Mass composition from the Auger surface detector

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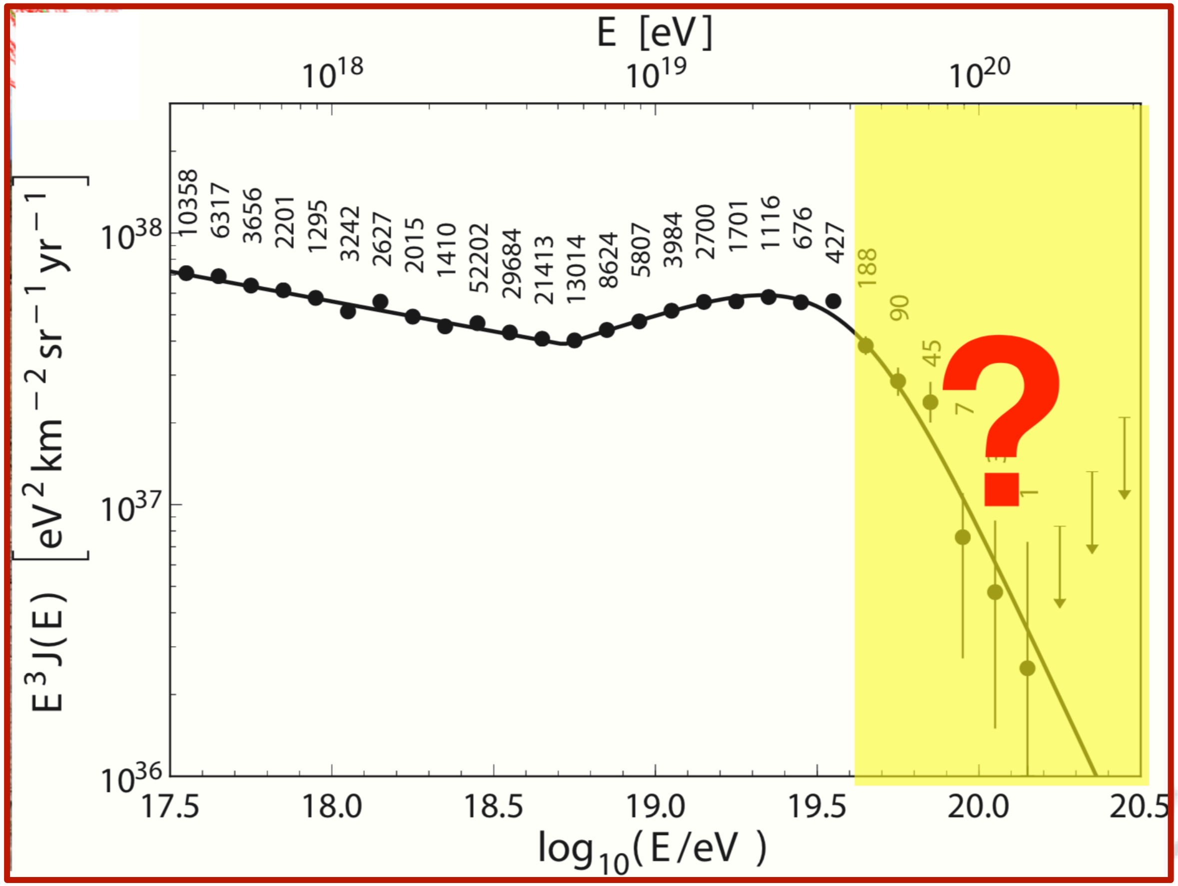
Nikhef annual meeting
Amsterdam, 11-12-2017

PIERRE AUGER OBSERVATORY

IN·DEI·NOMINE·FELICITER

The spectrum



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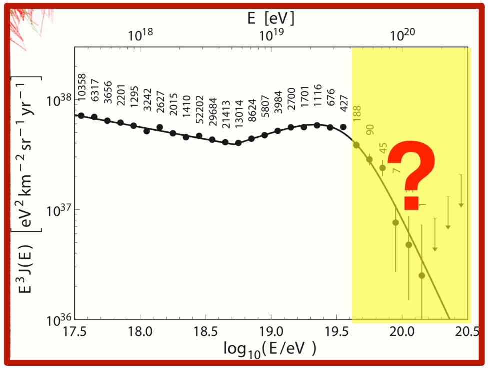
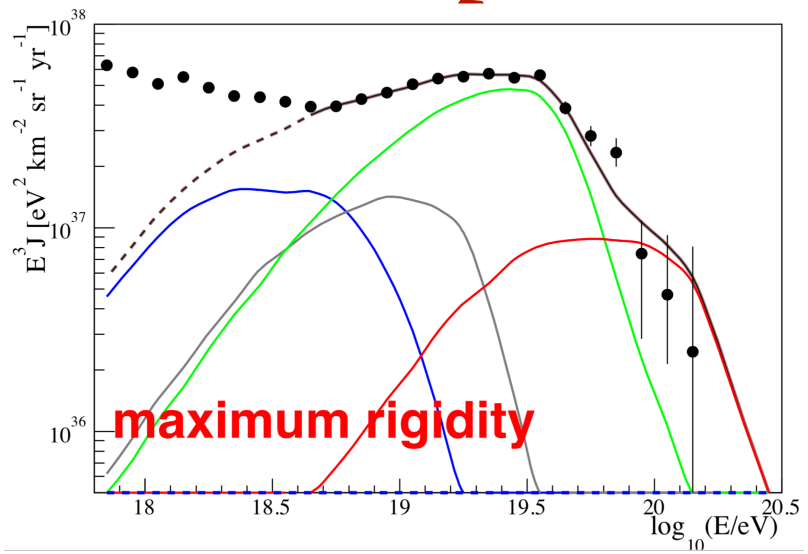
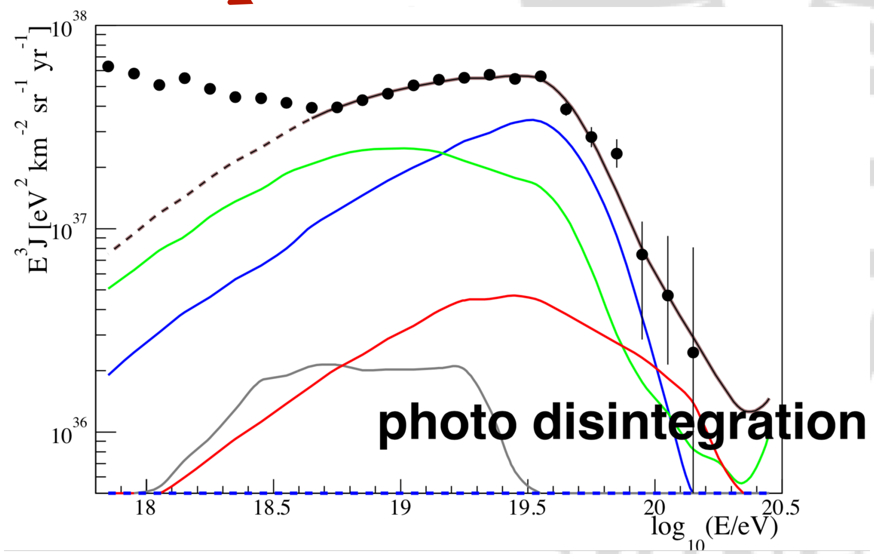
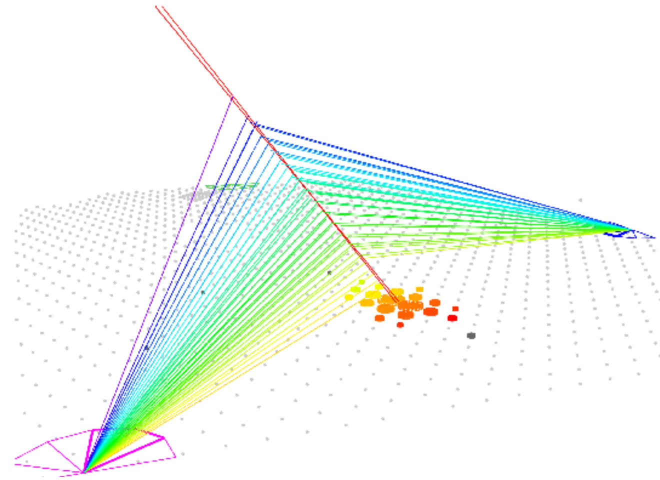


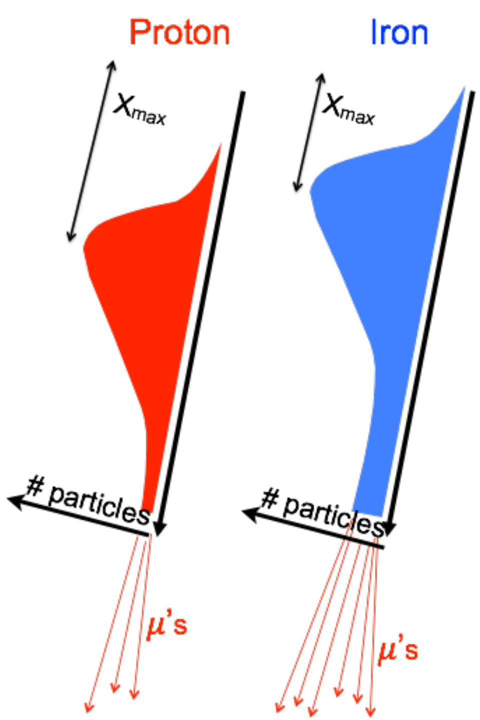


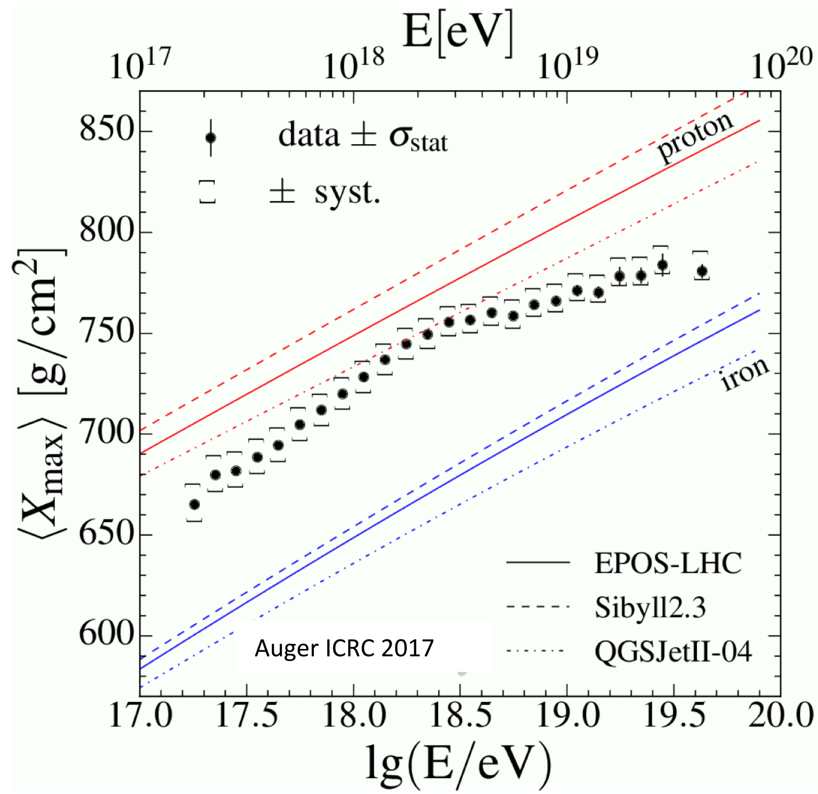


Fluorescence detection

- Fluorescence detection: energy and longitudinal profile.
- X_{max} most sensitive mass composition observable.
- only 10% duty cycle.
- No data for $E>10^{19.7}$eV.







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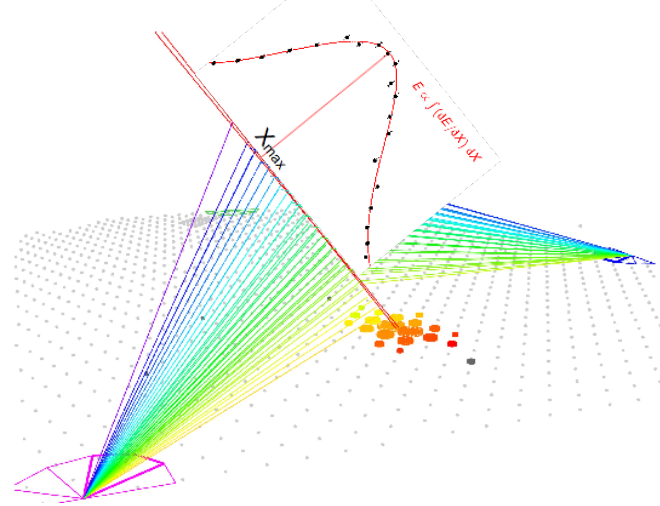
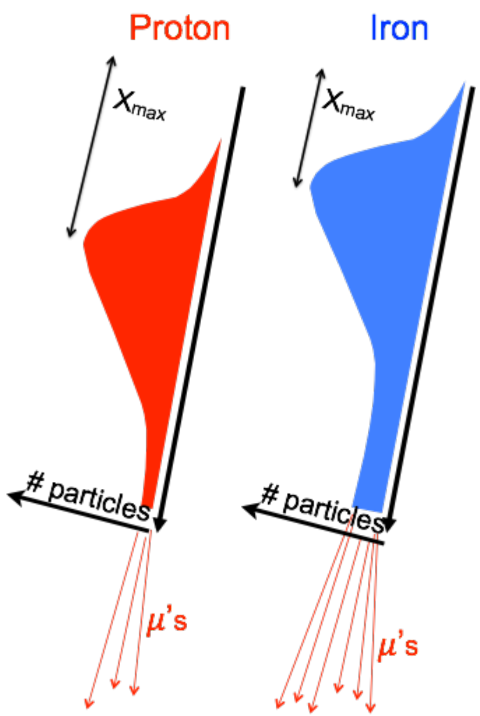
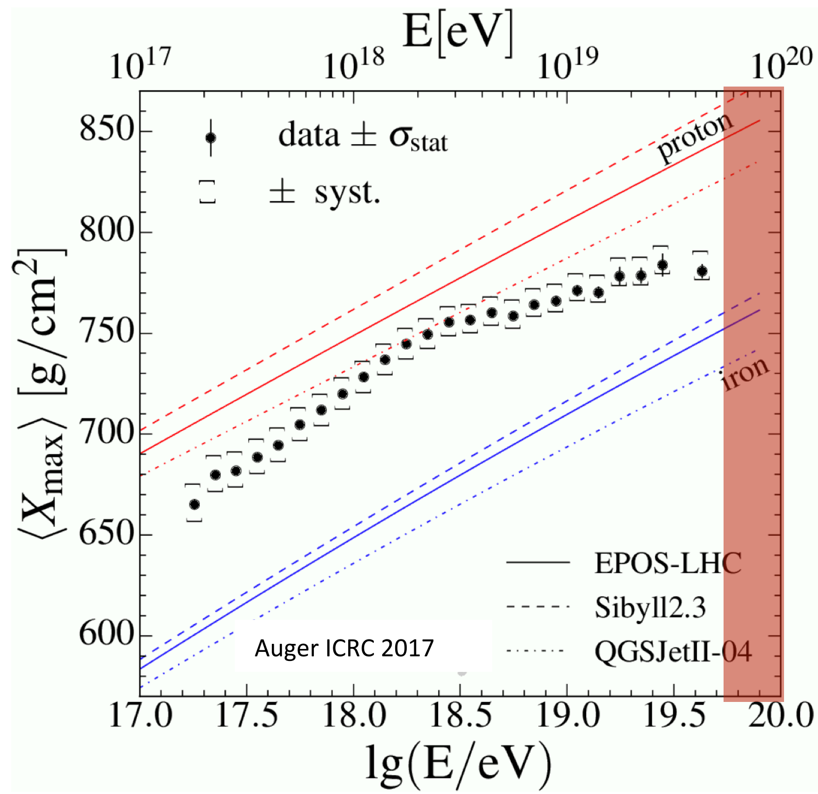
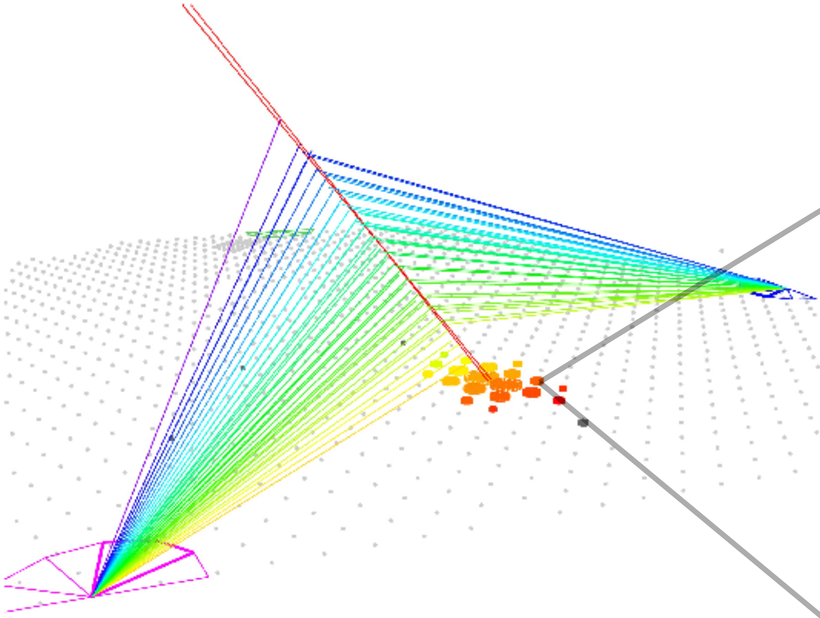
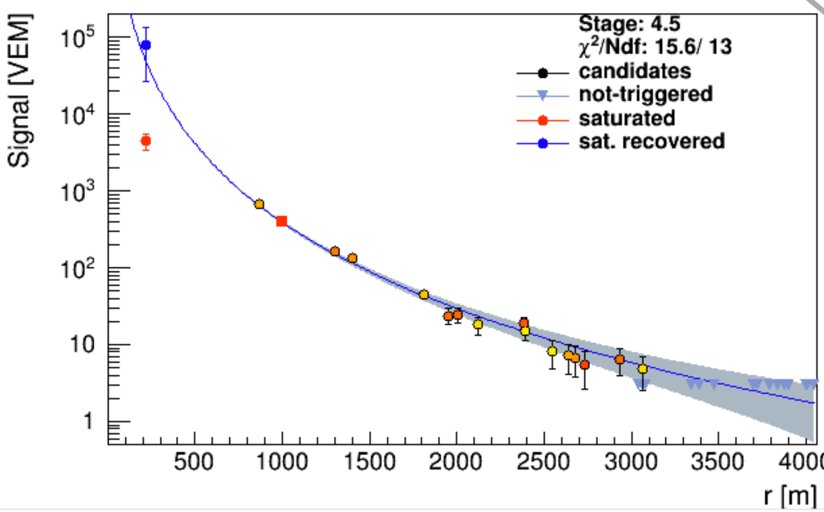


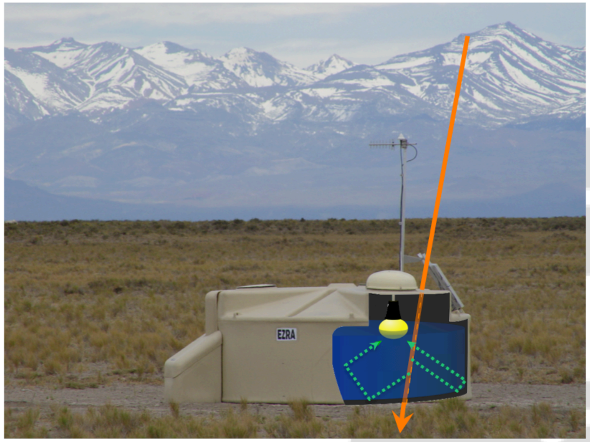


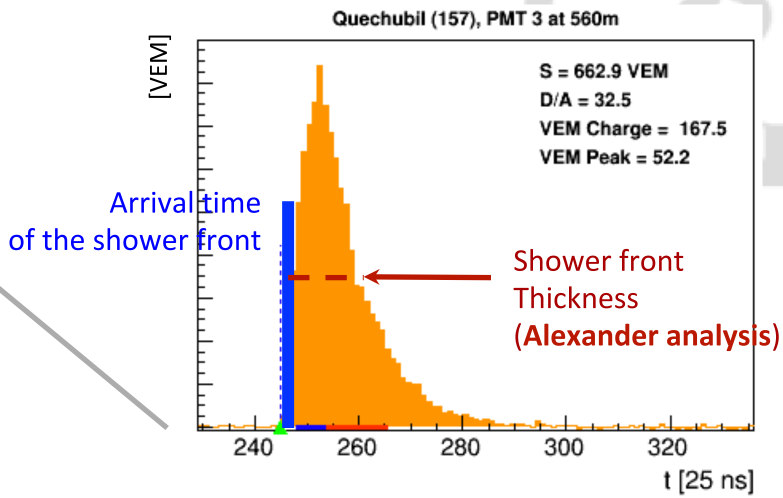


Particle detection





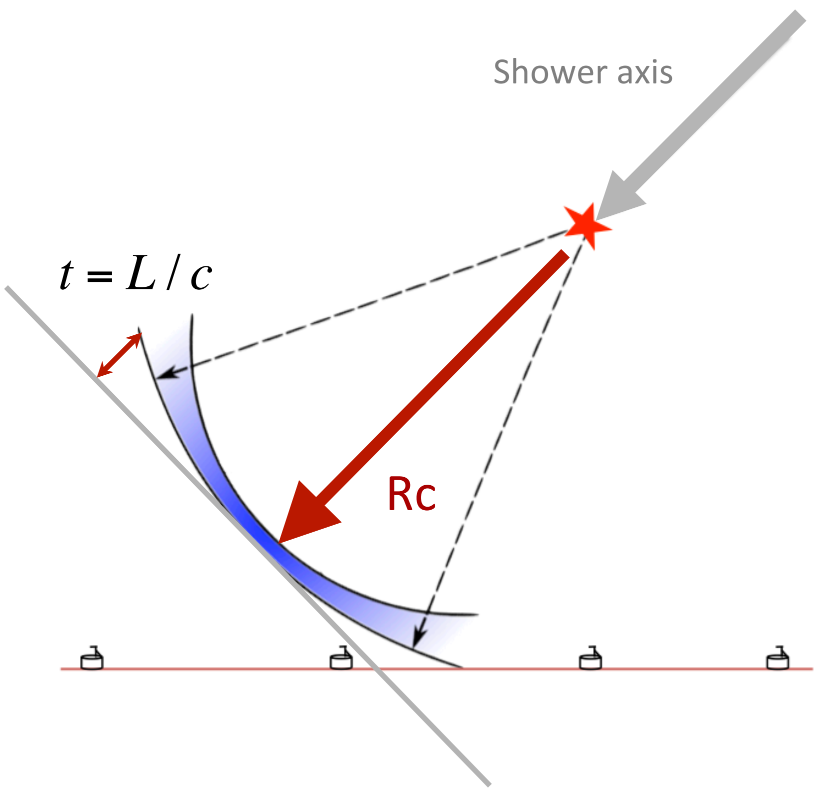


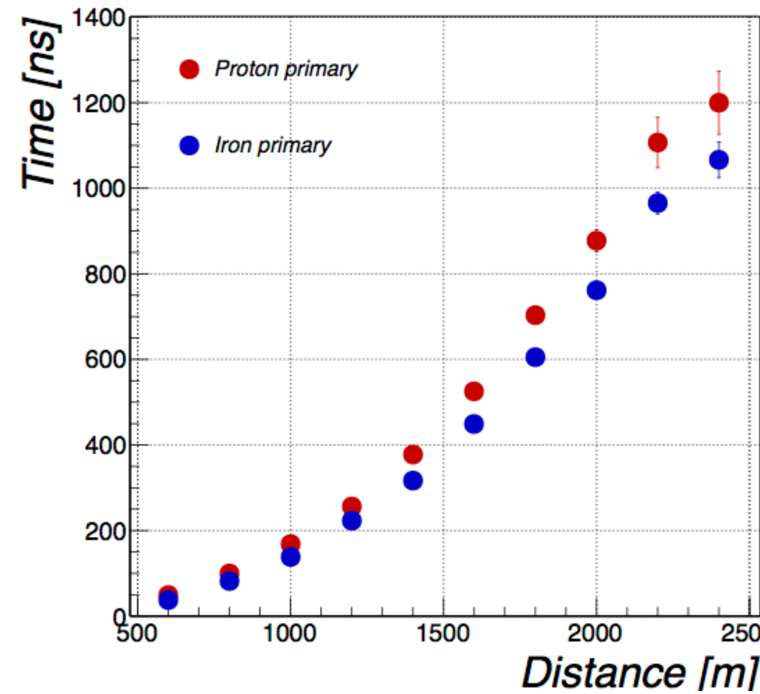


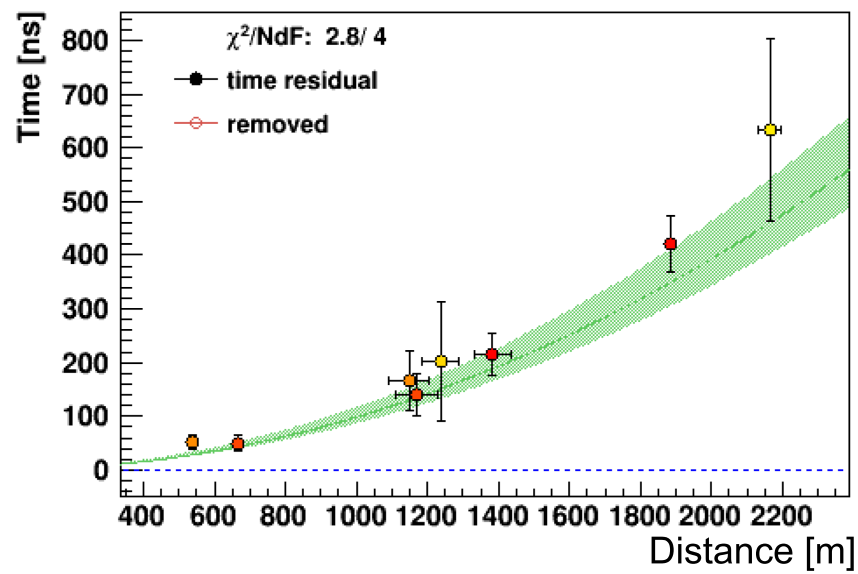
- Particle density at different locations
- **100% duty cycle**

- Time distribution of the incoming particles.
- Signal in VEM=Vertical Equivalent Muons.

Composition from SD: the time fit

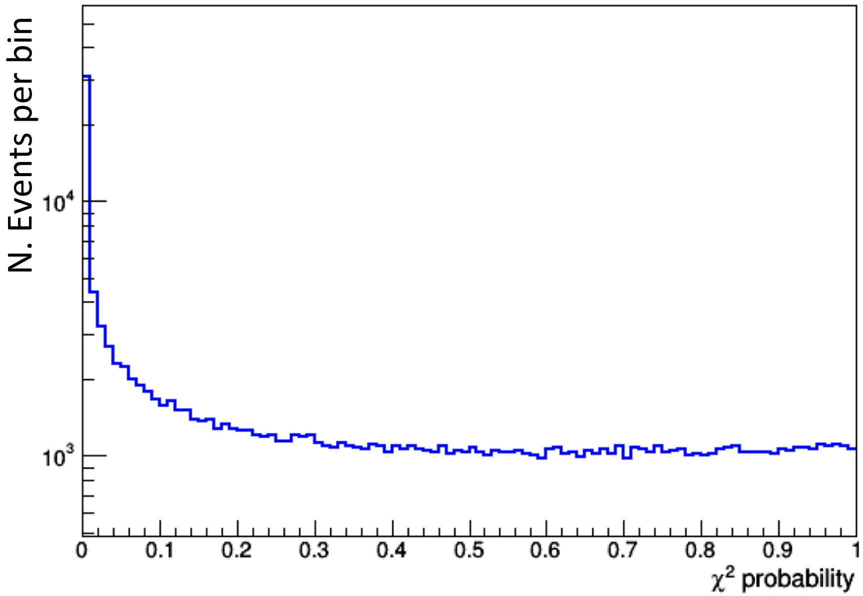






- Cosmic shower as a sphere expanding with the speed of light.
- Calculate the arrival times for a given shower origin.
- Find the origin that best fit the measured arrival times distribution.

Composition from SD: the time fit

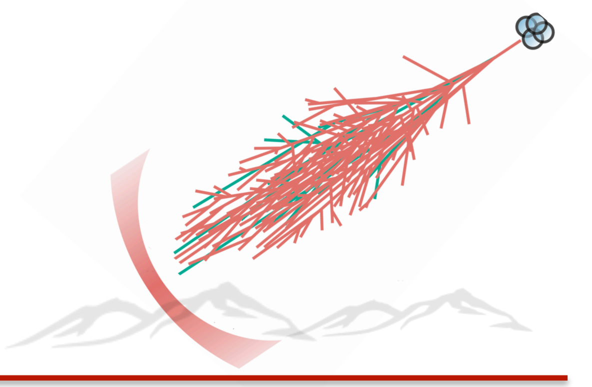


χ^2 probability distribution for events E>3EeV

Improving the time fit to better estimate the Radius of Curvature

1. Better estimation of the uncertainties
2. Improve the fit function

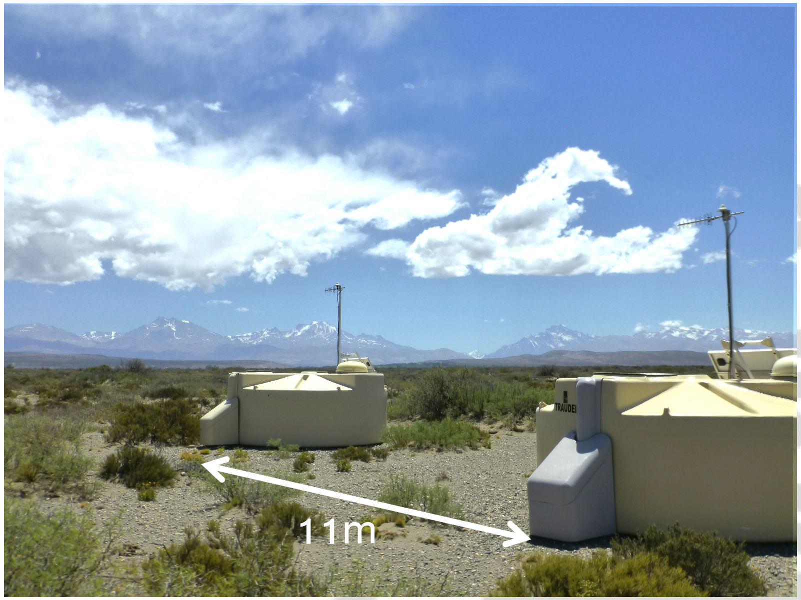
1. Uncertainties: a new model



From simulated showers:

$$V = a^2 \left(\frac{T^2}{n^2} + (c \cdot r \cdot \cos\theta)^2 \right) + b^2$$

- *n* total number of particles.
- *T* estimator of the shower thickness from the measured signal.
- *a b and c* free parameters to be determined using data from twin tanks.

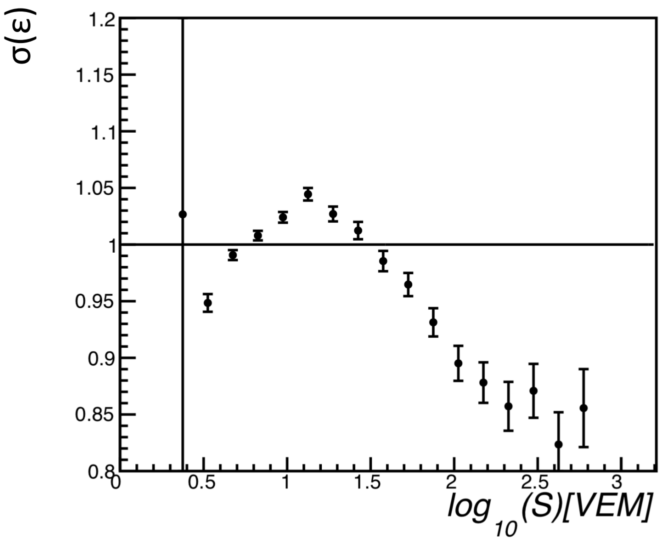


$$\varepsilon = \frac{t_1 - t_2}{\sqrt{V[t_1] + V[t_2]}}$$

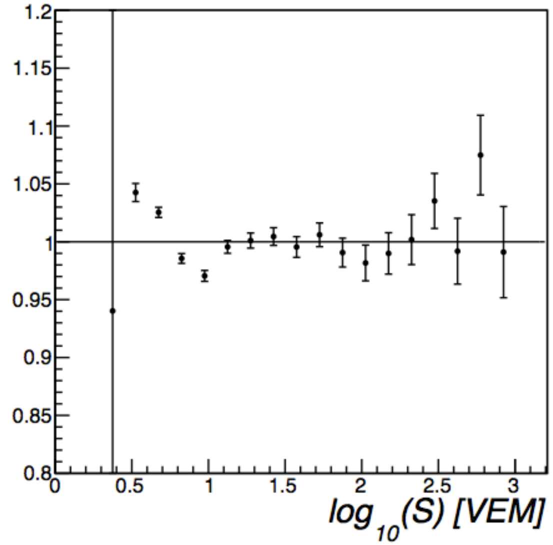
- t_1 and t_2 depend only on the local properties of the shower front.
- If the variance is correctly estimated, ε has σ=1.

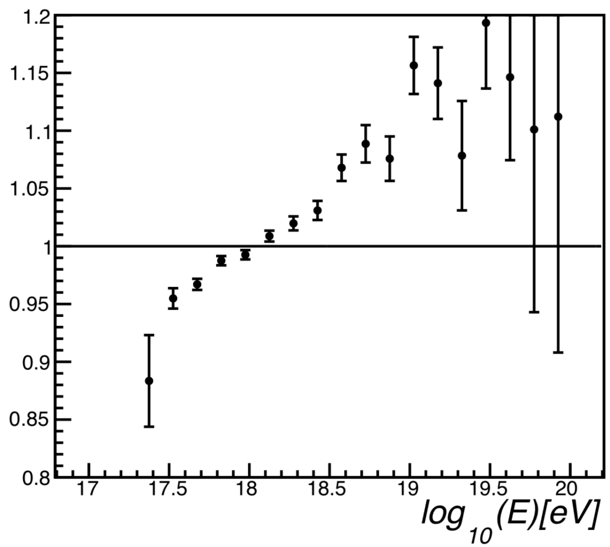
1. Uncertainties: new TVM

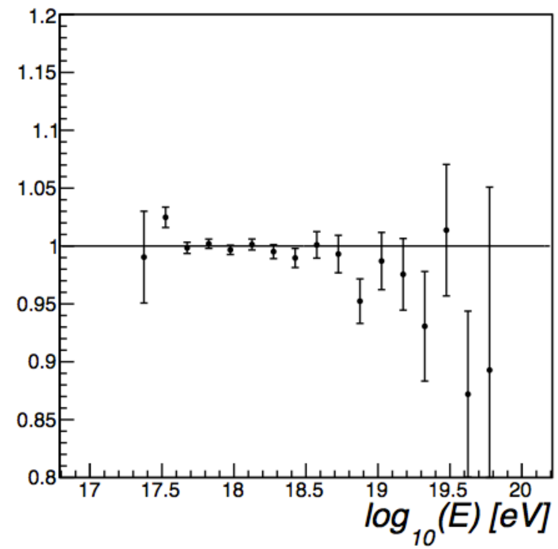
Old parameterization



New parameterization







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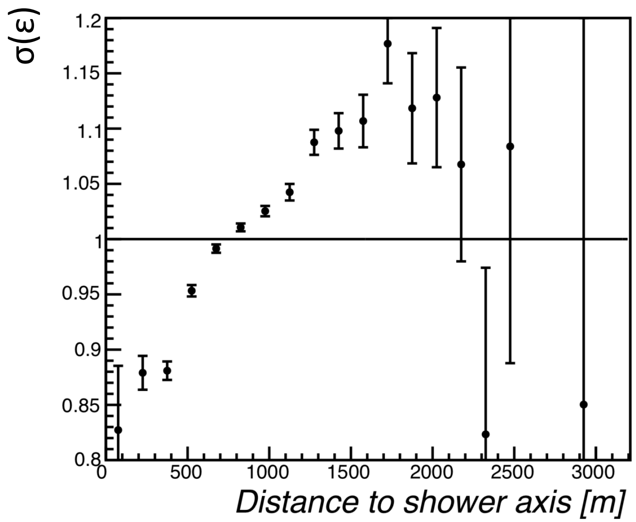

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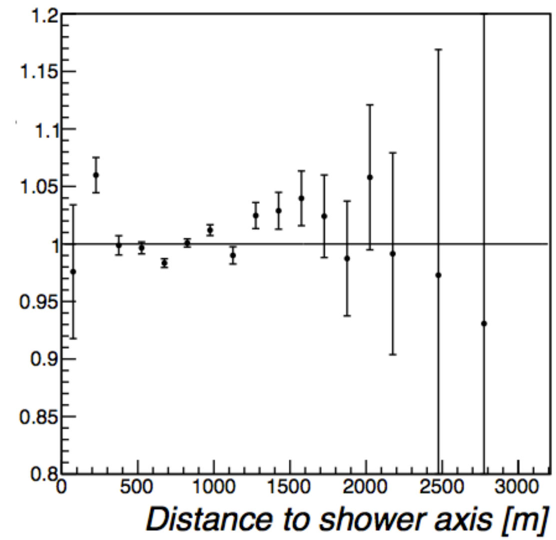
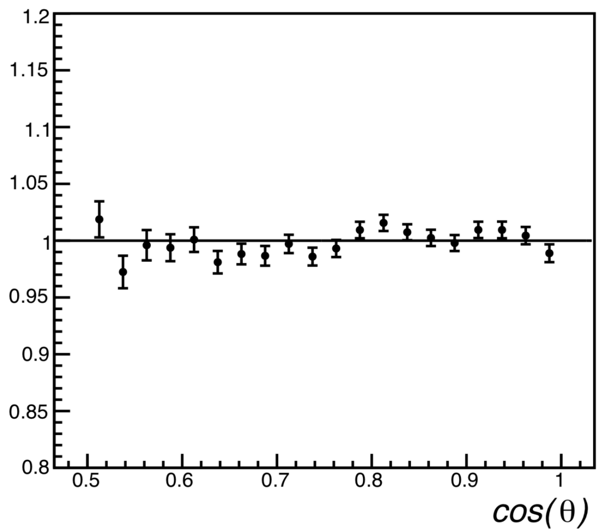
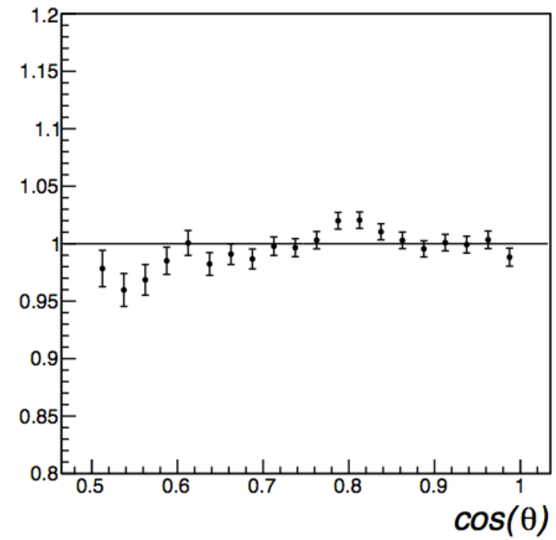
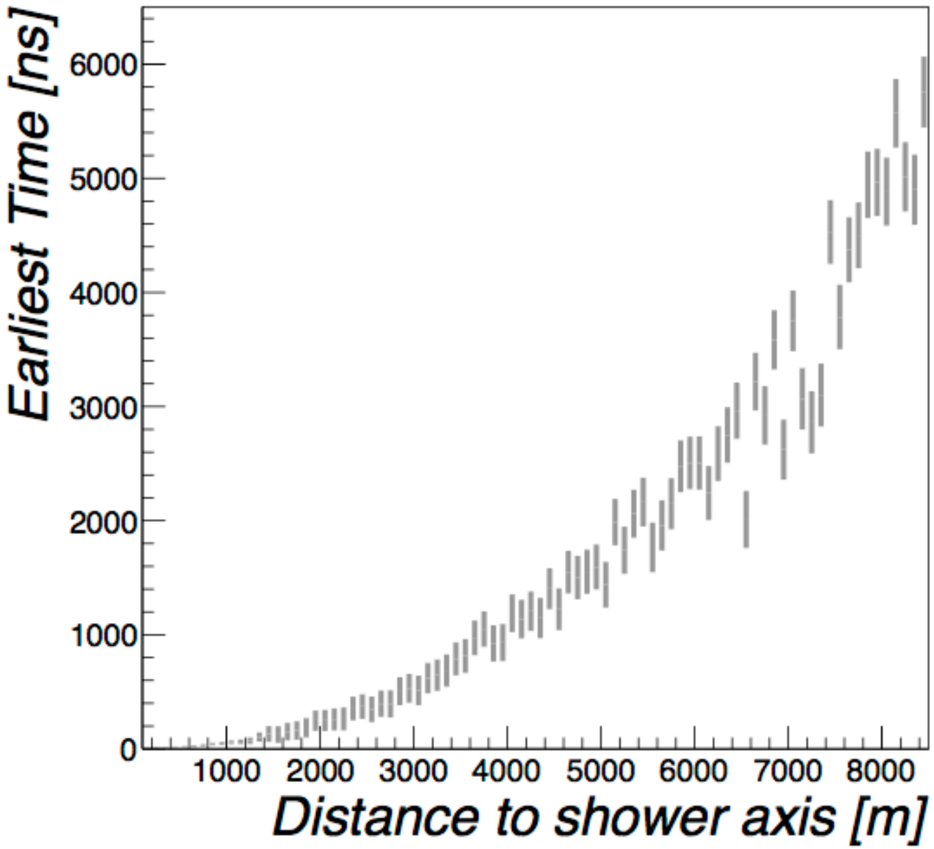






2. A better shape

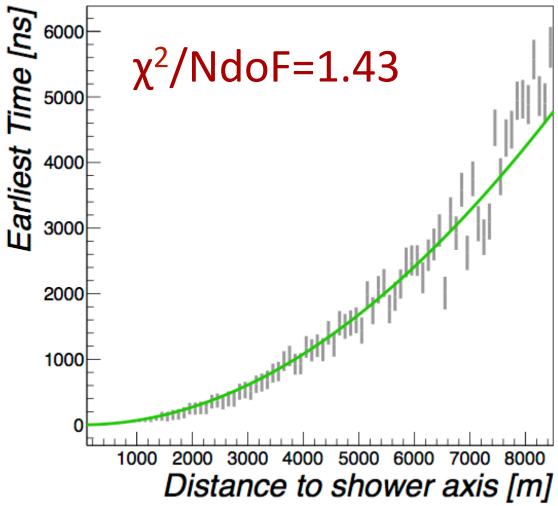
Does the expanding sphere describe properly a shower front shape?



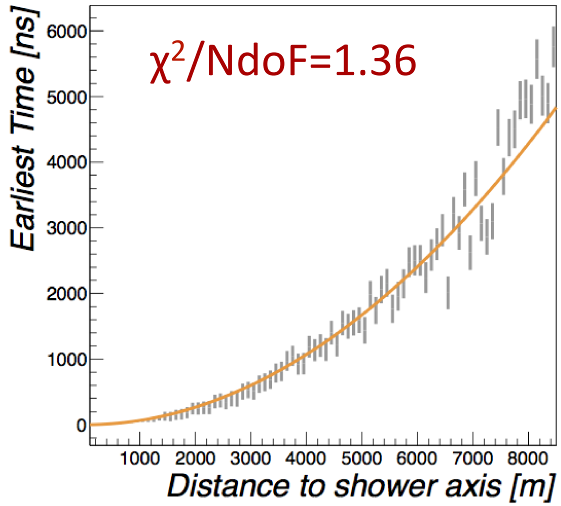
- Earliest arrival time until 8.5km from our simulated showers.
- Uncertainties placed according with the new Time Variance Model.

2. A better shape

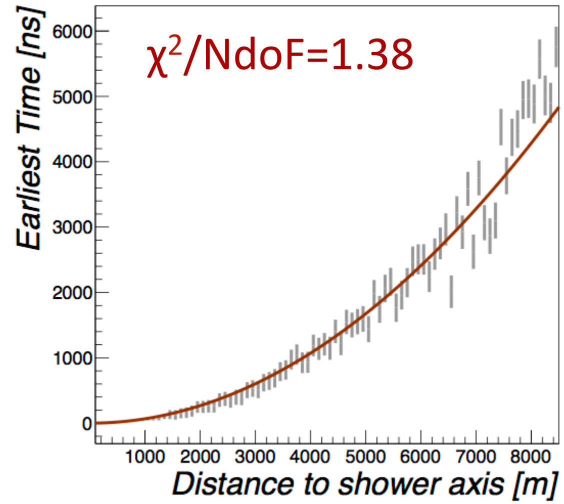
Sphere



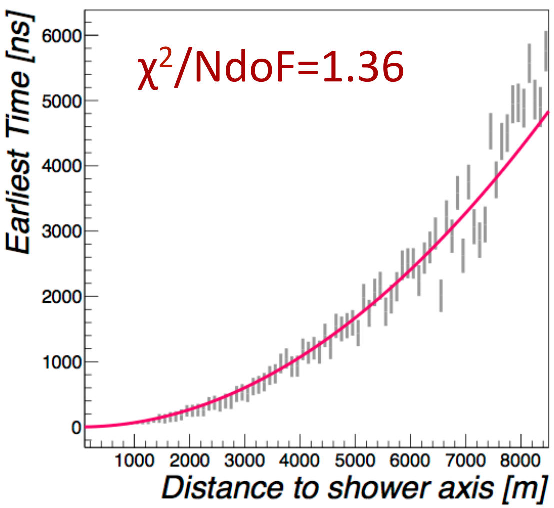
Ellipse 2 param.



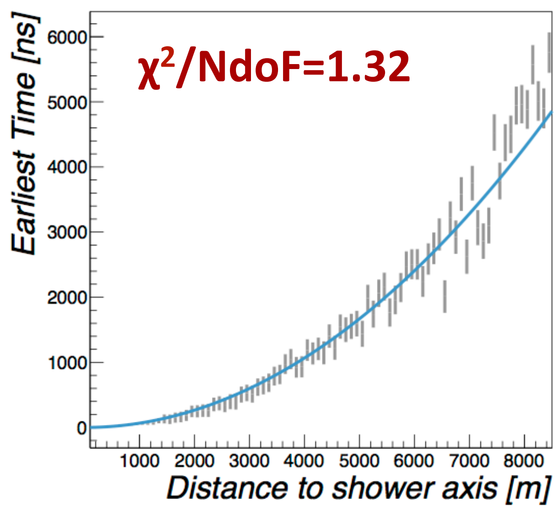
Ellipse 3 param.



Hyperbola



Catenary



Summary and Outlook

Summary:

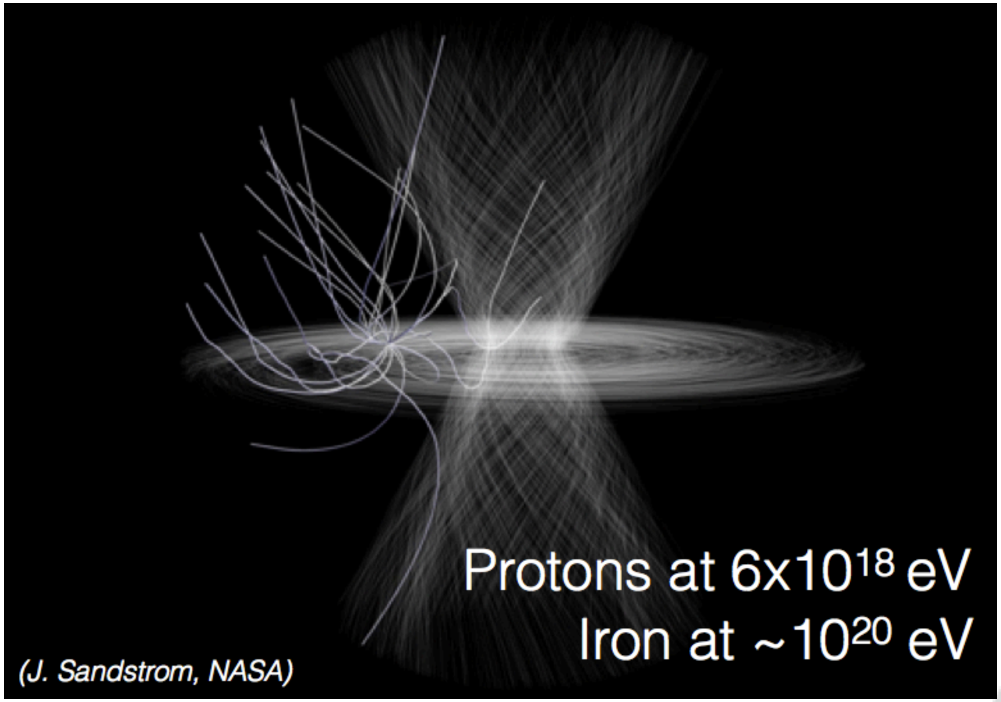
- Data from the Auger Surface detector (SD) include more statistics and cover the interesting energy region above $10^{19.7}$eV.
- We are improving the time fit to use an SD parameter (R_c) sensitive to the mass composition of the primary cosmic ray.
- The new model for the uncertainties gives good performance when tested with data.
- Catenary has the smallest χ^2/NdoF and fits better than the currently used expanding sphere.

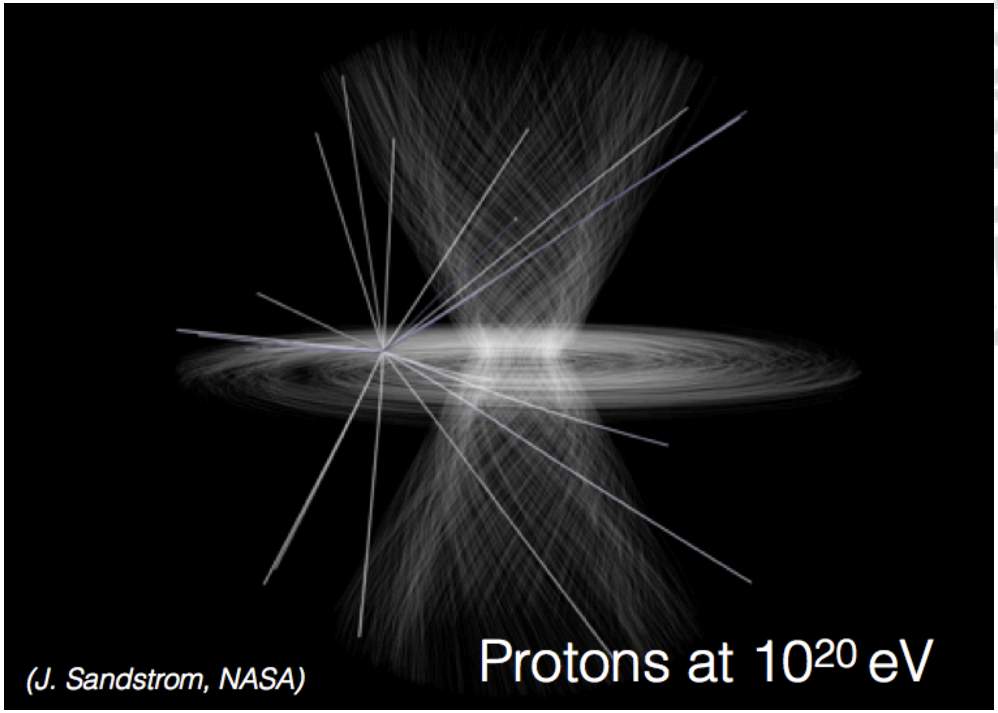
READY TO GO!

Outlook:

- Fit the new shape with new uncertainties on all Auger SD events.
- Perform a mass composition analysis.

Backup

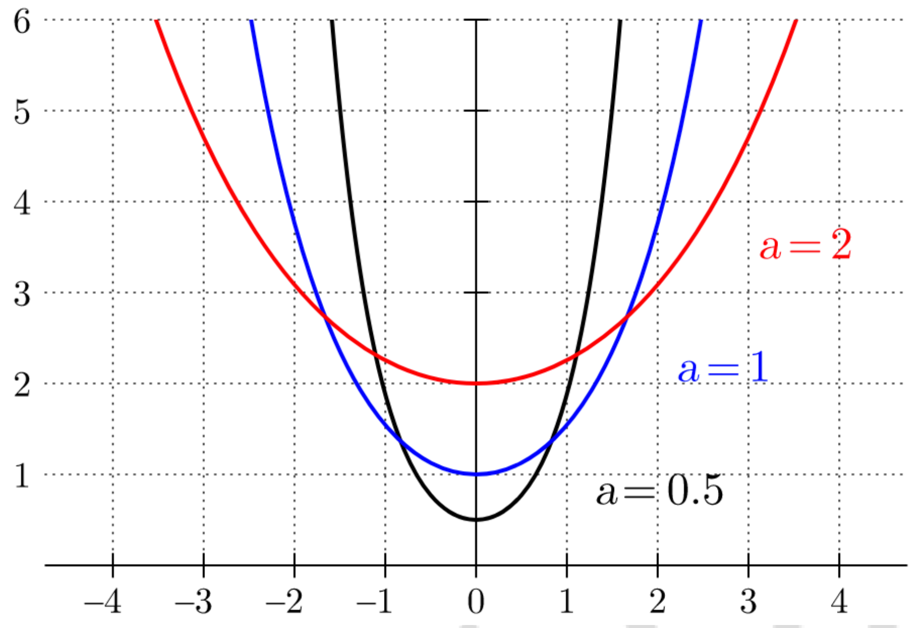

Protons at 6x10^18 eV
Iron at ~10^20 eV
(J. Sandstrom, NASA)


Protons at 10^20 eV
(J. Sandstrom, NASA)

Catenary…what??

A catenary is the curve that an idealized hanging chain or cable assumes under its own weight when supported only at its ends.

The catenary curve has a U-like shape, superficially similar in appearance to a parabolic arch, but it is not a parabola.

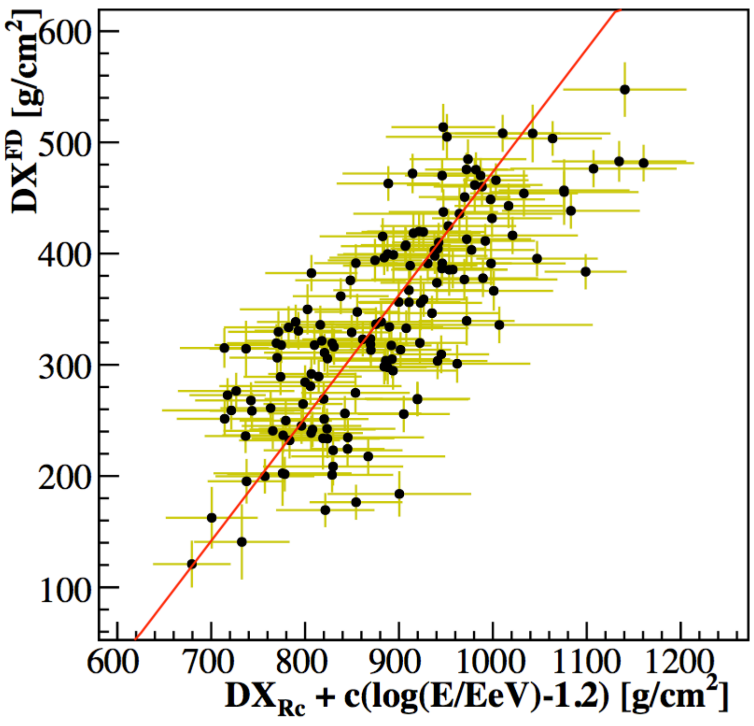


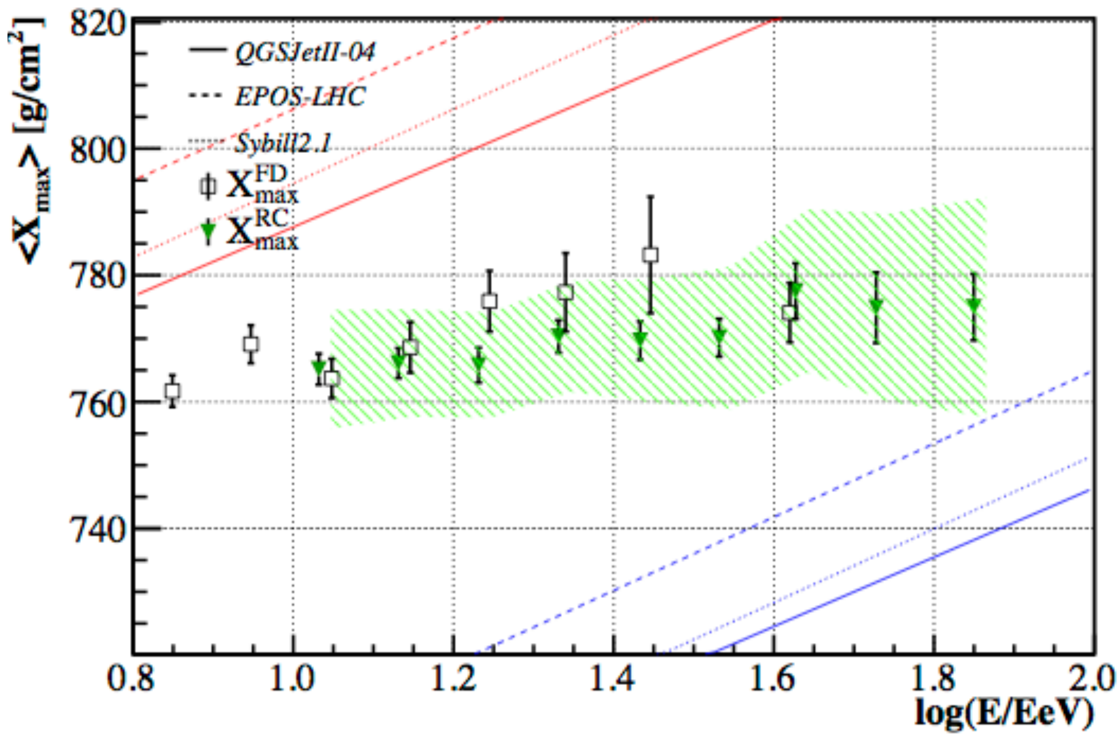
Its equation has the form:

$$y = a\cosh\left(\frac{x}{a}\right) = \frac{a\left(e^{\frac{x}{a}} + e^{-\frac{x}{a}}\right)}{2}$$

R_c as mass estimator

From Guus van Aar PhD thesis

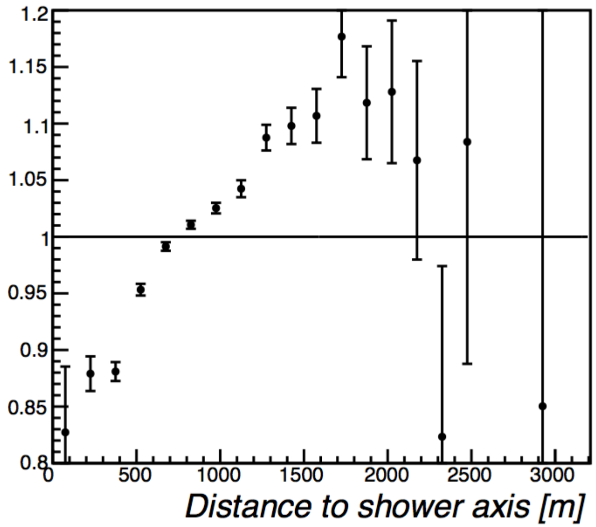


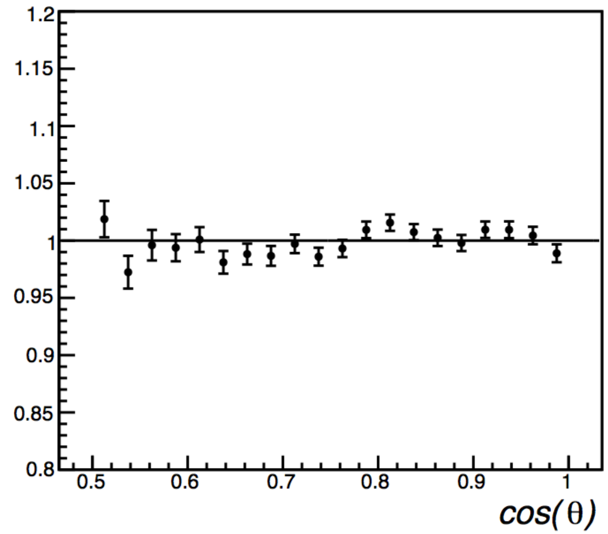


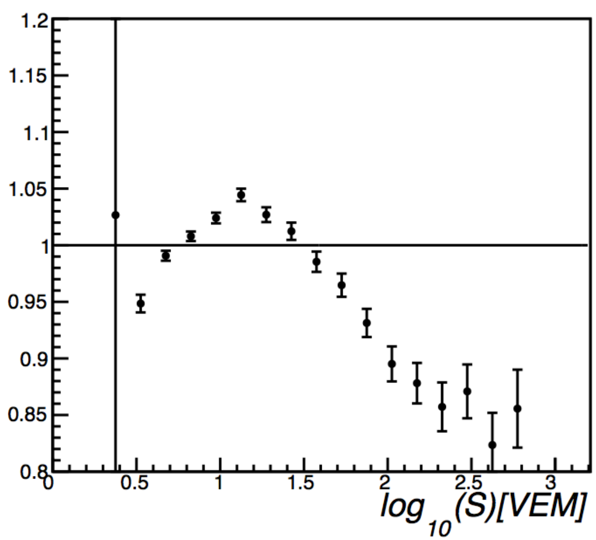
DX is the atmospheric depth between the ground and a given point in the atmosphere.

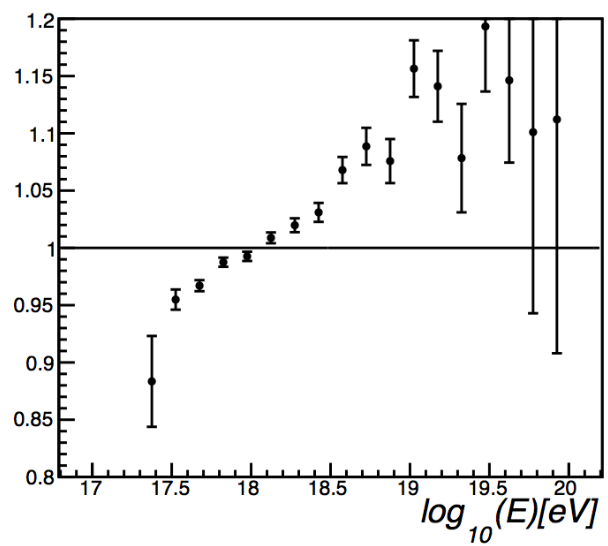
Green triangles are the average X_{max} obtained from the R_c using the calibration curve.

Standard TVM performance









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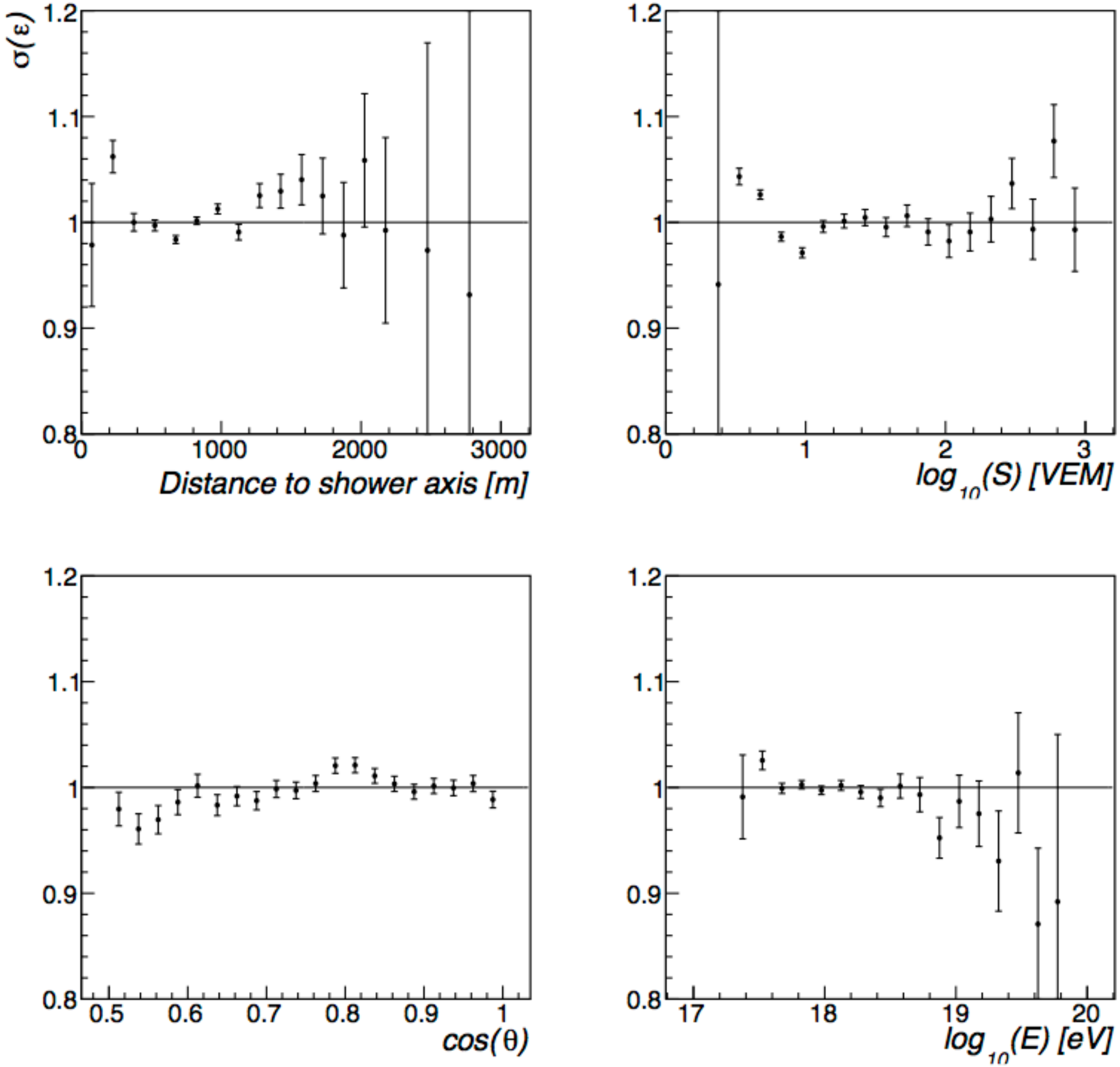

The Time variance model describes well the uncertainties on the data.