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Evidence for the formation of a highly excited hadronic blob in $\bar{p}\,^4$He annihilation

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Abstract

The production of charged kaons in $\bar{p}\,^4$He annihilation at rest into four and five charged prongs ($\pi^\pm\pi^-\pi^+K^\mp$, $2\pi K^-K^+$ with and without an additional proton with momentum $\geqslant 300$ MeV/c) is studied experimentally. Annihilations with and without π^0 production and with baryonic number $B = 0$ and $B \geqslant 1$ are identified. The data on He are compared with similar data obtained on a hydrogen NTP gas target with the same apparatus (the magnetic spectrometer Obelix exposed to the $\bar{p}$ beam extracted from the LEAR accelerator at CERN) and analyzed with the same criteria. Strangeness production on ^{4}He from $B \geqslant 1$ annihilations without π^0 turns out to be six times higher than on hydrogen. Our results agree with some theoretical predictions based on the assumption that annihilation develops through the formation and the statistical decay of a highly excited hadronic gas. According to these predictions, nearly all nucleons in He are directly involved in the annihilation process.

Keywords: $\bar{p}$He annihilation; Strangeness production; Hadronic blob

1. Introduction

$\bar{p}$ annihilation on nuclei has been studied widely both experimentally and theoretically. Many data can be explained in terms of a two-step mechanism consisting of $\bar{p}$ annihila-

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tion on a single nucleon followed by the interaction of the annihilation products, mostly pions, with the residual nucleus according to standard meson–nucleon physics. This "conventional" mechanism leads to final states which may be very similar to those produced by annihilation on free nucleons; in this case the main difference is in the meson energy spectra as some amount of energy may be delivered to the residual nucleus.

However, there is a variety of $\bar{p}$-nucleus annihilations which have no relation with those on free nucleons as they require necessarily the involvement of more than one nucleon. This gives rise to "unconventional" hypotheses on the annihilation mechanism. The most appealing one predicts that the presence of several nucleons in the annihilation region gives rise to the formation of a quark–gluon plasma (QGP), a state of the matter which is supposed to exist in some early stage of our Universe. A specific signature of QGP formation is expected to be a "high" production of strangeness. Unfortunately, data on strangeness production in the annihilation on nuclei are few and most of them can be explained also in terms of the conventional two-step mechanism. Many questions about possible highly excited states of the hadronic matter are the same as in the heavy-ion collision field (see [1]).

In this paper we contribute to the study of strangeness production on nuclei by analyzing the following $\bar{p}\,{}^4\mathrm{He}$ annihilation reactions at rest with four and five final charged particles:

$$\bar{p}\,{}^4\mathrm{He} \to 2\pi^+2\pi^-,\ \pi^+\pi^-K^+K^-,\ \pi^+\pi^-\pi^\pm K^\mp, \tag{1}$$

$$\to 2\pi^+2\pi^-p,\ \pi^+\pi^-K^+K^-p,\ \pi^+\pi^-\pi^\pm K^\mp p \tag{2}$$

with $p_\pi > 80\ \mathrm{MeV}/c$, $p_K > 150\ \mathrm{MeV}/c$ and $p_p > 300\ \mathrm{MeV}/c$.

This work is an extension of a previous analysis [2], which was devoted to the study of single and multinucleon annihilations in similar channels but without strangeness.

In order to point out the different features of single and multinucleon annihilations, in this work we have analyzed also a set of annihilation data at rest on a gaseous hydrogen target obtained with the same apparatus and processed with the same criteria.

The peculiarity of our study lies in the evaluation of strangeness production through the measurement of both charged kaons, which have different features: while K^- can be strongly absorbed by nucleons, K^+ can be absorbed weakly, so that the latter ones reflect the basic mechanisms of strangeness production.

We have identified specific annihilation channels, namely those without π^0 production, where K^+ production in ${}^4\mathrm{He}$ turns out to be six times higher than that on free proton. This enhancement is high enough to be consistent with the idea of the formation of a highly excited hadronic gas, but it is too low for the formation of a quark–gluon plasma.

The paper is organized as follows. In Section 2 we give a partial overview of theoretical predictions and experimental results. In Section 3, after the description of the apparatus and of the selection criteria of 4 and 5 prong events, we attack the crucial problem of identifying the charged kaons among a much higher number of pions and protons. In Section 4, we select the 4 and 5 prong reactions (1) and (2), identify those without π^0 production and with $B = 0$ and $B \geqslant 1$ and, finally, evaluate the ratios between the number of kaons and the number of all four- (five-)prong events for different channels. In Section 5 we discuss the systematic errors and in Section 6 we compare our results on helium and hydrogen and discuss them in the light of theoretical predictions. Finally, in Section 7 we summarize our main conclusions.