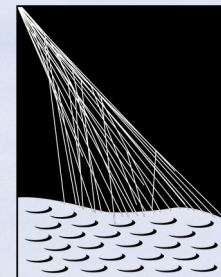




**FCT** Fundação para a Ciência e a Tecnologia

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR



**PIERRE  
AUGER**  
OBSERVATORY

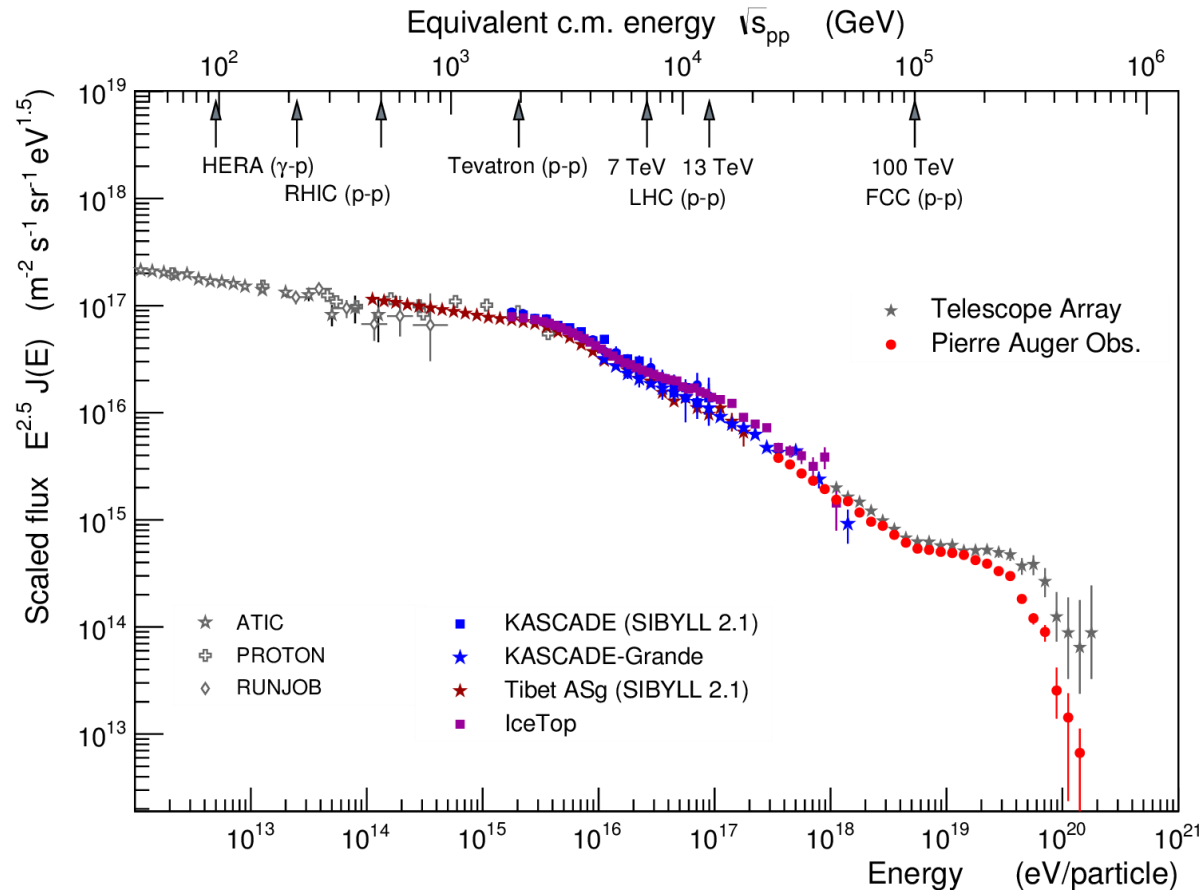


Felix Riehn  
LIP Jornadas 2020  
Braga, 15. 02. 2020





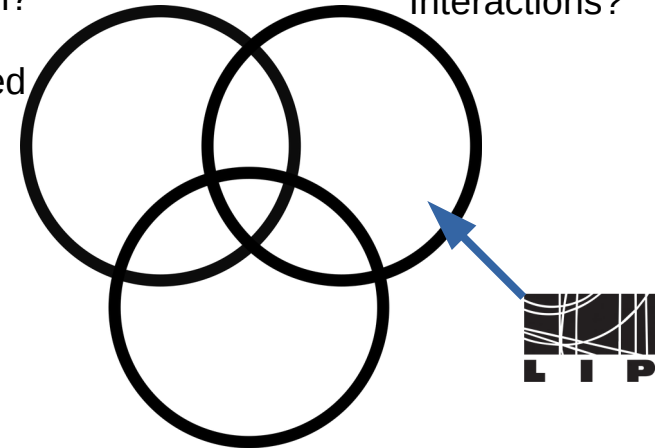
# Cosmic ray spectrum



Three linked problems:

Where do they  
come from?  
How  
accelerated

Nature of  
Interactions?



What are these  
particles?  
protons, nuclei?



# Extensive air showers

Proton, 100 TeV



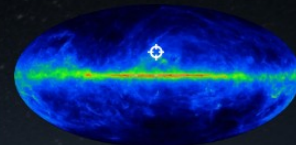
$\gamma, e^{\pm}, \mu^{\pm}$



# Auger Event display

Event ID: 12018427

Date: 06/27/2011  
Time: 5:10:23  
Theta: 43.1°  
Phi: 156.65°  
Energy:  $4.59 \times 10^{19}$  eV

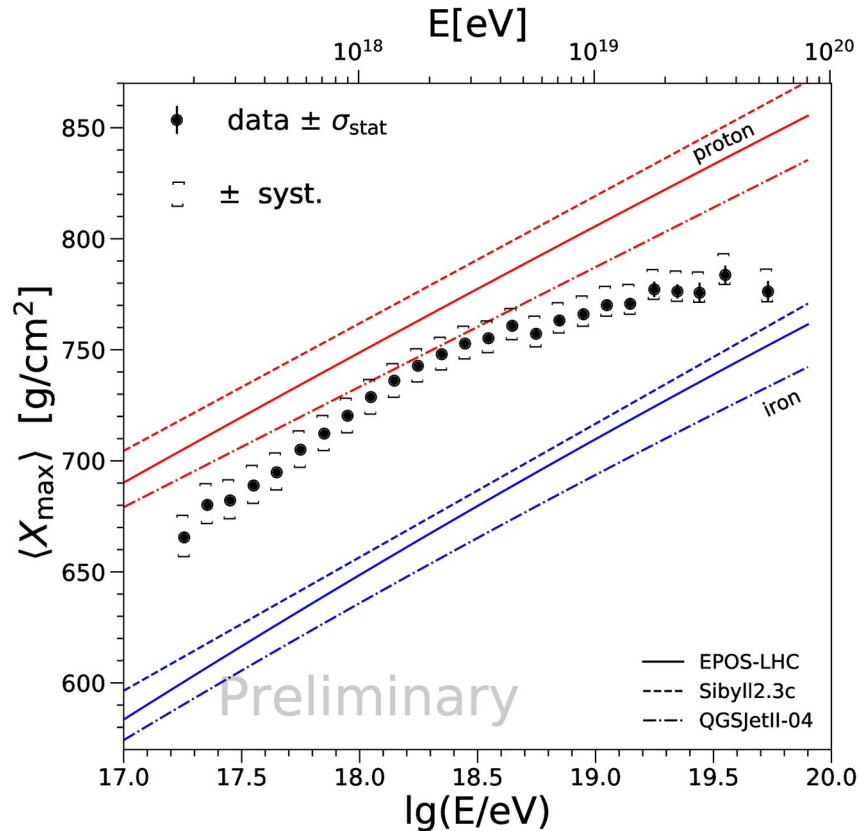
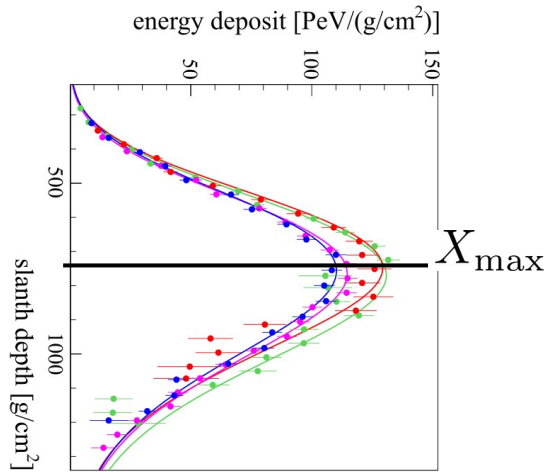
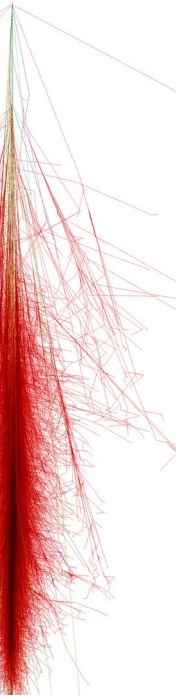


Galactic Longitude: 1.66°  
Galactic Latitude: 27.3°

Number Stations: 16

ID	Time	Signal
849	<div></div>	<div></div>
853	<div></div>	<div></div>
1211	<div></div>	<div></div>
1217	<div></div>	<div></div>
802	<div></div>	<div></div>
1218	<div></div>	<div></div>
1223	<div></div>	<div></div>
1219	<div></div>	<div></div>
1225	<div></div>	<div></div>
1220	<div></div>	<div></div>
1222	<div></div>	<div></div>
1224	<div></div>	<div></div>
804	<div></div>	<div></div>
864	<div></div>	<div></div>
859	<div></div>	<div></div>
868	<div></div>	<div></div>

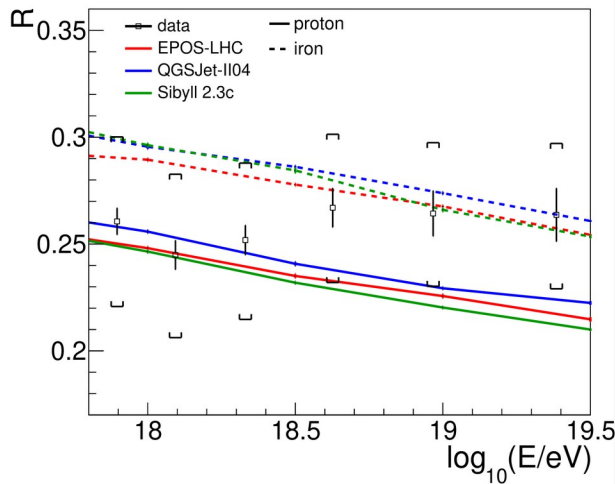
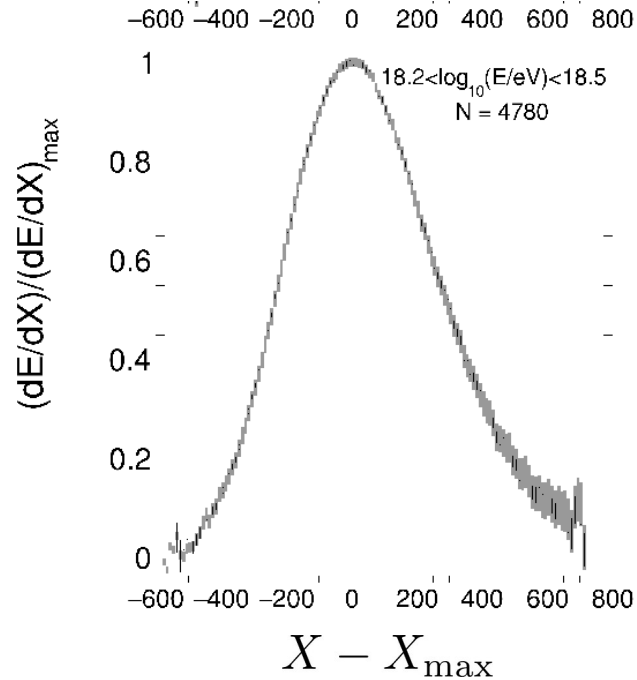
# How do we determine what the cosmic rays are?



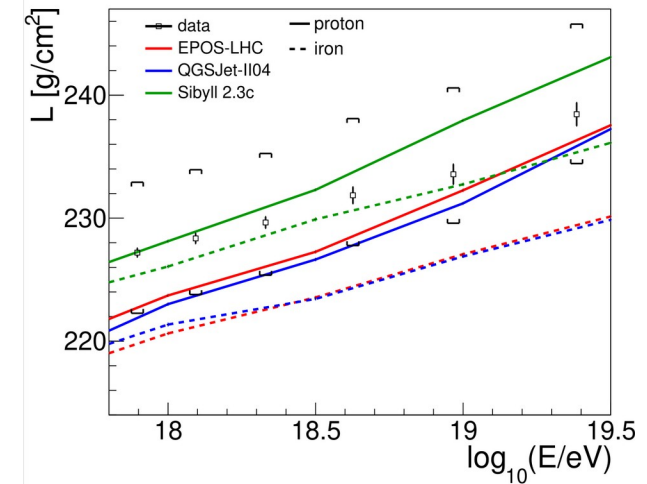
Need model to  
determine  
mass

Can we trust  
them ?

# Average longitudinal profile



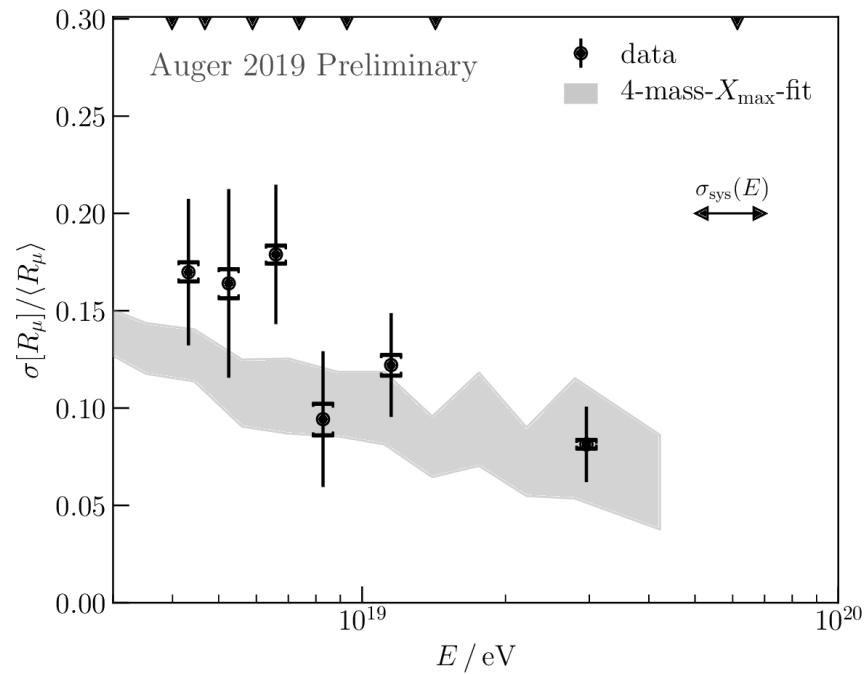
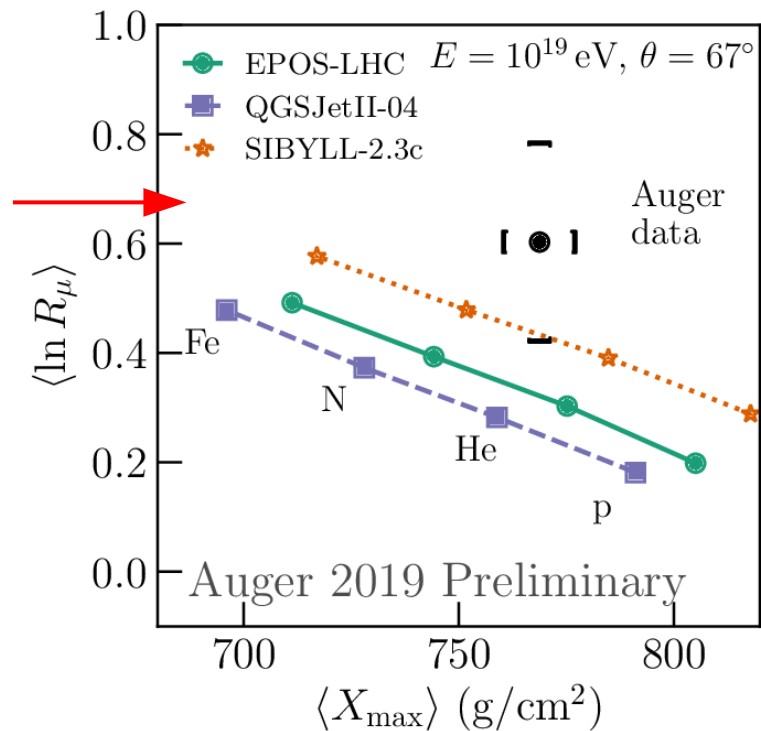
(thesis F. Diogo)



Models seem good

→ interpretation of  $X_{\max}$  as mass of primary ok!

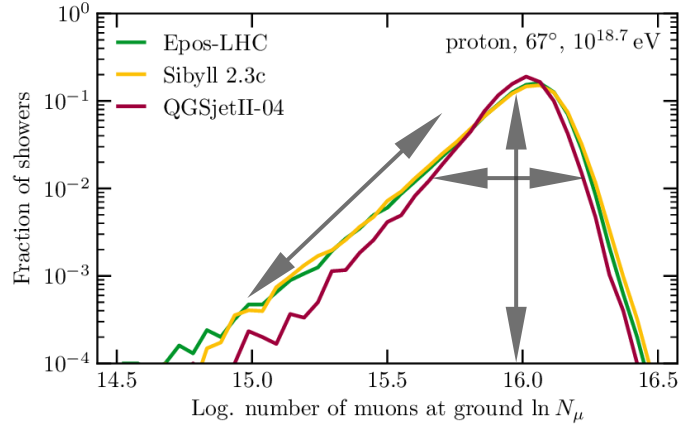
# Number of muons and fluctuations



(L. Cazon, R. Conceição, H. Dembinski, FR)

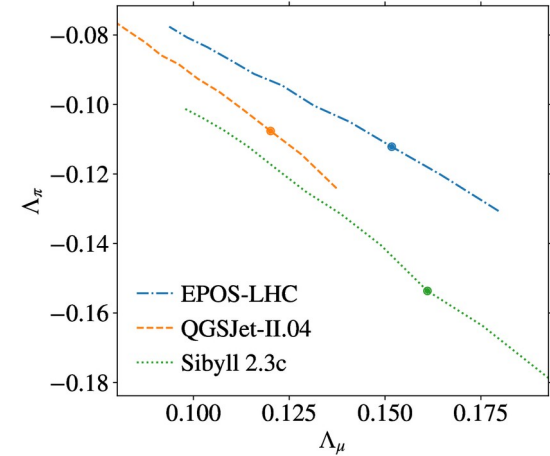


# Muons in the future: one, two, ...?



$\langle N_\mu \rangle$	<input checked="" type="checkbox"/>
$\sigma(N_\mu)$	<input checked="" type="checkbox"/>
$\Lambda_{N_\mu}$	<input type="checkbox"/>

Phenomenology:

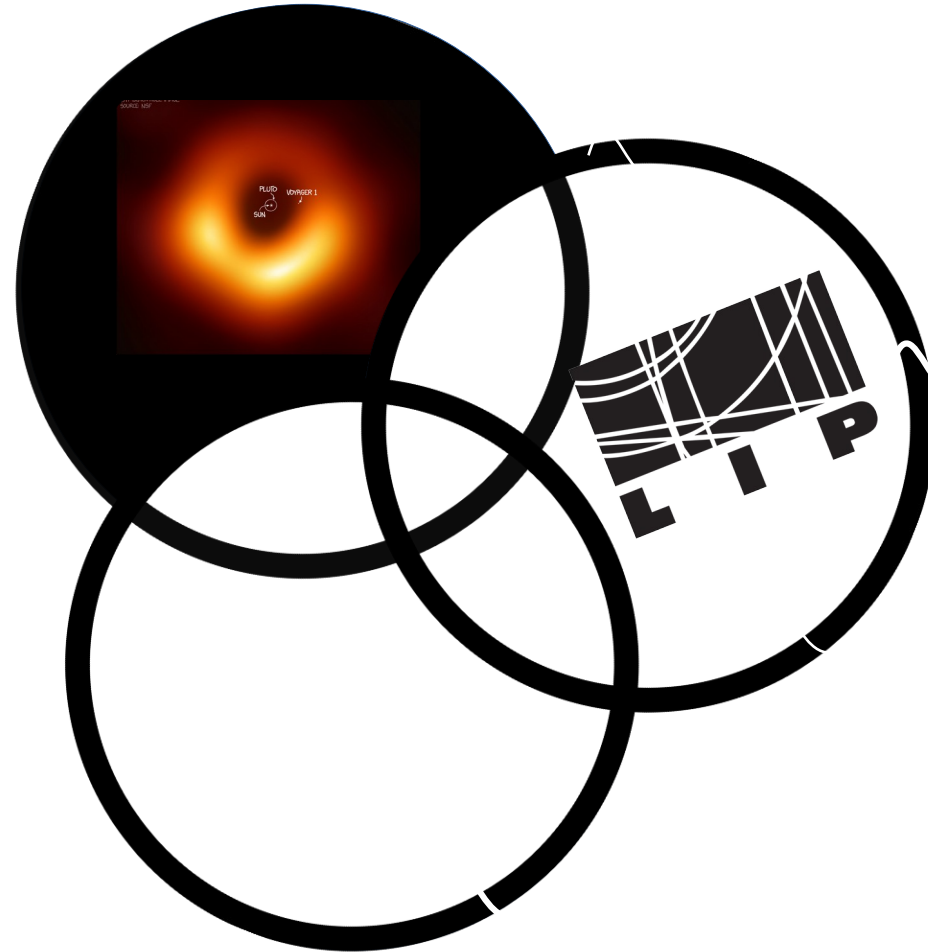


(L. Cazon, R. Conceição, M. Martins, FR)

Measurement requires high statistics

Ideally precise measure of number of muons

AugerPrime & **MARTA**





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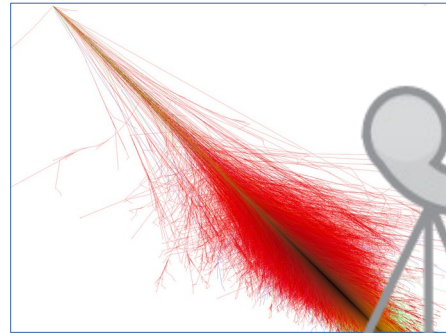
LABORATÓRIO DE INSTRUMENTAÇÃO  
E FÍSICA EXPERIMENTAL DE PARTÍCULAS





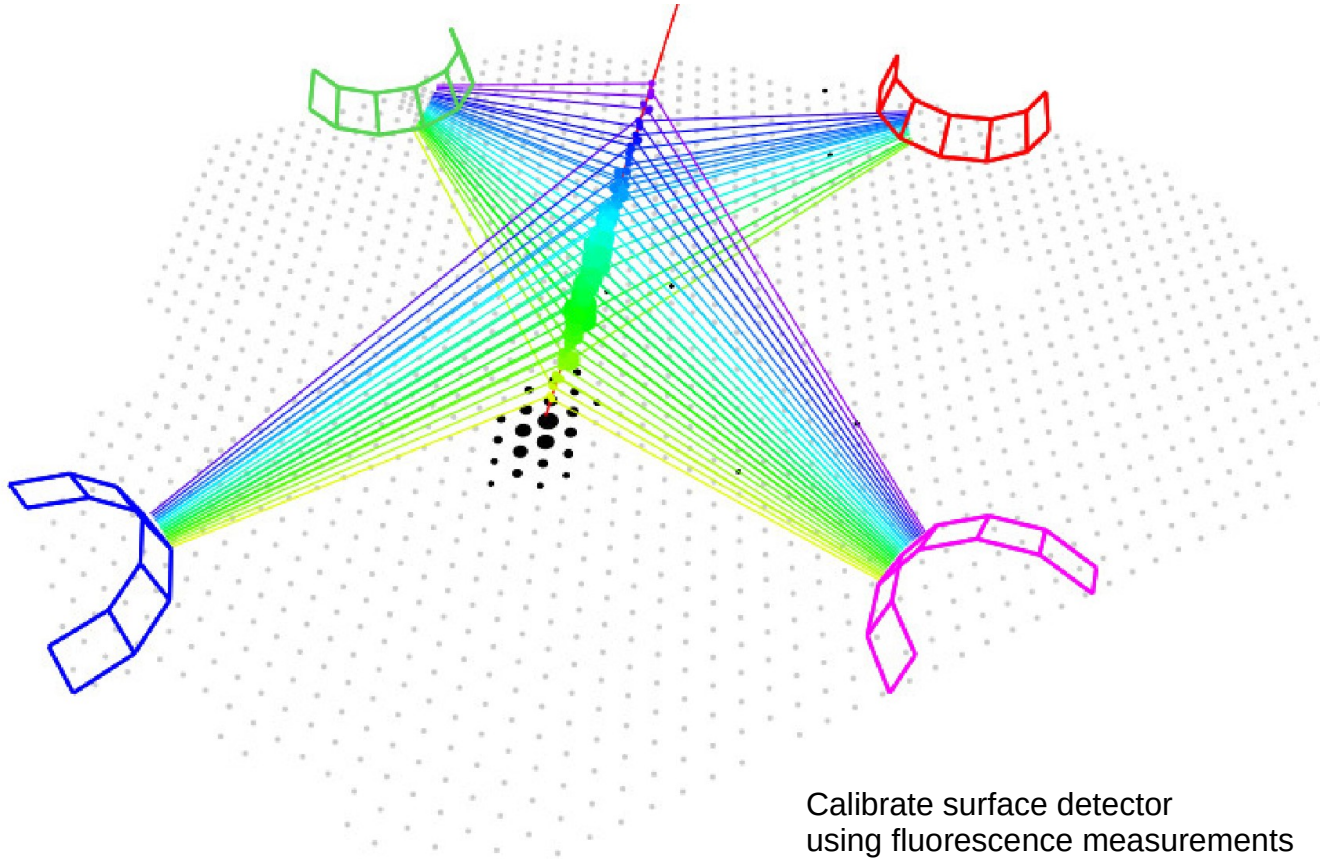
Measurement of the average shape of longitudinal profiles  
of cosmic ray air-showers at the Pierre Auger Observatory

The Pierre Auger Collaboration, JCAP03(2019)018

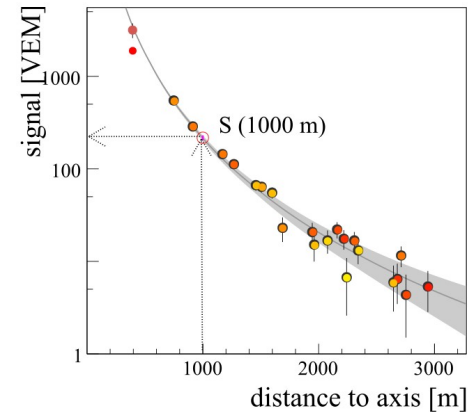
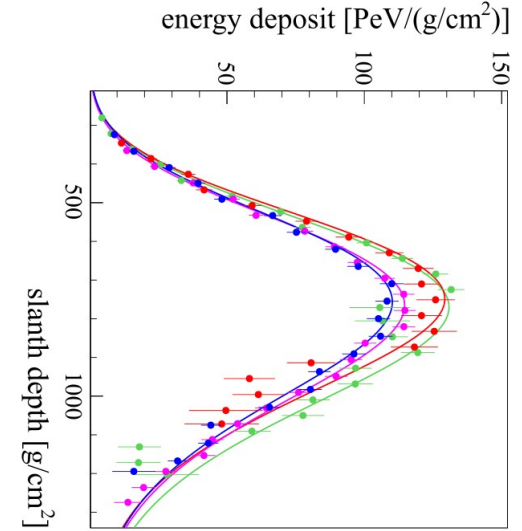


# Hybrid measurement

Extensive air showers  
initiated by **cosmic rays**

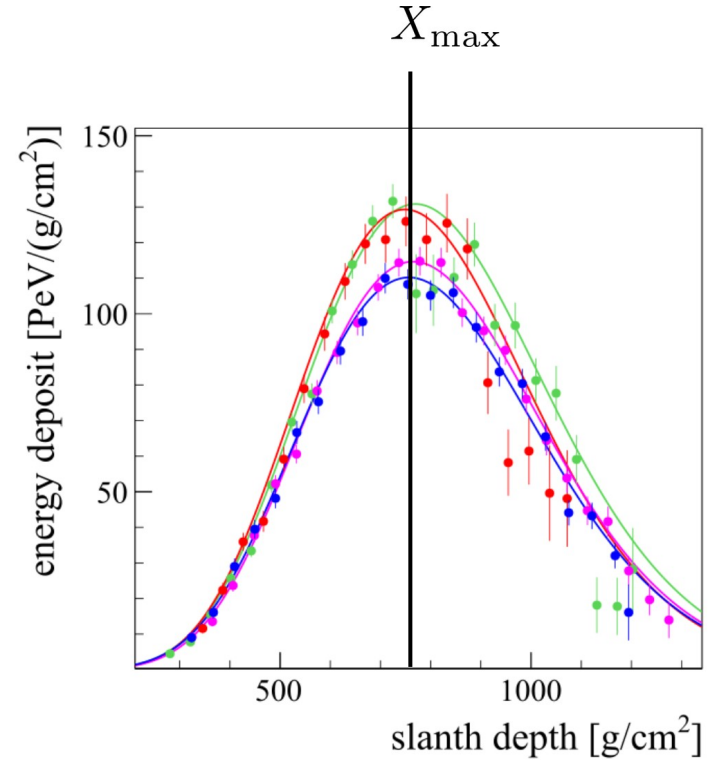
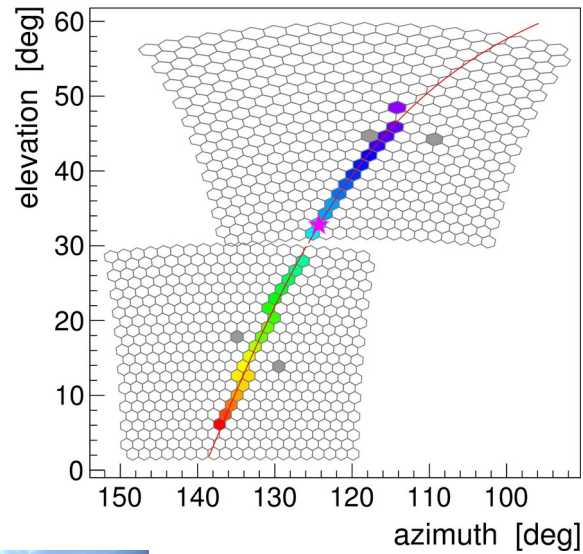
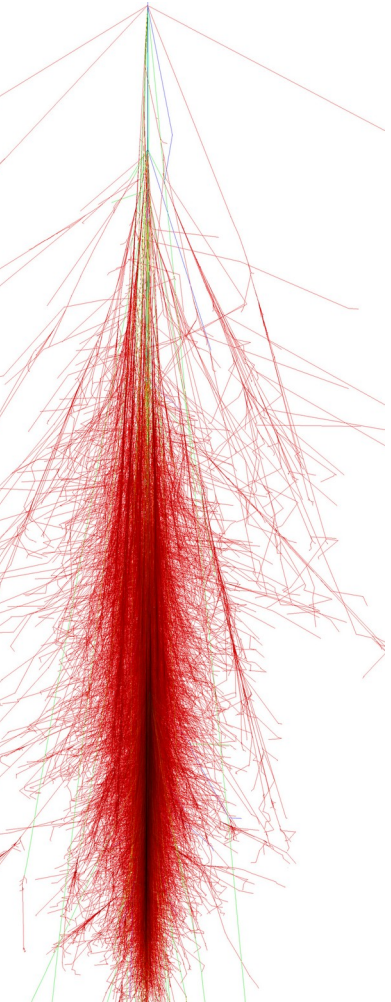


Calibrate surface detector  
using fluorescence measurements





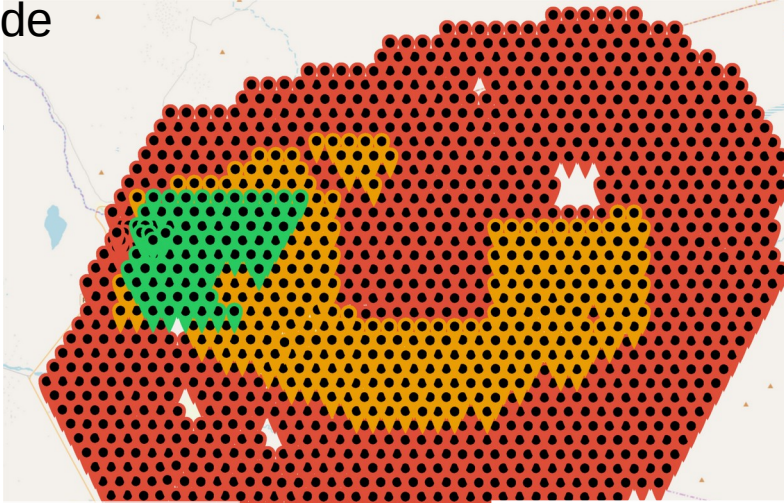
# Distinguish primaries



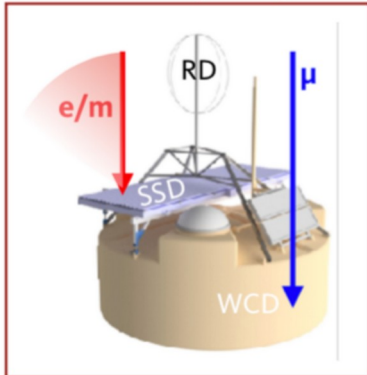
$$X_{\max} \propto \ln A$$

# In the future

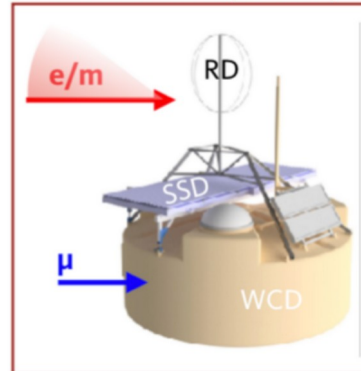
Surface detector &  
radio upgrade



VERTICAL (0-60°)

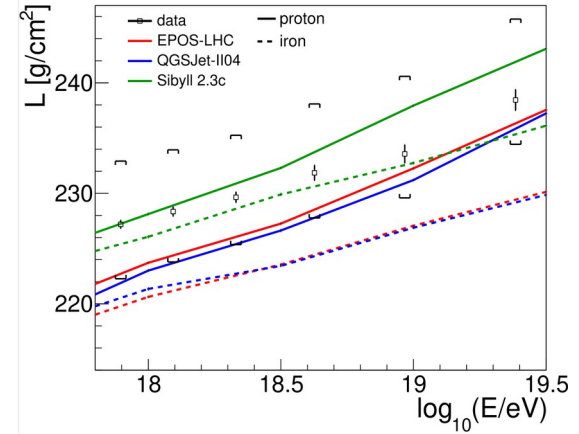
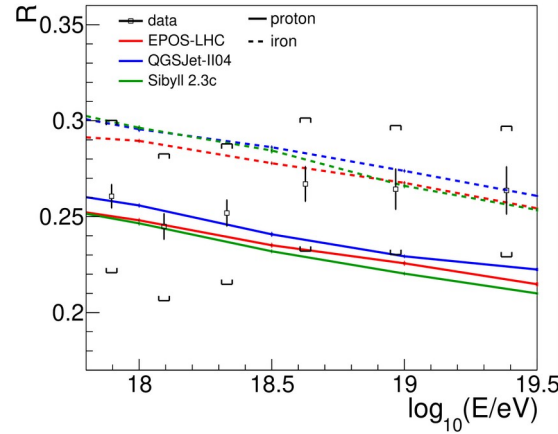
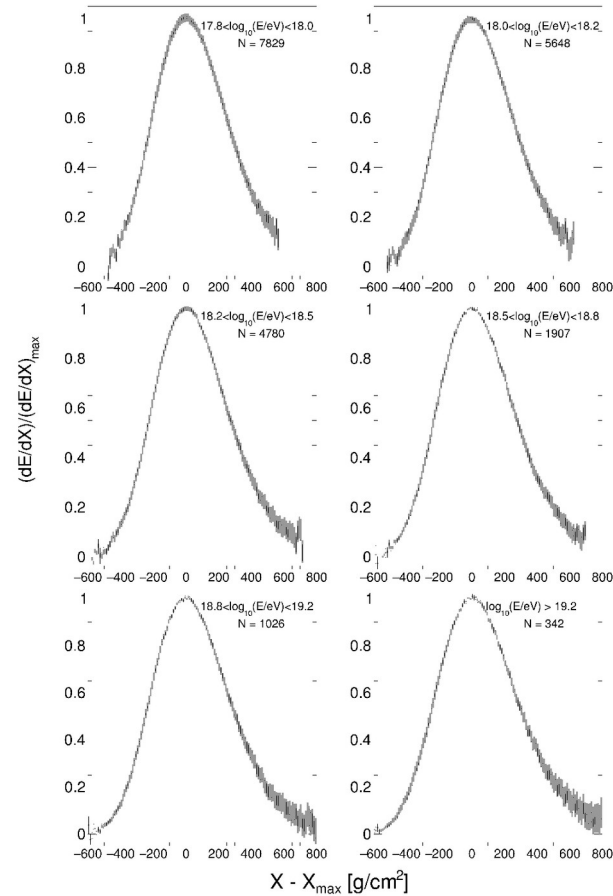


HORIZONTAL (60-90°)



# Average longitudinal profile

(F. Diogo, S. Andringa, R. Conceição)



Models seem good

→ interpretation of  $X_{\max}$  as mass of primary ok!