Recent Results from the Pierre Auger Observatory

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PIERRE AUGER OBSERVATORY

ICHEP PARIS 2010

- **The Pierre Auger Observatory**
- **Understanding the Instrument**
- **UHECR Energy Spectrum (GZK-Effect)**
- **Arrival Directions**
- **Composition** (hadrons, photons, neutrinos)
- **Outlook & Discussion**

bmb+f - Förderschwerpunkt Astroteilchenphysik Großgeräte der physikalischen Grundlagenforschung

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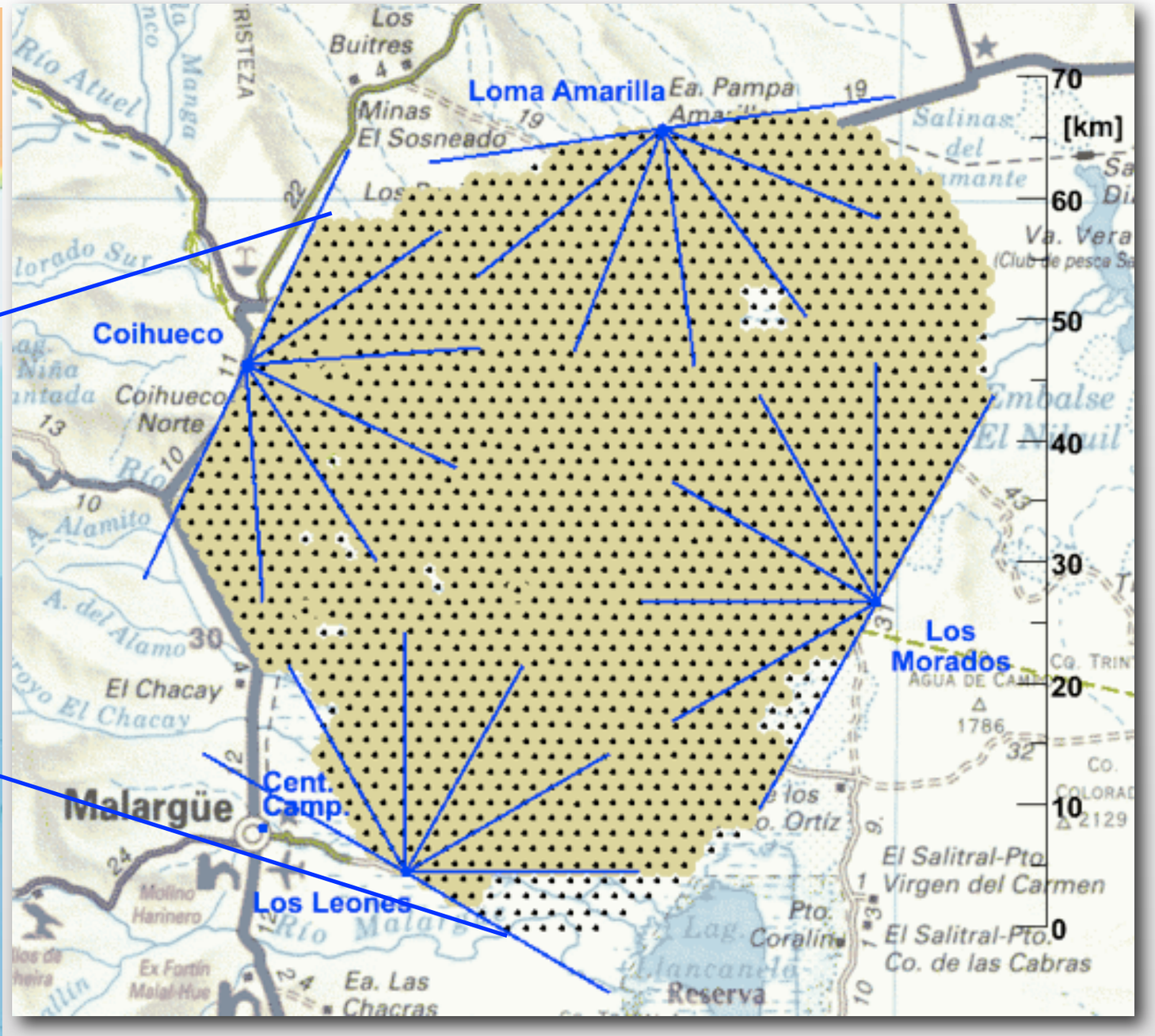
Pierre Auger Observatory in Argentina

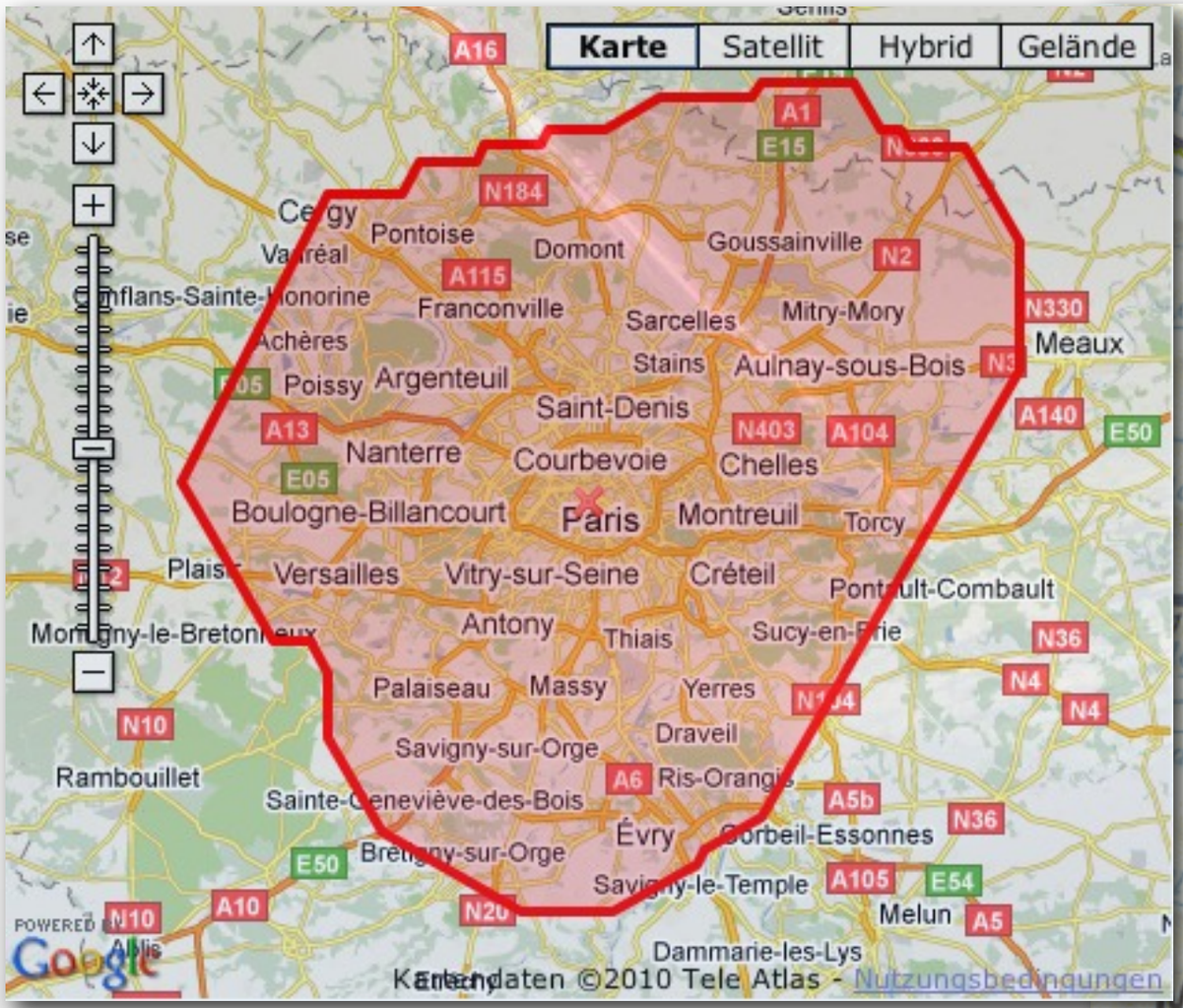


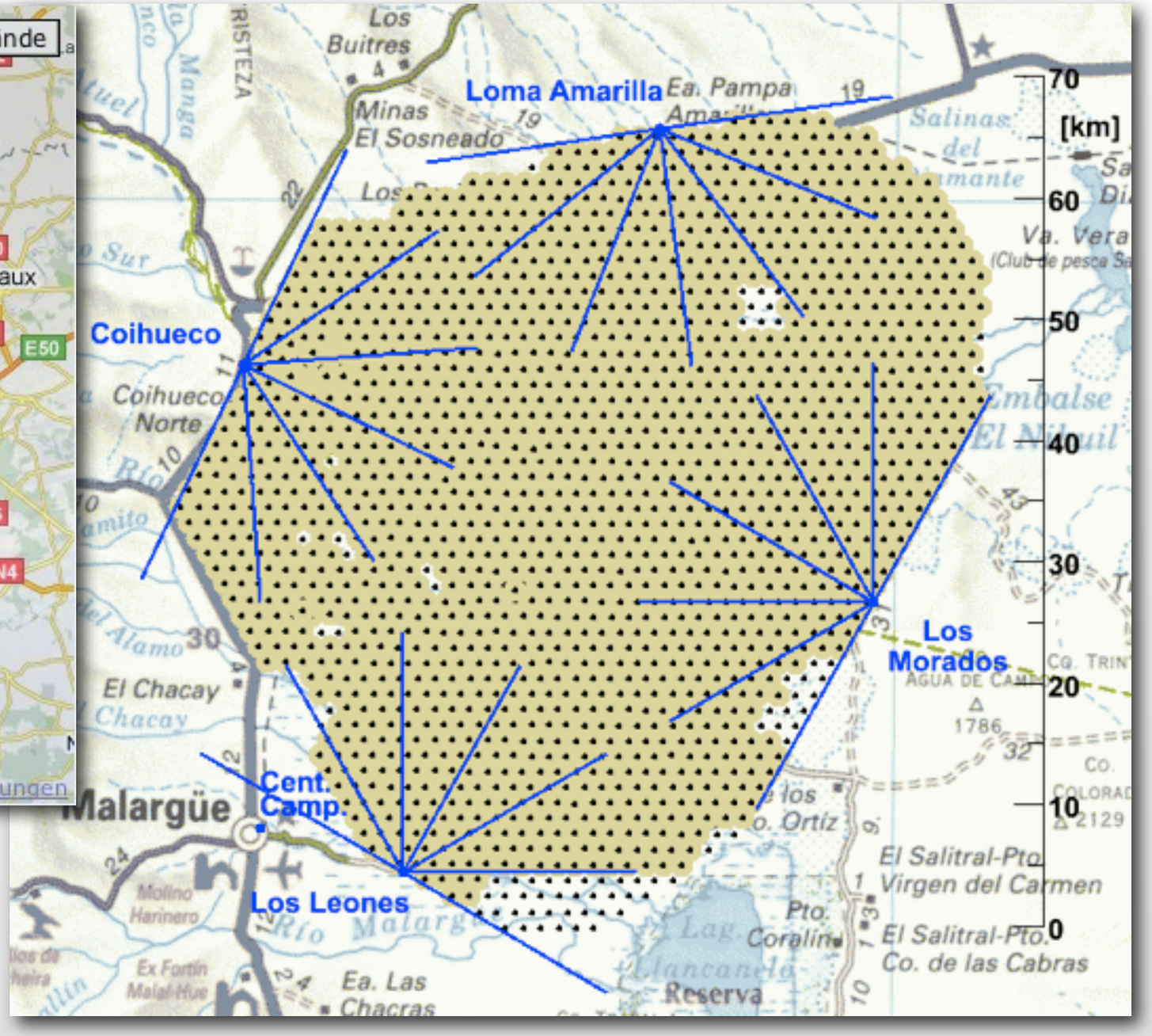
3000 km² area on a plateau 1450 m a.s.l.

1660 Detector Stations +

27 FD Telescopes at periphery

Pierre Auger Observatory in Argentina





...compared to size of Paris

3000 km² area on a plateau 1450 m a.s.l.
1660 Detector Stations +
27 FD Telescopes at periphery

A Telescope and a Water Cherenkov Station

27 fluorescence telescopes...

...1660 Water Cherenkov tanks

Hybrid: More than Sum of the Two

Surface Detecor Based:

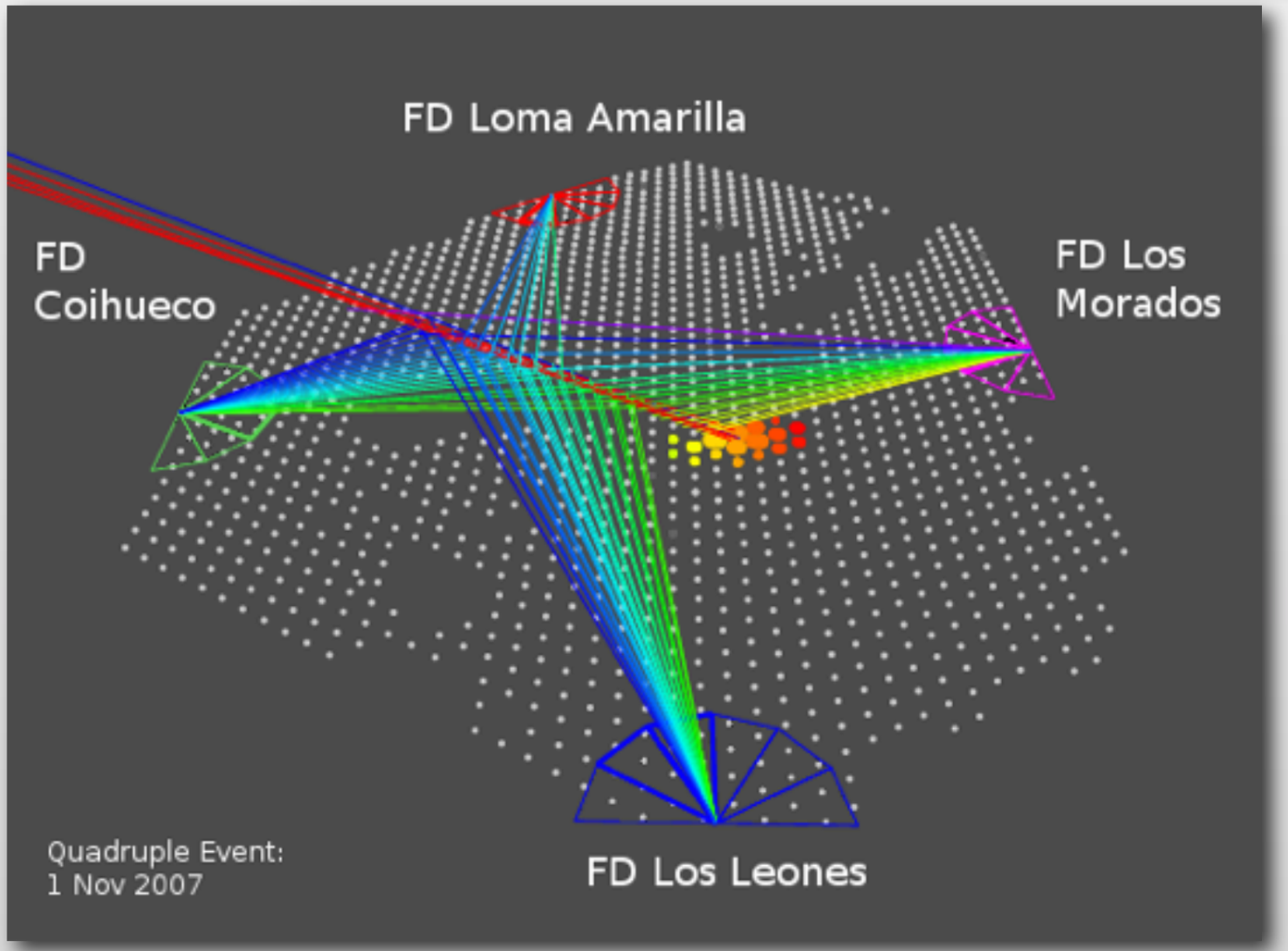
+ High Statistics (24 hrs a day)
+ Simple geometrical exposure
– Calibration of Energy from EAS-simul.

Fluorescence Detecor Based:

+ High Resolution
+ Low energy threshold
+ Calibration by laboratory expt's
– about 15 % duty cycle
– complicated aperture

Hybrid Based:

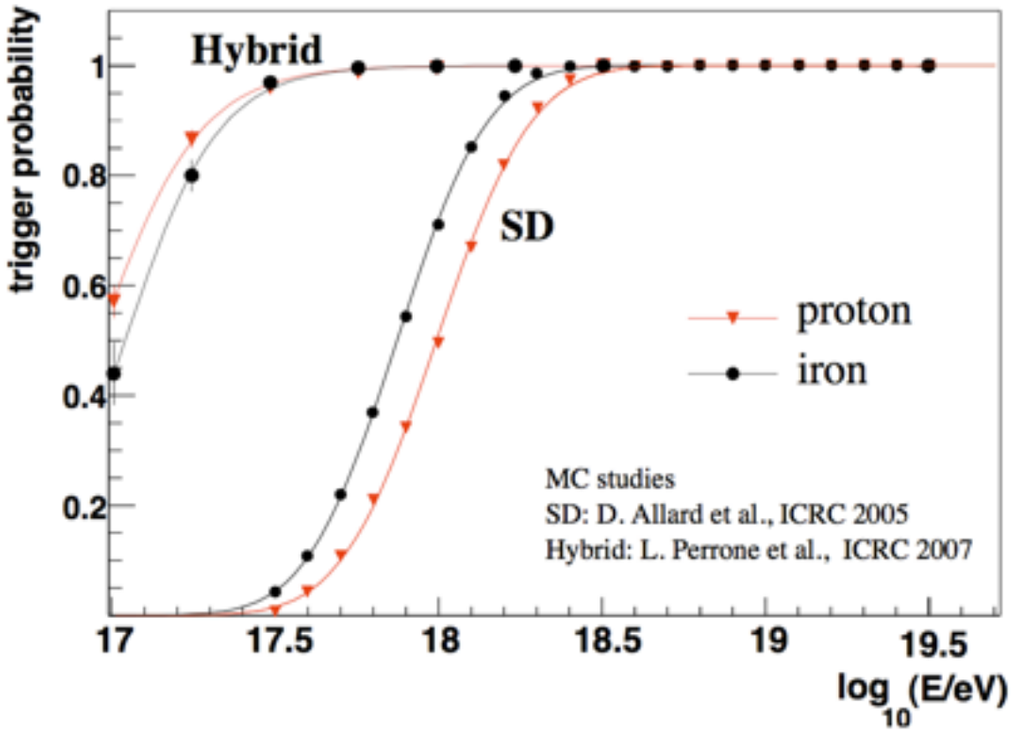
+ Well known calibration
+ Flat, well known aperture
+ Low energy threshold

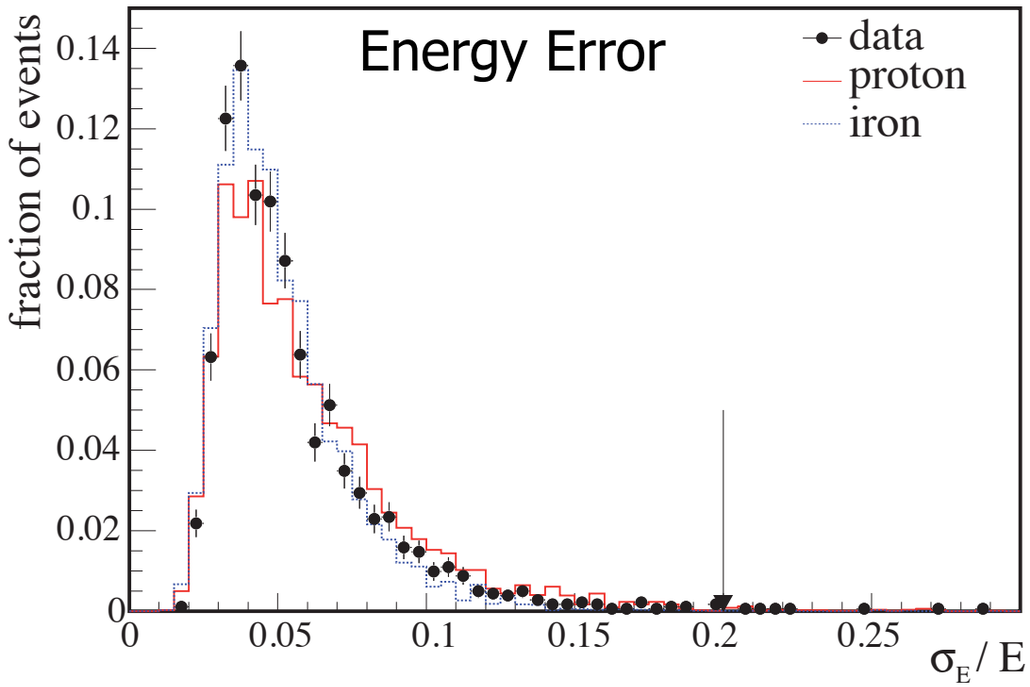


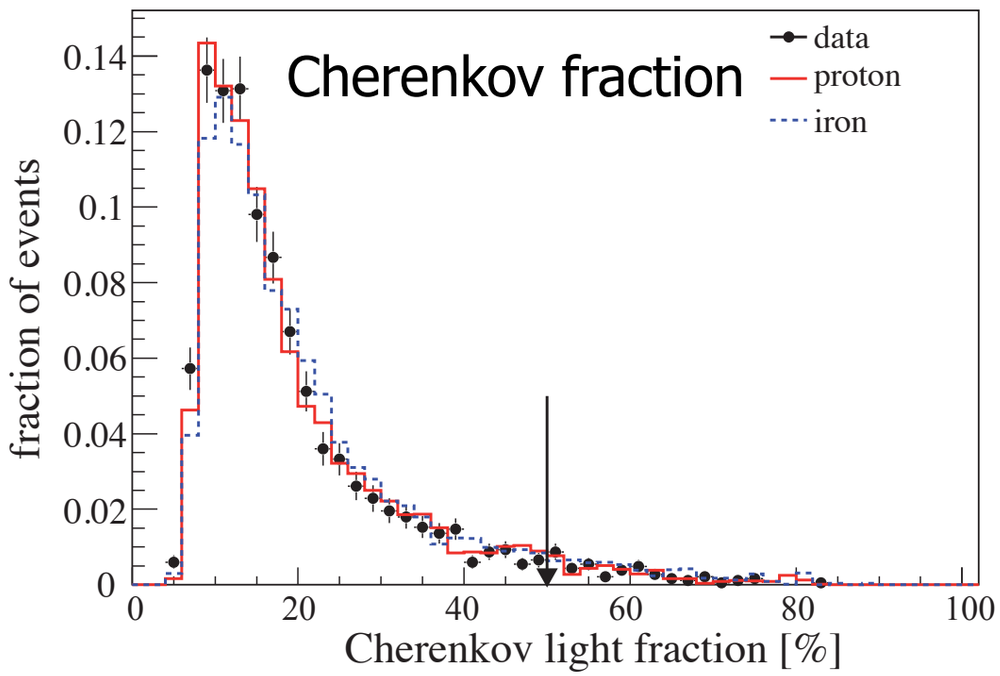
FD is used to calibrate SD

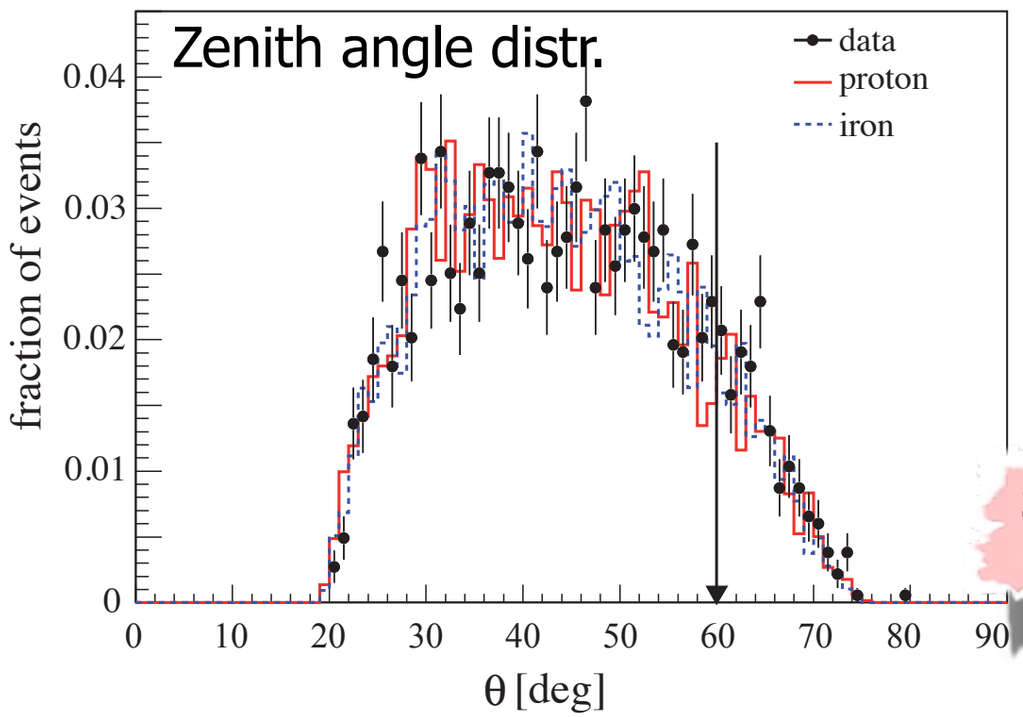
Understanding the Instrument

Very detailed MC studies performed as well as very many systematic checks making use the 2-fold detection technique



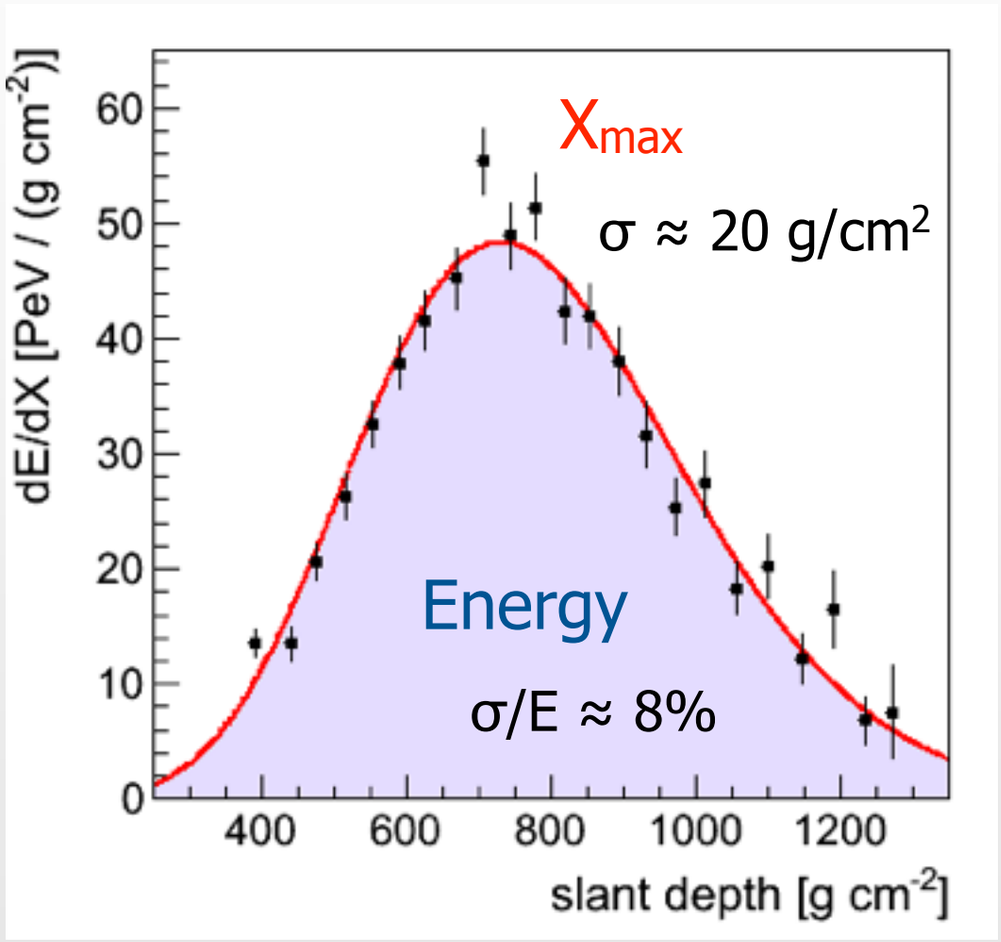




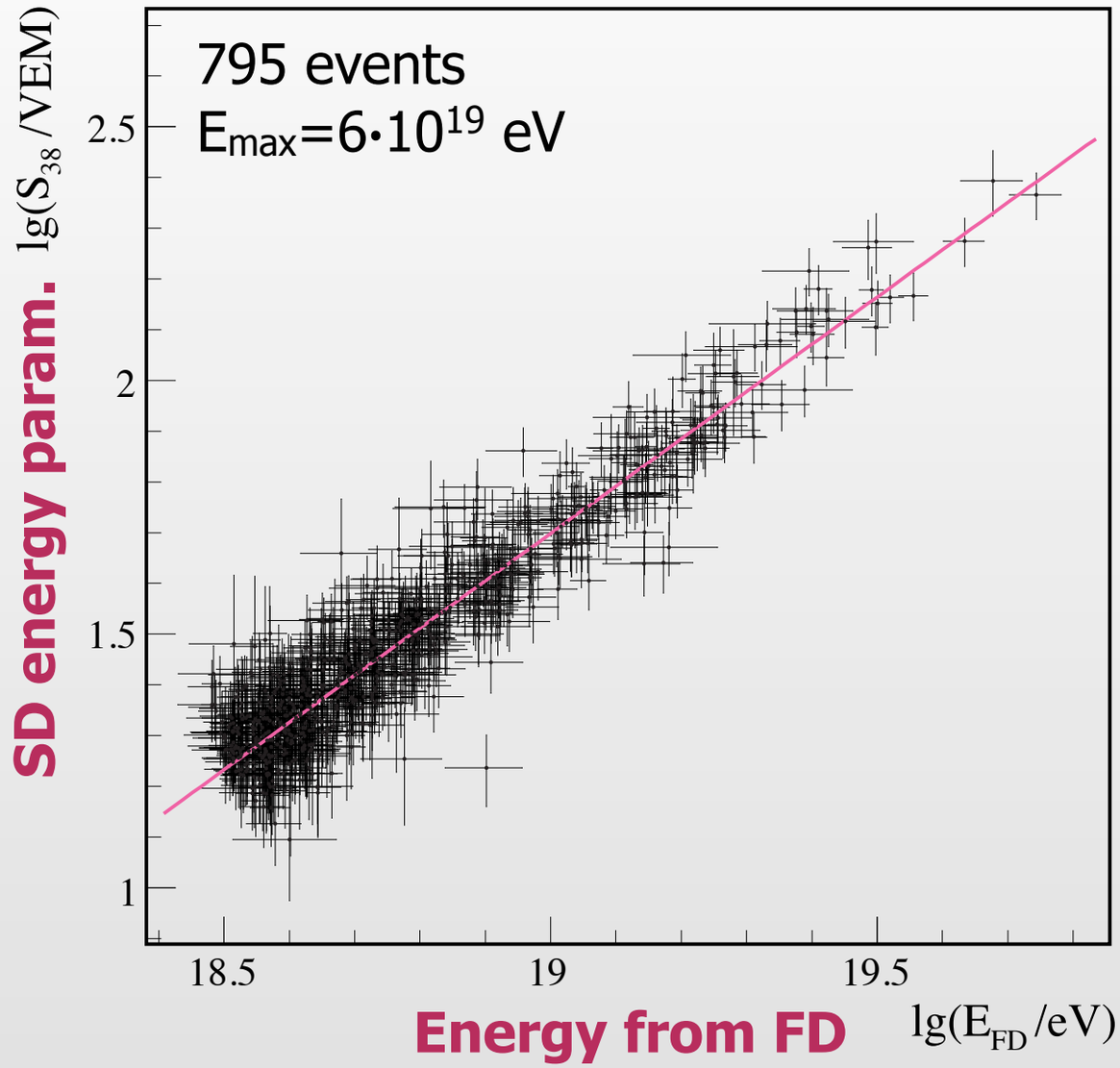


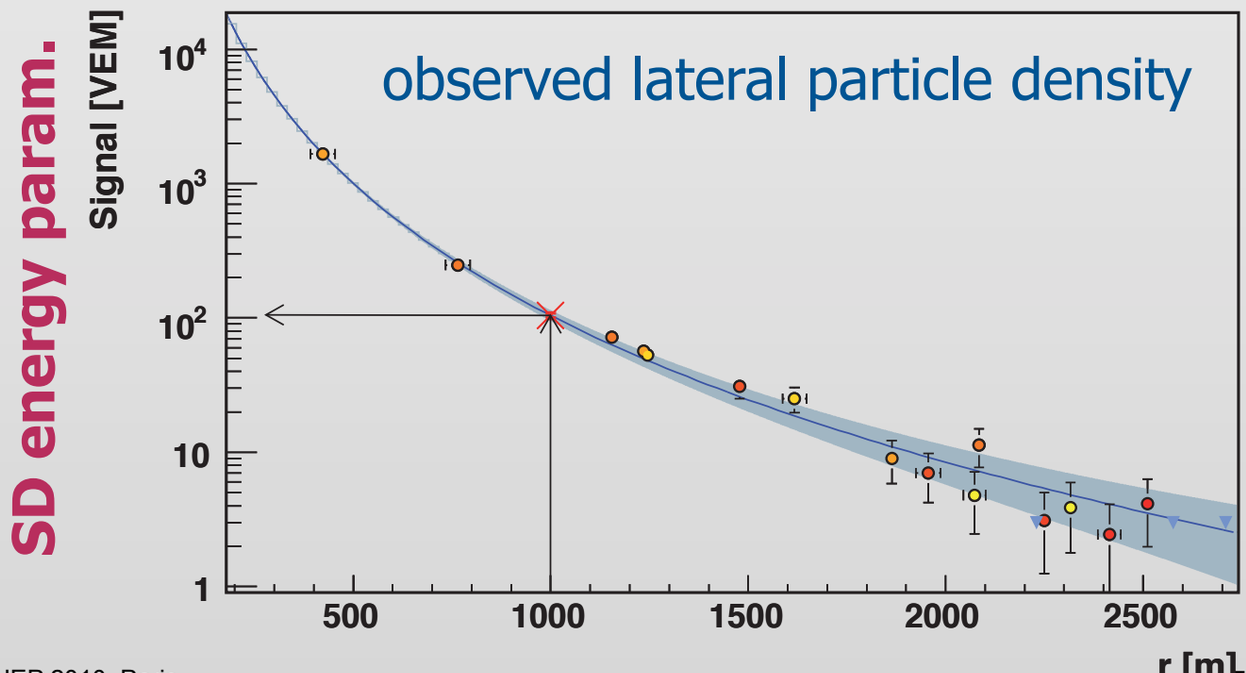
Submitted for publication

Ground Array calibrated by Fluorescence Obs.

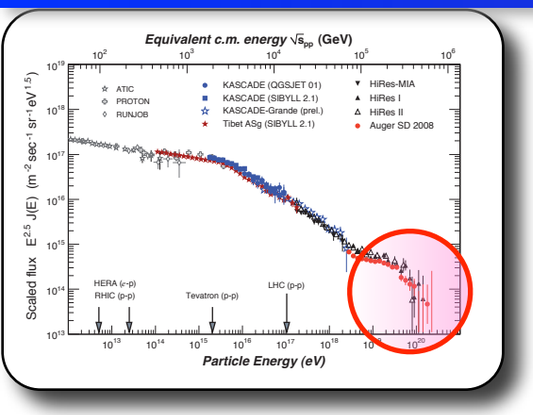


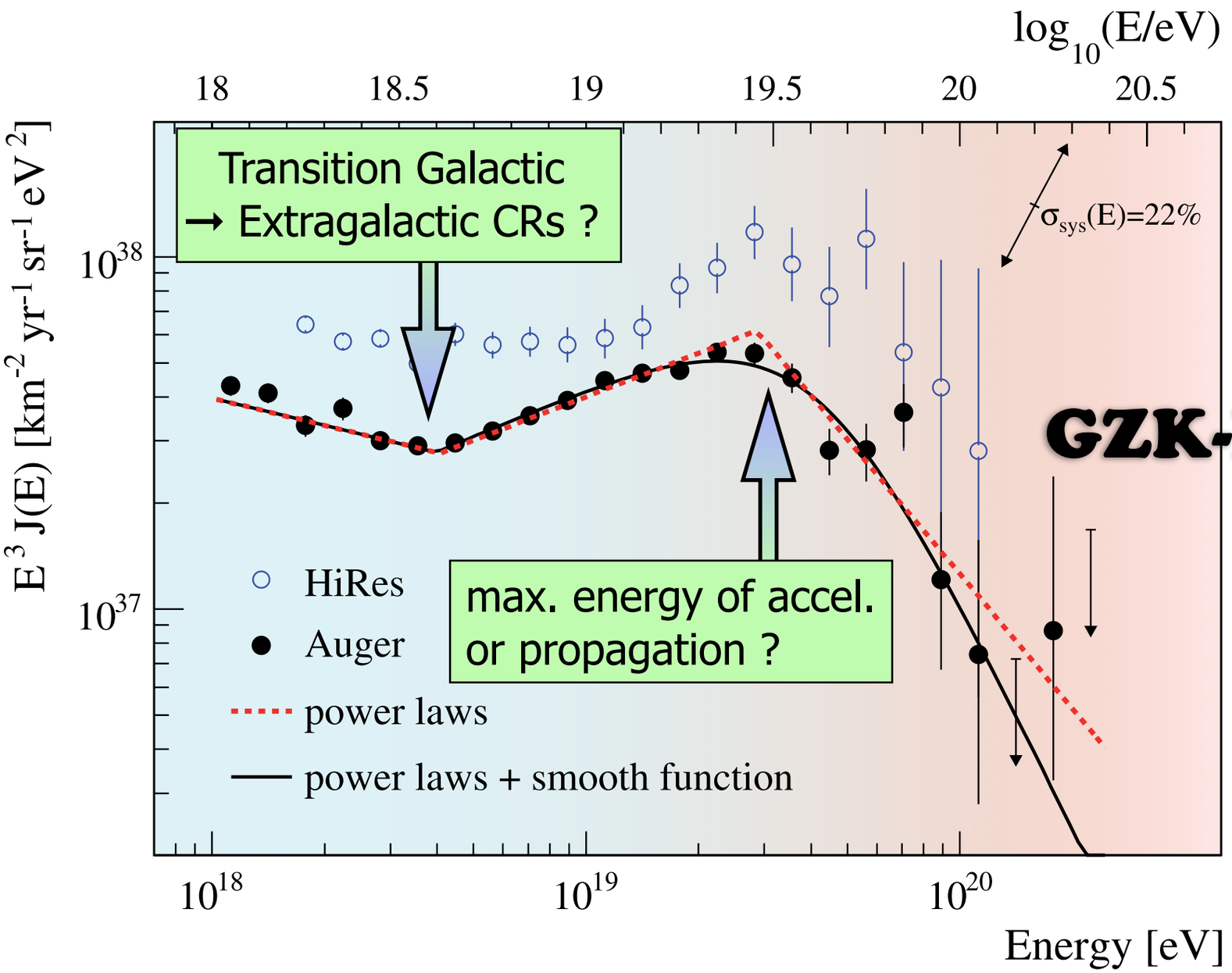
Auger @ ICRC09





Auger Energy Spectrum





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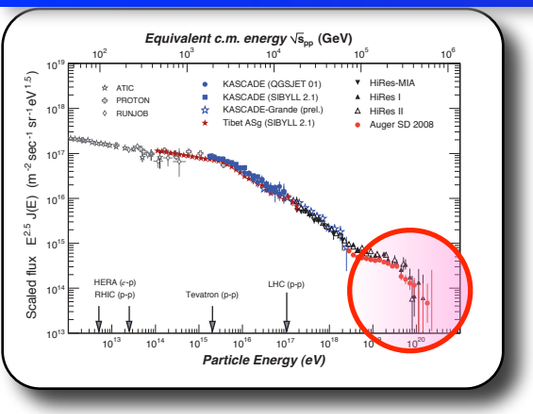
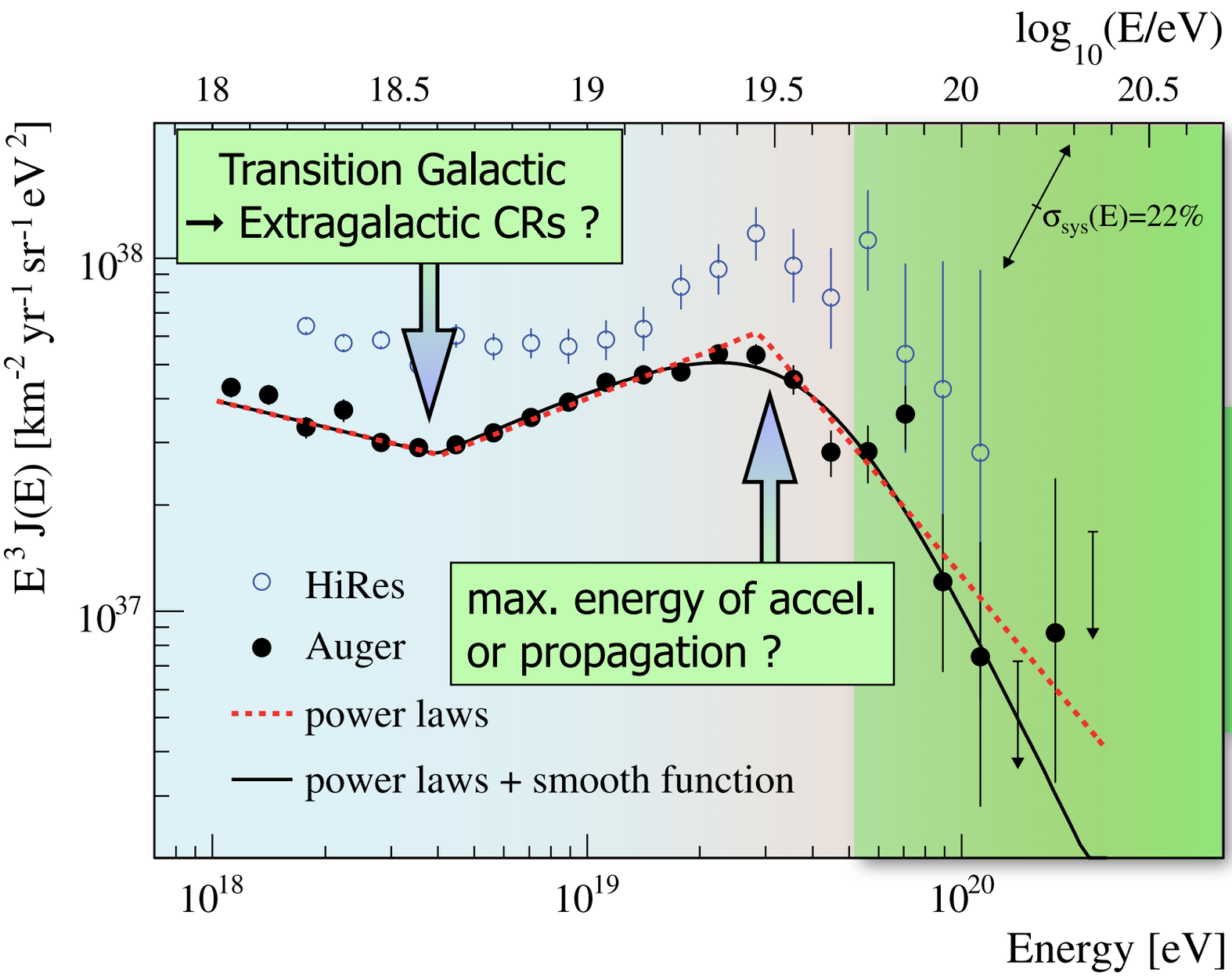
&
Phys. Lett. B 685 (2010) 239–246

GZK-Effect?

- Simple astrophys. models fit data surprisingly well
- Constraining models needs composition measurement

Auger Energy Spectrum





Phys, Rev. Lett. 101 (2008) 061101 & Phys. Lett. B 685 (2010) 239–246

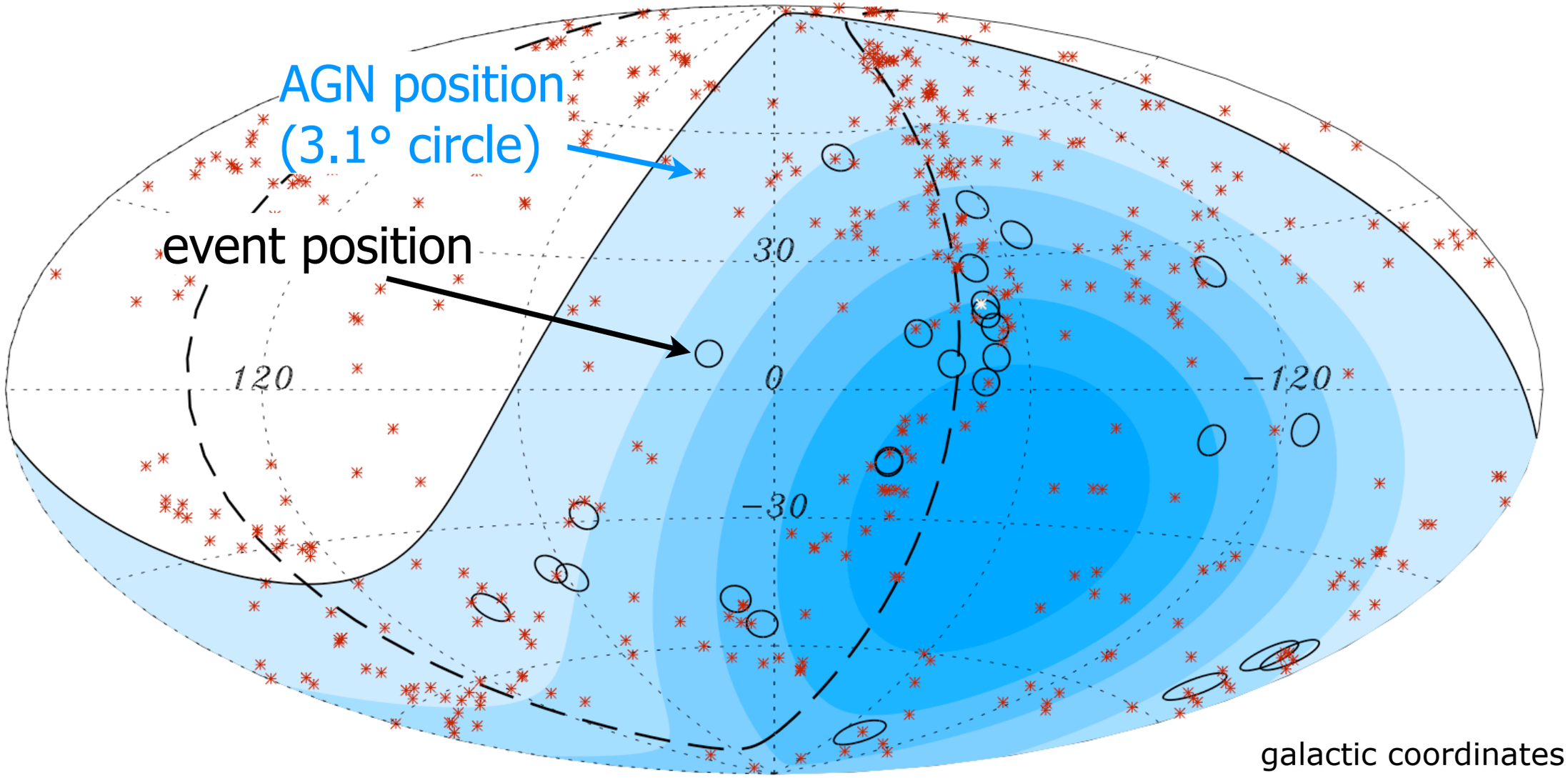
Anisotropic distribution

(69 events)

- Simple astrophys. models fit data surprisingly well
- Constraining models needs composition measurement

Sky Plot at E ≥ 55 EeV

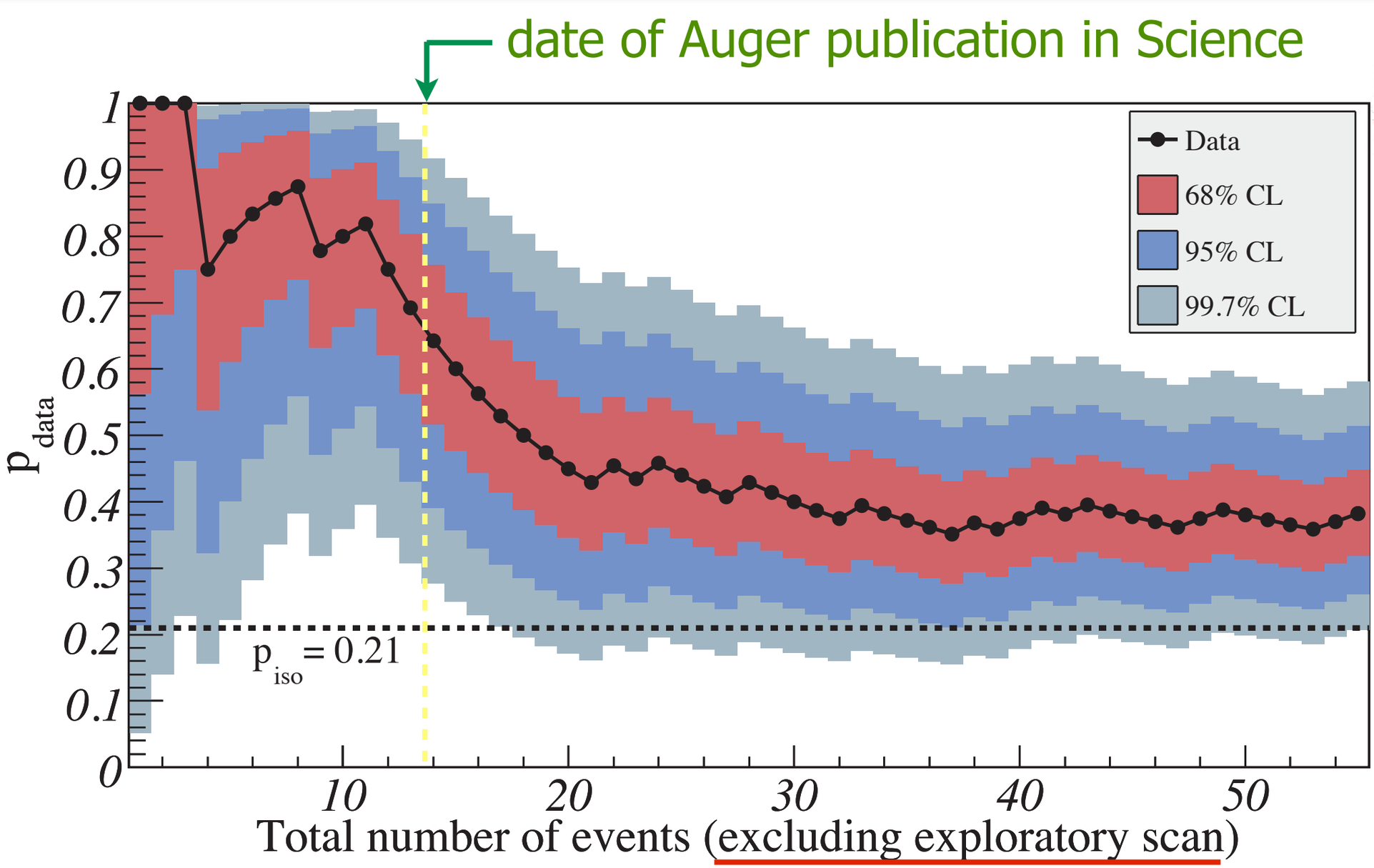
First results reported in Science 318 (2007) 938



69 events observed (up to 31.12.2009; 20370 km^2 sr y) compared to position of nearby AGN (d<75 Mpc) from VC-V, exposure weighted

expect 14.5 directional correlations by chance, 29 observed

Evolution of Degree of Correlation



does signal stabilise ?

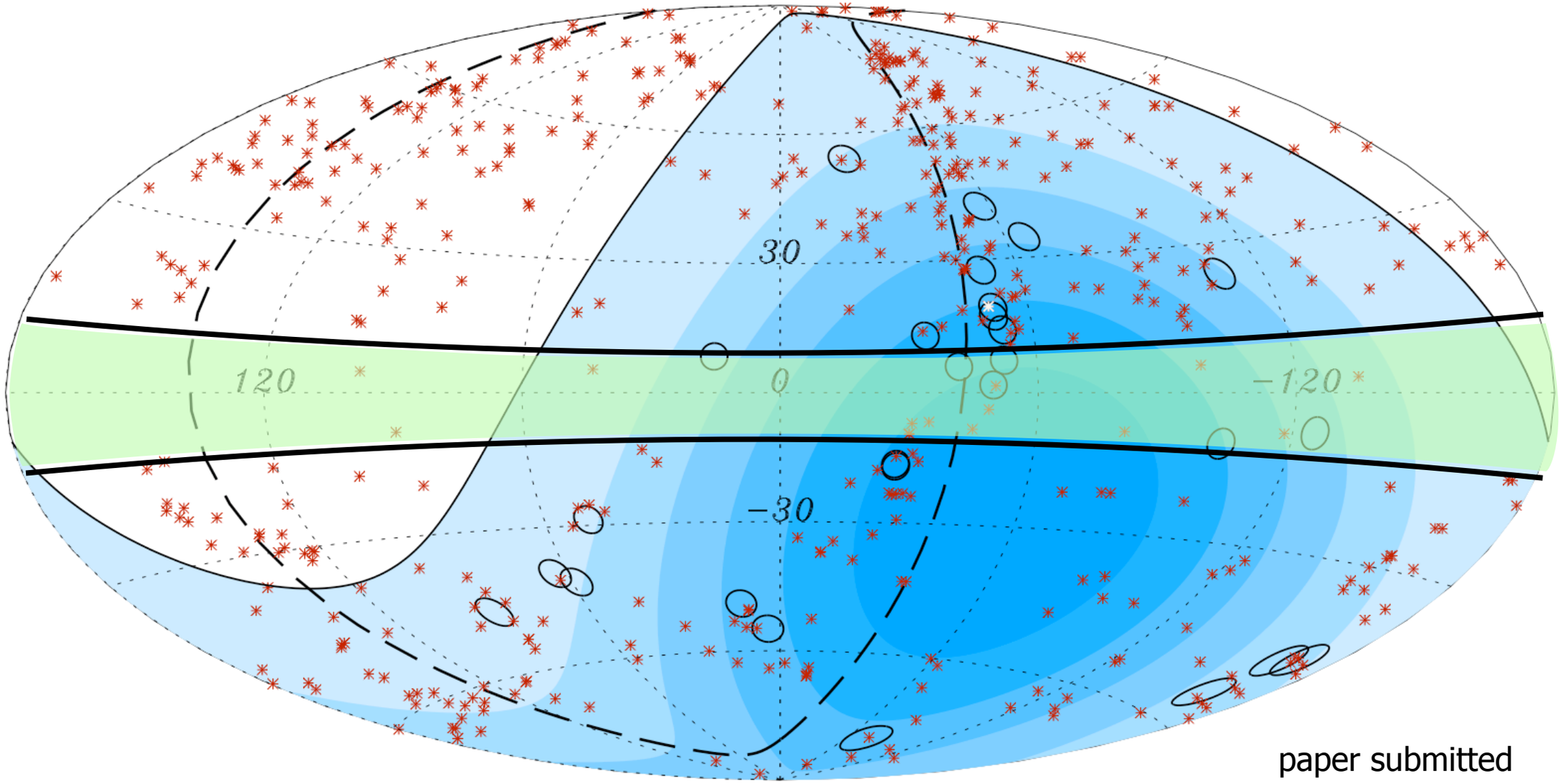
← 38 %

After publication in 11/2007, correlation degree dropped from 69^{+11}_{-13} % (9/13) to 38^{+7}_{-6} % (21/55)

0.3 % probability to find such a correlation from an isotropic distr.

Weaker Correlation near Galactic Plane

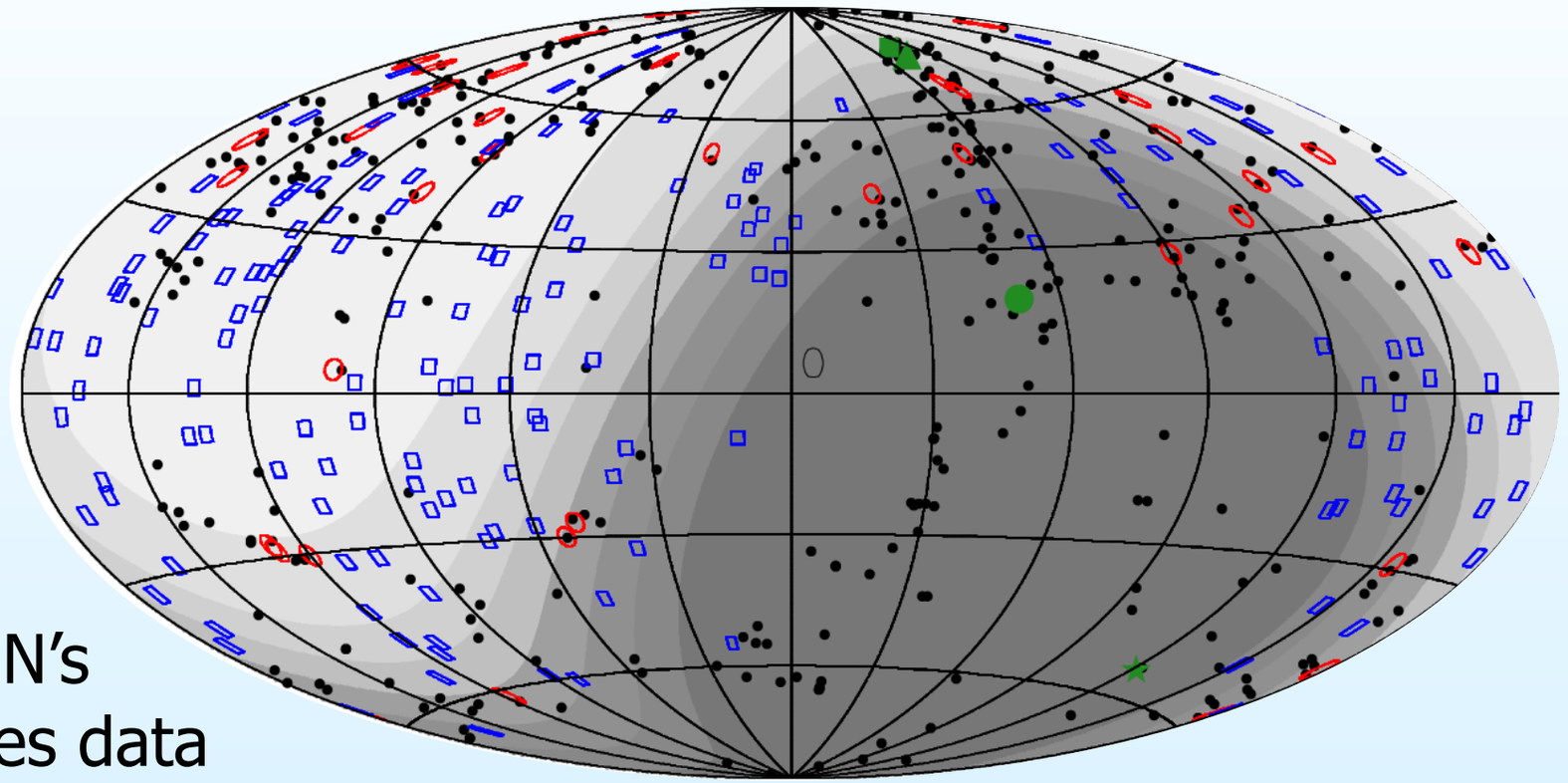
First results reported in Science 318 (2007) 938



paper submitted

when 10° around galactic plane is excluded,
correlation fraction increases from 38 to (46±6)%, while 24% is expected by chance from isotropic distribution

Conflict with HiRes in the North ?

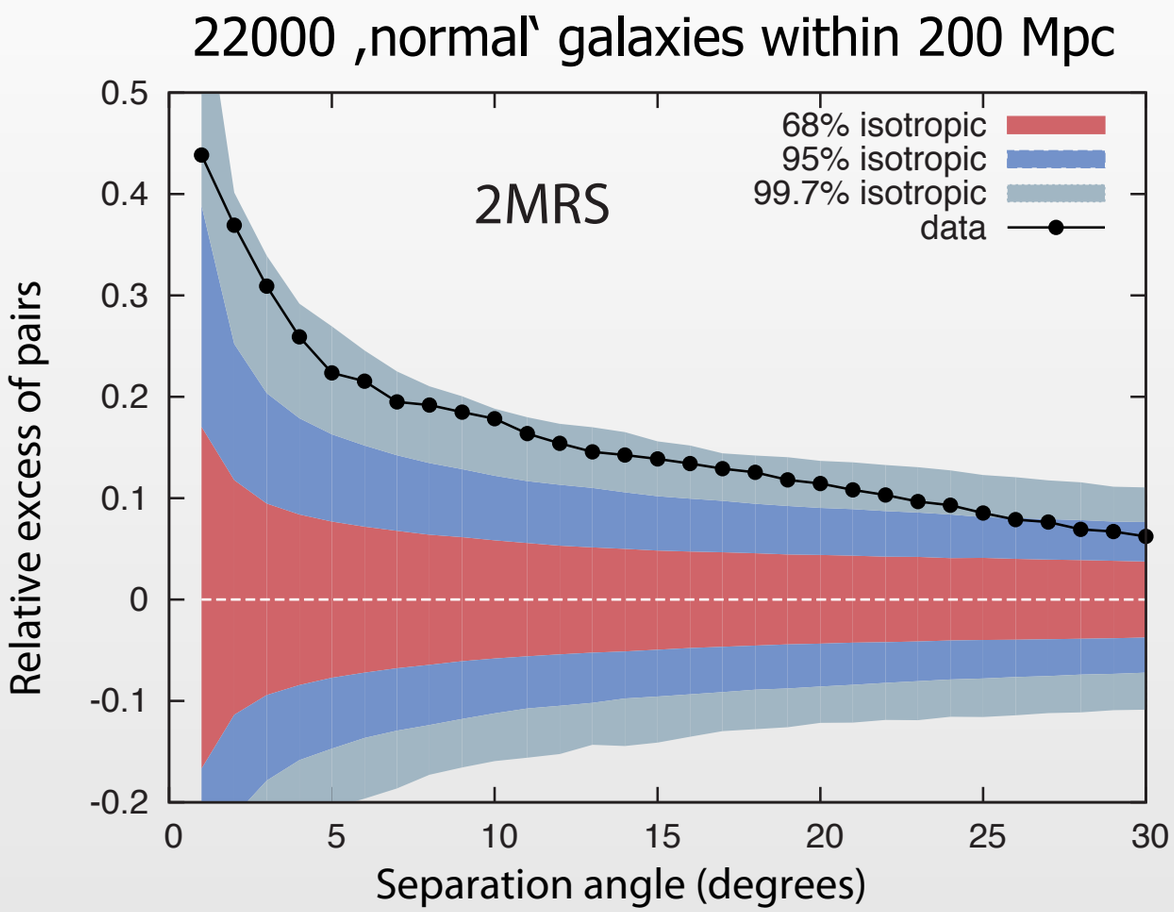


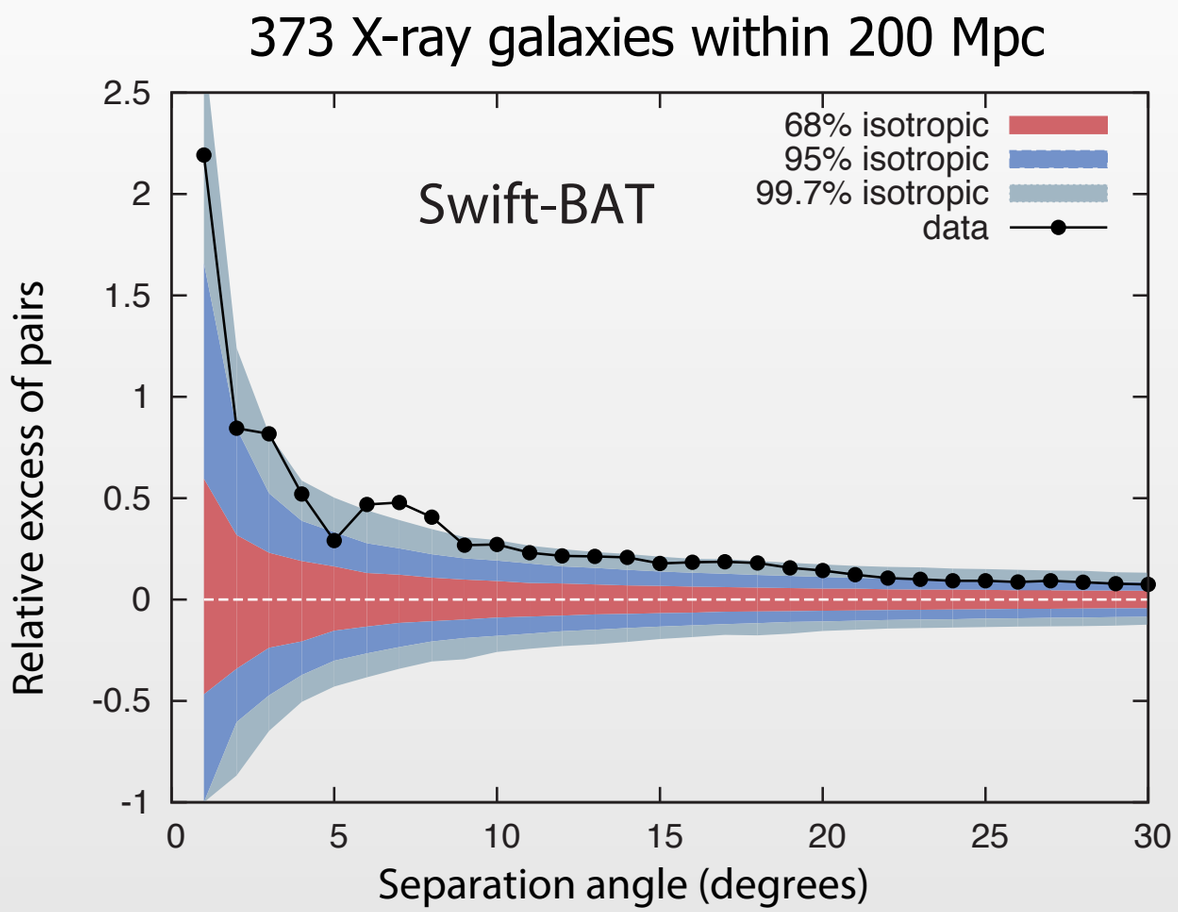
Black - AGN's
Blue - HiRes data
Red - correlated events (from scan in z, ψ and E_{min})

Applying Auger Scan-Parameters:
2 correlations observed out of a set of 13 events; 2.7 expected by chance, 4.9 expected for 38% signal strength
➠ **too low statistics to make any pos/neg claim**

Moreover…
- very sensitive to energy threshold (and resolution!)
- different matter and magnetic field distribution N vs S
- different levels of completeness in VC-V N vs S

Cross Correlations with other Cat`gs

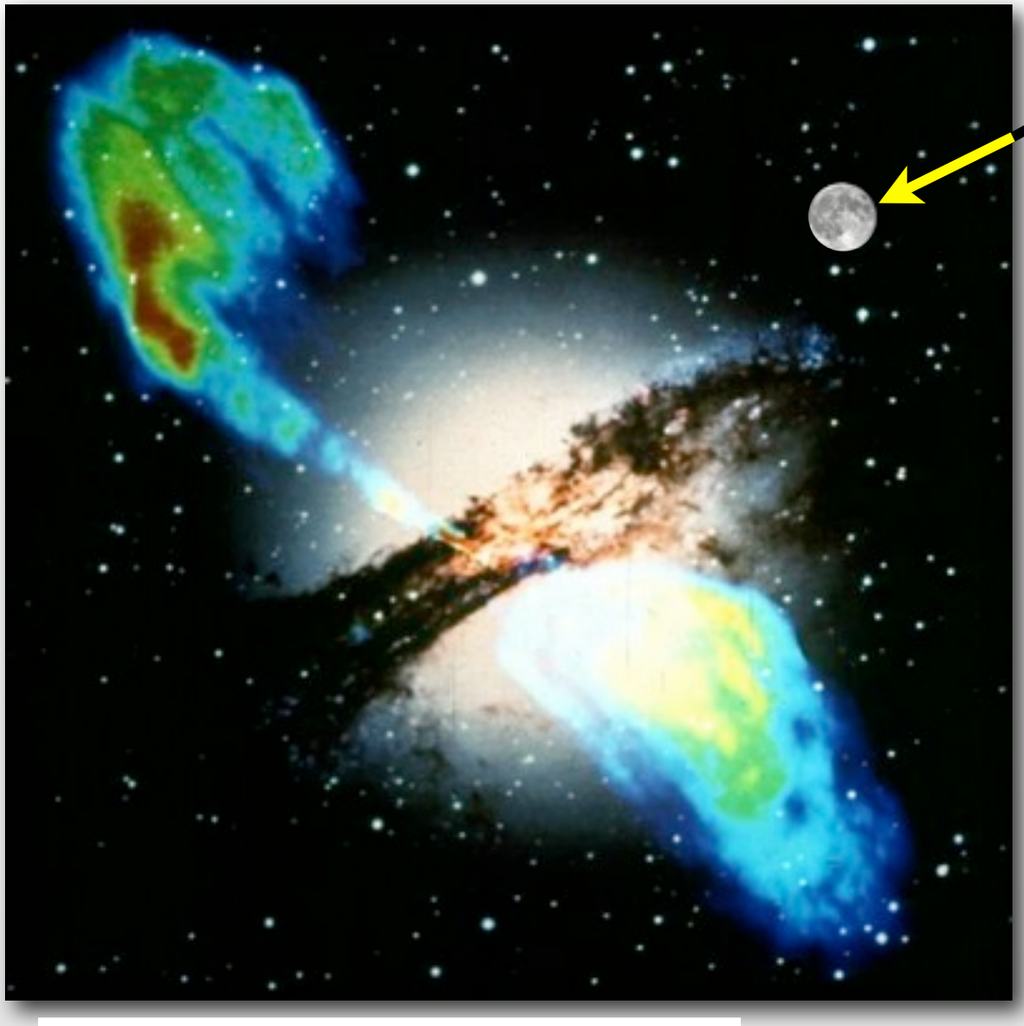




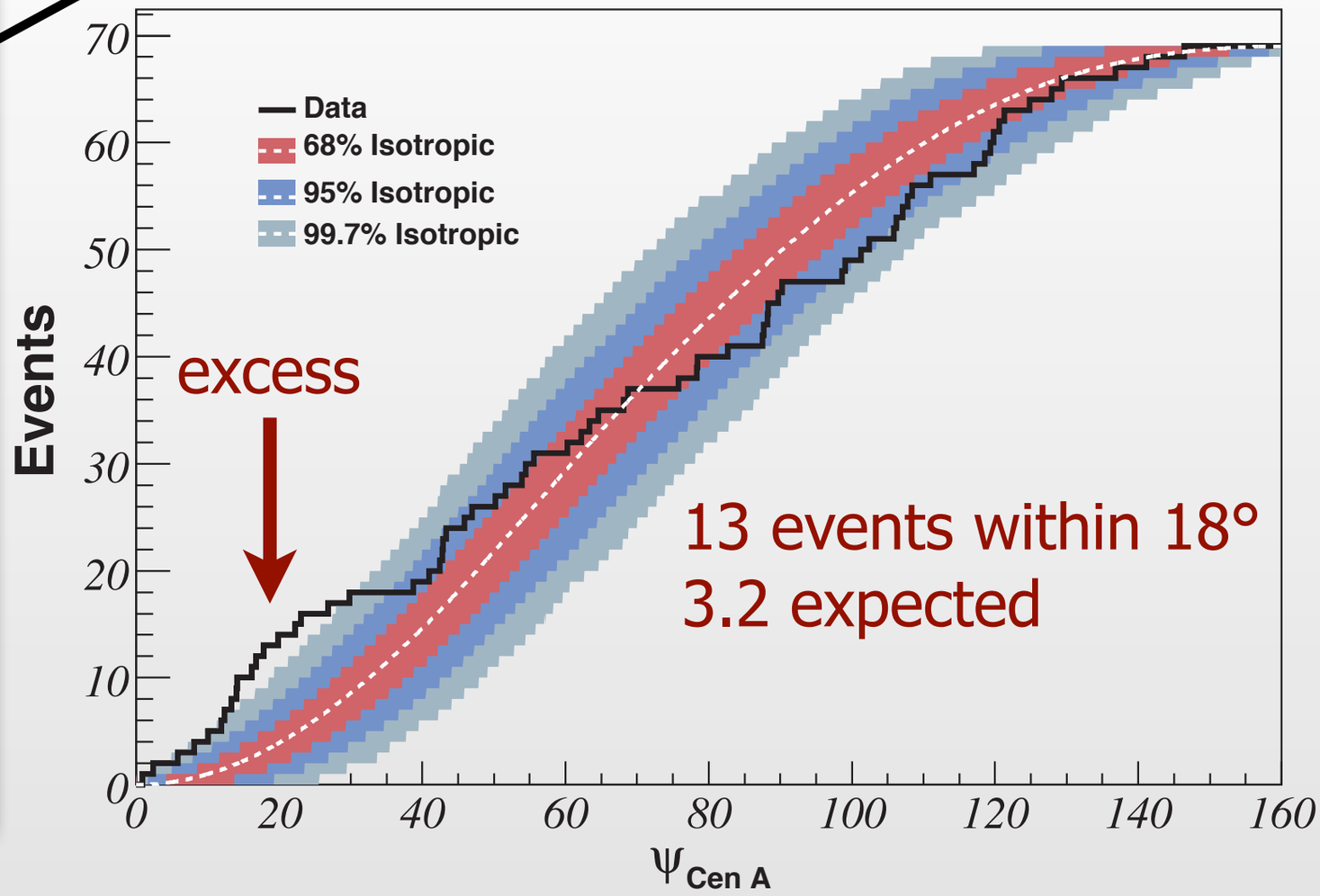
- ★ each CR arrival direction (E>55 EeV) forms a pair with each object in catalogue (d< 200 Mpc)
- ★ plot fractional excess of pairs in data vs isotropic distribution
- ★ ≈ **1% of isotropic samples yield more pairs**

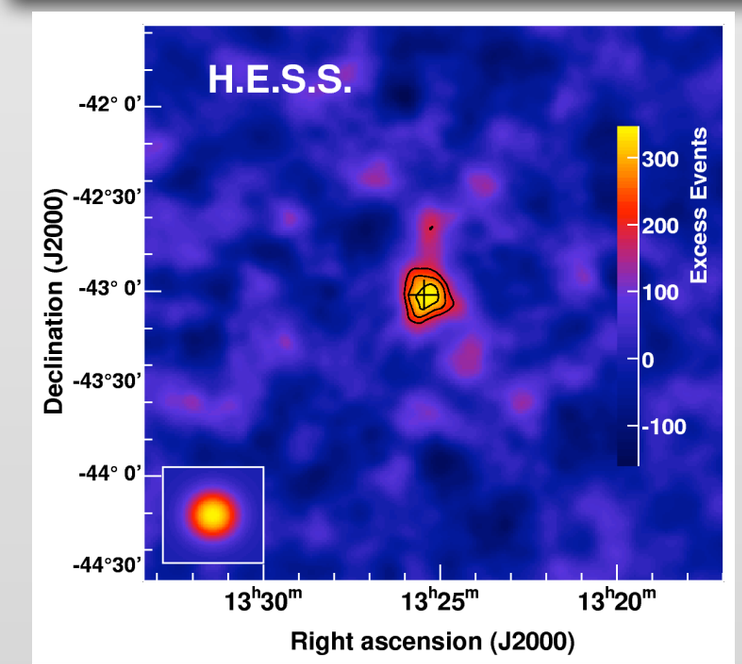
paper submitted

Centaurus A appears interesting



moon for comparison of scale





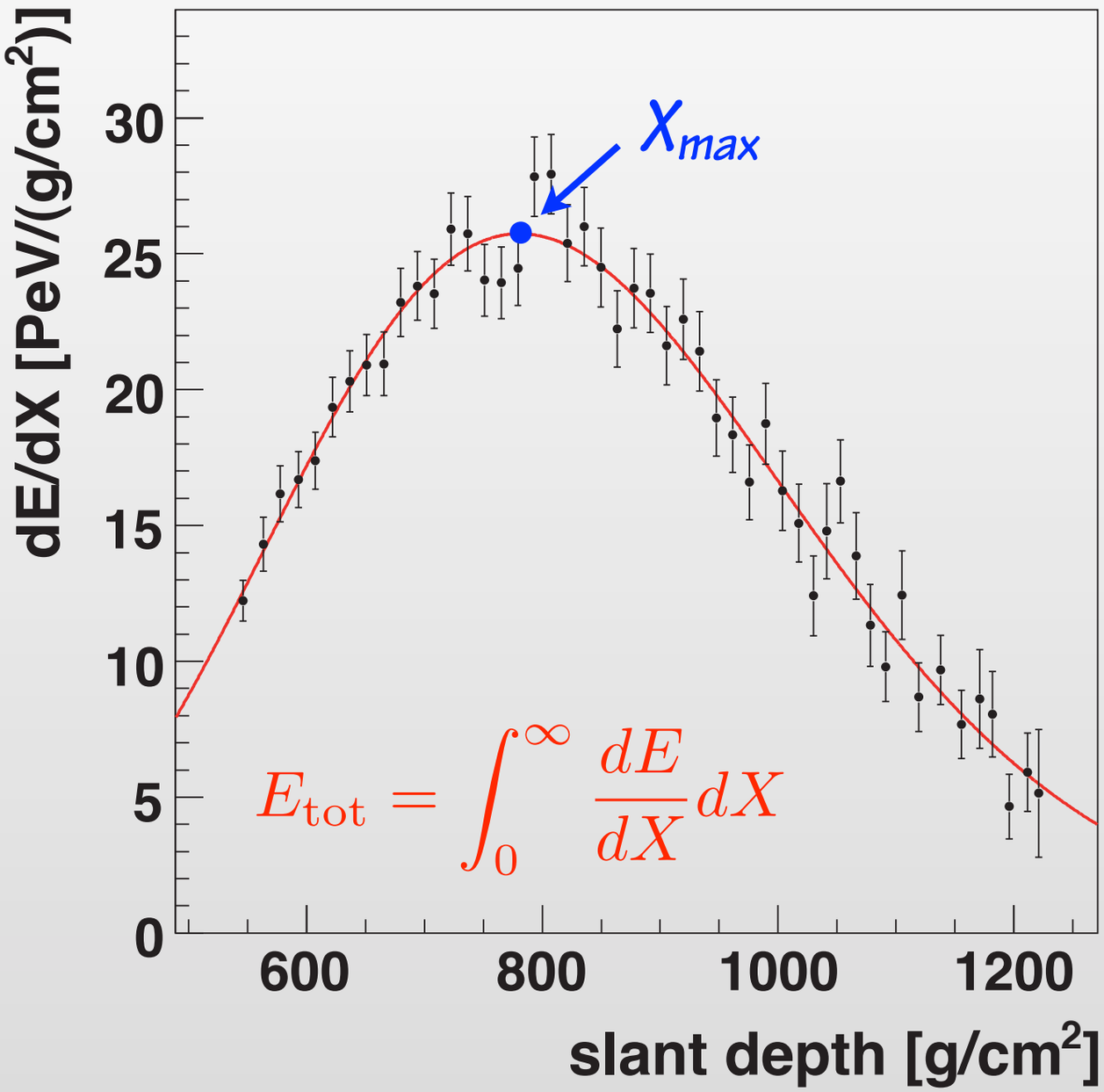
central AGN core
now also seen by HESS and FERMI-LAT

Cen A nearest AGN (FR-I); d~ 3.8 Mpc
(→ GZK hardly visible)

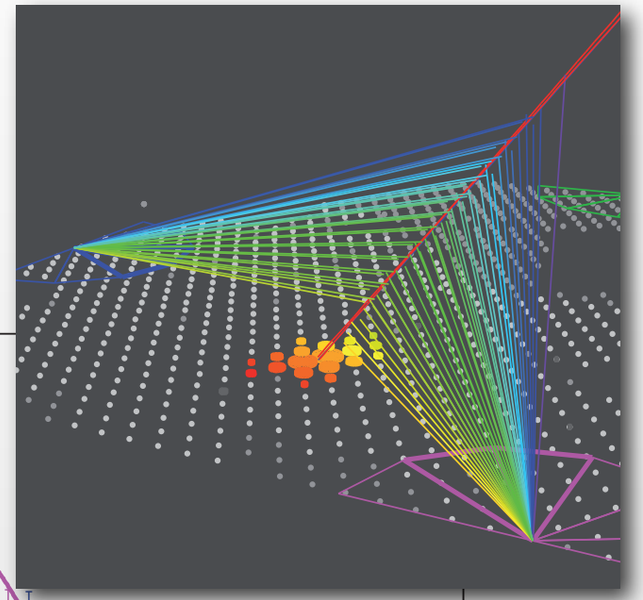
paper submitted

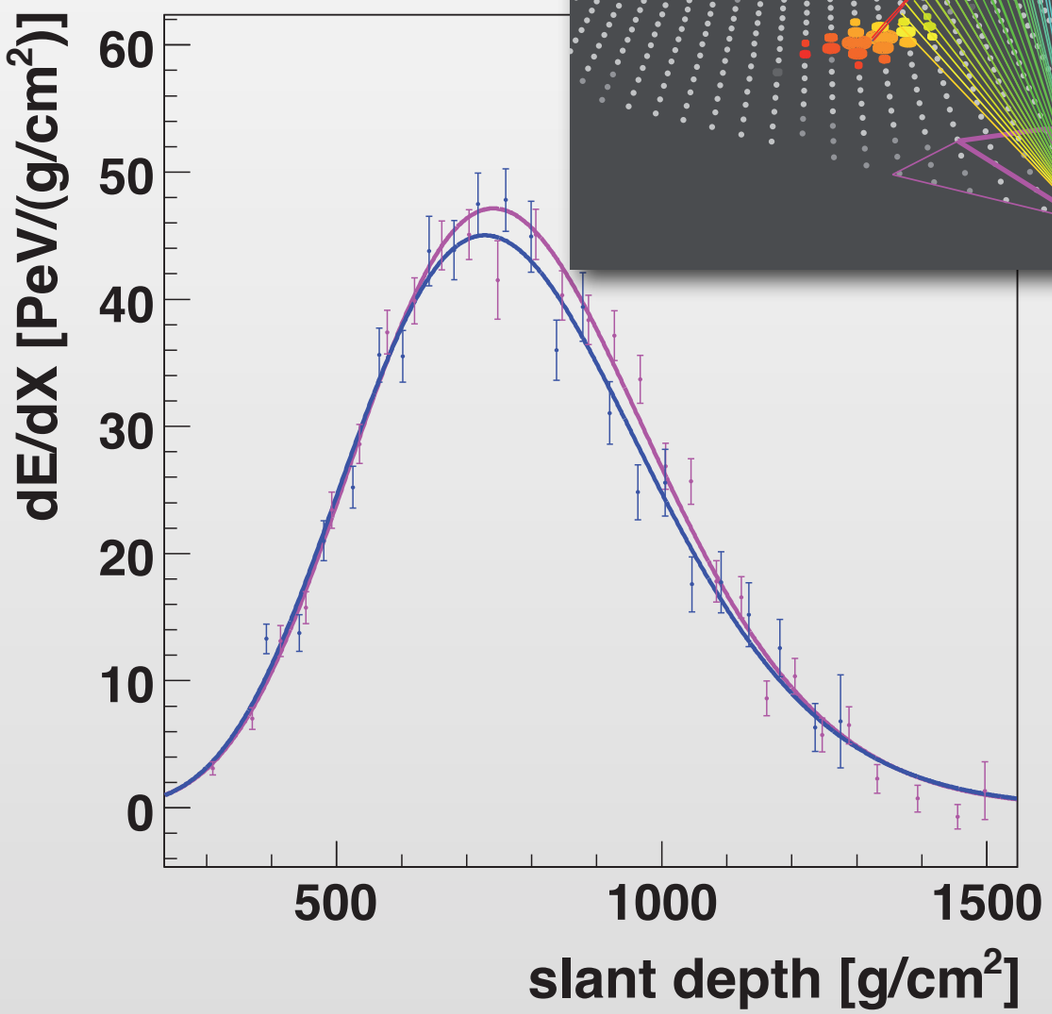
Composition from X_{max} observations

Example: Auger Hybrid



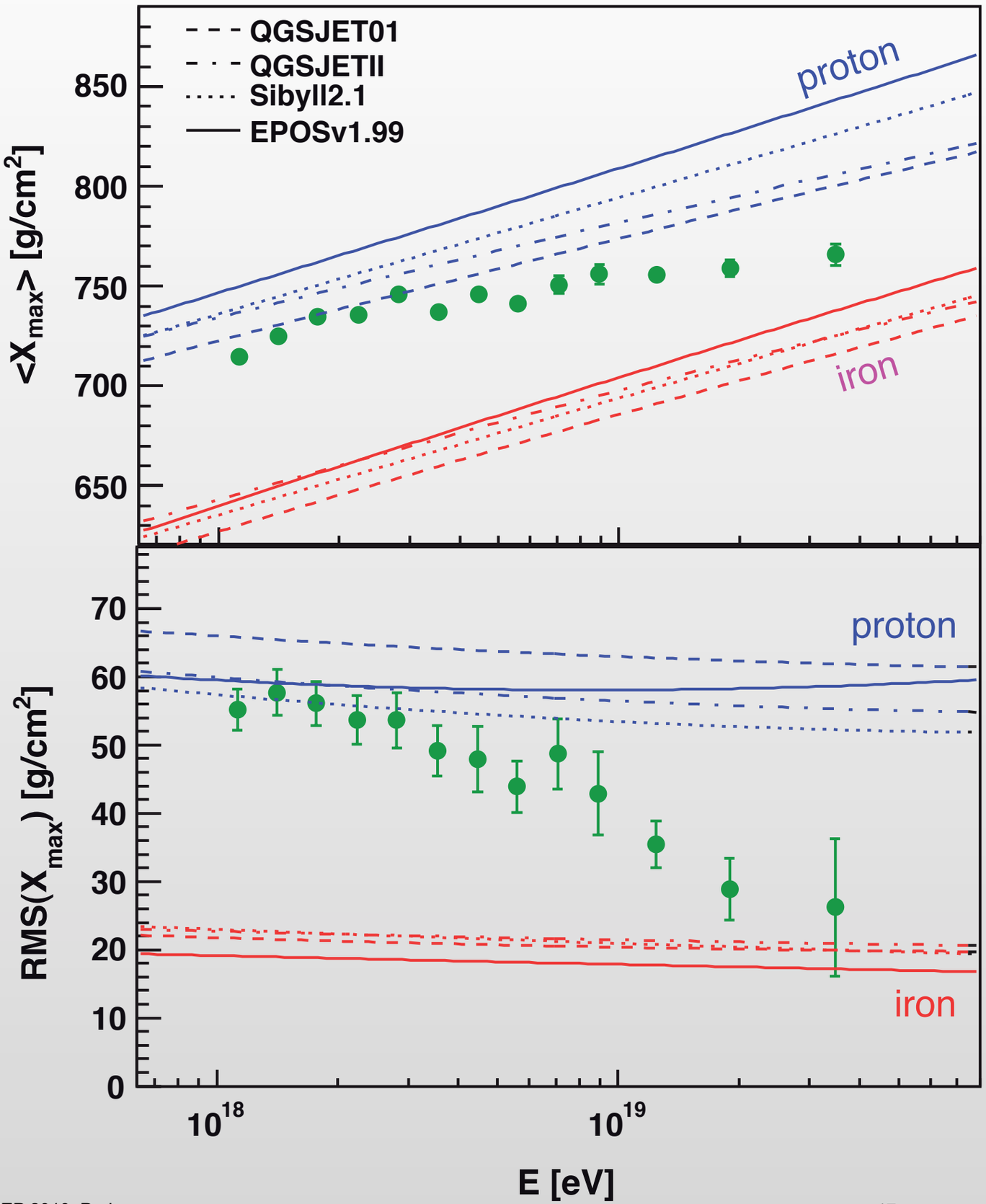
Check by stereo events





Analysis of stereo data: $\sigma(X_{max})$ = 20 g/cm^2

Heavy Composition favoured at high Energy



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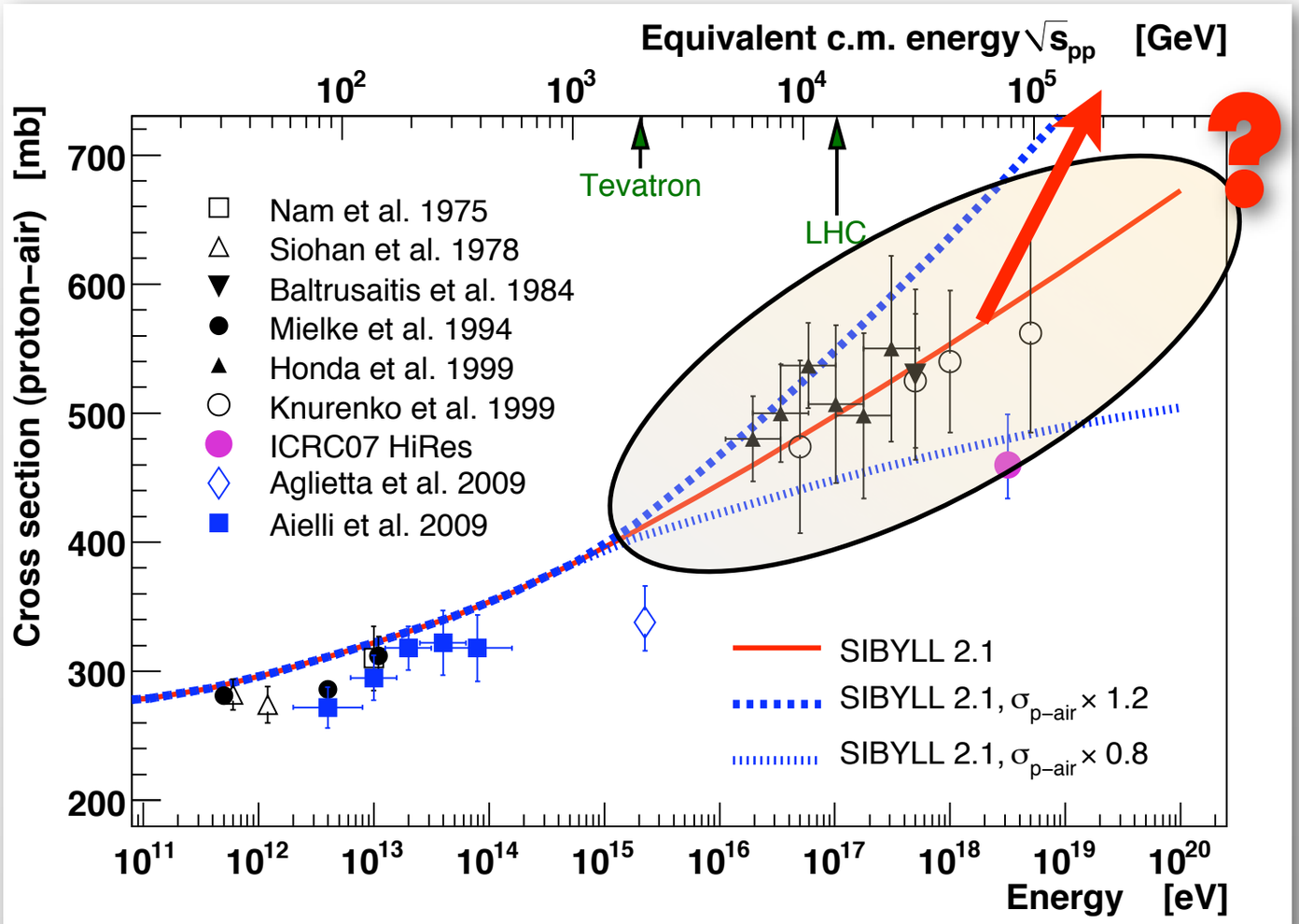
Both mean X_{max} and
RMS of X_{max}
favour heavy composition at
high energies...

but...

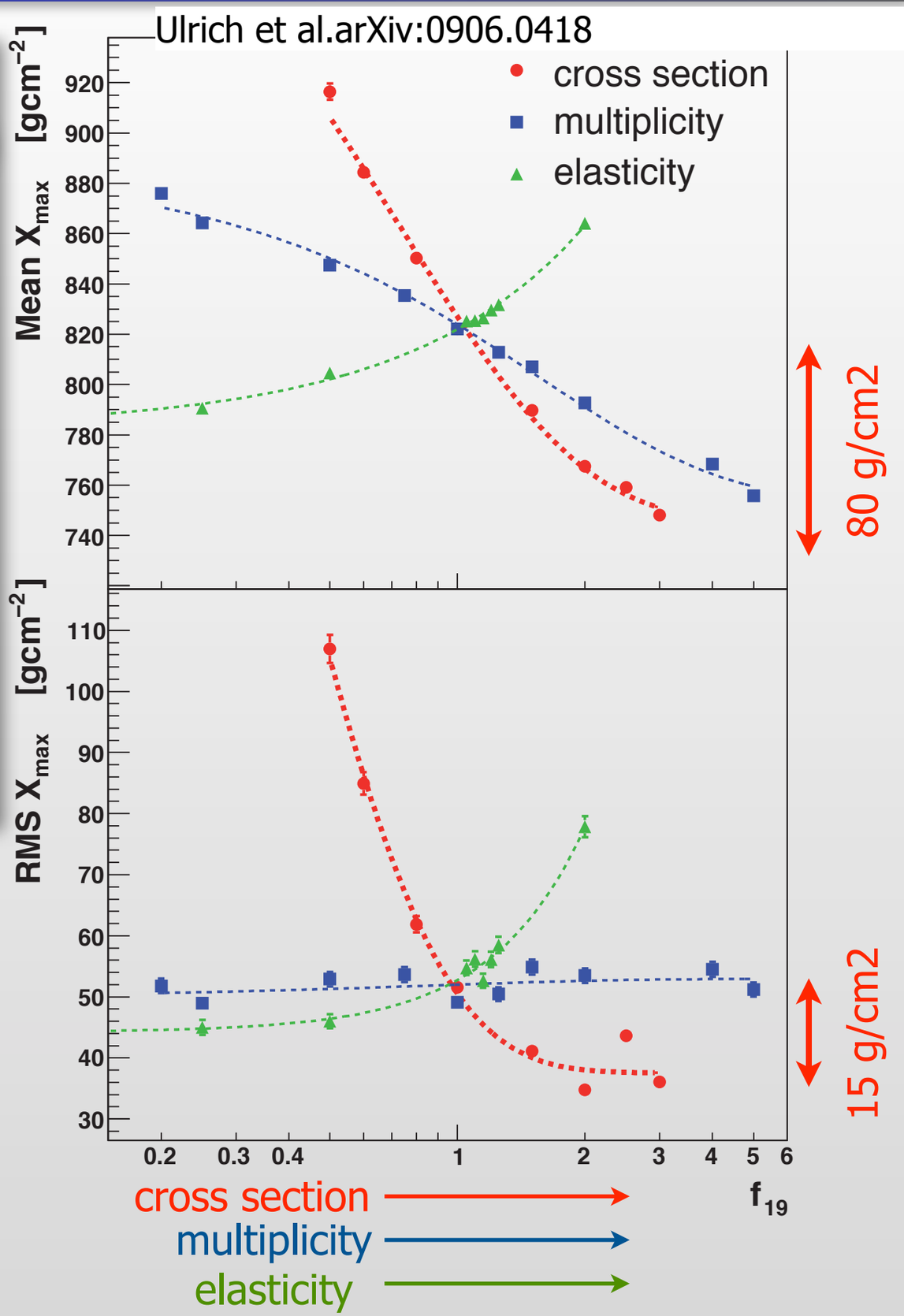
Strongly increasing X-Section ?



Composition measurement related to interaction processes;

Increasing p-Air X-section could bring down X_{max} and its RMS

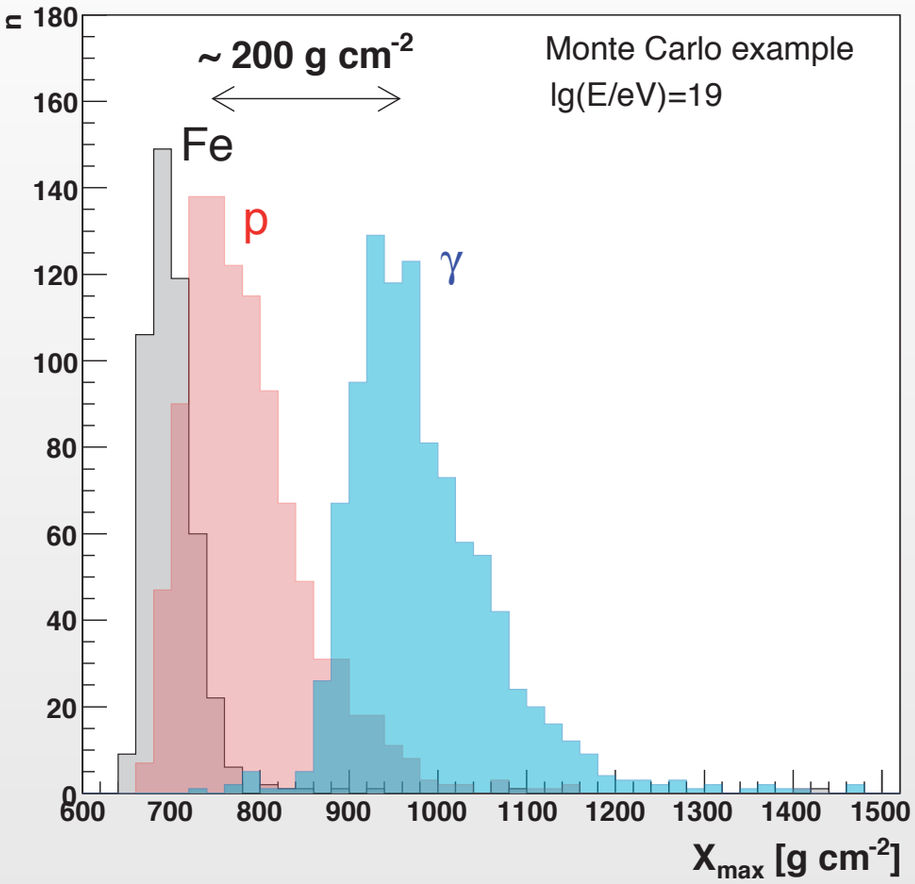
But details difficult to meet!



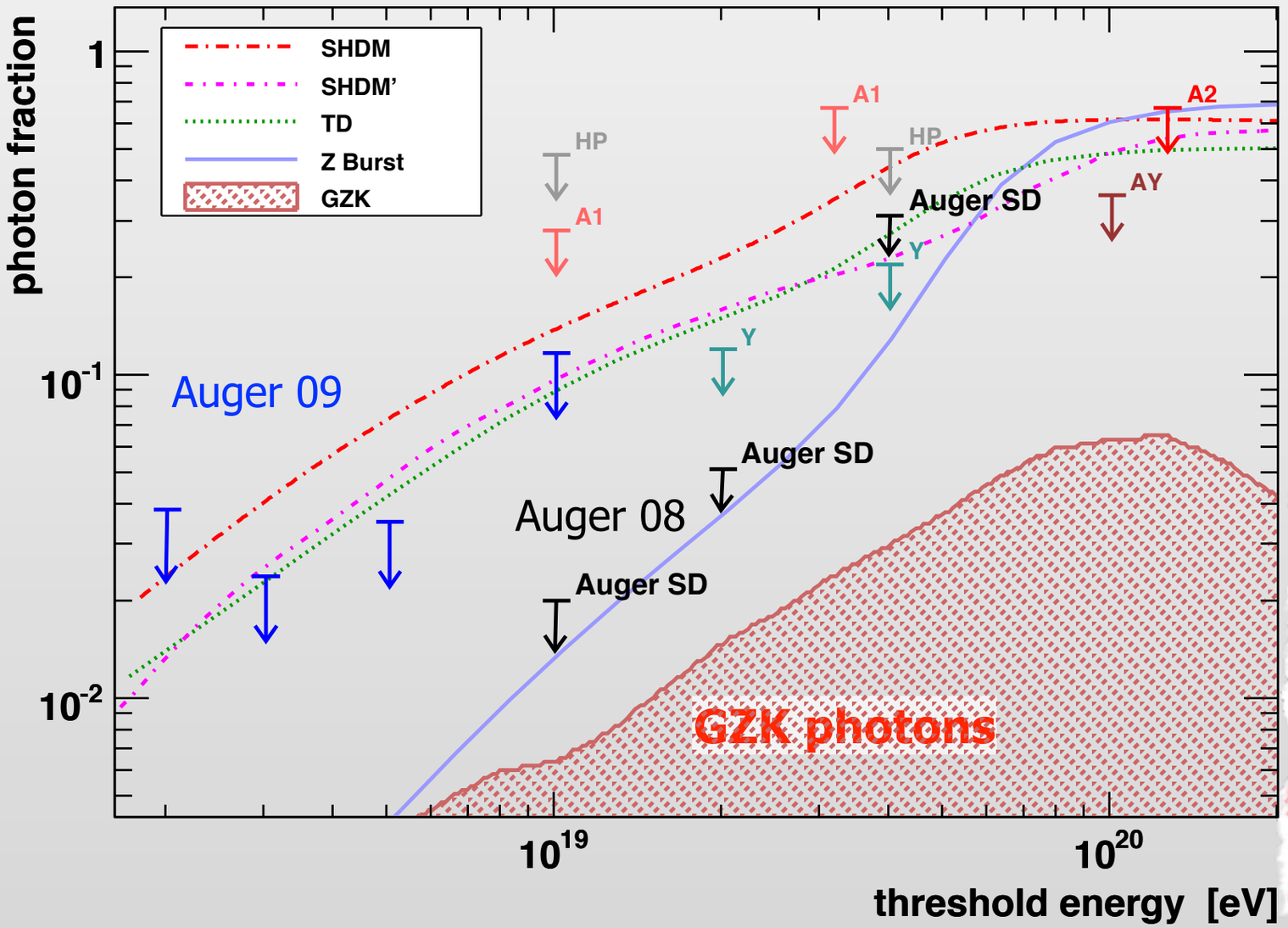
Strongest Upper Limits on Photons

Very good γ-Hadron Discrimination by X_{max} Measurements

γ-induced showers less sensitive to EAS modelling



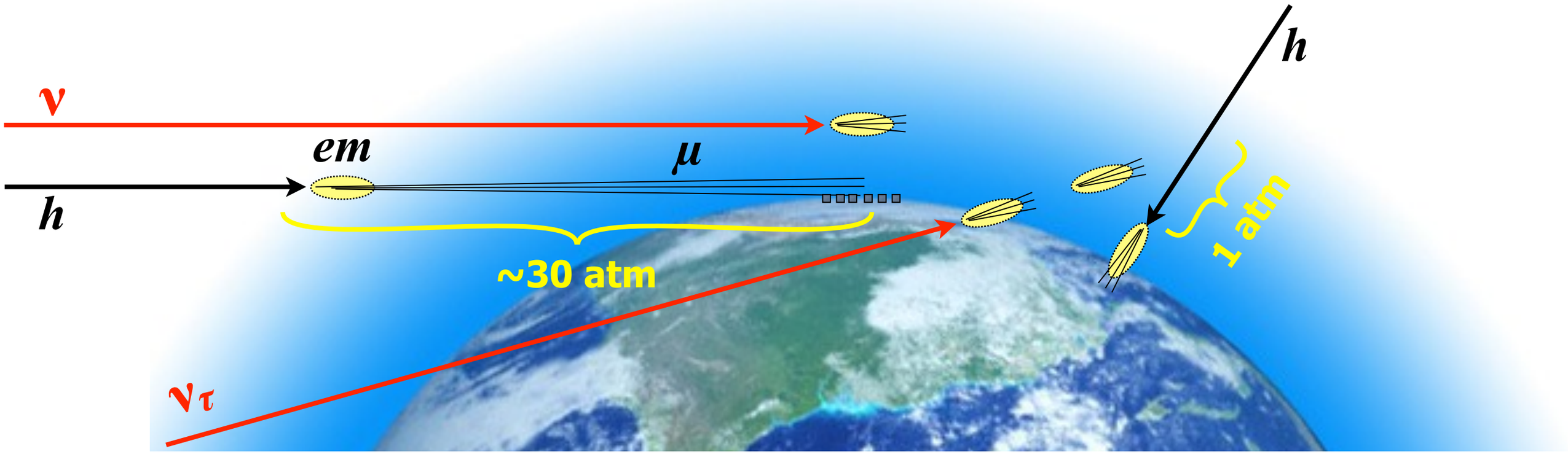
Astropart. Phys. 31 (2009) 399-406



Top Down & SHDM Models largely ruled out GZK-Photons in reach

EeV Neutrinos by Horizontal EAS

Only a neutrino can induce a young horizontal shower !



shower front

after 1 atm

electromagn. cascade

after 3 atm

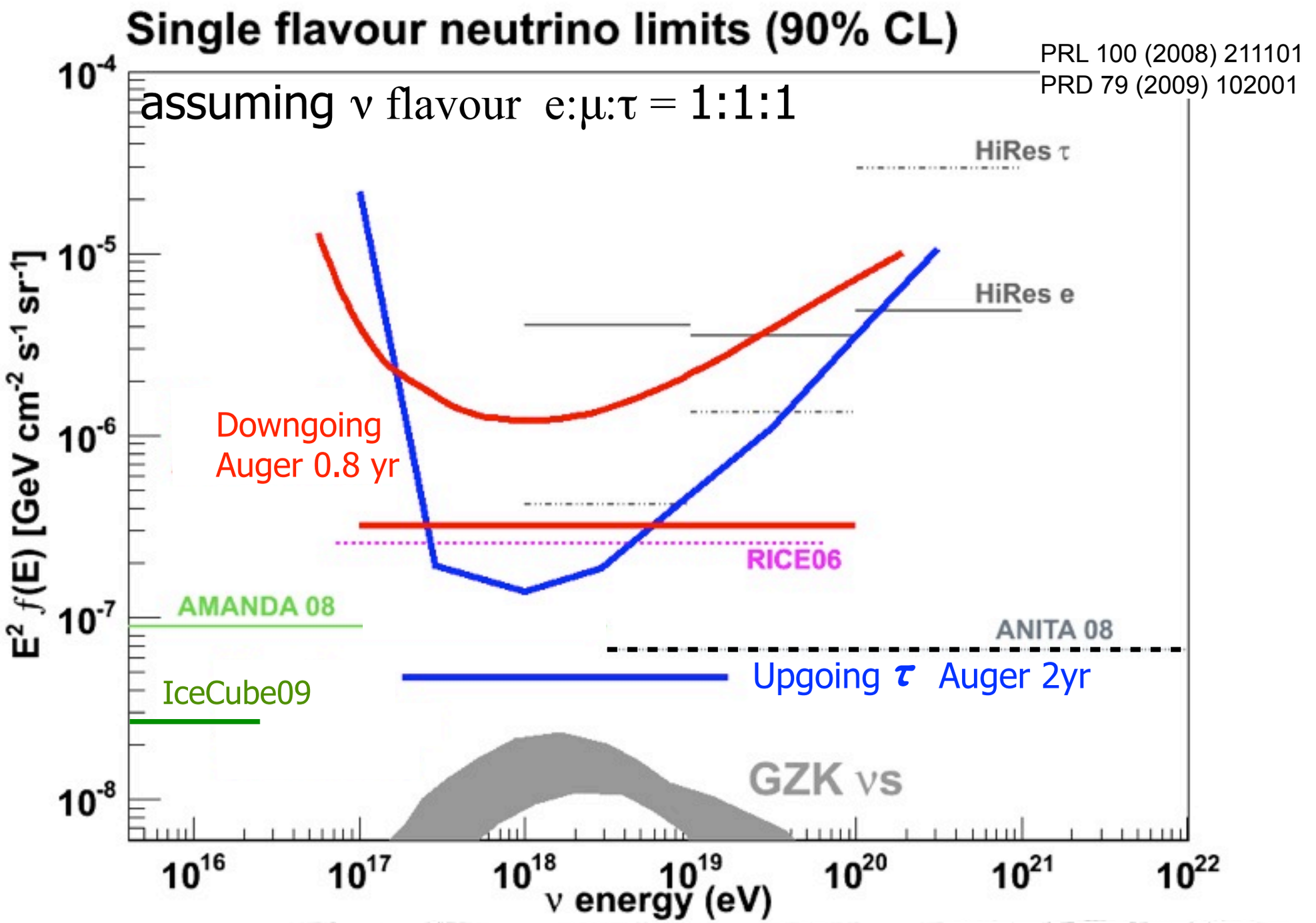
hard muons

+ 20% electrons in equil. with muons

'young' showers (*ν*)
- Wide time distribution
- Strong curvature
- Steep lateral distribution

'old' showers (*h*)
- Narrow time distribution
- Weak curvature
- Flat lateral distribution

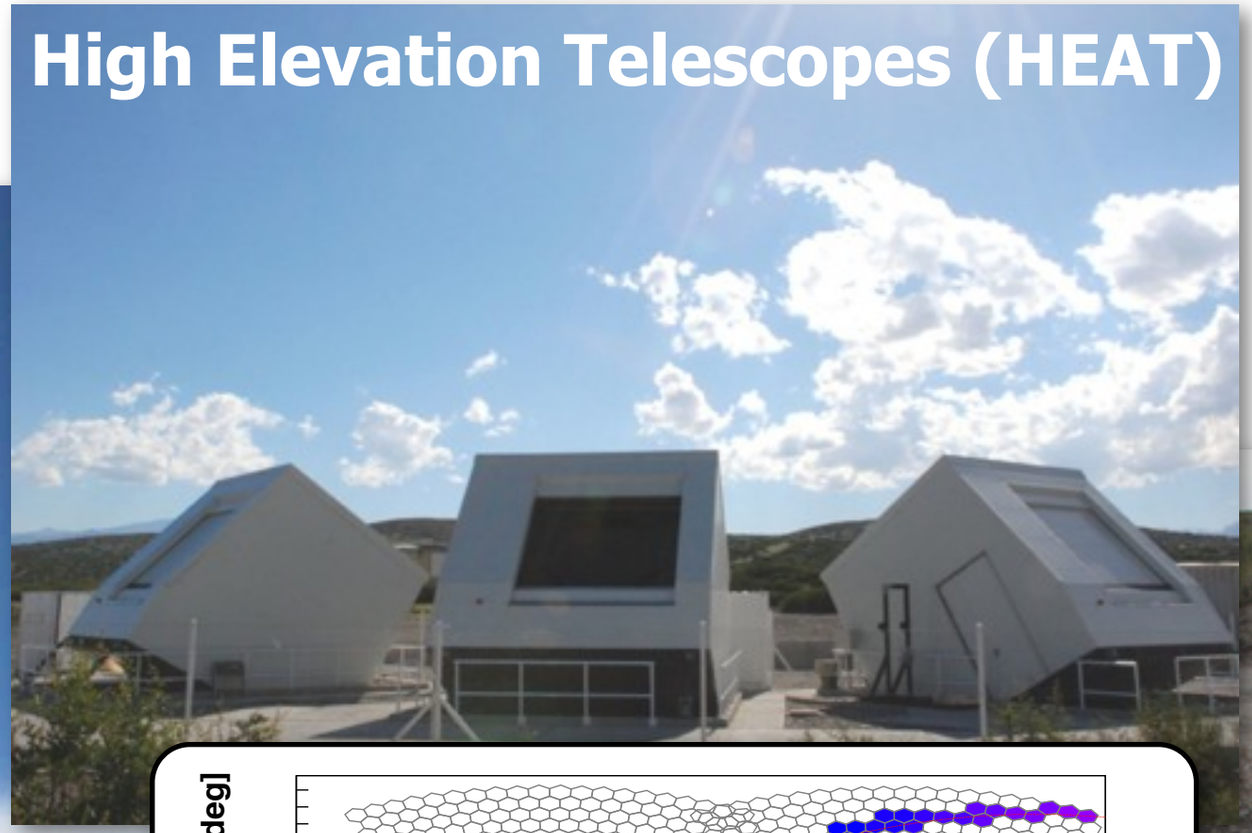
UHE Diffuse Neutrino Flux Limits

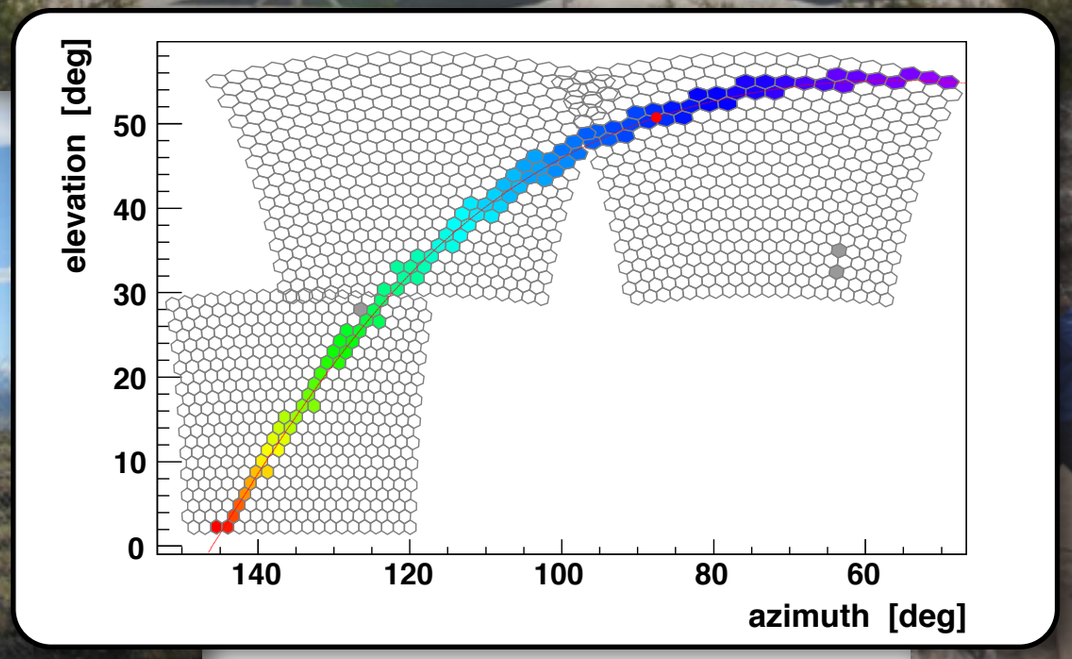


Several astrophys. models excluded; cosmogenic neutrinos in reach !

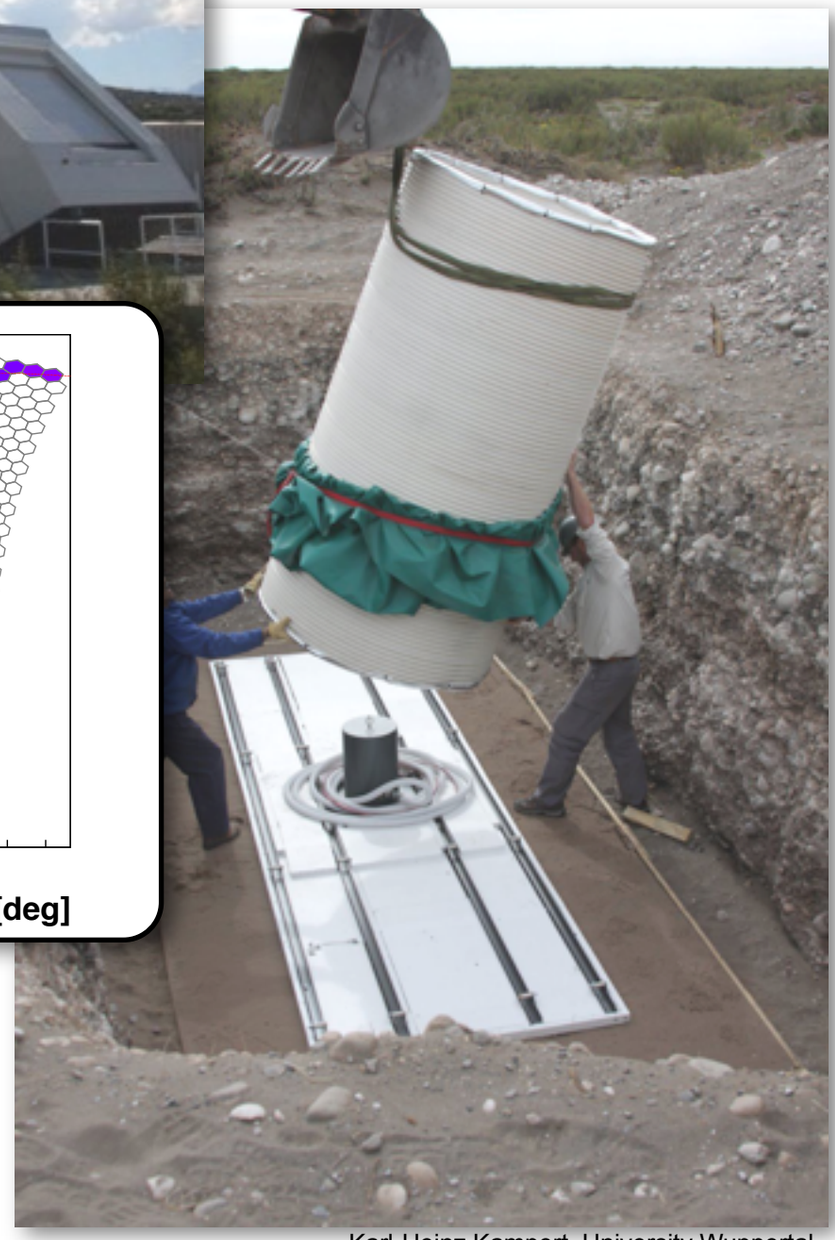
Auger Enhancements

High Elevation Telescopes (HEAT)





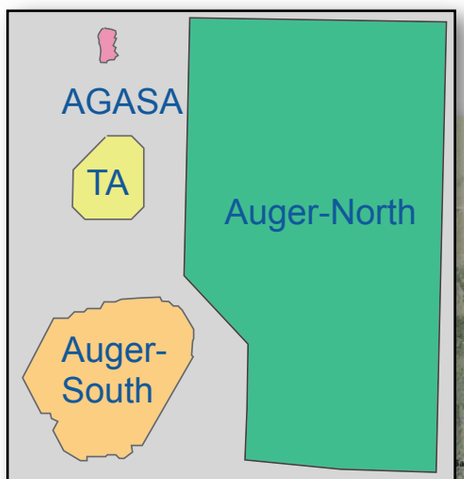
20 km² radio antenna field

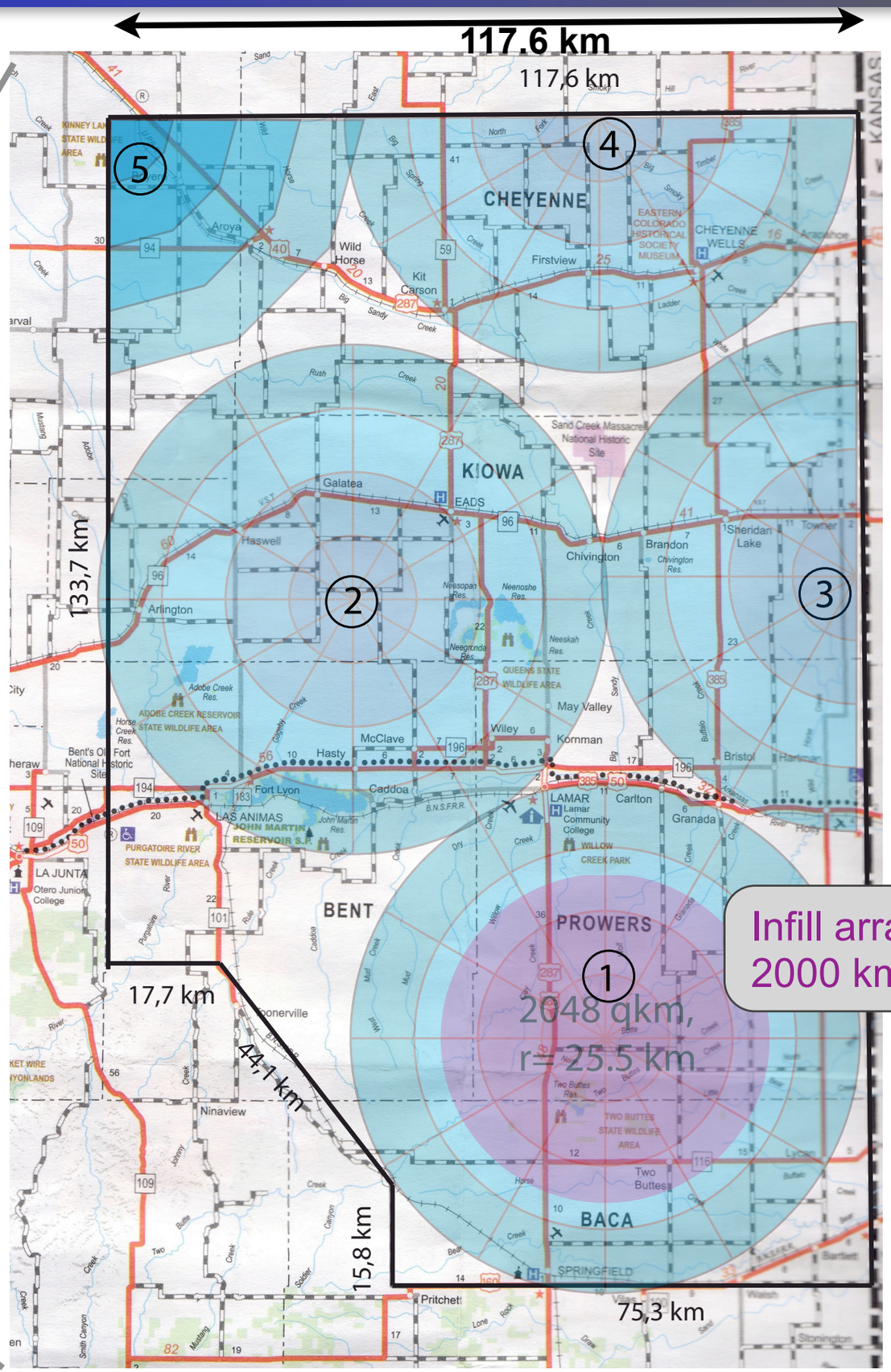


Infill and Muon Detector (AMIGA)

Auger North in Colorado

- **Optimized for science and costs**
- **Surface array with 4000 stations:**
  20,000 km² with
  √2-mile = 2.3 km grid
- **Infill array with 400 stations:**
  2,000 km² with
  1-mile = 1.6 km grid
- **39 fluorescence telescopes**





Summary

- Auger collects data with an annual exposure of 7000 km^2 sr yr
- Largest statistics and highest quality ever
- Suppression of E-spectrum above GZK-Energy
- Arrival directions of events above GZK-threshold show correlation to nearby matter distribution
- Correlation has weakened, significance remains constant
- Trend to heavier composition above 10^{19} eV
  (but hadronic interactions may change, too; independent SD data...)
- Suffering from X_{max} statistics in GZK-energy range
- strongest photon and neutrino limits ~10^{18} eV
  almost rule out top down models
- Auger South is being extended to a multi-hybrid observatory allowing high quality measurements also below ankle
- Strong Auger-North R&D activity has begun