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CERN Student Project Notes

For the summer, I was assigned to work on the ALICE experiment with Alice Ohlson. I wrote several programs throughout the summer that were used to calculate jet v_2 using a non-standard method described by my supervisor in her Ph.D. thesis. Though the project is not yet complete, significant progress has been made, and the results so far seem promising.

In heavy-ion collisions of sufficient energies, a quark-gluon plasma (QGP) is produced. Such collisions may be broken into two parts: a soft component and hard component. The soft component of the collision is the QGP and is governed by hydrodynamic flow. This means that more high-energy particles are ejected along the reaction plane and fewer along the axis perpendicular to the reaction plane. The experimental approximation of the reaction plane is called the event plane.

Jets, the hard component of the collisions, are emitted independently of the QGP geometry. Because jets interact with the QGP, however, we find that there is a correlation between the jet axis and the event plane. Jet v_2 is the second Fourier coefficient used to describe the correlation between the jet axis and the event plane. It is important not only because it can tell us about the initial geometry of the QGP, but mostly because it gives us information about the path-length dependent energy loss of the jet as it passes through the QGP.

The standard method for calculating the jet v_2 of events first involves calculating the event plane in each event, then calculating the correlation between the jet axis and the event plane, averaged over many events. The equations are shown as Eq. 1 and Eq. 2, where Ψ_{EP} is the event plane, Ψ_{jet} is the jet axis, and φ is the particle angle.

$$\Psi_{EP}=\frac{1}{2}\arctan\frac{\sum_i w_i \sin(2\varphi_i)}{\sum_i w_i \cos(2\varphi_i)} \qquad \text{Eq. 1}$$

$$v_2^{jet}=\frac{\langle\cos[2(\Psi_{jet}-\Psi_{EP})]\rangle}{\langle\cos[2(\Psi_{EP}-\Psi_{PP})]\rangle} \qquad \text{Eq. 2}$$

The event plane calculation sums over all of the particles in a particular event, while the jet v_2 is averaged over many events. The weights in the event plane calculation are chosen to maximize the event plane resolution, the term in the denominator of the jet v_2 calculation.

One major problem associated with this method of calculating jet v_2 is that because the event plane calculation is summed over all of the particles in a particular event, the presence of jets biases the event plane towards the jet axis, which leads to an overestimation of jet v_2. I was able to show this in some simple simulations done at the beginning of the summer in which jets were placed on top of events where particles were randomly generated according to an exponential decay function. We saw that, indeed, in the transverse momentum (p_T) range associated with the jets, the v_2 was greatly overestimated.

Solutions to this problem have been suggested, with the most common being to remove all of the particles from the jet cone and preferentially weight the particles around it or to remove the pseudorapidity ranges associated with the jets. The problem with the former option is that you can introduce artificial correlations elsewhere when you begin weighting your particles in such a way. And the major problem with the second option is that you severely cut down the event plane resolution when entire pseudorapidity ranges are removed.

Thanks to recent advances in jet reconstruction algorithms, the QA method, as described in my supervisor's Ph.D. thesis, attempts to account for the jets in the jet v_2 calculation rather than remove them. By defining a vector **G** = **Q** + **A**, where **Q** represents the bulk components of a collision and **A** the jet components, one can calculate jet v_2 and reconstruct the event plane according to Eq. 3 and Eq. 4.

$$v_2^{jet}=\frac{4\langle G_x\rangle\langle G_y^2\rangle-4\langle G_x G_y^2\rangle}{\left(8\langle G_y^2\rangle^2-\frac{8}{3}\langle G_y^4\rangle\right)^{\frac{3}{2}}} \qquad \text{Eq. 3}$$

$$\Psi_{EP} = \frac{1}{2} \arctan \frac{\sum_i w_i \sin[2(\varphi_i - \Psi_{jet})]}{\sum_i w_i \cos[2(\varphi_i - \Psi_{jet})] - \langle A \rangle} + \Psi_{jet} \qquad \text{Eq. 4}$$

In my simulations to test this method, I used data from real Pb-Pb events and embedded PYTHIA jets on top. The jets were reconstructed prior to embedding so that the jet axis and jet momenta were well known for the analysis. The event plane and jet v_2 were calculated using the standard method with just the background tracks, the background tracks with jets included, the background tracks with jets included and a 2 GeV track cutoff, and with the QA method.

We found that while the standard method accurately calculated the jet v_2 with just background tracks, and as soon as jets were added, the jet v_2 was greatly overestimated. We saw this especially in very central and very peripheral events. The QA method seemed to function well at recovering the jet v_2, but this method was found to require a lot of statistics so that the term in the denominator of v_2^{jet} was not undefined.

Moving forward with the project, I would like to run over much more statistics for the QA method, as well as look at using different weights for the event plane calculations to try and increase the event plane resolution.