Young Scientists Meeting of the CRC TRR 257

Report of Contributions

https://indico.kit.edu/e/4479

Contribution ID: **1** Type: **not specified**

NNLO QCD corrections to Delta Gamma in the B anti-B system

Friday, September 27, 2024 3:05 PM (25 minutes)

In this talk I will present the newest results of the theoretical determination of Delta Gamma in the B anti-B system. This calculation is carried out as a matching calculation between two effective field theories, Delta B = 1 and Delta B = 2. Particular challenges in including penguin operators on the Delta B = 1 side as well as the computation of higher order corrections in mc/mb will be discussed.

Authors: Prof. STEINHAUSER, Matthias (KIT); Prof. NIERSTE, Ulrich (KIT); Dr SHTABOVENKO, Vladyslav (Siegen University); REECK, Pascal (KIT TTP)

Presenter: REECK, Pascal (KIT TTP)

Session Classification: Young Scientist Talks

Contribution ID: **2** Type: **not specified**

Anomalous Couplings in Higgs plus Jet Production

Wednesday, September 25, 2024 4:35 PM (25 minutes)

We present NLO QCD results for Higgs boson production in association with one jet, including anomalous Higgs-top and Higgs-gluon couplings, and with full top quark mass dependence. We will compare the full theory with varied anomalous couplings to the Standard Model. Of special interest will be the $p_{T,H}$ distribution, since the high-pT tail is sensitive to heavy new physics.

Authors: CAMPILLO, Benjamin (KIT); HEINRICH, Gudrun (KIT); KERNER, Matthias (KIT); KUNZ, Lucas (KIT - ITP)

Presenter: CAMPILLO, Benjamin (KIT)

Session Classification: Young Scientist Talks

Contribution ID: **3** Type: **not specified**

Four top final states - fixed order NLO vs. NLO+PS

Friday, September 27, 2024 9:55 AM (25 minutes)

Upon the observation of the four-top (4t) production in both ATLAS and CMS and the expected increase in precision in the upcoming HL-LHC runs, we are motivated to revisit the theoretical calculations of the process. We study the calculations from fixed order perturbative QCD using HELAC-NLO, which employs the Narrow Width Approximation (NWA) at NLO accuracy in both production and decay, in comparison with methods which use matching to Parton Showers (PS), specifically POWHEG and MC@NLO methods. We also study the effect of including Matrix Element Corrections (MECs) in the NLO+PS methods. Such a comparison could assess the extent to which parton shower effects can reproduce all the contributions required at the NLO level in QCD for the 4t process. In addition, it could help to identify regions of phase space for specific observables that are indeed sensitive to parton showers, that are absent in our fixed-order predictions for this process. The study is made for the 4 lepton and 3 lepton channels.

Author: ALSAIRAFI, Manal (RWTH Aachen)

Co-authors: Mr DIMITRAKOPOULOS, Nikolaos (RWTH Aachen); Prof. WOREK, Malgorzata (RWTH Aachen)

Presenter: ALSAIRAFI, Manal (RWTH Aachen)

Session Classification: Young Scientist Talks

Contribution ID: **4** Type: **not specified**

Higgs boson production in weak-boson fusion and $H \to b\bar{b}$ decay at NNLO with realistic event selection criteria

Wednesday, September 25, 2024 4:10 PM (25 minutes)

The b-quark Yukawa coupling y_b can be measured in $H \to b\bar{b}$ decay. While $H \to b\bar{b}$ is the main decay mode of the Higgs boson, measuring it experimentally is challenging because of the large number of b-quarks from other QCD processes. However, Higgs boson production in weak-boson fusion (WBF) can be distinguished from those QCD backgrounds by the presence of two nearly back-to-back forward jets. In order to isolate such a signal it is important to have a good theoretical model of this process in the kinematic region defined by event selection criteria.

We present fully-differential results for Higgs boson production in weak-boson fusion followed by $H \to b\bar{b}$ Higgs decay in the narrow-width approximation, at NNLO in QCD. The nested soft-collinear subtraction scheme is used to cancel infrared divergences between real and virtual corrections and obtain finite predictions.

We find that the perturbative corrections to this process reduce the fiducial cross-section by about 40% in comparison to the leading-order predictions. Such large corrections can be attributed to a number of distinct sources, the strongest of which is the tendency of the QCD radiation in the $H \to b\bar{b}$ decay to reduce the transverse momentum of b-jets to the point where they no longer pass the b-jet selection criteria.

Authors: NOVIKOV, Ivan (KIT); MELNIKOV, Kirill (TTP KIT); BEHRING, Arnd (CERN); ASTERIADIS, Konstantin (TTP); Dr RÖNTSCH, Raoul (University of Milan)

Presenter: NOVIKOV, Ivan (KIT)

Session Classification: Young Scientist Talks

Contribution ID: **5** Type: **not specified**

AsyInt for massive two-loop four-point integrals at high energies

Wednesday, September 25, 2024 1:25 PM (25 minutes)

In this talk, I will present analytic techniques for massive two-loop four-point Feynman integrals at high energies and the toolbox AsyInt. In the high-energy region, the Feynman integrals involving massive particles, such as the top quark, Higgs and vector bosons, can be asymptotically expanded and directly calculated in the small-mass limit. With AsyInt, analytic results for higher-order terms in the expansion parameter and the dimensional regulator can be obtained.

Author: ZHANG, Hantian (KIT)

Presenter: ZHANG, Hantian (KIT)

Session Classification: Young Scientist Talks

Contribution ID: **6** Type: **not specified**

Quark-Mass Effects in Higgs Production

Thursday, September 26, 2024 9:30 AM (25 minutes)

We present results for the Higgs production cross section in the gluon-gluon-fusion channel at next-to-next-to-leading order with finite quark masses. While the impact of finite quark masses are power-suppressed, the precision of state-of-the-art theory predictions makes an exact determination of this effect indispensable. With this result, we address one of the leading theory uncertainties of the cross section.

Authors: ESCHMENT, Felix (RWTH Aachen - TTK); Mr NIGGETIEDT, Marco (RWTH Aachen University); CZAKON, Michal (RWTH Aachen University); Mr PONCELET, Rene; SCHELLENBERGER, Tom (RWTH Aachen)

Presenter: SCHELLENBERGER, Tom (RWTH Aachen)

Session Classification: Young Scientist Talks

Contribution ID: **7** Type: **not specified**

The gradient flow extended to the Standard Model

Friday, September 27, 2024 11:30 AM (25 minutes)

The gradient flow (GF) has proven to be an effective tool in lattice QCD, with applications such as the extraction of thermodynamic quantities from the flowed energy-momentum tensor and the non-perturbative calculation of the QCD beta function. Additionally, it shows promise for determining operator renormalization matrices in effective field theories. However, its application has been largely confined to pure QCD, limiting its utility in broader contexts, such as Standard Model Effective Field Theory (SMEFT). In this talk, I will present a gradient flow formulation for the minimal flavor-violating Standard Model in the unbroken phase as a first step towards the systematic GF based calculation of SMEFT operator renormalization. I will highlight key results such as the flowed wave function renormalizations through next-to-next-to leading order.

Authors: BORGULAT, Janosch (RWTH Aachen University); HARLANDER, Robert (RWTH Aachen University); Mr KOHNEN, Jonas (RWTH Aachen University)

Presenter: BORGULAT, Janosch (RWTH Aachen University)

Session Classification: Young Scientist Talks

Contribution ID: **8** Type: **not specified**

Emulation of cosmic-ray antideuteron fluxes from dark matter annihilation

Wednesday, September 25, 2024 1:50 PM (25 minutes)

Cosmic-ray antimatter, particularly low-energy antideuterons, constitute a sensitive probe of dark matter annihilating in our Galaxy. We study this smoking-gun signature and explore its complementary to indirect search via cosmic-ray antiprotons. We revisit the Monte Carlo simulation of antideuteron coalescence and cosmic-ray propagation, allowing us to assess uncertainties from both processes. In particular, we incorporate uncertainties in the Λ_b production rate and the coalescence momentum and consider two distinctly different propagation models. To this end, we further the development of the neutral emulator DarkRayNet enabling a fast prediction of propagated antideuteron energy spectra for a wide range of annihilation channels and any admixtures thereof. We find that our network can predict the various spectra with excellent accuracy, offering a significant speed-up over the full simulation. Employing the network's output, we then test the detectability of antideuterons from dark matter annihilation with AMS-02 and the upcoming GAPS experiment for a wide range of dark matter masses.

Author: RATHMANN, Lena

Presenter: RATHMANN, Lena

Session Classification: Young Scientist Talks

Contribution ID: **9** Type: **not specified**

Towards HH at NNLO QCD: the n_h^2 contribution

Thursday, September 26, 2024 9:55 AM (25 minutes)

The virtual corrections for $gg \to HH$ at NLO QCD have been efficiently approximated using a Taylor expansion in the limit of a forward kinematics. The same method has been recently applied to the calculation of a subset of the NNLO corrections, which are desirable given the significant impact, at NLO, of the uncertainty due to the choice of the top mass renormalization scheme.
In this talk, I will report on the progress in the calculation of another contribution at NNLO, given by diagrams in which the two Higgs bosons couple to different top quark loops. For this contribution a naive Taylor expansion cannot be used, and I will instead discuss an approach based on asymptotic expansions in different kinematic limits.

Author: VITTI, Marco (Karlsruhe Institute of Technology - TTP & IAP)

Presenter: VITTI, Marco (Karlsruhe Institute of Technology - TTP & IAP)

Session Classification: Young Scientist Talks

Contribution ID: **10** Type: **not specified**

Leaving academia, where am I?

Thursday, September 26, 2024 2:15 PM (45 minutes)

Presenter: Dr BRØNNUM-HANSEN, Christian (Agency for Climate Data)

Session Classification: Career Event

Contribution ID: **11** Type: **not specified**

A Brownian career

Thursday, September 26, 2024 3:00 PM (45 minutes)

Presenter: Dr MOSCATI, Marta (Deezer & Johannes Kepler Universität Linz)

Session Classification: Career Event

Contribution ID: **12** Type: **not specified**

BSM Higgs Stories - Today and in the Past

Wednesday, September 25, 2024 3:00 PM (1h 10m)

Presenter: MUHLLEITNER, Milada Margarete (KIT)

Session Classification: CRC Talk

Contribution ID: **13** Type: **not specified**

N-jettiness soft function at NNLO in QCD

Friday, September 27, 2024 9:30 AM (25 minutes)

We discuss the calculation of N-jettiness soft function at NNLO. Motivated by the connection between NNLO subtraction schemes and modern slicing methods, we derive a simple finite representation of the renormalized N-jettiness soft function, where the hard partons N acts as a parameter. We demonstrate the analytic cancellation between the bare soft function and its renormalization matrix in color space.

Author: AGARWAL, Prem

Co-authors: Dr PEDRON, Ivan (KIT); MELNIKOV, Kirill (TTP KIT)

Presenter: AGARWAL, Prem

Session Classification: Young Scientist Talks

Contribution ID: **14** Type: **not specified**

Lorentz-Equivariant Geometric Algebra Transformers for High-Energy Physics

Friday, September 27, 2024 12:20 PM (25 minutes)

Extracting scientific understanding from particle-physics experiments requires solving diverse learning problems with high precision and good data efficiency. We propose the Lorentz Geometric Algebra Transformer (L-GATr), a new multi-purpose architecture for high-energy physics. L-GATr represents high-energy data in a geometric algebra over four-dimensional space-time and is equivariant under Lorentz transformations, the symmetry group of relativistic kinematics. At the same time, the architecture is a Transformer, which makes it versatile and scalable to large systems. L-GATr is first demonstrated on regression and classification tasks from particle physics. We then construct the first Lorentz-equivariant generative model: a continuous normalizing flow based on an L-GATr network, trained with Riemannian flow matching. Across our experiments, L-GATr is on par with or outperforms strong domain-specific baselines.

Author: SPINNER, Jonas

Presenter: SPINNER, Jonas

Session Classification: Young Scientist Talks

Contribution ID: **15** Type: **not specified**

Choosing the Right Features for Anomaly Detection

Friday, September 27, 2024 11:55 AM (25 minutes)

Weakly supervised methods have emerged as a powerful tool for model agnostic anomaly detection at the LHC. While remarkable performance has been achieved for specific sets of high-level input features, a further exploration of different input feature sets of various types will lead to more model agnostic and better performing setups. In this talk, we explore low-level features as well as some high-level features, including subjettiness based feature sets and energy flow polynomials.

Authors: MÜCK, Alexander; GEUSKENS, Joep; LANG, Lukas; HEIN, Marie (RWTH Aachen University); KRÄMER, Michael (RWTH Aachen University); MASTANDREA, Radha

Presenter: HEIN, Marie (RWTH Aachen University)

Session Classification: Young Scientist Talks

Contribution ID: **16** Type: **not specified**

Heavy-to-light form factors to three loops

Friday, September 27, 2024 10:20 AM (25 minutes)

In this talk, we discuss the computation of form factors for decays of heavy into light quarks at third order in QCD for various currents. We describe the different steps of the calculation and use the results to compute the hard matching coefficients in Soft-Collinear Effective Theory for all currents. Further, we extract the hard function in the factorization formula of $B \to X_s\gamma$ to three loops using the tensor coefficients at light-like momentum transfer. Future applications to charged-current semi-leptonic decays are briefly sketched.

Authors: FAEL, Matteo; HUBER, Tobias; LANGE, Fabian; MÜLLER, Jakob; SCHÖNWALD, Kay; STEINHAUSER, Matthias

Presenter: MÜLLER, Jakob

Session Classification: Young Scientist Talks

Contribution ID: **17** Type: **not specified**

A look into the f0(980) through the lens of rare B meson decays

Thursday, September 26, 2024 12:20 PM (25 minutes)

The nature of many experimentally observed hadronic resonances has been a topic of debate ever since the 1960's. In this work, we focus on studying the $f_0(980)$, the second lightest unflavoured scalar resonance. We comment on the different descriptions for it in the quark model, and focus specifically on the pure $s\bar{s}$ picture. We mainly explore the $B_s^0 \to f_0(980)\mu^+\mu^-$ decay. We analyse the impact of the form factors, which are difficult to determine theoretically. They come from the hadronic matrix element and contain the hadronic information of the decay. Using the framework of the Weak Effective Theory, we utilize Wilson coefficients derived from observables of rare decays with the same quark-level transition, like $B \to K^{(*)}\mu^+\mu^-$, to probe the hadronic nature of the $f_0(980)$, even in the presence of possible New Physics. The effect of different theoretical form factor calculations on several observables is explored in detail. A range for the experimental untagged branching ratio integrated in the $[1, 6]$ q^2 bin (where q^2 is the square of the 4-momenta of the muon pair) is found to be $\mathcal{BR}_{\text{exp}} \in [0.04, 2.11] \times 10^{-7}$, according to the current form factor calculations, which all assume a pure $s\bar{s}$ state. The viability of extracting the form factors from experimental data is also studied, finding that determining one of them from the branching ratio would be possible with good precision.

Author: DEL PALACIO LIROLA, Jaime (University of Siegen)

Presenter: DEL PALACIO LIROLA, Jaime (University of Siegen)

Session Classification: Young Scientist Talks

Contribution ID: **18** Type: **not specified**

Yukawa- and Higgs self-coupling corrections to di-Higgs production

Thursday, September 26, 2024 10:20 AM (25 minutes)

The upcoming HL-LHC phase gives hope to tighten the experimental constraints on one of the core parameters of the SM: the Higgs self-coupling. The most prolific process to consider in this context is double Higgs boson production. Theoretical higher order calculations, both QCD and electro-weak, are required to match the experimental precision. In this talk we present our calculation of electro-weak NLO contributions comprising Yukawa-type and Higgs self-coupling corrections at two-loop level.

Authors: VESTNER, Augustin (KIT-ITP); HEINRICH, Gudrun (KIT); KERNER, Matthias (KIT); JONES, Stephen (IPPP); STONE, Tom (IPPP)

Presenter: VESTNER, Augustin (KIT-ITP)

Session Classification: Young Scientist Talks

Contribution ID: **19** Type: **not specified**

Can we predict $B \to Ka$ decay rate without specifying UV physics?

Friday, September 27, 2024 2:40 PM (25 minutes)

We revisit the transition rate of $b \to s$ and a light axion-like particle a, to address overlooked contributions and ambiguities. Existing bottom-up approaches often lack clarity and predictive power. By recalculating the effective Hamiltonian in the minimal DFSZ model, we show that previous results are valid at one loop by coincidence, while significant two-loop contributions were missed. We then compare the DFSZ predictions with model-independent results and identify the sources of ambiguity. Finally, we argue that only with a specific choice of basis, the correct leading-log term can be derived in the bottom-up approach.

Authors: GAO, Xiyuan (KIT); Prof. NIERSTE, Ulrich (KIT); Dr ZIEGLER, Robert (KIT)

Presenter: GAO, Xiyuan (KIT)

Session Classification: Young Scientist Talks

Contribution ID: **20** Type: **not specified**

Nonleptonic B-decays at NNLO

Thursday, September 26, 2024 11:55 AM (25 minutes)

The decay of B mesons can be predicted within the Heavy Quark Expansion as the decay of a free bottom quark plus corrections which are suppressed by powers of $1/m_b$. This talk describes the calculation of the NNLO QCD corrections to nonleptonic decays of a free bottom quark including charm quark mass effects. In particular I will outline the challenges in connection to the computation of master integrals, the renormalization of the effective operators and the problems which arise from calculating traces with γ_5 in d dimensions.

Author: EGNER, Manuel (KIT TTP)

Presenter: EGNER, Manuel (KIT TTP)

Session Classification: Young Scientist Talks

Contribution ID: **21** Type: **not specified**

Heavy sterile Neutrinos from B decays and new QCD corrections to their semi-hadronic decay rates

Thursday, September 26, 2024 11:30 AM (25 minutes)

In modern experiments on flavour physics it is possible to search for the decays of B's, D's, or τ's into final states with heavy neutrinos N (a.k.a. heavy neutral leptons). I present a common study of theorists and experimentalists from Belle II on constraints on $B \to D^* \ell N$. Next I discuss the status of the theory predictions of the various N decay rates. In scenarios in which N interacts with SM particles only through sterile-active neutrino mixing, the dependence of
the lifetime on the relevant mixing angles is important to determine whether N decays in the detector or outside. To calculate the inclusive decay rate into semi-hadronic final states reliably one needs to include radiative QCD corrections. I present analytic results for the QCD-corrected decay rates and discuss their phenomenological impact.

Authors: BERNLOCHNER, Florian (Universität Bonn); FEDELE, Marco (KIT, TTP); PRIM, Markus (Universität Bonn); Mr KRETZ, Tim (Karlsruher Institut für Technologie (KIT - TTP)); NIERSTE, Ulrich (Institut fuer Theoretische Teilchenphysik, KIT CS)

Presenter: Mr KRETZ, Tim (Karlsruher Institut für Technologie (KIT - TTP))

Session Classification: Young Scientist Talks

Contribution ID: **22** Type: **not specified**

Satisfiability modulo theories solvers and particle physics

Wednesday, September 25, 2024 1:00 PM (25 minutes)

The field of Satisfiability Modulo Theories (SMT) focuses on techniques for determining the satisfiability of first-order logic formulas within formal theories. Despite its relatively short existence of approximately 20 years, SMT solvers have shown remarkable capabilities, combining expressive power with practical efficiency. They find successful applications across various research and industry domains, though their potential remains largely unexplored in particle physics. In this talk I will explore the fundamental principles of SMT solving and demonstrate its practical utility based on novel approach to perform the multiplet decomposition of the color structure of QCD processes. The talk is intended for everybody who encounters hard-to-solve combinatorial problems: SMT solvers represent a mature, industrial-grade solving technology that may offer a straightforward solution to your problem with minimal effort required on your part.

Author: CHARGEISHVILI, Bakar (KIT)

Presenter: CHARGEISHVILI, Bakar (KIT)

Session Classification: Young Scientist Talks

Contribution ID: **23** Type: **not specified**

Higher-order QED×QCD Corrections To Semi-leptonic Decays

Friday, September 27, 2024 2:15 PM (25 minutes)

A systematic treatment of electromagnetic and strong corrections to the semi-leptonic decays is needed in order to have a precise determination of phenomenological parameters of the Standard Model (SM), such as CKM matrix elements. Under the presence of QED, the matrix element associated to the effective semi-leptonic operator on the lattice has to be renormalised, thus requiring a matching to the continuum results.
To this end, we calculate the corresponding pertubative matching coefficients up to $O(\alpha\alpha_s)$.
In our work, we emphasise the importance of appropriate choices of renormalisation conditions on the lattice and show how these impact the resulting perturbative matching. In particular, we find that the renormalization conditions defined and used in the literature thus far lead to extraneous and unnecessary QCD contributions that reflect in an artificial dependence on the lattice matching scale.
We suggest improvements to rectify this problem and present the complete expression for the Leading-Log (LL) and Next-to-Leading-Log (NLL) strong corrections to the electromagnetic contributions of the low-scale Wilson Coefficient.
Additional steps will also be discussed, including matching the full SM at the Electroweak scale and the 3-loop anomalous dimensions of the semi-leptonic operator necessary to achieve the NLL result.

Author: MORETTI, Francesco (TTP)

Presenter: MORETTI, Francesco (TTP)

Session Classification: Young Scientist Talks