S1389
Shape Coexistence at N=60: Single-Particle Structure in ^{95,96}Sr
Safety and Technical Readiness Report for Schedule 126

G. Hackman, 2014-04-24

0. Revision History

2014-04-24	initial release
2014-04-29	first submission to Science Division (no changes from 2014-04-24)

1. Scope

This Safety and Technical report covers delivery of beam to SEBT3A during Schedule 126 from June 16 to 28, 2014. This period covers HMTF scheduled time, which may (optionally) require delivery of beam to TIGRESS; stable-beam setup time of TIGRESS and its associated detectors; and execution of Experiment S1389, "Shape Coexistence at N=60: Single-Particle Structure in ^{95,96}Sr."

This report has been prepared as described in TRIUMF Safety Note 3.3 [1].

2. Identification

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3. Description

Experiment S1389 as planned for Schedule 126 will measure gamma yields and kinematic scattering of ^{95}Sr(d,p) in inverse kinematics. Kinematics will be measured with the now-established SHARC array of Si detectors. TIGRESS will be used with 12 detectors to provide gamma-ray tagging of specific excited states. Beam-like single-particle transfer particles will be differentiated from fusion-evaporation products on the C component of the CD2 foils with a very thin plastic scintillator at zero degrees (“Trifoil”). The beam will be stopped in the Trifoil 1.0 m downstream of the scattering target location. During experiment setup (first week of the scheduled time) and occasionally during the experiment, beam will be re-directed to SEBT3 and the TBragg detector for beam composition analysis.

3.1 Beam Properties

For beam tuning, the expected beams will be:

- Species: ^{95}Mo or ^{86}Kr
- Energy: 5A MeV
- Intensity: up to 5×10^{7} particles per second on target

For the experiment:

- Species: ^{95}Sr
- Energy: 475 MeV total (5A MeV)
- Intensity: up to 1×10^{7} particles per second on target including contaminants (primarily ^{95}Mo,^{95}Rb)

Beam intensity is limited by the dose rate that the trifoil can withstand and the data rates in the silicon detectors. It is currently understood that the dominant stable beam contaminant will be ^{95}Mo from CSB background. RIB intensities of ^{95}Sr is expected to be 1,000,000 per second delivered to the experiment; the other expected A=95 radionuclides (^{95}Y, ^{95}Rb) will not be extracted from the ion source at higher rates. For the purposes of calculating radiation decay hazards, we will take ^{95}Sr at 1,000,000 per second and consider decay to the ultimate stable descendent, ^{95}Mo.

The intercepting elements (apertures or targets) are:

- Ta apertures, 0.5 mm thick, 2/3/5 mm holes
- CD_2 , < 5 mg/cm^2 on 0.5 mm Al frame

3.2 Apparatus

3.2.1 Experiment apparatus: TIGRESS

The experiment will use both halves of the TIGRESS support structure populated with twelve HPGe clovers, the instrumented vacuum chamber of the TIGRESS beam dump, the enclosed TIGRESS electronics shack. All these devices have been subject to design reviews and have been in operation.

3.2.2 Experiment apparatus: SHARC

SHARC is a large solid-angle coverage arrangement of silicon (Si) double-sided strip detectors (DSSDs) and annular detectors. The scattering chamber consists of two major functional components; a low gamma-attenuation chamber (shell) that is spherical upstream transitioning to cylindrical downstream, and a stainless steel cover or back flange. The shell is cantilevered with compression support braces off of the lead wall support structure of the beam dump. The shell is aligned to the beamline. The back flange holds the frame for the Si detectors, and also has electrical and mechanical feedthroughs for signals and for the target “wheel”. Preamplifiers are mounted to the downstream support structure.

3.2.3 Experiment apparatus: Trifoil

A thin (~10 to 100 ug/cm^2) foil of scintillating plastic mounted to three phototubes has been shipped from LPC Caen to TRIUMF. The foil is retractable so that it may be removed during beam tuning. Al foils up to 60 um thick will be installed in front of the plastic. This arrangement will stop beam-like particles (e.g. transfer residues) in the scintillator, while fusion-evaporation products will stop in the Al foil.

3.2.4 Beam diagnostics apparatus at SEBT3A

For stable beam tuning, apertures of diameter 2 mm, 3 mm and 5 mm, made of Ta, will be installed on the target wheel.

The beam dump is currently instrumented with a Ø2.5 cm Ta-lined Faraday cup for high-current (>1 pA) measurement, and fast, thin, 3 cm by 3 cm square inorganic YAP:Ce (Ce-doped $Y_3Al_5O_{12}$) scintillator for low-rate total incident beam diagnostics, respectively. It is unlikely that this scintillator will be used.

The Si will be protected from high-intensity beam by Al protector plates. These plates will have Ø1.0 cm apertures. One plate will be permanently installed upstream of the Si's.

Faraday cup current will be provided to operations via EPICS.

3.2.5 TBragg

The TBragg gas ionization counter [2] has been used as diagnostics for beams requiring charge breeding, including ^{94,95}Sr. The device has been used in beam for several beam times beginning in 2012. It is installed on SEBT3 just past the bending magnet.

3.2.6 Apparatus readiness

All apparati have been most recently used for S1389 in Schedule 124 (Summer 2013).

4. Hazards and Safety Measures

4.1 Radiation Safety Concerns

4.1.1 Beam-Dump Interactions

An underappreciated radiation hazard under normal operations comes from neutrons following interactions of stable heavy-ion beams with beamline components, in particular the beam dump. The beam dump is lined with tantalum specifically to reduce this hazard. At the proposed energy and beam tuning intensities of 5×10^7 /s, the beam dump will emit approximately 5000 neutrons/s, based on Figure 7-2 of [3]. Gross mis-steering of the beam into a massive beamline component would result in a neutron dose equivalent at 90 degrees of approximately 3 nSv/h (more downstream) (Figure 7-3, ref. [3]). At the full intensity of 5×10^7 particles per second, neutron surveys will be unnecessary.

4.1.2 Radioactive Beam Decay

Isotope	Half-life	Gamma ray energies and intensities
^{95}Rb	377 ms	
^{95}Sr	23.9 s	685.6 (22%), 2717.3 (5%), 2933.1 (4%), …
^{95}Y	10.3 m	954.0 (16%), 3576.0 (6%), 2632.4 (5%), …
^{95}Zr	64.0 d	756.7 (54%), 724.2 (44%)
^{95}Nb	35.0 d	204.1 (2.3%), …

Table 1. A=95 activities pertinent to this experiment

^{95}Sr and its progeny are all 100% β^- emitters, and ^{95}Rb is has an 8% beta-delayed neutron branch. All the beam will stop in the trifoil. At the full 1,000,000 radioactive beam particles per second the hazard from stopped beam and prompt decay of ^{95}Sr and ^{95}Y is equivalent to a 54 μCi (millicurie) source. Using a standard "rule of thumb" for beta exposure [4], this corresponds to a radiation field of about 100 μSv/h at a distance of 50 cm from an unshielded beam dump. The Zr and Nb activity does not reach equilibrium; by the end of the six (6) days schedule for radioactive beam delivery, they will build up a total activity of approximately 2 μCi, corresponding to 4 uSv/h at 50 cm. Comparable activities will be deposited at stripping sites in ISAC-I.

4.1.3 Reaction Product Decay

On the thickest 5 mg/cm^2 target, a reaction with a total inclusive cross section of about 5 b leads to a the reaction rate of at most 10,000 /s with 10,000,000 beam particles per second. The dominant reactions producing activities would be fusion-evaporation of contaminant ^{95}Mo on C in the CD_2 target. The maximum activity from these residues at saturation would only be 10 kBq. As such, the decay of reaction products presents no greater risk than a 0.3 μCi source. Furthermore the evaporation residues have half-lives of approximately an hour.

4.1.4 Calibration Sources

Gamma calibration will be performed with standard sealed gamma-ray sources. Regular sealed source handling procedures will be followed.

Calibration of the SHARC CD detectors will require installation of an open alpha source in the target vacuum chamber. These sources will be handled with gloves. During installation or removal, an assistant will have a pancake monitor handy, and will survey the installer's gloves, all tools, and the immediate vicinity of the vacuum chamber will be surveyed.

4.1.5 Contamination Control

Contamination of the vacuum vessels, namely the target chamber or beam dump, can occur from implanted scattered beam, diffusion, or open sources. If an area is to be worked on it must be surveyed following these protocols:

a) If a vacuum section has been evacuated and has received beam: A work permit must be filled out. Immediately upon opening the vessel, a scientist with a respirator must swipe accessible parts the section in question and an operator or surveyor must survey the swipes with a beta or gamma counter. If the swipes indicate loose contamination, Radiation Safety must be contacted for further instructions. If no loose contamination is found, the work permit may be closed and work may proceed.

b) If a vacuum section has been evacuated but has not been exposed to beam: No work permit or respirators are needed.

The Si detectors will be destroyed if they are touched, so they cannot and will not be swiped. They may be surveyed with a pancake monitor or Geiger counter, but only if they are not contacted.

When the trifoil is removed, care should be taken, as the dose rate from ^{95}Zr,Nb will reach 10 mSv/h at 1 cm.

4.2 Mains Electrical Safety

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 TIGRESS collaboration and which did not receive CSA or equivalent certification from the vendor, has been inspected and labeled to be in compliance.

4.3 High Voltage Safety

High voltage, low current (HV) power supplies are required for semiconductor bias and PMT power. The clover detectors typically operate with 4000 V bias. The suppressor PMTs operate at typically 800 to 1300 V. No energized components of these detector elements are accessible.

The Si detectors operate with less than 150 V bias.

The HV supplies for the clovers and scintillators are standard CAEN HV modules in SY1527LC mainframes. RG-59 cables with SHV connectors for the clovers were fabricated in the TRIUMF electronics shop. Kerpen cables and Radiall connectors for the 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 TIGRESS collaboration members under the supervision of TRIUMF technical staff. The 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 HV supplies for the Trifoil are NIM module supplies.

The typical current draw the scintillator phototubes is 300 to 700 uA, so the current trip limit on each channel will be set at 1 mA. The current draw on the clover detectors is itself 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 superstructure frame is attached to the main electronics shack signal point ground. For safety, this ground is connected to the building ground. The single-detector support stands will also be connected to the same single-point 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 superstructure frame and single-detector stands themselves cannot be energized to a voltage above safety ground.

There are no unusual exposed HV supplies or energized contacts that can be accessed during regular operation.

4.4 Gas handling safety

For this experiment we will use non-flammable, non-explosive P8 gas [2].

4.5 Liquid Nitrogen Safety

The liquid nitrogen distribution system comprises 24 VDC solenoid valves, Tygothane tubing, Armaflex insulation, LED Sensors, and a PLC-based control system. All components 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 10 years old. All exhaust hoses are directed down towards the floor. Six TRIUMF 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 8pi and Room 156 liquid nitrogen systems. There have been no incidents or injuries in 15 years of combined operation.

The only “low spot” i.e. caves, pits, etc. in the ISAC-II experimental hall is the active sump, which is normally inaccessible and requires a work permit issued by operations for access.

4.6 Vacuum and Pressure Vessel Safety

There are no unusual vacuum system components, nor precautions needed to be taken. No pressure vessels or combustible or explosive gases are used in this experiment.

4.7 Industrial Safety

The rails and the two halves of the array may present pinch-point hazards.

5. Responsiblities

The ultimate responsibility for safety lies with the Safety Coordinator, Greg Hackman.

6. Decommissioning and disposal

The SHARC detectors will be returned to York. They will be surveyed as any other component removed from a beamline. If activitation or contamination is found they will be stored until the activity is at an acceptable level for shipping.

Undamaged target foils on target frames will be stored in the ISAC-II source locker if they are found to be activated or contaminated, or in the TIGRESS lab (room 156) if they are not measured to be active. If a damaged foil (broken, burnt, etc.) is found to be unactivated or uncontaminated, it will be removed and disposed of in regular garbage; otherwise the foil and its frame will either be stored in the ISAC-II source locker until they are safe, or they will be disposed of as radiological waste.

7. Bibliography

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[6] Laurie M. Unger and D. K. Trubey, "Specific Gamma-Ray Dose Constants for Nuclids Important to Dosimetry and Radiological Assessment," ORNL/RSIC-45/R1, 1982.