The Cosmic Ray All-Particles Spectrum from the NUCLEON Experiment in comparison with EAS data

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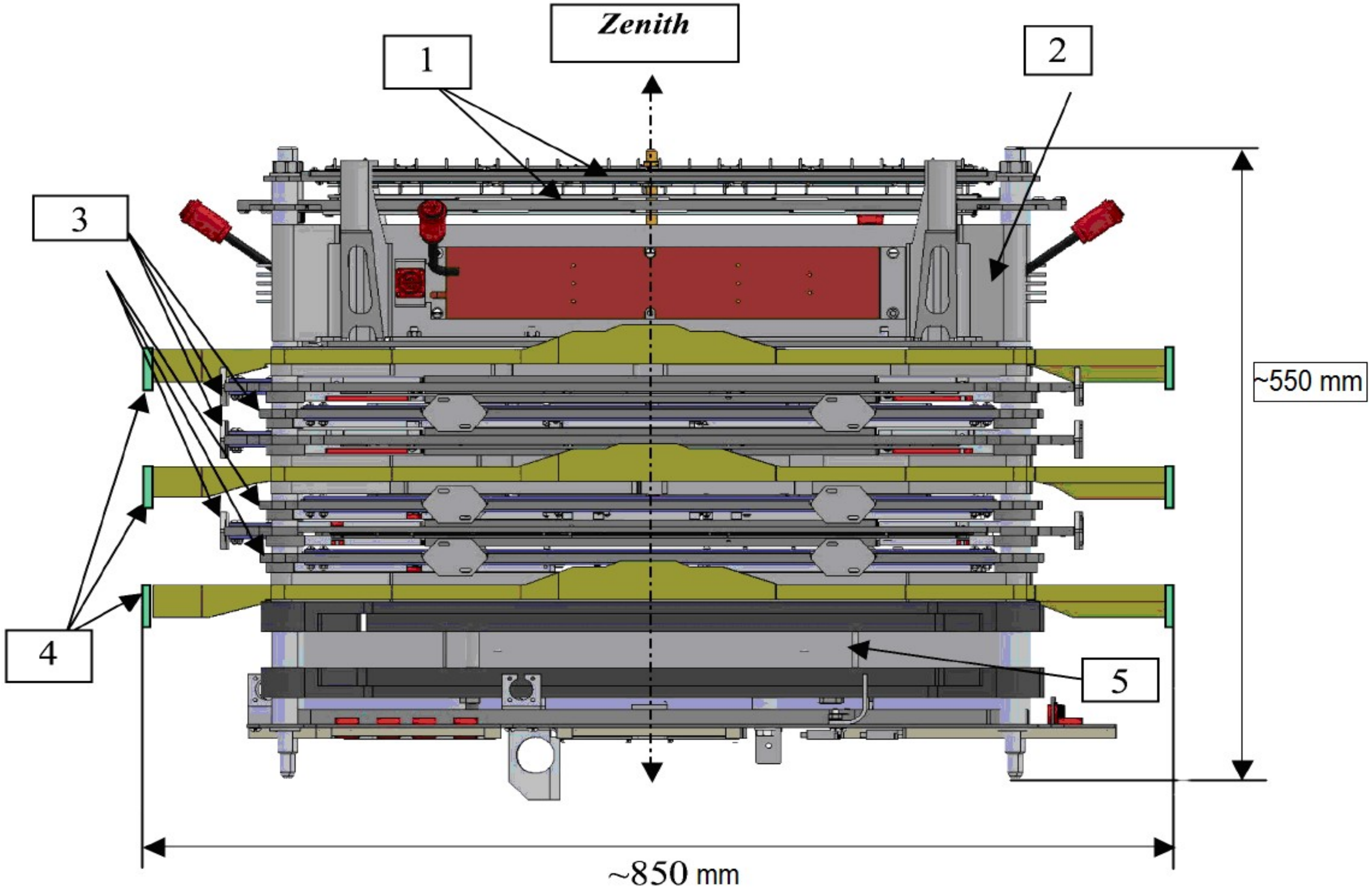
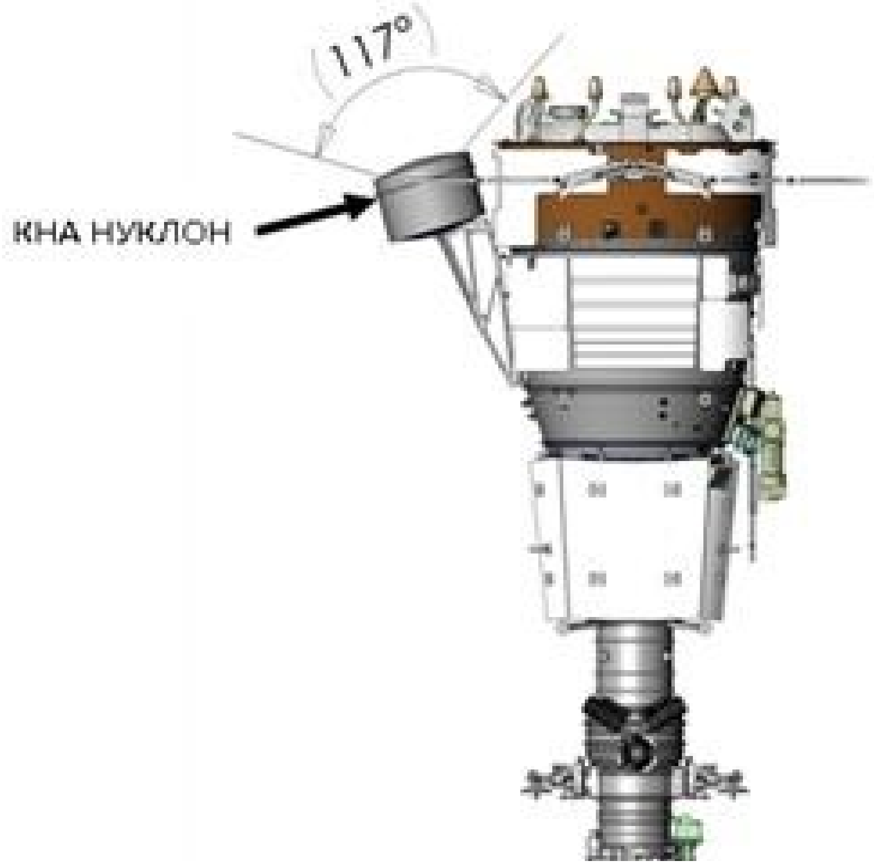
The cosmic ray all-particles spectrum is a very important result obtained by the NUCLEON space experiment. This spectrum was directly measured up to energies near 500 TeV. The ground-based experiments provide very large statistics but their results depend on applied models. The NUCLEON experiment allows to compare results of direct measurements and data of ground-based experiments. The all-particles spectrum is presented. The shape of this spectrum differs from the power-law dependence. This difference is caused by the universal «knee» found in the rigidity spectra measured by the NUCLEON experiment. The obtained all-particles spectrum is well consistent with the data from ground-based experiments HAWC and TAIGA.

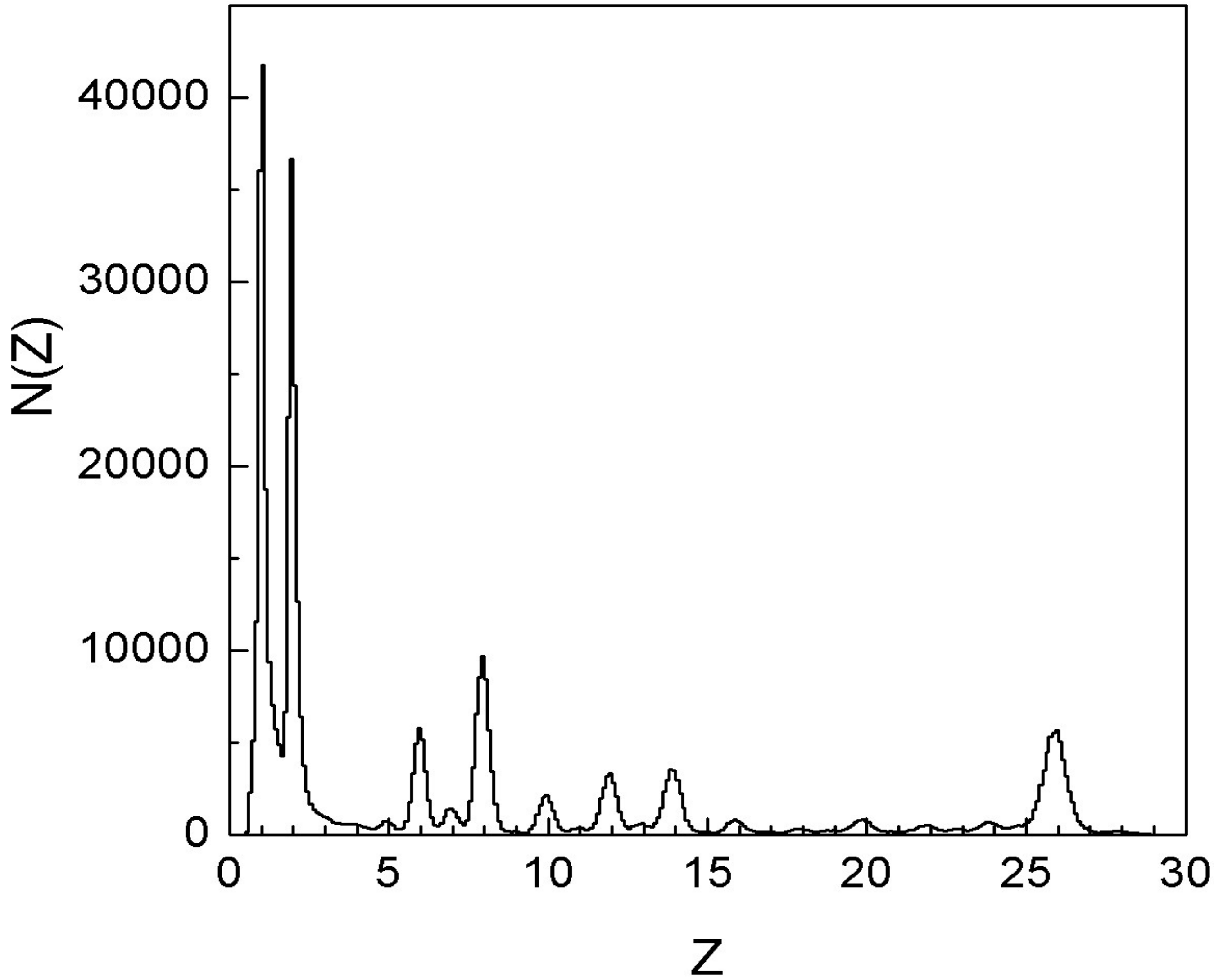
The NUCLEON device consisted of the charge measurement system (1), carbon target (2), energy measurements system (3), trigger system (4), calorimeter (5). The charge measurement system included four silicon pad layers. The energy measurement system included six layers of silicon microstripe detectors. The energy measurements were based on the new kinematic method KLEM (Kinematic Lightweight Energy Meter). The geometrical factor was near 0.2 m^{2}sr for the KLEM system and near 0.06 m^{2}sr for the calorimeter.



The NUCLEON device was installed onboard the Russian satellite RESURS-P №2. The circular orbit was solar-synchronious with inclination 97.276 and mean altitude 475 km. The satellite was launched in 26 December 2014 and operated for three years. The main aim of the experiment were measurements of charge composition and energy spectra of cosmic rays at 2-500 TeV energy range.

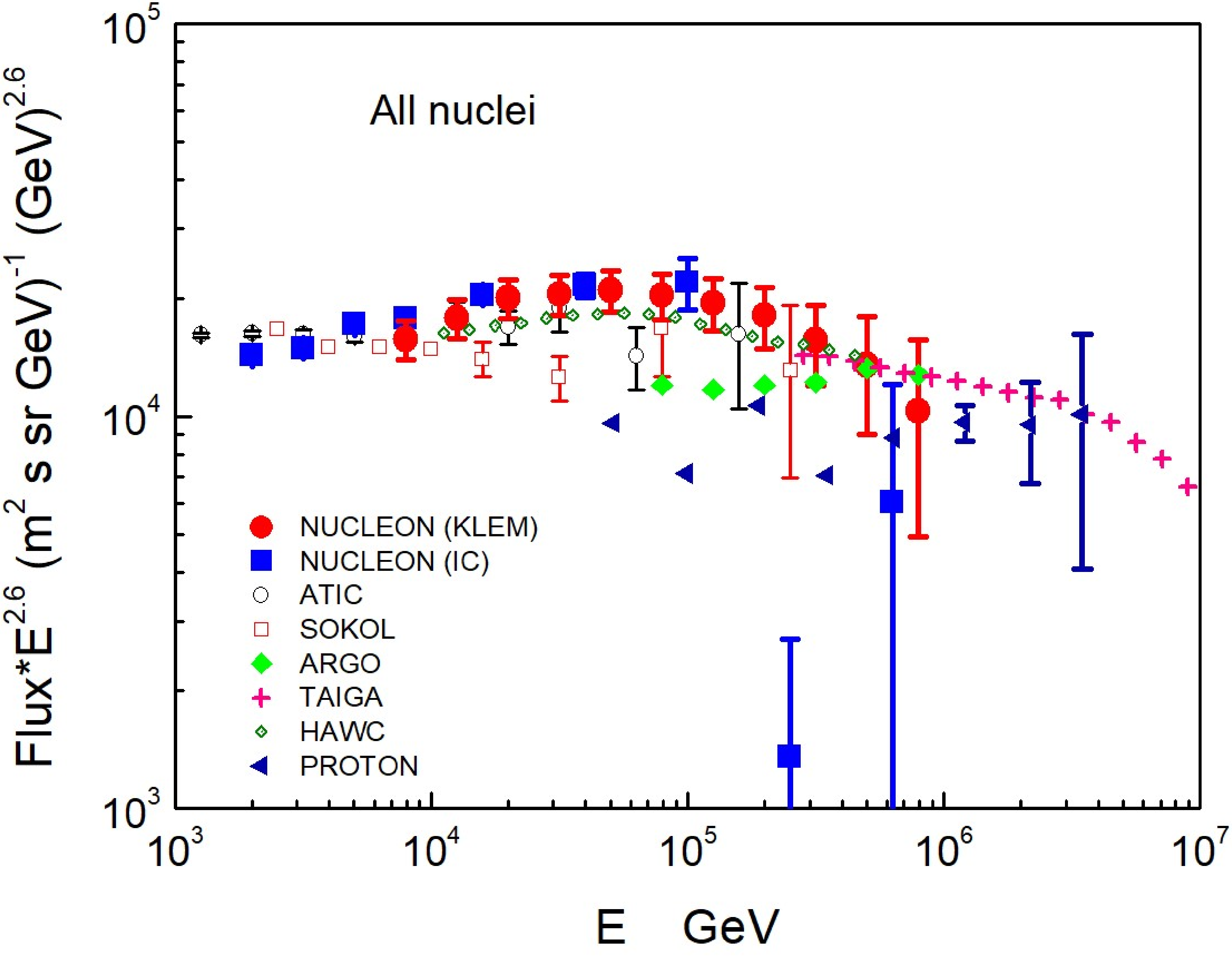


The charge distribution



- The all-particles spectrum was directly measured up to energies near 500 TeV by the NUCLEON experiment.
- We have measured the charge composition too
- Measurements at higher energies are limited by statistics.
- The results of ground-based experiments (HAWC, TAIGA, ARGO-YBJ) include all-particles spectrum with large statistics up to very high energies.
- It is possible to compare results of direct and ground-based experiments

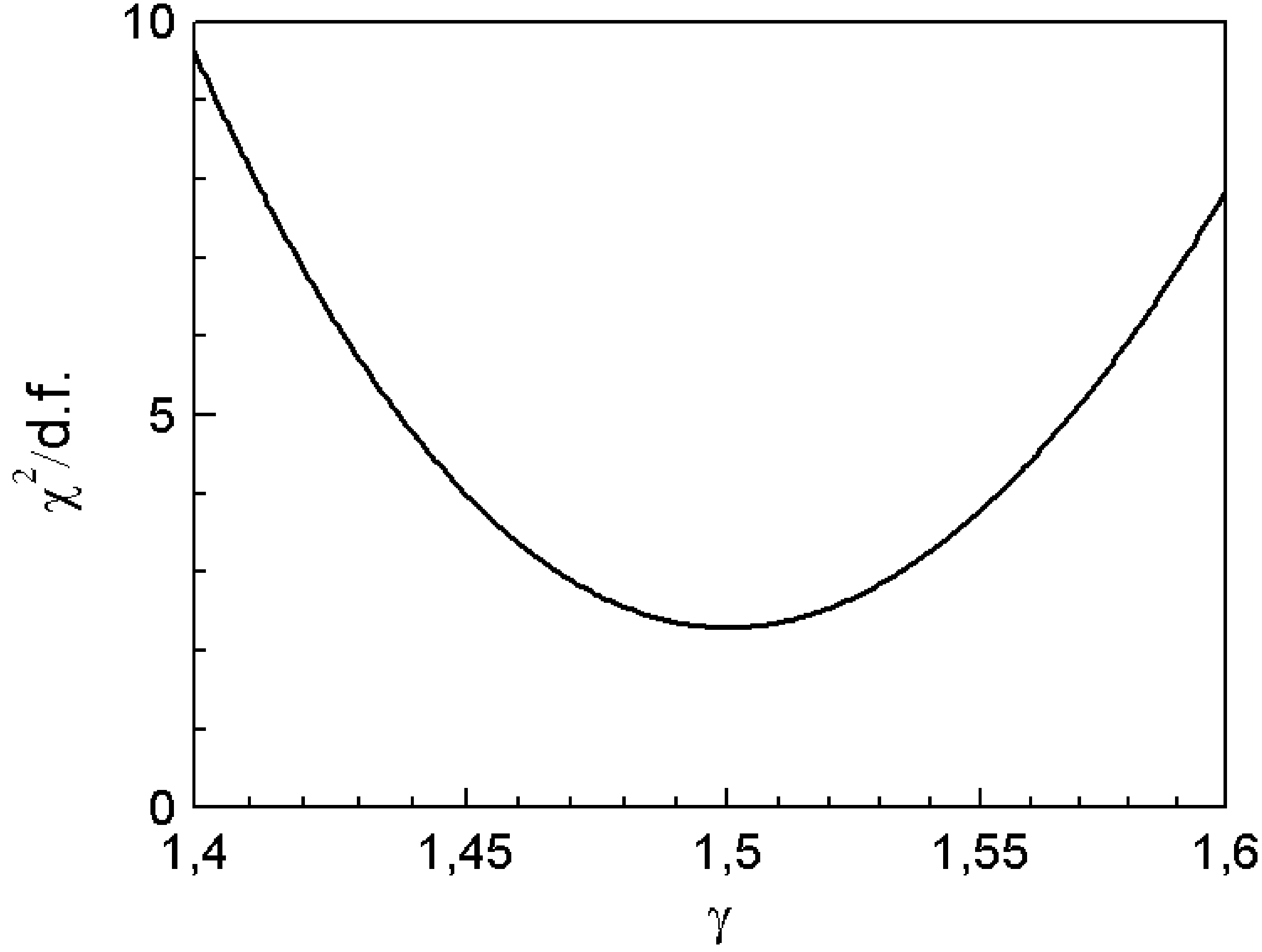
All-particles spectrum



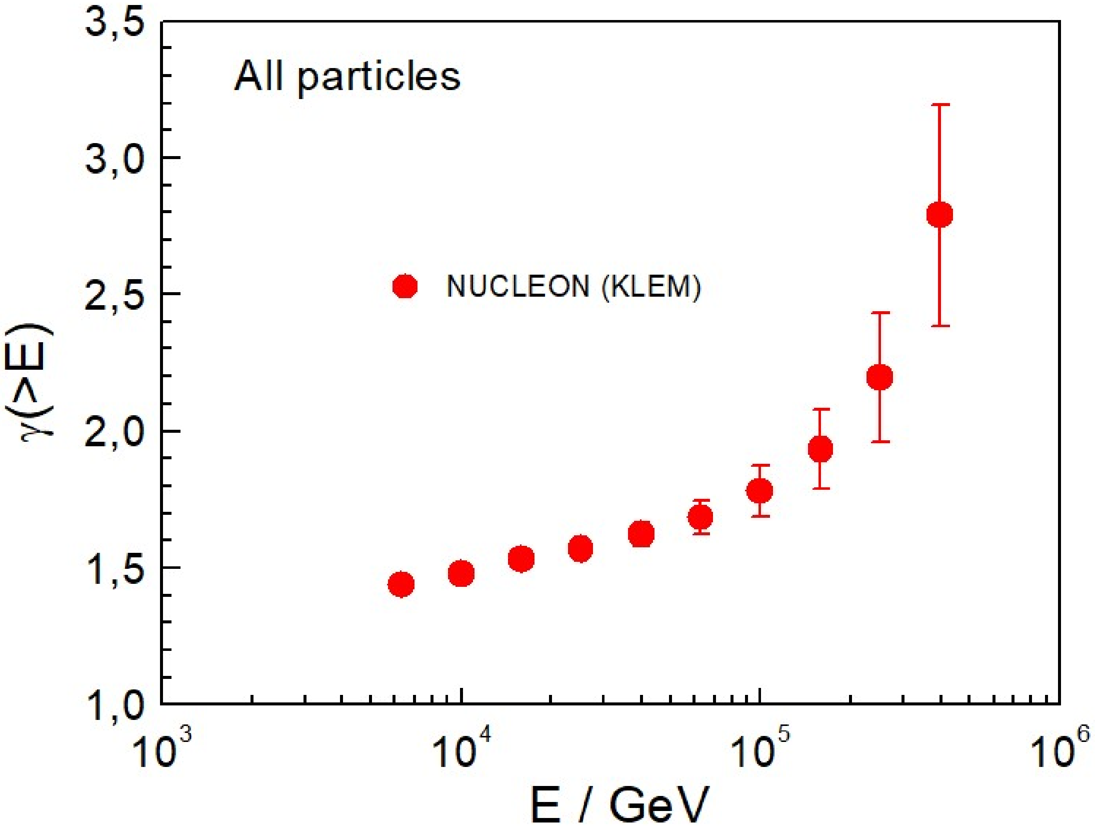
Main properties of the spectrum

- Spectra measured by the NUCLEON and HAWC and TAIGA experiments are very close.
- Spectra are not exactly power law. What is the reason of this effect? The difference of the spectrum from the power law can be evaluated by chi-square test

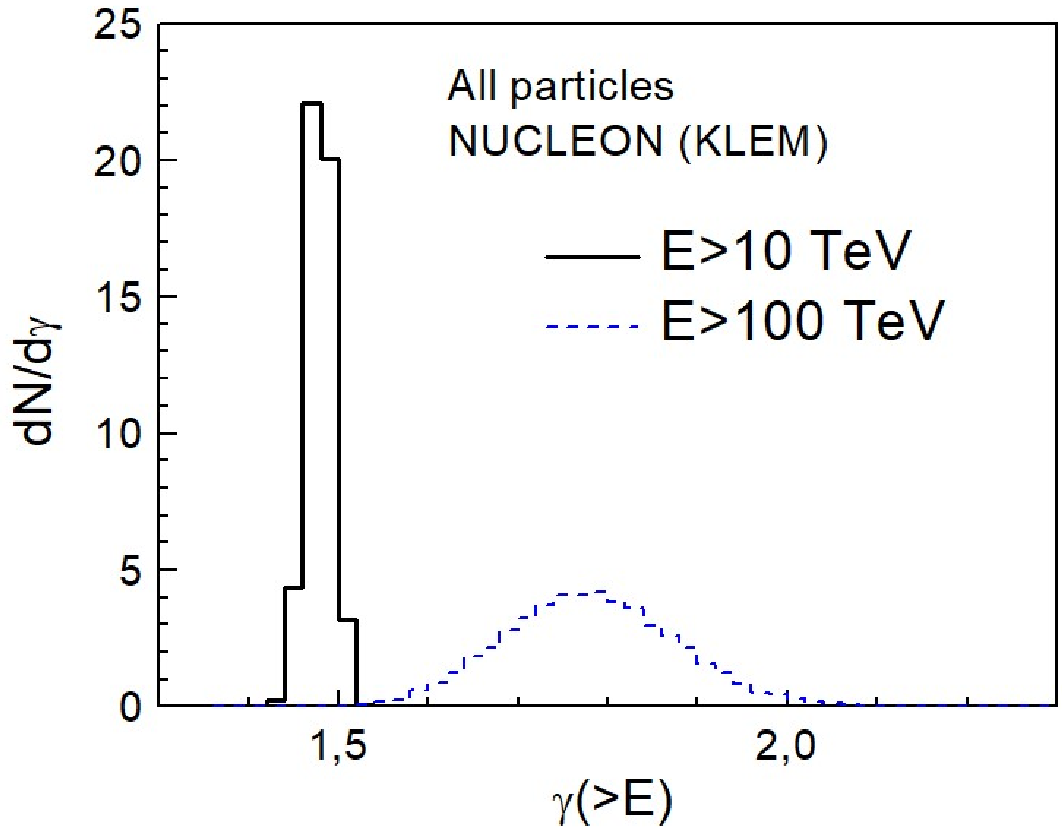
The χ2 per degree of freedom dependence on the spectral index γ. min(χ2)=2.21



The spectral index dependence on energy threshold, $\gamma(>10\ TeV)=1.48\pm0.014$ $\gamma(>100\ TeV)=1.78\pm0.096$. 3σ

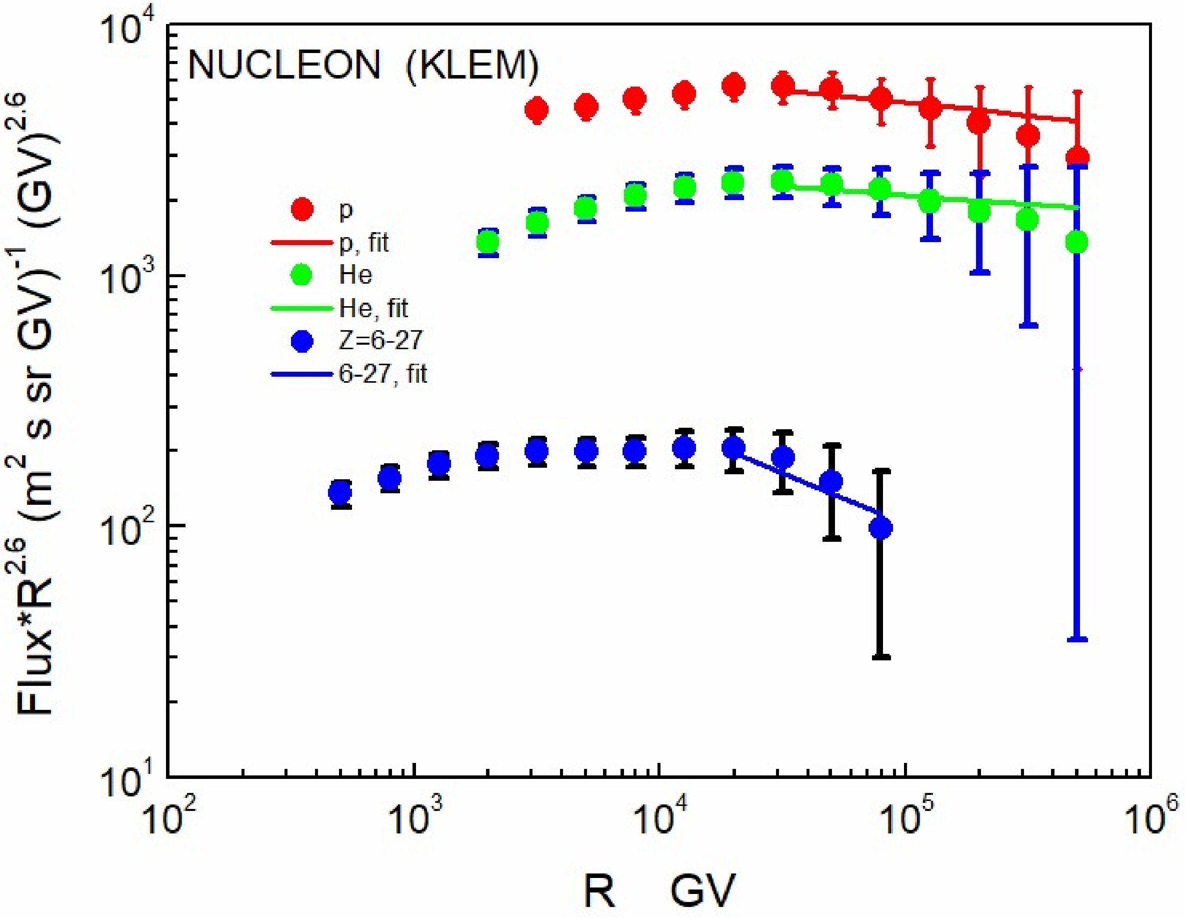


Reconstructed spectral index distributions obtained by the deconvolution



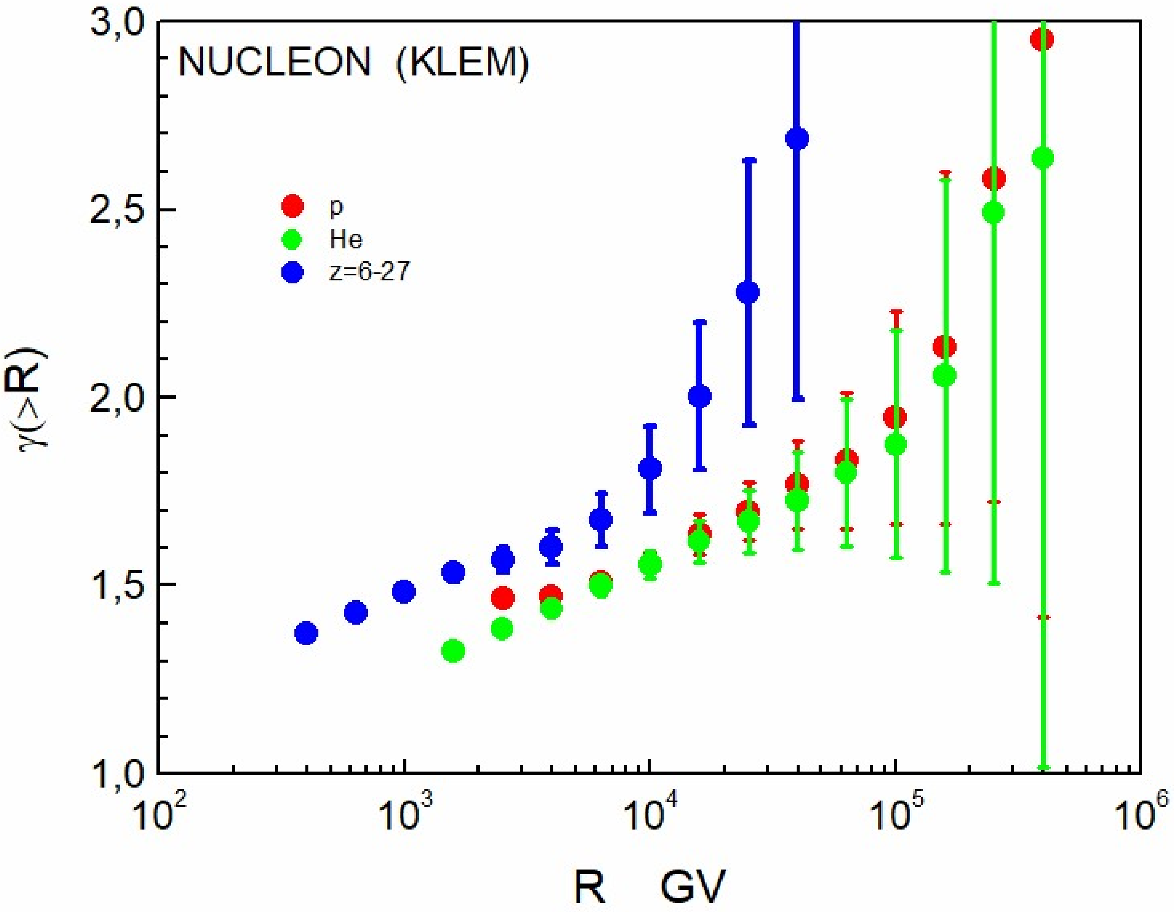
The universal knee in the magnetic rigidity spectra.

E. Atkin, V. Bulatov, V. Dorokhov, N. Gorbunov, S. Filippov, V. Grebenyuk, D. Karmanov, I. Kovalev, I. Kudryashov, A. Kurganov, M. Merkin, A. Panov, D. Podorozhny, D. Polkov, S. Porokhovoy, V. Shumikhin, A. Tkachenko, L. Tkachev, A. Turundaevskiy, O. Vasiliev, A. Voronin. New universal cosmic-ray knee near a magnetic rigidity of 10 TV with the NUCLEON space observatory. *JETP Letters*, 108(1):5–12, 2018

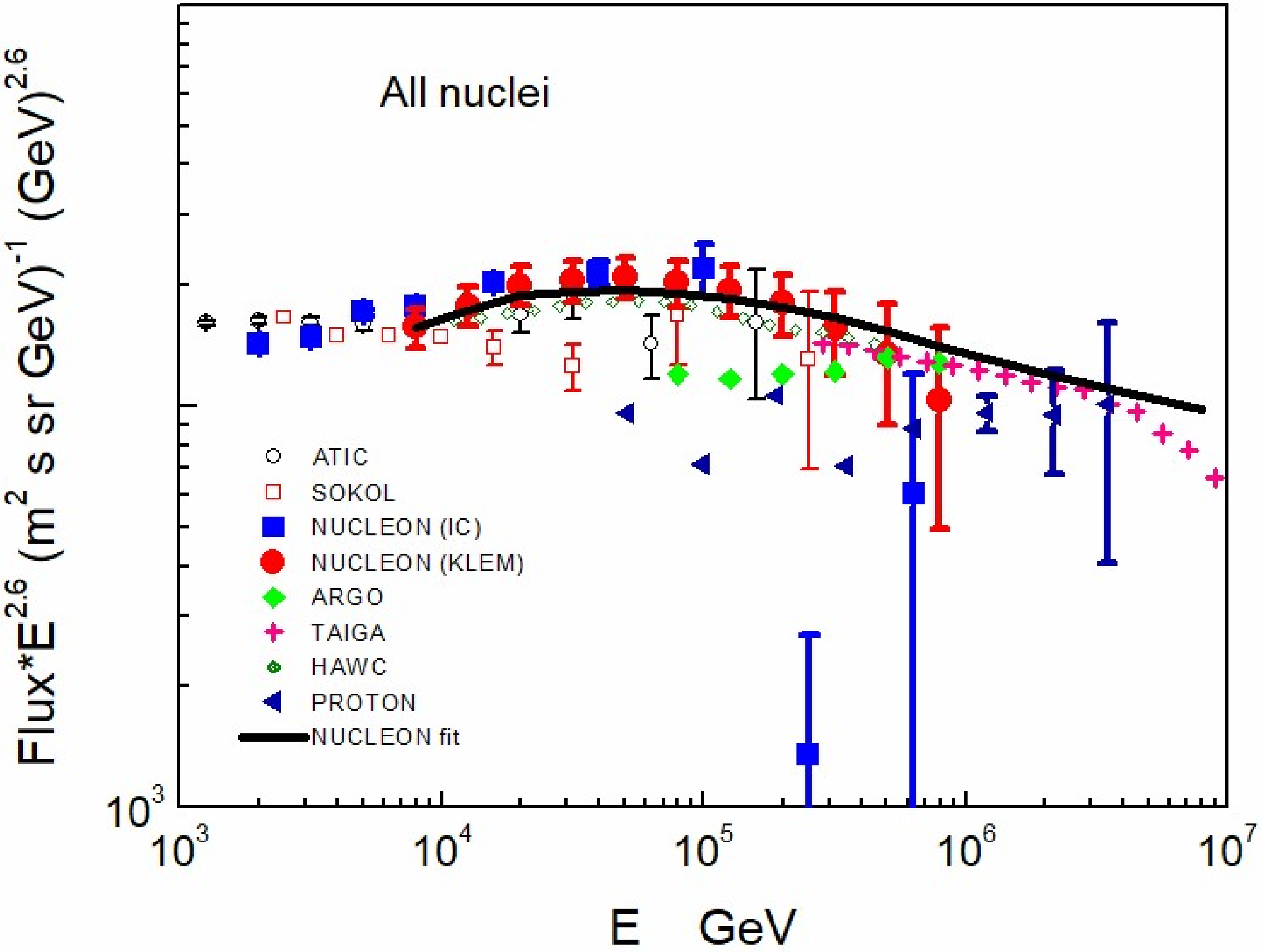


Indices of rigidity spectra

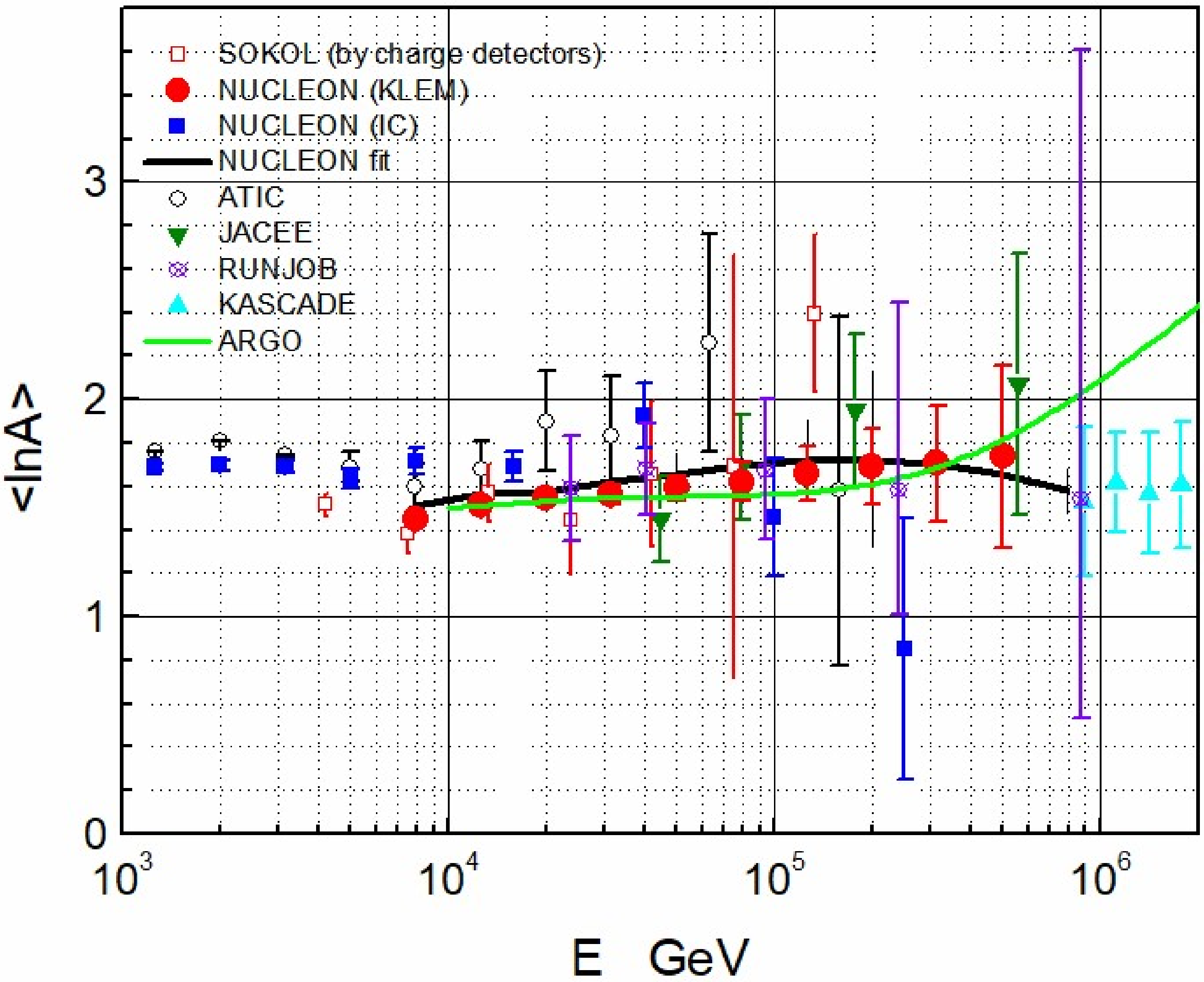
$$\gamma(R > R_t) = 1 / < \ln(R / R_t) >$$



The extrapolation of the spectrum



The mean logarithm of the mass number



SUMMARY

- The energy spectrum of all particles was in good agreement with the data from terrestrial experiments.
- There were notable differences from the power law.
- The values of the mean logarithm of the mass number confirm the ARGO data