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NUCLEON ASIC and Ladder Electronics for Cosmic Ray Experiment

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The goal of the NUCLEON satellite mission is the measurements of the elemental energy spectra of high-energy (10**11 -10**15 eV) cosmic rays. It requires a high dynamic range of the readout electronics. The silicon strip detectors were used, the readout ASIC developed and both placed on the ladder. The ADC, data control interface, detector loads, high voltage distributer and service electronics were installed on the ladder as well. Dynamic range of the readout electronics, tested at the SPS beem is 1 – 40 000 mip. Such ladder can be used for future HEP and space cosmic ray experiments.

Summary

The main objective of the NUCLEON satellite mission is the direct measurements of the elemental energy spectra of high-energy (10**11 -10**15 eV) cosmic rays. The technique, used in NUCLEON project for the measurement of the energy of cosmic rays, is based on a kinematic reconstruction of the distribution of secondaries as well as data of the joined minicalorimeter.

The analog 32 channel ASIC with unique high dynamic range (1 – 40 000 mip) has been developed for the electromagnetic minicalorimeter of the NUCLEON project, of about 3000 channels in total. The ASIC allows to record signals of relativistic particles and nuclei with a charge from Z = 1 up to Z > 50 from silicon detectors, having capacitances up to 100 pF.

The transfer function of charge sensitive amplifier (CSA), having two subranges of various gains, allowed to reach high dynamic range of the readout electronics. The division of the full dynamic range (from noise to saturation) into two subranges should be considered as a special feature of the designed CSA circuit. The subranges in the designed scheme are automatically switched. An auxiliary class B amplifier is brought at the CSA output. For small signals this amplifier is off and CSA gain is determined by a relatively small feedback capacitance value (~6.6 pF). For higher amplitudes (starting from ~3 pC (adjustable)), the class B amplifier is dynamically switched on. In this case, an additional capacitor is added into the CSA feedback via the class B amplifier. Its gain and a value of additional capacitance added to the CSA feedback circuit define the total CSA gain in the large amplitude region. The latter become smaller, than one in the small amplitude region. Thus the equivalent feedback capacitance value of the CSA is ~67 pF. A long channel nMOS (L=100 μm, W=1 μm) has been used to discharge feedback capacitance and to specify the gate bias of the input transistor. The chip showed a 120 pC dynamic range at a SNR of 2.5 for the minimal energy (1 mip) particles.

The ASIC structure includes 32 analog channels, consisting of CSA, shaper (peaking time of 2 us) and T&H circuit. All analog chain outputs is collected by analog multiplexor with output current driver and supplied by calibration system. Low power consumption (< 1.5 mW per channel) is a feature of the developed ASIC. The ASIC was fabricated by the 0.35 um CMOS process via Europractice and tested in the SPS beam.

The developed ladder consists of the multilayer PCB. Silicon strip detectors, readout ASICs, 16-bit ADC, data control interface, controller, silicon detector loads, high voltage distributer and service electronics are installed on the ladder. Such ladder architecture, providing out the digitized data, can be used for future HEP and space cosmic ray experiments.

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