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)

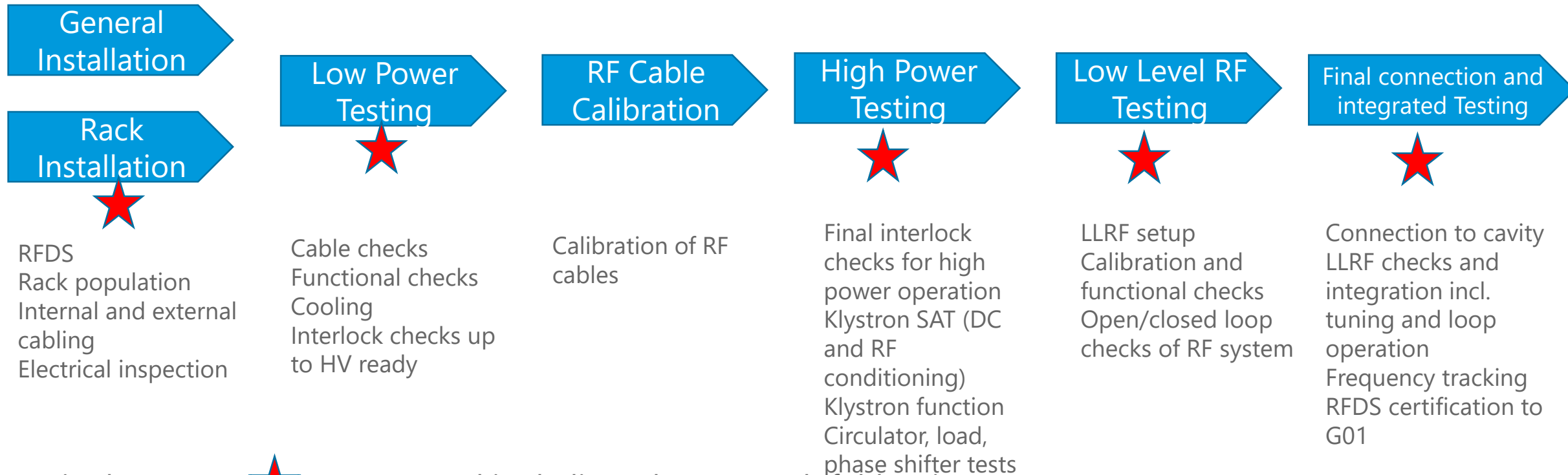HBL: =ESS.ACC.A05.A02.E01 to ESS.ACC.A05.A06.E04 (HBL-1 to HBL-20)

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:

General Installation →

Rack Installation → ⭐

Low Power Testing ⭐ →

RF Cable Calibration →

High Power Testing ⭐ →

Low Level RF Testing ⭐ →

Final connection and integrated Testing ⭐

RFDS
Rack population
Internal and external cabling
Electrical inspection

Cable checks
Functional checks
Cooling
Interlock checks up to HV ready

Calibration of RF cables

Final interlock checks for high power operation
Klystron SAT (DC and RF conditioning)
Klystron function
Circulator, load, phase shifter tests

LLRF setup
Calibration and functional checks
Open/closed loop checks of RF system

Connection to cavity
LLRF checks and integration incl. tuning and loop operation
Frequency tracking
RFDS certification to G01

Main documents. ⭐ are stored in dedicated system sub folders in:
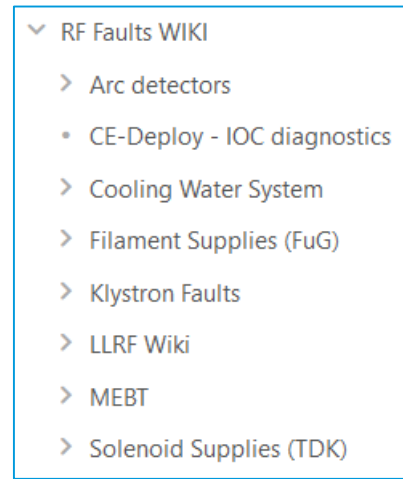https://chess.esss.lu.se/enovia/link/21308.51166.48128.11070

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

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, etc.

RFQ and DTL RF Systems

RFQ RF System: Scope

Detailed system schematics exist: https://chess.esss.lu.se/enovia/link/ESS-0115056/21308.51166.38912.26339/valid
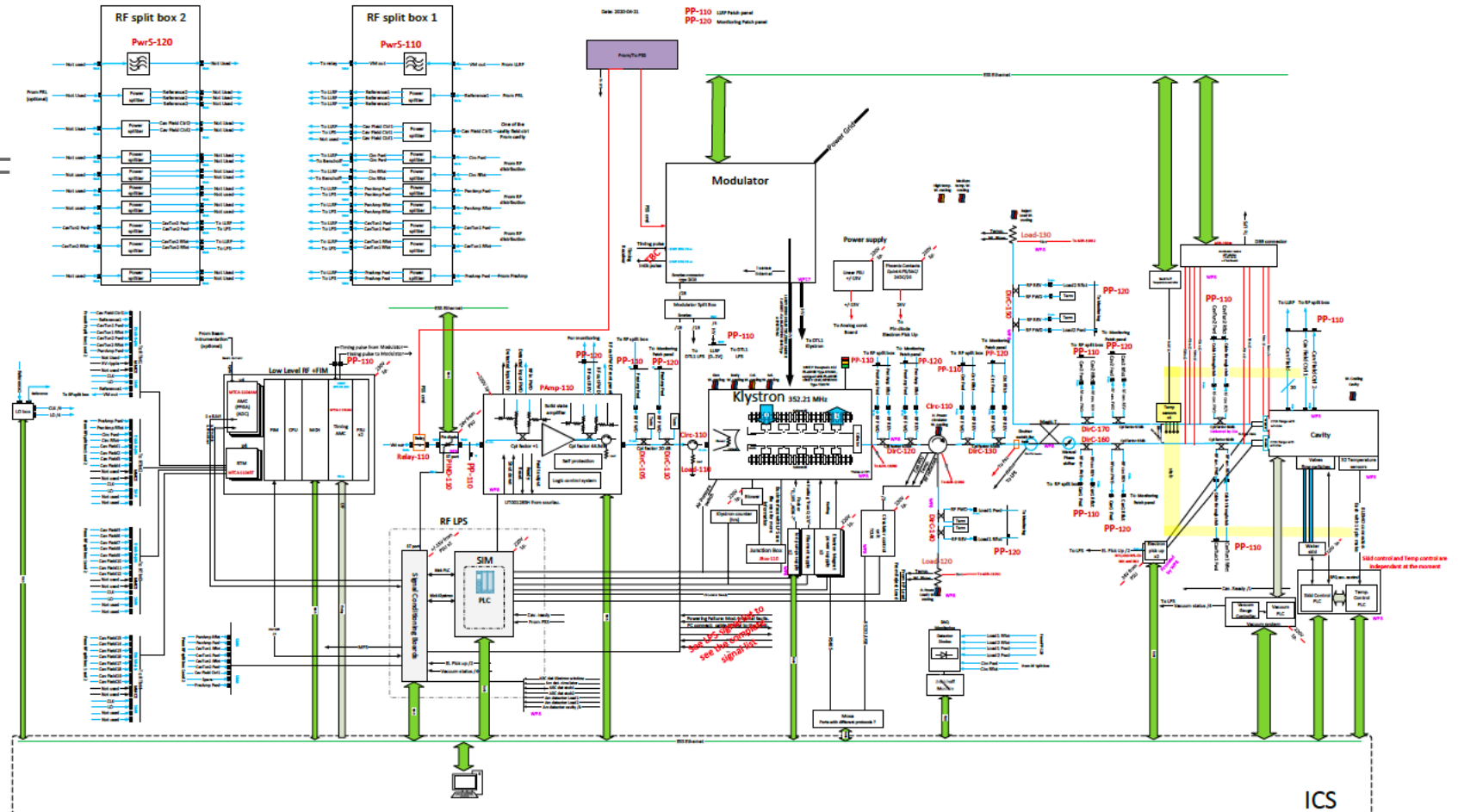
Scope includes:

- 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 block diagram

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
1.	📁 DTL2 Installation and Testing	Workspace Folder				
2.	📄 ESS-3475742	Validation Report	1	✔		DTL2 Klystron Interlock Checklist
3.	📄 ESS-3727481	Installation Report	1	✔		Busbar Schedule Of Test Results - DTL 2 (DTL 031)
4.	📄 ESS-3728369	Installation Report	1	✔		RF rack installation checklist DTL 2
5.	📄 ESS-3919818	Drawing file	1	✔		DTL 2 Patch panel
6.	📄 ESS-4058025	Site Acceptance Test	1	✔		DTL2 High Power Test Protocol Thales TH217
7.	📄 ESS-4788304	Validation Report	1	✔		LLRF Test Report for System: DTL-020: Powe

	Name	Type	Rev			Ver	Title/Label
1.	📁 System-Schematic	Workspace Folder					
2.	ESS-0115054	Drawing file	1	✔			block diagram teststand2
3.	ESS-0115055	Drawing file	1	✔	ⓘ		block diagram Medium Beta
4.	ESS-0115056	Drawing file	1	✔	ⓘ		block diagram RFQ
5.	ESS-0115061	Drawing file	1	✔	ⓘ		block diagram spoke
6.	ESS-0115057	Drawing file	1	✔	ⓘ		block diagram DTL
7.	ESS-0260158	Drawing file	1				Master Oscillator and Phase reference line
8.	ESS-0115060	Drawing file	2	✔	ⓘ		block diagram MEBT
9.	ESS-0115056	Drawing file	2				block diagram RFQ
10.	ESS-0115057	Drawing file	2				block diagram DTL
11.	ESS-0115055	Drawing file	2				block diagram Medium Beta
12.	ESS-0115060	Drawing file	3				block diagram MEBT
13.	ESS-0115061	Drawing file	2				block diagram spoke

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

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.
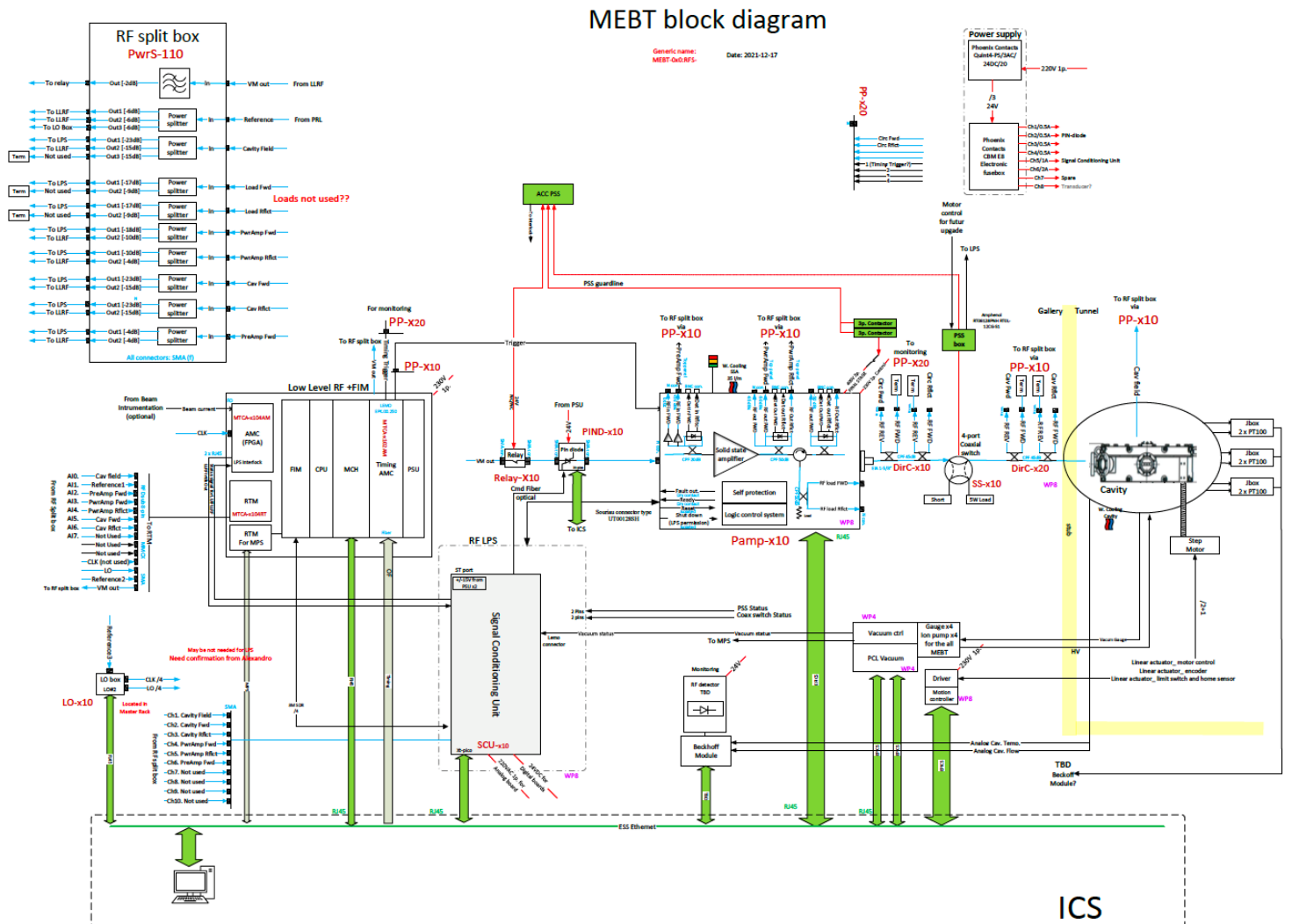
MEBT 1-3

MEBT RF System: Scope

Detailed system schematics exist: https://chess.esss.lu.se/enovia/link/ESS-0115060/21308.51166.30977.1064/valid

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

Schematics defines interfaces
- Naming
- Utilities
- ICS

MEBT block diagram

2025-02-03

MEBT RF Systems

MEBT TRR: https://confluence.esss.lu.se/display/ATC/MEBT+Bunchers+TRR

Block Diagram: https://chess.esss.lu.se/enovia/link/ESS-0115060/21308.51166.30977.1064/valid
RFDS certification: https://chess.esss.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).
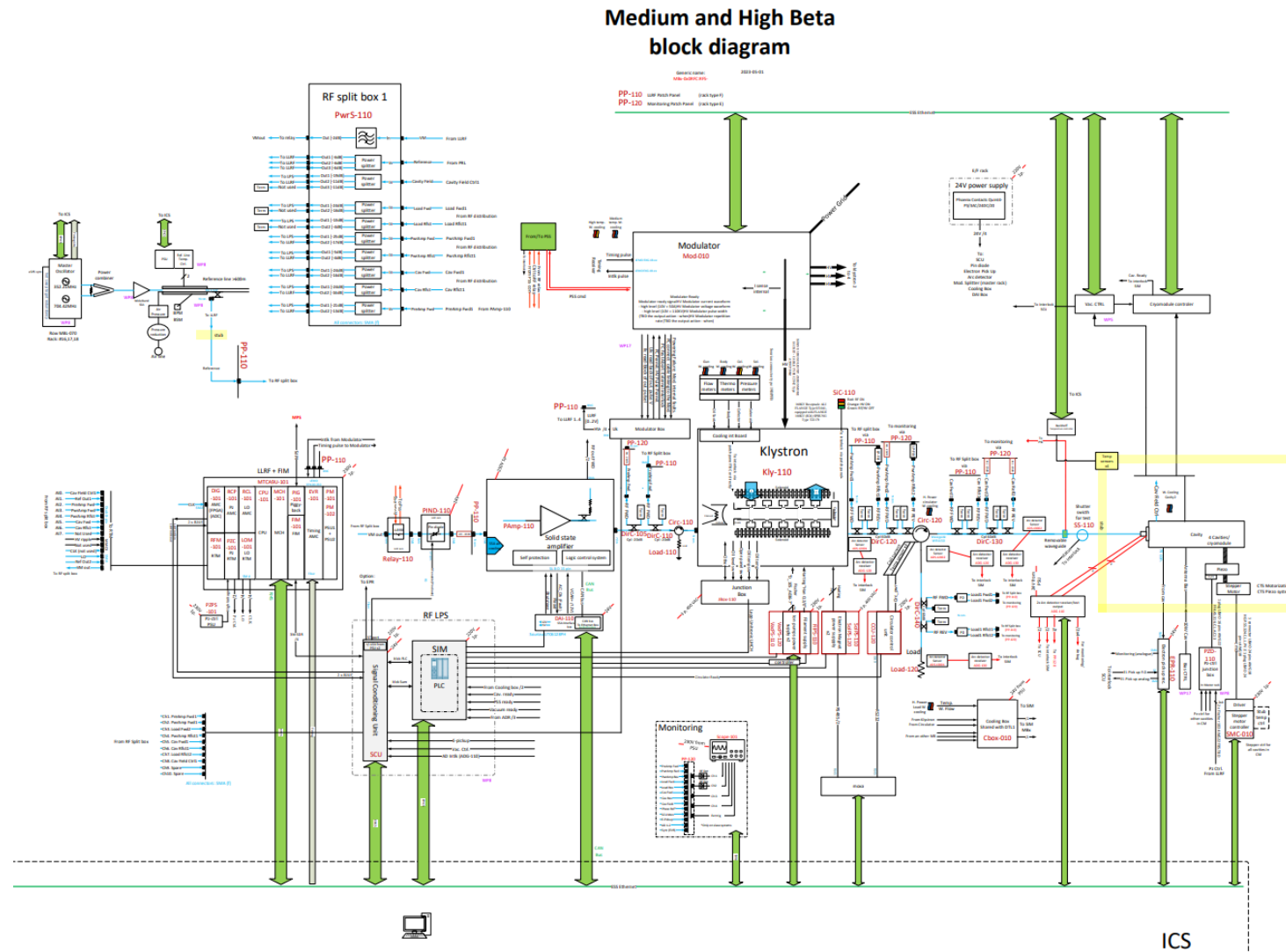
MBL and HBL

MBL/HBL RF System: Scope

Detailed system schematics exist: https://chess.esss.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

Medium and High Beta block diagram

MBL and HBL Summary Status

Amplifier system in operation and reliable (so far).

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

Name ▼		Type	Rev	Title/Label
⊟ 📁 MBL-030-S2		Workspace Folder		
▶ 📄 ESS-3640169		Validation Report	1	VKP-8292A.102 Klystron Interlock Checklist
▶ 📄 ESS-3810879		Installation Report	1	RF rack installation checklist MBL03-2
▶ 📄 ESS-3963130		Installation Report	1	Busbar Schedule Of Test Results - MBL 030-05
▶ 📄 ESS-4170222		Validation Report	1	Low Power Test protocol for CPI VKP-8292A 704 MHz klystron SN102 - MBL030-S2 Results
▶ 📄 ESS-5524549		Verification Report	1	MBL-030RFC Klystron 3 LLRF test report

Tests with beam

Except field stability performance during beam mainly tests to check beam compensation functionality from timing data information:

- Dynamic detune
- Beam destination
- Beam current (intendent)
- Beam length
- Beam present
- Bad pulse
- PMortem event

Verification plan in ESS-3122750

Checklist and NCRs

Start up checklist meeting with OP held with minor action

- Save and Restore pending final adjustments
- Alarm handler strategy not agreed

NCRs:

- Klystron cooling pipe quality; Suppliers have improved quality since it was detected. Already delivered units are inspected regularly for degradation.

THE END

Scope for SAR4

For each system, present:

Brief Scope description and status

Brief status of system(s)

Status of documentation (could refer to CIDL here)

Known issues deemed OK to proceed

Are there any NCRs related to system(s)?

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

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?