TAIGA Astrophysical Complex – status, results, plans

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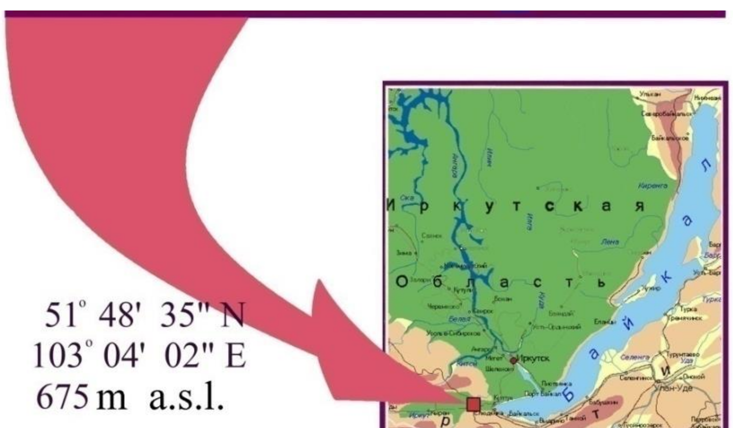
L.Kuzmichev(SINP MSU), for TAIGA collaboration

DLCP 2022, JINR, Dubna

07.06 2022

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

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



The main aim of TAIGA project:

Very high- energy gamma-ray astronomy
(E > 10 TeV)
Cosmic Rays: 10^{14} - 10^{18} eV

TAIGA - collaboration

Germany

participation is frozen

Italy

Turino University (Turino)

Russia

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

Content of the report

1. TAIGA Astrophysical Complex

2. Very high energy Gamma-ray astronomy – scientific and methodic topics

3. The approach for gamma-ray detecting in TAIGA

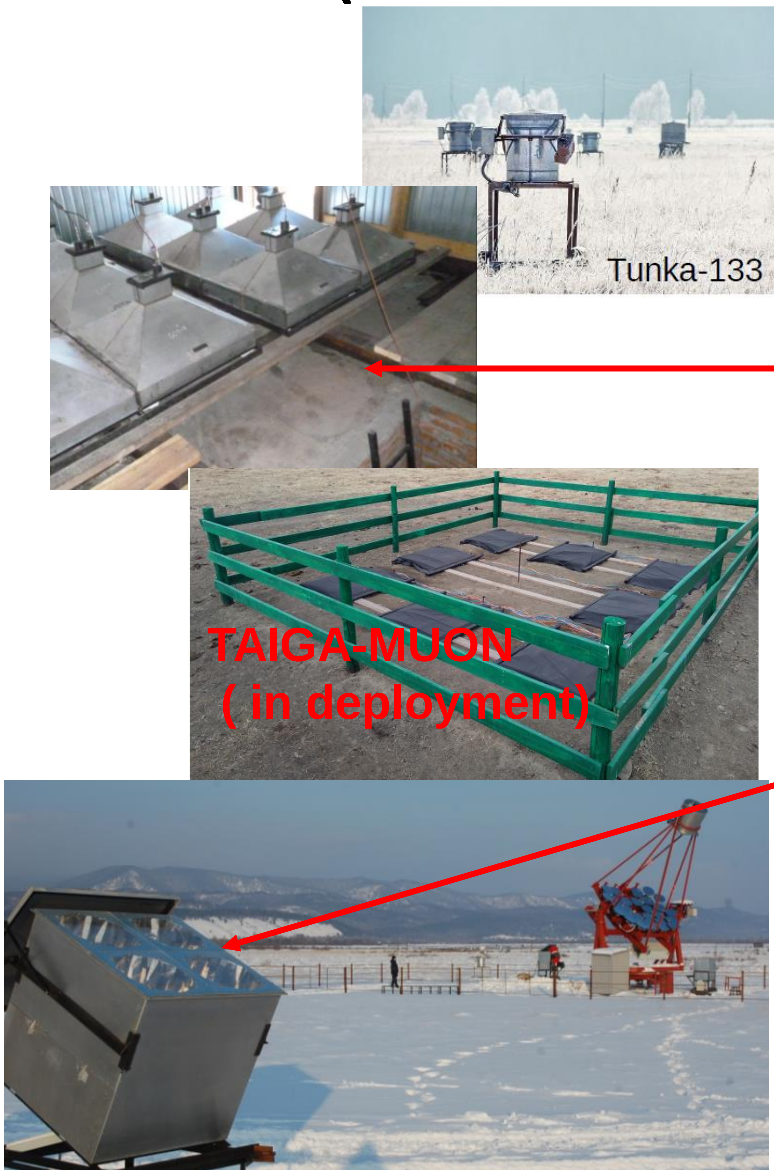
4, The main results

5. Scientific program and plan for 3-5 years

6. Future direction of the experiment

TAIGA Astrophysical Complex

(50 km from the lake Baikal)



Tunka-133 Cherenkov EAS array (2009)
Area – 3 km^2

Tunka-Grande (2015)
Detection of charged particles (electrons, muons)

TAIGA – HiSCORE
(finishing of deployment in 2021)

TAIGA -IACT
IACT – Imaging Atmospheric Cherenkov Telescope

10 ^{18} eV

Cosmic Rays (protons and nuclei)

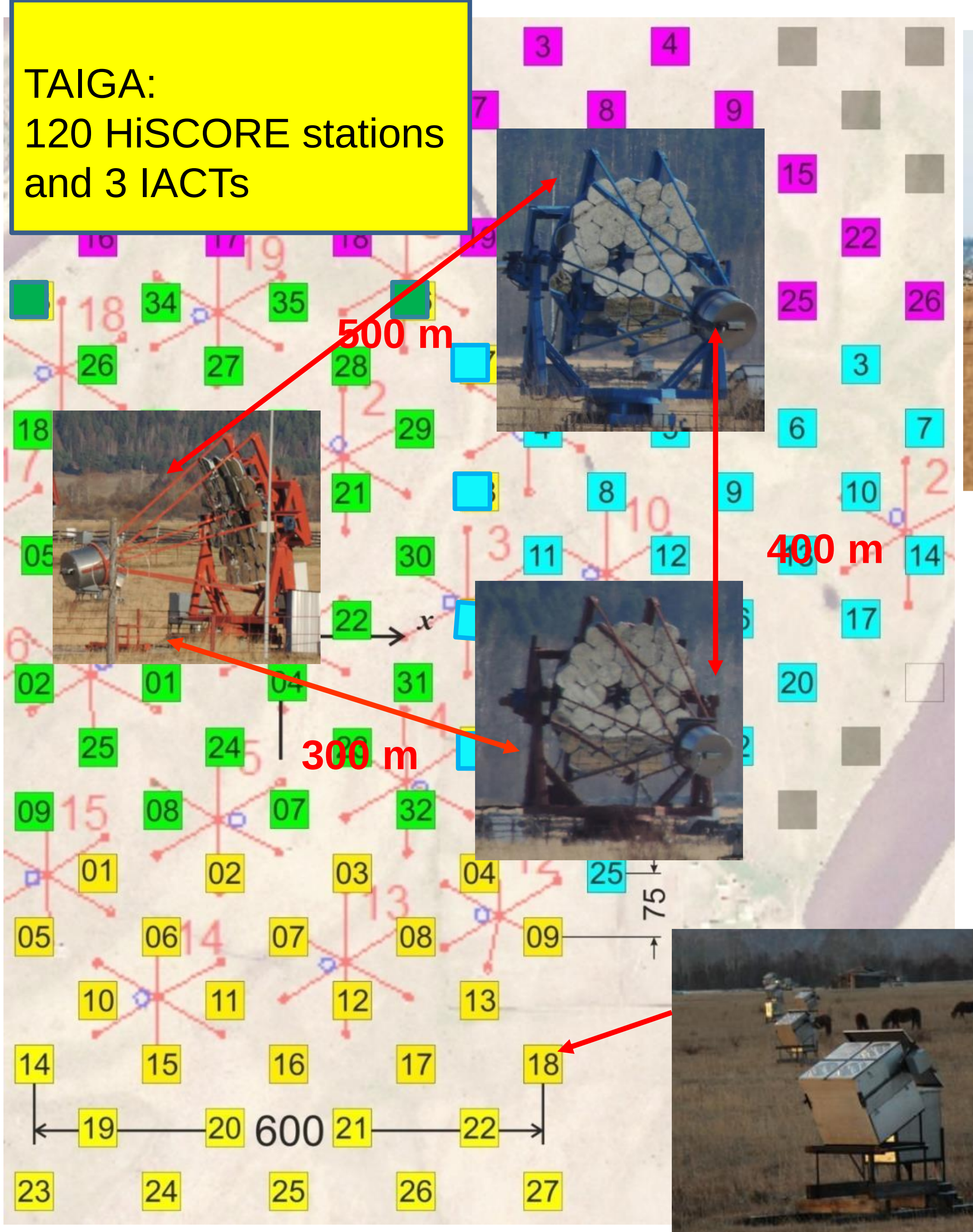
10 ^{14} eV

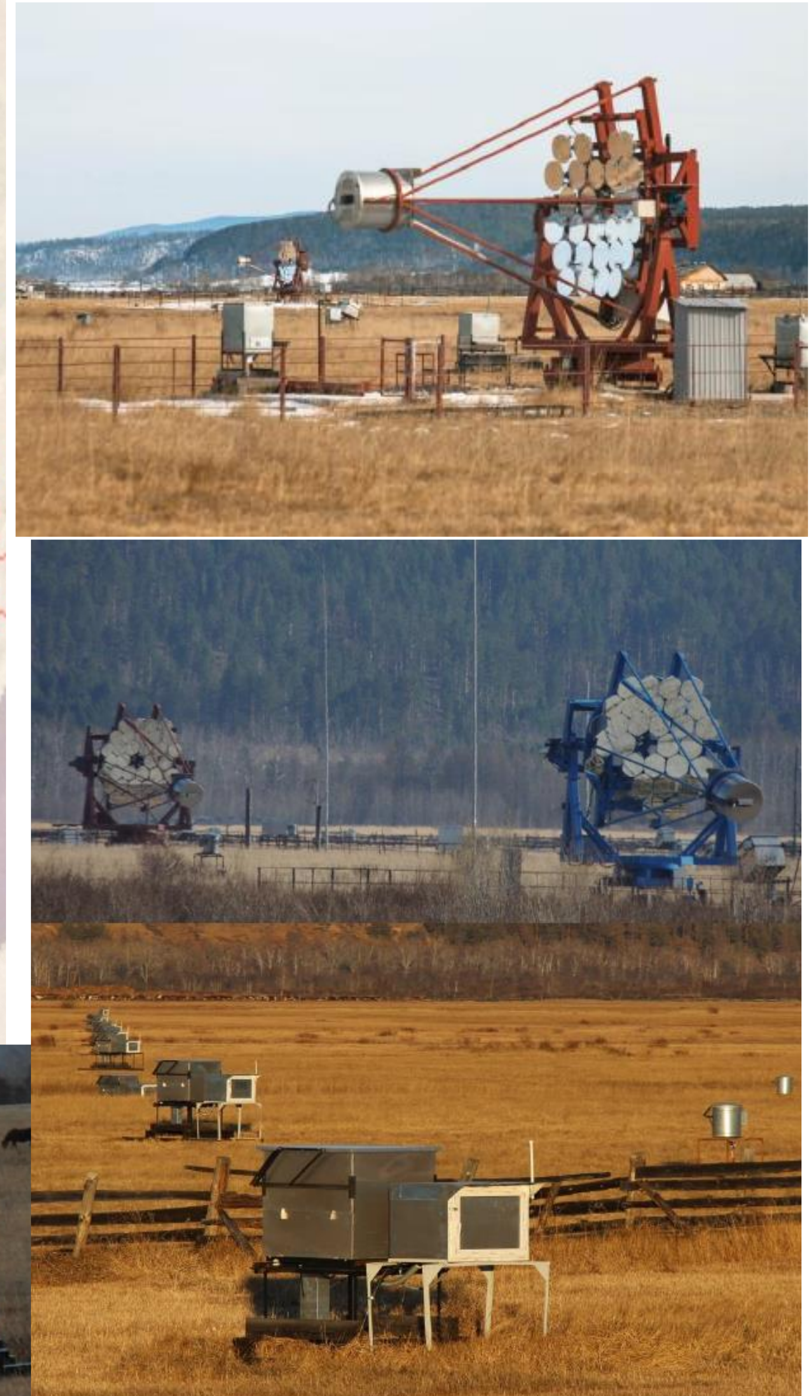
Gamma-ray astronomy

10 ^{12} eV

Installing the camera on the third IACT (April 19, 2022)

TAIGA:
120 HiSCORE stations
and 3 IACTs





TAIGA IACT

Study of angular Cherenkov photon distribution from EAS – image of EAS

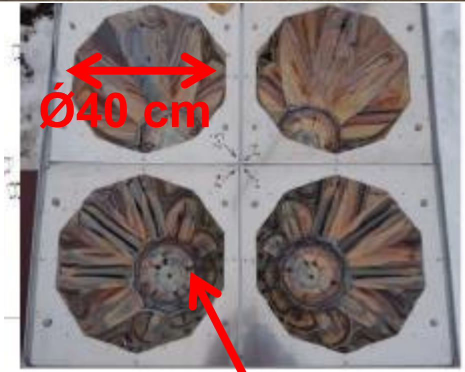
Area of mirrors - 9.6 m^2 (34mirrors)
Focus length 4.75 m
FoV 9.6^o
pixel FoV 0.36°

600 pixels(pmt XP1911 Ø 19 мм)

PSF ~0.1°
CCD for checking telescope pointing direction.

Large camera FoV is an opportunity
detection of EAS from long distances (up to 500 m)

TAIGA- HiSCORE (FoV ~60°)



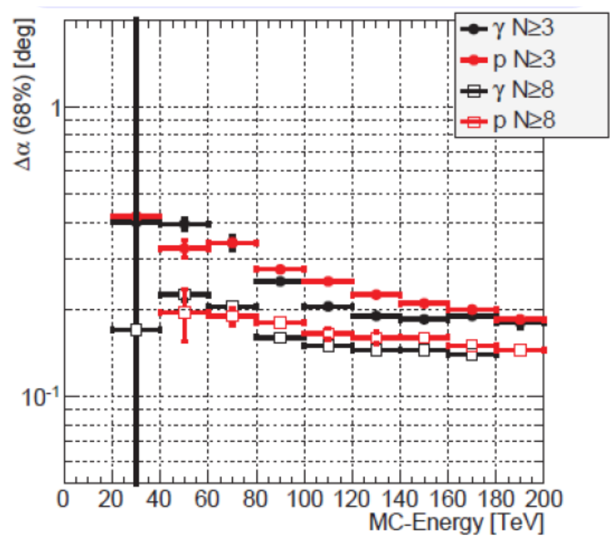
S tot = 0.5 m²

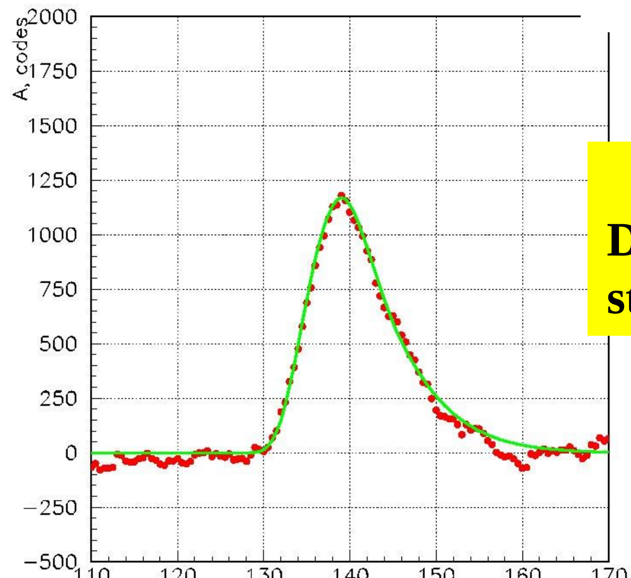
Winston cone and PMT with 20-25 cm photocathode diameter

Network of 120 stations (step 106 m)
Reconstruction of the EAS arrival direction
0.4- 0.15 degrees

Energy
30% – 15%

Angular resolution





Digitization of signal by DRS4 board with 0.5 ns step

Very high energy gamma-ray astronomy

1. Origin of Cosmic rays

2. Relativistic jets and AGN

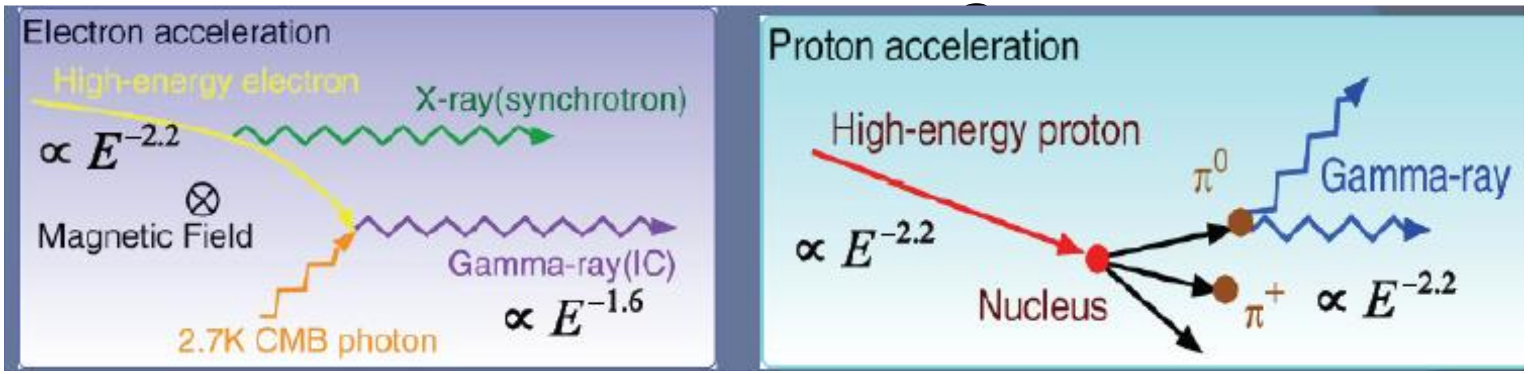
3. Search for Dark matter

4. Transparency of the Universe and axions

Pulsar Wind Nebular (PWN) – electron acceleration - Crab nebular

Supernova remnants (SNR) – proton acceleration - SNR Tycho, CTA-1, SNR1006

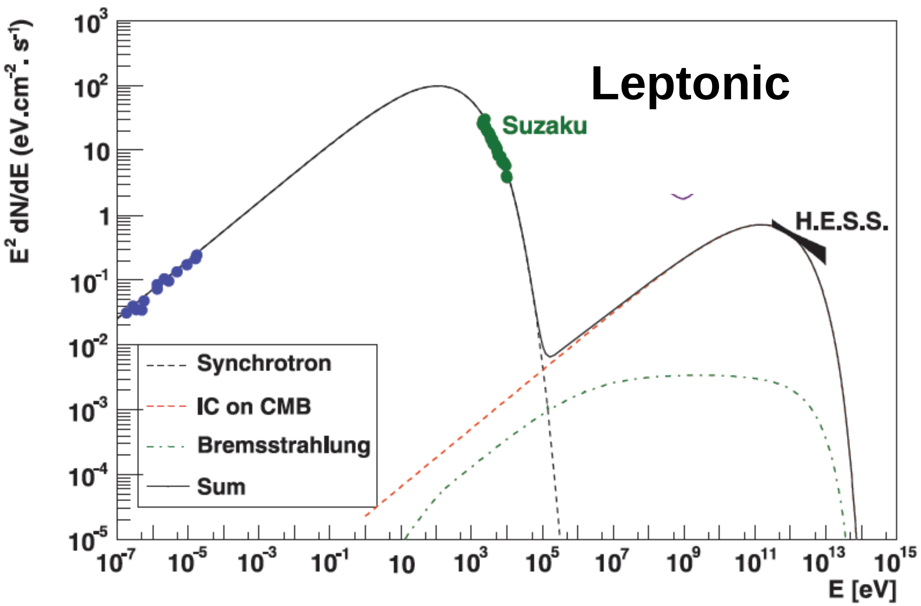
What is the mechanism for gamma-rays generation

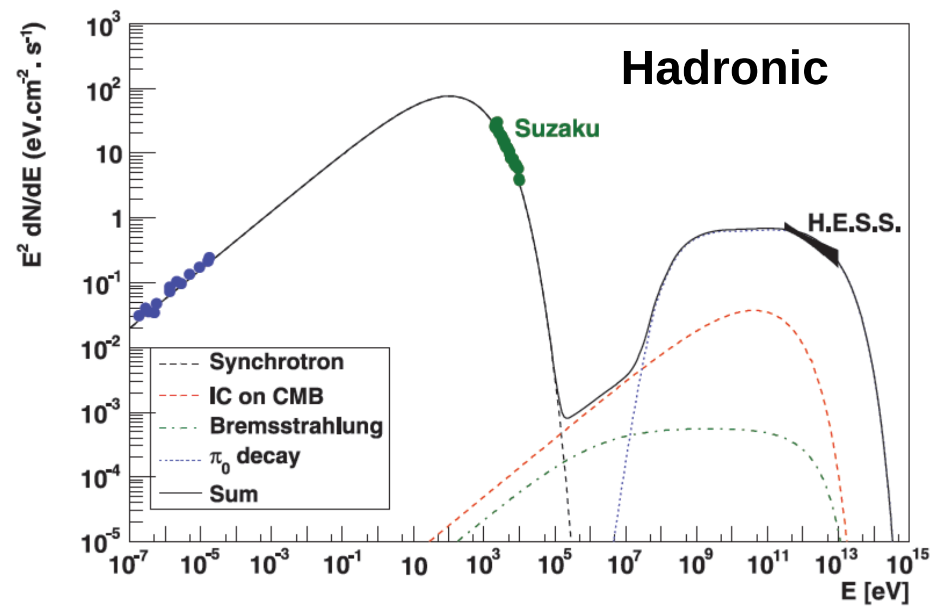


Leptonic

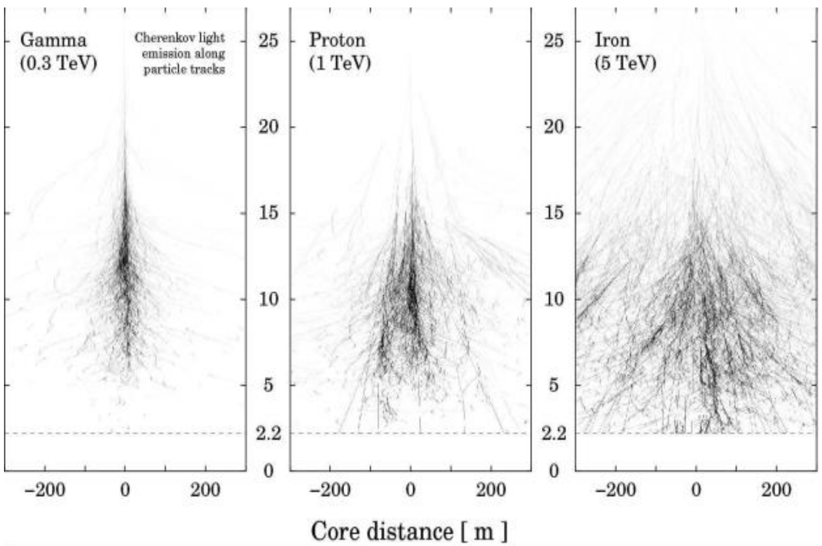
Hadronic

SNR 1006 : To understand of gamma-ray generation we should study the edge of the energy spectrum





The main methodic task: how to separate the EAS from gamma-rays from the EAS from cosmic rays



Three approaches;

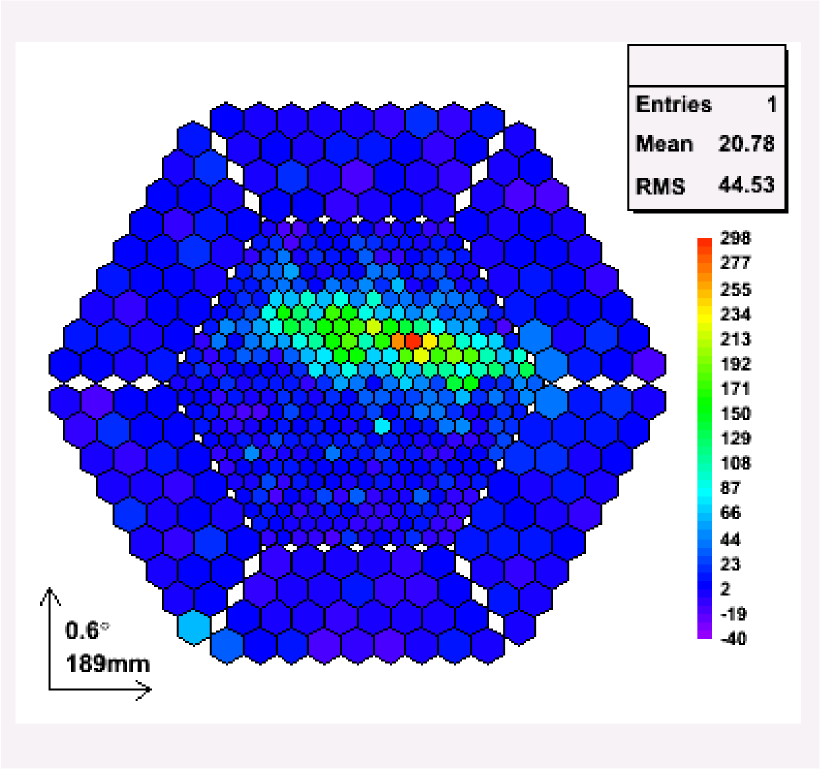
1. By angular distribution of Cherenkov photon from EAS
   All IACT observatories)

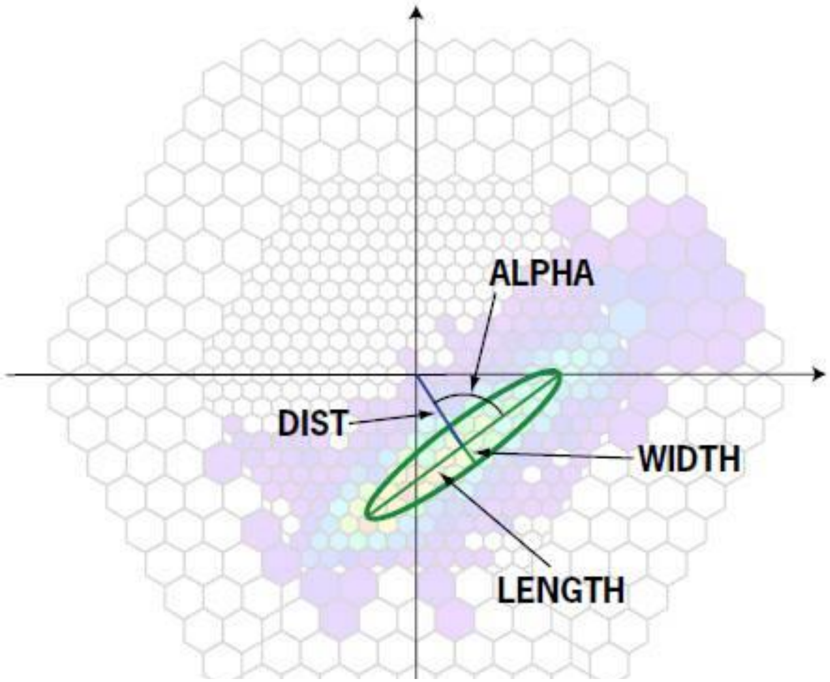
2. By the Lateral distribution of charged particles.
   HAWC array in Mexico

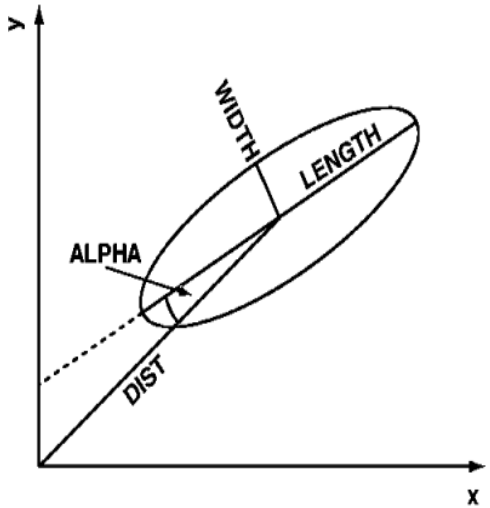
3. By the number of muons in EAS
   LHAASO array in Tibet

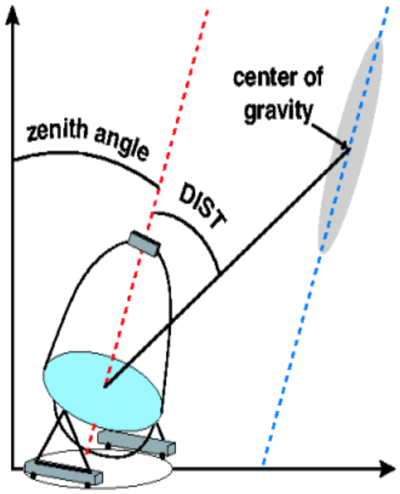
HAWC and LHAASO placed on 4300 m usl

Image of EAS in IACT and Hillas parameters



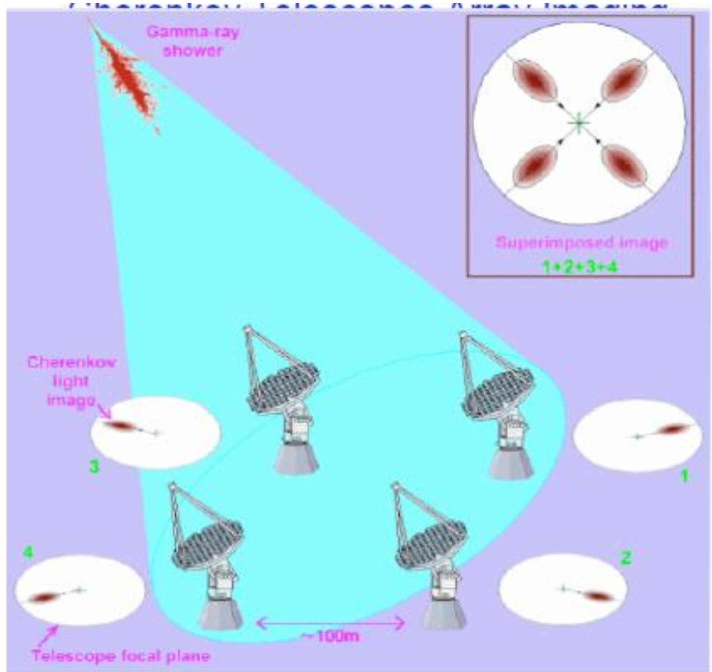


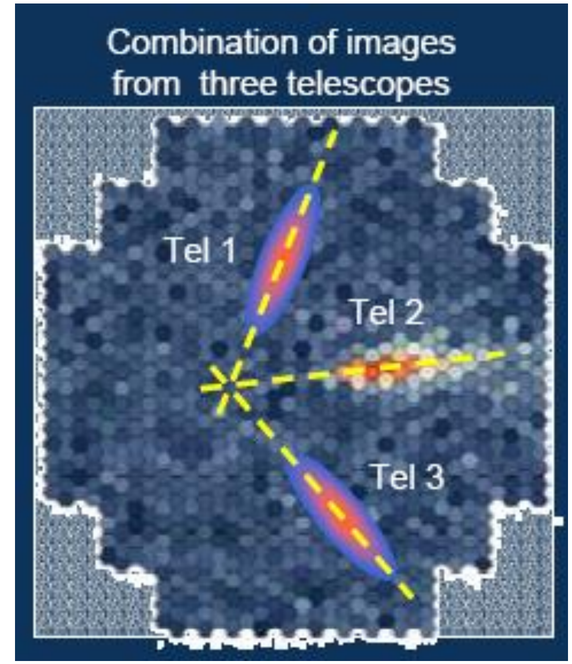




Imaging Atmospheric Cherenkov Arrays (2-5 IACT)

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

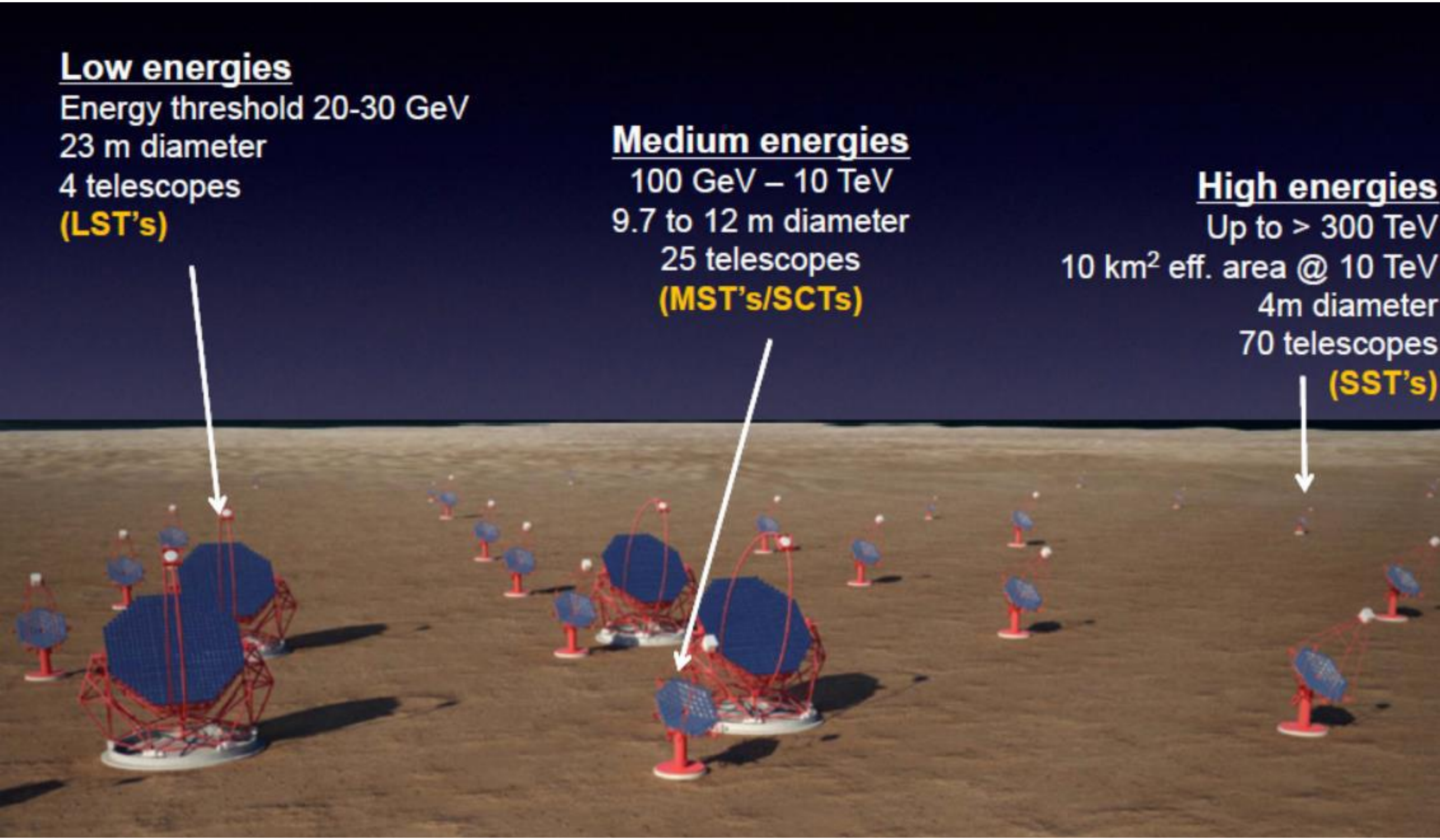




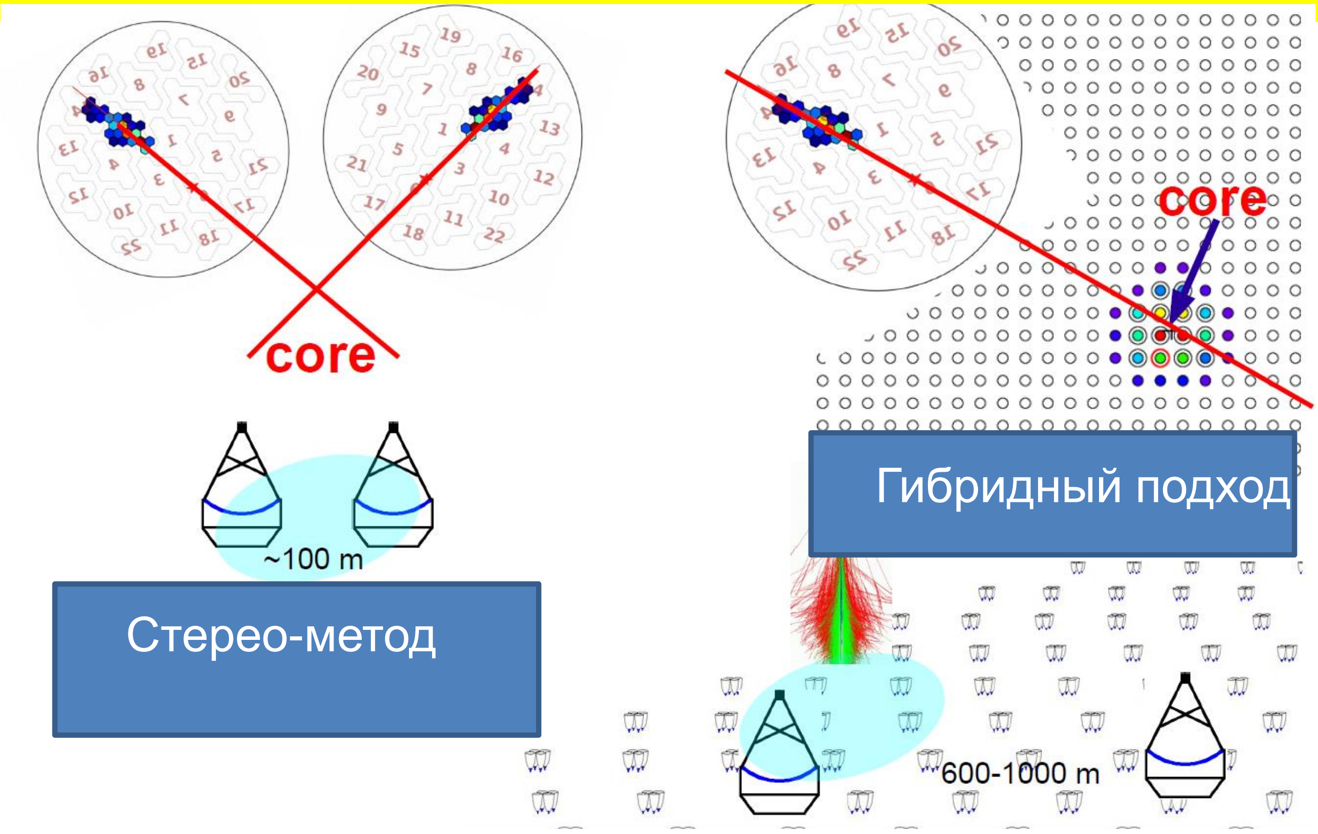
The main method of gamma-ray selection is using stereoscopic method – detection of one EAS by two and a large number of IACTs

To study the area of gamma-ray energies above 100 TeV, installations with an area of ~ 10 km^2 are needed

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



The approach for gamma-ray detecting in TAIGA

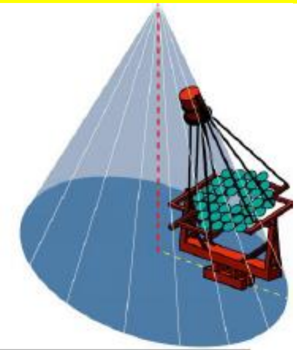


CTA - a lot of expensive telescopes per unit area

TAIGA –few expensive telescopes and a lot of cheap wide-angle stations – a cheaper approach to reach large area installation

Three method for gamma-ray detection for TAIGA

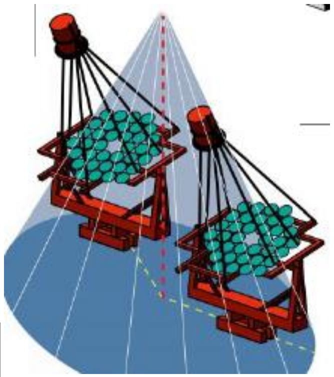
1. Stand –alone mode of telescope operation
   E >2 TeV



Mono mode
E > 2 ТэВ

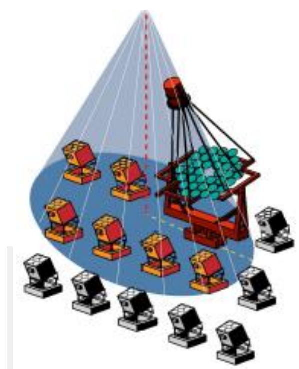
2. Stereo-mode for large distance between telescopes

   E ≥ 8TeV



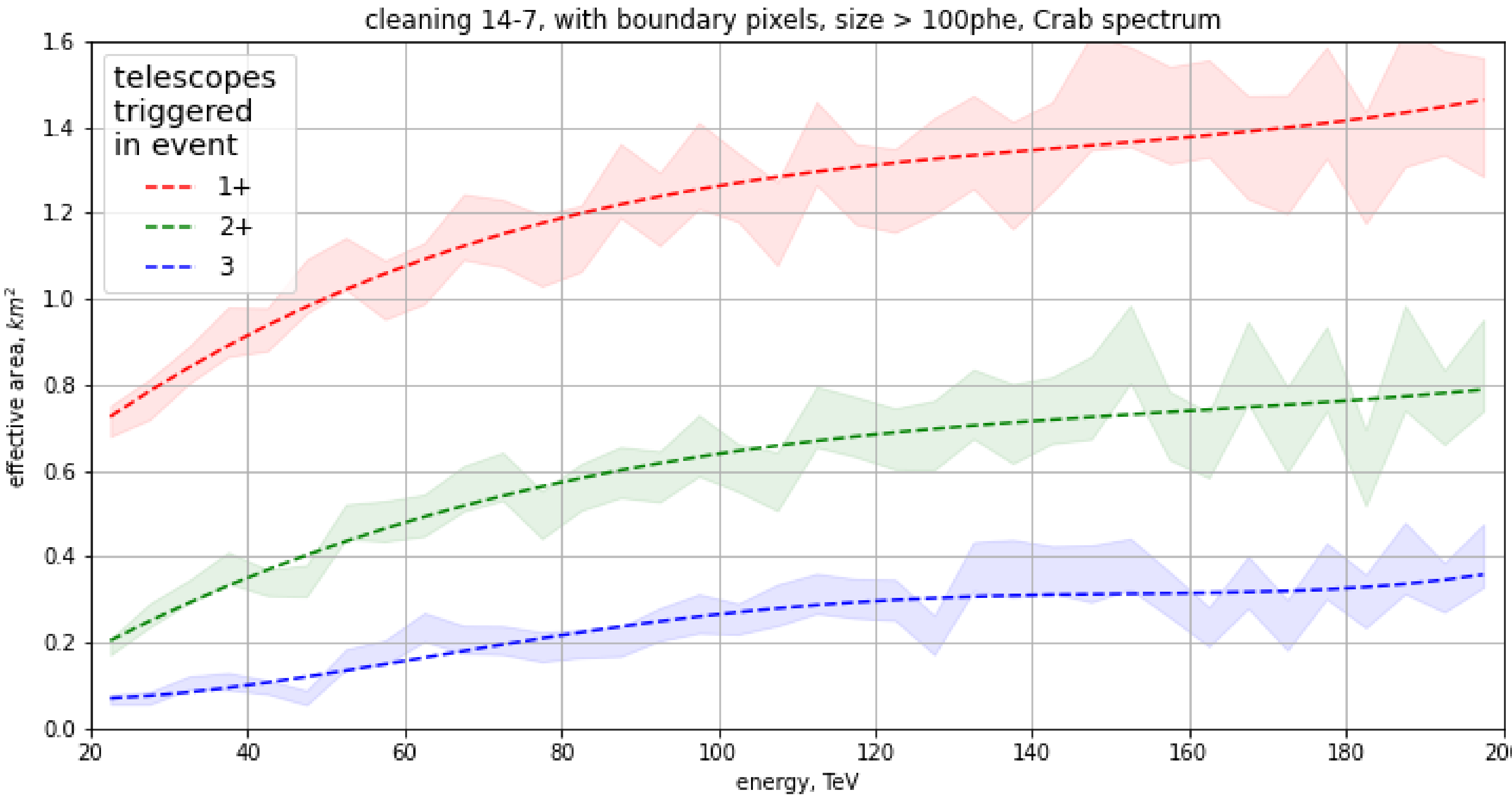
Stereo mode
E > 8 ТэВ

3. Hybrid approach – common operation of HiSCORE and telescopes
   E ≥ 40 TeV

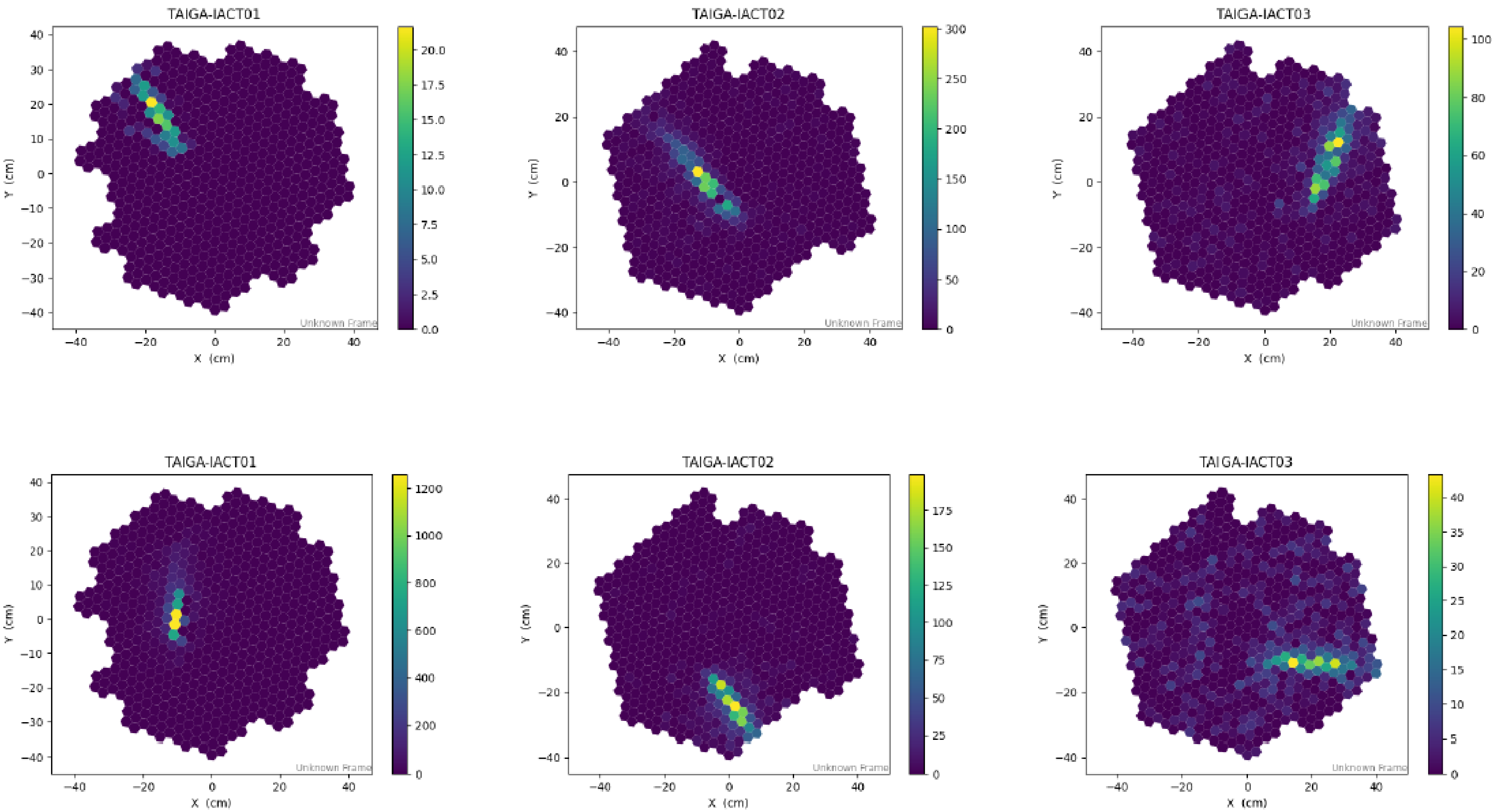


Hybrid mode
E > 40 ТэВ

Effective area of IACTs system

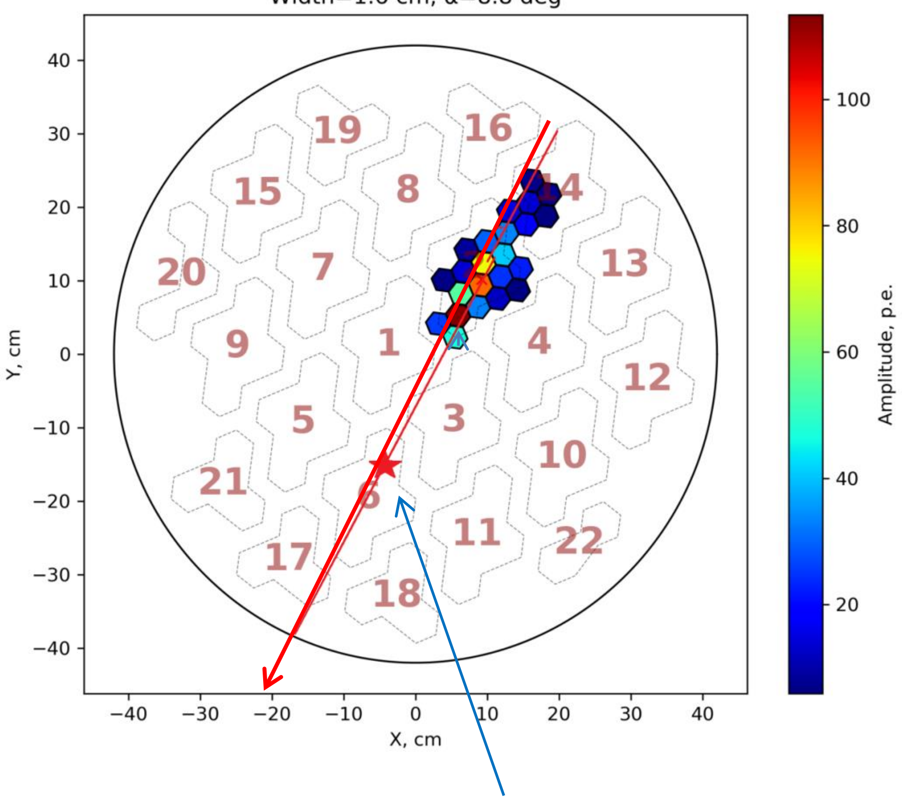


Stereo events.
Images in all 3 IACTs from one EAS



Example of hybrid gamma-like event

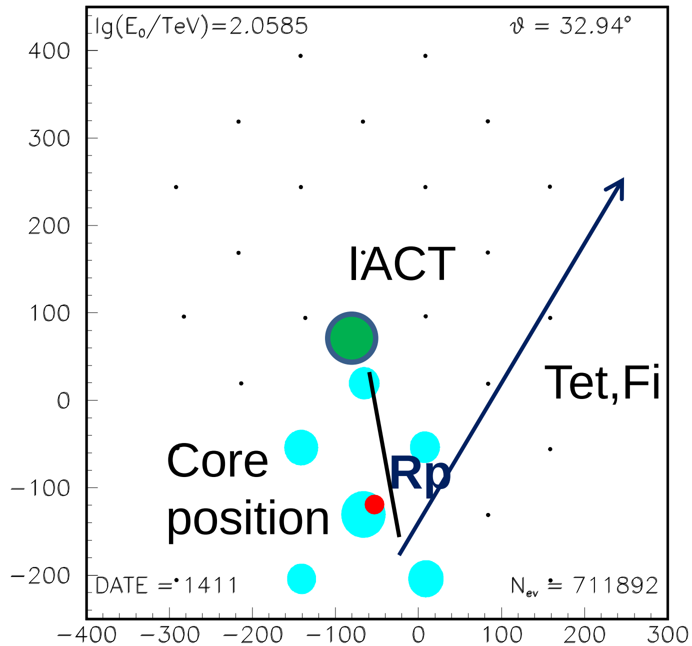
Width=0.13°, length=0.69°, alpha=8.9°, size=709p.e.



HiSCORE data

E = 55 TeV

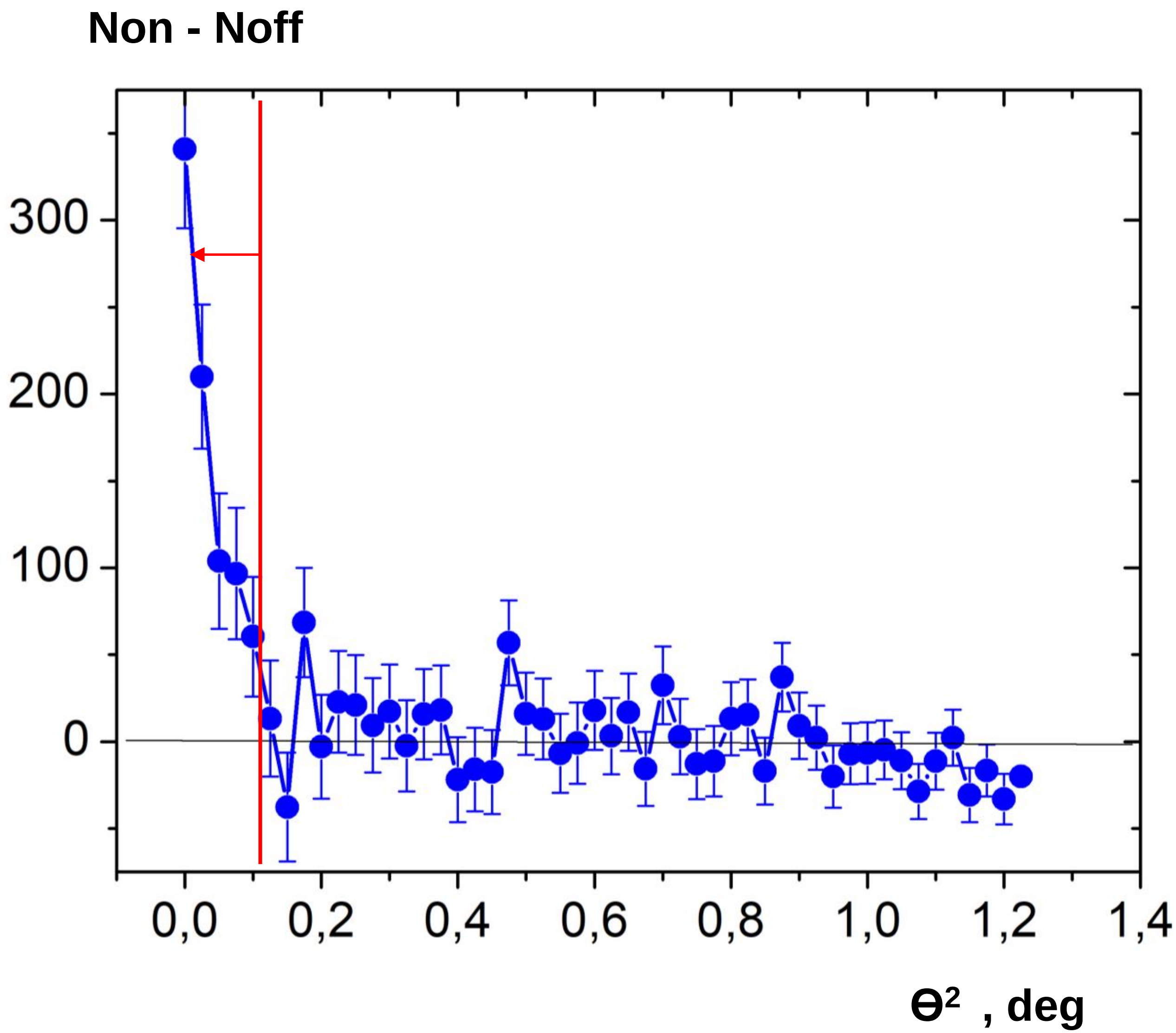
Tet = 32.9, Fi = 33. 58



IACT data

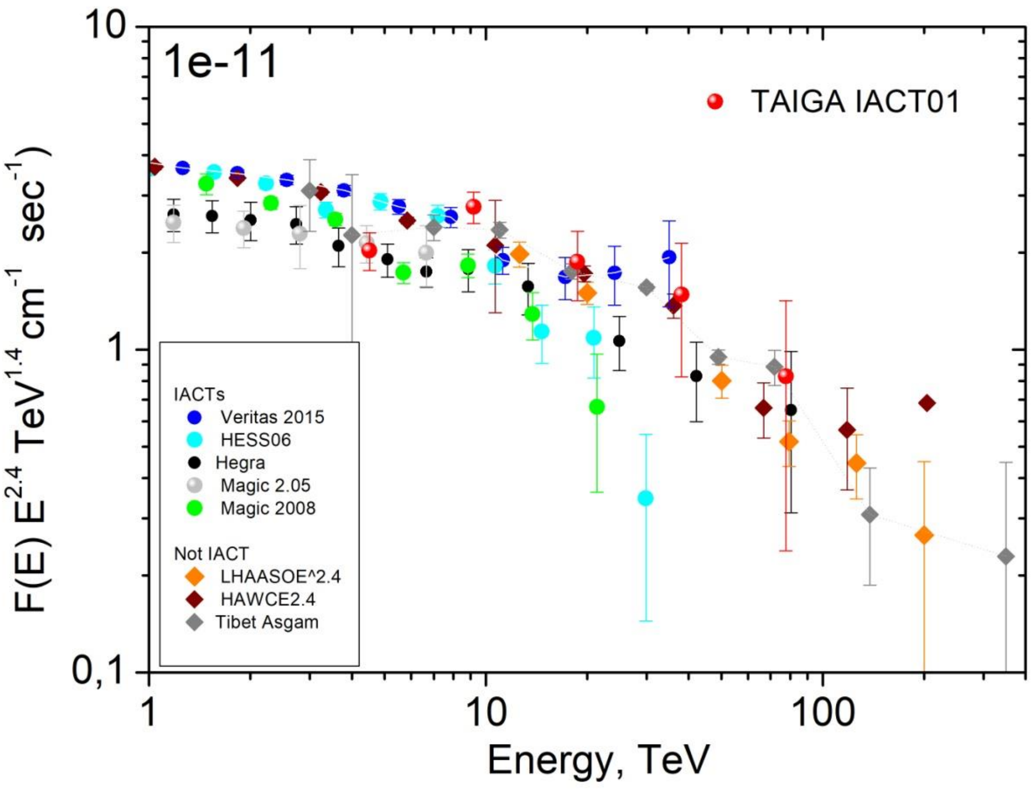
TAIGA some new results

Gamma-rays from Crab (150 h)



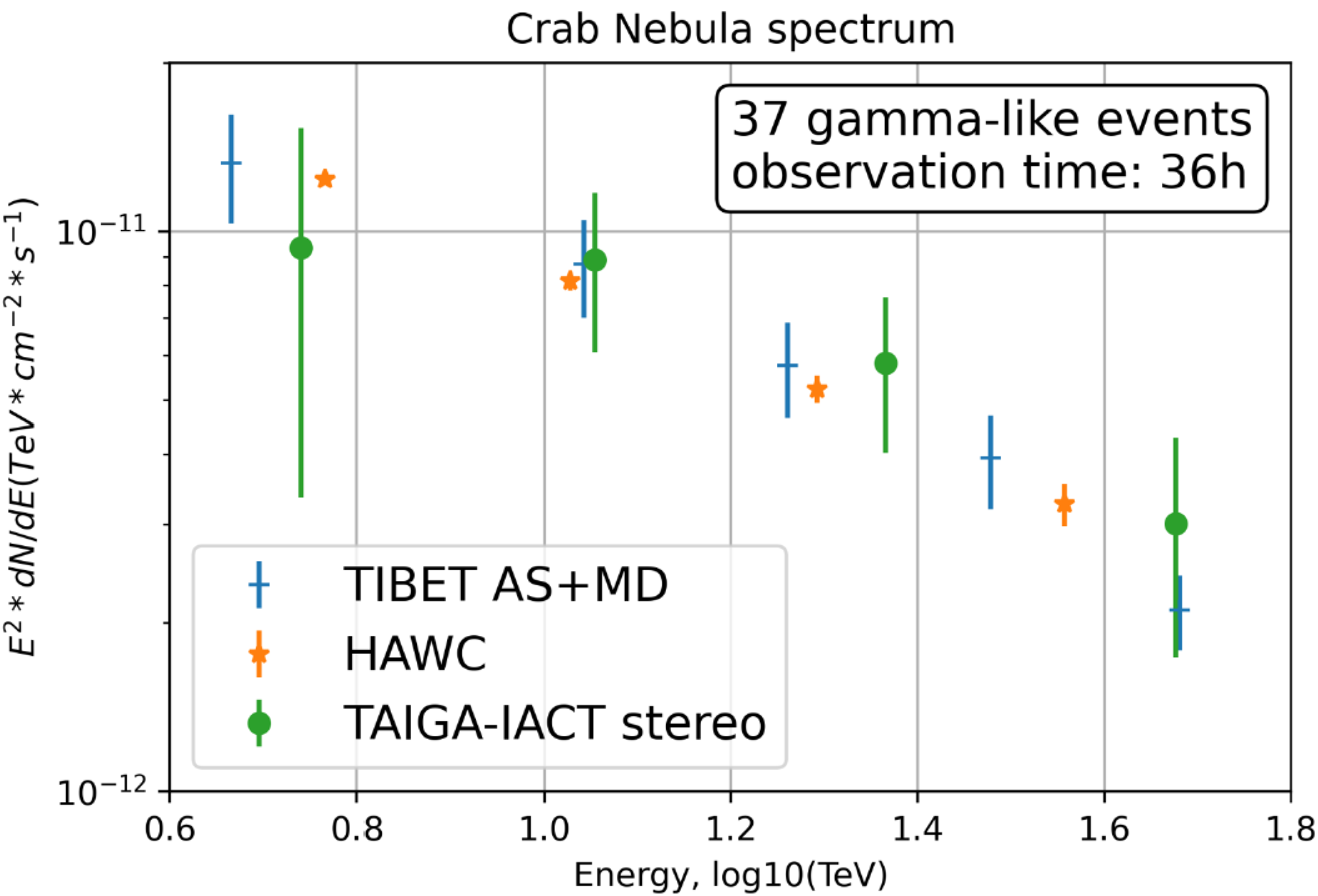
618 events
12.6 sigma

Energy spectrum from Crab by the date of the IACT-1



Gamma-ray spectrum from the Crab according to the 1st telescope
For 150 hours of observation.

Energy spectrum from Crab Nebular (stero-method)



Program for 4-5 year

The TAIGA will be the northernmost gamma-ray observatory, and this location provides certain advantages for observing sources with large declinations - the source of gamma rays in SNR Tycho. CTA-1, will be in the field of view of the TAIGA for 500 hours per one year

1. Study of the energy spectrum of gamma-rays from galactic sources
PWN :Crab Nebular, Dragonfly
SNR: J2227+610 (G106.3+2.7), J2031 +415 (Cygnus Cocoon), я
SNR Tycho, CTA-1

2. Search for new sources of gamma quanta, search for gamma-rays associated with high-energy neutrinos and gamma-ray bursts (GRB)

3. Search for high-energy gamma quanta from in OB associations. Possible gamma-ray bursts from binary (pulsar + massive star) stars.

Program (continuation)

4. Long-term monitoring and investigation of the edge of the energy spectrum of bright bazaars (Mrk-421, Mrk-501, etc.) as a method of searching for anomalies in the propagation of gamma-rays in the Universe and searching for axion-like particles.

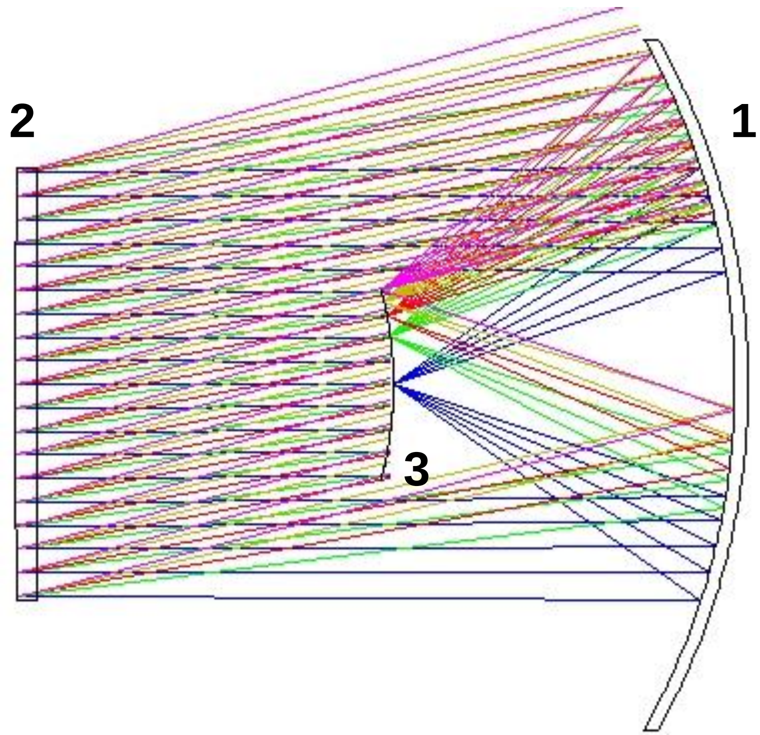
5. Investigation of the spectrum and mass composition of cosmic rays in the range of 100-1000 TeV using gamma-ray astronomy methods

6. Continue study on the CR mass composition at ultrahigh energies (Tunka-133, Tunka-Grande)

7.. Search for nanosecond optical transients using the HiSCORE setup (FoV = 60°) and a telescope system. The "discovery" of the signal from the ISS and the Calypso satellite.

Wide angle small Cherenkov imaging telescope on SiPMs (SIT)

Shmidt camera



FOV ~30°

S ~ 0.5 m^2

Number of pixels ~ 400
FOV for one pixel ~ 1 °

Energy threshold ~ 30 TeV

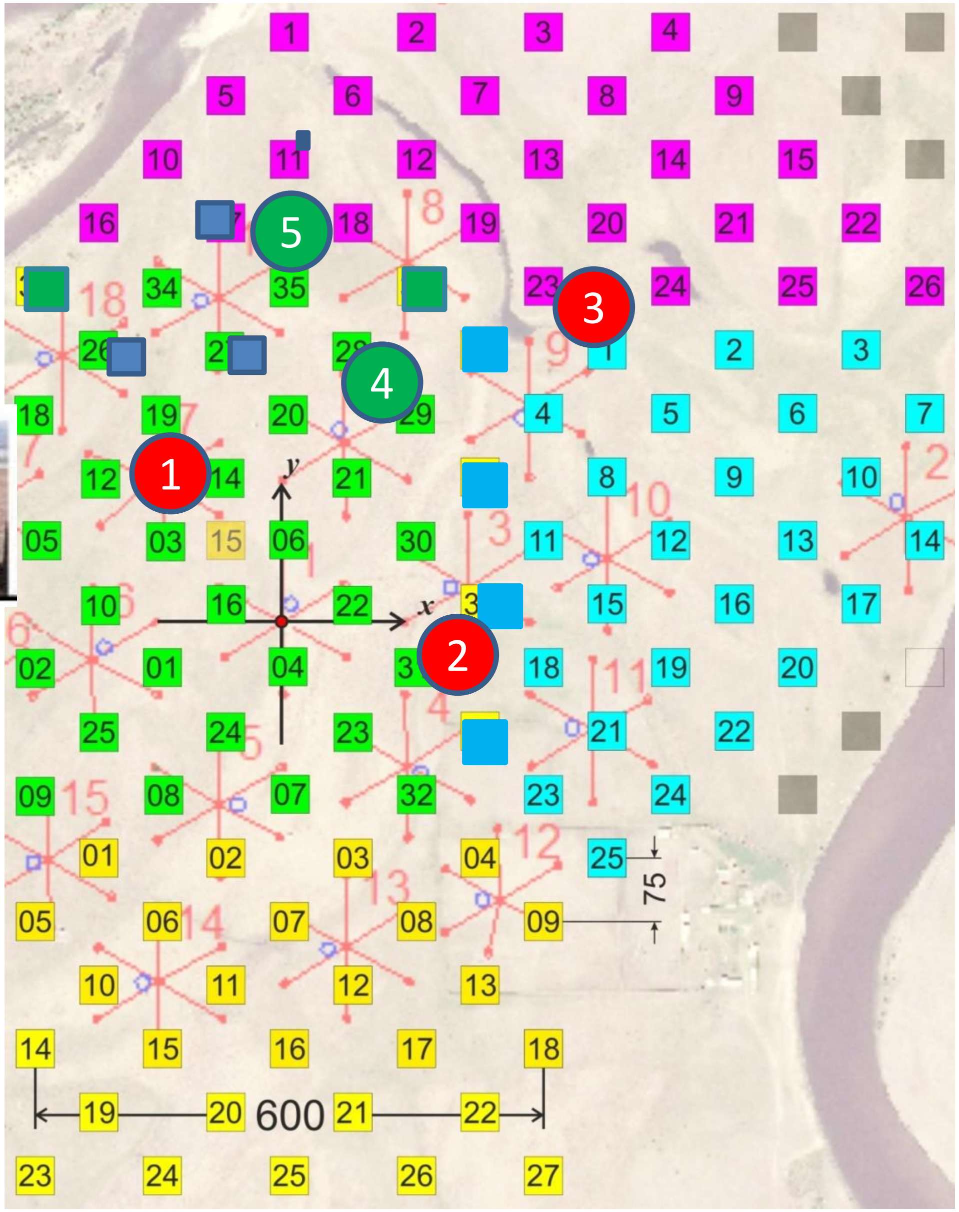
F=1.5 m

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

SIT prototype

Hadron rejection
in 10 times

TAIGA -2022-24



2 new IACTs

SIT

We have a problem with PMT
For new IACT/
Plan to use PMT of MELZ
production after
modernization

TAIGA-10, 10 km^2

Energy range 50 TeV – 1PeV

1. 1000 c HiSCORE station

2. 100 small IACTs (SIT)

3. 5-10 IACTs

200 gamma from Crab with energy > 100 TeV 100 hours
4 sigma with hadron rejection only by angle.

10 sigma for additional rejection by SIT

Thank you