T 88: Top Physics IV

Time: Friday 9:00–10:30 Location: KH 00.011

T 88.1 Fri 9:00 KH 00.011

Measurement of $t\bar{t}$ spin correlations using Run 2 and 3 data with the ATLAS detector — Diptaparna Biswas, Carolina Costa, Markus Cristinziani, Carmen Diez Pardos, Ivor Fleck, Gabriel Gomes, Jan Joachim Hahn, •Nikolaos Kamaras, Vadim Kostyukhin, Nils Benedikt Krengel, Austin Olson, Inês Pinto, Sebastian Rentschler, Elisabeth Schopf, Katharina Voss, Wolfgang Walkowiak, and Adam Warnerbring — Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen

The top quark is the heaviest known elementary particle and decays before hadronization. Consequently, measurements of the angular distributions of top quark decay products provide direct access to the top quark's spin, enabling a precise test of perturbative Quantum Chromodynamics in top-antitop quark pair ($t\bar{t}$) production. This contribution presents studies towards the measurement of $t\bar{t}$ spin correlations using the Run 2 and Run 3 datasets collected with the ATLAS detector from proton-proton collisions at a centre-of-mass energy of 13 TeV and 13.6 TeV, respectively. The analysis focuses on the dilepton decay channel, requiring two leptons of opposite charge (electrons or muons) and at least two jets, with at least two identified as originating from a b-quark. To reconstruct the top quark kinematics and subsequently the angular distributions of the decay products, several top reconstruction methods are employed. The $t\bar{t}$ spin correlation coefficients will be extracted from these angular distributions using a standard profile likelihood fit for unfolding to both parton and particle level.

T 88.2 Fri 9:15 KH 00.011

Quantum entanglement in top-quark pairs using events with large transverse momentum with the ATLAS detector — •Chiara Deponte and Andrea Knue — Technische Universität Dortmund, Deutschland

Quantum entanglement of top-quark pairs is studied by measuring the full spin density matrix using data recorded with the ATLAS experiment in Run 2. Since top quarks have a very short lifetime, their spin information is transferred to its decay products. The angular distributions of these particles in a helicity-based coordinate system in the $t\bar{t}$ rest frame are then used to measure the entries of the spin density matrix. After the reconstruction of the full $t\bar{t}$ event, Profile Likelihood Unfolding is performed to remove detector and reconstruction effects. Entanglement is predicted at the $t\bar{t}$ production threshold and for high $M_{t\bar{t}}$. The presented analysis is performed in a phase-space region with high top-quark velocities and production angles. In this region the expected number of events is low so the analysis is statistically limited. Therefore, the single-lepton channel is used to find a balance between statistical and systematic uncertainties. This talk focuses on studies regarding the size of the jet-related systematic uncertainties.

T 88.3 Fri 9:30 KH 00.011

Quantum Spin Correlations at Colliders — •Monika Alexandra Wüst and Thorsten Ohl — University of Würzburg, Institute of Theoretical Physics and Astrophysics, Würzburg

The study of beyond-classical correlations in final states at colliders has received a lot of attention recently. For example, entanglement of particle pairs has been observed at the LHC. Most importantly, measurements of such correlations provide new tests of the Standard Model. More complicated final states are being studied and future colliders with polarized initial states will boost the interest even further. Experimentally, the challenge is to reconstruct the spin-density matrix of a final state from phase space distributions. As a practical matter, the computation of spin-density matrices is beyond the reach of analytical calculations for multi-particle final states. While the event generator Whizard has computed the spin density matrix from the beginning, most of it is projected out in the common event formats. We present first results from an automated framework for the computation of general density matrices and quantum observables using event samples generated by Whizard. We discuss applications for spin-1/2 (qubit) and spin-1 (qutrit) particles in bipartite and tripartite quantum states at colliders. Analytic calculations are used to test components of Whizard matrix elements that have not been tested by comparing cross sections and classical correlations.

T 88.4 Fri 9:45 KH 00.011

Is Assignment All You Need? — •Siemen Aulich, Katharina Behr, and Eleanor Jones — DESY, Hamburg, Germany

Many of the recent highlights of particle physics research are related to top quark physics'. These include both the tests of spin correlations and quantum effects in pairs of top quarks ($t\bar{t}$), and the observation of a possible quasi-bound state resonance in the $t\bar{t}$ invariant mass spectrum. Both effects are predominantly studied in dilepton decays in a mass range close to the production threshold.

Probing this system requires a precise reconstruction of the top quarks, which is complicated by the presence of the two neutrinos. While analytical regression strategies primarily focus on inferring the neutrino momenta, the problem of correctly assigning b-jets to their parent top quarks remains largely unstudied. However, many of the sensitive variables used in $t\bar{t}$ precision measurements depend critically on the correct assignment of the jets. Inspired by the success of machine learning architectures in tackling the assignment challenge for hadronic decay channels, this work investigates using a transformer model for the dilepton channel. An architecture specifically tailored to this channels topology is shown to outperform all existing methods. Furthermore, it is investigated how these efforts can be combined with neutrino regression methods to offer a full reconstruction pipeline. Applying these methods to existing and upcoming analyses promises further enhancements in the sensitivity and precision of searches and measurements alike.

T 88.5 Fri 10:00 KH 00.011

ML-Based Kinematic Top Quark Reconstruction in Dileptonic Decays — •Mads Hansen Baattrup[1], Alexander Grohsjean[2], Peer Stelldinger[3], and Christian Schwanenberger[1,2] — [1]Deutsches Elektronen-Synchrotron, Notkestr. 85, 22607 Hamburg, Germany — [2]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Hochschule für Angewandte Wissenschaften Hamburg, Berliner Tor 5, 20099 Hamburg, Germany

Reconstruction of the full kinematic properties of dileptonic $t\bar{t}$ events is important for precision tests of the standard model and also plays a role for many searches beyond the standard model (BSM). It is intrinsically challenging because of the presence of two undetected neutrinos, leaving the system underconstrained. Conventional analytical methods rely on assumptions and fixed mass constraints to close the system of equations. These methods introduce significant biases in important observables - particularly in the $m_{t\bar{t}}$ threshold region, which is highly relevant for both precision measurements and BSM-sensitive analyses.

In this work, we investigate supervised machine-learning-based reconstruction methods using transformer architectures and conditional generative models. We aim to learn the conditional phase-space distribution of parton-level quantities given event observables. This will reduce reconstruction biases while improving resolution relative to traditional analytical methods.

T 88.6 Fri 10:15 KH 00.011

Enhancing Top-Quark Reconstruction Across Topologies in ATLAS — •Constantin Eckardt — DESY, Zeuthen, Germany

Searches for beyond-the-standard-model physics at particle detectors such as ATLAS often involve top-quark associated events. Top-quark reconstruction in most searches is typically optimized for a specific decay topology. By incorporating multiple reconstruction algorithms, each tailored to different top-decay configurations, one can further expand the reconstruction reach and improve overall efficiency. This work presents studies of a range of top-quark reconstruction algorithms developed for different decay topologies and applied to a variety of physics cases. These studies are used to guide the further optimization of a recently launched umbrella tool within ATLAS – THAT (Top Hacker Across Topologies) – which recommends the most effective reconstruction algorithm on a per-event basis. Such a tool has the potential to enhance many different analyses that rely on accurate and efficient top-quark reconstruction.