Comment on "ϕ-Meson Production as a Probe of the Quark-Gluon Plasma"

In an interesting paper,[1] Shor has pointed out that the production of ϕ mesons in nuclear collisions at high energies would serve as a probe for detecting the existence of the quark-gluon plasma (QGP). The paper is based on two main assumptions. Production of ϕ from the QGP will not be suppressed by the Okubo-Zweig-Iizuka (OZI) rule. The large abundance of strange quarks predicted[2] to exist in the plasma would increase ϕ-meson production in the hadronization process after the formation of the QGP and, therefore, ϕ-meson production would become comparable to ω-meson production. Secondly, in hadronic phase the rescattering cross section of ϕ mesons with nonstrange hadrons is very small and hence they will retain information on conditions of the plasma. The purpose of this note is to hint at an interesting consequence of this idea which will provide a more certain test for the existence of the QGP.

Shor has exploited the suppression predicted by OZI rule for certain processes to propose the existence of the QGP. This is analogous to the idea being suggested for the production[3,4] and detection of glueball resonances in particle physics. The OZI rule forbids processes involving ϕ-meson production in πp and pp collisions because these involve disconnected, "hairpin"-type quark-line diagrams. In the dual unitarization scheme,[5] twists in the quark line found on the s-channel exchange particles can be exploited to invoke a certain "cancellation mechanism" to explain the suppression of the amplitude. It has further been proposed[6] by Yazaki *et al.* that the twists in the t-channel quark lines do not give rise to such a cancellation mechanism and the production of ϕ mesons due to fragmentation process is strongly suppressed, whereas the suppression is far less effective for the central production of ϕ mesons. They have obtained the ratio of central to fragmentation cross sections to lie in the range 3 to 25. Recent experimental data[7] lend support to this finding.

In the case of heavy nuclear collisions at high energies, the nuclear fragmentation region is characterized by the existence of a large baryon density ($\simeq 1$ fm^{-3}), which is nearly 10 times that of a normal large nucleus ($\simeq 0.16$ fm^{-3}); and in this region, the two nuclei nearly stop each other, generating a dense fireball. At ultrarelativistic energies (over 30 GeV per nucleon), the two nuclei in a central collision pass through each other, leaving between them a very excited state of the vacuum which defines the central regime[8] at relatively low net baryon density. At low baryon density and temperature, nuclear matter consists of confined hadrons. With increasing temperature or baryon density, or both, one can gradually reach the states in which quarks and gluons are completely deconfined. Present Monte Carlo estimates[9,10] from lattice gauge theory indicate a deconfinement temperature at zero net baryon density around 200 MeV, while the deconfinement density at zero temperature is variously estimated to be 5–10 times the normal nuclear matter density. Shor finds that the ratio of ϕ to ω production decreases slowly as baryon density (or chemical potential μ) decreases if ϕ production takes place after quark-gluon-plasma formation. However, in the ordinary hadronic collisions where OZI suppression is supposed to work, the ratio will rapidly increase by a minimum factor of 3 as baryon density decreases and we go from the fragmentation region to central production of ϕ mesons.

In conclusion, Shor predicts the existence of QGP exclusively in the central region if ϕ production occurs at a rate larger by an order of magnitude than that of ordinary hadronic collisions which are subject to OZI-rule suppression. However, the exact OZI-rule suppression is not clearly known. For example, $\phi\phi$ production[4] in πp and pp collisions is experimentally found to be far less suppressed than single-ϕ production. Moreover, the factor of suppression decreases by an appreciable amount as we go from the fragmentation region to the central rapidity regime. Therefore, we suggest looking for the variation in ϕ production as a function of baryon density. A small decrease[1] in ϕ production with baryon density would signal the existence of QGP while an increase[6] in ϕ production by a minimum factor of 3 would reveal ordinary hadronic production at high energies. It may be added that nuclear collisions if studied at the stopping regime, i.e., at alternating gradient synchrotron energies, would reveal plasma production at large baryon density. Then we can extract information on ϕ production from QGP in the fragmentation region. However, if we work only in the central region the conclusions of Ref. 1 will still remain valid.

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[1]Asher Shor, Phys. Rev. Lett. **54**, 1122 (1985).
[2]J. Rafelski and B. Müller, Phys. Rev. Lett. **48**, 1066 (1982).
[3]C. P. Singh and S. N. Ram, Phys. Rev. D **31**, 219 (1985).
[4]S. J. Lindenbaum, Phys. Lett. **131B**, 221 (1983).
[5]C. Schmid, D. M. Webber, and C. Sorensen, Nucl. Phys. **B111**, 317 (1976).
[6]S. Yazaki, M. Fukugita, T. Inami, and N. Sakai, Phys. Lett. **68B**, 251 (1977).
[7]A. M. Cooper *et al.*, Nucl. Phys. **B146**, 1 (1978).
[8]G. Baym, Nucl. Phys. **A434**, 705 (1985).
[9]J. Kogut *et al.*, Phys. Rev. Lett. **51**, 869 (1983).
[10]J. Polonyi *et al.*, Phys. Rev. Lett. **53**, 644 (1984).