CANADA

Report of the
National Advisory Board
on Science and Technology

BIG SCIENCE COMMITTEE REPORT ON THE KAON PROJECT

Presented to the
Prime Minister of Canada

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Conseil consultatif national des sciences et de la technologie

October 17, 1990

The Right Honourable Brian Mulroney, P.C., M.P.
Prime Minister of Canada
Langevin Block
Ottawa, Ontario
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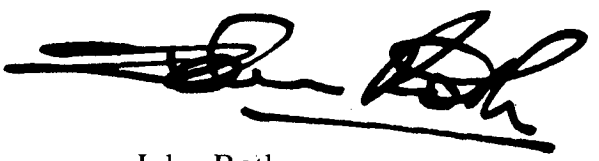
Dear Prime Minister,

The Big Science Committee of the National Advisory Board of Science and Technology is pleased to submit this report on the proposed KAON facility. This paper summarizes the committee's assessment and recommendations regarding the KAON project and proposes options for Canadian research in particle physics.

The Big Science Committee recommends that the Federal Government not fund the KAON proposal. While not unanimous, this recommendation has been endorsed by the vast majority of NABST members. The rationale for this negative recommendation is detailed in the report.

I would like to thank you on behalf of NABST, and in particular on behalf of the members of my committee, for the opportunity to review the KAON project. I trust you will find our report useful.

Yours truly,



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REPORT OF THE BIG SCIENCE COMMITTEE ON THE KAON PROJECT

The Honourable William C. Winegard, Minister for Science, has requested the Big Science Committee of NABST to review the proposed KAON facility, applying its criteria for "Big Science" projects, and to develop a set of recommendations for a course of action on the KAON proposal and on Canadian research in particle physics. This report summarizes the committee's assessment and recommendations.

INTRODUCTION

For the purpose of this report, it will be assumed that the reader is familiar with the background to the KAON discussions and has a general familiarity with the issues facing this decision. The *Report of the Long Range Planning Committee on Subatomic Physics*, which is attached, provides an excellent overview of the challenges facing this field of research and the purpose and capabilities of the various facilities. This report focuses on the assessment of KAON against our previously established criteria for Big Science projects, and against a first cut of Canada's S&T priorities. It will also put forth recommendations on how to proceed in the area of particle physics, and how to provide leadership and direction to future Big Science proposals.

ASSESSMENT

Scientific Excellence and Value

The first criteria for a Big Science proposal are scientific excellence and value. While the KAON proposal would not approach the energy levels of the European facilities at CERN or the proposed American Supercollider, it would achieve new levels of beam intensity at significant energy levels. The role of KAON would be to search for and to examine very rare events, since its high intensity would permit millions of possible events per second. The international community of particle physicists has agreed on the need for such a facility. Competing proposals from facilities in other countries have also come forward to create KAON type capabilities; however, it is a credit to the TRIUMF team that the international community of particle physicists has thrown its moral and financial support behind the Canadian proposal. At this point KAON has received pledges of some $200 million toward an eventual construction of the facility.

It is the view of the Big Science Committee that the proposed KAON facility would meet the criteria of international scientific merit and value.

Social and Economic Benefits

Training of Engineers and Scientists: The KAON facility would result in a doubling in the number of particle physicists in Canadian programs and would allow Canada to attract and retain high calibre researchers and professors to this facility and related programs.

Perhaps the more relevant question for Canada is: "Would this be the most cost effective way of training the human resources Canada needs in particle physics?" Canada has a well respected subatomic physics community which includes the team at TRIUMF as an important component. The *Report of the Long Range Planning Committee on Subatomic Physics* recommends that Canada should only proceed with KAON if the total annual budget for subatomic physics research is raised to $150 million over and above the cost of constructing the facility. This level would be required to support the KAON facility and its programs and the work of Canadian researchers at international facilities. Below this level the report recommends accessing one of the international collaborations.

Technological Benefits: The main purpose of the work at KAON would be to explore the validity of the "Standard Model" and to improve the world's understanding of quarks, leptons, bosons, the Higgs particle and so forth; consequently, social or industrial benefits are not direct objectives of the project.

The construction of the facility would push a number of technologies and manufacturing processes to new plateaus; however, the contributions to KAON from other countries would be in the form of high tech manufactured goods and not cash. Consequently the opportunity for Canadian content in the high tech portion of KAON would be limited.

It is the view of the committee that the technological spin-offs from this project would be low when compared with other more practically oriented S&T programs, or other projects that better fit Canada's social and economic objectives.

Regional Development: The KAON facility would retain the community of particle physicists that has developed around TRIUMF and the construction of the facility and its ongoing maintenance would provide continued employment. However the experience at TRIUMF and other facilities indicates that we should not expect a high level of industrial spin-offs.

Public Awareness: The Canadian public today is concerned about protection of the environment and quality of life, plant closures due to globalization, the lack of Canadian industrial competitiveness, high interest rates and the national debt. While the B.C. Government is firmly behind this proposal, it is the view of the committee that the Canadian people would see this as a billion dollar expenditure that would measurably increase the national debt while not addressing any of the priorities facing the nation.

The committee further believes that the majority of Canada's scientific community would not view this initiative as a direct benefit; only 2-3% of Canada's 6800 NSERC funded scientists are involved in this field of study. The proposed annual operating costs of KAON are disproportionately large when compared to the NSERC's annual budget of $423 million and would come at a time when many of the other scientific disciplines in Canada are underfunded. Many scientists are concerned that proceeding with this very costly project could ultimately lead to further reductions in other disciplines.

Cost Effectiveness

This issue of cost effectiveness has many aspects. Certainly the proposal to build a KAON facility using TRIUMF as a source would be one of the most cost effective ways of creating such a facility if "cost effectiveness" is viewed in that context. However, creating such a facility may not be "cost effective" for Canada.

The issue of ongoing evolution must also be faced. CERN has just asked for approval for its next phase, to double energy levels at a cost of some 1.8 billion Swiss francs. A decision on KAON must be a long term decision and would require that we be prepared to finance not only the construction and operating costs as presently contemplated, but also the ongoing evolution costs which would be significant. Failure to fund such evolutions would shorten the useful life of the facility.

The issue of the cost of constructing and operating such facilities is not unique to Canada. CERN has started a movement toward user fees to support the operating and evolution cost of the European facility and we can expect that user fees will be established for non-members by the time KAON is in operation. It is the Committee's view that participant user fees will become a normal part of operating international research facilities and that we must plan to cover such fees as part of funding the various scientific disciplines.

Management

The TRIUMF team has the demonstrated skills and track record in the operation of such a facility. This resource, backed with project management skills that the B.C. Government could assemble, ensure that KAON construction and operation would not be a concern.

Science and Technology Priorities

Canada does not yet have clearly set-out S&T priorities to support its social and economic goals. Consequently, as part of this report, the Big Science Committee, in conjunction with the NABST S&T Priorities Committee, has developed a framework for Canadian Big Science S&T priorities.

The fundamental platform for Canada's strength in science and technology is the quality of our talent in the "Small Science" programs. Today this base is being weakened by underfunding, and strengthening our Small Science programs must be our first priority. At this point in time, increasing the granting councils' funding is our highest priority to improve the capabilities and knowledge of our people in all disciplines.

As a second priority, the Committee believes that Big Science projects ($25 million or more over five years for any single project) can be used to stimulate innovation and be a catalyst for change. However, the prioritization criteria for Big Science projects must take into account the ability of the economy to fund such projects. When the economy produces chronic deficits, as is the situation in Canada today, then any additional Big Science project can only be financed through borrowing.

Therefore, it is the opinion of the Committee that in the foreseeable future Canada should concentrate its efforts on R&D to improve the capabilities and knowledge of its people and should invest in projects that have foreseeable spin-offs to ensure that Canada develops an economy that can compete with the best in the world, producing stimulating new jobs and new opportunities for future generations of Canadians.

RECOMMENDATIONS

The cost of particle physics facilities has escalated through Big Science to what may be referred to as World Scale Science. Many of the other G7 nations have pooled their resources and are now tackling these fundamental questions about the make-up of our universe together. The researchers of the U.K., France, Germany, Italy, Sweden and Japan are all working within collaborative programs.

While the proposal to build a Canadian facility would be appealing, the Committee believes that gaining access to one of the world's leading facilities would better serve the needs of all Canadian physicists. Based on this conclusion, the Committee's recommendations are as follows:

- The federal government should not fund the KAON proposal. The expenditure represented by KAON would distort the funding of science in Canada to an extent that cannot be justified by the reasonably anticipated benefits of the project. To maintain and advance a dynamic scientific community in subatomic physics, Canada should invite the Canadian particle physics community to propose a set of international projects consistent with a specified funding envelope.

- The funding for access to these projects should flow through NSERC, specifically be added to the envelope of NSERC and be managed through the peer review process. NSERC should be asked to establish long term funding levels for this field to allow the subatomic physics community to plan and organize the research programs properly.

- The role of TRIUMF will have to change. Responsibility for planning and implementing this transition is not clear as funding responsibility for the work at TRIUMF is currently split between NRC and NSERC. The Committee recommends that the funding of TRIUMF be clarified and that one of the agencies be named to take the lead to plan and implement the transition with the management of TRIUMF.

- The federal government should increase the granting councils' annual budget to better support Canada's <u>TOTAL</u> scientific effort.

- Big Science Projects can be a catalyst for innovation, but in the present economic circumstances, major investments can only be considered if the project goals <u>DIRECTLY</u> address Canada's economic and social priorities.

REPORT OF THE

LONG RANGE PLANNING COMMITTEE

FOR

SUBATOMIC PHYSICS

May 1990

DETAILED OVERVIEW

and

SUMMARY of RECOMMENDATIONS

A Report to
the Presidents of
The Natural Sciences and Engineering Research Council
and
The National Research Council

Submitted by Robin L. Armstrong, Chairman LRPC-SP

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Introduction

This report is the response to a request from the Minister of Science, the Honourable William C. Winegard, made in the summer of 1989 to the President of the Natural Sciences and Engineering Research Council (NSERC), Dr. Arthur W. May, and the President of the National Research Council (NRC), Dr. Pierre O. Perron. The Minister asked the two Presidents to provide him with advice on options for a balanced Canadian program in subatomic physics over the next decade and with a 25 year vision. Noting that at present the annual federal expenditure on subatomic physics is about 50 million dollars ($50M), the Minister suggested that the following options be considered for annual expenditures in the 1990s: $150M, $75M, $50M and $40M.

To meet the Minister's request, NSERC and NRC officials proposed the establishment of a Long-Range Planning Committee on Subatomic Physics (LRPC-SP) and set out terms of reference. The subatomic physics community was asked to comment on the terms of reference and to suggest names of individuals to serve on the Committee.

The LRPC-SP held its first meeting on November 1, 1989. At this meeting the terms of reference were finalized, the procedures to be followed by the Committee were defined, and a schedule of meetings and special assignments agreed upon. Community input was obtained through the submission of briefs to the Committee, through a series of four specialized "Town Meetings" covering different sub-fields, and a two-day general "Town Meeting". After appropriate reflection and discussion, the Committee reached the consensus reflected in the recommendations presented below.

What is Subatomic Physics?

Subatomic physics is concerned with the study of matter at distance scales smaller than that of the atom. It is convenient to subdivide subatomic physics into nuclear physics and particle physics.

Nuclear physics is the study of the properties of the atomic nucleus. It provides a link between the physics of the elementary particles and the properties of nuclear matter. The shape of the nucleus, the disposition of nucleons inside, the microscopic interactions between a few nucleons, and the collective behaviour of the large number of nucleons present in a heavy nucleus can be studied by observing radioactive decays, and by scattering beams of particles from nuclear targets. In addition to its intrinsic interest, nuclear physics is an essential part of astrophysics. Stars generate energy as a result of the nuclear reactions and decays that take place within them. These astrophysical processes fuel stellar evolution and are responsible for synthesizing the chemical elements. Our understanding of the structure and development of the universe thus depends on our knowledge of the nuclear physics that drives it. The development of particle beams of higher energy and greater intensity, the use of polarized beams and targets, the use of heavy-ion beams, and the use of more sophisticated particle detectors are opening new areas of nuclear physics and astrophysics research.

Particle physics is the study of the structure of matter at the smallest distance scale that is available in the laboratory. This scale is reduced every time that a new accelerator with a higher particle-beam energy is built. At the present time particle physics is concerned with the study of quarks and leptons, which are candidates for the basic building blocks of matter, and their interactions including the concept of fundamental symmetries. A model called the Standard Model has been developed which has been astonishingly successful in describing all the known laws of physics. Nonetheless, the Standard Model leaves certain important questions unanswered, such as whether the quarks and leptons are indeed the ultimate "elementary particles" sought since the time of the Greek philosophers. Pushing back the energy frontier has in the past always produced major breakthroughs in our understanding of the laws of nature. Based on the successes of the past and the opportunities for the future, the United States government has been convinced to give its approval to build the multi-billion dollar Superconducting Super Collider (SSC).

Nuclear physics is a mature field of research. As such, it has contributed extensively to modern technology and to the economy. The results of basic nuclear physics are used in nuclear power generation, nuclear medicine, solid state physics, metallurgy, chemical analysis, food preservation, and so on. Particle physics is a more recent endeavour and hence has so far contributed less directly to our economic well-being. However, there have been indirect contributions. Technical developments achieved to permit research to be performed on the edge of feasibility have found industrial applications. For example, products have emerged as a result of the development of large-scale superconducting magnets required for high energy particle accelerators, fast electronics required in high-rate detectors, and novel computing systems required in theoretical work. In addition, indigenous industrial capability sharpened to meet the needs of research has found new markets.

A brief history and status report of Canadian facilities

As a result of excellent basic and applied research, Canada emerged as a world leader in nuclear physics in the 1950s. For example, the NRX reactor at Chalk River, regarded as the best research reactor in the world at the time, was the forerunner of our nuclear power industry based on the CANDU reactor. The world's first tandem accelerator was installed at Chalk River in 1959, and seven major nuclear installations were funded by AECB in a five- year period in the early 1960s. The various universities across Canada that acquired accelerators hired additional nuclear physicists, and began training more graduate students. But by the mid-1970s, these facilities were beginning to reach the end of their useful lifetime, the faculty associated with them were aging, and research money was scarce. The new questions that had emerged as a result of the exploitation of these machines required new facilities to be built, with the result that the TRIUMF laboratory was established. Of the original facilities, only the Saskatchewan Accelerator Laboratory (SAL) presently survives as a pure nuclear physics laboratory. This facility has recently been upgraded by the addition of a storage ring so that SAL now provides continuous currents of electrons. The other modern nuclear physics facility

in Canada is the recently completed Tandem Accelerator SuperConducting Cyclotron (TASCC) at Chalk River; it provides heavy-ion beams.

In 1974, the first beam was extracted from TRIUMF and its proud history of achievements was soon to begin. This new facility provided a major boost to Canadian subatomic physics despite the fact that its early development was seriously hampered by under-funding. Even at it peak, the laboratory was funded at only half the level of its direct competitors. Nonetheless, TRIUMF has produced more than its share of achievements in the regime known as intermediate-energy physics, at the boundary between nuclear physics and particle physics. The TRIUMF laboratory has been Canada's contribution to the world network of accelerators for the last 15 years and has enjoyed a high level of international participation. However, as it approaches its twentieth year, the scientific impact of the original TRIUMF cyclotron is declining and it is urgent that a decision be taken on the future of the TRIUMF laboratory.

In 1971, the Institute of Particle Physics (IPP) was formed to coordinate the growing Canadian activity in particle physics. IPP helped to establish a Canadian experimental program in the field based mainly on accelerators in the USA, in particular, Fermilab near Chicago. In 1980, IPP proposed the construction of an electron storage ring at Fermilab. Although the proposal was not funded, it led to participation in a more ambitious accelerator project called HERA at the DESY laboratory in Hamburg, Germany. Canada broke with its tradition and provided a modest but significant contribution to accelerator construction abroad. During the 1980s, a strong and internationally recognized program was developed by IPP; currently it is centred around the large detectors called ARGUS and ZEUS at DESY in Hamburg, and OPAL at CERN in Geneva, Switzerland.

Recently the decision to proceed with the Sudbury Neutrino Observatory (SNO) has been taken and project construction has begun. In both the IPP and SNO programs the members of the High-Energy Physics group at NRC have been major participants, and the NRC infrastructure support vital. It therefore came as an unwelcome shock, in the midst of this planning exercise, to be informed by NRC authorities of their intention to withdraw from subatomic physics over the next five years.

Demographics

The total number of subatomic physics experimentalists in Canada is about 170. They are assisted by just over 60 research associates paid from NSERC grants, about 40 of whom are involved in particle physics research. The number of theorists is about 65. The number of particle physics experimentalists has increased by about a factor of two during the past decade as a result of new faculty hiring in the universities, by a shift of individuals from nuclear physics to particle physics, and by the establishment of a particle physics group at the University of Victoria. They now represent about 40% of the total. The nuclear physicists are on average older, and hence more of them will retire over the next decade. Over the same period the total number of subatomic physics graduate students has grown to 250, an increase of 55%. Much of this growth comes from the

number of students studying experimental particle physics, which has gone up to 40, an impressive increase of 191%. There is no doubt that this trend will continue during the coming decade.

New thrusts in particle physics for the 1990s

The underlying fundamental question for particle physics in the 1990s is: What is the origin of mass?

One problem relating to this issue is the origin of the electro-weak symmetry breaking in the Standard Model. Within this model the W and Z particles will, if no new physics intervenes, start to interact strongly in such a way that the cross-sections for certain processes will violate the unitarity bound at a mass scale of around 1 TeV. In the Standard Model this impossibility is circumvented by the existence of the Higgs particle which, it is postulated, is too massive to directly manifest itself at the present generation of accelerators. The search for the Higgs particle (which in the Standard Model gives all other particles their masses) is the major motivation for the choice of the design energy for the SSC. However, there may be no Higgs particle. In that case, some other new phenomenon such as quark substructure, or new symmetries of nature, must be discovered.

A second related problem is concerned with the mechanism for charge conjugation-parity (CP) violation. So far, CP violation has only been observed in the neutral K-meson system. If CP violation is properly described within the Standard Model, where it is part of the "mass matrix" generated by the Higgs particle, then it is possibly within experimental reach in the beauty-quark (b-quark) system. However, present accelerators lack the necessary intensity to explore this possibility.

Within the Standard Model the strong interactions of the quarks are described by Quantum Chromodynamics (QCD) and the unified electro-weak interactions by the Glashow-Weinberg-Salam theory. Although QCD is given by a formally simple and aesthetically pleasing equation, we have only a rudimentary understanding of it and of the phenomena it contains. For example, we are able to postulate the existence of new forms of matter called "glueballs" but we cannot yet predict their properties. To search for glueballs and otherwise experimentally explore the ramifications of QCD will require accelerators of much higher intensity than those of the present generation.

In tackling these questions, subatomic physics will continue to attract many of the brightest young people in our society. These individuals are also the most mobile; they are driven by science and are sought by foreign graduate schools as students, and by foreign universities and laboratories upon graduation. They are highly prized by our own institutions, which are beginning to rebuild their faculties after a prolonged period of restricted hiring. If Canada is to attract and retain such scientists, it is important to embark now on a program that will ensure access for them to the front-line experimental facilities available in the world. To achieve this Canada will have to increase its level of support for subatomic physics.

The exploration of these boundaries of our knowledge of the nature of matter will require the construction of new accelerators with either higher energies than those of existing machines or with greater intensities. The world community of subatomic physicists has proposed an array of facilities to be built in the 1990s to carry out experiments during the first decade of the next century. In view of the construction costs of these accelerators, no country can afford to build all of them. By the same token, no industrially developed country can expect access to these accelerators unless they contribute to their construction, either by building one at home, or by contributing components to one abroad. Canada has been leading the world on KAON-Factory proposals since the first KAON-Factory workshop held at the University of British Columbia in 1979. It is because of its expertise and reputation that TRIUMF has created the KAON-Factory opportunity for Canada as its contribution to the world network of particle accelerators. This is one of the high intensity machines; it is particularly well-suited to the study of QCD physics, but it could provide answers to any of the outstanding questions of particle physics. No one can predict with certainty at which facility the critical discoveries of the next decade will be made.

The importance of having a major facility at home cannot be overstated. The construction of the KAON-Factory will create an outstanding research environment and give Canada credibility as a nation among our G-7 partners. KAON physics is acknowledged by the world community as a priority for the future. The KAON-Factory will form the centrepiece of Canadian subatomic physics for many years to come. We will be recognized as having made our contribution to the international network of particle accelerators so that our scientists, with their record of achievement, will continue to be welcomed at foreign laboratories. The publicity surrounding a major discovery made at a laboratory in Canada will reflect positively on Canada; the publicity relating to a major discovery made at a laboratory outside of Canada (even if the group includes Canadian scientists) has much less impact for Canada. What is even more important is that a Canadian-based facility will bring to Canada a host of scientists from around the world. The equipment that they will bring and the intellectual stimulation that they will generate among our scientists and students will be invaluable. A major national laboratory also offers expertise for the planning and preparation of experiments to be carried out abroad. Such a facility can provide an important stimulus to high technology industry throughout Canada. Technologies and production methods developed for KAON-Factory contracts could provide a variety of industries with other opportunities to compete successfully for international contracts for similar specialized equipment.

We strongly support a positive decision to proceed with the KAON-Factory, but with the condition that the decision be made in calendar year 1990. There are good reasons for the condition imposed. It has been acknowledged that Canada has a head start to be the site of this major international facility and we now have a window of opportunity to negotiate substantial foreign contributions for its construction. A portion of the specialized manpower to build the KAON-Factory has been assembled for the Project Definition Study and will be hired away if a decision is delayed over a long period. A final and very important reason is that no other initiatives for the future can be given serious consideration until there is a decision on the KAON-Factory.

If the KAON-Factory is approved, it must be funded in a manner which ensures its timely completion, provides for adequate exploitation of the facility by Canadian physicists, and maintains a balanced program in subatomic physics through the provision of adequate support for other parts of the discipline. In the event of insufficient funding, the entire Canadian subatomic physics program would suffer, and this would be worse than not funding the KAON-Factory at all.

Building on the foundation

The community of subatomic physicists is presently, and has been for the past decade, very active. There are many projects now in progress that have a high potential for yielding important physics results over the next five to ten years. Some are already probing the frontiers of particle physics; others are exploring the frontiers of nuclear physics and astrophysics. Projects presently in progress represent wise investments of research dollars and adequate resources must now be allocated for their effective exploitation. At the same time, investments for the future must be made so that new facilities and experiments will come on-line as some of the existing ones reach the end of their useful lifetime. **It is the unanimous view of the Committee that a substantial shift in the relative support from nuclear to particle physics must occur over the next decade, and that this should be achieved through an increase in total funding**. The demographics in the subatomic physics community in Canada and the funding patterns in other countries support this recommendation. The message is not that we are critical of the present nuclear physics program, nor of the potential for important work in nuclear physics in the future. Rather, we are convinced that Canada must also participate at the new frontiers of particle physics because such research is fundamentally exciting, necessary to keep subatomic physics vibrant in Canada, and essential if we are to retain the brightest physicists as our university departments rebuild. Canada has to date not been seen by its international partners to have contributed sufficiently to the costs associated with particle physics research. It has recently been made clear, in particular by the CERN Council, that in the future Canada will not retain its access to facilities in foreign countries unless this situation is changed. **Therefore, we strongly recommend that increased spending on subatomic physics research is required; we believe that status-quo funding will result in a serious deterioration of our international reputation**.

The important Canadian initiatives that must be exploited in the short and intermediate term are the following:

a) At two high-energy facilities in Europe there are new large detectors for which Canadians have supplied important subsystems. These are OPAL at CERN in Geneva, and ZEUS at DESY in Hamburg. OPAL has recently completed its first data collection run, and ZEUS will begin to acquire data in 1991. The OPAL experiment provides information on the Standard Model coupling of quarks and leptons to the carrier of the electro-weak force. The first experiment already has provided a very important result: it indicated that there are no more than the three generations of neutrinos that have been reported at low energies. At ZEUS, electrons are used to probe the structure of the proton as a test of QCD and to

search for substructure to the quarks and leptons. The scientific productivity of these projects promises to be high throughout most of the 1990s.

b) The tremendous success in the exploration of the b-quark system with the ARGUS detector at DESY in Hamburg during the 1980s will continue for a few more years as the group exploits its new microvertex drift chamber.

c) The TRIUMF laboratory, which is Canada's largest basic science facility, is at a cross-roads as it awaits the decision on the KAON-Factory. Although NSERC funding for experiments in the meson hall has decreased, there is still excellent work being done, for example, the radiative muon capture studies and the muon spin resonance program. In addition, there are still important programs being pursued in the proton hall including, for example, experiments which provide information on parity violation in proton-proton scattering. These programs promise to provide valuable scientific results for at least several more years. However, there is increasingly strong competition from PSI in Switzerland, KEK in Japan, and LAMPF and BNL in the USA. TRIUMF personnel have developed forefront expertise in many high technology areas for support of scientific programs both at TRIUMF and elsewhere. A TRIUMF-based group, now working at BNL with the E-787 detector, is playing a leading role in the search for rare K-meson decays that are expected to provide a window on possible new physics beyond the Standard Model.

d) The TASCC facility at Chalk River, completed in 1989, is a unique heavy-ion facility. With the beams available there, scientists study what happens when nuclei are subjected to extremes of temperature, density, spin, and even, composition. The facility incorporates the world's most sensitive gamma-ray spectrometer and its highest resolution on-line isotope separator. This is a highly competitive field with competition coming from accelerators such as GANIL in France, NSCL in the USA, GSI in Germany, and RIKEN in Japan.

e) The SAL facility presently provides the only source of continuous intermediate-energy beams of electrons and tagged photons in the world. This allows, for example, tests of chiral symmetry, of microscopic models of nuclear structure, and of the importance of three-nucleon forces. The laboratory will begin to experience competition within a five year period as other facilities such as CEBAF in the USA, Mainz in Germany, and NIKHEF in Holland come on stream.

f) The SNO facility will be constructed during the next five years, and will operate for at least five years after that. This laboratory will make Canada the world leader in neutrino astrophysics. Experiments at SNO will contribute to our understanding of both energy generation in the sun, and of the fundamental properties of the neutrino.

New initiatives other than the KAON-Factory

Now that the SSC is an approved project, interest in it is beginning to develop among Canadian particle physicists. There is no doubt that proposals relating to experiments at the SSC will come from IPP scientists in the near future. This laboratory will define the energy frontier; as such, it will be one of the world's most important centres for fundamental research in particle and accelerator physics during the coming decades. We support the view that Canadian physicists should play an important role in this enterprise.

The Large Hadron Collider (LHC) proposed for CERN, although not yet approved, could come on-line before the SSC is operational. Some of the particle physicists will undoubtedly consider it an attractive alternative to the SSC. However, we do not believe that it is appropriate for Canada to pursue full or associate membership in CERN as a means to gain access to the LHC. But rather, in this case and in general, we believe that Canada should retain maximum flexibility by engaging in focused, bi-lateral agreements with CERN.

A new breed of accelerator, called a b-Factory, has been proposed as the accelerator of choice to tackle the problem of CP violation. Although no such machine has yet been built, various proposals are under development with those at SLAC and Cornell in the USA at the most advanced stage. There is interest among Canadian particle physicists in the projects in the USA. Such a proposal could afford Canada the opportunity for participation in machine construction as well as a significant role in the experimental programs. The latter would build on the expertise developed in the ARGUS experiment at DESY in Hamburg. In the event of a negative decision on the KAON-Factory, a proposal involving contributions towards a b-Factory should be given careful consideration.

There is interest among the relativistic heavy-ion physicists in an approved project called RHIC in the USA. These scientists currently carry out experiments at various laboratories outside of Canada and participation at RHIC would represent a natural progression for them.

A project called ISAC has been proposed for TRIUMF. With the intense proton beam from TRIUMF, intense pure ion beams of almost any radioisotope could be produced and accelerated by ISAC. Such beams are desirable for astrophysical studies of nuclear reactions and could yield the most exciting results relating to our understanding of stellar evolution in the next decade. Canadian scientists currently use isotope separators in Europe and at TASCC, and would be in a position to exploit ISAC. A facility of this kind would complement the SNO project and give Canada high international visibility in nuclear astrophysics.

Theoretical support

Subatomic physics theory has a role to play both in direct support of the experimental program and as a semi-autonomous discipline. In the final analysis these are not separate roles, as the ultimate theory is one which can account for all experimental observations. If you can't measure it, even in principle, then it isn't physics! The support required for theoretical subatomic physics is non-trivial, primarily because of computing needs, but it is small compared to the costs to build and operate major accelerator laboratories.

There is a strong case for having theoretical support in association with major experimental initiatives. **The Committee therefore recommends that Centres for Theoretical Subatomic Physics be established as a focus for theoretical activities in association with various Canadian programs such as KAON, and a particle physics program at the SSC or LHC.**

Infrastructure support

To perform their research efficiently and successfully, the subatomic physicists need professional and technical assistance and assembly space, as well as access to specialized machine shops, design and engineering expertise, and electronic shops. Adequate computing facilities, which can be accessed easily by the community, are a vital ingredient for successful research. This essential backbone of support is called infrastructure.

The network of infrastructure that presently exists in Canada is built on expertise and facilities at NRC, AECL, TRIUMF and various universities. The network lacks focus and cohesion. It is all too common for funding decisions to be made for accelerator upgrades, or detector development, without due regard for securing the necessary infrastructure support. The recent decision on SNO is a good case in point. Hard on the heels of a positive decision by the federal government to go ahead with the project, NRC announced its intention to withdraw from subatomic physics research, thereby inadvertently placing the project in jeopardy.

TRIUMF is already providing substantial infrastructure for Canadian subatomic physics. In principle, it might be argued that TRIUMF could supply all of it, independent of the KAON-Factory, and the future of the present cyclotron. However, it is not at all obvious that this would be the most sensible or desirable solution.

We recommend a comprehensive examination of the question of an appropriate infrastructure base for experimental subatomic physics in Canada immediately following the KAON-Factory decision. Further, we recommend that NRC stays its decision on phasing out support for subatomic physics until this review has been completed and until a detailed plan for devolution can be developed.

Research funding and management

The funding for subatomic physics comes at present from three separate agencies - NSERC, NRC and AECL. This of itself is not necessarily bad, provided that decisions for the re-allocation of funds are coordinated between the agencies. The deliberations leading to this report were complicated by the AECL contribution. Our planning exercise was initiated at the request of the Presidents of NRC and NSERC, and yet the status-quo budget provided included the AECL contribution for TASCC, with all salaries and overhead accounted for in the latter instance. It was the view of the Committee that this money was in no way fungible, but rather was tied to the TASCC facility. Of even greater concern is the NRC contribution to TRIUMF. In some scenarios, our recommendations imply a transfer of funding over time from the TRIUMF-based cyclotron program to other projects, and yet we have no reason to have confidence that this would occur. Yet it must occur, or any attempt at rationally guiding the evolution of subatomic physics will be thwarted. We feel strongly that the federal funds allocated to subatomic physics by the three agencies must be somehow linked so that the overall level of funding, and with it the subatomic physics program, cannot be disrupted by the unilateral decision of an individual agency.

The management of our home-based facilities and their experimental programs are at the moment carried out in a somewhat ad-hoc fashion. SAL is entirely funded by NSERC and operated by the University. TRIUMF is operated by a consortium of universities through a contribution from NRC, with the Canadian experiments funded by NSERC. TASCC is operated and funded by AECL with facilities developed with contributions from both NSERC and AECL and the participation of university physicists supported by NSERC. A recent example which illustrates the limitations of the present structure is the dispute that arose this past fall between TRIUMF management and NRC and the concomitant recommendation by the NRC council to reduce the TRIUMF budget as of fiscal 1991-92. **We feel strongly that there is a need for a review of these procedures with a minimum goal of improved coordination.**

The funding scenarios

a) $150M - Canada a World Leader

We believe that Canada has the intellectual and physical resources to participate in subatomic physics at a comparable level to that of its G-7 partners. It is our perception that Canada as a member of the G-7 is expected by the other members to take a lead role in science. Through the construction and operation of the KAON-Factory as the key element of its overall program in subatomic physics, Canada will be seen to do so. The $150M scenario is the only one of the four funding scenarios in which the KAON-Factory is possible. **We recommend with highest priority that the KAON-Factory be approved.**

This level of funding will also permit Canadian scientists to participate in the new frontier area of TeV-scale physics at the SSC or LHC. That this be so is essential: we

would not recommend the KAON-Factory at the expense of TeV-scale physics. The KAON laboratory will have a dual role to play. As one of the nodes in the world network of accelerator laboratories, it will provide the facilities for Canadian physicists and their international colleagues to pursue an important subset of fundamental physics experiments. At the same time, it will serve as a vital infrastructure base for the Canadian community working abroad on TeV-scale accelerators.

Finally, this scenario will sustain the present program in particle physics through the 1990s, and support a rich program in nuclear physics through hypernuclear studies at KAON, heavy-ion nuclear physics at TASSC, photonuclear physics at SAL, nuclear astrophysics with the timely completion of SNO, and some participation in nuclear physics experiments abroad. This level of funding will support a program in which the quality and capacity of the research community is well utilized with a full experimental program on existing facilities while new accelerators and detectors are under construction for the next generation of experiments. That is, at $150M annual expenditure Canada can be a world leader in subatomic physics, with the KAON-Factory being the centrepiece of a balanced program in particle and nuclear physics research.

This funding decision allows for the operation of the KAON-Factory and leaves the necessary resources for TeV-scale physics and for nuclear physics. It is strongly recommended.

As an indication of the distribution of funds to the various facilities in 1995 we suggest the following:

KAON	$ 98M
SSC/LHC...	$ 30M
TASCC...	$ 15M
SAL	$ 3.5M
SNO	$ 3.5M
Total	$150 M

b) $75M - Canada a Significant Collaborator

In this scenario, we believe that **Canadian physicists can still have a major impact in TeV experiments and that our participation in such experiments should be the flagship of the subatomic physics program**. The SSC laboratory will be a prime focus of such research. Canada will soon have to consider what relationship it wishes to have to this laboratory; the USA has already requested a contribution from Canada.

CERN can be expected to remain pre-eminent in subatomic physics research and it is very possible that the LHC will be built. A large fraction of the Canadian particle physics research program is presently based at CERN, and its Council is pressing Canada for a formal relationship. **It will certainly be an urgent priority to negotiate such a relationship with CERN to ensure that the present program can continue through the 1990s and that future opportunities including the LHC are not jeopardized**.

By rejecting the KAON-Factory proposal, Canada loses the opportunity to be seen as a world leader in particle physics research. However, a KAON-Factory will be built somewhere in the world, and many of our physicists presently supporting the KAON-Factory for Canada will want to use such a facility no matter where it is located. Another group will likely propose participation in a b-Factory to be built in the USA.

Not all of the interesting particle physics initiatives will be simultaneously possible, not only because of the costs involved, but also because there is not a sufficiently large community to permit all the programs to be adequately staffed.

If the decision for the KAON-Factory in Canada is negative, it is important that the particle-physics community move quickly to develop a consensus on a balanced program which emphasizes the high-energy frontier, and ensures that Canadian involvements are appropriate for those of a strong collaborator.

Without the KAON-Factory, Canadian subatomic physics would largely be carried out at TRIUMF, TASCC, SAL and SNO at home, and at high-energy and high-intensity facilities abroad. This funding level would provide adequate support for an evolving experimental program at the home-based laboratories and also allow a reasonable level of participation abroad.

The future of TRIUMF must be carefully assessed. Whatever the future of the cyclotron, this national laboratory should evolve as the major Infrastructure Institute for subatomic physics in Canada. In addition, a strong nuclear physics program could continue in the 1990s using such special features of the cyclotron as its continuously variable energy, cw operation and polarized beams. Consideration should also be given to the construction of the ISAC radioactive beam facility at TRIUMF.

As an indication of the distribution of the $75M to the various facilities in 1995 we suggest the following:

SSC/LHC...	$ 30M
TRIUMF	$ 25M
TASCC...	$ 14M
SAL	$ 3M
SNO	$ 3M
Total	$ 75M

It should be noted that although the amount indicated for particle physics (SSC/LHC...) is $30M here, as in the $150M scenario, the program will be significantly smaller. This is because of the need, in the absence of the KAON-Factory in Canada, to support abroad the work of Canada's KAON physicists, and to contribute to the building of facilities abroad, in addition to the provision of apparatus for particle physics experiments.

In suggesting any redistribution of funds, we are cognizant of the lack of coordination among the three federal agencies that fund subatomic physics. This is a concern because of the joint requirements of funds to support peer-evaluated experimental programs, and the machine maintenance and infrastructure needs. These must not be considered in isolation. It may therefore be helpful to express the above distribution of funds in another way. It would correspond to an expenditure of $31M on the experimental and theoretical program allocated by peer review, $28M on infrastructure (TRIUMF, SAL, IPP), $13 on the TASSC operation and $3M on SNO. Here TASSC is singled out since, as mentioned above, it is funded by a source which the Committee felt was not within its purview.

c) $50M and $40M - Canada a Minor Participant

We do not recommend either the $50M or the $40M scenarios. In either case serious harm would be done to the subatomic physics program.

The $50M scenario was defined as "status-quo" funding which, according to our determinations, is in fact an annual expenditure of $56M. It must be noted at the outset that this level of funding is insufficient to fully exploit the physics potential of the present experimental facilities and projects. If the funding remains at this level, Canada will not be able to retain its present world reputation in subatomic physics. As previously stated, the CERN Council is unwilling to allow continued participation by the Canadian contingent, now numbering about 80, unless Canada makes an appropriate financial contribution. In addition, the USA is asking for contributions to the SSC construction and to a possible b-Factory. Therefore, to preserve our hard-earned present position in particle physics, let alone to pursue new initiatives that require the next generation of facilities, we must increase our expenditure on subatomic physics. Our present funding per particle physicist is significantly less than that provided in Europe, the USA, and Japan.

It is our fear that at the present level of support, given the likelihood that in the future we will be required to contribute to international facilities, many of the young subatomic physicists will leave Canada to pursue their quest for answers to the important physics issues of the day. We will certainly not be able to attract others to fill any of the increasing number of vacancies that will occur in our university physics departments during the coming decade. This will undoubtedly have a large negative impact on the education and training of a new generation of scientists which Canada needs to stay competitive among the industrialized countries.

If there are to be no new funds we strongly recommend that status-quo funding not be used as an excuse for status-quo research programs. To remain at all competitive we must retrench at home to those facilities that provide unique capabilities, while shifting a large part of our subatomic physics research abroad over a period of time. **The Committee anticipates that at least half of the funds available for the experimental programs and infrastructure would be allocated to particle physics.**

The essential first step of retrenchment at home would centre around TRIUMF. At this level of funding the Committee believes that the cyclotron must be phased down over a period of about five years, in a manner that would allow rational and responsible completion of existing programs at the laboratory. By the end of this period the TRIUMF laboratory would be the major Canadian base for the development and testing of components to be used for particle physics experiments to be carried out at foreign accelerators.

We are concerned that this scenario could mean a quick death to accelerator technology in Canada, and that our ability to undertake significant accelerator development projects would be lost. This would be a disaster as Canada will continue to need people trained in accelerator technology as accelerators now find common application in medicine (production of isotopes, PET machines) and in material science (synchrotron radiation facilities).

It is impossible to suggest a rational plan in the context of this scenario without having a realistic view of the potential total costs of supporting the foreign-based particle physics program.

In the bleak scenario of a reduction to $40M, it would be readily apparent to the international community that Canada does not intend to contribute its share to the total research output in subatomic physics, or to the international network of accelerators for particle physics. Although such a situation is almost unthinkable, the Committee believes that, even at this funding level a reduced subatomic physics program could and should be maintained.

With no ability to contribute substantially to foreign facilities, Canadian subatomic physicists would be left with no guarantee of access to these facilities. It is still quite probable, however, that small Canadian groups would be invited to participate in certain exciting physics projects. To maximize this possibility, it would be essential to maintain the TRIUMF laboratory as a home-base of infrastructure support.

In the view of the Committee, this "third world" attitude to subatomic physics would be a disaster for Canada and would result in a program of research over which we had little control, in particular in the emerging areas of particle physics, since it would depend on which scientists were prepared to remain in the country under such conditions. Some sub-disciplines would have to shut down to fund the remainder in a viable fashion. It would, however, be preferable to a complete withdrawal from a discipline which is at the forefront of the world's quest for knowledge.

Peer review and the need for a LRPC-SP

The basis for all decisions for the funding of experimental facilities and projects must remain a system of peer review. Any one of the existing laboratories should continue to be funded, if and only if, experimentalists with approved projects choose to come to that laboratory to do their experiments. We have made reference to more initiatives than can possibly be realized. Our reason for so doing is that the choices will ultimately be made by the degree of interest and expertise within the community, and by the process of peer review.

However, the world situation is evolving rapidly and is not under Canada's control. **We therefore recommend that the LRPC-SP be established as an on-going Committee to monitor the changing situation, and to modify the plans for Canadian participation in subatomic physics as appropriate**.

SUMMARY OF RECOMMENDATIONS

1. We recommend with highest priority that the KAON-Factory be approved. It is essential for overall planning in the subatomic physics community that the decision be made in calendar year 1990. This positive decision coupled with the $150M funding scenario provides the necessary resources to operate the KAON-Factory and to pursue participation in TeV-scale physics and nuclear physics.

2. In the event of a negative decision on the KAON-Factory we recommend the following: (a) that the funding base be increased to $75M with most, if not all, of the additional resources being allocated to particle physics; (b) that the particle-physics community produce, with some urgency, a coordinated plan which provides new initiatives at the TeV-scale and possible entry into b-physics; (c) that Canada should not pursue associate membership of CERN, but rather negotiate appropriate bi-lateral agreements; (d) that the future of TRIUMF be carefully assessed with particular attention being directed to the ISAC proposal.

3. We do not recommend either the $50M or $40M scenarios, but rather warn against the damage that could be done in either case. However, if either is selected as the operational funding base, this decision must not be used as an excuse for retaining status-quo research programs.

4. The basis for all decisions for the funding of experimental facilities and projects must remain a system of peer review. An on-going LRPC-SP should be established to monitor, and comment on, the rapidly changing world situation.

5. Centres for Subatomic Physics Theory should be established in association with various Canadian programs such as KAON, and an initiative in TeV-scale physics.

6. An ongoing LRPC-SP should, as its first priority following the decision on the KAON-Factory, examine the question of an appropriate infrastructure base for experimental subatomic physics in Canada.

7. NRC should stay its decision on phasing out support for subatomic physics until a review of the infrastructure needs for subatomic physics has been completed and until a detailed plan for devolution can be worked out.

8. A review of the funding procedures and management structures for subatomic physics research be undertaken with a minimum objective of achieving improved coordination.

Appendix A

Long-Range Planning Committee on Subatomic Physics
LRPC-SP
1989-90

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Appendix B

Joint NSERC/NRC Long-Range Planning Committee on Subatomic Physics

Terms of Reference

The Minister of State Science and Technology has asked the Presidents of NSERC and NRC to advise him on the major areas of research interest and opportunities in subatomic physics. The long-range planning committee is therefore asked to develop options for an appropriate plan for Canadian involvement over the next decade in the context of a 25 year vision. Various funding options will be identified by NSERC and NRC for this study.

In developing its plans, the Committee shall conduct an in-depth study of, and explicitly report on, the following issues:

1. The major research challenges and fundamental scientific questions in the field and their significance.

2. The quality of research training and the demand for graduates in the public, university and private sectors.

3. The opportunities for economic and social benefits to Canada (including spin-off benefits).

4. The current and potential demographics of the research community.

5. Existing and forecast Canadian intellectual strengths and weaknesses as well as existing and forecast Canadian-based facilities.

6. Extent of integration of the preferences and priorities of the subatomic physics community.

7. The facilities required and the infrastructure necessary for research within Canada, and the Canadian infrastructure necessary for effective participation abroad.

8. The realistic costs of the various experimental components.

9. The organizational arrangements that would ensure a well-coordinated planned development of the proposed research endeavours by the Canadian community.

The Committee is also asked to address explicitly the issue of Canadian involvement in subatomic physics research. Should Canada be a leader, a strong collaborator, a minor partner or a non-participant? This must be set in an international context and with particular reference to recent questions regarding the desired extent of interaction and formal linkages between Canada and CERN and the U.S.A., particularly with respect to their proposed major projects (the LHC and SSC).

JEH and JC
1989.11.23