China's Spallation Neutron Source Goes Operational

By XIN Ling (Staff Reporter)

The newly completed China Spallation Neutron Source, or CSNS, in Dongguan, Guangdong Province. *Credit: IHEP.*

It is a hot summer morning amid the endless greenness of lychee orchards 30 km southeast of downtown Dongguan, near China's southern coastline, when project manager CHEN Hesheng and his team gathered with excitement in the control room of the China Spallation Neutron Source (CSNS) to witness a historic moment: the production of the first neutron beam lines from the machine they had just completed after more than six years of construction.

People had been busy getting ready for the debut since early morning, August 28, 2017. Then at 10:56 am, within a fraction of a second after CHEN's instructions, neutron spectrums were detected respectively at target stations 6 and 20. It was a success! The control room burst into cheers. It was like a dream come true – now China has its own "super neutron microscope" to peep into the structure and dynamics of materials.

With a 1.87 billion yuan (about 280 million US dollar) budget, a new science hub is born in south China in the nation's avid quest for innovation.

The Neutron Source Club

Spallation neutron sources are a major kind of facility for materials research at the atomic level. By dashing neutrons into a sample and tracking their trajectory and energy transformation, scientists are able to reveal the molecular/magnetic structure and behavior of a wide range of materials from high-temperature superconductors, polymers, metals to biological samples.

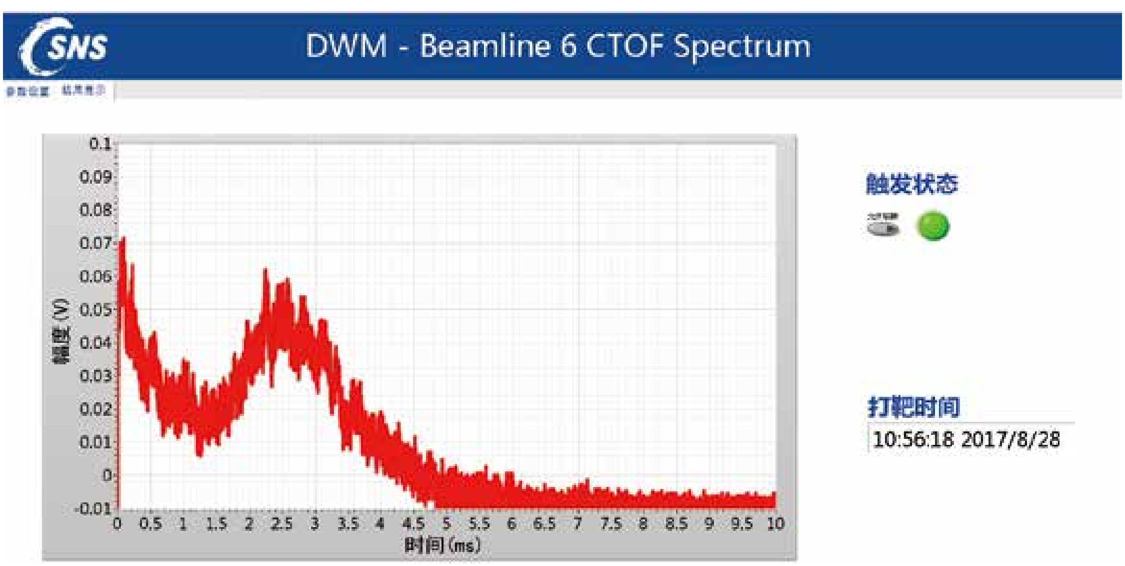
Compared with other microscopic probes like the X-ray, neutrons have unique advantages thanks to their electric neutrality, high penetration and sensitivity to light atoms. "Neutrons can be used to study materials under extreme conditions, for example how combustible ice forms in the deep ocean high pressure environment. This is beyond what a synchrotron radiation facility can do," said CHEN Hesheng, a particle physicist and former director of the CAS Institute of High Energy Physics.

However, due to their technical complexity and high costs, only three spallation neutron sources are in operation in the world today: the Spallation Neutron Source (SNS) based at the Oak Ridge National Laboratory in Tennessee, US; the Japan Proton Accelerator Research Complex (J-PARC) in Ibaraki, Japan; and the ISIS neutron source running in Oxfordshire, UK. Another one, the European Spallation Source (ESS), is under construction in Lund, Sweden.

CSNS has just earned China a ticket to that club.

According to CHEN Yuanbo, an IHEP researcher who was deputy project manager of CSNS, a typical spallation neutron source consists of three systems: the accelerator system, the target system and the instrument system.

CSNS's linear accelerator can speed up negatively



The first neutron beam line of CSNS was produced at 10:56 am, August 28, 2017. *Credit: IHEP.*

charged hydrogen ions to about 80 MeV of energy. The particles, stripped off their electrons and converted to protons, are then injected into a 75m-diameter circular accelerator (dubbed the rapid cycling proton ring) to be further accelerated to 1.6 GeV.

The protons will then go into the target system to produce neutrons. At the heart of CSNS's target system, there is a 7m-high, 4m-wide and 68-tonne cylindrical container in which neutrons are blasted – or "spalled" – out of a set of 15 tungsten plates by the high energy protons. They are then slowed down to energies suitable for scattering and scientific study.

"Each proton can release 20 to 30 neutrons," said CHEN Yuanbo. However, the neutrons are very fast and active, and need to be decelerated by moderators – which are liquid hydrogen in CSNS's case – before they can be guided to different instruments for experiments.

"Back then, we had long discussions over the design of the target," he recalled. Liquid mercury targets used by SNS and J-PARC usually have longer life spans, but they tend to cause bubbles and erosion problems which lead to the facility's instability. In the end, they decided to adopt a tungsten target design similar to that of the ISIS.

As for the instrument system, due to the tight budget, CSNS has to start with three general purpose neutron-scattering spectrometers, and hope for more to come in within the next few years.

J-PARC director Yujiro Ikeda regarded CSNS as "a good project to initiate the spallation source facility in China." "Young Chinese scientists and engineers are so enthusiastic to implement their ideas and cope with challenges in their design, after critical and sincere discussions and hard work. I'd like to congratulate CSNS team's endeavors," he told *BCAS*.

Despite of adverse weather conditions (such as frequent summer rains) in Guangdong, the construction of CSNS went smoothly. Civil engineering work was finished at the end of 2015 so the commissioning could start right in time.

According to CHEN Hesheng, the facility will be fully operational next year. "Scientists from 22 domestic universities have already applied to use it. It will also be open to researchers from outside China," he said. CSNS will be free for the public, only collecting a small amount of fee from companies with special needs, according to *China Daily*.

For China and for the World

Like many other large science facilities built or being built in the country, CSNS spelled out China's ambition as a rising power in basic research.

"China has two research reactors, one in Beijing and one in Sichuan, which can be used for neutron scattering," observed ISIS director Robert McGreevy. "But if it is to have access to the highest performance neutron scattering in the future, which it presumably will do as a leading research nation, then spallation is the most sensible option."

Thom Mason, the director of SNS, saw a strong determination behind CSNS to promote industrial upgrading via scientific innovation.

"Because of China's strength in manufacturing, understanding materials and developing new and better materials is part of the science underlying advanced manufacturing", Mason commented. "As China is increasingly interested in driving innovation and moving beyond manufacturing technologies developed in other countries, having strong domestic R&D facilities oriented to the studies of materials will be an important national asset."

In fact, the idea of building such a facility for both scientific and industrial uses has been well received by the Chinese government since it was first proposed in the early 2000s – after CAS officials visited the ISIS and became interested in building one such facility of their own. In 2005, CSNS was on the top of a list of nine research infrastructures to be constructed between 2005 and 2010.

While most big science facilities are located in Beijing and Shanghai, CSNS is one of the few which are hosted by south China, aiming to boost research in the region including Hong Kong and Macau.

And it will benefit not only China but the global community through international collaboration. "There are few such spallation neutron sources in the world, so it is to everyone's advantage to collaborate as much as possible," McGreevy said.

The completion of CSNS is a big excitement for YAO Daoxin, a condensed matter physicist from the School of Physics and Engineering, Sun Yat-Sen University in Guangzhou, who has already applied to use the facility. He also hoped that his former overseas colleagues, including those from the Oak Ridge National Laboratory, will "come and work at CSNS",

Installation of one of the helium containers at the CSNS construction site on May 5, 2015. *Credit: IHEP.*

and that CSNS will welcome researchers from all over the world "with open arms".

Challenges and Opportunities

Although CSNS has been completed, most of its instrument slots are still empty due to limited funding. For instance, the time-of-flight spectrometer which will be of great help to YAO's materials research is not among the "day-one instruments".

"Spectrometers are like the 'eyes' of a spallation source," he told *BCAS*. As spallation sources are expensive to build and operate, it is important that they are used efficiently by accommodating as many instruments as possible. Typically, a target station can fit up to 20 instruments.

Unfortunately, spectrometers are costly, too – each of them worth 10 million RMB or more. All CSNS has now is a multi-purpose reflectometer, a small angel diffractometer, and a high intensity diffractometer. And they have proposed to the government for money for another 12 to 13 spectrometers.

The money for those spectrometers, YAO said, should not be confined to governmental sources only. It could also come from the investment of potential users.

In fact, the lack of potential users from different sectors has been a major challenge for CSNS. Most users will be from the academia, such as universities and research institutes. But for the manufacturing and pharmaceutical sector, including industrial giants PetroChina, Sinopec and China Guangdong Nuclear Power Group, should also be encouraged to be engaged in.

The challenges have not stopped CSNS people from blueprinting an ambitious future. From the very beginning, the facility was design to be upgradable to a much more powerful level: 500 kW beam power.

According to CHEN Hesheng, the power upgrade will be achieved by boosting the energy of the linear accelerator to about 250 MeV, using superconducting technologies readily developed by IHEP and partner institutions. Land has also been reserved for a second target, which will produce neutron beams at a quite different frequency.

"The higher frequency is better for 'harder' materials and higher resolution, while the lower frequency for 'softer' materials and lower resolution. With more research emphasis nowadays on areas like biophysics, it would be good for CSNS to have a low frequency target station, which might be 5 or 10 Hz," McGreevy explained.