THERMAL EFFECTS IN HEAVY-ION COLLISIONS

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CONTENTS

- **Searching for the QGP and Mixed Phase (MP)**

- $J/\Psi(c\bar{c})$ **suppression measured in Pb-Pb collisions at the SPS energies**

In the context of a phase transition to the QGP charmonium states $c\bar{c}$ should no longer be formed due to color screening
H.Satz, Rep.Prog.Phys. 63 (2000) 1511

- **Open charm enhancement observed by NA50 Collaboration in Pb-Pb collsions at 160 (GeV/A)**

It can be due to the QGP creation in the center rapidity region

- **Elliptic flow for high** p_t **particles**

- **Cronin effect for** p_t**-spectra**

- **Broadening of transverse mass spectra observed at SPS, RHIC energies**

- **Conceptional project**

Design and construction of
Nuclotron-based Ion Collider Facility (NICA)
and Multiple-Purpose Detector (MPD)

- **NICA goals and physics problems**

The first stage

1. Multiplicity and global characteristics of identified hadrons including multi-strange particles
2. Fluctuations in multiplicity and transverse momenta
3. Direct and elliptic flows for various hadrons
4. Interference and particle correlations

The second stage

1. Electromagnetic probes (photons and dileptons)

Local equilibrium of hadrons

$$f_h^{HE} \;=\; C_T^{HE}\{1 \;\pm\; exp((\epsilon_h - \mu_h)/T)\}^{-1} \;\;,$$

where $+$ is for fermions and $-$ is for bosons, ϵ_h and μ_h are the kinetic energy and the chemical potential of hadron h respectively, T is the temperature, C_T^{HE} is the normalization coefficient depending on T.

Quark distribution

$$f_q^{HE}(x, \mathbf{p}_t; T) = \int_0^1 dx_1 \int_0^1 dx_2 \int d^2p_{1t} d^2p_{2t} f_h^{HP}(x_1, p_{1t}) \times$$
$$f_q^h(x_2, p_{2t})\delta((x - x_1x_2)\delta^{(2)}(\mathbf{p}_t - \mathbf{p}_{1t} - \mathbf{p}_{2t})$$

Factorized form for $f_q^h(x, p_t)$

$$f_q^h(x, p_t) = f_q(x) g_q(p_t) \;\;,$$

Broadening for quark distributions

We assume

$$g_q(p_t) = \frac{\gamma_q}{\pi} exp(-\gamma_q p_t^2) \ .$$

Then we get

$$f_q^{HE}(x \simeq 0, p_t) = f_q^h(x \simeq 0) \frac{\gamma_q}{\pi(1 + 2\gamma_q m_h T)} (1 + \frac{T}{m_h}) exp(-\frac{\gamma_q p_t^2}{1 + 2\gamma_q m_h T}) \ .$$

At non zero x

$$f_q^{HE}(x, p_t) \simeq \frac{\gamma_q}{\pi} \frac{f_q^h(x)}{1 + 2\gamma_q \tilde{m}_h^s(x_1) T} (1 + \frac{T}{\tilde{m}_h^s(x_1)}) exp(-\frac{\gamma_q p_t^2}{1 + 2\gamma_q \tilde{m}_h^s(x_1) T}) \ ,$$

Finally we have broadening

$$< p_t^2 >_q^{HE} = < p_t^2 >_q^h + 2 m_h T$$

MQGS graphs

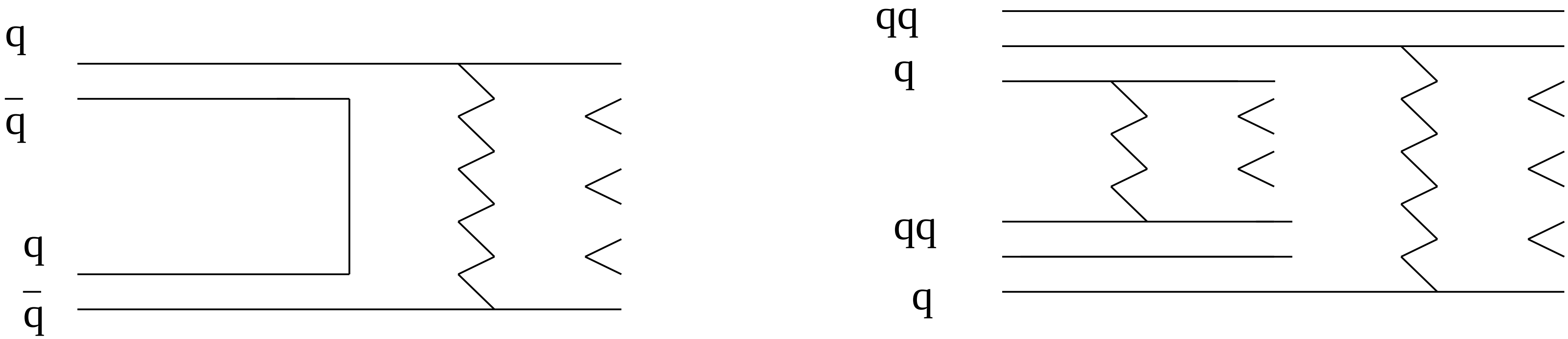

Figure 1: The planar graph (left diagram) and the cylinder graph (right diagram) *G.Veneziano, Phys.Lett., B52,220 (1974)*

Inclusive hadron spectrum

$$\rho_{h_1}^{HE}(x,p_t) \;=\; F_q^{h_1}(x_+,p_t)F_{\bar{q}}^{h_1}(x_-,p_t)\ ,$$

where

$$F_q^{h_1}(x_\pm, p_t) = \int_{x_\pm}^1 dx_1 \int f_q^{HE}(x_1, p_{1t}) D_q^{h_1}(\frac{x_\pm}{x_1}), p_{2t})\delta^{(2)}(p_{1t} + p_{2t} - p_t) d^2p_{1t} d^2p_{2t} \ ,$$

Here $x_\pm = \frac{1}{2}(\sqrt{x_t^2 + x^2} \pm x)$ and $x_t = 2m_{h_1t}/\sqrt{s_{NN}},\ m_{h_1t} = \sqrt{m_{h_1}^2 + p_{1t}^2}$.

p_t-spectrum

$$\rho_{h_1}^{HE}(x \simeq 0, p_t) \simeq f_q^h(x \simeq 0)\frac{\gamma_q\gamma_c}{\gamma_T + \gamma_c}\frac{1}{\pi}(1 + \frac{T}{m_q})exp(-p_t^2\frac{\gamma_T\gamma_c}{\gamma_T + \gamma_c}) \ ,$$

where $\gamma_c = 2\tilde{\gamma}_c$ and $\tilde{\gamma}_c$ is the slope of the exponential p_t^2-dependence for $D_q^{h_1}$,
$\gamma_T = \gamma_q/(1 + 2m_hT\gamma_c)$ and $\bar{\gamma}_T = 1/(2m_qT)$.

Finally we have similar broadening for hadron p_t-spectrum

$$< p_t^2 >_{h_1}^{HE} \simeq < p_t^2 >_{h_1}^{pp} + 2m_hT$$

A simple exponential approximation of p_t-spectra for produced hadrons h_1
is usually utilized to parametrize experimental data :

$$\frac{dN}{dm_{h_1t}^2 dy}|_{y=0} \ = \ Cexp(-\frac{m_{h_1t}}{T^*})$$

where the parameter T^* is extracted form fitting the data. There are experimental data on the T^* values for different hadron masses and different m_t domains - "low p_t" when $m_{h_1t} - m_{h_1} \ < 0.6 \ GeV$ and "high p_t", $0.6 \ < \ m_{h_1t} - m_{h_1} \ < 1.6 \ GeV$

At low p_t

$$\frac{dN}{dm_t^2 dy}|_{y=0} \ \simeq \ Cexp(-\frac{m_{h_1}}{T^*})exp(-\frac{p_{h_1t}^2}{2m_{h_1}T^*})$$

The experimental measurements at the SPS energies show that $T^* \simeq 200 - 250MeV$ for $K^{\pm}, \phi, \Omega, \Lambda$ hadrons at low p_t. It is close to our estimation for $< p_{h_1t}^2 >$ inputting $T = 110 - 120MeV$ that corresponds to the phase transition to the mixed phase in central A-A collisions at $\sqrt{s}/A = 5 - 10GeV$ and $< p_{h_1t}^2 > \simeq 120 - 140(MeV/c)^2$.

SUMMARY

I. Assuming a local equilibrium for colorless quark objects of type mesons and baryons created in central A-A collision we got distributions of quarks in these clusters depending on x, p_t and temperature T.

II. There is broadening effect over the transverse momentum p_t. Namely, $< p_t^2 >_q^{HE} = < p_t^2 >_q^h + 2 m_h T$

III. We estimated the transverse mass spectrum of hadrons produced in central A-A collisions from interaction of these colorless clusters.

IV. This estimation within the QGSM resulted in also some broadening for the transverse momentum square of produced hadrons which is the same as the broadening effect for quark distributions

V. The obtained results do not contradict to the existing experimental data obtained at SPS energies on the transverse mass spectra of hadrons in central A-A collisions at low p_t.