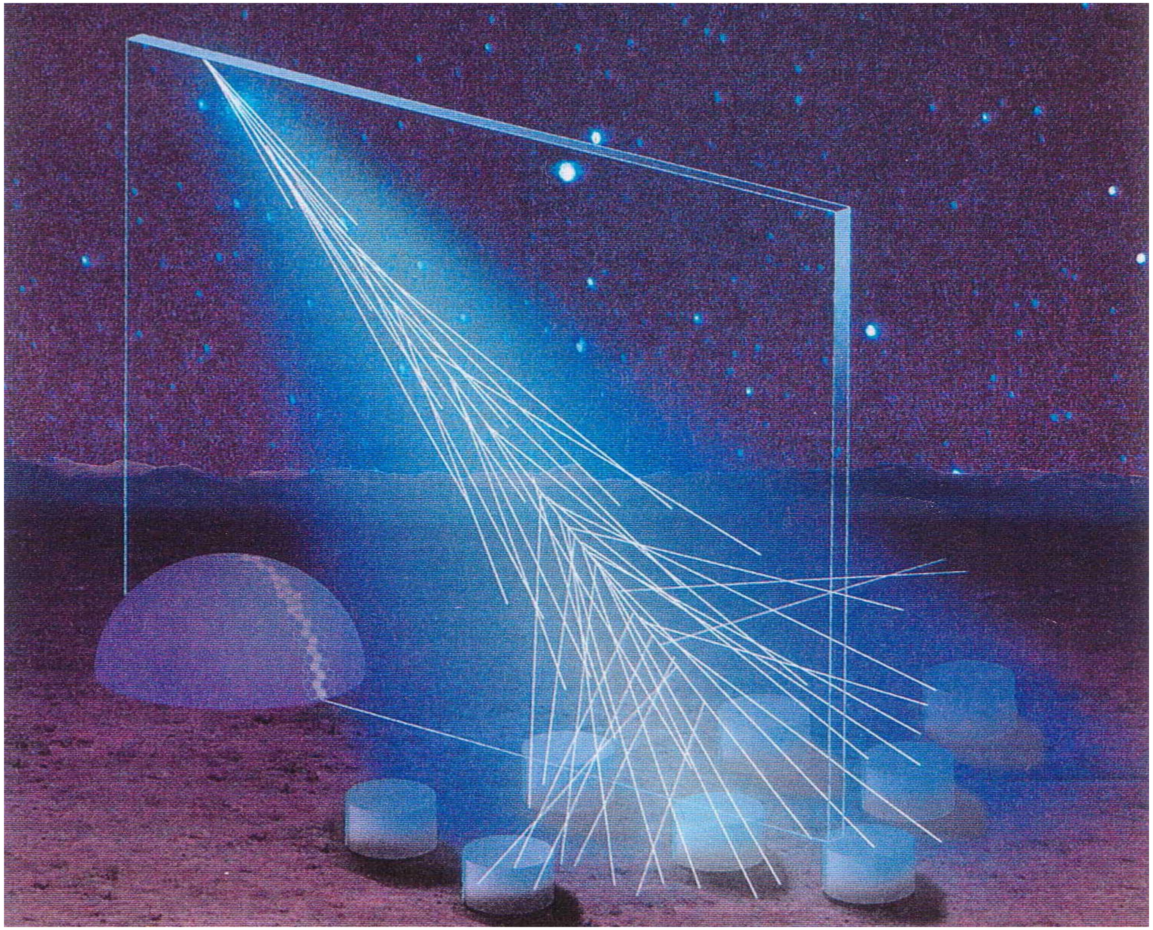
Highlights from the Pierre Auger Observatory

M. Bohacova
for the Auger collaboration



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PIERRE AUGER OBSERVATORY

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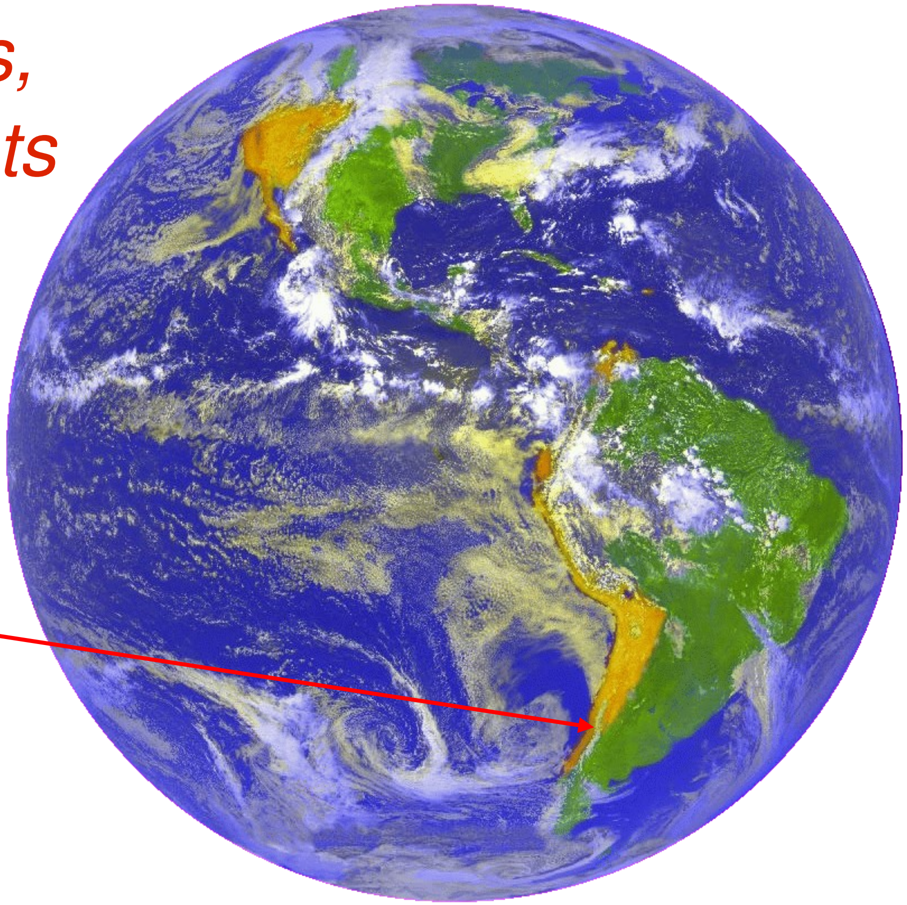
Pierre Auger Project

Detection of Ultra High Energy Cosmic Rays

18 countries,
476 scientists

Malargüe,
Mendoza province,
Argentina



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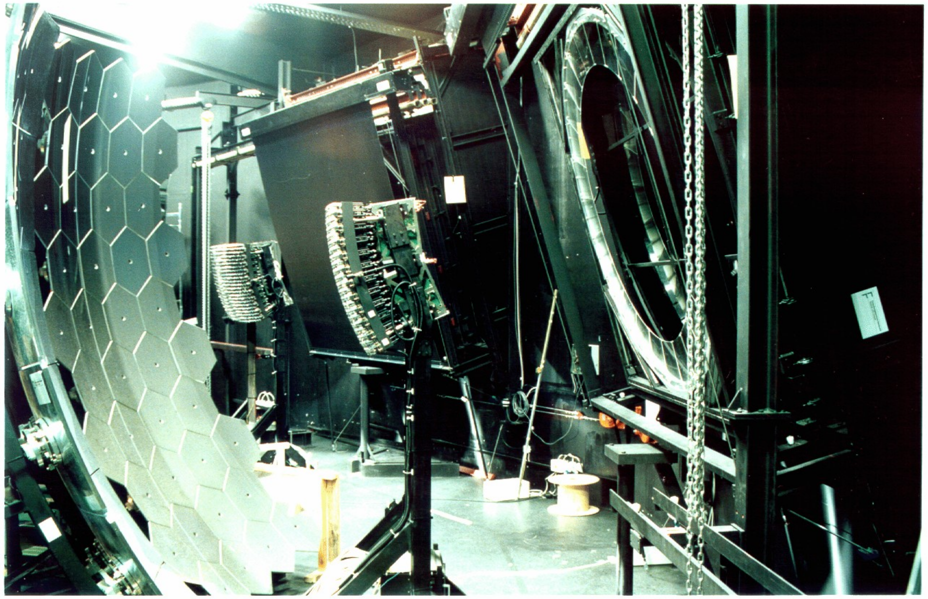
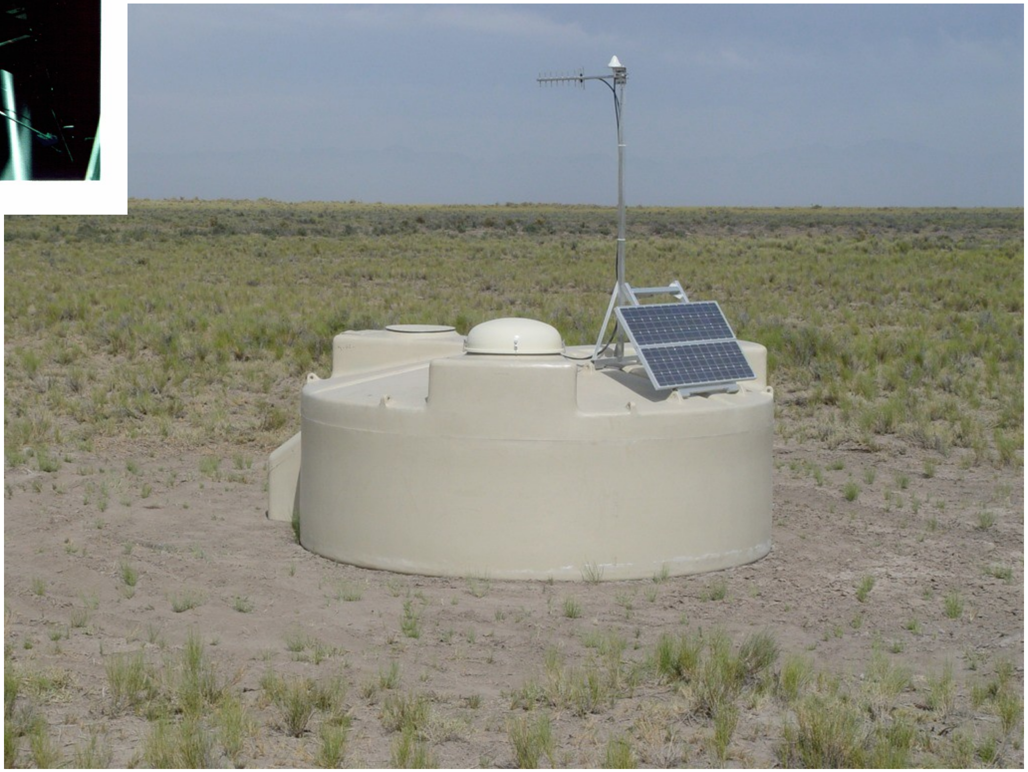
Two detection techniques



Fluorescence telescopes

- 30° x 30° field of view
- 440 PMT camera

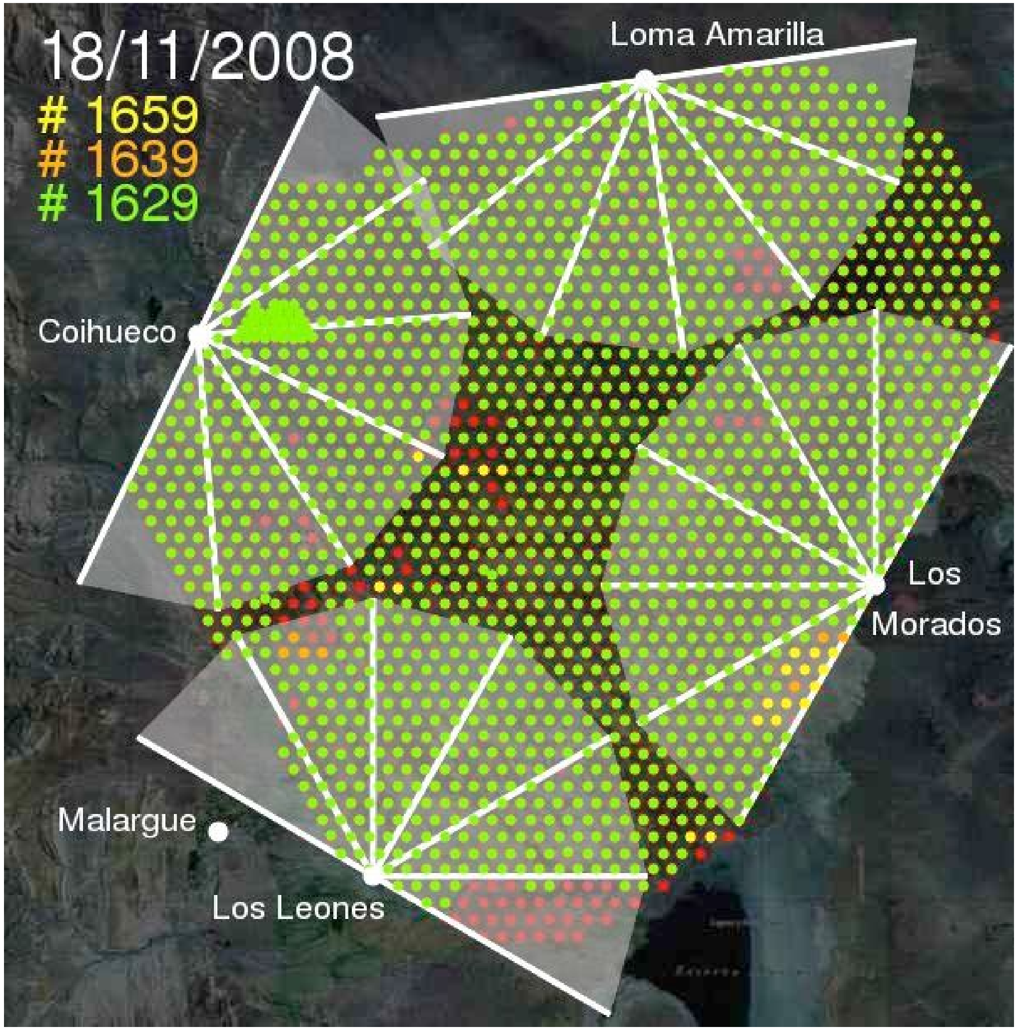


Cherenkov water tanks

- 12 tons of water
- 3 PMTs (9 inch)
- 1.5 km appart

Hybrid detector

- *24 telescopes in 4 buildings*
- *1663 water Cherenkov Detectors*
- *Covering 3000 km²*



Science results

- *Energy spectrum*
- *Anisotropy*
- *Photon limit*
- *Neutrino limit*
- *Mass composition*

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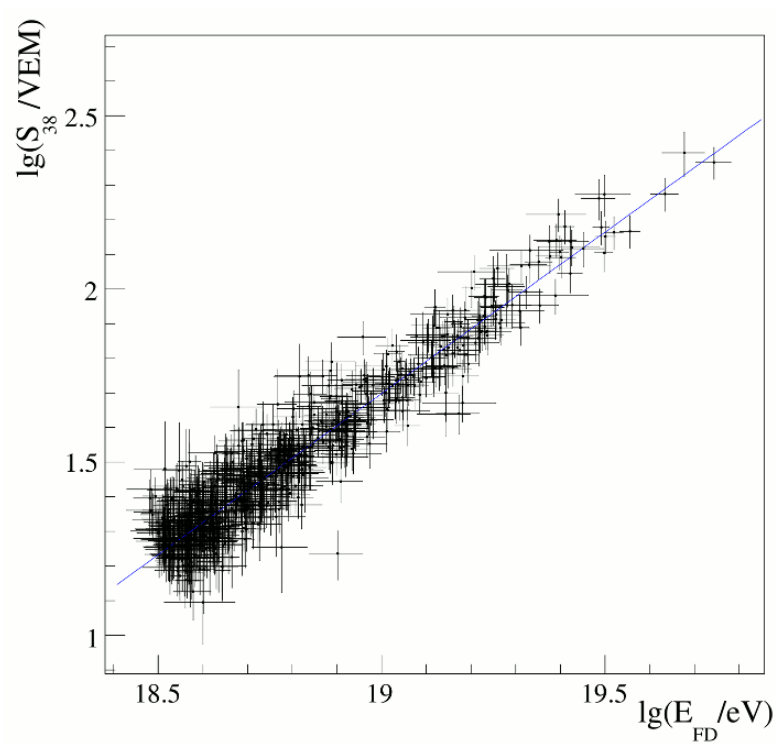
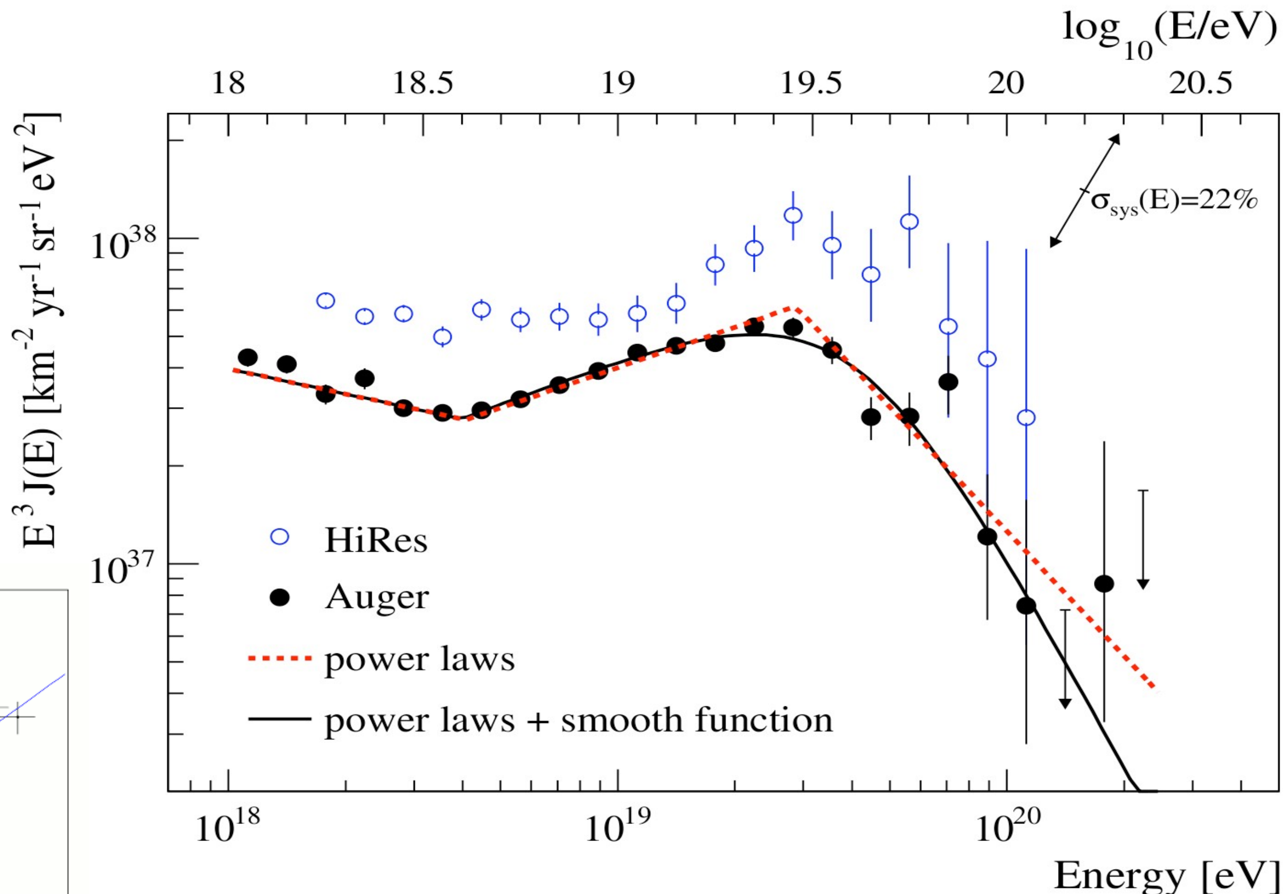
Energy spectrum

- *Model independent energy determination*





- *GZK suppression*
  (about right for protons)
- *or maximum accelerator energy reached?*

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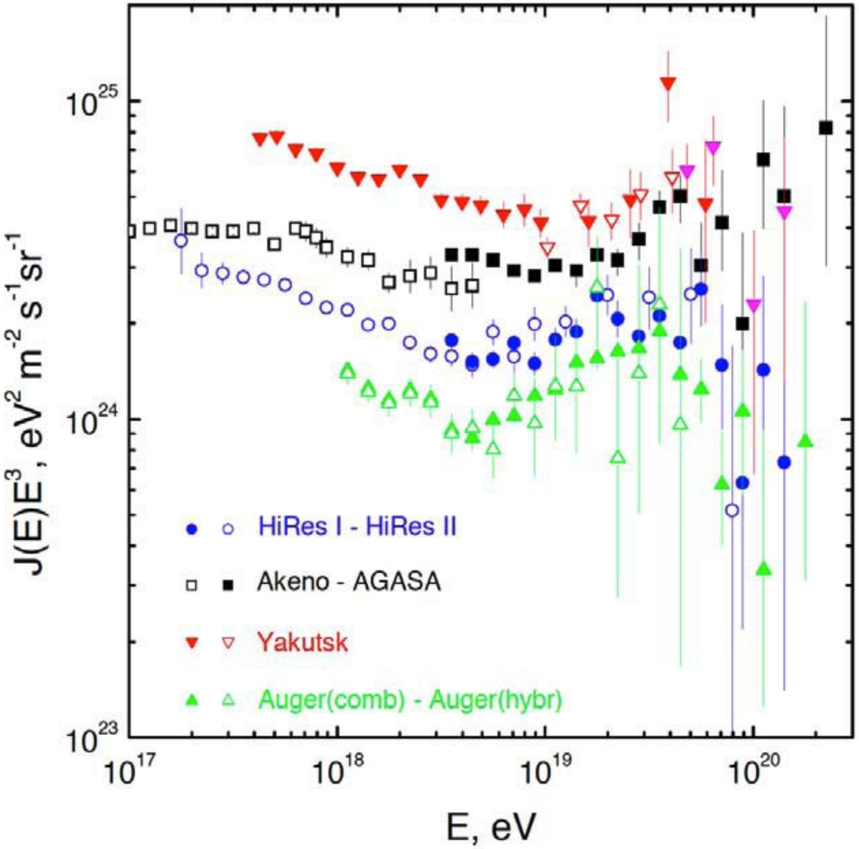
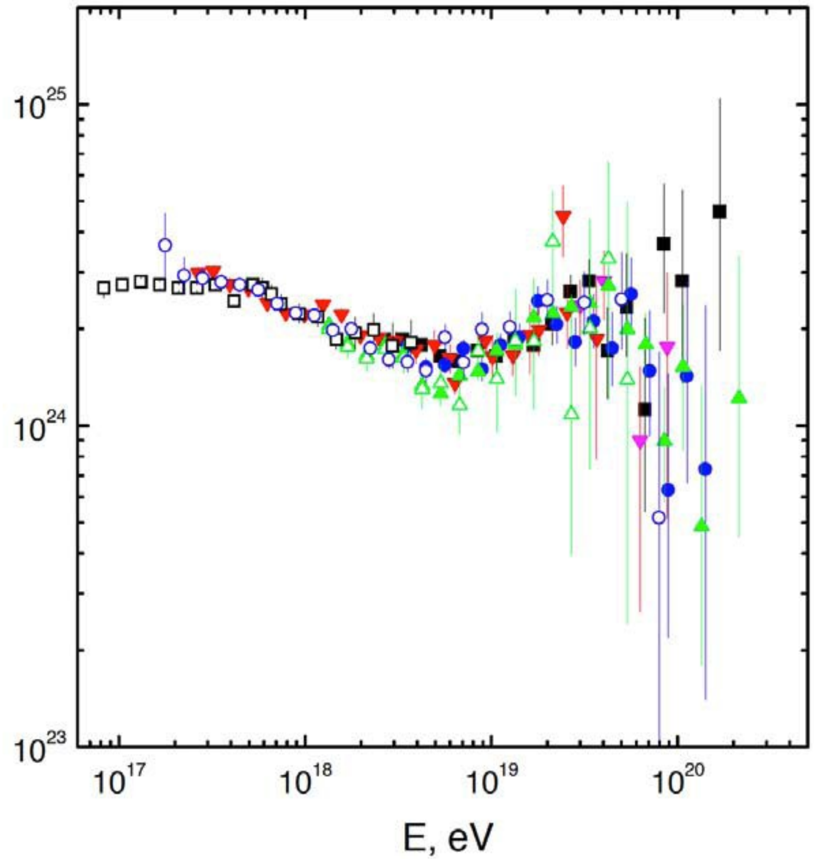
Energy spectrum

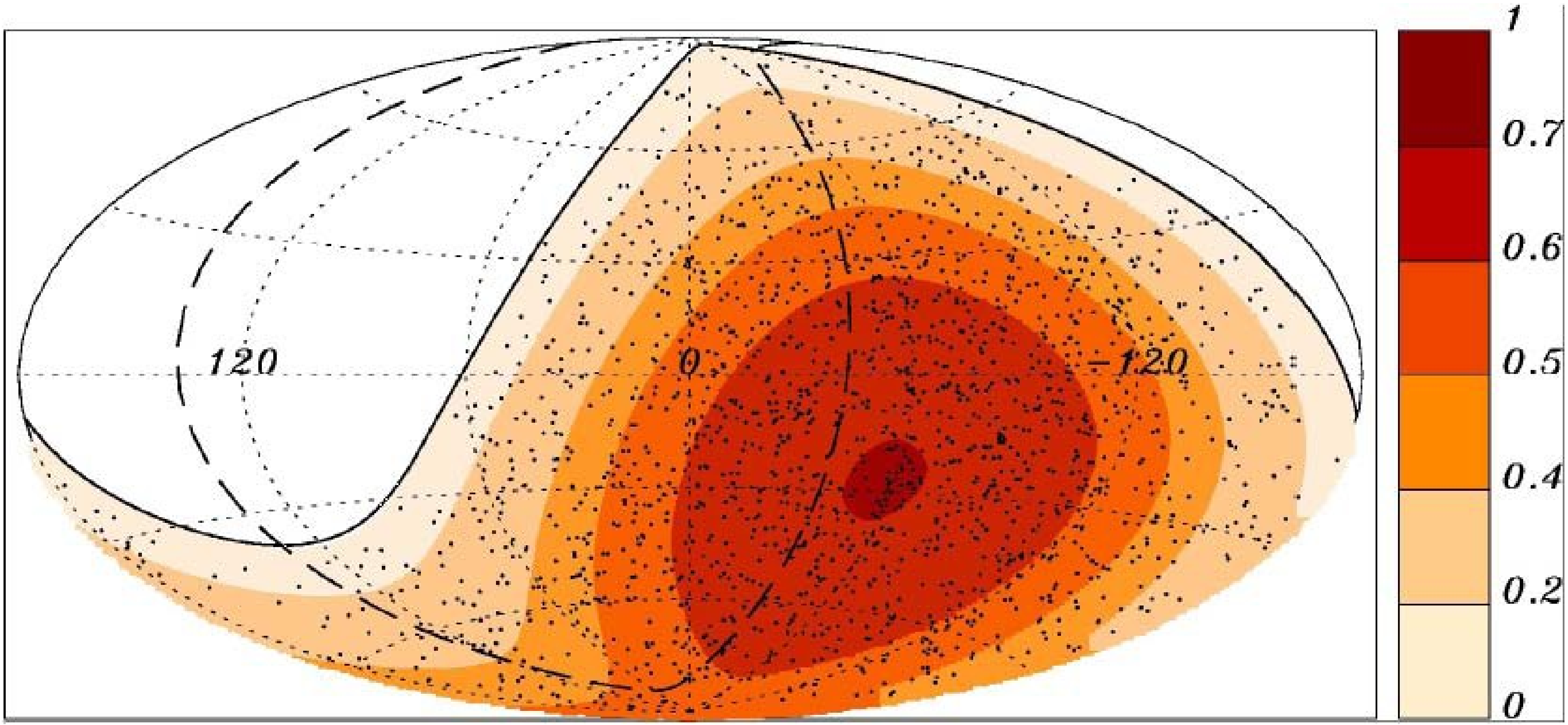




- *Shifted spectra agree in shape*

Anisotropy

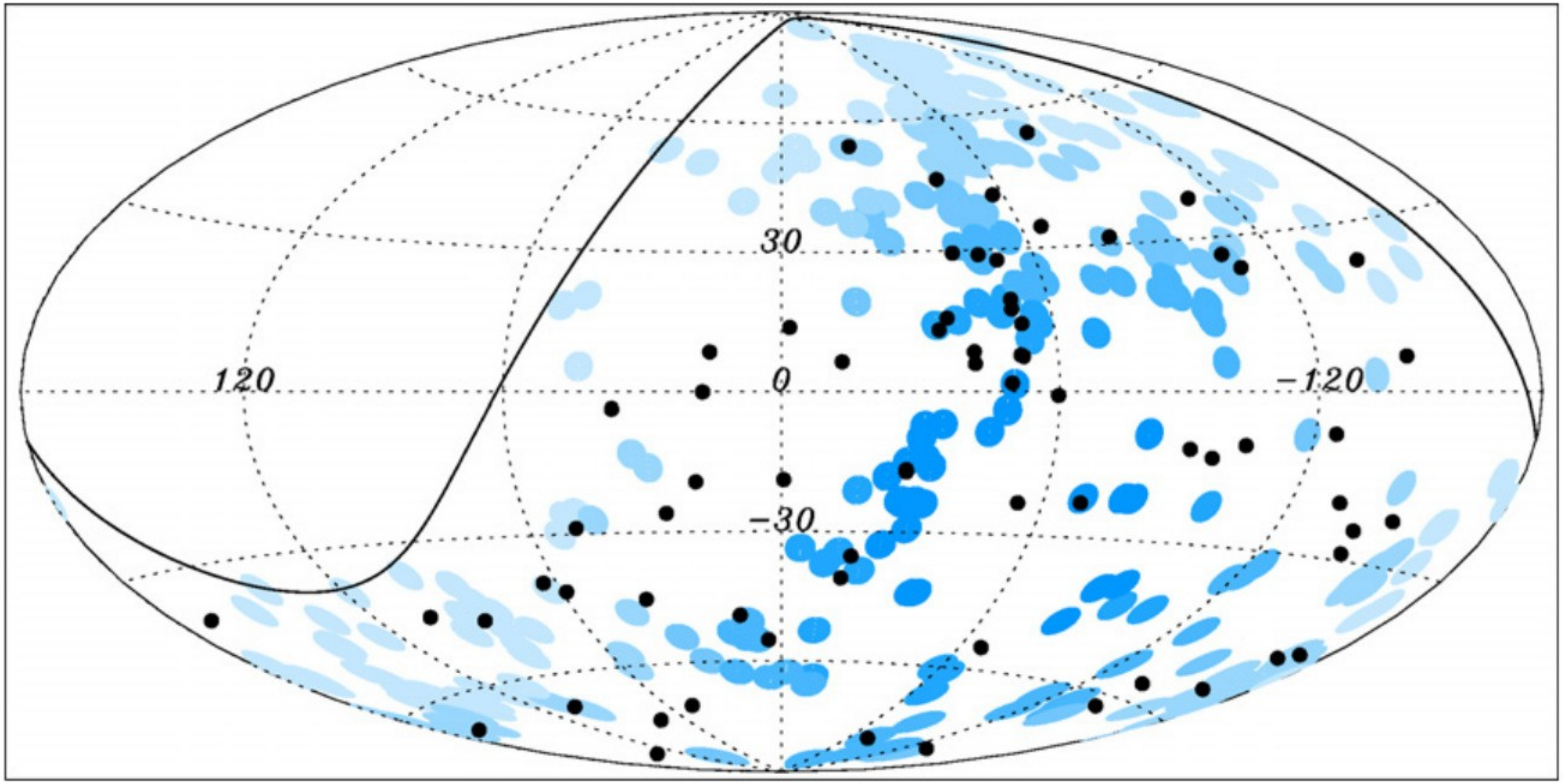
Auger events with E > 10^{19} eV



No enhancement along galactic disk: UHE particles are extragalactic

Anisotropy

Auger events with E > 55 EeV,D<75Mpc
correlation with VCV catalogue, < 3.1 °)

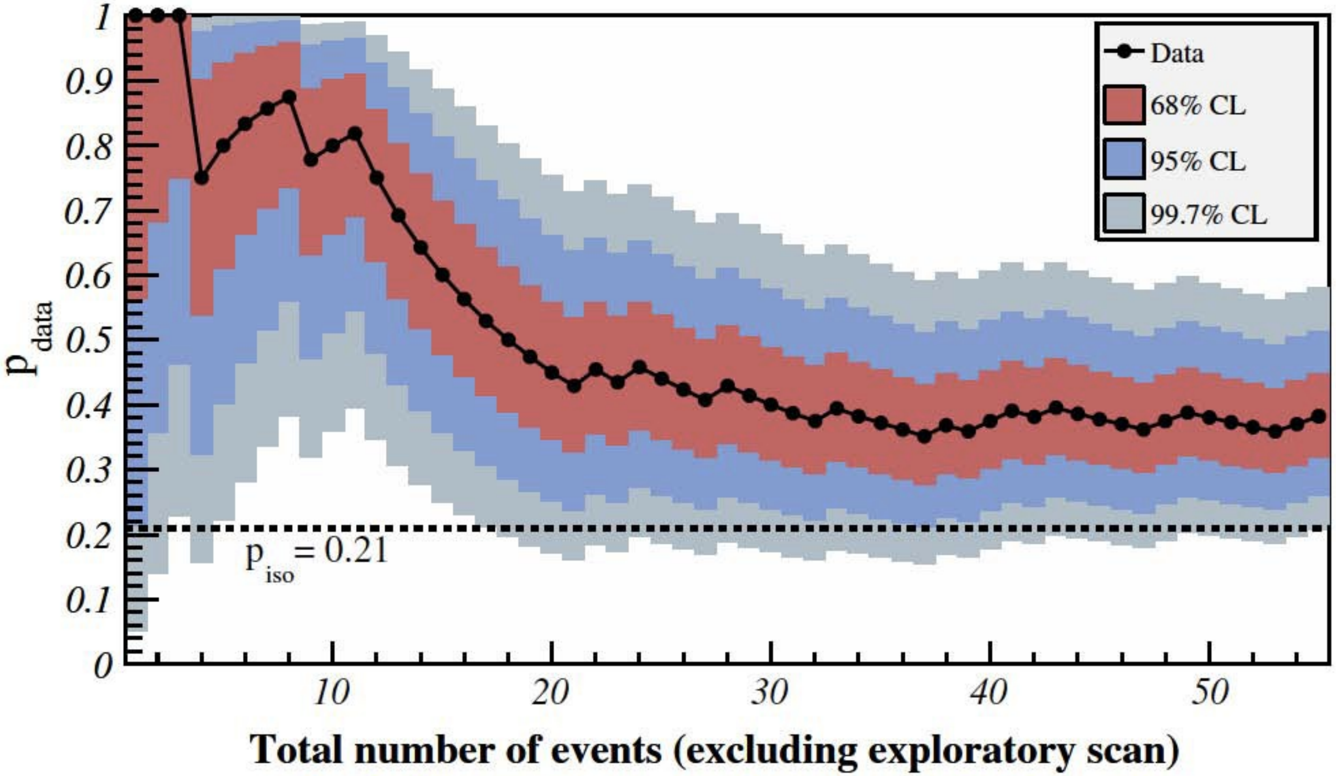


- Suggests proton primary

Astroparticle Physics 34 (2010) 314

Anisotropy

Auger events with E > 55 EeV



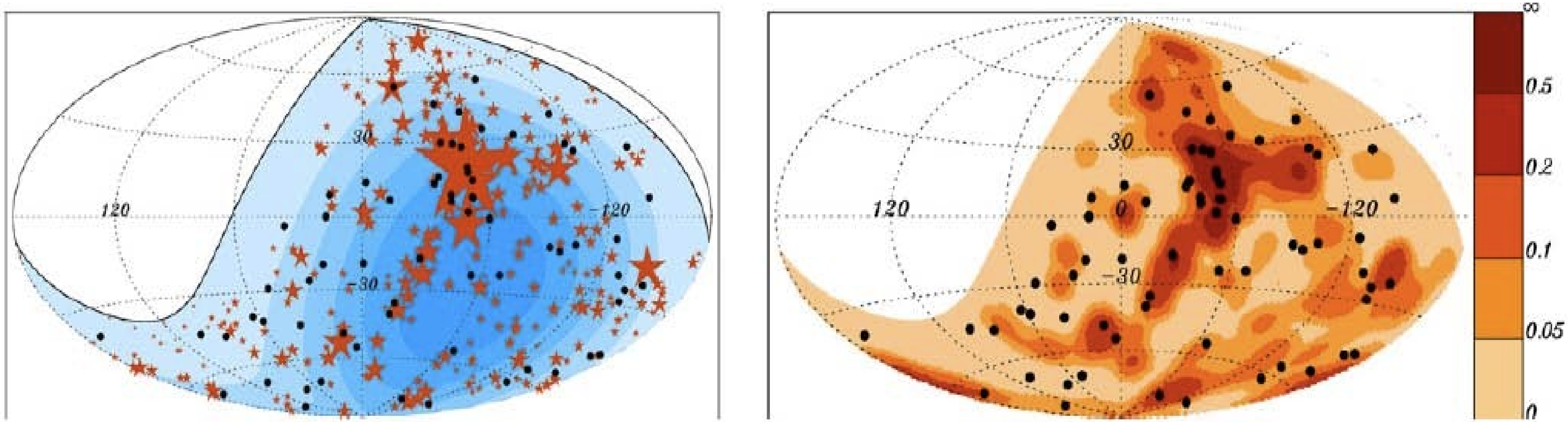
current signal: p = 0.38 (+0.07 -0.06)

Was p = 0.69 (+11 -13) (Science2007)

Anisotropy

Excess in Cen A region

Auger events with E > 55 EeV

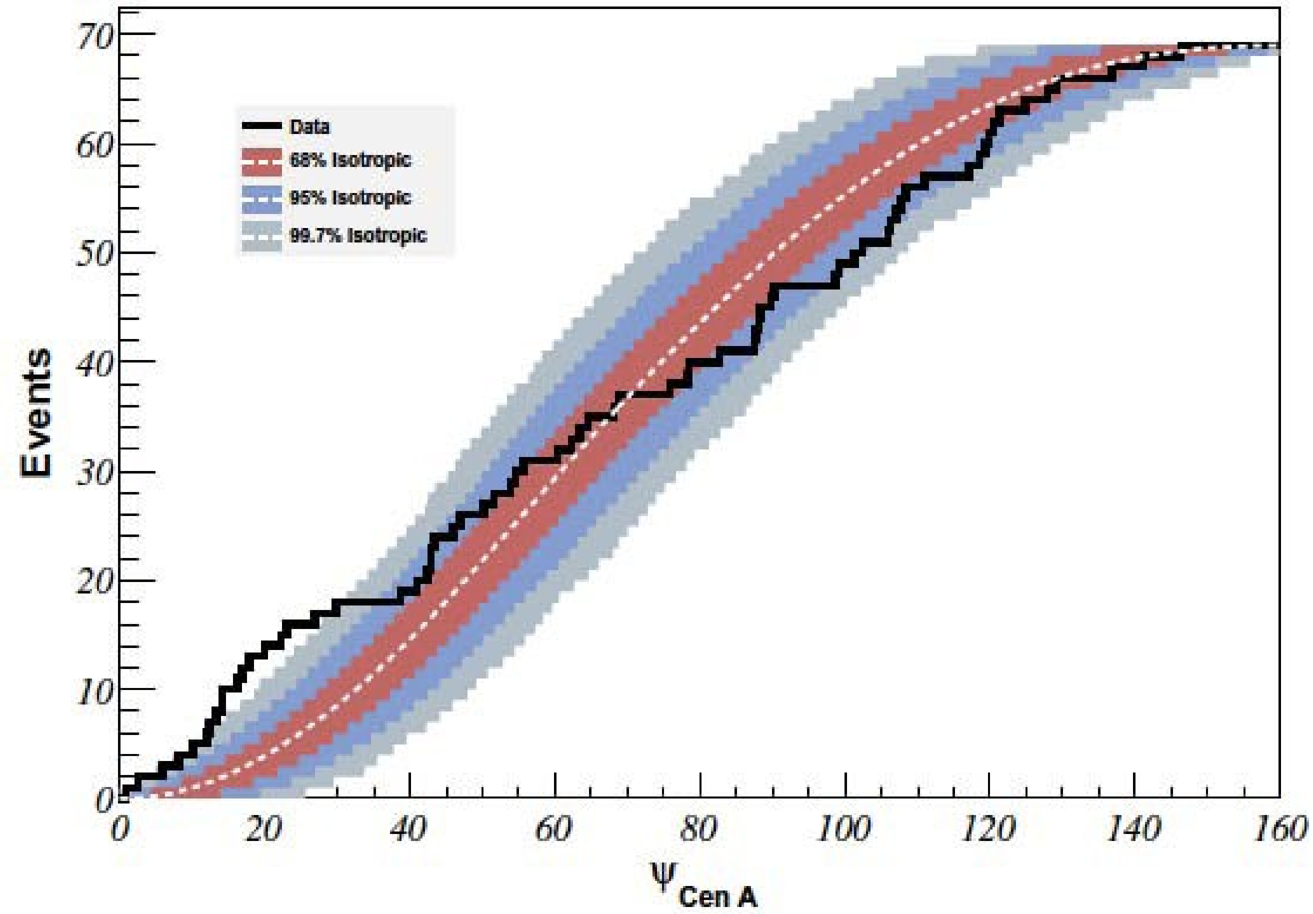


- Red stars (left) – 58-month Swift-BAT (X-rays) catalog AGNs, size proportional to assigned weight
- Density map (right) - 5°smoothing

Anisotropy

Excess in Cen A region

Angular Distance: CR - Cen A



4% chance prob. for isotropic distribution

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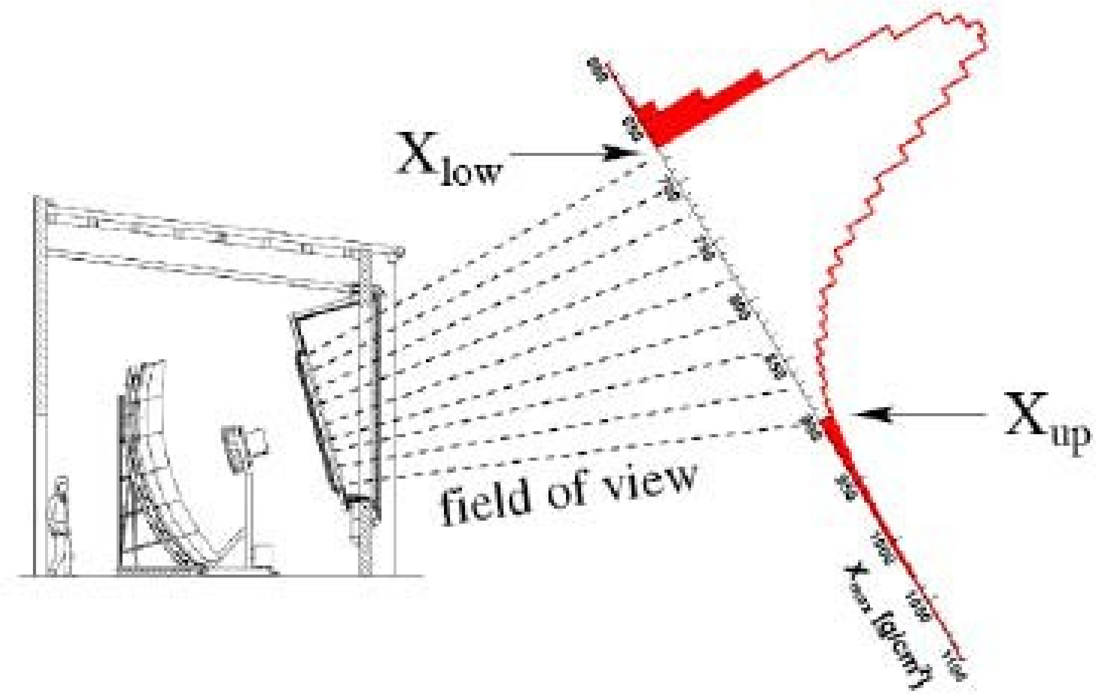

Xmax: height of shower maximum, grows with log(E)

p: penetrate deeper, larger X max

Fe: develop earlier, smaller X max

difference about 70 g/cm^2

- Xmax(p) fluctuates much more than Xmax(Fe)
- RMS(Xmax(p)) ≈ 60 g/cm^2 RMS(Xmax(Fe)) ≈ 20 g/cm^2

largely due to σ_{inel} of primary particle.

1 Fe ≈ 56 protons of E_0 /56

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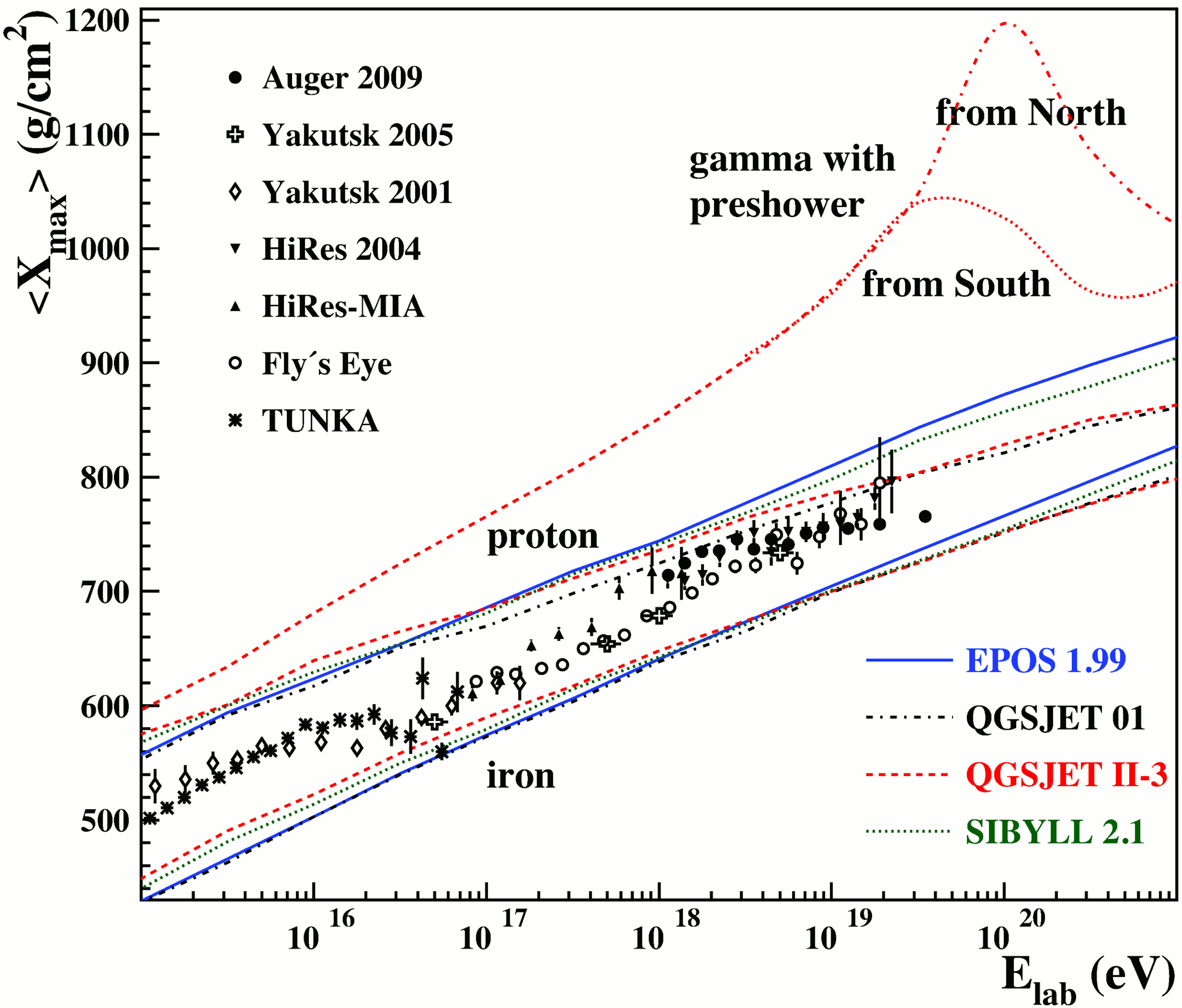
Xmax prediction



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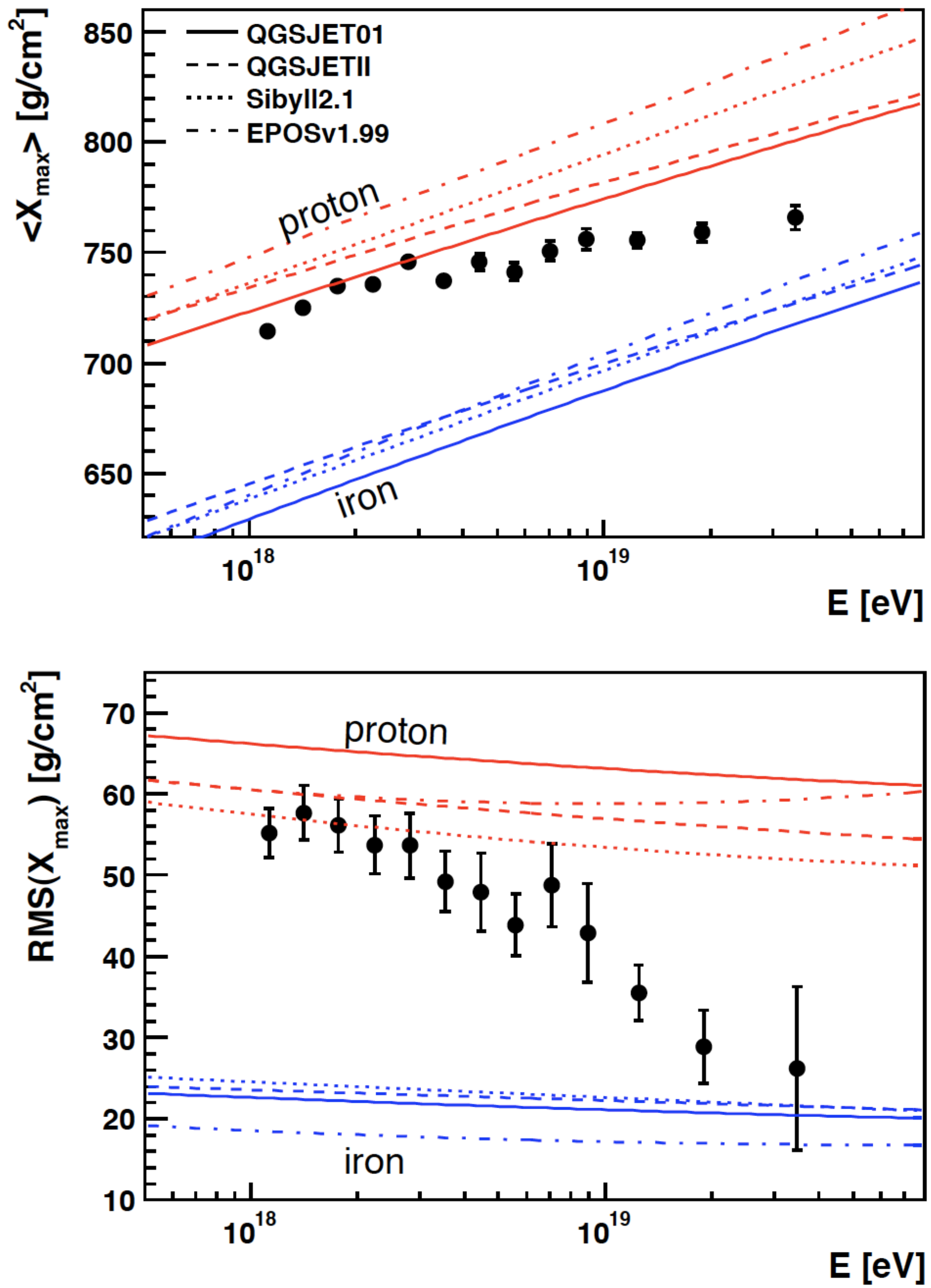
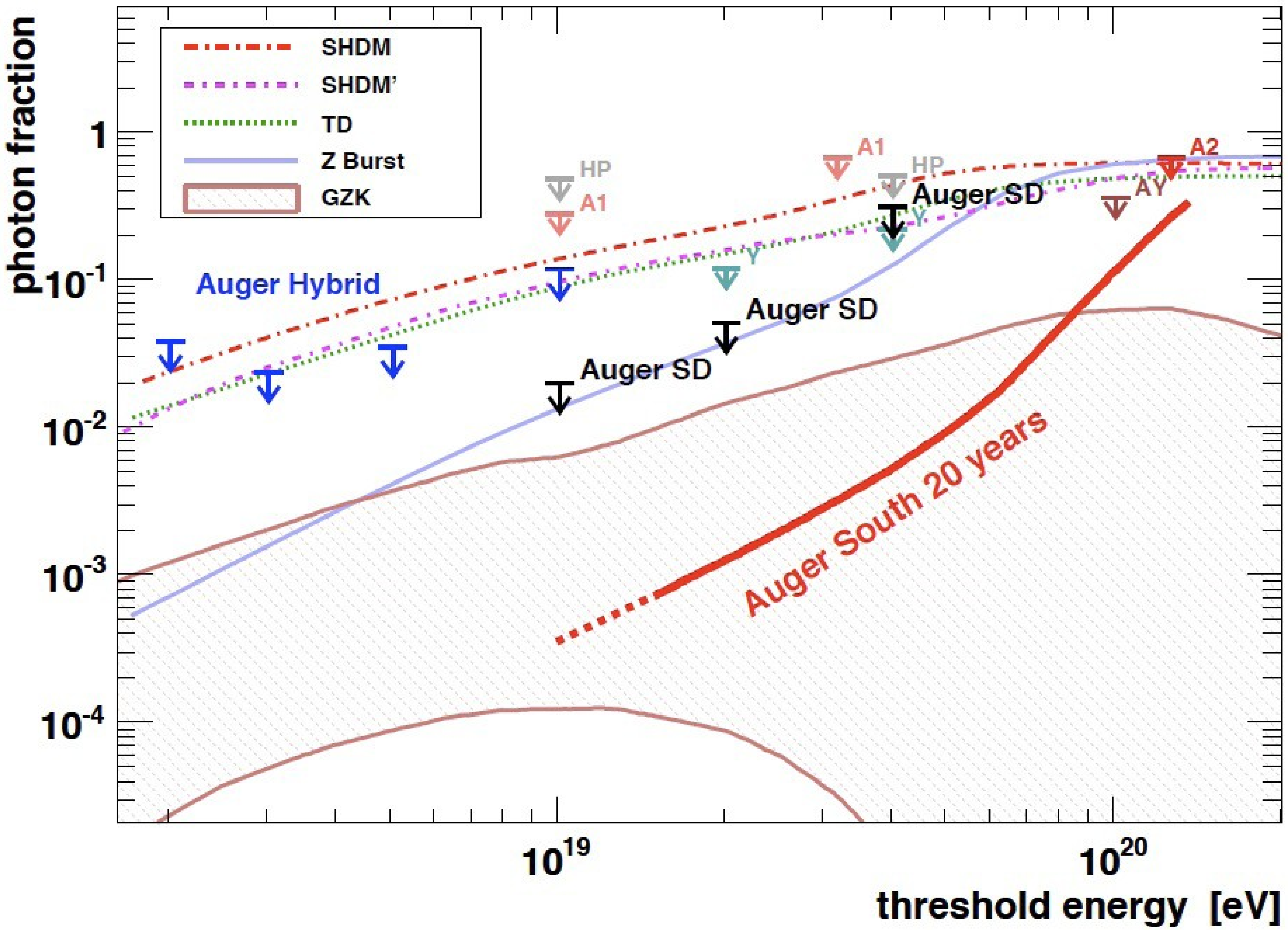
Mass Composition



- Mixed to heavy at highest energies

Photon limit



Current limit ~2% - ruling out
some top down scenarios

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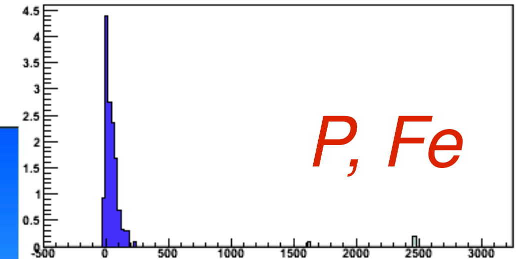
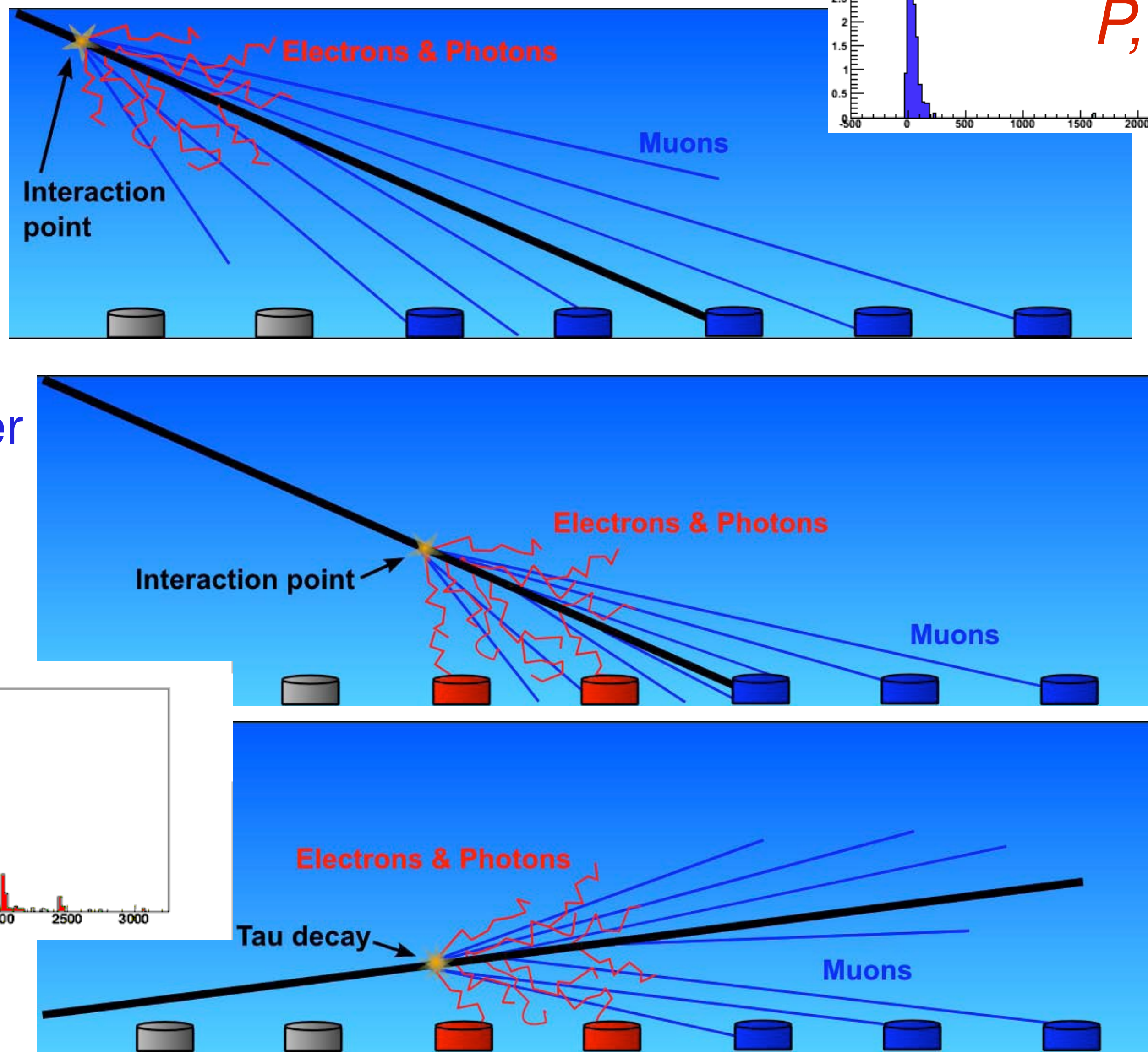
Sensitivity to neutrino showers

nearly horizontal showers :
atmosphere >> 1000 g/cm^2



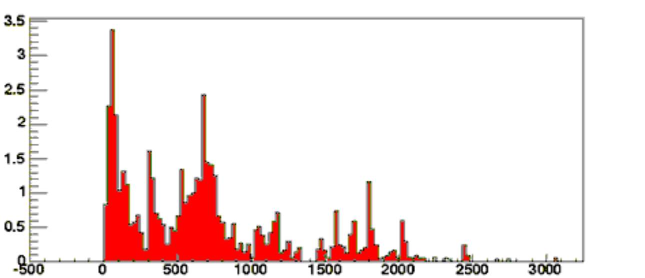
- no el.mag., only muons
- plane shower front,
- sharp arrival time dist.



ν

ν

- full el.mag. component,
- curved shower front,
- broad arrival time dist.



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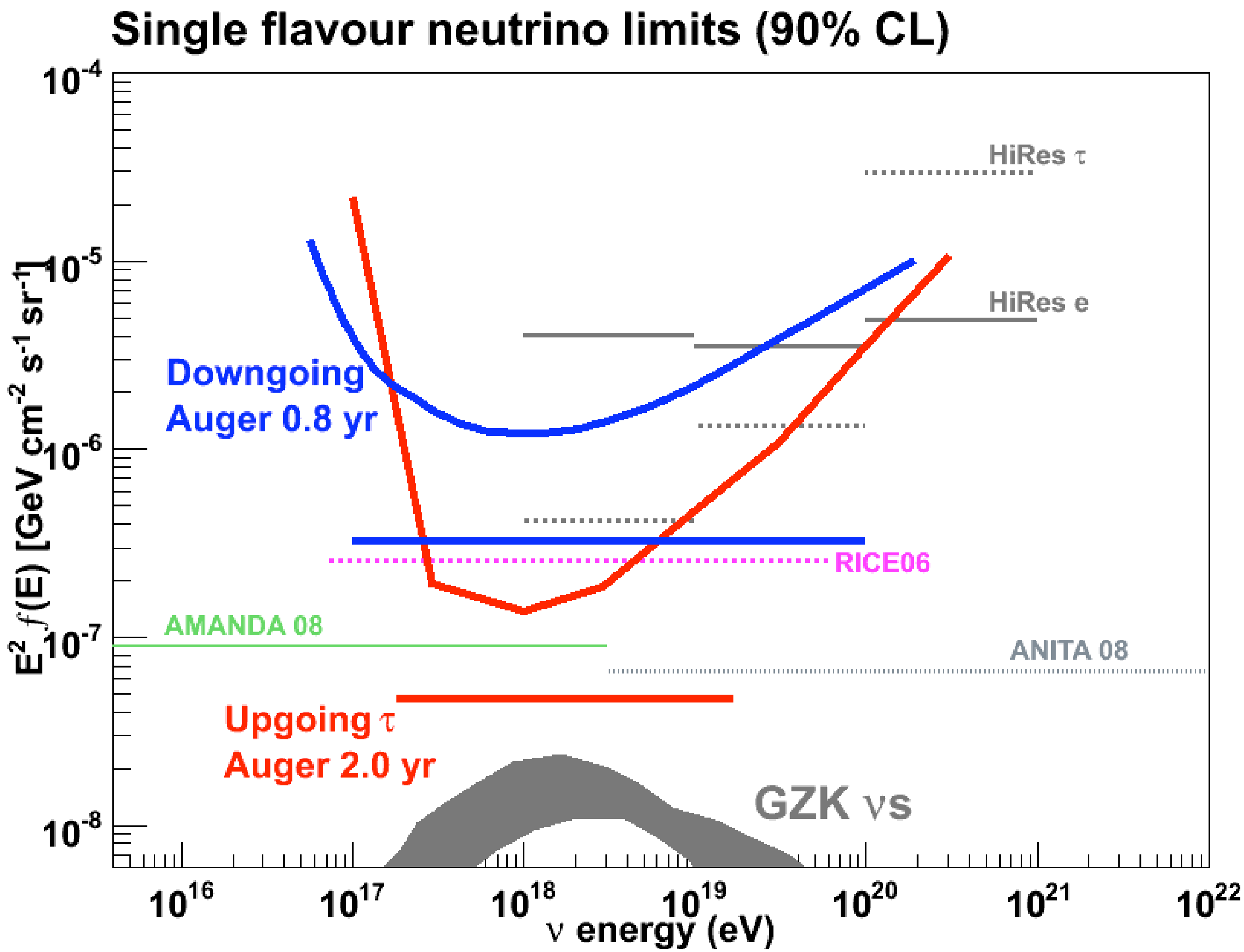
Neutrino limit

No neutrino candidate observed yet



Maximum sensitivity where the highest GZK neutrino flux is expected

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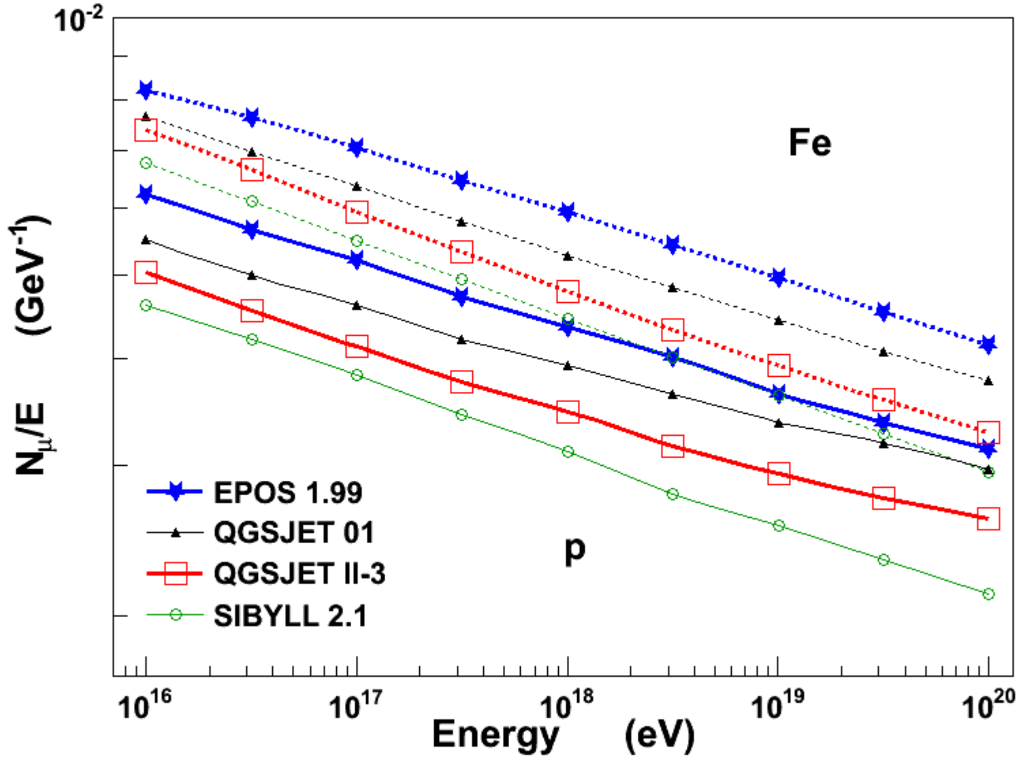
Muon content

Discrepancy (baryon and pion spectra) among models

Much more muons in EPOS – different approach to baryon production (collective effects)



3 times less baryons = 40 % less muons
(~difference between proton and iron)

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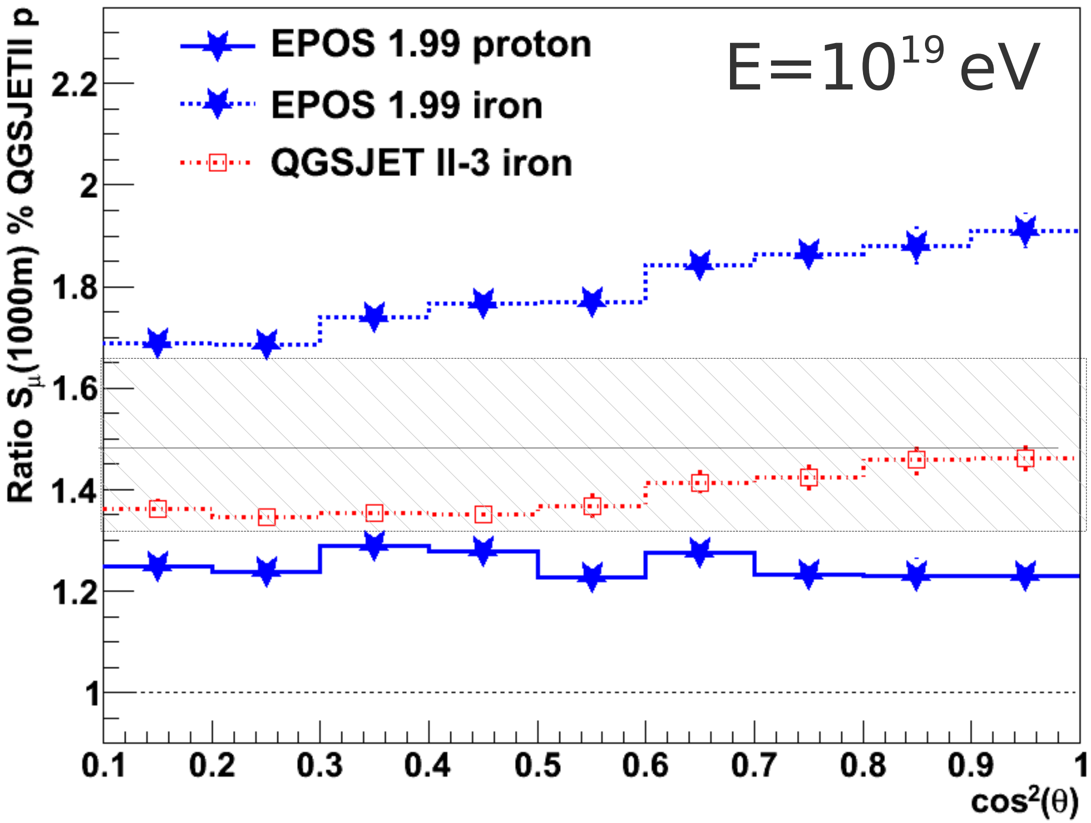
Muon Density @ 1000 m

- EPOS consistent with Auger data

intermediate mass needed for <Xmax>, RMS (Xmax) and muons

- QGSJETII underestimates the number of muons



PAO data

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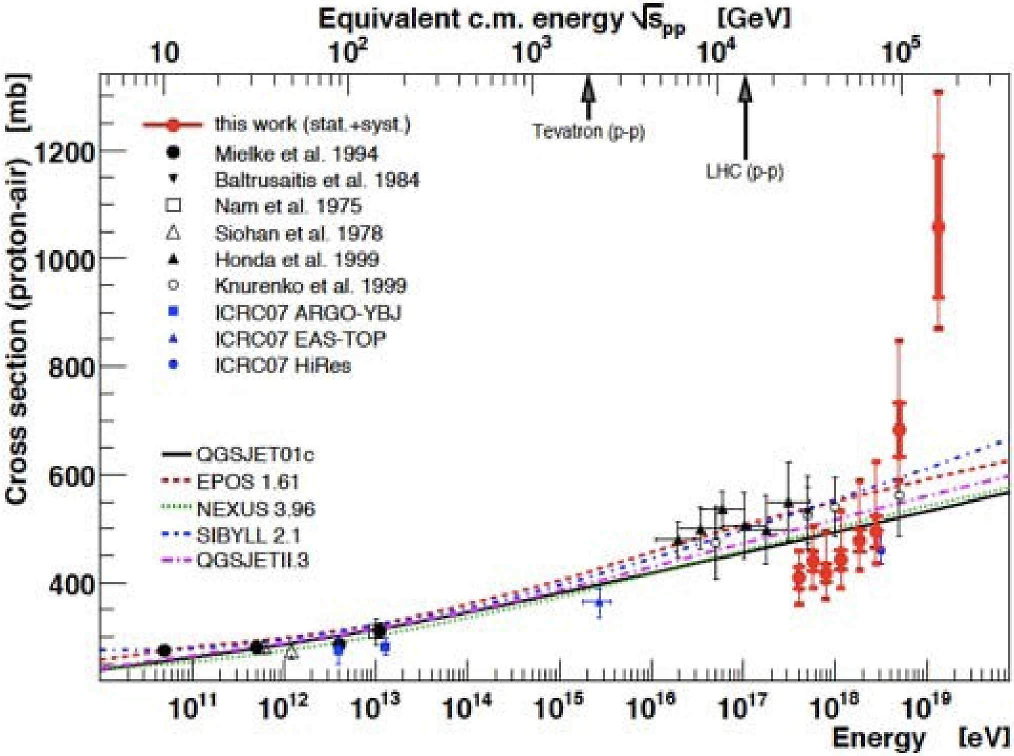
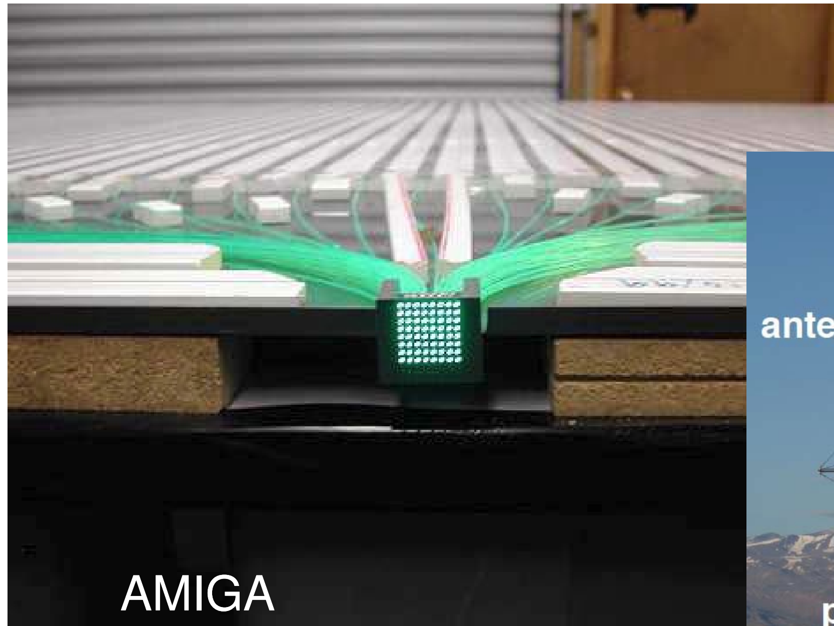
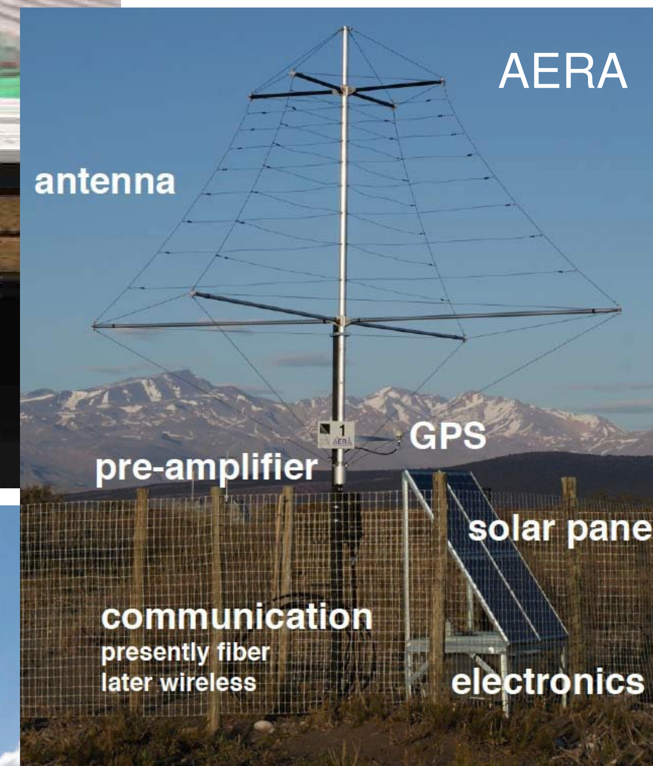


In order to explain the data as primary protons the cross section would have to grow enormously at high energies

Auger south enhancements

Lower the energy threshold to 0.1 EeV





- ***HEAT****: view the atmosphere above FD*
- ***AMIGA****: infill and muon counters*
- ***AERA****: coherent radiation of secondaries at radio frequencies*

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Auger south + enhancements E > 10^{17} eV

+

CERN experiments

LHCf: testing very forward region,
laboratory equivalent energy of 10^{17} eV

TOTEM: p-p cross-section at similar energies

→ Particle physics at 10^{19} eV

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Summary

- Spectrum with clear suppression above $10^{19.5}$ eV
- Anisotropy above 55 EeV (weaker but still present)
- Excess in Cen A region
- Photon limit disfavours top-down scenarios
- Shower maxima suggest heavy composition at highest enegies
- Discrepancies in hadronic interaction models

puzzles remain...

- AUGER south upgrade
  to extend the sensitivity down to 10^{17} eV
- need more statistics

We continue to pursue the idea of AUGER NEXT

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