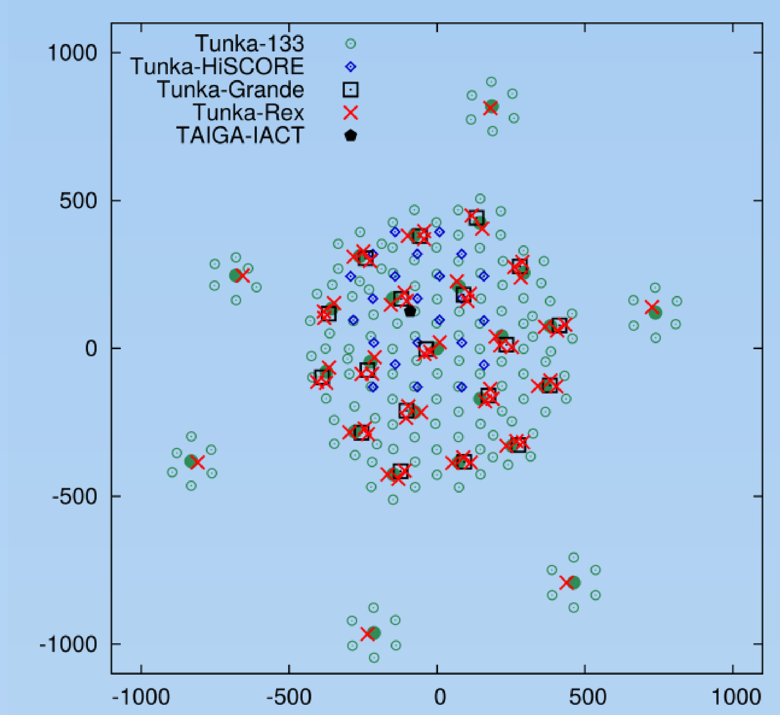
Scintillation detectors for TAIGA experiment

Kirilenko P.S., Kravchenko E.A. for TAIGA collaboration

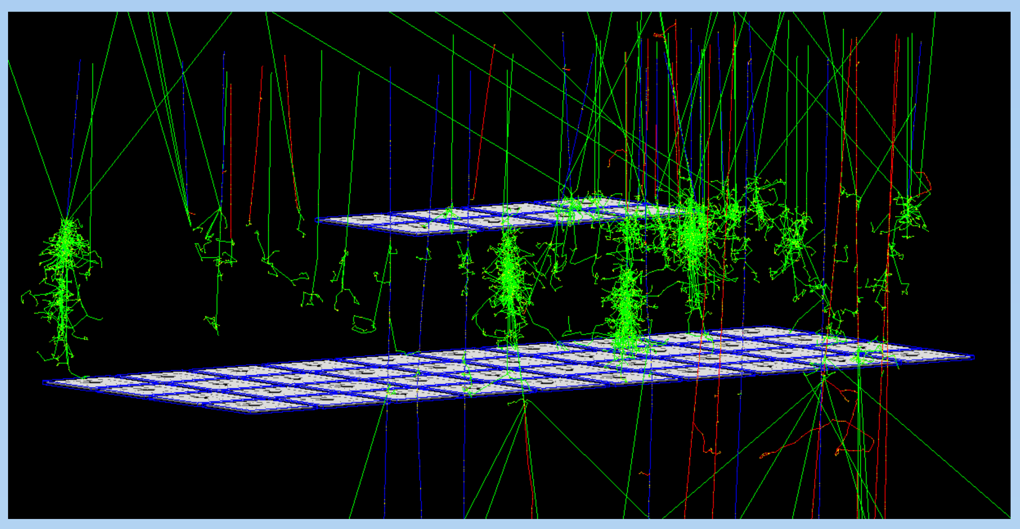
Novosibirsk State University
Budker's Institute of Nuclear Physics

Introduction

TAIGA stands for Tunka Advanced Instrument for high-energy astrophysics and Gamma-Astronomy. This observatory is situated at the Tunka valley, Buryatia Republic, Russia and includes different types of detectors, which are dispersed at an area of about 1 km2[1].The task of TAIGA-MUON installation is an identification of electromagnetic and hadronic EAS (Extensive Air Showers) by measuring of a muon fraction. It is planned for each TAIGA-MUON detector to comprise 8 scintillation counters on a surface and 40 counters underground. This system will complement the existing Tunka-GRANDE facility of scintillation detectors. The effective area of scintillation counter is 0.9 m2. For collection of scintillation light and its transition to PMT lightguides are used. The lightguide is an acrylic glass bar with an admixture of organic re-emitter. This design allows to use small PMTs with diameter of photocathode of 25 mm. An average signal amplitude from a single muon is about 18-20 photoelectrons. The first prototype of the counter was installed and tested using infrastructure of Tunka-GRANDE installation in 2017. The mass production of counters has begun in 2018 at the Novosibirsk State University.



Map of the TAIGA experiment



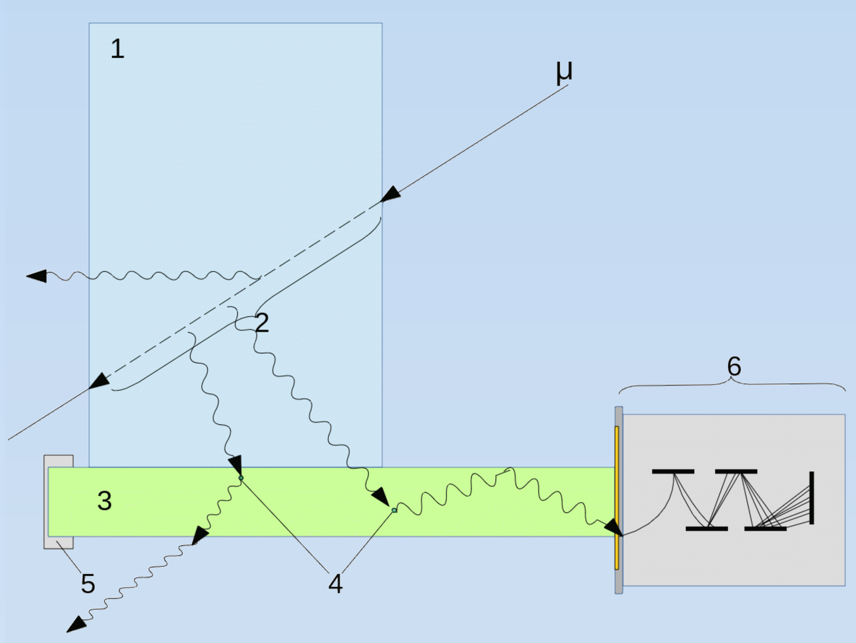
TAIGA-MUON simulation example

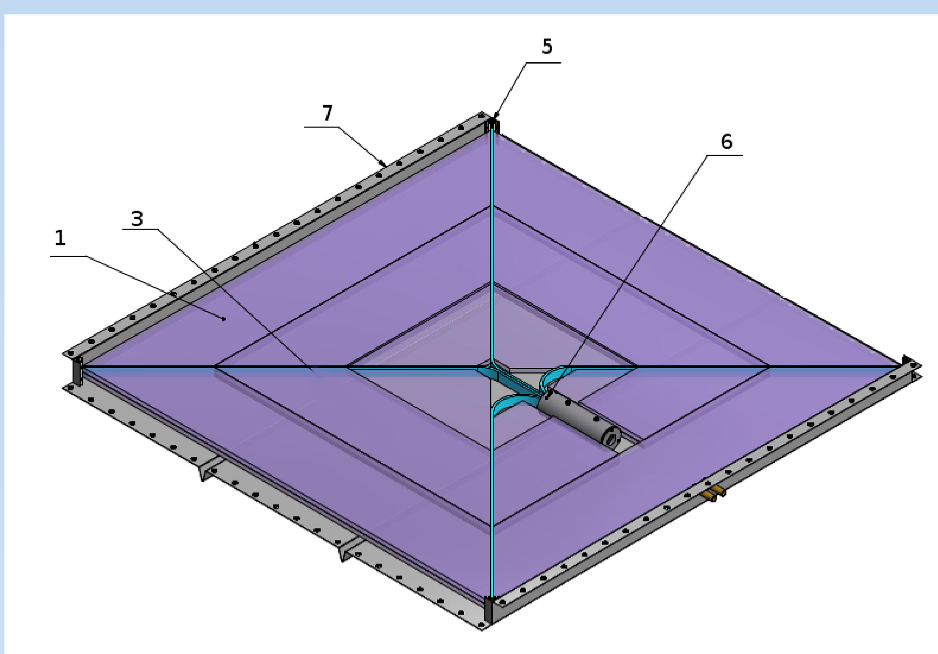
Scintillation detector

Operation conditions of Tunka valley, like groundwater and extremely low temperatures dictate some technical requirements for detector, as

- Impermeability
- Resistance to large temperature changes
- No service requirements

In addition to this, big number of detectors in final muon system creates last requirement — low cost of each detector. Main idea comes from colliding experiments of BINP. For collection of Cherenkov light in detectors KEDR and SND, wavelength shifters are used[2]. Shifters are plastic bars with special dye that molecules adsorbs light and re-emmit it isotropically. Emitted light is being captured in full internal angle of shifter bar and transported to PMT. Shifters make collection of scintillation light more efficient and allow us to use PMTs with small photocathode, which are much cheaper.





Scintillation detector scheme: 1-Scintillator, 2-Muon energy loss, 3-Shifter bar, 4-BBQ dye molecules, 5-Diffuse reflector, 6-PMT, 7- Container.

Components and details

During the prototype tests, a few combination of materials were tested. As a result, these components were chosen for the mass production of detectors :

- Scintillator : polystyrene (98.49%), diphenyl phenylene (1.5%), POPOP (0.01%)
- Shifter : organic glass, BBQ dye
- PMT : FEU-85 (MELZ-FEU)

The first prototype of this kind of detector was created only with two shifter bars and had effective registration area of 0.25m2. Because of very simple construction, some other technical features were developed, as:

- Optimal scintillator and shifter bars polishing rate
- Influence of optical contact between shifters and PMT

References:

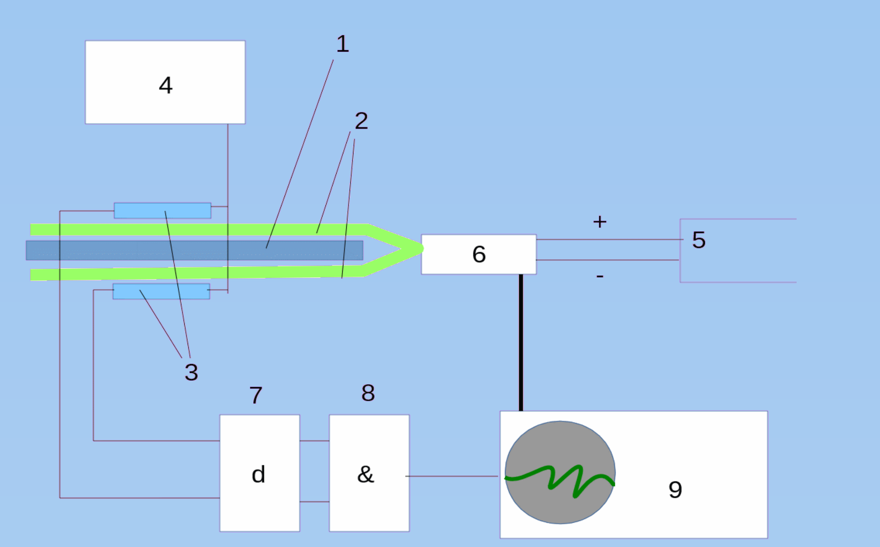
[1]1. The TAIGA experiment: From cosmic-ray to gamma-ray astronomy in the Tunka valley N.Budnev et alPublished in Nucl.Instrum.Meth. A845 (2017) 330-333

[2]M.Yu.Barnyakov et al Development of aerogel Cherenkov counters with wavelength shifters and phototubes.NIM A419(1998)584-589.

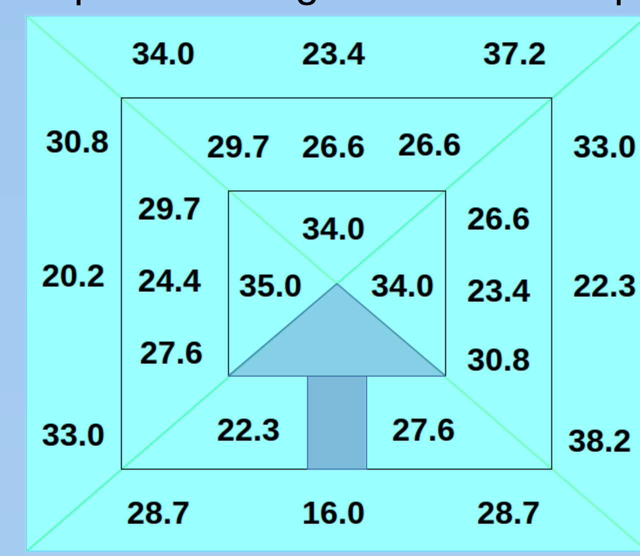
[3]Recent results of the Tunka-Grande experiment R. Monkhoyev and others. Proceedings of the International Baikal Youth Scientific School on Fundamental Physics, Editorial and Publishing Department, ISZF SB RAS, Irkutsk, 2017, p. 43-45

Detector optimization

For detector optimization an external trigger installation was created. The idea of the installation is to use an essential muon background. The external trigger consists of two small scintillation counters connected with coincidence circuit. It allows to isolate the region of detector with an area of 10x10cm2 and measure an amplitude of signal in an exact point.



Area calibration scheme: 1-scintillator, 2-shifters, 3-trigger detectors, 4,5-power supply, 6-PMT, 7-discriminator, 8-coincidence circuit, 9-oscilloscope.



Example of spatial amplitude distribution, photoelectrons

To make the spatial distribution of amplitude more equable, some solutions were undertaken, as:

- Different scintillator thickness, 1cm for inner sector, 2cm for external
- Reflective wrapper for external and middle layers
- Light absorbers between scintillator and shifter

More equable spatial amplitude distribution enlarges the efficiency of signal/noise separation, when the detector works with internal trigger defined by discriminator.

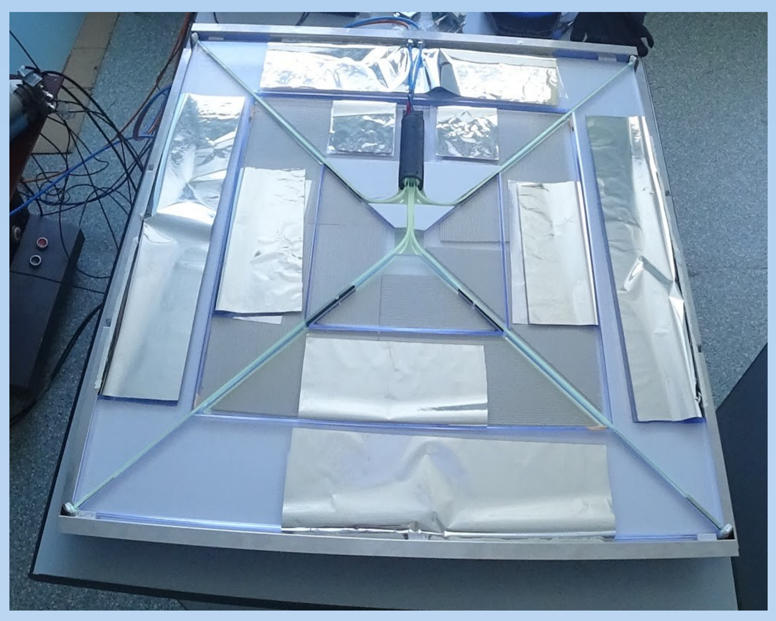
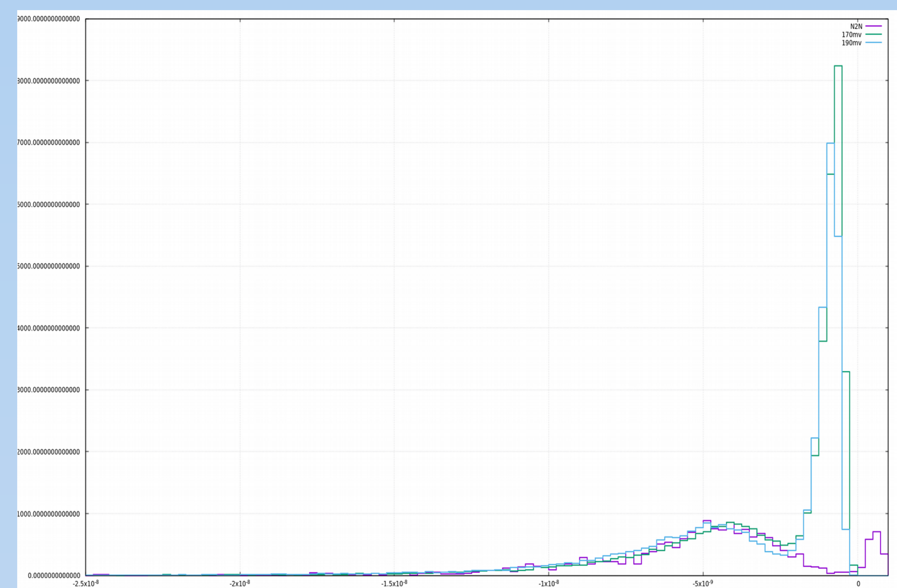


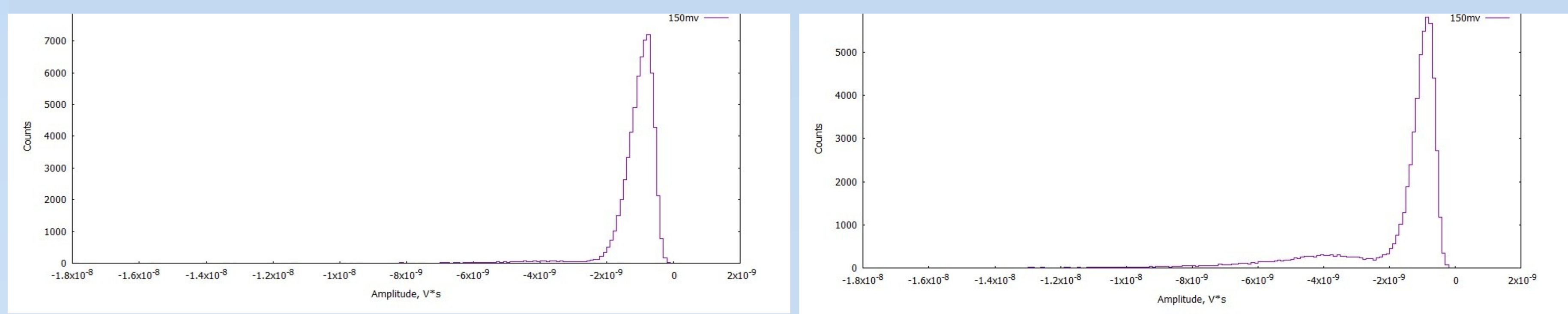
Photo of serial detector



Comparison of amplitude distributions for external and internal trigger

As it is shown, flat design with usage of shifter bars allows to separate the peak of minimum ionization. Moreover, this design allows us to use scintillator with 1 and 2cm thickness, when with usage of shifter fiber it is possible only with 4cm of scintillator.

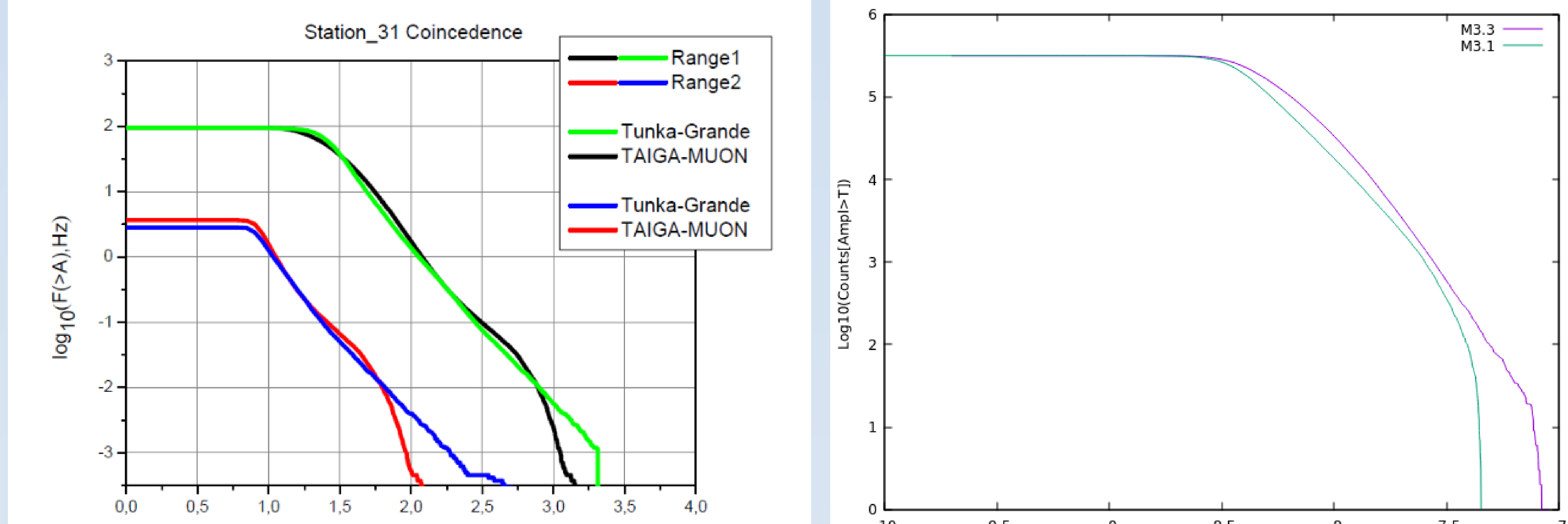
Also it was noticed that signal caused by soft radiation may be efficiently reduced by the layer of absorber covering the scintillator. It is very important, because some of materials, likely to make container of, may be radioactive.



Impact of absorber on the amplitude spectra: without (left) and with absorber (right)

Field trials of detectors

In 2017, full-scale detector was tested in Tunka valley using infrastructure of Tunka-GRANDE station[3]. Test with simultaneous trigger has shown satisfactory results and now counter is used as a trigger for Cherenkov telescopes. Same experiment was provided with two serial counters in 2018 and shown the advantages of modified design



Integral energy spectra of two detectors, Tunka-133 & TAIGA-Muon (left) and two TAIGA-MUON (right)