DRAFT Version 0.4

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

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October 19, 2001

1 Canada's Subatomic Physics Programme

Science has sought to understand the nature and structure of matter and the laws of motion and change. In the past this quest has uncovered the classical forces and laws of motion, the chemical elements and their atomic nature, the structure of atoms and the quantum laws of motion, the nuclear forces, and the structure of the nucleus. Subatomic physics is the branch of science that continues this quest for understanding at the most fundamental and universal level. Research today includes string theory (attempting the ultimate unification of Einstein's General Relativity with the quantum description of particles and forces) and the theoretical description of particle and nuclear phenomena, experiments studying particle interactions at the highest energies where new particles and forces are expected, precision experiments at moderate energy seeking evidence of new physics through subtle deviations from our present expectations, and experiments probing the complex many-body behavior of forces in the nucleus and the reactions that produce energy and the chemical elements inside stars.

Subatomic physics requires particle accelerators and detectors of a scale that exist only at national and international laboratories. Scientists from institutions in many countries collaborate over periods of a decade 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 Sudbury Neutrino Observatory (SNO), and the TRIUMF laboratory, home of the world's largest proton cyclotron and the new ISAC radioactive isotope accelerator. At the same time, Canadian physicists play key roles in high priority projects at other international laboratories.

Canada has developed a unique programme that over the last 15 years has successfully integrated the study of nuclear physics (the study of phenomena involving the many-body system of protons and neutrons comprising the nucleus of all atoms) and particle physics (the study of the more elementary particles, the quarks and leptons, that are the building blocks of the nucleons and atoms). By all measures, the Canadian programme has been exceptional in its international impact given its size. Members of the experimental programme have taken leadership roles in each of the large projects Canada has been involved in, and our theory community has made important contributions to the current paradigm, known as the Standard Model.

justified Large, long-term, capital-intensive 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 19) funds capital equipment, infrastructure (MFA), and operating support for subatomic physics. Operating funds are provided primarily through project grants to experimental groups that include researchers from several universities, rather than individual investigator grants. The community has insisted on using international peer review as the primary mechanism for funding projects and researchers – GSC 19 has approximately half of its members drawn from the very best of the international subatomic physics community.

Canadian participation in subatomic physics research demonstrates our membership in the community of advanced nations that value fundamental research driven by the human quest for understanding. By focusing on a small number of important projects, Canadian subatomic researchers have made visible and recognizable contributions in collaborations where any nation is in the minority. Canada hosts subatomic physics facilities (TRIUMF/ISAC, SNO) that draw researchers from around the world to mutual benefit. Subatomic physics is technology-intensive, providing opportunities for training in instrumentation, integrated electronics, advanced computation, and data mining. 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 ubiquitous World Wide Web was originally developed at CERN as a means for subatomic researchers to document and communicate their work.

As with many fields, subatomic physics in Canada has a demographic bulge of faculty hired during the rapid growth of the universities in the 1960's and nearing retirement. These senior researchers provide valuable experience and they often remain active as emeritus professors. The fast-paced and international nature of the field means that project leadership is usually done by the younger generation. The universities have now begun to replace the retirements, with X faculty having being hired in the last Y years, with Z ongoing searches underway, and W open positions expected in the next 3 years. We expect the result will be a younger community with less emphasis on traditional nuclear structure physics and more on nuclear astrophysics, particle physics, astroparticle physics, and string theory. This will result in increased competition for funding, but a community well-positioned to continue to be leaders in the world.

2 A Vision of Subatomic Physics Research for Canada

Subatomic physics research encompasses the searches for identifying the elementary constituents of matter and their interactions. Great strides have been made in this quest during the last century resulting in key discoveries that have led to the development of an elegant theory known as the Standard Model. This is considered as one of the most important scientific achievement of the 20th century since it accounts for a description of all phenomena that can be observed at the shortest distance scales possible with a minimal set of particles and a small number of fundamental forces. It has also extremely profound implications on our understanding of the development of our Universe and its behavior at very early times after the "Big Bang." The validity of the Standard Model has been and continues to

be tested with high precision. Already its accuracy allows us to use it for guiding extrapolation to higher and higher energies (and shorter periods just after the Big Bang). However, we believe that it is only an approximate theory, valid at relatively low energies. There are many questions which the Standard Model leaves unanswered.

We are forced to confront the ideas behind the Standard Model when one considers the extreme environments present in the cosmos such as neutron stars, black holes, supernovae, and gamma rays bursters. The simplicity of the Standard Model is brought into question by some of the most recent observations like the mass structure in the neutrino sector and also the evidence for dark matter and dark energy in the universe.

Theoretical extrapolations beyond the standard model as constrained by

experimental tests seemed to indicate a grand unification of the four

fundamental forces identified at our energy(distance) scale when one extrapolates to the scale of the Universe.

One of the key ingredient of the Standard Model which has not been experimentally established is the mechanism by which mass is generated, the so-called HIGGS mechanism. This is the focus of high energy physics experiments at the energy frontier, first at the TEVATRON and later in this decade at the LHC. The search for evidence of a new level of unification of the forces will dominate the high energy program but will also involve many high precision test at lower energies. A candidate theory is Supersymmetry which implies a duplication of our matter world as represented by the elementary particles discovered so far with a complementary set of supersymmetric partners. Searches for such new particles are underway and there is a specific interest in the possible weakly interacting neutral partner being a possible candidate for the dark matter in the Universe.

In principle the Standard Model has the basic physics to compute the properties of the complex structures which can be made from its elementary building blocks. This however has been possible only in simple cases and one still has to rely on effective theories (inspired by the Standard Model) to make progress. Experimental studies of nuclear systems and of quantum chromodynamics are linked to these efforts.

The energy sources in the Universe are derived from nuclear reactions that take place in stars. A frontier in subatomic physics deals with our understanding of the most cataclysmic events in the cosmos by which the heavy elements found in planets are made. Again great strides have been made and there is rather satisfying understanding of the nucleosynthesis for light nuclei up to Iron. Our present knowledge of nuclear physics doesn't allow to predict confidently how heavier elements (up to Uranium or beyond) are formed. This is due to the limitation imposed by our experimental facilities which have relied so far on stable beams. A new generation of nuclear physics experiments is starting with the realization of radioactive beam facilities which provide access to a much wider range of nuclei and will push our modeling of nuclear matter in unchartered territory. The New Nuclear Physics research is starting and the world community of nuclear physicists is refocusing their effort in that direction. Nuclear models are asked to represent the observed properties of nuclei under extreme conditions of isospin (ratio of the number of proton and neutrons), shape and temperature. There is already some evidence that the shell model of nuclei must be revised as one moves away from the region of stable nuclei.

As implied above a new vision for the field of subatomic physics must include the boundary with astronomy. Astronomy incorporates ideas from particle and nuclear physics while subatomic physics uses atronomical observations to extend its reach. The interdependence of these two fields of research is presenting a most exciting opportunity in our quest for understanding the origin and evolution of the Universe. This is an area of considerable interest and our community is developing tools to contribute to the world effort.

3 The STRATEGY

The Canadian subatomic physics community is an active participant in the global effort to refine our description of the basic constituents of matter and their interactions. To provide a focused effort drawing on unique Canadian capabilities, a community based long range plan (LRP) has been developed that identifies the high priority scientific projects that should be supported. This reallocation exercise is linked to the third such LRP, recently competed under the auspices of NSERC. The LRP offers options for various funding scenario which could result from the reallocation and our proposals here reflect the scientific priorities in this plan.

The selection of projects is based upon an international peer-review system, with funding decisions made by a Grant Selection Committee which has always included a large international component and maintains the highest standard of selectivity. This selection must also strike the appropriate balance between properly supporting the highest priority projects in the Canadian programme and maintaining its intellectual breadth. Guided by the five-year plan recommendations, GSC 19 members respond to the specific proposals put forward by investigators thereby effectively making peer-review decisions that maximize the significance and impact of the Canadian effort on the world stage.

As the modus operandi in the discipline involves long time scales, 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 experiment to successful completion.

3.1 A Focus on our Priorities

The current program is based on three large international efforts addressing some of the most important questions in the field:

1. A search for physics beyond the Standard Model in the neutrino sector with the unique SNO detector, which has just started to provide new, exciting results.
2. The detailed study of nuclear astrophysical phenomena using the ISAC facility at TRIUMF, one of the leading, if not the leading source of radioactive ion beams in the world. The Canadian program has chosen to focus its research on the nuclear astrophysics phenomena and the nuclear structure issues relevant to them.
3. A major participation in the search for an understanding of the origin of mass and evidence for possible extensions beyond the Standard Model such as Supersymmetry at the Large Hadron Collider (LHC). Canadian physicists are providing key components of the accelerator and of the ATLAS detector and taking a lead role in developing the physics analysis effort, expected to start in 2006.

These three main components of the program are balanced by concerted effort in the search for CP violation in the B and K systems, a key test of the Standard model prediction for the asymmetry between matter and anti-matter, a program to study the basic properties of the nucleon in terms of its constituents (quarks and gluons) at the HERA, TJNAF facilities; a program of high precision tests of the Standard Model at TRIUMF and ISAC (Twist and TRINAT) and several smaller efforts confronting QCD inspired models of mesons and baryons.

In the longer term , the community has identified where it would like to be positioned in the next decade. We are preparing instrumentation which would be required for such efforts as the Next Linear Collider or for an accelerator based second generation experiment for precise measurement of the parameters of neutrino oscillations.

In parallel a strong astrophysics program is developing with the search for dark matter candidates using a Canadian technology based on bubble detectors, a participation in the study of very high energy cosmic gamma ray source at the STACEE facility, while the ISAC program of nuclear astrophysics testing models of supernovae is just underway. Future observation of neutrino sources with SNO will extend the overlap of the subatomic program with the field of astrophysics.

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this section to be incorporated in a detail description of the Canadian program:

In detail the Canadian program in subatomic physics is based upon the following efforts:

1. Complete the approved stages of the SNO experiment in very short order: This will produce the following key information:
    - Determine the contribution of charged and neutral current reactions
    - Establish unambiguously neutrino oscillations and their parameters(mixing angles and mass differences)
2. Exploit aggressively ISAC-I and its radioactive accelerated beams:
    - Determine some key reaction cross sections in the CNO/ NeNa cycles
    - Precision studies of weak decays to search for physics beyond the STD model.
    - Nuclear structure of very far from the stability line isotopes
3. Deliver the contributions pledged for the LHC and ATLAS:
    - Delivery of the Canadian contributions on schedule
    - Participation in the CDF physics programme to access TeV physics and train the future ATLAS team
    - Development of competitive analysis capabilities for the ATLAS-Canada community

In parallel,

- vigorously search for CP violation in the quarks sector in the
  BABAR and Rare K+ decay program(E949)
- Precision studies of the nucleon quarks structure, of its spin structure, of its electromagnetic and weak form factors: ZEUS, HERMES,HIGS,G0 programs
- High precision searches for Physics beyond the standard model in dedicated experiments at TRIUMF: (TRINAT,TWIST)
- Hadronic physics and QCD at TJNAF.
- Develop the ideas and the technology for the future:
    - Define a Canadian participation in an international accelerator based neutrino program.
    - Participate in the definition of the future HE program based on
      lepton colliders and in its instrumentation R/D.
    - Build the infrastructure to start a Nuclear Physics program at ISACII.
    - Participate in the second generation experiments at The TJNAF
    - Establish a Non accelerator based particle astrophysics program
      in Canada, exploiting the opportunities at the SNO site for neutrino astronomy and dark matter searches, at the STACEE observatory for Ultra High energy gamma ray astronomy and possibly others.

4 Specific Proposals

The subatomic physics community in Canada has developed a program which strikes a balance between a small set of carefully selected high priority large initiatives, enough breadth to maintain vital intellectual stimulation, and a mechanism for the development of future innovative projects. This program is based on detailed scientific and financial planning and has been subject to extensive international peer review. The scope of the program, commensurate with the expertise of our scientists, provides opportunities for Canadians to continue to take on leadership roles. Rebuilding our program in subatomic physics during a period of reduced research funding has only been established through careful management of capital spending, maintaining operating funding for both experiment and theory at a reduced level, and aggressively winding down extremely successful projects as data taking ends.

As detailed in the SAP Five Year Plan, we have in place a scenario of investigation which addresses many compelling questions. Our highest priority projects, ATLAS, ISAC, and SNO, are all forefront investigations with extremely high scientific impact. The stage is set to capitalize on the initial science successes of ISAC and SNO. We must also complete the Canadian contribution to the ATLAS detector and prepare to exploit the physics of the LHC in a significant manner.

4.1 Support for the status quo scenario

The Five Year Plan includes a carefully developed financial plan based on the current level of funding, the "status quo" scenario. This plan supports the three highest priority projects, SNO, ISAC, and ATLAS, along with a limited set of projects to maintain breadth in the Canadian subatomic physics research community. It also recognizes the importance of planning for the future, with a moderate allocation of funds aimed at new initiatives. We request $ in support of the status quo scenario.

4.2 Enhanced operating support for the highest priorities

Operating support for the highest priority projects must be increased beyond the status quo scenario in order for Canadian scientists to maintain their leadership roles. Over a period of four years, that scenario leaves operating support flat; the consequence of this is that the ability to do the science diminishes.

Canadian subatomic physicists have always provided innovative ideas to drive experiments and have fulfilled important leadership responsibilities in running those experiments and in physics analysis. However, the status quo scenario has, for example, SNO scientists at a significant disadvantage relative to their own collaborators in the U.S. and the U.K. Current funding levels allow the Canadian team to fulfill their operational responsibilities but limit their impact in physics analyses and even in the dissemination of their results. Similarly, the ATLAS collaboration does not yet have the necessary resources to maintain the growing team at CERN required to install the Canadian built instrumentaion over the 2003-2005 timeframe and to take leadership roles in the physics analysis efforts which are now under development. It is the strong presence of a Canadian research team at international facilities which accounts for the productivity, impact, and profile of the group as a whole. At our home facility, TRIUMF, the ISAC researchers are funding limited in the number and rate of experiments Canadian scientists are able to perform, leaving significant measurements to other national groups. Canadian leadership at ISAC is at stake.

We have a focused set of highest priority projects of great scientific importance. That set capitalizes on the strengths of our scientists, who have consistently demonstrated leadership and are fully capable of continued significant impact given the appropriate level of resources.

We request $ to maximize the intellectual impact of the investments already in place.

4.3 Support of particle and nuclear astrophysics

Many exciting scientific opportunities arise at the interface between astronomy, particle, and nuclear physics. We recognize the emergence of an active new community in Canada committed to this exciting new area.

The solar neutrino measurement at SNO is currently the highest profile Canadian activity. However, the SNO collaboration is also part of the ongoing global supernovae watch, will be sensitive to details of the solar neutrino spectrum as their data set grows, and is beginning to consider long range prospects such as filling the detector with a scintillator sensitive to low energy neutrinos. The PICASSO project is focused on puzzling indirect evidence that much of the mass in our universe is in the form of dark matter. Directly detecting this dark matter and understanding its nature is one of the great challenges in modern science. The PICASSO group has developed a small prototype of a novel dark matter detector and proposes to mount a very sensitive search for dark matter candidates.

The expertise of SNO scientists in building large, low background detectors has already proved to be an asset for the PICASSO program. Furthermore, the SNO site represents a unique outstandingly low radioactivity and cosmic-ray background environment for these future investigations. Additionally, a group presently studying high energy gamma rays with particle physics detector techniques is interested in the VERITAS project in the future. That international project has among its objectives looking at supernovae remnants to determine whether they may be the source of ultra-high energy gamma rays. Gamma rays with energies of multi-TeVs have been observed and the mechanism for their production is a fascinating mystery; an understanding may lie in the fundamental interactions of particles.

Furthermore, the radioactive beams facility, ISAC, is opening a new world of nuclear physics motivated by questions of astrophysical importance. Finally, on the theoretical front, there is an explosion of interest in possibilities linking our understanding of the origins of the universe and its fundamental constituents, in the form of superstring cosmology. Clearly the Canadian nuclear and particle astrophysics community has many exciting prospects ahead and should be strengthened.

The success of SNO, with its unique deep underground laboratory, the development of the world's premiere radioactive beams facility ISAC, and the innovative work of Canadian scientists present a suberb opportunity to expand Canada's impact in particle and nuclear astrophysics. The subatomic physics community is prepared to invest heavily in this new field of research. We request funds to properly support new initiatives in this area as determined by the peer review process, including the scale-up of the dark matter search experiment PICASSO to be competitive with other international experiments.

4.4 Support of university based advanced technology capability

All the major experimental projects in subatomic physics are carried out at large facilities serving the international subatomic physics community. However, much of the advanced technology required for these experiments in initially developed in Canadian university groups which need adequate technical and engineering resources. This requires maintaining technical staff with high level design and engineering skills. Such establishments are already in place at a few institutions such as the University of Alberta and the University of Toronto. They facilitate the R&D associated with new and existing projects and effectively leverage contributions from the home institutions. The presence of this infrastructure is essential for the health of graduate programs, as training in the development of new technologies is an essential element.

4.5 The strengthening of SAP theory

The development of the science associated with subatomic physics is critically dependent on the presence of a vibrant and active community of theorists in this field. There is recent faculty renewal of subatomic theorists in nearly all the university departments significantly involved in this field of research. Several of these appointments have been in superstring theory, an area of growing interest globally. In addition, the recently established Perimeter Institute will greatly enhance activity in and the profile of our field in Canada.

Subatomic theorists identified, during the recent planning exercise, their top priority as being the enhancement of their research environment with the ability to competitively hire research personnel,

such as postdoctoral fellows. The development of a stimulating and productive atmosphere within a university group, including the interaction between experimentalists and theorists, is vital. This is particularly important for the training of highly qualified personnel.

We request $ in support of research personnel at the postdoctoral level in subatomic theory.

Furthermore, initiatives are needed nationally to provide opportunities for the exchange of ideas and to promote collaborations. One such suggestion has been the establishment of a Canadian Institute for Theoretical Physics, CITP. The model is one of a national institute distributed across the country, with nodes in the west, the east and in Ontario. Participating universities would be expected to contribute adequately to the CITP. The scientific activities would comprise the organization and funding of large thematic programs involving significant numbers of participants, conferences and workshops, graduate student and postdoctoral fellowships, and outreach to industry. Interdisciplinary activities would be particularly encouraged. The draft proposal for the CITP suggests an envelope of $500k per node, based on the experience of the existing Canadian mathematics institutes.

Feedback on whether the Canadian Subatomic physics community wishes to recommend proceeding with this proposal in this reallocations exercise is solicited.

4.6 The establishment of a National Computing Initiative for SAP

It is a priority to establish in Canada a computing infrastructure which will meet the requirements of the new generation of experiments, including ATLAS, TWIST, and BaBar. Several applications have been submitted to the Canadian Foundation for Innovation in that context, with success in each competition. However, long term planning is required by our international involvement in science, including allowing for the scenario of not receiving CFI support. We would be remiss to ignore our intensive upcoming computing needs. The subatomic physics community has identified the need to increase in a coordinated way the number of people with expertise in system design, software professionals, and physicist programmers supporting these computing systems and developing the software systems used to enable Canadian physicists timely access to the data produced by their experiments.

We propose a National Computing Initiative to provide these resources.

4.7 A Fund for future projects

Experimental projects in subatomic physics take shape over very long periods of time, of order a decade. These projects tend to be at the forefront of technological development. Funds are needed for the R & D required to ensure the success of future projects. There are needs which can be clearly identified now, such as equipment for ISAC I and II at TRIUMF. There are other projects which we can identify as extremely likely to need significant resources in the near future, including development work for instrumentation for the future Linear Collider. We request $ for the development of these new initiatives.

5 Consequences of No Reallocation Funding

The subatomic physics community has identified a prioritized programme, focussing over the next five years on maximizing the scientific return of SNO and ISAC, 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 ends up reducing the overall resources to the community, the LRP identified a number of specific areas where cuts would have to be made:

- The next generation rare K decay experiment, KOPIO, would have to be significantly curtailed. This would be a severe blow, given Canada's leadership in this ground-breaking experimental programme.
- Instrumentation for ISAC II would have to be delayed, jeopardizing our lead in the radioactive beam research frontier.
- We would be unable to scale up the PICASSO experiment to make it an internationally competitive project.

By making these cuts, we would be avoiding explicit cuts in our highest priority projects.

However, we note that the "status quo" scenario in the LRP makes no provision for inflation for our highest priority efforts. This means that even with the difficult decisions outlined above, the fields's highest priority experiments, SNO, ISAC and ATLAS would suffer significantly and we would impair the ability of Canadian scientists to continue to be leaders in these key areas. The Canadian SNO team would be unable to fully participate in the physics analysis of this experiment as they would have to first fulfil their responsibilities to operate the facility itself. The SNO collaboration itself will be unable to desseminate the impact of its research most effectively, further harming Canada's impact and competitiveness. The ISAC I science programme, especially the more difficult and low rate astrophysics measurements, will be delayed. Progress on the design and construction of ISAC II will also be affected, leading to Canada losing ground in the high-energy beam programme. ATLAS/Canada collaboration will not be able to meet its schedule to test the remaining calorimeter modules, while at the same time completing construction of the hadronic endcap and forward calorimeter.

The community's overall ability to perform the essential R&D for the next generation experiments will be impaired through less University-based infrastructure support and the needed funding to develop next-generation experiments such as PICASSO+, TIGRESS and KOPIO. The resources to provide the data processing and scientific computation to analyze the current large data sets being gathered by Canadian scientists will not be available. This would effect experiments such as E949, TWIST, CDF II, ZEUS and SNO, which depend increasingly on Canadian data-processing capability.

There would be a further erosion in support for Canadian students and postdocs working on experiments at the major international laboratories, reducing our effectiveness in the international context and having an adverse effect on training of our students.

6 Implementation of the Last Exercise

The last Reallocations Committee recognized that the subatomic physics submission emphasized fundamental and important questions in the overlapping areas of nuclear and particle physics. That submission was made following detailed planning by the community which laid out clear priorities for a well focussed program. Two of the proposals were supported by the Reallocations Committee. Fully funded was the proposal for support of the Five Year Plan, in the amount of \$1.2M. The request for \$0.6M in support of research and development and smaller new initiatives was partially funded at \$225k. The Reallocations Committee also recognized the validity of a third proposal, namely the need to increase the Canadian contribution to the construction of the ATLAS detector. However, they chose to consider that as part of the support of the Five Year Plan.

In addition, there was a general increase to the NSERC reallocations pot distributed proportionally, with our share being \$294k. This total of \$1,719,452 less the \$1.176M put into the reallocations pot meant a net reallocations gain of \$543k, to be phased in over the four years 1999 through 2002.

This positive outcome in the reallocations exercise was enhanced by increases to the NSERC research grants budget. The SAP envelope, which was \$18.8M in 98/99, has risen to \$20.5M in 01/02. The phase-in of the full reallocations amount will bring the envelope to \$20.7M in 02/03. It should be noted that this funding level, adjusted for inflation, is below the pre-1996 level.

GSC recommendations to implement the reallocations decisions were made taking into account all these positive changes to the funding environment. Consequently, it is not always possible to make a completeseparation of decisions specifically targetted to reallocation funds. More has been accomplished than would have been possible with only the reallocated funds. However, as will be described below, GSC decisions have been entirely consistent with the vision and plan of the subatomic physics community and, correspondingly, with the recommendations of the last Reallocations Committee.

With respect to the reallocations funding in support of the subatomic physics Five Year Plan, the top priorities are clearly the ISAC, ATLAS, and SNO projects. Funds were allocated to support the capital needs of our top priorities, in accordance with the detailed planning document of the community. These capital needs peaked during the period of implementing this exercise, with the corresponding pressure on operating budgets. Total spending on SNO, ISAC, and ATLAS peaked at \$9.58M in 2000, of which \$4.3M was capital.

Because of the new funds, it was possible to expand the scope of the ATLAS project to include construction of a second wheel of the hadronic end cap calorimeter. Furthermore, as capital costs for this project have now begun to decline, significantly increased operating funds are targeted to allow successful delivery of the detector components under construction as well as the opportunity to engage in the development of physics analysis tools. Ongoing support at an appropriate level is necessary to ensure the Canadian ATLAS collaboration will play a significant role when physics data taking commences.

The period of implementing the last reallocations decisions coincides with the milestones of first delivery of unaccelerated radioactive beam at ISAC followed by delivery of the high energy beam. Continuing strong and timely support of the ISAC experimental program is necessary in order to fully exploit this unique facility. This recognition has been reinforced by the award of reallocations funds for new detector systems, such as the gamma ray detector for DRAGON ($227k) and the 4π positron detector ($163k), along with the associated operating funds.

Support of the now fully operational SNO project has generated their first exciting and definitive investigations of the solar neutrino problem. The collaboration measures a total solar neutrino flux in excellent agreement with the prediction of the standard solar model, while also finding a deficit in the charged current rate. The implication is that neutrinos do oscillate between species and some discrimination between models has already been accomplished. The unique neutral current measurement with salt in the water is underway. The SNO results have had an extremely high profile, even in the popular media.

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. There has been no shortage of innovative ideas however, with excellent candidates for this type of support in every NSERC grants competition.

Reallocations funds in support of R & D and smaller new initiatives have begun to address this need. In particular, a few projects with the potential for tremendous future impact internationally have been supported with reallocations funds.

These include R & D and prototype work on the KOPIO project ($630k during implementation period), an initiative growing out of the existing rare kaon decay program aimed at understanding the mechanism of CP violation. The PICASSO group is developing a novel detection system for dark matter - one of the most fascinating aspects of our universe - which will also exploit the unique characteristics of the SNO site. ($468k during implementation period) They have demonstrated the ability to make interesting measurements even at the prototype stage. Both these projects were initiated by Canadians.

Research and development funds were also awarded for the proposed search for states with exotic quantum numbers at the TJNAF Hall D. ($62k) Two projects aimed at a future international Linear Collider facility have been funded through reallocations. ($270k + $53k) Such a facility is likely to be the highest priority for particle physics beyond the LHC, with the capability to precisely characterize discoveries made at the LHC. Early participation in such an important project is critical for Canadian scientists to make an impact in the future. The possibility also exists for accelerator development with TRIUMF expertise.

As noted by the last Reallocations Committee, our subatomic physics effort has a high profile internationally. New funding has been critically important 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.

7 Concluding Remarks