

Annual Report

Funding Programme:	Helmholtz Joint Research Groups
Project ID No.:	HRJRG-303
Project Title:	Measurements of Gamma Rays and Charged Cosmic Rays in the Tunka-Valley in Siberia by Innovative New Technologies
Principal Investigator:	Dr. Ralf Wischnewski, DESY
Report Period (=Calendar Year):	01/2013-12/2013

1) Group Structure

Please report briefly on the structure and personnel development of your group.

The Project HRJRG-303 contains two sub-projects: Tunka-HiSCORE and Tunka-Rex. Both are working at the unique Russian Cosmic Ray facility in the Tunka valley / Siberia, where they either

(A) use installed facilities to add new components (Tunka-Rex using the airshower array Tunka-133), or

(B) build a completely new detector array (Tunka-HiSCORE), that uses the existing infrastructure at the Tunka-site.

Both Tunka-HiSCORE and Tunka-Rex use the science data from Tunka-133 (reconstructed air-shower). As for theoretical works and data analysis, the INR group led by G. Rubtsov is of special importance as backbone theoretical activity.

The personnel at DESY, KIT and UHH is the same as at the start of this HRJRG group in 2012. A close and continuous collaboration with a new group from Humboldt University Berlin / Institute for Computer Science, has been established in 2012, in the context of the precision timing calibration system developed for HiSCORE.

Tunka-HiSCORE:

Main contributors to Tunka-HiSCORE are University of Hamburg, DESY, MSU, and ISU. Key contributions come from Humboldt University Berlin/Institute for Computer Science (not being an official HRJRG-partner).

DESY:

Group leader: Dr. Ralf Wischnewski

PhD students: Andrea Porelli (HRJRG-PhD), started in fall 2012.

Students: Manuel Rueger (from HUB/Informatics), wiss.Hilfskraft at DESY

Other support at DESY: DESY-HH/Zeuthen electronic workshop (Summator, WhiteRabbit).

University of Hamburg (UHH):

Group leader: Dr. M. Tluczykont, Key scientist Prof. Dr. D. Horns.

PhD students: Sergey Epimakhov (HRJRG PhD) started in 2012, after finishing his Diploma at MSU (Tunka-133 group). Maike Kunnas. (UHH PhD) started in 2012.

Other support at UHH: Technical staff for design/production of Winston cone (light concentrator) and analog summator board; production funded by DESY.

Humboldt University / Inst. for Computer Science (HUB):

Martin Brueckner, Dr. Frank Winkler (project supervisor).
(HUB is not a formal HRJRG-member; but in close collaboration).

Moscow State University (MSU): Contributing to the project with hardware development, production and deployment, with physics analysis, and data taking shift crew.

Irkutsk State University (ISU): Main contribution is construction, production and deployment of station hardware; assembly of the Winston cones; data taking shift crew. Pre- and post-installation calibration tasks.

Tunka-Rex:

Almost all members of the HRJRG contribute to the Tunka-Rex project to a certain extent. There are two groups, at KIT and ISU, which are dedicated mainly to Tunka-Rex and are summarized here.

KIT group:

Group leader: Dr. Frank Schröder, leader of a young investigator group formed of the two PhD students of the HRJRG working at KIT.

PhD students: Roman Hiller, Dmitriy Kostunin. Both have started their PhD work in summer 2012 and their by now made good progress. Their PhD theses likely can be finished in time, i.e. by summer 2015.

Students: During spring 2013, an Italian student from the university of Torino, Federico Bocci, joint the group for his bachelor thesis.

Other people at KIT who dedicate at least a part of their time to Tunka-Rex, e.g., for the development and construction of the antennas, or scientific advice: Dr. Andreas Haungs, Dr. Tim Huege, Dr. Matthias Kleifges, Dr. Oliver Krömer, Dr. Christoph Rühle, Heike Bolz

ISU group:

PhD student Yulia Kazarina works almost full-time on Tunka-Rex. Moreover, Tunka-Rex gets significant support by the electronics engineer Rashid Mirgazov. Several students have been involved in deployment and measurement shifts, and one student also in data analysis.

2) Network/ Meetings

Please describe how the group works together. Have there been any international meetings organized by or attended by the group? What is the contribution of the group to the networking of international partners and the Helmholtz Centre?

The three **german groups** interact by tele-conferences and face-to-face visits; they convegne at various national physics meetings (eg. DPG annual meeting, German Astroparticle-physics- or Helmholtz-association-related meetings).

A dedicated two-day HRJRG PhD-student meeting (HRJRG-PhD-Days) was held in May 2013 at Hamburg University, to bring all PhDs working in the group together.

Detailed exchange between **german and russian groups** is done on the Tunka-HRJRG / Taiga collaboration meetings held twice per year in Russia, and by mutual visits. Interaction with the russian partners was close while preparing the new installations in Siberia (weekly

Skype-conferences) and during the autumn expedition (September-November 2013), when the first 9-Station HiSCORE array was successfully deployed, commissioned and calibrated. In these activities and during routine HiSCORE/Tunka-Rex shift work in Tunka all German and Russian HRJRG members have been working at the Tunka site.

The HRJRG had already a visible effect, shaping future gamma ray astronomy activities in Russia: In 2013, a Russian MEGA-grant was awarded to Razmik Mirzoyan (MPI Munich) to support the development of a gamma ray facility at the Tunka site, a meanwhile international collaboration dubbed TAIGA. The TAIGA collaboration brings the work initiated by the HRJRG-group to another level. The MEGA-grant was also regarded as a result of successful initial work of HRJRG-303. The faster than originally anticipated development of Tunka-HiSCORE prototype arrays is partially due to additional financial and manpower support from this Russian source.

New technologies developed within this HRJRG (radio-, non-imaging gamma ray detection) will have an impact on planning next generation international facilities. The precision timing technique "White Rabbit", extensively verified for the first time at the HiSCORE prototype array in 2013, has recently been selected as the timing system for the international Cerenkov Telescope Array CTA.

Tunka-HiSCORE:

Specifically, the following HiSCORE-related international meetings/trips occurred in 2013.

- Collaboration meetings in Moscow / Dubna in February and November (6 and 4 DESY/UHH/HUB participants, respectively)
- April 2013: R. Wischnewski, M. Brueckner, M. Tluczykont (DESY/HUB/UHH) installed new hardware/software at Tunka and recorded first nsec-timing of airshowers with the early 3-station prototype.
- October/November 2013: Installation work at Tunka-site for the 9-station-array of 3 DESY/HUB and 2 UHH colleagues (M. Brueckner, M. Rueger, R. Wischnewski, S. Epimakhov, M. Tluczykont)
- Shift-work of A. Porelli and S. Epimakhov in November/December at Tunka.
- Several visits of S. Epimakhov (UHH) to MSU
- Visits at UHH and DESY of N. Budnev, V. Prosin, L. Kuzmichev.

Tunka-Rex:

In addition to the general HRJRG meetings we had dedicated online meetings for Tunka-Rex whenever necessary. Moreover, there have been several journeys in 2013 by individual people involved in Tunka-:

- The PhD student Dmitriy Kostunin (KIT) traveled for a shift to the Tunka site beginning of 2013.
- Beginning of autumn 2013, Frank Schröder (KIT) and Dmitriy Kostunin (KIT) travelled to the Tunka site to complete the deployment of the array. At this occasion, Frank

- Schröder gave a one hour lecture to approximately 50 students at ISU.
- End of 2013, Yulia Kazarina (ISU) and Rashid Mirgazov (ISU) travelled to KIT for joint work and discussions.

3) Scientific Progress / Milestones

How has your work plan progressed? What important milestones could be achieved during the report period? Is the progress of your work in accordance with original planning or has the work plan been changed?

The work is progressing well within the original plan. Tunka-Rex reports stable data taking and first physics results. The 9-station HiSCORE prototype array, commissioned only 1.5 years after starting the HRJRG group, exceeds by far the original goal of a 3 station mini-array. Below, we detail the relevant work packages (WP) and milestones.

Tunka-HiSCORE:

HS-WP1: Today, at least one solution exists for each detector component (milestone HS-MS1). In April 2013, a 3-station prototype array was deployed and operated. In October 2013, a 9-station prototype array with two DAQ systems and two timing systems (HS-MS3) was deployed in the Tunka valley, and took data for the rest of the season (until April 2014). This is a very important milestone for Tunka-HiSCORE and exceeds the projected 3-station array within the HRJRG timeframe. This array allows us to evaluate the different detector components for a final detector hardware layout that will be implemented in 2014 (25 stations). A rich data set was obtained and is currently being analyzed by different group members, mainly PhD students.

HS-WP2: Understanding of the detector via the comparison of simulation and real data results has progressed. Data reconstruction and analysis of the 9-station array data is currently being performed using algorithms previously developed in the framework of simulations.

Tunka-Rex:

In summer 2013, milestone MA-RS3 was successfully taken:

At several international conferences we presented first results on the combined measurements of Tunka-Rex and the Tunka air-Cherenkov detector. In particular, we demonstrated that Tunka-Rex is indeed able to detect cosmic-ray air showers. Moreover, we observe a correlation between the radio amplitude measured with Tunka-Rex and the energy of the air shower reconstructed by the air-Cherenkov detector. This means that the reconstruction of the energy is possible with the radio measurements, as expected. The cross-calibration of the energy scale with the air-Cherenkov detector, and the determination of the achievable energy resolution with Tunka-Rex are foreseen for 2014. In 2014, we expect also first results regarding the reconstruction of the shower maximum, a statistical estimator for the mass of the primary cosmic rays.

Milestone MA-RS4 has been postponed to 2014. We decided that it is most useful for our main scientific goals, to continue with the stand-alone operation of HiSCORE and Tunka-Rex in 2013. We now plan to add additional Tunka-Rex antennas to HiSCORE in 2014.

4) Financial Plan / Time Schedule

Can you comply with the financial plan and time schedule or do you see a need for adjustment?

Tunka-HiSCORE:

The time schedule could be met. As described above, a substantially larger prototype array could be commissioned only 1.5 years after the start of HRJRG-303.

A minor delay has arisen only for the planned combination of Tunka-HiSCORE with Tunka-Rex. We decided to first focus on the verification of the individual detectors before considering joint operation of both systems.

UHH: The need for travel funds at UHH exceeded the planned value; substantial compensation from other funds at University of Hamburg was needed. An adjustment of the travel funds for UHH planned deployments in the last year of HRJRG-303 would be appreciated by UHH.

Tunka-Rex:

We are completely on schedule regarding the main goal of Tunka-Rex, namely the cross-calibration of the radio measurements with the Air-Cherenkov measurements of Tunka-133.

The only delay we have regards the combination of HiSCORE with Tunka-Rex antennas. The original schedule turned out to be too tight, because HiSCORE and Tunka-Rex first must be tested and understood individually to a certain degree. We now consider to connect Tunka-Rex antennas to HiSCORE stations in the next deployment season (autumn 2014). KIT provided some additional money from own funds to produce the required antennas.

Thus, we see no problem in the financial plan.

However, a scientific evaluation of these new measurements likely will not be possible anymore in the frame of HRJRG-303, but only if we get additional funds, e.g. by a prolongation of this group. This concerns only the joint operation of Tunka-Rex and HiSCORE. Tunka-Rex itself is on schedule.

5) Publications of the Group

Tunka-HiSCORE:

Nine international conference presentations were made, out of which five were published in refereed journals.

Tunka-HiSCORE - A new array for multi-TeV gamma-ray astronomy and cosmic-ray physics

O. Gress et al (Tunka-HiSCORE collaboration)

Nuclear Instruments and Methods in Physics Research A. 2013. V. 732 - P. 290-294 DOI:

10.1016/j.nima.2013.06.034

The Tunka - multi-component EAS detector for high energy cosmic ray studies,
S. Berezhnev, D. Besson, N.M. Budnev, M. B ker et al
Nuclear Instruments and Methods in Physics Research A. 2013. -V. 732. P.281-285.
doi.org/10.1016/j.nima.2013.05.180

Hardware and first results of Tunka-HiSCORE
M. Kunnas, M. Br ckner, N. Budnev et al (Tunka-HiSCORE-collaboration)
Nuclear Instruments and Methods in Physics Research A 2013
dx.doi.org/10.1016/j.nima.2013.12.025

The HiSCORE experiment and its potential for gamma-ray astronomy
M. Tluczykont et al (Tunka-HiSCORE-collaboration),
J. Phys.: Conf. Ser. 2013. -V.409. -P. 012120. doi:10.1088/1742-6596/409/1/012120

The HiSCORE project
M. Tluczykont, M. Brueckner, N. Budnev et al (Tunka-HiSCORE-collaboration)
Acta Polytechnica 2013, in press; <http://workshop2013.iaps.inaf.it/>

Status of the HiSCORE experiment
R. Wischnewski et al. (Tunka-HiSCORE-collaboration), #1164, Proc. of 33rd ICRC, 2013, Rio de Janeiro, Brazil, Conference: C13-07-02

Components of the HiSCORE detector and prototype test results
S. Epimakhov et al. (Tunka-HiSCORE-collaboration), #0885, Proc. of 33rd ICRC, 2013, Rio de Janeiro, Brazil, Conference: C13-07-02

Results from the WhiteRabbit sub-nsec time synchronization setup at HiSCORE-Tunka
M. Br ckner et al. (Tunka-HiSCORE-collaboration), #1158, Proc. of 33rdICRC, 07/2013, Rio de Janeiro, Brazil, Conference: C13-07-02

A White Rabbit setup for sub-nsec synchronization, timestamping and time calibration in large scale astroparticle physics experiments
M.Brueckner and R.Wischnewski, #1146, Proc. of 33rd ICRC, 2013, Rio de Janeiro, Conference: C13-07-02

Furthermore, four talks were presented at the 2013 spring meeting of the German physics association (DPG-Tagung), and one talk at a Helmholtz workshop. At various CTA-consortium meetings, talks regarding experience with the precision timing system have been given.

Tunka-Rex:

5 contributions at international conferences. The proceedings of two of them have been published in 2013 in refereed journals.
Moreover, two further proceedings of conferences held in 2012 have been published in refereed journals in 2013.

Tunka-Rex: Status and Results of the First Measurements
D. Kostunin et al. - Tunka-Rex Collaboration, 2013, accepted by Nulc. Instr. and Meth. A, Proceedings of RICAP 2013, Roma, Italy, DOI: 10.1016/j.nima.2013.10.070

The Tunka Radio Extension (Tunka-Rex): Status and First Results
F.G. Schröder et al. - Tunka-Rex Collaboration, 2013, #0452, Proceedings of the 33rd ICRC 2013, Rio de Janeiro, Brazil

The Tunka-Rex antenna station
R. Hiller et al. - Tunka-Rex Collaboration, 2013, #1278, Proceedings of the 33rd ICRC 2013, Rio de Janeiro, Brazil

Status and first results of the Tunka Radio Extension
R. Hiller et al. - Tunka-Rex Collaboration, 2013, Proceedings of the 14th ICATPP Conference 2013, Como, Italy, accepted for publication by World Scientific

Status and First Results of Tunka-Rex, an Experiment for the Radio Detection of Air Showers
R. Hiller et al. - Tunka-Rex Collaboration, 2013, Proceedings of the 13th TAUP 2013, Asilomar, California USA, in preparation

A list of all Tunka-Rex publications is also available at: <http://www.ikp.kit.edu/tunka-rex/publications.php>

Furthermore, we have presented two talks at the important national conference in physics: the spring meeting of the German physics association (DPG-Tagung).

6) External Funding

Tunka-HiSCORE:

None, except: UHH, DESY own funds; as well as in-kind contributions by the Humboldt University.
The 9-station array build in 2013 and ongoing activities for a larger prototype array in 2014 are partially supported from the Russian MEGA-grant.

Tunka-Rex:

None, except KIT own funds.

7) Patent Applications

No. of pending/granted patents

None.

8) Awards received by Group Members

Yulia Kazarina (Tunka-Rex), Russian PhD student at ISU, won an i-Progress scholarship:
<http://www.hap-astroteilchen.de/ueber-uns/i-progress.php>

This enabled her to stay for one month at KIT at the end of 2013. Her stay turned out a substantial benefit for both her PhD work as well as the Tunka-Rex project.