Antimatter production and interaction in relativistic heavy ion collisions

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Observation of antimatter nuclei and measurement on antiproton-antiproton interaction at Relativistic Heavy-Ion Collider (RHIC) are briefly reviewed in this report. First, relativistic heavy ion collision and the history of earlier antimatter discovery are introduced. Second, the result for the discovery of antihypertriton is presented. Third, the observation of antihelium-4 is introduced. Forth, the production mechanism of antimatter nuclei in heavy ion collisions is discussed. Finally, the measurement of interaction between antiprotons is reported.

KEYWORDS: Antimatter, antihypertriton, anti-helium 4, interaction between antiprotons, relativistic heavy-ion collision

1. Introduction

Relativistic heavy-ion collisions provide a unique environment for not only the formation of quark-gluon plasma (QGP) but also the production of antimatter nuclei. At RHIC energy, a deconfined quark-gluon plasma matter could be formed at extreme high temperature and baryon density. Enough evidences have been accumulated and demonstrated that a strong coupled QGP matter has been produced in central Au + Au collisions at RHIC energies [1]. Different from elementary particle collisions, large amounts of energy are deposited into a more extended volume than nucleon size via heavy ion collisions. These nuclear interactions produce hot and dense matter containing roughly equal numbers of quarks and antiquarks. Then the QGP expands rapidly and cools down and undergoes a transition into a hadron gas phase where the nucleus and anti-nucleus will emerge.

The ideal of antimatter can be traced back to the end of 1890s, when Schuster discussed a hypothesis of the existence of antiatoms as well as antimatter solar system by hypothesis in his letter to Nature magazine [2]. However, the modern concept of antimatter is originated from the negative energy state solution of a quantum-mechanical equation, which was proposed by Dirac in 1928 [3]. Two years later, C. Y. Chao found that the absorption coefficient of hard γ-rays in heavy elements was much larger than that was expected from the Klein-Nishima formula or any other [4]. This "abnormal" absorption is in fact due to the creation of the pair of electron and its anti-partner, i.e. positron. This experiment gives an indirect signal of the first anti-particle, namely positron. Two years later, Anderson observed positrons by a cloud chamber [5]. Later on the anti-proton ($\overline{\mathrm{p}}$) was detected in 1955, and since then antimatter nuclei such as $\overline{\mathrm{d}}$, $^{3}\overline{\mathrm{H}}$, $^{3}\overline{\mathrm{He}}$ have been observed in accelerator experiments [6] .

The recent progress regards the observation of antihypertriton ($^{3}_{\overline{\Lambda}}\overline{\mathrm{H}}$) [7] and antihelium-4 ($^{4}\overline{\mathrm{He}}$, or $\overline{\alpha}$) [8] nuclei in Relativistic Heavy Ion Collider (RHIC) which was reported by the STAR (Solenoidal Tracker At RHIC) experiment as well as the longtime confinement of antihydrogen atoms [9] based on an antiproton decelerator facility by ALPHA collaboration have stimulated broad interests in both nuclear and particle physics communities. All of the measurements performed above have implica-