The NUCLEON Space Experiment present status and the first results

D.Podorozhny, E.Atkin, V.Bulatov, V.Dorokhov, N.Gorbunov, S.Filippov, V.Grebenyuk, D.Karmanov, I.Kovalev, I.Kudryashov, M.Merkin, A.Pakhomov, A.Panov, D.Polkov, S.Porokhovoy, V.Shumikhin, L.Sveshnikova, A.Tkachenko, L.Tkachev, M.Torochkov, A.Turundaevskiy, O.Vasiliev, A.Voronin

Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow,

Joint Institute for Nuclear Research, Dubna, Russia

National Research Nuclear University “MEPhI”, Moscow

SDB Automatika, Ekaterinburg, Russia

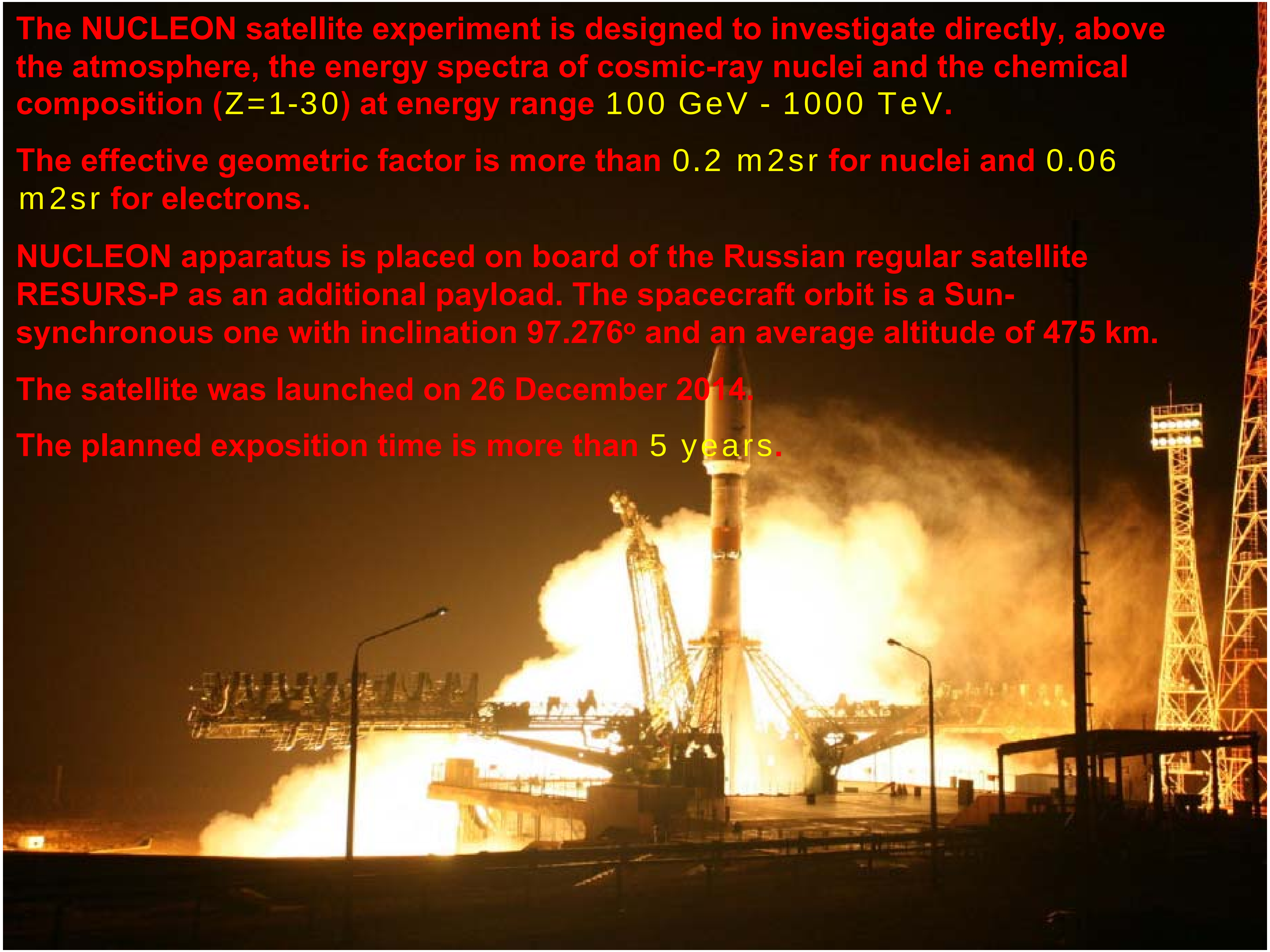
The NUCLEON satellite experiment is designed to investigate directly, above the atmosphere, the energy spectra of cosmic-ray nuclei and the chemical composition (Z=1-30) at energy range 100 GeV - 1000 TeV.

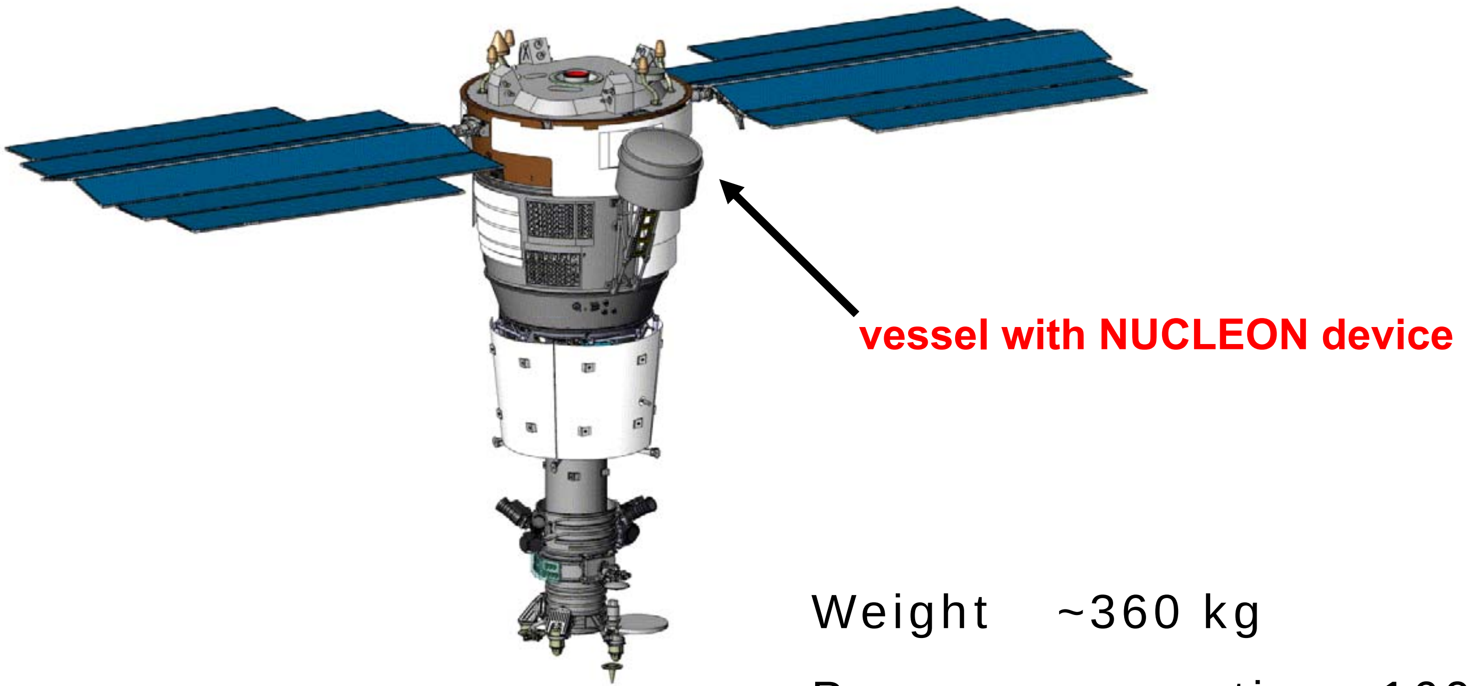
The effective geometric factor is more than 0.2 m2sr for nuclei and 0.06 m2sr for electrons.

NUCLEON apparatus is placed on board of the Russian regular satellite RESURS-P as an additional payload. The spacecraft orbit is a Sun-synchronous one with inclination 97.276^{o} and an average altitude of 475 km.

The satellite was launched on 26 December 2014.

The planned exposition time is more than 5 years.

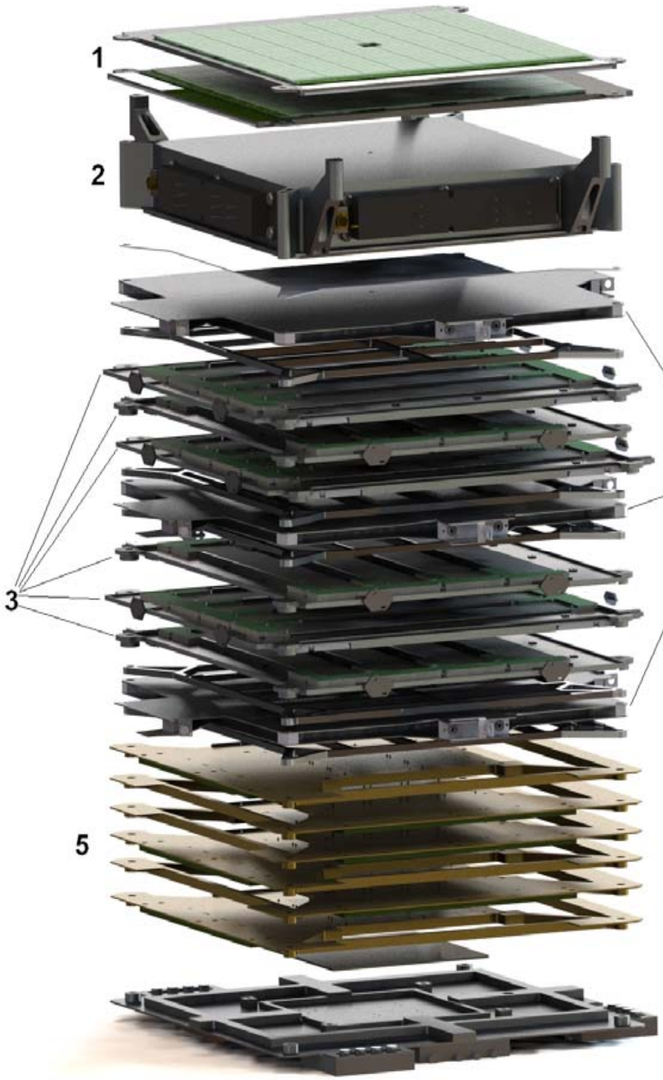




Weight ~360 kg

Power consumption ~160 W

Telemetry ~10 GB/day



The NUCLEON apparatus includes:

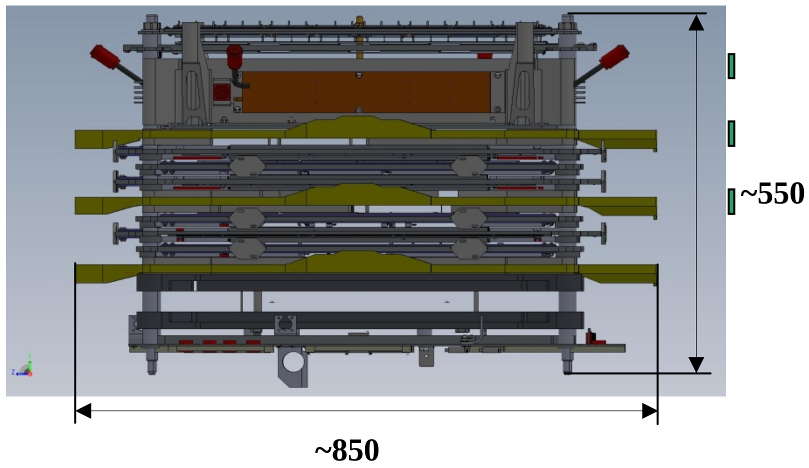
- the charge measurement system (1) consisting of the four pad silicon detectors layers (2048 channels),
- carbon target (2);
- tracker of six layers of silicon microstrip detectors (6912 channels) divided by six thin tungsten layers (3);
- the trigger system (four) of the six scintillator layers (108 channels)
- six layers (five) of the silicon- tungsten calorimeter (1536 channels).

Total - 10604 channels, failure rate is 0.6%

Active device area – 0.50x0.50 m (for calorimeter – 0.25x0.25 m)

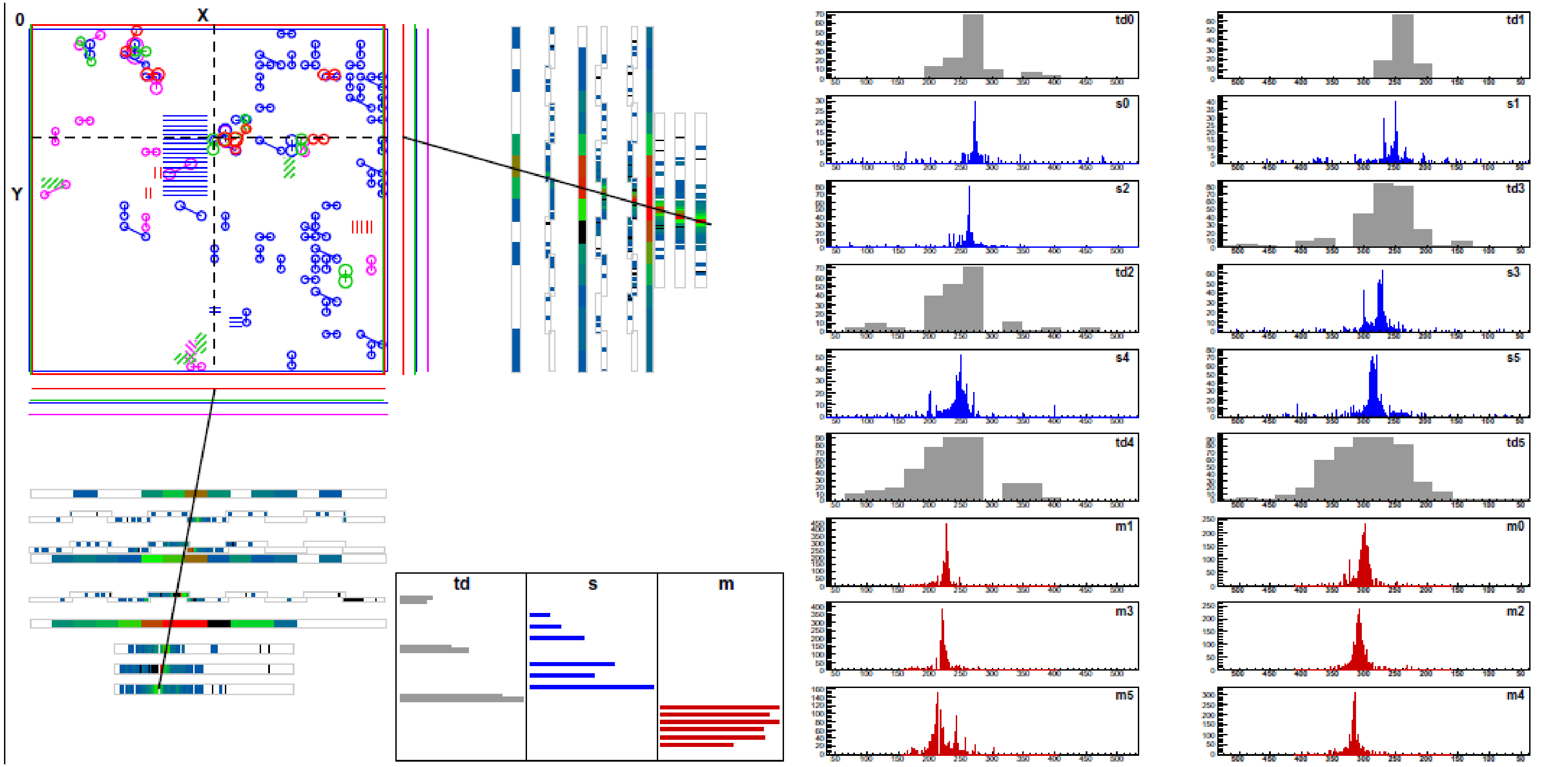
Total depth ~ 16 radiation lengths

Assembled device dimensions ~0.85x0.85x0.55 m



The set of data obtained by all detectors for an event can be presented in the form of a “portrait” of the event.

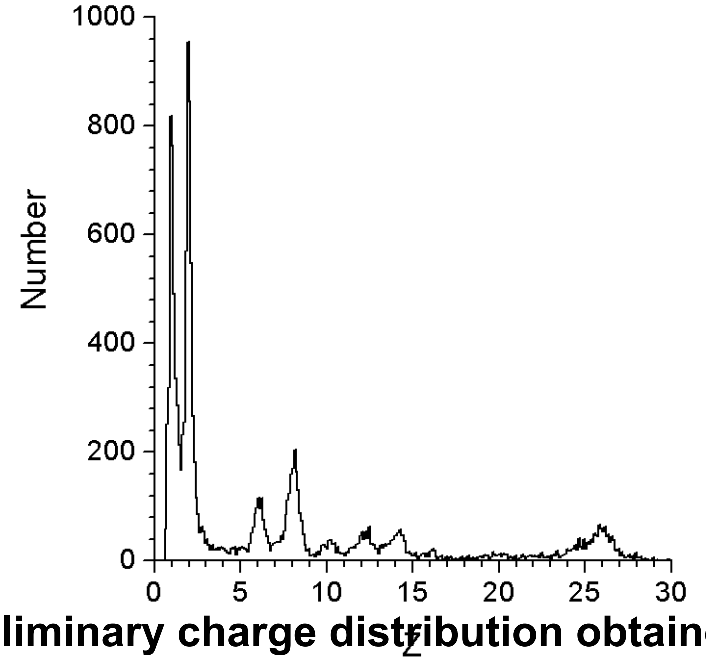
One example of an event “portrait”



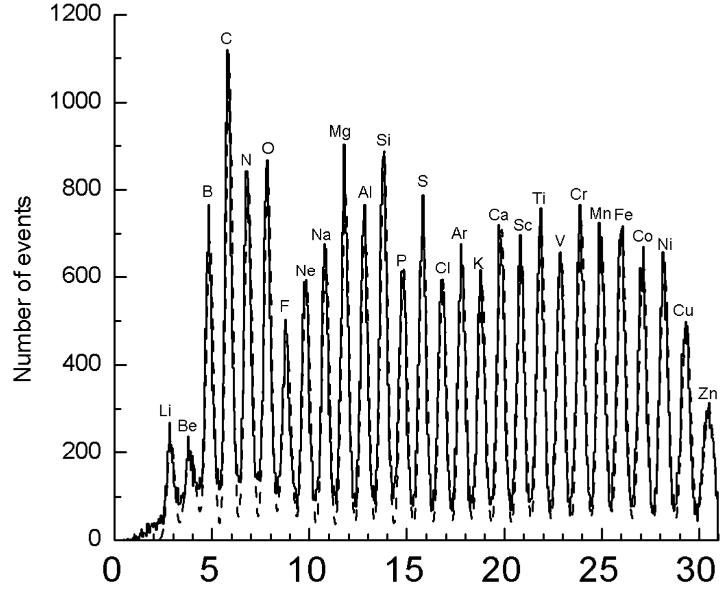
Charge measurements

The charge measurement system consists of four layers. Each layer – 8 leders with 8 silicon detectors (60x60 mm). Each detector is divided to 16 pads (1.5x1.5 cm). Each readout channel is used for two pads to decrease number of channels.

Dynamic range of a readout channel ~1000 mip. Coverage of active area in the layer by silicon about 98%. For 4 layers – ~100%. The signals from microstrip detectors are used to reconstruct a shower axis. Then charge detector pads near the axis are selected.



Preliminary charge distribution obtained by the space experiment (resolution ~0.3 ch. u.)



The charge distribution obtained by the beam test (resolution ~0.2 ch. u.)

It is possible to improve resolution of measurements by further optimization of the algorithms related to the shower axis reconstruction, active silicon pads selection and others.

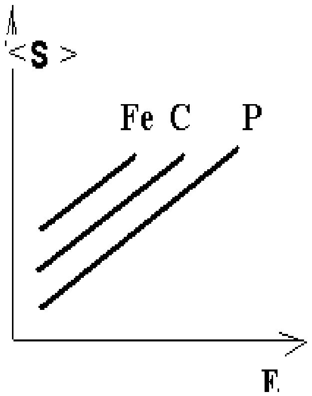
Energy measurements

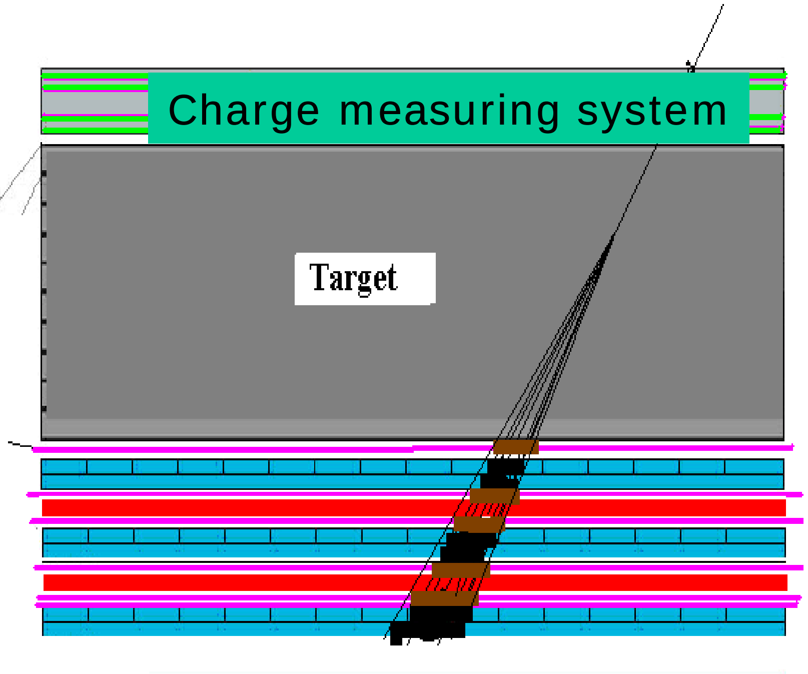
Two techniques for measuring energy:

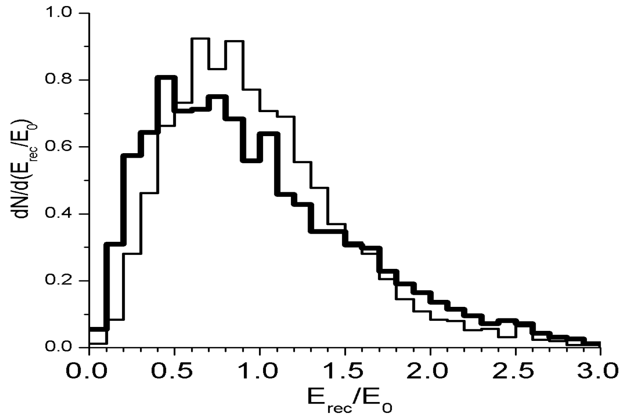
Kinematic Lightweight Energy Method (KLEM) is based on measurements of spatial density of secondary particles at first stage of development of nuclear and electromagnetic cascades (a combination of kinematic techniques and of ultra-thin calorimeter method).

$S = \sum \eta_i^2 N_i$

$\eta_i = -\ln tg(\theta/2)$







Normalized reconstructed energy distributions for pion beams of 150 GeV (thin line) and 350 GeV (thick line) (KLEM technique)
RMS~60%

Spatial density of secondaries is determined by microstrips with 484 μm pitch. Every strip is connected to its own readout channel. The pairwise-perpendicular strip orientation makes it possible to perform analysis for each (X and Y) direction independently and improve the primary particle energy resolution.

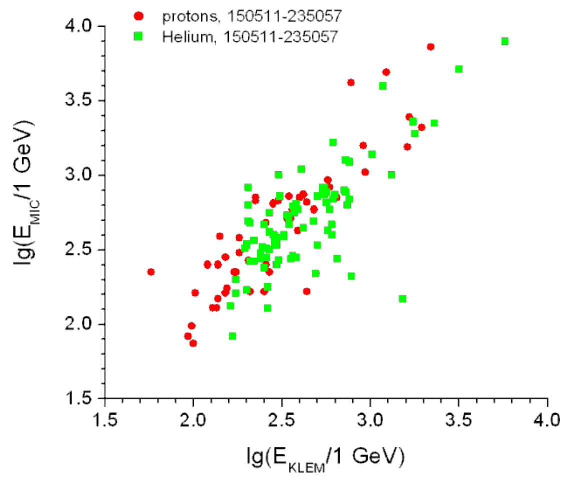
The particle energy also can be reconstructed by traditional calorimeter technique for cascades traversing not only the tracker but the calorimeter too. The energy is determined by signals in the calorimeter microstrip (pitch ~1 mm) detectors.

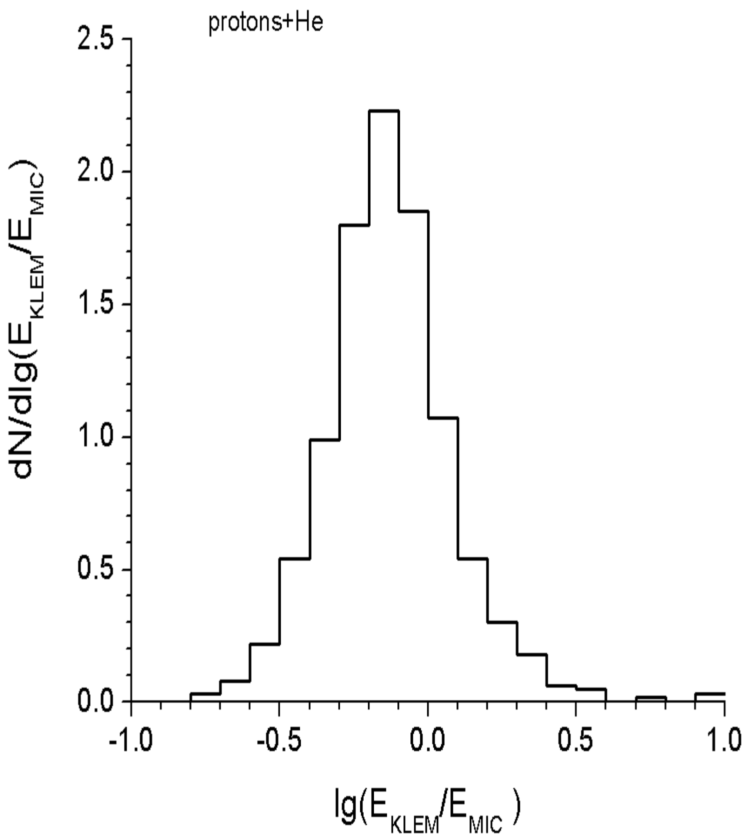
Using both methods – KLEM and calorimetric – could improve the accuracy of measurement of the primary particle energy by test new KLEM technique versus the traditional calorimetric method.

For example the distribution of ratio EKLEM/EMIC for primary protons and helium nuclei. The energy was determined by two methods simultaneously for each event (EKLEM and EMIC). The Pearson product-moment correlation coefficient for EKLEM and EMIC is equal to 0.82. Energy values determined by two methods are close.

The middle ratio EKLEM/EMIC is equal to 0.87. It is a systematic error of energy measurements and it is significantly less than statistical errors.

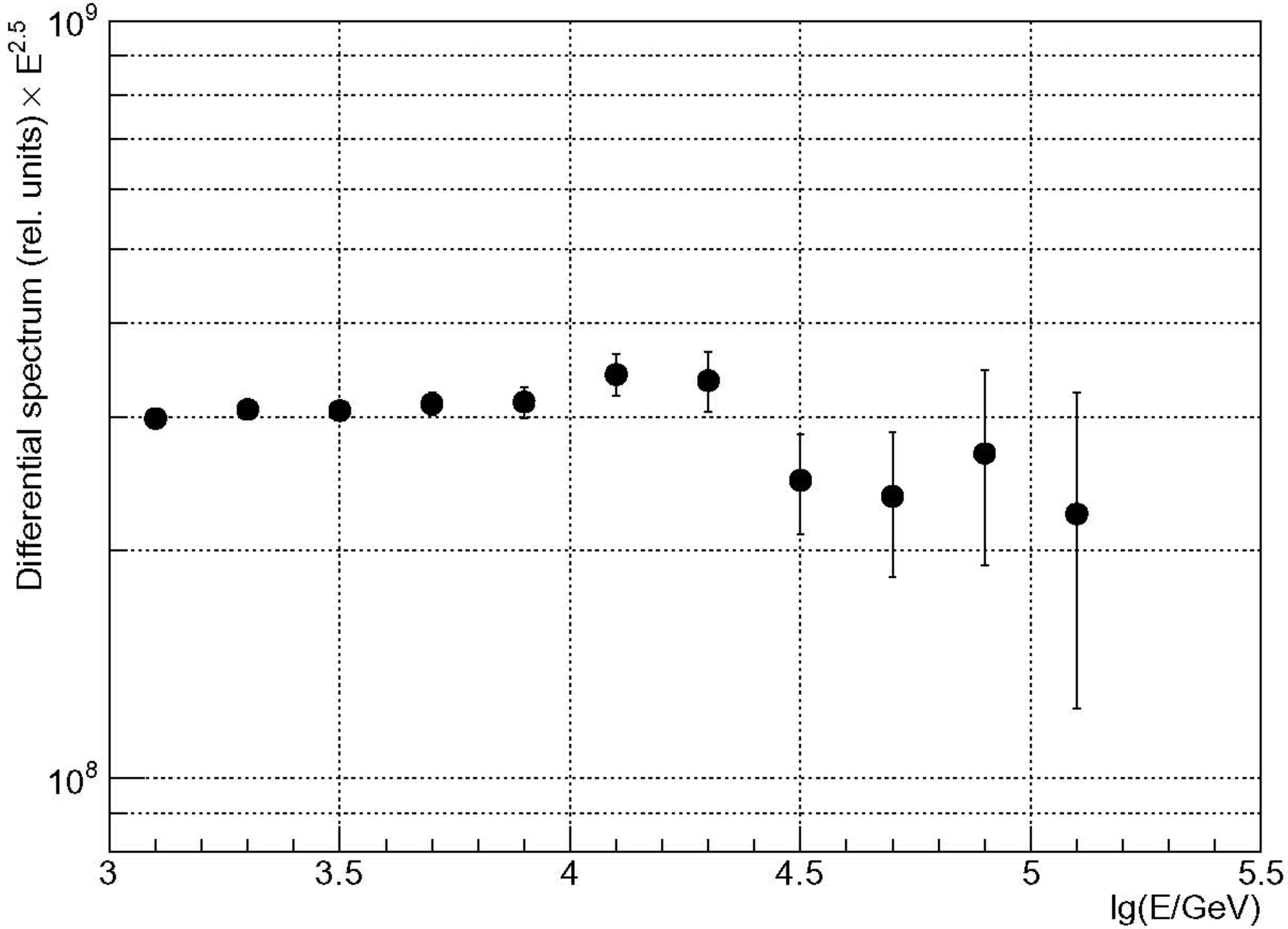
.





Statistics

Edep MIP	E TeV (Estimated)	N (Cal-r) 6 months	N (KLEM) 6 months	N (Cal-r) 5 years (expected)	N (KLEM) 5 years (expected)
10^4	1	19 000	80 000	190 000	800 000
10^5	10	850	3 750	8 500	37 500
10^6	100	20	90	200	9 000
10^7	1000	0	2	5	20



Very preliminary

Differential all-particle spectrum by MIK inside the working aperture

Conclusion

NUCLEON astroparticle experiment has started from January 2015

The planned exposition time is more than 5 years

All the device systems are working good

By now cosmic nuclei database has collected more than 80 000 at energies above 1 TeV

Very preliminary:

There is an indication of a feature in the all-particle spectrum within 20-100 TeV energy range