High Fidelity Simulation of High Granularity Calorimeters with High Speed

Round Table on Machine Learning @ DESY 2020

Erik Buhmann, Sascha Diefenbacher, Engin Eren, Frank Gaede, Gregor Kasieczka, Anatolii Korol, Katja Krüger

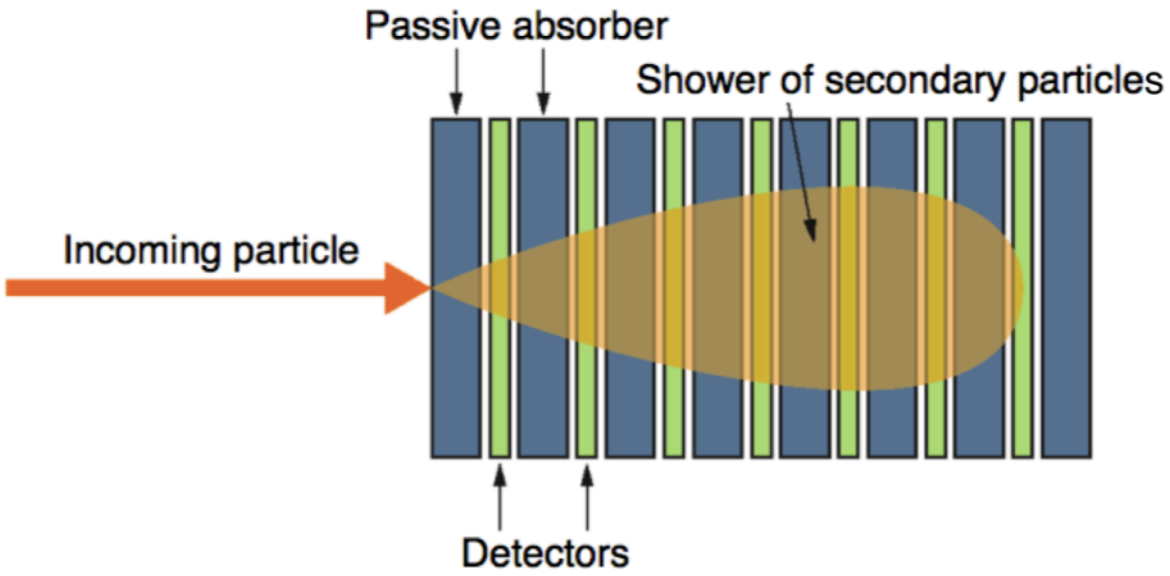
04.12.2020

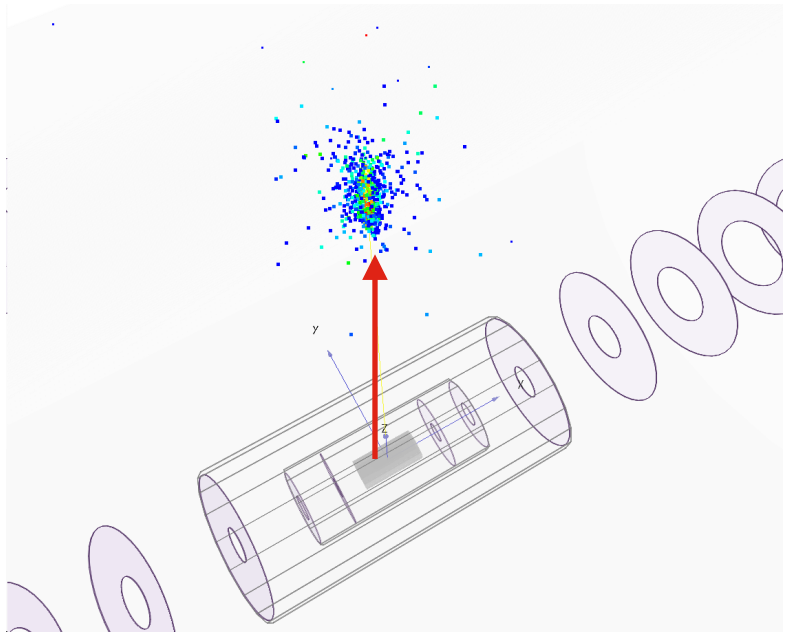
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

CLUSTER OF EXCELLENCE QUANTUM UNIVERSE

Calorimeters in a HEP Experiment

- Incoming particle initiates the showers and secondary particles are produced
- These secondary particles further produce other particles until the full energy is absorbed





One type of EM calorimeter: sampling calorimeter

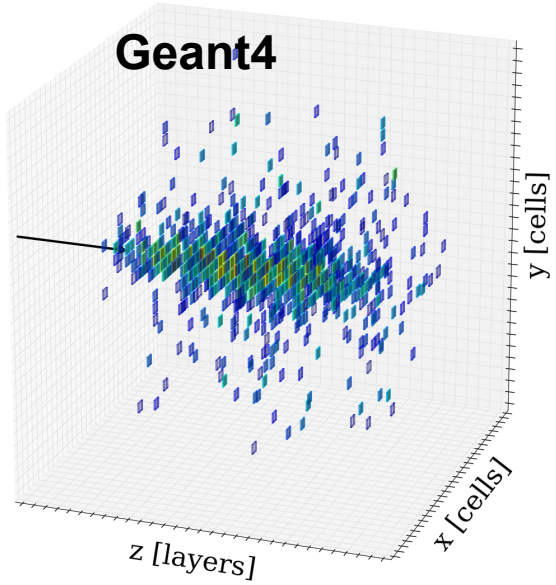
- Alternating layers of passive absorbers and active detectors
- Only **fraction** of particle energy is recorded (visible energy)

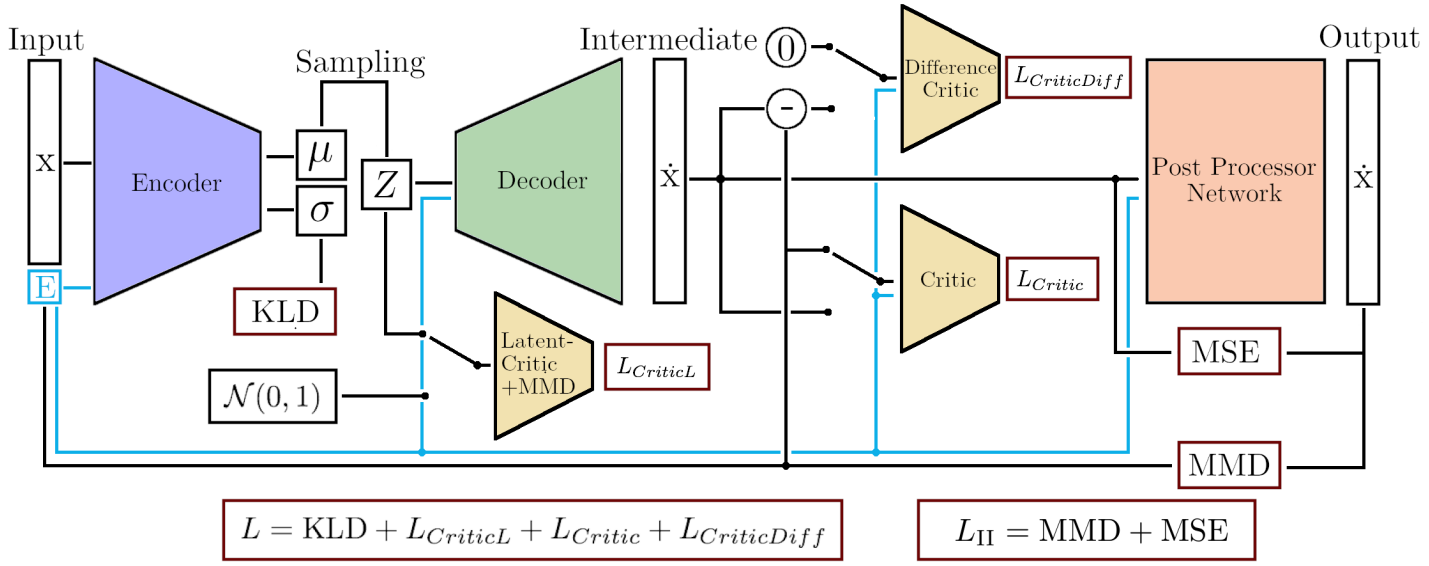
Shooting photon perpendicular to the ILD-ECAL (Si-W)

Photon energy: 10-100 GeV, continuous!

Results

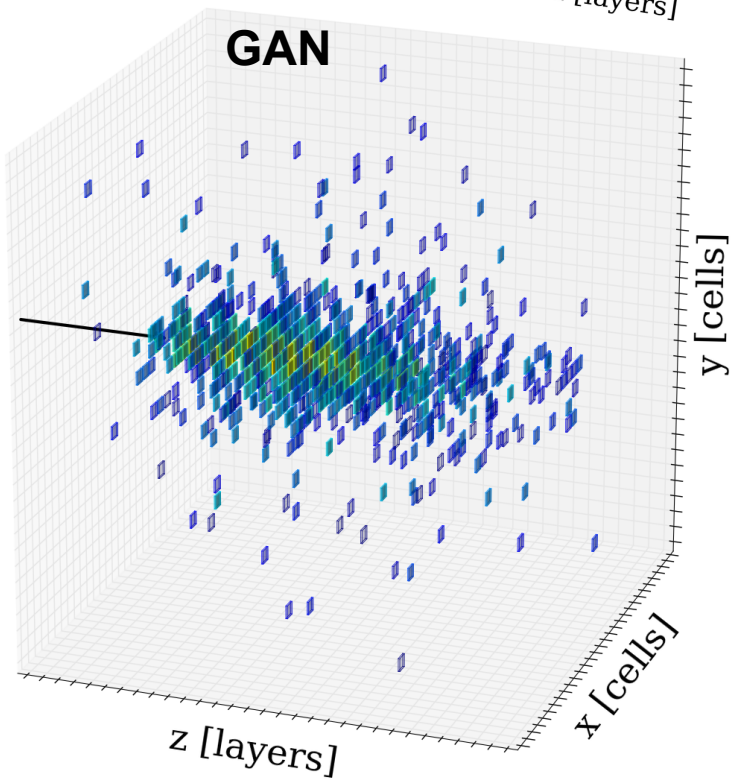
looks realistic???

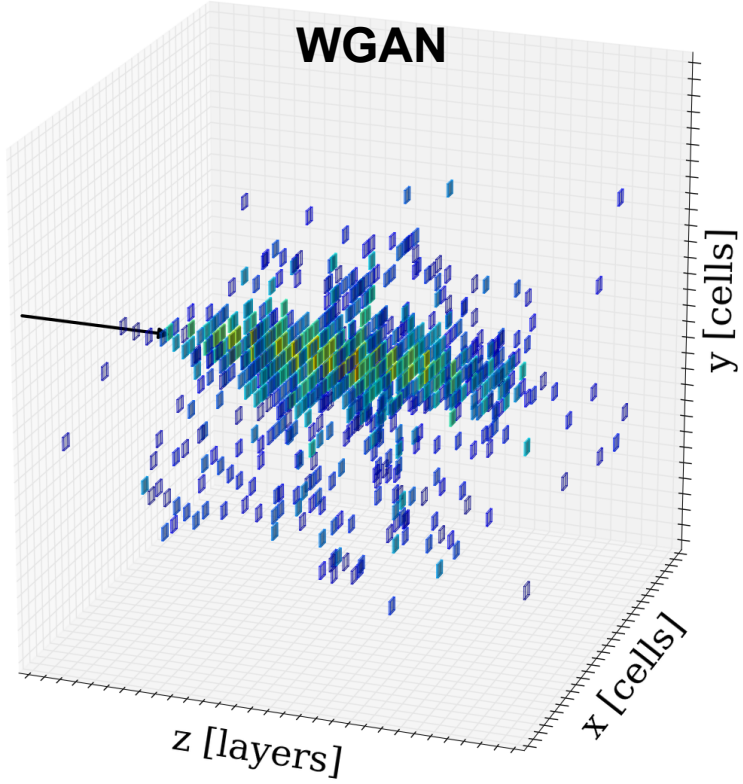


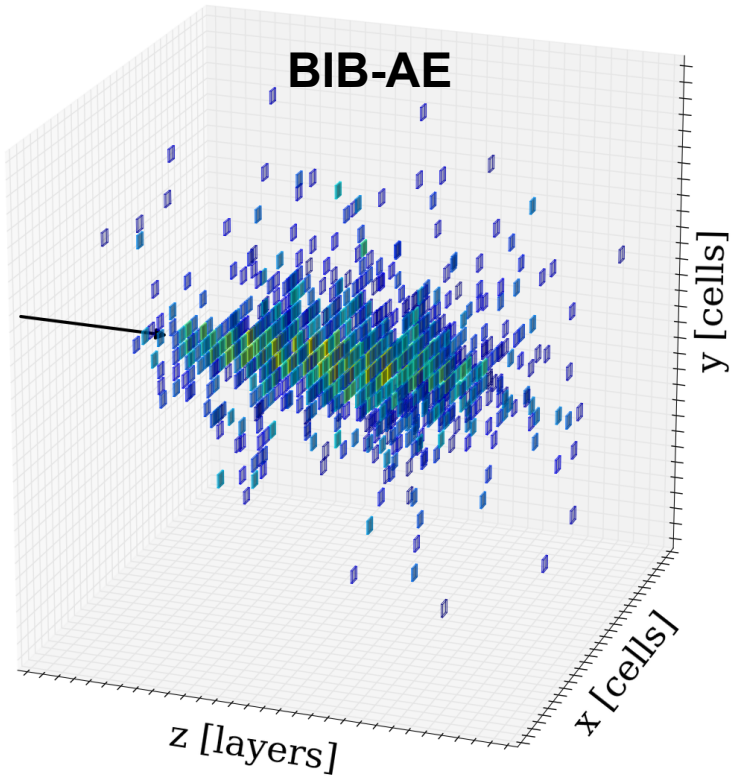


$$L = \text{KLD} + L_{CriticL} + L_{Critic} + L_{CriticDiff}$$

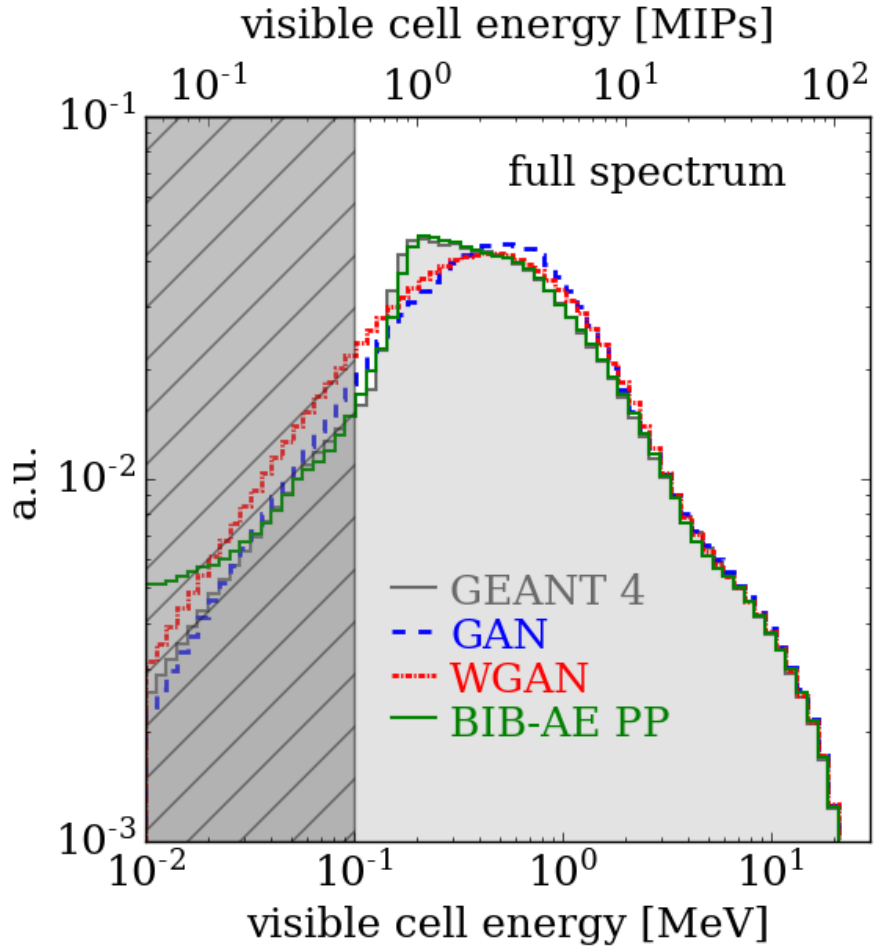
$$L_{\text{II}} = \text{MMD} + \text{MSE}$$

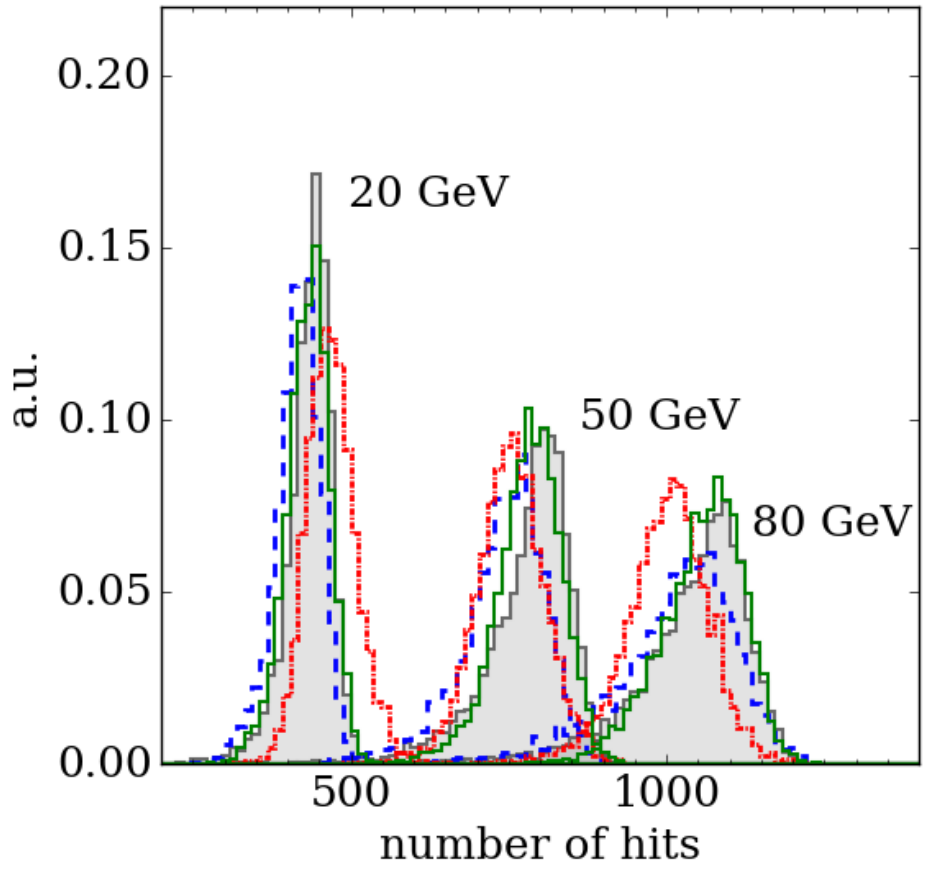






Results: Cell energy and Number of hits

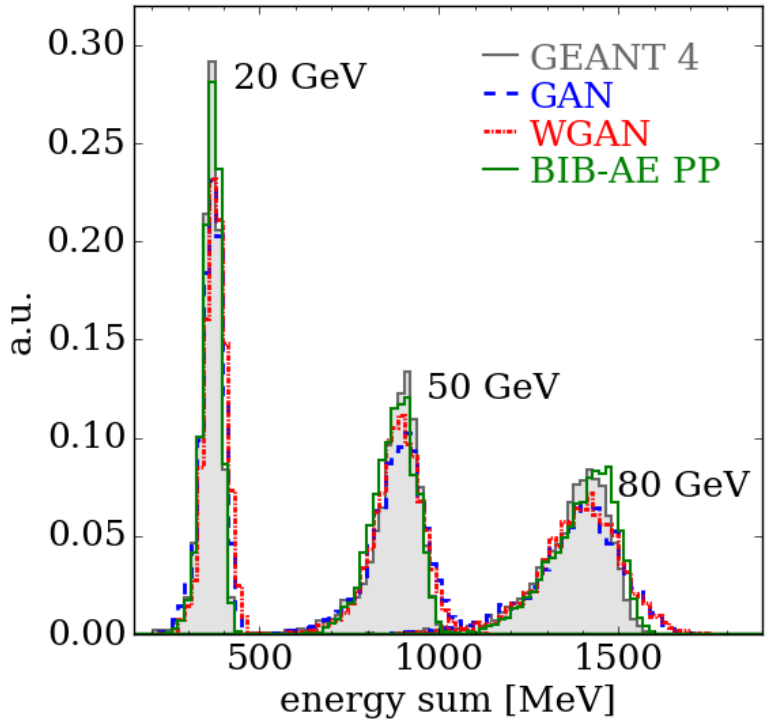


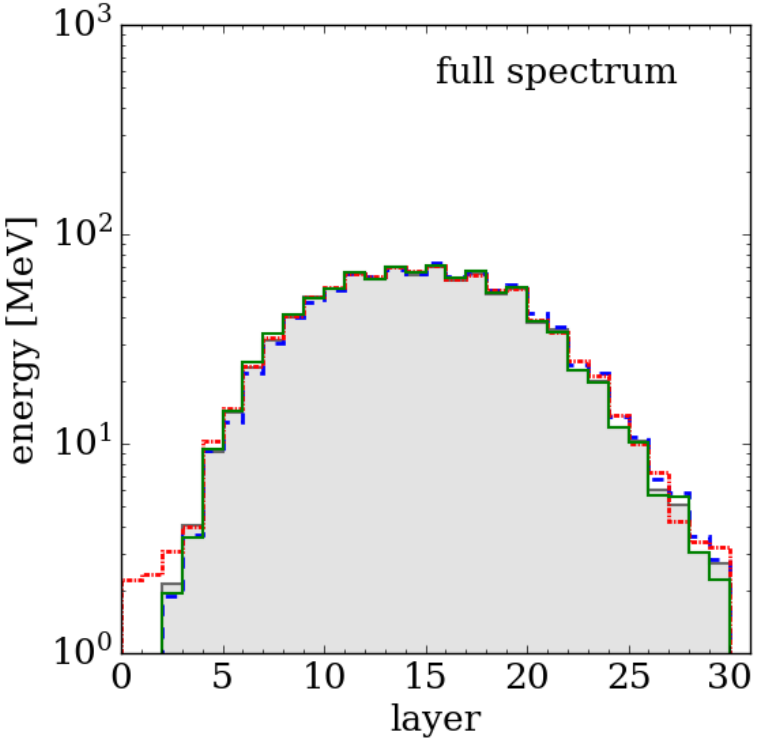


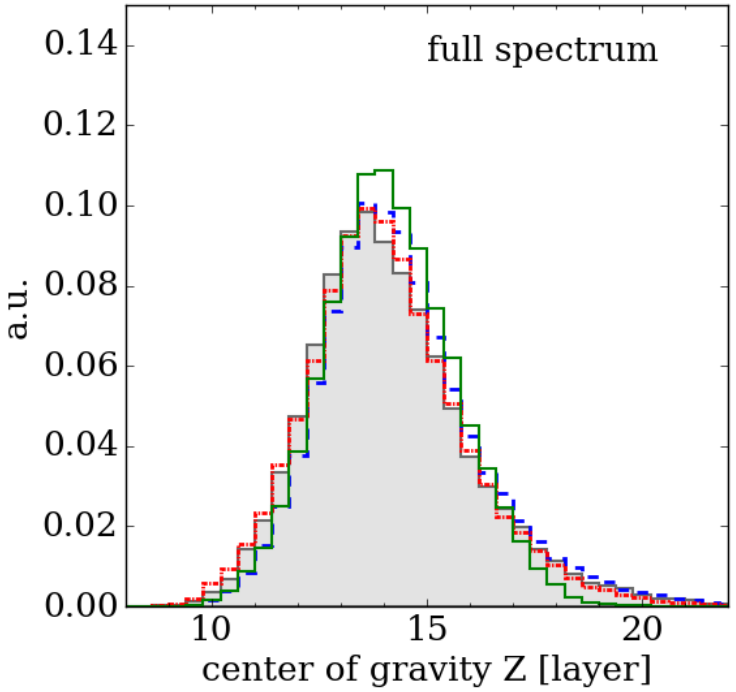
- Both GAN and WGAN fail to capture MIP bump around 0.2 MeV
- ✓ BiB-AE is able to produce this feature thanks to Post-Processing network

- GAN and WGAN slightly underestimate the total number of hits
- ✓ BiB-AE reproduces the shape and width

Results: Other important distributions







✓ the shape, center and width of the peak are well reproduced for all models

✓ reproduce the bulk of the distributions very well.
- slight deviations for the WGAN appear around the edges

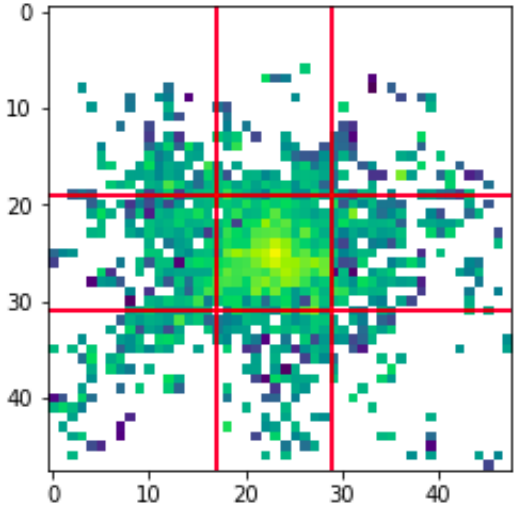
- Deviations for BiB-AE
  ✓ Explainable via latent space encoding

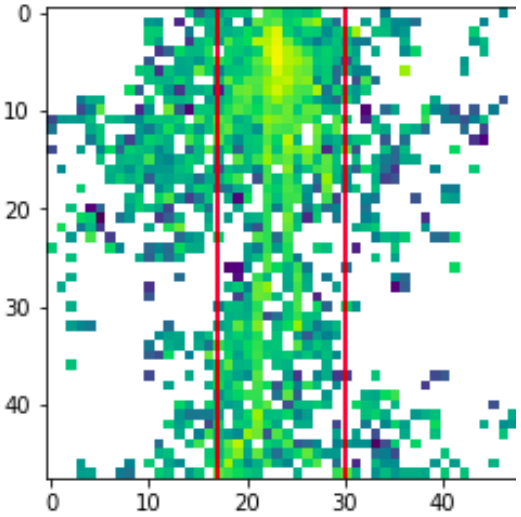
Hadron Showers

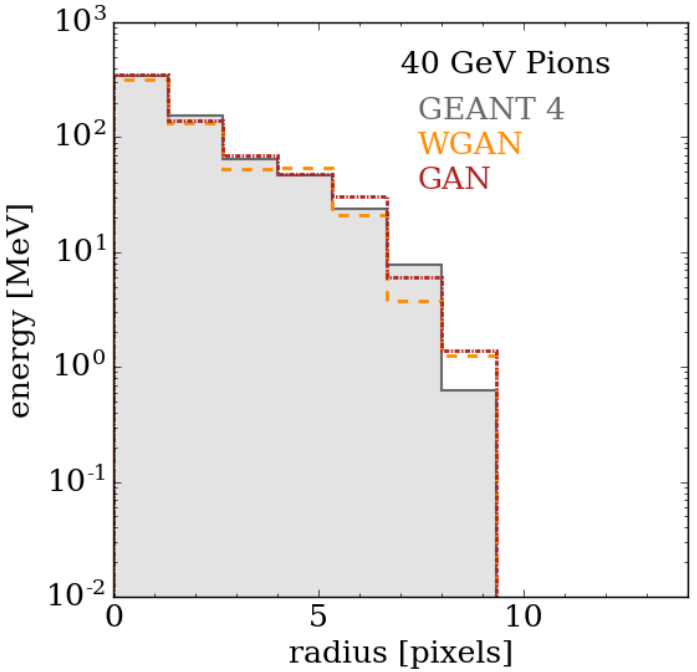
harder particles…

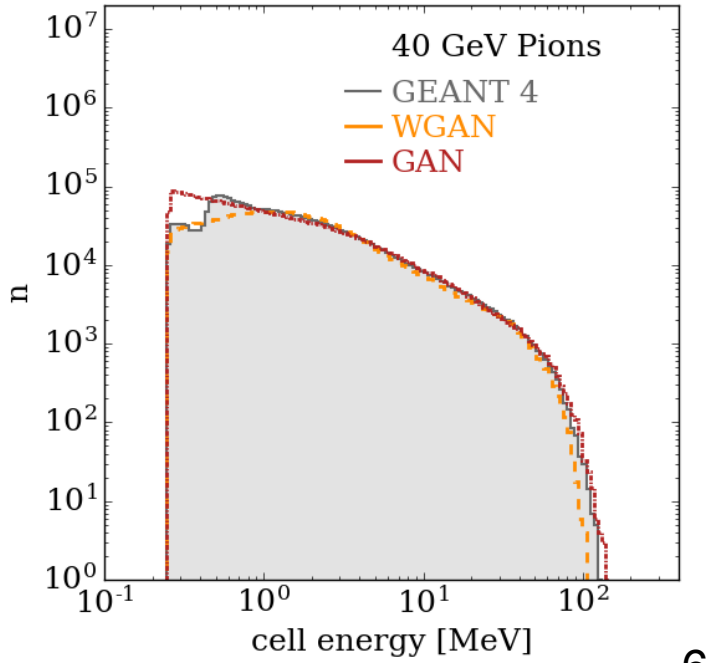
- After success with GAN based simulation for electromagnetic showers, we started to address hadronic (pion) showers
- Much more complex shower structure
- Currently training with a smaller 3D image containing only the shower core
- Started with GAN, WGAN and BIB-AE

WORK IN PROGRESS









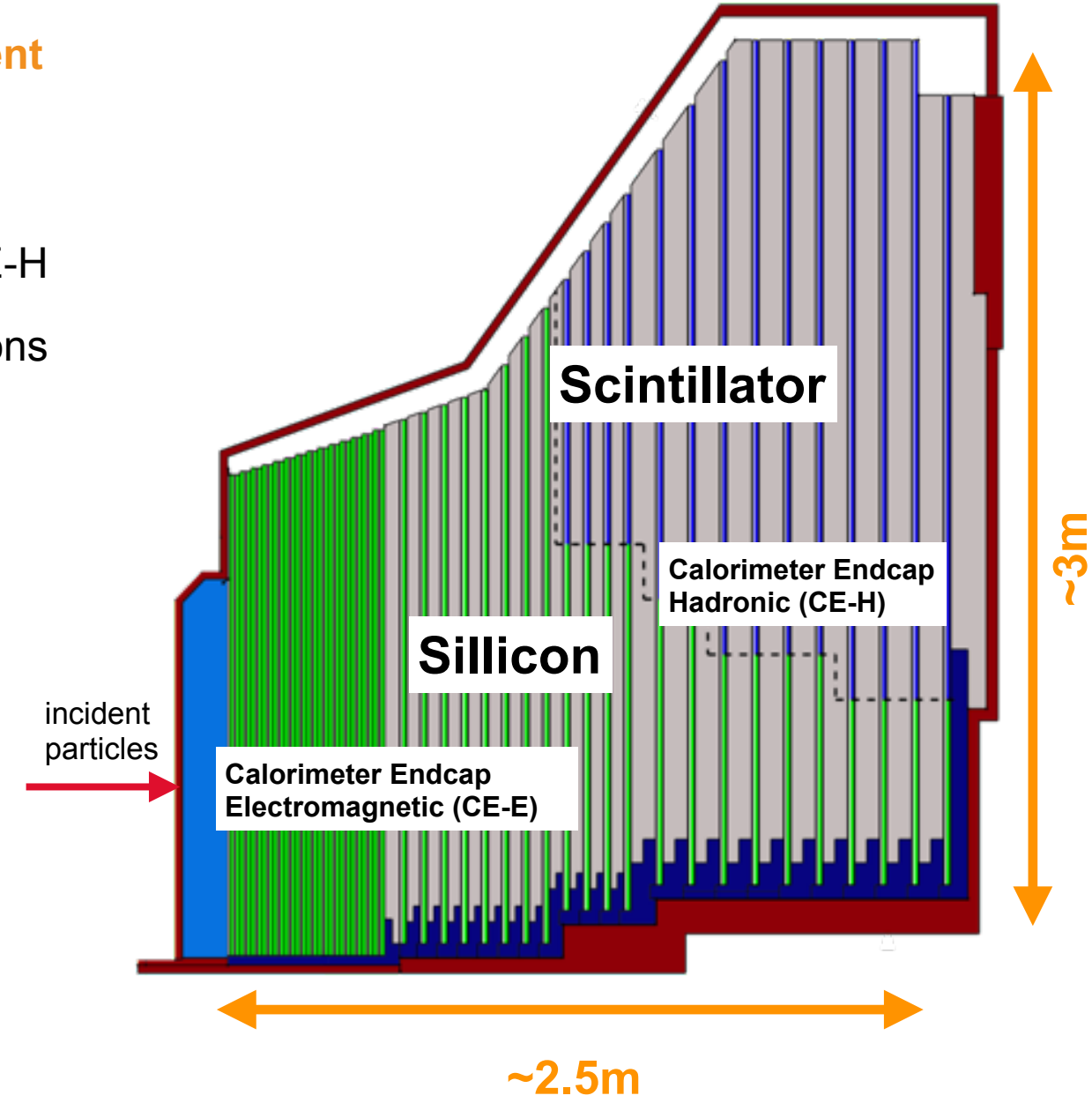
New Challenge: CMS HGCal

Planned High Granular Calorimeter for CMS Experiment

- HGCAL is a **sampling** calorimeter
- Silicon sensors in CE-E and high radiation regions of CE-H
- Scintillating tiles with SiPM readout in low-radiation regions of CE-H
- 3D imaging calorimeter with timing capabilities

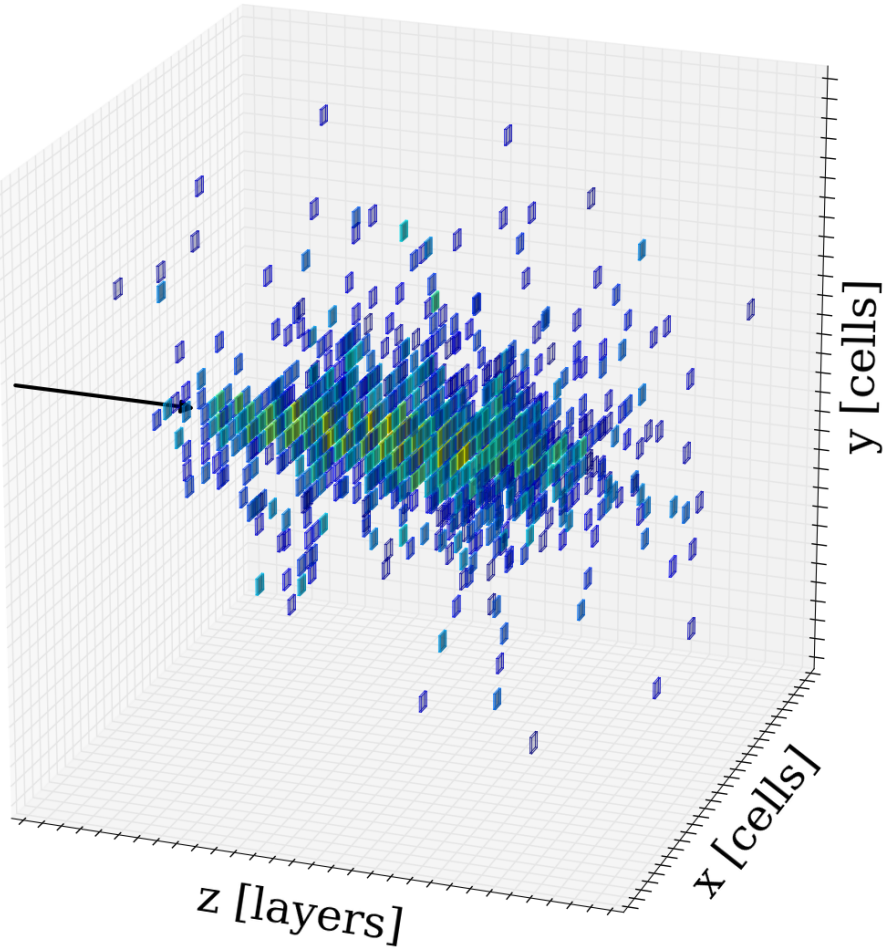
Application of generative networks to CMS HGCal has started in our group with **close collaboration** with experts in the field

Stay tuned for our preliminary results!!



Conclusion

- Application of generative models to high resolution EM shower simulation
  - ✓ Modelling of MIP peak and high fidelity
  - ✓ Speedup: 3 orders of magnitude
- Architectures:
  - GAN
  - WGAN
  - BIB-AE (**New!**)
- Future Plans:
  - condition on incident position/angle
  - hadronic showers
  - CMS HGCal
  - integrate into existing tools / frameworks



Paper: [arxiv:2005.05334] (submitted to journal, soon to be published)