Measurement Of The *b*-tagging Efficiency Using Multijet Events In ATLAS

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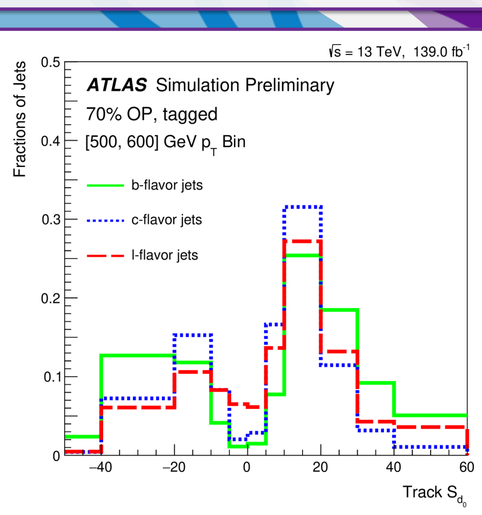
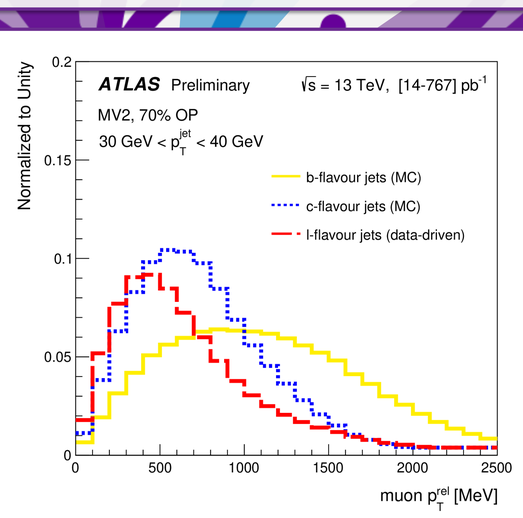
1.Introduction

- The identification of jets containing *b*-hadrons (***b*-jets**) is important to many analyses performed in ATLAS.
- Multivariate algorithms are trained on **Monte Carlo** (MC) samples to identify *b*-jets.
- The performance in data must be well understood to perform **precision measurements and searches**.





2.$t\bar{t}$ Calibrations [1]

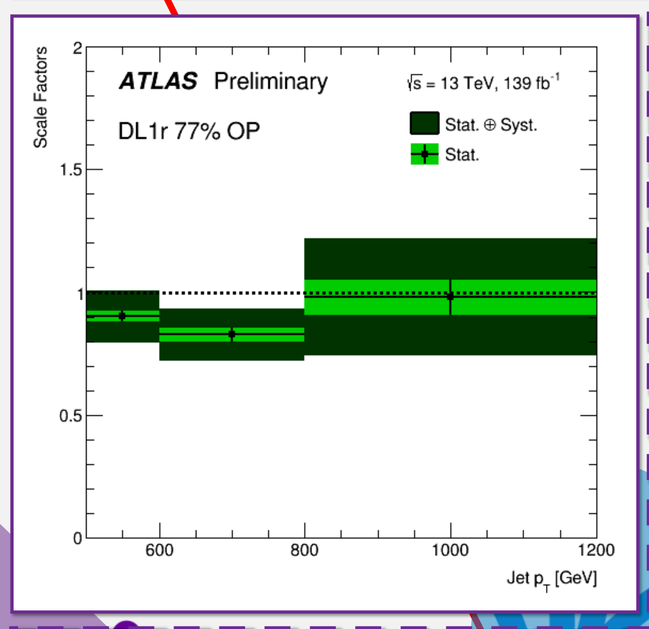
- The baseline method for measurement of the *b*-tagging efficiency uses dilepton $t\bar{t}$ events.
  - Calibration relies on assumption that top-quark decays exclusively by $t \to Wb$.
  - Rapidly falling p_T spectrum results in calibration not being applicable above 400 GeV.
  - Precision at low jet p_T limited by $t\bar{t}$ modelling uncertainties reaching 8-10%.

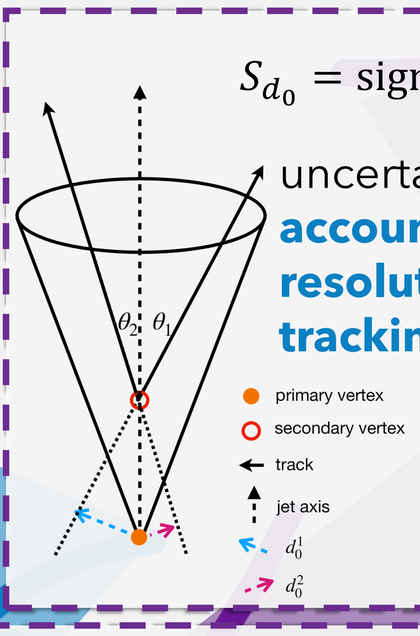
3.Multijet Calibrations

- Calibrations performed using **multijet** events are **orthogonal to $t\bar{t}$ calibrations**.
- Calibrations subject to different systematic uncertainties.
- Larger cross section of $b\bar{b}$ events gives greater statistical precision at the same luminosity.
  - Allows for calibration up to a jet p_T of 1.2 TeV.
  - Improved precision at low jet p_T.

4.Semi-leptonic Decays

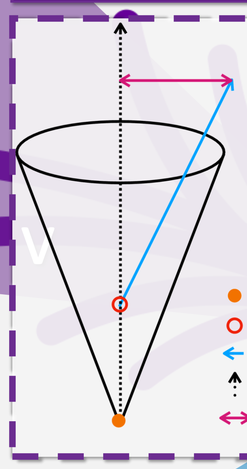
- Semi-leptonic events contain the decay $b \to \mu + X$
  - $BR(b \to \mu + X) = 20\%$
- Muons are well reconstructed, provides good resolution on variables used to perform calibrations.
- Both the **muon in jet** and ***b*-tag** enhance *b*-jet contribution in selected sample.





$$S_{d_0} = \text{sign} \times \frac{d_0}{\sigma_{d_0}}$$

uncertainty **accounts for resolution of tracking**.



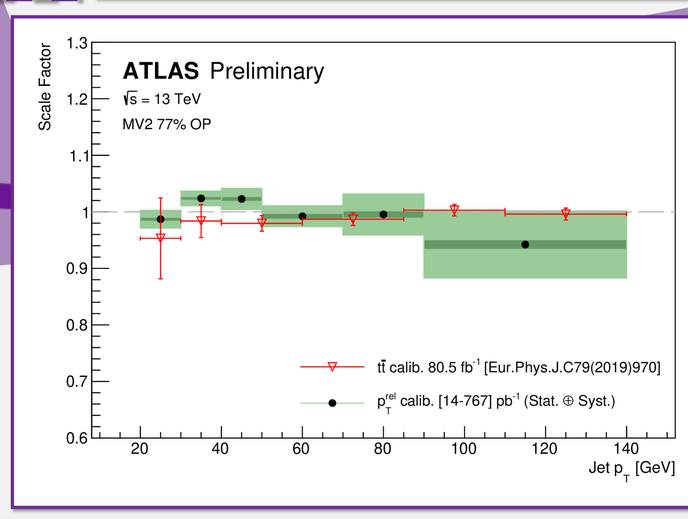
- Due to large mass of *b*-hadrons the decay products have more momentum in the hadrons rest frame.
- p_T^{rel} defined as the momentum of the muon transverse to the jet+muon axis.

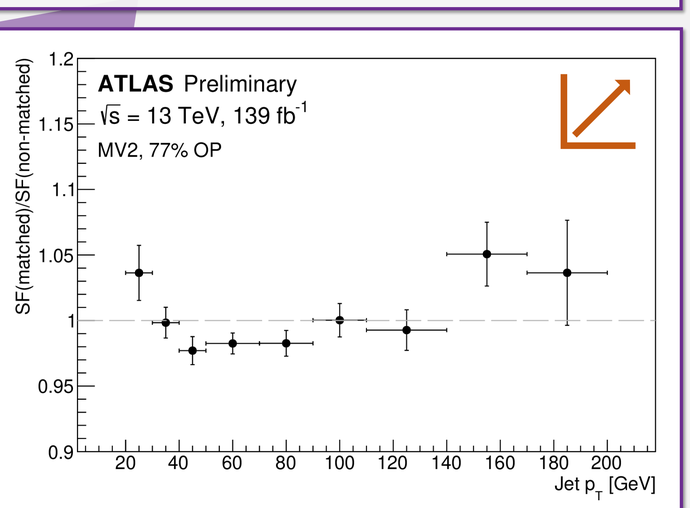
5.Calibration Strategy

- Both Calibrations use **template fitting method**.
- Events selected must pass a muon-in-jet requirement.
- Fraction of events containing *b*-jets enhanced by requiring at least one jet tagged at 85% OP
  - Calibration performed on remaining jets in event.
  - Enhances amount of *b*-jets as commonly produced in $b\bar{b}$ pairs.

6.High p_T Calibration [2]

- Uses **signed transvers impact parameter significance** (S_{d_0}) in template fit.
- Events selected using **un-prescaled single jet trigger**.
- Uncertainty on result dominated by systematic uncertainties related to:
  - Multijet event modelling.
  - Track reconstruction.





7.Muon p_T^{rel} Calibration [3]

- Uses muon p_T^{rel} in template fit.
- Events selected using pre-scaled muon-in-jet trigger.
- Dominant uncertainties from modelling in the simulation:
  - At low jet p_T modelling of the **muons momentum in the *b*-hadrons rest frame** (p^*).
  - Above 70 GeV modelling of **jets containing two *b* or *c*-hadrons**.
- Scale factors **extrapolated from semi-leptonic to inclusive** *b*-hadron decays.
  - Uses **tag-and-probe** method on dilepton $t\bar{t}$ events.
  - Ratio of SF derived with muon matched to jet to events without this.
- Calibration is a good candidate to assess the b-tagging performance with **a small integrated luminosity** (at the start of Run III for example).

References:
[1] ATLAS Collaboration, "ATLAS b-jet identification performance and efficiency measurement with $t\bar{t}$ events in pp collisions at $\sqrt{s} = 13\ TeV$", Eur. Phys. J. C 79 (2019) 970
[2] ATLAS Collaboration, "Measuring the b-jet identification efficiency for high p_T jets using multi-jet events in proton-proton collisions at $\sqrt{s} = 13\ TeV$ recorded with the ATLAS detector", ATL-PHYS-PUB-2022-010
[3] ATLAS Collaboration, "Measurement of the b-jet identification efficiency with the p_T^{rel} method in multi-jet events using pp collisions at $\sqrt{s} = 13\ TeV$ with the ATLAS Detector", ATL-PHYS-PUB-2022-025

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