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):	01/2014-12/2014

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 the installed facility and 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.

For science cross-calibration, both Tunka-HiSCORE and Tunka-Rex make use of 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, and described again below. A close collaboration with a group from Humboldt University Berlin / Institute for Computer Science, had been established already 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.
Other support at DESY: DESY-Zeuthen electronic workshop (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, 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.

Humboldt University / Inst. for Computer Science (HUB):
Martin Brueckner (Scientist), M.Herrmann (Bachelor student), 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:

The Tunka-Rex group is the same as last year. We strengthened our collaboration with ISU by exchanging one diploma student from ISU for two months (iProgress grant from Helmholtz Alliance for Astroparticle Physics). Moreover, Yulia Kazarina (PhD student on Tunka-Rex in Irkutsk) started a two-semester stay at KIT financed by a grant from the Russian president.

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.
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, with two guest-semesters at KIT. Tunka-Rex is also supported by the electronics engineer Rashid Mirgazov. Several students have been involved in deployment and measurement shifts, and 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).

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 (skype-conferences) and during the autumn expedition (October/ November 2014), when the 28-Station HiSCORE

array was deployed. In these activities and during routine HiSCORE/Tunka-Rex shift work in Tunka most german and russian HRJRG members have been working at the Tunka site. Exchange of information for calibration and analysis of data (data, procedures, software) was less intense, despite several attempts from the german side.

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 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”, verified for the first time at the HiSCORE prototype array in 2013/2014 and now routinely operating, has been selected in 2014 as the timing system for the international Cerenkov Telescope Array CTA.

On the German-Russian Workshop "Cooperation between the Helmholtz Association of German Research Centers and the Russian Foundation for basic research: Experience, Solutions, Prospects", held in March 2014 in Moscow, the project was presented in a talk.

Tunka-HiSCORE:

A selection of HiSCORE-related meetings/trips in 2014

- Collaboration meetings in Dubna in April/December (9 and 7 talks by DESY/UHH participants, respectively)
- February 2014: calibration of the 9-station array (R.Wischnewski)
- November 2014: Installation work at Tunka-site for the 28-station-array of 3 DESY/HUB colleagues (M.Brueckner, M,Herrmann, R.Wischnewski)

Tunka-Rex:

In addition to the general HRJRG meetings we had dedicated online meetings for Tunka-Rex whenever necessary. Several journeys in 2014 by people involved in Tunka-Rex:

- Collaboration meetings in Dubna in April/December (4 talks in total by KIT)
- Shift work in Tunka of D. Kostunin and R.Hiller (KIT)
- Installation work of 19 additional antennas in autumn 2014 by F. Schröder and D. Kostunin (KIT).

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: Science data are taken with the two new astrophysics installations; the physics calibration and data-analysis are on track.

The new 28-station **HiSCORE** array, installed in November 2014, is an extension of the 9-station HiSCORE prototype array from 2013; it is tuned to a detection of a signal from a galactic source. This facility with 0.25 km2 sensitive area exceeds by far the original plan as given in the HRJRG-proposal.

For **Tunka-Rex**, data have been taken successfully also in the 2014/2015 season. Additional 19 Tunka-Rex antenna are installed and ready for operation with the Tunka-Grande scintillator array.

HiSCORE:

Data were taken with the 9-station array during the 2013/14 and 2014/15 operational seasons. The analysis of these data is in progress, with the main goal being a detailed performance evaluation in terms of angular resolution and energy threshold, and comparison to Monte Carlo simulations. Studies using cosmic ray data show that the expected angular resolution of order 0.1 degrees can realistically be reached. Different air-shower reconstruction algorithms are being tested and compared. At the end of the year 2014, an effort was started to compare the various available reconstruction algorithms and to ultimately develop a joint reconstruction framework.

Combined data runs with Tunka-Rex antenna connected to the HiSCORE DAQ system were attempted. The resulting data show that the HiSCORE readout-system, optimized for array-wide nsec-timing, does not meet the requirements of Tunka-Rex. Therefore, the planned task of combining both activities was stopped.

The novel idea to combine the HiSCORE timing-array technique with the imaging technique (IACT telescope) was implemented in a toy-simulation framework. Results show the potential to improve the gamma-hadron separation of HiSCORE by more than a factor 2 at the detection threshold.

Tunka-Rex:

The technical progress is even better than planned: in autumn 2014, 19 additional antennas have been deployed, which will be triggered by the new scintillator array Tunka-Grande. Moreover, three antennas were deployed to examine joint operation with the HiSCORE prototype stations.

The scientific progress at Tunka-Rex is almost as planned. However, the calibration of the antennas turned out more difficult than thought. Therefore, there is a slight delay, but the main scientific result, namely the cross-calibration of radio and air-Cherenkov measurements, can

still be achieved in 2015 at the end of the PhD theses done in the frame of Tunka-Rex. Preliminary results on the reconstruction of the shower energy and the shower maximum look promising.

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 for the experimental installation. As described above, a 28-stations array has been installed by fall 2014. This substantially larger prototype array could be commissioned only 2.5 years after the start of HRJRG-303.
Analysis and calibration of data has been taken longer than planned, thus both HRJRG-PhD students will finish their thesis with some delay.
Travel funds at UHH were already exhausted in 2013, University funds had to be used for meetings, conferences and measurement shifts.

Tunka-Rex:

The time schedule has to be slightly adjusted in 2014, after having been completely on-track for 2012 and 2013. Both PhD students employed at KIT for the HRJRG get an extension of half a year. In this time frame we will be able to finish the cross-calibration of Tunka-Rex and Tunka-133, and to give an estimate for the reconstruction precision.

5) Publications of the Group

Tunka-HiSCORE:

The HiSCORE concept for gamma-ray and cosmic-ray astrophysics beyond 10 TeV,
M. Tluczykont, D. Hampf, D. Horns, D. Spitschan, L. Kuzmichev, V. Prosin, C. Spiering, R. Wischnewski
Astroparticle Physics, Volume 56 (2014) p. 42
DOI: 10.1016/j.astropartphys.2014.03.004
e-Print: arXiv:1403.5688

TAIGA - the Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy - present status and perspectives,
N.M. Budnev et al. (TAIGA Collaboration) (2014) 14 pp.
Published in JINST 9 (2014) 09, C09021
DOI: 10.1088/1748-0221/9/09/C09021

The HiSCORE Project,
M. Tluczykont et al. (Tunka-HiSCORE Collaboration)
Acta Polytechnica CTU Proceedings 1(1), p.283-287 (2014)

Status of the Tunka-HiSCORE group and first results from the 9-station prototype array,
M. Tluczykont et al. (Tunka-HiSCORE Collaboration)
COSPAR proceedings, in Proc. of the 40th COSPAR Scientific Assembly (2014), Moscow, 2014cosp...40E3358T

Hardware and first results of TUNKA-HiSCORE,
M. Kunnas et al. (Tunka-HiSCORE Collaboration)
Nucl.Instrum.Meth. A 2014 V.742. P.269-270.
DOI: 10.1016/j.nima.2013.12.025

Timing Arrays (Invited talk),
M. Tluczykont et al. (Tunka-HiSCORE Collaboration)
Proceedings of the 24th ECRS 2014, Kiel, Germany, accepted

Amplitude calibration with the HiSCORE-9 array,
S.Epimakhov et al. (Tunka-HiSCORE Collaboration)
Proceedings of the 24th ECRS 2014, Kiel, Germany, accepted

Simulation of the Tunka Area International Gamma-ray Advanced experiment,
M. Kunnas at al.(TAIGA-Collaboration)
Proceedings of the 24th ECRS 2014, Kiel, Germany, accepted

Timing calibration and directional reconstruction for Tunka-HiSCORE,
A.Porelli et al. (Tunka-HiSCORE Collaboration)
Proceedings of the 24th ECRS 2014, Kiel, Germany, accepted

Furthermore, three talks were presented at the 2014 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 HiSCORE precision timing system have been given.

Tunka-Rex:

The Tunka-Rex Experiment for the Detection of the Air-Shower Radio Emission,
Y. Kazarina et al. (Tunka-Rex Collaboration)
Proceedings of the 6th ARENA 2014, Annapolis, USA, submitted

Amplitude Calibration of the Tunka Radio Extension (Tunka-Rex),
R. Hiller et al. (Tunka-Rex Collaboration)
Proceedings of the 24th ECRS 2014, Kiel, Germany, accepted

The Tunka Radio Extension: Latest Analysis Results,
D. Kostunin et al. (Tunka-Rex Collaboration)
Proceedings of the 24th ECRS 2014, Kiel, Germany, accepted

Tunka-Rex: the Cost-Effective Radio Extension of the Tunka Air-Shower Observatory,
F.G. Schröder et al. (Tunka-Rex Collaboration)
Proceedings of the 2nd UHECR 2014, Springdale, Utah, USA, accepted by JPS Conference Proceedings
e-Print: arXiv: 1504.01541

A list of all Tunka-Rex publications is also available at: http://www.ikp.kit.edu/tunka-rex/publications.php . Furthermore, two talks have been presented at the spring meeting of the German physics association (DPG-Tagung).

6) External Funding

Tunka-HiSCORE:

UHH, DESY significant own funds (eg. travel funds) and in-kind contribution by the Humboldt University.
UHH: 80 8-inch PMTs (~100kEur); winston cone production, summator board production.
DESY: Time system components purchased.

The 28-station array build in 2013 and 2014 and ongoing activities for the construction of an Imaging Air Cerenkov Telescope (IACT) in Tunka are also 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

None.