Helmholtz Young Investigator Group VH-NG-303

Terascale Physics: From Datataking at LHC to Understanding at ILC

Philip Bechtle
Group Leader

Activity Report 2010

1 Introduction

As of March 2011, 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. Joao Costa	Postdoc	Analysis, ATLAS Core Software
Gordon Fischer	PhD Student	τ performance analysis
Dr. Björn Gosdzik	Ex. PhD Student	SUSY spin measurements
Michael Böhler	PhD Student	ATLAS SUSY Analysis, ATLAS Core Software
Mathias Uhlenbrock[1]	PhD Student	SUSY parameter studies, τ performance analysis
Sebastian Johnert	PhD Student	τ performance analysis, ATLAS MC Generators
Ivan Marchesini	PhD Student	ILC analysis, CALICE data analysis
Milan Zvolsky	Master Student	ATLAS SUSY Analysis
Almut Pingel	Diploma Student	ATLAS Analysis on τ fake rates
Björn Sarrazin	Diploma Student	SUSY Parameter Determination with Fittino
Associated Members of the Group		
Dr. Takanori Kono	Postdoc	SUSY Parameter Determination with Fittino
Dr. Nick Styles	Postdoc	ATLAS Analysis on τ fake rates
University Partners		
Prof. Dr. K. Desch[1]	Univ. Bonn	

In the year 2009, the main focus of the activities of the group lay on the commitments in the context of the ATLAS experiment at the Large Hadron Collider (LHC) at CERN.

ATLAS was taking data from March to November 2010, and again since March 2011. An integrated Luminosity of $\mathcal{L}^{int} = 35\,\mathrm{pb}^{-1}$ was analyzed by the collaboration and the group for various aspects of SM and New Physics measurements. In addition, the core software developed in the group has been further refined and used in large scale processing extensively. A more detailed record of these activities follows below.

The group is also involved strongly in project B8 within the DFG Collaborative Research Center SFB 676, which has been prolounged by the DFG for another 4 years in May 2010.

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

In addition to analyzing the data of the LHC, the group is very active in the field of the interpretation of the LHC data in accordance with precision data from many other experiments. The first results using parametrizations of LHC results have been prepared in 2010 and released in early 2011.

In February of 2011, the first PhD thesis supervised completely within the group, was defended successfully (in contrast to the previous PhD theses, which started before the start of this YIG, where the supervision was taken over within the YIG). In April 2011, two more diploma theses mainly provided in 2010 are expected to be handed in successfully, and more thesis defenses are expected in June 2011.

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.

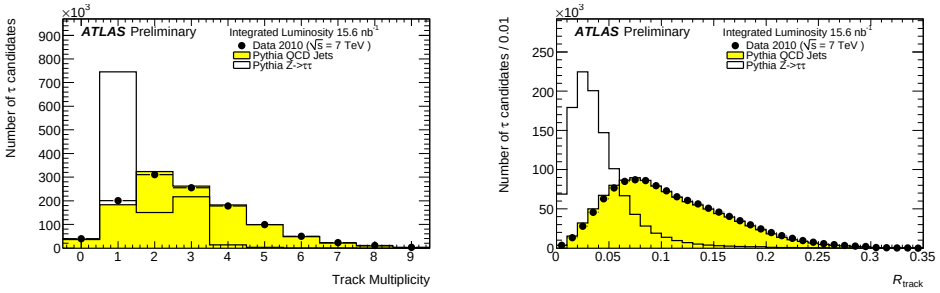
These aspects include the ATLAS Core Software maintenance and development, the reconstruction of τ Lepton final states and the analysis of events with τ leptons in the context of the Standard Model (SM) and Supersymmetry (SUSY). In the SUSY area, the emphasis has currently been shifted away from final states with τ leptons to states with electrons or muons, due to the higher sensitivity in the first data. The activities on the ATLAS trigger within the previous years have been successfully finished, and the main activity on the detector development is now entirely the core software and the physics analysis tools development.

1.2 Commitments in the Context of the Proposed ILD Experiment

The activities of the group in the area of the ILC concentrate on two aspects: First, the analysis of Triple Gauge Couplings (TGC), beam polarizations and involvement of a group member in CALICE. Second, the interpretation of LHC data in order to draw conclusions for the Linear Collider. For the first time in 2010, real LHC results are available for the latter task.

2 ATLAS Core Software and Physics Analysis Tools

In 2010, Michael B"ohler finished the development of the auto configuration tool [1] and presented it at international conferences, together with his contributions to the whole ATLAS processing chain [2]. It is used for all data and MC re-processing in ATLAS. The main thrust in the core software area then moved towards the Cut Flow Service, mainly developed and maintained by Joao Costa. This tool is necessary to keep track of the cuts used in the various steps of data processing, such that the final analyst of any analysis can understand the history of the processing of the given data or MC sample. Also this is used widely in the collaboration now.



(a) (b)

Figure 1: *Agreement between data and simulation for the τ lepton reconstruction in the ATLAS experiment. The data points selected from QCD events is in perfect agreement with the background simulation (full histogram). The signal (open histogram) shows a clear distinction from the background [3, 4, 5, 7].*

Group member Sebastian Johnert continued support of the HepMCAnalysis tool, used widely to compare settings within Monte Carlo Generators or Generators with each other.

3 ATLAS Analyses

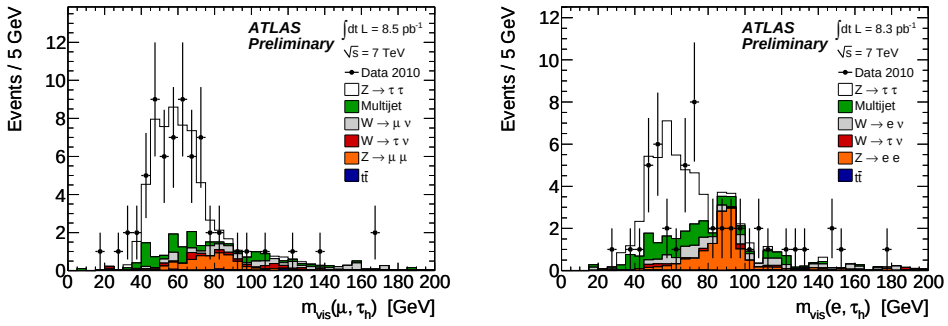
The analysis of the 2010 ATLAS data obviously was the dominating activity of the group. these activities [1], focused on τ leptons and SUSY, are briefly summarized below.

Before going into the details of the τ lepton reconstruction and ID properties, the focus of the work of group members Mathias Uhlenbrock and Bj"orn Gosdzik was lying on the basic understanding of the τ reconstruction and the possible ID variables [3, 4, 6]. An example of the very early results can be seen in Fig. 1. Many kinematic and discriminating variables have been scrutinized and compared with different MC tunes to understand the data, effects of quality cuts, and to understand how to best describe it.

After that, work shifted back to measuring the properties of the τ ID algorithms. Group members Almut Pingel and Nick Styles concentrate on the measurement of the misidentification probability of QCD jets as τ leptons from data. This measurement is far advanced, has lots of details in terms of detailed understanding of different jet origins and the effects of kinematical cuts, and is expected to be public very soon.

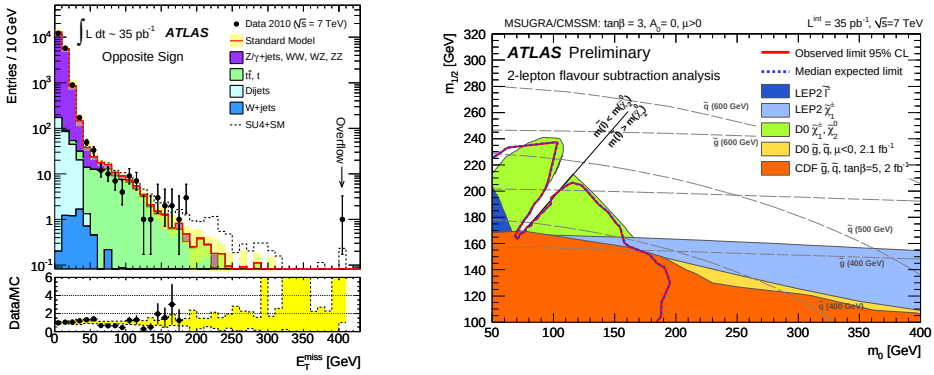
Group member Gordon Fischer concentrated on the discovery of $Z \to \tau\tau$ [8], which is shown in Fig. 2. Using only a part of the available data, a very clear discovery and good data-MC agreement is achieved. His work now concentrates again on extracting the τ ID efficiency using these events from data, which is also well progressed, but not yet public.

Group member Sebastian Johnert concentrates on $W \to \tau\nu_\tau$, also close to finalization. In his main contribution to the analysis, he uses his extensive experience from developing comparison tools for MC generators in order to extract uncertainties from the dependence of MC generators, pdfs and MC tunes on the



(a) (b)

Figure 2: *First measurement of Z^0 decays to 2 τ leptons in the ATLAS experiment for decays of the τ leptons in hadrons and a muon (a) and hadrons and an electron (b) [8].*

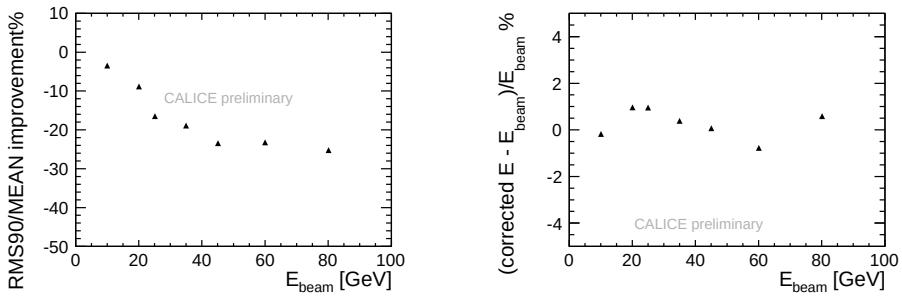


(a) (b)

Figure 3: *Results of the ATLAS search for SUSY final states with 2 leptons. In (a), the distribution of E_T^{miss} for events with opposite sign lepton pairs is shown. In (b), the non-observation of an excess of those events over the SM and after flavor subtraction is turned into an exclusion in the mSUGRA parameter space [9, 10].*

overall selection efficiency, needed for a reliable cross-section measurement.

The main thrust of the SUSY analyses of the group currently concentrates on various aspects of the SUSY searches with leptons [9, 10], and continues to include many methods of feature extraction, as a preparation of a possible signal. Group members Joao Costa, Michael B"ohler and Milan Zvolsky contribute strongly to performance measurements based on data, specific to the lepton ID in SUSY events, on the determination of systematic uncertainties, and on the optimization of cuts for different regions in the possible SUSY parameter space. The first public results of this effort are shown in Fig. 3. Unfortunately, a very good agreement between data and background expectation (the latter both based on MC and independently on data driven methods) is observed. With $\mathcal{L}^{int} = 35\,\mathrm{pb}^{-1}$ of luminosity, the Tevatron exclusion area is largely matched, expect for very heavy



(a) (b)

Figure 4: *Results of measurements of hadrons in the CALICE calorimeter, using a sophisticated leakage correction algorithm. In (a), the relative improvements in the uncertainty of the energy measurement of the shower are shown, while in (b) it is evident that the method introduces no bias on the mean of the measured cluster energies.*

squarks, where the Tevatron is more sensitive to direct gluino production.

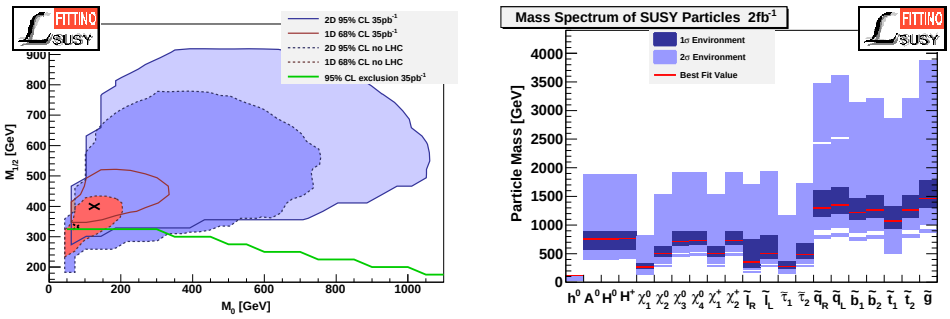
In parallel to this effort, group member Bj"orn Gosdzik has worked on two different methods to extract fundamental information about SUSY once it may be discovered: CP violation in the SUSY sector, and a direct measurement of the spin of intermediate particles in SUSY or Universal Extra Dimension (UED) decay cascades. While the further did not confirm the sensitivity of LHC predicted by phenomenologists [7], the latter is very promising and expected to be published soon.

4 ILC Analyses

In addition to finishing the simultaneously measurement of TGCs and beam polarizations, already published partly in the ILD LOI in 2009, the main activities of group member Ivan Marchesini shifted towards analysis of CALICE data. There, based on his previous experience with complex fits from his TGC and polarization analysis, developed a sophisticated correction algorithm to derive the amount of leakage of the tail of a shower after the back end of a highly granular calorimeter. Results from this algorithm and comparison to the previous reconstruction can be seen in Fig. 4. It can be seen that for higher cluster energies, a tremendous increase in resolution by up to 25% is achieved, while reducing the bias of the cluster energy measurements to almost 0. This result is expected to be published in a CALICE note very soon.

5 New Physics Parameter Determination

As in the previous years, the activities on data interpretation is concentrated on the HiggsBounds [11, 12] and Fittino [13]. In case of HiggsBounds, a new version containing many more Higgs search channels, mainly from the Tevatron, has been released, and preparations for a final and complete calculation of χ^2 contributions



(a) (b)

Figure 5: *Results of a fit of the mSUGRA model to precision data and parametrizations of first LHC results. In (a), the change in the allowed parameter space after including the non-observation of SUSY at the LHC is shown. In (b), the allowed mass ranges of the SUSY particles for an assumed non-observation of SUSY in* $\mathcal{L}^{int} = 2\,\mathrm{fb}^{-1}$ *is shown. In this case, the sparticles can evade direct detection, while only the lightest Higgs boson remains in the kinematically accessible region [13].*

from all search channels is currently close to release.

Group members Takanori Kono, Mathias Uhlenbrock and Bj"orn Sarrazin concentrate on the further development and physics applications of the Fittino framework. In addition to the development of new features (Genetic Algorithms, RooStats Workspaces, etc) and the further development of the treatment of ambiguities, the main effort is the inclusion of LHC analyses in the form of a re-implementation of the official analyses in a precise and fast detector simulation, such that in principle any model can be tested against the data. This is exemplified in Fig. 5. A very good agreement of our implementation compared to the public benchmark point analysis in ATLAS is achieved, and the results are used to perform a global fit of the precision data, cosmological measurements and the LHC parametrization in the mSUGRA model. In addition, projections in case of a further non-observation in 2011 and 2012 are provided. In this case, the exclusion of a light Higgs boson will be the only chance to exclude SUSY, since the overall χ^2/ndf of the fit of mSUGRA also for higher luminosity in the SUSY searches stays acceptable, yielding the non-trivial result that MSUGRA cannot be excluded by SUSY searches at LHC easily.

6 Other Activities

Also, as in the previous years, group members Philip Bechtle and Gordon Fischer have been strongly involved in setting up a cosmic ray detector for the use in high schools. The project is now fully integrated into a Germany-wide “Netzwerk Teilchenwelt” and run by DESY Physik Begreifen.

References

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