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Imaging Camera and Hardware of Tunka-IACT

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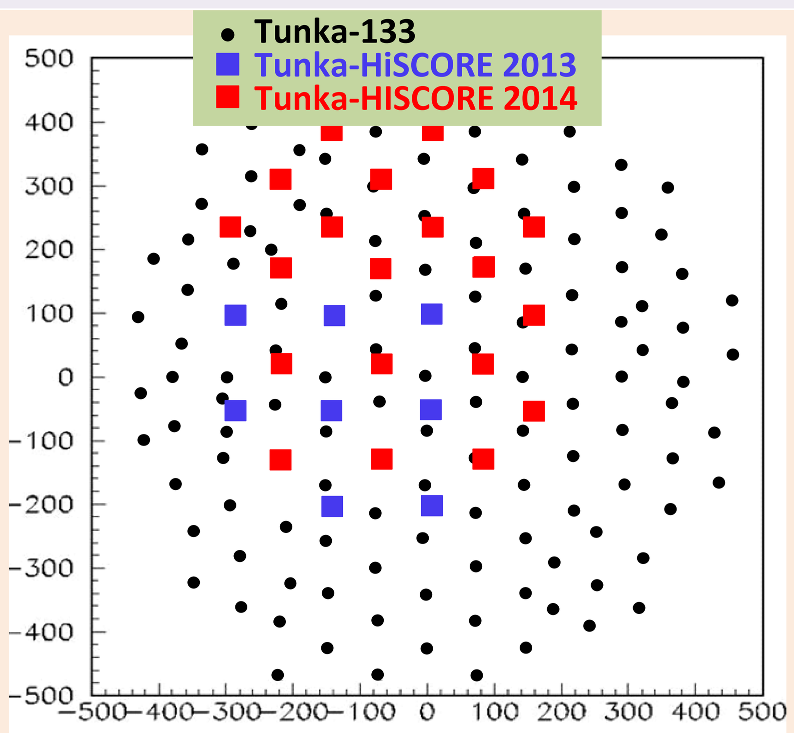
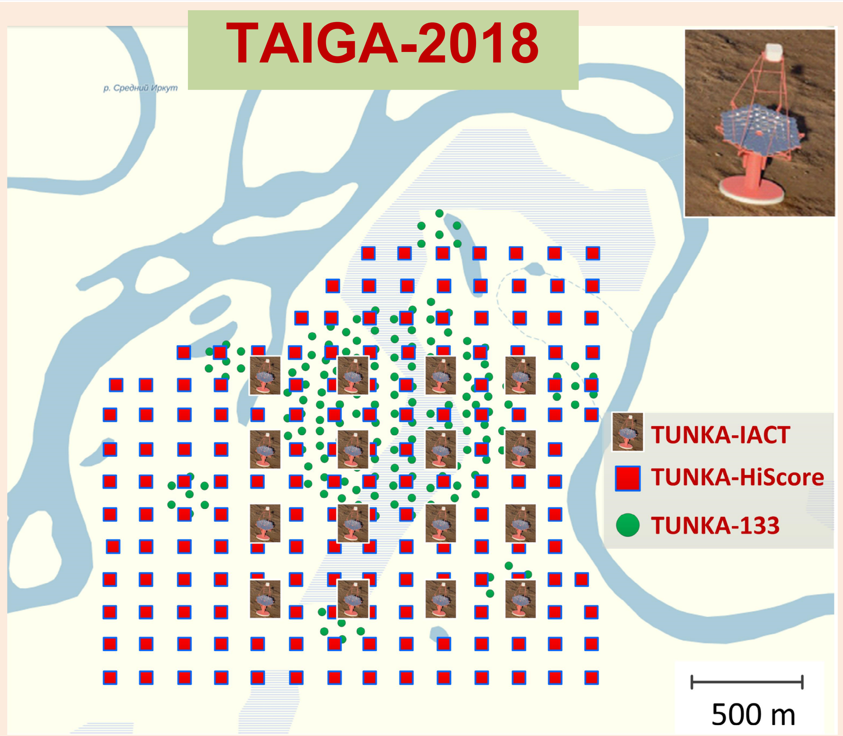
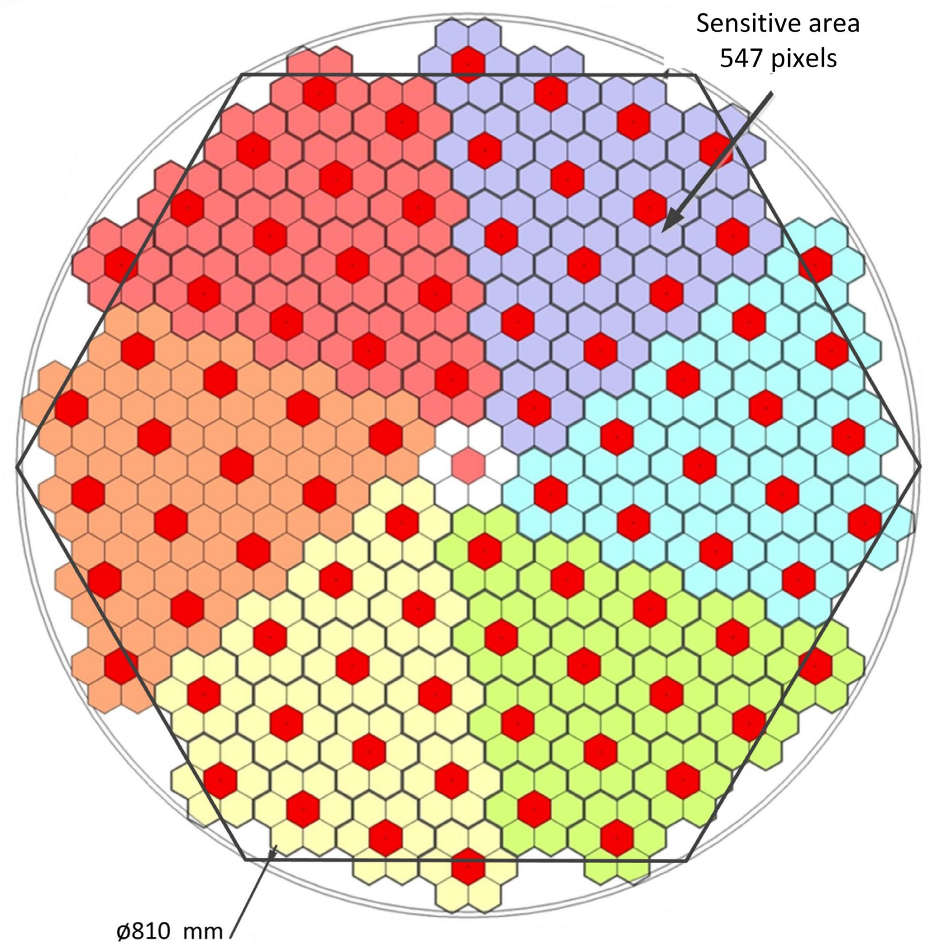
TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy) is a new hybrid detector system for ground-based gamma-ray astronomy at energies from few TeV to several PeV, and for cosmic-ray studies from 100 TeV to several 100s PeV. TAIGA is located in the Tunka valley (Siberia, Russia), where since 2009 the Tunka-133 Cherenkov EAS detector is in operation. The concept of the TAIGA Observatory foresees the creation of a complex of detectors able to provide the hybrid detection of EAS and to effectively separate gamma-induced EAS from hadron-induced ones: Tunka-133, a wide-FOV (~2 sr) integrating air Cherenkov detector with 185 stations spread over an area of ~3 km²; HiSCORE (Hundred*i Square-km Cosmic ORigin Explorer), an array of wide-angle (FOV~0.6–0.85 sr) integrating air Cherenkov stations; Tunka-IACT array, a net of IACT with ~ 4 m mirrors; Tunka-GrandE, an array of particle detectors, both on the surface and underground(~ 2000 m²).



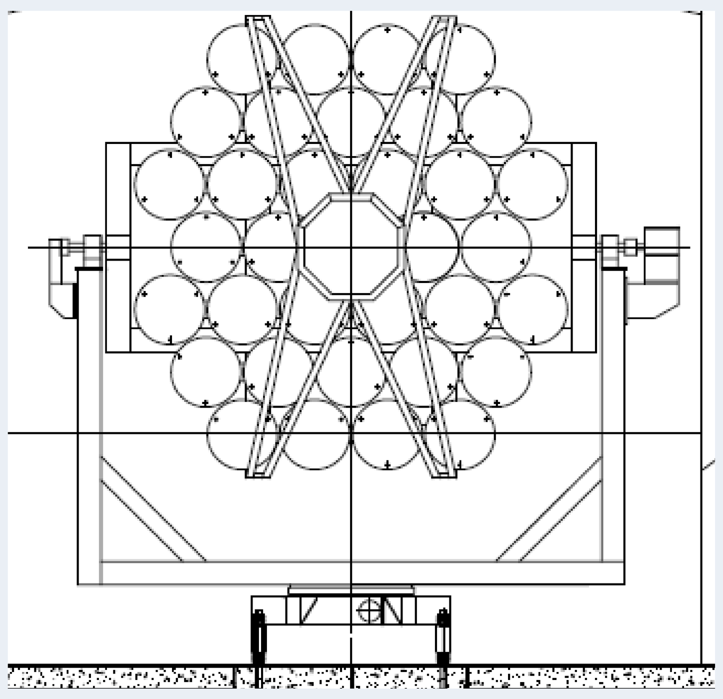


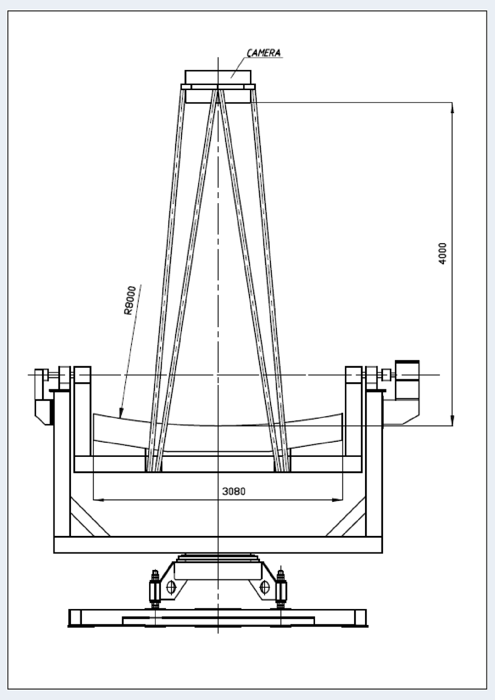
The **key advantages** of the gamma-observatory TAIGA is the joint operation of wide-angle and narrow-angle detectors of Tunka-HiSCORE and Tunka-IACT. By operating the telescopes in mono-scopic mode with distances of the order of 600 m between the telescopes, the total area covered per telescope is larger than the area that could be covered using the same number of telescopes as a stereoscopic system (requiring distances of roughly 300 m in the 10–100 TeV energy regime).

Camera



Tunka-IACT setup



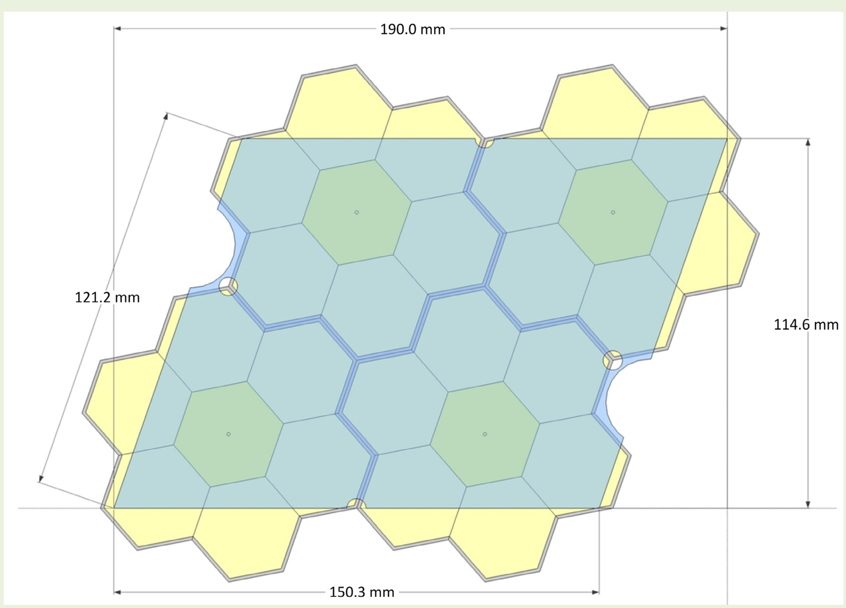


Mirror:
- Davies-Cotton optic type
- Focal length: 4750 mm
- 34 spherical mirror segments
- Diameter of each segment: 60 cm
- Diameter of the mirror: 4.3 m

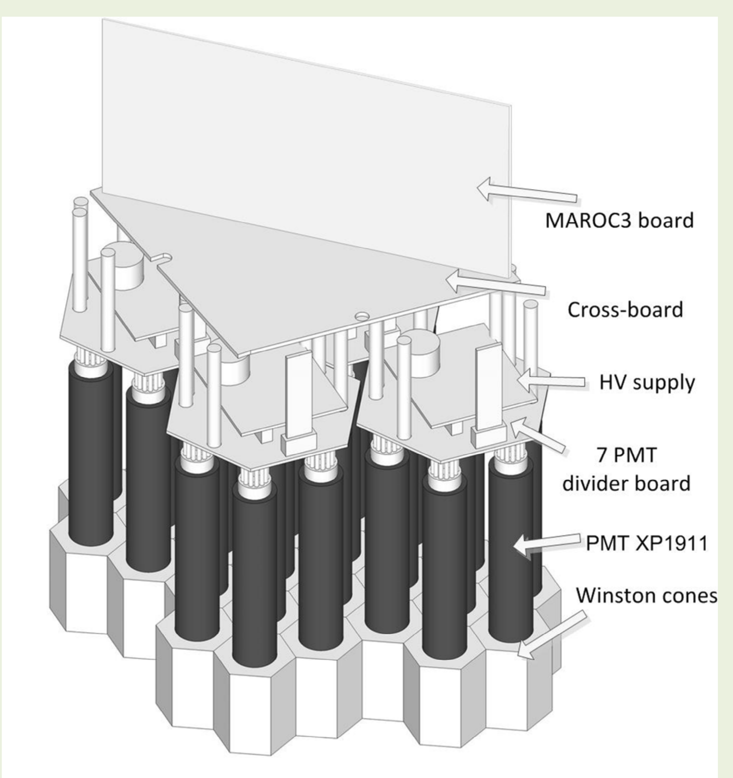
Camera:
- 547 hexagonal-shaped pixels
- PMT XP1911: window of DIA 15 mm
- Winston cone: 30 mm input size, 15 mm output
- FOV of single pixel: 0.36°
- Full FOV: 9.72°

Operation at the conditions of hard Siberian winter!!!

Basic camera unit



Basic cluster: 28 PMT-pixels arranged in four hexagonal cells 7HEX. The shaded area: the cross-board plate. Signal processing: PMT DAQ board based on the MAROC3 ASIC .

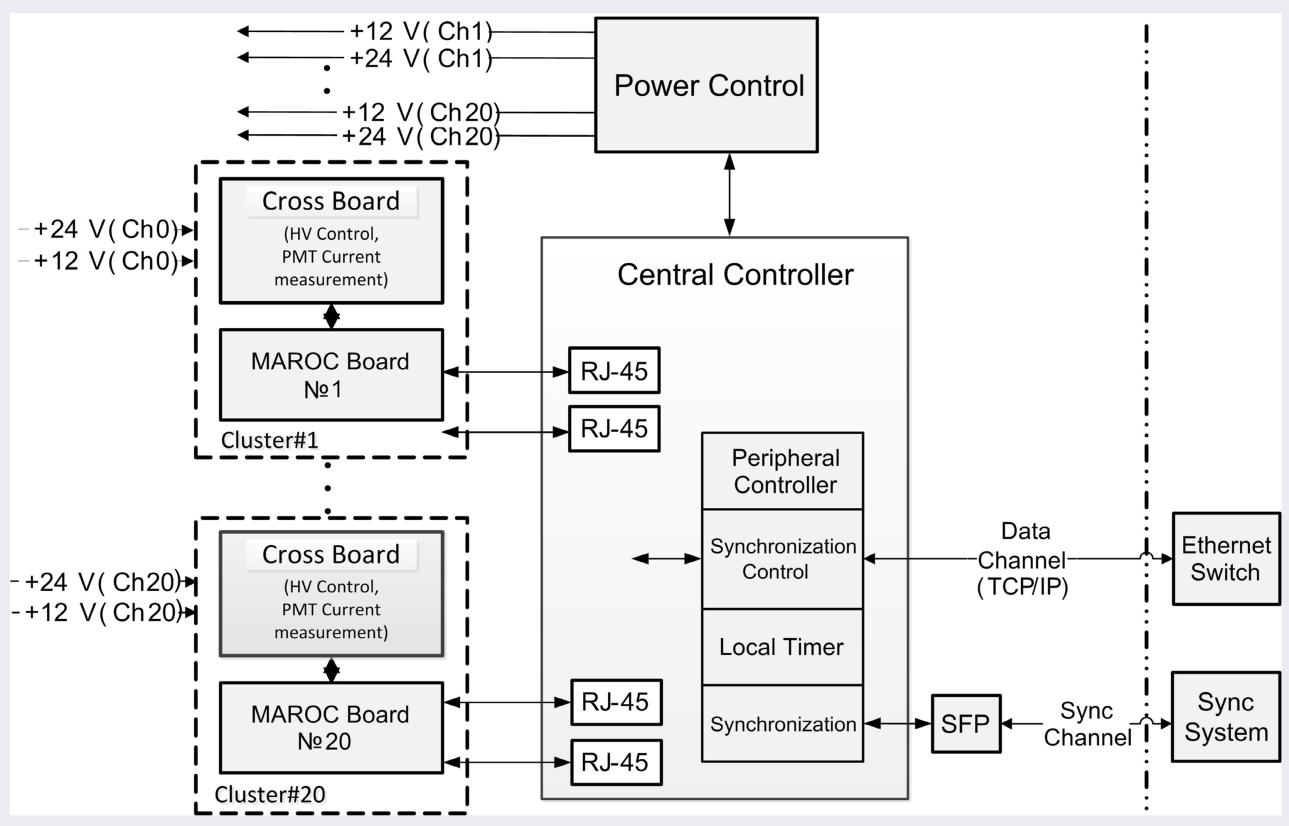


Tunka-IACT DAQ

Detection system: 20 identical clusters are served by the Central Controller.

Central Controller:
- PMT board operation control (HV setting and PMT current monitoring);
- the common trigger formation; synchronization;
- cluster data collection, intermediate storage and the traffic to the data collection center (≥20 Mbit/s).

Communication between the boards and the controller: LVDS standard; timing of trigger signals ≤ 5 ns.



MAROC3 ASIC board

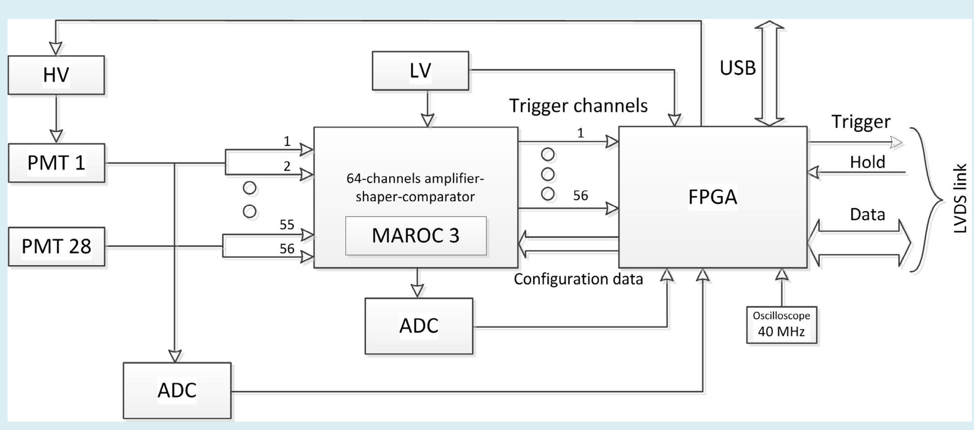
The basis of The camera readout electronics is the 64-channel ASIC MAROC3, which receives signals from the 28 PMTs.

Each channel includes: preamplifier with 6 bit adjustable amplification, a charge-sensitive amplifier and a comparator with an adjustable threshold. The ASIC chip comprises a 12-bit Wilkinson ADC. It has a multiplexed analogue output to an external ADC with a shaped signal proportional to the input charge, and 64 output trigger signals.

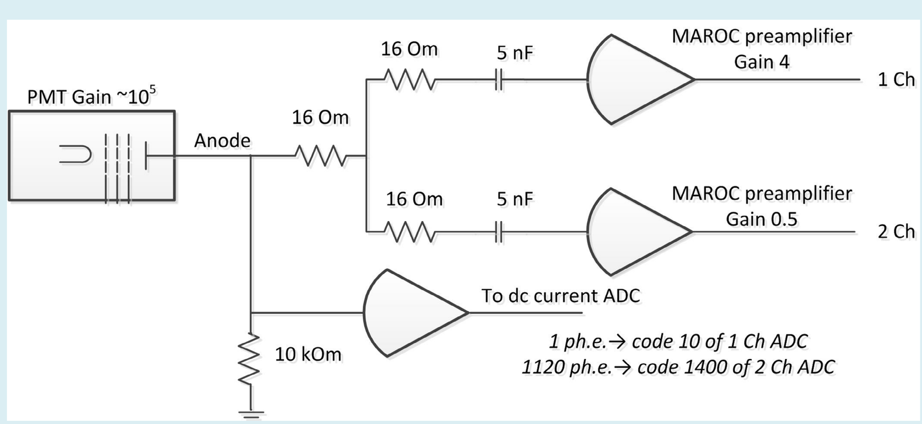
FPGA (FPGA EP1C6Q240C6): formation of the first level trigger (*n*-majority coincidences from 28 PMTs); control of the settings of the 64-channel ASIC; the ADC operation. The system of the MAROC3 control includes generating a local trigger, analog-to-digital converting, the loading of the MAROC3 configuration and the interface with the upper level system.

Two channels of MAROC3 process the signals from one PM splitted to provide the necessary dynamic range.

Cluster MAROC3 board

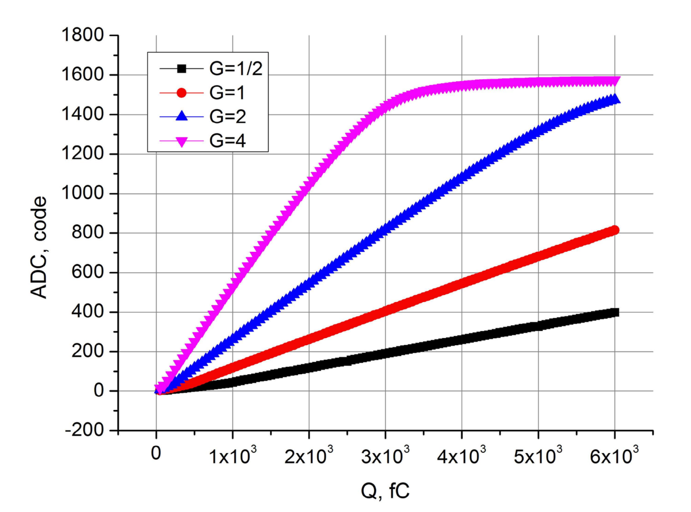


Splitter

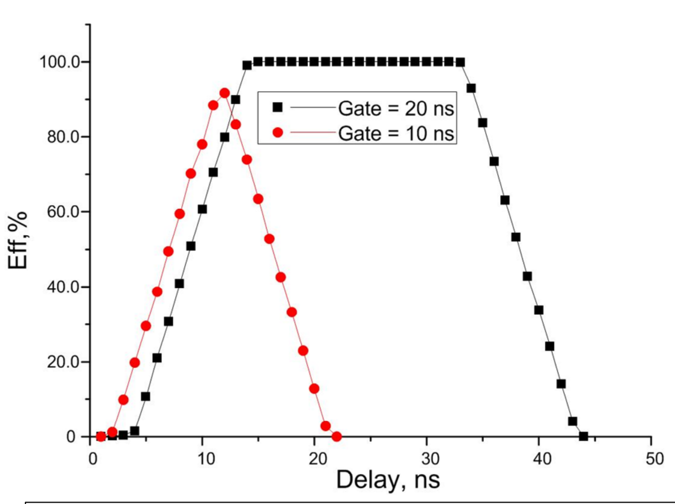


"Dead" time is not more than 200 μs which is about 1% of full-time detection at the expected rate of ~ 50 s^{-1}

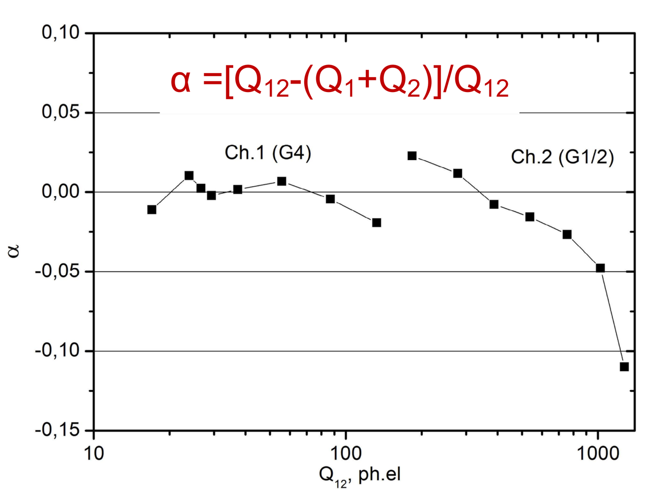
ASIC MAROC3 board test



Calibration characteristics of a spectrometric tract of the ASIC MAROC3 for different preamplifier transmission coefficients.



Dependence of the first level trigger formation efficiency on the delay.



The linearity of the spectrometric tract

Conclusion

We have developed a registration system of the IACT camera of the TAIGA Gamma Ray Observatory. It is based on 547 photomultipliers XP1911, combined in clusters of 28 PMTs. The PMT signals are processed by an electronic board on the basis of the 64-channel ASIC MAROC3. The signals from each PMT are processed by two independent channels of the ASIC, corresponding to different gains of the preamplifiers. This ensures that the linear range of the PMT signals is at least 1000. At present, the construction of a prototype camera for the first IACT is underway.

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