The KLEM-NUCLEON Instrument Detailed Simulation

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Abstract

The elaborate simulations of the KLEM device within NUCLEON satellite mission has been performed. They take into account the distribution of material surrounding the device onboard the satellite.The developed trigger criteria allow essential suppression of the background. Energy reconstruction algorithm based on secondary particle distribution has been optimized. The simulated data analysis allows to reconstruct energy spectra. The first stage of charge detector optimization is considered and it is shown that we can measure secondary to primary nuclei ratio at high energies.

1. Introduction

Definitive information on primary cosmic ray spectra and composition can be obtained only by direct measurements, when a real primary particle is detected. But direct measurements are usually restricted for high energy range due to impossibility of a significant mass calorimeter launching in the near-Earth orbit. It was proposed a new approach for the investigation of high energy cosmic rays nuclei with $E>10^{11}$ eV [1, 2]. This method allows to construct a relatively lightweight device with large geometric factor. In this paper we present the Monte-Carlo simulation results for the energy spectra reconstruction measured by KLEM. We have also estimated the influence of trigger criteria and proposed the charge detector optimization.

2. The algorithm of NUCLEON experiment simulation

The KLEM device is placed within the pressurized container. This container is mounted near the accumulator module of the satellite. Solar batteries are out of the working aperture of the KLEM device. The schemes of the container and the position of the device onboard the regular satellite are shown in fig.1.

The new structure of spectrometer KLEM is described in [3]. The geometric factor of the device is increased by means of decrease of the gap between

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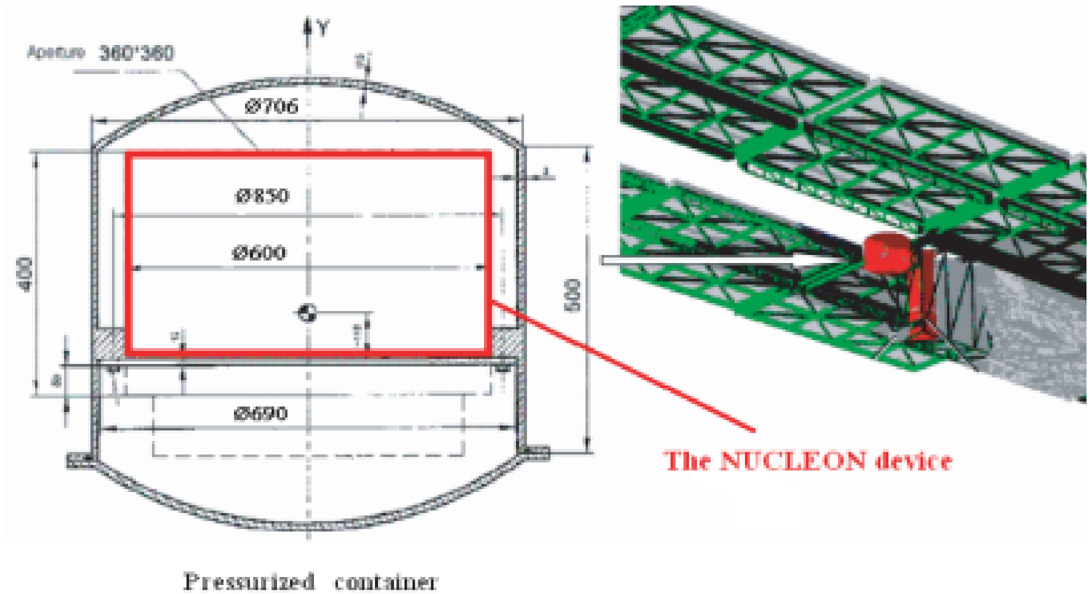

Fig. 1. The structure of the pressurized apparatus container and its position onboard the regular satellite

the target and converter in this version of design [6]. The energy reconstruction method is based on measuring of spatial density of secondary particles by silicon microstripe detectors. The GEANT 3.21 code with QGSJET model of multiple production at high energy and FLUKA model at low energy (<50 GeV) was applied to simulate the device. The KLEM method simulation results are not sensitive to hadronic interaction model in framework of the wide class of models [6].

3. Monte-Carlo simulation results

All cosmic ray nuclei (Z=1÷28) from upper hemisphere were simulated with threshold 50 GeV per particle. The values of power like spectrum exponents and intensties are taken from [4,5,7]. We took into account not only particles interacted in the substance of the device but also particles interacting in the material surrounding the device. These particles comprise the background. We simulated >120000 events which could cause the device responce. We worked out the multilevel trigger criteria included the simple onboard selection by signal thresholds and off-line analysis of spatial distribution of ionization. By these trigger criteria we reject ~ 0.08 of good events and add ~ 0.05 from background events. Further we simulated cosmic ray fluxes inside the working aperture by one year exposition. It was shown that trigger criteria are absolutely energy independent at high energies (>200 GeV/n). We study an opportunity to decrease the

Table 1. Accuracies of spectral exponent determination

E_{thr} GeV	10^2	$3{\cdot}10^2$	10^3	$3{\cdot}10^3$	10^4	$3{\cdot}10^4$	10^5	$3{\cdot}10^5$
p	0.0017	0.0043	0.012	0.031	0.086	0.203	0.406	1.46
C	0.0041	0.011	0.033	0.074	0.219	0.998		
Fe	0.0027	0.0058	0.014	0.031	0.074	0.170	0.461	1.42
All particles	0.0009	0.0023	0.0060	0.014	0.037	0.087	0.209	0.435

threshold energy. We reconstructed energy for every simulated event by means of the algorithm [6] for all components of cosmic rays. The accuracies of γ exponent determined by one year exposition statistics of the NUCLEON apparatus for different threshold energies are presented in table.1. At energies more then 100 GeV the accuracies of γ exponent determination are estimated as 0.0017 for protons, 0.0041 for carbon, 0.0027 for iron, 0.0009 for all particles.

4. Charge detector optimization

The NUCLEON apparatus allows to achieve energies >400 GeV per nucleon for rare secondary nuclei. These working energies are sufficiently higher than energies achieved by the HEAO C-3 satellite experiment [4]. The development of precise charge detector is necessary for these measurements. The first stage of charge detector optimization is presented below. We consider the silicon detectors that are applicable for charge measurements by the KLEM experiment due to little size of device and characteristics of the vehicle. Three versions of charge detector design for KLEM spectrometers are simulated. Firstly it was one layer of simple silicon detector of thickness 0.3 mm. Secondly we simulated the system of detectors consisted of 5 layers of 0.5 mm silicon detectors separated by 4 of 1 mm aluminium. Thirdly the system of detectors consisted of two 0.3 mm silicon detector and one 8 mm silicon detector was simulated. Thin layers were mounted above the main thick layer and below it. We took into account all procceses caused the fluctuations of ionization excluded back scattered particles. The best charge resolution was achieved by third version of the detector design. However in this case we lose 0.04 of protons and 0.22 of Fe due to inelastic interactions in the silicon. We exclude the events with nuclear fragmentaion in the detector but the part of wrongly identified nuclei is equal to 0.005-0.01 for selected events. We present the measured charge distributions for three versions of charge detectors in fig.2.

These results are obtained for Li,Be,B and sub-Fe nuclei. Thus we can measure fluxes of rare nuclei. Preliminary analysis shows the rare nuclei measurements is possible by significantly sophisticated device with 3 layers of silicon (third version). However the improving of technology is necessary for it.

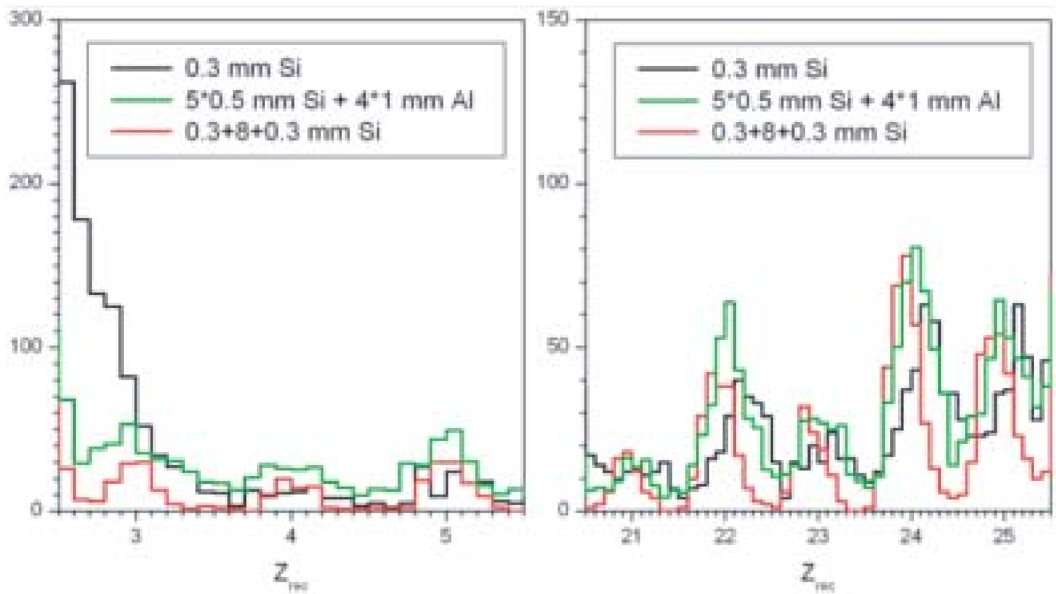

Fig. 2. The reconstructed charge distributions for rare nuclei

5. Summary

The performed simulation has shown an opportunity to use the KLEM technique by the NUCLEON satellite experiment. Elaborated selection criteria allow to discriminate background events. Energy reconstruction methods are applicable to restore energy spectra without distortions. We study opportunities of decrease of threshold energy and improvement of charge detector resolution.

6. Acknowledgements

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7. References

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