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ATLAS Physics Objects: Status and Performance at 13 TeV

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The ATLAS experiment is designed to study the proton-proton collisions produced at the Large Hadron Collider at CERN. During the early Run 2 data-taking period, the ATLAS trigger and data acquisition system has been used to collect a data sample useful to study the initial performance of the detector and physics objects at the new center-of-mass-energy of 13 TeV. After all the upgrade work accomplished during the Long Shutdown 1 period, many improvements are expected among which a higher b-jet tagging efficiency for the same level of light-jet rejection as in Run 1. First analysis of data shows an overall good behaviour of the detector and a reasonably well understood physics objects reconstruction.

This document gives an overview of the identification and reconstruction efficiencies, resolution and performance of the ATLAS physics objects achieved in the proton-proton collisions collected between spring and summer 2015.

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1. Introduction

Between spring and summer 2015, the ATLAS experiment [1] recorded data at a center-of-mass energy of 13 TeV, initially with bunch-crossing time intervals of 50 ns and 25 ns afterwards. A total integrated luminosity of 133 pb^{-1} and 127 pb^{-1} were recorded during the 50 and 25 ns running periods, respectively, until middle of September, with an overall data taking efficiency close to 90%. During these periods, the average number of simultaneous inelastic proton-proton interactions per bunch crossing, commonly known as pileup, was 20 and 17, respectively. The peak luminosity achieved so far did not exceed the Run 1 peak luminosity. This paper focuses on a general description of various physics objects performance studied using different samples of this initial Run 2 data.

2. The ATLAS detector

The ATLAS detector at the Large Hadron Collider covers almost the entire solid angle around the nominal interaction point. It consists of an inner tracking detector surrounded by a superconducting solenoid magnet producing a 2T axial magnetic field; electromagnetic and hadronic calorimeters providing accurate energy and momentum measurements; and an external muon spectrometer incorporating three large toroid magnet assemblies.

Many improvements were performed during the shutdown period between Run 1 and Run 2, the so-called Long Shutdown 1 (LS1), to consolidate the detector and decrease the execution time of the trigger and reconstruction software, among which a fourth layer in the pixel detector, the so-called Insertable B-Layer (IBL) [2], was installed in ATLAS. The IBL was inserted inside the existing pixel detector at a radius of about 3.3 cm from the beam line while the beam pipe was replaced. Thanks to this new layer and its pixels high granularity, the track impact parameter resolution is expected to improve. By analyzing the data taken in 2015, an improvement of close to a factor of 2 with respect to Run 1 is observed to its longitudinal or transverse components for low p_{T} tracks, as shown in Fig. 1 [3].

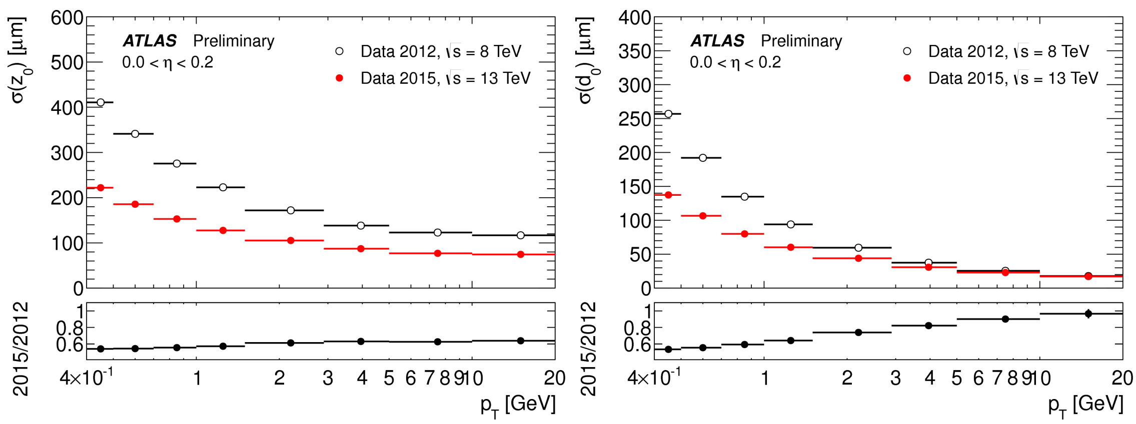

Figure 1: Improvement on the longitudinal (left) and transverse (right) track impact parameter resolution as a function of track transverse momentum observed in data taken in 2015 with respect to 2012 data [3].

3. Electron and muon performance

Three different electron identification criteria are defined using an updated likelihood function obtained after combining various discriminating variables like shower shapes, track properties and track to cluster matching [4]. Electron identification efficiencies are measured using a tag-and-probe method in a selected data sample of Z boson candidates decaying into a pair of electrons. They vary between 75% and 95% depending on the electron candidate's energy, with an uncertainty of 3 to 5% [5]. Differences in efficiency observed between data and Monte Carlo (MC) simulations are corrected by in-situ calibration.

Similarly, various reconstruction methods are used to identify muons. Samples of selected J/ψ and Z event candidates are used to determine the muon reconstruction efficiency for low and high transverse momentum muons. The left plot in Fig. 2 shows the reconstruction efficiency for muons identified in the central region of the detector using the medium criteria as a function of the muon transverse momentum for both data and Monte Carlo. The muon momentum scale is understood with a precision of $\sim 0.2\%$ [6].

Important to top physics is the leptons isolation. Both track and calo-based isolation definitions have been studied. The calo-based electron isolation is defined as the sum of clusters' transverse energies in a cone of radius of 0.2 around the electron after excluding cells corresponding to the electron, and is shown on the right plot of Fig. 2 for both data and MC simulation [7]. Isolation distributions for muons have also been studied and found to be in good agreement with simulation within the available event statistics [6].

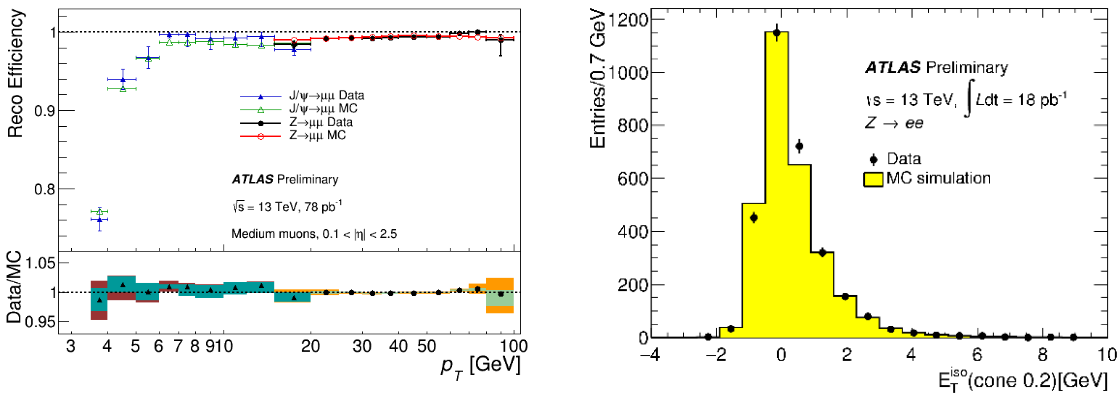

Figure 2: The muon reconstruction efficiency as a function of the muon's transverse momentum for both data and MC simulation is shown on the left. On the right, the electron isolation energy in a cone of radius of 0.2 is shown for both data and MC simulation [6, 7].

4. Jet and missing transverse energy performance

Jets play an important role in top quark physics. ATLAS reconstructs jets using the anti-*kt* algorithm with a radius parameter of 0.4 starting from topological clusters. Jets are calibrated after applying corrections as a function of their transverse momentum and pseudo-rapidity (defined in terms of the polar angle coordinate θ as $\eta = -\ln\tan(\theta/2)$) based on Monte Carlo simulations, as well as in-situ corrections from Run 1 data.

In- and out-of-time pile-up subtraction is applied based on a Jet Vertex Tagger discriminant [8]. Dedicated selections of good jets mainly coming from di-jets and of fake jets where events contain at least one jet with unbalanced transverse momentum are used to study the jets quality. Overall, a good agreement with Monte Carlo simulations is found. Various jet property variables are studied with a general good agreement apart from a few exceptions, already known from the Run 1 data analysis. Various properties of pixel and IBL hits on tracks inside the cones of reconstructed jets are compared between data and simulation. The left plot in Fig. 3 shows the number of IBL hits of tracks in jets with $p_{\mathrm{T}} > 150$ GeV as a function of ΔR(jet,track), the separation between the track and the jet axis. Good agreement between data and Monte Carlo is obtained [9]. Initial studies of large-R jets reconstruction show a good understanding of various jet sub-structure variables, promising to be useful for high p_{T} boson and top tagging.

The missing transverse energy uses selected calibrated hard objects to measure the missing transverse momentum in an event. Its soft term is reconstructed from detector signal objects not associated with any selected hard object. Both track and calo-based soft terms have been studied with the Run 2 data. While the track-based missing transverse energy from the hard objects is found to be robust in the presence of pileup, both the track and calo-based soft terms show a linear dependence on the number of primary vertices. Using a selected sample of Z decays into two muons, the distribution of missing transverse energy is compared with Monte Carlo simulation finding an agreement within 20% [10].

5. b-tagging and tau performance

The identification of jets originated from b-quarks (b-jets), commonly known as b-tagging, is very important for the ATLAS top physics program. Different algorithms making use of multi-variate discriminants were developed to identify b-jets in Run 1. During LS1, many algorithmic updates in the basic taggers and final multi-variate discriminant were performed. The performance of the new Run 2 multi-variate discriminant MV2c20 [11] has been studied and compared to the one used in Run 1, MV1. Its performance has been assessed by measuring the rejection of light-flavour jets as a function of the b-jet tagging efficiency. Monte Carlo simulation studies show that the rejection of light-flavour jets is expected to improve by a factor of four for a wide range of b-jet tagging efficiencies (shown on the right of Fig. 3), as a result of the installation during LS1 of the highly granular IBL.

The identification of hadronically decaying tau leptons has also been studied using the initial Run 2 data. Various selected data samples of minimum bias, di-jets, W or Z bosons plus jets and Z boson decays into two tau leptons have been used to study different discriminating variables. Reasonably good agreement with simulation has been achieved but further detailed studies with more data are needed.

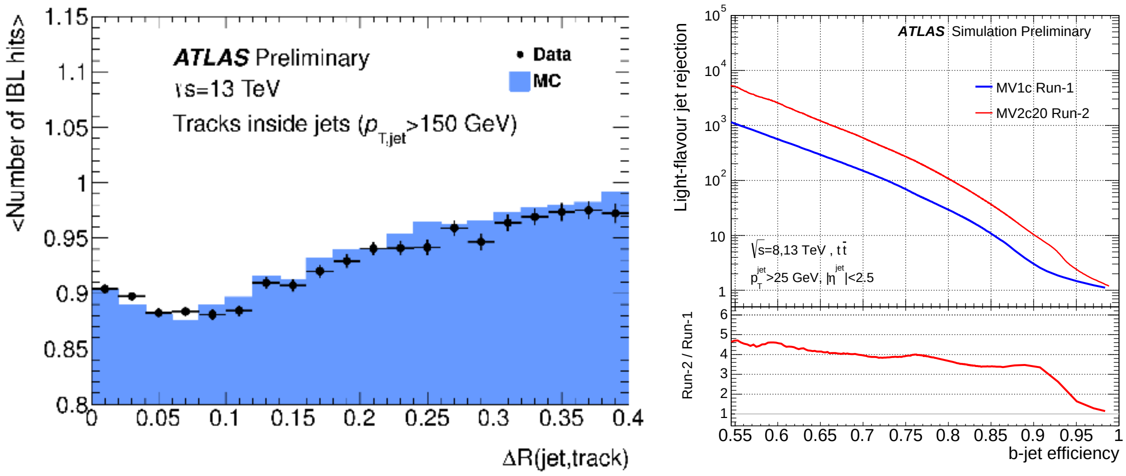

Figure 3: On the left, the number of IBL hits on track as a function of ΔR(jet,track) in data and simulation is shown for jets with $p_T > 150$ GeV. On the right, the comparison of the expected light-flavour jets rejection as a function of b-jet tagging efficiency for both MV1c and MV2c20, the b-jet tagging algorithms used in Run 1 and Run 2 respectively. The ratio of MV2c20 and MV1c rejections is shown at the bottom [9, 11].

6. Conclusions

During the initial data taken in Run 2, ATLAS acquired a sample of proton-proton collisions with high efficiency. A significant improvement on the impact parameter resolution with respect to Run 1 has been shown, thanks to the addition of a fourth layer in the pixel detector during the shutdown between Run 1 and Run 2. Initial studies of the ATLAS physics objects performance show a reasonably good agreement with Monte Carlo simulations. These studies pave the way for potential new discoveries during Run 2.

References

[1] ATLAS Collaboration, JINST 3 (2008) S08003.

[2] ATLAS Collaboration, CERN-LHCC-2010-013, ATLAS-TDR-19, http://cds.cern.ch/record/1291633. CERN-LHCC-2012-009, ATLAS-TDR-19-ADD-1, http://cds.cern.ch/record/1451888.

[3] ATLAS Collaboration, http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/IDTR-2015-007.

[4] ATLAS Collaboration, ATLAS-CONF-2014-032, http://cds.cern.ch/record/1706245.

[5] ATLAS Collaboration, ATL-PHYS-PUB-2015-041, http://cds.cern.ch/record/2048202.

[6] ATLAS Collaboration, ATL-PHYS-PUB-2015-037, http://cds.cern.ch/record/2047831.

[7] ATLAS Collaboration, http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/EGAM-2015-003/index.html.

[8] ATLAS Collaboration, ATLAS-CONF-2014-018, http://cds.cern.ch/record/1700870.

[9] ATLAS Collaboration, ATL-PHYS-PUB-2015-018, http://cds.cern.ch/record/2037683.

[10] ATLAS Collaboration, ATL-PHYS-PUB-2015-027, http://cds.cern.ch/record/2037904.

[11] ATLAS Collaboration, ATL-PHYS-PUB-2015-022, http://cds.cern.ch/record/2037697.