

# QuHack4IA

Quantum Hackathon  
for Industrial Applications

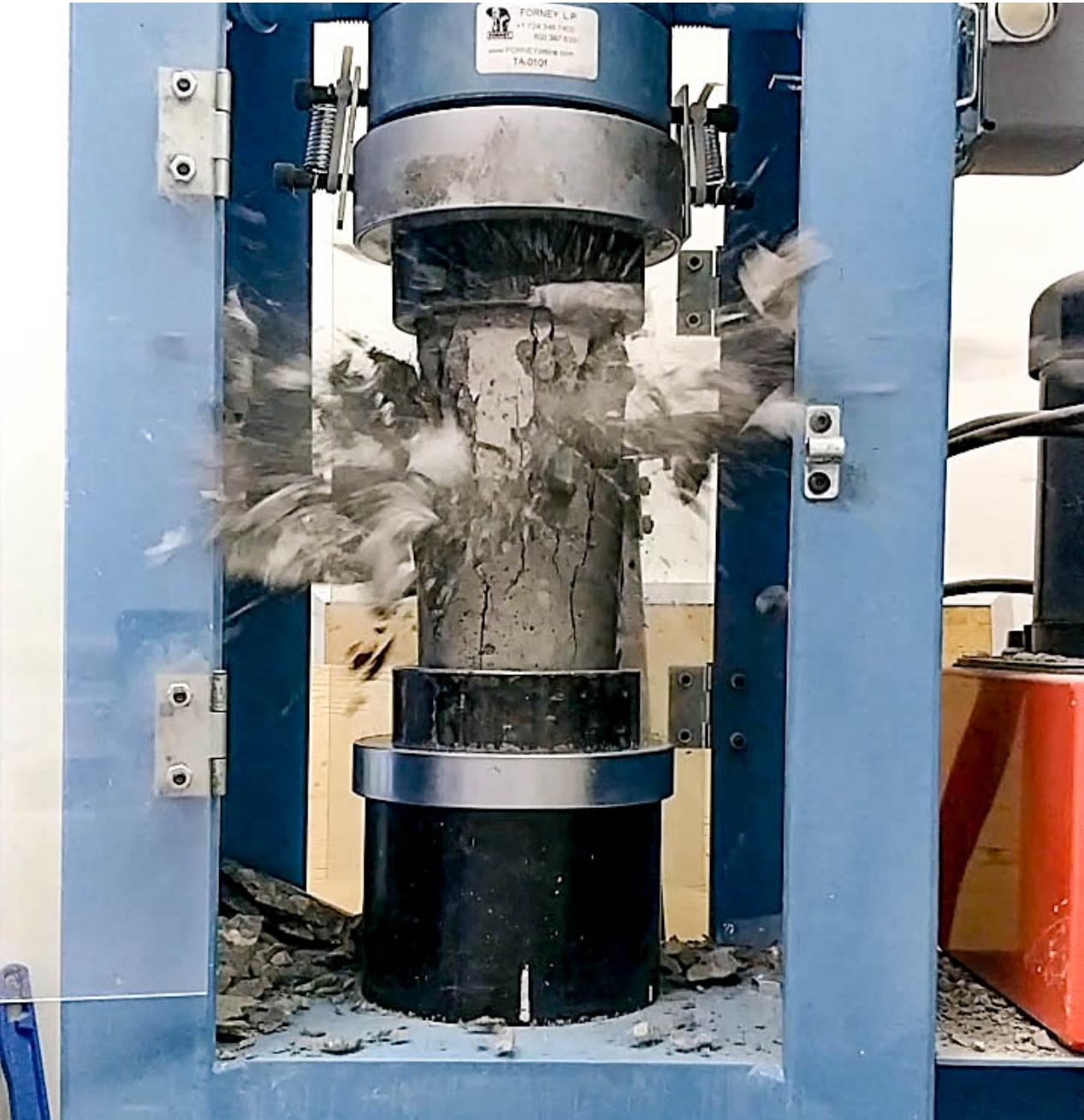
Team #4  
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Tutors: Simone Gasperini,  
Filippo Orazi



12-13 settembre 2023  
Bologna

# Concrete Compressive Strength Data Set



## Industrial applications

- Civil engineering
- Construction industry

## Regression problem

1. Dataset exploration and preprocessing
2. QNN model
3. Training and evaluation

# Dataset exploration

Input Variables (kg in a m<sup>3</sup> mixture)

1. Cement
2. Blast Furnace Slag
3. Fly Ash
4. Water
5. Superplasticizer
6. Coarse Aggregate
7. Fine Aggregate
8. Age \*

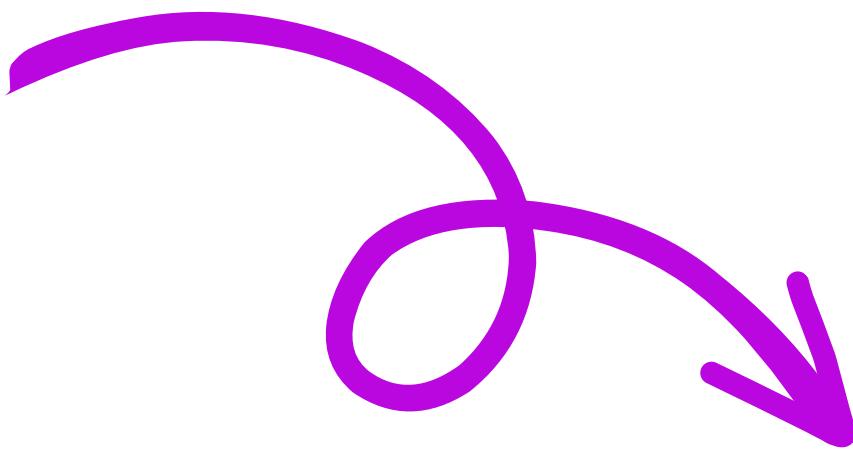
\* Day (1~365)



Output Variable (MPa)  
Concrete compressive strength

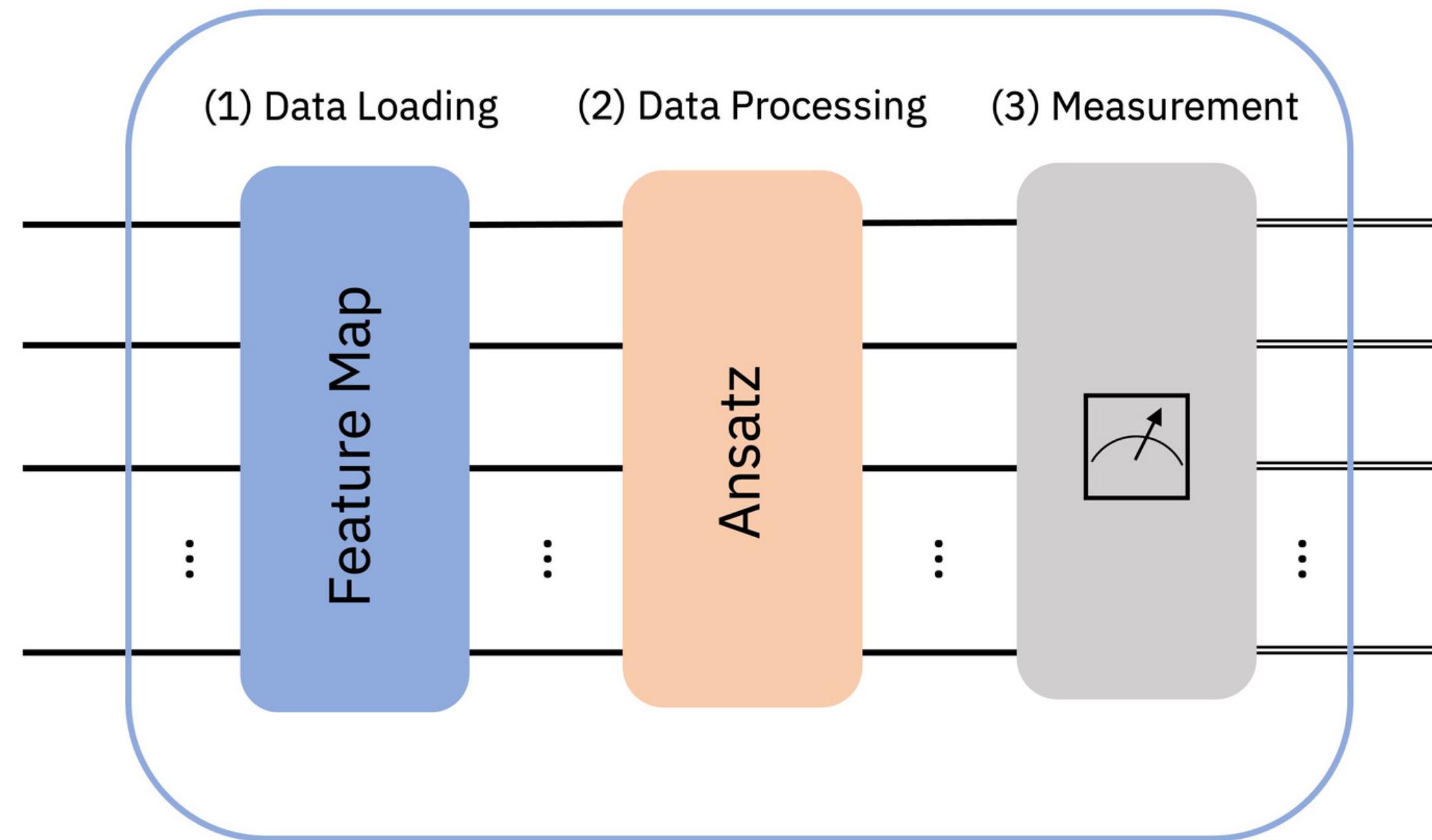
# Preprocessing

Normalization:  
feature rescaling  $x, y \in [-1, 1]$



Classical model reference:  
Mean Squared Error (MSE)  $\approx 0.01459$

# Variational Quantum Neural Network



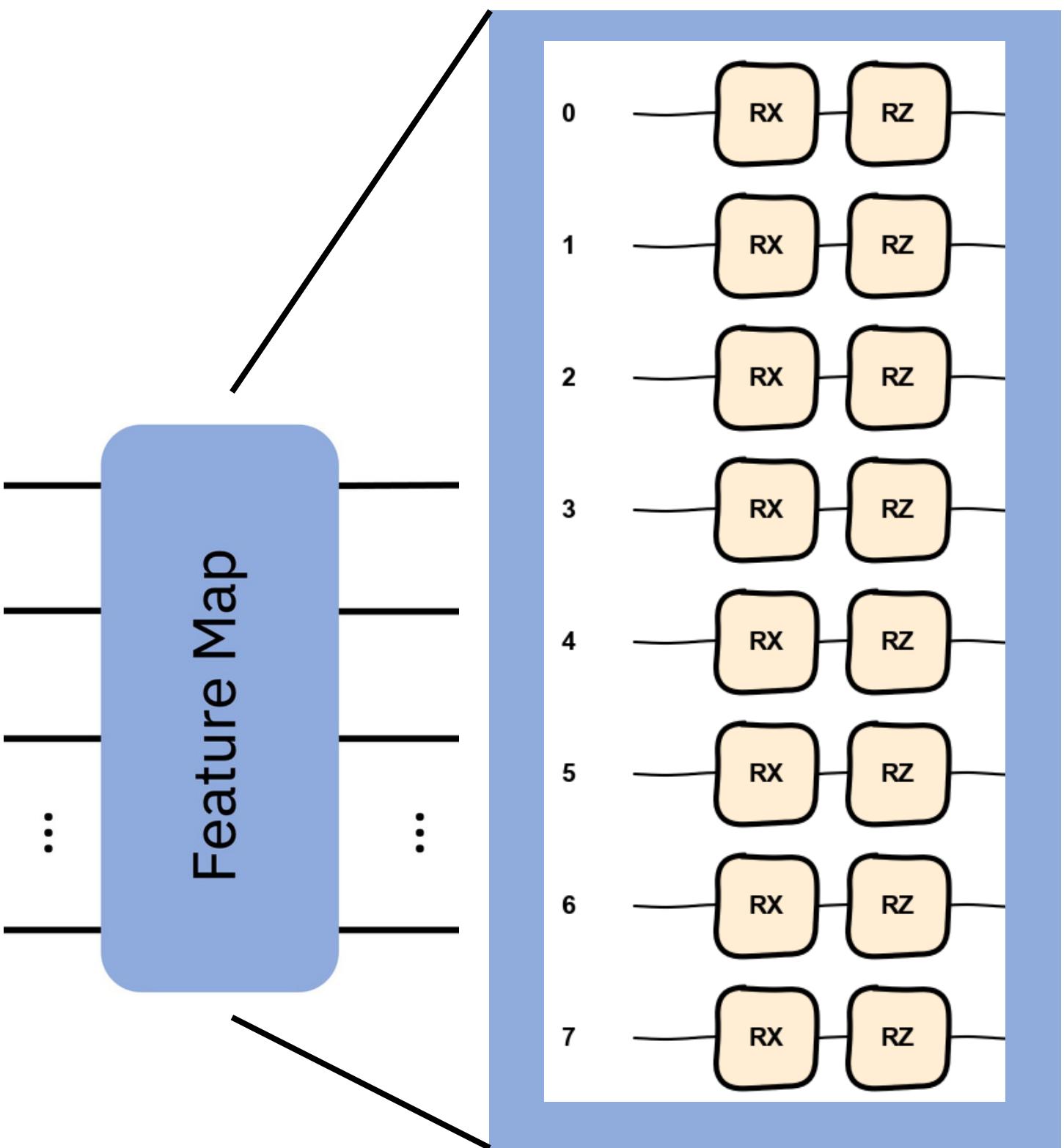
# QNN model

$\Phi$ : input data  $\mapsto$  quantum states

Angle encoding,  $\theta \in [-\pi, \pi]$

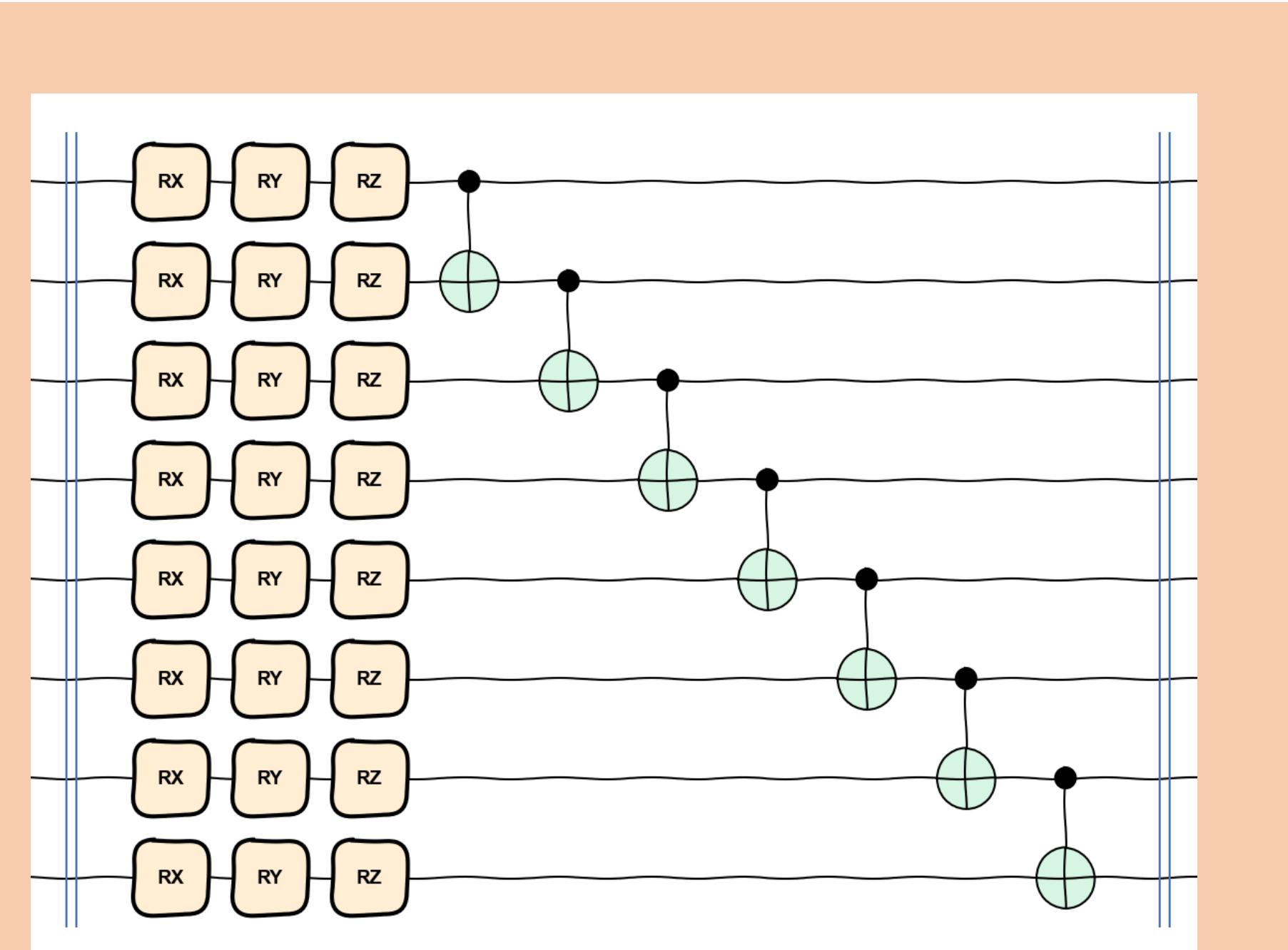
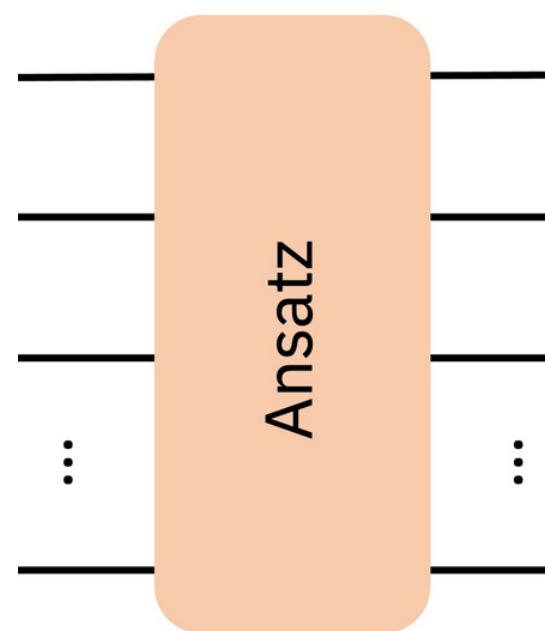
2 different encodings:

- linear  $\theta = \pi x$
- non linear  $\theta = 2 \arctan(x)$



# QNN model

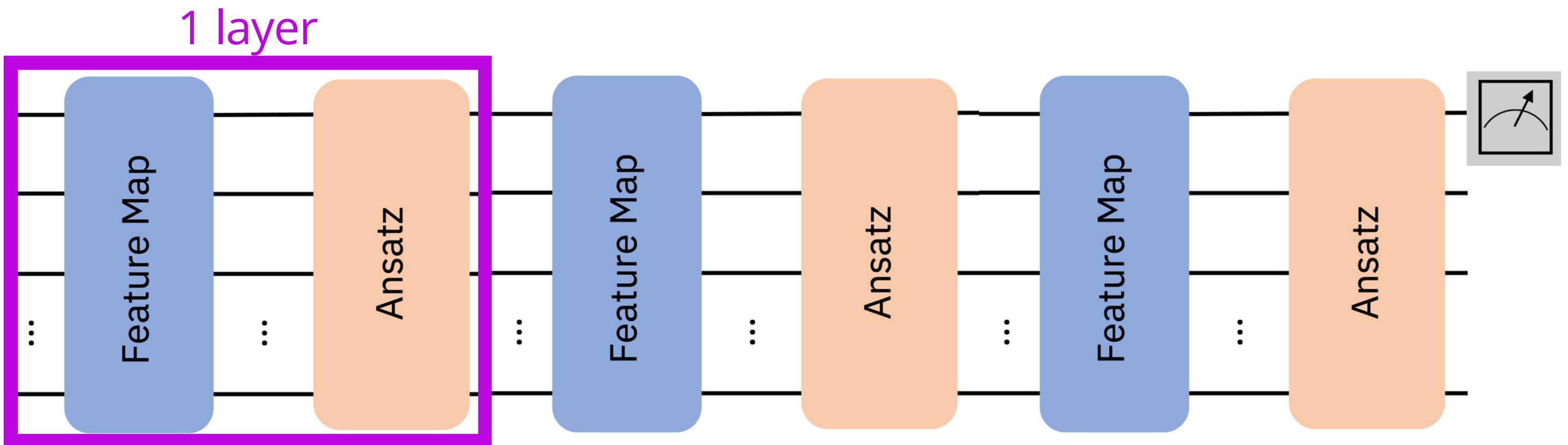
Custom circuit ansatz:



Sublayer

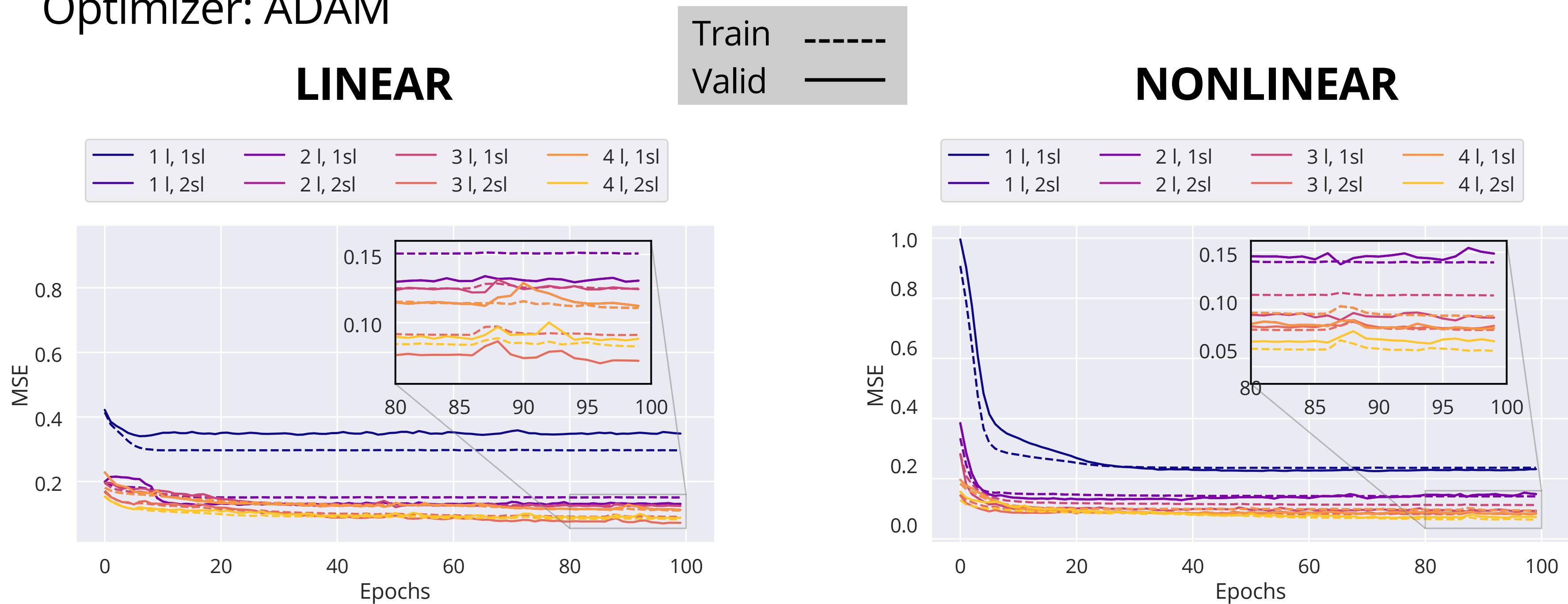
# QNN model

# Data re-uploading and measurement

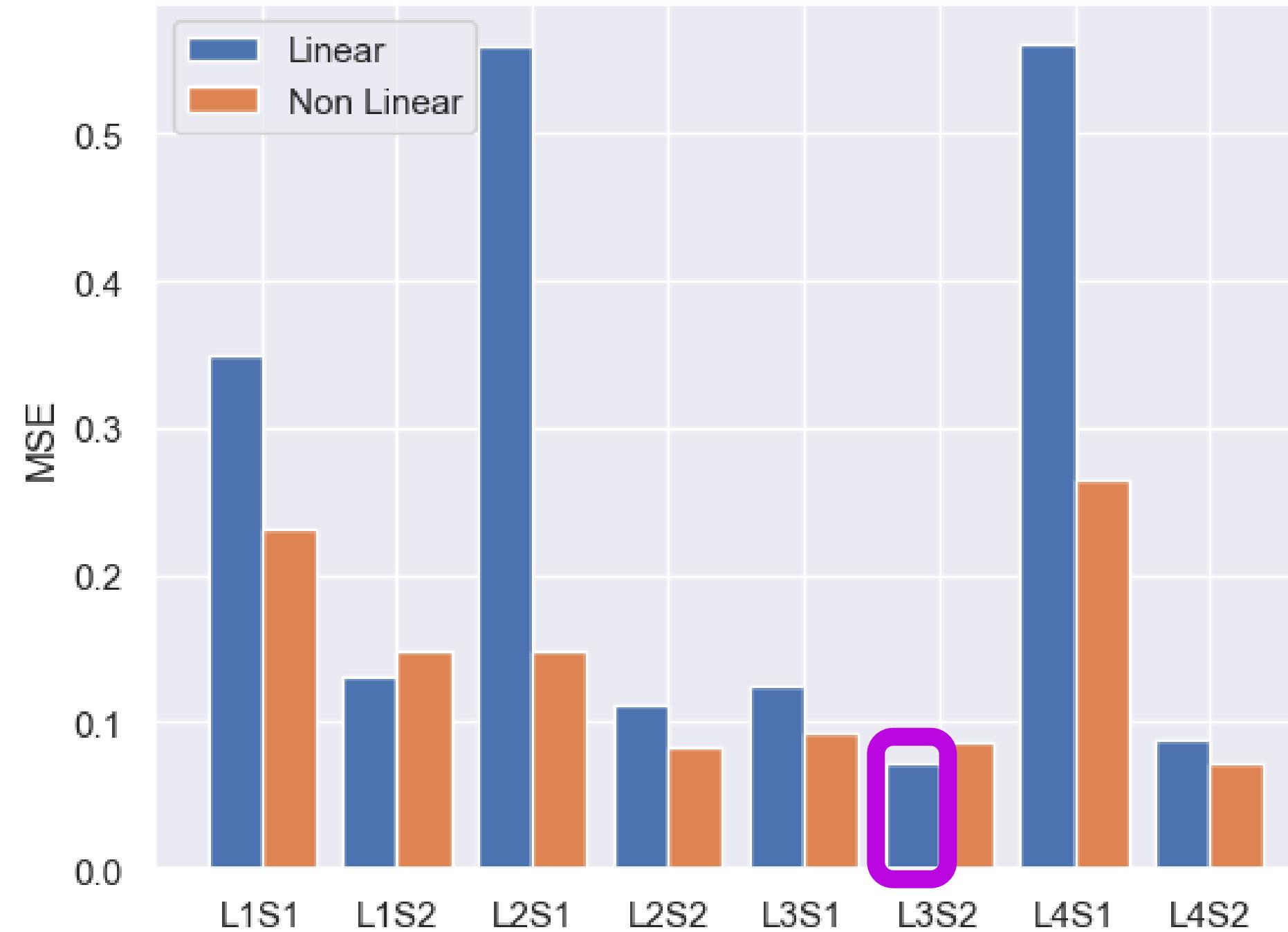


# Training and evaluation

Optimizer: ADAM



# Hyperparameter tuning



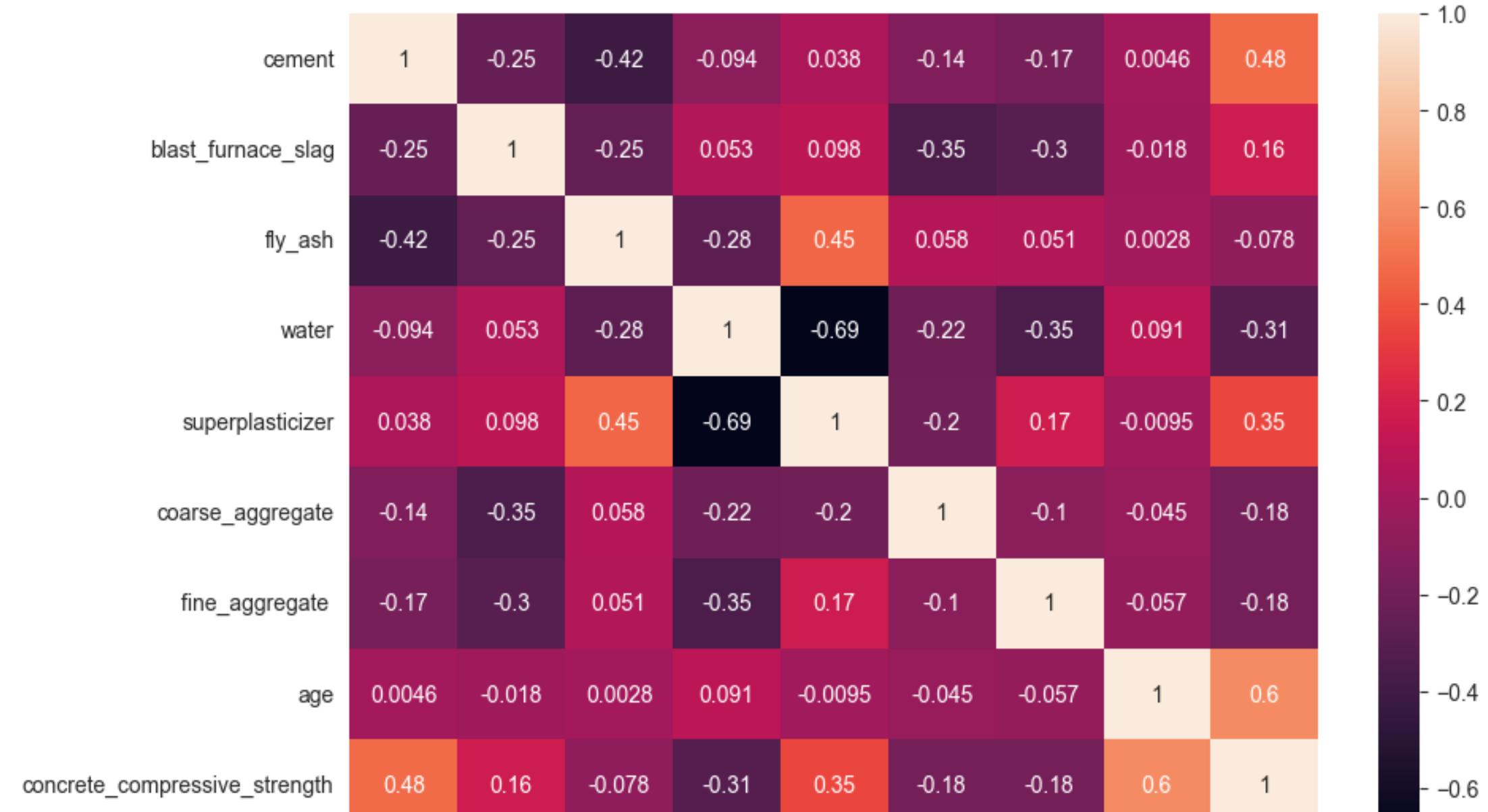
## TEST SET

Classical model:  
MSE  $\approx 0.01459$

Quantum model:  
MSE  $\approx 0.10057$

# Advanced task

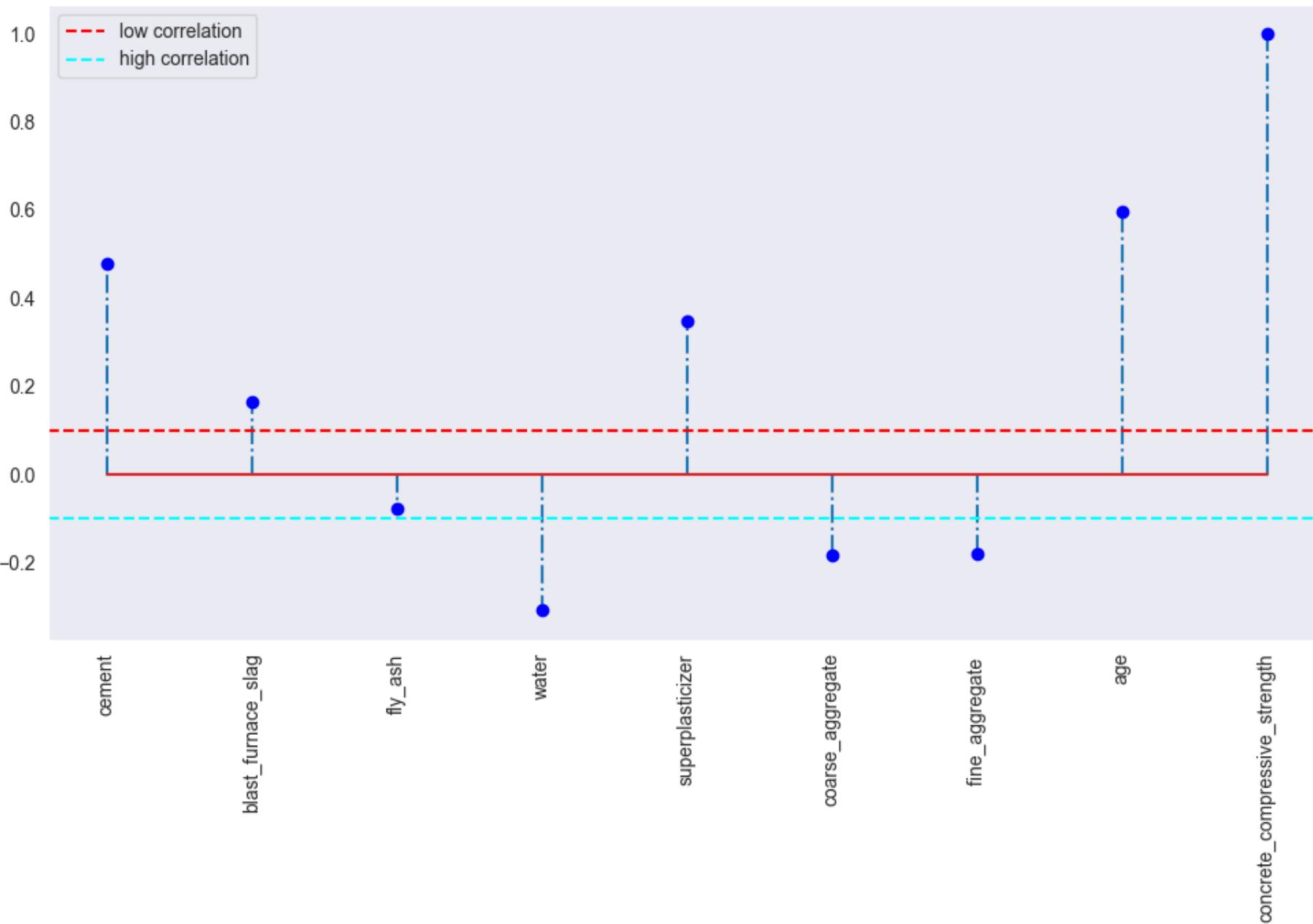
## Multivariate analysis



Spearman correlation

# Advanced task

## Removing feature fly ash



### Classical model

Normalized dataset:

$MSE \approx 0.014592$

Normalized dataset with features reduction:

$MSE \approx 0.014218$

### Quantum model

Normalized dataset:

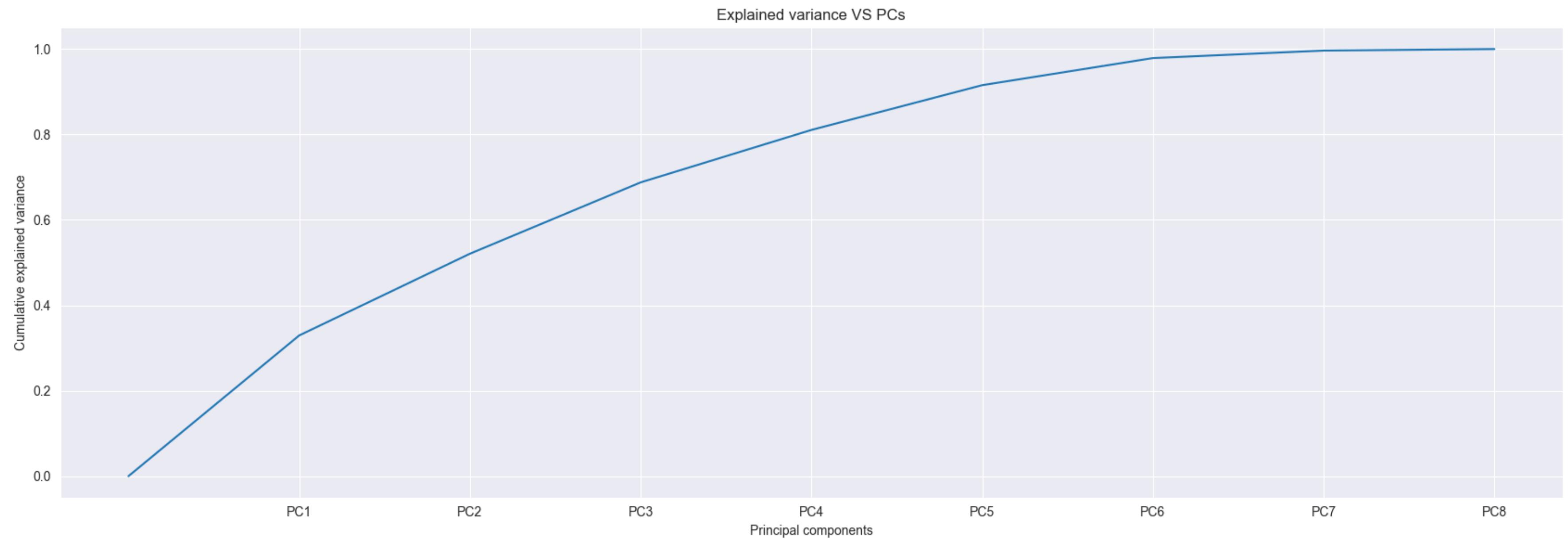
$MSE \approx 0.10057$



Normalized dataset with features reduction:

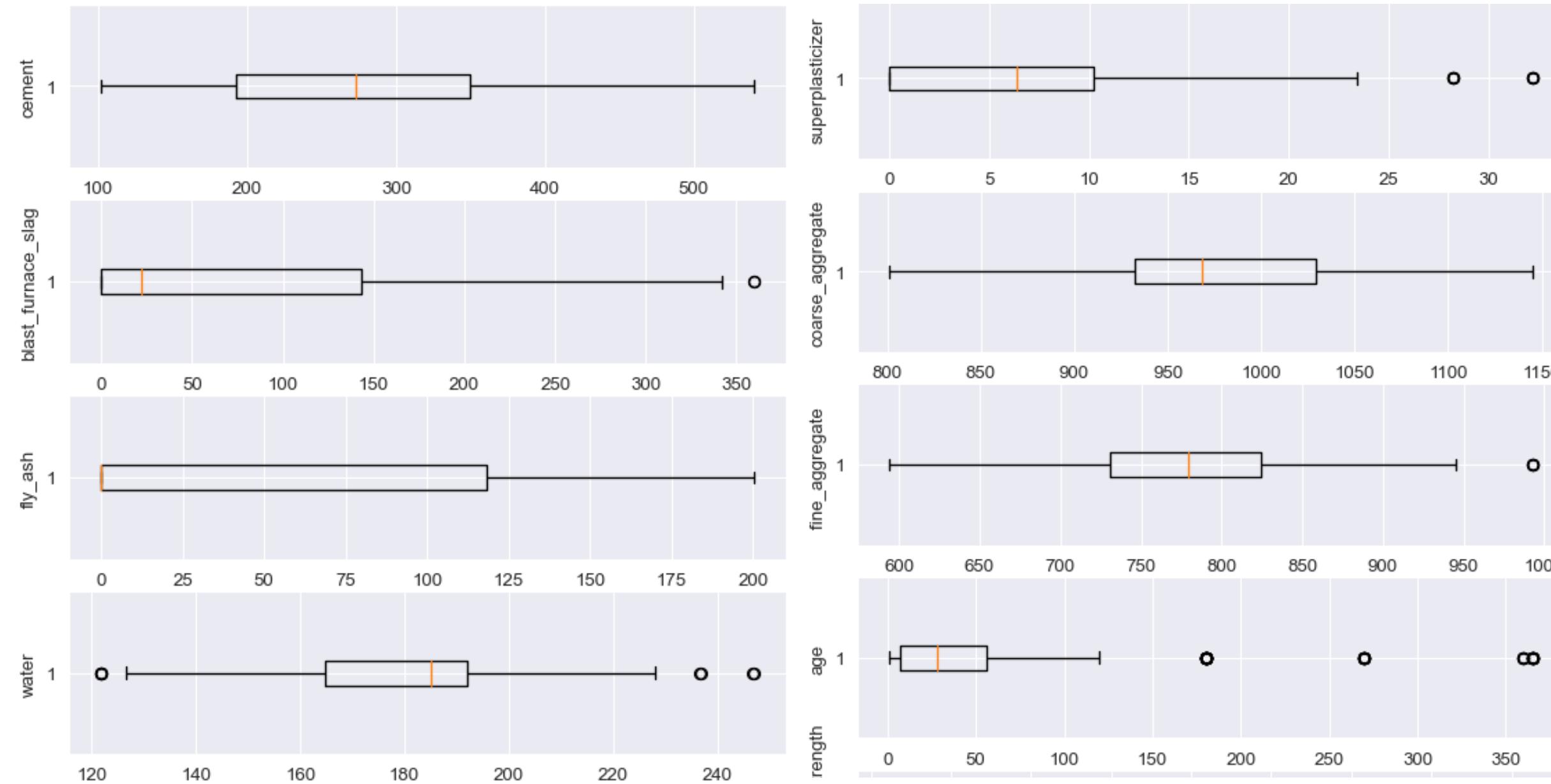
$MSE \approx 0.03909$

# PCA analysis

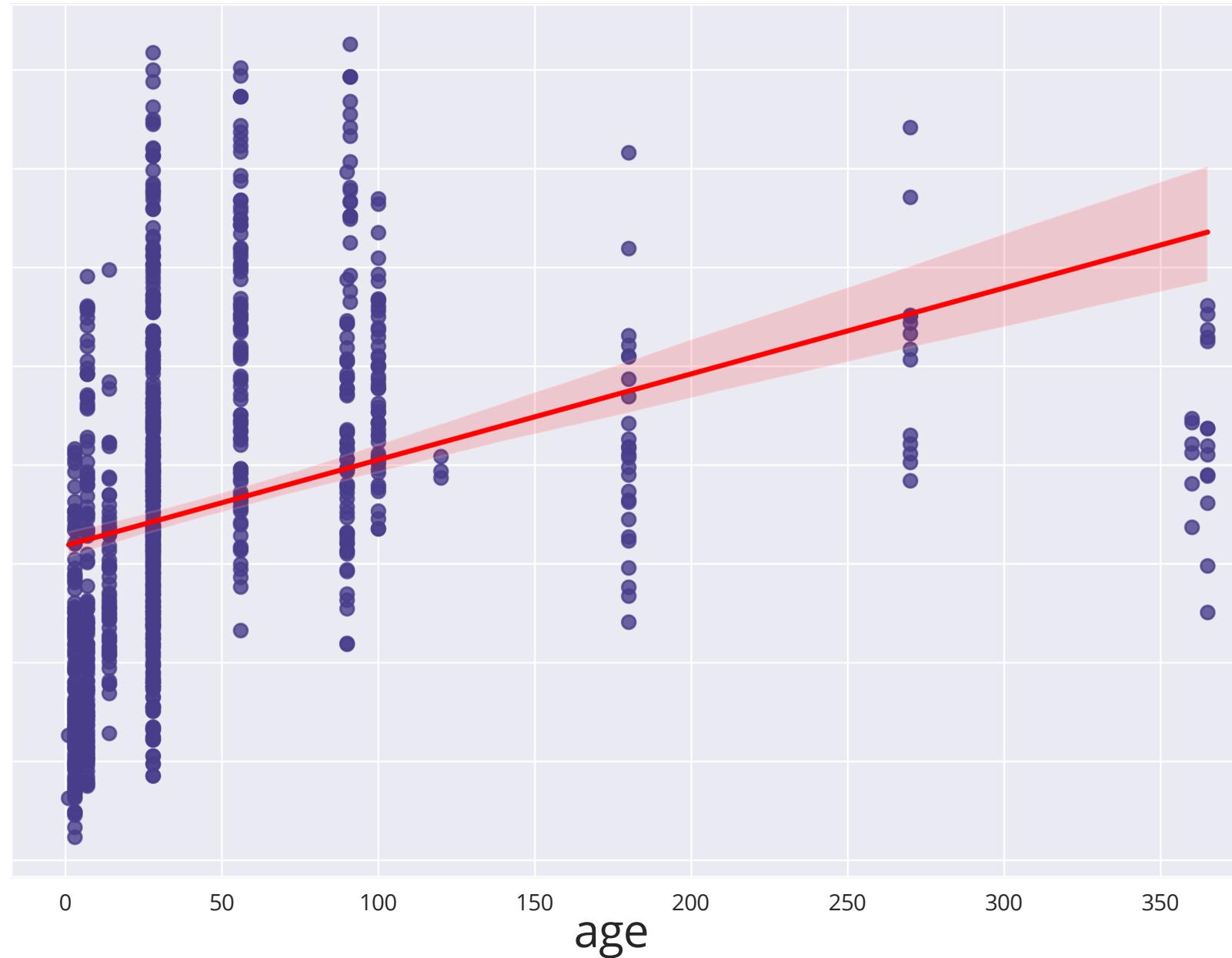


# Advanced task

## Removing outliers



# Correlation between age and target



## Classical model

Normalized dataset:

$MSE \approx 0.01459$

Normalized dataset with features reduction and without outliers:

$MSE \approx 0.014927$

## Quantum model

Normalized dataset:

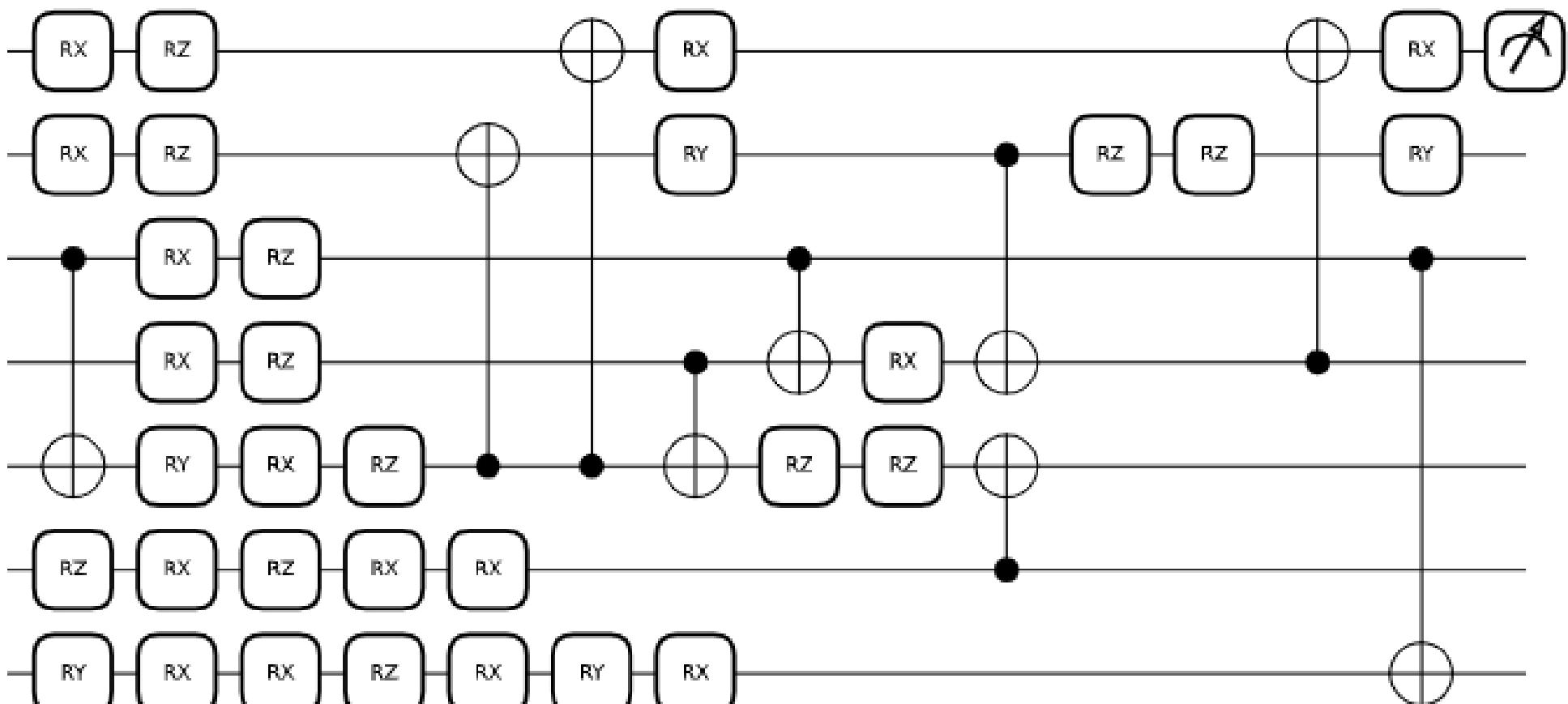
$MSE \approx 0.10057$

Normalized dataset with features reduction and without outliers:

$MSE \approx 0.04339$

# Advanced task: different QNN architecture

Random ansatz circuit

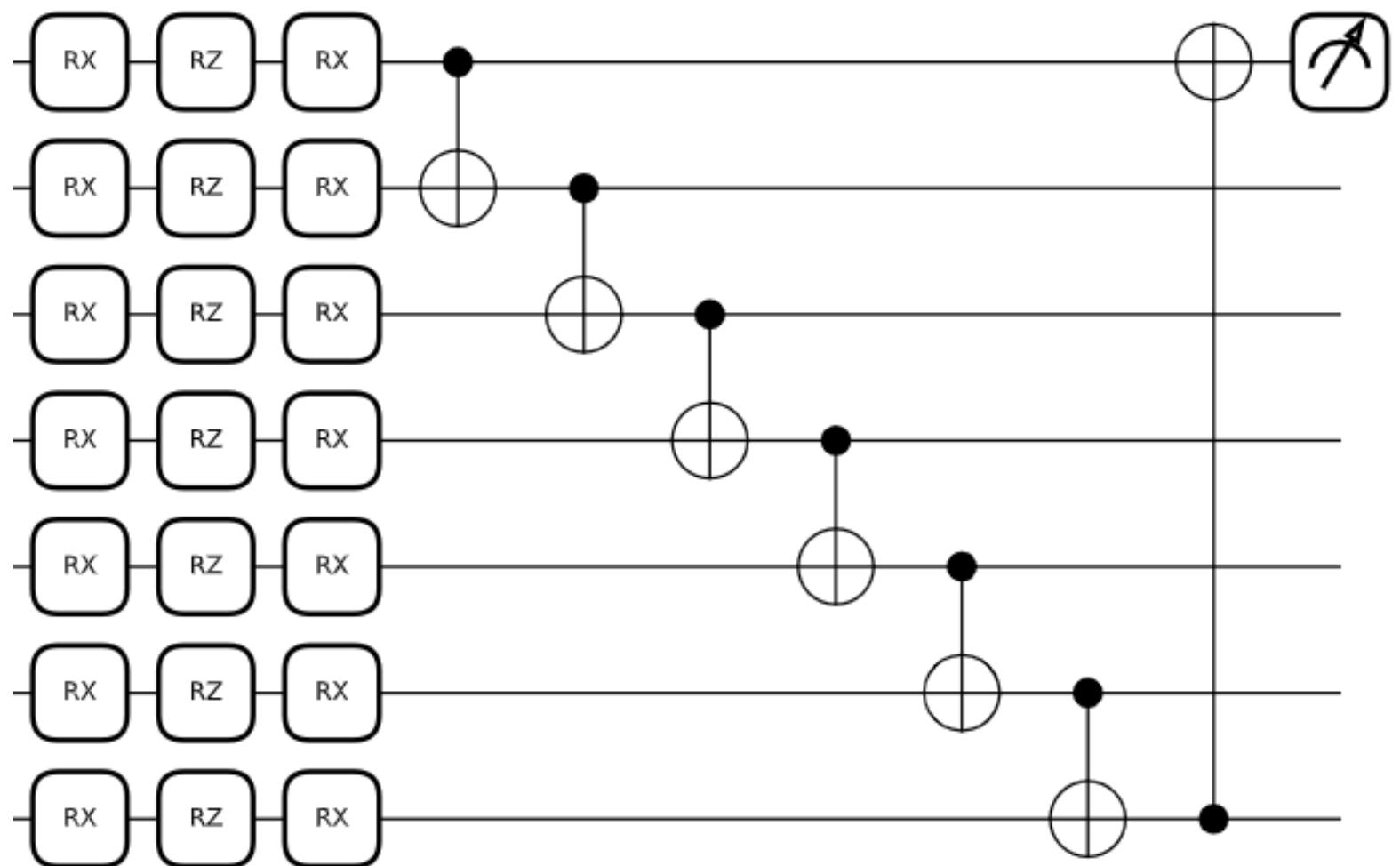


4 layers and 4 sublayers  
MSE  $\approx 0.13877$



# Advanced task: different QNN architecture

Common ansatz circuit on Pennylane



1 layer and 2 sublayers  
MSE  $\approx 0.11281$





# Compress Bot

--Welcome to Compress Bot--

Hi, I am Compression Bot, I can help you calculate the force required to reach the compression point from your mixed ingredients.

Now give me some important ingredients related to your mixture:

Cement (kg/m<sup>3</sup>): 540

Blast furnace slag (kg/m<sup>3</sup>): 0

Water (kg/m<sup>3</sup>): 173

Superplasticizer (kg/m<sup>3</sup>): 0

Coarse aggregate (kg/m<sup>3</sup>): 1125

Fine aggregate (kg/m<sup>3</sup>): 613

Age (days): 28

Calculate your result...

This is your result: 27.699999 MPa

# Team



An engineer, a mathematician, physical engineer and a physicist

It's not a joke 😂

## Thank you for attention!

We are happy to answer your questions

