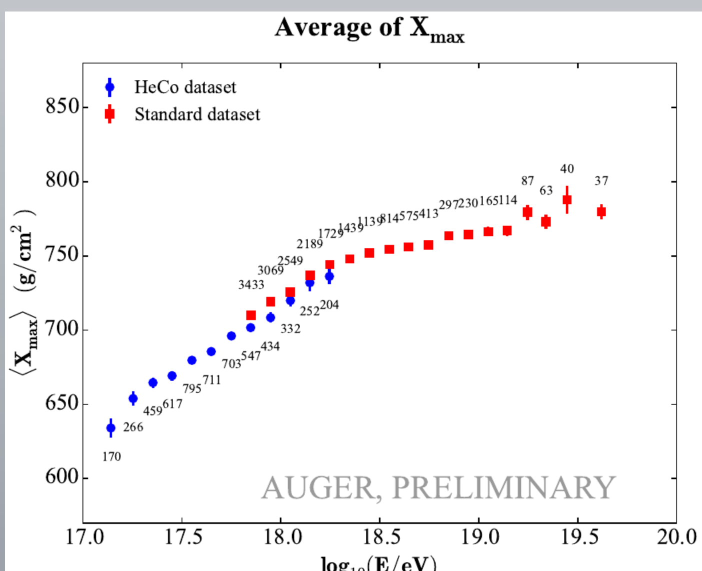
Auger HEAT – Composition and Cherenkov rich events

Extension of X_{max} measurement with Fluorescence Telescopes down to 10^{17} eV, *and further*

Julian Rautenberg
for the Pierre Auger Collaboration

Bergische Universität Wuppertal



Großgeräte der physikalischen Grundlagenforschung

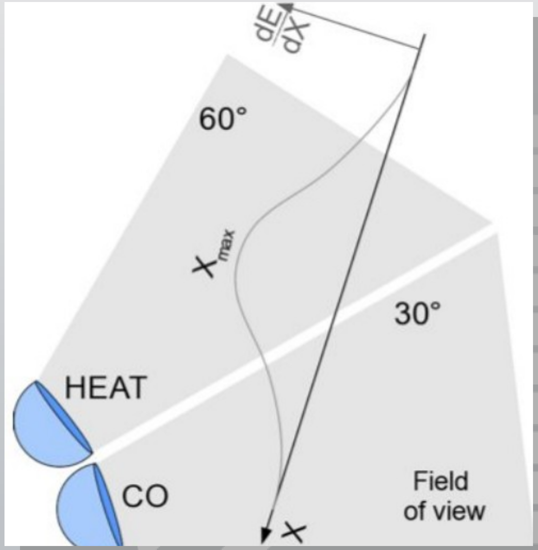
Auger HEAT – Motivation

Low-energetic shower:

- develop earlier in the atmosphere and
- have less dE/dx

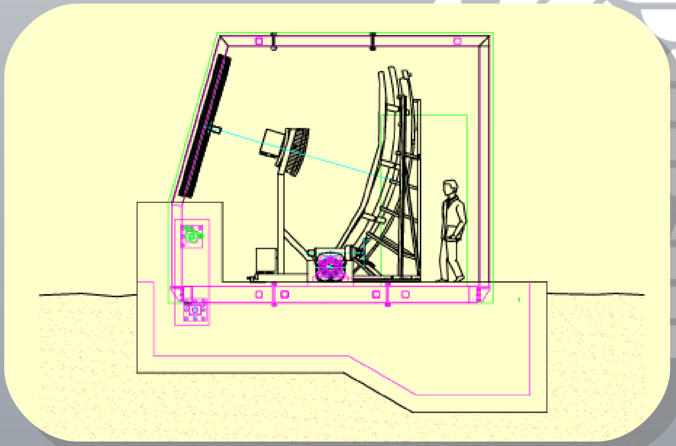
To lower E-threshold for Fluorescence Telescopes the field of view needs:

- higher and
- closer



High Elevation Auger Telescopes

- Tilt 3 FDs to 30 – 60 degree
- Co-located with FD Coihueco
- Overlooking low-energy area (AMIGA, AERA)
- Downward mode for cross-calibration



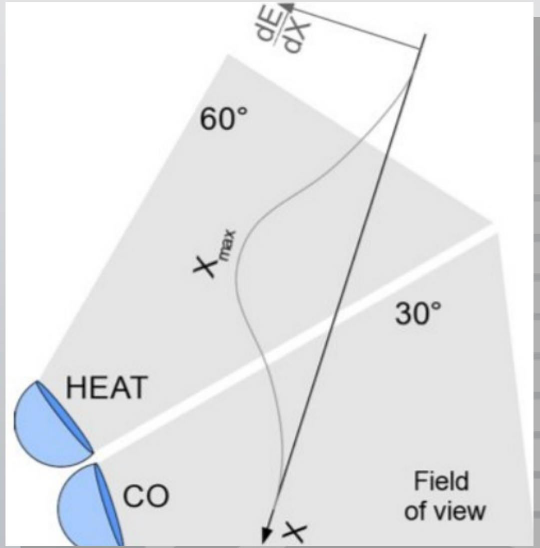
Auger HEAT – Motivation

Low-energetic shower:

- develop earlier in the atmosphere and
- have less dE/dx

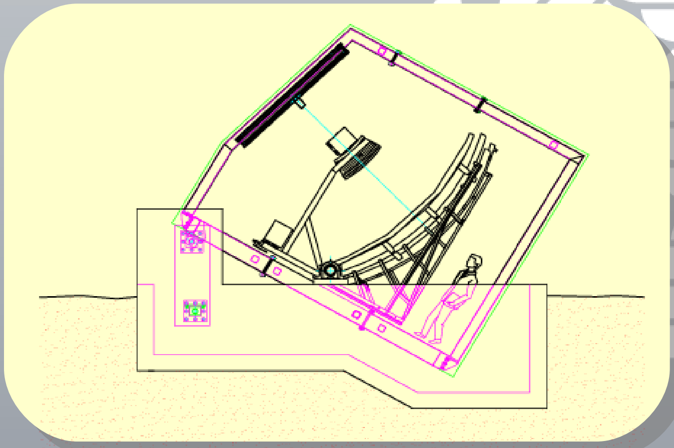
To lower E-threshold for Fluorescence Telescopes the field of view needs:

- higher and
- closer



High Elevation Auger Telescopes

- Tilt 3 FDs to 30 – 60 degree
- Co-located with FD Coihueco
- Overlooking low-energy area (AMIGA, AERA)
- Downward mode for cross-calibration



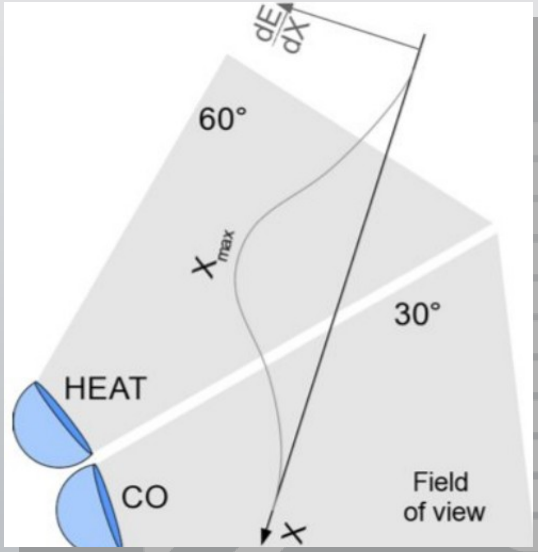
Auger HEAT – Motivation

Low-energetic shower:

- develop earlier in the atmosphere and
- have less dE/dx

To lower E-threshold for Fluorescence Telescopes the field of view needs:

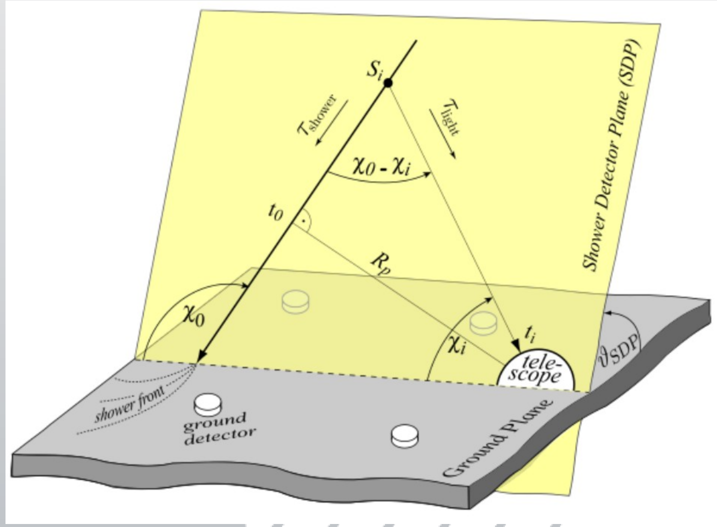
- higher and
- closer



High Elevation Auger Telescopes

- Tilt 3 FDs to 30 – 60 degree
- Co-located with FD Coihueco
- Overlooking low-energy area (AMIGA, AERA)
- Downward mode for cross-calibration

Auger HEAT – Shower Reconstruction

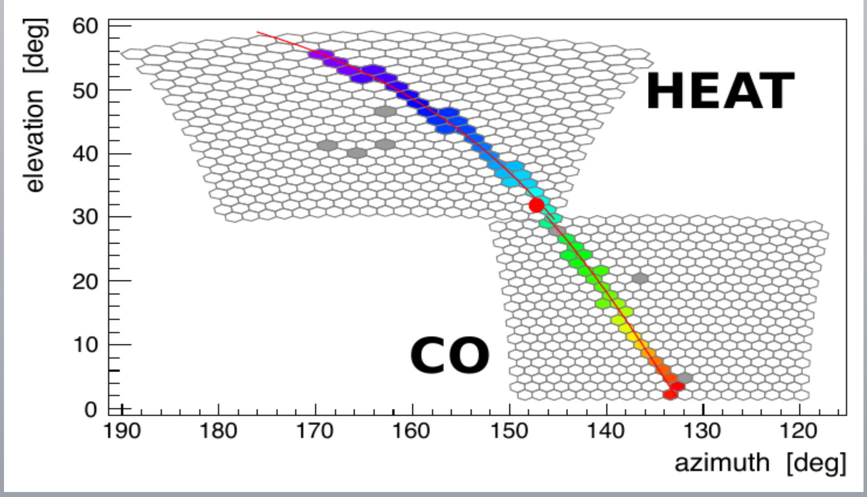


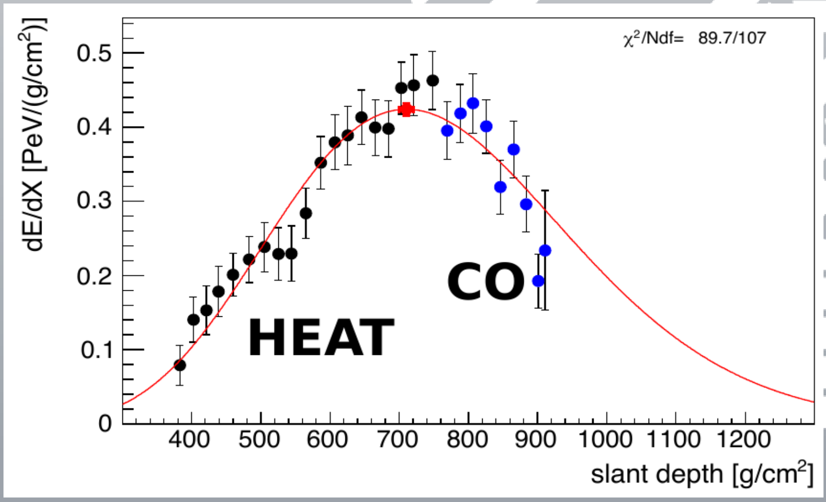
FD reconstruction:

- Fit shower-detector plane (SDP)
- Time-fit of axis within SDP
- Use geometry to correct dE/dx for attenuation

HECO reconstruction:

- Combine HEAT & Coihueco to one *virtual eye*



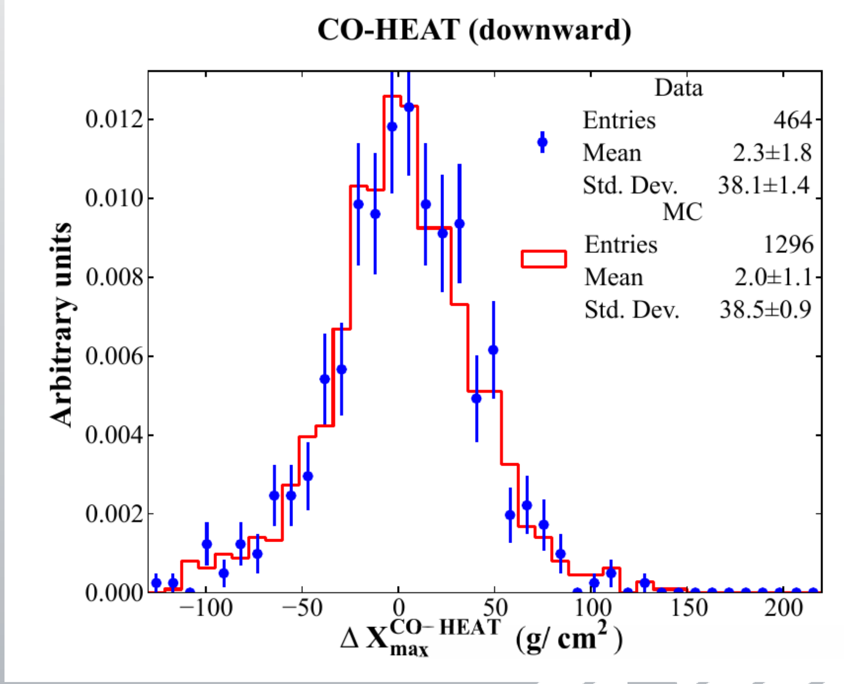


Auger HEAT – Data Analysis

Data:

Phys.Rev. D90 12 (2014)

- Co 12.2004 – 12.2012
- HEAT 06.2010 – 08.2012



Co – HEAT (downward) cross-check shows good description of data by MC

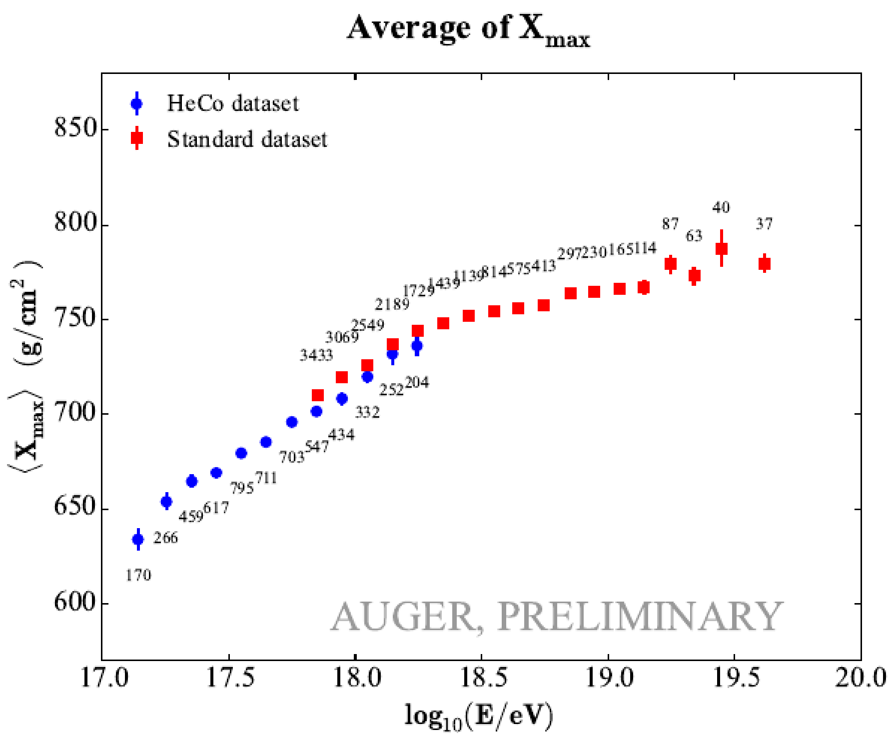
Data-Selection:

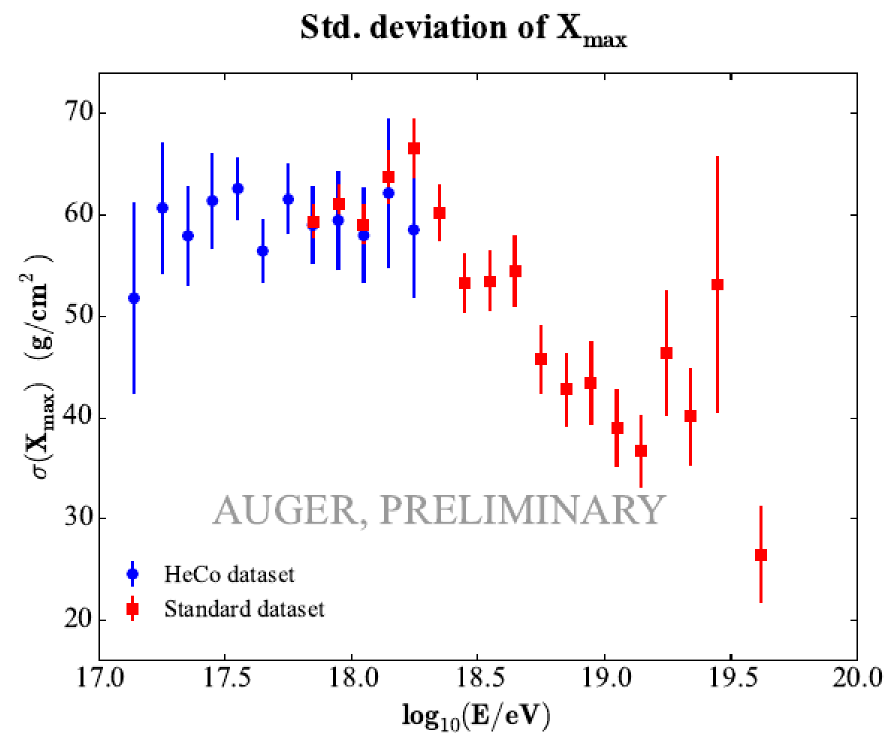
- Similar to standard FD analysis
- FOV restricted to un-biased shower-geometry (X_{low} – X_{up}) (large drop in acceptance for HEAT)

Auger HEAT – X_{max} moments

7 g/cm^2 difference in <X_{max}> between HEAT/Co (withing uncor. sys.)

Good agreement in $\sigma(X_{max})$





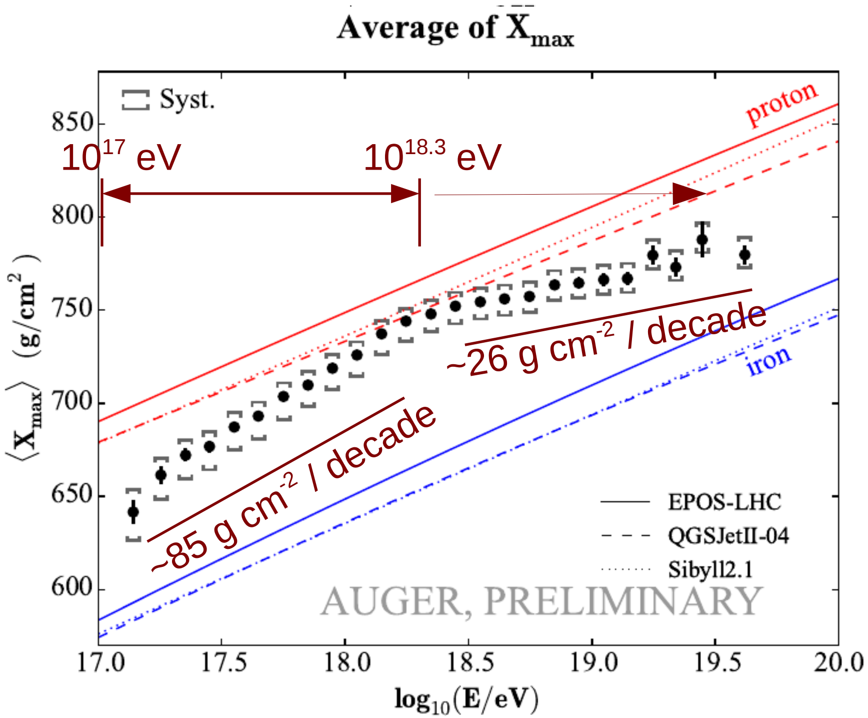
Auger HEAT – Combined X_{max} moments

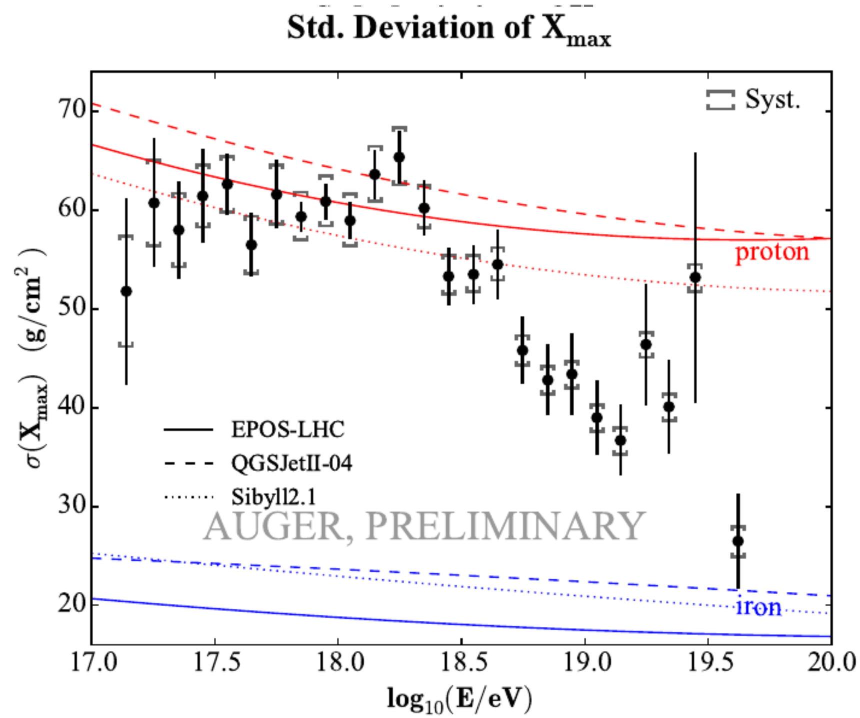
Slope of X_{max} expected for constant composition is ~60 g cm^{-2} / decade

Below $10^{18.3}$ eV too steep → composition becoming *lighter*

Above $10^{18.3}$ eV too shallow → composition becoming *havier*

$\sigma(X_{max})$ about constant up to ~$10^{18.3}$ eV, where it starts to drop off



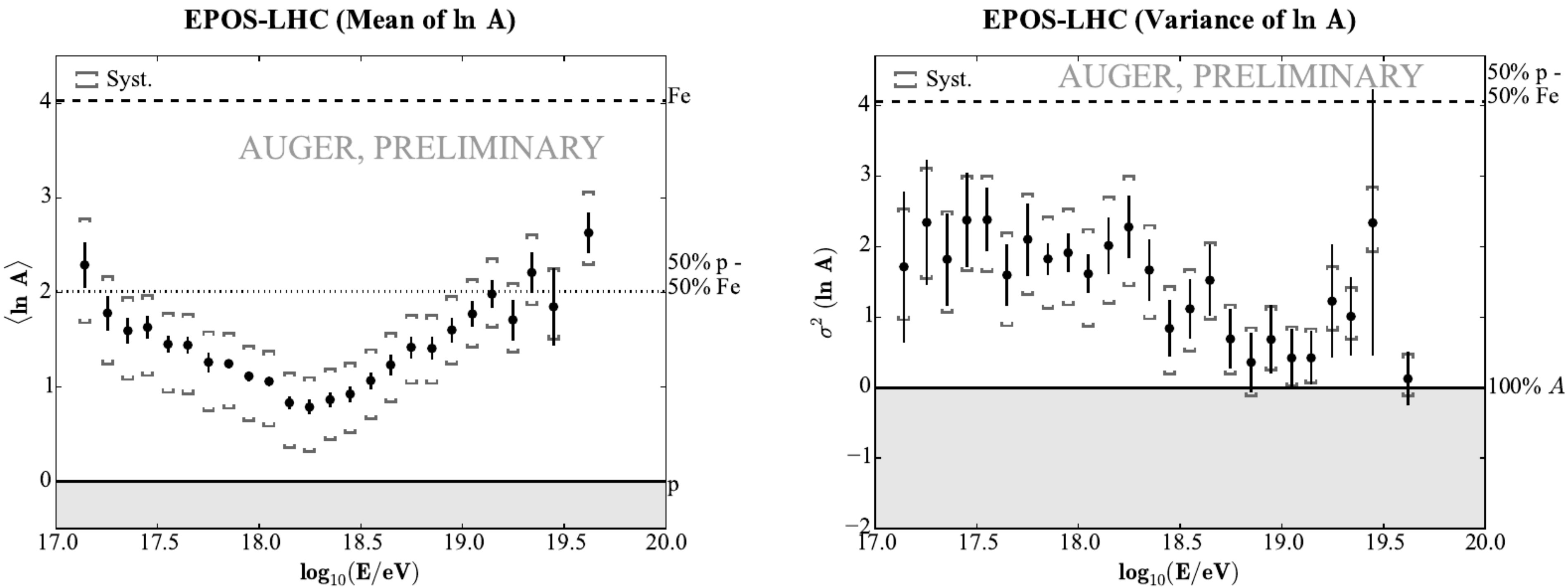


Auger HEAT – Combined X_{max} moments

Determing ln A moments:

$$\langle X_{\max}\rangle = \langle X_{\max}\rangle_p + f_E \langle \ln A\rangle$$

$$\sigma^2(X_{\max}) = \langle \sigma_{sh}^2\rangle + f_E^2\, \sigma^2(\ln A)$$



PIERRE AUGER OBSERVATORY
BERGISCHE UNIVERSITÄT WUPPERTAL

Auger HEAT – … and further

Idea:

- use showers with additional Cherenkov-light component
- Lower energetic showers detectable → lower E-threshold
- Shower geometry pointing towards the telescope

But:

- Very time-contracted shower are harder to reconstruct
- Only few showers hit a surface detector station

Solution:

- Profile constrained geometry fit
- For given χ_0 time-fit is just a linear regression:

$$\boldsymbol{t_i} = t_0 + \frac{R_p}{c} \tan\left(\frac{\chi_0 - \chi_i}{2}\right)$$

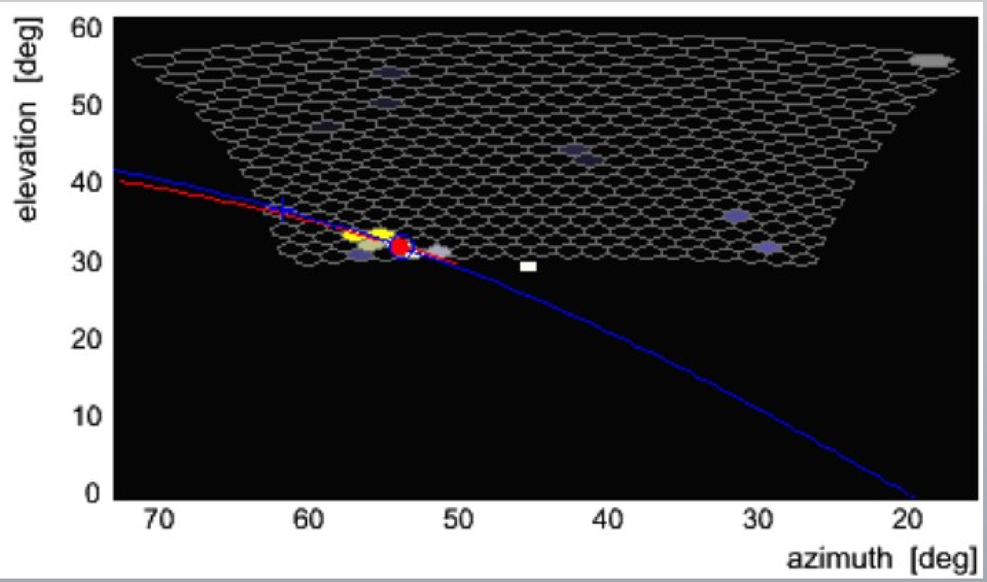
- Combined χ^2 gives optimal reconstruction

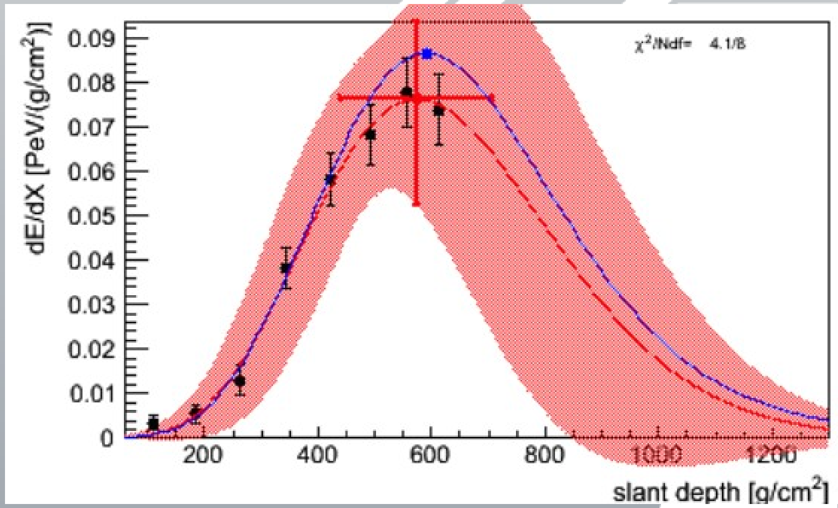
Auger HEAT – PCGF example

Extreme example with short light-trace in 7 PMTs giving only 8 time-bins.

Good agreement for reconstructed profile (red) for MC (blue).

Analysis ongoing – fast light-spot requires optimization of reconstruction.





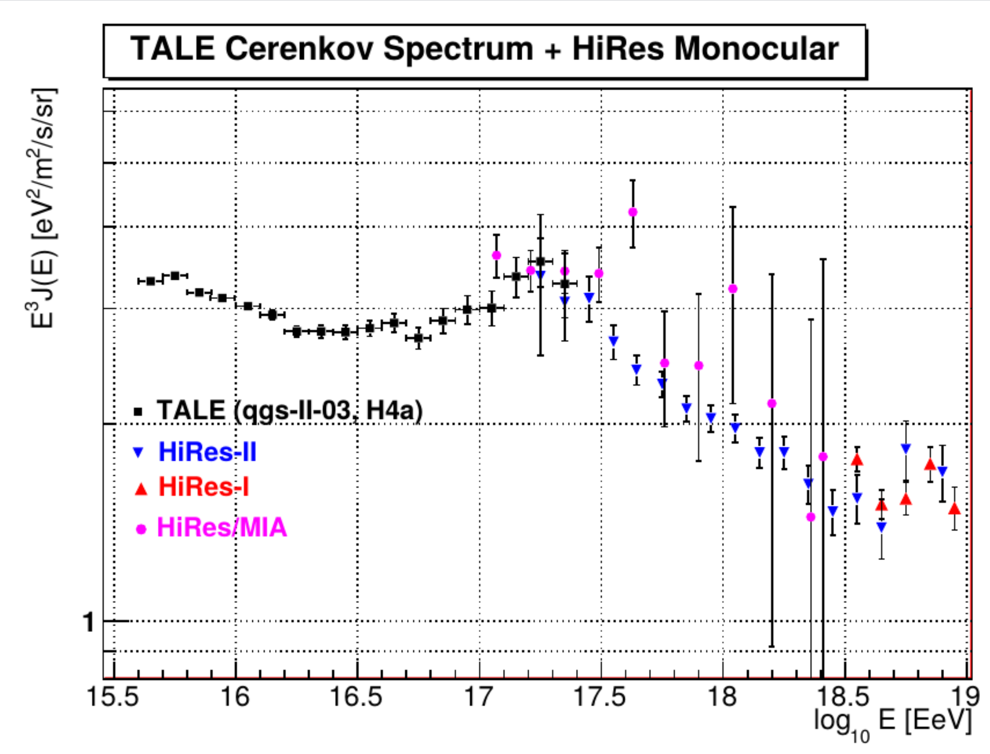
Auger HEAT – PCGF by TALE

Telescope Array Low Enery (TALE) extension

PoS(ICRC2015)422

PCGF as approch towards an imaging air Cherenkov telescope (IACT)

Spectrum starting at $10^{15.6}$ eV, but exposure depends on composition assumption



BERGISCHE UNIVERSITÄT WUPPERTAL

Auger HEAT – Summary

Pierre Auger Observatory – HEAT extension
for low energy fluorescence observation
down to 10^{17} eV with regular analysis.

Potential for below 10^{16} eV
with Cherenkov rich events.

Overlap with KASCADE-Grande / IceTop etc.
for conclusive picture

Auger HEAT – Systematics

Systematic uncertainties on the resolution dominated:

- by detector at low energies (low light level) and
- by attenuation-correction at high energies (larger distance)

Systematic uncertainty on scale more flat.