1. The Large Hadron Collider
▶ The Large Hadron Collider (LHC) is the world’s largest and most powerful particle accelerator
▶ It circulates protons around a long tunnel, before bringing them into collision
▶ Particle detectors positioned within the tunnel then record the resulting debris
▶ we use the data they collect to scrutinise our best theories of particle physics

2. The CMS detector
▶ The CMS detector records enormous amounts of collision data
▶ rate is equivalent to the worldwide internet traffic in 2010!
▶ CMS has an onion-like structure; each layer comprises a sub-detector, responsible for measuring a specific type of particle: electrons, photons, ...

3. Measurements of the Higgs boson
▶ The Higgs boson is critical to particle physics; without it, the fundamental particles would have no mass!
▶ It is very unstable, decaying after just 10^{-22} seconds!
▶ However, decays to lighter particles are rare
▶ This analysis measures the extremely rare decay of the Higgs boson to two electrons
(H → ee) so rare that if we observe it, evidence of new physics
▶ Finding H → ee decays to measure is very challenging
▶ one in a billion chance of decaying to two electrons

4. What is machine learning?
▶ In our analysis, rare H → ee events are buried amongst many other competing “background” processes
▶ To find them, we need sophisticated ML techniques
▶ These are algorithms that can “learn from experience”
▶ They are typically given a task to perform e.g. separate two types of particle
▶ The algorithm is fed useful features to predict particle labels
▶ It learns to how connect these inputs with the labels, to best achieve the learning task
▶ One common ML algorithm is a deep neural network (DNN), inspired by synapses in the human brain
▶ used ubiquitously in medicine, law, and particle physics

5. Machine learning for H → ee
▶ The task for ML is to separate H → ee from backgrounds
▶ As inputs, algorithms are given measurements from each collision e.g. Higgs boson momentum
▶ Many complex ML algorithms are tested, including recurrent DNNs, networks that have an artificial memory
▶ The resulting models learn to separate H → ee from background events with high accuracy
▶ The improvement from ML is equivalent to doubling our dataset, for free!

6. Results
▶ From our data, we constrain the maximum allowed probability of H → ee decays to be < 0.03%
▶ This is a world leading result!
▶ 6.5 times more sensitive than best previous CMS measurement
▶ The future for H → ee searches is also bright
▶ LHC resumes operation in 2022, taking twice as much data
▶ can perform even more sensitive searches for new physics including new particles, dark matter, or even extra dimensions

References