Report: The First FRIB-China Workshop on Physics of Nuclei and Hadrons

July 2015

Workshop Summary

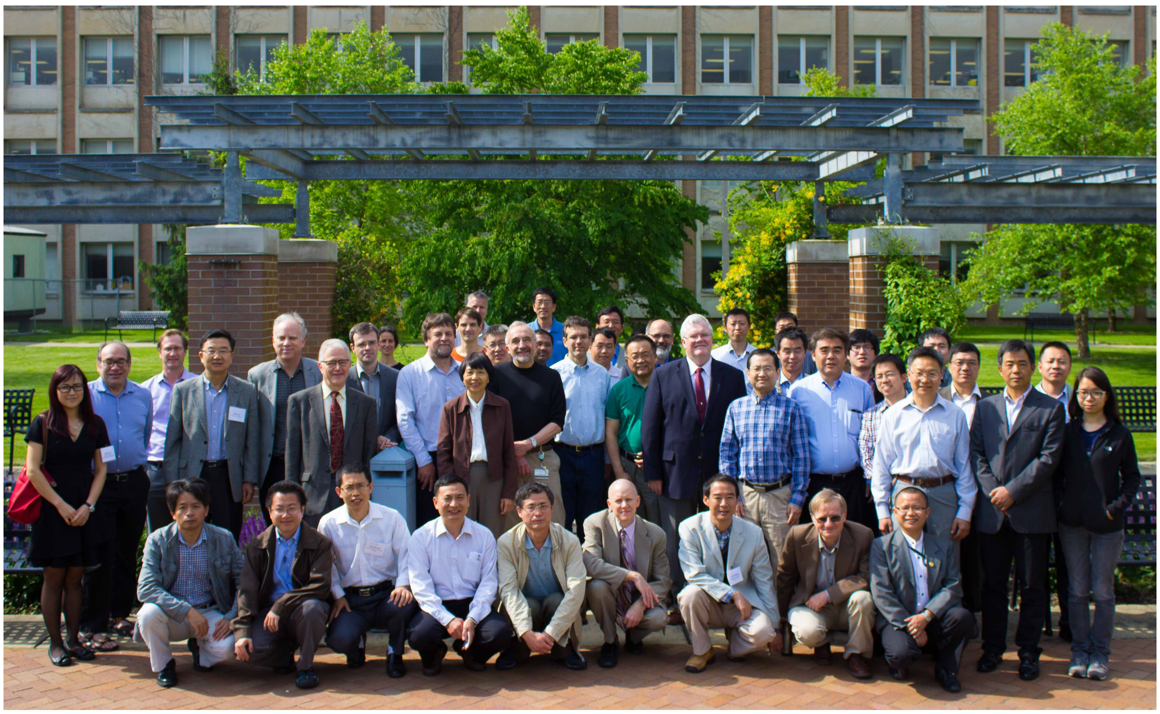
The first FRIB-China Workshop on Physics of Nuclei and Hadrons took place May 28-30, 2015 at NSCL. The goal was to explore various forms of collaborative endeavors in experiment and in theory relevant to the FRIB science program. The Workshop, chaired by Paweł Danielewicz, was organized by a joint US-China committee. It was sponsored by NSCL, FRIB, the Department of Physics and Astronomy of MSU, and by the Chinese – US Theory Institute of Physics of Exotic Nuclei (CUSTIPEN). The Workshop was attended by about 70 participants, including 22 attendees from China.

The Workshop was opened by Drs. Siddharth Chandra, Director of MSU Asian Studies Center; Thomas Glasmacher, Director of FRIB; and Phil Duxbury, Chair of MSU Physics and Astronomy Department. The plenary part of the scientific program concentrated on the recent progress in collaborative efforts tied to FRIB and efforts involving interdisciplinary connections. Prospects for the evolution of the FRIB-China collaborative efforts were discussed in a separate session featuring talks by Dr. Timothy Hallman (DOE) and Prof. Yanlin Ye (Chair, Nuclear Physics Society of China/ Peking University). The parallel sessions were dedicated to the meetings of eight Working Groups: (i) Nuclear Structure/Direct Reaction Experiments, (ii) Facilities, (iii) Nuclear Astrophysics Experiments, (iv) Fundamental Interactions Experiments, (v) Nuclear Structure Theory, (vi) Central Nuclear Reactions/EOS, (vii) QCD Theory, and (viii) Education. The Working Group reports were presented during the last day of the Workshop. The Workshop was closed by Dr. Steve Hsu, MSU Vice President for Research and Graduate Studies.

Within the Workshop, the general discussions on the evolution of collaborative efforts started following the talks by Dr. Hallman and Prof. Ye and continued after the presentations of the Working Group reports. The Groups assessed the areas of strength for the two sides and existing collaborations. IMP-Lanzhou is, in particular, helping FRIB to build room temperature magnets. Long-term collaborations exist in the area of transport theory for central reactions and computational density functional theory. Topics around which new collaborations could be developed and potential benefits to the two sides were identified. After the presentations of Working Group summaries, the panel discussion took place. It is apparent that there is a lack of information about various research areas in the two countries, about the ways the science is organized and managed, and about academic and scientific culture. For a collaborative effort to succeed, it is essential to have good understanding of your partner. There is a shortage of manpower on both sides. Educational efforts are hampered by students at different levels of advancement being spread out geographically. The latter challenge is partially addressed by the TALENT courses, so far taking place in the US and Europe. Once the TALENT lectures are developed they can be brought to the students in China. In parallel, summer schools with hands-on training at the two Chinese laboratories would be very beneficial to the students

It has been concluded that there is a need for an agreement that is significantly broader than current institution-to-institution collaborations. The outcome of the workshop was a set of resolutions passed unanimously.

The material generated during the workshop can be found on the CUSTIPEN website http://custipen.pku.edu.cn/meeting/1st-frib-china-workshop.html.



FRIB-China Workshop Resolutions

The FRIB-China Workshop participants unanimously endorsed a set of resolutions. The adopted resolutions represent a first step towards a comprehensive plan to jointly address the compelling scientific opportunities in US and China in the study of atomic nuclei and their role in the Cosmos.

All Working Groups suggested that a coordinated collaborative framework, broader than the current institution-to-institution collaborations, is needed to capitalize on scientific opportunities. To this end, a coordinating committee is needed to identify the next steps and focus the efforts. Based on this, the first resolution was: **1. We endorse the establishment of a FRIB-China Task Force.**

The immediate tasks for the new Task Force could be:

- Carry out surveys of low-energy nuclear physics communities in US and China with respect to current needs.
- Produce a proposal to DOE/China funding agencies for an experimental counterpart to CUSTIPEN – to stimulate joint experimental collaborative projects.

To take advantage of the existing organizational structures, it will be beneficial to include FRIB-related research areas into the agency-to-agency agreement that now exists in high-energy physics between the US and China. Such a step could be useful to raise the profile of nuclear physics in China. Hence, the Workshop participants recommended: **2. We encourage US and Chinese science and funding agencies to include nuclear physics opportunities related to FRIB in the US/PRC joint committee on high-energy physics.**

Opportunities have been established to send Chinese postdocs abroad, supported by Chinese government. Such programs could be used to enhance collaborative efforts in FRIB-related areas. The Task Force could help to identify the best candidates. To increase the prestige of the fellowship, and to make it more attractive for the candidates, one could give them a special title such as China-FRIB Postdoctoral Fellow and provide additional US salary support. Hence, **3. We recommend the establishment of a prestigious postdoctoral fellowship based on the newly established government postdoctoral fellowship program in China.**

In order to prepare the future and advance the science goals, the fourth resolution states: **4. We recommend that the Task Force start planning for regular topical workshops on joint initiatives. This activity will be critical for educating our communities on the needs and opportunities.**

Education and outreach are key components of any vision of the future of the field of nuclear science. The TALENT initiative, currently involving North America and Europe, could be an excellent platform to provide an advanced and comprehensive theoretical training to graduate students and young researchers in China in low-energy nuclear physics. Other initiatives should be explored to address training in experimental nuclear physics. This leads to the following recommendation: **5. We recommend that the Chinese community join the TALENT initiative.**

Finally, to assess the progress, **6. We propose that the second FRIB-China workshop on Physics of Nuclei and Hadrons takes place in China in late 2016.**

FRIB-China Working Group Reports

Nuclear Structure/Direct Reactions Experiments

Overarching and broad discussion items and considerations

- There is limited knowledge about experimental projects in both directions. It is important to improve that situation in order to stimulate concrete discussions about collaborations
- There is a strong interest in providing training opportunities for graduate students in experimental nuclear physics in China. Some funds are already available for training opportunities abroad, including in the US.
- Personnel to perform high-priority efforts in experimental nuclear science at NSCL/FRIB is constrained, and there is a need to further enhance technology development – such developments can also enhance future development in China.
- Experience in China is initially mainly in decay experiments, stopped beam experiments and experiments around the Coulomb barrier – it is easier to kick-off collaborations in these areas.

Tentative, non-exhaustive and non-prioritized list of research topics for which collaborations could be fruitful.

In general, it was concluded that collaborative efforts should be part of a coordinated and well-organized framework with clear science and/or technological development goals that are mutually beneficial.

- Detectors with good timing/position resolution for tracking – e.g. diamond detectors
- Active Target Time Projection Chamber
- Software development – FPGA programming
- Laser spectroscopy
- Laser ionization – isotope harvesting applications
- Fragment separator development and operation
- Magnet design and construction – design know-how limited in China, but well-developed construction capabilities

Some concrete ideas:

- Improve mutual understanding of projects, interests and objectives: workshop in China with the main goal to have a detailed exchange around areas of mutual interest and for US researchers to learn about facilities available in China
- The workshop could become the kick-off for an effort to create an experimental version of CUSTIPEN: CUSEIPEN
- Evaluate what resources/opportunities are available to start on a small scale soon and expand later

Compiled by Remco Zegers

Facilities

Time: May 29, 2015
Location: FRIB
Participants:
  IMP: Jiansong Wang, Xiaodong Tang, Xiaohong Zhou, Jianjun He
  ND: Wanpeng Tan
  CIAE: Zhihong Li
  FRIB: Yan Zhang, Georg Bollen

The purpose of this working group is to identify the mutual interests in the present and future facilities in US (eg. NSCL and FRIB) and China (eg.HIRFL and HIAF). The discussions covered a wide variety of topics such as accelerator technology, rare isotope production, beam manipulation, beam instrumentation, beam harvesting, beam physics, and facility operation. A brief summary of each discussed topic is given below.

- Accelerator technology: IMP is helping FRIB to build room temperature magnets and map fields after finishing. Other possible collaborations will be further explored by the accelerator groups from both sides.

- Rare isotope production and radiation damage: production and separation of rare isotopes are crucial components. IMP is interested in the RF separator developed at NSCL to improve the beam purity. High radiation levels generated at production targets pose great a challenge for proper design of target materials and monitoring systems. IMP is actively studying the radiation damage induced by heavy ions. Similar research is being carried out by FRIB in collaboration with Germany and France. Future collaboration between IMP and FRIB on this subject will be explored.

- Beam manipulation: Stopping fast ions efficiently and re-accelerating them as a high quality beam is crucial for high precision measurements. It plays a crucial role in the study of superheavy nuclei at IMP and is the central technology for ReA3. An IMP group is currently developing a gas stopper, but it is still in the preliminary stages; FRIB is developing a more efficient gas stopper, which can work with higher beam intensities. Collaborations on this and related subjects will be mutually beneficial. For example, collaborative discussions on cooling, bunching, charge breeding, and reacceleration will continue soon during a visit of Dr. Hang (IMP) who will visit Prof. Bollen (FRIB).

- Beam instrumentation: Collaborations on beam instrumentation may include new timing detectors such as diamond detector developed at NSCL, and fast MCPs with excellent timing resolution developed at IMP. Such instrumentation would be useful at many facilities worldwide.

- Facility operation: IMP is interested in learning from the current operation and management of NSCL to improve the performance and reliability of the HIRFL facility.

Two subjects, gas stoppers and RF separators, are recommended to be the starting points of the collaborations in Facilities at IMP and FRIB.

Compiled by Xiaodong Tang

Nuclear Astrophysics Experiments

There were four participants in the nuclear astrophysics breakout session: Jianjun He (IMP Lanzhou), Zhihong Li (CIAE Beijing), Michael Smith (ORNL), and Wanpeng Tan (Notre Dame). To explore future possible collaborative efforts, we identified began by identifying science topics, facilities & institutions, and specific projects & benefits. Our list is representative rather than exhaustive or complete. At the end of our session, we also discussed possible mechanisms for such collaborative efforts.

We found possible collaborative projects in four major research areas: Stellar Explosion measurements [rp-process, r-process] at radioactive ion beam (RIB) facilities; Big Bang Nucleosynthesis measurements at Underground Laboratories; Stellar Evolution measurements [pp, CNO burning] at Underground Labs and Stable Beam facilities; and Theory for Nuclear Astrophysics. These areas span the breadth of nuclear astrophysics research. We further identified parallel facilities and institutions in each of these areas. For radioactive ion beam facilities, China is developing BRIF [CIAE Beijing] and HIAF [IMP Lanzhou], while the US is developing FRIB [MSU]. Currently, China operates RIBLL [IMP Lanzhou] while the US operates ReA3 [MSU], Twinsol [Notre Dame], CARIBU [ANL], and MARS [TAMU]. For Underground Labs, CHINA is planning JUNA [JinPing] while the US is planning CASPAR [South Dakota]. For Stable Beam Facilities, China is operating a Tandem [CIAE Beijing] and an Ion Platform [IMP Lanzhou], while the US has numerous facilities including ATLAS [ANL], Notre Dame, TAMU, and others. Finally, theoretical research in nuclear astrophysics is pursued at numerous institutions in both countries. Ongoing projects relevant for astrophysics in China are being carried out at Shanghai Jiaotong Univ., Beihang Univ., Peking Univ., and ITP Beijing; in the US, some of the many institutions include ORNL, LANL, ANL, MSU, Notre Dame, UC San Diego, and others.

We then identified five specific future collaborative projects, and we discussed the benefits of each for both China and the U.S.

The first project is detector testing, system, commissioning, experimental planning & execution for the Separator for Capture Reactions (SECAR) project. The SECAR Collaboration [MSU / ORNL / Notre Dame / LSU…] leads the effort in the U.S., while the Chinese institutions are yet to be determined. The benefits to the U.S. include access to beamtime to commission subsystems and enhanced experimental manpower, whereas the benefits to the Chinese include future access to FRIB beams.

The second project is the development of time projection chambers (TPCs). MSU leads the effort in the U.S., while the Chinese institution will be IMP Lanzhou. The benefits to the U.S. include participation in IMP experiments, whereas the benefits to the Chinese include access to equipment development expertise.

The third project is the development of a 4π BGO gamma detector array. The JENSA collaboration [ORNL, The Colorado School of Mines…] leads the effort in the U.S., while the Chinese institution will be JUNA [JinPing]. The benefits to the U.S. include participation in JUNA experiments, whereas the benefits to the Chinese include access to equipment development expertise.

The fourth project (already in progress) is structure reaction theory for explosions and simulations. ORNL leads the effort in the U.S., while the Chinese institutions include Beihang Univ., Southwest Univ., and ITP Beijing. The benefits to the U.S. include access to nuclear theory expertise, whereas the benefits to the Chinese include access to nuclear astrophysics expertise.

The fifth project is the development of a Gas Jet Target system. The JENSA collaboration [ORNL, the Colorado School of Mines …] leads the effort in the U.S., while the Chinese institutions will include IMP Lanzhou. The benefits to the U.S. include participation in IMP experiments, whereas the benefits to the Chinese include access to equipment development expertise.

Finally, we discussed possible mechanisms for these and other collaborative efforts in nuclear astrophysics. Regarding communication and coordination, we strongly advocate establishing nuclear astrophysics representatives from both the U.S. and China in any "coordinating council" for these projects. Regarding people exchange, we advocate these programs provide airfare, whereas local expenses be provided by the host and salary provided by the researcher's home institutions. Regarding equipment exchange, we advocate establishing short- or medium-duration loans, whereas equipment funding should originate from the home institutions. Finally, we advocate a strong participate in joint educational activities.

Compiled by Michael Smith

Fundamental Interactions Experiments

The Facility for Rare Isotope Beams (FRIB) will provide an unprecedented opportunity for the search of permanent electric dipole moments (EDM) of rare isotopes. EDMs violate both T- (time-reversal) and P- (parity) symmetries and, by the CPT theorem, CP- (the combination of charge (C) and parity) symmetry. CP-violation has long been thought to be one of the key ingredients needed to explain the matter-antimatter asymmetry of the visible universe. The amount of CP-violation currently encoded in the Standard Model (SM), observed only in the weak interaction, is far too feeble to explain this observed asymmetry. EDMs are a clean signature of CP-violation and are complementary to CP-violation searches at the LHC. Since SM EDMs are expected to be very small, any observation of an EDM at present and projected levels of sensitivity would mean the discovery of new physics beyond the SM or a non-zero value for θ_{QCD} angle, a parameter, which describes CP-violation within the strong interaction. EDMs of paramagnetic systems, diamagnetic systems, and neutrons have a complementary sensitivity to new sources of CP-violation such as supersymmetry. Thus far, a non-zero EDM has yet to be measured.

The conventional EDM experiment involves observing a large ensemble of spin-polarized particles in parallel magnetic and electric fields. A small frequency shift that is linearly dependent on the electric field would signal an EDM. Performing such a measurement requires exquisite control of the stability and uniformity of the applied magnetic field and of systematic effects that mimic an EDM-like signal. Rare isotopes provide significant discovery potential for EDM searches because they amplify the observable EDM by orders of magnitude compared to stable species. This implies that less stringent control of the magnetic field environment and systematic effects are required in order to have a highly sensitive EDM search. Diamagnetic systems, which have octupole-deformed nuclei, such as Ra, Rn, and Pa, are favorable candidates because the combination of their unusual nuclear structure and highly relativistic atomic structure amplify the effects of CP-violating interactions originating within the nucleus by several orders of magnitude compared to nearly spherical nuclei such as Hg or Xe. Another attractive feature of rare isotopes is that the theoretical uncertainties in interpreting EDM results are more under control than for their stable counterparts. Nuclear theory calculations for octupole-deformed species are more robust because knowledge of just a few nuclear energy levels are required to calculate the new physics sensitivity, which is not true for Hg nucleus. We'll also note that Fr is a very promising candidate for EDM searches in paramagnetic systems. Its atomic theory is relatively simple because it has only one valence electron and its highly relativistic atomic structure gives it the largest enhancement factor of all the alkali atoms.

FRIB is expected to provide quantities of Ra (radium), Rn (radon), and Pa (protactinium) that rivals or are orders of magnitude more than what is currently available. In order to take full advantage of this upcoming opportunity, several technical, chemical, atomic, and nuclear physics techniques will have to be developed in the intervening years. Because of the specific atomic structure of each of these isotopes and their different half-lives, a variety of different techniques will be required to collect the atoms, spin-polarize them, and then monitor the spin precession in order to perform the EDM searches. This presents a broad range of opportunities for EDM collaborations for the foreseeable future.

At the workshop, we enumerated the specific scientific opportunities, the areas where technical expertise could be shared, and the initial opportunities for collaboration. First, tighter collaboration between nuclear and atomic theorists and experimentalists are required to both identify promising EDM candidates as well as to interpret EDM results. This is particularly relevant since the first EDM results from the ^{225}Ra laser trap experiment have just been published along with a program of sensitivity upgrades. Furthermore, there are plans for a new ^{171}Yb laser trap experiment which will initially be used to test upgrades for the ^{225}Ra experiment & to study laser trap systematics and, eventually, to control for systematic effects as a co-located magnetometer for the ^{225}Ra experiment. Another intriguing possibility is ^{229}Pa, which has long been thought to be significantly more sensitive than ^{225}Ra. However, there is not yet enough information available about ^{229}Pa to put this claim on firm quantitative footing. This is strong motivation for ^{229}Pa nuclear structure studies at the NSCL. Because of its chemistry, half-life, and nuclear spin, the most promising experimental techniques for searching for the ^{229}Pa EDM may be an atomic beam experiment or a small ion storage ring experiment. These possibilities need to be explored more carefully by studying the possible systematic limitations of these two alternate approaches. Finally, there is also an ongoing EDM effort that utilizes Rn isotopes. Some of the development work for Rn EDM, which includes nuclear structure studies, can occur now at the NSCL and eventually at FRIB.

Many of the experimental techniques & challenges are largely common to all EDM experiments. This includes laser spectroscopy, generation, control, & monitoring of magnetic fields, generation, control, & monitoring of high electric fields, and sustaining deep ultra high vacuum. By working together, we can avoid reinventing the wheel, while pursuing different approaches. One significant and urgent need for FRIB EDM experiments is knowledge of the radiochemistry needed to extract and purify the relevant isotopes. We resolved to share the aforementioned technical expertise via the following collaboration mechanisms. First, we plan on submitting joint proposals to our mutual funding agencies. Second, we plan on regular visits to our respective labs. Third, we agreed to the possibility of co-advising Ph.D. students from both sets of institutions. Finally, we resolved to co-organize bilateral workshops that would alternate between the Yellow Mountains of China and the Grand Rapids of Michigan. This fundamental interactions and precision measurements with rare isotopes workshop would include a range of topics beyond EDMs, such as atomic and nuclear theory, radiochemistry, tests of parity violation, nuclear moments and radii, and precision mass measurements.

Compiled by Jaideep Singh

Nuclear Structure Theory

Fifteen people participated in the nuclear structure theory working group, including Mark Caprio (Notre Dame), George Fann (ORNL), Xiao-Tao He (Nanjing University of Aeronautics and Astronautics), Calvin Johnson (San Diego State), Chen Ji (TRIUMF), Witek Nazarewicz (MSU), Junchen Pei (Peking University), Zhongzhou Ren (Nanjing University), Yue Shi (MSU), Furong Xu (Peking University), Cenxi Yuan (Sun Yat-sen University), and Chunli Zhang (Peking University). George Fai of the Department of Energy was an observer. Caprio, He, Ji, and Yuan gave short presentations pertaining to potential areas of scientific collaboration.

Most of our discussion followed along three threads: the outline of a coherent, collaborative physics program; the resources needed to carry out that physics program; and structural recommendations in support of the joint research.

We broadly identified some potential areas of common physics interest and relevance to experimental programs in both countries:

- Open quantum systems as an umbrella concept, covering nuclei far from stability including both neutron- and proton-rich nuclei, direct nuclear reactions, and nuclear astrophysics.
- Microscopic models of nuclei as an umbrella concept, with a focus on advanced density functional theory and configuration-interaction methods. This would include ab initio calculations with realistic forces and rigorous effective theories, collective excitations in atomic nuclei and how they arise from nuclear forces, phenomenological interactions with applications to important experimental problems, and the structure physics of superheavy nuclei.

Because we had only a relatively short time allotted to discuss physics goals, these areas should be refined in further discussions.

To carry out our joint research goals we need access to:

- Human resources/manpower.
- Computing resources.
- Education and innovation resources.

We discussed the best strategic vision towards these resources. In particular, in our discussions we felt that exchanging postdocs, rather than only graduate students, made better use of resources because they would be able to more effectively absorb and transmit innovations in theory and computing.

Because the research environments in the US and China are structured differently, it is clear that we need not only to identify physics goals and resources but also we need to address structural issues to make collaborations more effective. Our basic recommendations follow; as participants from both countries come to better understand each other's structures and realities, these will need to be refined:

- We strongly endorse an education program in the mode of nuclear TALENT.

- We encourage the formation of a Chinese nuclear physics and/or nuclear theory coordinating committee, to help develop coherent research plans across many institutions. Those plans will be further discussed with the FRIB Theory Alliance and CUSTIPEN to form topical collaborations.
- We recommend the establishment of a joint US-China nuclear physics coordination committee involving principal stakeholders, including funding agencies. One possible path is to encourage the inclusion of nuclear physics in the US/PRC joint committee on high energy physics.
- We support and encourage junior scientists to apply for the Chinese government postdoctoral fellowships and suggest that the Chinese nuclear physics community identifies excellent candidates to apply for these fellowships.

Compiled by Calvin Johnson

Central Nuclear Reactions/EOS

Attendees:
Pawel Danielewicz (NSCL/MSU); Justin Estee (NSCL/MSU); Chuck Horowitz (IU); Bao-An Li (TAMUC); YuGang Ma (SINAP) ; Pierre Morfouace (NSCL/MSU); Zhiyu Sun (IMP); Betty Tsang (NSCL/MSU); Zhigang Xiao (TsingHua University); FengShou Zhang (BNU); YingXun Zhang (CIAE)

Most of the attendees have strong and successful on-going US-based and China-based collaboration projects mainly in the areas of nuclear reactions and transport models to extract information of the EoS. Many of the US colleagues are frequent visitors (at least once a year) to China. Similarly, nearly all our Chinese colleagues have been frequent visitors to NSCL or other US laboratories. Most of the current US-China collaborations relevant to FRIB physics are small programs involving hosting of US or Chinese personnel for short periods of time and continuation of the research via the internet. None of the projects discussed in the working group is of the scale envisioned by the organizers in the FRIB-China Workshop. Thus we proposed that a task force be formed with the following charges:

1. To survey the needs and interest from working scientists (not just the workshop participants who do not represent the communities).
2. To document the best practice for successful collaborations.
3. To find consensus on projects of mutual benefits and interest that fit into the agencies/FRIB visions and missions.
4. To devise ways to obtain funding and support both in the US and China. Some Chinese participants have expressed that there is especially needs to encourage and provide travel funds to Chinese researchers in isolated universities/institutions.

As a result of our discussions, Zhigang Xiao agrees to discuss the CUSEIPEN initiative at the Lanzhou collaboration meeting in July/August to gauge interests from the Chinese side. There is an initiative from the US side to explore an Asia USEIPEN program that will include China as well as Japan, Korea and other Asian countries.

Compiled by Betty Tsang

QCD Theory

There were three people present in the QCD working group: Martin Savage (INT, Univ. of Washington), Yi-Bo Yang (Univ. of Kentucky), and C.-P. Yuan (MSU). The focus of this working group was exclusively on Lattice QCD.

Status and Plans

The US Lattice QCD (LQCD) effort is organized under the USQCD collaboration, and continues to develop broad support for the nuclear physics experimental and theoretical programs. Its efforts can be broadly classified into four sub-areas: Hadron Structure, Hadron Spectroscopy, Nuclear Structure and Astrophysics and Fundamental Symmetries. USQCD is a collaboration of collaborations, comprised of more than 120 physicists. Facilitated by funding from the DOE (~$1.5M/yr), these physicists collaborate closely with computer scientists and applied mathematicians through the SciDAC Institutes. USQCD continues to enhance its software stack, responding to the ongoing changes in hardware architecture and to the development of new algorithms. USQCD operates its own capacity computing resources (with ~$2M/yr from HEP+NP DOE), and acquires capability leadership-class computing resources through peer-reviewed processes. Members of USQCD are also able to acquire (smaller) compute resources from NERSC, other peer-reviewed programs, XSEDE and university operated hardware.

Lattice gauge theorists in USQCD presently are able to make optimal use of peta-scale compute resources, and are transitioning to work at the physical values of the light-quark masses including fully dynamical QED. USQCD has been obtaining an approximately constant fraction of US leadership-class resources for the last several years, and it is important that this continues going forward.

USQCD has started to produce gauge-field configurations at the physical pion mass, and plans to refine this to include isospin breaking and QED in the near future. The plan includes multiple lattice volumes, lattice spacings and multiple discretizations. With regard to low-energy nuclear physics, the community has entered into an era where fruitful collaborations with nuclear many-body theorists are becoming a reality, and these connections will strengthen in the future to provide reliable refinements of the nuclear forces.

There is a much smaller, and recently formed, LQCD collaboration at Berkeley with many members also involved with USQCD projects.

The Chinese LQCD effort consists of a small number of small collaborations, who generally collaborate with US lattice gauge theorists. There is no national–level organization of the effort. The physics emphasis currently is charm physics related to Belle, exotic states (tetra-quarks etc), and the spin-structure of the nucleon. Most of the computational resources used by Chinese LQCD efforts are from the US, acquired through collaboration. Chinese Lattice gauge theorists have access to the Tianhe-1a capability compute resource, but must pay for compute time – resulting in limited capability resources at present (in 2014, approximately 0.5 M GPU hrs were used for LQCD on Tianhe-1a). There are plans to hire a number of Lattice gauge theorists in the near future, and to deploy modest scale GPU clusters.

The Chinese Lattice gauge theorists are planning their own lattice generation programs, but require an enhanced workforce to optimally execute their program. They have a desire to make multiple hires in this area in the near future. The current physics plan is to provide support for the Bess-III experimental program.

Potential for Collaboration

There is already successfully a functioning collaboration(s) between Chinese and US Lattice gauge theorists that is presently focused deconstructing the nucleon spin. Larger-scale collaborations presently look challenging as there is no formal Chinese Lattice collaboration analogous to USQCD.

In broad-brush strokes, it might be useful to capitalize on the possibility of China providing junior scientists, at the level of graduate students and postdoctoral fellows to work in the US. They would acquire a US graduate education, build a publication record and reputation. Further, this would also build the stature of the field in China. One consequence would be that US provides the compute resources during this "build period". It would be desirable for such students to remain as postdoctoral fellows (or faculty members) for a period subsequent to graduation to contribute to the US program (to balance the gains/losses). This would go some way to addressing US workforce issues, but additional funding would be required to support these junior scientists within the US. The most significant gain is on the Chinese side as they would then gain a modern trained workforce with state-of-the-art knowledge and capabilities in this area. This parallels somewhat how Germany and Japan have trained a fraction of their junior scientists.

Potential Issues

There are a few issues that might prove to be problematic. The first is intellectual property (IP). The codes, algorithms and software technology have required the efforts of many US scientists and consumed significant funding from the DOE and NSF. It likely would be a mistake to hand this over to other scientists who are then free to compete for future discoveries in the field. Legal documents might solve this problem, but we do not have sufficient expertise to understand the full implications. Another issue is cyber-security. Presumably this could be handled in a way that is similar to the collaboration between USQCD and staff scientists at the US national laboratories, such as LLNL and LANL. However, the IP issue raised previously remains even with those collaborations

Another issue that is somewhat less well-defined is one of academic assessment –

what is required for a scientists to succeed within China versus the US. For instance, what defines the "minimum publishable unit'', and what defines a great publication. At present, these do not appear to perfectly coincide, and the real question is how close do the definitions in the two countries have to be for successful collaboration of high scientific quality.

One issue that needs to be addressed by both countries is the career path of a lattice gauge theorist, particularly those supported for a period for software development, e.g., what is the career path of someone who develops algorithms for LQCD calculations? In the US, such talent can make much more money in the private sector (e.g., Google, NVIDIA,…). Universities have a difficult time hiring such people for what appear to be historical reasons, but the analogous problem seems to have been addressed at some level by high-energy experiment. National laboratories have less difficulty hiring such people.

Conclusions

There is tremendous opportunity for a mutually beneficial collaboration in the future, however China is currently behind the US in all areas related to LQCD. Further, there is presently no well-defined mechanism for Chinese Lattice gauge theorists to easily acquire significant compute resources, neither capability nor capacity.

There are many unknowns at present in all of the aspects that are required to initiate a significant LQCD collaboration. The first thing to do is to better understand the forms such a collaboration could take, the resources available to such a collaboration from both countries, and a set of initial physics objectives. Formulating a plan to support and educate junior scientist from China is a high priority to bring the countries LQCD efforts closer in sophistication. However, this must be balanced by contributions to the US program.

Compiled by Martin Savage

Education

The Nuclear Talent initiative (www.nucleartalent.org) has successfully organized and run eight advanced courses in nuclear theory. The initiative started as a collaboration between Northern American and European institutions, with the ambitious aims to provide an advanced and comprehensive training to graduate students and young researchers in low-energy nuclear theory. The network aims at developing a broad curriculum that will provide the platform for a cutting-edge theory for understanding nuclei and nuclear reactions. At many Universities such advanced courses in a specific field may be missing. Parts of the reason for the lack of such a training possibility is the fact that many research groups are small and fragmented. The network aims at filling this gap.

During the discussions there was a general agreement that education plays a central role in forming the next generation of nuclear scientists, and that initiatives like Nuclear Talent can aid in filling these needs on the theoretical side. It was agreed that the Chinese community should join the Nuclear Talent initiative. Various participants discussed also the possibility of hosting and running Talent courses in the near future at Chinese laboratories and universities.

The Talent initiative is now also in a stage where the next steps on how to develop the program are being discussed. Several plans were discussed at the meeting, ranging from the development of structured modules which will provide our students with a modern education in nuclear physics, degrees of synchronization between existing course material as well as exploring how new facilities and centers like the coming FRIB theory alliance at MSU can aid in tailoring sustainable long-range education plans in nuclear physics.

In addition to theory education, there is need of experimental hands-on training for nuclear physics students and postdocs in China. This could be achieved by adopting the model of the Exotic Beam Summer School held in the US, which has hands-on training coupled with the more traditional lecture activities that cover both theory and experiment.

Compiled by Morten Hjorth-Jensen

Appendix: The First FRIB-China Workshop Program

May 27, 18:30-20:30 Reception at Quality Inn University, Lansing

Day 1: May 28 (Thu)

8:30 Welcome and Agenda (NSCL, Lecture Rm) Gelbke

08:30 Welcome
Siddharth Chandra (Director of Asian Studies Center, MSU),
Thomas Glasmacher (FRIB, MSU), Phil Duxbury (Physics & Astronomy, MSU)
08:45 Organizational Remarks
Pawel Danielewicz (MSU)
09:00 FRIB Scope and Status
Thomas Glasmacher (MSU)
09:30 FRIB Theory Center
Filomena Nunes (MSU)
09:45 Goals of the Workshop
Witek Nazarewicz (MSU) and Yanlin Ye (PKU)
10:00 Break

10:30 Ongoing Collaborative Projects (NSCL, Lecture Rm) Danielewicz

10:30 CUSTIPEN, US Perspective
Bao-An Li (TAMU Commerce)
10:45 CUSTIPEN, China Perspective
Furong Xu (PKU)
11:00 High-Energy Nuclear Physics in China & Collaboration with RHIC
Yugang Ma (SINAP-CAS)
11:30 Joint U.S.-China Lattice QCD Efforts
Yi-Bo Yang (U Kentucky)
12:00 DFT with Continuum
Junchen Pei (PKU)
12:20 Lunch

13:40 Possible Collaborative Projects: Experiment (NSCL, Lecture Rm) Mittig

13:40 Instrumentation at FRIB and HIAF
XiaoDong Tang (IMP-CAS)
14:05 FRIB Experimental Equipment for Next Decade
Michael Smith (ORNL)
14:30 Fundamental Interactions
Zhengtian Lu (ANL)
14:55 High Rigidity Spectrometer
Remco Zegers (MSU)

15:20 Nuclear Astrophysics: Jin Ping Facility
Zhihong Li (CIAE)
15:45 Low-Energy Reaction Experiments
Huimin Jia (CIAE)
16:10 Break
16:40 Facility Developments, Including Reacceleration
Georg Bollen (MSU)
17:20 External Target Facility at CSR
Zhiyu Sun (IMP-CAS)
17:50 Mass Measurements and Related Physics
Yuhu Zhang (IMP-CAS)

Day 2: May 29 (Fri)

08:30 Science Reviews 1 (NSCL, Lecture Rm) Tsang

08:30 Heavy-ion Research Facility in Lanzhou and Its Science, HIAF Project
Xiaohong Zhou (IMP-CAS)
09:10 RIB Physics Research in China
Yanlin Ye (PKU)
09:40 Equation of State
Zhigang Xiao (Tsinghua)
10:10 Break

10:40 Possible Collaborative Projects: Theory (NSCL, Lecture Rm) Horowitz

10:40 Clustering in Exotic Nuclei
Zhongzhou Ren (Nanjing U)
11:00 Nuclear Reactions
Danyang Pang (Beihang U)
11:20 High Performance Computing
George Fann (ORNL)
11:40 Education
Morten Hjorth-Jensen (MSU)
12:00 Lunch

13:00 Science Reviews 2 (NSCL, Lecture Rm) Yuan

13:00 Hadron Structure from Lattice QCD
Jianwei Qiu (BNL)
13:30 Nuclear Structure from Lattice QCD
Martin Savage (INT)
14:00 Ab-initio Nuclear Structure Theory
Scott Bogner (MSU)

14:30-16:30 Parallel Working Groups

- Nuclear Structure/Direct Reaction Experiments (Lecture Rm)
- Facilities (Rm. 2129)
- Nuclear Astrophysics Experiments (Rm. 3129)
- Fundamental Interactions Experiments (Rm. 4129)
- Nuclear Structure Theory (Rm. 1221B)
- Central Nuclear Reactions/EOS (Rm. 1221A)
- QCD Theory (PA)

16:30 Break

17:00 FRIB-Asia Collaborative Scheme: What Makes Sense? (NSCL, Lecture Rm) Thoennessen

17:00 DOE Perspective
Tim Hallman (DOE)
17:30 China Perspective
Yanlin Ye (PKU)
18:30 Dinner at Kellogg Center

Day 3: May 30 (Sat)

9:00 Working Groups Summary 1 (NSCL, Lecture Rm) Ye

- Nuclear Structure/Direct Reactions Experiments (Zegers)
- Facilities (Tang)
- Nuclear Astrophysics Experiments (Smith)
- Fundamental Interactions Experiments (Singh)

11:00 Break

11:30 Working Groups Summary 2 (NSCL, Lecture Rm) Xu

- Nuclear Structure Theory (Johnson)
- QCD Theory (Savage)
- Central Nuclear Reactions/EOS (Tsang)

12:30 Lunch

14:00 Panel Discussion: What Makes Sense? (NSCL, Lecture Rm) Nazarewicz

Paweł Danielewicz (MSU), Yugang Ma (SNIAP), Brad Sherrill (NSCL), Xiaodong Tang (IMP), Remco Zegers (NSCL), Yuhu Zhang (IMP)

16:00 Closing
Stephen Hsu (MSU. Vice President for Research and Graduate Studies)