Single Top-Quark and Higgs-Boson Measurements with the ATLAS-Detector

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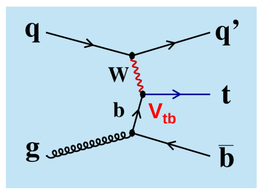
Single Top-Quark Production at the LHC

The top-quark is the heaviest elementary particle and was discovered in 1995 at the Tevatron based on top-antitop-quark pair production events via the strong interaction.

In addition to the pair production process the standard model of particle physics predicts the production of single top-quarks via the weak interaction. The most important subprocess proceeding via the exchange of a virtual W boson in the t channel is depicted below.



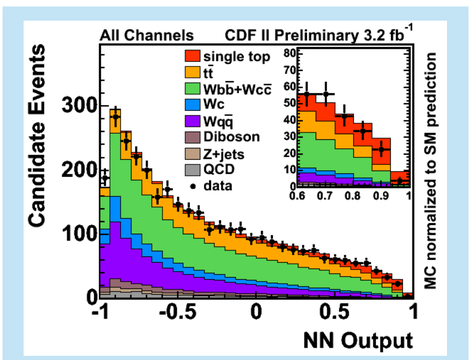
The single top-quark process was first observed at the Tevatron in March 2009. However, the cross-section measurement and the resulting constraints on the CKM matrix element V_{tb} are still statistically limited.

The Wuppertal YI Group aims at a precision measurement of the single-top t-channel cross section which can be translated into a precise determination of V_{tb}.

At a center-of-mass energy of 14 TeV the t-channel cross section is predicted to be 247 13 pb, leading to a few thousand reconstructed single top-quark events per year even at very moderate luminosities. The cross-section measurement will therefore be systematically limited.

Tevatron Experience

Since 2003 W. Wagner and D. Hirschbühl have done research with the CDF detector at the Tevatron. They developed one of the multivariate techniques, based on neural networks, that lead to the first observation of single top-quark production in March 2009.



The histogram shows the neural network discriminant isolating single top-quark candidate events at the rigtht hand side close to 1, while background events accumulate on the left near -1.

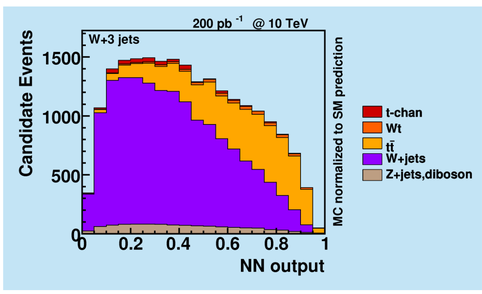
The Wuppertal group is dwelling on its Tevatron experience and plans to construct discriminants that optimize the statistical sensitivity, but also minimize the systematic uncertainties as these will become of growing importance.

Preparations for Early LHC Measurements

The LHC has restarted a few days ago. After an initial phase of a few months it is planned to operate the machine at a proton-proton center-of-mass energy of 10 TeV and collect collision data corresponding to about 200 pb^{-1} in 2010.

The Wuppertal YI Group is contributing to studies of the ATLAS-Single-Top group preparing analyses on this first LHC data set.

In the context of these studies Philipp Sturm has devised a method to estimate the W+jets and top-antitop-quark backgrounds in a side-band region in which the events feature a W-boson candidate and 3 high-E_T jets. The constructed discriminant based on neural networks is shown below.



The 10 TeV single-top analysis was developed together with the ATLAS group in Grenoble and has been documented in the ATLAS notes:
ATL-PHYS-INT-2009-091 and ATL-COM-PHYS-2009-572.

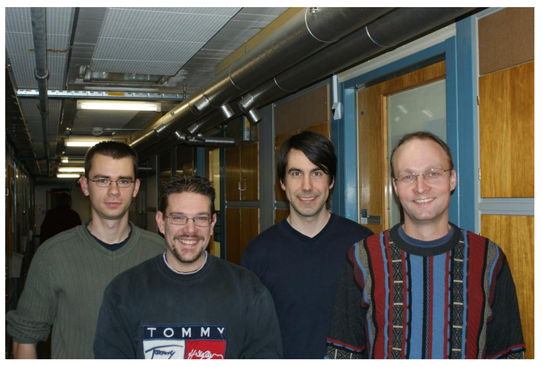
The Group

Prof. Dr. Wolfgang Wagner (group leader, Junior-Professor)

Dr. Dominic Hirschbühl (postdoctoral researcher)

Dipl.-Phys. Georg Sartisohn (Ph.D. student)

Dipl.-Phys. Philipp Sturm (Ph.D. student)

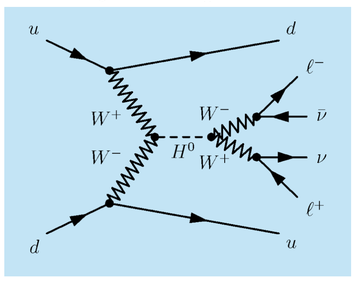


The Wuppertal Helmholtz YI Group in front of their CERN office.
From left to right:
Georg Sartisohn, Dominic Hirschbühl, Philipp Sturm, Wolfgang Wagner.

Hunting the Higgs-Boson

One of the main aims of the LHC is the hunt for the Higgs boson. The Wuppertal YI Group contributes to this effort within the ATLAS collaboration by studying Higgs boson production via the fusion of two weak gauge bosons.

We prepare to select Higgs candidate events in the decay channel $H^0 \rightarrow W^+W^- \rightarrow l^+ \nu\, l^- \nu$ which contributes to the Higgs discovery potential in the mass regime 130 < m_H < 180 GeV/c².



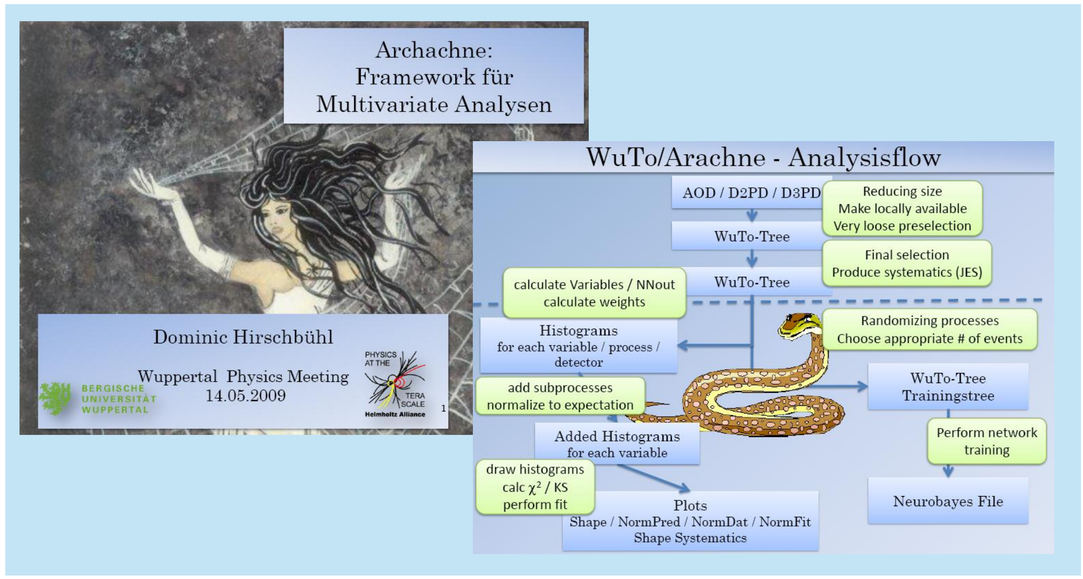
The measurement of the cross section of the vector-boson-fusion process will be essential to establish the Higgs boson as the agent of electroweak symmetry breaking.

Experimentally, the vector boson fusion process is distinguished by two high-E_T jets in the forward and backward regions of the detector which makes it similar to the single-top t-channel process where one such jet is expected. In this sense there is an experimental link between the two channels and we expect to profit from our experience in the single-top analyses.

Studies with early LHC data to understand the backgrounds are prepared by Georg Sartisohn.

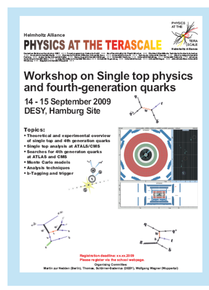
Arachne – A Framework for Efficient Analyses

Challenging data analyses rely on an efficient access to the data and a fast turn around of new analysis ideas and their application to the collision data and the samples of simulated events. To facilitate the creation and administration of hundreds of histograms, the training and application of multivariate techniques, such as neural networks, and the determination of systematic uncertainties using ensemble tests, Dominic Hirschbühl and Georg Sartisohn have written a software framework for the Wuppertal data analyses: Arachne. Their work is based on previous experience with the CDF and CMS experiments.



Alliance Activities

The Wuppertal YI Group has and will continue to contribute to several alliance activities. Below you find a list of contributions made in 2009.



W. Wagner has initiated and co-organized a workshop on “Single-Top Physics and Fourth-Generation Quarks” that took place at DESY on 14. – 15. of September 2009.
The meeting was a great success and attracted 25 physicists, mainly from within Germany, but also from abroad.
People agreed to meet again in 2010 and continue the discussion.

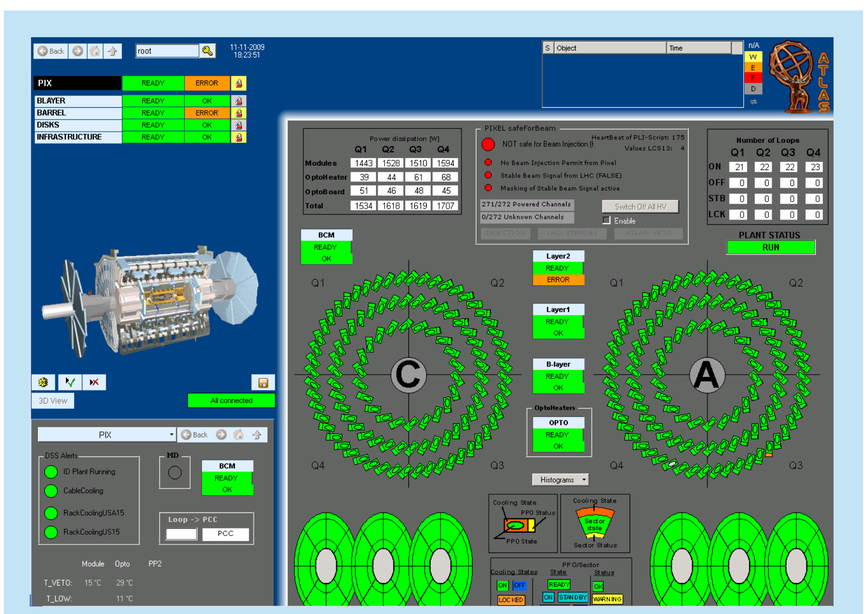
- W. Wagner contributed to the Alliance workshop on “Detector Understanding with the First LHC Data” giving a talk on “The First Hundred Days of the Tevatron – From the Commissioning Run to ICHEP 2002”
- On the Annual Alliance meeting 2009 Ph. Sturm reported on his “Studies on the Single Top-Quark t-channel Measurement with the ATLAS Experiment”.
- At the school “Physics at the Terascale” that is planned for 8. – 12. March 2010 D. Hirschbühl and W. Wagner will prepare a tutorial on “selection of top-antitop-quark events in CDF data and a ‘simple’ top-quark mass measurement”. The school is intended for Bachelor and Master students at German Universities.
- Together with P. Uwer (Helmholtz YI Group leader at Humboldt Universität Berlin) W. Wagner will contribute a chapter on “Top-Quark Physics” to the planned Alliance Book “Physics at the Terascale”.

Contributions to the Operation of the ATLAS Pixel Detector

Before collision data can be analysed in search for new particles, like the Higgs boson, or before making precision measurements of known processes, good usable data have to be recorded by the ATLAS detector. For this to happen, a stable operation of the system is crucial.

The Wuppertal YI Group has made and will continue to make several contributions to the operation of the ATLAS pixel detector.

- Test and deployment of opto-heater power supplies (D. Hirschbühl).
  These power supplies are used to stablize the temperature of optical transmitters in the pixel detector readout system.
- Maintenance and further development of the interlock part of the pixel finite-state machine (D. Hirschbühl).
- Pixel shifts and pixel on-call experts (D. Hirschbühl, Ph. Sturm).
- Pixel calibration shifts (G. Sartisohn, W. Wagner).
  In these shifts occupancy and noise maps of the pixel detector are computed and written to the calibration data base.
  Data quality is monitored by checking quantities such as hit efficiencies, the track rate, residuals, the number of clusters per event, and the measured charge deposition (cluster time-over-threshold).



Display of the Finite-State Machine (FSM) controlling and monitoring voltages, currents, temperatures, and pressures of the ATLAS pixel detector.

Review Articles on Top-Quark Physics

In 2009 W. Wagner and D. Hirschbühl have published two review articles on top-quark physics.

Dominic Hirschbühl, Wolfgang Wagner and Jeannine Wagner-Kuhr,
Die Sumo-Ringer im Teilchenzoo, Physik-Journal 8 Nr. 7 (2009) 37 – 42.

The „Physik-Journal“ is a periodical sent to the members of the German Physical Society (DPG) on a monthly basis.

Joseph R. Incandela, Arnulf Quadt, Wolfgang Wagner, Daniel Wicke,
Status and prospects of top-quark physics, Prog. Part. Nucl. Phys. 63 (2009) 239-292.