Helmholtz Young Investigator Group VH-NG-303

Terascale Physics: From Datataking at LHC to Understanding at ILC

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Group Leader

Activity Report 2007

1 Introduction

The Young Investigator Group VH-NG-303 has started its work on May 1st 2007. During that year, in addition to the group leader, two Diploma students, three PhD students and one Postdoc have joined the group. Furthermore, members of the DESY ATLAS and ILC groups and the University of Bonn have joined the activities of the group as full time (S. Brunet, I. Marchesini, M. Uhlenbrock) or part time (N. d'Ascenzo, P. Schade) associated members. The activities of the group are centered at DESY and University of Hamburg, with two group members (C. Zendler[1] and M. Uhlenbrock[1]) being mostly in Bonn. In addition, individual group members are spending time at CERN in Geneva.

As of February 2008, the time of writing of this report, the following scientists and students are members of the young investigator group:

Members of the group		*Current task*
Dr. Philip Bechtle	Group Leader	involved in all activities
Dr. David Côté	Postdoc	τ Reconstruction, τ Infrastructure, Analysis
Gordon Fischer	PhD Student	Trigger configuration
Björn Gosdzik	PhD Student	τ performance analysis
Carolin Zendler[1]	PhD Student	ATLAS SUSY τ analysis
Michael Böhler	Diploma Student	ATLAS τ reconstruction development
Sebastian Johnert	Diploma Student	τ performance analysis
Associated Members of the Group		
Dr. Sylvie Brunet	Postdoc	Trigger configuration, τ performance analysis
Nicola d'Ascenzo	PhD Student	ILC analysis
Ivan Marchesini	PhD Student	ILC analysis, ILC Monte Carlo mass production
Peter Schade	PhD Student	ILC analyses
Mathias Uhlenbrock[1]	Diploma Student	Fittino SUSY parameter studies
University Partners		
Prof. R. D. Heuer	Univ. Hamburg	
Jun. Prof. J. Haller	Univ. Hamburg	
Prof. K. Desch	Univ. Bonn	

The main focus of the activities of the group lies on the commitments in the context of the ATLAS experiment at the Large Hadron Collider (LHC) at CERN, the secondary focus is the preparation for experiments at the future International

[1] co-supervised with Prof. K. Desch at the University of Bonn

Linear Collider (ILC). In addition, members of the group are involved in outreach activities and the finalization of work in the context of the BaBar experiment at SLAC and the LEP experiments at CERN.

In the next sections, the main commitments of the group are outlined, followed by detailed descriptions of the activities in the individual projects.

1.1 Commitments in the Context of the ATLAS Experiment

The ATLAS collaboration is setting up and running the ATLAS experiment at CERN. It currently consists of 167 institutes from 37 countries. Its main objective is the discovery of new fundamental structures of matter and its interaction, and solving the open questions around the nature of Dark Matter and the generation of elementary mass of elementary particles. The Young Investigator Group covers several highly visible key aspects of the operation of the detector, reconstruction of the data and analysis. These aspects include the commissioning and configuration of the Trigger, the reconstruction of τ Lepton final states and the analysis of events with τ leptons in the context of the Standard Model (SM) and Supersymmetry (SUSY).

1.2 Commitments in the Context of the Proposed ILD Experiment

The International Large Detector (ILD) is a proposed detector for the ILC. Since the precision physics foreseen at the ILC will call for detectors with unprecedented experimental resolution and very low material budget, the development of many new technologies is necessary. To get an idea of the optimal parameter space of such a new detector concept, physics studies based on fully simulated events are mandatory. The Young Investigator Group plays a central role in these analyses by providing the infrastructure for the event generation, simulation and reconstruction and by performing analysis itself.

2 ATLAS Trigger Configuration

The ATLAS Trigger consists of a three layer system, capable of handling the input data rate of the detector of 40 MHz and reducing it to an output rate of around 200 Hz without loosing important physics events. The first layer, called first level trigger, is realized in specialized custom-built electronics. The other two layers, the second level trigger and the event filter, are located in a computer farm with an anticipated number of around 10 000 CPU cores running several ten thousands of processes. The task of the group here is comprised of significant contributions to the reliable configuration of this system at the start of each run and during the run.

Group member G. Fischer has provided configuration tools for the trigger, which perform the loading of database setup information into the trigger electronics and into the trigger processes, and the monitoring of these transactions. The latter part is important to track problems and to reliably emulate the operation of the trigger when creating simulated events.

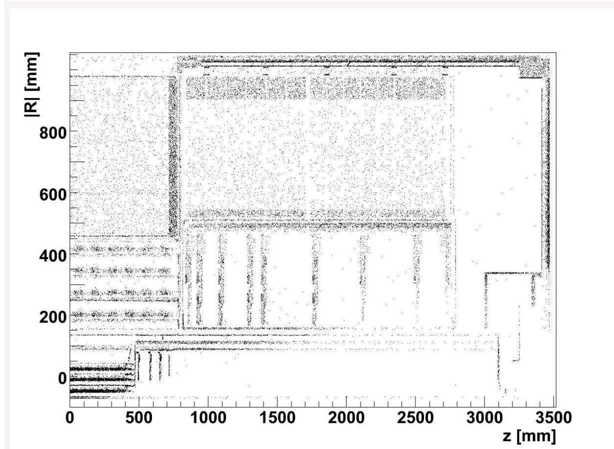


Figure 1: *Vertices of $\gamma \rightarrow e^+e^-$ conversions in the ATLAS detector. The distribution in the rz plane represents the material distribution in the ATLAS inner detector.*

Group member S. Brunet has provided the so-called Run Time Tester (RTT) for the trigger configuration. This tool runs the trigger configuration software for each individual version of the ATLAS software package and automatically checks for unintended deviations from previous versions of the software. This is essential to track errors in the code which do not show up on small scale tests but only with the full set of processes and information. In addition, S. Brunet is one of the on-call experts of the trigger configuration system and will represent the group during the start-up of the experiment at CERN in the summer of 2008.

3 ATLAS Tau Reconstruction

The efficient and precise reconstruction of hadronically decaying τ leptons in the ATLAS detector is of paramount importance for many analyses in the SM, SUSY and in the search for Higgs bosons. In order to develop and test the τ identification using simulated events or real data, a framework providing all necessary information for running the reconstruction and for performing various physics analyses is necessary. A new structure for such a framework, called DPD, has been realized for the first time in the ATLAS experiment by members of the group under the leadership of group members D. Côté and S. Brunet. It is now widely used by the ATLAS τ group and the basis for future development of algorithms as well as analyses to measure the performance of the identification and reconstruction. It has also been selected as the basis of the DPD development for other ATLAS physics groups.

Another key project of the group is the improvement of the τ reconstruction and identification itself. Group member M. Böhler has started the precise identification of the conversions of photons into electron-positron pairs inside the cone of the hadronic decay products of τ leptons, which effectively increase the number of reconstructed tracks of the τ decay. The identification of these conversions is important both for the correct identification of the τ leptons, because the background from hadronic jets is lower for a small number of tracks, and for the correct reconstruction of the number of tracks, which can be important for many physics measurements. An example of the distribution of simulated conversions, following the distribution of detector material, can be found in Fig. 1. Since this is an involved and complex analyses, several core software tools have been developed or improved to make the study feasible.

The τ reconstruction and ID algorithms have to be optimized in a different way for different physics purposes (SM, SUSY, Higgs, etc.), since the properties of the τ leptons (angular distributions, spins, momenta) are different, and because of different backgrounds. In order to identify and meet the needs of the different physics groups, group member B. Gosdzik has surveyed the different optimizations used in ATLAS and analyzed their properties. This project will continue through the further optimization of the analyses and algorithms to ensure the best tune of the τ reconstruction.

In addition, group member C. Zendler is working on the RTT for the τ algorithms, essentially fulfilling the same tasks as described for the trigger configuration in Section 2.

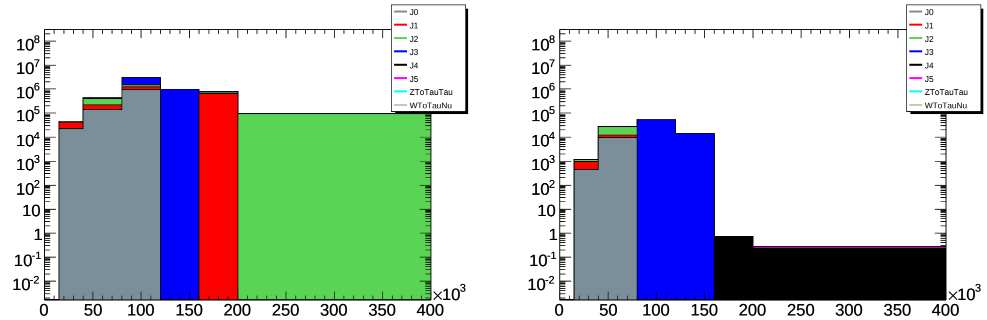
4 ATLAS Analyses

After the beginning of datataking with the ATLAS experiment later this year, one of the most important tasks will be the measurement of the properties of the detector and the reconstruction algorithms. For τ leptons this means that information about the τ energy and angular resolution, reconstruction and identification efficiency and about the fake rates from other objects have to be measured using real data. The preparation of these measurements, which are vital for many other analyses and potential discoveries, is one of the core activities of the group.

Group member S. Brunet has developed an analyses measuring the most important background for hadronically decaying τ leptons from data, namely hadronic jets falsely identified as τ leptons. This analysis, using simulated events as a replacement for the future data, is published in [1] and results of the fake rate analysis are shown in Fig. 2. This measurement is going to be on of the very first possible measurements regarding τ leptons at ATLAS.

After the fake rate analyses described above and once further luminosity (at least around $\int\mathcal{L} \approx 100\,\mathrm{pb}^{-1}$), the measurement of the efficiency and resolution of the τ identification from the real data is one of the next vital analyses. Results from the analysis of $Z^0 \rightarrow \tau\tau$ final states, along $Z^0 \rightarrow \mu\mu$ for comparison of group member S. Johnert are shown in 3. Using these results, the τ identification efficiency can be extracted relative to the μ identification efficiency.

The main goal of the ATLAS experiment is the discovery of new structures of matter. SUSY is one of the key candidates for such a new structure, explaining many of the theoretical and experimental deficiencies of the standard model and including dark matter. A large part of the favoured SUSY parameter space has a strong or even exclusive contribution of τ leptons in the final state. The Young Investigator group is currently involved in an analysis for the extraction of information about the SUSY parameter space using τ final states.



(a) (b)

Figure 2: *Distributions of the p_T spectrum of jet pairs in the ATLAS detector. In (a), the p_T spectrum of the probe jets before τ identification and in (b) the same spectrum after τ identification is shown. From the ratio of these distributions, the fake rates can be calculated. As it can be seen, the contamination from real τ leptons is negligible.*

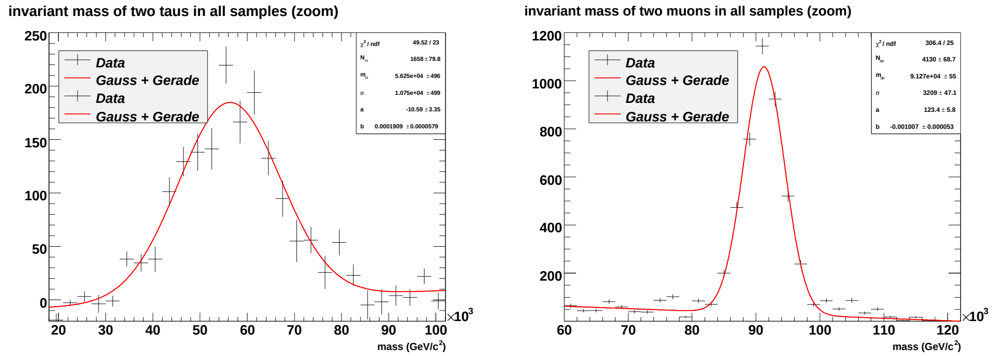
Group member C. Zendler is studying the measurement of observables sensitive to SUSY parameters, such as so-called edges in invariant mass distributions. Ultimatively, the results of the SM analyses presented above will be used to control the systematic uncertainties of this analysis. This analysis for the first time showed the correlation between different properties of the final state, such as τ helicity distribution and transverse momentum spectrum. Further analyses for a precise disentanglement of these properties have been started by members of our partner group at the University of Bonn. Fig. 4 shows the extraction of kinematic information from a typical SUSY final state. This analysis is published in [2].

5 ILC Analyses

The analyses in the context of the proposed ILD experiment are designed to gain further detailed understanding of the physics reach of ILC and to study the optimization of an ILC detector based on a combination of silicon and gaseous tracking and particle flow calorimetry.

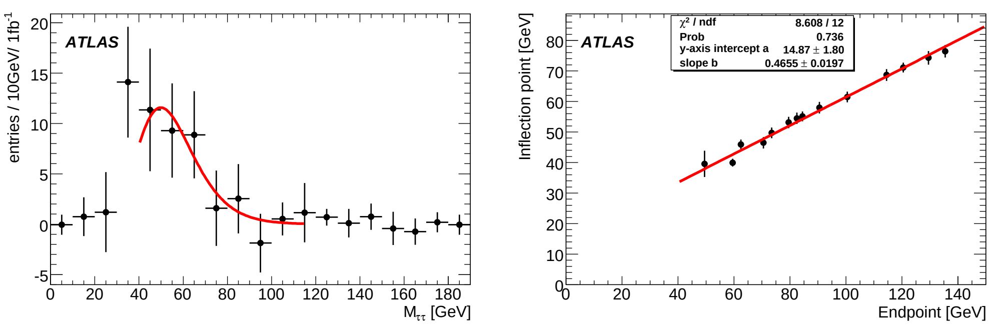
In order to do so, a large number of analyses is necessary, each in need of the same set of a large number (in the order of several millions) of fully simulated SM background events. Since the required amount of computing of around 30 CPU years cannot be handled by individual analysts or individual institutes, the Young Investigator Group is leading an international effort to use Grid computing for this task. Group member I. Marchesini is the main developer of the Grid interface tools.

Based on these efforts, three analyses are performed within the group. N. d'Ascenzo is working on an analysis for the SUSY process $e^+e^- \to \chi_2^0\chi_1^0 \to \mu^+\mu^-\chi_1^0\chi_1^0$, which is important for precision studies of SUSY masses and couplings and tests the muon identification and background rejection the forward region in



(a) (b)

Figure 3: *Distributions of the lepton-lepton invariant mass after the selection for $Z \to \ell\ell$. In (a), the $\tau\tau$ mass spectrum and in (b) the $\mu\mu$ mass spectrum is shown after opposite-sign minus same sign subtraction.*



(a) (b)

Figure 4: *Results of a measurement of the SUSY decay chain $\chi_2^0 \to \tau\tilde{\tau} \to \tau\tau\chi_1^0$. (a) shows the invariant mass of the $\tau\tau$ system, and (b) shows the relation between the inflection point of the curve in (a) and the true endpoint of the $m_{\tau\tau}$ spectrum.*

the detector. It is performed in collaboration with the Young Investigator Group of Dr. E. Garutti, working on calorimetry and muon identification in the hadronic calorimeter. The analysis of I. Marchesini measures the polarization of the e^+ and e^- beams individually using physics events from $e^+e^- \to W^+W^-$. This allows for an absolute calibration of the external beam polarization measurement and for a test of the particle flow performance of the detector. This analysis is done in cooperation with the Emmy-Noether Group of Dr. J. List, which is working on the external beam polarization measurement. Group member P. Schade measures the polarization of τ leptons in the SUSY events from $e^+e^- \to \tilde{\tau}^+\tilde{\tau}^- \to \tau^+\tau^-\chi_1^0\chi_1^0$, which is sensitive to the $\tilde{\tau}$ mixing and tests the tracking and beam background rejection performance of the detector. This analysis is performed in cooperation with the ILD tracking group at DESY.

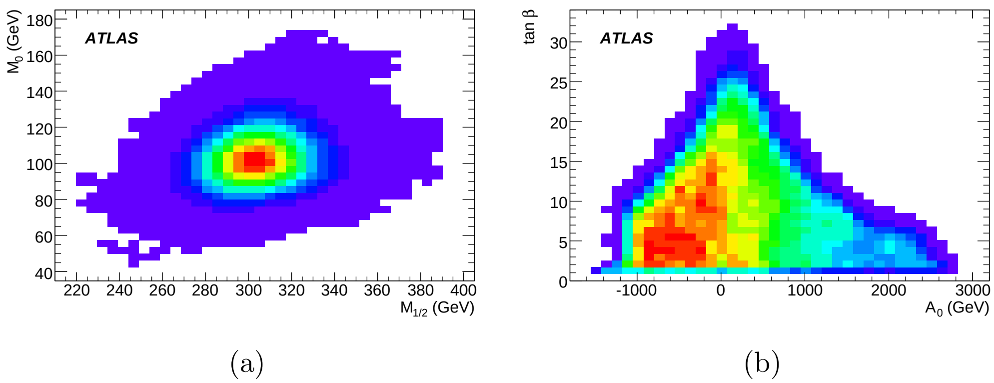


Figure 5: *Results of a Markov Chain MC analysis of the mSUGRA parameter space, using simulated measurements on* $10\,\mathrm{pb}^{-1}$ *of ATLAS data and assuming* $\mathrm{sign}\mu = +1$.

6 SUSY Parameter Determination

Once first measurements of new physics will be available, the main task will be to acquire information about the underlaying theory and the parameters of this theory from the observables. Together with the University partners in Bonn, the group is strongly involved in preparing these interpretations using the program Fittino [3], developed by members of the group. In addition, precision experiments at lower energies allow constraints of new physics already now, and the combination of the possible future observables with these low energy constraints is studied extensively. Results of a study of SUSY parameter determination using simulated first ATLAS data are shown in Fig. 5. Parts of this interpretation are published in [2]. A separate much more extensive publication is being prepared in addition.

The Higgs searches at LEP and at the Tevatron provide a strong constraint on new physics scenarios. However, for most analyses performed outside the LEP and Tevatron collaborations, the application of the model independent search results on a new model of new physics is not straightforward. In order to handle all statistical issues correctly and in order to combine the data in the most efficient way, the group is involved in the development of the program HiggsBounds, which will correctly and maximally sensitively determine whether any new physics model with Higgs bosons or Higgs like states is excluded by existing data or not. A publication [4] about this interpretation is in its final stages of preparation.

7 Other Activities

The group is strongly involved in outreach activities at DESY and the University of Hamburg. Group leader P. Bechtle is the coordinator of a project to equip schools in the vicinity of the DESY locations Hamburg and Zeuthen with detectors for cosmic rays, which can be run by teachers and pupils. A successful workshop at DESY for teachers has been organized and 4 detectors are currently in operation at DESY and different schools. Group member G. Fischer supports the project and the communication with teachers and pupils. In addition to that, the group is active in various other activities ranging from presentations about high energy physics for pupils and teachers to outreach activities for the general public.

In addition to his duty in the ATLAS τ reconstruction, D. Côté has been appointed as one of the coordinators of the ATLAS Reconstruction Integration, which is one of the core computing tasks of the ATLAS experiment, coordinating the development of online and offline software and ensuring the seamless cooperation of all software tools needed for detector operation and analysis. In this highly visible position D. Côté will represent the group at CERN during the first datataking of the ATLAS experiment.

Finally, some of the previous commitments of the group members have been finalized or published during their affiliation with the Young Investigator Group. Some of these activities are reported in [5]. Also, activities of S. Brunet and D. Côté in the context of the BaBar experiment have been published since the beginning of their affiliation with the Young Investigator Group in [6, 7].

References

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[2] ATLAS Collaboration, "Exclusive Measurements for SUSY Events with ATLAS at the Large Hadron Collider", in preparation (2008).

[3] P. Bechtle, K. Desch and P. Wienemann, "Fittino, a program for determining MSSM parameters from collider observables using an iterative method," Comput. Phys. Commun. **174** (2006) 47.

[4] P. Bechtle *et al.*, "HiggsBounds: a program for checking bounds from Higgs Searches at LEP and Tevatron for models with an arbitrary number of neutral Higgs bosons", in preparation (2008).

[5] P. Bechtle [BaBar collaboration], "Radiative $b \to d$ Penguins", arXiv:0705.4458 [hep-ex] (2007).

[6] S. Brunet, "Measurements of $|V_{ub}|$ at BaBar", Contribution to the Proceedings of the EPS HEP Conference 2007.

[7] S. Banerjee *et al.*, "Validating Geant4 versions 7.1 and 8.3 against 6.1 for BABAR", Contribution to the Proceedings of CHEP 2007.