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Progress of High-Power Conditioning for the UTEF Linac

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September 17th, 2026



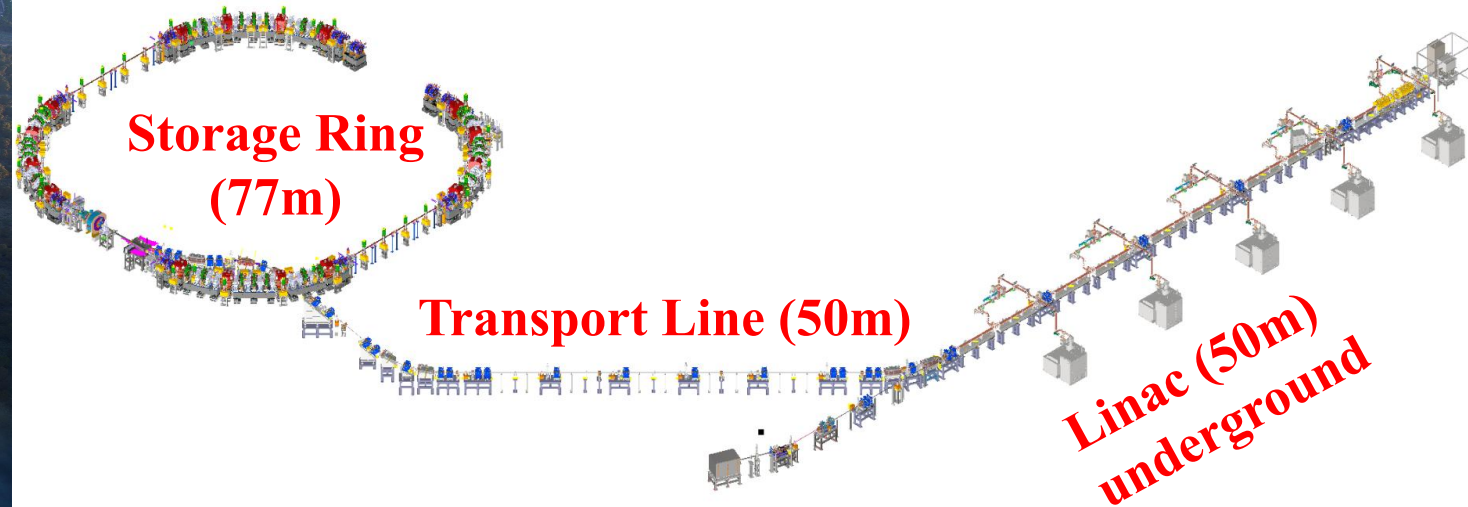
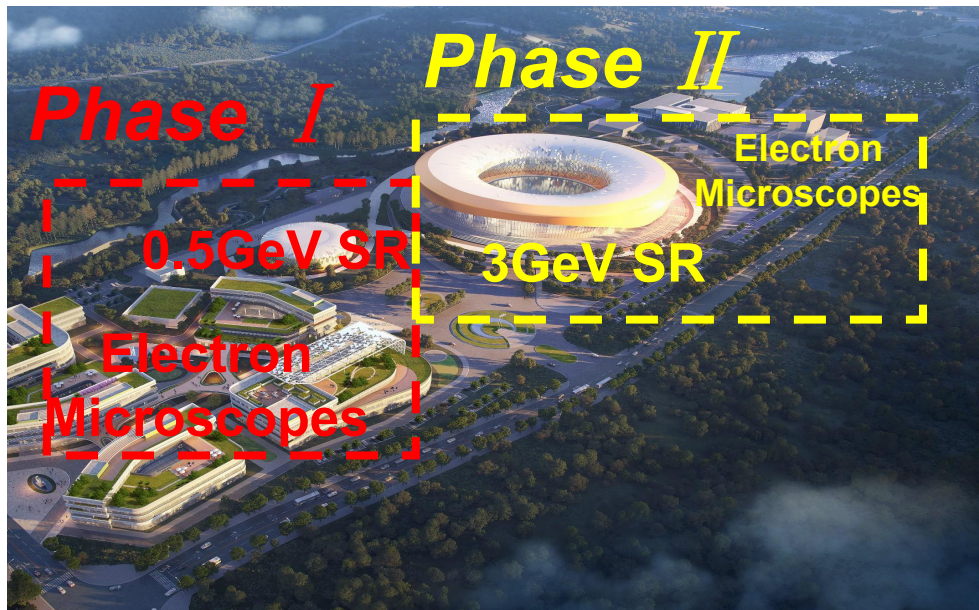
Outline

1. Introduction of UTEF Linac
2. Design and Status
 - I. Control system
 - II. Interlock protection
 - III. Automatic Conditioning
3. Summary



Introduction of UTEF

- Ultrafast Transient Experimental Facility (UTEF) : Comprising two core components - a synchrotron radiation facility delivering high-brilliance and high-flux photon sources, and an advanced cluster of electron microscopes.
- The SR facility is developed in 2 phases, phase I is a pre-research project, including a 500MeV light source and an electron microscope platform; phase II including a 3 GeV light source and an electron microscope cluster.



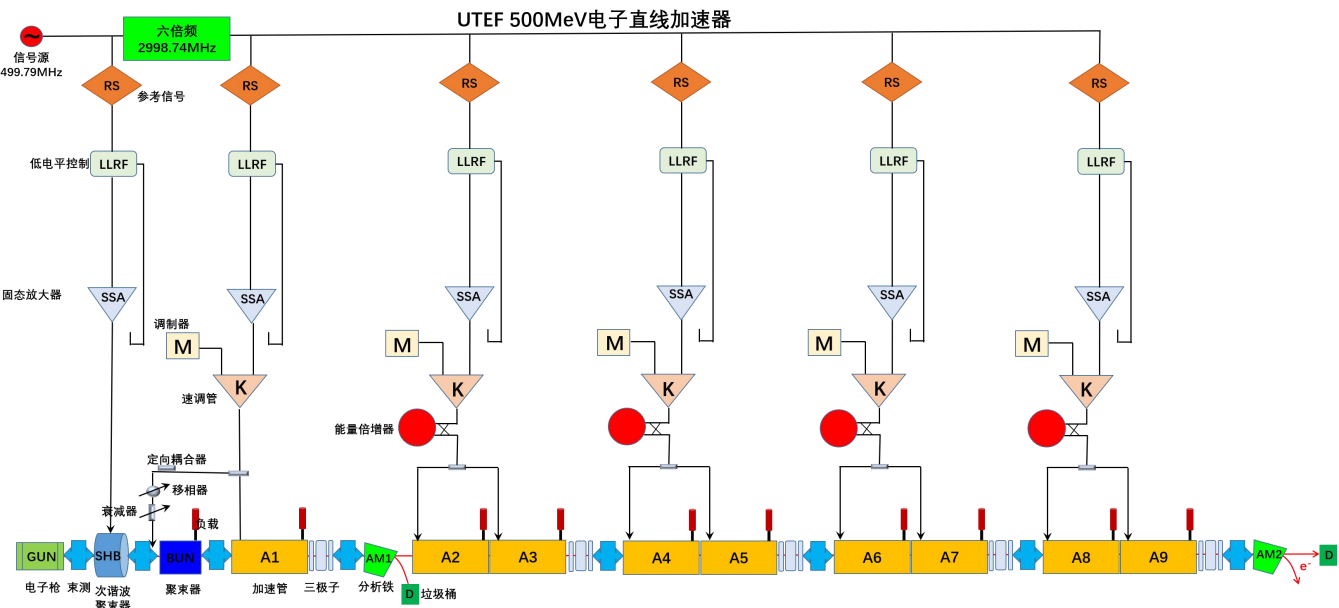
Layout of UTEF phase I



Introduction of UTEF Linac

Key Parameters of 500 MeV Linac

Parameters	value	unit
Beam energy	500	MeV
Beam charge	≥ 1	nc
Beam length	≤ 1	ns
Energy spread	≤ 0.5 (rms)	%
Normalized emittance	≤ 50 (rms)	mm.mrad
Repetition rate	2	Hz
Working frequency	499.79/2998.74	MHz
Amplitude stability	0.2 (rms)	%
Phase stability	0.1 (rms)	°



Layout of Linac

- 1 subharmonic buncher at 499.79 MHz
- 1 constant-impedance TW buncher, 9 constant-gradient TW accelerating tubes at 2998.74 MHz
- 5 high-power transmission systems at 2998.74 MHz
- 4 pulse compressors at 2998.74 MHz
- 6 LLRF system



Introduction of UTEF Linac

Timeline of Installation

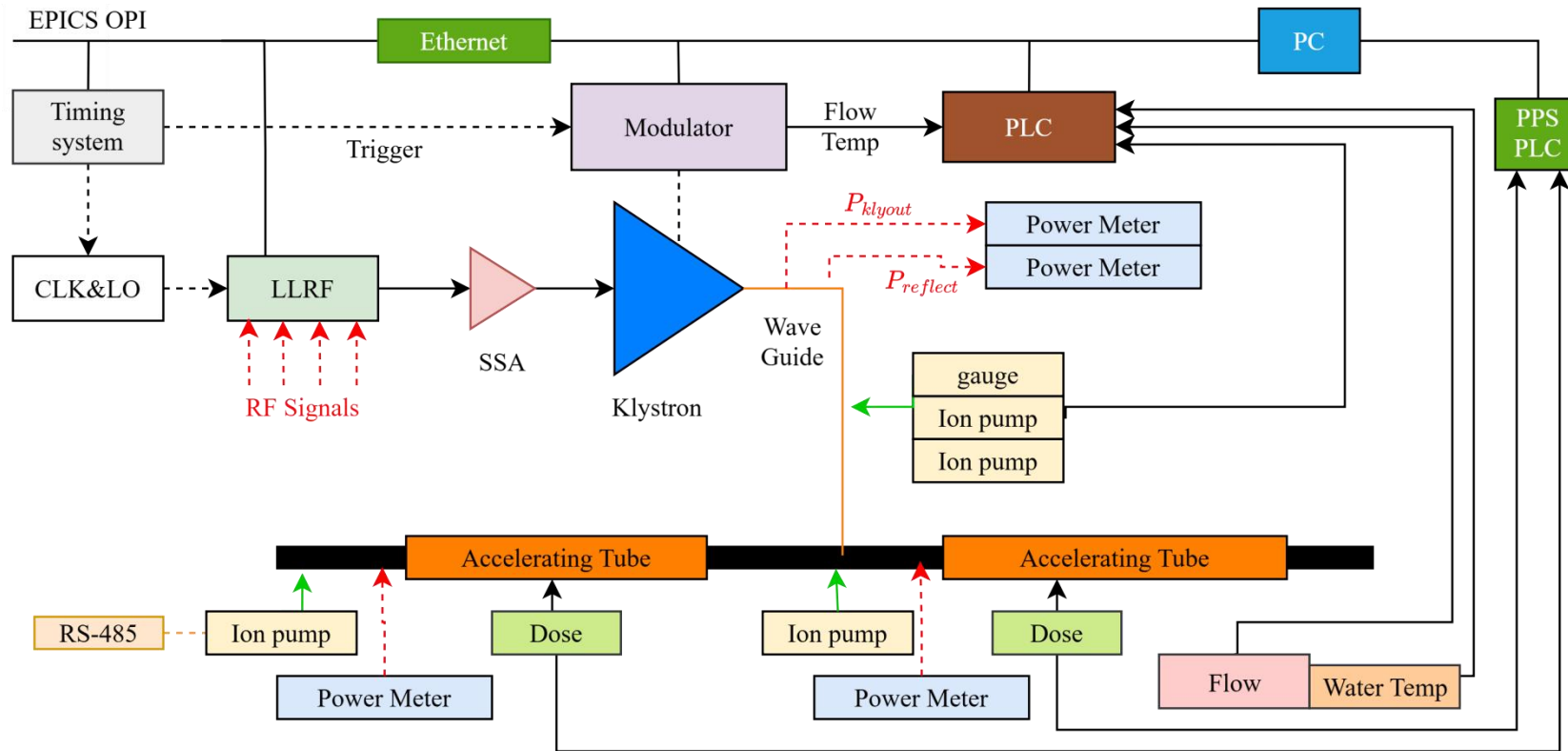


Linac tunnel(Feb. 2026)



Service tunnel (Feb. 2026)

- ❑ May 2025: Civil construction of the linac tunnel completed, enabling installation of support systems.
- ❑ Sep 2025: Majority of Linac support girders installed.
- ❑ Feb 2026: Complete installation of all components in Linac.
- ❑ Apr 2026: The target vacuum levels were achieved in the beamlines and RF power waveguides.
- ❑ May 2026: Completed remote control of major equipment such as power supplies and vacuum systems.
- ❑ June 2026: Begin conditioning of the accelerating structures (using temporary deionized water).





LLRF system/hardware

Power Meter
STD-MOE
LLRF
CLK & LO
SSA
Oscilloscope



photo of LLRF station



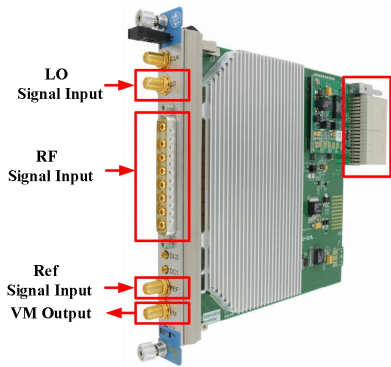
NATIVE-R2



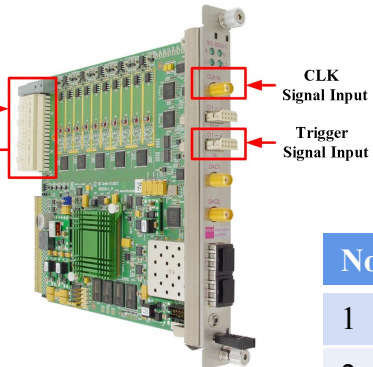
SSA



CLK & LO



DWC8VM1

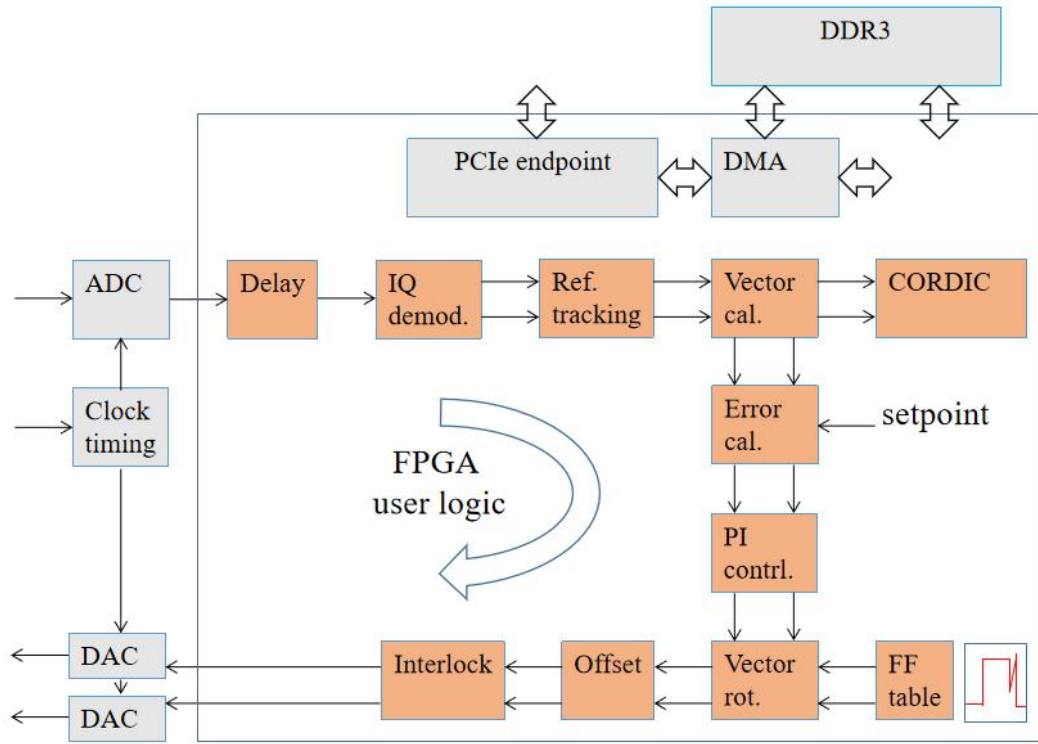


SIS8300KU

No.	Items	Frequency
1	Main RF	499.79/2998.74MHz
2	LO	474.80/2973.75MHz
3	IF	24.99MHz
4	ADC Clock	124.95MHz

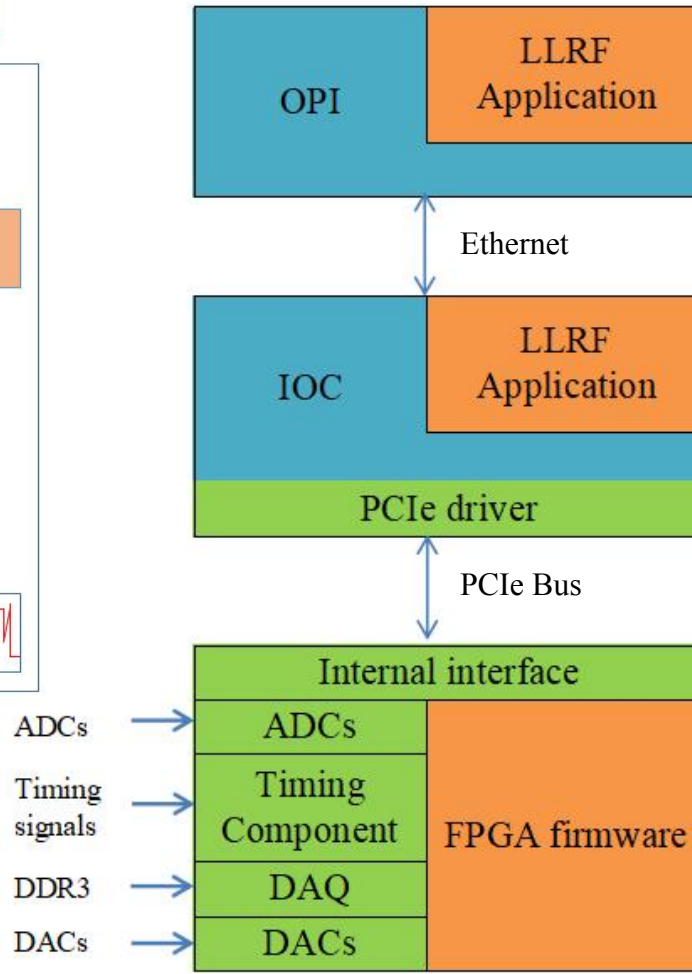


LLRF system/software

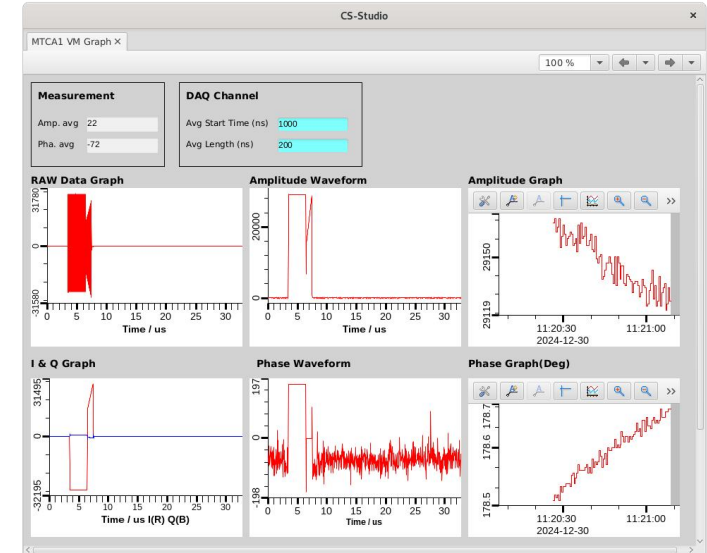


LLRF firmware

- Completed the firmware-to-host full development.



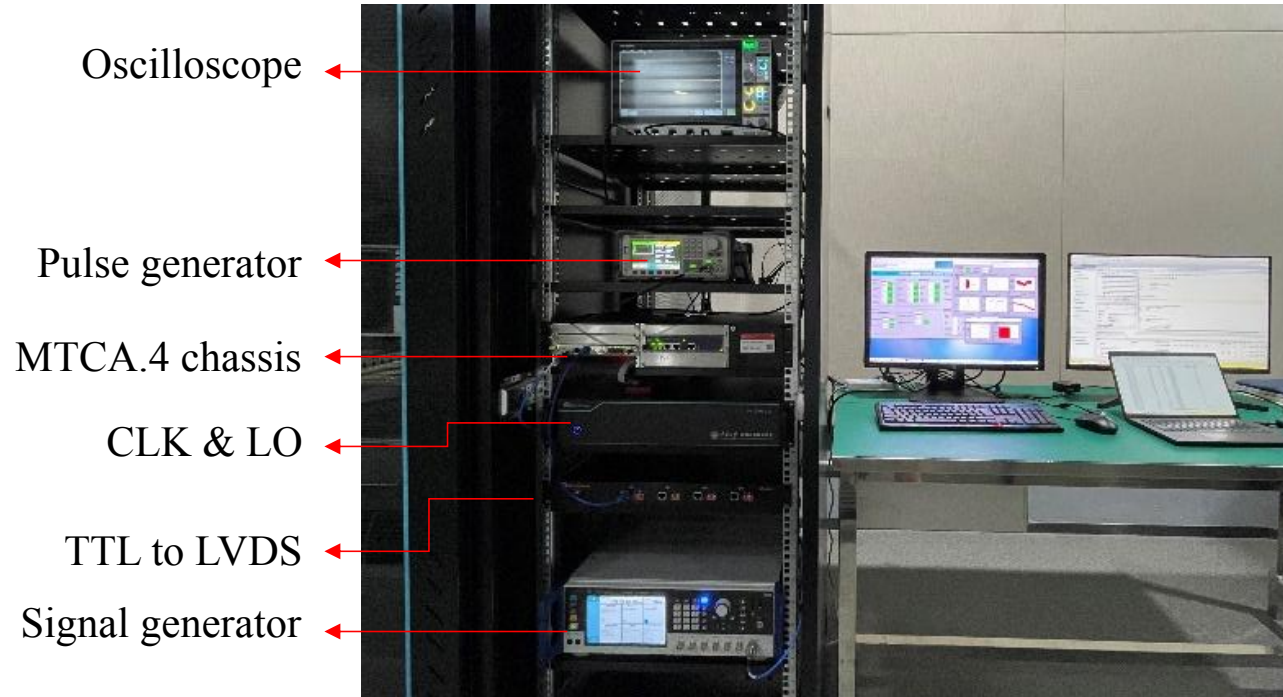
Software and firmware



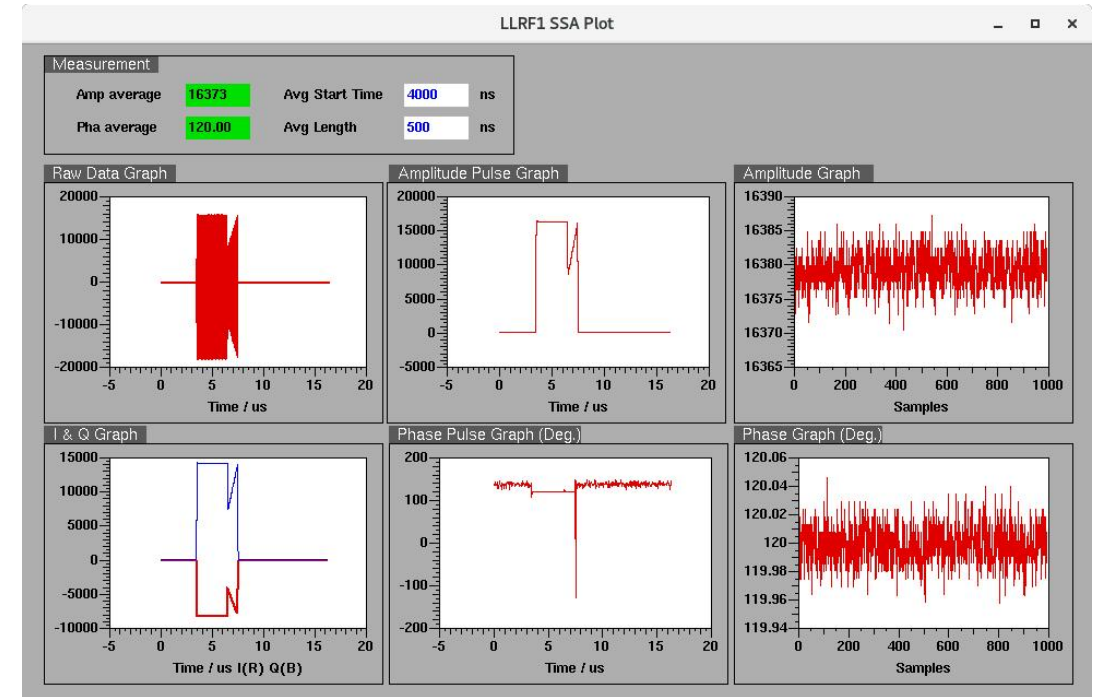
LLRF OPI



LLRF system



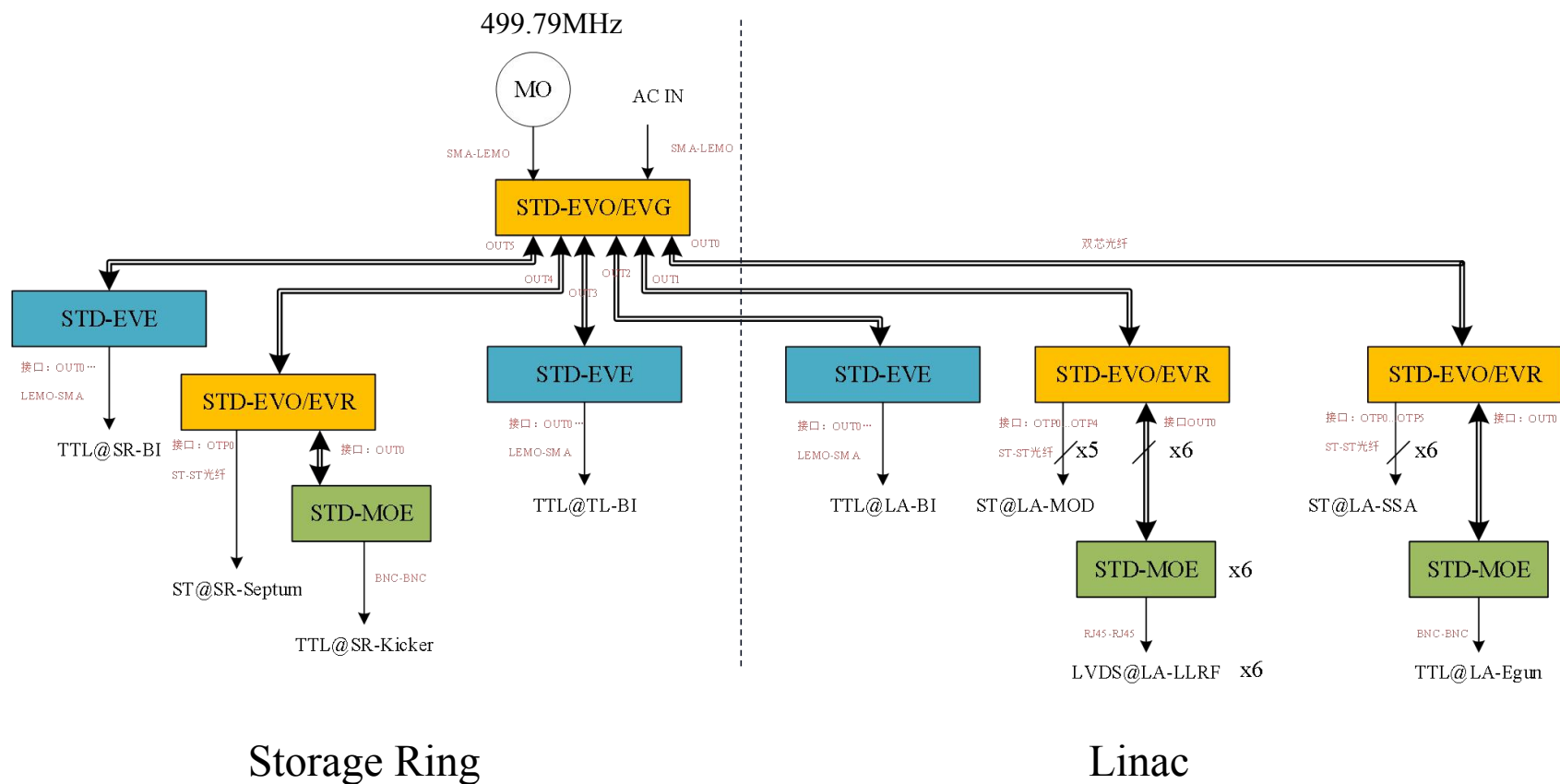
Desktop testing



A/P stabilities(rms) : 0.01% , 0.01°



Timing system



STD-EVO



STD-EVE



STD-MOE



Control parts for Conditioning

- ❑ Since the cooling water system is unavailable, two temporary water-cooling units are deployed for cooling water supply—one for the accelerator tube and one for the modulator.
- ❑ The conditioning of the accelerator tube is conducted section by section.

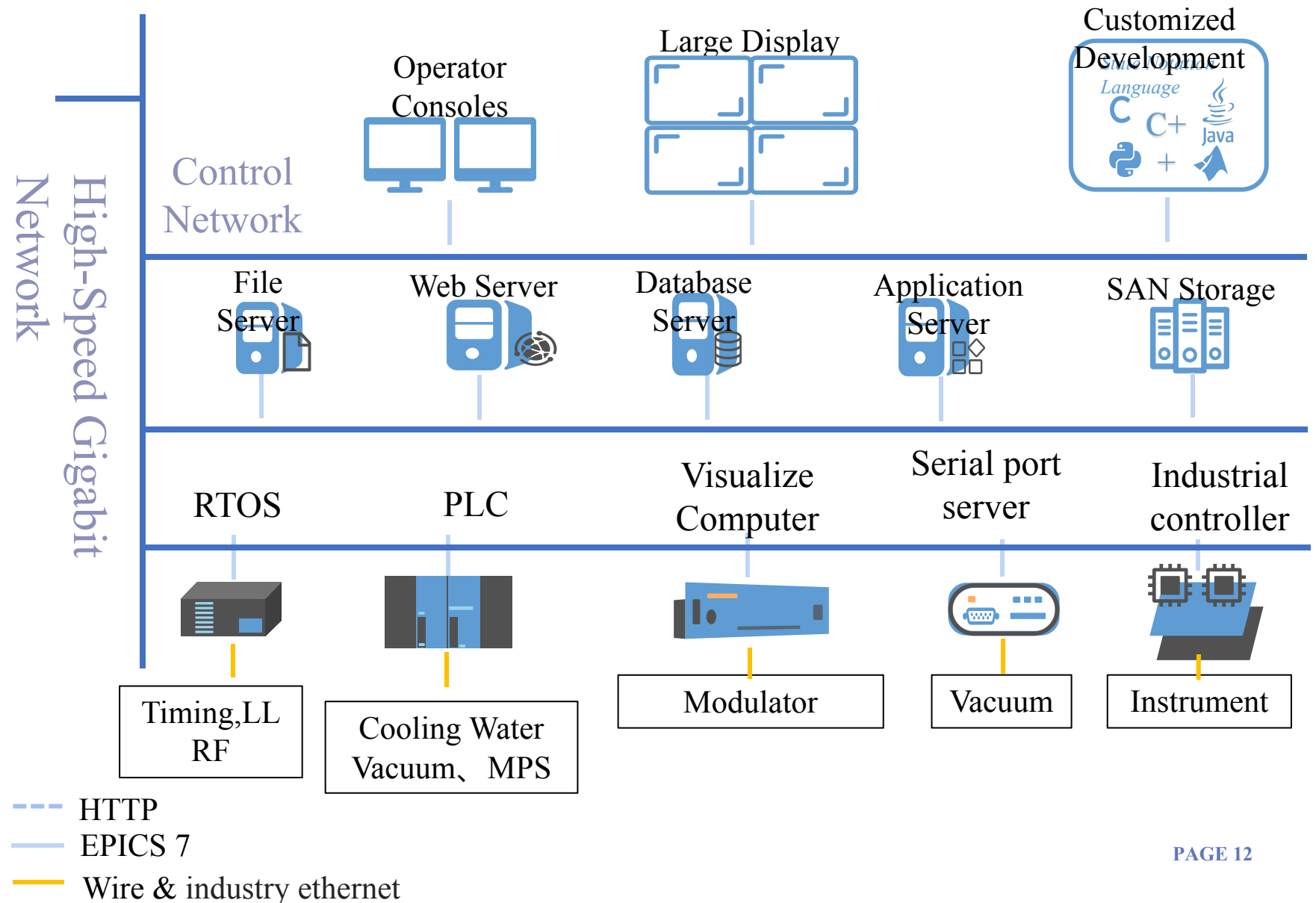
No.		Control devices	Qt. (sets)	Interface Type
1	PPS system	PPS PLC	1	Modbus TCP/IP
2	MPS system	MPS PLC	1	Modbus TCP/IP
3	Radio Frequency	Modulator	5	Modbus TCP/IP
4		LLRF	6	Wire
5		Water flow	78	Wire
6	Timing system	Timing system	6	Wire
7	Vacuum	Ion pump	50	RS-485 serial port
8		Gauge	14	RS-485、 wire
9		Gate valve	6	Wire



Software architecture

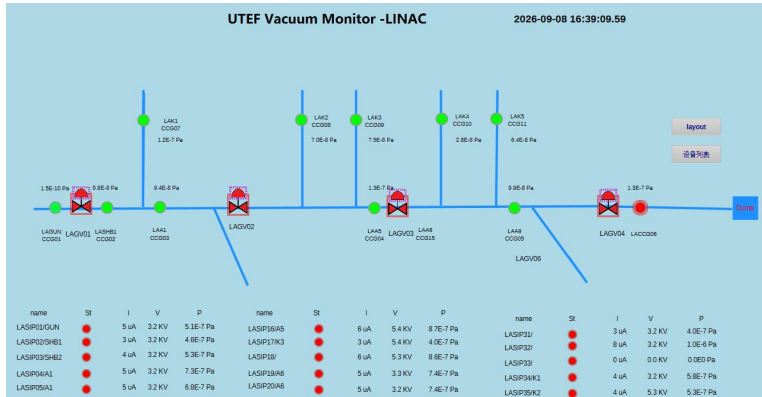


PVE virtualization server cluster
Computing: 3*24 Core
Disk: 3*4*16=192TB

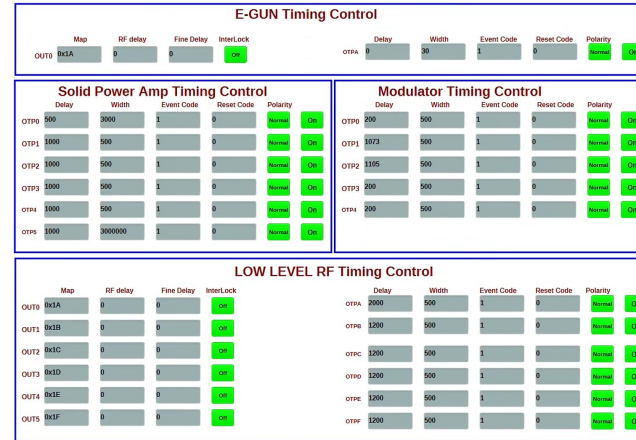




High-level applications



Vacuum Monitor

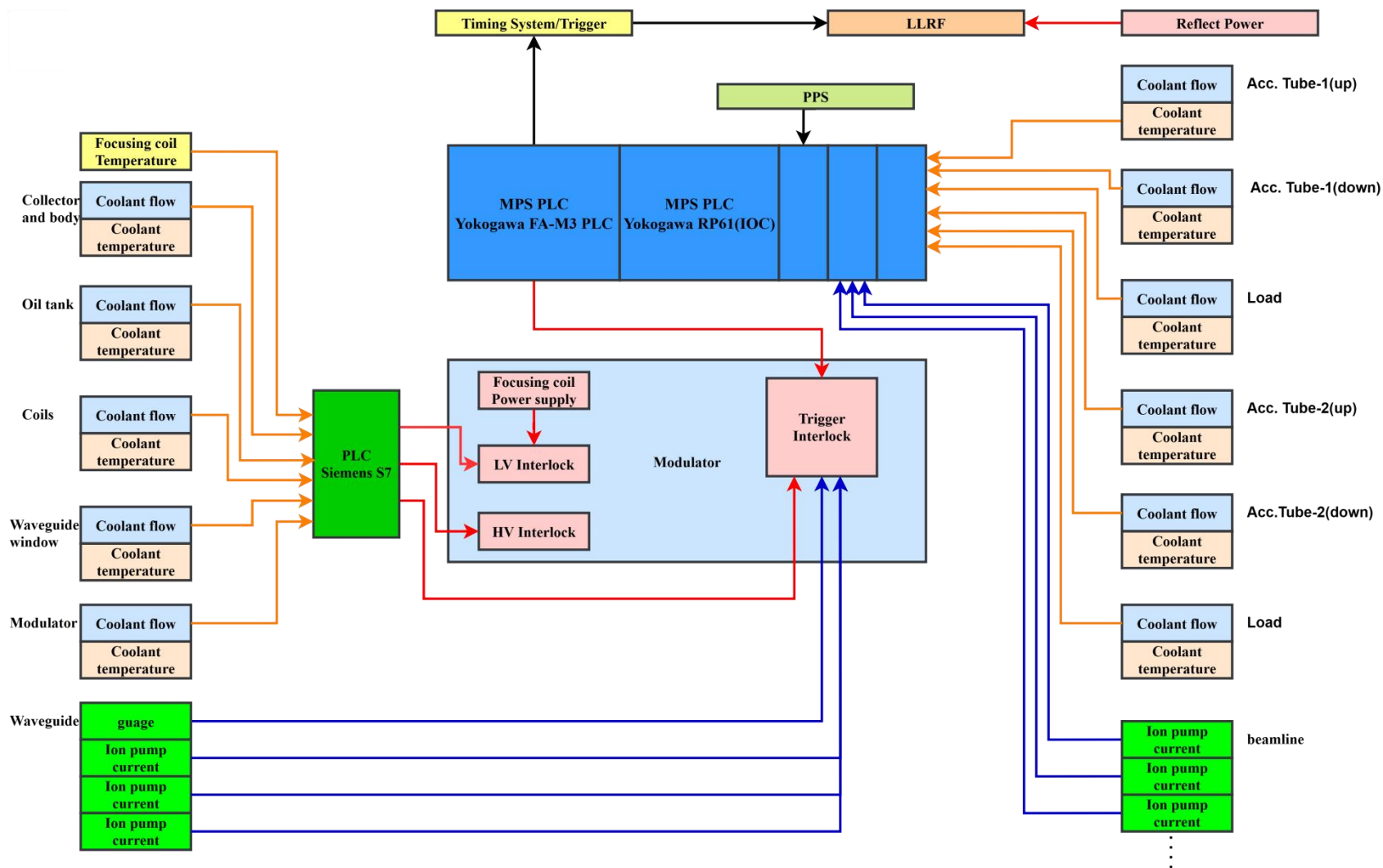


Timing OPI





Interlock protection system



Interlock protection system



MPS PLC



Interlock OPI



Automatic Conditioning

□ Targets:

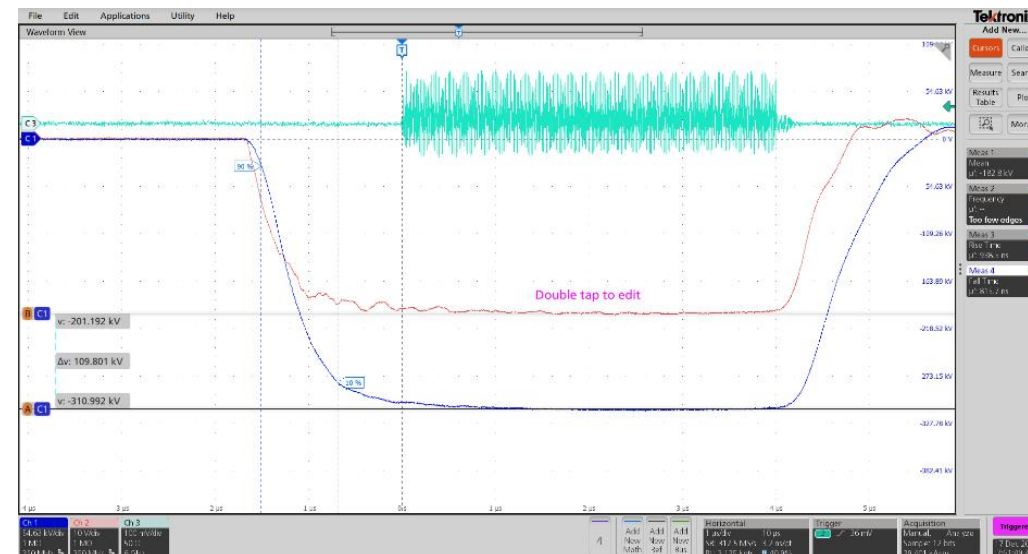
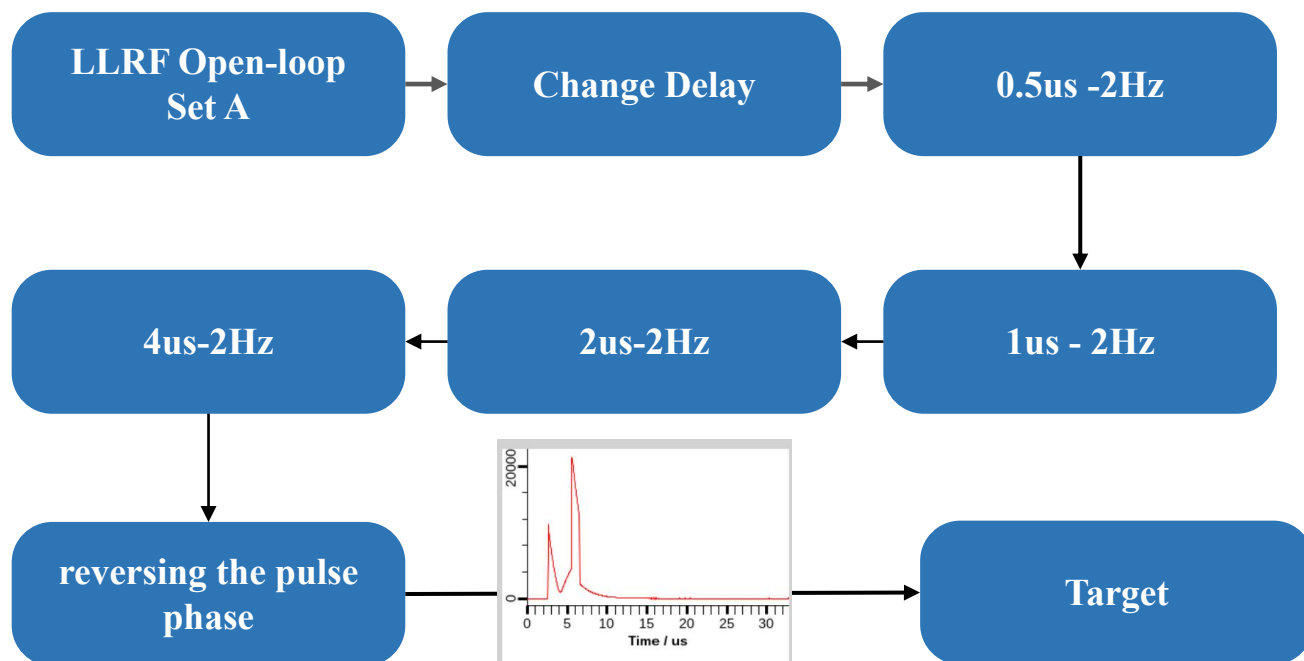
Klystron output (@ 4 μ s): 40 MW.

Accelerating tube input (post-compressor): 32 MW.

□ Repetition rate : 2Hz

□ RF conditioning — gradually raising RF power to condition high-power components.

□ Goal — mitigate surface discharge, vacuum outgassing, and multipacting before full-power operation.

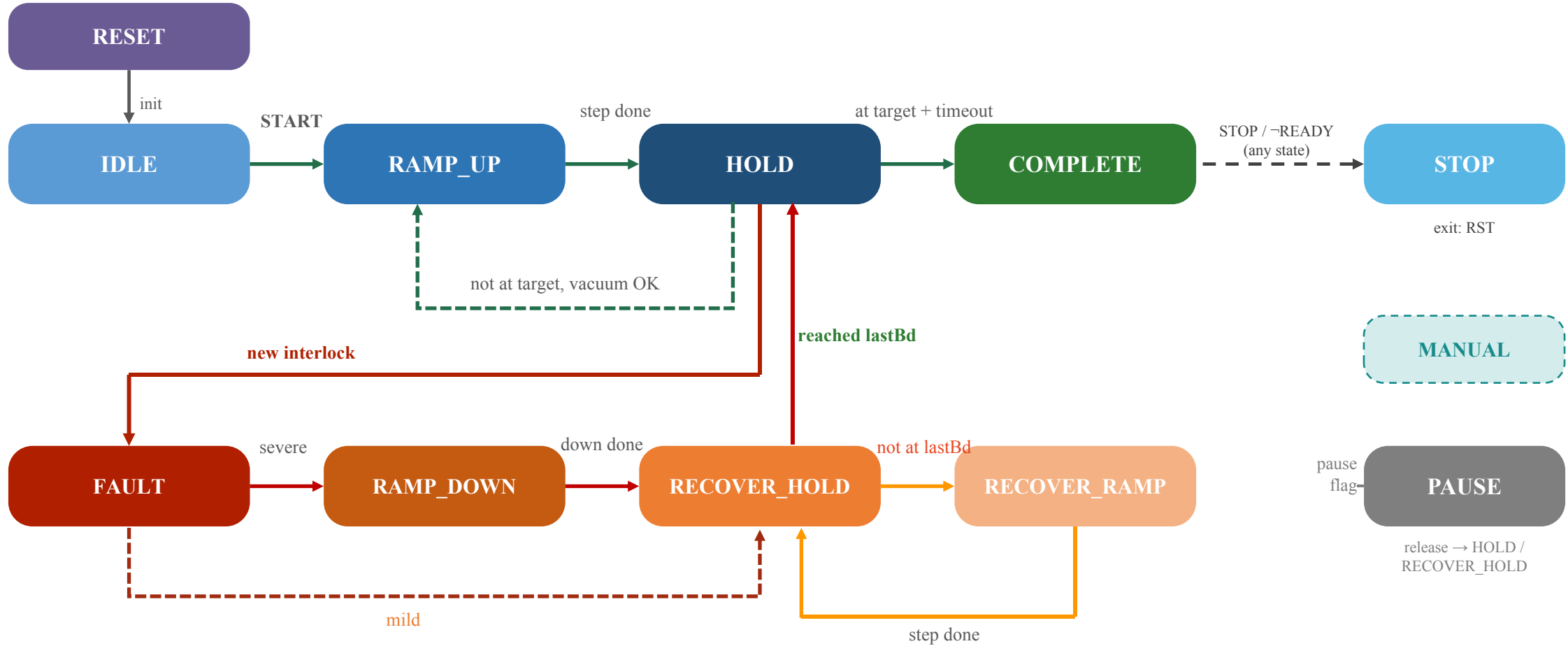




Automatic Conditioning

Conditioning State Machine — 11 States + Global Transitions

□ SNL language



→ Normal Ramp-up Cycle

→ Fault Recovery Chain



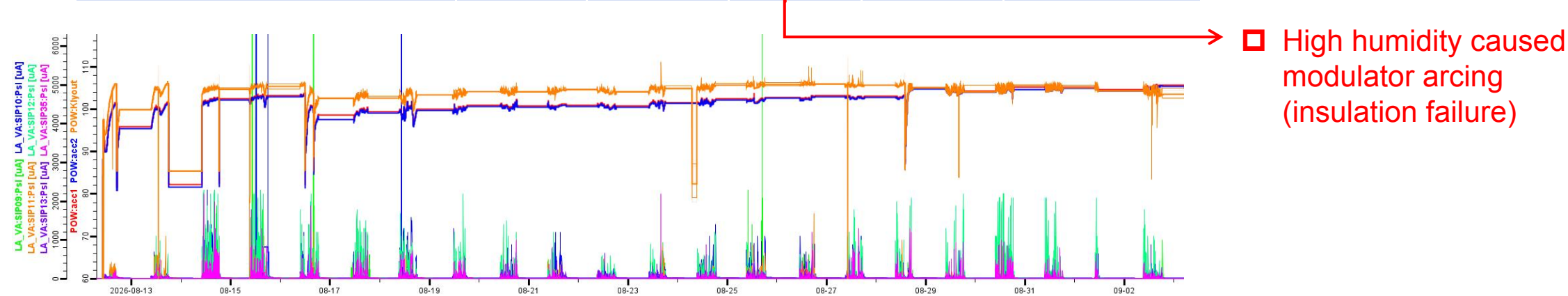
- ❑ Centralized interface
- ❑ Historical interlock filter available
- ❑ Auto-send daily 24h summary report

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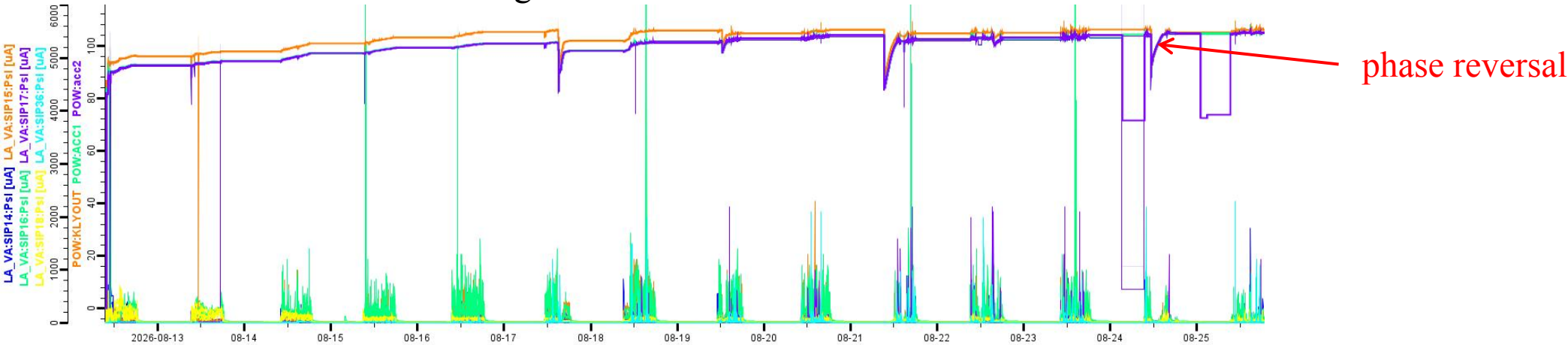


Conditioning Progress

tube No	A2-A3	A4-A5	A6-A7	A8-A9	Average
conditioning time /day	20	13	24	21	19.5



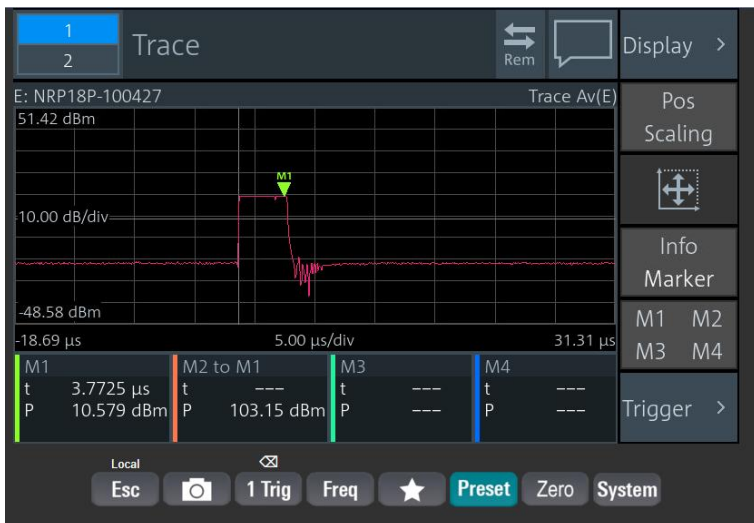
Conditioning results of A2-A3



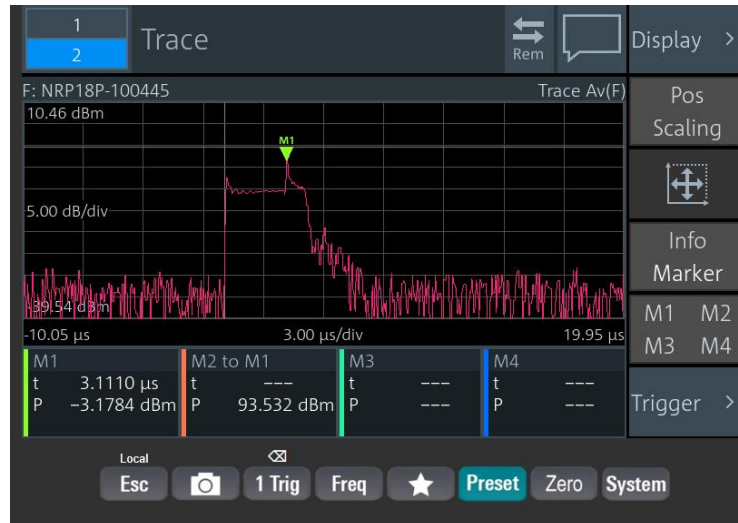
Conditioning results of A4-A5



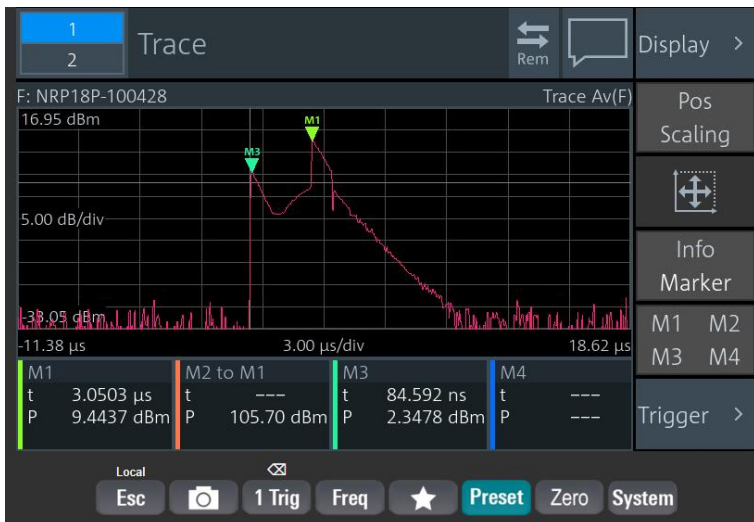
Conditioning Progress



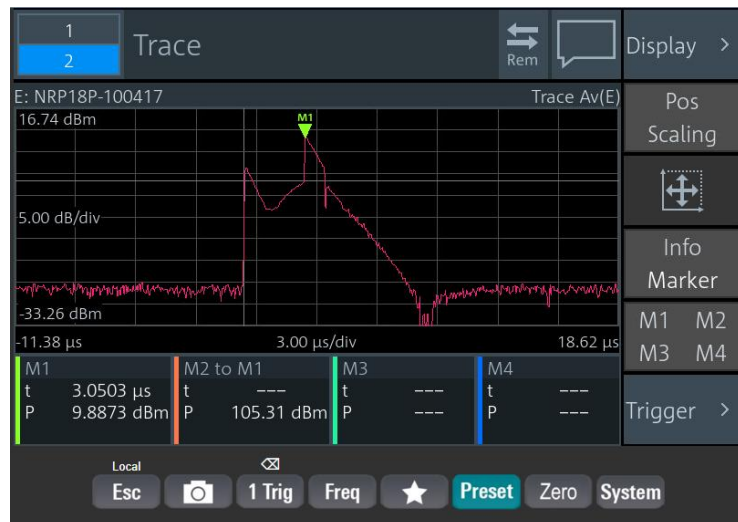
klystron output



reflect power



power of the upstream tube



power of the downstream tube



Summary

- All components of UTEF Linac have been installed.
- The mTCA-based LLRF system is operating stably.
- Completed data acquisition & interlock system development for the RF system,
- Developed automated conditioning.
- High-power conditioning of accelerating tubes A02–A09 has been completed, all reaching the target power level.

THANK YOU !

All Suggestions are welcomed !



SSA,CLK&LO



Solid state amplifier

- 1.Working frequency: 499.784MHz/2998.704MHz
- 2.Bandwidth: $\geq \pm 2.5\text{MHz}@1\text{dB}$
- 3. Pulse width: 0.5-30 μs /0.5-4 μs
- 4.Repetition rate: 1-50Hz
- 5. Output power: $\geq 2000\text{W}/1000\text{W}$
- 6.Rising edge/Falling edge: $\leq 0.1/0.1\mu\text{s}$
- 7.Rising edge jitter: $\leq 5\text{ns}$
- 8. Pulse flatness: $\leq 0.2\%$ (rms)
- 9. Pulse phase shift: $\leq 1^\circ$ (rms)
- 10. Amplitude stability: $\leq 0.02\%$ (rms)
- 11. Phase stability: $\leq 0.02^\circ$ (rms)

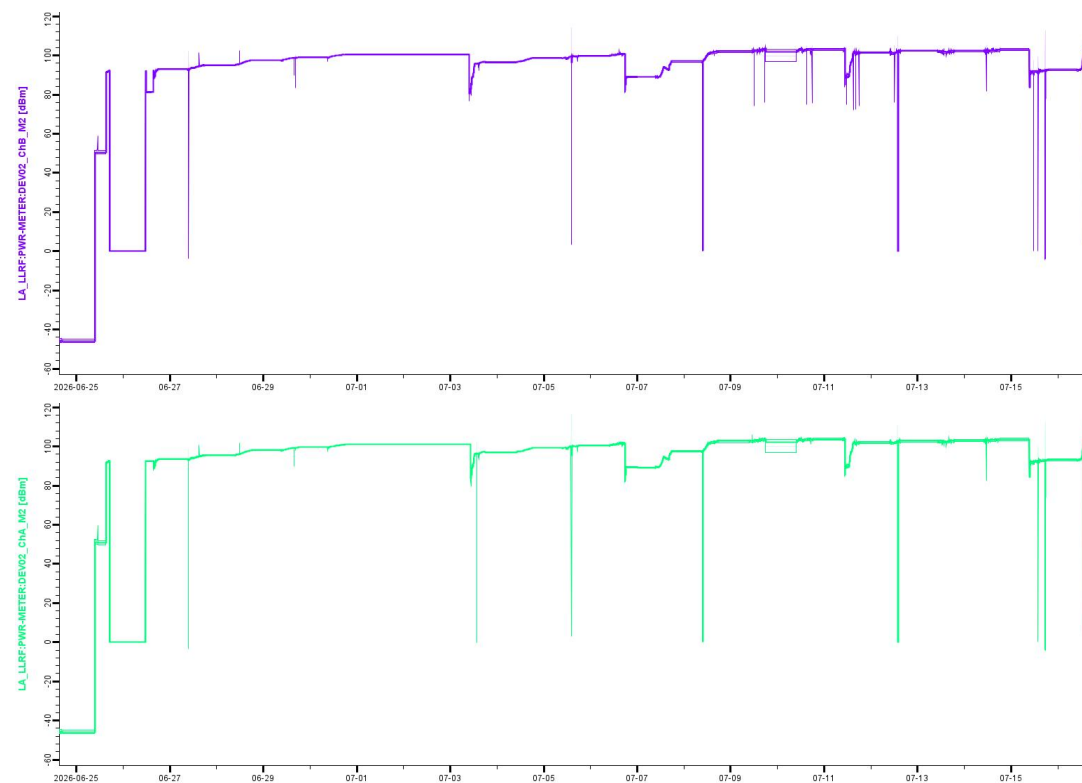


CLK & LO

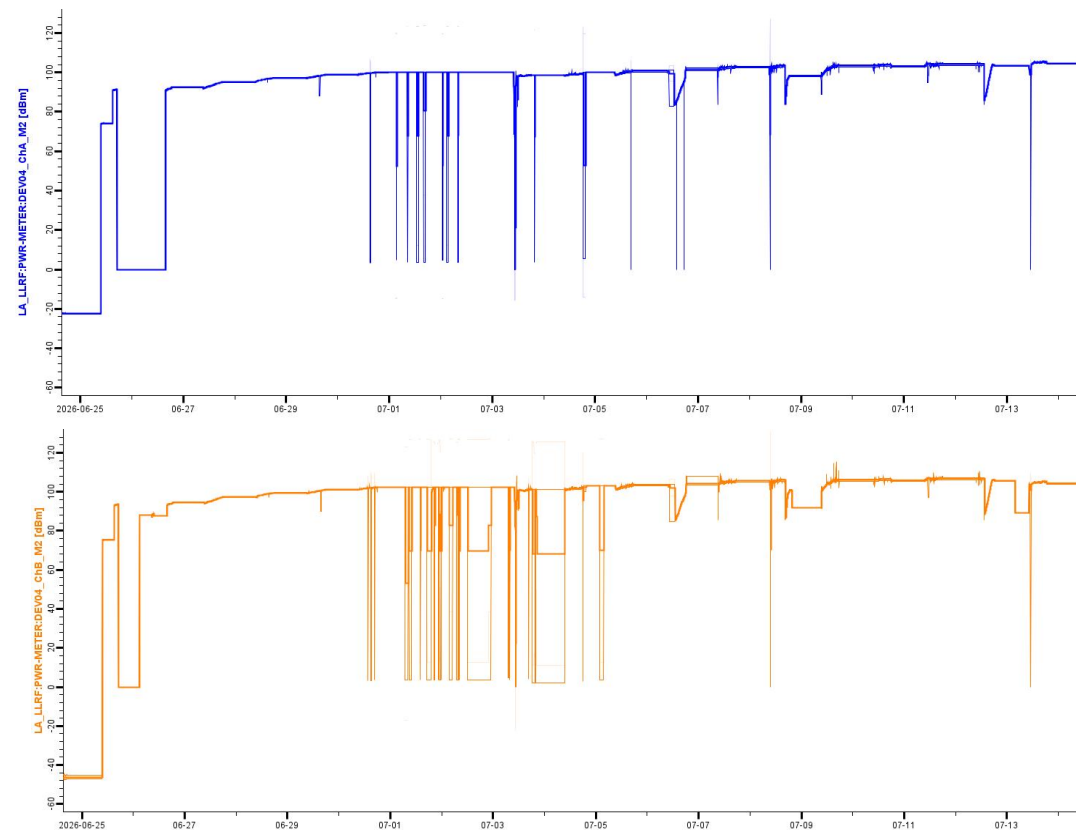
No.	Items	Frequency
1	Main RF	499.79/2998.74MHz
2	LO	474.80/2973.75MHz
3	IF	24.99MHz
4	ADC Clock	124.95MHz

- 1. Working frequency: 499.790/2998.74MHz
- 2. Input power (CW) : 0-3dBm
- 3. Ref. signal power (CW) : $\geq 15\text{dBm}$
- 4. LO signal power (CW) : $\geq 15\text{dBm}$
- 5. Clock signal power (CW) : $\geq 15\text{dBm}$
- 6 .LO phase noise: $<50/36\text{fs} @[10\text{Hz}, 10\text{MHz}]$
- 7. Harmonic suppression: $> 50\text{dBc}$
- 8. Spurious noise suppression: $> 65\text{dBc}$
- 9. Power stability: $< \pm 0.1\text{dB} (1\text{min})$

Facility	Equipment	Num.	Pulse width	Delay step	Jitter(RMS)	Connector
Linac	E-gun	1	1ns	5ps	30ps	BNC
	Modulator	5	4μs	10ns	150ps	ST
	Solid state amplifier	6	4μs	10ns	150ps	ST
	LLRF	6	4μs	10ns	150ps	*RJ45
	Beam inspection	3	4μs	10ns	150ps	SMA
Transport line	Beam inspection	3	4μs	10ns	150ps	SMA
Storage line	LLRF	2	4μs	10ns	150ps	SMA
	Septum	1	60μs	10ns	150ps	ST
	NLK	1	0.5μs	5ps	150ps	BNC
	Beam inspection	9	4μs	10ns	150ps	SMA
	Beam inspection	7	4μs	10ps	150ps	SMA
	Beam line					



A06-A07



A08-A09