

Generative Adversarial Network for Particle Physics

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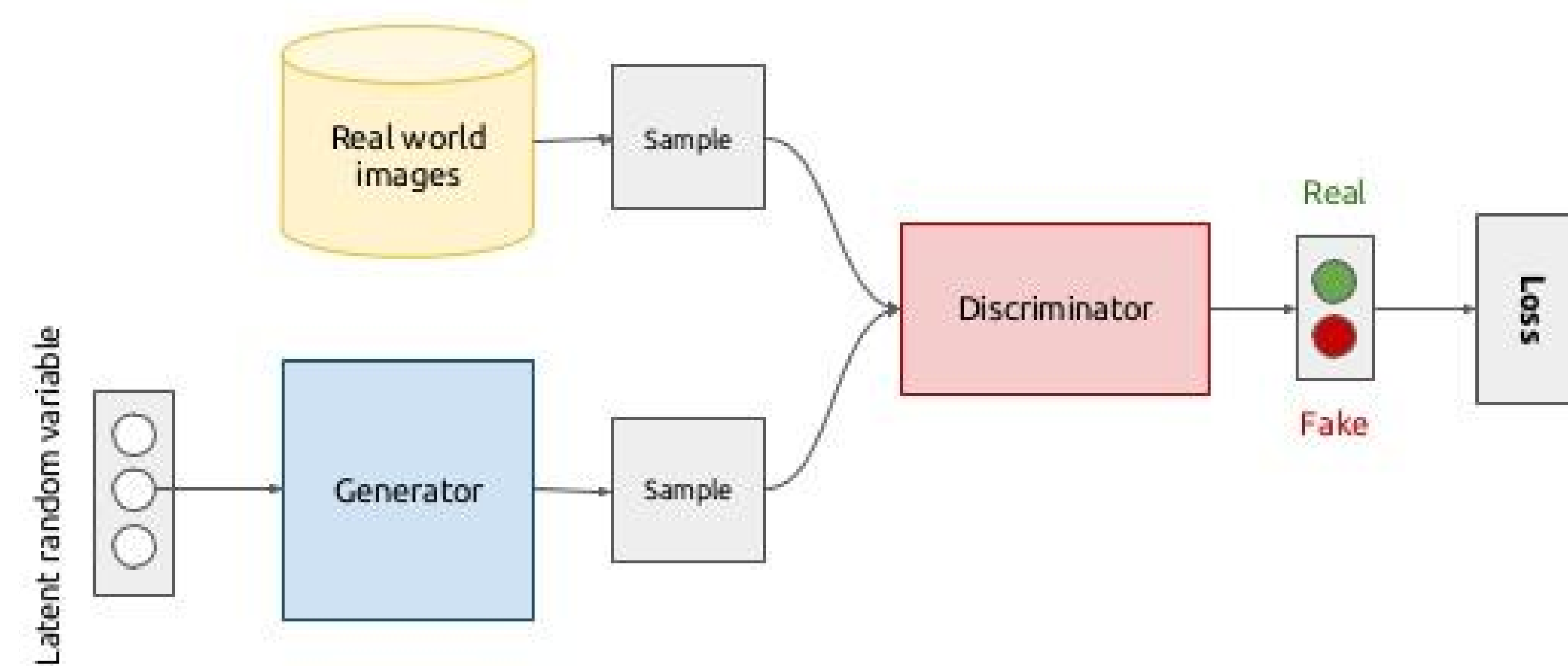
Summary

A more efficient method for simulating Large Hadron Collider (LHC) events. Using a conditional GAN trained on real data, we simulate calorimeter readings for a given particle type and energy.



The Conditional GAN

Using data provided by Bendavid et. al¹ at CERN, we use a Conditional Generative Adversarial Network (GAN²) to simulate the sensor data that is recorded from these collision events. Our model simulates a 2D slice from the 3D array of sensors.



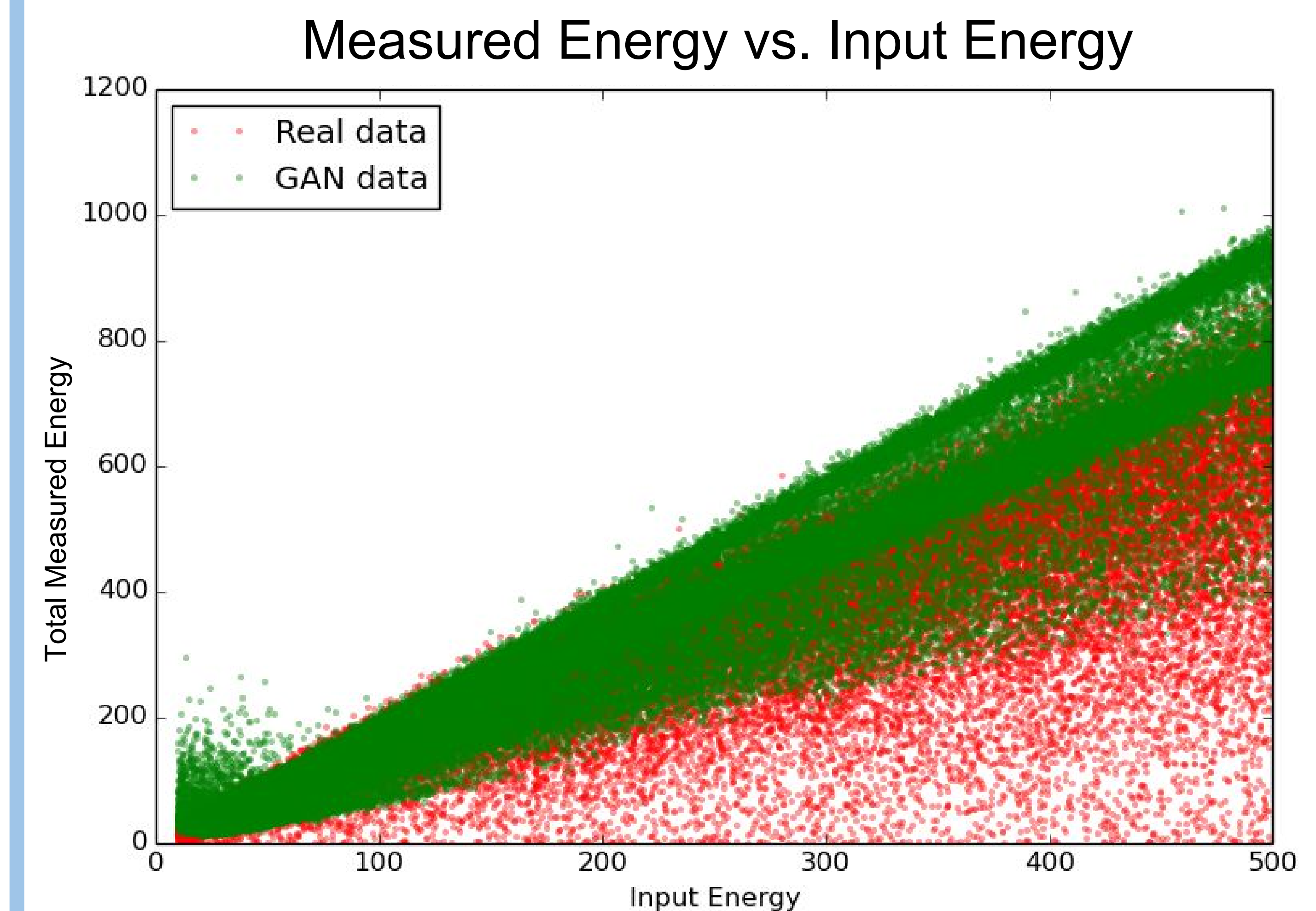
Source: <http://www.slideshare.net/xavigiro/deep-learning-for-computer-vision-generative-models-and-adversarial-training-upc-2016>

Model Architecture

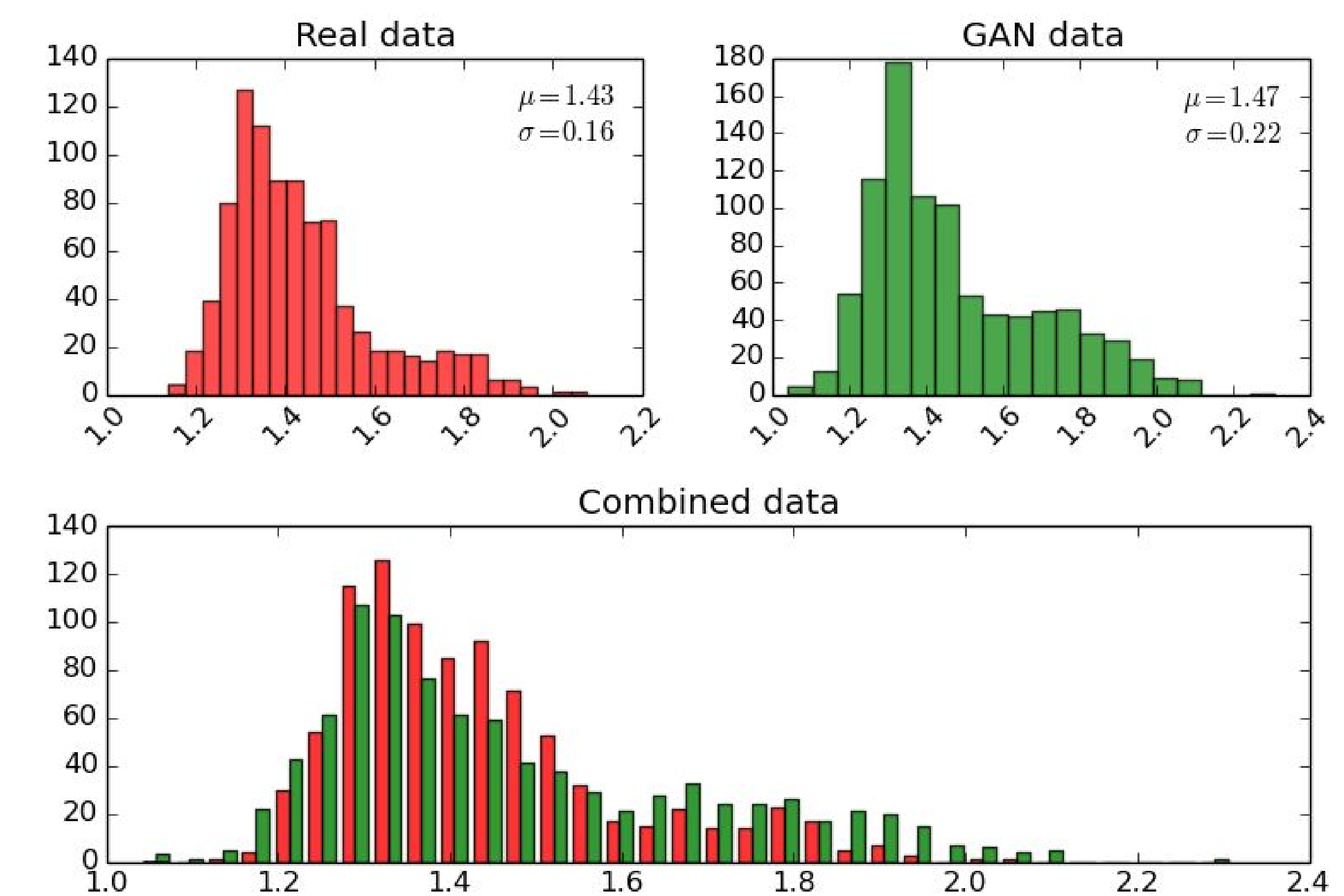
- **Architecture of generator and discriminator**
 - Fully-connected layers
 - ReLU activation
 - Dropout
- **Minibatch discrimination³** - Adds variability to generated images. Prevents the generator from fixating on one typical example by alerting the discriminator when images look suspiciously identical.
- **Averaging input data** - We reduced data sparsity and increased smoothness by averaging input examples together
- **Measured energy feature** - Informing the discriminator of total energy output of each sample forced the generator to come up with samples that had an appropriate total energy level.

Evaluation

GANs can be tricky to train. Since the generator and discriminator are trained against each other, there is no objective measure of performance. Our problem-specific metric for evaluation is the ratio of measured ECAL energy to input energy. Ideally, generated samples should preserve the distribution of this ratio across events.



Distribution of Measured-Input Energy Ratio



Citations:

1. Bendavid, Josh, et al. "Imaging Calorimeter Data for Machine Learning Applications in HEP." 2016.
2. Mirza, Mehdi, and Simon Osindero. "Conditional generative adversarial nets." arXiv preprint arXiv:1411.1784 (2014).
3. Glover, John. "An Introduction to Generative Adversarial Networks (with Code in TensorFlow) - AYLIEN." AYLIEN. N.p., 26 Aug. 2016. Web. 12 Dec. 2016.
4. Plots generated using Matplotlib and Seaborn

The Large Hadron Collider

In LHC experiments, two high-energy beams of particles collide, and the resulting "particle shower" is recorded by electromagnetic calorimeter (ECAL) sensors that surround the beams. The current methodology for simulating such particle collision events is slow and expensive.

