Context and Environment of Subatomic Physics Research at Canadian Universities

prepared by
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It is our hope that this document can provide an overview of some of the most important information needed to understand the Canadian research context and environment needed for your funding decisions. This document cannot cover all aspects of the overall research environment and the context in which the research is conducted, such as the quality of the research space, the age and status of equipment and other infrastructure, technical support personnel, the level of engagement and interactions of the students and postdocs, interactions between researchers within an institution or institutions within geographical proximity, as well as the level of support of the institution's administration, all vital elements in the success and productivity of a research group; instead we focus on the lab and computing infrastructure, graduate student support requirements and regional aspects.

Roles of Canadian research funding agencies in support of subatomic physics

The decisions that you make as SAPES members are of crucial importance to the Canadian subatomic physics research enterprise, as the NSERC Subatomic Physics (SAP) Envelope is the only major means of operating funds for Canadian subatomic experiment and theory research. i.e. funding for research travel, students, nearly all postdoctoral fellow support, and the MRS centre technical support staff comes ONLY from SAPES funding. The additional operating research funds provided through Canadian universities, or other federal or provincial agencies, are limited in scope and are often not accessible to researchers in non-applied areas. In addition to the SAP Discovery Grants Program (Individual or Project), subatomic physicists also rely on the SAP-RTI program to provide funding for equipment. Historically, the RTI funds were used to build experiments and provide the Canadian hardware contributions to the experiments of large international collaborations, and more recently RTI funds have been used as seed capital funds for projects that apply for larger CFI support. For most subatomic physicists in Canada, the NSERC SAPES awards are their sole source of research operating funding. It should be noted that unlike the USA, universities are not allowed to charge overhead on NSERC grants (an equivalent of overhead is paid separately), and grant holders are not allowed to pay themselves summer stipends from the grants (as Canadian universities pay twelve month salaries).

The NSERC Subatomic Physics Envelope also supports several resource facilities through the Major Resources Support (MRS) program. The resources at these facilities are available to the entire subatomic physics community normally allocated via a national resource allocation board. At the University of Alberta, the CPP+ MRS Centre is available to provide engineering and electronics support. The MRS facilities at Carleton and Winnipeg are available to support subatomic physics related detector development work. The resources include engineering design, hardware fabrication and installation, and data acquisition/simulation expertise. The Université de Montréal MRS facility provides electronics design and support for subatomic physics projects. Additional technical support is available through TRIUMF via a gate review process at cost.

Two NSERC scholarship programs that are commonly used by subatomic physics researchers are the Undergraduate Summer Research Assistantship (USRA) and Postgraduate Scholarship (PGS) competitions. These are awarded directly to the student and in the case of the USRA require an additional funding commitment from the supervisor's NSERC grant. It is important to note that these scholarships are only available to Canadian citizens and permanent residents, so international students studying in Canada are excluded from this means of support. NSERC also runs a series of smaller, more competitive graduate scholarship programs (e.g. Vanier Scholarships) as well as a small PDF fellowship program.

The Canada Foundation for Innovation (CFI) is a major federal source of research infrastructure funding. CFI will fund up to 40% of the costs for a major piece of experimental equipment, with the requirement that 60% of the funds come from elsewhere, including provincial matching funds, industrial or international contributions. In principle the CFI funds, when matched, can be used to make large capital contributions to the experiments of large international collaborations. However, the CFI grant cycle has some uncertainty and the process for decision-making on a grant is independent of NSERC SAPES. All applications have to go through internal university competitions, as there are rigid quotas on how many applications an institution can forward to CFI. For major projects (>$10M) the CFI matching budget from one university/province is usually not enough, so these projects have to be spread over many universities and provinces, each of which have slightly different timelines. The most recent Innovation Fund competition was in 2023, and the next two are expected for 2025 and 2028. CFI also contributes funds to the ongoing operations and maintenance needs of national research facilities on a cost-shared basis through the Major Science Initiatives (MSI) program, including SNOLAB. CFI also provides funding to the Digital Research Alliance of Canada, which currently operates a variety of national high performance computing centres discussed further below.

The Canada Research Chairs (CRC) program provides direct funding for 2000 research professorships in a wide array of disciplines in Canadian universities. Holders of these chairs often have reduced teaching loads and preferential access to certain types of federal research funding. There are CRC chairs in subatomic physics at the universities of McGill, Carleton, York, Toronto, Winnipeg, Regina, Alberta, SFU and UBC. Of these, six are Tier-2 chairs, which are tenable for five years and renewable once, are for exceptional emerging researchers having the potential to lead in their field. The remaining 3 are Tier-1 chairs, tenable for seven years and renewable once, are for outstanding researchers acknowledged by their peers as world leaders in their fields.

In December 2014, the Government of Canada launched the first two competitions of the Canada First Research Excellence Fund (CFREF), a new mechanism to support research in Canada. All CFREF awards are for up to seven years and there is no prescribed size for CFREF awards. Following the 2nd competition, in September 2016 CFREF announced it would support the creation of the Canadian Particle Astrophysics Research Centre (CPARC), with $63.7 million in funding over seven years. CPARC was renamed the Arthur B. McDonald Canadian Astroparticle Physics Research Institute (McDonald Institute) in May 2018. The McDonald Institute is headquartered at Queen’s University, with members located at seven affiliated Canadian universities – Alberta, British Columbia, Carleton, Laurentian, McGill, Montréal and Toronto. The new centre also partners with the Canadian Institute for Advanced Research (CIFAR), the Institute of Particle Physics (IPP), the Perimeter Institute, SNOLAB and TRIUMF. The McDonald Institute is primarily involved in and supporting projects based at SNOLAB, or potentially based there: direct detection of dark matter projects, including PICO, NEWS-G, SuperCDMS,

DEAP-3600 and the future liquid argon program; and neutrino physics projects such as SNO+, nEXO, LEGEND, and the supernova watch experiment HALO. In addition, a central thrust of the McDonald Institute is to strengthen astroparticle theory across Canada. The McDonald Institute also supports related programs in high-energy neutrinos and new R&D initiatives. The McDonald Institute used the funds to create 15 faculty positions spread across Canada (Queen's 7, Alberta 2, Carleton 2, Laurentian 1, Montreal 1, Toronto 1), 52 positions for researchers, engineers, designers, and technicians, as well as provide opportunities for 22 postdoctoral fellows and 43 graduate students on an annual basis. An additional research scientist position equivalent to faculty rank was also established at TRIUMF. Additional research positions have been created at various institutions across Canada made possible from pooled funds administered by the McDonald Institute and provided by CFREF. These HQP positions average fifty on an annual basis, providing funding for postdoctoral fellowships, graduate students, and undergraduates. Queen's University has fulfilled its commitment to add seven new faculty members, including three in cross-disciplinary fields (materials engineering, isotope geo-chemistry and chemistry), in support of the McDonald Institute. The 15 new faculty hires (whose salaries were bridged by CFREF funds) were initially ineligible to apply for NSERC grants during the bridging period; hence their research was supported by the McDonald Institute and university funds during this period. Starting gradually at the end of the 3rd year of the award, a number of Queen's faculty were moved off McDonald Institute funds and onto Queen's University funds to allow them to apply for NSERC funding. Starting in 2021, all CFREF-supported faculty members are eligible to apply to NSERC as co-PI (though not as PI until the end of the bridging period). The McDonald Institute funding is ending in August 2024, removing a large amount of funding for technical support from the community. An application for a re-focused McDonald Institute to the federal government is currently being considered by the government, but a timeline for funding or scope of a possible continuation of the McDonald Institute is unclear at this time. The subatomic physics envelope does not have the capacity to fund what dropped off when the CFREF funding ended.

Also noteworthy is that within the Canadian research environment there are various resources, such as subsidized technical shops, that can be accessed through the leveraging of institutional and grantee resources. Moreover, the cost sharing of resources from grantees on different research projects within an institution, or even from different institutions, is common and the use of the MRS centres facilitate and encourage these efficiencies.

Canadian subatomic physics research institutes

TRIUMF, Canada's particle accelerator centre, is funded via a separate mechanism. TRIUMF was incorporated in 2021 and at the time of writing of this document is owned by 21 Canadian universities. The main source of TRIUMF's ongoing operations funding is $267.3M in core operating funds plus $25M for infrastructure projects over five years (2020-25) from the Government of Canada administered through the National Research Council of Canada (NRC). Additional funds come indirectly from CFI (through Canadian universities), and capital funds come from the province of British Columbia including for the construction of buildings. In addition to its extensive on-site research programs, TRIUMF is a vital national support centre for all types of subatomic physics research, including detector construction and testing facilities. The individual CFI awards are now being used to build unique research infrastructure that TRIUMF is unable to support through its NRC funding. A number of TRIUMF research scientists have academic appointments at partnering universities, some of which are jointly funded, and supervise graduate students from the universities with which they are affiliated. Note that in the table in the

Appendix, students listed under TRIUMF are also listed by the universities where they are registered as TRIUMF is not a degree granting institution. .

SNOLAB, Canada's underground physics laboratory, is located two kilometres below the earth's surface in the Vale Creighton nickel mine near Sudbury Ontario. SNOLAB operations are currently funded through CFI and the Province of Ontario with in-kind support from Vale. Inc. The construction of the surface facilities and underground laboratories of SNOLAB were funded by the International Joint Venture program of the CFI, the Ontario Innovation Trust, the Northern Ontario Heritage Fund Corporation and FedNor. SNOLAB research scientists can have academic appointments at partnering universities and supervise graduate students from across the country. SNOLAB research scientists receive NSERC grants that support the training of our vibrant research community and next generation of innovators.

Perimeter Institute (PI) is an independent, resident-based research institute devoted to foundational issues in theoretical physics located in facilities in Waterloo, Ontario. PI receives public funding from both the Ontario Government and Government of Canada, as well as from CFI. Private funds come from a variety of individuals, corporations, and foundations – including BMO Financial Group, SunLife Financial and others. Researchers are also supported by grants from a variety of sources, including NSERC, Templeton Foundation and the Simons Foundation. In particular, PhD students at Perimeter are supported through NSERC Discovery Grants held by PI faculty through their adjunct status at nearby partner universities. In addition to its full-time faculty members, PI has Associate Faculty members who are regular faculty members at partnering Canadian universities and are also employed part-time at PI. PI offers a course-based Master's program, Perimeter Scholars International, through which students receive an M.Sc. from the University of Waterloo. PI faculty supervise Ph.D. students who receive their degree from the partnering university where their supervisor has an affiliation. Note that in the table in the appendix, students listed under Perimeter Institute may also be listed by the universities where they are registered.

The subatomic theory community is further supported by smaller institutes such as the University of Alberta Theoretical Physics Institute (TPI) and the Winnipeg Institute for Theoretical Physics (WITP). These serve as regional hubs for the provinces of Alberta and Manitoba respectively, and connect these provinces with larger organizations such as the Perimeter Institute. Funding for the research at these institutes is primarily through NSERC SAP Discovery Grants, which provide a vital role in supporting theory effort, where they are predominantly used to fund HQP; the capacity for sub-atomic theory HQP is presently underutilized, being limited only by the available funding. Operating funds for these Institutes are typically provided by University administrations, e.g. WITP receives financial support from Brandon University, the University of Winnipeg, and the University of Manitoba.

The Canadian nuclear and particle physics communities are self-organized into two institutes, the CINP and IPP, which are federally-incorporated non-profit corporations. Both institutes are supported by a combination of NSERC MRS funds and internal funds provided by their institutional members. The IPP and CINP provide representation of their respective research communities to various bodies, such as the Canadian Subatomic Physics Long Range Planning Committee, ICFA and NuPECC, and enhance university-based theoretical and experimental subatomic physics research in Canada. The IPP has the additional role of coordinating the participation of Canadians in international particle physics

collaborations, and employs Research Scientists who hold academic appointments at IPP Institutional Member universities and who can be located at an IPP university or at a laboratory, in Canada or abroad. IPP Research Scientists hold NSERC grants and supervise undergraduate and both M.Sc. and Ph.D. students who receive their degrees through their affiliated university. IPP also operates and partially funds a Summer Fellowship program for undergraduate students, which has them work with a Canadian research team in May and June before placing them at CERN for July and August as part of CERN's Summer Student Programme.The Early Career Theory Fellowship was launched by IPP in 2019 to connect Canadian postdocs with foreign research groups. CINP has run a summer undergraduate research scholarship program since 2014, which has been very successful and expanded since 2020. This highly competitive program is open to both domestic and international students enrolled in Canadian universities (unlike the NSERC USRA). An important component of this program is the optional Travel Award, which allows the student to work at a lab or with a second collaborator for an extended period. In 2021, CINP launched the Graduate Fellowship program, which is intended to attract or retain very gifted PhD candidates to conduct nuclear physics research in Canada. This program is in its initial stages, and it is hoped funds can be found to significantly increase the value and number of fellowships in future years. The CINP does not presently employ any Research Scientists, as NSERC has indicated that any personnel so-hired would not be eligible to apply for grants.

The Digital Research Alliance of Canada (Alliance) was established by the federal ministry of Innovation, Science and Economic Development Canada (ISED) to provide Canadian scientists and scholars with the digital infrastructure needed to conduct innovative and world-leading research. The Alliance replaced Compute Canada in 2018, an organization that previously managed computing facilities across Canada. ISED also funds CANARIE which provides the overall Canadian research community with high-speed network connectivity between research institutions and the Compute Canada computing centres.

The subatomic physics community uses computing resources for the storage, analysis and reconstruction of data, production of simulated data samples, and theoretical calculations. The primary source of computing resources and support is obtained from the Alliance via a competitive resources allocation process based on scientific merit. These resources are shared and located at four national computing centres at the universities of Victoria, Simon Fraser, Waterloo and Toronto. These centres provide resources for the ATLAS Tier-2 facilities as well as resources for the entire subatomic physics community in Canada. In addition, ATLAS-Canada operates a Tier-1 centre in the SFU data centre that is co-managed with TRIUMF. CANARIE provides a dedicated link between the Tier-1 and CERN, as well as providing high-speed connections from the Alliance centres to the subatomic physics centres around the world. HEPNET is responsible for national and international network connectivity for the Canadian subatomic physics community. HEPNET was established in 1990 by the Institute of Particle Physics (IPP) and funded by NSERC as a national resource. HEPNET has been funded by NSERC since its inception.

Canadian M.Sc. and Ph.D. programs

One of the unique aspects of the training of physics graduate students in Canada is the structure of the Master of Science (M.Sc.) degree program. In Canada, the completion of the M.Sc. degree in physics in most institutions requires the production of a substantial (~100 pages) thesis on original research, as well as the completion of a required number of graduate level physics courses. In many institutions, an oral defense of the M.Sc. thesis is required. It normally takes 2-3 years to complete a M.Sc. degree, with this

time divided about 1/3 on coursework and 2/3 on research under the close supervision of the supervisor. Subatomic physics M.Sc. students are exposed to a large number of research techniques, but not to the depth or level of research independence expected of a Ph.D. student. Some M.Sc. students have a desire to enter industry in the early stages of their career, and may have little interest in an academic career, and therefore begin their M.Sc. with no intention of continuing towards a Ph.D.

The successful completion of the Ph.D. degree requires a significantly greater level of research depth and independence. Ph.D. students are required to take additional graduate courses, complete a comprehensive exam, and orally defend a 100-200 page thesis. Students performing particularly well in their M.Sc. studies may have the opportunity to transfer directly to the Ph.D. program after their first year of Master's studies. Other students may elect to complete the M.Sc. first and then apply to the Ph.D. program. In some universities, it is possible for an exceptionally strong student to directly enter the Ph.D. program without having an M.Sc. In most Canadian universities, if a student enters a Ph.D. program without an M.Sc., either via direct entry or transfer, it is not possible for the student to later receive an M.Sc. degree should problems arise in the course of their Ph.D. studies. The typical graduate student spends 3-5 years in the Ph.D. program, in addition to the time spent in the M.Sc. program.

As alluded to above, subatomic physics graduate students at Canadian universities usually take graduate classes and do research work in a concurrent manner from an early stage of their graduate studies. Typically, both M.Sc. and Ph.D. students also have Teaching Assistantship (TA) duties for four or eight months of the year. This differs from some other countries, where the physics graduate student spends several years exclusively working on graduate classes and passes a qualifying exam before transitioning 100% to research. During the full duration of the M.Sc. and Ph.D. degrees, subatomic physics students are normally supported by a combination of TA funds, Research Assistantship funds from their supervisor's NSERC grants, and scholarships. Note, however, that in some institutions TA funds are not available to all international students and the difference is made up from the supervisor's NSERC research grant. Subatomic physics students performing research at offshore labs typically try to complete their courses in a manner that enables them to move to the labs for extended periods of time. When they move to the labs, they no longer receive TA funds and the funding difference is made up from the supervisor's NSERC research grant. When students are posted at a lab such as CERN, there can be a significant difference in the cost-of-living as compared to their home city, and a Cost Of Living Adjustment (COLA) must be provided from the grant. Even within Canada, some cities have particularly expensive housing, and where funds allow, some supervisors provide a cost of living supplement, such as when stationing students at TRIUMF for an extended period. Most Canadian universities and/or physics departments have a minimum level of funding required for all graduate students, and the supervisor must then fund what student requires to reach the minimum funding level, after all TA and scholarships are accounted for. For example the NSERC PGS scholarship for Masters students is only $17,500/year and the PhD NSERC PGS is only $21,000 per year, which is typically much less than the minimum required funding at most Canadian universities, so even scholarship students require funding from their supervisors' NSERC grants or TAs. More information on these support levels are given in the table in the Appendix to this document.

Regional differences in the training of Highly Qualified Personnel (HQP)

Canada is a sparsely populated country of vast geographic extent. As a result of this geography, and the fact that education is a provincial jurisdiction, it is not surprising that a number of regional variations in

physics HQP training have developed. The university system is primarily publicly funded through the provinces, with tuition fees varying considerably from province to province. Some provincial governments, e.g. Ontario and Quebec, operate graduate scholarship programs, but others do not. Tuition fees and other academic costs cannot be paid directly from the NSERC grant of the supervisor, but rather is paid by the students from the support they receive from research grants, teaching and any scholarships that they might hold. The universities in Quebec, Ontario, Saskatchewan, Alberta and B.C. follow a fairly traditional model, with most of the research performed at the larger, research-intensive Ph.D. granting universities. Quebec is distinguished with a significantly lower tuition rate for Quebec students than the rest of the country. Tuition fees in the other provinces are more similar, with Alberta being the lowest and Ontario the highest ($4,733/year UofA and $6,390/year UofT, both for domestic students). In all provinces, the cost of supporting a student from the supervisor's grant is two times less expensive than the cost of hiring a postdoc.

HQP training in subatomic physics also involves undergraduates extensively, especially at primarily undergraduate institutions. Universities in Atlantic Canada are a prime example of the role of undergraduates in NSERC-funded research. Relative to its population, the Atlantic region has a very large number of small, primarily undergraduate universities and a much smaller number of Ph.D. granting institutions. These primarily undergraduate universities attract students from across Canada, many of them very good students. As part of their B.Sc. Honours project requirements, they take part in the research of physics faculty members. In addition to their contributions to NSERC-funded research, the students graduating from these undergraduate research programs often go on to become subatomic graduate students across the country and therefore have a broad impact on HQP training in Canada.

To further illustrate the regional differences in HQP-training, we also profile the universities in the province of Manitoba. The University of Manitoba (UofM) is the only Ph.D.-granting institution, and the other universities in that province are all primarily undergraduate. Active researchers at the universities of Winnipeg and Brandon hold adjunct faculty status at the UofM and as such can directly supervise M.Sc. and Ph.D. students. Their graduate students register and take their classes through the UofM, but spend significant time at the campuses of their supervisors.

A sense of the institutional and regional differences and similarities can be obtained from the table in the Appendix. Although the table and other information provided in this document provide information about the various institutions engaged in subatomic physics in Canada, in order to fully understand the overall research environment and the context in which the research is conducted, a site-visit to the various institutions is required.

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Appendix:

Table of information provided by various Canadian universities in geographic order from east to west

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
Memorial – Grenfell campus (Corner Brook, NL)	2 Theory	Atlantic Computational Excellence Network (ACEnet)	Low energy QCD, precision PV tests of Standard Model, Searches of physics beyond SM. Collaborative projects with JLab, Mainz, Dubna. (1 PhD, 1 MSc)	Ph.D. program available through St. John's campus of Memorial. Supervisor contributes $8k-19k (NSERC) grant
St. Francis Xavier (Antigonish, NS)	1 Exp	One room lab space (newly developed) & Atlantic Computational Excellence Network (ACEnet)	Belle II, BaBar	Undergraduate institution
Saint Mary's (Halifax, NS)	3 Exp	Subatomic physics has been listed in SMU's strategic research plan. 2 rooms lab space, Linux servers, Atlantic Computational Excellence Network (ACEnet)	Leads CFI-funded IRIS and CANREB facilities at TRIUMF. Offshore research at GSI, Mainz (Germany); JLab, MSU (USA), RIKEN (Japan) (3 PDF, 3 PhD, 1 MSc)	$28-32k
Acadia (Wolfville, NS)	1 Theory	Designated room for undergraduate students working in subatomic theory	Non-perturbative QCD effects in rare B decays, light-front holographic QCD, hadron structure	Undergraduate institution
Mount Allison (Sackville, NB)	1 Exp, 1 Theory, 1 adjunct Theory (Acadia)	1 detector lab, computers	Experimental research at at JLab and HIGS (USA) and a member of EIC-Canada. Theory: non-perturbative computation of rare B decay observables for LHCb	Undergraduate institution
McGill (Montréal, QC)	IPP scientist:1, HEP exp: 4, HEP theory: 6, NP theory: 2, NP exp: 2	ATLAS lab for characterization of sTGC thin gap muon chambers and development of liquid-argon electronics, Photon detector laboratory with test equipment, nEXO lab for photon detector development, Machine shop	Particle and Nuclear Theory, ATLAS, Belle II, CALICE, TRIUMF collinear laser spect, CPT, VERITAS, HELIX, TITAN, EXO. Total SAP: (11.5 RA/PDF, 37 PhD, 24 MSc)	$25.5k from NSERC grant, $6k TA. Departmental merit based scholarships available. Students working at national labs receive cost-of-living allowances.

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
Concordia (Montréal, QC)	1 Theory	Unix server	Theory: part-time RA, 3PhD, 1 MSc	$8-10K from NSERC grant; $7.5k TA; $5k scholarship, International Fee Remission, additional performance-based scholarships ($3K-$10.8K); Total = $22.5k
Université de Montréal (Montréal, QC)	5 Exp, 2 Theory	500m^2; class 10 000 clean room with class 1000 section;300m^2 detector construction space; local computing. In house Tandem Van de Graaff facility, proton and heavy ion test beams for detector calibrations; irradiation facility to study radiation hardness of materials and detector components; low energy (keV) mono-energetic neutron facility for detector calibrations; machine shops with 3 NC lathe/milling machines, 2 technicians; MRS Supported Groupe Technologique for particle physics instrumentation R&D, prototyping and development of detector read-out modules, support of SAP projects	Experimental Particle Physics Program: ATLAS, PICO, SuperCDMS (2 PDF, 6 PhD, 4 MSc); Theory (1 PDF, 2 PhD, 3 MSc)	$17.6k (MSc) and $20.1k (PhD) from NSERC grant; $2k TA; $1.5k scholarship; Total=$21.1k (MSc) and $23.6k (PhD). Performance-based scholarship also available (10k$)
Carleton University (Ottawa, ON)	11 Exp, 6 Theory (Note:1 Exp supported via CPARC CFREF)	Half of large research wing devoted to SAP Research; Large high bay assembly area for detector assembly and testing; ATLAS CFI funded lab for muon chambers assembly (Phase1 NSW upgrade); SNOLAB CFI cryogenic facility for development of noble liquid detectors and optical readout; ATLAS CFI award for chip and sensor testing (Phase2 ITk upgrade) - Access to the Carleton University Microfab Facility (CUMFF) for sensor R&D and access to the	Particle Physics Experimental Program: ATLAS, EXO, DEAP, HyperK (13 PDF, 18 PhD, 9 MSc); Theory (2 PDF, 4 PhD, 3 MSc)	$20k from NSERC grant for PhD ($18k for MSc), $11.8k TA, ~$5k scholarship; total = $35k ($31k for MSc)

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
		Carleton University nanofabrication facility (FANSSI) for sensor QC; Computer farm with ~400 cores + > 400 TB storage for HEP with dedicated computer room with stand-alone HVAC system; Access to precision machine shop at the Science Technology Centre; NSERC MRS personnel (design, electronics, machining) and detector facilities available to community; CFREF and CPARC technical team. Partnership with NRC fabrication facility for wide bandgap material R&D (GaN). Participation to DRD1 and DRD3.		
Queen's University (Kingston, ON)	10 Exp, 2 Theory Includes 1 IPP RS	Two clean rooms, Four general laboratories; optical cryostat, CDMS test cryostat, bubble chamber, optical spectrometers for scintillation studies, dark rooms for PMT testing, low background counting facilities (radon emanation); local computing HPVCL on campus; three admin assistants, an engineer, and 4 technical staff members supporting the SNOLAB effort. Through CPARC: 5 additional administrative staff and are starting to hire technical staff. (one so far) Through the MRS: 3 technical staff. 3 non-CPARC admin. supporting the group	Current Particle Physics Program: DEAP-3600, SNO+, PICO, NEWS-G, SuperCDMS and CUTE (test facility), SBC, KDK (at Oak Ridge), IceCube (6 PDF, 9 PhD, 13 MSc)	$12k from NSERC grant, $8k TA, $6k scholarship; Total=$26k

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SNOLAB (Sudbury, ON)	15 Exp research scientists (adjunct professors at Laurentian and other Universities)	4,900 m^2 underground clean room research laboratory with associated services and infrastructure including lay down areas, personnel facilities and material handling. 3,300 m^2 surface facility including clean room laboratories, meeting rooms, control rooms, office space, warehouse, laydown areas and material handling. Low background counting facilities. Scientific, technical and logistics support for experiments	SNO+, DEAP-3600, DarkSide, Argo, PICO, HALO, Scintillating Bubble Chamber, DAMIC, SENSEI, EXO/nEXO, SNO+, SuperCDMS, CUTE	
Toronto (ON)	10 Exp, 4 Theory (includes 2 IPP RS)	1 prototyping lab (50m2); 1 Construction Lab (100m2); 1 clean room (100m2); 1 storage room (40m2); 1 general laboratory space (140 m^2 in 4 rooms) Access to computing via SciNet and NDRIO/Alliance with local workstations; Access to machine shop, electronics design/fabricaion and graphics services; 2 technicians (supported on CFI) Departmental Physics Computing Services is an excellent resource for support, software and hardware advice	Particle Physics Experimental Program: ATLAS, SuperCDMS, Mathusla, DUNE, T2K, SRF (8 PDF; 30 PhD+ MSc); Theory (1 PDF, 10 PhD+MSc)	$21k from NSERC grant, $7k TA, $7-12k scholarship; Total=$35-40k Note: HEP students at the University of Toronto are admitted to both direct-entry PhD and MSc (usually followed by PhD). First year grad students usually do 1-year M.Sc. with required courses and a research report.

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Toronto (ON)	10 Exp, 4 Theory (includes 2 IPP RS)	1 prototyping lab (50m2); 1 Construction Lab (100m2); 1 clean room (100m2); 1 storage room (40m2); 1 general laboratory space (140 m^2 in 4 rooms) Access to computing via SciNet and NDRIO/Alliance with local workstations; Access to machine shop, electronics design/fabrication and graphics services; 2 technicians (supported on CFI) Departmental Physics Computing Services is an excellent resource for support, software and hardware advice	Particle Physics Experimental Program: ATLAS, SuperCDMS, Mathusla, DUNE, T2K, SRF (8 PDF; 30 PhD+ MSc); Theory (1 PDF, 10 PhD+MSc)	$21k from NSERC grant, $7k TA, $7-12k scholarship; Total=$35-40k Note: HEP students at the University of Toronto are admitted to both direct-entry PhD and MSc (usually followed by PhD). First year grad students usually do 1-year M.Sc. with required courses and a research report.
York (Toronto, ON)	3 Exp, 4 Theory	Two labs for small construction projects; 320 compute ores, machine shop	ATLAS, T2K, ALPHA, DUNE. Experiment (2 PDF, 4 PhD, 3 MSc) Theory (2 PDF, 2 MSc)	$9k-$15k from NSERC grant, $11k TA, $4k scholarship; Total=$24-$30k
McMaster (Hamilton, ON)	1 Exp (Nuclear)	CFI-funded detector lab, local computing and lab space available	Radioactive beam experiments at TRIUMF and Argonne (2 PhD)	Supervisor contributes $13.5k, univ TA and scholarship brings total to $27.5k

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
Guelph (ON)	2 Exp 2 Theory	Laboratory for detector development projects Extensive Machine Shop Contributed 700-core CFI-funded cluster to SHARCNET	Led the NSERC funded TIGRESS gamma-ray spectrometer, the CFI-funded DESCANT neutron detector array and GRIFFIN gamma-ray spectrometer. Offshore experiments at Argonne (USA), RIKEN (Japan), Munich(Germany). Theoretical studies of nuclear forces, ab-initio nuclear structure calculations, nuclear astrophysics. Experiment: (1 PDF,1 Research Assoc, 6 Ph.D, 4 M.Sc.) Theory: (1 PDF, 5 PhD, 4 MSc)	$17k from NSERC grant, $13k TA, Total=$30k
Perimeter Institute (Waterloo, ON)	11 PI faculty (all theory)	Office and seminar space; local computing resources	Particle theory, quantum fields and strings, quantum gravity; 6 postdocs and 16 graduate students at or associated with PI. See discussion on p.3 re grad student supervision.	Resident PI students have most support from NSERC grant, (no TA as there is no undergraduate program at PI), plus a scholarship
Western Ontario (London, ON)	2 Theory (1 cross-appointe d with PI)	Computing resources: SHARCNET	Theory (1 PDF, 3 PhD)	$18k from NSERC grant (note: 1 international student comes at that level of funding, additional students come progressively more expensive), $5k TA, $4k scholarship; Total=$27k
Manitoba (Winnipeg, MB)	5 Exp, 2 Theory, Additional research-active Emeriti (1 exp.) and 8 Adjuncts	Computer cluster, Clean room, 3 CFI-funded detector labs, 3D printers (plastic, carbon-fiber), Various subtractive machines (CNC, laser metal fusion 3D printer, etc.), Low energy proton source detector test facility, Access to nano-fabrication lab, New automated chip placement and bonding	Cold neutrons at SNS and NIST ultra-cold neutrons at TRIUMF; MOLLER at JLab; P2 at MESA/Mainz; francium atomic parity violation and TITAN ion trapping at TRIUMF/ISAC, Electron-Ion Collider, Belle II and Chiral Belle at SuperKEKB. 35 graduate students enrolled in SAP, Exp: 29, Theory: 6.	PhD students $24k, MSc students $22.65k from grant, additional support available, plus COLA and TA-buyout for offsite students

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
Winnipeg (MB)	3 Exp + 1 adjunct from TRIUMF; 2 Theory	Four labs, including clean room, gas systems, detectors, DAQ electronics, lasers, magnetometers, magnetic shielding, neutron guide-coating facility, neutrino detector development equipment, underwater detector calibration facility, theory lab, NSERC MRS resource (S. Ahmed)	TUCAN EDM experiment, neutrinos (Super-K, Hyper-K and the IWCD, WCTE at CERN), Nab experiment at SNS, electron scattering, particle theory, string theory, astroparticle theory; (5 PDF; 10 PhD, and 5 MSc; most of the students are at Manitoba, two are at McGill, and one is in the Applied Computer Science MSc program at UW)	Supervisor typically contributes $24k; total funding as at UManitoba
Brandon (MB)	1 Theory		Numerical and analytic studies in non-equilibrium field theory, non-perturbative field theory and transport theory (2 PhD, 1MSc at Manitoba; co-supervised with Winnipeg)	Supervisor typically contributes $19k; total funding as at UManitoba
Regina (SK)	Nuclear Physics: 3 Exp +1 emeritus + 3 adjunct from JLab; ParticlePhysics : 2 Exp + 1 adjunct from BCIT; 3 Theory	Three labs including detector construction and testing space, two CPU clusters; 3D printer, access to electronic and machine shops at subsidized rate. Non-SAP faculty in related areas: 1 nuclear imaging, 1 neutron imaging search underway	GlueX and Meson form factors at JLab; Electron-Ion Collider; Nuclear structure and nuclear astrophysics at ISAC, NSCL/FRIB (USA) & GANIL (France); T2K. Nuclear Physics Expt: JLab (2 PDF, 6 PhD, 1 MSc supported via a mix of NSERC and local funds), EIC (1 PhD, 1 MSc). Particle Physics Expt: HyperK, EMPHATIC, WCTE, IWCD, Halo-1kT(4 PhD, 1 MSc) supported by NSERC, McDonald Inst, CFI, RTI; Theory (1 MSc, 1 visiting scholar) supported by NSERC, EduCan Emerging Leaders Prog	Nuclear Physics: Supervisor contributes up to $28.6k, to this add: TA=$3-5k and scholarships from Fac.Grad.Studies. Total=$23-34k. Particle Physics: Supervisor contributes $27k. To these add: TAs = $5k-$10K and/or scholarships from Fac.Grad.Studies. Total=$27-34k (amount committed to the student)

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
Saskatchewan (Saskatoon, SK)	1 Exp, 2 Theory	Faculty are members of the Subatomic Physics Institute (SPIN). 2 detector testing rooms. Collaboration with Canadian Light Source on campus has been helpful on many occasions. non-SAP faculty in related areas; 1 theory cosmology, 1 accelerator physics, 1 applied nuclear	Experiments at Triangle Universities Nuclear Lab (USA). Particle physics theory and phenomenology. (Exp: 2 MSc. Theory: 1PDF, 3 PhD, MSc). Theory research program includes: QCD sum rules and hadronic physics; Dark matter and particle astrophysics; Nuclear Compton scattering and photonuclear reactions	Supervisor contributes $10.5k, TA+ scholarship: $10.5k. Total: $21k
Alberta (Edmonton, AB)	7 Exp, 3 Theory	8 labs (Radon free shop, Low background counting, IceCube Lab, Radioactive work lab, X-Ray lab, Assembly Lab, Detector lab, Clean Assembly Lab); Electronics shop, Machine shop, CPP+ personnel available to the community (engineer, detector technician, electronics technician); ATLAS Tier-3 cluster, IceCube GPU Cluster	Particle Physics Experimental Program: ATLAS, DEAP-3600, Darkside, IceCube, MoEDAL, NEWS-G, PICO, P-ONE, SBC, SNO+.	MSc students: $31.1k from all sources. PhD students: $32.8k from all sources. Increasing 3% each year of seniority.
Calgary (AB)	2 Exp, 1 Theory	2 research labs; Clean Room for trace metal sample preparation; 3 magnetic sector mass spectrometers (two thermal ionization sources, one inductively coupled plasma source); Machine shop	Experimental Program: high precision mass measurements, double beta decay, and investigation of nuclear isomers using TITAN; ALPHA antihydrogen at CERN. Theory: R-process nucleosynthesis (1 RA, 1 PhD, 1 MSc.); Hadronic-to-quark-matter phase transition (1 RA, 1 PhD)	$11.8k from NSERC grant, $13.2k from TA, Total: $25k

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
Simon Fraser (Burnaby, BC)	Particle Physics: 4 Exp Nuclear Physics & Chemistry: 2 Exp, 1 Theory	2 particle labs (ATLAS ITk & P-ONE) Particle: ISO-6 clean room & CFI infrastructure for ATLAS ITk upgrade. ITk sensor probing, module production and ITk petal assembly. Clean area, P-ONE calibration system development and module production Computation: ATLAS Tier-1 Data Centre moved from TRIUMF to SFU Compute Canada facility at SFU in 2018. Also hosting ATLAS Tier-2 and small Tier-3. Nuclear: D/T neutron generator, 8pi HpGe/BGO spectrometer, segmented HpGe counting station, radiochemistry lab, alpha spectrometer, XRFIN system Local machine shop and a major nano/micro fabrication and characterization facility (4D labs).	ATLAS (4 PDF, 7 graduate students) ATLAS ITk (2 PDF, several, engineers and technicians) P-ONE (2 PDF, 2 graduate students) Nuclear: In-trap decay spectroscopy using TITAN; gamma-ray and decay spectroscopy @ ISAC-1,2; integrated plunger program using neutron activation & spectroscopy	Particle: $21k for PhD students from NSERC grant, + TA and scholarships; Total=$34.5k NSERC, $6.5k TA, $7k SFU grad fellowship/support. Note: Assuming 1 term of TA-ship per year, and good grades a PhD student must receive about $17k from the NSERC grant. If their grades dip below a certain level it is $20k. If they do not TA, it is $26.5k.
Northern British Columbia (Prince George, BC)	2 Exp (including one emeritus)	One lab room for training: radioactive sources, solid-state and scintillation detectors, and data acquisition system	Ultra-cold neutrons at TRIUMF; Qweak/Moller at Jlab; Dragon at TRIUMF-ISAC	Mostly undergraduate; some MSc students at $5k/yr from NSERC

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
British Columbia (Vancouver, BC)	SAP: 8 Exp, 6 Theory (Includes 1 IPP RS) (does not include those reported by TRIUMF)	Use of TRIUMF facilities; Electronics shop (phas.ubc.ca/elab) Machine shop: (phas.ubc.ca/machine-shop) Student Machine shop: the above are staffed by 18 engineers/engineering technicians	ATLAS, Belle II, BaBar, TREK at JPARC, CAST at CERN, NA62 at CERN, SuperCDMS, DarkLight at JLab, and Theory group.	~ $10.5k from TA, ~$15k from supervisor-for non-scholarship students Students may have supervisors buy out 1 or 2 of their 4 TA units per year for 1 or 2 of their years, so for PhD students in their final 1-2 yrs, typically $5k from TA, $20k from supervisor. Top-ups for Scholarship students: for NSERC scholarship holders: $8,700 for CGSM, $6,000 for PGSD, $0 for CGSD for UBC internal 4 year grad scholarship holders: $8000 ALL PhD students get a $5,198 full tuition award for 1st 4 years of PhD. MSc students do not get a tuition award. Scholarship students do not receive RAs until their scholarship runs out. Grad funding to the student total package ranges from $26,133 for non-scholarship MSc students, to $40,119 for CGSD awardees as seen in: https://phas.ubc.ca/graduate-program-financial-support

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
TRIUMF-Accelerator Physics (Vancouver, BC)	13 staff	TRIUMF accelerator facilities, SRF testing facilities, Ion source test stands, target laboratories, beta-NMR and MuSR facilities	Research Program: SRF and cyclotron development, target and ion-source development, wakefield acceleration (5 PDF, 13 PhD, 2MSc, 4 Engineers in Training (EIT)). See discussion on p.3 re grad student supervision.	TRIUMF-administered grads (GSRAs) receive minimum total compensation of $30K/$25K for PhDs/Masters, net of tuition, student fee, and health care costs. Other grads placed at TRIUMF are eligible for sabbatical-like support during their residency. For more information: www.triumf.ca/Academic Programs/Graduate Student and Post-Doc Program/TRIUMF Resident Graduate Student Support
TRIUMF – Nuclear Physics (Vancouver, BC)	11 Exp, 3 Theory	TRIUMF facilities: DRAGON, TUDA, TIGRESS, GRIFFIN, GPS, DESCANT, TRINAT, TITAN, FRANCIUM, IRIS, EMMA, RadMolecules (new, in progress), TRIUMF Storage Ring (new, planned)	Nuclear Physics Program: (11 Exp, 3 Theory faculty) paid from NSERC grants in Sept 2022-Aug 2023 ~30 Undergrads/ year, ~8 MSc/MPhys, ~16 PhD students and ~20 postdocs/ research associates. (These are only those supervised by TRIUMF faculty, does not include students involved in TRIUMF program but supervised by external faculty).	See above.

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support
TRIUMF – Particle Physics (Vancouver, BC)	14 Exp, 2 Theory	TRIUMF facilities: TUCAN (UCN) facility, detector facilities, ATLAS upgrade facilities; ATLAS Tier-1 and T2K Tier-1 (hosted at SFU), M11 test beam (e, μ,π), PMT test facility, Photon Sensing Facility. Proton Irradiation Facility (PIF) and Neutron Irradiation Facility (NIF)	Particle Physics Experimental Program: ATLAS, T2K/Hyper-K, TUCAN, ALPHA, nEXO, DEAP, HALO, Muon g-2, NA62, PIENU (20 PDF, 12 PhD, 11 MSc); Theory (3 PDF, 1 PhD, 4 MSc). See discussion on p.3 re grad student supervision.	See above.
Victoria (BC)	9 Exp, 3 Theory Includes 2 IPP RS, plus 19 TRIUMF adjuncts	Large shared lab space; clean room; machine shop; electronics shop; local computing cluster plus access to Alliance grid; 2 Computing Research Associates; detector physicist with expertise in hardware, FPGA programming and GEANT available to the community if MRS is approved	Particle Physics Experimental Program: ATLAS, T2K, HyperK, Belle II, BaBar, Mathusla, ALTAIR Accelerator/ARIEL/ILC (6 PDF, 33 PhD and MSc); Theory (2 PDF, 8 PhD and MSc)	Department Minimum: Domestic PhD: $28.7k (from NSERC grant+ $3.0k TA, Grad award $3.5k) Domestic MSc: $26.8k (from NSERC grant+ $3.0k TA+Grad award $3k$23.8k) International: + 1.5k tuition top-up.