Evaluation of the project “Tunka Advanced Instrument for cosmic ray physics and Gamma astronomy (TAIGA)”

A) The report about the project provided by PI covered all needed information for assessment of the project.

B) *Evaluation of the goals of the experiment and comparison with international scenario*

The detector TAIGA is devoted to study the flux of gamma rays and charged cosmic rays in the energy range of 10^{13} – 10^{18} eV. The detector will consist of several parts such as timing Cherenkov light detectors (TAIGA-HiSCORE), up to 16 imaging Cherenkov telescopes (IACT), and muon detector. Immediate goal of the TAIGA experiment is to construct the first stage of the setup before end of 2019. It would include 110-120 timing Cherenkov light detectors (area of 1 km2), three TAIGA-IACT detectors and 250 m^2 of muon detectors.

Detection of gamma rays from universe is very effective way to investigate different sources of high-energy cosmic rays (gamma rays are not influenced by magnetic field in galaxy). For such measurement the ability to distinguish gamma rays from signal caused by hadrons is crucial. Combined detectors of TAIGA setup provide information about the profile of extensive air shower (EAS, core position, direction, and energy) and by this way to determine the nature of the original particle.

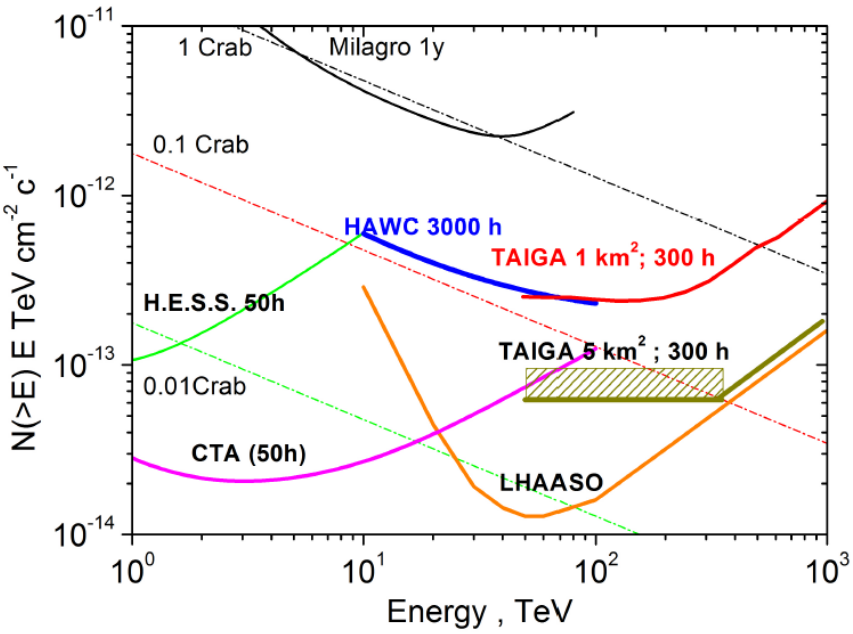
At present, the timing TAIGA-HiSCORE array on an area of 0,5 km^2 with about 55 wide-angle Cherenkov detectors with field of view of 0,6 sr and first IACT detector are in operation. Up to the end of 2019 the number of Cherenkov detectors will be doubled and four IACT detectors will be put in operation. The construction of muon detectors with total area of 250 m^2 is also planned. Such complex detector system (sensitive area of 1 km^2) could be able to detect gamma rays in energy region above 30 TeV.

The final aim is to build a network of 500 wide-angle timing Cherenkov light detectors, up to 16 imaging atmospheric Cherenkov telescopes covering area of 5 km^2 and muon detectors with a total sensitive area of 2000 m^2, distributed over an area of 1 km^2. The expected integral sensitivity of TAIGA detector for detection of gamma rays with an energy of 100 TeV is about $2{,}5 \times 10^{13}$ $TeV.cm^{-2}.s^{-1}$ (for 300 hours).

The experiments in this field could be represented for example by MILAGRO (1999-2011), ARGO-YBJ (2006-2013) (1^{st} generation experiments), HAWC (2013-), ASγ+MDs (2^{nd} generation experiments) or LHAASO. Last of these experiments was selected as a benchmark for TAIGA.

The first phase of LHAASO will consist of the following major components: i) 1 km^2 array (LHAASO-KM2A) for electromagnetic particle detectors (ED) divided into two parts: a central part including 4931 scintillator detectors 1 m^2 each in size (15 m spacing) to cover a circular area with a radius of 575 m and an outer guard-ring instrumented with 311 EDs (30 m spacing) up to a radius of 635 m; ii) An overlapping 1 km^2 array of 1146 underground water Cherenkov tanks 36 m^2 each in size, with 30 m spacing, for muon detection (MD, total sensitive area $\sim$ 42,000 m^2); iii) A close-packed, surface water Cherenkov detector facility with a total area of about 78,000 m^2 (LHAASO-WCDA); and iv) 12 wide field-of-view air Cherenkov telescopes (LHAASO-WFCTA). The commissioning of one fourth of the detector was planned to be implemented in 2018. The completion of the installation is expected by the end of 2021.

Important factor for comparison of experiments is integral flux detected by setup (see next figure).



C) <u>Contribution of JINR and plans</u>

The TAIGA detector consists of three main parts (TAIGA-HiSCORE Cherenkov array, TAIGA-IACT array and TAIGA-muon. The first of them, TAIGA-HiSCORE, is composed currently of 43 optical stations (area of 0,4 km^2) distributed in a regular grid with a spacing of 106 m. In one station 4 PMT with photocathode of 20 or 25 cm are located. The detectors are divided into clusters (30 stations each). Each station is connected to the central DAQ by optical cable. TAIGA-IACT is a network of telescopes (34 mirrors, 60 cm diameter each, focal length of 4,75 m). The camera of the telescope includes 547 PMTs (19 mm diameter). The telescope includes drive system with motor controller and two stepper motors for axis control. On every telescope CCD camera is installed for pointing calibration. The total area of muon detectors (Tunka-Grande) operated since 2015 is about 100 m^2. The number of muons in an air shower induced by charged cosmic ray is about 30 times higher than in gamma ray events. Therefore TAIGA includes also muon detectors to supress background. As the first step, 19 scintillating stations were constructed having a surface and an underground part (Tunka-Grande). As next step, TAIGA/muon counter (1 m^2 area) with 4 scintillator sector has been constructed and tested. The light from the bars is detected by FEU-85 PMT. The first cluster with 50 counters was deployed in autumn 2017.

JINR team has full responsibility in the IACT design, mechanical manufacturing and tests. In December 2016 the first TAIGA-IACT telescope was put into operation. The second IACT mechanical frame was delivered to Tunka in August 2018. JINR team was also responsible for tests of all PMTs for both IACT telescopes (1200 pieces). Team members from JINR also participate in shifts, MC simulations and data processing. TAIGA collaboration established committee of group leaders and JINR is represented by I. Tkachev.

Plans of JINR team are well defined and for period to the end of 2019 include redesign and production of mechanical frame of IACT No. 3, production of 35 mirrors for IACT No. 3 and participation in realization of the scientific programme of TAIGA facility.

D) Publications, participation of students, contributions on conferences

There are 6 publications in WOS concerning of TAIGA experiment (4 in refereed journals – JINST, 2x NIM A, Physics of particles and nuclei; 2 contributions on international conferences) with co-authors from JINR. There is no PhD thesis finished in last three years. The project was presented by Y. Sagan (early stage scientist) at Annual Conference of Young Scientists and Specialists organized by JINR Dubna.

E) Group size, composition and budget

At present, the full collaboration has 72 members from 13 institutions. JINR team includes 17 people (14 people are presented in the report, but in co-authors 3 other people from JINR are included). The team has appropriate composition to the role of JINR – 4 senior scientists, 2 early stage scientists, 5 engineers, 2 designers and 1 technician.

The total budget is surprisingly small, just 50 000 USD per year. The total budget for period of 2018-2020 is 150 000 USD.

Final conclusion:

1) Strength of the project:

- Very interesting and competitive research subject on international level.

- Participation of leading scientific institutions from Russian federation.

- Support of regional university and research centres (Irkutsk, Novosibirsk).

- Well established research team.

2) Weaknesses of the project:

- Small participation of students.

- Limited international cooperation.

3) Recommendation:

- Increase number of publications in refereed journals and number of PhD theses.