Update of the measurement of the all-particle cosmic-ray differential spectrum

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The progress since last analysis meeting (22/11/95, see [3]) in the measurement of the all-particle differential spectrum of the cosmic rays are described here. We use two different methods for calculating the primary energy of the cosmic ray: the first one uses the Cherenkov light density at 90 meters core distance (ρ_{90}) corrected with the light radius of the Cherenkov lateral distribution; and the second one the size of the shower (N_e), also corrected with the light radius. Both methods are primary independent.

1 Energy determination with the Cherenkov light

Our usual method of energy determination out of ρ_{90} and the light radius is used (see our Rome contribution[1], our internal reports[2, 3] or [4] for more details).

Since last report we have solved some of our problems. Some work in different points suggested by A. Lindner have also been done:

1. For the energy calibration, we now use our new and more accurate MC library. It encloses proton, helium, oxygen and iron showers with energies up to 4 PeV (zenithal angles 10 and 25 degrees). Therefore, no extrapolation up to Knee energies is required now.

2. We have applied a correction for the error of EGS in the CORSIKA 4.068 code. A complete library for all of the primaries in the energy range 10 TeV - 10 PeV was generated with the aid of the 'thin-sampling' procedure[5] and the correct EGS step. This allowed us to parametrize the effect of this error and correct it in our library (see comments and plots by F. Arqueros of last Analysis Meeting).

3. We have found an explanation for what we called 'depression' in our last reports. R. Plaga suggested that it may be caused by a wrong parametrization of the high gain amplifier. C. Prosch and himself did some measurements at La Palma that showed that the behaviour of the HG amplifier is not at strongly non linear as we assumed in the analysis program (see his contribution to the last Analysis Meeting). At the time it is impossible to analyze all of our data again with the new parametrization, but A. Moralejo has done it for some runs and the depression nearly vanished. Anyway, as the

effect was due to the HG, we can say now that we are free from problems at the energies implied in our Knee studies.

4. The absolute light calibration is nearly stable. We select runs according to their average value of ρ_{90} and of the light radius. Variations greater than $\sim$5% are not allowed. On the other hand, we do not observe changes in the position of the Knee for different subsamples (up to this 5%).

5. We have studied the non-linearities in ρ_{90} at E>1 PeV (as the one shown by A. Lindner in the last analysis meeting). In fig 1, we have plotted ρ_{90} vs the reconstructed energy for runs 1867-1914. We find no evidence for a non linearity in ρ_{90}, at least at the level of that shown by A. Lindner.

As a result of the changes in the MC calibration, the spectral indices have been only slightly altered (see fig 2). The spectral index below the Knee is $\gamma = 2.5 \pm 0.1$ and above the Knee $\gamma = 2.9 \pm 0.2$. The position of the Knee has not changed is also slightly lower ($\sim$ 2 PeV).

2 Energy determination with Ne

We have developed a new method to calculate the primary energy of the cosmic ray independently of the primary nature, out of the size of the shower corrected with the light radius. This method is very similar to the one we use with ρ_{90}. For a given primary energy, showers initiated by different primary particles have different sizes: the heavier the primary, the smaller the size of the shower (see fig 3a), though fluctuations are important. On the other hand, in average, the heavier the primary, the higher the light radius of the Cherenkov light lateral distribution. Therefore, we can use the light radius (r_L) to correct the number of electrons until we get a parameter proportional to the energy independently of the primary nature. We apply a simple correction of the sort we also use for ρ_{90}: $Ne^{corr} = Ne \cdot r_L^{\alpha}$, where α is a parameter we calculate with the MC. We ilustrate this correction in fig 3.

We now apply this method to real data in order to determine the all-particle differential spectrum of the cosmic rays. We select the same runs (1867-2000) we use with the ρ_{90} method. A cut in the age of the shower (s) $0.2 < s < 1.6$ is applied to avoid badly reconstructed events. We show the results on fig 4, where we plot the differential spectrum for $0 < \theta < 18^{\circ}$ showers in the energy range 30 TeV - 30 PeV. We obtain an spectral index of 2.5$\pm$0.1 below the Knee changing to 3.2$\pm$0.2 above a Knee at 2 PeV. The position of the Knee agrees well with that calculated with ρ_{90}.

3 Future prospects

- New data are being analyzed at present in Madrid. We shall have more statistics soon. These new data will be free from the problems in the HG.

- Some checks using the chemical composition can be performed. We can track strange behauviours of the detectors at E>1 PeV by plotting the r_L distributions.

- We will crosscheck the accuracy of the energy determination with both our new methods by plotting one reconstructed energy versus the other for real and MC data. We have performed a preliminary test and they seem to agree well.

- Comparison can also be done with the energy and spectra as calculated using R. Plaga and A. Lindner procedures.

References

[1] J. Cortina et al., Proc. 24th ICRC Rome (1995), vol 1 HE sessions, p 499

[2] J. Cortina, A. Moralejo and F. Arqueros, 'A preliminary measurement of the spectrum of the cosmic rays with AIROBICC', HEGRA internal report 7/6/95.

[3] J. Cortina, A. Moralejo and F. Arqueros, 'Present status of the all-particle cosmic ray differential spectrum', HEGRA internal report 11/22/95.

[4] J. Cortina and F. Arqueros, 'A new method for the determination of the primary energy in the cosmic rays', 'Facultad Ciencias Fisicas Complutense de Madrid' internal report.

[5] C. Portocarrero, private communications. For more details, see Proc. 24th ICRC Rome (1995), vol 1 HE sessions, p 373.

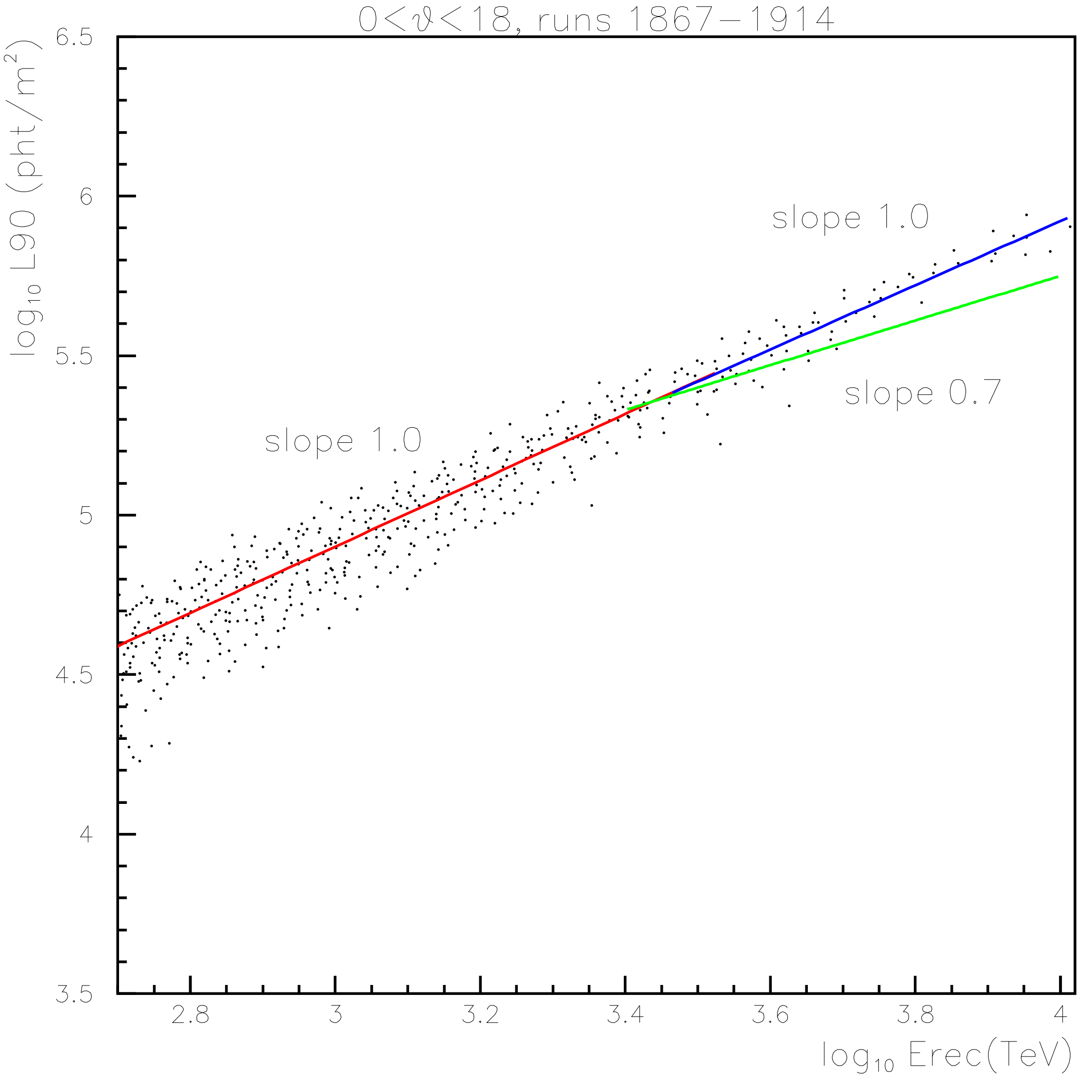


Figure 1: Cherenkov light density at 90m as a function of reconstructed energy for zenith angles smaller than 18 degrees. The points can be fitted to a linear law with slope 1.0 below and above the Knee. As a comparison, we have also plotted a law similar to that shown in the Madrid meeting by A. Lindner (slope 0.7).

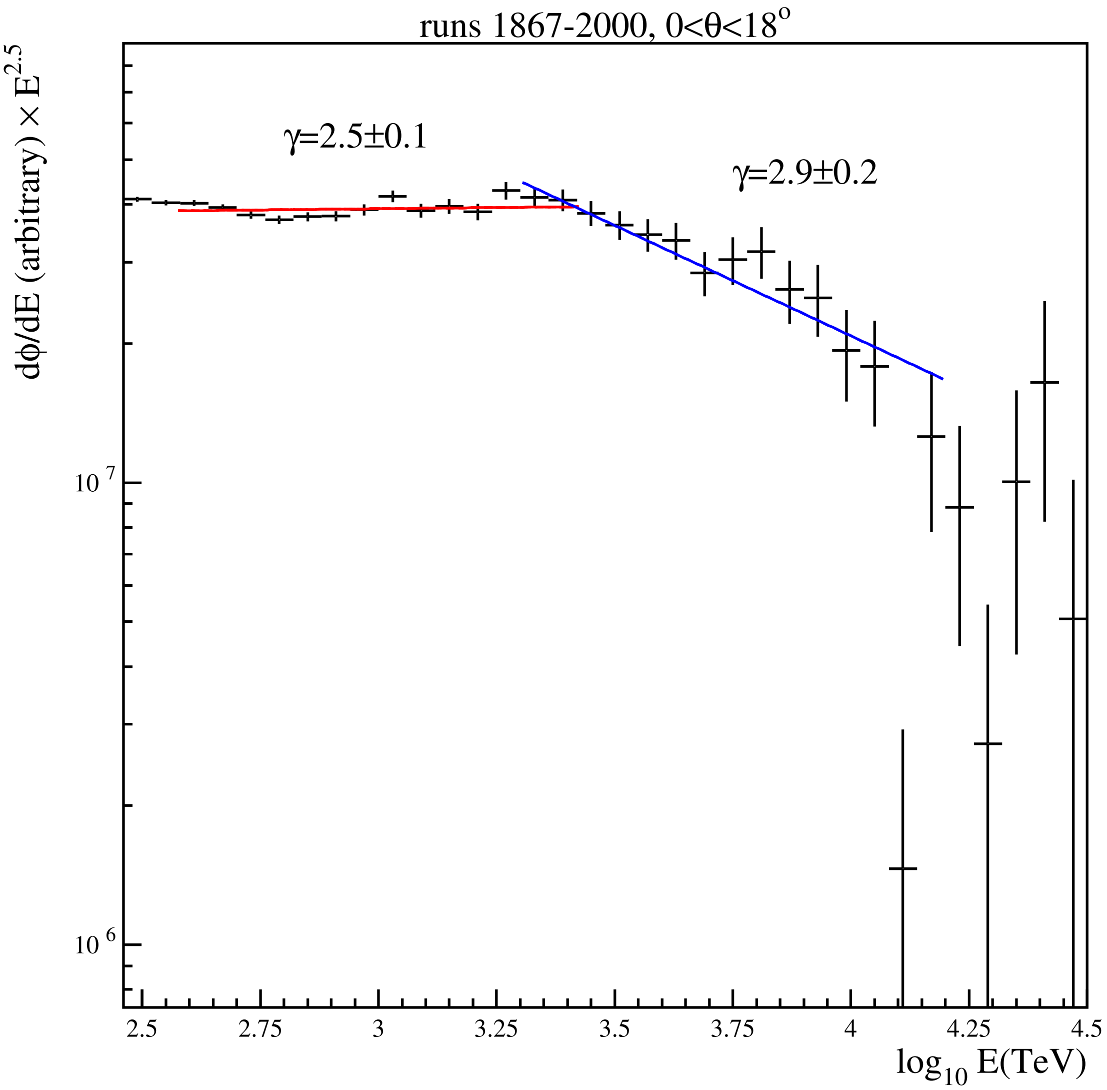
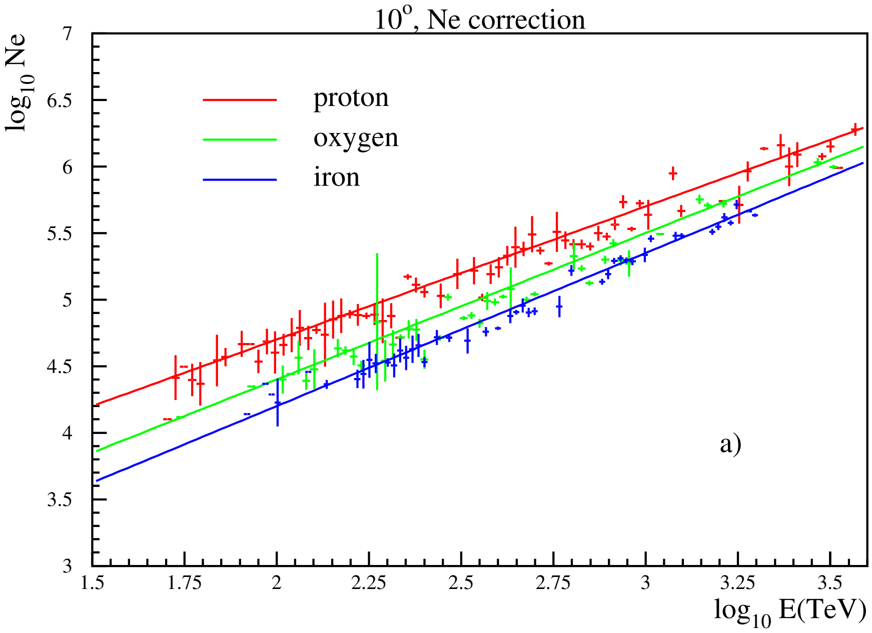


Figure 2: All-particle differential spectrum of the cosmic rays with an energy determined from ρ_{90} corrected with the light radius. Showers are selected in the zenith angle interval 0-18 degrees in runs 1867-2000.



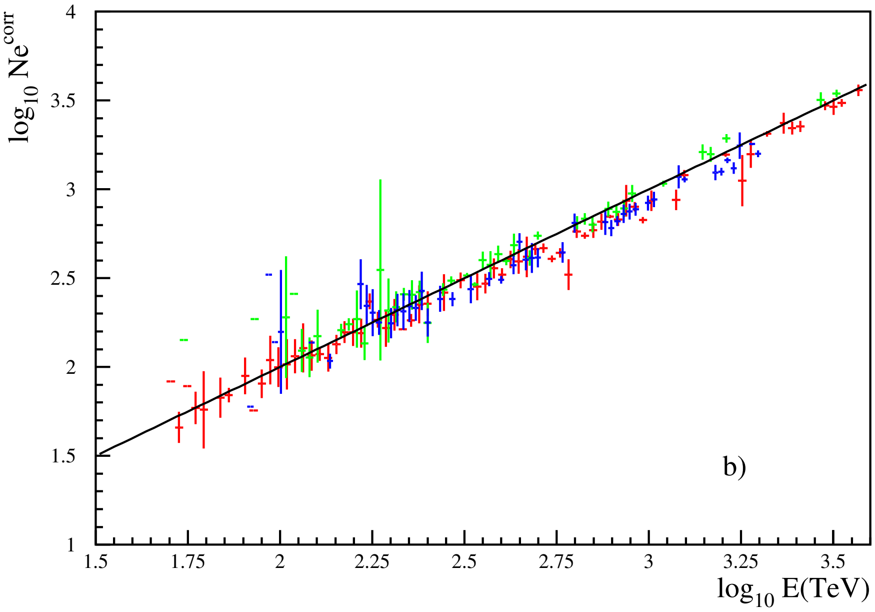


Figure 3: a) Shower size as a function of energy for proton, oxygen and iron initiated showers. b) These same showers after applying a correction to Ne in the form: $Ne^{corr} = Ne \cdot r_L^{1.4}$

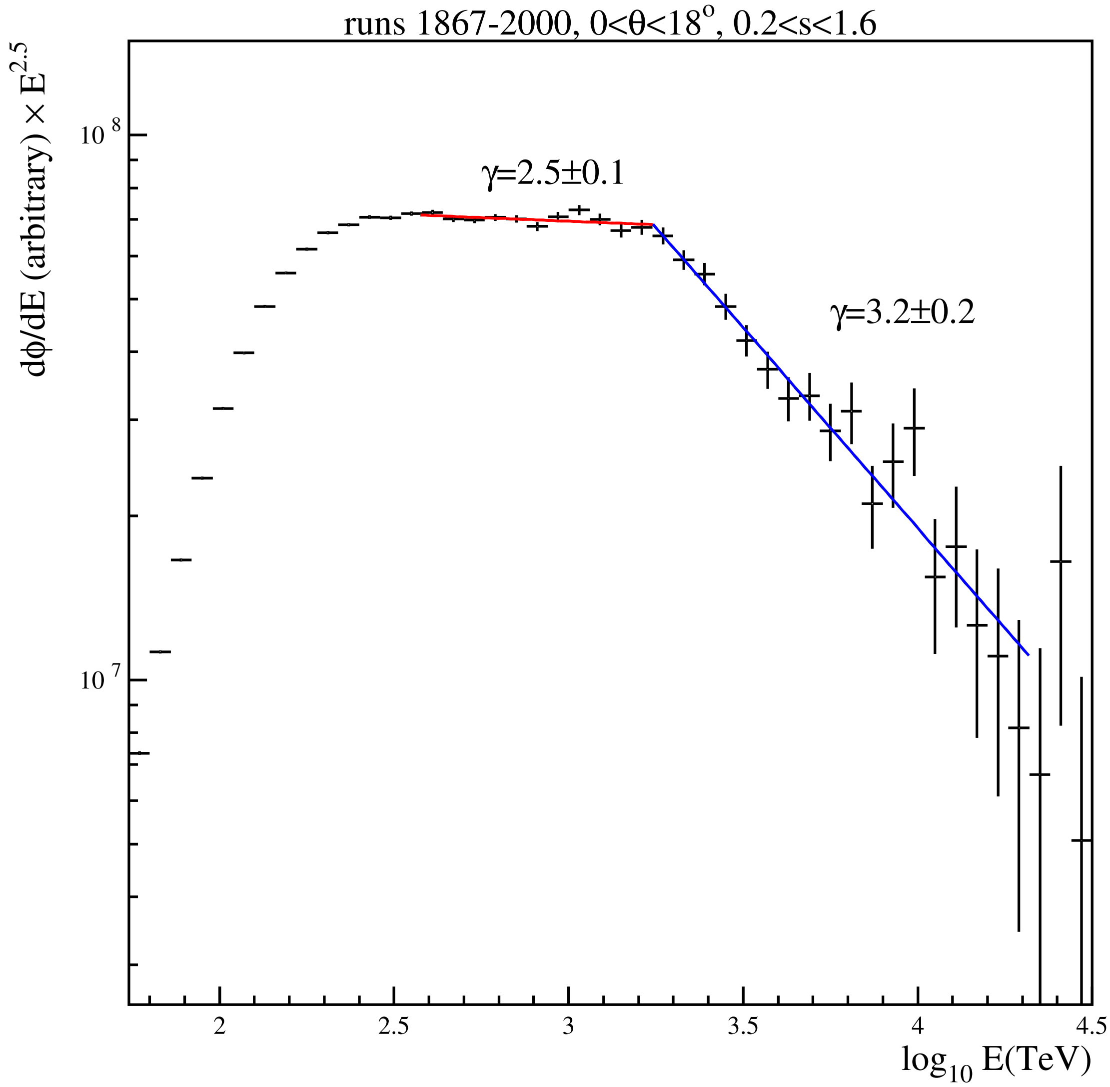


Figure 4: All-particle differential spectrum of the cosmic rays with an energy determined from the size of the shower corrected with the light radius of the Cherenkov lateral distribution. Showers are selected in the zenith angle interval 0-18 degrees in runs 1867-2000.