1 - 1 Progress of Theoretical Nuclear Research in 2012 at IMP

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During the year of 2012, the researchers of Theoretical Physics Group at IMP have carried out their research work on in nuclear physics, heavy ion physics and hadron physics. Some important results have been obtained.

Based on different mean-field interactions, a correlation among the symmetry energy S_0, the slope parameter L, and the curvature parameter K_{sym} at saturation density has been established[1]. The density-dependence of the symmetry energy around the saturation density is determined. With the obtained density-dependent behavior of the symmetry energy, the neutron skin thickness of ^{208}Pb and some properties of neutron stars are investigated and discussed. The isoscalar giant monopole resonance (ISGMR) in Cd, Sn, and Pb isotopes has been studied within the framework of the self-consistent Skyrme Hartree-Fock+BCS and quasiparticle random phase approximation (QRPA)[2]. It is shown that the SkP parameter set underestimates the various energies for all isotopes due to its low value of the nuclear matter incompressibility. The SLy5 parameter set, supplemented by an appropriate pairing interaction, gives a reasonable description of the scaling energies in Cd and Sn isotopes and a good centroid energy in Pb isotopes. A better description of ISGMR in Cd and Sn isotopes is achieved by the SkM* interaction.

Within an isospin and momentum-dependent transport model, the transverse emission of preequilibrium nucleons, light clusters and charged pions from the isotopic ^{112,124}Sn + ^{112,124}Sn reactions at a beam energy of 400 AMeV have been investigated[3]. It is found that the transverse momentum distribution of isospin ratios depend strongly on the stiffness of nuclear symmetry energy. The collision centrality and the mass splitting of neutron and proton in nuclear medium play a significant role in determining the distribution structure of the ratios, but do not change the influence of symmetry energy on the spectrum. The in-medium effect on the dynamics of heavy ion collisions (HIC) has been explored[4]. It is found that the in-medium cross sections play a significant role in isospin emission and result in a flatter distribution for transverse flows and elliptic flows of free nucleons compared with the in-vacuum ones. The rapidity distribution of the difference between neutron and proton transverse flows is sensitive to the stiffness of the nuclear symmetry energy as a promising observable, which cannot be influenced by the in-medium effect and collision centrality. The competition between the stiffness and the momentum dependence of the symmetry potential on reaction dynamics are compared and systematically analyzed[5]. It is found that the difference of the neutron and proton directed flows and the transverse momentum distribution of the neutron/proton ratio are sensitive to the stiffness of symmetry energy, which cannot be changed with the controversial effective mass splitting. The elliptic flows of free nucleons at high transverse momentum within mid-rapidity emission are to be promising observables as distinguishing the nucleon effective mass splitting. Based on a relativistic Boltzmann-Uehling-Uhlenbeck transport model, the proton- and ^{3}He-induced reactions on ^{197}Au target at beam energies of 2.8, 5, 10, and 16.587 GeV/u are studied[6]. It is found that the ^{3}He-induced reactions give much larger cross sections of pion production as compared with the proton-induced reactions. Pion production from the ^{3}He-induced reaction is more inclined to low-angle emission. Neutrino production via positively charged pion is also discussed accordingly. The spallation reaction p+^{197}Au at the incident beam energy E_{beam}= 800 MeV/u is studied[7]. It is shown that the external strong magnetic field affects the production of heavier fragments more strongly than the n/p of produced fragments. The n/p of free nucleons is greatly affected by the strong magnetic field, especially for the nucleons with lower energies.

In hadron physics, the decay widths and the line shapes of the open-charm radiative and pionic decays of Y(4274) have been investigated[8]. The calculation indicates that the decay widths of Y(4274)$\rightarrow D_s^+ D_s^{*-} \gamma$ and Y(4274)$\rightarrow D_s^+ D_s^- \pi^0$ can reach up to 0.05 keV and 0.75 keV, respectively. It is also shown that there exists a very sharp peak near the large end point of photon energy. According to our calculation, we suggest further experiments to carry out the search for the open-charm radiative and pionic decays of Y (4274). The isovector nD_0^*(2400)^0 molecular state has been proposed[9] to explain the enhancement structure around 3250 MeV (X_c(3250)^0) in the $\Sigma_c^{++}\pi^-\pi^-$ invariant mass spectrum newly observed by the BaBar Collaboration. The investigation shows that the isovector nD_0^*(2400)^0 molecular state can decay into $\Sigma_c^{++}\pi^-\pi^-$, which is consistent with experimental observation. These studies provide direct support to the isovector nD_0^*(2400)^0 molecular state assignment to X_c(3250)^0. The roles of the nucleon resonances in the Λ(1520) photoproduction off a proton target are investigated[10] within the effective Lagrangian method. The important nucleon resonances predicted by the constituent quark model (CQM) are considered and the results are found to be well comparable with the experimental data. Besides the dominant $D_{13}(2080)$, the resonance $[(5/2)^-]_2(2080)$ predicted by the CQM is found to be important for reproducing the experimental data. Other nucleon resonances are found to give small contributions in the channel considered. Via the Initial Single Pion Emission (ISPE) mechanism, the $\varphi(1020)\pi^+$ invariant mass spectrum distribution of $Y(2175)\to\varphi(1020)\pi^+\pi^-$ has been studied[11]. The $\varphi(1680)\to\varphi(1020)\pi^+\pi^-$ process due to the ISPE mechanism has also been investigated. The obtained results suggest to carry out the search for these charged strangeoniumlike structures in future experiments, especially Belle II, Super-B and BESIII. Inspired by the observed Y(2175) state, its nonstrange partner Y(1915), which has a resonance structure with mass around 1915 MeV and width about 317～354 MeV, has been predicted[12]. Experimental search for Y (1915) is proposed.

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1 - 2 Three-body Force Effect on Off-shell Mass Operator and Spectral Functions in Nuclear Matter

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Nucleon spectral function in nuclear matter is of special interest since it may play an important role in understanding the nature of the nucleon-nucleon correlations, especially the short-range and tensor correlations[1]. Experimentally, the information about the nuclear spectral function in nuclear systems can be extracted from the electron- and/or proton-induced knockout reactions. Theoretically, the nuclear shortrange correlations and the spectral function in nuclear matter have been investigated extensively using various microscopic nuclear many-body approaches.

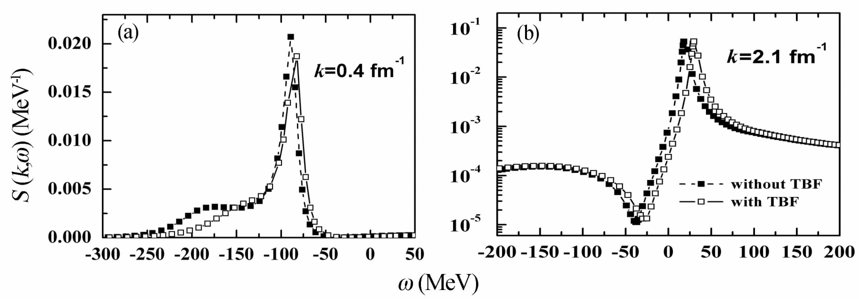

Fig. 1 Spectral function $S(k,\omega)$ at density of 0.34 fm^{-3}.

In the present work[2], we have investigated the off-shell mass operator and the nuclear spectral function in nuclear within the framework of the Brueckner theory extended to include a microscopic three-body force (TBF). Special attention has been paid on the TBF effect. The first two terms in the hole-line ex-