

# The Context and Environment of Subatomic Physics Research at Canadian Universities

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In June 2014, Samir Boughaba, NSERC's Research Grants Team Leader for Physics, Astronomy and Computer Science, requested that the CINP and IPP jointly prepare a short document on "the context of Canadian subatomic physics research" for distribution to SAPES shortly before the fall policy meeting, with the opportunity for the committee to ask questions on it. This was in response to our request (echoed annually also in the SAPES Chair's report) to reinstate the discontinued SAPES fall site visits, given their value to both international and domestic members of the committee in understanding the Canadian research context and environment. We do not believe that this brief can even begin to provide the depth of knowledge that university site visits could provide to SAPES, but it is our hope that this document can at least provide an overview of some of the most important information. In order to understand the overall research environment and the context in which the research is conducted, including 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, a site-visit is required.

## **Roles of Canadian research funding agencies in support of subatomic physics**

The decisions that you make as SAPES member are of crucial importance to the Canadian subatomic physics research enterprise, as the NSERC Subatomic Physics Envelope is the only major means of operating funds support for Canadian subatomic experiment and theory research. 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. Subatomic physicists also rely on the SAP-RTI program to provide funding for equipment, and historically, the RTI funds were used to build experiments and provide the Canadian hardware contributions to the experiments of large international collaborations. 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.

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 resource allocation boards. At the University of Alberta, the CPP+ MRS Centre is available to provide help with NSERC-funded projects. The MRS facilities at Carleton, Queen's and Victoria 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.

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 is uncertain and the process for decision-making on a grant is independent of NSERC SAPES. 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 Compute Canada, which operates a variety of national high performance computing centers 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, Laurentian, Queen's, York, Guelph, Winnipeg, Alberta, and UBC.

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 Fund awards. Following the 2<sup>nd</sup> 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 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. CPARC is primarily involved in and supporting projects based at SNOLAB, or potentially based there: direct detection of dark matter projects, including: PICO, NEWS, SuperCDMS and DEAP-3600, and neutrino physics projects such as: SNO+, nEXO and Majorana. CPARC plans to use the funds to create 41 positions for researchers, engineers, designers and technicians, as well as provide opportunities for about 18 postdoctoral fellows and 40 graduate students on an annual basis. Queen's University has committed to adding seven new faculty members – including two Tier II Canada Research Chairs – in support of CPARC. New faculty whose salaries are bridged by CFREF funds will be ineligible to apply for NSERC grants during the bridging period; their research is to be supported from CPARC and university funds during this period. However, many of the new faculty hires associated with CPARC will be regular positions that are fully funded from the outset by the universities and therefore are NSERC grant eligible. The next CFREF competition is expected to be launched in 2021-22. All eligible Canadian postsecondary institutions, including those successful in the two inaugural competitions, will be entitled to apply. CPARC is expected to apply for funds in that future competition.

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 national laboratory for particle and nuclear physics in Vancouver, is funded via a separate mechanism. The main source of TRIUMF's ongoing operations funding is \$267M over five years (2015-20) from the Government of Canada through the National Research Council of Canada (NRC). Additional funds come indirectly from CFI (through the consortium of Canadian universities operating TRIUMF), and capital funds come from the province of British Columbia. 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. 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 will also be listed by the universities where they are registered.

SNOLAB, Canada's underground physics laboratory, is located two kilometers below the earth's surface in the Vale Creighton nickel mine near Sudbury Ontario. SNOLAB has its operations currently funded 40% through the CFI Major Sciences Initiatives (MSI) program, with 40% from the Ontario MRI program and 20% from an in-kind contribution by Vale Inc. The construction of the surface facilities and underground laboratories of SNOLAB have been 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 the universities with which they are affiliated.

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, Templeton Foundation, SunLife Financial and others. Researchers are also supported by grants and awards from NSERC and Templeton. In addition to its full-time faculty members, PI has Associate Faculty members who are regular faculty members at a partnering Canadian universities and are also employed part-time at PI. PI offers a course-based Master's program 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.

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 NSERC 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 both M.Sc. and Ph.D. students who receive their degrees through their affiliated university. 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.

Compute Canada is an organization formed by the research community across Canada and is funded by CFI (and the corresponding provincial funding organizations) via the MSI program. The subatomic physics community uses computing resources for the analysis and reconstruction of data, production of simulated data samples, and theoretical calculations. The majority of the resources are owned and operated by Compute Canada, who is transitioning to four national computing centers located at the universities of Victoria, Simon Fraser, Waterloo and Toronto. Access to substantial resources is allocated, based on merit, by a resource allocation committee. Formerly, in addition to the Compute Canada facilities, there were the ATLAS Tier 1 computing centre at TRIUMF, and small local clusters at many institutions. The ATLAS Tier 1 centre at TRIUMF, as well as the ATLAS Tier 2 centres in Victoria, SFU, Toronto and McGill are transitioning to the new Compute Canada facilities. In particular, the ATLAS Tier 1 centre is transitioning to the Compute Canada facility at SFU in 2017-18. The computing centres are linked with a high-speed research network provided by CANARIE (funded by Industry Canada to provide a national research network and connections to the international

community). CANARIE provides the subatomic physics community with a dedicated link from TRIUMF to CERN, as well as high-speed connections from the Compute Canada centres. Apart from desk-top computers, which are purchased with NSERC Subatomic Physics Project, Team or Individual Discovery grants, small local clusters at several institutions and the former ATLAS Tier 1 as mentioned above, essentially all computing in Canada is now provided via Compute Canada.

### **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 classes. In many institutions, an oral defense of the M.Sc. thesis is required. It typically 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. Many 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 classes, 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 typically 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 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 typically supported by a combination of teaching assistantship funds, research assistantship funds from their supervisor's NSERC grants, and scholarships. 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. 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, 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 than the rest of the country. Tuition fees in the other provinces are more similar, with Alberta being the lowest and Ontario the highest. In all provinces, the cost of supporting a student from the supervisor's grant is two to three 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 being 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.

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**Appendix:**  
**Table of information provided by various**  
**Canadian universities in geographic order of east to west**



<b>Institution</b>	<b>No. funded SAP Faculty</b>	<b>Local facilities</b>	<b>SAP Research Programs</b>	<b>Typical Grad Student Support from Supervisor/yr</b> assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
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.
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)	Typical supervisor support \$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 Mainz (Germany). Theory: non-perturbative computation of rare B decay observables for LHCb.	Undergraduate institution
McGill Montréal, QC)	Particle Physics: 7 Exp, 6 Theory Nuclear Physics: 2 Exp, 3 Theory (includes 2 IPP RS)	ATLAS sTGC lab for characterization of thin gap chambers, Photon detector laboratory with test equipment nEXO lab for photon detector development, Machine shop	Particle and Nuclear Theory, ATLAS, Belle-II, CALICE, TRIUMF colinear laser spect, CPT, VERITAS, HELIX, TITAN, EXO. Total SAP: (11.5 RA/PDF, 37 PhD, 24 MSc)	\$18.2k from NSERC grant, \$4.8k TA, Departmental merit based scholarships available. Students working at national labs receive cost-of-living top-ups.
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

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support from Supervisor/yr assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
Université de Montréal (Montréal, QC)	7 Exp, 2 Theory	500m <sup>2</sup> ; class 10 000 clean room with class 1000 section;300m <sup>2</sup> 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 - High energy physics instrumentation R&D, prototyping and development of detector read-out modules, support of SAP projects	Experimental Particle Physics Program: ATLAS, Pico/PICASSO, Belle II (3 PDF, 6 PhD, 4 MSc); Theory (1 PDF, 2 PhD, 2 MSc)	\$15.6k (MSc) and \$18k (PhD) from NSERC grant; \$2k TA; \$1.5k scholarship; Total=\$19.1k (MSc) and \$21.5k (PhD). Performance-based scholarship also available (10k\$)
Carleton University (Ottawa, ON)	10 Exp, 5 Theory  (Note: one Experimentalist is 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); Computer farm with ~400 cores + > 400TB storage for HEP with dedicated computer room with stand alone HVAC system; Access to precision machine shop at the Science Technology Center; NSERC MRS personnel (design, electronics, machining) and detector facilities available to community; CFREF and CPARC technical team.	Particle Physics Experimental Program: ATLAS, EXO, DEAP, ILC (10 PDF, 10 PhD, 10 MSc); Theory (3 PDF, 7 PhD, 1 MSc)	\$16k from NSERC grant for PhD (\$12k for MSc), \$10.5k TA, ~\$5k scholarship; total = \$31.5k (\$27.5k for MSc)



Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support from Supervisor/yr assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
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 we have 3 technical staff 3 non-CPARC admin supporting the group.	Current Particle Physics Program: DEAP-3600, SNO+, PICO, NEWS-G, SuperCDMS and CUTE (the test facility), KDK (at Oak Ridge), Icecube  SNO+, Deap-3600, SuperCDMS, PICO/PICASSO(6 PDF, 9 PhD, 13 MSc)	\$12k from NSERC grant, \$8k TA, \$6k scholarship; Total=\$26k
Laurentian (Sudbury, ON)	6 Exp One is a CRC. One is supported by CPARC. One is an Emeritus Professor.	SNOLAB Lab on campus shared among the experiments, 4 rooms for computer, electronics and test work, 1 room for detector testing and storage, 2 chemistry labs, 2 half rooms for storage; also uses SNOLAB cleanroom space; 2 technical personnel (2 technicians and 0.25 admin CPARC support for the group)	EXO, HALO, PICO, SNO+ 3RA/Postdoc, 4 PhD, 5 MSc students Plus 1 RA/Postdoc, 1 student supported by CPARC in support of CPARC faculty	Average \$16k from NSERC grant for MSc, \$19k for PhD, \$8k TA for MSc, \$12k TA for PhD, \$1k university stipend (one-time); Note: international students do not all get a TA, difference is support from NSERC grant Total = \$25k for MSc, \$32k for PhD
SNOLAB (Sudbury, ON)	6 Exp research scientists (adjunct professors at Laurentian University)	4,900 m <sup>2</sup> underground clean room research laboratory with associated services and infrastructure including lay down areas, personnel facilities and material handling. 3,300 m <sup>2</sup> surface facility including clean room laboratories, meeting rooms, control rooms, office space, warehouse, laydown areas and material handling. Low background counting facilities. IT support including Gb/s networking and guested experiments. Scientific,	SNO+, DEAP-3600, PICO/PICASSO/COUPP-60, HALO, DAMIC, MiniCLEAN, SuperCDMS	

<b>Institution</b>	<b>No. funded SAP Faculty</b>	<b>Local facilities</b>	<b>SAP Research Programs</b>	<b>Typical Grad Student Support from Supervisor/yr</b> assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
Toronto (ON)	8 Exp, 4 Theory (includes 2 IPP RS)	technical and logistics support for experiments.  1 prototyping lab (50m2); 1 clean room (40m2) + 1 Construction Lab (100m2) + 1 dirty/storage room (20m2); Access to computing via SciNet(www.scinet.utoronto.ca.) Departmental Physics Computing Services does not provide CPUs, but is an excellent resource for software and hardware advice.	Particle Physics Experimental Program: ATLAS, T2K, SRF (4 PDF; 18 PhD; 4 MSc); Theory (3 PDF, 10 PhD, 3 MSc)	\$17k from NSERC grant, \$6k TA, \$9k scholarship; Total=\$32k Note: HEP students at the University of Toronto do not do Thesis M.Sc. but instead do 1 year M.Sc. which require 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	CFI-funded detector lab, local computing and lab space available.	radioactive beam experiments at TRIUMF and Argonne (2 PhD)	Supervisor contributes \$11.5k, univ TA and scholarship brings total to \$25.5k
Guelph (ON)	3 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. TRIUMF-ISAC and ISAC-II focus complemented by offshore experiments at Argonne (USA), RIKEN (Japan), Munich (Germany). Theoretical studies of nuclear forces, ab-initio nuclear structure calculations, nuclear astrophysics. Experiment: (5 PDF, 9 Ph.D, 7 M.Sc.) Theory: (1 PDF, 6 M.Sc.)	\$17k from NSERC grant, \$13k TA, Total=\$30k
Perimeter Institute (Waterloo, ON)	10 Theory (6 full-time; 4 associates; 1 emeritus)	Office and seminar space; local computing resources	Particle theory, quantum fields and strings; 15 PDF, 12 PhD, 10.5 MSc	\$23k from NSERC grant, no TA as there is no undergraduate program at PI, \$7k scholarship; Total=\$30k

<b>Institution</b>	<b>No. funded SAP Faculty</b>	<b>Local facilities</b>	<b>SAP Research Programs</b>	<b>Typical Grad Student Support from Supervisor/yr</b> assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
Western Ontario (London, ON)	2 Theory (1 cross-appointed with PI)	Computing resources: SHARCNET	Theory (1 PDF, 3 PhD)	\$18k from NSERC grant (with cap for international students: i.e. 1 international student comes at that level of funding, additional ones come progressively more expensive. ), \$5k TA, \$4k scholarship; Total=\$27k
Manitoba (Winnipeg, MB)	4 Exp with 1 search underway, 1 Theory, 4 additional research-active Emeriti (3 exp, 1 theory) and 6 Adjunct (5 exp, 1 theory)	2 CFI-funded detector labs on campus. Facilities include VME DAQ setups, local workstations and core server.	Canadian Penning Trap at Argonne; cold neutrons at SNS; ultra-cold neutrons at TRIUMF; Qweak/MOLLER at JLab; Parity Violation at MESA/Mainz; Atomic Parity Violation and TITAN at TRIUMF/ISAC. 25 students enrolled in SAP GS, at the UM, in total. Of these: 7 PhD and 9 Msc funded from UM, 4 Phd + 3 Msc funded from UW , 2 PhD funded from TRIUMF. 7 PDF/RA.	Supervisor typically contributes \$14.4k, univ TA and scholarship brings total to \$22.2k. Students working at national labs receive cost-of-living top-ups.
Winnipeg (MB)	4 Exp + 1 adjunct from TRIUMF; 1 Theory	Four labs, including clean room, gas systems, detectors, DAQ electronics, lasers, NMR equipment, SQUIDS, Xe polarizer, magnetometers, magnetic shielding	Neutron EDM search with Ultra-cold neutrons at TRIUMF, neutrinos, electron scattering, particle theory, string theory (6 PhD and 3 MSc at Manitoba)	See U.Manitoba line for financial information
Regina (SK)	Nuclear Physics: 3 Exp + 1 emeritus; Particle Physics: 1 Exp + 1 adjunct from TRIUMF, 1 Theory	Three labs including detector construction and testing space, two CPU clusters; access to electronic and machine shops at subsidized rate. non-SAP faculty in related area: 1 nuclear imaging.	GlueX and Meson Form Factors at JLab, Proton Polarizabilities at Mainz, Nuclear Structure at ISAC & Michigan, T2K. Nuclear Physics Expt: JLab (1 PDF, 4 PhD, 2 MSc, two Research Scientists supported via mix of NSERC and local funds). Particle Physics Expt: T2K (1 PDF, 1 PhD, 1 MSc)	Nuclear Physics: Supervisor contributes \$10-24k, Particle Physics: \$16.4k. To these add: TA=\$5k and scholarships from Fac.Grad.Studies. Total=\$23-34k.
Saskatchewan (Saskatoon, SK)	1 Exp, 2 Theory	Faculty are members Subatomic Physics Institute (SPIN). 2 detector testing rooms. Collaboration with Canadian	Experiments at Triangle Universities Nuclear Lab (USA). Particle physics theory and phenomenology. (Exp: 2 MSc.	Supervisor contributes \$10.5k, TA+ scholarship: \$10.5k. Total: \$21k

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support from Supervisor/yr assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
Alberta (Edmonton, AB)	8 Exp, 2 Theory	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.  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; Westgrid as part of Compute Canada, Thor cluster for ATLAS, Theory cluster	Theory: 1PDF, 3 PhD, MSc). Theory rsearch program includes: QCD sum rules and hadronic physics; Dark matter and particle astrophysics; Nuclear Compton scattering and photonuclear reactions  Particle Physics Experimental Program: ATLAS, DEAP, IceCube, PICO/PICASSO, SNO+, MoEDEL, ALTA: (10 PDF, 9 PhD, 5 MSc); Theory (2 PDF, 1 PhD)	\$10.3k from NSERC grant, \$20.7 TA, \$3.3k scholarship
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 anti-hydrogen at CERN.  One Theoretical and Computational: (i) R-process nucleosynthesis: astrophysical sites and sensitivity to nuclear physics input (1RA, 1 PhD and 1 MSc.; software development: r-java 2.0 and SiRop ). (ii) Hadronic-to-quark-mater phase transition (1RA, 1PhD; software development: Burn-UD)	\$11.8k from NSERC grant, \$13.2k from TA, Total: \$25k
Simon Fraser (Burnaby, BC)	Particle Physics: 3 Exp Nuclear Physics & Chemistry: 2 Exp	Particle: Use of TRIUMF: Leads Western Canada group producing parts for new ATLAS tracking system (ITk) for high-luminosity LHC, involving clean room & TRIUMF infrastructure. Use of SFU: 4-D labs to test ITk production modules. Computation: SFU has hosted an ATLAS Tier-2 since 2003. SFU has led ATLAS Tier-1 project at TRIUMF since before 2005, now moving to Compute Canada facility at SFU in 2017-18. There is also a small Tier-3 stite on campus.	ATLAS: Higgs discovery (WW and tau-tau channels), jet physics, jet calibration, search for BSM physics, muon and tau ID. Leading roles in ATLAS upgrade (ITk and new muon small wheel) and high-performanc computing (Tier-1, Tier-2). 3 PDF, 6 graduate students. Nuclear: In-trap decay spectroscopy using TITAN, gamma-ray and decay spectroscopy using ISAC-1, ISAC-11 at TRIUMF, integrated plunger program	Particle: \$18k from NSERC grant, \$5k TA, \$3.5k scholarship; Total=\$26.5k Nuclear: \$13-15k from NSERC, \$6k TA, \$0-2k scholarship. Total=\$21-23k.  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

Institution	No. funded SAP Faculty	Local facilities	SAP Research Programs	Typical Grad Student Support from Supervisor/yr assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
Northern British Columbia (Prince George, BC)	2 Exp (including one emeritus)	<p>Nuclear facilities: D/T neutron generator, 8pi HpGe/BGO spectrometer, segmented HpGe counting station, radiochemistry lab, alpha spectrometer, XRFIN system.</p> <p>There is also a local machine shop as well as a major nano fabrication and characterization facility (4D labs). Some ATLAS upgrade work is happening in 4D labs now.</p> <p>One lab room for training: radioactive sources, solid-state and scintillation detectors, and data acquisition system</p>	<p>using neutron activation &amp; spectroscopy</p> <p>Ultra-cold neutrons at TRIUMF; Qweak/Moller at Jlab; Dragon at TRIUMF-ISAC</p>	<p>certain level it is \$20k. If they do not TA, it is \$26.5k.</p> <p>Mostly undergraduate; some MSc students at \$5k/yr from NSERC</p>
British Columbia (Vancouver, BC)	<p>Particle: 8 Exp, 7 Theory;</p> <p>Nuclear: 1 Exp (Includes 1 IPP RS)</p>	<p>Use of TRIUMF facilities; Shared BELLE II, BaBar, T2K lab space, Shared High Bay assembly facility (shared with entire Phys/Astro Dept), ATLAS lab space; Large projects: people use detector lab and scintillator shop at TRIUMF. Detectors apparatus with gas system and DAQ may be done at TRIUMF instead at UBC.</p>	<p>Particle Physics Experimental Program: ATLAS, T2K, PIENU, TREK at JPARC, SuperCDMS, Belle II, BaBar (5 PDF, 14 PhD, 5 MSc); Theory (3 PDF, 16 PhD, 1 MSc)</p> <p>Nuclear Physics Experimental Program: ISAC/ARIEL; Nuclear expt 4 PhD 8 MSc</p> <p>Nuclear theory 1 MSc</p>	<p>\$13-16K from NSERC grant, \$9.4-9.8K from TA; PhD students get \$4.8K tuition award (Masters \$2K tuition award)</p> <p>Total (minimum)= \$23.8K for MSc, \$27.4K for PhD students with no scholarships. Scholarship students do less TAing and some get an award top-up as well.</p>
TRIUMF-Accelerator Physics (Vancouver, BC)	12 staff	<p>TRIUMF accelerator facilities, SRF testing facilities, Ion source test stands, target laboratories, beta-NMR and MuSR facilities</p>	<p>Research Program: SRF and cyclotron development, target and ion-source development, wake field acceleration (12 PDF, 11 PhD, 4MSc, 6 Engineers in Training (EIT))</p> <p>Support varies for different home universities.</p>	<p>Support varies for different home universities.</p>

<b>Institution</b>	<b>No. funded SAP Faculty</b>	<b>Local facilities</b>	<b>SAP Research Programs</b>	<b>Typical Grad Student Support from Supervisor/yr</b> assuming students are at the university (when at the labs, the supervisor pays the TA rate plus COLA)
TRIUMF – Nuclear Physics (Vancouver, BC)	10 Exp, 3 Theory	Full TRIUMF facilities	Nuclear Physics Program: ISAC/ ARIEL RIB Exp (16 PDF, 7 PhD, 8 MSc) Theory (3 PDF, 2 PhD, 1MSc), see discussion on p.2 re. grad student supervision	Support varies for different home universities.
TRIUMF – Particle Physics (Vancouver, BC)	11 Exp, 2 Theory	Full TRIUMF facilities: UCN facility, detector facilities, ATLAS upgrade facilities; ATLAS Tier-1, Tier-3, T2K Tier-1, M11 test beam, PMT test facility	Particle Physics Experimental Program: ATLAS, T2K, UCN, ALPHA, nEXO, DEAP, HALO, Muon g-2, NA62, PIENU (22 PDF, 9 PhD, 5 MSc); Theory (2 PDF, 1 PhD, 2 MSc), see discussion on p.2 re. grad student supervision	Support varies for different home universities.
Victoria (BC)	8 Exp, 3 Theory Includes 2 IPP RS	Large shared lab space; clean room; machine shop; electronics shop; small local cluster plus access to Compute Canada grid (WestGrid); MRS detector development expert available to the community	Particle Physics Experimental Program: ATLAS, T2K, Belle II, BaBar, ALTAIR Accelerator/ARIEL/ILC (9 PDF, 10 PhD, 6 MSc); Theory (2 PDF, 1 PhD, 3 MSc)	Department policy Minimum: PhD: \$17.9k from NSERC grant, \$2.6k TA, Grad award \$5k; Total \$25.5k MSc: \$17.0k from NSERC grant, \$2.6k TA, Grad award \$4k; Total \$23.6k