XVII Symposium KCIK-ICTQT on

QUANTUM INFORMATION

13-15 May 2026, Sopot-Gdańsk, Poland

BOOK OF ABSTRACTS

Presented in alphabetical order

Updated May 28th 2026

INVITED SPEAKERS

Karol Bartkiewicz

Adam Mickiewicz University, Poznań, Poland

Spin chirality across quantum state copies detects hidden entanglement

Abstract: Entanglement can hide from standard detection in two fundamentally different ways: as multicopy correlations invisible to any single-copy measurement on an unknown state, and as bound entanglement invisible to the Peres–Horodecki criterion. We show that both forms share a common origin in spectral structures accessible only through joint measurements on multiple state copies, and can be detected by a unified architecture built on controlled-SWAP circuits. We prove that the difference between partial transpose moments and purity moments, Ck = μk – Ik, decomposes exactly as a chirality–chirality correlator—the same scalar spin chirality that governs chiral spin liquids and the topological Hall effect—revealing the specific physical content that multi-copy entanglement detection probes. For two-qubit states, chirality measures the signed volume of the correlation tensor parallelepiped, providing a geometric entanglement signature from just two measurements. Using the same circuit infrastructure, we develop a multi-channel spectral classifier for bound entanglement that combines realignment spectral features with chirality corrections. This classifier achieves 100% recall at zero false positives across all known 3×3 bound entangled families—compared with ∼50% for the computable cross-norm or realignment (CCNR) criterion, which certifies entanglement when the trace norm of the realignment matrix exceeds unity, and ∼58% for the range criterion, which certifies entanglement through the structure of product vectors in the state's range. A new marginal-noise construction produces states where the CCNR trace norm drops below the detection threshold, rendering them invisible to CCNR and to all other single-parameter criteria, while the non-Hermiticity gap between singular values and eigenvalues of the realignment matrix persists—enabling detection through the multi-channel approach. These CCNR-invisible states are still detected by the range criterion, but evade the PPT test and all moment-based witnesses. We demonstrate both capabilities experimentally on IBM Quantum processors: negativity reconstruction with mean errors of 0.002–0.027, chirality detection for pure and mixed states, and bound entanglement detection across two structurally distinct families (Horodecki and chessboard) using a single family-agnostic classifier on a gate-based superconducting processor.
 Entanglement can hide from standard detection in two fundamentally different ways: as multicopy correlations invisible to any single-copy measurement on an unknown state, and as bound entanglement invisible to the Peres–Horodecki criterion. We show that both forms share a common origin in spectral structures accessible only through joint measurements on multiple state copies, and can be detected by a unified architecture built on controlled-SWAP circuits. We prove that the difference between partial transpose moments and purity moments, Ck = μk – Ik, decomposes exactly as a chirality–chirality correlator—the same scalar spin chirality that governs chiral spin liquids and the topological Hall effect—revealing the specific physical content that multi-copy entanglement detection probes. For two-qubit states, chirality measures the signed volume of the correlation tensor parallelepiped, providing a geometric entanglement signature from just two measurements. Using the same circuit infrastructure, we develop a multi-channel spectral classifier for bound entanglement that combines realignment spectral features with chirality corrections. This classifier achieves 100% recall at zero false positives across all known 3×3 bound entangled families—compared with ∼50% for the computable cross-norm or realignment (CCNR) criterion, which certifies entanglement when the trace norm of the realignment matrix exceeds unity, and ∼58% for the range criterion, which certifies entanglement through the structure of product vectors in the state's range. A new marginal-noise construction produces states where the CCNR trace norm drops below the detection threshold, rendering them invisible to CCNR and to all other single-parameter criteria, while the non-Hermiticity gap between singular values and eigenvalues of the realignment matrix persists—enabling detection through the multi-channel approach. These CCNR-invisible states are still detected by the range criterion, but evade the PPT test and all moment-based witnesses. We demonstrate both capabilities experimentally on IBM Quantum processors: negativity reconstruction with mean errors of 0.002–0.027, chirality detection for pure and mixed states, and bound entanglement detection across two structurally distinct families (Horodecki and chessboard) using a single family-agnostic classifier on a gate-based superconducting processor.

Mohamed Bourennane
Stockholm University, Sweden

Topological quantum photonics

Abstract: Quantum photonic technologies offer a powerful platform for quantum communication, computation, and sensing, but their scalability is fundamentally limited by the fragility of quantum states in the presence of disorder, fabrication imperfections, and environmental noise. Overcoming this challenge is essential for realizing practical quantum systems. In this talk, I will present a new approach based on topological quantum photonics, where photonic structures are engineered to provide intrinsic robustness to quantum states of light. By combining quantum optics with topological photonic design, we move beyond conventional implementations toward noise-resilient quantum platforms. I will discuss our experimental efforts to generate and manipulate single photons and entangled states in integrated and laser-written photonic circuits. In particular, I will show how topological and non-Hermitian structures can enable protected transport, localization, and interference of quantum light. We investigate the robustness of entanglement and high-visibility quantum interference under controlled disorder, providing a pathway toward stable and scalable quantum photonic systems. This work establishes a bridge between topological wave physics and quantum information science, opening new opportunities for robust quantum technologies, including secure communication and scalable quantum processing.

Paweł Caban
University of Łódź, Poland

Violation of Bell inequalities in 2x3 dimensional systems

Abstract: We consider the CH inequality for the case of qubit-qutrit system. We derive necessary and sufficient condition for violation of the inequality as well as some sufficient ones. Remarkably we provide importance of local parameters in the violation of the inequality. Namely there are some families of mixed states violating the inequality for which correlation part alone is useless in Bell-CH test.

Andre Chailloux
Centre Inria de l’Université Grenoble Alpes, France

Quantum algorithms for decoding problems inspired by Regev's reduction

Abstract: Chen, Liu and Zhandry introduced a new family of quantum algorithms for decoding problems, inspired by Regev's reduction. The idea is to solve a decoding problem in a linear code in order to solve a corresponding decoding problem in the corresponding dual code. This approach has already provided convincing quantum advantage. In this talk I will briefly present this family of quantum algorithms and the applications for post-quantum cryptography and more generally for finding quantum advantage. I will then focus on links to quantum state discrimination problems and the open questions in this field.

Ignacio Cirac
Max Planck Institute of Quantum Optics, Germany

Efficient Preparation and manipulation of Tensor Network Quantum States

Abstract: Tensor Network States, like matrix product or projected entangled pair states play an important role in both, quantum information theory and many-body physics. They offer a compact and efficient representation, enabling accelerated numerical computations and providing intuitive insights into many-body phenomena. In this talk, I will discuss how certain states can be efficiently prepared and manipulated using quantum devices, highlighting the use of local operations and classical communication.

Marek Czachor
Gdańsk University of Technology, Poland

Swapping Space for Time: A new and quite counterintuitive type of quantum interferometry

Abstract: Young's double-slit experiment requires two waves produced simultaneously at two different points in space. In quantum mechanics, the waves correspond to a single quantum object, even as complex as a big molecule. An interference is present as long as one cannot tell for sure which slit is chosen by the object. The more we know about the path, the worse the interference. In the paper we show that quantum mechanics allows for a dual version of the phenomenon: self-interference of waves propagating through a single slit but at different moments of time. The effect occurs for time-independent Hamiltonians and thus should not be confused with Moshinsky-type time-domain interference, a consequence of active modulation of parameters of the system (oscillating mirrors, chopped beams, time-dependent apertures, moving gratings, etc.). The discussed phenomenon is counterintuitive even for those who are trained in entangled-state quantum interferometry. For example, the more we know about the trajectory in space, the better the interference. Exactly solvable models lead to formulas deceptively similar to those from a Youngian analysis. The models are finite dimensional, with interaction terms based on two-qubit CNOT quantum gates. The effect is generic and should be observable in a large variety of experimental configurations. Moreover, there are reasons to believe that this new type of quantum interference was in fact already observed in atomic interferometry almost three decades ago, but was misinterpreted and thus rejected as an artifact of unknown origin.

References:
[1] Full text: https://doi.org/10.3389/fphy.2019.00079 /// arXiv:1808.03271

Michał Eckstein
Jagiellonian University in Kraków, Poland

A unified framework for causation and correlations in relativistic spacetimes

Abstract: The limits imposed by relativity on causal influences and nonlocal correlations remain the subject of ongoing controversies. We present a unified framework to study both nonlocal and temporal correlations within general relativistic spacetimes, and expose its intriguing implications. Firstly, we show that the violation of the no-signalling constraints in

Minkowski spacetime implies either a logical paradox or an operational infringement of Poincare symmetry. Secondly, we inspect the possibility of jamming of nonlocal correlations and its devastating consequences for device-independent cryptography. Finally, we show that in black hole spacetimes certain nonlocal correlations under and across the event horizon can be jammed by any agent without breaching relativistic causality. Our results controvert some recent claims about the possibility of witnessing causal loops in Minkowski spacetime and the alleged superluminal nature of jamming mechanisms.

References:
The talk is based on the recent work: arXiv:2512.23702 by M.E., T. Miller, R. Horodecki, R. Ramanathan and P. Horodecki.

Zbigniew Ficek
University of Zielona Góra, Poland

Nonreciprocity in bosonic coupling without breaking time-reversal symmetry

Abstract: The role played by dissipative reservoirs in the unidirectional transmission and creation of quantum correlations between bosonic modes mutually coupled through the simultaneously present linear mode-hopping and nonlinear squeezing interactions is investigated. Under such double two-mode coupling, it is found that while the Hamiltonian of the system is clearly Hermitian the dynamics of the quadrature components of the field operators can be attributed to non-Hermicity of the system. It is manifested in an asymmetric couplingbetween the quadrature components which then leads to a variety of novel features. In particular, we identify how in the case of thermal reservoirs the double two-mode coupling creates single-mode correlations that the double coupling converses thermal states of the modes into single-mode classically or quantum squeezed states. When the modes are influenced by squeezed reservoirs, we find that the two-photon correlations present in these reservoirs are responsible for unidirectional flow of populations and correlations among the modes. We find that the flow of the population is sensitive to the relative phase of the reservoirs and depending on the phase it can create either the first-order coherence between the modes or two photon correlations responsible for entanglement between the modes.

Michał Gawełczyk
Wrocław University of Science and Technology, Poland

Controlling quantum dot charge and spin states with sound

Abstract: Semiconductor quantum dots (QDs) combine optically addressable charge excitations with long-lived, coherent spin qubits, and offer a controllable interface between them [1]. Recent progress on QD homogeneity further extends spin coherence times. Additionally, it provides a uniform ensemble of nuclear spins with a controllable interface to the QD spin [2], which can act as a quantum memory [3]. However, what QDs lack are direct phonon-mediated charge and spin transitions despite strong energy modulation by elastic waves [4]. This limitation hinders their integration into hybrid quantum systems based on acoustic (phononic) interconnects, which offer a promising strategy for coherently linking solid-state quantum systems with complementary functionalities. We propose a family of acousto-optical schemes that overcome this limitation and enable coherent control of both charge and spin degrees of freedom in QDs. For charge-state preparation, we develop acousto-optical parametric control of the "swing-up" type [5], which also allows for higher-harmonic driving that separates the control field frequency from the much larger state splitting [6]. For spin states, we use

a detuned optical coupling to an excited state (trion) to break spin conservation, enabling acoustic spin control [7]. To overcome gate infidelity due to relatively long operation times in the presence of quasistatic noise in QDs, we propose error-mitigating control sequences. Finally, we propose a parametric variant of acousto-optical spin control that naturally enables faster operation. Because the same interaction structures arise for quantized acoustic modes in the coherent-state limit, these methods can enable generating QD-phonon entanglement, state transfer, and generation of nonclassical multi-phonon states in phononic resonators.

References:
[1] C. Schimpf et al., PRX Quantum 6, 040309 (2025).
[2] N. Shofer et al., Phys. Rev. X 15, 021004 (2025).
[3] M. H. Appel et al., Nat. Phys. 21, 368 (2025).
[4] J. Rosiński et al., arXiv:2601.14162.
[5] M. Kuniej et al., npj Quantum Inf. 11, 161 (2025). [6] M. Kuniej et al., arXiv:2603.09849.
[7] M. Kuniej et al., Phys. Rev. Lett. 136, 046904 (2026).

Khrystyna Gnatenko

Ivan Franko National University of Lviv, Ukraine

Properties of Multiqubit Quantum States Representing n-Partite Graphs and Their Quantification Using Quantum Computing

Abstract: Quantum states representing complex structures have recently attracted significant attention due to their wide-ranging applications in quantum information science and quantum computing. These states play an essential role in various quantum technologies, including quantum error correction, quantum cryptography, and quantum machine learning. In addition, studying these states opens up the possibility of constructing quantum protocols for detecting properties of complex systems using quantum programming. We investigate multi-qubit quantum states associated with bipartite graphs $G(U,V,E)$. For a general quantum state defined on a bipartite graph with arbitrary structure, we derive an analytical expression for the entanglement distance [1]. Furthermore, we establish a relationship between quantum correlators and the number of vertices with odd and even degrees in the subsets U and V. These quantities are essential for understanding the structure of bipartite graphs and for identifying possible matchings. Building on these theoretical results, we propose quantum protocols that allow one to determine the number of vertices with odd and even degrees in both partitions of a bipartite graph. As a specific example, we analyze a bipartite star graph. For this case, the entanglement distance and the number of odd-degree vertices in the sets U and V are evaluated using quantum programming [1]. We also extend our analysis to multi-qubit states corresponding to tripartite graphs. These states are generated by applying RXX, RYY, and RZZ gates to an arbitrary separable n-qubit state. We derive the entanglement distance for such states and study its dependence on both the state parameters and the structural properties of the corresponding tripartite graphs. In addition, we introduce a quantum protocol for counting closed cycles of length four in a tripartite graph, which suggests the potential for achieving quantum advantage in solving this problem. Finally, we examine quantum states that can be represented by weighted graphs [2,3]. These states also correspond to single-layer variational quantum states [2], which are important in quantum machine learning. The entanglement of these states is calculated both analytically and using quantum programming for graph states with arbitrary structure.

References:
[1] Gnatenko Kh. P. Studies of properties of bipartite graphs with quantum programming // Phys. Lett. A. — 2026. — Vol. 566. — Art. 131191. — 7 p.

[2] Gnatenko Kh. Quantum and classical calculations of the entanglement distance of multi-qubit one-layer variational quantum states // 2025 IEEE International Conference on Quantum Computing and Engineering (QCE), Albuquerque, NM, USA, 2025,. — P. 470–471
[3] Gnatenko Kh. P. Relation of curvature and torsion of weighted graph states with graph properties and its studies on a quantum computer // Eur. Phys. J. Plus. — 2025. — Vol. 140, — Art. 241. — 7 p.

Philippe Grangier
Laboratoire Charles Fabry, IOGS, CNRS, France

Heading towards an Algebraic Heisenberg Cut

Abstract: Following an article by John von Neumann on infinite tensor products, we develop the idea that the usual formalism of quantum mechanics, associated with unitary equivalence of representations, stops working when countable infinities of particles (or degrees of freedom) are encountered. This is because the dimension of the corresponding Hilbert space becomes uncountably infinite, leading to the loss of unitary equivalence, and to sectorization. By interpreting physically this mathematical fact, we show that it provides a natural way to describe the "Heisenberg cut", as well as a unified mathematical model including both quantum and classical physics. By considering simple examples we also show that although the full force of the sectorisation theorems requires taking the infinite limit, early signs of the macroscopic behaviour appear before infinity. Such an approach can make sense of the quantum-classical transition as a primarily algebraic one.

References:
[1] M. Van Den Bossche & P. Grangier, Foundations of Physics 53:45 (2023) [https://arxiv.org/abs/2209.01463]

Marcin Jarzyna
University of Warsaw, Poland

Coherent beam combination in the photon starved regime

Abstract: Optical signals exhibit losses during transmission in free space due to diffraction. This can have severe consequences when the transmission distance is large or the input signal is weak, on the level of single photons, causing signal reception difficult. Detection of such weak optical signals requires telescopes with large apertures to catch as much light as possible. However, due to effects of atmospheric turbulence large telescopes typically require adaptive optics, which makes them prohibitively costly. I will discuss single-photon coherent beam combination, which is an economic alternative that combines signal beams gathered by a number of small apertures through a set of interferometers and feedback loops. In contrast to the standard high-power approach I will focus on the photon-starved regime, where the efficiency of combination is limited by the discrete nature of photons. Crucially, such an approach not only allows one to combine the beams coherently into a single mode containing most of the received power but also vastly improves signal to noise ratio, opening the possibility to perform daytime deep-space communication and satellite quantum key distribution.

Jan Kołodyński
Institute of Physics, Polish Academy of Sciences, Poland

Quantum information meets particle physics: Detecting entanglement in para-positronium annihilation photons

Abstract: Para-positronium (p-Ps) annihilation into two photons is predicted to yield a maximally entangled singlet state, yet experimental verification remains a subject of debate. Although a new generation of detectors has recently enabled the analysis of the spherical distribution generated by annihilation photons undergoing Compton scattering, ambiguous claims persist regarding the nature of the entanglement proven. We employ the QED S-matrix formalism and Feynman diagrams to derive rigorous differential cross-sections for varied photonic states, while concurrently identifying constraints imposed by the conservation of fundamental symmetries. We evaluate the validity of the commonly used R-factor, identifying specific classes of initial states where it serves as a reliable entanglement witness. By extending our analysis to two-qubit X-states, we introduce a novel method surpassing the R-factor for verifying entanglement from scattering data. Our quantum-information perspective establishes a basis to rigorously identify and validate entanglement in more complex annihilation experiments, such as those involving ortho-positronium (o-Ps) and multi-photon decays.

Piotr Kopszak
University of Wrocław, Poland

Entanglement recycling in two-step port-based teleportation

Abstract: In my talk I describe the protocol involving the repetitive (twofold, to be precise) application of Port-Based Teleportation to the same resource. The quantities characterizing the resulting protocol, so-called Two-Step PBT are provided for two scenarios, relying on application of pretty-good measurement, i.e. deterministic and probabilistic PBT with non-EPR resource. This results show that two-step PBT is an accurate protocol, provided the resource is sufficiently large. In particular, the deterministic two-step PBT obtains fidelity that is remarkably close to the optimal MPBT fidelity for teleportation of two quantum states. Additionally, the recycling fidelity, i.e. the quantity characterizing the degradation of the resource state for repetitive application of probabilistic protocol, for both EPR and optimized resource will be shown, implying that entanglement recycling with two-step PBT is possible in the former case as well.

Tristan Kraft
Technical University of Munich, Germany

Bounded-Error Quantum Simulation via Hamiltonian and Lindbladian Learning

Abstract: Analog Quantum Simulators offer a route to exploring strongly correlated many-body dynamics beyond classical computation, but their predictive power remains limited by the absence of quantitative error estimation. Establishing rigorous uncertainty bounds is essential for elevating such devices from qualitative demonstrations to quantitative scientific tools. In this talk, I will introduce a general framework for bounded-error quantum simulation, which provides predictions for many-body observables with experimentally quantifiable uncertainties. The approach combines Hamiltonian and Lindbladian Learning--a statistically rigorous inference of the coherent and dissipative generators

governing the dynamics--with the propagation of their uncertainties into the simulated observables, yielding confidence bounds directly derived from experimental data. I will discuss experimental demonstrations of this framework on trapped-ion quantum simulators implementing long-range Ising interactions with up to 51 ions, and validate it where classical comparison is possible. We establish error bounds directly from experimental measurements alone, without relying on classical simulation--crucial for entering regimes of quantum advantage. The learned models reproduce the experimental evolution within the predicted bounds, demonstrating quantitative reliability and internal consistency. Bounded-error quantum simulation provides a scalable foundation for trusted analog quantum computation, bridging the gap between experimental platforms and predictive many-body physics. The techniques I will present directly extend to digital quantum simulation.

Barbara Kraus

TUM School of Natural Sciences at the Technical University of Munich, Germany

Phases of matrix-product states with symmetries and measurements

Abstract: Two matrix product states (MPS) are in the same phase in the presence of symmetries if they can be transformed into one another via symmetric short-depth circuits. We consider how symmetry-preserving measurements with feedforward alter the phase classification of MPS in the presence of global on-site symmetries. We demonstrate that, for all finite abelian symmetries, any two symmetric MPS belong to the same phase. We give an explicit protocol that achieves a transformation between any two phases and that uses only a depth-two symmetric circuit. In the case of non-abelian symmetries, symmetry protection prevents one from deterministically transforming symmetry-protected topological (SPT) states to product states directly via measurements, thereby complicating the analysis. Nonetheless, we provide protocols that allow for asymptotically deterministic transformations between the trivial phase and certain SPT phases [1]. We extend this analysis and the protocols to nilpotent groups [2].

Marek Krośnicki

Institute of Theoretical Physics and Astrophysics, Faculty of Mathematics, Physics and Informatics, University of Gdańsk, Poland

Electronic structure of ^{229}Thorium-Doped CaF_2 crystals. A step towards to Nuclear Clocks

Abstract: The ^{229}Th isotope has an extremely low-lying excited nuclear isomeric state with an excitation energy of 8.4 eV and is the only nucleus that can be manipulated by lasers in the UV range. Therefore, the construction of nuclear clocks based on the low-energy isomer of thorium-229 has been proposed, and the development of such clocks is advancing [1, 2]. In order to decrease the probability of internal conversion of the nuclear isomer, the Th atom has to be stripped of its valence electrons, which can be achieved by inserting thorium into an ionic crystal such as CaF_2. However, the performance of the clock then critically depends on how thorium atoms interact with their solid-state environment [2, 3]. In this talk, we show how ab initio model potential embedding methods can be used to describe the interaction of thorium ions with a calcium fluoride crystal. As the nuclear transition frequency of the clock is strongly governed by the fundamental forces acting inside the nucleus, an operating Thorium clock can, in the future, be used as a probe of these fundamental interactions and processes such as the electron nuclear-bridge.

References:
[1] K. Beeks et al. "The thorium-229 low-energy isomer and the nuclear clock". In: Nature Reviews Physics 3 (2021), pp. 238–248. doi: 10.1038/s42254-021-00286-6.
[2] Tian Ooi et al. "Frequency reproducibility of solid-state thorium-229 nuclear clocks". In: Nature 650.8100 (2026), pp. 72–78. doi: 10.1038/s41586-025-09999-5.
[3] Kamil Nalikowski et al. "Embedded cluster approach for accurate electronic structure calculations of ^{229}Th:CaF_2". In: Phys. Rev. B 111 (11 2025), p. 115103. doi: 10.1103/PhysRevB.111.115103. url: https://link.aps.org/doi/10.1103/PhysRevB.111.115103.

Josef Lazar
Academy of Sciences of the Czech Republic, Czech Republic

Quantum Technology Landscape at the Czech Academy of Sciences and Beyond

Abstract: This contribution outlines the current state and future trajectory of quantum technologies within the Institute of Scientific Instruments and the Czech Academy of Sciences. As a key player in the multidisciplinary programme of the AV21 Strategy of the Academy of Sciences, putting together a number of institutions we focus on interinstitutional synergies bridging the gap between basic and applied science in the quantum field. The topics cover Quantum Metrology and Communications: Development of cold quantum objects for frequency/time metrology and the creation of a national time scale for synchronizing not only data networks. Experimental milestones include progress in trapping and laser-cooling Calcium ions and also hybrid systems with Aluminum ions for optical quantum clocks. Infrastructure and larger collaborations cover integration into European initiatives such as EuroQCI and FOREST to build secure quantum communication backbones and fiber-based distribution of precise time across borders. Among future frontiers is and emerging research into hybrid quantum gates combining trapped atoms, molecules, and nanoparticles. The topic of quantum computing is addressed by a deployment of the LUMI-Q consortium's quantum computer in the Czech Republic. Aligned with the European Chips Act and the Quantum Europe Strategy, the Czech scientific community set a national Strategy for Quantum Technologies with the prospect to contribute to the European digital security and industrial competitiveness.

Marcin Markiewicz
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

When interference is not enough: a definitive Bell test for path-identity experiments

Abstract: Interference effects arising from path identity in multi-crystal parametric down-conversion setups have recently been interpreted as evidence of Bell inequality violation without entanglement. We show that this conclusion is misleading. Although the analysis in previous works focuses on the amplitude of a specific four-photon component, the experimentally accessible probabilities necessarily involve measurements on the full quantum state, which exhibits mode entanglement. At the same time, we demonstrate that phase modulation alone is insufficient to define complementary local observables required for a conclusive Bell test in this scenario. As a result, the observed correlations under phase-only settings admit a local realistic description, despite the presence of interference terms. To overcome this limitation, we propose a modified scheme in which the measurement settings are implemented via on–off control of local down-conversion processes. This extension enables the definition of genuinely incompatible measurements and leads to a violation of the Clauser–Horne inequality. Our results resolve the apparent paradox of "Bell violation without entanglement" and clarify that both the

structure of the quantum state and the physical implementation of measurement settings are essential for establishing Bell non-classicality in path-identity interferometry.

References:
[1] https://doi.org/10.1103/h2l1-fcz9
[2] https://arxiv.org/abs/2602.18381

Acknowledgement:
This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase' project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.

Muhammad Mohsin
University of Lodz, Poland

Violation of CGLMP Inequality In two-qutrit state

Abstract: We investigate the optimization of Bell-type inequalities in bipartite 3×3 (qutrit-qutrit) quantum systems, focusing on the structure of nonlocal correlations beyond two-dimensional Hilbert space. The most general density state is expressed in the Gell-Mann basis, allowing it to be parameterized through local Bloch vectors and an 8×8 real correlation functions. Measurable observables are obtained from arbitrary Hermitian operators and their associated projectors are used to construct the joint probabilities to enter the CGLMP inequality. By explicitly evaluating, we derive an analytical expression for the Bell parameter I_3 in terms of the correlation tensor and the measurement-dependent geometric coefficients. To optimize the violation of the inequality, we employ the adjoint representation of $SU(3)$, which maps local unitary transformations to orthogonal transformations acting on $\mathbb{R}^8$. This reduces the optimization problem to the geometry of a constrained subset of the 7-sphere.

Giovanna Morigi
Saarland University, Germany

Time complexity of a monitored quantum search with resetting

Abstract: Searching a database is a central task in computer science and is paradigmatic of transport and optimization problems in physics. For an unstructured search, Grover's algorithm predicts a quadratic speedup, with the search time $\tau(N) = \Theta(\sqrt{N})$ and N the database size. Numerical studies suggest that the time complexity can change in the presence of feedback, injecting information during the search. Here, we determine the time complexity of the quantum analog of a randomized algorithm, which implements feedback in a simple form. The search is a continuous-time quantum walk on a complete graph, where the target is continuously monitored by a detector. Additionally, the quantum state is reset if the detector does not click within a specified time interval. This yields a non-unitary, non-Markovian dynamics. We optimize the search time as a function of the hopping amplitude, detection rate, and resetting rate, and identify the conditions under which time complexity could outperform Grover's scaling. The overall search time does not violate Grover's optimality

bound when including the time budget of the physical implementation of the measurement. For databases of finite sizes monitoring can warrant rapid convergence and provides a promising avenue for fault-tolerant quantum searches.

Pedro Nicacio Falcao

Jagiellonian University in Kraków, Poland

Nonstabilizerness dynamics in many-body localized systems

Abstract: Nonstabilizerness, also known as "magic", characterizes the deviation of a quantum state from the stabilizer manifold and serves as a resource for quantum computational advantage. In this talk, we investigate the dynamics of nonstabilizerness in disordered many-body localized (MBL) systems using the stabilizer Rényi entropy (SRE). Using a phenomenological framework, we analytically and numerically show that disorder fundamentally alters the spreading of nonstabilizerness, driving a power-law growth of the SRE that stands in stark contrast to the rapid saturation characteristic of ergodic systems. Our theoretical predictions are validated by numerical simulations of the disordered transverse-field Ising model, yielding excellent agreement across a range of disorder strengths, system sizes, and initial states. We further identify a universal relationship between SRE and entanglement entropy, with both quantities sharing a common scaling in the MBL regime. Our results shed new light on the interplay between disorder, interactions, and quantum complexity in many-body systems.

Michał Oszmaniec

Center for Theoretical Physics, Polish Academy of Sciences, Poland

Towards verifiable and useful quantum advantage in photonics

Abstract: Photonics is one of the leading platforms for demonstrating quantum computational advantage. However, compared with qubit-based architectures, photonic schemes have long lacked rigorous complexity-theoretic justification in experimentally relevant regimes. In this talk, I will present recent progress towards closing this gap. First, I will discuss new hardness guarantees for Boson Sampling in the saturated regime, where the number of optical modes scales linearly with the number of photons [1]. I will then describe a general framework for computing linear cross-entropy benchmarking scores and proving anticoncentration for photonic quantum advantage schemes in this same regime [2]. Finally, I will outline possible useful applications of photonic sampling devices, in particular to generative machine learning with Gaussian Boson Sampling [3].

References:

[1] A. Bouland, D. Brod, I. Datta, B. Fefferman, D. Grier, F. Hernandez, and M. Oszmaniec, Complexity-theoretic foundations of BosonSampling with a linear number of modes, arXiv:2312.00286, accepted to PRX.

[2] Z. Kolarovszki, Á. Kaposi, Z. Zimborás, and M. Oszmaniec, General framework for anticoncentration and linear cross-entropy benchmarking in photonic quantum advantage experiments, arXiv:2604.15258, 2026.

[3] Z. Kolarovszki, B. Bakó, M. Oszmaniec, C. Oh, and Z. Zimborás, Generative modeling with Gaussian Boson Sampling: classically trainable Bosonic Born Machines, arXiv:2603.11195, 2026

Sohyun Park

University of Bristol, the United Kingdom

Can tachyons explain all possible non-local effects?

Abstract: One of the most counter-intuitive features of quantum mechanics is the existence of correlations between distant particles that are stronger than any classical model allows. Classically, reproducing such correlations would require faster-than-light communication, for example by exchanging tachyons. Yet, in a theory such as quantum mechanics, in which measurement outcomes are probabilistic, these so-called non-local correlations are consistent with special relativity, and this has motivated two complementary research programmes: studying the most general non-local phenomena compatible with relativity, and proposing underlying mechanisms that could generate them. We focus on the second programme, in particular a model in which tachyons propagate forwards in time in a hidden absolute frame. Such a model can reproduce all quantum non-local correlations, and even non-signalling correlations beyond quantum mechanics, such as PR boxes, all of which are independent of the space-time relations between the parties' measurement events. One would therefore be tempted to think that such a tachyonic model could explain all non-local phenomena consistent with relativity. We show, however, that it fails for jamming: a non-local phenomenon in which a third party, the jammer, can affect correlations without changing local marginals by an action that is space-like separated from the measurement events, under specific space-time constraints. In a tachyonic model, varying the time at which the jammer acts would lead to a space-time point at which jamming must break down, which would allow the presumed "hidden" absolute frame to be exposed, thereby violating the principle of relativity. Since jamming itself is fully consistent with relativity, this contradiction implies that a tachyonic model cannot explain it, even with arbitrarily fast tachyons. Hence tachyonic models are not strong enough to explain all possible non-local effects that are consistent with relativity.

Łukasz Pawela

Institute of Theoretical and Applied Informatics, Polish Academy of Sciences, Poland

Closing the scaling gap: towards fair quantum-classical runtime comparisons

Abstract: Claims of quantum advantage increasingly depend not only on asymptotic scaling, but also on how runtime is defined and which classical baselines are used. In this talk, I will discuss two recent works that revisit these issues from complementary perspectives. First, we reconsider reported scaling advantages in approximate QUBO optimization and show that replacing PT-ICM with a stronger classical reference based on simulated bifurcation largely closes the previously reported quantum-classical gap, while also illustrating how conclusions drawn from small problem sizes can be misleading. Second, we introduce experimentally grounded, end-to-end runtime definitions for digital and analogue quantum computing and use them to reassess recent advantage claims under more realistic benchmarking assumptions. The main message is that credible quantum-classical comparisons must be full-stack. Runtime estimates should include relevant system-level overheads, performance should be measured with operationally meaningful metrics, and quantum methods should be compared against strong classical implementations rather than weak reference points.

Gniewomir Sarbicki

Nicolaus Copernicus University in Toruń, Poland

ale

Abstract: Randomized measurements access nonlinear functionals without full tomography, yet turning third-order local single-copy data into a strong entanglement test remains difficult. We convert the reduction criterion into an experimentally measurable separability criterion by testing it on squared affine combinations of the identity, the local marginals, and the state itself. The obtained 4 × 4 matrix is built from experimentally accessible second- and third-order local invariants and has to be positive on separable states, hence the entanglement is certified when its minimum eigenvalue becomes negative. We show that the sign of its minimal eigenvalue can be inferred from single-copy randomized measurements with dimension-independent sample complexity.

Sergii Strelchuk
University of Oxford, the United Kingdom

From Classical to Quantum Learning Theory: Learnability, Boosting and Quantum Advantage

Abstract: Learning theory has been a transformative force in modern computer science; its conceptual and mathematical tools - from the foundations of PAC learning and VC dimension to boosting, compression, generalization bounds - have reshaped algorithms, complexity theory, and statistics. At the frontier of Quantum Machine Learning, Quantum Learning Theory investigates the mathematical limits and capabilities of quantum algorithms. It explores the learnability of concepts under quantum access models, defining the sample complexity and query efficiency that distinguish quantum learners from their classical counterparts. At the same time, it addresses questions motivated by physics: how efficiently can we predict properties of complex quantum systems, and how does quantum information alter the principles of inference and generalization? Where, and under what assumptions, can we expect to obtain quantum advantage? In this talk, starting from classical learning theory I will introduce the foundations of quantum learning theory and its various access models which include both working with classical and quantum data. I will explain how what is known about efficient learnability in these models and when can one 'boost' the performance of a weak learner of quantum properties.

Volodymyr Tkachuk
Ivan Franko National University of Lviv, Ukraine

Encoding the Decision Partition Problem in Central-Spin Hamiltonians and Solving It on Quantum Processors

Abstract: The decision version of the integer number partition problem asks whether a given set of positive integers can be divided into two groups whose sums are exactly equal. This classical problem is known to be NP-complete, yet it appears naturally in an unexpected place in physics: the central-spin decoherence model. In this model, a single “central” spin

interacts with many surrounding bath spins, and the total effect of the bath on the central system is determined by the weighted sum of their orientations. If the weights of these interactions are chosen to match the integers of a partition instance, then finding a bath configuration that produces zero net influence on the central spin is precisely equivalent to finding a perfect partition. In other words, the physical question “Is there a bath state that cancels the field on the central spin?” is exactly the same as the computational question “Does a perfect partition exist?” This correspondence builds a bridge between a fundamental decoherence model and a canonical NP-complete problem. It provides a physical interpretation of perfect partitions as “silent” bath configurations that do not affect the central spin. It also suggests practical ways to study the partition problem using quantum hardware. I will discuss how to explore partitioning via central-spin dynamics and how current quantum processors can be used to detect zero-field configurations and probe perfect partitions.

POSTER PRESENTERS

Gerard Anglès Munné

Faculty of Mathematics, Physics and Informatics, University of Gdansk, Poland

Holographic quantum codes with trappedions

Abstract: Holography is a central concept at the intersection of gravity, condensed matter theory, and quantum information, linking the bulk of a system to its boundary. A model realizing key features of holographic systems is the holographic pentagon code by Pastawski et al. Here we experimentally implement small instances of the holographic pentagon and heptagon codes with trapped ions and test their properties: For the pentagon code, we recover logical bulk qubits from their nearby boundary and test the Ryu-Takayanagi entanglement area law. For the heptagon code, we show that the transversal Hadamard gate native to the constituent Steane codes induces a one-qubit, correctable error in the holographic code. Our implementation paves the way towards the us.

Dhruv Baheti

Faculty of Mathematics, Physics and Informatics, University of Gdansk, Poland

Dynamics Cross-Resource Recycling on Networks

Abstract: In this work, we therefore adopt a resource-informed viewpoint while emphasizing dynamical usage and circulation. Many practically relevant protocols—such as entanglement distillation or device-independent cryptographic schemes—do not fully consume their quantum inputs in a single irreversible step. Instead, they involve testing, post-selection, or partial measurement, after which residual quantum systems may remain. From the perspective of one task, these leftover states may be deemed insufficient or discarded; from the perspective of another, they may still possess operational value. This motivates the central idea of a "zero-waste" dynamic quantum resource market: rather than irreversibly discarding states that fail to meet the quality threshold of a particular protocol, we consider mechanisms by which such states may be reintroduced into a networked setting and reassigned to alternative tasks whose resource requirements are less stringent. In this sense, we do not construct a resource theory of tasks per se, but instead analyze how task-level protocols powered by quantum resources induce structured flows across different resource-theoretic frameworks. The resulting framework enables not only abstract theoretical analysis of the dynamic relations between different resource theories but also allows us to comment on practical implementation tasks as we do in the second half of this work where we introduce "multi-hop" conversion chains and energy efficient public thermal servers.

Artur Barasiński

Faculty of Physics and Astronomy, University of Wrocław, Poland

Efficient Characterization of Quantum Correlations in Three-Beam Gaussian Fields via Photon-Number-Resolving Detection

Abstract: Quantum correlations in symmetric three-beam Gaussian states are characterized using quantum universal invariants—single-, two-, and three-beam purities—expressed via intensity moments up to sixth order. The states are

experimentally generated using entangled photon pairs from parametric down-conversion. The analysis reveals the coexistence of bipartite and genuine tripartite entanglement in states resembling noisy GHZ/W states.

Luis Cort Barrada

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Classical–Quantum Hybrid Algorithms for Constrained Search in Imaginary Time

Abstract: We introduce a hybrid quantum–classical algorithm for computing the ground-state energy of quantum systems via imaginary-time evolution under expectation-value constraints. The method is based on the constrained-search formulation of imaginary-time evolution. At each time step, the exact constrained non-unitary update is replaced by a unitary evolution that reproduces the constrained imaginary-time dynamics, thereby enabling implementation on a quantum computer, while the constraints are enforced classically.

Jiafu Cheng

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Optimal Choice of Guessed Channels in Quantum Noise Deconvolution with Partially Known Noise

Abstract: Quantum noise deconvolution enables recovery of ideal expectation values of observables without implementing physical error correction or full process tomography. Recent work has shown that such recovery is possible even when the noise channel is only partially known, by introducing a guessed channel and performing classical post-processing. However, the effectiveness of this approach depends crucially on the choice of the guessed channel, and no systematic analytical criteria for selecting it have been established. In this work we analytically investigate the role of the guessed channel in quantum noise deconvolution for single-parameter families of quantum channels. Focusing on depolarizing, dephasing, and amplitude damping noise models, we derive explicit expressions for the recoverable observable sets and analyze how their structure depends on the choice of the guessed channel. We show that for unital channels, optimal guessed channels can be identified analytically and are closely related to symmetry and spectral properties of the superoperator representation. In contrast, amplitude damping, as a canonical non-unital noise model, exhibits qualitatively different behavior, revealing which features of noise deconvolution rely on unitality and which persist beyond it. Our results provide the first analytical guidelines for choosing guessed channels in partial knowledge noise deconvolution and clarify the fundamental distinction between unital and non-unital noise in this context.

References:

[1] https://arxiv.org/abs/2505.08640v2

Przemysław Czapla

Institute of Physics, Polish Academy of Science, Poland

Towards Rigorous Entanglement Detection of Para-Positronium Annihilation Photons

Abstract: The annihilation of ground-state para-positronium (p-Ps) into two photons is a fundamental process in quantum electrodynamics (QED). While conservation of angular momentum and parity dictates that the resulting photons emerge in a maximally entangled polarisation singlet state, unambiguous experimental verification of this entanglement remains an open challenge. However, newly developed detectors such as J-PET, which rely on Compton scattering where photon polarisation information is preserved, open the door to witnessing entanglement without making strong assumptions about the initial photonic state. In this work, we employ the S-matrix formalism of QED and analyse the relevant Feynman diagrams to rigorously derive the differential cross-sections for correlated photons. Having established these foundations, we review the validity and constraints of the commonly used R-factor, identifying the specific classes of initial photonic states for which it can be reliably used as an entanglement witness and quantifier. We consider the well-established class of two-qubit X-states, extending our analysis to provide tools that go beyond the R-factor for the verification of entanglement from scattering data. By applying these quantum information methods, we investigate the precise dependence of entanglement quality on the R-factor and derive a rigorous analytical form of the differential cross-section applicable to a wide range of photon states. Our results reveal that while the R-factor is well-defined only for a specific subclass of X-states, noise analysis demonstrates it remains a robust measure even under the classical mixing of polarisation angles. Ultimately, the framework proposed provides a foundation for generalising entanglement witnesses to ortho-positronium and other multi-photon decays.

Mikołaj Czechlewski
Faculty of Mathematics, Physics and Informatics, University of Gdansk, Poland

On polynomial classical complexity of quantum entanglement distillation

Abstract: We pose a question of the theoretical distillation rate of quantum entanglement for hashing protocol is achievable in classical post processing. Our approach is an interplay of breeding protocol and classical decoding problem.

Bogdan S. Damski
Jagiellonian University in Kraków, Poland

Product Weyl–Heisenberg Covariant Mutually Unbiased Bases and Extremal Non-Stabilizerness

Abstract: This work investigates the emergence of discrete quantum structures—specifically Mutually Unbiased Bases (MUBs) and Symmetric Informationally Complete (SIC) measurements—within composite Hilbert spaces of dimension d = p^n. While standard constructions often rely on the global Weyl-Heisenberg group, we focus on designs covariant with respect to the product Weyl-Heisenberg group. We introduce "magick" (product magic), a quantifier of non-stabilizerness tailored to the multipartite structure. We demonstrate that fiducial states generating product-covariant SICs and MUBs are extremal points of this quantity: SIC fiducials maximize magick over the entire Hilbert space, while MUB fiducials maximize it over the set of equimodular states. Notably, these constructions result in "a priori isoentangled" sets, where all bases share the same entanglement spectrum by design. We provide explicit analytical constructions for these fiducial states in prime-power dimensions p^n for p >= 5, and a novel construction for p = 3 using Galois rings. Finally, we discuss the non-existence of such product-covariant MUBs for systems of more than two qubits, supported by numerical evidence. These results provide a unifying framework linking non-stabilizerness, entanglement, and the geometry of quantum designs.

References:
[1] https://arxiv.org/abs/2603.15550

Otavio Augusto Dantas Molitor

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Quantum Computation with Decoherence-Free Subsystems within the Mixed Schur-Weyl Duality

Abstract: One possible alternative to realize passive protection of quantum information by encoding it in some decoherence-free subsystem (DFS). By assuming collective unitary noise, it was already shown that by exploring the symmetries of the system (symmetric group and general linear group) one can use the Schur-Weyl duality to encrypt quantum information in the subsystem pertaining to the symmetric group algebra, on which the noise acts trivially. Moreover, this encoding is universal, that is, every unitary operator can be constructed by exchange-only interactions in the logical qudits. We go one step forward and ask whether it is possible for another model of noise, which acts with the same unitary on part of the subsystems and with the complex conjugate of the same unitary on the rest. Noise of this form provides a natural extension of the standard collective-noise model. Its physical relevance stems from the fact that the same symmetry transformation may act on different subsystems with different tensor character, namely through the fundamental representation on some factors and the dual, complex-conjugate representation on others. From the mathematical perspective, this is precisely the regime governed by mixed Schur-Weyl duality, whose commutant is no longer the symmetric group algebra but the algebra of partially transposed permutations, equivalently the walled Brauer algebra. For this reason, the mixed model is not only conceptually well motivated, but also provides a natural framework for seeking new decoherence-free subsystems and symmetry-protected encodings beyond those available in the usual U-tensor-n setting. Here we show the possibility of constructing DFSs within this framework and aim at proving whether the logical qudits are universal. This work is still ongoing.

Acknowledgement:

This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase' project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.

Jorge Escandón-Monardes

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Multiparameter estimation with a photonic quantum switch

Abstract: Several experiments have demonstrated the advantages that indefinite causal order offers for quantum information. For instance, the quantum switch, which is the most prominent example of an indefinite causal order process, has been shown to enhance the precision of some metrological tasks compared to fixed order strategies. In this work, we experimentally demonstrate the advantages of indefinite causal order for multiparameter estimation in a photonic quantum switch. Our setup uses multicore optical fibers technology to coherently control the order of three quantum operations, two of them being noisy channels with variable noise strength. Our setup can estimate parameters even in noisy regimes where the consecutive application of the operations in a fixed order would make it unattainable. Additionally, we assess the Fisher information matrix for different configurations of the setup and different amounts of noise, showing that the best configuration of the quantum switch depends on a priori information and weighing of the parameters. Our results highlight the pertinence of indefinite causal order for quantum information under noisy conditions.

Acknowledgement:

This work is supported by ANID - Millennium Science Initiative Program - ICN17−012. JEM is supported by Narodowe Centrum Nauki, UMO-2025/56/C/ST2/00058.

Alfonso Fernandez
Jagiellonian University in Kraków, Poland

Towards Characterizing the Reachable Set for Qubit Evolution Under Constrained Lindblad Dynamics

Abstract: Fixing the norm of Markovian generator can be seen as constraining the energy scale of the induced dynamics. Under this constraint, not all states of a system are reachable in an arbitrary short amount of time from a given initial one, and it is legitimate to investigate what type of “time-geometry” arises on the state space. We investigate different norms on classical Markovian generators, discuss the sets of reachable states in a given time, and highlight the appearance of a Finsler-type “time metric”. We also outline the steps towards a quantum generalization of these results, deriving some bounds for the case of a qubit.

Markus Grassl
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

An Update on the SIC-POVM Problem

Abstract: More than 25 years ago, Gerhard Zauner conjectured that SIC-POVMs exist in all finite dimensions. The conjecture remains open. We provide an overview of various methods to compute SIC-POVMs, and how to turn numerical solutions into exact ones.

Acknowledgement:
This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase’ project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.

Mykhailo Hontarenko
Jagiellonian University in Kraków, Poland

Towards Characterizing the Reachable Set for Qubit Evolution Under Constrained Lindblad Dynamics

Abstract: We investigate the geometry of reachable sets for a single qubit evolving under the Gorini-Kossakowski-Sudarshan-Lindblad (GKSL) master equation with norm-constrained generators. To establish a physically motivated time unit, we bound the space of Lindbladian operators using the Hilbert-Schmidt and Trace norms. We analytically derive the optimal mixing between Hamiltonian and dissipative dynamics, and propose a conjecture on the rank-deficient form of the most efficient purely dissipative generators. We verify our analytical bounds by numerically mapping the reachable sets on the Bloch ball. Crucially, our numerical simulations show that instantaneous tangent-space approximations (CVXPY) perfectly reproduce the reachable boundaries obtained from full-time global optimal control (SLSQP). These limits are further confirmed by extensive Monte Carlo sampling. Ultimately, our findings strongly suggest that local optimization is sufficient to capture global reachability, significantly simplifying the study of quantum control under dissipative constraints.

Acknowledgement:
We acknowledge financial support by the European Union under ERC Advanced Grant TAtypic, Project No. 101142236

Michał Horodecki

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Modular Machine for On-Chip Autonomous Energy Transport in cQED

Abstract: We propose an on-chip superconducting energy renewal machine composed of two autonomous modules: a thermal engine and a refrigerator. The system is designed to rectify existing thermal gradients into an energy resource for irreversible processes in quantum computing, such as qubit resetting. More specifically, the engine is formed by two transmons that harness and retain a non-thermal resource in a resonator as an active field state with population inversion. We show that the generated resource can be used, within the same architecture, to supply the power required to reset a target qubit. For moderate coupling strengths and temperatures, we achieve effective charging of the resonator to about fifteen photons via the designed asymmetric four-wave mixing, which mitigates the cross-Kerr anharmonicity of the resonator (responsible for the detuning of higher excitations). The resource cools the qubit down to the ground state with an occupation probability below 10^{-4} within a few microseconds and is able to maintain this state for hundreds of microseconds.

Acknowledgement:

National Science Centre, Poland Grant Opus-21 (No. 2021/41/B/ST2/03207).

Felix Huber

Faculty of Mathematics, Physics and Informatics, University of Gdańsk, Poland

A Lovász theta lower bound on Quantum Max Cut

Abstract: We prove a lower bound to quantum Max Cut of a graph in terms of the Lovász theta function of its complement. For a graph with m edges, $\text{qmc}(G) \geq \tfrac{m}{4}\big(1 + \tfrac{8}{3\pi}\tfrac{1}{\vartheta(\bar{G}) -1}\big)$, with the bound achieved by a product state. The proof extends a result by Balla, Janzer, and Sudakov on classical Max Cut and is also inspired by the randomized rounding method of Gharibian and Parekh. The bound outperforms the classical bound when applied to quantum Max Cut.

Ryszard Kukulski

IT4Innovations National Supercomputing Center, Czech Republic

High-rate QKD

Abstract: In this work we present a framework for optimizing QKD protocols based on semidefinite programming. The goal is to increase the secure key ratio of QKD for a given value of QBER. We present appropriate methodology for our findings and discuss applications. Finally, we compare the results of our optimization with state-of-the-art QKD protocols.

Mateusz Kuniej
Wrocław University of Science and Technology, Poland

Higher-harmonic acoustic control of a quantum emitter

Abstract: Acoustic control of quantum systems via phonons enable the development of miniaturized quantum technology devices for on-chip integration. Optically active quantum dots (QDs) are crucial for these platforms. However, the absence of direct acoustic transitions between charge states slows their integration. The recently introduced acousto-optical swing-up scheme achieves high-fidelity transitions, but its design for sub-THz phonon frequencies limits practical implementation. Thus, a method for low-frequency acoustic coupling of QD charge states is still lacking. We show that this limitation can be overcome by higher-harmonic-assisted processes that arise from acoustic modulation of the optical transition energy. Such parametric modulation generates multi-phonon-like resonances when a harmonic of the modulation matches the Rabi frequency. We find that charge state can be prepared using an acoustic driving with frequency lower than the energy splitting, thus linking experimentally accessible acoustic control to THz-scale optical transitions. As a proof of principle, we simulate the control of optically dressed states with a 0.34 THz splitting using 42 GHz acoustic drive. To study the system dynamics and the impact of thermal phonons, we perform simulations within a non-Markovian formalism. Our results indicate high state preparation fidelity, comparable to previous works. We also present an effective model that captures the key features of the evolution. While our work focuses on QD charge state preparation, the mechanism is more general. Similar type of interaction arises for quantized modes, so our results provide a foundation for multi-phonon processes in QDs coupled to phononic resonators. Potential applications include photon-phonon entanglement, and the optical generation of nonclassical states, both relevant for future technologies.

References:

[1] https://doi.org/10.48550/arXiv.2603.09849

Wiesław Leoński
University of Zielona Góra, Poland

Violation of the inequalities for the correlations in space and time for various states

Poster 1: The Legget-Garg inequality violation for two-mode Kerr-type stat

Abstract: We consider states generated by a system of two mutually coupled quantum Kerr-type oscillators, continuously driven by an external coherent field. For such a model, we discuss the temporal correlations observed in the states generated by the system and examine violations of the Leggett–Garg inequality (LGI). Using projections onto different Bell states, we analyze various measurement scenarios and demonstrate that the possibility of violating the LGI depends on the choice of projector [1].

Poster 2: The Bell-CHSH inequality violations 'identification and quantification for W-Class States

Abstract: Quantum states that violate the Bell-CHSH inequality have found a wide range of applications, and nonlocality, as the strongest form of quantum correlations, is a suitable resource for quantum information processing. Considering two-qubit states that are reduced from the W-Class states, we determine the violation of such the inequality using the parameter introduced by Horodecki et al. [2,3]. In the communication, we analyze the relations between the pairs of bipartite negativity, concurrence, and the nonlocality parameter. In the study, we determine the boundary values of these quantities for states that either violate or satisfy the Bell-CHSH inequality [4].

References:
[1] J. K. Kalaga, A. Kowalewska-Kudłaszyk, W. Leoński, J. Peřina Jr., Opt. Express 32, 9946-9957 (2024)
[2] R. Horodecki, P. Horodecki, and M. Horodecki, Phys. Lett. A, 200, 340 – 344 (1995)
[3] R. Horodecki, Phys. Lett. A, 210, 223 – 226 (1996)
[4] J. K. Kalaga, W. Leoński, and J. Peřina Jr., Entropy 26, 1107 (2024)

Paulina Lewandowska
IT4Innovations National Supercomputing Center, Czech Republic

Shared entanglement for three-party causal order guessing game

Abstract: In a variant of communication tasks, players cooperate in choosing their local strategies to compute a given task later, working separately. Utilizing quantum bits for communication and sharing entanglement between parties is a recognized method to enhance performance in these situations. In this work, we introduce the game for which three parties, Alice, Bob and Charlie, would like to discover the hidden order in which they make the moves. We show the advantage of quantum strategies that use shared entanglement and local operations over classical setups for discriminating operations' composition order. The role of quantum resources improving the probability of successful discrimination is also investigated. Our research provides a basis for examining computational model featuring a specific gate set while examining the diverse operations achievable through permutations of its elements.

References:
[1] https://iopscience.iop.org/article/10.1088/1367-2630/ada4d2

Antonio Mandarino
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Statistics of topological defects across a phase transition in a digital superconducting quantum processor

Abstract: When a quantum phase transition is crossed within a finite time, critical slowing down disrupts adiabatic dynamics, resulting in the formation of topological defects. The average density of these defects scales with the quench rate, adhering to a universal power law as predicted by the Kibble-Zurek mechanism (KZM). In this study, we aim to investigate the counting statistics of kink density in the 1D transverse-field quantum Ising model. We demonstrate on multiple quantum processing units up to 100 qubits, that higher-order cumulants follow a universal power law scaling as a function of the quench time. We also show the breakdown of the KZM for short quenches for finite-size systems. Tensor network simulations corroborate our quantum simulation results for bigger systems not in the asymptotic limit.

References:
[1] https://doi.org/10.1088/2058-9565/addf75

Acknowledgement:
This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase' project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.

Patryk Michalski
Center for Theoretical Physics, Polish Academy of Sciences / University of Warsaw, Poland

Certifying Majorana Fermions with Bipartite and Network Bell Inequalities

Abstract: Bell inequalities provide a fundamental tool for probing nonlocal correlations, yet their quantum bound—the maximal value attainable within quantum theory—is rarely accessible analytically. In this work, we introduce a general construction of Bell inequalities for which this bound can be computed exactly. Our framework extends both the Clauser-Horne-Shimony-Holt and Gisin's elegant inequalities, yielding Bell expressions maximally violated by any number of pairwise anticommuting Clifford observables together with the corresponding maximally entangled state. Under suitable assumptions, these inequalities also enable device-independent certification of Majorana fermions, understood as multiqubit realizations of Clifford algebra generators. Moreover, the Bell inequalities introduced here can certify nonbilocality in the three-on-a-line network and enable self-testing in this scenario. Finally, we identify an additional equivalence that must be included in the notion of self-testing, beyond local isometries and transposition: partial transposition of the shared state and the measurements, which in certain cases leaves all observed correlations unchanged.

Vikash Mittal
Institute of Physics, Polish Academy of Science, Poland

Discrete time quantum walk of locally interacting walkers

Abstract: In this work, we introduce a general model for local interactions between quantum walkers conditioned on the internal state of their coins. By choosing their particular case, we systematically study the impact of these interactions on the dynamics of two initially localized and noncorrelated walkers. Our general interaction framework, which reduces to several previously studied models as special cases, provides a versatile platform for engineering quantum correlations with applications in quantum simulation, state preparation, and sensing protocols. It also opens up the possibility of analyzing many-body interactions for larger numbers of walkers.

Moein Naseri
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Noise Cancellation in Quantum Battery Charging

Abstract: We introduce an operational framework for quantum battery charging based on asymptotic thermodynamic convertibility. The charged state is treated as a noisy nonequilibrium resource, while a subsequent free distillation step under thermal operations removes its unusable noisy component and converts the useful fraction into a target charged state. This motivates a dimensionless charge variable given by the asymptotically distillable free-energy fraction. Within this framework, we derive exact expressions and optimization principles for ultrashort-stroke charging power, identifying the optimal initial states and bounded coherent controls through the noncommutativity between the state and the free Hamiltonian. For a thermally prepared qubit cell, we show that incoherent Gibbs populations carry no first-order charging power, whereas a preparatory coherence pulse activates a finite ultrashort response. We then turn to finite-time charging and show that instantaneous power and cycle-averaged useful output are fundamentally distinct objectives. A square-pulse

unitary benchmark yields a universal throughput-optimal stopping rule, whereas an active-gain Dicke-ladder benchmark exhibits a nonuniversal, finite-size- and temperature-dependent partial-charge optimum. Finally, for many-body systems under extensive control, we prove a quadratic upper bound on the maximal charging power and show that its saturation requires macroscopic coherence.

Acknowledgement:
MN was funded by the European Commission by the QuantERA project ResourceQ under the grant agreement no. UMO2023/05/Y/ST2/00143.

Ritopriyo Pal
Center for Theoretical Physics, Polish Academy of Sciences, Poland

Persistent local content of GME qubit states under finite von Neumann measurements

Abstract: Multipartite fully nonlocal (MFNL) behaviors give rise to the strongest form of nonlocal correlations obtainable from local measurements of composite quantum systems, characterized by zero contribution from any nosignaling behavior that admits a local hidden variable model across any non-trivial bipartition. While MFNL behaviors are powerful resources, often achieving the fully nonlocal limit for Genuinely Multipartite Entangled (GME) states of qubits appears to require the access to infinite measurement settings for each party. This is the case for the two qubit maximally entangled state as well as the two dimensional GME stabilizer subspace of the five-qubit code. In this work, we investigate whether this is a universal property of qubit GME states. We show that for N qubit GHZ states as well as all pure, single-excitation states of 3 qubits, we can always find a non-zero local content for any finite number of von Neumann measurements. This suggests that full nonlocality, if at all achievable, is only possible in the asymptotic limit in the number of local measurements for such states. Finally, we discuss how any pure GME state can be activated to exhibit MFNL by considering a finite number of copies of the state.

Aby Philip
Institute of Fundamental Technological Research, Polish Academy of Science, Poland

Robustness of quantum data hiding against entangled catalysts and memory

Abstract: Quantum data hiding stores classical information in bipartite quantum states that are, in principle, perfectly distinguishable, yet remain almost indistinguishable without access to a quantum communication channel. Here, we investigate whether this limitation can be overcome when the communicating parties are assisted by additional quantum resources. We develop a general framework for state discrimination that unifies catalytic and memory-assisted local discrimination protocols and analyze their power to reveal hidden information. We prove that when the hiding states are separable, neither entangled catalysts nor quantum memory can increase the optimal discrimination probability, establishing the robustness of separable data-hiding schemes. In contrast, for some entangled states, a reusable quantum memory turns locally indistinguishable states into ones that can be discriminated almost perfectly. Our results delineate

the fundamental limits of catalytic and memory-assisted state discrimination and identify separable encodings as a robust strategy for quantum data hiding.

References:
[1] https://arxiv.org/abs/2511.04408

Hanussek Philipp
Sorbonne Universite, France / Institute of Theoretical and Applied Informatics, Polish Academy of Sciences, Poland

Quantum-inspired dynamical models on quantum and classical annealers

Abstract: We propose a practical, physics-inspired benchmarking suite to challenge both quantum and classical computers by mapping real-time quantum dynamics to a common optimization format. Using a parallel-in-time encoding, we convert the real-time propagator of an n-qubit, possibly non-Hermitian, Hamiltonian into quadratic unconstrained binary optimization (QUBO) instances that are executable in a solver-agnostic manner on quantum annealers and classical optimizers alike. This enables direct, like-for-like performance comparisons across fundamentally different computational paradigms. To stress-test the framework, we consider eight representative dynamical models spanning single-qubit rotations, multi-qubit entangling gates (Bell, GHZ, cluster), and PT-symmetric and other non-Hermitian generators, and evaluate success probability and time-to-solution as standard benchmarking metrics. Applying this methodology to two generations of D-Wave quantum annealers and to state-of-the-art classical solvers (Simulated Annealing and the GPU-accelerated VeloxQ), we find that Advantage2 consistently outperforms its predecessor, while VeloxQ retains the shortest absolute runtimes, reflecting the maturity of classical heuristics. We further extend the benchmarks to large-scale instances (N~10^5), establishing a demanding classical baseline for future hardware. Together, these results position the parallel-in-time QUBO framework as a versatile and physically motivated testbed for quantitatively tracking progress toward quantum-competitive simulation of dynamical systems.

References:
[1] https://journals.aps.org/prapplied/accepted/10.1103/rrf3-jm5m

Diego Ponterio
Jagiellonian University in Kraków, Poland

Product Weyl-Heisenberg covariant mutually unbiased bases and extremal non-stabilizerness

Abstract: In this work we investigate discrete structures in product Hilbert spaces. For monopartite systems of size d one relies on the Weyl-Heisenberg group WH(d), while in the case of composite Hilbert spaces with local dimensions d_i we identify designs covariant with respect to the product group. In analogy with magic — a quantity attaining its maximum for states fiducial with respect to WH(d) — we introduce a similar quantifier of product magic, defined with respect to the product group. The maximum of this quantity over all equimodular vectors yields fiducial states that generate d = product of d_i a priori isoentangled mutually unbiased bases (MUBs), which, when supplemented by the identity, form their complete set. Such fiducial states are explicitly constructed in all prime-power dimensions d = p^n with p >= 3. The result for p >= 5 extends the construction of Klappenecker and Rotteler, whereas for p = 3 it is mathematically distinct and is

based on Galois rings. The global maximum of the quantifier of product magic for d = 2^3 yields fiducial states corresponding to the symmetric informationally complete (SIC) generalized measurement of Hoggar. Our approach feeds into a unifying perspective in which highly symmetric quantum designs emerge from fiducial states with extremal properties via structured group-orbit constructions.

Sumit Rout

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Quantum Work Extraction beyond Classical Limits

Abstract: The nonequilibrium free-energy difference determines the maximum average work extractable in any single thermodynamic process, but it does not fully characterize the limits of a single device across multiple controls. Operationally, classicality allows only mutually commuting Hamiltonians, in arbitrary dimension. We show that, after calibrating away known thermal offsets, every classical device must satisfy an absolute compatibility bound on its work responses. We derive this bound for bounded Hamiltonians and exhibit an explicit incompatible realization that violates it. Our results identify incompatibility as an operational resource for work extraction and provide a model-independent benchmark for certifying quantum thermodynamic advantage.

Acknowledgement:

This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase' project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.

Juan Pablo Rubio Perez

Center for Theoretical Physics, Polish Academy of Sciences, Poland

Efficient classical training of Bosonic Born Machines beyond binary outputs

Abstract: Sampling from outputs of randomly instantiated quantum devices is a common tool used to prove quantum advantage. Quantum Circuit Born Machines (QCBMs) harness this advantage by approximating a target probability distribution using quantum circuits from which samples can be efficiently obtained. Training a QCBM against Total Variation distance, however, would require either an inefficient classical computation or sampling from the generated distribution at each step. Current approaches to classically efficient training bypass this by computing expectation values of operators on particular classes of circuits, as in the IQP, fermion sampling, and diluted photonic settings. These techniques are only defined for distributions supported on binary strings. Photonic circuits with particle number detectors, however, naturally produce distributions over tuples of non-negative integers: when the number of modes is comparable to the number of photons, bosons collide and multiple photons are detected in the same mode, outputs that cannot be faithfully represented as binary strings. In this work, we generalize the current QCBM training paradigm to work on non-binary distributions, including those natively produced by photonic hardware. We achieve this by generalizing the MMD^2, expressing it as a function of expectation values of elements of the Pontryagin dual of the group the distribution is encoded in. For the groups of interest, these elements are phase operators, which admit classically efficient algorithms. When the group is defined over binary strings, we recover the expressions for the IQP, fermion sampling, and diluted photonic settings. Finally, we

test these expressions in the Gaussian and Fock schemes by generating a distribution close to that of real-world data to show the scalability and adaptability of the general scheme.

Lucas Pollyceno

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Security of DIQKD from multipartite information causality

Abstract: The information causality (IC) principle was proposed as a way to bound quantum nonlocality without invoking the full Hilbert-space formalism. Beyond its foundational role, constraining nonlocal correlations via physical principles has direct implications for device-independent (DI) cryptographic security. Here we show that IC alone suffices to guarantee security of quantum key distribution (QKD) protocols against individual attacks by post-quantum eavesdroppers, within a range of quantum-attainable parameters. This follows from a strong monogamy of Bell inequality violations, proven to arise from the multipartite formulation of IC. In contrast, the original bipartite IC fails to imply such monogamy or to ensure DIQKD security, highlighting the necessity of the multipartite framework.

Acknowledgement:

This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase' project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.

Marcin Rudziński

Jagiellonian University in Kraków, Poland

Entangling power and Schmidt-resolved fidelity diagnostics for two-qubit quantum channels.

Abstract: We introduce a proper notion of entangling power for bipartite quantum channels by averaging a genuine mixed-state entanglement measure over pure product inputs. In parallel, we derive two complementary fidelity diagnostics: the average input-output fidelity over all pure states and the corresponding average restricted to product states. For two qubits, we prove that these two quantities determine the entire Schmidt-orbit averaged fidelity profile through a single fidelity-bias parameter.

Matthias Salzger

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Higher-order quantum processes respecting closed labs in a spacetime have quantum controlled causal order

Abstract: In quantum causality and quantum information, there is a vast landscape of abstract quantum protocols that permit cyclic or non-acyclic causal structures between quantum operations. This includes widely studied frameworks for indefinite causal order and higher-order quantum processes, such as process matrices. However, a longstanding open question is which is the largest class of such abstract processes that admit physical realisations without post-selection. In this work, we provide a rigorous answer by adopting a top-down approach grounded in relativistic causality principles, motivated by the fact that physical

experiments are implemented consistently with such principles in spacetimes with acyclic lightcone structures. Building on the framework of causal boxes, which 29ealized29e29e the most general quantum information-processing protocols compatible with fixed background spacetimes, we 29ealized29 additional physically motivated constraints (Acting Once + Local Order) capturing the closed-laboratory assumptions of the process matrix framework at a fine-grained spacetime level. We prove that any protocol 29ealized29e in a classical acyclic spacetime and satisfying these spatiotemporal closed-lab conditions is behaviourally equivalent to a quantum circuit with quantum control of causal orders (QC-QC), providing a top-down derivation of QC-QCs from physical principles. Our results therefore show that QC-QCs constitute precisely the class of higher-order quantum processes, including those with indefinite orders, that can be physically 29ealized within classical spacetime, ruling out the possibility of any experiment in this regime that realise more general non-causal processes under such a closed-labs assumption. This clarifies the relationship between abstract higher-order process matrix frameworks and experimentally accessible quantum protocols, and the interplay between coarse-grained cyclic and fine-grained acyclic operational causal structures.

Acknowledgements:

MS is supported by National Science Centre, Poland (Preludium project, Classicality and compositionality of general probabilistic theories in infinite dimensions, project no.2024/53/N/ST2/01192 and Opus project, Categorical Foundations of the Non-Classicality of Nature, project no. 2021/41/B/ST2/03149). VV's research at ETH was supported by an ETH Postdoctoral Fellowship. VV also acknowledges support from the PEPR integrated project EpiQ ANR-22-PETQ-0007 as part of Plan France 2030.

Luís Felipe Santos

University of Sao Paulo, Brazil / International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Waiting time statistics for a double quantum dot coupled to an optical cavity

Abstract: A double quantum dot coupled to an optical cavity is a prototypical example of a nontrivial open quantum system. Recent experimental and theoretical studies show that this system is a candidate for single-photon detection in the microwave domain. This motivates studies that go beyond just the average current, and also take into account the full counting statistics of photon and electron detections. With this in mind, here we provide a detailed analysis of the waiting time statistics of this system within the quantum jump unraveling, which allows us to extract analytical expressions for the success and failure probabilities, as well as for the interdetection times. Furthermore, by comparing single- and multiphoton scenarios, we infer a hierarchy of occurrence probabilities for the different events, highlighting the role of photon interference events in the detection probabilities. Our results therefore provide a direct illustration of how waiting time statistics can be used to optimize a timely and relevant metrological task.

References:

[1] https://journals.aps.org/pra/abstract/10.1103/PhysRevA.111.042415

Shubhayan Sarkar

Faculty of Mathematics, Physics and Informatics, University of Gdańsk, Poland

Entanglement is not sufficient for most practical entanglement-based QKD protocols

Abstract: Quantum key distribution (QKD) is the most explored application of quantum information theory. A central problem in entanglement-based QKD (EB-QKD), is whether every entangled state can be used to extract a key. We observe that entanglement is not sufficient for standard practical EB-QKD protocols where the input choices are announced by the parties that want to share a secure key, such as E91 or entanglement-based BB84 type protocols, when even an arbitrarily small amount of leakage of classical side information occurs. We do this by identifying a class of two-qubit isotropic states that are entangled but cannot be used to distil the key under such protocols for any possible measurement by the parties. Counter-intuitively, this gap persists even when the leakage occurs from the "junk" rounds of the protocol, i.e, rounds that cannot be used to generate any key. We then extend this result to arbitrary dimensions and parties by identifying a class of isotropic states that are not useful to extract a secure key under such protocols, even if they are entangled. Finally, we demonstrate that our approach provides a tool to upper-bound the scalability of repeater-based QKD architectures in a protocol-independent manner. Interestingly, we find that allowing for even a tiny noise in the preparation drastically reduces the scalability of the QKD network.

References:
[1] https://arxiv.org/abs/2603.06400

Marek Sawerwain
University of Zielona Góra, Poland

Quantum features in handwritten images of digits and letters

Abstract: Determining the form of features is an important task in the field of machine learning, which in many cases determines the quality of e.g. classification or decoding information in the context of an autoencoder. In this paper, an analysis of quantum features that are determined for a set of images containing single letters and handwritten characters (the Polish alphabet) was carried out in terms of quality in the classification and autoencoder task. In particular, a parametric quantum circuit that creates quantum features for a 2D set representing an image of a given sign will be analyzed. The circuit will be designed with particular emphasis on multi-body entanglement that can occur in a 2D encoded image.

References:
[1] https://link.springer.com/chapter/10.1007/978-3-031-97570-7_17
[2] https://www.amcs.uz.zgora.pl/?action=paper&paper=1823

John Selby
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Generalised Process Theories

Abstract: Process theories have been very widely applied, from the foundations of physics through to computational linguistics. They are conceptually based on the idea that we can describe all of these things in terms of systems which interact and evolve via processes, and that we can explore their behaviour by considering how these systems and processes compose. And, traditionally, process theories have mathematically been formulated in the language of symmetric monoidal categories. So why do we need to generalise any further? Well, very simply, there are situations where the formal notion of a process theory does not seem applicable, but where the conceptual idea of a process theory still does. That is, where we still have systems, processes, and their composition, but which does not neatly fit the mould of a symmetric monoidal category. This poster is based on arXiv:2502.10368 and two follow up projects.

References:
[1] https://arxiv.org/abs/2502.10368

Acknowledgement:

JHS was funded by the European Commission by the QuantERA project ResourceQ under the grant agreement UMO2023/05/Y/ST2/00143. JHS conducted part of this research while visiting the Okinawa Institute of Science and Technology (O IST) through the Theoretical Sciences Visiting Program (TSVP).

Amrapali Sen

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Superluminal Transformations and Indeterminism

Abstract: Quantum theory is widely regarded as fundamentally indeterministic, yet classical frameworks can also exhibit indeterminism once infinite information is abandoned. At the same time, relativity is usually taken to forbid superluminal signalling, yet Lorentz symmetry formally admits superluminal transformations (SpTs). Dragan and Ekert have argued that SpTs entail indeterminism analogous to the quantum one. Here, we derive a no-go theorem from natural assumptions, which can be interpreted as: superluminal transformations (SpTs) and finite information cannot coexist. Any theory accommodating SpTs must therefore allow unbounded information content, leading to a deterministic ontology akin to that of classical theories formulated over the real numbers. Thus, any apparent indeterminism arising from superluminal transformations reflects only probabilities arising from subjective ignorance, unlike the objective nature of probabilities in quantum theory, indicating that the claimed indeterminacy from superluminal extensions is not quantum.

References:

[1] https://arxiv.org/abs/2601.15263

Acknowledgement:

This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase' project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.

Michał Senderski

Gdańsk University of Technology, Poland

Modeling Nanodiamond Clusters for NV Center-Based Quantum Technologies

Abstract: Nitrogen-vacancy (NV) centers in diamond constitute one of the most promising solid-state platforms for quantum information processing and quantum sensing. Their unique spin properties, combined with optical addressability, make them suitable candidates for the realization of robust qubits and quantum devices operating at or near room temperature. In this work, I present a computational approach to modeling nanodiamond clusters as a preliminary step towards the investigation of NV centers in cinfined geometries. The study focuses on constructing atomistic models of nanodiamond structures and analzing their structural and electronic properties using classical simulations and density functional theory (DFT). Computational tool such as LAMMPS, ONETEP and OVITO are employed to explore the stability and geometry of clusters. The primary goal is to identify the most realistic and representative models of nanodiamonds. The use of linear-scalling DFT enables the investigation of larger systems, while classical approaches are explored to assess whether computational costs can be reduced, for example by employing relaxation with classical potentials as ReaxFF. This is a crucial step in finding relationshipsw between physical properties and size od nanodiamonds. Futher, NV centers would

be investigated. Although the current stage of the project focuses on the host material, it establishes a foundation for future work involving explicit modeling of NV centers and their quantum properties. Ultimately, this approach is intended to contribute to bridging atomistic simulations of materials with their potential applications in quantum information science. This poster presents the current progress of the project and outlines the planned research directions toward the integration of material modeling and quantum information frameworks.

Abhyoudai Sajeevkumar Shaleena

International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Understanding Bell inequality violations in 2-2-d and 2-d-2 systems

Abstract: Motivated by the semi-analytical optimization of tight bounds for Bell inequalities in the tripartite case corresponding to the $4 \times 4 \times 2$ scenario with three qubit subsystems [1], we consider a similar task in a more complicated setting involving d-dimensional subsystems. In particular, using approaches based on the Schmidt decomposition and recent results for optimal violation of CHSH inequality [2], we provide a semi-analytical expression for values of maximal violation for certain tripartite Bell inequality in a case of $2-2-d$ and $2-d-2$ dimensional subsystems. Specifically, the obtained results open the way to witnessing nonlocality for a certain family of states arising from a three-body decay beyond the qubit setting [3].

References:

[1] Horodecki, P., Sakurai, K., Shaleena, A.S. et al. Three-body non- locality in particle decays. J. High Energ. Phys. 2025, 160 (2025). https://doi.org/10.1007/JHEP10(2025)160

[2] Alexander Bernal, J. Alberto Casas, Jesus M. Moreno, Maximal Clauser-Horne- Shimony-Holt violation for qubit-qudit states, Phys. Rev. A 112, 042404 (2025)

[3] K. Sakurai, A. S. Shaleena et al. (2026), work in progress.

Acknowledgement:

This work is carried out under the Maestro project no. 2021/42/A/ST2/00356 under the title „Relativistic Causality and Information Processing", funded by the National Science Center, Poland.

Leonard Sikorski

Faculty of Mathematics, Physics and Informatics, University of Gdansk, Poland

Update on the Bound Key Conjecture

Abstract: A long-standing open problem in the theory of quantum resources is whether there exist states that need quantum key as a resource when being created using only local operations and classical communication (LOCC), but from which no quantum key is obtainable using only LOCC. Motivated by the analogous term in entanglement theory such states would be called bound key states. A related question is whether there exist entangled states from which no cryptographic key can be distilled, or conversely whether the distillable key is faithful as a measure of entanglement. We refer to such states mathematical bound key. In this work we shed some light on those questions, discussing the non-triviality of defining a measure of key cost in analogy to the entanglement cost. This difficulty arises from the way the class of general states that contain quantum key, so-called private states, are defined. We consider two restricted definitions. We also show a surprising dichotomic relationship between the existence of mathematical bound key and an asymptotic version of the bound key conjecture. We also generalize the concept of bound key to the multipartite setting of conference key agreement and discuss ways in which a key cost can be defined. In turn, we have computed key cost for the most general definition,

in case of a wide class of bipartite states called generalized private states. We then pose a fundamental question if a tripartite entangled state can be a free resource in theory of multipartite key, and show a tripartite entangled state which is a candidate to be free, as it does not increase secure key of a wide class of states when provided as an additional resource. Finally, we provide a lower bound on the dimension a bound entangled state needs to have to be close to a private state in trace distance, which indicates a non-negligible memory cost of networks safe from certain attack on its nodes.

Chirag Srivastava

Faculty of Mathematics, Physics and Informatics, University of Gdańsk, Poland

Quantum waste management: Utilizing residual states in quantum information processing

Abstract: Quantum resource theories use distillation protocols to convert less resourceful states into fully resourceful ones. However, these protocols often also generate an additional, unused output—referred to as a residual. We propose a framework for the quantum residual management, in which states discarded after a resource distillation protocol are repurposed as inputs for subsequent quantum information tasks. This approach extends conventional quantum resource theories by incorporating secondary resource extraction from residual states, thereby enhancing overall resource utility. As a concrete example, we investigate the distillation of private randomness from the residual states remaining after quantum key distribution (QKD). More specifically, we quantitatively show that after performing a well-known coherent Devetak-Winter protocol, one can locally extract private randomness from its residual. We further consider the Gottesman-Lo QKD protocol and provide the achievable rate of private randomness from the discarded states that are left after its performance. We also provide a formal framework that highlights a general principle for improving quantum resource utilization across sequential information processing tasks.

References:

[1] https://arxiv.org/abs/2510.27687

Jędrzej Stempin

Faculty of Mathematics, Physics and Informatics, University of Gdansk, Poland

Locally interacting Discrete-Time Quantum Walk of Multiple Particles

Abstract: Discrete-time quantum walks provide a versatile framework for modeling quantum transport and computation, and can be viewed as a natural discretization of relativistic dynamics such as the Dirac equation. In the single-particle setting, they have been extensively studied, with applications ranging from the exploration of topological phases to serving as controllable toy models of complex quantum systems. Extending these models to interacting many-particle systems, however, poses substantial analytical and computational challenges. In this work, we generalize the model of two locally interacting particles to systems with an arbitrary number of particles. To address the resulting complexity, we exploit underlying symmetries of the dynamics and apply tools from representation theory to achieve a significant reduction of the effective Hilbert space, enabling a more tractable description of the many-body evolution. We further investigate the behavior of inter-particle correlations and provide explicit examples of existing models that can be unified within this framework, highlighting its generality and descriptive power.

Alexander Streltsov
Institute of Fundamental Technological Research, Polish Academy of Science, Poland

Second Law of Entanglement Manipulation with Entanglement Battery

Abstract: A central question since the beginning of quantum information science is how two distant parties can convert one entangled state into another. It has been conjectured that such conversions could be executed reversibly in an asymptotic regime, mirroring the reversible nature of Carnot cycles in classical thermodynamics. While a conclusive proof of this conjecture has been missing so far, earlier studies have excluded reversible entanglement manipulation in various settings. We show that arbitrary mixed state entanglement transformations can be made reversible under local operations and classical communication, when assisted by an entanglement battery — an auxiliary quantum system that stores and supplies entanglement in a way that ensures no net entanglement is lost. In particular, the rate of transformation in the asymptotic limit can be quantitatively expressed as a ratio of entanglement present within the quantum states involved. Our setting allows us to consider different entanglement quantifiers which give rise to unique principles governing state transformations, effectively constituting diverse manifestations of a "second law" of entanglement manipulation. These findings resolve a long-standing open question on the reversible manipulation of entangled states and are also applicable to multipartite entanglement and other quantum resource theories, including quantum thermodynamics.

References:

[1] https://journals.aps.org/prl/abstract/10.1103/kl56-p2vb

Michał Studziński
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

Oscillator partition functions in walled Brauer algebras

Abstract: The walled Brauer algebras govern the Schur-Weyl duality associated with unitary groups acting on mixed tensor spaces, and they play an important role in areas ranging from AdS/CFT to quantum information theory. In the stable regime, these algebras are semisimple and their representation theory is well understood. Outside this regime, however, they become non-semisimple: the natural representation on tensor space develops a non-trivial kernel, and the corresponding quotient algebra remains semisimple, but with representation dimensions that differ from those of the stable case. In this work we introduce restricted Bratteli diagrams, obtained by modifying the standard Bratteli diagrams for walled Brauer algebras. This construction provides a systematic way to transfer representation-theoretic data from the stable regime to the non-semisimple one, and to compute the resulting changes in representation dimensions. For values close to the stable threshold, we show that the restricted diagrams display a stability property that makes it possible to count efficiently the paths responsible for these corrections. Remarkably, the associated generating functions are governed by the partition function of an infinite tower of simple harmonic oscillators. We briefly discuss implications for the construction of orthogonal bases of matrix invariants in gauge theory, as well as related applications in quantum information theory.

References:

[1] https://arxiv.org/abs/2509.04234

Gianluigi Tartaglione
University of Salerno (UNISA), Italy

Uncertainty equality for SU(N) observables enabling the experimentally friendly detection of k-inseparability via purity measurements

Abstract: We derive an exact uncertainty relation for arbitrary quantum states of finite-dimensional Hilbert spaces. For any given k-partition of a d-dimensional multipartite system, we introduce the total uncertainty as the sum of the uncertainties associated with all possible tensor products of local SU(N) observables, where each observable acts on the corresponding subsystem. We show that the total uncertainty exactly equals the algebraic sum of the global state purity and the purities of all possible state reductions. For systems containing at least one single-qubit subsystem, this equality implies saturation of the Robertson-Schrodinger uncertainty inequality, with the missing term needed for saturation equal to the bipartite qubit-environment entanglement for a pure global state, or to the qubit two-Renyi entropy for a mixed global state. Leveraging on these results, we show how for any finite-dimensional multipartite system the Hilbert-Schmidt squared norm of the system correlation matrix t can be expressed exclusively in terms of the global and reduced state purities. We then derive a correlation matrix-based necessary condition for k-separability of arbitrary finite-dimensional quantum states and show, in the case of n qubits, how it is related to a necessary criterion for Bell nonlocality in scenarios with two dichotomic measurements per party. Since the number of global and reduced state purities always scales as 2^k irrespective of the local Hilbert space dimension, for sufficiently large systems the purity-based formulation of the k-separability criterion always yields an exponential advantage over the direct evaluation of the t-matrix norm, allowing for a more efficient practical verification of multipartite entanglement and nonlocality via simple experimental schemes based on purity measurements.

References:

[1] https://arxiv.org/abs/2603.17844

Masood Valipour
Nicolaus Copernicus University in Toruń, Poland

Optimization of two-photon absorption: Indistinguishable photon pairs

Abstract: We consider an interaction of a three-level atom of a ladder configuration with a unidirectional propagating light prepared in a continuous-mode two-photon state. We study the probability of two-photon absorption by the atom using the result obtained within the input-output formalism in the framework of standard assumptions made in quantum optics. Namely, a flat coupling constant, rotating wave approximation, and the extension of the lower limit of integration over frequency to minus infinity. Thus, we assume that the bandwidth of the light pulses is much smaller than their central frequencies. In this approach, the evolution of the atom interacting with a wave packet of a definite number of photons is given by a set of hierarchical equations. The starting point in our consideration is the analytical formula for the probability of two-photon absorption for the three-level atom. We study the time-dependent probability of the excitation of the system. In this work, we determined the optimal pulse shape for efficiently exciting the system to its final state and compared it with Gaussian pulses, which are more practical to generate in the laboratory. In the present work, we address the complementary and physically distinct situation in which the two photons are spectrally indistinguishable, so that each of them can excite either of the two atomic transitions. This changes the structure of the absorption process in an essential way, because the two excitation pathways become quantum-mechanically indistinguishable and interfere. Consequently, the problem is not a simple extension of the distinguishable-photon case. Instead, it requires understanding how bosonic

symmetrization and interference reshape the optimal temporal and spectral properties of the input field, and how these effects depend on the atomic parameters.

Marek Winczewski

Faculty of Mathematics, Physics and Informatics, University of Gdansk, Poland

Energy Cost of a Quantum Operation: From Axioms to a Hamiltonian Framework

Abstract: We present an axiomatic, platform-agnostic framework for determining the energy cost of a quantum operation. We formalize an approach that captures the realistic energy expense of quantum processes. Our results fit at the center of the emerging field of quantum energy. The cost is the minimal energy a classical control device must invest to implement the operation, focusing on energy supplied to the system. The energy cost function is fixed by two requirements proposed as axioms: subadditivity in time (sequential composition costs at most the sum) and locality (adding idle subsystems does not change the cost). This yields a hardware-independent minimal cost defined as the infimum over all physical implementations. To make the definition actionable, we introduce a Hamiltonian control framework. An implementation is viewed as a quantum system coupled to a mesoscopic interface under classical drives and, when relevant, baths. The Hamiltonian formalism bridges the information-theoretic view of operations as CPTP maps with thermodynamic notions of work, heat, and energy by modeling the action of drives and dissipation in a time-dependent Liouvillian that assigns well-defined energy flows to each channel. The protocol energy is the time-integrated sum of the positive, incoming work and heat power flows across channels over the protocol duration. Once a platform or a specific device is fixed, this definition becomes a computable, architecture-dependent measure of energy cost that satisfies the axioms and, by construction, upper bounds the minimal cost.

References:

[1] https://arxiv.org/abs/2507.23108

Jakub Wójcik

Center for Theoretical Physics, Polish Academy of Sciences, Poland

On Non-Existence of Stabilizer Absolutely Maximally Entangled States in Even Local Dimensions

Abstract: We demonstrate that absolutely maximally entangled (AME) states consisting of N=4n qudits with n in {1,2,3,...}, each of even local dimension, cannot be realized as graph states. This result imposes strong constraints on AME states in composite local dimensions and characterizes the limitations of graph-state constructions for highly entangled multipartite quantum systems. In particular, this study provides an independent solution of the recently discussed case of the AME state of four quhexes and clarifies its characterization within the stabilizer formalism. At the same time, we provide a general construction for mixed k-uniform states whose purity is determined by the optimal stabilizer representations. For the specific case of (N=4, d=6), this yields a mixed AME state of optimal purity 1/2, not subject to canonical graph-state constraints.

References:

[1] https://arxiv.org/abs/2603.18193

Jan Wójcik
Faculty of Mathematics, Physics and Informatics, University of Gdańsk, Poland

Mean hitting time perspective on quantum advantage in quantum walk model

Abstract: We explore the effects of stochastic resetting on discrete-time quantum walks (DTQW) on a finite one-dimensional lattice with two absorbing boundaries. These absorbing sites act as detectors and allow us to study the mean time to absorption (MTA) - a quantity central to first-passage problems. In the classical case, resetting typically increases the MTA when the walk starts symmetrically between the absorbing sites. Surprisingly, in the quantum scenario, we observe the opposite: stochastic resetting can optimize and reduce the MTA. The quantum walk exhibits a dependence on the reset probability, featuring a clear minimum at an optimal value. This behavior is rooted in quantum mechanics. Unlike classical resetting, which only affects position, quantum resetting modifies both the walker's position and its quasi-momentum distribution, a consequence of the uncertainty principle. This leads to reduced interference-based reflection from absorbing boundaries and faster absorption overall. We provide heuristic estimates of the optimal reset rate and demonstrate agreement with numerical results. Our findings reveal a clear quantum advantage in scenarios where classical walks cannot be optimized and suggest practical applications for speeding up quantum algorithms through controlled resets.

Adamantia Zampeli
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

(*Relativistic) quantum causal instruments*

Abstract: A notorious problem in quantum field theory is the description of quantum measurements on fields and the extraction of information. To achieve this, one has to construct quantum instruments consistent with causality and locality of the underlying relativistic theory. I discuss a path towards this construction that passes through the construction of Kraus operators for relativistic fields. I explain how the problem of consistency appears already in continuous measurements of non-relativistic theory and I mention a formulation that works for quantum fields.

Acknowledgement:
This work is carried out under the Maestro project no. 2021/42/A/ST2/00356 under the title „Relativistic Causality and Information Processing", funded by the National Science Center, Poland.

Beata Zjawin
International Centre for Theory of Quantum Technologies (ICTQT), University of Gdańsk, Poland

How typical is contextuality?

Abstract: Identifying when observed statistics cannot be explained by any reasonable classical model is a central problem in quantum foundations. A principled and universally applicable approach to defining and identifying nonclassicality is given by the notion of generalized noncontextuality. Here, we study the typicality of contextuality — namely, the likelihood that randomly chosen quantum preparations and measurements produce nonclassical statistics. Using numerical linear programs to test for the existence of a generalized-noncontextual model, we find that contextuality is fairly common: even

in experiments with only a modest number of random preparations and measurements, contextuality arises with probability over 99%. We also show that while typicality of contextuality decreases as the purity (sharpness) of the preparations (measurements) decreases, this dependence is not especially pronounced, so contextuality is fairly typical even in settings with realistic noise. Finally, we show that although nonzero contextuality is quite typical, quantitatively high degrees of contextuality are not as typical, and so large quantum advantages are not as typical. We provide an open-source toolbox that outputs the typicality of contextuality as a function of tunable parameters.

References:

[1] https://arxiv.org/abs/2510.20722

Acknowledgement:

This work is carried out under the `International Centre for Theory of Quantum Technologies 2.0: R&D Industrial and Experimental Phase' project (contract no. FENG.02.01-IP.05-0006/23). The project is implemented as part of the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Funds for a Smart Economy 2021-2027 (FENG), Priority FENG.02 Innovation-friendly environment, Measure FENG.02.01.