• The TAIGA experiment started in the 2000s as a cosmic ray project (TUNKA-25, TUNKA-133) and has recently expanded into γ-ray astronomy (a few TeV – several PeV).

• Combines all the techniques for γ-ray detection:
  √ IACT with the 10 m² mirror (the polarmost in the world)
  + two IACTs in 2018-2019;
  √ wide angle (0.6 sr) Cherenkov timing detectors (up to 110 detectors in 2018);
  √ muon detectors.

• Larger inter-IACT distance than in stereosystems (~600–800 m vs. ~150 m).

• Low investments, high sensitivity, an attractive approach for exploring the galactic PeVatrons.

• The first stage of the combined approach to γ-ray detection (IACT + timing array) has started, first IACT data obtained & analyzed.
### TAIGA history

- 2009: the array of 133 PMT detectors (Tunka-133) was inaugurated (UHE cosmic rays above 0.1 EeV).
- 2014: Tunka-Grande was built – 19 scintillation stations with an area of 13 m² each taken from EAS-TOP and KASCADE-Grande, but featuring new DAQ) for the EAS electron and muon measurement simultaneously with the radio antennas of Tunka-Rex and the PMTs of Tunka-133.
- 2015: the first IACT is under construction to study VHE γ-rays in addition to VHE & UHE cosmic rays.
- 2016: commissioning the first IACT prototype with 6 mirrors installed, first images received (12/2016).
- 2017: installing 29 mirrors of the IACT (09/2017), coming into full operation.
- 2018: the radio EAS array Tunka-Rex started deployment in the frame of a Helmholtz-Russia Joint Research Group. Currently it has 63 antenna stations distributed over the whole area of Tunka-133 for the UHE CR radio measurements at any time of the day in the same energy region as Tunka-133.
- 2019: TAIGA-HSCore was put in operation with the same detection principle as Tunka-133, but featuring more sensitive and accurate PMT detectors (currently 0.4 km² area, VHE CR >40 TeV).

### TAIGA in 2018–2019

Summary of the TAIGA development plans for the next two years:

- Commissioning the 2nd IACT (2018) and the 3rd one (2019) in addition to the first one with the same parameters.
- Expanding wide angle Cherenkov timing array up to 110 detector stations (FOV 0.6 sr each) for covering 1 km² area (and later 5 km² area).
- Installing the array of muon detectors of ~200 m² size for covering 1 km² total (and then up to ~3000 m² size).
- Discrimination of γ-ray events originating from the Crab Nebula, Markarian 421, and Tycho’s SNR against CR background.

### TAIGA parameters

Basic parameters of the TAIGA installation and constituent detectors:

- Location: 51°N 103°E (the northernmost & polartmost IACT of the world).
- γ-ray low energy threshold: ~40 TeV (IACT + timing array), ~2–3 TeV (IACT only).
- Effective area: 0.4 km² currently, 1 km² in 2018–2019.
- The expected integral sensitivity: ~2.5x10⁻¹⁸ TeV/cm²/sec for 300 hours of a source observation (2 seasons of operation) at 100 TeV.

- IACT parameters:
  - 10 m² mirror; 10′ x 10′ field of view;
  - ~550 PMTs/camera;
  - 22 64-channel DAQ boards, each based on MAROC3 ASIC;
  - Integration time 35 ms;
  - effective radius of EAS detection ~600 m (IACT + timing array).

- Timing array parameters:
  - 0.6 sr field of view of one detector station;
  - 4 PMTs/station;
  - inter-station distance >100 m;
  - total number of stations ~43 (for now), ~110 (in 2018);
  - stations direction: South (23°) for the Crab observation;
  - measurement precision:
    - energy: ~15–20%;
    - shower arrival direction: ~0.1°–0.4°;
    - shower core position: ~10–15 m.
TAIGA principle of operation

TAIGA principle of operation is different from stereoscopic operation of a few IACTs as well as from monoscopic operation of a single IACT. Instead, it’s rather a combination of mono and stereo regimes within a hybrid approach, when information from the 2nd telescope is unavailable (because it is located at a large distance from the 1st one or is absent at all), but is replaced by the same information from the timing array. Therefore, ‘IACT + timing array’ now works instead of ‘IACT + IACT’.

Stereoscopic operation of IACTs (standard approach).

Inter-IACT distance ~100–150 m

Combined operation IACT + timing array (TAIGA approach).

Inter-IACT distance may be increased to ~600–800 m
TAIGA-IACT first data

An important characteristic of any IACT image is the so-called ‘image size’, that is a total sum of all photoelectrons in the image. It’s similar to the number of photoelectrons Q measured by the timing array TAIGA-HISCORE. The comparison of the IACT image size with the prediction of this value obtained in TAIGA-HISCORE is presented in the left figure. The prediction was taken as a result of the fit of lateral distribution function measured by HISCORE. The dependence of the measured value on its predicted value is linear with some fluctuation around the theoretical line. This result both confirms the correct functioning of the IACT and demonstrates the possibility of using the IACT as an additional hit detector in the TAIGA-HISCORE installation.

In the right figure the spectra of image size are presented for comparison of experiment and simulation. For illustration we show two Monte Carlo predictions: 3–1000 TeV and 100–10000 TeV. The figure demonstrates good agreement between the joint events and simulated ones with energies greater than 100 TeV, which is closer to the HiSCORE-predicted core position (red line). Therefore, first IACT data indicated good agreement with the timing detectors data, which means a successful start of the first stage of the combined approach to γ-ray EAS detection (IACT + timing array).

Another advantage is a geographical location of TAIGA, which allows 500 h/year observing Tycho’s SNR, unavailable for HAWC and LHAASO arrays. The other possible candidates for TAIGA observation (with a 1 km² area) are listed in a table.

Selected references


TAIGA advantages

TAIGA assumes relatively inexpensive approach to ground-based gamma-ray astronomy – a combined technique of using monoscopic IACTs simultaneously with timing detectors. The first IACT of TAIGA has already taken first data, two additional IACTs will be developed and put in operation in 2018–2019 for covering a total area of 1 km². The TAIGA expectation of sensitivity to local sources is compared with various ground-based experiments in the figure.