## Boosted $H \rightarrow b + \bar{b}$ tagging

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## Identify boosted X ightarrow $b+ar{b}$

- $\bullet$  Higgs boson in Standard Model has a mass of 125 GeV/c^2 and a mean life time of about  $1.6 \times 10^{-22}~s$
- *H* decaying to  $b\bar{b}$  has the largest branching factor in the Standard Model
- Identify large-R jets containing pairs of b hadrons

$H \rightarrow$	bĐ	WW	au au	ZZ	$\gamma\gamma$	$\mu\mu$
Branch Ratio(%)	58	21	6.3	2.6	0.23	0.022

Table: Standard Model Higgs decay mode



Figure: Boosted  $H \rightarrow b + \bar{b}$ 

$$\Delta R^2 = \Delta y^2 + \Delta \phi^2 = 1$$

Based on the unique features of b-jets

- Hadrons containing *b* quarks have long lifetime and decay inside the detector
- The *b* quark is much more massive than anything it decays into, its decay products tend to have higher transverse momentum



Figure: Identification of jets initiated by b-hadron decays

### X<sub>bb</sub> tagging using Deep Neural Network

- Select Higgs vs. QCD or Top boosted jet
  - $\bullet\,$  QCD and Top boosted jets are two major backgrounds when identifying Higgs to  $b\bar{b}$
- Take the *b* tagging information and kinematics of each event as optional inputs
- Three outputs corresponding to probabilities of Higgs QCD Top



Figure: Deep Neural Network

### Mass de-correlated X<sub>bb</sub> tagger

- There are two main issues when developing this tagger
  - Issue 1: Some taggers tend to reshape the large-R jet mass distribution of background into the distribution of signal
  - Issue 2: The classification power is hard to improve in the meantime
- This figure shows the shape of QCD large-R jet mass distribution before and after tagging to demonstrate the first issue



Figure: Large-R jet mass distributions

#### How to solve these problems

- Issue 1: Select the variables which do not correlate to jet mass as inputs
- Issue 2: Try different network architecture to improve the classification power
- More detail involved like reweighting strategy optimization, hyperparameter optimization...



Figure: One by one check for suitable inputs

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- New tagger developed successfully, denoted as D<sub>Xbb</sub> (left)
- This figure shows the shape of large-R jet mass distribution(normalized) before and after tagging



Figure: Higgs and multijet mass distributions before and after  $D_{Xbb}$ 



Figure: Higgs and multijet mass distributions before and after *DL1r* 

- New tagger developed successfully, denoted as D<sub>Xbb</sub>
- These two figures show the discriminant distribution, for the double b-tagging algorithm D<sub>Xbb</sub> (left) and DL1r benchmark (right)



Figure:  $D_{Xbb}$  discriminant distribution



Figure: DL1r discriminant distribution

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- New tagger developed successfully, denoted as D<sub>Xbb</sub>
- These two figures show the background rejection as a function of signal efficiency, evaluated for either QCD(left) or top(right) backgrounds



Figure: Multijet rejection VS. Higgs Eff

Figure: Top rejection vs. Higgs Eff

- Multijet (left) and top (right) jet rejection as a function of large-R jet pT with a constant 70% Higgs tagging efficiency.
- Error bars correspond to the statistical uncertainty.



Figure: Multijet jet rejection as a function of large-R jet pT



Figure: Top jet rejection as a function of large-R jet pT

## Summary

Boosted  $H 
ightarrow b + ar{b}$  tagging

- One ATLAS public note is sign-off
  - ATL-PHYS-PUB-2020-019
  - The first boosted X $\rightarrow$ bb tagger recommendations in ATLAS
- Mass de-correlated X<sub>bb</sub> tagger with high classification power was developed
- This tagger can be used in future ATLAS analysis associated with boosted Higgs
  - Precise differential measurements of Higgs boson production
  - Searching for Beyond the Standard Model (BSM) scenarios which introduce new heavy resonances which can decay to Higgs bosons
- On going analysis using this tagger
  - $Y \rightarrow X + H \rightarrow q + \bar{q} + b + \bar{b}$  search
  - A dark Higgs boson decaying to two b-quarks

#### Important Talks

#### Boosted $H ightarrow b + ar{b}$ tagging

- Xbb Tagging Meeting
- Flavour Tagging Algorithm Meeting

# Thanks

# Back Up

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- New tagger developed successfully, denoted as D<sub>Xbb</sub>
- This figure shows the shape of large-R jet mass distribution before and after tagging



Figure: Large-R jet mass distributions of Higgs samples compared to top samples before and after  $D_{Xbb}$ 

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- DL1r
- This figure shows the shape of large-R jet mass distribution before and after tagging



Figure: Higgs and multijet mass distributions before and after *DL*1*r* 



Figure: Higgs and multijet mass distributions before and after *DL1r* 

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#### • Optimised $D_{Xbb}$ discriminant computation

$$D_{Xbb} = \frac{pHiggs}{((1-f_{Top})*pQCD+f_{Top}*pTop)}, f_{Top} = 0.25$$

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### Training

• Loss vs. Epochs



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