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The Subatomic Physics (GSC 19) Submission for the 2002 NSERC Reallocations Exercise

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1 A Vision for Canada's Subatomic Physics Programme

Subatomic physics seeks to understand the nature and structure of matter at the most fundamental and universal level. Development of this understanding contributes to our knowledge of the origin and evolution of the universe and leads to questioning the very structure of space and time. This field of research represents a fascinating intellectual challenge in which Canadians are fully engaged.

Nature's building blocks, particles called quarks and leptons, are characterized by their interactions via the electromagnetic force, the weak force which governs some types of radioactive decay, and the strong force which binds the quarks into nucleons. A beautifully elegant theoretical model has been developed, wherein all these forces share a common underlying nature while also exhibiting individual characteristics. This Standard Model has been experimentally verified with high precision yet leaves many questions unanswered. We do not, for instance, understand the origin or pattern of masses of the elementary particles. This is likely tied to the unification of two of the forces into the electroweak force at higher energies. The concept of an underlying simplicity drives the search for evidence of further unification,which may have been in play during the extreme conditions of the origin of the universe.

While particle physics deals with unearthing a fundamental simplicity, nuclear physics confronts head on the complex many-body systems of protons and neutrons comprising the nucleus. A frontier in nuclear physics is a detailed understanding of the nuclear reactions that fuel the stars and forge the chemical elements.

Canadian subatomic physicists have developed a unique programme, successfully integrating the study of nuclear and particle physics. Our experimentalists have been leaders in the large projects Canada has been involved in and our theory community has made important contributions of both formal and phenomenological work. The programme has come about by identifying endeavours of fundamental importance through a process of long range planning. In this context, the Canadian subatomic physics community has three projects as its highest priorities, in fact, as its highlights.

ISAC: The Isotope Separator and ACelerator at the TRIUMF laboratory in Vancouver, now one of the world's most advanced radioactive ion beam sources, will make pioneering measurements of the nuclear processes that governed the forging of the heavier elements in the early universe.

SNO: The Sudbury Neutrino Observatory will make definitive measurements of the total number of neutrinos coming from the sun. Neutrinos are weakly interacting particles which are produced in nuclear reactions and travel directly from the sun's core to earth. SNO is focussed on solving the "solar neutrino problem", the discrepancy between the observed and predicted solar neutrino flux. Considered one of the most important physics questions today, SNO has completed the first phase of three in its quest to unravel this difficult challenge. It is already a Canadian science success story, with the 2001 results producing one of the most highly quoted particle physics papers.

ATLAS: Canadians are part of a global collaboration constructing the ATLAS detector for CERN's Large Hadron Collider. The LHC will be the energy frontier for particle physics by 2006 when studies will begin of the highest energy particle collisions ever produced in a laboratory. One of this experiment's central goals is the discovery of the origin of mass, which the current paradigm associates with the breaking of the electroweak symmetry and a new particle called the Higgs boson. However, this experiment will advance our understanding of particle physics on several fronts, including the search for new fundamental particles and possibly even evidence for new phenomena such as extra space-time dimensions.

The adventure of subatomic physics goes well beyond these three projects. We do not understand how it is that our universe seems to be full of matter and devoid of anti-matter. What is the ultimate fate of the universe; is the new concept of dark energy at work? Our community needs the opportunity to explore more broadly. So the Canadian programme includes a balance of smaller experimental initiatives also of great importance, and wherein we have often taken a lead role.

Some of the most fascinating and profound questions in science today lie at the interface of astronomy and physics. These include experimental and theoretical questions which go to the heart of the origin, structure and evolution of the universe. For example, the composition of the universe is an outstanding mystery, with evidence that most of its mass is in the form of an unknown Dark Matter. These questions, which capture the imagination not only of the scientific community but also of the general public, lie within the realm of the emerging area of particle astrophysics. In Canada, we have an active and growing community working in this exciting area. This includes those applying particle physics techniques to problems of astrophysical interest along with experiments which use astronomical phenomena to study questions related to particle physics, most notably SNO. However, they tend to fall between NSERC Grant Selection Committees. Acknowledging its scientific importance, our community advocates that particle astrophysics be recognized and encouraged as an intrinsic part of the subatomic physics research effort in Canada.

2 The Strategy

Canadian participation in subatomic physics research is part of our nation's commitment to the community of advanced nations that value fundamental research. Our field is now undergoing vigorous renewal in Canadian universities, with 26 academic appointments in the last 5 years and a significant number more upcoming. Subatomic physics requires particle accelerators and detectors of a scale that exist only at national and international laboratories, shared by scientists from many countries collaborating over periods of a decade or more to construct the apparatus and jointly publish the results. Canada hosts two subatomic physics facilities that draw researchers from Canada and around the world: the underground SNO facility, and the TRIUMF laboratory, home of the new ISAC radioactive beam accelerator. At the same time, Canadian physicists play key roles in high priority projects at other international laboratories. We must continue to support SNO and ISAC as part of our contribution to advancing the field of subatomic physics.

Large, long-term, technically challenging international collaborations require careful management and planning. The Canadian subatomic physics community and NSERC have done so through several mechanisms. The infrequent but large capital equipment requirements are funded not through the NSERC-wide major-equipment competition, but rather by an "envelope" from which the Grant Selection Committee (GSC) funds capital equipment, infrastructure, and operating support for subatomic physics. Operating funds are provided primarily through project grants to experimental groups that include researchers from several universities. International peer review is the primary mechanism for funding projects and researchers – the GSC has approximately half of its members drawn from the very best of the international subatomic physics community. To provide a focused effort drawing on unique Canadian capabilities, a community based long range plan (LRP) has been developed. This reallocation exercise is linked to the third such LRP. This is foremost a scientific plan, identifying our goals and priorities. By focusing on a small number of important projects, Canadian subatomic physics researchers have made visible and essential contributions in multinational collaborations. This selection strikes the appropriate balance between properly supporting the highest priority projects and maintaining the intellectual breadth of the Canadian programme. Our LRP has also identified where we want to be positioned for opportunities in the next decade, carrying forward our strategy of selecting projects where Canadians are able and welcome to take on leadership roles.

Subatomic physics is technology-intensive, providing opportunities for training in instrumentation, integrated electronics, advanced computation, and data analysis. It is also unique in the scale and breadth of collaborations, providing students and researchers with experience in international cooperation and management of large and long-term projects. The tools developed for subatomic research have had important applications in research, industry, and to the general public. Much of medical diagnostic instrumentation is derived from nuclear and particle detector technology. The widespread availability of superconducting magnets for magnetic resonance imaging was made possible by the development of superconducting material and magnet technology for particle accelerators and detectors. Synchrotron radiation and neutron scattering facilities for the physical and life sciences are direct applications of subatomic physics technology. The World Wide Web was originally developed at CERN as a means for subatomic researchers to document and communicate their work. Our programme must continue to support R&D of advanced instrumentation.

2.1 The New Subatomic Physics Long Range Plan (2002-06)

The LRP is a scientific plan that also lays out funding priorities to assist the GSC in making its recommendations. The so-called "status quo scenario" maps out our scientific plans for the case of a constant funding envelope. The LRP also identifies the consequences of decreased funding resulting from this reallocation exercise and explores the new opportunities arising with an increase in our resources. In any scenario, subatomic physics research requires detailed attention to the balance between operating funds and planning for capital expenditures. With the long time scales involved in our discipline, it is crucial to sustain long term objectives with a stable working environment. The Canadian community has established its reputation by being reliable collaborators who deliver on our international commitments, and providing the intellectual leadership to direct each project to successful completion.

Our present LRP emphasizes a concentration of resources on three highest priority projects, ISAC, SNO and ATLAS. These priorities exist in the context of many important issues in subatomic physics. Consequently, the scientific program argued for in our LRP recognizes the need for breadth and to plan for smaller projects in a longer term context. We describe the key elements of the status quo scenario in the LRP, as that forms the basis for our reallocation requests.

ISAC and Nuclear Physics: Nuclear astrophysics is the primary focus of the Canadian program at the new ISAC facility at TRIUMF. ISAC's radioactive ion beams allow the study of key reaction chains which otherwise occur only during explosive nucleosynthesis in stars. Our understanding of the production of heavy elements and of the nuclear structure of isotopes far from the line of stability will be significantly advanced with this facility. ISAC and the DRAGON spectrometer have been specifically designed to measure, for example, the $^{15}O(\alpha,\gamma)^{19}Ne$ reaction rate which would provide a trigger for evolution from the hot CNO (Carbon, Nitrogen, Oxygen) cycle towards a Na-Ne novae.

The current stage of ISAC, ISAC-I, is restricted to isotopes with nuclear mass A less than 30 atomic mass units (u) and energies of 1.5 MeV per nucleon. The upgrade to ISAC-II, which will accelerate radiactive ions with $A < 150$ u up to energies of 6 MeV per nucleon, has been approved and delivery of first beams is expected in 2005. The ISAC-II nuclear astrophysics program will be expanded beyond that of ISAC-I with the ability to access further nuclear reaction chains. Both reaction dynamics and nuclear structure under extreme conditions will be studied. The beams at ISAC will also be exploited for sensitive tests of physics beyond the Standard Model.

A small number of other important projects is also supported. At TRIUMF, the TWIST experiment will make the world's most precise measurements of muon decay. Canadian nuclear physicists are studying the lack of mirror-symmetry in nature and the detailed properties of the proton at the Thomas Jefferson National Laboratory in the U.S.and are making nuclear mass measurements, which are critical input to other experiments, at Argonne National Laboratory and at CERN.

SNO and the Interface with Astrophysics: The Sudbury Neutrino Observatory has dominated the scientific scene with its first results. SNO is a unique facility consisting of a large acrylic vessel filled with heavy water, immersed in a much larger light water "shield", all located 2 km underground in the INCO Creighton nickel mine. The heavy water allows the detection of all neutrino types. In its first phase of operations, SNO has measured a total solar neutrino flux in excellent agreement with the prediction of the standard solar model, while also finding a deficit in electron neutrino interactions. The interpretation is that neutrinos oscillate between species. Increasingly precise measurement of the parameters of neutrino oscillations continues, with the second phase of the experiment, with salt in the water, underway.

SNO is just one example of a project which draws together particle and nuclear physics with the observation of astrophysical phenomena. This is a research area of growing global importance which our LRP advocates that we take on as an integral part of our subatomic physics research program. On the theoretical front, there is an explosion of interest in linking our understanding of the origins and structure of the universe to the nature of its fundamental constituents and their interactions, in the form of superstring cosmology. A small experimental particle astrophysics program in Canada includes a dark matter search using a novel Canadian technology and explorations of the phenomena of ultra-high energy gamma rays. Continuing opportunities at the SNO site are being explored.

ATLAS and Particle Physics: At the energy frontier, the ATLAS experiment is our best opportunity to further the understanding of interactions among the elementary particles and for the discovery of phenomena which may exist beyond our current understanding. The Canadian ATLAS group is designing, prototyping, and constructing key components of the detector which measure the energy of particles produced in the collisions at the LHC. This includes the development of advanced electronics which must meet unprecedented radiation hardness standards. The status quo scenario of the LRP has the Canadian group meeting its international committments with delivery of its contributions on schedule and developing competitive analysis capabilities.

This top priority effort on ATLAS is balanced by an excellent and well rounded program of particle physics projects. Canadian roles in the extreme experimental scrutiny of the Standard Model include the very broad programmes of the OPAL experiment using high-energy e^+e^- collisions at the LEP-II collider at CERN and the ZEUS experiment at the HERA e^-p collider in Hamburg, Germany. A key test of our understanding of the asymmetry between matter and antimatter in our universe is the study of CP violation. Canadians have driven work on the rarest decay mode ever measured at the E787 K decay experiment at Brookhaven and are part of the BaBar team at the Stanford Linear Accelerator Center which has confirmed CP violation in the B system. The Canadian effort at the current energy frontier facility, the Fermilab Tevatron, has not only unearthed the top quark but will provide invaluable experience for our ATLAS Canada team as data taking commences.

Ideas and Technology for the Future: The subatomic physics community has identified where it would like to be positioned for the future. Instrumentation for the nuclear physics program of ISAC II must be developed and constructed. R&D for instrumentation for the future international Linear Collider has begun; this facility has been identified worldwide as the next major initiative beyond the LHC. We are also looking to define Canadian participation in an international accelerator based second generation experiment for precise understanding of the parameters of neutrino oscillations.

Financial Plan: The LRP included the development of a funding model for the next five years.

	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
SNO Facility	2,325	2,380	2,400	2,450	2,450	2,500
SNO Operating	1,261	1,261	1,500	1,500	1,500	1,500
ISAC Operating	1,252	1,423	1,442	1,540	1,335	1,365
ATLAS Operations	1,550	1,590	2,000	2,200	2,450	2,700
Particle Astrophysics	68	201	200	200	250	250
Theory Support	1,920	1,880	2,100	2,190	2,277	2,277
Other Particle Physics	3,944	3,416	3,495	3,230	3,050	2,975
Other Nuclear Physics	1,507	1,408	1,435	1,345	1,155	1,155
Infrastructure	1,491	1,508	1,610	1,655	1,700	1,745
R&D	190	359	374	320	320	320
Capital	4,133	2,161	2,686	4,040	4,504	5,214
Total	19,641	17,587	19,242	20,670	20,991	22,001

Table 1: The funding allocations recommended for the "status quo" Long-Range Plan (all figures are in thousands).

The plan for the situation of status quo funding is summarized in Table 1. The explicit increase in funding for SNO and ATLAS are important elements of this plan. However, the support for SNO, for example, remains below the historic level prior to NSERC cuts in 1995. The plan allows for only minimal support for particle astrophysics, and an essentially "flat" funding level for ISAC science and the theoretical effort. Capital funding is projected, primarily for a second generation rare K-decay experiment (KOPIO) and the ISAC-II programme, with a small amount set aside for unidentified initiatives in the last two years of the plan.[1]

2.2 Implementation of the Last Reallocations Exercise

The last reallocations exercise was carried out in a context where our three highest priority projects had large capital needs. Extremely difficult decisions, including the closure of facilities, were made in our 1996-2000 LRP. A five-year spending plan was developed with a profile moving capital costs of ISAC instrumentation, SNO and ATLAS forward, the overall envelope being constrained to balance over a five year period. That Reallocations Committee recognized that the subatomic physics submission emphasized fundamental and important questions in the interrelated areas of nuclear and particle physics. They supported the community's five year plan and its specific proposal for research and development funds aimed at positioning the Canadian subatomic physics community for the future. We have now succesfully implemented this plan, and the scientific benefits of this commitment are being realized.

- The period of implementing the last reallocations decisions coincides with the milestone of first delivery of radioactive beam at ISAC. The scientific program is now well underway. Recognition of the need for strong and timely support of the ISAC program resulted in the award of reallocations funds for new detector systems, along with the associated operating funds.

[1] The average operating support in the GSC 19 envelope ($14.121M) is subject to the Reallocation Exercise.

- Support of the now fully operational SNO project has generated their first exciting and definitive investigations of the solar neutrino problem. The SNO results have had an extremely high profile, even in the popular media.
- It has been possible to expand the scope of the ATLAS project using additional increases in the GSC's envelope. Furthermore, as capital costs for ATLAS have now begun to decline, increased operating funds have been allocated to ATLAS for successful delivery of the detector components under construction and the development of physics analysis tools.

Funding to develop the next generation of experiments has been extremely limited due to the capital needs of the large high priority projects in the program. Reallocations funding of a few projects with the potential for tremendous future impact has begun to address this need. These include work on a second generation rare K-decay project (KOPIO), development of a novel detection system for dark matter (PICASSO), and work associated with the proposed search for states with exotic quantum numbers (TJNAF Hall D). Two projects aimed at a future international Linear Collider have been funded through Reallocations awards. This facility will be the highest priority for particle physics beyond the LHC, with the capability to precisely characterize discoveries made at the LHC. Early participation in this important project is critical for Canadian scientists to make an impact in the future.

New funding has been crucial in meeting committments to our national and international collaborations and in making progress towards our scientific goals. Reallocations funds targeted for new initiatives put Canadian subatomic physicists in position to continue their leading roles in this field of research.

3 Specific Proposals

3.1 Support for a Balanced Program

Our top priority experimental projects are all forefront investigations with the highest scientific impact. At the ISAC facility, we have begun to use radioactive beams to explore on earth conditions which otherwise exist only in extreme astrophysical environments. By the end of the implementation period of this reallocation exercise, SNO will have greatly advanced our understanding of the neutrino sector. At that time, we will launch the investigation of electroweak symmetry breaking and explore possible physics beyond the Standard Model using the ATLAS detector at the LHC. These three priorities reflect investments by Canada ranging from 7 to 15 years in scope, and will ensure Canada's leadership role in subatomic physics at an international level.

The LRP also supports a well-rounded program of smaller excellent projects along with theoretical investigations. This balance encourages scientific creativity while acknowledging our limited resources. Furthermore, it ensures that we maintain a healthy roster of experiments taking data during the lengthy construction periods of the largest projects. As supported in the last reallocations exercise, our LRP also includes R&D funding for future projects. This support allows us take a few chances on developing instrumentation with the promise of big scientific impact and it assures us a role in the future endeavours which we know will be the most important global projects in subatomic physics.

The LRP identified specific cuts which would have to be made in the event of a reduction of resources in this reallocations exercise. These cuts focussed primarily on R&D expenditures for future initiatives, compromising our opportunities in the long term, and are described in Section 4. The future of Canadian research in subatomic physics must not be sacrificed. Support of our Long Range Plan's status quo scenario will position us to achieve a set of important scientific goals by the end of this reallocation period. Furthermore, it will ensure that we continue to make progress in exploring the most fascinating questions in subatomic physics.

We request the return of $1,412K in support of a strong Canadian program in subatomic physics with identifiable important achievements and goals, and provisions for continued excellence in the long term.

3.2 Maximize Science Return for Highest Priority Projects

The status quo scenario of the community's LRP supports its highest priorities at a base level. However, under this scenario Canada would fall short of maximizing its scientific opportunities and fully exploiting its considerable investments. We therefore request a level of support which would allow our groups to display greater leadership internationally in the three projects identified by the community as most important for the field.

ISAC and Radioactive Beam Science: The support of Canadian groups to exploit the ISAC facility in its first five years of operation is highly constrained. The number of experiments that can be done is limited in part by the number of investigators. Canadian universities are now making hires in nuclear astrophysics, recognizing the scientific opportunities that exist at ISAC and which are now attracting international collaborators, such as the study of the $^{15}O(\alpha,\gamma)^{19}Ne$ reaction. With the spectacular success of TRIUMF in developing this state of the art radioactive beam facility, a strong refocusing of the Canadian Nuclear Physics programme has occurred with at least 24 FTE working in the ISAC experimental programme. Academic institutions have responded by creating and filling three new positions in 2001, with a further three currently advertised. The net loss through retirements is approximately one FTE.

We request operating support for these five additional experimenters at the average level of support in this subfield of subatomic physics. This amounts to $325K per annum.

SNO Physics Analysis: Funding for the SNO facility has been given the highest priority in the programme over the last four years, slowly increasing in a context where overall operating support has fallen by approximately 15%. This has allowed the group to commission the detector and deliver the first dramatic physics results. However, operating support for the SNO university groups had to be severely constrained. Furthermore, because the Canadian groups have large operational responsibilities at the SNO site, their ability to focus on the analysis of the data and extraction of the large scientific potential of SNO has been affected. Now, four new Canadian scientists are joining the team and will provide the Canadian groups with a capacity in data analysis comparable to that available to their foreign partners. The timing is excellent for analysis of the new data being taken with salt added to the water, Phase II.

We therefore request additional support for this very positive development, initially at $120K per annum growing to $315K by year four. The growth accounts for inflation in the salary and travel component of the overall operating grants at a rate of 2.5% per annum.

Development of ATLAS Analysis Capability: The LRP allocates sufficient support for the ATLAS Canada collaboration to discharge its obligations with regards to the installation and commissioning of the parts of the detector provided by Canada. The upcoming period will be very intense, demanding a significant presence at CERN. The Canadian ATLAS team must also be involved in the Data Challenge now being implemented at CERN, an important step in developing and testing the data analysis strategy and tools. The core of this effort will consist of 5.0 FTE professional researchers working closely with a team of ATLAS faculty members and students. This team will develop the Grid tools and the software infrastructure necessary to support an analysis effort in Canada.[2] We expect that the capital investment in hardware will be obtained via CFI and NSERC equipment competitions.

We request an increase of $360K for the Canadian ATLAS physics groups to fund the professional staff required for the development of their simulation and data analysis teams during the period 2003-2006.

3.3 Support of Particle Astrophysics

Many exciting scientific opportunities arise at the interface between astronomy, particle, and nuclear physics. The solar neutrino measurement at SNO is currently the highest profile Canadian activity. The SNO collaboration is also part of the ongoing global supernovae watch and is considering long range options beyond its current scientific programme. The PICASSO project is focused on the detection of a puzzling new form of matter which appears to dominate the mass of the universe. Directly detecting this dark matter and understanding its nature is one of the great challenges in particle astrophysics. The group has successfully developed a prototype of a novel Dark Matter detector and proposes to mount an internationally competitive project. The expertise of SNO scientists in building large, low background detectors has already proved to be an asset for the PICASSO programme. Furthermore, the SNO site represents an environment with unique low radioactivity and cosmic-ray backgrounds for these future investigations. Another Canadian project involves the study of ultra-high energy gamma rays. Gamma rays with energies well beyond the expected range have been observed and the mechanism for their production is unknown; an understanding may lie in the fundamental interactions of particles. There is potential for our scientists to participate in the next generation experiment, VERITAS.

The existing group of Canadian particle astrophysicists is being strengthened through new academic appointments, one made in 2001 and four searches underway. Our LRP gave high priority to the development of new particle astrophysics projects. Partial capital funding was identified in the last years of the LRP for the next phase of the PICASSO experiment, which involves underground installation of a prototype detector at SNO. However, only in the scenario of significantly increased funding to subatomic physics was it possible to properly support either PICASSO or VERITAS.

Given the strong interest worldwide and the growth in the Canadian community of particle astrophysicts, we request additional operating support of $330K.

3.4 Strengthening of Subatomic Physics Theory

The development of subatomic physics is critically dependent on the presence of a vibrant and active community of theorists. This exists in Canada in the form of a theoretical community with diverse interests and a record of scientific impact of international calibre. Furthermore, the future looks very exciting because we have begun a period of significant renewal among theoretical faculty, with new appointments at nearly all the institutions involved in subatomic physics. Several of these appointments have been in superstring theory, greatly strengthening the Canadian role in this area of immense interest. In the past two years, 10 new theory appointments have been made and an additional 5 searches are currently in progress. These represent a turn over of 20% of the community. Additionally, the recently established Perimeter Institute will provide new national opportunities for the exchange of ideas and collaboration among theorists.

[2] Data Grids are geographically separated computing resources, configured for shared use with large data movement between sites.

During the recent planning exercise, theorists identified their highest priority as the enhancement of their research environment with the ability to hire top quality research personnel at the postdoctoral level. The Canadian theory community is directly competing with researchers worldwide for a small pool of extremely talented people. An overall increase in funding for theorists, at the 20% level, is required. This increase would, as usual, be distributed through the stringent peer review process to the most deserving researchers.

We request an amount of $430K to support new researchers and to improve the research environment of subatomic physics theory in Canada.

3.5 Advanced Technology Development for Future Projects

It is not uncommon for new experiments to set as their goal an improvement in sensitivity or precision by several orders of magnitude over previous work. This requires the development of new advanced technologies. Canadian subatomic physicists have developed such advanced technologies at an internationally competitive level, resulting in innovations such as extremely sensitive radioactivity assaying techniques, radiation-hard electronics, novel x-ray detectors, and gallium-arsenide charge-coupled readout devices. Many of these have possible applications in other areas such as for medical imaging in the case of the x-ray detectors. This R&D is currently being supported by approximately $360K per annum made possible only through the last Reallocation exercise.

The LRP identified as high priority the need to perform R&D on tracking detectors and accelerator alignment techniques for a future Linear Collider, scaling up the PICASSO experiment to a 1-ton detector, new photon tracking detectors for the KOPIO experiment, and a novel lead-scintillator calorimeter for a next generation neutrino study. We estimate these R&D efforts will require approximately $800K per year over the next four years. The five-year plan, however, was only able to identify a total of $320K in the "status quo" budget. We therefore propose an additional investment of $480K per annum. Without this infusion of additional R&D support, the long-term competitiveness of the Canadian programme will be compromised.

4 Consequences of No Reallocation Funding

The subatomic physics community has identified a prioritized programme, focusing over the next five years on maximizing the scientific return of SNO and ISAC, developing the Canadian contribution to the ATLAS effort, maintaining breadth by strategically supporting a modest number of smaller projects, and selecting a small number of longer-term projects for R&D. In the case where the reallocation process reduces the resources to the community, the LRP identified a number of specific areas where we would be forced to make cuts: Instrumentation for ISAC II would have to be delayed, jeopardizing our lead in the radioactive beam research frontier. The PICASSO experiment could not be scaled up to an internationally competitive project. The next generation rare K decay experiment, KOPIO, would have to be significantly curtailed, a severe blow given Canada's leadership in this ground-breaking programme.

By making these cuts, we would be avoiding explicit cuts in our highest priority projects. Reduced funding would also limit the resources available for the computing facilities required for data processing and scientific analysis of the very large data sets being collected in several of our current experiments. The community's overall ability to perform the essential R&D for the next generation experiments will be curtailed to the point of jeopardizing the future of Canadian subatomic physics.

5 The Importance of Subatomic Physics to Canada

The primary objective of subatomic physics research is the pursuit of fundamental knowledge about our Universe, its origin and development. As such, this field represents one of the great challenges to Canadian minds but it also links to other fields of research where similar experimental or theoretical techniques can be applied. Thus it represents an excellent training ground for problem solving skills. The subatomic physics record in the development of highly-qualified personnel is particularly strong. Over the last five years, subatomic physics researchers supervised to completion over 100 Ph.D. candidates, and currently have over 75 Ph.D. candidates under supervision. Over the same period, over 120 postdoctoral researchers were supervised. These young people predominantly enter the work force in academic or research positions in not only subatomic physics, but disciplines ranging from geophysics to financial modelling to large scale computation and networking.

As only one example of the impact of subatomic research on the health of Canadians, one can link the development of positron emission tomography, the imaging technology of choice for cancer management, to the technologies of isotope production separators, multi-element detector arrays, data acquisition, image reconstruction and analysis and simulation techniques. These are all techniques which originated in subatomic experiments over the last several decades. There are many other examples of this synergy in Canada, a very visible one being the MDS Nordion isotope manufacturing facility adjacent to TRIUMF.

The demands of subatomic physics experiments on data handling techniques are driving the development of new tools for global computing over the World Wide Web. Canadian groups are involved in the Grid computing development project, which has immense potential in business and commerce. While the economic and societal impacts of this pursuit are open for speculation, Canada would be notable in its absence in the development of such technologies. In fact, Canada's leadership in developing a fully optical network across the country and the physical extent of the country make Grid technologies particlary attractive.

Working in large international collaborations prepares students for the global economy in an internationally competitive environment. Most groups are multinational in composition and use management techniques akin to the industrial world. All our programs are internationally peer-reviewed and expose our students and postdoctoral fellows to reporting, scheduling and decision making in a global context.

A strong fundamental research program has important feedback in other disciplines. It is because challenging our knowledge of the Universe is demanding the development of new sophisticated tools that such consequences are realized. In the final analysis, however, being involved at the leading edge of our field is what is important for Canada. The funding of our proposals would support a world-class program in subatomic physics anchored on the recent remarkable achievements of the small but internationally competitive community.