Efficiency of ML Anomaly Detection Triggers for Emerging Jets

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FERMILAB-POSTER-24-0128-CMS-V

Emerging Jets (EMJs)

- Astronomical observations (e.g. galaxy rotation curves) indicate the existence of dark matter.
- Hidden Valley models propose a dark QCD-like sector that couples to the SM through a mediator particle [1]
  - EMJ: Phenomenological model where long-lived dark mesons decay into SM quarks, producing sub-jets with displaced vertices.
- A recent analysis [2] investigated pair production of scalar bi-fundamental mediators.
  - No significant deviation from the SM was observed.
- In this work we focus on the s-channel and on how novel AD triggers could help find this signal.

Anomaly Detection (AD) Triggers

- Traditional triggers are based on prior knowledge of the signal, or on kinematic cuts.
- AD ML techniques find signals which are different from typical events, independent of a model.
- AD triggers are trained on typical events, so they fail to reconstruct rare or beyond SM signals.
- Two AD Triggers:
  - **CICADA**: Convolutional Autoencoder [3]
  - **AXOL1TL:** Variational Autoencoder [4]

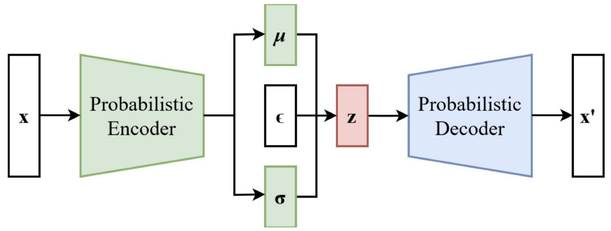

Figure 1: Structure of a variational autoencoder

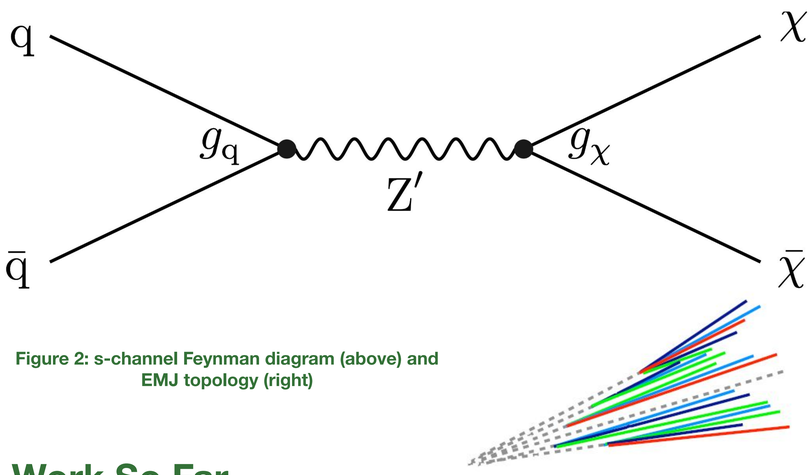

Figure 2: s-channel Feynman diagram (above) and EMJ topology (right)

Work So Far

- Development of s-channel Pythia MC production code.
- Production of s-channel samples for mass values ranging from 100 GeV to 2000 GeV.
- *Substantial improvement in trigger efficiency observed when including AD triggers for lower Z' mass, but negligible improvements for higher mass.*
- Study of how jet kinematic distributions are impacted by cuts on the AD scores.
- Derived ROC curves from AD scores and observed good discrimination of EMJ events against typical events.

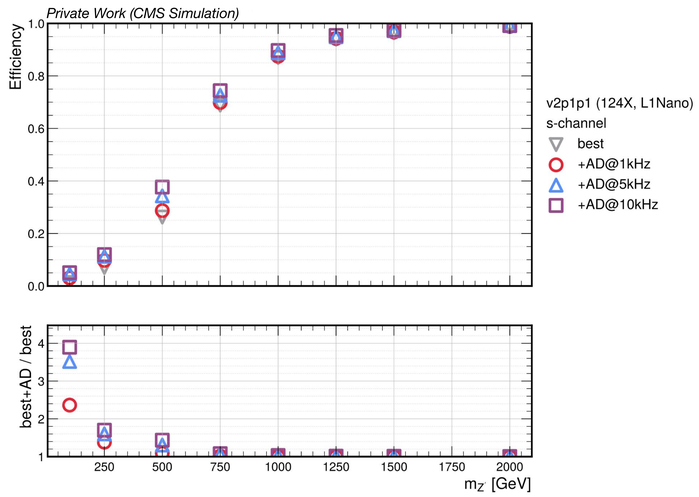

Figure 3: Efficiency of CICADA v2.1.1 as a function of Z' mass

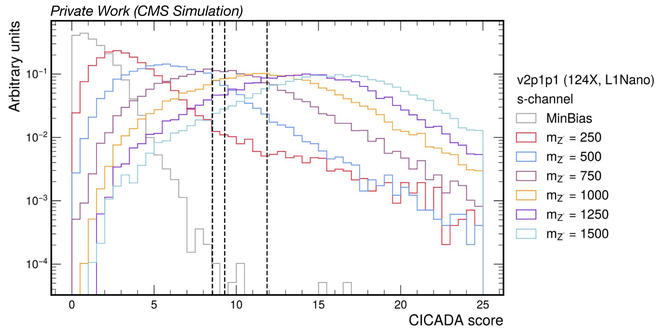

Figure 4: Distributions of CICADA v2.1.1 AD scores for various Z' masses

Future Work

- Study background mass sculpting due to AD triggers.
- Include novel LLP triggers in trigger efficiency study.
- Study LLP and AD trigger efficiencies as a function of the lifetime of the long-lived dark mesons.

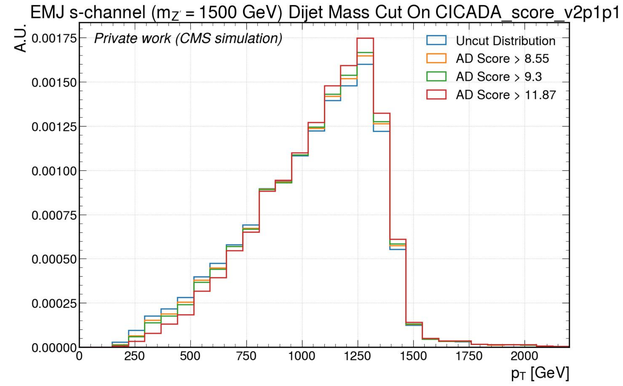

Figure 5: Dijet mass distributions for Z' mass of 1500 GeV with different CICADA v2.1.1 AD Score Thresholds

Acknowledgements

- LPC's Guest & Visitor Program
- NSF award 2111134
- This work has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

Bibliography

[1] arXiv:1502.05409v3

[2] arXiv:2403.01556v1

[3] CERN-CMS-DP-2023-086

[4] CERN-CMS-DP-2023-079

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