IRIS-HEP Fellows Program Project Proposal

Advanced ML Techniques and Hybrid Dual-Readout Systems for Electroweak Jet Identification and Particle Flow Enhancement in Future Collider Detectors

Applicant: Oleksandr Shelestiuk

Mentor: Christopher G. Tully

Project duration: 12 Weeks

Proposed start date: 20 June 2024

Introduction and project description

Nowadays, future particle detectors strive to explore new frontiers in high-energy physics. Therefore, the optimization of the detectors and increase of their performance is vital to fully embrace the discovery potential of experiments. One promising direction for enhancing detector capabilities is the development of segmented crystal dual-readout calorimeters.

The future of data models for complex instruments faces significant challenges in accommodating the discovery of new physics signatures. This project adopts a comprehensive approach to address these challenges. Firstly, it focuses on integration of advanced machine learning (ML) techniques to search for new physics phenomena, particularly in the form of electroweak jets. Secondly, it is describing low level single particle separation in the jet measurements to provide handles in the data model for identifying electroweak jets.

The low-level systems are based on the use of hybrid dual-readout segmented crystals, which enable photon/neutral hadron separation. This not only enhances particle flow but also allows for a deeper understanding of jet energy measurements, specifically addressing the limitations posed by the neutral hadron component.

Also, the project is based on analysis of the signatures of weak boson splitting within jet features. Understanding these signatures is vital for optimizing the reconstruction and tagging of electroweak jets. Moreover, a combined top-bottom approach will be employed to correlate the analysis performance with low-level reconstruction, providing comprehensive insights essential for future collider detector development.

By integrating advancements in dual-readout calorimetry with corresponding machine learning techniques, this project aims to provide novel insights into the future of collider detector development. This dual-development approach not only promises to enhance our understanding of electroweak jets but also offers valuable contributions to the broader field of high-energy physics research.

Proposed Timeline

- Week 1 & 2: Familiarize myself with Monte Carlo techniques that can be integrated. Conduct a thorough literature review on segmented crystal dual-readout calorimeters, electroweak jets, and relevant machine learning (ML) techniques. Run existing examples.
- Week 3 & 4: Simulating data using Monte Carlo (MC) algorithms. Generate truth data for various particle interactions.Validate the quality and consistency of data. Organizing and managing the generated data, ensuring proper documentation.
- Week 5-6: Consider ML algorithms and select the most appropriate. Development of initial models and start model training using the preprocessed data.
- Week 7: Optimizing model hyperparameters to improve performance. Experiment with different regularization techniques to prevent overfitting.
- Week 8-9: Develop specialized models for electroweak jet tagging tasks. Experiment with different architectures and features to capture weak boson splitting signatures.
- Week 10-11: Evaluate the performance of the developed model on validation datasets.
- Week 12: Document all work and add notes. In addition, work on the final presentation to IRIS-HEP.

References:

1. Junmou Chen, Tao Han, Brock Tweedie, “Electroweak Splitting Functions and High Energy Showering”: https://arxiv.org/abs/2203.11129
2. Tao Han, Yang Ma, and Keping Xie, “Electroweak fragmentation at high energies: A Snowmass White Paper”: https://arxiv.org/abs/1611.00788
3. Maja Karwowska, Łukasz Graczykowski, Kamil Deja, Miłosz Kasak, and Małgorzata Janik, on behalf of the ALICE collaboration, “Particle identification with machine learning from incomplete data in the ALICE experiment”: https://cds.cern.ch/record/2893904/files/2403.17436.pdf
4. Marco T. Lucchini, Wonyong Chung, Sarah C. Eno, Yihui Lai, Lorenzo Lucchini, Minh-Thi Nguyen, Christopher G. Tully, “New perspectives on segmented crystal calorimeters for future colliders” : https://arxiv.org/abs/2008.00338