Project Proposal [FYS9429]

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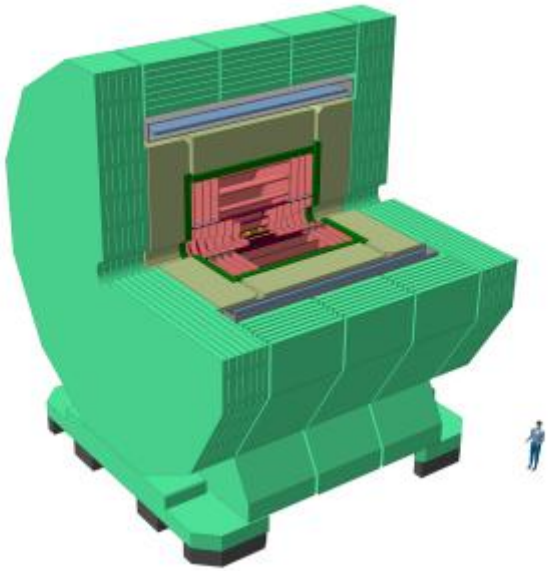
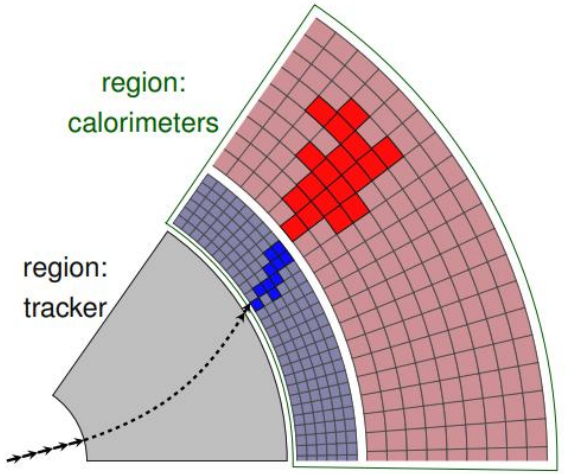
Introduction

- Calorimeters are used in high-energy physics (HEP) experiments to measure the energy of particles produced in collisions.
- Simulations of calorimeters are also performed to validate experimental results.
- Today, this is mainly done by Geant4, a Monte Carlo-based framework for modelling particle-matter interactions.





Challenges

- Geant4 is computationally slow, and simulation demand is increasing…
- **Generative models** can potentially bridge this gap.
- Existing work:
  - GANs, VAEs, Diffusion, Normalizing Flows, Flow Matching, Hybrids.

Requirements

- Models need to be **fast** and **accurate**.
- How can one validate if the model is faithfully representing underlying physics?
- Models also need to create **realistic** simulations (e.g. conditioning on energy, type, and angle of the particle entering the calorimeter).
- Models need to be able **generalize** across different detector geometries (geometry agnostic).

Proposal

- Develop a generative model to address the challenge of creating calorimeter simulations.
- More specifically, I will focus on a diffusion-based model, potentially with attention mechanism.
- The recently released *step2point* dataset is used as the ground truth. This dataset features Geant4 simulations as point clouds for three different particle types (photon, electron, π^-) entering the calorimeter of the Open Data Detector with varying energy and angle.

Proposal

- One semester project (100%)
- To start simple, I will develop a diffusion model that can generate point clouds without any conditioning and only for the electromagnetic calorimeter.
- Possible extensions :
  - Include conditioning parameters (energy, particle type, angle).
  - Include also the hadronic calorimeter.