Экспериментальный комплекс TAIGA: статус, результаты, перспективы.

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Черенковские чтения-2019,
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Content of report

1. Introduction: Astrophysical complex in Tunka Valley

2. High energy gamma-ray astronomy and TAIGA project

3. TAIGA current status

4. The experiment in future

Astrophysical complex in Tunka Valley

Tunka Valley, Republic Buryatia
- 50 km to west
from Lake Baikal.

-**High energy cosmic rays and gamma-astronomy arrays**

- **Optical telescope MASTER**

All installations in Tunka Valley

1. Tunka-133
2. Tunka-Grande
3. Tunka-REX

Cosmic rays with energy > 10^{15} eV

4. TAIGA-HiSCORe
5. TAIGA-IACTS
6. TAIGA-MUONs

TAIGA (Tunka Advanced Instrument for cosmic rays and Gamma - Astronomy)

The main aim of TAIGA project:

Study of very high energy (>30 TeV) gamma rays from Galactic accelerators with large area array (~10 km^2)

Cosmic rays and gamma ray with energy > 10^{15} eV

Tunka-133 - 175 optical detectors on the area of 3 km²

Tunka-REX – 64 antennas for detection of radio signals from EAS

Tunka- Grande – 380 scintillation counters for detection of EAS charged particles

1.High-energy gamma-astronomy and the TAIGA project

The TAIGA experiment - a hybrid detector for very High energy gamma-ray astronomy and cosmic ray physics in the Tunka valley

The main idea: A cost effective approach for construction of large area installation is a joint operation of wide-field-of-view timing Cherenkov detectors (the *non-imaging technique) with a few small-size imaging Air Cherenkov Telescopes.*

The first stage of TAIGA - 1 km^2 area installation with 120 wide-angle timing detectors and 3 IACTs.
Commissioning of installation in 2019

TAIGA - collaboration

Germany

Hamburg University(Hamburg)
DESY (Zeuthen)
MPI (Munich)

Italy

Torino University (Torino)

Romania

ISS (Bucharest)

Russia

MSU (SINP) (Moscow)
ISU (API) (Irkutsk)
INR RAS (Moscow)
JINR (Dubna)
MEPhI (Moscow)
IZMIRAN (Moscow)
BINR SB RAS (Novosibirsk)
NSU (Novosibirsk)
ASU (Barnaul)

Scientific Program

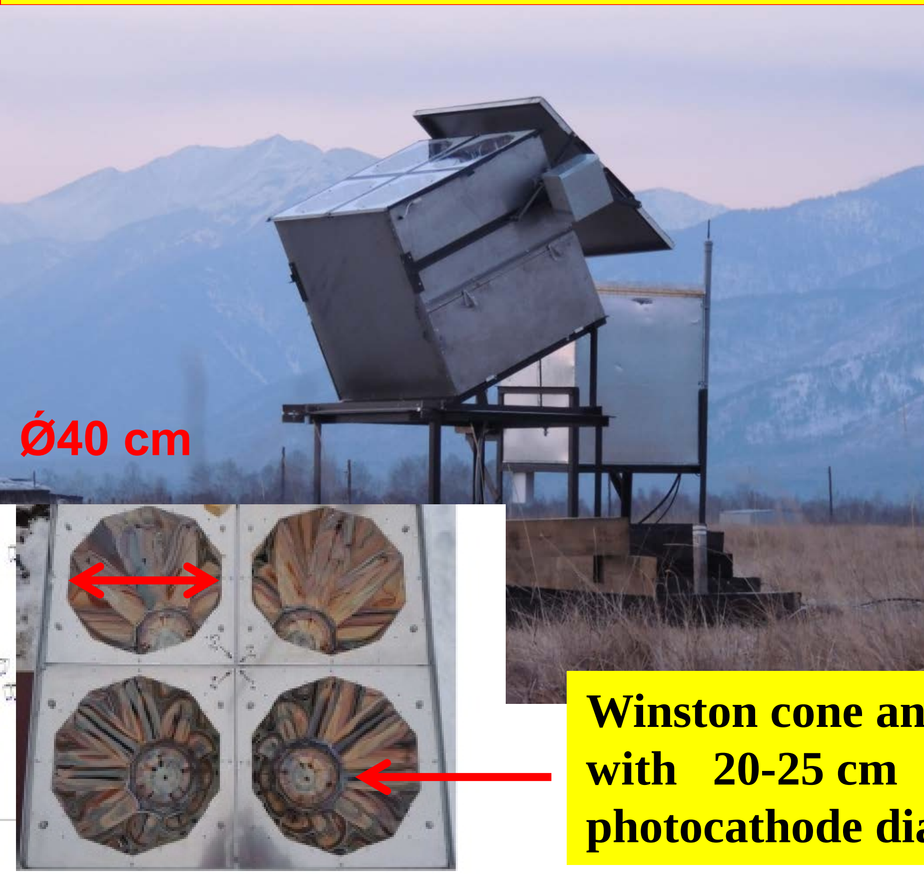
1.Study of high-energy edge of spectrum of galactic gamma-ray sources. Search for Pevatrons

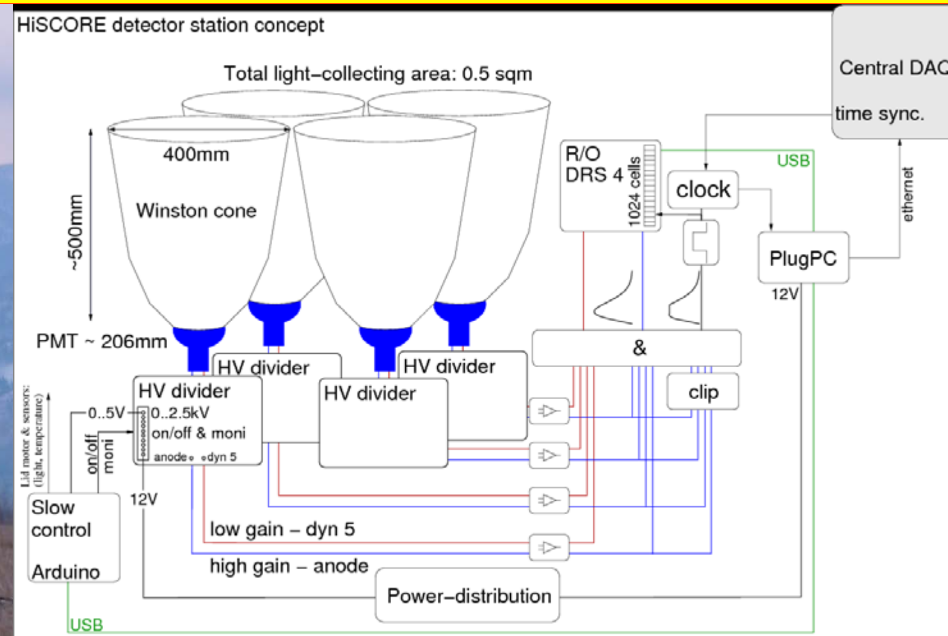
2. Monitoring of the bright extragalactic sources

3.Apply the new hybrid approach (joint operation of IACTs and wide-angle timing array) for study of cosmic rays mass composition in the “knee” region (10^{14} -10^{16} eV)

4. Fundamental physics (photon-axion oscillation, indications of Lorentz invariance violation etc).

Wide angle station



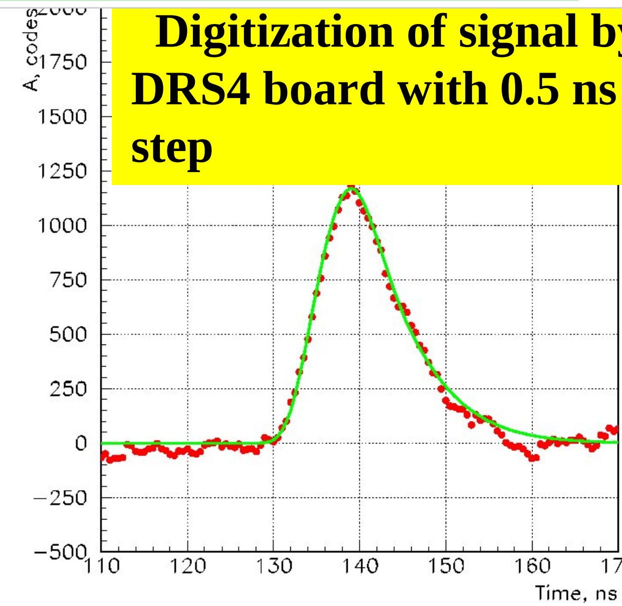


Winston cone and PMT with 20-25 cm photocathode diameter

S tot = 0.5 m^2

(R5912, R7081, ET9352)

Digitization of signal by DRS4 board with 0.5 ns step

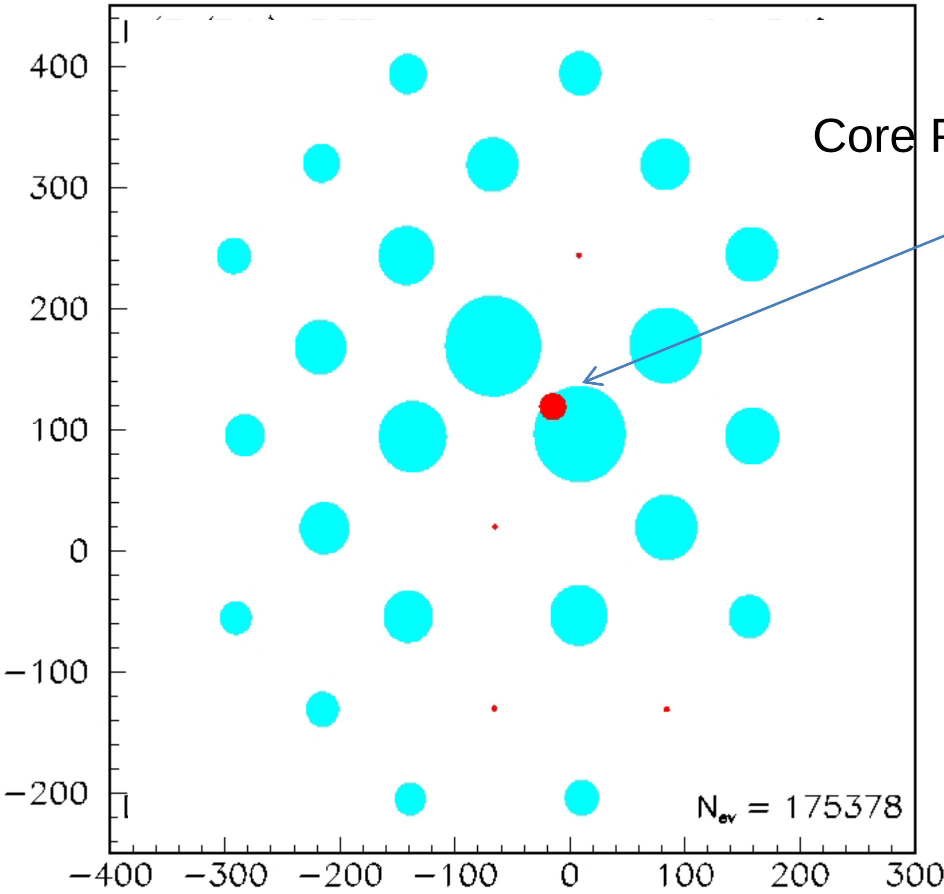


Synchronization and data taking via optical cable

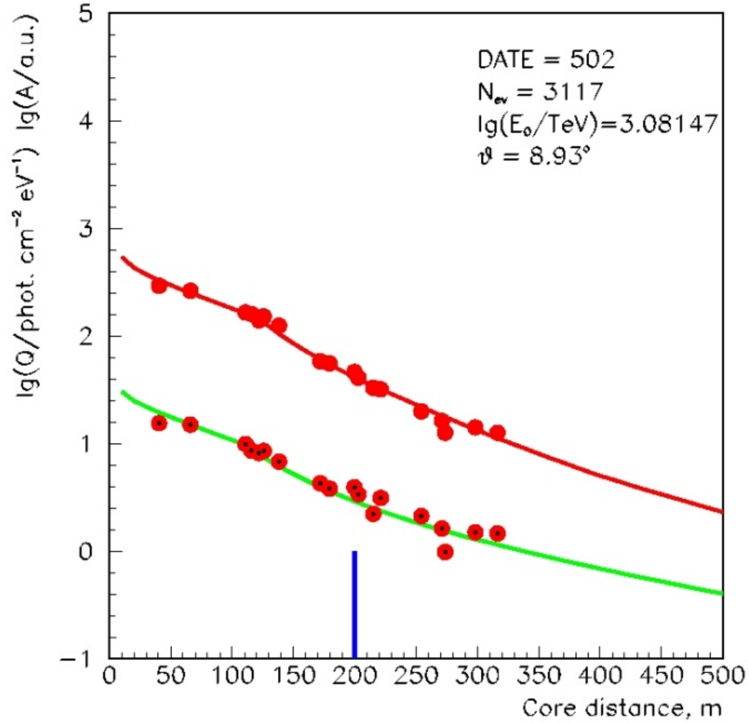
Event example

R ~ Lg (Photon flux)

Core Position



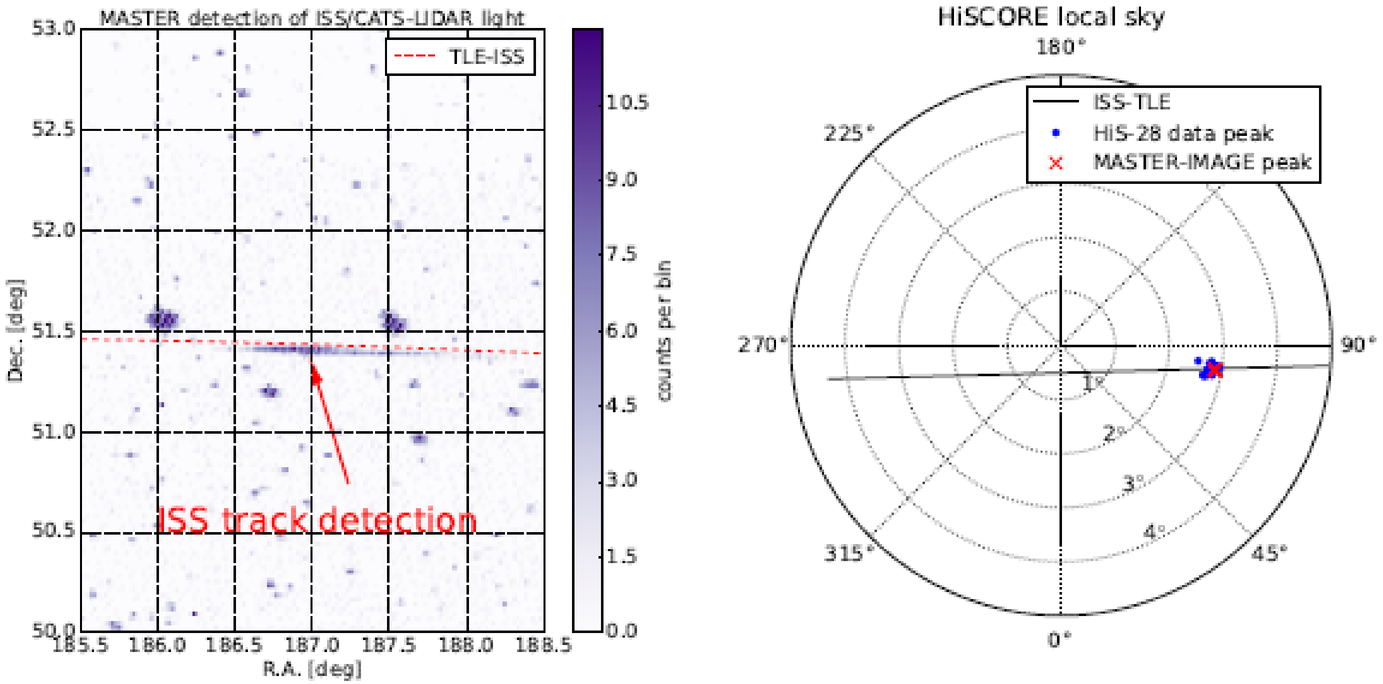
Lateral Distribution Function (LDF)



Energy determination:

$$\mathbf{E = C \cdot Q(200)^{094}}$$

Common observation of ISS LIDAR by HiSCORE and optical telescope MASTER



Absolute pointing of HiSCORE $\alpha_{miss} \sim 0.1°$

TAIGA-IACT

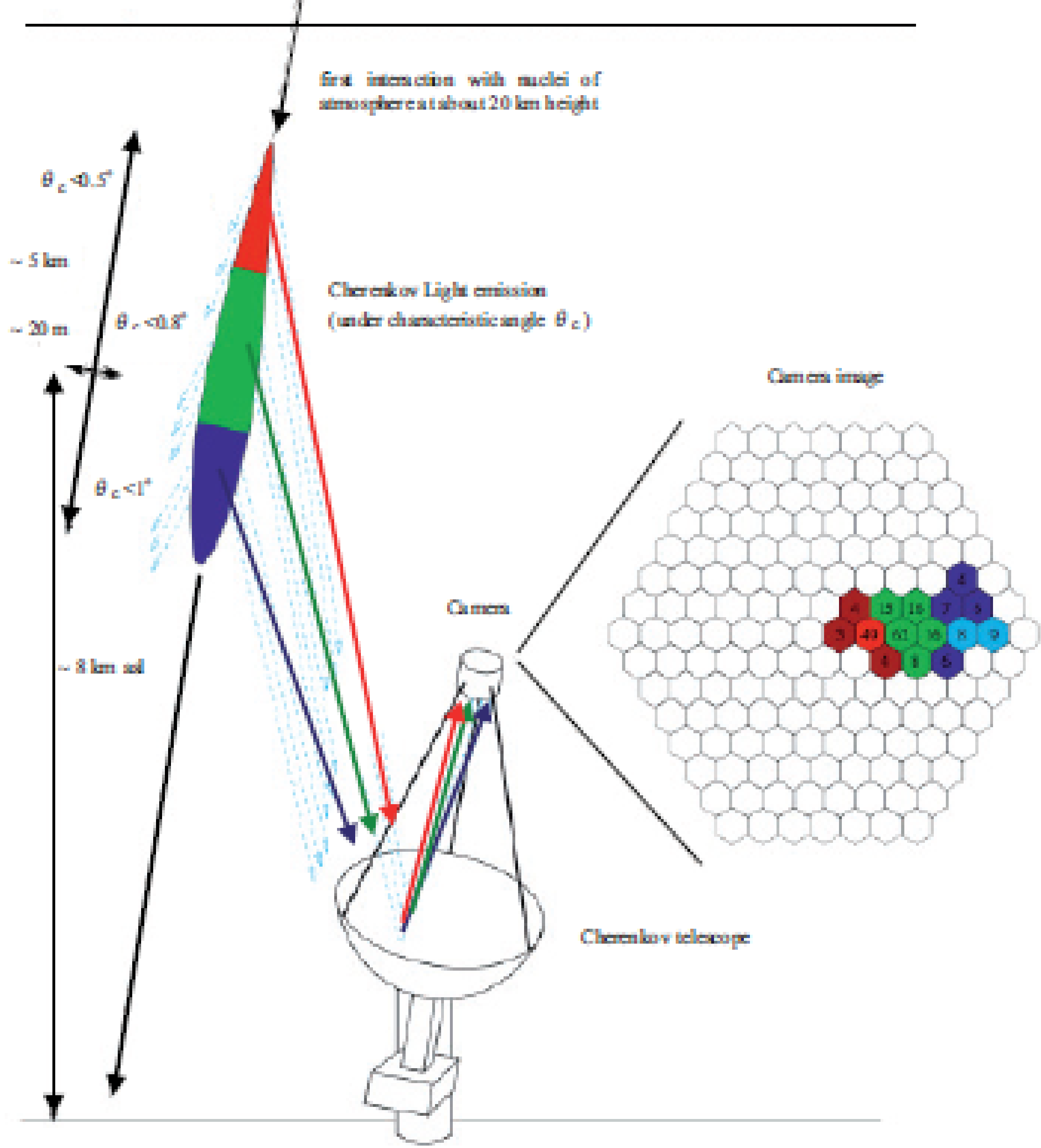
(the Northernmost telescope)

D = 4.32m F = 4.75m

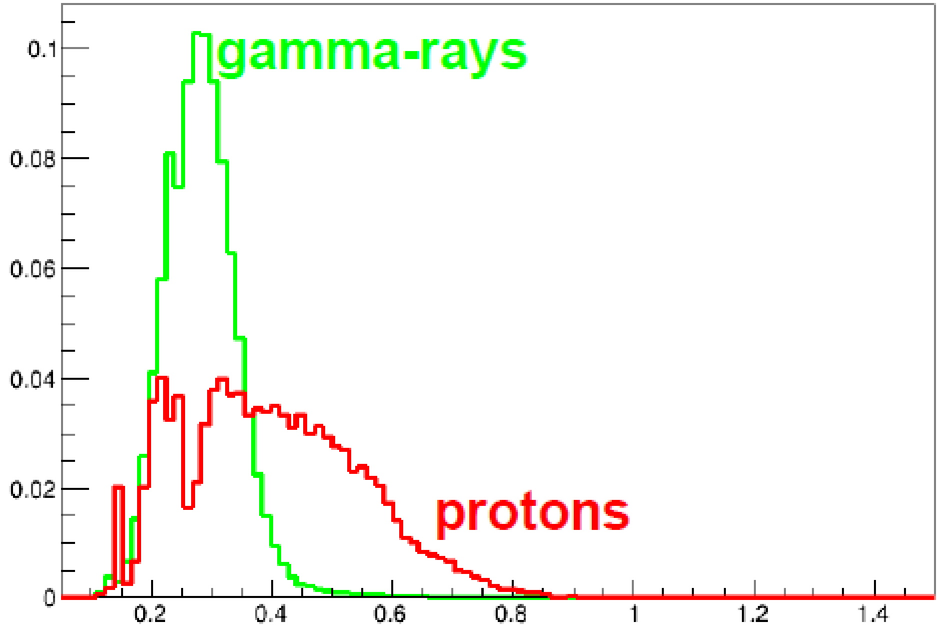
29 glass mirrors of 60 cm diameter

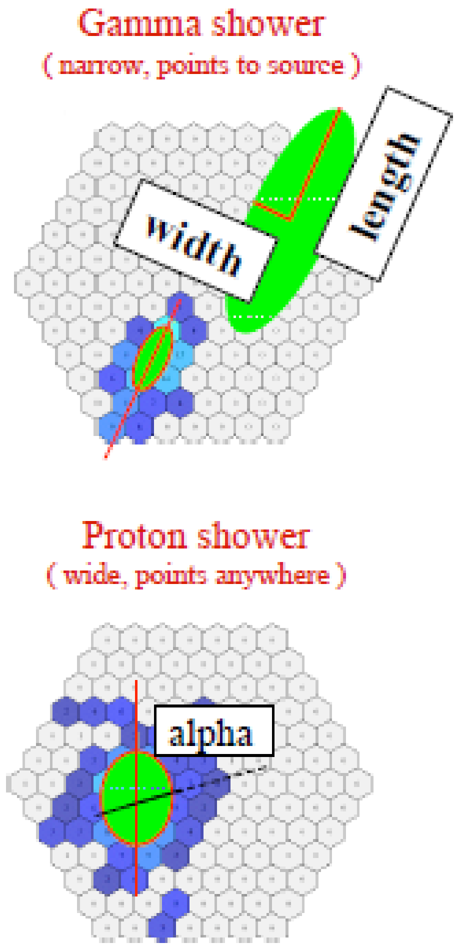
Camera : 560 PMTs (XP 1911) with 15 mm useful diameter of photocathode
Winston cone: 30 mm input size, 15 mm output size
aperture single pixel = 0.36°
FOV diameter ~ 9.6°

Energy threshold ~1.5 TeV


first interaction with nuclei of atmosphere at about 20 km height
θ c <0.5°
~ 5 km
~ 20 m
θ c <0.8°
θ c <1°
Cherenkov Light emission
(under characteristic angle θ c)
Camera image
Camera
~ 8 km asl
Cherenkov telescope

Selection events from gamma-rays by Hillas parameters

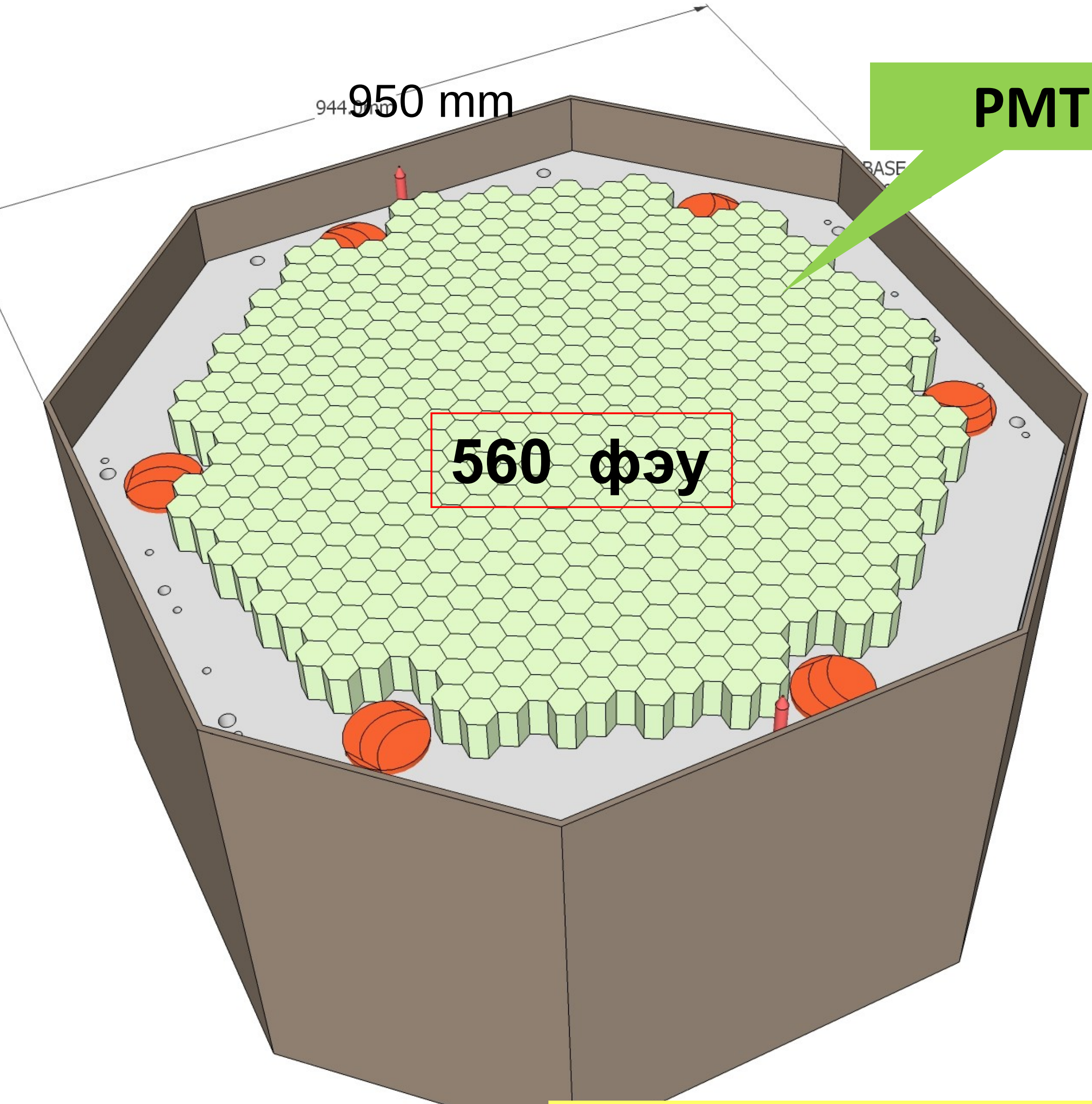


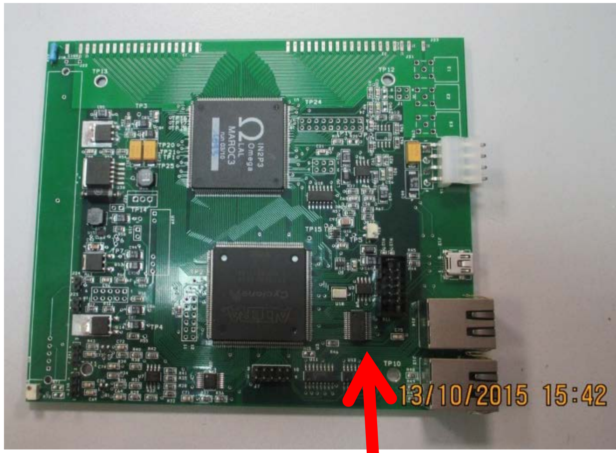


Nγ / √ (background) ⟶ Nγ × K1 / √ (background) × **K2**

Q = K1 / √ **K2** - Q -factor

Camera of the TAIGA-IACT





Maroc-3
64 channel board

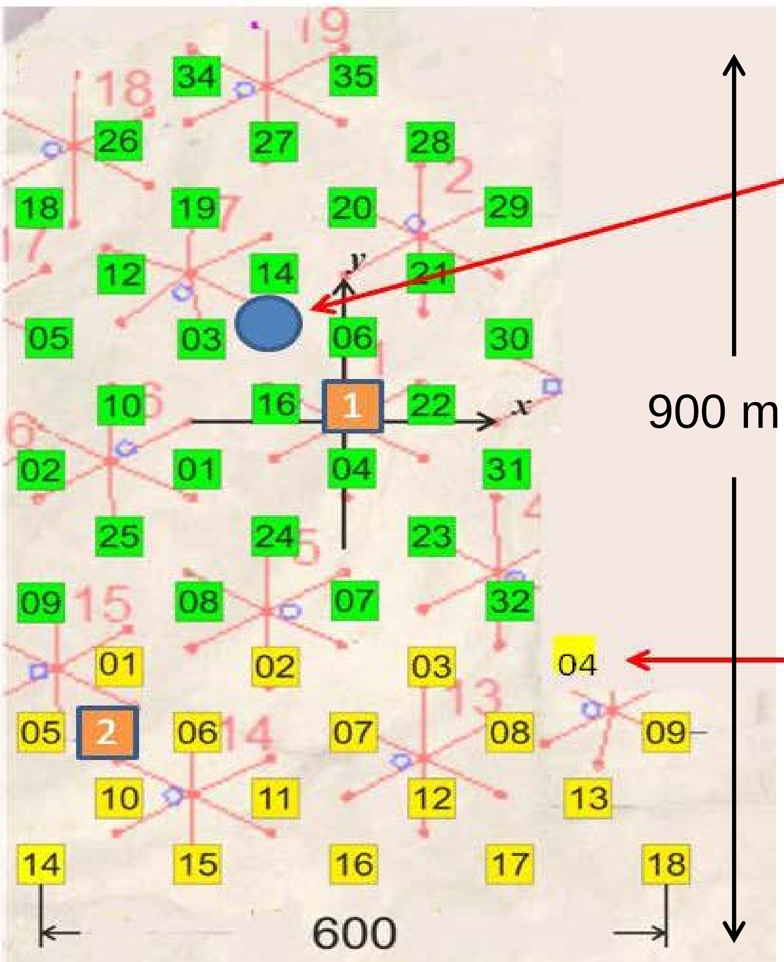
Cluster – 28 PMTs
22 clusters per camera

DAQ - MAROC3

February, 2018

2. TAIGA current status

Season 2017-2018



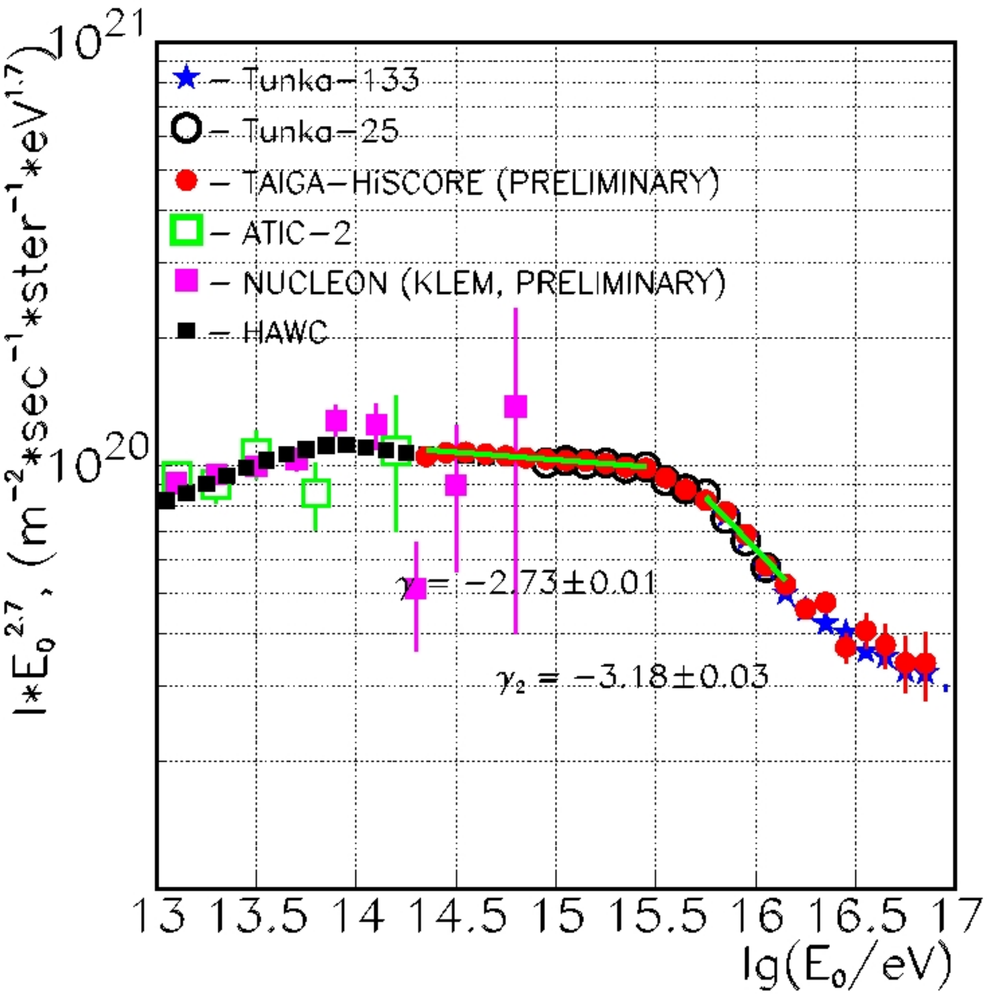
43 detectors , 106 m spacing,S~0.5 km^2

IACT:

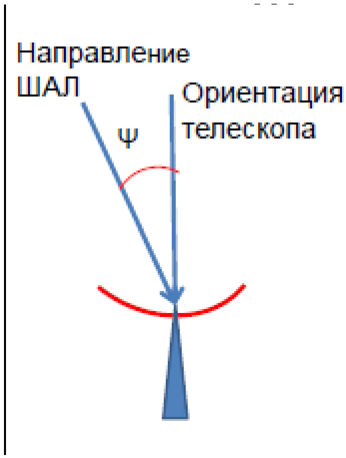
S of mirrors 8.5 m^2
Focus 4.75 m
FOV 9.5^o
One pixel 0.36°
560 pixels (in 22 clusters)
PSF ~0.1°
CCD – for checking telescope pointing direction.

HiSCORE station:
4 PMTs of 8'' size
with Winston cones
(light collection 0.5 m^2)
FoV ~0.6 sr

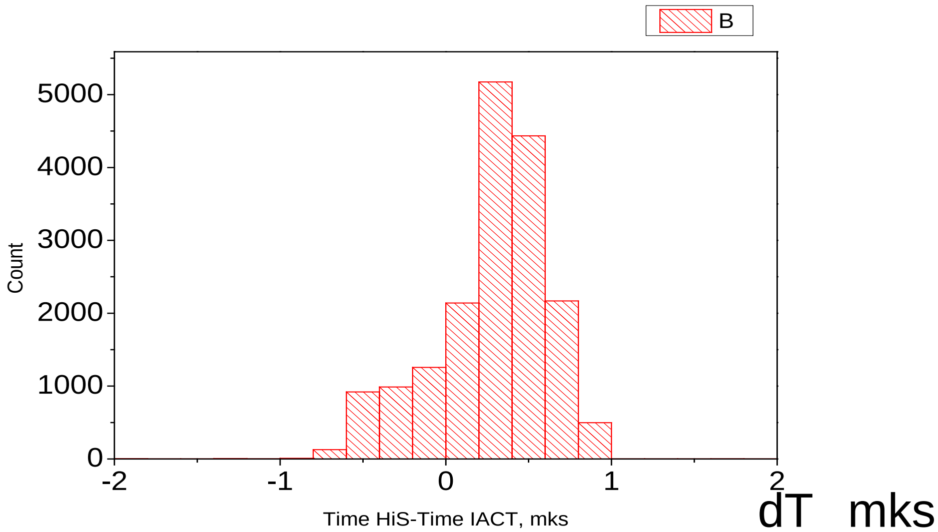
CR energy spectrum 2018



Statistics of Hybrid events



Distribution of T (iact) –T (Hiscore)

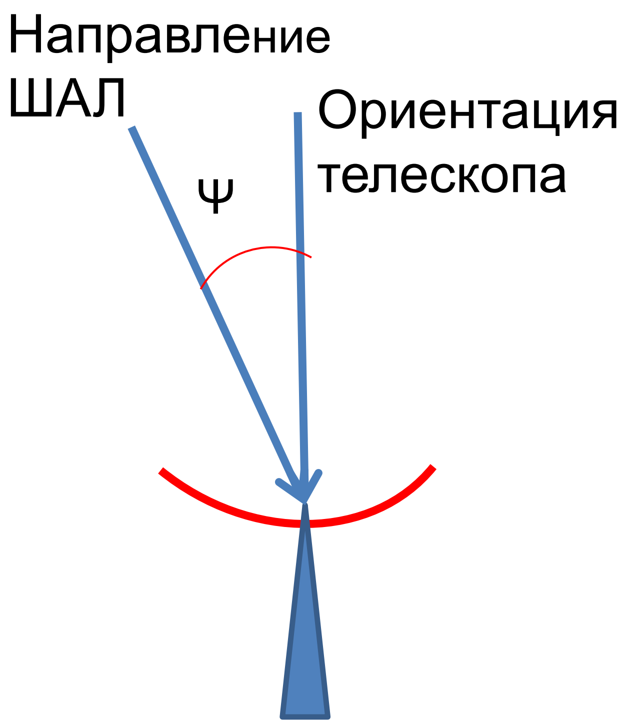


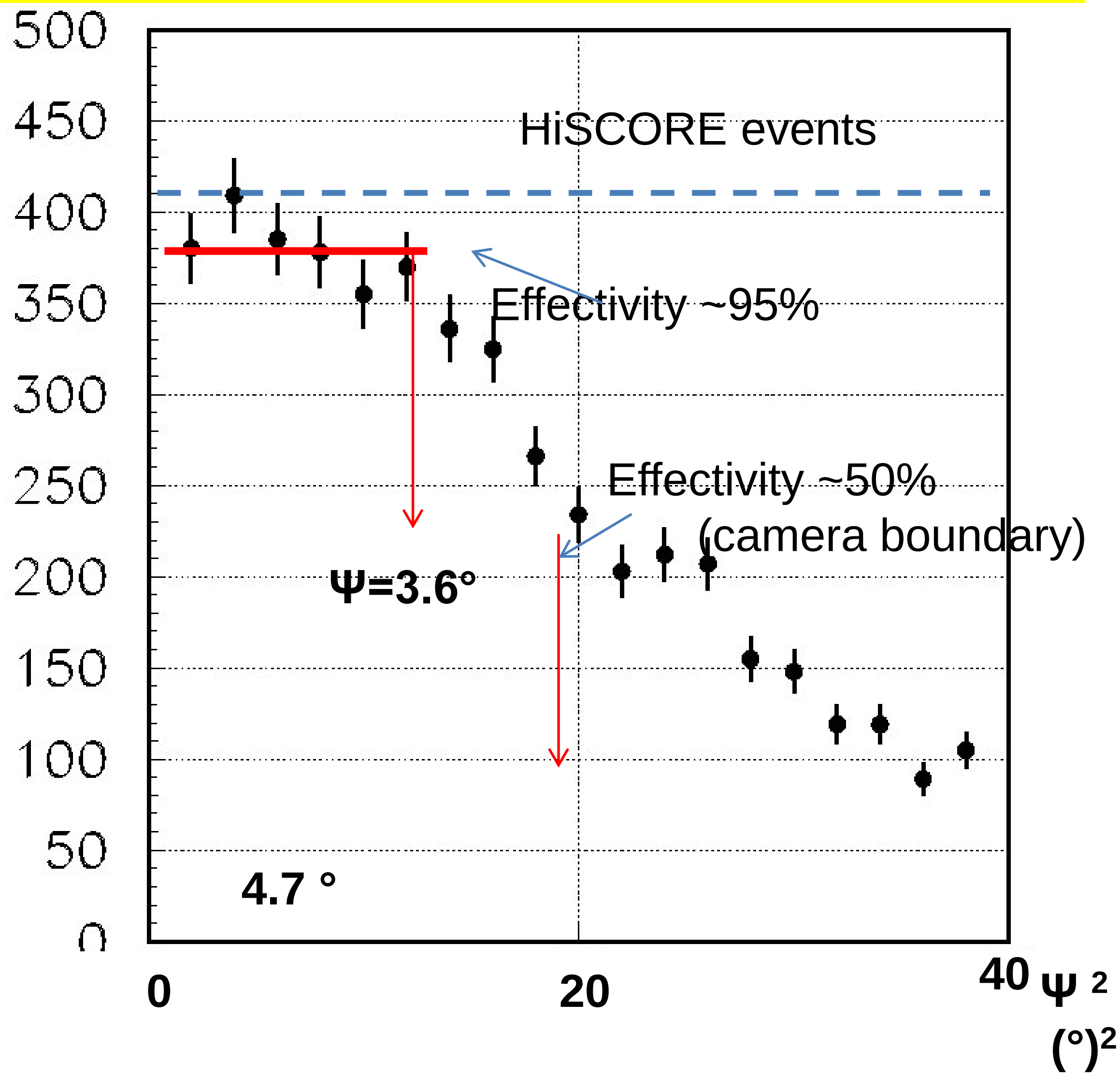
IACT only: effective time 25 hr, Size>60 pe., Npix>4 **95000**

HiSCORE only Ndet ≥ 4, (0.25 km^2) **1.33 · 10^6**

IACT + HiSCORE joint events **14000**

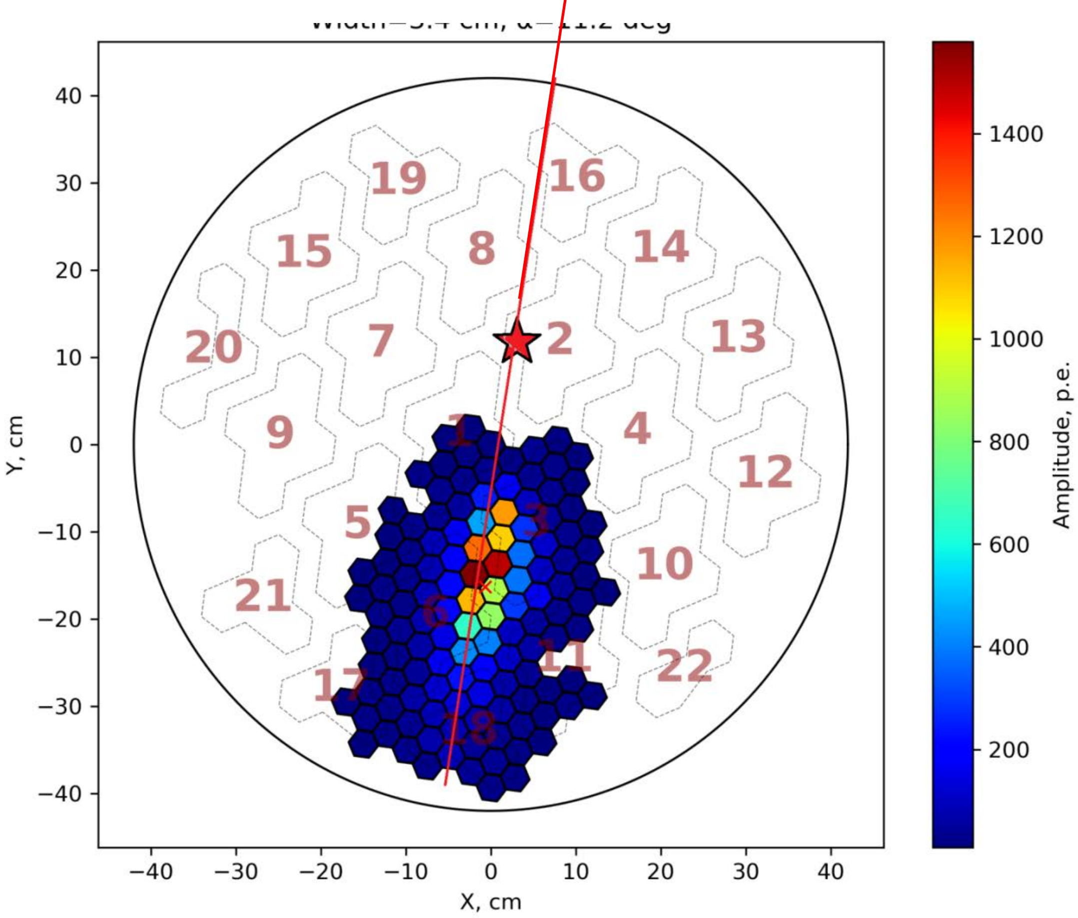
Ψ² – распределение для совместных событий





IACT and HiSCORE joint events

EAS core position



17000 joint events in 25 hours

~200 events in 1° around direction on Crab

“Hadron –like” event

Hillas parameters of image:

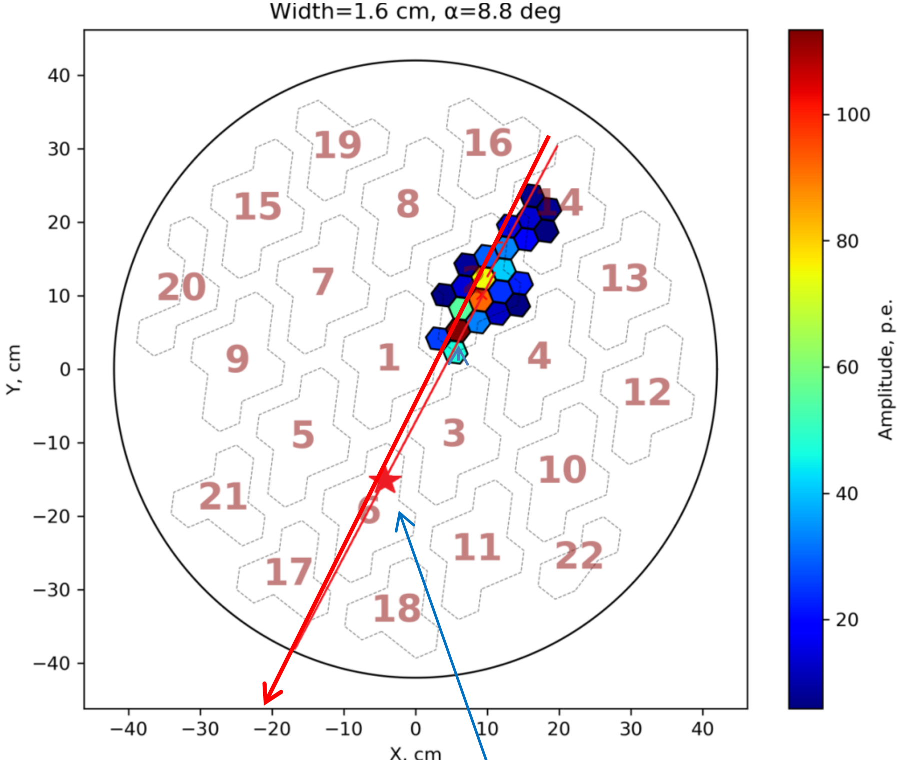
Size = 18500 pe.
Width = 0.4° alpha = 11°

Energy from HiSCORE:
840 TeV

FIRST EXAMPLE OF HYBRID "GAMMA-LIKE" EVENT

IACT data

Width=0.13º, length=0.69º, alpha=8.9º, size=709p.e.

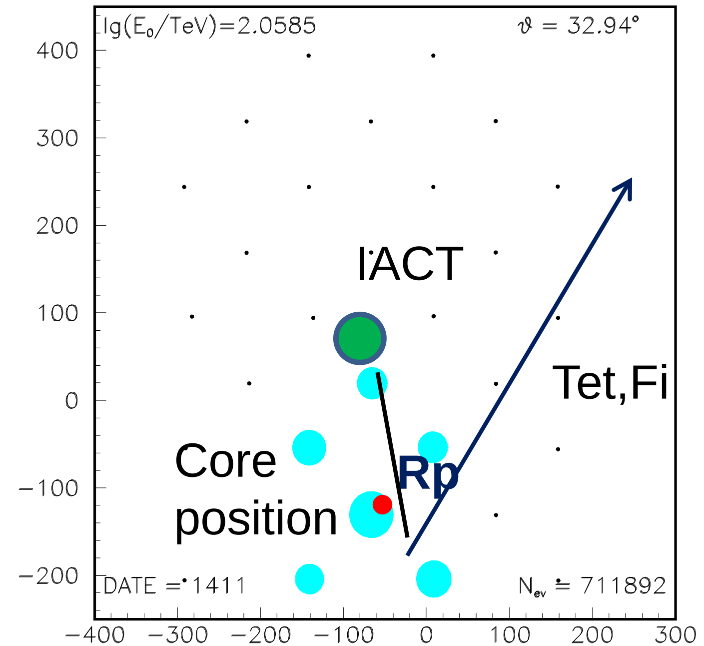


Recalculated core position in IACT plane after introduction of scaling factor Rp' = Rp/1500

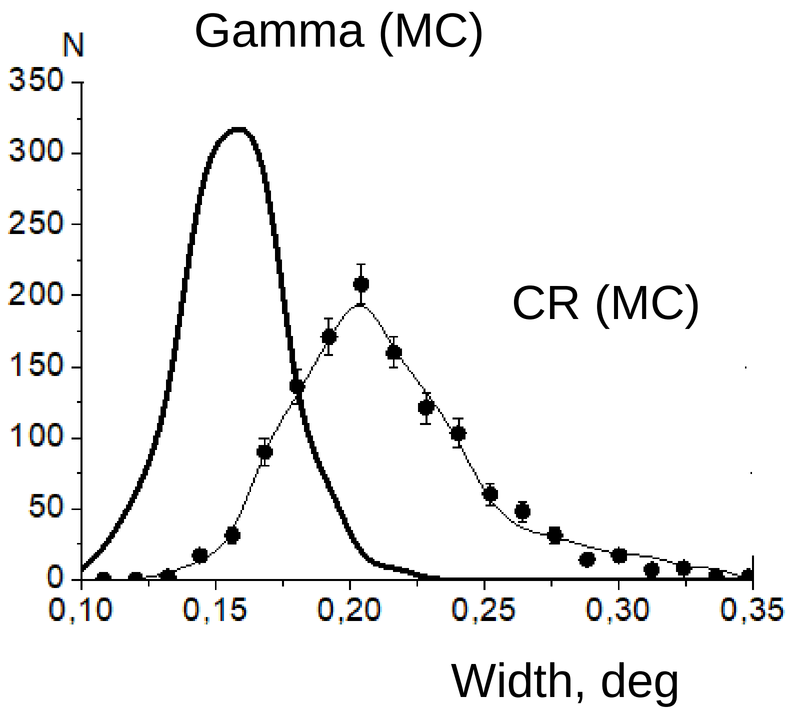
HiSCORE data

E = 55 TeV

Tet = 32.9, Fi = 33. 58



Width for joint events : Experiment &MK



Cuts:

Width <0.17°

Alfa< 15°

Hadron rejection – 0.01
gamma events - 0.5

Q-factor ~5

Gamma-like events

Ψ – the angle (the direction at the Crab, the shower direction by HiSCORE)

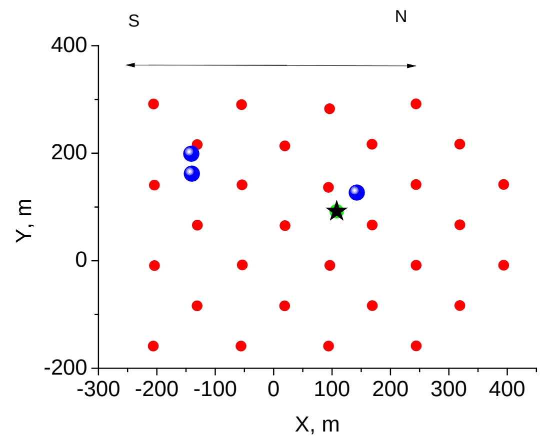
Effective Time – 25 hours

Full number of events with Gam <1°

Criteria for Hillas parameters:

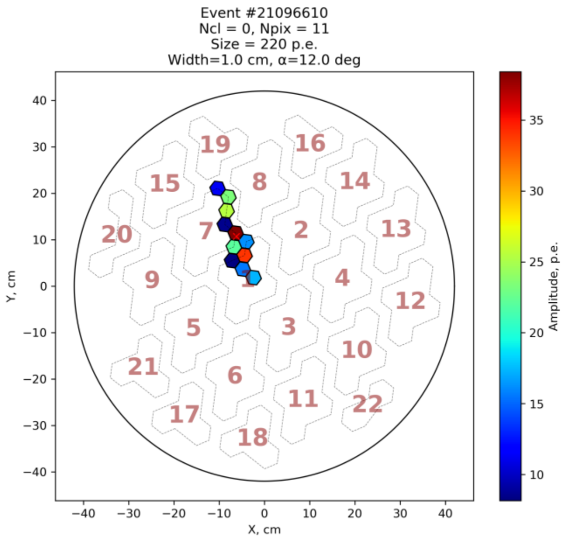
width < 0.17 ° alfa < 15°

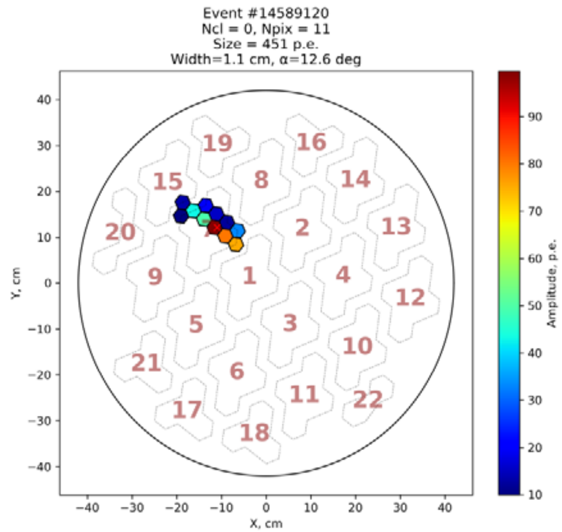
7 events

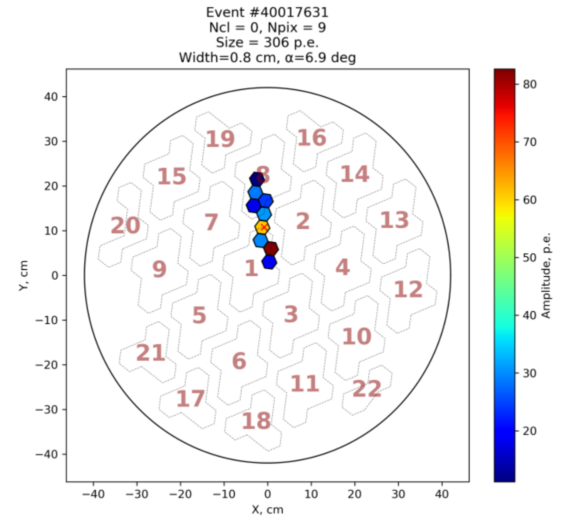


Energy gamma ~ 40-60 TeV

Distances ~ 50 m, 299 m, 270 m







Candidates on Gamma-events

Cuts:

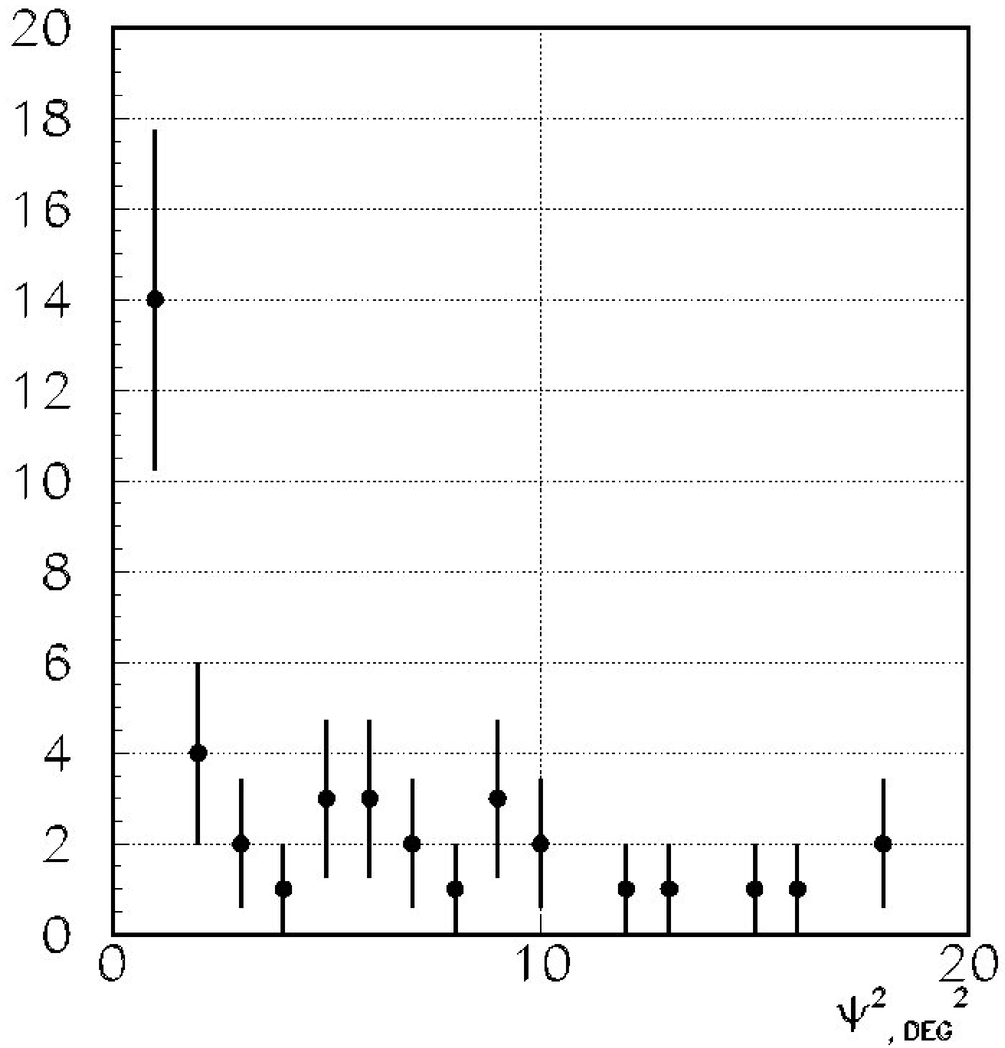
Width <0.17°

Alfa< 15°

50 events

14 событий
Ψ<1°

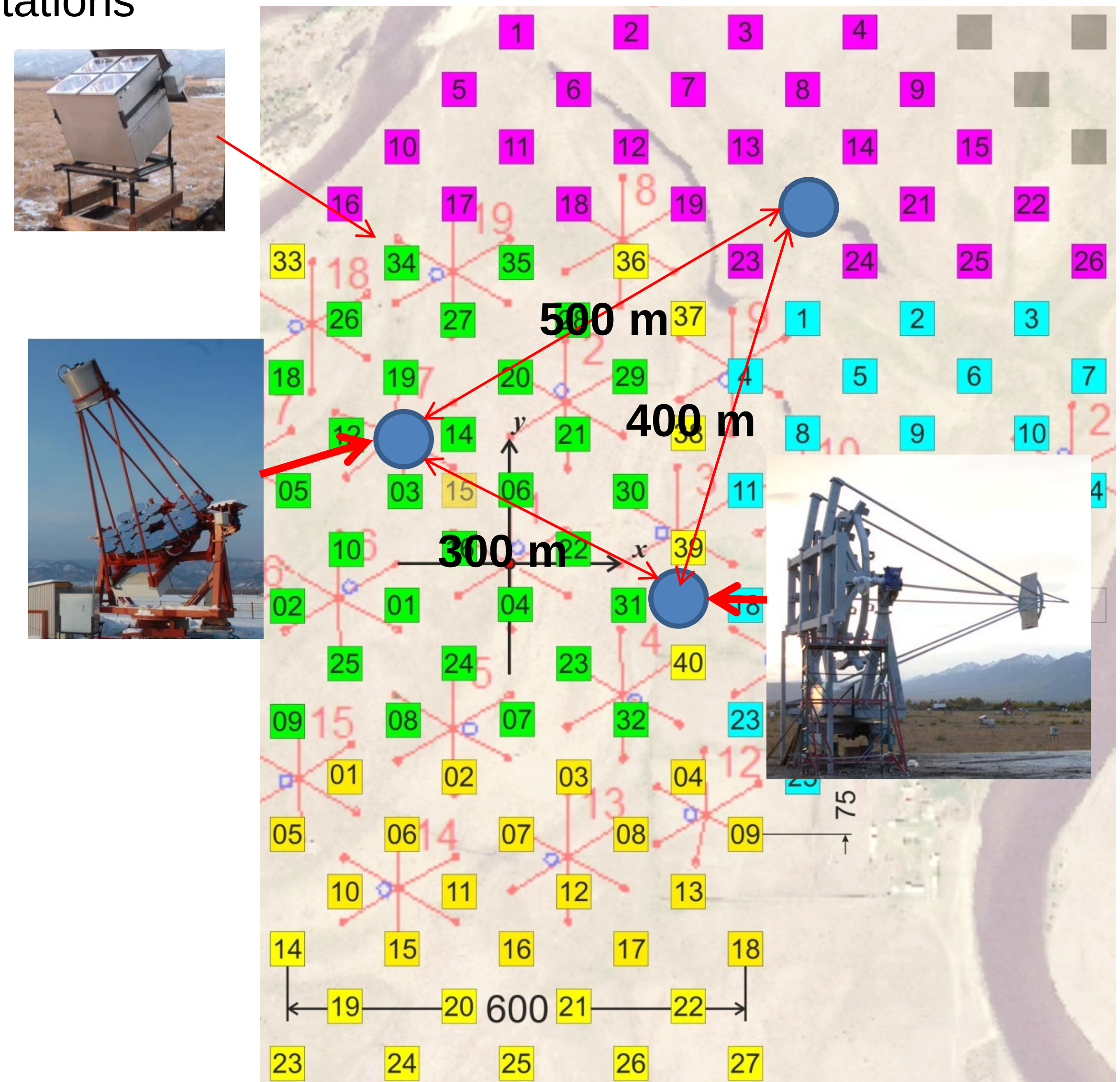
E – 45-60 TeV



3. The future of experiment

Plan for 2019-20

120 stations



For 100 hours

3·10^5 hybrid events (CR mass composition)

50-100 hybrid events from Crab (E ≥.40 TeV)

Mirrors and camera
In May 2019

Long term plan for TAIGA

+

+

- **1000 wide angle optical station on the 10 km^2 area, energy threshold 30 TeV**

- **10-15 IACTs (10 m^2 mirrors).**

- **Muon detectors with total area 3.0 10^3 m^2.**

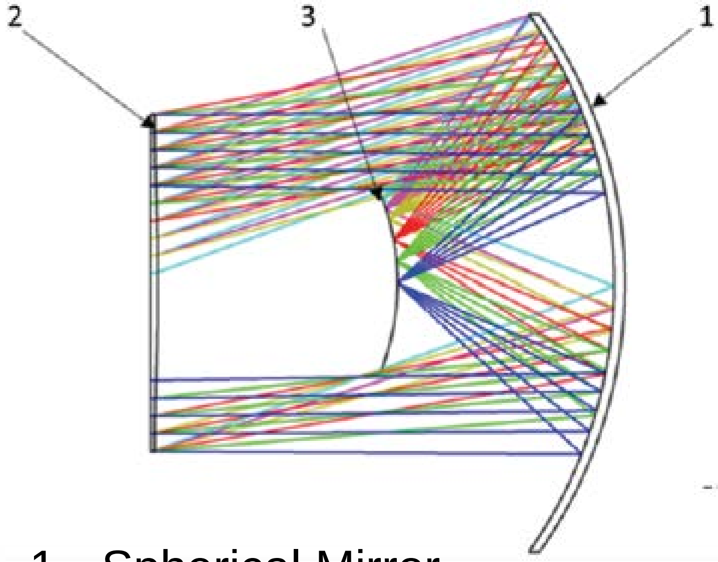
Installation should be placed at 2000 m u.s.l

Wide-angle telescope on SiPMs

HiSCORE and IACT – only 1% of joint events

We need to increase FOV of camera to 60° the same as HiSCORE.
The first step, camera with FOV ~ 15°

Shmidt camera



1. Spherical Mirror
2. Corrected lens
3. Focal surface

FOV ~15°

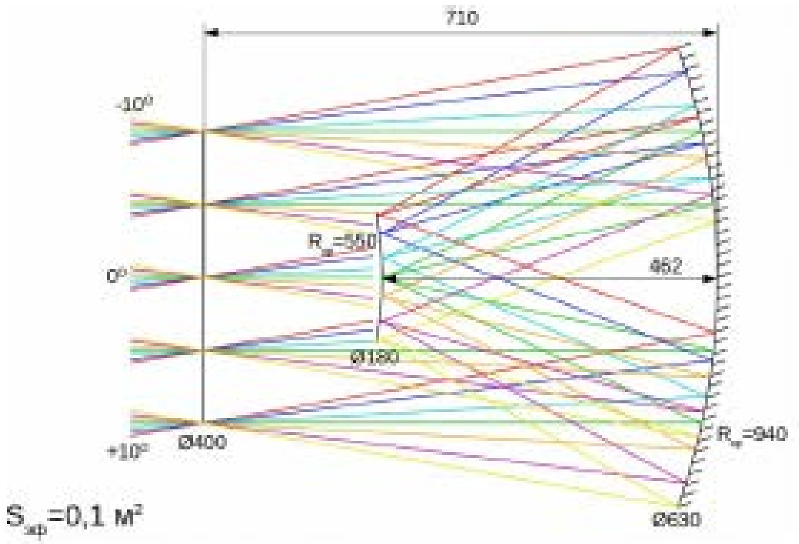
S ~ 1 m^2

Number of pixels ~ 1000-1200
FOV for one pixel ~ 0.4 °

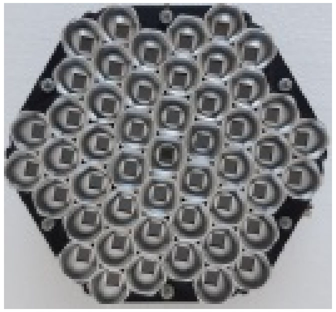
Energy threshold ~ 10 TeV

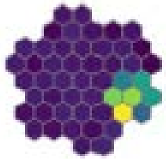
What SiPM?
Electronic: CITIROC or FADC?

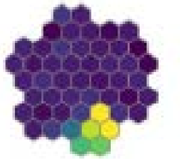
Camera on 49 -SiPMs



Test camera on 49 SiPM
SensL MicroFC-60035-SMT

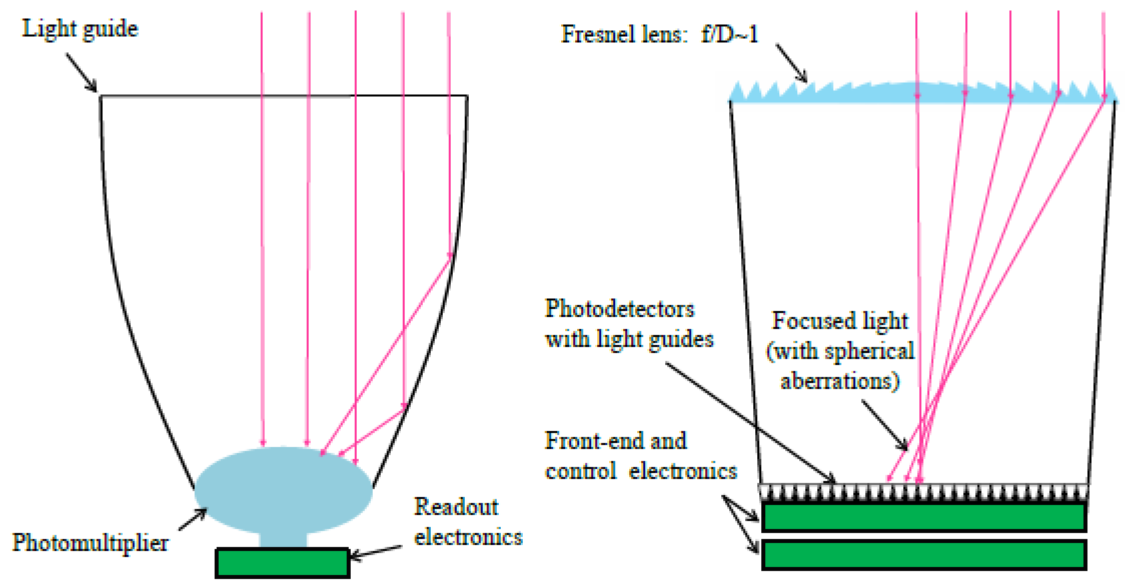






Haw to decrease HiSCORE energy threshold ?

M.Shayduk et al (2015)



100 channel
May be another optical system

Background per channel in 100 smaller then
Energy threshold in 10 times smaller
(5 times for HiSCORE station with 4 PMT)

$\Delta\Omega$~0.6 sr >> 0.03 (for EAS)

Conclusion

1 TAIGA - 10 km^2 hybrid array 1000 wide-angle stations and 15-20 IACTs). The sensitivity for local sources in the energy range 30 -200 TeV is expected be **– 10^{-13} TeV cm^{-2} sec^{-1} (for 500 h observation)**

2. Deployment of the full scale TAIGA prototype -120 wide-angle stations and three IACTs is planned for 2019-2020.

The expected sensitivity for 300 hours source observation with this array in the range 30 – 200 TeV is about **2.5 10^{-13} TeV/(cm^2 sec),** extending the energy range of existing and planned experiments to the ultra-high energy range.

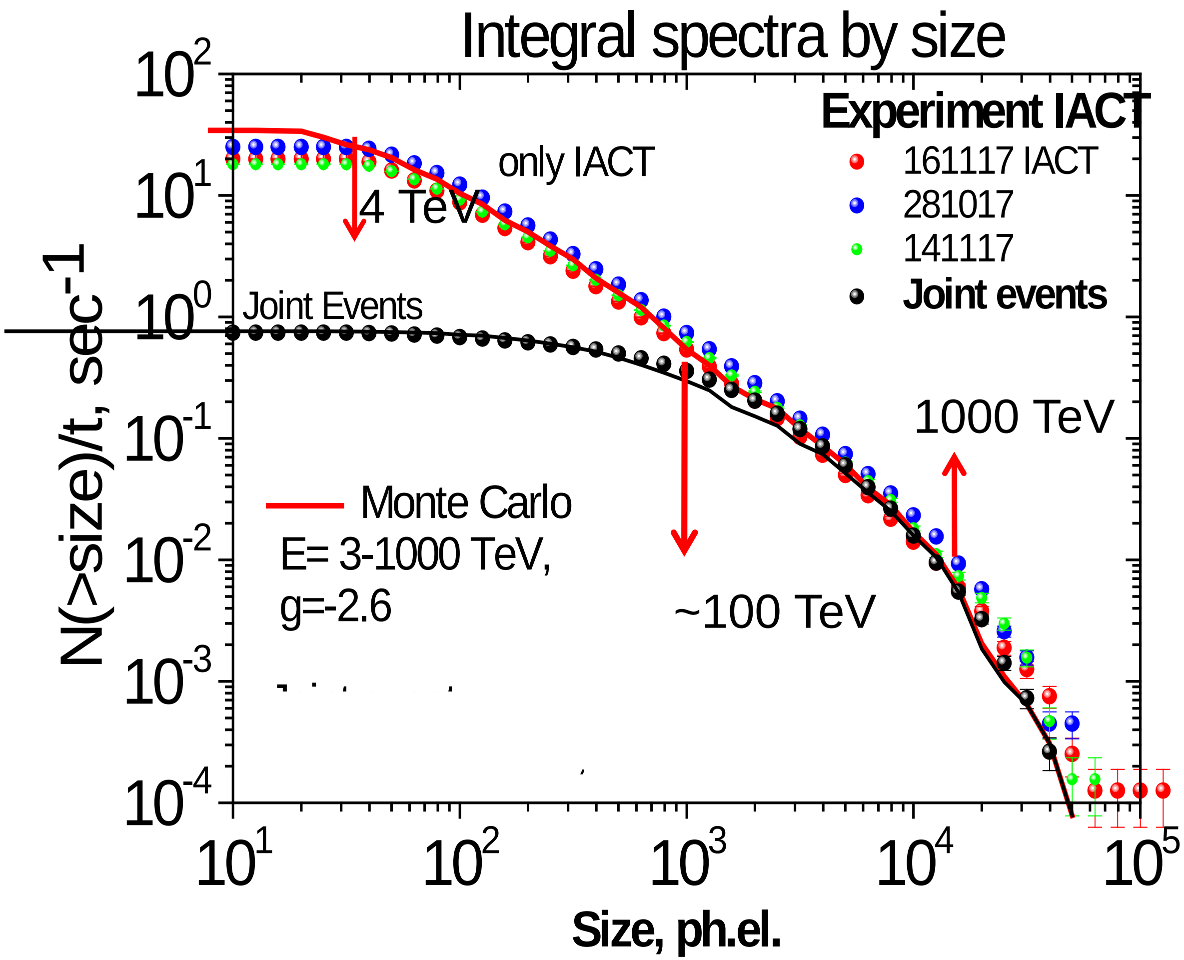
3. The first commission seasons were successful:

- CR energy spectrum below the knee
- Lidar on board ISS – light calibration source for TAIGA
- First results from joint operation of HiSCORE and IACT

4. Work has begun on the creation of a new cameras based on SiPM

Thank you

Integral spectra by size for the IACT events and joint events



HiSCORE energy spectra In linear scale

Peak energy
~100 TeV – CR
~ 50 TeV – gamma