

# Quantum Computing Applications

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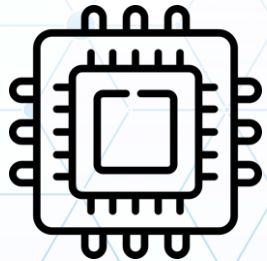


# Getting to the first quantum applications

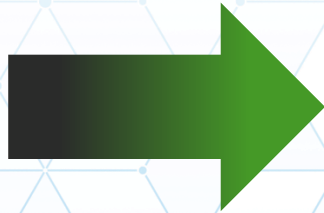


Hardware Manufacturers

Algorithms/Software developers



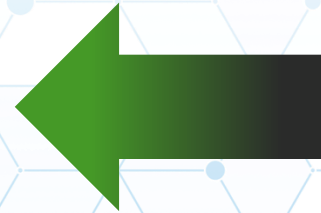
More qubits



Better qubits

Quantum Applications

Less resources



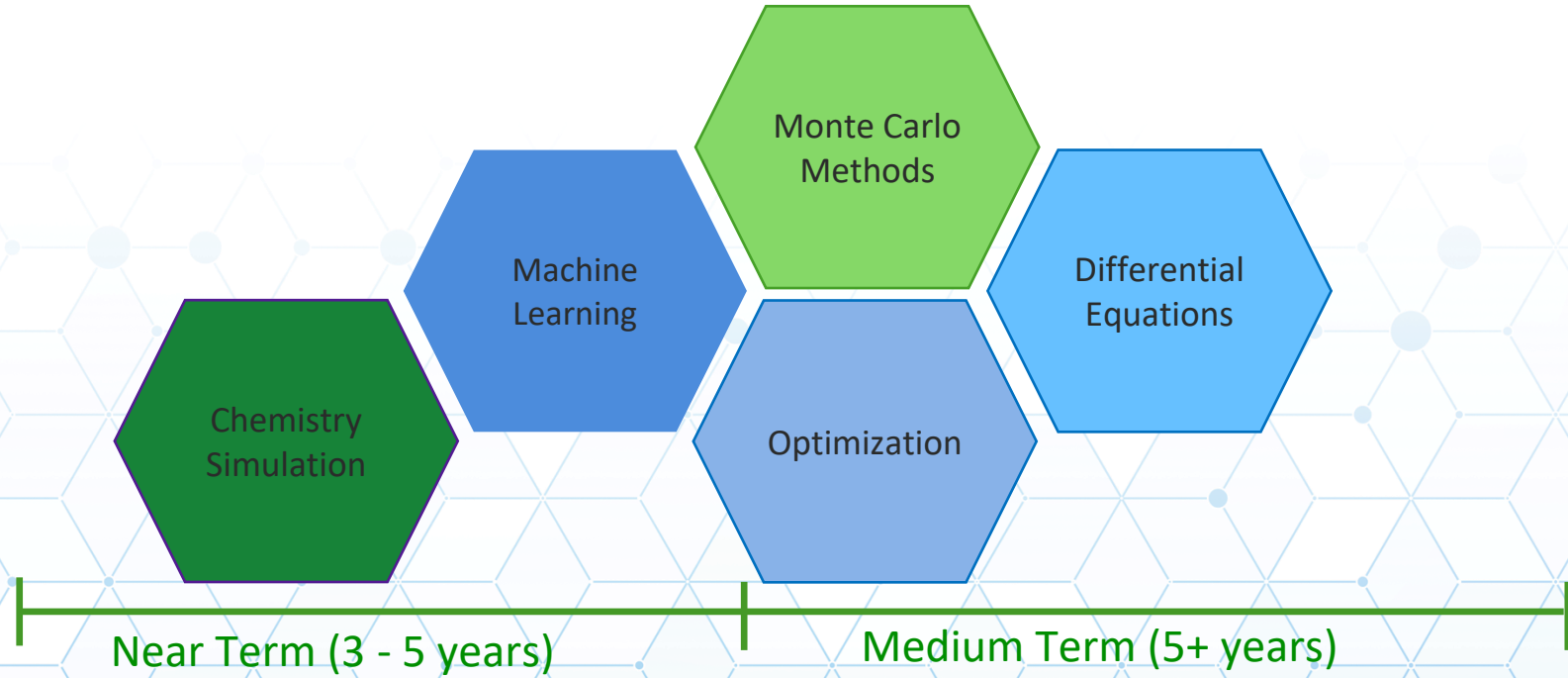
Better performance



# Why Quantum Algorithms?

- Quantum is **NOT** a faster processor
- Quantum is a fundamentally **DIFFERENT** way of performing computation that can be **MUCH FASTER** for **CERTAIN** tasks
- Quantum computing will NOT replace classical HPC computing, but we expect it to remove bottlenecks and open the way to new applications
- We need to rethink and invent new algorithmic solutions

# We focus on hard computing problems



# Demonstration of quantum classifier



MNIST digits



Quantum algorithm/software



Quantum computer



**First ever 10—class classification on a quantum computer!**

[nature.com/articles/s41534-021-00456-5](https://www.nature.com/articles/s41534-021-00456-5)

**Quantum Accuracy: 77.50%**

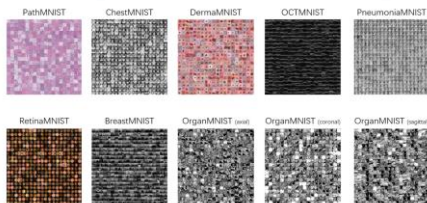
Target Class	0	1	2	3	4	5	6	7	8	9
0	84.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1	5.3%	81.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	26.1%
2	1.1%	9.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	6.4%
3	0.0%	0.0%	73.7%	4.2%	4.8%	13.6%	0.0%	0.0%	0.0%	4.3%
4	0.0%	0.0%	1.1%	1.1%	3.0%	0.0%	0.0%	0.0%	0.0%	1.1%
5	0.0%	0.0%	5.3%	62.5%	0.0%	0.0%	4.5%	0.0%	0.0%	4.3%
6	0.0%	0.0%	1.1%	15.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	0.0%	9.1%	0.0%	16.7%	95.2%	0.0%	0.0%	0.0%	0.0%	0.0%
8	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%	96.4%	0.0%	0.0%	4.3%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	19.1%	94.7%	5.0%	4.3%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	18.1%	1.1%	1.1%
9	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%	0.0%	0.0%	80.0%	8.7%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	89.1%	0.0%
9	0.0%	0.0%	2.4%	0.0%	0.0%	0.0%	1.1%	0.0%	2.9%	9.1%
Output Class	0	1	2	3	4	5	6	7	8	9



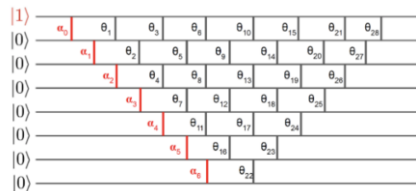
# Quantum neural networks for medical images



Medical images



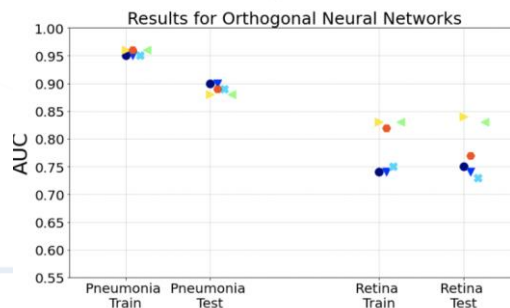
Quantum neural network



IBM Quantum computer



**Faster training and more explainable models for medical diagnosis**  
arXiv:2109.01831



# Demonstration of quantum Monte Carlo

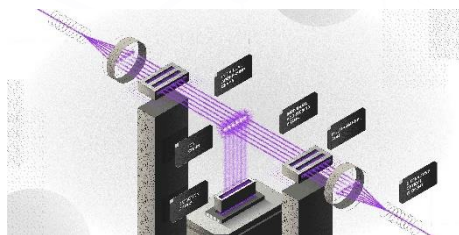


arXiv:2109.09685

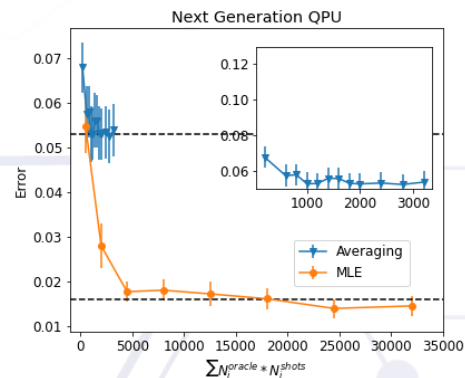
Novel algorithms

```
q : |0>|2>|3>|4>|5>|6>|7>|8>|9>
q0 : -X-B-B-Z-B-B-B-B-B-B-
q1 : ---S---S---S---S---
q2 : ---S---S---S---S---
q3 : ---S---S---S---S---
T : |0>|2>|3>|4>|5>|6>|7>|8>|9>
T : |0>|1>|2>|3>|4>|5>|6>|7>|8>|9>|10>|11>|12>|13>|14>|15>
q0 : -X-B-B-Z-B-B-B-B-B-B-Z-B-B-B-
q1 : ---S---S---S---S---S---S---
q2 : ---S---S---S---S---S---S---
q3 : ---S---S---S---S---S---S---
T : |0>|1>|2>|3>|4>|5>|6>|7>|8>|9>|10>|11>|12>|13>|14>|15>
T : |0>|1>|2>|3>|4>|5>|6>|7>|8>|9>|10>|11>|12>|13>|14>|15>|16>|17>|18>|19>|20>|21>
q0 : -X-B-B-Z-B-B-B-B-B-B-Z-B-B-B-Z-B-B-B-
q1 : ---S---S---S---S---S---S---S---S---
q2 : ---S---S---S---S---S---S---S---S---
q3 : ---S---S---S---S---S---S---S---S---
T : |0>|1>|2>|3>|4>|5>|6>|7>|8>|9>|10>|11>|12>|13>|14>|15>|16>|17>|18>|19>|20>|21>
```

State-of-the-art hardware



Results



I. Kerenidis, @ EPIC Quantum Computing Platforms

# Prospects - Challenges

- Powerful yet **subtle** quantum tools

- Promising research directions

- Machine Learning, Monte Carlo simulations, Optimization, Chemistry simulations

- Final remarks

- Quantum computing is about practical solutions to real-world problems.
- We need to focus on finding these applications and build the hardware we need