ONSET OF DECONFINEMENT AND CRITICAL POINT – FUTURE ION PROGRAM AT THE CERN SPS

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Abstract. A new experimental program to study hadron production in collisions of nuclei at the CERN SPS is presented. It will focus on measurements of fluctuations and long correlations with the aim to identify properties of the onset of deconfinement and search for the critical point of strongly interacting matter.

Key words: quark-gluon plasma, deconfinement, critical point, relativistic nuclear collisions

1. Introduction

Over the 50 years of CERN history numerous experimental programs were devoted to a study of the properties of strong interactions [1]. Rich data on collisions of hadron and ion beams were collected. These results together with the data from other world laboratories have significant impact on our understanding of strong interactions and at the same time lead to new questions and define directions of future experimental and theoretical studies [2]. In particular, recently obtained exciting results [3, 4] on nucleus-nucleus collisions from the CERN SPS and the BNL RHIC suggest that the onset of deconfinement is located at the low SPS energies [5]. The most important open issues related to this finding are as follows. Is it possible to observe the predicted signals of the onset of deconfinement in fluctuations and anisotropic flow measurements? What is the nature of the transition from the anomalous energy dependence seen in the central Pb+Pb collisions at the SPS energies to the smooth dependence observed in p+p interactions? Does the critical point of strongly interacting matter exist and, if it does, where is it located?

In order to answer these questions it was proposed [6] to perform a sequence of new measurements of hadron production in collisions of protons and nuclei with nuclear targets at CERN by use of the upgraded NA49 apparatus [7].

The NA49 apparatus at the CERN SPS served during the last 10 years as a very reliable, large acceptance hadron spectrometer and delivered unique...
high precision experimental data over the full range of SPS beams (from proton to lead) [8, 10] and energies (from 20A GeV to 200A GeV) [3, 4]. The most efficient and cost effective way to reach the physics goals of the proposed new experimental program is to use the upgraded NA49 detector, its reconstruction software and over many years accumulated experience in physics analysis.

The paper is organized as follows. The key physics questions addressed by the new program are formulated in Section 2. The basic requirements concerning the future measurements are discussed in Section 3. In Section 4 different experimental opportunities to study nucleus-nucleus collisions are briefly reviewed. The paper is closed by the summary, Section 5.

2. Key questions

One of the key issues of contemporary physics is the understanding of strong interactions and in particular the study of the properties of strongly interacting matter in equilibrium. What are the phases of this matter and how do the transitions between them look like are questions which motivate a broad experimental and theoretical effort. The study of high energy nucleus-nucleus collisions gives us a unique possibility to address these questions in well-controlled laboratory experiments.

2.1. ONSET OF DECONFINEMENT

Recent results [3, 4] on the energy dependence of hadron production in central Pb+Pb collisions at 20A, 30A, 40A, 80A and 158A GeV coming from the energy scan program at the CERN SPS serve as evidence for the existence of a transition to a new form of strongly interacting matter, the Quark Gluon Plasma (QGP) in nature [5]. Thus they are in agreement with the conjectures that at the top SPS and RHIC energies the matter created at the early stage of central Pb+Pb (Au+Au) collisions is in the state of QGP [11, 15]. The key results are summarized in Fig. 1.

The most dramatic effect can be seen in the energy dependence of the ratio \( \langle K^+ \rangle / \langle \pi^+ \rangle \) of the mean multiplicities of \( K^+ \) and \( \pi^+ \) produced per event in central Pb+Pb collisions, which is plotted in the top panel of the figure. Following a fast threshold rise, the ratio passes through a sharp maximum in the SPS range and then seems to settle to a lower plateau value at higher energies. Kaons are the lightest strange hadrons and \( \langle K^+ \rangle \) is equal to about half of the number of all anti-strange quarks produced in the collisions. Thus, the relative strangeness content of the produced matter passes through a sharp maximum at the SPS in nucleus-nucleus collisions. This feature is not observed for proton-proton reactions.