PAULI REPULSION ENERGY AND THE PROPERTIES OF DOOR-WAY STATES IN RELATIVISTIC CENTRAL HEAVY ION COLLISIONS

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The basis for the analysis results of which is presented in the current talk is the data, demonstrated in the paper by J.W. Harris, (Nucl. Phys. A734, 3 (2004)). A summary of some results from RHIC is contained in it. The key point is the number of quarks and anti-quarks produced in the 3% most central collisions of heavy ions. For Au + Au at 100 A·GeV energy collision:

$$\sum_i N_i \sim 14000.$$

Here N_i – the number of quarks of the sort *i.*

Among the other data:

$$T = 177\ MeV; \quad \mu_B = 29\ MeV,$$

which are obtained from ratios of yields of various particles. Here μ_B – the baryonic chemical potential.

What are the consequences?

STATISTICS OF THE DEGENERATE RELATIVISTIC QUARK GAS

Fermi energy:

$$\varepsilon_F = (3\pi)^{1/3} \left(\frac{N}{V} \right)^{1/3} \hbar c.$$

Total energy at zero temperature (Pauli energy):

$$E_{Pauli} = \frac{(9\pi)^{2/3}}{4} \frac{\sum N_i^{4/3}}{V^{1/3}} \hbar c; \quad \frac{3}{4} \varepsilon_F = \frac{E_{Pauli}}{N_i}.$$

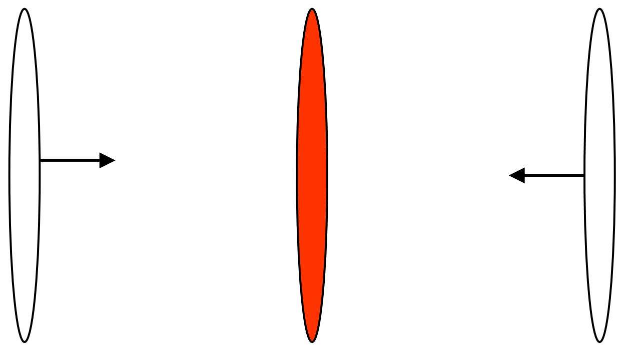
Taking into account 18 types of quarks and anti-quarks (light ones only) and assuming that all

$$N_i = N_{i'} = N$$

one can obtain:

$$E_{Pauli} / GeV \approx 0.46 N^{4/3} / V^{1/3}$$

The doorway collision volume of a symmetric central events grows smaller due to the relativistic contraction



and takes the form

$$V = \frac{2\pi r_0^3 A^2 m_N c^2}{3E}$$

where *E* is the total collision energy. Define the critical energy by the equality:

$$E_{cr} = E_{Pauli} = E$$

it is possible to express maximal number of quarks of the certain sort (which is equal to the number of states) as follows:

$$N_{\max} = \frac{2^{9/2}(m_N c^2)^{1/4} r_0^{3/4}}{3^{5/4}\pi^{1/4}(\hbar c)^{3/4}} \frac{A^{1/2}E^{1/2}}{\kappa^{3/4}}$$

where κ=18 – the number of the quark types. Finally:

$$N_{\max} = 0.40 \cdot A^{1/2}E^{1/2} / GeV^{1/2}.$$

For

$$A = 197;\ E/A = 100\ GeV; \quad \kappa N_{max} = 20000.$$

For

$$\sum_i N_i = 14000; \quad E_{Pauli} / N = 1.78\ GeV;$$

$$E_{Pauli} = 24.9\ TeV.$$

The temperature in the doorway system may be determined from the relation:

$$E = \frac{V}{\pi^2 (\hbar c)^3} \int \frac{\varepsilon^3 d\varepsilon}{e^{-\mu/T} e^{\varepsilon/T} + 1}.$$

For $e^{-\mu/T} \ll 1$

$$E \approx E_{Pauli(}(N) + \frac{\mu^2 T^2 V}{2(\hbar c)^3}.$$

Assuming quark chemical potential to be $\mu \approx \mu_0 = \varepsilon_F$

one may obtain

$$T = \left(\frac{3}{\pi}\right)^{1/3} \frac{(N_{\max} - N)^{2/3}}{2^{1/2} N_{\max}^{1/3} V^{1/3}} \hbar c.$$

For $\sum_i N_i = 14000; \quad T = 725\ MeV.$

STATISTICS OF THE OBSERVED SYSTEM

Assuming that $e^{-\mu/T} \sim 1$ one can obtain:

$$\frac{N}{V} = \frac{1}{\pi^2(\hbar c)^3}\int \frac{\varepsilon^2 d\varepsilon}{e^{-\mu/T}e^{\varepsilon/T}+1} \approx \frac{2T^3}{\pi^2(\hbar c)^3}\varsigma(3),$$

where *ξ(x)* – Riemann function. For

$$\sum_i N_i = 14000; T = 177\ MeV;$$

$$V = 46300\ fm^3; R_V = 22\ fm.$$

Is this sphere a border of asymptotics?

QUARK FERMI SURFACE AND BOSONIZATION

The necessary condition of bosonization is: $pc \; \square \; \varepsilon_F$

where p is the linear momentum of a quark in a boson,

$$\varepsilon_F = \frac{(9\pi)^{2/3}}{3}\frac{N^{1/3}}{V^{1/3}}\hbar c = 0.61\cdot\left(\frac{N}{V}\right)^{1/3}(GeV)$$

For π-mesons for example:

$$\sum_i N_i = 14000; \quad \varepsilon_F = \frac{p_\pi c}{3} = 23.3 MeV;$$

$$V = 2.5\cdot 10^8 \; fm^3; R_V = 150 \; fm.$$

For K- and ρ-mesons this radius is also larger than 22 *fm.*

CONCLUSIONS

1. Pauli exclusion principle is a good candidate to an origin of the upper limit to the hadron multiplicity in the central relativistic heavy ion collisions.
2. Door-way states of such collisions are relatively cold.
3. The analyzed observables of experiments are related to large distances.
4. Presented approach allows one to predict maximal multiplicity of the quark production at LHC energies:

$$\sqrt{S_{NN}} = 5.5\,TeV; \quad \kappa N_{\max} = 1.05 \cdot 10^5$$

THANK U 4 ATTENTION!

MY GREATE GRATITUDE TO ORGANIZING COMITTEE !