EUROPEAN AI FOR FUNDAMENTAL PHYSICS CONFERENCE
EuCAIFCon 2024

MACHINE LEARNING APPLICATIONS AT THE ATLAS EXPERIMENT

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EUROPEAN AI FOR FUNDAMENTAL PHYSICS CONFERENCE (EuCAIFCon 2024)

30 April – 3 May 2024, Amsterdam, Netherlands

IFAE
Institut de Física d'Altes Energies
EXCELENCIA SEVERO OCHOA

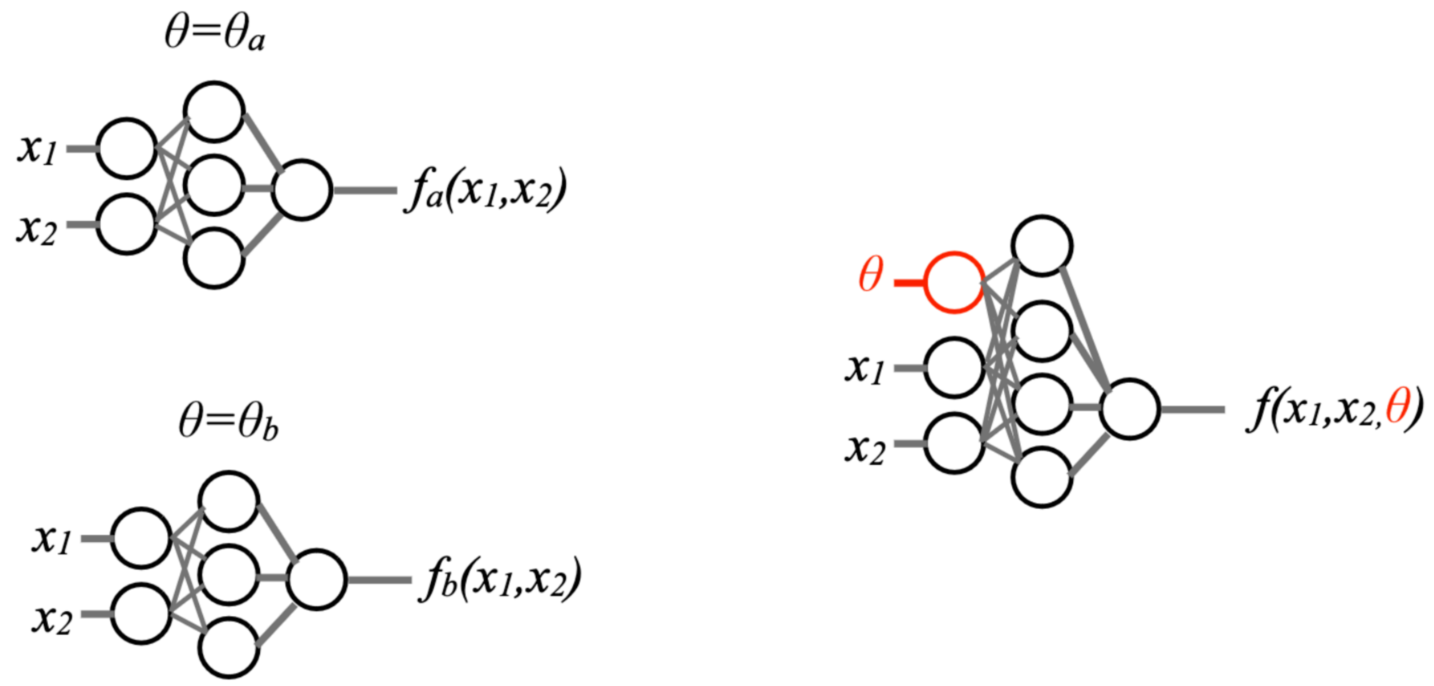
ATLAS EXPERIMENT

SEARCHES - 1

SUPERVISED, CLASSIFICATION S vs B

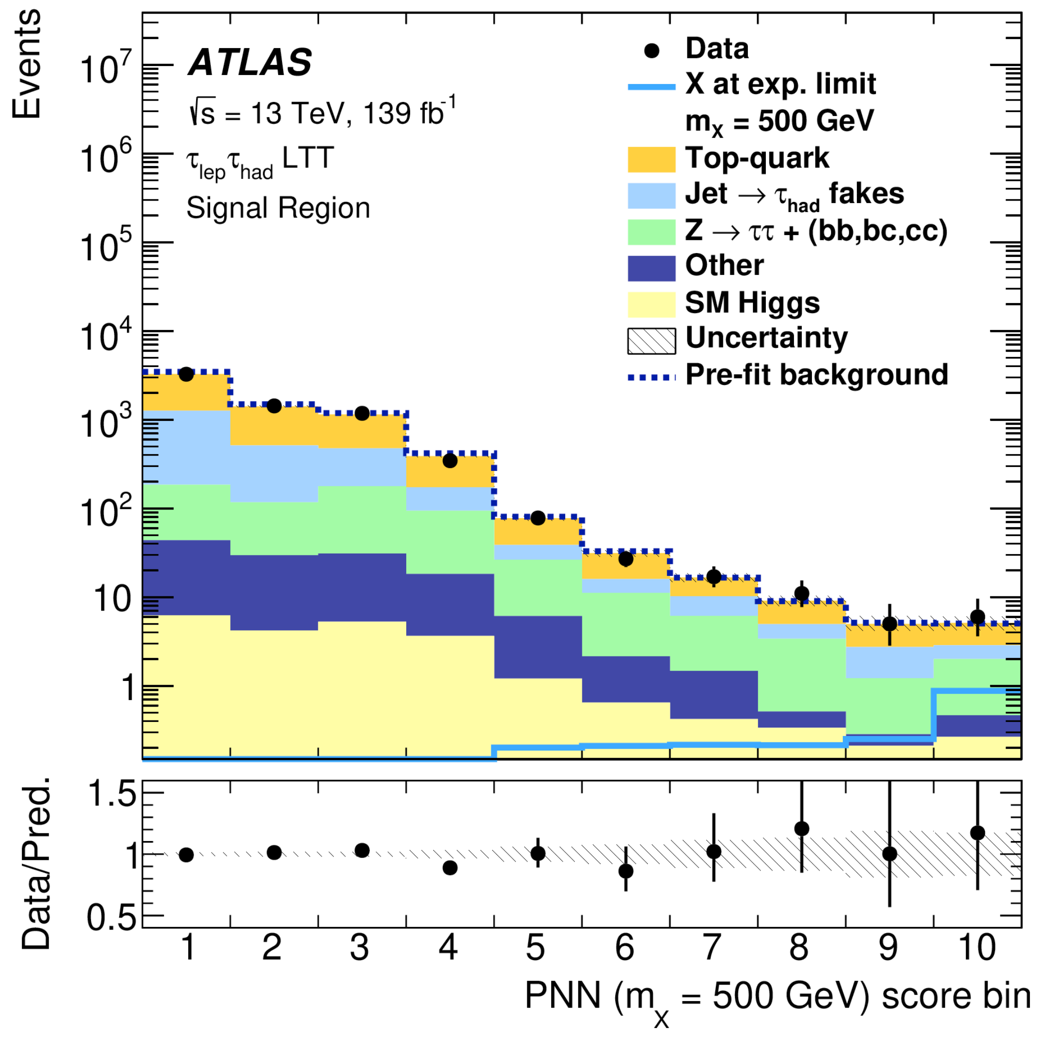
Parameterized DNN/BDT/GNN

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



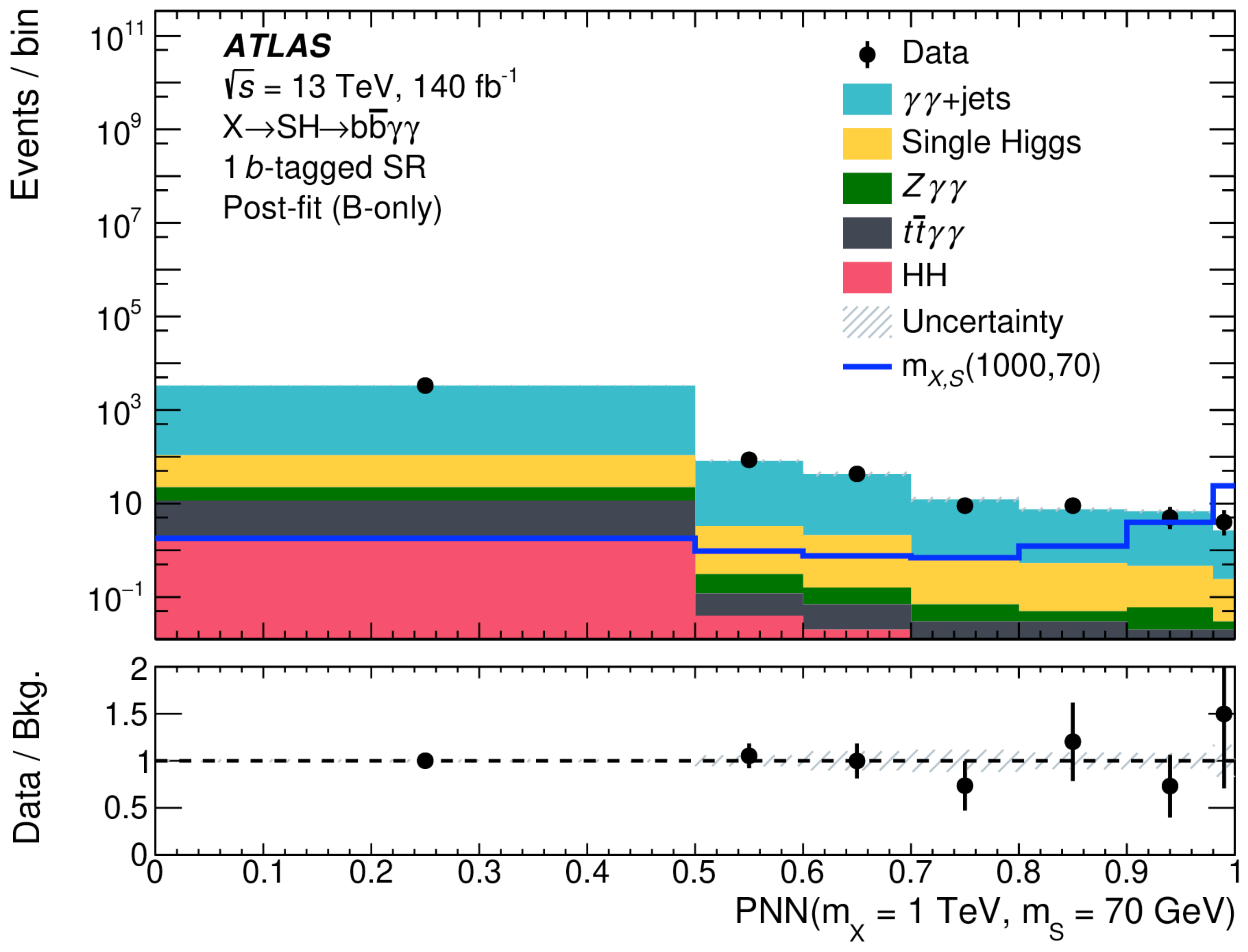
Increase training statistics by adding up multiple models, optimal for large range of parameters

1 par: HH→bb ττ



HDBS-2018-40

2 par: X→SH→bbγγ



HDBS-2021-17

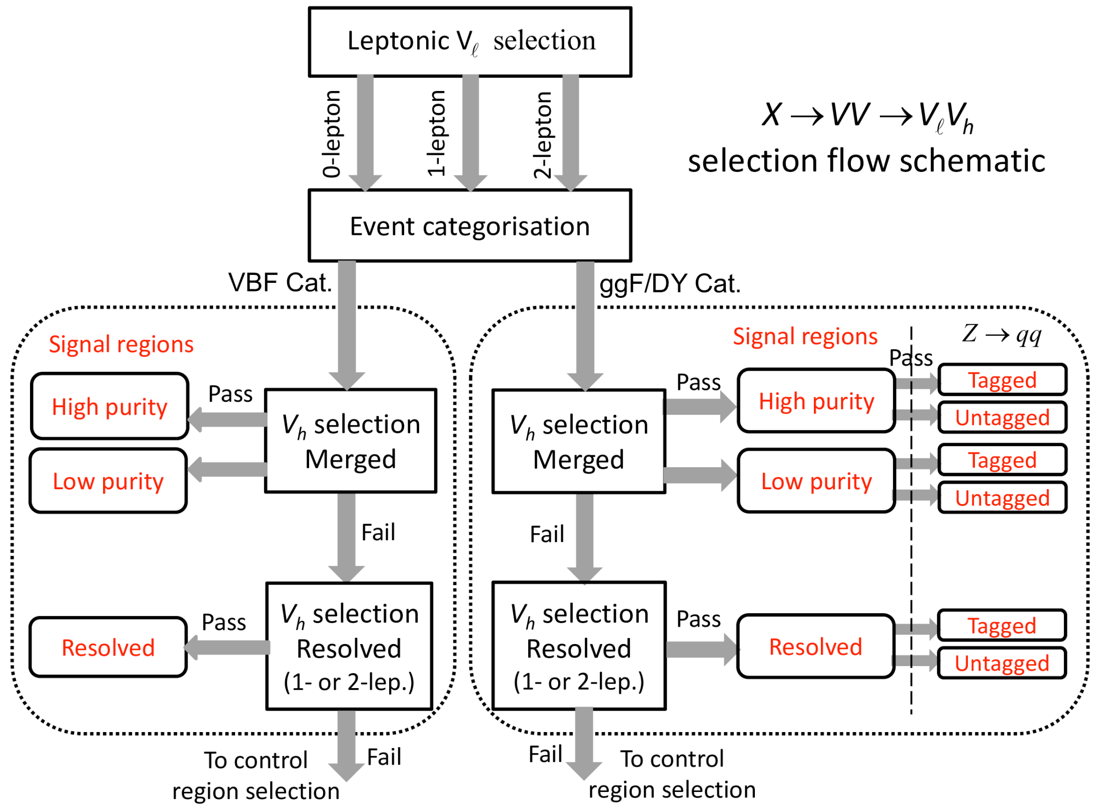
SUPERVISED, CLASSIFICATION S vs S

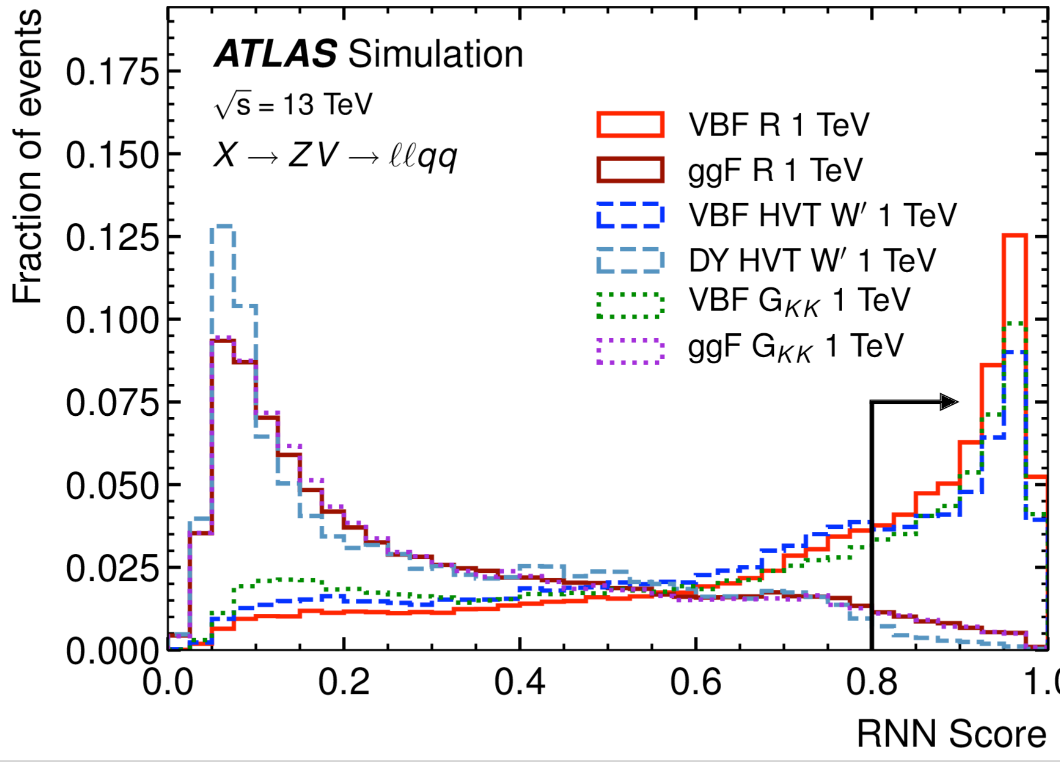
Multi-class classification

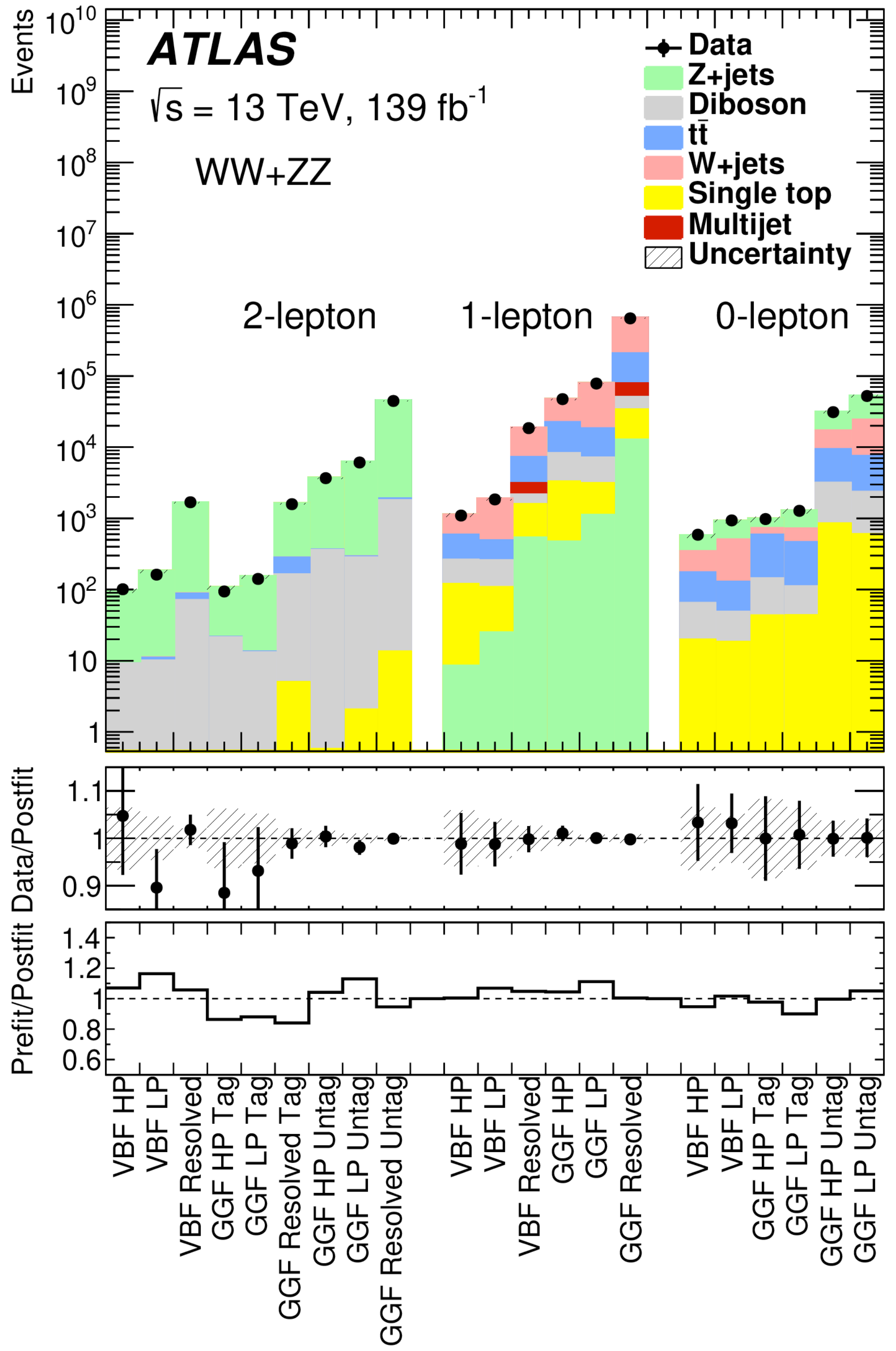
Use ML to optimize purities of signal classes, then optimize background rejection

Exploit different signal topologies in a single search, better signal class purity

X→ZV→llqq, VBF vs ggF/DY







HDBS-2018-10

SEARCHES - 2

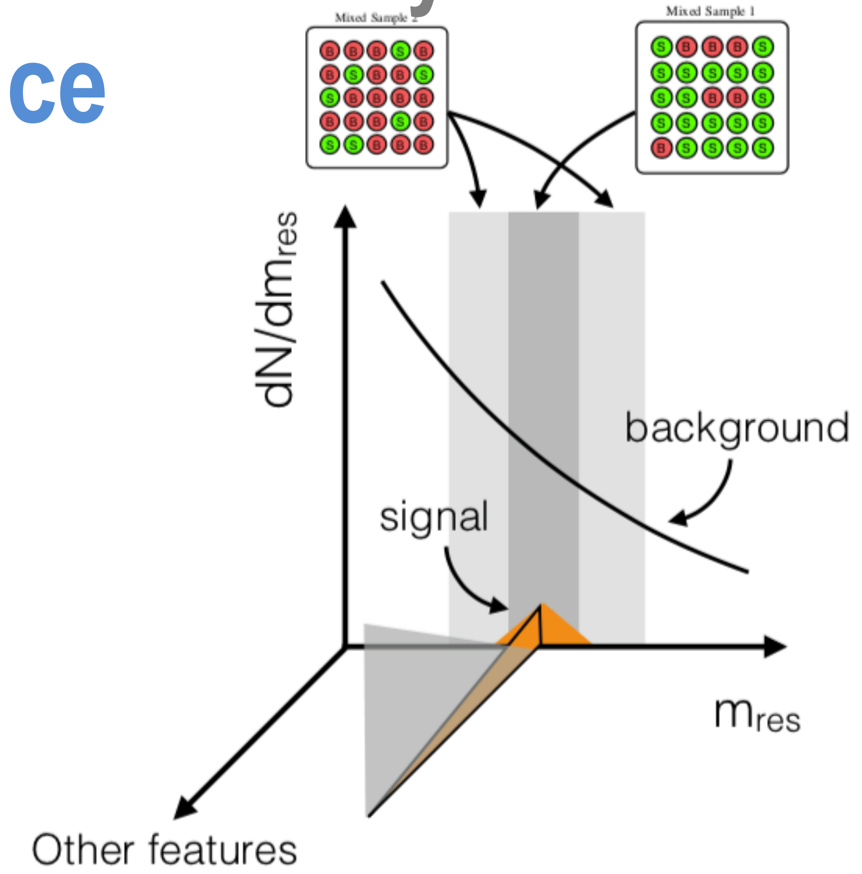
WEAKLY-SUPERVISED, CLASSIFICATION S vs B

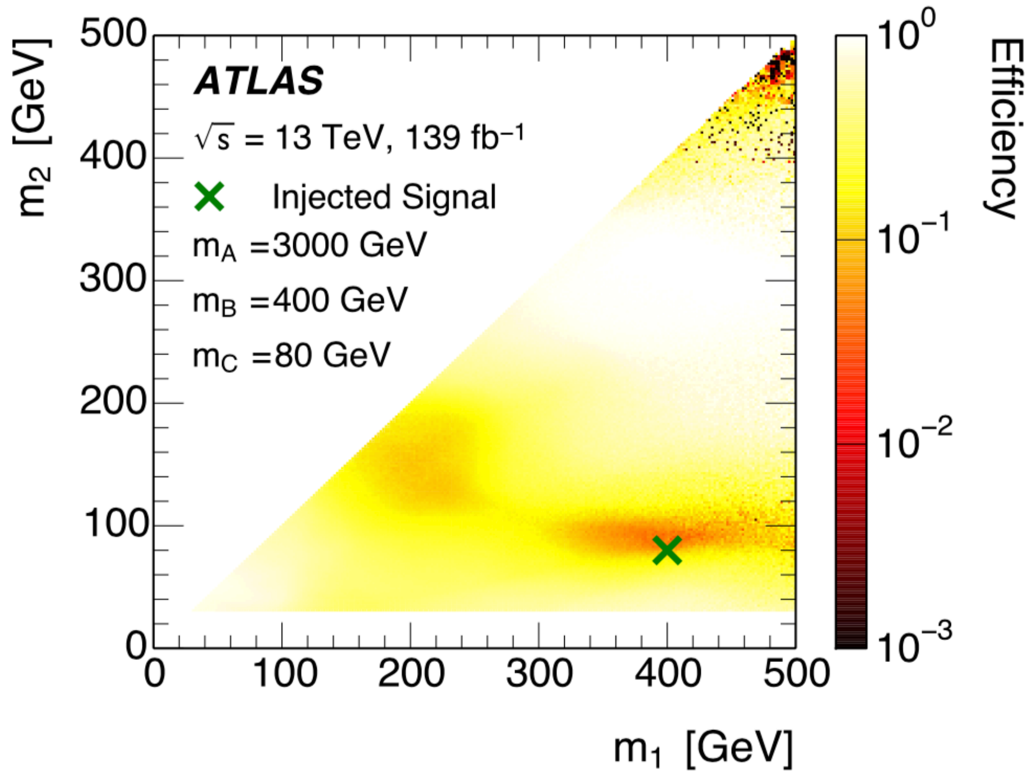
Classification without labels (CWoLA)

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 →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





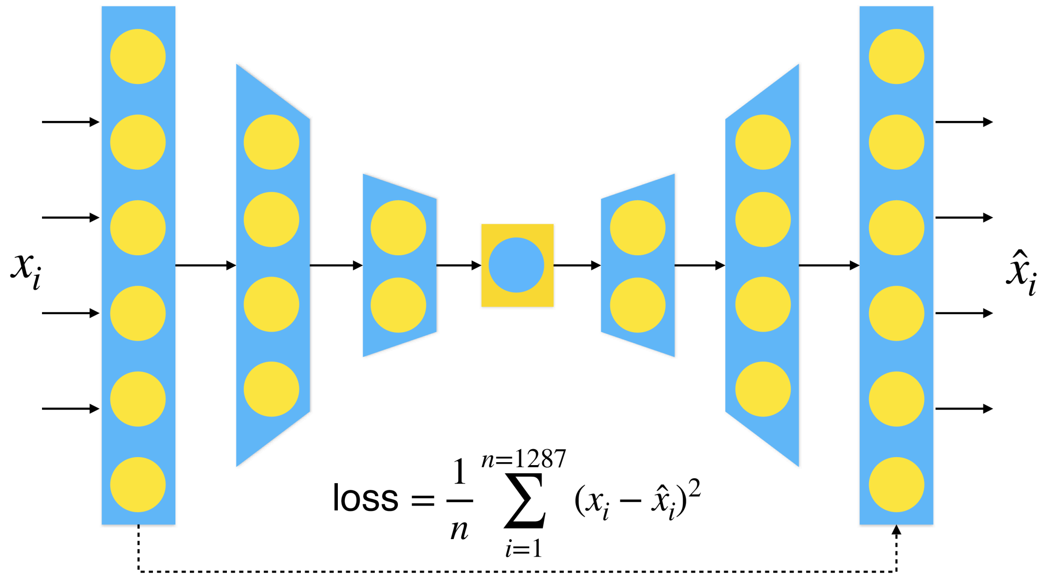
HDBS-2018-59

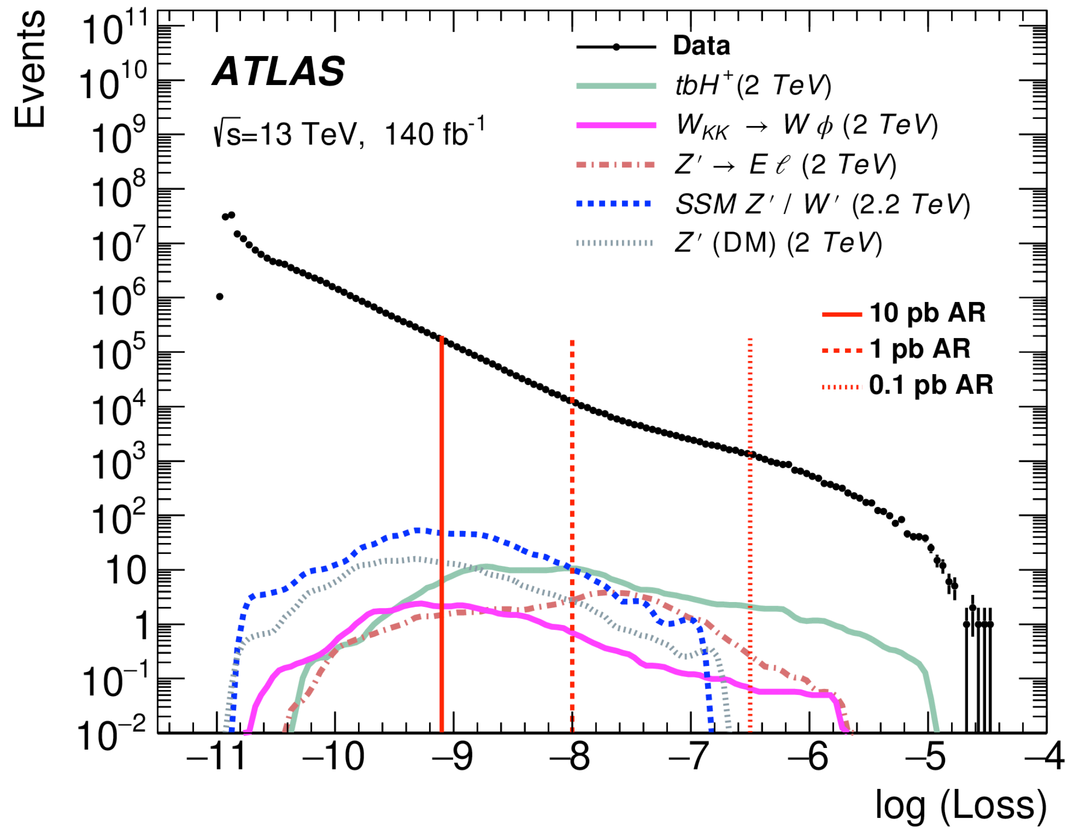
UNSUPERVISED, ANOMALY DETECTION

Model agnostic search

X →j Y, 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)

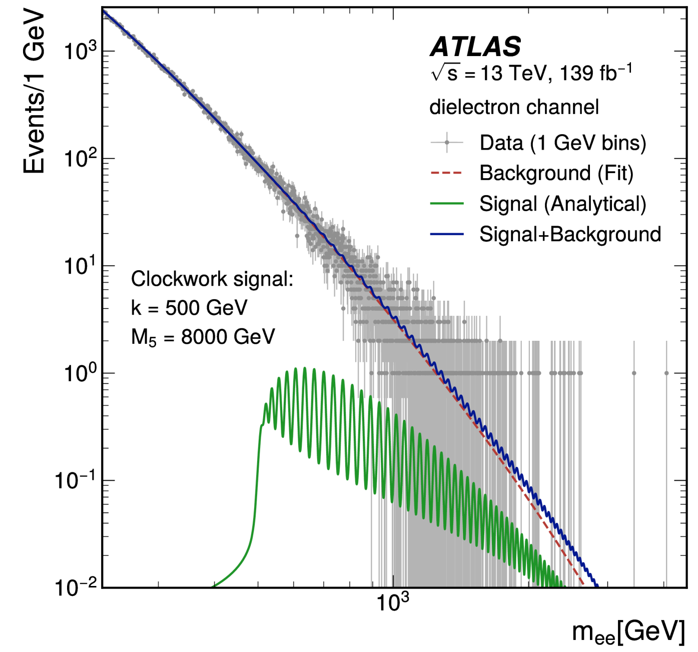


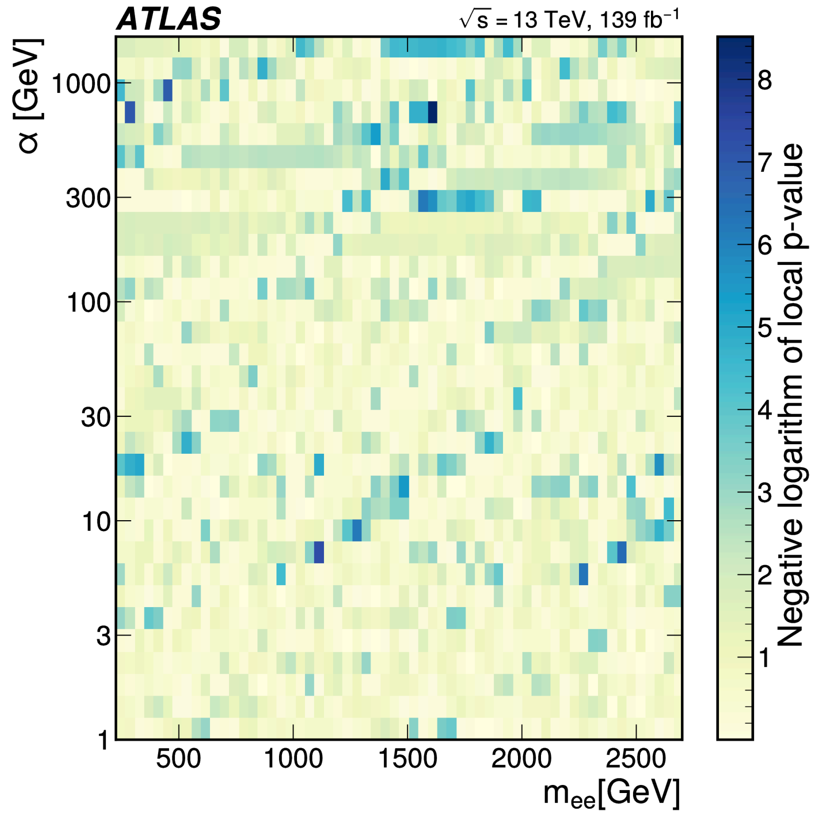


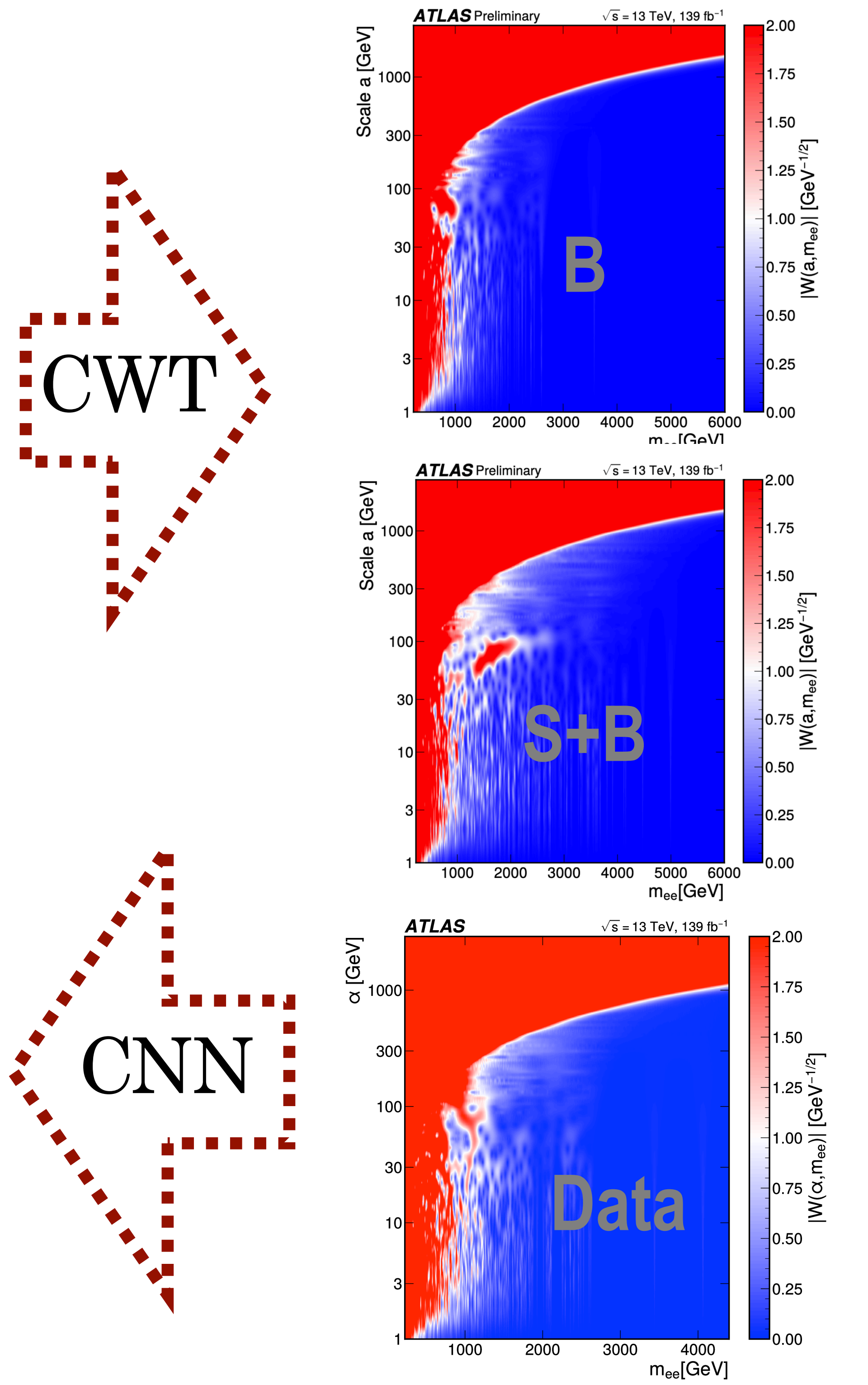
EXOT-2022-07

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

- Signature: periodic signal, wavelet of m_ee, m_γγ
- 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

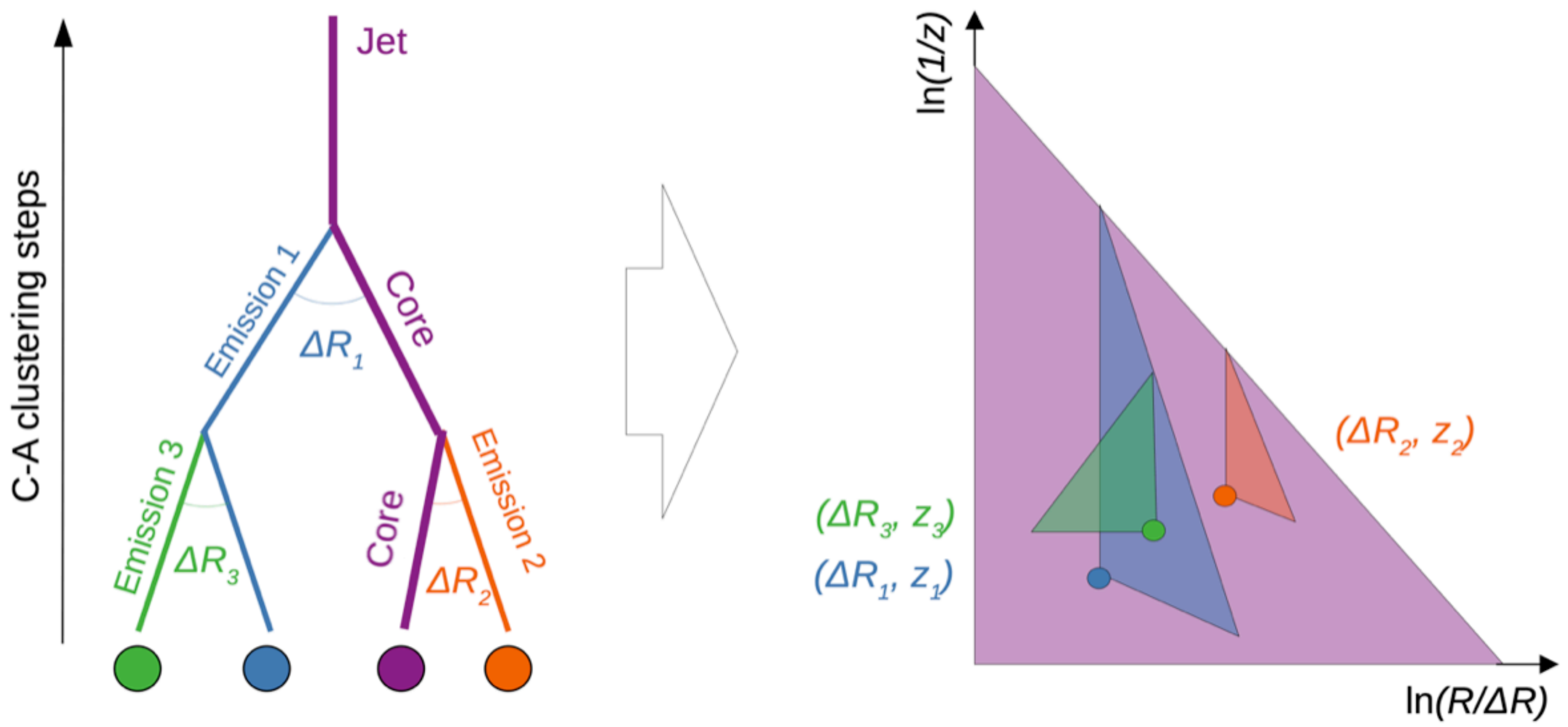
EXOT-2019-40

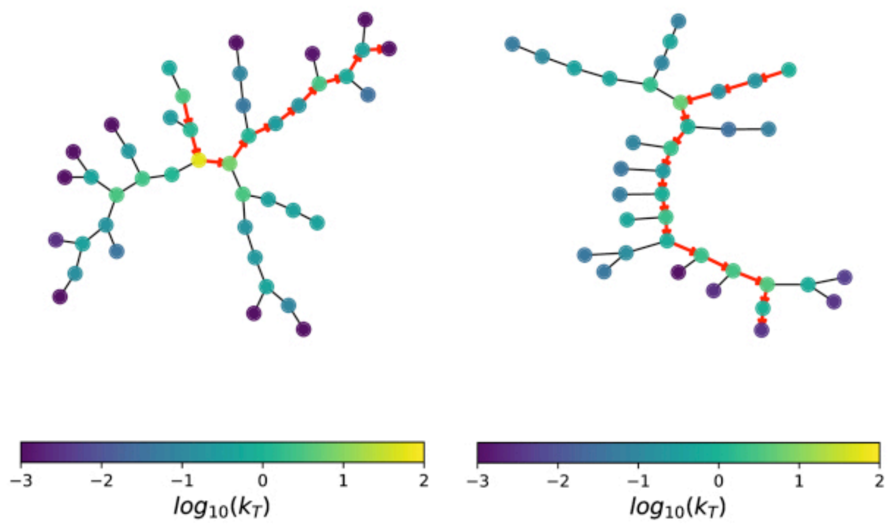
OBJECTS

BOOSTED W-BOSON TAGGING

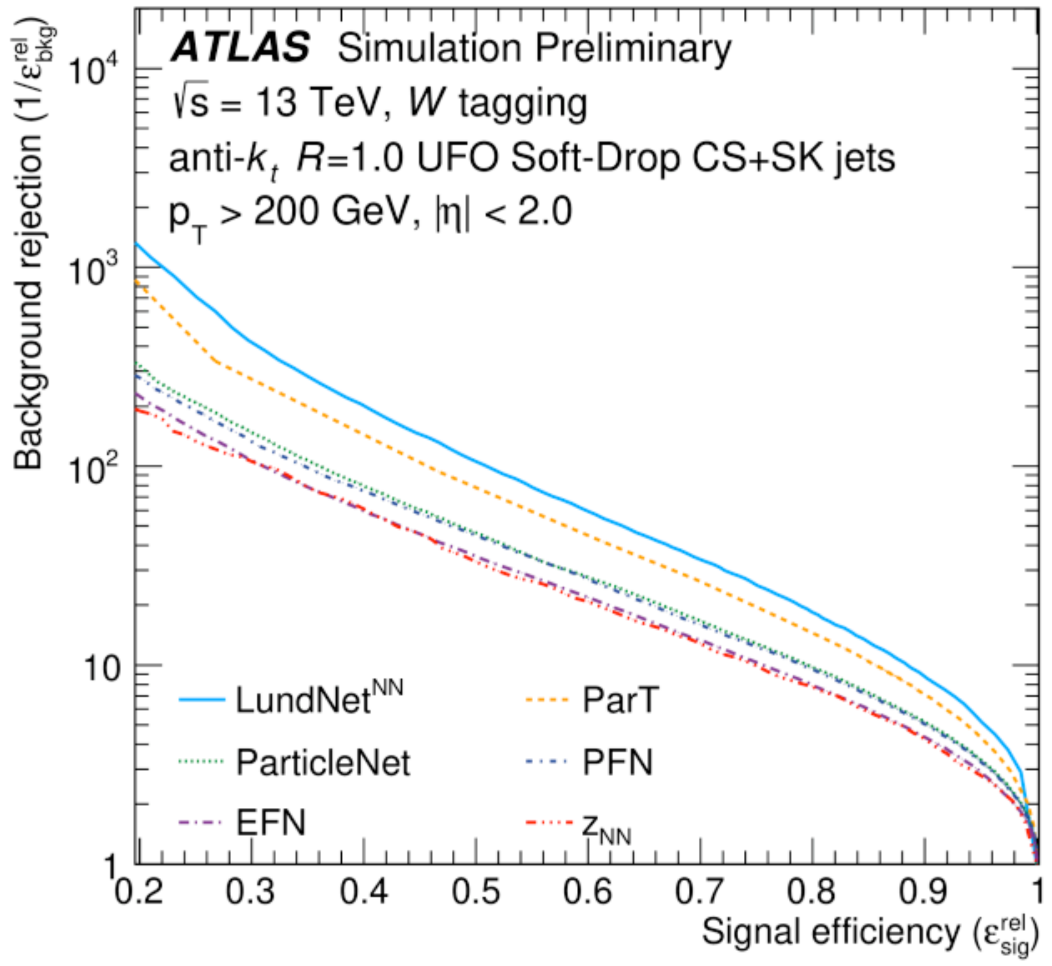
Lund Plane tagger

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





W jet QCD jet

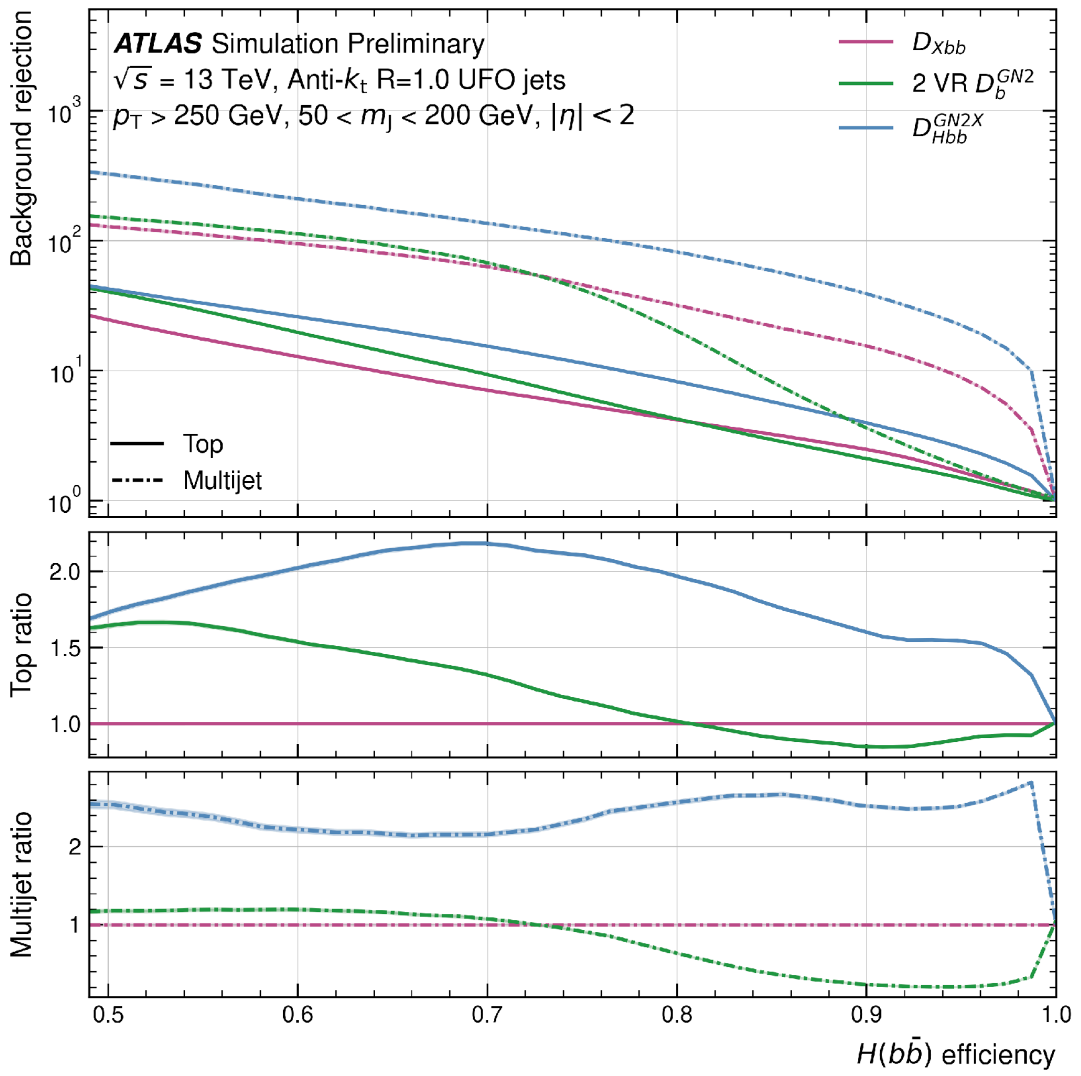


ATL-PHYS-PUB-2023-017

H TAGGING

H⟶bb tagger

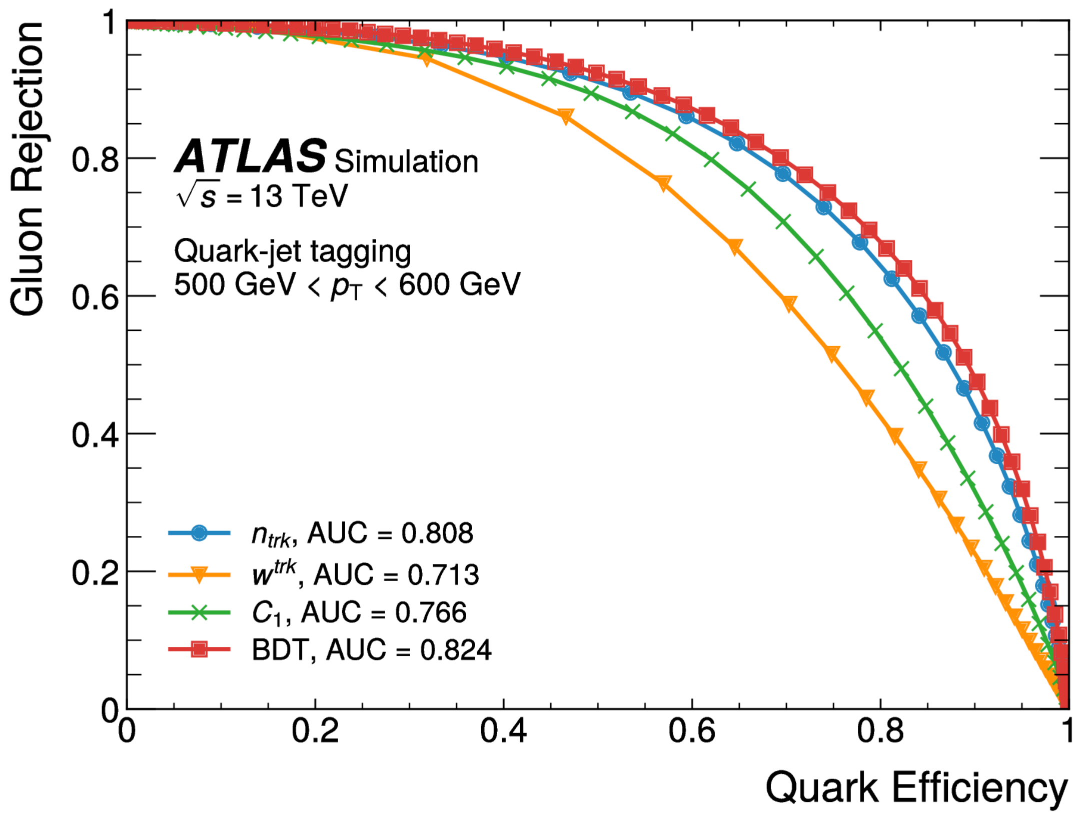
New boosted hadronically decaying Higgs tagger using low level information to identify two b/c-quarks outperforms previous high-level information taggers



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

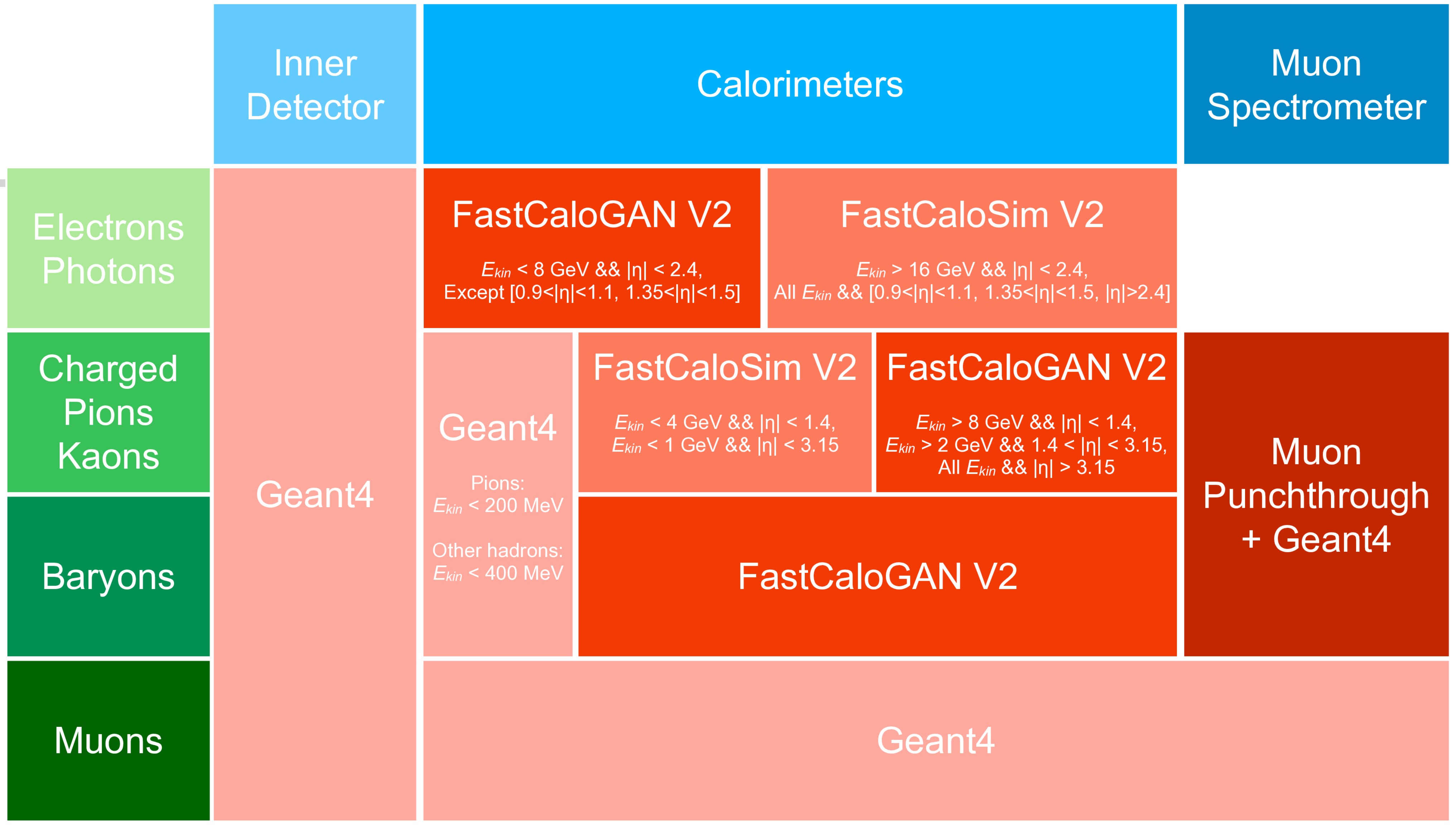
SIMULATION

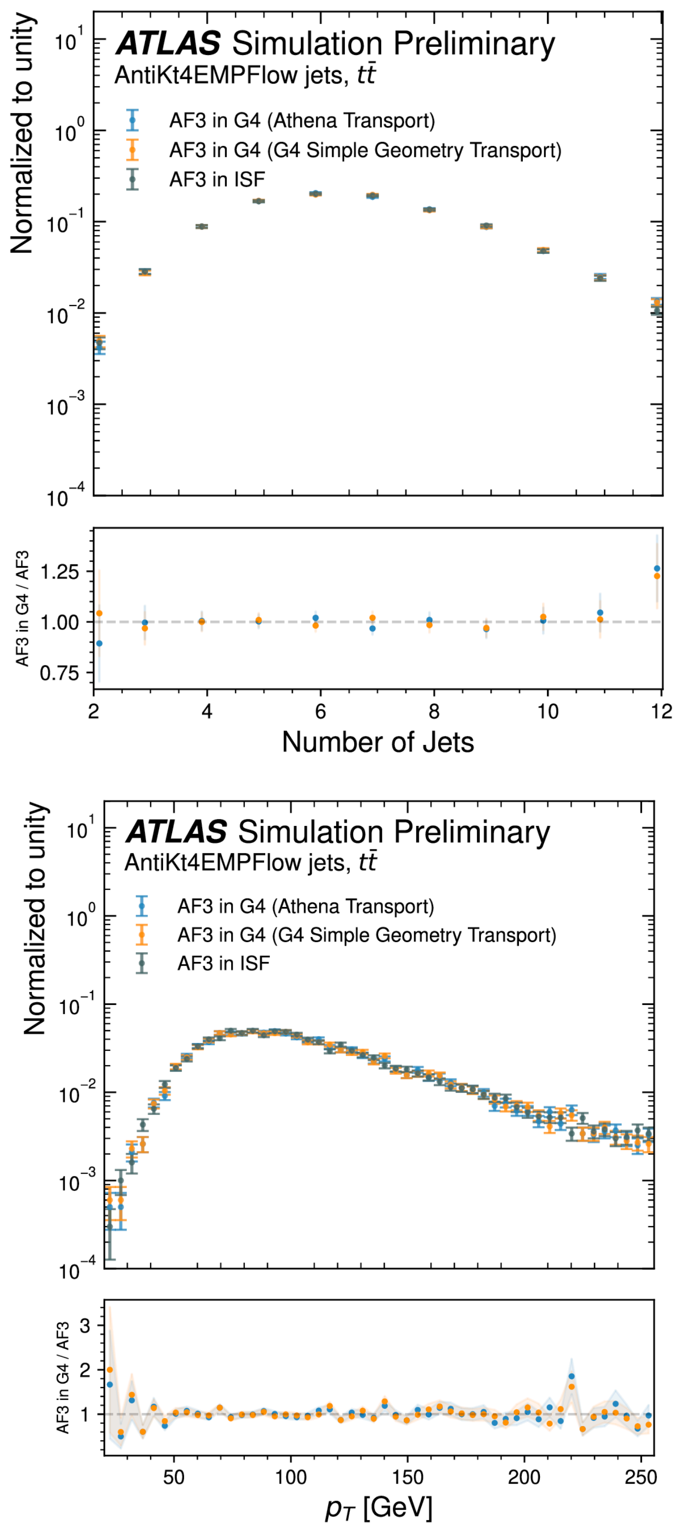
FAST SIMULATION
AtlFast3

Fast simulation tool for Run3 that balances modeling 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 |η| spaced bins)
- Separate parameterisation in longitudinal and lateral shower development
- Energy decorrelation in layers using PCA
- Average lateral energy distribution parameterized as 2D probability functions

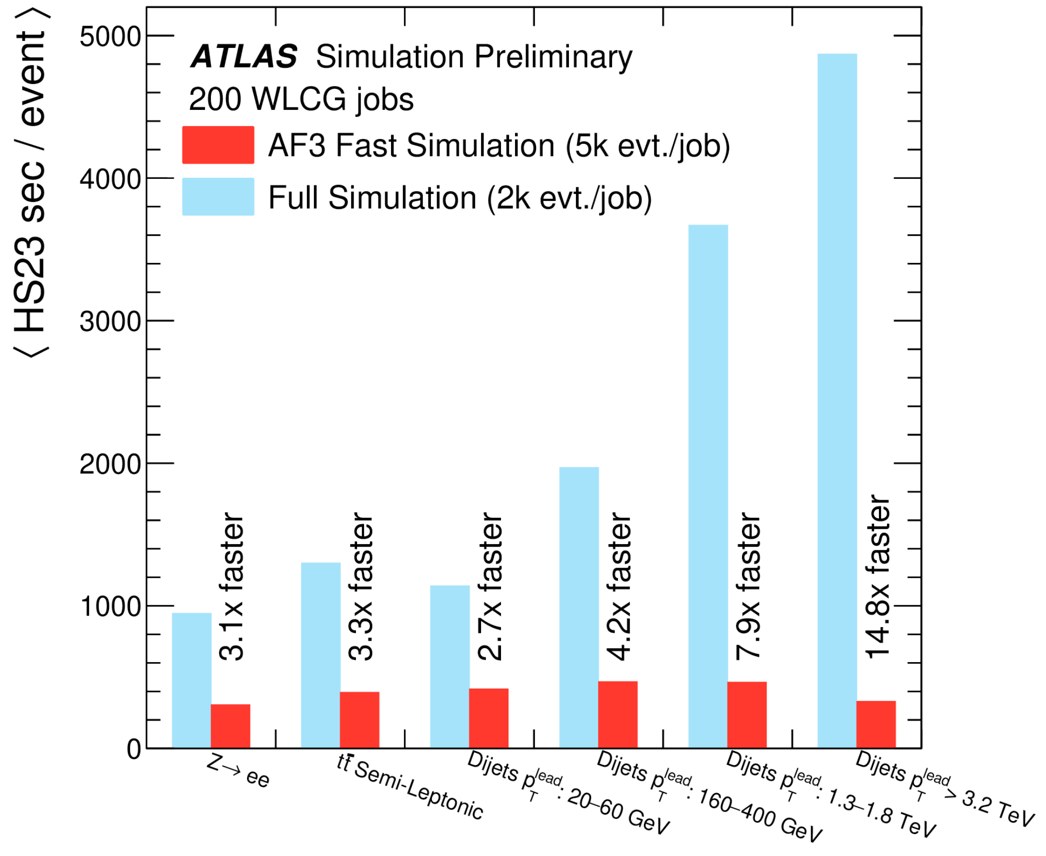
FastCaloGAN
- Parameterizes interactions of particles using 300 GAN, for each particle type and |η| slice, factorizes the shower parametrization into longitudinal and lateral energy distributions for different energy points with interpolation between them
- Using Wasserstein GANs trained on each of 100 bins in |η| 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