

## The modern concept of the INCA project elements

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The modern concept of elements of a device designed to study the spectrum and composition of the primary cosmic radiation up to energies of  $\sim 10^{16}$  eV and based on new technologies is considered.

### 1. Introduction

The main goal of the INCA project [1] is the design of a multipurpose spectrometer for fundamental studies of the primary cosmic radiation (PCR), in part, for measurements of the spectrum and composition of PCR components at "knee" energies up to  $\sim 10^{16}$  eV. The project employs a new-type device, namely, ionization-neutron calorimeter (INCA), measuring both ionization and neutron signals and exploiting bipolar pixel silicon-based detectors developed in the framework of this project.

### 2. Properties of INCA

General Properties. Basic characteristics of the current INCA conception are listed in Tables 1 – 3 and schematically shown in Figs. 1 – 4. A layout of INCA is shown in Fig. 1. The INCA's exterior consists of two layers (*A* and *B*) separated with a gap (Figs. 1 and 3). The layer *A* constitutes a 1-cm thick polyethylene layer containing a 1-mm thick charge detector (CD) divided into  $5.5 \times 5.5$  cm<sup>2</sup> sections and coated by a 3-mm thick polyethylene film. The layer *B* is made of 5-cm thick polyethylene; PMTs and phototriodes are coming through its openings. "Helium-2" neutron counters are placed inside this layer. The interior calorimeter has 50 levels, each consisting of the alternating lead and polyethylene layers with a thickness of 1 and 29 mm, respectively, and the layer of the long (200 cm) plastic scintillator blocks with the thickness 10 mm (see Fig. 2). Each of the scintillation blocks may include the light spectrum shifters (optical fibers or strips). Polyethylene and lead constitute  $\sim 78\%$  and  $22\%$  of the total weight. This is equivalent respectively to 4.3 and 0.3 in proton

**Table 1.** The basic technical and scientific characteristics of the INCA device

Parameter	Value
Total weight	11050 kg
Total dimensions:	$220 \times 220 \times 220 \text{ cm}^3$
Calorimeter dimensions	$200 \times 200 \times 200 \text{ cm}^3$
Thickness of the polyethylene reflector	5
Thickness of the charge detector's platform	1
Gaps between calorimeter, reflector, CD platform	4
Number of scintillators ( $5 \times 1 \times 200 \text{ cm}^3$ )	2000
Number of photodetectors (PMT, phototriodes)	4000
Number of avalanche photodiodes	400
Number of silicon detector plates ( $5.5 \times 5.5 \text{ cm}^2$ )	8000
Number of ADC channels	16000
Number of the neutron- and $\gamma$ -pulse counting channels	525
Power consumption	500 W
Primary information volume of registered event	51 kb
Active life time of scientific equipment	$\geq 3$ years
Thickness in proton's mean free paths for interaction	$4.6 \lambda_{\text{int}}^p$
Thickness in radiation lengths	$13 t_0$
Device aperture	$\sim 2.7 \pi$
Geometry factor	$10 - 48 \text{ m}^2 \text{sr}$

interaction paths,  $\lambda_{\text{int}}^p$ , or to 4 and 9  $t_0$  in radiation lengths. Figure 3 shows the INCA's section in the plane traversing through one of the SNM17 counters. Figure 4 demonstrates a side view of one scintillator block.

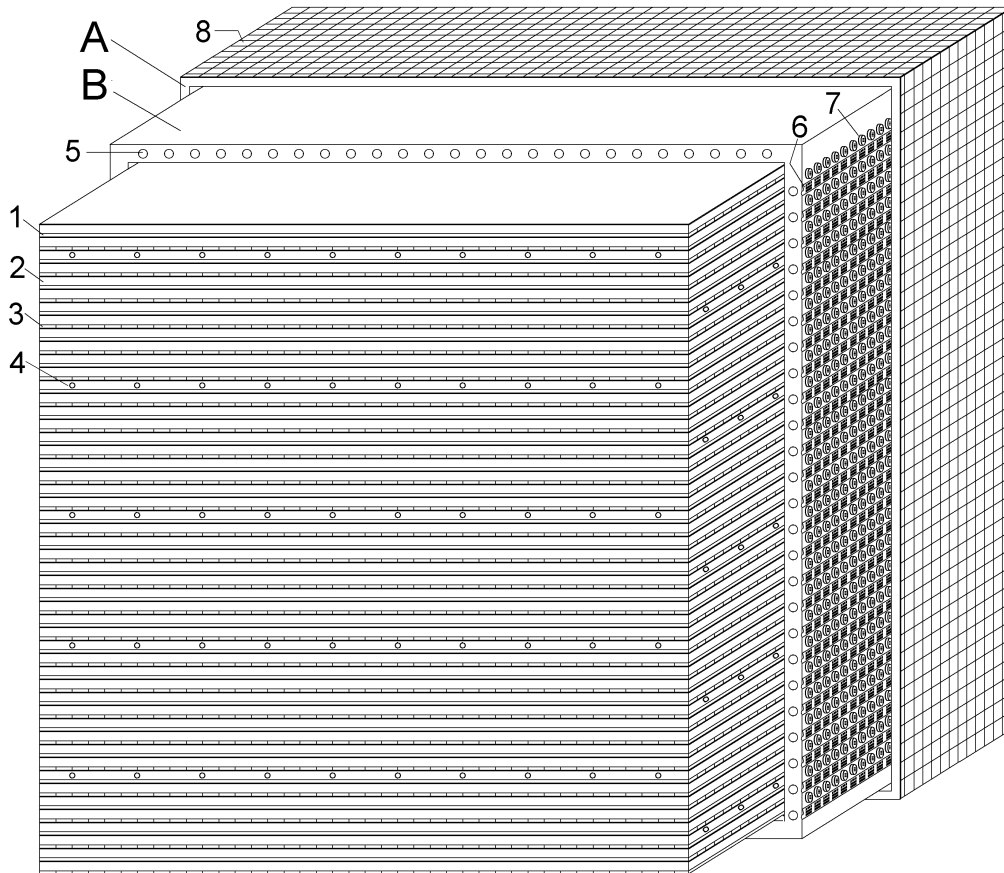
Scintillators. The plastic scintillation strips are used as position-sensitive detectors of the neutron and ionization signals. PMTs, photo-triodes, and avalanche diodes are used as photodetectors. At the ends of the 80% of scintillation strips, phototriodes are placed for registering the ionization component in the amplitude-measurement mode. Light-guide fibers passing through scintillators transmit neutron-produced single light pulses to avalanche diodes, which are used together with PMTs placed at the ends of 20% of strips for neutron registration in the pulse-counting mode. The use of difference in signal intensity at the ends of scintillator bars makes it possible to measure the cascade axis coordinates with an accuracy down to  $\delta \lesssim 1 \text{ mm}$  that corresponds to an angular resolution of  $\sim 1'$ . The usage of Cd or Gd admixtures introducing into scintillators or coating of scintillation detectors makes it possible to increase essentially the efficiency of neutron-capture registration.

**Table 2.** Distribution of the INCA's power consumption

Function	Voltage, V	Power, W
Stabilised power supply of phototriodes and neutron counters	2000	50
Stabilised power supply of the charge detector and avalanche photo-diodes	100	10
Power supply of the calorimeter and charge detector registration channels	5	240
Control and data acquisition systems	–	100
Power reserve	–	100
Total		500

**Table 3.** Primary information content of registered event.

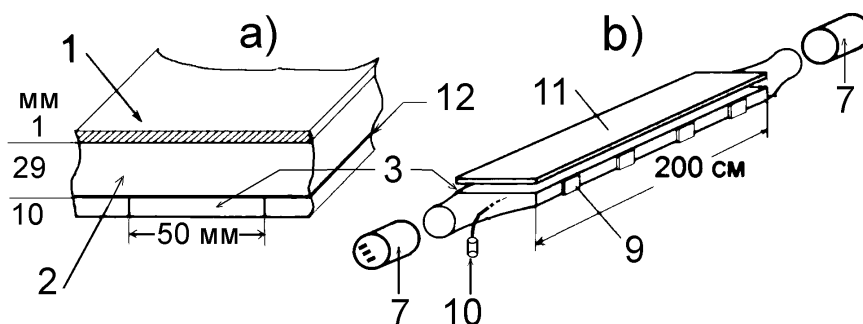
System	Channels number	Content of data per channel	Additional conditions	Total, Kb
Calorimeter	8000	12 bit	2 ADC per phototriode	12
Charge detector	8000	12 bit	1 ADC per section	12
Pulse counting system	525	1 bite	50 bins per channel	26
Monitor/control systems	–	–	–	1
Total				51



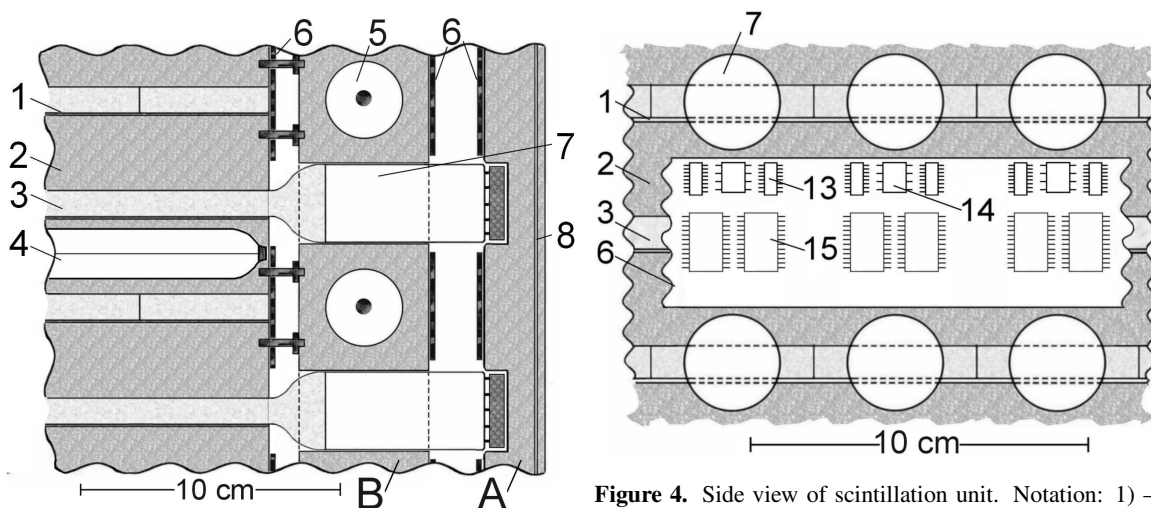
**Figure 1.** Layout of INCA: (1) lead; (2) polyethylene ; (3) plastic scintillators; (4) SNM-17 gas detectors; (5) Helium-2 gas detectors; (6) electronics boards; (7) photodetectors; (8) charge detectors. *A* and *B* are outward layers.

As scintillators detect mainly signals from delayed  $\gamma$ -rays produced in neutron captures and passing to relatively big distances from the point of their origin, 100 SNM17 200-cm long gas neutron counters destined to detect just neutrons are placed inside the each fifth polyethylene layer at 20 cm intervals.

Charge Detectors. The preferable charge detector (CD) version is a double-layer semiconductor one. However,



**Figure 2.** a) Section of one calorimeter layer; b) layout of scintillation block with photodetectors and light guides. Notation: 1) – 8) are the same as in Fig. 1; 9) photo plates; 10) fiber with avalanche photo diode; 11) wavelength-shifting light guide; 12) layer containing Cd or Gd. Proportions are not fulfilled.



**Figure 3.** Cross section of scintillation unit and outer part of INCA. Notations are the same as in Figs. 1 and 2.

**Figure 4.** Side view of scintillation unit. Notation: 1) – 12) are the same as in Figs. 1 and 2; 13) amplitude-digital converter AD7888AR; 14) operational amplifier 5442; 15) shifting register (CMOS-based serial-to-parallel code converter) 564IR13.

instead of microstrip detectors, it is supposed to apply newly-developed detectors exploiting the concept of bipolar  $n-p-n$  transistor pixels. First high-sensitive matrix-structural detector have been developed and tested. Experimental results correspond to our expectations.

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## References

- [1] Aleksandrov K.V. *et al.*, Nucl. Phys. B (Proc. Suppl.) **122** (2003) 427; *ibid*, **113** (2002) 344; Nucl. Instr. Meth. in Phys. Res. **A459** (2001) 135.