Helmholtz Young Investigator Group VH-NG-303
Terascale Physics: From Datataking at LHC to Understanding at ILC

Philip Bechtle
Group Leader

Activity Report 2009

1 Introduction

As of March 2010, 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. Sylvie Brunet	Postdoc	Trigger configuration, τ performance analysis
Dr. Joao Costa	Postdoc	Analysis, ATLAS Core Software
Gordon Fischer	PhD Student	Trigger monitoring, τ performance analysis
Björn Gosdzik	PhD Student	τ reconstruction and performance analysis
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
Almut Pingel	Diploma Student	ATLAS Analysis on τ fake rates
Björn Sarrazin	Diploma Student	SUSY Parameter Determination with Fittino
Members until the end of 2009		
Dr. David Côté	Postdoc	ATLAS Core Software
Dr. Nicola d'Ascenzo	Ex PhD Student	ILC analysis
Dr. Peter Schade	Ex PhD Student	ILC analyses
Carolin Zendler[1]	PhD Student	ATLAS SUSY τ analysis
University Partners		
Jun. Prof. Dr. J. Haller	Univ. Hamburg	
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. After the finalization of the Letter of Intent for the International Large Detector (ILD) experiment at the International Linear Collider (ILC) [1] in March 2009, the activities on ILC physics have been slightly reduced. In addition, studies on parameter determination for new physics models, especially Supersymmetry (SUSY), play a large role in the program of the group.

David Côté, who contributed strongly to the success of the group in the area of ATLAS Core Software development, left the group in February 2010 after his

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

tenure as ATLAS Prompt Reconstruction Organization Coordinator. His successes in his work in ATLAS are highlighted by the fact that his application for a CERN fellowship position was accepted, although he is not of origin from a CERN member state. He is replaced by Dr. Joao Costa.

Another focus of the work of the group was the preparation of a new proposal for a Collaborative Research Center of the DFG for the prolongation of SFB 676. The scientific evaluation was highly successful, and the final decision over the proposal will be taken by the DPG in May 2010.

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. In addition, the analysis of first data taken in November and December 2009, the commissioning of the core software under data taking conditions, and the validation of the Monte Carlo Simulations against the data were highlights of the work of the group.

1.2 Commitments in the Context of the Proposed ILD Experiment

After the finalization of the ILD Letter of Intent [1] in March 2009, the activities of the group have been focused more strongly towards the ATLAS experiment. Anyhow, a new study of the simultaneous measurement of Triple Gauge Couplings in WW events at ILC has been developed. Also, two PhD theses have been successfully defended: Nicola d'Ascenzo [2] (supervised in close collaboration with the YIG of Erika Garutti) and Peter Schade [3].

2 ATLAS Trigger Configuration

Group member Sylvie Brunet has been acting as a trigger configuration expert throughout her activities at CERN in the year 2009. She continued her responsibilities for the preparation of the trigger information during the data processing at the Tier0, and the inclusion of this data into the data format ESD, which contains

the fundamental reconstructed objects together with the trigger information. Together with this activity, significant contributions have been made to set up the trigger reconstruction on the CERN analysis farm for simulating the HLT, which is in pass-through mode for early data taking.

3   ATLAS Commissioning and Core Software

Group member David Côté worked as a post-doc in the group from September 2007 to end of February 2010, when he started a CERN Fellowship position. He served as a Prompt Reconstruction Operations Coordinator (PROC) from February 2009 to February 2010. As such, he is responsible for the whole software executed at the ATLAS Tier0, in particular for the reconstruction software, and has to overlook the data flow and availability of resources.

Numerous new features to automate and largely increase the flexibility of the Tier0 processing were developed, such as: externalize Tier0 configuration to AMI database filled by PROC, auto-configuration of the reconstruction software, and implementation of new "job transforms". Also, the Tier0 calibration loop was conceived and developed, which marks the transition from the commissioning phase to the factory mode aimed for physics data taking. In this mode, the express stream data is reconstructed at Tier0 withing roughly one hour after data taking, deriving calibration constraints, which then are fed into the bulk of the reconstruction of the physics stream data.

In 2009, five reprocessing campaigns have been performed using the Tier0. During those, the data and MC reprocessings have been gradually unified, notably via a new "Simplified Release Strategy". In addition, David also acted as software coordinator for the so-called "fast" reprocessings which used the Tier0 software.

Significant work was put into the continued development of RecExCommon (the ATLAS-wide reconstruction executable for production) to merge cosmics/collisions and data/MC scripts together into a single executable; add the production of Derived Physics Data (a format for which the first examples were written by members of the group in 2007 and 2008) in RecExCommon; and to invent a new data-driven auto-configuration mechanism and implement it.

In the same time, all the setup executables for reconstruction jobs used in production, the so-called "job transforms", have been re-wrote and unified. A lot of flexibility was added, which helped a lot for the fast code development during commissioning in 2009/2010. There is now a unified setup for Tier0, Grid ProdSys and normal users. Also, the "job transforms" are now used identically for data and MC and will now become the basis for all job transforms in ATLAS (simulation, digitization, etc.).

Group member Michael Böhler acted as a release coordinator for one of the three main software releases in ATLAS until end of March 2010. In addition, he has implemented the auto-configuration tool introduced above. It allows the efficient automatic configuration of reconstruction and simulation jobs. A sketch of this tool is displayed in Fig. 1. Without it, the python scripts controlling the job execution would have to know all beam and detector related settings, which is impossible in production. The autoconfiguration gathers automatically
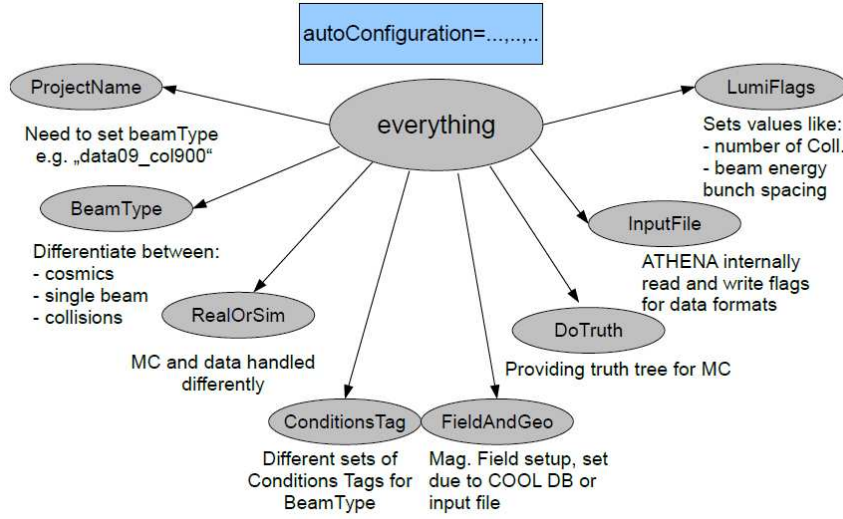
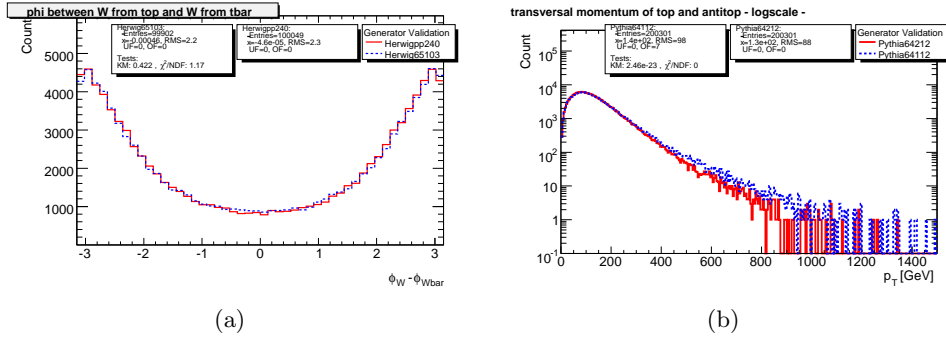Figure 1: *Overview over the setup controlled by the autoconfiguration.*

(a) (b)

Figure 2: *Examples of the validation histograms automatically produced by the HepMCAnalysis tool.*

all information from databases relevant for the reconstruction or simulation and configures the software.

Significant contributions to the validation of MC generators, both generally and in the context of the ATLAS experiment, have been made by Sebastian Johnert. He is one of the authors of the HepMCAnalysis tool [4], which allows to automatically compare all predictions of different generators. It is heavily used in the GENSER project and in the ATLAS experiment, where it is used as a part of the Real Time Testing (RTT) of the MC production. An example of the comparisons is shown in Fig. 2.

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
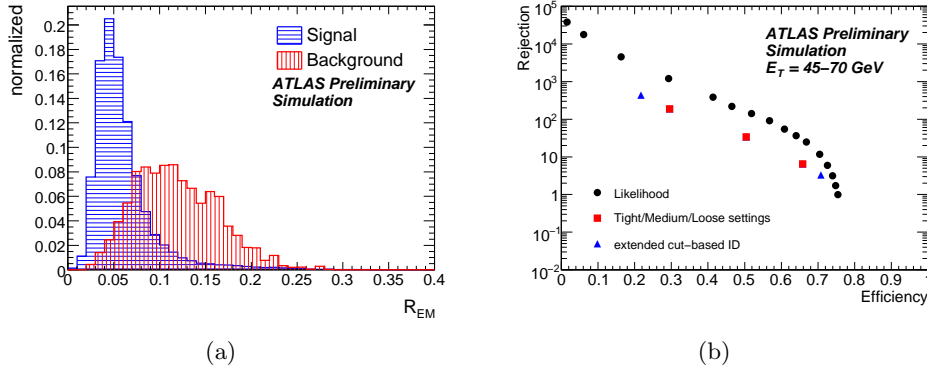
Figure 3: *(a) Example of a distribution of discrimination variables: Electromagnetic radius R_{EM}. (b): Resulting identification performance for τ leptons.*

data taking and on the more advanced reconstruction of photon conversions into electrons inside a hadronic τ decay.

Björn Gosdzik is responsible for the cut-based safe identification of τ leptons in ATLAS [5]. An example of the identification variables is shown in Fig. 3(a), the electromagnetic radius R_{EM} of the τ candidate. Using this and other variables and carefully optimizing them using a genetic algorithm to find the optimal set of cuts in a 4- or 8-dimensional variable space for candidates in different categories (number of prongs, transverse momentum), an impressive suppression of background jets from QCD can be obtained despite the simple rectangular cuts and the limited set of variables. The performance is shown in Fig. 3(b) for different efficiencies, and compared with the performance of a significantly more complicated likelihood selection. The safe cut-based ID is now used as a standard selection for τ leptons in the data of the ATLAS experiment, which is currently being collected.

5 ATLAS Analyses

The validation of the data and the path towards the first measurement of misidentification rates ("fake rates") using the data of the ATLAS experiment is one of the main current analysis targets of the group. Group members Sylvie Brunet, Almut Pingel, Mathias Uhlenbrock, Björn Gosdzik and Philip Bechtle contributed strongly to this field. With significant contributions from the YIG the first data-MC comparisons of τ candidates in the ATLAS data have been presented [6, 7]. Significant work has been put into understanding the data and the necessary cleanup cuts. In comparison both between data and MC (see Fig. 4) for different selections and also in comparison with the expected signal (see Fig. 3(a)), a very promising outlook for the observation of the first real τ leptons in ATLAS is obtained. The first measurement of fake rates of the τ identification is planned using the first 10 to $20\,\mathrm{pb}^{-1}$ of accumulated data.

In parallel to the actual analysis of the first data, preparations for the measurement of the efficiency of the τ ID using the process $Z \to \tau\tau$ are ongoing. An ATLAS-internal report about this analysis was prepared. Fig. 5(b) shows the expected mass spectrum of $\tau\tau \to \mathrm{had}\,\ell$ final states and the control channel $Z \to \ell\ell$,
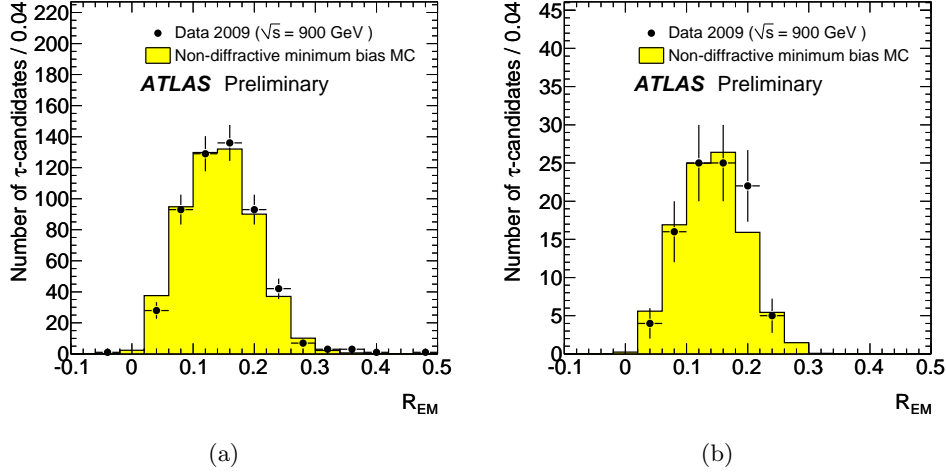
Figure 4: *Examples for the validation of τ selection variables using data collected with the ATLAS detector at $\sqrt{s} = 900$ GeV.*
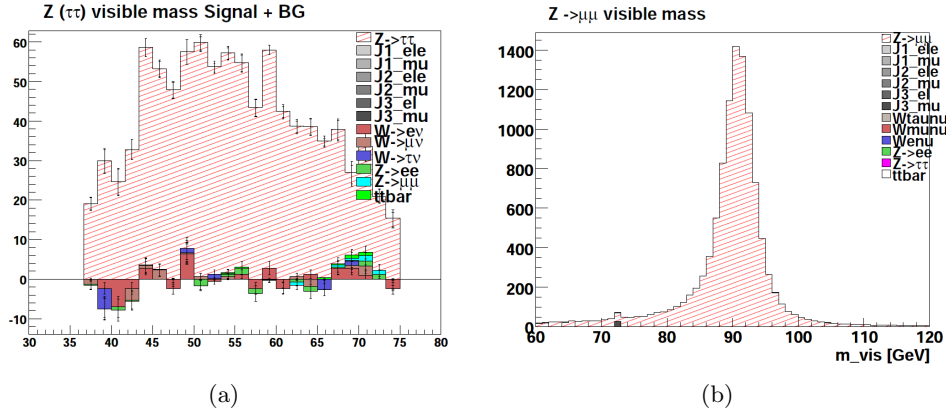

Figure 5: *Study for the selection of Z^0 decays for the determination of the τ lepton identification efficiency from data. In (a), the selected events from $Z \to \tau\tau \to$ had$\ell 1$ after background selection using data is shown. In (b), the normalization from $Z \to \ell\ell$ is shown.*

used for the normalization of the number of expected τ leptons. For this analysis, several techniques for the extraction of the efficiency have been developed, and many systematic studies of background subtraction schemes and the determination of the kinematical selection efficiencies have been presented. This analysis will be performed using the first $100 - 200 \, \mathrm{pb}^{-1}$ of data.

Together with the partner University in Bonn and a phenomenology-group at the University of Hamburg, the activities for measuring key observables of SUSY particle production and decay have been continued. Carolin Zendler has finalized her analysis in the context of the YIG by the inclusion of the safe τ ID into the analysis of the kinematic endpoint of the $m_{\tau\tau}$ spectrum of the process $\chi_2^0 \to \tau\tau\chi_1^0$ [8]. In parallel, Björn Gosdzik has started a project in close cooperation with Prof. Gudrid Moortgat-Pick of the University of Hamburg, which has the goal
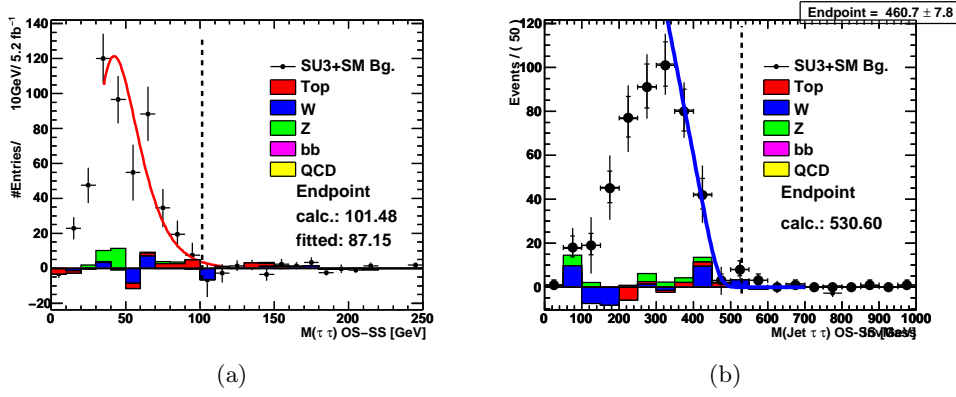
(a)	(b)

Figure 6: *Study for the measurement of SUSY properties with τ decays.*

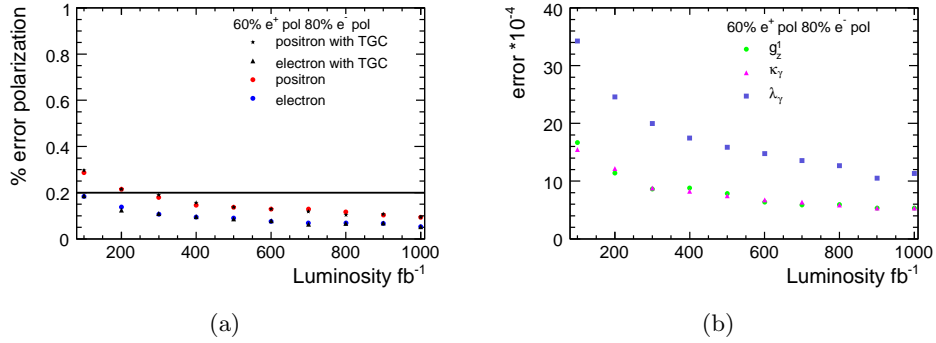|	
(a)	(b)

Figure 7: *Results of the study of the simultaneous measurement of beam polarizations in (a) and Triple Gauge Couplings in (b) for different luminosities at ILC.*

of the measurement of CP properties of SUSY particles.

Group member Michael Böhler has expanded the studies of the $m_{\tau\tau}$ endpoint studied above. For the first time, the feasibility of the measurement of SUSY masses in decays where all observable leptonic SUSY decays occur via τ leptons has been studied, showing significant precision if a proper calibration for the missing neutrino momentum is performed (see Fig. 6), but also the need for very high luminosity and 14 TeV of beam energy. Since these measurements are not feasible at $\sqrt{s} = 7$ GeV, the focus of Michaels thesis has been shifted to the precision analysis of $\chi_2^0 \rightarrow \ell\ell\chi_1^0$ final states, which show promising sensitivity using only $1\,\text{fb}^{-1}$ of data for SUSY scenarios with light squarks and gluinos.

All these SUSY studies will eventually, in case SUSY is discovered, provide key input into the SUSY parameter determination activities described below.

6 ILC Analyses

In the context of the preparation of experiments at the ILC, the group uses two analyses to probe the physics capabilities of the proposed ILD detector: the simultaneous measurement of beam polarizations and Triple Gauge Coupling (TGCs)
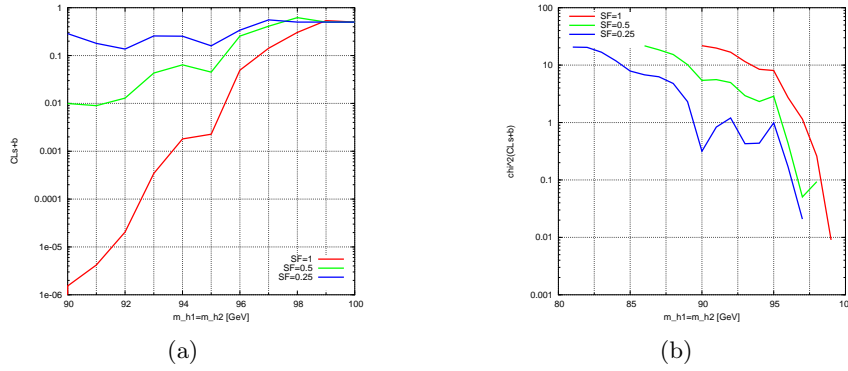
Figure 8: *Transforming the topological limits on Higgs bosons from LEP Higgs searches into χ^2 contributions. In (a), the observed CL_{s+b} for the topology $e^+e^- \to H_1 H_2 \to b\bar{b}b\bar{b}$ is shown as a function of the Higgs masses and $m_{H_1} \approx m_{H_2}$. In (b), the corresponding χ^2 contributions are shown.*

using $e^+e^- \to W^+W^-$ events [9], and the measurement of the τ polarization in $e^+e^- \to \tilde{\tau}^+\tilde{\tau}^-$ production [10]. While the former needs precision reconstruction of the hadronic and leptonic W decays, the latter focuses on very high demands on hermiticity, and cleanliness and precision of the tracking at low momenta. The TGC measurement is the first to explore the correlation of the TGC measurement with the measurement of the beam polarization from the same final state. As shown in Fig. 7, high precision is obtained for all observables using complex multidimensional fits. It could be shown for the first time that the measurements are only softly correlated and hence no deterioration of the TGC precision is obtained. While the TGC measurement is an important physics measurement in its own right, the measurement of the beam polarization will serve as a calibration of the external polarimeters.

7   New Physics Parameter Determination

In the context of the HiggsBounds project [11, 12], already introduced in the activity reports of the previous years, significant progress has been made both in the inclusion of more Higgs search channels as well as in the methodological development. For the use in global fits of new physics models, the existing published information from LEP and the Tevatron in terms of topological search results is not sufficient. The reason is the fact that for a given model prediction, only for an almost exactly SM-like Higgs boson it is known at exactly which confidence level the SM-like Higgs boson is allowed or excluded. For a model with generic Higgs sector, the previously available information only allowed to know whether the model was allowed or excluded at the $95\,\%\,CL$. Thus it is not possible to calculate a contribution to a χ^2 fit.

HiggsBounds now significantly improves this situation. For LEP searches, it will provide the exact confidence level at which each possible scenario with Higgs like states is allowed or excluded. An example for this is shown in Fig. 8, where in Fig. 8(a) the CL values for the $e^+e^- \to H_1 H_2 \to b\bar{b}b\bar{b}$ search at different masses
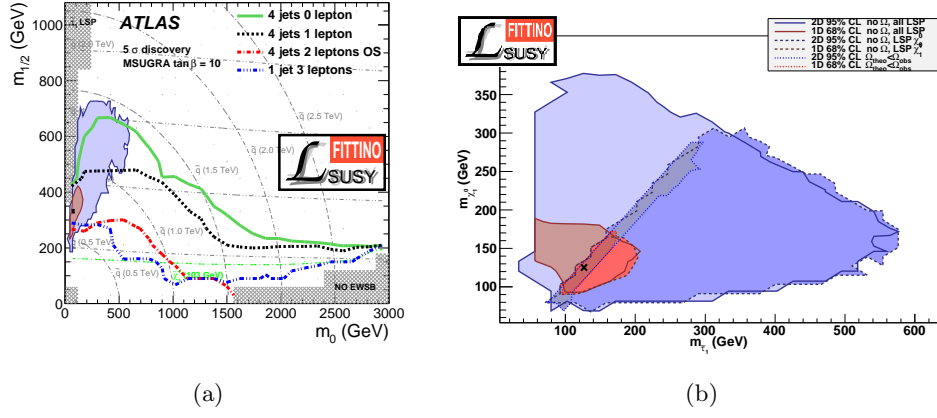
Figure 9: *Predictions for the mSUGRA parameter space using existing measurements in (a) and the allowed mass space for the NLSP and the LSP in (b).*

and values of $\sigma \times BR$ are shown, while Fig. 8(a) shows the corresponding χ^2 contributions. In the future, this is expected to be used in several projects of global parameter determination of new physics models.

In the context of the Fittino project [13, 14, 15], a large number of new results on SUSY scenarios using existing measurements has been produced. The available data highlight that for modes with assumptions on the SUSY breaking, the discovery of SUSY is expected soon at LHC, if SUSY is realized in nature. For the first time, a detailed analysis of the allowed space of SUSY masses has been performed. The predicted mass scale of the heaviest particles is below 1.6 TeV, hence in the range accessible by LHC (see Fig. 9(a)). In the same time, scenarios with challenging conditions for the precision reconstruction are predicted, with many τ leptons in the final state and small mass differences between LSP and NLSP (see Fig. 9(b)).

In the area of developments of possible fits including data of the LHC, significant progress has been made in the development of fitting techniques and statistical methods. For the first time, a method to calculate confidence levels for the identification of the settings of digital parameters, model choices or for the interpretation of observables (i.e. for every discreet choice in the interpretation) has been proposed (see Fig. 10). It allows to determine the probability of how often one model will be experimentally preferred over another one (see Fig. 10(a)) or to what extend the uncertainty of the assignment between a prediction and an observable affects the precision of a parameter determination (see Fig. 10(b)).

Finally, studies on the ultimate reach of the precision determination of SUSY parameters also for models without assumptions on the SUSY breaking have been performed, both for expectations for high luminosity measurements at LHC and for ILC measurements. One comparison between the two is shown in Fig. 11, which depicts the precision of the possible postdiction of the dark matter relic density Ω_{CDM} using collider data. It can be observed that the result from ILC represents an improvement over LHC by more than one order of magnitude, allowing to precisely test the assumption of a possible LSP as dark matter constituent. Or maybe also as a test of the understanding of the primordial production of the LSP.
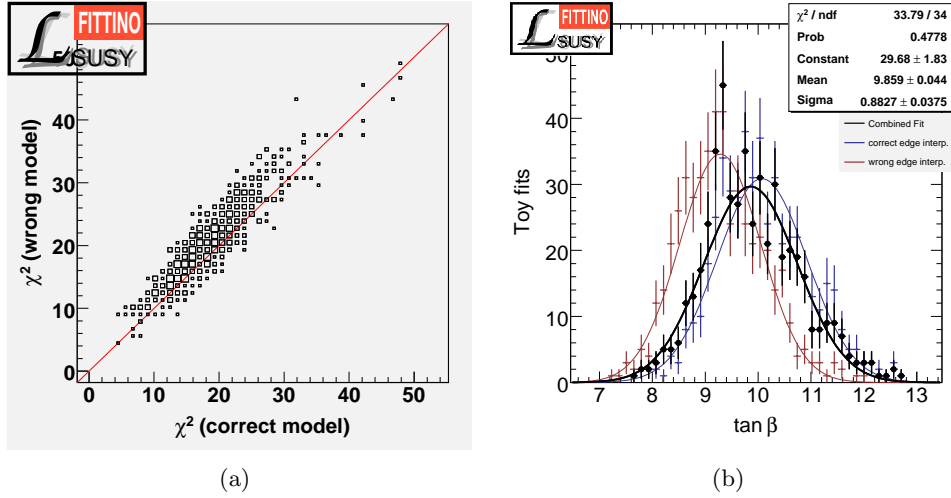
Figure 10: *Development of new techniques for model discrimination and treatment of ambiguities in the interpretation of observables: (a) shows the determination of the CL of the most probable interpretation of the observables. (b) shows the determination of the parameter uncertainty for* $\tan\beta$ *in the presence of ambiguities.*

8 Other Activities

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 has been integrated into a Germany-wide "Netzwerk Teilchenwelt". Together with a high-school teacher, proposals for the use of the detector in schools have been developed and new measurements (using the given detector), such as a measurement of the average speed of the cosmic ray particles, have been pioneered.

A new activity is the preparation of a possible Fixed-Target experiment at the DESYII accelerator, or also other electron accelerators, preferentially FLASH or even XFEL. This experiment, called HIPS (Hidden Particle Search) would be ideally suited to search for Spin-0 or Spin-1 bosons with quantum numbers identically to Higgs bosons or photons, but with almost negligible coupling to SM particles. These are strongly motivated in almost every generic GUT. The development of a signal generator and a simulation of the background has been started.
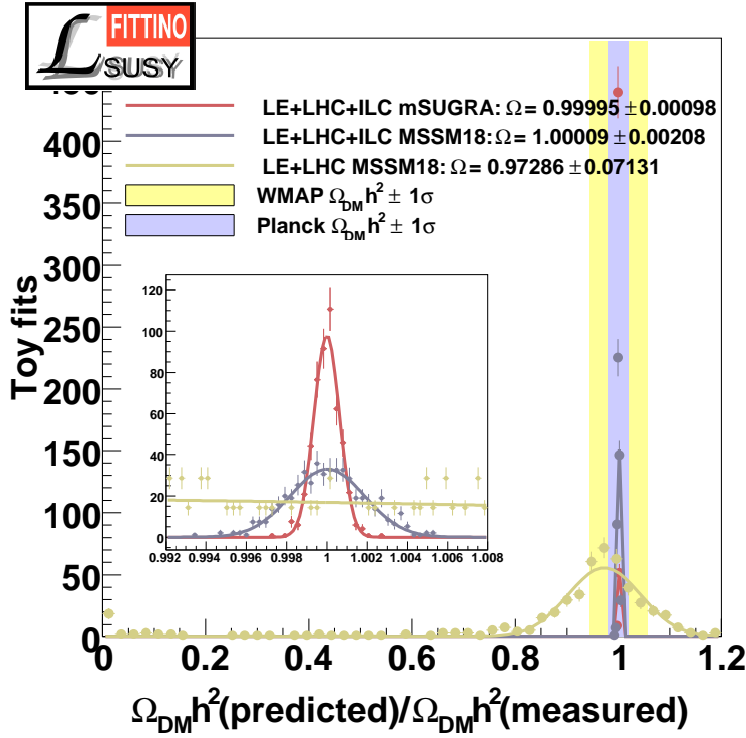
Figure 11: *Postdiction of Ω_{CDM} from precision measurements at colliders. The precision using ILC+LHC is superior over using only LHC observables by more than one order of magnitude.*

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