Proposal for TRIUMF Commitment
(5YP 2015-2020)

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PROJECT/COMMITMENT TITLE: **SuperB Beam Polarisation**

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PROJECT DESCRIPTION:

SuperB is a new major international high energy physics facility located in Italy designed to measure the properties of particles produced in electron-positron collisions. The collision energies are selected to be just above the threshold for producing particles containing a b-quark with an option to also operate at lower energies just above the threshold for producing particles containing the c-quark. This facility, which will have first beams for physics in 2018, will be the highest luminosity electron-positron collider ever built. As such, SuperB will produce 100 times the data of existing facilities designed to probe the "flavour sector" of subatomic physics through precision measurements and searches for rare processes. It will also have the unique feature of using a polarised electron beam, which enables it to probe with unprecedented precision fundamental processes that depend on chirality.

The electron beam polarization requires a polarized gun, spin rotators and a Compton polarimeter. The Canadian SuperB group proposes that TRIUMF support SuperB by taking a lead role in one component of the beam polarization project. This will require recruiting a TRIUMF Research Scientist with the interest and expertise to lead the gun, rotator or polarimeter effort. At this time we leave open which of the three specific projects to pursue in order to maintain the flexibility required to accommodate TRIUMF's other constraints and the potential candidate pool. A future CFI application to support this activity can be anticipated. Other TRIUMF resources needed for the project will depend on which option is considered.

With its ultra-high luminosity, polarised beam, and the ability to run at both the b-quark and c-quark thresholds, SuperB is a unique and versatile facility and no other machine with all of these capabilities is planned. SuperB is sensitive to energy scales exceeding those of the LHC via the presence of new quantum effects revealed in precision measurements or rare decays of b-quarks, c-quarks, or tau leptons. Observation of such effects would indirectly imply the existence of massive new particles in yet-to-be-discovered fundamental processes. The physics community has recognized that flavour factories are needed in order to reach the next level: two other B physics experiments are either taking data (LHCb, which exploits the large particle production rate in proton-proton collisions) or under construction (SuperKEKB/Belle-II). SuperB is able to access a much broader physics program than LHCb because of differences in the production mechanisms between proton-proton and electron-positron machines. SuperKEKB/Belle-II, the other ultra-high luminosity electron-positron collider at the b-quark threshold energies, is being built in Japan; but it has a lower design luminosity than SuperB, and unlike SuperB cannot have polarised beams, nor is it designed with the flexibility of operating at the c-quark threshold

SuperB is an international effort involving accelerator and particle physicists from Canada, France, Italy, Norway, Poland, Russia, Spain, U.K., and the U.S. The project is classified as the highest priority project in the National Research Plan of Italy(http://www.miur.it/Documenti/ricerca/pnr_2011_2013/PNR_2011-2013_23_MAR_2011_web.pdf). The Canadian SuperB collaboration involves researchers from Victoria, UBC, Montreal, and McGill. It is currently supported by an NSERC project grant and has submitted a CFI grant proposal to support the construction of the SuperB drift chamber.

SCIENTIFIC JUSTIFICATION: SuperB will record an unprecedented number of B mesons, charm particles, and tau leptons. This will enable us to search for processes that are forbidden by the Standard Model, but predicted to exist in theories beyond the Standard Model. This data sample also permits us to make measurements with unprecedented precision. By comparing these results with predictions of the Standard Model and theories beyond the Standard Model, we are able to search for new physics.

In addition to the extensive physics program enabled by the high luminosity at the SuperB centre-of-mass energies, the polarisation of the electron beam enables SuperB to measure the weak neutral current vector coupling, g_V, constants of the b-quark, c-quark and muon at significantly higher precision than any previous experiment. The precision of the measurements of the vector coupling to the tau and electron will be comparable to that attained at SLC and LEP. Within the framework of the Standard Model these measurements of g_V can be used to determine the weak mixing angle, θ_W, through the relation: $g_V(f) = T_3(f) - 2Q(f) \sin^2\theta_W$, where $T_3(f)$ is the 3rd component of weak isospin of fermion f, Q(f) is its electric charge in units of electron charge. For each identified final-state fermion-pair in the process $e^+e^- \rightarrow$ f fbar, SuperB determines $g_V(f)$ by measuring the left-right asymmetry, $A_{LR}(f) = (\sigma_L - \sigma_L)/(\sigma_L + \sigma_L) = (s\, G_F) / (\sqrt{2}\, \pi\, \alpha\, Q(f)) \cdot g_A(e) \cdot g_V(f) \cdot \langle Pol \rangle$, where $g_A(e) = T_3(e) = -0.5$ is the neutral current axial coupling of the electron, G_F is the Fermi coupling constant, s is the square of the centre-of-mass energy, α is the fine structure constant, and $\langle Pol \rangle = 0.5\{(Ne_R - Ne_L)/(Ne_R + Ne_L)_{RH\text{-}beam} - (Ne_R - Ne_L)/(Ne_R + Ne_L)_{LH\text{-}beam}\}$, is the average beam polarisation.

These asymmetries arise from γ-Z interference and although the Standard Model asymmetries are small ($\sim 3\times10^{-4}$ for the leptons, ($\sim 3\times10^{-3}$) for charm and ~1.3% for the b-quarks), the unprecedented precision is possible because of the high luminosity of SuperB together with a 70% beam polarisation measured to ±0.5%. To achieve the required precision all detector-related systematic errors are made to cancel by flipping the polarisation from R to L in a random, but known, pattern through a run. <Pol> is to be measured with both a Compton polarimeter, which has an uncertainty at the interaction point of <1% and by measuring the forward-backward polarisation asymmetry of the tau-pairs using the kinemetic distributions of the decay products of the tau. The latter can be used to determine a time-integrated <Pol> to 0.5% in a manner entirely independent of the Compton polarimeter, which will provide bunch-by-bunch polarization measurements.

SuperB will measure $\sin^2\theta_W$ at a centre-of-mass energy of 10.58GeV which will be of higher precision than those made by the QWEAK experiment and the proposed Möller scattering experiment at Jefferson Lab. In addition, the measurements will be carried out with five fundamental fermions: electron, muon, tau, c-quark and b-quark and at an energy intermediate between those experiments and the Z-pole. The universality of the neutral current vector couplings will thus be probed with unprecedented precision.

The 3σ discrepancy (Physics Reports V427, No.5-6) between the LEP measurements of the right-handed b-quark couplings to the Z and the Standard Model will be experimentally probed with higher precision at SuperB. Also, measurements with the projected precision will enable SuperB to probe parity violation induced by the exchange of new bosons. Candidates for such particles could be at TeV-scale or at lower energies with small couplings. The measurements will be sensitive to windows on new physics for which the LHC is not sensitive. Moreover, measurements at SuperB will have a unique possibility to probe parity violation in the lepton sector mediated by light and very weakly coupled particles often referred to as 'dark forces'. Recently, such forces have been considered as a possible connecting link between SuperB and dark matter. The enhancement of parity violation in the muon sector has been an automatic consequence of some models that aim at explaining the unexpected result for the recent Lamb shift measurement in muonic hydrogen. The left-right asymmetry of the $e^+e^- \rightarrow \mu^+\mu^-$ in such models is expected to be enhanced at low-to-intermediate energies, and the SuperB facility may provide a conclusive test of such models, as well as impose new constraints on parity-violating dark sector.

The polarised electron beam opens other physics opportunities as it will enable SuperB to search for CP violation in the tau sector, measure the tau electric dipole moment and the g-2 of the tau with precision by allowing measurements of the polarization of a single tau, rather than measurements of correlations between two tau leptons produced in the same event. The polarization also will significantly improve the sensitivity of searches for lepton flavour violation in tau decays at SuperB, given a specific LFV interaction, and better determine the features of the LFV interaction, once they are found.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

The accelerator-based program of IPP consists of the frontier-energy physics studying proton-proton collisions with ATLAS at the LHC, neutrinos physics with T2K and precision physics using electron-positron collisions using BaBar. In this decade, both T2K and BaBar are undergoing a transformation to the next-generation experiments while ATLAS will study p-p collisions at even higher energies. These three projects, ATLAS, T2K and SuperB are high priority accelerator-based projects of the Canadian Long Range Plan for subatomic physics and by the end of this decade will provide complementary windows on new physics.

A TRIUMF Research Scientist making these contributions to the SuperB project will have an extremely high impact and visibility on the overall project and will enhance TRIUMF's international reputation as it enters into a collaboration with the world's first high energy physics laboratory to be built in a generation.

BROADER IMPACTS:

The challenge of building and commissioning an advanced instrument and the excitement of addressing today's big scientific questions will attract the best students and postdoctoral fellows. The training of these highly qualified personnel (HQP), as well as technicians and engineers, in designing, building, commissioning and using SuperB will benefit the Canadian economy. These individuals will take their acquired skill and knowledge from the associated technologies as well as their overall problem-solving skills into Canadian industry. Students and postdocs working within large high energy physics collaborations develop skills needed to work effectively in an international team. Such skills include a high level of effective communication, as they are called on regularly to present their work to the rest of the members of the collaboration. Based on our record of training HQP on previous experiments with large international collaborations we expect to provide research training to approximately three dozen Canadian graduate students and 18 postdoctoral fellows with SuperB. SuperB will also be used in the training of three dozen undergraduate students, either through final-year projects within the programs of the four universities or as co-op and summer studentships for people from universities across Canada. HQP previously trained by this team have careers broadly distributed through the Canadian economy: medical physics, software and data-mining, the financial sector, innovation commercialization, and various other technology related industries, as well as in research institutes and academia.

The construction phase of SuperB will engage local industry in a project requiring innovative technical solutions. The team will involve Canadian industry in the costing of the hardware project and it's expected that much of the funding will be directly fed back into the Canadian economy. But a greater medium term economic impact comes from the transfer to industry via HQP of the technical expertise acquired in the development of the front-end electronics, robotics, and gas and high voltage systems. Technical innovations arising from this work can be commercialized via AAPS Inc.

MAJOR MILESTONES:

Description	Date
Start of SuperB civil construction	2013
Beneficial occupancy of detector hall	2016
First collisions	2018

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF						
EXTERNAL						
TOTAL						To be determined
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Research Scientist	1 FTE	1 FTE	1 FTE	1FTE	1 FTE	
other						To be determined

TRIUMF RESOURCES:
If the Compton polarimeter is selected, the project will require resources from the Science Division's Detector Facilities.
If the polarised electron gun or spin rotators are selected, the project will require resources from the Accelerator Division.
The profile of the project resource requirements are still to be determined.

EXTERNAL FUNDING INFORMATION:
CFI application for hardware, commissioning manpower and operational costs for contributions to the polarisation system and polarimeter.
The SuperB NSERC project grant will be expanded to support this effort.

ONGOING OPERATIONAL REQUIREMENTS:
CFI IOF funds for operational manpower and maintenance.
Travel to the Cabibbo Lab for operational support and maintenance will be requested in the NSERC project grant

DECOMMISSIONING REQUIREMENT:
Canadian funded equipment will remain the property of the institution providing the equipment.
Conventional practice has been to have decommissioning costs borne by the host lab (Cabibbo Lab in this case) if the equipment is not recovered by the owner. This will have to be incorporated into the MOU.

Accepted:	Date: