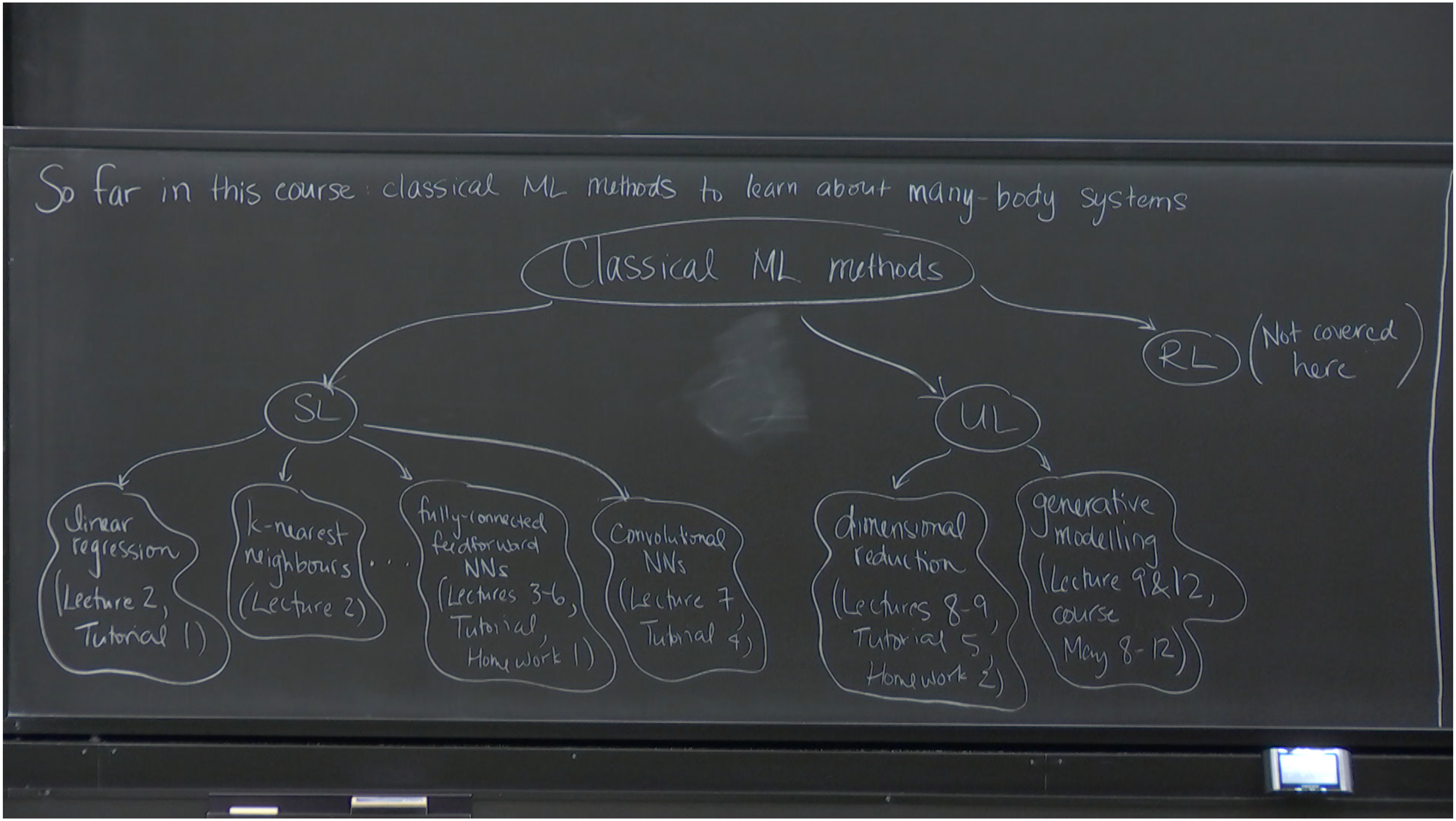
Title: Machine Learning Lecture - 230323

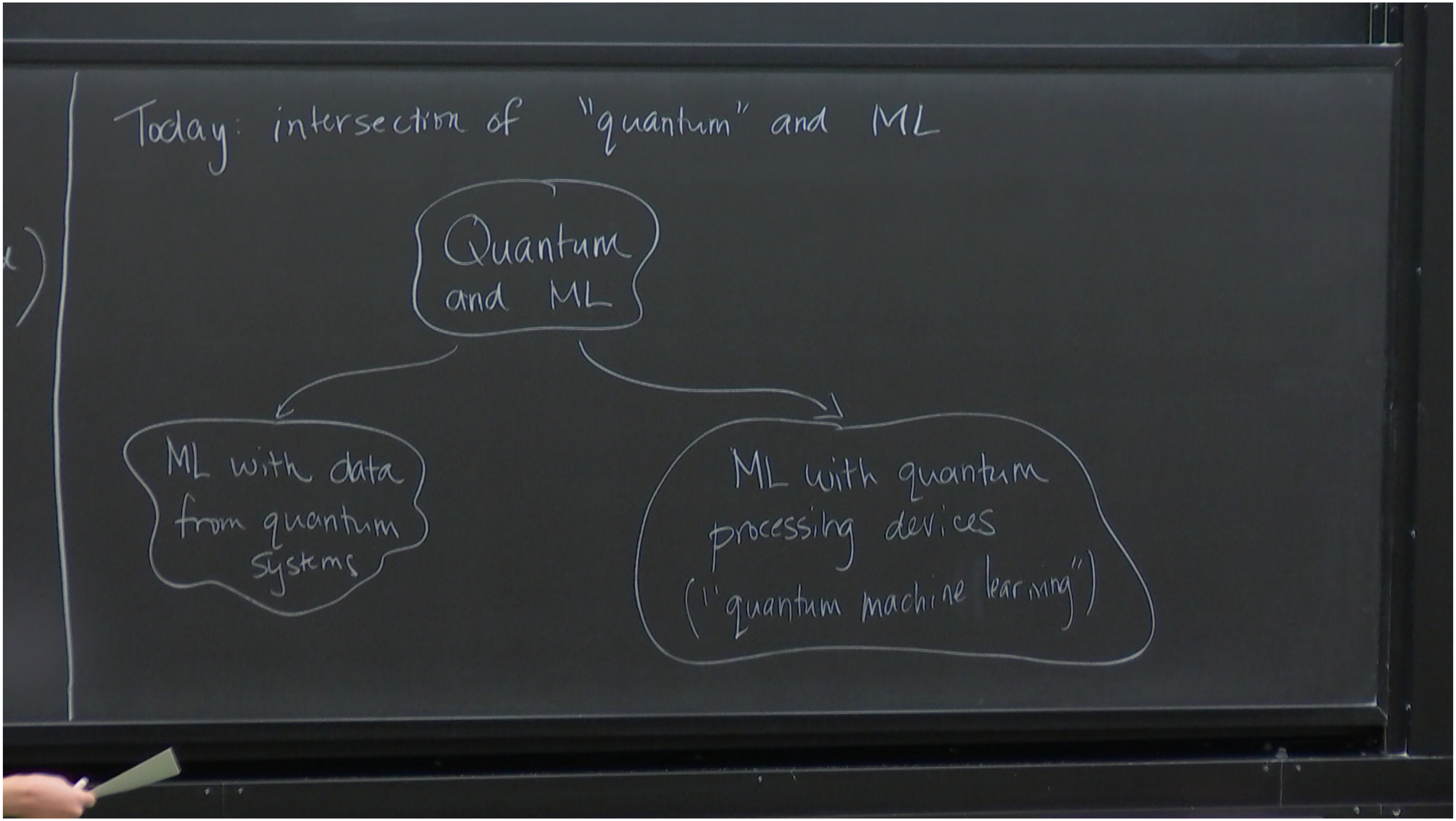
Speakers: Lauren Hayward

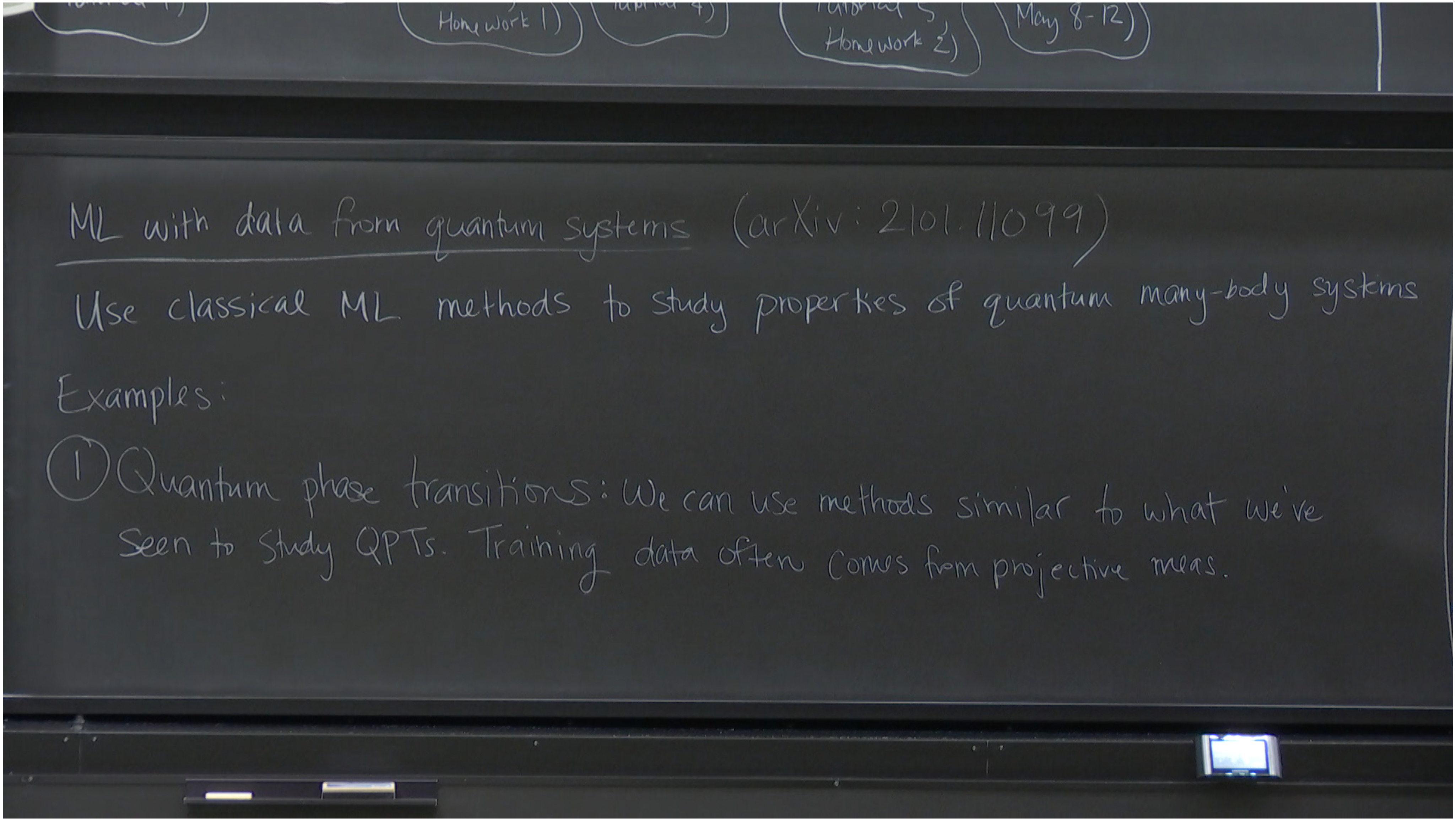
Collection: Machine Learning for Many-Body Physics (2022/2023)

Date: March 23, 2023 - 9:00 AM

URL: https://pirsa.org/23030035


So far in this course: classical ML methods to learn about many-body systems
Classical ML methods
SL
UL
RL
(Not covered here)
linear regression (Lecture 2, Tutorial 1)
k-nearest neighbours (Lecture 2)
. . .
fully-connected feedforward NNs (Lectures 3-6, Tutorial, Homework 1)
Convolutional NNs (Lecture 7, Tutorial 4)
dimensional reduction (Lectures 8-9, Tutorial 5, Homework 2)
generative modelling (Lecture 9 & 12, course May 8-12)


Today: intersection of "quantum" and ML
Quantum and ML
ML with data from quantum systems
ML with quantum processing devices ("quantum machine learning")


Homework 1)
Homework 2)
May 8-12)
ML with data from quantum systems (arXiv: 2101.11099)
Use classical ML methods to study properties of quantum many-body systems
Examples:
① Quantum phase transitions: We can use methods similar to what we've
seen to study QPTs. Training data often comes from projective meas.

stems

② Quantum state tomography

Goal: Given (limited) meas. data, reconstruct the corresponding (unknown) quantum state

Generative modelling with NN architectures (eg: RBMs) can be used to produce an efficient NN repr. of the q. state

(3) Finding approx. ground states

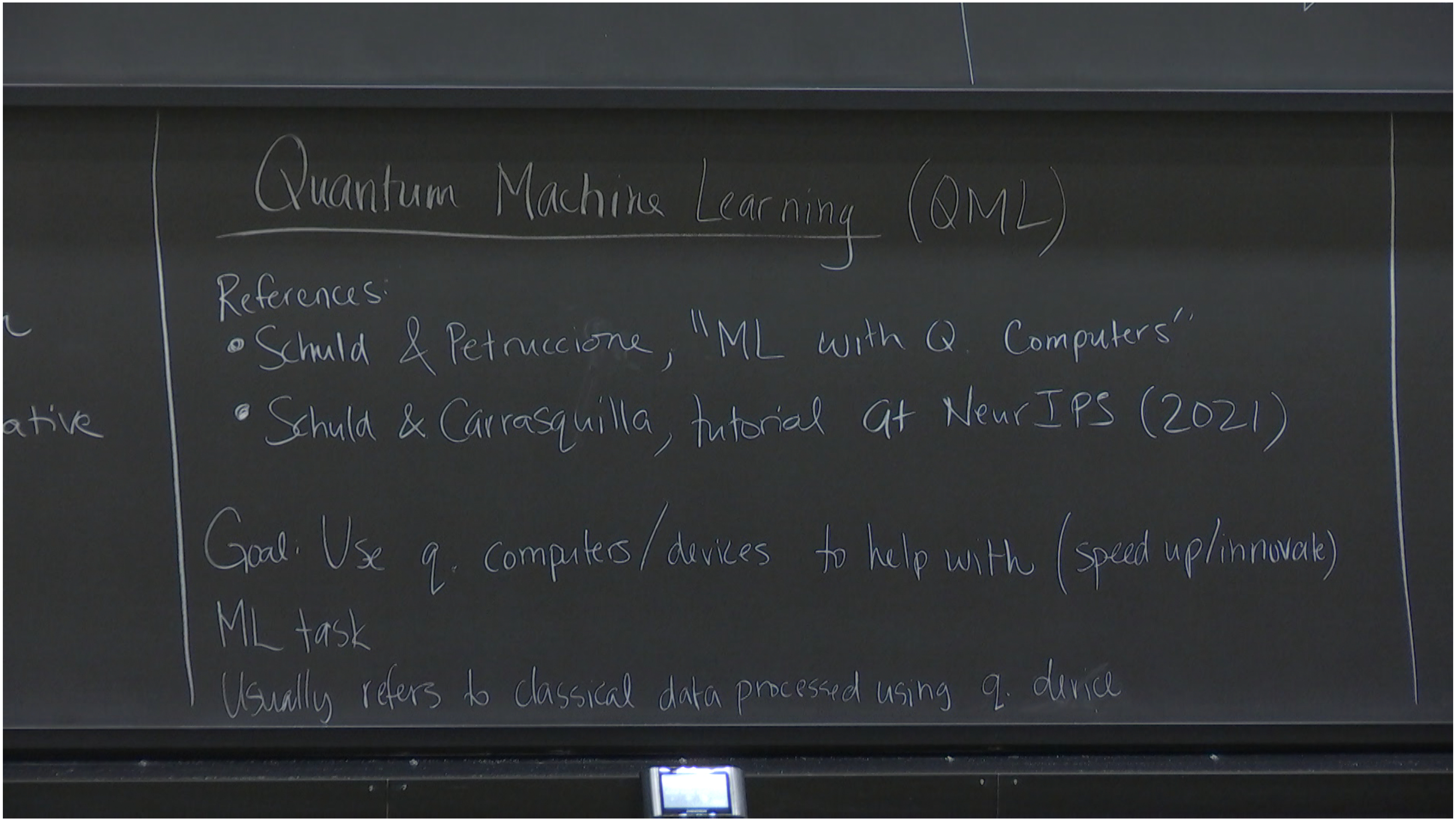
Given a Hamiltonian of quantum many-body system, train a generative model to approx. the g.s.

(eg: Mohamed's work w̄ RNNs)

Quantum

References:

- Schuld & Pet


Quantum Machine Learning (QML)
References:
• Schuld & Petruccione, "ML with Q. Computers"
• Schuld & Carrasquilla, tutorial at NeurIPS (2021)
Goal: Use q. computers/devices to help with (speed up/innovate) ML task
Usually refers to classical data processed using q. device

ML)

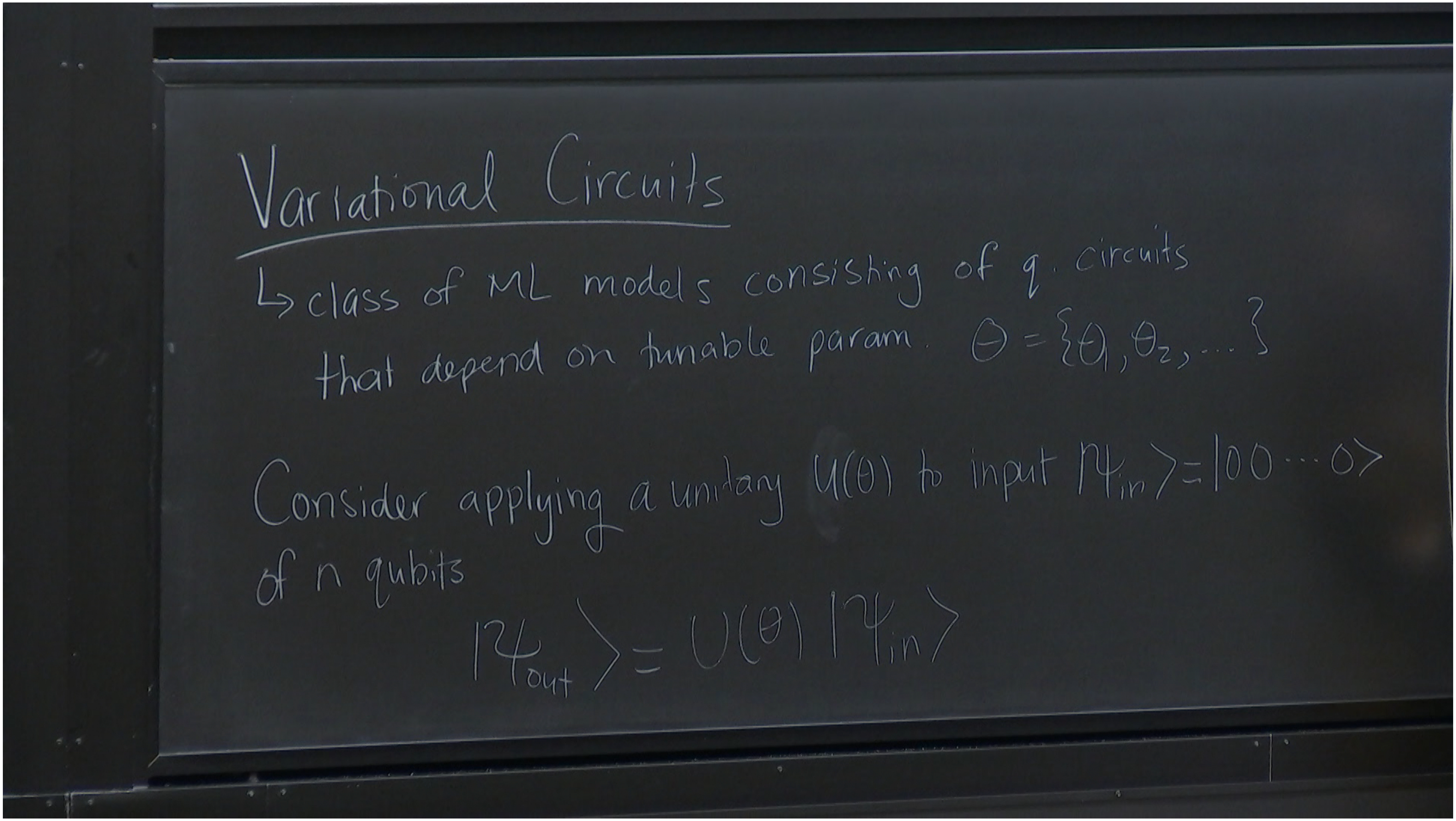
Computers"

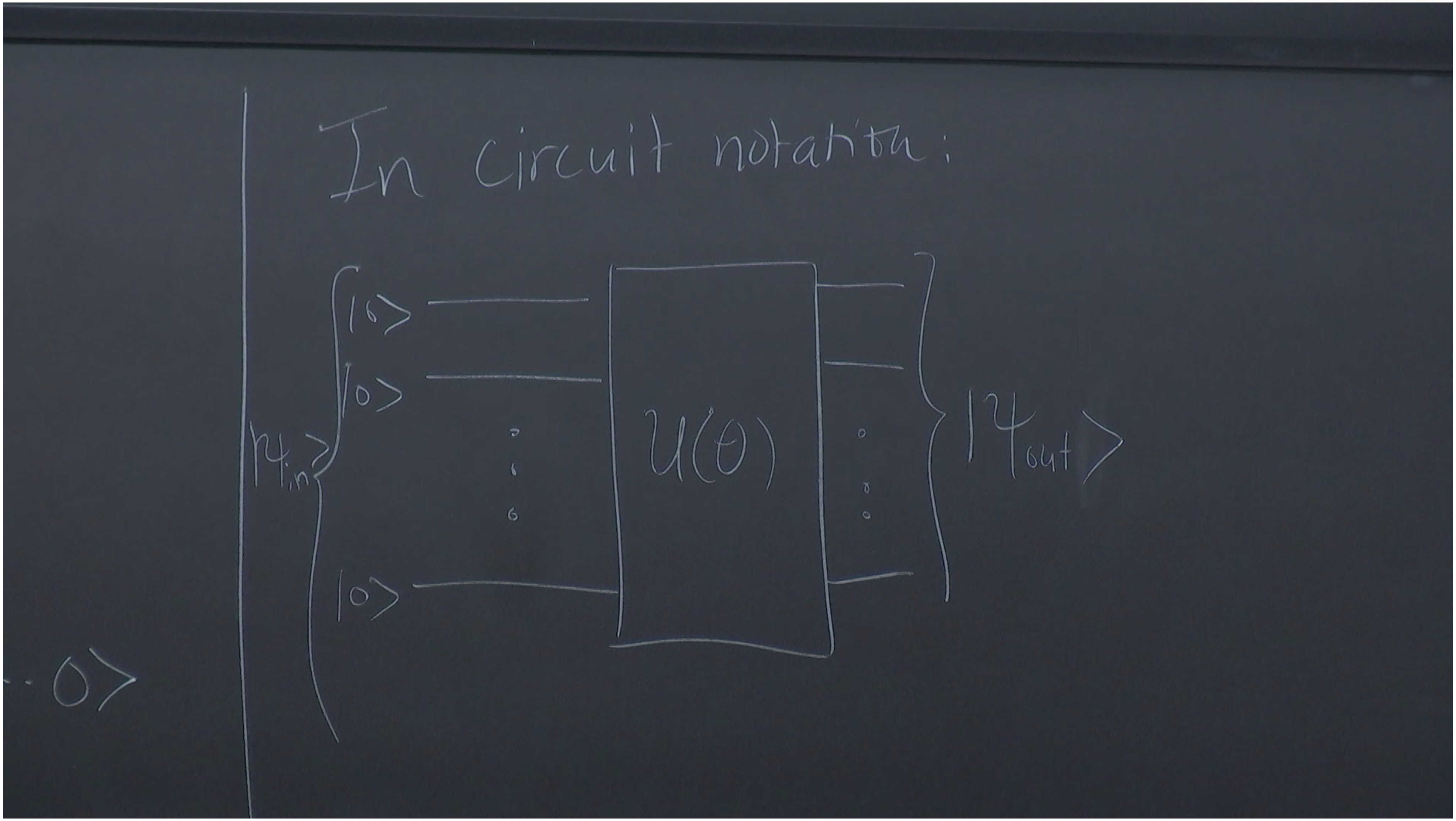
NeurIPS (2021)

with (speed up/innovate)

q. device

Here, we will focus on the goal of using q. devices (including "near-term" devices) as ML models known as "variational circuits"


Variational Circuits
↳ class of ML models consisting of q. circuits
that depend on tunable param. $\Theta = \{\theta_1, \theta_2, \dots\}$
Consider applying a unitary $U(\theta)$ to input $|\psi_{in}\rangle = |00\cdots0\rangle$
of n qubits
$|\psi_{out}\rangle = U(\theta)|\psi_{in}\rangle$

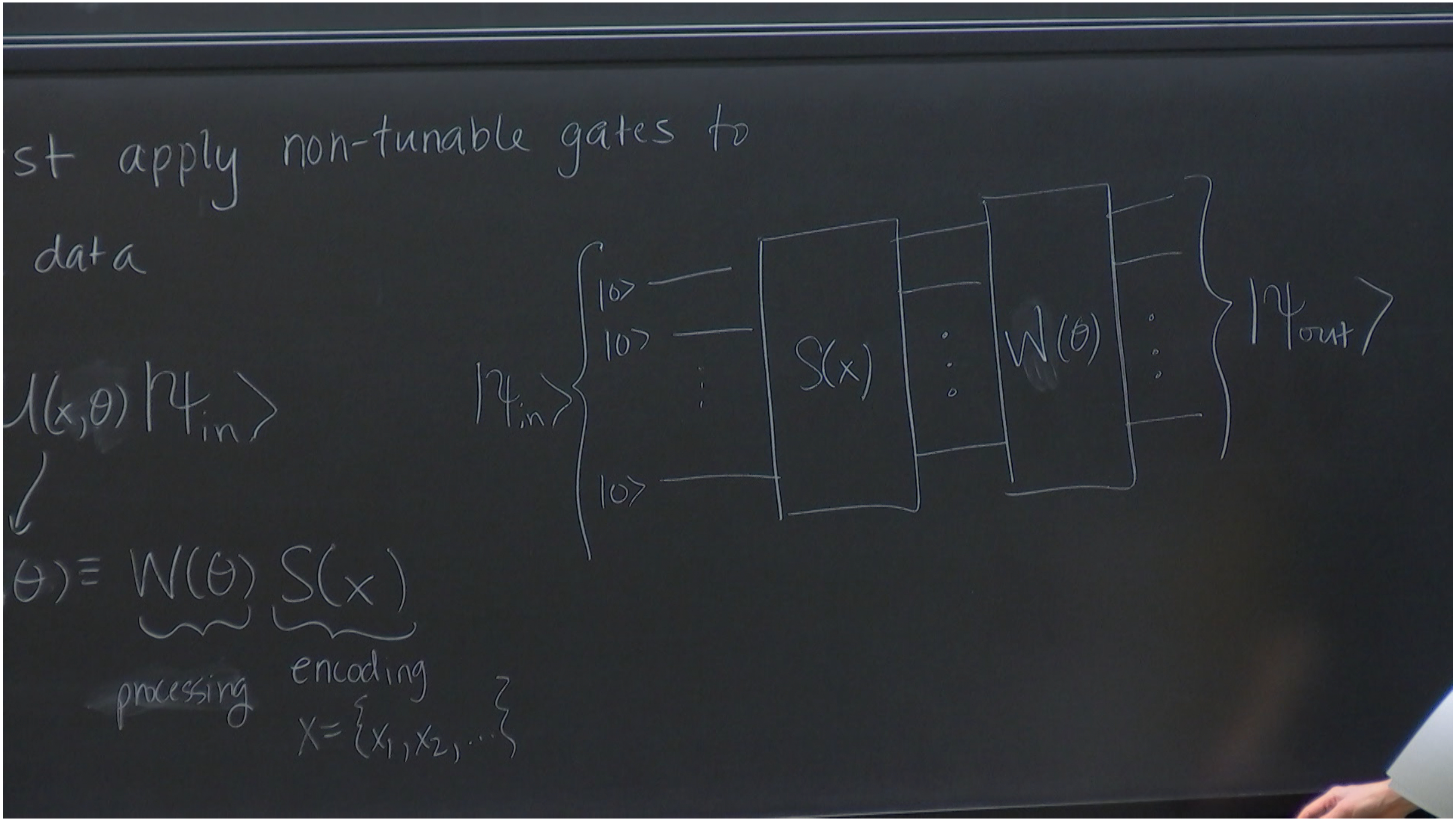

In circuit notation:
|0⟩
|0⟩
|0⟩
$U(\theta)$
$|\psi_{in}\rangle$
$|\psi_{out}\rangle$
0⟩

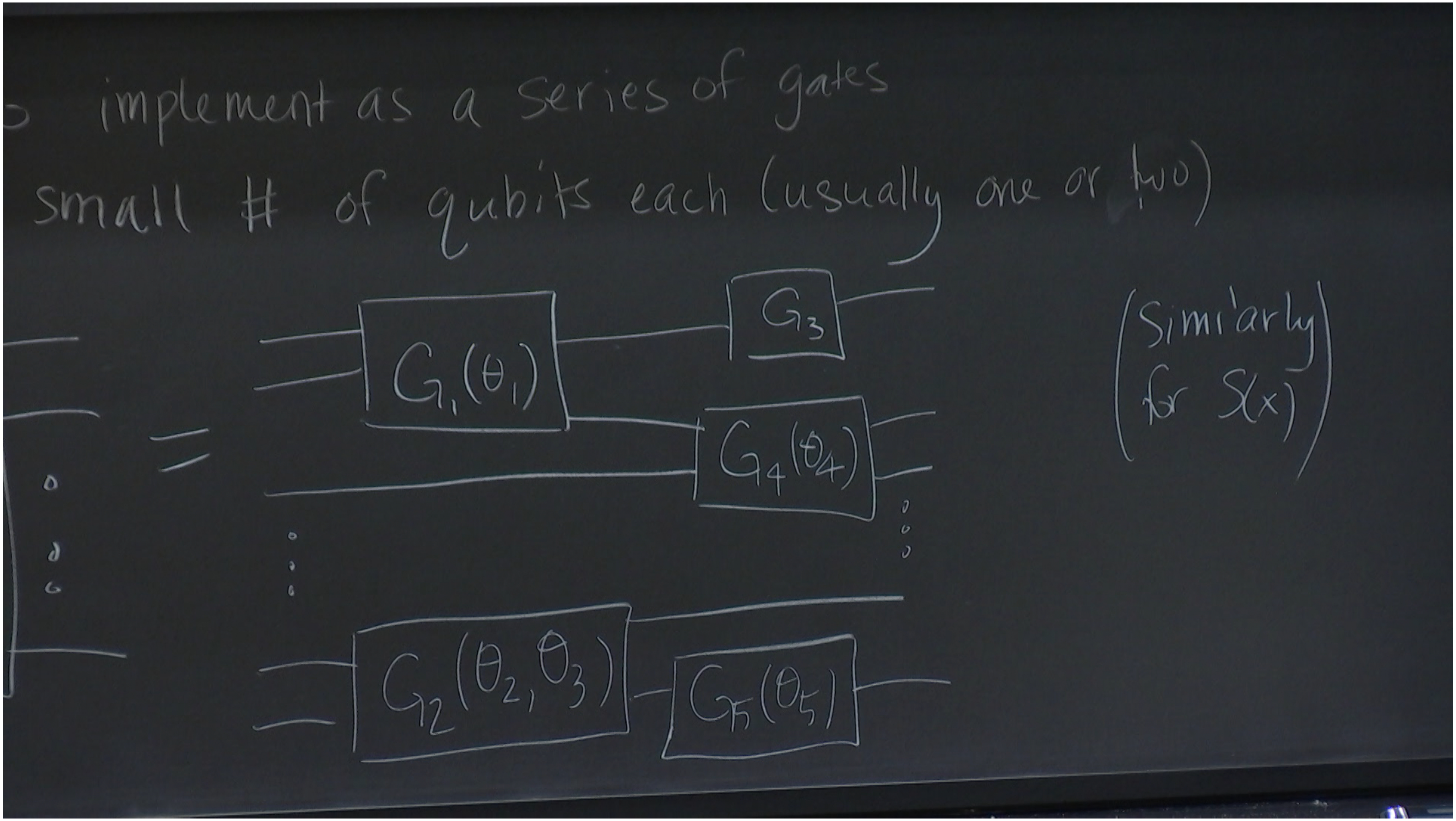
We can first apply non-tunable gates to encode the data

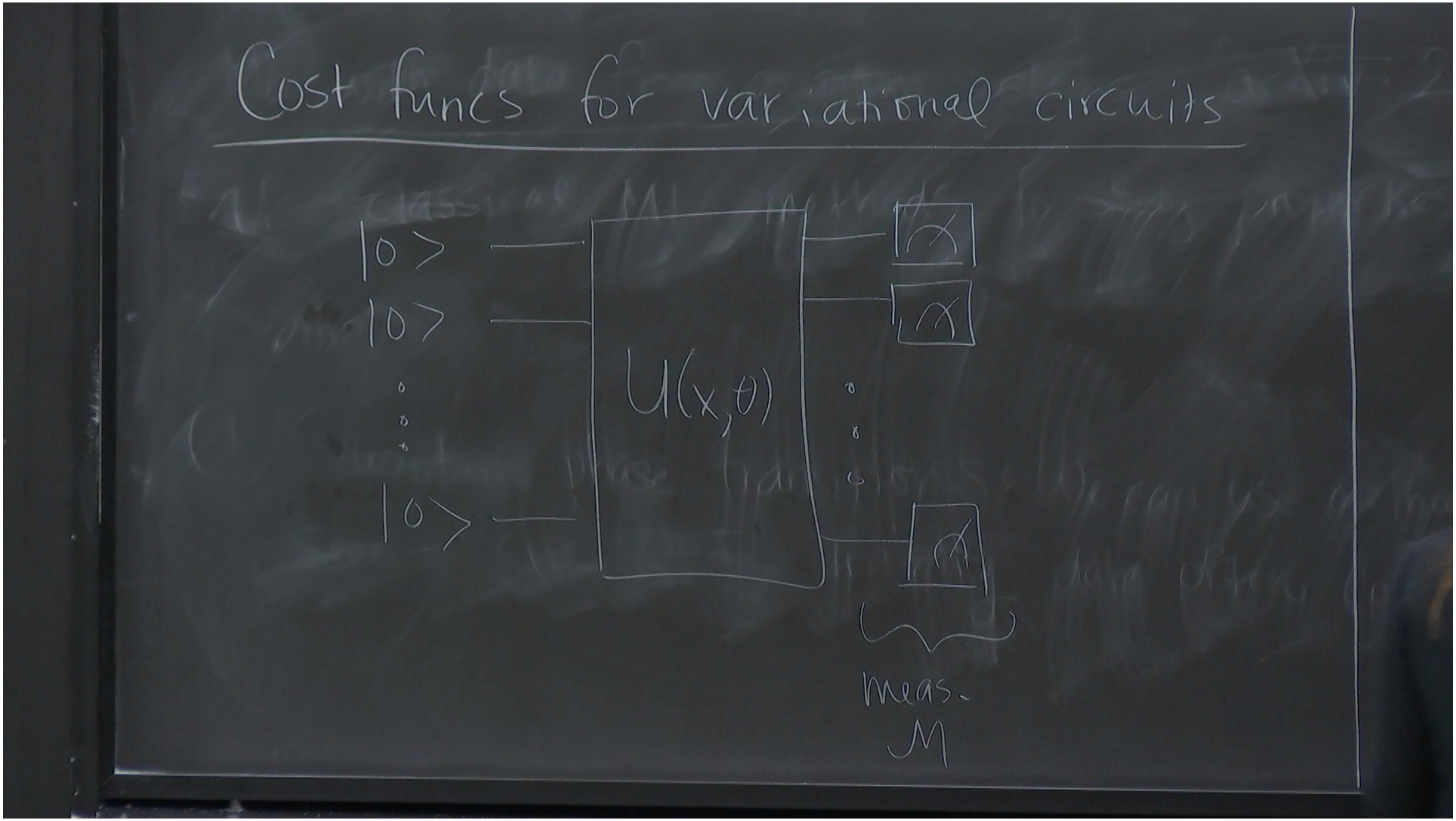
$$|\psi_{out}\rangle = U(x,\theta)|\psi_{in}\rangle$$

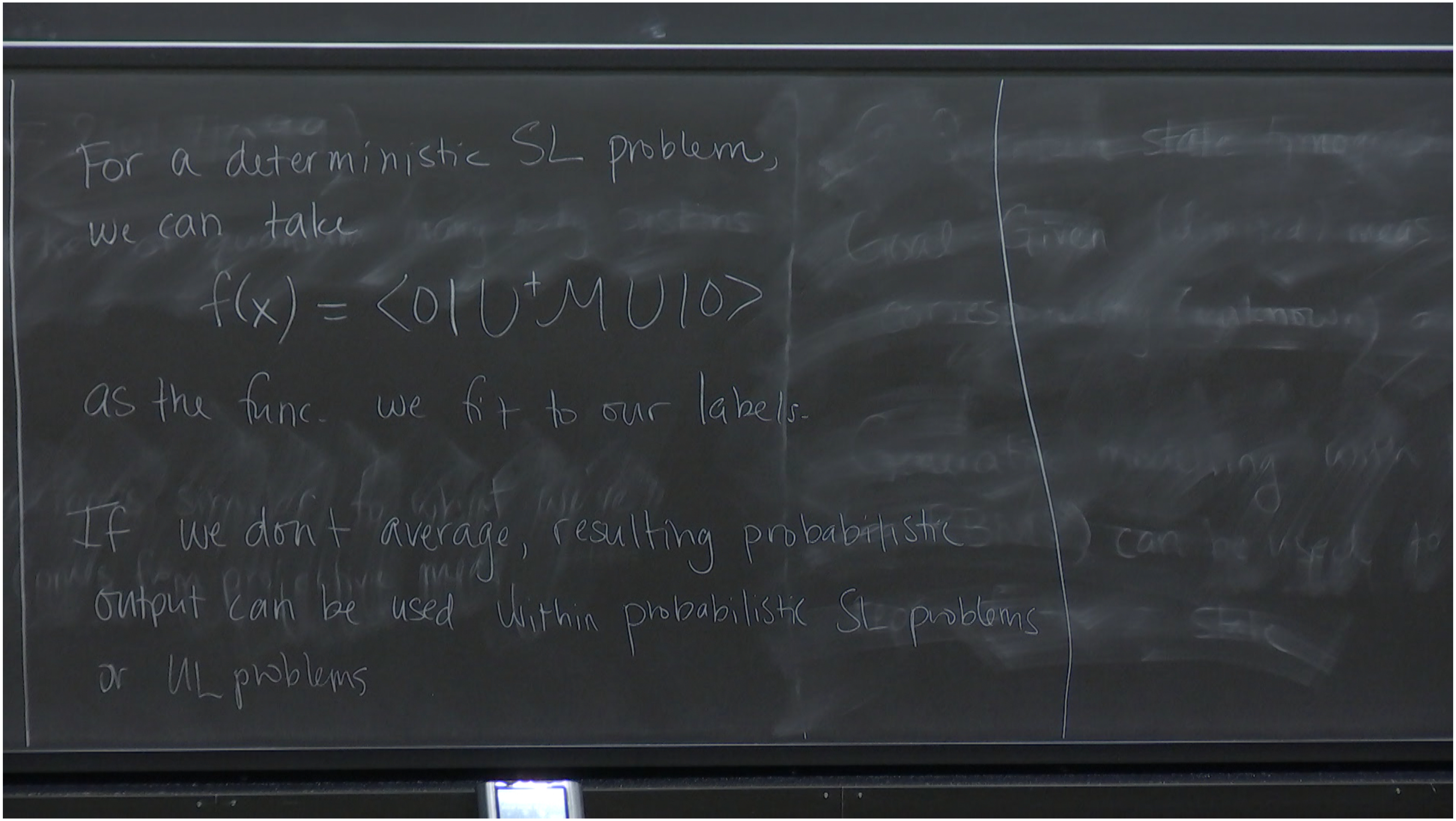
$$U(x,\theta) = W(\theta)\underbrace{S(x)}_{\text{encoding}}$$

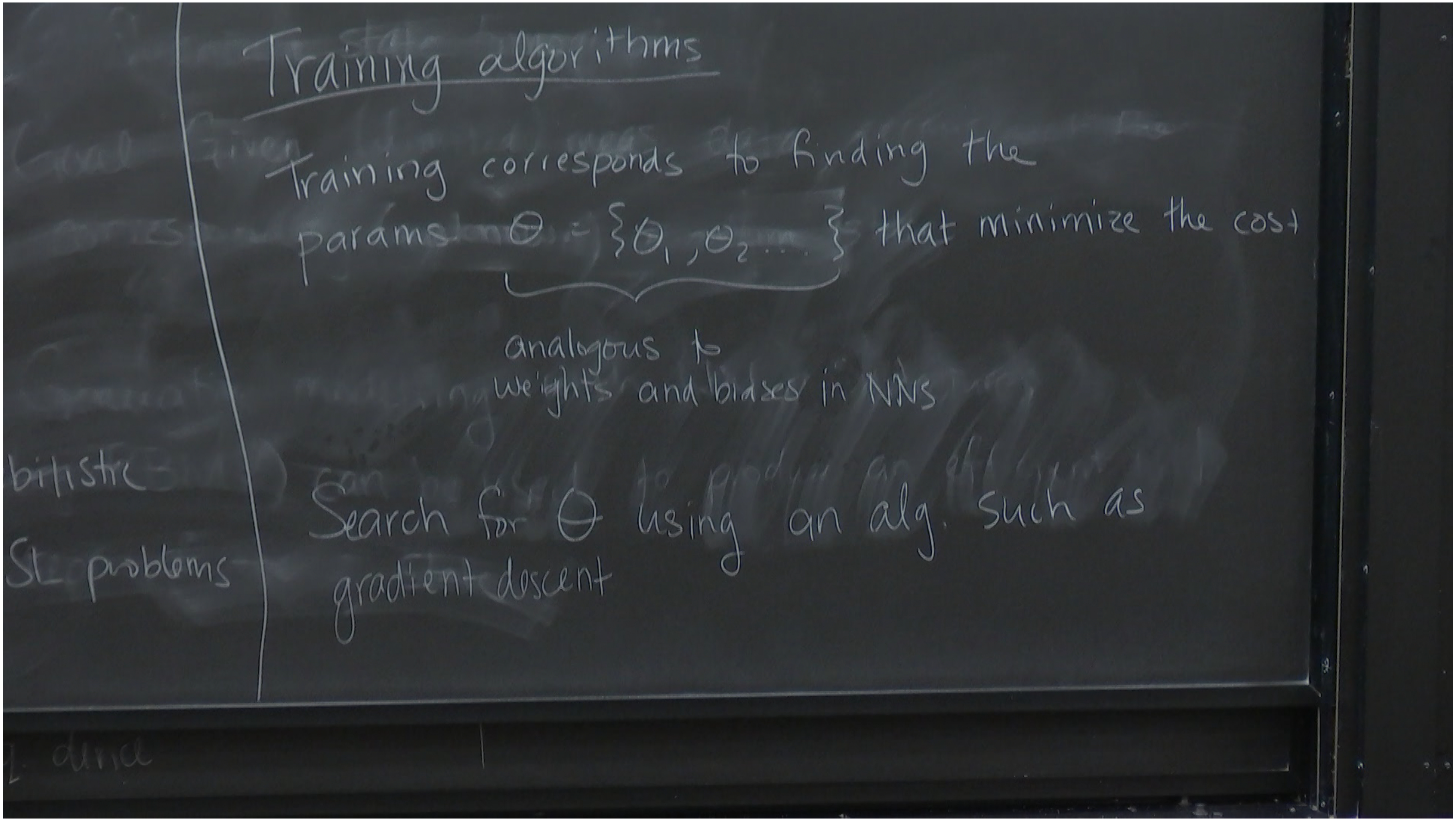
$x = \{x_1, x_2, \ldots\}$


st apply non-tunable gates to
data
U(x,θ)|ψin>
(θ) ≡ W(θ) S(x)
processing
encoding
x={x1,x2,...}
|ψin>
|0>
|0>
|0>
S(x)
W(θ)
|ψout>


implement as a series of gates
small # of qubits each (usually one or two)
$G_1(\theta_1)$
G_3
$G_4(\theta_4)$
$G_2(\theta_2, \theta_3)$
$G_5(\theta_5)$
(Similarly for S(x))


Cost funcs for variational circuits
|0>
|0>
|0>
U(x,θ)
meas.
M

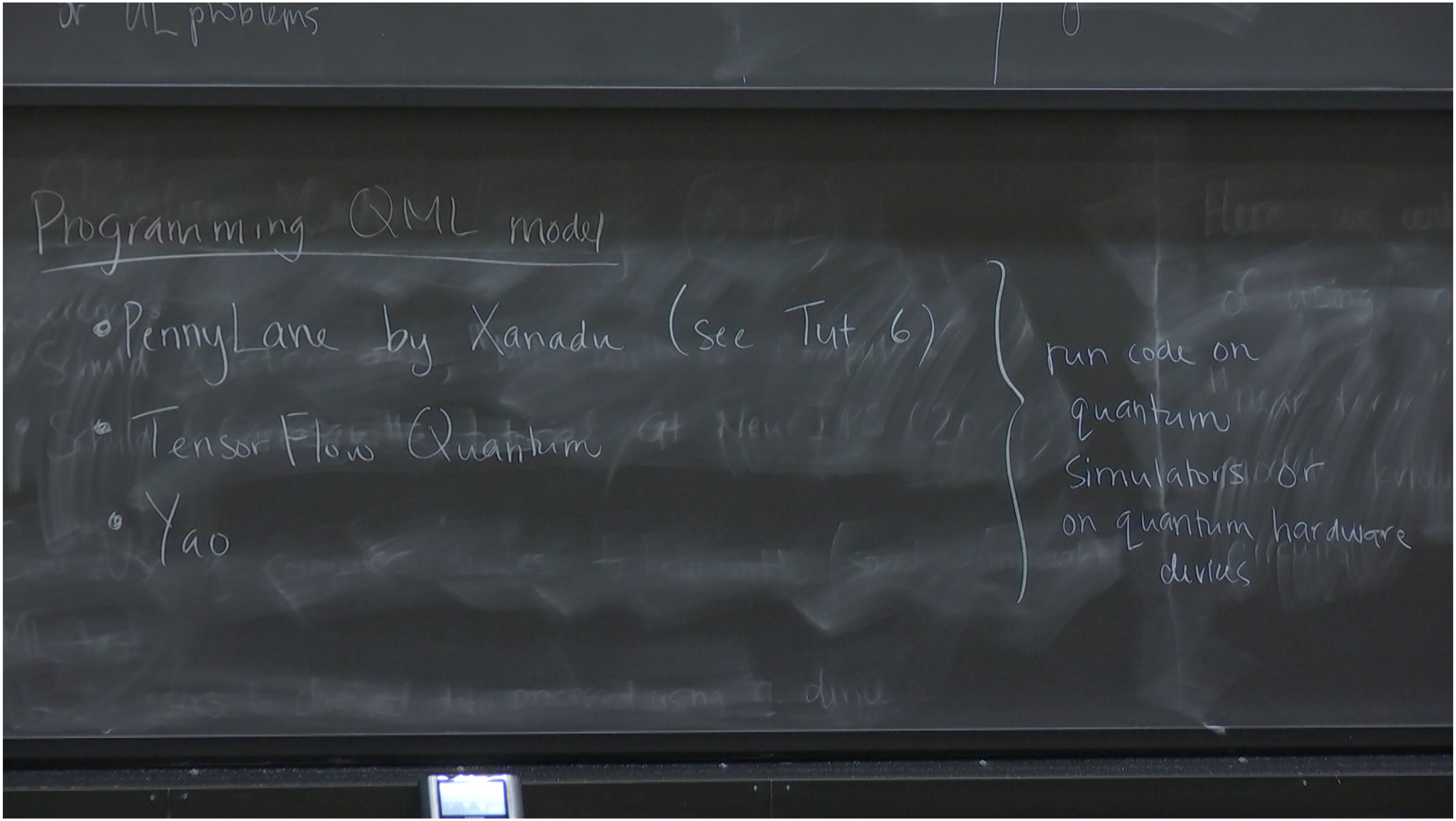

For a deterministic SL problem,
we can take
$f(x) = \langle 0 | U^\dagger M U | 0 \rangle$
as the func. we fit to our labels.
If we don't average, resulting probabilistic
output can be used within probabilistic SL problems
or UL problems

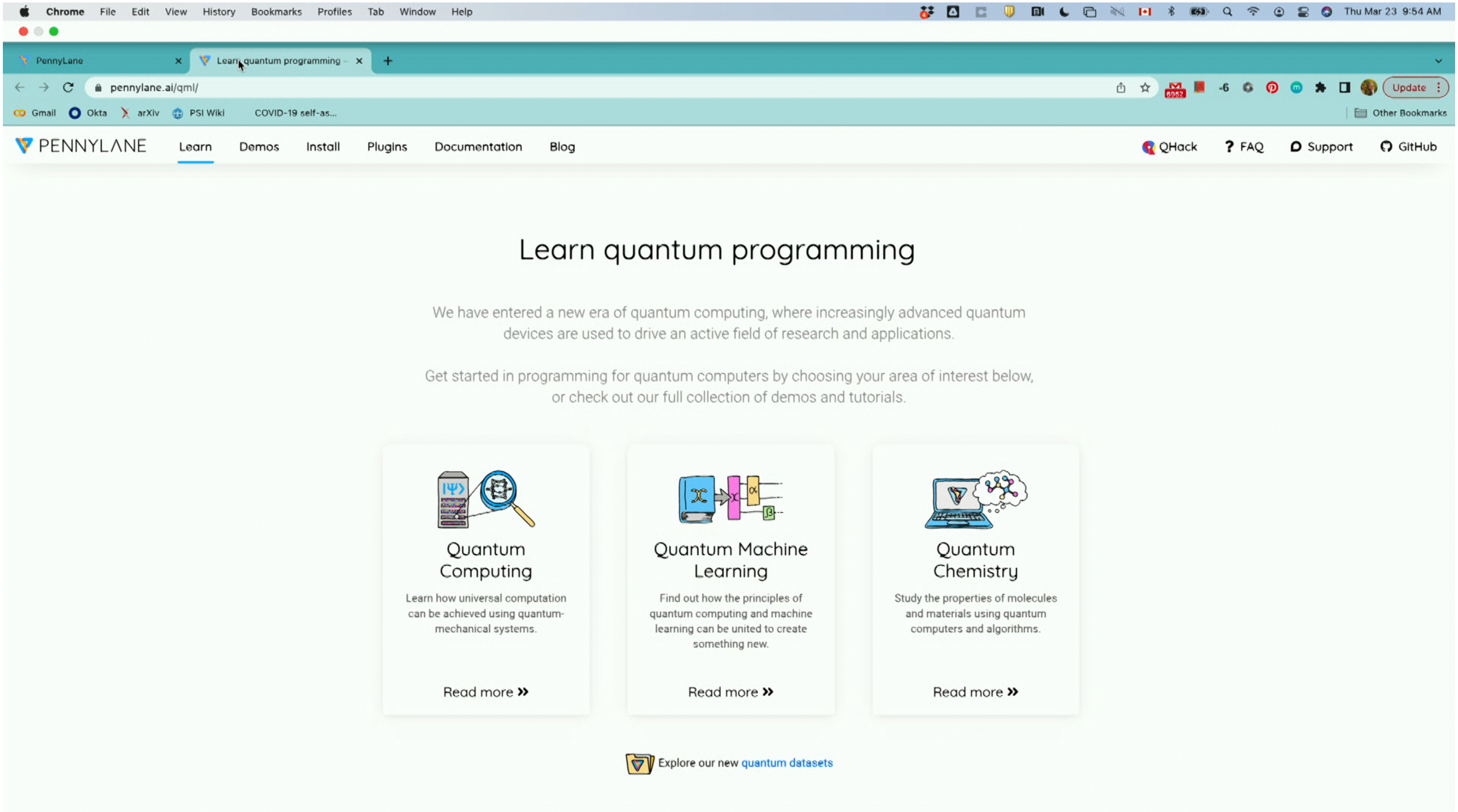

Training algorithms
Training corresponds to finding the
params Θ = {Θ1, Θ2 ...} that minimize the cost
analogous to
weights and biases in NNs
Search for Θ using an alg. such as
gradient descent
SL problems

To compute the gradients:

- use finite-diff. methods or "parameter shift rules"
- be aware of "barren plateaus": regions in param. space where all gradients are close to zero

Active area of research!


Programming QML model
• PennyLane by Xanadu (see Tut. 6)
• TensorFlow Quantum
• Yao
run code on quantum simulators or on quantum hardware devices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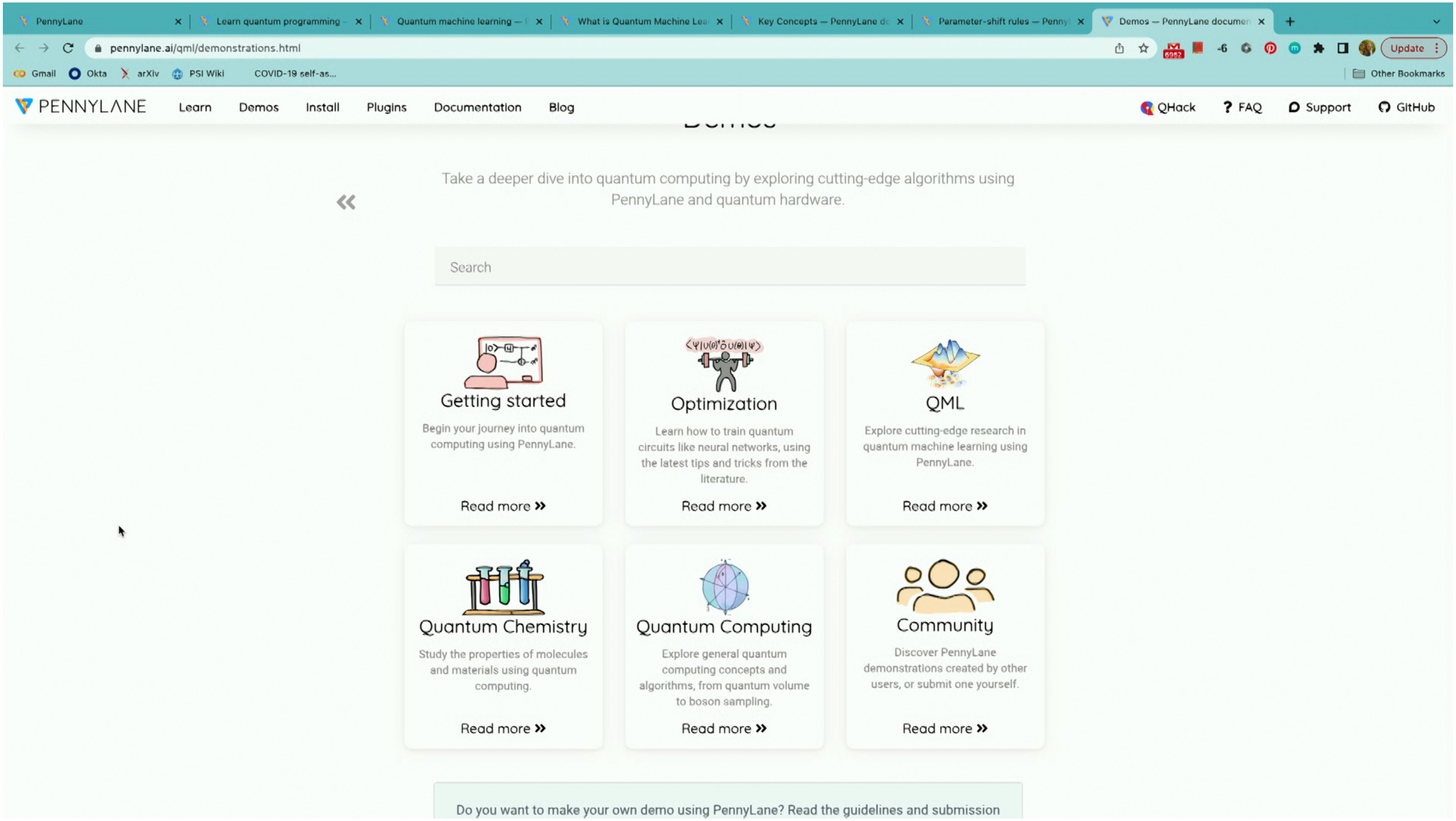
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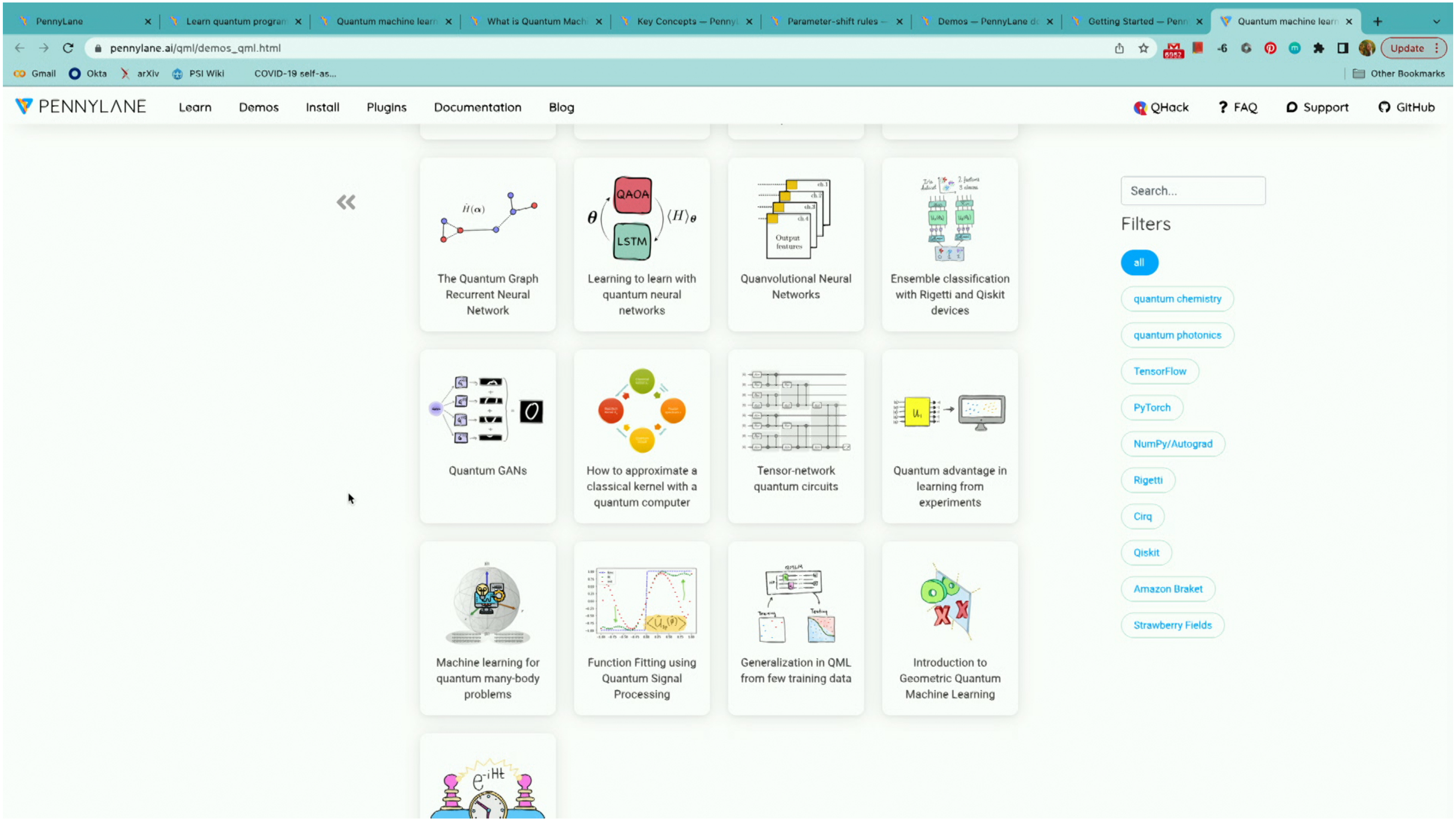
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