LHCC Poster Session - CERN, 13 March 2013

B-Tagging Performance in ATLAS

Why B-tagging?

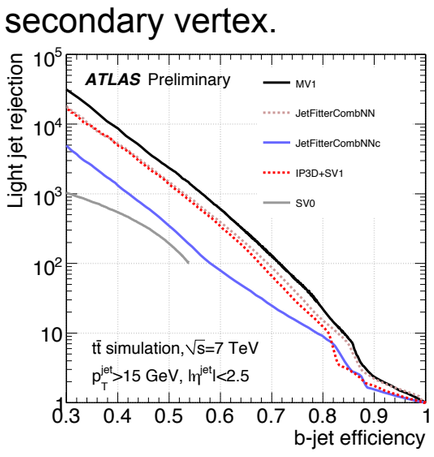
Identification of jets formed from b-quark fragmentation is important for many physics analyses.

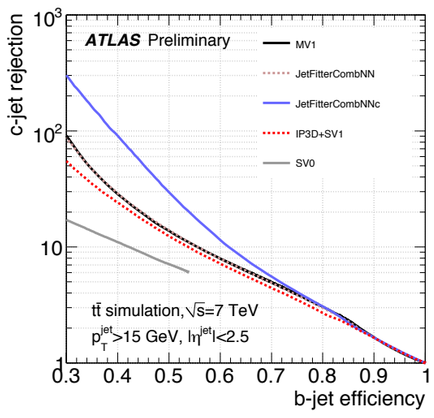
- Higgs *(H→bb)*
- Top *(t→Wb)*
- SUSY/ Exotics *(X_1→X_2b)*
- Standard Model

B-tagging Algorithms in ATLAS

B-jets have a number of unique characteristics which b-tagging algorithms can exploit to identify them.

- The long lifetime of a b-quark allows for the identification of a secondary vertex, located close to the primary vertex.
- The large mass of the b-quark enables discrimination based on the invariant mass of the secondary vertex.





Tagger	Summary
SV1	Identification of a secondary decay vertex (SV), exploiting the fact that a b-jet will involve heavier hadronic decays (larger SV mass) and contribute a large proportion of energy to the jet.
IP3D	Impact parameter significance of all tracks – longitudinal and transverse
JetFitterNN	Neural network using the secondary vertex fitting chain along with additional tagging weights
MV1	Neural network using the output weights of JetFitter +IP3D, IP3D and SV1 as inputs

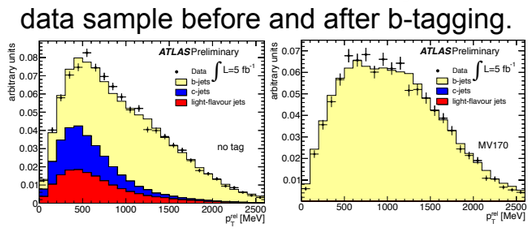
Measuring B-tagging Efficiencies

ATLAS-CONF-2012-043 | ATLAS-CONF-2012-097

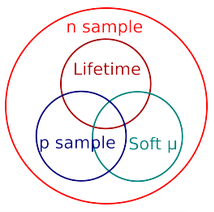
In order to benefit from the b-tagging algorithms available, the tag weight distributions need to be calibrated taking into account the effect of systematic uncertainties.
These calibrations are released as scale factors to correct the efficiencies in simulation to those measured in data.

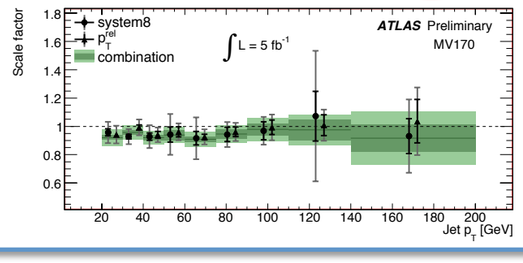
$p_T$rel and system8

- The *$p_T$rel* method uses semi-leptonic muon decays of b-hadrons. Measuring the relative transverse muon momenta creates a variable, $p_T$rel, which has a flavour dependent spectrum. Template fits estimate the flavour fraction of jets in a data sample before and after b-tagging.



- The *system8* method uses three uncorrelated event selections, one of which uses $p_T$rel, to solve a set of eight constrained equations to extract b-tag efficiencies.



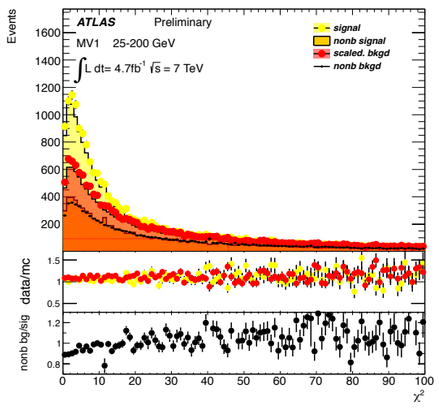


Top-Pair Methods

As the top quark to b-quark branching ratio is approximately unity, a single lepton and dilepton top-pair selection can provide a sample of pure b-jets with kinematics relevant to physics analyses. These methods can calibrate higher transverse momenta jets than dijet methods. The large luminosity delivered at 7 TeV has allowed this method to produce competitive results.

Kinematic Fit

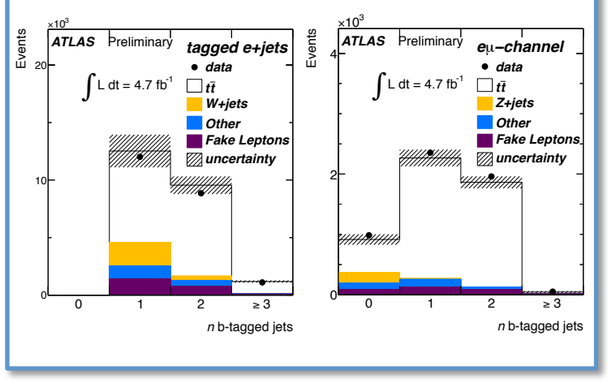
The *kinematic fit* method uses the single lepton top-pair topology to identify a purified sample of b-jets using kinematic constraints. A X^2 fit is performed to find the permutation of jets which best satisfies the event hypothesis.



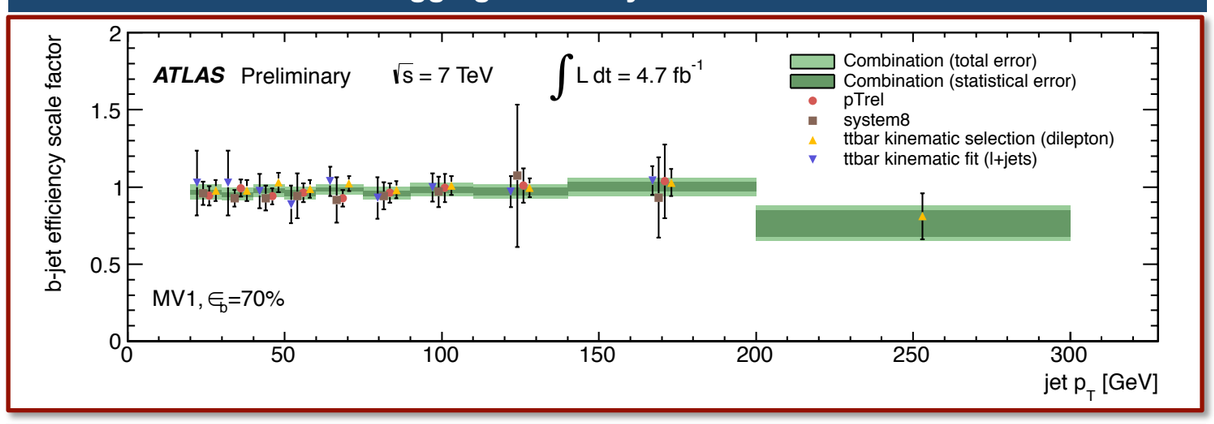
Kinematic Selection

The *kinematic selection* method uses the fraction of tagged leading jets in data. The single-lepton and dilepton decays are used. Using flavour fractions and mistag efficiencies from simulation, one can extract the b-tag efficiency for true b-jets.

$$f_{btag} = \epsilon_b f_{\text{b jets}} + \epsilon_c f_{\text{c jets}} + \epsilon_l f_{\text{light jets}} + \epsilon_t f_{\text{tau jets}} + \epsilon_{\text{fake}} f_{\text{fake}}$$



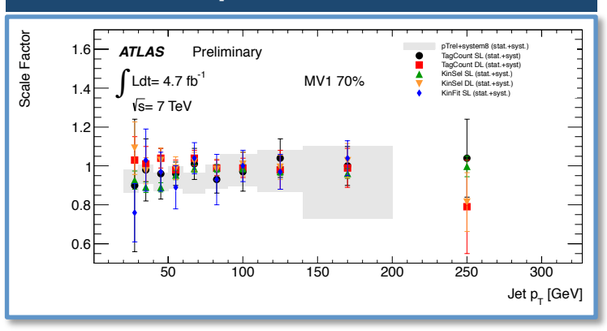
Final 2011 B-Tagging Efficiency Scale Factor Combination



Tag Counting

The *tag counting* method builds on the premise that a perfect tagger will identify two b-jets in a top-pair sample. By comparing the number of expected tagged jets in bins of jet multiplicity in simulated data to real data, one can extract the b-tag efficiency.

Top-Pair Results



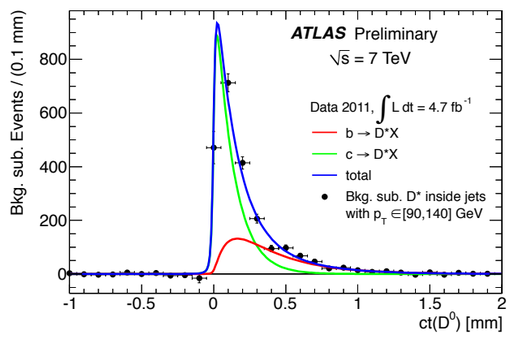
Measuring Mistag Rates

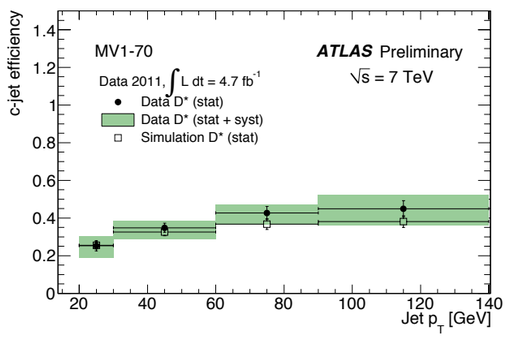
ATLAS-CONF-2012-039 | ATLAS-CONF-2012-040

Whilst important to know the b-tagging efficiency, it is important to calibrate the contamination in the various taggers coming from the mistagging of jets which come from charm and light decays.

Measuring Charm Jet Efficiency

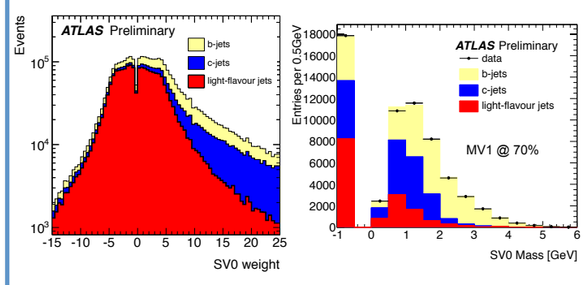
It is possible to measure the tagging efficiency of a c-jet with b-tagging algorithms, using a D*+ analysis. This analysis uses b- and c-jet templates in order to extract the c-jet efficiency using a sample pre- and post-tag. The efficiency is then solved from: $\varepsilon_{D^*} = f_b\varepsilon_b + (1-f_b)\varepsilon_c$

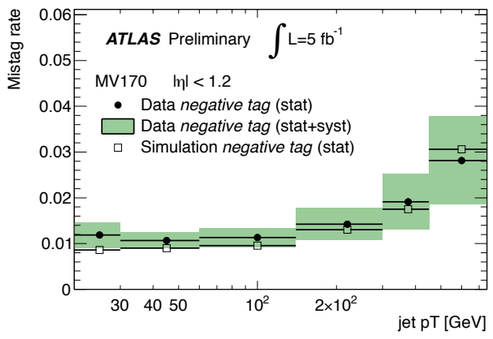




Measuring Light Jet Efficiency

Displaced vertices can be misidentified resulting in the mistagging of light jets. The appearance of these vertices is expected to be symmetric about the primary vertex, whereas true secondary vertices have an asymmetry. Reversing the signed decay length and impact parameters provides negatively tagged events which can be used to estimate the negative tag rate on a sample mainly made of light jets which can be extrapolated to get the mistag rate.





Combination Procedure

- A maximum likelihood fit on the product of constrained Gaussian probability density functions is performed in all transverse momenta and pseudo-rapidity bins to identify the scale factor which gives the best simulation to data correction.
- The combination correlates relevant systematic uncertainties between the different calibration methods. The final b-tag scale factors can then have these components of systematic uncertainties varied individually at the physics analysis level to fully propagate uncertainties.

Future Results and Taggers

For 8 TeV, calibration procedures are being carried out which have produced preliminary results compatible with the corresponding 7 TeV results.

Improvements to b-tagging algorithms have also been taking place, with improvements to MV1 and commissioning of new taggers aimed at improving c-jet rejection, as well as light jet rejection.

Ian Connelly, for the ATLAS Collaboration

ATLAS EXPERIMENT