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2023 Pujiang Innovation Forum Bulletin XIV

Frontier exploration in basic science boosted by the open sharing of big science installations

Editor's Note: The Future Science Forum of the Pujiang Innovation Forum 2023, with the theme of "Frontiers of Fundamental Physics in the "Big Science" Era: Massive Scientific Facilities, International Collaborations and Innovations", experts from particle physics and related fields conducted in-depth discussions on physical research empowered by big science installations at home and abroad. This bulletin summarizes views of guests at the Future Science Forum for your reference.

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Frontier exploration in basic science boosted by the open sharing of big science installations

Advanced big science installations are pillars of a country and important platforms of basic scientific and technological conditions that support original innovation. Particle physics, which explores structures and patterns of atomic and sub-nuclear scale substances, has gradually become a research paradigm that relies on big science installations and international cooperation to tackle frontier problems. China is seizing the major opportunity of accelerated evolution in the new round of technological revolution to conduct international dialogues with countries around the world based on the construction and application of big science installations. The guests present agreed that in the current international environment, it is still necessary to promote international scientific and technological cooperation with open thinking and actions, plan and participate in global scientific and technological governance, improve the efficiency of big science installations, promote international cooperation in advanced technologies, and realize the integrated development of education, technology and talents in reliance on international big science cooperation.

I. From microscopy to cosmoscopy: exploration of new frontiers in physics research enabled by big science installations

First, big science installations assist scientists in obtaining new discoveries, revealing new patterns and exploring new applications continually. Luciano Musa, Senior Research Fellow at the European

Nuclear Center and former spokesperson for the LHC-ALICE International Cooperation Group, stated that the European Organization for Nuclear Research (CERN) has the world's largest particle physics laboratory, and is able to reveal various fundamental particle laws and cosmic laws. Toshitaka Kajino, Professor at Beijing University of Aeronautics and Astronautics/University of Tokyo, and Director of International Center for Cross-Science Research on Big Bang Cosmology and Origin of Elements, pointed out that the discovery of supernovae is the result of international cooperation in multiple bands, means and disciplines, such as the Gamma Ray Observatory (E&M), Optical Observatory (LAMOST, Subaru), Jiangmen Underground Neutrino Observatory (JUNO), and Laser Interferometer Gravitational-Wave Observatory (LIGO, Kagra).Zhan Wenlong, Academician of the Chinese Academy of Sciences, and Member of the Construction Commission of the National People's Congress, stressed that the Huizhou Nuclear Science Center (HNSC) can generate a beam with a light intensity of μ, and theoretically, the physical motivation of μ may discover evidence of the existence of a fifth force through g-2; from an application perspective, μ spin probes can be applied to superconductors, and μ meson perspectives can be applied to fields such as large-mass and thick-volume imaging, heavy metal detection, etc.

Second, big science installations are increasingly large, and material structure research is tending lower limits in scale. Karim Trabelsi, Researcher of IJC Laboratory, France, and Spokesperson of Belle II International Cooperation Group, stated that CERN has manufactured the world's largest accelerator and detector for studying the smallest particles in the universe, and also kept developing new technologies using computer algorithms in an attempt to exceed limits. The Large Hadron Collider (LHC) is a circular accelerator with a tunnel perimeter of as large as 27 kilometers. Particles are magnetically constrained by superconducting magnets to move around the circular structure almost at the speed of light, generating over 1 billion particle collisions per second to excite new microscopic particles. A Large Ion Collider Experiment (ALICE) generates extremely high temperatures and energy densities by colliding lead nuclei with center of mass energy of 2.76TeV per nucleus, generating a quark-gluon plasma that is sufficient to release quark confinement. Toshitaka Kajino stated that neutrino mass ranking constrained by synthetic isotope ratio in supernova nuclei is a reverse mass ranking formed based on three major conditions – the SN1987A supernova model, solar system abundance and observed values of cosmic rays. Currently, he is conducting research on the nuclear synthesis law of ^{138}La and ^{11}B by capturing neutrinos based on the SN1987A model.

Third, big science installations keep evolving through upgrading and iteration. Zhao Zhentang, Academician of the Chinese Academy of Engineering, Researcher of the Shanghai Institutes for Advanced Studies, Chinese Academy of Sciences, and Director of the Shanghai Light Source Science Center, said that synchrotron radiation light sources were designed and built for high-energy physics only in first generation, dedicated to synchrotron radiation applications in the second generation, and developed in reliance on ID (attenuator/wiggler) low emissivity mainly in the third generation. Now, fourth-generation installations are developing rapidly around the world, with focus on diffraction limiting emissivity with high coherence. Zhan Wenlong stated that the ability of the high-intensity Heavy Ion Accelerator Facility (HIAF) and the China Initiative Accelerator Driven System (CIADS) to transport relativistic strong ion beams (RI2B) is iterated and upgraded constantly.

Fourth, energy levels of big science installations are increasingly higher, and the scope of empowerment is widening. Karim Trabelsi stated that Belle II is based on the SuperKEKB accelerator and Belle II detector of Japan's High Energy Accelerator Research Organization (KEK), and is designed as a double-ring circular electron-positron collider with asymmetric energy. After ten years of operation, the SuperKEKB collider achieved instantaneous brightness of 2.226×10^34 cm^-2s^-1, which has broken the CERN record and set a new record in physics. Zhao Zhentang stated that the Shanghai Synchrotron Radiation Facility, as a representative of China's third-generation synchrotron radiation facility, generates X-rays that can be used to study structure of matter in atomic and molecular scales, and applied to spectroscopic and macromolecular structure research through imaging. It can be applied to both basic scientific research and industrial applications. As a result, the Shanghai Synchrotron Radiation Facility has given rise to many heavyweight scientific research and industrial technology achievements since its completion and opening in 2009.

II. From domestic to international: integrated development of education, science and technology, and talents boosted by global interconnection

First, the construction and operation of big science installations requires international support. Ma Yugang, Academician of Chinese Academy of Sciences, Dean of the Research Institute of Fudan University, thought that particle and nuclear physics belongs to the field of big science, and large-scale international cooperation is a natural attribute for it. Without international cooperation, the Solenoidal Tracker (STAR) at the Relativistic Heavy Ion Collider (RHIC) would not have been so successful. Luciano Musa pointed out that the European Organization for Nuclear Research (CERN), founded in 1954, has always been committed to the development of geographical and cultural diversity. CERN has 23 member states, 12 EU member states, 10 associate member states and 4 observers, with users from over 110 countries, in which 23% are women. Karim Trabelsi stated that for Belle II, as a unique installation for exploring and understanding the universe, international cooperation is the key to expanding the human understanding of the limits of the universe. This calls for integrating international forces, and leveraging advanced technologies to design and build detectors, and collect, process, analyze and interpret data.

Second, international cooperation based on big science installations is an effective way to train young talents. Ma Yugang thought that international cooperation is an effective way to train young talents, and enhance bilateral friendship and multilateral communication. Karim Trabelsi pointed out that Belle II's organizational members come from around the world, and its diverse working environment helps young people grow. Toshitaka Kajino emphasized that basic physics research is to discover principles from phenomena, so researchers must be down-to-earth and avoid following suit. He sent a message to young scientists – exploring the truth, working hard and discussing with others.

Third, international cooperation and exchanges based on big science installations promote interdisciplinary integration. Zhan Wenlong stated that in future research on the μ-meson, from a disciplinary perspective, fundamental physics is the key, and the power of interdisciplinary integration is indispensable; from the perspective of big science installations, heavy ion accelerator facilities (HIAFs) and plasma wake-field accelerators (PWFAs) play a crucial role, while other scientific instruments such as spectrometers should also be used.

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