PROCEEDINGS OF SCIENCE

Preliminary results of the cosmic ray study in the NUCLEON space experiment

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The orbital NUCLEON detector was launched at 26 December 2014 for 5 years of data taken. The experiment is designed to measure cosmic ray energy spectrum and charge composition at 100 GeV – 1000 TeV and Z = 1-30 respectively. The NUCLEON apparatus structure, methods of primary cosmic ray charge and energy measurements are described. Preliminary results of the measurements of the cosmic nuclei energy spectra and the charge composition are presented from the first year and a half of data taking from orbit.

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PoS(ICHEP2016)792

1. The NUCLEON experiment aims and its design

The NUCLEON satellite experiment is designed to investigate directly the energy spectra of cosmic ray (CR) nuclei and the CR composition before the “knee” from 100 GeV to 1000 TeV. The additional aim is the CR electron spectrum measurement from 20 GeV to 3 TeV. The “knee” energy range, $10^{14} - 10^{16}$ eV, is a crucial region for the understanding of the CR acceleration and propagation in the interstellar medium. It is important to obtain more data with elemental resolution since the “knee” region is interesting for astrophysics.

The NUCLEON device was designed and produced by a collaboration of SINP MSU (main investigator), JINR (Dubna) and some other Russian scientific and industrial centers. It is placed as an additional payload on board of the RESURS-P №2 satellite (left of Figure 1) that was launched at 26 December 2014. The spacecraft has a sun-synchronous orbit with an inclination of ~97 degrees and a middle altitude of ~475 km.

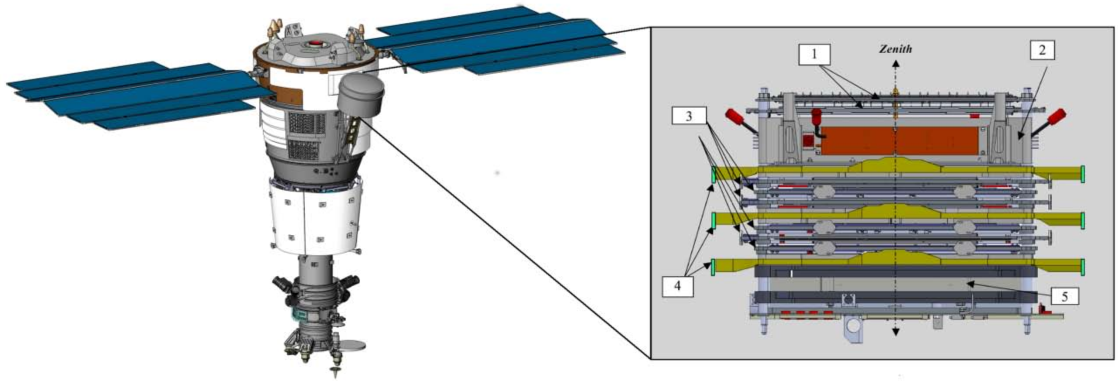

Figure 1. Left: the RESURS-P №2 satellite with the NUCLEON detector. Right: the simplified layout of NUCLEON experiment detectors.

The simplified layout of NUCLEON experiment is presented in right of Figure 1: (1) – 4 planes of the silicon pads for primary particle charge measurement; (2) - carbon target; (3) - 6 silicon microstrip planes of the energy measurement system utilizing the KLEM technique; (4) - 3 double scintillator planes of the trigger system; (5) – 6 silicon microstrip planes divided by tungsten absorber planes of the calorimeter(MIK) with the total depth ~ 16 radiation lengths; more than 10000 electronic channels in total.

The primary energy is measured by registration of spatial density of the secondary particles with the KLEM (Kinematic Lightweight Energy Meter) method [1] and/or with the calorimeter (MIK). The effective geometric factor is more than 0.2 m^2sr for the KLEM and near 0.06 m^2sr for the calorimeter. The Monte-Carlo simulation shows that accuracy of energy measurement with the KLEM procedure is ~60% for energies E > 1 TeV, which is confirmed by the results of tests at CERN SPS beams. The charge measurement system was tested at CERN SPS and provide the charge resolution $\Delta Z/Z$ better than 0.3. The NUCLEON statistics obtained for a year and a half data taking is about $1.5 \cdot 10^7$ triggers.

2. The NUCLEON experiment preliminary results

The preliminary results of the CR study at the NUCLEON experiment is presented in Figures 2 - 4 in comparison with the corresponding measurements of other experiments: ATIC [2], JACEE [3], SOKOL [4], CREAM [5], TRACER [6] and AMS-2 [7]. The NUCLEON data

PoS(ICHEP2016)792

have the large systematic uncertainties in the low energy part of the CR spectra due to trigger system suppression of such events. The different trigger effects are under investigation presently with Monte-Carlo simulation. This is the reason that NUCLEON results are given for energies starting with E > 3 TeV where the trigger system efficiency is ~100%.

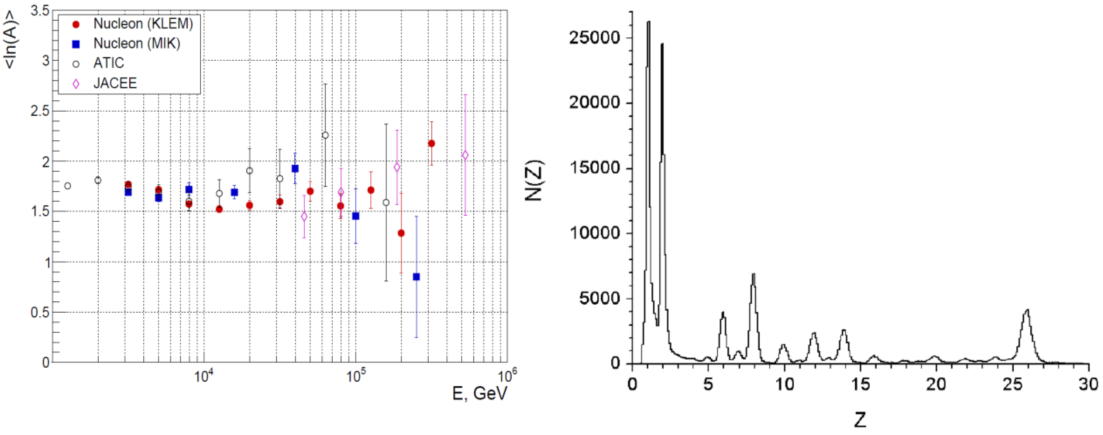

Figure 2. Left: the CR <ln(A)> dependence of energy. Right: the different CR nuclei abundance.

As it followed from the CR <ln(A)> dependence of energy presented in the left of Figure 2 there is reasonable accordance between NUCLEON data and of the ATIC[2] and JACEE[3] data at the present level of available statistics. The difference between the NUCLEON data that was obtained with KLEM or calorimeter measurements may be considered approximately as the existing systematical uncertainties. At right of the Figure 2 the different CR nuclei abundance is shown as it measured by the NUCLEON charge measurement system. Besides of proton and He peaks the C, O, Fe and some other nuclei peaks are clearly seen. Relative values of proton and He peaks are essentially modified by the trigger system event selection.

In the Figure 3 the preliminary results of the CR proton and He nuclei spectra measurements are presented in comparison with the ATIC[2], SOCOL[4], CREAM[5], TRACER[6] and AMS-2[7,8] data. Similarly, in the Figure 4 the preliminary results of the CR C, O and Fe nuclei spectra measurements are presented. Besides, in the bottom right panel the p/He ratio dependence of energy is presented. Everywhere the NUCLEON results are shown for KLEM and calorimeter approach measurements separately and their reasonable accordance to the other experimental data is obtained.

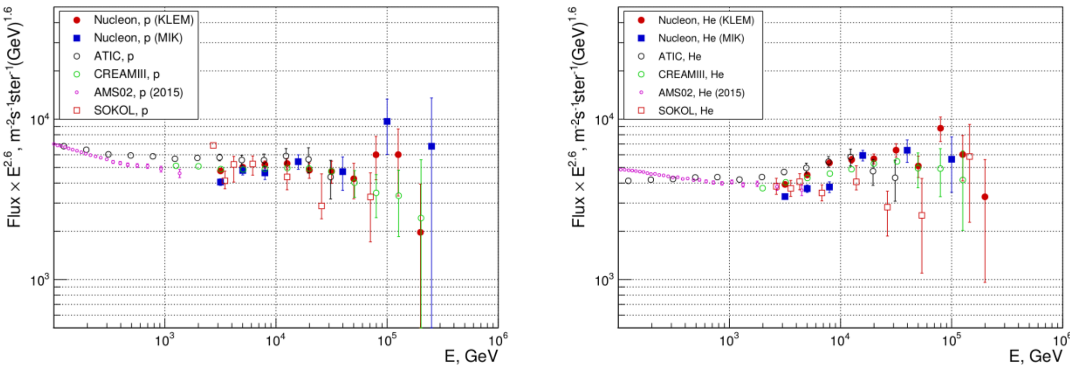

Figure 3. Preliminary results of the CR proton and helium spectra measurements.

PoS(ICHEP2016)792

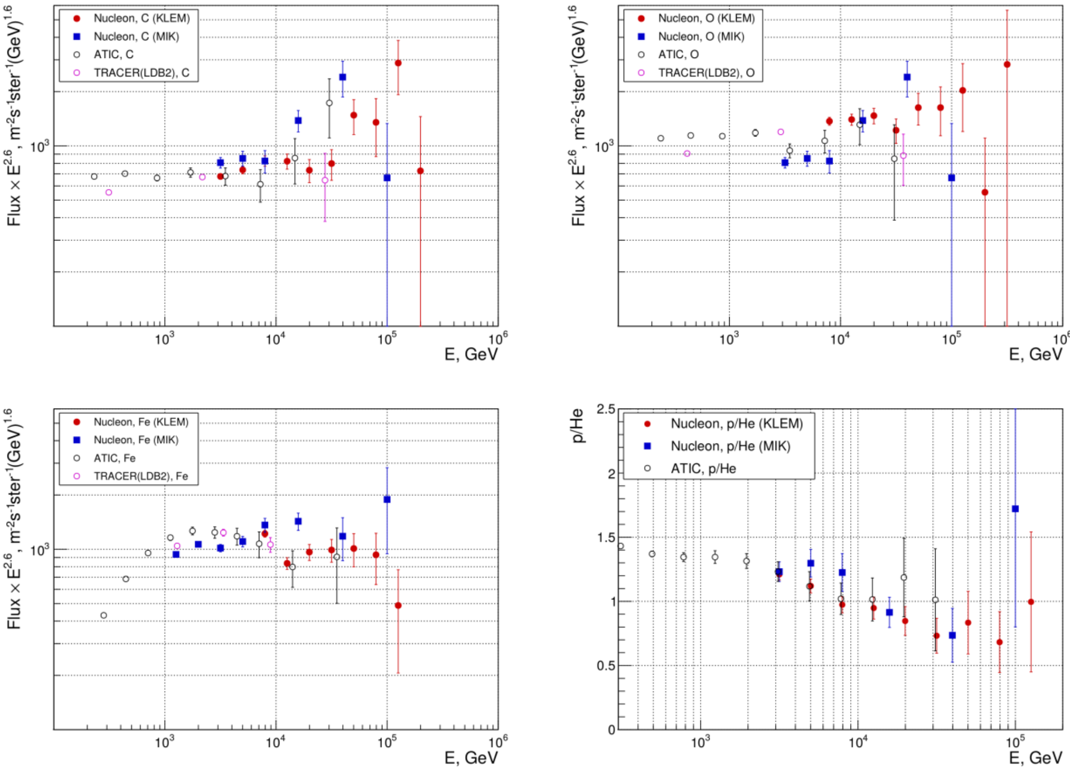

Figure 4. Preliminary results of the CR C, O and Fe nuclei spectra and p/He ratio measurements

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PoS(ICHEP2016)792