Evidence for the Onset of Deconfinement and Quest for the Critical Point by NA49 at the CERN SPS*

(for the NA49 Collaboration)

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Abstract—The NA49 results on hadron production obtained in PbPb collisions at SPS energies from 20 to 158 A GeV are shown and discussed as evidence for the onset of deconfinement. The primary measures are the pion yield, the kaon-to-pion ratio and the slope parameter of transverse mass distributions. The possible indication of the QCD critical point signatures was investigated in the event-by-event fluctuations of various observables such as the mean transverse momentum, particle multiplicity and azimuthal angle distributions as well as in the particle ratio fluctuations. The energy dependence of these observables was measured in central PbPb collisions in the full SPS energy range while for analysis of the system size dependence data from pp, CC, SiSi, and PbPb collisions at the top SPS energy were used.

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1. INTRODUCTION

It was early shown [1] that nucleus–nucleus collisions at the CERN SPS offered the possibil-

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Fig. 1. (a) Phase diagram of strongly interacting matter in the plane temperature \( T \) versus baryonic chemical potential \( \mu_B \). The dark band is a lattice QCD estimate [8] of the first-order phase boundary between quark–gluon plasma and hadrons which ends in a critical point \( E \) and then proceeds to a crossover. Symbols denote the chemical freeze-out parameters of heavy-ion collisions at different energies as extracted by statistical model fits [9–11] to the data of the hadron composition at RHIC (STAR), SPS (NA49), AGS, and SIS. The open symbols schematically indicate possible values of initial parameters of the reaction systems, which then might evolve along paths as depicted by the vertical lines. (b) Results of a statistical model fit to NA49 hadron yields in 158 \( A \) GeV central PbPb collisions [11].

The location of the hadron chemical freeze-out points of the high density fireball produced in nucleus–nucleus collisions is shown in Fig. 1a. They are obtained from fits of a statistical hadron gas model to hadron abundances [9–11]. It provides a good fit to the total yields of numerous particle species with three parameters, namely a temperature \( T \), a baryochemical potential \( \mu_B \), and a strangeness saturation parameter \( \gamma_s \) (Fig. 1b). The resulting freeze-out points for central PbPb collisions in the CERN SPS energy range are seen to approach the estimated phase boundary and the critical point \( E \).

In the vicinity of the QCD critical point large event-by-event fluctuations of various observables are expected [12, 13]. This paper reports the status of the search for such fluctuations. Results will be presented from analysis of central PbPb collisions, which were recorded for SPS beam energies of 20, 30, 40, 80, and 158 \( A \) GeV (\( \sqrt{s_{NN}} = 6.3, 7.6, 8.7, 12.3, \) and 17.3 GeV) as well as from \( pp \), CC, and SiSi interactions at 158 \( A \) GeV.

2. EXPERIMENT

The experiment was carried out with the NA49 large-acceptance hadron detector [14] employing a system of time projection chambers (TPCs) for efficient tracking in the forward hemisphere of the reactions, precise momentum reconstruction in the magnetic field, and particle identification using the energy loss \( dE/dx \) in the TPC gas. Two time-of-flight (TOF) walls of 900 scintillator pixels each situated...