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Physikalisches Kolloquium

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MC 122 und Zoom

https://uni-due.zoom-x.de/j/64228670246?pwd=RjVQeFNIUkRKRkpiNVpKYXhJaFNLdz09 (gilt für alle Vorträge)

Finding Neuromorphic Advantage in Quantum Magnetism

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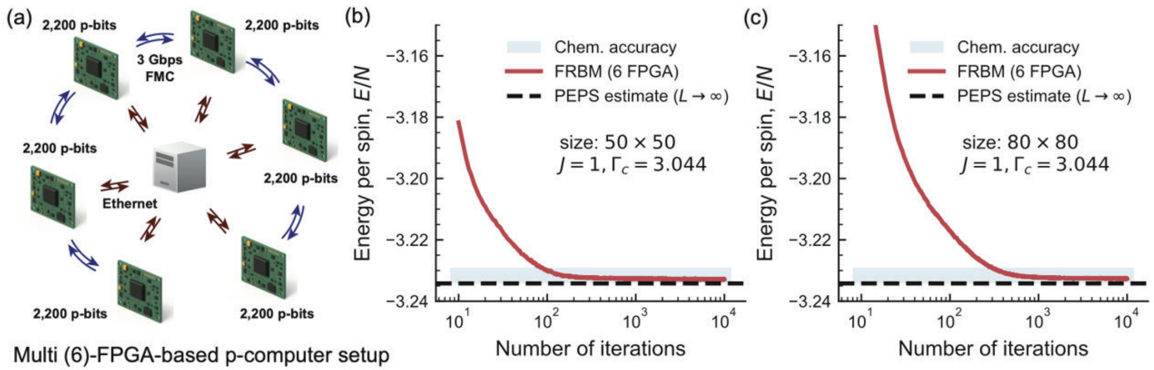

Figure: Multi-FPGA results for large-scale neural quantum states. (a) Six-FPGA probabilistic computer with boards coordinated over Ethernet; each FPGA hosts up to 2200 probabilistic bits. (b) Training convergence for a 50 ×50 lattice (2500 spins) at the quantum critical point Γc/J = 3.044, where J is the exchange interaction. (c) Same for an 80 ×80 lattice (6400 spins), showing empirically that convergence within chemical accuracy (blue shaded region) is maintained as system size increases. The dashed line indicates a PEPS benchmark at the thermodynamic limit.

Neuromorphic computing promises much faster and much more energy-efficient computations with applications domains spanning the whole compute continuum. Nevertheless, rather little is known about applications of neuromorphic computing in computational physics such as the simulation of magnetic materials. In this talk we present our results on exploring and benchmarking neuromorphic computing for probabilistic simulations of quantum magnetism. Extending on early explorations with in-memory computing [1], we explore potential advantage of probabilistic computers [2] for quantum simulations of magnetic systems with neural-network quantum states (NQS). We find that the massively parallel nature of neuromorphic hardware offers important scaling advantages over existing digital hardware for the costly Monte Carlo sampling. Interestingly, we find that this advantage can be predicted based on knowledge of the autocorrelation time of the sampling algorithm. This allows us to estimate orders of magnitude faster and more energy-efficient variational quantum Monte Carlo simulations of quantum Heisenberg models [3]. Moreover, we present the results of an NQS implementation for a probabilistic computer on field programmable gate arrays (FPGAs) [4]. For the two-dimensional transverse-field Ising model at criticality, we obtain accurate ground-state energies for lattices up to 80 × 80 (6400 spins) using a custom multi-FPGA cluster. Furthermore, we introduce a dual-sampling algorithm to train deep Boltzmann machines, replacing intractable marginalization with conditional sampling over auxiliary layers. Finally, beyond existing neuromorphic paradigms, we show that even better scaling is in reach by adopting new magnetic device concepts, specifically those harnessing Brownian skyrmion dynamics [5]. Our results open a path to find neuromorphic computational advantage in probabilistic quantum simulation of quantum magnets and suggest high potential to break existing computational barriers for selected computational science problems in general.

References

[1] D. J. Kösters, et al. APL ML 1, 016101 (2023), [2] S. Niazi et al., Nat Electron 7, 610–619 (2024), [3] R.J.L.F. Berns, Phys. Rev. Applied 25, 024085 (2026)
[4] S. Chowdhury, et al., arXiv:2512.24558 (2025), [5] Th. Winkler et al., arXiv:2508.19623 (2025)