The Modern Concept of the INCA Project

A.P. Chubenko[1], R.A. Mukhamedshin[3], V.V. Ammosov[1], G.I. Britvich[1], P.A. Chubenko[1], A.D. Erlykin[1], G.I. Kol'tsov[5], G.I. Merzon[1], V.N. Murashev[5], V.P. Pavlyuchenko[1], V.A. Ryabov[1], O.G. Ryazhskaya[3], A.L. Shchepetov[1], N.M. Sobolevskii[3], A.P. Soldatov[1], N.I. Starkov[1], I.S. Trostin[4], V.G. Vasil'chenko[1], G.T. Zatsepin[3], G.B. Zhdanov[1], and A.P. Zhukov[3]
(1) Lebedev Physical Institute, Moscow, 119991 Russia
(1) Institute for High-Energy Physics, Protvino, 142284 Russia
(3) Institute for Nuclear Research, Moscow, 117312 Russia
(4) Institute for Theoretical and Experimental Physics, Moscow, 117259 Russia
(5) Moscow State Institute of Steel and Alloys, Moscow, 117936 Russia

Abstract

A recent concept of the INCA project is presented. New approaches based on the ionization-neutron calorimetry and designed for direct studies of the energy spectrum of the primary cosmic radiation (PCR) in the "knee" range ($10^{15} - 10^{16}$ eV) and the electron spectrum at $10^{11} - 10^{13}$ eV are discussed. Newest types of semiconductor bipolar detectors and scintillator detectors developed for the INCA project are considered.

1. General Concept

The main ideas of the INCA project [1,2] are (1) to use mainly a light substance that permits to maximize the geometrical factor; (2) to measure primary energy by analyzing both the neutron yield and ionization component in cascades; (3) to use the neutron counting for separation of $e^{\pm}/\gamma$-initiated cascades.

The INCA instrument is a $2 \times 2 \times 2$ m^3 cube of 10-t weight (Fig.1) consisting of the inside and outside parts. The construction is characterized by $\lesssim 4\pi$ geometry. While neglecting edge effects etc., the geometric factor is ~ 48 m^{2}sr. The total thickness is $\sim 4.6\lambda^p_{int}$ (at $E_0 \sim 1$ PeV) and ~ 13 radiation lengths.

The inside absorber (Fig.1*a*) consists of 50 layers. Each layer is divided into 40 logs (Fig.1*b*), 40 mm thick each (1-mm lead, 29-mm polyethylene, and 10-mm plastic scintillator strips). Logs in alternate layers are mounted at right angles. Signals produced by the charged and neutron components are read out by two opposite photodetectors (Fig.1*d*). The position and direction of the shower axis are determined with the use of the difference in analogue signals caused by the ionization with an accuracy of ~ 1 cm and $\sim 0.1°$, respectively. Light materials

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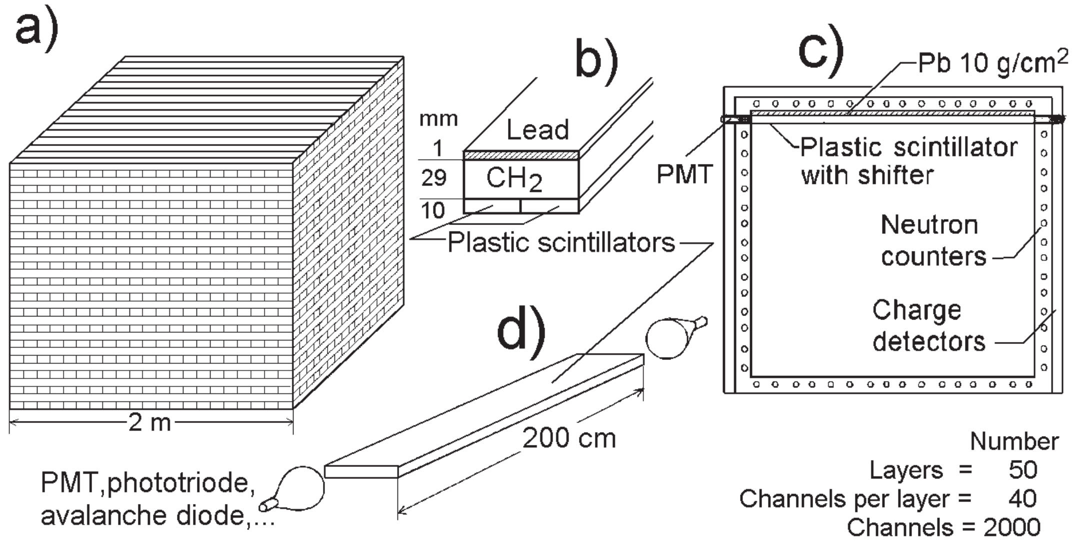

Fig. 1. The (a) inside and (c) outside parts of the INCA satellite; (b) a log; (d) a plastic scintillator strip with photodetectors.

(polyethylene and scintillators) and lead make up $\sim$ 80% and $\sim$ 20% by total weight, respectively.

The outside (Fig.1*c*) consists of charge detector, neutron counter layer, and a layer of plastic scintillator strips combined with shifters and PMTs and covered with a lead layer.

2. Calorimeter Detectors

2.1. Plastic Scintillators

Newest plastic scintillator strips made of the extruded polyethylene and enriched by orthocarborane (4–5 %) [3] will be used as position-sensitive detectors to measure both the neutron and ionization signals. Fig.2*b* shows that their properties permit to separate signals caused by neutrons and MIPs. The main maximum on a measured amplitude spectra (Fig.2*a*) is caused by neutrons.

2.2. Photodetectors

The high energy of cascades under consideration permits to measure the ionization signal with vacuum phototriodes or newly developed plastic photosensitive plates mounted at scintillator-strip ends. These photodetectors are characterized by a wide dynamic range ($\sim 10^7$), simplicity, low cost and weight, and high reliability. The threshold sensitivity of the scintillation detector based on phototriodes is about 20 MIPs.

As neutrons produce signals distributed in time and following one after

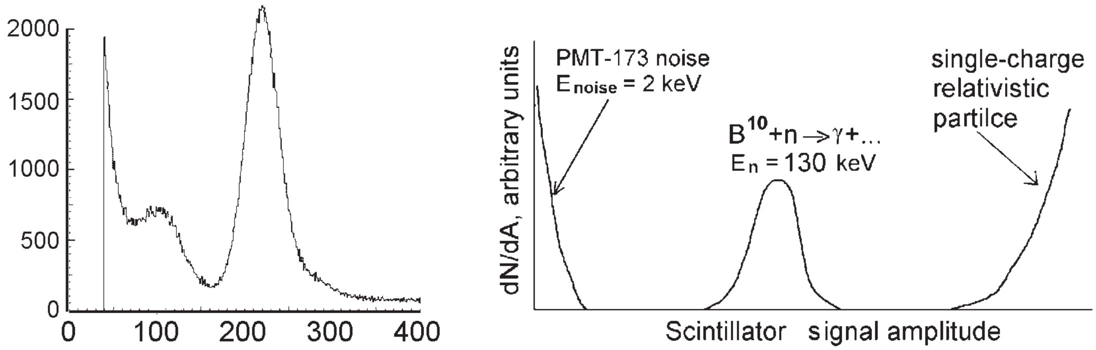

Fig. 2. (a) Amplitude spectrum produced by captured neutrons and measured by PMT; (b) a sketch of spectra produced by PMT noise, neutrons, and MIP particles.

another, the corresponding photodetectors must detect single neutron-produced light pulses. Therefore PMTs or avalanche diodes are mounted at the ends of about 10% of scintillator strips to measure these pulses during time gates of $\sim 300\,\mu$s after the beginning of a cascade satisfying to specific criteria.

At the present time, newest pixel silicon-based bipolar transistor detectors of charged particles applying a concept of a local-injection mechanism for the amplification of the drift component of a weak ionization current are under design (Sect. 3.1.). Preliminary analysis shows that high-sensitive photodetectors could be designed on the same base and applied instead of PMTs.

3. Charge Detectors

3.1. Semiconductors

Newest, functionally integrated, silicon-based pixel bipolar transistor detectors with a high space-time resolution and high signal-to-noise ratio are under design. A concept of a local-injection mechanism is used for the amplification of the drift current component produced by a charged particle penetrating the bipolar transistor structure (Fig.3). We propose to apply a matrix-structure pixel chain detector containing a large number of cells. First experimental samples show promising features as compared with standard microstrips. Fig.4 shows an output amplitude distribution caused by 5-MeV α-particles in the structures. The peak corresponds to the passage of particle through the sensitive pixel. The coefficient of the internal amplification of current pulse was found to be $\gtrsim 100$, although a low-resistance ($\sim$ 20 ohm/cm) silicon was applied as a basis for the structures. Preliminary analysis shows that high-sensitive photodetectors could be designed on the same base and applied instead of PMTs and avalanche diodes.

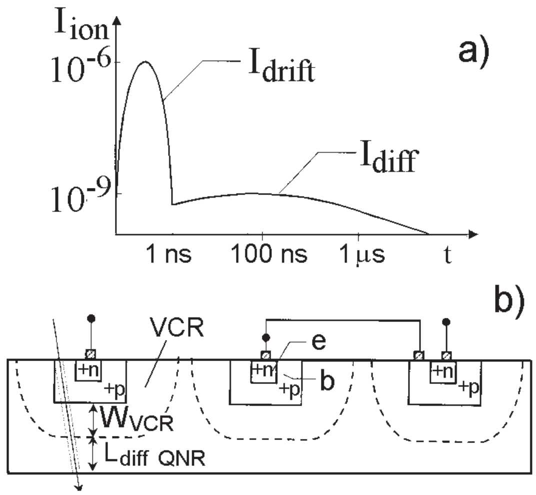

Fig. 3. Bipolar pixel structures: (a) schematic time dependence of current produced by charged particles; (b) a structure scheme.

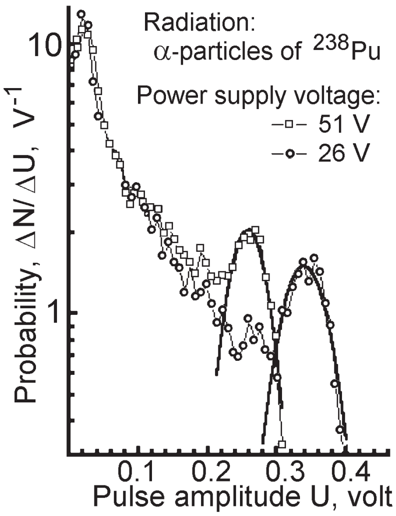

Fig. 4. Output amplitude distribution of signals caused by 5-MeV α-particles in pixel structures.

3.2. Scintillator Charge Detector

The use of specific(”phoswich”) scintillators as charge detectors for the separation of different primary particles (protons, deuterium and tritium nuclei, e.g.) by analyzing the pulse shape [4] is under consideration.

4. Summary

A new technique for investigation of primary cosmic radiation is elaborated in the framework of the INCA project to study the PCR spectrum in the ”knee” range and the electron spectrum at $E_e > 1$ TeV.

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5. References

1. Aleksandrov K.V. *et al.* 2001, Nucl. Instr. Meth. in Phys. Res. A459, 135.
2. Aleksandrov K.V. *et al.* 2001, Nucl.Phys.B (Proc.Suppl.) 97, 189; 2002, ibid, 113/1-3, 344.
3. Britvich I.G. *et al.* 2002, Instr. & Experimental Techniques 45 no.5, 644.
4. Toke J. *et al.* 1993, Nucl. Instr. Meth. in Phys. Res. A334, 653; Ghetti R. *et al.*, 1993, A335, 156.