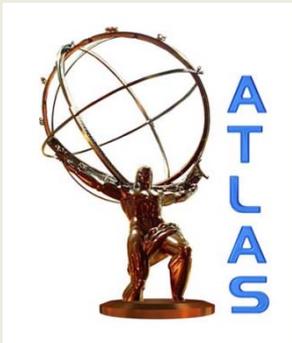


Lifetime signature for the identification of boosted top at ATLAS



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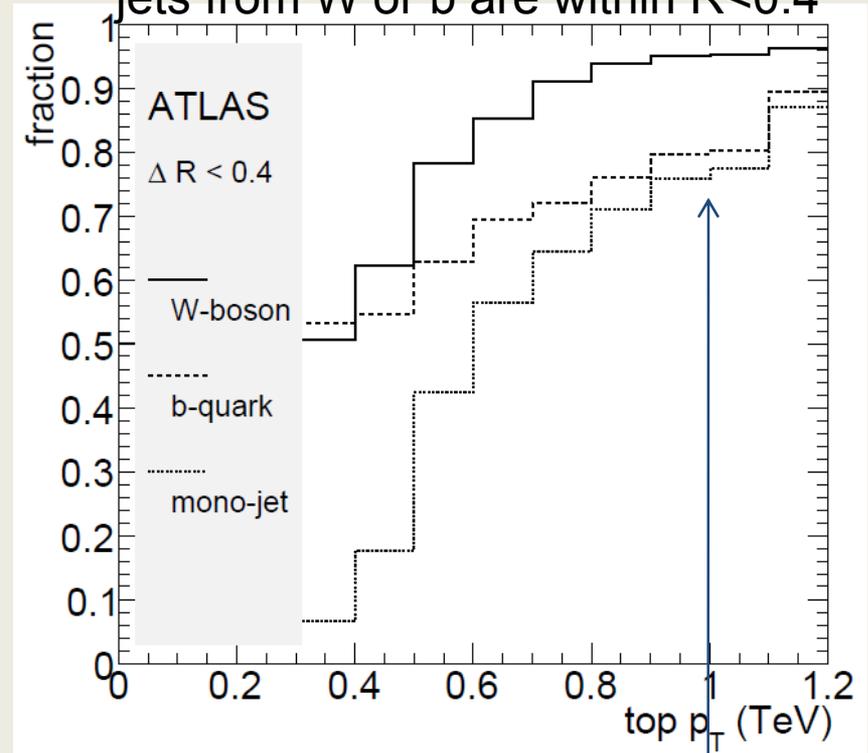
Physics Motivation

- Identification of high- p_T top is one of the key issue to search for BSM physics at LHC.
 - Z' , KK gluon decaying into $t\bar{t}$
- The p_T of top from high-mass BSM particle tends to be too high to resolve the all of jets individually.
- A single reconstructed jet may contain both quarks from W and the corresponding b-quark:

top mono-jet.

How to identify?

The fraction of top quark where jets from W or b are within $R < 0.4$



More than 70% of tops are reconstructed as mono-jet @ $p_T=1\text{TeV}/c$.

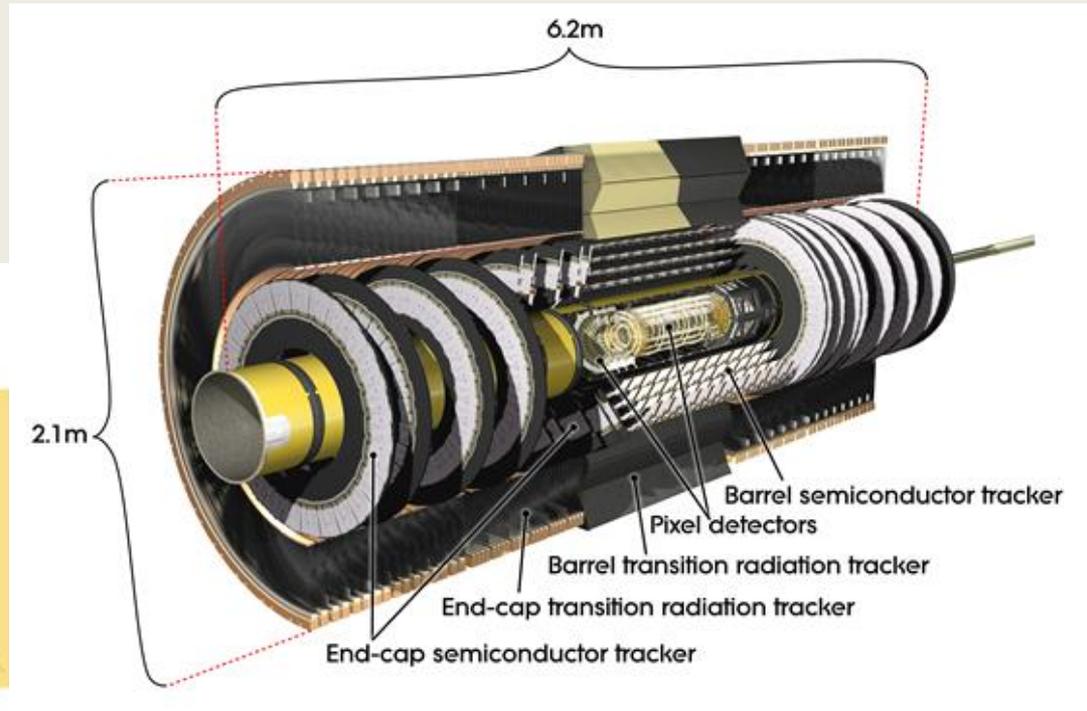
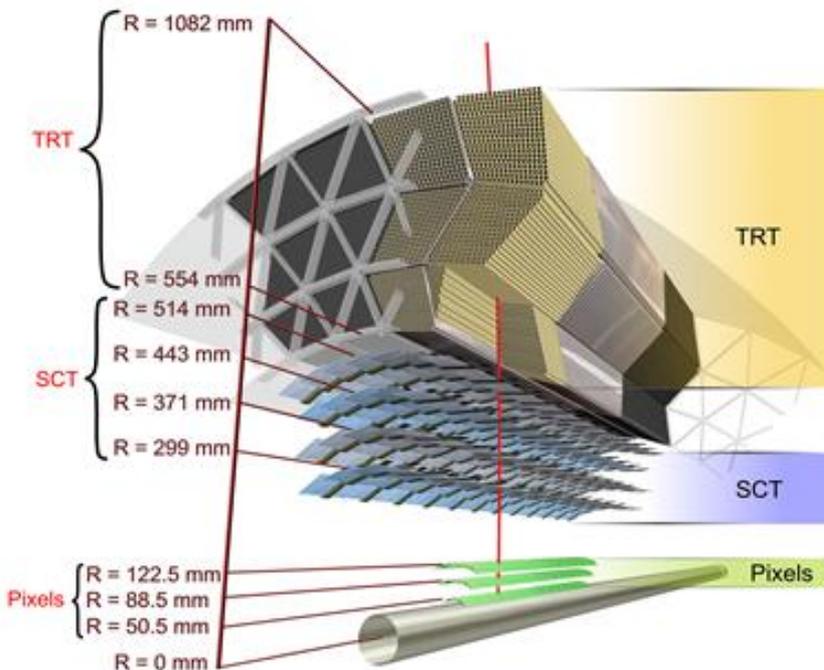
b-tagging for identification of boosted top

- Currently, no b-tagging is assumed for high mass $t\bar{t}b\bar{a}$ resonance search at ATLAS.
 - *c.f.* Gustaaf's talk today
- Lifetime signature is one of the possible ways for the identification of high- p_T top mono-jet.
 - More sensitive BSM search would be possible using the combination with other methods.

The ATLAS inner detector

In 2T solenoidal field:

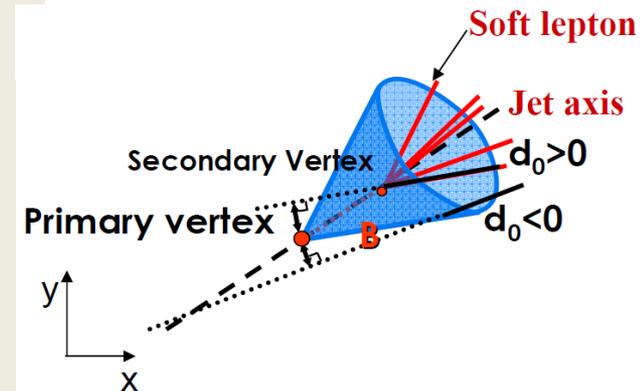
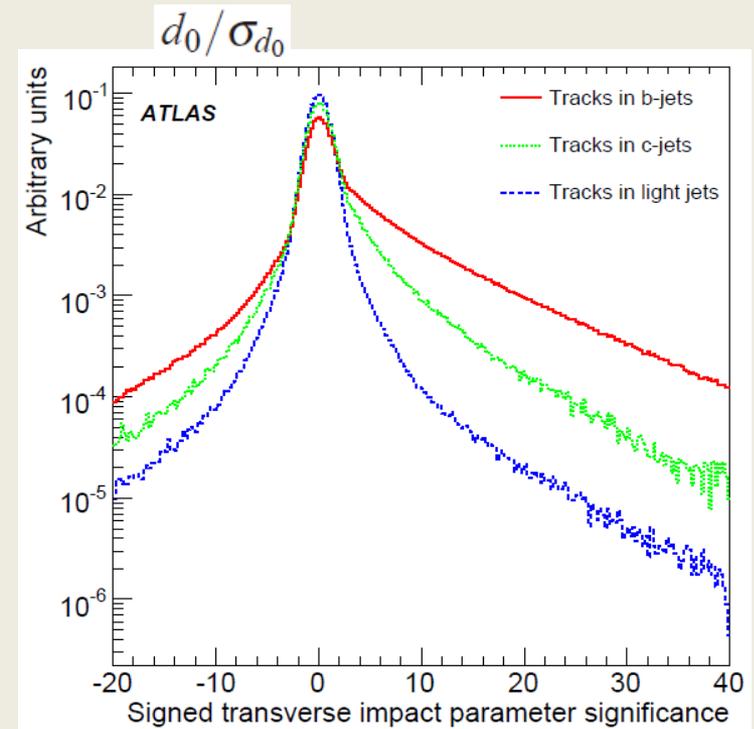
- Pixels
- Silicon Strip Detector (SCT)
- Transition Radiation Tracker



- Pixels
 - 3 layers for barrel, 80.4M readout channels
 - Typical pixel size: $50\mu\text{m} \times 400\mu\text{m}$
- SCT
 - 4 layers for barrel, 6.3M readout channels
 - Typical strip pitch $80\mu\text{m}$

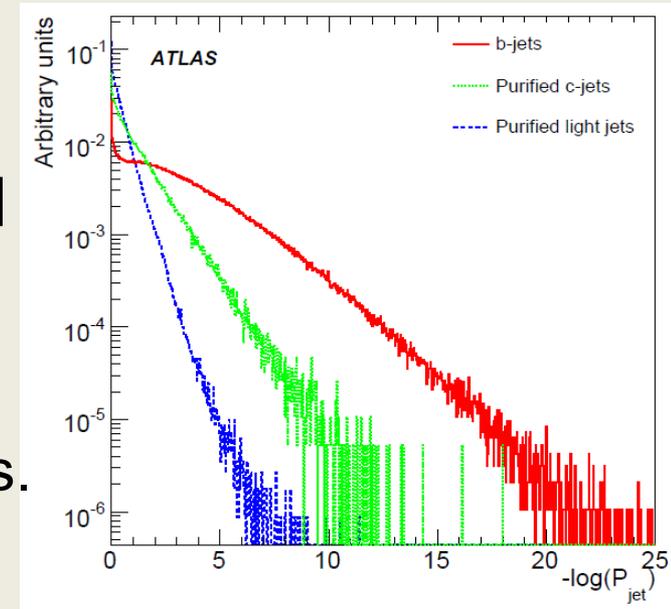
ATLAS b-tagging algorithms

- Figures from ATLAS-CSC note: CERN-OPEN-2008-020
- Spatial tagging (i.e. life-time tagging).
 - Use that B hadrons have a significant flight path length.
 - $E(B) \sim 50\text{GeV}$: $L \sim 5\text{mm}$
 - Secondary vertex in jets
 - Tracks with high positive impact parameter
- Soft lepton tagging
 - Low- p_T electron/muon from B/D decay.
 - Efficiency is quite limited by its branching ratio.
 - Useful for the commissioning of other taggers.



Simpler tagging algorithm

- Simple Track counting
- Simple IP based tagger: so-called JetProb
 - Based on IP distribution of prompt tracks.
 - Performance depends on fake tracks.



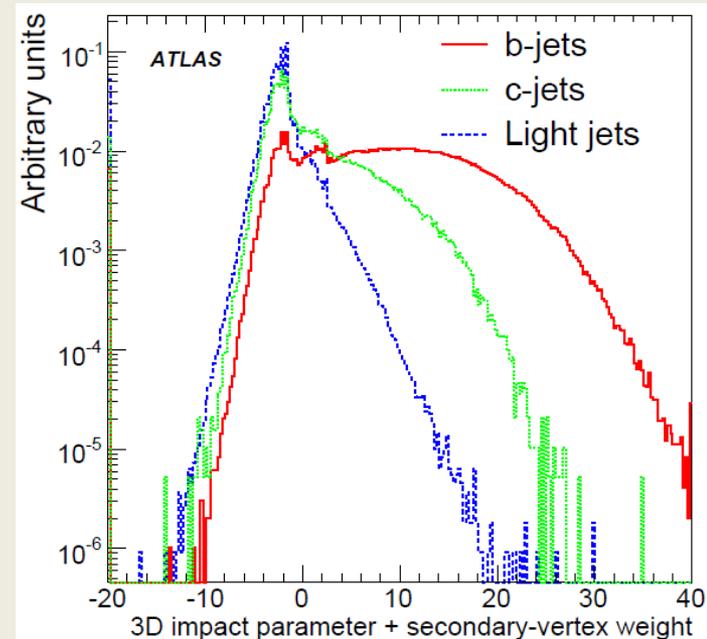
$$P(jet) = \Pi \cdot \sum_{i=0}^{N_{jet}} \frac{-\ln(\Pi)^i}{i!} \quad \text{where} \quad \Pi = \prod_{i \in jet} \int_{S_i}^{+\infty} f(S) dS$$

- Simple SV based: so-called SV0
 - Fits the secondary vertex and gets the secondary vertex.
 - Less sensitive to fake track but sensitive to resolution.

Likelihood for b-tagging

- IP based tagging: IP2D (only transverse IP), IP3D (also longitudinal IP)
 - Use separate distributions for b and light jets
 - Powerful but difficult to calibrate
- SV based tagging: SV1
 - Use Mass, energy fraction and number of 2-track vertices.
- Kalman fitter for the explicitly fit of the $B \rightarrow D \rightarrow X$ decay chain: so-called JetFitter
- IP3D+SV1 combined

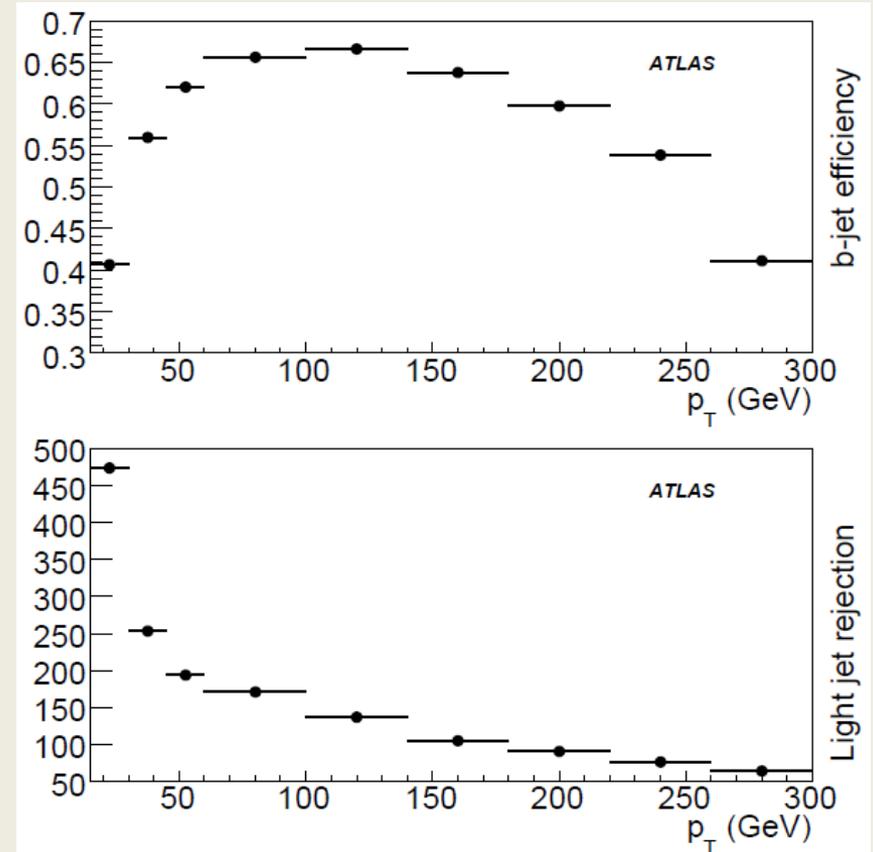
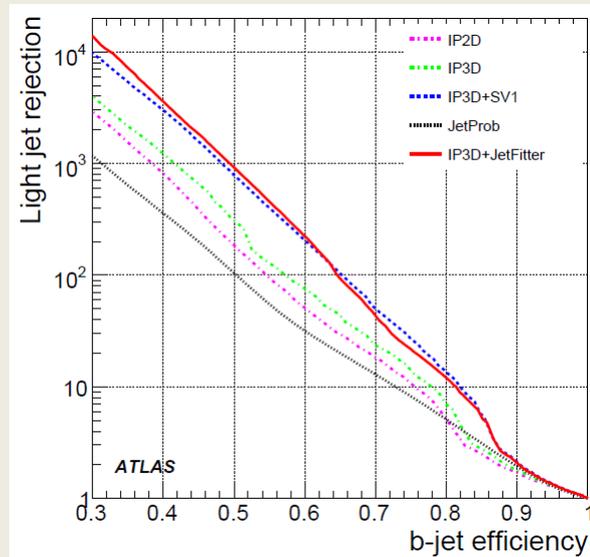
W_{jet} by IP3D+SV1



$$W_{jet} = W_{tracks} + W_{vertex} = \sum_{i=1}^{N_{trk}} \ln \frac{b(S_i)}{u(S_i)} + \ln \frac{b(M, F, N)}{u(M, F, N)}$$

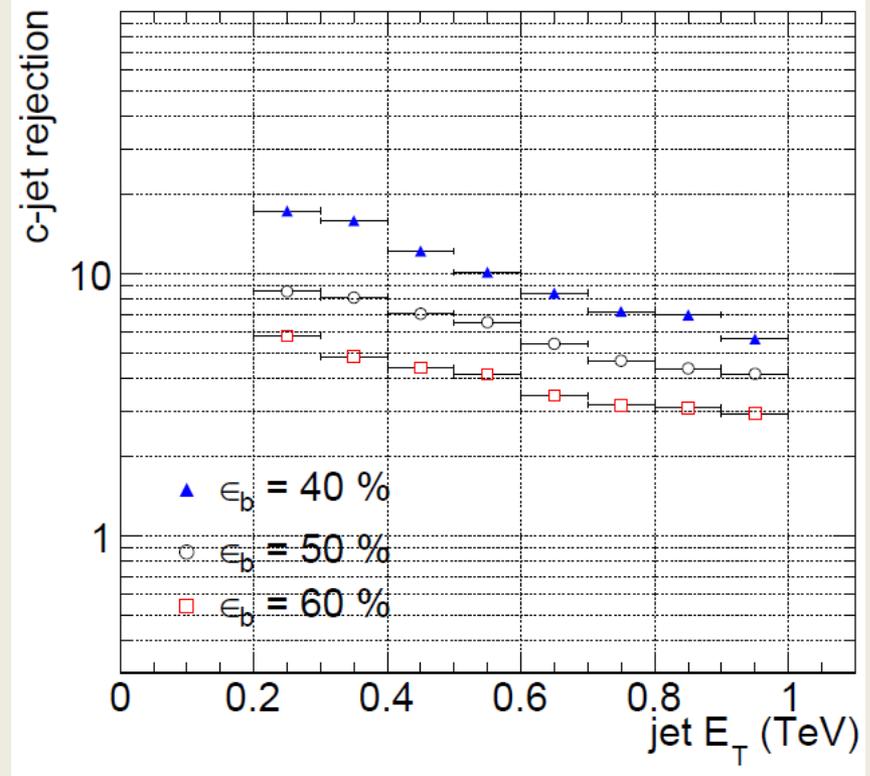
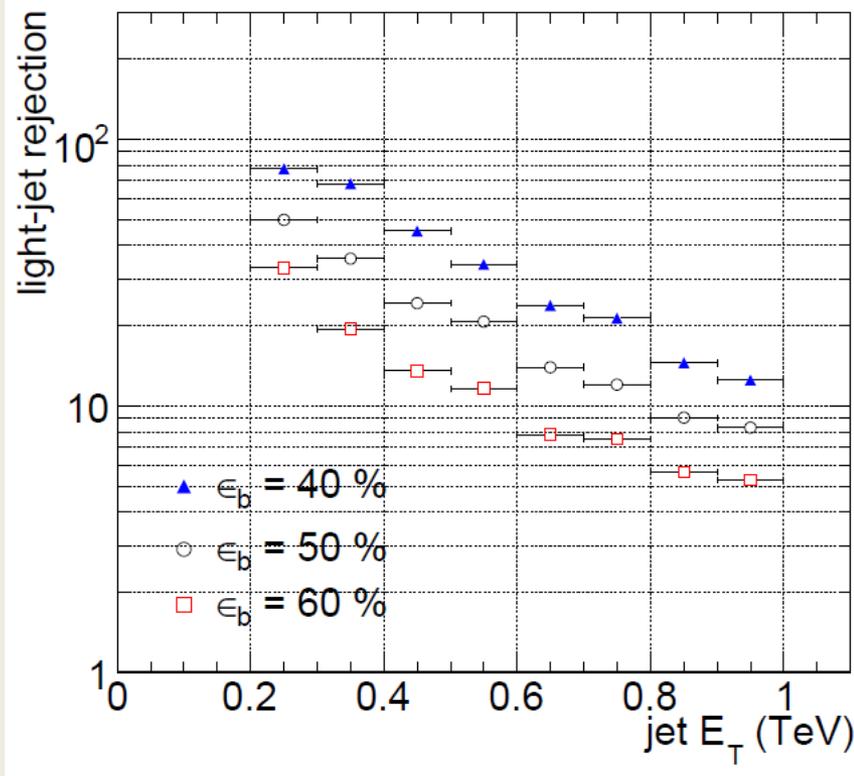
b-tagging performance

- Strongly depend on kinematics
 - Collimated tracks and 'late' B decay cause the issue
- Performance evaluation with $t\bar{t}$ events



IP3D+SV1 tagging algorithm
@ a fixed cut of $w > 4$

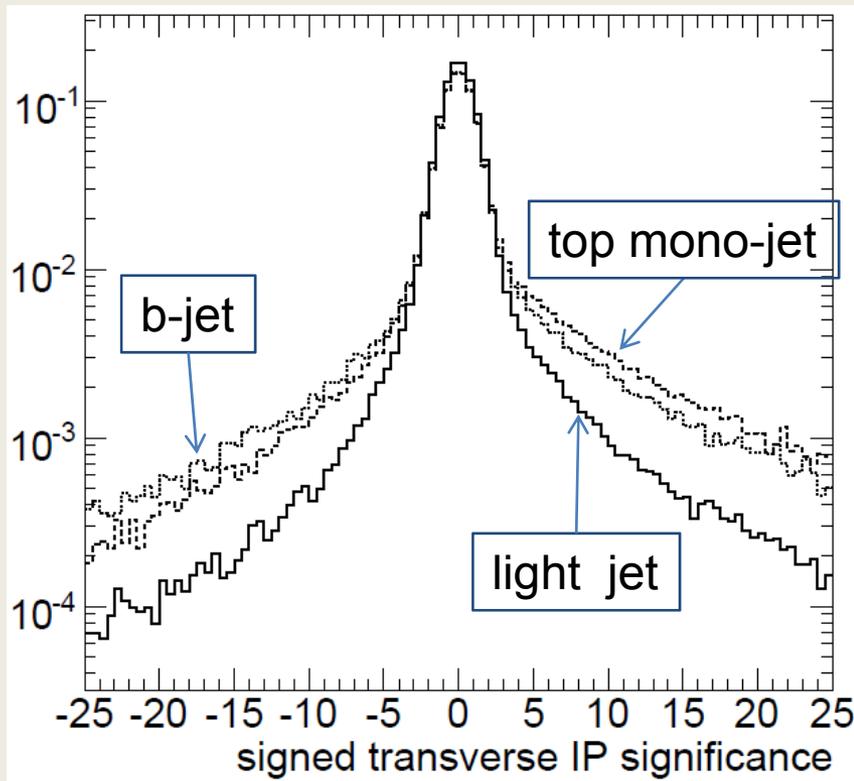
Performance for higher pT region



- Use IP3D+SV1 algorithm
- Rejection for 1TeV light jet is $\sim x5$ worse than that for a few hundred GeV jets.

Application of b-tagging for high- p_T hadronic top mono-jet

Z_H ($m=2\text{TeV}$)- \rightarrow qqbar

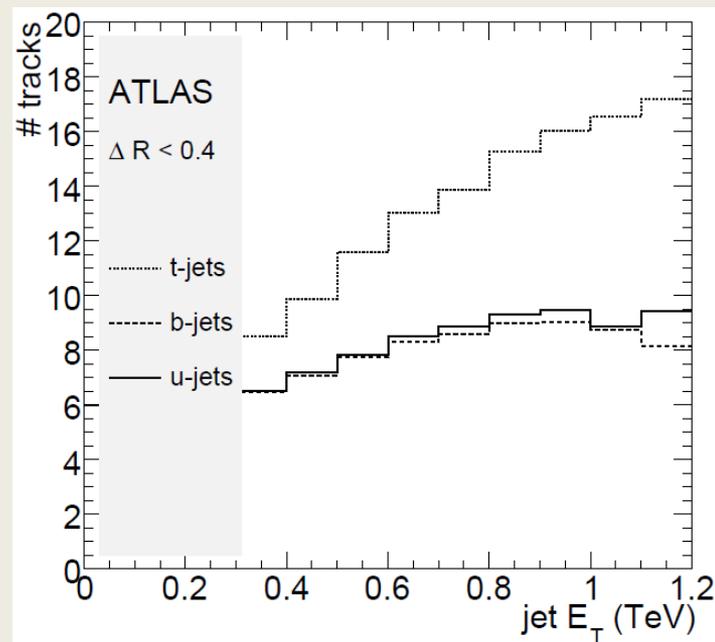


for all tracks inside each jets

- Evaluation with the $Z_H \rightarrow t\bar{t}$, $b\bar{b}$, $c\bar{c}$ and $u\bar{u}$ MC.
- Use only hadronic top mono-jet.
 - i.e. no-leptonic decay sample
- Apply the b-tagging for top mono-jet itself (not for sub-jets).
- Signed IP distribution for top mono-jet show more symmetric one.
 - Reflects the uncertainty on the B-hadron flight direction.

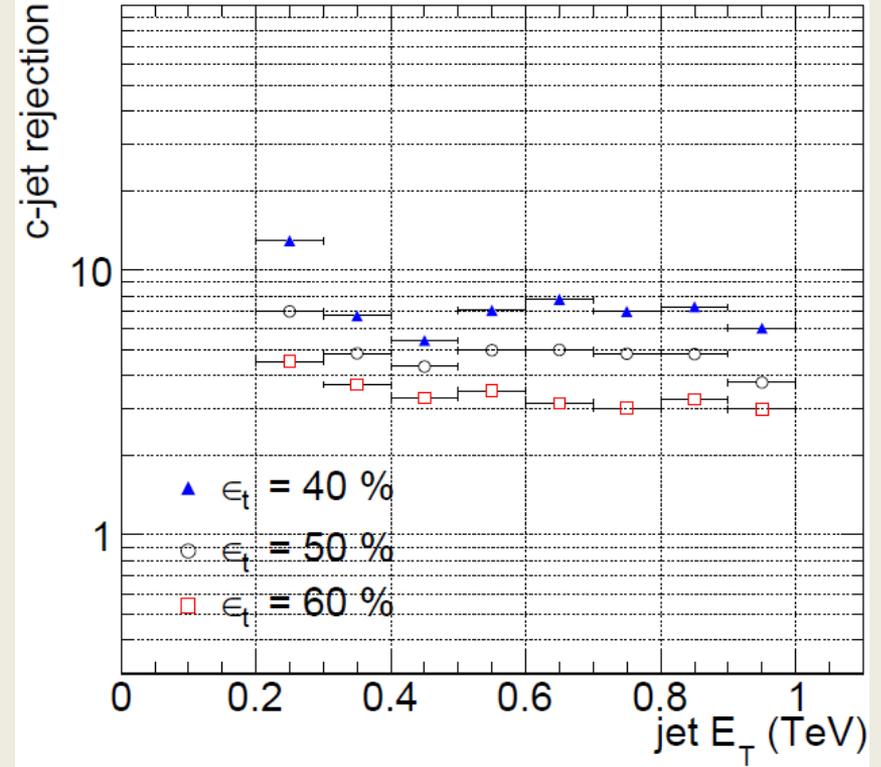
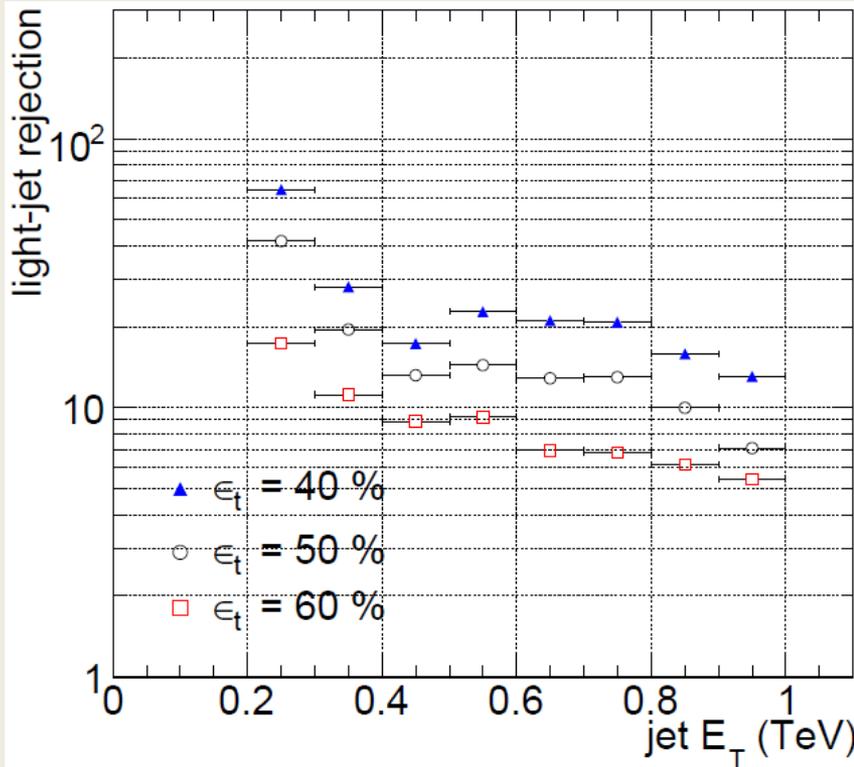
Degraded performance for top mono-jet

- Negative IP significance due to the uncertainty of B-hadron direction in top mono-jet.
- Large mismatch btw mono-jet and B-hadron limits the track-jet association cone size.
- Tracks from W-decays make the dense environment for b-tagging.



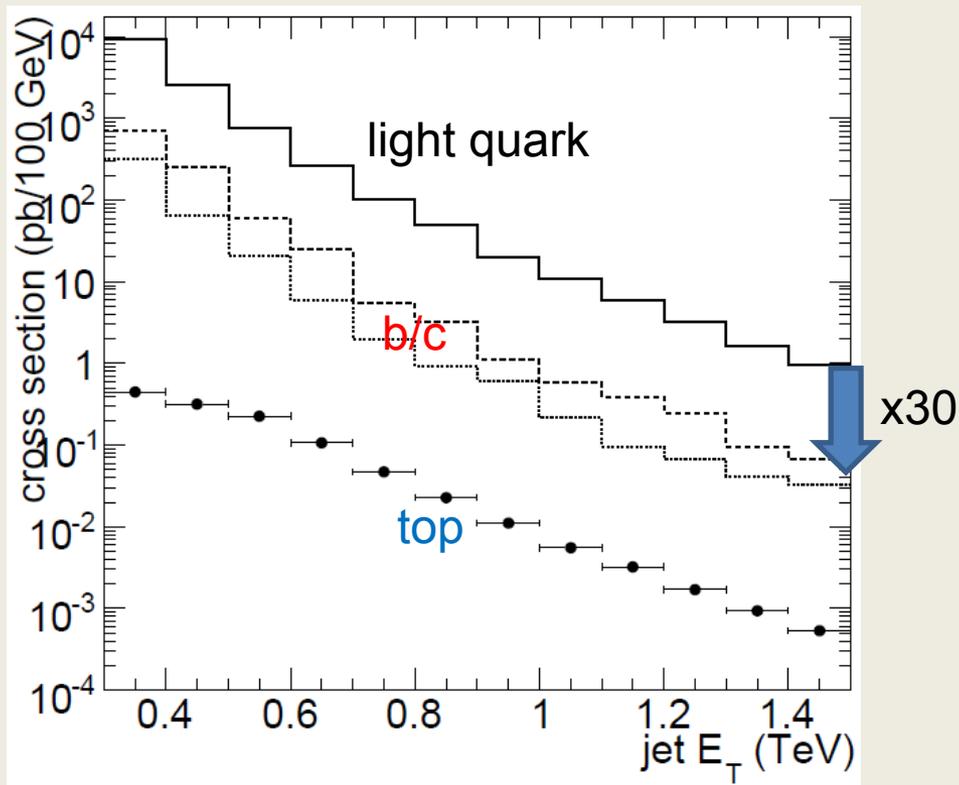
Number of reconstructed tracks ($p_T > 1\text{GeV}$) within the jets.

Top mono-jet tagging performance with the application of b-tagging



- Use IP3D+SV1 algorithm
- In the case of leptonic W decay, tagging performance is comparable with that for normal b-jet
- Light jet rejection power of ~ 20 for 40% efficient high-pT top mono-jet identification (up to $E_T=800$ GeV)

For the extraction of top mono-jets



- $u/b \sim 30$ and it is hard to extract SM high- p_T top mono-jets only with tagging based on lifetime signature.
- Additional method, such as jet substructure, is necessary for the extraction of SM high- p_T top mono-jets.
 - Combination of the cuts would show improved performance.

Conclusion

- Application of b-tagging for high-pT top mono-jet has been studied.
 - Potential of the lifetime signature of B-hadron embedded in the hadronic top mono-jet is discussed.
 - Reduction of the dijet background by a factor of 30 is feasible.
 - The efficiency of the identification of top mono-jets is greater than 30% for $E_T < 800 \text{ GeV}$.
 - Top mono-jet reconstruction on the basis of a combination of the lifetime and jet substructure signature is possibility.

Outlook

- Evaluate the combination of sub-jet structure and lifetime signature method for identifying high- p_T top mono-jet.
- Are there better algorithm for the identification of high- p_T bottom/top?
- Application of b-tagging for the extracted sub-jets.
 - How we can associate the tracks to correct jet?
 - Track association based on $dR(\text{track-subjet})$?
 - Tracks from W -decays make the dense environment for b-tagging.
 - Momentum resolution for such tracks is quite worse ($\sigma(p)/p \sim 20\%$ @ $p=100\text{GeV}/c$).