LHCC Poster Session – Nov 18, 2021

Digluon Tagging using √s= 13 TeV pp Collisions in the ATLAS Detector

ATL-PHYS-PUB-2021-027

Physics Motivation

A variety of beyond Standard Model (BSM) theories predict new bosons with two-prong decays at masses other than the W, Z, and Higgs bosons. Light (pseudo) scalar particles (*a* bosons) from extended Higgs sectors or axion-like particle models could result in Lorentz-boosted digluon jets ($a \to gg$). The decay $a \to gg$ can be dominant in certain two-Higgs doublet models via quantum loop-induced processes [1]. There could be a new heavy vector-like fermion that couples to *a* and allows for $a \to \gamma\gamma$ or $a \to gg$ decays. Also, in models without a diphoton component, like models with warped extra dimensions that can have only Quantum Chromodynamics (QCD) extended in the bulk, the corresponding radion would decay predominantly to gluons [2].

Schematic & Innovations

Background $Z \to \mu\mu$ + QCD jets

Reweight w/ data using new technique. Matches event, jet, and substructure observables

Signal ($Z \to \mu\mu$) $H \to aa \to 4g$

Innovative classifier w/ jet and event level info. DisCo [3] loss to decorrelate output with m_{jj}

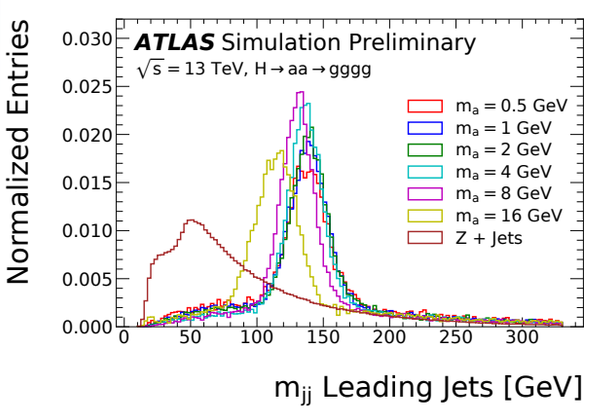
Digluon vs QCD jet classifier from jet tagger latent space output embedding

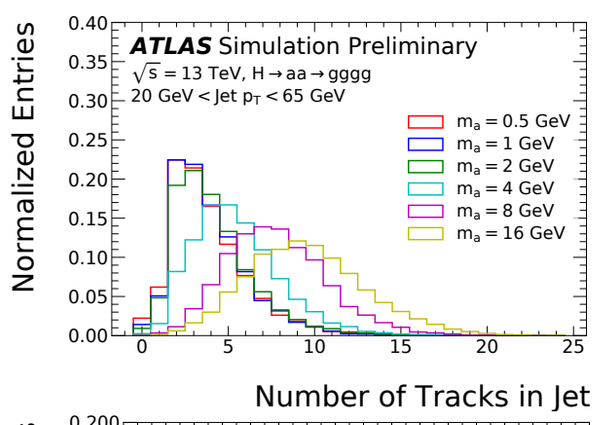
$H \to aa \to 4g$ event classifier

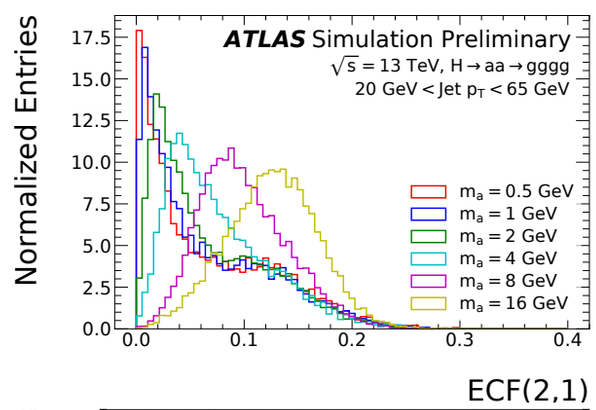
Signal Digluon Jets vs Background QCD Quark / Gluon Jets

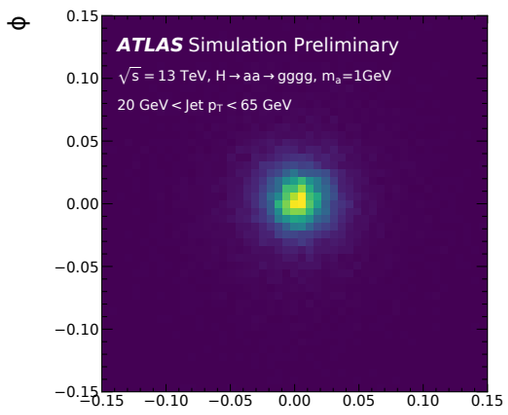
In the intermediate a mass (m_a) regime, the *a* is light and has a significant Lorentz boost in the laboratory frame such that its decay products are collimated into a single jet with radius $\lesssim 0.4$.

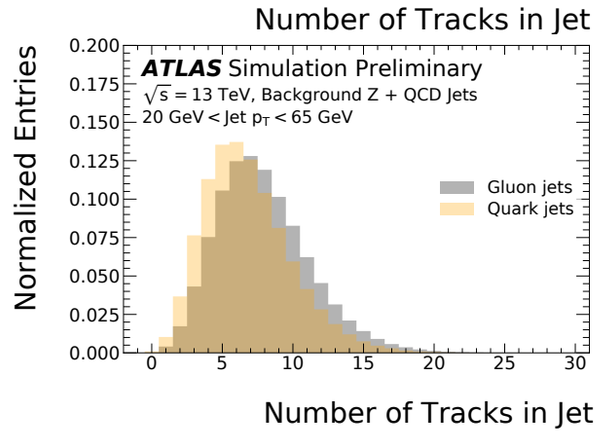
The main background comes from generic QCD quark and gluon jets. Jet substructure variables (shown below) can help us discriminate signal and background jets. The radiation patterns shown in the averaged jet (η-ϕ) images (shown on the right side) made using associated track p_T in one jet p_T bin highlight this further.

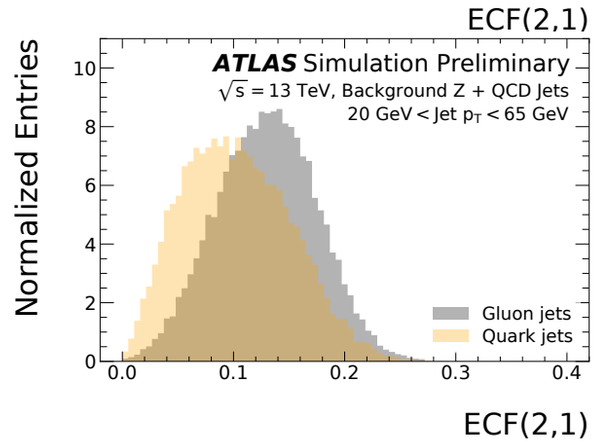


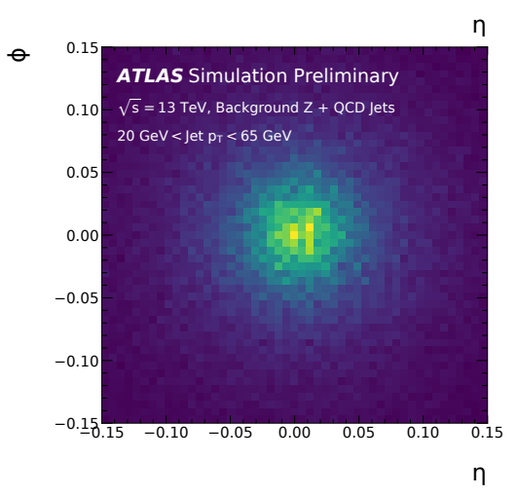




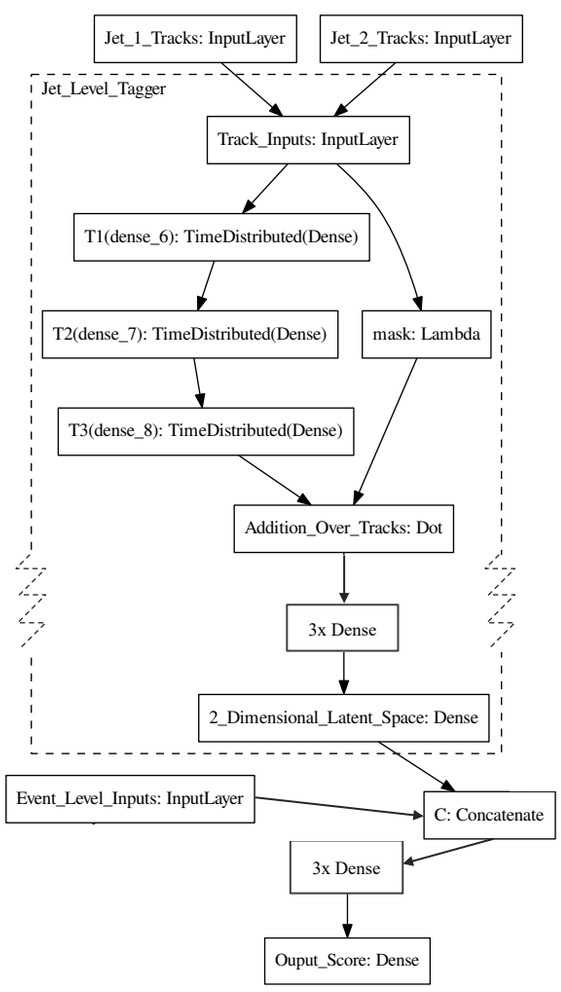








The combined mass of the two digluon jets in $H \to aa \to 4g$ events shows a clear resonance. The 2-point energy correlation (ECF(2,1)) and number of tracks show digluon jets (ex. at low m_a) are more collimated and have fewer tracks than QCD jets.



Classifier Architecture

Comprised of two main components:

1. Jet level tagger that accepts variable length track inputs from each jet (shown in dashed box on the left)
2. Event level fully connected module

Tracks in jets used as variable length inputs (features: p_T, distance from jet axis) and processed w/ deep sets implemented as particle flow network. The network embeds each track into a latent space then sums all latent space vectors together before returning the final 2D latent space vector for each jet.

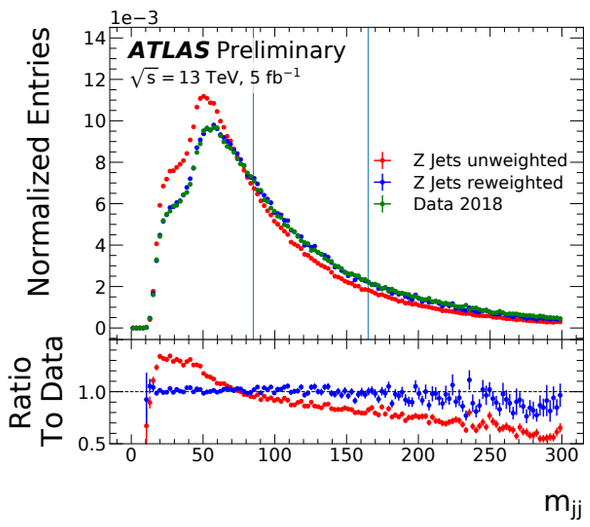
The event level module combines the embeddings of both leading jets, and info from the jet and Z boson 4-vectors.

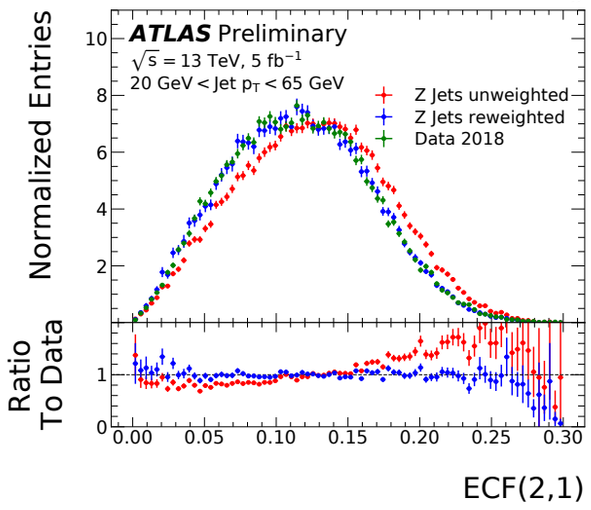
A single probability score for each event is returned. Separate taggers are trained for each of the mass points that are tested. Note that the jet level tagger is generic, but the event level tagger is specific to the signal channel targeted and adaptable for other cases.

Training & Performance

Loss function has a distance correlation term to decorrelate the output and m_{jj} for ABCD background estimation [4].

The background events are reweighted using a MC - Data classifier with the same architecture to ensure matching of event & substructure observables for better digluon tagging (see below).

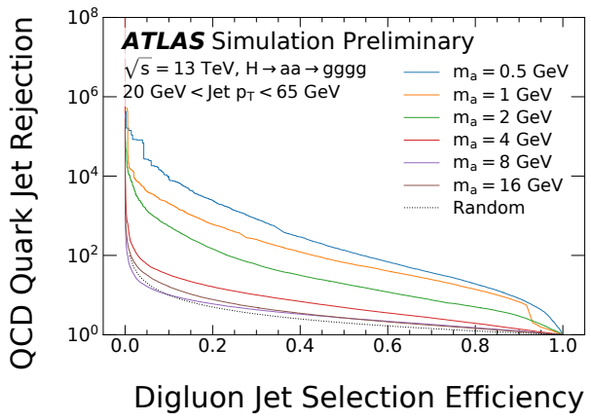


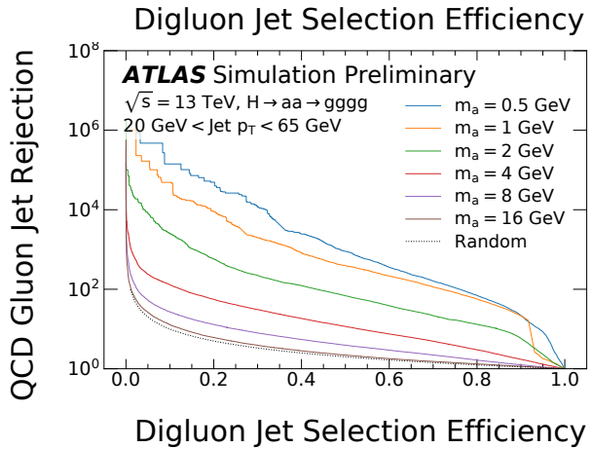


Reweighting is done in sidebands outside the blue lines in the m_{jj} plot.

The digluon jet tagger evaluated by training a dense network on the 2D output. ROC curves for digluon vs QCD jets are shown below for one jet p_T bin.

High QCD jet rejection achieved for low scalar masses, w/ tagger degrading at higher masses; consistent w/ plots above that show resemblance to QCD jets. Better gluon jet rejection illustrates the constraints from the singlet initiated digluon decay versus gluon jets.





Conclusions & Outlook

- A novel method to tag a → gg digluon jets from prompt decays of light BSM scalars which can couple to SM Higgs boson is presented
- The tagger learns the unique radiation pattern from single jets.
- A novel variable high dimensional MC reweighting technique is shown.
- The tagging method can be extended to boosted object searches such as $a \to qq$ (u,d,s) or *cc* which are also well motivated for BSM physics.

Murtaza Safdari, for the ATLAS Collaboration

Bibliography

[1] G. C. Branco et al., Theory and phenomenology of two-Higgs-doublet models, Phys. Rept. 516 (2012) 1, arXiv: 1106.0034

[2] K. Agashe, M. Ekhterachian, D. Kim, and D. Sathyan, LHC Signals for KK Graviton from an Extended Warped Extra Dimension, JHEP 11 (2020) 109, arXiv: 2008.06480

[3] G. Kasieczka and D. Shih, Robust Jet Classifiers through Distance Correlation, Phys. Rev. Lett. 125 (2020) 122001, arXiv: 2001.05310

[4] G. Kasieczka, B. Nachman, M. D. Schwartz, and D. Shih, Automating the ABCD method with machine learning, Phys. Rev. D 103 (2021) 035021, arXiv: 2007.14400

ATLAS EXPERIMENT