Quantum device measurement and tuning using machine learning

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Liuqi Yu

(University of Basel)

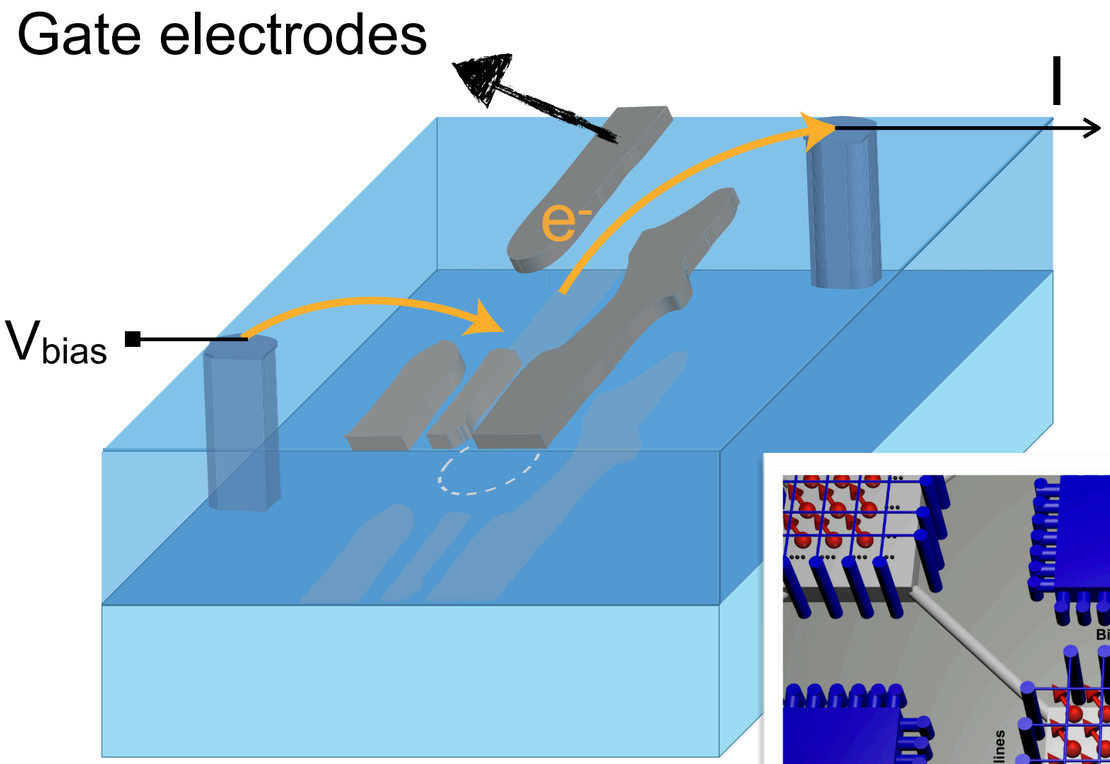
Machine learning:

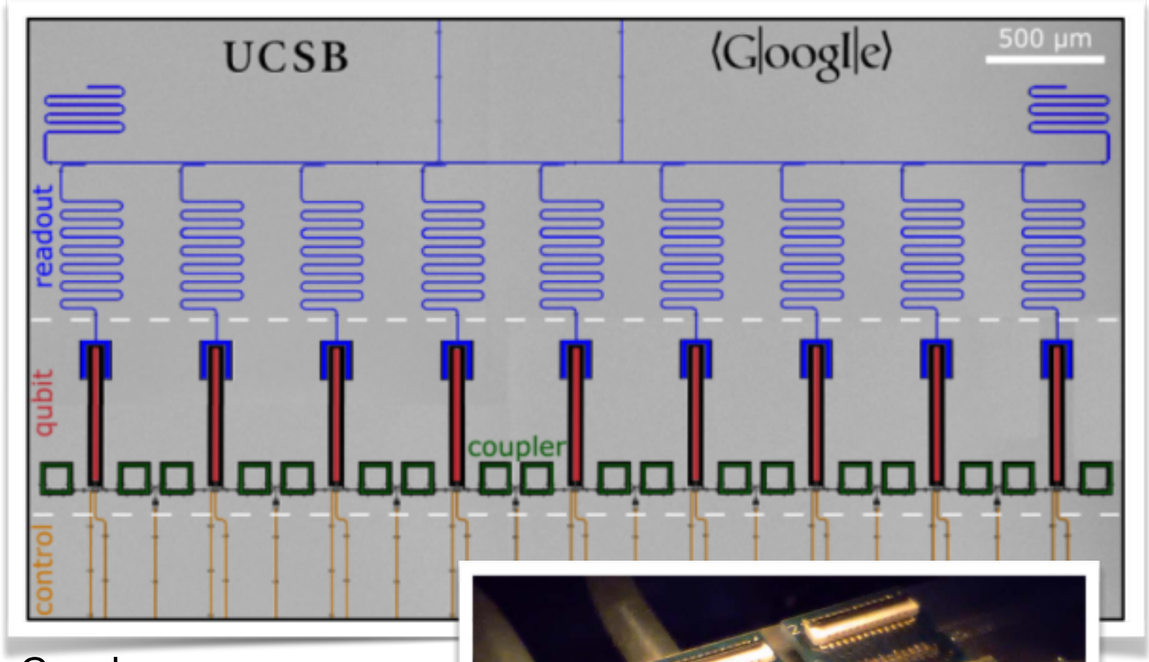
M. Osborne

H. Moon

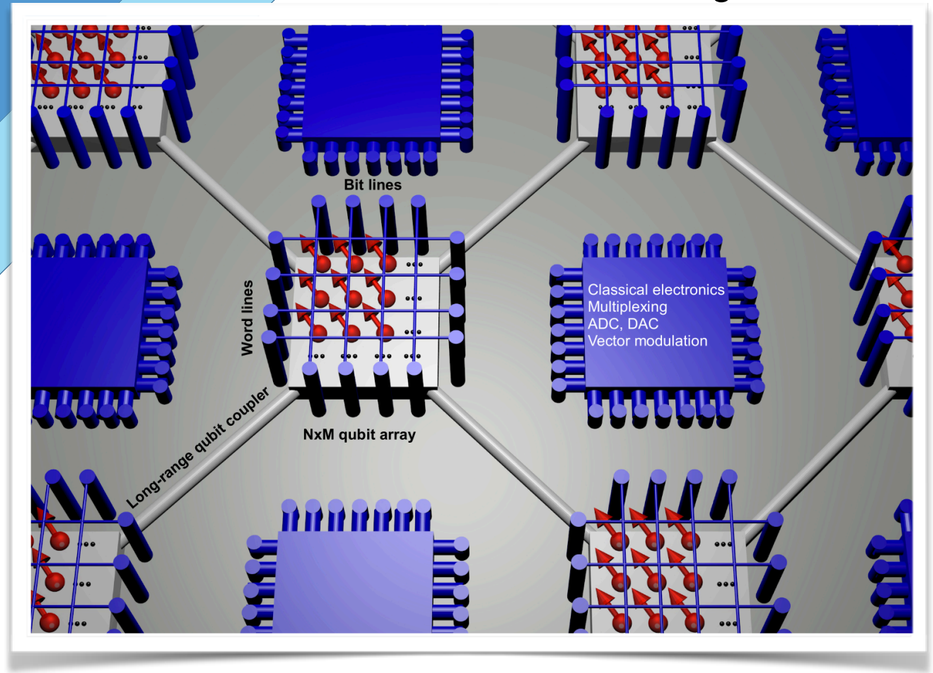
V. Nguyen

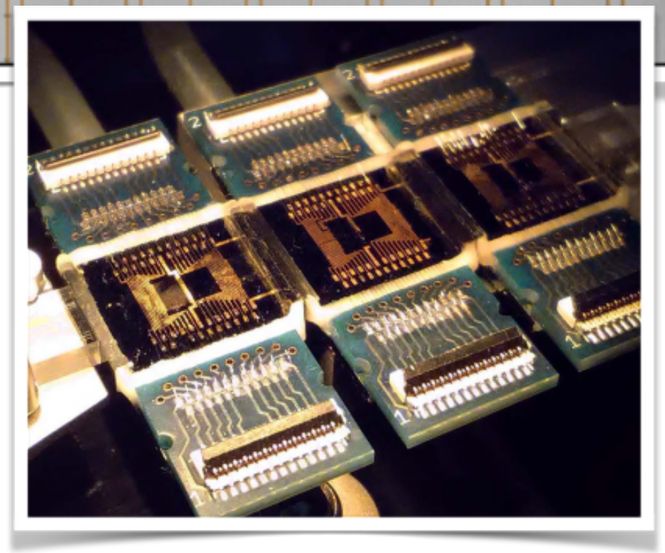
Quantum devices





Google





NQIT, Oxford

Vandersypen, L. M. K. *et al*. *npj Quantum Inf*. **3,** 34 (2017)

Measurement and tuning

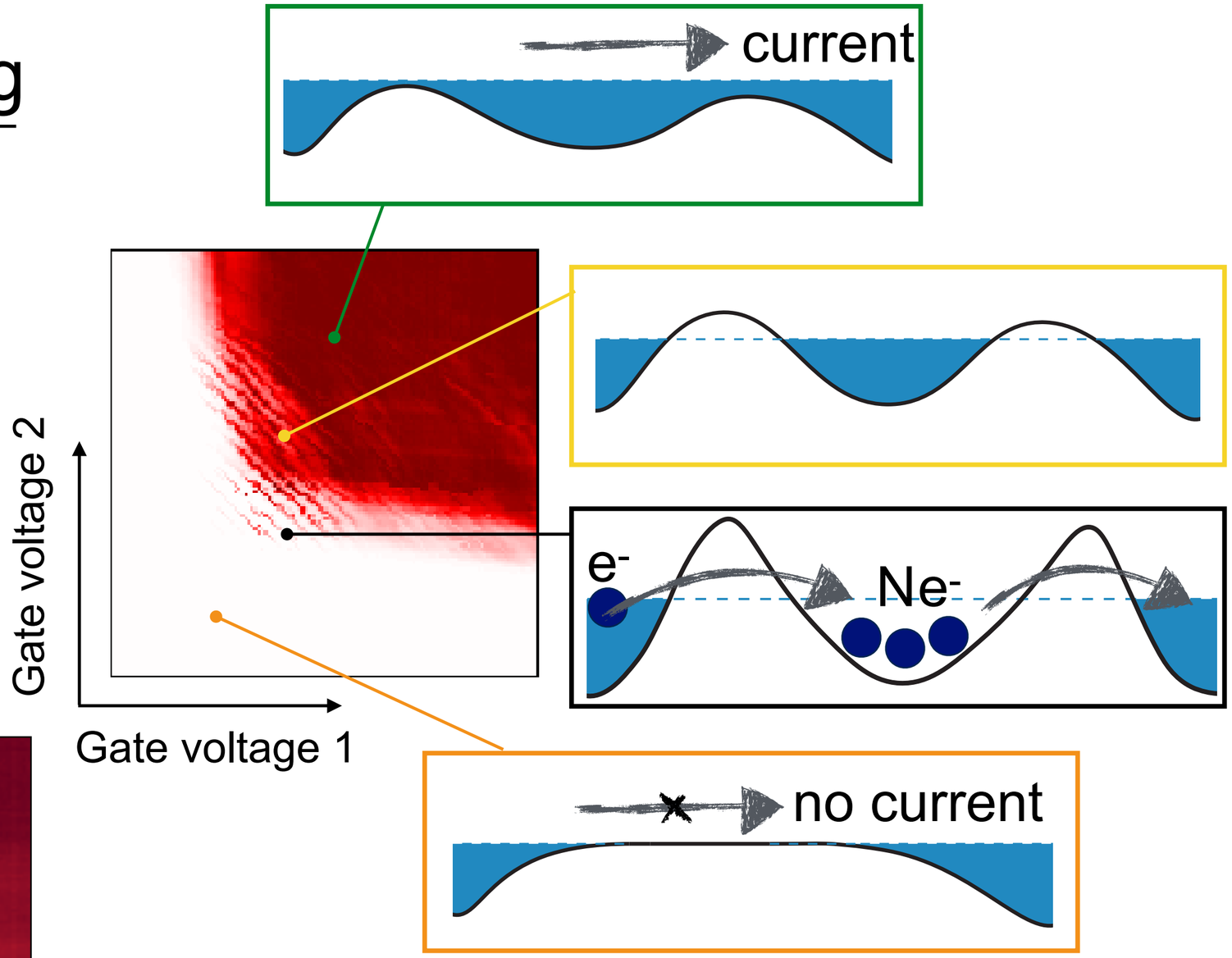
1 qubit (4 gates)

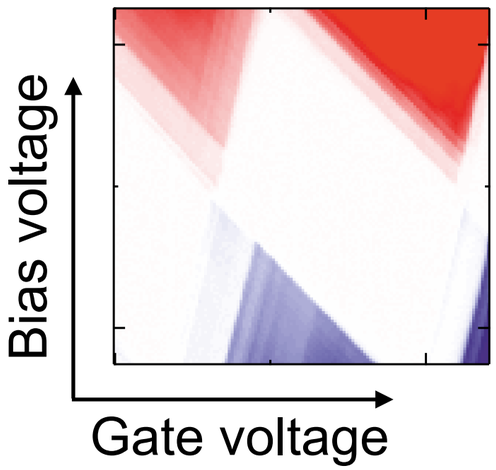
↓

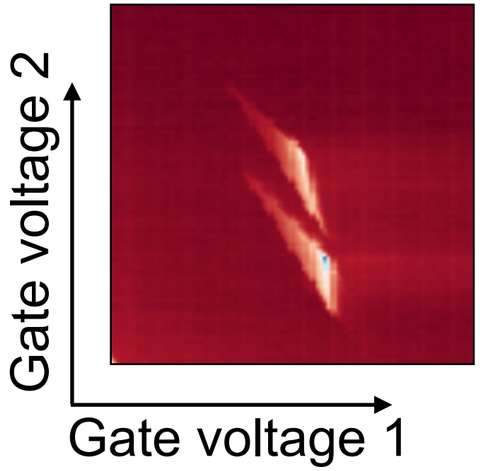
4 x10^{12} points

↓

127 years

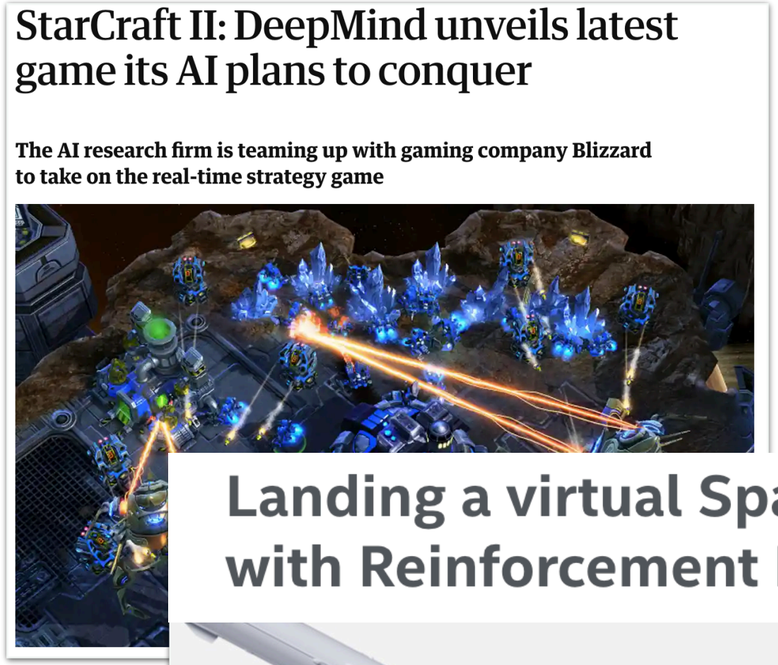






How to automate the measurement and tuning of quantum devices?

The AI revolution



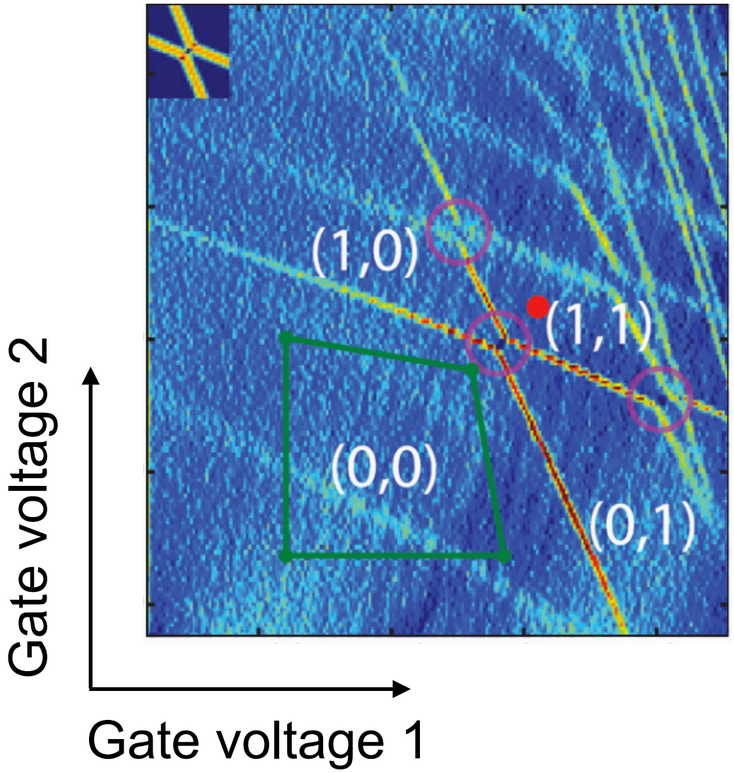
StarCraft II: DeepMind unveils latest game its AI plans to conquer

The AI research firm is teaming up with gaming company Blizzard to take on the real-time strategy game

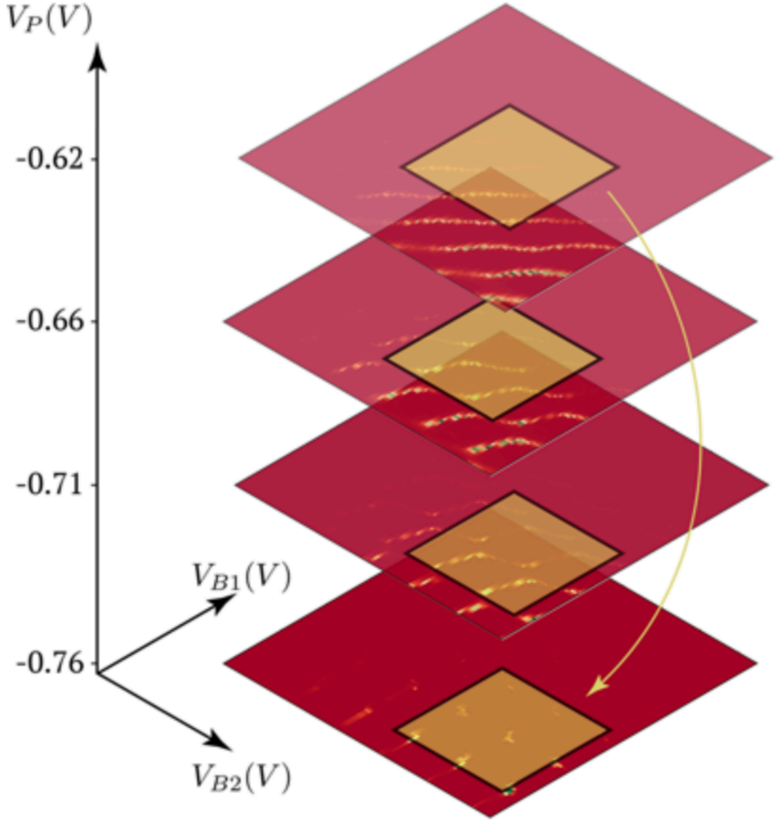
Big data
Massive computer power
Powerful algorithms

Automated tuning

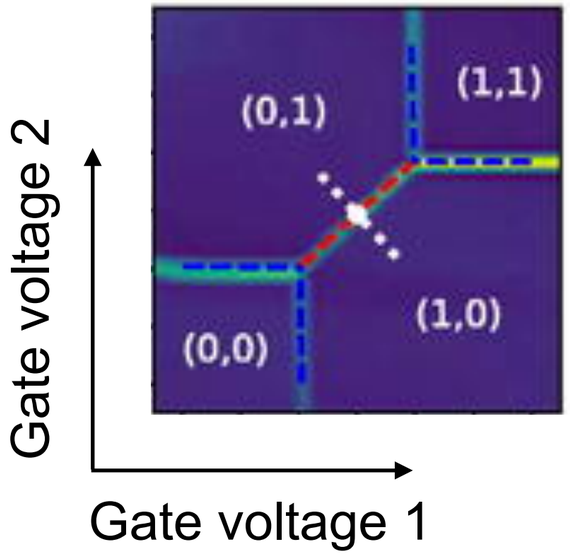
Baart, T. A. *et al. Appl. Phys. Lett.* **108,** 213104 (2016)



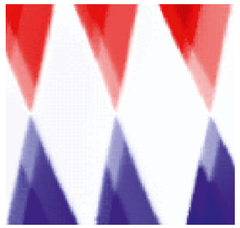
Kalantre, S. S., et al. *npj QI* **5**, 6 (2019)



van Diepen, C.J., *Appl. Phys. Lett.* **113**, 033101 (2018)
Teske, J.D., *Appl. Phys. Lett.* **114**, 133102 (2019)

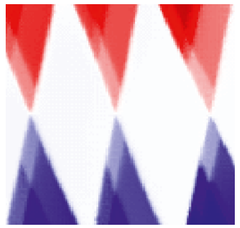


Machine learning algorithm measuring and tuning a device in real time



Device measurements

Device tuning



Device measurements

Device tuning

Deep learning

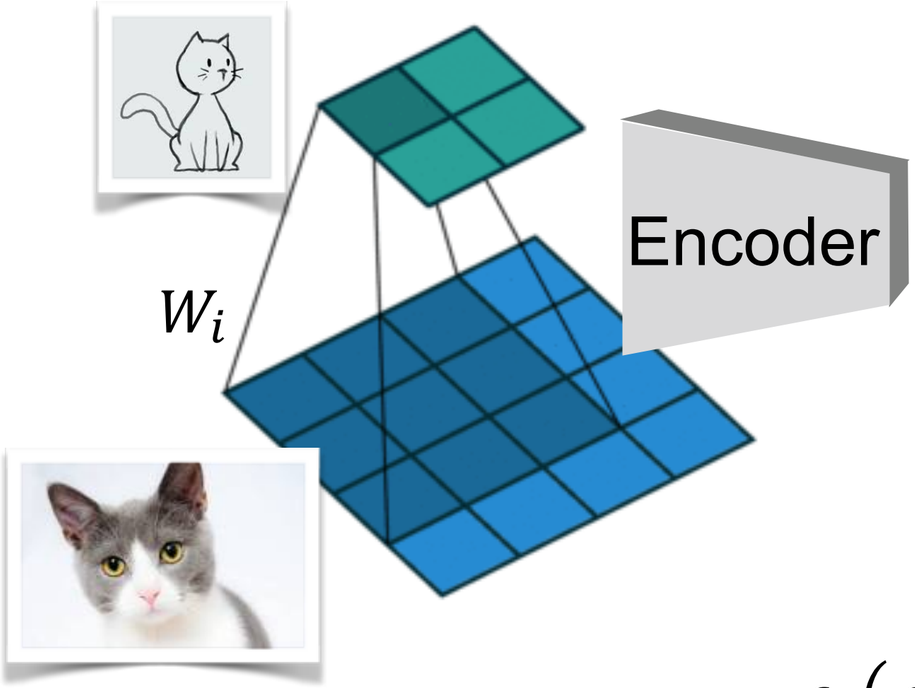
Image recognition

a cat

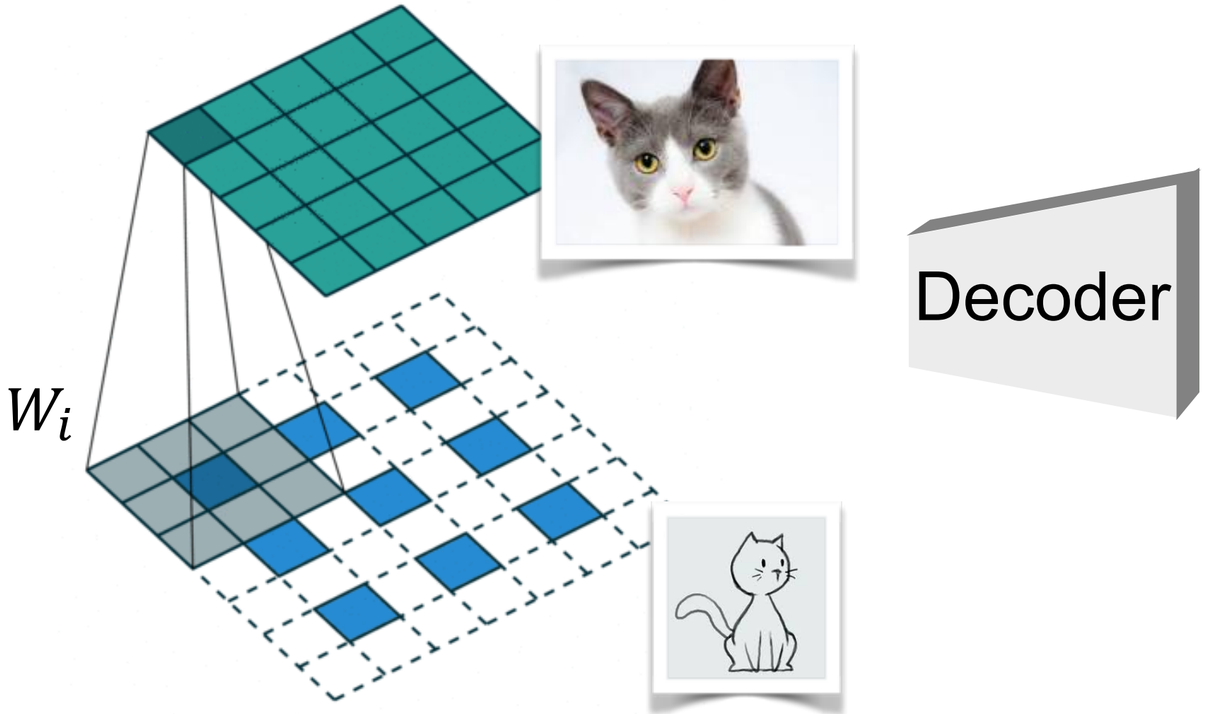
Deep generative models

Deep learning

Image recognition



Deep generative models

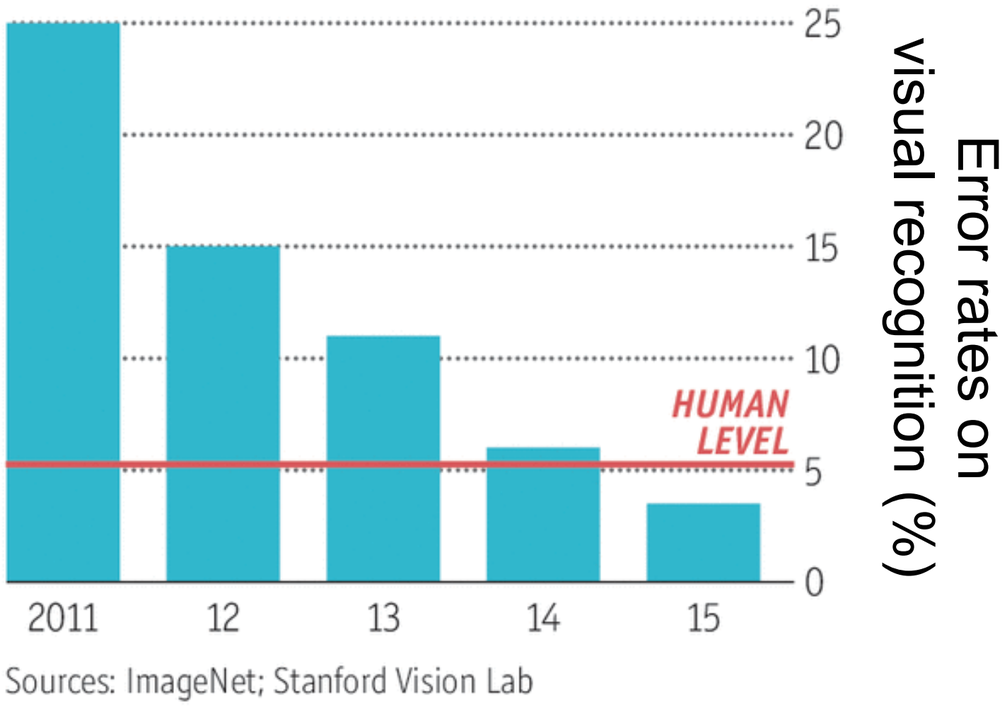


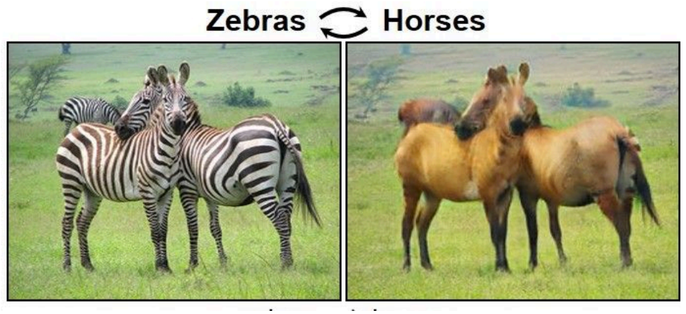
$$y = f_1\left(f_2\left(f_3(\ldots)\right)\right)$$

where $f_i(\mathbf{x}) = \max(W_i\mathbf{x} + \mathbf{b}_i, 0)$

Image recognition and deep generative models

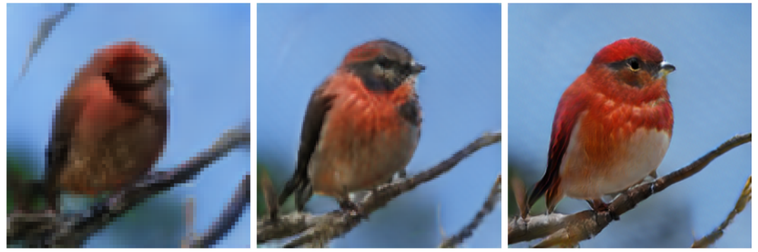
IMAGENET 1.2 M training images





Jun-Yan Zhu*, Taesung Park*, Phillip Isola, and Alexei A. Efros, ICCV 2017

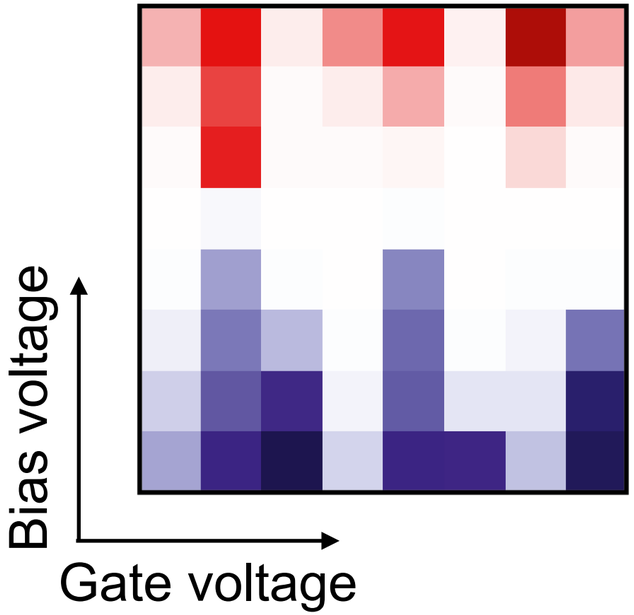
this bird is red with white and has a very short peak

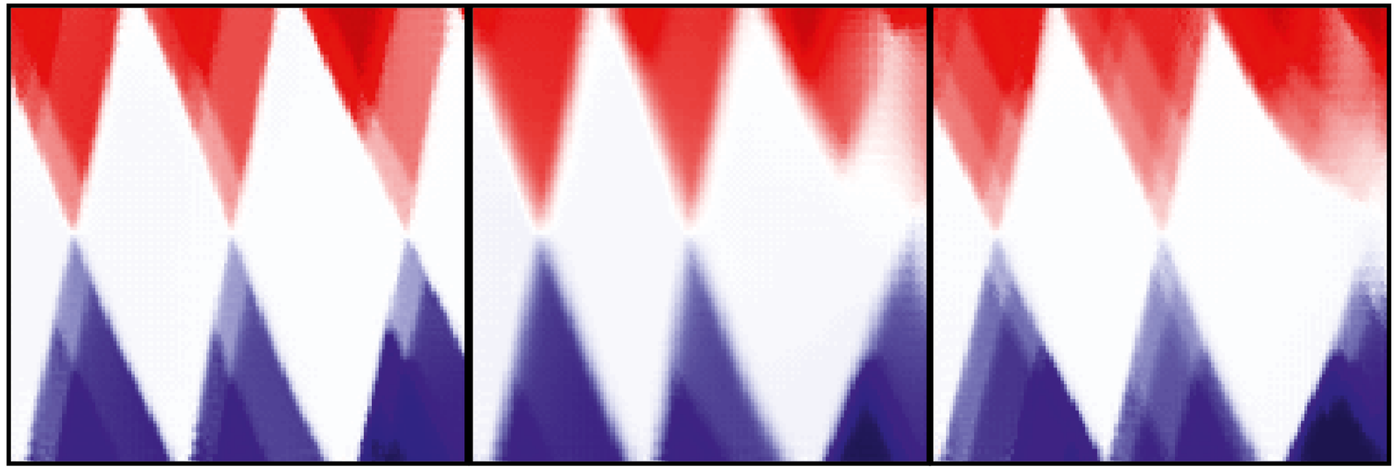


Xu, T., Zhang, P., Huang, Q., Zhang, H., Gan, Z., Huang, X., & He, X. arXiv:1711.10485 (2017)

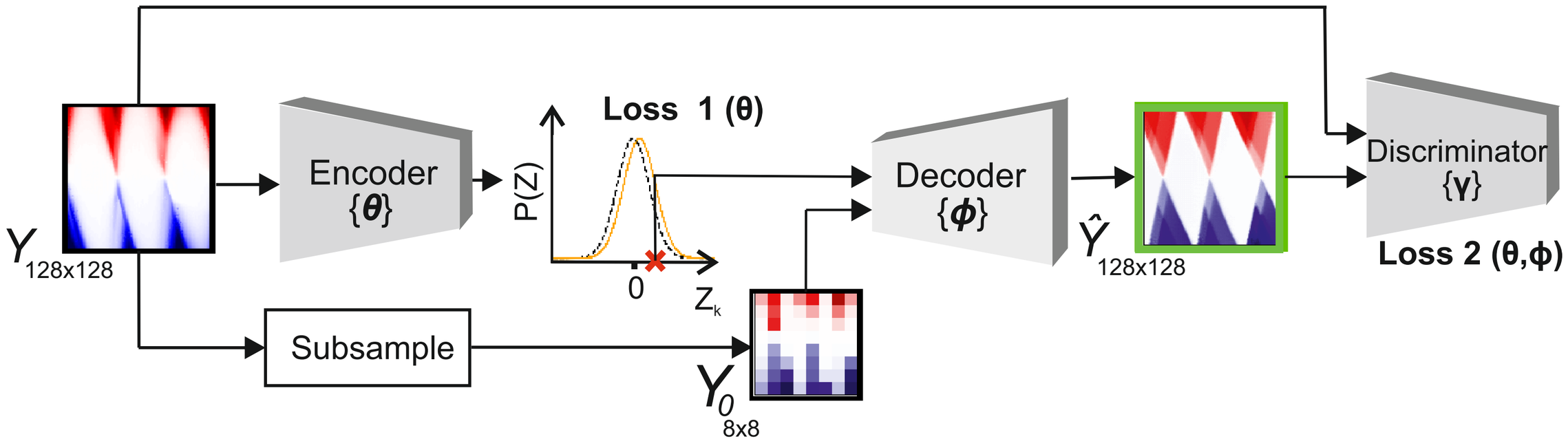
NVIDIA, ICLR 2018

Reconstructions



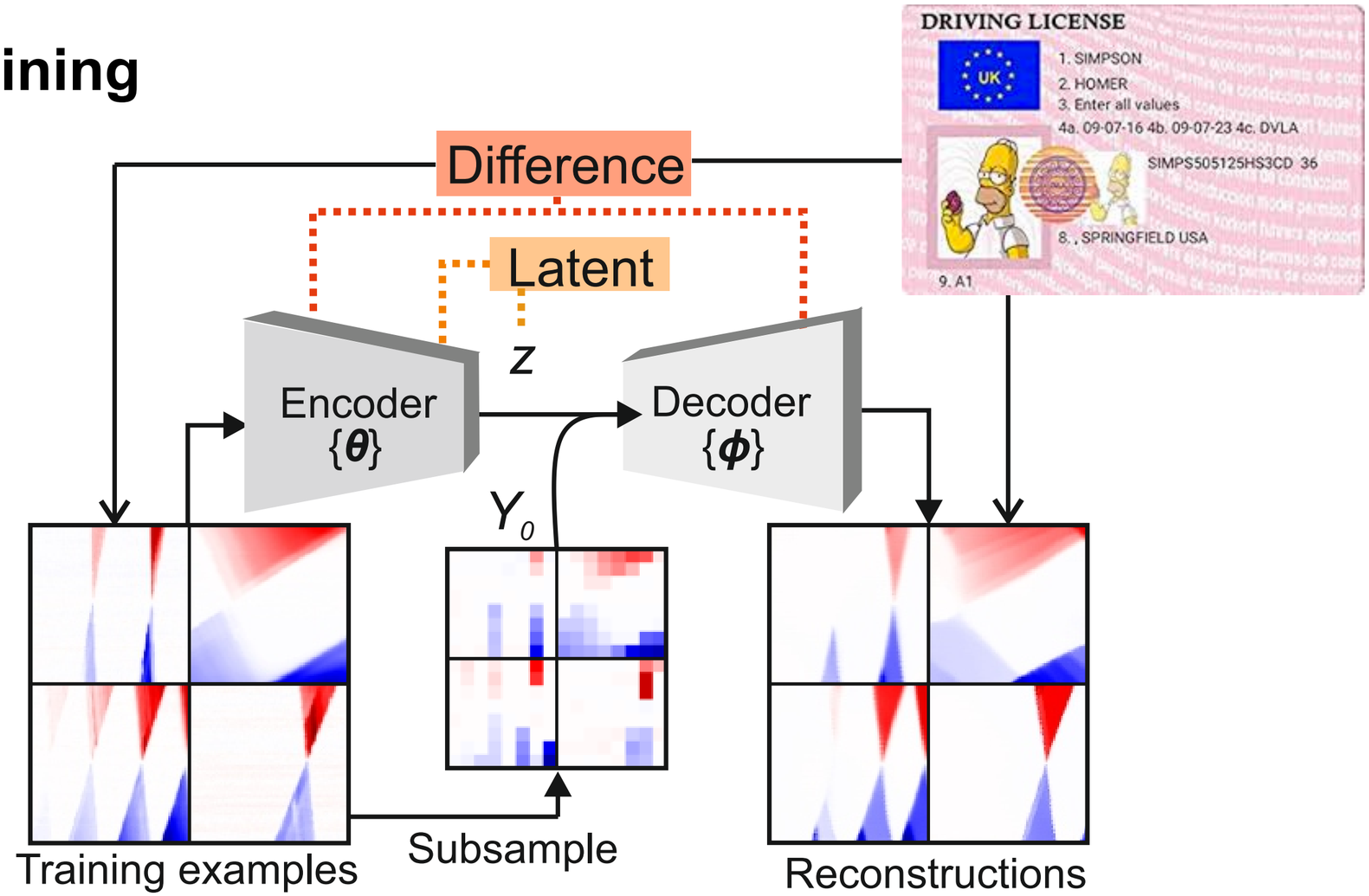


Deep generative model



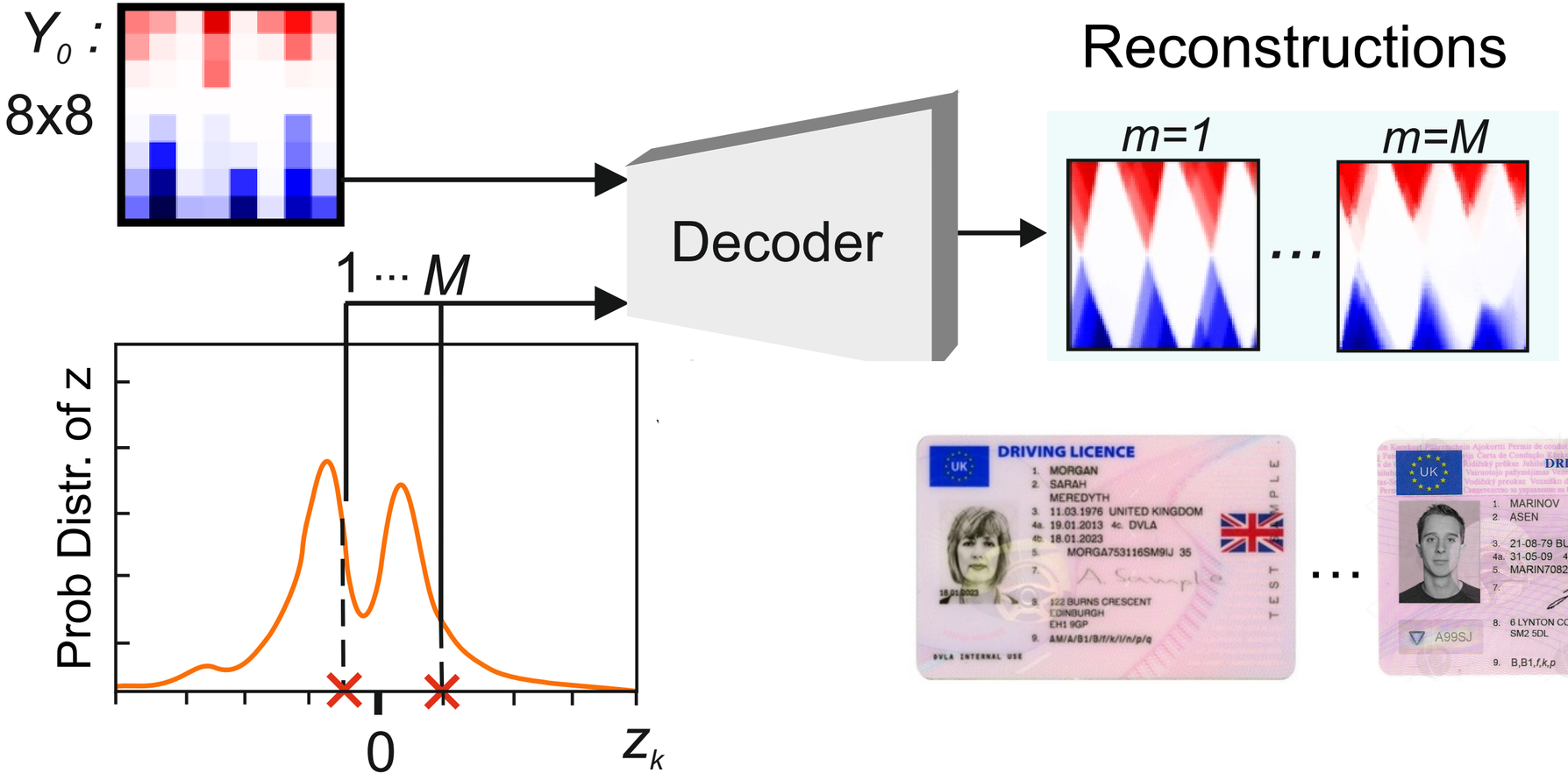
Deep generative model

Training

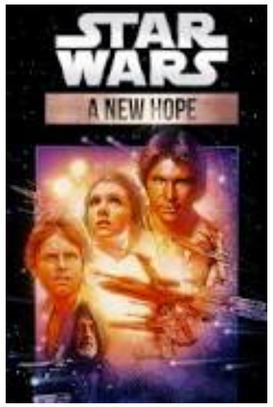


Deep generative model

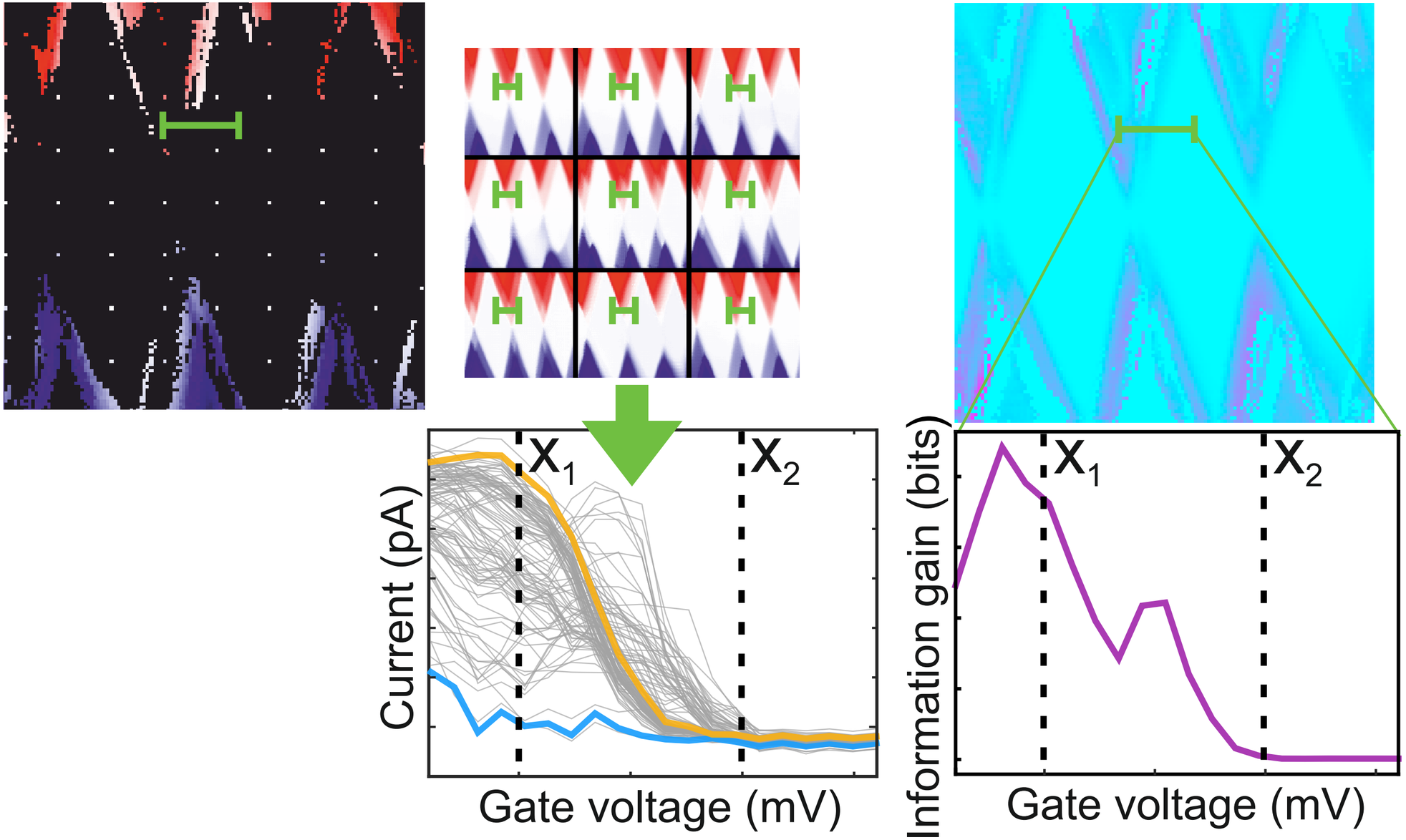
Reconstructions



Information theoretic models

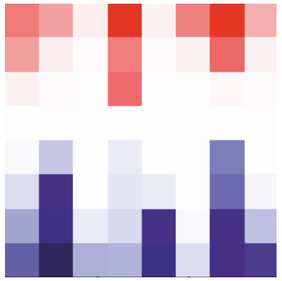


Information gain map

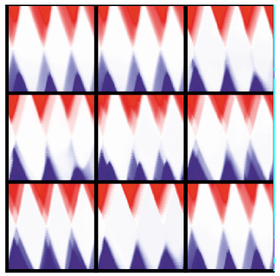


Machine learning for quantum device measurement

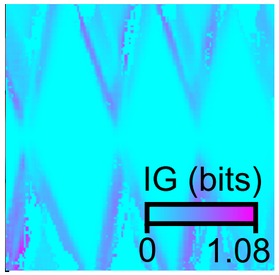
Initial scan



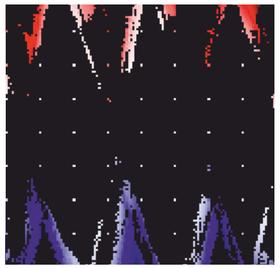
Reconstructions



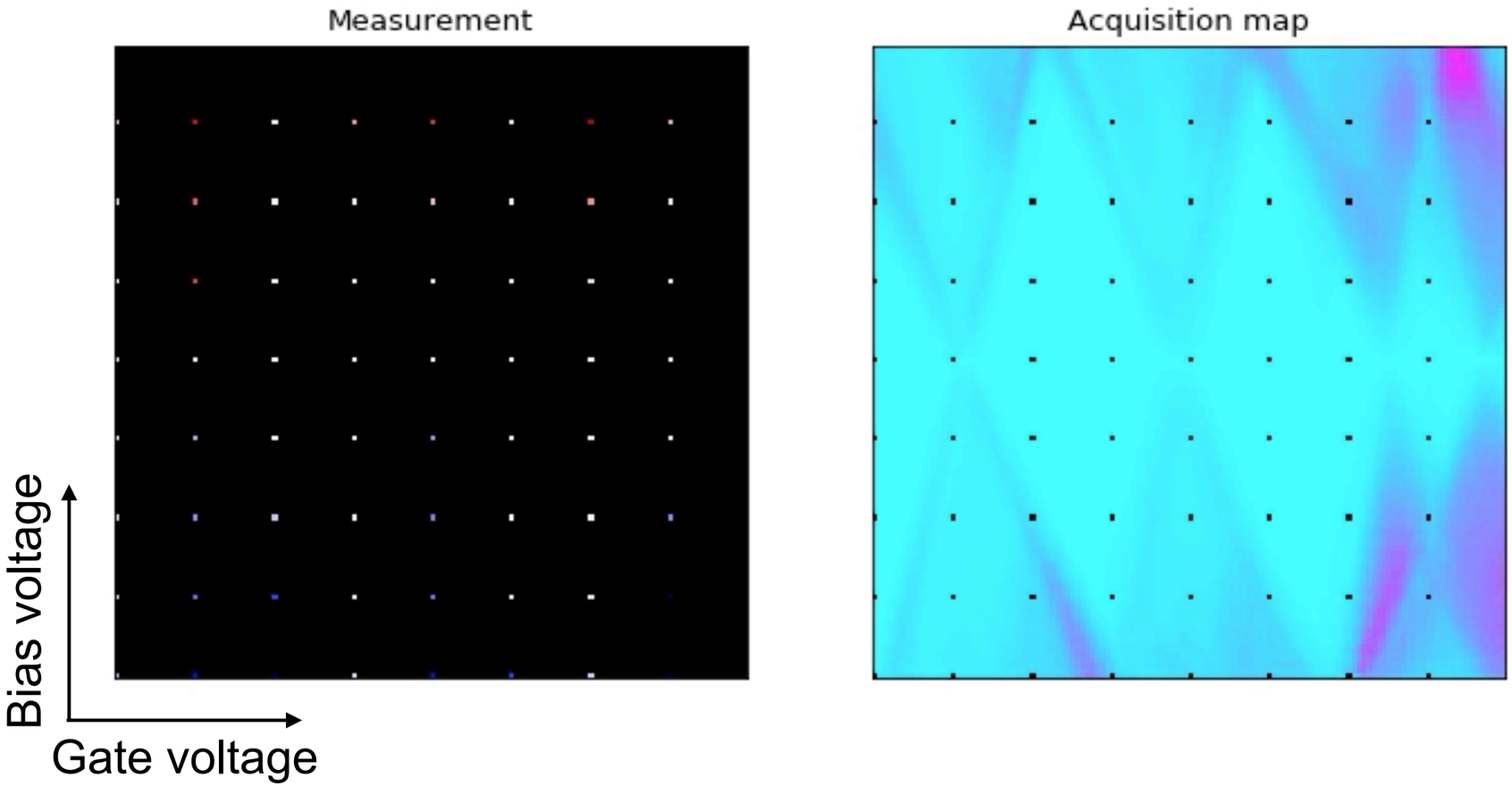
Predicted information gain



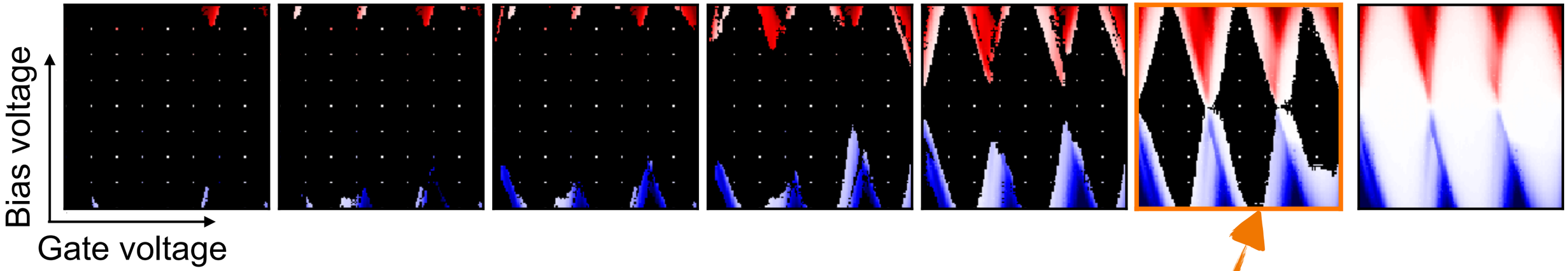
Next measurement



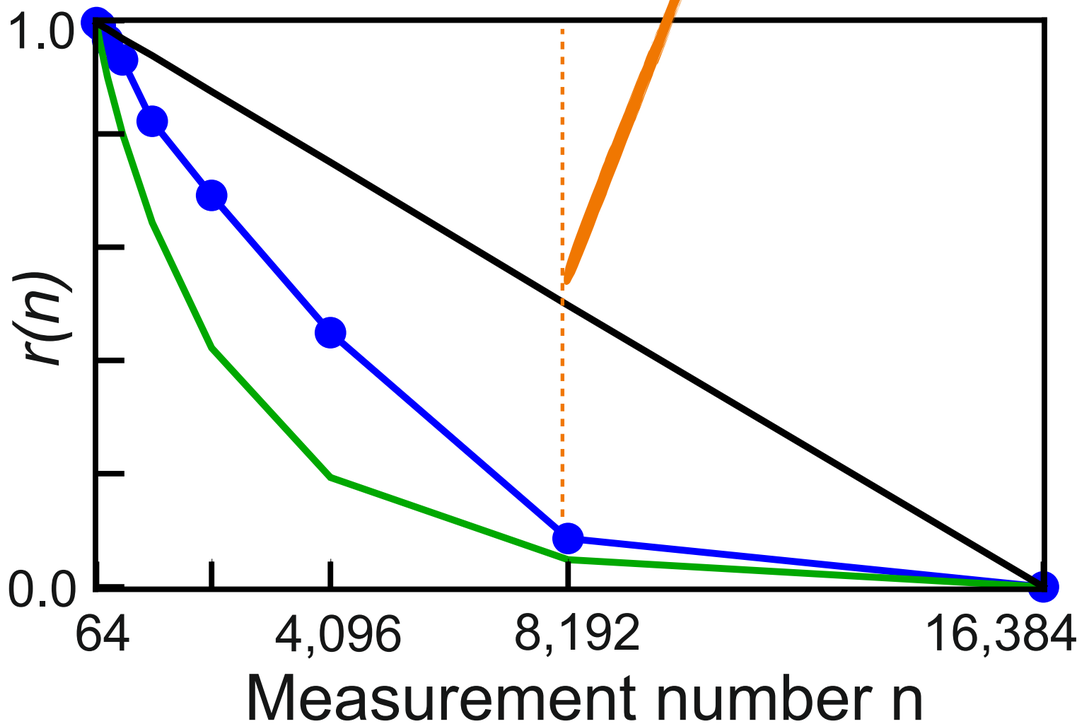
Machine learning for quantum device measurement



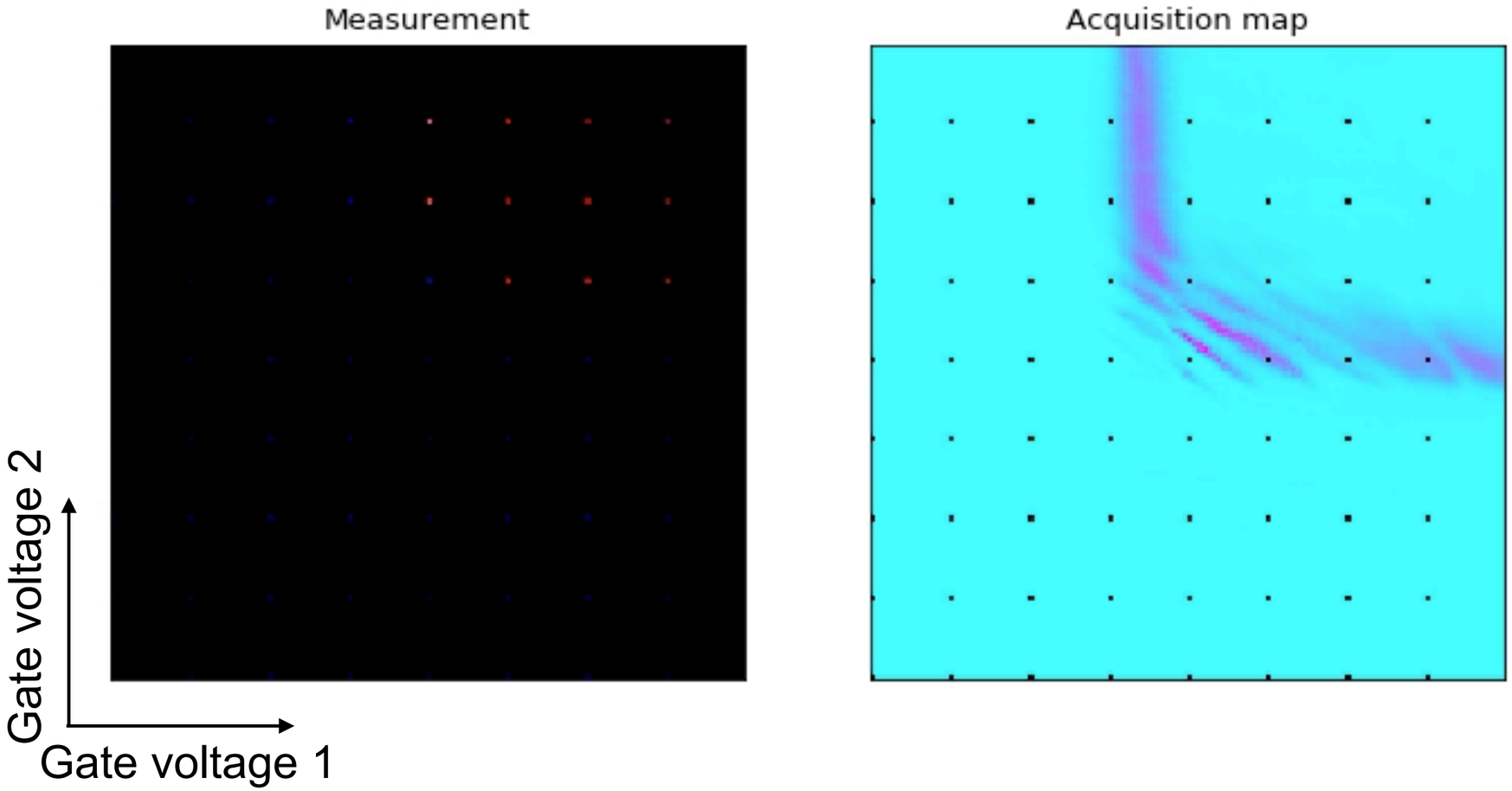
Machine learning for quantum device measurement



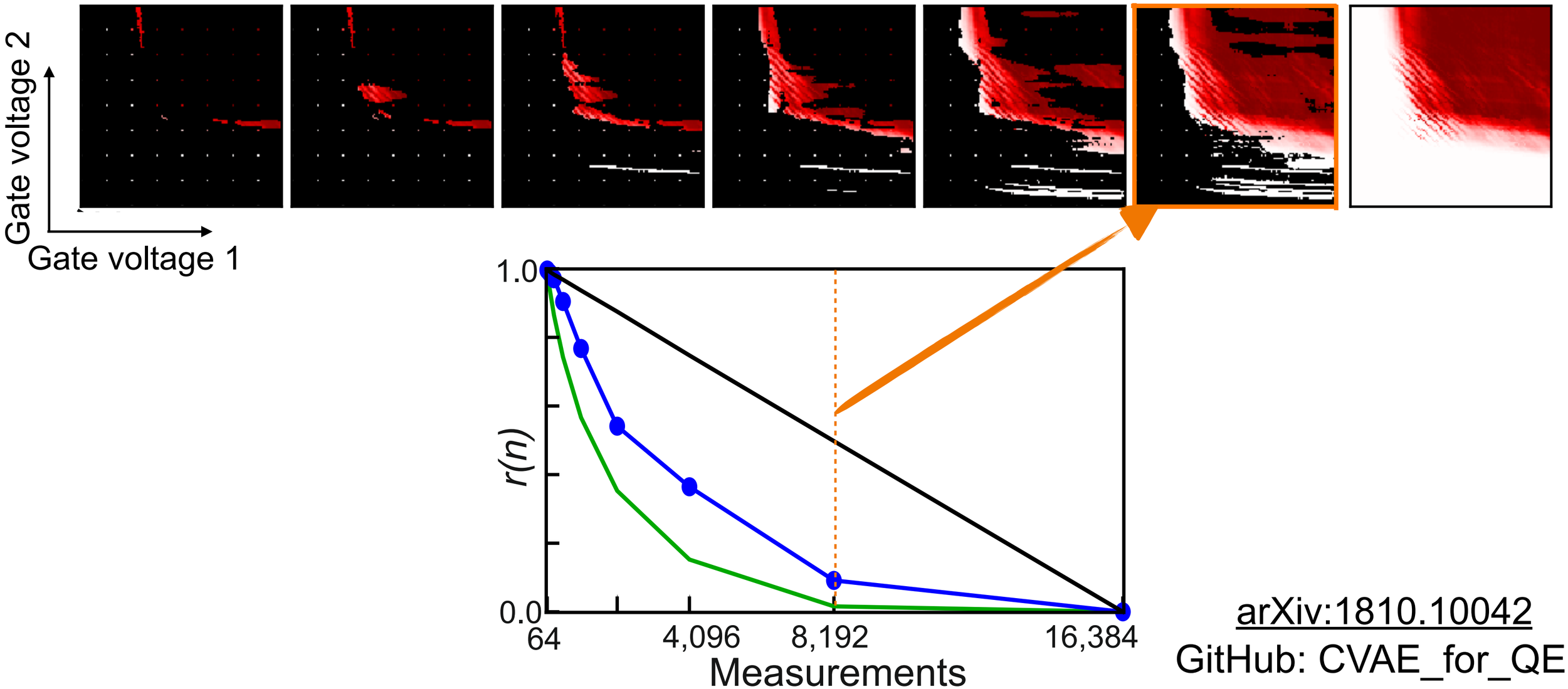
$$r(n) = \frac{\text{unmeasured current gradient}}{\text{total current gradient}}$$



Machine learning for quantum device measurement

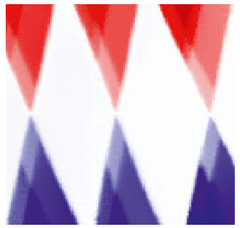


Machine learning for quantum device measurement



arXiv:1810.10042

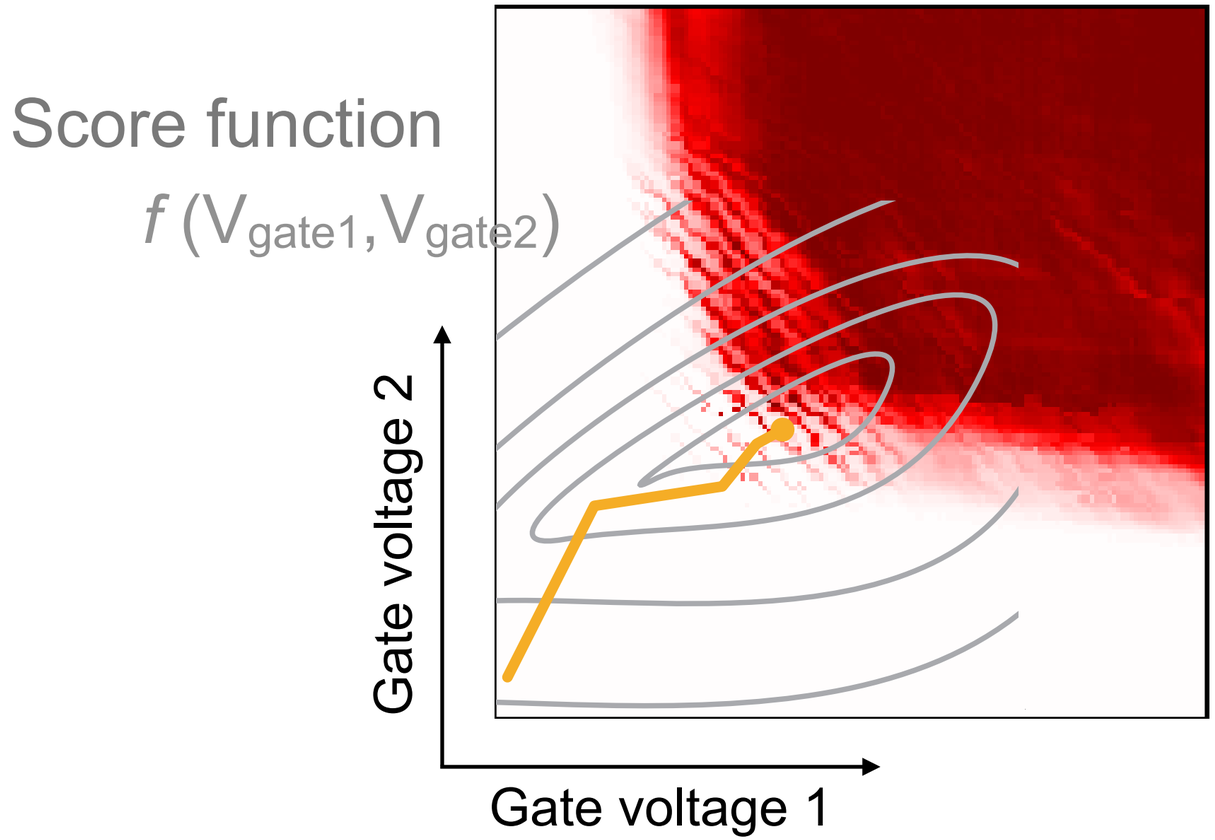
GitHub: CVAE_for_QE



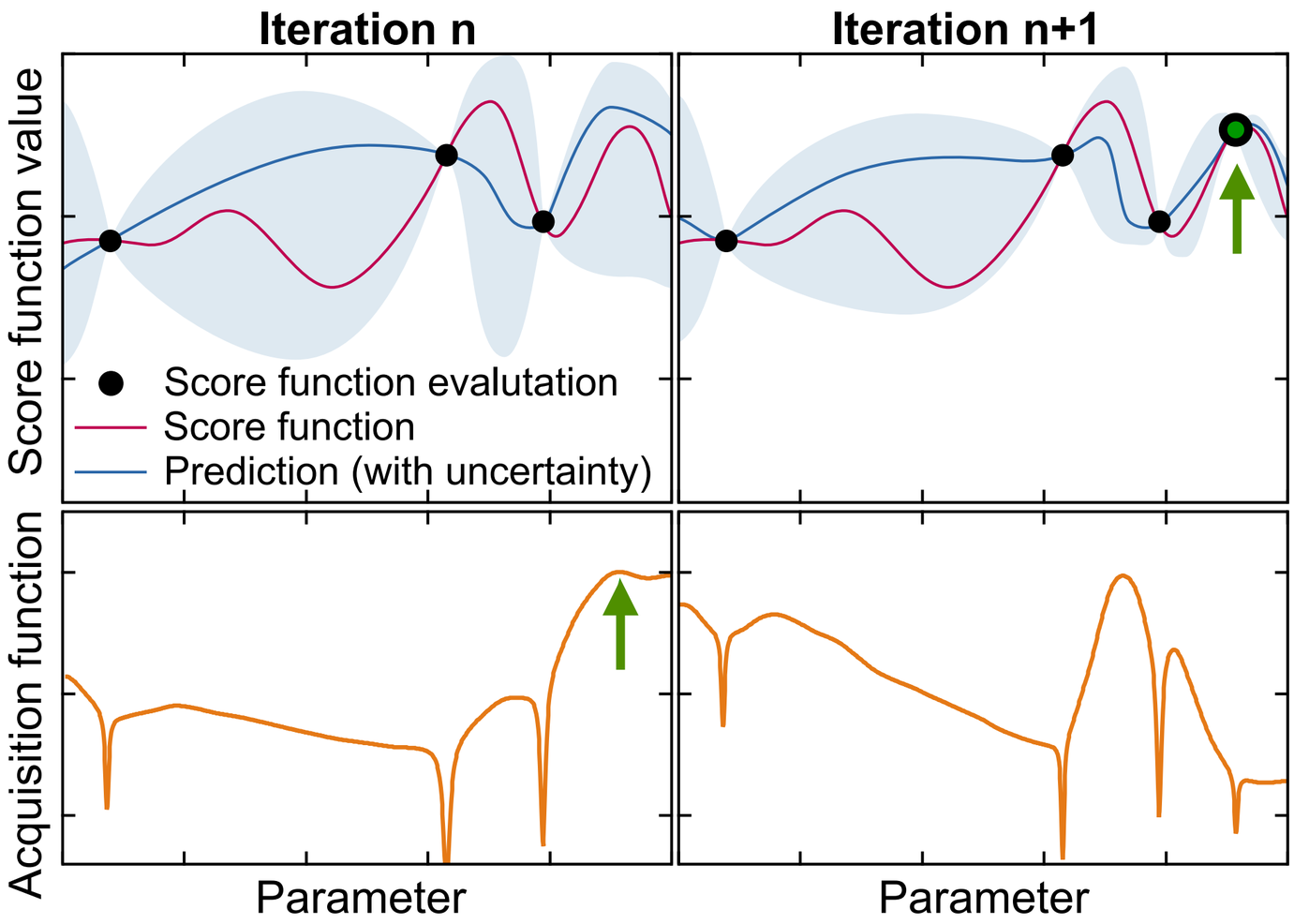
Device measurements

Device tuning

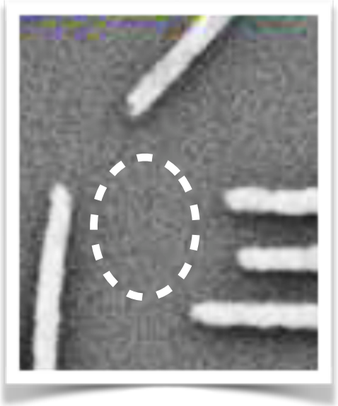
Machine learning for quantum device tuning

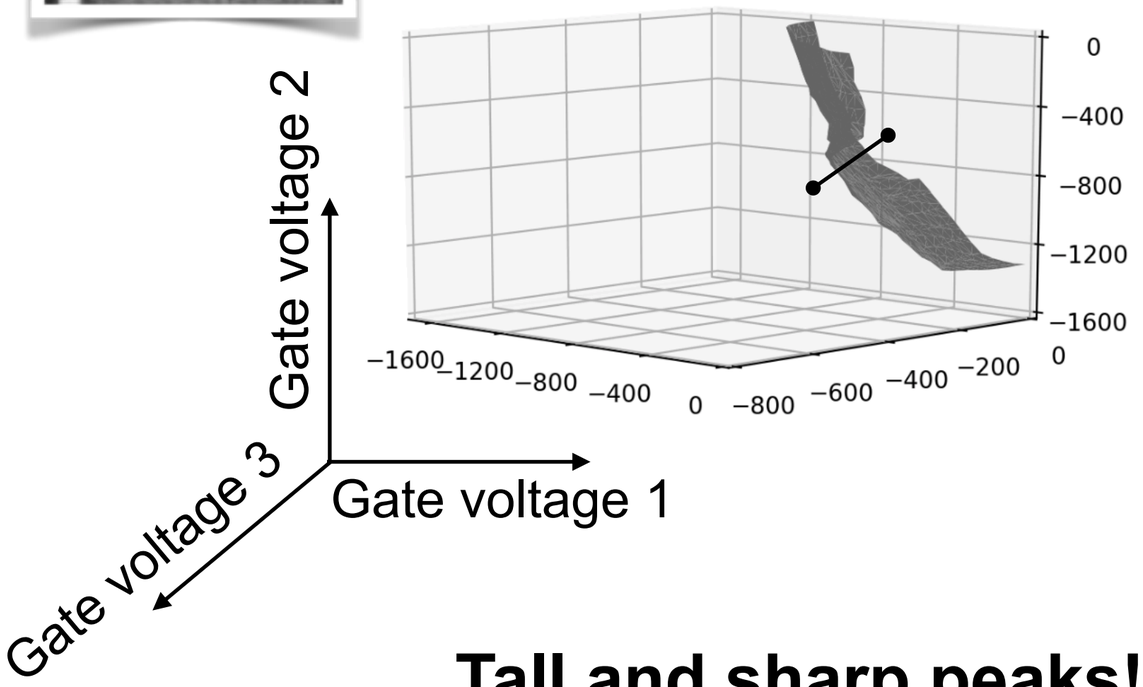


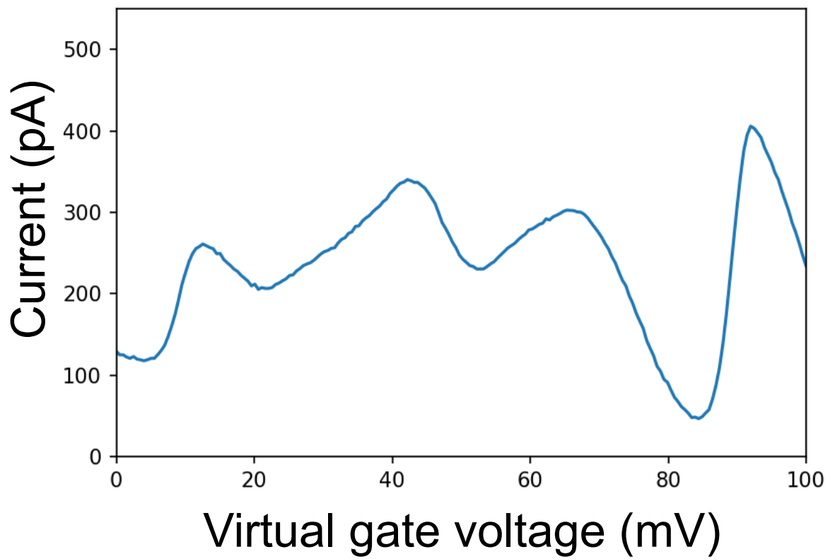
Bayesian optimisation

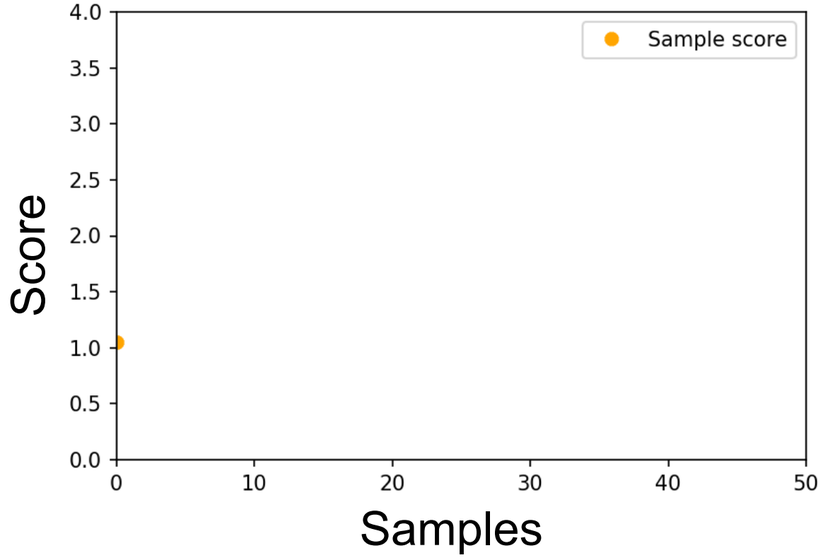


Machine learning for quantum device tuning



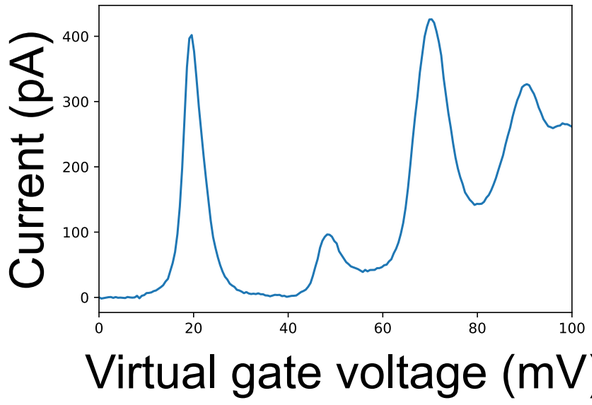


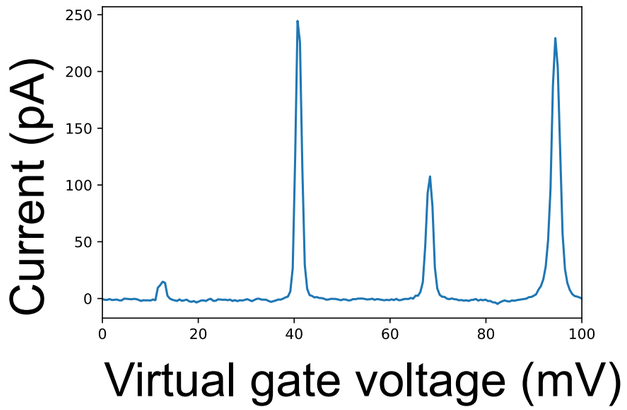


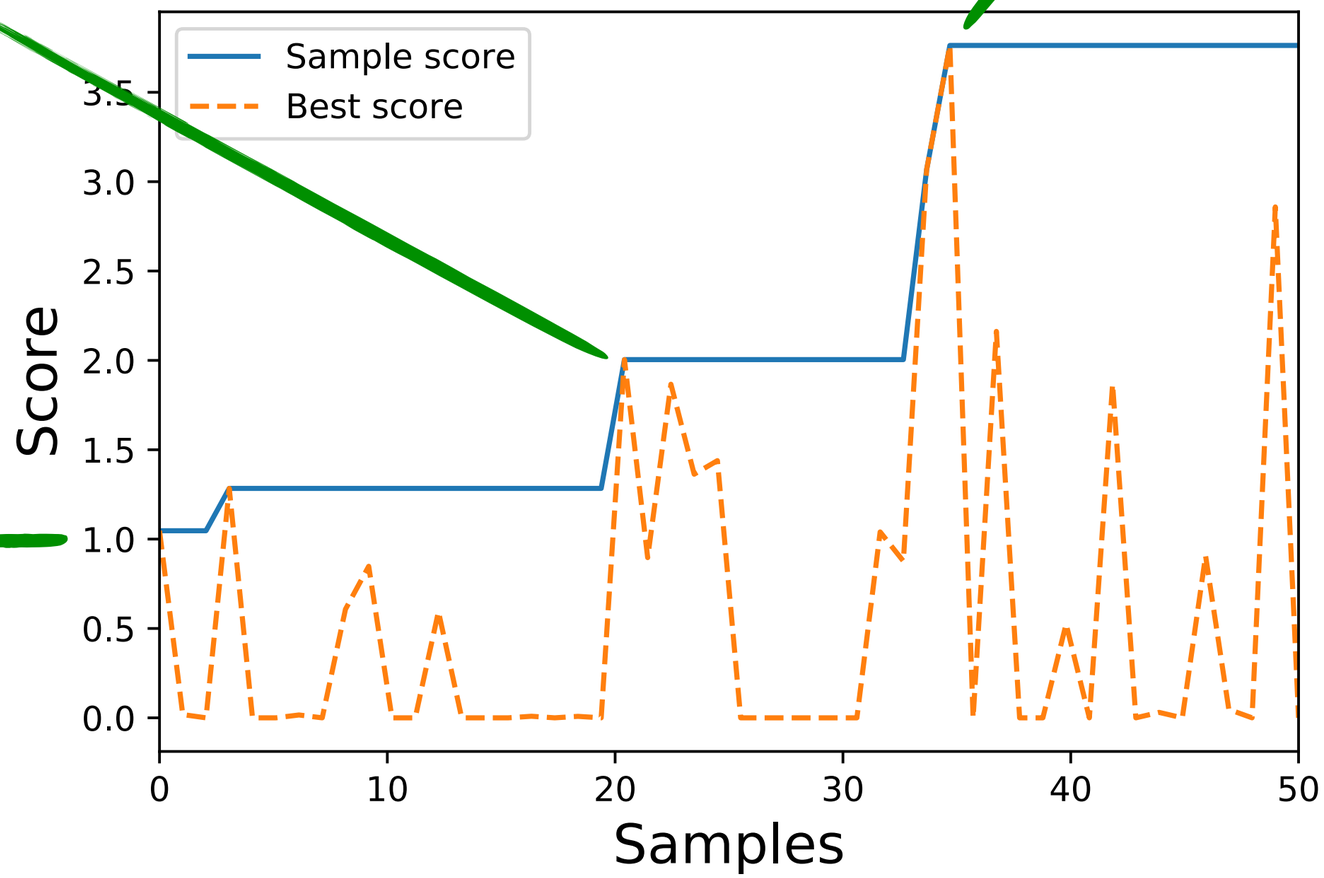


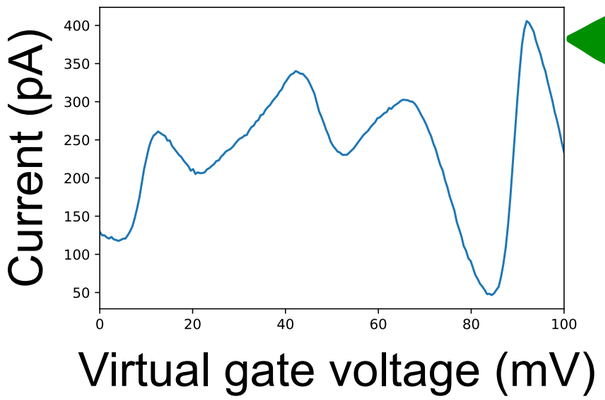
Tall and sharp peaks!

Machine learning for quantum device tuning

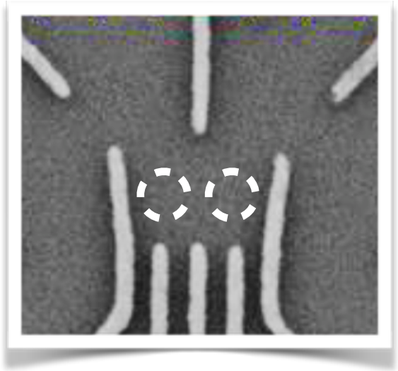




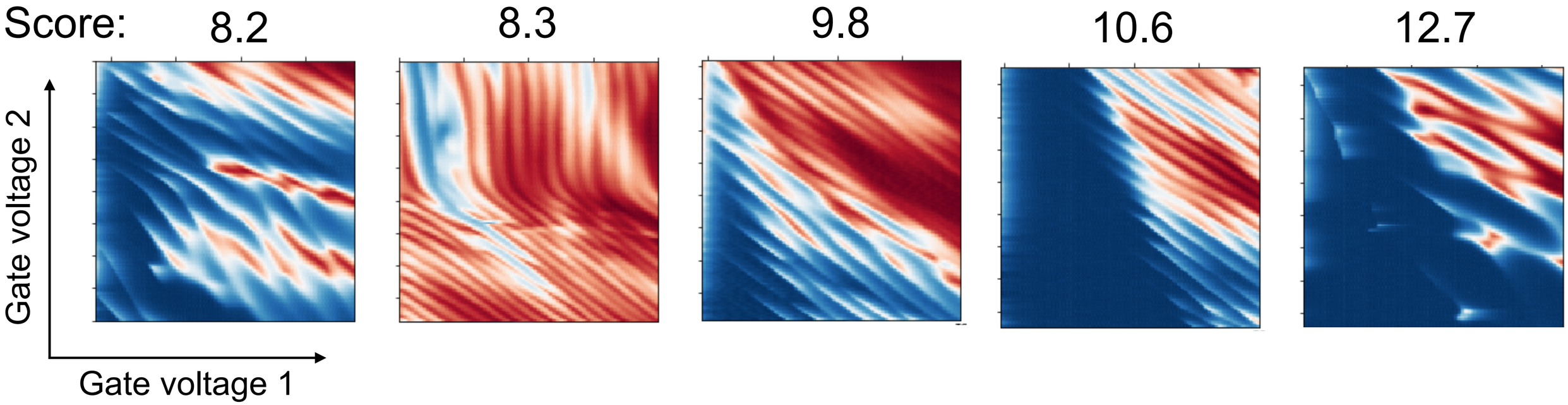




Machine learning for quantum device tuning



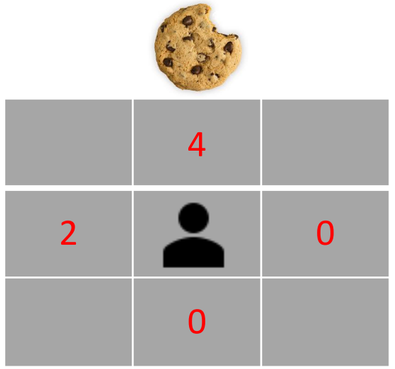
Bias triangles!

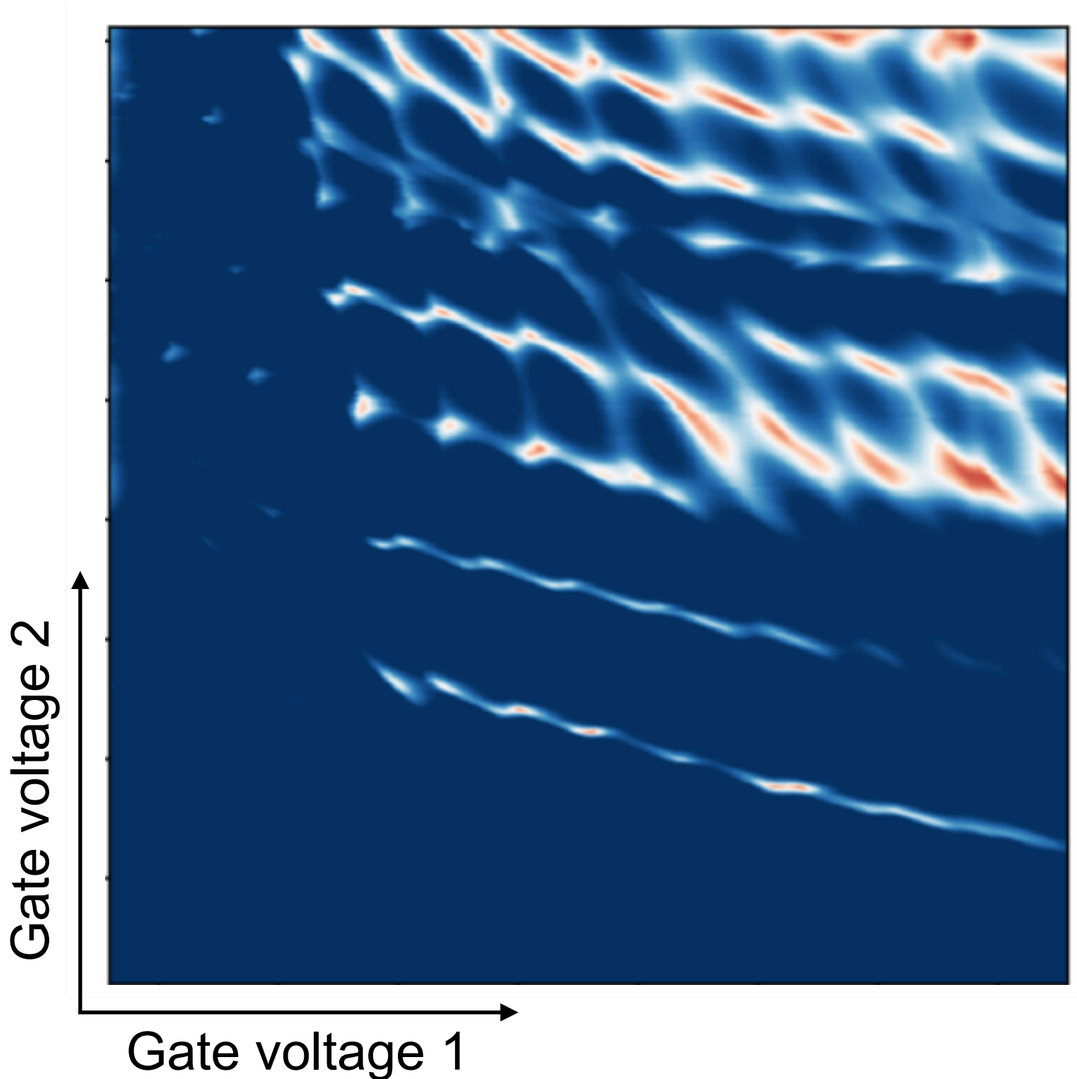


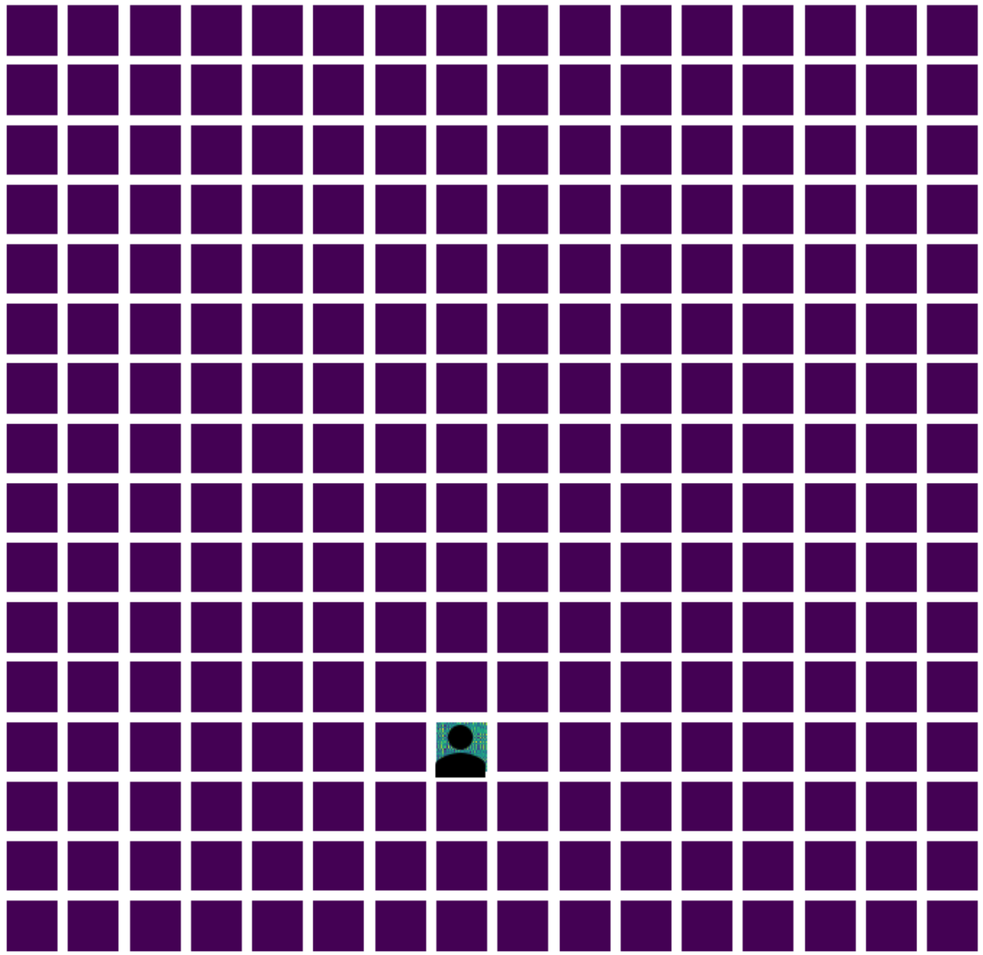
Reinforcement learning for finer tuning

Deep Mind (2015)

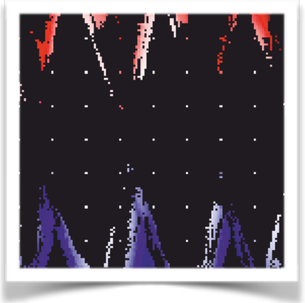
Reinforcement learning for finer tuning



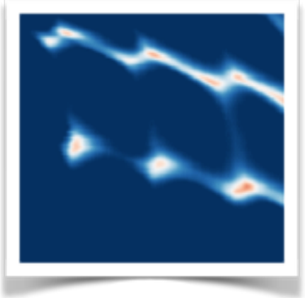




Summary

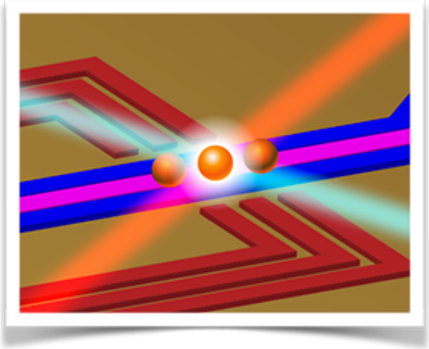


- **Efficient quantum dot measurements using machine learning**



- **Efficient quantum dot tuning using machine learning**

- **Perspectives:**



  - **Characterise and tune large quantum dot circuits**
  - **Apply our findings to different qubit realisations**

Thank you