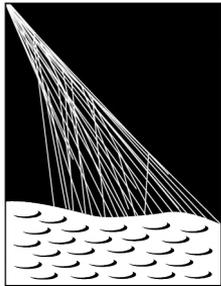


Measurement of fluctuations in the number of muons in inclined air showers with the Pierre Auger Observatory



PIERRE
AUGER
OBSERVATORY

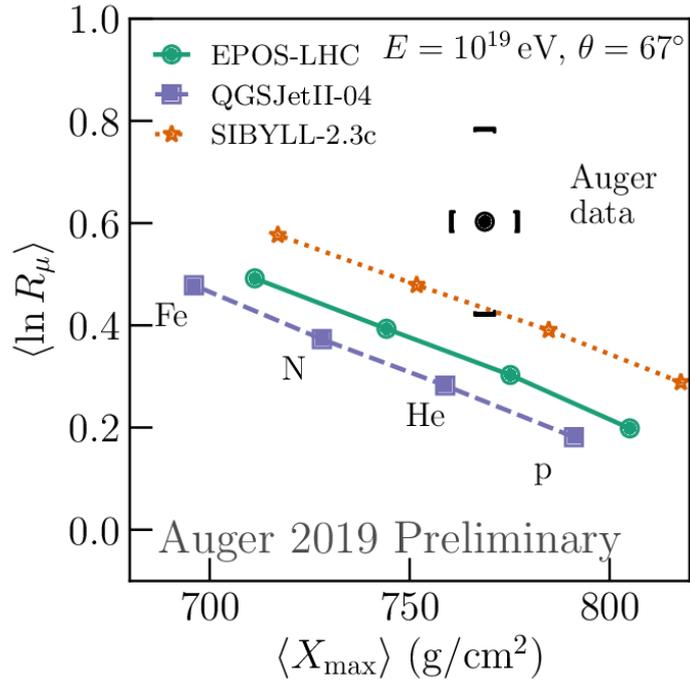
Felix Riehn for the Pierre Auger Collaboration

International Cosmic Ray Conference
July 29th 2019, Madison, WI, USA



Message I

update for $\langle N_\mu \rangle$



PHYSICAL REVIEW D **91**, 032003 (2015)

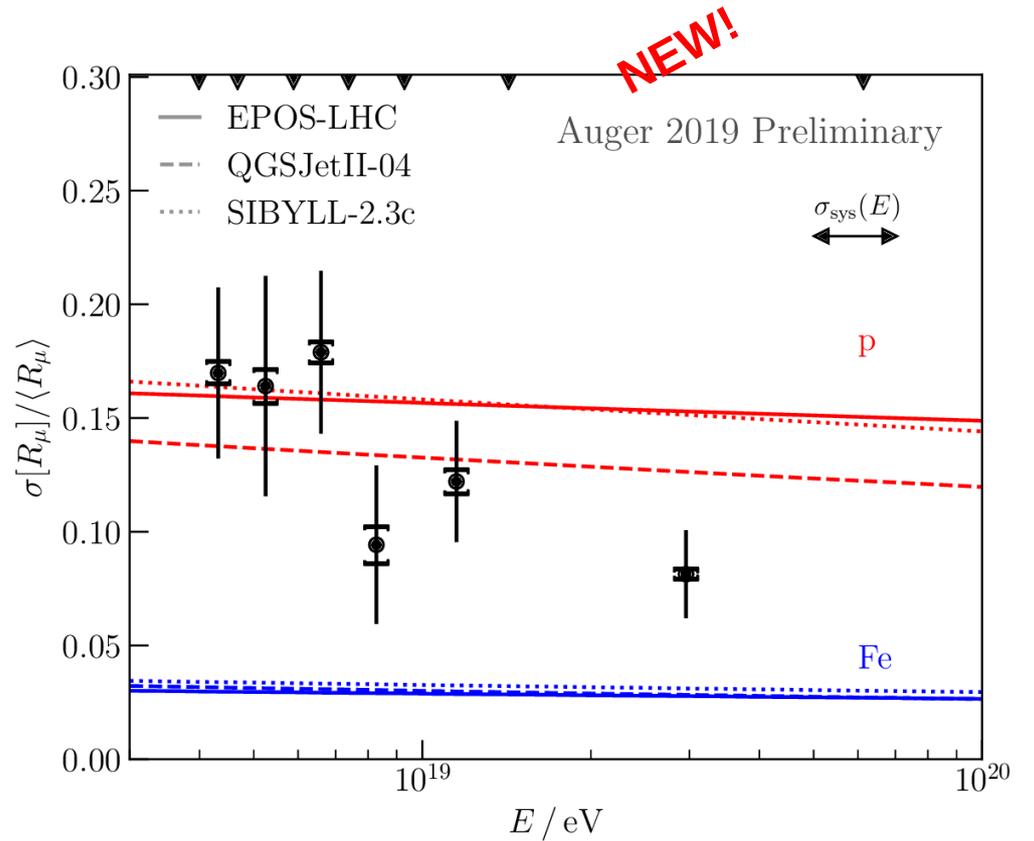
Muons in air showers at the Pierre Auger Observatory: Mean number in highly inclined events

Now 2x events !

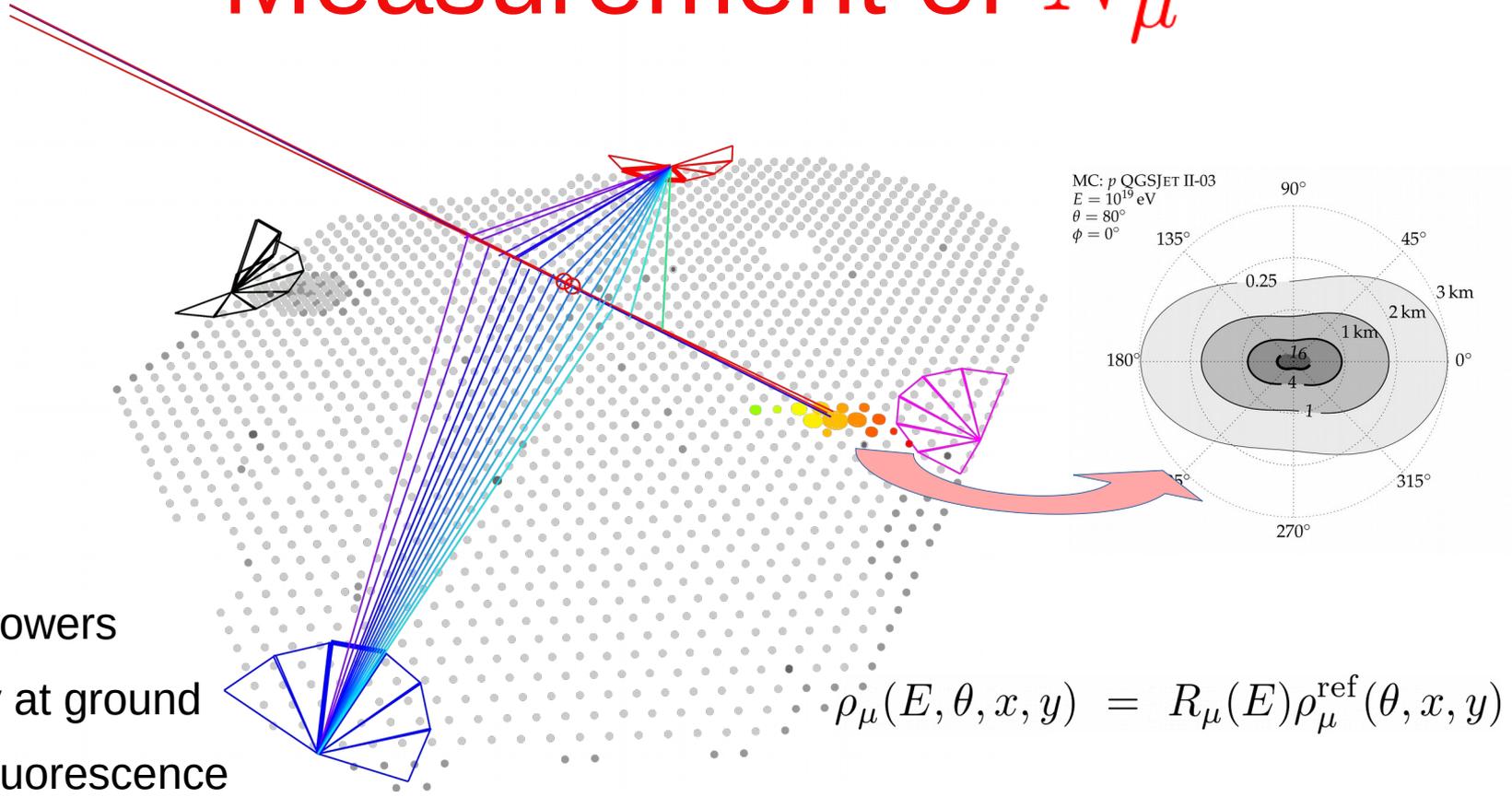
- consistent with previous measurement
- new model ! (Sibyll now consistent)

Message II

First measurement of the
energy dependence of the
fluctuations in the number of muons
→ data within model predictions



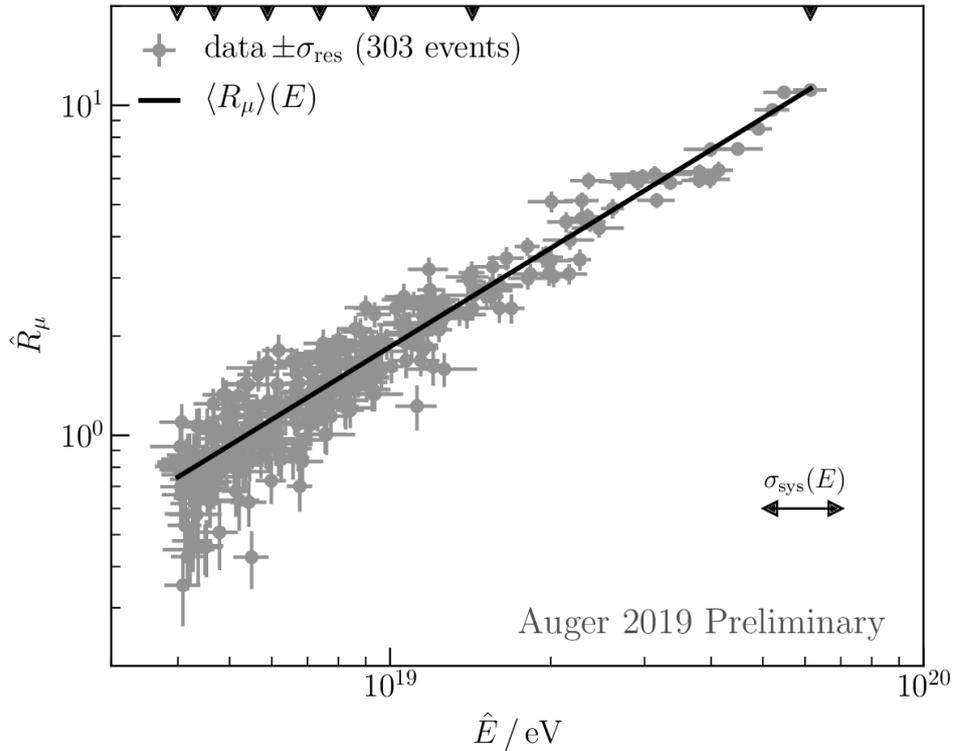
Measurement of N_μ



→ \hat{R}_μ, \hat{E}

(Pierre Auger Collab., JCAP 1408 (2014), no. 08 019)

Unfolding



Measurements \hat{R}_μ, \hat{E} Include detector effects

statistical model of shower + detection process } unbinned likelihood

Approximations:

$\langle R_\mu \rangle \sim a E^b$ + Detector ~ Gaussian
Shower ~ Gaussian

$$= \ln \mathcal{L}(a, b, \sigma_{\text{intrinsic}})$$

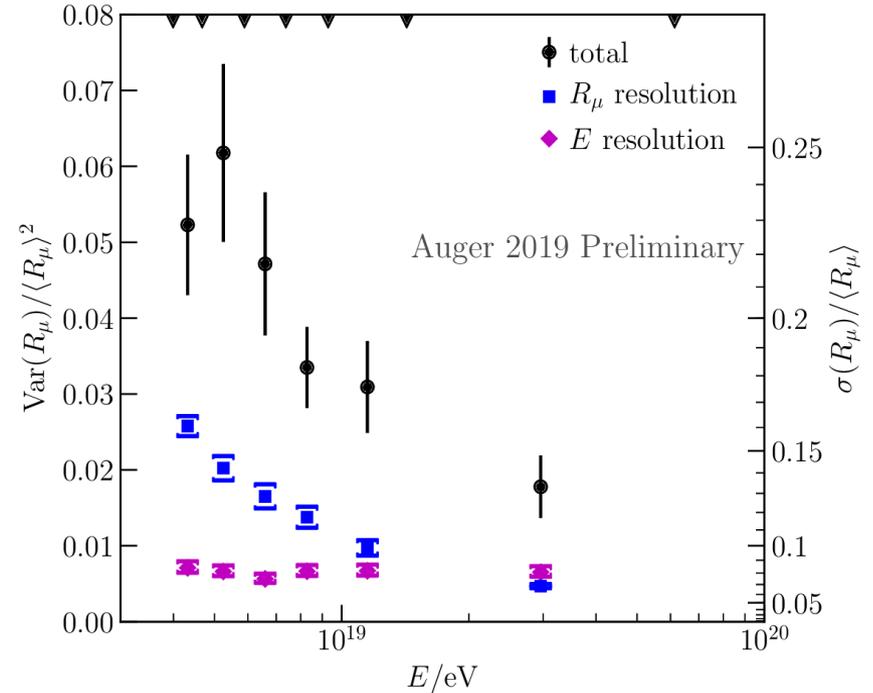
Fit!

Extraction of intrinsic fluctuations

interactions shower composition

$$\sigma_{\text{total}}^2 = \sigma_{\text{intrinsic}}^2 + \sigma_{\text{res}}^2(R_\mu) + \sigma_{\text{res}}^2(E)$$

↑ data Model this



Systematic effects

Measure $\sigma(R_\mu)/\langle R_\mu \rangle$

→ some systematics cancel

Most important:

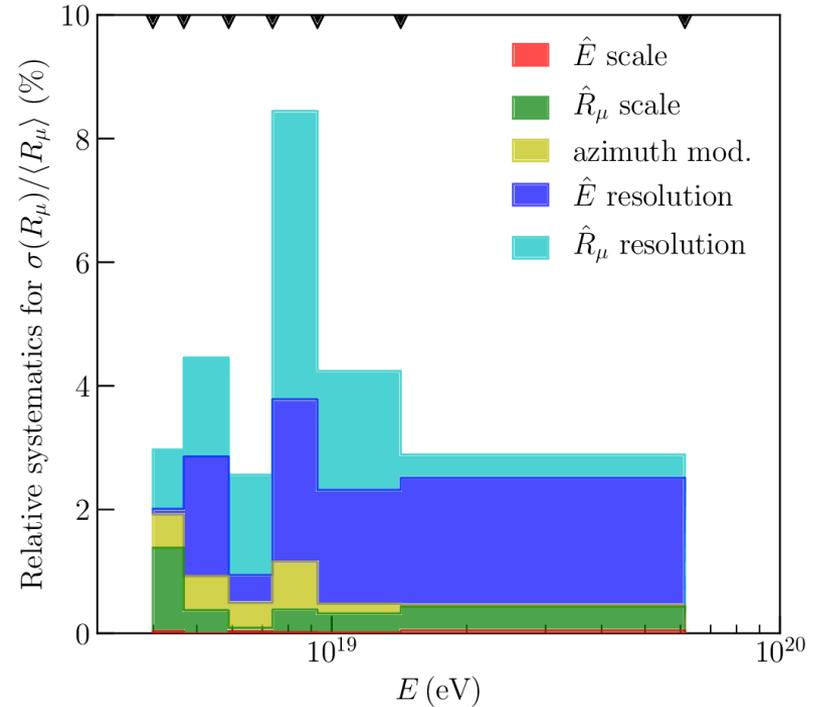
* resolution uncertainty

- R_μ (surface detector array)

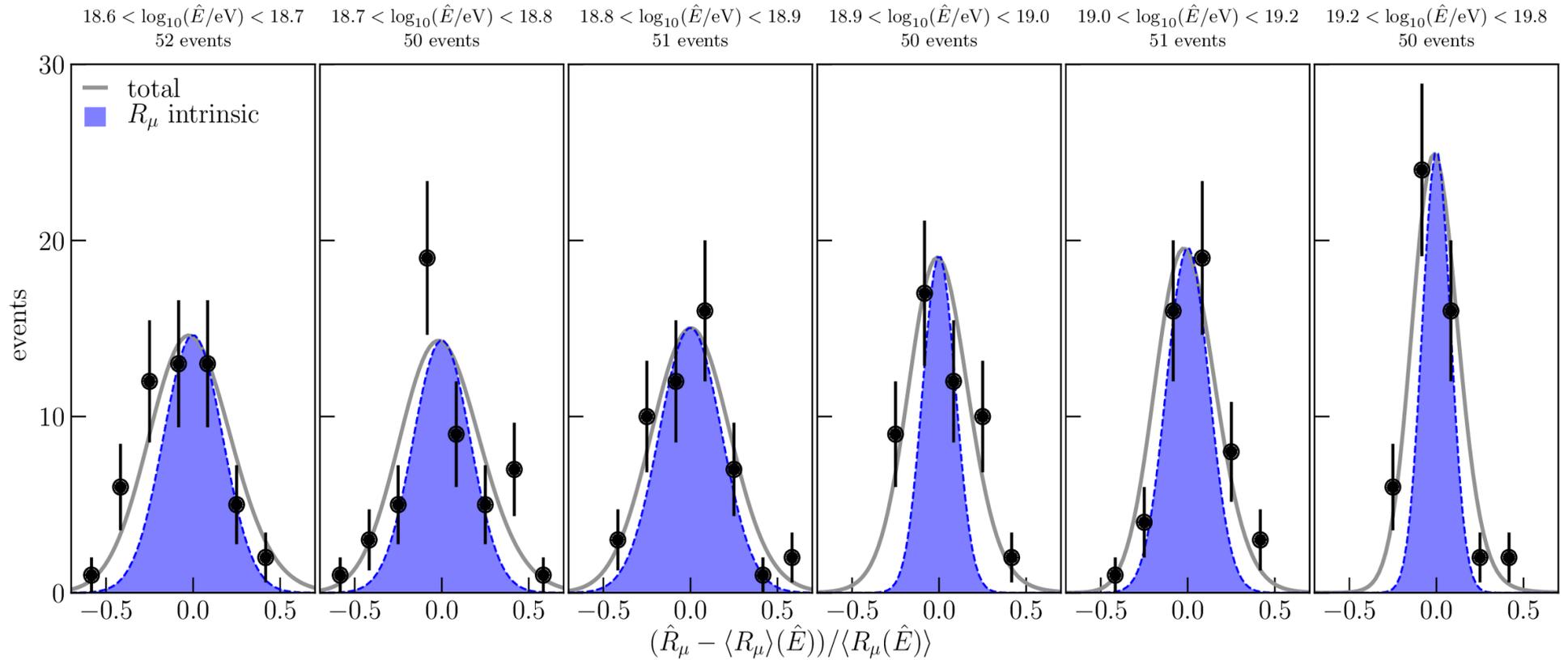
- E (fluorescence detector)

* reconstruction uncertainty → azimuth mod.

Total: < 8.4 %

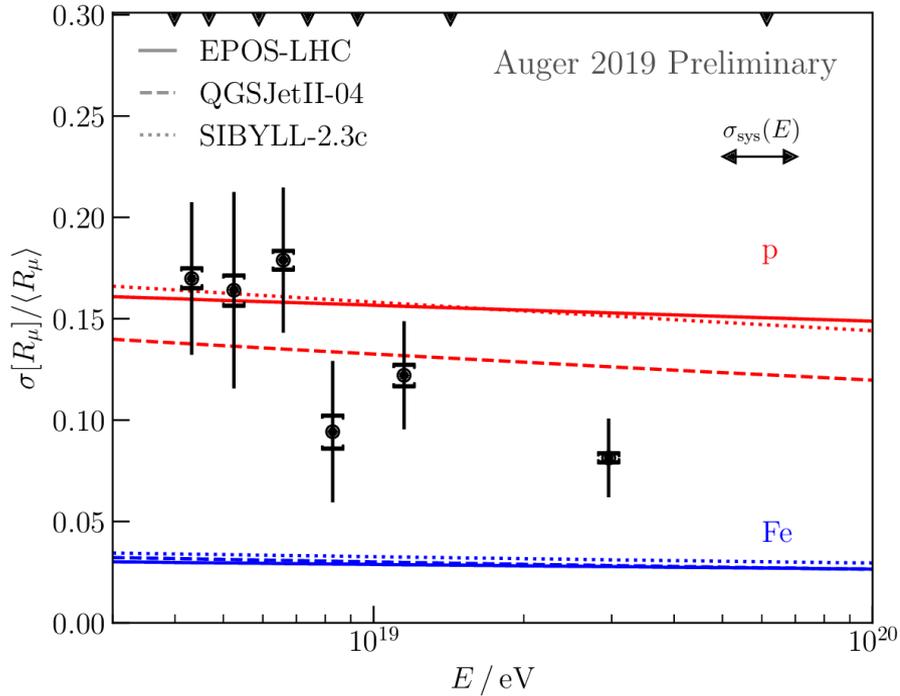


Full distribution

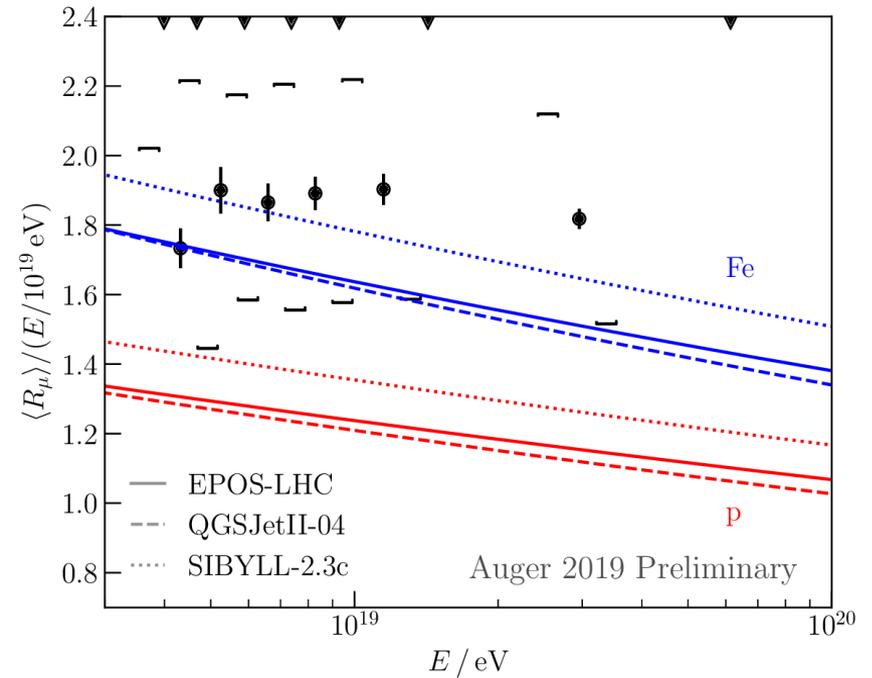


Width and average

Fluctuations



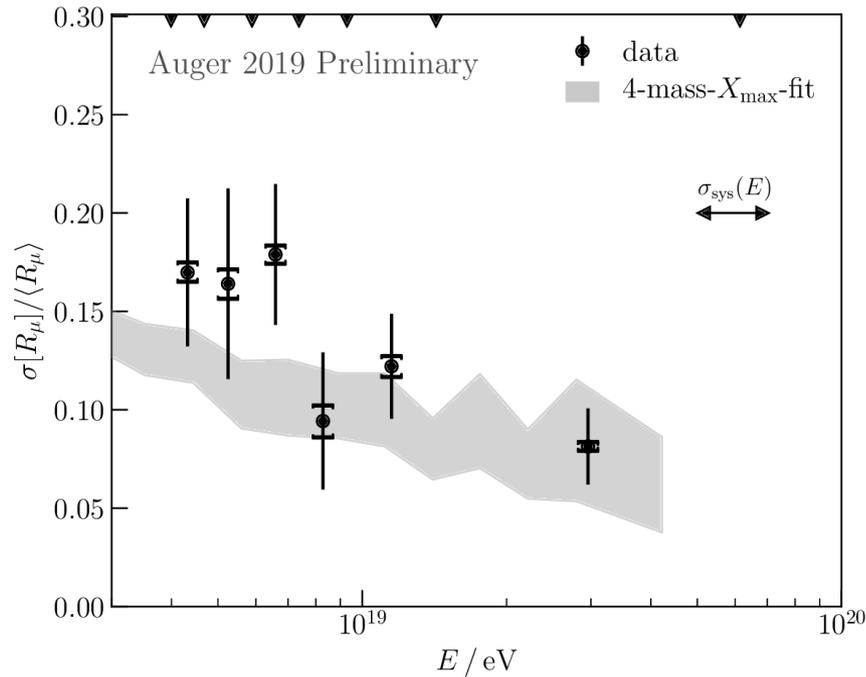
Average



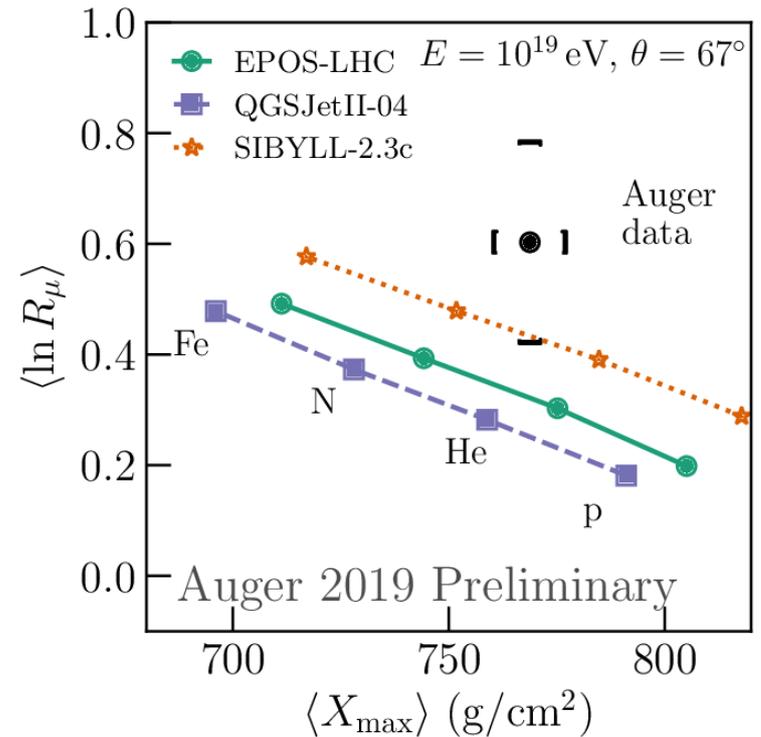
Given realistic mass composition ? ...

Including composition

Fluctuations

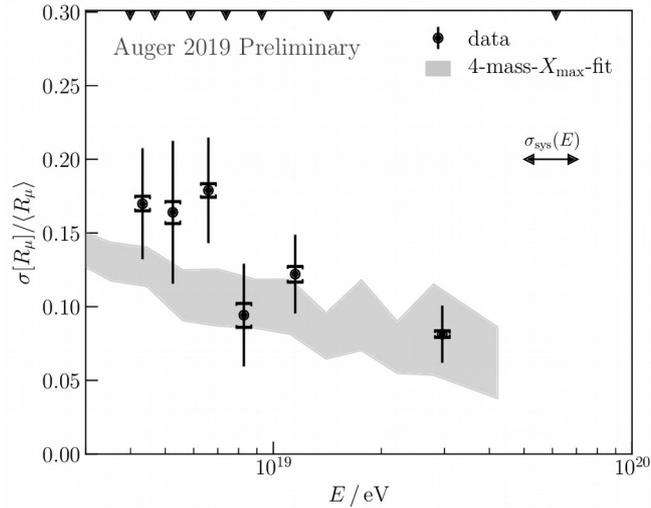


Average



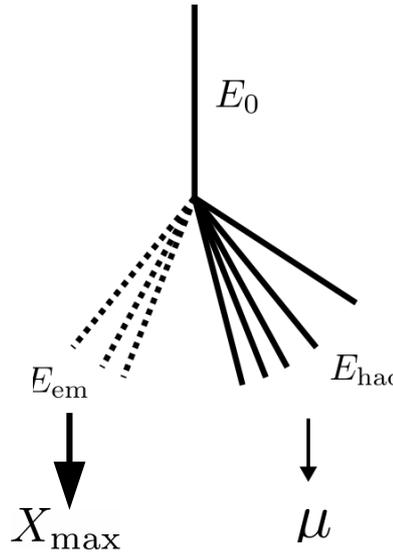
Interpretation

Fluctuations

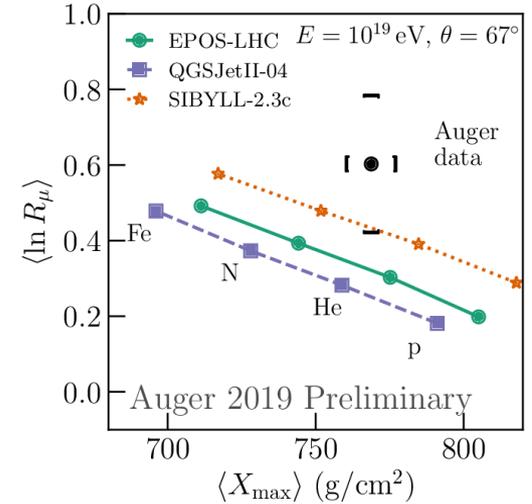


First interaction

(Phys. Lett. B 784 (2018) 68–76, talk by R. Conceição CRI15h)



Average



Full shower / hadronic cascade

(WHISP report, talk by L. Cazon CRI15e)

Solve muon problem:

more muons **but** preserve fluctuations \rightarrow

No big change in first interaction!

Summary

- * first measurement of fluctuations in number of muons

- * update of average number of muons

- fluctuations compatible with model predictions
and composition measurement

Muon problem:

- **not** an effect of first interaction !

- fluctuations + average:

small mismatch accumulating over shower development

