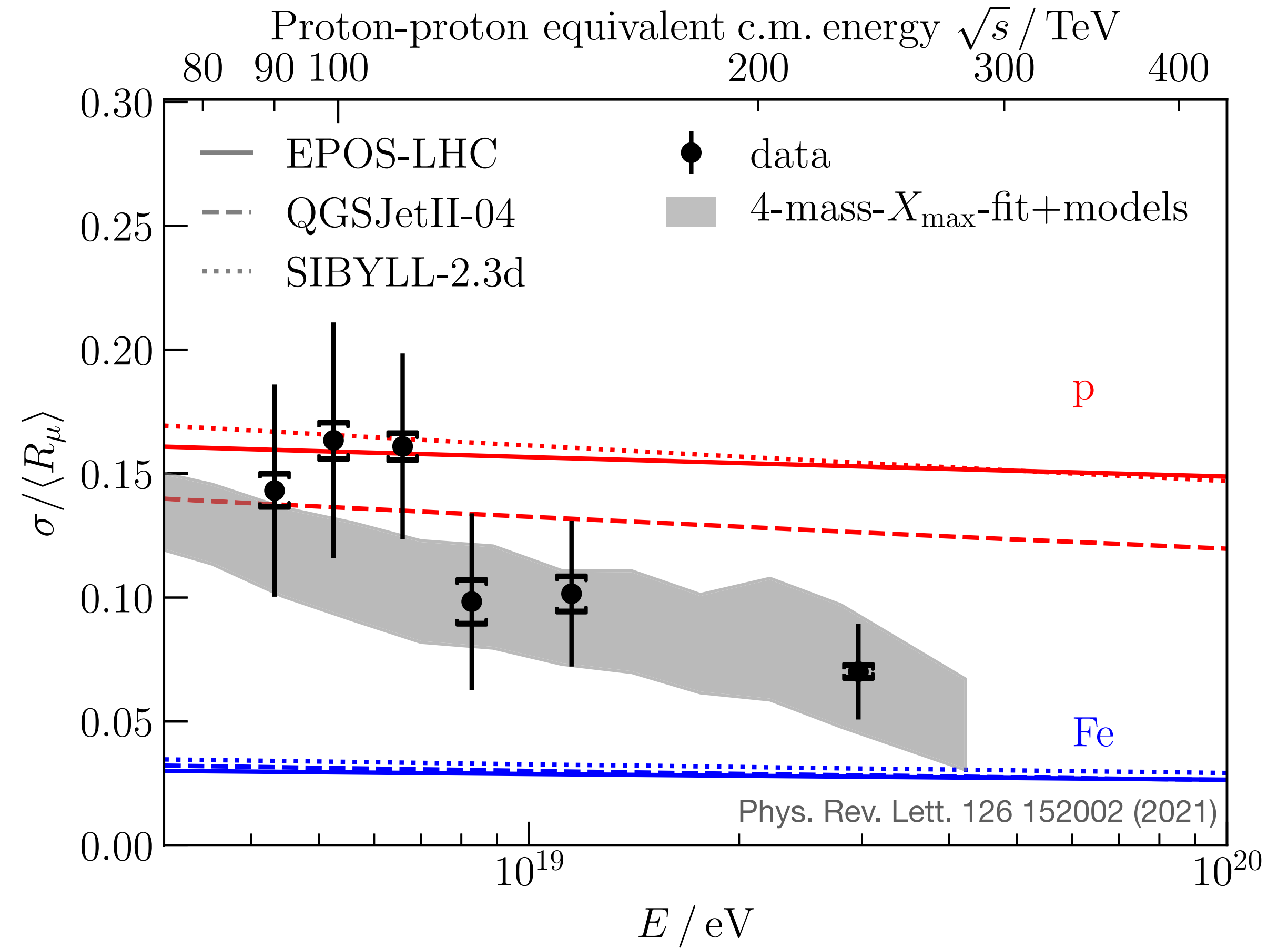
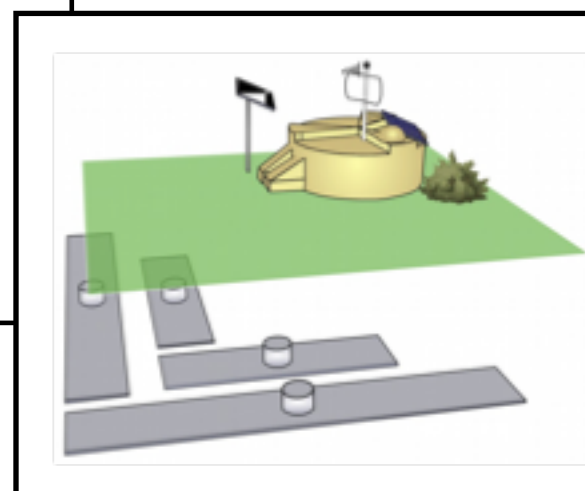
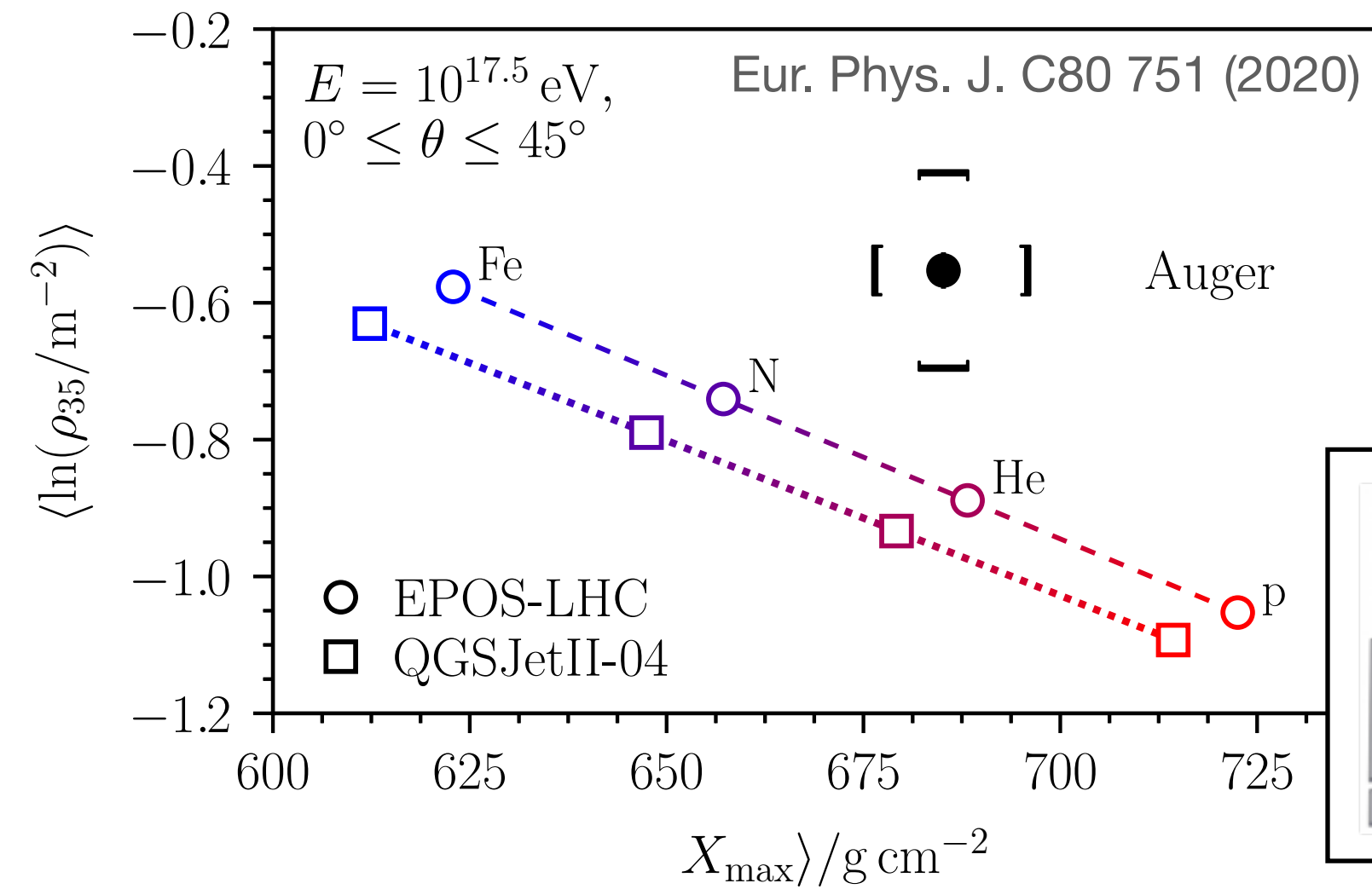
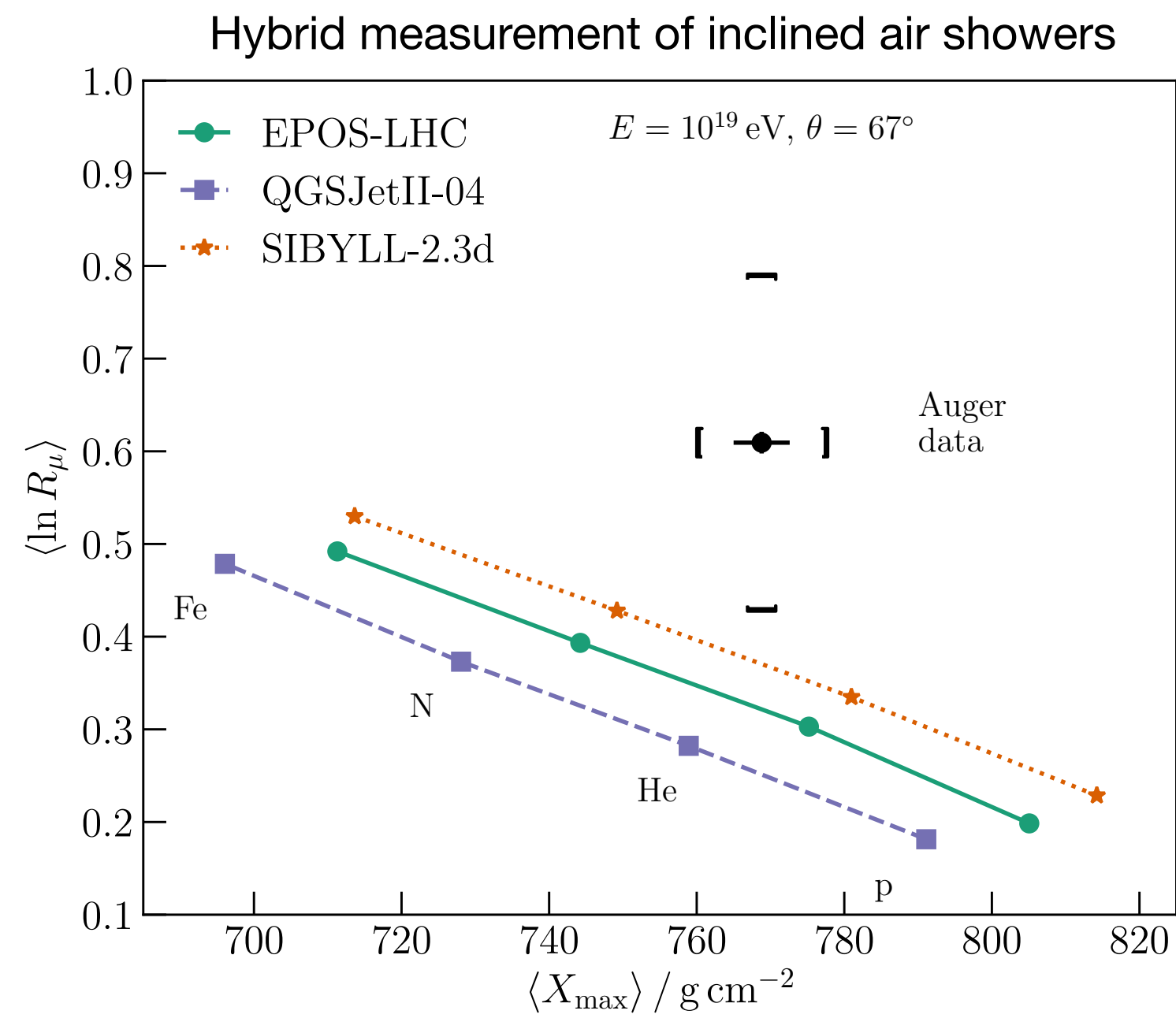


“Cherenkov” spectrum:
extension down to 10^{16} eV

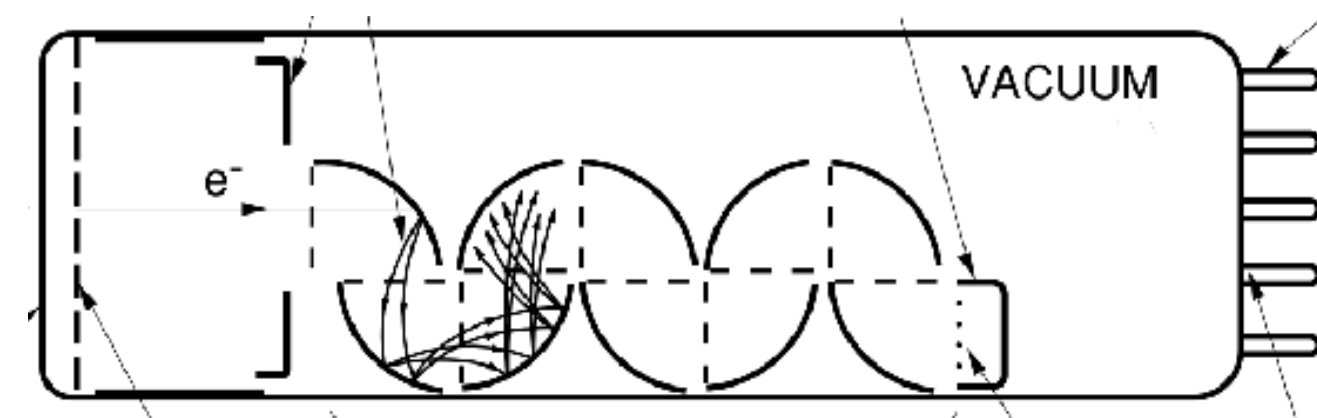


- Composite of 5 different measurements (but common energy scale)
- Corrected for the effects of resolution
- Unexpected “instep” inflection point

Hadronic Interactions

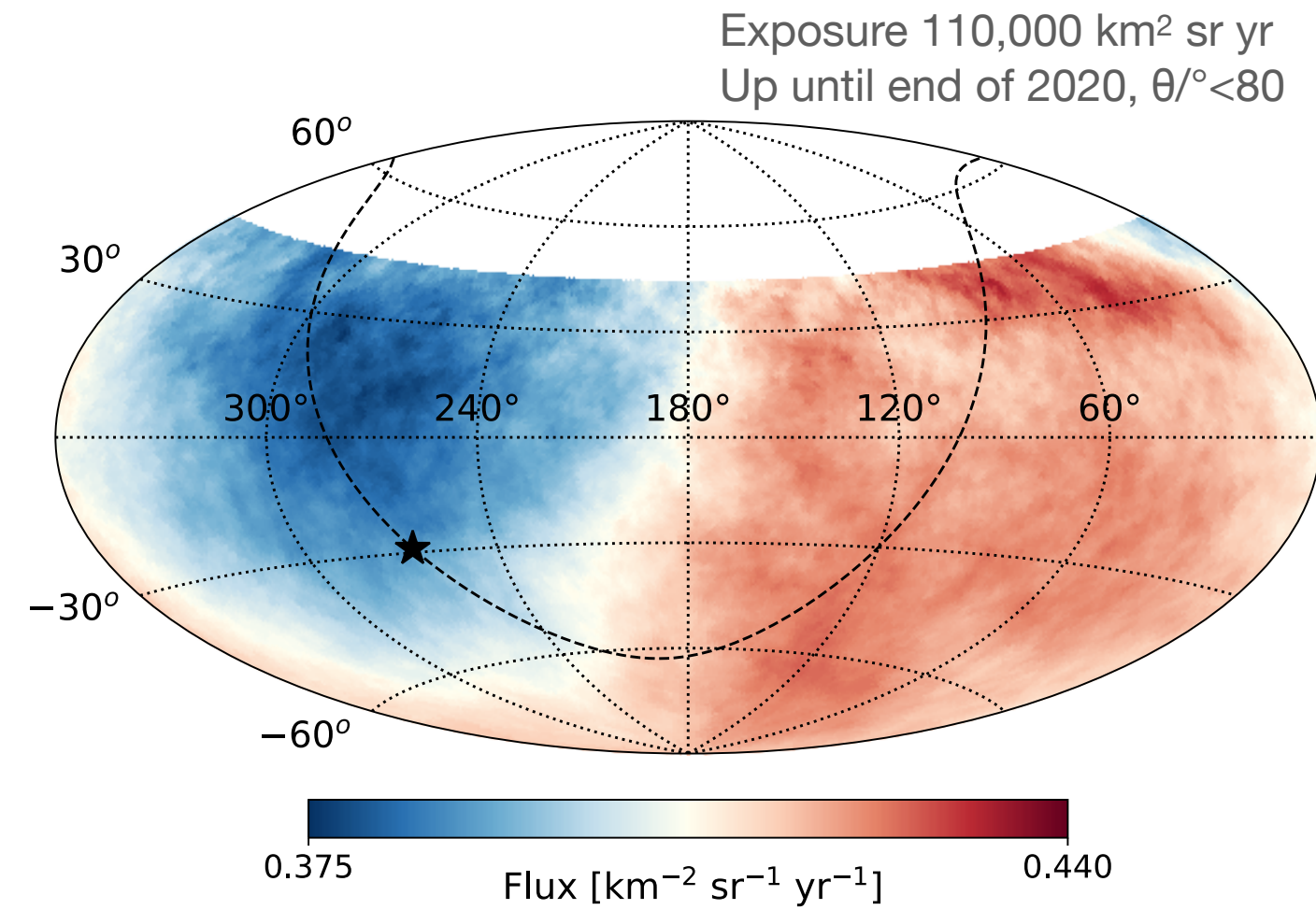


Fluctuations in muon number driven by first interaction

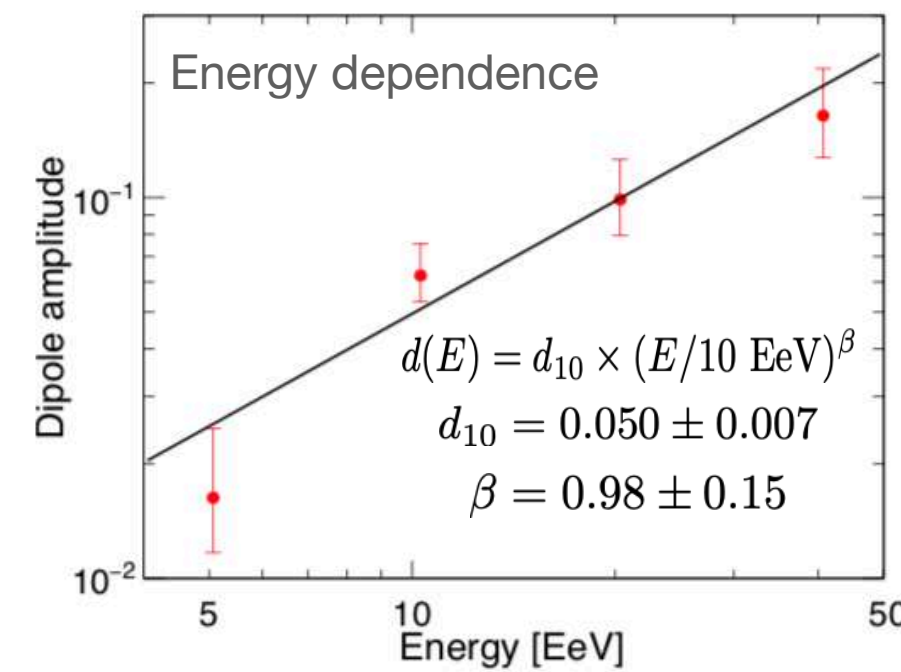
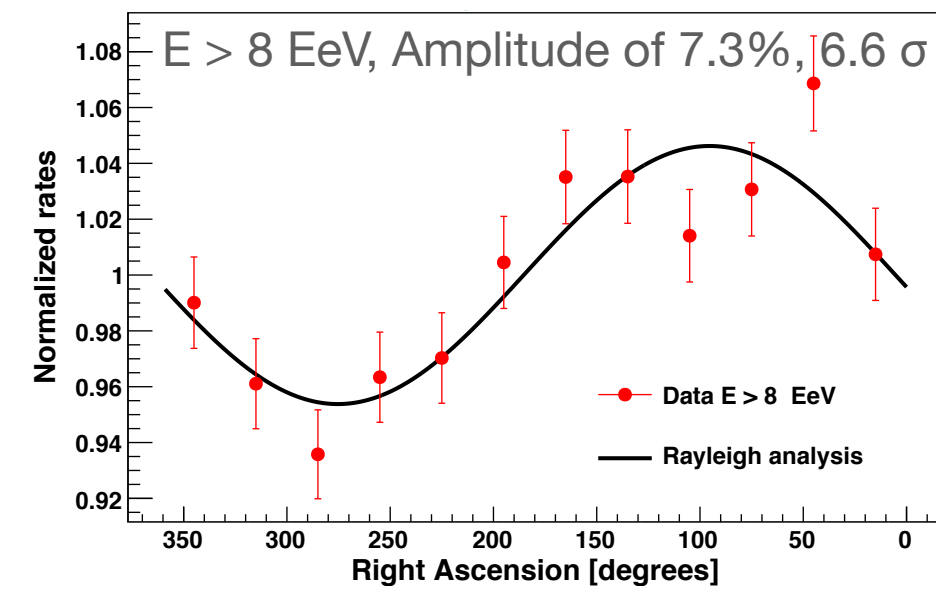


Anisotropy

Large Scale



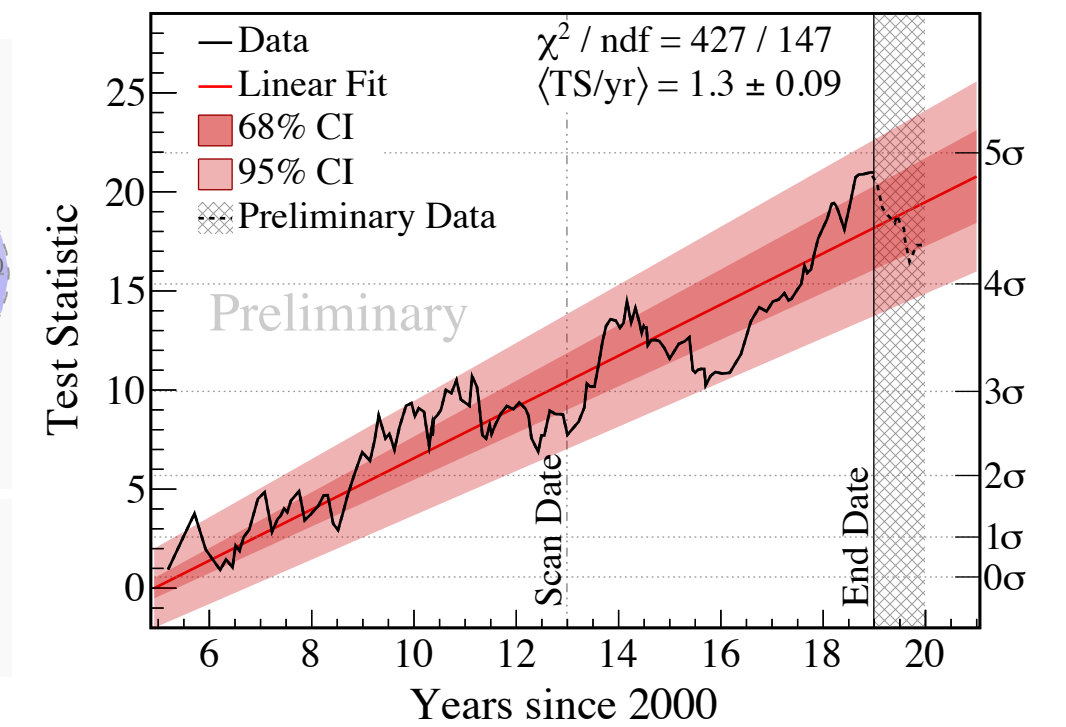
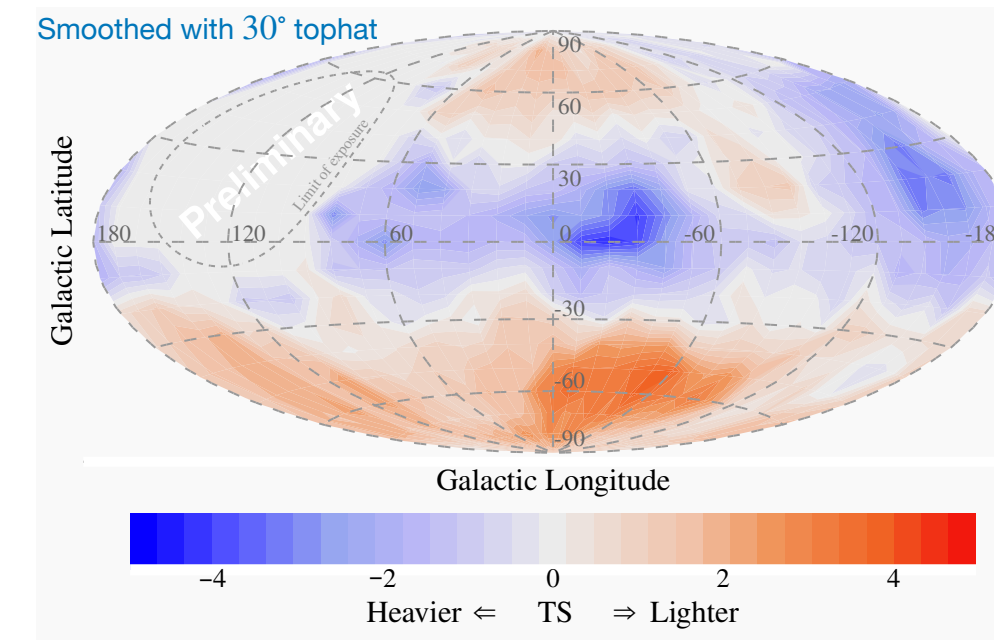
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Mass-dependent preliminary

Difference in mass on and off galactic plane?

(Note: does not imply galactic sources)

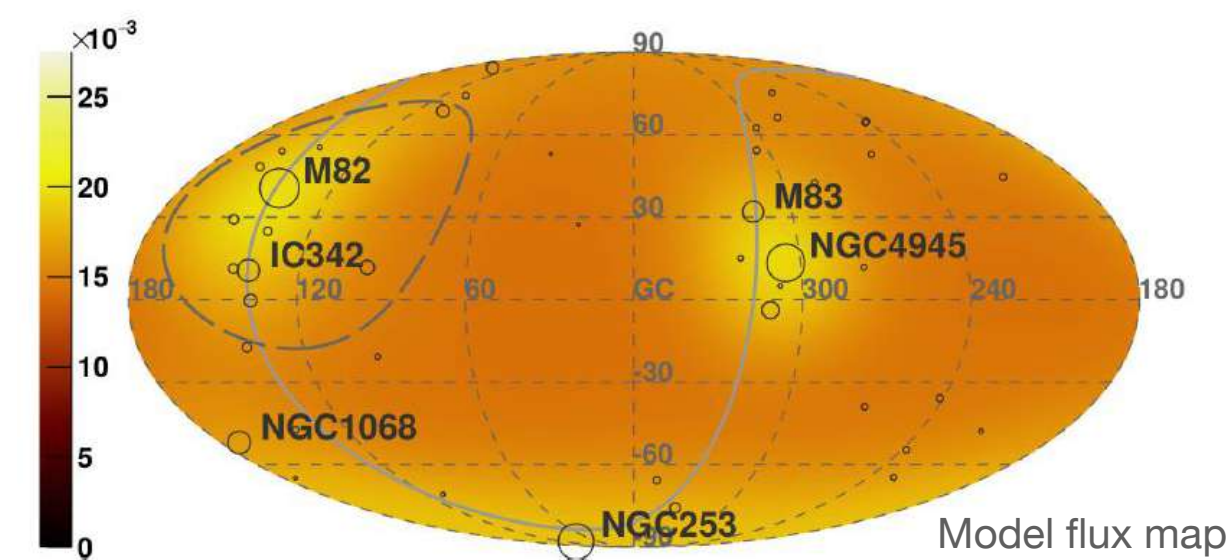


Accounting for trials and systematics: 3.3σ

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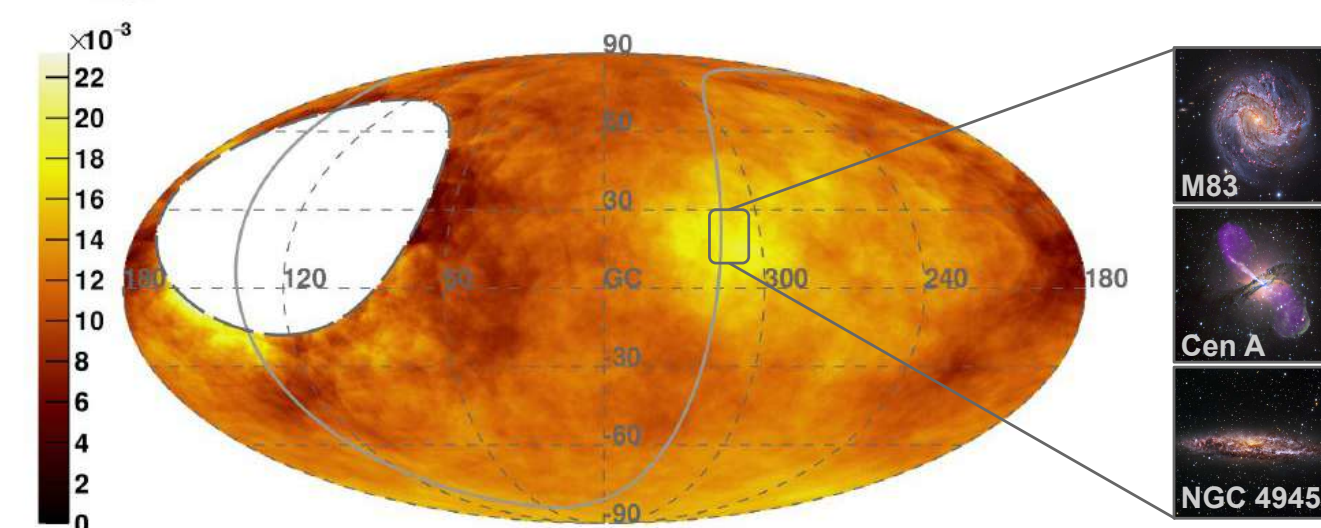
Highest energies - Catalogs

Starburst galaxies (radio) - expected $\Phi(E_{\text{Auger}} > 38 \text{ EeV})$ [km² sr¹ yr⁻¹]

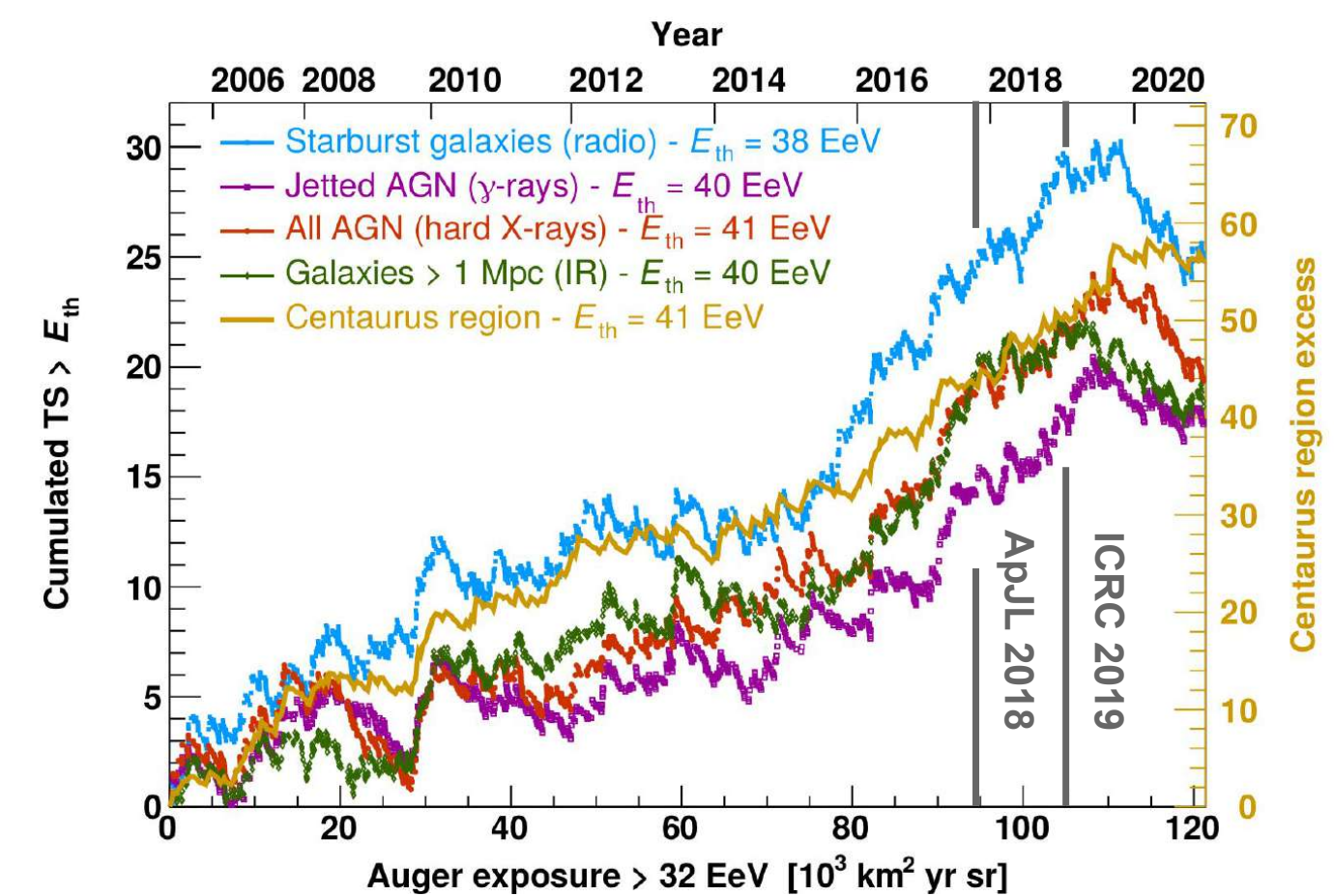


Starburst galaxies as sources?

$\Phi(E_{\text{Auger}} > 41 \text{ EeV})$ [km² sr¹ yr⁻¹] - Galactic coordinates - $\Psi = 24^\circ$



Excess from the Centaurus region?



Range of post-trial excess

4.0σ

3.1σ

ICRC21 307 (2021)

Ap. J. Lett 853 L29 (2018)

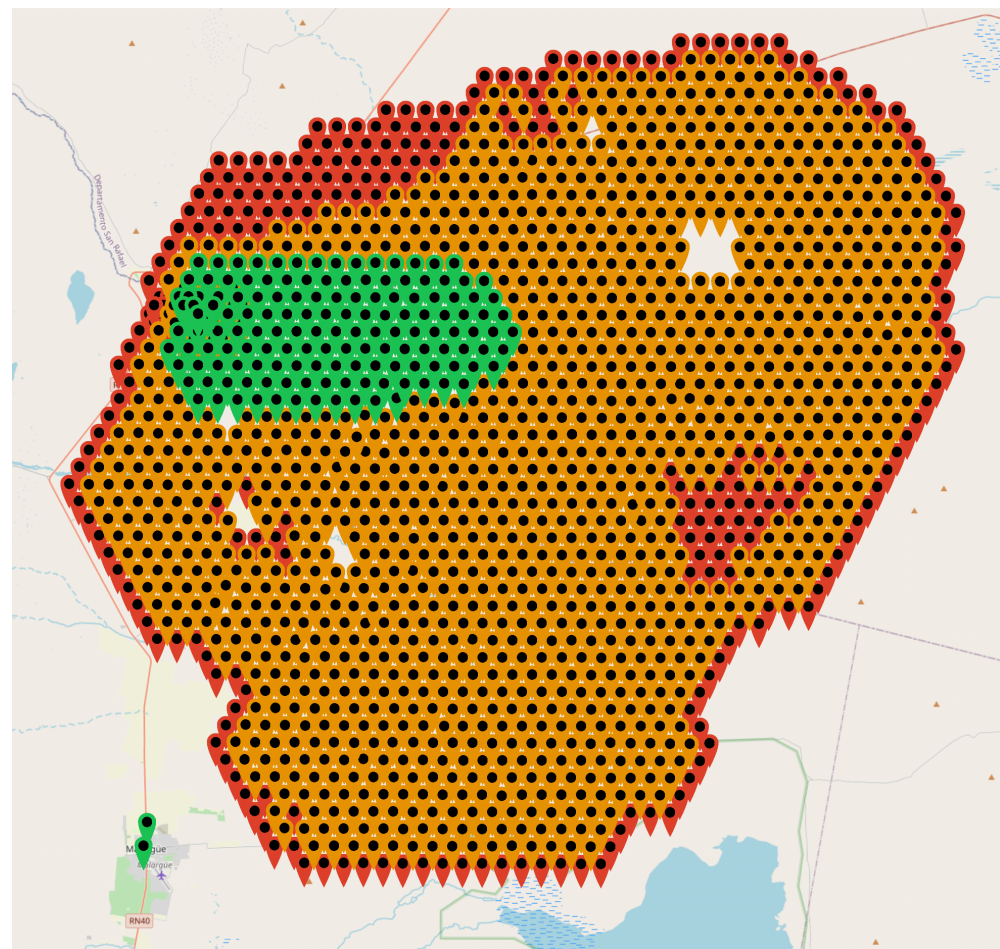
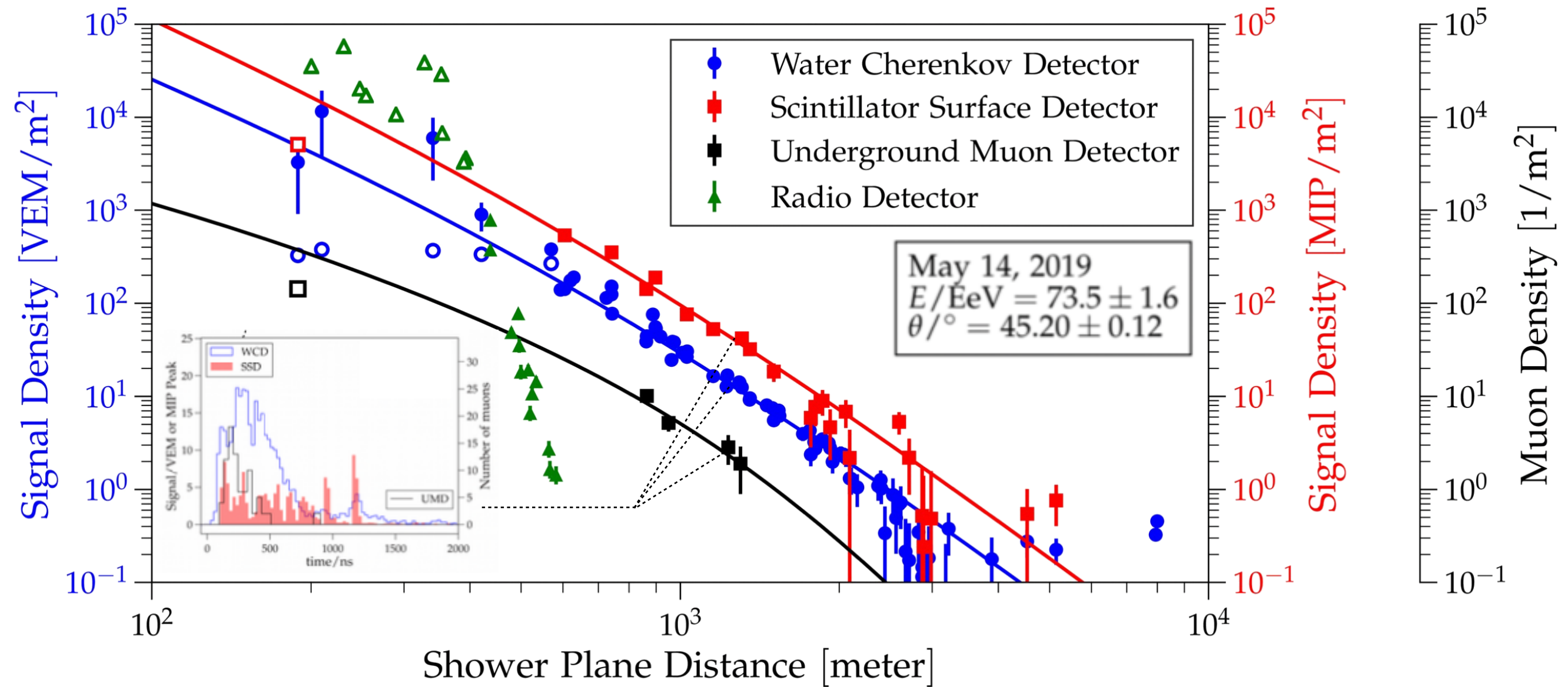
AugerPrime

Objective: Composition measurement up to 10^{20} eV

- Composition enhanced anisotropy studies
- Improved ability to test hadronic interactions

Components:

- 3.8 m² scintillator
- Electronics upgrade
- Small PMT (increased dynamic range)
- Radio antennas for inclined air showers
- Buried scintillator detectors for muon counting (in subset of array)
- Increased duty cycle of fluorescence detector



Scintillator deployed
+Acquiring data

