Measurement of the top quark charge asymmetry and polarization

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1) Project Goals

- Perform the measurement of the top quark charge asymmetry and polarization at the ATLAS experiment at the Large Hadron Collider (LHC).
- Correct the measurements for detector effects, such that they can be compared to the theory calculations at the particle level.
- Compare the corrected measurement with the state-of-the art Standard Model (SM) and Beyond Standard Model (BSM) predictions.

The P2IO project on the measurement of the top quark charge asymmetry and polarization started in March 2012. The measurements are being performed within the ATLAS (A Toroidal LHC Apparatus) collaboration of the LHC, CERN, Geneva. These measurements contribute to understanding one of the most interesting known experimental particle physics puzzles: the asymmetries in top quark events are reported to differ notably from the SM predictions by the Tevatron experiments. Tevatron is colliding protons against antiprotons at the energies of approximately 1/4 of the LHC proton-proton collision energy. The SM extensions or improvements that can account for the Tevatron asymmetry in some cases predict deviations from the SM in top quark production at LHC. Similarly, some of the BSM models that can account for the Tevatron asymmetry predict non-zero top quark polarization at LHC. In order to enable systematic testing of SM and BSM models against the experimental data, it is useful to correct the data for detector effects. This enables data-theory comparisons at the particle level, prior to detector simulation and comparisons of the data to benchmark, BSM models that can account for the Tevatron asymmetry, like models with light axi-gluons.

2) Description of work achieved

The research activity involved data analysis (including the BSM models comparisons) and activities related to collaboration appointment obligations.

My collaboration appointments are in the area of Monte Carlo modeling in top quark production processes. I am working on assessments on modeling of SM top quark production in association with the phenomenology, theory experts and the ATLAS Monte Carlo generators group. I am responsible for these areas within the ATLAS collaboration as well as in the intra-collaboration boards taking place in association with the CMS experiment within the top LHC working group.

The data analysis activities were done with the LHC Run 1 data, taken at a centre-of-mass energy 7 TeV collected during 2011 pp collisions. The measurements are done in the dilepton decay channel (each top and anti-top quark decay to a b-quark and a lepton-neutrino pair). Developing the 7 TeV data analysis and background estimates, we contributed to the ATLAS top quark polarization measurement, that has been published. The top quark polarization is found to be consistent with the SM prediction of no net polarization of top quarks in top-antitop production events.

In the dilepton decay channel the charge asymmetry of the top and anti-top quark as well as the charge asymmetry of their daughter leptons can be measured. The lepton and top anti-top quark asymmetries provide complementary information for BSM searches. A novel approach to correct the measurements for detector effect, the Fully Bayesian Unfolding, was used. This approach enables good control of unfolding as well as systematic uncertainties, hence enabling a precise measurement.

The corrected measurements are being compared to light axi-gluon models with parameters set so that the Tevatron charge asymmetry measurements are reproduced. The theoretical

BSM benchmarks were provided by the LPT Orsay member. The benchmarks were provided in a format suitable for direct comparison to the unfolded data (MadGraph LesHouche level events) as well as in the format that enables studies of axi-gluon model kinematic properties. We performed studies of the kinematics of the particle level events produced with MadGraph and Pythia, that provide us information on how to improve the models. Example plots are provided in Figure 1, left. The axi-gluon samples are compared to the experimental data (black dots) and to the events generated with the Next-to-leading order generator PowHeg-BOX. There is some tension between the predictions of the SM+BSM axi-gluon model and the experimental data, indicating the space of improvement of the generation setup.

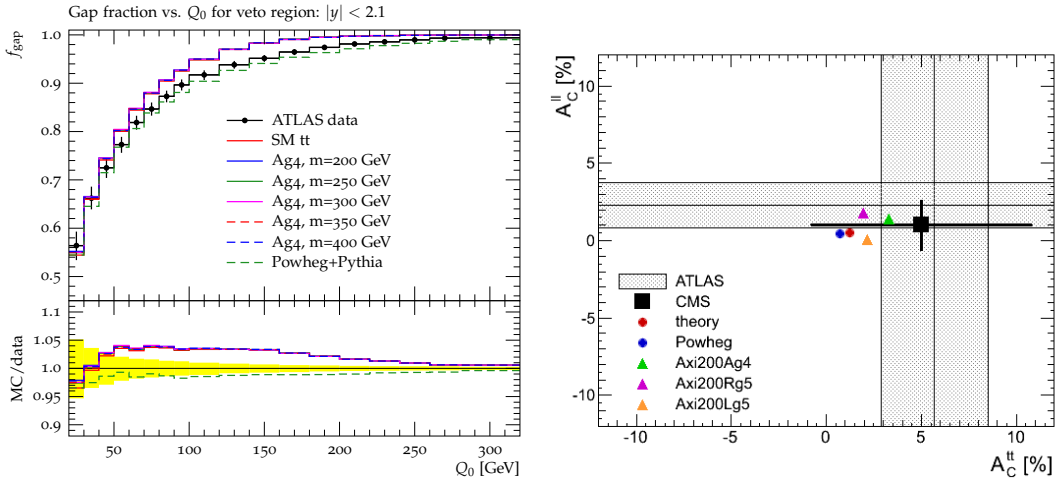

Figure 1: Left: predictions of the SM+BSM axi-gluon model events produced with MadGraph+Pythia for gap fraction observables measured by the ATLAS collaboration in Eur.Phys.J. C72 (2012) 2043. Right: prediction of the SM+BSM axi-gluon models for the lepton and top quark based asymmetry in top-antitop production at the LHC. The asymmetry values are compared to the experimental data and the SM prediction.

In Figure 1, right, the performance of the SM+BSM axi-gluon model is shown for the lepton and top quark based asymmetry in top-antitop production at the LHC. The asymmetry values are compared to the experimental data and the SM prediction. Since our measurement is not yet approved for public presentation, the preliminary result of the ATLAS collaboration (preceding the project) is overlaid for comparison.

3) Publications and Talks

3.1) Publications (approved for access outside the ATLAS collaboration)

- A. Karneyeu, L. Mijović, S. Prestel, P. Skands, *MCPLOTS: a particle physics resource based on volunteer computing*, The European Physical Journal C, 74:2714, February 2014.
- L. Mijović on behalf of the ATLAS Collaboration, *Top quark pair properties (spin correlations, charge asymmetry and complex final states*, EPS2013 Proceedings, November 2013, to appear in PoS.
- ATLAS Collaboration, G. Aad, L. Mijović *et al.*, *Measurement of top quark polarization in top-antitop events from proton-proton collisions at* $\sqrt{s}$*= 7 TeV using the ATLAS detector*, Phys. Rev. Lett 111, 232002 (2013), (my contribution: baseline event selection, data-MC comparisons and QCD estimates in dilepton channel).

- ATLAS Collaboration, G. Aad, L. Mijović *et al.*, *Monte Carlo generator comparisons to ATLAS measurements constraining QCD radiation in top anti-top final states*, ATL-PHYS-PUB-2013-005 (my contribution: steering of analyses, dedicated sample production, note editing).
- L. Mijović on behalf of the ATLAS Collaboration, *Latest top physics results at ATLAS*, Il Nuovo Cimento C, Vol35, Issue 6, 2012.

3.2) Invited talks

Apart from regular reports at the ATLAS internal meetings, I was invited to give the following public talks:

- *TH uncertainties: towards harmonization across LHC*, TOPLHC WG open session, July 2012,
  `https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=189617` .
- *Shower systematics in matching generators*,
  MC generators and future challenges, a joint ATLAS/CMS/LPCC workshop, August 2012
  `http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=212260` .
- *Overview des systématiques liées aux radiations (parton-shower, ISR/FSR, fragmentation, color reconnection, underlying évent), top LHC-France, March 2013*,
  `https://indico.in2p3.fr/conferenceDisplay.py?confId=7693` .
- *Top quark pair properties (spin correlations, charge asymmetry and complex final states) at LHC in ATLAS*,
  EPS HEP 2013, Stockholm, July 2013, `http://eps-hep2013.eu/`
- *Beyond Standard Model with the top quark, Annual Scientific Council of P2IO, Saclay, September 2013*,
  `https://indico.in2p3.fr/conferenceDisplay.py?confId=8320`
- *Résumé des conférences d'été, Séminaires du SPP, September 2013*
- *Radiation systematics, TOPLHC WG open session, November 2013*,
  `http://indico.cern.ch/event/217721/`.

4) Relevance of the project within P2IO

The project was performed within the field of particle physics and top quark physics that is one of the goals of the P2IO laboratories. A large part of the activity was done at the ATLAS experiment, one of the big P2IO laboratory projects. Given that the asymmetries in top quark events are reported to differ notably from the SM predictions by the Tevatron experiments, the top quark charge asymmetry is one of the hot topics of particle physics currently. The P2IO project allows CEA to be one of the leading laboratories for this analysis. The P2IO project programme promoted collaboration between the CEA-Saclay and LPT Orsay members. The charge asymmetry LHC experimental data analysis was performed by the CEA-Saclay members of the project. The data analysis was performed by the CEA-Saclay members of the project while the theoretical BSM benchmarks were provided by the LPT Orsay member. We intend to extend the collaboration between the CEA-Saclay and LPT Orsay also pass my departure from the P2IO funded position.

5) Position after P2IO

I will continue to work as an experimental high-energy particle physicist working at the Physikalisches Institut of the Universitt Bonn. The position of *Wissenschaftlicher Mitarbeiter* at the university has been granted initially for 2 years with the possibility for extension to up to four years. I will work in the group of Dr. Markus Cristinziani on a project supported by an ERC Consolidator Grant. My research will be in the fields of top quark, Higgs boson physics and tagging of heavy flavour jets.