



## HiRes Stereo Cosmic Rays Composition Measurements.

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**Abstract:** The High Resolution Fly's Eye (HiRes) fluorescence detectors have been collecting extensive air shower (EAS) data for more than 6 years. The obtained statistics allows us to more precisely estimate the mass composition of the ultra high energy cosmic rays (UHECR). In this study we summarize the stereo shower parameters measurements, especially  $X_{max}$  measurements. The sensitivity limitations of our detector, the effect of the hadronic model choice on the estimate, and systematic errors of our measurements are also presented.

### Introduction

Knowledge of the chemical composition of the UHECR is essential in our understanding the nature of this phenomenon. The particle's mass sets certain restrictions on the acceleration mechanisms and, as a consequence, the physical conditions at the CR origin. The propagation effects are also important. For example, the observation of GZK cutoff requires that most of the UHECR flux be protonic. Recent theoretical models [1] assume a transition from particles originating in our Galaxy to extragalactic particles with the latter being dominant at energies above  $3 \cdot 10^{18}$ eV. This transition should be reflected in a composition change.

We observe UHECR through their interactions with the Earth's atmosphere which result in extensive air showers. Analyzing these showers gives us an estimates of the incident particle energy and its position in the atmosphere. However, we can not determine the type of the element we observe on event by event basis. A statistical approach allows us to make estimates of the presence of different elements in the collected data.

### Method

#### $X_{max}$ analysis

The most traditional statistical method of mass composition analysis consists of measuring the slant depth at the EAS maximum ( $X_{max}$ ) and studying its distribution with respect to the particle's energy. There are noticeable differences in the distribution parameters (mean and width) for different elements. Namely, EAS associated with lighter particles develop deeper in atmosphere and have wider distributions (see Figure 1). While at the first glance these differences are quite significant, the selection of the sample for analysis presents a rather tough balancing act. Our measurements should not have any preference for the type of particle we observe, and at the same time we need have enough data for statistical studies.

#### Monte Carlo simulations and Reconstruction

The main source of the distortions of the  $X_{max}$  distributions is the limited field of view of the detector which covers up to  $30^\circ$  in elevation. This design introduces strong bias in observing EAS associated with low energy iron particles as well as systematic errors in reconstructing shower parameters. We use MC simulations to investigate this effect and

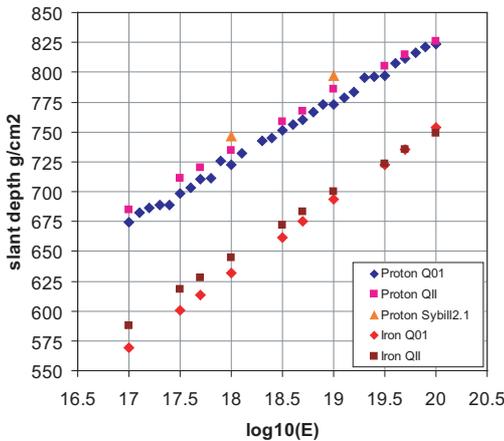


Figure 1:  $\langle X_{max}(E) \rangle$  for different hadronic interaction models: QGSJET01, QGSJETII and Sybill2.1

to estimate our reconstruction biases. Two datasets simulating the detector response to the proton and to the iron air showers respectively were used [2]. Our analysis shows that by using energy depended cuts on the measured shower track zenith angle we can compensate for the detector efficiency bias (Figure 2). An unbiased analysis is possible for proton and iron showers in energy range from  $10^{18}$ eV to  $3 \cdot 10^{19}$ eV. This cut also preserve the shape of the  $X_{max}$  distribution (i.e.  $\langle X_{max} \rangle$ ).

### The Presentation

We validate the method to select a composition-unbiased sample using MC data sets. These cuts are than applied to our collected data. In this talk we present the resolution and systematics of our  $\langle X_{max} \rangle$  measurements for that sample and compare it with expectations for light and heavy compositions and for different hadronic models.

### Acknowledgments

This work has supported by US NSF grants PHY-9100221, PHY-9321949, PHY-9322298, PHY-9904048, PHY-9974537, PHY-0073057, PHY-0098826, PHY-0140688, PHY-0245428, PHY-

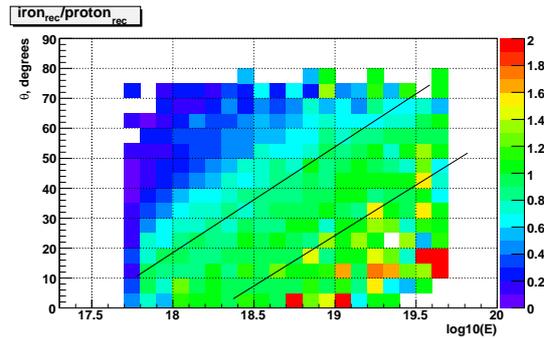


Figure 2: The relative efficiency of the reconstruction (Ratio of reconstructed iron showers to reconstructed proton showers with respect to energy and zenith angle). Black lines shows efficiency preserving cut.

0305516, PHY-0307098, PHY-0649681, and PHY-0703893, and by the DOE grant FG03-92ER40732. We gratefully acknowledge the contributions from the technical staffs of our home institutions. The cooperation of Colonels E. Fischer, G. Harter and G. Olsen, the US Army, and the Dugway Proving Ground staff is greatly appreciated.

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