**GRIFFIN Facility Safety Report**
**Schedule 127, Fall 2014, 1st Oct to 6th Oct 2014**
**Experiment:** S1007 – Equilibrium of $^{115m}$Cd during the s-process
**Spokespersons:** Smarajit Triambak, University of the Western Cape, South Africa, striambak@uwc.ac.za , 011 2721 959 3468
Chandana Sumithrarachchi, NSCL, Michigan State University, chandana@nscl.msu.edu, 517 908 7499
**Safety Coordinator:** Adam Garnsworthy, TRIUMF, garns@triumf.ca, x6491

**Description**
This beamtime represents the first experiment using an early-implementation of the new GRIFFIN facility. A **$^{115}$Ag beam** will be used to search for the existence of 'gateway levels' at low excitation energy in $^{115}$Cd. These would be identified through the observation of gamma-ray coincidences of transitions above and below the particular candidate states of interest. The presence of linking transitions would provide a mechanism for the de-excitation of the 44.6 day $^{115m}$Cd state to the $^{115}$Cd ground state through stellar (γ,γ') reactions. Which would provide a direct signature for the ground and isomeric states not being in equilibrium at lower stellar thermal energies, thereby increasing the s-process yield of $^{115}$Cd. In addition, this data can provide assignments of spins and parities to excited states in $^{115}$Cd from the determination of gamma-ray multipolaries from measurements of gamma-ray angular correlations.

Upstream and downstream SCEPTAR will be used with the Moving Tape Collector. 14 GRIFFIN clovers and 2 TIGRESS clovers will be used for a full 16 clover detectors in the array.

**Beam Parameters and Radiation**
Please note that this beam was previously delivered to the 8pi spectrometer in April 2010 during schedule 117.

A high-powered zirconium carbide (ZrC) ISAC target material will be used in conjunction with a surface ion source (SIS) and TRILIS used to enhance the Ag rate. A beam of $^{115}$Ag ($T_{1/2}$ = 20.0 mins, Q value = 3.1 MeV) will be delivered to the GRIFFIN facility via the new ILE1B beamline with a total beam energy of 20-30 keV at a beam intensity of ~$6\times10^4$ pps. The experiment will be performed in long cycles of approximately 10 mins beam-on implantation followed by a roughly 40 mins period of decay observation with the beam off. A tape move will then remove the remaining activity from the chamber to the tape box before the next cycle.

The anticipated beam contaminants are $^{115m}$Ag ($T_{1/2}$ = 18 s) and $^{115m}$In ($T_{1/2}$ = 4.4 hrs) which will be produced at rates of ~$1.9\times10^3$ pps and ~$10^5$ pps respectively. These isomeric states decay predominantly to the ground states of $^{115}$Ag and $^{115}$In via isomeric transitions. The ground state $^{115}$Cd daughter following the beta decays of the $^{115}$Ag nuclei has a much longer half-life of 53 hours, while its isomeric state $^{115m}$Cd has a half-life of 45 days. The beta decays will mainly produce the ground state in $^{115}$Cd (60% of the time). Following the tape cycle mentioned above, it is estimated that the activity on the tape at any given time should be less than 5kBq which does not present a radiation hazard outside of the array.

**GRIFFIN Facility - Experimental Equipment**

***Moving Tape Collector***

The radioactive beam is implanted into a moving tape collector at the central focus of the detectors. The tape can be moved behind a Pb wall to remove activity from sight of the detectors. A typical experiment is operated in a periodic cycling mode with each cycle consisting of a tape move, background measurement, beam delivery with data collection, beam blocked and observation of source decay. The relative timings of the cycle depends on beam intensity and half lives. Operation of the cycle is controlled by a sequencer program running on the GRIFFIN Master Collector module in the DAQ system.

***SCEPTAR***

The SCEPTAR array consists of an upstream and downstream hemisphere of ten plastic scintillators each used for the detection of beta particles. The scintillator is located in vacuum and light-guides connect them to PMTs external to the vacuum system. The PMTs are biased to -800 to -1200 V. The scintillator paddles are covered with aluminized mylar which could be removed and disposed of in the case of contamination.

***PACES***

The upstream half of SCEPTAR can be replaced with an array of five lithium-drifted silicon detectors (PACES). These detectors located inside vacuum are used to detector internal conversion electrons. The detectors and FETs are cooled to liquid nitrogen temperature by a cold-finger connected to a drip-feed liquid nitrogen dewar. The bias voltage is -500V.

***Zero-Degree Scintillator***

The downstream half of SCEPTAR can be replaced with a single BC422Q scintillator located at zero degrees to the beam axis. The PMT for this scintillator is also located in vacuum and is biased to between -800 and -1500V. The distance of the scintillator from the tape can be changed from outside the chamber via a movable rod.

***GRIFFIN HPGe Clovers***

The GRIFFIN array consists of sixteen hyper-pure germanium (HPGe) clover detectors used for detecting gamma rays. Each clover operates at liquid nitrogen temperature and with an applied bias voltage of +3500 to +4000V. Each clover can be surrounded by a set of BGO Compton suppression shields. The BGO PMTs are biased to between +800 to +1200 V.

***$LaBr_3$ Scintillators***

Eight cerium-doped lanthanum bromide ($LaBr_3(Ce)$) scintillators can be installed into the GRIFFIN support structure and used for the fast coincidence timing of gamma rays. The $LaBr_3$ PMTs are biased to between -800 to -1500 V. Each crystal has a natural radioactivity from the small concentration of $^{138}La$ ($T_{1/2}$ = $1.05 \times 10^{11}$ yrs) and is equivalent to a 70 Bq (1.89 nCi) source.

**GRIFFIN Facility - Other Hazards**

***Calibration Sources***

Gamma-ray calibrations will be performed with standard sealed gamma-ray sources. Calibration and testing of the Si(Li) detectors and plastic scintillators will require an open gamma & internal conversion electron source ($^{207}$Bi), open beta+/beta- source ($^{22}$Na/$^{90}$Sr), or open mixed alpha source ($^{239}$Pu/$^{241}$Am/$^{244}$Cm), contained within the GRIFFIN vacuum chamber. These sources have been routinely used at TIGRESS and 8pi for a number of years.

Sealed gamma-ray sources will be used in accordance with regular sealed source handling procedures. The open sources, i.e. $^{207}$Bi, $^{22}$Na, $^{90}$Sr and alpha sources, will be enclosed within the GRIFFIN vacuum chamber during Si(Li) and plastic scintillator detector calibrations/testing. These sources will be handled only by competent and trained TRIUMF personnel with gloves. During installation or removal, an assistant will have a pancake monitor to survey the source installer's gloves, all tools, and the immediate vicinity of the vacuum chamber and work surface.

***Vacuum and Industrial Safety***

Vacuum components native to the GRIFFIN setup have been well tested under experimental conditions and there are no unusual vacuum components. The vacuum interlock chain as described in [TRIUMF-Document-112205, “ISAC Vacuum System Interlock Specification (ILE1B:IV6)”] is adequate for normal working conditions. No pressure vessels are used. The two hemispheres of the GRIFFIN support structure may present pinch-point hazards. Trained TRIUMF staff will be on hand to open the hemispheres when required.

***Liquid Nitrogen***

The GRIFFIN germanium detectors and Si(Li) detectors are cooled with an automated liquid nitrogen filling system and monitored by competent and trained TRIUMF personnel. The liquid nitrogen distribution system is comprised of 24 VDC solenoid valves, Tygothane tubing, Armaflex insulation, LED Sensors, and a PLC-based control system.

All components of the liquid nitrogen distribution system have been designed, assembled, and commissioned by competent TRIUMF technical staff. Tygothane has a typical service life of 15 years; the hoses used for this experiment are all less than 3 years old. All exhaust hoses are directed to floor level.

At least five Gamma-Ray Spectroscopy at ISAC staff members are fully trained in liquid nitrogen handling, and will solely be responsible for refilling supply dewars and other system maintenance. Hose breaks will be avoided by instructing experimenters not to perform any activities that would flex the hoses during a fill cycle or during the half-hour period after the fill cycle finishes. Similar procedures are used on the TIGRESS and Room 156 liquid nitrogen systems. There have been no incidents or injuries in great than 15 years of combined operation.

***High Voltage and Electrical Safety***

High voltage, low current (HV) power supplies are required for germanium, lithium-drifted silicon (Si(Li)) semiconductors, as well as BGO suppressor, plastic and lanthanum bromide ($LaBr_3$) scintillator photo-multiplier (PMT) bias. The germanium clover detectors typically operate with +3500 to +4000 V bias while PMTs are typically biased between +800 and +1200 V. The Si(Li) will be operated with -500 V bias. No energized components of these detector elements are accessible.

All electrical services have been installed by professional contractors under the supervision of the site electrical engineer. In accordance with regulations, equipment purchased by the GRIFFIN collaboration and which did not receive CSA or equivalent certification from the vendor has been inspected by a TRIUMF electrician.

The HV supplies for the germanium clovers, BGO scintillators, plastic scintillators and $LaBr_3$ scintillators are standard CAEN HV modules in SY1527LC or SY4527B mainframes. RG-59 cables with SHV connectors for the clovers, Si(Li), plastic scintillators and $LaBr_3$ were fabricated in the TRIUMF electronics shop. Kerpen cables and Radiall connectors for the BGO scintillators were also fabricated in the TRIUMF electronics shop. Break-out boxes to adapt the Radial connectors to the LEMO HV cables on the scintillators were fabricated by GRIFFIN collaboration members under the supervision of TRIUMF technical staff. The BGO scintillator HV modules are interlocked such that HV cannot be applied until the Kerpen/Radiall connectors are installed properly to both the HV module and the breakout box.

The typical current draw of the BGO scintillator, plastic scintillators and $LaBr_3$ scintillator PMTs is 300 to 700 μA, so the current trip limit on each channel will be set at 1 mA. The current draw on the germanium or Si(Li) detectors is unmeasurable under normal operating conditions; measured current indicates small and expected leakage in the HV cables themselves. The current trip limit shall be set to 1 μA.

The GRIFFIN cable trays are grounded to building ground. The GRIFFIN support structure frame is attached to the main electronics shack single point ground. For safety, this ground is connected to the building ground. Accidental application of HV or line AC to any of the frames due to insulation breach, interlock failure, or neglect, will result in an immediate short to ground. This will trip the appropriate line breakers or HV supplies. The support structure frame cannot be energized to a voltage above safety ground. The procedure for removal or testing of this GRIFFIN electrical ground is described in Document-110056, “GRIFFIN Electrical Ground Removal/Testing Procedures”.

***Flammable Gases***

Presently no flammable gases or gas detectors are used with GRIFFIN.