Zwischenbericht (Sachbericht)

Fördermaßnahme: Helmholtz- (Hochschul-) Nachwuchsgruppen	
Förder-Nr.:	VH-NG-303
Titel des Vorhabens:	Terascale Physics: From Data Taking at LHC to Understanding at ILC
Federführender Wissenschaftler:	Dr. Philip Bechtle
Federführendes Helmholtz-Zentrum:	Deutsches Elektronen-Synchrotron DESY
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Beteiligte Universitäten und andere Partner:	Universität Bonn, Universität Hamburg
Berichtszeitraum:	01.01.2008 bis 31.08.2008

Helmholtz Young Investigator Group VH-NG-303

Terascale Physics: From Datataking at LHC to Understanding at ILC

Philip Bechtle
Group Leader

Activity Report 2008

1   Introduction

As of March 2009, 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 Infrastructure, Analysis, ATLAS Core Software
Gordon Fischer	PhD Student	Trigger configuration, τ performance analysis
Björn Gosdzik	PhD Student	τ reconstruction and performance analysis
Carolin Zendler[1]	PhD Student	ATLAS SUSY τ analysis
Michael Böhler	PhD Student	ATLAS τ reconstruction, SUSY Analysis
Associated Members of the Group		
Dr. Sylvie Brunet	Postdoc	Trigger configuration, τ performance analysis
Sebastian Johnert	PhD Student	τ performance analysis, ATLAS MC Generators
Mathias Uhlenbrock[1]	PhD Student	SUSY parameter studies, 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
University Partners		
Prof. R. D. Heuer	Univ. Hamburg	
Jun. Prof. J. Haller	Univ. Hamburg	
Prof. K. Desch[1]	Univ. Bonn	

As in the previous year, 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 Linear Collider (ILC). Here the preparation of a Letter of Intent (LOI) document [1] for the International Large Detector (ILD) Concept was the main focus. In addition, members of the group are active in developments of methods to determine the allowed parameter regions of New Physics models, especially in the context of Supersymmetry (SUSY).

During 2008, the group leader spent seven months at the University of Freiburg in the role of an interim Professor as a temporary replacement for Prof. Dr. K. Jakobs. Also, together with the University partner at the University of Hamburg, a new subproject within the Collaborative Research Project 676 of

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[1]Members of the university partner group of the University of Bonn

the DPG "Particles, Strings and the Early Universe" could be successfully acquired. The group leader also serves as one of the two co-speakers of the new subproject "Interpretation of Physics Results from LHC and other Experiments" and as co-speaker of the subproject "Physics beyond the Standard Model at the e^+e^- linear collider ILC".

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 YIG is a member of the ATLAS collaboration. 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 continues to cover 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, ATLAS Core Software maintenance and development, 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). Although the start up of the experiment has been moved from September 2008 to September 2009 after an incident with the LHC accelerator during commissioning, the preparations of the future measurements at ATLAS are still in full swing.

1.2 Commitments in the Context of the Proposed ILD Experiment

The main focus of the ILC activities was the preparation of the physics analyses for the LOI. Three analyses have been performed and included in the document. The performance goals of the detector were successfully met. The next steps will focus on using these analyses to characterize the dependence of the physics results on the machine design, in order to make sure that the machine parameters (e.g. beam backgrounds, energy spread) do not negatively affect the physics output unnecessarily.

2 ATLAS Trigger Configuration

The ATLAS Trigger consists of a three layer system, capable of handling the input data rate of the detector of $40\,\mathrm{MHz}$ and reducing it to an output rate of around $200\,\mathrm{Hz}$ 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. The trigger activities of the group focus on two main parts: The inclusion of the trigger information into the analysis data structures, especially the Event Summary Data (ESD), and the monitoring of the Trigger configuration.

The main task of group member Sylvie Brunet is the inclusion of the trigger information into the ESD at Tier0 processing, was not existing before September. This is mandatory information for all future analyses, where it will be necessary to know which triggers have been fired for which events and why. She also contributed to set up the trigger reconstruction at the CERN Analysis Farm (CAF) for the early data taking thru mode). In addition her task is to make sure that the trigger information (trigger decisions, trigger configuration, serialization and unpacking, offline monitoring) is working and propagated properly to experts and analysers (via ESDs, AODs, DPDs) when data are reconstructed at Tier0, just after data taking at Point1. This implies to follow closely Point1, Tier0 and trigger activities. In addition, the activities on the Real Time Tester (RTT) detailed in the last report have been continued.

Group member Gordon Fischer is working on the monitoring of the Trigger configuration in close cooperation with DESY Zeuthen and the Humboldt University in Berlin. Here the main task is to compare the Trigger setup as defined in the database with the Trigger information saved in the event data in the ESD (see above) and make sure that the intended configuration in the database has been transferred correctly to all components of the Trigger.

3   ATLAS Core Software

In 2008, group member David Côté has been focusing mainly on activities in the core software management of the ATLAS experiment. He served as a chair of the DPD task force, defining the data structures and tools for the Derived Physics Data (DPD) event format for the whole collaboration. This data format is expected to be the basis of most first performance analyses of the detector and many physics analyses.

After that, he has been appointed as ATLAS Prompt Reconstruction Operations Coordinator, responsible for the first pass reconstruction for alignment and monitoring, the data quality sign off and the bulk reconstruction of data. This involves the coordination of the use of the Tier0 GRID computing centre for the central ATLAS reconstruction and the coordination of the software releases used there. In addition, he is one of the main developers responsible for the integration of all analysis tools and reconstruction codes, also for different running conditions like cosmic data taking, single beams and collisions, into one main ATLAS reconstruction application.

This work is a very central part of the core ATLAS activities. Since beginning of 2009 it is supplemented by group member Michael Böhler, who is contributing to the release management of the ATLAS software.

The group has entered an new field of activities together with other members of the DESY ATLAS group, namely the handling of Monte Carlo Generators in the ATLAS software and especially the development of tools for the validation of the MC Generators. Group member Sebastian Johnert is one of the core developers of the HepMCAnalysis framework which can be used to check kinematic distributions of all kinds of all commonly used generators against each other in a simple way, including a web interface.

4 ATLAS Tau Reconstruction

One of the main activities of the group since it's beginning is the work on the reconstruction and identification of τ Leptons. Here the focus is lying on the development of a maximally simple and robust τ-Lepton identification for first data taking and on the more advanced reconstruction of photon conversions into electrons inside a hadronic τ decay.

The main task of group member Björn Gosdzik is the development of a so-called "safe" selection of hadronically decaying τ leptons against an overwhelming background of QCD jets. The main tasks are the identification of variables which are minimally dependent on noise or miscalibration in the calorimeter and on the details of the hadronic shower development in the calorimeter, and the tuning of the cut-based selection. The final selection has been implemented in the ATLAS software and is expected to be the main τ identification method for the data of the first one or two years of datataking. Current research focused on a detailed study of systematic uncertainties of the selection efficiencies and background rejection.

Once the ATLAS detector is going to be well understood, the reconstruction and identification of hadronically decaying τ leptons can be strongly enhanced in many respects. One possibility is the direct reconstruction and identification of conversions of photons from π^0 decays into a pair of an electron and a positron. CD Such decays distort the track spectrum and alter the properties of the τ jet towards those of the QCD jets. In addition, they are a nuisance for a possible estimation of the τ decay mode, which is an interesting observable for many New Physics studies (see e.g. [2]). The conversion reconstruction has been documented inside the ATLAS collaboration [3] and is going to be studied with first data using conversions in minimum bias events.

5 ATLAS Analyses

The fake rate analyses which has already been mentioned in the last report has been published in [4]. This analysis is going to be crucial to test the properties of the tau reconstruction and identification concerning its effects on the expected backgrounds. The ongoing work of the group members Sylvie Brunet and Mathias Uhlenbrock has shifted from the analysis itself to detailed studies of the required luminosities, starting with as little as $10\,\mathrm{pb}^{-1}$, the necessary triggers, the expected systematics and the disentanglement of quark jets and gluon jets.

In the same way as the fake rate analysis above is necessary for understanding the rejection rate of the background of the tau identification, the study of real τ leptons in data is necessary to control the selection efficiency. Group member Gordon Fischer therefore performs studies for an analysis of $Z \to \tau\tau\ell\,had$ events, where one τ lepton decays leptonically (providing a trigger and some help to suppress the QCD backgrounds) and the other one decays hadronically, which allows to test the reconstruction and ID. Also here the focus has been moved from the pure development of the analysis to detailed systematic studies. The focus of our group lies mainly on understanding effects of Opposite-Sign and Same-Sign τ pairs in the background, which is important for the background subtraction, and on understanding the differences in the kinematic selection efficiencies between

$Z \to \mu\mu$ (control sample) and $Z \to \tau\tau$ (signal) events.

During 2008, the group has ramped up the activities in the SUSY analysis sector. The main focus is still not the development of analyses for the early discovery of SUSY, but for the measurement of SUSY properties and the identification of SUSY among other candidates of New Physics.

Group member Carolin Zendler has extended her analysis to fully hadronic and semileptonic τ-pair final states [5] and re-optimized it for datataking at a centre-of-mass energy of 10 TeV. Using a luminosity of 200 pb^{-1} it could be feasible to get a first estimate of the neutralino and slepton mass scales. Also here the current focus lies on systematic uncertainties, which are partly similar to those in the $Z \to \tau\tau$ analysis due to the similar opposite- minus same-charge techniques. This analysis is also the basis of the development of a technique to measure the $\tilde{\tau}_1$ mixing from τ polarization [2].

Group member Michael Böhler is currently extending the di-τ analysis towards the combination of the τ-pair with other objects in the SUSY decay chain in order to measure more kinematic quantities. That is necessary if the SUSY scenario realized in nature is such that most of the decay chains end with τ-pairs and a neutralino, and not with other leptons. As mentioned in Section 7, such scenarios are strongly preferred by current data. The challenge here lies in the correct identification of the objects belonging to one decay change against large combinatorial backgrounds.

6   ILC Analyses

In the context of the ILD LOI, the following analyses have been performed. They are all aimed to test specific parts of the detector or the accelerator.

Group member Ivan Marchesini has finished a study of the measurement of the beam polarization in $e^+e^- \to W^+W^-$ events in the detector [6, 1]. This allows the calibration of the external polarimeters. Since many physics processes where the analysis makes use of the beam polarization (such as SM FB-Asymmetry analyses or analyses of the chargino and neutralino sector of SUSY) require a precise knowledge of the beam polarization in the order of a relative precision of 0.2 %, an efficient analysis is necessary to reach that level of precision with as little luminosity as necessary. A method involving the measurement of W production angle distributions has been developed which allows to reach the precision goal with around 200 fb^{-1} of data, and which allows to measure many different observables independently at the same time, while decreasing the systematic uncertainties from unknown triple gauge couplings (TGC). Currently this method is extended into a simultaneous measurement of TGCs and polarizations.

The analysis for the ILD LOI of Peter Schade measures the τ polarization in $e^+e^- \to \tilde{\tau}^+\tilde{\tau}^- \to \tau^+\chi_1^0\tau^-\chi_1^0$ events, which is the complimentary measurement to the one in [2] at ATLAS. A precision of around 10 % on the polarization has been reached and many detailed systematic studies have been done, which helped to set the bar for the necessary level of particle ID efficiency and $\gamma\gamma$ background rejection in the detector.

The LOI analysis of Nicola d'Ascenso for $e^+e^- \to \tilde{\mu}_L\tilde{\mu}_L$ and $e^+e^- \to \chi_2^0\chi_1^0$ production showed that given sufficiently high resolution in the tracking system

and a very clean muon ID in the muon system, the masses of $\tilde{\mu}_L$, χ_2^0 and χ_1^0 can be measured with sub-percent precision already in the continuum at a centre-of-mass-energy of 500 GeV. One focus here lies on disentangling dominant ($\tilde{\mu}_L\tilde{\mu}_L$) and subdominant ($\chi_2^0\chi_1^0$) production modes of an identical final state ($\mu\chi_1^0\mu\chi_1^0$), which was demonstrated successfully.

7   New Physics Parameter Determination

While many signals of possible New Physics, such as from Supersymmetry, are expected to be visible at LHC with as little as $1\,\text{fb}^{-1}$ of data (the equivalent of the first two years), the discovery of a low-mass Higgs boson might take considerably longer, and heavy Higgs bosons in many SUSY models might be entirely undetectable at LHC. This could create a situation during the coming years where the exploration of the parameter space of possible models of New Physics has to rely on the exclusion limits of Higgs Boson searches and not on a discovery.

The program HiggsBounds [7] performs this. For any given model involving (pseudo)scalars, it evaluates the published results from LEP and the Tevatron and determines whether the model point is excluded or not. In order to achieve the highest sensitivity, it determines whether the model point can be tested using the SM combinations of the experiments, which are very sensitive but only applicable to SM-like Higgs bosons, or whether the very general but slightly less sensitive model independent exclusion limits have to be used. Current activity centers on including the latest published results, make the SM-likeness test more elaborate and most importantly in calculating χ^2 contributions to fits of New Physics models from the confidence limits of the searches. This will allow to use the present Higgs searches as full inputs to any fit of a new Physics model

A lot of work has been gone into fits of SUSY models (mSUGRA, GMSB, general low-scale models in the MSSM) using a wide variety of data. First, Markov Chain MC have been used to explore the parameter space of high-scale models with various sets of existing observables from LEP, SLD, the Tevatron, cosmological observations, the B-factories and low-energy physics such as $(g-2)_\mu$. The two main results from these studies are that the preferred mass range of SUSY particles in such models is well in the reach of LHC and ILC, and that the current data prefers low a mass difference between the LSP and the NLSP, which could be important input for future LHC measurements and for the ILD design. In addition, methods for model discrimination at LHC have been developed and expectations for the increase in precision at ILC have been derived. A publication on this is going to be out soon.

6

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