SQAI-NCTS Workshop on Quantum Technologies and Machine Learning

Report of Abstracts

https://indico.phys.nthu.edu.tw/e/2025_SQAI-NCTS_quantum

Abstract ID : **99**

Area Law and Provably Efficient Algorithm for Quantum Gibbs States in Long-Range Interacting Systems

Content

The quantum Gibbs state represents thermal equilibrium and is crucial in various fields. In this work, we analyze bipartite quantum correlations in quantum Gibbs states within long-range interacting systems and present an algorithm that constructs these states efficiently and accurately. First, we clarify the optimal condition under which the bipartite information measures adhere to the area law under power-law decaying interactions [1]. We show that the area law is satisfied when the power-law exponent exceeds $(D + 1)/2$ for a spatial dimension D. By considering the clustering property, which noncritical systems exhibit, our findings extend the applicability of the area law beyond the traditional boundary of $D + 1$, establishing its validity even in areas lacking thermodynamic extensivity. Next, we introduce an algorithm that constructs the matrix product operator of the quantum Gibbs state in one-dimensional long-range interacting systems, maintaining accuracy within a specific error margin [2]. This algorithm is based on the idea of the renormalization group and ensures precision, with its runtime scaling quasi-polynomially with system size.

[1] Donghoon Kim, Tomotaka Kuwahara, and Keiji Saito, Phys. Rev. Lett. **134**, 020402 (2025)
[2] Rakesh Achutha, Donghoon Kim, Yusuke Kimura, and Tomotaka Kuwahara, Phys. Rev. Lett. **134**, 190404 (2025)

Primary author: KIM, Donghoon (RIKEN)

Co-authors: Mr ACHUTHA, Rakesh (IIT); Dr KIMURA, Yusuke (RIKEN); Dr KUWAHARA, Tomotaka (RIKEN); Prof. SAITO, Keiji (Kyoto University)

Presenter: KIM, Donghoon (RIKEN)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **KIM, Donghoon** on **Sunday, April 6, 2025**

Abstract ID : **100**

Entanglement area law in interacting bosons: from Bose-Hubbard, ϕ^4, and beyond

Content

The entanglement area law is a fundamental principle that defines the informational structure of quantum many-body systems and serves as the backbone for tensor network algorithms. Traditionally, this law has been established under two key assumptions: the system must have bounded local energy and exhibit short-range interactions. However, extending the area law to scenarios with unbounded local energy and long-range interactions remains a significant challenge, particularly in bosonic systems where these standard assumptions do not hold. In this work [1], we rigorously prove the entanglement area law across a broad class of one-dimensional interacting bosonic systems, including models such as the Bose-Hubbard and ϕ^4 models, as well as systems exhibiting long-range interactions. Our approach overcomes the limitations of conventional assumptions by showing subexponential decay in the boson number distribution. Consequently, we establish that it is possible to approximate ground states using matrix product states with quasi-polynomial bond dimensions. These findings provide crucial insights for simulating bosonic systems with long-range interactions and advancing quantum simulation methodologies.

[1] Donghoon Kim and Tomotaka Kuwahara, arXiv:2411.02157

Primary author: KIM, Donghoon (RIKEN)

Co-author: Dr KUWAHARA, Tomotaka (RIKEN)

Presenter: KIM, Donghoon (RIKEN)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **KIM, Donghoon** on **Sunday, April 6, 2025**

Abstract ID : **102**

Toward Neutral Atom Array Quantum Processors in Singapore

Content

he development of 200 qubits or more quantum processors is divided into subtasks running in parallel to tackle the various technical and conceptual challenges. On the technical side, we are developing a compact 2D MOT, a science chamber for the 3D MOT with an ultrahigh vacuum environment, and a 2D tweezer array of neutral atoms. The 2D MOT segment improves the atom flux and segregates the vacuum for the 3D MOT thanks to a differential tube. The atoms are cooled down to the microKelvin range in the 3D MOT and loaded in the tweezer array. On the conceptual side, we are evaluating key atomic transitions for the realization of quantum computing operations. We are also working on developing static tweezer arrays using spatial light modulators to trap the atoms. Subsequently, we will be developing mobile tweezers for the rearrangement of the atoms during the later stages of the project.

Primary authors: Dr CHEN, Zilong (National University of Singapore); Prof. WILKOWSKI, David (National University of Singapore)

Co-authors: Dr ALIYU, Mujahid (National University of Singapore); NGUYEN, Xuan Thanh (National University of Singapore); Dr XIA, Tong-Yan (National University of Singapore)

Presenter: NGUYEN, Xuan Thanh (National University of Singapore)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **NGUYEN, Xuan Thanh** on **Tuesday, April 15, 2025**

Abstract ID : **103**

Chebyshev and tensor cross interpolation for Monte-Carlo-based option sensitivities

Content

High dimensionality is one of the key challenge in mathematical finance, where option pricing and sensitivity computations must be both accurate and real-time. Finite-difference Monte Carlo methods often suffer numerical instability, especially for second-order derivatives (a.k.a. Gamma). Chebyshev-interpolation can stabilize sensitivities, but it suffers from the curse of dimensionality as input parameters increase.

We handle this high dimensions by compressing tensorized Chebyshev coefficients using Tensor Cross Interpolation (TCI). Addressing interpolation nature of TCI, we fix the Monte Carlo seed to suppress sampling noise of MC. From the resultant compressed chebyshev coefficients, we compute first- and second-order sensitivities.

We validate our method on three benchmarks—a noisy sine function; an Asian-barrier option; and a European basket option under a multi-asset Black–Scholes model. we discuss how exploiting low-rank structure of option price gives better accuracy and computational time compared to conventional Monte Carlo method.

Primary author: SAKURAI, Rihito

Co-authors: Prof. OKUBO, Tsuyoshi (The University of Tokyo); Prof. TODO, Synge (The University of Tokyo)

Presenter: SAKURAI, Rihito

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **SAKURAI, Rihito** on **Thursday, April 17, 2025**

Abstract ID : **104**

Stabilizer Rényi Entropy and Conformal Field Theory

Content

Along with entanglement, nonstabilizerness (or magic) of quantum systems has been recognized as a crucial resource for achieving quantum computational advantage. The stabilizer Rényi entropy (SRE) has recently been established as a computationally tractable measure of nonstabilizerness, with numerical studies revealing universal behavior of the SRE in critical quantum spin chains. In this work, we unveil the origin of this universality through boundary conformal field theory calculations of the SRE. Our analysis demonstrates that the SRE of the entire system contains a universal constant term linked to the g-factor of the boundary condition imposed by Bell-state measurements, while the mutual SRE exhibits universal logarithmic scaling with a coefficient determined by the scaling dimension of a boundary operator. These findings establish a field-theoretical framework for understanding the universal features of nonstabilizerness in quantum many-body systems.

Primary author: HOSHINO, Masahiro (University of Tokyo)

Presenter: HOSHINO, Masahiro (University of Tokyo)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HOSHINO, Masahiro** on **Thursday, April 17, 2025**

Abstract ID : **105**

Generative diffusion model with inverse renormalization group flows

Content

The renormalization group (RG) framework, which establishes a connection between a microscopic model at short distances and its coarse-grained counterpart at larger scales, has been a pivotal tool for understanding many-body phenomena across vastly different scales, ranging from elementary particles to condensed matter. Central to the RG's success is its multiscale nature, enabling systems with distinct short-scale behaviors to exhibit similar patterns at macroscopic scales.

On another front, recent advances in machine learning have positioned diffusion models [1, 2] as one of the most prominent examples of generative models, achieving a great success across various domains, including computer vision, audio synthesis, and point cloud generation. Nevertheless, diffusion models have so far largely overlooked the inherent multiscale structures of natural data, and their slow generation process remains a bottleneck for expanding their applications to important domains in physics [3].

In our work [4], we introduce a novel class of generative diffusion models inspired by the concept of the RG, which leverage the multiscale properties of natural data to realize efficient and high-quality data generation. Specifically, we establish a connection between the flow equations in the RG framework and the convex diffusion equations underlying diffusion models. This connection allows us to construct a diffusion model that generates data in a coarse-to-fine manner by reversing the RG flows, thereby naturally incorporating the multiscale structures in natural data. To validate the effectiveness and versatility of our approach, we apply the model to real-world problems in two distinct domains: protein structure prediction and image generation. Our numerical results demonstrate that the RG-based diffusion models consistently outperform conventional models across all tested datasets, enhancing sample quality and/or accelerating sampling speed by an order of magnitude.

In the presentation, we first illustrate the theoretical formulation of the RG-based diffusion model, and then, demonstrate the numerical results that support the validity of the model. The framework of our RG-inspired scalable approach to data generation is general and would bear a close connection to machine learning approaches for analyzing, e.g., (Boltzmann) distributions in quantum and classical many-body systems.

[1] J. Sohl-Dickstein, E. Weiss, N. Maheswaranathan and S. Ganguli, Proc. of the ICML, 2256 (2015).
[2] J. Ho, A. Jain, and P. Abbeel, Adv. In NIPS 33, 6840 (2020).
[3] K. A. Dill, S. B. Ozkan, M. S. Shell, and T. R Weikl, Annu. Rev. Biophys. 37, 289 (2008).
[4] **K. Masuki** and Y. Ashida, arXiv:2501.09064 (2025).

Primary authors: Prof. ASHIDA, Yuto (The University of Tokyo); MASUKI, Kanta (The University of Tokyo)

Presenter: MASUKI, Kanta (The University of Tokyo)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **MASUKI, Kanta** on **Wednesday, April 23, 2025**

Abstract ID : **106**

Interplay Between Stripe Order and Superconductivity in a Modulated XY Model

Content

In strongly correlated electron systems, superconductivity and charge density waves often coexist in close proximity, suggesting a deeper relationship between these competing phases. Recent research indicates that these orders can intertwine, with the superconducting order parameter coupling to modulations in the electronic density. To elucidate this interplay, we study a two-dimensional XY model with a periodic modulation of the coupling strength in one spatial direction. Using a combination of tensor network methods and Monte Carlo simulations, we reveal a non-monotonic, dome-like dependence of Tc on the modulation wavelength, with the peak Tc shifting to longer wavelengths as the modulation strength grows. The origin of this phenomenon is traced back to an effective pinning of vortices in the valleys of the modulation, confirmed by a comparison to modulated q-state clock models. These findings shed new light on the phase behavior of intertwined superconducting and charge-ordered states, offering a deeper understanding of their complex interactions.

Reference:
[1] arXiv:2506.16068 (2025)
[2] npj Quantum Mater. 10, 22 (2025)

Primary author: Dr SONG, Feng-Feng (ISSP UTokyo)

Co-authors: Prof. ALEXANDER, Wietek (MPIPKS); Mr CHUGH, Aditya (UToronto); Prof. KAWASHIMA, Naoki (ISSP UTokyo); Dr NUOMIN, Hanggai (Duke University)

Presenter: Dr SONG, Feng-Feng (ISSP UTokyo)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **SONG, Fengfeng** on **Wednesday, April 30, 2025**

Abstract ID : **107**

Lattice Chiral Fermion without Hermiticity

Content

We discuss the naive lattice fermion without the issue of doublers. A local lattice massless fermion action with chiral symmetry and Hermiticity cannot avoid the doubling problem from the Nielsen-Ninomiya theorem. Here we adopt the forward finite-difference, deforming the 5-Hermiticity but preserving the continuum chiral symmetry. The lattice momentum is not Hermitian without the continuum limit now. We demonstrate that there is no doubling issue with an exact solution and showcase the numerical implementation of the hybrid Monte Carlo.

Primary authors: MA, Chen-Te; Prof. ZHANG, Hui (South China Normal University)

Presenter: MA, Chen-Te

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **MA, Chen-Te** on **Sunday, May 4, 2025**

Abstract ID : **109**

Quantum anomaly detection for the agriculture application

Content

We hypothesize that the expressive power of the quantum kernel space may be superior to that of the classical kernel space, and are studying quantum anomaly detection. Unlike factory products, quantum anomaly detection was applied to the image inspection process of various agricultural products with various standards. In this study, a learning model was constructed using various quantum kernel SVMs using a small number of agricultural product image datasets collected by a company. The quantum kernels prepared in this study consisted of a small number of rotation gates and control gates. The F1 score of each quantum kernel showed a significant effect of using CNOT gates. After confirming the results with a quantum simulator, the usefulness of the quantum kernel was confirmed on a quantum computer. Learning by SVMs incorporating specific quantum kernels showed significantly higher AUC values compared to classical kernels.

Primary author: Prof. TOMONO, Takao (Keio Universiy)

Co-author: Mr TSUJIMURA, Kazuya (Toppan Holdings)

Presenter: Prof. TOMONO, Takao (Keio Universiy)

Track Classification: Poster presentation

Comments:

Original articles is as follows. https://doi.org/10.1140/epjqt/s40507-025-00335-4

Status: ACCEPTED

Submitted by **TOMONO, takao** on **Monday, May 5, 2025**

Abstract ID : **111**

Tensor network methods for solving nonlinear PDEs

Content

Tensor network decompositions are a famous way to compress tensors of coefficients of multivariate wavefunctions in quantum physics and chemistry. Their efficiency hinges on the approximate separability of the variables. This separability can be underpinned by different assumptions. In addition to the area laws of the wavefunctions governed by the Schroedinger equation, a similar separation of length scales manifests in the solution to the Navier-Stokes Equations (NSE) in certain regimes. Higher efficiency of the tensor network (Matrix Product States/Tensor Train) is achieved by splitting the original variables (such as the two spatial directions in the 2D NSE) into further virtual variables similarly to digits in the binary system. The sought tensor is reshaped into a higher-dimensional tensor indexed by those virtual variables, and is approximated by a tensor network. Specifically, if the Matrix Product States is used with binary virtual variables, the corresponding decomposition is called the Quantized Tensor Train, but this can be generalized trivially. If the original variables are discretized via a structured mesh, the virtual variables correspond to different length scales within that mesh, and hence the physical space. In the case of the NSE exhibiting a scale-locality of the turbulent energy cascade (e.g. a jet or the Taylor-Green vortex flow in a rectangular or unbounded domain), this leads to the separability of the virtual variables. Numerical experiments demonstrate that the number of tensor network parameters required to represent such velocity field is reduced by more than an order of magnitude compared to direct numerical simulation.

Based on the joint work https://www.nature.com/articles/s43588-021-00181-1

Primary author: DOLGOV, Sergey (University of Bath)

Presenter: DOLGOV, Sergey (University of Bath)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **DOLGOV, Sergey** on **Monday, June 16, 2025**

Abstract ID : **112**

Dualities among scar states

Content

In this work we consider a particular class of Hamiltonians, known as stochastic matrix form (SMF) Hamiltonians, for which there is a systematic understanding of how to construct exact quantum many body scar (QMBS) states at zero energy. We study a particular example of a one-dimensional SMF Hamiltonian, for which there are QMBS subspaces that are connected through a Krammers-Wannier duality, implemented by a sequential quantum circuit (SQC). We argue, through a numerical analysis, that QMBS states connected by the action of the Krammers-Wannier SQC are more robust than those states that do not have a dual counterpart. We further show, that due to these unexpected properties, first order perturbation theory can be used as a good approximation to the exact results.

Primary author: FONTANA, Weslei (NTHU)

Presenter: FONTANA, Weslei (NTHU)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **FONTANA, Weslei** on **Wednesday, June 18, 2025**

Abstract ID : **113**

Rokko: Integrated interfaces for dense and sparse parallel eigensolvers

Content

Recently, a number of state-of-the-art hybrid parallel eigensolver libraries have been developed: EigenExa and ELPA for dense matrices, and Anasazi and SLEPc for sparse matrices, and so on. However, there are yet only a few application programs that use these solvers. This is partially due to the different function interfaces for each solver. Also, different compile and link procedures for different languages C++ / C / Fortran and different machine environments as well as the complicated dependencies on lower level libraries often become barriers of introducing new solver libraries. To overcome these difficulties, we have developed a bundle of integrated interfaces, "Rokko," which covers all the eigensolver libraries on an equal footing. Rokko allows users to select a solver at run-time by adopting the factory method. This feature enables users to readily take a benchmark of all the solvers to determine the optimal solver for the matrices used in their application programs and for their machine environment. In addition, to resolve the compile and link problems, we provide a build system which automatically detects solver libraries based on CMake utility program. Although the primary interfaces provided by Rokko are for the C++ language, we also provide the C / Fortran bindings. We illustrate simplicity of using Rokko through code fragments. We also present the results of diagonalization benchmark tests of the minij matrix and lattice Hamiltonian matrix for the antiferromagnetic quantum Heisenberg model to demonstrate the small overhead in the Rokko interfaces.

Primary author: SAKASHITA, Tatsuya (The University of Tokyo)

Presenter: SAKASHITA, Tatsuya (The University of Tokyo)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **SAKASHITA, Tatsuya** on **Friday, June 20, 2025**

Abstract ID : **114**

Quantum Scalar Field Theoretic Extension of Boltzmann Machines to Solve a Class of Moment Matching Problems

Content

Background
The Boltzmann machine is a generative machine learning model originated from the toy model of magnetic materials in statistical mechanics. It can approximate a probability distribution by adjusting the set of potential parameters and the number of units. In particular, over the last decade, there has been a significant amount of research on approximating ground state wave functions of quantum many-body systems via the Boltzmann machine. However, in order to achieve high expressive power, it is inevitable to increase the number of units. The computational complexity of the total variation distance between a target distribution and the Boltzmann machine is known to be NP-hard [1], hence we have to develop alternative methods to obtain the scalability. In this research, I generalize the Boltzmann machine and prove that it gives a solution of some moment matching problems without increasing the number of units, by utilizing the result of constructive quantum field theory.

My contribution
Firstly, we introduce the Scalar Field Machine (SFM) as a generalization of the Boltzmann machine, originated from $\phi 4$ scalar field model in constructive quantum field theory:
\begin{equation}
d\gamma_{N}^{\beta,m,J}=\frac{1}{Z_{N}}\exp\left[-\sum_{i=1,\cdots,N}\beta_i\left(\phi_{i}^{2}-m_{i}\right)^2+\sum_{i=1,\cd
1}J_{i,i+1}\phi_{i}\phi_{i+1}\right].
\end{equation}
The main modifications from ordinal Boltzmann machines are as follows:
i) We extend the spin variable ϕ from {0, 1} values to R values.
ii) The reference measure is not limited to the Gaussian, allowing for multimodality.
iii) If the distribution to be approximated is N -dimensional, the number of units in the learning model is also fixed at N.
Our main theorem is as follows. The proof utilizes techniques cultivated in rigorous statistical mechanics and constructive quantum field theory.
Theorem. Let $C_i > 0,\ C_N = 0,\ M_i > 0$ for $i = 1, \cdots, N$ and $\{X_i\}_{i=1,\cdots,N}$ be the set of random variables distributed from the target N-dimensional two-modal symmetric distribution μ such that
\begin{equation}
\mathbb{E}*{\mu}\left[X_i^2\right]=M_i,\quad \mathbb{E}*{\mu}\left[X_{i}X_{i+1}\right]=C_i.
\end{equation}
Then, there exists a SFM $\gamma_N^{\beta,m,J}$ that satisfies the all above-mentioned conditions.

Application(Approximation of entangled dynamics).
As an application, we demonstrate that short-time entangled behavior of the dynamically decoupling quantum harmonic oscillators can be approx-
imated by the SFM. The dynamics is constructed via the stochastic quantization, which is equivalent to the canonical quantization [2]. However, for long-time dynamics, the SFM approximation begins to break down, hence it needs to update the distribution successively. The optimal update rule for this is currently under investigation.

References
[1] A. Bhattacharyya, S. Gayen, et al."Computational explorations of total variation distance,"ICLR 2025.
[2] N. C. Petroni and L. M. Morato, "Entangled states in stochastic mechanics,"J. Phys. A. 33, 5833

(2000).

Primary author: KAJISA, Takahiro (The University of Electro–Communication)

Presenter: KAJISA, Takahiro (The University of Electro–Communication)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **KAJISA, Takahiro** on **Monday, June 23, 2025**

Abstract ID : **115**

Mitigation of the barren plateaus through a Multilayer Variational Quantum Circuit

Content

We present a Multilayer Variational Quantum Circuit (MLVQC) classifier designed to address the challenges of barren plateaus in quantum neural network training. Our approach builds upon the concept of Variational Quantum Circuits (VQC), which are promising candidates for hybrid quantum-classical computations, particularly under the constraints of noisy intermediate-scale quantum (NISQ) devices. We leverage the multilayer architecture to mitigate the effects of barren plateaus, which are known to hinder optimization in high-dimensional quantum systems. We evaluated the performance of the proposed Multilayer VQC on benchmark datasets, including MNIST, FashionMNIST, and CIFAR-10. Our results demonstrate that incorporating normalization techniques significantly reduces the occurrence of barren plateaus, allowing for more effective training of the quantum model. Additionally, our experiments show that careful design of measurement and normalization strategies can further improve the accuracy and stability of the quantum classifier. This work contributes to the ongoing effort to enhance the scalability of variational quantum algorithms by addressing fundamental challenges, thereby advancing the applicability of quantum machine learning.

Primary authors: Mr TSENG, SHENGCHIEH (NTU Phys); Prof. CHEN, Samuel Yen-Chi (Wells Fargo); Prof. KAO, Ying-Jer (NTU Physics)

Presenter: Mr TSENG, SHENGCHIEH (NTU Phys)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **TSENG, SHENGCHIEH** on **Tuesday, June 24, 2025**

Abstract ID : **116**

Quantum imaginary time evolution on 1D infinite-size lattice

Content

This work presents an implementation of the Quantum Imaginary Time Evolution (QITE) and QLanczos algorithms on a 1D infinite-size lattice. We transform the uniform matrix product state (uMPS) into a quantum circuit and use the concept of the time-dependent variational principle (TDVP) to implement QITE. Our study includes simulation results for the transverse-field Ising model, obtained from both quantum simulators and actual IBM-Q devices. These quantum circuit simulation results will be compared with those from classical tensor network TDVP algorithms. A key aspect of our approach is that the cost function, which is obtained directly from measurements on the quantum circuits. Consequently, the results are inherently statistical distributions rather than deterministic values. We'll analyze how the measurement methods impact the accuracy and convergence of the QITE algorithm.

Primary authors: HUNG, Hao-Ti (NTU Physics); Mr TSAO, Tung (NTU Physics); KAO, Ying-Jer (NTU Physics)

Presenter: HUNG, Hao-Ti (NTU Physics)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **HUNG, Hao-Ti** on **Wednesday, June 25, 2025**

Abstract ID : **117**

Clifford-augmented MPS technique for fermionic systems

Content

Reducing entanglement entropy is a key strategy for improving the efficiency of Matrix Product States (MPS), especially when simulating highly entangled quantum systems. Clifford-augmented MPS (CAMPS) is a recent approach that incorporates Clifford gates into the MPS ansatz to transform the basis in a way that compresses entanglement without altering the physical content of the state. This enhancement enables better classical simulability by exploiting the efficient representation of stabilizer-like structures, while preserving accuracy for non-stabilizer states. In this talk, we develop a fermionic counterpart of CAMPS using Grassmann tensor networks, which naturally encode fermionic statistics. This framework allows us to explore the impact of Clifford transformations on entanglement and computational cost in fermionic systems directly without relying on the fermion-spin transformation. Some benchmark results for the tight-binding model are presented.

Primary author: YOSPRAKOB, Atis (YITP, Kyoto University)

Presenter: YOSPRAKOB, Atis (YITP, Kyoto University)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **YOSPRAKOB, Atis** on **Thursday, June 26, 2025**

Abstract ID : **118**

Direct calculation of parton distribution functions with time evolved tensor network states

Content

Parton distribution functions (PDFs) describe universal properties of hadrons. They provide insights into the non-perturbative internal structure of bound states in high energy physics, and are highly significant for experiments. Calculating PDFs involves evaluating matrix elements with a Wilson line in a light-cone direction. This poses significant challenges for Monte Carlo methods in Euclidean formulation of lattice gauge theory, where the light cone cannot be directly accessed. In contrast, the PDF can, in principle, be calculated directly from light-cone matrix elements in the Hamiltonian formalism. This seems particularly appealing since recent developments in quantum computing and tensor network approaches allow for an efficient representation and time evolution of states in Hilbert space. Using a tensor network ansatz, we introduce a new strategy to obtain the PDFs directly in the Minkowski formalism, and apply it to the Schwinger model. We present the PDF for different fermion masses and study systematic errors. Our work demonstrates the feasibility of tensor networks for dynamical calculations in gauge theories and represents a first step towards such computations for QCD.

Primary authors: BAÑULS, Mari Carmen (Max Planck Institute of Quantum Optics); CICHY, Krzysztof (Adam Mickiewicz University); LIN, C.-J. David (Institute of Physics, National Yang Ming Chiao Tung University); SCHNEIDER, Manuel (National Yang Ming Chiao Tung University)

Presenter: SCHNEIDER, Manuel (National Yang Ming Chiao Tung University)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **SCHNEIDER, Manuel** on **Thursday, June 26, 2025**

Abstract ID : **119**

A holographic aspect of dynamical mean-field theory

Content

Dynamical mean-field theory (DMFT) has been one of the most standard numerical methods for strongly correlated electron systems. We discuss that DMFT for interacting electrons with the semi-circle density of states can be viewed as a holographic renormalization group, similar to the holographic tree-tensor-network description of the Bethe lattice-type Ising model. In particular, the scaling dimension for Green's function can be related to that of the corresponding correlation function for outer-edge boundary electrons, which is consistent with a p-adic AdS/CFT. We calculate the scaling dimension within DMFT for the Bethe lattice Hubbard model and then discuss the effect of the Mott transition.

Primary author: OKUNISHI, Kouichi (Department of Physics, Graduate School of Science, Osaka Metropolitan University)

Presenter: OKUNISHI, Kouichi (Department of Physics, Graduate School of Science, Osaka Metropolitan University)

Track Classification: Invited talk

Comments:

I would appreciate it if you could schedule my presentation for August 25-27. Thank you!

Status: ACCEPTED

Submitted by **OKUNISHI, Kouichi** on **Friday, June 27, 2025**

Abstract ID : **120**

Adaptive Tensor Tree Method with Annealing of Mini-batch Samples for Generative Modeling on Quantum Devices

Content

We proposed the Adaptive Tensor Tree (ATT) method, which uses the tensor tree network within the Born machine framework to construct a generative model. This method expresses the target distribution function as the squared amplitude of a quantum wave function represented by a tensor tree. The core concept of the ATT method involves dynamically optimizing the tree structure to minimize the bond mutual information.
In this presentation, we introduce a new technique that utilizes an annealing process on mini-batch samples to enhance the performance of the ATT method. We will demonstrate the effectiveness of this new ATT approach using various datasets.

Primary author: Prof. HARADA, Kenji (Graduate School of Informatics, Kyoto University)

Co-authors: Prof. KAWASHIMA, Naoki (Institute for Solid State Physics, The University of Tokyo); Prof. OKUBO, Tsuyoshi (Institute for Physics of Intelligence, The University of Tokyo)

Presenter: Prof. HARADA, Kenji (Graduate School of Informatics, Kyoto University)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **Prof. HARADA, Kenji** on **Friday, June 27, 2025**

Abstract ID : **121**

Trainable Quantum Neural Networks for Multiclass Image Classification with the Power of Pre-trained Tree Tensor Networks

Content

Tree tensor networks (TTNs) offer powerful models for image classification. While these TTN image classifiers already show excellent performance on classical hardware, embedding them into quantum neural networks (QNNs) may further improve the performance by leveraging quantum resources. However, embedding TTN classifiers into QNNs for multiclass classification remains challenging. Key obstacles are the high-order gate operations required for large bond dimensions and the mid-circuit postselection with exponentially low success rates necessary for the exact embedding.

In this work, to address these challenges, we propose forest tensor network (FTN)-classifiers, which aggregate multiple small-bond-dimension TTNs. This allows us to handle multiclass classification without requiring large gates in the embedded circuits. We then remove the overhead of mid-circuit postselection by extending the adiabatic encoding framework to our setting and smoothly encode the FTN-classifiers into a quantum forest tensor network (qFTN)-classifiers. Numerical experiments on MNIST and CIFAR-10 demonstrate that we can successfully train FTN-classifiers and encode them into qFTN-classifiers, while maintaining or even improving the performance of the pre-trained FTN-classifiers. These results suggest that synergy between TTN classification models and QNNs can provide a robust and scalable framework for multiclass quantum-enhanced image classification.

Primary author: Mr MUROTA, Keisuke (The university of Tokyo)

Co-author: KOBORI, Takumi (The university of Tokyo)

Presenter: KOBORI, Takumi (The university of Tokyo)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **KOBORI, Takumi** on **Sunday, June 29, 2025**

Abstract ID : **122**

Higher-order tensor renormalization group with the all-mode technique

Content

We propose an all-mode technique for Higher-Order Tensor Renormalization Group (HOTRG) by introducing a general framework for all-mode averaging in the coarse-graining step, utilizing a squeezer transformation. Since the all-mode approach yields numerical results that contain only statistical errors and are free from systematic errors, our results could be directly compared with exact solutions without ambiguity arising from systematic deviations. We demonstrate the proposed method in the two-dimensional Ising model, showing agreement with exact results, and discuss its extension to three dimensions.

Primary authors: NAKAYAMA, Katsumasa (RIKEN); Prof. TAKEDA, Shinji (Kanazawa Univ.)

Presenter: NAKAYAMA, Katsumasa (RIKEN)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **NAKAYAMA, Katsumasa** on **Monday, June 30, 2025**

Abstract ID : **123**

Thermal Hall transport in extended Kitaev models

Content

In this presentation, we discuss the thermal Hall conductivity in the Kitaev model with additional interactions under a magnetic field, employing a finite-temperature tensor network method. We find that the thermal Hall conductivity divided by temperature, κ_{xy}/T, significantly overshoots the value of the half-integer quantization and exhibits a pronounced hump while decreasing temperature, in agreement with the experimental observations in a candidate material α-$RuCl_3$. Moreover, we show that the field-direction dependence of κ_{xy}/T is consistent with the sign of the Chern number associated with the Majorana fermions across a wide range of magnetic fields, indicating that the topological Majorana fermion picture remains valid, even within the polarized phase beyond the quantum critical point. We also demonstrate that the additional off-diagonal interactions, known as the Γ and Γ' terms, significantly affect κ_{xy}/T. Our findings establish a comprehensive theoretical framework for understanding the thermal Hall transport in Kitaev materials such as α-$RuCl_3$ and provide key insights into the detection of exotic quasiparticles in quantum spin liquids.

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **Prof. OKUBO, Tsuyoshi** on **Monday, June 30, 2025**

Abstract ID : **124**

Parallel Gradient Estimation of Parameterized Quantum Circuit

Content

The Variational Quantum Algorithm (VQA) [1], which utilizes parameterized quantum circuits (PQCs), is one approach to solving problems that are challenging for classical computers using Noisy Intermediate-Scale Quantum (NISQ) devices. Utilizing gradients in VQA is expected to accelerate convergence [2]. However, as the number of parameters increases, the number of required quantum circuit types also increases, leading to longer execution times on actual devices and higher financial cost. Therefore, it's necessary to reduce the number of quantum circuit types required for gradient estimation.

Existing methods require at least one type of quantum circuit per parameter to estimate its gradient [3,4]. For example, the Hadamard Test [4] utilizes a single quantum circuit with an additional ancilla qubit to estimate the gradient of a single parameter in a PQC with N qubits.

In this study, we propose a novel method for estimating the gradients of multiple parameters in parallel using a single type of quantum circuit, thereby reducing the number of circuit types required for gradient estimation. In this method, by utilizing mid-circuit measurement and reset, only two ancilla qubits are needed. Based on indicators such as circuit type and shot count cost, the required accuracy for gradient estimation, and the number of parameters for which gradients need to be estimated, we discuss the conditions under which the proposed method is advantageous.

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **IMAMURA, Soichiro** on **Monday, June 30, 2025**

Abstract ID : **125**

Matrix-product-state approach for real-space qubits-wavegudie systems

Content

We present a matrix-product-state-based approach for simulating a qubits-waveguide system in real space. In this representation, the photon mode is described as a Bogoliubov mode, and the vacuum of the waveguide also becomes the Bogoliubov vacuum. This entangled Bogoliubov vacuum makes a simulation difficult because it requires large bosonic degrees of freedom for a faithful representation of the vacuum. The presented approach overcomes this difficulty by using single-site update schemes based on the controlled-bond expansion. We simulate a system consisting of four qubits and 400 bosonic waveguide modes and reproduce the qubit decay rate expected from superradiance phenomena.

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Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **GOTO, Shimpei** on **Monday, June 30, 2025**

Abstract ID : **128**

Embedding of General Tree Tensor Networks into Quantum Circuits

Content

The Variational Quantum Algorithm[1], VQA, is an algorithm to obtain a desirable quantum state by repeatedly updating parameters in its circuit. While it is analogous to the gradient-based machine learning, it has been a promissing algorithm that works on current Noisy Intermediate-Scale Quantum devices (NISQ)[2].

However, VQA training process has a significant problem, called barren plateau[3, 4].
In the VQA step, circuit parameters are updated based on the gradients of the target cost function with respect to the circuit parameters.
If the value of the gradients is too small, the algorithm cannot determine how to update the parameters, since any adjustment to the parameters would result in little improvement to the cost function.
It is shown that the gradients of parametrized quantum circuits suffer exponential decay with the number of qubits. This decay is called barren plateau.
In addition, a research showed that the more expressive circuits have smaller gradient values[5], which implies VQA would suffer a trade-off between its performance and trainability.

Many ideas have been proposed to train quantum circuits by VQA without getting trapped in barren plateau[6, 7, 8].
Rudolph showed that using MPS to obtain initial circuit parameters of VQA is effective to avoid the barren plateau[9], and therefore boosts the training process.
A quantum state expressed as MPS is first optimized using classical computing resources. The optimized MPS is then embedded into quantum circuits and used as the initial parameter sets of the VQA steps.

Our approach is to extend this algorithm to tree tensor networks (TTN).
It receives Hamiltonian as an input. Then it finds near-optimal structure of TTN using structural optimization[10, 11].
This step generates any form of binary TTN, including MPS, enhancing its expressibility. The optimized TTN is then embedded into a quantum circuit that consists of layers of gates. Each layer has the same structure as the original TTN[12]. We propose an embedding algorithm with a calculation cost that is linear to the number of qubits.

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **INOMATA, Kazuki** on **Thursday, July 24, 2025**

Abstract ID : **129**

A Bandit Approach to Discriminating Two Unknown Quantum States

Content

We address the problem of distinguishing two unknown quantum states with as few experiments as possible. Instead of estimating the full density matrix via tomography, we treat each measurement as an online decision-making problem. This problem can be formulated as a linear bandit, in which the probability of each outcome is a linear function of an unknown vector encoding the true state. Using standard bandit methods such as LinUCB and Thompson Sampling, we develop adaptive strategies that choose the next measurement basis on the fly. Numerical simulations confirm that our method requires fewer experiments for state discrimination than full-state tomography.

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Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **HARA, Satoshi** on **Friday, July 25, 2025**

Abstract ID : **130**

Neural Quantum State Study of the Toric Code under Heisenberg

Content

We employ convolutional neural network quantum states (NQS) to investigate the topological phase transition in the toric code when perturbed by isotropic Heisenberg interactions, a regime that has remained largely unexplored. Neural networks have recently demonstrated remarkable versatility in tackling quantum many-body problems, capturing volume-law entanglement and complex correlations [1]. The toric code, an exactly solvable model hosting topological order and anyonic excitations, serves as a benchmark for quantum memory architectures. While the impact of external magnetic fields on the toric code has been extensively studied, the role of intrinsic spin-spin interactions remains poorly understood [2-3].
In our approach, we use a translationally invariant convolutional ansatz that respects the underlying Hamiltonian symmetry. We further reinforce rotational symmetry by averaging network inputs over all lattice orientations.[4] By variationally optimizing this CNN-based NQS, we accurately compute ground- and first-excited-state energies on finite lattices, from which we extract the energy gap and ground-state fidelity as functions of the Heisenberg coupling strength. To pinpoint the critical point in the thermodynamic limit, we analyze the behave of Wilson loop operator.
Our results demonstrate clear signatures of a topological–trivial phase transition driven by Heisenberg interactions. This study not only extends the applicability of neural quantum states to interaction-driven topological phenomena but also provides new insights into the interplay between topological order and conventional spin interactions.

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Track Classification: Poster presentation

Comments:

the abstract is edited by chatgpt o4-mini-high

Status: ACCEPTED

Submitted by **JANG, WON** on **Friday, July 25, 2025**

Abstract ID : **131**

Targeting the most typical state among the thermal pure quantum states

Content

We propose a new class of typical quantum states, called Markov-shielded typical (MST) states, for one-dimensional quantum systems with open boundary conditions. Unlike conventional typicality arguments based on random sampling[1], MST states are derived from a variational principle that naturally connects to the variational formulation of ground states. This connection enables a numerical scheme in which thermal states can be efficiently and stably constructed by gradually increasing the temperature, starting from the ground state.

Our formulation builds on the generalized Markov free energy, introduced in Ref.[2] as a variational lower bound on the thermodynamic free energy. For a density operator ρ, it is defined as $F_M(\rho;T) = \mathrm{Tr}[\rho H] - TS_M(\rho)$, where $S_M(\rho)$ is the Markov entropy computed from local reduced density matrices. The approximate quantum Markov property of Gibbs states[3] ensures that the generalized Markov free energy $F_M(\rho;T)$ closely approximates the thermodynamic free energy when evaluated on states within local regions. This insight justifies restricting the minimization of F_M to the set of pure states $\rho = |\psi\rangle\langle\psi|$, leading to the definition of MST states as those pure states that variationally minimize $F_M(|\psi\rangle\langle\psi|;T)$.

We implement this scheme using matrix product states (MPS) as a variational ansatz. Numerical results for the transverse-field Ising model show that the MST-MPS method achieves high accuracy for local observables, even at low temperatures and with small bond dimensions. These results highlight the practical significance of MST as an efficient and scalable numerical method for simulating finite-temperature quantum systems.

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **IWAKI, Atsushi** on **Saturday, July 26, 2025**

Abstract ID : **132**

Interference-caged quantum many-body scars: the Fock space topological localization and interference zeros

Content

We propose a general mechanism for realizing athermal finite-energy-density eigenstates—termed interference-caged quantum many-body scars (ICQMBS)—which originate from exact many-body destructive interference on the Fock space graph. These eigenstates are strictly localized to specific subsets of vertices, analogous to compact localized states in flat-band systems. Central to our framework is a connection between interference zeros and graph automorphisms, which classify vertices according to the graph's local topology. This connection enables the construction of a new class of topological ICQMBS, whose robustness arises from the local topology of the Fock space graph rather than from conventional conservation laws or dynamical constraints. We demonstrate the effectiveness of this framework by developing a graph-theory-based search algorithm, which identifies ICQMBS in both a one-dimensional spin-1 XY model and two-dimensional quantum link models (QLM) across distinct gauge sectors. In particular, we discover the proposed topological ICQMBS in the two-dimensional QLM and provide an intuitive explanation for previously observed order-by-disorder phenomena in Hilbert space (ODBDHS). Our results reveal a synergy between graph theory, flat-band physics, and quantum many-body dynamics, and lay the foundation for a general mechanism of localization in Hilbert space—grounded not in symmetry, but in interference and topology.

Primary authors: Prof. HUANG, Yi-Ping (National Tsing Hua University); TAN, Tao-Lin

Presenter: TAN, Tao-Lin

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **TAN, Tao-Lin** on **Monday, July 28, 2025**

Abstract ID : **133**

k-Mixture Exponential Hopfield Network

Content

In this study, we propose the *k-Mixture Exponential Hopfield Network* (kMEHN) as a framework that bridges the Classical Hopfield Network (CHN) and the Modern Hopfield Network (MHN) by integrating their structural characteristics.
The CHN defines an energy function using a single symmetric weight matrix, where stored patterns correspond to stable energy minima \1.
In contrast, the MHN achieves high memory capacity and rapid convergence by employing a smooth, nonlinear energy function over a continuous vector space \2.

The proposed kMEHN inherits the Hebbian rule-based construction of weight matrices from CHN, and combines multiple such matrices via a sum of exponential terms, as used in the exponential-type MHN \[3], thereby forming a novel network that exhibits intermediate properties between the two models.
A key feature of kMEHN is its ability to construct an energy landscape that smoothly integrates contributions from multiple independent groups of memory patterns.
Each weight matrix $W^{(k)}$ is constructed from a specific set of memory patterns $\{\xi_\mu^{(k)}\}_{\mu=1}^{P_k}$ as follows:

(Equation 1)
$W^{(k)} = \frac{1}{N} \sum_{\mu=1}^{P_k} \xi_\mu^{(k)} (\xi_\mu^{(k)})^\top$

Here, each pattern $\xi_\mu^{(k)} \in \{-1, 1\}^N$ is a binary vector of length N, and P_k denotes the number of patterns in the k-th memory group.
The energy function of kMEHN for a state vector $s \in \{-1, 1\}^N$ is given by:

(Equation 2)
$E(s) = -\sum_{k=1}^{K} \exp(s^\top W^{(k)} s)$

This structure enables the integrated influence of multiple memory matrices, rather than relying on a single quadratic form as in CHN, resulting in an energy landscape formally similar to that of MHN.

To evaluate whether the proposed model functions effectively as an associative memory system, we conducted simulations using 4×4 black-and-white binary images.
The state space consisted of all possible image patterns (2^{16} in total), from which several patterns were selected as memory patterns.
The selected memory patterns were partitioned into K groups. Since there are multiple possible ways to partition the patterns, we exhaustively enumerated all possible group partition configurations. For each partition, we constructed a network based on the energy function defined above (Equation 2).

For every constructed network, we computed the energy of all possible states in the state space and identified local minima as those states whose energy could not be lowered by a single spin flip.
Among these local minima, those that matched memory patterns exactly were defined as **target states**, while all others were considered **spurious states**. This allowed us to quantitatively evaluate the number of target and spurious states for each partitioning.

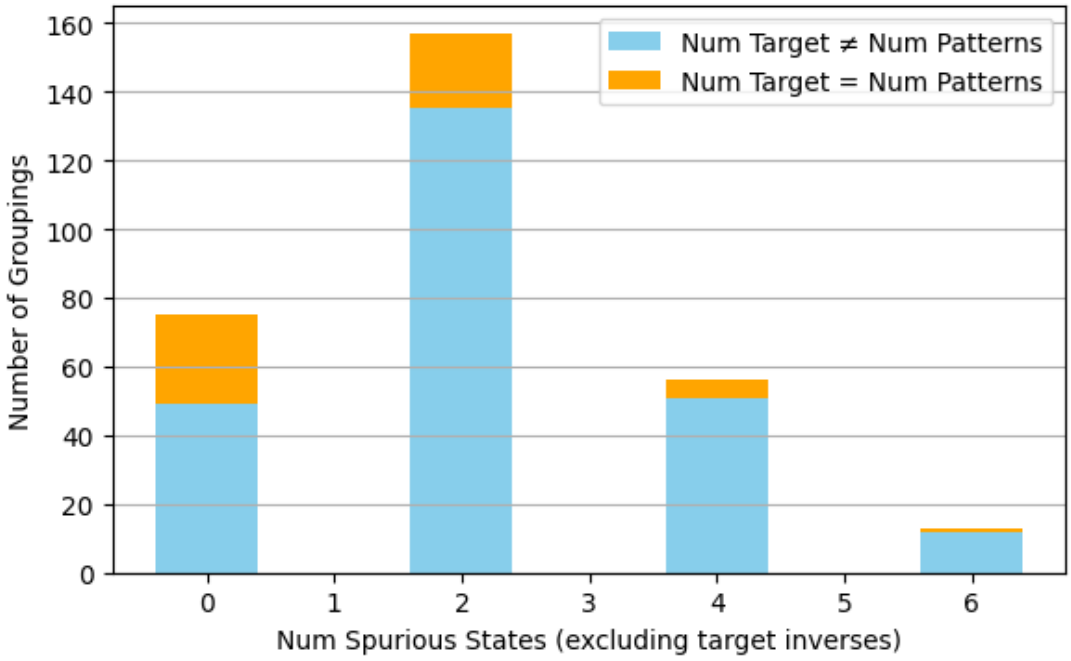

Figure 1: 7 memory patterns, K = 3 groups.

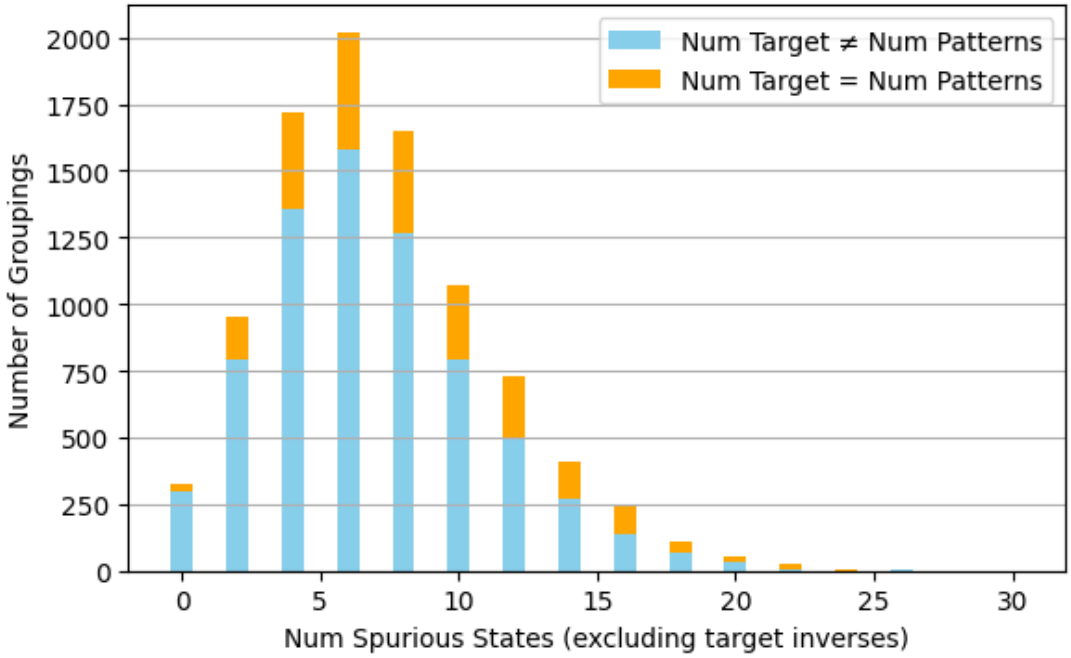

Figure 2: 10 memory patterns, K = 3 groups.

Figure 1: Spurious State Histogram **Description**:
Histograms showing the number of group partition patterns for each spurious state count (excluding bit-inverted target patterns).

- The horizontal axis indicates the number of spurious states.
- The vertical axis shows the number of partitioning patterns with that count.

- Bars are color-coded: **orange** for partitions in which the number of target states matches the number of memory patterns, and **sky blue** otherwise.

Due to the energy function depending on the quadratic forms involving the weight matrices, flipping all bits of a memory pattern does not change the energy, since these quadratic values remain the same. As a result, these inverted patterns consistently appear as spurious states.
These inverted patterns were excluded from the spurious state counts in the histograms.
Additionally, having the number of target states equal to the number of memory patterns indicates that all memory patterns are correctly stored, which is a desirable property for associative memory models.

The results demonstrate that there exist specific partitioning strategies in which spurious states are entirely eliminated.
This finding highlights a promising direction for controlling or reducing spurious states through the design of energy-based heterogeneous associative memory networks.

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Presenter: Mr HONDA, Yuki (Mie University)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **HONDA, Yuki** on **Monday, July 28, 2025**

Abstract ID : **134**

Tensor network formulation of the lattice Yang-Mills theory with spectral clustering

Content

Tensor network approach provides us with a novel framework to study the field theories on a lattice without resorting to the probabilistic interpretation. Therefore, the tensor network approach is expected to be free from the sign problem. On the other hand, we have to introduce a reliable regularization scheme to discretize the continuous degrees of freedom, otherwise we cannot perform tensor network computations. In this study, we introduce the spectral clustering technique, a non-linear dimensional reduction scheme commonly employed in machine learning, to initially compress tensor network representations before applying tensor network algorithms. We discuss its efficacy in tensor renormalization group calculations on the SU(2) and SU(3) Yang-Mills theories on a square lattice.

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Presenter: AKIYAMA, Shinichiro

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **AKIYAMA, Shinichiro** on **Tuesday, July 29, 2025**

Abstract ID : **135**

Topological entanglement swapping in spin-ladder systems

Content

We study how quantum measurements can transform quantum phases in spin ladder systems through an entanglement swapping protocol. Consecutive Bell measurements are performed between the legs of two independent ladders, followed by uniform post-selection of the measurement outcomes. We analyze the resulting phase realized in the unmeasured outer legs.

Our analysis is based on topological indices protected by the D_2=Z_2×Z_2 spin rotational symmetry as well as the lattice translation symmetry. We find that these indices remain unchanged through the measurement process, leading to a nontrivial inheritance rule. Namely, the output state is topological if only one of the ladders is initially topological, while it becomes trivial if both are.

To illustrate this, we explicitly construct post-measurement states using matrix product states (MPS), in which the rung singlet (trivial) and Haldane (SPT) phases are represented by a product of singlets and a valence bond solid state, respectively. The MPS results are consistent with the index characterization and further reveal that the correlation length increases after measurement, indicating enhanced fluctuations.

Finally, we perform a field-theoretical analysis using bosonization. By identifying the locking positions of bosonic fields associated with string order parameters, we determine the resulting phase and confirm consistency with both the index argument and MPS analysis. Interestingly, the post-measurement correlation length is approximately equal to the sum of those before measurement.

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Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **HAMADA, Mizuki** on **Wednesday, July 30, 2025**

Abstract ID : **136**

Flow Matching at Scale: A Machine Learning Framework for Efficient Large-Size Sampling of a Many-Body System

Content

We introduce a machine learning model based on flow matching to overcome the limitations of Monte Carlo (MC) sampling methods. We demonstrate its capability in the 2D XY model, where a single network, trained in configurations from a small (32X32) lattice at only sparse temperature points, can generate high-fidelity samples for both a much larger system (>128X128) and a continuous temperature range without retraining. The generated configurations are in good agreement with key thermodynamic observables and exhibit the Berezinskii-Kosterlitz-Thouless (BKT) transition signatures. This dual generalization is achieved because the flow matching framework learns a continuous, temperature-conditioned mapping, while the inductive biases of our U-Net architecture ensure the learned local physical rules are scale-invariant. By pairing these methods through operator fusion, our approach achieves superior sampling efficiency and computational speed on large lattices compared to highly optimized, GPU-accelerated MCMC algorithms. Our approach establishes a robust method for studying critical phenomena in the thermodynamical limit and can be easily applied in other classical or quantum many-body systems.

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HUANG, Yi-Ping** on **Wednesday, July 30, 2025**

Abstract ID : **137**

Numerical calculation of dynamical structure factor for various total spin quantum numbers using tensor network

Content

We present a novel approach that combines tensor networks with generating functions to compute the dynamical structure factor of one-dimensional quantum spin chains with spin values S=1/2,1,3/2, and 2. We will compare our results with those from the Lanczos method and linear spin wave theory. Furthermore, we will assess if the obtained spectral shapes and low-energy excitations align with experimental data for 1D materials, discussing the method's applicability to real materials.

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Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **TAKAHASHI, Tomoya** on **Wednesday, July 30, 2025**

Abstract ID : **138**

Environment expansion for MPS time evolution

Content

In the time evolution following a quench of a low-entropy quantum state, the entanglement will generically grow with time. In a tensor network simulation of the time evolution, the bond dimension will thus need to grow if we want to accurately represent the time-evolved state. In this talk, we shall discuss optimized techniques for expanding the bond dimension in the time-dependent variational principle (TDVP) algorithm for matrix product states, following the methods proposed for the density matrix renormalization group algorithm in arXiv:2403.00562. We use the randomized singular value decomposition to construct two schemes, pre-expansion and post-expansion, being essentially optimized versions of two-site TDVP and subspace expansion, respectively. By combining these expansion routines with a truncation each time step, we can efficiently grow the bond dimension while keeping the error controlled, which we demonstrate through benchmark calculations.

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **OSBORNE, Jesse** on **Wednesday, July 30, 2025**

Abstract ID : **139**

Magnetic effects of non-magnetic impurities in gapped short-range resonating valence bond spin liquids

Content

We study the effect of a small density n_v of quenched non-magnetic impurities, {\em i.e.} vacancy disorder, in gapped short-range resonating valence
bond (RVB) spin liquid states and valence bond solid (VBS) states of quantum magnets. We argue that a large class of short-range RVB liquids are stable at
small n_v on the kagome lattice, while the corresponding states on triangular, square, and honeycomb lattices are unstable at any nonzero n_v due to
the presence of emergent vacancy-induced local moments.
In contrast, VBS states are argued to be generically unstable (independent of lattice geometry) at nonzero n_v due to such a local-moment instability. Our
arguments rely in part on an analysis of the statistical mechanics of maximally-packed dimer covers of the diluted lattice, and are fully supported by our
computational results on $O(N)$ symmetric designer Hamiltonians.

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **ANSARI, MD ZAHID** on **Thursday, July 31, 2025**

Abstract ID : **141**

Quantum-HPC Hybrid Simulation for Quantum Chemistry.

Content

Abstract:

Quantum chemistry has long been considered one of the most promising applications of quantum computing. However, due to the limitations of current NISQ (Noisy Intermediate-Scale Quantum) devices—particularly in terms of circuit depth and noise—these devices have only been applied to systems of around 20 qubits, where classical computers can still provide exact solutions.
In this talk, I will introduce one of the recent efforts led by IBM and collaborators to overcome these limitations: the Sample-based Quantum Diagonalization approach 1, which enables quantum chemistry simulations for systems with more than 50 qubits. The key features of this method include:
(1) incorporating the idea of efficiently estimating a suitable basis using sample data from quantum circuits 2,
(2) selecting shallow circuits executable on current NISQ devices,
(3) introducing a configuration recovery scheme to mitigate noise-induced degradation, and
(4) scaling up the diagonalization process through hybrid integration with classical supercomputers.
By combining these techniques, this approach has enabled quantum chemistry calculations for 50-qubit-scale systems—beyond the reach of classical exact methods.

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2 K. Kanno et al., arXiv:2302.11320 (2023).

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Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Thursday, July 31, 2025**

Abstract ID : **142**

Prethermal time crystalline phases and noise-induced dynamics on digital quantum computers.

Content

We explore the emergence of exotic non-equilibrium phases such as prethermal discrete time crystals (DTCs) and discrete time quasicrystals (DTQCs) in two-dimensional quantum many-body systems simulated on IBM's digital quantum computers. Using superconducting qubit architectures arranged in programmable geometries, including heavy-hex, Kagome, and Lieb lattices, we implement kicked Ising models with periodic driving and investigate the relaxation dynamics of initially prepared product states. In the first part, we demonstrate the realization of robust prethermal DTCs and DTQCs on a 133-qubit heavy-hexagonal lattice, where periodic-doubling oscillations and incommensurate amplitude modulations emerge before thermalization. These results highlight the potential of digital quantum computers to simulate large-scale Floquet dynamics beyond the reach of classical computation 1. In the second part, we show that quantum noise, typically regarded as detrimental, can in fact stabilize novel prethermal DTC phases. Using ancilla-mediated constructions of Kagome and Lieb lattices, we identify two distinct types of noise-induced DTCs: one enabled by symmetry charge pumping at the boundaries, and another supported purely by random gate fluctuations. These effects are further validated through noisy matrix-product state simulations 2. Together, these findings point to a new role for quantum noise as an active ingredient in engineering and probing emergent spatiotemporal orders, and they establish a path towards quantum simulation of prethermal phases in higher dimensions.

1 K. Shinjo, K. Seki, T. Shirakawa, R.-Y. Sun, and S. Yunoki, "Unveiling clean two-dimensional discrete time quasicrystals on a digital quantum computer", arXiv:2403.16718.
2 K. Shinjo, K. Seki, and S. Yunoki, to be submitted.

Primary author: Prof. YUNOKI, Seiji (RIKEN)

Presenter: Prof. YUNOKI, Seiji (RIKEN)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Thursday, July 31, 2025**

Abstract ID : **143**

Quantum Computational Physics

Content

Computational physics —the third pillar of physics exploration next to theory and experiment — has, for the past seven decades, evolved alongside tremendous progress in computing hardware. Today the field is on the verge of leaving behind classical computing resources, and pivoting towards quantum hardware, allowing for "quantum on quantum"simulations. In this talk will discuss the "assembler-level" of such quantum computing, asking what kind of quantum many-body phenomena one can induce in digital quantum circuits that employ not only the conventional set of unitary gates, but also mid-circuit measurements and active feedback. In essence, such quantum circuits allow for the dynamical creation, manipulation and decoding of collective entanglement structures.

As an example, I will discuss novel types of quantum criticality that can arise from shallow quantum circuits and which are generally described by (2+0)-dimensional non-unitary conformal field theories. Nishimori universality has emerged as a seemingly ubiquitous fixed point for such critical theories, which we discuss for mixed-state transitions arising from weak measurement or incoherent noise (or both). Putting Nishimori physics in competition to other critical theories, such as percolation, self-dual (Kramers-Wannier) quantum criticality or a novel tricritical theory at the intersection of phases with strong, weak or broken Z_2 symmetry, RG flows between these critical theories can be established and embedded in rich phase diagrams —some of which we have numerically explored on IBM's 127-qubit quantum processors.

Primary author: Prof. TREBST, Simon (University of Cologne)

Presenter: Prof. TREBST, Simon (University of Cologne)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Friday, August 1, 2025**

Abstract ID : **144**

Renormalization group and classification of anyons as projection

Content

The projection and projective representation play a fundamental role in constructing and calculating models in physics. These techniques, combined with the analysis of entanglement and related variational techniques, resulted in various numerical techniques for realizing and analyzing renormalization group (RG) flows or quantum phase transitions.

In this presentation, we introduce a rigorous quantum Hamiltonian formalism realizing massless RG as a projection. More precisely, we treat generalized symmetry of a physical system as an algebra or ring in mathematics, and formulate its reduction to the quotient rings by its ideals. This classification of rings also provides the corresponding classification of anyons in one higher space-time dimension. Our research clarifies the algebraic aspect of RG (or projective representation of RGs), and we expect that our proposal will be realized in numerical methods using tensor-network calculations.

Primary author: Dr FUKUSUMI, Yoshiki (National Center for Theoretical Science, Taiwan)

Co-author: Dr FURUTA, Yuma

Presenter: Dr FUKUSUMI, Yoshiki (National Center for Theoretical Science, Taiwan)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **FUKUSUMI, Yoshiki** on **Friday, August 1, 2025**

Abstract ID : **145**

Probing Quantum Phases of Matter on Quantum Processors

Content

Quantum fluctuations and interactions give rise to exotic phases of matter with remarkable properties, pushing the boundaries of our understanding of many-body quantum systems. Solving these problems is notoriously difficult on classical computers due to the exponential complexity of quantum many-body physics. Quantum processors, on the other hand, provide a powerful new way to explore these systems, offering a more direct and potentially groundbreaking approach. In this talk, we will first discuss how to prepare the ground state of the toric code Hamiltonian using an efficient quantum circuit on a superconducting quantum processor 1. The measured topological entanglement entropy is found to be near the expected value of log 2, we simulate anyon interferometry to extract the braiding statistics of the emergent excitations, and study the dynamics of the confinement transition. We will then investigate a class of novel, highly entangled quantum phases that exist only in non-equilibrium settings and demonstrate how to probe their stability using a quantum processor [3].

1 Satzinger, Liu, Smith, et al., Knap, FP, Roushan, Science 374, 1237 (2021).

2 Cochran, Jobst, et al., FP, Knap, Roushan, Nature 642, 320 (2025).

[3] Will, Cochran, Rosenberg, Jobst, Eassa, Smith, Roushan, Knap, FP, arXiv:2501.18461

Primary author: Prof. POLLMANN, Frank (TMU)

Presenter: Prof. POLLMANN, Frank (TMU)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Friday, August 1, 2025**

Abstract ID : **146**

Neural Canonical Transformations

Content

Neural canonical transformation leverage modern generative models to parametrize variational density matrix of many-particle systems and optimize them via the variational free energy principle. The approach finds applications in studying the equations of state of electron gas, dense hydrogen, and quantum solids. In this talk, I will present physical motivation behind the design of the method and some physical results related to lithium quantum solid.

Primary author: Prof. WANG, Lei (IOP, Chinese Academy of Science)

Presenter: Prof. WANG, Lei (IOP, Chinese Academy of Science)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Friday, August 1, 2025**

Abstract ID : **147**

Analysis of thermal Hall conductivity in a kagome lattice antiferromagnet using a tensor network method

Content

Although kagome lattice antiferromagnets are expected to host a wealth of quantum phases, many aspects of their physical properties remain unresolved, requiring further investigation. In this poster, we focus on the thermal Hall conductivity, which contains information about quasiparticle excitations, and report finite-temperature results obtained with tensor-network methods. In particular, we show that within the 1/9-magnetization plateau region, the thermal Hall conductivity changes sign, revealing a striking heat-transport anomaly that points to the emergence of an exotic quantum state.

Primary author: NAKANISHI, Yuma (University of Tokyo)

Co-authors: IDO, Kota (Institute for Solid State Physics, University of Tokyo); MISAWA, Takahiro (Institute for Solid State Physics, University of Tokyo); MORITA, Satoshi (Keio University); OKUBO, Tsuyoshi (Institute for Physics of Intelligence, The University of Tokyo); YAMAJI, Youhei (National Institute for Materials Science)

Presenter: NAKANISHI, Yuma (University of Tokyo)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **NAKANISHI, Yuma** on **Friday, August 1, 2025**

Abstract ID : **149**

Quantum Convolutional Neural Network Classifier with 2-Dimensional Tensor Networks

Content

The success of convolutional neural networks (CNN) in image classification has prompted the development of various quantum and quantum-inspired algorithms seeking to perform the very task and explore possible advantages. A recently proposed framework, quantum convolutional neural networks (QCNN), has found great potentials in solving physical problems, yet its capacity of performing other machine learning tasks such as image classification remains to be explored. Replacing convolution kernels with variational quantum circuits (VQCs) may benefit possible quantum advantages, but its simulation suffers poor efficiency as the number of qubits becomes large. We present an effective approach to study the performance of QCNN in classifying classical images using convolution kernels based on Projected Entangled Pair States (PEPS), a type of tensor networks (TN) able to capture 2-dimensional correlations, which has proven capable of efficiently simulating generic quantum circuits. We show that a QCNN model with single PEPS convolutional layer achieves similar accuracy to other TN-based machine learning models on the MNIST and Fashion-MNIST datasets with the bond dimension needed much lower. An interesting finding is that the accuracies vary little with the bond dimension χ of the PEPS kernel, and a χ as low as 2 retains similar performance, implying that low entanglement settings could work well for VQC-QCNN.

Primary author: HSING, Chia-Wei (Blueqat)

Co-authors: CHEN, Samuel Yen-Chi (Wells Fargo); Prof. GOAN, Hsi-Sheng (National Taiwan University); KAO, Ying-Jer

Presenter: HSING, Chia-Wei (Blueqat)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HSING, Chia-Wei** on **Friday, August 1, 2025**

Abstract ID : **150**

Quantum-Inspired Digital Annealing for Multi-Student Course Timetabling and Quantum Algorithm Validation

Content

In course registration, students face numerous challenges in course selection. In this study, we formulate these course-selection problems as a Quadratic Unconstrained Binary Optimization (QUBO) model, transforming course allocation into a complex combinatorial problem, and employ the Quantum Inspired Digital Annealing (QIDA) method for optimization.
While previous approaches such as Evolutionary Algorithms (EA) and Simulated Annealing (SA) have demonstrated certain effectiveness, their efficiency and solution quality are limited when handling large-scale datasets. We compare our results with those obtained by SA to demonstrate the advantage of QIDA to multi-student course timetabling optimization. Additionally, we validate quantum algorithm compatibility by comparing Quantum Approximate Optimization Algorithm (QAOA) outcomes,
confirming the potential of quantum-inspired and quantum methods for timetabling optimization

Primary authors: Mr LIU, Yu-Cheng (National Pingtung University); Prof. OHZEKI, Masayuki (Tohoku University); Prof. OU, Chia-Ho (National Pingtung University)

Presenter: Mr LIU, Yu-Cheng (National Pingtung University)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **CHUNG, Chia-Min** on **Wednesday, August 13, 2025**

Abstract ID : **151**

Generative quantum advantage for classical and quantum problems

Content

Recent breakthroughs in generative machine learning, powered by massive computational resources, have demonstrated unprecedented human-like capabilities. While beyond-classical quantum experiments have generated samples from classically intractable distributions, their complexity has, to-date, thwarted all efforts in efficient learning. This challenge has hindered demonstrations of generative quantum advantage: the ability for quantum computers to both learn and generate desired outputs substantially better than classical computers. We resolve this challenge by introducing a class of shallow quantum models that sample from universal classes of deep circuits. These models are hard to simulate classically, are efficiently trainable, have no barren plateaus or proliferating local minima, and can learn distributions that are provably out of reach for classical models. Using a 68 qubit superconducting quantum processor, we apply these models to two scenarios: learning classically intractable probability distributions and learning quantum circuits for accelerated physical simulation. Our results demonstrate that both learning and sampling are efficient in the current beyond-classical regime, opening new possibilities for quantum-enhanced generative models with provable classical hardness.

Primary author: Prof. HUANG, Robert (Hsin-Yuan) (Caltech)

Presenter: Prof. HUANG, Robert (Hsin-Yuan) (Caltech)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Thursday, August 14, 2025**

Abstract ID : **152**

Complexity beyond entanglement - magic of many-body systems

Content

Driven by groundbreaking experimental advances, quantum matter is currently entering the era of quantum error correction - where elementary computations can be demonstrated in a fault-tolerant manner. From a many-body theory viewpoint, these developments motivate the question: what are states that are challenging to realize in the presence of error correction? Entanglement alone is not informative about state complexity, and in fact, it is a free resource in such situations. In this talk, we will tackle quantum state complexity of many-body systems under the lens of non-stabilizerness - also known as magic. Magic quantifies the difficulty of realizing states in most error corrected codes, and is thus of fundamental practical importance. However, very little is known about its significance to many-body phenomena.

I will start the seminar by giving a short review on magic in spin systems, with a focus on quantities that can be used to compute it - stabilizer Renyi entropies and robustness of magic. Then, I shall present method(s) to measure magic in tensor network simulations, and illustrate a series of applications to many body systems, including its relevance in critical matter and gauge theories, and its relations to entanglement. These results indicate that a large amount of quantum resources are required to generate interesting many-body phenomena under the assumption of error correction; at the same time, a picture emerges where error correction is - unexpectedly - intimately tied to various forms of correlated quantum matter, in a universal manner.

Primary author: Prof. DALMONTE, Marcello (ICTP)

Presenter: Prof. DALMONTE, Marcello (ICTP)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Thursday, August 14, 2025**

Abstract ID : **153**

Neural Network and Its Applications to Emergent Quantum Phenomena

Content

I overview recent progress in explorations on efficient algorithms and their applications of neural network for strongly correlated electron systems. For correlated electron systems, restricted Boltzmann machines combined with the pair-product wavefunctions have shown a state-of-the-art accuracy among other quantum many-body solvers [1,2]. They have contributed to understanding of quantum spin-liquid phase in frustrated quantum spin models 2. Not only to simplified theoretical models, the applications of the restricted Boltzmann machine to real materials with ab initio calculations have succeeded in reproducing detailed materials dependence as well as universality of physical properties observed in experiments for superconductivity in a number of high-Tc cuprate superconductors [3,4] and for quantum spin liquids in organic salts [5], which demonstrates that the AI has become NOT the level of the benchmark tests BUT a productive useful tool to uncover physics of challenging emergent quantum matter. It has also contributed to reveal the mechanisms of superconductivity and quantum spin liquids, which also enable to proceed to materials design by parameter search beyond ab initio calculations.

In the Boltzmann machine, the hidden variables are classical, in which the structure of the quantum entanglement is hidden and elusive as a black box. I also address recent attempts to quantize the hidden variable by using fermionic variables to make the entanglement structure more transparent and the solver more accurate, which has been made possible by enjoying the fractionalization of electrons discovered in the preceded Boltzmann machine simulations [6,7].

1 Y. Nomura. A. S. Darmawan, Y. Yamaji, M. Imada, Phys. Rev. B 96, 205152 (2017).
2 Y. Nomura, M. Imada, Phys. Rev. X, 11, 031034 (2021).
[3] J.-B. Moree, M. Hirayama, M. T. Schmid,, Y. Yamaji, M. Imada, Phys. Rev. B, 106, 235150 (2022).
[4] M. T. Schmid, J.-B. Moree, R. Kaneko, Y. Yamaji, M. Imada, Phys. Rev. X, 13, 041036 (2023).
[5] K. Ido, K.Yoshimi, T. Misawa, M. Imada npj Quantum Mater, 7, 48 (2022).
[6] M. Imada, J. Phys. Soc. Jpn. 90, 111009 (2021).
[7] M. Imada, J. Phys. Soc. Jpn. 93, 104002 (2024).

Primary author: Prof. IMADA, Masatoshi (Sofia University)

Presenter: Prof. IMADA, Masatoshi (Sofia University)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Thursday, August 14, 2025**

Abstract ID : **155**

Probing Quantum Dynamics using NISQ Devices: From Ground States to Exotic Symmetries

Content

This talk presents methods for simulating both imaginary and real-time dynamics on noisy intermediate-scale quantum (NISQ) hardware to investigate complex physical phenomena.
First, we introduce a quantum circuit-based algorithm for imaginary-time evolution to determine the ground state of 1D infinite-size systems. This approach, based on the time-dependent variational principle (TDVP), is performed via simulations on IBM Q. We critically compare the results of updating the algorithm using an exact state vector versus using statistical data from noisy hardware measurements. Next, we shift to real-time evolution to probe the exotic E8 symmetry in the quantum Ising chain. We implement these dynamics using two distinct methods: direct Trotter decomposition and Riemannian quantum circuit optimization. Our findings show that despite noise and hardware limitations preventing access to the full spectrum, distinct frequency peaks associated with the E8 symmetry can still be clearly observed by preparing different initial states.

Primary author: Prof. KAO, Ying Jer (NTU)

Presenter: Prof. KAO, Ying Jer (NTU)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Thursday, August 14, 2025**

Abstract ID : **157**

Quantum Magic in Discrete-Time Quantum Walk

Content

Quantum magic, which accounts for the non-stabilizer content of a state, is essential for universal quantum computation beyond classically simulable resources. However, the way magic builds up during structured unitary dynamics remains largely open. Here, we investigate the generation and evolution of quantum magic in discrete-time quantum walks (DTQWs)–a simple, tunable unitary model realizable on a wide range of architectures. We use Stabilizer Renyi Entropy as a measure of quantum magic and investigate single- and two-walker quantum walks on a one-dimensional lattice, considering a wide range of initial coin states. Our results reveal that DTQWs can dynamically generate significant magic, with the amount and structure dependent on the initial state of the coin. In the case of a single walker, we found a nontrivial and complementary relationship between magic and entanglement at long times. In the two-walker setting, even states close to stabilizer form can evolve into highly magical states when subjected to quantum walk protocols. The generation of magic can occur independently of entanglement growth, emphasizing its distinct role as a quantum resource. We further show that the dynamical magic generation is robust under realistic noise—specifically, decoherence in the coin degree of freedom—demonstrating that this process persists across noisy settings. Finally, we discuss an experimentally feasible scheme to measure magic using current technology. Our findings position DTQWs as accessible and controllable platforms for producing quantum magic, offering a new perspective on their role in quantum information proces

Primary author: MITTAL, Vikash (National Tsing Hua University, Hsinchu, Taiwan)

Presenter: MITTAL, Vikash (National Tsing Hua University, Hsinchu, Taiwan)

Track Classification: Poster presentation

Status: ACCEPTED

Submitted by **HUANG, Yi-Ping** on **Sunday, August 17, 2025**

Abstract ID : **158**

Quantum algorithmic primitive for quantum machine learning

Content

In this talk I will present an efficient quantum algorithmic primitive that can accelerate some quantum algorithms.
The applications include machine learning, such as the problem of constructing a unitary emulator from a given
set of input and output quantum states.

Primary author: Prof. YAMAMOTO, Naoki (Keio University)

Presenter: Prof. YAMAMOTO, Naoki (Keio University)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Monday, August 18, 2025**

Abstract ID : **159**

Advanced tensor network algorithms for quantum many-body problems and quantum computation

Content

Tensor networks offer a powerful and versatile framework for addressing the complexity of quantum many-body systems and the challenges in quantum computing. This talk presents recent advances in applying tensor network algorithms within quantum-classical hybrid computing frameworks, particularly their integration with high-performance computing (HPC) environments. We explore how tensor networks serve as efficient representations for quantum states, enabling breakthroughs in quantum embedding schemes, error correction protocols, and circuit simulation techniques. We further highlight the emerging role of tensor-network-based Monte Carlo methods, which combine the strengths of stochastic sampling and structured representations to enhance simulation accuracy and scalability.

Primary author: Prof. TODO, Synge (Univ. of Tokyo)

Presenter: Prof. TODO, Synge (Univ. of Tokyo)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Monday, August 18, 2025**

Abstract ID : **160**

Quantum gravity and Machine learning

Content

The best-known example of quantum gravity theory is the holographic principle (the AdS/CFT correspondence), in which a quantum gravitational geometry is equivalent to a lower dimensional non-gravitating quantum system. To find a consistent gravity counterpart starting from the latter is an important problem in quantum gravity and string theory. This is called "Bulk reconstruction," and is a key idea revealing the mechanism of the holographic geometry. Various methods were proposed to solve this inverse problem. We use deep learning and identify the neural network as the emergent geometry, to reconstruct the bulk geometry. As the quantum data, the lattice QCD data such as chiral condensate, hadron spectra or Wilson loop is used as input data to learn and reconstruct the emergent geometry of the bulk. The requirement that the bulk geometry is a consistent solution of an Einstein-dilaton system determines the bulk gravity action backwards, to complete the reconstruction program. We demonstrate that our geometric neural networks work as a method solving quantum gravity, and the flexibility of accommodating various inverse problems in neural networks is a key in applying machine learning to physical problems.

Primary author: Prof. HASHIMOTO, Koji (Kyoto University)

Presenter: Prof. HASHIMOTO, Koji (Kyoto University)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Monday, August 18, 2025**

Abstract ID : **161**

The structure of dynamical quantum critical points

Content

Dynamical quantum phase transitions (DQPTs) are characterized by nonanalytic behavior in the return rate, a dynamical analogue of the equilibrium free energy. For a translationally invariant one-dimensional system (or 2D cylinder) we define the return rate per site as , which can be expressed via the dominant eigenvalue of the transfer operator. Analytically continuing to complex , each eigenvalue branch defines a sheet of a multivalued function, and together these sheets form a Riemann surface. The return rate corresponds to the dominant sheet, with nonanalyticies arising when different sheets intersect. These branch crossings mark dynamical critical points, and the resulting web of intersections defines the structure of the DQPT. This perspective highlights that DQPTs are governed by the branching geometry of the transfer-operator spectrum, rather than by the accumulation of Fisher zero lines onto the real axis, as in equilibrium phase transitions. Using MPS transfer matrix methods, we show how to compute the derivatives of the return rate function, which gives a series expansion representation of each eigensurface and directly reveals the nonanalytic structure.

Primary author: Prof. MCCULLOCH, Ian (NTHU)

Presenter: Prof. MCCULLOCH, Ian (NTHU)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Monday, August 18, 2025**

Abstract ID : **162**

Extraction of Conformal Data in Critical Two-Dimensional Classical Models using Tensor Networks Renormalization

Content

We propose a scheme to extract the conformal data of critical two-dimensional classical models from tensor network renormalization based finite-size scaling. The key point is to identify the length scale below which the system is in the finite-size scaling regime. The scheme can work with any tensor network renormalization method that preserves the translation invariance. In particular, we benchmark against three tensor network renormalization methods: HOTRG, PTMRG, and CTRG. In this work, we apply the scheme to 2D Ising model and 3-state clock model at criticality. Our results show that all conformal data can be extracted with high accuracy. Moreover, we show how to define entanglement scaling for 2D classical systems, from which the central charge can be extracted accurately.

Primary author: Prof. CHEN, Po-Chung (NTHU)

Presenter: Prof. CHEN, Po-Chung (NTHU)

Track Classification: Invited talk

Status: ACCEPTED

Submitted by **HO, Renee** on **Wednesday, August 20, 2025**