# Summary of Results from the CINS-CNI 2020 Survey

October 5, 2020

**Overview and Discussion**

The Canadian Institute for Neutron Scattering (CINS) and the Canadian Neutron Initiative (CNI) partnered to survey the Canadian neutron beam user community in August–September 2020. Approximately one-third of the 100 principal investigators at Canadian universities who use neutron beams participated in the survey, in addition to several researchers from industry and government.

The results reveal that: (1) Canadian researchers have been facing severe reductions in access to neutron beams since the NRU Reactor, the source of neutrons for the Canadian Neutron Beam Centre (CNBC), closed in March 2018, and since the agreement with the Spallation Neutron Source (SNS) in the USA expired in January 2018; and (2) a national neutron beam program could provide substantial value by making these versatile and irreplaceable tools more accessible to the Canadian research community.

The results also show that Canadian researchers' capacity to apply neutron beams to their research is continuing to decline even now, more than two years after the closure of the NRU and expiry of the SNS agreement. As such, it may take several more years before the full extent of the reduction in capacity can be clearly identified and fully appreciated.

For years, Canadian researchers have enjoyed advantages provided directly and indirectly by the CNBC and SNS, and these advantages have helped Canadians to be competitive in beam time competitions: Canadian scientists and their students and post-docs have received valuable training and experience, and have collected data and published papers that can be cited as relevant prior research. Some such users have become leaders in their scientific fields and have attracted international collaborators, who now in turn assist them to access beam time at facilities in their home countries (e.g. the European facilities restrict access to scientific teams composed primarily of scientists from the countries that fund them). Canadians have been welcomed to apply to facilities in the USA, in part because the CNBC welcomed many scientists from the USA in return and Canada made a major contribution to the construction of instruments at the SNS. Such residual advantages will decline over the next several years, however, as (1) the backlog of projects that build on results from the CNBC and the SNS is cleared; (2) current students graduate, and training new ones in neutron beam techniques becomes harder; (3) Canadians' reputation in the field and their attractiveness as collaborators declines; (4) Canadian researchers divert their interests elsewhere in response to not getting enough beam time; and (5) the residual welcome of Canadian scientists at the USA facilities wears down.

The results of this survey provide insight into how a national neutron beam program—one that serves the differing needs of both expert and non-expert users—could halt and reverse the decline in Canadian capacity to use neutron beams for materials research, placing Canada again into a leadership position in this field.

**Key Results and Observations**

1. **Neutron beams are important for research across a wide variety of fields** (Figure 1). A full 93% of respondents agree that neutron scattering is somewhat to very important to their research.
2. **Fewer researchers have accessed neutron beams in the last two years, and those who did reported that it is much more difficult** (Figure 2). Of all respondents, 40% have not conducted an experiment at all in the last two years. Two-thirds (68%) of respondents agree that getting beam time has become more difficult, with 24% saying the difficulty has increased to the point that it deters them from applying. Those who reported no real change in difficulty in getting beam time consist of only those who, in the past two years, have only used capabilities that the CNBC did not provide (e.g. small-angle neutron scattering, cold neutrons, time-of-flight methods, and spin echo neutron scattering).
3. **The change in access levels is dramatic for those who have been affected** (Figure 3). For the majority (68%) who have been affected, there is a strong contrast in the sufficiency of beam time obtained in the two years before and after the CNBC closed in 2018. Only 10% are getting enough beam time since the closure, whereas previously 73% received sufficient beam time. Nearly half (45%) have applied for beam time but received insufficient amounts (none or too little), while an equal number (45%) have been deterred from even applying. Furthermore, the fraction of all respondents who did not apply in a two-year window doubled from 19% to 41% after the CNBC closed.
4. **The effect of the increased difficulty is different for expert vs. non-expert users** (Figure 4):
    a. Expert users find that it is more difficult to succeed in competitions and are getting much less beam time than before; about 80% of such respondents did not receive enough beam time to meet their research objectives.
    b. Non-expert users (except for a few who were already not using the CNBC) find that it is much more difficult and are deterred from applying; only 25% of non-expert respondents applied in the last two years, and 60% of those did not receive enough beam time to meet their research objectives.
5. **Beam time applications continue to decline due to the challenges in getting beam time**. Respondents reported a further 24% reduction in experiments planned for the immediate future, as compared to the past two years.
6. **Because follow-up measurements are often needed, insufficient beam time is often a barrier to completion for a research project. Lack of scientific support for data analysis after experiments were completed was also identified as a major challenge** (Figure 5). Challenges in data analysis and other identified barriers, such as training and "time required to invest in the experiment," could be met (or at least partially relieved) with adequate scientific support.
7. **Neutron users would value support that could be provided by a coordinated national program for the stewardship of Canada's capability to conduct research with neutron beams** (Figure 6). While all the potential services would be valued by Canadian researchers, the most valued service would be to establish partnerships that secure access to beam time for Canadians, followed by training in neutron beam techniques.

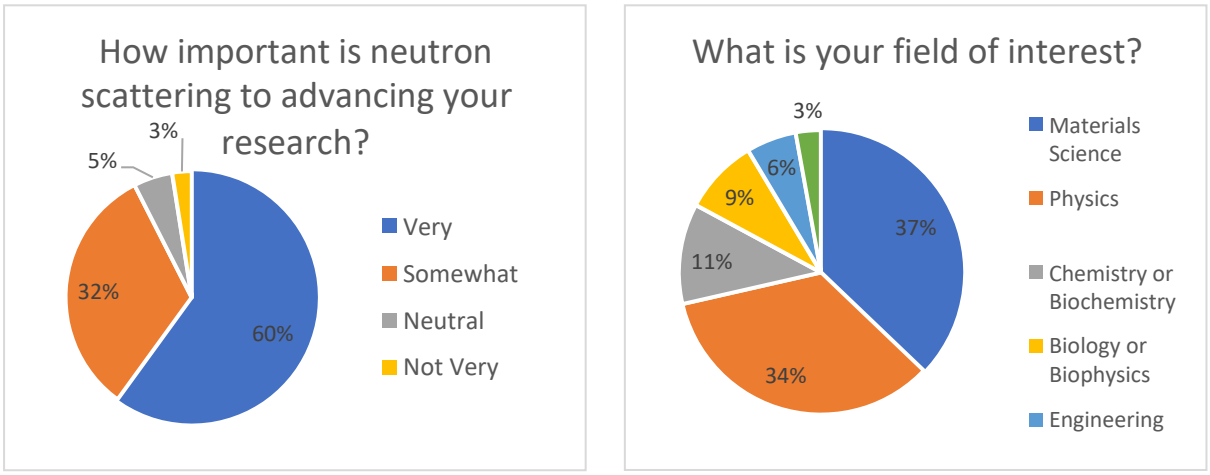


*Figure 1 – Left: Value of neutron beams to respondents. Right: Respondents' primary research fields.*

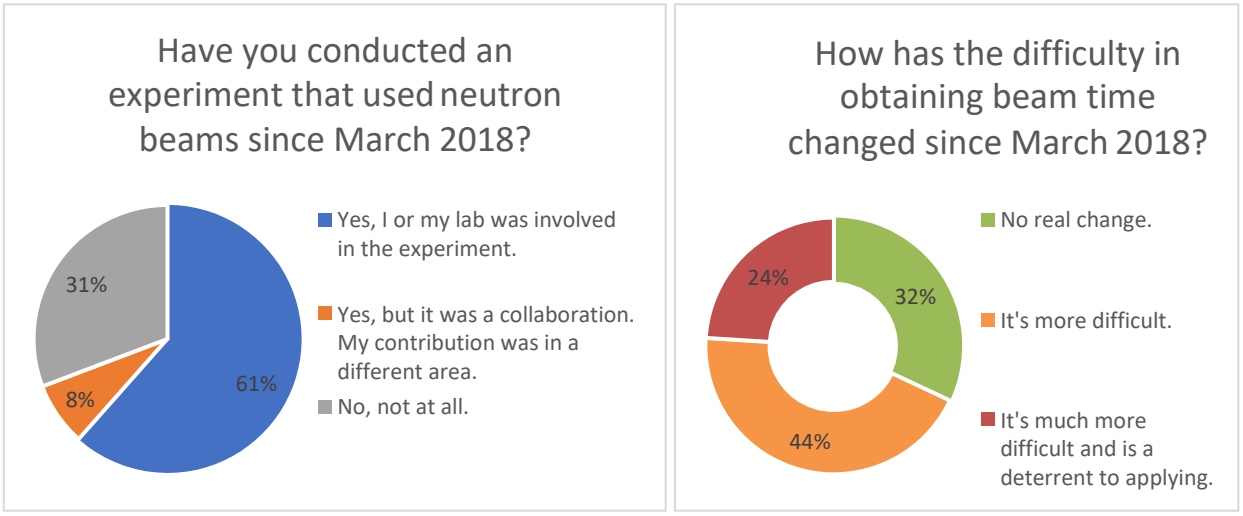


*Figure 2 – Left: Fraction of respondents who have continued to use neutrons in the last two years. Right: Fraction of respondents who have experienced changes in difficulty in obtaining beam time.*

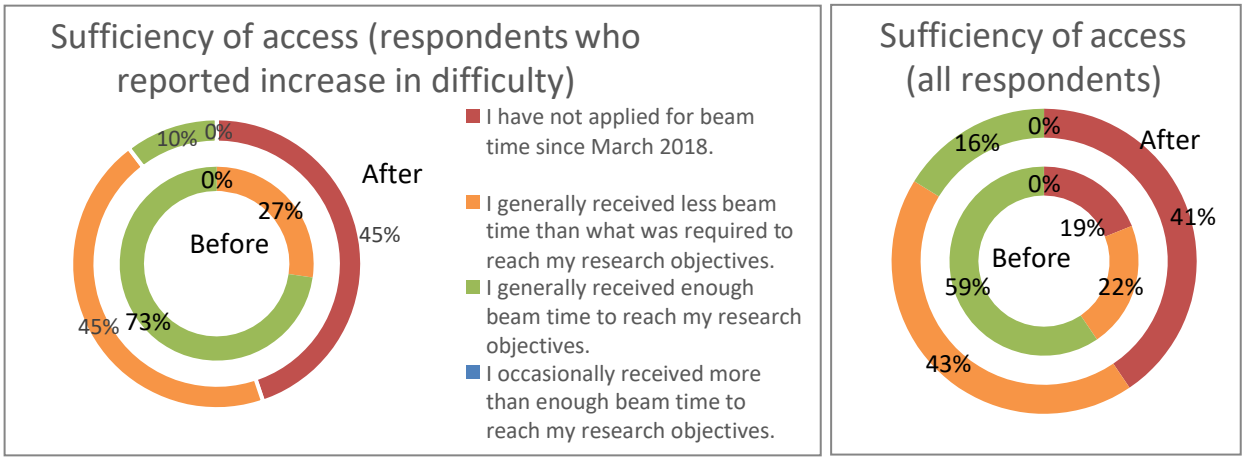


*Figure 3 – Sufficiency of beam time in the two years before and after the CNBC closed in March 2018, for those who reported an increase in difficulty (left) and for all respondents (right).*

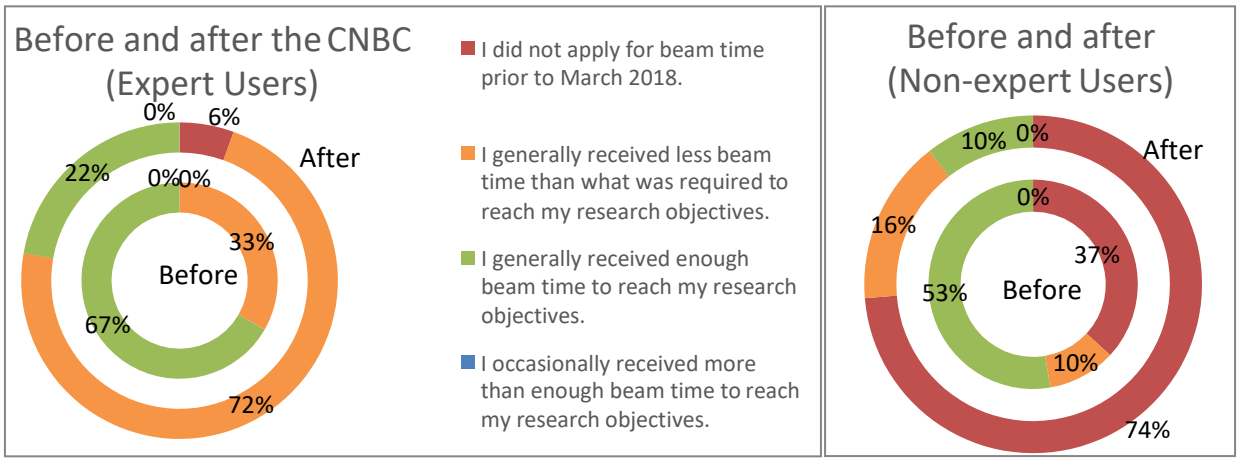


*Figure 4 – Sufficiency of beam time in the two years before and after the CNBC closed, for expert users (left) and for non-expert users (right). Expert users were defined as those who reported three or more publications in the past two years.*

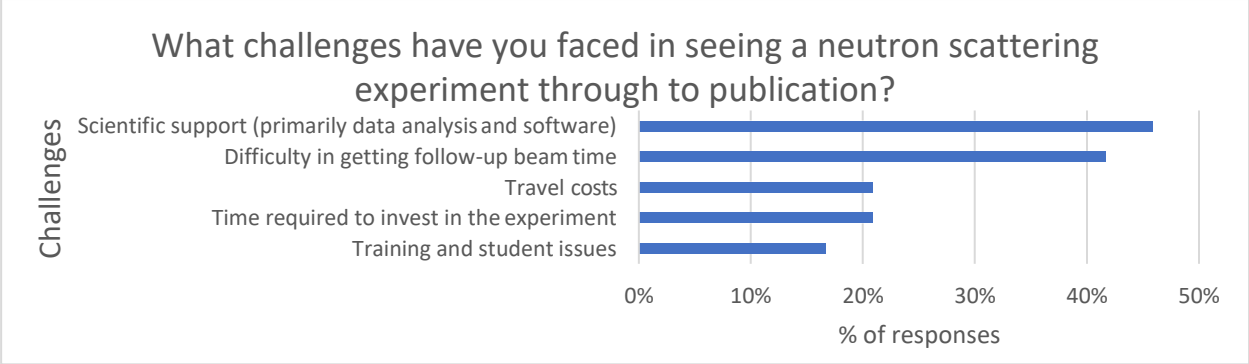


*Figure 5 – In the above open-ended question, respondents described barriers they face to completing publications after they conduct a neutron beam experiment. Identified barriers were grouped into the categories shown.*

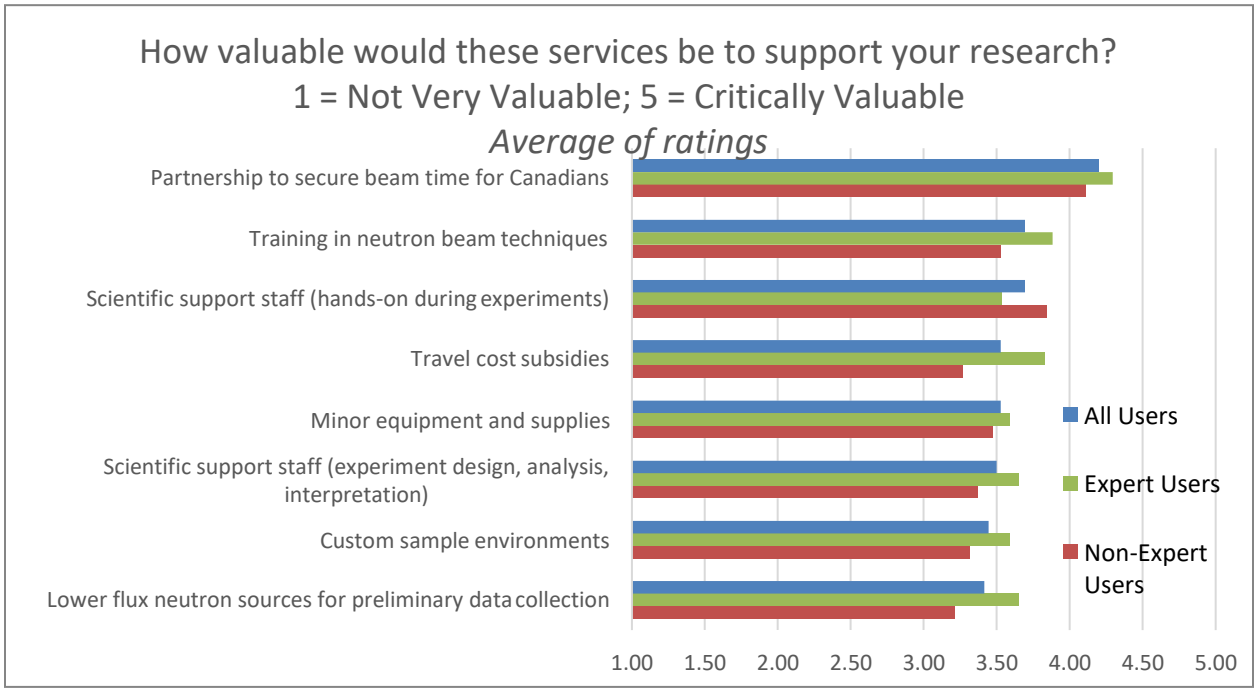


*Figure 6 – Average rating (1 to 5 scale) of respondents for each of the above potential services that could be provided by a coordinated national program for the stewardship of Canada's capability to conduct research with neutron beams.*

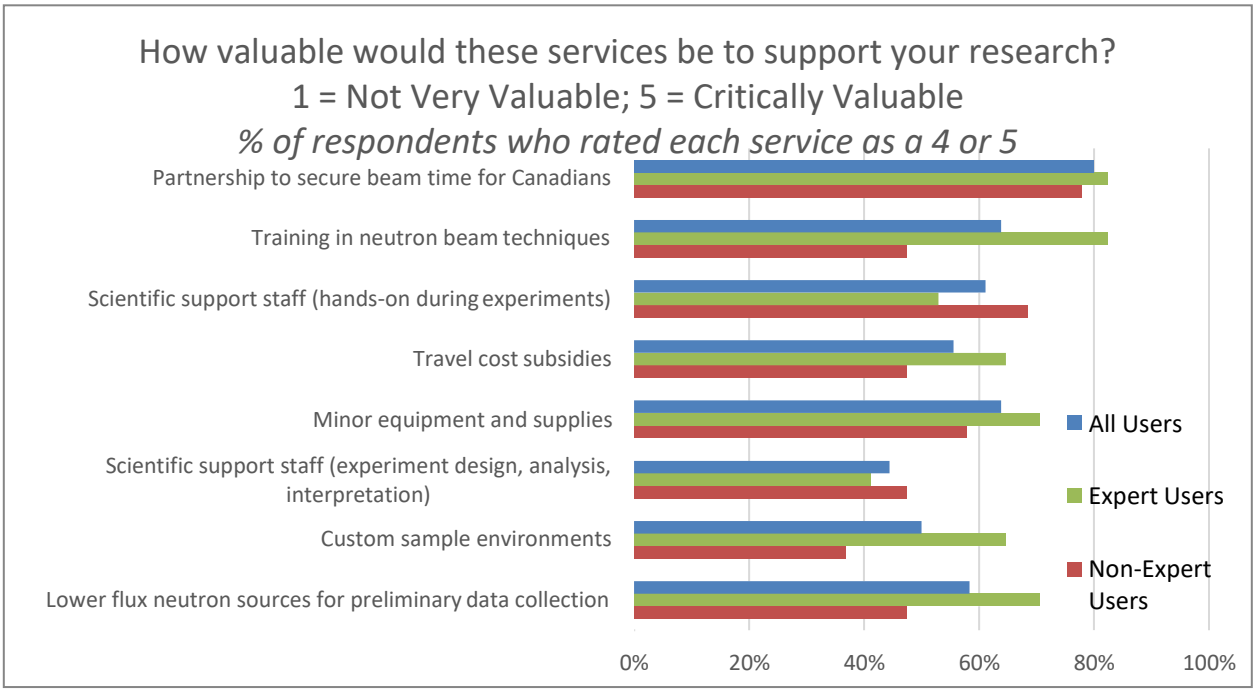


*Figure 7 – Percentage (%) of respondents who rated each service as highly or critically valuable (i.e. 4 or 5 on the scale).*

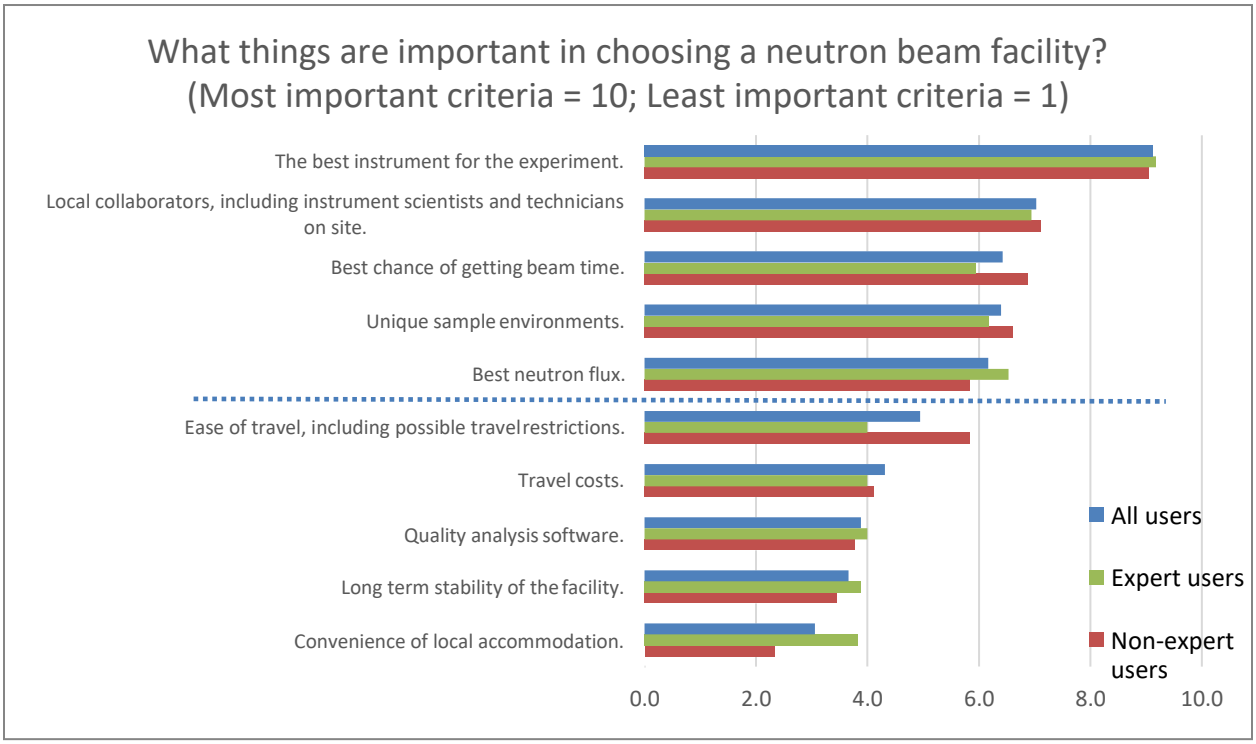


*Figure 8 – Respondents ranked the above 10 criteria for selecting beam time. The results show relative, rather than absolute, importance. The rankings show a clear division between the top five and the bottom five criteria.*

8. Differences between the services that expert and non-expert users would highly value (Figure 7) include:
    a. **Over 80% of expert users would highly value training in neutron beam techniques**—demonstrating that training would be just as valuable among expert users as partnerships to secure beam time for Canadians.
    b. **Nearly 70% of non-expert users would highly value hands-on scientific support.** They also highly rated off-site scientific support (e.g. designing the experiment, analyzing, and interpreting the results) more frequently than did expert users.
    c. More expert users than non-expert users would highly value the provision of (1) travel cost subsidies; (2) minor equipment and supplies; (3) custom sample environments;, and
    (4) opportunities for preliminary data collection using low-flux instruments.
9. In choosing a neutron facility, all respondents' criteria are consistent with the obstacles they face and the services they require (Figure 8). After identifying the best instruments, they consider their need for local scientific support and their chance of getting sufficient beam time. These criteria are closely followed by sample environments and the neutron flux, both of which are related to the best instrument for the experiment. Non-expert users are much more concerned about the logistics of travel to the facility than expert users, who do it more frequently. Other considerations related to travel and long-term stability of the facility are considered less frequently. Note that while users may not choose a facility for its quality analysis software, lack of such software or their ability to use it was frequently identified by all users as a barrier to seeing the experiment through to publication (Figure 5).
10. Consistent with the preference to apply to the facility that has the best instrument for an experiment, users may apply to a variety of facilities when they need to conduct multiple experiments. Of all users who conducted an experiment in the last two years, 40% used more than one facility (Figure 9).
11. **Since the CNBC closed, Canadian users have accessed facilities in the USA for 80% of their beam time** (Figure 9), which is consistent with their above criteria: The USA offers a wide range of competitive scientific capabilities at its three major neutron user facilities, and often offers the best chance of getting beam time because the European facilities restrict access to scientific teams composed primarily of scientists from the countries that fund them. In addition, travel to the USA is usually simpler or less expensive.
12. The top six neutron facilities used by Canadians are listed below. Their relative usage between the last two years since March 2018 and for the next 18 months varies, as shown in Figure 10, but the USA facilities are consistently the top three.
    a. NIST Center for Neutron Research, USA
    b. Spallation Neutron Source, USA
    c. High Flux Isotope Reactor, USA
    d. Institut Laue-Langevin, France
    e. ISIS Neutron and Muon Facility, United Kingdom
    f. Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM-II), Germany
13. The McMaster Nuclear Reactor (MNR) accounts for 1% of beam time used by respondents since March 2018, and 2% of their planned beam time in the next 18 months.

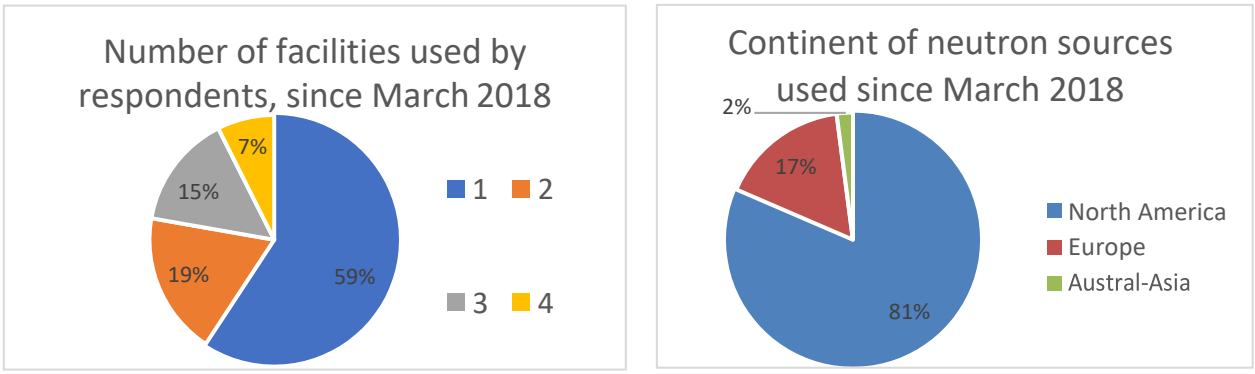


*Figure 9 – Number of neutron sources used by respondents in the past two years (left) and where they are located (right).*

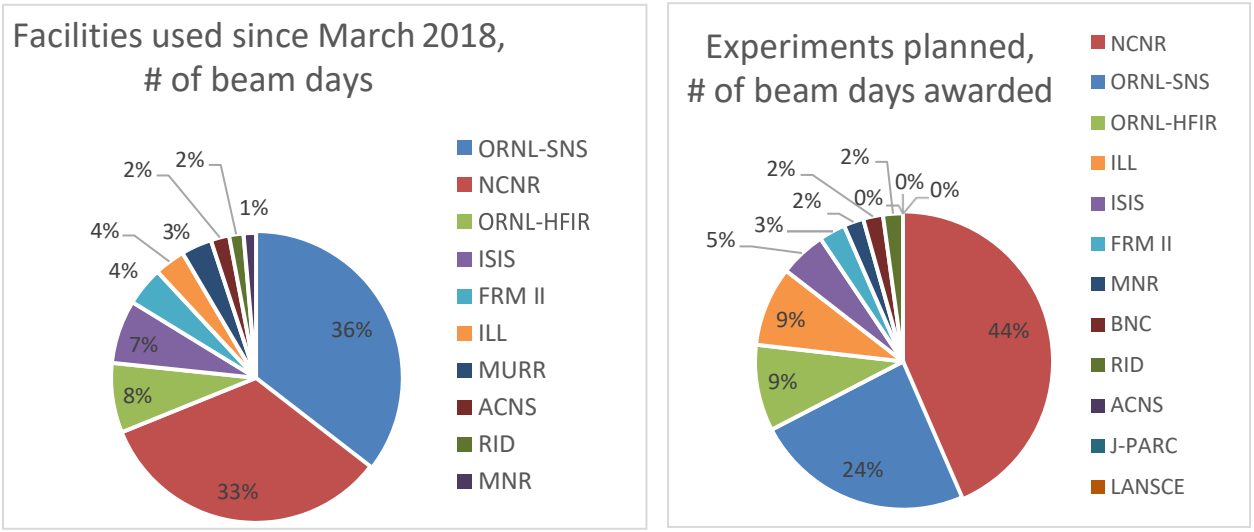


*Figure 10 – Neutron facilities used recently (left) or planned to be used within the next 18 months (right) by respondents, as a percentage of the total beam time used (left) or awarded (right).*

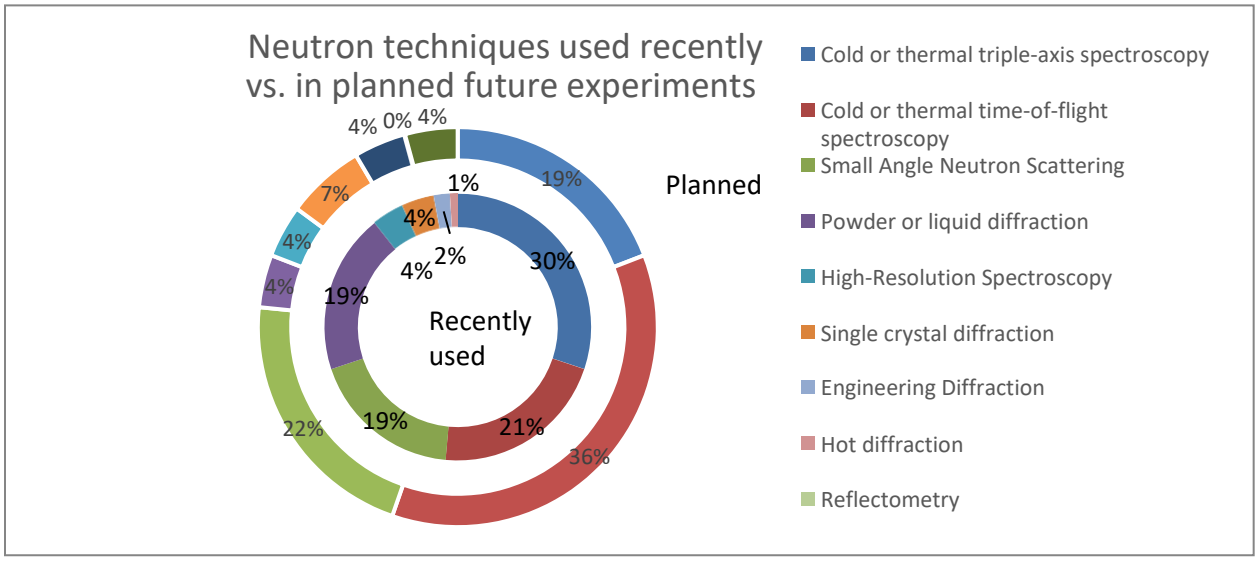


*Figure 11 – Neutron techniques used by respondents since March 2018 (inner ring) or planned to be used in the next 18 months (outer ring), as a percentage of the number of experiments conducted (inner ring) or planned (outer ring).*

14. **Canadians' usage has been well distributed among most of the main categories of neutron techniques, but this distribution is changing following the CNBC's closure** (Figure 11). The most-used techniques that were previously available at the CNBC (e.g. triple-axis spectroscopy, powder diffraction, high-resolution spectroscopy) are harder to access and are shrinking as a proportion of the user community's experiments. Together, time-of-flight spectroscopy and small-angle neutron scattering, which were not available at the CNBC, now comprise a majority (58%) of all planned experiments. Engineering (e.g. stress scanning) seems to be underrepresented in respondents. Imaging was unrepresented in the survey.
15. **Travel Costs:** Travel costs per experiment, as estimated by users, averaged $3,100, with a range from $1,000 to $10,000. Respondents reported conducting 106 experiments over the last two years, which leads to an estimate of $164,300 per year for total travel costs. Adding travel costs of 60 non-expert non-respondents would place the total travel costs of the Canadian neutron beam community for experiments at over $200,000 per year.
16. **Categorization of "Expert" vs. "Non-expert" Users:** Following the method of the Danish user community, CINS has previously categorized expert users as those who publish at least four papers in two years.[1] For this analysis, the threshold was lowered to three papers in two years, since it is now more difficult to complete neutron beam experiments, and there is an apparent divide at two papers in respondent data on publications (Figure 12).
17. **Publications:** Expert users published an average of 2.7 papers per year, while non-expert users published 0.3 per year. From this sample, we project an estimate of the Canadian neutron beam community's current publication rate at 75 publications per year. This number is significantly lower than the 100–110 neutron scattering papers identified by Banks and Harroun (footnote 1) for 2016 and 2017. This result confirms that there is already a drop in total publications from the community following the CNBC's closure. The full magnitude of the drop remains to be seen, as many publications in the last two years were based on data collected at the CNBC, and the impact of deterrence from applying elsewhere continues to reduce the number of experiments being planned (point 5). In other words, a new equilibrium in experiments and publications has not yet been reached.
18. **Demographics:**
    a. Neutron users are a multidisciplinary community, with materials science and physics being the top fields (Figure 1).
    b. Neutron users from Canadian university research faculties are primarily male (over 80%) with few visible minorities (11%).
    c. No respondents declared themselves as Indigenous or a person with a disability.

[1] Banks D and Harroun TA. 2019. Seventy years of scientific impact using neutron beams at the Chalk River Laboratories. FACETS 4: 507–530. doi:10.1139/facets-2019-0003

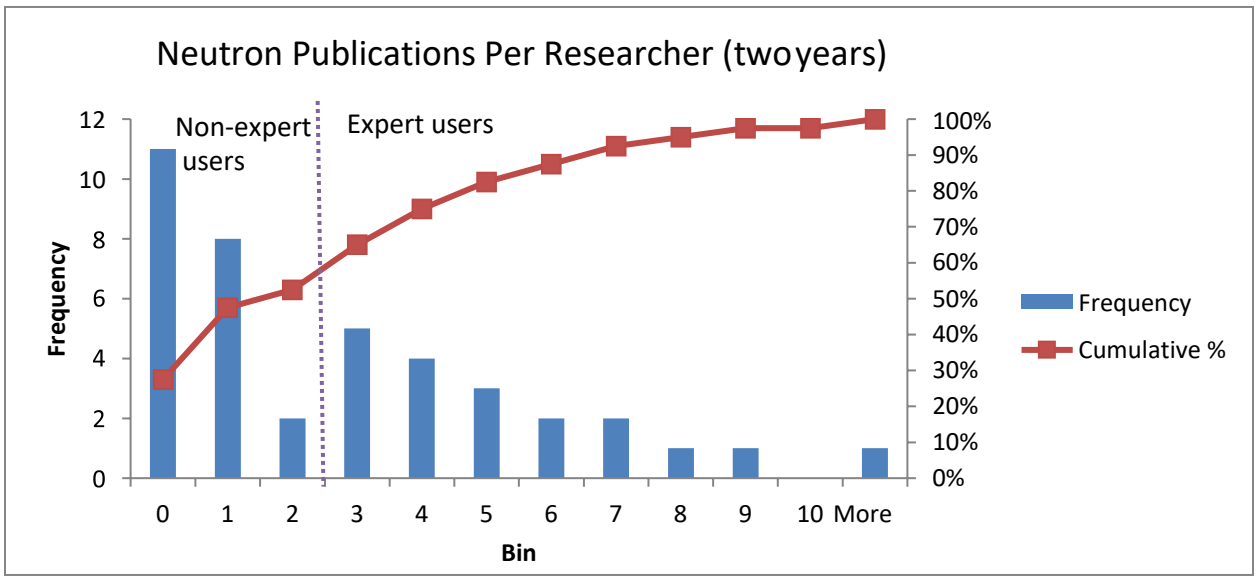


*Figure 12 – Neutron publications per respondent over the past two years.*