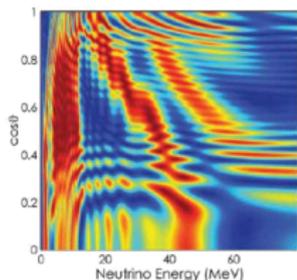
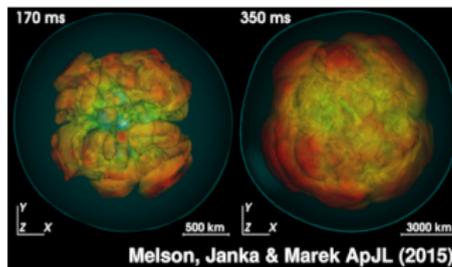
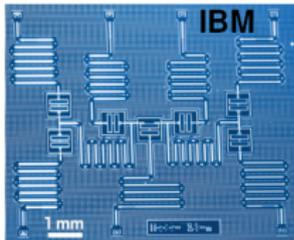


# Quantum Simulation of Collective Neutrino Oscillations

Alessandro Roggero



Duan et al. (2006)

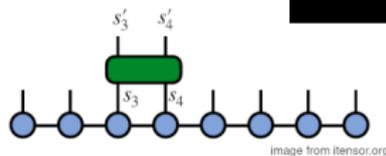
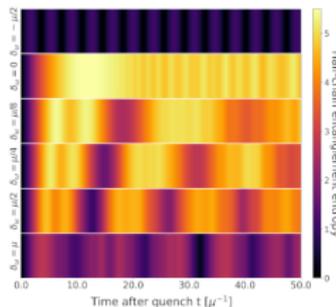
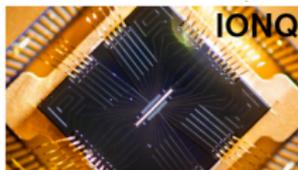


image from itensor.org

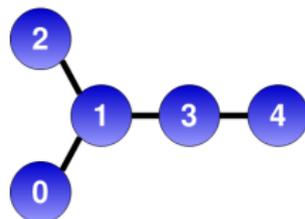


Zoom – 21 February, 2025



# Quantum simulation of collective neutrino oscillations

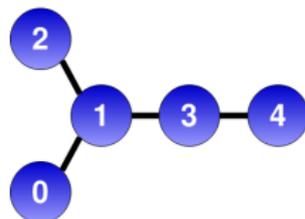
$$H = \sum_i \omega_i \vec{B} \cdot \vec{\sigma}_i + \frac{\mu}{2N} \sum_{i < j} J_{ij} \vec{\sigma}_i \cdot \vec{\sigma}_j$$



- with only 2 flavors direct map to spin 1/2 degrees of freedom (qubits)
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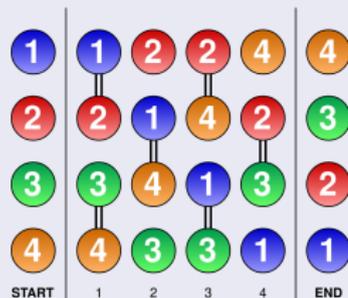
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## SWAP network

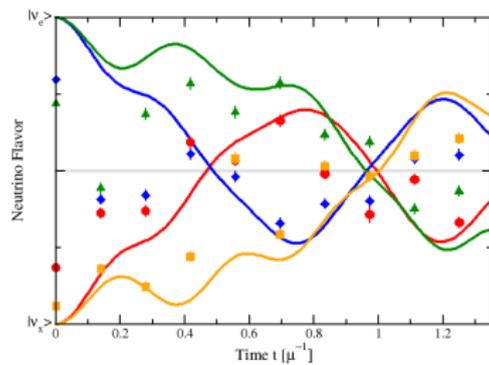


- SWAP qubits every time we apply time-evolution to neighboring terms
- in  $N$  steps we perform full evolution using only  $\binom{N}{2}$  two qubit gates
  - NOTE: final order will be reversed

Kivlichan et al. PRL (2018)

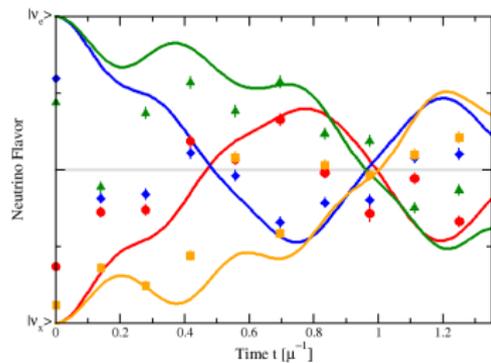
B.Hall, AR, A.Baroni, J.Carlson PRD(2021)

# N=4 on IBM (2021)



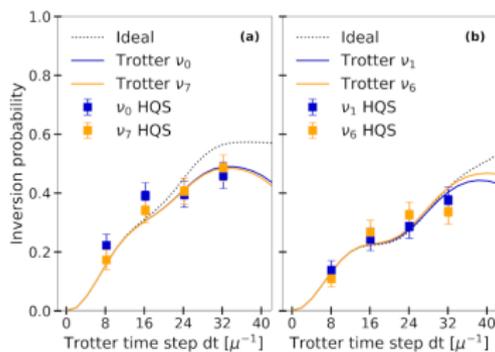
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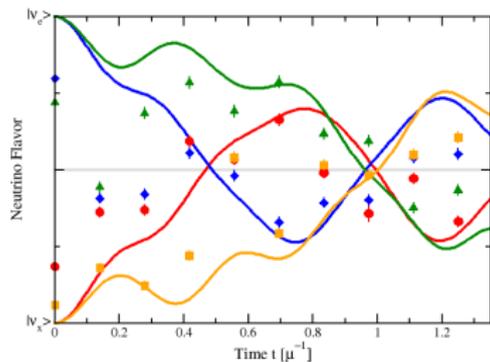
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## N=8 on Quantinuum (2023)



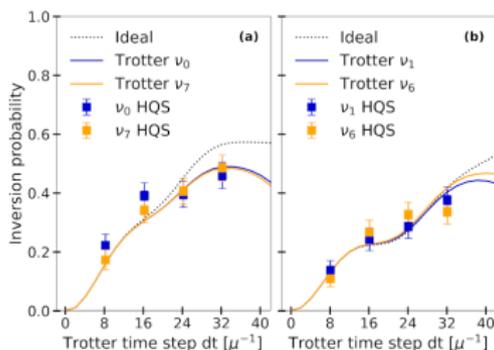
V.Amitrano et al. PRD(2023)

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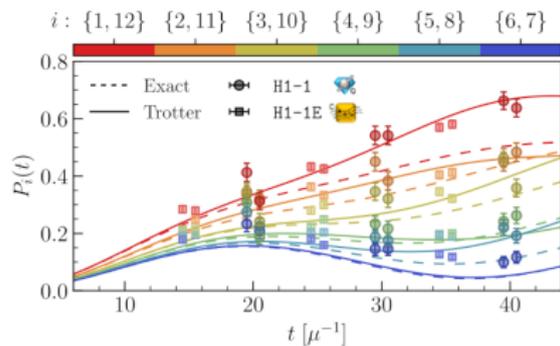
B.Hall et al. PRD(2021)

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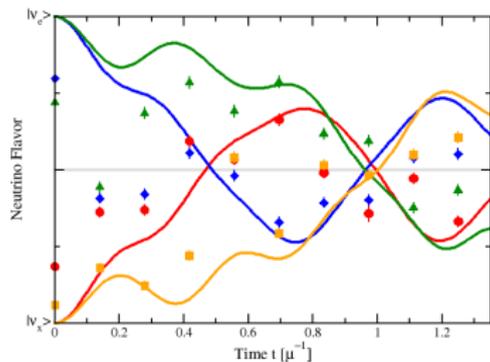
V.Amitrano et al. PRD(2023)

## N=12 on Quantinuum (2023)



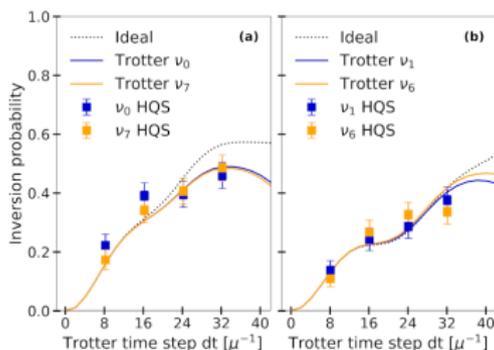
Illa & Savage PRL(2023)

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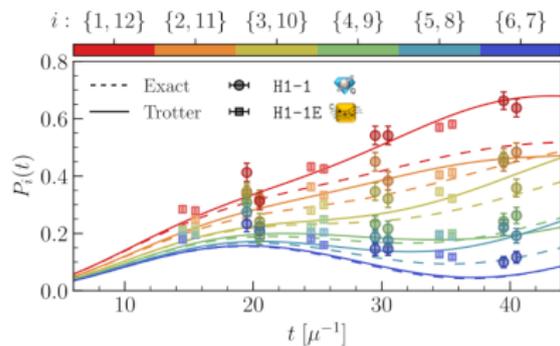
B.Hall et al. PRD(2021)

## N=8 on Quantinuum (2023)



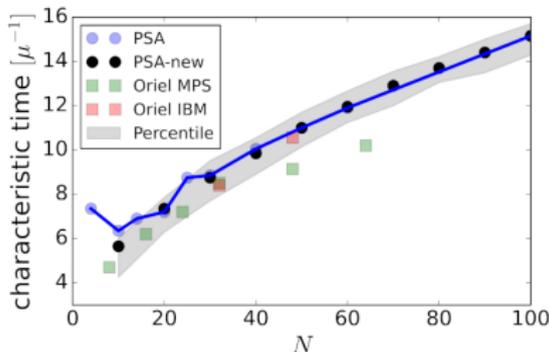
V.Amitrano et al. PRD(2023)

## N=12 on Quantinuum (2023)



Illa & Savage PRL(2023)

## N ≥ 48 on IBM (now)



O.Kiss et al. (coming soon)

# Opportunities for QUART&T

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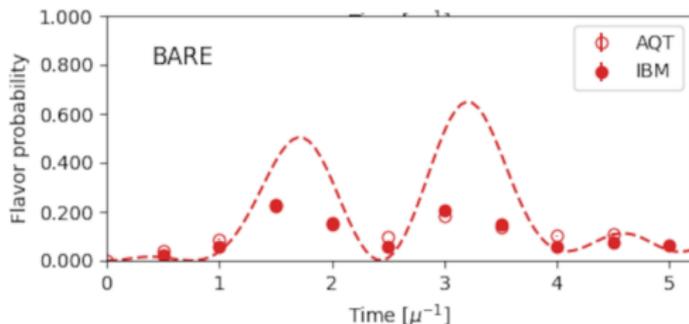
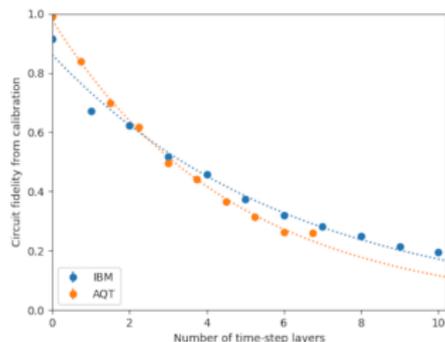
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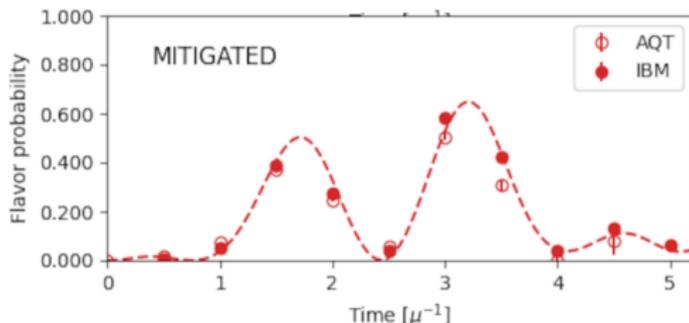
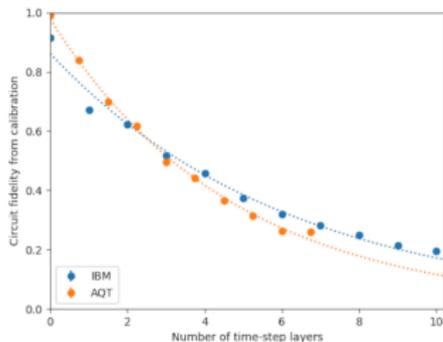
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