Determination of Critical Exponents in Finite Systems^G

A. Wörner for the ALADIN-Collaboration

Many observations in nuclear fragmentation studies suggest that nuclear multifragmentation might reveal a critical phenomenon [1,2]. Generally the nature of a second order phase transition in an infinite system can be characterized by critical exponents. Studying the breakup of 1 AGeV Au nuclei interacting with a carbon target, critical exponents were deduced for nuclei which resemble those for an infinite liquid-gas system [3,4].

In order to investigate the influence of the finite size on critical exponents we performed percolation simulations on cubic lattices. The left part of Fig. 1 shows the exponents γ and β [3] which were extracted from the second moment of the cluster-size distribution and the size of the heaviest cluster, respectively. For a given system size, different points along the lines correspond to different assumptions on the critical bond probability, thus mimicking our ignorance of the location of the critical point in nuclear systems. However, even allowing for this additional 'degree of freedom' these lines never approach the $\beta - \gamma$ pair representative for the infinite percolating system (dot in Fig. 1) if the system is of typical nuclear size $L^3 = 6^3$-10^3.

Furthermore, the apparent exponents β and γ are affected by the choice of the control parameter. As an example the right part of Fig. 1 shows β and γ if $S_{BOUND} = \sum_{s\geq 2} s$ is used as a control parameter instead of the bond probability. (S_{BOUND} is comparable to the observable Z_{BOUND} which characterizes the energy deposition in nuclear collisions [5].)

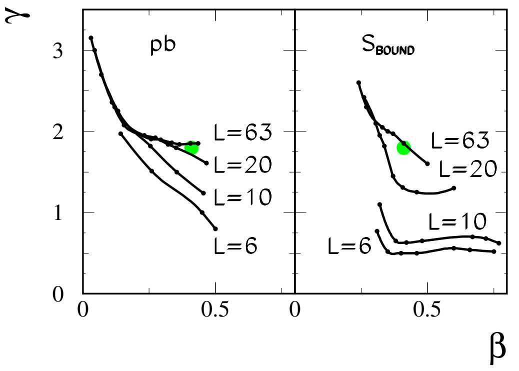

Figure 1: Apparent exponents γ and β for various lattice sizes L and for bond probability (left) and S_{BOUND} (right) as control parameter. The correct values for the infinite 3d percolation-modell ($\gamma = 1.8, \beta = 0.41$) are marked by the dot.

Apparent τ-parameters obtained from fits to the cluster size distributions in the range $2 \leq s \leq L^3/3$ and assuming a pure power law $s^{-\tau_1}$ or a product of a power law and an exponential function $s^{-\tau_2} exp(-s/m_0)$ are shown in Fig. 2 by the circles and dots, respectively. Identical values for τ_1 and τ_2 signal a pure power law. When approaching the critical region from the 'gaseous' phase - the transition to a pure power law takes place - even for systems as small as 4^3 - at the true critical bond probability of the infinite system p_c=0.249 and at the correct value of τ_c=2.18 (upper two parts of Fig. 2). Furthermore, using S_{BOUND} as the control parameter this analysis provides - independently of system size - also the 'correct' τ value and a critical S_{BOUND} which coincides with the average S_{BOUND} evaluated at the true critical bond probability pb$_c$.

Applying this method to the projectile fragment distributions suggests for Au as well as for U induced reactions a transition at $Z_{BOUND}/Z_{PROJ} \approx 0.43$ which corresponds to an excitation energy per nucleon of approximately 9-10 MeV [5] and a critical exponent $\tau = 2.5 \pm 0.1$ (Fig. 3).

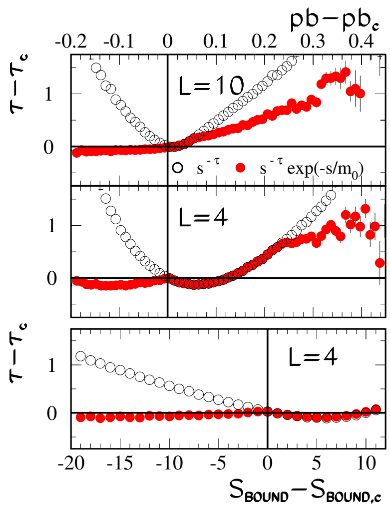

Figure 2: Deviation of the extracted values for τ from the critical exponent $\tau_c = 2.18$ for a pure powerlaw-fit (circles) and a product of a powerlaw and an exponential function (dots) versus the deviation of the control parameter from its infinite critical value.

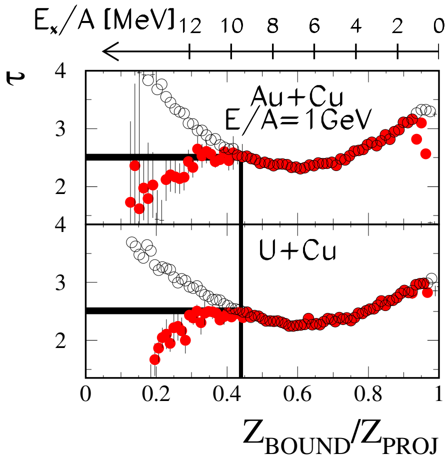

Figure 3: Apparent exponents τ versus Z_{BOUND}/Z_{PROJ} for Au+Cu and U+Cu reactions at E/A=1GeV.

References

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