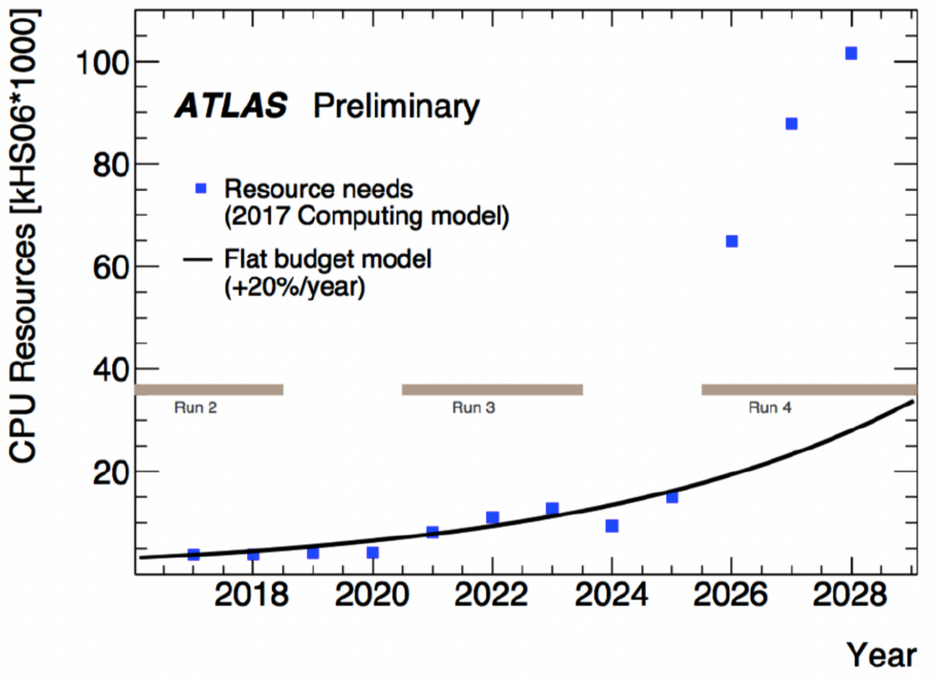
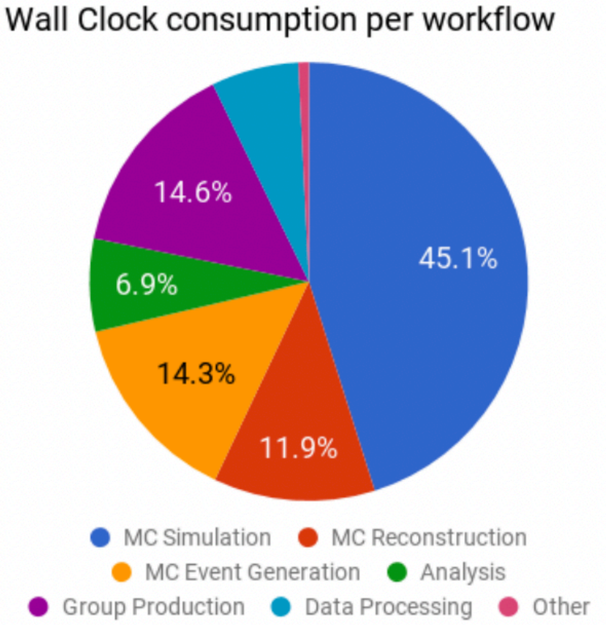
Why Fast Calorimeter Simulation ?

- HL-LHC ⟶ enormous computing resources
- Top CPU consumer: MC simulation (~50%), especially calorimeter simulation
- Fast shower simulation: an important approach to help overcome the computational challenge





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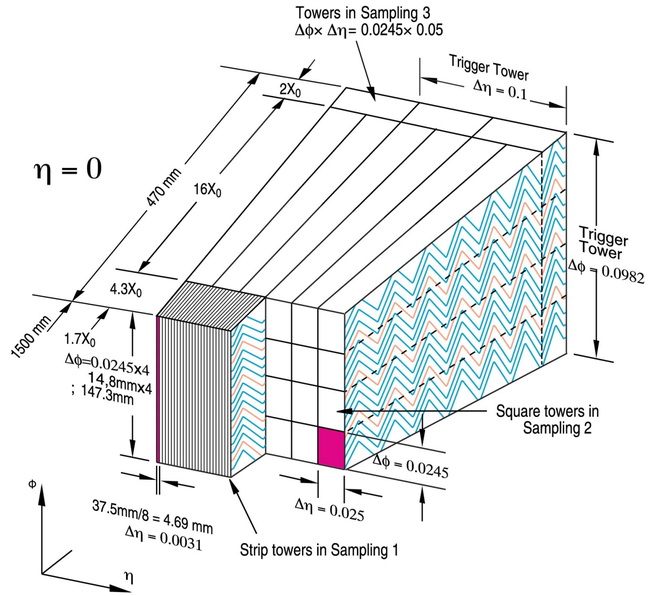
Why Quantum GAN ?

- Training of classical GAN is time consuming
  - fast shower simulation could be viewed as generating a 3D image
  - large and high granularity calorimeter ⟶ complex model, hard to train (especially in HL-LHC)

- Limited performance of classical GAN

- Quantum GANs could have more representational power
  - reduce the training time
  - improve the final accuracy



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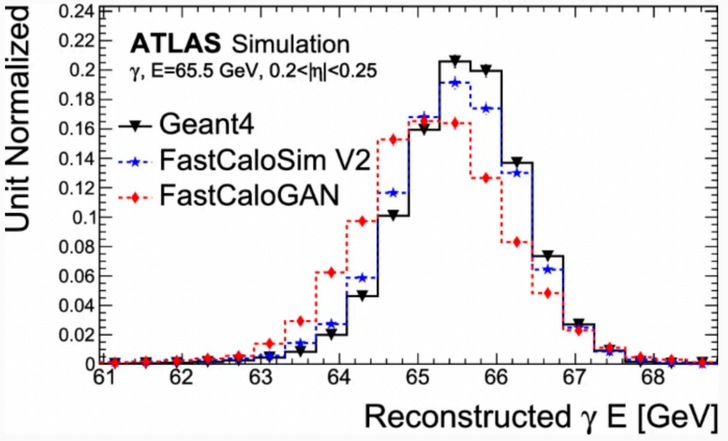
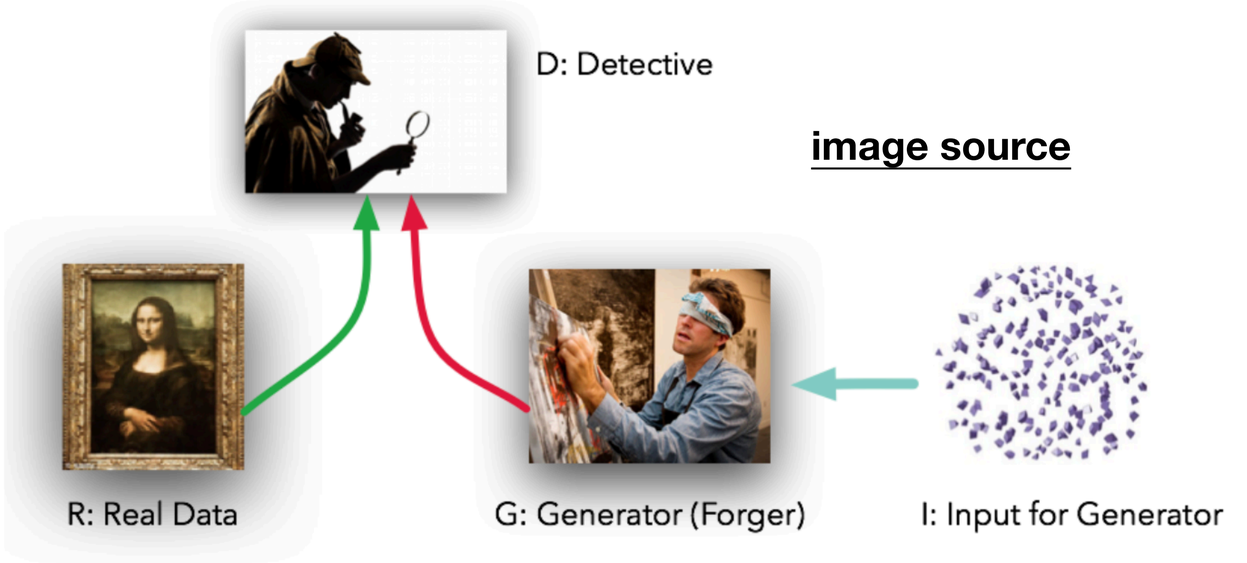


Methods

- Quantum/Classical GANs have two models fighting against each other
  - generator: create fake data that looks like the real data
  - discriminator: tells the difference between fake data and real data

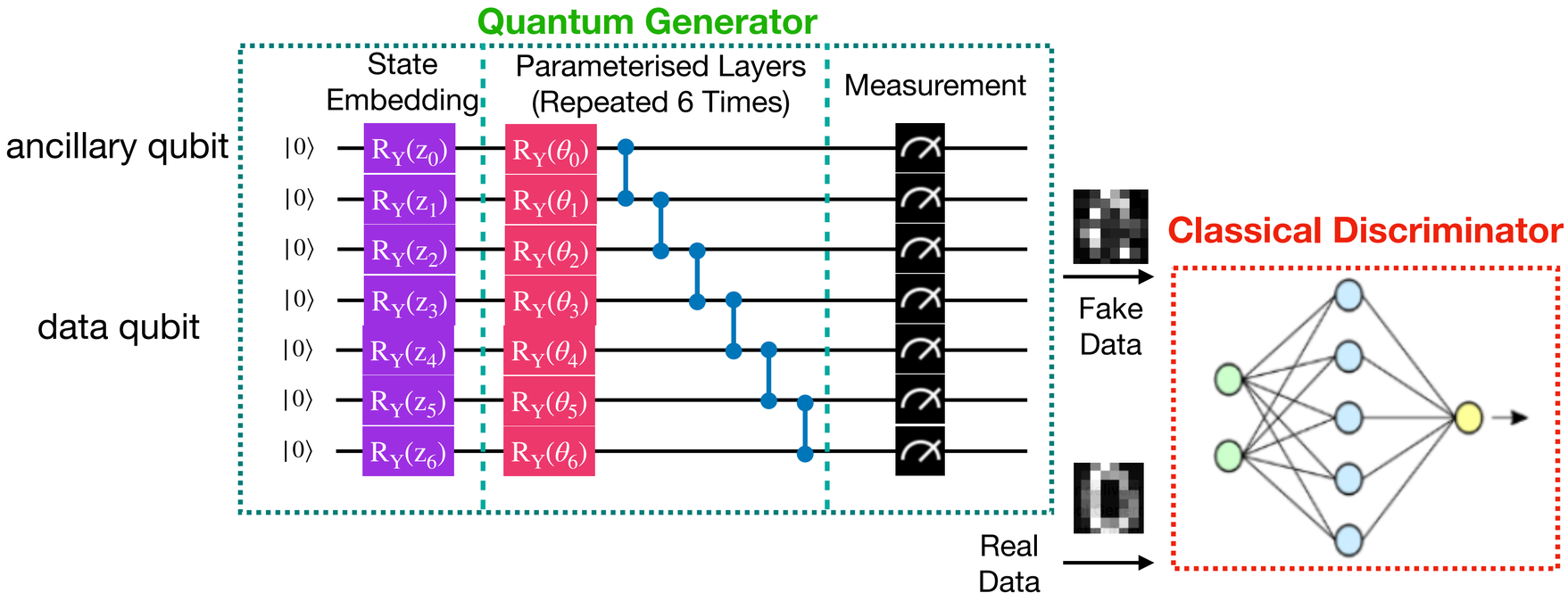


- Two possible approaches under the investigation of IHEP community
  - hybrid version: quantum generator and classical discriminator
  - full quantum version: quantum generator and quantum discriminator

- Noisy intermediate-scale quantum (NISQ) era → hybrid version

Generate Handwritten Digits

- As a proof of concept, generate handwritten digits ($8 \times 8 = 64$)
  - 6 data qubits ⟶ $2^6 = 64$ pixels
  - 1 ancillary qubit ⟶ non-linear transformation through partial measurement



Results and Future Plan

- With 7 qubits (6 data qubits + 1 ancillary qubit), we are able to generate handwritten digits with 64 pixels ($2^6 = 64$) using the quantum simulator

- Future Plan
  - Test the model using the real quantum computer
  - Implement a hybrid classical-quantum GAN for fast shower simulation
  - Test the impact of data embedding, noise, ….