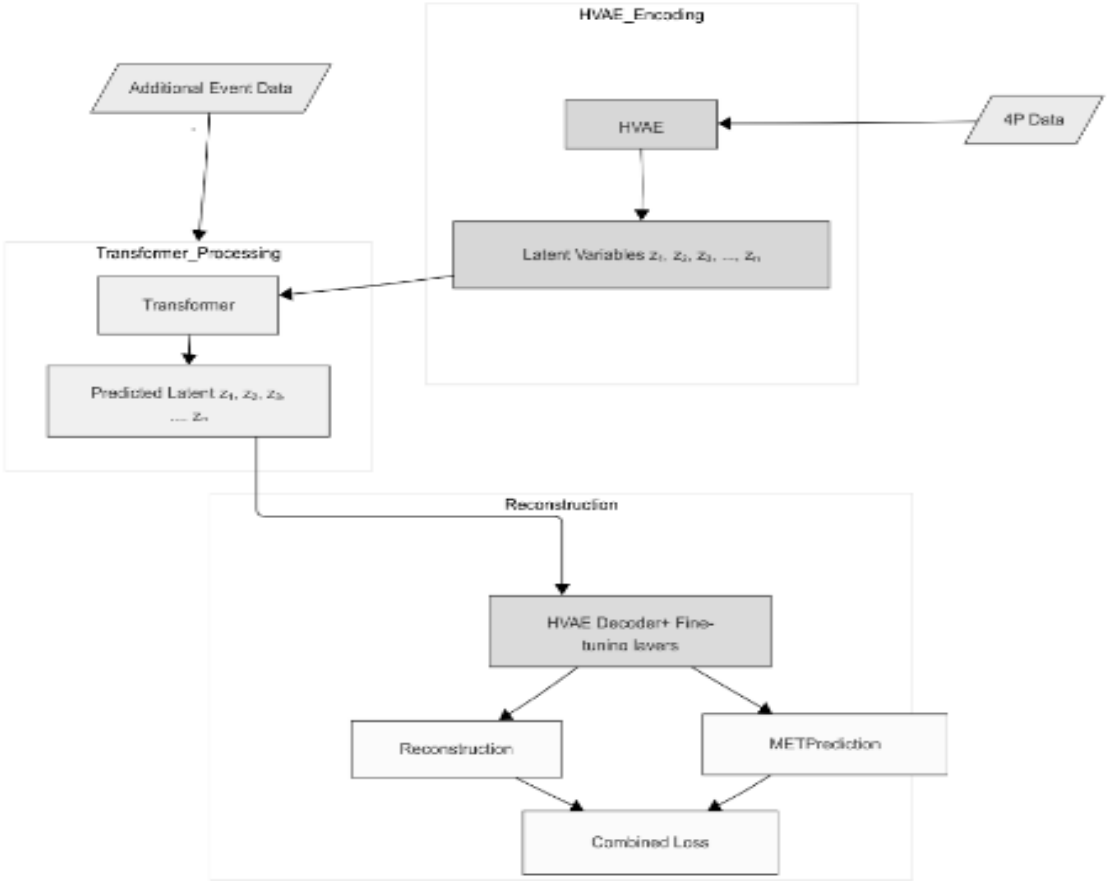
Background Enrichment augmented Anomaly Detection (BEAD) for new physics searches at LHC

1. Project Description

This proposal suggests adding a new model to **BEAD (Background Enrichment for Anomaly Detection)**, a modular Python package for detecting signs of new physics such as dark matter in high-energy physics (HEP) data using deep learning. BEAD supports data handling, model training, inference, plotting, and diagnostics, and focuses on learning from background data to highlight rare, unexplained events. The proposed model replaces discrete latent models (e.g., VQ-VAE) with a Hierarchical Variational Autoencoder (HVAE) and integrates a Transformer to capture deeper patterns. This aims to improve BEAD's performance on unlabeled data, reduce reliance on simulations, and enhance its sensitivity to subtle anomalies.

2. Model Architecture



3. Timeline

Week 1 - 3	Phase 1	● Setup environment, explore HEP data, and design HVAE architecture. ● Pre-train HVAE on background data and validate reconstruction.
Week 4 - 5	Phase 2	● Implement Transformer, integrate with HVAE latent, and train prediction task.
Week 6	Midterm Evaluation	● Submit midterm deliverables and gather mentor feedback. ● Complete any remaining blog posts and documentation
Week 8 - 9	Phase 3	● Add fine-tuning layers, train multi-task objectives, and test anomaly scoring. ● Tune model for high accuracy.
Week 10 -11	Phase 4	● Evaluate the model . ● Compare with other existing models and draw conclusions.
Week 12	Final Submission	● Complete final blog posts and document all aspects of the project
After completion		● Continue working at the organization and contributions in HEP research.

4. About Me

I'm a second-year Electronics Engineering student at Veermata Jijabai Technological Institute, Mumbai, with a minor in AI/ML. I began programming with C++ in high school and later developed a strong foundation in Python, machine learning, and deep learning. Fascinated by quantum mechanics and its intersection with artificial intelligence, I'm eager to explore applications of ML in high-energy physics. My summer break runs from mid-May to the end of July, during which I'll have no academic commitments. I plan to start the project on 1st June and expect to contribute around 40 hours per week during this period, with additional flexibility on weekends.