STS S01020500-IST10117-R00

SECOND TARGET STATION (STS) PROJECT

Interface Sheet for Instrument Detector Systems and Integrated Control System

Matthew Pearson
Anton Khaplanov

5th March 2024

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

STS S01020500-IST10117-R00

SECOND TARGET STATION (STS) PROJECT

Interface Sheet for Instrument Detector Systems and Integrated Control System (ICS)

Author(s)

Prepared by: Matthew Pearson, STS Lead Control Systems Engineer
Name, Title

Approved by: Anton Khaplanov, STS Neutron Detectors Lead
Name, Title

Date Published:
5th March 2024

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831-6283
managed by
UT-BATTELLE, LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

Approvals

Interface Sheet for Instrument Detector Systems and ICS		ISSUE DATE: 5th March 2024
PREPARED BY Matthew Pearson	PROJECT Second Target Station	DOCUMENT NUMBER: S01020500-IST10117-R00

	Signature / Date					
	Rev. 00	Date	Rev. 01	Date	Rev. 02	Date
ICS Configuration Control Manager	Steven Hartman	Digitally signed by Steven Hartman Date: 2024.03.05 15:07:02 -05'00'				
Instrument Systems Configuration Control Manager	Van Graves	Digitally signed by Van Graves Date: 2024.03.06 14:12:28 -05'00'				
ICS Task Leader	Matthew Pearson	Digitally signed by Matthew Pearson Date: 2024.03.05 12:07:55 -05'00'				
STS Neutron Detectors Lead	Khaplanov, Anton	Digitally signed by Khaplanov, Anton Date: 2024.03.05 12:48:47 -05'00'				

Revision	Description
00	Initial Release

TABLE OF CONTENTS

TABLE OF CONTENTS viii
1. Purpose 9
2. Scope 9
    2.1 Interfacing Parts or Components 10
3. Acronyms and Definitions 10
4. References 11
    4.1 Documents Applicable to the Interfacing SSCs 11
5. Interface Definition 12
    5.1 Technical Description of the Interface 12
        5.1.1 Interface 1. Helium-3 (He3) 8-pack detectors - Electronics, software, and power supplies 12
        5.1.2 Interface 2. SiPM Anger camera - Electronics, software, and power supplies 16
        5.1.3 Interface 3. QIKR detector - Electronics, software, and power supplies 18
        5.1.4 Interface 4. Timepix4 MCP detector (TBD) - Electronics, software, and power supplies 20
        5.1.5 Interface 5. Single channel beam monitor - Electronics, software, and power supplies 20
        5.1.6 Interface 6. Position sensitive beam monitor (TBD) - Electronics, software, and power supplies 23
        5.1.7 Interface 7. Equipment and industrial safety - PLCs and interlocks 23
        5.1.8 Interface 8. Expected event rates - Computing and network 24
    5.2 Interface Data 25
        5.2.1 Power Supplies 25
        5.2.2 Equipment and industrial safety 27
        5.2.3 Numbers of detectors 28
        5.2.4 Expected event rates 30

1. PURPOSE

This document defines the interface between Instrument Systems detector systems and Integrated Control Systems (ICS). The interface will provide inputs to the design of the detector systems and the software, electronics and computing designs that will be part of the ICS. Requirements that may be derived from this document will be included in the requirements documents for Instrument Systems and ICS. The interface will be applicable to all types of neutron detectors across the STS instruments.

2. SCOPE

The scope of this document is the complete interface definition between Instrument Systems neutron detectors and the software, electronics and computing designs that will be part of the ICS. The interface points are summarized in the parent Interface Control Document [1] between Work Breakdown Structure (WBS) S.04 Instrument Systems and WBS S.06 Integrated Control Systems.

The scope of this document includes the various types of neutron detectors that will be used at the STS, such as He3 (Helium-3) gas detectors, SiPM (Silicon Photomultiplier) detectors, commercial neutron detectors such as Timepix-based MCP (Multi-Channel Plate) or scintillator detectors. The document also covers the various types of beam monitors, which can be considered small or single channel detectors. The interfaces to each type of detector system will be very different and will be detailed in separate sections.

This document covers event-based neutron detectors and does not cover commercial frame-based visible light cameras that are used for applications such as sample viewing, equipment monitoring and direct observation of a neutron beam via a scintillator screen (usually called a ‘neutron camera’). The interfaces to those camera systems are covered separately in [2].

Some of the detector technologies that will be used at the STS are well-established or are a long way into R&D (research and development), and these will be discussed in detail in the following sections. Some other detector technology is still TBD (to be determined) or in very early R&D and so these will not be discussed at this stage and those sections marked as TBD. In the future, TBD sections will be expanded as a result of project decisions and the evolving R&D programs.

In this document, where the term ‘software’ is used this indicates detector control, calibration, readout and local visualization software provided by ICS. The software used for saving data into files will be handled by the scientific software interface sheet [3], which also deals with interfaces to data analysis software.

The interface points are summarized in section 2.1. As the detector systems and ICS preliminary design progresses, additional interface points may become apparent and will be captured in this document. Cable tray needs, power panel and grounding interfaces will be handled in separate interface sheets between ICS and Conventional Facilities (CF) and between Instrument Systems and CF.

2.1 INTERFACING PARTS OR COMPONENTS

No.	Detector System	ICS Controls & Data Acquisition
1	He3 8-pack detector	Electronics, software, and power supplies
2	SiPM Anger camera	Electronics, software, and power supplies
3	QIKR detector	Electronics, software, and power supplies
4	Timepix4 MCP detector (TBD)	Electronics, software, and power supplies
5	Single channel beam monitor	Electronics, software, and power supplies
6	Position sensitive beam monitor (TBD)	Electronics, software, and power supplies
7	Equipment and industrial safety	PLCs and interlocks
8	Expected event rates	Computing and network

3. ACRONYMS AND DEFINITIONS

AC Alternating Current (AC power)
ASI Amsterdam Scientific Instruments
BNC Bayonet Neill–Concelman (connector type)
DAQ Data Acquisition System
DC Direct Current (DC power or signal)
DSP-T Data System Packetizer (Timing)
FEM Front End Module
FTS First Target Station
He3 Helium-3
HV High Voltage Power
ICD Interface Control Document
ICS Integrated Control Systems
ILL Institute Laue-Langevin (ILL)
IS Interface Sheet
LV Low Voltage Power
MB Megabyte (1E6 bytes)
MCP Multi-Channel Plate
ODB Optical Distribution Board
PDB Power Distribution Board
PDU Power Distribution Unit
PMT Photo Multiplier Tube
ROC Read Out Card/Controller
RS422 Recommended Standard 422 (electronics digital communication standard)
SHV Safe High Voltage (connector type)
SiPM Silicon Photomultiplier
SNS Spallation Neutron Source
SPI Serial Peripheral Interface
SSC Structure, System or Component
STS Second Target Station
TBD To Be Decided
TTL Transistor-Transistor Logic (in terms of voltage level specification)
WBS Work Breakdown Structure

4. REFERENCES

4.1 DOCUMENTS APPLICABLE TO THE INTERFACING SSCS

Ref	Document Titles	Document Control System Location
[1]	Interface Control Document for S.04 Instrument Systems and S.06 Integrated Control Systems	S01020500-ICD10004
[2]	Interface Sheet for Instrument Cameras and Integrated Control System	S01020500-IST10115
[3]	Interface Sheet for Scientific Software and Integrated Controls and Data Acquisition Systems	S01020500-IST10121
[4]	Detector Needs for STS Instruments	S04000000-TRT10000
[5]	Interface Sheet for Instrument Vacuum Systems and ICS Process Controls	S01020500-IST10122
[6]	Interface Sheet for Instrument Systems and Integrated Control Systems Computing and Network	S01020500-IST10123
[7]	Interface Sheet for Instrument Motion Systems and ICS Process Controls	S01020500-IST10118

5. INTERFACE DEFINITION

5.1 TECHNICAL DESCRIPTION OF THE INTERFACE

The interface for each of the points listed in section 2.1 is described below. Where the word ‘responsible’ is used, this will indicate that either Instrument Systems or Integrated Control Systems are responsible for designing, specifying, purchasing (or fabrication), installation, and testing the equipment or sub-system.

5.1.1 Interface 1. Helium-3 (He3) 8-pack detectors - Electronics, software, and power supplies

This interface deals with He3 linear position-sensitive (LPSD) 8-pack detectors that are widely used at the existing SNS First Target Station (FTS). The technology involved is mature, and the implementation used at STS is likely to be the same or very similar to the existing systems. For large area detectors the He3 gas is usually in tubes that are assembled to form 8-packs, with the gas tubes on the front and the front-end electronics and power distribution mounted on the rear side (see Figure 1 and Figure 2). These types of detectors are expected to be used on the STS instruments CHESS, VERDI, BWAVES (possibly) and EXPANSE [4].

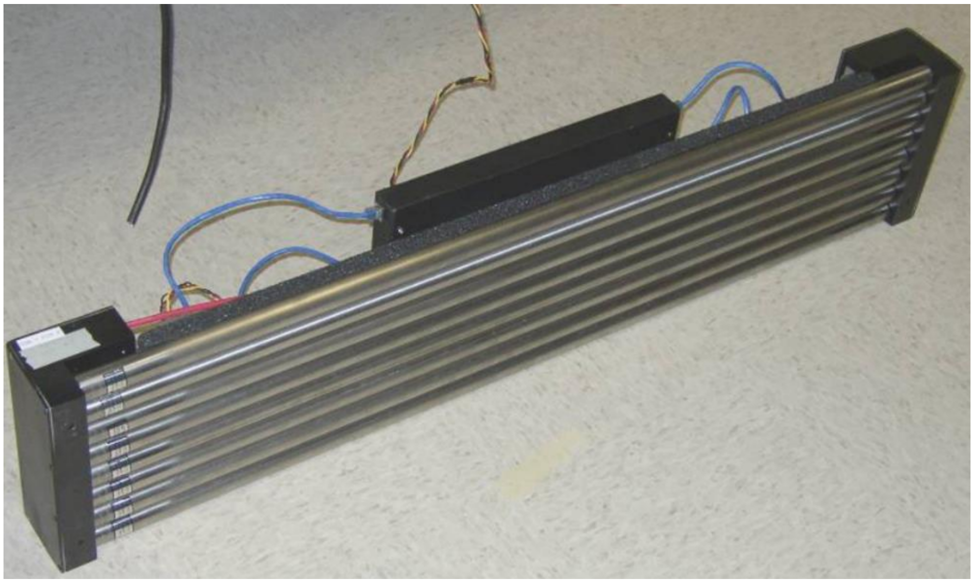


Figure 1: He3 8-pack assembly (front side showing the He3 tubes)

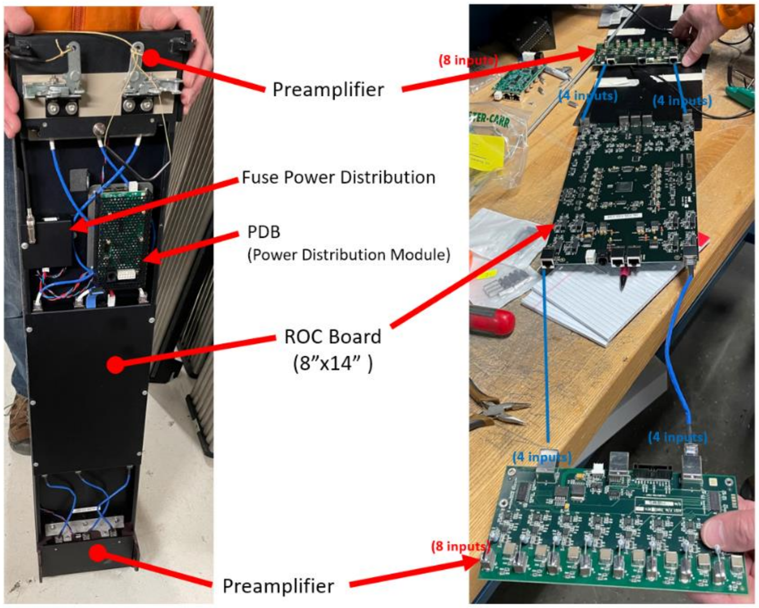


Figure 2: He3 8-pack assembly (rear view showing the electronics) and a different view showing the extracted electronics

The detection of neutrons in He3 gas will produce an analog signal that needs to be amplified and conditioned by pre-amplifier modules. The pre-amplifiers output an analog signal that is read into a Read-Out Controller (ROC) board that is responsible for signal digitization and discrimination. It will be possible to adjust digitization and discrimination settings. The ROC is therefore both a control and data read-out module. In addition, there is power distribution in the form of high voltage (for the detector He3 tubes) and low voltage (for the electronics). LV power distribution is achieved via fuse blocks and a Power Distribution Board (PDB).

The ROC communicates to downstream data aggregation modules that provide an interface to a remote data acquisition system. One of these modules is called a Front-End Module (FEM) which can attach to eight ROC modules (meaning eight 8-pack detectors). Figure 3 shows a photograph of a FEM that is installed at an instrument at the FTS.

Figure 3: FEM data aggregation module (the front shows the remote communication interface for a data acquisition system and the rear cables are originating from several ROC modules in 8-pack detectors)

He3 8-pack detectors are typically in a vacuum chamber. The FEMs can be mounted close to the detectors in vacuum (which is the case in Figure 3) or can be mounted external to the vacuum chamber (taking cable length limitations and vacuum feedthrough connector density into account).

Multiple FEMs are needed for a typical large detector assembly. These are further aggregated into a top-level module called a Data System Packetizer (DSP-T). The ‘T’ in DSP-T means ‘timing’ because the SNS timing optical signal is received and decoded by the DSP-T to provide a way to timestamp the detected neutron events. The DSP-T is a rack mounted device that communicates directly with the data acquisition computers running the detector control and readout software.

As much as possible the interface will follow existing practices at the First Target Station. In general, the interface between Instrument Systems and ICS can be summarized by stating that Instrument Systems are responsible for the detector hardware, frame and overall assembly and ICS are responsible for the electronics, software, and power supplies. This is described in detail in the itemized list below, which also details some of the practicalities regarding detector assembly and installation.

Instrument Systems:

- Responsible for the He3 8-pack, tubes, and mechanical frame.
- Responsible for providing physical dimensions of the mechanical frame and working with ICS to ensure the electronics can be mounted to the frame.
- Responsible for attaching the front-end electronics (provided by ICS) to the rear of the mechanical frame assembly. This includes the pre-amps, ROC and PDB modules. Also responsible for connecting the tube signal outputs to the pre-amp inputs.
- Responsible for providing electrical signal specification and requirements regarding He3 tube signal amplification and discrimination.
- Responsible for calibrating detector 8-packs that will be necessary for initial commissioning and operations.
- Responsible for providing high voltage (HV) power supplies specification (so that they can be selected and purchased by ICS, see below). This may include the recommendation of a preferred vendor and model for the HV power supplies.
- Responsible for the HV power cabling from the HV power supplies (provided by ICS) to the 8-pack assemblies (including the associated vacuum feedthroughs).
- Responsible for the low voltage (LV) power cabling from the LV power supplies (provided by ICS) to the electronics (meaning the electronics on the 8-pack assemblies and any collocated FEM modules) inside a vacuum tank (including the associated vacuum feedthroughs). This also includes responsibility for LV power fuse/distribution boxes.
- Responsible for providing enough vacuum feedthrough connectors for the data acquisition electronics communication cabling. The cabling for this will be the responsibility of ICS (see below).
- Responsible for providing space for the attachment of the downstream electronics modules such as the FEM modules. These may or may not be in the vacuum chamber. This may mean providing a mounting frame for the attachment of the electronics if a standard 19” rack is not used.
- Responsible for providing space for the racks that will hold the HV and LV power supplies.
- Responsible for the cable trays for the HV power, LV power and data acquisition communication cabling between the external racks (provided by ICS) and the vacuum chamber and within the

vacuum chamber. This design would typically be done in collaboration with ICS and Conventional Facilities (CF).

Integrated Control Systems:

- Responsible for the front-end electronics boards that attach to the rear side of the He3 8-pack. This includes the pre-amps, ROC, and Power Distribution Board (PDB). Responsible for providing these to Instrument Systems so that they can install these on the 8-pack detectors.
- Responsible for the downstream electronics modules (the FEM and DSP-T modules). If these electronics are rack mounted, then also responsible for the rack.
- Responsible for providing information to Instrument Systems on the physical size and mounting requirements for front-end electronics and downstream FEMs and DSP-T modules.
- Responsible for the communication cabling between the pre-amplifiers, ROC, PDB and downstream modules. This includes cables on both sides of the vacuum feedthrough ports (with the vacuum feedthrough ports being part of the vacuum vessel provided by Instrument Systems).
- Responsible for the racks and/or mounting hardware for the downstream data aggregation modules (e.g., the DSP-T).
- Responsible for the HV and LV power supplies and associated racks and rack Power Distribution Units (PDUs).
- Responsible for providing information to Instrument Systems on the LV power connectors used by the electronics. This can include connector pinouts and cabling schematics.
- Responsible for the LV power cabling to any rack mounted electronics outside of a vacuum tank (such as the DSP-T module).
- Responsible for the AC power cabling between the HV/LV racks and the electrical power panels on the instrument.
- Responsible for the software integration of the electronics and power supplies into the instrument controls and data acquisition system.
- Responsible for the local data visualization and detector calibration software needed for detector commissioning and initial operations.

The division of responsibility of the interface is illustrated below in Figure 4.

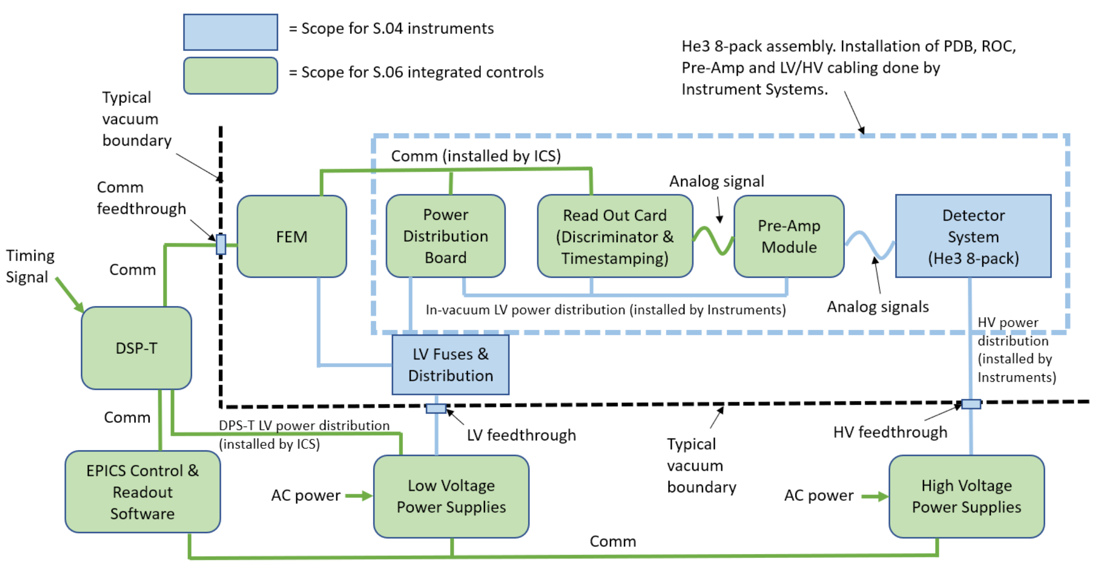


Figure 4: ICS and Instruments interface for He3 8-pack detectors

5.1.2 Interface 2. SiPM Anger camera - Electronics, software, and power supplies

This interface deals with the new generation of Anger cameras that are currently being developed and deployed at HFIR and the SNS. These cameras make use of an array of Silicon Photomultiplier sensors (SiPM) to detect the light from a scintillator screen. The electronics that sit behind the SiPM array perform pre-amplification, digitization and centroiding. These electronics are already being developed and integrated into the existing FTS data acquisition system, and so it is expected that the STS will use the same electronics designs. A photograph of a SiPM Anger camera is shown below (Figure 5) along with an existing installation at HFIR [4]. These types of detectors are expected to be used at the STS instruments PIONEER and CENTAUR.

Figure 5: SiPM Anger camera and an array of 3 cameras installed at HFIR [4].

As can be seen in Figure 5 the electronics design is very much an integral part of the detector and assembly. The pre-amps and ROC boards all sit within the frame of the detector and accept a HV bias signal, LV power and communications on the rear side. The PDB providing LV power to the detector are separate externally mounted electronics. For these detectors the ‘HV’ is really a low voltage bias signal of approximately 30V, but it will be labelled as HV to distinguish it from the LV power for the electronics.

The electronics designs have been developed by the SNS detector group and made compatible with the network communication protocols that are used by the SNS data acquisition system. It is expected that a commercial company will fabricate the detectors, or detector components for the STS project, along with the electronics, and therefore the electronics that are part of the detector assembly will be in Instrument Systems scope. The downstream electronics modules (FEMs and DSP-T) and the power supplies will be in ICS scope. The main interface between Instrument Systems and ICS will therefore be at the rear side of the detector assembly in Figure 5. The interface is itemized in the following lists.

Instrument Systems:

- Responsible for the detector (SiPM Anger camera) and associated assembly (SiPM detecting medium, frame, pre-amps, and SiROC on-board electronics).
- Responsible for coordinating with ICS on the design of the detector on-board electronics (pre-amp and SiROC modules) to ensure compatibility with the rest of the data acquisition system provided by ICS.
- Responsible for performing detector calibration that will be necessary for initial commissioning and operations.
- Responsible for providing high voltage (HV) power supplies specification (so that they can be selected and purchased by ICS, see below). This may include the recommendation of a preferred vendor and model for the HV power supplies.
- Responsible for the HV power cabling from the HV power supplies (provided by ICS) to the detector assemblies.
- Responsible for the low voltage (LV) power cabling from the LV power supplies (provided by ICS) to the detector assemblies. This also includes responsibility for LV power fuse/distribution boxes and the mounting of the PDB electronics (the PDB electronics will be provided by ICS).
- Responsible for providing space for the mounting of the downstream electronics modules such as the FEM and DSP-T modules.
- Responsible for providing space for the racks that will hold the HV and LV power supplies.
- Responsible for the cable trays for the HV power, LV power and data acquisition communication cabling between the external racks (provided by ICS) and the detectors assembly. This design would typically be done in collaboration with ICS and Conventional Facilities (CF).

Integrated Control Systems:

- Responsible for the downstream electronics modules (the FEM and DSP-T modules).
- Responsible for the LV PDB electronics and will provide those to Instrument Systems for installation.
- Responsible for providing information to Instrument Systems on the physical size and mounting requirements for the downstream FEMs, DSP-T and PDB modules.
- Responsible for the communication cabling between the detectors and the downstream electronics modules.
- Responsible for the racks and/or mounting hardware for the downstream electronics modules.
- Responsible for the HV and LV power supplies and associated racks and rack Power Distribution Units (PDUs).
- Responsible for the LV power cabling to any rack mounted electronics (such as the FEM and DSP-T module).
- Responsible for the AC power cabling between the HV/LV racks and the electrical power panels on the instrument.
- Responsible for the software integration of the electronics and power supplies into the instrument controls and data acquisition system.
- Responsible for the local data visualization and detector calibration software needed for detector commissioning and initial operations.

The division of responsibility of the interface is illustrated below in Figure 6.

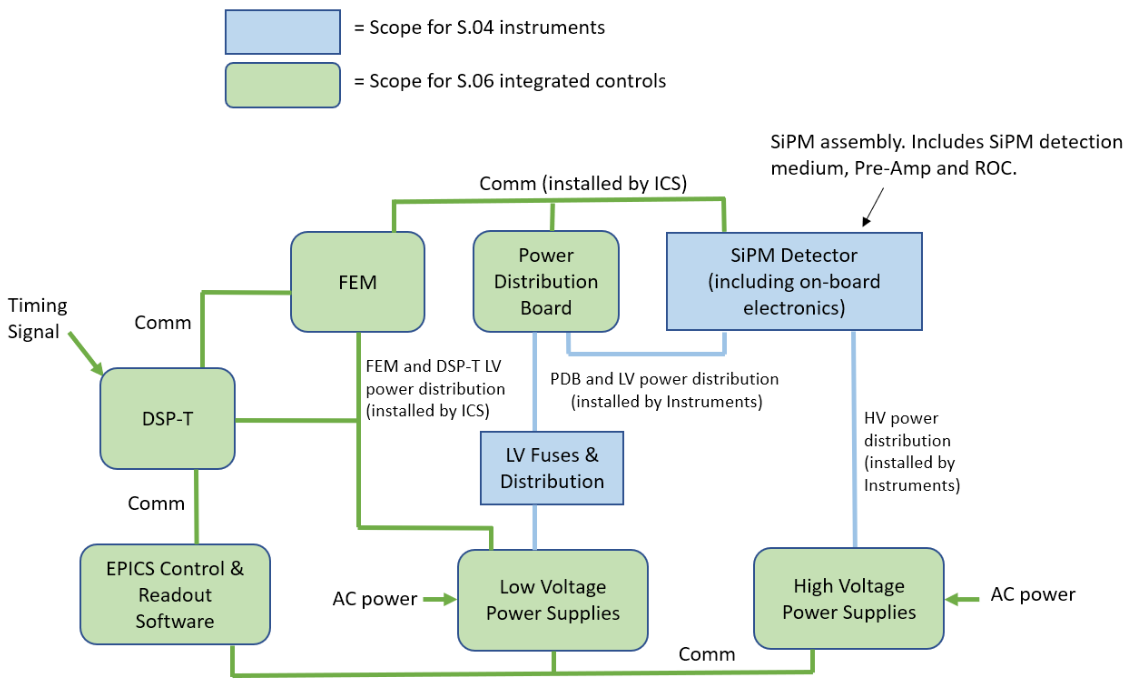


Figure 6: ICS and Instruments interface for SiPM Anger camera detectors

5.1.3 Interface 3. QIKR detector - Electronics, software, and power supplies

The R&D program for the QIKR detector technology is still ongoing. One solution being tested is a Timepix3-based scintillator detector from LoskoVision and Amsterdam Scientific Instruments (ASI) called the LumaCam. This commercial detector would be provided with its own front-end electronics and control and readout software. The ICS would be responsible for interfacing to the vendor software and providing any external control hardware such as LV power supplies and timing trigger signal. The following itemized list summarizes the expected interface; however, the specifics may change because of the R&D program and advances in detector design by the vendor.

Instrument Systems:

- Responsible for the Timepix3-based detector and the on-board electronics provided by the vendor.
- Responsible for the low-level detector control and readout software that is provided by the vendor. Or, if no software is provided, responsible for documentation describing the remote software interface.
- Responsible for describing pixel event centroiding algorithms that need to be integrated into the ICS data acquisition system, or for providing libraries with centroiding algorithms.
- Responsible for performing detector calibration that will be necessary for initial commissioning and operations.
- Responsible for describing the hardware interface to the detector, such as the communication, HV power, AC or LV DC power, timing system trigger, etc.

- Responsible for the cable trays for the AC or LV DC power, and signal cabling between the external racks (provided by ICS) and the detector assembly. This design would typically be done in collaboration with ICS and Conventional Facilities (CF).

Integrated Control Systems:

- Responsible for the LV power supplies and associated racks and rack Power Distribution Units (PDUs).
- Responsible for the AC power cabling between the LV racks and the electrical power panels on the instrument.
- Responsible for the AC or LV DC power cable to the detector.
- Responsible for the timing system trigger cable to the detector.
- Responsible for the downstream electronics modules (the ODB and DSP-T modules).
- Responsible for the software integration of the detector and power supplies into the instrument controls and data acquisition system. This includes the implementation of pixel event centroiding algorithms (which would be defined by Instrument Systems).
- Responsible for the computing system which runs the vendor supplied software.
- Responsible for the local data visualization and detector calibration software needed for detector commissioning and initial operations.

The division of responsibility of the interface is illustrated below in Figure 7.

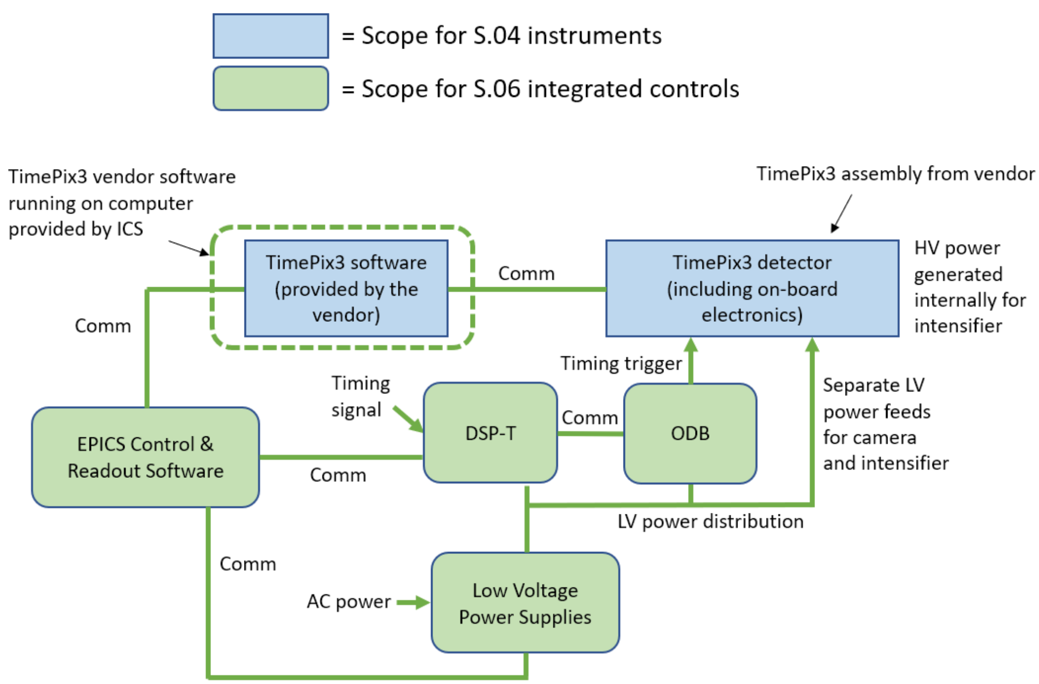


Figure 7: ICS and Instruments interface for ASI TimePix3 scintillator detector

The current LumaCam prototype is also supplied with a motor and motor controller from the vendor. The motor is used to fine tune the focal plane distance. Additional analog and digital signals are wired from the motor controller to the detector to provide control of the intensifier HV (which is generated internally). These additional signals are not shown in Figure 7 as the specifics of this interface will be decided later, depending on the specific equipment the vendor provides with the detector. ICS will provide input to Instrument Systems for the specification of additional motors, controllers and required signals, to ensure compatibility with the control system.

5.1.4 Interface 4. Timepix4 MCP detector (TBD) - Electronics, software, and power supplies

This section is TBD pending R&D programs and decisions on the Timepix4 detector technology.

Interface notes:
Interface should follow experience developed at FTS with the Timepix3 detector.
MCP detectors need a HV supply.
MCP based detectors need a vacuum system (that interface can follow S01020500-IST10122).
HV may need an interlock based on vacuum pressure level.

5.1.5 Interface 5. Single channel beam monitor - Electronics, software, and power supplies

STS plans to use Quantum Detector beam monitors that contain a scintillator and a Photo Multiplier Tube (PMT). The pre-amplifier is integrated into the beam monitor assembly (see Figure 8).

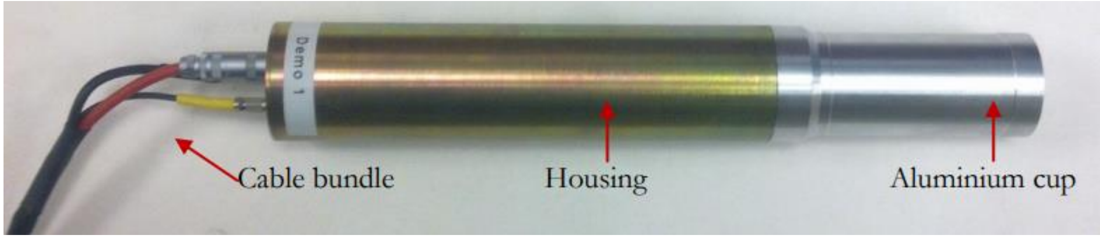


Figure 8: Quantum Detectors scintillator beam monitor assembly (scintillator, PMT and pre-amplifier)

The beam monitor can be purchased along with an electronics module that performs signal discrimination, provides LV power (6V) and additional functions such as analog signal monitor, manual threshold adjustment and a NIM logic level (-1V) digital output. This could be integrated into the ICS, but it is not the preferred integration method and would lack remote threshold adjustment and requires the use of European AC mains power.

The preferred integration method is integration with the existing SNS beam monitor controller. This controller was designed to work with the Ordela He3 chamber beam monitors but could be adapted to work with the Quantum Detector beam monitor. This would provide a consistent interface to both types of single channel beam monitor. The main features of the SNS beam monitor controller are itemized below, along with the adaptations that would be needed.

- Provides HV power (remote controllable, and the ability to interlock the power). This can connect directly to the HV connector on the beam monitor.
- Provides LV power for the beam monitor assembly. For the Ordela beam monitor this powers the pre-amp and discriminator, but for the Quantum Detector beam monitor it would only power the pre-amps. A different voltage output is needed (+/-6V).
- Receives the digital pulses (via RS422) and convert them to a BNC connector and TTL voltage for input into a ODB module. The Quantum Detector beam monitor does not have a discriminator

built into it and so the SNS beam monitor controller would need to be adapted to receive the analog signal so that it can perform the discrimination. Alternatively, this could be a discrete adaptor module that is placed close to the beam monitor and coverts the analog signal into a RS422 digital signal that the existing controller can receive.

- Provides a way to control the discriminator settings (via Serial Peripheral Interface protocol, SPI, using RS422).
- Optionally timestamp events and provide a TOF spectrum for debugging/info.

The integration method described above can be visualized in the following diagram in Figure 9. This involves changing the existing SNS beam monitor controller to be able to receive the analog signal and perform the discrimination and provide the necessary +/-6V LV power.

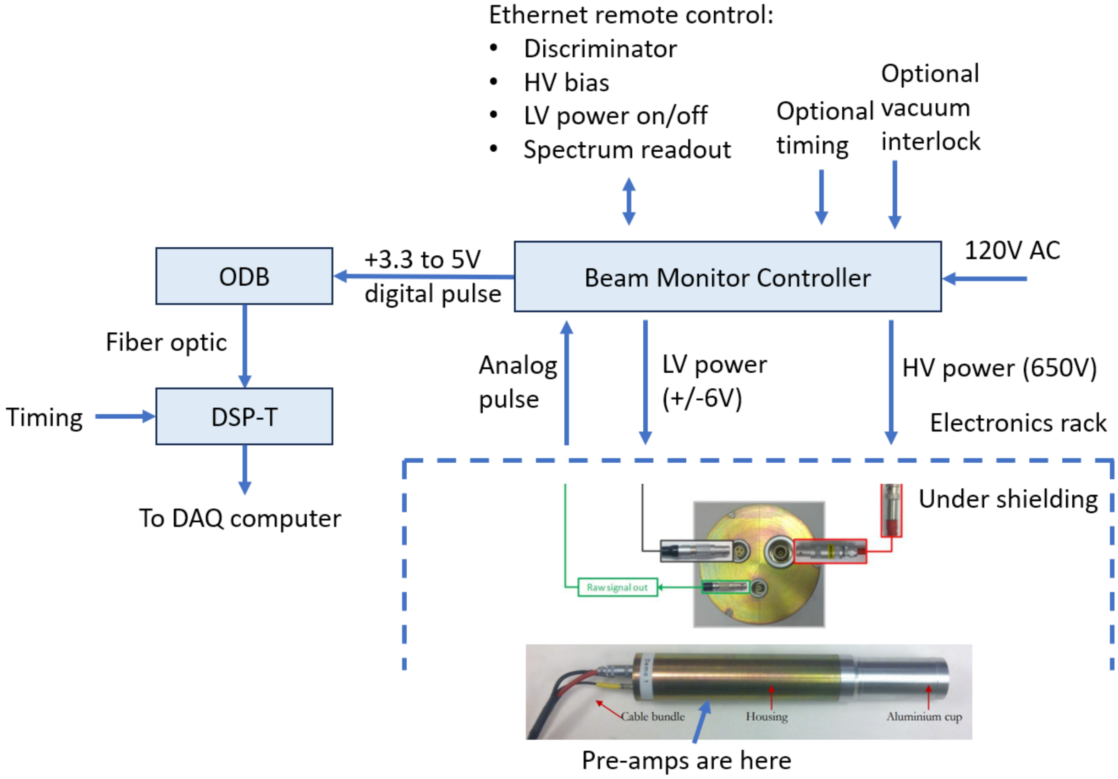


Figure 9: Quantum Detector beam monitor integration and adapted to work with existing SNS beam monitor controller

The cable that can be seen in Figure 8 can be provided by the vendor Quantum Detectors and bundles together HV, LV and the analog pulse. This can be routed under shielding to the location of the electronics rack containing the SNS beam monitor controller and the ends of the cable can be considered the interface between Instrument Systems and ICS. The interface can therefore be listed as:

Instrument Systems:

- Responsible for the beam monitor assembly (shown in Figure 8)
- Responsible for the beam monitor cables from the beam monitor to the electronics rack, if the cables can be used as-is from the vendor. If a different cable set is needed, to cater for under shielding discriminator location (see below), then ICS will be responsible for these and will provide them to Instrument Systems to install under shielding.

- Responsible for providing connector and electrical signal specification and requirements regarding analog signal discrimination.
- Responsible for providing information on the LV and HV power requirements of the beam monitor assembly.
- Responsible for providing space for the racks that will hold the discriminator and beam monitor controller. If the discriminator is separate from the rack and closer to the beam monitor assembly (see below) then also responsible for providing space for the mounting of the discriminator module.
- Responsible for the cable trays for the LV power, HV power and signal cabling between the external racks (provided by ICS) and the beam monitor assembly. This design would typically be done in collaboration with ICS and Conventional Facilities (CF).

Integrated Control System:

- Responsible for the beam monitor controller and the necessary modifications to the design to interface with the Quantum Detector beam monitor.
- Responsible for the discrete discriminator module that may be used (see below).
- Responsible for providing information to Instrument Systems on the physical size and mounting requirements for a discrete discriminator module.
- If a discrete discriminator module is used then responsible for the signal, LV and HV cabling and will provide these to Instrument Systems to install.
- Responsible for the downstream electronics modules (the ODB and DSP-T modules).
- Responsible for the AC power cabling between the beam monitor controller rack and the electrical power panels on the instrument.
- Responsible for the software integration of the beam monitor controller into the instrument controls and data acquisition system.
- Responsible for the local data visualization and calibration software needed for beam monitor commissioning and initial operations.

In some cases, it may be preferable to house the discriminator circuit closer to the beam monitor front-end. In this case the interface will remain the same except that the discriminator circuit will be a separate module that communicates remotely to the existing SNS beam monitor controller using the same protocol and cabling that is currently used for the Ordela beam monitors. The discriminator circuit could be located as close as possible outside the shielding blocks or could be placed near the beam monitor assembly under shielding (as shown in Figure 10).

If the discriminator circuit is placed near to (or attached to) the beam monitor assembly under shielding, then the interface will be slightly different as the vendor cabling would not be used. In this case ICS would be responsible for the cabling in terms of specifying and purchasing the cabling and would provide the cables to Instrument Systems to install. Decisions on cabling and location of the discriminator will be made during preliminary design.

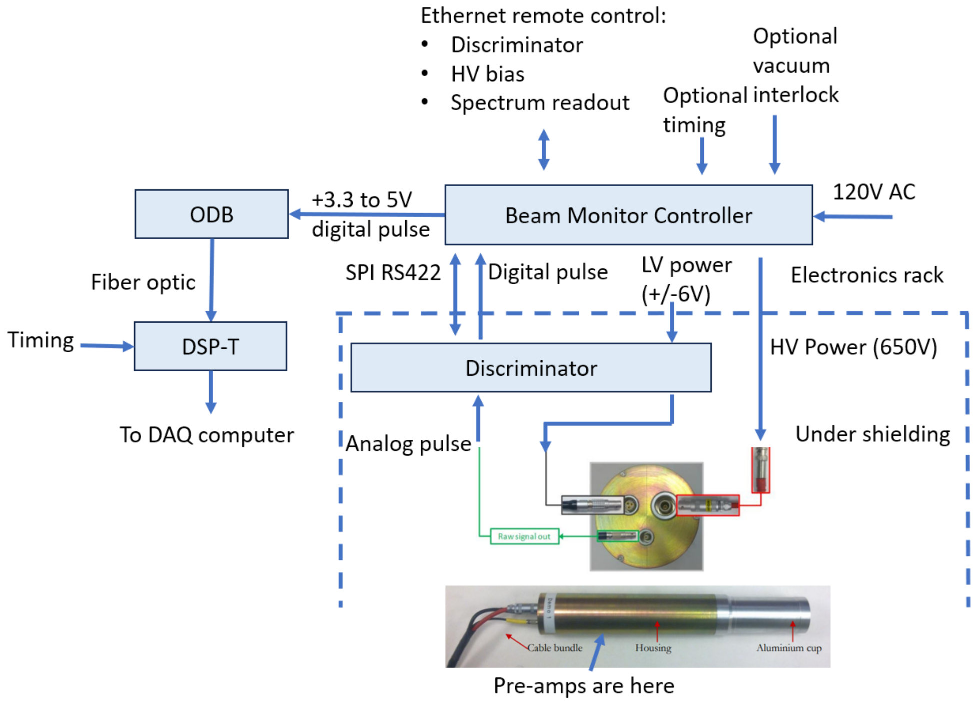


Figure 10: Quantum Detector beam monitor integration and adapted to work with existing SNS beam monitor controller, separate discriminator module (under shielding)

5.1.6 Interface 6. Position sensitive beam monitor (TBD) - Electronics, software, and power supplies

This section is TBD pending R&D programs and decisions on position sensitive beam monitors.

Interface notes:
The Institute Laue-Langevin (ILL) produces a multi-tube monitor that may be used by STS and the signal output from this has already been shown to work with an SNS pre-amp. It may be possible to use these monitors in different ways. One way is to wire the tubes together to produce one logical tube and we can read the signal from both ends in the same way as a single He3 tube in an 8-pack. Or the tubes can be operated independently and produce a signal per-tube, which could provide position sensitivity in one dimension or two dimensions if the tubes are read from both ends. Note that this monitor type simplifies to a non-position sensitive monitor if readout one-ended. In this case it will be used in a similar way to the Quantum Detectors scintillator monitor.

5.1.7 Interface 7. Equipment and industrial safety - PLCs and interlocks

This interface is focused on detector HV control in a vacuum chamber. Detector systems that use HV and operate inside a vacuum chamber have to interlock the HV with the vacuum chamber air pressure to avoid electrical arcs. This interlock would typically be implemented in a vacuum system PLC. Related vacuum PLC interfaces are described in more detail in [5].

Instrument Systems:

- Responsible for developing a list of interlocks that includes details on vacuum pressure levels and HV control.

Integrated Control Systems:

- Responsible for interfacing a PLC to the relevant vacuum pressure gauge readings and the HV power supply control.
- Responsible for implementing the PLC interlock logic to automatically ramp down HV in the desired air pressure range.

5.1.8 Interface 8. Expected event rates - Computing and network

This interface deals with the expected data rates from each type of detector. Detector data handling (data transmission, processing, storage, and visualization) can often be a driving factor for the design of the instrument computing and network systems which are the responsibility of the ICS. In some cases, the computing and network may be a limiting factor in how fast an instrument detector can operate and so it is important to accurately capture the requirements to realize the best solution for detector data handling.

Instrument Systems:

- Responsible for providing information on the peak and average neutron event rates for each detector module (8-pack, Anger camera, Timepix4, etc.) as well as expected peak and average neutron event rates for a whole detector system.

Integrated Control Systems:

- Responsible for calculating the detector data rates (in terms of MB/s)
- Responsible for the computing and network systems that will process and transport the detector data. This interface is discussed in more detail in [6].

5.2 INTERFACE DATA

This section will be updated as the preliminary and final design of the detector systems progress. Some data is presented on power supplies, expected numbers of detector and event rates. Details on electronics and software interfaces will be added later.

5.2.1 Power Supplies

As described in section 5.1.1, ICS will provide the power supplies and develop the remote control software, and Instrument Systems will be responsible for the LV and HV power cabling to the detector. An example of the kinds of LV and HV power supplies that are currently used at the SNS are described below.

The Spellman HV power supplies are usually used for He3 detectors at the SNS. A photo of a front panel is shown below in Figure 11. Several of these may be used for large detector systems. A single 30W HV power supply is more than sufficient for 20-30 He3 8-pack modules. The voltage is usually set around 1500V to 1900V, and the current draw is typically less than 1mA.

Figure 11: Spellman rack mounted HV power supply front panel

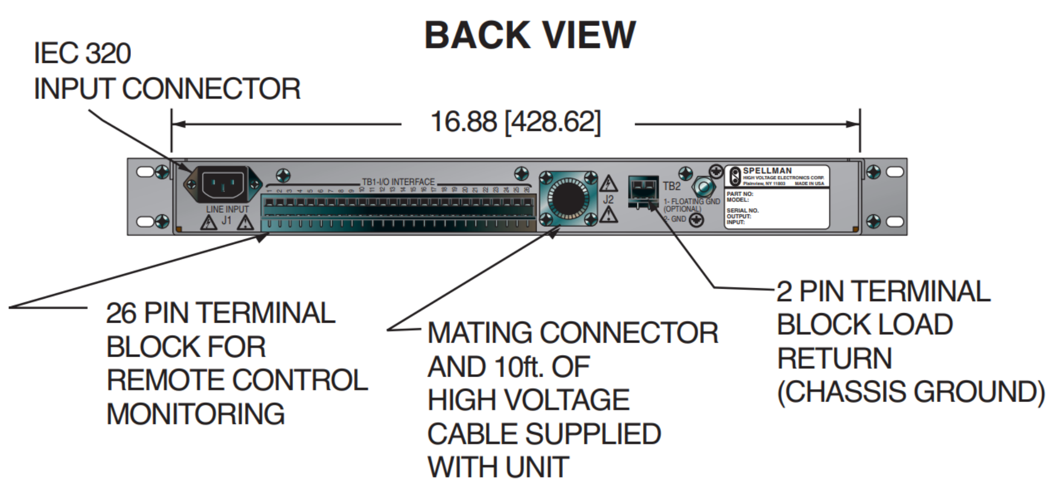


Figure 12: Spellman rack mounted HV power supply rear side schematic

A schematic showing the rear side of a Spellman power supply is shown in Figure 12. It shows the AC power cord input (provided from a rack PDU), remote I/O control (which may be used as an interface to the ICS) and the HV connector. The HV connector is the main interface point between ICS and

Instrument Systems. Various options exist for the type of HV connector, but for the ‘SL’ series (that are typically used at the SNS) a proprietary cable connector is used which would necessitate purchasing compatible cable sets from Spellman.

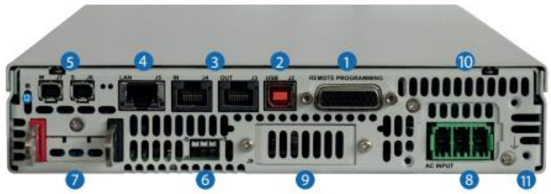
For detector systems requiring a high number of HV channels (such as the PIONEER and CENTAUR detector systems) the solution chosen is normally a crate and card based system from CAEN. The example shown below in Figure 13 shows a double width card with 24 channels using SHV (Safe High Voltage) coaxial connectors.

Figure 13: CAEN power supply crate (CAEN SY4527LC) and multi-channel card (CAEN 1540)

There are several models of LV power supplies used at the SNS. One example are the TDK Lambda rack mount single channel programmable power supplies (Figure 14 and Figure 15).

Figure 14: TDK Lambda programmable power supply front panel

GH1kW/1.5kW Rear Panel Description



1. Isolated Analog Programming, Monitoring and other control connector (DB26 Female)
2. USB Interface connector (Type B).
3. RS-232/RS-485 IN/OUT Remote Digital Interface (RJ-45 type) for Multi-Drop connection
4. LAN (LXI 1.5) Interface connector (RJ-45 type with LAN status indicators).
5. Auto paralleling Bus connectors (mini I/O type) for connecting Master unit-to-Slave and Slave unit-to-Slave unit.
6. Remote/Local Output Voltage Sense Connections (spring cage).
7. Output Connections: Rugged busbars (shown) for models up to and including 100V Output;
   Output connector: PHOENIX CONTACT GIC 2.5/4-G-7,62 for models with Outputs >100V.
   Plug connector: PHOENIX CONTACT GIC 2.5/4-ST-7,62 for models with Outputs >100V.
8. GH1.5kW Input: 85~265VAC, Single Phase, 50/60 Hz.
   AC Input Connector: PHOENIX CONTACT Power Combicon PC 5/3-G-7,62
   AC Input Plug Connector: PHOENIX CONTACT Power Combicon PC 5/3-STCL1-7,62
   Series with strain relief. (Model shown) GH1kW AC Input Connector: IEC320 C16.
9. Optional Interface Position for IEEE 488.2 SCPI or AnyBus Interface.
10. Exhaust air assures reliable operation when units are zero stacked.
11. Functional Ground connection (M3x8mm screw).
12. Reset button. Set default Power Supply settings.

Figure 15: TDK Lambda programmable power supply rear panel

The interface between Instrument Systems and ICS are the output connectors, labelled number 7 in Figure 15, that can be configured in different ways (rugged bus bar option shown).

5.2.2 Equipment and industrial safety

In an evacuated detector system, it is necessary to protect the system against electrical discharge by monitoring the air pressure to ensure HV is turned off (or below a certain voltage, say 100V) at certain air pressures. A typical He3 detector HV level is approximately 1800V. Standard atmosphere is 760 Torr. At the SNS and HFIR facilities a typical pressure range in which HV is permitted is <2 mTorr and >700 Torr.

For some detector systems that are attached to motorized stages it is also necessary to prevent motion when the HV is turned on. This is to prevent electrical discharge due to vibrations that may change the distances between components. This can be achieved by disabling motor power when the HV is turned on.

As described in section 5.1.7, Instrument Systems will provide details of the interlocks needed (as part of the vacuum system design) and ICS will design, implement and test the interlock system. The interlock would normally be implemented in a PLC system that interfaces to the detector vacuum system, the HV power supplies, and if necessary the motion control system, as shown in a schematic in Figure 16.

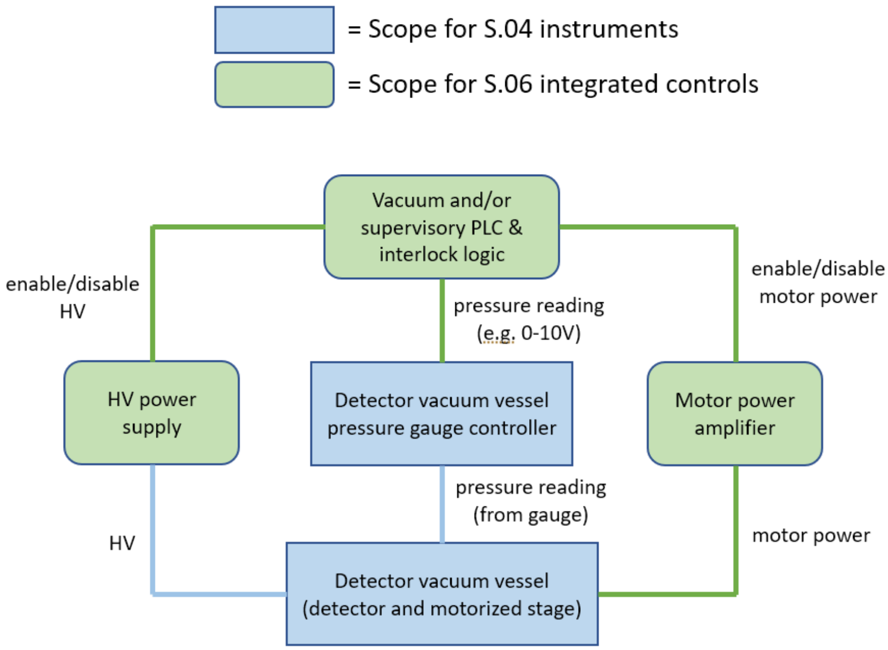


Figure 16: Detector vacuum vessel interlock schematic (HV and motor power interlock)

The scope of responsibility of the simplified components and cables shown the Figure 16 are color coded in a way consistent with the interfaces described in section 5.1 and the interface sheets dealing with vacuum systems [5] and motion systems [7].

5.2.3 Numbers of detectors

This section contains a brief description of each of the STS instruments detector and beam monitor systems.

5.2.3.1 CHESS

CHESS will initially be built with 105 He3 8-pack modules (see section 5.1.1) in a cylinder configuration in a large vacuum vessel. This may increase to 159 8-pack modules at a later date. The He3 tubes will be 1.4m in length and 1” diameter and the signal will be digitized such that there are 256 pixels per tube.

Up to 23 FEM boards will be mounted in vacuum, with the downstream electronics modules (DSP-T and ODB modules) mounted externally along with the LV and HV power supplies. The detector vacuum vessel will provide vacuum feedthrough ports for communication and power cabling.

CHESS will use 4 non-position sensitive beam monitors. Two of these are expected to be scintillators and two multi-tubes in single-ended configuration.

On the 1st floor of CHESS there will be 5 electronics racks that are mostly dedicated to the detector and detector vacuum system. The racks will contain detector electronics, power supplies, vacuum instrumentation and a PLC system.

5.2.3.2 PIONEER

PIONEER will be built with 119 SiPM Anger cameras (see section 5.1.2) that will operate in air in a circular configuration of 10 towers, each tower holding 16 cameras. An additional lower detector array will contain 14 cameras.

PIONEER will use 4 non-position sensitive beam monitors. Additionally, a position-sensitive camera is considered for beam profile diagnostics.

Around the detector assembly PIONEER will have 7 electronics racks that will contain the HV and LV power supplies and rack-mounted detector electronics modules.

5.2.3.3 VERDI

VERDI will use 120 He3 8-pack detectors (see section 5.1.1). The tube length will be 1m long.

VERDI will contain 2 position sensitive and 1 non-position sensitive beam monitors.

5.2.3.4 CENTAUR

CENTAUR will contain approximately 108 SiPM Anger cameras arranged in several banks at varying distances along a vacuum vessel. The detectors will be similar to those used on PIONEER except that they will be vacuum compatible. The front end of the detector will be in vacuum and most of the electronics will be in air. In terms of the interface to ICS there is not expected to be a difference to that already described in section 5.1.2.

CENTAUR will use 2 non-position sensitive beam monitors.

5.2.3.5 QIKR

The interface described in section 5.1.3 is specific to QIKR. It is expected that QIKR will use the LumaCam detector. There is currently an ongoing R&D program that is evaluating the current version of the LumaCam detector, and so the specifics of the interface may change in the future.

The detector will be mounted on the end of a motorized detector arm.

QIKR will use one non-position sensitive multi-tube beam monitor.

The upper directed beamline has been removed from project scope. However, in terms of detector systems, it is expected to duplicate what the lower beamline has.

5.2.3.6 BWAVES

BWAVES is expected to use 32 He3 8-pack detectors.

BWAVES will use beam monitors, but the specific type and number is TBD.

5.2.3.7 CUPI2D

CUPI2D is expected to use a Timepix4-based detector, a LumaCam and a CMOS or CCD based camera. The R&D project for this detector is pending the development of the detector technology (see section 5.1.4).

5.2.3.8 EXPANSE

EXPANSE is expected to use 35 He3 8-pack detectors, with a short 15cm length arranged in a cylinder configuration.

5.2.4 Expected event rates

The expected event rates per detector module (and total) have been described in [4] and are reproduced below along with the equivalent data rate in terms of MB/s (assuming 8-bytes per detector event).

Instrument	Global Average Rate (million events/second)	Average Data Rate (MB/s)
CHESS	2.5	20
PIONEER	6.0	48
VERDI	6.0	48
CENTAUR	5.0	40
QIKR	200	1600
BWAVES	0.01	0.08
EXPANSE	0.1	0.8

Table 1: Estimated average raw data rates for each STS instrument (except CUPI2D)

Table 1 does not show the rate estimate for CUPI2D, which will aim to collect data at a rate ‘as fast as possible’, within the limits of the detector data acquisition system, network, and software systems.

In [6] the average event rates over 1 year have been estimated, taking multiple factor into account. This mainly affects the design of the computing, network and software systems and so are not reproduced here. Note that in case of Timepix-based detectors such as the LumaCam and Timepix4/MCP detector, the raw data rates may be significantly reduced depending on the algorithms available.