Detection, analysis and interpretation of the emulsion chamber signal

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Abstract: It was reported that the discrepancy between results of different balloon-borne experiments with calorimeter-type emulsion chambers (JACEE and RUNJOB) were critical for understanding the origin of cosmic rays and the acceleration mechanisms in the Galaxy. Based on our previous study of the emulsion chamber detectors, we search for mundane scenarios that could lead the analysis astray. We look for a consistency among different kinds of emulsion chamber observables. We show that our analysis is congruent with the reported experimental data. It can be seen that contrasting assessments of experimental signal observed by RUNJOB can lead to variations in conclusions. We can deduce that the contradictions between different observations appear only at the stage of data interpretation.

Introduction

We test the hypothesis that the most likely origin of the change in conclusion on primary mass composition was not of astrophysical origin, but due to the methodical peculiarities in one particular experiments. We are focusing on what can be learned from observations with instruments that return vast quantities of data. It is important to recognize critical points in the experimental procedure.

Corrections and data

The RUNJOB experiment has two objective obstacles - a large background [2] and not negligible effect of the atmospheric depth. One can notice the effect of detection threshold and detection efficiency in different observations from Figure 1. The absolute intensity is obtained [2] using the relation \( I = \frac{\sum N \times e^{-\delta}}{\sum \eta \Omega T e^{-t/\Lambda}} \), where \( I \) is the absolute intensity, \( N \) - the observed number of primary, \( \eta \) - the detection efficiency, \( S \) - the geometrical chamber area, \( \Omega \) - the effective solid angle, \( t \) - the effective depth of observation, and \( \Lambda \) - attenuation length of the primary in the atmosphere. The factor \( e^{-\delta^2} \) takes into account the fluctuation of the energy determination where \( \delta = (lo10/\sqrt{2}) \alpha \sigma, \alpha \) is the index of a power-law spectrum, and \( \sigma \) is the dispersion of the energy resolution. There were several reports on estimation [10, 2, 1, 8] of the RUNJOB detection efficiency (the difference can be \( \sim 10 - 30\% \)). This is important for evaluation of systematic differences with other experiments.

The energy spectra of cosmic ray primaries

Figures 2-6 present the energy spectra of cosmic ray primaries obtained in different observations. One can conclude that the data scattering is most likely due to the limited statistics, accuracy of the corrections, and applied methods. To show the importance of statistical errors in present case, one can use method from [9]. For instance, RUNJOB reported two “final” sets: \( \beta_p = 2.74 \pm 0.08 \), \( \beta_{He} = 2.78 \pm 0.20 \) [3] and \( \beta_p = 2.78 \pm 0.06 \), \( \beta_{He} = 2.74 \pm 0.12 \). The actual statistical (see Table 3 [11] for \( N \)) errors (\( \sigma \sim \beta/\sqrt{N} \)) are large \( \sigma = 0.2 - 0.3 \) for proton and He, and \( \sigma \approx 0.4 \) for heavy primaries. If errors are large, the similarity of indices would not mean that the spectra were parallel. This accuracy is not enough to detect possible differences (if they exist) of the order \( \Delta\beta_{p,He} \approx 0.1[14] \).
Comment on RUNJOB 1996

Change in conclusions on primary mass composition occurred after the RUNJOB 1996 flights, based on two chambers, RUNJOB 1996-3 and RUNJOB 1996-4. One can notice from Table 1 that the fourth block from RUNJOB 1996-IV had smaller statistics (see also [12]). The effect depends on applied methods. Using chamber information from [11, 1], one can estimate the contamination effect for nucleons (Fig. 7).

Figure 1: Observation of showers detected in the calorimeter. Estimations are made on the basis of data from [10]. Squares with crosses: RUNJOB 1995 (4 blocks). Rhombuses: RUNJOB 1996 (4 blocks). Solid circles: RUNJOB 1997-5b (1 block). Solid stars: RUNJOB 1999-10 (2 blocks). Open stars: RUNJOB 1999-11 (2 blocks). The apparent difference can be explained by the detection conditions and the detection efficiency [10, 2].

Conclusions

We assume that the expert conclusion on the same data set can be at variance among different scientists, and interpretations can be re-evaluated and re-examined. The contradictions in the individual conclusions on mass composition are likely to be due to the problems related to the identification of particles, to the procedure of the signal evaluation, and to the underestimation of statistical and systematic errors. The RUNJOB experiment helps us to build the knowledge to generate the next set of hypotheses and experiments.

References


[3] Derbina, V. A. et al. (The RUNJOB collab-
Figure 3: Helium energy spectra. Compilation of measurements from the RUNJOB observations. Marks are the same as in Fig.2. Solid line: the PR model [12]. Dotted line: the HJ model [12].

Figure 4: CNO energy spectra. Compilation of measurements from the RUNJOB observations. Marks are the same as in Fig.3.


Figure 5: NeMgSi energy spectra. Compilation of measurements from the RUNJOB observations. Marks are the same as in Fig.3.


Figure 6: Iron energy spectra. Compilation of measurements from the RUNJOB observations. Marks are the same as in Fig.3.

Figure 7: Path length distribution in proton m.f.p. for proton events in target and upper calorimeter in the RUNJOB 1996 chamber. Solid line: expected distribution of showers from proton primaries. Dotted line: expected distribution of proton primaries contaminated with secondary nucleons from interaction of heavy primaries with air nuclei. The limited statistics would make signal more difficult to detect.