Deep Graph Neural Networks for Fast HGCAL Simulation

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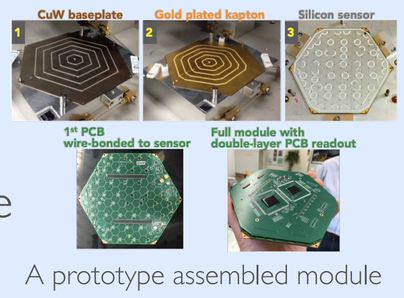
Particle Simulations

- Simulations of events are very important in high energy physics
- Classical physics simulation programs such as GEANT4 are accurate but can be slow and inefficient
- Machine Learning (ML) is a potential alternative where we approximate simulations at much higher speeds

HGCAL

- The High Granularity Calorimeter will be a major new addition to CMS as part of the HL-LHC upgrade
- Very high granularity (i.e. lots of pixels) plus its irregular geometry means high computational effort

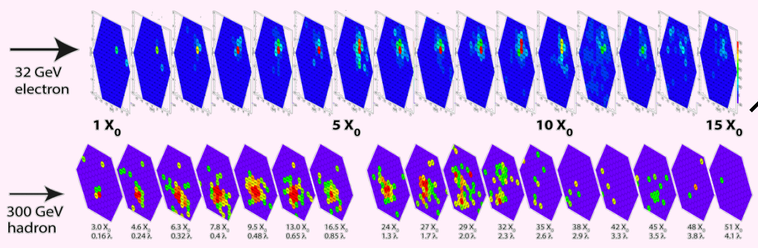


A prototype assembled module

Our Goal

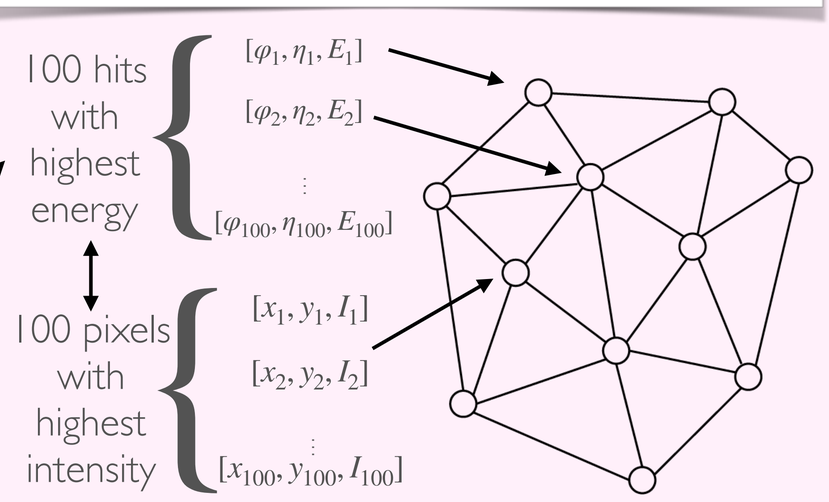
- Building off of the recent success in fast simulations for simpler detectors using ML and convolutional neural networks, we want a model to quickly and efficiently simulate events for the more complex HGCAL
- To do so, we explored graph neural networks

- Convolutional neural networks (CNNs) convert detector array data into 3D images - this is inefficient due to sparsity of data and irregular geometry of HGCAL



- We propose Graph Neural Networks instead, where we represent detector ***hits*** as the nodes
- We thus have a network which is 1) sparse, 2) generalizable to any geometry and 3) more naturally suited to the data

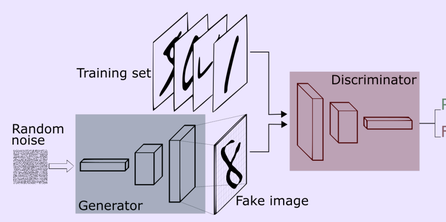
Graph Neural Networks

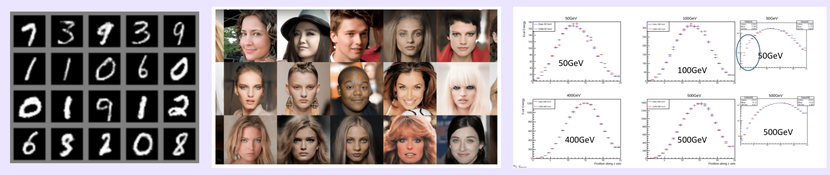


For ease of testing we used the **MNIST handwritten** digits dataset (right) instead and **sparsified** it to match the form of HGCAL data (up)

Generative Adversarial Networks

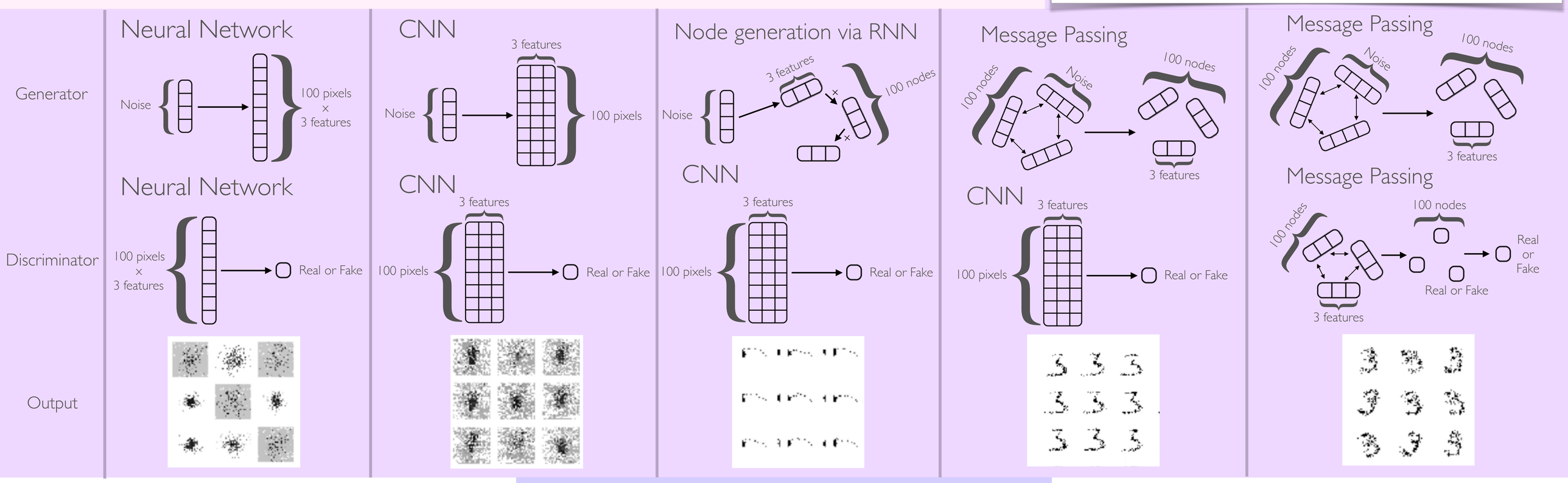
- The challenge was that there are no published graph generative models yet - we had to develop one
- We used generative adversarial networks as our framework





Examples of convolutional GANs in action above. Left: MNIST digits. Center: Faces. Right: ECAL detector data

Architectures and Results



Summary

- Developed a new graph GAN for faster HGCAL data generation
- It was successful on sparsified MNIST dataset
- It should generalize well, unlike CNNs, to HGCAL data since it is geometry independent
- Next step (in progress) is to apply to HGCAL data

Animations of the training process

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This project is supported by National Science Foundation under Cooperative Agreement OAC-1836650. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.