Karlsruhe Institute of Technology

VAE-WGAN and Fast Simulation of Electromagnetic Calorimeter Responses

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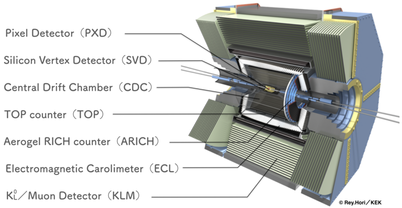
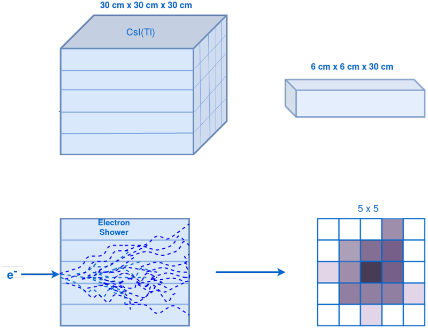
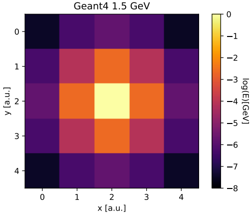
Motivation

- Simulation of particle showers in electromagnetic calorimeter is a computationally expensive and time consuming process
- Deep learning generative models like Variational Autoencoder (VAE) and Wasserstein Generative Adversarial Network (WGAN) show a promising development in the area of fast simulation of calorimeter responses.
- Inspired from the studies on precise simulation of HGCAL showers using WGAN Network (arXiv:1807.01954v2)

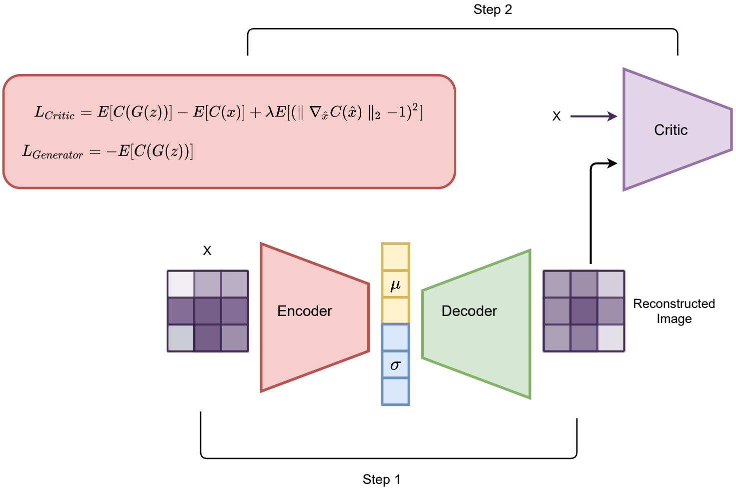
Introduction







VAE + WGAN



$$L_{Critic} = E[C(G(z))] - E[C(x)] + \lambda E[(\| \nabla_{\hat{x}} C(\hat{x}) \|_2 - 1)^2]$$

$$L_{Generator} = -E[C(G(z))]$$

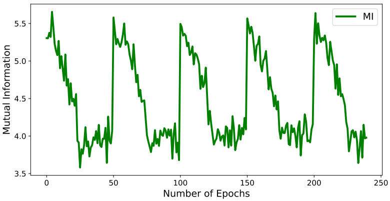
$$L_{VAE} = E_{z \sim q(z|x)} \log p(x|z) - \beta \, D_{KL}[q(z|x) || p(z)] - \gamma \mathrm{MI}$$

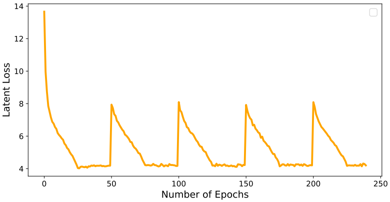
Training

$$L_{VAE} = E_{z \sim q(z|x)} logp(x|z) - \beta D_{KL}[q(z|x)||p(z)] - \gamma \text{MI}$$

- VAE based approches for disentangled representations
- KL annealing is used to improve the performance and avoid posterior collapse issues
- GAN based approaches for high quality synthesis
- To avoid trade-off, this is seperated into two successive problems
    - First learn latent space representation using VAE
    - Then GAN for high fidelity synthesis

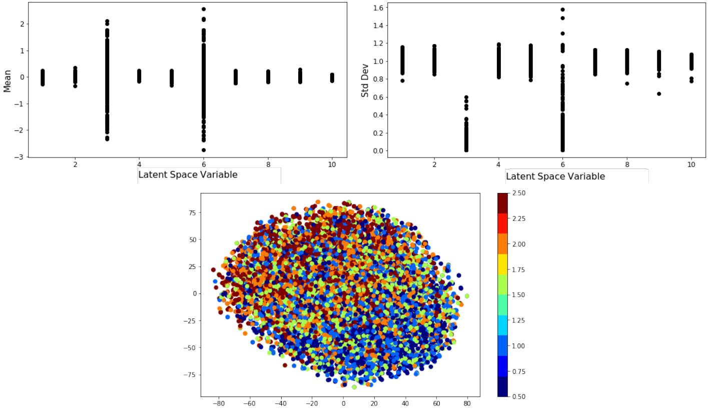
Mutual Information (MI) between X and Z





- MI shows the amount of information the decoder absorbs from latent vectors while generating output
- Model maintains a good positive MI value which means output values are related to latent vectors.

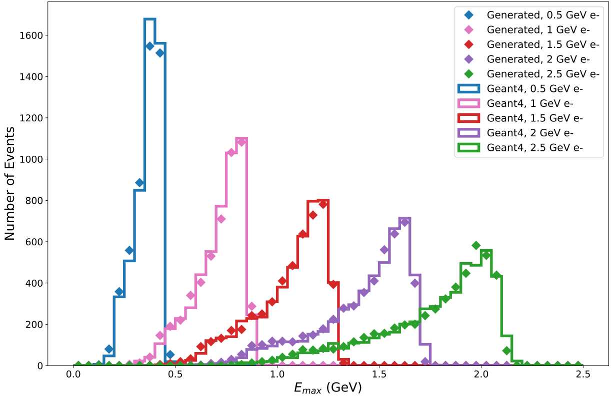
Information Encoded μ and σ



Latent space t-SNE plot

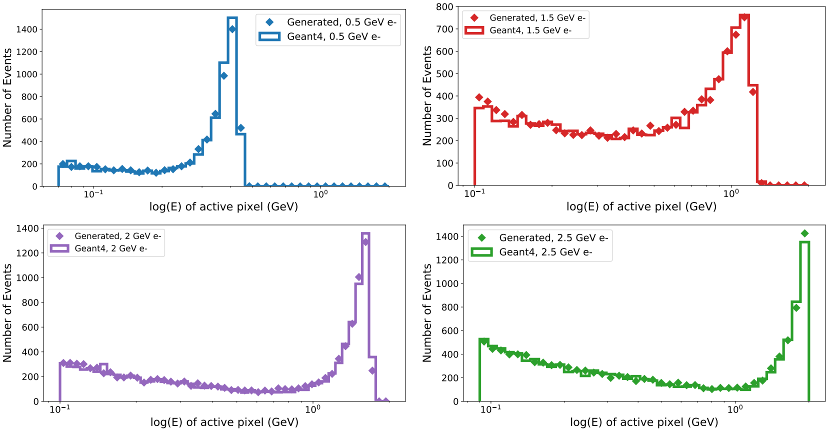
- 2 latent space variables contain most of the information
- t-SNE plot shows the regularization of latent space for each class
- 2 GeV variables are the interpolated latent space variables.

Maximum Energy Distribution



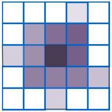
- Maximum value of energy deposited in the 5 x 5 crystals
- 2 GeV distribution is interpolated by the model
- Distribution agreement is comparable to WGAN

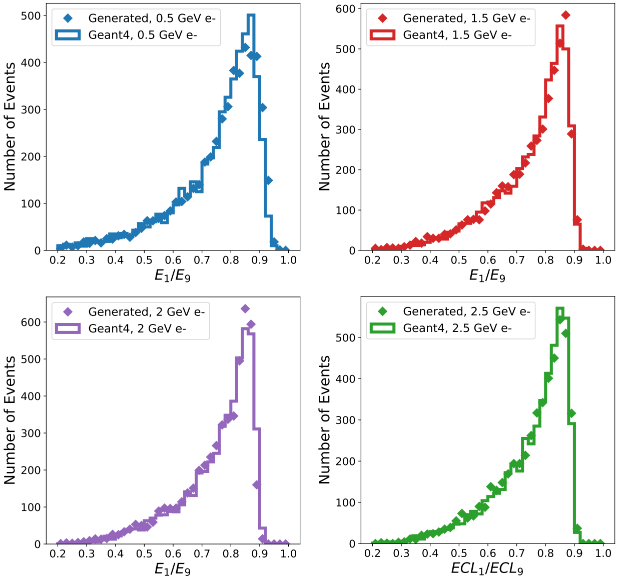
Cell Energy Distribution



- Distribution of energy deposition in every cell
- Good agreement between Geant4 distribution and VAE+WGAN model distribution

E_1 / E_9

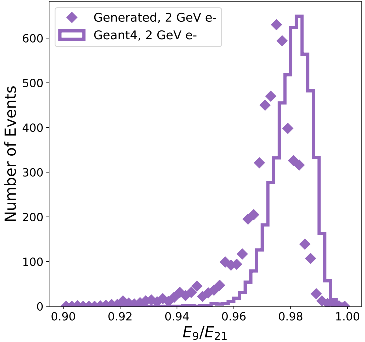




Generated, 0.5 GeV e-
Geant4, 0.5 GeV e-
Generated, 1.5 GeV e-
Geant4, 1.5 GeV e-
Generated, 2 GeV e-
Geant4, 2 GeV e-
Generated, 2.5 GeV e-
Geant4, 2.5 GeV e-
Number of Events
E1/E9
ECL1/ECL9

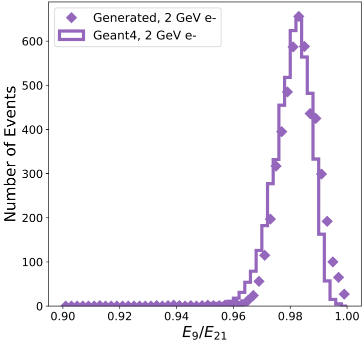
E_9 / E_{21}

WGAN



- Ratio of energy deposited in the inner 9 cells to that of 21 cells excluding the corner cells

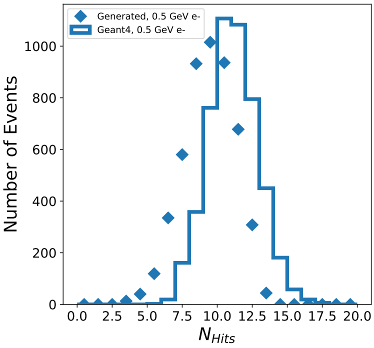
VAE + WGAN



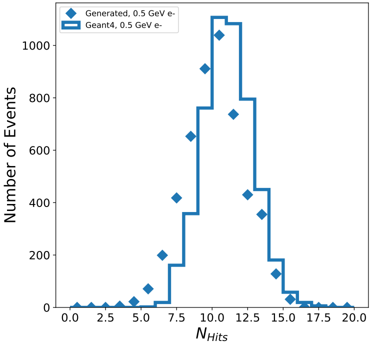
- A slight improvement in the distribution is seen for the new model

Number of Hits

WGAN



VAE + WGAN

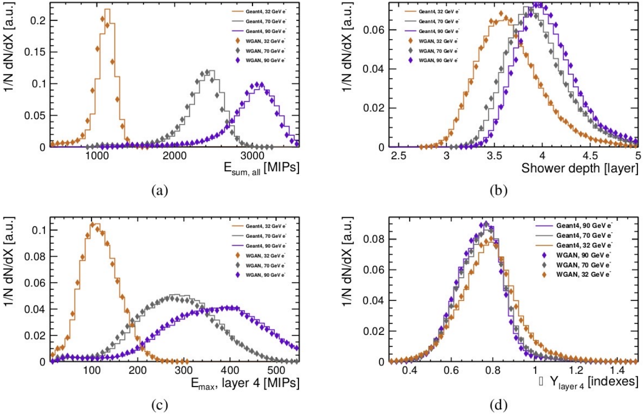


- The distribution of number of cells having energy deposited inside it
- Further studies planned to improve the agreement

Summary and Next Steps

- VAE+ GAN model is tested on Geant4 electron showers
  - It shows an improvement for variable E_9/E_{21}
  - N_{Hits} still needs improvement
- Model with InfoGAN and VAE is currently in progress (arXiv:1606.03657)
- Aiming for a model with good generation quality and latent space disentanglement.

Backup



Results from arXiv:1807.01954v2