PROCEEDINGS OF SCIENCE

Energy spectra of protons and helium nuclei measured by the cosmic ray NUCLEON experiment

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The NUCLEON satellite experiment is designed for direct measurements of the energy spectra of cosmic-ray nuclei and the chemical composition (Z=1−30) at an energy range up to 1000 TeV. The energy spectra of protons and helium nuclei are presented. Some spectral peculiarities were found. The differences of protons and helium spectra are investigated.

35th International Cosmic Ray Conference - ICRC2017
10-20 July, 2017
Bexco, Busan, Korea

[1]Speaker

PoS(ICRC2017)212

1. Introduction

The “knee” energy range - 10^{14} - 10^{16} eV - is a crucial region for the understanding of cosmic rays, acceleration and propagation in the interstellar medium. It is important to obtain more data with elemental resolution.

There are no direct measurements of cosmic ray nuclei spectra in the “knee” energy range. The main information about cosmic ray nuclei at 10^{12} - 10^{14} eV has been obtained by balloon (ATIC[1,2], CREAM [3,4], TRACER [5]) and satellite (AMS02 [6,7] for lower energies, SOKOL [8]) experiments. The space experiments CALET [9] and DAMPE [10] are performed now. However, additional direct measurements at energies of up to 1000 TeV are necessary.

The NUCLEON satellite experiment is designed to directly investigate, above the atmosphere, the energy spectra of cosmic-ray nuclei and the chemical composition from 2 to almost 1000 TeV (before the “knee”). The highest measured energy is equal to 900 TeV.

2. The NUCLEON design

The NUCLEON device [11-16] was designed and produced by the collaboration of SINP MSU (the main investigator), JINR (Dubna) and a number of other Russian scientific and industrial centres. Currently, it is placed on board the RESURS-P №2 satellite. The spacecraft’s orbit is a Sun-synchronous one, with an inclination of 97.276° and a middle altitude of 475 km. The satellite was launched on 26 December, 2014.

Scientific objectives and detection techniques determined the detector design. The general composition of the NUCLEON apparatus is presented in fig. 1.

The new Kinematic Lightweight Energy Meter (KLEM) technique was applied. The primary energy is reconstructed by registration of spatial density of the secondary particles. The particles are generated by the first hadronic inelastic interaction in a carbon target. The equivalent thickness of the carbon target is equal to 0.23 proton interaction lengths.

A new energy measurement method, KLEM (Kinematic Lightweight Energy Meter), was proposed in [17-21]. The technique can be used over a wide range of energies (10^{11}–10^{16} eV) and gives an energy resolution of 70% or better, according to simulation results.

3.Experimental results

The energy spectra of protons and helium nuclei are presented in fig.2. There is a hint to a peculiarity of proton spectrum at 30-50 TeV. However the statistical significance is small, near 2 standard deviations.

More significant effect is the possible break of spectra. The proton spectrum breaks at energy near 10 TeV. The break of the helium spectra is near 20-30 TeV. It can be assumed that spectra of different components break at the constant rigidity near 10 TV.

There is an astrophysical model predicted these spectral peculiarities [22]. This model is based on assumption of presence of three types of cosmic rays sources.

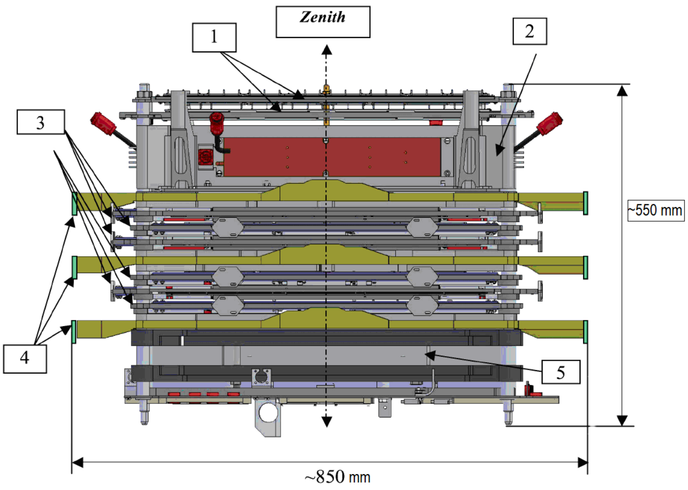

Figure 1: Simplifed layout of NUCLEON experiment scientifc equipment. (1) - two pairs of charge measurement system planes; (2) - carbon target; (3) - 6 planes of energy measurement system utilizing the KLEM technique; (4) - 3 double trigger system planes; (5) – calorimeter.

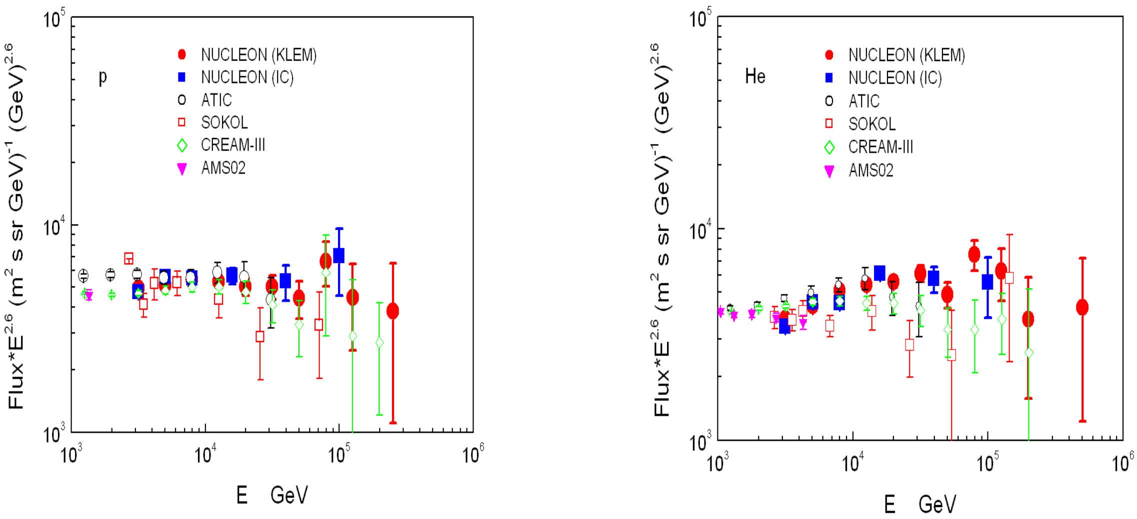

Figure 2. Protons (left) and helium (right) spectra

The ratio of protons and heluum spectra is presented in fig.3 as function of energy per particle and energy per nucleon. This figure confirmes the difference of proton and helium spectra. The helium spectrum is more hard at energies more than 4 TeV per particle.

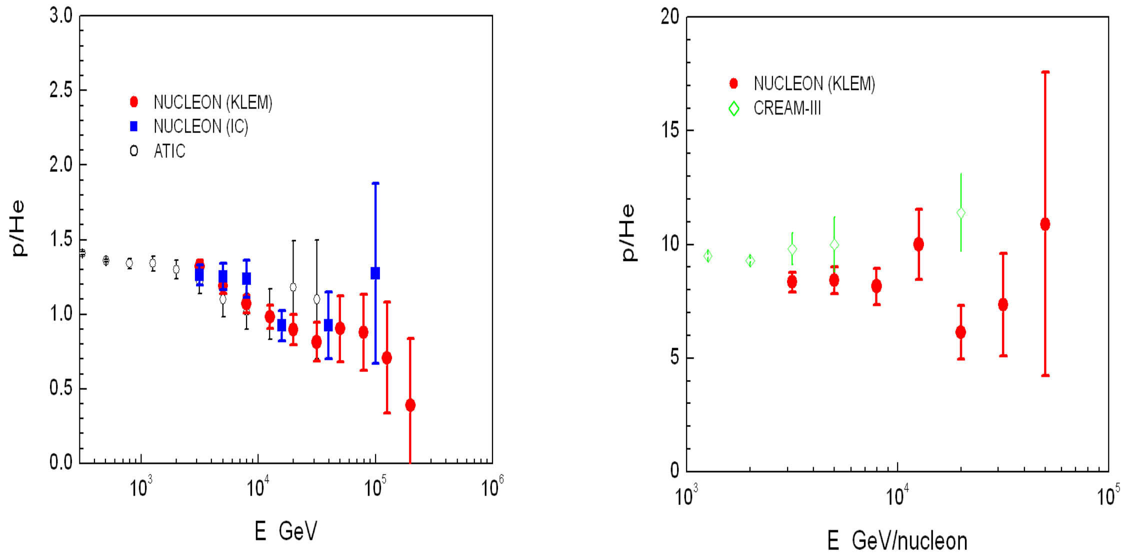

Figure 3. Protons to helium ratio as function of energy per particle (left) and energy per nucleon (right)

4.Conclusion

The obtained energy spectra show good consensus on two different techniques of energy measurements. Thus, operability of a new KLEM technique in the wide energy range is confirmed. The protons and helium spectra are different. The helium spectrum is harder than protons one at energies more than 4 TeV per particle.There are hints to peculiarities of proton and nuclei spectra. There are signs of a break of spectra at rigidity near 10 TV. These effects can possibly be explained by the presence of different sources of cosmic rays.

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