Tagging b-jets from Higgs decay at the LHC with Interaction Network

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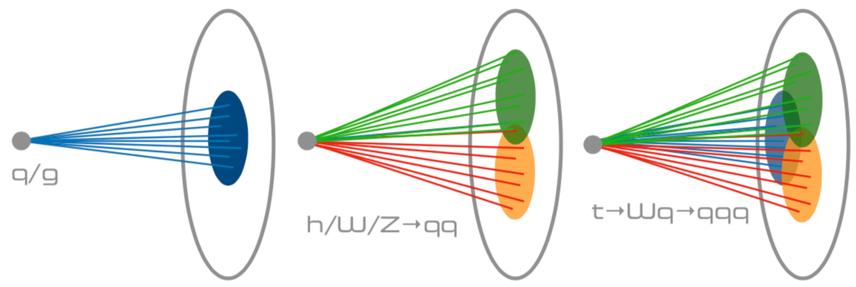
Tagging boosted Higgs decaying into two b quarks

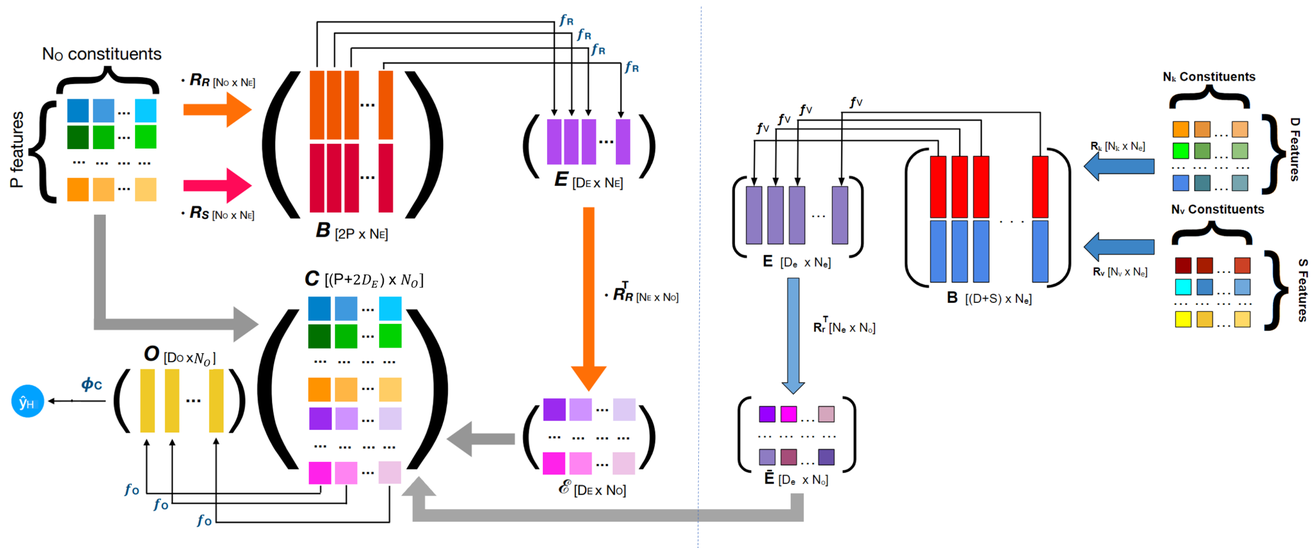


- Higgs boson most probable decay is into a b quark and a b anti-quark.
- Produce b quarks generate a shower of other particles called *jet*.
- When the H is boosted, **the two b-jets merge into a single one.**
- The challenge is to distinguish merged b-jets from single gluon or quark jet, as well as merged jets from top, W and Z decay.
- State-of-the-art approaches uses machine learning applied to expert features or images representation of raw data.
  - Feature-based DeepDoubleX tagger [1]

Our challenge: **Develop a tagger which take as input the measured particles inside a jet and identify merged b-jets from Higgs decay.**

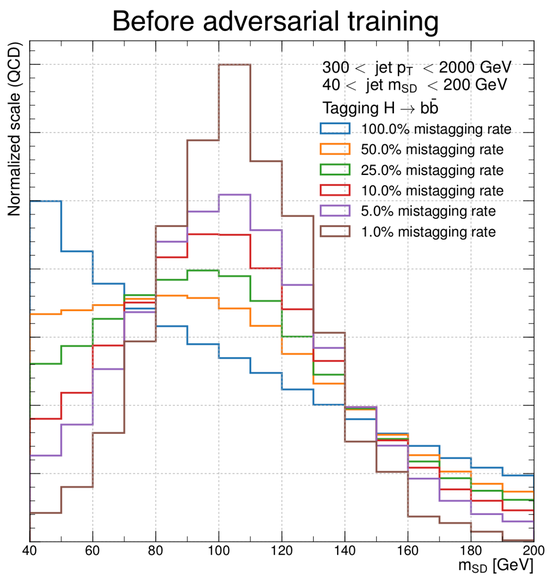
Interaction network for particle-base jet tagger

1. From jet to be classified, two graph a re created:
   a. Fully connected graph with the first 100 particles, ordered in p_T, inside the jet.
   b. Fully connected graph with the first 30 charged particle and first 5 secondary vertices inside the jet.
2. The two graph are fed into two different interaction network [2].
3. Post interaction representation is appended to the input
4. A dense network process the information and return the probability for the jet to contain a H→bb decay.

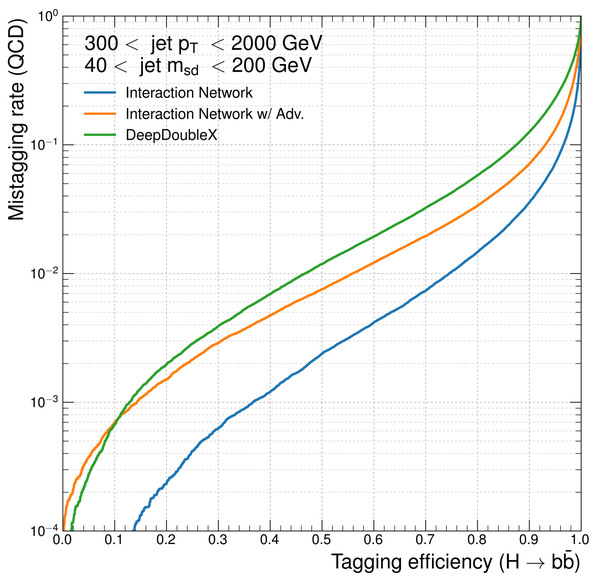


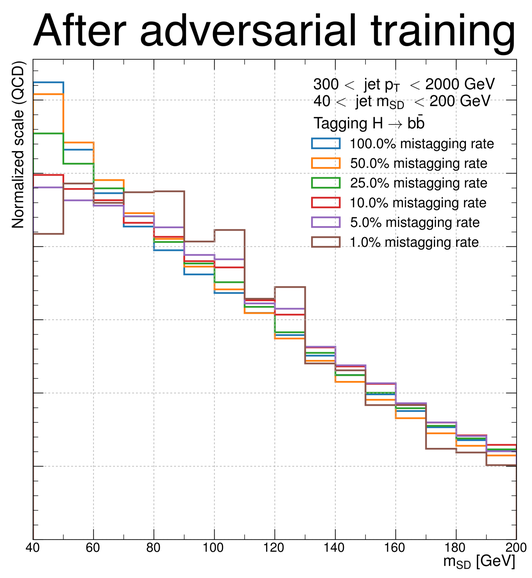
Prevent mass sculpting with adversarial training

- One of the feature learnt by the net during the training is the jet mass
- Artificial mass peak arise in background events which survive the tag selection



Using adversarial training [3], we can stop mass sculpting of the QCD background signal with minimal decrease in performance.

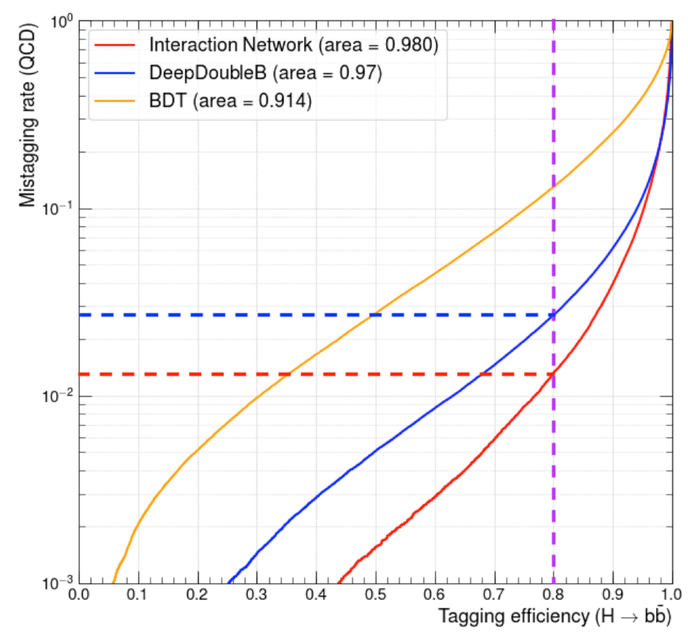


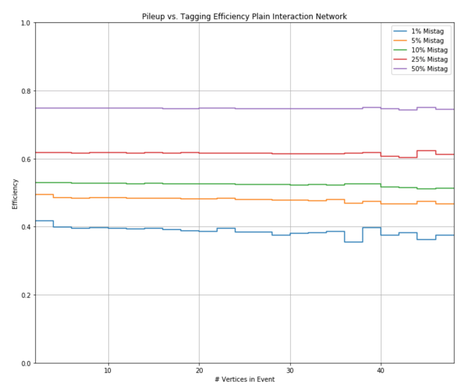


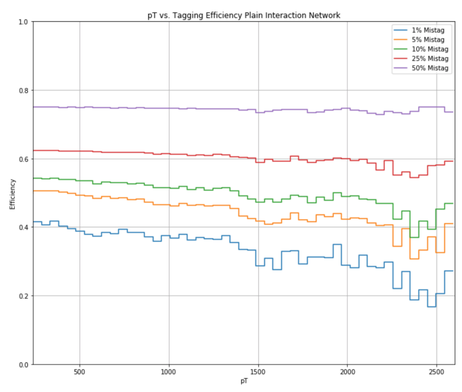
Results

Interaction networks improve H→bb tagging efficiency.

- **Mis-tag rate is reduced by 50%** at a tegging effieicncy of 80%.
- No PU dependence
- Reduced p_T dependence w.t.r. to DeepDoubleX







References

[1] CMS Collaboration, *Performance of Deep Tagging Algorithms for Boosted Double Quark Jet Topology in Proton-Proton Collisions at 13 TeV with the Phase-0 CMS Detector*, Jul, 2018.
[2] P. W. Battaglia et al., *Interaction Networks for Learning about Objects, Relations and Physics*, arXiv:1612.00222.
[3] G.Louppe et al., Learning to Pivot with Adversarial Networks, arXiv 1611.01046

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