Insight into the magnetic response of hadron gas using non-extensive statistics

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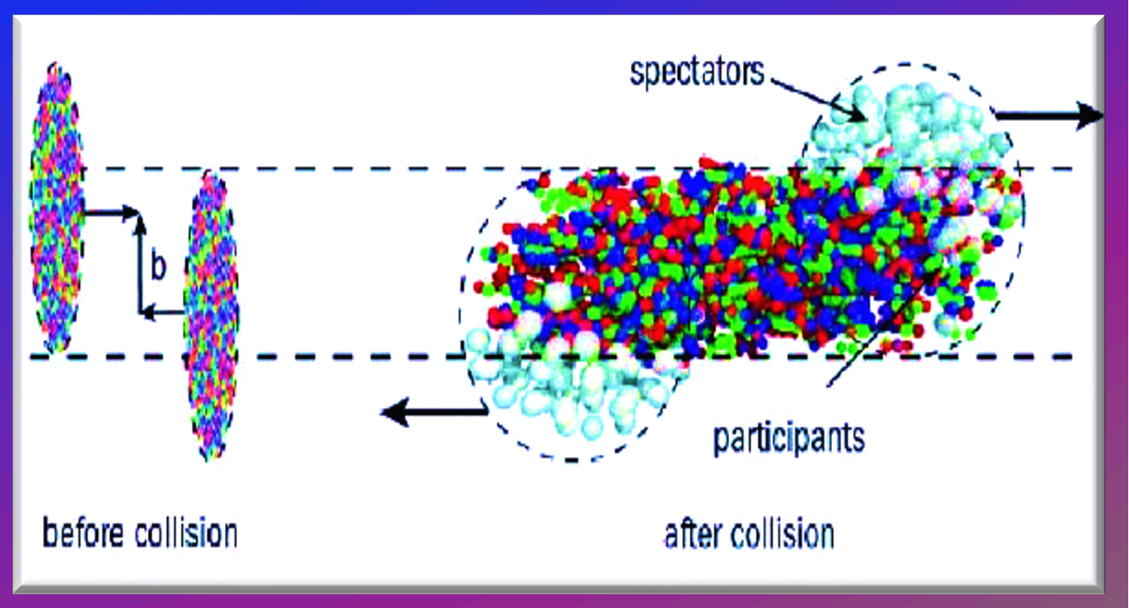
Physics Motivation

- Relativistic heavy-ion collisions create an extremely strong electromagnetic field ($\vec{B}$) due to spectator protons
- B may reach up to order of $m_\pi{}^2 \sim (10^{\wedge}{}^{18}\mathrm{G})$ and $15m_\pi{}^2$ for RHIC and LHC energies
- Can affect the thermodynamic and transport properties of the final state dynamics of the system



Formulations

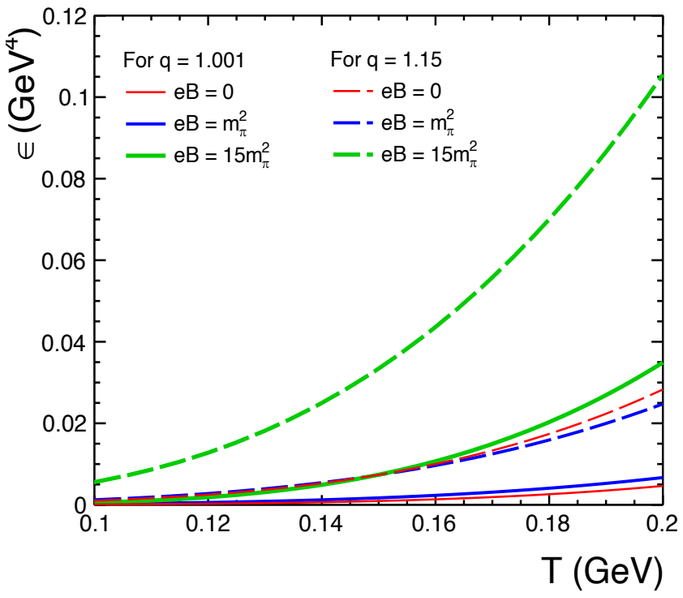
$$E_{i,n} = \sqrt{p^2 + m_i^2} \qquad E_{i,c}(p_z, k, s_z) = \sqrt{p_z^2 + m_i^2 + 2|e_i|B(k + 1/2 - s_z)}$$

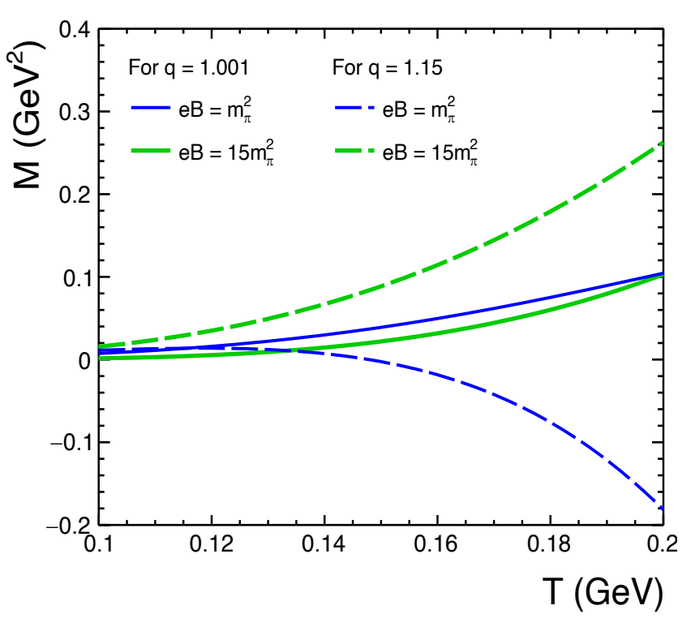
$$\epsilon_c = \sum_i \sum_k \sum_{s_z} \frac{g_i |e_i| B}{(2\pi)^2} \int dp_z E_{i,c} \left[1 + (q-1)\frac{E_{i,c} - \mu}{T}\right]^{\frac{-q}{q-1}} \qquad P_c = \sum_i \sum_k \sum_{s_z} \frac{g_i |e_i| B}{(2\pi)^2} \int dp_z \frac{p^2}{3E_{i,c}} \left[1 + (q-1)\frac{E_{i,c} - \mu}{T}\right]^{\frac{-q}{q-1}}$$

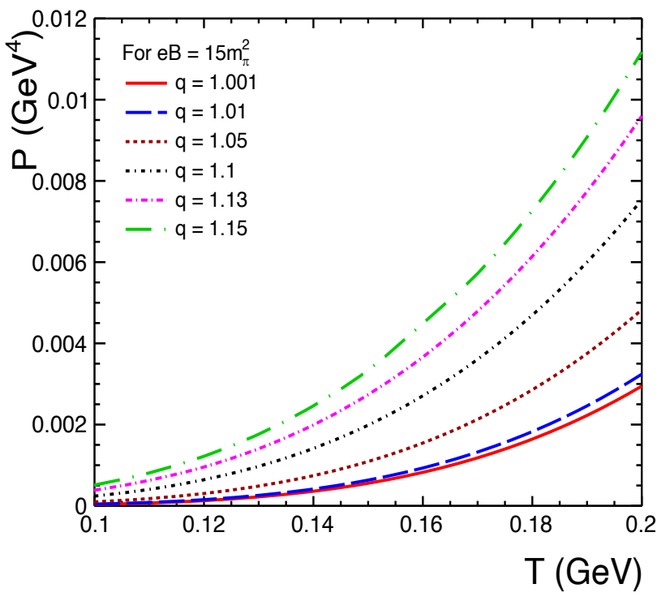
$$\epsilon_n = \sum_i g_i \int \frac{d^3p}{(2\pi)^3} E_{i,n} \left[1 + (q-1)\frac{E_{i,n} - \mu}{T}\right]^{\frac{-q}{q-1}} \qquad P_n = \sum_i g_i \int \frac{d^3p}{(2\pi)^3} \frac{p^2}{3E_{i,n}} \left[1 + (q-1)\frac{E_{i,n} - \mu}{T}\right]^{\frac{-q}{q-1}}$$

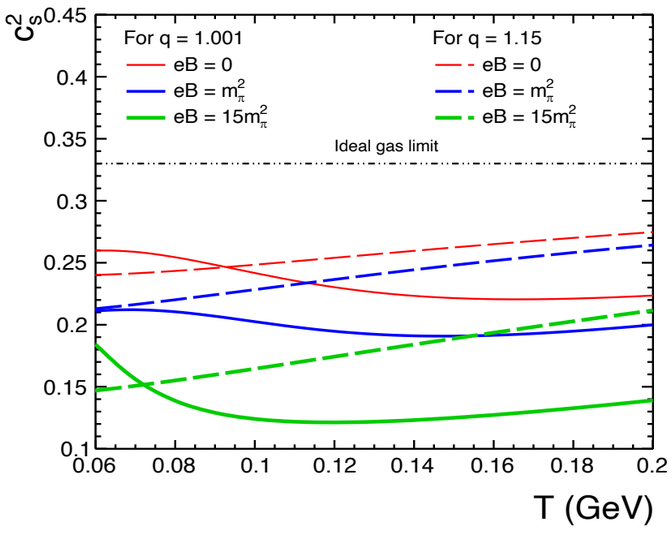
$$M = \frac{\epsilon_{total} - \epsilon}{B} \qquad c_s^2 = \frac{\partial P}{\partial \epsilon} \qquad \gamma = \frac{\partial \ln P}{\partial \ln \epsilon}$$

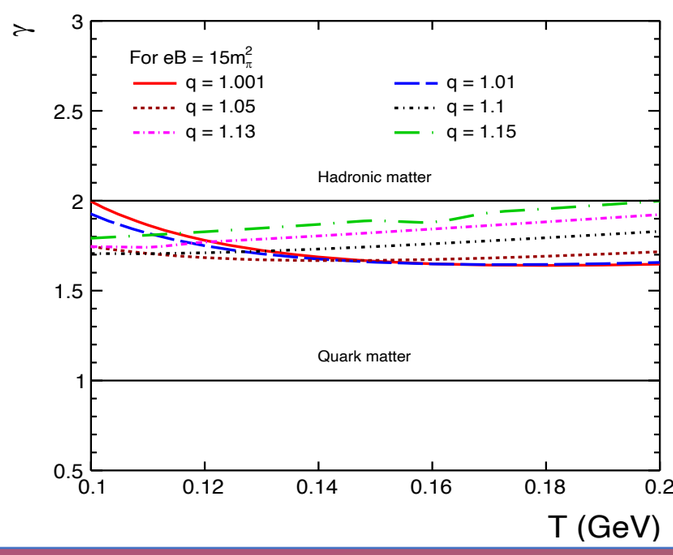
Results











Summary

- We have taken the non-extensive Tsallis statistics to study a hadron gas that is formed in peripheral heavy-ion collisions
- Observe that when the system is away from equilibrium, it has higher values of energy density, pressure
- Indicates a diamagnetic to paramagnetic transition for non-central heavy-ion collisions as one moves from RHIC to the LHC energies
- $c_s{}^2$ decreases with increase in magnetic field strength, hence the system is more interacting in the presence of a finite magnetic field.

References

1. G. S. Pradhan, D. Sahu, S. Deb, R. Sahoo, arXiv:2106.14297
2. G. Kadam, S. Pal and A. Bhattacharyya, J. Phys. G 47, 125106 (2020).
3. G. Endro¨di, JHEP 04, 023 (2013).