High Fidelity Simulation of High Granularity Calorimeters with High Speed

4th Inter-experiment Machine Learning Workshop

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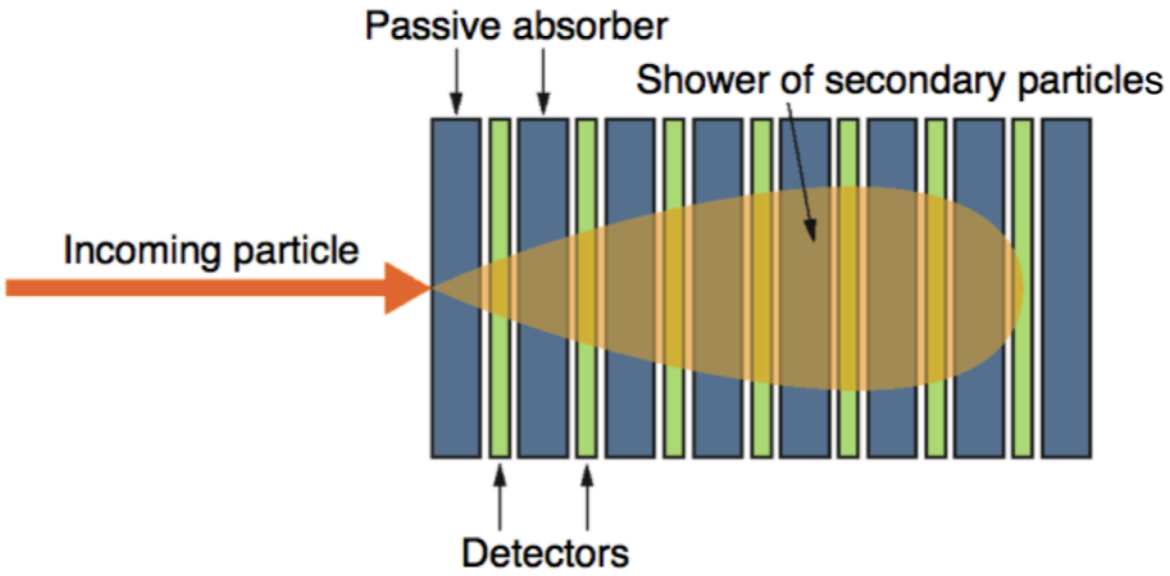
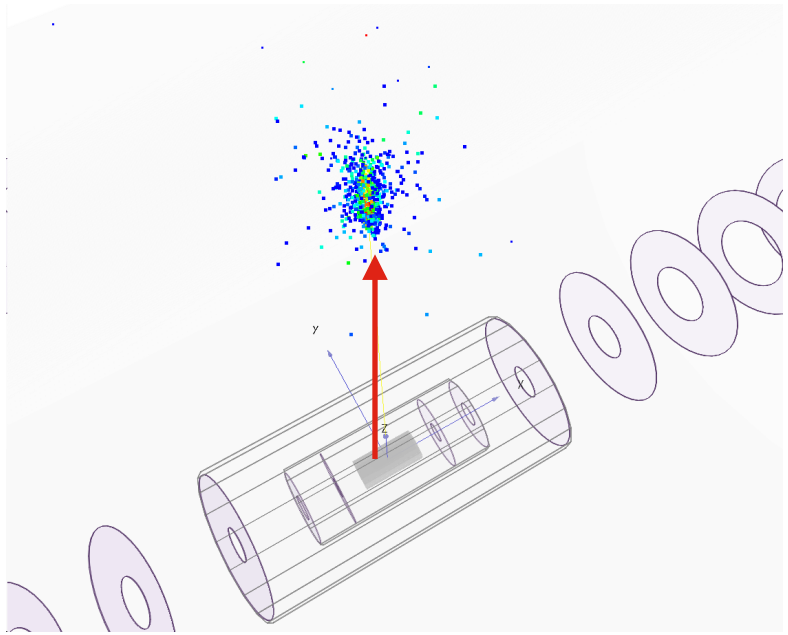
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

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

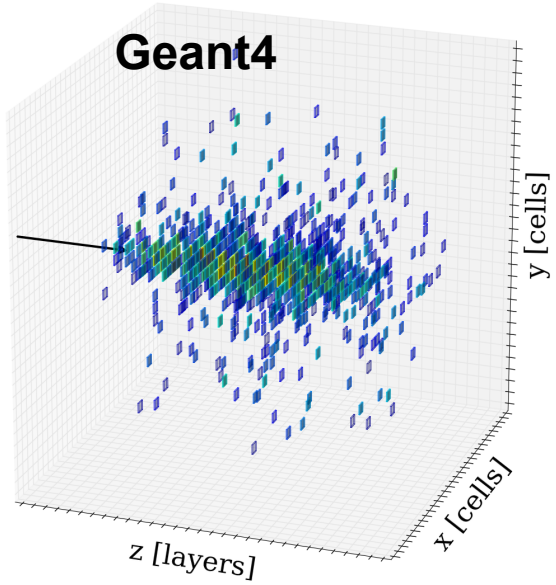
- Alternating layers of passive absorbers and active detectors
- Only **fraction** of particle energy is recorded (visible energy)

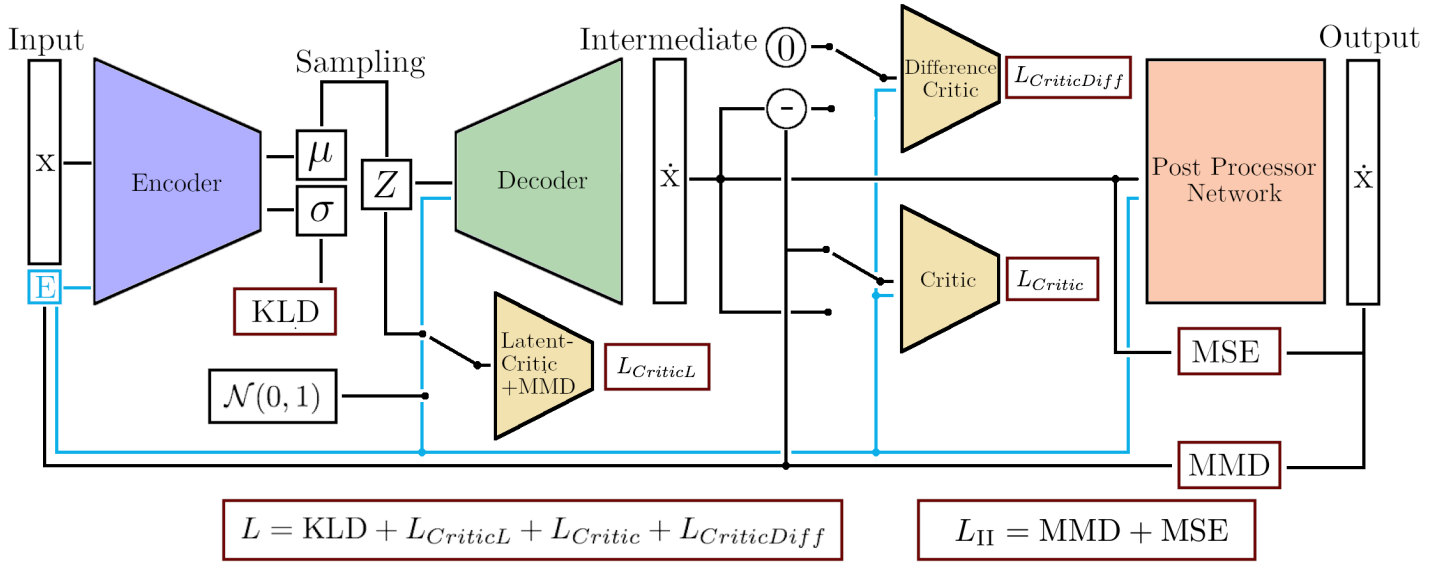
Shooting photon perpendicular to the ILD-ECAL (Si-W)

Photon energy: 10-100 GeV, continuous!

Results

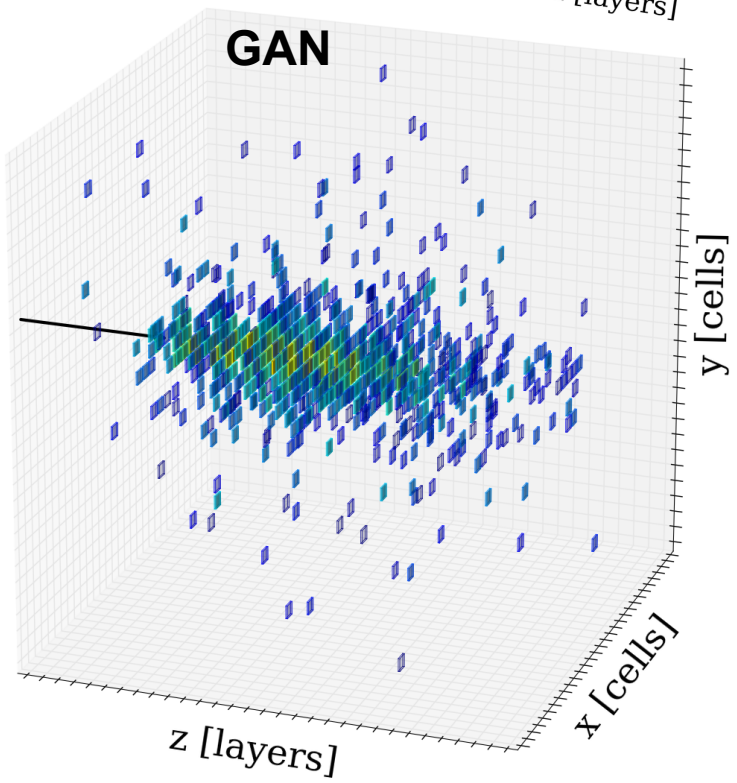
looks realistic???

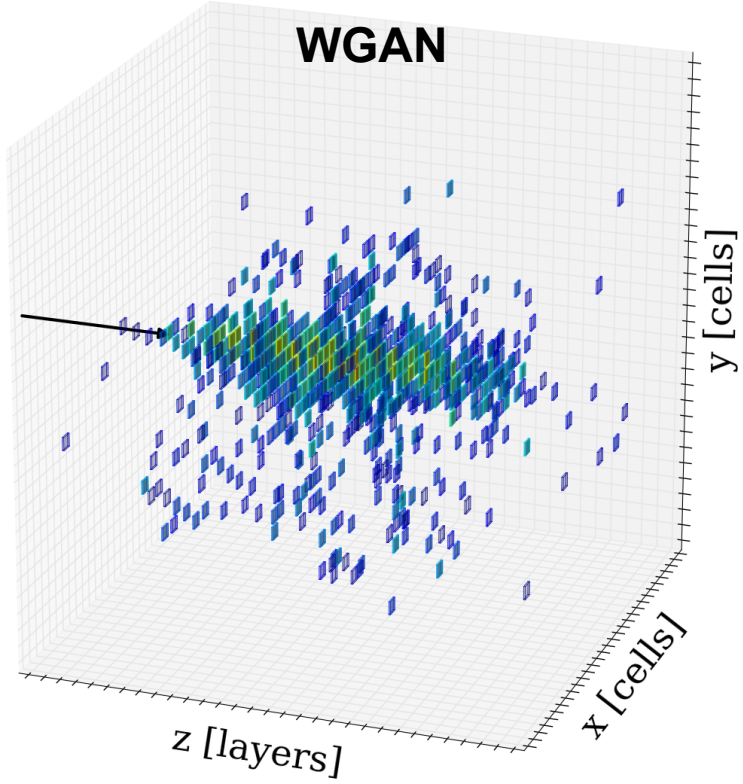


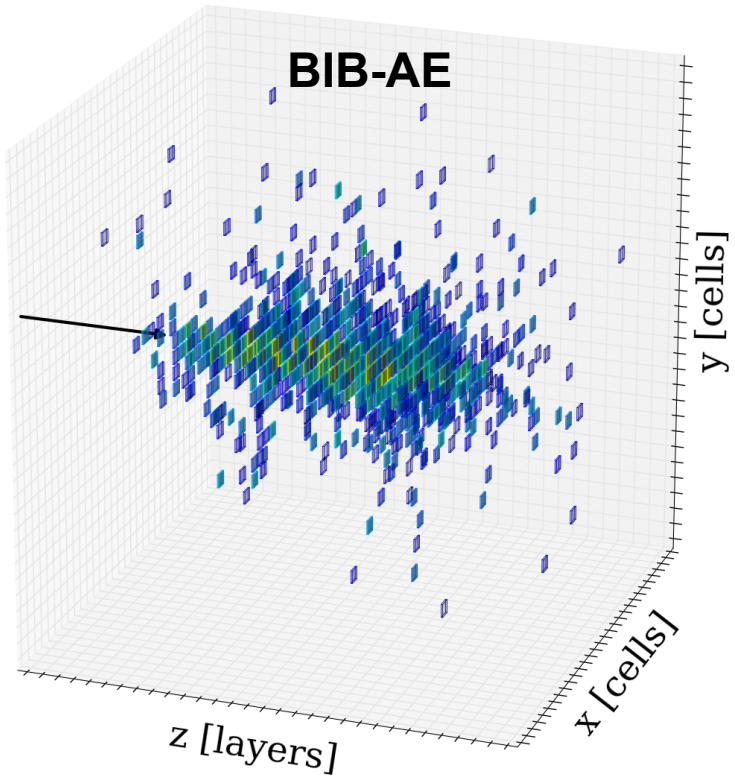


$$L = \text{KLD} + L_{CriticL} + L_{Critic} + L_{CriticDiff}$$

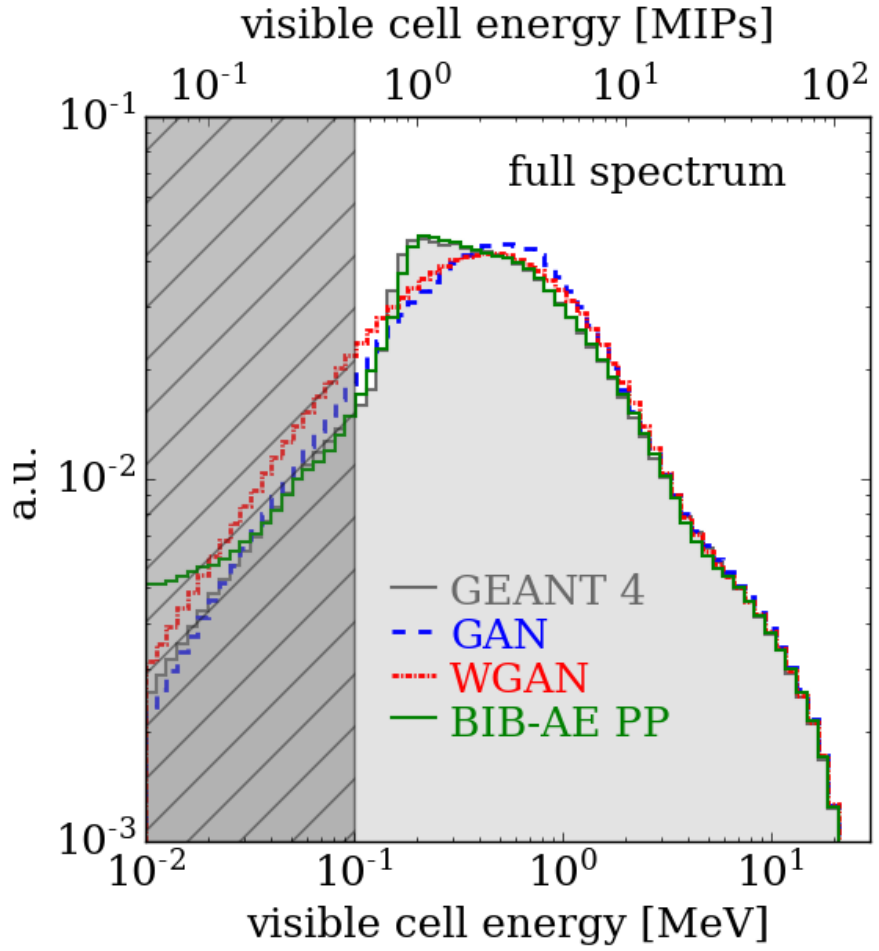
$$L_{\text{II}} = \text{MMD} + \text{MSE}$$

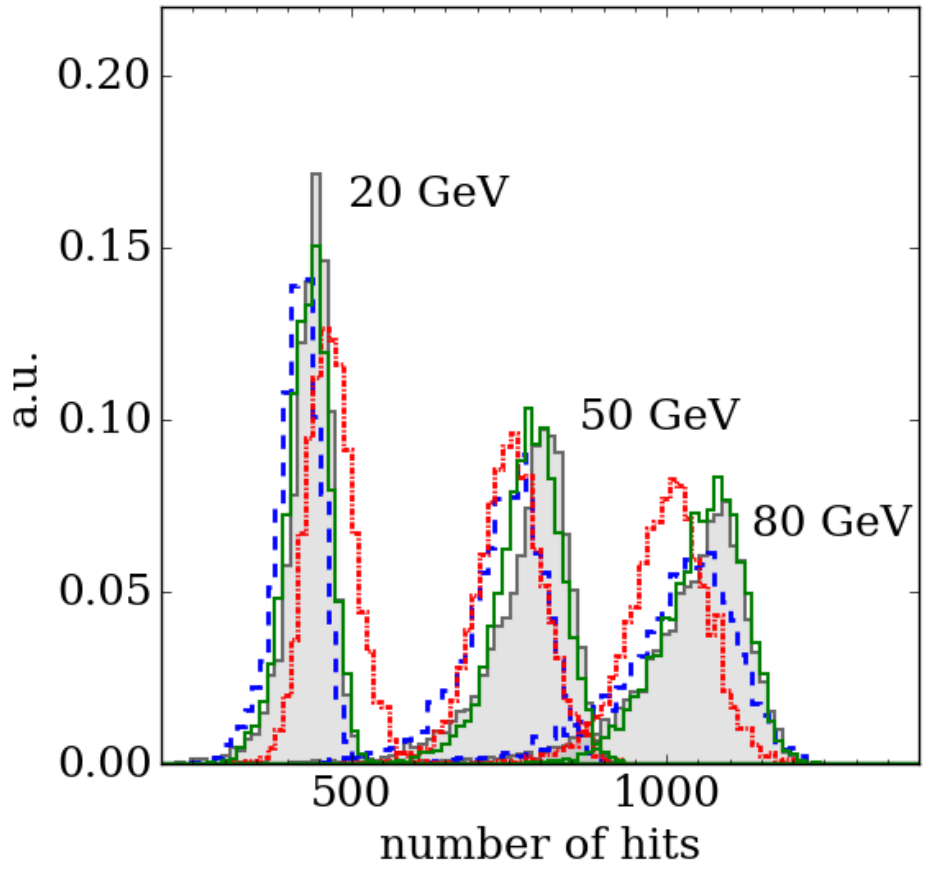






Results: Cell energy and Number of hits

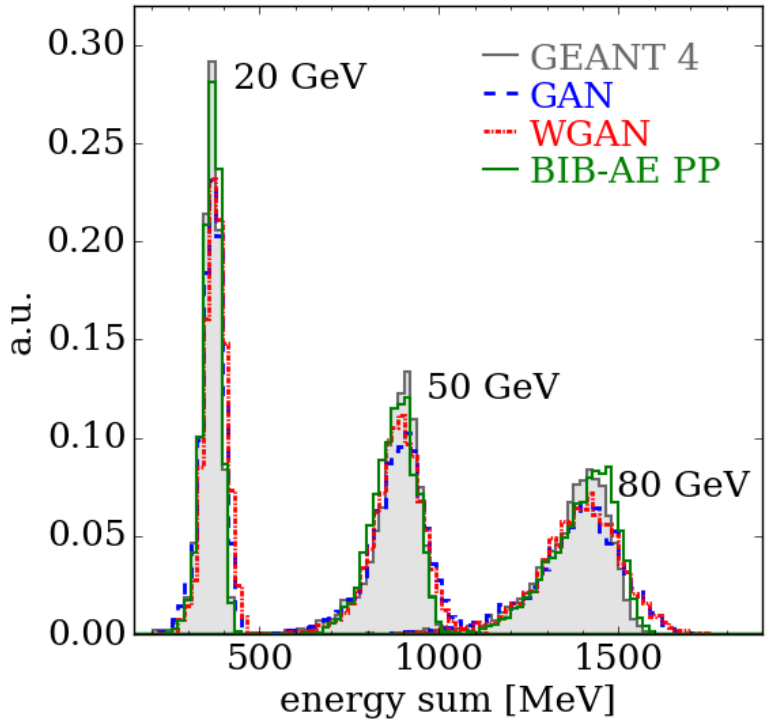


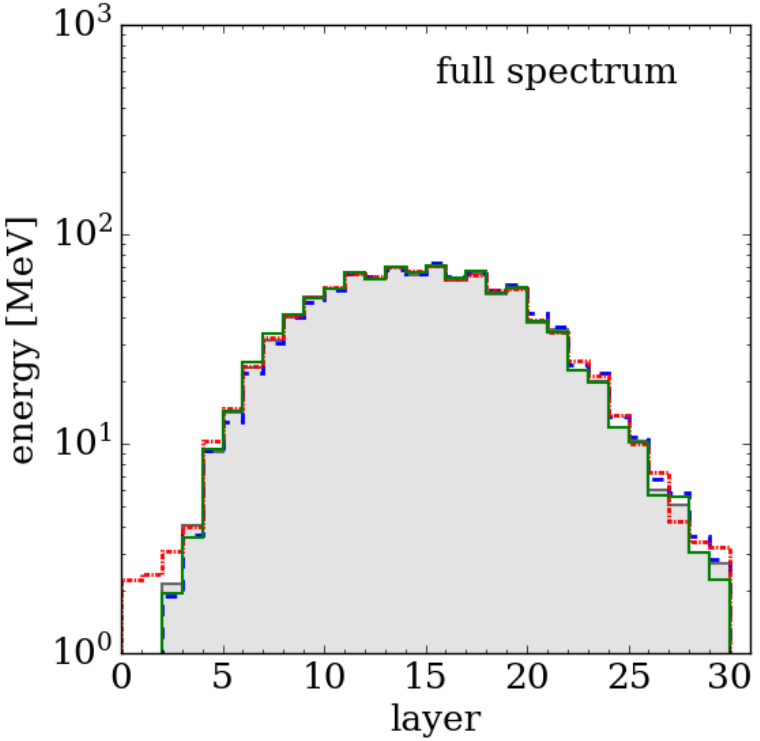


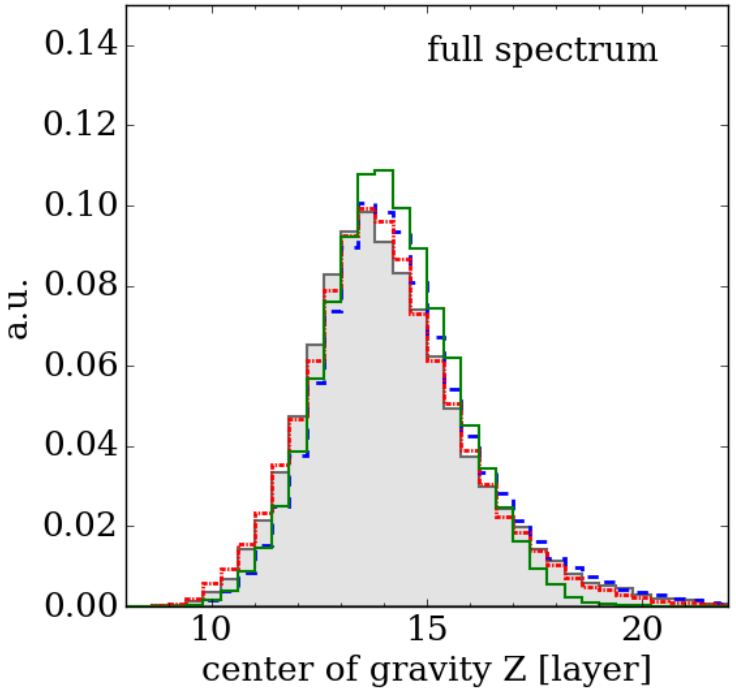
- Both GAN and WGAN fail to capture MIP bump around 0.2 MeV
- ✓ BiB-AE is able to produce this feature thanks to Post-Processing network

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

Results: Other important distributions







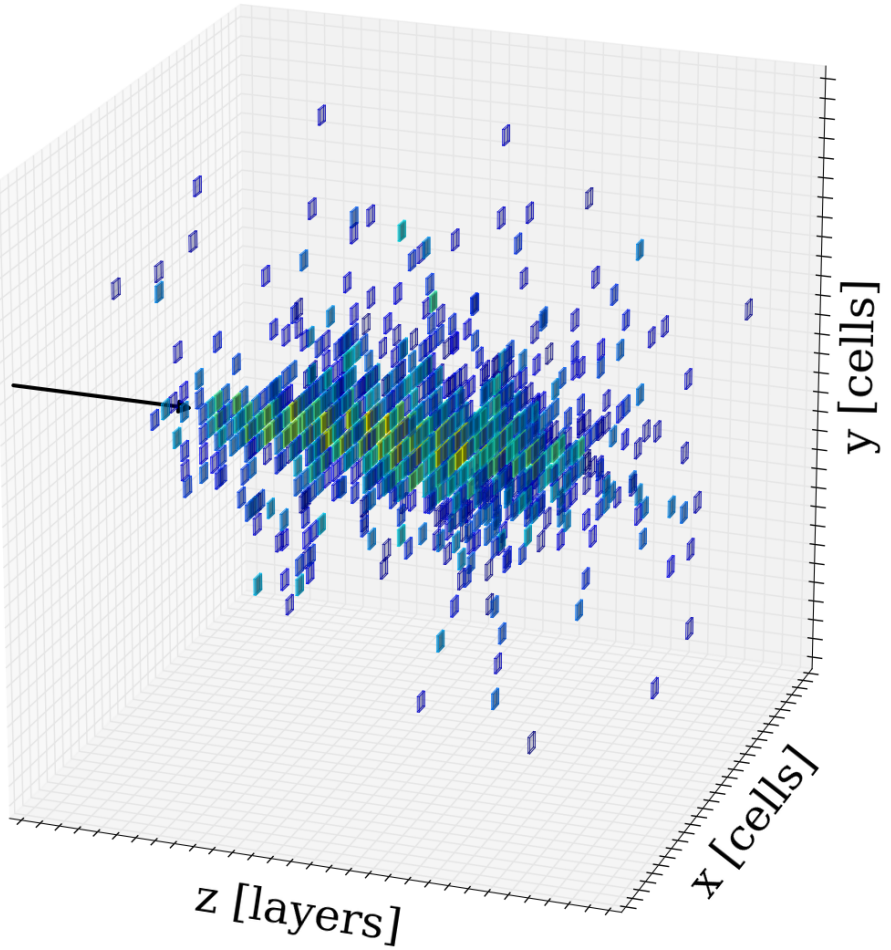
✓ the shape, center and width of the peak are well reproduced for all models

✓ 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

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
  - integrate into existing tools / frameworks



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