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P00024324

Dynamic Scaling in Hadronization and Multidimensional Intermittency

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Abstract

The intermittency pattern associated with an out-of-equilibrium quark-hadron phase transition in high-energy-density collisions, is derived. Imposing dynamic scaling as a fundamental property of inside-outside hadronization, a dynamic critical exponent is introduced and a set of new power-laws is obtained. The deviations from the corresponding pattern of a static, second-order phase transition are examined and the phenomenological aspects of this new solution are discussed.

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1. Introduction

Recently, we have studied the connection of a second-order quark-hadron phase transition with the intermittency phenomenon in high-energy hadronic collisions [1]. A multidimensional intermittency pattern, dependent on two universal indices has been produced and its phenomenological consequences, especially in explaining Fialkowski's universality [2], have been discussed. The study was based on a simplified picture for the inside-outside hadronization process as a second-order phase transition in thermal equilibrium. The corresponding power-laws for the factorial moments $F_2^{(D)}(M)$, found in this treatment, are summarized as follows [1] :

$$\begin{aligned} F_2^{(1)}(\delta y) &\sim M^{1-D_1} & F_2^{(1)}(\delta\phi) = F_2^{(1)}(\delta q_\perp) &\sim M^{D_2-1} \\ F_2^{(2)}(\delta q_\perp, \delta\phi) &\sim M^{D_2} & F_2^{(2)}(\delta\phi, \delta y) = F_2^{(2)}(\delta q_\perp, \delta y) &\sim M^{D_2-D_1} \\ F_2^{(3)}(\delta y, \delta q_\perp, \delta\phi) &\sim M^{1+D_2-D_1} & (\delta y \sim M^{-1}, \delta\phi \sim M^{-1}, \delta q_\perp \sim M^{-1}) & \quad (1.1) \end{aligned}$$

where D_1, D_2 are fractal dimensions in rapidity and impact parameter space, respectively, with the constraint $D_1 + D_2 = \frac{3\delta}{\delta+1}$, δ being the isothermal critical exponent. In order to derive eqs.(1.1) we have used the properties of the S-matrix, in the inclusive sector, together with appropriate self-similarity constraints on the densities generated by inside-outside hadronization. In what follows we argue that a modified intermittency pattern, associated with an out-of-equilibrium quark-hadron phase transition can also be derived, within the same framework. This new pattern takes into account the proper-time evolution of the hadronizing system and connects the intermittency indices with the dynamic critical exponent as well. Using this new solution to confront intermittency measurements might be valuable not only for observing the onset of a quark-hadron phase transition in nuclear collisions but also for finding-out whether this transition is a process in thermal equilibrium or a critical phenomenon out of equilibrium. Theoretically the possibility of an out-of-equilibrium hadronization process [3] may have far reaching consequences. It may suggest that the creation of hadrons in such a process is likely to be associated with the formation of stable dissipative structures in quark matter, a wellknown phenomenon in non equilibrium thermodynamics of complex systems [4]. In this context, one may speculate that the hadronization mechanism, responsible for the creation of hadrons both in nuclear collisions and in the early Universe, is still hidden behind the yet unexplored sector of nonequilibrium thermal QCD.

In section 2 dynamic scaling is formulated both in configuration and momentum space as a basic constraint on the two-point correlation function corresponding to inside-outside hadronization out of equilibrium. A multiplicative solution is obtained in which dynamic effects are restricted in transverse dimensions whereas correlations in rapidity remain time-independent. In section 3 the intermittency pattern associated with dynamic scaling is derived and the dependence of the intermittency indices on the dynamic critical exponent is explicitly shown. Phenomenological aspects of

this new solution are discussed and a comparison with the pattern (1.1) of the corresponding phase transition in thermal equilibrium is made. Finally, in section 4 our conclusions and final remarks are briefly summarized.

2. Dynamic scaling

The two-point correlation function in momentum space corresponding to an inclusive process $h_A + h_B \rightarrow h_1 + h_2 + \text{anything}$, initiated by the collision of two hadrons or nuclei, has the representation [1] :

$$\tilde{\rho}(\vec{q}_1, \vec{q}_2) = \int \prod_{i=1}^2 d\tau_i d\xi_i d^2\vec{r}_{\perp i} \exp[i\vec{q}_{\perp i} \cdot \vec{r}_{\perp i} - i\tau_i m_{T_i} \cosh(y_i - \xi_i)] \rho(x_1, x_2) \quad (2.1)$$

where we have introduced light-cone variables (τ, ξ) in the longitudinal 1+1 space-time ($z = \tau \sinh \xi, t = \tau \cosh \xi$) and conjugate variables (m_T, y) in momentum space ($q_{\parallel} = m_T \sinh y, E = m_T \cosh y$). The integrand $\rho(x_1, x_2)$ in eq.(2.1) depends on the hadronic currents in the final state [1] and in the context of inside-outside hadronization we may write :

$$\rho(x_1, x_2) = \delta(\xi_1 - y_1) \delta(\xi_2 - y_2) C(\xi_1, \vec{r}_{\perp 1}, \tau_1; \xi_2, \vec{r}_{\perp 2}, \tau_2) \quad (2.2)$$

$$\tilde{\rho}(\vec{q}_1, \vec{q}_2) = \int \prod_{i=1}^2 d\tau_i d^2\vec{r}_{\perp i} \exp[i\vec{q}_{\perp i} \cdot \vec{r}_{\perp i} - i\tau_i m_{T_i}] C(y_1, \vec{r}_{\perp 1}, \tau_1; y_2, \vec{r}_{\perp 2}, \tau_2) \quad (2.3)$$

In the integral transform (2.3), $C(y_1, \vec{r}_{\perp 1}, \tau_1; y_2, \vec{r}_{\perp 2}, \tau_2)$ represents the time-dependent, two-point correlation function of the hadronizing system, in 3D ordinary space. The spatial coordinates in this fluid are specified by rapidity ($\xi = y$) in longitudinal direction and transverse vectors $\vec{r}_{\perp}$ in impact parameter space (3D Feynman-Wilson fluid). As a time-scale we take the proper-time τ , along the hyperbolas $t^2 - z^2 = \tau^2$, a natural scale for inside-outside hadronization. With these specifications one may now proceed to impose dynamic scaling as a basic constraint on the two point correlation function, assuming that hadronization is an out-of-equilibrium phase transition. For this purpose, introducing new variables :

$$\begin{aligned} y &= y_1 - y_2, & y_0 &= \frac{1}{2}(y_1 + y_2) \\ \vec{k} &= \vec{q}_{\perp 1} - \vec{q}_{\perp 2}, & \vec{Q} &= \vec{q}_{\perp 1} + \vec{q}_{\perp 2}, & \vec{r} &= \frac{1}{2}(\vec{r}_{\perp 1} - \vec{r}_{\perp 2}), & \vec{R} &= \frac{1}{2}(\vec{r}_{\perp 1} + \vec{r}_{\perp 2}) \\ \omega &= m_{T1} - m_{T2}, & M_T &= m_{T1} + m_{T2}, & t &= \frac{1}{2}(\tau_1 - \tau_2), & \tau_0 &= \frac{1}{2}(\tau_1 + \tau_2) \end{aligned} \quad (2.4)$$

and integrating over $\vec{R}$ and τ_0 in eq.(2.3) we obtain :

$$\tilde{\rho}(\vec{k}, y, \omega) = \int e^{i\vec{k} \cdot \vec{r}} e^{-i\omega t} C(\vec{r}, y, t) d^2\vec{r} dt \quad (2.5)$$

For simplicity the dependence on $y_0, \vec{Q}, M_T$ has been ignored in both sides of eq.(2.5) since it does not affect the intermittency power-laws. It only reminds that imposing dynamic scaling one has to take into account the fact that the system is finite and therefore instantaneous correlation functions obey finite size scaling dictated by a fractal dimension, $D_F = \frac{\delta D}{\delta + 1}$. Following these remarks we introduce now a dynamic critical exponent z and write the scaling condition [5] :

$$C(\lambda \vec{r}, \lambda y, \lambda^z t) = \lambda^{D_3 - 3} C(\vec{r}, y, t) \quad (2.6)$$

where D_3 is the fractal dimension of the hadronizing system embedded in 3D configuration space ($D_3 = \frac{3\delta}{\delta + 1}$).

The central issue in our study is to find-out whether there exist intermittency patterns in momentum space associated with dynamic scaling (2.6) and, therefore, reflecting an out-of-equilibrium quark-hadron phase transition. In other words we are searching for a solution of eq.(2.5) satisfying a similar scaling relation in momentum space :

$$\tilde{\rho}(\lambda \vec{k}, \lambda y, \lambda^z \omega) = \lambda^{-\alpha} \tilde{\rho}(\vec{k}, y, \omega) \quad (2.7)$$

where the exponent α must depend on the basic indices of the process, the dynamic critical exponent z and the fractal dimensions involved. Combining now eq.(2.5) with the constraints (2.6) and (2.7) we find a stronger scaling relation :

$$\tilde{\rho}(\lambda \vec{k}, \mu y, \lambda^z \omega) = \lambda^{-\frac{\alpha + z + D_3 - 1}{2}} \mu^{-\frac{\alpha - z - D_3 + 1}{2}} \tilde{\rho}(\vec{k}, y, \omega) \quad (2.8)$$

suggesting a multiplicative solution both in configuration and momentum space as follows :

$$\begin{aligned} \tilde{\rho}(\vec{k}, y, \omega) &= \tilde{\rho}_2(\vec{k}, \omega) \rho_1(y) & C(\vec{r}, y, t) &= C_2(\vec{r}, t) \rho_1(y) \\ \tilde{\rho}_2(\lambda \vec{k}, \lambda^z \omega) &= \lambda^{-\frac{\alpha + z + D_3 - 1}{2}} \tilde{\rho}_2(\vec{k}, \omega) \\ \rho_1(\mu y) &= \mu^{-\frac{\alpha - z - D_3 + 1}{2}} \rho_1(y) \\ C_2(\lambda \vec{r}, \lambda^z t) &= \lambda^{\frac{D_3 + \alpha - z - 5}{2}} C_2(\vec{r}, t) \end{aligned} \quad (2.9)$$

Equations (2.9) show that the instantaneous correlation function $C(\vec{r}, y, t = 0)$ corresponds to a Cartesian product of two fractals in configuration space [6], one in rapidity space with fractal dimension $D_F = D_1$ and the other in impact parameter space with $D_F = D_2$. We find :

$$D_1 = \frac{1}{2}(D_3 + z + 1 - \alpha), \quad D_2 = \frac{1}{2}(\alpha - z - 1 + D_3), \quad D_1 + D_2 = D_3 \quad (2.10)$$

The critical behaviour out of equilibrium is restricted therefore in a 2D system with a correlation function satisfying in momentum space the scaling law :

$$\tilde{\rho}_2(\lambda \vec{k}, \lambda^z \omega; \vec{Q}, M_T) = \lambda^{-D_2 - z} \tilde{\rho}_2(\vec{k}, \omega; \vec{Q}, M_T) \quad (2.11)$$

where, for completeness, the dependence on $\vec{Q}$ and M_T has been included. Equation (2.11) introduces a power-singularity at $\vec{k} = 0$ which, for a specific range of values of the exponent z , becomes integrable and leads to intermittency effects in transverse momentum space. In fact the scaling law (2.11) can be recast into the form :

$$\tilde{\rho}_2(\vec{k}, \omega; \vec{Q}, M_T) = k^{-D_2-z} \tilde{\rho}_2(\vec{k}_0, \frac{\omega}{k^z}; \vec{Q}, M_T) \quad (2.12)$$

where $k = |\vec{k}|$ and $\vec{k}_0 = \vec{k}/|\vec{k}|$. On the other hand, in the limit $k \rightarrow 0$ one has the kinematic relations :

$$\begin{aligned} \omega &\approx (m^2 + \frac{Q^2}{4} + \frac{\vec{k} \cdot \vec{Q}}{2})^{1/2} - (m^2 + \frac{Q^2}{4} - \frac{\vec{k} \cdot \vec{Q}}{2})^{1/2} \approx \frac{\vec{k} \cdot \vec{Q}}{(4m^2 + Q^2)^{1/2}} \\ M_T &\approx (m^2 + \frac{Q^2}{4} + \frac{\vec{k} \cdot \vec{Q}}{2})^{1/2} + (m^2 + \frac{Q^2}{4} - \frac{\vec{k} \cdot \vec{Q}}{2})^{1/2} \approx (4m^2 + Q^2)^{1/2} \\ \frac{\omega}{k^z} &\approx \left[\frac{\vec{k}_0 \cdot \vec{Q}}{(4m^2 + Q^2)^{1/2}} \right] k^{1-z} \end{aligned} \quad (2.13)$$

and hence for $z \leq \min(1, 2 - D_2)$ the density-density correlation function has an integrable singularity at $k = 0$, of the form :

$$\tilde{\rho}_2(\vec{k}, \omega; \vec{Q}, M_T) \approx k^{-D_2-z} \tilde{\rho}_2(\vec{k}_0; \vec{Q}) \quad (2.14)$$

where, due to eqs.(2.13), the dependence on M_T and $\frac{\omega}{k^z}$ has been absorbed by the dependence on $\vec{Q}$. In section 3, the intermittency pattern generated by eq.(2.14) is derived and its phenomenological consequences are discussed.

3. Intermittency

The study of factorial moments in small domains $\delta\Omega_D \sim M^{-D}$ ($M \gg 1$) of momentum space [7] may transform scaling laws to measurable intermittency effects [1,8]. For this purpose we write the second factorial moment $F_2^{(2)}(\delta\Omega_2)$, in $2D$ transverse momentum space, in terms of the correlation function $\tilde{\rho}_2(\vec{k}, \omega; \vec{Q}, M_T)$ as follows :

$$F_2^{(2)}(\delta\Omega_2) \sim (\delta\Omega_2)^{-2} \int_{\delta\Omega_2} d^2\vec{Q} d^2\vec{k} \tilde{\rho}_2(\vec{k}, \omega; \vec{Q}, M_T) \quad (3.1)$$

Similarly, the $1D$ projection onto any direction in this space is written as follows :

$$F_2^{(1)}(\delta\Omega_1) \sim (\delta\Omega_1)^{-2} \int_{\delta\Omega_1} dk_1 dQ_1 \int_{\Omega} dk_2 dQ_2 \tilde{\rho}_2(\vec{k}, \omega; \vec{Q}, M_T) \quad (3.2)$$

In eq.(3.2) the momentum components (k_2, Q_2) , orthogonal to the projection axis, are integrated over the entire $1D$ momentum space Ω whereas the components (k_1, Q_1) are

integrated over a small domain $\delta\Omega_1$ along the projection axis. Equation (3.2) probes $1D$ intermittency effects and, in particular, may reveal the intermittent behaviour in azimuthal angle ($\delta\phi$) or in transverse momentum ($\delta q_\perp$). Integrating-out $\vec{Q}$ and Q_1 in the vicinity of a reference momentum vector $\vec{Q}^{(0)}$, extra factors $\delta\Omega_2$ and $\delta\Omega_1$ are obtained in eqs.(3.1) and (3.2) as follows :

$$F_2^{(2)}(\delta\Omega_2) \sim (\delta\Omega_2)^{-1} \int_{\delta\Omega_2} d^2\vec{k} \tilde{\rho}_2(\vec{k}, \omega; \vec{Q}^{(0)}, M_T) \quad (3.3)$$

$$F_2^{(1)}(\delta\Omega_1) \sim (\delta\Omega_1)^{-1} \int_{\delta\Omega_1} dk_1 \int_{\Omega} dk_2 dQ_2 \tilde{\rho}_2(\vec{k}, \omega; \vec{Q}, M_T) \quad (3.4)$$

with $Q_1 = Q_1^{(0)}$ in the integrand of eq.(3.4). Introducing new variables, $\vec{k}' = M\vec{k}$, in eqs.(3.3) and (3.4) and using eq.(2.14), we find in the intermittency limit $M \gg 1$, the power-laws :

$$F_2^{(2)}(M) \sim M^{D_2+z} \int_{\Omega_2} d^2\vec{k}' k'^{-D_2-z} \tilde{\rho}_2(\vec{k}'_0; \vec{Q}^{(0)}) \quad (3.5)$$

$$F_2^{(1)}(M) \sim M^{D_2+z-1} \int_{\Omega_1} dk_1 \int_{\Omega} dk_2 dQ_2 k'^{-D_2-z} \tilde{\rho}_2(\vec{k}'_0; Q_1^{(0)}, Q_2) \quad (3.6)$$

where Ω_1, Ω_2 are M -independent domains of momentum space and $\tilde{\rho}_2(\vec{k}'; Q_1, Q_2) \equiv \tilde{\rho}_2(\vec{k}'; \vec{Q})$. The validity of these power-laws relies upon the restriction $z \leq 2 - D_2$ which guarantees that the integrals in eqs.(3.5) and (3.6) are finite. Inserting now the power laws (3.5-3.6) into the multiplicative solution (2.9), a complete multidimensional intermittency pattern is obtained as follows :

$$\begin{aligned} F_2^{(1)}(\delta y) &\sim M^{1-D_1} & F_2^{(1)}(\delta\phi) = F_2^{(1)}(\delta q_\perp) &\sim M^{D_2+z-1} \\ F_2^{(2)}(\delta q_\perp, \delta\phi) &\sim M^{D_2+z} & F_2^{(2)}(\delta q_\perp, \delta y) = F_2^{(2)}(\delta\phi, \delta y) &\sim M^{D_2-D_1+z} \\ F_2^{(3)}(\delta y, \delta q_\perp, \delta\phi) &\sim M^{1+D_2-D_1+z} \end{aligned} \quad (3.7)$$

Due to finite size effects, the scaling relations (2.9) leading to eqs.(3.7) are valid in a restricted range of scales, $y \ll Y$, $|\vec{r}| \ll r_0$ where Y, r_0 correspond to longitudinal and transverse size of the system (Feynman-Wilson fluid). This constraint implies, in general, intermittency breaking effects for very small domains in transverse momentum space ($|\vec{k}| \ll r_0^{-1}$) and puts a limitation to the applicability of eqs.(3.7) when one considers the extreme intermittency limit $M \rightarrow \infty$. Such breaking effects are expected to appear consistently with our treatment, in high-statistics measurements of intermittency patterns, in the region $M \gg r_0 Q^{(0)}$ [1].

Comparing now eqs.(3.7) with the pattern (1.1), corresponding to a static quark-hadron phase transition ($z = 0$), we observe that the dynamic critical exponent z does not affect the qualitative features of this pattern, it only introduces an effective fractal dimension in impact parameter space, $D'_2 = D_2 + z$ ($0 < D'_2 \leq 2$), higher than D_2 ($0 < z \leq 2 - D_2$). Physically, the pattern (3.7) becomes more transparent if we express the fractal dimensions D_1, D_2 in terms of the static critical exponent

δ [9], assuming that the projection of the critical system onto rapidity space is a normal system in thermal equilibrium (1D Feynman-Wilson fluid hypothesis). In other words, we consider the sector of the general solution (3.7) specified by the constraint $D_2 = 2D_1 = \frac{2\delta}{1+\delta}$ and thus generating a multidimensional intermittency pattern dependent on two critical exponents (δ, z) as follows :

$$\begin{aligned}
\ln F_2^{(1)}(\delta y) &= \frac{\ln M}{\delta + 1} \\
\ln F_2^{(1)}(\delta \phi) &= \ln F_2^{(1)}(\delta q_\perp) = \left(\frac{\delta - 1}{\delta + 1} + z \right) \ln M \\
\ln F_2^{(2)}(\delta q_\perp, \delta \phi) &= \left(\frac{2\delta}{\delta + 1} + z \right) \ln M \\
\ln F_2^{(2)}(\delta q_\perp, \delta y) &= \ln F_2^{(2)}(\delta \phi, \delta y) = \left(\frac{\delta}{\delta + 1} + z \right) \ln M \\
\ln F_2^{(3)}(\delta y, \delta q_\perp, \delta \phi) &= \left(1 + z + \frac{\delta}{\delta + 1} \right) \ln M
\end{aligned} \tag{3.8}$$

The predictive power of eqs.(3.8) relies upon the knowledge of the actual values of the critical exponents (δ, z) which belong to the yet unknown universality class of an out-of-equilibrium hadronization process in 2D (impact parameter space). In order to connect these fundamental parameters with the basic theory of strong interactions, new methods for treating critical phenomena in non equilibrium thermal QCD are obviously required. In the meantime, intermittency measurements in high-energy collisions remain a valuable, phenomenological instrument for exploring the nature of quark-hadron phase transition and extracting critical exponents [1]. In this framework, a comparison of power-laws (3.8) with experiments may decide whether intermittency measurements favour a nonzero value for the dynamic critical exponent ($0 < z \leq \frac{2}{\delta+1}$) suggesting a non equilibrium quark-hadron phase transition. For this purpose, a systematic study of Fialkowski's universality [2] extended to lower dimensions is needed [1], taking into account the fact that at current experiments a conventional component is dominant [10], prohibiting the formation of a genuine intermittency pattern of the form (3.8). In such a treatment and in order to minimize the uncertainties of the two-component scheme [11], high precision measurements of the moments $F_2^{(D)}(M)$, in a number of hadronic processes, are needed. Obviously, the proposal for such a programme becomes more promising when it refers to future experiments with relativistic heavy ions (RHIC, LHC) in which one expects to achieve appreciable quark-gluon plasma cross section and, therefore, cleaner and stronger intermittency effects.

4. Conclusions

We have discussed multidimensional intermittency effects associated with quark-hadron phase transition out of equilibrium. We have formulated dynamic scaling as a critical property of the S -matrix component communicating with hadronization channels. A basic ingredient in this approach was the assumption of inside-outside cascade in longitudinal direction, leading to a Feynman-Wilson fluid in $3D$, out of equilibrium. In this picture, rapidity was identified with the longitudinal coordinate and proper time with the time-scale of the hadronization process.

A multiplicative solution for the density-density correlation function has been found in which dynamic effects are restricted in transverse $2D$ space whereas fractality in rapidity remains a characteristic static property of the $1D$ critical Feynman-Wilson fluid [12]. Correspondingly, a multidimensional intermittency pattern, for a specific range of values of the dynamic critical exponent, naturally emerges and a particular sector of this solution specified by two critical exponents (δ, z) has been considered.

In the absence of a theory of dynamic critical phenomena in QCD, intermittency measurements of high precision are of particular importance since they may decide whether a nonzero value of the dynamic critical exponent ($z > 0$) suggesting a non equilibrium phase transition, is required by the actual experiments. In particular, we have argued that a systematic study of Fialkowski's universality, within our model, extended to lower dimensions in momentum space may provide us with a suitable method to extract phenomenologically the actual values of the critical exponents (δ, z) and probe the nature of quark-hadron phase transition in high energy-density collisions.

Acknowledgment : This work was supported in part by BP Cyprus Ltd.

References

1. N.G. Antoniou, F.K. Diakonov, I.S. Mistakidis and C.G. Papadopoulos, "Criticality, Fractality and Intermittency in Strong Interactions", preprint CERN-TH.6990/93, UA/NPPS-5-93; N.G. Antoniou, F.K. Diakonov and I.S. Mistakidis, Phys. Lett. **B293** (1992) 187.
2. K. Fialkowski, Phys. Lett. **B272** (1991) 139 ; Proc. Cracow Workshop on Multiparticle Production 1993, World Scientific, Singapore, to be published.
3. P. Carruthers, Summary talk presented at LESIP I (Local Equilibrium in Strong Interaction Physics, Bad Honnef, Germany, September 2-6, 1984).
4. G. Nicolis and I. Prigogine, *Self-Organization in Non-Equilibrium Systems* John Wiley and Sons, New York 1977.
5. S-K. Ma, *Modern Theory of Critical Phenomena* Benjamin Publishing Co., Reading / Mass. 1976.
6. K. Falconer, *Fractal Geometry*, John Wiley and Sons, New York 1989.
7. A. Bialas and R. Peschanski, Nucl. Phys. **B273** (1986) 703 ; **B308** (1988) 803.
8. I.M. Dremin and M.T. Nazirov, Z. Phys. **C59** (1993) 647.
9. R.B. Stinchcombe, *Order and Chaos in Nonlinear Physical systems* p.295, Edited by S. Lundquist, N.H. March and M.P. Tosi, Plenum Press, N. York 1988.
10. P. Carruthers and I. Sarcevic, Phys. Rev. Lett. **63** (1989) 1562.
11. N.G. Antoniou, E.N. Argyres, C.G. Papadopoulos and S.D.P. Vlassopoulos, Phys. Lett. **B260** (1991) 199.
12. N.G. Antoniou, A.P. Contogouris, C.G. Papadopoulos and S.D.P. Vlassopoulos, Phys. Rev. **D45** (1992) 4034 ;