Universal scaling of the azimuthal anisotropies due to energy loss

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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
5. v_3-scaling of charged particles
6. Conclusions

The scaling law

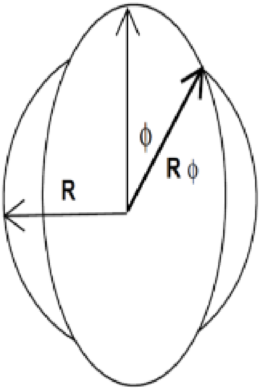
$$\frac{v_2(p_T)}{\epsilon_1 Q_s^A L} = f(\tau)$$

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

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

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

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



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

$$L = (1 + N_A^{1/3})/2$$

Saturation momentum

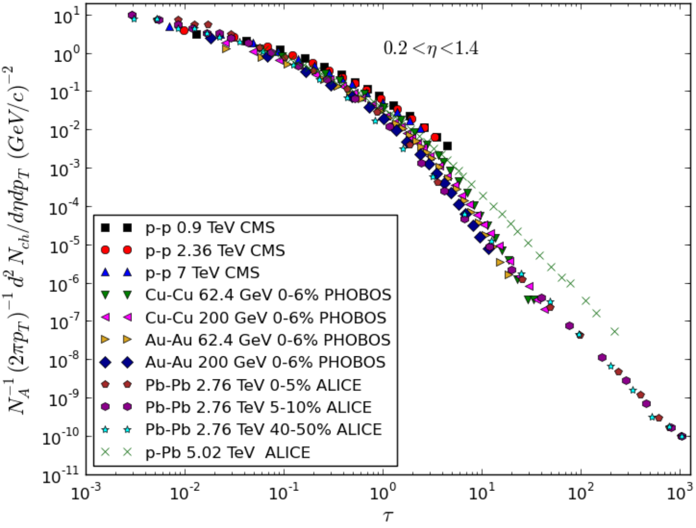
$$\tau = \frac{p_T^2}{(Q_s^A)^2} \qquad \left(Q_s^A\right)^2 = (Q_s^p)^2 \, A^{\alpha(s)/2} N_A^{1/6}$$

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

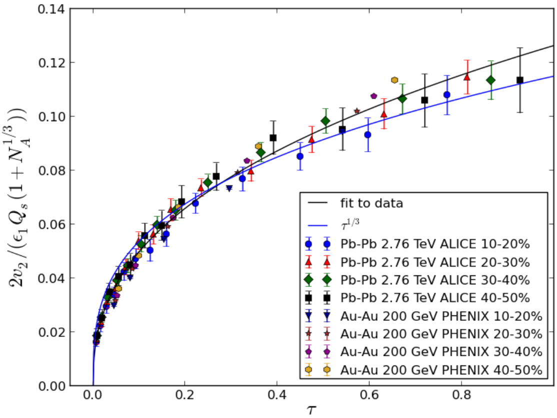
$$(Q_s^p)^2 = Q_0^2 \left(\frac{W}{p_T}\right)^{\lambda}$$

with $Q_0 = 1$ GeV, $W = \sqrt{s} \times 10^{-3}$, $\sqrt{s_0} = 245$ GeV and $\lambda = 0.27$.

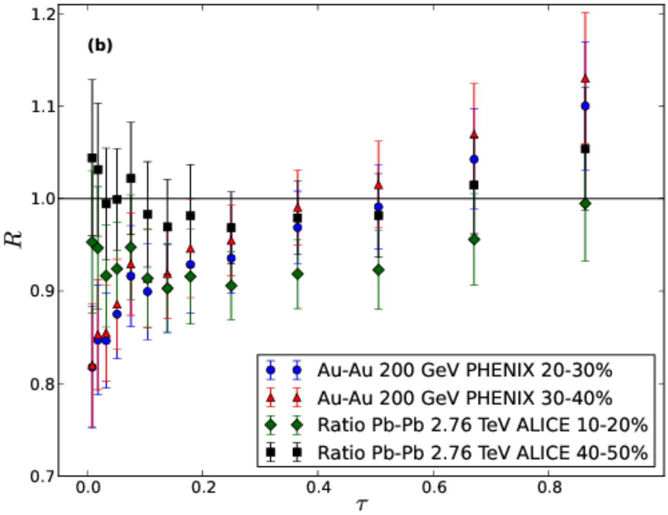
Multiplicity spectra



v_2-scaling of charged particles

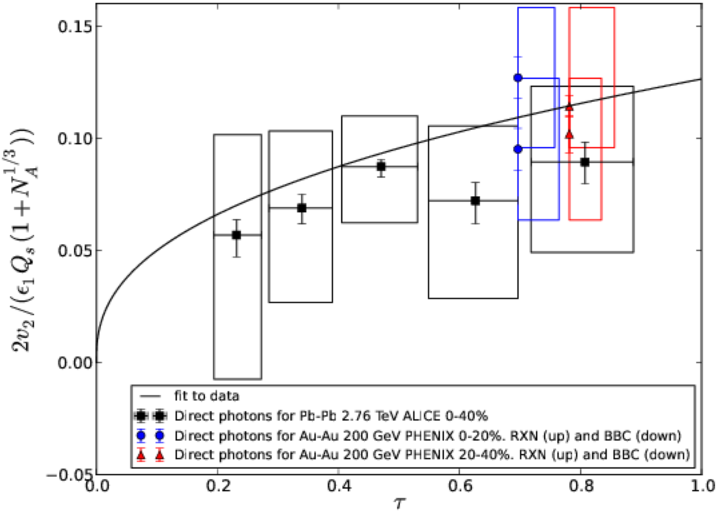


C.Andres, J.Dias de Deus, A. Moscoso, C. Pajares and C. Salgado, Phys. Rev. C **92**, 034901 (2015).

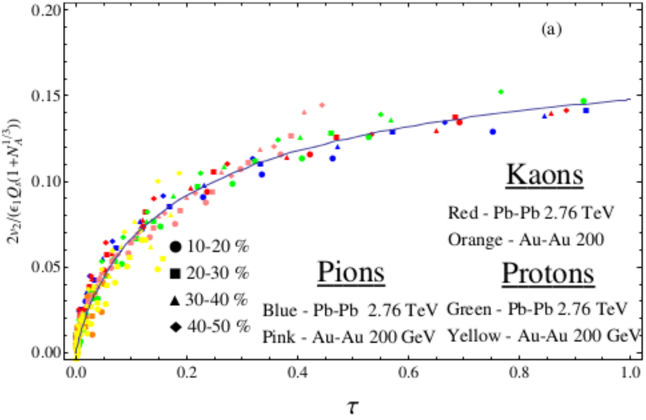


(b)
1.2
1.1
1.0
0.9
0.8
0.7
R
0.0
0.2
0.4
0.6
0.8
τ
Au-Au 200 GeV PHENIX 20-30%
Au-Au 200 GeV PHENIX 30-40%
Ratio Pb-Pb 2.76 TeV ALICE 10-20%
Ratio Pb-Pb 2.76 TeV ALICE 40-50%

v_2-scaling of photons



v_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.

Energy loss

$$P(p,\phi) = Ce^{-\frac{p_0}{\sqrt{\tau/2}}} \qquad \tilde{\tau}^2 = \tau/2$$

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

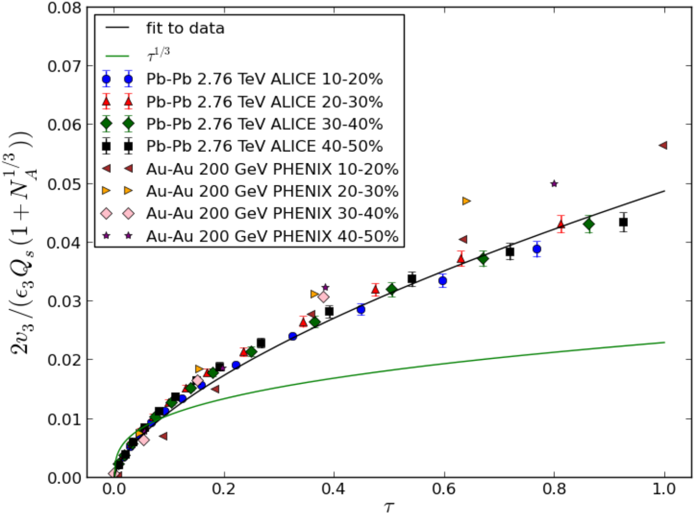
$$P(p,\theta) = Ce^{-\frac{p}{\tilde{\tau}}}e^{-\frac{p^{2/3}\tilde{\tau}^{1/3}\ell}{\cos(\theta-\theta_0)}}$$

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

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

$$f(\tau) = \tau^{1/3}$$

v_3-scaling of charged particles



- The interaction of the produced parton with the rest gives rise to the scaling of Vn.
- They are responsible of the p-p, p-A and A-A ridge structures.

M. A. Braun, C. Pajares and V. V. Vechernin, Eur. Phys. J. **A51**, 44 (2015).

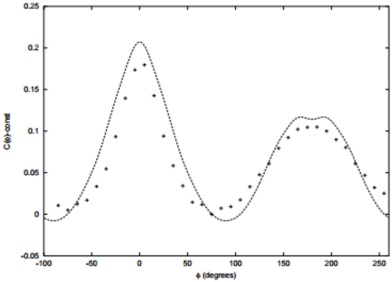


Figure 10: Correlation coeficient $C(\phi)$ for p-Pb collisions at 5.02 TeV for central collisions compared to the data in [3] (with the ZYAM procedure).

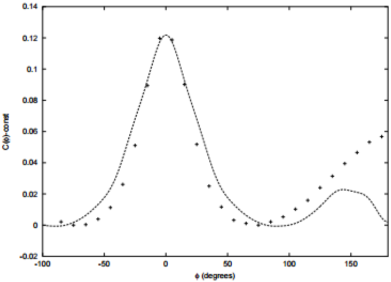


Figure 15: Correlation coeficient $C(\phi)$ for pp collisions at 7 TeV with triple multiplicity compared to the the experimental data from [1]
(with the ZYAM procedure at positive ϕ)

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 $\mathbf{v_3}$**-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.