List of Talks

- **Speaker:** Riccardo Roma
  Title: Intro QED-circuit
  Abstract: tba

- **Speaker:** Lars Lauer
  Title: Intro Non-local games
  Abstract: In this talk we introduce the definition of non-local games and show on the basis of the CHSH game why quantum strategies are better than classical strategies.

- **Speaker:** Alexander Frei
  Title: Nonlocal games and group algebras
  Abstract: We begin with a quick introduction to nonlocal games and their strategies given in terms of quantum correlations, and elaborate the concepts at the example of the famous CHSH game (after Clauser–Horne–Shimony–Holt). After this swift introduction we reformulate the previously defined quantum correlations as state space of certain free groups, which serves as a common universal setting. This description allows in turn to compare strategies in a representation-free way that further reduces to well-known self-testing results. We will moreover find here how quotients come into play when comparing strategies and showcase a first such result at the CHSH game introduced above.

- **Speaker:** Anurag Saha Roy
  Title: Calibration and characterisation of superconducting qubits
  Abstract: tba

- **Speaker:** Pierre Botteron
  Title: Nonlocal boxes and communication complexity
  Abstract: The famous CHSH game displays strict demarcations between three canonical families of correlations known as classical, quantum and non-signalling. Although Alice and Bob cannot win more

than 75% of the time in the classical case (Bell's Inequality), they can outperform this limit as long as they are provided with quantum correlations and thereby reach Tsirelson's Bound ≈ 85%. Doing even better, post-quantum strategies, formalized with non-local boxes, can win with up to 100% probability, yet without violating non-signalling axiom (no fasterthan- light communication). This tells that Quantum Mechanics is not fully singled out by (1) the non-signalling axiom and (2) non-locality, which led Popescu and Rohrlich to raise a question in 1994: what could be missing axioms?—5— Among many attempts, communication complexity is conjectured to provide an answer: as opposed to quantum correlations which are known to induce non-trivial communication complexity, some post-quantum boxes are shown to render it trivial. To this day, the question is still open, and in the present report, after making a detailed historical overview, we provide a new partial answer. We propose a new approach to distillation with what we call the algebra of boxes and orbit of a box, which leads to disclosing new trivial areas, some numerically and others explicitly.

- **Speaker:** Oufkir Aadil
  Title: Selected topics of quantum learning
  Abstract: Learning quantum systems is crucial for quantum control, optimisation and computing. In this mini lecture, we'll explore some fundamental learning problems of quantum systems including quantum state discrimination, quantum state certification, tomography, shadow tomography and possibly learning quantum Pauli channels. For each of these problems, we can characterise the optimal copy complexity up to constant when the measurements are independent and non adaptive. For this, we'll cover random measurements constructed from Haar distribution for the upper bounds and Le Cam and Fano's methods for the lower bounds.

- **Speaker**: Nicolas Faroß
  Title: Intro Quantum Algorithm
  Abstract: We begin with the basics of quantum algorithms and show how these can be constructed from simple building blocks called quantum gates. In the second part, we take a look at Grover's algorithm, which outperforms classical algorithms at searching in unstructured

data.

- **Speaker**: Padraig Daly
  Title: Maps on the space of quantum channels
  Abstract: Quantum superchannels are maps whose input and output are completely positive trace preserving (CPTP) maps. Rather than taking the domain to be the space of all linear maps I motivate and state a new definition of superchannel acting on the operator system spanned by CPTP maps. Arvesons extension theorem allows us to show that a Stinespring-like characterisation theorem for superchannels applies to this class of maps. I then discuss some implications of this new approach and how it differs from the usual definition.

- **Speaker**: Junichiro Matsuda
  Title: Spectral approaches to quantum graphs and applications to quantum information
  Abstract: Motivated by quantum information theory (QIT), the notion of quantum graphs was introduced in the early 2010s, and it has developed in the interactions between QIT, operator algebra theory, quantum group theory, etc. A quantum graph is a non-commutative analogue of a classical graph, which appears as the confusability graph $\mathrm{span}\{K_i^\dagger K_j\}_{i,j}$ of a quantum channel $\Phi = \sum_j K_j(\cdot)K_j^\dagger$ in QIT. I will give a brief introduction to quantum graphs and show recent results and applications to QIT.

- **Speaker**: Akihiro Miyagawa
  Title: Fock spaces and free probability
  Abstract: I will briefly introduce full Fock space and explain its relation to free semicircular elements which are central objects in free probability. After that, I will explain the q-Fock space as a deformation of the full Fock space and talk about my research.

- **Speaker**: Azin Shahiri
  Title: The Tilted CHSH games: quantum values and strategies a systematic classification
  Abstract: In this talk we give a complete and systematic classification

of the so-called family of tilted CHSH games, which define a parametric generalisation of the classical CHSH game.
We begin for this with a classical result about the universal C*-algebra generated by a pair of projections. We recast this result in terms of their order-two unitaries and uncover this way a previously unknown description in terms of their anticommutation, which gives a meaningful interpretion of its representation theory.
With this at hand, we then get to introduce the tilted CHSH games in terms of their bias polynomial. The description from above then allows us to reduce the computation of their quantum value to a simple optimization problem. The solution to the optimisation problem allows us then to reveal the regions solved by quantum versus classical strategies and the symmetries inherent in the class of tilted CHSH games (as opposed to the mentioned in Ac´ın–Massar–Pironio). We then move on to the classification of optimal quantum strategies for the tilted CHSH games. Using the optimal parameters found above, the computation of optimal quantum strategies reduces to a simple matrix problem.
As a result we find unique solutions in terms of entire states on certain group algebras (as suggestively introduced in another talk by the coauthor) and determine those regions with partial entanglement versus those requiring maximal entanglement. We finally present these in terms of their correlation tables on group generators. This gives a representation-free description and which eliminates all ambiguity (as opposed to self-testing).

- **Speaker**: Katsunori Fujie
  Title: The spectra of random matrices and free probability
  Abstract: Free probability theory was a mathematical branch initiated by D. V. Voiculescu in 1980's to tackle the famous open problem in operator algebra, that is called free group factor isomorphism problem. One of the successful growth of free probability is the application to random matrix theory. In this talk, I will present, as a related result, that the eigenvalue distribution of the principal submatrix of unitary-invariant random matrix is asymptotically determined by Markov–Krein correspondence when its size is sufficiently large. If time permits, I would also like to introduce our recent results. This talk

is based on a joint-work with Takahiro Hasebe (Hokkaido University).

- **Speaker**: Atsuya Hasegawa
  Title: An optimal oracle separation of classical and quantum hybrid schemes
  Abstract: Recently, Chia, Chung and Lai (STOC 2020) and Coudron and Menda (STOC 2020) have shown that there exists an oracle $\mathcal{O}$ such that $\mathsf{BQP}^{\mathcal{O}} \neq (\mathsf{BPP}^{\mathsf{BQNC}})^{\mathcal{O}} \cup (\mathsf{BQNC}^{\mathsf{BPP}})^{\mathcal{O}}$. In fact, Chia et al. proved a stronger statement: for any depth parameter d, there exists an oracle that separates quantum depth d and $2d+1$, when polynomial-time classical computation is allowed. This implies that relative to an oracle, doubling quantum depth gives classical and quantum hybrid schemes more computational power. In this talk, we show that for any depth parameter d, there exists an oracle that separates quantum depth d and $d+1$, when polynomial-time classical computation is allowed. This gives an optimal oracle separation of classical and quantum hybrid schemes. To prove our result, we consider d-Bijective Shuffling Simon's Problem (which is a variant of d-Shuffling Simon's Problem considered by Chia et al.) and an oracle inspired by an "in-place" permutation oracle.