



SAR4 Klystron based RF Systems (incl. modulators)

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FBS Nodes



Systems included for SAR4

RF systems

- RFQ : =ESS.ACC.A01.E01 RF System (RFQ)
- DTL : =ESS.ACC.A02.A01.E01 to ESS.ACC.A02.A05.E01 RF System (DTL-1 to DTL-5)
- MEBT : =ESS.ACC.W02.E01 to ESS.ACC.W02.E03 (MEBT-1 to MEBT-3)
- Spk : =ESS.ACC.A03.A02.E01 to ESS.ACC.A03.A14.E02 (Spk-1 to Spk-26)
- MBL: =ESS.ACC.A04.A02.E01 to ESS.ACC.A04.A10.E04 (MBL-1 to MBL-36)
- HBL: =ESS.ACC.A05.A02.E01 to ESS.ACC.A05.A06.E04 (HBL-1 to HBL-20)

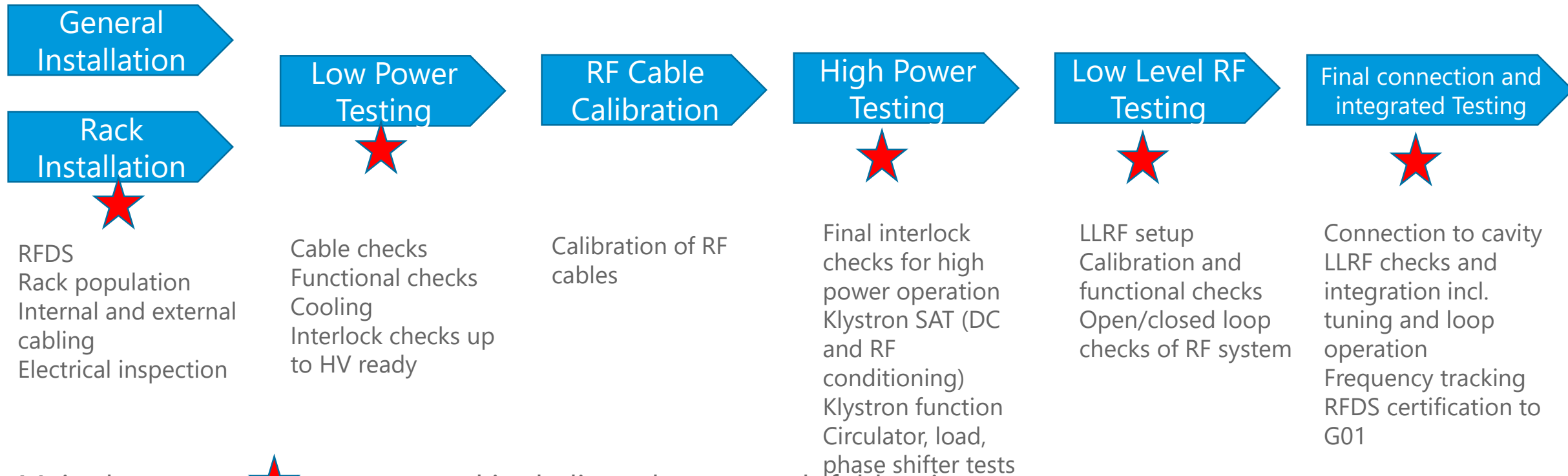
Modulators

- RFQ =ESS.ACC.A01.T01 RFQ-010:RFS-Mod-010
- DTL-2 =ESS.ACC.A02.A02.T01 DTL-020:RFS-Mod-020
- DTL-4 =ESS.ACC.A02.A04.T01 DTL-040:RFS-Mod-040
- MBL =ESS.ACC.A04.A02.W01.T01 to ESS.ACC.A04.A10.W01.T01 (Modulators -010 to -090)
- HBL =ESS.ACC.A05.A02.W01.T01 to ESS.ACC.A05.A06.W01.T01 (Modulators -010 to -050)



Typical RF System: Testing

RF system:
Installation and test sequence as follows:



Main documents.  are stored in dedicated system sub folders in:

<https://chess.ess.lu.se/enovia/link/21308.51166.48128.11070>

Earlier documentation (DRs, FAT, inspections, lab tests...) are in i-base, confluence, collaboration space or CHESS. Eventually this will be consolidated₅



RF Reliability

We now try to track all faults, errors and unplanned events.
Faults are being:

- Prioritised
- Followed up
- Documented in a RF wiki

The aim is to understand the cause of the faults and eliminate reoccurrence which may include re-design, different components



RFQ and DTL RF Systems

RFQ RF System: Scope



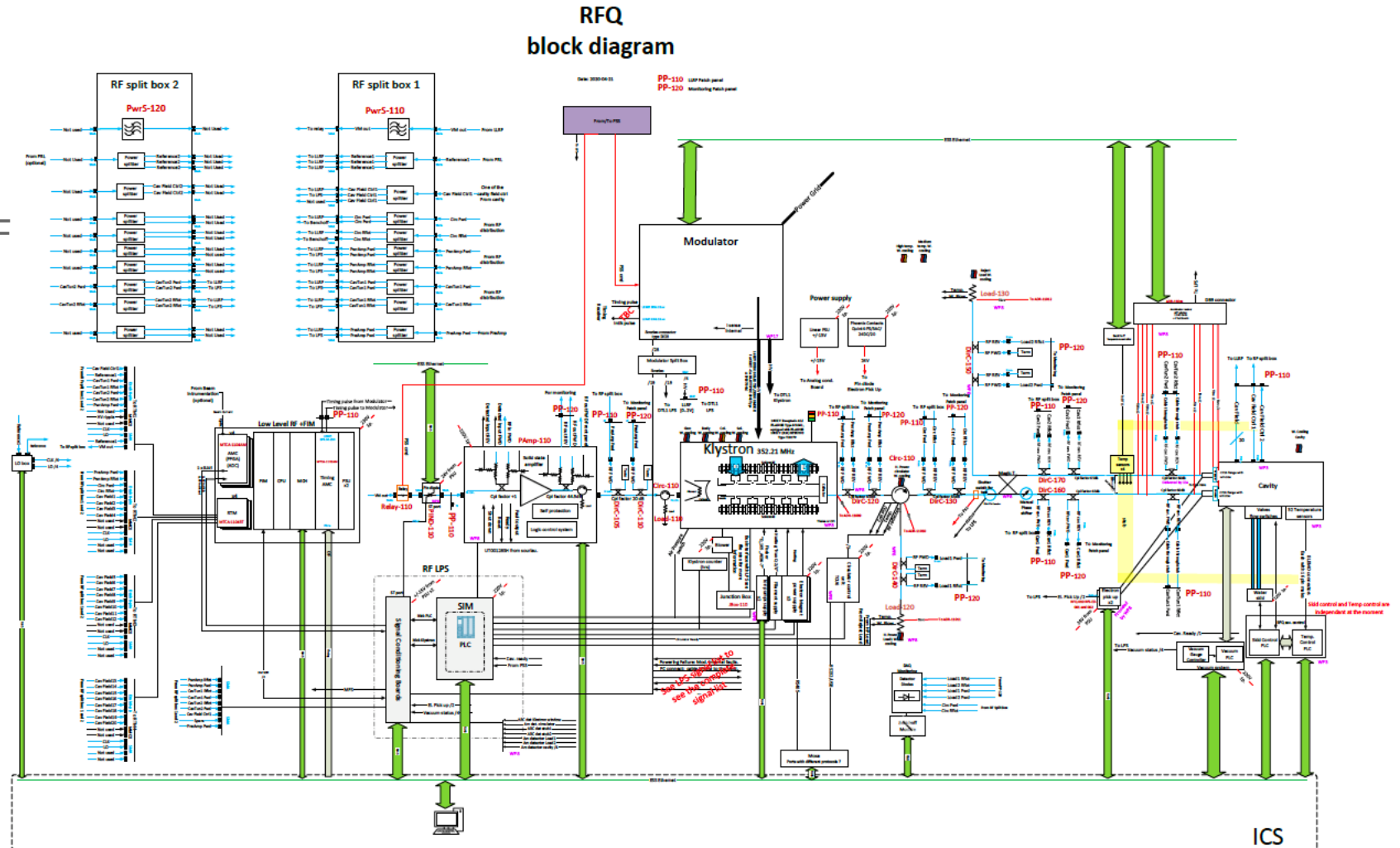
Detailed system schematics exist: <https://chess.ess.lu.se/enovia/link/ESS-0115056/21308.51166.38912.26339/valid>

Scope includes:

- LLRF
- Interlock systems incl arc detection, electron pickup
- PSS relay and Pin diode (fast RF abort)
- Klystron and auxiliary supplies
- RFDS
- Pre-amplifiers

Schematics defines interfaces

- Naming
- Utilities
- Modulator
- ICS



RFQ, DTL 1-5 RF System: Testing status



Example folder (DTL 2) of key tests. Note earlier testing is stored elsewhere.

| Name | Type | Rev | Ver | Title/Label |
|-------------------------------|----------------------|-----|-----|-----------------------------------------------------|
| DTL2 Installation and Testing | Workspace Folder | | | |
| ESS-3475742 | Validation Report | 1 | ✓ | DTL2 Klystron Interlock Checklist |
| ESS-3727481 | Installation Report | 1 | ✓ | Busbar Schedule Of Test Results - DTL 2 (DTL 031) |
| ESS-3728369 | Installation Report | 1 | ✓ | RF rack installation checklist DTL 2 |
| ESS-3919818 | Drawing file | 1 | ✓ | DTL 2 Patch panel |
| ESS-4058025 | Site Acceptance Test | 1 | ✓ | DTL2 High Power Test Protocol Thales TH217 |
| ESS-4788304 | Validation Report | 1 | ✓ | LLRF Test Report for System: DTL-020: Powe |

Block Diagram Folder:

<https://chess.esss.lu.se/enovia/link/21308.51166.25345.1735>

RFDS certification:

<https://chess.esss.lu.se/enovia/link/ESS-3624174/21308.51166.22016.7932/valid>

| Name | Type | Rev | Ver | Title/Label |
|------------------|------------------|-----|-----|--------------------------------------------|
| System-Schematic | Workspace Folder | | | |
| ESS-0115054 | Drawing file | 1 | ✓ | block diagram teststand2 |
| ESS-0115055 | Drawing file | 1 | ✓ | block diagram Medium Beta |
| ESS-0115056 | Drawing file | 1 | ✓ | block diagram RFQ |
| ESS-0115061 | Drawing file | 1 | ✓ | block diagram spoke |
| ESS-0115057 | Drawing file | 1 | ✓ | block diagram DTL |
| ESS-0260158 | Drawing file | 1 | | Master Oscillator and Phase reference line |
| ESS-0115060 | Drawing file | 2 | ✓ | block diagram MEBT |
| ESS-0115056 | Drawing file | 2 | | block diagram RFQ |
| ESS-0115057 | Drawing file | 2 | | block diagram DTL |
| ESS-0115055 | Drawing file | 2 | | block diagram Medium Beta |
| ESS-0115060 | Drawing file | 3 | | block diagram MEBT |
| ESS-0115061 | Drawing file | 2 | | block diagram spoke |



LLRF

LLRF is, by necessity, tested in phases:

Pre-cavity system testing, testing with the cavities, testing with increasing beam, pulse width and timing configurations

Detailed LLRF test reports are typically scripted.

- Script setup up the machine and runs the test
- Data is automatically stored and configured
- Results are published following the template

Automatic reporting:

- Ensures consistent setup
- Repeatability of tests
- Consistent report layout makes it easier to find the relevant data



RFQ/DTL: ~~Open~~ Resolved Issues since SAR2B

All NCL e-bends have been modified, re-installed and low/high power tested.

All Magic-Tees have been modified, re-installed and low/high power tested.



RFQ, DTL 1-5 Summary Status

Amplifier system in operation and reliable (so far).

Some improvements to the LPS state-machine signal list has been implemented.
The GUIs have been updated accordingly.

Various LLRF enhancements applied.



MEBT 1-3

MEBT RF Systems

MEBT TRR: <https://confluence.ess.lu.se/display/ATC/MEBT+Bunchers+TRR>

Block Diagram: <https://chess.ess.lu.se/enovia/link/ESS-0115060/21308.51166.30977.1064/valid>

RFDS certification: <https://chess.ess.lu.se/enovia/link/ESS-3624174/21308.51166.22016.7932/valid>

| Name | Type | Rev | Ver | Title/Label |
|-------------|---------------------|-----|-----|------------------------------------------------|
| MEBT1 | Workspace Folder | | | |
| ESS-3872112 | Verification Report | 2 | ✓ | MEBT LLRF Control System's Verification Report |
| ESS-3881474 | | | | |
| ESS-3911914 | | | | |
| ESS-4003173 | | | | |
| ESS-4003756 | | | | |
| ESS-4004277 | | | | |
| ESS-4017641 | | | | |

| Name | Type | Rev | Ver | Title/Label |
|-------------|------------------|-----|-----|-------------|
| MEBT2 | Workspace Folder | | | |
| ESS-3872112 | | | | |
| ESS-3881476 | | | | |
| ESS-3914749 | | | | |
| ESS-4003179 | | | | |
| ESS-4003757 | | | | |
| ESS-4004278 | | | | |
| ESS-4017641 | | | | |

| Name | Type | Rev | Ver | Title/Label |
|-------------|---------------------|-----|-------|------------------------------------------------|
| MEBT3 | Workspace Folder | | | |
| ESS-3712641 | Installation Report | 1 | 5 (5) | RF rack installation checklist MEBT3 |
| ESS-3872112 | Verification Report | 2 | ✓ | MEBT LLRF Control System's Verification Report |
| ESS-3881475 | Validation Report | 1 | ✓ | MEBT SSPA Site Acceptance Test SN A90924D_2101 |
| ESS-3914759 | Validation Report | 1 | ✓ | MEBT030 Low power tests report |
| ESS-4003181 | Validation Report | 1 | ✓ | High power test report on MEBT System 3 |
| ESS-4003758 | Drawing file | 1 | 1 (1) | Patch panel MEBT 3 |
| ESS-4017641 | Report | 1 | 1 (1) | LLRF MEBT SSPA closed loop tests |



MEBT: LLRF

Verification reports

MEBT LLRF SSPA closed loop tests for MEBT 1, 2 and 3: [ESS-4017641](#)

- Carried out at 22 kW into an external load, ie before connection to the cavity

MEBT LLRF Control System Verification Report: [ESS-3872112](#)

- Covers all three systems

MEBT TRR: [LLRF system MEBT TRR.pptx](#)

- Contains additional results at reduced power levels.



MEBT Summary Status

Amplifier system in operation and reliable (so far).



MBL and HBL

MBL/HBL RF System: Scope



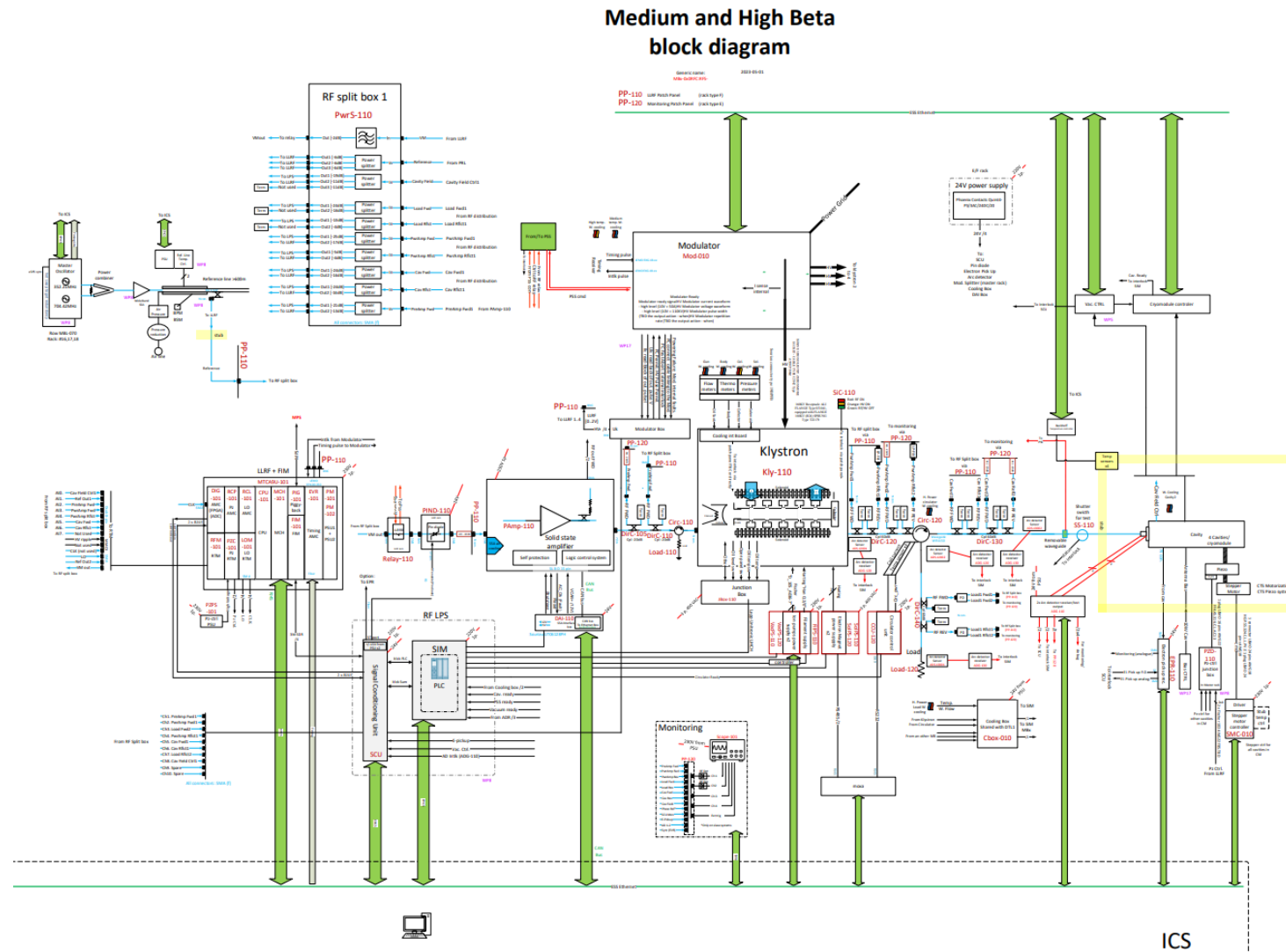
Detailed system schematics exist: <https://chess.ess.lu.se/enovia/link/ESS-0115055/21308.51166.31860.53872/valid>

Scope includes:

- LLRF
- Interlock systems
- PSS relay and Pin diode (fast RF abort)
- RFDS (Coax)

Schematics defines interfaces

- Naming
- Utilities
- ICS





MBL and HBL Summary Status

Amplifier system in operation and reliable (so far).

HBL-050 currently used for Klystron testing but operational with cavity.

Various LLRF enhancements applied.



Tests with beam

Except field stability performance during beam mainly tests to check beam compensation functionality from timing data information: (ESS-3122750)

- Dynamic detune
- Beam destination
- Beam current (and to detect changes)
- Beam length
- Beam position
- Bad pulse
- PMortem event

Most of the above tests can be verified without beam



Checklist and NCRs

Start up checklist meeting with OP held with minor actions.

- Save and Restore pending final adjustments

NCRs, if any, to be added in final version



THE END



Scope for SAR4

For each system, present:

Brief Scope description and status

Brief status of system(s) -HBL-050 used for RF testing but operational with cavity, LLRF

Status of documentation (could refer to CIDL here) -

Known issues deemed OK to proceed - **RF loads, LLRF maturity?, filament trips?**

Are there any NCRs related to system(s)? -**Klystron cooling pipe quality (Morten)**

Does the system have any SSCI2S (rad safety) function? **Klystrons?**

Applicable codes and compliance (e.g required periodic inspections)

Describe briefly any tests needed with beam (and point to plan)

Have start up checklist been performed? Any issues found?

Have all recommendations from previous reviews (not just TRR) been addressed?