Performance and calibration of quark/gluon jet taggers using 140 fb^{-1} pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

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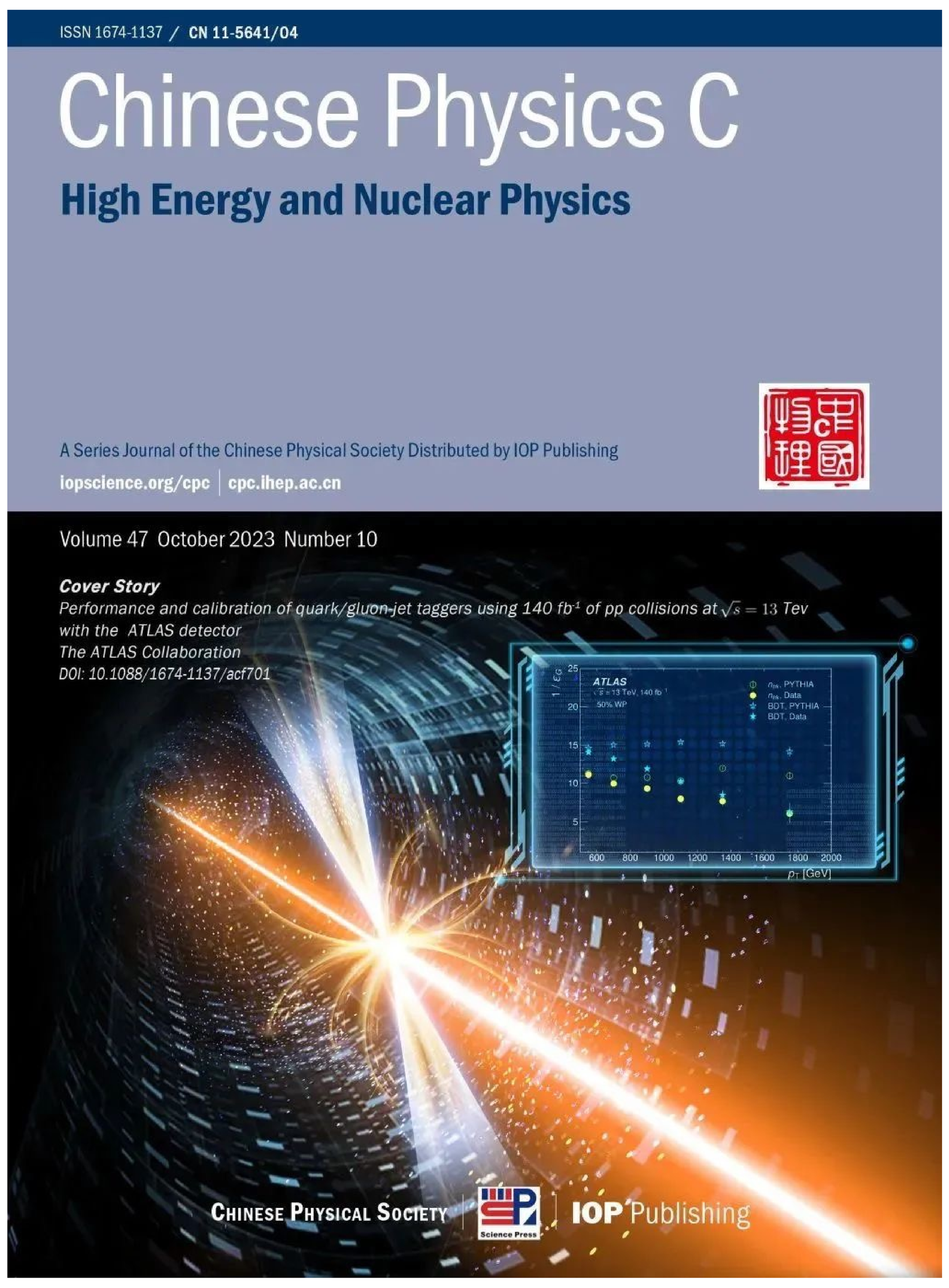
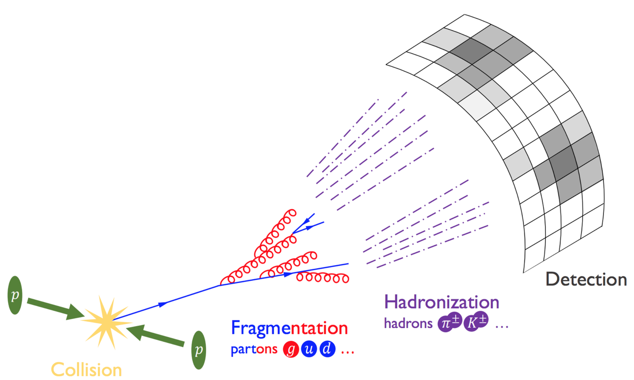
Abstract

The identification of jets originating from quarks or gluons, often referred to as quark/gluon tagging, plays an important role in various physics analyses at the Large Hadron Collider. In this analysis, two taggers are studied: one tagger is based on requirements on the number of inner-detector tracks associated with the jet, and the other combines several jet substructure observables using a boosted decision tree. A method is established to determine the quark/gluon fraction in data, by using quark/gluon-enriched subsamples defined by the jet pseudorapidity. Differences in tagging efficiency between data and simulation are provided for jets with transverse momentum between 500 GeV and 2 TeV and for multiple tagger working points.



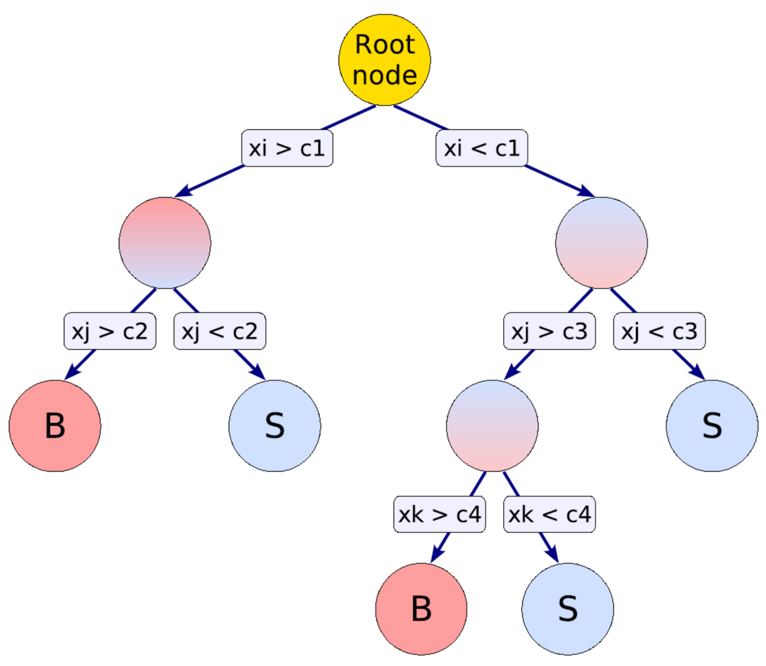


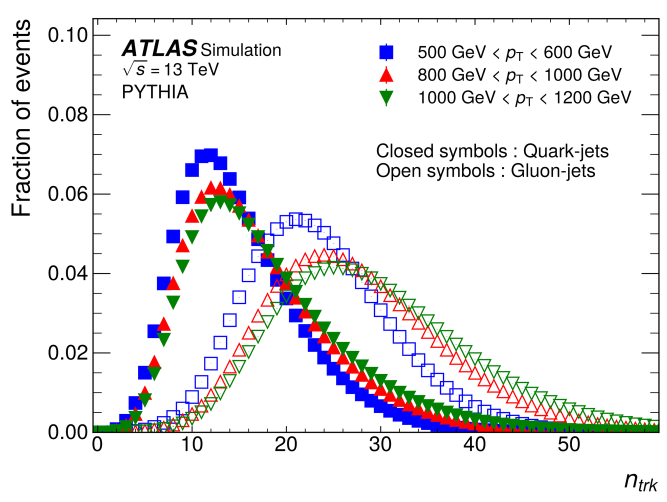
Event Selection

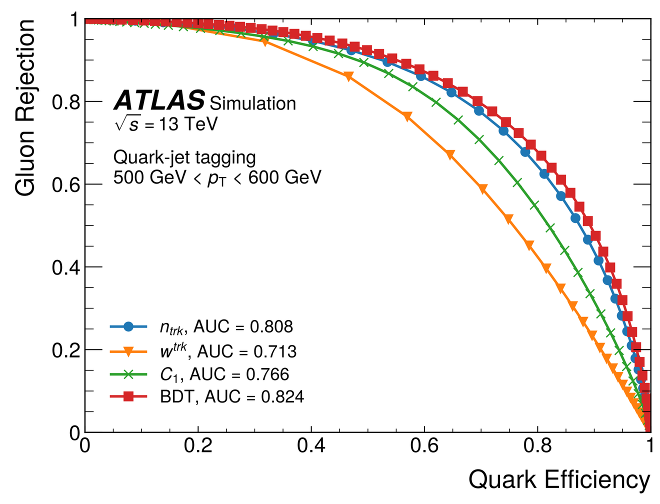
Selection	Multi-jet sample
Trigger	HLT_j420
Number of jets	≥ 2
$p_{\mathrm{T}}(j_1)$	> 500
$p_{\mathrm{T}}(j_2)$	> 500
$p_{\mathrm{T}}(j_1)/p_{\mathrm{T}}(j_2)$	< 1.5
$\lvert\eta(j_1)\rvert$	< 2.1
$\lvert\eta(j_2)\rvert$	< 2.1
Target parton	Quark(Higher $\lvert\eta\rvert$) or Gluon (Lower $\lvert\eta\rvert$)

Tagger definitions

- The number of tracks (N_{trk}) in a jet is used to define a single-variable q/g tagger.
- A brand new tagger based on Boosted Decision Trees (BDT) is built, using the information coming from the jet p_{T}, N_{trk}, track width (W_{trk}), and two-point energy correlation function ($C_1^{\beta=0.2}$), which takes into account the energy distribution within the jet.







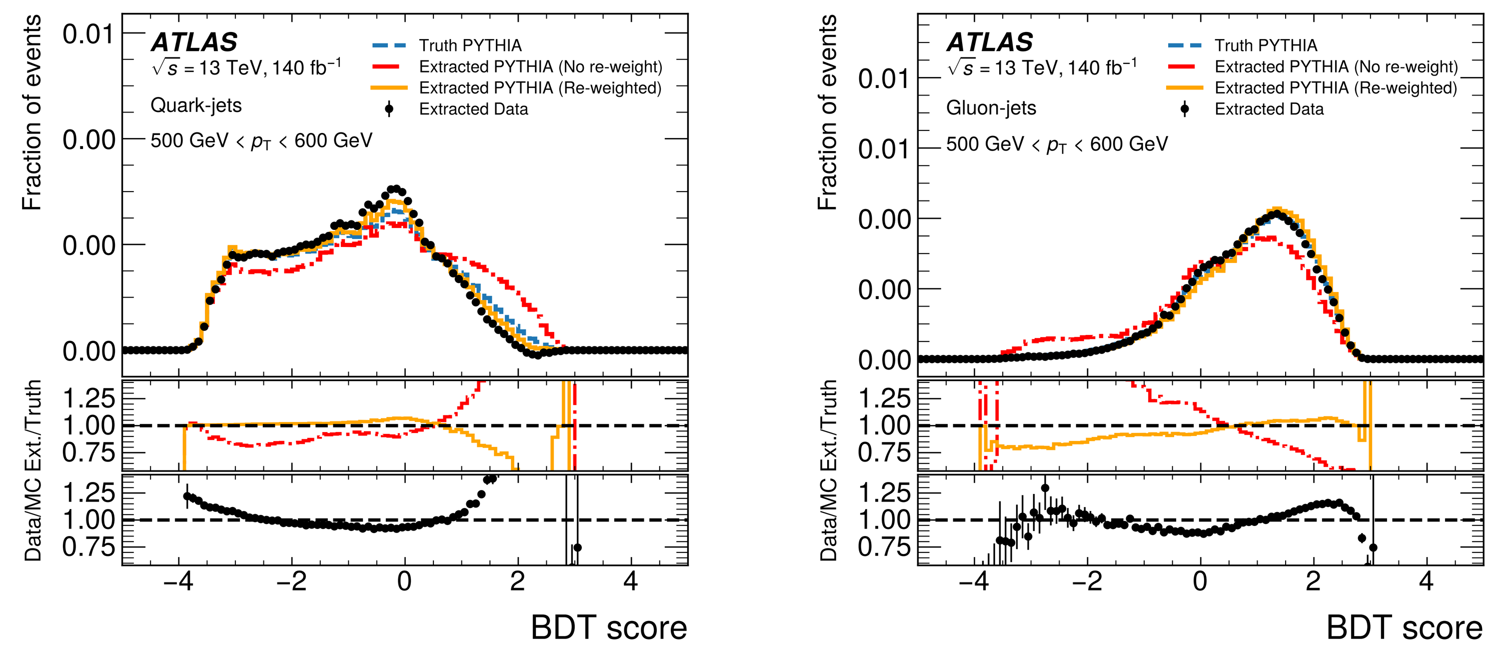
Matrix method

To measure the performance of the q/g taggers under study, samples containing solely quark-jets or solely gluon-jets are needed. To extract the shape of q/g tagging variables for quark- and gluon-jets in data, a method that exploits samples with different q/g fractions is used, called the matrix method.

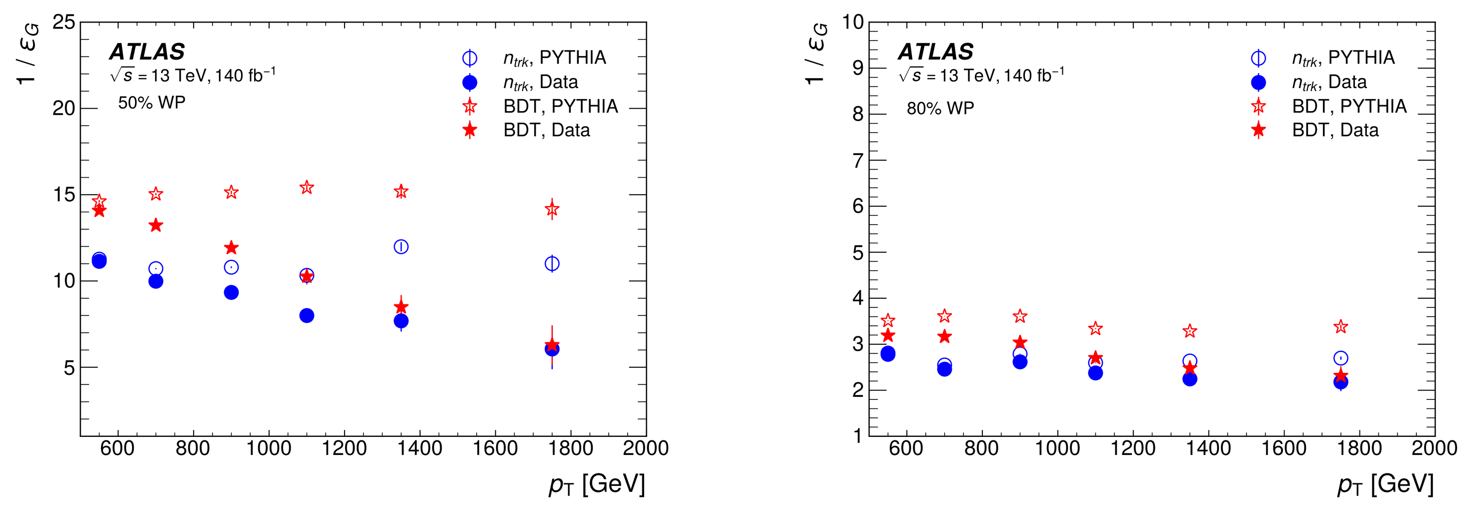
In the matrix method, the distribution of a jet variable x for forward jets, $p_F(x)$, and for central jets, $p_C(x)$, can be written as :

$$\begin{pmatrix} p_F(x) \\ p_C(x) \end{pmatrix} = \underbrace{\begin{pmatrix} f_{F,Q} & f_{F,G} \\ f_{C,Q} & f_{C,G} \end{pmatrix}}_{\equiv F} \begin{pmatrix} p_Q(x) \\ p_G(x) \end{pmatrix}. \qquad (1)$$

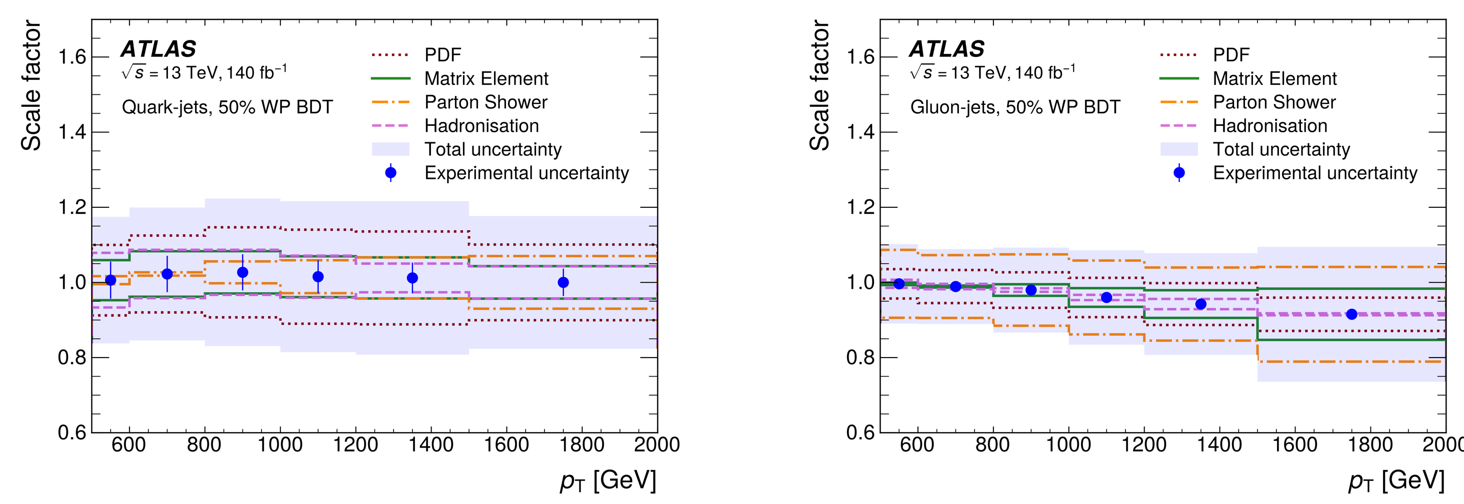
Here $p_Q(x)$ and $p_G(x)$ are the distributions of the variable x for pure quark- and gluon-jets, respectively, and the matrix F contains the fractions of quark- or gluon-jets in the samples of jets in the forward/central region. Such fractions are taken from MC simulation. The matrix method allows the extraction of $p_Q(x)$ and $p_G(x)$ by the inversion of matrix F.



Results



The N_{trk}-only tagger achieved a gluon-jet rejection rate of approximately 90% at a fixed quark-jet efficiency (WP) of 50%, while the BDT-tagger slightly outperformed it with a rejection rate of around 93%.



The scale factors are measured in different jet-p_{T}intervals and are found to range from 0.92 to 1.02, with a total uncertainty of around 20% which increases at higher p_{T}. The main source of uncertainty comes from the different modelling choices in MC simulation and amounts to approximately 18% for both taggers.

Conclusion

The performance of N_{trk}- and BDT-taggers for quark- and gluon-initiated jets is studied. A matrix method, incorporating data from quark-enriched and gluon-enriched samples in dijet events (500 GeV - 2 TeV p_{T}), estimates the tagging variables' distribution for both jet types. The variables align well with the MC predictions, showing less than 25% uncertainty across various regions.

The q/g taggers developed in this study and the measurement of their SFs will benefit various analyses such as SM measurements that rely on the correct identification of jet origins, or new physics searches by enhancing their sensitivity to the presence of new particles.

References

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[3] ATLAS Collaboration. Performance and calibration of quark/gluon-jet taggers using 140 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. 7 2023.

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