Jet-Flavour Tagging at FCC-ee

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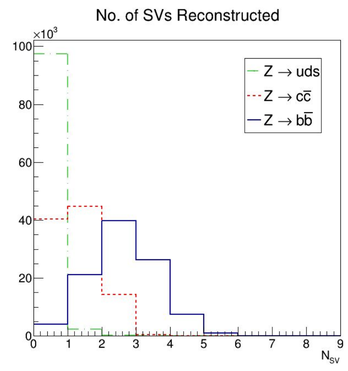
Motivation

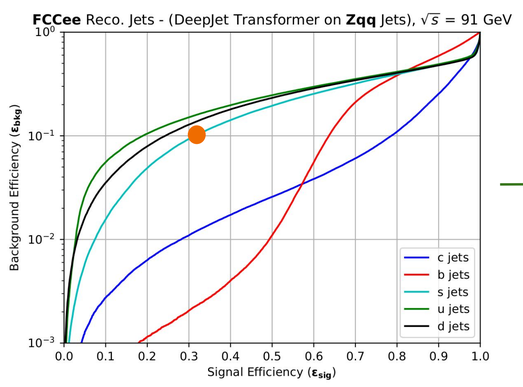
- Jet-flavour tagging is a very important tool for studies with hadronic final states (e.g. Higgs couplings).
- Many well-performing jet-flavour tagging algorithms have been employed at the LHC experiments.
- New analyses techniques (e.g. s-tagging) become possible at the future e+e- collider
- Flavour tagging is a good tool to set detector requirements and to test detector performance.
- Improvement in tagging efficiency and accuracy with the use of advanced ML based algorithms.



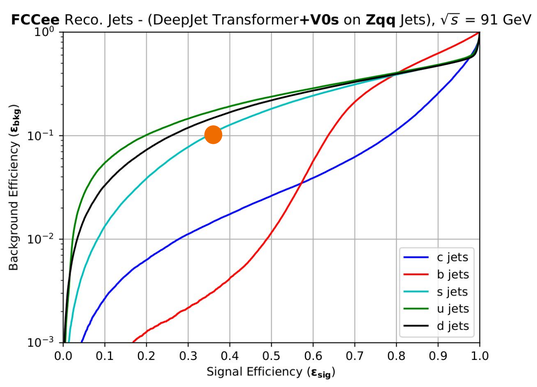
Input Features

Z→qq̄ @ 91.2GeV

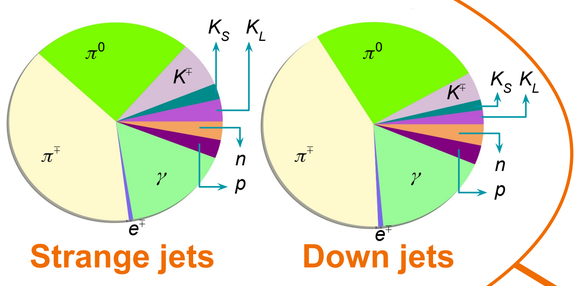
- Jet-level variables
- PF Variables
  - Charged & Neutral
- Secondary vertex variables
  - Relevant for b- & c-tagging
- V^0 variables
  - Relevant for s-tagging

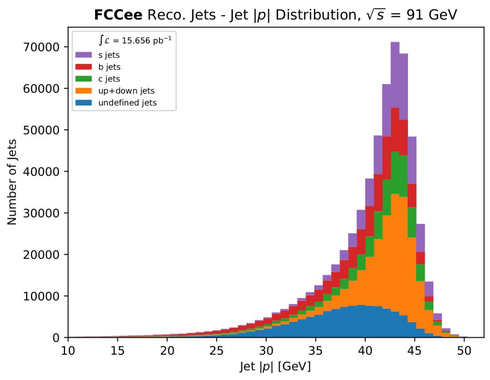


Add V^0



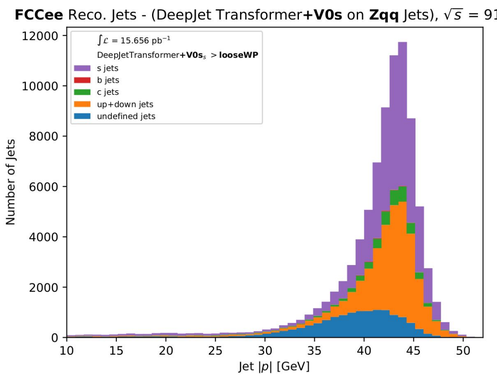
Few percent improvement in s-tagging after adding **V^0s**

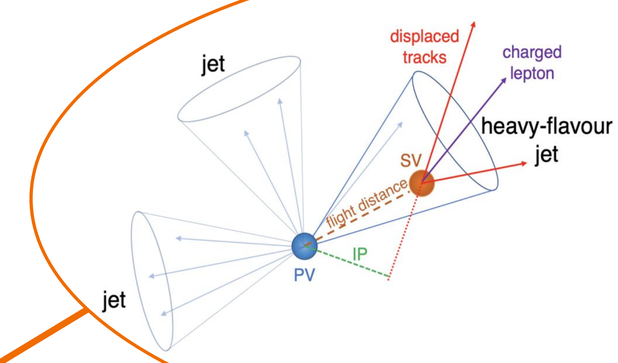




apply s-tagger with 10% background efficiency

ud-jets are the majority of the **background**. **PID** variables are **required** for further improvement





Tagging with Transformer-based Neural Network Architecture[1][2]

Tagging with Graph Neural Network Architecture[3]

Jet-flavour Tagging at Future e^+e^- colliders

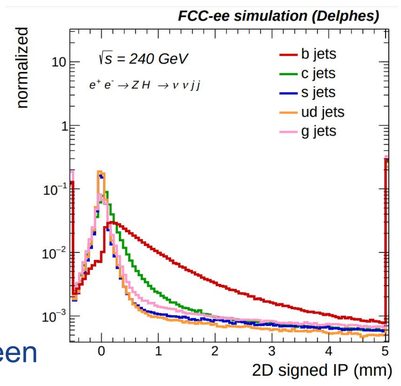
Tagging with Recurrent Neural Network Architecture[4]

Input Features

H→qq̄/gg@240GeV

- Kinematic Variables
- Displacement Variables
  - More relevant to identify b & c jets
- Identification Variables
  - PID important to identify s jets

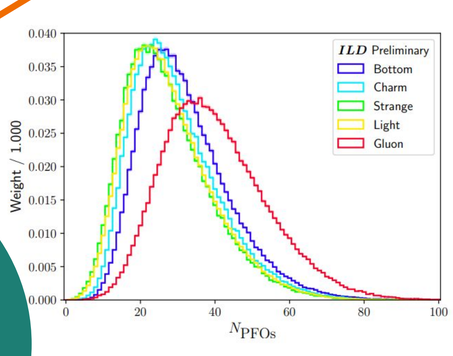
PID using **ToF** & **dN/dx** has been incorporated in **Delphes**



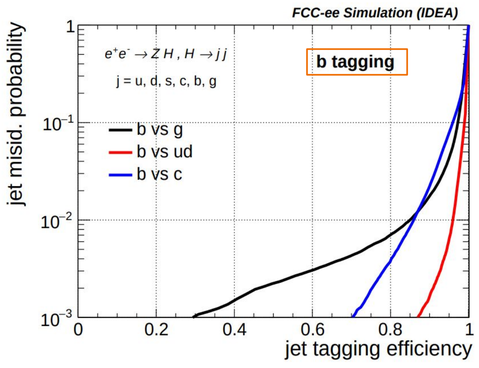
H→qq̄/gg@250GeV

Input Features

- Jet-level Variables
  - Kinematics
  - LCFIPlus tagger results
  - PFO multiplicities
- Variables for 10 leading particles in jets
  - Kinematics
  - Charge
  - PID truth likelihoods



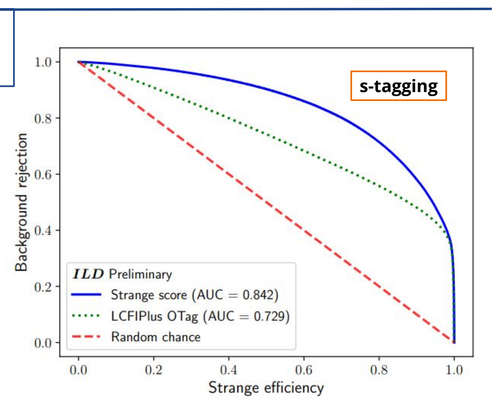
Performance



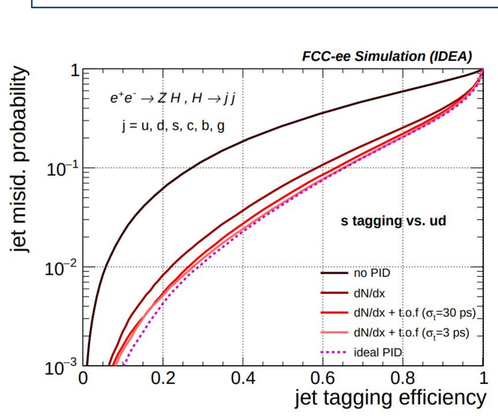
For high-purity region, gluon jet rejection is worse than c-jet rejection due a significant probability of gluon splitting

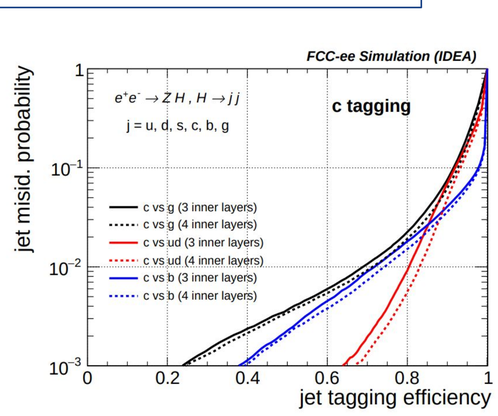
Performance

Significant improvement in strange and gluon tagging over ILC baseline tagger that does not use any PID information



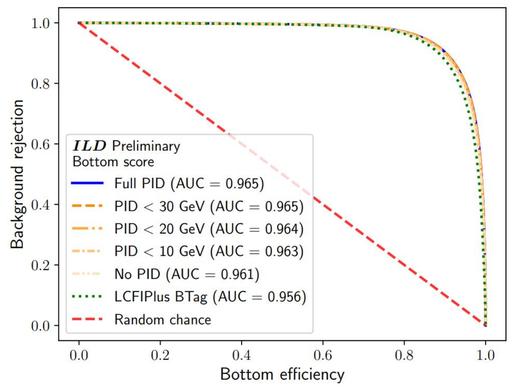
Performance with Different Detector Designs

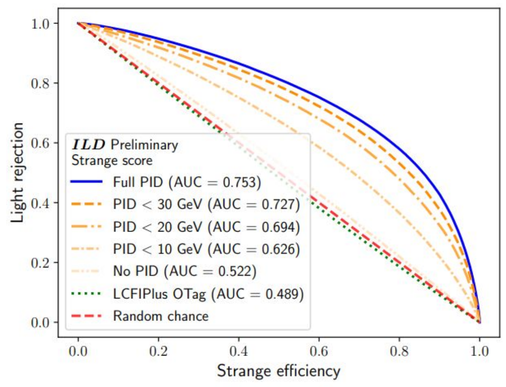




- **dN/dx** brings most of the gain
- Performance with **dN/dx + ToF (30 ps)** is very **close to perfect PID**
- **2x** improved background rejection with an **additional pixel layer**

Performance with Different Detector Designs





- No PID to **PID < 30 GeV** at fixed mistag rate: **s-tagging** efficiency **doubles**
  - **20%** increase for **PID < 10 GeV**
- **Insignificant** impact on **b-tagging** performance

Flavour tagging algorithms from LHC experiments are inspiring tagging efforts at future colliders like FCCee. Improved performance with the use of advanced ML models and additional properties: V^0 reconstruction (K_S & Λ^0) and PID capabilities (cluster counting, ToF, compact RICH, etc.)

With contributions from M. Basso, F. Badeschi, F. Blekman, V. Cairo, F. Canelli, A. De Moor, A. Macchiolo, L. Gouskos, A. Ilg, E. Plörer, M. Selvaggi

[1] Vaswani, et al., arXiv:1706.03762; [2] Suehara, et al., arXiv:1506.08371; [3] Bedeschi, et al., arXiv:2202.03285; [4] Albert, et al., arXiv:2203.07535