The decoherence curve for the undeground experiments

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Abstract

The measurement of the number of two detector coincidences as a function of their reciprocal distance is the oldest type of measurements in the investigations of cosmic ray initiated extensive air showers. In CosmoAleph the measurements are made which concern coincidences caused by muons of very high energies: $E_\mu \geq 70 \cdot \sec\Theta$, GeV , where Θ - is a zenith angle of incident coherent muons.

The number of observed coincidences depends on:

– the function of lateral distribution of coherent muons $\rho_\mu(r)$;

– and the total number of muons coming in a coherent group $N_\mu(> 70 \sec\Theta)$.

Additionally, both factors depend on the mass A of the primary nucleus, which has initiated this group of muons.

The question is still open whether the measurements of such coincidences in a form of decoherence curve make it possible to estimate the mass composition of primary cosmic radiation.

1. Introduction

In transparencies 1 and 2 there are shown: the layout of CosmoAleph and the data on the number of registered coincidences while in transparency 3 the points of the decoherence curve are presented in the interval of distances 0 – 250 m (new measurements were discussed by M. Schmelling in this workshop). The points lie along the straight line in a logarithm-linear reference system quite well. The coincidences at great distances between detectors may be coused by very large showers. Lateral density distributions of muons in large showers with total number of $N_e = 2 \cdot 10^7$ are presented in transparency 4 for a series of different energy thresholds: 1 to 100 GeV/c and for the distances in the range of about 30 m to ~1000 m from the EAS axis. The shapes of lateral distributions near the axis for proton – like showers and iron – like showers are presented in transparencies 5 and 6 for the showers with

$\log N_e = 5.1 \div 5.5$ (Kiel data for $E_\mu \geq 2\,\mathrm{GeV}$). A good agreement with the results of CORSIKA programme in Karlsruhe is worth noticing and makes us believe that the results obtained with this programme are correct up to energies about 10^{15} GeV.

2. **An analytical method for the decoherence curve**

The number of expected coincidences may be calculated analytically if assumptions were made that the shape of the muon density lateral distribution $\rho_\mu(r)\,dr$ was constant (transparency 7) and if different slope values of the spectrum $j(>N_\mu) \sim N_\mu^{-\gamma}$ were taken into consideration (transparency 8). The obtained results are presented in transparency 9 for different angles Θ and slopes γ of the spectra. They are in a reasonable agreement with the experimental data.

3. **Full Monte – Carlo Calculations**

The analytical method described above has two disadvantages. Firstly, an assumption on the constant shape of lateral distribution may not be valid. Secondly, it does not take local fluctuations into account. The fact that the shape of the distribution depends on the threshold energy of muons as well ason the nuclei mass A can be observed in transparencies 10 and 11. It should be remembered that this shape is also dependent on the primary nucleus energy. The distributions can be aproximated by a curve of a universal shape (see transparency 11). The factors α and β become then energy and mass functions.

However, when using the CORSIKA programme in measurements of decoherence curve, it is practically impossible to notice and observe fluctuations because the programme is too slow. Therefore, a special programme : JOLKA, based on UA5 generator for fast calculations was introduced. The generator was checked for the data with $N_\mu > 200$ GeV and the results are shown in transparency 12. In transparency 13 a comparison between the experimental and the JOLKA results is presented for the showers with $N_e = 1.1 \cdot 10^5$ and a high energy threshold for muons $E_\mu = 52.7\,\mathrm{GeV}$.

There again confirmation is obtained for the CORSIKA programme to predict correctly the number of muons and their lateral distributions up to about 10^{15} eV.

Monte Carlo method is a very simple procedure. Groups of muons, choosen according to their angular distributions and energy spectra, are ‘thrown’ on the investigated area where the detectors are located (transparency 14). Milions of showers are searched to find those which have given coincidences (transparency 15). The results obtained both with the full Monte Carlo simulations and with the fast simulation are presented in transparency 16. It can be seen that they sufficiently explain the experimental results.

4. Discussions and Summary

When looking at the material presented so far, one may get impression that we can understand our measurements in CosmoAleph up to 250 m. They give an significant contribution to our understanding of high energy muons in cosmic radiation. The situation is, however, not so clear:

a) the new CosmoAleph results on the number of coincidences at distances between detectors greater than 250 m differ from the expectations (see M. Schmelling)

b) the MGU results for large showers with $N_e = 10^6$ are not consistent with expectations, either (transparency 17).

Both these results have one in common: they mean that muon densities at larger distances from the shower are greater then expected. Whether such situation should be connected with a nuclear interactions model or with chemical composition of primary cosmic radiation, is a question still to be answered.