

# Search for the Higgs Boson at CERN using machine learning

FRANK SAUERBURGER



# CERN, the LHC and ATLAS

- **What?** Collide high-energetic protons to produce new particles
- **Why?** Understand fundamental nature of matter and its interactions

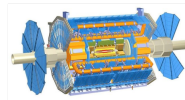
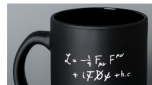
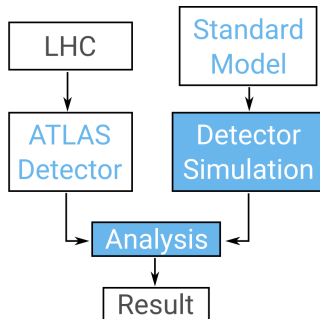


27km ring



≈35 collisions  
every 25ns

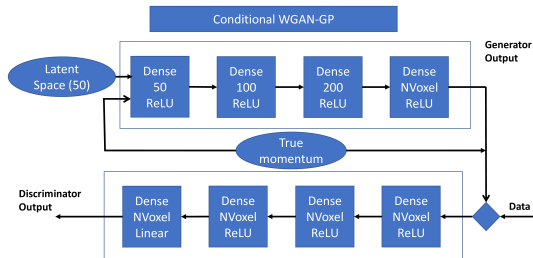
Images: CERN, ATLAS



- Machine-learning applications **in this talk** (in the summary)

# Calorimeter GAN

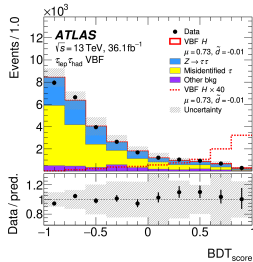
- **Challenge:** Require up to  $10^{10}$  simulated events
- Particles formed in collision produce *shower* of secondary particles
- Simulation of detector response  $\approx 10\text{min}$  with detailed interaction model (Geant4)
- **New approach:** FastCaloGAN
- Improved Wasserstein Generative Adversarial Networks [[1701.07875](#),[1704.00028](#)]
- Up to 1000× faster, good accuracy



[2109.02551]

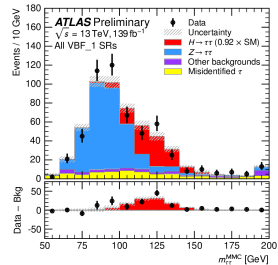
# Higgs Boson event selection

- Higgs Boson produced in one of  $10^9$  events ([lhc-xsecs.org](http://lhc-xsecs.org))
- **Challenge:** Filter events with Higgs Boson
- Consider systematic uncertainties for model selection
- Datasets: training, validation (model selection), test (data comparison)



Boosted Decision Tree output

[Phys. Lett. B **805** (2020) 135426]



Select events with **Higgs**

[ATLAS-CONF-2021-044]



# Summary

- Large datasets of measured and simulated events
  - Collider-based physics is well suited for machine learning
- Machine learning used at all stages within ATLAS Collaboration
- Further applications in high-energy physics
  - NNs to interpolate between different simulated datasets
  - Directly constrain *New Physics* with machine learning [[1805.00013](#)]
  - FPGA-based NNs to trigger events (40MHz event rate) [[JINST 13\(2018\) 07, P07027](#)]
  - NNs to simulate initial proton configurations [[2109.02671](#)]
  - ...
- Exciting interplay  
**high-energy physics ↔ machine learning**



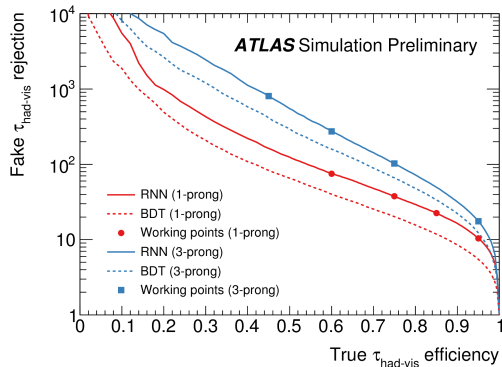
# RNN $\tau$ -Lepton identification

- **Challenge:**  
Identification of short-lived  $\tau$ -leptons
- $\tau$ -leptons have distinct signature in detector

- Appear in interesting decays  
(e.g. Higgs Boson)

$$H \rightarrow \tau\tau \rightarrow \{\pi^\pm, \pi^0, \nu, \gamma, \dots\}$$

- Recurrent in the number of decay products
- Better performance with RNN (solid lines)



[ATL-PHYS-PUB-2019-033]