S800 Spectrograph Service Level Description

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Revision History

Revision	Issued	Changes
R001	8 February 2021	Original Issue
R002	10 February 2023	Clarification about maximum rigidity
R003	19 December 2023	New maximum rigidity limit for analysis line

Authorizing Document

None.

Authorized Documents

None.

Authorized Committees and Boards

None.

Named Program Roles

None.

Awareness Training

None.

Enabling Training

None.

1 Objective

This documents describes the level of service FRIB will be able to provide for the operation of S800 and for user support for experiments as well as S800 specific user responsibilities.

2 Abbreviations

AT-TPC: Active Target Time Projection Chamber
CAESAR: Cesium iodide array
D: Dipole
DAQ: Data acquisition system
Data-U: Data-analysis user area
DC: Drift chamber
GRETINA: Gamma ray energy tracking in-beam nuclear array
GUI: Graphical user interface
H: Horizontal steerer
LENDA: Low-energy neutron detector array.
LHDT: Liquid hydrogen/deuterium target.
Q: Quadrupole
S: Sextupole
SeGA: Segmented Germanium arrays
SLRD: Service level and responsibilities description

3 S800 Overview

The S800 is a large acceptance, high-resolution spectrograph designed for experiments using radioactive beams produced at FRIB. Besides acting as a "recoil tagger", correlating recoil nuclei detected in its focal plane with particles and photons emitted in the reaction target, the S800 allows for the extraction of relevant kinematical information, and excitation energies, making it perfect for reaction studies. The high energy/momentum resolution is achieved using an analytical reconstruction method that uses the magnetic-field maps of the spectrograph to correct high-order aberrations. A sophisticated system of detectors, electronics, and data acquisition guarantee optimum performance. More technical details can be found in the S800 technical article[1].

4 Standard Configuration

4.1 Physical Configuration

The S800 is composed of two main parts: the analysis line and the spectrograph.

The analysis line extends from the object position to the target station (see Fig. 1), with a total length of 22 m. The maximum rigidity is close to 5 Tm, and the momentum acceptance depends on the ion optics used (see section 4.2.1).

The spectrograph extends from the target to the focal plane (see Fig. 1). It has a maximum magnetic rigidity of 4 Tm, and a total length of 18 m. The acceptance figures-of-merit are given by a momentum acceptance of around ±3%, and a solid-angle acceptance of 20 msr (±3.5° in the dispersive plane and ±5° in the non-dispersive plane) with a significant reduction on the limits of the momentum acceptance. The energy and scattering angle resolutions depend on the

[1] D. Bazin *et al.*, Nuclear Instruments and Methods B 204, 629 (2003)

experimental conditions, such as the object size, target thickness and whether or not tracking is used prior to the target, and also on the optics mode used (see section 4.2.1).

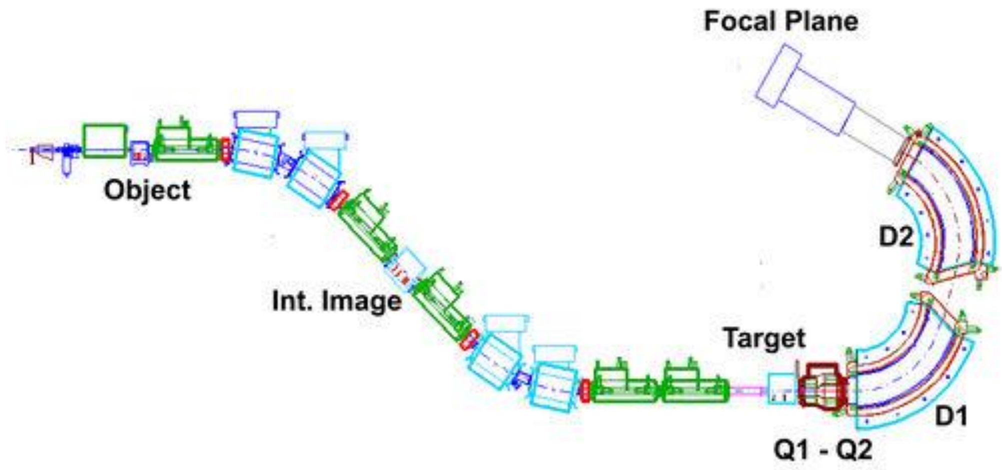

Figure 1: S800 layout. The analysis line extends from the object station to the target. The spectrograph includes two quadrupoles (Q1, Q2) and two large dipoles (D1, D2) (see text for details.)

4.2 Operational Features

4.2.1 Operational Modes

The analysis line allows two different optics modes to be used, each having different characteristics. The modes currently supported are described below.

Dispersion matched mode:

In this mode the whole S800 (analysis line + spectrograph) is achromatic. This mode is used in experiments where the highest momentum resolution is required.

- Maximum momentum acceptance of the analysis line: ±0.5%.
- Maximum magnetic rigidity: around 4.9 Tm
- Dispersion at the target: 11 cm/%; ±0.5% momentum spread implies a target 11 cm long in the dispersive direction.
- In the case of 2” wide targets the momentum acceptance is reduced to ±0.25%
- If an angular resolution better than 10 mrad is needed by the experiment, the tracking detectors can be used to measure the angles of the incoming particles.

Focused mode:

In this mode the analysis line is achromatic, which means that the beam is focused on target and the momentum spread of the beam at the object is not cancelled at the focal plane. This mode is used in experiments where the momentum resolution is not critical or small targets have to be used

- Maximum momentum acceptance of the analysis line: ±2%,
- Maximum magnetic rigidity: around 4.9 Tm
- The momentum resolution is set by the momentum acceptance in the ARIS fragment separator. If a better momentum resolution is desired, the momentum of the incoming particles can be measured using the tracking detectors.

4.2.2 Trajectory Reconstruction

The S800 spectrograph is equipped with only a few magnets to correct aberrations. The aberrations introduced mostly by the fringe fields of the magnets are calculated based of measured field maps, and corrected for analytically (inverse-map calculations). This method avoids tracking of each individual particle in the magnetic fields of the spectrograph, and therefore faster data processing. The standard S800 analysis code provides all the necessary functions and interface to perform these calculations.

4.3 Detectors

4.3.1 Object Box

The object box of the S800 analysis line contains a thin plastic scintillator (125 µm) for time-of-flight measurements. For lighter projectiles, a thickness of 1 mm is also available. This detector can withstand rates of up to 1 MHz. Energy-loss Si PIN detectors are also available and supported; they can be installed for experiments that require this extra information (please, note that maximum rates of these detectors are in the order of 1,000 pps). Other types of detectors provided by experimenters (such as diamond timing detectors) can be accommodated; their installation and integration is conducted by the user in coordination with the S800 device scientists.

4.3.2 Intermediate Image Station

The intermediate image box is equipped with two 10 cm x 10 cm tracking Parallel Plate Avalanche Counters that provide measurements of positions and angles in both the dispersive and non-dispersive planes. Maximum rates of up to few hundreds of kHz are possible. Best detection efficiencies are achieved for particles with Z>10.

4.3.3 Focal Plane Station

The S800 focal plane is equipped with various detectors for trajectory reconstruction as well as particle identification.

Tracking detectors: Two tracking drift-chamber (DC) detectors are used to measure the positions and angles in the focal plane. Each tracking DC has a position resolution of about 0.5 mm in both dispersive and non-dispersive directions. The detectors can be used with count rates up to 5,000 counts per second.

Particle identification detectors

Downstream of the two tracking DC detectors are an ion chamber for energy loss measurement, followed by a large thin plastic timing scintillator, followed by a 32-fold segmented CsI(Na) hodoscope.

- The tracking DC detectors require at least the timing scintillator functioning to provide a time reference to measure the drift time of the electrons.
- The timing resolution in the focal plane is around 400 ps in focus optics. This resolution is slightly better in dispersion-matching optics, where beam size in the focal plane is smaller.
- The ion chamber is able to separate elements up to Z=50, after momentum and position corrections are applied.
- The hodoscope crystals cover the active area of the focal plane and provide a total kinetic energy measurement of a particle that stops within a crystal. Good charge separation has been demonstrated for isotopes up to Z=30. The hodoscope can also be used as an isomer gamma-ray detector when biased at higher voltages. An aluminum plate can be installed in

front where excited nuclei are stopped and their subsequent isomeric gamma decay is detected.

4.3.4 The S800 Target Area

The experimenters are responsible for detector systems installed in the S800 target area. S800 device scientists and S3 vault coordinator will provide support as needed.

The GRETINA, CAESAR CsI(Na), SeGA Germanium arrays, LENDA neutron array, as well as the plunger, the LHDT target and the AT-TPC have standard setups used with the S800.

4.4 Electronics and Data Acquisition

4.4.1 Detector Electronics

The S800 detector electronics and data acquisition is based on VME and CAMAC electronics. The dead time of the S800 DAQ is ~20% at trigger rates ~2000 pps, and the typical data volume is ~0.4 KB/event. The electronics is the full responsibility of the S800 device scientists.

4.4.2 S800 Trigger Module

The S800 trigger module allows to define remotely the trigger logic involving the S800 and ancillary detectors. The module also provides clock and time-reset signals to timestamp S800 and experiment events.

4.4.3 S800 Data Acquisition

The DAQ software is based on the standard NSCLDAQ system. The formatted events from the S800 data stream can be immediately processed by the supported S800 back end software package (scalers, SpecTcl, event dumper…). At the end of every experiment, the data acquisition software and scaler files are recorded in a remote git repository, available to users upon request to S800 device scientists.

4.4.4 Merging of S800 DAQ with Ancillary DAQs

The S800 data acquisition system provides means to combine various devices together in event driven streams of data. As mentioned earlier, the trigger module allows the user to choose S800 or secondary single events, coincidences, and any combinations of the above. The merging of ancillary DAQs with the S800 DAQ is the responsibility of the users, and require coordination with the S800 device scientists.

4.5 Analysis Software and Tools

4.5.1 S800 Analysis Software

The standard S800 data analysis software is based on SpecTcl. It is kept on a remote git repository and available to users upon request to S800 device scientists. The development of analysis software for ancillary data acquisition systems merged with the S800 DAQ is under the responsibility of the users. Support from S800 device scientists should be explicitly requested.

4.5.2 Dedicated Computers and Software for S800 Operation

All S800 software is run from a dedicated computers in Data-U4. The use of these computers is restricted to device and beam scientists, as well as trained users for some of the functionality.

In standard configuration, these computers provide access to the following:

- Full Phoebus CSStudio tuning page, needed to tune the S800 and change magnetic settings
- NMR magnetic field readings of the S800 dipoles

- High Voltage control GUI
- Gas Handling system GUI
- Trigger control via a GUI
- Constant Fraction Discriminator GUI
- S800 scalers
- S800 standalone SpecTcl
- Readout GUI for S800 data acquisition

4.5.3 S800 Configuration Files

The configuration of the S800 data acquisition is stored in configuration files located in the S800 account (/user/s800/s800daq/Configurations). It is possible to automatically copy these configuration files alongside the "raw" and "formatted" data files for each run of a running experiment. This requires coordination between users and S800 device scientists.

4.6 Ancillary Systems

The S800 can accommodate ancillary detector system. Typical setups might include GRETINA, LENDA, LHDT, ATTPC, SeGA, CAESAR, Plunger, AT-TPC, etc. For any new experiment setup to be included, please coordinate with S800 device scientists.

5 Instrument Support Level

5.1 Support by Device Scientist

FRIB provides support of S800 by a device scientist. Setup of the instrument will be coordinated by the device scientist. On-site support is normally available from 9 a.m. to 5 p.m. on working days. On-call support for critical technical assistance during the experiment outside of the normal working hours can be requested by contacting the operator in charge (OIC), who will then contact the device scientist on call.

The device scientists responsible for the S800 provide the following support:

- Answer technical questions for users during the preparation of experiment proposals.
- Provide software packages necessary for using the S800 data acquisition and data analysis.
- Ensure the proper functioning of the device as specified in the standard configuration.
- Perform device setting changes during the experiment as required by the experimenters.
- Provide support during the experiment to ensure proper functioning of the device.
- Assist users in inspecting and understanding the on-line data from S800 detectors.
- Assist users during the off-line analysis phase.

5.2 Additional Support

S800 device scientists can train users to operate part of the S800 equipment. Training sessions are offered once per experiment, at a pre-arranged time with the experimenters. Offered training segments (with training durations) include

- Target change (excluding the big target scattering chamber): 1/2 hour.
- Target change involving the big target scattering chamber: 1/2 day.
- Installation of camera in target area: 1/2 hour.
- Tracking DC detectors calibrations (use of masks): 1/2 hour.
- Operation of S800 DAQ and S800 SpecTcl analysis software: 2 hours.
- Diagnostics and monitoring using S800 SpecTcl: 1 hour.

- Securing the S3 vault: 1/2 hour.
- Basic troubleshooting procedures: 1 hour.
- Basic operation of drives (e.g. masks, gate valves, beam blockers, etc.): 1/2 hour.
- Recording of setting savesets and calculation of inverse maps: 1/2 hour.

Special requirements in the S800 setup that go beyond the standard configuration described in this document shall be communicated to the device scientist and stated in the spokesperson questionnaire. Changes in the S800 setup outside the scope of the questionnaire will be subject to schedule and resource limitations.

6 Additional Instrument Support not covered in this Service Level Description

Any request for support not covered in this SLRD should be submitted to the FRIB Manager of User Relations prior to the submission of an experiment proposal for pre-approval.