

PanShower: One model for all calorimeter showers

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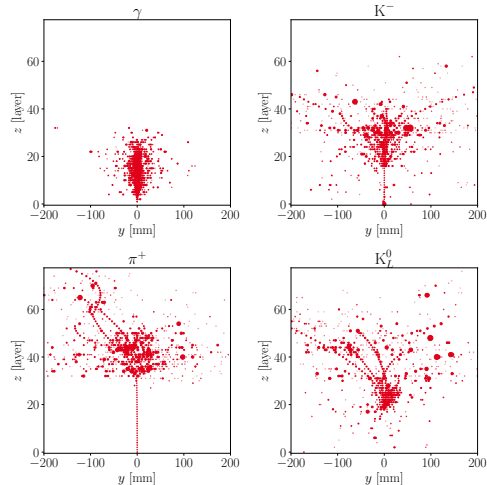
Motivation & Dataset

Goal:

- ▶ previous models for specific particle types
 - ▶ CaloClouds¹: photons
 - ▶ CaloHadronic²: positively charged pions
- ▶ one model for all particle types

Dataset:

- ▶ simulated with Geant4
- ▶ E_{inc} in $[5, 126]$ GeV
- ▶ particles:
 e^- , e^+ , γ , π^+ , π^- , K_L^0 , K^+ , K^- , n , $\bar{n}$, p , $\bar{p}$
- ▶ all possible angles (including curvature)
- ▶ similar preprocessing as in [1] and [2]

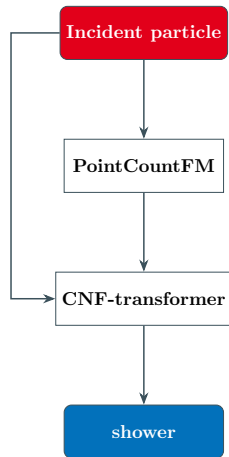


¹Erik Buhmann et al. *CaloClouds: fast geometry-independent highly-granular calorimeter simulation*. 2023. [arXiv: 2305.04847](https://arxiv.org/abs/2305.04847)

²Thorsten Buss et al. *CaloHadronic: a diffusion model for the generation of hadronic showers*. 2025. [arXiv: 2506.21720](https://arxiv.org/abs/2506.21720)

PanShower Model Overview

- ▶ conditional flow matching³
- ▶ based on point clouds
- ▶ attention mechanism for point interactions⁴
- ▶ conditioning on incident particle properties
 - ▶ E_{inc}
 - ▶ particle type
 - ▶ normalized momentum
- ▶ PointCountFM generates number of points per layer
- ▶ CNF-Transformer generates point positions and energies
 - ▶ as a three-dimensional point cloud
 - ▶ layer index as condition
 - ▶ one embedding vector per calorimeter layer
 - ▶ one embedding vector per particle type

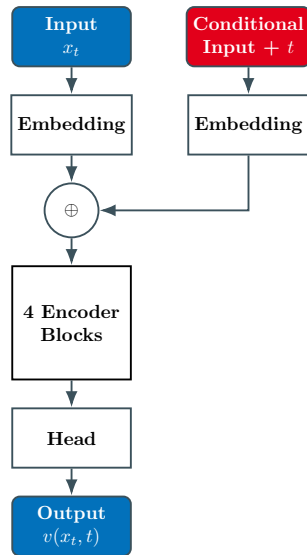
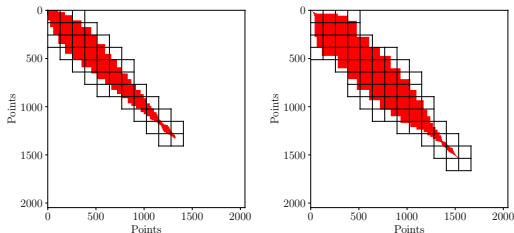


³Yaron Lipman et al. *Flow Matching for Generative Modeling*. 2023. [arXiv: 2210.02747](https://arxiv.org/abs/2210.02747)

⁴Ashish Vaswani et al. *Attention Is All You Need*. 2017. [arXiv: 1706.03762](https://arxiv.org/abs/1706.03762)

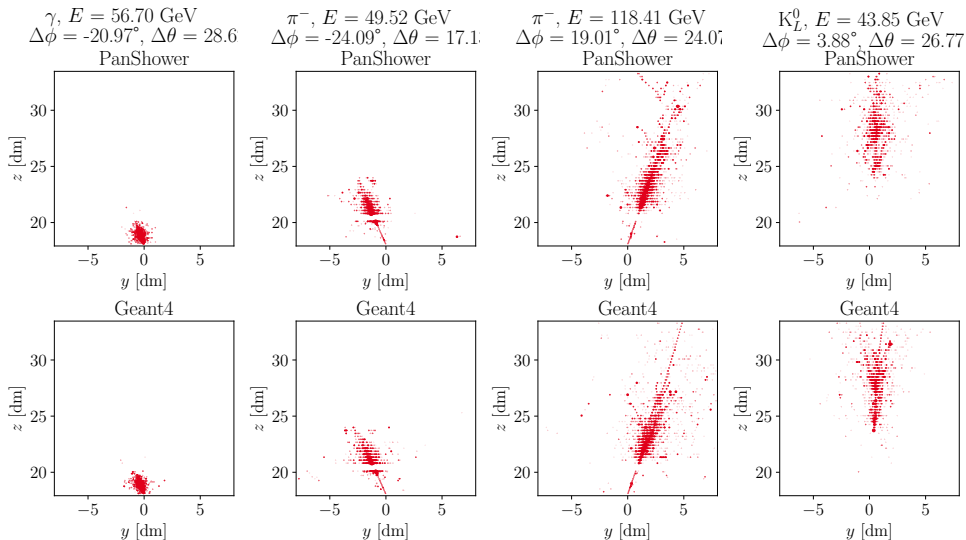
Architecture Details

- ▶ model learns $v_c(x_t, t)$
- ▶ transformer encoder blocks with self-attention
- ▶ using flex-attention⁵
- ▶ only points up to two calorimeter layers apart can interact

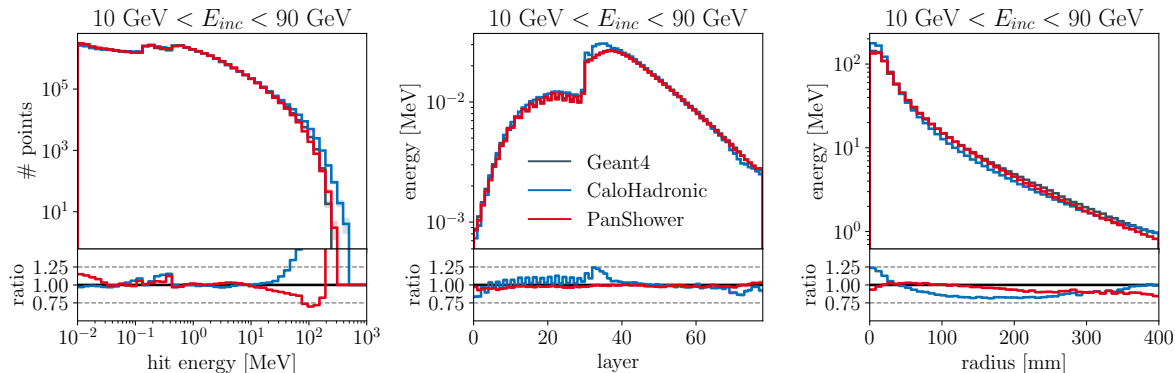


⁵ Juechu Dong et al. *Flex Attention: A Programming Model for Generating Optimized Attention Kernels*. 2024. [arXiv: 2412.05496](https://arxiv.org/abs/2412.05496)

Individual Showers



Hit Level Observables



- hit energy, layer energy and radius distributions for π^+ showers
- comparison between PanShower, CaloHadronic and Geant4
- high fidelity in all observables

Paper coming soon!