Karlsruhe Institute of Technology

Updates on Fast Simulation of Particle Showers in Electromagnetic Calorimeter using Deeplearning Models

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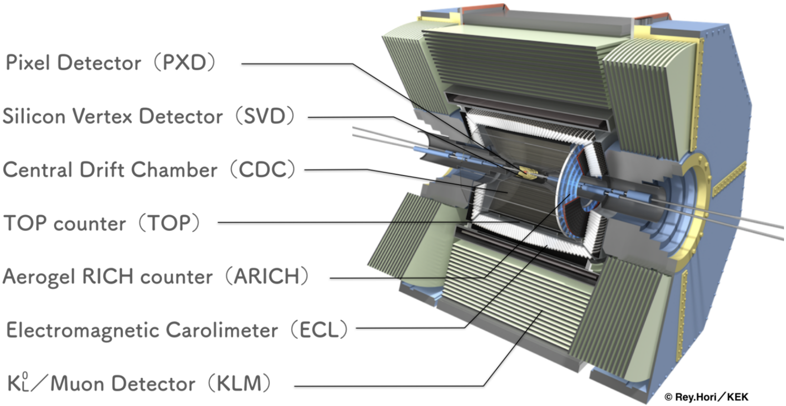
Sections

- Previous work
  - Wasserstein GAN and simulation of electron showers (backup slides).
  - W-GAN inspired from Erdmann et al. [1807.01954]
- Latest Works
  - Testing the WGAN model for electron showers in Belle II electromagnetic calorimeter.
  - Fast simulation of hadronic showers using WGAN.
  - Studies on the combination of VAE and GAN.

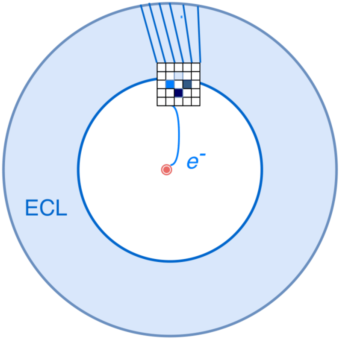
Test the model for MC showers in Belle II ECL

Belle II Detector



Particle Gun Condition

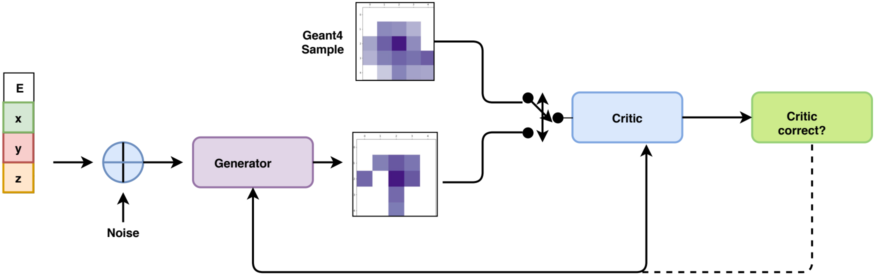
- Beam background level: **BGx1**
- e^- samples, 1 particle per event.
- $11.4^\circ < \theta_{generated} < 156.1^\circ$
- $0^\circ < \phi_{generated} < 360^\circ$
- Basf2 $release - 04 - 01 - 04$
- Energy generated $\rightarrow 0.5GeV, 1GeV, 1.5GeV, 2GeV, 2.5GeV$



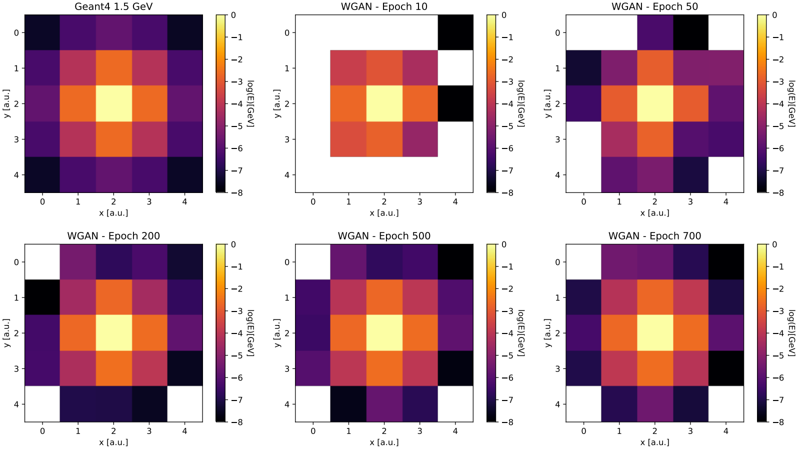
Wasserstein GAN

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

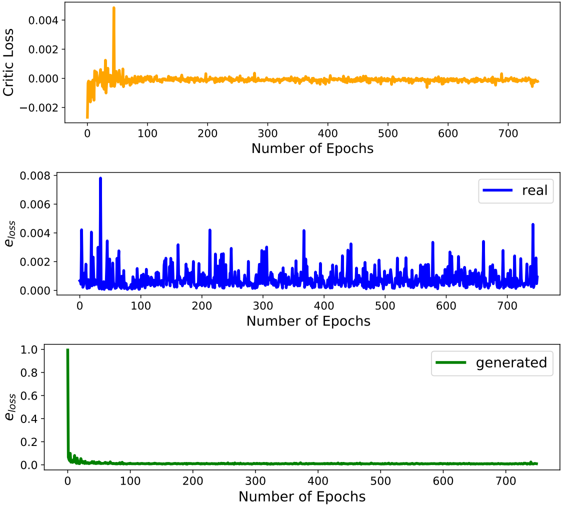
$$L_{Generator} = -E[C(G(z))]$$



Geant4 and Generated images

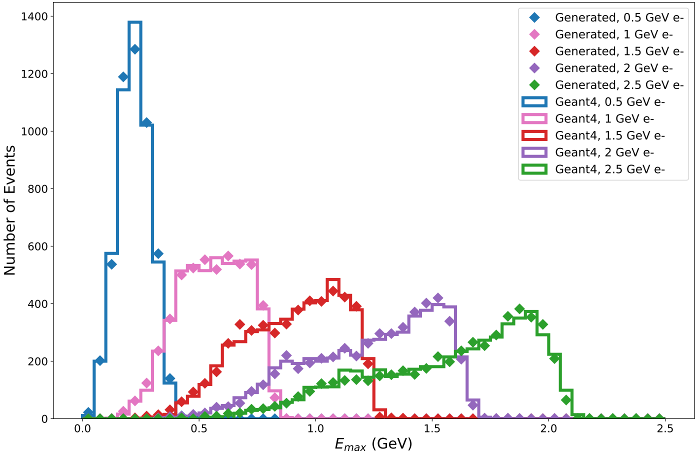


Loss Curves



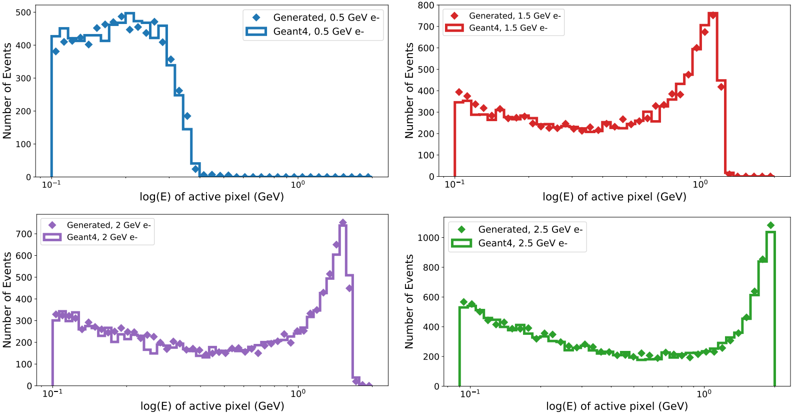
Critic Loss
0.004
0.002
0.000
−0.002
0
100
200
300
400
500
600
700
Number of Epochs
real
e_{loss}
0.008
0.006
0.004
0.002
0.000
0
100
200
300
400
500
600
700
Number of Epochs
generated
e_{loss}
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
Number of Epochs

Maximum Energy Distribution



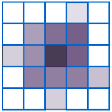
Maximum value of energies deposited in the 5 x 5 crystals

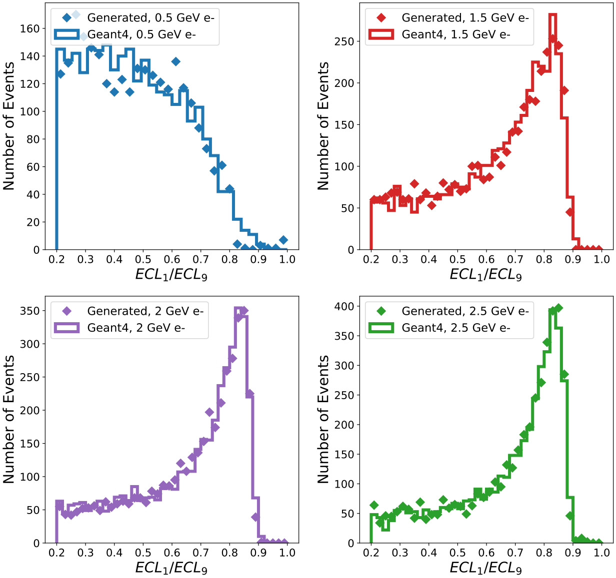
Cell Energy Distribution



Distribution of single cell energy deposition

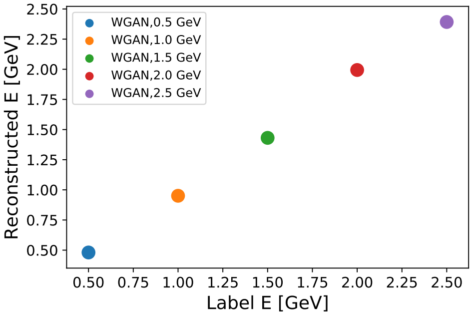
ECL_1 / ECL_9





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
ECL1/ECL9

Results



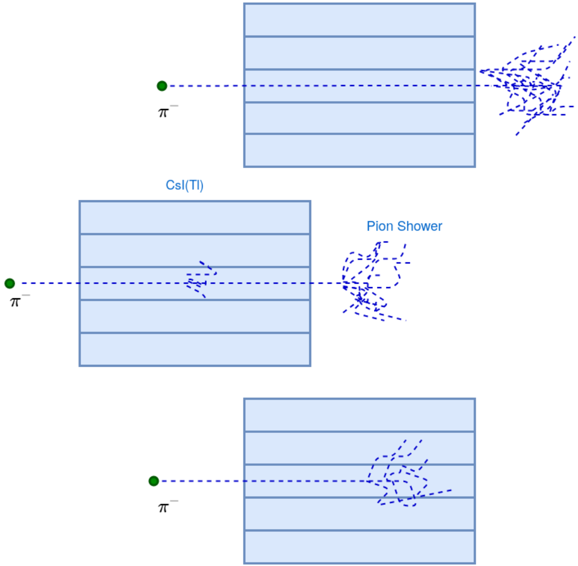
Eenergy labels reproduced by the energy regressor

Fast Simulation of Hadronic Showers in Electromagnetic Calorimeter

Challanges in simulating Pion Showers in ECL

- Crystals are almost 1 interaction length deep, so we expect e^{-1} (around 37%) of incident hadrons not to interact.
- For pions, interaction length is even longer.
- So around 45% of incident pions do not shower inside the crystal.
- Since pions are minimum ionizing particles, they peak around 200 MeV in this case.

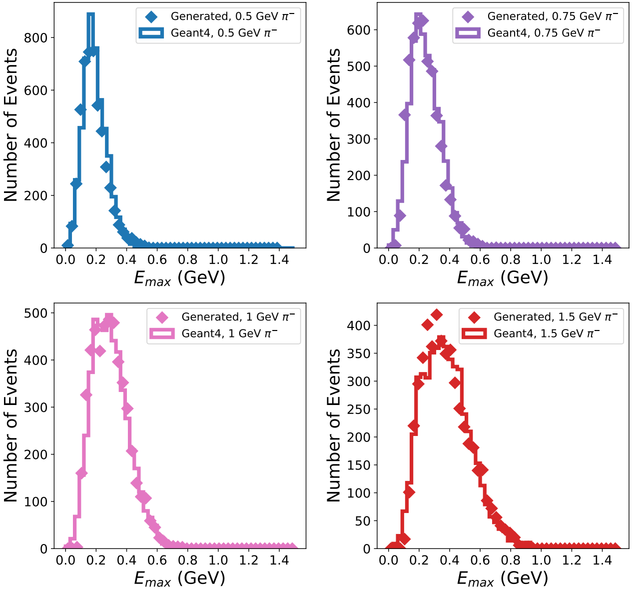
Pion Showers in Electromagnetic Calorimeter



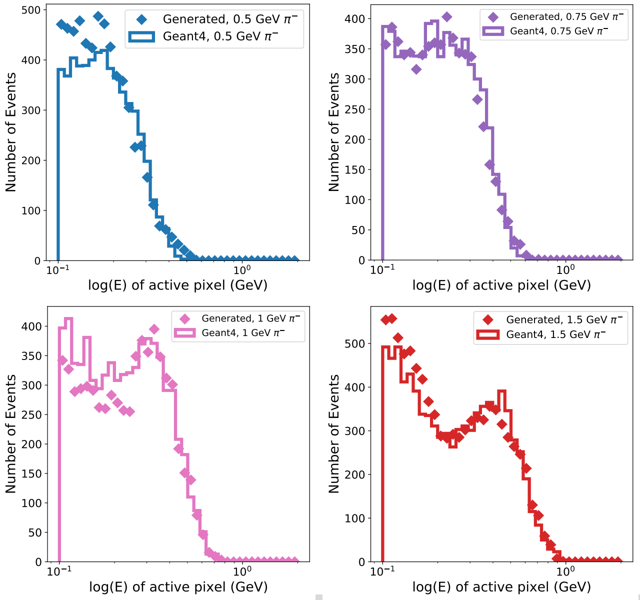
Training the Model with Hadronic Showers

- Pions of energies 0.5 GeV, 0.75 GeV, 1 GeV and 1.5 GeV were chosen for training the model.
- First hadronic interaction depth variable was used to find the point where the first hadronic interaction occured inside the crystals.
- This value was used to identify the events causing pion showers in calorimeter crystals.
- First hadronic interaction depth label was fed to the generator and critic which improved the performance of the model.

Maximum Energy Distribution

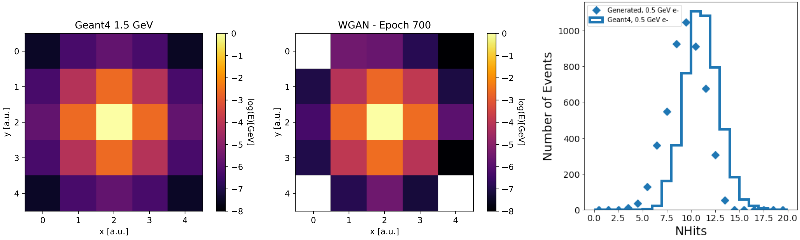


Cell Energy Distribution



Drawbacks with WGAN

- WGAN produces lesser number of hits than Geant4.

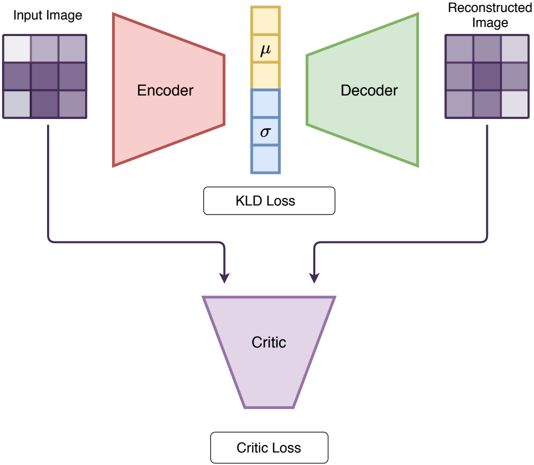


- As a result it affects other variables including shower shape variables ECL_1/ECL_9 and ECL_9/ECL_{25} etc.

GAN and VAE

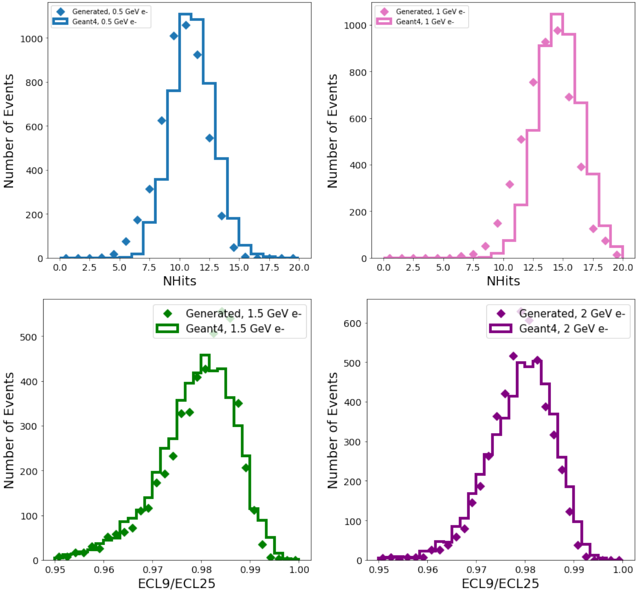
- Absence of an encoder for carrying out inference on samples is a limitation of GANS.
- Given a sample x we cannot derive corresponding random variable z.
- One way of addressing this problem is to combine an Encoder with GAN.
- For a better study of latent space and to solve the variable issues mentioned above with GANS, a study of combining GANS and VAE is in progress.

VAE-GAN



Input Image
Encoder
μ
σ
Decoder
Reconstructed Image
KLD Loss
Critic
Critic Loss

Improvements in Number of Hits



Summary and Next Steps

- WGAN was tested for Belle II MC electron showers and Geant4 hadronic showers. It agrees well for many variables.
- The lesser number of hits produced by the model compared to the Geant4 shower is a drawback of WGAN model.
- To solve the number of hits problem, a combination of VAE and GANS are currently being studied.
- Next step: Test the new VAE-GAN model on high granularity electromagnetic calorimeter crystals.