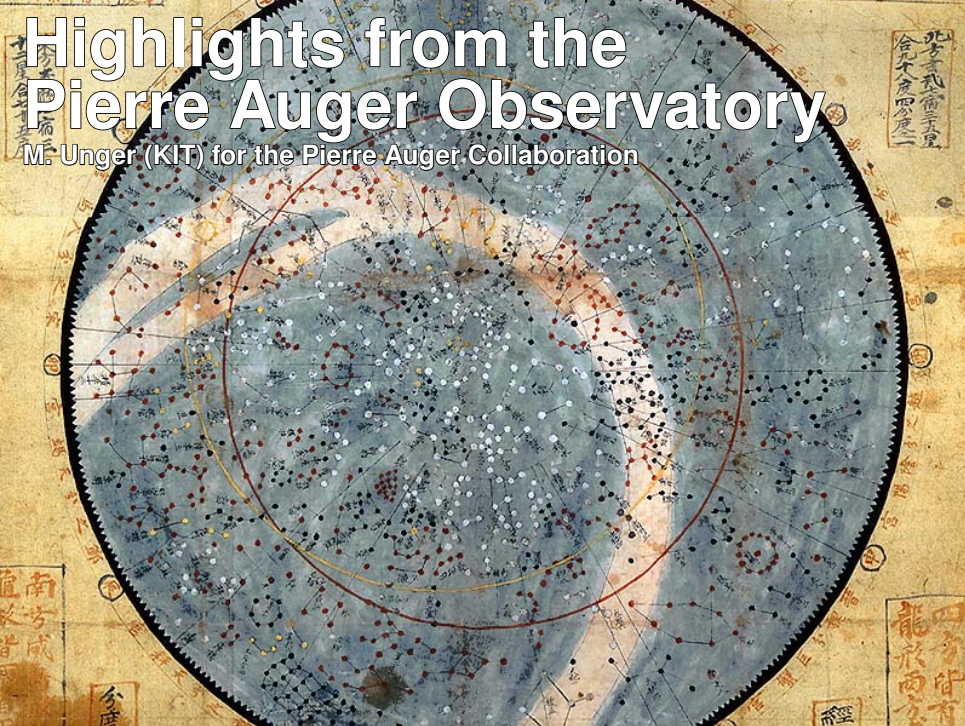


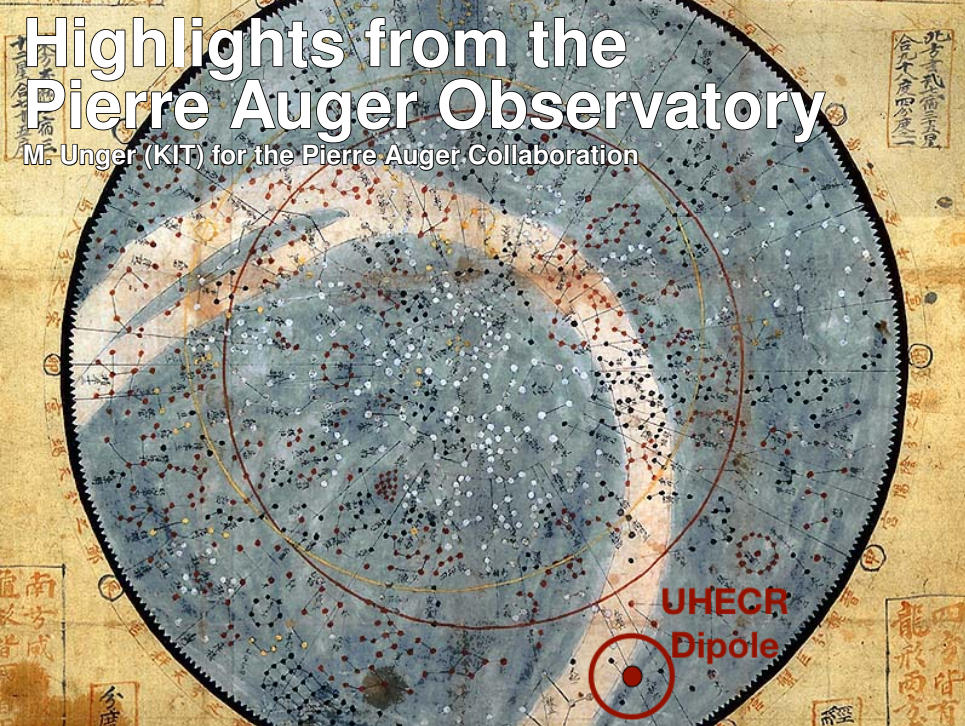
Highlights from the Pierre Auger Observatory

M. Unger (KIT) for the Pierre Auger Collaboration

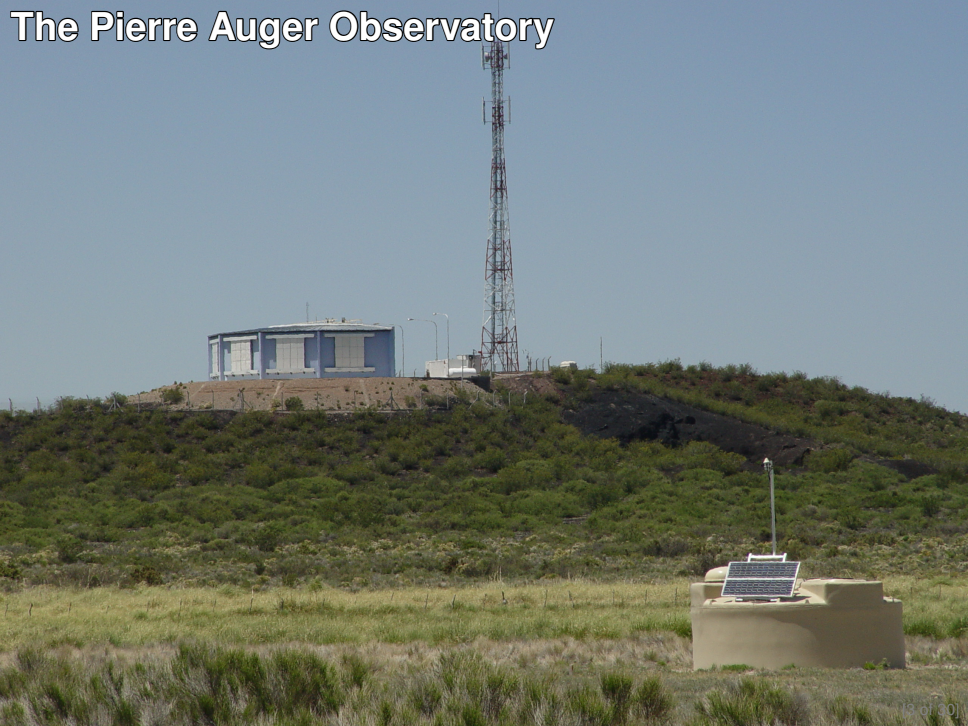


Highlights from the Pierre Auger Observatory

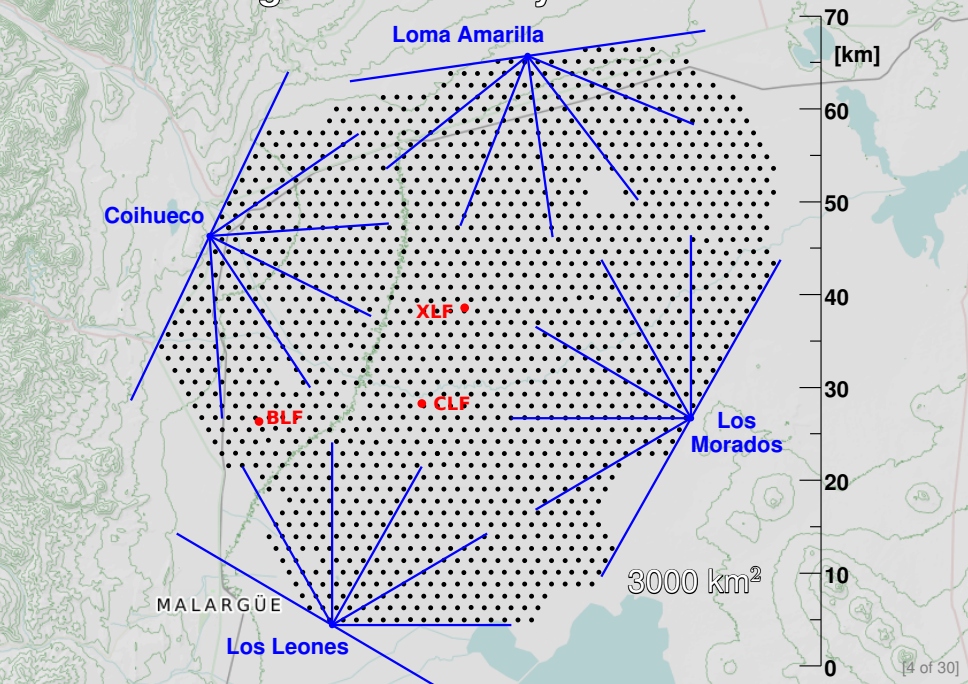
M. Unger (KIT) for the Pierre Auger Collaboration



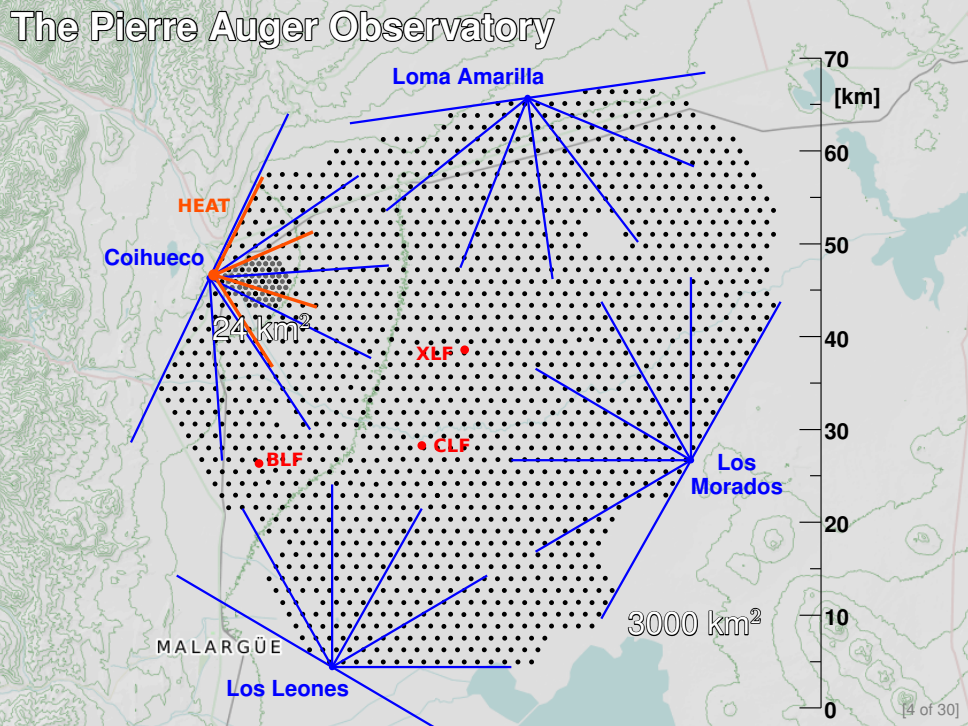
The Pierre Auger Observatory



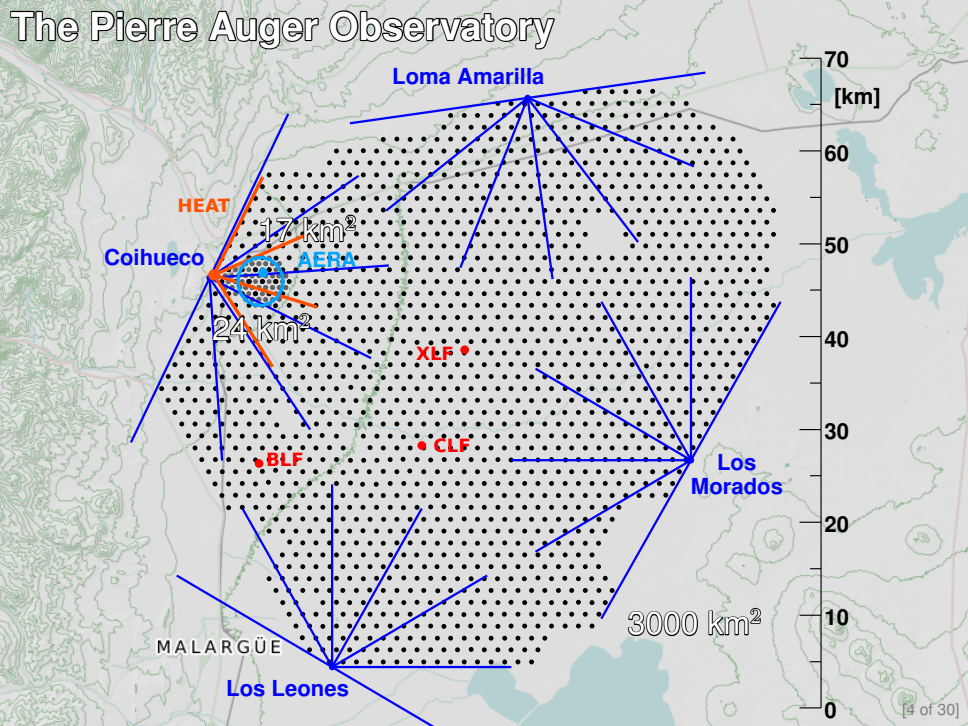
The Pierre Auger Observatory



The Pierre Auger Observatory



The Pierre Auger Observatory



UHE Exposure

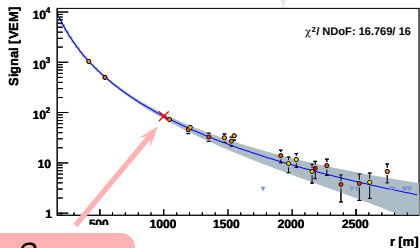
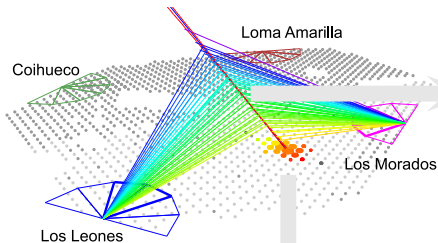
Auger Anisotropy ICRC17: $9.0 \times 10^4 \text{ km}^2 \text{ sr yr}$

Auger Spectrum ICRC17: $6.7 \times 10^4 \text{ km}^2 \text{ sr yr}$

TA Spectrum ICRC17:
 $0.8 \times 10^4 \text{ km}^2 \text{ sr yr}$

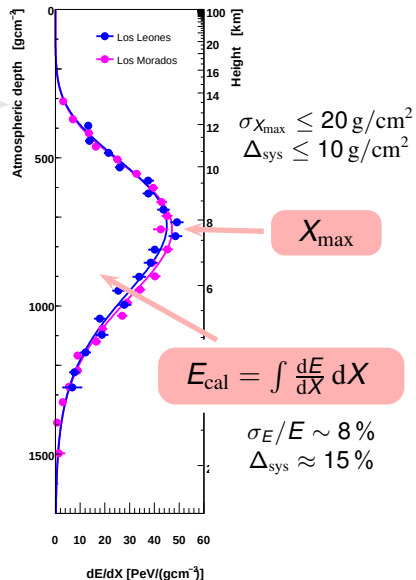
AGASA

Hybrid Detection of Air Showers

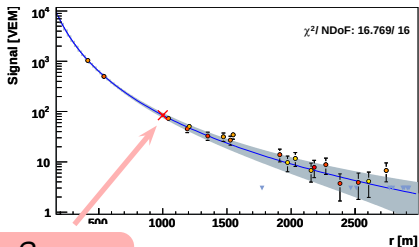
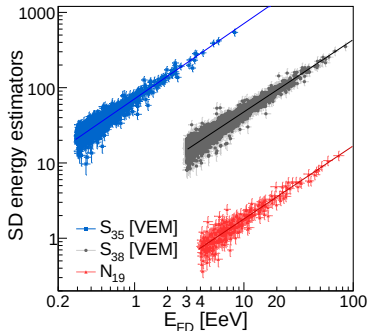


S_{1000}

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

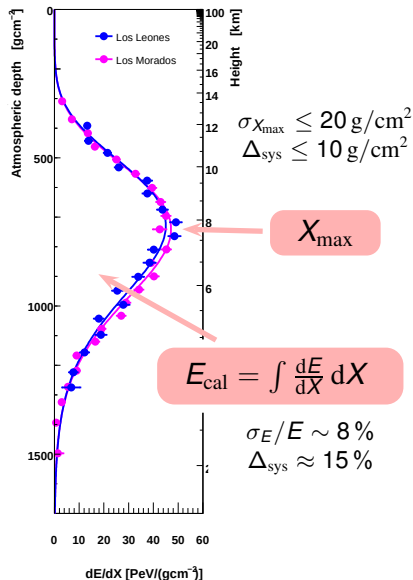


Energy Calibration

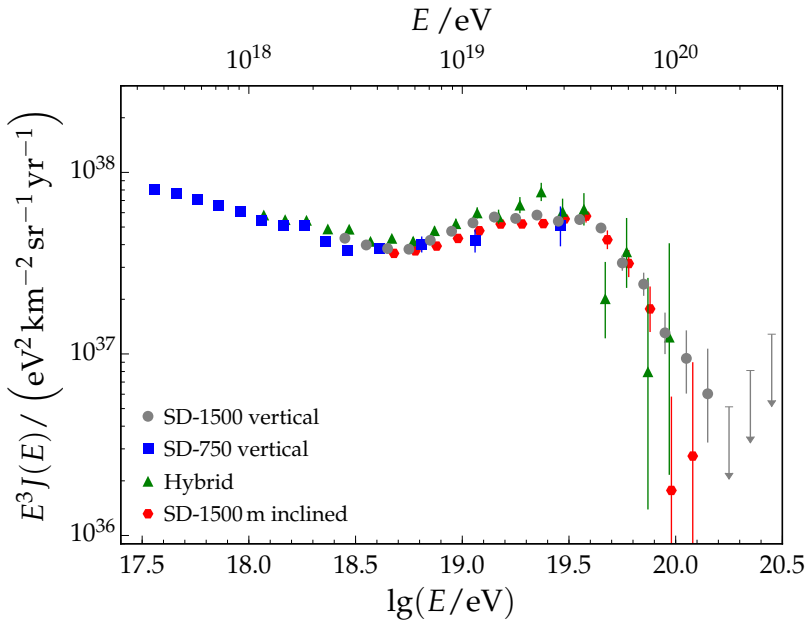


S_{1000}

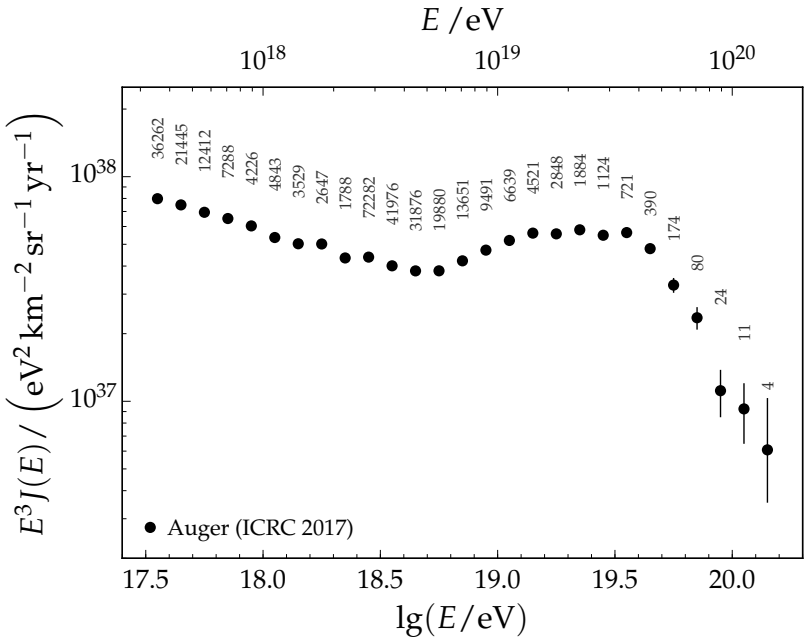
$$E_{\text{surface}} = f(S_{1000}, \theta)$$



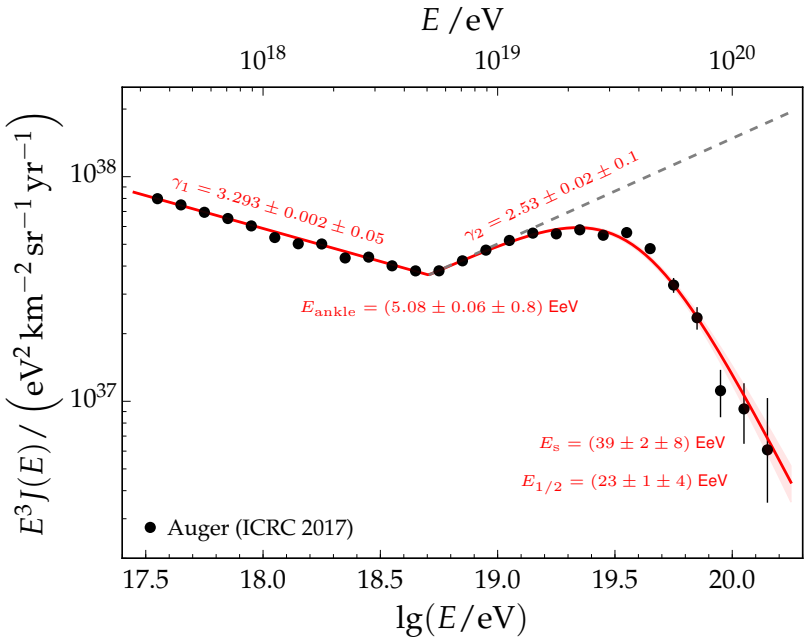
Energy Spectrum



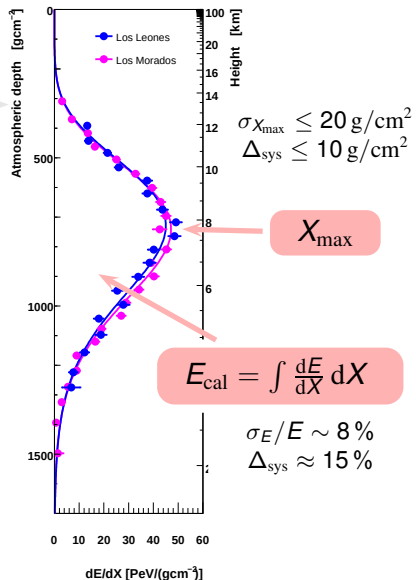
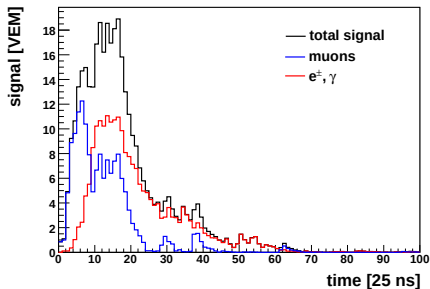
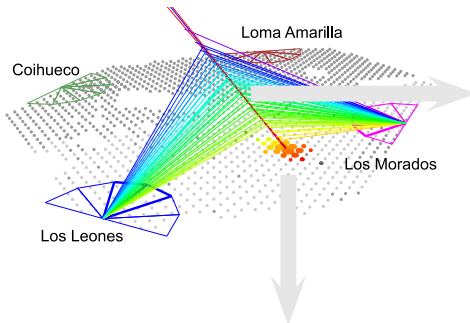
Combined Energy Spectrum



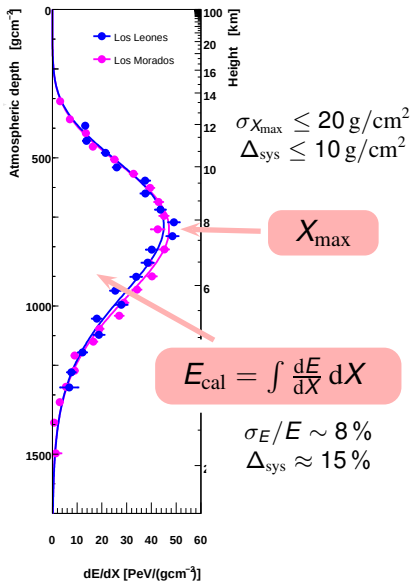
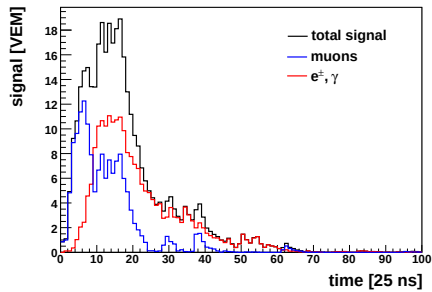
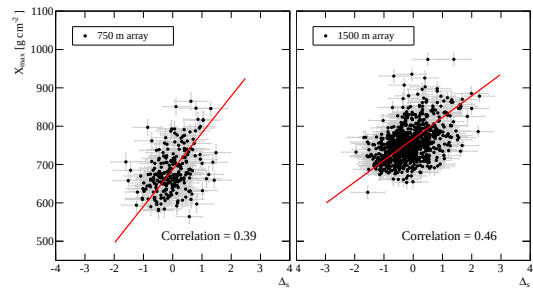
Combined Energy Spectrum

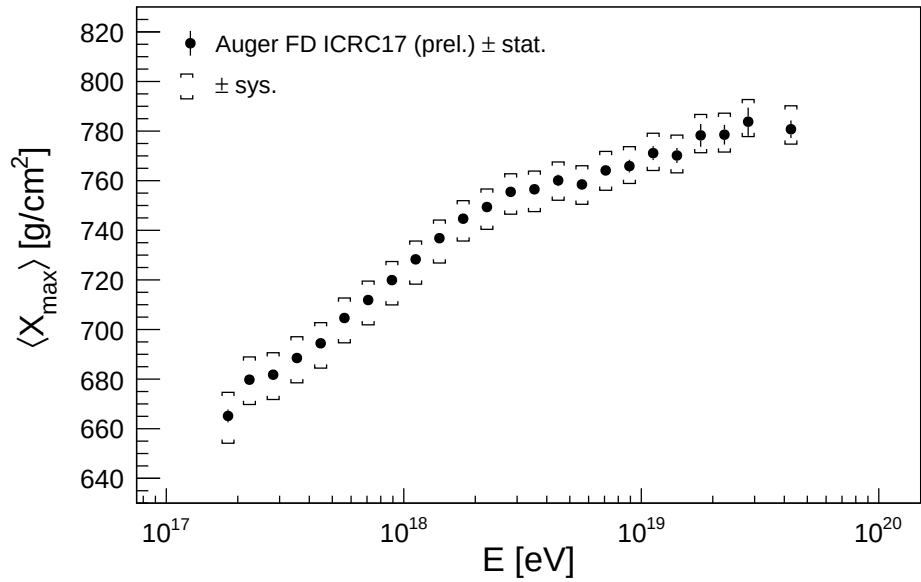


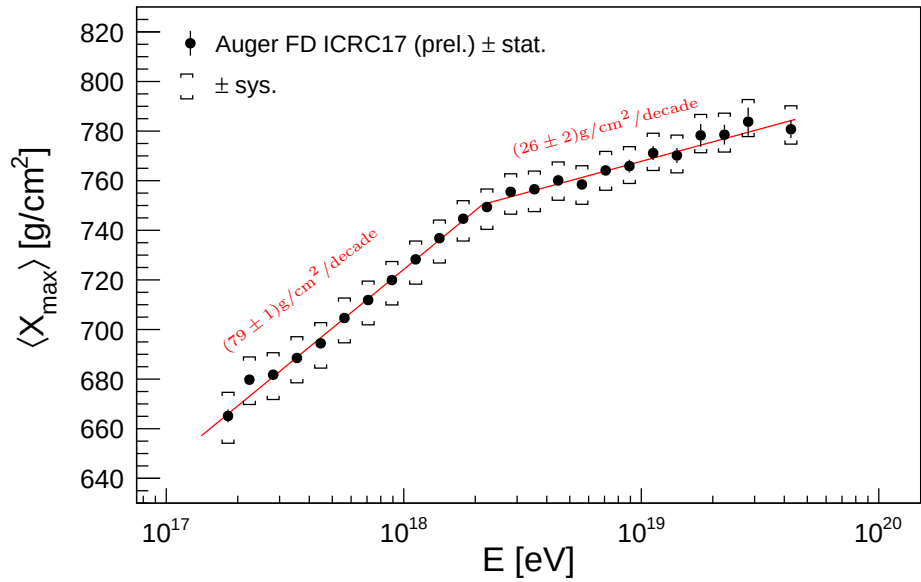
Mass Composition



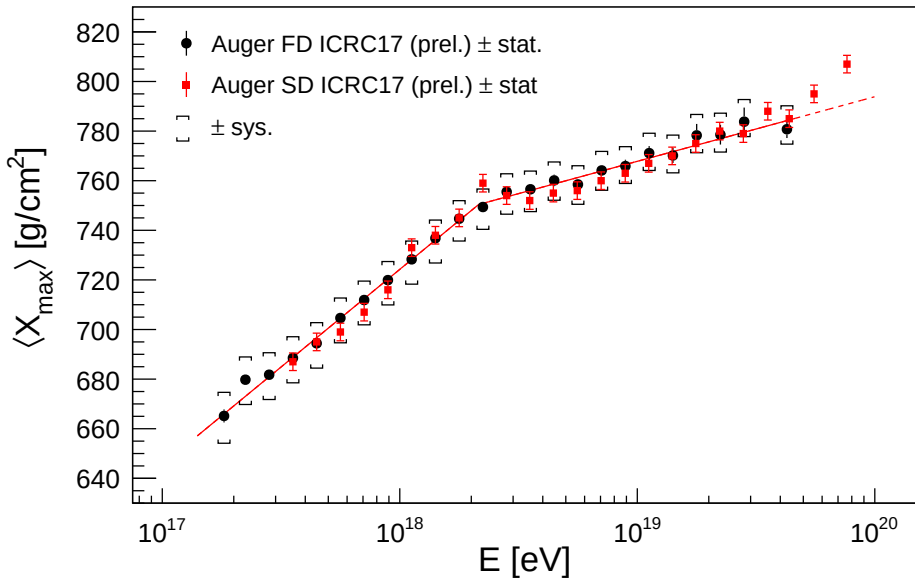
Mass Composition



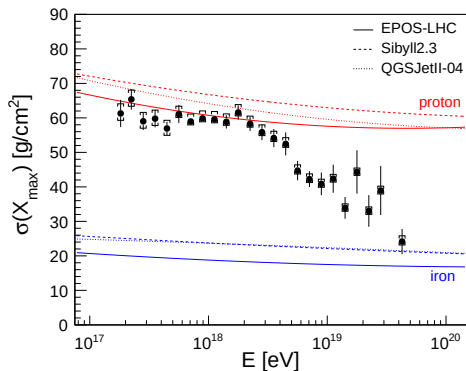
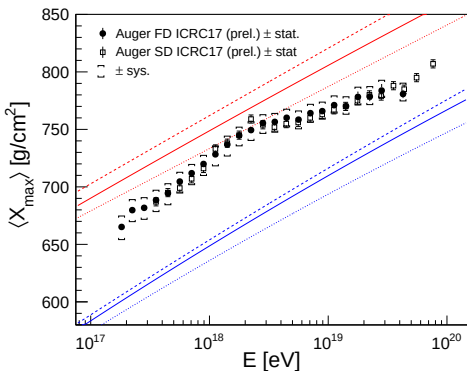




Average $X_{\max}$ Fluorescence and Surface Detector



Average $X_{\max}$ and $X_{\max}$ -fluctuations



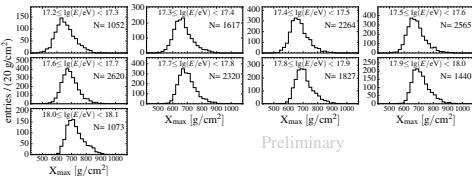
lines: air shower simulations using post-LHC hadronic interaction models

(p-He-N-Fe)-fit of $X_{\max}$ Distributions

FD data:

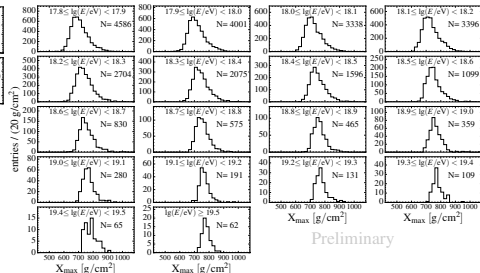
(compatible with TA distributions, see WG report, V. de Souza et al., CRI167, Tuesday, 14:45)

$\lg(E/\text{eV}) = 17.2 \dots 18.1$



Preliminary

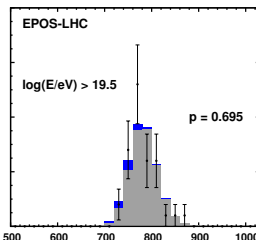
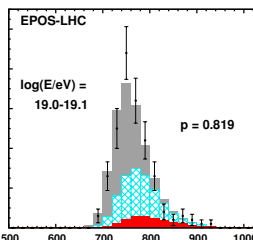
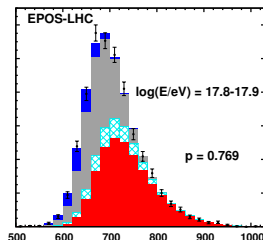
$\lg(E/\text{eV}) = 17.8 \dots > 19.5$



Preliminary

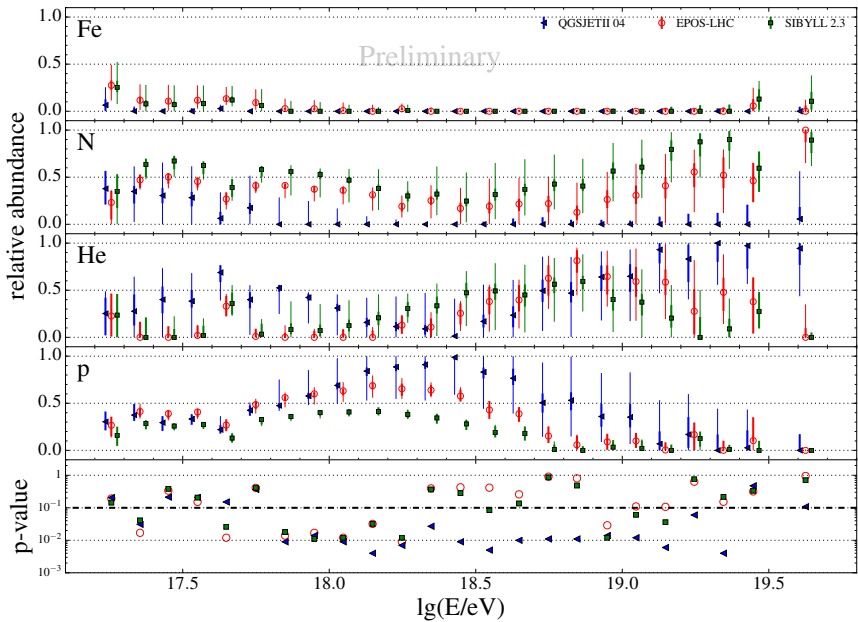
Examples of 4-component fit:

pHeNFe



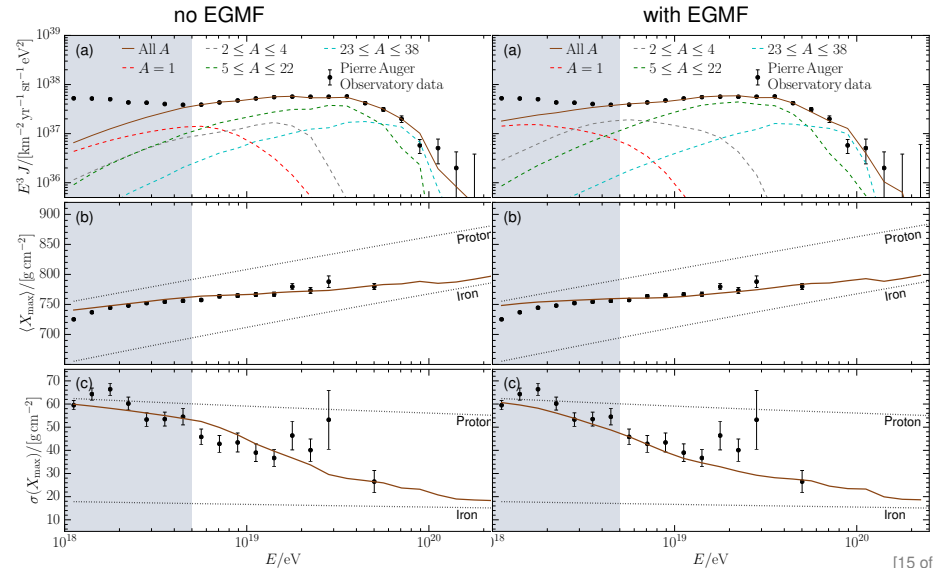
$X_{\max} [\text{g/cm}^2]$

Composition Fractions



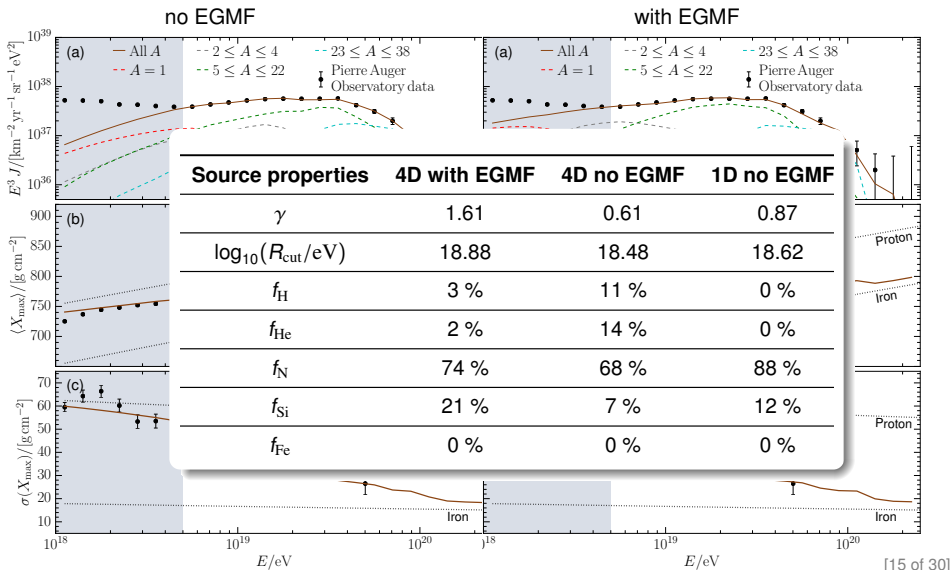
Combined Fit of Spectrum and $X_{\max}$ Distributions

rigidity-dependent cutoff at source: $E_{\max} = R_{\text{cut}} Z$, power law injection $E^{-\gamma}$,
propagation with CRPropa3, Gilmore12 EBL, Dolag12 LSS



Combined Fit of Spectrum and X_{max} Distributions

rigidity-dependent cutoff at source: $E_{\text{max}} = R_{\text{cut}} Z$, power law injection $E^{-\gamma}$,
propagation with CRPropa3, Gilmore12 EBL, Dolag12 LSS



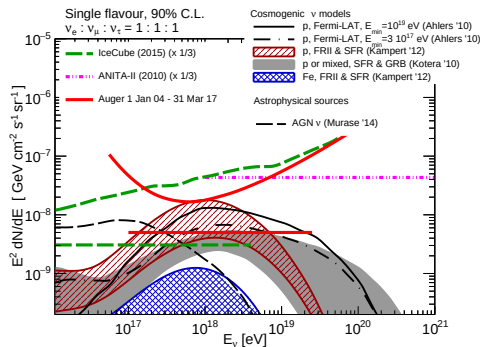
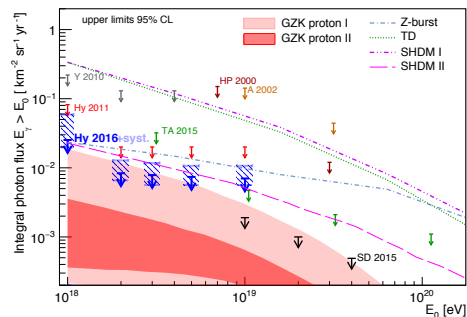
Searches for Cosmogenic Photons and Neutrinos



$\gamma\gamma$

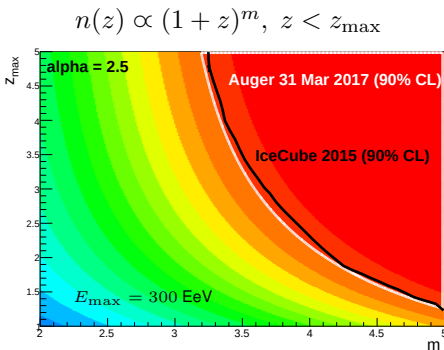


$e^+ + 3\nu$



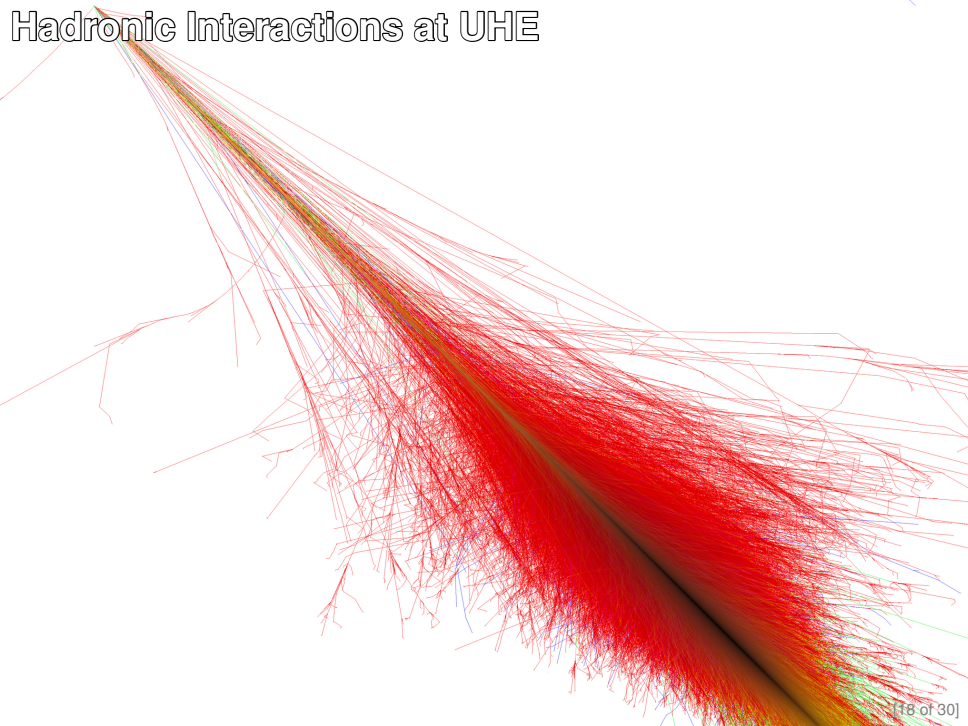
Constraints on Source Evolution from ν Limits

Diffuse flux neutrino model	Expected events (1 Jan 04 - 31 Mar 17)
Cosmogenic - proton - strong source evolution	
Cosmogenic - proton, FRII evol. (Kampert 2012)	~ 5.2
Cosmogenic - proton, FRII evol. (Kotera 2010)	~ 9.2
Cosmogenic - proton - moderate source evolution	
Cosmogenic - proton, SFR evol (Aloisio 2015)	~ 2.0
Cosmogenic - proton, SFR evol, $E_{\max} = 10^{21}$ eV (Kotera 2010)	~ 1.8
Cosmogenic - proton, SFR evol. (Kampert 2012)	~ 1.2
Cosmogenic - proton, GRB evol. (Kotera 2010)	~ 1.5
Cosmogenic - proton - normalized to Fermi-LAT GeV γ -rays	
Cosmogenic - proton, Fermi-LAT, $E_{\min} = 10^{19}$ eV (Ahlers 2010)	~ 4.0
Cosmogenic - proton, Fermi-LAT, $E_{\min} = 10^{17.5}$ eV (Ahlers 2010)	~ 2.1
Cosmogenic - mixed and iron	
Cosmogenic - mixed (Galactic) UHECR composition (Kotera 2010)	~ 0.7
Cosmogenic - iron, FRII (Kampert 2012)	~ 0.35
Astrophysical sources	
Astrophysical - radio-loud AGN (Murase 2014)	~ 2.6
Astrophysical - Pulsars - SFR evol. (Fang 2014)	~ 1.3

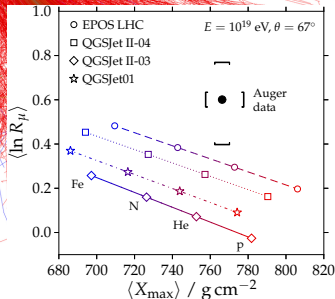
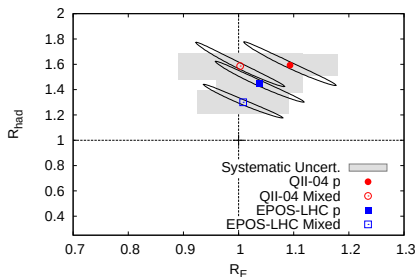
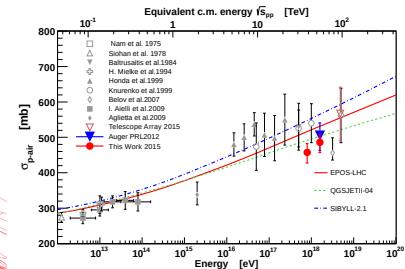


EXCLUDED ($> 90\%$ CL), **DISFAVORED** ($85\% < \text{CL} < 90\%$), **ALLOWED**

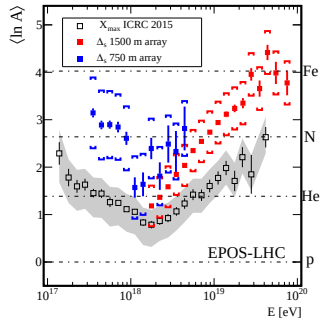
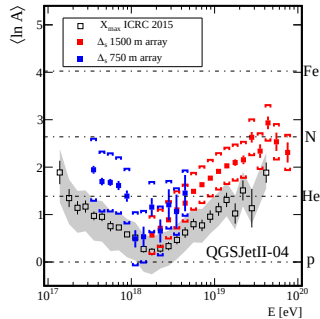
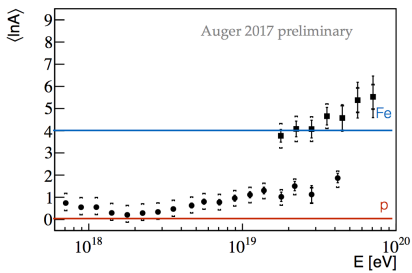
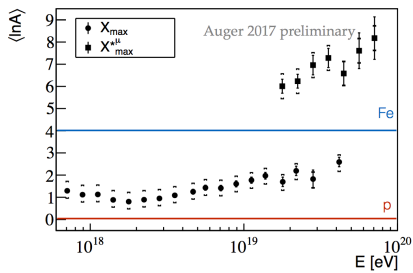
Hadronic Interactions at UHE



Hadronic Interactions at UHE



Hadronic Interactions at UHE: $\langle \ln A \rangle$ compatibility



Search for Intermediate-scale UHECR Anisotropies

Active Galactic Nuclei

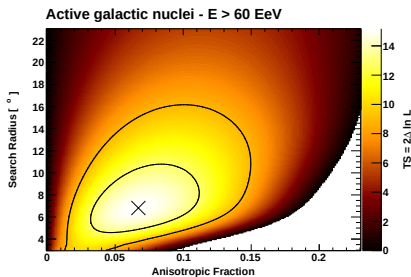
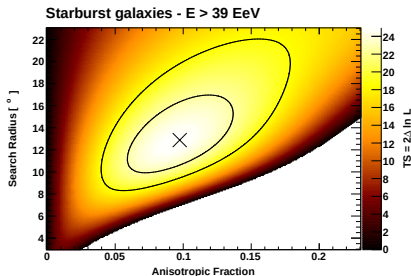
- 2FHL AGNs
- flux proxy: $\Phi(> 50 \text{ GeV})$
- 17 objects within 250 Mpc

Star-forming of Starburst Galaxies

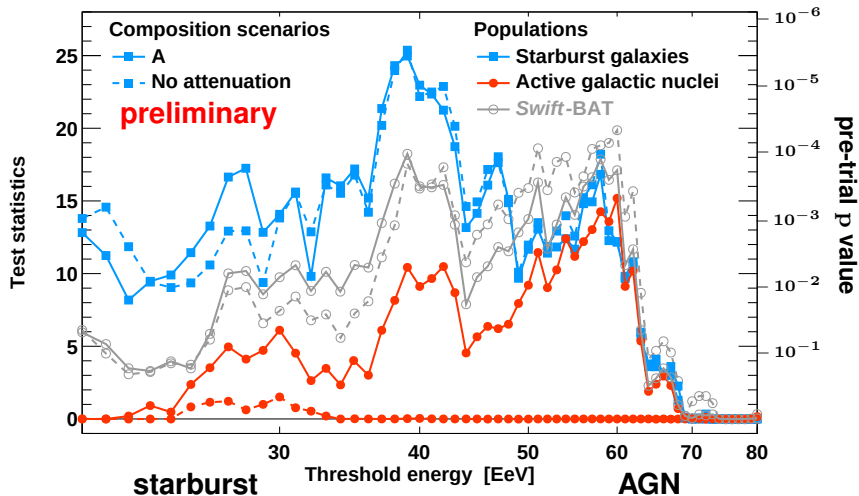
- Fermi-LAT search list (Ackermann+2016)
- $\Phi(> 1.54, \text{GHz}) > 0.3 \text{ Jy}$
- flux proxy: $\Phi(> 1.54, \text{GHz})$
- 23 objects within 250 Mpc

Likelihood ratio analysis

- smearing angle ψ
- H_0 : isotropy
- H_1 : $(1 - f) \times \text{isotropy} + f \times \text{fluxMap}(\psi)$
- $\text{TS} = 2 \log(H_1/H_0)$



Search for Intermediate-scale UHECR Anisotropies



$f = 10\%$, $\psi = 13^\circ$

pre-trial* p-value: 4×10^{-6}

post-trial** p-value: 4×10^{-5}

post-trial** significance: 3.9σ

$f = 7\%$, $\psi = 7^\circ$

pre-trial* p-value: 5×10^{-4}

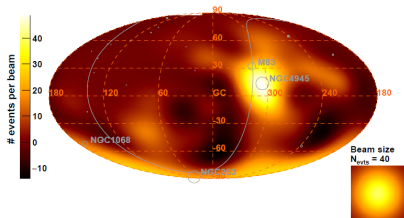
post-trial** p-value: 3×10^{-3}

post-trial** significance: 2.7σ

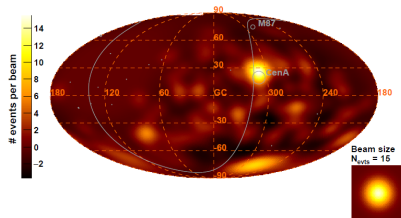
Search for Intermediate-scale UHECR Anisotropies

preliminary

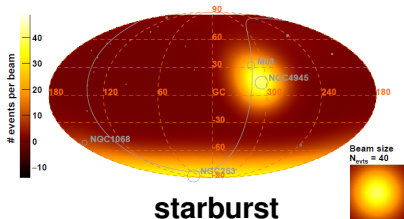
Observed Excess Map - $E > 39$ EeV



Observed Excess Map - $E > 60$ EeV

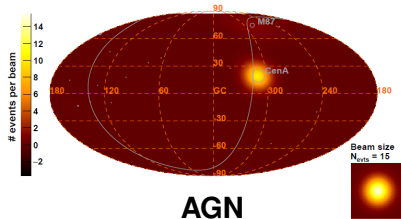


Model Excess Map - Starburst galaxies - $E > 39$ EeV



starburst

Model Excess Map - Active galactic nuclei - $E > 60$ EeV



AGN

$$f = 10\%, \psi = 13^\circ$$

$$\text{pre-trial* p-value: } 4 \times 10^{-6}$$

$$\text{post-trial** p-value: } 4 \times 10^{-5}$$

$$\text{post-trial** significance: } 3.9\sigma$$

$$f = 7\%, \psi = 7^\circ$$

$$\text{pre-trial* p-value: } 5 \times 10^{-4}$$

$$\text{post-trial** p-value: } 3 \times 10^{-3}$$

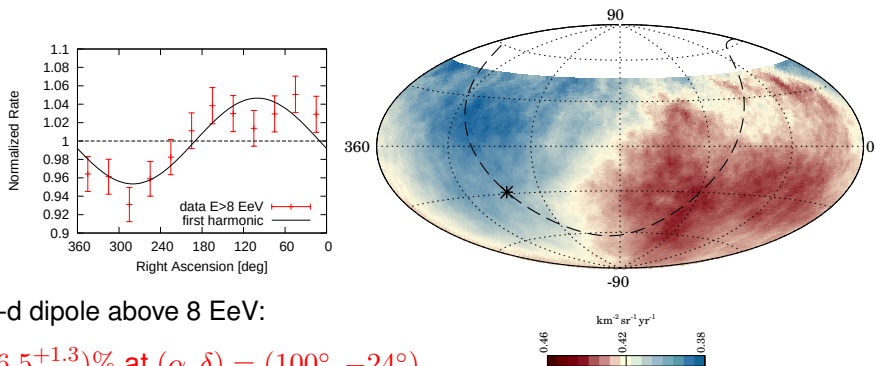
$$\text{post-trial** significance: } 2.7\sigma$$

Observation of Dipolar anisotropy above 8 EeV

Harmonic analysis in right ascension α

E [EeV]	events	amplitude r	phase [deg.]	$P(\geq r)$
4-8	81701	$0.005^{+0.006}_{-0.002}$	80 ± 60	0.60
> 8	32187	$0.047^{+0.008}_{-0.007}$	100 ± 10	2.6×10^{-8}

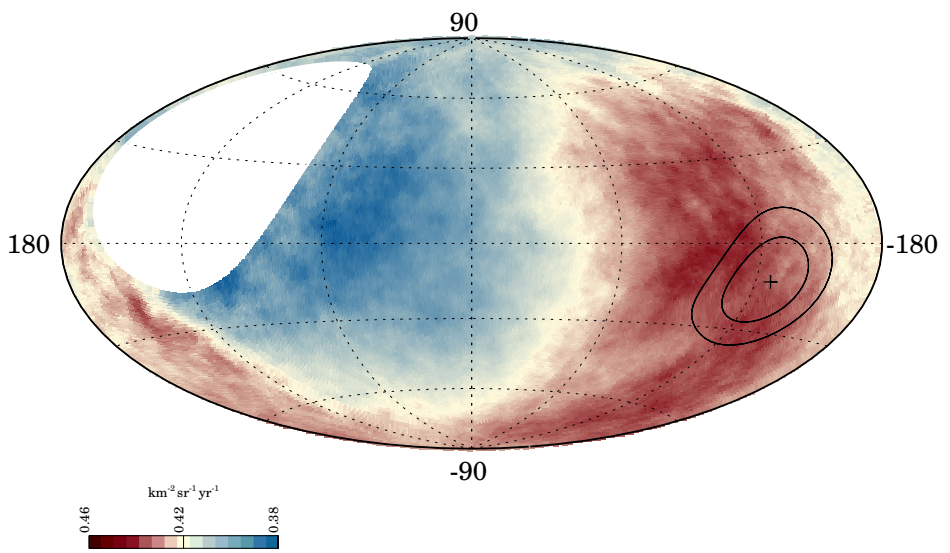
significant modulation at 5.2σ (5.6σ before penalization for energy bins explored)



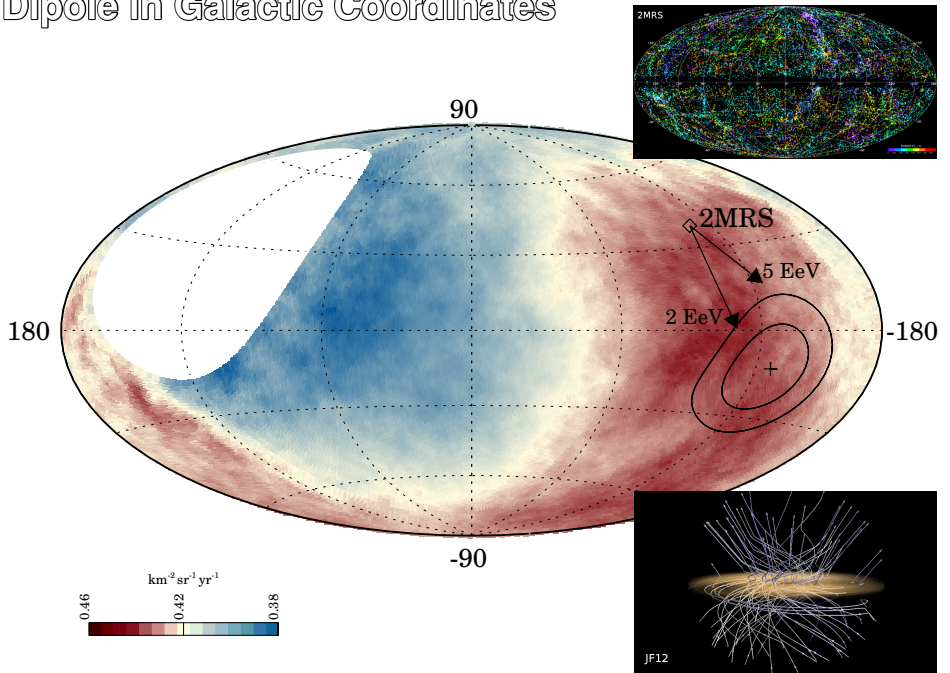
3-d dipole above 8 EeV:

$(6.5^{+1.3}_{-0.9})\%$ at $(\alpha, \delta) = (100^\circ, -24^\circ)$

Dipole in Galactic Coordinates



Dipole in Galactic Coordinates



Summary of Results

spectrum, composition, secondaries:

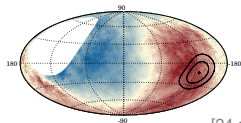
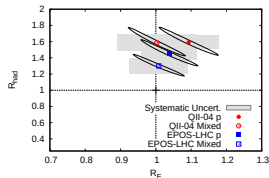
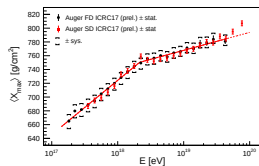
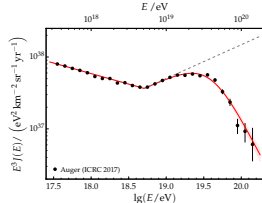
- high-exposure study of UHE flux
→ strong flux suppression
- FD/SD composition studies
→ light composition at ankle
→ mixed composition at UHE
→ Galactic Fe around $10^{17.2}$ eV?
- constraints on p-dominated sources via ν/γ
- compatible with rigidity-dependent $E_{\max}$

hadronic interactions:

- standard UHE cross section
- muon deficit in models

arrival directions:

- indication for intermediate-scale anisotropy
- observation of dipolar anisotropy



Questions for the next ICRCs

- Origin of the flux suppression?
- Proton fraction at UHE?
- Rigidity-dependence of anisotropies?
- Hadronic physics above $\sqrt{s} = 140$ TeV?

need large-exposure detector with
composition sensitivity!

arXiv:1604.03637v1 [astro-ph.IM] 13 Apr 2016

The Pierre Auger Observatory Upgrade “AugerPrime”

Preliminary Design Report



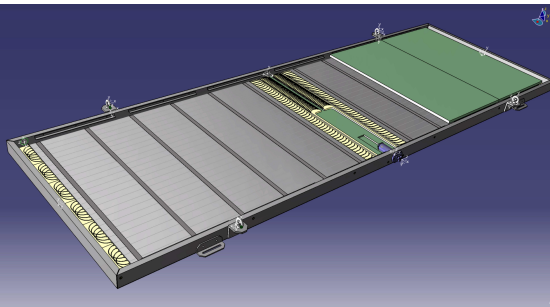
The Pierre Auger Collaboration
April, 2015



Observatorio Pierre Auger,
Av. San Martín Norte 304,
5613 Malargüe, Argentina

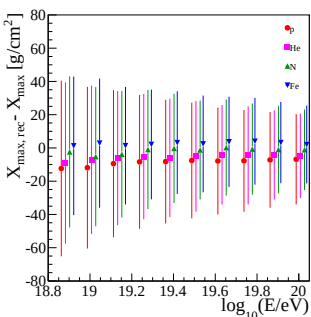
Detector Upgrades for AugerPrime

- 3.8 m² scintillators (SSD) on each 1500-m array station
- upgrade of station electronics
- additional small PMT to increase dynamic range
- buried muon counters in 750-m array (AMIGA)
- increased FD uptime

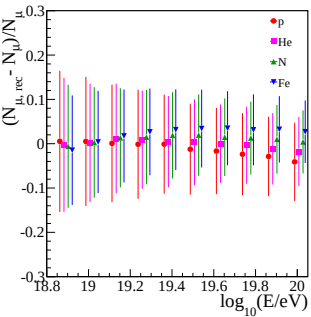


Expected Performance of AugerPrime

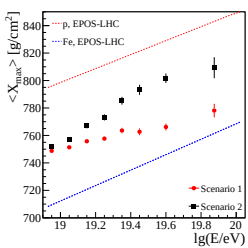
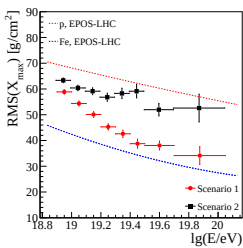
$X_{\max}$ determination:



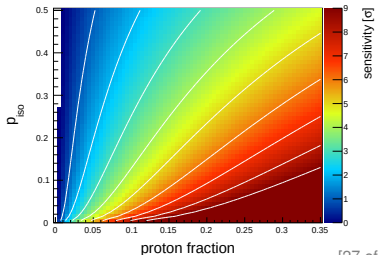
muon determination:



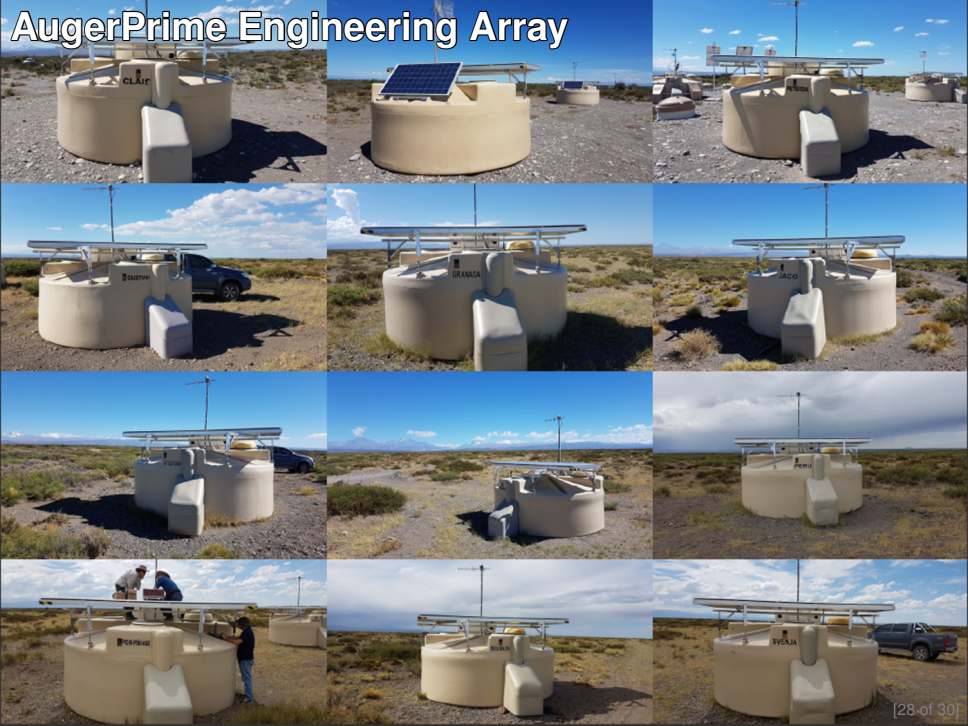
high- vs. low- R_{cut} scenario:



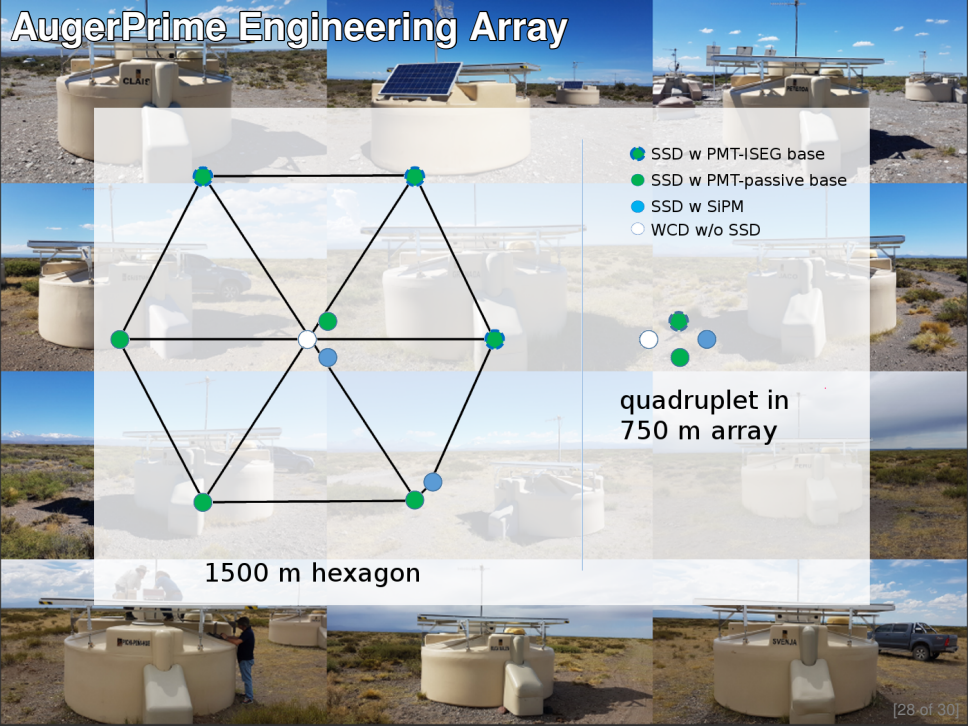
low- Z particle astronomy:



AugerPrime Engineering Array



AugerPrime Engineering Array

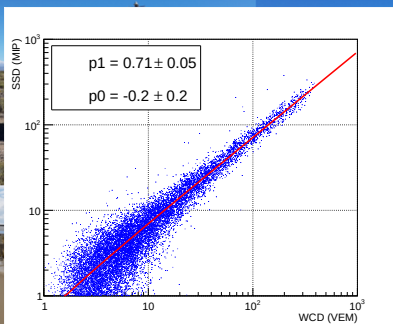
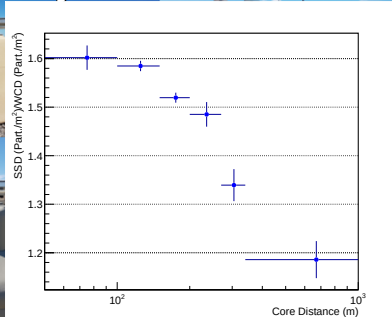
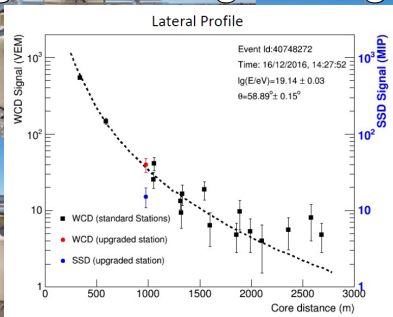


- SSD w PMT-ISEG base
- SSD w PMT-passive base
- SSD w SIPM
- WCD w/o SSD

quadruplet in
750 m array

1500 m hexagon

AugerPrime Engineering Array



- design finalized and tested
- 180 SSDs to be shipped 2017
- finish construction by 2019
- data taking until 2025



Dipolar anisotropy of cosmic rays above 8 EeV
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Report of the TA-Augur Working Group on Energy Spectrum
Report of the TA-Augur Working Group on Composition
Report of the IC-TA-Augur Working Group on Composition

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