ATLAS Note

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Jet Observables using Subjet-assisted Tracks

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This note presents the details of the Monte-Carlo studies on the subjet-assisted oberservables for groomed large-radius jet. In particular the observables for the Energy Correlation Functions and n-Subjettiness variables used by the ATLAS collaboration, C2, D2, τ_{21} and τ_{32} are discussed using subjet-assisted tracks; the mass observable contructed with this technique, m^{TAS}, is presented and discussed with a modified four-momentum prescription. In all the variables studied, large improvement have been found using this novel techniques, the first ones evaluating in terms of QCD event rejection in W/Z boson, top quark and Higgs boson tagging; the second one in terms of precision reconstruction of the large-radius jet mass.

Contents

1 Introduction

Jets are collimated streams of particles resulting from quarks and gluons fragmentation and hadronization. The distribution of energy inside a jet contains information about the initiating particle. When a massive particle such as a top quark, Higgs boson or W/Z bosons is produced with significant Lorentz boost and decays into quarks, the entire hadronic decay may be captured inside a single jet. The mass of such jets (jet mass) is one of the most powerful tools for distinguishing massive particle decays from the continuum multijet background; the Energy Correlation Functions and n-Subjettiness C2, D2, τ_{21} and τ_{32} provide an ad-hoc tool pupusely developed for the multijet background and constitue a fundamental part of many for boson taggers. This note documents the so-called subjet-assisted techniques with the ATLAS detector *insref*. The track-assisted subjet mass m^{TAS} definition is presented and confronted with the standard development in ATLAS, m^{comb} and m^{TA}. Energy Correlation Functions and n-Subjettiness with the modified subjet-assisted technique is presented and confronted with the standard one in ATLAS. The note ends with conclusions and future outlook in *insref*.

2 ATLAS detector

ATLAS (A Toroidal ApparatuS) is a multi-purpose particle detector with nearly 4π coverage in solid angle. A lead/liquid-argon sampling electromagnetic calorimeter is split into barrel ($|\eta| < 1.5$) and end-cap ($1.5 < |\eta| < 3.2$) sections. A steel/scintillating-tile hadronic calorimeter covers the barrel region ($|\eta| < 1.7$)

ATLAS	Description and performance
Magnetic field	2 T solenoid; 0.5 T toroid barrel and 1 T toroid end-cap
Tracker	Inner detector: IBL, Silicon pixel and strips, TRT $\sigma_{p_T}/p_T \simeq 5 \times 10^{-4} p_T \otimes 1\%$
EM calorimeter	EMB, EMEC and pre-sampler (Liquid Argon and lead) $\sigma_E/E \simeq 10\%/\sqrt{E} \otimes 0.7\%$
Hadronic calorimeter	Tile (Fe and scintillating tiles) and HEC (Cu and LAr) $\sigma_E/E \simeq 50\%/\sqrt{E} \otimes 3\%$
Muons	Inner detector and muon spectrometers $\sigma_{p_T}/p_T \simeq 2\%$ at 50 GeV $\sigma_{p_T}/p_T \simeq 10\%$ at 1 TeV
Trigger	L1 and HLT (L2 and EF) Rates from ~40 MHz to ~75 kHz (L1) and to ~200 Hz (HLT)

and two end-cap copper/liquid-argon sections extend to higher pseudo-rapidity ($1.5 < |\eta| < 3.2$). Finally, the forward region ($3.1 < |\eta| < 4.9$) is covered by a liquid-argon calorimeter with Cu (W), absorber in the electromagnetic (hadronic) section. Inside the calorimeters there is a 2 T solenoid that surrounds an inner tracking detector which measures charged particle trajectories covering a pseudo-rapidity range $|\eta| < 2.5$ with pixel and silicon micro-strip detectors (SCT) and additionally which covers the region $|\eta| < 2.0$ with a straw-tube transition radiation tracker (TRT). Outside the calorimeter there is a muon spectrometer: a system of detectors for triggering up to $|\eta| < 2.4$ and precision tracking chambers up to $|\eta| < 2.7$ inside a magnetic field supplied by three large superconducting toroid magnets.

A breakdown of the ATLAS sub-detector performance is shown in Table **??**.

3 Monte Carlo Samples

refraseMT The samples used are divided into two main groups: SM background and beyond SM signal. The SM background includes the QCD multijet samples, produced with a falling p_T spectrum. The beyond SM signals are $W' \to WZ \to q\bar{q}'q\bar{q}$, $Z' \to t\bar{t}$ (top quarks considered in the full hadronic channel $(t \to W(\to q\bar{q}')b)$) and RS-Graviton $\to hh \to b\bar{b}b\bar{b}$, i.e. final states have only jets in all the samples. The details of the samples are given in Table 1; the masses considered span from 0.5 to 5 TeV to improve and diversify the kinematic space covered.

A set of kinematic distributions for the W' is shown in Figure **??**: on the left the p_T distribution where the kinks correspond to the Jacobian peak of the mass considered and the η distribution on the right. The green dots represent the distribution before the selection, which is $p_T > 250$ GeV and $|\eta| < 2.0$ and the red dots after this selection. This selection typical for many searches for BSM physics. All the other samples and the background can be found in the Appendix. In what follows, it will also be used the nomenclature

Process	ME Generator & Fragmentation	ME PDFs	UE Tune	Resonance Masses
QCD multijet	Pythia 8	NNPDF23LO	A14	N/A
$W' \to WZ$	Pythia 8	NNPDF23LO	A14	1.5, 2.5, 3, 4, 5 TeV
$Z' \to t\bar{t}$	Pythia 8	NNPDF23LO	A14	1.5, 1.75, 2.5, 3, 4, 5 TeV
$G_{RS} \to hh(\to b\bar{b})$	Pythia 8	NNPDF23LO	A14	0.5, 1, 1.5, 2, 2.5, 3 TeV
$W' \to \tilde{W}\tilde{W}$ with $m_{\tilde{W}} = m_t$	Pythia 8	NNPDF23LO	A14	1.5, 2.5, 3, 4, 5 TeV

Table 1: Overview of the Monte Carlo Samples used. The first line shows QCD standard model process, the second, the third and the forth the beyond SM samples considered; the last line the "massive W/Z" sample.

boosted W/Z for the W' sample, *boosted tops* for the Z' sample, *boosted Higgs* for the G_{RS} sample and *massive W* for the $W' \to \tilde{W}\tilde{W}$ with $m_{\tilde{W}} = m_t$. *refraseMT*

4 Object Definition

4.1 Large-radius jet mass definitions

4.2 Energy Correlation Functions

ECF Test

4.3 n-Subjettiness

5 Track-assisted subjet mass

6 Energy Correlation Functions and n-Subjettiness

7 Conclusions

Appendix

In a paper, an appendix is used for technical details that would otherwise disturb the flow of the paper. Such an appendix should be printed before the Bibliography.

List of contributions

Auxiliary material

In an ATLAS paper, auxiliary plots and tables that are supposed to be made public should be collected in an appendix that has the title 'Auxiliary material'. This appendix should be printed after the Bibliography. At the end of the paper approval procedure, this information can be split into a separate document – see `atlas-auxmat.tex`.

In an ATLAS note, use the appendices to include all the technical details of your work that are relevant for the ATLAS Collaboration only (e.g. dataset details, software release used). This information should be printed after the Bibliography.