

Progress Report

Bao-An Li on behalf of the CUSTIPEN Governing Board

- **Objectives**
- **Activities**
- **Examples of scientific accomplishments**

Supported by all of you and the following

Nuclear Theory Program Division of Nuclear Physics

State Key Laboratory of Nuclear Physics & Technology



U.S. DEPARTMENT OF ENERGY



National Laboratory of Heavy-Ion Accelerator



Major International Collaboration Project between PKU (F.R. Xu) and TAMU-Commerce (B.A. Li)



1st CUSTIPEN Workshop, 2013, Beijing 中差奇诗令物理理论研究所第一次计讨会

CUSTIPEN was officially launched on May 1, 2013 at Peking University

CUSTIPEN Governing Board

Chinese Members:

Yugang Ma (Shanghai Institute of Applied Physics) Zhongzhou Ren (Nanjing University) Furong Xu (**Managing Director**, Peking University) Yanlin Ye (**Co-Director**, Peking University) Wenlong Zhan (Chinese Academy of Science) Huanqiao Zhang/Chengjian Lin (CIAE) Yuhu Zhang (Institute of Modern Physics, CAS) Shangui Zhou (Institute of Theoretical Physics, CAS)

U.S. Members:

P. Danielewicz (Co-Director, Michigan State University)
Bao-An Li (Principal Investigator, Texas A&M-Commerce)
W. Nazarewicz (FRIB and Michigan State University)

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- J. Piekarewicz (Florida State University)
- B. Sherrill (FRIB and Michigan State University).

The complexity of the new problems/challenges require varied expertise, theoretical tools, computing resources, minds, manpower and funding that are hard to find in a single country



CUSTIPEN's objective:

Initiate International incubator activities (DOE's perspective according to George Fai)

Japan-US Theory Institute for the Physics of Exotic Nuclei (JUSTIPEN)

2013 Collaboration with Chinese theorists CUSTIPEN

Mutual Benefits to Nuclear Physics Programs in Both China and U.S.

- Both countries have invested heavily in RIB facilities and experiments, CUSTIPEN provides jointed theoretical supports to explore compelling sciences with exotic nuclei
- China continuingly sends many high-quality Ph.D students, postdocs and visiting scientists in nuclear physics to the USA, CUSTIPEN facilitates continued collaborations of these people and their US partners after they return to China

 Sharing complementary expertise in data analyses and interpretation:
 Example1: IQMD analysis of NSCL data on isospin diffusion by the CIAE group (Tsang et al., PRL, Y.X. Zhang et al. PLB)
 Example2: RMF analysis of ANL data on chiral doublet bands in ¹³³Ce by the PKU group (Ayangeakaa et al. PRL)
 Example3: Shell model analyses of IMP data on the masses of exotic nuclei by Alex Brown et al. (Tu et al, PRL and Y.H. Zhang et al. PRL)

Achievements so far

DOE CUSTIPEN budget provides travel funds for 15 visits/year 68 person-times between 5/1/2013- 7/1/2017

- Joint publications acknowledging DOE support for CUSTIPEN: Over 40 published, several under review and/or in preparation
- 13 CUSTIPEN workshops organized in China and USA
- Un-quantifiable mutual benefits to nuclear physics programs in both countries
- Facilitate the selection and placement of FRIB-CSC Fellows
- Facilitate new collaborations, e.g., J. Piekarewicz+R.X. Xu



13 workshops in Beijing, Lanzhou, Shanghai, Hengyang, Huizhou, Huzhou and Texas often involving people from other countries and <u>many young people</u>

Size: from L, M to S

CUSTIPEN Mini-Workshop on Nuclear Reactions Nov. 16, 2016, Texas A&M University-Commerce



CUSTIPEN Mini-Mini-Real-Working Shop around 1 table "Critical Questions about Nuclear Symmetry Energy" August 15-16, 2013, Commerce, Texas



CUSTIPEN-supported collaborations of Furong Xu's group at PKU with:

 Witek Nazarewicz's group at MSU in development of Gamow coupled-channel method for three-body systems PRC 96, 044307 (2017)

by Wang, Michel, Nazarewicz, and Xu





FIG. 7. GCC wave function of the g.s. of ${}^{26}O$ in the Jacobi coordinates nn and ${}^{24}O-2n$.

- James Vary's group at Iowa State U.
 in *ab-initio* nuclear structure calculations with many-body perturbation theory PRC 94, 014303 (2016) by Hu, Xu, Sun, Vary, and Li
- Carlos Bertulani's group at Texas A&M U.-commerce in isoscalar and isovector pairing with the Skyrme-Hartree-Fock-Bogoliubov theory PRC 91, 047303 (2015) by Chen, Bertulani, Xu, and Zhang
- 4. Thomas Papenbrock's group at UT&ORNL
- 5. Calvin Johnson's group at San Diego State U.
- 6. Rup Machleidt's group at U. of Idaho, 7. Bruce Barrett's group at U. of Arizona

3D-HFB developments

PRC editor 's suggestion

PHYSICAL REVIEW C 90, 024317 (2014)

Adaptive multi-resolution 3D Hartree-Fock-Bogoliubov solver for nuclear structure

J. C. Pei (裴俊琛),^{1,2,3} G. I. Fann,⁴ R. J. Harrison,^{5,6} W. Nazarewicz,^{2,7,8} Yue Shi (石跃),^{2,3} and S. Thornton⁵ ¹State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University, Beijing 100871, China ²Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA ³Joint Institute for Nuclear Physics and Applications, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA EDITORS' SUGGESTION

Adaptive multi-resolution 3D Hartree-Fock-Bogoliubov solver for nuclear structure





Danielewicz, J. Estee, U. Garg, W. Lynch, A. McIntosh, P. Morfouace, R. Shane, M. B. Tsang, S. Tangwancharoen, S. Yennello

R. Wang, Z. Xiao, Y.X. Zhang, Y.F. Zhang, Y. Zhang 2.0

The LSU-LNNU Collaboration supported by CUSTIPEN:



Kristina D. Launey, Jerry P. Draayer (LSU, USA)



F. Pan, X. Guan, Y. Zhang, L.-R. Dai

(Liaoning Normal University, China) Funded by NSFC, NSF, DOE and the LSU-LNNU joint program.

Joint publications of the LSU-LNNU team during 2015–2017

- Shape (phase) transitions in nuclei described by the collective model, the interacting boson model, and mean-field plus pairing model are studied intensively [Phys. Rev. C <u>91</u> (2015) 034305; <u>92</u> (2015) 044303; <u>93</u> (2016) 044302; <u>93</u> (2016) 044312; <u>94</u> (2016) 024309; <u>96</u> (2017) 034323; Phys. Lett. B <u>751</u> (2015) 423; Nucl. Phys. A <u>950</u> (2016)1; <u>952</u> (2016) 70]
- 2) Exact solutions of mean-field plus various types of pairing interactions are obtained and applied to elucidate pairing correlations in nuclei and related problems [Nucl. Phys. A <u>947</u> (2016) 234; <u>957</u> (2017) 51; Phys. Rev. C <u>95</u> (2017) 034308; Ann. Phys. <u>376</u> (2017) 182; J. Phys. A <u>50</u> (2017) 064002; J. Stat. Mech. (2017) 023104.].

Most of them acknowledged CUSTIPEN

An international collaboration involving IMP/Lanzhou, National Astronomical Observatories of China, TAMU-Commerce and Notre Dame

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Research highlights from the journals of the American Astronomical Society

Research Highlight

Fixing the Big Bang Theory's Lithium Problem

By Susanna Kohler on 15 February 2017 FEATURES



Artist's representation of the evolution of the universe, with time flowing to the right in the direction of the arrow. The Big Bang theory is the most widely accepted cosmological model of the universe, but it still contains a few puzzles. [NASA]

Non-extensive statistics in Big Bang Nucleosynthesis

S.Q. Hou (IMP, currently at TAMUC), Jian-Jun He (leader), A. Parikh, D. Kahl, C.A. Bertulani (TAMUC), T. Kajino, G.J. Mathews (Notre Dame), and G. Zhao, Astrophysics Journal 834, 165 (2017)

Transport code comparison project

-an international collaboration supported by ICNT/NSCL and CUSTIPEN

China: Lie-Wen Chen, Jun Xu, Ying-Xun Zhang, Yong-Jia Wang, Z.Q. Feng, Q.F. Li, Z.X. Li, J. Su, J. L. Tian, N. Wang, W.J. Xie, F.S. Zhang, G.Q. Zhang, Z. Zhang,

US: Pawel Danielewicz, M.B. Tsang, C. M. Ko, B. A. Li, ...

Japan, Germany, France, Italy, Korea, Canada, India:

Akira Ono, Hermann Wolter, D.Cozma, J. Aichelin, M. Colonna, A. L Fevre, T. Gaitanos, C. Hartnack, K. Kim, Y. Kim, M. Papa, T.Song, J.Weil, S.Gupta, Swagato, N. Ikeno, Y. Nara, T.Ogawa, A. Ohnishi, D. Ollinychenko, H. Petersen,

More manuscripts are in preparation

PHYSICAL REVIEW C 93, 044609 (2016)

Understanding transport simulations of heavy-ion collisions at 100A and 400A MeV: Comparison of heavy-ion transport codes under controlled conditions

Jun Xu,^{1,*} Lie-Wen Chen,^{2,†} ManYee Betty Tsang,^{3,‡} Hermann Wolter,^{4,§} Ying-Xun Zhang,^{5,∥} Joerg Aichelin,⁶ Maria Colonna,⁷ Dan Cozma,⁸ Pawel Danielewicz,³ Zhao-Qing Feng,⁹ Arnaud Le Fèvre,¹⁰ Theodoros Gaitanos,¹¹ Christoph Hartnack,⁶ Kyungil Kim,¹² Youngman Kim,¹² Che-Ming Ko,¹³ Bao-An Li,¹⁴ Qing-Feng Li,¹⁵ Zhu-Xia Li,⁵ Paolo Napolitani,¹⁶ Akira Ono,¹⁷ Massimo Papa,¹⁸ Taesoo Song,¹⁹ Jun Su,²⁰ Jun-Long Tian,²¹ Ning Wang,²² Yong-Jia Wang,¹⁵ Janus Weil,¹⁹ Wen-Jie Xie,²³ Feng-Shou Zhang,²⁴ and Guo-Qiang Zhang¹

Beijing Normal University—NSCL/MSU Collaboration supported by CUSTIPEN





www.elsevier.com/locate/nuclphysa

Nuclear energy release from fragmentation Cheng Li^{a,b}, S.R. Souza^d, M.B. Tsang^{a,b,e}, Feng-Shou Zhang^{a,b,c,*} 10 ⁵⁶Fe ⁹²Kr ¹⁴¹Ba ²³⁵I J ²⁰⁸Pb 238 1.0 38 E_b(MeV/u) ²³⁰Th Fission/Fragmentation 0.8 ∆E(MeV/u) ²³²Th 6 0.6 0.4 2 0.2 0 2 3 5 7 8 6 50 100 200 250 300 0 150 **Fragments number** Α

The three-fragment with nearly equal size is the most optimal cases to release the nuclear energy for the ^{235,238}U and ^{230,232}Th.

Texas connections

Texas A&M University, Texas A&M University-Commerce, Texas Advanced Computing Center, ------IMP, SINAP, CIAE, Beihang, BNU, SJTU, HNU,..... collaborations

- EOS of neutron-rich nuclear matter Joe Natowitz (2 CUSTIPEN-supported trips), Che Ming Ko (1), Hang Liu (1), A. Bonasera, R. Wada, B.A. Li/Y.G. Ma, D.Q. Fang, J.S. Wang, Z.Q. Chen, M.R. Huang, X.G. Chao, G. Zhang, C.W. Ma, L.W. Chen, Jun Xu, Y.X. Zhang, F.S. Zhang
- Nuclear reactions with rare isotopes Carlos Bertulani (4)/F.R. Xu. J.J. He, I. Tanihata, D.Y. Pang......

Texas Example 1: Exotic α Emission from α Conjugate Nuclei Collisions

Xiguang Cao et al @ SINAP & J. Natowitz et al. @ TAMU



FIG. 5: Ikeda-like diagram for the possible α-conjugate components of ⁴⁰Ca. Separation energy (-Q) in MeV for each decay channel is shown.



Texas-Example2: Progress of Particle and Nuclear Physics, Volume 81 (2017) Nucleon Effective Masses in Neutron-Rich Matter

Bao-An Li*1,a, Bao-Jun Cai^{2,b,c}, Lie-Wen Chen^{3,c}, Jun Xu^{4,d}

^aDepartment of Physics and Astronomy, Texas A&M University-Commerce, Commerce, Texas 75429-3011, USA ^bDepartment of Physics, Shanghai University, Shanghai 200444, China

^cSchool of Physics and Astronomy and Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai 200240, China

^dShanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China



Opportunities and Challenges for US-China Collaboration

Dr. Timothy J. Hallman Associate Director for Nuclear Physics

- Will the early successes with US-China collaboration be followed up ?
- If so, what will be the nature of our collaboration: Yes, going small scope, collaborator to collaborator (CUSTIPEN) ? well !

modest scope, targeted at specific experiments (STAR TOF, Daya Bay)? major, but separate comparable investments in programs and facilities? major, comparable investments in each other's programs and facilities in complementary scientific thrusts (RIKEN Experience at RHIC)? joint internationalization of major facilities in complementary scientific thrusts in the US and China ?



Answers

meeting?

at this



谢谢, thank you all for your



laser nuclear physics

TAMU+SINAP+UT

Nuclear fusion from laser-cluster interaction

Laser pulse in



Coulomb explosion @ TPW laser @ UT

SINAP+TAMU+SIOM



CD2 target @ SGII-U @ SIOM



H. J. Quevedo, G. Zhang, A. Bonasera, et al., Neutron enhancement from laser interaction with a critical fluid, Submitted to, Phys. Lett. A (2017)

Exotic α Emission from α Conjugate Nuclei Collisions

Xiguang Cao et al @ SINAP & J. Natowitz et al. @ TAMU

²⁸Si + ¹²C, ²⁸Si, ¹⁸⁰Ta @35MeV/u, NIMROD-ISiS

- A significant proportion of events constituted of alpha-like fragments is observed
- Subset of events with α-like mass equals 28 have rod or disk shape in momentum space, especially for the 7 α channel
- The hierarchy effects is also observed for decay channels with α-like mass equals 28
- ♦ The same conclusion holds for ²⁸Si+²⁸Si and ²⁸Si+¹⁸⁰Ta, showing the target effect can be negligible

