The status of the TAIGA project

(Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy)

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for the TAIGA collaboration

Experimental challenges of TAIGA

In γ-ray astronomy:

- Search for galactic PeVatrons
- VHE spectra of few known sources & absorption on CMB
- Diffuse emission, galactic plane, local supercluster

In cosmic rays:

- Spectrum and mass composition for E ~ $10^{14} - 10^{18}$ eV

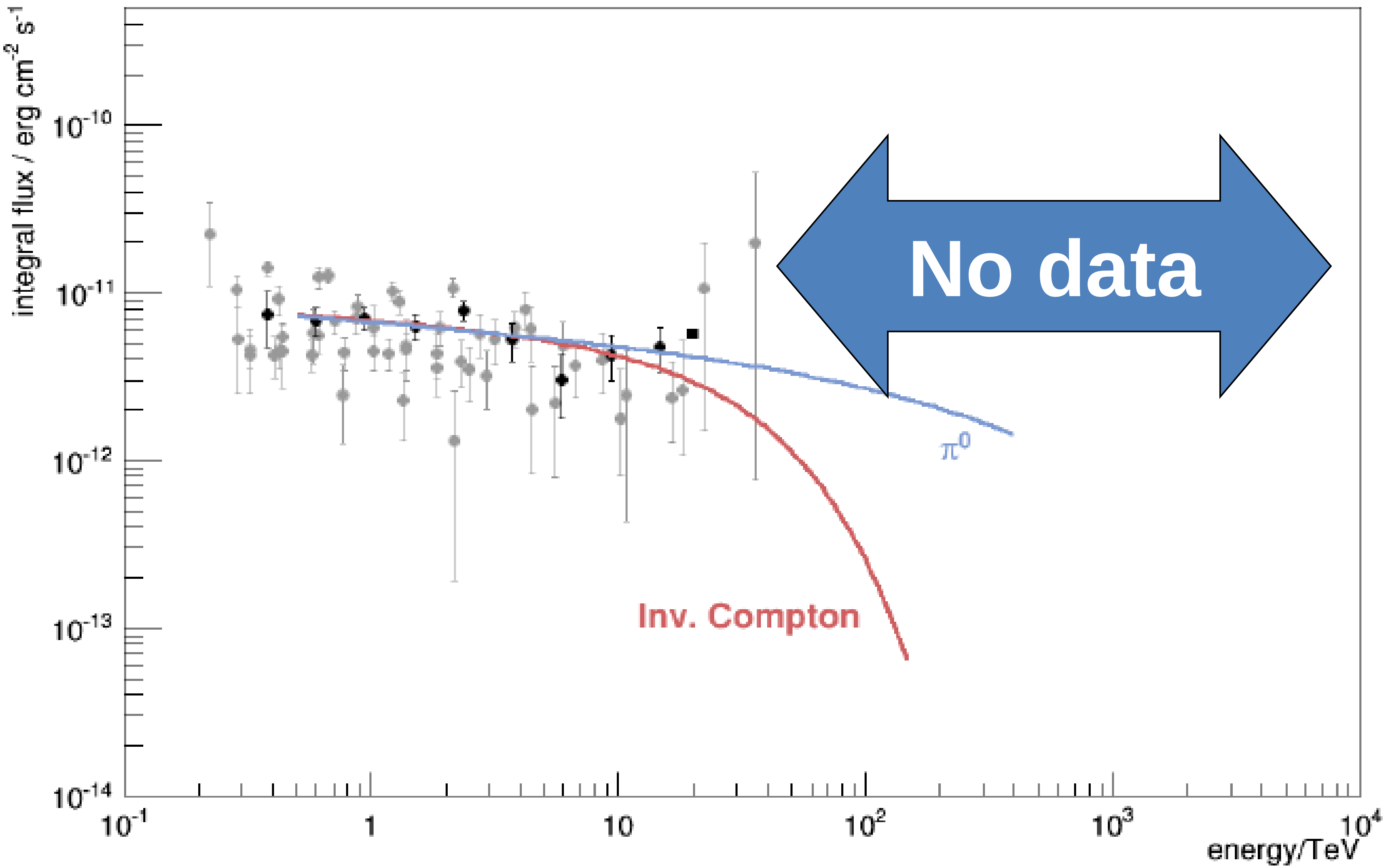
In particle physics:

- Study of possible Lorentz invariance violation
- Axion/photon possible conversion
- Pp cross-section measurement, ...

Galactic PeVatrons

- Almost 200 sources of gamma rays with E ≥ 0.1 TeV are currently known, mostly thanks to the IACT technique great success in recent 10-20 years
- •Highest ever measured photon energies from these sources are limited to ≤ 80 TeV
- •Where are the sources of Galactic cosmic rays, accelerating particles to PeV energies, can we measure at 100's of TeV ?
- •One obvious drawback of all currently existing detectors is their relatively small collection area
- •One needs to provide detectors with a collection area of the order ≥ 1 km² for providing signal statistics in a reasonable time

VHE-UHE Gamma-ray astronomy



TAIGA: Tunka Advanced Instrument for Gamma & cosmic-ray Astrophysics

TAIGA is a multiple-component detector for studying γ & cosmic-rays in the energy range from few x 10^{12} till ~ 10^{17} eV

The detector complex is located in Tunka valley at ~ 50 km west from the lower tip of the lake Baikal

51° 48' 35" N
103° 04' 02" E
675 m a.s.l.

TAIGA: Tunka Advanced Instrument for Gamma & cosmic-ray Astrophysics

TAIGA combines the following detector components:

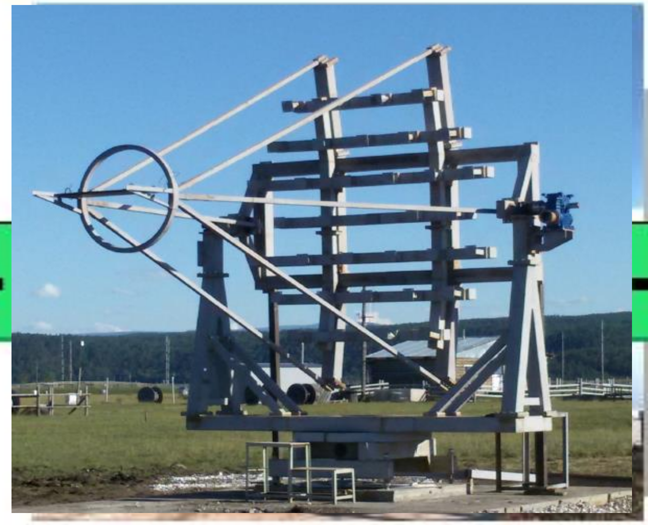
- **TUNKA-133 air Cherenkov integrating** (175 stations, operational)
- **HiSCORE air Cherenkov integrating** (until now operating with 28 stations, ~30 more stations are added during this summer, planning to commission in the next)
- **Imaging Atmospheric Cherenkov Telescope** (1st telescope under assembly on site, parts of 2 more telescopes under preparation)
- **Surface and underground μ, $e^{\pm}$ detectors** (19 stations operating, each of 1.5 m^2 area; planning to complete till ~200 m^2 area)
- **Radio emission from EAS,** TAIGA hosts an array of 63 detectors

Why a multi-component air shower detector ?

- A given type detector component can detect one (or more) specific emission from an air shower like **Cherenkov light**, or **muons and/or $e^{\pm}$**, i.e. all the emission types that arrive to the ground level
- Different detector components are put into coincident operation and hence can provide additional/higher background rejection
- Can provide a wide dynamic range in energy

- Combination of the operation of a non-imaging detector (like HiSCORE) with that of an imaging type (like the Imaging Air Cherenkov Telescope) can provide mutually strong benefits for the background rejection, accuracy, very large collection area and last but not least, lowest possible cost for the detector

TAIGA gamma-observatory



- 500 wide angle optical stations on the 5 km^2 area, energy threshold 30 Te

- up to 16 IACT (10 m^2 mirrors).

- Muon detectors with total area 2.0 10^3 m^2.

Tunka-REX: TUNKA Radio EXtension
Cosmic and g-rays for E ≥ 10^{15} eV
Array of 63 antennas

TUNKA-133, TAIGA-HiSCORE

(High Sensitivity Cosmic Origin Explorer**)**

(results were presented in V.Prosin talk)

TAIGA - HiSCORE

(High Sensitivity Cosmic Origin Explorer).

Non-imaging air Cherenkov array
Angular resolution : ~ 0.4 - 0.1 degree
Large Field of view (FOV): ~ 0.6 sr
Area: from 0.25 km^2 ➡ 5 km^2

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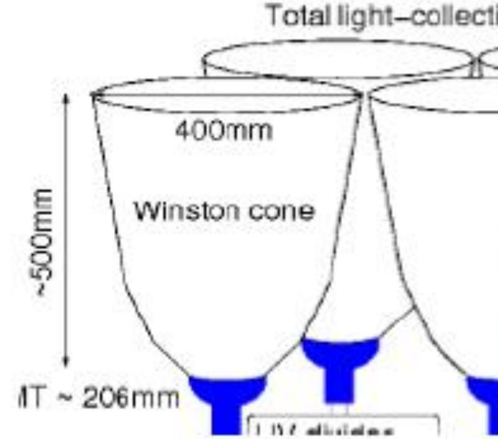
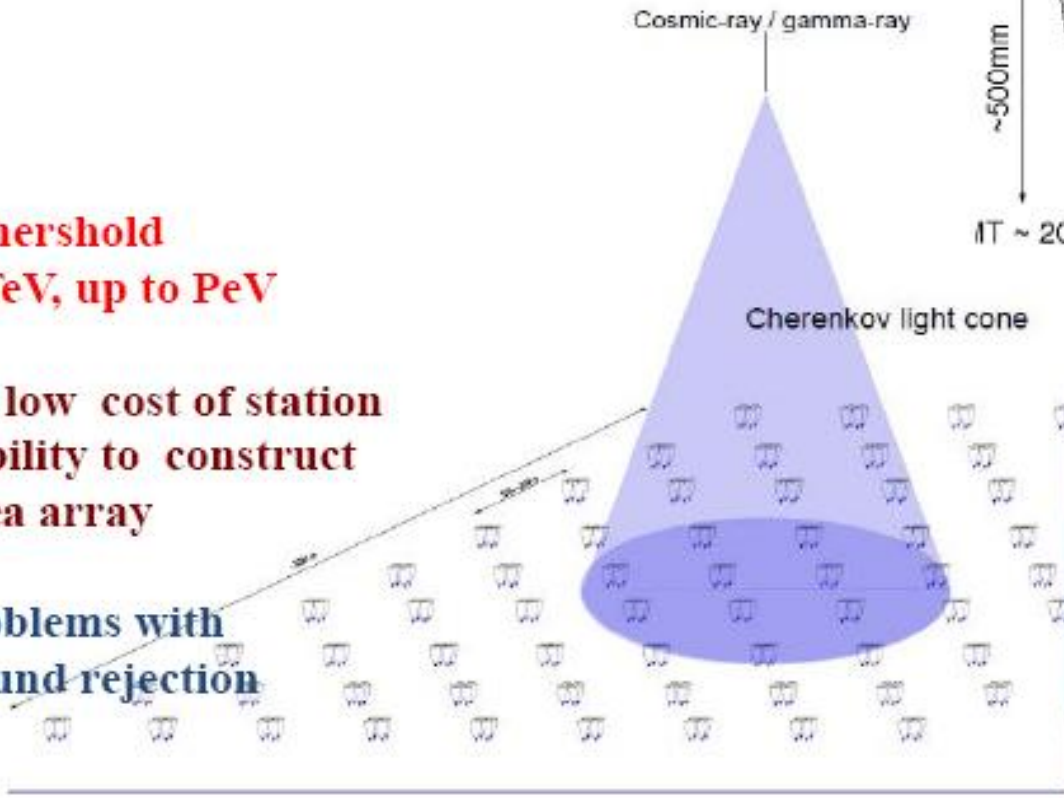
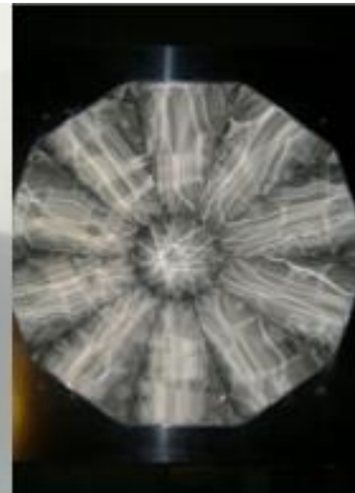




Energy thershold
Eγ > 30 TeV, up to PeV

Relativly low cost of station – possibility to construct large area array

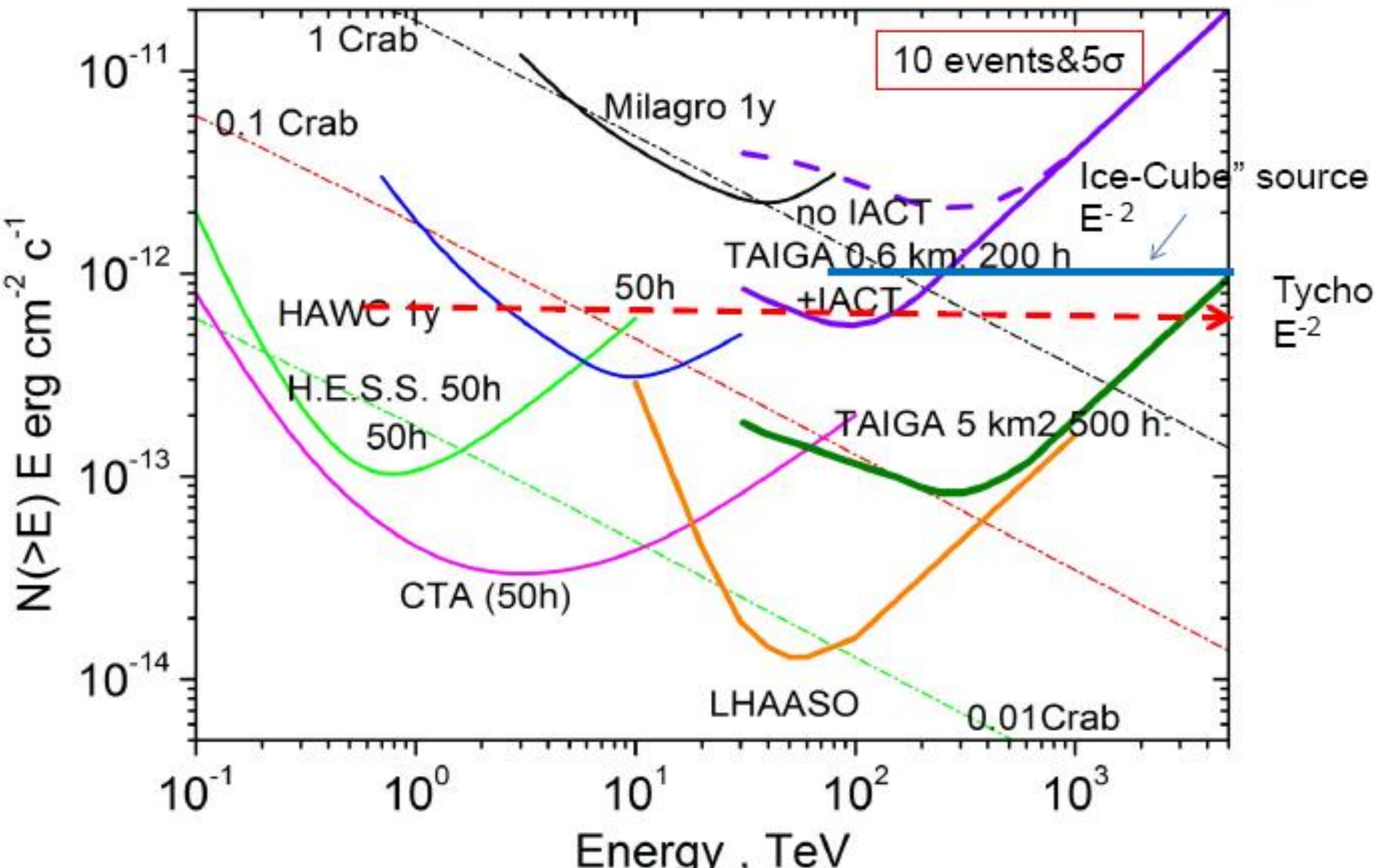
But – problems with background rejection



TAIGA-HiSCORE

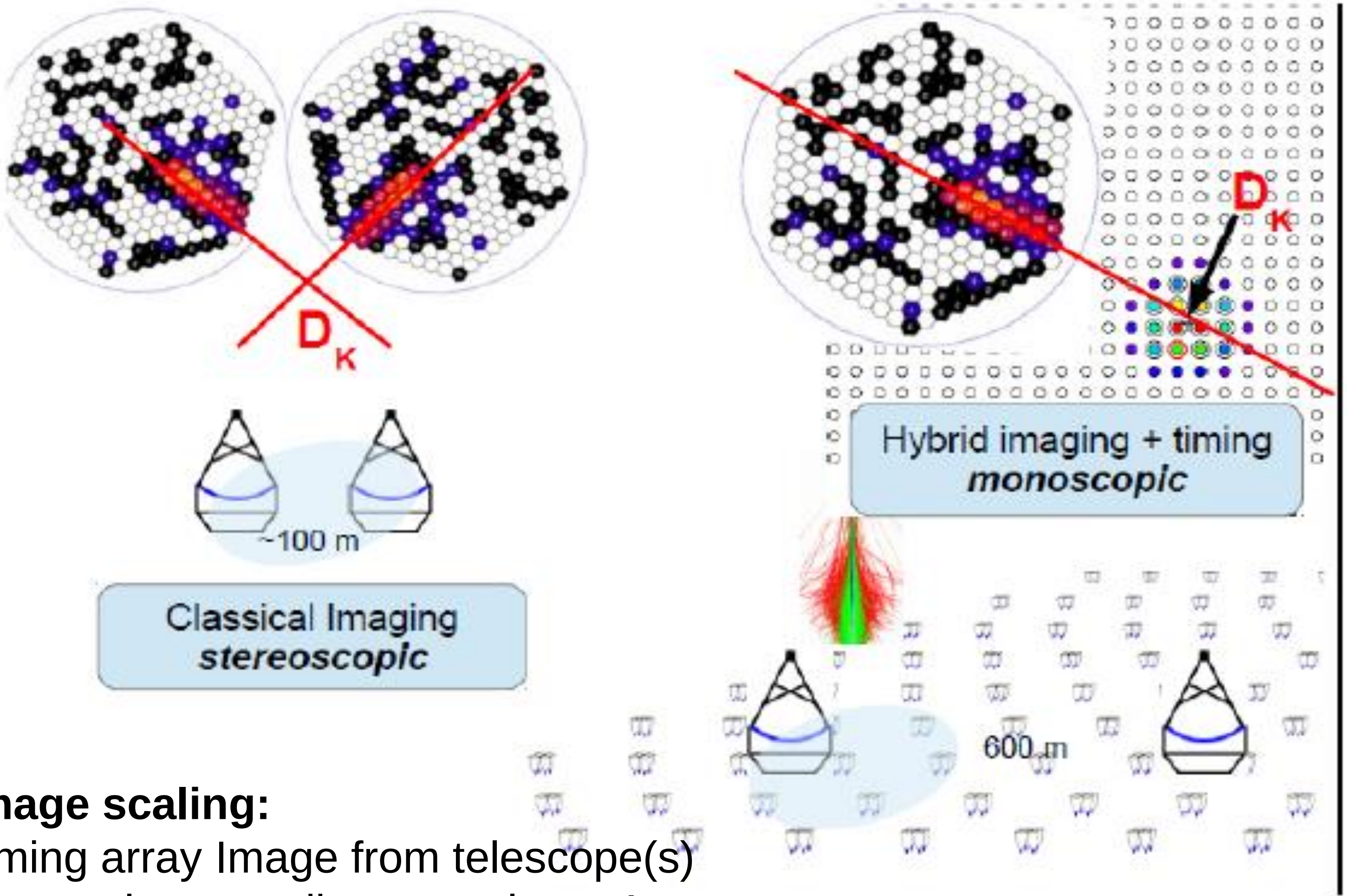
- One would expect that the γ-initiated EAS will provide a relatively smooth pattern on the ground, while those initiated by hadrons, should show irregular patterns and used for hadron background rejection
- By using MC simulations and comparing with the available data, we are currently studying in detail these aspects
- Besides, the threshold of such a detector shall be relatively low, in order to compare its performance with that of an imaging detector like CTA

Integral sensitivity to local sources



HiSCORE + IACT

Hybrid approach to hadron rejection

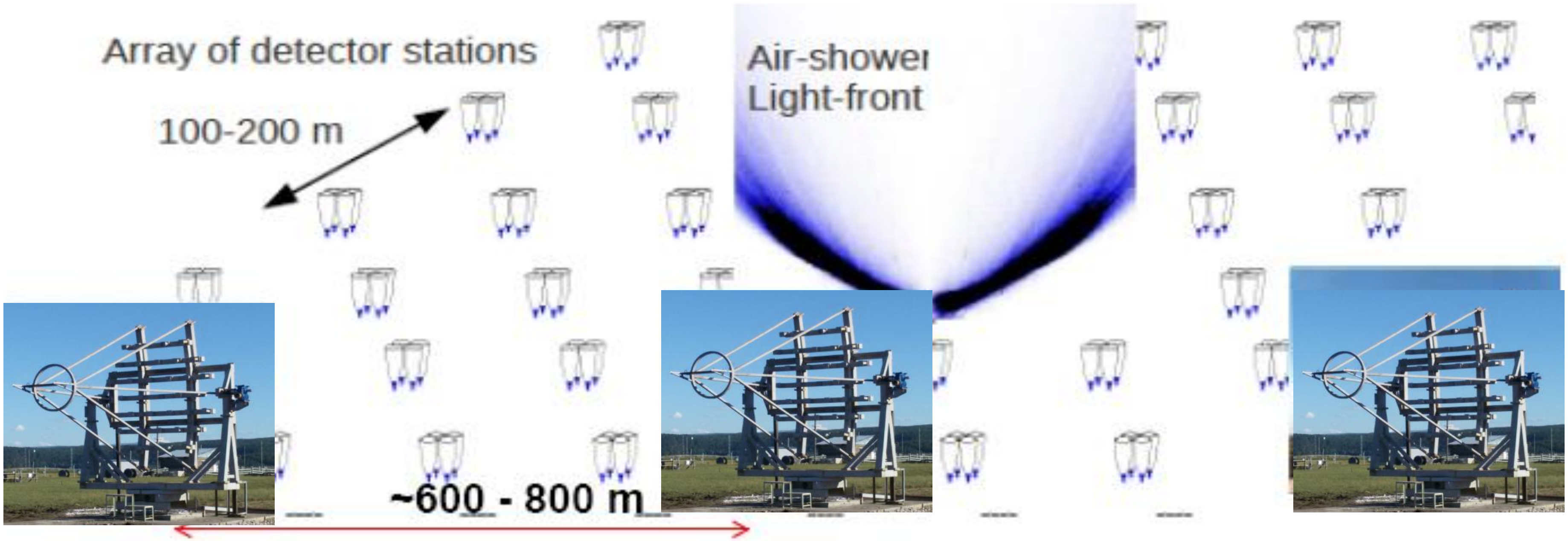


Hybrid Image scaling:

D_K from timing array Image from telescope(s)

1) large inter-telescope distance = large A_{eff},
2) scaled width separation parameter

TAIGA : Imaging + non-imaging techniques



TAIGA - HiSCORE: core position, direction and energy Gamma/ hadron separation - TAIGA-IACT (image form, monoscopic operation)

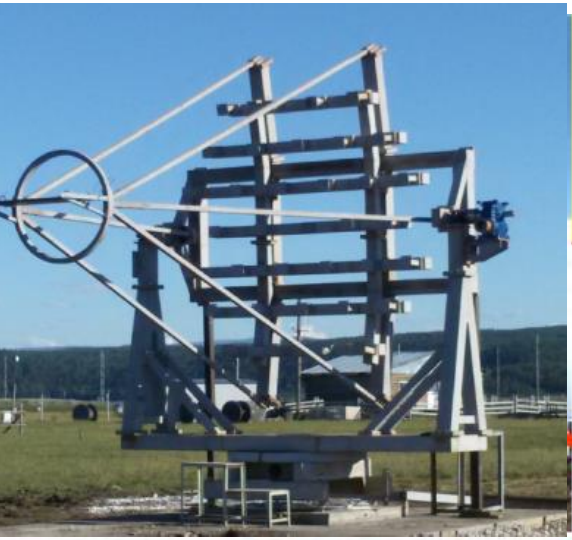
HiSCORE + IACT detectors,

combining the imaging with the non-imaging technique

- **provide background rejection**
- **increase of the measurements from a few TeV to hundrets TeV energy range**

TAIGA HiSCORE – IACT prototype array

- 28 HiSCORE stations have been deployed and operated since fall 2014
- This summer the number of HiSCORE stations has been increased by another 30; these will be commissioned in the next
- We plan to operate these 58 HiSCORE stations in coincidence with the 1st IACT, which is currently under assembly in the Tunka valley
- The 2nd IACT is planned to be installed in 300m from the 1st one



TAIGA-IACT

D = 4.32m F = 4.75m

34 mirrors of 60 cm diameters

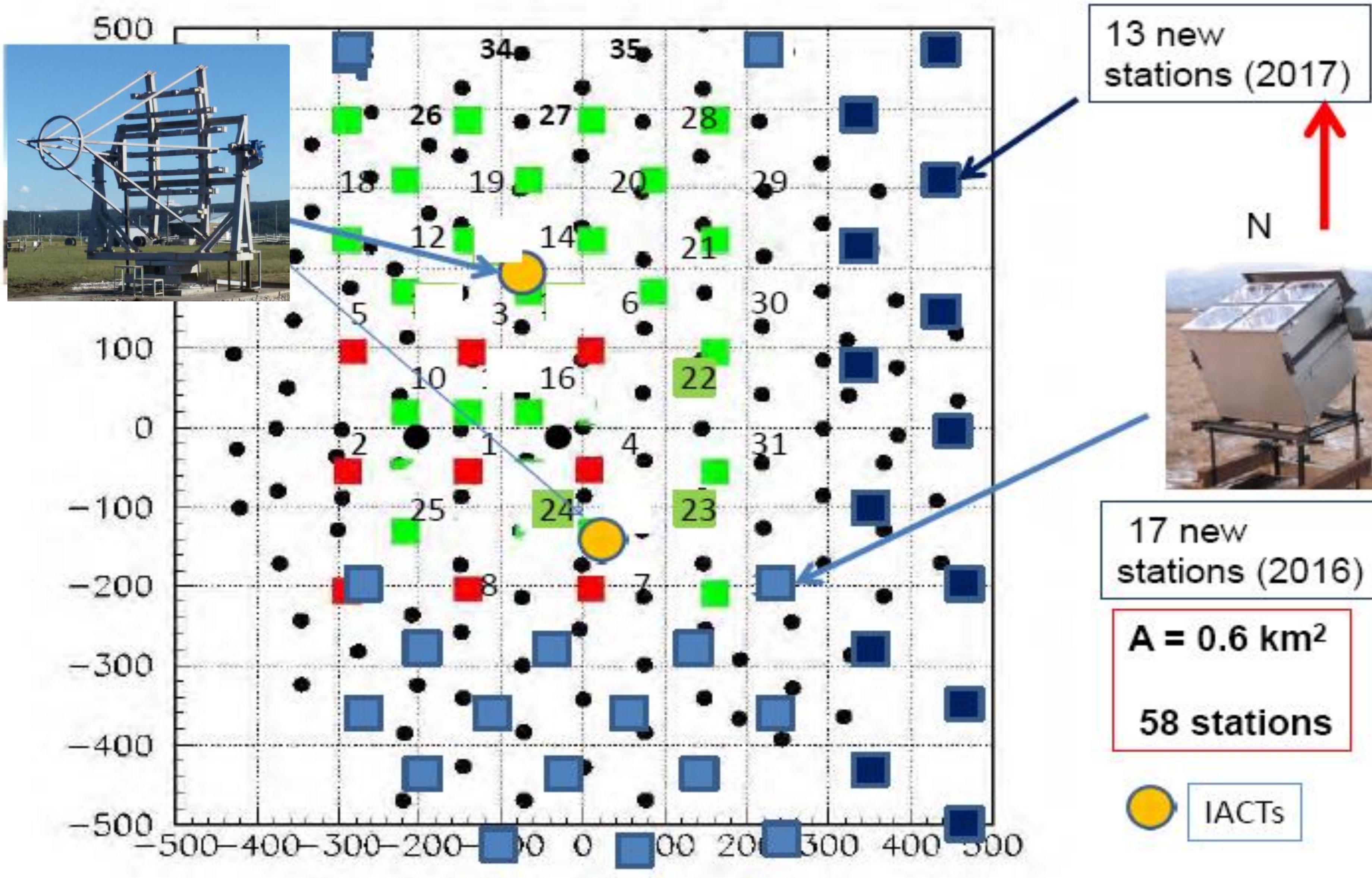
Camera : 547 PMTs (XP 1911) with 15 mm useful diameter of photocathode
Winston cone: 30 mm input size, 15 output size
1 single pixel = 0.36 deg
full angular size 9.6x9.6 deg

Energy threshold ~1.5 TeV

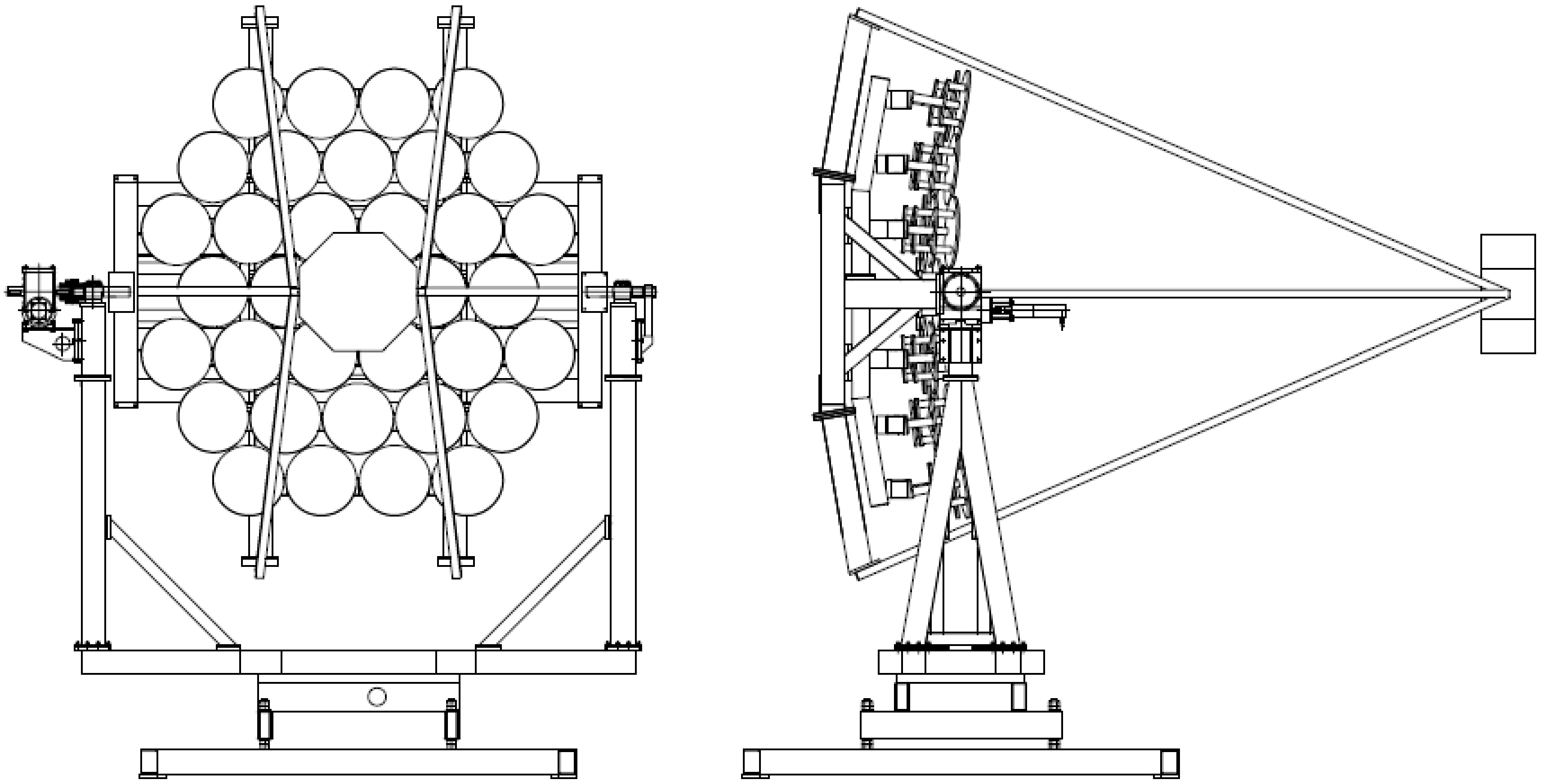
Cost : 300 Keur

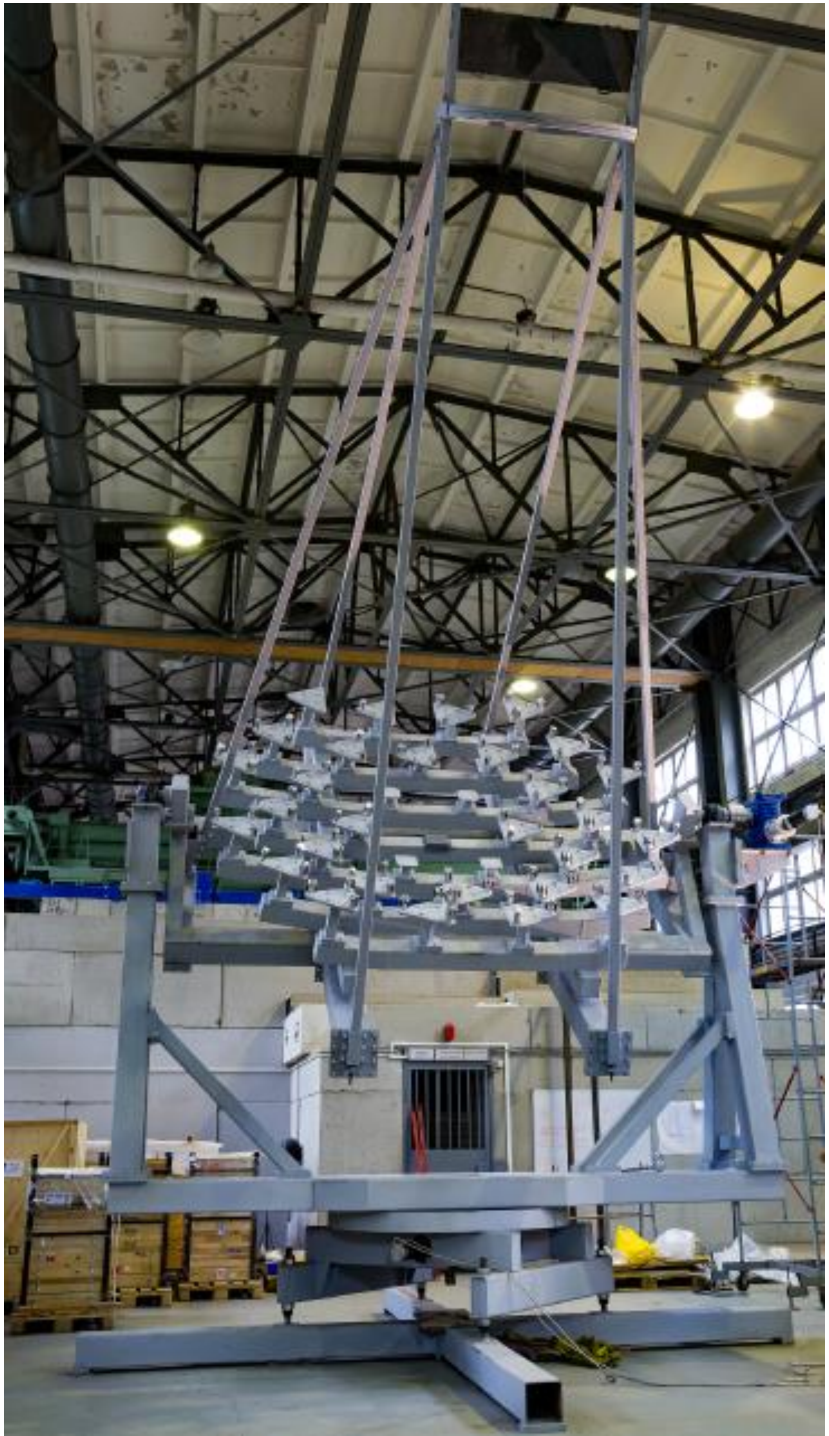
Commission of the first telescope – October 2016

One of TAIGA high-priority goals: operate 58 HiSCORE stations with the 1st IACT



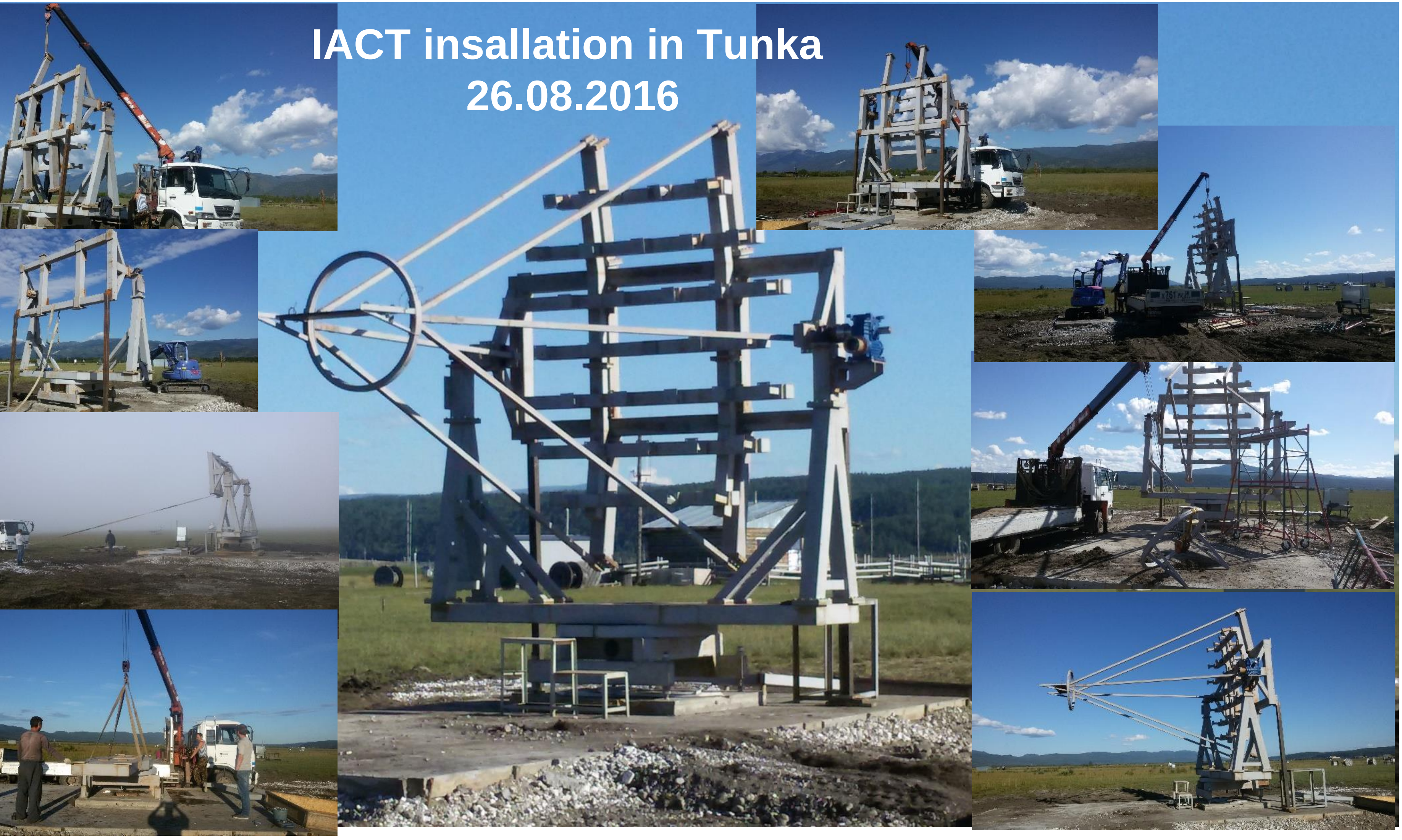
IACT fabrication in JINR, Dubna





The mechanical structure of the TAIGA-1 telescope in a workshop hall of the JINR in Dubna in June 2016

IACT insallation in Tunka
26.08.2016



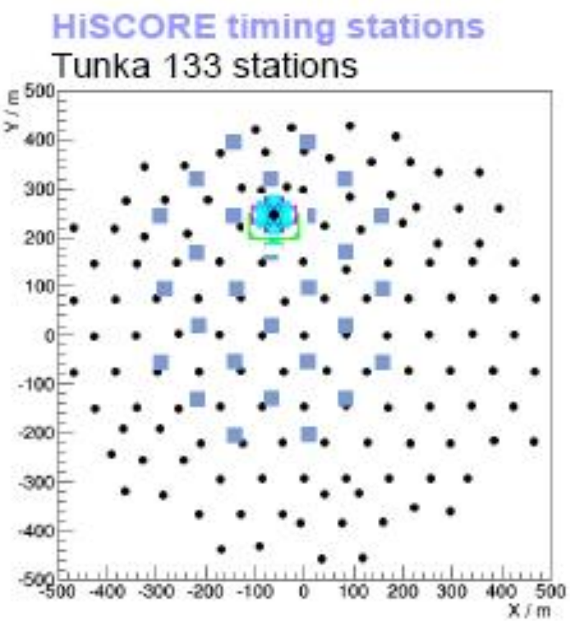
TAIGA

Since 2014

- 28 stations on 0.25 km²
- Tilting mode – 25° southwards

2016:

- First telescope
- Hybrid timing+imaging



Tunka-IACT setup

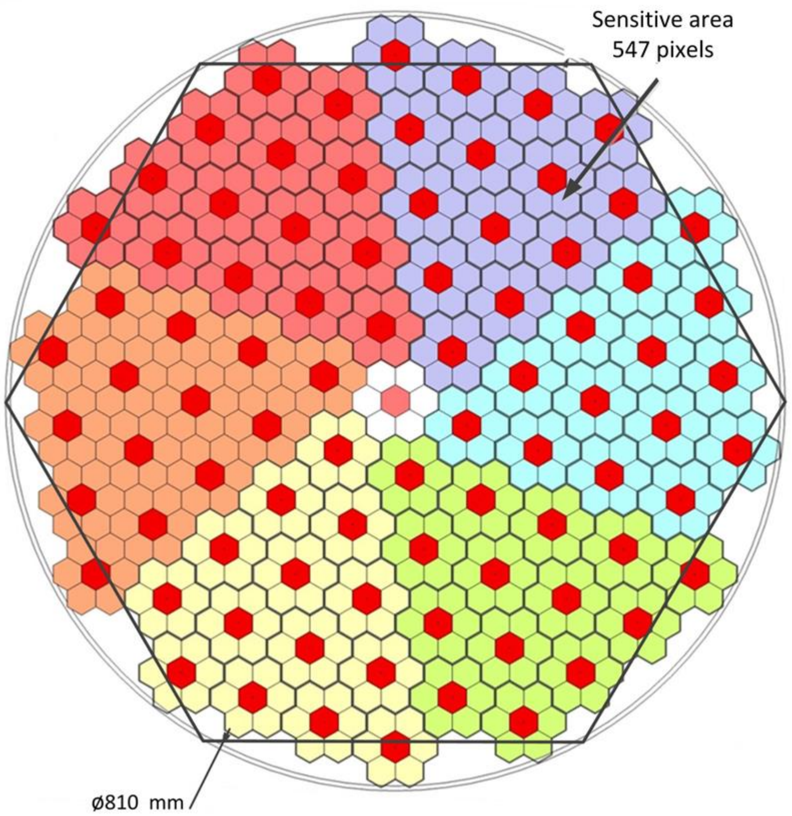
Mirror:

- 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:

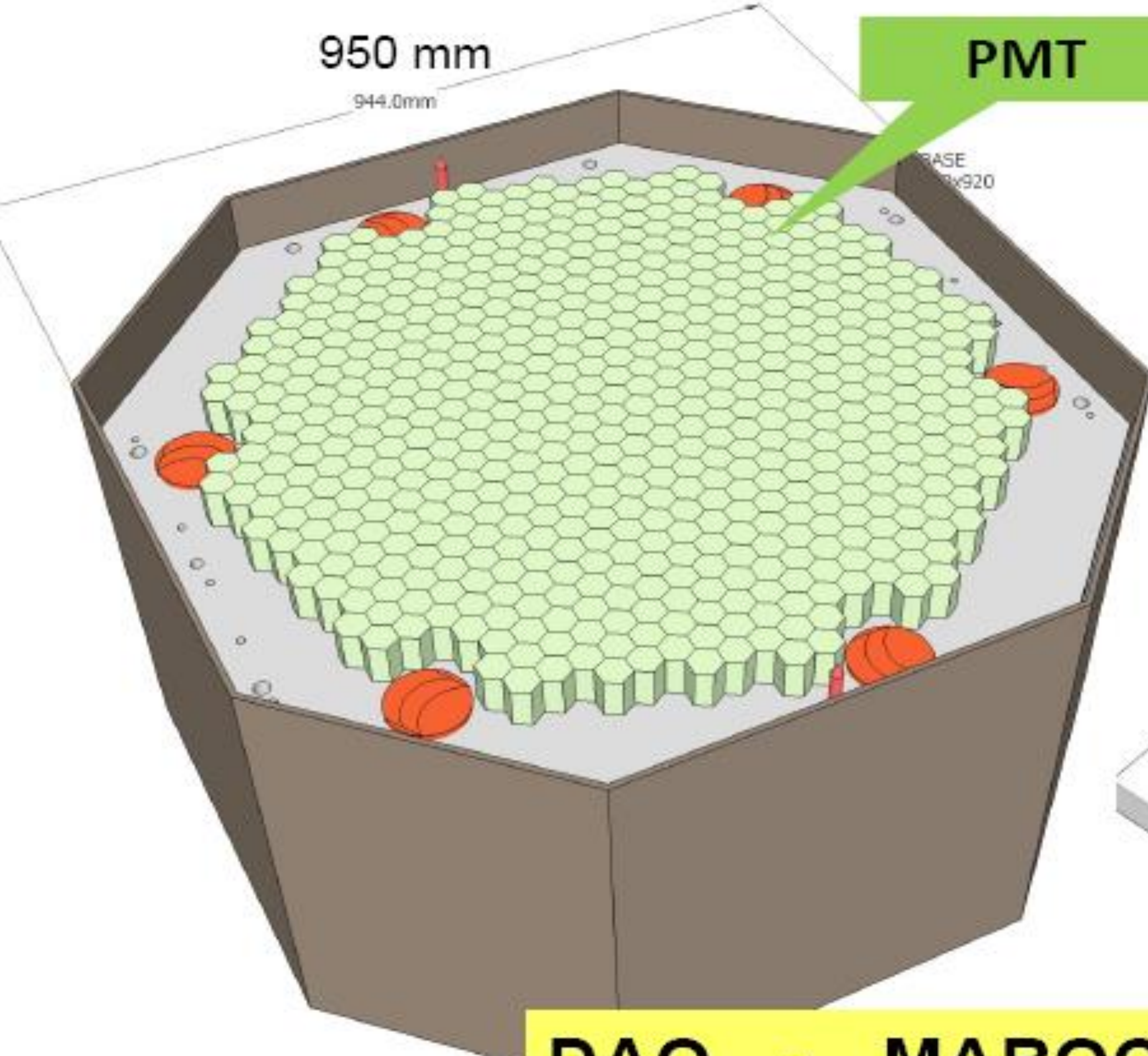
- 547 hexagonal-shaped pixels
- PMT XP1911: window of diam 15 mm
- Winston cone: 30 mm input size,
 15 mm output
- FOV of single pixel: 0.36°
- Full FOV: 9.72°

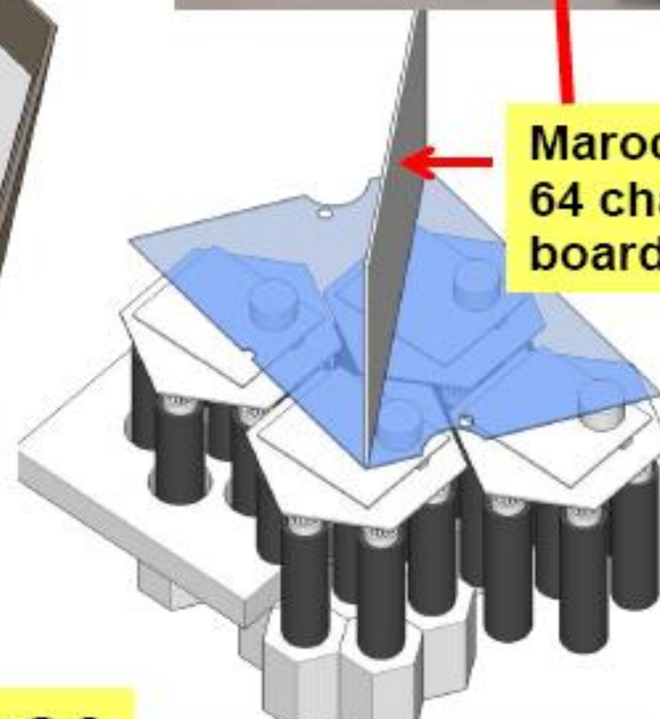
Camera



Operation at the conditions of hard Siberian winter!!!

Camera of the TAIGA-IACT

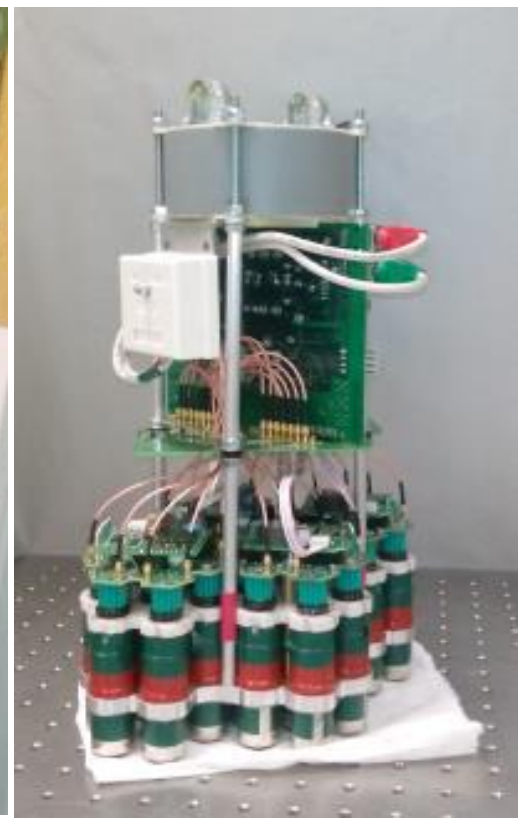


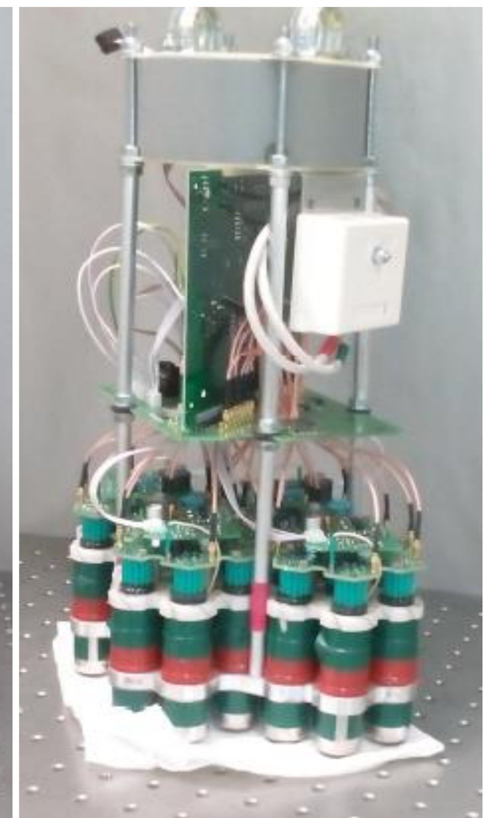


DAQ - MAROC3

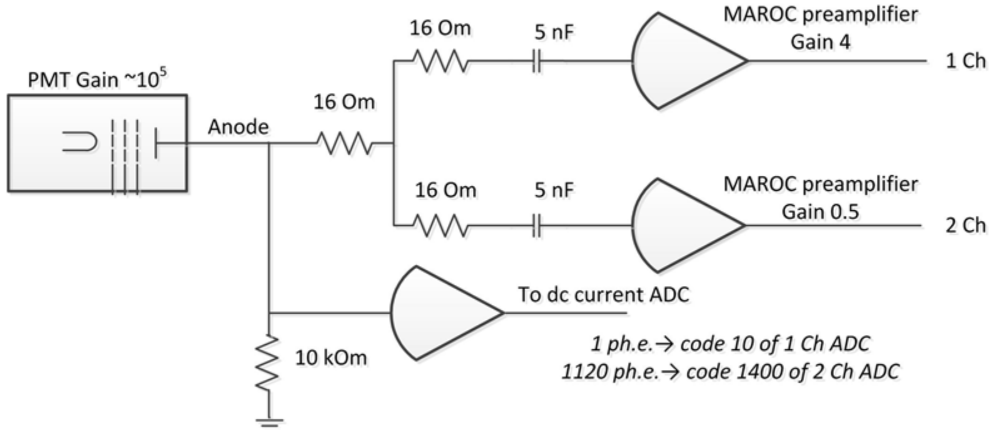
Cluster – 28 PMTs

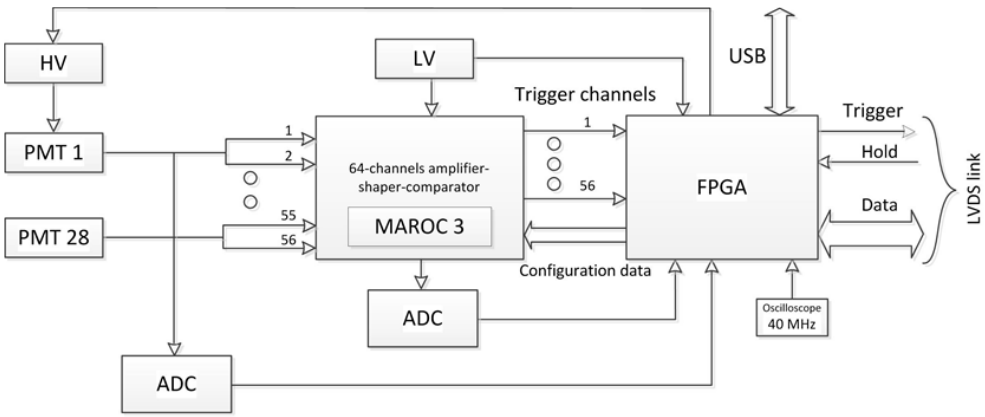
07.09.2016
IACT camera assembling

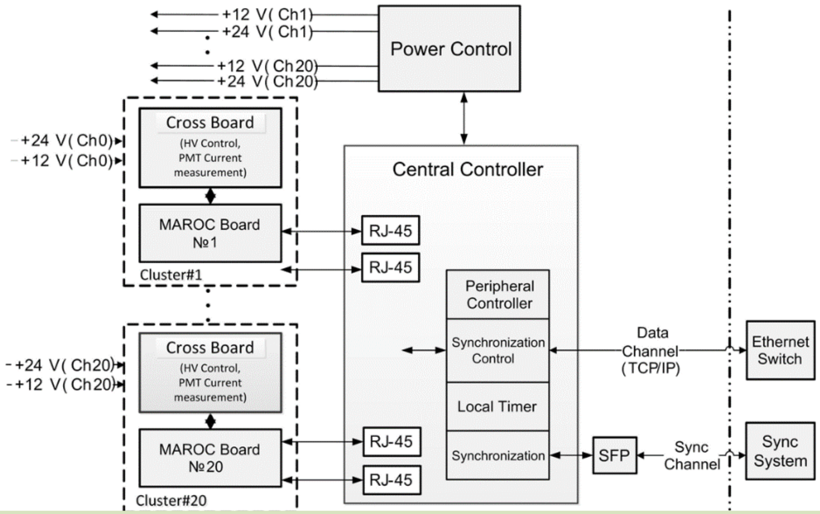




Two channels of MAROC3 process the signals from one PM splitted to provide the necessary dynamic range.







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

Tunka-IACT DAQ

TAIGA-REX (TUNKA Radio Extension)

Tunka-Rex, Tunka-133, Tunka-Grande cross-calibration

(It was presented in V.Prosin talk)

Conclusion

1 TAIGA - 5 km^2 hybrid array (500 wide-angle stations and 10-16 IACT).

The sensitivity for local sources in the energy range 30 -200 TeV is expected be **– 10^{-13} erg cm^{-2} sec^{-1} (for 500 h observation)**

2. Deployment of a TAIGA prototype -

58 wide-angle stations and one IACT will be finished in 2017. The sensitivity of the prototype in energy range 30 - 200 TeV is expected to be **– 10^{-12} erg cm^{-2} sec^{-1} (for 200h observation)**

3. The first season of prototype TAIGA-HiSCORE has been successfully carried out. The analysis of the experimental data is in progress. All particle energy spectrum has been reconstructed.

Peak energy in the threshold region is near to 100 TeV (60 TeV for gammas).

10 -25 excess above background in 0.4 deg/ around Crab.

TAIGA future

- We hope TAIGA is going to become an important cosmic ray detector
- A novel concept is under tests and checks
- The multi-detector instrument will cover with high sensitivity the energy range from a few TeV till ~ 10^3 TeV

Thank you

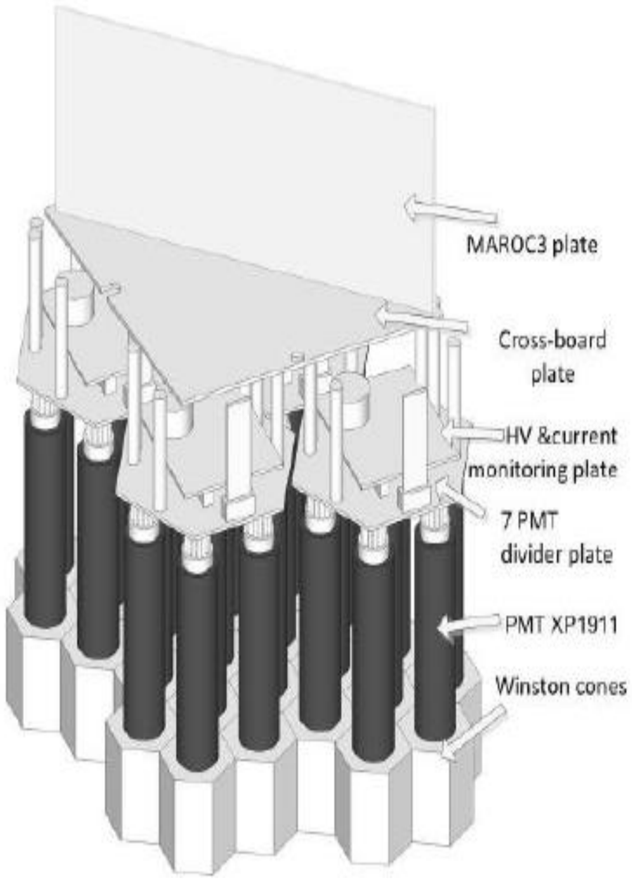
MAROC3 ASIC board

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.

Single cluster design of the TAIGA IACT

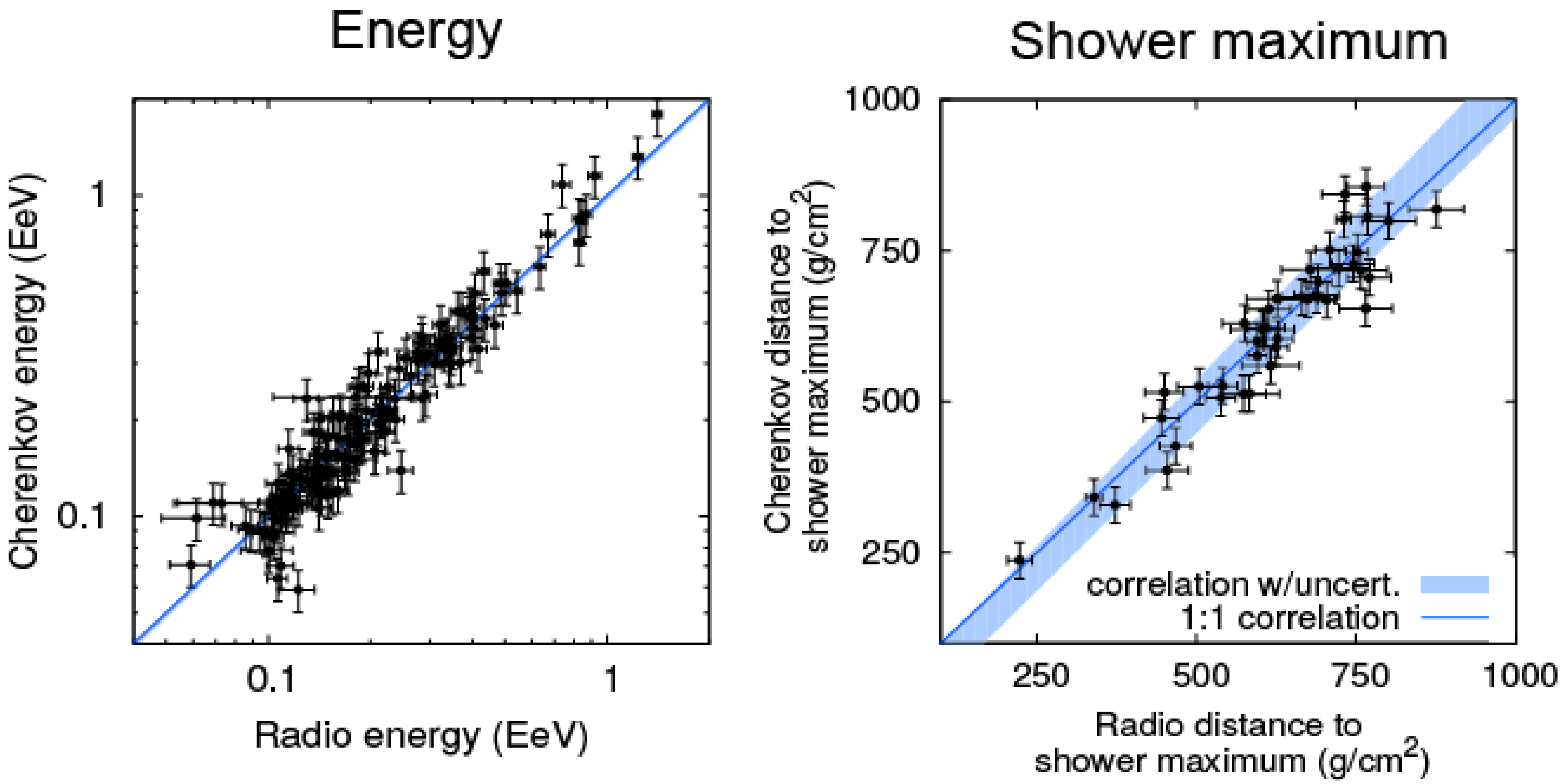


Assembly of 28 PMT with dividers, HV supplys, cross board and MAROC board

Novel concept: TAIGA hybrid detector, combining the imaging with the non-imaging technique

- The benefit of this will be to construct an array of a large size, using much lower number of IACTs (compared to CTA), set on distances of 800 -1200 m from each other
- The operational range of a single IACT will be extended to impact distances of 400 – 600 m
- In this way a single IACT shall be able to provide a collection area of ~ $(0.5 - 1) \times 10^6$ m^2 at small zenith angle observations
- Another benefits are the low-cost, the simplicity, the ease of transportation and the robustness of not-moving HiSCORE stations
- With the TAIGA prototype array, including 2 IACTS, we shall be able to check experimentally this working principle
- For tis purpose we plan to install the 2nd IACT on 300m from the 1st one and scan the distance range till 600 m, at least in one direction

Cross-check with Tunka-133



resolution: 15%

resolution: 38 g/cm^2

Tunka-Rex Collaboration, JCAP 1601 (2016) no.01, 052 [`doi:10.1088/1475-7516/2016/01/052`]