

What do FD events with *well measured Profiles* say about X_{max} and $X_{max} RMS$?

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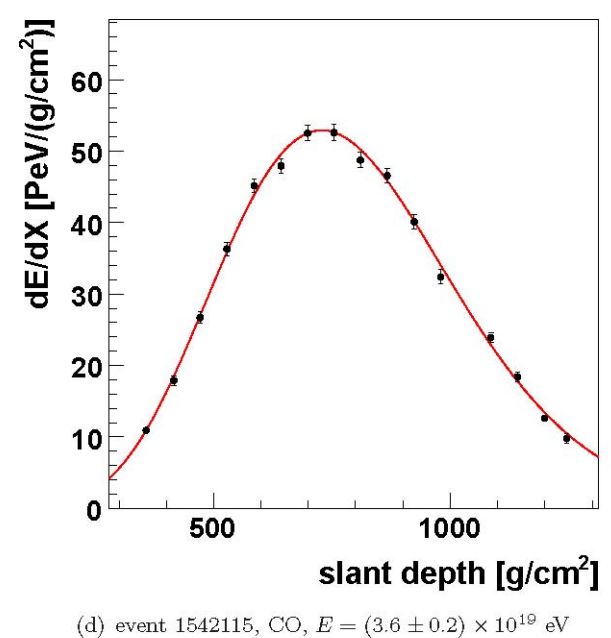
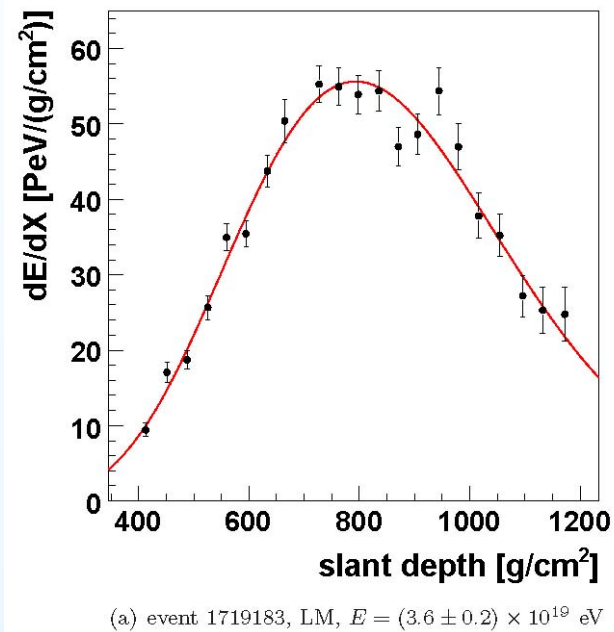
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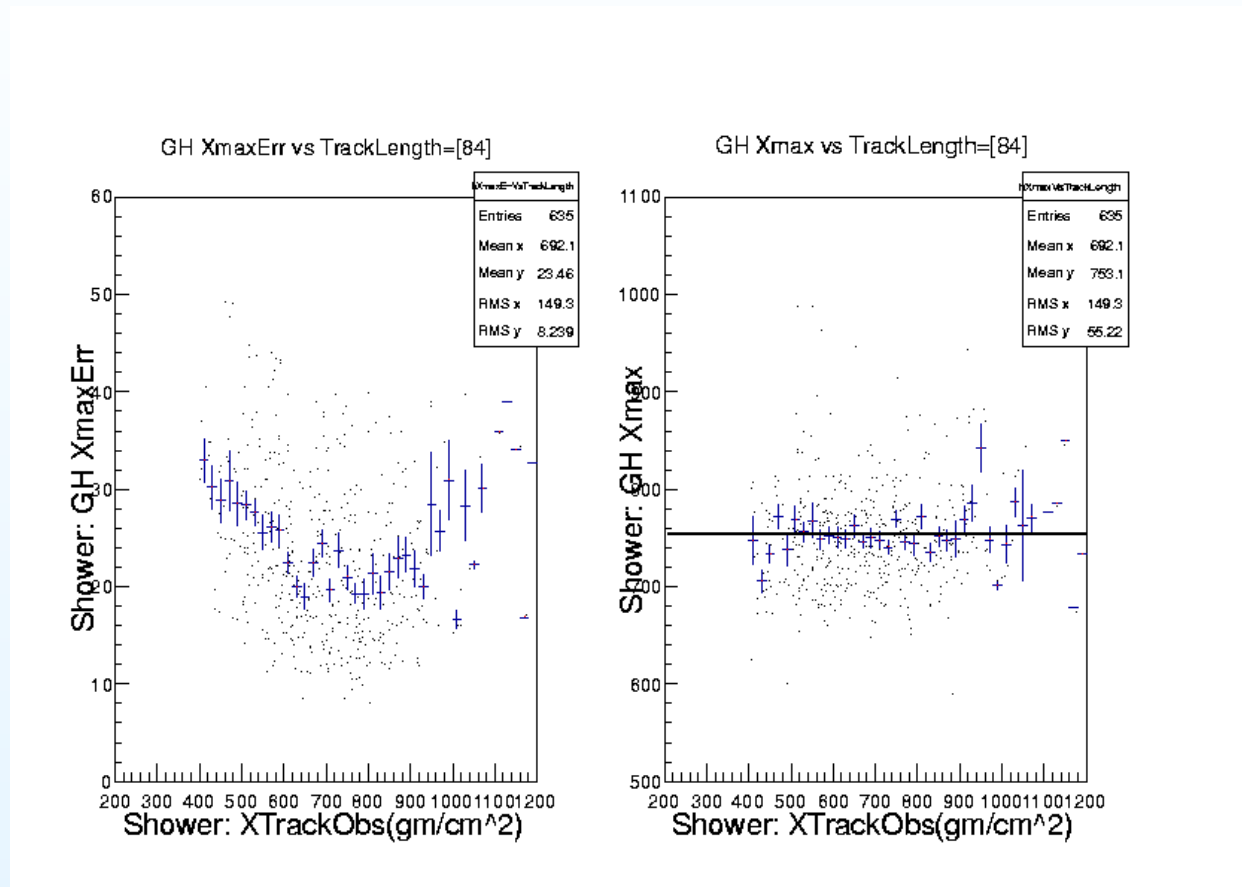
Robert Lauer (UNM), Miguel Mostafa (CSU/PSU) and Patrick Young (LANL)

While studying shower profiles ...



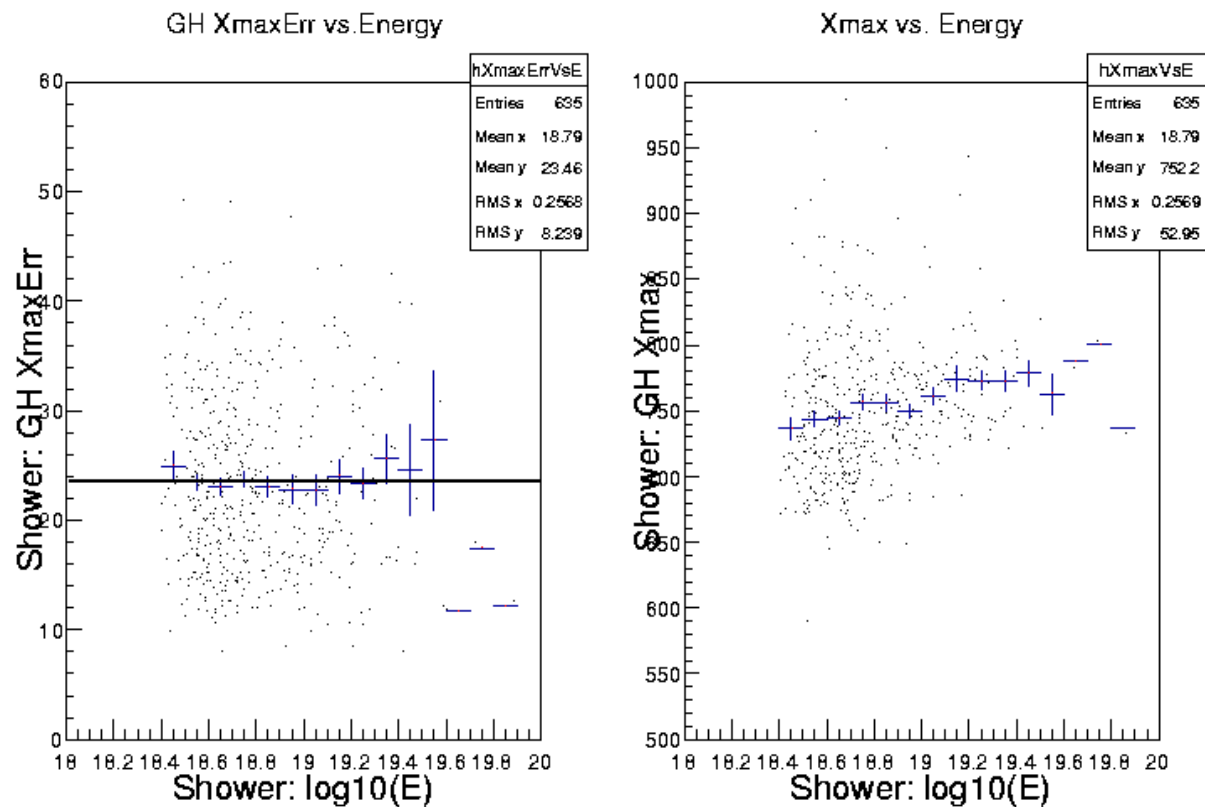
- A subset of FD showers show classic shower profiles with shower maximum, X_{max} , clearly within the field of view (FOV) and with an observed track length $\gtrsim 600 \text{ gm/cm}^2$. (The typical shower FWHM $\sim 525 \text{ gm/cm}^2$.)
- While our initial interest was that these events should allow a measurement of the Gaisser Hillas, X_0 and λ parameters, these events should also provide unbiased measurements of X_{max} .

Now accept *shorter showers* ...



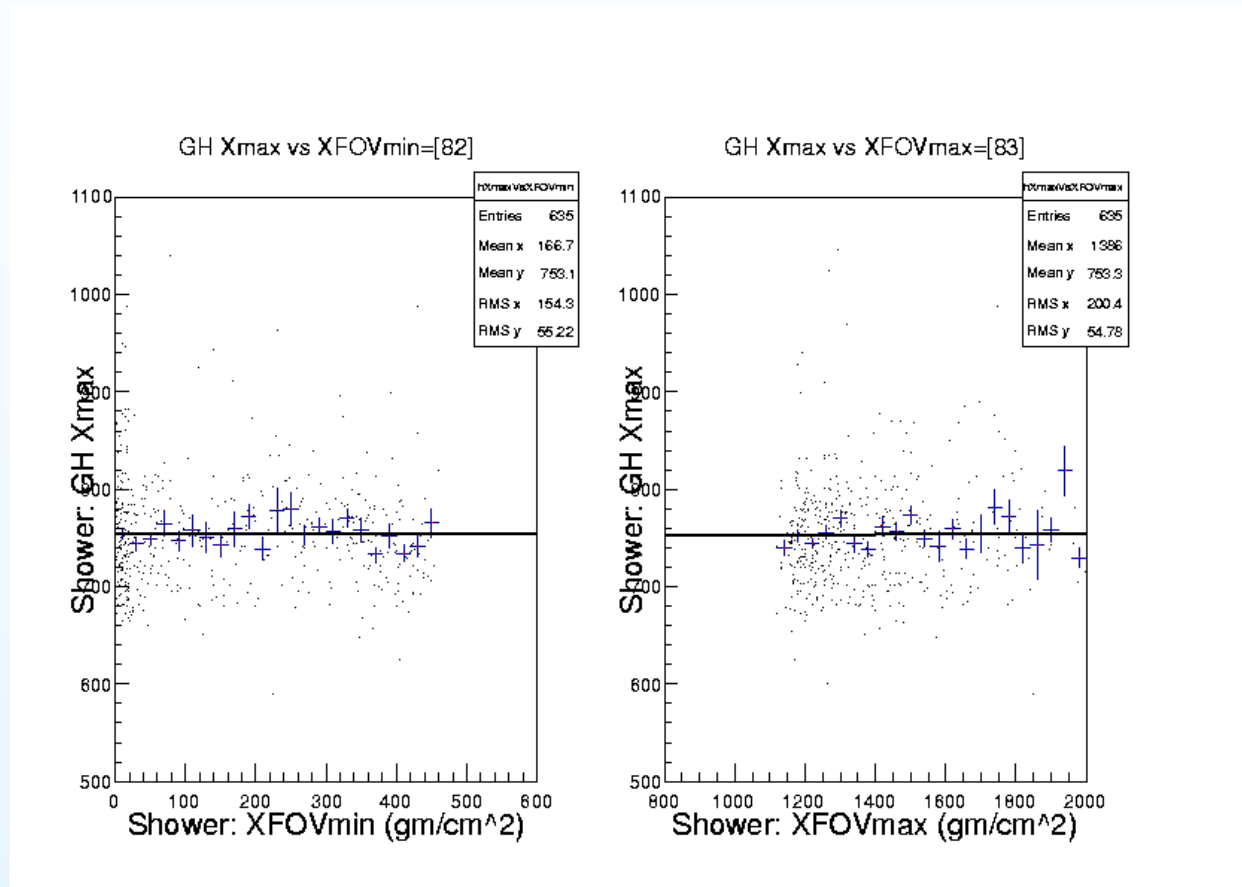
- Long ($X_{\text{trackObs}} > 600 \text{ gm/cm}^2$), unbiased ($X_{\text{FOVmin}} < 450 \text{ gm/cm}^2$, $X_{\text{FOVmax}} > 1150 \text{ gm/cm}^2$, $X_{\text{max}} - X_{\text{TrackMin}} > 100 \text{ gm/cm}^2$ and $X_{\text{TrackMax}} - X_{\text{max}} > 150 \text{ gm/cm}^2$) ADST events selected with shower zenith $\leq 60^\circ$ and $E_{\text{shower}} \geq 3 \text{ EeV}$.
- Change to: $X_{\text{trackObs}} > 400 \text{ gm/cm}^2$ and zenith $\leq 70^\circ$... otherwise the same.

Variations with shower energy ...



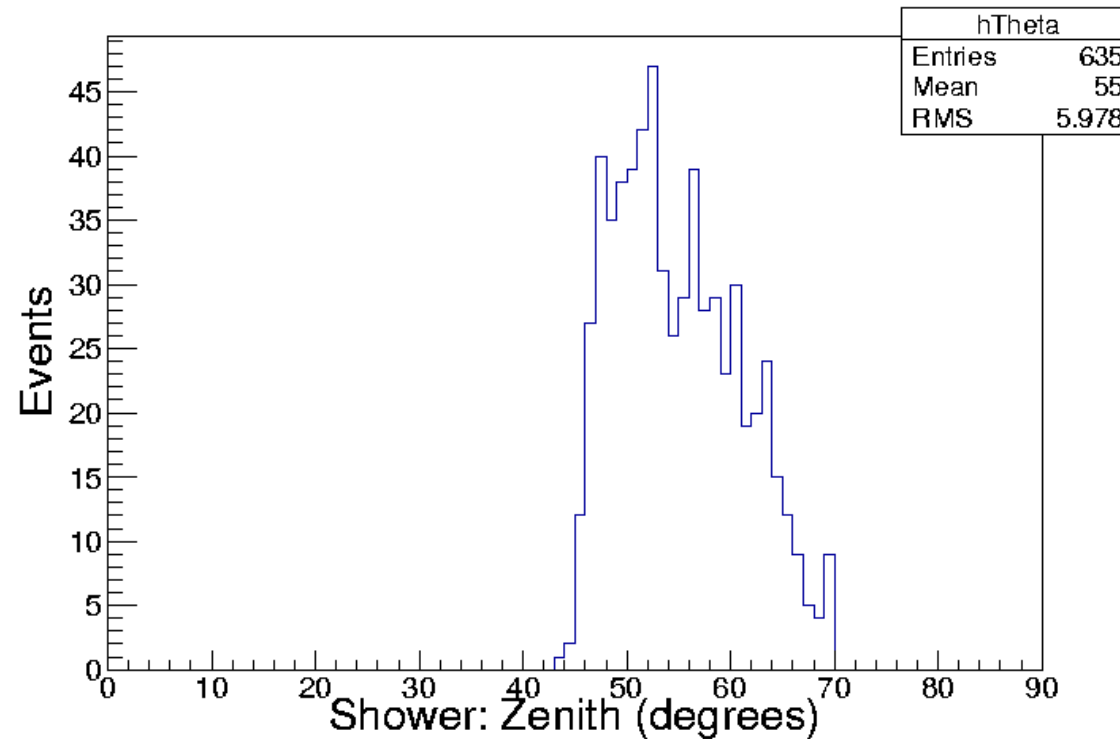
- No variation in X_{max} measurement error, δX_{max} .
- Known X_{max} elongation rate ...

Check for X_{max} biases ...



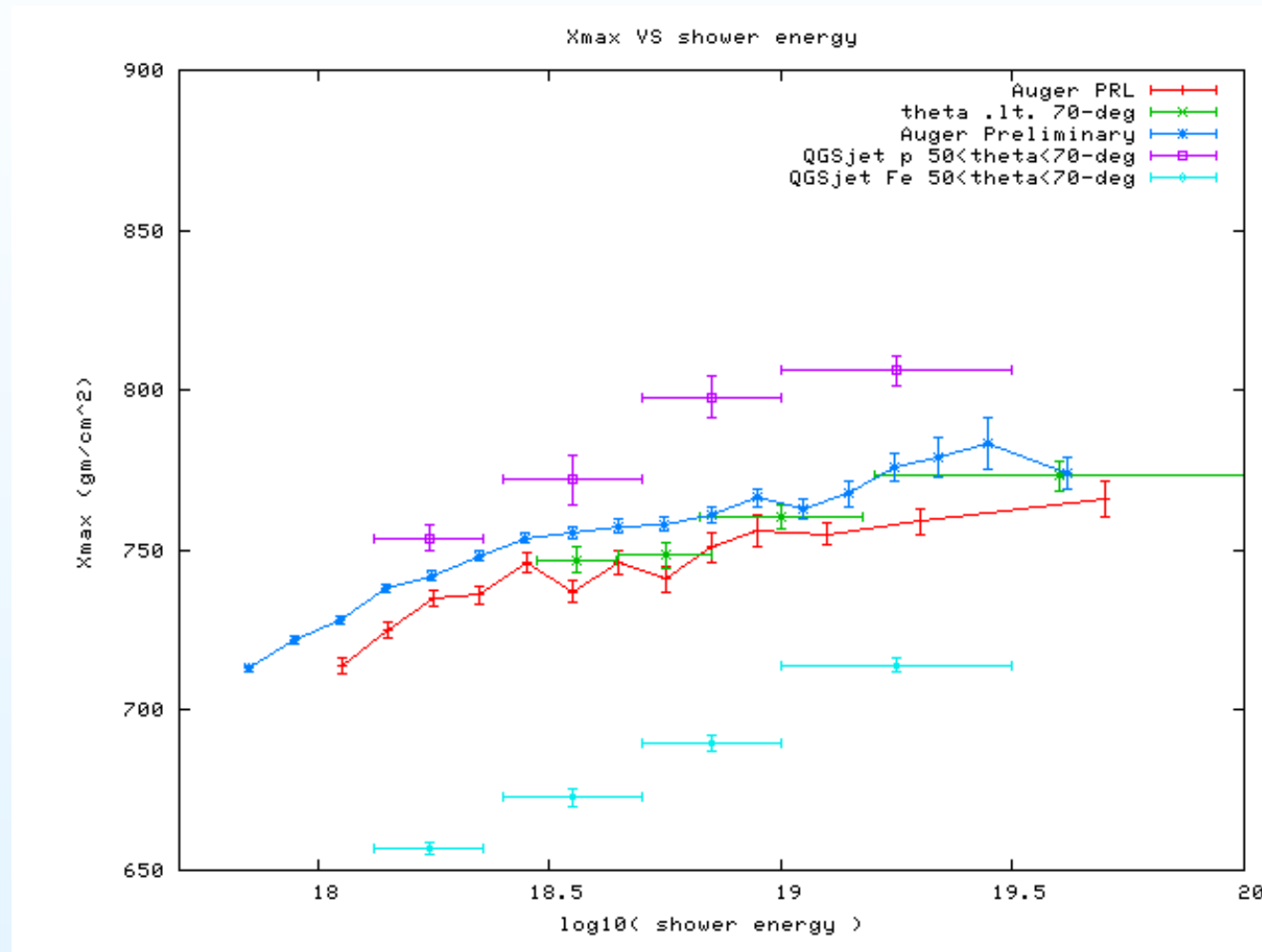
- Set maximum XFOVmin = 450 gm/cm² so that XFOVmin + (Xmax - XTrackMin \geq 100 gm/cm²) = 550 gm/cm² was less than any observed X_{max} .
- Set minimum XFOVmax = 1150 gm/cm² so that XFOVmax - (XTrackMax - Xmax \geq 150 gm/cm²) = 1000 gm/cm² was greater than almost all observed X_{max} .

Cuts limit event zenith angles ...



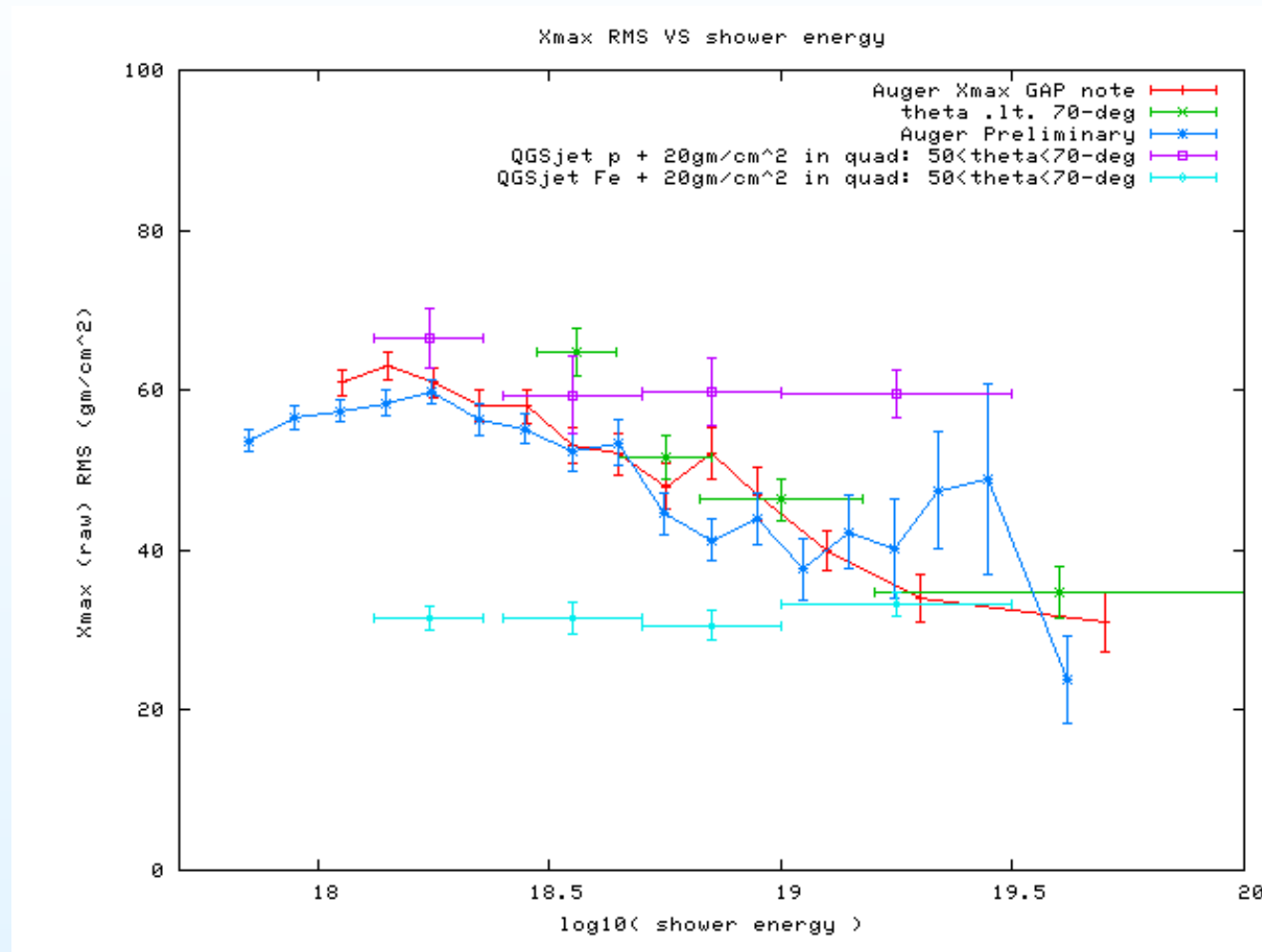
- The selection cuts, to avoid biases in reconstructed values of X_{max} , restrict the range of zenith angles, θ , of the accepted events.
- The minimum $X_{FOVmax} = 1150 \text{ gm/cm}^2$ selection restricts $45^\circ \lesssim \theta$.

X_{max} VS Energy ...



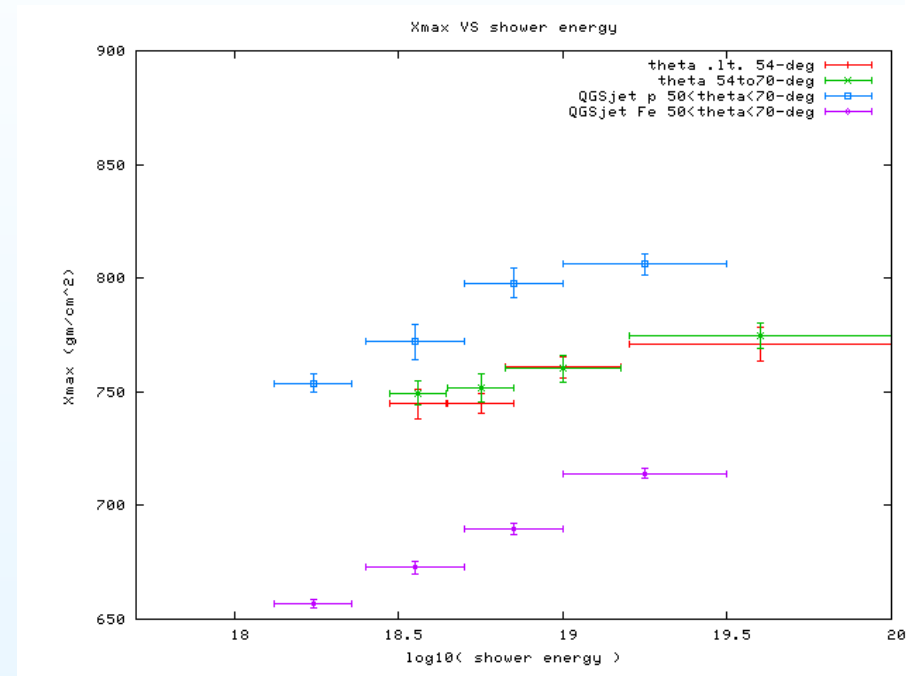
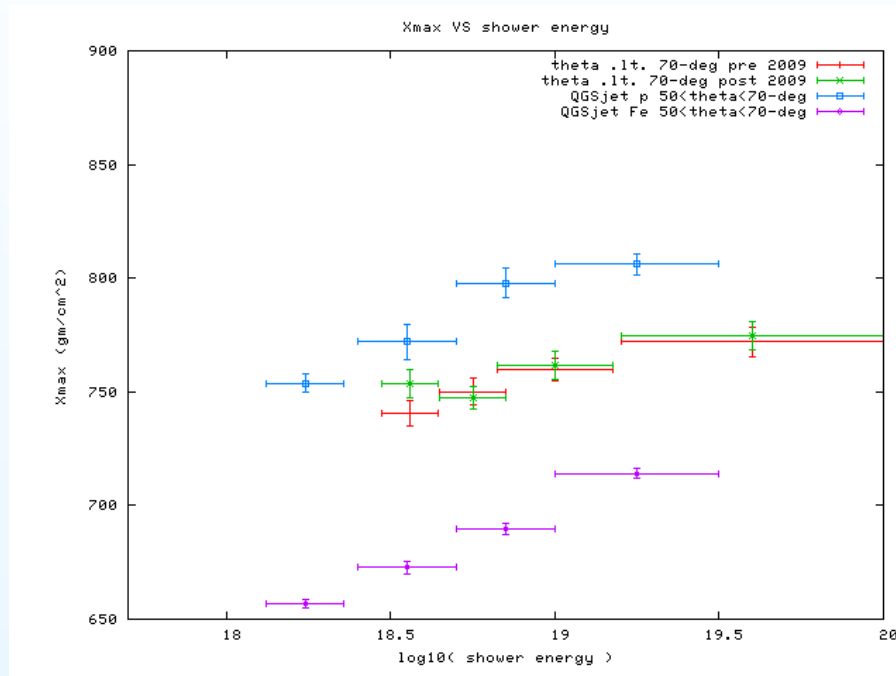
- Four bins in energy; ADST result in green.
- Good agreement with Auger results ...

$X_{max}RMS$ VS Energy ...



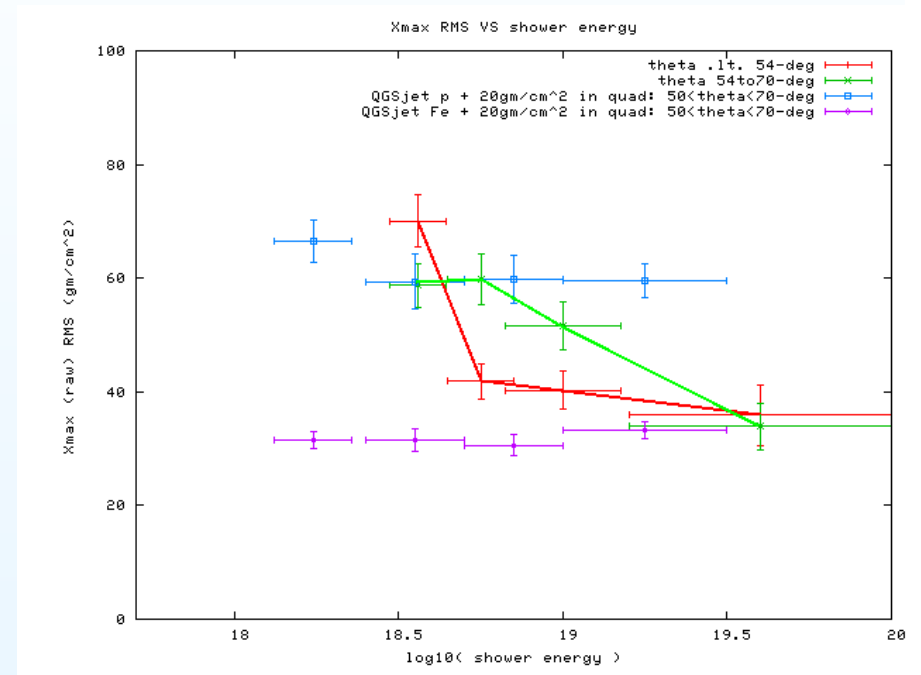
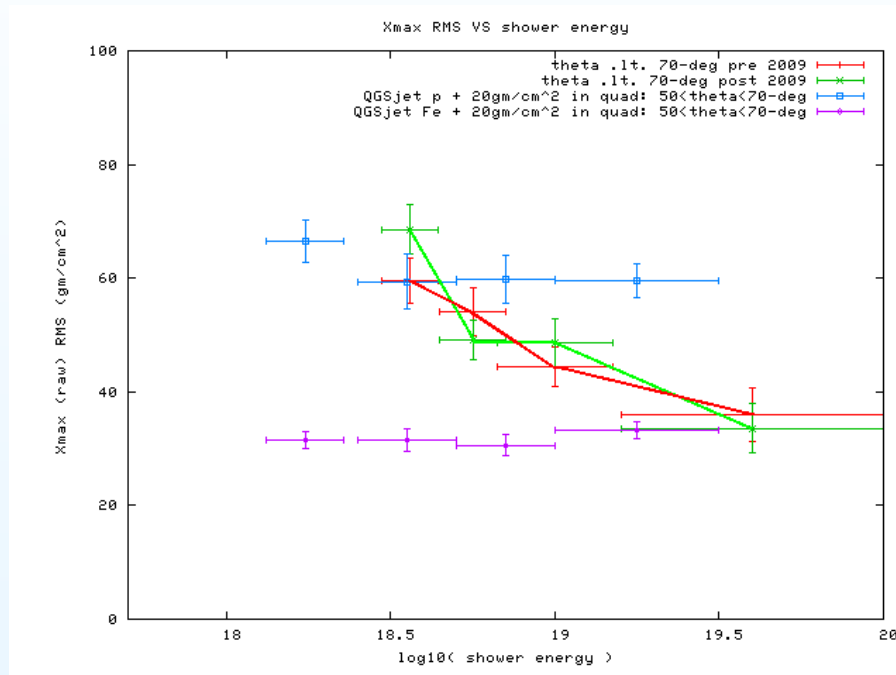
- Four bins in energy; ADST result in green.
- First energy bin, $3.0 < E < 4.47$ EeV, somewhat higher than Auger results ...

Split X_{max} data into 2 halves ...



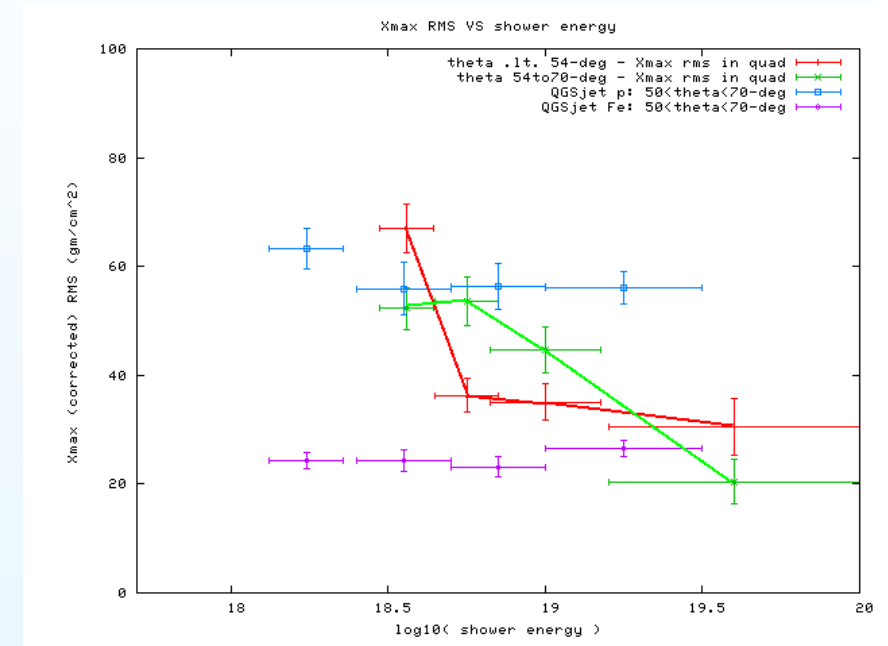
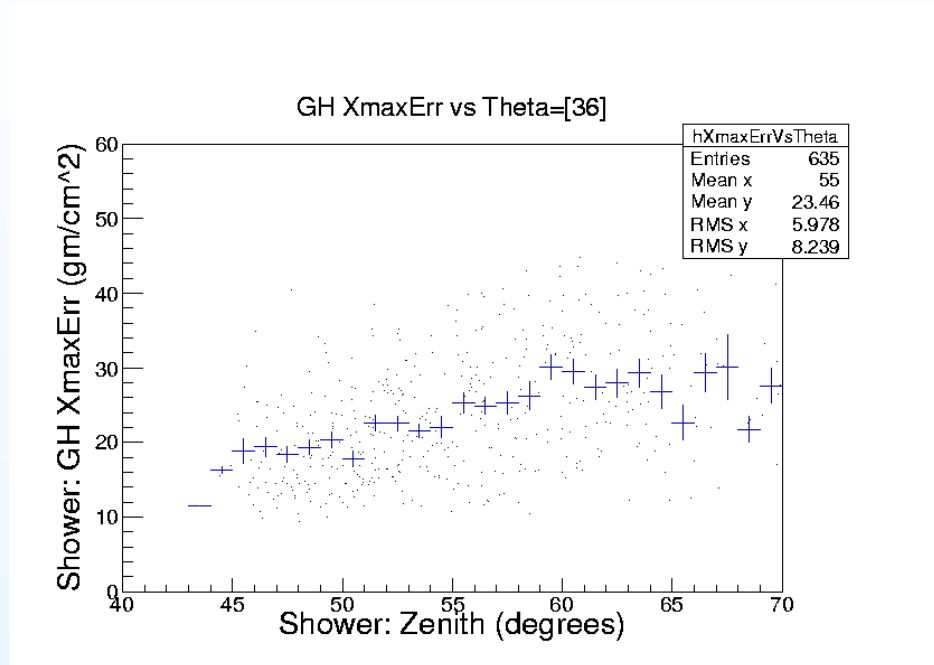
- Left: Data split in time: midpoint January 1, 2009
- Right: Data split in zenith angle: midpoint $\theta = 54^\circ$
- Agreement between the two “half” data-sets is almost too good ...

Split X_{max} RMS data into 2 halves ...



- Left: Data split in time: midpoint January 1, 2009
- Right: Data split in zenith angle: midpoint $\theta = 54^\circ$
- While the trend with energy is qualitatively the same between the two “half” data-sets, **the details are noisy**. Is this “just” statistics? What is this saying?
- Does the variation with zenith angle suggest some systematic (analysis) bias?

Split X_{max} RMS data into 2 halves ... (con't)



- Left: The measurement error in X_{max} increases with zenith angle ...
- Right: X_{max} RMS data split in zenith angle: red points $\theta < 54^\circ$, green points $\theta > 54^\circ$. The plotted points are now corrected for X_{max} measurement error (subtracted in quadrature).
- The two zenith angle bins again give rather different results ...

Summary ...

- Our study for: Can shower profiles measure more than X_{max} and E ? (reported at the Lisbon collaboration meeting) allowed for a simple study of the variation of shower X_{max} and $X_{max} RMS$ with energy.
- And independent analyses are always a good idea ...
- The comparison of our ADST-based measurement of X_{max} VS energy is in good agreement with official Auger results.
- The comparison of the ADST-based measurement of $X_{max} RMS$ VS energy is in qualitative agreement with official Auger results.
- The inconsistency of results from two zenith angle “half-data” sets, suggests that large variations are possible in $X_{max} RMS$ measurements. **Baring an analysis mistake, what is this saying about the size of (systematic) uncertainties in $X_{max} RMS$?**

Additional/backup slides



Additional slides