Machine learning approaches in Lattice QCD - an interdisciplinary exchange

Report of Contributions

https://indico.cern.ch/e/ml4lattice

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

Welcome

Tuesday 10 June 2025 09:50 (10 minutes)

Presenter: KRSTIC MARINKOVIC, Marina (ETH Zurich)

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

Optimal transport for anomaly detection at LHC

Tuesday 10 June 2025 10:00 (50 minutes)

Presenter: HOWARD, Jessica N. (Kavli Institute for Theoretical Physics)

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

Machine learning RG-improved SU(3) gauge actions

Tuesday 10 June 2025 11:30 (50 minutes)

I describe how RG-improved SU(3) gauge actions can be parametrized through machine learning gauge covariant convolutional neural networks. I discuss how the approach benefits from the straightforward accessibility of gauge field derivatives and the capability to generate targeted learning.

Presenter: WENGER, Urs (University of Bern)

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

Stochastic differentiation of Monte Carlo simulations for parameter inference in quarkonium suppression

Tuesday 10 June 2025 14:00 (35 minutes)

In many scientific domains, phenomena are being described by demanding Monte Carlo simulations. A common problem setting is that these simulations depend on input parameters, whose values are a priori not clear. To determine the input parameters one usually falls back to fitting the output of the simulator to some target. This can become particularly challenging, when the simulator is expensive to evaluate and the number of input parameters increases. In this talk I will discuss the approach of differentiating the simulator, which enables parameter inference by gradient descent. For Monte Carlo simulations involving discrete probabilities it is possible to build on the REINFORCE gradient estimator to differentiate the full stochastic simulation. I demonstrate this method for the simulation of quarkonium suppression. Quarkonium suppression refers to the phenomenon of bound states dissociating in the quark gluon plasma and can be measured by the nuclear modification factor R_{AA}. The underlying simulator that predicts this suppression solves a Lindblad equation by sampling stochastic trajectories. I showcase how to obtain a low variance gradient estimator and fit the quarkonium transport coefficients to nuclear modification factor data.

Presenter: MAGORSCH, Tom

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

Optimizing static quark states with Neural Network parametrized general Wilson loops

Tuesday 10 June 2025 14:35 (35 minutes)

Presenter: MAYER-STEUDTE, Julian

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

Protecting continuum symmetries on the lattice - exact prior information for reinforcement learning

Tuesday 10 June 2025 15:40 (50 minutes)

Presenter: Prof. ROTHKOPF, Alexander (Korea University)

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

Discussion

Tuesday 10 June 2025 16:30 (45 minutes)

Presenter: BRAMBILLA, Nora

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

Monte Carlo estimates of flow fields for sampling and noise problems

Wednesday 11 June 2025 10:00 (35 minutes)

Presenter: KANWAR, Gurtej (University of Edinburgh)

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

Applications of flow models to the generation of correlated lattice QCD ensembles

Wednesday 11 June 2025 11:20 (50 minutes)

Machine-learned normalizing flows can be used in the context of lattice quantum field theory to generate statistically correlated ensembles of lattice gauge fields at different action parameters. In this talk, we show examples on how these correlations can be exploited for variance reduction in the computation of observables. Different proof-of-concept applications are presented: continuum limits of gauge theories, the mass dependence of QCD observables, hadronic matrix elements based on the Feynman-Hellmann approach, and the computation of glueball correlators. In all cases, statistical uncertainties are significantly reduced when machine-learned flows are incorporated as compared with the same calculations performed with uncorrelated ensembles or direct reweighting.

Presenter: ROMERO LÓPEZ, Fernando

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

Applications of Stochastic Normalizing Flows to gauge theories and defects

Wednesday 11 June 2025 13:50 (35 minutes)

In recent years, flow-based samplers have emerged as a promising alternative to standard sampling methods in lattice field theory. In this talk, I will introduce a class of flow-based samplers known as Stochastic Normalizing Flows (SNFs), which are hybrid algorithms combining neural networks and non-equilibrium Monte Carlo methods. I will then demonstrate that SNFs exhibit excellent scaling with volume in lattice SU(3) gauge theory. Afterward, I will discuss theories with defects and present a general strategy for applying flow-based samplers to such systems. In particular, I will showcase an application of our approach to scalar field theory for calculating entanglement entropy, as well as an application to SU(3) gauge theory aimed at addressing topological freezing.

Presenter: CELLINI, Elia (University of Turin / INFN Turin)

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

Application of generative models on SU(3) gauge theories in 4 dimension

Wednesday 11 June 2025 14:25 (35 minutes)

Presenter: KOMIJANI, Javad (ETH Zurich)

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

Score-Based Diffusion Models for Lattice Gauge Theory

Wednesday 11 June 2025 16:40 (35 minutes)

Presenter: VEGA, Octavio

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

Discussion

Wednesday 11 June 2025 15:40 (1 hour)

Presenters: KRSTIC MARINKOVIC, Marina (ETH Zurich); Prof. RYAN, Sinead (Trinity College Dublin)

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

Progress in learning contour deformations for observables

Thursday 12 June 2025 10:00 (50 minutes)

Presenter: DETMOLD, William

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

Diffusion models for lattice field theory

Thursday 12 June 2025 11:30 (50 minutes)

Presenter: Prof. AARTS, Gert (Swansea University)

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

Machine Learning Low-D Systems

Thursday 12 June 2025 13:50 (50 minutes)

I discuss how machine learning is used in stochastic simulations of low-D strongly correlated systems. In particular, I show how machine learning is used to alleviate the numerical sign problem in systems that are doped and/or non-bipartite. I further discuss how flow-based generative models can be used to address ergodicity issues in low-D simulations. Finally, I argue that low-D systems offer a great testbed for testing novel algorithms that could potentially be used in lattice gauge theory simulations.

Presenter: Prof. LUU, Thomas (Forshungszentrum Jülich)

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

Simulations of machine-learned RG-improved SU(3) gauge action

Thursday 12 June 2025 14:40 (35 minutes)

Presenter: HOLLAND, Kieran

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

Stochastic automatic differentiation for Lattice QCD

Thursday 12 June 2025 16:20 (50 minutes)

Presenter: RAMOS MARTINEZ, Alberto (Univ. of Valencia and CSIC (ES))

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

Discussion

Thursday 12 June 2025 17:10 (45 minutes)

Presenter: KRONFELD, Andreas (Fermi National Accelerator Lab. (US))

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

Random Matrix Theory for a nano-GPT

Friday 13 June 2025 10:00 (35 minutes)

Presenter: HAJIZADEH, Ouraman (Independent Researcher)

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

Optimized Multi-Grid Solvers: Power, Precision, and (Matrix) Products

Friday 13 June 2025 10:35 (50 minutes)

Presenter: WEINBERG, Evan (NVIDIA Corporation)

Contribution ID: **24** Type: **not specified**

Recent Performance Using MILC and QUDA on Various GPU Systems

Friday 13 June 2025 11:55 (50 minutes)

I plan to show performance data for the MILC code calling QUDA for configuration generation. There will be a combination of benchmark runs and production runs on various systems. I will also show some recent results for deflation, multigrid, and gauge flow performed by Leon Hostetler with the assitance of Evan Weinberg. If there is time I will discuss some work to prepare for a new ensemble with a lattice spacing of about 0.03 fm and physically light quarks.

Presenter: GOTTLIEB, Steven

Contribution ID: **25** Type: **not specified**

Closing

Friday 13 June 2025 12:45 (15 minutes)

Presenter: KRSTIC MARINKOVIC, Marina (ETH Zurich)

Contribution ID: **26** Type: **not specified**

Efficient Multilevel Sampling of Lattice Field Theory Near Criticality

Thursday 12 June 2025 15:45 (35 minutes)

We present a hierarchical generative framework for efficient sampling of scalar field configurations near criticality. The method leverages a multiscale structure where coarse and intermediate fields are sampled via conditionally constructed Gaussian Mixture Models (GMMs). Normalizing Flows (NFs) refine these samples through invertible transformations that match the target distribution. This approach enables high Effective Sample Size (ESS) and mitigates critical slowing down. Our results demonstrate improved scalability and accuracy over traditional and superresolution-based methods.

Presenter: SINGHA, Ankur