Status Report

-on-

FD $X_{max}$ Composition Analysis

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At least ... three problems

- Variety of model predictions for $<X_{\text{max}}>$ ... possibly an intrinsic limitation?
- and absolute normalizations are always difficult!
- and modest difference between p/Fe!
But ... what about $X_{\text{max}}$ distribution?

(left) QGSjet p VS Fe Xmax distributions

(right) $<X_{\text{max}}>$ VS energy

- Use the new CONEX generator ... fast!!
- Nexus, QGSjet01 (not QGSjet II), and Sibyll ... with Root output!
- (only QGSjet results shown for p, He, carbon and Fe)
- They agree where there is data ... i.e. below $10^{17}$ eV.
- Nexus most different ... drop it for now!
$X_{max}(E)$ ... mostly linear in log10E

QGSjet protons: generated uniformly between $0.1 < X_{max} < 100$ EeV
(top) $< X_{max} >$ VS E;
(2 bottom rows) $X_{max}$ distribution
(left) “all”
(right) with linear log10E removed
Compatible with ... simple functional form!

QGSjet protons: $0.1 < X_{max} < 100$ EeV in 6 “equal” bins
So ... function(MC, \(p/Fe\), \(\log_{10}E\))

LEFT: functional form (solid curve) VS Monte Carlo simulation: QGSjet, \(p\), \(1 \sim 3 \times 10^{18}\) eV
RIGHT: functional form evaluated at: \(3 \times 10^{17}\) eV, \(3 \times 10^{18}\) eV, and \(3 \times 10^{19}\) eV.
What about ... p VS Fe?

- $X_{\text{max}}$ distributions from QGSjet
- **AND** in QGSjet the $p$:Fe differences **decrease** with energy!
Next ... use it!!

First (in process) ... try it out to fit HiRes Stereo data = Sokolsky talk (ICRC 2005)

HiRes data = circles (●), dE/E = 25%, dXmax = 30 gm/cm²

*With thanks for Pierre’s help! ... but the mistakes are ours!*

In parallel we are checking for bugs ...

Fly’s Ey vs HiRes > 10^{18} eV
Practice fit ... HiRes data \( \geq 1 \text{EeV} \)

Fit \( X_{max} \) distribution to \( \propto p + (1 - f) \propto Fe \)

Repeat fit in 5 gm/cm\(^2\) steps ... because we do not know possible data:MC (absolute) offsets

Repeat assuming data \( \propto E^{-3} \) or \( \propto E^{-2} \)

In parallel keep checking for bugs ...

(Left) fit \( \chi^2 \) VS grammage offset

(right) proton fraction, \( f \), VS grammage offset

![Graphs showing fit results](image)
Two minima ... $44\%p : 56\%Fe$

Offset QGSjet p,Fe $X_{max}$ distributions deeper into the atmosphere

i.e. move QGSjet-p $< X_{max} >$ away from the data
Two minima ... 100% p : 0% Fe

Offset QGSjet p,Fe \( X_{max} \) distributions less deep into the atmosphere

i.e. move QGSjet-p \( < X_{max} \) toward the data
Just in time ... small-x gluons!

Predictions for Sibyll with new saturation model (running VS fixed coupling).

New model brings the prediction (blue) closer to the HiRes stereo data ... this is the same direction favored by the 100%p:0%Fe solution!
Summary ... **good news and bad news!**

- Progress toward analyzing full $X_{\text{max}}(E)$ data distributions (instead of just data $< X_{\text{max}}(E) >$).
- Still early ... so beware of possible bugs!
- First comparison of QGSjet p+Fe to HiRes Stereo data $> 1\text{EeV}$ has both good news and bad news.
- Good news is that a simple sum of QGSjet p-$X_{\text{max}}(E)$ + Fe-$X_{\text{max}}(E)$ agrees with the data.
- Bad news is we still don’t know the fraction of protons ... **but** it could be 100%!
- Next step: analyse Auger FD $X_{\text{max}}$ data!