Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
September 17, 2012

PROJECT/COMMITMENT TITLE: ATLAS Calorimetry Upgrades

PROPONENT: Rob McPHERSON **TRIUMF CONTACT:** Rob McPHERSON

PRINCIPAL COLLABORATORS: ATLAS-Canada

PROJECT DESCRIPTION:

The ATLAS end-cap and forward calorimeters use liquid argon as the active detector element. The Canadian-built Hadronic End-Caps (HEC), including the HEC front-end electronics, and Forward Calorimeters (FCal) are inside common cryostats and a common liquid argon volume with the Electromagnetic End-Caps (EMEC) and share electronics crates.

This commitment proposal covers two specific projects – an upgrade of the HEC/FCal mother board for the LAr Trigger Digitizer and Driver Board (LTDDB) to be installed during the 2018 "Phase 1" shutdown of the LHC, and an upgrade of the FCals themselves, scheduled for the 2022-23 "Phase 2" shutdown. These are combined in a single "ATLAS Calorimetry" commitment because requirements, especially for Phase 2, still being evaluated, exact nature of Canadian (and TRIUMF) contributions must evolve to meet requirements.

The scope of HEC and FCal trigger electronics upgrades for phase 1 will be finalized over the coming six months. The minimum upgrade will be a new HEC front-end-crate baseplane to allow for the endcap signal density to be increased. ATLAS-Canada is proposing to design, build and test new HEC and FCal baseplanes as well as the new LTDDB if needed. The new baseplane will probably use a new type of connector, much more compact than currently used standard sockets, requiring detailed simulation and R&D over the next year to assess issues both of cross-talk and radiation hardness. The new electronics would be installed in 2018, so this 5YP would include the final design and production periods, including manufacturing and acceptance tests.

Plans for FCal upgrades depend on whether it is considered feasible to open the common cryostat volume, given that this would be an exceptionally difficult procedure which would have to be performed inside the ATLAS cavern, now that the cryostat has been activated by several years of service. If the cryostat is opened, the FCal could be replaced by a new one with thinner gaps for the LAr. If it is not, then a "miniFCal" could be inserted in front of the existing cryostat as an active shield. The initial design study for the MiniFCal looked at the use of diamond detectors in a standard copper parallel plate calorimeter. This study demonstrated that there are significant problems with this option in terms of signal reduction after irradiation, diamond sensor costs and sensor supply. For this reason the group is investigating two alternatives, one using High Pressure (up to 10 bar) Xenon and the other using Liquid Argon. The liquid Argon option probably requires more material, which could limit overall response and will be investigated via an Engineering study involving both Canada and CERN. The HP Xenon option requires basic R&D to determine gas properties. This R&D will be complete before the next 5YP, and one or other of the options is expected to proceed as a construction project in Canada. TRIUMF would be a natural place to construct either a mini-FCal or a new FCal, and while either of these is a relatively small detector, space, design office, machine shop time and engineering / project management support would be required. Constructing a full FCal would require hiring temporary unskilled labour for assembly. Canada might be asked to help design the tooling for this delicate operation, which would require two or three FTE of someone like Roy Langstaff.

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) was to find and study 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 a 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.

As the LHC luminosity increases beyond its design rate of 10^{34} $cm^{-2}s^{-1}$, the rates for most triggers involving the calorimeters will increase linearly; however the total Level-1 trigger rate is limited by the input capacity of the Level-2 system. Maintaining our current electron and photon trigger performance (and thus our efficiency for detecting W and Z bosons, among other important signals) with higher instantaneous luminosities and pileup will be challenging. Studies indicate that our full online calorimeter readout granularity is sufficient for selecting isolated electrons in all parts of ATLAS, but the granularity available to the Level-1 trigger is insufficient. It will also be necessary to use more information from the hadronic calorimeters in the trigger to suppress jet backgrounds. We plan to upgrade our Liquid Argon Calorimeter electronics to allow the full detector granularity to be used in the Level-1 trigger, greatly reducing the load at Level-2 and allowing single-lepton trigger thresholds to be maintained below 30 GeV.

One of the key features of the ATLAS Calorimeter system is that it is a hermetic system providing coverage out to a pseudorapidity of 4.5. This characteristic results in excellent missing $\mathbf{E}_T$ resolution and good measurements of forward jets which are an important ingredient in the study of physics channels such as vector boson fusion production of the Higgs Bosons. Coverage at high pseudorapidity is provided by the Forward Calorimeters (FCal). The Canadian groups were significant contributors to the construction of the FCals. The FCal detectors were designed to operate up to the design luminosity of the LHC but will face challenges at HL-LHC due to ion build-up, voltage sag on HV protection resistors and even potentially boiling of the liquid argon. One solution to these problems is to build and install new FCals. The Canadian groups have been exploring a less invasive option which is the installation of a new calorimeter (MiniFCal) in front of the existing FCals. The MiniFCals would lower the ionization and heat load on the existing detectors so that their continued function could be assured, and would contain active readout elements so the electromagnetic showers would not be lost.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

Liquid argon calorimeters were the primary detector construction projects of the Canadian ATLAS community, and all but two of the ten Canadian ATLAS institutes sit on the LAr Institute Board. It is vitally important to fulfill our implicit commitments to these detectors and make sure that they continue their excellent performance into the future. Our engagement in this activity reflects strongly on our reputation for commitment to excellence.

BROADER IMPACTS:

The R&D on very dense electronics has many possible applications in the world outside particle physics.

The technologies considered for forward calorimeter upgrades typically also have applications in medical imaging detectors.

MAJOR MILESTONES:

Description	Date
RTI funding for HP Xe miniFCal R&D and electronics	2013-4-1
Letter of Intent for Phase 2 Upgrades submitted to LHCC	March 2013
Approval of LAr electronics as ATLAS Upgrade Project	February 2013
Phase 1 LAr Upgrades Technical Design Report	Spring / summer 2014
Decision on Phase 2 FCal upgrades	Not known yet
Installation of LAr electronics during Long Shutdown	2018
Final assembly and surface commissioning of FCal / miniFCal	Around 2021

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE (fy15)	TWO (fy16)	THREE(fy17)	FOUR (fy18)	FIVE (fy19)	TOTAL
TRIUMF						
EXTERNAL	*	*	*	*	*	0.5M-9M$
TOTAL						0.5M-9M$
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Det. Elx. Grp Ldr	26	26	26	26	26	182
LTDDB:						
Design engineer	26					46
Technician (tests)		26	26			52
FCal:						
Design engineer		10	26	26	26	88
Small clean room			10	52	52	114
Det.Grp. support			5	10	10	25

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). Production costs would need to be covered by external funding (CFI). Designing and building tooling for insertion is a large part of the project. Uncertainty on project cost is large: miniFCal Xenon and LAr options would be <500kCHF (detector only); FCal replacement ~9MCHF. *Funding profile is not known but would peak toward the end of the next 5YP.

ONGOING OPERATIONAL REQUIREMENTS: TRIUMF would not be directly involved in detector operation, with the exception of TRIUMF BAEs, students and post-docs in the course of their normal research activities.

DECOMMISSIONING REQUIREMENT: Detectors will be shipped to CERN and installed in ATLAS. 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: