Hidden new physics signals at the Large Hadron Collider

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10th IDPASC School

6th of September 2021

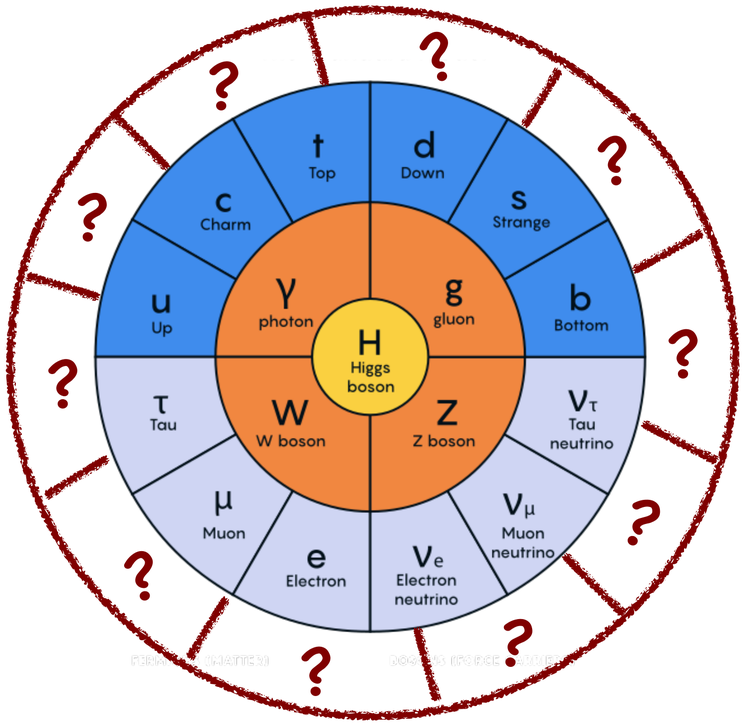
Supervisors: Filipe Joaquim and Juan Aguilar-Saavedra

Motivation

The **Standard Model** (SM) is currently the theory that better describes our Universe at its most fundamental level;

So far, data collected at the Large Hadron Collider (LHC) has not provided significant evidence for physics beyond the Standard Model (SM). **However...**

Results from non-accelerator experiments provide irrefutable evidence for the existence of new physics.



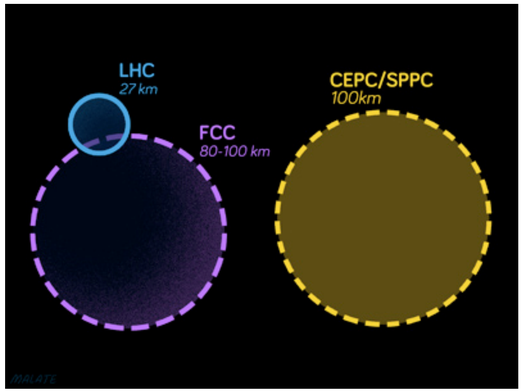
Searches for new physics at the LHC are of utmost importance!

Motivation

There are **two** possible explanations for the lack of new physics signals at the LHC:

- The new physics energy scale is higher than the 13-14 TeV LHC centre-of-mass energy;

  → Future colliders are required.



- New physics signatures are more elusive than previously thought and current searching strategies may have missed them.

This possibility requires more investigation!

Goals of this PhD project

- Put forward new physics signals that LHC searches may be missing and contextualise them within the framework of well-motivated models;

- Develop new tools based on machine learning techniques for identification of non-conventional experimental signatures at the LHC;

- Analyse LHC's run-3 data using the previously developed tools and interpret it in the context of the models identified in the first point.

OUR MOST RECENT WORK

J. A. Aguilar-Saavedra, F. R. Joaquim and J. F. Seabra, JHEP **03**, 012 (2021) [arxiv:2008.12792[hep-ph]]

Mass Unspecific Supervised Tagging (MUST) for boosted jets

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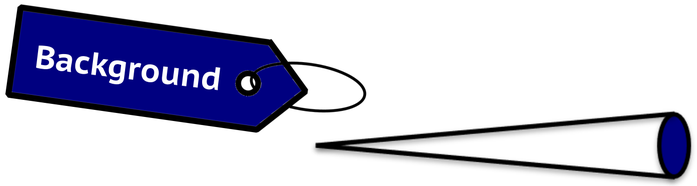
What is MUST?

A new strategy for training jet taggers based on multivariate methods, where the mass and transverse momentum of jets are input variables, together with jet substructure observables, varying over wide ranges.

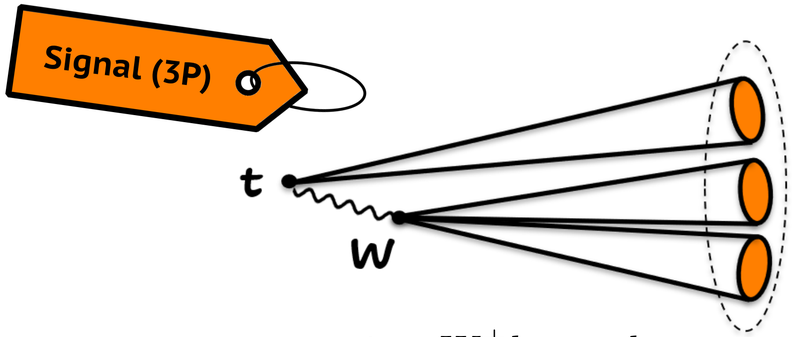
Why is jet tagging so important?

After quantifying the mass of jets, one can get invaluable insights into collision events by inferring the number of quarks and gluons clustered inside them (**prongs**).

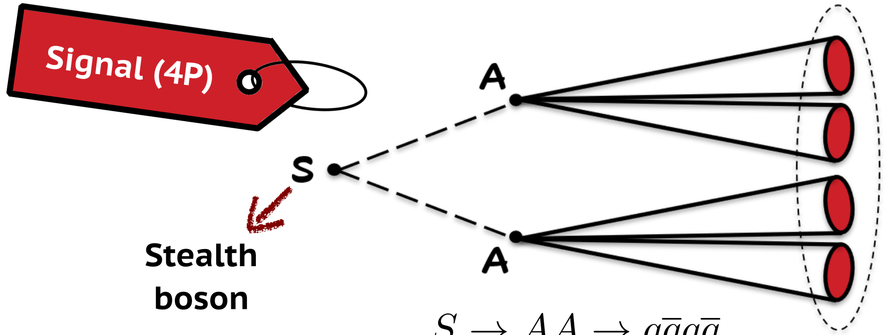


QCD jets

$W/Z/H \to q\bar{q}$



$t \to W^+ b \to q\bar{q}b$



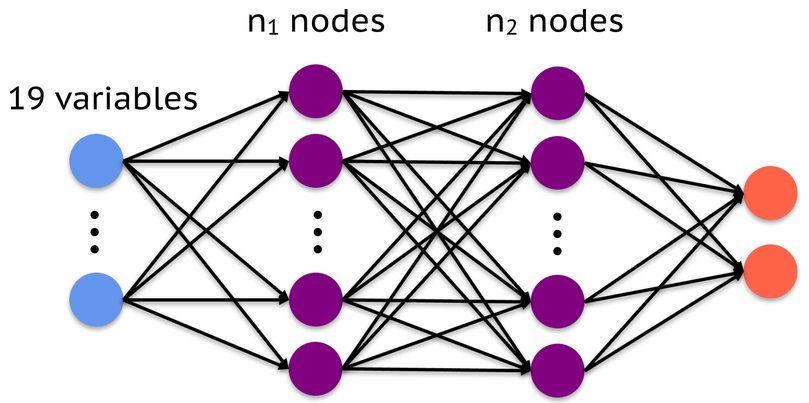
$S \to AA \to q\bar{q}q\bar{q}$

(A possible new physics signal)

Jet tagging tools are crucial in new physics searches to distinguish QCD jets (Background) from those produced in collimated decays of heavy particles (Signal).

BUILDING MUST-TAGGERS

•Given training data with QCD jets and multi-pronged ones, we develop five taggers based on simple neural networks, with just two hidden layers;



•The 19 input variables are the mass and transverse momentum of a jet, as well as 17 N-subjettiness observables,

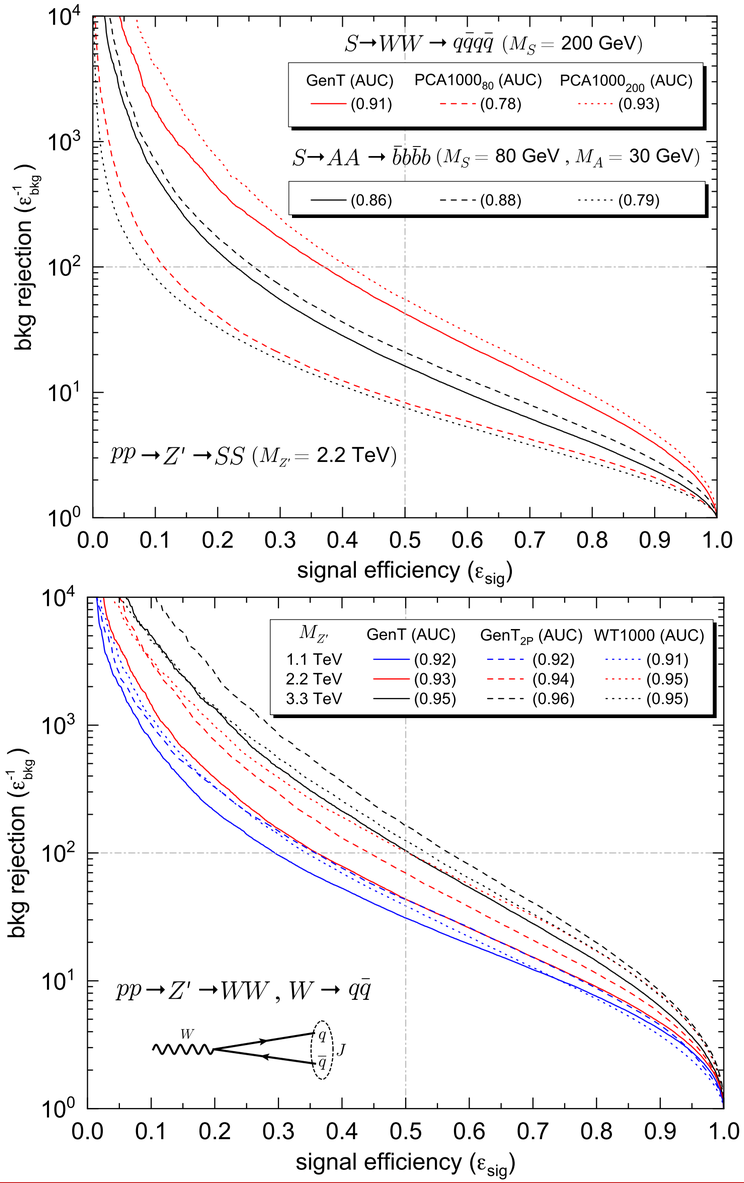
$$\left\{\tau_1^{1/2}, \tau_1^1, \tau_1^2, \cdots, \tau_5^{1/2}, \tau_5^1, \tau_5^2, \tau_6^1, \tau_6^2\right\},$$

which characterise jet substructure.

Tagger	Events used in training	n_1	n_2	Output layer
GenT	Background + 2P + 3P + 4P	2048	128	Sigmoid
GenT_{2P}	Background + 2P	1024	64	Sigmoid
GenT_{3P}	Background + 3P	1024	64	Sigmoid
GenT_{4P}	Background + 4P	1024	64	Sigmoid
Prongness selection tagger	2P + 3P + 4P	2048	128	Softmax

What can we achieve with MUST?

- **Generic taggers** with great performance over **wide ranges of jet mass and transverse momentum**;



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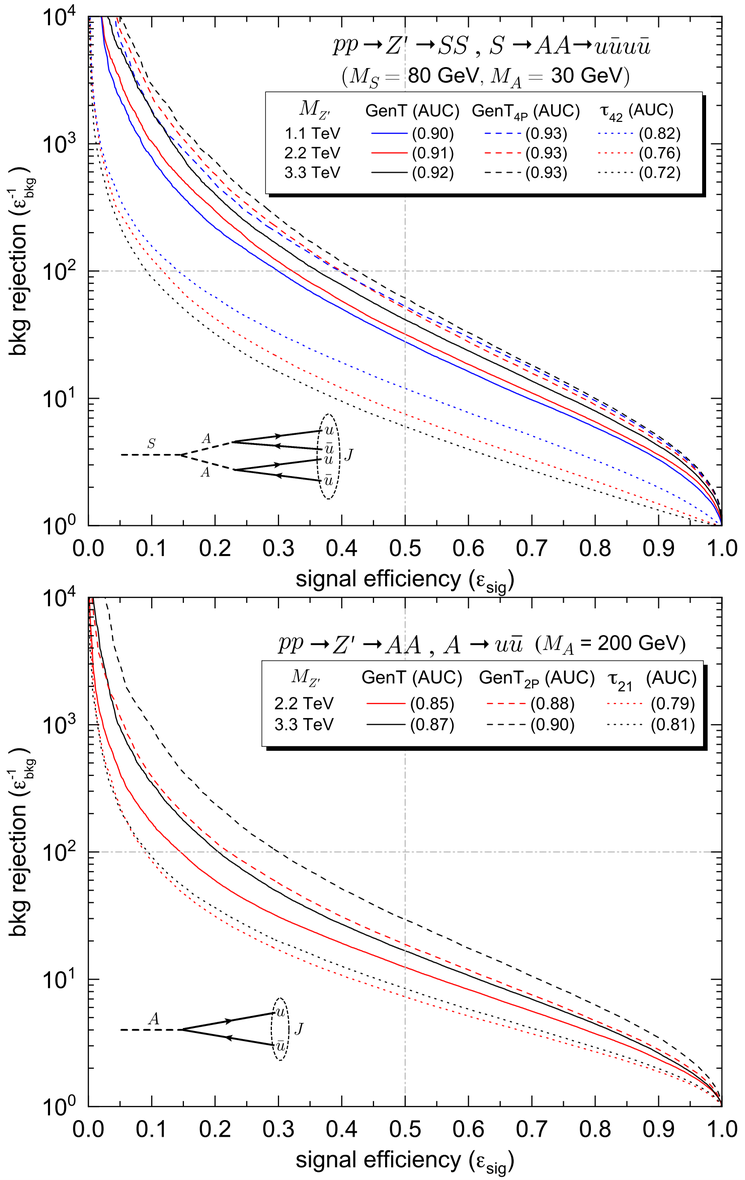
- Better performance than variables commonly used in experiments;



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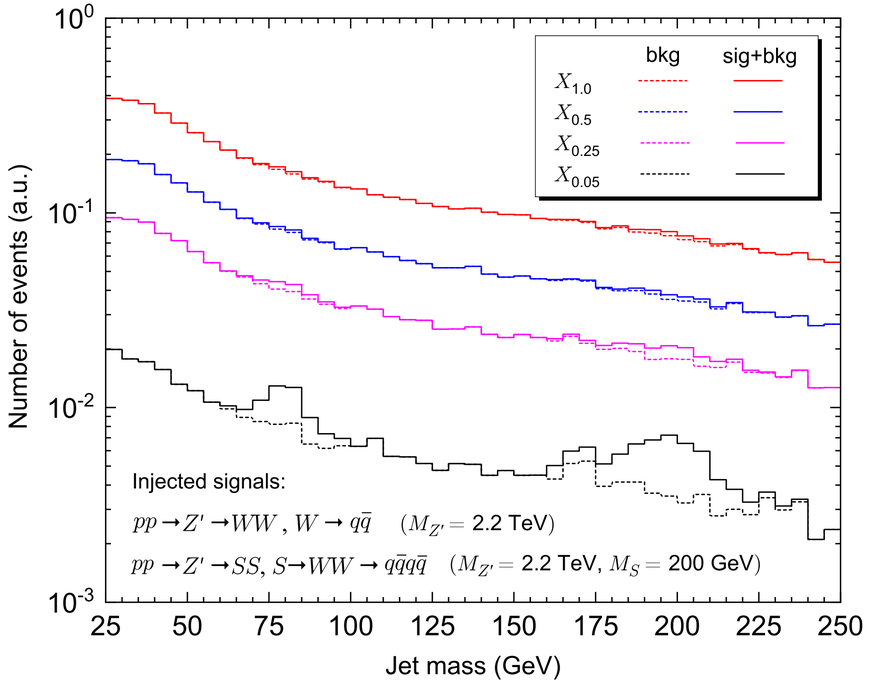
- **Mass decorrelation**;



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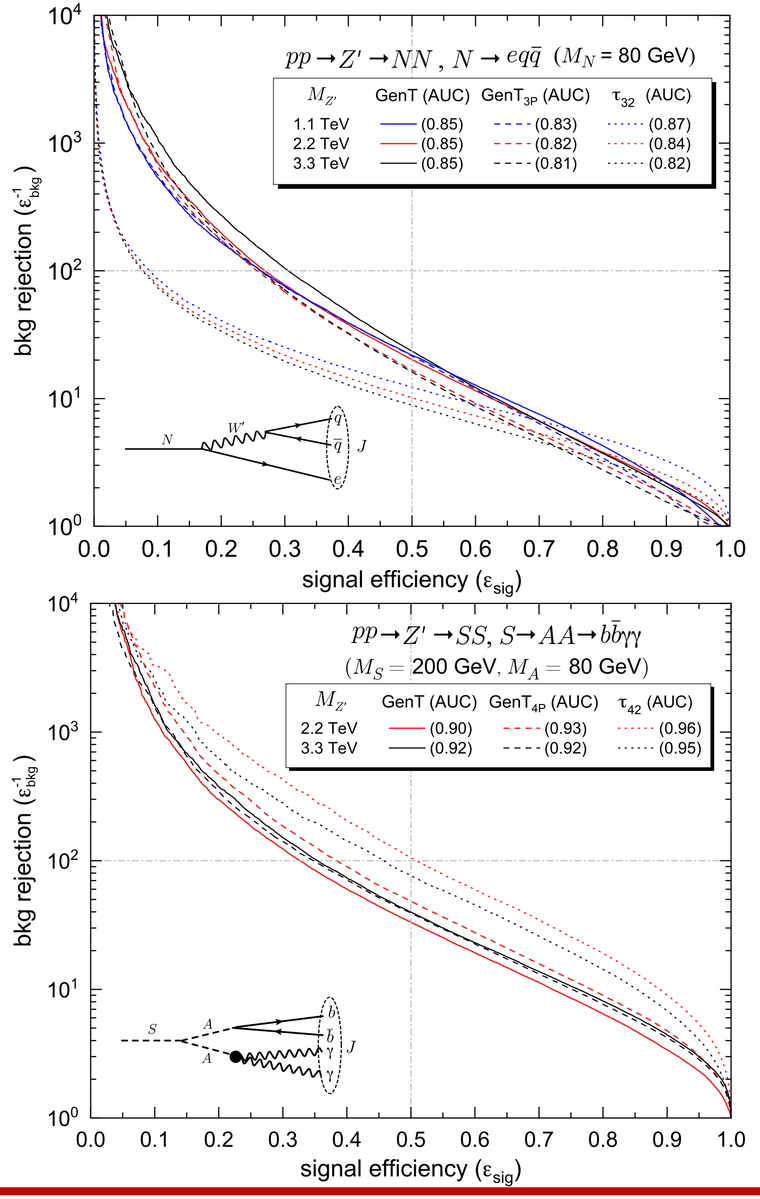
- **Mass decorrelation**;

- Good efficiency on **signals not used in training**;



What can we achieve with MUST?

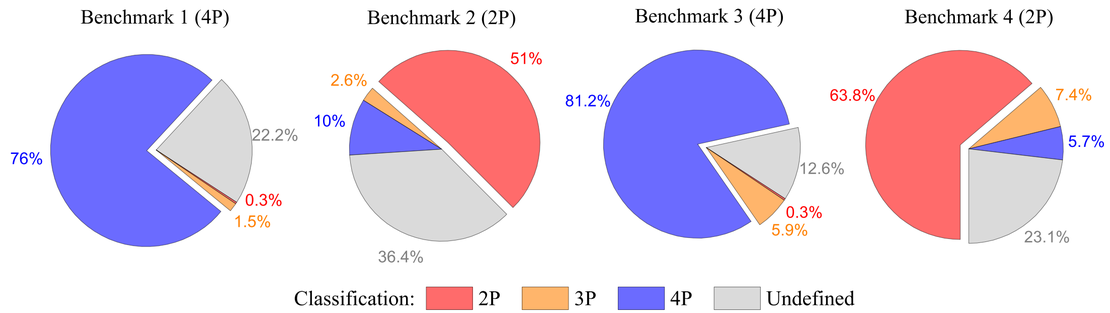
- **Generic taggers** with great performance over **wide ranges of jet mass and transverse momentum**;

- Better performance than variables commonly used in experiments;

- **Mass decorrelation**;

- Good efficiency on **signals not used in training**;

- Discrimination of different kinds of signal events.



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