Effect of the equation of state on particle spectra, elliptic flow and HBT radii

Danuce M. Dudek[1], W.-L.Qian[2], S.S.Padula[1], G. Krein[1], Y. Hama[2], C.Wu[4], O.Socolowsky Jr.[5], T. Kodama[6]

[1]Instituto de Física Teórica – UNESP, [2]Universidade de São Paulo, [4]Shanghai Institute of Applied Physics, [5]Universidade Federal do Rio Grande, [6]Universidade Federal do Rio de Janeiro

INTRODUCTION:

We present results of a systematic study of the role of the equation of state in the hydrodynamic model. By using the same initial conditions and freeze-out scenario, the effects of different equations of state are compared by calculating their respective hydrodynamical evolution, particle spectra, elliptic flow and HBT radii. Three different types of equation of state are studied, each focusing on different features, such as nature of the phase transition, strangeness and baryon densities. Different equations of state imply different hydrodynamic responses, the impact thereof on final state anisotropies are investigated. The results of our calculations are compared to the data from RHIC at $\sqrt{s_{NN}}$= 130 GeV and $\sqrt{s_{NN}}$= 200 GeV . It is found that the three equations of state used in the calculations describe the data reasonably well; differences can be observed, but they are quite small. The insensitivity to the equation of state seems to weaken the need for a locally thermalized description of the system, at least for the observables analyzed in this work.

HYDRODINAMICAL MODEL:

In the hydrodynamical model it is assumed that the hot and dense matter formed in a high-energy collision is in local thermal equilibrium. This system is described dynamically by conserved quantities such as energy-momentum tensor, baryon number, strangeness, etc.

$$\partial_\nu T^{\mu\nu} = 0 \qquad T^{\mu\nu} = (\varepsilon + p)u^\mu u^\nu - p g^{\mu\nu}$$

$$\partial_\nu n_i u^\nu = 0, \qquad i = 1,2,\ldots,N$$

INITIAL CONDITIONS AND DECOUPLING CRITERIA:

The initial conditions for Au+Au collisions are given by NeXus at mid-rapidity plane and they are fluctuating event by event. To decoupling criteria used the Cooper-Frye prescription:

$$E\frac{dN}{d^3k} = \int_\Sigma d\sigma_\mu k^\mu f(x,k)$$

where f(x,k) is the thermal distribution function and Σ is a hypersurface of constant temperature.

EQUATION OF STATE:

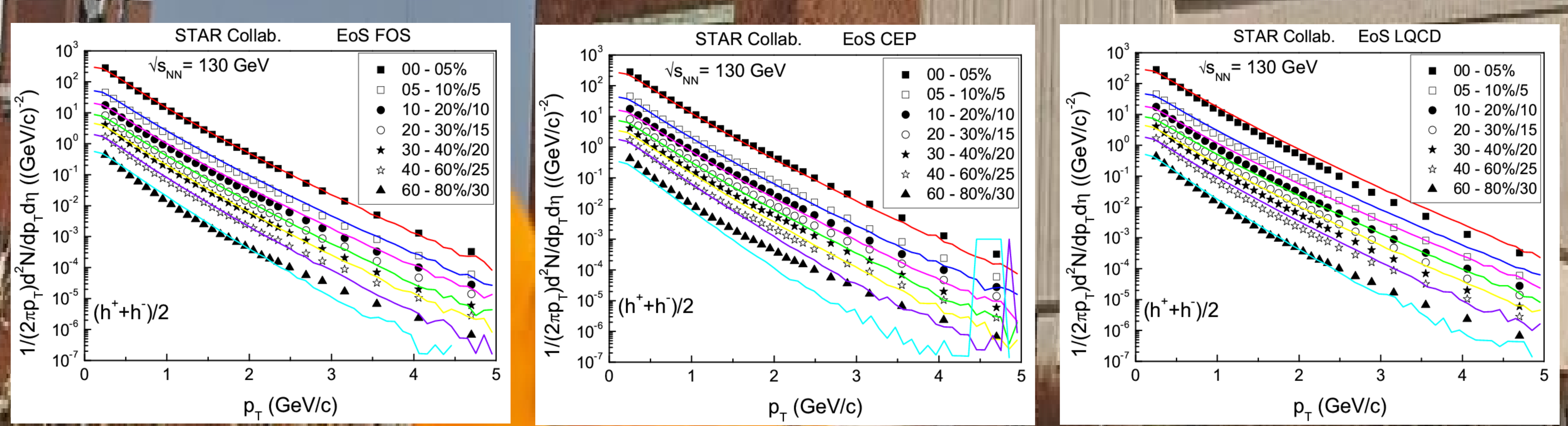
When high-energy collisions were simulated it was common to use equations of state with a first-order phase transition to connect the QGP phase with the hadron phase. However, lattice QCD showed that the transition is a smooth crossover at zero baryon density, which may be of first order at large baryon density and possesses a critical end point. Here we adopt three diferents EoS: EoS of 1st order transition with local strangeness neutrality (FOS), lattice QCD inspired EoS with a phenomenological critical point (CEP) and parameterized EoS fitting to the lattice QCD data (LQCD).

OBSERVABLES:

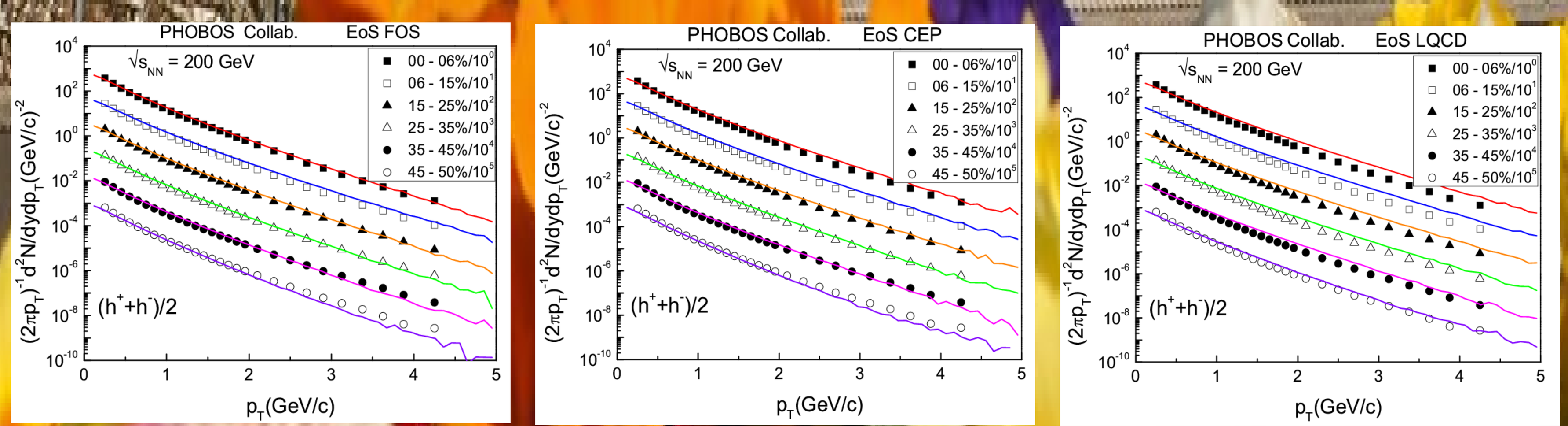
Particle spectra:

The overall normalization factor was fit by using the charged particle yields $dN_{ch}/d\eta$. The p_T spectra of all charged particles were used to fit the kinetic freeze-out temperature. The fits were done as a function of the centrality window.

$\sqrt{s_{NN}}$=130 GeV



$\sqrt{s_{NN}}$=200 GeV



Elliptic flow:

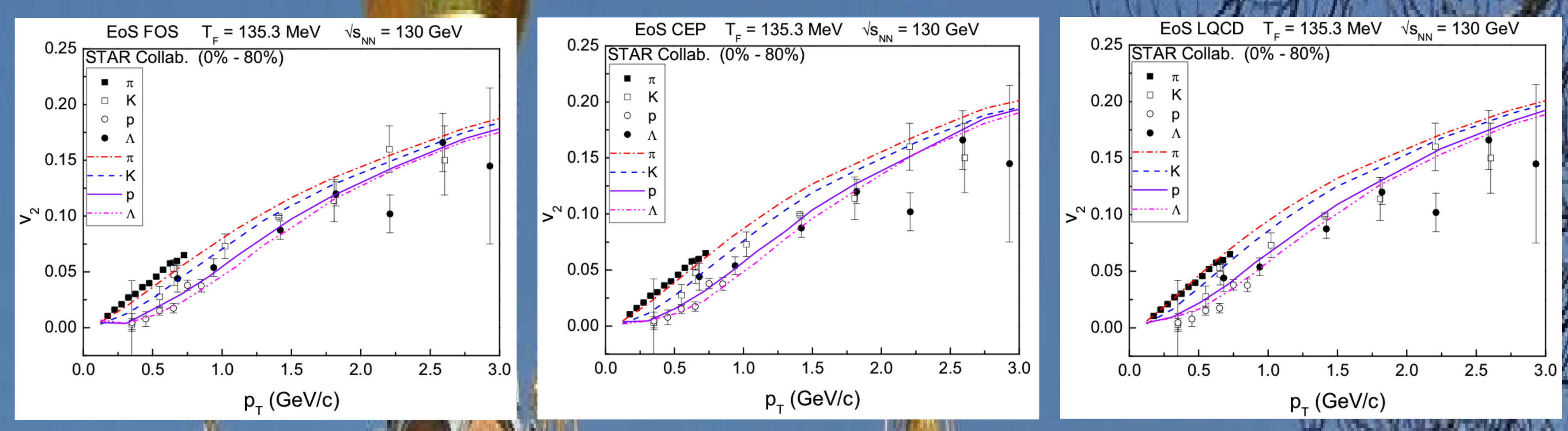
The elliptic flow is defined as the second Fourier coefficient of the azimuthal distribution $dN/d\phi$,

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi p_T}\frac{d^2N}{dy\,dp_T}[1 + 2v_1\cos(\phi-\psi_1) + 2v_2\cos[2(\phi-\psi_2)] + \ldots]$$

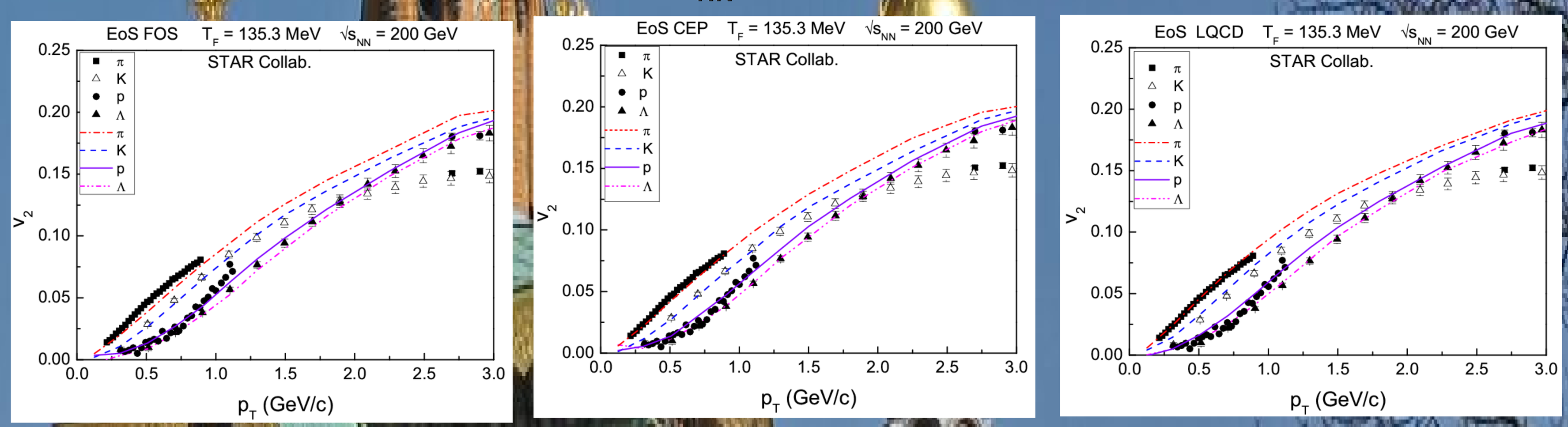
$$v_n(p_T, y) = \langle\cos[n(\phi-\psi_n)]\rangle \quad n = 1,2,3,\ldots$$

Elliptic Flow (v_2) - identified particle and charged hadron

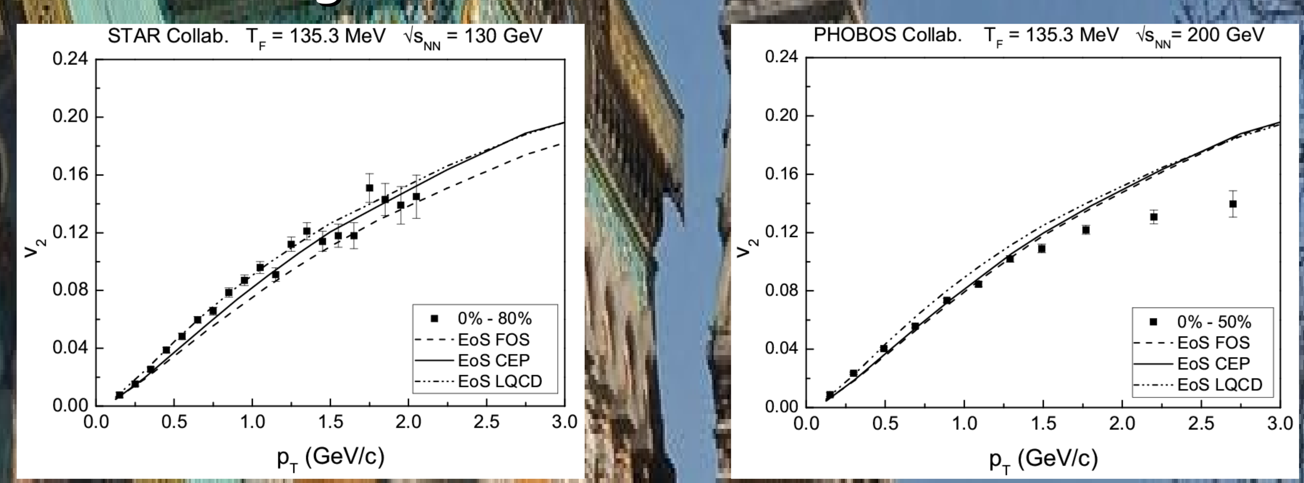
$\sqrt{s_{NN}}$=130 GeV



$\sqrt{s_{NN}}$=200 GeV



Elliptic flow - charged hadron

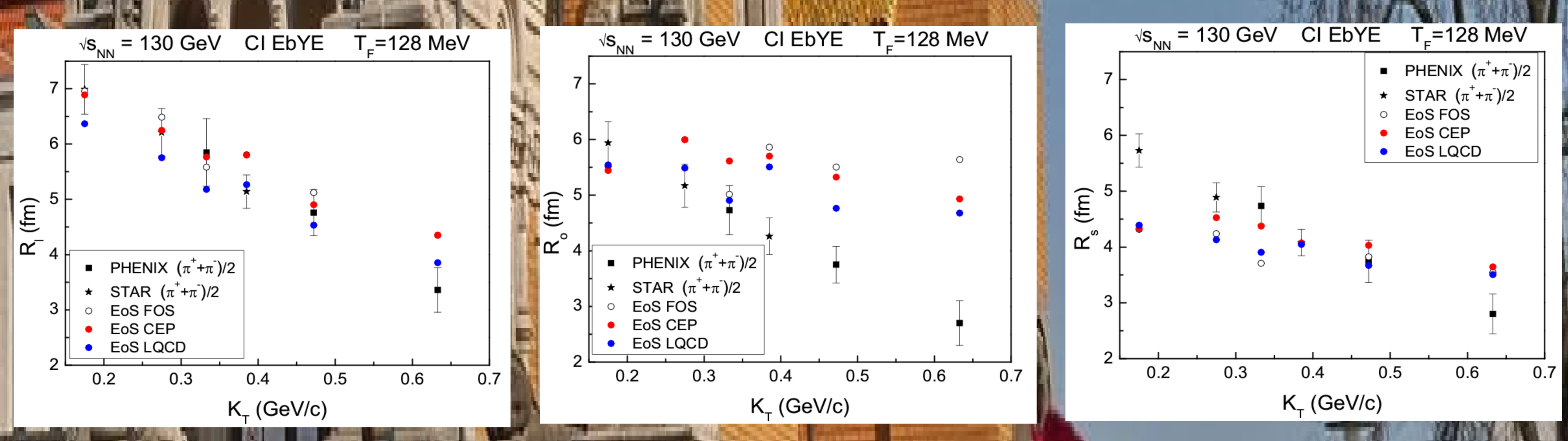


HBT-radii:

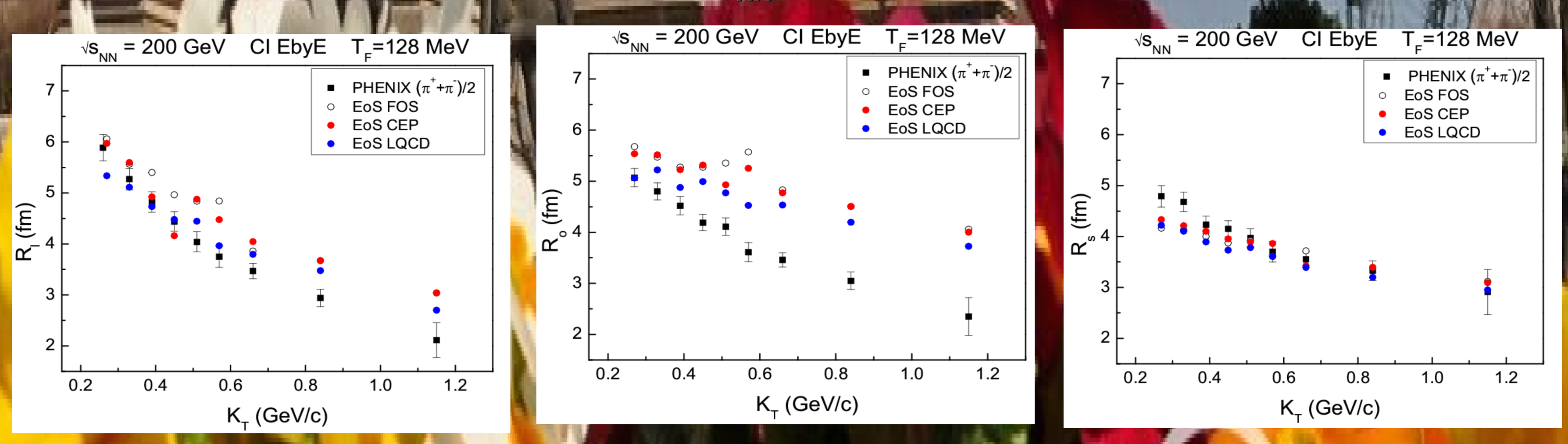
Bose-Einstein correlation function of identical pions. The fit of the correlation function to estimate the system size was done using

$$C(\vec{q},\vec{K}) = 1 \pm \lambda(\vec{K})\exp\left\{-q_o^2R_o^2(\vec{K}) - q_s^2R_s^2(\vec{K}) - q_l^2R_l^2(\vec{K})\right\}$$

$\sqrt{s_{NN}}$=130 GeV



$\sqrt{s_{NN}}$=200 GeV



CONCLUSION:

We use three diferents EoS to fit experimental data of spectra, v_2 and HBT radii. All EoS can describe the experimental data reasonably, especially for small p_T in the case of v_2 and particle spectra. For HBT radii, we can see a very similar behavior for all EoS. Based on this, we conclude that these observables are not very sensitive to EoS.

BIBLIOGRAFY:

[1] Y.Hama,T.Kodama and O.Socolowski Jr. Braz.J.Phys. 35, 24, (2005). [2] P.Huovinen, P.Petreczky Nucl.Phys.A 837, 26, (2010). [3] J. Adams et al. Phys.Rev.C 70, 44901, (2004). [4] B.B. Back et al. Phys.Rev.B 578, 297 (2004). [5] K.H. Ackermann et al. Phys.Rev.Lett. 86, 402 (2001). [6] B.B. Back et al. Phys.Rev.Lett. 89, 222301 (2002). [7] C. Adler et al. Phys.Rev.Lett. 87, 182301 (2001). [8] C. Adler et al. Phys.Rev.Lett. 89, 132301 (2002). [9] B.B. Back et al. Phys.Rev.C 72, 051901 (2005). [10] B.I. Abelev et al. Phys.Rev.C 77, 054901, (2008). [11] S.S. Adler Phys.Rev.Lett.83, 152302, (2004). [12] K. Adox Phys.Rev.Lett. 88, 192302 (2002). [13] B.B.Back Phys.Rev.C 73, 031901, (2006). [14] C. Adler Phys.Rev.Lett. 87, 082301, (2001).