



Recent results from the Pierre Auger Observatory

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 for the Pierre Auger Collaboration





Content

- › Aim of the Observatory
- › Detectors
- › Flux spectrum & Shower depth
- › Composition
- › Conclusion & Outlook



Aim of the Observatory

- › Find the origin of the highest-energy cosmic rays
 - top-down scenarios = relics from the BB
 - bottom-up = astrophysical sources
 - injection spectrum
 - effects in the intergalactic medium
 - effects in the atmosphere (hadron physics)
 - anisotropy
- › Searches for: Dark Matter, Lorentz Invariance Violation,



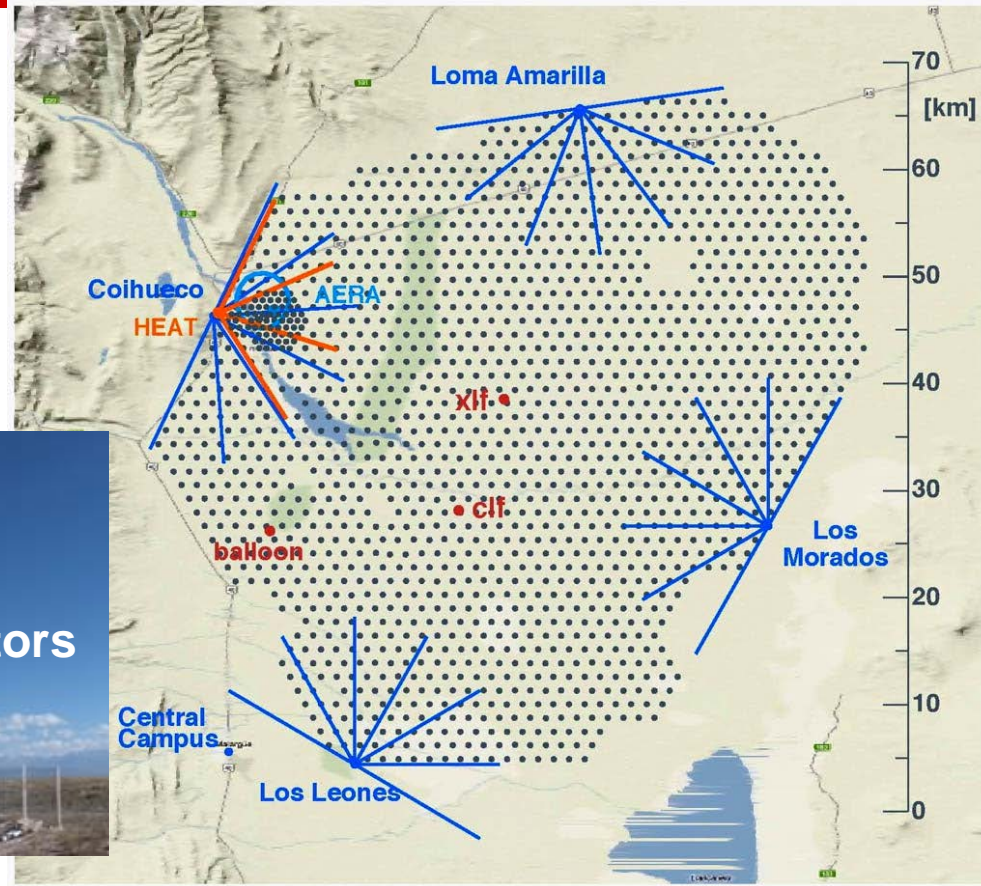


Detectors

fluorescence detection

particle detection

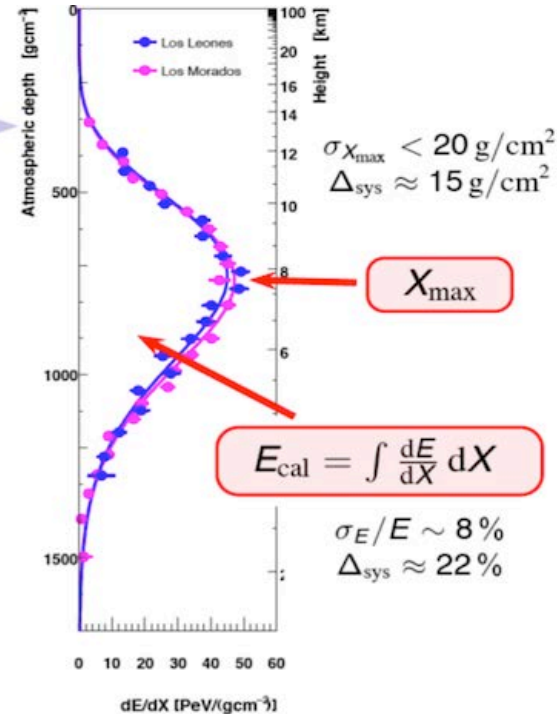
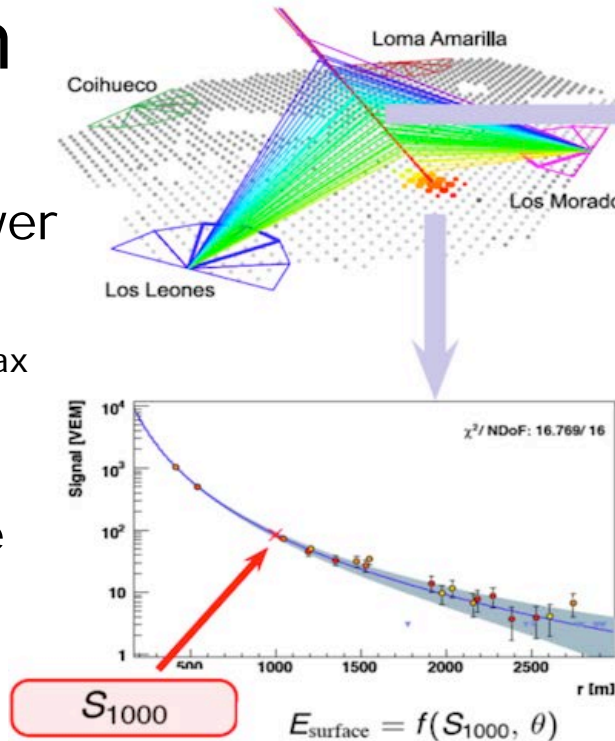
monitors



Information

Estimators

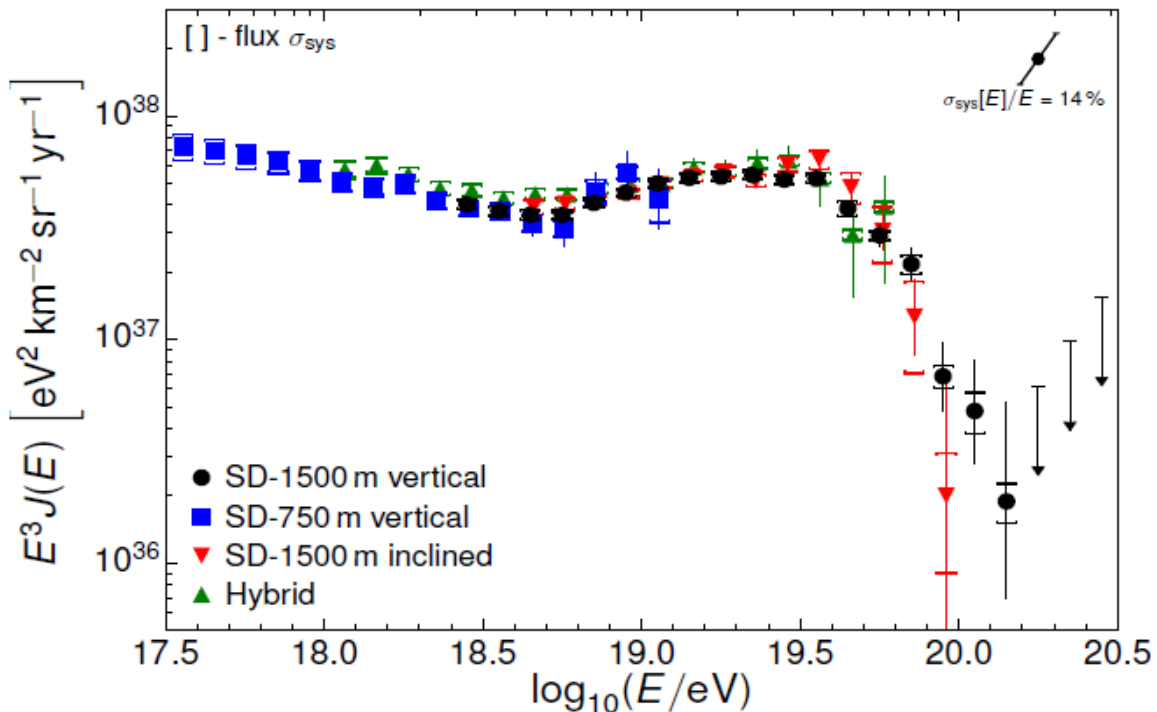
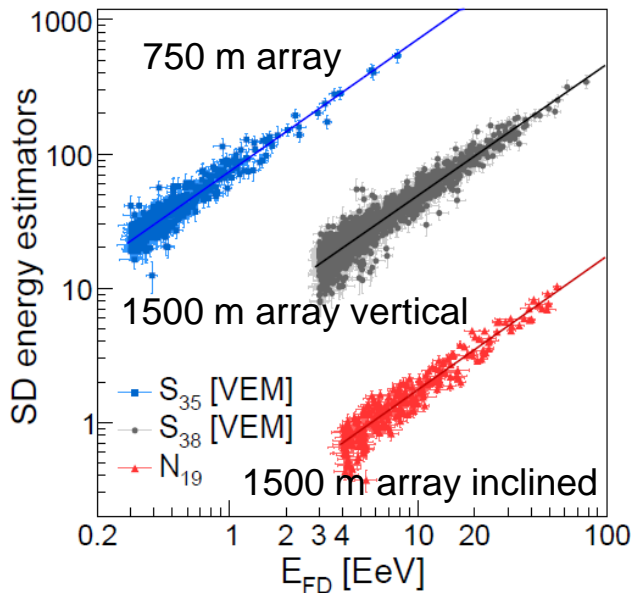
- longitudinal shower profile by fluorescence (X_{\max} and E)
- lateral shower profile by surface detectors (S_{1000})



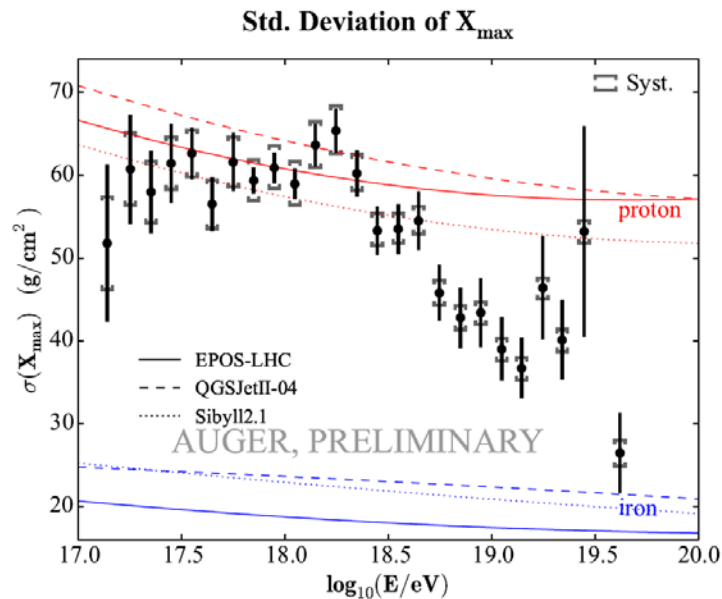
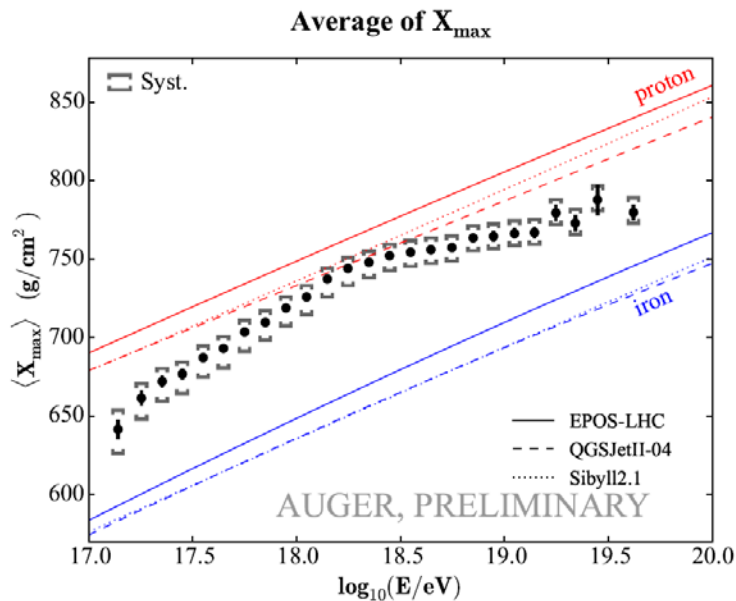
(R. Ulrich, APS meeting 2010)



Energy spectrum



Shower depth



Astrophysical scenarios

Assume

Identical sources

Emitting only ^1H , ^4He , ^{14}N , ^{56}Fe

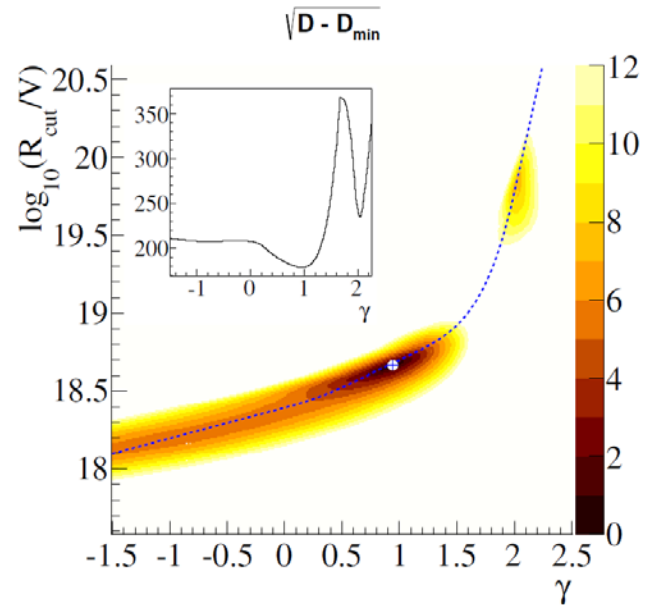
Injection spectrum at source is
broken power law with parameters

γ and R_{cut}

$$\frac{dN_{\text{inj},i}}{dE} = \begin{cases} J_0 p_i (E/E_0)^{-\gamma}, & E/Z_i < R_{\text{cut}} \\ J_0 p_i (E/E_0)^{-\gamma} \exp(1 - E/Z_i R_{\text{cut}}), & E/Z_i > R_{\text{cut}} \end{cases}$$

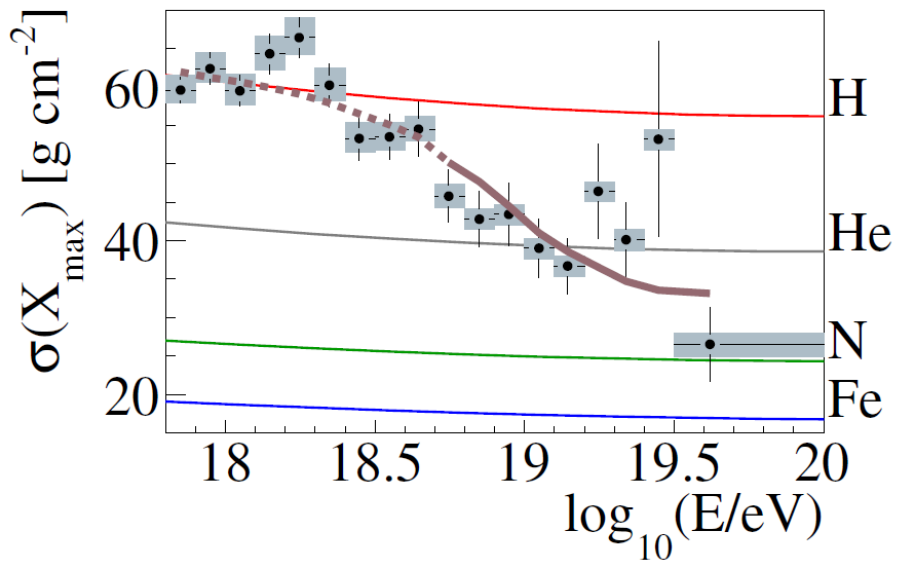
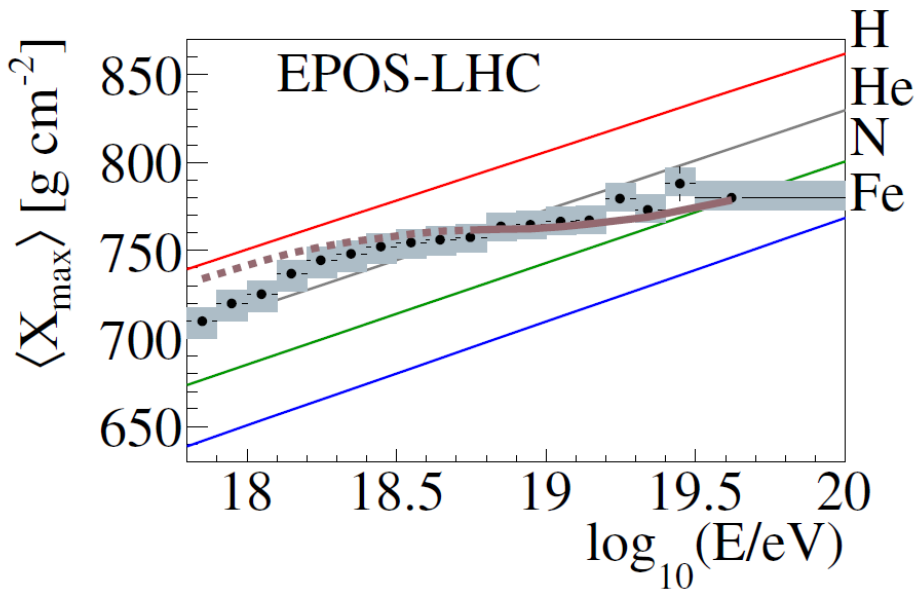
1st min.: maximum-rigidity scenario

2nd min.: photo-disintegration model



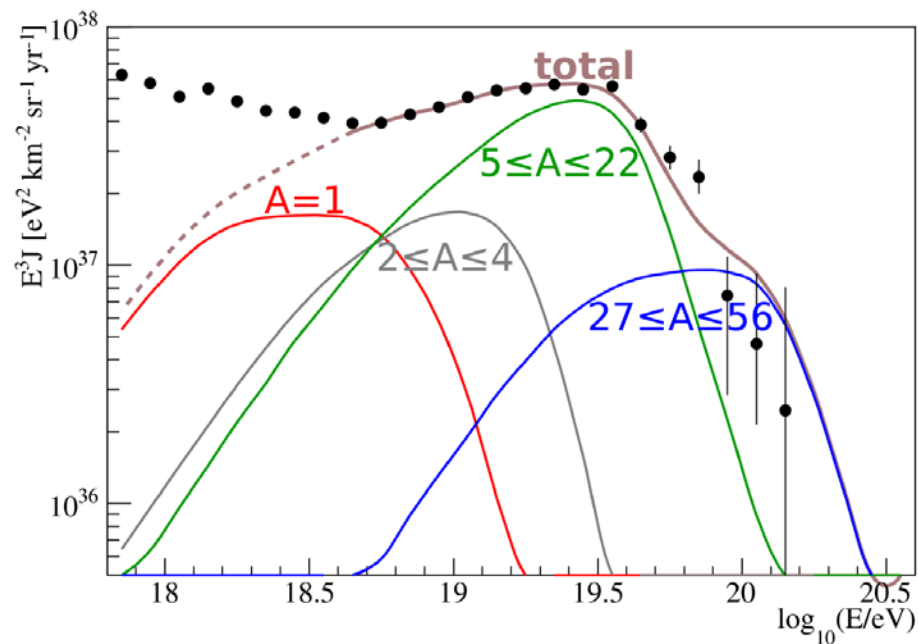


Composition from shower maximum



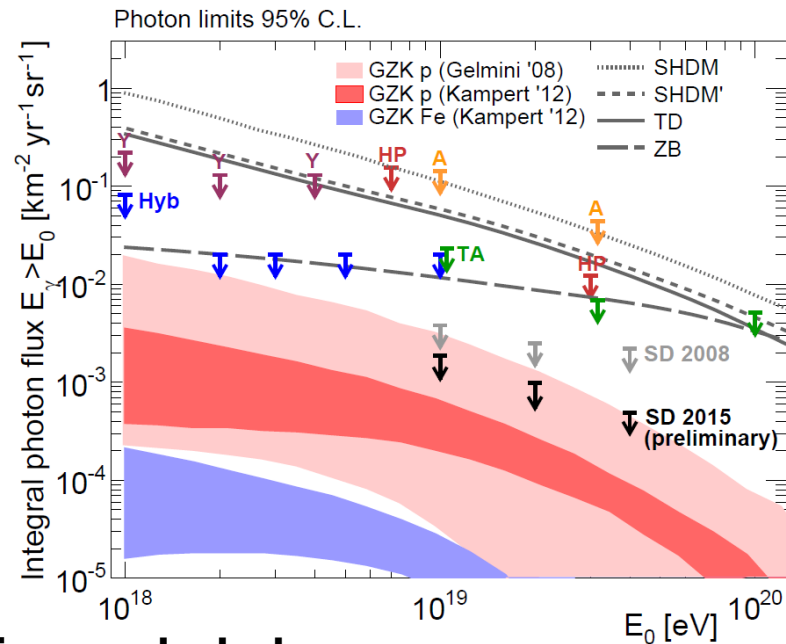
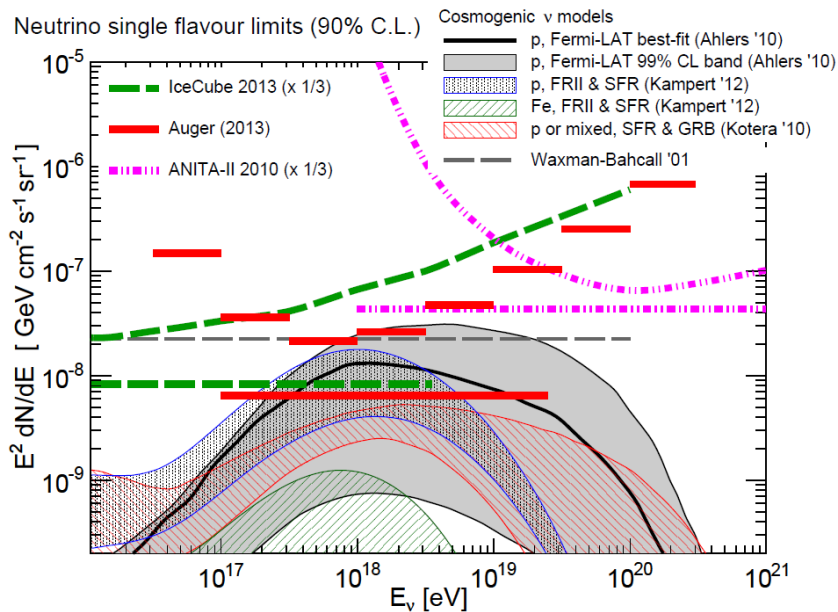
Composition: combined analysis

- › From the source, through the galaxy and atmosphere, until detection
- › Fit of the flux spectrum by four groups of masse
- › Changing from light to heavy





Neutrino & photon signals (none)



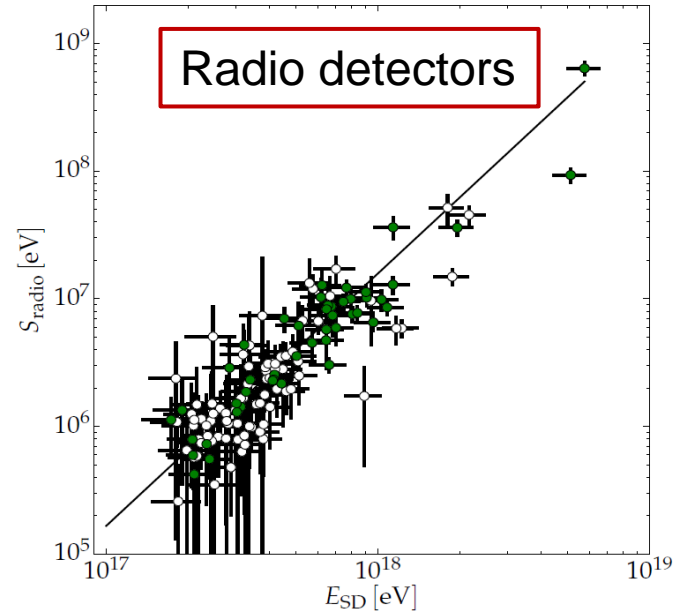
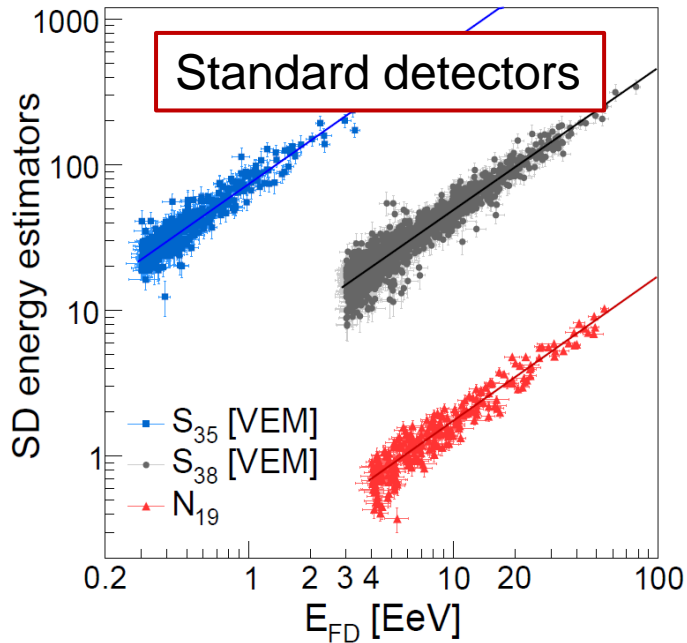
top-down scenarios excluded



New extensions



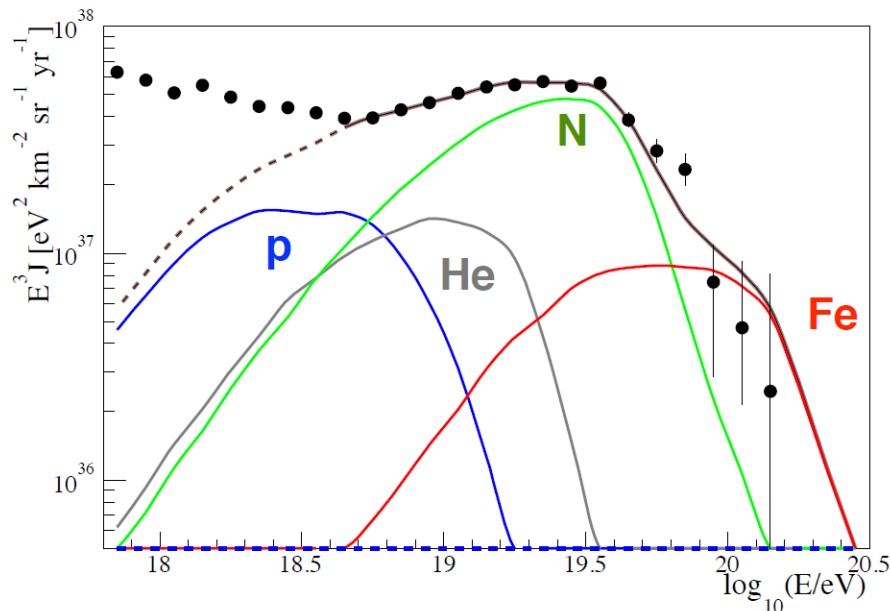
Radio signal: addition to standard



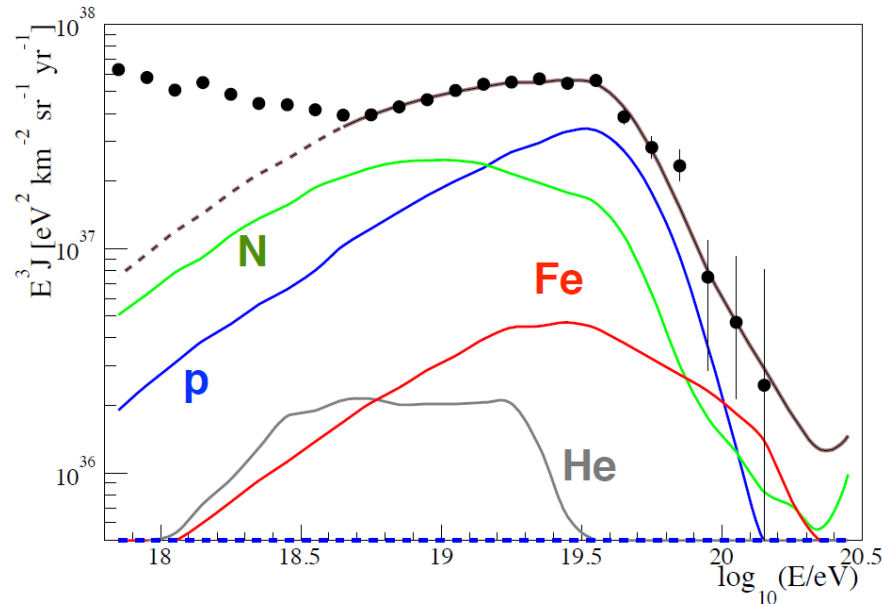


Upgrade of detectors: Auger prime

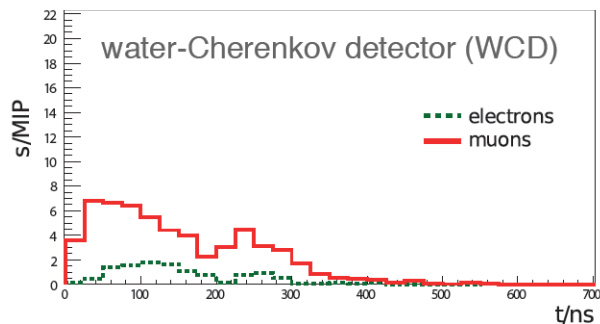
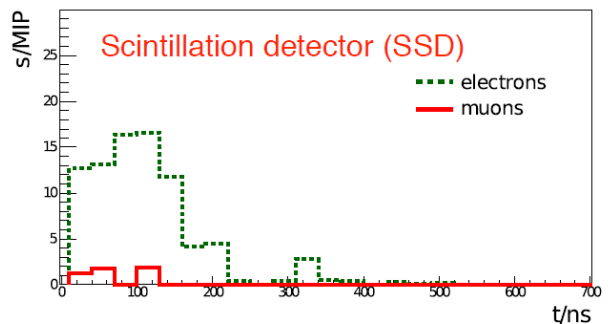
Scenario 1: maximum rigidity model



Scenario 2: photo-disintegration model



Measure the EM versus the μ signals





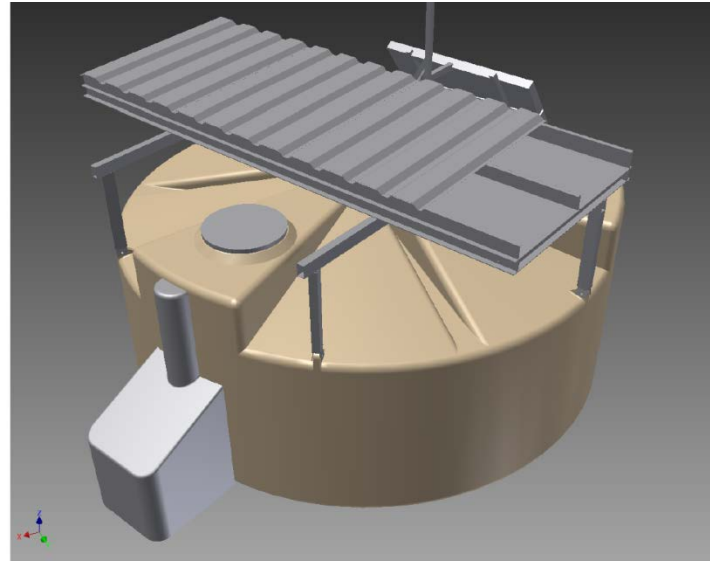
Auger Prime

Water-Cherenkov:

- > both muons and EM

Scintillator:

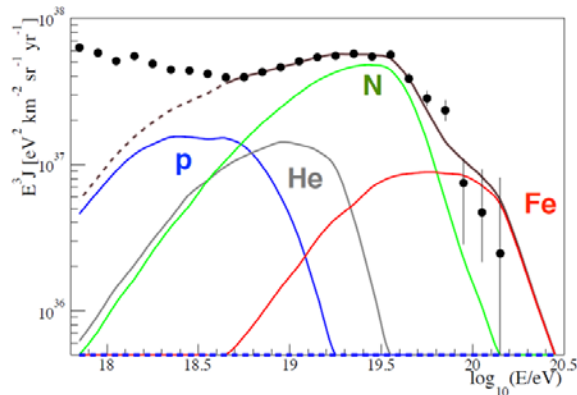
- > mainly EM



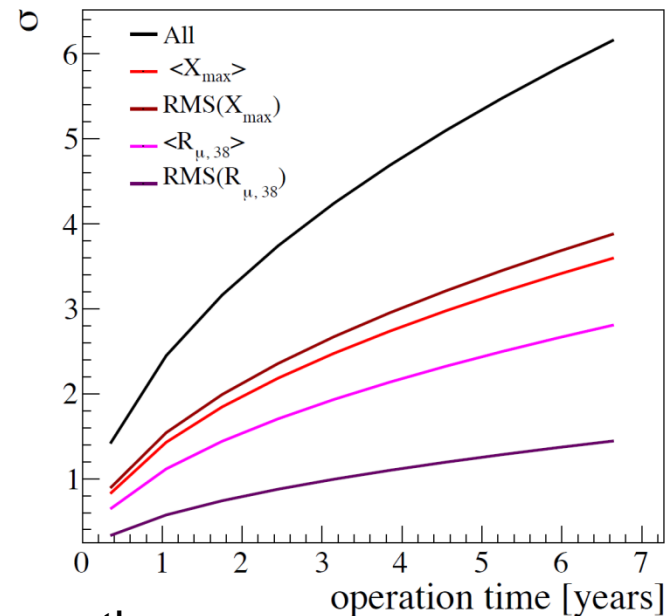
Use both signals to improve the separation between light and heavy composition

Improvement on source models

Scenario 1: maximum rigidity model



scenario 1: maximum-rigidity scenario NO protons
scenario 2: 10% protons added



significance to decide between these
two scenarios using events $^{10}\log(E/eV) > 18.7$



Conclusion & Outlook

- › more than 10 years of operation
 - composition: light – heavy
 - top-down scenarios excluded
 - two astrophysical scenarios: rigidity limited & photo-disintegration
 - need better distinction between light and heavy
- › **Auger Prime** to decide on source scenarios, acceleration mechanisms, and to perform hadronic-interaction studies





Thank you





university of
 groningen

kvi - center for advanced
 radiation technology

astroparticle physics

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Anisotropy studies

- › Select events with energy > 40 EeV: 602 events
- › Make a binned analysis with different
 - angular bins between 1° and 30°
 - different energy thresholds (up to 80 EeV)
 - Use different astrophysical catalogues
- › Strongest correlation (4.6σ) with Super-galactic plane and Centaurus A (closest radio-loud AGN)



Correlation study: 12° and $E > 54$ EeV

