

The NUCLEON-mission for cosmic rays investigation

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Abstract. A new approach to Cosmic Rays Investigation is proposed. The main idea is to combine two experimental methods (KLEM and UHIS) for the NUCLEON Project. The KLEM (Kinematic Lightweight Energy Meter) is aimed to study of chemical composition and elemental energy spectra of galactic CRs in extremely wide energy range 10^{11} - 10^{16} eV. The UHIS (Ultra Heavy Isotope Spectrometer) is suggested to use for the ultra heavy CR nuclei registration beyond the iron peak. Combination of the two techniques would give a unique instrument with a number of advantages.

1. Introduction.

The general results of the available experimental data analysis in the considered field of knowledge are listed in reviews (Baring 1999; Beatty 1999) and partly quoted below:

1. Energy range 10^{14} - 10^{16} eV is a crucial region for understanding CR origin, acceleration and propagation in our Galaxy. It is very important to accumulate more data in this energy range with elemental CR resolution.

2. Experimental data for nuclei with $Z < 30$ in low-energy region is in a good agreement with theoretical model, but for nuclei with $Z > 30$ available experimental data are limited and do not allow to make definite conclusion about chemical composition. Therefore new data for the nuclei beyond the iron peak ($Z > 30$) is required.

It is emphasized in the reviews that a new experiment over a wide charge and energy range is needed. It would help to test existing theoretical conceptions and would become a basis for further studies in this very important field of knowledge. Long-term balloon experiments like ATIC (ATIC Collaboration 1999), TRACER (Cahbanner 1999), CREAM (Beatty 1999) may begin to solve the mentioned above problems. But a real solution of the problems would be possible only with a long-term (not less than 2-3 years) large aperture (not less than $10 \text{ m}^2 \text{ sr}$)

satellite experiment.

In recent years, the KLEM (Kinematic Lightweight Energy Meter) (Adams 2000) and the UHIS (Ultra Heavy Isotope Spectrometer) (Hasebe 1998) research programs have been proposed. The KLEM program is based on measuring the primary particle energy by determining the angular distribution of secondaries produced in a target layer. The proposed technique can be used over a wide range of energies (10^{11} - 10^{16} eV) and gives an energy resolution of 60% or better. The UHIS program is based on well-known dE/E algorithm and is intended to measure the isotope composition of ultraheavy particles ($Z > 10$) beyond the iron-peak nuclei in galactic cosmic rays of the energies from $\sim 100 \text{ MeV/n}$ to 500 MeV/n . The instruments of both programs have a modular structure and assume step-by-step development. First step is the construction of a small size and weight device to improve the experimental techniques; second one is the construction of a device with the required factor of an exposure to realize a wide-ranging space experiment to solve the scientific problems mentioned above. As the first step of the programs development we propose to unify the small KLEM and the small UHIS devices into one with the common name NUCLEON.

2. The NUCLEON-mission.

The experimental tasks of the NUCLEON Project:

- to determine energy spectrum and chemical composition of high-energy CRs in wide energy range 10^{11} - 10^{15} eV;
- to measure fluxes of super heavy CR nuclei beyond the iron peak up to $Z \approx 40$.

The possible design of the NUCLEON apparatus is schematically shown in Fig.1. The upper part consists of three layers (SD1-SD3) of silicon detectors with thickness $h \sim 300$ microns. The SD1 layer consists of silicon pad detectors with size $\sim 1 \text{ cm}^2$. Each pad has its own readout channel. The SD1 layer designed for precision measurement of primary high-energy particle charge. The layers SD2 and SD3 consist of silicon microstrip detectors with perpendicular orientation. They are designed to identify a primary particle trajectory with. They also confirm SD1 charge (ionization) measurements.

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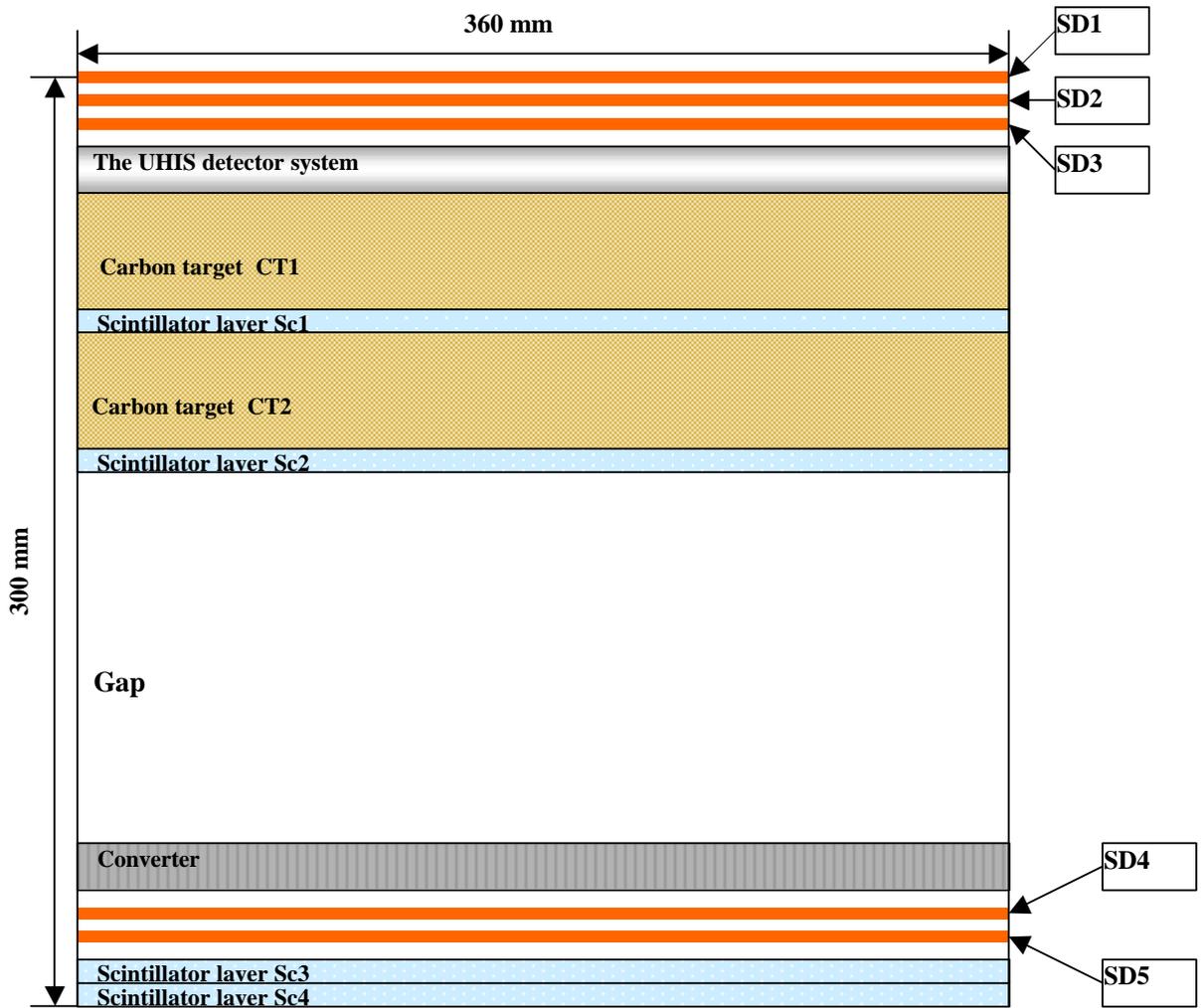


Fig.1. Schematic view of the NUCLON instrument.

The UHIS system is located below the SD3 layer. It has a modular structure of particle telescopes. The structure of particle telescopes is not yet completely established. One of the possible versions is schematically shown in Fig.2. Telescope consists of a number of silicon detectors layers (with thickness 0.3–5.0 mm and overall dimensions 360x360 mm²). Two of them UD1 and UD2 are similar to the layers SD2 and SD3 and consist of silicon microstrip detectors orientated in perpendicular directions. For the UHIS task these four layers (UD1, UD2 and SD2, SD3) are used for trajectory determination of a primary particle with required accuracy. The lowest layer UD9 is similar to SD1 and is used in the trigger system for anticoincidence. It is supposed 6 layers of UHIS device (UD3-UD8) will be made by the Li-drift silicon detector technology. Three upper layers (UD3-UD5) have 2 mm thickness and three lower ones (UD6-UD8) have 5 mm thickness. The Si-detectors of layers UD3-UD8 are intended to be used for isotope identification by dE/E algorithm.

The UHIS system is a part of the KLEM "alive" target and it allows an interaction point of high-energy particle to be determined. The rest part of the KLEM target consists of two carbon blocks CT1 and CT2. Each of them is ~4 cm

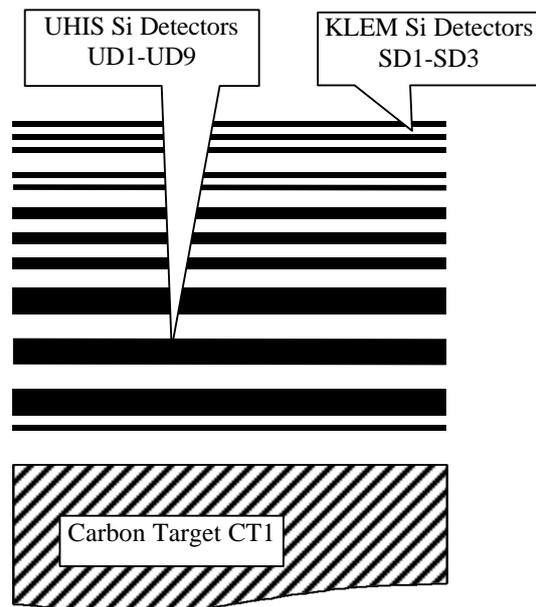


Fig.2. The possible schematic view of the UHIS instrument.

thick and has a scintillator layer (Sc1 or Sc2 respectively) underneath. Sc1 and Sc2 are used to generate first and second level triggers for the KLEM system. They are also used to determine, what part of the KLEM target (CT1 or CT2) the interaction has occurred in.

There is ~15 cm gap between the targets and the lead converter, which is aimed to expand the beam "cluster" of secondary particles produced in the target and to improve the spatial resolution. The lead converter with thickness 1-2 cm converts almost all secondary γ -quanta to charged particles. This significantly increases the number of secondary particles and therefore improves accuracy of a primary particle energy determination. Two layers of silicon microstrip detectors SD4 and SD5 are located right below converter. The strips in the SD4 and SD5 are 36 cm long and have 50-micron pitch. Every strip is connected to its own readout channel. Two layers SD4 and SD5 with perpendicular strip orientation give a possibility to perform analysis for each (X and Y) direction independently and improve the primary particle energy resolution. There are two more layers of scintillator Sc3 and Sc4 with thickness 0.5 cm below SD5. Together with Sc1-Sc2 they are aimed to generate necessary trigger signals for the KLEM system. The scintillation planes Sc1-Sc4 consist of the plastic strips. The light signals from strips are collected by fibers to 64 channels-PMTS.

It is planned the NUCLEON-device will have the separate and parallel triggers to select high energy CR events or super heavy CR nuclei where KLEM and UHIS detectors will be used. The super heavy nuclei will be selected by the requirement of stopping primary in Si-

detectors of the UHIS system. The trigger for high energy CR events will be based on the requirements: the first inelastic interaction is in the UHIS detectors or in carbon target and the primary particle trajectory is within aperture of the KLEM device.

According to Monte-Carlo simulation for the NUCLEON apparatus design accuracy for CR parameter measurements is planned to be:

for high-energy CR component (10^{11} - 10^{15} eV/particle):

- accuracy of energy measurement is better than 60% in individual event for all energy range;
- charge resolution is about 0.1 charge unit for all nuclei with $Z=1$ -30;

for low-energy CR component (10^8 - 5×10^8 eV/nucleon):

- isotopic resolution is better than 0.5 atomic mass units in charge range $Z=10$ -40.

During R&D stage of the NUCLEON Project the technical decision to arrange the NUCLEON apparatus on a regular satellite was established. Such decision leads to very significant cost reduction of the NUCLEON experiment. As a regular satellite it is supposed to use serial spacecraft "Kosmos" type, which has vacant space and maintenance for mounting and functioning of the NUCLEON apparatus. In this case an additional device for scientific information accumulation and transmission has to be mounted. It is suggested to install an additional remote control system (DSTK) with its own hermetic container, which has been used in "Konus-A" project (within satellites "Kosmos-2326" and "Kosmos-2367").

Scheme of mounting of the NUCLEON and DSTK devices in a regular satellite is presented in Fig.3.

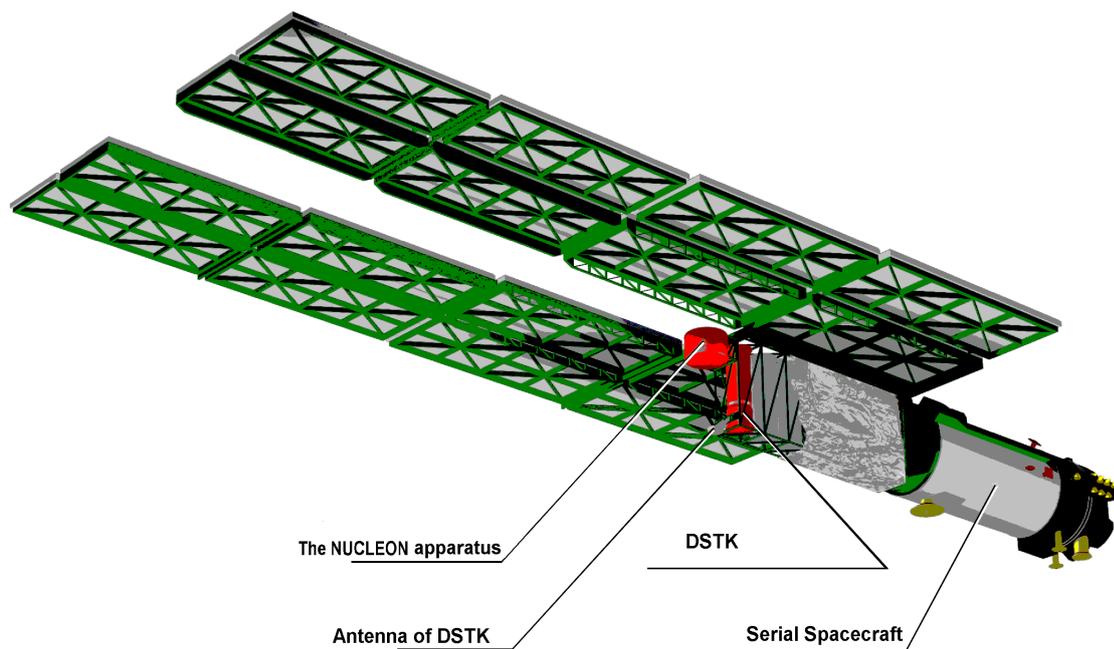


Fig.3. Supposed scheme of mounting of the NUCLON and DSTK devices in a regular satellite.

The NUCLEON scientific apparatus has the following characteristics:

- Geometrical factor:
 - >0.12 m²sr for the high-energy component,
 - >0.25 m² sr for the low-energy component;
- Weight of scientific equipment <60 kg;
- Power consumption <95 W;
- Maximum size > 400x400x350 mm³ (the NUCLEON scientific apparatus is a monoblock);
- Flow of scientific and auxiliary information <50 Mb per day;
- Exposure time in orbit >1 year;
- Time of launching - 2004-2005.

3. Conclusions.

The unification of the two research programs into one with the common name of NUCLEON increases the scientific significance of the project in general and essentially decreases the total costs of both programs development. Combination of two techniques is not simple mechanical unification of two instruments in one block, but leads to the creation of the unique instrument, with a number of advantages in comparison with the KLEM and UHIS instrumentation.

4. Summary

The Russian Academy of Sciences and Russian Space Agency ROSAVIACOSMOS enables the NUCLEON-mission in a very real sense. The study found no

engineering problems that would preclude a realization of the project. NUCLEON instrumentation should be developed by the state-of-the-art technologies. The NUCLEON-mission helps to do the first step in the solution of the very important cosmic ray astrophysical problems.

5. Acknowledgements. This work was supported by the Russian Academy of Sciences and Russian Space Agency ROSAVIACOSMOS.

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