第 28 卷 第 12 期
2004 年 12 月

高 能 物 理 与 核 物 理
HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS

Vol.28, No.12
Dec., 2004

Summary of International Symposium on Nuclear Physics in Dalian

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It is my special pleasure to give the closing speech of this successful symposium. It is not an easy task for me to summarize this nicely organized and exciting symposium on nuclear physics. However, let me try to do my best as much as possible. I would like first to classify the subjects of the symposium into six categories as follows:

· **Quark degrees of freedom**

Quark mean field, Chiral $SU(3)$ quark model, Tenser charge of nucleon, Narrow baryon state

· **Microscopic problems**

Shell model, Relativistic projected SM, Extended pairing model, Relativistic Hartree approach

· **Exotic nuclei**

Relativistic description, RMF theory for hypernuclei

· **Heavy ion collision**

Neck dynamics, Sub-barrier fusion, Isospin effects

· **High spin**

Identical bands, Shapes along the yrast line

· **Nuclear astrophysics**

Reaction with unstable nuclei, Nucleosynthesis

One can see that the subjects of the symposium are really wide.

1 Quark degrees of freedom

So far, the QCD seems to be the correct framework to describe the structure of nucleon. However, the quark men field or quark potential models have also played an important role in understanding many aspects associated with quark degrees of freedom, as we heard in this symposium.

A comprehensive discussions and comments on the constituent quark models were given by Wang, which are impressive. According to him, the two body interactions which are widely employed in the quark confinement must be wrong, but has no solution yet. The relation of Dawson-Furnstahl theory to Dirac hole theory was discussed by Zhang with RRPA calculation. According to her , there exist no contradiction between the two theories. Shen told us that the quark mean field model can be applied to describe the properties of spherical nuclei and Lambda-hypernuclei, by treating baryon as constituent quarks. The Hadron-Hadron interactions have been calculated extensively by using the different quark models. The N-N interaction calculated with the extended chiral $SU(3)$ model was reported by Dai, the phase shifts for the ${}^1S_0$ and ${}^3S_1$ are improved. Mao reported an exciting result of the HERMES experiment, which shows a preliminary clear evidence for the narrow 5-quarks baryon state in the quasi-real photoproduction. The tensor charge of nucleon is an interesting quantity associated with the quark degrees of freedom as reported by He with non-perturbation QCD. I do hope that some exciting experimental result, concerning the tensor charge will come out in the near future.

Great efforts have been expanded on finding the quark effects in nuclei. This is still a subject to be waiting for a more clear answer. A big puzzle is the so called missing spin. The fraction of nucleon spin carried by quark spins is small, $\Delta\Sigma \approx 20\%$. The gluon polarization is not yet well known, and there might be some other unknown mechanisms. There is some debate about "missing spin" itself, anyhow, the missing spin is still open for a more confident explanation.

2 Microscopic problems

We must understand the structure of nuclei consisting of many hadrons. The philosophy of the shell model is a general and solid base for the microscopic description of nuclei as a many body system. We heard from Draayer the mixed mode pseudo $SU(3)$ shell model, which shows that the competing mixed modes can be used to track the dynamics of nuclear system. The theory was applied to deformed heavy nuclei, for example ^{160}Gd, the spectra can be well reproduced and the M1 strength distributions are reasonable. The shell model description for the rotational motion of nuclei has been a challenge. The major problem is the explosively large dimension of the shell model space when it is applied to heavy nuclei. The angular momentum projection seems a good way to solve the problem. Along with this line Long reported an ambitious model in which the relativistic mean field many body states are projected to have good angular momenta. The preliminary results are certainly encouraging.

Pan told us the extended pairing model, showing the exact solution and that the three and higher many body interactions become important if the strength of the pairing interaction increases.

Mao showed the results of the anti-nucleon spectra in the vacuum of finite nuclei, calculated with the extended relativistic Hartree model, which include the tensor couplings for the ω- and ρ- mesons. The results are to be compared with future experiments.

3 Exotic nuclei

Radioactive beams open entirely new frontiers of nuclear physics. Nowadays, unstable nuclei can be accelerated and used as primary beams. While the secondary beam facilities provide also even a more wide range of radioactive beams. One most exciting thing is the discovery of neutron halo and skin nuclei, in which the spatial neutron distribution has a very long tail of low density. One may anticipates that many aspects of unstable nuclei, such as the shell closure, ordering of single particle states, correlations and collective motion, are different from traditional pictures. It is a real challenge for nuclear theory.

A review about the exotic nuclei was given by Meng. He showed that the properties of exotic nuclei and nuclear matter at the extreme condition can be described satisfactorily based on the relativistic mean field, and considering the effective interaction, nonlinear, density dependent terms and deformation. An integrated discussions and comments on hypernuclei and its relativistic mean field description were given by Ning. He showed that it is an interesting field because the hyperon added to nucleus as impurity can dramatically change the properties of nucleus.

I do expect in the near future the more confident theory that can well describe the very weakly-bound nuclear system.

4 Heavy ion collision

Synthesizing the new super-heavy nuclei by means of heavy ion fusion reaction is a frontier of nuclear physics. The key point is that sell-stabilized nuclei beyond those of liquid-drop nuclei are protected against the spontaneous fission. The accurate theoretical prediction of the synthesizing super heavy elements requires the further detailed study of the dynamics of the heavy ion fusion reaction.

Wu reported results of the study of the neck dynamics in heavy ion fusion reaction at the microscopic level, the obtained dynamic barrier is much lower than the static barrier. Moriyama reported the importance of the shell effects in the heavy ion sub-barrier fusion reaction in the superheavy region. One important frontier in nuclear physics is in intermediate and high energy region. A review for the isospin effect in heavy ion collision was given by Li. She pointed out that the peripheral heavy ion collision is also a useful tool for the study of the E-symmetry.

The heavy ion reactions at very low energy present also very interesting phenomena due to the very rich of the active many body correlations in such low energy states.

5 High spin state

In-beam experiments have become an very powerful method for studying many aspects of high spin states. The highest spin found in nuclei is about $70\hbar$. Many fascinating phenomena have been discovered in such rapidly rotating nuclei.

Liu showed that the dramatic shape changes along the yrast line can be described and interpreted as the symmetry break and the phase transition of collective motion within the framework of algebraic theory. An other interesting phenomena in superdeformed nuclei is the identical bands, the two bands have almost the same transition energies or the same dynamic moment of inertia, which is so far not well understood. He reported the calculations for the IBs by using the particle number conserving cranking model, a reasonable agreement between theory and experiment can be achieved.

6 Nuclear astrophysics

Most important nuclear input in astrophysics are: reaction cross sections of unstable nuclei, the sub-coulomb cross sections, a better mass formula, the beta-life times and so on. Radioactive beams are fitted to the measurements of the cross sections of unstable nuclei. Bai reported new measurement of astrophysical S-factor of the radioactive proton capture on ^{11}C. Bai also emphasized the electron screening effect in fusion reaction at energies of astrophysical interest . Nucleosynthesis is a very important aspect of nuclear astrophysics. Chen reported results of some new reaction rates and reaction network calculations for hydrogen burning, the hot CNO cycle and particularly the rp-process.

I was very much impressed by many interesting talks in this symposium, which stimulate our enthusiasm for nuclear physics study. In the 1980s there is a widespread feeling in the physical community that one knows "enough" about nuclei. I think, this attitude has been proved to be incorrect at all by the developments of nuclear physics in the past 20 years. Many important frontiers of nuclear physics have been formed, and nuclear physics has also offered the new frontiers for applications. I shall not try to discuss them in detail, but I would like simply to point out their two characters. First, these frontiers are subjects both in the high energy and low energy regions. Second, they are strongly supported by revolutionary developments of experimental techniques and the worldwide new big facilities, such as the super-array gamma-detector systems, the radioactive beam accelerators of new generation, and the well known RICH and SEBAF. I do not surprise about the developments of nuclear physics both today and in the future. In fact, the problems we encountered in nuclear many body system are often of a general nature that are also meet in other scientific fields, such as, atomic, molecule, condensed matter and particle physics. Nuclear physics has not only many frontiers of basic science but also broad areas of applied science. Atomic nuclei are very complex object, because they involve many individual hadrons and because the interaction between hadrons is not known well. Nevertheless, the spectra of nuclei, the interaction of nucleus with hadrons show often a number of systematic features that provide challenges for physicists. No doubt, the nucleus is a unique object for the study of numerous aspects of many body finite system, such as single particle motion, collective motion and its interaction with individual constitutes. Of course, atoms and molecules are many body systems, but they are very different from the system of nucleons, because the formers have only one nucleus or just few nuclei which more or less govern the electrons. I hope that my closing speech will more or less encourage further studies of various aspects of nuclear structure and interactions. These studies will be important not only in understanding nuclear many body system more insight, but also in applying our knowledge of nuclear physics to other fields of physics.

On behalf of all participants I express my heartfelt thanks to the organizing committee for having arranged such a successful and exciting symposium. I shall close this talk by extending the best wishes from all of us and from the institutions and universities that we represent for the future of the Dalian-Louisiana joint center for nuclear physics.

Enjoy nuclear physics. Thank you.