The Pierre Auger Observatory

Mass Composition and Particle Physics

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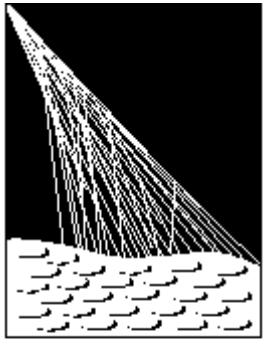


PIERRE AUGER OBSERVATORY

UNIVERSITY OF LEEDS

The Pierre Auger Observatory : A Hybrid Detector

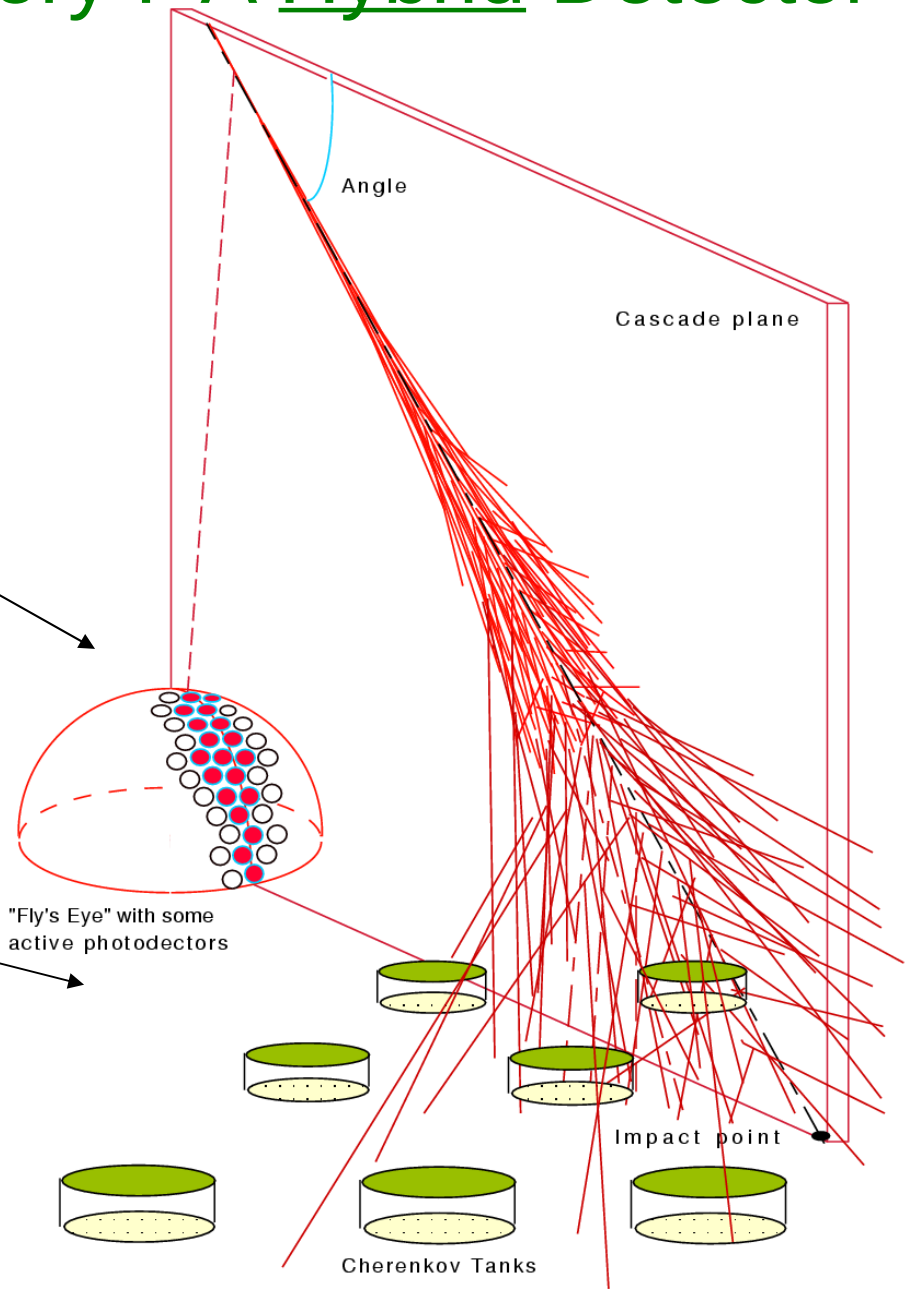
Two well established techniques are combined to detect ultra-high energy ($E>10^{18}$ eV) cosmic-ray showers

Fluorescence detector (FD)

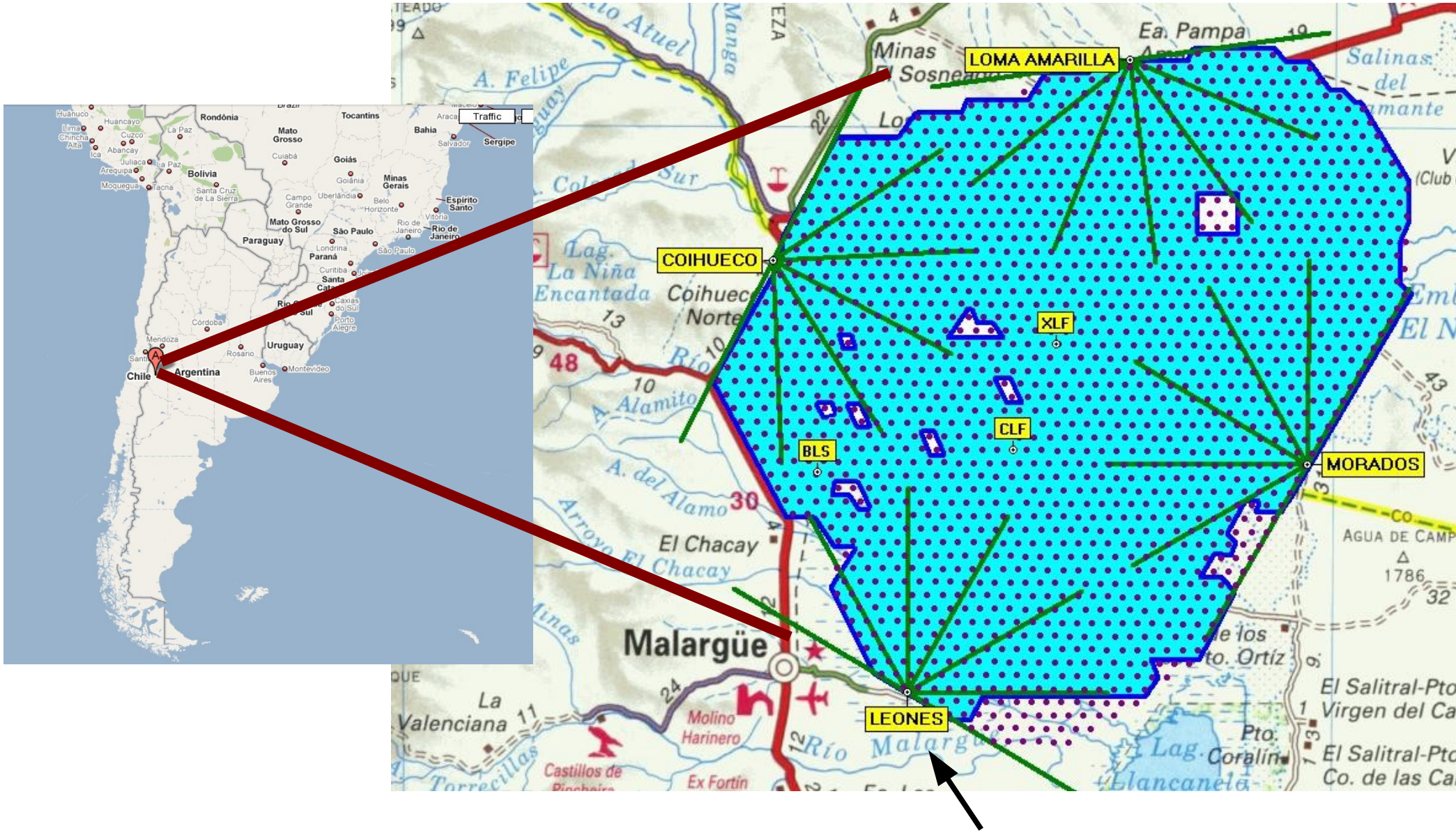
- Images the longitudinal development of the shower
- Model independent calorimetric energy measurement
- ~10% duty cycle

Surface detector (SD)

- Measures particles at ground level
- High statistics (~100 % on-time)
- Well defined area

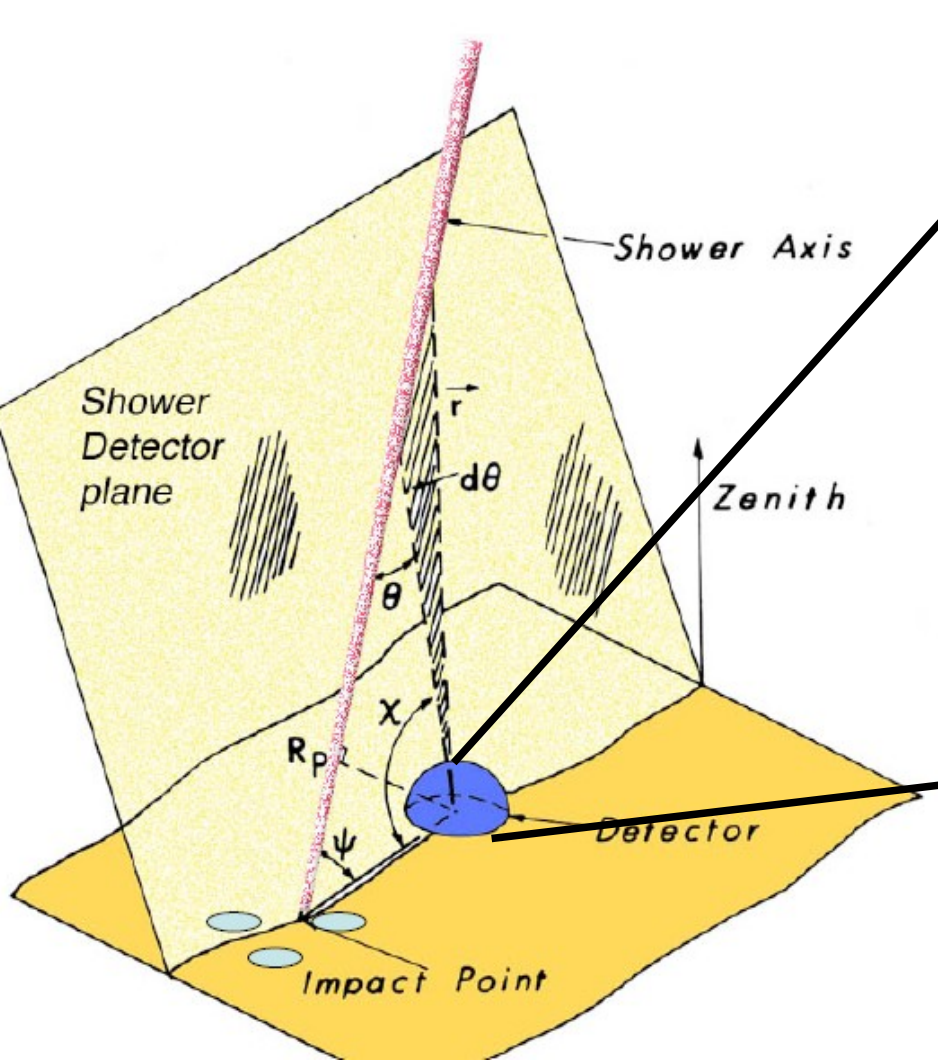


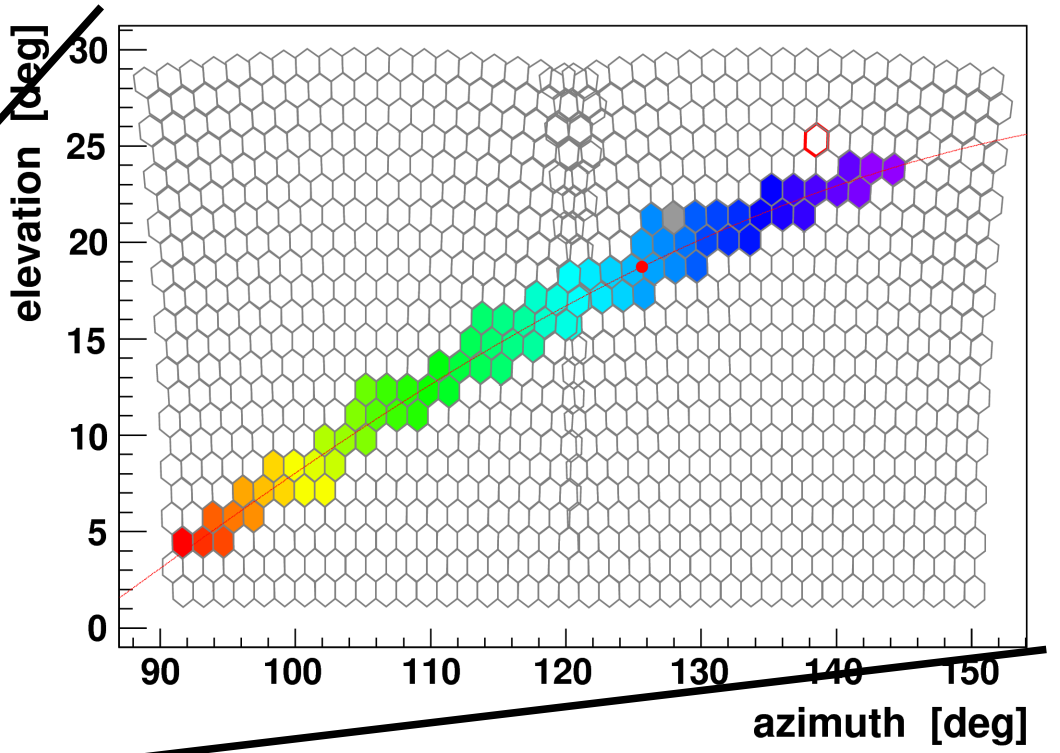
~1600 Surface detectors, 1.5 km apart
~3000 km^2
Altitude : 1.4 km

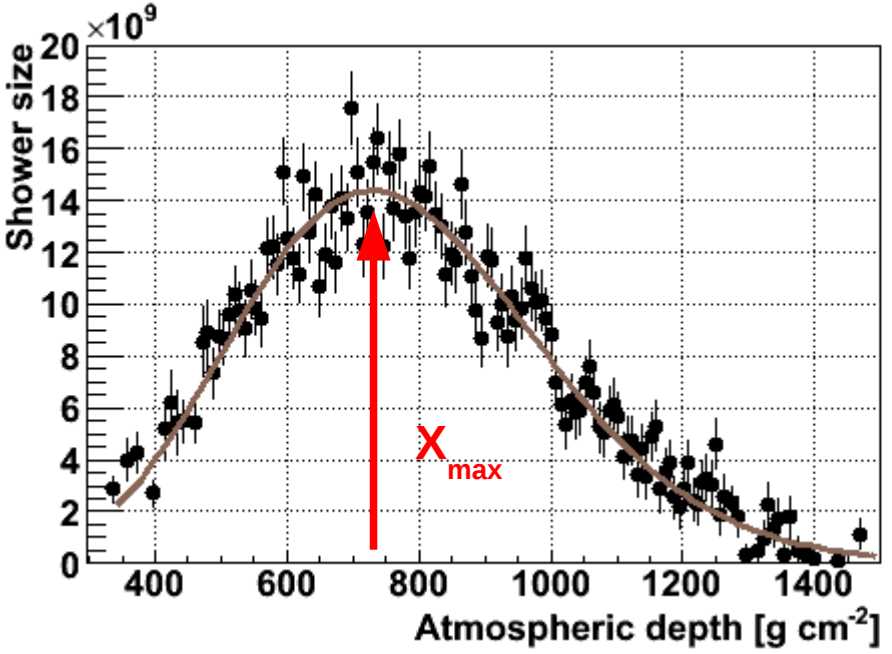


Previous largest array : AGASA : ~ 100 km^2

Fluorescence detectors



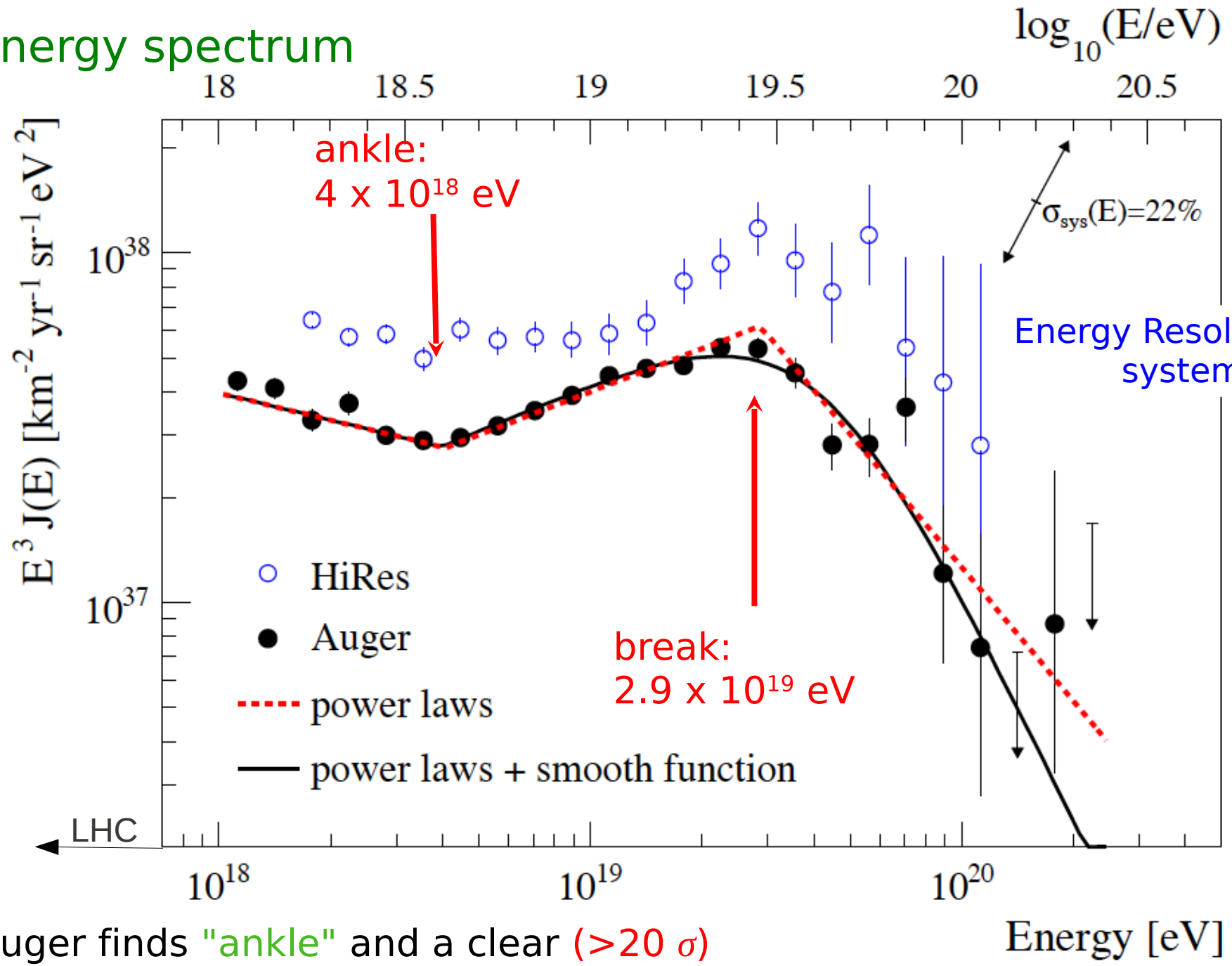




FD:

longitudinal profile,
calorimetric energy,
X_{max} for mass comp.

Energy spectrum



Auger finds "ankle" and a clear (>20 σ) spectral steepening at E ≈ 2.9 x 10^{19} eV.

12790 km² sr yr ≈ 2 full-Auger years
zenith angle: 0-60°

GZK cutoff ?

CR (p) above about $5*10^{19}$ eV interact with CMB photons to produce a Δ resonance

$$p+\gamma_{CMB} \longrightarrow \Delta^{+} \longrightarrow p+\pi^{0}\ (n+\pi^{+})$$

Is the steepening at $2.9x10^{19}$ eV the GZK effect?

Cannot be deduced from spectrum alone

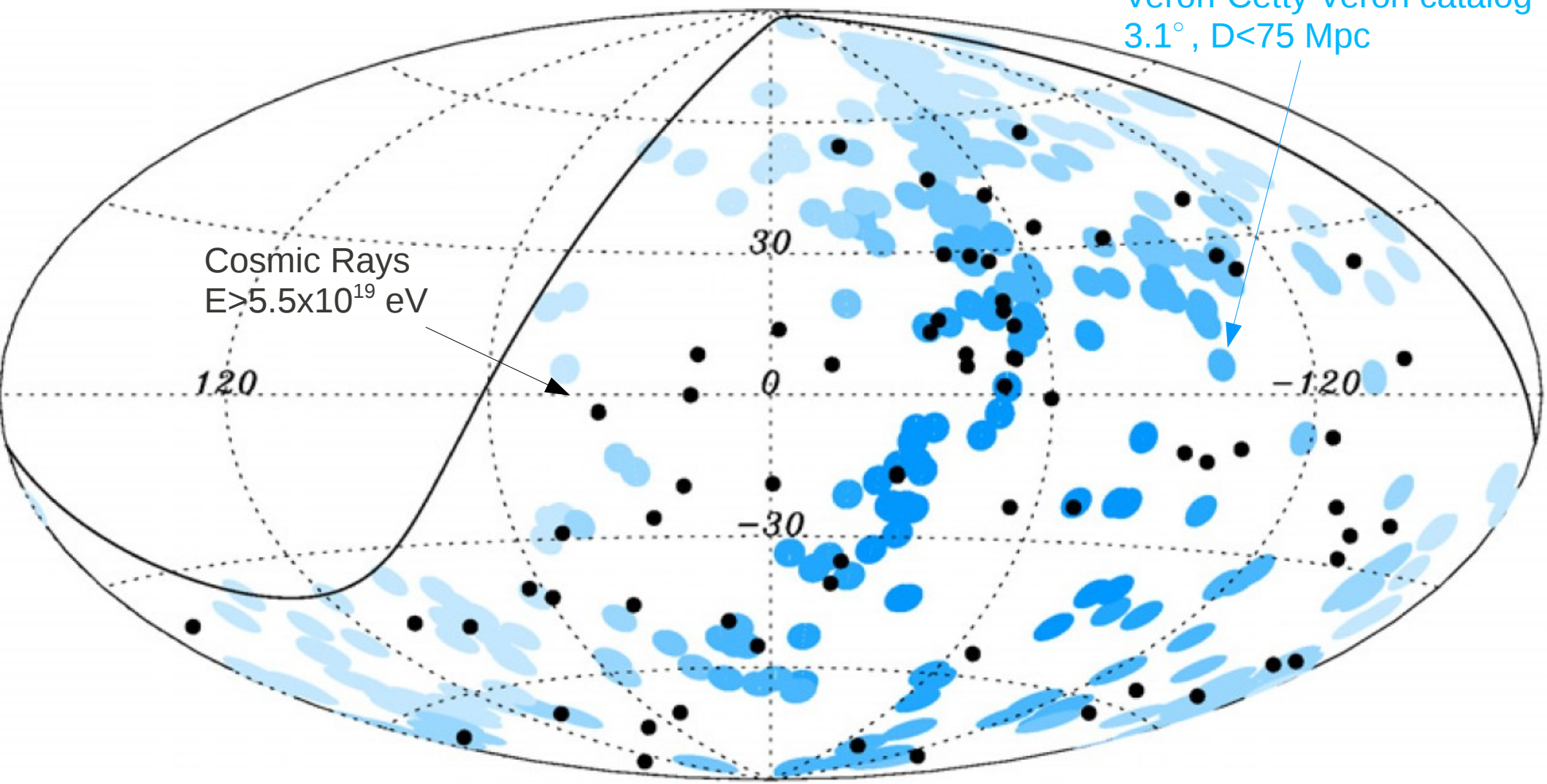
Possibilities :

- Protons : GZK
- Nuclear primaries are also absorbed
- Mixed composition with similar cutoff
- Maximum energy of accelerator
- .....

Need information on composition !

Anisotropy

69 Highest Energy Events >5.5x10^{19} eV (Dec 2009)



Update on the correlation of the highest energy cosmic rays with nearby extragalactic matter
Astroparticle Physics 34 (2010) 314

Anisotropy signal

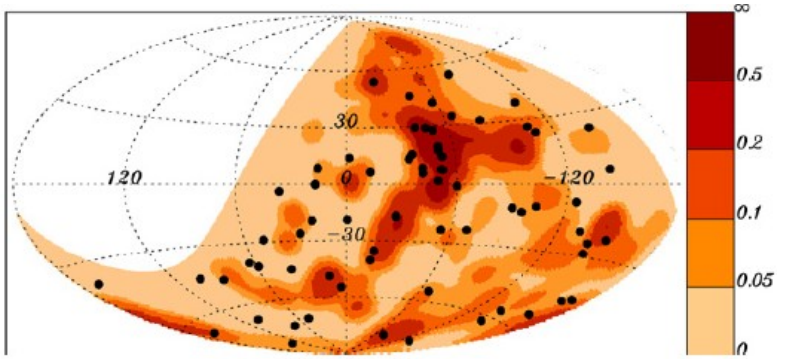
current signal: $p = 0.38^{+0.07}_{-0.06}$

P. Abreu et al. / Astroparticle Physics 34 (2010) 314–326

AGN correlation (as defined in Science paper) has weakened.

New data do not strengthen the case for anisotropy,
but they do not contradict the earlier result either.

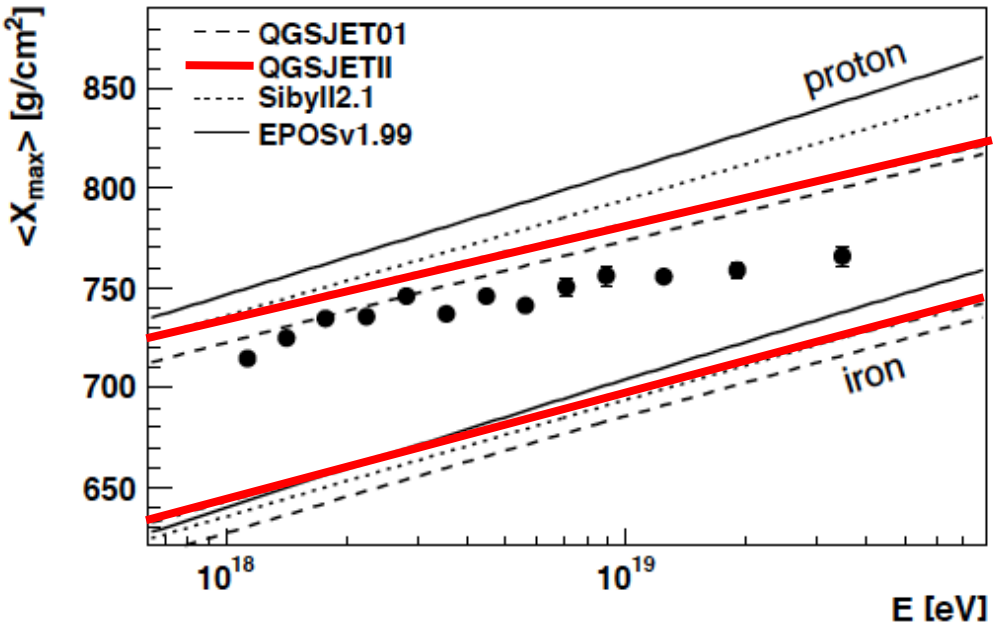
Other catalogues / analyses confirm anisotropy and
the correlation of CRs with “nearby matter”



More data and information on composition needed !

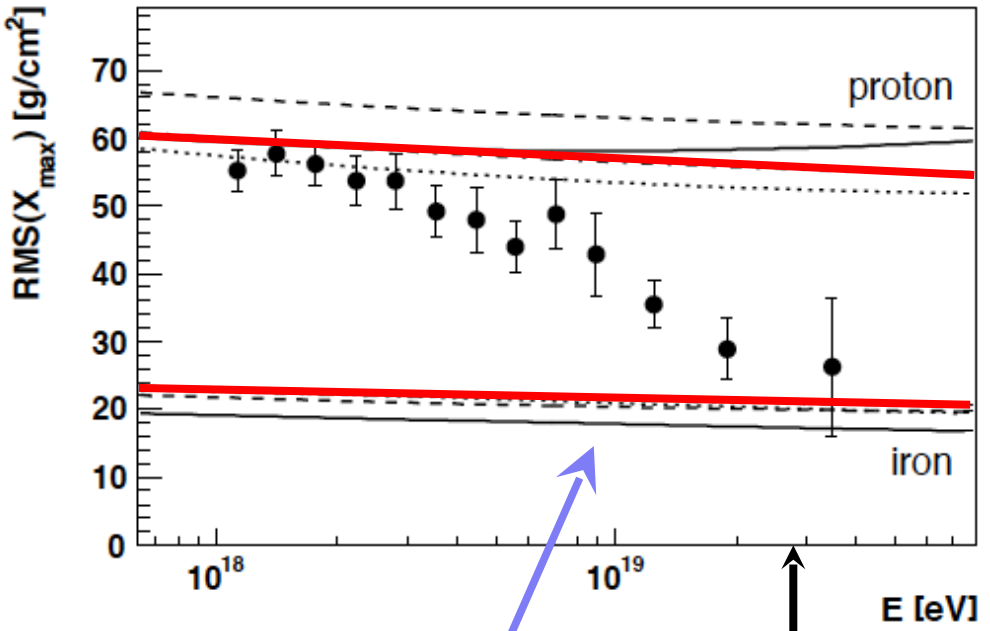
Composition

X_{max}



model dependent interpretation

$RMS(X_{max})$



difficult to influence with model changes

(spectral steepening)

Composition turns heavier or proton cross-section rises steeply ?

Composition mis-match ?

Spectrum: GZK cut-off
Anisotropy: correlation with nearby matter

Suggestive of protons ($E > 6 \times 10^{19}$ eV)

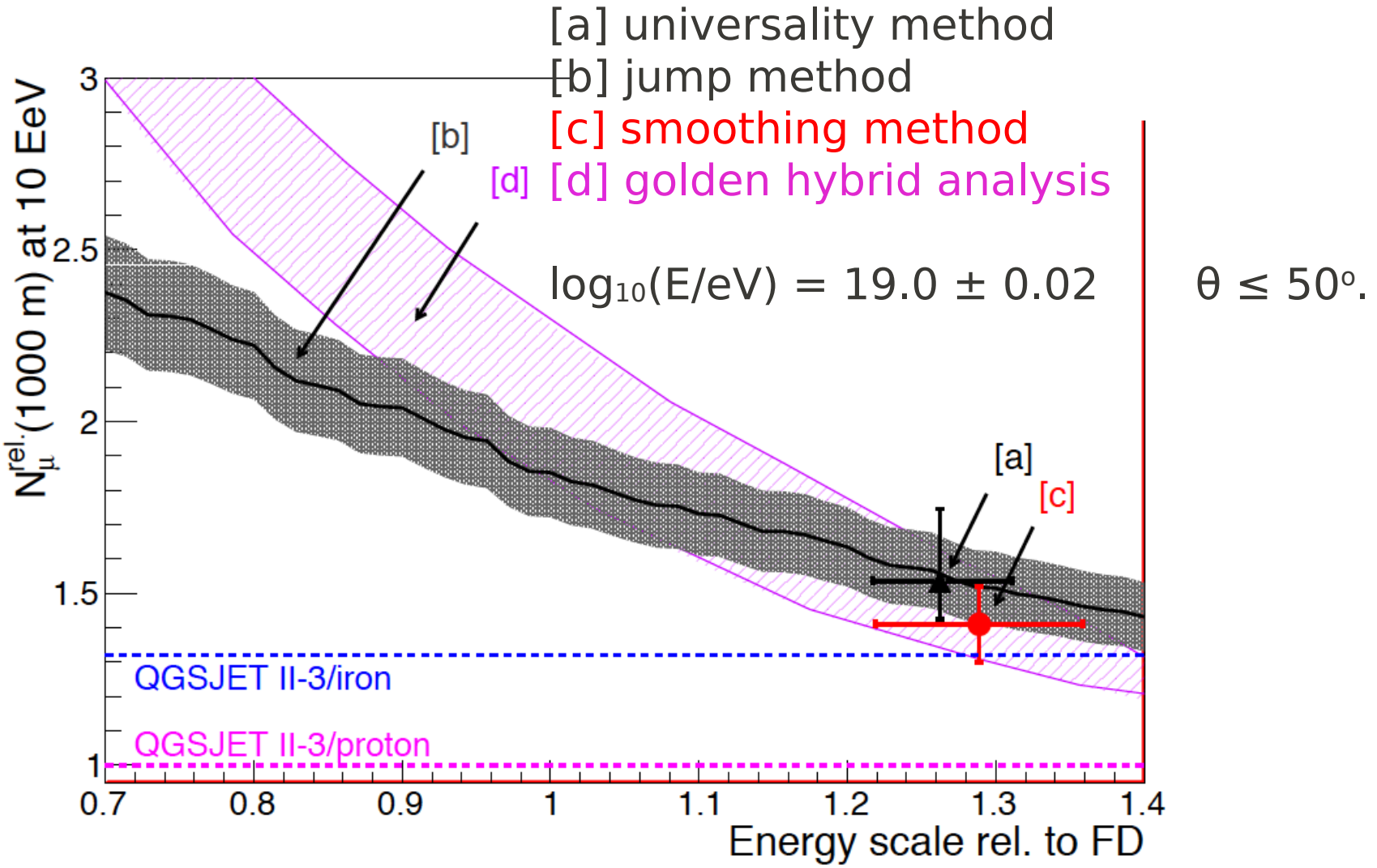
Composition: X_{max}, $t_{1/2}$, ...

mixed/heavy ($E < 4 \times 10^{19}$ eV)

strongly model dependent

Need hadronic interaction models to be modified to make p-sims look more like data ???
(e.g. cross sections, particle production, ...)

Hadronic interaction models



Model predictions : ~50% too low muon numbers
~30% too low energy reconstructed (fluorescence yield ??)

(See talk on hadronic interaction models by R.D. Parsons, up next)

Summary

The Pierre Auger Observatory is taking high-quality data

Spectral steepening at 2.9×10^{19} eV

GZK effect ? UHECR are protons ?

UHECRs seem to be extragalactic and correlate with nearby matter

UHECR are protons ?

Mass composition seems to become heavier with energy

Mixed/heavy composition ?

Interpretation with current models

Particle physics at $E > 10^{19}$eV ?

- Hadronic interaction models seem to require modification
- Muon and energy scale seem to be off

See the poster "*A summary of recent results from the Pierre Auger Observatory*" (H.Cook, L.Lu)