BOOK OF ABSTRACTS

16th Central European Quantum Information Processing Workshop

June 3rd–June 6th 2019, Skalica, Slovakia
http://ceqip.eu

CEQIP 2019

CEQIP 2019 (Central European Quantum Information Procesing workshop) is traditionally focused on current challenges and paradigms of mathematical and computational aspects of emerging quantum technologies. One of the strengths is the traditionally strong social program creating very friendly and creative atmosphere. Besides traditional wine tasting and a cipher game we plan to visit surrounding natural beauties.

Venue

CEQIP 2019 will be held in the Culture House of "free kings town" Skalica situated approximatively 60 km north of Bratislava on the borders with Czechia. The town has a long history dating thousands years in the past, part of it you will discover when coming there.

Invited speakers

- ⋆ Daniel Cavalcanti (Barcelona)
- ⋆ Jens Eisert (Berlin)
- ⋆ Teiko Heinosaari (Turku)
- ⋆ Mária Kieferová (Waterloo)
- ⋆ Alexander Müller-Hermes(Copenhagen)
- ⋆ Marcin Pawlovski (Gdansk)

Selection Comittee

- ⋆ Daniel Reitzner (chair)
- ⋆ Mário Ziman
- ⋆ Daniel Cavalcanti
- ⋆ Vedran Dunjko
- ⋆ Sergey Filippov
- ⋆ Otfried Gühne
- ⋆ Teiko Heinosaari
- ⋆ Mária Kieferová
- ⋆ Marcin Pawlowski
- ⋆ Matej Pivoluska
- ⋆ Zoltan Zimboras

Organizing Team

- ⋆ Jan Bouda
- ⋆ Daniel Reitzner
- ⋆ Michal Sedlák
- ⋆ Mária Surovcová
- ⋆ Mário Ziman

The workshop is organized by Research Center for Quantum Information, Institute of Physics, Slovak Academy of Sciences (Bratislava) and Quantum Laboratory, Faculty of Informatics, Masaryk University (Brno).

Program

Monday, 3. 6. 2019

16:30	Registration (with refreshment)
17:30	Evening session
17:30	**Jens Eisert** (I)
18:10	**Costantino Budroni** (C)
18:35	**Miguel Navascues** (C)
19:00	End of session
19:00	Welcome dinner (Masaryk winery)

Tuesday, 4. 6. 2019

08:00	Breakfast
09:00	Morning session
09:00	**Marcin Pawlowski** (I)
09:40	**Felix Huber** (C)
10:05	**Gael Sentís** (C)
10:30	Coffee & Refreshment
11:00	**Alexander Müller-Hermes** (I)
11:40	**Aleksander Marcin Kubicki** (C)
12:05	**Mirjam Weilenmann** (C)
12:30	End of session
13:00	Lunch
14:00	Afternoon session
14:00	**Daniel Cavalcanti** (I)
14:40	**Pawel Mazurek** (C)
15:05	**Marco Erba** (C)
15:30	End of session
15:30	Coffee & Refreshment
16:00	Poster session
18:30	Cipher game registration
18:30	Dinner
19:00	Cipher game

Wednesday, 5. 6. 2019

08:00	Breakfast
09:00	Morning session
09:00	**Mária Kieferová** (I)
09:40	**Roope Uola** (C)
10:05	**Michal Oszmaniec** (C)
10:30	Group photo
10:35	Coffee & Refreshment
11:00	**Teiko Heinosaari** (I)
11:40	**Łukasz Pawela** (C)
12:05	**Nikolai Miklin** (C)
12:30	End of session
12:30	Lunch
13:30	Conference trip and dinner

Thursday, 6. 6. 2019

08:00	Breakfast
09:30	Morning session
09:30	**Anubhav Chaturvedi** (C)
09:55	**Libor Caha** (C)
10:20	**Jędrzej Kaniewski** (C)
10:45	End of session
10:45	Take Away Refreshment
11:00	Conference bus

(I) Invited talk (35 + 5 min.)
(C) Contributed talk (20 + 5 min.)

Invited talks

1. **Daniel Cavalcanti:** STATISTICAL MECHANICS OF QUANTUM COMMUNICATION NETWORKS

   The main goal of quantum communication is the development of a quantum internet, a network of quantum memories that can exchange quantum information. It's very likely that the first generations of this network will make use of the current infrastructure of optical fibers, which imposes strong limitations in the distance in which quantum information can be sent. It will be necessary to devise methods to counter-attack the losses in direct transmission, such as the use of quantum repeaters. The efficiency of such strategies will crucially depend on the connectivity and topology of the network. In this talk I am going to discuss the statistical properties of quantum communication networks. I will analyse several properties such as it's connectivity and typical path lengths, and will show a phase transition from a disconnected to fully connected network naturally appears in quantum networks.

2. **Jens Eisert:** TOWARDS CLOSING THE LOOPHOLES OF SHOWING A QUANTUM ADVANTAGE

   Quantum devices promise the efficient solution of problems out of reach for classical computers. However, before reaching the ultimate goal of realizing Shor-class fault tolerant quantum computers, one has to unambiguously show the possibility of a quantum advantage in the first place. In this talk, I will discuss prospects of achieving a complexity-theoretic quantum advantage that both live up to rigorous standards and is practically feasible. On the technical level, we will see how new proof techniques of anti-concentration bounds and average-case complexity come into play. On the more physical level, we will elaborate on how such schemes can be realized with realistic near-term quantum devices.

3. **Teiko Heinosaari:** HEISENBERG MEETS GALOIS — A STRUCTURAL VIEWPOINT TO NOISE AND DISTURBANCE

   The trade-off between noise and disturbance is one of the most fundamental features of quantum measurements. In the two extreme cases a measurement either makes no disturbance but then has to be totally noisy or is as accurate as possible but then has to disturb so much that all subsequent measurements become redundant. Most of the measurements are, however, somewhere between these two extremes. There is a structural correspondence between certain order relations defined on meters and channels that properly explains the trade-off between noise and disturbance. A suitable mathematical framework to investigate the correspondence further is the Galois connection induced by the compatibility relation between channels and meters. Forming the Galois connection gives immediately two closure maps, one on the set of meters and another one on the set of channels. The closure map on the set of meters can be interpreted as a mathematical description of the information leak.

4. **Mária Kieferová:** SIMULATING THE DYNAMICS OF TIME-DEPENDENT HAMILTONIANS WITH A TRUNCATED DYSON SERIES

   We provide a general method for efficiently simulating time-dependent Hamiltonian dynamics on a circuit-model-based quantum computer. Our approach is based on approximating the truncated Dyson series of the evolution operator, extending the earlier proposal by Berry et al. [Phys. Rev. Lett. 114, 090502 (2015)] to evolution generated by explicitly time-dependent Hamiltonians. Two alternative strategies are proposed to implement time ordering while exploiting the superposition principle for sampling the Hamiltonian at different times. The resource cost of our simulation algorithm retains the optimal logarithmic dependence on the inverse of the desired precision.

5. **Alexander Müller-Hermes:** WHEN DO COMPOSED MAPS BECOME ENTANGLEMENT BREAKING?

   For many completely positive maps repeated compositions will eventually become entanglement breaking. To quantify this behaviour we develop a technique based on the Schmidt number: If a completely positive map breaks the entanglement with respect to any qubit ancilla, then applying it to part of a bipartite quantum state will result in a Schmidt number bounded away from the maximum possible value. Iterating this result puts a successively decreasing upper bound on the Schmidt number arising in this way from compositions of such a map. By applying this technique to completely positive maps in dimension three that are also completely copositive we prove the so-called PPT squared conjecture in this dimension. We then give more examples of completely positive maps where our technique can be applied, e.g. maps close to the completely depolarizing map, and maps of low rank.

6. **Marcin Pawlovski:** OLD AND NEW RESULTS ON THE NUMBER OF MUTUALLY UNBIASED BASES

   The maximal number of mutually unbiased bases (MUBs) for a given Hilbert space dimension is not know despite of a lot of research in this area. In this talk I give a review of what is known and what is yet to be ascertained. I start by defining MUBs and briefly explaining their importance in quantum information. Then I discuss their importance in mathematics by presenting related problems. Next I come to the main part of my talk and present known results and some failed attempts. I conclude by indicating some potentially promising directions for future research.

Contributed talks

1. **Costantino Budroni:** MEMORY COST OF TEMPORAL CORRELATIONS

   A possible notion of nonclassicality for single systems can be defined on the basis of the notion of memory cost of classically simulating probabilities observed in a temporal sequence of measurements. We further explore this idea in a theory-independent framework, namely, from the perspective of general probability theories (GPTs), with classical and quantum theory as special examples. Under the assumption that each system has a finite memory, we investigate what are the temporal correlations achievable with different theories, namely, classical, quantum, and GPTs beyond quantum mechanics. We derive inequalities able to distinguish temporal correlations where the underlying system is classical, quantum, or more general.

2. **Libor Caha:** VERY ENTANGLED SPIN CHAINS AND COMBINATORIAL TECHNIQUES IN CONDENSED MATTER PHYSICS

   How entangled can a ground state of a simple quantum matter be? It turns out that power law violation of entanglement entropy is possible, as shown for recent Motzkin spin-2 and Fredkin spin-3/2 chains. We demonstrate that one can find such surprising properties even in spin-1 chains (qutrits on a line). We present the PF model, a translationally invariant spin chain with 1/poly(N) gap, sqrt(N) half-chain entropy for a particular ground state (conjecture: can be made unique, partial analytical result). Building on combinatorial techniques, we use correspondence to relate entropy of a middle part (also for Fredkin and Motzkin chains), derive 1 and 2-point correlation functions, and violation of the cluster decomposition property. We discuss these models with periodic boundary conditions.

3. **Anubhav Chaturvedi:** THE GROUND OF QUANTUM COMMUNICATION ADVANTAGE

   Where does quantum advantage spring from? Our answer is a non-classical ontic-feature called preparation contextuality (PC) and advantage in oblivious communication tasks is its operational signature. We construct oblivious communication tasks tailored to given communication complexity (CC) problems. The maximal classical success probability of these oblivious communication tasks forms our preparation non-contextual inequalities. We use the very set-up responsible for advantage in CC problems to orchestrate an advantageous protocol for the associated oblivious communication tasks and the violation of the associated inequalities. We conclude by gathering the implications of our results and other evidence in support of PC as the primal ontic-feature underlying quantum advantage.

4. **Marco Erba:** AXIOMATIC CONSTRUCTION OF PROBABILISTIC THEORIES, AND A SIMPLICIAL THEORY WITH ENTANGLEMENT

   GPTs provide a toolbox to investigate the probabilistic structure of physical theories. A parallel approach is based on category theory. The latter allows to provide a notion of compositionality, and to get a solid grasp relying on diagrammatic reasoning. One aim of our work is to bridge the two approaches. The categorial structure of Operational Probabilistic Theories is legitimized by some requirements that a physical theory should have. We explicitly construct an example of OPT. This is simplicial and causal: in this respect, classical. This theory is also bilocal and exhibits entanglement, while not satisfying atomicity of composition. This OPT is relevant from the point of view of the axiomatics of probabilistic theories, and is well-suited for cryptographic and computation protocols.

5. **Felix Huber:** EXPONENTIALLY MANY MONOGAMY AND CORRELATION CONSTRAINTS FOR MULTIPARTITE STATES

   We present a family of correlations constraints that apply to all multipartite quantum systems of finite dimension. The size of this family is exponential in the number of subsystems. We obtain these relations by defining and investigating the generalized state inversion map. This map provides a systematic way to generate local unitary invariants of degree two in the state and is directly linked to the shadow inequalities proved by Rains [IEEE Trans. Inf. Theory 46, 54 (2000)]. The constraints are stated in terms of linear inequalities for the linear entropies of the subsystems. For pure quantum states they turn into monogamy relations that constrain the distribution of bipartite entanglement among the subsystems of the global state.

6. **Jędrzej Kaniewski:** A WEAK FORM OF SELF-TESTING

   Self-testing refers to the phenomenon that observing certain nonlocal statistics determines the quantum state and the measurements performed (up to some generic well-understood equivalences). In this work we prove the existence of a new, weak form of self-testing. More specifically, we show that the maximal violation of a certain bipartite Bell inequality certifies the presence of a specific state, but does not uniquely determine the measurements. Nevertheless, our Bell functional seems to be equally good for cryptographic purposes. This shows that the usual strong rigidity is not necessary for device-independent applications.

7. **Aleksander M. Kubicki:** RESOURCE QUANTIFICATION FOR THE NO-PROGRAMMING THEOREM

   The no-programing theorem prohibits the existence of a universal programmable quantum processor. This statement has implications to quantum computation but also to other tasks of quantum information processing. Nonetheless, it is well known that, even when the strict model is not implementable, it is possible to conceive of it in an approximate sense. Unfortunately, the minimal resources necessary for this aim are still not completely understood. Here, we investigate quantitative statements of the theorem, improving exponentially previous bounds on the resources required by such a hypothetical machine. The proofs exploit a new connection between quantum channels and geometric Banach space theory which allows us to use classical tools from the later theory in a clean and simple way.

8. **Paweł Mazurek:** THERMAL PROCESSES AND STATE ACHIEVABILITY

   Resource Theory of Thermal Operations (TO) aims at describing possible transitions of micro-scale systems interacting with a macroscale environment under the assumption of energy conservation. For initial states diagonal in a local Hamiltonian basis, these transitions are described by Thermal Processes (TPs). We address the problem of saturating predictions of TO with limited resources by i) characterizing the set of states that can be achieved through TPs, ii) characterizing all extremal TPs through transportation matrices. We show that for dimension >3 there exist extremal TPs that are not required in the implementation of any transition allowed by TPs. Full version of the paper arXiv:1810.05578.

9. **Nikolai Miklin:** SELF-TESTING OF UNSHARP MEASUREMENTS

   We consider unsharp quantum measurements as a recourse in sequential scenarios. We analyse the case of two-outcome qubit measurement and show that generalized measurements allow for a strict advantage as compared to their probabilistic realization with projective measurements. We propose a scheme for semi-device-independent self-testing of unsharp measurements and show that essentially all binary qubit measurements can be self-tested in a robust manner. We conclude by relating the problem to the analysis of semi-device-independent one-way quantum key distribution. We present new trade-off relations that follow from our main results and find the exact bound on the critical success probability for the case of individual eavesdropping attacks.

10. **Miguel Navascues:** COARSE-GRAINING CLASSICAL AND QUANTUM NETWORKS

    Current tools to certify non-classical properties of quantum states, such as entanglement and Bell nonlocality, are just practical for systems of a very modest size, of around 4 sites. Our approach to solve this "many-body quantum information problem" uses a class of linear transformations, called connectors, which join or chunk different sites of the considered network in a way that preserves the property under investigation. Applying these operations recursively, very quickly we end up with a network of manageable size, whose properties can be explored via usual techniques. Using a normal desktop, we test this framework by certifying entanglement, Bell nonlocality and supra-quantum Bell nonlocality in networks with hundreds of sites.

11. **Michał Oszmaniec:** OPERATIONAL RELEVANCE OF RESOURCE THEORIES OF QUANTUM MEASUREMENTS

    For any resource theory it is essential to identify tasks for which resource objects offer advantage over free objects. We show that this identification is possible for all resource theories of quantum measurements in which free objects form a convex subset of measurements on a given Hilbert space. To this aim we prove that every resource measurement offers advantage for some quantum state discrimination task. Moreover, we give an operational interpretation of robustness, which quantifies the minimal amount of noise that must be added to a measurement to make it free. Finally, we apply our results to two classes of free measurements: incoherent measurements (measurements that are diagonal in the fixed basis) and separable measurements (measurements whose effects are separable operators).

12. **Łukasz Pawela:** POVM DISCRIMINATION

    In this work we study the problem of discrimination of von Neumann measurements, which we associate with measure-and-prepare channels. There are two possible approaches to this problem. The first one is simple and does not utilize entanglement. We focus only on the discrimination of classical probability distributions, which are outputs of the channels. We find necessary and sufficient criterion for perfect discrimination in this case. A more advanced approach requires the usage of entanglement. We quantify the distance between two measurements in terms of the diamond norm. We provide an exact expression for the optimal probability of correct distinction and relate it to the discrimination of unitary channels. Finally, we consider unambiguous discrimination schemes.

13. **Gael Sentís:** UNSUPERVISED CLASSIFICATION OF QUANTUM DATA

    We introduce the problem of unsupervised classification of quantum data, namely, of systems whose quantum states are unknown. We derive the optimal single-shot protocol for the binary case, where the states in a disordered input array are of two types. Our protocol is universal and able to automatically sort the input under minimal assumptions, yet partially preserving information contained in the states. We quantify analytically its performance for arbitrary size and dimension of the data. We contrast it with the performance of its classical counterpart, which clusters data that has been sampled from two unknown probability distributions. We find that the quantum protocol fully exploits the dimensionality of the quantum data to achieve a much higher performance.

14. **Roope Uola:** QUANTIFYING QUANTUM RESOURCES WITH CONIC PROGRAMMING

    Resource theories can be used to formalize the quantification and manipulation of resources in quantum information processing such as entanglement, asymmetry and coherence of quantum states, and incompatibility of quantum measurements. Given a certain state or measurement, one can ask whether there is a task in which it performs better than any resourceless state or measurement. Using conic programming, we prove that any general robustness measure (with respect to a convex set of free states or measurements) can be seen as a quantifier of such outperformance in some discrimination task. We apply the technique to various examples, e.g. joint measurability, POVMs simulable by projective measurements, and state assemblages preparable with a given Schmidt number.

15. **Mirjam Weilenmann:** ANALYSING CAUSAL STRUCTURES IN GENERALISED PROBABILISTIC THEORIES

    Causal structures give us a way to understand the origin of observed correlations. These were developed for classical scenarios, but quantum mechanical experiments necessitate their generalisation. We study causal structures in a broad range of theories, including quantum and classical theory. We propose a method for analysing differences between such theories based on the measurement entropy and apply it to various causal structures, deriving new relations that are in a sense minimal requirements of any causal explanation. We also make several technical contributions that give insight for the entropic analysis of quantum causal structures. In particular, we prove that for any causal structure and any generalised probabilistic theory, the set of achievable entropy vectors is a convex cone.

Posters

1. **Edgar Aguilar:** SIMPLE TESTABLE RANDOM NUMBER GENERATOR

   In this paper we design and analyze a testable random number generator based on simple optical elements; a photon source, a beam-splitter, and a detector. As an additional component used to analyze the quality of generated randomness we use a movable shutter. We analyze the amount of produced entropy in a measurement device-independent fashion. That is, we place partial assumptions on the photon source and the beam-splitter, while we leave the detectors mostly uncharacterized. Finally, we perform an experimental implementation of this minimalist protocol and show an explicit trade-off between entropy produced and assumptions on the physical devices made.

2. **Fabian Bernards:** SEARCHING FOR A GENERALIZATION OF THE I3322 BELL INEQUALITY

   We present a symmetric and extremal Bell inequality for three parties and three measurements per party with two outcomes each. Further, we investigate the relevance of the Bell inequality, i.e whether it can detect states as entangled that could not be detected with previously known Bell inequalities and discuss whether it can be regarded as a generalization of Sliwa's I3322 inequality.

3. **Konstantin Beyer:** WHEN IS A SZILÁRD ENGINE REALLY QUANTUM?

   In quantum thermodynamics "quantumness" is often only investigated in the context of device-dependent concepts such as entanglement or coherences. We propose a scenario based on quantum steering to demonstrate quantumness of thermodynamical systems in a semi-device-independent way. In quantum thermodynamics we usually have a asymmetric situation. The system is well-known, whereas we have no detailed information about the surrounding environment. This asymmetry is reflected in the steering task, where one side (the system) is taken to be device dependent while the other part (the environment) is treated device independent. As an illustrative example we consider a modified qubit version of a Szilárd engine.

4. **Shin-Liang Chen:** ROBUST SELF-TESTING OF PAULI OBSERVABLES AND ITS APPLICATIONS IN DEVICE-INDEPENDENT CERTIFICATION OF ALL TWO-QUBIT ENTANGLED STATES

   Recently, Bowles et al. [Phys. Rev. Lett. 121, 180503 (2018)] proposed a method for certifying all entangled states in a device-independent manner. This is achieved by self-testing the Pauli measurements and the maximally entangled states between the main system (of which entanglement is being certified) and auxiliary systems. In this work, with the swap method, we present a robust formulation, in the sense that the part of self-testing need not be nearly perfect and thus the scheme is more realistic and experimental friendly. Besides, we also self-test the three Pauli observables and the maximally entangled state in the scenario of Gisin's elegant Bell inequality. With this, one can even use fewer measurement settings to device-independently certify entangled states.

5. **Benjamin Dive:** CHARACTERISATION OF MULTI-LEVEL QUANTUM COHERENCE WITHOUT IDEAL MEASUREMENTS

   Coherent superpositions are vital for any genuine quantum behavior. They are typically verified in interference experiments but very little is known about how to extract the number of coherently superposed amplitudes from this. A fundamental issue is that performing a phase-sensitive measurement is as challenging as creating a coherent superposition, making it hard to justify a perfect measurement for verifying the initial state. To overcome this issue, we construct a coherence certifier derived from simple statistical properties of an interference pattern, such that imperfections can never overestimate the coherence. We test how robust this measure is to underestimating the coherence in the case of imperfect state preparation or measurement, and find it to be very resilient in both cases.

6. **Gerhard Dueck:** EFFICIENT DESIGN OF QUANTUM CIRCUIT FOR IBM'S QX ARCHITECTURES

   IBM has made several quantum computers available to researchers via cloud services. Two architectures with five qubits, one with 14, and one with 20 qubits are available to run experiments. The IBM architectures implement gates from the Clifford+T gate library. However, each architecture only implements a subset of the possible CNOT gates. In this paper, we show how Clifford+T circuits can efficiently be mapped into IBM quantum computers. Quantum circuits can be based on different gate libraries. Two frequently used libraries are NCV and and Clifford+T. Some work has been done to efficiently transform NCV circuits to Clifford+T. We show that it is advantageous to consider the target architecture while transforming the NCV circuit.

7. **Máté Farkas:** ON THE DIFFERENT MEASURES OF INCOMPATIBILITY ROBUSTNESS

   Incompatibility is a feature of quantum measurements that classical theories do not possess, and as such, characterising incompatible measurements is a fundamentally interesting task. In this work, we analyse five commonly used robustness-based measures of incompatibility, using analytic techniques to study their semidefinite programming formulation. First, we derive their properties from a resource theoretic standpoint, highlighting some of their limitations. Then we provide readily applicable universal and measurement-dependent bounds on them. Using these results, we find the most incompatible pair of measurements for a given measure, and show that these are not the unique maximisers for all possible measures.

8. **Artem Glinov:** QUANTITATIVE DESCRIPTION OF CORRELATIONS ACCOMPANYING NON-MARKOVIAN QUANTUM DYNAMICS UNDER MIXING OF MARKOVIAN PROCESSES

   We consider a depolarizing-like channel acting on the ancilla A (A is introduced in a microscopic non-Markovianity model developed by H.-P. Breuer, G. Amato and B. Vacchini) and resulting in a convex mixture of specially defined Markovian and non-Markovian (being a convex combination of Markovian processes in a system S) dynamical maps in S+A. We introduce the special value of a depolarization parameter (a transition parameter) that is a bound between two regimes and find it in a particular example of two decay processes. We show that in this case the non-Markovianity measure of the process in S based on distinguishability is a monotonic and bijective function of the transition parameter. We also obtain a lower bound of non-Markovianity in our example and an upper bound in a general case.

9. **Waldemar Klobus:** ON k-UNIFORM MIXED STATES

   We investigate the maximum purity that can be achieved by k-uniform mixed states of N qubits.We propose a scheme to explicitly construct k-uniform states using a set of specific N-qubit Pauli operators. We give particular examples of k-uniform states for any k with N up to 6 qubits. We observe that in some cases the set of N-qubit Pauli operators for a k-uniform mixed state can be constructed with the use of a specific orthogonal array.

10. **Aleksandra Krawiec:** MAJORIZATION UNCERTAINTY RELATIONS FOR MIXED QUANTUM STATES

    Majorization uncertainty relations are generalized for an arbitrary mixed quantum state ϱ of a finite size N. In particular, a lower bound for the sum of two entropies characterizing the probability distributions corresponding to measurements with respect to two arbitrary orthogonal bases is derived in terms of the spectrum of ϱ and the entries of a unitary matrix U relating both bases. The results obtained can also be formulated for two measurements performed on a single subsystem of a bipartite system described by a pure state, and consequently expressed as an uncertainty relation for the sum of conditional entropies.

11. **Ryszard Kukulski:** GENERATING RANDOM QUANTUM CHANNELS

    In this work we study the techniques of generating random quantum channels. We present three possible approaches to the problem of sampling random channels. We show that each of these approaches leads to the Lebesgue measure and that these approaches are mathematically equivalent. However, this methods differ in their physical interpretation, mathematical background and computational complexity. On the other hand, we analyzed the invariant state and showing that due to the measure concentration phenomenon it converges asymptotically to the maximally mixed state. Furthermore, we related investigation of random quantum channel to their classical counterpart of random stochastic matrices and demonstrated common properties of the spectra of operators used in both set-ups.

12. **Leevi Leppäjärvi:** NO-FREE-INFORMATION PRINCIPLE IN GENERAL PROBABILISTIC THEORIES

    In quantum theory, the no-information-without-disturbance and no-free-information theorems express that those observables that do not disturb the measurement of another observable and those that can be measured jointly with any other observable must be trivial. We show that in the framework of general probabilistic theories these statements do not hold in general and continue to completely specify these two classes of observables. As a particular class of state spaces we consider the polygon state spaces, in which we demonstrate our results and show that while the no-information-without-disturbance principle always holds, the validity of the no-free-information principle depends on the parity of the number of vertices of the polygons.

13. **Paulina Lewandowska:** BENCHMARKING AND COMPARISON OF THE RIGETTI AND IBM Q QUANTUM ARCHITECTURES

    We have an access quantum computers implementing the gate model of quantum computation. These are the best developed machines, which can be thought of as fully quantum computers, by which we understand that the qubits can be in an entangled state. There are currently two main providers of such architectures. The first one is IBM. In order to access the machine and make programming it simpler for the community, a Python library, qiskit is provided by IBM. The second one is Rigetti. As was the case for IBM, Rigetti also provides a Python library, pyquil, which enables easy access to the machine. In this work, we present and comparison thats architectures. The main goal is to introduce a new benchmark, based on the problem of discrimination of quantum measurements, for NISQ devices.

14. **Jyun-Yi Li:** HIDDEN TELEPORTATION POWER FOR ENTANGLED QUANTUM STATES

    An ideal quantum teleportation transfers an unknown quantum state intact from one party to another via the use of a maximally entangled state. If Alice and Bob only share a classical resource, the teleportation fidelity, i.e., the maximal average fidelity between the state to be teleported and the state received is at most $f_c = 2/(d+1)$. If they share an entangled state ρ with teleportation fidelity $f < f_c$ and upon successful local filtering, the teleportation fidelity becomes larger than f_c, we say that ρ has hidden teleportation power. Here, we investigate (1) the hidden teleportation power of a 1-parameter family of states, (2) the trade-off between the success probability of local filtering and the extent to which the teleportation fidelity can be increased by this means.

15. **Keren Li:** Optimizing a Polynomial Function on a Quantum Simulator

Gradient descent method, as one of the major methods in numerical optimization, is the key ingredient in many machine learning algorithms. For the vast resource consumption when dealing with high-dimensional problems, a quantum version of this iterative optimization algorithm has been proposed recently [arXiv:1612.01789]. Here, we develop this protocol via reducing the data copies to make it possible to implement with current technology. And, for the optimization problem of homogeneous objective function. Moreover, a prototypical experiment was shown with a 4-qubit Nuclear Magnetic Resonance quantum processor, utility demonstrating an optimization process of polynomial function iteratively. Our results facilitate the implement of quantum gradient descent process on other quantum systems.

16. **Pei-Sheng Lin:** Exploring Bell inequalities for the device-independent certification of multipartite entanglement depth

Techniques developed for device-independent (DI) characterizations allow one to certify certain physical properties of quantum systems without assuming any knowledge of their internal workings. In this work, we consider a one-parameter family of multipartite, two-setting, two-outcome Bell inequalities and demonstrate the extent to which they are suited for the DI certification of genuinely multipartite entangled quantum states, including the generalized Greenberger-Horne-Zeilinger (GHZ) states with unbalanced weights and the W states. We also construct two-setting, two-outcome Bell inequalities—based on the so-called GHZ paradox—to certify the entanglement present in various graph states, including the ring graph states and the fully-connected graph states.

17. **Marcin Łobejko:** Quantum circuit heat engine

Joint work with Paweł Mazurek and Michał Horodecki

The model of a quantum circuit heat engine (QCHE) is defined as a working body acting separately with the (cold and hot) heat baths and the energy storage system (a battery). A single step of the engine is defined as the unitary and energy conserving operation, i.e. a quantum gate. For the general QCHE we prove the fundamental attainable efficiency, given as a function of a cold and hot temperature, which is below the Carnot efficiency. The reason is that the engine is quasi-autonomous, i.e. there is no additional control like external fields commonly used in a non-autonomous setting. Furthermore, for our model of the QCHE we discuss the problem of the work definition for the fully quantum systems. So far the only reasonable definition of the work (consistent with the fluctuation theorems) is given by the change in a mean energy of the battery which has additionally a translational symmetry, i.e. these changes do not depend on how much energy is currently stored in the battery. However, this symmetry impose a nonphysical property that the battery cannot have a ground state. We solve this problem showing that the battery with a ground state can be used as a proper energy storage system only if the work is defined as a change of the ergotropy instead of a mean energy.

18. **Filip Maciejewski:** Mitigation of readout noise by classical post-processing based on Quantum Detector Tomography

Joint work with Zoltán Zimborás and Michał Oszmaniec

We propose a simple scheme to reduce readout errors in any experiment on a quantum system with finite number of measurement outcomes. Our method relies on performing classical post-processing which is preceded by Quantum Detector Tomography, i.e., the process of reconstructing a Positive-Operator Valued Measure (POVM) describing a given quantum measurement device. If the reconstructed POVM differs from the ideal one only by an invertible classical noise, it is possible to correct the outcome statistics of later experiments performed on the same device. We analyze the influence of deviations from the noise model and the finite-size statistics on the performance of our correction scheme. Finally, we provide a characterization of readout noise occurring in IBM quantum devices, which show the agreement with the adopted noise model. We test our mitigation scheme for single- and two-qubit experiments on the IBM devices and observe improvement of results for the following tasks - Quantum State Tomography (QST), Quantum Process Tomography (QPT), and implementation of quantum algorithm's - Grover's and Bernstein-Vazirani.

19. **Esteban Martínez Vargas:** Certified Answers for ordered quantum discrimination problems

We investigate the problem of quantum discrimination for sets of pure states with an intrinsic ordering. This structured quantum discrimination problems allow a novel scheme that provides a certified level of error, this means, the answers do not deviate from the true value more than a specific distance. We investigate two paradigmatic problems: the Quantum Change Point (QCP) and the Quantum Position Error Identification (QPEI). We give a formulation of this problem as a semidefinite program. We observe that there are problems where there is a significant gain when considering more errors. In particular, for the QCP the minimum error efficiency can be reached with schemes that allows less errors than the maximum possible. In general this is not the case, as in QPEI.

20. **M. Hamed Mohammady:** Conditional work statistics of quantum measurements

We introduce a definition for conditional energy change due to generalised quantum measurements. This uses the concept of weak values to quantify the initial energy of the system conditioned on observing an outcome. By determining the conditional energy change of both system and measurement apparatus, we obtain the full conditional work statistics of quantum measurements, and show that this vanishes for all measurement outcomes if the measurement process conserves energy. Additionally, by incorporating the measurement process within a cyclic heat engine, we quantify the non-recoverable work due to measurements. This is shown to always be non-negative, thus satisfying the second law, and will be independent of the apparatus specifics for two classes of projective measurements.

21. **Nikolajs Nahimovs:** LACKADAISICAL QUANTUM WALKS WITH MULTIPLE MARKED VERTICES

    The concept of lackadaisical quantum walk – quantum walk with self loops – was first introduced for discrete-time quantum walk on one-dimensional line. Later it was successfully applied to improve the running time of the spacial search on two-dimensional grid. We study search by lackadaisical quantum walk on the two-dimensional grid with multiple marked vertices. First, we show that the lackadaisical quantum walk, similarly to the regular (non-lackadaisical) quantum walk, has exceptional configuration, i.e. placements of marked vertices for which the walk has no speed-up over the classical exhaustive search. Next, we demonstrate that the weight of the self-loop suggested in the previous papers is not optimal for multiple marked vertices. And, last, we show how to adjust the weight of the self-loop to overcome the aforementioned problem.

22. **Jaroslav Pavličko:** EQUIVALENCE OF PROGRAMMABLE QUANTUM PROCESSORS

    Programmable quantum processor is a device that has two quantum registers – data and program. The state of the program register determines which completely positive map (program) on the data register is applied. By definition two processors are equivalent if they implement the same set of programs on states of the data register. For example, any post-processing of the program register generates equivalent processors. We will show that such post-processing equivalence is not a necessary condition for processors' equivalence. Further, we will formulate and investigate the equivalence relations in various settings, e.g. for restricted class of processors and probabilistic settings.

23. **Martin Plávala:** QUANTUM AND CLASSICAL IMPLEMENTATIONS OF THE POPESCU-ROHRLICH BOX CORRELATIONS

    We construct all of the qubit no-signaling channels that maximally violate the CHSH inequality, we show that that they have a block-diagonal structure and that all of them are measure-and-prepare channels. We also present a classical no-signaling protocol using post-selection that implements the PR-box correlations without the need for any quantum system, even though the protocol is based on quantum teleportation.

24. **Václav Potoček:** USING MULTI-OBJECTIVE EVOLUTIONARY ALGORITHMS FOR QUANTUM CIRCUIT DISCOVERY

    We present a genetic algorithm designed to discover quantum circuits that can achieve an arbitrary, possibly parameterized, mapping between inputs and desired outputs. We exploit a multi-objective evolutionary search strategy to build quantum circuits 'from scratch', by combining and tuning a task-generic selection of quantum gates. We demonstrate its performance in two test cases, showing convergence to textbook circuits for the quantum Fourier transform and for Grover's search algorithm, along with alternative structures that achieve the same functionality. At the same time, by its multi-objective nature, the algorithm finds several alternative circuits that explore trade-offs between accuracy and measures of circuit complexity and implementability, such as the number of gates.

25. **Zbigniew Puchała:** ALL QUANTUM MEASUREMENTS CAN BE SIMULATED USING PROJECTIVE MEASUREMENTS AND POSTSELECTION

    We report an alternative scheme for implementing generalized quantum measurements that does not require the usage of auxiliary system. Our method utilizes solely: (a) classical randomness and post-processing, (b) projective measurements on a relevant quantum system and (c) postselection on non-observing certain outcomes. The scheme implements arbitrary quantum measurement in dimension d with the optimal success probability $1/d$. We apply our results to bound the relative power of projective and generalised measurements for unambiguous state discrimination. Finally, we test our scheme experimentally on IBM quantum processor. Due to noise involved in the implementation of entangling gates, the quality with which our scheme outperforms the standard construction using the auxiliary system.

26. **Peter Rapčan:** THE EFFECTIVE SYSTEM SIZE AND THE CENTRAL CHARGE OF SOME CFT-MAPPABLE SPIN CHAINS

    Some critical spin chains, such as the infinite Ising or XX chains in appropriate magnetic fields, can be described by conformal field theories (CFTs), characterized by their central charges. We show there is a relationship between the central charge of the corresponding CFT and an effective system size sufficient to take into account when calculating observables for a subsystem of such chains in their ground states.

27. **Daniel Reitzner** and **Mário Ziman:** SEARCHING FRIENDS WITH GROVER ALGORITHM

    In this work we address two questions concerning Grover's algorithm. In the first part we give an answer to the question on how to employ Grover's algorithm for actual search over database. We introduce a quantum model of an unordered phone book (quantum database) with programmable queries to search in the phone book either for a number or for a name. In the second part we investigate how successful the algorithm can be if the number of elements of the database is not known precisely. This question reduces to analysis of the distinguishability of states occurring during Grover's algorithm. We found that using an unambiguous discrimination scheme even a seemingly good guess that is close to the optimal one, can result in a rather small success rate.

28. **László Ruppert:** OPTIMALITY OF MUTUALLY UNBIASED BASES FOR QUANTUM TOMOGRAPHY

One could think that the optimality of Mutually Unbiased Bases (MUB) was proven by Wooters and Fields a long time ago. But in fact, they only proved that if there are $d+1$ bases in a d-dimensional quantum system, then these will be optimal for tomography purposes if they are mutually unbiased. In our work we propose a more general framework with which we can calculate the estimation error for arbitrary measurement sets analytically. Using this we prove the optimality of MUB measurements in a much more general setting. We also provide some other applications, by comparing the efficiency of the most popular methods in two, four and in arbitrary dimensions, and connect our figure of merit to the widely used measure, fidelity.

29. **Michal Sedlák:** OPTIMAL QUANTUM LEARNING OF UNITARY CHANNELS

We address the question of quantum memory storage for quantum dynamics. In particular, we design an optimal protocol for $N \to 1$ probabilistic storage-and-retrieval of unitary channels on d-dimensional quantum systems. If we access the unknown unitary gate only N-times, the optimal success probability of perfect single-use retrieval is $N/(N-1+d^2)$. The derived size of the memory system exponentially improves the known upper bound on the size of the program register needed for probabilistic programmable quantum processors. Our results are closely related to probabilistic perfect alignment of reference frames and probabilistic port-based teleportation.

30. **Georgiy Semin:** COMPARISON OF THE LOW DENSITY LIMIT AND COLLISION MODEL FOR OPEN QUANTUM DYNAMICS.

The low-density limit is a common fully quantum description of Markovian open dynamics for a system interacting with a diluted gas. If the motion of gas particles can be treated as classical, then the collision model in the so-called stroboscopic limit can be used as an alternative approach to the same problem. We derive corresponding master equations in both approaches and compare them for the cases of Gaussian and rectangular interaction potentials for the system and gas particles. We show that the validity of the stroboscopic limit in collision model is equivalent to the validity of the Born approximation for fast gas particles. Both approaches give the same result for gases of high temperature.

The study is supported by Russian Science Foundation under Project No. 17-11-01388.

31. **Shivang Srivastava:** ON QUANTUM SECRET SHARING PROTOCOLS OVER NOISY CHANNELS

Noise in channels exists due to the imperfection of the channel, which decreases the success probability of quantum communication. Secret Sharing protocol was developed in Cryptography to reduce the eavesdropping scenario by distributing information among candidates who only by collaboration with one another can decipher the information but not individually. Quantum Secret Sharing involves the same algorithm for Quantum Information which is more subject to noise and becomes complex to decipher when influenced by such channels. Furthermore, a protocol also requires the security analysis to know the probability of eavesdropping or information stealing. This is the starting point of my PhD and our goal is to address the security of QSS Protocols in noisy environment.

32. **David Trillo:** REMOTE TIME MANIPULATION

We find that there exist non-relativistic heralded scattering protocols that, if successful, freeze out, speed up or even reverse the free dynamics of an ensemble of quantum systems. This time warping effect is universal, i.e., it is independent of the particular interaction between the scattering particles and the target systems, or the (possibly non-Hermitian) Hamiltonian governing the evolution of the latter. We fully characterize the vectors $(T_1, ..., T_n)$ of possible time translations which we can effect on n target systems through a scattering protocol of duration T'; the core result is that time can be freely distributed between the systems, and reversed at a small cost. For high n, our protocols allow one to quickly send a single system to its far future or past.

33. **Shih-Xian Yang:** MULTIPARTITE BELL-INEQUALITY VIOLATION USING RANDOMLY CHOSEN TRIADS

We consider the problem of demonstrating non-Bell-local correlations by performing local measurements in randomly chosen triads on a multipartite Greenberger-Horne-Zeilinger state. Our numerical results up to the 8-partite scenario suggest that if each triad is randomly, but uniformly chosen according to the Haar measure, one always (except possibly for a set of measure zero) finds Bell-inequality-violating correlations. In fact, a substantial fraction of these is even sufficient to exhibit various higher-order entanglement. Equivalently, these quantum violations appear to be fairly resistant to white noise, indicating that such a device-independent demonstration of high-order entanglement can in principle be performed in an experimental situation without sharing a global reference frame.

34. **Shenggen Zheng:** SYMMETRIC BOOLEAN FUNCTIONS COMPUTED BY EXACT ONE QUERY QUANTUM ALGORITHM

The well-known Deutsch-Jozsa promise problem can be seen as an N-bit partial symmetric Boolean function DJ defined as: DJ(X)=1 for $|X|$=N/2, DJ(X)=0 for $|X|$ is 0 or N, and it is undefined for the rest cases, where N is even, $|X|$ is the Hamming weight of X. Deutsch and Jozsa proved that the promise problem can be computed by one exact quantum query algorithm. A natural question is what common characters are for the Boolean functions with the same exact quantum query complexity? In this paper, we prove that any partial symmetric Boolean function f has exact quantum 1-query complexity if and only if f can be computed by the Deutsch-Jozsa algorithm.

Invited talks

1. **Daniel Cavalcanti:** Statistical Mechanics of Quantum Communication Networks
2. **Jens Eisert:** Towards closing the loopholes of showing a quantum advantage
3. **Teiko Heinosaari:** Heisenberg meets Galois — a structural viewpoint to noise and disturbance
4. **Mária Kieferová:** Simulating the dynamics of time-dependent Hamiltonians with a truncated Dyson series
5. **Alexander Müller-Hermes:** When Do Composed Maps Become Entanglement Breaking?
6. **Marcin Pawlovski:** Old and new results on the number of mutually unbiased bases

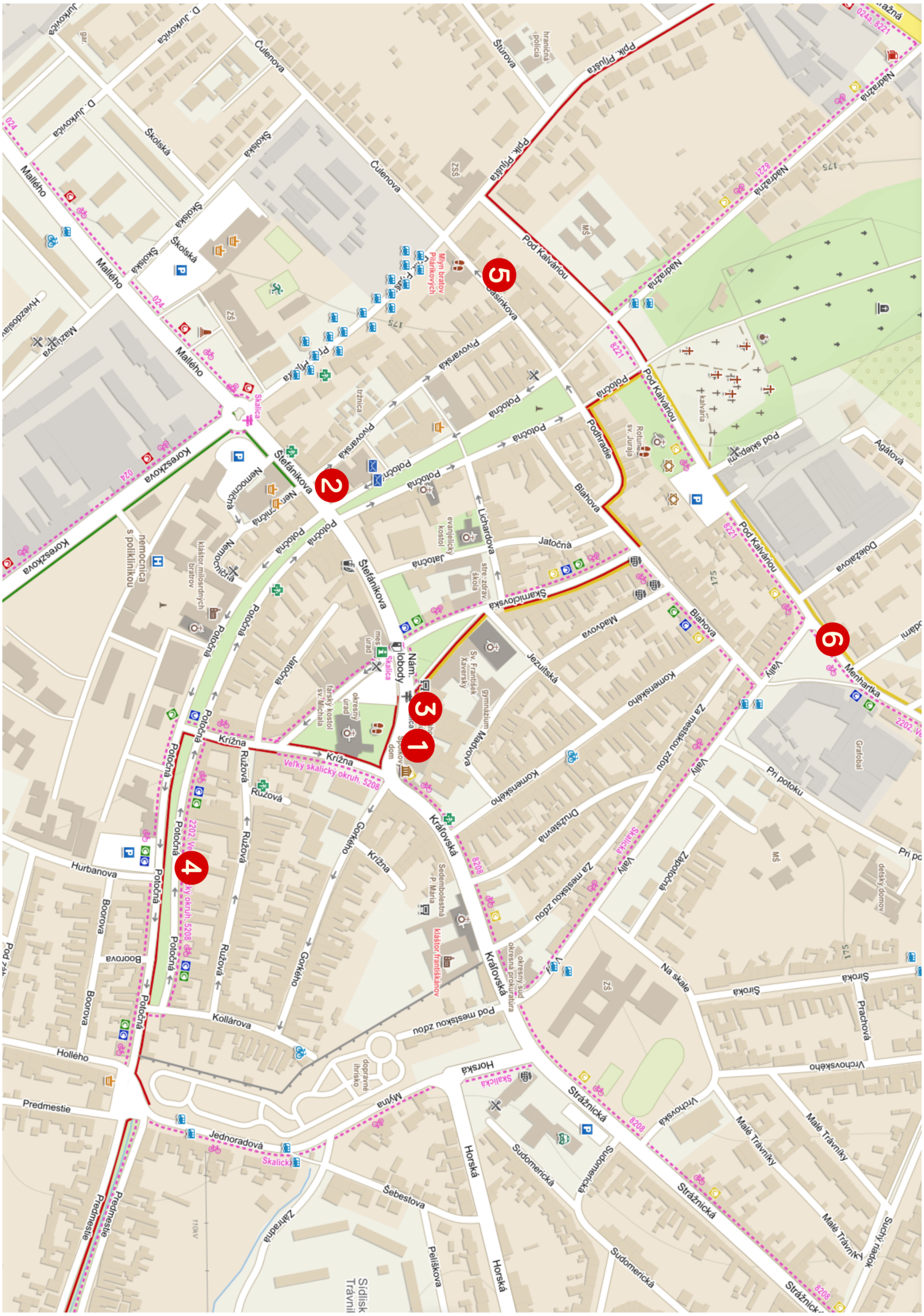
Contributed talks

1. **Costantino Budroni:** Memory cost of temporal correlations
2. **Libor Caha:** Very entangled spin chains and combinatorial techniques in condensed matter physics
3. **Anubhav Chaturvedi:** The ground of quantum communication advantage
4. **Marco Erba:** Axiomatic Construction of Probabilistic Theories, and a simplicial theory with entanglement
5. **Felix Huber:** Exponentially many monogamy and correlation constraints for multipartite states
6. **Jędrzej Kaniewski:** A weak form of self-testing
7. **Aleksander M. Kubicki:** Resource Quantification for the No-Programming Theorem
8. **Nikolai Miklin:** Self-testing of unsharp measurements
9. **Amit Mukherjee:** Uncertainty principle as a postquantum nonlocality witness for the continuous-variable multimode scenario
10. **Miguel Navascues:** Coarse-graining classical and quantum networks
11. **Michał Oszmaniec:** Operational relevance of resource theories of quantum measurements
12. **Łukasz Pawela:** POVM discrimination
13. **Gael Sentís:** Unsupervised classification of quantum data
14. **Roope Uola:** Quantifying quantum resources with conic programming
15. **Mirjam Weilenmann:** Analysing causal structures in generalised probabilistic theories

Posters

1. **Edgar Aguilar:** Simple Testable Random Number Generator
2. **Fabian Bernards:** Searching for a generalization of the I3322 Bell inequality
3. **Konstantin Beyer:** When is a Szilárd engine really quantum?
4. **Shin-Liang Chen:** Robust self-testing of Pauli observables and its applications in device-independent certification of all two-qubit entangled states
5. **Benjamin Dive:** Characterisation of multi-level quantum coherence without ideal measurements
6. **Gerhard Dueck:** Efficient Design of Quantum Circuit for IBM's QX Architectures
7. **Máté Farkas:** On the different measures of incompatibility robustness
8. **Artem Glinov:** Quantitative description of correlations accompanying non-Markovian quantum dynamics under mixing of Markovian processes
9. **Waldemar Klobus:** On *k*-uniform mixed states
10. **Aleksandra Krawiec:** Majorization uncertainty relations for mixed quantum states
11. **Ryszard Kukulski:** Generating random quantum channels
12. **Leevi Leppäjärvi:** No-free-information principle in general probabilistic theories
13. **Paulina Lewandowska:** Benchmarking and comparison of the Rigetti and IBM Q quantum architectures
14. **Jyun-Yi Li:** Hidden teleportation power for entangled quantum states
15. **Keren Li:** Optimizing a Polynomial Function on a Quantum Simulator
16. **Pei-Sheng Lin:** Exploring Bell inequalities for the device-independent certification of multipartite entanglement depth
17. **Marcin Łobejko:** Quantum circuit heat engine
18. **Filip Maciejewski:** Mitigation of readout noise by classical post-processing based on Quantum Detector Tomography
19. **Esteban Martínez Vargas:** Certified Answers for ordered quantum discrimination problems
20. **M. Hamed Mohammady:** Conditional work statistics of quantum measurements
21. **Nikolajs Nahimovs:** Lackadaisical quantum walks with multiple marked vertices
22. **Jaroslav Pavličko:** Equivalence of programmable quantum processors
23. **Martin Plávala:** Quantum and classical implementations of the Popescu-Rohrlich box correlations
24. **Václav Potoček:** Using multi-objective evolutionary algorithms for quantum circuit discovery
25. **Zbigniew Puchała:** All quantum measurements can be simulated using projective measurements and postselection
26. **Peter Rapčan:** The effective system size and the central charge of some CFT-mappable spin chains
27. **Daniel Reitzner:** Searching friends with Grover algorithm
28. **László Ruppert:** Optimality of Mutually Unbiased Bases for Quantum Tomography
29. **Michal Sedlák:** Optimal quantum process storing-and-retrieving protocols
30. **Georgiy Semin:** Comparison of the low density limit and collision model for open quantum dynamics.ť
31. **Shivang Srivastava:** On quantum secret sharing protocols over noisy channels
32. **David Trillo:** Remote time manipulation
33. **Shih-Xian Yang:** Multipartite Bell-inequality violation using randomly chosen triads
34. **Shenggen Zheng:** Symmetric Boolean functions computed by exact one query quantum algorithm

27\. **Mário Ziman:** Searching friends with Grover algorithm



Points of interest:

(1) Skalica culture center (conference venue)
(2) St. Michael Hotel
(3) Hotel Tatran
(4) Guest-house Potočná
(5) Masaryk winery
(6) Route to the docks