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Jet suppression and jet substructure in Pb+Pb and Xe+Xe collisions with the ATLAS detector

Martin Spousta
on behalf of the ATLAS Collaboration

Faculty of Mathematics and Physics, Charles University
V Holešovičkách 2, Prague 180 00, Czech Republic

Abstract

This short summary presents latest measurements of the nuclear modification factor, R_{AA}, for $R = 0.4$ jets in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ATLAS detector at the LHC. The analysis is performed over a large range of transverse momentum, up to $p_T = 1$ TeV, and differentially in jet p_T, rapidity, and collision centrality. The jet R_{AA} is measured also differentially in the jet mass, m, which provides new information on the dependence of the energy loss on the substructure of jets. Latest results by ATLAS on the dijet momentum balance in Xe+Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV are presented and compared to the same quantity measured in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. These recent measurements should help us understand mechanisms of parton energy loss and properties of hot and dense matter created in heavy-ion collisions.

Keywords: heavy-ion collisions, jet quenching, inclusive jet suppression, dijet asymmetry

1. Introduction

Jets and high-p_T hadrons produced in hard scattering processes provide an important probe of the properties of the quark gluon plasma created in high-energy nuclear (A+A) collisions. The products of the hard scattering evolve as parton showers that propagate through the medium and experience in-medium energy loss in a process referred to as “jet quenching”. This short paper summarizes selected recent jet quenching measurements performed using the ATLAS detector [1] at the LHC, namely the measurement of nuclear modification factor, R_{AA}, evaluated as a function of jet p_T, rapidity, collision centrality [2], and jet mass [3] and the new results on dijet momentum balance in Xe+Xe collisions [4].

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2. Inclusive jet suppression and jet mass

To quantitatively assess the impact of jet quenching effects on inclusive jets, the nuclear modification factor is measured. It is defined as

$$R_{\mathrm{AA}} = \frac{\frac{1}{N_{\mathrm{evt}}^{\mathrm{tot}}} \frac{\mathrm{d}^2 N_{\mathrm{jet}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}\Big|_{\mathrm{cent}}}{\langle T_{\mathrm{AA}} \rangle \frac{\mathrm{d}^2 \sigma_{\mathrm{jet}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}\Big|_{pp}}, \tag{1}$$

where N_{jet} and σ_{jet} are the jet yield in Pb+Pb collisions and the jet cross-section in *pp* collisions measured at the same center of mass energy per nucleon-nucleon collision, respectively. $N_{\mathrm{evt}}^{\mathrm{tot}}$ and $\langle T_{\mathrm{AA}} \rangle$ are the total number of Pb+Pb collisions within a chosen centrality interval and the nuclear thickness function, respectively.

Jet yields in Pb+Pb collisions and jet cross-sections in *pp* collisions are measured using 0.49 nb^{-1} of Pb+Pb collision data and 25 pb^{-1} of *pp* collision data collected at the same nucleon–nucleon centre-of-mass energy of 5.02 TeV in the year 2015 by the ATLAS detector. Jets, reconstructed using the anti-k_t algorithm [5] with radius parameter $R = 0.4$, are measured over the transverse momentum range of 40–1000 GeV in six rapidity intervals covering $|y| < 2.8$. The jet R_{AA} shows a strong suppression of jet yields measured in central Pb+Pb collisions. Figure 1 shows the R_{AA} evaluated as a function of p_{T} for central (0–10%) and mid-central (30–40%) collisions and compares the results from 5.02 TeV collisions to those measured in Pb+Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV [6]. The magnitude of R_{AA} increases with increasing jet transverse momentum, reaching a value of approximately 0.6 at 1 TeV in the most central collisions. The magnitude of R_{AA} is observed to be consistent with that reported for Pb+Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV in the kinematic region where the two measurements overlap. Not shown here is the quantification of centrality and rapidity dependence of the R_{AA}. The R_{AA} value is independent of rapidity at low jet p_{T}. For jets with $p_{\mathrm{T}} \gtrsim 300$ GeV a sign of a decrease with rapidity is observed. A comparison of the R_{AA} values with various theoretical predictions is also performed. All the models are capable of reproducing the general trends seen in the data. For $p_{\mathrm{T}} \lesssim 250$ GeV, the data agrees best with the SCET$_{\mathrm{G}}$ model [7, 8, 9, 10] with a specific value of the coupling strength between the jet and the medium, $g = 2.2$. For $p_{\mathrm{T}} \gtrsim 250$ GeV the LBT model [11] describes the data better. Disagreement between the data and the EQ model [12] using the parameters of the jet energy loss from 2.76 TeV Pb+Pb data can be explained as a consequence of stronger quenching in 5.02 TeV Pb+Pb collisions. For more details, see Ref. [2].

Jet cross-section in *pp* collisions and jet yields in Pb+Pb collisions are evaluated also as a function of m/p_{T} which allowed to calculate $R_{\mathrm{AA}}(m/p_{\mathrm{T}})$, which is summarized in Ref. [3]. The yields and cross-sections are reported for $R = 0.4$ anti-k_t jets with $|y| < 2.1$ and with p_{T} measured in the range of 126–500 GeV in Pb+Pb and *pp* collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. Calorimeter towers of size of 0.1×0.1 in $\eta \times \phi$ space are used as the jet constituents to calculate the jet mass. The measured distributions are fully corrected for jet response. The R_{AA} values show a suppression of jets that is consistent with suppression measured in the inclusive jet R_{AA} without significant dependence on m/p_{T}. This should provide a new information on the dependence of the energy loss on the substructure of jets.

3. Dijet asymmetry and jet quenching in Xe+Xe collisions

A short Xe+Xe run in 2017 provided the first heavy-ion collisions with nuclei lighter than Pb at the LHC. The possibility of studying jet quenching in collisions of nuclei lighter than Pb is attractive as the underlying event is smaller in the most central collisions where the collision geometry is the most symmetric. The decrease in the number of nucleons or the nuclear radius between Pb and Xe nuclei may be expected to affect the amount of jet quenching through a reduction in both the overall energy density and the path lengths of the hard-scattered partons in the medium.

The dijet asymmetry, defined as $x_{\mathrm{J}}^{\mathrm{meas}} = p_{\mathrm{T,1}}/p_{\mathrm{T,2}}$ with $p_{\mathrm{T,1}}$ and $p_{\mathrm{T,2}}$ being the leading and subleading jet transverse momentum, respectively, is measured in *pp* collisions at $\sqrt{s} = 5.02$ TeV, Xe+Xe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV, and Pb+Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The superscript 'meas' specifies that the dijet

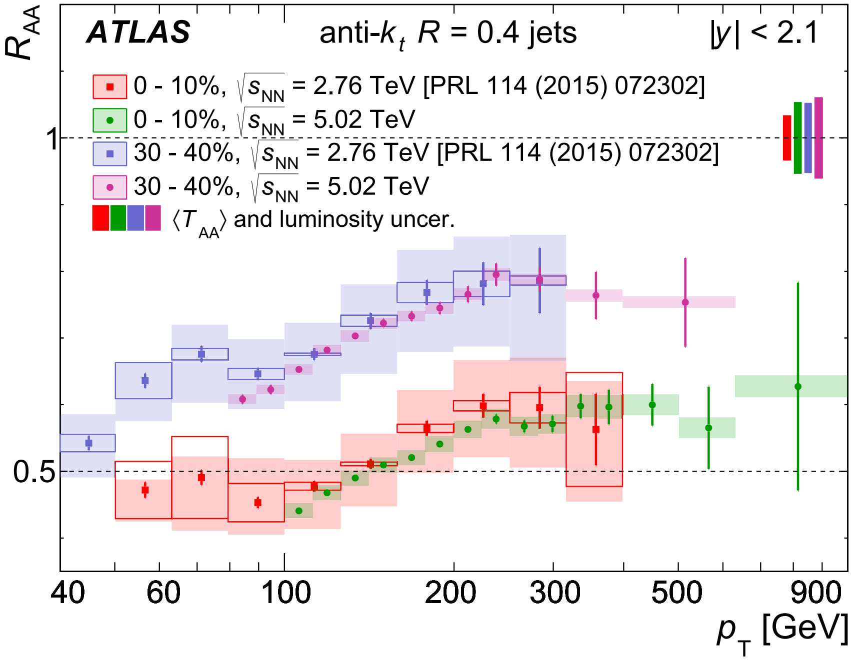

Fig. 1. The R_{AA} values as a function of jet p_T for jets with $|y| < 2.1$ in 0–10% and 30–40% centrality intervals compared to the same quantity measured in $\sqrt{s_{NN}} = 2.76$ TeV Pb+Pb collisions [6]. The error bars represent statistical uncertainties, the shaded boxes around the data points quantify bin-wise correlated systematic uncertainties. For $\sqrt{s_{NN}} = 2.76$ TeV measurement, the open boxes represent uncorrelated systematic uncertainties. The coloured shaded boxes at $R_{AA} = 1$ quantify the combined fractional $\langle T_{AA} \rangle$ and pp luminosity uncertainty. The horizontal size of error boxes quantifies the width of the p_T interval. Figure taken from [2].

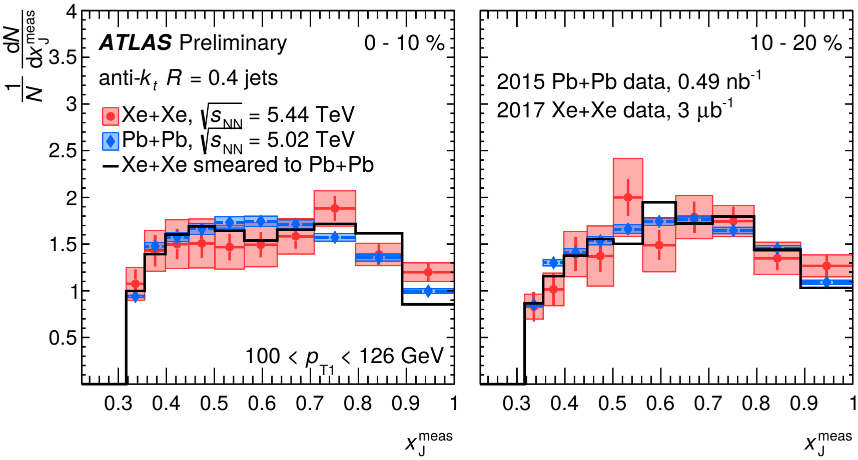

Fig. 2. The $1/N dN/dx_J^{meas}$ distributions for jet pairs with $100 < p_{T,1} < 126$ GeV in 0–10% and 10–20% centrality intervals. The Xe+Xe data are shown in circles, while the Pb+Pb distribution is shown for comparison in diamonds. Statistical uncertainties are indicated by the error bars while systematic uncertainties are shown with shaded boxes. The Xe+Xe systematic uncertainties include all of the JES and JER uncertainties on Xe+Xe data. The Pb+Pb systematic uncertainties include only the uncertainties that are uncorrelated between Xe+Xe and Pb+Pb collisions. The black line represents the inclusion of additional underlying event fluctuations based on the results of the fluctuations analysis. Figure taken from [4].

asymmetry is not corrected for resolution effects by the unfolding procedure. The measurement is performed differentially in $p_{T,1}$ and in collision centrality and total transverse energy deposited in forward calorimeter, ΣE_T^{FCal}. Figure 2 shows an example of x_J^{meas} distributions for two selections of the most central Xe+Xe and Pb+Pb collisions. In general, the x_J^{meas} distributions show a larger contribution of asymmetric dijets in the more central Xe+Xe collisions compared to that in *pp* data. This difference becomes less pronounced in more peripheral collisions and in 60–80% the Xe+Xe and the *pp* data are consistent. This trend is consistent with in-medium energy loss due to jet quenching and is also consistent with previous measurements of jet imbalance in Pb+Pb collisions [13]. The distributions in Xe+Xe are found to be consistent with Pb+Pb when compared in their respective centrality intervals indicating no significant dependence on the geometry of the event. They are also found to be consistent at fixed values of ΣE_T^{FCal}. For more details, see Ref. [4].

4. Summary

Jets represent an important tool allowing to access the information about the hot and dense medium created in heavy-ion collisions. Both inclusive jet yields and kinematic properties of dijet systems are observed to be modified in heavy-ion collisions compared to proton-proton reference. Precise measurement of inclusive jets in Pb+Pb collisions and new measurement of dijets in Xe+Xe collisions, both performed using the ATLAS detector at the LHC, should help us understand mechanisms of parton energy loss and properties of hot and dense matter created in heavy ion collisions.

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References

[1] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003. doi:10.1088/1748-0221/3/08/S08003.

[2] ATLAS Collaboration, Measurement of the nuclear modification factor for inclusive jets in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ATLAS detector, arXiv:1805.05635.

[3] ATLAS Collaboration, Measurement of $R = 0.4$ jet mass in Pb+Pb and pp collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ATLAS detector, ATLAS-CONF-2018-014.
URL `https://cds.cern.ch/record/2319867`

[4] ATLAS Collaboration, Charged hadron spectra and dijet p_T correlations measured in Xe+Xe collisions at $\sqrt{s_{NN}} = 5.44$TeV with the ATLAS detector, ATLAS-CONF-2018-007.
URL `https://cds.cern.ch/record/2318588`

[5] M. Cacciari, G. P. Salam, G. Soyez, The anti-k_t jet clustering algorithm, JHEP 04 (2008) 063. arXiv:0802.1189.

[6] ATLAS Collaboration, Measurements of the Nuclear Modification Factor for Jets in Pb+Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS Detector, Phys. Rev. Lett. 114 (7) (2015) 072302. arXiv:1411.2357, doi:10.1103/PhysRevLett.114.072302.

[7] Y.-T. Chien, A. Emerman, Z.-B. Kang, G. Ovanesyan, I. Vitev, Jet quenching from QCD evolution, Phys. Rev. D 93 (7) (2016) 074030. arXiv:1509.02936, doi:10.1103/PhysRevD.93.074030.

[8] Y.-T. Chien, I. Vitev, Towards the understanding of jet shapes and cross sections in heavy ion collisions using soft-collinear effective theory, JHEP 05 (2016) 023. arXiv:1509.07257, doi:10.1007/JHEP05(2016)023.

[9] I. Vitev, S. Wicks, B.-W. Zhang, A Theory of jet shapes and cross sections: From hadrons to nuclei, JHEP 11 (2008) 093. arXiv:0810.2807, doi:10.1088/1126-6708/2008/11/093.

[10] Z.-B. Kang, F. Ringer, I. Vitev, Inclusive production of small radius jets in heavy-ion collisions, Phys. Lett. B 769 (2017) 242–248. arXiv:1701.05839, doi:10.1016/j.physletb.2017.03.067.

[11] Y. He, T. Luo, X.-N. Wang, Y. Zhu, Linear Boltzmann transport for jet propagation in the quark-gluon plasma: Elastic processes and medium recoil, Phys. Rev. C 91 (2015) 054908, [Erratum: Phys. Rev.C97,no.1,019902(2018)]. arXiv:1503.03313, doi:10.1103/PhysRevC.97.019902, 10.1103/PhysRevC.91.054908.

[12] M. Spousta, B. Cole, Interpreting single jet measurements in Pb + Pb collisions at the LHC, Eur. Phys. J. C 76 (2016) 50. arXiv:1504.05169, doi:10.1140/epjc/s10052-016-3896-0.

[13] ATLAS Collaboration, Measurement of jet p_T correlations in Pb+Pb and *pp* collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the ATLAS detector, Phys. Lett. B 774 (2017) 379–402. arXiv:1706.09363, doi:10.1016/j.physletb.2017.09.078.