Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
2012 September 17

PROJECT/COMMITMENT TITLE: Compton Suppression Shields for GRIFFIN

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PROJECT DESCRIPTION:

The Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei (GRIFFIN) spectrometer has been funded through the Canada Foundation for Innovation (CFI), TRIUMF and the University of Guelph. This funding which totals $8.7M over 4 years includes 16 large-volume High-Purity Germanium (HPGe) Clover detectors, a custom-designed and high-performance digital data acquisition system and all mechanical infrastructure to couple these detectors to the ISAC-I beamline. The mechanical structure is based on the TIGRESS array which includes 16 full Compton-suppression shields for the HPGe. However the present funding received does not include any scintillation detectors for Compton-suppression of the HPGe clover detectors.

This project involves seeking addition funding for the suppression shield detectors. The shields in TIGRESS used the standard Photomultipler Tubes (PMTs) to detect scintillation light produced in the crystal when ionizing radiation is incident on it. New technologies can now be considered and it is proposed to use arrays Multi-Pixel Photon Counters (MPPC) (Sometimes known as Silicon Photo-multipliers (SiPMs)) for this purpose. This eliminates the need for High-Voltage to be provided to the detector (required to operate the PMTs) and so reduces additional project costs. The Compton suppression shield detectors using MPPC read-out will be constructed by our collaboration rather than purchased as a complete package from a manufacturer of radiation detectors. This significantly reduces total project cost.

-BGO scintillator crystals will be purchased already shaped and polished from an Ontario Company who have already proven to be capable of producing a prototype.
-Basic mechanical drawings exist already but full engineering drawings suitable for use in manufacture would need to be generated.
-Fabrication of detector housings could be done in either the TRIUMF Machine shop or scintillator shop, or in a Member university machine shop; Guelph, SFU, Toronto
-Mechanical assembly can be done by undergraduate, graduate students or Post-Doctoral Fellows under the supervision of a Technician
-Preamplifiers could be off-the-shelf or designed and built in-house. This will be defined as part of the R&D work.

SCIENTIFIC JUSTIFICATION:

GRIFFIN HPGe clover-type gamma-ray detector will surround an implantation location where the low-energy radioactive beam from ISAC will be stopped. Gamma-rays emitted from excited nuclear states populated in the beta decay of radioactive nuclei will be detected by the HPGe detectors. In some cases gamma rays can scatter out of the HPGe volume without depositing their full energy do not provide useful information, and simply increase the background in the HPGe gamma-ray spectrum. These

Compton scattered gamma rays will be detected in high-efficiency scintillator detectors surrounding the HPGe detectors. Signals from these suppression shields will veto the unwanted coincident signals from the corresponding HPGe detectors, thereby greatly improving the signal-to-background ratio in the gamma-ray spectrum and the overall sensitivity of the GRIFFIN spectrometer. The Compton suppression shields that have been designed for TIGRESS and GRIFFIN are comprised of three subsystems, i) a bismuth germanate (BGO) side shield that forms a square annulus surrounding the sides of the HPGe clover detector, ii) a BGO back catcher consisting of two units that surround the cold finger at the back of the HPGe crystals, and iii) a front shield system comprised of four individual BGO plates that can be inserted or withdrawn to change between the maximum efficiency and the optimal peak-to-background configurations of GRIFFIN. Each GRIFFIN suppression shield contains 20 optically isolated scintillator segments, each will read out by an array of MPPCs, in order to provide crystal-specific Compton suppression for the HPGe detectors.

In addition there are 8 locations in the GRIFFIN support structure which will house Lanthanum Bromide ($LaBr_3$) which are a very fast scintillator used for determining the lifetime of excited nuclear states. These 8 detectors will also be surrounded by a BGO Compton-suppression shield. These shields will dramatically increase the signal-to-background observed in these $LaBr_3$ detectors which will increase the sensitivity and reach of fast-timing data for excited nuclear states. The lifetime of excited states, along with the branching ratio of that decay pathway, provides a determination of the transitional matrix element. Transitional matrix elements and systematics of them are a sensitive probe of theoretical models of nuclear structure, and are especially important in the determination of shell structure in exotic nuclei and the evolution from spherical to deformed systems.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

The addition of Compton-suppression shields to the GRIFFIN spectrometer, as was originally envisioned, will significantly increase the overall sensitivity of the device. This will increase the capability to observe very weak components in the radioactive beam delivered to the device or to observe very weak decay branches in the decay of a parent nucleus. This increase in sensitivity will benefit all users of the facility which includes more than 10 faculty from 7 Canadian institutions and all their associated Post-doctoral research fellows, Graduate students and undergraduate students.

BROADER IMPACTS:

This project presents the opportunity for the training of highly qualified personnel in several areas. In the construction of the detectors the mechanical assembly of the detectors themselves will be performed by post-doctoral research fellows, graduate or undergraduate students. Students and post-docs will develop a knowledge of radiation detection using scintillation crystals and MPPCs as well as electronics design, construction and testing. There is a significant overlap between this project and medical imaging technologies for which these students would have a good training.

MAJOR MILESTONES:

Description	Date
Pre-Project R&D phase to determine suitability of MPPC for BGO	Aug 2013
Funding secured and project start	May 2014
Design of mechanical housing, MPPC grids and preamplifiers, completed	Oct 2014
All Cables and electronics modules completed	April 2015
First 5 sets of Shields completed	April 2015
Second 5 sets of Shields completed	April 2016
All 16 sets of Shields completed	April 2017

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE (FY14)	TWO (FY15)	THREE (FY16)	FOUR	FIVE	TOTAL
TRIUMF	0	0	0			0
EXTERNAL	$400k	$400k	$400k			$1.2M
TOTAL	$400k	$400k	$400k			$1.2M
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE (FY14)	TWO (FY15)	THREE (FY16)	FOUR	FIVE	TOTAL
Mechanical Designer	6wks					
Electronics Shop (Cables)	0.5wks					
Electronics Shop (MPPC Grids)	6 wks	1wks	1wks			
Electronics Shop (LV Modules)	4 wks					
Machine Shop (If TRIUMF)	12wks	10wks	10wks			
Technician	8wks	3wks	3wks			
BAE	4wks	2wks	2wks			

EXTERNAL FUNDING INFORMATION:
Based on successful R&D work during 2012/2013 an application would be submitted in Fall 2013 for a NSERC RTI grant.

ONGOING OPERATIONAL REQUIREMENTS:
There will be no operational support from TRIUMF directly for the suppression shields of GRIFFIN. Technical support will be provided as part of the on-going support for all Gamma-Ray Spectroscopy at ISAC activities associated with the GRIFFIN and TIGRESS spectrometers.

DECOMMISSIONING REQUIREMENT:
Detectors are small and portable, minimal decommissioning effort required.