Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
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PROJECT/COMMITMENT TITLE: Thin Gap Chambers for ATLAS Muon Spectrometer Upgrades

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PROJECT DESCRIPTION:

The ATLAS muon spectrometer was designed more than 15 years ago, before the idea of upgrading LHC luminosities above 10^{34} $cm^{-2}s^{-1}$ was considered. In order to take full advantage of an upgraded High-Luminosity LHC (HL-LHC) the "small" wheels of the muon spectrometer (the end-cap stations closest to the interaction point) must be replaced, so performance at high luminosity and background hit rates will match current performance, and the current trigger thresholds can be maintained. The new small wheels (NSW) will be added to the Level-1 trigger logic. They will perform real-time segment reconstruction at every bunch crossing and provide track positions and angular resolution better than 1 mrad to allow the Small Wheel to be used in the Level-1 trigger (the current resolution of ~3 mrad is not sufficient). The NSW will be used throughout ATLAS Phases 1 and 2 (up to 3000 /fb). They will comprise MicroMegas chambers for precision tracking sandwiched between Thin Gap Chambers for triggering; however, both technologies are capable of fast triggering and precision tracking, so the system is robust against failure of individual elements.

ATLAS-Canada will provide Thin Gap Chambers (sTGC) for the NSW; each chamber being a quadruplet of individual gas gaps with copper pads on one side for fast trigger readout, copper strips on the other side for precision readout, and anode wires in the gap with readout for the second coordinate. The current proposal is to build all of the two larger types of quadruplet chambers in Canada. This amounts to about 1/3 of the project built in Canada: 256 gas gaps plus spares built over 18 months (one per working day). The final product would be assembled at Carleton as 64 quadruplet (4-gap) chambers, and tested for efficiency in a cosmic ray testing facility at McGill prior to shipping to CERN. Assembly into phi sectors would be done at CERN after re-testing. The work to be done at TRIUMF would be primarily the carbon coating of the cathode planes, as well as some cathode plane assembly. For this we require a suitably ventilated room for carbon spraying and temperature/humidity-controlled drying, and a semi-clean area with suitably equipped granite tables for the other cathode plane work. This will need to be set up well before the period covered by the 2015-20 Five-Year Plan.

The NSW is well on the way to becoming a formal ATLAS Upgrade project for the Phase-1 upgrades to be installed during the long shutdown of 2018; however, it is likely that some trigger chambers of the "Big" wheels (those nearest to the beam pipe) will also need to be replaced with higher-resolution sTGC as part of the Phase-2 LHC shutdown of 2022-23. Producing these additional chambers would require only minor modifications to the setup for NSW cathode planes. It would imply that our needs for space would continue into 2017-19, and would require additional capital funds from NSERC or CFI. The Phase-2 Letter of Intent will be written in 2013, and decisions about technology choices, as well as agreements with institutes for providing components, would be made two or three years later. A Canadian commitment to Big Wheel upgrades would be contingent on successful progress on the NSW project.

SCIENTIFIC JUSTIFICATION:

The ATLAS experiment at the LHC studies proton-proton collisions at very high energy. The unprecedented energy densities created allow us to study the structure of matter at a much smaller scale than was previously possible, to extend investigations of the fundamental forces of Nature, to understand the origin of matter and to search beyond the Standard Model (SM) of particle physics for phenomena such as supersymmetry, quark substructure, and extra dimensions. One of the primary goals of the Large Hadron Collider (LHC) is finding and studying the SM Higgs boson. In July of 2012, both the ATLAS and CMS experiments announced a major and historic discovery: a new particle consistent with the Standard Model Higgs boson. The next steps are to confirm the identity of the new particle and understand as much as possible about its properties, and to build on this discovery to continue the ongoing extensive searches for physics beyond the SM.

The air-core toroids of the ATLAS muon spectrometer were designed to ensure good (per mille at p_T=300 GeV) measurement of muon transverse momentum into the forward regions of the detector; however, the existing forward muon triggers use only detectors in the middle station (of three) of each end-cap. Because of the background of charged particles coming from activated shielding, this will cause an unacceptable rate of false triggers as ATLAS begins to take data above its design luminosity of 10^{34} $cm^{-2}s^{-1}$. The monitored drift tubes which are the sensitive elements in the current precision muon tracking detectors will also suffer from too-high occupancy above the design luminosity. These effects can be mitigated if pointing track segments from the Small Wheels are incorporated into the Level-1 trigger, allowing triggers not genuinely coming from the IP to be excluded. The NSW is designed for both triggering and high-rate precision measurements and will allow ATLAS to maintain the current trigger thresholds for muon transverse momentum in the face of much higher rates and occupancies, thus permitting the current physics program to continue, but with much greater event counts. Without the NSW, studies of single-lepton-triggered processes (such as WZ and WW where one W decays to a single charged lepton and the other boson decays hadronically) would be hurt by prescaling, reducing the effective amount of data available for several precision measurements and searches for new particles.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

ATLAS is the flagship experiment for high-energy physics in Canada. It has been designated as the highest priority for the field in the last three NSERC-sponsored long-range plans and in the last two NSERC funding Reallocation Exercises and remains a top scientific priority in the current and next TRIUMF five-year plans.The NSW project is a collective initiative by at least six of the ten ATLAS-Canada institutes (University of Alberta, Carleton University, McGill University, Simon Fraser University, TRIUMF and the University of Victoria), and represents a large fraction of the ATLAS-Canada investigators. The proposed participation in the NSW project is a significant contribution to the detector upgrade; ongoing participation in detector development is required to maintain Canadian access to ATLAS data. The NSW project profits from TRIUMF Detector Group expertise building tracking chambers. It will give students, post-docs and technical personnel experience in detector research (prototype construction and design) and large-scale production with specialized methodologies (quality assurance and testing).

BROADER IMPACT:

Thin gap chambers are a very economical way to cover large areas with high-precision tracking and fast triggering. They have been or are used in several high-energy physics experiments and are being considered for applications outside the field. It would be useful to be able to produce such chambers in Canada. The resistive coating technique has applications in a number of related chamber technologies, and is not limited to thin gap chamber production.

MAJOR MILESTONES:

Description	Date
ATLAS Initial Design Review	2012-8-30
RTI funding: start commissioning construction area	2013-4-1
Module-0 construction	2014-4-1
CFI funding begins to flow (date unknown so far)	2014
Production chamber construction and delivery to CERN	2015-01-01 to 2016-06-30
NSW must be fully integrated and surface-commissioned by	2018-4-1
Phase 2 upgrades decision for Big Wheel trigger chambers	2014-2015

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE (fy15)	TWO (fy16)	THREE(fy17)	FOUR (fy18)	FIVE (fy19)	TOTAL
TRIUMF						
EXTERNAL	250,000$	100,000$	100,000/0	250,000/0	250,000/0	4M$/2.5M$
TOTAL	250,000$	100,000$	100,000/0	250,000/0	250,000/0	4M$/2.5M$
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
lead designer (VS)	25	20	25/0	20/0	20/0	162/97
project manager (RL)	10	10	10/0	10/0	10/0	70/40
lead tech (PB)						25
assistant tech						25
MHESA Rm#01	52	12	10/0	52/0	52/0	282/168
Part of HEC Clean Room	52	12	10/0	52/0	52/0	282/168
granite table	52	12	10/0	52/0	52/0	282/168
Renovations to MHESA Ventilation						TBA
Design Office	2		4/0			14/10
Machine Shop	4		8/0			22/14

EXTERNAL FUNDING INFORMATION: Applying for RTI funding to cover initial tooling and prototyping. If infrastructure modifications are needed, this would be the optimal time to make them (well before next 5YP). Applying for CFI (assuming there is a competition in 2014) to cover production of ~280 gas gaps. RTI-3 requests can cover tech support personnel for up to 2 years; CFI can also support technical personnel. Requirements beyond 2016 depend on whether the Big Wheel trigger chambers are upgraded and Canada participates in this upgrade, so (a/b) notation covers scenarios with or without BW upgrades. Uncertainties are about 30% for 2015-16, much larger for 2017-19.

ONGOING OPERATIONAL REQUIREMENTS: TRIUMF would not be directly involved in detector operation, with the exception of TRIUMF BAEs and grant-funded personnel as normal research activities.

DECOMMISSIONING REQUIREMENT: Chambers will be shipped to CERN and integrated with micromegas to form wheels. Decommissioning ATLAS components is a responsibility accepted by CERN; however technical expertise from TRIUMF staff who built and installed ATLAS systems is invaluable for making decommissioning a success, and some time is likely to be requested of them to support logistics planning, tooling design, etc. Decommissioning is not foreseen for at least 15 or 20 years.

Accepted: Date: