

The Spectator-Induced Electromagnetic Effect on Meson Production in Nucleus-Nucleus Collisions at SPS Energies

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Abstract. The electromagnetic interaction between the spectator system and the charged mesons produced in the course of the high energy heavy ion collision was studied experimentally and theoretically in earlier works [1,2]. This effect was found to result in very large distortions of the final state spectra of the produced mesons [3] and to bring new information on the space-time evolution of the non-perturbative meson production process [4]. In this paper a more extended analysis of this effect will be presented, including a comparative study between charged meson spectra produced in Pb+Pb collisions as well as collisions of Pb ions with smaller nuclei. The experimental results will be compared with Monte Carlo simulations, giving a fair overall understanding of the interplay between the strong and the electromagnetic interaction in the heavy ion collision. A universal behaviour of charged meson spectra emerges from the above comparative study. This gives a unique chance of using the spectator charge as a tool to study the space-time evolution of the high energy nucleus-nucleus reaction.

1 Introduction

Processes occurring in nucleus-nucleus collisions include the participant zone and the highly charged nuclear remnant (spectator system). Interesting information about dynamics of the nuclear collision is brought by the analysis of electromagnetic interaction between produced particles and spectator protons. Theoretical and experimental studies on how this phenomenon impacts on charge meson distributions in Pb+Pb collisions can be found in works [1,2]. These analyses have shown that the presence of spectator charge causes significant modification in the shape of meson spectra. This electromagnetic distortion is interrelated to the space-time scenario of collision and allows to draw conclusions about space-time evolution of particle production in nuclear reactions.

The aim of this paper is to extend the information about the spectator- induced electromagnetic effect. The main emphasis is put on comparison between charge π meson spectra produced in two different types of nucleus-nucleus collisions (Pb+Pb and “Pb+gas” reactions) and on results obtained from Monte Carlo simulations.

2 Electromagnetic effect in peripheral Pb+Pb and in Pb+gas collisions

2.1 Experiment and data

The data come from the NA49 fixed target experiment at SPS at CERN. It was dedicated to study hadron-hadron, hadron-nucleus, nucleus-nucleus collisions (in particular Pb+Pb reactions) in the

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^b All the experimental results and other experimental input used in this paper were obtained in the framework of the NA49 Collaboration. The theoretical calculations were performed in collaboration with A. Szczurek (H. Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences).

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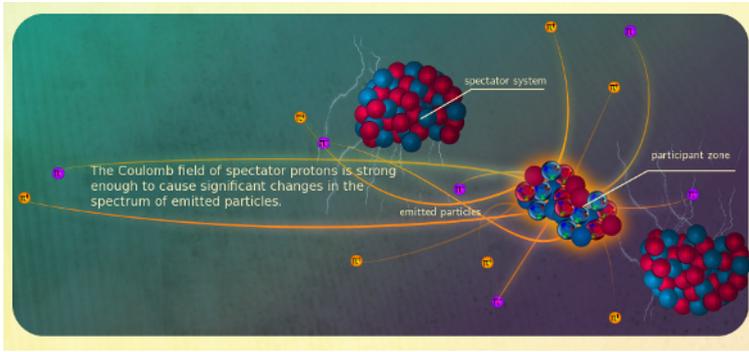


Fig. 1. Schematic picture of heavy ion collision at high energy.

range of beam energies from 20 to 158 GeV/nucleon. We have compared charged π meson spectra obtained from “Pb+gas” reactions and peripheral Pb+Pb collisions at beam energy of 158 GeV/nucleon. In this paper “Pb+gas” shall be understood as the collisions of large lead projectile with smaller nuclei of gas (Pb+N, Pb+O) in the vicinity of NA49 target (see [5] for more details discussion). The selection of peripheral Pb+Pb sample was made by a cut 150-300 on charged particle multiplicity. Only those of Pb+gas collisions were analysed in which the observed charged particle multiplicity was the same as the cut defining peripheral Pb+Pb interactions.

2.2 Charged pion spectra

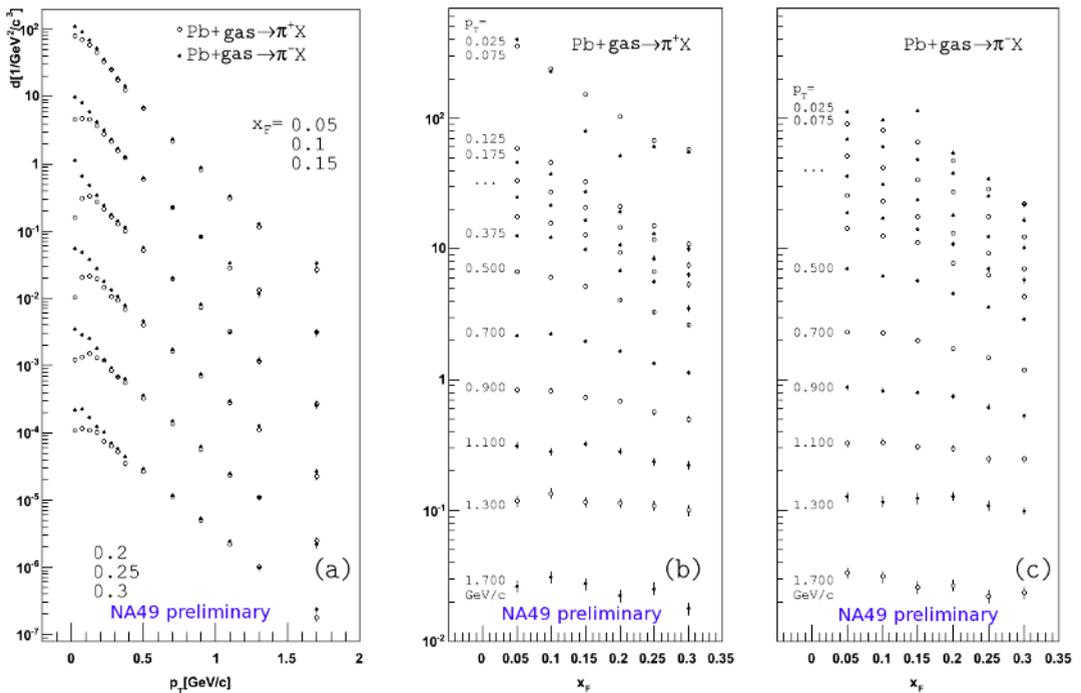


Fig. 2. Invariant density of charged pions produced in the projectile (Pb) hemisphere of asymmetric Pb+gas collisions drawn as a function of transverse momentum p_T and Feynman variable $x_F = p_L/\sqrt{s_{NN}}$ (nucleon-nucleon c.m.s).

The measured results on charged π meson production in Pb+gas collisions in projectile fragmentation region ($x_F > 0$) are shown in the Fig. 2. The invariant density of π^+ and π^- was plotted in a complementary way, as a function of p_T and x_F . The evident dominance of negative over positive pions in the p_T distribution chart (Fig. 2.(a)) can be explained as a result of the overlap of two factors: the isospin effect and the electromagnetic interaction between charged particles and spectator protons.

Firstly, particle production in nuclear collisions is affected by isospin. There is a surplus of neutrons over protons in Pb nucleus. The moderate excess of π^- over π^+ observed for $p_T > 0.3$ GeV/c in the p_T distribution chart can be explained by to the isospin content of the Pb projectile (see also [3]).

Significantly larger disparities in density of π mesons are observed for low values of transverse momenta ($p_T < 0.3$ GeV/c). The biggest disproportion between π^- and π^+ spectra occurs for $x_F = 0.15 = \frac{m_\pi}{m_N}$ which is matching to pions moving longitudinally with the same velocity as spectator system. The observed decrease (increase) in density of positive (negative) pions in Fig. 2.(a) is a consequence of Coulomb repulsion (attraction) of π^+ (π^-) by positively charged collision remnant of the projectile nucleus. This effect is also responsible for the very large difference evident in Fig. 2.(b),(c) between x_F distributions of positive and negative π mesons, measured at the lowest value of p_T (0.025 GeV/c).

2.3 Comparative studies of π^+/π^- ratios

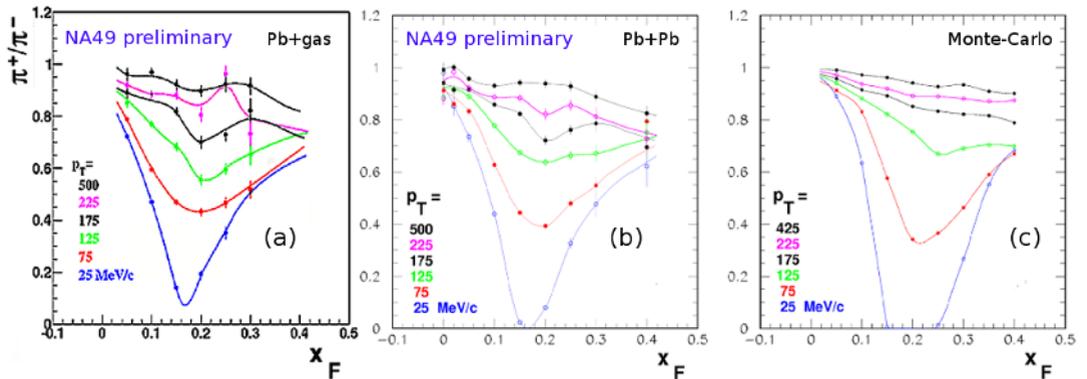


Fig. 3. π^+/π^- ratios drawn as a function of x_F (nucleon-nucleon c.m.s.) at several values of p_T for: (a) experimental data from Pb+gas collisions and (b) peripheral Pb+Pb reactions [3] and (c) the results of MC simulation for peripheral Pb+Pb collisions [3].

The comparative studies on electromagnetic distortion of π meson spectra in Pb+Pb and Pb+gas collisions give the information on how the electromagnetic effect depends on reaction type and geometry.

Fig. 3.(a), (b) presents the ratio of charged pions (π^+/π^-) plotted as a function of x_F for fixed values of p_T , respectively for Pb+gas and peripheral Pb+Pb collisions. These experimental data are then compared with the results of Monte Carlo simulation for the latter reaction (Fig. 3.(c)). The corresponding theoretical model of the peripheral Pb+Pb collisions, including the electromagnetic interaction, is described in detail in [1].

On each of the three panels, there is a characteristic structure as a function of x_F and p_T with sharp drop of π^+/π^- ratio for low values of p_T around $x_F = 0.15$ which disappears for higher values of transverse momenta. The quantitative agreement between the MC simulation and experimental data indicates that the observed “deformation” in charged pion ratios is indeed induced by the electromagnetic interaction of positively charged nuclear remnant with emitted particles. As described in work [1], the shape of electromagnetic deformation is sensitive to space-time evolution of the reaction. Therefore similarities in the shape between π^+/π^- ratios for peripheral Pb+Pb and Pb+gas collisions indicate similarities in the space-time process of pion production.

3 Conclusions

New data on pion production in collisions of the large Pb nucleus with smaller atomic nuclei have been obtained and presented in this work. The distributions of pions in latter collisions are evidently affected by the electromagnetic final state interaction between the electric charge of pions and that of spectator protons.

An overall similarity in this effect is apparent between the above “Pb+gas” reactions and peripheral Pb+Pb collisions, indicating similarities in the space-time evolution of pion production in both collision types.

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