Quantum100 $\otimes$ AI Workshop

Reporte der Beiträge

https://indico.uni-muenster.de/e/Q100xAI

Beitrag ID: **1** Typ: **Poster**

Entanglement Asymmetry and Quantum Mpemba Effect for Non-Abelian Global Symmetry

Entanglement asymmetry is a measure that quantifies the degree of symmetry breaking at the level of a subsystem. In this work, we investigate the entanglement asymmetry in $\widehat{su}(N)_k$ Wess-Zumino-Witten model and discuss the quantum Mpemba effect for SU(N) symmetry, the phenomenon that the more symmetry is initially broken, the faster it is restored. Due to the Coleman–Mermin–Wagner theorem, spontaneous breaking of continuous global symmetries is forbidden in $1+1$ dimensions. To circumvent this no-go theorem, we consider excited initial states which explicitly break non-Abelian global symmetry. We particularly focus on the initial states built from primary operators in the fundamental and adjoint representations. In both cases, we study the real-time dynamics of the R\'enyi entanglement asymmetry and provide clear evidence of quantum Mpemba effect for SU(N) symmetry. Furthermore, we find a new type of quantum Mpemba effect for the primary operator in the fundamental representation: increasing the rank N leads to stronger initial symmetry breaking but faster symmetry restoration. Also, increasing the level k leads to weaker initial symmetry breaking but slower symmetry restoration. On the other hand, no such behavior is observed for adjoint case, which may suggest that this new type of quantum Mpemba effect is not universal.

Hauptautor: FUJIMURA, Harunobu (The University of Osaka)

Co-Autor: SHIMAMORI, Soichiro (The University of Osaka)

Vortragende(r): FUJIMURA, Harunobu (The University of Osaka)

Beitrag ID: **3** Typ: **Poster**

Machine Learning Lagrangians

We provide a simple toy model of machine learning that reconstructs QFT Lagrangians from the data of scattering amplitudes. We evaluate the performance differences that depend on the neural network architecture, and discuss the model's predictive ability for heavy particles that are not explicitly present in law energy scattering data.

Hauptautor: YODA, Takuya (Kyoto University)

Co-Autor: HASHIMOTO, Koji (Kyoto University)

Vortragende(r): YODA, Takuya (Kyoto University)

Beitrag ID: **5** Typ: **Poster**

Entanglement studies with Belle Y(5⍰) data

Compared to the $\Upsilon(4S)$, the $\Upsilon(5S)$ can decay into excited B^{0*}, giving rise to $B^0/\bar{B}^0$ pairs in different quantum states. Directly after the $\Upsilon(5S)$ decay, the produced $B^{0(*)}\bar{B}^{0(*)}$ pairs are expected to be in a $J^{PC} = 1^{--}$ state. Following the radiative transition $B^{0*} \to B^0\gamma$, the system evolves into states with $J^{PC} = 1^{-+}$. Depending on the C-parity, the $B^0/\bar{B}^0$ can be in a symmetric (triplet) or antisymmetric (singlet) wave function, leading to different time evolutions of the entangled states. By mixing the two C-parity states $C = -1$ and $C = +1$, one can create a mixed state that is physically indistinguishable from a disentangled system.

We currently study these effects using $\Upsilon(5S)$ Monte Carlo data simulated from the Belle experiment. The analysis includes the reconstruction of the signal $B^{0(*)}$ meson pairs through the decay chain $B^0 \to D^-(\to K^+\pi^-\pi^-)\pi^+$, as well as obtaining the vertex and flavor information of the other B-meson inclusively. In addition, the $B^0/\bar{B}^0$ quantum states are separated using the variables M_{bc} and ΔE.

Hauptautoren: BERIET, Louise (Max Planck Institute); Frau GEIER, Vanessa (Max Planck Institute)

Vortragende(r): BERIET, Louise (Max Planck Institute)

Beitrag ID: **7** Typ: **Talk**

Quantum AI: Toward the next revolution driven by quantum computing and AI

Donnerstag, 13. November 2025 17:00 (30 Minuten)

A hundred years after the birth of quantum mechanics, we are entering its second revolution, the rise of quantum technology. A representative example is quantum computing, which performs computation based on the principles of quantum mechanics, and has already begun to demonstrate quantum advantage in certain physical simulations. In this talk, I will introduce our efforts to harness such quantum computers for/with AI. I will first outline how our early proposal quantum machine learning algorithms opened a pathway to integrate learning algorithms with quantum dynamics. I will then discuss recent advances in quantum computing with AI, where modern AI techniques are used to design, optimize, and control quantum algorithms. These developments mark the beginning of a new era where quantum computing and artificial intelligence evolve together, shaping the future of intelligent computation.

Vortragende(r): FUJII, Keisuke (The University of Osaka)

Sitzung Einordnung: Plenary

Beitrag ID: **8** Typ: **Talk**

AI-assisted theoretical discovery

Freitag, 14. November 2025 10:30 (30 Minuten)

We argue how AI can assist mathematics in three ways: theorem-proving, conjecture formulation, and language processing. Inspired by initial experiments in geometry and string theory in 2017, we summarize how this emerging field has grown over the past years, and show how various machine-learning algorithms can help with pattern detection across disciplines ranging from algebraic geometry to representation theory, to combinatorics, and to number theory. At the heart of the programme is the question how does AI help with theoretical discovery, and the implications for the future of mathematics.

Vortragende(r): HE, Yang-Hui (London Institute for Mathematical Sciences & Merton College, Oxford)

Sitzung Einordnung: Plenary

Beitrag ID: **9** Typ: **Talk**

Understanding diffusion models by Feynman's path integral

Mittwoch, 12. November 2025 14:30 (30 Minuten)

Diffusion models have emerged as powerful tools in generative modeling, especially in image generation tasks. In this talk, we introduce a novel perspective by formulating diffusion models using the path integral method introduced by Feynman for describing quantum mechanics. We find this formulation providing comprehensive descriptions of score-based diffusion generative models, such as the derivation of backward stochastic differential equations and loss functions for optimization.The formulation accommodates an interpolating parameter connecting stochastic and deterministic sampling schemes, and this parameter can be identified as a counterpart of Planck's constant in quantum physics. This analogy enables us to apply the Wentzel-Kramers-Brillouin (WKB) expansion, a well-established technique in quantum physics, for evaluating the negative log-likelihood to assess the performance disparity between stochastic and deterministic sampling schemes.

Vortragende(r): HIRONO, Yuji (University of Tsukuba)

Sitzung Einordnung: Plenary

Beitrag ID: **10** Typ: **Talk**

The road to AI-based discoveries

Donnerstag, 13. November 2025 09:30 (30 Minuten)

Modern machine learning and artificial intelligence fundamentally change how we analyze huge volumes of data in particle physics and adjacent scientific disciplines. These breakthroughs promise new insights into major scientific questions such as the nature of dark matter or the existence of physical phenomena beyond the standard model. This talk will provide an overview of recent, exciting developments with a focus on model agnostic search strategies (including first experimental results!) as well as foundation models and increasingly autonomous AI-based agents of discovery.

Vortragende(r): KASIECZKA, Gregor (Universität Hamburg)

Sitzung Einordnung: Plenary

Beitrag ID: **11** Typ: **Talk**

Deep learning spacetime from quantum data

Freitag, 14. November 2025 09:00 (30 Minuten)

According to the holographic principle, one of the most influential contemporary themes in physics, gravitational dynamics in the “bulk” spacetime is dual to the quantum physics of a system defined on its “boundary.” We employ a deep learning approach to infer the bulk spacetime geometry from boundary quantum data, such as conductivity and entanglement entropy. In particular, we apply this method to gain insights into the properties of quantum matter. Our approach is general and broadly applicable to a wide range of physics problems involving differential equations and integral formulations. Thus, it can also be useful for introductory physics and mathematics problems.

Vortragende(r): KIM, Keun-Young (Gwangju Institute of Science and Technology (GIST))

Sitzung Einordnung: Plenary

Beitrag ID: **12** Typ: **Talk**

Connecting string theory with particle physics and cosmology via AI

Donnerstag, 13. November 2025 09:00 (30 Minuten)

In this talk I discuss how understanding the observable consequences of quantum gravity, in particular string theory models, is accelerated using AI methods. This overview will highlight several examples of using physics inspired neural networks to solve Einsteins equations in higher dimensions, differentiable programming to find solutions to string theory equations of motion, and how conditional generative models enable an efficient study of the inverse problem connecting UV string theory constructions with observable quantities. Time permitting I comment on how automated workflows using LLMs can accelerate our research on these long-standing questions even further.

Vortragende(r): KRIPPENDORF, Sven (Cambridge University)

Sitzung Einordnung: Plenary

Beitrag ID: **13** Typ: **Talk**

Self-learning Monte Carlo method with equivariant transformer

Donnerstag, 13. November 2025 15:00 (30 Minuten)

Machine learning and deep learning have revolutionized computational physics, particularly in the simulation of complex systems. Equivariance plays a crucial role in modeling physical systems, as it enforces symmetry constraints that act as strong inductive biases on the learned probability distributions. However, incorporating such symmetries into models can sometimes lead to low acceptance rates in self-learning Monte Carlo (SLMC) methods.

In this work, we introduce a symmetry-equivariant attention mechanism for SLMC that can be systematically improved. We evaluate our architecture on the spin–fermion (double-exchange) model on a two-dimensional lattice. Our results demonstrate that the proposed method overcomes the poor acceptance rates observed in linear models and exhibits a scaling law analogous to that of large language models, with model quality improving monotonically with the number of layers [1]. This work paves the way toward more accurate and efficient Monte Carlo algorithms powered by machine learning for simulating complex physical systems.

[1] Y. Nagai and A. Tomiya, J. Phys. Soc. Jpn. 93, 114007 (2024).

Vortragende(r): NAGAI, Yuki (The University of Tokyo)

Sitzung Einordnung: Plenary

Beitrag ID: **14** Typ: **Talk**

Language of jets with transformers

Freitag, 14. November 2025 09:30 (30 Minuten)

Collisions of high energy particles trigger multiple interactions and result in complex patterns of particles in the final state. The resulting particle production patterns exhibit fascinating quantum phenomena such as spin correlation, color coherence and quantum entanglement. Theoretical particle physics has been evolving continuously to deepen our understanding of these phenomena, to determine the fundamental interaction of particles and searching for unknown matters in our Universe. How might the recent advances in deep learning accelerate this process? In this talk, we will present our recent works, focusing on ideas related to Transformer architectures.

Vortragende(r): NOJIRI, Mihoko (IPNS, KEK)

Sitzung Einordnung: Plenary

Beitrag ID: **15** Typ: **Talk**

Coding agents and the future of scientific software

The rise of AI coding assistants and agents is transforming how scientific software is written, debugged, and maintained. In this talk, I explore how large language models have reshaped research workflows, share a personal perspective on integrating these technologies, and discuss strategies for maximizing their effectiveness. I examine what current benchmarks measure, why vibe coding is an unsustainable pitfall, and why providing sufficient context is crucial. Finally, I offer an outlook on what the next few years may hold for AI-assisted scientific software and the evolving role of physicists in this new landscape.

Vortragende(r): NEUWIRTH, Alexander (UNIMIB & INFN)

Sitzung Einordnung: Plenary

Beitrag ID: **16** Typ: **Talk**

Representation learning for LHC physics

Freitag, 14. November 2025 11:00 (30 Minuten)

LHC physics, just like our lives, is being transformed by modern machine learning. This is motivated by the vast data stream and the role of simulations encoding fundamental physics knowledge. The scientific AI program around the LHC comes with unique advantages: we understand the feature space and scattering dynamics in terms of fundamental symmetries and quantum field theory; we have full control over uncertainties; and ML tasks are parts of an advanced statistical analysis framework. I will show how these strengths allow us develop and establish exciting concepts in representation learning, targeting requirements like accuracy, precision, and control.

Vortragende(r): PLEHN, Tilman (Heidelberg University)

Sitzung Einordnung: Plenary

Beitrag ID: **17** Typ: **Talk**

High-energy colliders are quantum machines

Donnerstag, 13. November 2025 11:30 (30 Minuten)

High-energy colliders, such as the Large Hadron Collider (LHC) at CERN, are genuine quantum machines by nature, and thus, following Richard Feynman's original motivation for quantum computing, the scattering processes occurring there should be more effectively simulated by a quantum system. While the dream of a fully-fledged quantum event generator for simulating scattering processes at colliders is still far in future, there is a huge interest in the particle physics community in leveraging the latest advances in Quantum Computing. The potential applications include quantum machine learning techniques for collider data analysis, enabling faster and more precise evaluations of the intricate multiloop Feynman diagrams, simplifying the complexity of jet clustering, simulating parton showers, and many others. In this talk, I will focus on two specific applications, the identification of the causal structure of multiloop Feynman diagrams, a fundamental ingredient in the Loop-Tree Duality which is closely linked to graph theory, and the integration and sampling of multidimensional functions. The latter represents an initial step toward realizing a partonic quantum event generator with next-to-leading order (NLO) accuracy and beyond.

Vortragende(r): RODRIGO, Germán (IFIC UV-CSIC)

Sitzung Einordnung: Plenary

Beitrag ID: **18** Typ: **Talk**

Interpretable AI for scientific discovery

Donnerstag, 13. November 2025 15:30 (30 Minuten)

While machine learning techniques are incredibly powerful, they are also notoriously difficult to interpret. This poses a problem fore research areas such as pure mathematics or certain fields in theoretical physics, which require rigor and understanding, while ML algorithms are often stochastic and black box. I will first give a brief overview of ML techniques that lead to rigorous, exact results. After that, I will focus on one technique called symbolic regression. I will explain how Kolmogorov-Arnold networks can be paired with genetic algorithms to obtain symbolic formulae instead of numeric expressions.

Vortragende(r): RUEHLE, Fabian (Northeastern University)

Sitzung Einordnung: Plenary

Beitrag ID: **19** Typ: **Talk**

AI augmented event generation for collider physics

Donnerstag, 13. November 2025 16:30 (30 Minuten)

The evaluation of fixed-order perturbative QFT transition matrix elements forms the central component of simulations of scattering events at collider experiments as provided by Monte Carlo event generators. In view of the physics requirements of the LHC experiments high-multiplicity processes at high perturbative accuracy need to be addressed. This posses a severe challenge to the current state-of-the-art algorithms for phase-space sampling and event generation. In this talk I will discuss two methods to augment event generation with AI methods in order to improve the generator performance: Neural Importance Sampling and Neural Network Surrogate Unweighting.

Vortragende(r): SCHUMANN, Steffen (ITP Uni Goettingen)

Sitzung Einordnung: Plenary

Beitrag ID: **20** Typ: **Talk**

Generative AI for brane configurations and gauge theory phases

Donnerstag, 13. November 2025 11:00 (30 Minuten)

The talk illustrates how a generative AI model can be trained to learn the relationship between geometry and quantum field theory, producing Type IIB brane configurations in string theory that realize these field theories and tracking variations of these brane configurations that distinguish gauge theory phases related by duality. We focus on a particular family of 4-dimensional supersymmetric gauge theories associated with Calabi–Yau geometries, which are realized by brane configurations that depend on the shape of the corresponding mirror curve of the Calabi-Yau. The generative AI model takes the complex-structure moduli of the Calabi-Yau mirror curve as input and generates the shape of the mirror curve from which we read off the corresponding gauge theory Lagrangian and phase. We illustrate how we can extend this method to gauge theories in different spacetime dimensions, leading to the discovery of a more general family of gauge theory dualities.

Vortragende(r): SEONG, Rak-Kyeong (Ulsan National Institute of Science and Technology)

Sitzung Einordnung: Plenary

Beitrag ID: **21** Typ: **Talk**

Building an AI generator for quantum gravity

Mittwoch, 12. November 2025 15:30 (30 Minuten)

Modern physics rests on two pillars: quantum mechanics which governs the microscopic world and general relativity which describes gravity and the structure of spacetime. Yet, these two pillars are fundamentally incompatible. String theory provides a promising way forward in unifying quantum mechanics with gravity, but it comes at a price of having an enormous number of solutions. The vastness of solutions stems from the multitude of choices for the internal space on which string theory is compactified, and additional structures (e.g. fluxes and branes) on these internal spaces. We do not know how many topologically distinct internal manifolds there are. Even for tractable subsets such as toric Calabi-Yau constructions, only upper bounds are known—rendering exhaustive searches infeasible, as brute-force enumeration would exceed the age of the universe. In this talk, I will present a transformer-based generative model capable of producing new Calabi–Yau manifolds with efficient and unbiased sampling. The model can self-improve through iterative retraining on its own high-quality outputs, offering a scalable approach to exploring quantum gravity. This talk is based on arXiv:2507.03732 [hep-th] and a companion community-driven platform for AI-assisted research in quantum gravity known as AICY.

Vortragende(r): SHIU, Gary (University of Wisconsin-Madison)

Sitzung Einordnung: Plenary

Beitrag ID: **22** Typ: **Talk**

Train by tunneling: Quantum annealing for AI optimization

Mittwoch, 12. November 2025 15:00 (30 Minuten)

Quantum annealing offers a hardware route to solving rugged discrete optimisation problems that appear throughout AI. This talk shows how to cast learning and inference tasks into QUBO or Ising form, then use forward and reverse annealing to navigate nonconvex loss landscapes. I will present compact case studies in classifier training, feature selection, model selection, and physics parameter fitting, benchmarking against classical heuristics and highlighting when tunnelling provides a real advantage. Practical guidance covers minor embedding, precision limits, and zooming strategies, as well as hybrid loops where annealers act as inner optimisers within standard ML workflows. Concretely, I will demonstrate neural network training with Ising-encoded losses, annealer-based solvers for differential equations, and fast, robust parameter-fitting workflows. Across these examples, I will summarise when quantum and thermal annealing excel, the practical limits of present hardware, and how to integrate quantum annealing into hybrid ML workflows for near-term impact.

Vortragende(r): SPANNOWSKY, Michael (IPPP Durham)

Sitzung Einordnung: Plenary

Beitrag ID: **23** Typ: **Talk**

From Ising to QCD: Phases, symmetry, and AI

Donnerstag, 13. November 2025 10:00 (30 Minuten)

At the centennial of quantum mechanics, I will survey the interface of AI × quantum physics with symmetry as the guiding theme. First, I will present work on the Ising model, which also marks its centennial, showing in the two-dimensional case that a convolutional neural network can extract phase transition signals and estimate the critical point without prior knowledge of the order parameter. Next, I will briefly touch on applications that use a Transformer with equivariant attention to semiclassical spin-fermion systems. Finally, I will introduce an extension toward quantum chromodynamics: a gauge-covariant Transformer, CASK, and design principles consistent with gauge symmetry. Building on these elements, I will discuss the horizons that AI × quantum physics can open on next-generation supercomputers.

Vortragende(r): TOMIYA, Akio (Tokyo Woman's Christian University)

Sitzung Einordnung: Plenary

Beitrag ID: **24** Typ: **Poster**

Pulsar Timing Array Parameter Inference with Neural Networks

Recent evidence for a stochastic gravitational-wave background (SGWB) by pulsar timing arrays (PTAs) has opened new avenues for probing physics beyond the Standard Model. However, Bayesian analyses of PTA data remain computationally demanding. Building on earlier work, we leverage simulation-based inference based on neural networks to accelerate SGWB parameter estimation. We explore state-of-the-art transformer encoder networks and observe significantly improved marginal posterior estimates, while maintaining a computational advantage over conventional Markov chain Monte Carlo methods. These techniques are further applied to more complex SGWB models, including higher-order polynomials and signals from early universe phase transitions. Our results show that neural inference can recover key parameters and generalize beyond simple power-law models, indicating promise as a scalable, model-flexible auxiliary method in PTA analyses.

Hauptautor: KNETSCH, Jan-Christopher

Vortragende(r): KNETSCH, Jan-Christopher

Beitrag ID: **25** Typ: **Poster**

AI-driven multistream pipeline for physics lectures

We apply AI to the education domain, aiming to prepare high-quality digital materials for students—specifically transforming lectures from a hadron physics course into reliable resources. The core challenge is to combine several streams of information (speech, formulas, figures) into a coherent product, which cannot be solved by a single-prompt approach. Our pipeline employs embedding-based semantic chunking to group related content within strict context limits, while preserving the lecturer's phrasing, explanatory style, and technical detail. Mathematical expressions are recovered as LaTeX with contextual accuracy, and figures are automatically integrated into the narrative. The system is implemented in a hybrid stack (Python, Deepseek API models, ollama interface for embeddings), enabling reproducible and extensible workflows. Beyond classroom use, the approach points toward future applications such as automated preparation of conference proceedings in the STEM domain.

Hauptautoren: MIKHASENKO, Aleksei (University of Bonn); Herr SEGAL, Ilya (Ruhr University Bochum); Prof. MIKHASENKO, Mikhail (Ruhr University Bochum); Frau THIESS, Saraya (Ruhr University Bochum)

Vortragende(r): MIKHASENKO, Aleksei (University of Bonn)

Beitrag ID: **26** Typ: **Poster**

Quantum error mitigation by BBGKY-informed sampling

The phase diagram of QCD at finite densities remains numerically inaccessible by classical computations. Quantum computers, with their potential for exponential speedup, could overcome this challenge. However, their current physical implementations are affected by quantum noise. In this contribution, I will introduce a novel quantum error mitigation technique based on a general BBGKY-like hierarchy. This mitigation scheme is applicable to any arbitrary N-qubits time-dependent quantum simulation. The core idea of our method is to draw connected BBGKY equations from the hierarchy and use them to constrain a random sampling of possible mitigations. Our preliminary results indicate that this scheme significantly improves the quality of the (1+1)-Schwinger model simulations, in particular when observing the chiral magnetic effect.

Hauptautor: SAPORITI, Theo (Université Paris-Saclay / CEA)

Co-Autoren: TAMAAZOUSTI, Mohamed (Université Paris-Saclay / CEA); KAIKOV, Oleg (Université Paris-Saclay / CEA); SAZONOV, Vasily (Université Paris-Saclay / CEA)

Vortragende(r): SAPORITI, Theo (Université Paris-Saclay / CEA)

Beitrag ID: **27** Typ: **Poster**

Automating quantum circuits design via large language models

Designing effective quantum circuits is a central challenge in quantum computing, covering a wide range of tasks including constructing feature maps for quantum machine learning, designing ansätze for variational algorithms, and tailoring circuits to specific problem instances. Over the years, a variety of quantum circuits have been proposed through manual design and exploration. However, due to their inherent theoretical complexity and the vastness of the design space, systematically exploring such circuits still requires substantial time and effort. In this work, we propose an agentic system that autonomously generates, evaluates, and refines quantum circuits using large language models. The system is composed of five components: Generation, Storage, Validation, Evaluation, and Review. Through iterative interaction of these components, the system continuously improves quantum circuit designs without human intervention. We demonstrate its capability on the automatic discovery of quantum feature maps for image classification tasks, where the best feature map generated outperforms existing quantum baselines and achieves competitive accuracy compared to classical kernels across MNIST, Fashion-MNIST, and CIFAR-10. Beyond feature maps, our framework naturally extends to variational quantum eigensolver, error mitigation strategies, and other algorithms, enabling LLM-driven automation in quantum algorithm design and highlighting a pathway toward problem adaptive quantum circuits. Such an automated design system not only supports experts but also lowers the barrier for researchers from other disciplines, facilitating broader participation in the quantum computing field.

Hauptautor: KENYA, Sakka (The University of Osaka)

Co-Autoren: FUJII, Keisuke (The University of Osaka); Prof. MITARAI, Kosuke (The University of Osaka)

Vortragende(r): KENYA, Sakka (The University of Osaka)

Beitrag ID: **28** Typ: **Poster**

Generative Unfolding of Jets and Their Substructure

Unfolding, for example of distortions imparted by detectors, provides suitable and publishable representations of LHC data. Many methods for unbinned and high-dimensional unfolding using machine learning based have been proposed, but no generative method has been shown to scale to the several hundred dimensions necessary to fully characterize LHC collisions. This project proposes a new generative unfolding framework that is capable of unfolding several hundred dimensions. It is shown to be effective to unfold the full substructure of light-flavor jets and of top jets. This is the first generative unfolding study to achieve high precision on high-dimensional jet substructure.

Hauptautor: PETITJEAN, Antoine (ITP, Universität Heidelberg)

Co-Autor: PLEHN, Tilman (Heidelberg University)

Vortragende(r): PETITJEAN, Antoine (ITP, Universität Heidelberg)

Beitrag ID: **29** Typ: **Poster**

Solving inverse problems of Type IIB flux vacua with conditional generative models

We address the inverse problem in Type IIB flux compactifications of identifying flux vacua with targeted phenomenological properties such as specific superpotential values or tadpole constraints using conditional generative models. These machine learning techniques overcome computational bottlenecks in traditional approaches such as rejection sampling and Markov Chain Monte Carlo (MCMC), which struggle to generate rare, finely-tuned vacua. As a proof of concept, we demonstrate that conditional generative models provide a more efficient alternative, specifically using conditional variational autoencoders (CVAEs). We introduce a CVAE framework tailored to flux compactifications, incorporating physical constraints directly into the loss function —enabling the generation of physically consistent vacua beyond the training set. Our experiments on conifold and symmetric torus background geometries show that the CVAE achieves a speedup of about O() compared to Metropolis sampling, particularly in narrow target ranges for superpotential values. Additionally, the CVAE generates novel, distinct flux configurations beyond the training data, highlighting its potential for probing computationally challenging regions of the string landscape. Our results establish conditional generative models as a powerful and scalable tool for targeted flux vacua generation, opening new pathways for model building in regions of the landscape previously inaccessible by traditional model building techniques.

Hauptautor: LIU, Zhimei (University of Cambridge)

Vortragende(r): LIU, Zhimei (University of Cambridge)

Beitrag ID: **30** Typ: **Poster**

Evaluating gluon scattering amplitudes in instanton backgrounds using physics-informed neural network (PINN)

In Yang-Mills theory, which describes the interactions of elementary particles, gluon scattering amplitudes in the presence of an instanton play a crucial role in understanding the phenomenon of confinement and in theoretical calculations for accelerator experiments. It is known that, in the strong coupling and $N \to \infty$ limit of $N=4$ Super Yang-Mills (SYM) theory, the gluon scattering amplitude can be evaluated from the minimal area of a string worldsheet in T-dual AdS space that satisfies specific boundary conditions [Alday, Maldacena, 2007].

We extend this problem by introducing an instanton into this framework, which allows the string to end on a D3-brane that appears in the T-dual AdS space. To solve the problem of optimizing the system while imposing such complex boundary conditions, we utilize the novel AI technique known as Physics-Informed Neural Networks (PINNs). PINNs flexibly and efficiently search for a solution that satisfies all conditions by including the deviation from the required physical constraints—such as the equations of motion, boundary conditions, and symmetries—into the loss function, and then training the neural network to minimize this loss.

Our analysis suggests that when the instanton scale exceeds the gluon wavelength, the amplitude is enhanced compared to the case without an instanton. This result is consistent with the qualitative theoretical estimations.

Hauptautor: Dr. TANAHASHI, Norihiro (Particle Physics Groups, Kyoto University)

Co-Autoren: OGIWARA, Gakuto (Saitama Inst. of Tech.); KYO, Koichi (Particle Physics Groups, Kyoto University); Prof. HASHIMOTO, Koji (Kyoto University); Prof. MURATA, Masaki (Saitama Inst. of Tech.)

Vortragende(r): KYO, Koichi (Particle Physics Groups, Kyoto University)

Beitrag ID: **31** Typ: **Poster**

Birational Transformations and 2d (0,2) Quiver Gauge Theories beyond Toric Fano 3-folds

We show that a family of birational transformations that relate toric Fano 3-folds defined by reflexive lattice polytopes can be identified with mass deformations of corresponding 2d (0,2) supersymmetric quiver gauge theories. These theories are realized by a Type IIA brane configuration known as brane brick models. We further show that the same family of birational transformations extends to more general toric Calabi-Yau 4-folds, including those defined by non-reflexive toric diagrams. Under these birational transformations, the mesonic moduli spaces of the associated abelian 2d (0,2) supersymmetric gauge theories and brane brick models share the same number of generators and the same Hilbert series when refined only under the U(1)R symmetry. Since these transformations categorize toric Calabi-Yau 4-folds and their corresponding 2d (0,2) supersymmetric gauge theories into non-trivial equivalence classes, we anticipate that our findings will pave the way for a 'Minimal Model Program' for quiver gauge theories corresponding to toric Calabi-Yau manifolds.

Hauptautor: KHO, Minsung (Ulsan National Institute of Science and Technology)

Co-Autoren: Dr. GHIM, Dongwook (IBS Center for Theoretical Physics of the Universe); SEONG, Rak-Kyeong (Ulsan National Institute of Science and Technology)

Vortragende(r): KHO, Minsung (Ulsan National Institute of Science and Technology)

Beitrag ID: **32** Typ: **Poster**

Models and constraints of pseudo goldstone dark matter

Abstract
Understanding the particle nature of dark matter remains one of the key challenges in contemporary physics. Although the thermal relic picture provides a natural explanation for the observed dark matter density, the continuing absence of positive signals in direct detection experiments calls into question the simplest WIMP hypotheses. A compelling alternative scenario emerges when dark matter originates as a pseudo-Goldstone particle associated with the breaking of a global symmetry.
In this framework, the symmetry structure that generates the dark matter mass also governs its couplings, leading to interactions that diminish rapidly at low momentum transfer. We investigate a dark sector possessing an O(N) symmetry that is spontaneously broken to O(N-1), giving rise to a family of pseudo-Goldstone states. Introducing a small explicit breaking term lifts their degeneracy, leaving a single stable particle protected by a residual discrete symmetry. The remaining, nearly degenerate states can engage in coannihilation processes that significantly affect the freeze-out dynamics and determine the final relic abundance.
This symmetry-based approach offers a natural mechanism for evading direct detection bounds while preserving the successful thermal history of dark matter, and it motivates new avenues for exploration through indirect searches and collider experiments.

Hauptautor: FARZAND, Sarah (Univeristy of Helsinki)

Vortragende(r): FARZAND, Sarah (Univeristy of Helsinki)