The NUCLEON Project

1. Goals of the experiment:

1a. Give a short description of the goals of the experiment - limited to ½ page.

The aim of the NUCLEON Project is direct Cosmic Rays (CR) measurements in the energy range 10^{11}-10^{15}eV and the atomic charge range up to Z≈30 in the near-Earth space to solve mainly the "knee" problem in the CR spectrum. The CR phenomena in this energy region are investigated in terrestrial experiments by measurement of EAS parameters or in balloon or space experiments. Below ~10^{14} eV the spectrum and composition are known from direct observation with detectors placed in balloons and earth satellites. However, at higher energies the CR flux is smaller and more difficult for direct and needs observation. Precise measurement of the CR composition and anisotropy will help to test the existing theoretical concepts and will become a basis for further studies.

In the recent article was shown a strong indication (the statistical significance is higher than 3σ) that there exits a universal break near the magnetic rigidity 10 TV in all nuclear components of cosmic rays. Since the acceleration of cosmic ray particles proceed mainly due to the interaction of particles with magnetic fields in supernova remnants and expressed in terms of magnetic rigidity of the particles, then the existence of universal knee in terms of magnetic rigidity in the spectra of nuclei is probably connected with the cosmic-ray acceleration limit by some generic or nearby source of cosmic rays.

1b. Explain what the project adds to the international scenario: limited to ½ page.

The "knee" energy range 10^{14} - 10^{16} eV is a crucial region for understanding CR origin, acceleration and propagation in our Galaxy. Existed data are not enough for creation of adequate interpretation of the "knee" nature in the framework of the CR acceleration mechanisms at the supernova explosion particularly about change of the mass composition as may be seen from Fig.1.

Indirect methods that are using for the measurements of Extensive Atmospheric Showers (EAS) at energies higher than 10^{14} eV is dependent on the accuracy simulation of the EAS particle interaction models. Besides the “knee” problem is connected with a problem of the CR contribution from galactic and extragalactic sources. The measurements of CR spectrum, composition and anisotropy in the wide energy interval are important part of the particle physics study. The direct measurements of CR mass composition as supposed to do at the NUCLEON experiment allow to clarify and may be to solve this problem.

2. Contributions of the JINR group:

2a. Give an itemized list of the specific contributions of the JINR group in hardware (including use of JINR computing resources for the project), software development and physics analyses - limited to 1 page.

The JINR responsibility is a production of the NUCLEON trigger system. The three trigger modules were produced and tested in assemble of the other detectors at CERN SPS beam tests. Besides JINR group was responsible for Nucleon apparatus beam tests at SPS CERN for years. Figs. 1-2.

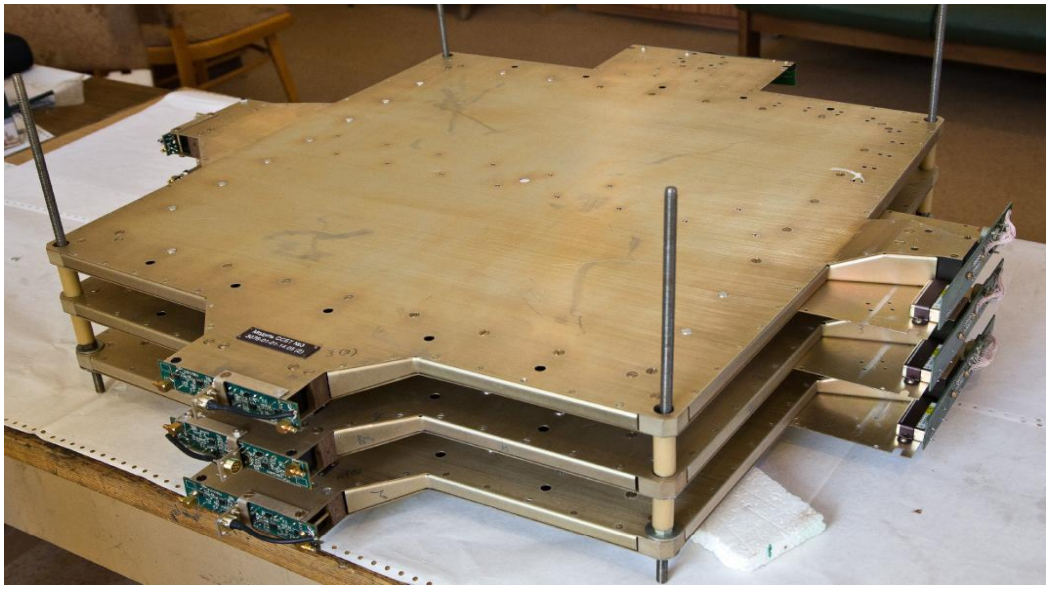

Fig. 1. Three NUCLEON trigger modules

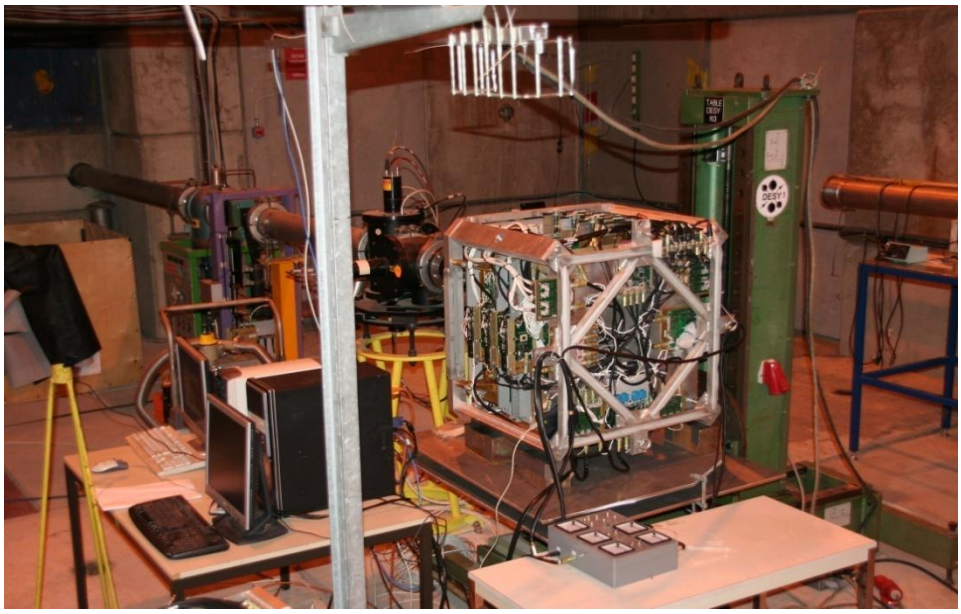

Fig. 2. Nucleon apparatus beam test at H8 beam line of SPS CERN

2b. Give a list of the responsibilities of JINR group members within the management structure of the collaboration, if any, giving the name of the JINR member, the managerial role and the appointment period.

In fact there is no management structure of the NUCLEON collaboration. Status and plans of works are discussed at the collaboration weekly meetings.

3. Plans. *Give a short description limited to ½ page of the JINR group plans (in data taking, analysis, detector R&D, upgrade activities…) till the end of the currently approved project.*

A project of the OLVE-HERO space detector is proposed for CR measurement in the range of 10^{12}-10^{16} eV and will include a large ionization-neutron 3D calorimeter with a high granularity and geometric factor of ~16 $m^2 \cdot sr$. The main OLVE-HERO detector is expected an image calorimeter of a boron loading of plastic scintillator with a tungsten absorber. Such a calorimeter allows to measure an additional neutron signal which will improve the energy resolution of the detector. More importantly, the rejection power between electromagnetic and nuclear CR

components will be increased by factor 30-50 in the whole energy range. The boron loading scintillator detector prototype has designed and tested at the H8 beam test area at CERN SPS during Pb ion run in 2016 and Xe ion run in 2017.

JINR group participates in the data taking, developing of the off-line and physical analysis programs, participation in the new post NUCLEON HERO-ОЛИВЭ project preparation including prototype design, fabrication and beam tests at NUCLOTRON of JINR and SPS of CERN.

4. Publications: *List the papers published in 2016, 2017 and 2018 in the refereed literature (no conference proceedings) in which the JINR group had a major contribution (e.g. author of the analysis, promoter of the experiment, corresponding author, realization of a key equipment etc.). Give title of paper, reference and describe in 1-2 sentences the JINR contribution. Mention the total number of papers published by the project in the same time period.*

1) New Universal Cosmic-Ray Knee near a Magnetic Rigidity of 10 TV with the NUCLEON Space Observatory, Atkin E., Bulatov V., Dorokhov V., Gorbunov N., Filippov S., Grebenyuk V., Karmanov D., Kovalev I., Kudryashov I., Kurganov A., Merkin M., Panov A., Podorozhny D., Polkov D., Porokhovoy S., Shumikhin V., Tkachenko A., Tkachev L., Turundaevskiy A., Vasiliev O., Voronin A., JETP Letters, Maik Nauka/Interperiodica Publishing, 108, № 1, p. 5-12.

2) First results of the cosmic ray NUCLEON experiment, Atkin E., Bulatov V., Dorokhov V., Gorbunov N., Filippov S., Grebenyuk V., Karmanov D., Kovalev I., Kudryashov I., Kurganov A., Merkin M., Panov A., Podorozhny D., Polkov D., Porokhovoy S., Shumikhin V., Sveshnikova L., Tkachenko A., Tkachev L., Turundaevskiy A., Vasiliev O., Voronin A., Journal of Cosmology and Astroparticle Physics, Institute of Physics (United Kingdom), 2017, № 7, p. 20.

3) The NUCLEON experiment. Results of the first year of data acquisition, Atkin E., Bulatov V., Dorokhov V., Filippov S., Gorbunov N., Grebenyuk V., Karmanov D., Kovalev I., Kudryashov I., Kurganov A., Merkin M., Panov A., Podorozhny D., Polkov D., Porokhovoy S., Shumikhin V., Sveshnikova L., Tkachenko A., Tkachev L., Turundaevskiy A., Vasiliev O., Voronin A. , Astroparticle Physics, Elsevier BV (Netherlands), 90, c. 69-74.

5. PhD theses: *List the PhD theses completed within the last 3 years, or expected to be completed within 2019, by JINR students within the project, giving the student name, thesis title and graduation year.* ***NO***

6. Talks:

6a. List the invited plenary talks given by members of the JINR group in 2016, 2017 and 2018 at international conferences, workshops…: give name and date of the Conference, title of talk and speaker name.

1. L.Tkachev. **New Trends in High-Energy Physics,** 24-30 September 2018, Montenegro, Budva, Becici, "Splendid Hotel. JINR activity in the NUCLEON and TUS/KLYPVE space experiments
2. A.Pan. Measurement of the output of slow neutrons on the test of the prototype calorimeter of the space detector OLBE-HERO at the SPS accelerator at CERN. VII Annual Conference of Young Scientists and Specialists Alushta-2018. 11-18 June 2018

6b. Give a similar list for parallel talks. ***NO***

7. Group size, composition and budget.

7a. Present in a Table the list of JINR personnel involved in the project, including name, status (e.g. PI, researcher, post-doc, student, engineer, technician…) and FTE. Mention the total number of people in the collaboration.

The total number of people in the NUCLEON collaboration author list - 22 people

List of the JINR NUCLEON project participants:

Name	employment	involvment	PhD
1. N.Gorbunov	head of sector	10%	yes
2. V. Grebenyuk	senior scientist	20%	yes
3. A. Kalinin	engineer	50%	yes
4. S. Porokhovoy	engineer	20%	no
5. M. Slunecka	senior scientist	10%	yes
6. A. Tkachenko	scientist	20%	in preparation
7. L. Tkachev	head of sector	20%	yes
8. A.Sadovsky	senior scientist	20%	yes
9. A.Rogov	senior scientist	10%	yes
10. A.Pan	engineer	70%	no
11. U.Nurtaeva	engineer	80%	no

7b. Indicate the expected changes in the group size, if any, till the end of the currently approved project.

Expected changes in the group size ±2 persons

7c. Present the JINR group budget from 2018 till the end of the currently approved project in a Table specifying the main budget items (equipment, computing, salaries, common funds, travel…)

This activity is going for extra-budgetary money – JINR and SINP MSU+ROSCOSMOS contracts

7d. Indicate the use of JINR computing resources for the group and for the project if any.

LIT computer farm