



Universität Hamburg

**Helmholtz-Hochschul-Nachwuchsgruppe VH-NG-206**  
 "R&D studies for new photo-detectors and their integration in HEP detectors"

**Activity Report 2009**

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**Group Members of the Helmholtz-Hochschul-Nachwuchsgruppe (2008)**

Group Leader:	Dr. Erika Garutti	DESY
Postdoctoral Fellow:	Dr. Niels Meyer	DESY
Postdoctoral Fellow:	Dr. Martin Göttlich	DESY
Graduate Students:	Sergey Morozov	DESY
	Nanda Wattimena	DESY

**Associate Group Members from the partner institutes (2008)**

University partners:	J. Prof. Dr. Johannes Haller	Univ. Hamburg
	Prof. Dr. Hans-Christian Schultz-Coulon	Univ. Heidelberg
	Prof. Dr. Tohru Takeshita	Univ. Shinshu
Graduate Students:	Nils Feege	Univ. Hamburg
	Alexander Kaplan	Univ. Heidelberg
	Wei Shen	Univ. Heidelberg
	Alexander Tadday	Univ. Heidelberg

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The Young Investigator Group VH-NG-206 has started its activity on the 1st of March 2006. During year 2009 two PhD thesis have been completed (one only published in Jan 2010) reporting on excellent analysis results in the core of the group activity. All the proposed topics are still well covered and progressing according to plans.

**Main commitments of the group:**

A list of the group main commitments can be found in the yearly report of 2007.

**A short description of the main activities of the group in the year 2009:**

Commissioning of the hadronic calorimeter prototype

The year 2008 has seen the installation of the AHCAL calorimeter prototype at Fermilab, Chicago, for the start of a new campaign of test beam at the Meson Test Beam Facility (MTBF). In year 2009 the last test beam campaign has been successfully carried out at Fermilab. The coordinating and expert roles of all group members have been maintained though the 2009 test periods. After the test beam completion, the data analysis is the main focus of the group, and results are starting to appear in notes to the collaboration and papers.

## Remote control room for ILC test experiments

The remote control room equipped via the HGF Sonderförderung SO-NG-064 has been operational through 2009 till the end of the test beam period at FermiLab. For year 2010 it is foreseen to resume operation during the next planned test beam at CERN.

## Software development and analysis of CALICE data

The group is active in the development of software tools for the calibration and in the analysis of the test beam data collected with the AHCAL prototype.

N. Meyer has maintained his role of software coordinator for the CALICE collaboration. Two PhD thesis have been finalized under the supervision of E. Garutti which include hadronic calorimeter data analysis: - "Study of the Neutralino Sector and Analysis of the Muon Resoponse of a Highly Granular Hadron Calorimeter at the International Linear Collider", by Nicola D'Ascenzo - "Calorimetry at the Internation Linear Collider From Simulation to Reality", by Nanda Wattimena.

## Research and study of new photo-detectors

The test-setup at the the University of Heidelberg has been further extended in order to facilitate a comprehensive characterization of SiPM devices. The setup allows measurements of the gain and dark-rate as well as the cross-talk and after-pulse probabilities as a function of the bias voltage and temperature. Further it is possible to raster-scan the SiPM surface with a focussed light spot which allows to determine sensitivity, gain and cross-talk probability depending on the geometrical position illumination. Focus has been set on the measurement of the cross-talk and after-puls corrected photon detection efficiency (PDE) as these effects would, if not taken into account properly, overestimate the PDE values. A combination of the measurement results allows to determine the individual noise contribution to the photon counting resolution of SiPMs and to define an application specific optimal operating voltage. Photodetectors from Hamamatsu, SensL and KETEK as well as the SiPM from MEPHI/Pulsar used already in the CALICE calorimeter prototype have been characterized and compared.

## The PET experiment

The multi-channel PET prototype financed through the Sonderförderung SO-NG-064 has been built and commissioning has started. The publication of the first commissioning data is expected in 2010. The prototype uses the small size LFS crystals read out individually Hamamatsu silicon-based photodetectors (MPPC). A novel readout electronics solution is being tested which allows the operation and individual calibration of a large number of photo-detectors. The prototype has been tested to reconstruct the position of point sources close to the centre of the field of view and a spatial resolution of 2.5 mm FWHM has been derived. The spatial resolution is mainly determined by the crystal width of 3 mm. Studies of the spatial resolution as a function of the distance to the centre of the field of view are foreseen. The achieved coincidence time resolution amounts to 870 ps FWHM, and is limited by the sampling rate of the readout electronics. We demonstrated that with a relatively simple approach a very good performance in terms of spatial resolution can be achieved.

In addition, we showed that we can reach a very good channel-to-channel homogeneity and stability of the system by monitoring the temperature and adjusting the MPPC

bias voltages individually. The well-understood test device allows us to test new developments for the multi-channel read-out of MPPC devices. This gives us the possibility to experimentally investigate the improvement of the image quality using TOF information.

We performed a full simulation of the test device with the GATE simulation toolkit which is based on GEANT4. The simulation is able to reproduce the spatial resolution which is obtained with the test device. This motivates the use of the GATE simulation to study the sensitivity of the test device and the benefits of time of flight information for the image quality. It also enables us to study systems composed of smaller crystal, e.g.  $1 \times 1 \times 15 \text{ mm}^3$ , which would be applicable for small animal PET.

### List of Publications

- 1) *Response of the CALICE Si-W electromagnetic calorimeter physics prototype to electrons.*  
C. Adloff et al.  
Published in Nucl.Instrum.Meth.A608:372-383,2009.
- 2) *CALICE scintillator HCAL - electromagnetic and hadronic shower analysis.*  
By CALICE Collaboration (Erika Garutti for the collaboration).  
Published in J.Phys.Conf.Ser.160:012077,2009.
- 3) *Response of the CALICE Si-W Electromagnetic Calorimeter Physics Prototype to Electrons.*  
By CALICE Collaboration (C. Adloff et al.).  
Published in J.Phys.Conf.Ser.160:012065,2009.
- 4) *"Study of the Neutralino Sector and Analysis of the Muon Resoponse of a Highly Granular Hadron Calorimeter at the International Linear Collider"*,  
Nicola D'Ascenzo, PhD thesis, Jan 2009.
- 5) *"Characterisation Studies of SiPMs"*, Patrick Eckert, Hans-Christian Schultz-Coulon, Wei Shen, Rainer Stamen, Alexander Tadday\*, Accepted for publication in NIM A, DOI information: 10.1016/j.nima.2010.03.169

### List of Proceedings:

- 1) *Time based readout of a silicon photomultiplier (SiPM) for Time Of Flight Positron Emission Tomography (TOF-PET)* P. Jarron, E. Auffray, S.E. Brunner, M. Despeisse, E. Garutti, M. Göttlich, H. Hillemanns, P. Lecoq, T. Meyer, F. Powolny, W. Shen, H.C. Schultz-Coulon, M.C.S. Williams, Symposium IEEE 2009, October 2009, Orlando, USA.
- 2) *Application of Silicon Photomultipliers to calorimetry and to Positron Emission Tomography*, E. Garutti, M. Göttlich, H.-C. Schultz-Coulon, A. Tadday, International Workshop on New Photon Detectors (PD09), Shinshu, Japan Proceedings of Science, pos.sissa.it, 2009.
- 3) *"Characterization Studies of Silicon Photomultipliers for a Calorimeter for the ILC"*, Patrick Eckert, Wei Shen, Hans-Christian Schultz-Coulon, Rainer Stamen, Alexander Tadday\*, Kolja Prothmann, Frank Simon, Christian Kiesling, Olaf Reimann, Erika Garutti, Martin Göttlich, Felix Sefkow, proceeding PD09 workshop on new photodetectors, PoS(PD09)021

- 4) *"Application of Silicon Photomultipliers to calorimetry and to Positron Emission Tomography"*, Martin Göttlich\*, Erika Garutti, Alexander Tadday, Hans-Christian Schultz-Coulon, proceeding PD09 workshop on new photodetectors, PoS(PD09)009
- 5) *"STIC: A Current Mode Constant Fraction Discriminator for Positron Emission Tomography using SiPMs (MPPC)"*, Wei Shen, Hans-Christian Schultz-Coulon, proceeding IEEE-NSS 2009, Orlando, USA, 2009.

05/05/10 *Johannes Schmitt*