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The Pierre Auger Observatory: Recent Results and Future Plans

John Kelley for the Pierre Auger Collaboration

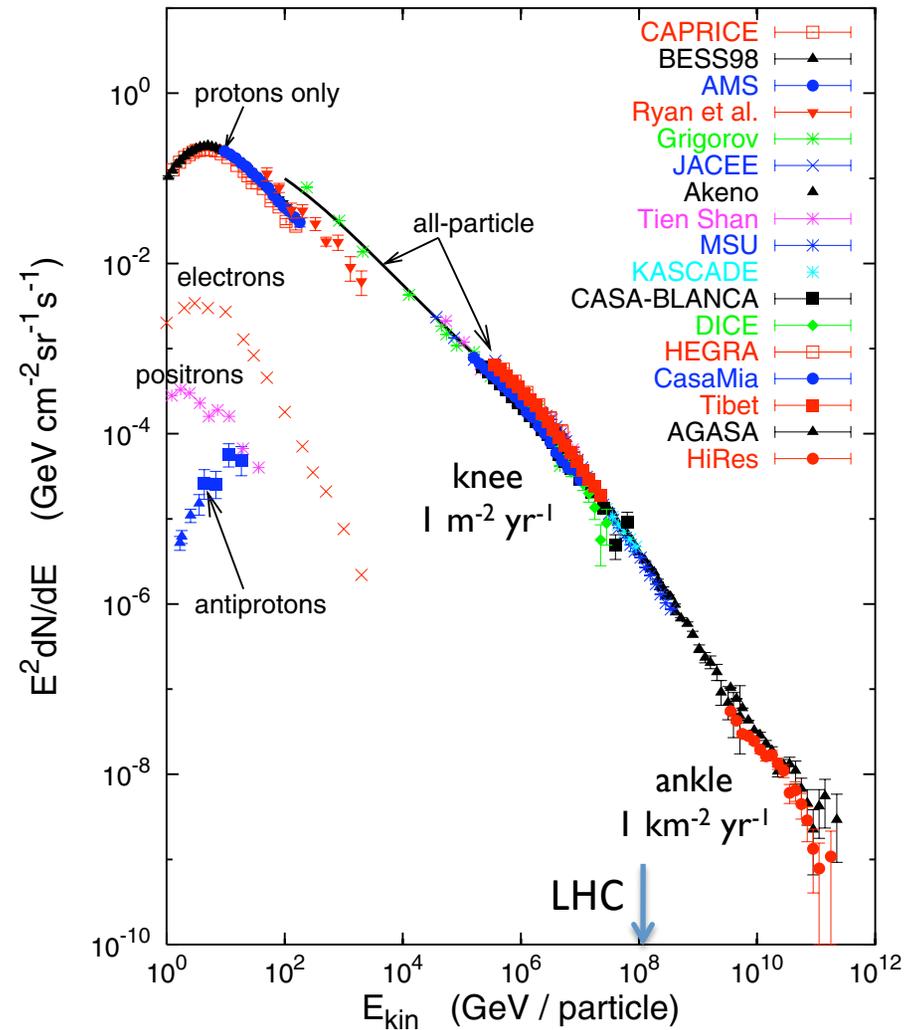
Radboud University Nijmegen
The Netherlands

Beyond 2010, Cape Town
February 4, 2010



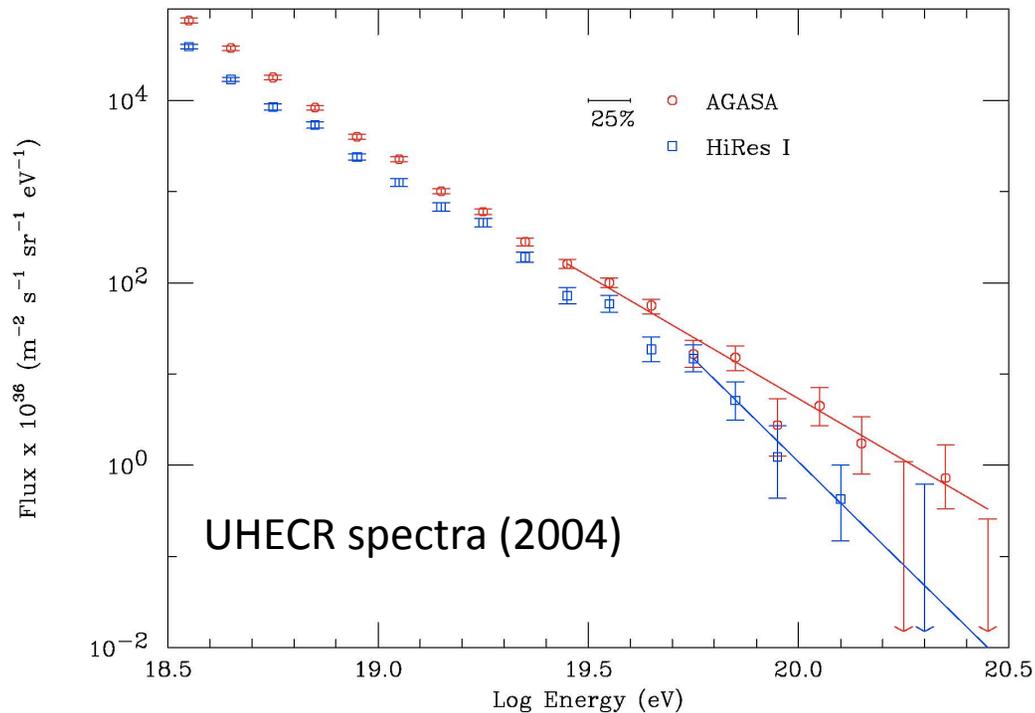
Cosmic Ray Spectrum

- Charged particles with steep power law spectrum
- Low flux at high energy: detect via extensive air showers
- Opportunities for new physics:
 - cosmic ray sources
 - cosmic ray composition
 - UHE particle interactions / propagation



Gaisser 2004

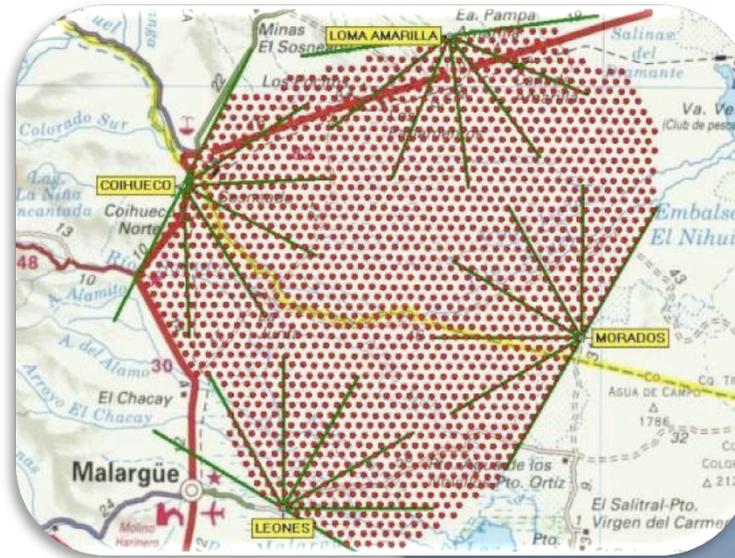
Ultra-High Energy Cosmic Rays (UHECR)



- Highest energy particles known in the Universe
- Composition unknown
- Sources + acceleration mechanism unknown
 - Astrophysical acceleration or decay of exotic particles? More later...
- Cutoff in spectrum or not?
 - Expected from interactions with CMB (GZK effect)

Pierre Auger Observatory

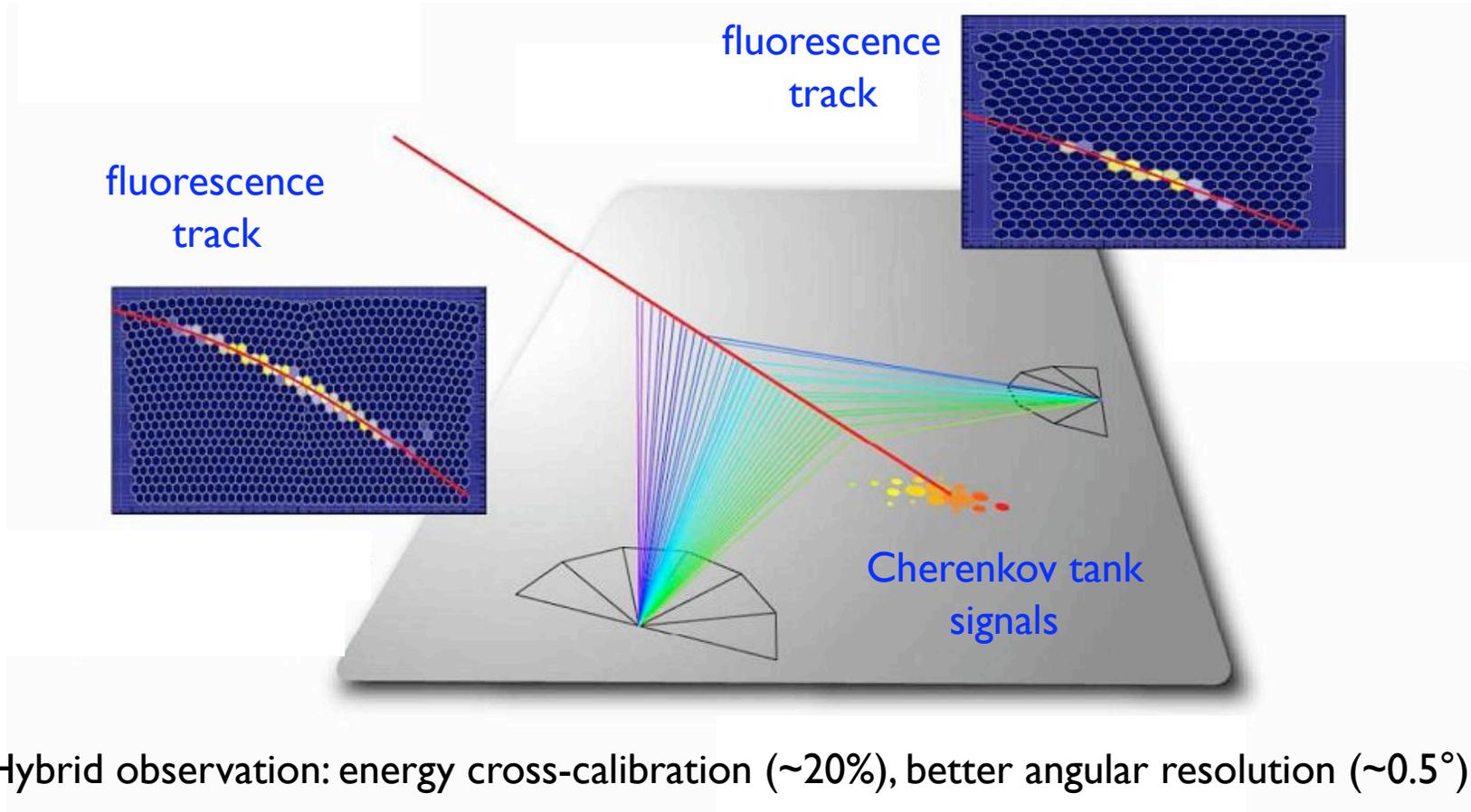
- Hybrid air shower detector
- Southern site (3000 km²) in Argentina completed 2008
- Northern site (21000 km²) planned for Colorado, U.S.A.



Auger South



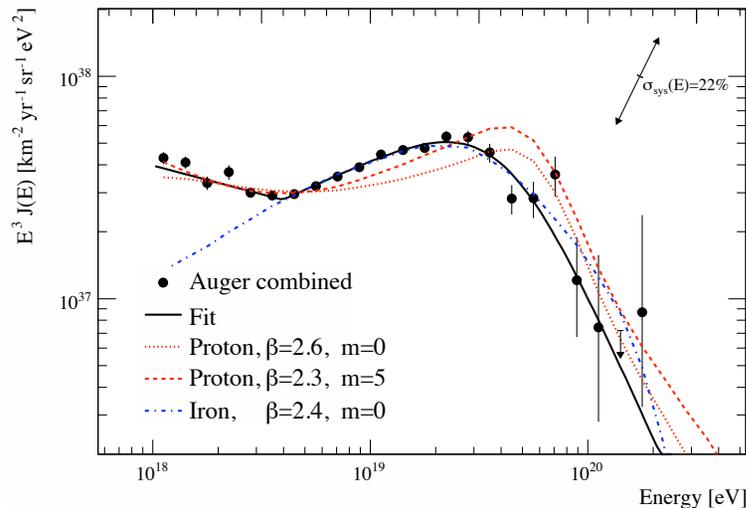
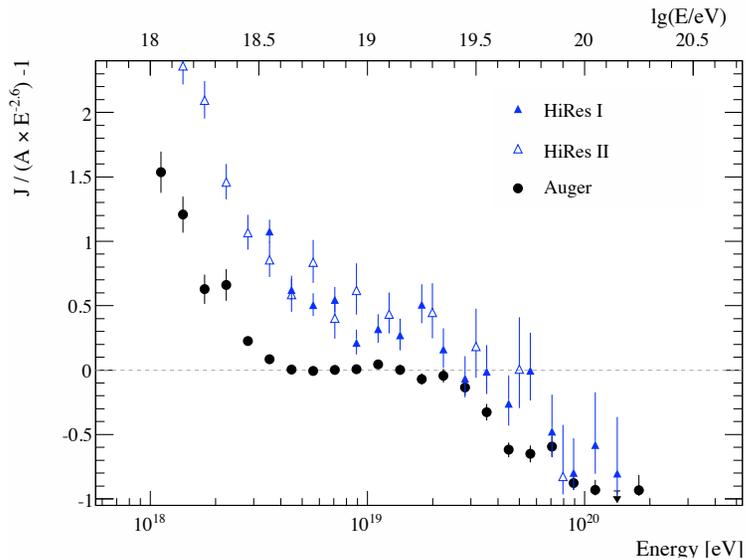
Hybrid Detection



Hybrid observation: energy cross-calibration ($\sim 20\%$), better angular resolution ($\sim 0.5^\circ$)

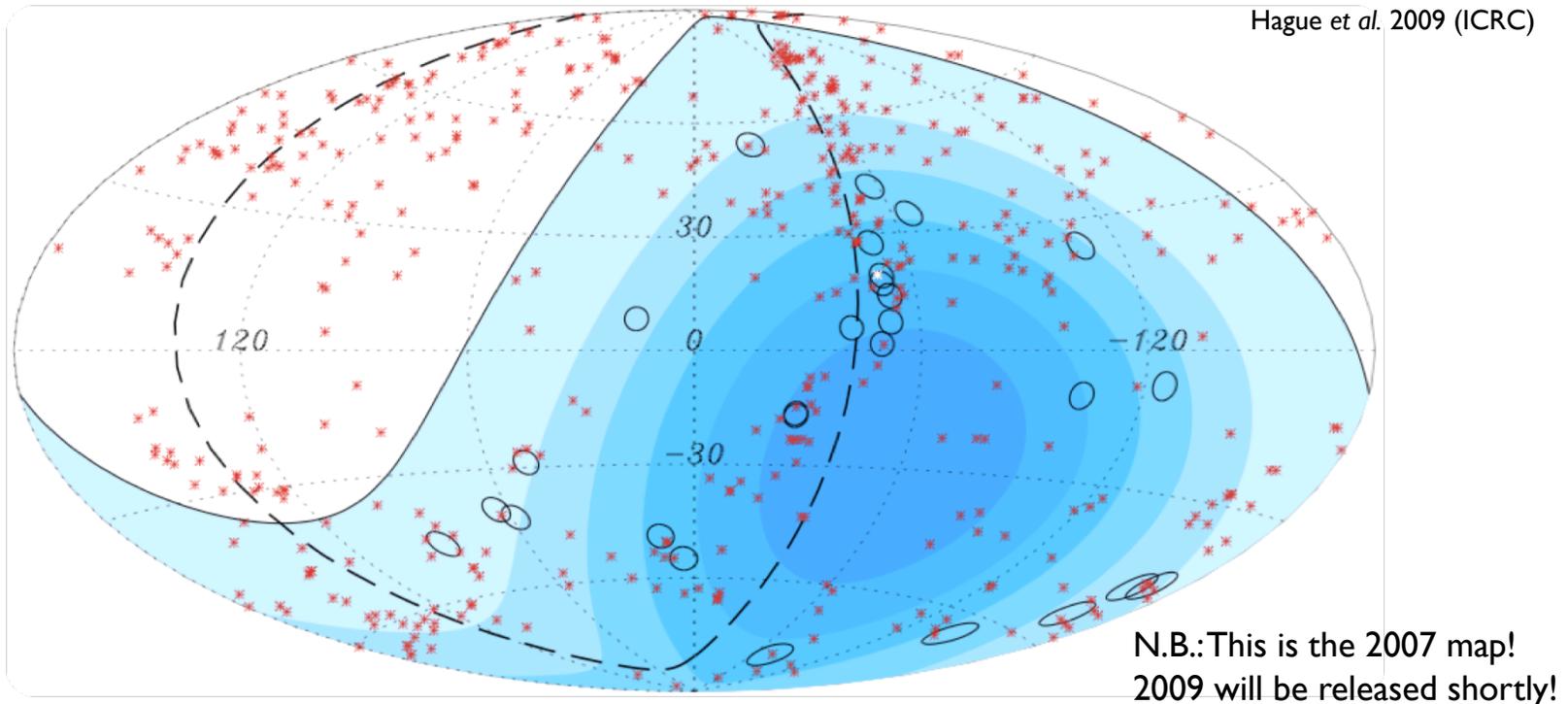
... but FD duty cycle is $\sim 10\%$

Latest Results: UHECR Energy Spectrum



- 2008: Continuation of power law rejected at 6σ (confirms HiRes)
- Suppression energy consistent with GZK onset
- 2009: combined FD + SD spectrum
 - protons with strong source evolution?
 - iron with another component below ankle?
- Difficult to rule out non-GZK causes
 - source cutoff?
 - Lorentz violation? see e.g. Scully & Stecker 2008

Latest Results: Anisotropy



2007: 27 events above 55 EeV (ovals); correlation with nearby AGN (red crosses)

2009: 58 events above 55 EeV: correlation with original AGN catalog weakens

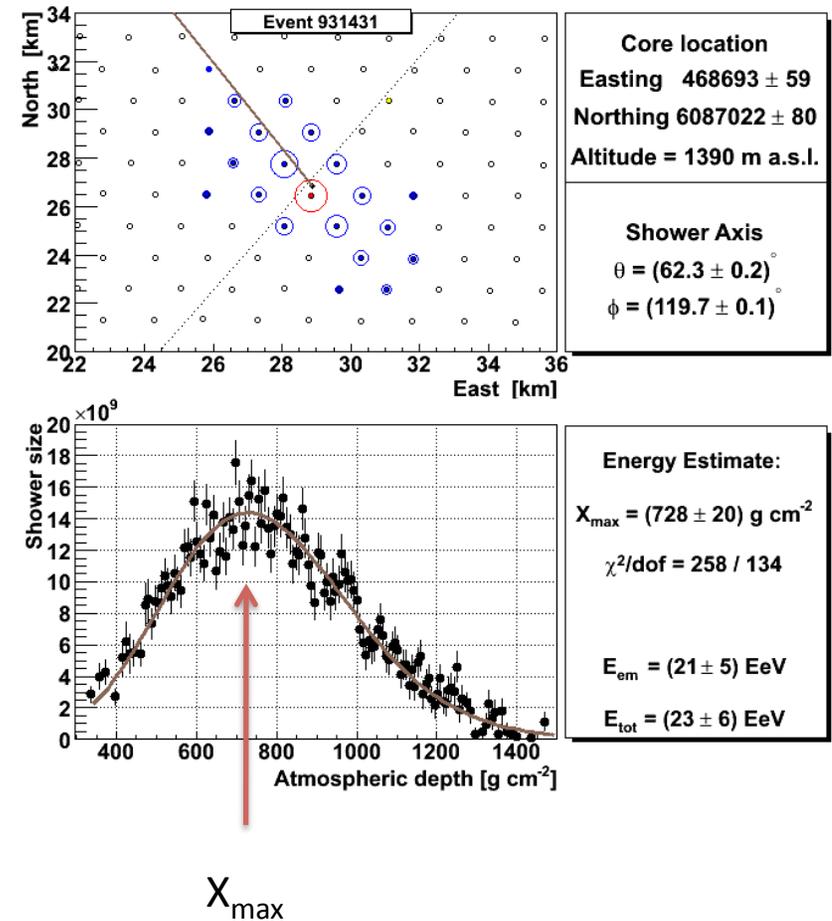
Isotropy rejected at 99% CL

A posteriori investigations of:

- Centaurus A region
- correlations with other catalog(s)
e.g. SWIFT-BAT

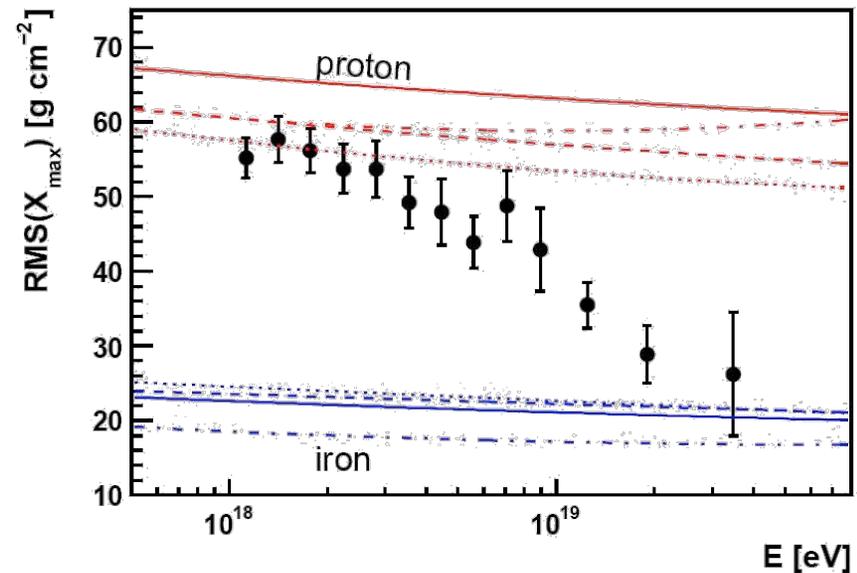
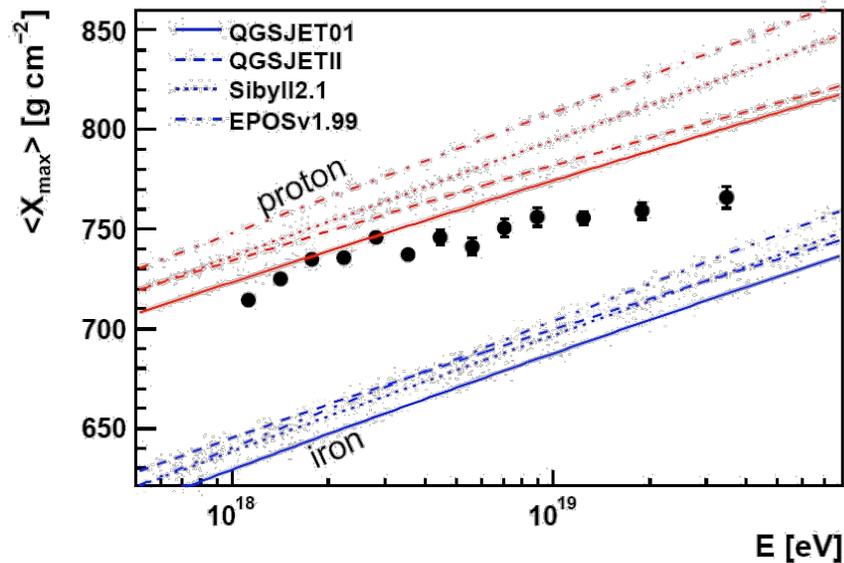
Composition

- Slant depth X_{\max} (integrated density) of shower maximum in atmosphere
 - energy and composition-dependent
 - higher in atmosphere for heavier nuclei (interact, lose energy sooner)
- Shower-to-shower fluctuations of X_{\max}
 - iron showers (~superposition of many single-nucleon showers) have fewer fluctuations



Latest Results: Composition

Bellido *et al.* 2009 (ICRC)
Abraham *et al.*, accepted PRL (2010)

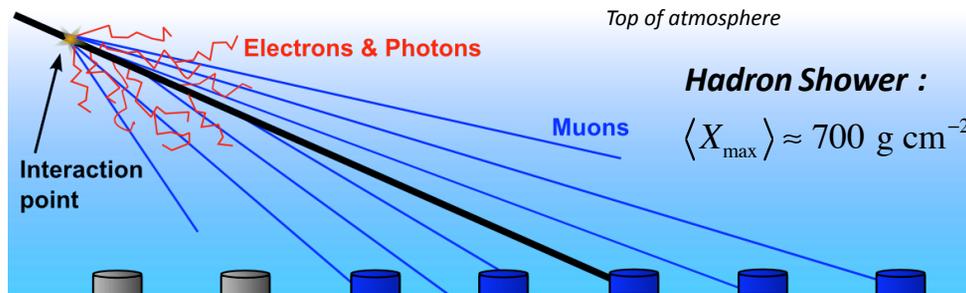


Both indicate composition getting heavier...

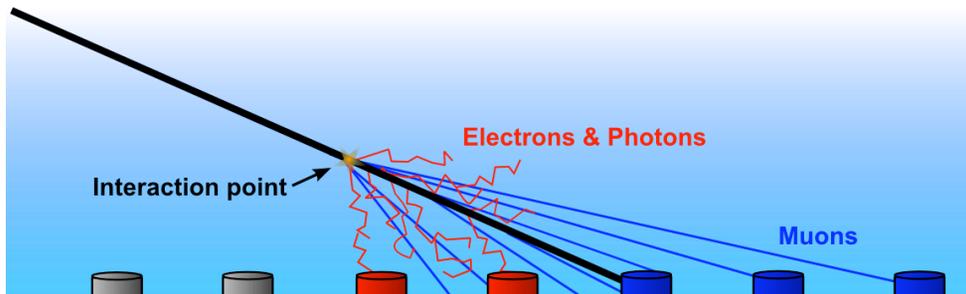
or protons behaving differently than expected?

(see e.g. Ulrich *et al.*, arXiv:0906.3075)

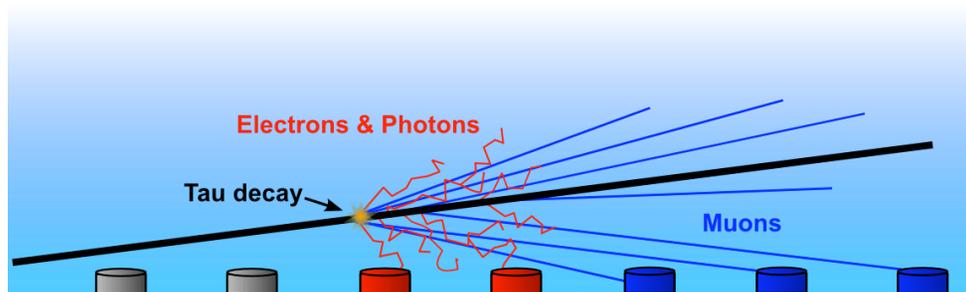
Neutrino Detection via Air Showers



“normal” inclined shower:
only muons left

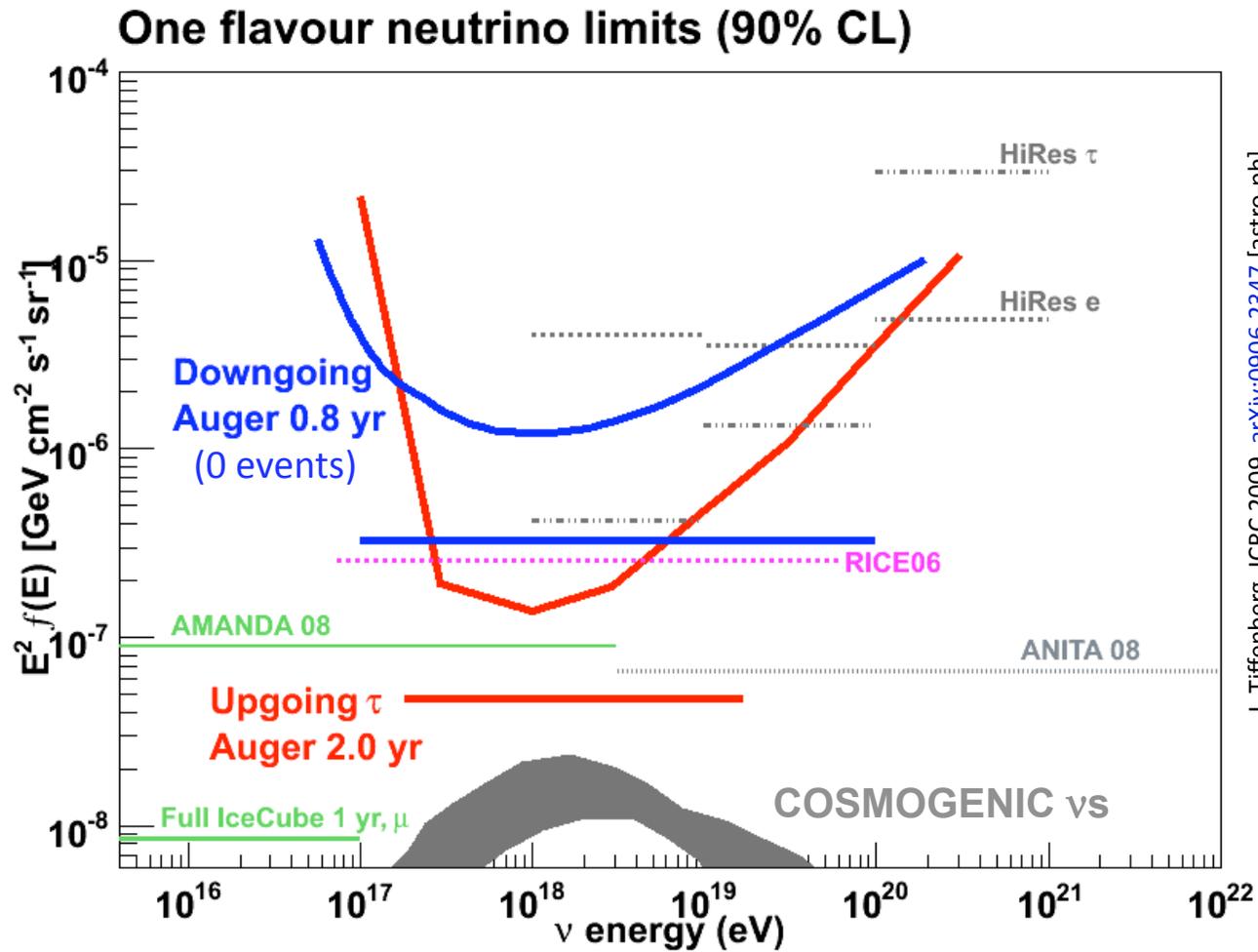


neutrino-induced shower:
young EM component
(broad signals in tanks)



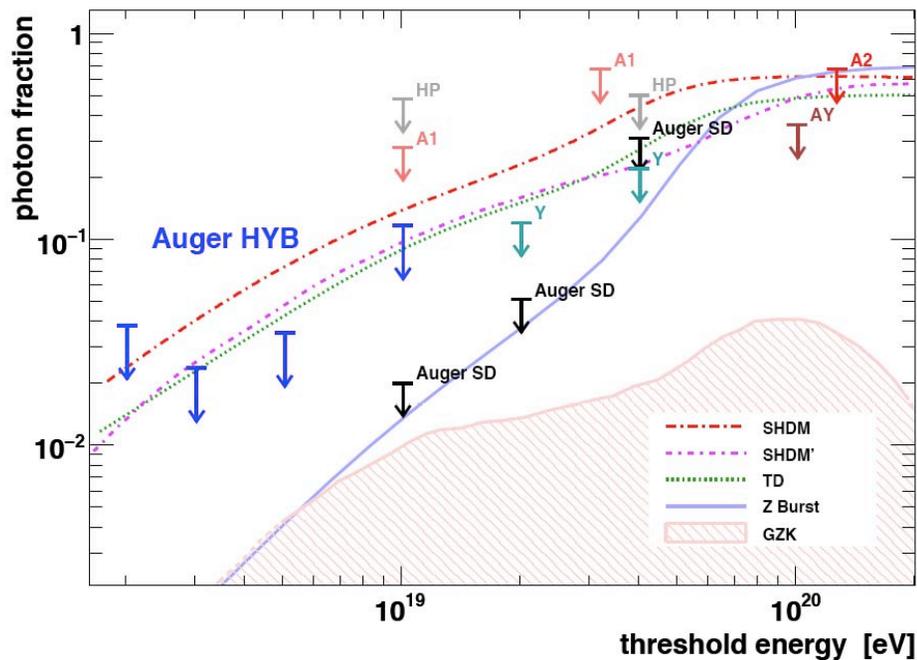
tau decay from Earth-skimming ν_{τ} :
dense target, but only one flavor

Limits on Diffuse Neutrino Flux



J. Tiffenberg, ICRC 2009, arXiv:0906.2347 [astro-ph]

Photon Fraction Limits

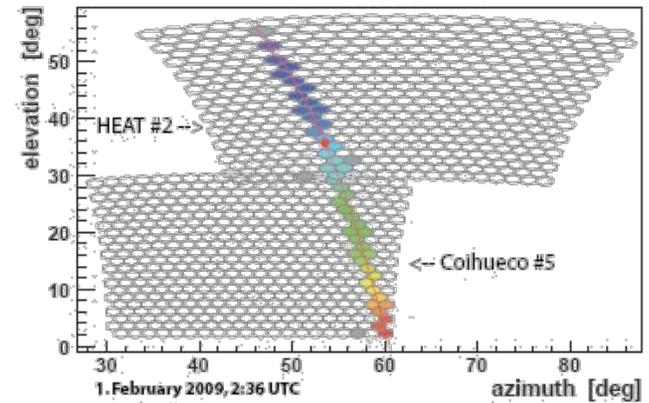
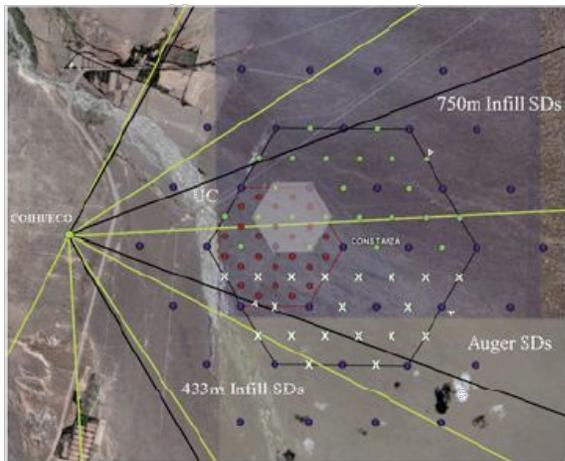


Abraham et al. 2009

- UHE photons predicted in many “top-down” models
 - super-heavy dark matter
 - topological defects
 - Z-bursts
- Photon-induced showers:
 - develop deeper in atmosphere
 - SD: measure shower front curvature, thickness
 - FD: measure longitudinal profile directly
- Data consistent with only hadrons
 - top-down models disfavored
 - GZK photon flux may be eventually accessible

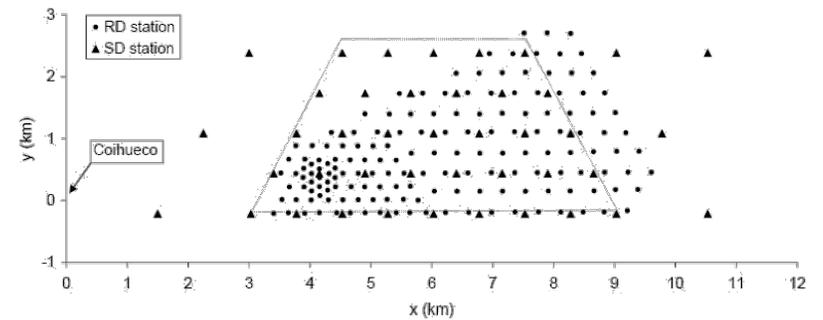
Enhancements at Auger South

HEAT: High Elevation Auger Telescopes



AMIGA: Auger Muon and Infill Ground Array

AERA: Auger Engineering Radio Array



Summary

- Pierre Auger UHECR results:
 - suppression in spectrum observed
 - suggestive anisotropy results... need more statistics
 - neutrino and photon limits: no hints beyond SM yet
 - composition getting heavier?
- Strategy for further research:
 - more data from Auger South
 - searches for exotics: Q-balls, magnetic monopoles, etc.
 - 7x larger array: Auger North
 - expand complementary detection techniques like radio

Thank you!

Czech Republic

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Germany§

Italy

Netherlands§

Poland

Portugal

Slovenia

Spain

United Kingdom

Argentina

Australia

Brazil

Bolivia*

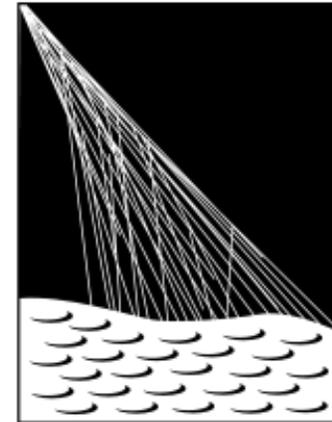
Mexico

USA

Vietnam*

**Associate Countries*

§ Radio Working Group



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