

Annual Report

Funding Programme:	Helmholtz Young Investigators Groups
Project ID No.:	VH-NG-803
Project Title:	Approaching the Fundaments of Physics using Top Quarks at the LHC
Group Leader:	Yvonne Peters
Helmholtz Centre:	DESY/Hamburg
Participating University:	University of Manchester
Report Period (=Calendar Year):	01/2016-12/2016

1) Group Structure

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

My group currently consists of

- Cecile Deterre; postdoc, started 01.09.2012
- Ralph Schäfer; PhD student, started 01.10.2012 (currently on illness leave)
- Roger Naranjo; PhD student, started 01.07.2013
- Abigail O'Rourke, PhD student, started 01.09.2014
- Thomas Daubney, PhD student, started 01.08.2015

In addition, we were able to attract Desy fellows to work with our group:

- Jay Howarth, started in October 2013, finished end of December 2016
- Callie Bertsche (worked sparsely with my group in October/November 2016)

The main work of the group consists of two areas: data analysis at ATLAS and tracking/tracker related activities. Tom Daubney worked on EU telescope support to gain his ATLAS authorship qualification, and on CMOS sensor testing. The rest of the group concentrated mostly on analysis in 2016.

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 group is integrated into the ATLAS group at Desy, especially working closely together with the colleagues working on CMOS activities. My team participates in the common meetings and discussions.

The group is well connected with my team at the University of Manchester, by having weekly common „top team meetings“ and working on complementary but similar topics. Since the two current PhD students (Roger Naranjo and Ralph Schaefer) will graduate at the University of Wuppertal, together with a University professor (P. Mättig) and myself, we also do regular meetings with P. Mättig. Within the University of Manchester, the group leader is well integrated, including having several coordinatory roles (more details will be give in the teaching section).

The group is also well situated within the ATLAS collaboration, with all postdocs and the YIG being (or having been) editors of conference notes or papers. Furthermore, Jay Howarth was convener of the top quark cross section group until September 2016. Thomas Daubney is fully integrated into the CMOS-MAPS community for the ATLAS upgrade.

Thomas Daubney is member of the PIER graduate school.

Abigail O'Rourke is German-wide ATLAS PhD representative.

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 mostly satisfied with the working conditions at the Helmholtz Centre. There are a few issues though, which have some negative impact on my YIG. Since this is a public report, I will not write details here. It might make sense though to discuss them.

My team is fully integrated into the ATLAS group at DESY. Since my YIG at DESY runs out in 2017, I am supposed to not attract DESY fellows anymore to work with my group, which is not ideal. I am also satisfied with the conditions at the University of Manchester, where I am fully integrated into the particle physics group and the structure of the university.

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?

The project of my YIG consists of two parts: top quark physics and tracker upgrade-related work. Both projects proceed well.

The work on top quark physics consists of topics in top quark properties, top quark production and a search in the top sector. Several of the topics we work on at DESY overlap with the work of my ERC team based at the University of Manchester. Weekly common meetings of the whole team are conducted to allow optimal knowledge-exchange. Regular trips to CERN and external workshops are conducted by members of the team to get in touch with colleagues.

In 2016, the measurement of the $t\bar{t}$ charge asymmetry in dilepton events with 8 TeV ATLAS data was published. Roger was the main author for this analysis, which consists the main part of his PhD. This measurement contains many different variables and fiducial measurements.

Furthermore, the first measurement of the full spin density matrix of $t\bar{t}$ production has been performed and published in 2016. Dileptonic $t\bar{t}$ events were used for this analysis. Ralph and Roger performed this analysis together. It includes many new observables, that were not considered before.

Abby and Jay concentrated on the measurement of differential distributions in $t\bar{t}$ dilepton events using 13 TeV ATLAS data. This result has been published now, and contains many important distributions which can be used for MC tuning and to probe the consistency of perturbative QCD calculations with data. Currently, Abby works on an extended version of this measurement, including double differential distributions with the latest ATLAS data sample. The plan is that this analysis gets published in 2017.

Cecile works on the search for events with 4 tops in the same sign dileptonic final state. This final state is particularly interesting, as the standard model cross section is quite small, but various models of physics beyond the standard model enhance this cross section. In particular, we study a maximally symmetric two-Higgs-doublet model (MS-2HDM), which was developed by theorists in Manchester, with whom we are in contact. Cecile validated the Monte Carlo production of the model. Cecile is currently editor of the internal note, and a result is planned for the summer conferences in 2017.

In addition to coordinating and participating in the effort of my YIG, I also coordinate various efforts of top analyses of my ERC team based in Manchester. The analyses have large overlap in terms of selection and tools with the work of the team based at DESY. This includes

analyses on jet pull, ttH, ttbb, charged Higgs and ttZ.

Overall, the progress on the top quark-related analysis is very good, and mostly in accordance with the plan. Due to issues with manpower on the 4 top analysis, this work proceeds somewhat slower than foreseen.

Besides the involvement of the group in the data analyses in top quark physics, we are also involved in a multitude of topics related to tracking and the tracker upgrade in ATLAS.

Cecile and Abigail work on a project related to a sonar detector control system. In 2016, this work was mostly reduced to maintenance and shifts. Abby spend the first half of 2016 at CERN, which enabled her to do expert-on-call shifts for the system.

Since August 2015, PhD student Tom started to work on setting up a test stand for testing a CMOS chip. The project is done in collaboration with M. Stanitzki. The project is embedded in the efforts to study an alternative tracker, where the strip detector would be replaced by CMOS-strips. The main concern to be tested is the radiation hardness of the CMOS sensors. Tom also did an authorship qualification task on the EUTelescope, which is used for test beam studies and embeds him very well into the efforts of the DESY ATLAS group. He finished his authorship qualification, but still provides support for test beam users.

In addition to these activities, the group leader was chair of an editorial board in ATLAS and deputy chair of an editorial board in D0. Jay was also member of an editorial board in ATLAS. Furthermore, the group leader and Cecile are members of the D0 collaboration. Cecile is member of the D0 editorial board for top quark properties analyses. Jay served as convener of the top cross section group within ATLAS from October 2015 to September 2016.

In summary, we have adjusted the work plan of the original proposal slightly to work on timely top quark analyses. On top quark measurements, the process is very good and better than expected in the original proposal. The search in the top sector got somewhat delayed due to issues with manpower, but within the running of the YIG a result is nonetheless expected. The involvement in the tracker upgrade is according to plan.

5) Financial Plan / Time Schedule

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

Most of the resources allocated for the financial year 2016 have been used. Due to the underspend in previous years there is still some saving on the accounts though, which is planned to be sent within 2017. I had applied for a budget-neutral extension of my YIG until end of 2017, which will allow to spend the budget and finish off ongoing analyses.

6) Status

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 hold a position as Reader at the University of Manchester (I got a promotion from Senior Research Fellow to Reader in August 2016).

7) Teaching Activities of the Group Leader

1. Winter term 2016: First year tutorials at the University of Manchester.
2. Spring term 2016: Lecture on particle physics for 3rd year undergraduate students at the University of Manchester.
3. Spring term 2016: Example classes for the particle physics lecture.
4. Winter term 2016: Lecture on Frontiers of particle physics for 4th year undergraduate students at The University of Manchester.
5. From the beginning of the academic year 2015/2016 (in september 2014) I ran 1 MPhys projects (with a pair of 4th year undergraduate students working on each project) at the University of Manchester until May 2016. All students graduated with very good project-marks in June (both students went on to do a PhD in particle

physics).

6. Since September 2016 I run 2 MPhys projects (one with a pair of 4th year undergraduate students, one with a single 4th year undergraduate student) at the University of Manchester.
7. I took on a couple of BSc students in Manchester (I had 2 student so far on the topic „The hunt for dark matter“ and one on „Beyond the Higgs discovery“).

Furthermore, I was postgraduate coordinator for the particle physics group in Manchester until November 2016 (taking care of PhD and MSc administration and admissions for the whole experimental particle physics group, consisting of approximately 13 academics, and being member of the school-wide PG committee), and am academic exchange advisor for the School of Physics and Astronomy at the University of Manchester since September 2015 (advising undergraduate students who go abroad during their 3rd year, including advertising the programme to the students, performing information sessions and approving their course choices). I also regularly participate in UCAS interviews at the University of Manchester (general admission interviews for new undergraduate students) and participated as physics consultant at the open day of the University of Manchester.

For all students I taught during my first year tutorials, I am personal tutor until the end of their studies in Manchester (currently 15 students).

In Manchester, together with my team there I took on two summer project students. All 2 students finished their projects well.

In addition, several of my team members and myself participated in various outreach activities.

8) Publications of the Group

Publications with major own contributions:

- 1) ATLAS Collaboration, “Measurements of top quark spin observables in $t\bar{t}$ events using dilepton final states in $\sqrt{s}=8$ TeV pp collisions with the ATLAS detector”, accepted for publication in JHEP, arXiv:1612.07004.
- 2) ATLAS Collaboration, “Measurements of the charge asymmetry in top-quark pair production in the dilepton final state at $\sqrt{s}=8$ TeV with the ATLAS detector”, Phys. Rev. D94 (2016) 032006
- 3) ATLAS Collaboration, “Measurements of top quark spin observables in $t\bar{t}$ events using dilepton final states at $\sqrt{s}=8$ TeV with the ATLAS detector”, ATLAS-CONF-2016-099 (2016).
- 4) ATLAS Collaboration, “Measurements of top quark spin observables in $t\bar{t}$ events using dilepton final states at 8 TeV with the ATLAS detector”, ATLAS-CONF-2016-099.
- 5) ATLAS Collaboration, “Search for new physics using events with b-jets and a pair of same charge leptons in 3.2 fb⁻¹ of pp collisions at $\sqrt{s}=13$ TeV with the ATLAS detector”, ATLAS-COM-CONF-2016-036 (2016)
- 6) Cecile Deterre, Why stop at two tops? Search for exotic production of top quarks in final states with same-sign leptons and b-jets at 13 TeV, on behalf of the ATLAS Collaboration. Proceedings of a poster presented at TOP2016 to be published in eCONF [arXiv:1611.06767]
- 7) ATLAS Collaboration, “Measurements of top-quark pair differential cross-sections in the electron-muon channel in pp collisions at $\sqrt{s}=13$ TeV using the ATLAS detector”, (TOPQ-2016-04), arXiv:1612.05220.

- 8) Roger Naranjo, "Measurements of the charge asymmetry in top-quark pair production in the dilepton final state at $\sqrt{s}=8$ TeV with the ATLAS detector", arxiv:1701.01275
- 9) ATLAS Collaboration, "Search for the Standard Model Higgs boson produced in association with top quarks and decaying into a $b\text{-}\bar{b}$ pair in pp collisions at $\sqrt{s}=13$ TeV with the ATLAS detector", ATLAS-CONF-2016-080, August 2016.
- 10) ATLAS Collaboration, "Combination of the searches for Higgs boson production in association with top quarks $\gamma\gamma$, multilepton, and $b\text{-}\bar{b}$ decay channels at $\sqrt{s}=13$ TeV with the ATLAS Detector", ATLAS-CONF-2016-068, August 2016.
- 11) ATLAS Collaboration, "Measurements of top-quark pair differential cross-sections in the lepton+jets channel in pp collisions at $\sqrt{s}=13$ TeV using the ATLAS detector", ATLAS-CONF-2016-040, August 2016.

In addition, several analyses, where one of the team members was editorial board chair of member, were published in refereed journals in 2016 (not listed). Furthermore, Cecile and myself are authors of all D0 publications from 2016, and Cecile, Jay, Roger, Ralph, and Abigail are authors of all ATLAS publications in 2016. Since fall 2016, Tom is also officially ATLAS author.

9) External Funding

No YIG-related additional external funding was acquired in 2016.

10) Patent Applications

No. of pending/granted patents

No patents were applied for during 2016.

11) Awards received by Group Members / Professorship Appointments offered to Group Leader

The group leader already has a tenure track position of a W2-equivalent at the University of Manchester.

Jay Howarth won the 3rd prize for his poster at the Top2016 conference.