Proton Induced Reactions in Search for Kaonic Nuclear Clusters at FOPI

P. Bühler [a], M. Cargnelli [a], L. Fabbietti, N. Herrmann [b], P. Kienle, J. Marton [a], P. Schmid [a], K. Suzuki, T. Yamazaki [c], E. Widmann [a], J. Zmeskal [a], and FOPI collaboration

[a] Stefan-Meyer-Institut für Subatomare Physik, Österreichische Akademie der Wissenschaften
[b] Heidelberg Universität, [c] RIKEN

1. Introduction

Recently exotic nuclear systems involving antikaon, $\bar{K}$ (K^- or $\bar{K}^0$), as a constituent have been predicted [1] based on phenomenologically constructed $\bar{K}N$ interaction, which reproduce low-energy $\bar{K}N$ scattering data, kaonic hydrogen atom data and the binding energy and width of $\Lambda(1405)$ under assumption that $\Lambda(1405)$ is a $\bar{K}N$ bound system. The $\bar{K}N$ interaction is uniquely characterized by its strongly attractive I=0 part. A few nucleon systems with $\bar{K}$ considered with the $\bar{K}N$ interaction are found to have very large total binding energy of ~100MeV (E=118MeV and 97MeV for $ppnK^-$ and $pppK^-$, respectively) strong enough to close the main decay channel of $\bar{K}N \to \Sigma\pi$ and therefore the states appear narrow and discrete [1], and have potentially extremely high density [2]. In addition to its exoticness, having an access experimentally to such cold and dense bound system provides a great possibility to explore QCD phase diagram and offer a unique playground to study possible quark-gluon structure, and will give direct hint to the quest for chiral symmetry restoration, origin of hadron masses, kaon condensation and structure of neutron star.

A goal of the project is to obtain a firm evidence of such kaonic nuclei by employing proton induced reactions at 4π detector FOPI at Gesellschaft für Schwerionenforschung (GSI), Darmstadt, Germany. An existence of such kaonic systems has been reported [3,4,5] however with substantially larger binding energies than prediction. It is vitally important that the project carries out an independent measurement with a different reaction to confirm the result, and to understand other interesting properties of the kaonic nuclei, namely their density distributions, decay branches, formation mechanism and so on.

2. Experiment

The project produces and identifies kaonic nuclei in proton induced reactions by making use of the FOPI detector at GSI. The FOPI is a fixed-target type experiment having nearly 4π coverage of the geometrical acceptance under 0.6T magnetic field produced by a superconducting magnet, being capable of detecting and tracking all charged particles from Heavy-Ion-Collision up to 500~1000Hz DAQ rate. We identify both K^0 meson from the invariant mass (IM) of $\pi^+ + \pi^-$and Λ hyperon from the IM of p+π^-. Detection of a K^0 implies that an $S = -1$ object is produced, and detection of a Λ is related to a decay of some $S = -1$ object.

We use 3.5GeV proton beam provided from UNILAC-SIS system of GSI, on a deuteron target in search for the ppK^-. This dibaryon system is the most elementary kaonic cluster and therefore important object to examine the theory. The key elementary reaction is $p + n \to \Lambda(1405) + K^0 + p$, where the $\Lambda(1405) \equiv \bar{K}N$ plays an essential role to open a channel to the high-density kaonic cluster. A missing-mass (MM) spectrum is constructed for ppK^- in the reaction: $p+d \to \Lambda(1405)p+K^0+p_s \to ppK^-+K^0+p$, and simultaneously an IM spectrum for $ppK^- \to \Lambda + p$ is obtained, where p_s is a spectator proton.

A liquid-deuterium target system was developped which has cell geometry of ϕ=4mm, length=40mm made of very thin 25μm kapton foil. This requirement is implied to minimize a detection loss of the spectator proton in the target. A silicon array detector was also developped to be installed surrounding the target. This new set of detector implies 1) detection of the slow spectator proton which may not be well detected in ordinary FOPI setup and 2) drastic improvement of z-axis vertex resolution (~30mm to ~0.3mm) which improves vertex matching accuracy and Signal-to-Background (S/N) ratio.

We ran an one week beamtime in Nobember 2005 with $\sim 10^6$Hz 3.5GeV proton. Data is being analyzed and the liquid-deuterium target, silicon array detector is going to be upgraded according to the result for the main experiment scheduled in early 2007.

References

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