The NUCLEON Space Experiment Preliminary Results

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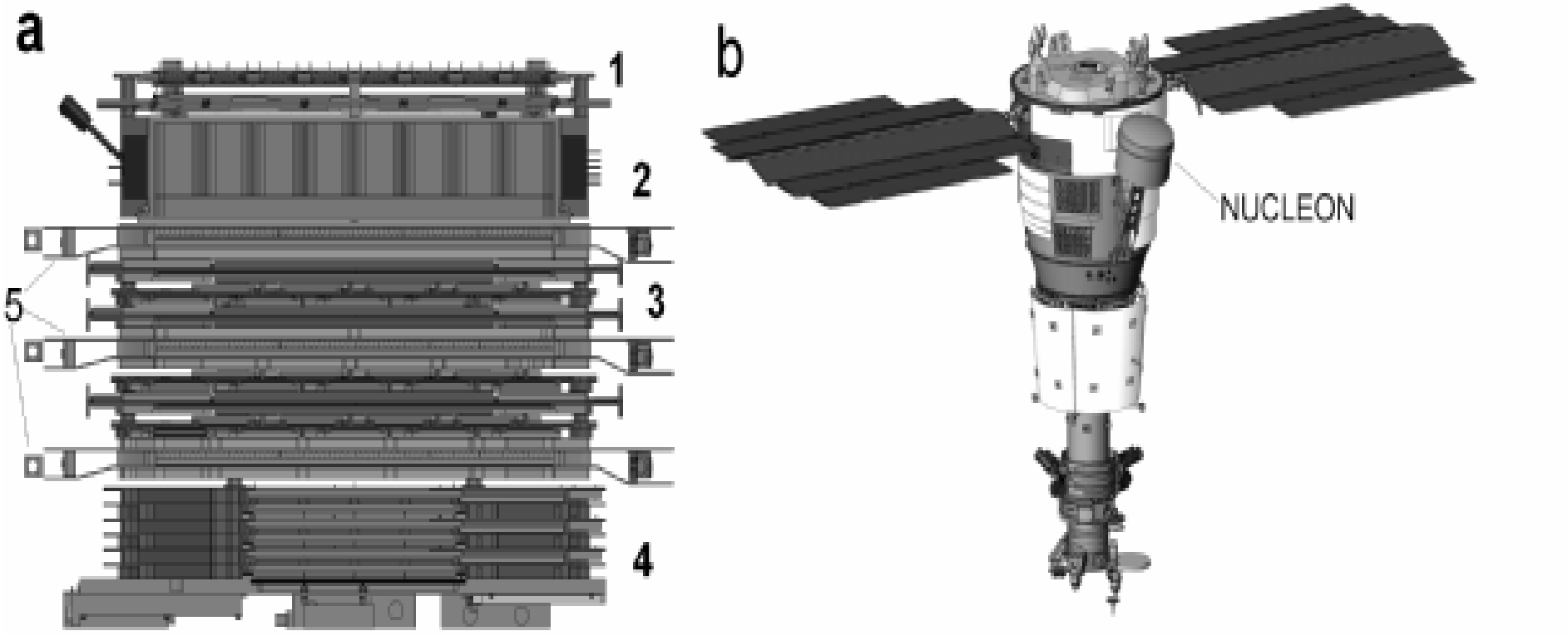
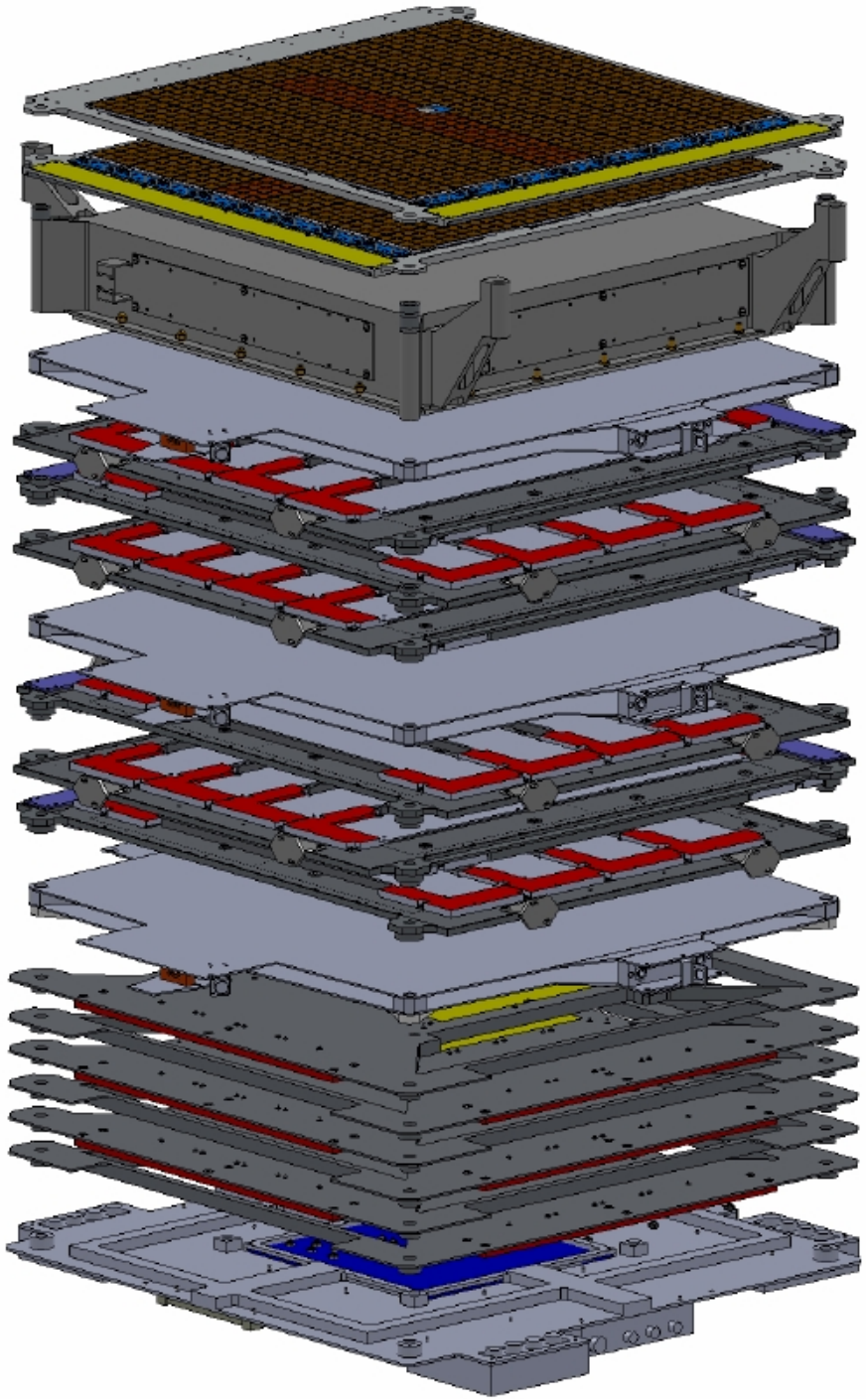
The NUCLEON satellite experiment is designed to investigate directly the energy spectra of cosmic-ray nuclei and CR composition (Z=1-30) at energy range 100 GeV-1000 TeV. The satellite has been launched on 26 December 2014. The planned exposition time is more then 5 years. The first preliminary results are presented including charge distributions and all particles energy spectra.

The NUCLEON design

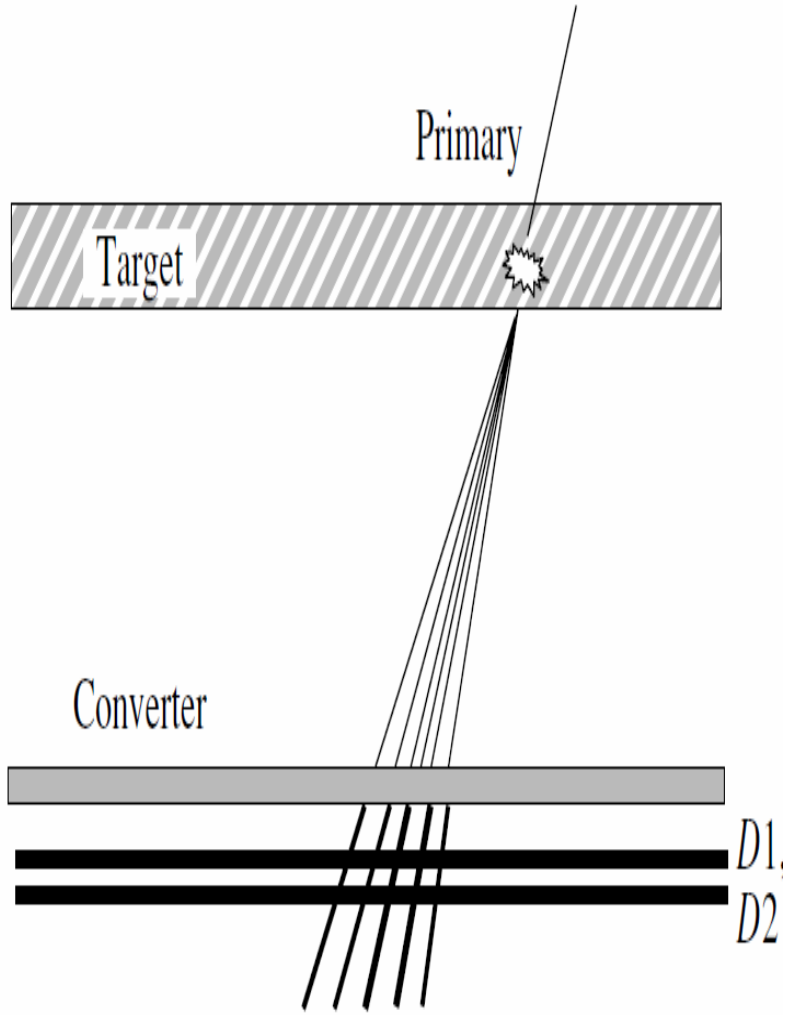
- The NUCLEON device was designed and produced by a collaboration of SINP MSU (main investigator), JINR (Dubna) and some other Russian scientific and industrial centers. It is placed now on board of the RESURS-P №2 satellite. The spacecraft orbit is a Sun-synchronous one with inclination 97.276° and a middle altitude of 475 km.
- The effective geometric factor is more than 0.2 m2sr for the KLEM (Kinematic Lightweight Energy Meter) system and near 0.06 m2sr for the calorimeter. The surface area of the device is equal to 0.25 m2. The charge measurement system must provide resolution better than the 0.3 charge unit.

NUCLEON

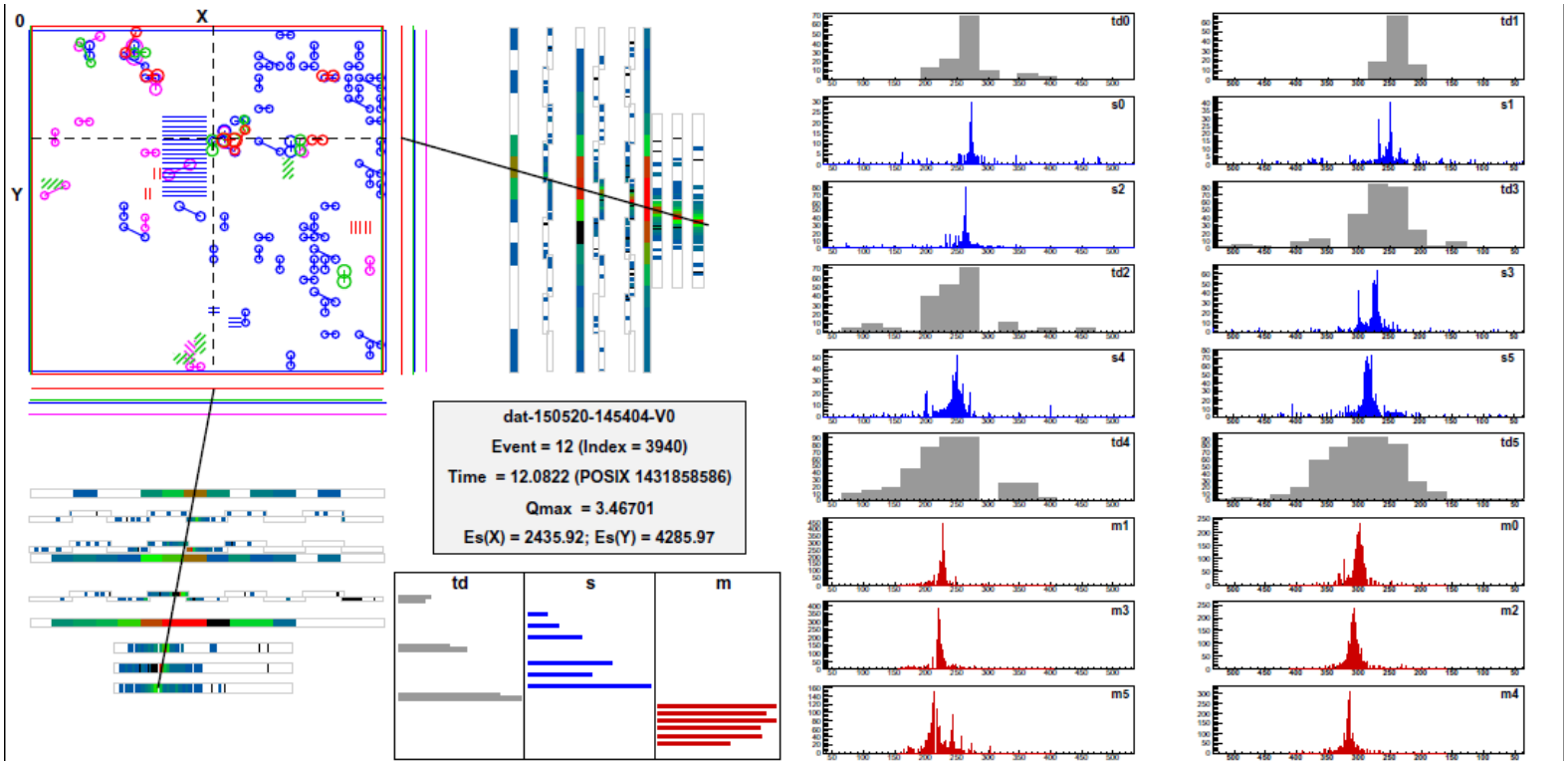




KLEM (Kinematic Lightweight Energy Meter)



The image of the event. The nucleus initialized the shower



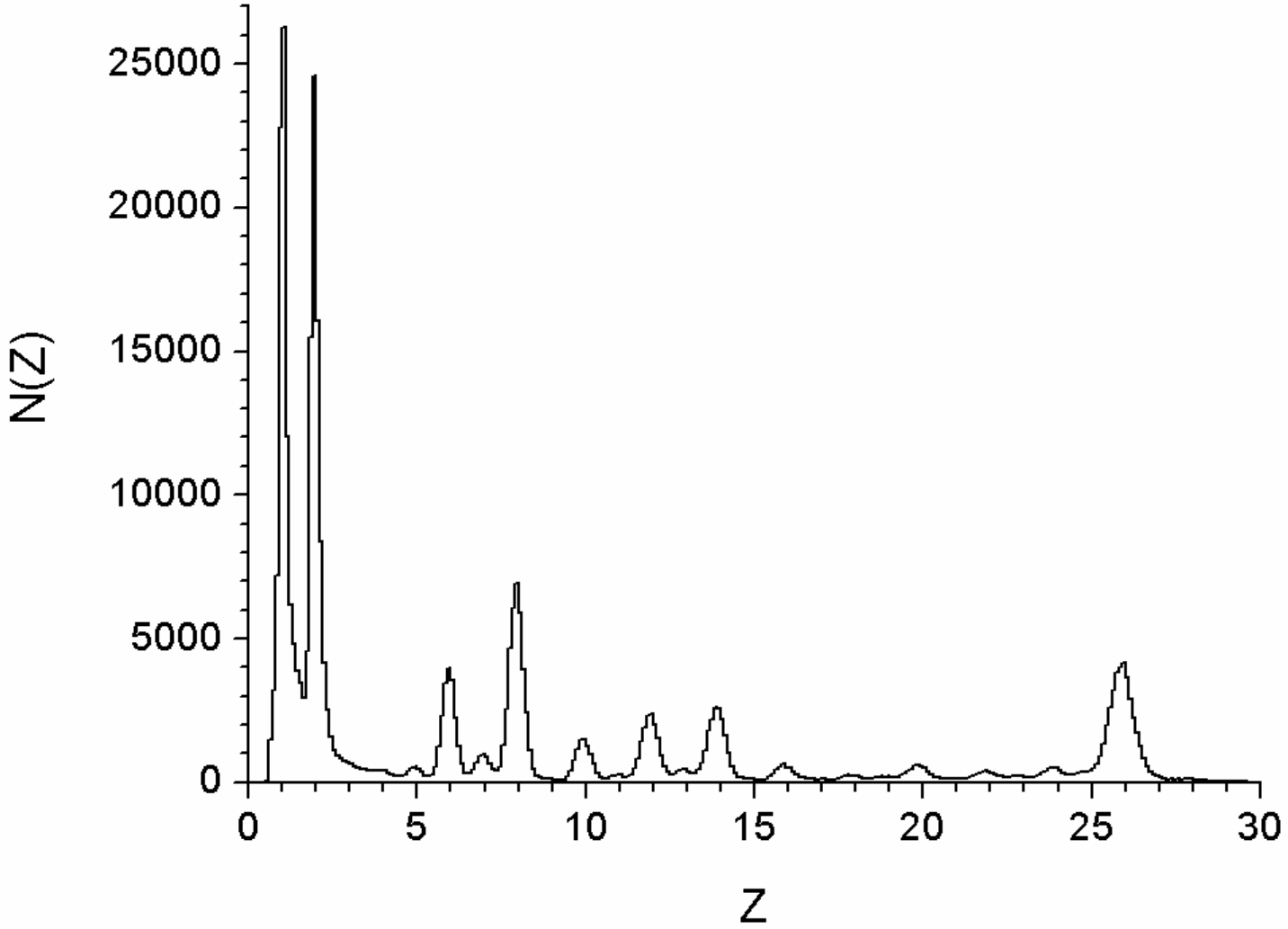
The trigger system

- The trigger system parameters were optimized by the first stage of the space experiment. This system is aimed to generate necessary trigger signals to register the event. Each of the six trigger planes consists of the 16 scintillator strips. The light signals from the strips are collected by the wavelength shifting fibers (WLS) to photomultiplier tubes (PMT). The dead time is equal to 200 ns.
- Selection criteria include signal registration for all 6 layers. Different thresholds are used for different layers according to the shape of showers.
- The trigger operational mode is determined by 6 thresholds of comparators. A single-channel PMT detects scintillation light from a layer. The signal arrives to the comparator. The trigger is given if at the same time not less than in N layers the signal exceeded the set thresholds.

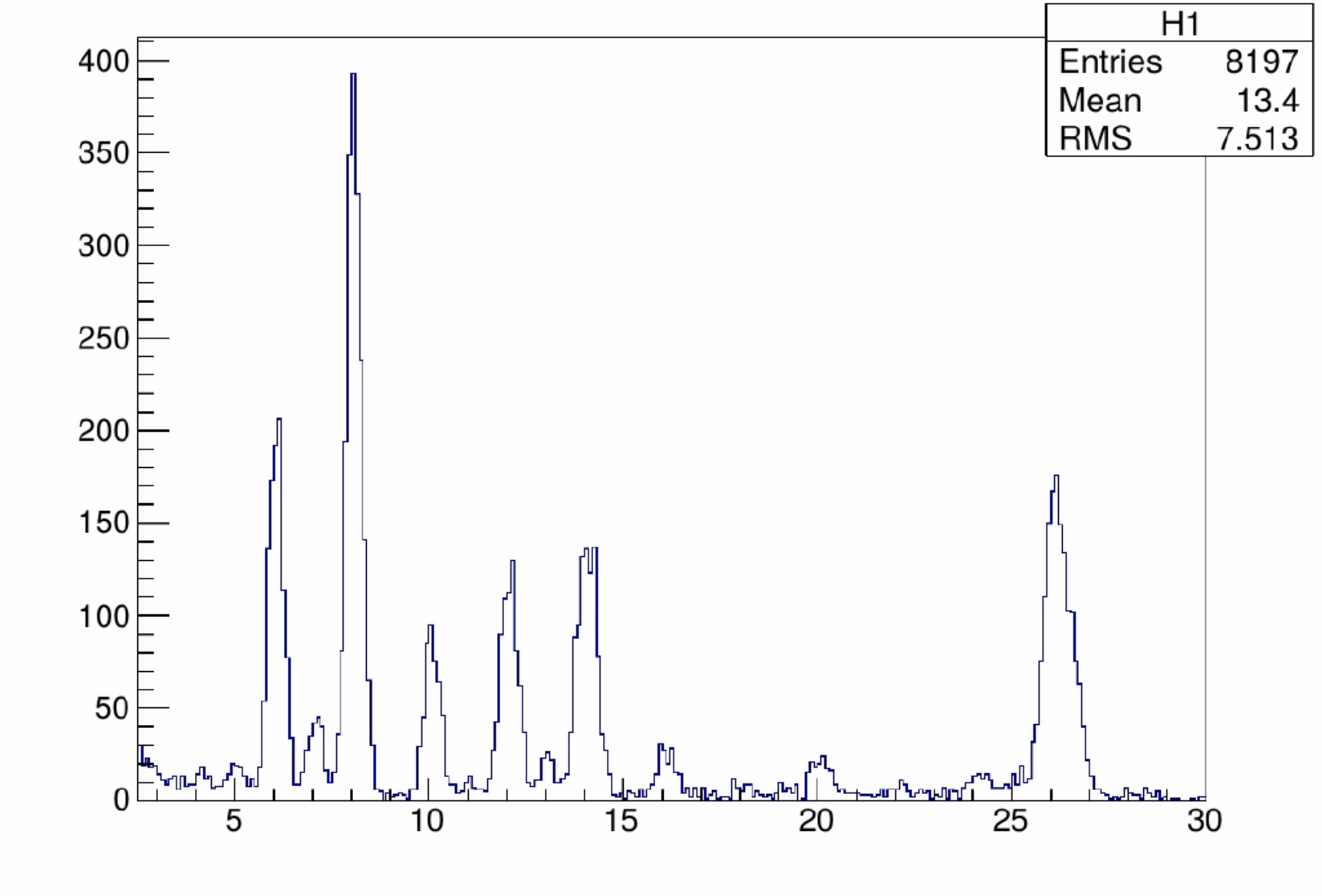
The charge measurements

- The charge detector system is designed for precision measurement of the primary particle charge and consists of four thin detector layers of 1.5×1.5 cm silicon pads. Each readout channel is used for the two pads to decrease number of channels. Signals of two pads from different parts of detector are summed. Probability of simultaneous registration of two particles is negligible. Charge measurement readout chips CR-1 have a dynamic range ~1000 mip. The charge measurement system must provide resolution better than the 0.3 charge unit according to results of simulation and beam tests.
- Microstrip detectors signals are used to reconstruct shower axis. Then charge detector pads near this axis are selected.

Preliminary charge distribution obtained by the NUCLEON experiment



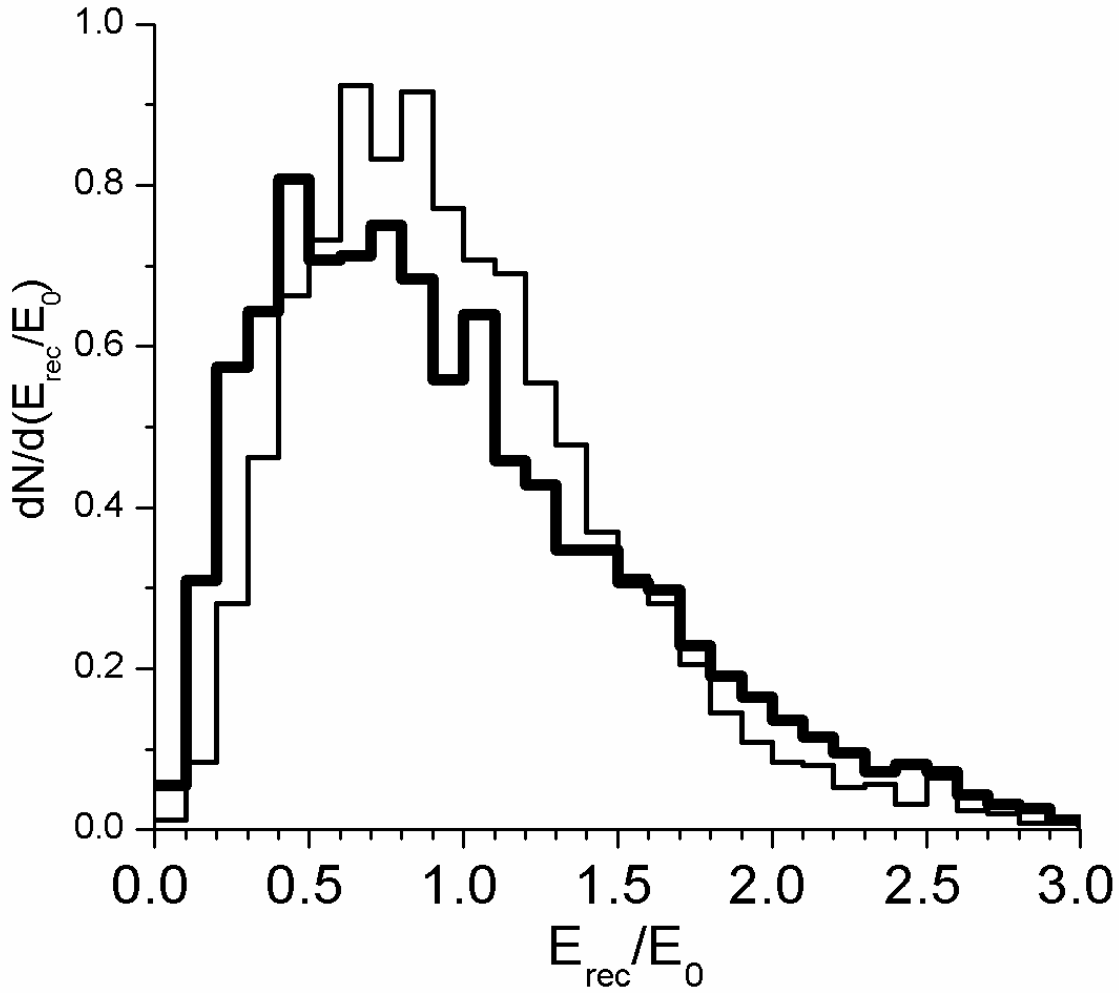
Charge distribution obtained for selected events



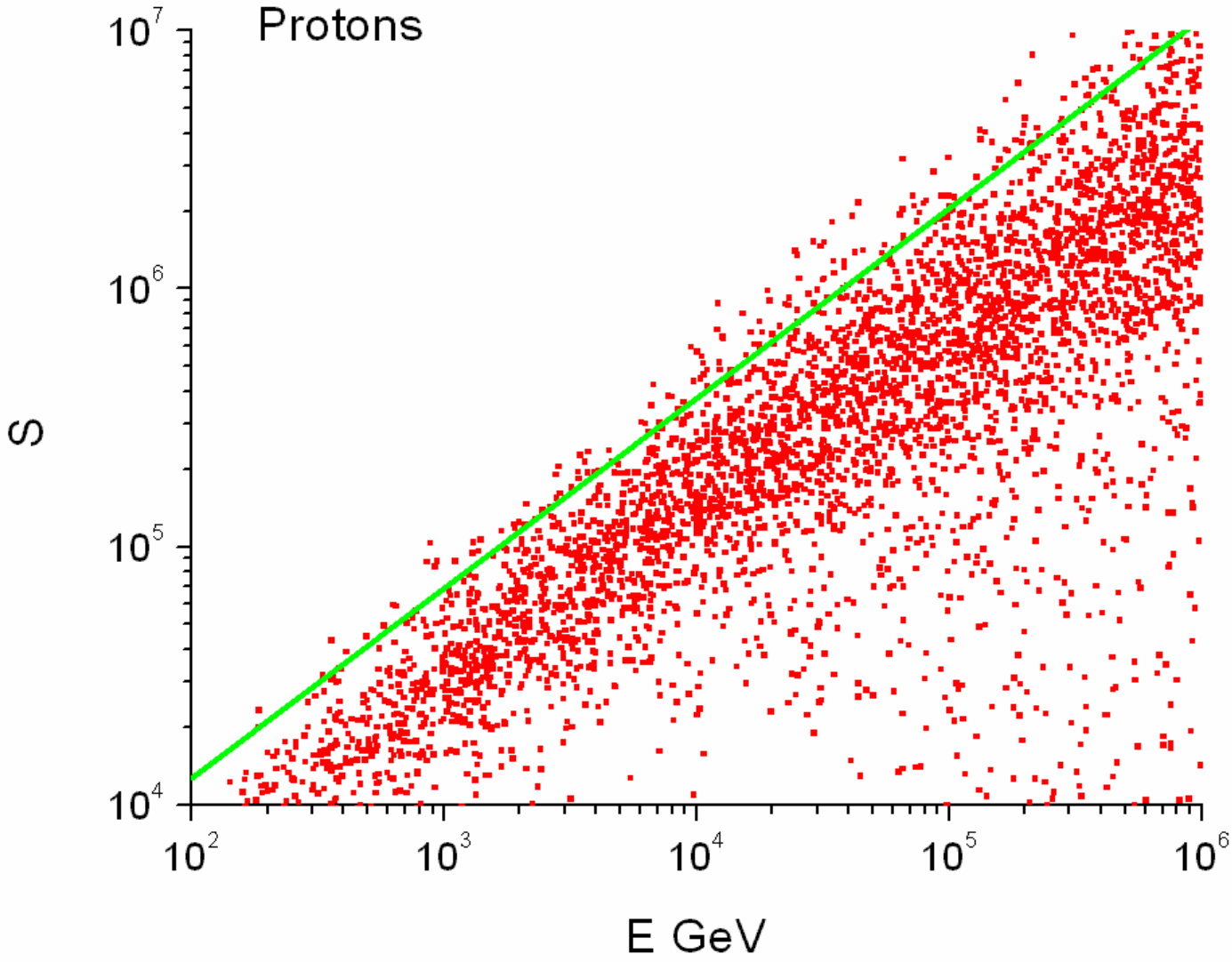
Energy measurements

- The energy measurement system is based on KLEM technique. Tungsten layers significantly increases the number of secondary particles and therefore improves the accuracy of a primary particle energy determination. The pitch of microstrips is equal to 484 μ m. The S-estimator is defined as: $S=\Sigma I_k ln^2(H/2x_k)$
  where x_k is a distance between the shower axis and the strip k, I_k is a signal in the strip k.

Pion beam tests results for 150 and 350 GeV. Reconstructed energy distributions



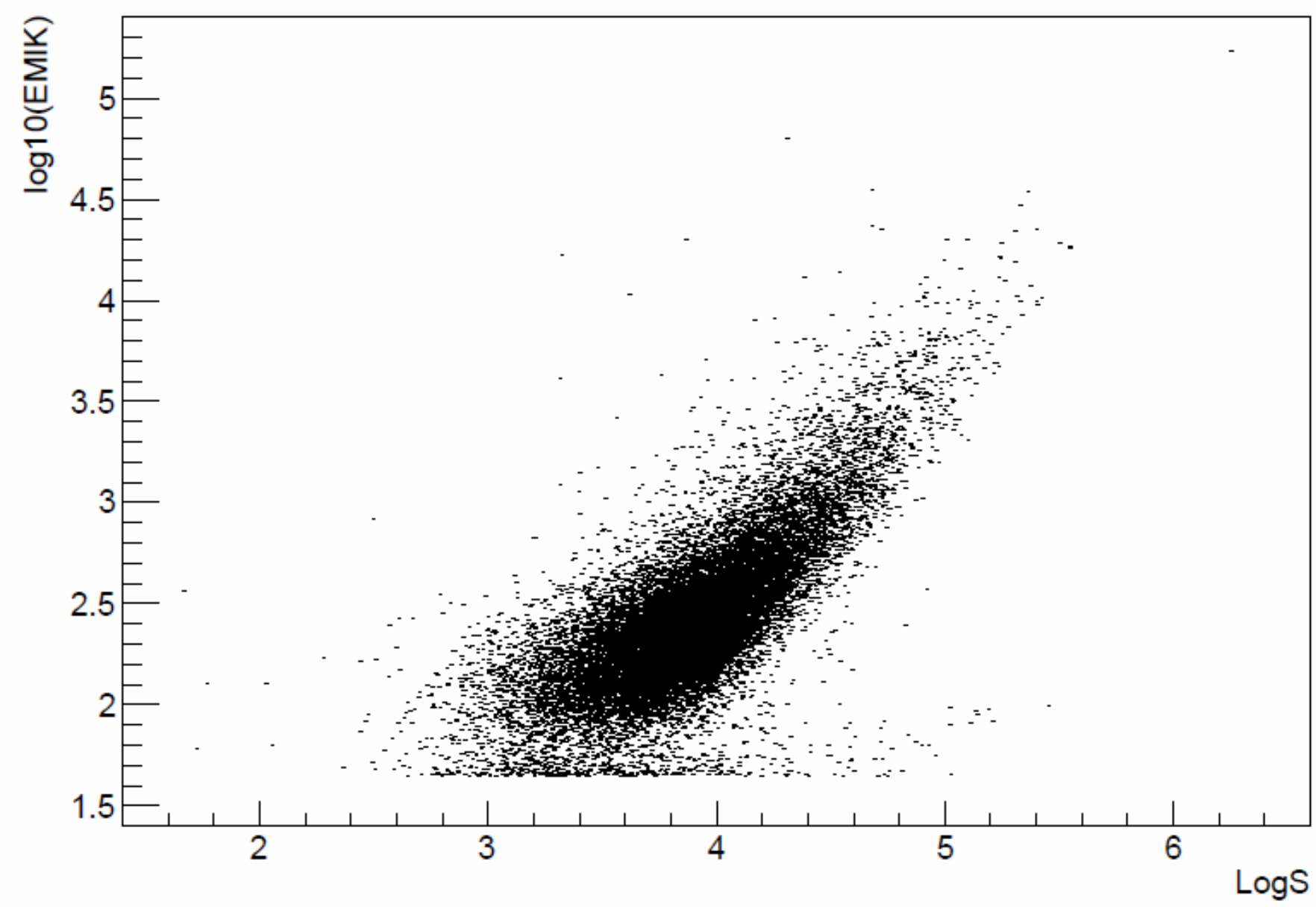
S(E) dependence (simulation)



$$E_{rec}=aS^{b}$$

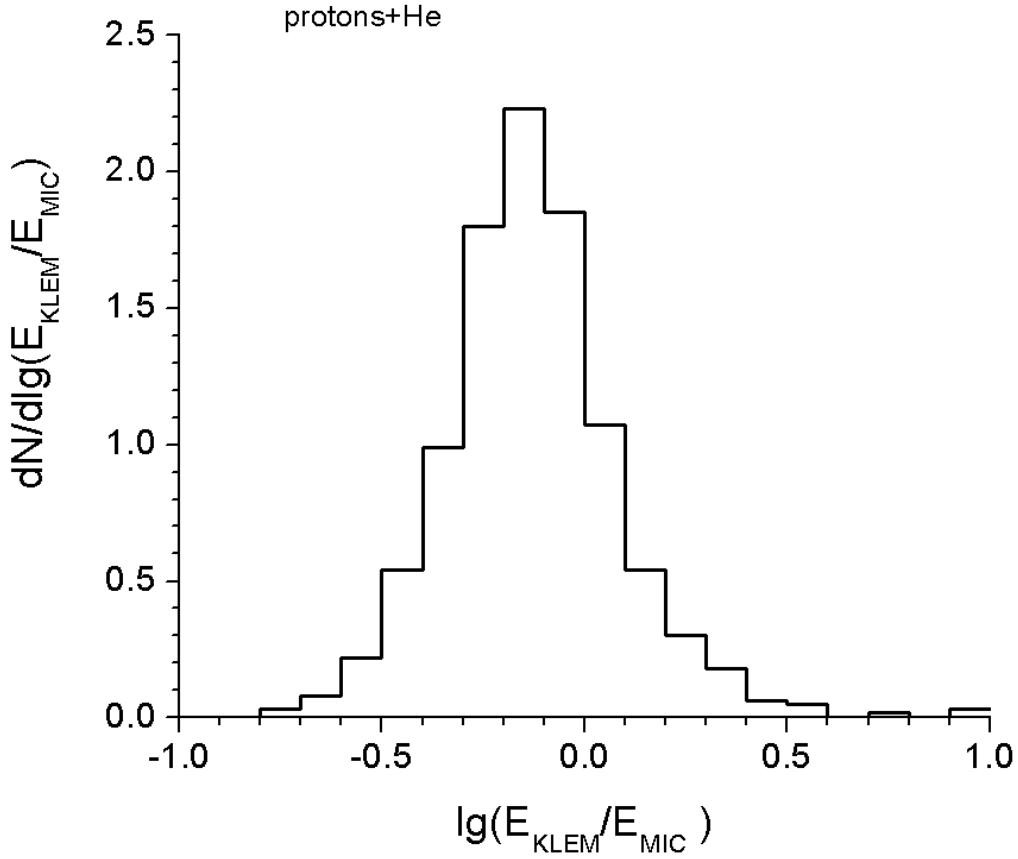
Values of parameters and probabilities of registration were determined for different nuclei by simulation results.

Calorimeter energy deposition vs S estimator (experimental results)

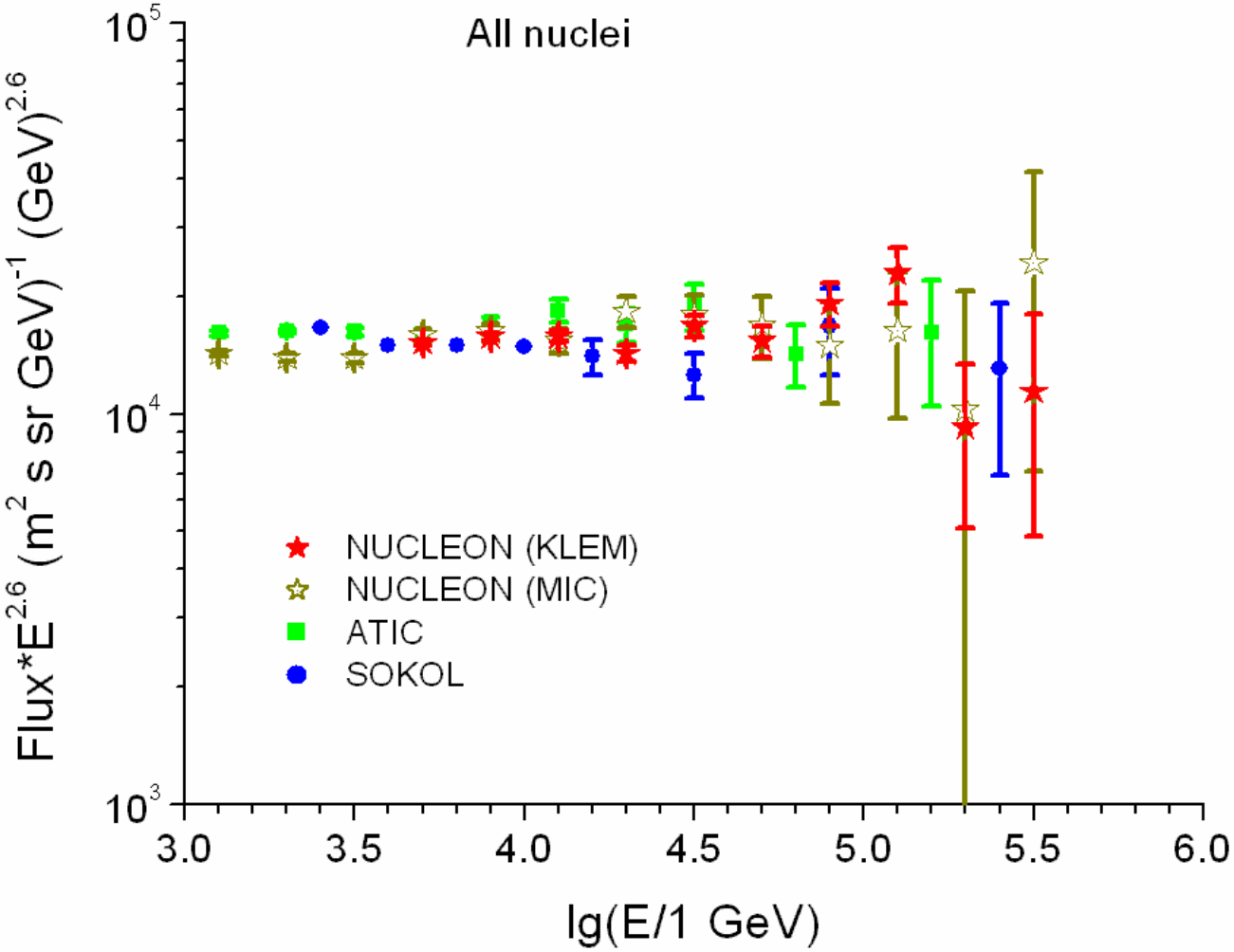


The Pearson product-moment correlation coefficient for EKLEM and EMIC is equal to 0.82. The distribution of ratio EKLEM/EMIC is presented for primary protons and helium nuclei.

Energy values determined by two methods are close. The middle ratio E_{KLEM}/E_{MIC} is equal to 0.87. It is significantly less than measurement errors.



All particles energy spectrum
Data obtained May 2015 - March 2016



SUMMARY

The NUCLEON device was designed and tested. The RESURS-P satellite was launched 26 December 2014. The expected performance is confirmed by simulation, beam tests and first space experiment results. All scientific objectives are achievable. We obtain and analyze the first data. The preliminary charge distributions and energy spectra are reconstructed.