MACHINE LEARNING APPLICATIONS AT THE ATLAS EXPERIMENT

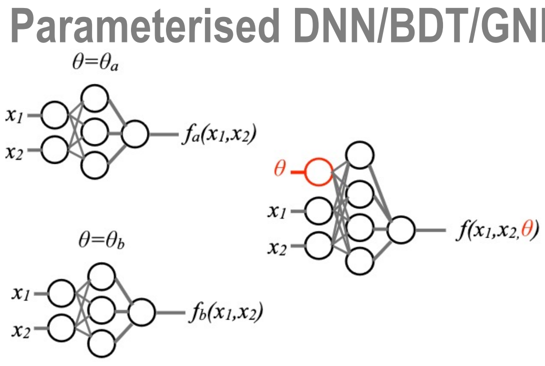
EUROPEAN AI FOR FUNDAMENTAL PHYSICS CONFERENCE

EuCAIFCon 2024 , 30 April – 3 May 2024, Amsterdam, Netherlands

SEARCHES

SUPERVISED, CLASSIFICATION S vs B

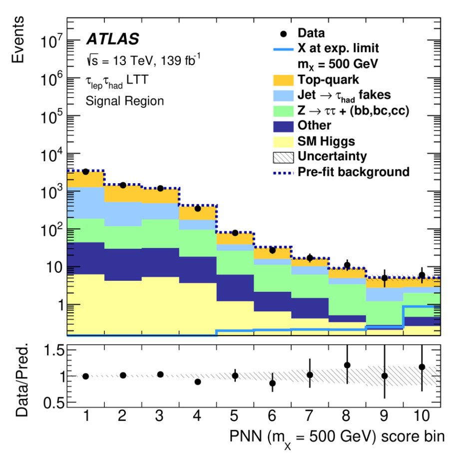
Parameterised DNN/BDT/GNN



Eur. Phys. J. C (2016) 76: 235

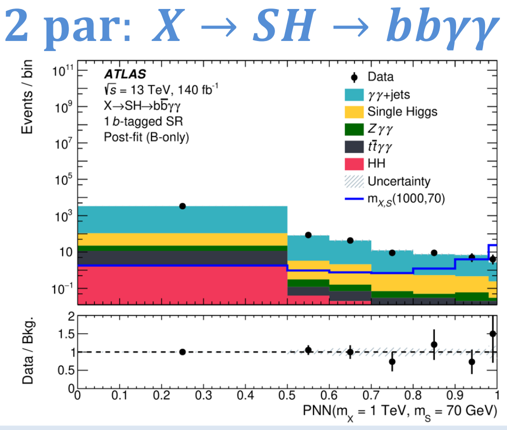
Increase training statistics by adding up multiple models, optimal for large range of parameters

1 par: $HH \rightarrow bb\,\tau\tau$



HDBS-2018-40

2 par: $X \rightarrow SH \rightarrow bb\gamma\gamma$



HDBS-2021-17

SUPERVISED, CLASSIFICATION S vs S

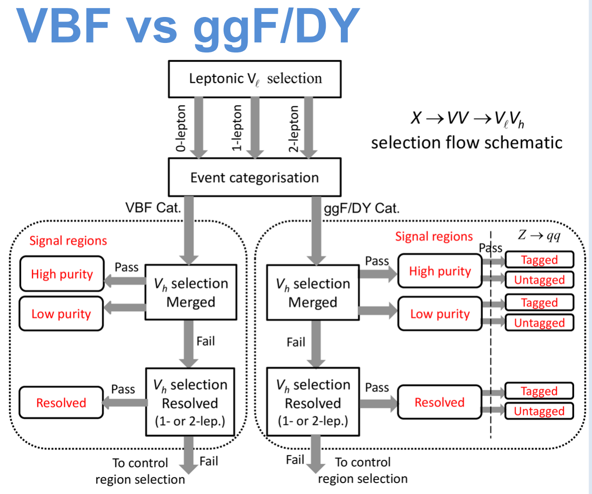
Multi-class classification

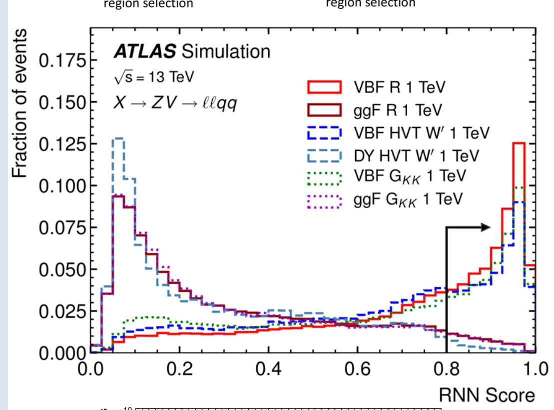
Use ML to optimise purities of signal classes, then optimise background rejection

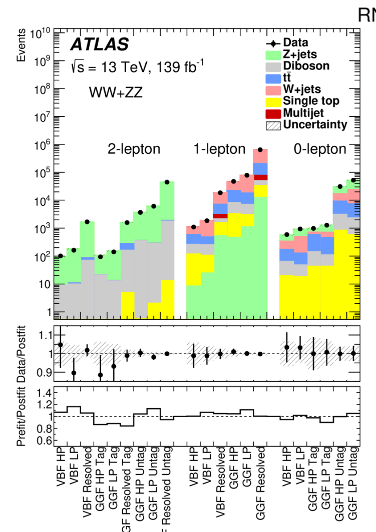
Pro: exploit different signal topologies in a single search, better signal class purity

$X \rightarrow ZV \rightarrow llqq$

VBF vs ggF/DY







HDBS-2018-10

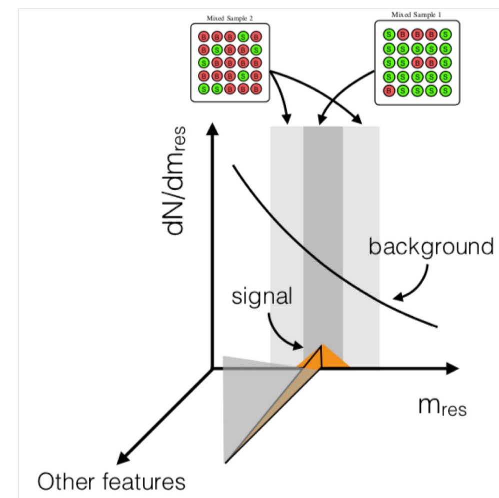
WEAKLY-SUPERVISED, CLASSIFICATION S vs B

Classification without labels (CWoLA)

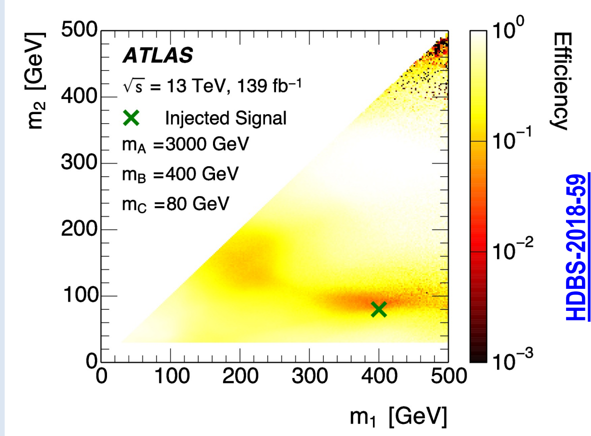
Instead of using signal and background, use mixed samples with different proportions of signal (S dominated vs B dominated)

Relies on assumption that mixed samples are of statistically similar size

$A \rightarrow BC$, di-jet resonance



- Features are masses of the first two jets (bump hunt)
- Generic search (small trial factor) for τ-leptons, b-quarks, t-quarks, W/Z/H bosons and asymmetric decays
- Signal regions and sidebands (background dominated), dedicated NN for each signal region
- NN able to detect injected signal



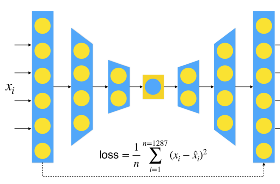
HDBS-2018-59

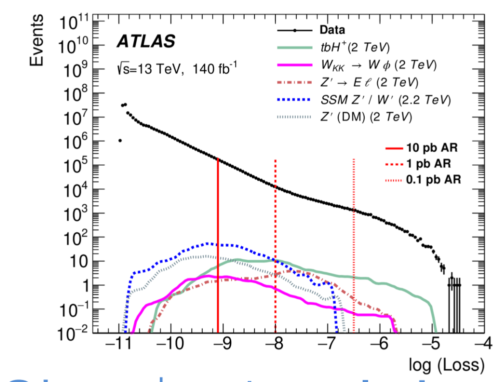
UNSUPERVISED, ANOMALY DETECTION

Model agnostic search

$X \rightarrow jY$, jet-Y resonance

Generic bump-hunt for jet+Y resonance using anomaly score (j+j, j+b-jet, 2 b-jet, j+e, b-jet+e, j+γ, j+μ, b-jet+μ , b-jet+ γ)

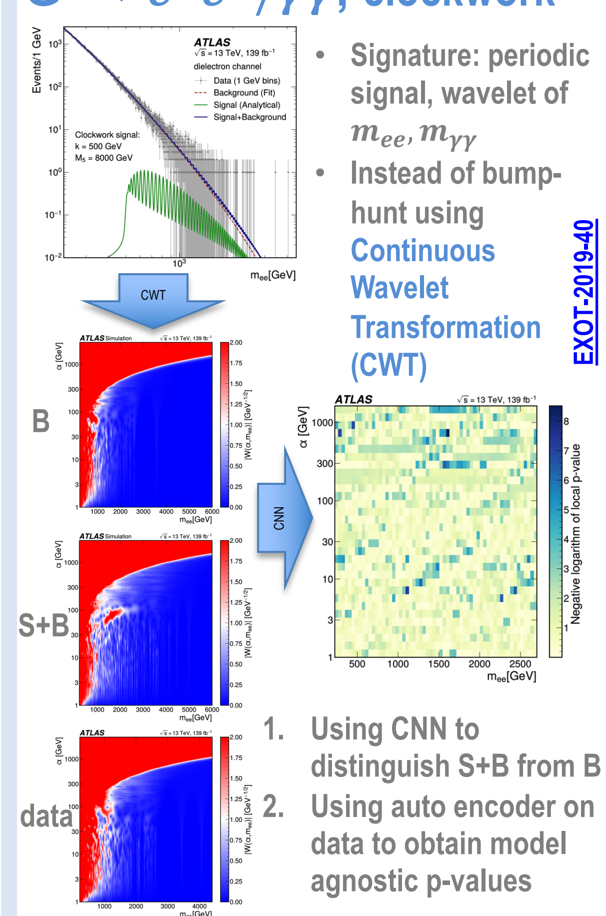




EXOT-2022-07

$G^* \rightarrow e^+e^-/\gamma\gamma$, clockwork

- Signature: periodic signal, wavelet of $m_{ee}, m_{\gamma\gamma}$
- Instead of bump-hunt using Continuous Wavelet Transformation (CWT)



1. Using CNN to distinguish S+B from B
2. Using auto encoder on data to obtain model agnostic p-values

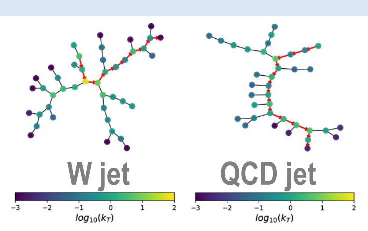
EXOT-2019-40

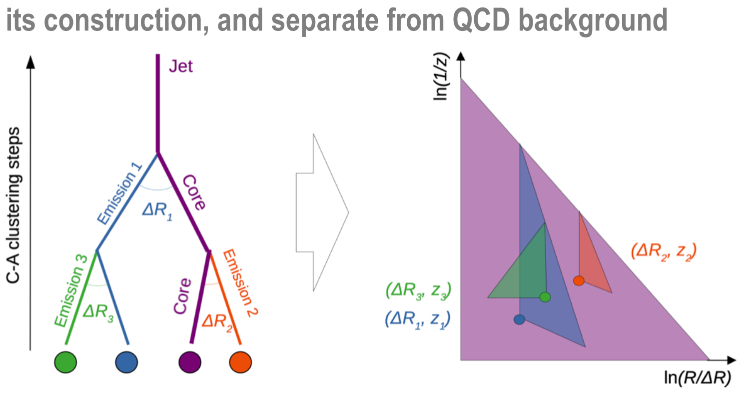
OBJECTS

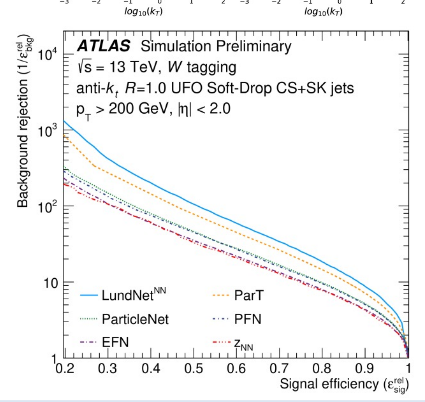
BOOSTED W-BOSON TAGGING

Lund Plane tagger

Identify jets originating from W bosons using the de-clustering information from successive splitting leading to its construction, and separate from QCD background





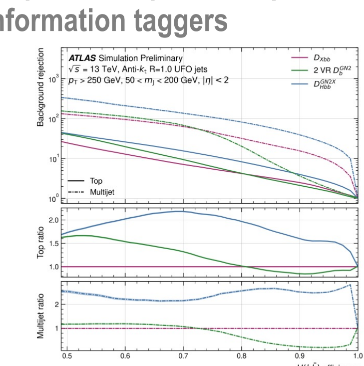


ATL-PHYS-PUB-2023-017

H TAGGING

$H \rightarrow bb$ tagger

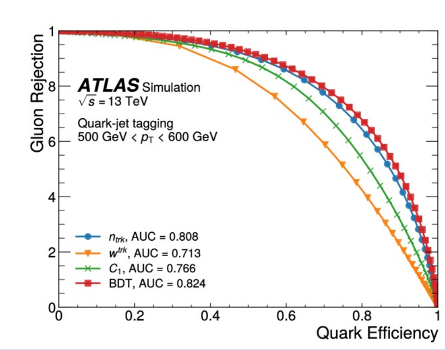
New boosted hadronically decaying Higgs tagger using low level information to identify two b/c-quarks outperforms previous high-level information taggers



ATL-PHYS-PUB-2023-021

q/g TAGGING

Identification of jets coming from quarks or gluons shows better performance using more low-level information. Two new taggers: (1) charged-particle constituent multiplicity, (2) jet kinematic and substructure variables and BDT



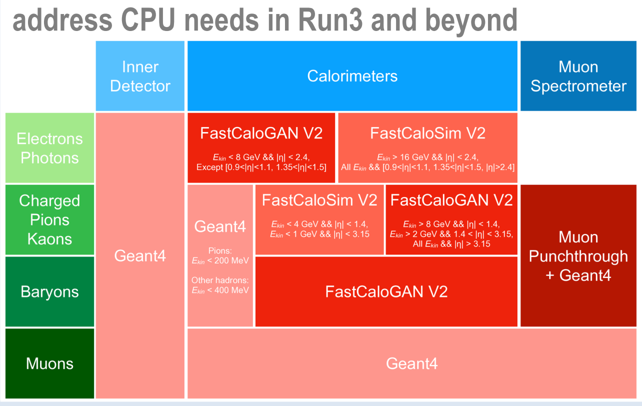
JETM-2020-02

SIMULATION

FAST SIMULATION

AtlFast3

Fast simulation tool for Run3 that balances modelling performance and CPU requirements to address CPU needs in Run3 and beyond

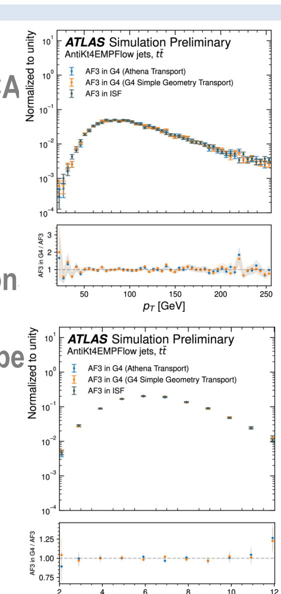


FastCaloSim v2

- Uses longitudinal and lateral shower development parametrization with PCA
- Parametrised modelling using Geant4 single photon, electron and pion samples (energy and $|\eta|$ spaced bins)
- Separate parameterisation in longitudinal and lateral shower development
- Energy decorrelation in layers using PCA
- Average lateral energy distribution parameterized as 2D probability function

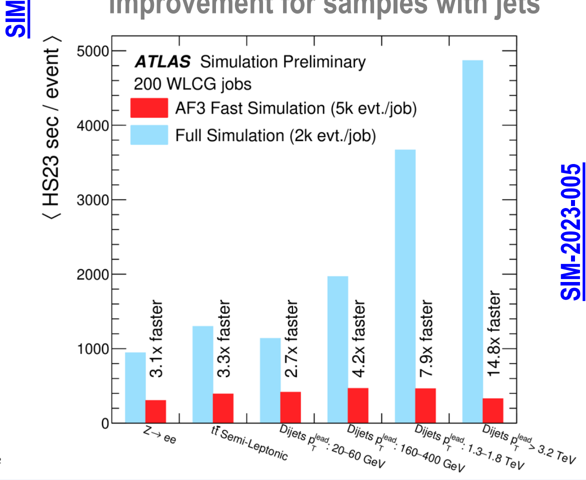
FastCaloGAN

- Parameterizes interactions of particles using 300 GAN, for each particle type and $|\eta|$ slice, factorizes the shower parametrization into longitudinal and lateral energy distributions for different energy points with interpolation between them
- Using Wasserstein GANs trained on each of 100 bins in $|\eta|$ and truth momentum condition
- Trained to reproduce energy in layers and total energy in a single step



SIM-2024-004

AF3 simulation 2-10 times faster than full simulation, greater improvement for samples with jets



SIM-2023-005

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