

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):	01/2015-12/2015

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
- 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
- Nicholas Bedford, PhD student, started 01.10.2015

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

- Jay Howarth, started in October 2013
- Alberto Gascon, started in November 2014

The main work of the group consists of two areas: data analysis at ATLAS and tracking/tracker related activities. During 2015, Abigail O'Rourke dedicated about half her time on both projects, while the rest of the group members concentrated more on data analysis in the top quark sector. Jay Howarth dedicated a major fraction of his time on fast track trigger activities. Alberto Gascon spent most of his time on silicon tracker related activities. Tom Daubney started to work on testing CMOS sensors for the ATLAS upgrade.

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 fully integrated into the ATLAS group at Desy, especially working closely together with the colleagues working on simulation for the ATLAS upgrade, SCT and 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, Cecile Deterre was convener of the top properties group until October 2015, and Jay Howarth was made convener of the top quark cross section group in September 2015. Thomas Daubney is fully integrated

into the CMOS-MAPS community for the ATLAS upgrade.

Thomas Daubney and Nicholas Bedford are both members 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 satisfied with the working conditions at the Helmholtz Centre. My team is fully integrated into the ATLAS group at DESY, while allowing autonomous working conditions at the same time. 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 2015, the $t\bar{t}$ charge asymmetry in dilepton events of 7 TeV ATLAS data was published, on which Cecile was main editor. Roger focused on the continuation of this analysis in 8 TeV data, where additional variables were considered and a fiducial measurement was added. Furthermore, several differential distributions were included. The 8 TeV charge asymmetry analysis is currently in the last stages of ATLAS-wide review, with the paper about to be submitted (in March or April 2016).

Ralph focused on the analysis of the full spin density matrix of dileptonic $t\bar{t}$ events, using 8 TeV ATLAS data. The analysis includes several new observables, that were developed a part of an STA of theorist W. Bernreuther. During 2015, optimization studies of the unfolding were performed, and the analysis was mostly completed. Currently, the analysis is in ATLAS-wide review, with the publication planned for 2016.

Jay concentrated mainly on the first analysis of the new 13 TeV ATLAS data we got in 2015 (LHC was switched on with this new energy in spring 2015). Jay worked together with Abigail on these analyses. The analysis of the first $t\bar{t}$ distributions and the subsequent first measurement of $t\bar{t}$ cross sections at this new energy were highlights at the summer conferences in 2015, and published in a conference note in fall 2015. Currently, Abigail and Jay work on analysing the full 2015 data sample, measuring differential distributions in dileptonic $t\bar{t}$ events. The analysis is currently in review, with a publication planned for 2016. This analysis is part of the thesis project of Abigail.

Cecile, Alberto and since October also the new PhD student Nick work 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. Alberto and Cecile validated the Monte Carlo production of the model. Nick started to get familiar with the framework, performing cross

checks off the background modeling in 13 TeV data. The plan is to perform a first analysis in 2016, with optimization of new variables later on.

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. In particular, I was involved in the first measurement of colour flow using jet pull, published in 2015, and measurements of $t\bar{t}b\bar{b}$ cross sections in semileptonic events as well as the search for heavy charged Higgs in the MS-2HDM.

Overall, the progress on the top quark-related analysis is very good, and in accordance with the plan.

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. Various changes to the software and tests of the system were performed in 2015. Abigail got qualified as ATLAS author for her project at the end of 2015. Alberto spent most of his time on working on the calibration loop of the SCT. Jay was very involved in fast track trigger (FTK) work. Cecile, Jay and Alberto took regular shifts at CERN. Ralph spent the beginning of 2015 at CERN, taking control room shifts and participating in operations.

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 started 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.

In addition to these activities, the group leader was member of an editorial board in ATLAS and 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. Cecile was serving as convener of the top quark properties group within ATLAS from September 2014 to November 2015, and Jay became convener of the top cross section group within ATLAS in October 2015.

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 earlier issues with employing a PhD student, but we are now also well on track with it. The involvement in the tracker upgrade is according to plan, and got a new boost with the employment of new PhD student Tom on the CMOS project.

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 2015 have been used. Due to the underspend in previous years there is still some saving on the accounts though.

The finance plan does not require an adjustment though. Due to the delay in PhD starting dates in previous years I will have to apply for an extension of half a year of my YIG after the end of the 5 years.

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 Senior Research Fellow (equivalent W2; tenure track) at the University of Manchester.

7) Teaching Activities of the Group Leader

1. Spring term 2015: First year tutorials at the University of Manchester.
2. Spring term 2015: Lecture on particle physics for 3rd year undergraduate students at the University of Manchester.
3. Spring term 2015: Example classes for the particle physics lecture.
4. From the beginning of the academic year 2014/2015 (in september 2014) I ran four different MPhys projects (with a pair of 4th year undergraduate students working on each project) at the University of Manchester until May 2015. All students graduated with very good project-marks in June (6 out of these 8 students went on to do a PhD in particle physics).
5. Since September 2015 I run one MPhys project (with a pair of 4th year undergraduate students) at the University of Manchester.
6. Since September 2015 I take on BSc students in Manchester (I had 1 student so far on the topic „The hunt for dark matter“).

In addition, I finished the New Academics Programme (NAP) at the University of Manchester in January 2016 with the best possible grade ‚excellent‘. This was a crucial step towards passing probation.

Furthermore, I am postgraduate coordinator for the particle physics group in Manchester since spring 2015 (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 10 students).

At DESY, my team participated actively in the DESY summer student programme, with 2 projects being offered and run by us. In Manchester, together with my team there I took on two summer project students. All 4 students finished their projects well, with the three students that are finishing their undergraduate programmes this year applying for a PhD in particle physics.

Furthermore, several of my team members and myself participated in various outreach activities (e. g. I gave a talk at a school in Manchester, Roger participated in the DESY open day, etc.).

8) Publications of the Group

Publications (with major own contributions):

- 1) R. Naranjo, Proceedings on “Top Physics in ALTAS”, on behalf of the ATLAS collaboration, Lomonosov conference, Moscow, January 2016, [arXiv:1603.06203 [hep-ex]].
- 2) ATLAS Collaboration, “Measurement of colour flow with the jet pull angle in ttbar events using the ATLAS detector at $\sqrt{s}=8$ TeV”, Phys. Lett. B. 750, 475-493 (2015).
- 3) ATLAS Collaboration, “Measurement of the charge asymmetry in dileptonic decays of top quark pairs in pp collisions at $\sqrt{s}=7$ TeV using the ATLAS detector”, JHEP 05,

061 (2015).

- 4) ATLAS Collaboration, ``Measurements of the $t\bar{t}$ production cross-section in the dilepton and lepton-plus-jets channels and of the ratio of the $t\bar{t}$ and Z boson cross-sections in pp collisions at 13 TeV with the ATLAS detector'', ATLAS-CONF-2015-049, September 2015.
- 5) C. Deterre, Proceedings on "Top mass measurements at the Tevatron", on behalf of the CDF and D0 Collaboration, Ischia, Italy, September 2015, PoS(TOP2015)036.
- 6) Y. Peters, Proceedings on ``Top Quark Pair Production Cross Section at the Tevatron'', on behalf of the D0 and CDF collaborations, EPS2015, Vienna, Austria, July 2015, [arXiv:1509.07629 [hep-ex]].
- 7) ATLAS Collaboration, ``Measurement of the $t\bar{t}$ production cross-section in pp collisions at 13 TeV using emu events with b-tagged jets'', ATLAS-CONF-2015-033, July 2015.
- 8) ATLAS Collaboration, ``Event Kinematic Distributions in Top-Quark Enriched Samples from 13 TeV pp Collisions in the ATLAS Detector'', ATLAS-COM-PHYS-2015-612, July 2015.
- 9) Y. Peters, proceedings on ``Recent Results of Top Quark Physics from the Tevatron'', on behalf of the D0 and CDF collaborations, Rencontres de Blois, Blois, France, June 2015, [arXiv:1507.02422 [hep-ex]].
- 10) M. Alhroob et al., „Development of a custom on-line ultrasonic vapour analyzer and flow meter for the ATLAS inner detector, with application to Cherenkov and gaseous charged particle detectors“, JINST 10 (2015) no.03, C03045.

In addition, several analyses, where one of the team members was editorial board chair or member, were published in refereed journals in 2015 (not listed). Furthermore, Cecile and myself are authors of all D0 publications from 2015, and Cecile, Jay, Roger, Ralph and myself are authors of all ATLAS publications in 2015. Since fall 2015, Abigail and Alberto are also officially ATLAS authors.

Public talks at conferences and seminar talks:

- 1) J. Howarth, "Early Run II results from ATLAS", DESY seminar, Hamburg and Zeuthen, Germany, November 2015.
- 2) Y. Peters, "Hot TOP(phys)ICS", Particle Physics Seminar, Bonn, Germany, November 2015.
- 3) C. Deterre, „Top mass measurements at the Tevatron“, on behalf of the CDF and D0 Collaboration, Top2015, Ischia, Italy, September 2015.
- 4) R. Naranjo, „Top Physics in ATLAS“, on behalf of the ATLAS Collaboration, 17th Lomonosov conference, Moscow, August 2015.
- 5) Y. Peters, "Measurements of $t\bar{t}$ production cross sections", on behalf of the CDF and D0 collaborations, EPS2015, Vienna, Austria, July 2015.
- 6) Y. Peters, "Recent top quark physics results from the Tevatron", on behalf of the CDF and D0 collaborations, Rencontres de Blois, Blois, France, May 2015.

- 7) Y. Peters, "Top Quarks: Selected TOPics at ATLAS", High energy physics seminar, Lancaster, England, May 2015.
- 8) J. Howarth, „Top Quark Properties (excluding spin and asymmetry)“, Topat2015, Fermilab, USA, March 2015.
- 9) A. O'Rourke, „Early dilepton ttbar cross section measurements at 13 TeV with the ATLAS experiment“, DPG spring meeting, Wuppertal, Germany, March 2015.
- 10) C. Deterre, „Entwicklung eines kombinierten Ultraschallflussmessers und Gasmischungsmessgeräts für das ATLAS Experiment“, DPG spring meeting, Wuppertal, Germany, March 2015.
- 11) R. Schäfer, „Measurement of ttbar spin correlations and top quark polarization at 8 TeV with the ATLAS experiment“, DPG spring meeting, Wuppertal, Germany, March 2015.
- 12) R. Naranjo, „Measurement of the ttbar charge asymmetry with 8 TeV ATLAS data“, DPG spring meeting, Wuppertal, Germany, March 2015.

In addition, Cecile presented the "LHC upgrade and ATLAS group report" to the DESY physics review committee in May 2015 at DESY.

Poster presentations at conferences:

- 1) J. Howarth, "First ttbar cross sections with 13TeV in ATLAS", Top2015, Ischia, Italy, September 2015.
- 2) A. O'Rourke, „Early dilepton ttbar cross section measurements at 13 TeV with the ATLAS experiment“, RAL summer school, Lancaster, September 2015.

9) External Funding

No YIG-related additional external funding was acquired in 2015.

10) Patent Applications

No. of pending/granted patents

No patents were applied for during 2015.

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.