

Annual Report

<b>Funding Programme:</b>	Helmholtz Young Investigators Groups
<b>Project ID No.:</b>	VH-NG-1103
<b>Project Title:</b>	Search for dark matter and other new physics with the Higgs boson at the ATLAS experiment
<b>Group Leader:</b>	Dr. Sarah Heim
<b>Helmholtz Centre:</b>	DESY
<b>Participating University:</b>	Hamburg
<b>Report Period (=Calendar Year):</b>	01/2018-12/2018

**1) Group Structure**

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

In addition to the existing group members, in September 2018 a new graduate student joined the group, so that the group now has 5 members:

group leader	Sarah Heim, since September 2016
postdoctoral fellow	William Leight, since October 2016
graduate student	Fang-Ying Tsai, since November 2016 (third year extension granted)
graduate student	Namgyun Jeong, since December 2016 (third year extension granted)
graduate student	Artem Basalaev, since September 2018

**Work areas during 2018**

Work on ATLAS data analysis

- Differential Higgs cross-sections in the  $H \rightarrow ZZ^* \rightarrow 4l$  channel: Sarah Heim, William Leight, Namgyun Jeong.
- $H \rightarrow \gamma \gamma^*$  (the second photon has an internal conversion to a pair of close-by leptons) search: Sarah Heim, Artem Basalaev
- $ll + MET$  search: Sarah Heim, Fang-Ying Tsai

Work on ATLAS detector performance

- improvements of the missing transverse momentum calculation: Sarah Heim, Fang-Ying Tsai
- electron identification and efficiencies: Sarah Heim
- muon software: William Leight

Work on ATLAS Upgrade (new inner silicon detector):

- strip module building: Sarah Heim, William Leight
- strip petal mechanical tests: Sarah Heim, Namgyun Jeong.

## 2) Network

*Please describe how you / your research group are integrated within the Helmholtz Centre and the partner university (e.g. as member of committees).*

The YIG is well integrated in the **DESY ATLAS group**. Some examples are below.

One of the topics of Kerstin Tackmann's group (former YIG) is differential cross-sections in the  $H \rightarrow \gamma\gamma$  channel (and since 2017 also in the  $H \rightarrow ZZ^* \rightarrow 4l$  channel). The differential cross section measurements fit very well to the  $H \rightarrow ZZ^* \rightarrow 4l$  projects of Sarah Heim's YIG, and the groups discuss in weekly meetings and collaborate on subprojects. Furthermore Artem Basalaev works closely with one of Kerstin's graduate students (Daniel Rauch) and one of her postdoctoral fellows (Kurt Brendlinger) on the search for the Higgs boson decaying into a photon and a pair of close-by leptons.

Close collaboration exists with the group of Beate Heinemann, who works also on the  $ll + MET$  search and has fellows and students on related analyses. Weekly meetings are held in this context and common projects are worked on. A student from Liverpool (Eloisa Arena) has started to work on the  $ll + MET$  analysis, under the co-supervision of Beate Heinemann and Sarah Heim.

Sarah Heim has recruited two DESY fellows to join her work in electron identification and efficiency measurements (Stefan Richter and Cyril Becot). While they are not direct members of the group, close collaboration exists. Since winter 2018, Cyril Becot is electron identification and efficiency subconvener.

Close collaborations also exist regarding the hardware work on the new ATLAS inner silicon detector ongoing at DESY, in particular with Sergio Diez-Cornell, whose student Alessia Renardi is working on module building together with Sarah Heim's group. A DESY fellow, Ruchi Gupta, has joined the effort on module testing. Collaboration also exists with people working on module building at DESY Zeuthen, in particular Ingo Bloch.

The members of the YIG take part in meetings and discussions with the **CMS and theory groups** at DESY.

Sarah Heim is a member of the **DESY scientific committee**, which is representative of the scientific staff at DESY. Its task is to advise the DESY Board of Directors on issues of fundamental scientific importance.

The **University of Hamburg** has granted the group leader the right to supervise and graduate PhD, master and bachelor students. In summer 2018 Sarah Heim taught 5 hours at a summer school organized by the University of Hamburg (Particles, Strings & Cosmology). Furthermore, in fall 2018, Sarah Heim joined CHAMPP, the Center in Hamburg for Astrophysics, Mathematical Physics and Particle Physics.

The YIG plays an active part in the **ATLAS collaboration**, through work and organizing roles in the Higgs, muon and missing transverse momentum performance groups, as well as the upgrade group.

## 3) Satisfaction

*How satisfied are you with the general working conditions provided by the Helmholtz Centre / partner university? Is there anything that meets your criticism?*

I am very satisfied with the conditions. The DESY ATLAS group provides a very supportive environment with people to talk to whenever I have questions or concerns, and a lot of opportunities for collaboration. The opportunity to do work on the new ATLAS inner silicon detector, afforded by the existing expertise and the DAF (detector assembly facility) is very exciting. The students benefit from the offered workshops, schools, and lectures by the Hamburg PIER graduate school.

#### 4) Scientific Progress / Milestones

*How has your work plan progressed? Which 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?*

All graduate students are **qualified authors** of the ATLAS collaboration. Namgyun Jeong's qualification work was signed off in spring 2018.

**Papers and public notes** were published in 2018. Will Leight and Sarah Heim played a leading role in the combination of the  $H \rightarrow ZZ^* \rightarrow 4l$  and  $H \rightarrow \text{gamma gamma}$  differential cross section measurements (**Phys. Lett. B 786 (2018) 114**). Will Leight and Namgyun Jeong contributed to the discovery of the Higgs boson production in association with two top quarks by performing background estimates in the  $H \rightarrow ZZ^* \rightarrow 4l$  channel. Sarah Heim was one of the editors of this paper (**Phys. Lett. B 784 (2018) 173**). Furthermore a public note was published with a projection study of the differential cross section measurements at the High-Luminosity LHC. Will Leight contributed to this study, which is part of a dedicated CERN Yellow Report (**CERN-LPCC-2018-04**). Furthermore, Sarah Heim was one of the editors of a paper about electron reconstruction and identification. This paper was submitted to EPJC.

Sarah Heim organized together with DESY colleagues a **3 day symposium** at DESY about Dark matter searches, co-funded by the Akademie der Wissenschaft Hamburg. The focus of the symposium was the complementarity of different approaches of dark matter searches: colliders, scattering and indirect searches. The symposium was attended by 90 participants, included keynote speakers and a Young Scientist Forum.

As in the last year, Will Leight served as ATLAS **muon reconstruction software convener**. Will Leight also continued his work as event selection and background contact by the  $H \rightarrow ZZ^* \rightarrow 4l$  group. Sarah Heim is contact person for questions regarding electrons in the ATLAS Higgs group.

Progress has been made by Sarah Heim and Will Leight regarding building and testing **prototype modules** of the new ATLAS inner silicon detector. Close collaboration with the wirebond experts was established. Sarah Heim also supported Sergio Diez Cornell's work regarding the commissioning of the new DAF (**detector assembly facility**, a class 6 clean room). The cleanroom is now in operation and used for prototyping and testing components for the new ATLAS Inner Tracker.

So far, the work agrees well with the original plan, with the addition of muon performance work, thanks to Will Leight's expertise. This fits very well, as all planned analyses have both electrons and muons in the final state. Furthermore the search for Higgs  $\rightarrow$  gamma gamma\* was taken on, instead of the search for dark matter decays of the Higgs boson in vector boson fusion production. The reason for this change is that the latter search is already well covered by other members of the ATLAS collaboration, while the search for Higgs  $\rightarrow$  gamma gamma\* is a new exciting effort of a small group of people, in which the graduate student can play a significant role.

#### 5) Financial Plan / Time Schedule

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

The current status is that both the financial plan and the time schedule can be complied with.

<b>6) Status</b> <i>Do you hold a joint Junior Professorship or a W2/W3 Professorship? Do you aim for such a position? What is the status of your negotiations in this respect?</i>
I do not hold a (junior) professorship, as this is not offered to YIG leaders by the University of Hamburg. In the future I do consider a habilitation at the University of Hamburg, but not currently.
<b>7) Teaching Activities of the Group Leader</b>
University of Hamburg Summer School on "Particles, Strings & Cosmology": 5 lectures on the Higgs boson
<b>8) Publications of the Group</b>
All members of the group are authors on publications by the ATLAS collaboration. Listed here are publications with significant contributions from the YIG.  The ATLAS Collaboration, Phys. Lett. B 786 (2018) 114 "Combined measurement of differential and total cross sections in the H->gamma gamma and the H->ZZ*->4l decay channels at $\sqrt{s}=13$ TeV with the ATLAS detector" Dataset: 36.1 fb-1 (13 TeV)  The ATLAS Collaboration, Phys. Lett. B 784 (2018) 173 "Observation of Higgs boson production in association with a top quark pair at the LHC with the ATLAS detector" Dataset: 36.1 - 79.8 fb-1 (13 TeV)
<b>9) External Funding</b>
Grant received from the Akademie der Wissenschaften for the organization of a three day colloquium about dark matter searches.
<b>10) Patent Applications</b> <i>No. of pending/granted patents</i>
No patent application was submitted.
<b>11) Awards received by Group Members / Professorship Appointments offered to Group Leader</b>
No awards/appointments were received.