



FastCaloGAN: A FAST SIMULATION OF THE ATLAS CALORIMETER WITH GANs

26th International Conference on Computing in High Energy & Nuclear Physics, Norfolk, VA, United States, 8 - 12 May 2023

THE CONTEXT

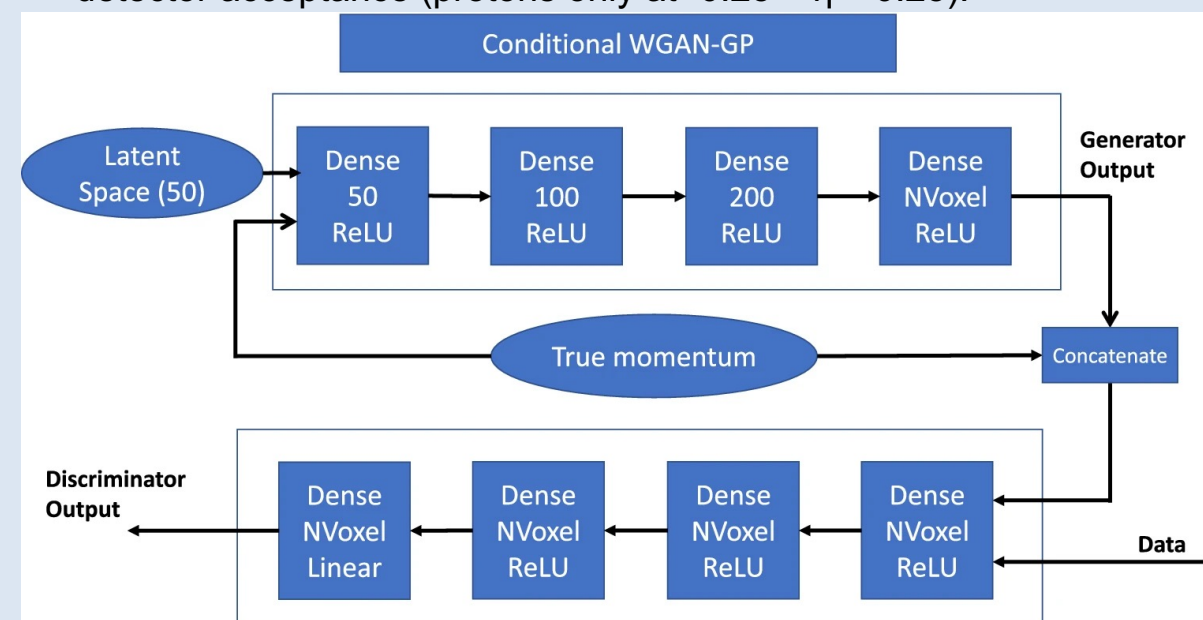
ATLAS employs a fast simulation system to simulate detector response, **ATLFAST3**:

- The slowest part is calorimeter simulation → to speed it up, ATLFAST3 combines different tools for different particle types and energies, depending on where they perform best (image below [1]);
- Tools: **FastCaloGAN** (machine-learning-based), FastCaloSim V2 (parametrisation-based), Geant4 (limited to specific cases).

	Inner Detector	Calorimeters	Muon Spectrometer			
Electrons Photons	Geant4	FastCaloSimv2				
Hadrons		Geant4 pions: $E_{vis} < 200$ MeV Other hadrons: $E_{vis} < 400$ MeV	FastCalo Sim V2 $E_{vis} < (8-16)$ GeV	FastCalo GAN $(8-16)$ GeV $< E_{vis} < (256-512)$ GeV	FastCalo Sim V2 $E_{vis} > (256-512)$ GeV	Muon Punchthrough +Geant4
Muons		Geant4		Geant4		

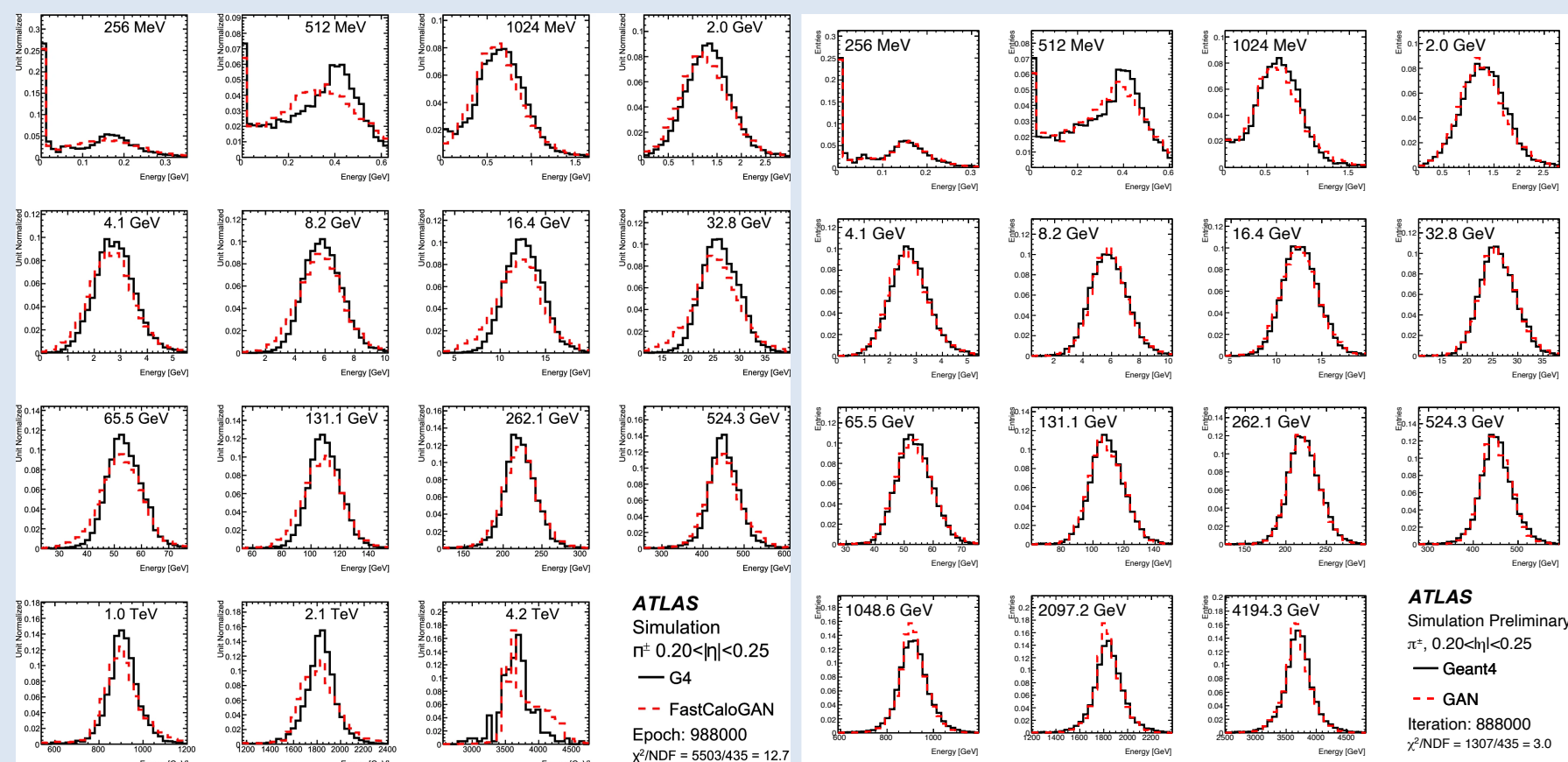
FastCaloGAN

- Based on Generative Adversarial Networks (GANs), with the **simultaneous training of 2 neural networks** (image below [2]):
 - Generator (G): given Geant4-simulated data as training sample, aims at generating sample the most similar to it;
 - Discriminator: fed data from both the training sample and the G-produced Geant4-like sample, tries distinguishing actual Geant4 data from G-produced data.
- When finished training, **FastCaloGAN simulates calorimeter response as similarly as possible to Geant4** (in the limit of this being a fast simulation and not a full one), **but much faster**;
- Currently able to simulate calorimeter showers for photons, electrons, pions and protons between 256 MeV and 4 TeV over full detector acceptance (protons only at $-0.25 \leq \eta \leq 0.25$).



PERFORMANCE EVALUATION PLOTS

- Done by comparing FastCaloGAN simulated data to the ones of Geant4 (the reference);
- Upper row: Geant4-FastCaloGAN comparison for pion simulation, with the old version of FastCaloGAN (left [1]) and the latest one (right [3]). **Remarkable improvement** - also observed for photons and electrons;
- Lower row, left: Geant4-FastCaloGAN comparison for proton simulation, introduced in the latest version [4]. **Already remarkable results**;
- Lower row, right: Geant4-FastCaloGAN-FastCaloSim V2 comparison for proton simulation [4]. **FastCaloGAN produces better results** than FastCaloSim V2, also correcting the large discrepancy at low energy.
- Work in progress: further improvement (better voxelisation, new GAN settings) and extension of use cases.



REFERENCES

- [1] The ATLAS Collaboration, AtlFast3: The Next Generation of Fast Simulation in ATLAS, *Comput Softw Big Sci* **6**, 7 (2022)
- [2] The ATLAS Collaboration, Fast simulation of the ATLAS calorimeter system with Generative Adversarial Networks, ATL-SOFT-PUB-2020-006
- [3] Public plots: atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/SIM-2022-001/
- [4] Public plots: atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/SIM-2023-004/

