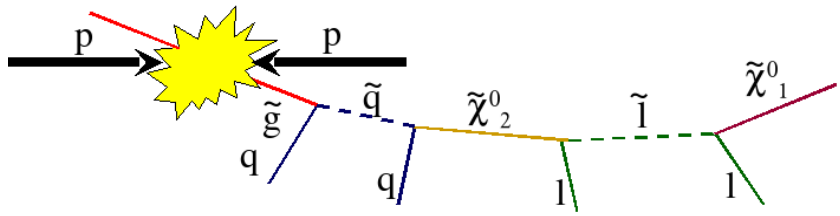
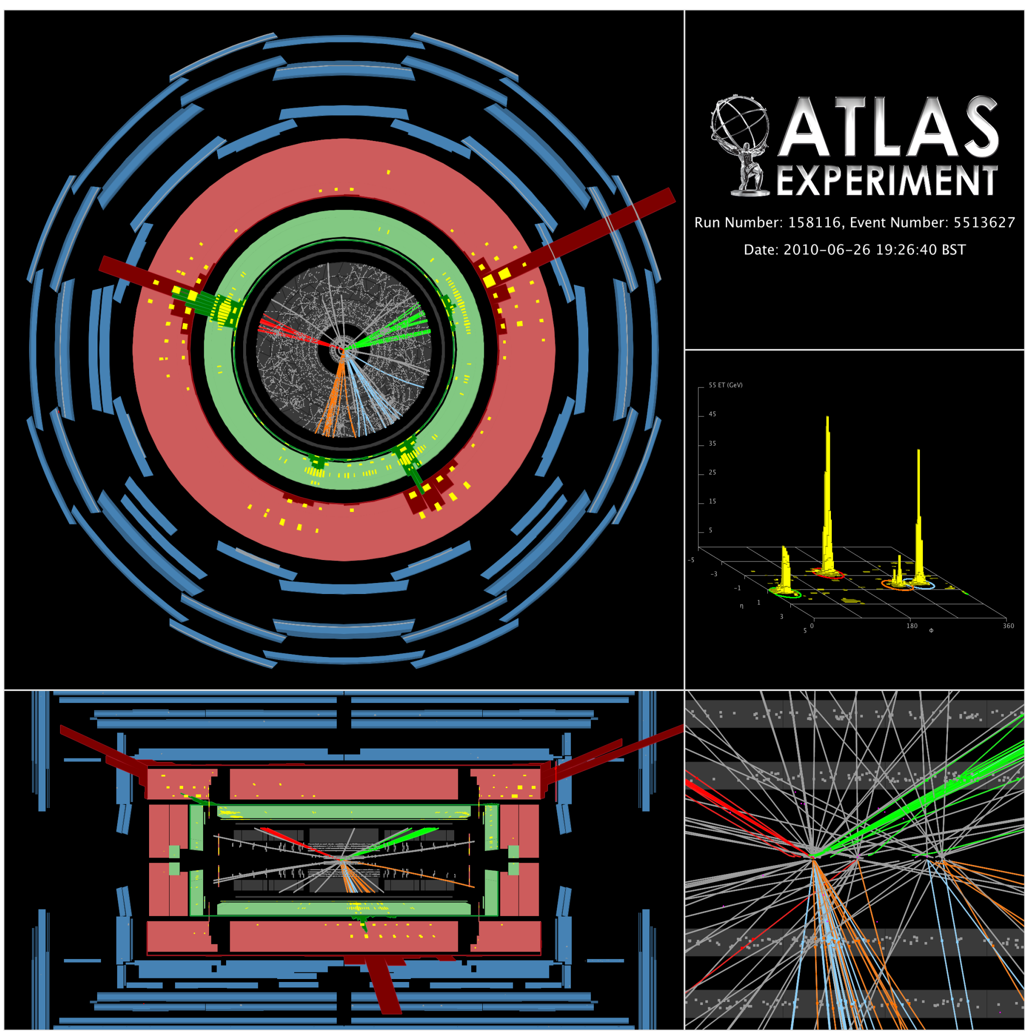
January 9, 2015



Master Thesis Topics 2015

in Experimental Particle Physics

at LS Schaile



At LS Schaile we offer a broad spectrum of master thesis topics in experimental elementary particle physics.

Contacts:
If you have questions of organisational nature, or if you would like to have some advice which master thesis topic would be most suitable for you please contact

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If you have already spotted your favorite topic or you have questions concerning a specific topic you can also address directly the contact person indicated for each topic.

1 Physics of the Top Quark and Quantum-Chromo-Dynamics (QCD)

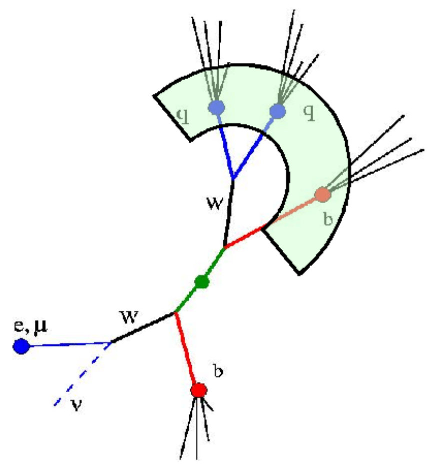

Figure 1: Semileptonic decay of a $t\bar{t}$-pair.

The top quark and QuantumChromoDynamics (QCD) are two parts of the standard model of particle physics which deserve detailed studies using the ATLAS experiment at LHC. Since LHC collides protons, QCD is the main interaction taking place between the constituents of the colliding particles. Understanding these processes is mandatory before any noticed deviation can be claimed a signal of a new physics phenomena. The main object of research are jets of many particles originating from a highly energetic quark or gluon produced from a hard scattering process.

The top quark is the heaviest known particle, whose properties are not fully investigated yet. Proton proton collisions at LHC are abundant with top quarks which allows to measure its properties with high precision. Also top quarks and additional jets are produced in the decay of a heavier quark from a hypothetical fourth generation.

Our research work is currently directed to:

- Top quark properties: production cross section, mass, decay modes and branching ratios, top-antitop quark spin correlation
- QCD multijet production, strong coupling constant, soft underlying event, multiparton interactions

Topics for MSc theses in one of these areas involve the analysis of measured data using existing software tools, the selection of relevant signal events out of many competing processes, the comparison of the measured results to expectations obtained from simulation studies, the interpretation of the final results in terms of the observed quantity and the systematic uncertainties of the measurement. The actual work will require some software development in the framework of the existing analysis software tools using C++

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2 Search for Supersymmetry

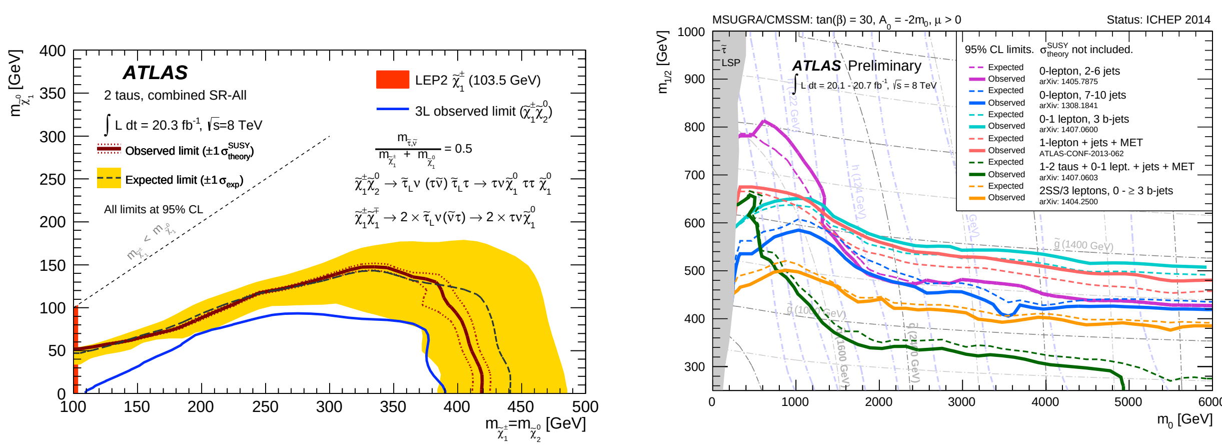

Figure 2: Expected and observed 95% CL exclusion limits in a simplified model with chargino-neutralino production as a function of the chargino and neutralino masses (left), and in the mSUGRA parameter space defined by the scalar and fermion mass parameters (right).

Supersymmetry (SUSY) is a well motivated extension of the Standard Model: Each fermionic degree of freedom is complemented by a bosonic degree of freedom and vice versa. As the supersymmetric partners of the known Standard Model particles have not been observed yet, it is assumed that Supersymmetry is a broken symmetry and therefore these partner particles have different masses. There are strong arguments, however, that the masses of the supersymmetric partners should not be too heavy and in reach of the LHC. SUSY also offers a plausible explanation for Dark Matter in the Universe.

Finding the new particles predicted by Supersymmetry is one of the major goals of the ATLAS experiment. The easiest way to produce SUSY particles at the LHC is through strong production. However, if coloured super-particles are heavy, as recent limits from ATLAS and CMS, and the Higgs boson search results seem to indicate, electroweak production may play a major role in the discovery of SUSY. Topics for master theses will focus on the preparation of Run-2, starting in late spring 2015, and on the analysis of the first data collected in it.

The LMU group is involved in the following areas, where topics for master theses can be offered:

- Strong production.
  We focus on the analysis of events with several jets, missing transverse energy and 1 lepton (electron or muon) in the final state. Such analyses are sensitive to a wide class of supersymmetric

models, among those gravity-mediated SUSY-breaking models (mSUGRA) and the phenomenological Minimal Supersymmetric Standard Model (pMSSM). A possible topic for a master thesis is to extend the current analysis to final states containing a large number of jets and only little missing transverse energy, which could not be accessed by former analyses. Such final states are predicted in a variety of supersymmetric models. Another domain of interest is the development and performance study of an advanced trigger strategy due to the increased luminosity at the LHC. The trigger is a crucial part of the experiment since at this stage the collision events are either recorded for further analysis or rejected. Possible topics include the feasibility of new trigger algorithms, their optimisation on SUSY models of interest, and measurement of trigger rates and efficiencies with LHC data.

- Direct stop production.
  The mass of the lightest stop, one of the supersymmetric partners of the top quark, is expected to be below $\sim 1-2$ TeV. It may thus be the lightest squark. Due to its close relation to the top quark, it may be hard to identify. Many specific searches were therefore designed to look for it, among them again an analysis in final states containing one isolated lepton, jets and missing transverse energy. One of the possible topics for a master thesis in the field of stop searches could be to reoptimise the analysis to also include final states with low energetic leptons. Such final states appear for example in models in which the masses of the stop and lightest supersymmetric particle are similar.

- Electroweak production.
  Supersymmetric particles like charginos, neutralinos and sleptons can be directly produced in electroweak processes. The detector signature which could reveal Supersymmetry in this case is missing transverse energy, little hadronic activity, and more than one lepton (electron, muon or tau) in the final state. Potential topics for a master thesis include the optimisation of the discovery potential and extension of the current analysis strategy to include final states where one or more leptons are tau leptons, the study of the Standard Model backgrounds producing fake leptons coming from misidentified jets or leptons from heavy-flavour decays, and trigger studies that allow us to find ways to cope with the higher instantaneous luminosity at LHC Run-2.

- Long-lived particles.
  A wide range of models, supersymmetric ones just being one example, predict some kind of long-lived particle. With lifetimes long enough to actually reach – or even traverse – the detector, the searches for these particle pose a distinct challenge, as they require dedicated reconstruction algorithms and calibrations as well as a detailed understanding of various parts of the detector. Possible topics for master theses include: the investigation and validation of new Monte-Carlo generators, to accurately simulate the predicted processes; as well as the evaluation of the discovery potential for long-lived particles in previously uncovered SUSY models. In addition, with the imminent restart of the LHC, studies of the possible reach of current analyses, given the new running conditions, could be performed.

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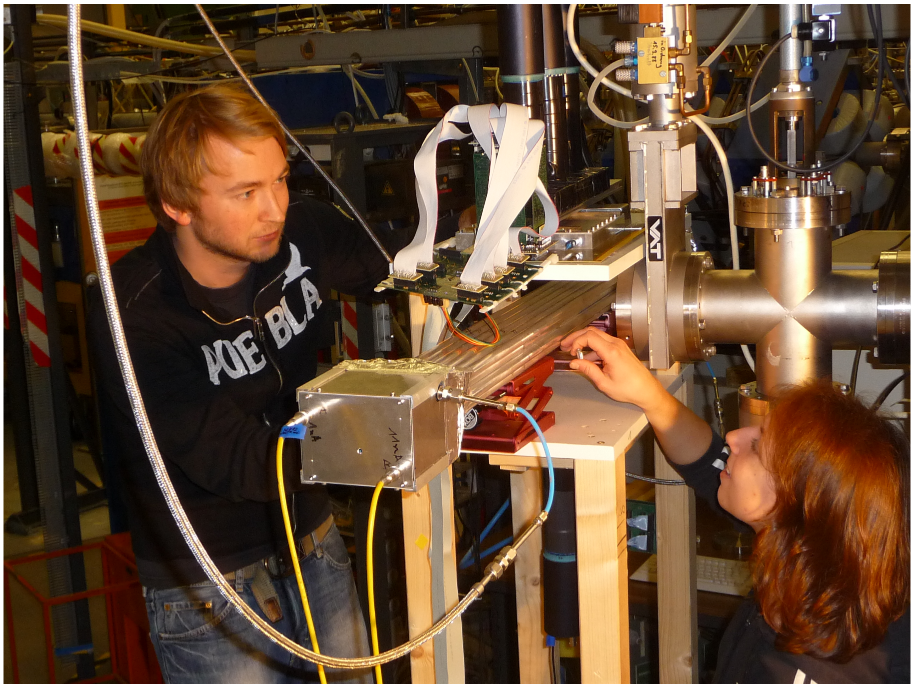

Figure 3: Irradiation measurements at the MLL Tandem Accelerator.

3 Detector-R&D and Particle Identification

The extreme radiation background conditions at LHC require the development of new and radiation hard particle detectors which shall replace existing and less radiation tolerant detector technologies in the ATLAS detector.

Our research is focused on:

- Micro pattern gaseous particle detectors like MICROmesh GAseous Structures (Micromegas) or Gaseous Electron Multiplier (GEM); such detectors shall have a spatial resolution of 20 to 100 micron and cover an active area of square meters.
- Szintillating detectors with Silicon Photomultiplier (SiPM) readout; the goal is to achieve spatial resolution in two dimensions by reading out two optically separated trapezoidal szintillators using SiPMs and wavelength shifting fibers.

Topics for MSc theses are directly connected to these areas of detector research & development. A thesis involves both hardware and software related work. This includes typically the conceptual planning of an experiment, setting-up the experimental apparatus, performing the measurements and, finally, analyzing and interpreting the results from the measurement.

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