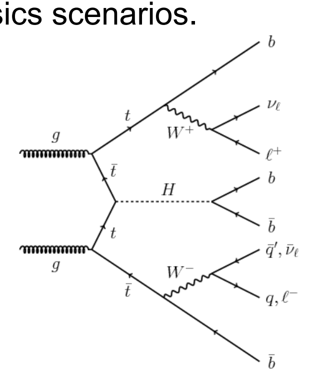
Jet flavour tagging for the ATLAS Experiment PANIC 2021 Poster Session

Jet flavour tagging in a nutshell

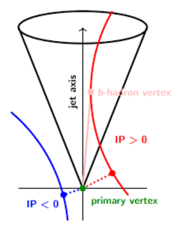
Jet flavour tagging is the set of algorithms designed to discriminate different flavours of jets, i.e. jets initiated by b, c or gluons and light quarks. Several important physics processes have b quarks in their final states: Higgs production, top production, many new physics scenarios.



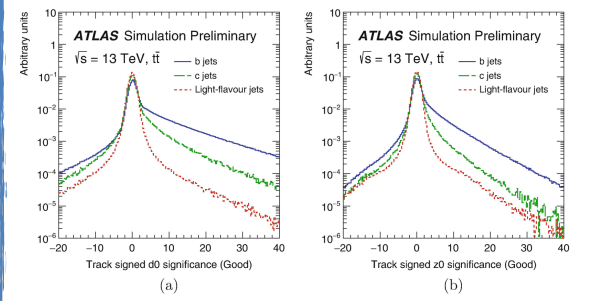
- Typically, b hadrons have **long lifetime** (~1.5 ps, ~3 mm flight length)
- **High mass** (~5 GeV)
- **High decay multiplicity**
- **b-to-c** decay

A comprehensive review of b-tagging in ATLAS is in Reference [1]

Impact Parameter (IP)

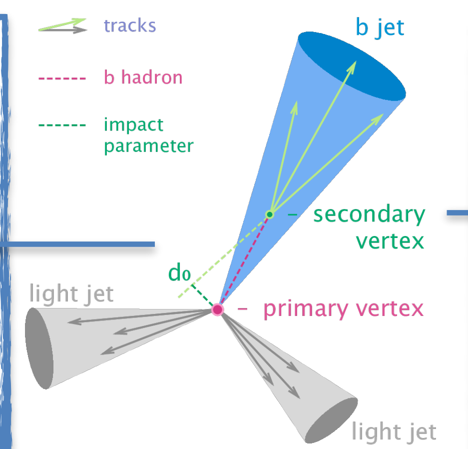


IP-based algorithms use a discriminant which is built starting from the signed-IP, for b,c and light jets.

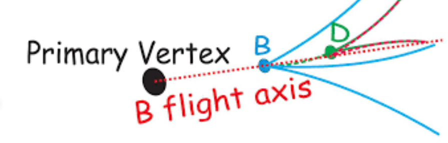


IP-based algorithms are:

- IP2D/IP3D: use the individual track likelihood;
- RNNIP: recurrent neural network;
- DIPS: use Deep Sets NN architecture



SV-based algorithms try to reconstruct the displaced vertex, and use SV-derived quantities for discriminating different flavour of jets.



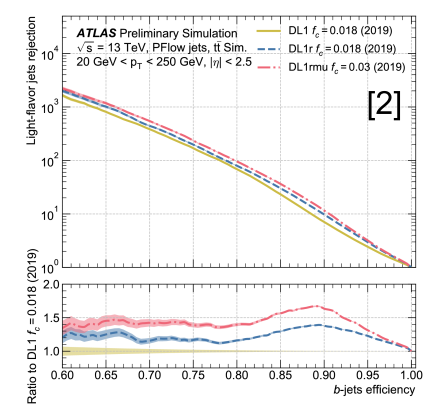
SV-based algorithms of two types:

- Inclusive secondary vertex finding, SSVF
- JetFitter: reconstruction of the entire b/c chain

High level taggers combine informations coming from low level taggers and use NNs to maximize performance.

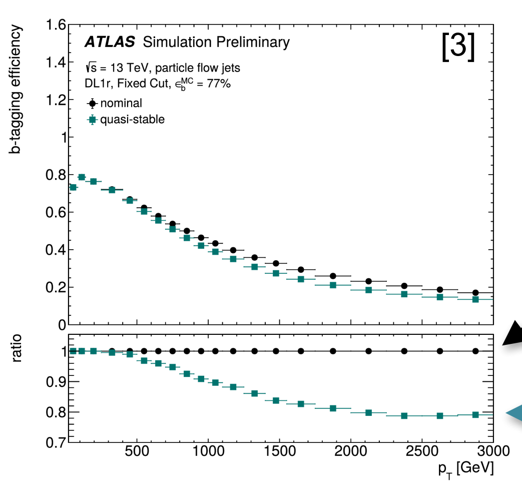
DL1, DL1r (uses RNNIP), **DL1mu** (uses muons).

DL1r is our current baseline tagger (for Run 2).



b-tagging performance

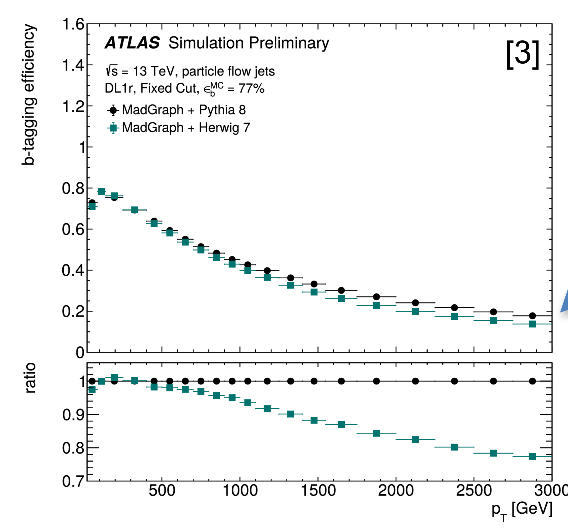
b/c-jet identification is increasingly **difficult at high jet p_T**: the flavour tagging efficiency decreases and shows significant dependence from the modeling in simulation.



Hadron simulation: highly boosted charged B/D hadrons may produce a few hits in the detector confusing secondary tracks and vertex reconstruction.

The **nominal** simulation does not emulate interactions of B-hadrons with the inner detector; only particles from B/D-hadron decays are propagated through the detector materials.

A dedicated simulation (**quasi-stable** model) taking into account EM interactions of B/D hadrons allows to establish the effect. Performance worsening in this plot is expected, as the tagger was trained on nominal MC simulations (retraining needed).



Jet modeling: different models of fragmentation and hadronization lead to dramatic differences in estimated performance, especially at high p_T.

Tracks associated to jets are assigned to different categories, based on their MC truth origin, with the aim of identifying the source of b-tagging inefficiency

"Noisy" tracks are:

- PileUp (tracks from other pp collisions)
- GEANT (secondary tracks, from interaction with the detector)
- Fragmentation (tracks from fragmentation/ hadronization)
- Fakes (tracks with less than 50% of the hits from a single MC truth particle);

"Good" tracks:

- B/D decay products.

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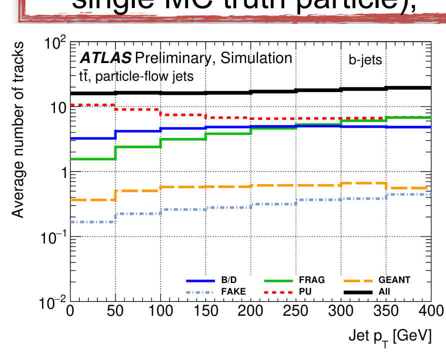
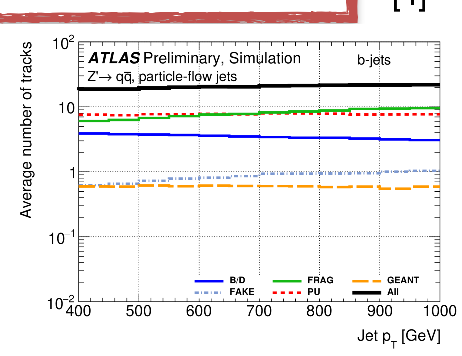
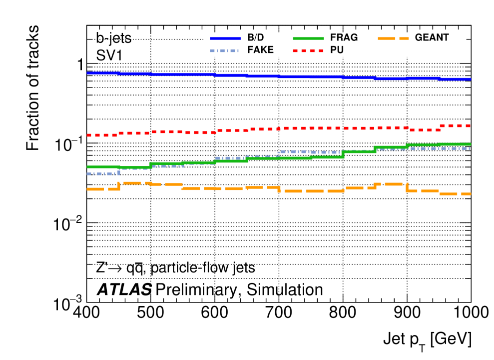
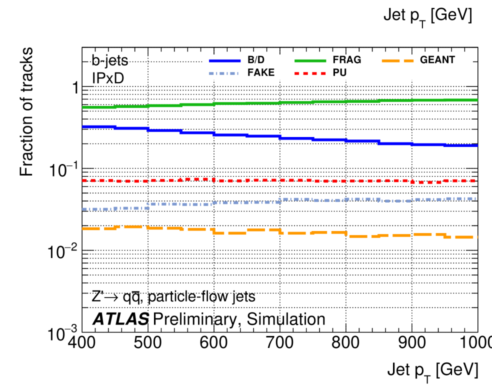




At high p_T, the number of reconstructed B/D tracks decreases with jet p_T while the number of fragmentation tracks increases, leading to performance loss.



IP-based algorithms do a pre-selection of tracks: as a result, the amount of PileUp is dramatically decreased while maintaining high the number of B/D tracks. Fragmentation tracks are not significantly reduced.



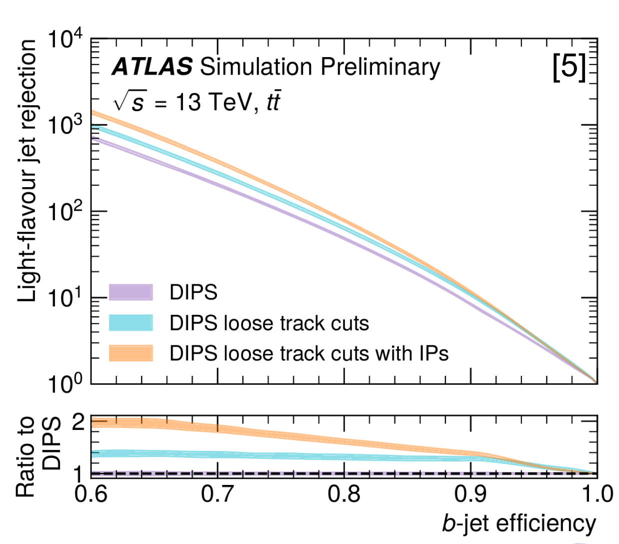
[4]

The tracks used by SV1 are determined by an additional pre-selection and in the process of vertex reconstruction, with the aim of discarding tracks coming from the primary vertex. The result is a very efficient reduction of noisy tracks, including fragmentation ones.

The future of b-tagging

New versions of flavour tagging algorithms are validated and others in development to improve the performance, addressing also the difficulties of the high p_T regime.

The strategy leading to higher efficiency can include looking more extensively at the track content of jets. For example, the new IP-based tagger, DIPS, being prepared for Run 3 operation (foreseeing a higher average number of interactions per bunch crossing w.r.t. Run 2), is shown to reach a better rejection of light-jets when using a track selection that is looser than the standard one.



Bibliography

1. Eur. Phys. J. C 79 (2019) 970
2. FTAG-2019-005
3. ATL-PHYS-PUB-2021-003
4. FTAG-2021-003
5. ATL-PHYS-PUB-2020-014

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