AUSTRIAN ACADEMY OF SCIENCES

HEPHY INSTITUTE OF HIGH ENERGY PHYSICS

Flow-based generative models for particle calorimeter simulation

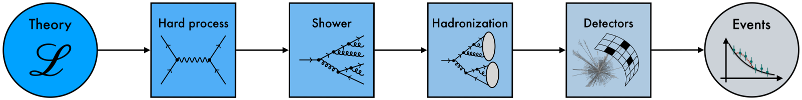
— EuCAIFCon, Amsterdam, NL —

Claudius Krause

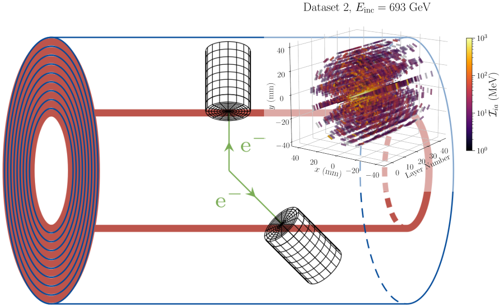
Institute of High Energy Physics (HEPHY), Austrian Academy of Sciences (OeAW)

April 30, 2024

Our computational ressources are limited!



Machine Learning and LHC Event Generation, A. Butter et al. [2203.07460], R. Winterhalder



We need fast and faithful surrogates.

⇒ Normalizing Flows are both.

latent space ⟷ Bijector ($\mathcal{L} = -\log p$) ⟷ data space

Flow-based generative models for particle calorimeter simulation

1. Learn how total energy is distributed across layers: $p_1(E_1, E_2, \dots, E_n | E_{\text{inc}})$
2. Learn normalized shower:

- **direct**: learn $p_2(\hat{\mathcal{I}}_{1:n} | E_{1:n}, E_{\text{inc}})$
- **autoregressive**: learn first layer $p_2(\hat{\mathcal{I}}_1 | E_1, E_{\text{inc}})$ and step from $(n-1)$ to n: $p_3(\hat{\mathcal{I}}_n | \hat{\mathcal{I}}_{n-1}, n, E_n, E_{n-1}, E_{\text{inc}})$

CaloChallenge datasets

Dataset		Method	generation time per shower [ms] ↓	AUC on voxels ↓
1: γ 368-dim		GEANT4	$\mathcal{O}(10^4)$	0.499(2)
	d	CaloFlow IAF	0.79 ± 0.01	0.761(2)
	d	CaloINN	0.51 ± 0.03	0.626(4)
1: π^+ 533-dim		GEANT4	$\mathcal{O}(10^4)$	0.609(4)
	d	CaloFlow IAF	1.00 ± 0.02	0.884(2)
	d	CaloINN	0.44 ± 0.01	0.784(2)
2: e^- 6480-dim		GEANT4	$\mathcal{O}(10^5)$	0.500(2)
	a	iCaloFlow IAF	13.2 ± 0.5	0.819(4)
	d	CaloINN	1.18 ± 0.03	0.743(2)
3: e^- 40500-dim		GEANT4	$\mathcal{O}(10^5)$	0.498(2)
	a	iCaloFlow IAF	16.7 ± 0.5	0.891(3)

Classify Showers vs. GEANT4 as metric.