



Universität Hamburg

Helmholtz-Hochschul-Nachwuchsgruppe VH-NG-206

“R&D studies for new photo-detectors and their integration in HEP detectors”

Activity Report 2007

Group Members of the Helmholtz-Hochschul-Nachwuchsgruppe (2007)

Group Leader:	Dr. Erika Garutti	DESY
Postdoctoral Fellow:	Dr. Niels Meyer	DESY
Postdoctoral Fellow:	Dr. Martin Göttlich	DESY
Graduate Students:	Nicola D’Ascenzo	DESY
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Associate Group Members from the partner institutes (2006)

University partners:	Prof. Dr. Rolf-Dieter Heuer	Univ. Hamburg
	Prof. Dr. Hans-Christian Schultz-Coulon	Univ. Heidelberg
	Prof. Dr. Tohru Takeshita	Univ. Shinshu
Graduate Students:	Marius Groll	Univ. Hamburg
	Saori Ito	Univ. Shinshu
	Alexander Kaplan	Univ. Heidelberg

The Young Investigator Group VH-NG-206 has started its activity on the 1st of March 2006. During year 2007 a new PhD student has joined the group from the university partner Heidelberg, A. Kaplan (supervised by Prof. H.-C. Schultz-Coulon) and two of the PhD students have concluded their doctoral work. In October the postdoctoral fellow Dr. M. Göttlich has joined the group.

Main commitments of the group:

The CALICE collaboration

The group is member of the CALICE (Calorimeter for a Linear Collider Experiment) collaboration, together with 38 institutes from 13 countries, whose main objective is the development of the next generation of calorimeters for future HEP detectors, based on innovative technologies to allow unprecedented granularity and segmentation of all detector components.

Among the detectors investigated by the collaboration, a highly granular hadronic calorimeter prototype has been developed based on a sampling structure with scintillating tiles (of smallest size $3 \times 3 \times 0.5 \text{ mm}^3$) individually readout by innovative silicon-based photo-detectors (Silicon-Photomultiplier (SiPM), from MEPHY/ PULSAR) mounted directly on each tile. Due to the green sensitivity of the photo-detector a wavelength shifting fiber is used to couple the scintillation light to the SiPM.

After the commissioning run in 2006, the fully equipped calorimeter prototype has been tested this summer at the CERN SPS test beam. The operation of the detector, mainly driven by the photo-detectors, has proved to fulfill expectations. The analysis of the physics data 2006 has been presented at conferences and reported in internal CALICE notes. The analysis of 2007 data has posed severe challenges to the software, not only for the larger number of channels to handle, but also for the increased volume of data to be processed.

A test beam at Fermilab, Chicago, is currently in preparation for the year 2008.

The PET experiment

During 2007 the group has intensified the laboratory activities of tests of new photo-detectors and their application to new fields.

The main challenges posed by the design of future Positron Emission Tomography machines are the improvement of the spatial and timing resolution and the combined operation with magnetic resonance. The Micro Pixel Photon Counter by Hamamatsu is a good candidate for this application. Its small size (down to $1 \times 1 \text{ mm}^2$) and the high photo-detection efficiency in the blue spectral region allow the direct readout of a highly segmented scintillator matrix improving the spatial resolution of the machine.

The group has tested the energy resolution at the 511 keV and the time response of a basic, but innovative, PET system made of two LSO crystals coupled to two MPPC photo-detectors.

The ALPS experiment

The group is also involved in the ALPS (Axion-Like Particle Search) experiment, a joint-venture of DESY, Laserzentrum Hannover e.V. and Hamburger Sternwarte. Scope of the experiment is detection of laser photons penetrating an optical barrier with very high sensitivity. Observation of these kind of signals can only be explained by so far undiscovered light particles, which emerge in beyond-standard-model theories. The sensitivity achievable depends on a combination of the laser power, the measurement time, and the quality of the photon detector. ALPS has been approved and commissioned in 2007 and continues to take data.

A short description of the main activities of the group in the year 2007:

Commissioning of the hadronic calorimeter prototype

One of the major group activity during its second year has been the preparation for the test of the hadronic calorimeter prototype for the ILC at the CERN test beam. The leader of the group (Dr. E. Garutti) has been again appointed run coordinator for the three months of June - August. All the group members have taken active part to the CERN test beam. They have actively contributed to the detector commissioning and the data taking, as well as to the first level analysis and data quality checks.

The second CALICE test beam has been a even greater success than the first one in 2006. The fully commissioned detectors were operated with a 96% up-time. Around 200 Millions events have been collected corresponding to 15 TBytes of data.

In parallel to the hardware activity the group has intensified the work on reconstruction

and calibration as well as physics analysis of the data collected. Results on preliminary hadronic shower analysis have been published in the PhD thesis of M. Groll. Deeper understanding on the calibration procedure and the performance of the detector at the electromagnetic scale are the topic of two more PhD thesis in the group.

Research and study of new photo-detectors

In the laboratory set-up tests on the new silicon photo-detector produced by Hamamatsu (Multi-Pixel Photon-Counter) provided the first set of data for publication. The studies on direct and indirect (via wavelength shifting fiber) coupling of these new devices to organic scintillator tiles have been completed.

New feasibility studies with inorganic scintillators were carried out in the framework of a possible application of MPPC to positron emission tomography (PET). This study demonstrated that the technological achievements in the photo-detector development open the possibility of the design of new generation PET machines, with improved space resolution and sensitivity. Two diploma thesis are based on the results obtained with the laboratory measurements (one at the University of Hamburg, the second at the university of Heidelberg).

In October 2007 Dr. M. Göttlich has joined the group with the main task of further develop the promising PET application research and build a small PET prototype to demonstrate the feasibility of a multi-channel detector based on this technology.

This part of the project is also supported by the University of Shinshu.

Optimization of the integration of photo-detectors in calorimeter readout

The Japanese prototype of electromagnetic calorimeter with MPPC readout has been tested at the DESY test beam during Feb.-Mar. 2007. The readout electronics used by the hadronic calorimeter prototype has been successfully adapted. The test beam experiment has provided a very important set of data, which confirms the applicability of the silicon-based photo-detectors for HEP detectors readout.

Contribution to ALPS

ALPS is a very small collaboration, so naturally our group is involved in all aspects of the experiment. During 2007, substantial contributions were made to characterizing the photon detector, operation of the experiment as a whole, offline software development, and data analysis. Status reports at two DESY PRC open sessions and at the DPG spring meeting in Heidelberg by Dr. N. Meyer also indicate the central role of our group inside ALPS.

List of Publications

- 1) M. Groll. *Construction and commissioning of a hadronic test-beam calorimeter to validate the particle-flow concept at the ILC*, PhD thesis.
- 2) A. Eggemann. *Messungen zur Anwendung von Geiger Mode Photodioden*, Diploma thesis.
- 3) N. D'Ascenzo, A. Eggemann, E. Garutti. *Study of Micro Pixel Photon Counters for a High Granularity Scintillator-Based Hadron Calorimeter*, DESY internal note DESY07-196, and arxiv-ph/0711.1287.

- 4) N. D'Ascenzo, A. Eggemann, E. Garutti, A. Tadday. *Application of Micro Pixel Photon Counter to calorimetry and PET.* Proceeding to the Workshop on Photon Detection, 13-14 June 2007, Perugia, Italy.
- 5) N. D'Ascenzo, E. Garutti, A. Tadday. *Application of MPPC to positron emission tomography.* PD07 conference proceeding, May 2007, Kobe, Japan.
- 6) E. Garutti, N. D'Ascenzo, M. Göttlich, H.-C. Schultz-Coulon, A. Tadday. *Application of novel Silicon-based photo-detector to calorimetry and medical physics.* IEEE conference proceeding, 31 Oct - 3 Nov 2007, Honolulu, Hawaii.