b-tagging in boosted $t\bar{t}$ decays

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  - Creation of MVb-tagger
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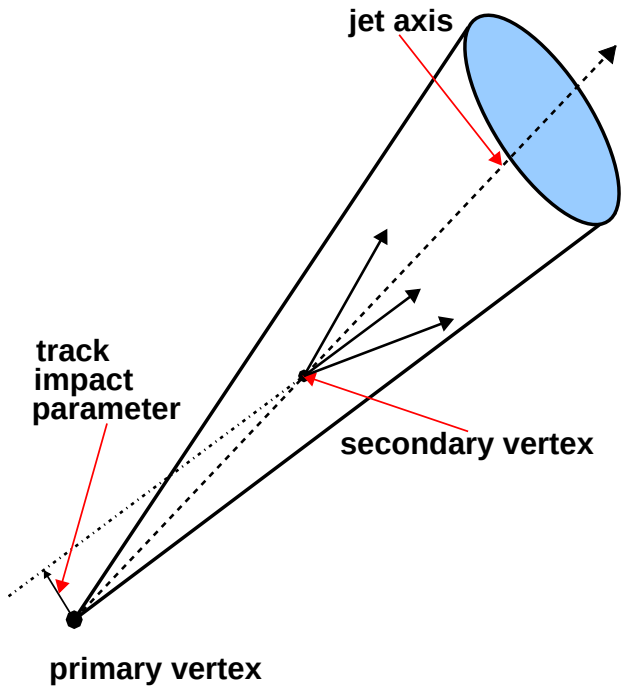
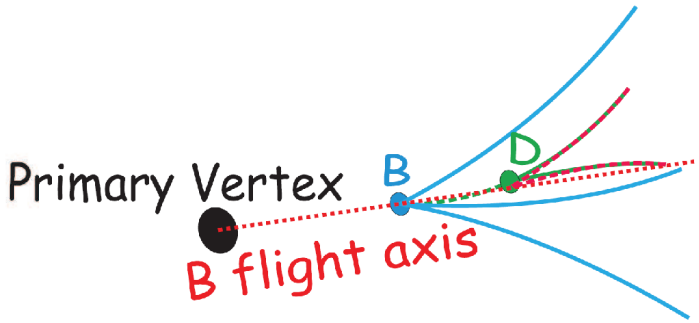
b-tagging algorithms in ATLAS

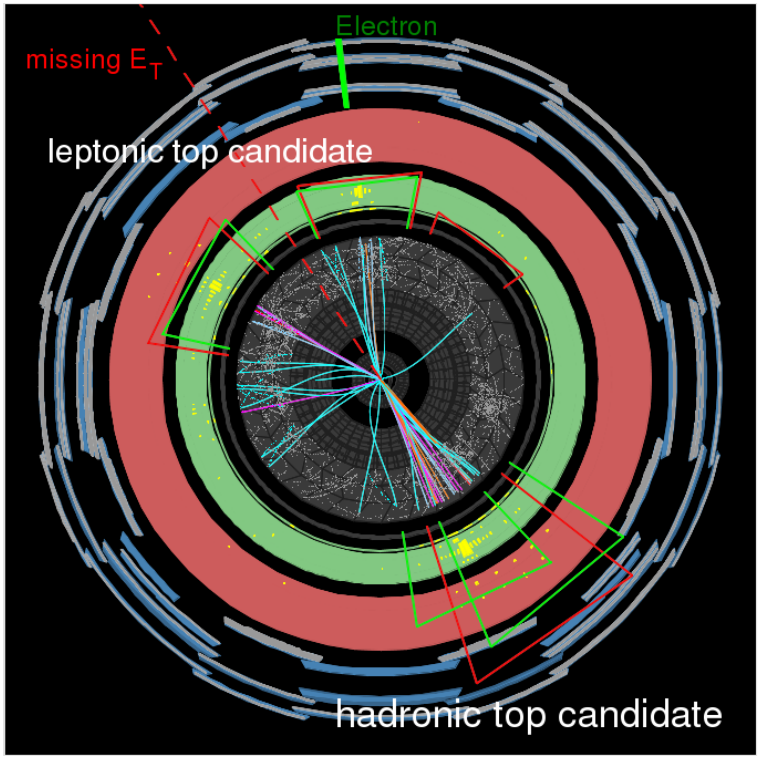
- SV based tagger
  - SV0 (signed decay length significance)
  - SV1 (Likelihood-Ratio of characteristic quantities at SV)
  - JetFitter (Multi-Vertex-Fit + Likelihood-Ratio)
- IP based tagger
  - IP2D (Likelihood-Ratio of impact parameters)
  - IP3D (Likelihood-Ratio of impact parameters)
- combined tagger
  - JetFitterCombNN
  - MV1 (ATLAS default)

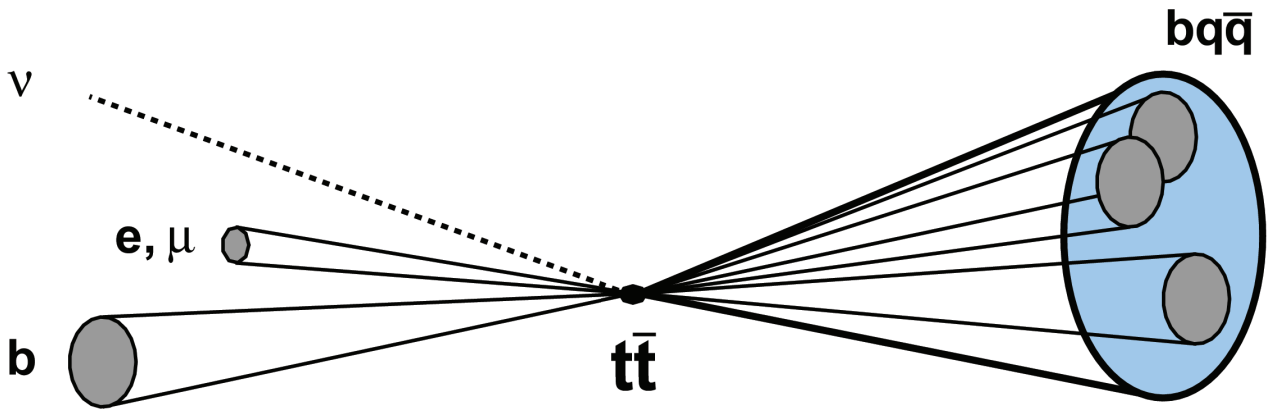




Topology of a boosted $t\bar{t}$ decay

- Increasing $\sqrt{s}$ and $\int \mathcal{L} dt$ leads to an increase of the sensitivity to search for boosted $t\bar{t}$ decays
- Simultanously the amount of events increases in which the decay products of the $t\bar{t}$-pairs overlap.
- Thus the identification of b-jets becomes more challenging.





boosted $t\bar{t}$ decay

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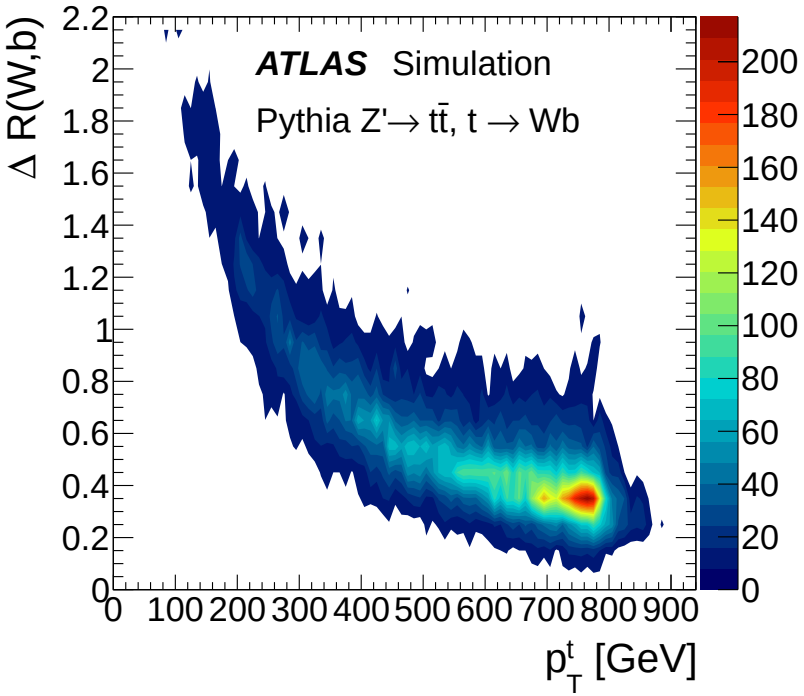
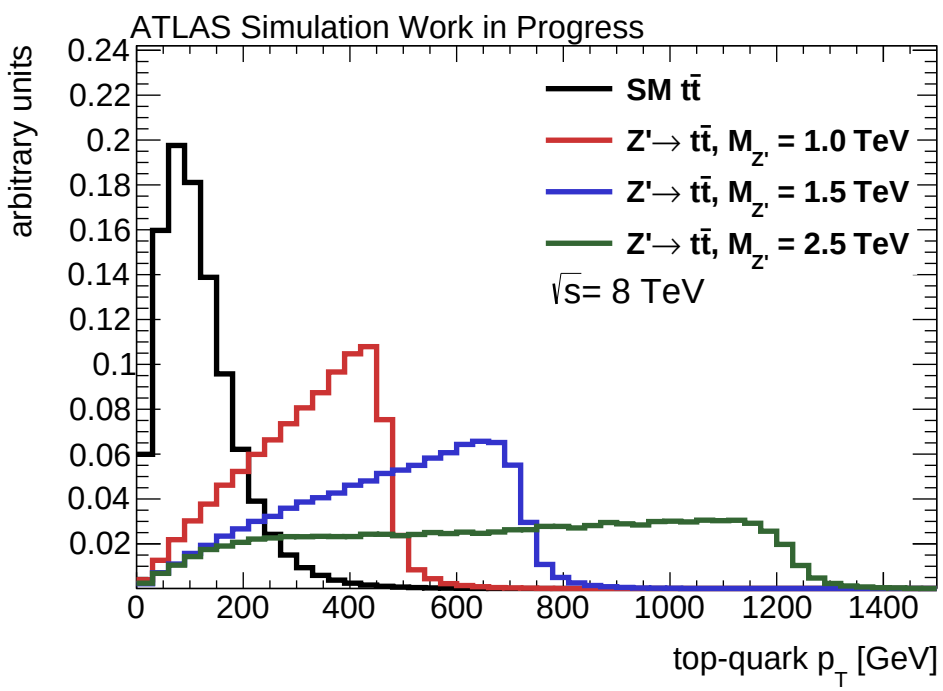




- Angular separation of decay products is approximately

$$dR \approx \frac{2M}{p_T} \tag{1}$$

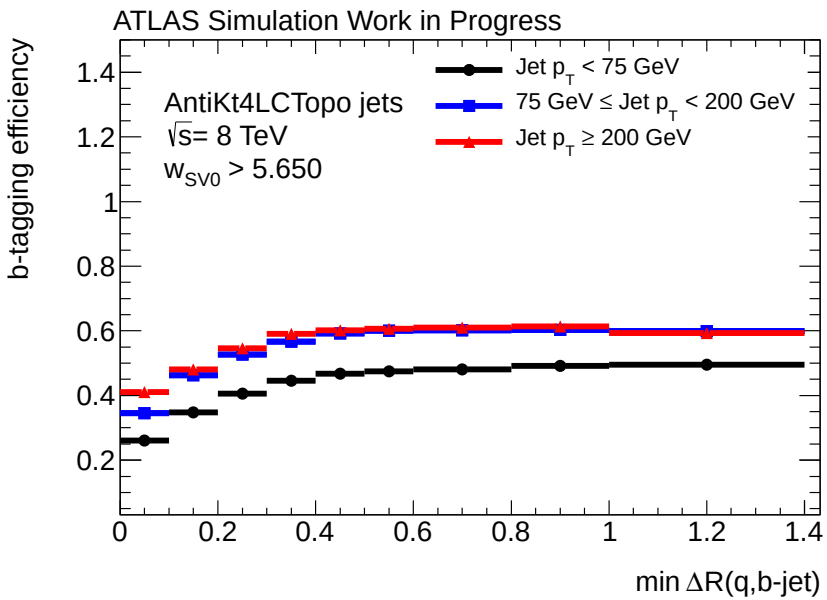
- In case of $p_T^{\mathrm{top}} > 350\,\mathrm{GeV}$, the decay products of the top-quark tend to have a separation of $dR < 1.0$

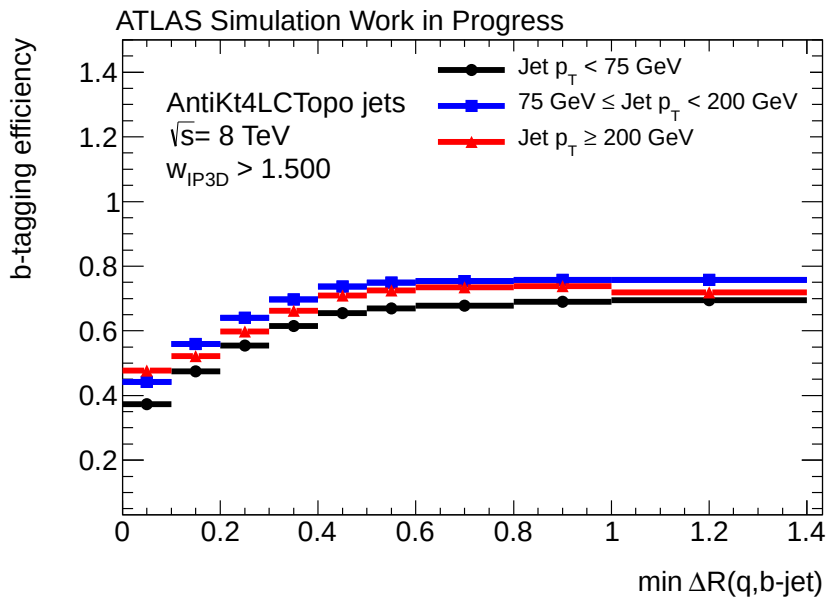
b-tagging of overlapping jets

- Investigate the performance of various b-taggers (and input quantities) for overlapping AntikT $R = 0.4$ calorimeter jets
  - Study the hadronic side of the top-quark decay by calculating

$$dR^{\min} = \min\{dR(b\text{−jet}, q), dR(b\text{−jet}, \bar{q})\} \qquad (2)$$

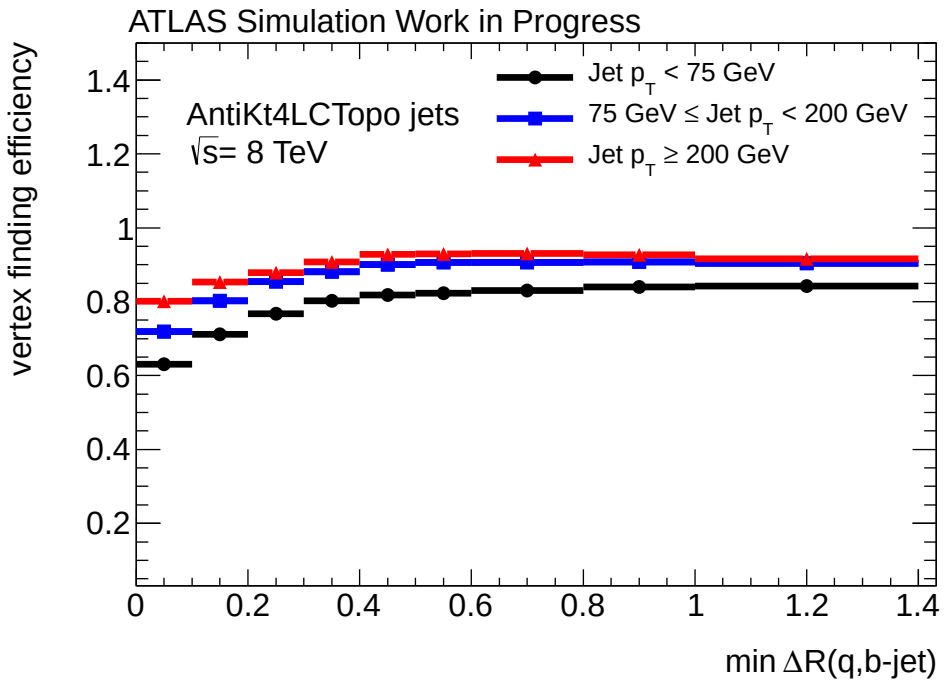
  - If the b-jet has a $dR^{\min} < 0.4$ it will be considered as overlapping
  - Loss of performance in case of small distances for SV- (left) and IP- (right) based taggers





Investigating the decrease of the tagging efficiency

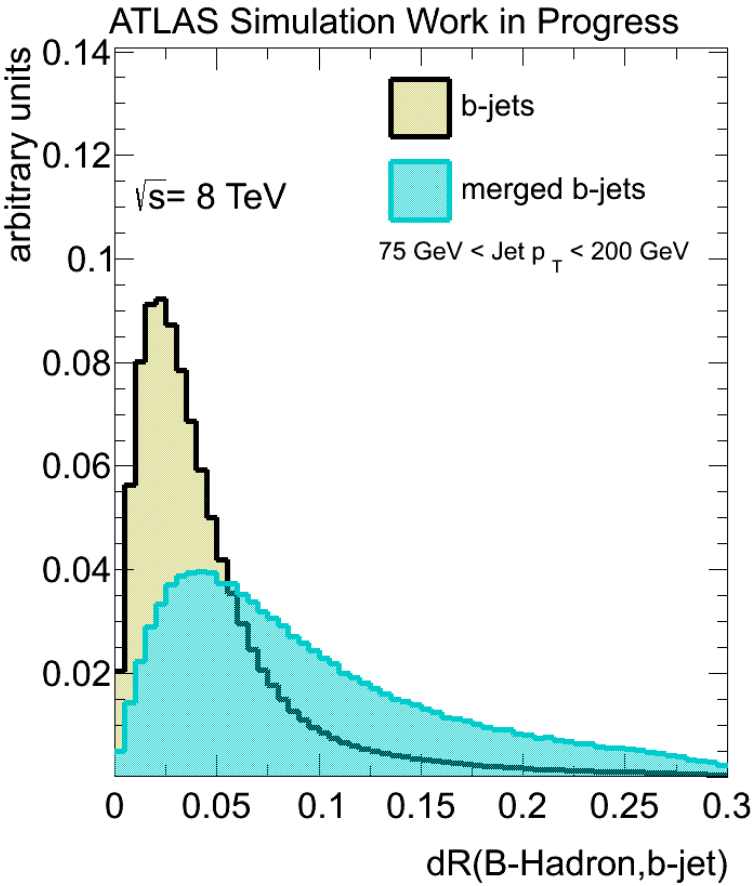
- **shift of the jet axis** due to additional activity next to a jet
- decrease of the **vertex-finding-efficiency** in dependence on $dR^{\min}$ (several tracks of the b-hadron decay are not associated to the jet)

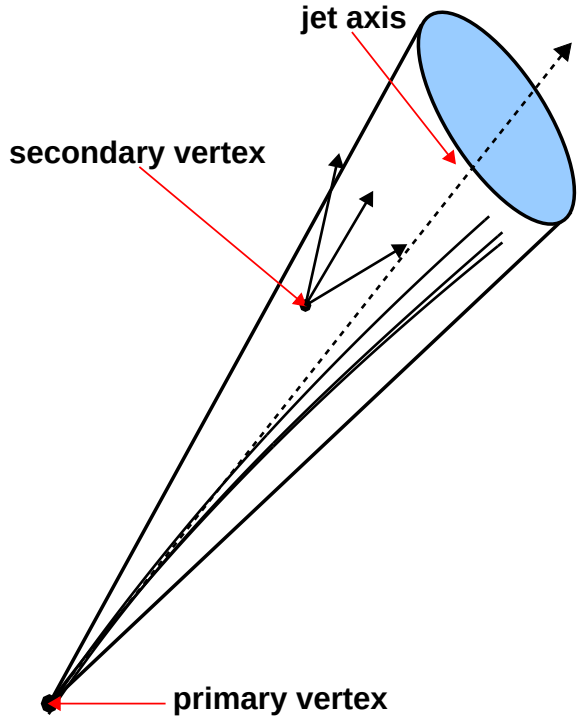


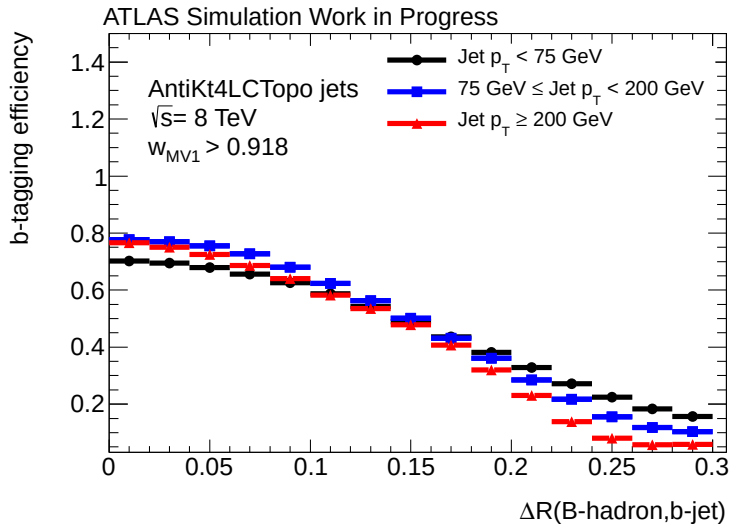
- negative effect on SV based quantities
- **additional tracks** affecting the impact parameter based tagger (IP2D, IP3D)

Shift of the jet axis

- distance of B-hadron (generator-level) and the corresponding b-jet (reconstructed).

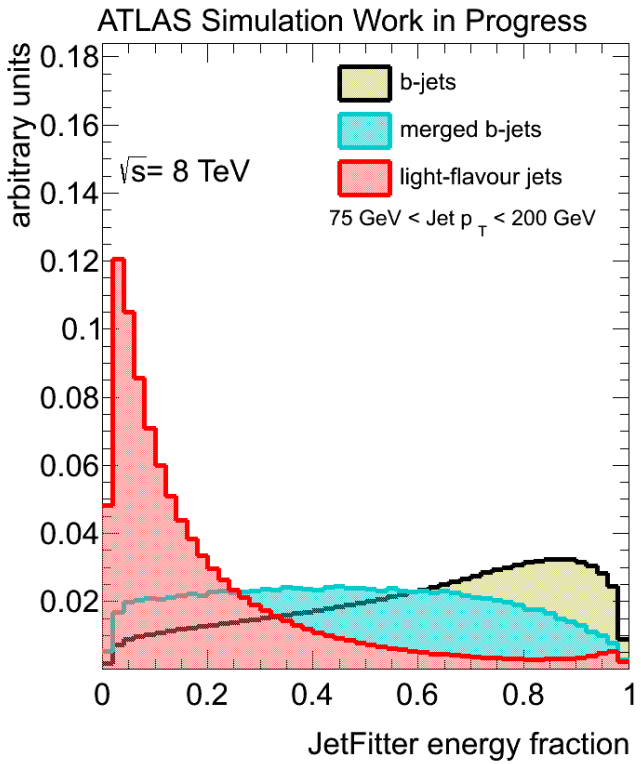


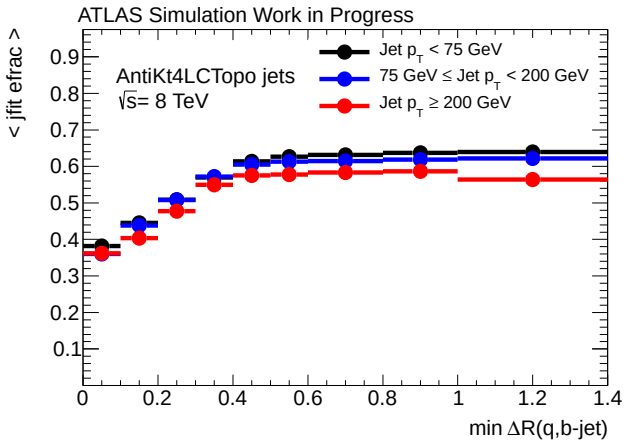




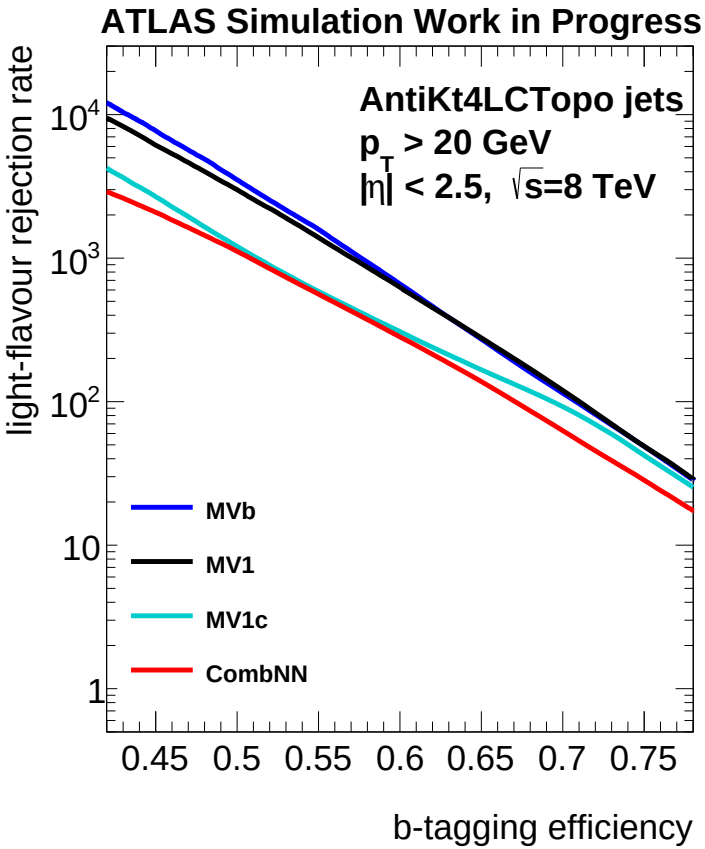
new MV-based tagger

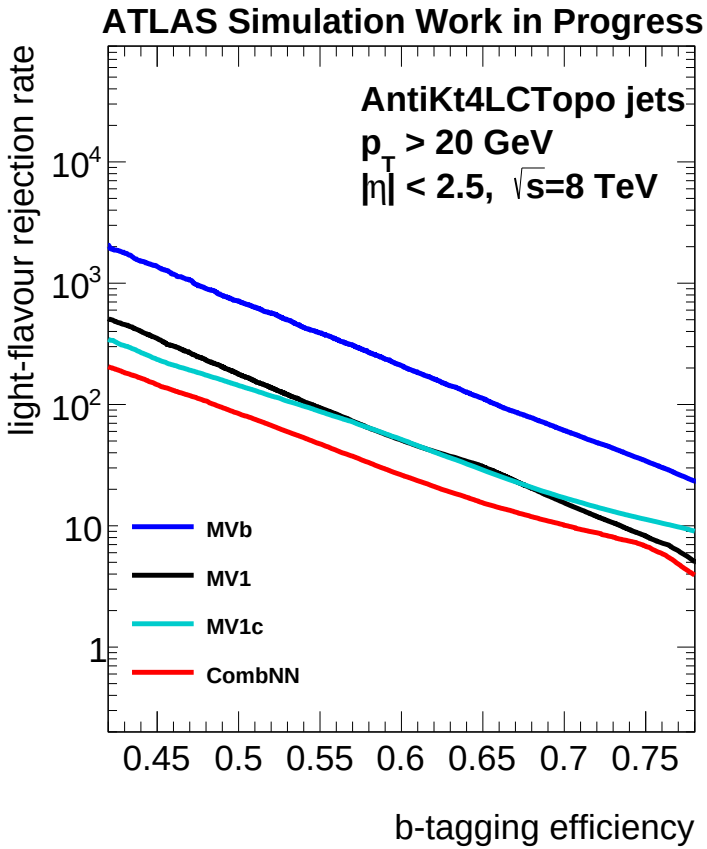
- Several *b*-tagging related quantities are affected by a jet overlap
- Creation of a new MV-based *b*-tagging algorithm using a BDT from TMVA
- Using 16 input quantities at the moment (see full list in the backup)
- Using those quantities, which are only slightly affected by an overlap and/or modifying some of the affected quantities





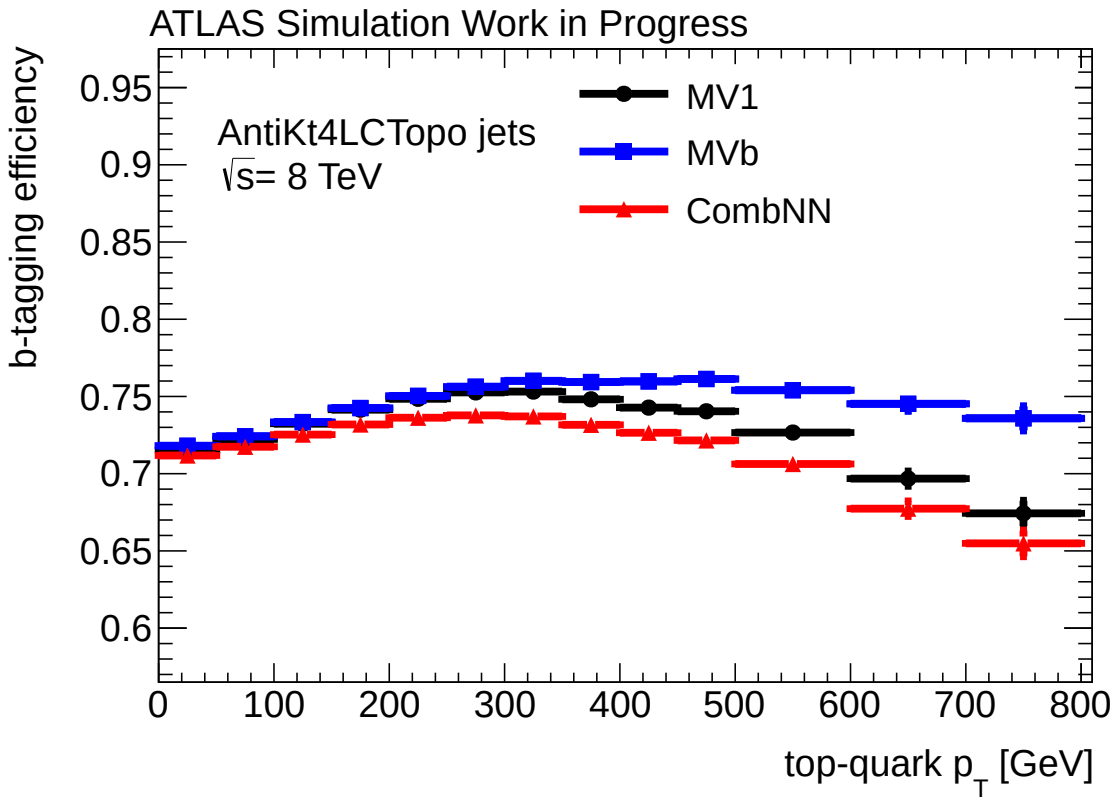
Comparing the performance of various b-taggers





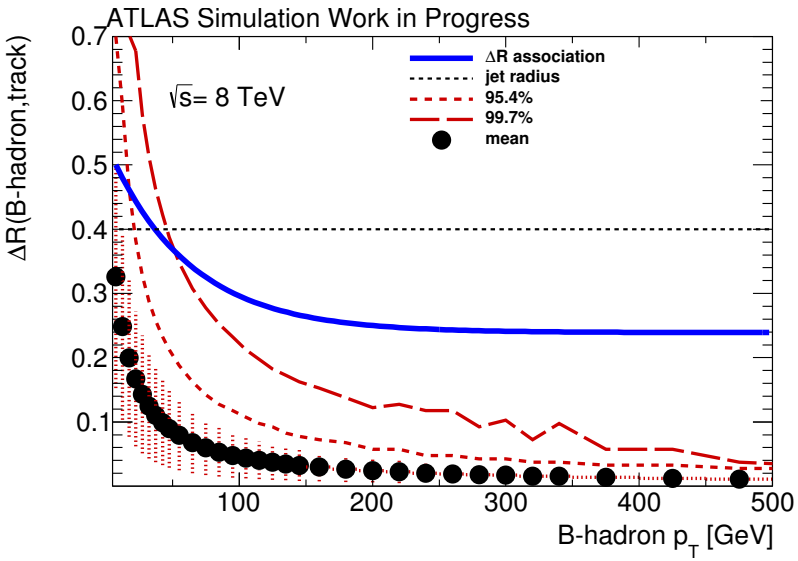
- MVb and MV1 tagger (ATLAS default) have now comparabel light-rejection in the SM $t\bar{t}$ sample
- MVb tagger performance is much better in the samples where the top-quarks are boosted $m_{Z'} = 2\ TeV$

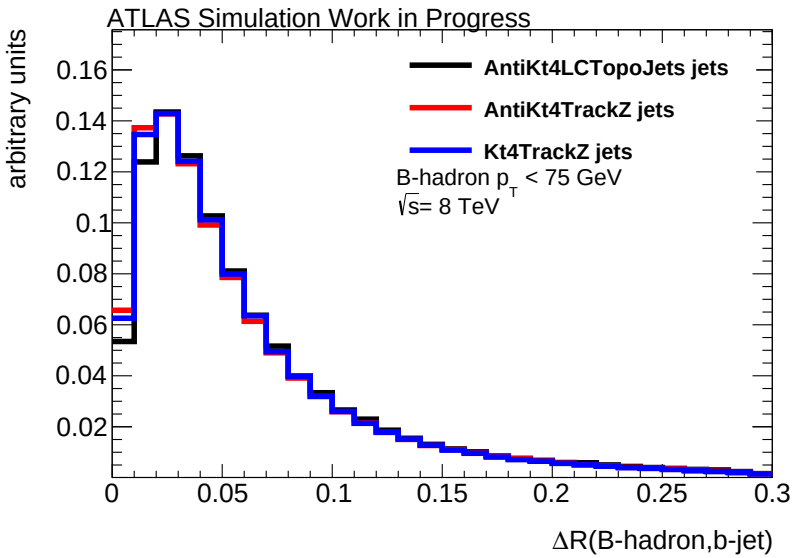
Comparing the performance of various b-tagger



- b-tagging efficiency in dependence on the top-quark p_T
- Performance in low top-p_T case is similar to MV1 (current default b-tagger) and much more stable in boosted decays
- evaluated in a SM $t\bar{t}$ sample

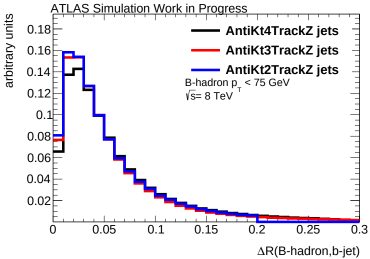
b-tagging of track jets

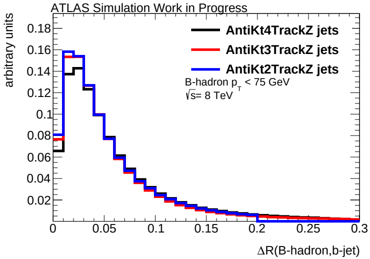


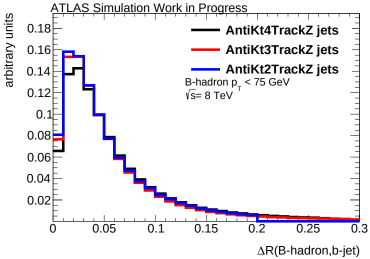


- Average distance in ΔR between B-hadrons and the associated tracks in dependence to the B-hadron p_T
- Usually this is much less then $\Delta R = 0.4$
- Alignment of B-hadron and jets is better for track-jets

b-tagging of track jets







- Alignment can be even improved, when moving to smaller trackjet cones

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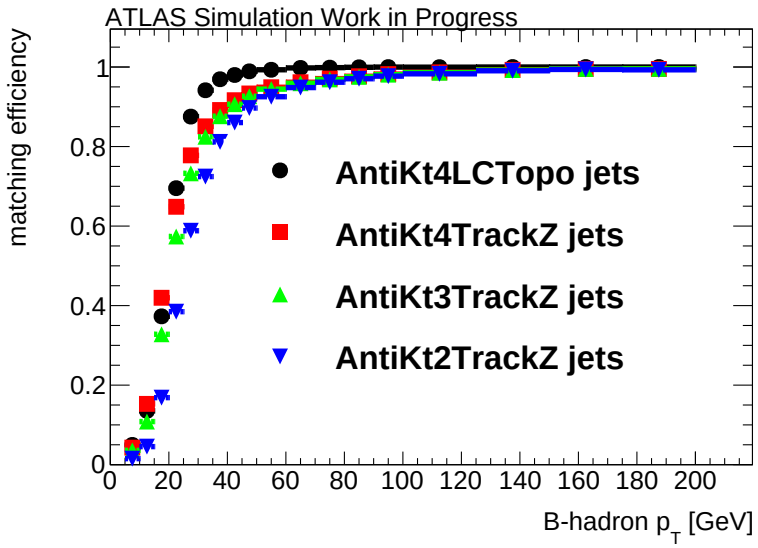
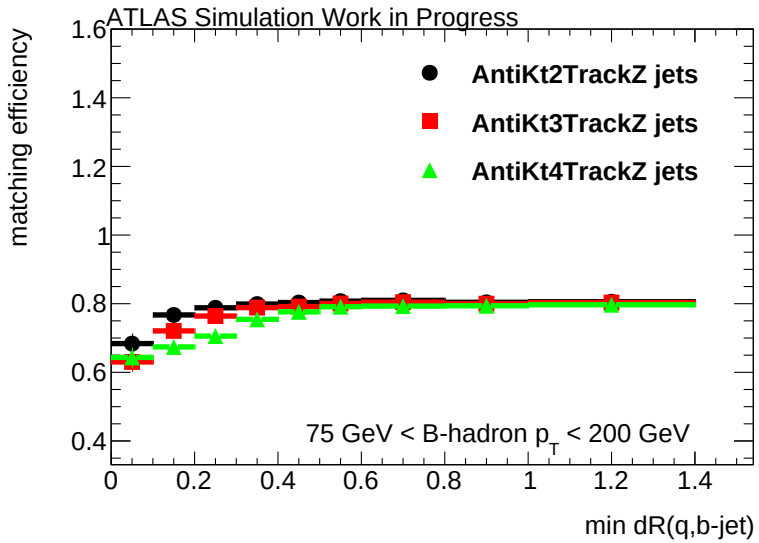
b-tagging of track jets





- Disadvantage: track jets carry smaller fraction of B-hadron energy
- Matching efficiencies of B-hadrons to jets degrades for track jets
- But find to almost each high p_T B-hadron a (track) jet

- Track jets with smaller jet radii show higher stability in the case of near by objects

Summary and Outlook

- Summary
  - Presented a b-tagger (MVb), which is dedicated to dense enviroments
  - It shows much better performance in boosted topologies (compared to the established b-taggers)
  - Migration of this study to track jets (smaller radii, different jet algorithm) is ongoing
    - Possible improvement of b-tagging due to a better alignment of the B-hadron and jet
    - Less pile-up dependent
- Possible improvements
  - Optimization of track selection for high p_T jets
  - Testing additional quantities to include into the tagger
- Outlook
  - MVb-tagger is in principle now available for physics analysis, but calibration in data is still in progress
  - Recently started study of including MVb-tagger into HEPTopTagger (in colaboration with other groups)