Development of the detectors and conducting experiments with Tunka-Grande and TAIGA-Muon scintillation detectors arrays

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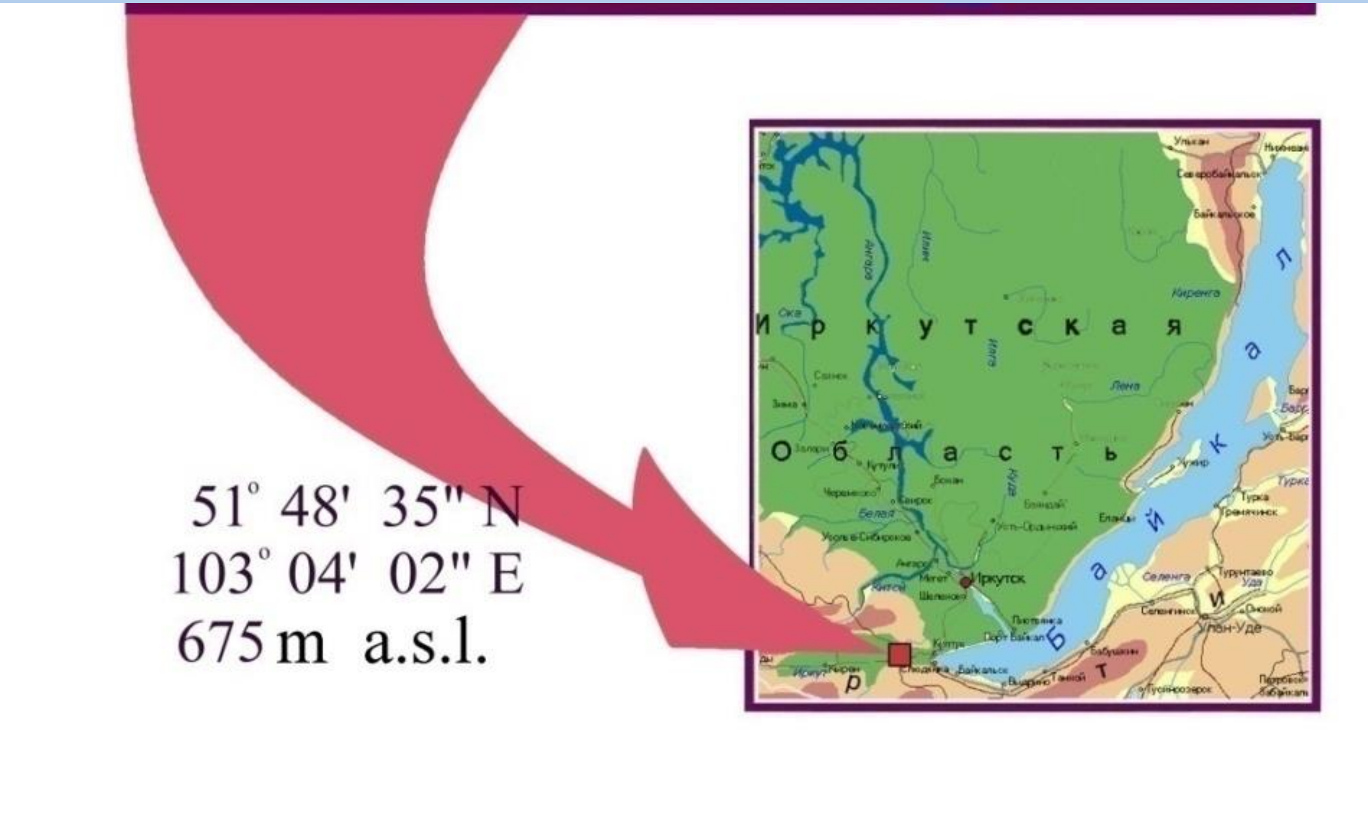
TAIGA (Tunka Advanced Instrument for cosmic rays and Gamma - Astronomy)

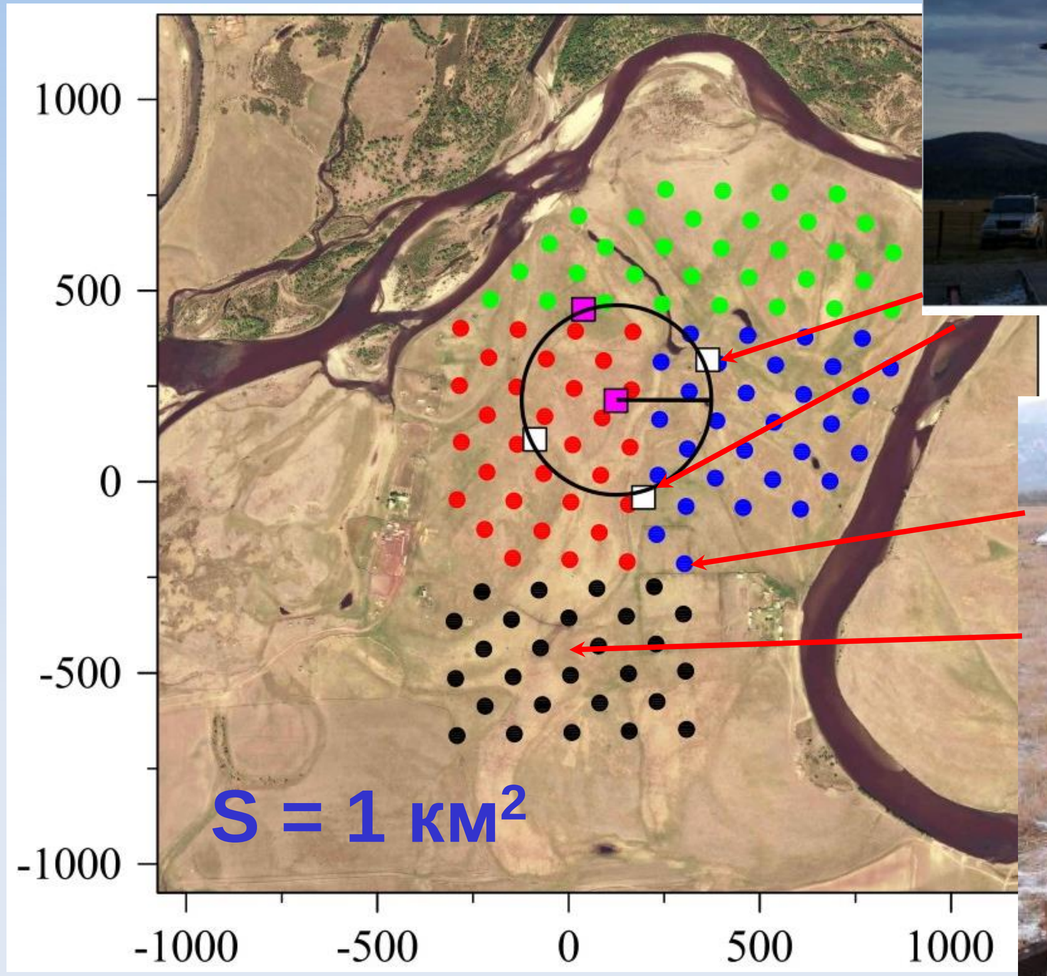


The Taiga experiment is one of the largest astroparticle experiments in Russia, located in the Tunka valley (Republic of Buryatia),~50 km east of the southern part of Lake Baikal.

Experimental program.

- Astronomy:
  - ✓ search for optical transients (including the SETI - Search for Extra Terrestrial Intelligence project)
- Gamma-ray astronomy:
  - ✓search for PeVatrons
  - ✓exploration of the high-energy end of the spectrum of known sources (where do they end?)
  - ✓multichannel (multimessenger) astronomy (registration of joint events with neutrinos, gravitational waves, etc.)
  - ✓search for diffuse radiation
- Cosmic rays (1014-1018 eV):
  - ✓ energy spectrum and mass composition of cosmic rays
- Particle physics:
  - ✓ axion-photon conversion
  - ✓ search for violations of Lorentz invariance

TAIGA Cherenkov light detectors



IACT

HiSCORE

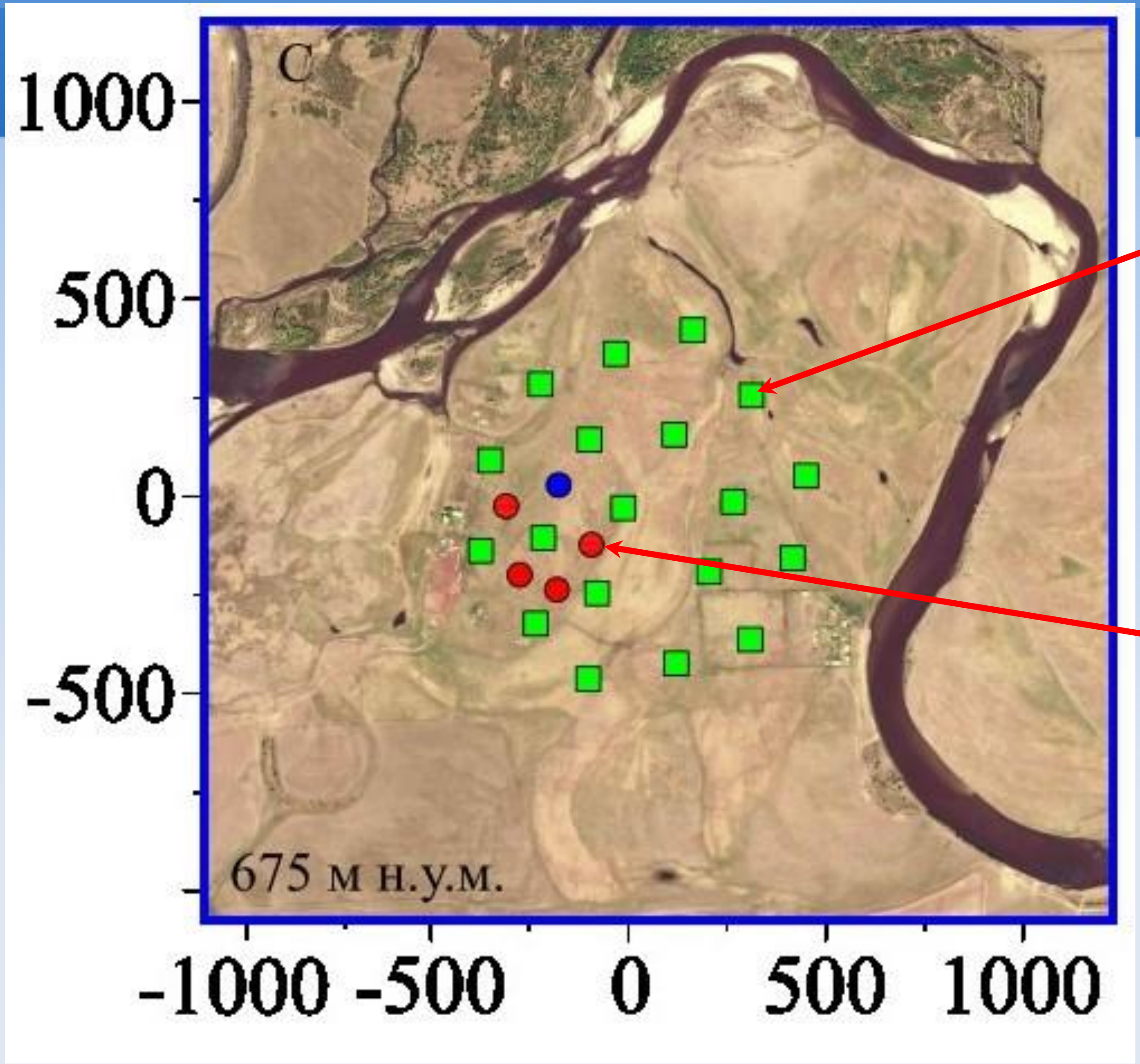
A specific feature of the Taiga experiment is the simultaneous use of different detector techniques to detect extensive air showers (EAS):

- ~120 wide angle Cherenkov light detectors HiSCORE
- 3(+2) Imaging Atmospheric Cherenkov Telescopes
- 380 scintillation counters with S = 0.64 m^2 (Tunka-GRANDE) and 52(+148) scintillation counters with S = 1 m^2 (TAIGA-muon)

Cherenkov detectors give fast signal, thus making it possible to reconstruct the incoming direction of the primary cosmic particle with high precision. Also Cherenkov detectors provide information about the number of fast secondary charged particles in the shower and the shape of the shower at high altitudes.

Scintillation detectors provide information about the number of charged particles and the number of muons in the EAS at the ground level.

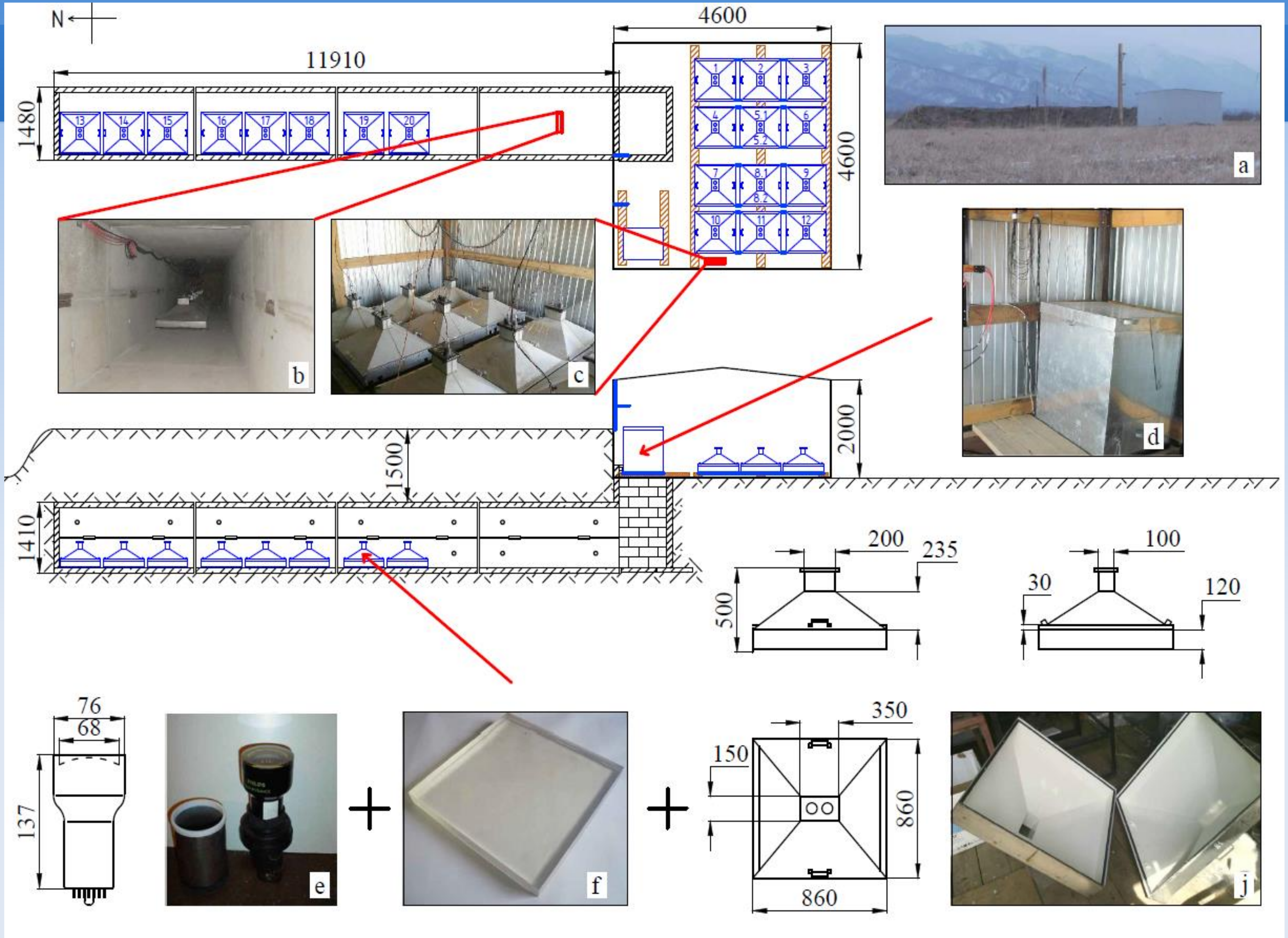
TAIGA scintillation detectors



Tunka-Grande scintillators

TAIGA-Muon scintillators

Tunka-GRANDE



- In operation since 2015.
- Uses refurbished counters from Kascade-GRANDE experiment.
- 19 stations
- each station has 12 surface + 8 underground detectors
- $S_{det} = 0.64\ m^2$
- The energy range of Tunka-Grande array is 10^{16}–10^{18} eV

Development and production of scintillation detectors for the TAIGA experiment.

The principle of detection and separation of EASs initiated by protons or gamma-quanta at energies > 100TeV:

- in a hadron shower the number of muons is 30 times greater than in an electromagnetic shower → muons are weakly absorbed in matter → place counters underground to detect muons
- estimates show that for reliable separation of EAS it is necessary to cover at least 0.2% of the experiment area → about 2000 m^2 detection area needed for 1 km^2 of TAIGA

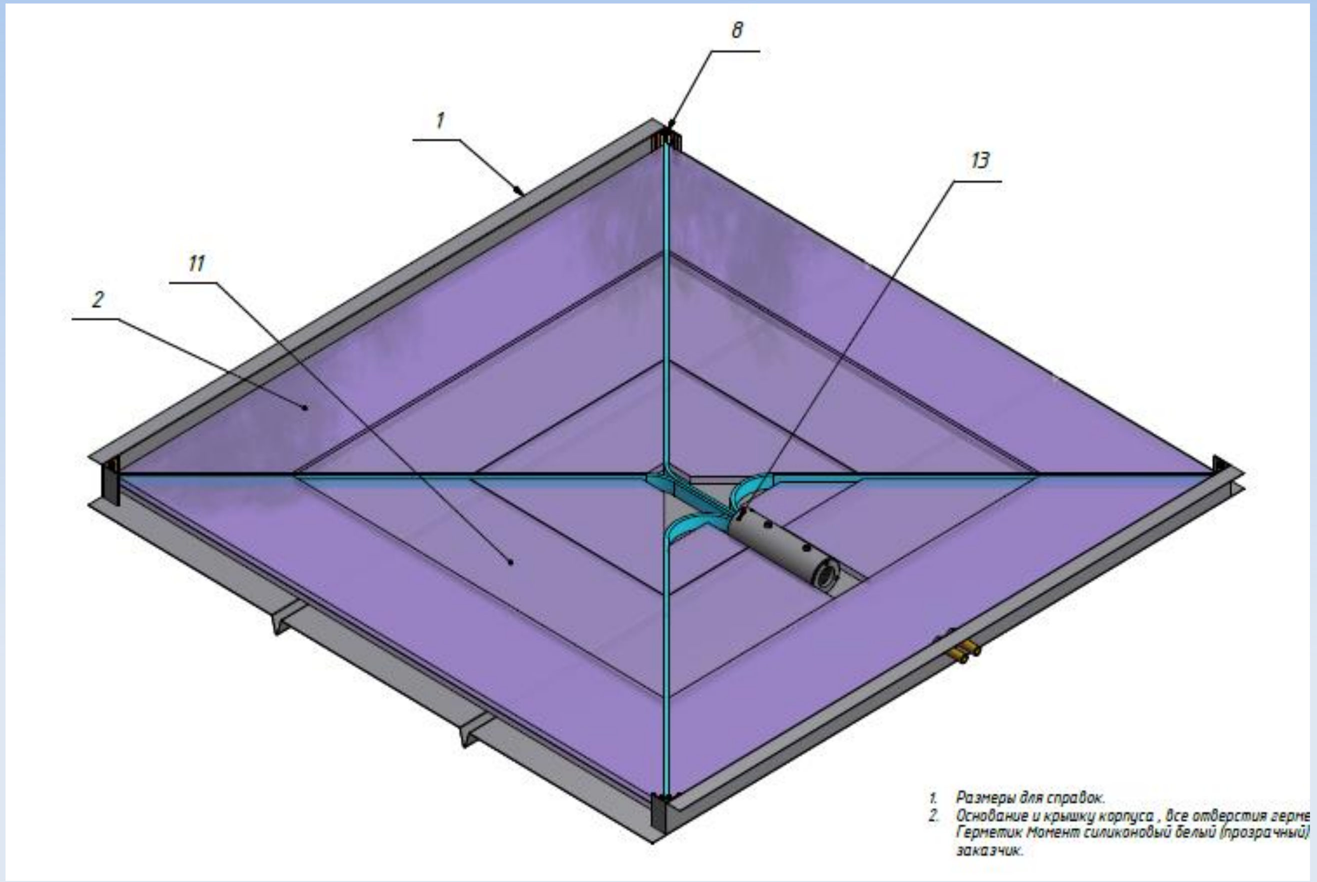
We need a detector with an area of ~1 m^2, inexpensive, sealed, capable of operating at temperatures from -40 to +40 °C, which can be buried in the ground to a depth of 1.5-2.0 m (groundwater!).

TAIGA-Muon detector design (1)

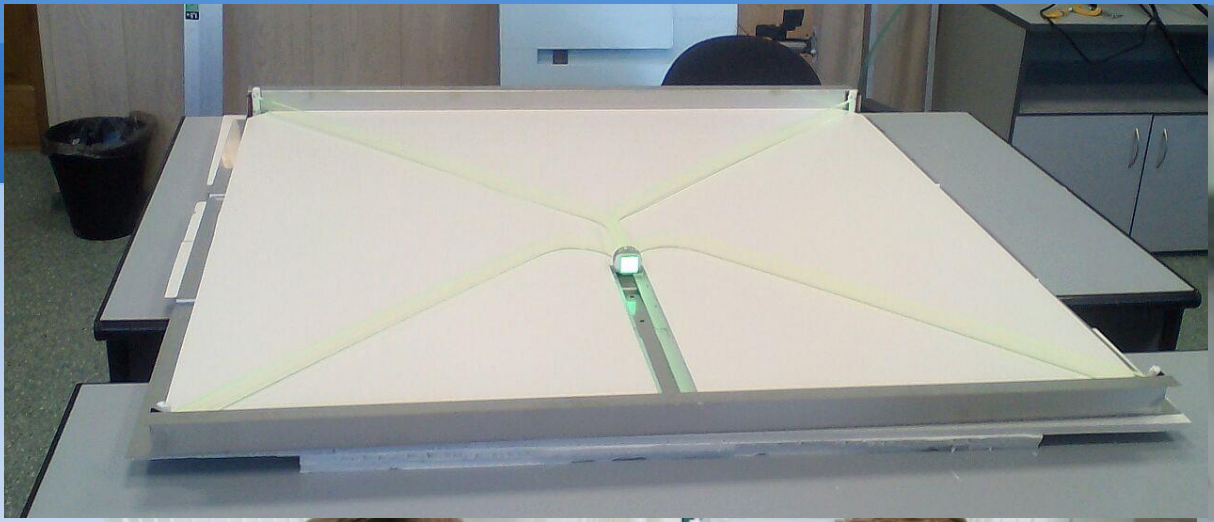
The designing concept of ASHIPH aerogel threshold Cherenkov counters developed for the KEDR detector (BINP, Novosibirsk) is implemented.

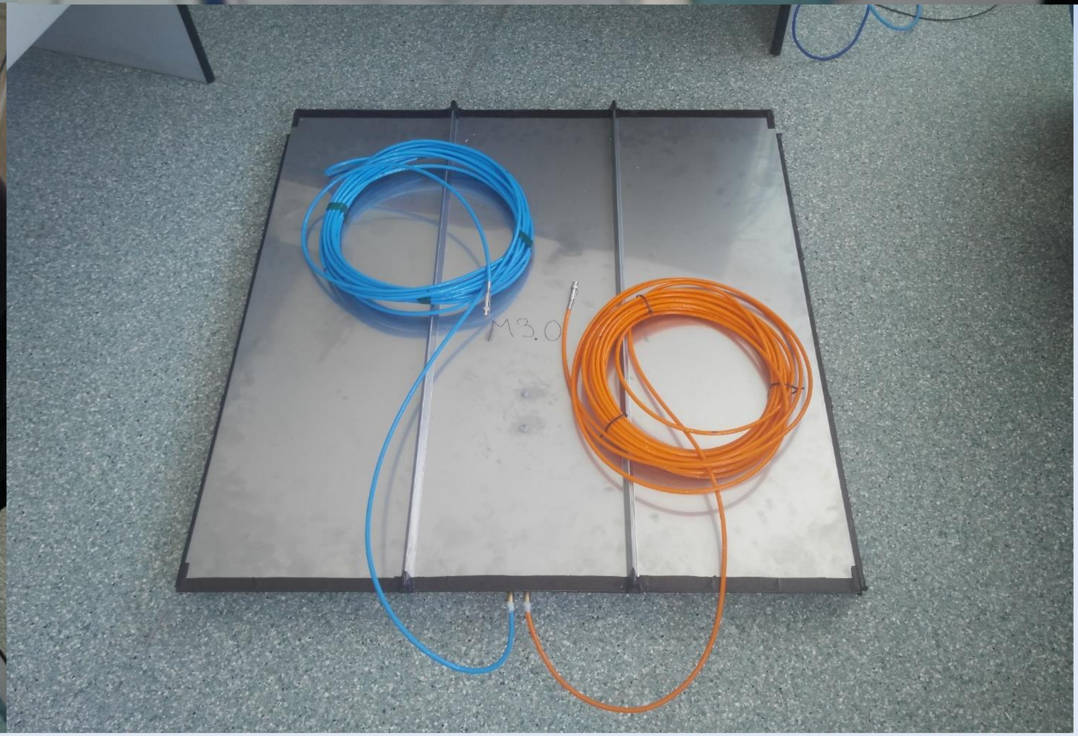
The scintillation light (λ = 415 nm) is transported to bar edges where it hits the wavelength shifter bar. After the reemission (λ = 500 nm) part of the light is captured into the angle of total internal reflection and transported to PMT.

- polystyrene based scintillator is produced by Uniplast company (Vladimir, Russia)
- re-emitting plastic produced by Research Institute of Polymers (Dzerzhinsk, Russia)
- FEU-85-4 $ø_{pc}$ = 28 mm (MELZ-FEU, Moscow, Russia)
- scintillator thickness 1-2 cm
- $S_{det} = 0.94$ m^2
- A_{mean} = 30 pe, RMS = 20%



TAIGA-Muon detector design(2)





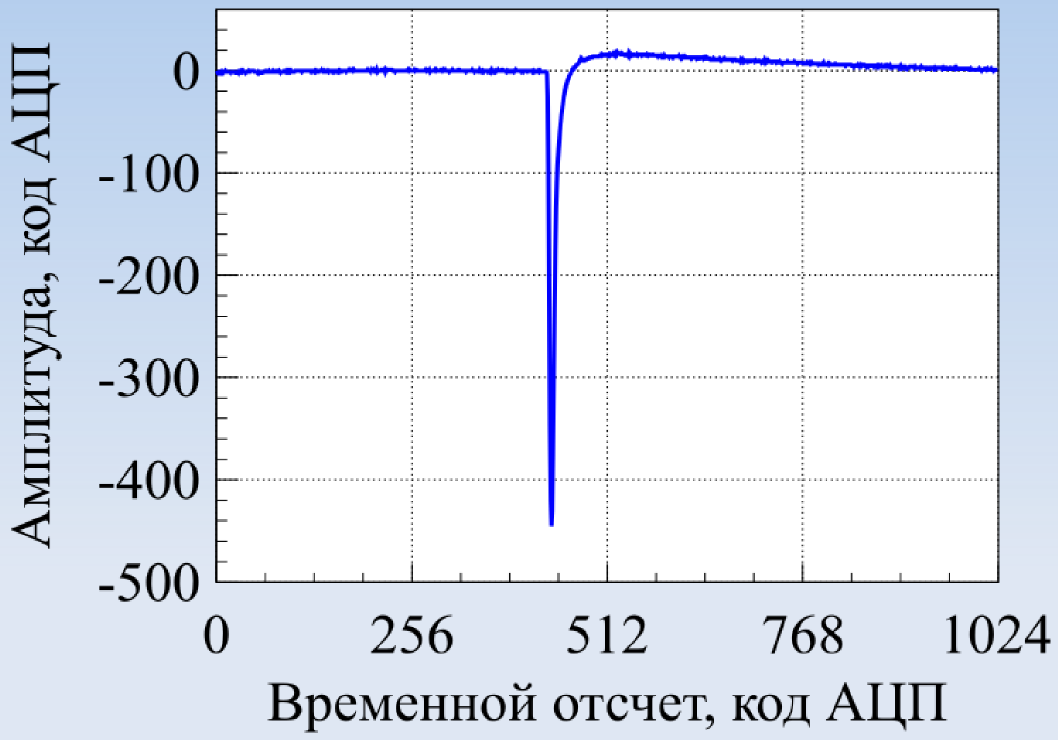
80 detectors are produced.

More than 100 will be produced in 2024-25.

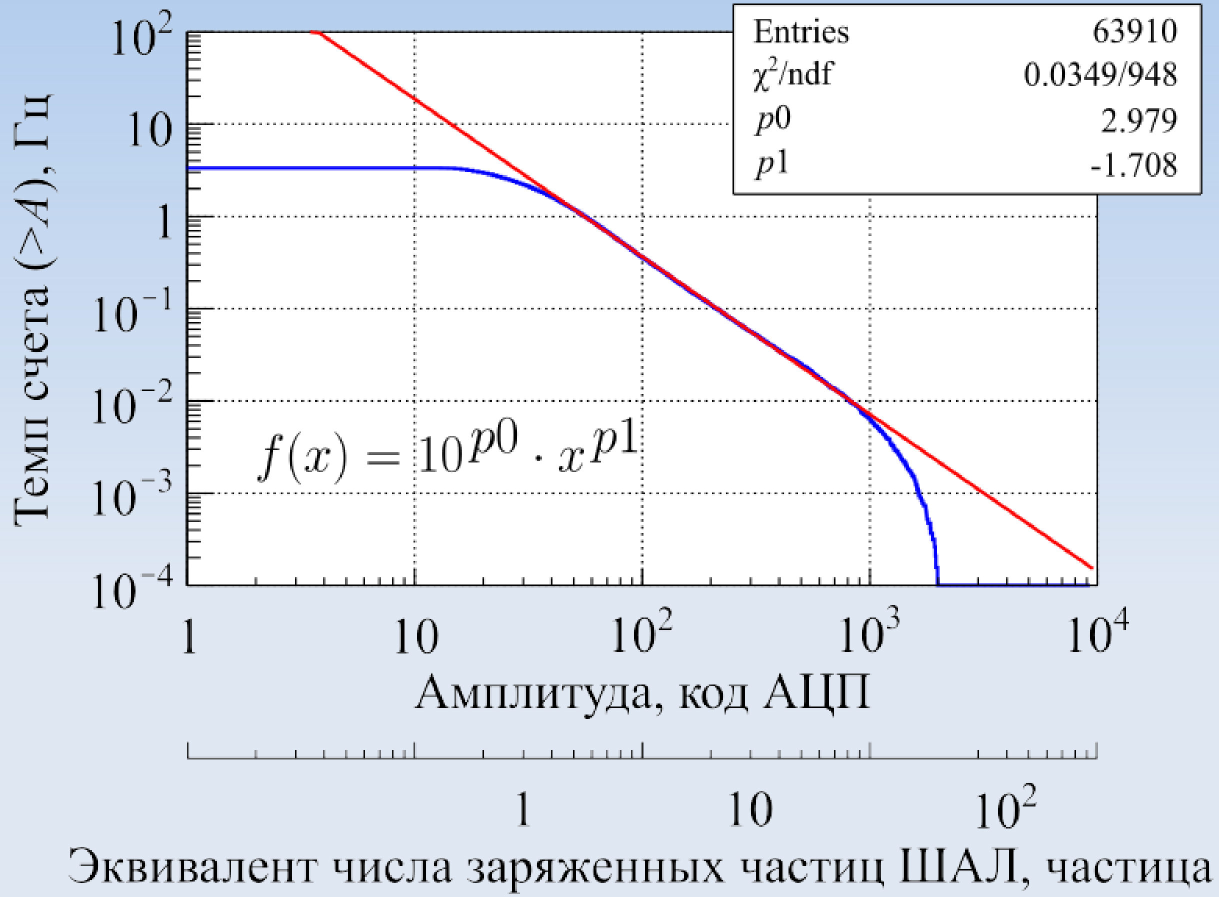
TAIGA-Muon station installation

TAIGA-Muon detector performance

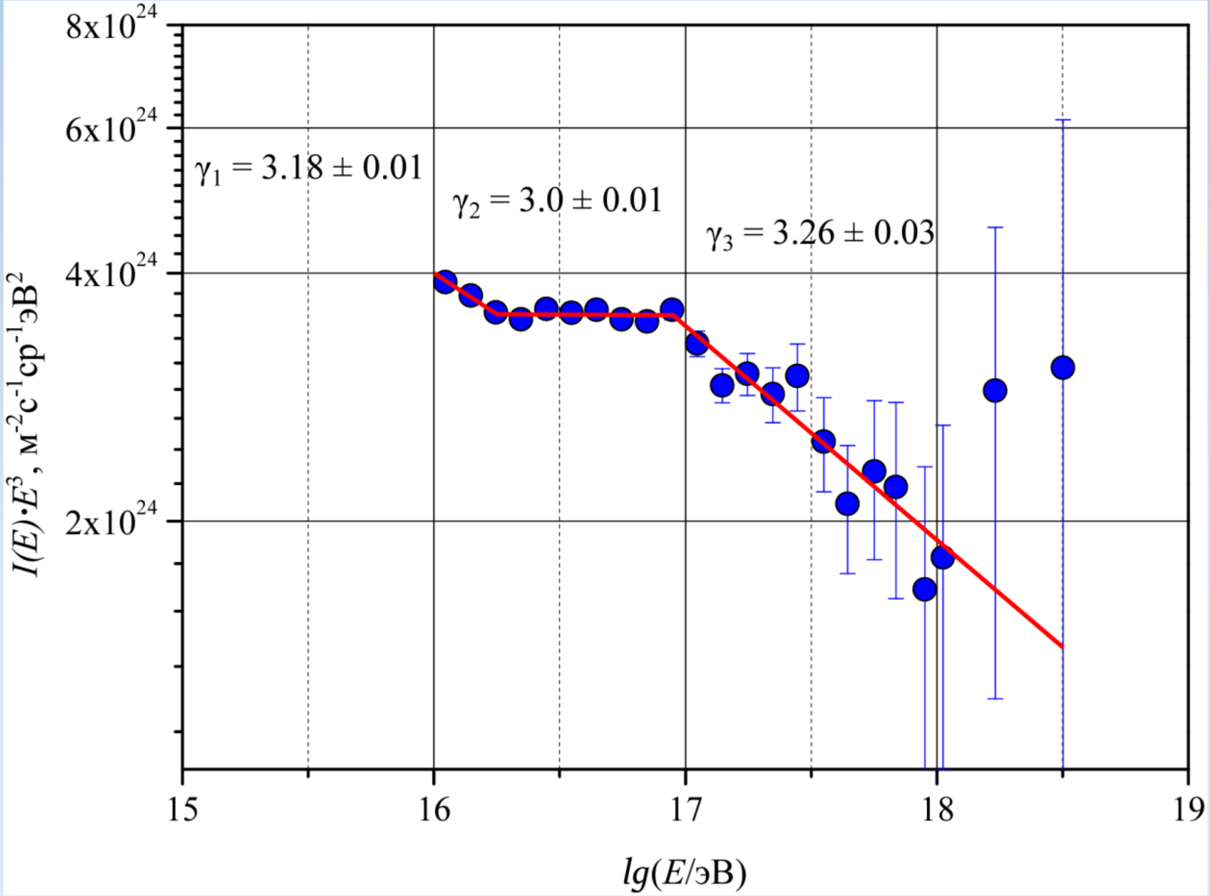
Counter pulse image



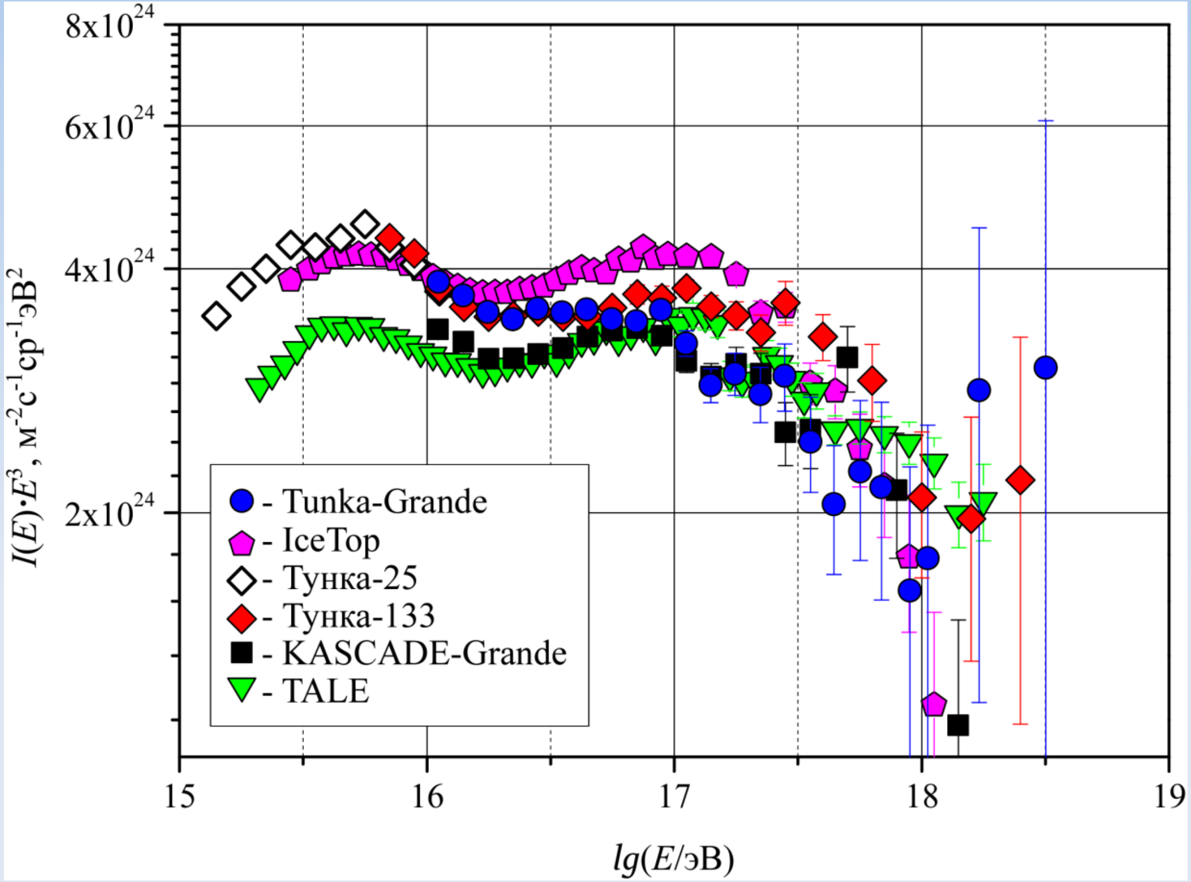
Counter integral spectrum of EAS events



Cosmic rays energy spectrum measurements with Tunka-GRANDE



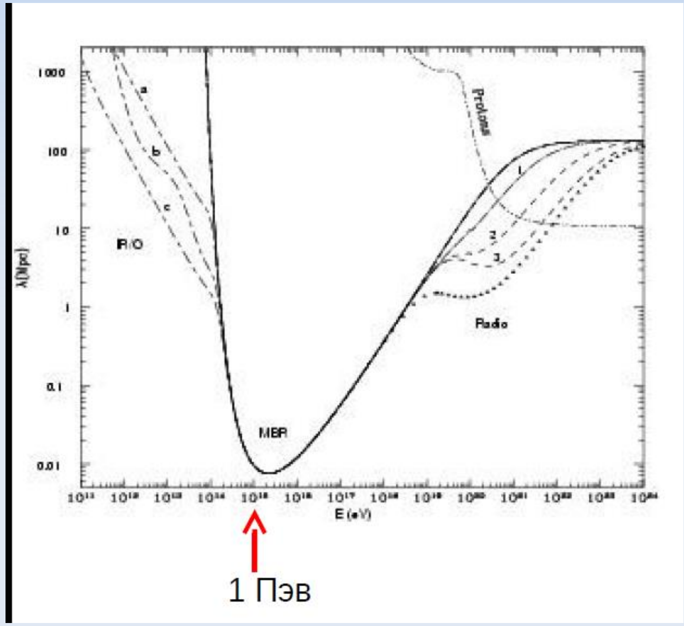
Comparison with other experiments

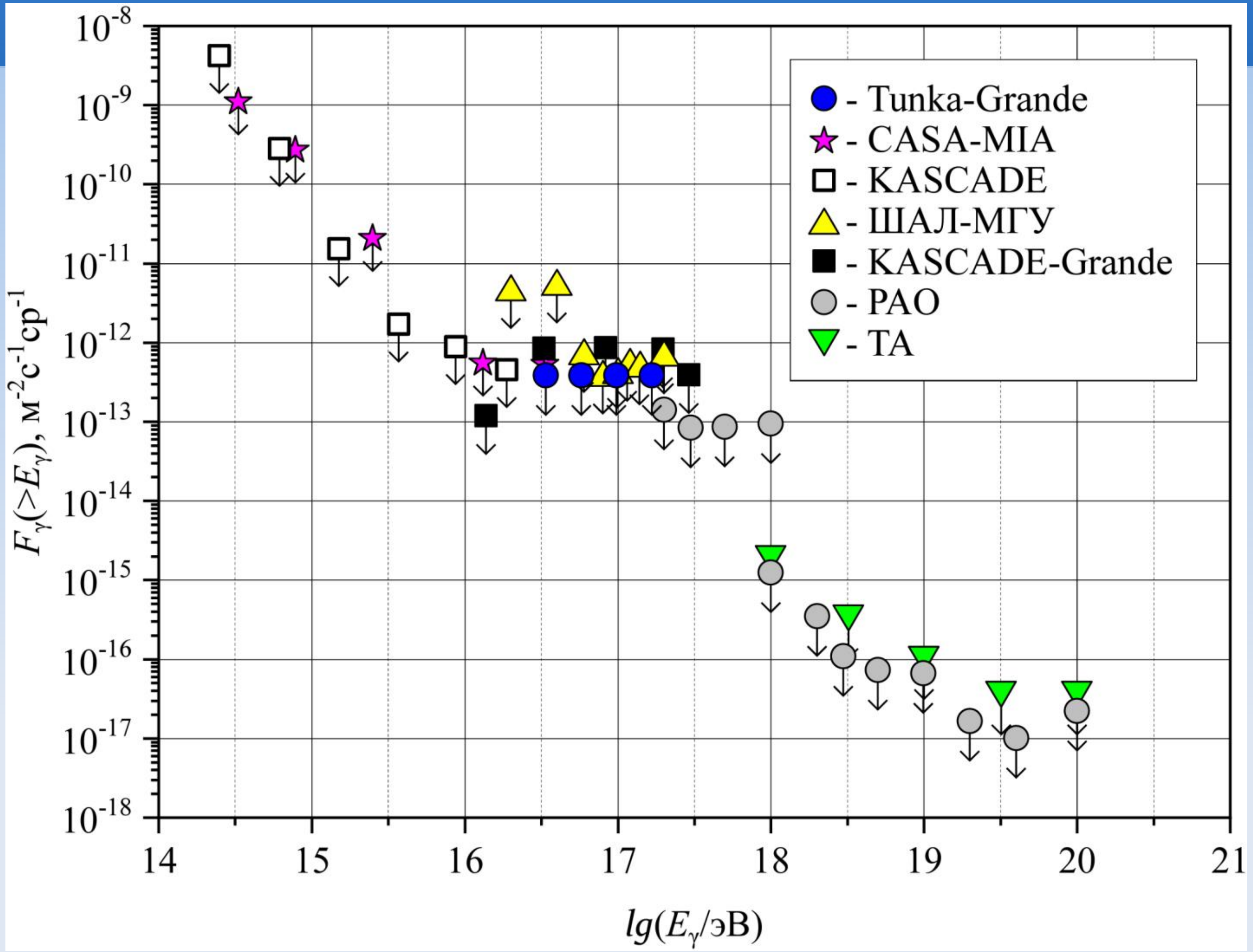


Searh for diffuse gamma-quanta in CR

Motivation: γ + photon → $e^+ + e^-$

Due to the interaction of gamma-quanta with cosmic microwave and light the “transparency” of the Universe is greatly limited at energies above 1 PeV→ detection of such high energy radiation means New physics (Axion, Dark Matter decay...)





Conclusion

- The modernization and expansion of the scintillation detector system of the TAIGA experiment continues.
- For TAIGA experiment, specialized scintillation detectors were developed. The specific features of the detectors are their low cost, large area and the ability to operate in a wide temperature range.
- The first physical results were obtained from the Tunka-GRANDE installation: the energy spectrum of cosmic particles were measured, an upper limit was also set on the flux of CR gamma-quanta.
- Installation of new scintillation detectors in the TAIGA experiment will allow obtaining new data on the flux of gamma-quanta, investigate multichannel events (in coincidence with Baikal-GVD and IceCube) and also obtain data on the mass composition of cosmic rays.