Cosmic Ray Composition Measured by HiRes in Coincidence with FE2

T. Abu-Zayyad[1], M. Al-Seady[1,5], K. Beiov[1], D.J. Bird[2], J. Boyer[3], G. Chen[1], R.W. Clay[2], H.Y. Dai[1], B.R. Dawson[2], Y. Ho[3]. M.A. Huang[1], C.C.H. Jui[1]; M. Kidd[4], D. Kieda[1], W. Lee[3], E.C. Loh[1], E.J. Mannel[3]. J.N. Matthews[1], T. Q'Halloran[4], A. Salman[1], K.M. Simpson[2], J. Smith[1], P. Sokolsky[1], P. Sommers[1], S.F. Taylor[1], S.B. Thomas[1], L. Wiencke[1], C.R. Wilkinson[2]

[1] Department of Physics and Institute for High Energy Astrophysics, University of Utah. Utah 84112, USA
[2] Department of Physics and .Vathematical Physics. University of Adelaidc S.A. 5005, AUSTRALIA
[3] Department of Physics. Columbia University. New York 10027. LISA
[4] Department of Physics, University of Illinozs at Urbana- Champaign; Illinois 61801. USA
[5] Permanent address: Physics Dept.. Faculty of Science, Alexandria Univ.. EGYPT

Abstract

We report in this paper the progress we made in determining the cosmic ray primary composition between 3 x 10^{16} to 3 X 10^{17} eV by the detection of coincidence events between the HiRes prototype and the Fly's Eye II detector.

Introduction

The Fly's Eye composition measurement (Gaisser et al 1993, Sokolsky S,•. Bird et al 1993) indicate the primary composition is dominated by a heavy component below 3 x 10^{17} eV. The measurement by the stereo Fly's Eve between 1 x 10^{17} to 3 x 10^{17} is done at. the threshold energy of the Fly's Eye detector and needs to be confirmed. In order to understand the nature of the 'knee' in the energy spectrum, it is also of great importance to push the measurements down in energy, to reduce the gap between the direct. measurement and indirect measurement, and to provide more composition information from above the 'knee'.

The HiRes detector is designed to study cosmic rays at a much higher energy, but because of its small pixel size, the threshold energy is also reduced. With the combination of the HiRes prototype and Fly's Eye II, we were able to extend our measurement down to 3 x 10^{16}eV.

The HiRes prototype consists of 14 mirrors that look over the Fly's Eye II detector which is 3.4 km away. HiRes has an effective mirror area of 3.5m^2 and 1 degree pixel size. Fly's Eye II consists of 36 mirrors looking at the half sky toward the HiRes direction. The Fly's Eye II mirror area is 1.7m^2 effective, the pixel size is 5.5 degrees. Fly's Eye IT ;was operational at the early stages of the HiRes prototype. Coincidence data were taken between the period of April 93 to March 95 and 2000 real coincidence shower events were collected. Possible systematic errors are currently under investigation by the detector. Monte Carlo and results will be reported at the conference.

Data analysis

Shower reconstruction uses information from both detectors. Fly's Eye TI data is used with HiRes data in stereo geometrical reconstruction of the shower. The HiRes data, is then used to reconstruct the shower profile. Two methods are used to determine the shower trajectory. The first is using the two shower-detector-planes and the second is to use HiRes I plane and PMT trigger times along with FE II PMT pointing directions. Both methods yield consistent results. Figure.1 shows the zenith angle distribution of the triggered events and Figure.2 shows the impact distance (R_p) distribution. The zenith angle of those triggered events is peaked at 30 degrees and the average distance from they shower to the HiRes detector is about 2. 7 km.

The shower profile and energy are reconstructed by the Monte Carlo method. That is, given the track geometry and the tube signal. we try different shower profiles with different shower size, taking into account the light scattering, attenuation and mirror aberration. The trial profile which predicts tube signals which best match the measured signals is chosen as the answer. The Gaisser-Hillas function (Gaisser Hillas 1977) is used for the shower profile generation. In addition to the maximum shower size, X_{max} and X_0 are the other two free parameters in the Gaisser- Hillas function. The primary energy is estimated by calculating the total integral track length using this function. The coincidence events corers the energy region from 3 x 10^{16}eV to 3 x 10^{17}eV (Figure.3).

One typical shower profile is shown in Figure.4. The top plot shows the predicted contribution of the light signal from each component along the shower track. The thick solid line represents the contribution from the air fluorescence light, the thin solid line is the direct Cherenkov light viewed by the detector, the dotted line shows the rayleigh scattered Cherenkov light, the dashed line is the aerosol scattered Cherenkov light. The bottom plot compares the predictions with the experimental data. The predictions are the sums of the lights in the top plot.

Status

We, are currently in the process of developing the combined Fly's Eye and HiRes Monte Carlo to study the possible systematic bias in the event trigger, data reconstruction, etc. We are also probing the effect of the variation of the atmosphere on the reconstructed shower X_{max} Our data will eventually be compared with the refined shower Monte Carlo

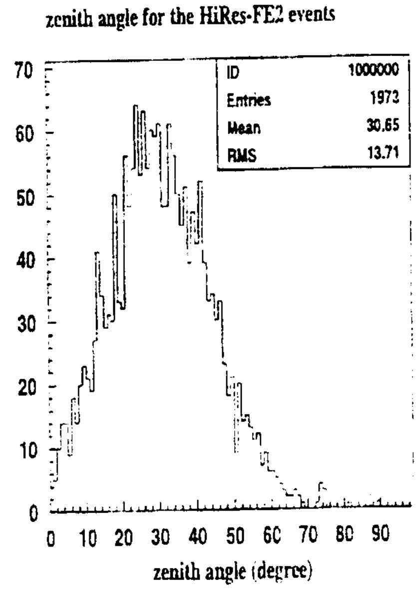

Figure 1: zenith angle distribution for the HiRes and FE2 coincidence events.

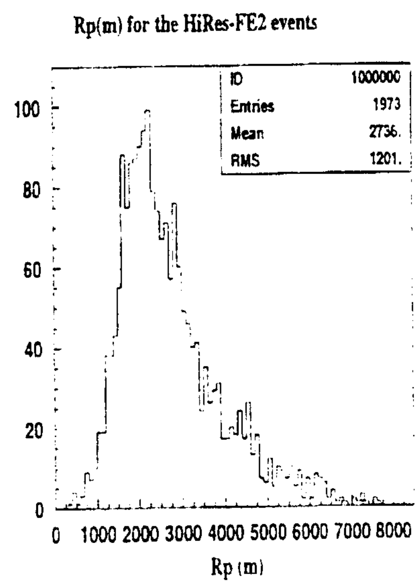

Figure 2: Impact distance distribution for the HiRes and FE2 coincidence events.

to derive the composition. The preliminary results show that the composition is heavy in the energy region of 3 x 1016 to 3 x 1017eV. We hope to present our composition conclusions during the conference.

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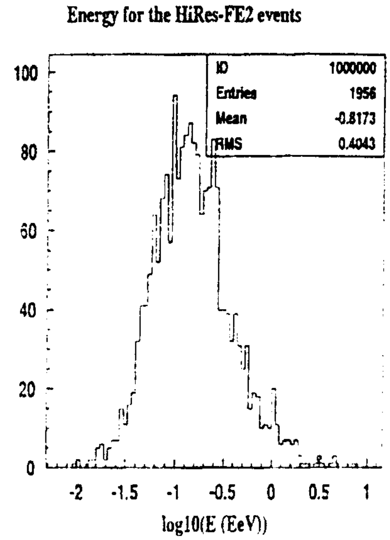

Figure 3: Energy distribution for the HiRes and FE2 coincidence events.

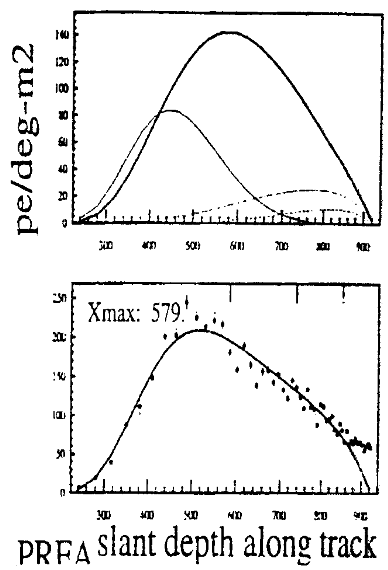

Figure 4: One example of the shower profile seen by Hides and FE2.

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