

RECENT RESULTS FROM INTERMEDIATE COLLISION SYSTEMS (OO/NeNe) FROM THE ATLAS EXPERIMENT*

PAVEL VANA 

on behalf of the ATLAS Collaboration

Institute of Particle and Nuclear Physics, Charles University
Prague, Czech Republic
`pavel.vana@cern.ch`

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These proceedings give an overview of the latest measurements in light-ion collision systems with the ATLAS detector at the LHC using the 5.36 TeV $^{16}\text{O}+^{16}\text{O}$ and $^{20}\text{Ne}+^{20}\text{Ne}$ collisions data recorded in July 2025. The increased Sub Farm Output rate enabled higher rates for low- p_{T} and minimum-bias triggers. The measurement of azimuthal anisotropies in O+O and Ne+Ne collisions, utilising two-particle correlations with template-fit subtraction and four-particle subevent cumulants, is presented. The preliminary measurement of the dijet transverse momentum balance in O+O and pp collisions at 5.36 TeV is also presented.

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1. Introduction

One of the main goals of the heavy-ion programme at the Large Hadron Collider (LHC) at CERN is to study the production and properties of the quark–gluon plasma (QGP). QGP is the state of matter that is created during the ultra-relativistic collisions of heavy ions, in which the quarks and gluons are no longer confined in colour-neutral hadrons. QGP produced in such collisions undergoes collective expansion driven by strong pressure gradients, which convert initial-state spatial anisotropies into momentum anisotropies of the final-state hadron distribution.

One of the main motivations for studying such phenomena in light-ion collisions is the search for collective behaviour and the onset of jet quenching in systems smaller than Pb+Pb or Xe+Xe, as previously measured by the

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ATLAS detector [1] at the LHC. It is known that the initial-state geometry has influence on the flow harmonics. Theory predicts different shapes for the oxygen and neon nuclei, so one can ask whether the differences in the initial-state geometry will manifest themselves in the resulting flow harmonics.

Two methods for probing the presence and properties of the QGP are discussed in these proceedings: measurements of the azimuthal anisotropy of charged particles and the dijet transverse momentum balance.

2. Light-ion data taking

In July 2025, light-ion data taking took place for one week at the LHC. Collisions of the $^{16}\text{O}+^{16}\text{O}$ and $^{20}\text{Ne}+^{20}\text{Ne}$ at the nucleon–nucleon centre-of-mass energy of 5.36 TeV were recorded by the ATLAS detector. In total, 8.08 nb^{-1} of O+O collisions and 1.03 nb^{-1} of Ne+Ne were recorded.

In order to increase the rate of the low- p_T triggers and the minimum-bias triggers, ATLAS was able to increase the data-acquisition Sub Farm Output (SFO). The SFO system handles the recording of ATLAS data at Point 1 (P1) and its subsequent transfer to the CERN Computer Center. During standard proton–proton operations, ten SFO servers operate with an aggregated throughput of 8 GB/s. During the July 2025 oxygen–oxygen run, the recording rate was increased by $\approx 40\text{--}50\%$, as seen in figure 1. To ensure reliable operation far outside the SFO design working point, the transfer from SFO was suspended during data taking and resumed after data taking concluded.

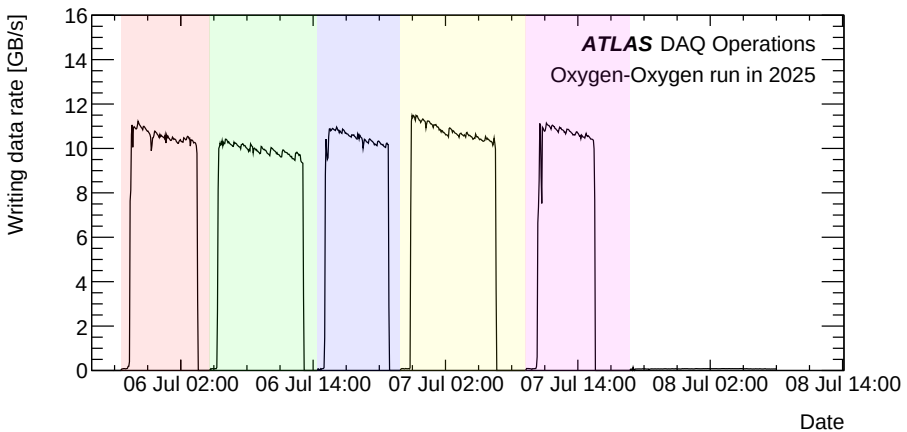


Fig. 1. The example of the recorded event rate. Differently coloured regions indicate subsequent ATLAS runs. Figure is taken from [2].

3. Azimuthal anisotropy of charged particles in O+O and Ne+Ne

The anisotropy of particle distributions in heavy-ion collisions is quantitatively characterised by a Fourier series in the azimuthal angle ϕ

$$\frac{dN}{d\phi} \propto 1 + 2 \sum_{n=1}^{\infty} v_n \cos(n(\phi - \Psi_n)) , \quad (1)$$

where v_n and Ψ_n represent the magnitude and orientation of the n^{th} -order anisotropy, respectively. The v_n coefficients are commonly referred to as flow harmonics, with v_2 being the elliptic flow, v_3 corresponding to the triangular flow, and so on. Typically, v_2 is the largest harmonic due to the lenticular shape of the average overlap region.

A recent measurement by the ATLAS Collaboration [3] presents anisotropic flow coefficients v_2 , v_3 , and v_4 in O+O and Ne+Ne collisions at 5.36 TeV using two-particle correlations and the four-particle subevent cumulants. The standard two-particle correlation method with template fit, which subtracts the non-flow contribution (flow harmonics denoted as v_n^{sub}), was compared with the multi-particle cumulants method (results denoted as v_n), which suppresses correlations from jets and dijets.

Figure 2(a) shows the results of the elliptic flow and triangular flow evaluated using the template fit method and four-particle cumulants for O+O and Ne+Ne as a function of the centrality of the collision utilising charged particles with $p_T > 0.5$ GeV. Figure 2(b) shows the ratio of each

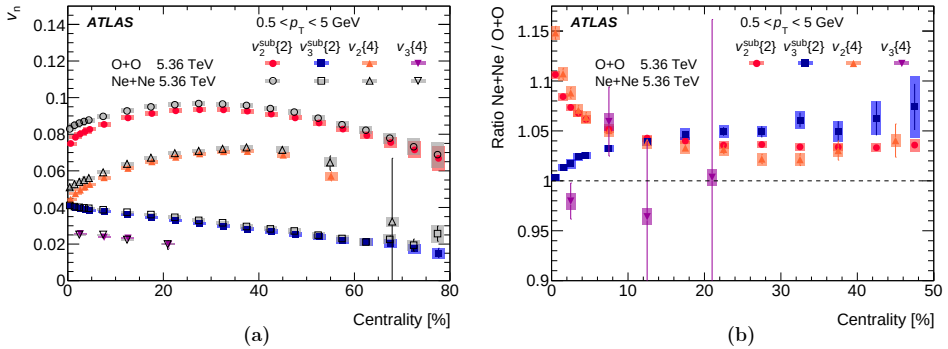


Fig. 2. (a) Flow harmonics $v_n^{\text{sub}}\{2\}$ and $v_n\{4\}$ coefficients in O+O collisions (coloured solid markers) and Ne+Ne collisions (open black markers) at $\sqrt{s_{NN}} = 5.36$ TeV, shown as a function of centrality. The Ne+Ne points are slightly displaced along the horizontal axis for visual clarity. (b) Ratios of the flow coefficients in Ne+Ne to those in O+O collisions, corresponding to the results in panel (a). The vertical lines and vertical bars indicate statistical and systematic uncertainties, respectively. For the ratios, systematic uncertainties correlated between the O+O and Ne+Ne measurements largely cancel. Figure is taken from [3].

flow harmonic between Ne+Ne and O+O collisions. From these results, one can notice that the effect of non-flow contributions does not depend on the centrality of the collision. From the ratio, one can see a clear difference between v_2 and v_3 measured in O+O and Ne+Ne collisions. The growth of the v_2 ratio suggests the impact of differences in the initial-state geometries of oxygen and neon.

4. Dijet transverse momentum balance in O+O and pp collisions

The quantity characterising jet quenching in the dijet system is the dijet system momentum balance

$$x_J = \frac{p_{T_2}}{p_{T_1}}, \quad (2)$$

where p_{T_1} and p_{T_2} are transverse momenta of the jets with the highest (leading jet) and second-highest (sub-leading jet) transverse momenta in the event, respectively.

A recent study by the ATLAS Collaboration [4] presents a preliminary measurement of the dijet balance in O+O and pp collisions for leading jets with transverse momenta between 63 and 251 GeV, with dijet pairs selected with the azimuthal distance $\Delta\phi > 7\pi/8$ (for $\Delta\phi = |\phi_1 - \phi_2|$), and both jets in the rapidity region $|y| < 2.1$. The presented x_J distributions are unfolded for the jet response and jet energy resolution. The resulting x_J distributions are normalised by the yield of dijets in each leading jet selection.

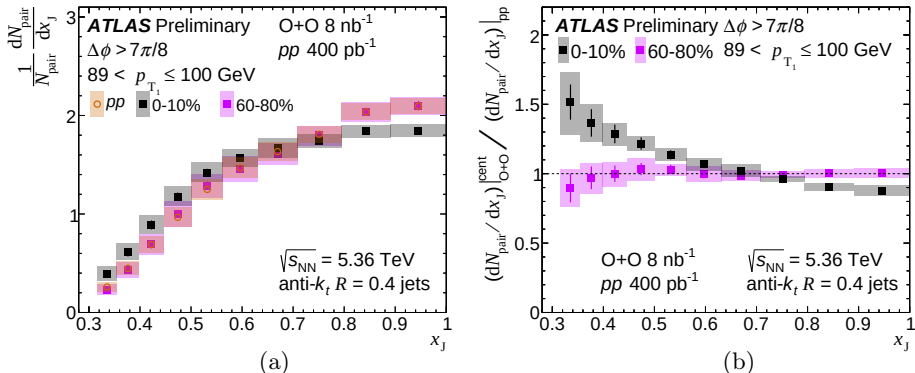


Fig. 3. Comparison of unfolded x_J distributions (a) in O+O collisions and pp collisions with $\Delta\phi > 7\pi/8$ for $89 < p_{T,1} \leq 100$ GeV in central (0–10%) and peripheral (60–80%) collisions, and (b) compares ratios between the self-normalized x_J distributions in central (0–10%) and peripheral (60–80%) O+O collisions. Vertical error bars represent the statistical uncertainty, and the shaded areas represent the total uncertainty. Due to the area normalisation of the x_J distribution, the direction of the systematic variations at low and high x_J are anti-correlated. Figures are taken from [4].

Figure 3(a) shows the x_J distributions for $89 < p_{T,1} \leq 100$ GeV in central (0–10%) and peripheral (60–80%) O+O collisions and for the pp collisions. In figure 3(b), the ratio of the x_J distributions measured in O+O collisions to the x_J distributions measured in the pp collisions is presented. It shows a significant difference between the x_J distribution measured in central O+O collisions and in the pp collisions. These results signal the presence of jet quenching in the O+O collisions. For more details, see [4].

5. Conclusions

These proceedings summarise two recent measurements of light-ion collisions at the LHC with the ATLAS detector. These measurements compare properties of the QGP quantified by the flow harmonics and the behaviour of hard probes quantified by the dijet momentum balance in O+O, Ne+Ne, and pp collisions, all at the collision energy of 5.36 TeV.

Measurements of flow harmonics in O+O and Ne+Ne collisions reveal a significant contribution from non-flow effects, and, moreover, indicate collective behaviour in both systems. The differences in v_2 between O+O and Ne+Ne also suggest the impact of the different initial-state geometry in both systems.

A clear signature of jet quenching in O+O collisions was observed by measuring dijet momentum balance distributions and comparing them with those in pp collisions. The presented measurement thus provides new inputs for understanding path-length dependence and the onset of jet quenching in the quark–gluon plasma.

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