TAIGA: status, results and perspectives

L.Kuzmichev (SINP MSU)
On behalf of TAIGA Collaboration

IV International Workshop
"Data life cycle in physics", DLC-2020
09/06   2020

Content of report

1. Introduction: Astrophysical complex in Tunka Valley

2. High energy gamma-ray astronomy and TAIGA project

3. TAIGA current status

4. First results

5. The experiment in future

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)

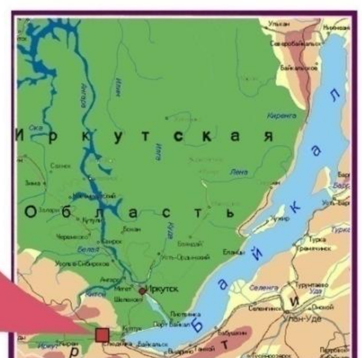
BINR SB RAS (Novosibirsk)

NSU (Novosibirsk)

ASU (Barnaul)

1. Astrophysical complex in Tunka Valley

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



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

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

- **Optical telescope MASTER**

All installations in Tunka Valley

1. Tunka-133
2. Tunka-Grande

Cosmic rays with energy > 10^{15} eV

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

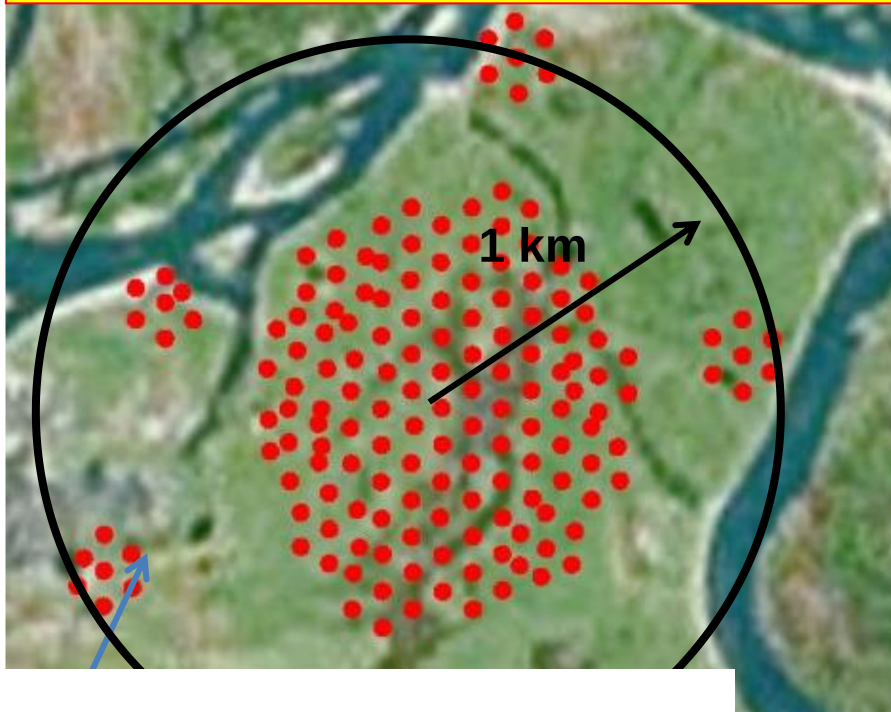
TAIGA (Tunka Advanced Instrument for cosmic rays and Gamma - Astronomy)

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)

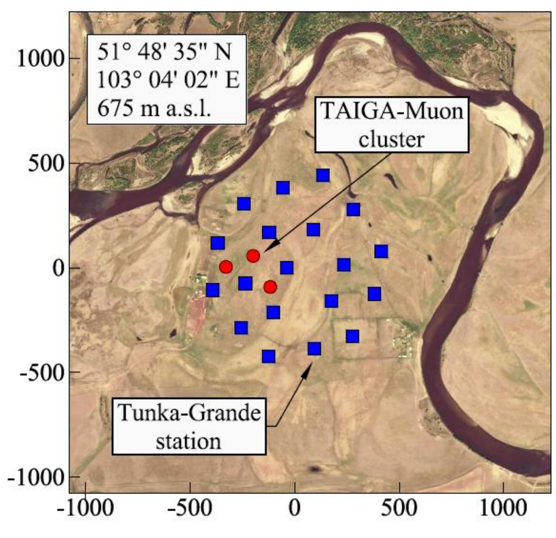
Cosmic rays and gamma ray with energy $> 10^{15}$ eV

Tunka-133 -
175 optical detectors on the area of 3 km^2

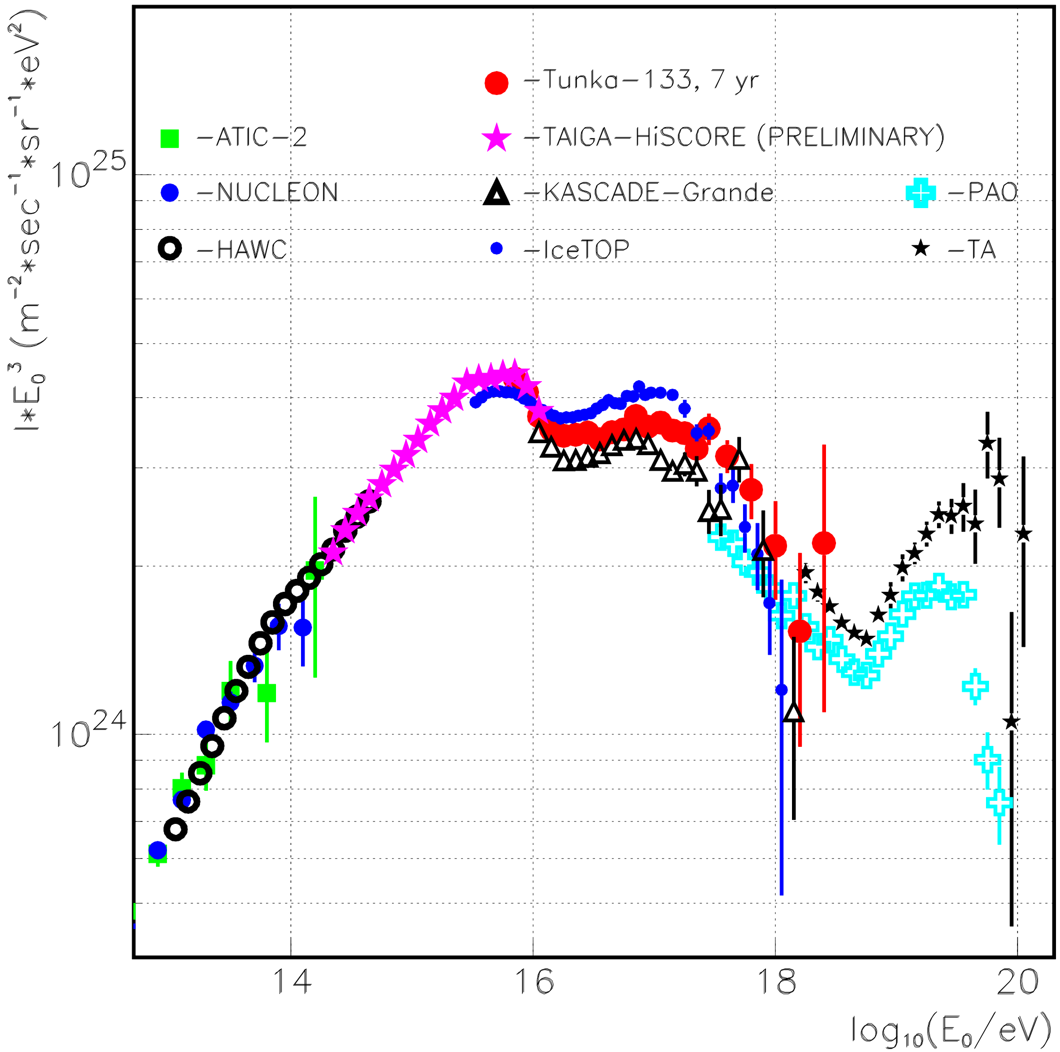


Tunka- Grande –
380 scintillation counte
for detection of
EAS charged particles

TAIGA_Muon



CR energy spectrum: HiSCORE +Tunka-133 – from 10^{14} – 10^{18} eV



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

The Sources of Gamma-rays

More 200 sources with gamma-ray > 1 TeV

1. SNR

2. PWN

3. Pulsars (Crab)

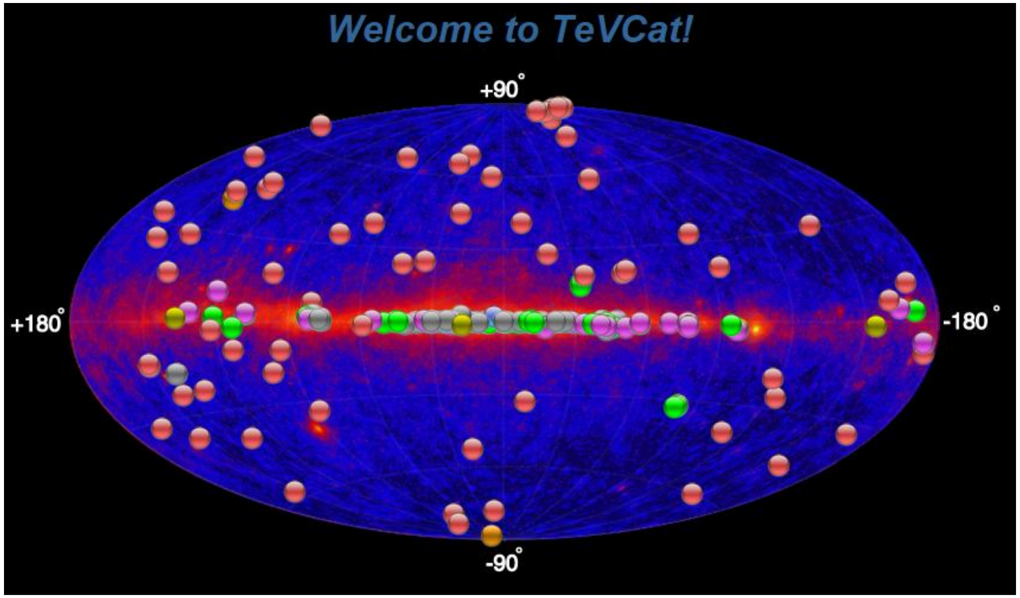
4. Binaries systems

5. Galactic center

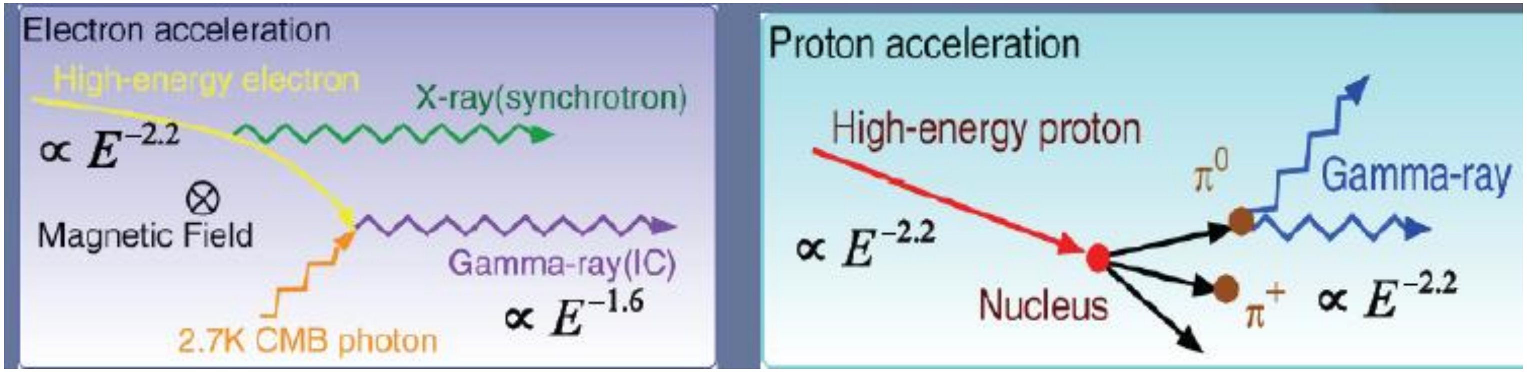
6. Blasars

7 radiogalaxies

8. GRB (GRB190114C)

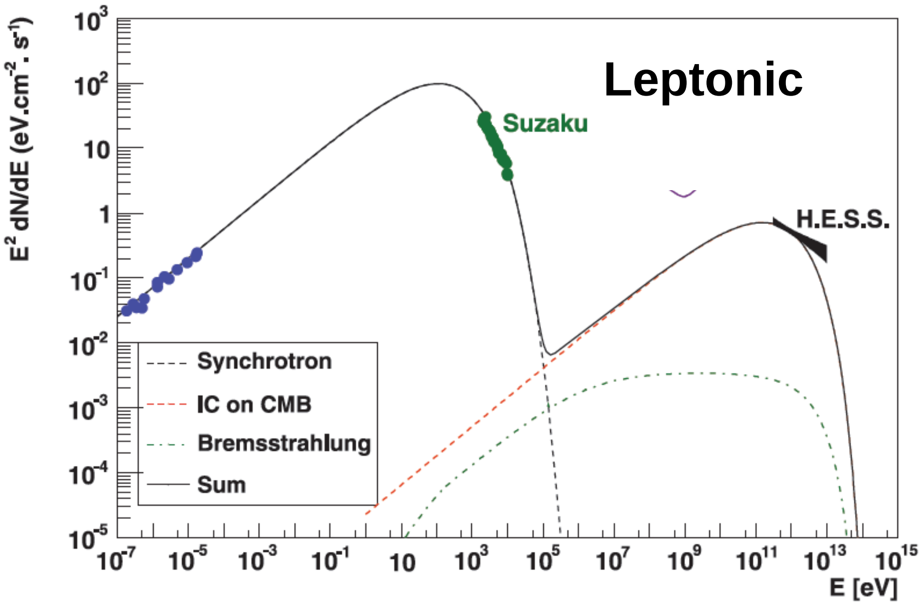


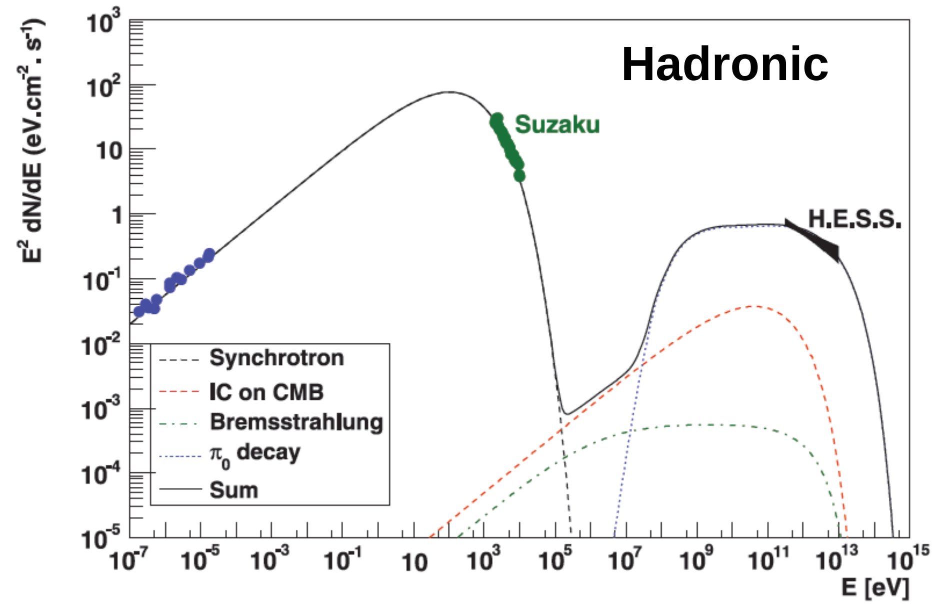
Gamma-ray generation



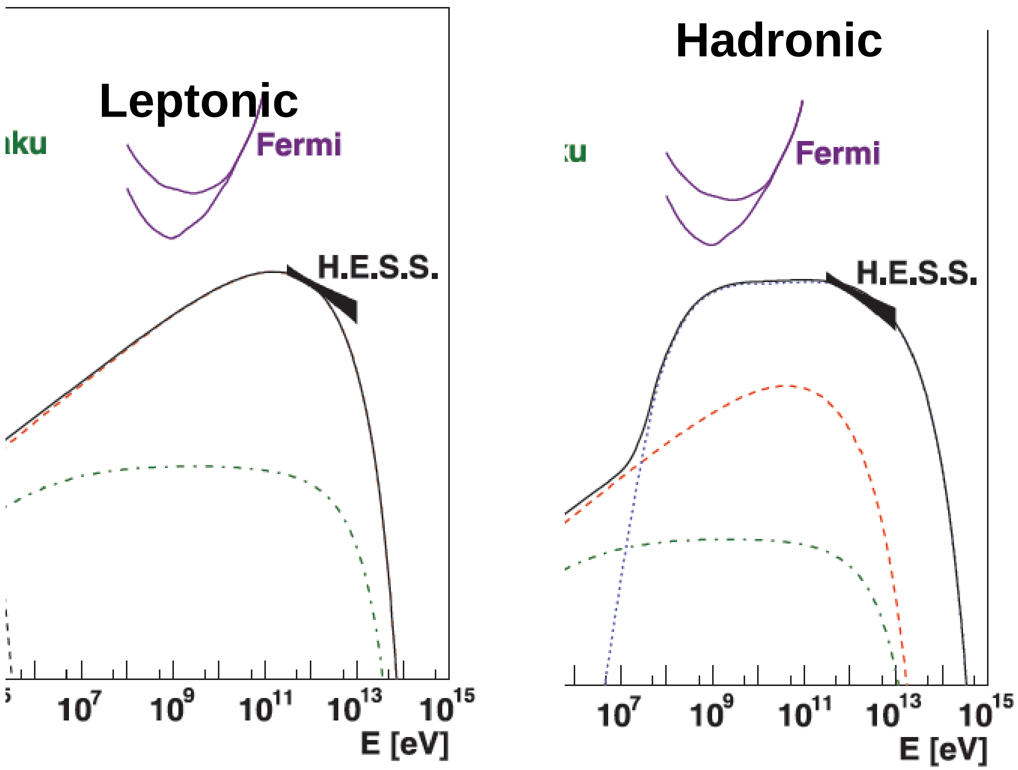
Leptonic **Hadronic**

SN 1006 : what is the mechanism of gamma-ray generation?





How to understand the gamma-quantum generation mechanism

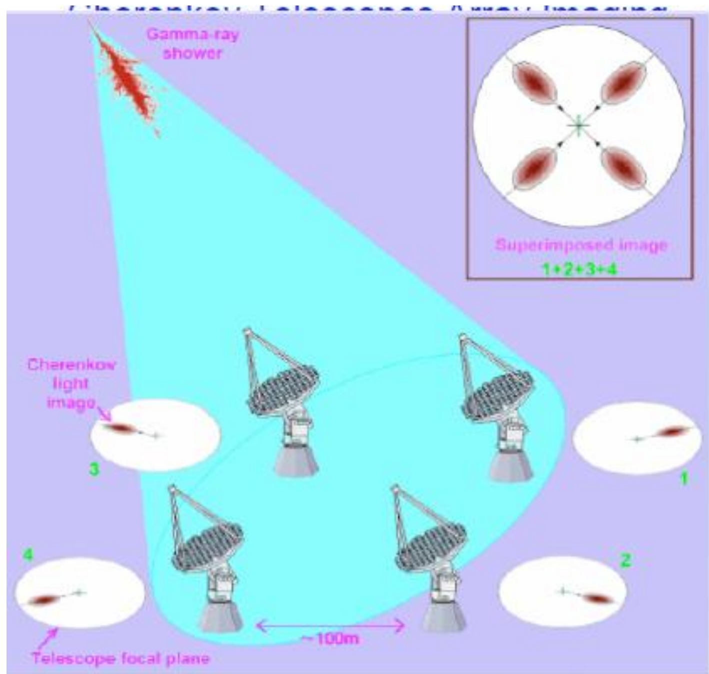


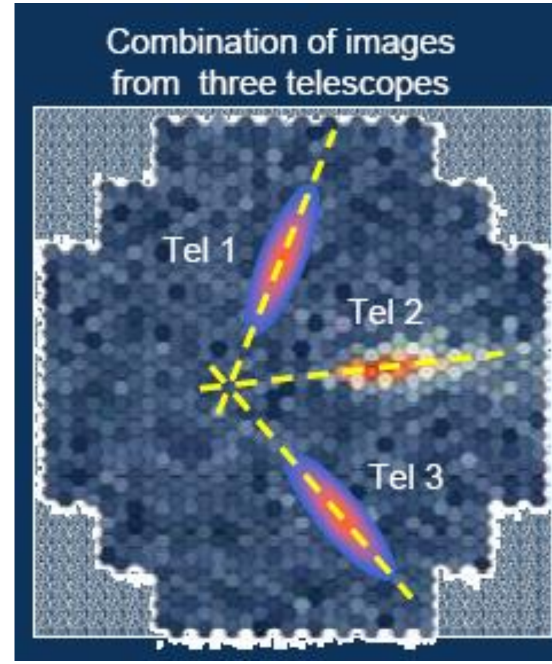
One way – to study high-energy cut-of of energy spectrum

The contribution of gamma rays generated by electrons during IC scattering should be suppressed at high energies due to a decrease in the scattering cross section (Klein-Nishima effect)

Imaging Atmospheric Cherenkov Arrays (2-5 IACT)

Whipple
HEGRA
H.E.S.S.
MAGIC
VERITAS
S ~ 0.1 km^2

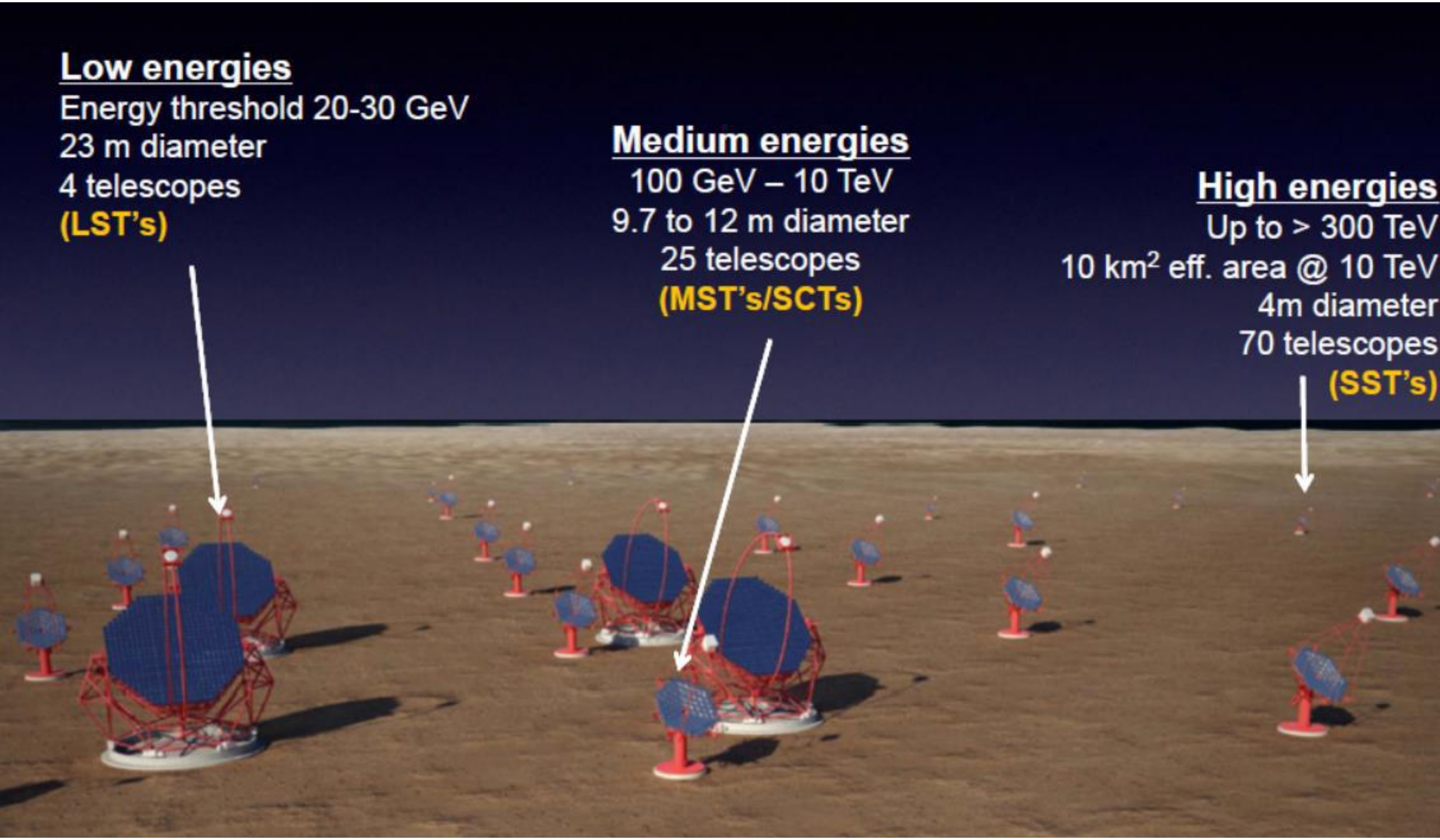




The basis of the gamma-ray selection - method is the detection of one EAS with two and a large number of telescopes - stereoscopic method

To study the of gamma-ray with ultra high energies, we need installations with area of ~ 10 km^2

CTA project : 100 IACT on the area 10 km^2



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 2020

Scientific Program

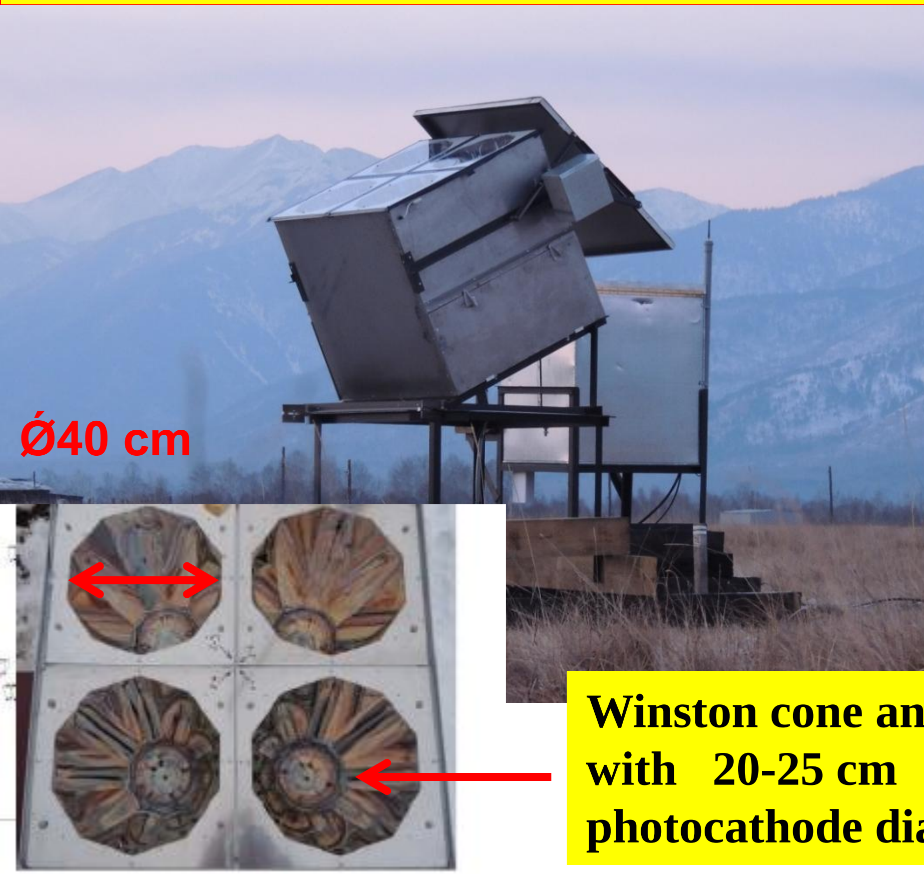
Search for the acceleration limit of particle in known supernova remnants and PWN: Crab Nebulae и Boomerang (PWN), Tycho и Cas A (SNR), Dragonfly Nebula (2HWC J2019+367) ARGO J2031+4157 (Cygnus Cocoon)

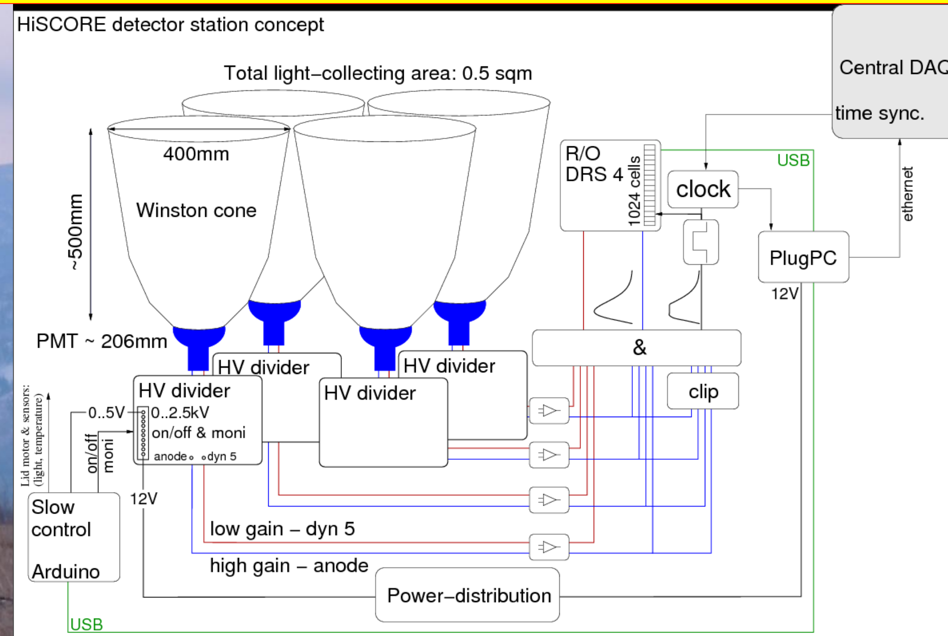
Long-term monitoring and study of the edge of the energy spectrum bright blazars as a method for searching for distribution anomalies gamma rays in the universe and the search for axion-like particles. (1ES 0229+200, 1ES 1959+650, Mrk501, Mrk421, Arp 220, M82)

Search for excess diffuse gamma – rays with energies above 100 TeV Gamma-ray in accompany with neutrino (10^{-4} from CR) if part of IceCube neutrino from Galactic source

Study of CR mass composition in energy range 100-3000 TeV by hybrid approach

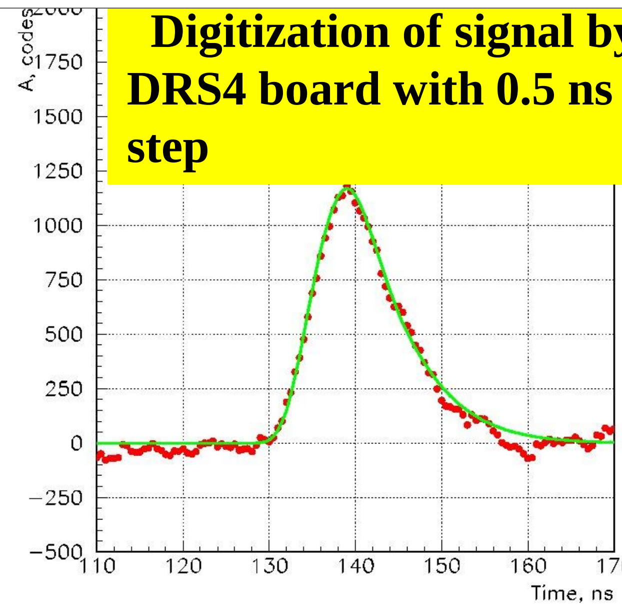
Wide angle station





Winston cone and PMT with 20-25 cm photocathode diameter

Digitization of signal by DRS4 board with 0.5 ns step



S tot = 0.5 m^2

(R5912, R7081, ET9352)

Synchronization and data taking via optical cable

TAIGA-IACT

Area of mirrors - 9.6 m^2 (34mirrors) *
Focus length 4.75 m
FOV 9.6^o
pixel FoV 0.36°

560pixels(pmt XP1911)

PSF ~0.1°

CCD for checking telescope pointing direction.

Four approaches to detecting gamma rays in the TAIGA experiment

1. Autonomous work of one telescope E < 10-15 TeV

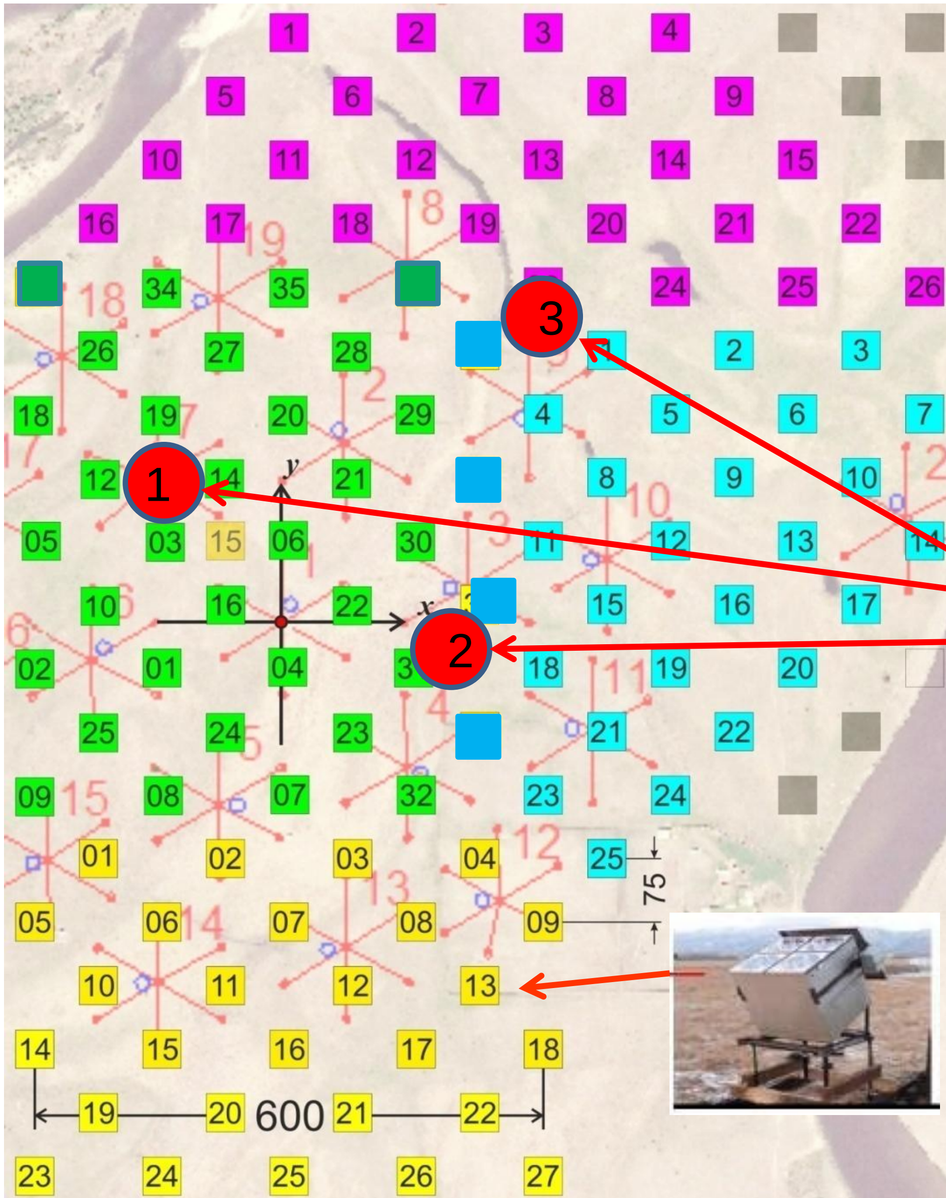
2 Stereoscopic approach for large distances between telescopes E ≥ 10 TeV

3. Hybrid approach – joint operaton HiSCORE and IACTs E ≥ 40 TeV

4. HiSCORE и muon detectors E ≥ 300-500 TeV

3. TAIGA current status

TAIGA - march 2020 : 86 stations и 2 telescopes



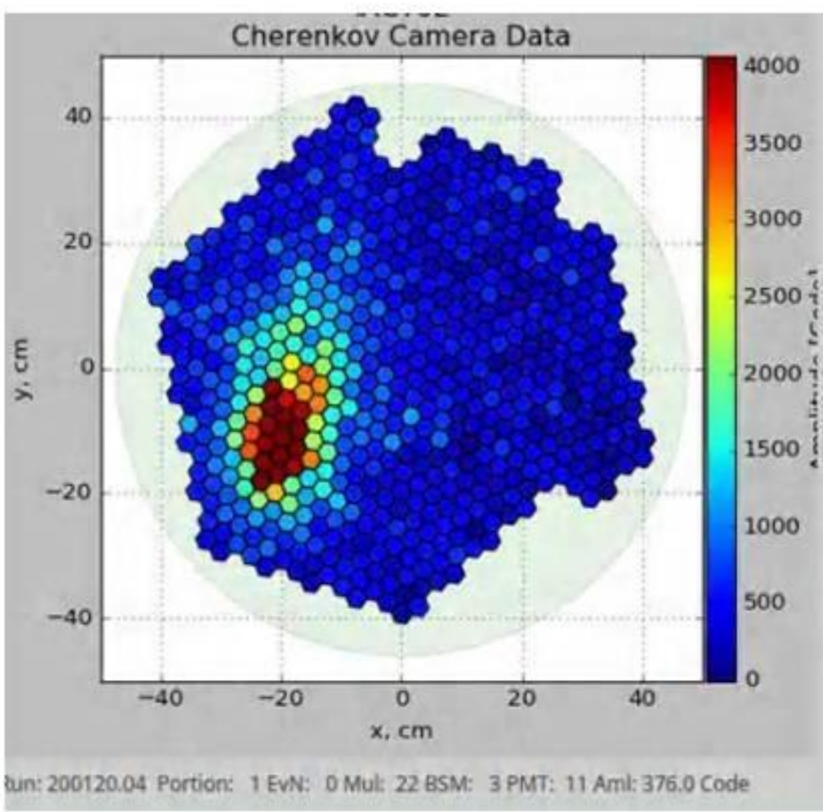
The 3 telescope will start operation only at the end of this year

2.5 month delay due to covid-19

Installing the camera on a second telescope (January 20, 2020)

The second IACT in Tunka(c 20.01 2020)

The second IACT



one of the first evnts

Two telescopes 320 m distance

4.The First results

Season 2019-2020 :

4 sources from October to May

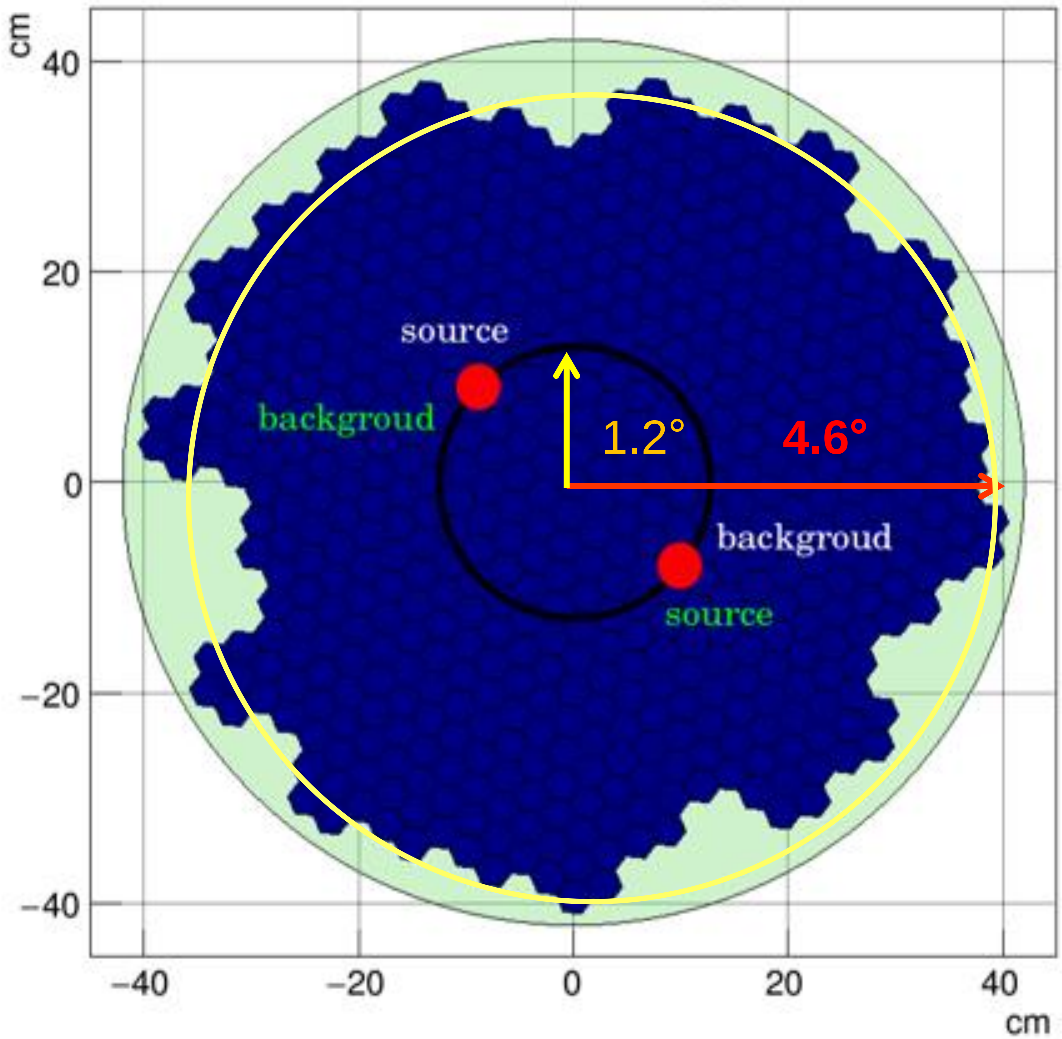
Boomerang

Crab   - 6 sigma

Mkr421 – 5 sigma

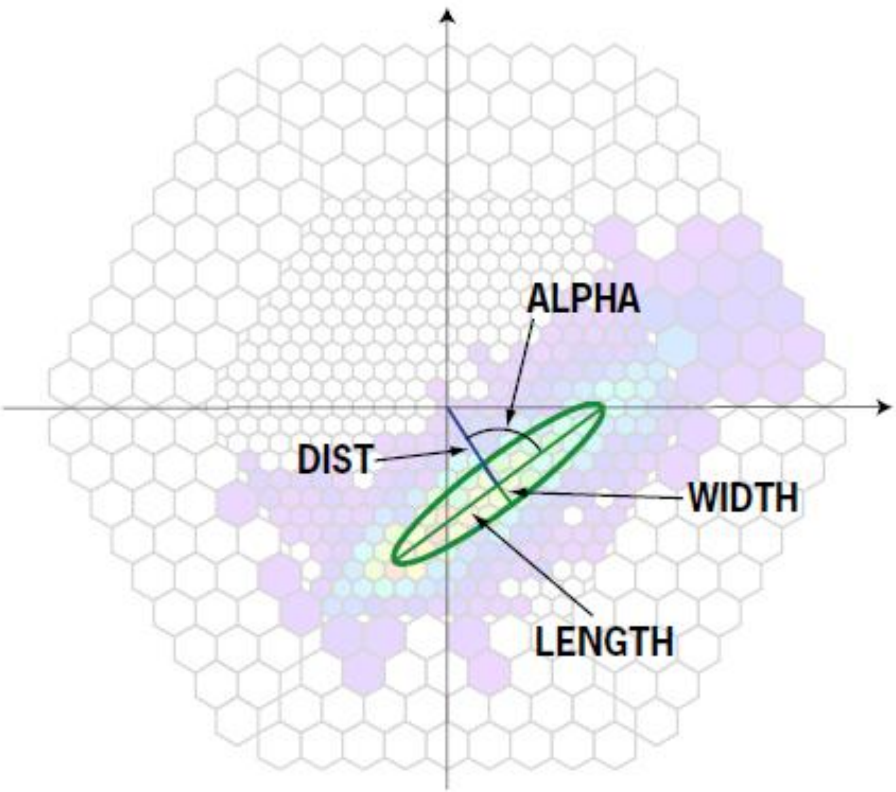
Mrk501

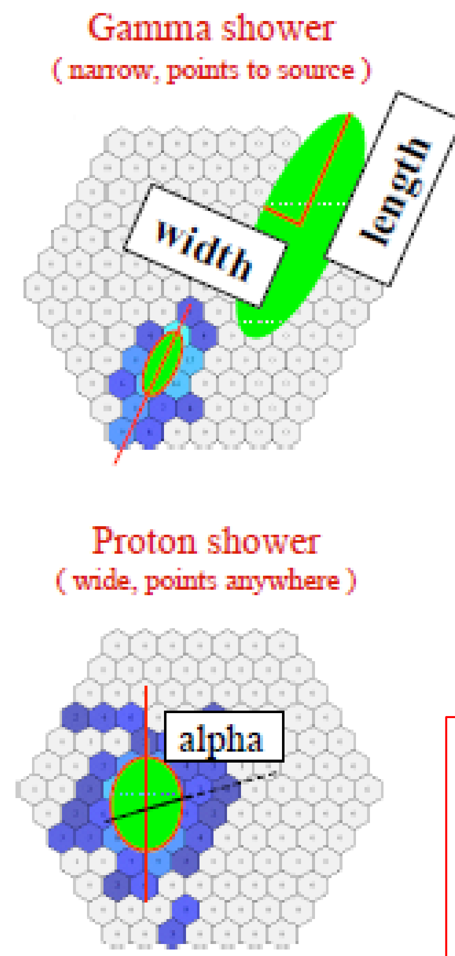
Wobbling



source
backgroud
1.2°
4.6°
backgroud
source
cm
40
20
0
−20
−40
−40
−20
0
20
40
cm

Hillas parameters

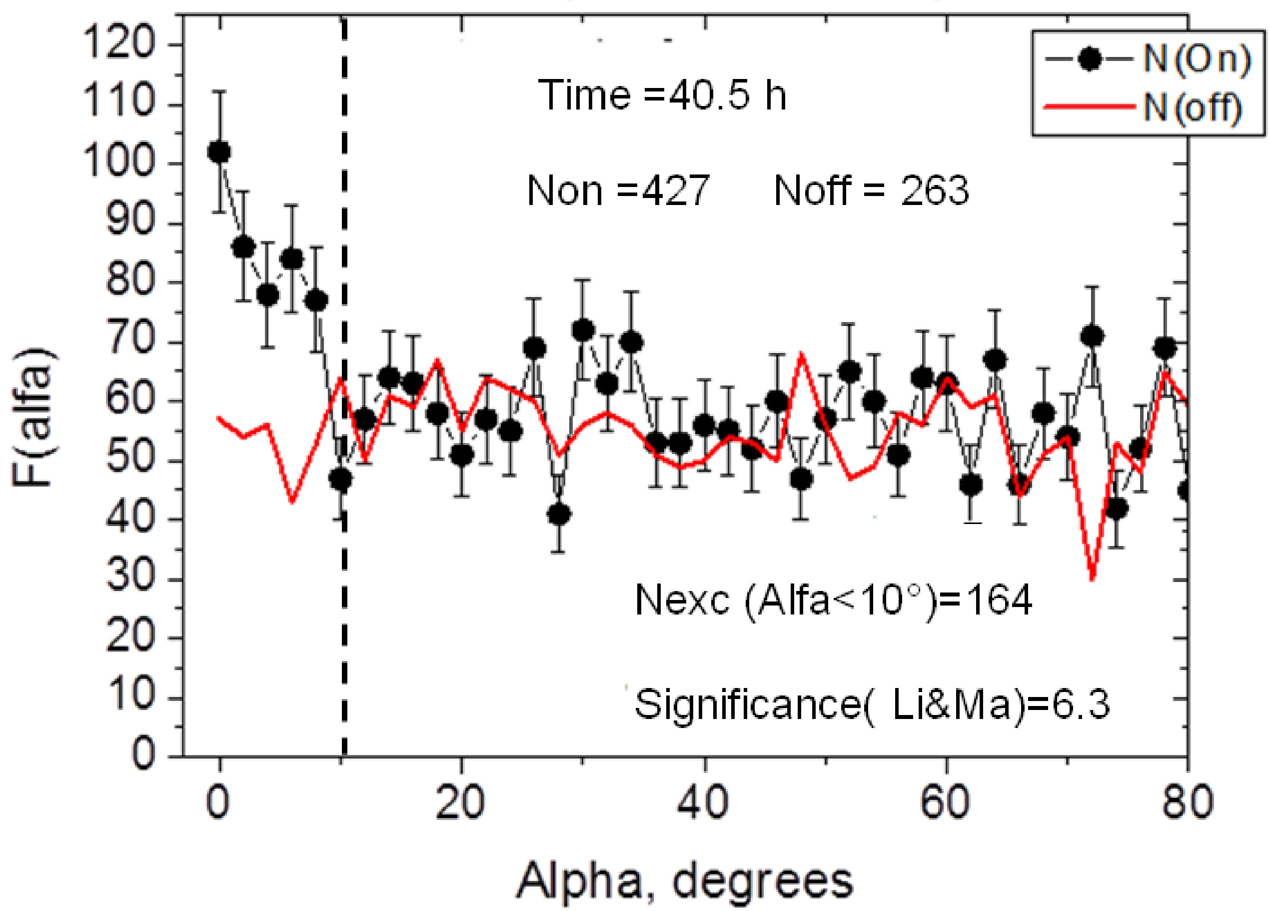




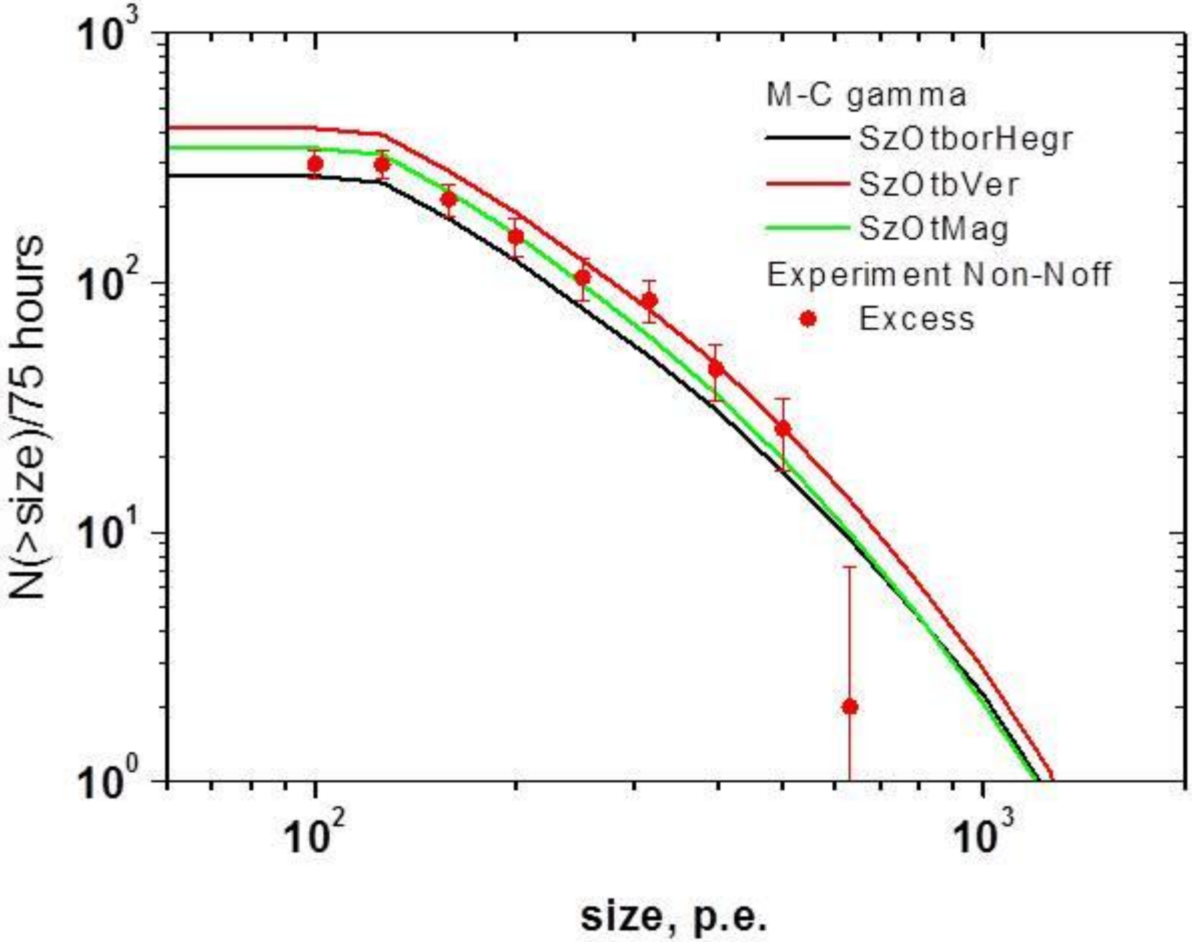
Size -
total number of P.E in image

Alfa distribution for Crab

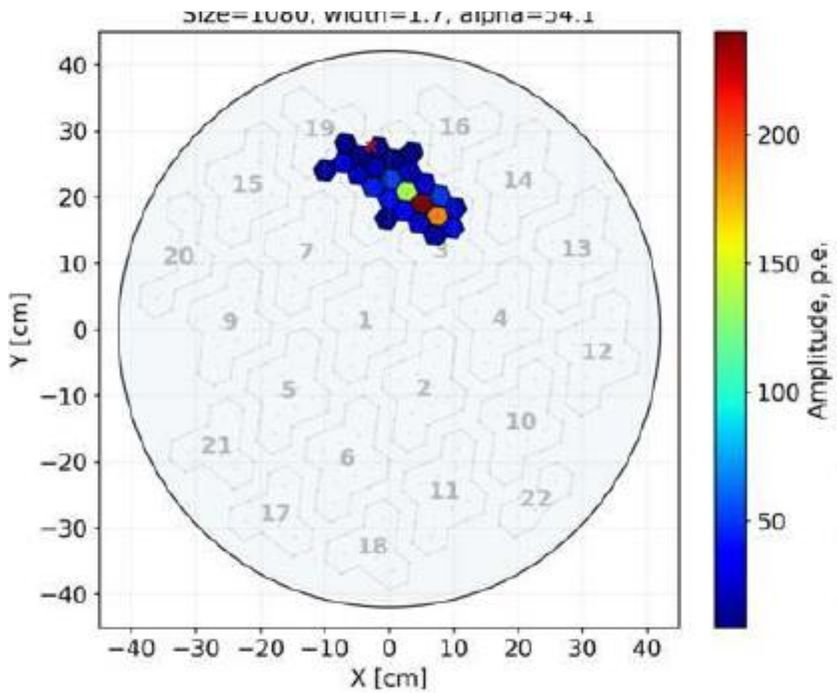
Preliminary!



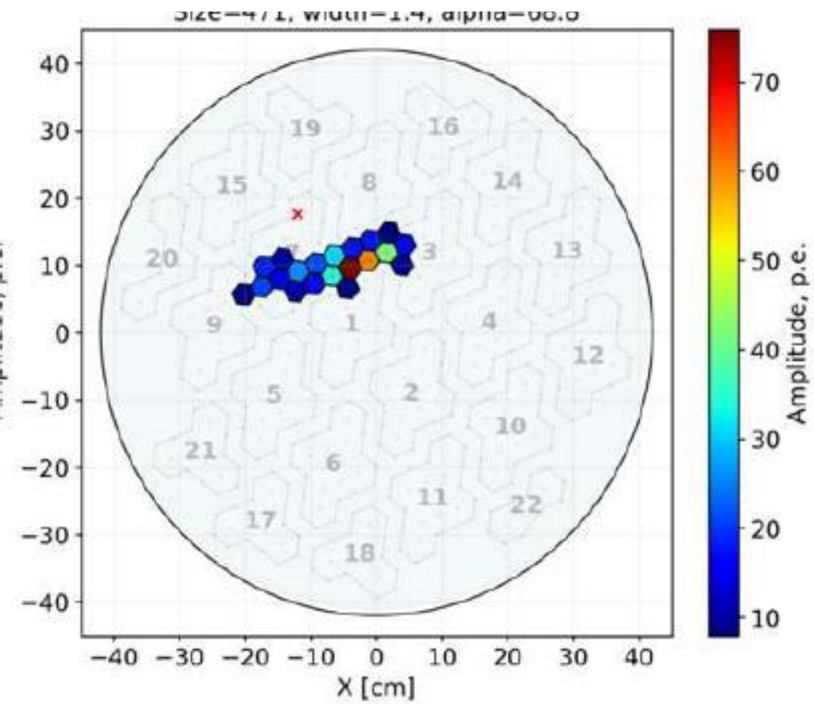
Integral SIZE spectrum



EAS detection by two telescopes at a distance of 300 m - stereoscopic approach for high energies



Size = 1080 pe, Width = 0.20 °



Size = 471 pe, Width = 0.17°

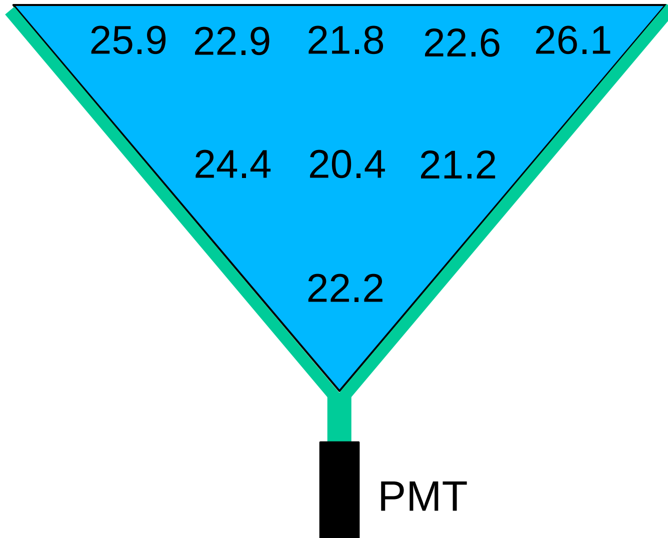
5. The future of experiment

The TAIGA-Muon scintillation array

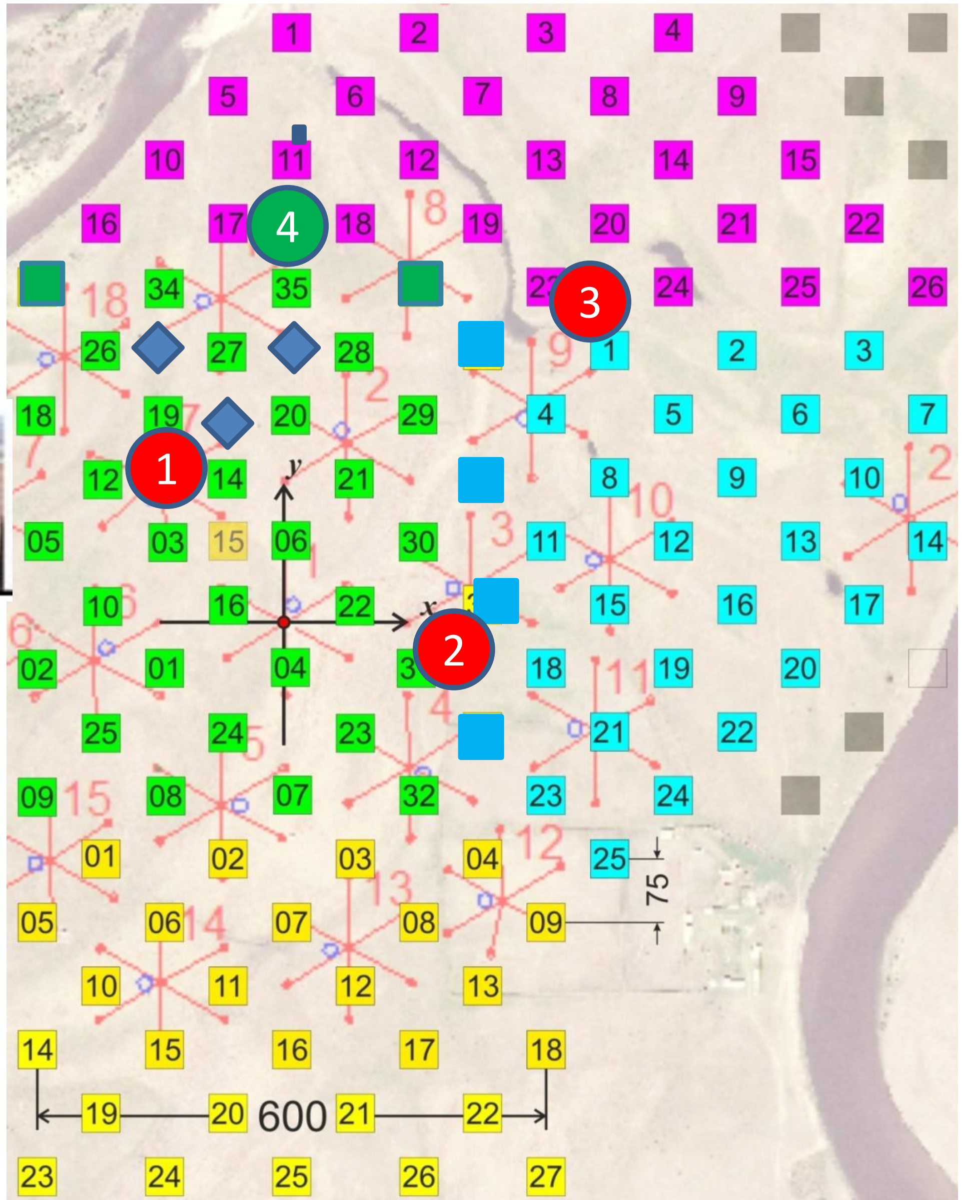
Counter dimension 1x1 m^{2}.

Wavelength shifting bars are used for collection of the scintillation light.

Mean amplitude from cosmic muon is 23.1 p,e, with ±15% variation.



TAIGA -2022

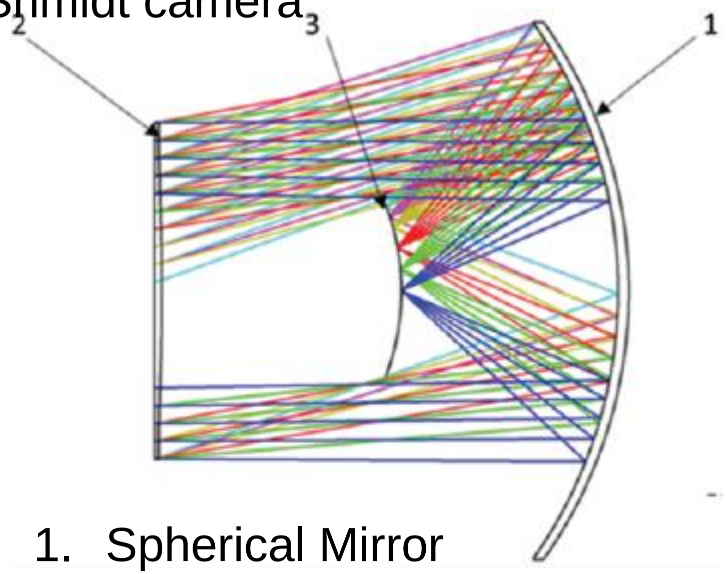


)

Wide-angle telescope on SiPMs

FoV of TAIGA-HiSCORE detectors is 60° but TAIGA-IACT – 10° as a result we have only 4% of joint events.
To study the gamma-ray with energy above 30 TeV we started off a development of a Small Image Telescopes (SIT) with a SiPM-based camera with a FoV up to 60° and an effective recording area of 1m^2. We intend to test 3 variants of the SIT optical system: spherical mirror, a system of Fresnel lenses, combination of the two mentioned technologies

Shmidt camera



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

FOV ~15°

S ~ 1 m^2

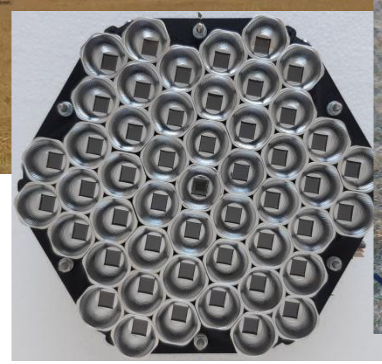
Number of pixels ~ 1000-1200
FOV for one pixel ~ 0.4 °

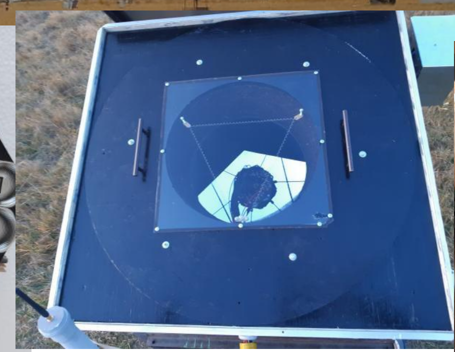
Energy threshold ~ 10 TeV

A compact-size wide Field of View IACT with a SiPM-based camera for energies above 10 TeV.

Prototype SIT (FOV ~ 20°, S ~ 0.1 m^2 , 49 SIPM SensL MicroFC-60035-SMT, 6 ×6 mm^2) was installed in the Tunka Valley for operation together with the TAIGA-HiSCORE array in September 2019.

Prototype SIT

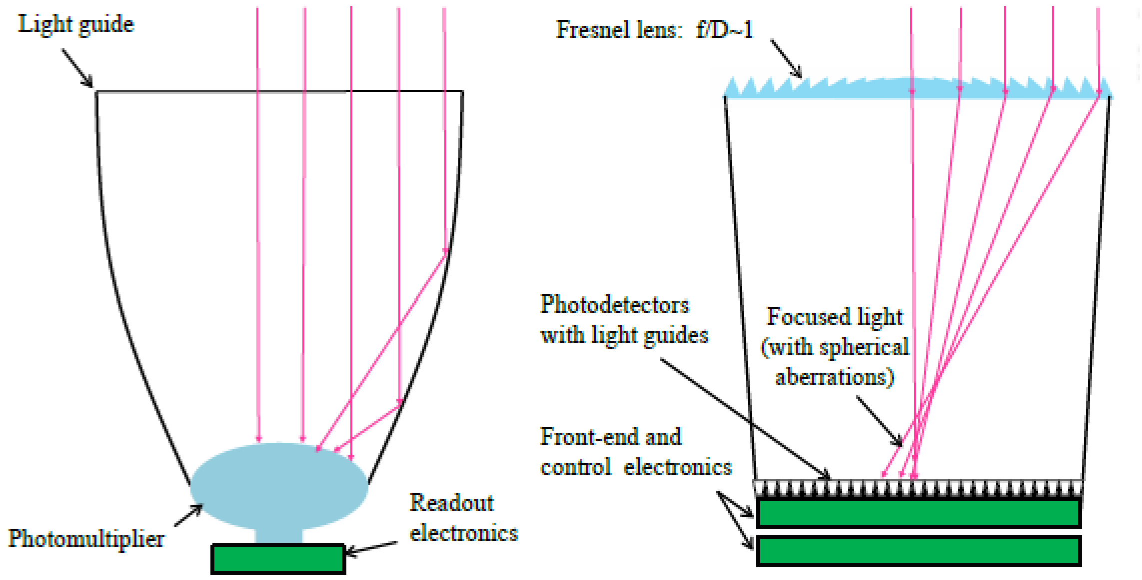




Examples of detected events by the SIT prototype

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)

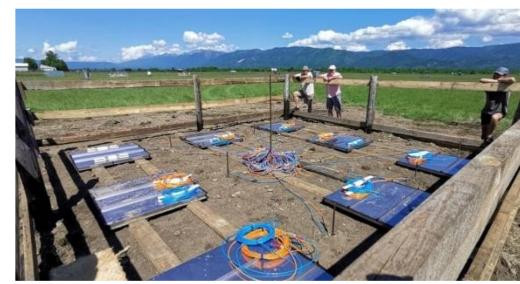
A future 10 square kilometer scale hybrid array for astroparticle physics, gamma-astronomy and cosmic ray physics

A site requirement:
- altitude – 2000 m about,
- no artificial light background,
- good astroclimate,
- enough vacant rather flat space,
- acceptable logistic condition,
- availability of electrical power

Tunka, Altay…..??????????

+

+



TAIGA-HiSCORE - array.
A net of 1000 non imaging wide-angle detectors distributed on area 10 km^2 with spacing 100 m about
An EAS core position, direction and energy reconstruction.

TAIGA-IACT - array
of 12 - 16 IACT with mirrors – 4.3 m diameter.
Charged particles rejection using imaging technique.

TAIGA-Muon array
of scintillation detectors, including underground muon detectors with area -2000 – 3000 m^2
Charged particles rejection

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 will finished at the end of 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
- Detection of gamma-rays from Crab and Mrk-421
- 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 for the attention