T 23: Top physics 1

Time: Monday 16:00–18:15 Location: Geb. 30.95: Audimax

T 23.1 Mon 16:00 Geb. 30.95: Audimax

Quantum Entanglement in Top Quark Pairs in the Lepton+Jets Final State — Arnulf Quadt, Baptiste Ravina, •Theresa Reisch, and Elizaveta Shabalina — II. Physikalisches Institut, Georg-August-Universität Göttingen

Quantum entanglement is a fundamental prediction of quantum mechanics and the experimental achievements with electrons and photons were recognised by the Nobel Prize in Physics 2022. At the LHC, quantum entanglement can be observed in top quarks, testing quantum mechanics at high energies. Therefore, a sensitivity study for a possible measurement of quantum entanglement in the top quark pair production in the lepton+jets final state is presented.

The angular separation between the decay products of the top quarks can act as an indicator of quantum entanglement, when the two top quarks are produced near threshold. The two strongest spin analysers in this final state are the charged lepton and the down type quark which is accessed via c-tagging. The result is then compared to parton level predictions using a calibration curve. As the biggest challenge for this analysis, the parton shower systematic uncertainty, comparing Powheg+Pythia 8 to Powheg+Herwig 7.13 predictions, is discussed.

The study is performed with ATLAS Monte Carlo simulations under Run 2 conditions.

T 23.2 Mon 16:15 Geb. 30.95: Audimax

Measurement of $t\bar{t}$ spin entanglement in the 1-lepton channel in ATLAS — Katharina Behr, Eleanor Jones, and •Fiona Ann Jolly — DESY, Hamburg, Germany

The top quark, one of the heaviest known elementary particles, is mostly produced in pairs ($t\bar{t}$) at the LHC. These $t\bar{t}$ final states are sensitive to undetected and rare processes predicted by the Standard Model (SM), one of them being the quantum entanglement of $t\bar{t}$ spins. One of the kinematic regions most sensitive to entanglement is characterised by low values of the invariant mass of the $t\bar{t}$ system, just above the kinematic 'turn-on' for $t\bar{t}$ production ($m_{t\bar{t}} \geq 2m_t$) The presence of entanglement is probed via a high-precision measurement of an angular variable sensitive to the $t\bar{t}$ spin correlation in this region.

In this talk, sensitivity studies for using the 1-lepton $t\bar{t}$ decay channel for quantum entanglement measurements in the resolved decay topology are presented. The calculation of the relevant angular variable relies on the identification of the down-type quark jet coming from the W boson decay, which has the highest spin-analysing power among the hadronic top quark decay products. If this jet is not identified, the b-jet coming from the hadronic top quark decay is used. Hence, one of the key challenges is the correct assignment of jets to the $t\bar{t}$ decay products. To achieve this, the $t\bar{t}$ system is reconstructed using a reconstruction approach called SpaNet. Background estimates in the turn-on region are also shown.

T 23.3 Mon 16:30 Geb. 30.95: Audimax

Measurements of Top-quark Pair Spin Correlation in the ℓ + Jets Channel Using the ATLAS Experiment — •Oleksandr Burlayenko[1], Andrea Knue[2], and Zuzana Rurikova[1] — [1]University of Freiburg — [2]TU Dortmund

The top quark, the heaviest known fundamental particle exhibits a lifetime of $\mathcal{O}(10^{-25}s)$, which is shorter than both the quantum chromodynamic (QCD) hadronization time scale $1/\Lambda_{QCD} \approx 10^{-24}$s and the spin decorrelation time scale $m_t/\Lambda^2_{QCD} \approx 10^{-21}$s. This allows studying the spin properties of a bare quark, as the angular distribution of its decay products preserves its spin information.

Within the Standard Model (SM), $t\bar{t}$ pairs have correlated spins, with the degree of correlation being sensitive to the production mechanism. The most recent measurement performed by ATLAS uses 13 TeV data in the dilepton channel.

This work presents ongoing studies of the $t\bar{t}$ spin correlation in the ℓ + jet channel at $\sqrt{s} = 13$ TeV. While this channel provides a larger dataset, the analyzing power is reduced compared to the dilepton channel.

To improve event reconstruction, machine learning techniques are employed. Combined with an optimization study, these techniques exhibit high performance in eliminating non-reconstructable events. Furthermore, the measurement of SM-like spin correlation in a blinded Asimov profile likelihood template fit will be presented, considering the full impact of systematic uncertainties and various spin correlation sensitive observables.

T 23.4 Mon 16:45 Geb. 30.95: Audimax

Search for same-sign top pair production with the Standard Model Effective Field Theory at the ATLAS experiment — Noemi Cavalli[1,2], Merve Nazlim Agaras[3], Maximiliano Sioli[2], Matteo Negrini[2], Kevin Alexander Kroeninger[1], Aurelio Juste Rozas Rozas[3], and •Aaron van der Graaf[1,2] — [1]Technical University of Dortmund — [2]University of Bologna — [3]The Institute for High Energy Physics of Barcelona

Model-independent searches for new physics at high energies by using the Standard Model (SM) Effective Field Theory (SMEFT) are an important part of todays physics program. Same-sign top-quark pair production is highly suppressed in the SM while several models beyond the SM enhance the production. SMEFT is used obtain model-independent predictions for the production of the same-sign top pairs beyond the SM. Three EFT operators are considered to simulate the searched signal. The full Run 2 dataset collected by the ATLAS detector from proton-proton collisions is used for this search for same-sign top-quark pairs, in the dilepton final state. A Neural Network (NN) is employed to build separate signal regions (SR) enriched in same-sign top events resulting from different EFT operators. Within the defined SRs, a second NN is applied to perform a signal-background discrimination. In order to attain an accurate estimation of background contributions in the SRs, several Control Regions (CRs) are defined. The background estimation and the signal search are performed by using a maximum likelihood fit over all analysis regions.

T 23.5 Mon 17:00 Geb. 30.95: Audimax

Search for $t\bar{t}\gamma\gamma$ production in lepton+jets channel in pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], •Arpan Ghosal[1], Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen — [2]Shandong University, China

The top quark pair production ($t\bar{t}$) in association with one or more photons is a key Standard Model process for measuring the strength of the electroweak coupling of the top quark with the photon. While the production of $t\bar{t}$ with one photon is well-studied, the rarer $t\bar{t}$ production with two photons ($t\bar{t}\gamma\gamma$) still remains unobserved. The $t\bar{t}\gamma\gamma$ process is not only a good candidate for probing the electroweak coupling of the top quark, but it is also significant as an irreducible background to the $t\bar{t}$ production in association with a Higgs boson decaying to two photons. Understanding the $t\bar{t}\gamma\gamma$ process can help tighten constraints on anomalous electric and magnetic dipole moments, through which new CP-violating sources can manifest. The talk will discuss the ongoing efforts in the search for the $t\bar{t}\gamma\gamma$ process in the single-lepton $t\bar{t}$ decay channel using the full Run 2 dataset collected by the ATLAS detector at $\sqrt{s} = 13$ TeV.

T 23.6 Mon 17:15 Geb. 30.95: Audimax

NNLO soft function for 0-jettiness in (associated) $t\bar{t}$ production — Guido Bell[1], Alessandro Broggio[2], Bahman Dehnadi[3], •Sebastian Edelmann[1], Matthew A. Lim[4], and Rudi Rahn[5] — [1]Theoretische Teilchenphysik, Center for Particle Physics, Universität Siegen, Siegen, Germany — [2]Faculty of Physics, University of Vienna, Wien, Austria — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [4]Department of Physics and Astronomy, University of Sussex, Sussex House, Brighton, UK — [5]Department of Physics and Astronomy, University of Manchester, Manchester, UK

In order to compare theoretical predictions to the exceptionally accurate LHC data, it is essential to have a thorough understanding of $t\bar{t}$ and $t\bar{t}X$ production cross sections, where $X = \gamma, W, Z, H$. Since jettiness slicing has already been successfully applied to compute NNLO corrections including massless partons, our aim is to develop this method for processes that include top quarks. At small values of the 0-jettiness variable, it can be shown that the cross section factorizes into hard, beam, and soft functions. While beam functions are universal

and known from massless calculations, our focus consists in computing the relevant soft functions for massive partons. We have already automated the calculation of the real-virtual contribution to the $t\bar{t}$ soft function, utilizing a generic measurement function, that includes all information about the observables, and performing numerical integration over the remaining phase-space variables. This calculation will lay the groundwork for implementing associated $t\bar{t}$ production processes in the Monte-Carlo event generator GENEVA.

T 23.7 Mon 17:30 Geb. 30.95: Audimax

EFT interpretation of a $t\bar{t}\gamma$ differential cross-section measurement using full Run 2 data with the ATLAS experiment — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], Gabriel Gomes[1], •Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

The production of top quark pairs in association with a photon ($t\bar{t}\gamma$) is an important process to investigate the coupling between the photon and the top quark. Precise measurements of this coupling allow testing the Standard Model (SM) and probe for new physics effects. The Standard Model Effective Field Theory (SMEFT) models physics phenomena beyond the SM via the introduction of higher dimension operators. In this talk, the measurement of the differential $t\bar{t}\gamma$ cross-section using 140 fb^{-1} of data collected by the ATLAS detector in proton-proton collisions at $\sqrt{s} = 13$ TeV and its interpretation in the context of SMEFT will be presented. The measurement is performed at particle level in the single lepton and dilepton decay channels of the top quarks. The differential cross-section as a function of photon transverse momentum is used to set constraints on the electroweak dipole moments of the top quark.

T 23.8 Mon 17:45 Geb. 30.95: Audimax

Global EFT Fits using *TopCPToolkit* & *FastFrames* — Arnulf Quadt, Baptiste Ravina, and •Daniel Werner — II. Physikalisches Institut, Georg-August Universität Göttingen

The Effective Field Theory (EFT) is a promising approach in the search for physics beyond the Standard Model (BSM), without having to adhere to a specific BSM model. The top-electroweak sector ($t\bar{t}Z$, $t\bar{t}W$, $t\bar{t}H$, etc.) is of particular interest to constrain a number of EFT operators, and a global fit to these processes is needed. This in turn requires reliable, robust and efficient analysis software.

With the prospect of rising luminosities in Run 3 and especially the high-luminosity LHC, new analysis frameworks are needed in the ATLAS collaboration with a stronger focus on reducing computing times and disk space usage. Saving disk space is achieved by introducing the common derivation format DAOD_PHYS for most Run 3 ATLAS analyses. For producing individual ntuples from this format, the framework *TopCPToolkit* was developed based on Combined Performance (CP) algorithms, and also featuring dedicated analysis tools that can be inherited from commonly used analysis tools.

Filling histograms with values derived from these ntuples is achieved through the newly developed framework *FastFrames*. This framework uses ROOT's RDataFrames and improves the performance greatly, compared to previous workflows in the ATLAS Top working group.

This talk will focus on work of applying *TopCPToolkit* and *FastFrames* to produce ntuples and histograms to provide the basics for EFT fits of top+X processes in the framework of a Run 3 analysis.

T 23.9 Mon 18:00 Geb. 30.95: Audimax

Search for charged lepton flavour violation in top-quark production and decay with the ATLAS experiment — Diptaparna Biswas[1], Beatrice Cervato[1], Markus Cristinziani[1], Carmen Diez Pardos[1], Ivor Fleck[1], Arpan Ghosal[1], •Gabriel Gomes[1], Jan Joachim Hahn[1], Vadim Kostyukhin[1], Nils Krengel[1], Buddhadeb Mondal[1], Stefanie Müller[1], Katharina Voss[1], Wolfgang Walkowiak[1], Adam Warnerbring[1], and Tongbin Zhao[1,2] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen — [2]Shandong University, China

In the Standard Model with massless neutrinos, the flavour of charged leptons cannot be altered in weak interactions. However, the observed neutrino oscillations allow for charged lepton flavour violating processes, even though suppressed much below our current experimental sensitivity. Hence, experimental evidence of such rare processes would provide signs of new physics beyond the SM.

Investigations targeting a direct search for charged lepton flavour violation will be presented using proton–proton collision data collected by the ATLAS detector between 2015 and 2018 at $\sqrt{s} = 13$ TeV. In $t\bar{t}$ pair production, decays of a top quark into an electron–muon pair and an up-type quark are examined as well as single top-quark production in association with an electron–muon pair. In the $t\bar{t}$ case, the final state of interest is obtained when the SM top-originated W decays hadronically, and similarly for the single top production. A multivariate discriminant, namely a boosted decision tree, is implemented and optimised for signal discrimination purposes.