Universal scaling of the azimuthal anisotropies due to energy loss

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May 24th 2016
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Outline

1. Experimental scaling of $v_2$ of charged particles
2. $v_2$-scaling of photons
3. $v_2$-scaling of pions and kaons
4. Energy loss
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6. Conclusions
The scaling law

\[ \frac{v_2(p_T)}{\epsilon_1 Q_s^A L} = f(\tau) \]

\[ \epsilon_1 = \frac{2}{\pi} \int_0^{\pi/2} d\varphi \cos 2\varphi \frac{R^2 - R_\varphi^2}{R^2} \]

\[ \alpha = \arcsin \left( \frac{b}{2R_A} \sin \varphi \right) \]

\[ R_\varphi = \frac{R_A \sin(\varphi - \alpha)}{\sin \varphi} \]

\[ \alpha = R^2 = \langle R_\varphi^2 \rangle = \frac{2}{\pi} \int_0^{\pi/2} d\varphi R^2_\varphi \]

\[ \tau = \frac{p_T^2}{(Q_s^A)^2} \]

\[ L = \left( 1 + N_A^{1/3} \right)/2 \]
Saturation momentum

\[ \tau = \frac{p_T^2}{(Q_s^A)^2} \]

\[ (Q_s^A)^2 = (Q_s^p)^2 A^{\alpha(s)/2} N_A^{1/6} \]

\[ \alpha(s) = \frac{1}{3} \left( 1 - \frac{1}{1 + \ln \left( \frac{\sqrt{s}}{\sqrt{s_0}} + 1 \right)} \right) \]

\[ (Q_s^p)^2 = Q_0^2 \left( \frac{W}{p_T} \right)^\lambda \]

with \( Q_0 = 1 \) GeV, \( W = \sqrt{s} \times 10^{-3} \), \( \sqrt{s_0} = 245 \) GeV and \( \lambda = 0.27 \).
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Multiplicity spectra
v$_2$-scaling of charged particles

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$v_2$-scaling of photons
$\nu_2$-scaling of pions and kaons

![Graph showing $\nu_2$-scaling of pions and kaons]
If there are domains or clusters of strings which decay in partons, these partons interact with the color field of other clusters or domains, losing energy or momentum in their path to get out the area of the collision.

In QED, the loss of energy of a charged particle moving in an external E.M. field is known. It has been shown, on the basis of ADS/CFT, that in N=4 SUSY with Nc large the same result is obtained.
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Energy loss

\[ P(p, \phi) = C e^{-\frac{p_0}{\sqrt{\tau/2}}} \]
\[ \tilde{\tau}^2 = \tau/2 \]

\[ p_0(p, \ell) = p \left( 1 + \kappa p^{-1/3} \tilde{\tau}^{2/3} \ell \right) \]

\[ P(p, \theta) = C e^{-\frac{p}{\tilde{\tau}}} e^{-\frac{p^{2/3} \tilde{\tau}^{1/3} \ell}{\cos(\theta - \theta_0)}} \]

\[ v_n \propto p^{2/3} \tilde{\tau}^{1/3} \ell \]
\[ \tilde{\tau} \sim Q_s \]

\[ \frac{v_n}{\ell Q_s} = \frac{p^{2/3} Q_s^{1/3} \ell}{\ell Q_s} = \left( \frac{p^2}{Q_s^2} \right)^{1/3} \]

\[ f(\tau) = \tau^{1/3} \]
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The interaction of the produced parton with the rest gives rise to the scaling of $V_n$.

They are responsible of the p-p, p-A and A-A ridge structures.

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Figure 10: Correlation coefficient $C(\phi)$ for p-Pb collisions at 5.02 TeV for central collisions compared to the data in [3] (with the ZYAM procedure).
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Figure 15: Correlation coefficient $C(\phi)$ for pp collisions at 7 TeV with triple multiplicity compared to the experimental data from [1]
(with the ZYAM procedure at positive $\phi$)
Conclusions

- A **universal scaling law of the elliptic flow** of charged particles, photons, pions, kaons and protons in A-A collisions at all centralities and energies is found.

- Universal **$v_3$-scaling** of charged particles is also obtained.

- The scaling law for $v_2$ is naturally explained by the interaction of produced partons with the existing color field.

- The same explanation applies for the **ridge structures** in p-p, p-A and A-A collisions.

- Energy loss **cannot** explain the scaling of $v_3$. 