

Annual Report

Funding Programme:	Helmholtz-Russia Joint Research Groups
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Project Title:	Physics Analysis and Calorimetry at the Terascale
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Activity report**a) Progress within the work plan delineated in the application**

The project of the HRJRG started on the 1st of November 2007 and a lot of effort went into the setup of the structure of the group and into the administrative regulation of the cooperation between the German and the Russian institutes. It took quite some time to sort out the financial aspects of the funding and the payment of the individual grants in Russia. A kick-off meeting with all members of the group took place beginning of February 2008 in connection with the traditional ITEP Winter School of Physics, in which several members, especially the young scientists of the group participated. Taking advantage of the presence of several members of ITEP and MSU at DESY for an ILC HCAL meeting, the second annual meeting of the HRJRG was organized at DESY on the 15th of December 2008.

In the area of physics the results of HERA on the structure of the proton, the underlying event, multi-parton interactions and dependencies of several QCD processes provides crucial input for searches of new physics phenomena and other studies at the LHC. The understanding of the HERA results with their consequences for the LHC needs a strong effort in phenomenology.

The analysis of HERA data progressed with a new ansatz for a fit of the proton parton density functions. These new parton density functions will be employed for simulations of physics processes at the LHC. Phenomenological calculations and studies have been performed for the production of prompt photons and W- and Z- bosons at the LHC. These processes are most important standard candles in particle physics and will also be employed to validate the detector performance and calibration. Also the matrix elements for the production of W- and Z-bosons associated with jets and Heavy quarks have been calculated in kt-factorization scheme, published and implemented into the Monte Carlo generator Cascade. There is ongoing work for implementing the calculation for the production of forward jets into the same Monte Carlo generator. All these processes are the basis to achieve the goal to develop of a model for the underlying event, multi-parton interactions and the study of possible saturation effects at the LHC.

The physics analyses for the CASTOR calorimeter concentrated on the study of dijet events with an associated forward jet in the calorimeter. As it turns out, even with applying in the realistic parameters for the jet energy measurement and resolution, it is possible to distinguish between two parton evolution schemes for the proton structure, the usual DGLAP type and the more BFKL like type, when requiring a modest jet energy within the CASTOR calorimeter. Another study could prove the ability of the calorimeter to contribute essentially to the tuning of the expected underlying event structure as well as the determination and

extrapolation of the underlying energy pedestal in the jet profiles, which have to be subtracted for precision measurements. Both studies have been presented in the HERA-LHC workshop in May and have been well received in the ensuing discussion.

For the CASTOR calorimeter at the CMS experiment at LHC major milestones were achieved in passing successfully regular follow-up status reviews. These approvals allowed the start of procurements and production of mechanics and electronics. It was possible to construct all necessary ingredients with final parameters for one octant in a very short time. The properties of this setup were tested with beam in a pretty long, three weeks data taking time employing already the final front-end electronics built at DESY. The analyses are still ongoing and show promising results.

At the same time the mechanics shell of half a calorimeter was produced at DESY and later on filled for one out of four octants. After extensive commissioning tests this half calorimeter had been installed in its position of the CMS experiment end of September. As it turned out, the magnetic stray field of the CMS solenoid is much higher than predicted by simulations provided by experiment engineers, especially in the CASTOR area, and several components of the Iron support structure moved. Since CASTOR is very close to the fragile beam pipe it had to be removed for further investigations after the unfortunate stop of the LHC machine. Detailed measurements have been performed and revealed that the chosen Photo-Multiplier readout tubes would not operate in this magnetic field. Therefore a new type was searched for and identified in the kind of mesh-type as used for the SPACAL calorimeter in the H1 Experiment. With a thorough review by the CMS management this type and the suggested necessary mechanics changes were approved. Since this type of PMT's is very expensive and has a very long delivery time, some of the SPACAL PMT's will be re-used. Although they do not have a radiation hard entrance window, according to their specifications they will operate correctly for the first data taking, which is essential for our physics goals. MSU agreed to take care of the production of the necessary new PMT bases.

Meanwhile the second half shell has been produced at DESY and delivered to CERN. Presently both half shells have been filled with the final radiation hard Quartz and the Tungsten plates.

Following the presently envisaged schedule for the LHC beam operation it is necessary to install the complete CASTOR calorimeter end of June 2009 on beam line. In addition new measurements in a test beam are necessary to calibrate the changed setup. This is now agreed for one week in mid of May 2009. All schedules for mechanics, data acquisition electronics and software are streamlined to achieve these ambitious and challenging goals.

In the framework of the CALICE collaboration, a hadron calorimeter (HCAL) prototype has been tested with muon, electron and hadron beams in the energy range 6-80 GeV at the CERN SPS in the years 2006-2007. In 2007 the set-up has been moved to the meson test beam facility at Fermilab, USA, where a larger energy range was available, in particular hadron energies as low as 2 GeV were provided and thus complement the data set in a region which is important for linear collider applications with single particle reconstruction (particle flow approach), but still suffers from large model uncertainties. It is desirable to extend the data taking with the all-scintillator combination by one more beam period in spring or early summer of 2009. The data analysis is progressing well.

The measurements with the test beam calorimeter are extremely helpful for the general development of methods, nevertheless such a setup is not a prototype in the sense that it can be scaled up to a full collider detector. It has too many external components and is not compact enough. In order to demonstrate the potential of the SiPM technology to be amenable at a realistic and scalable detector concept a prototype is under development which addresses the main integration issues with few detector layers in a compact structure. This activity is supported by the European infrastructure integration initiative EUNET. In the EUNET framework, an absorber structure is being developed together with readout and calibration electronics embedded in the detector volume. This structure should be validated

with latest generation photo-sensors and tiles, where the compactness imposes sharper requirements on precision and performance, with respect to the existing test beam calorimeter. In 2008, the mechanical concept has been defined and design has started for construction in 2009. Two mixed signal readout ASIC prototypes have been produced, the performance of the analogue part has been successfully tested, the digital part is under study. Major components of the DAQ system have been realized in prototypes, and two options for a calibration system are available. By the end of the year an electronic layout for the first read-out board equipped with electronics was ready, which is now being equipped with 144 tiles and SiPMs for a first test.

Later in 2009 a complete detector layer with about 1700 channels shall demonstrate the feasibility of a full-size version in terms of mechanical tolerances, thermal stability and electronic signal integrity.

At ITEP an optimized SiPM scintillator cell for an integrated readout layer has been developed. The scintillator thickness was changed from 5mm to 3mm to decrease the total volume of the HCAL. A new casting form for the tiles with optimized geometry has been produced. The tile-size tolerances after painting tile edges were found to be at acceptable level of 100µm. The new principle of attaching the tiles to the printed circuit board has been successfully tested.

Using LED flashes, cosmics and radioactive sources the SiPMs produced by Center of Perspective Technologies were tested (in total 600 detectors). Based on efficiency measurements the working point has been selected. The noise at half-MIP signal appeared below 100Hz. The long term stability of the detectors has been studied. In parallel, new package for SiPM has been developed which allows mounting into the 3mm thick tile. 160 tiles were equipped with new SiPMs, tested and sent to DESY for the use in the HCAL prototype. The total efficiency of the tile was found to be around 95%. In parallel, the possibility of the direct read-out without WLS fiber has been studied. Using MC simulation, possible tile geometry which gives a uniform over the tile area response was found.

A new type of SiPMs for direct readout has been developed at MEPhI. The main requirements to the direct readout SiPMs are:

- maximum of spectral sensitivity corresponds to the emission spectrum of the plastic scintillator (430nm);
- the SiPM signals should have one-photo-electron resolution to allow the gain calibration;
- the optical cross talk is below 10%;
- the sensitive area is 10mm² or more.

The technology of the SiPM production with the p-over-n type has been developed. For this the full simulation of the technological process and necessary tests were performed. Pilot batch of new SiPMs with different topologies has been produced. The sensitive areas of new detectors are 3x3, 2x5 and 5x5mm². The new SiPMs are being tested using LED flashes with different wave lengths.

b) Milestones achieved

The different areas of activity have a different status of achieved milestones.

In the area of phenomenology and theoretical calculations the progress is slightly faster than envisaged in the application. Until the first LHC data arrive, the models will be further refined.

The project of the CASTOR calorimeter passed the successfully the milestones in early 2008, but experiences now delays due to the unfortunately delayed start of data taking at the LHC. The present plans of the LHC machine see the first collisions now roughly one year later than anticipated in the application. The concept of the calorimeter had to be changed due to the very high magnetic stray field, which were not foreseen by the calculations provided by the experiment engineers. Nevertheless the project is on its way to fulfil the new schedule.

In the area of the ILC activity all given milestones were passed successfully.

c) Compliance with financial plan and schedule

See appended information.

d) Publications, talks, prizes, etc. Please attach as annex if applicable.

S.P. Baranov, A.V. Lipatov, N.P. Zotov, Phys. Rev. D 77, 074024 (2008)

S.P. Baranov, A.V. Lipatov, N.P. Zotov, Phys. Rev. D 78, 014025 (2008)

S.P. Baranov, A.V. Lipatov, N.P. Zotov, Eur. Phys. J.C 56, 371 (2008)

M.Deak, F.Schwennsen, JHEP 0809, 035 (2008)

Proceedings of the workshop: HERA and the LHC workshop series on the implications of HERA for LHC physics, DESY-PROC-2009-02:

Talks and proceeding contributions from M.Deak, A.Knutsson and Z.Rurikova

M. Danilov, Novel Photo-Detectors and Photo-Detector Systems.

Presented at 8th International Conference on Position Sensitive Detectors,
Glasgow, Scotland, 1-5 Sep 2008, e-Print: arXiv:0812.1098 [physics.ins-det]

I.Katkov, Performance Studies of the Final Prototype for the CASTOR Forward Calorimeter at the CMS Experiment.

Presented at 2008 IEEE Nuclear Science Symposium (NSS) and Medical Imaging Conference (MIC), 18-25 Oct 2008, Dresden, Germany