Annual Report

Funding Programme:	**Helmholtz Joint Research Groups**
Project ID No.:	HCJRG-300
Project Title:	Novel Technologies for the Upcoming Silicon Micro-Strip Detector of the ATLAS Experiment at CERN
Principal Investigator:	Dr. Ingrid-Maria Gregor
Report Period (=Calendar Year):	01/2016-12/2016

1) Group Structure

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

The HCJRG-300 group "Novel Technologies for the Upcoming Silicon Micro-Strip Detector of the ATLAS Experiment at CERN" is, on the DESY side, lead by two senior scientists (Dr. Ingo Bloch, Dr. Ingrid-Maria Gregor). Two further DESY senior scientists (Dr. Marcel Stanitzki, Dr. Sergio Diez Cornell) are supporting the developments and the research of the group. Additionally, two postdoctoral and two PhD students are associated to the joint research group. The subject of their PhD theses is closely tied to the planned research of this group.

The postdoctoral researcher and PhD student working full time on the project only started late in The recruitment has proven to be more challenging than we had anticipated and only towards the end of the first year we were able to recruit two excellent candidates. Both did start to make a significant impact on the project in 2016 already.

Personnel employed for this joint research group:

- Postdoctoral researcher: Dr. Marko Milovanovic (starting date 01.12.2015)
- PhD student: Martin Stegler (starting date 17.08.2015)

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 group works closely together and communicates predominantly via e-mail, video meetings and phone conferences. The contacts are on a regular weekly basis. Additionally, a number of very beneficial face-to-face meetings were arranged alongside various international meetings. For example, the senior scientists of the German and the Chinese partners did have a half a day meeting during the ATLAS ITk Week in Geneva (June 2016). The principal investigators of both teams had an additional face-to-face meeting alongside the ATLAS Upgrade Week in November 2016. Furthermore, was the principle investigator Dr. Hongbo Zhu visited DESY in year 2016.
Strengthened by the HCJRG activities, the collaboration between DESY and IHEP was further extended and intensified. In addition, to the team working on the research described in this report, a number of IHEP researchers are now based at DESY including two IHEP scientists funded by the DESY-ONACPR program.

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?

In 2016, the joint research group did catch up on the program with the postdoctoral researcher and PhD student being appointed end of 2015. All milestones have been reached and the project is well on track.
All key contributions to the work packages have been completed. In the following the achievements of the three individual work packages are summarised.

WP1: Silicon micro-strip detector performance before and after irradiation:

In the reporting-period a dedicated study on silicon strip sensors was conducted within this work package: 30 prototype sensors of 1x1 cm^2 size (called ATLAS07-Mini-Sensors) were prepared and then split into three groups. A group of ten sensors was irradiated, the second group was irradiated and then underwent several thermal cycles. The last group of sensors was only thermal cycled. Each test consisted of 100 cycles between +50°C and -20°C, corresponding to the operation temperatures in the ATLAS detector. and emulating several years of ATLAS operation (accelerated ageing). Afterwards the sensor response was tested using a beta source followed by detailed study at the DESY electron test beam. During the test beam study, important parameters such as charge collection efficiency, electrical noise, signal to noise ratio and others were measured - the analysis and interpretation of the results is ongoing with promising initial findings.
In addition, a set of sample sensors were tested at the Diamond facility at RAL in the UK to investigate the bond-pads for the wire-bond connection on the sensor parameters. It was observed that the bond-pads have an impact on the charge collection efficiency in the region of the pads (see Figure 1). The observed effect is enhanced after irradiation. This has been reported at an international conference [1] and a publication of this observation is in progress [2].

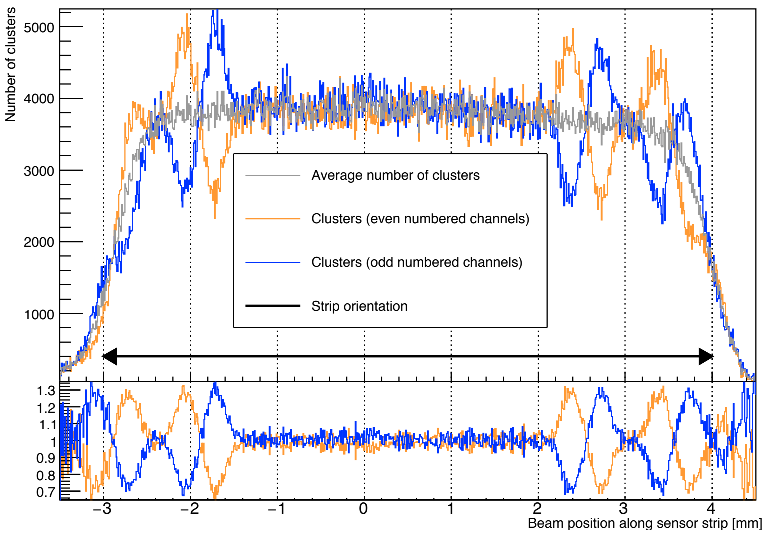

Figure 1: Number of clusters versus the beam position along the sensor. Clusters in even numbered channels and in odd numbered channels are different. It was shown that this effect is caused by the bond pads on the surface of the sensors [2].

WP2: Thermal effects

Within this work package the thermal effects on the sensors and modules are investigated, evaluating mechanical stability and detector performance before and after thermal cycling emulating the future operation life cycle of the full detector. In the reporting-period finite element analyses were conducted of the end-cap sensors and modules during the years of operation at the LHC simulating the thermo-mechanical behaviour. This included the emulation of the expected maximal temperatures and the entailed mechanical deformations and stresses within the module. The mechanical stresses are induced through different thermal expansion coefficients of the various materials needed for the module. These cannot be avoided and thus other parameters have to be used to reduce the overall effect. A dedicated study was conducted to understand the thermo-mechanical parameters close to the maximal mechanical stress allowed within the module.
The simulated results were confirmed by measurements with thermo-mechanical prototypes (see also WP3) to cross-check the degree of deformation at increased temperatures. Figure 2 shows an IR picture of a thermo-mechanical module demonstrating the temperature distribution on the surface of the module.
As these results are extremely important for the overall module design for the ATLAS ITk Detector, the study was extended to include piezo-resistive effects within the sensors to evaluate the effects on the surface resistors and capacitances.

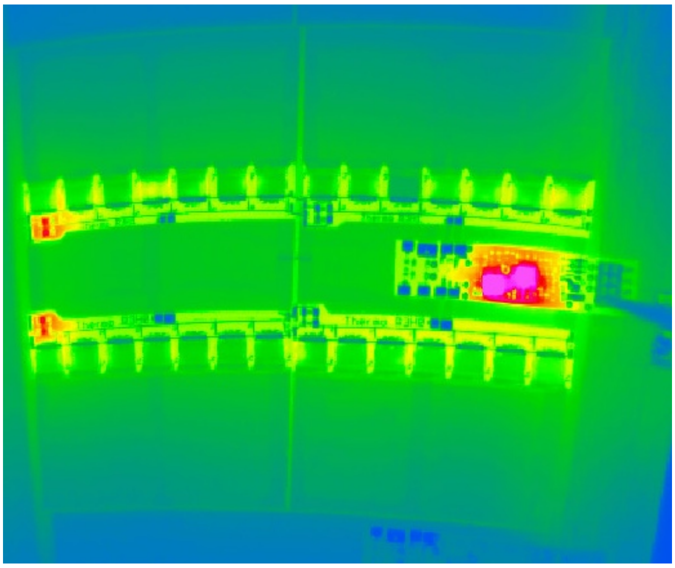

Figure 2: IR picture of a powered thermo-mechanical module.

WP3: Powering Decision

Within this work package systematic studies of different powering concepts for the silicon strip modules are conducted to provide input to further the challenging powering decision for the high and low-voltage technology choice for the future ATLAS tracking detector. Based on the work within this program, as well as other groups' work, the powering decision was already taken in the reporting year – well in advance compared to the original schedule. The silicon strip modules will be based on DC-DC low voltage powering as this technique has been proven to be more robust during a long-term operation as required at the HL-LHC.
Now, as an important extension of this study, the DC-DC powering needs to be implemented on system level by means of a "power board". A power board is a small circuit board housing the custom ASICS and peripheral electronics to be placed on surface of the silicon sensor. As this is located directly on the surface of the sensor the board has to be developed with care to

ensure a reliable operation during operation without harming the sensor.
In the reporting-year the joint research group worked on the development of a prototype power board for a thermomechanical module as also used for the studies described in WP1 and WP2 (see above). This includes a commercial DC-DC coil to supply simplified read-out chips to enable the thermal performance studies in WP2. Thermo-mechanical modules are simplified modules using instead of fully functional sensors only plates of silicon with the same thermo-mechanical behaviour as a final sensor, but no particle detection capabilities. This solution was chosen as these “dummy” sensors are much more cost effective and can be purchased on a short time scale. The particle detecting properties of the final sensors are not needed for these studies.
The thermo-mechanical modules include each a prototype power board, prototype hybrids with glass readout chips including a resistive layer to emulate the power dissipation of a real ASICs. The glue layer needed to attach the power board to the silicon surface can be seen as an insulating layer and thus has a direct impact on the thermal-mechanical performance and thus the layer thickness has to be optimised with care to ensure a good thermal connection while securing the power board on the surface during the full operation life time. The layer was varied to study impact of change from current baseline hybrid-to-sensor glue (Epolyte epoxy) to new UV-cured glue. Half of these modules were glued with the baseline glue, the other half with new UV curing glue. These studies are tightly coupled with WP1.
These studies are still ongoing and will be concluded in 2017.

4) Financial Plan / Time Schedule

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

The costs for personnel were fully used for the year 2016 as indicated in the project proposal. A number of smaller cost items of material required for the described research was purchased, but due to a delay in the ordering of very complex silicon strip sensors organised by the ATLAS collaboration a planned larger purchase could not be completed in 2016. This order has been submitted now at about 70kEUR are allocated for these sensors and additional thermal prototype sensors to be purchased in the first half of 2017.

5) Publications of the Group

[1] Presentation at an international conference: Luise Poley, DESY at the IEEE Nuclear Science Symposium Strasbourg, IEEE 2016
[2] Investigations into the impact of bond pads and p-stop implants on the detection efficiency of silicon micro-strip sensors (submitted, not published)

6) External Funding

- none -

7) Patent Applications

No. of pending/granted patents

- none -

8) Awards received by Group Members

- none -