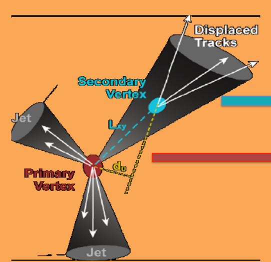
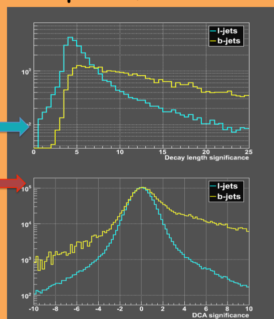
b-tagging performance and calibration with the ATLAS detector

b-quark jet identification is a crucial part of many physics analyses





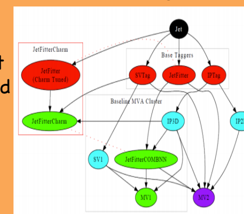
Begin by reconstructing the primary vertex (PV).

Impact parameter (IP): Extrapolate trajectories of particles in the jet towards PV and look for cases when several tracks are significantly displaced from the PV. They are candidates for b-decay (b-d) products.

Secondary vertex (SV): Construct the common point of origin for particles in the jet and see if this point is significantly displaced from PV.

Many different algorithms are used for efficient reconstruction of SV and large IP of jet-associated tracks:

- SV0/SV1: b-d vertex
- IP3D: b-d track impact
- JetFitter: reconstructed b&c decay vertices
- MV1: JetFitter+SV1+IP3D (combined in a NN)

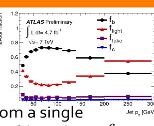


For physics analyses the performance of each b-tagging algorithm needs to be measured in data.

CALIBRATION METHODS: The results are provided as scale factors correcting the efficiency in Monte Carlo simulations to that measured in data. Scale factors are parameterized as functions of jet transverse momentum and pseudorapidity.

b-jet tagging efficiency calibration: ttbar based methods

- Using ttbar events (both dilepton and lepton+jets channels). Highly enriched in b-jets. Used for calibration in the whole range of jet pT's



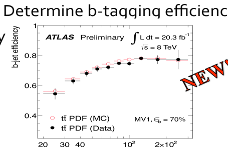
Kinematic selection, Tag-and-probe

In the kinematic selection, the b-tagging efficiency can be extracted from a single equation for the fraction of tagged leading jets in data: $f_{tagged} = f_b \varepsilon_b + (1 - f_b)\varepsilon_l$, where f_b is the fraction of real b-jets in the selected jet sample and ε_l is the light efficiency taken from simulation

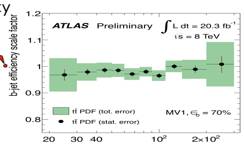
- Tag-and-probe method helps to enrich the sample with b-jets:
  - Measure fraction of events with tagged leading jet
  - Determine b-tagging efficiency

PDF

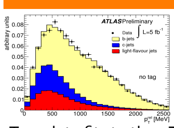
- PDF method - applied to very pure ttbar dilepton sample:
  - Exploit the event-by-event kinematic correlations between jets to improve precision



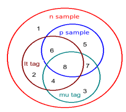
NEW!



muon based methods

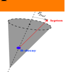


- Use events with muons in jets – enriched with semileptonic b-hadron decays
- Two methods have been developed:



pTrel

Template fits to the pTrel distribution are used to estimate the different flavor fractions.



System 8

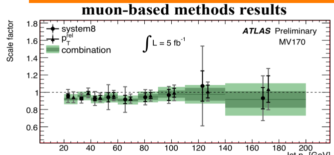
The system8 method uses uncorrelated selection criteria to construct a system of eight equations based on number events surviving any given subset of these criteria. Three cut criteria:

1) the requirement pTrel of the muon

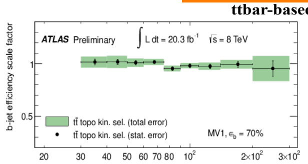
2) the lifetime tagging criterion under study

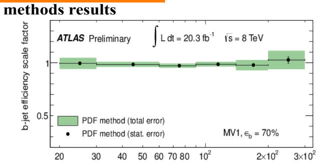
3) a second jet in the event was tagged by another tagging algorithm

muon-based methods results



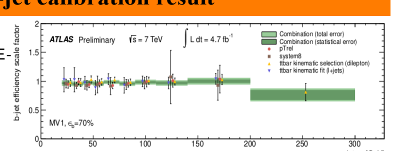
ttbar-based methods results





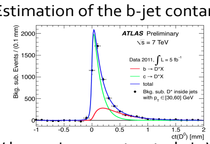
Combined b-jet calibration result

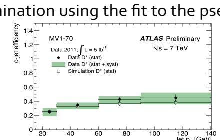
The combination uses bin by bin, a BLUE-like method incorporating the full information on correlations between individual results.

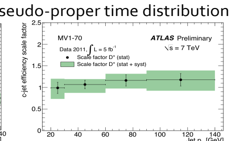


c-jet tagging efficiency calibration: D* method / W+c method

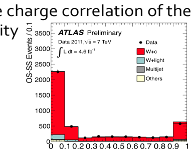
- Two methods: On a sample enriched with D* / W bosons produced in association with c-jets
  - D^{*+} mesons reconstructed in the exclusive decay $D^{*+} \rightarrow D^0(\rightarrow K^-\pi^+)\pi^+$
  - Estimation of the b-jet contamination using the fit to the pseudo-proper time distribution

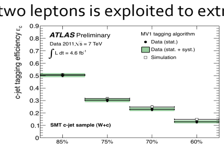


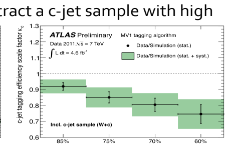




- W boson is reconstructed via W→eν decay
- The charge correlation of the two leptons is exploited to extract a c-jet sample with high purity



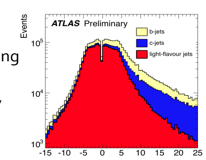




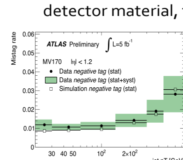
Light jet mistag rate calibration: negative tag method

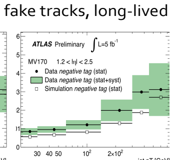
Negative tag method: Difficult to measure the mistag rate in data directly (can't prepare a data sample free of heavy flavor)

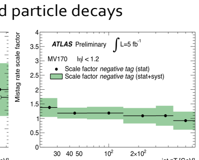
Instead, measure inclusive negative tag rate (calculated by reversing track impact parameter and decay length significance signs).

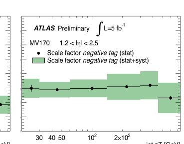


- Mistag rate: fraction of the light flavor jets identified as b-jets by a tagging algorithm
- Measured on dijet data:
  - Measure the inclusive negative tag rate
  - Correct for the contribution from heavy flavor, interaction in the detector material, fake tracks, long-lived particle decays





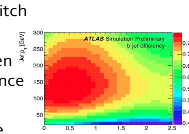




Future b-tagging performance

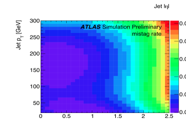
After the two-year shutdown (2013-2015) is over, the LHC will switch to 14 TeV of the center-of-mass energy.

The ATLAS tracker has been upgraded - a new layer (IBL) has been installed. The work is ongoing to evaluate the detector performance with the new layout.



ATLAS will operate this tracker during the High Luminosity Large Hadron Collider (HL-LHC) stage, accumulating a total integrated luminosity of 3000 fb^{-1} after ten additional years running.

Tagging parameterizations derived on MC are used by physics analyses to estimate the HL-LHC ATLAS performance.



A real challenge for b-tagging at HL-LHC is a large number of pp interactions per bunch crossing (140 in average, 200 in peak).

Dmitri Sidorov, Oklahoma State University
on behalf of the ATLAS collaboration