Development of CSNS LINAC LLRF Base on MicroTCA

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Over view of CSNS Linac

Normal conducting cavity LLRF

- Hardware framework
- High power protection
- Auto cavity conditioning program

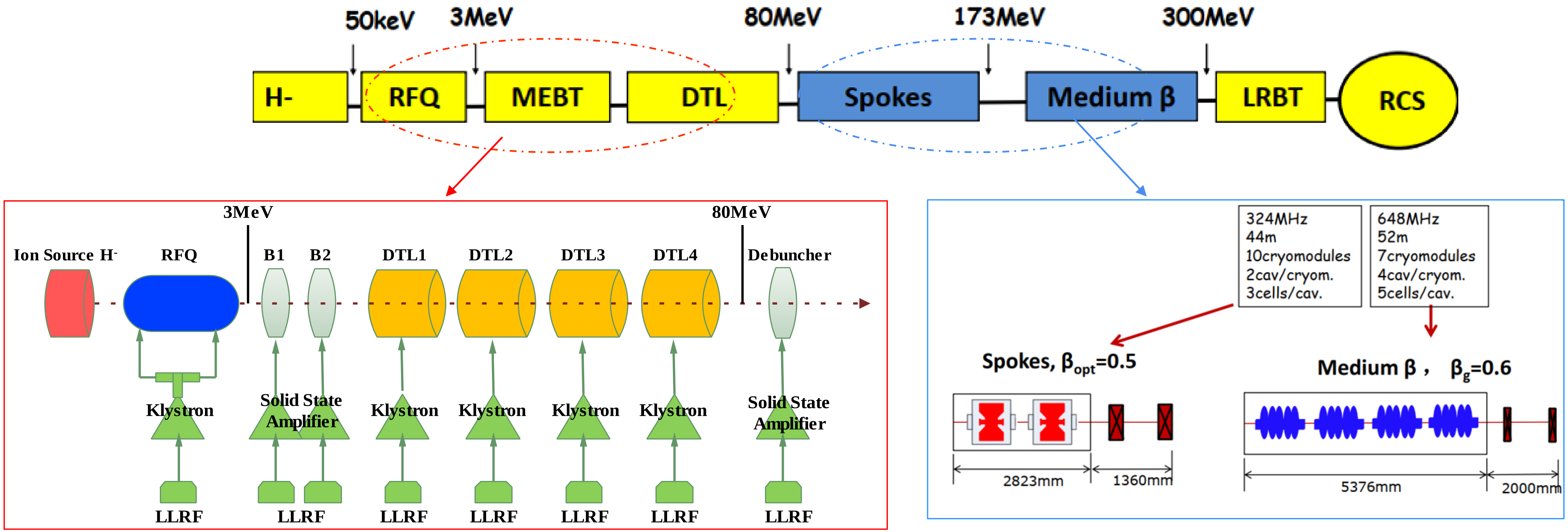
Superconducting cavity LLRF

- Replace Normal conducting cavity LLRF by MicroTCA
- Theory learning and simulation

Overview of the CSNS Linac

- Repeated Rate 25Hz
- Beam pulse width ~450us

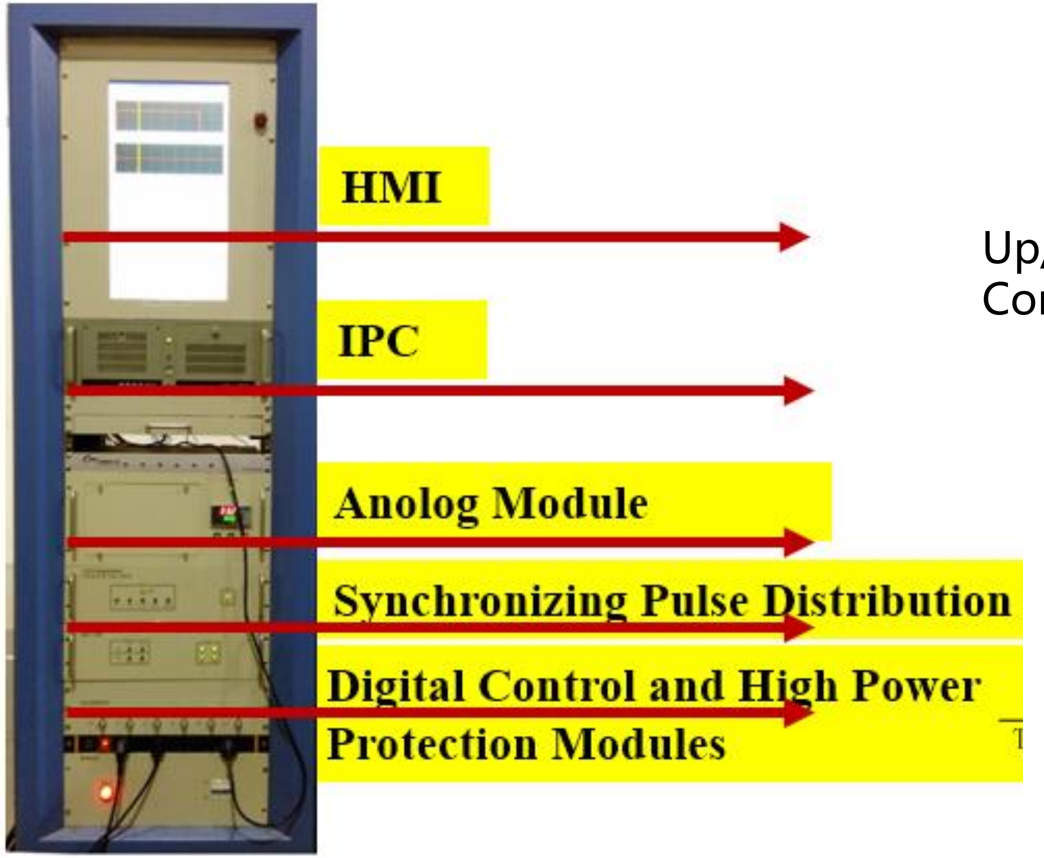
	Phase I	Phase II
Beam(mA)	~6	~30
Linac Energy(MeV)	80	300
Freq (MHz)	324	324/648

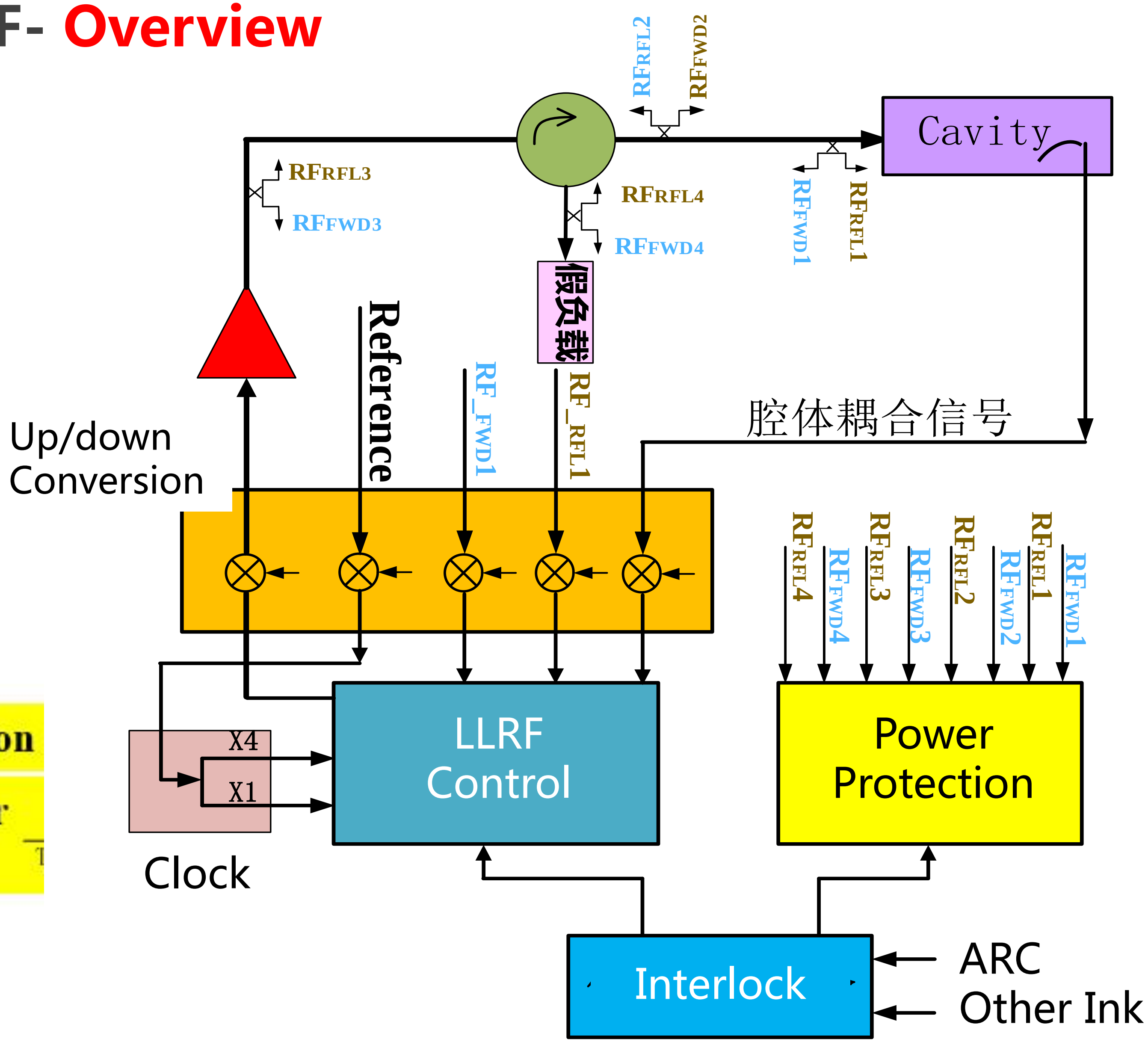


Phase I: 80MeV, Running now

Phase II: 300MeV, Preparation stage.
20 Spoke & 28 Ellip Cavities

Normal conducting cavity LLRF- Overview





Normal conducting cavity LLRF-Analog module

- The analog module consists of two units :

—The analog up-down conversion unit: RF 324MHz, LO 360MHz, IF 36MHz.

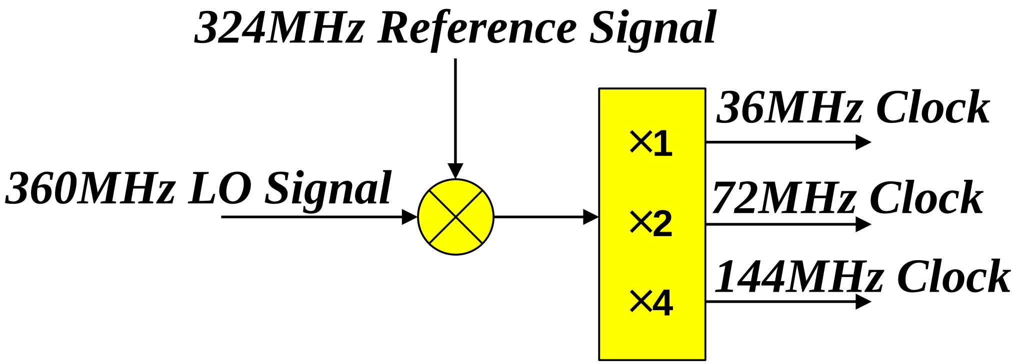
4×down conversion channels

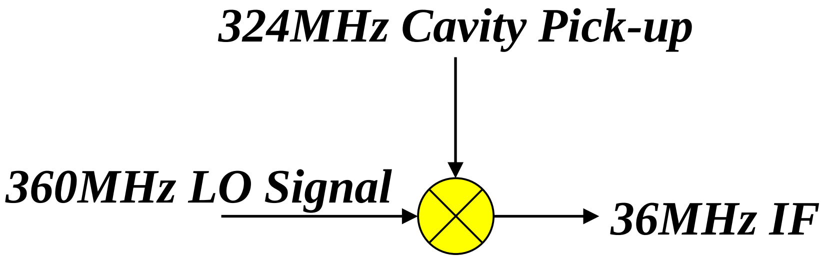
2×up conversion channels

—The clock generation unit:

144MHz, 36MHz, 72MHz

all the analog modules in the thermostat chamber, the temperature within ±0.1℃ of the setpoint.





Normal conducting cavity LLRF-Digital module

❖**Hardware**

—1×FPGA: Altera Stratix II family EP2S90F1020

—2×ADCs with 4 sampling channels: Linear LTC2156, 170Msps 14-bit, DDR LVDS output to FPGA.

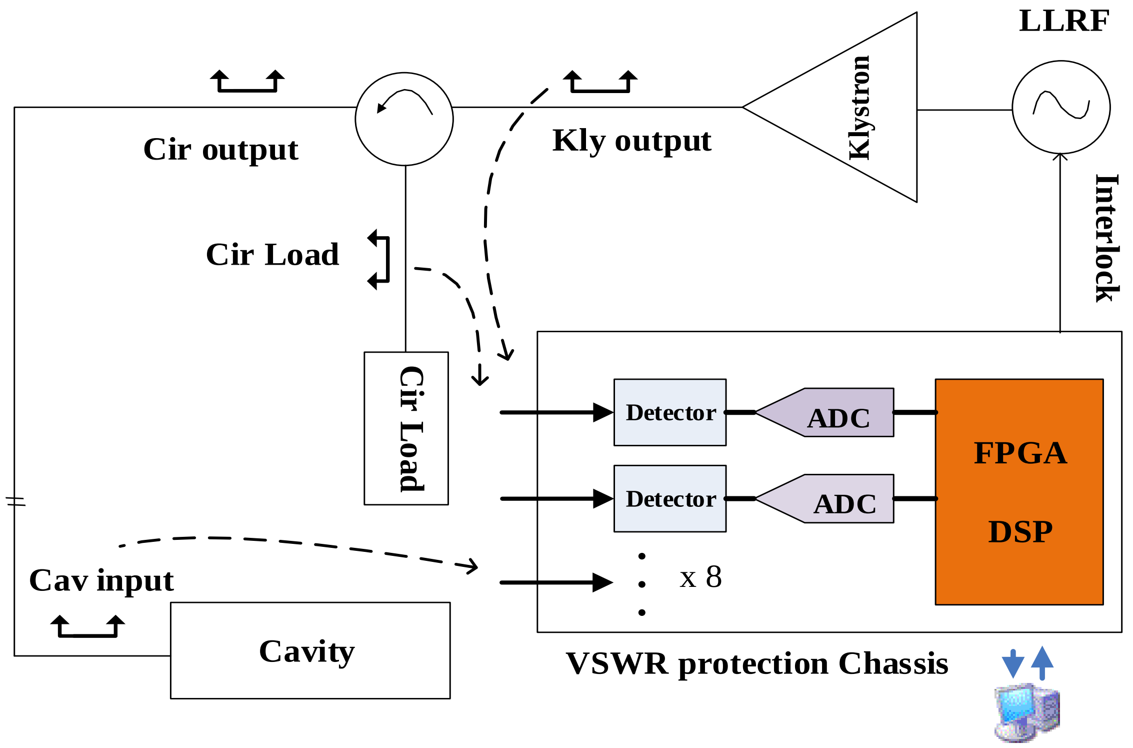
—2×DSPs: TI C6713

❖**ADCs Sampling frequency 144MHz, IF 36MHz, quadruple frequency sampling gets I, Q, -I, -Q……**

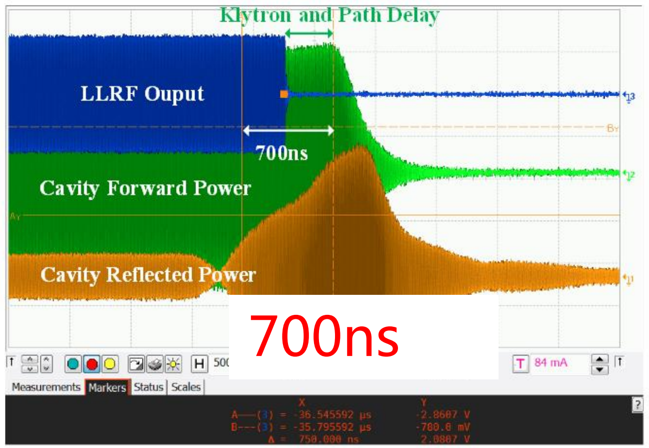
Normal conducting cavity LLRF- Power measurement and protection(1)

- The system measures the forward and reflected power of klystron output, CIR output and cavity input, etc.
- High power protection base on VSWR(Voltage Standing Wave Ratio).
- Response time≈700ns

	速调管输出	环行器输出	环行器负载	腔体入口
正向功率	1553.5kW	1515.3kW	11.3kW	1487.2kW
反向功率	6.4kW	11.5kW	0.4kW	40.8kW
驻波比	1.14	1.19	1.44	1.40
入腔功率	1547.1kW	1503.9kW	10.9kW	1446.4kW



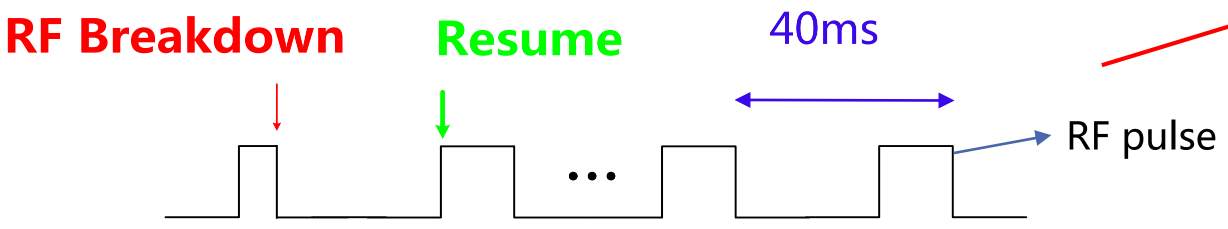
System block diagram



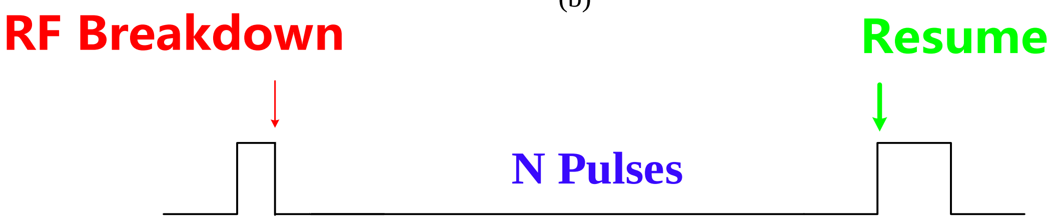
Response time of protection

Normal conducting cavity LLRF- Power measurement and protection(2)

Vacuum of cavity vs. protection resume time.

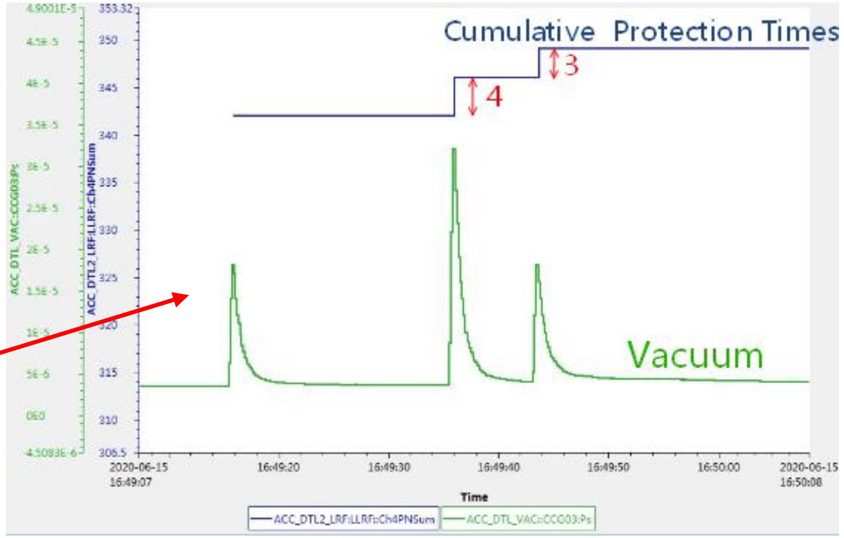


(b)

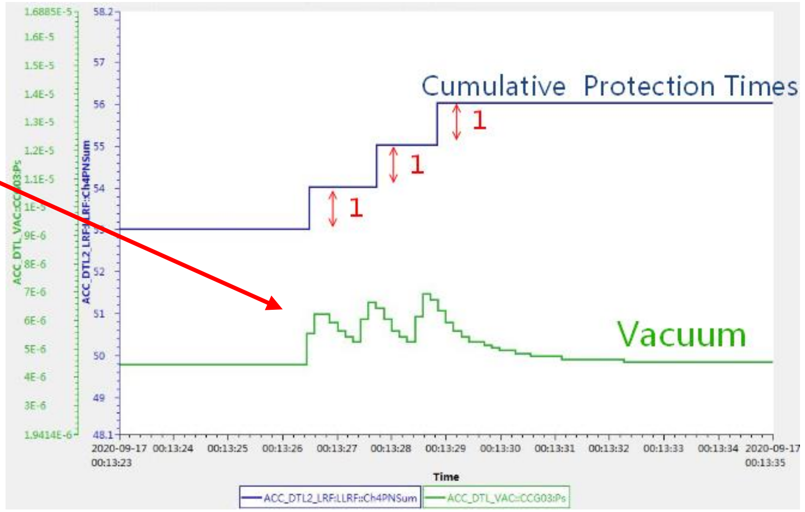


(c)

Improve Protection Scheme



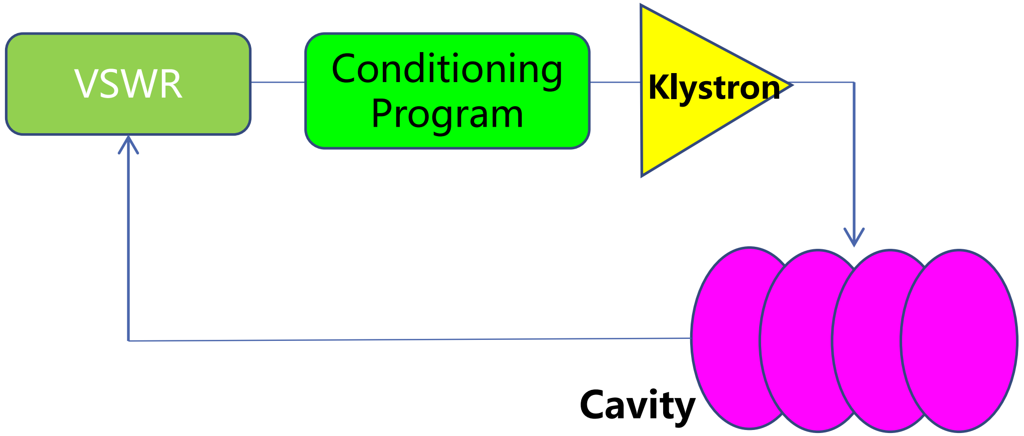
The vacuum changes obviously without resume delay

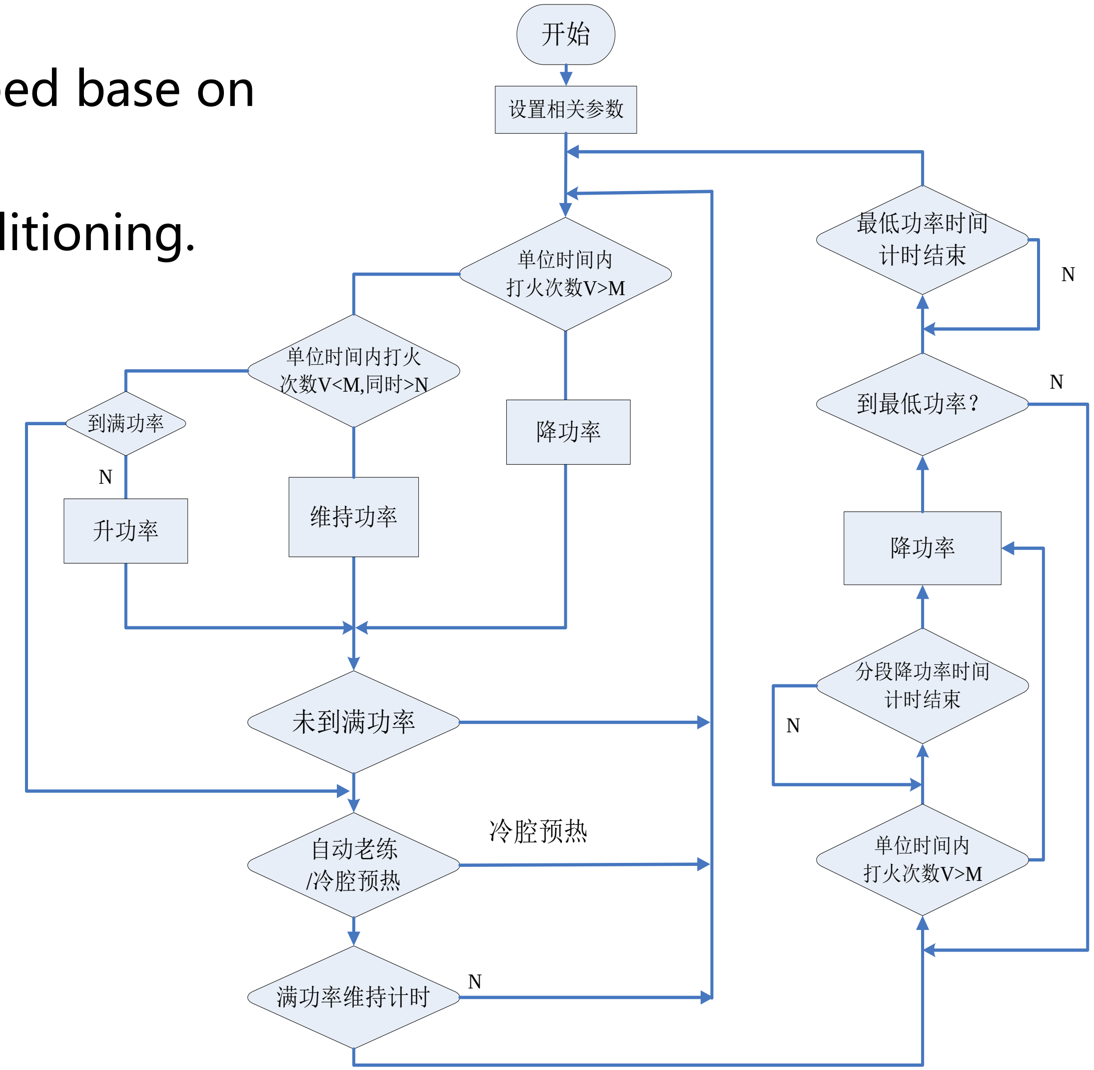


The vacuum changes little with resume delay

Normal conducting cavity LLRF-Auto cavity conditioning program(1)

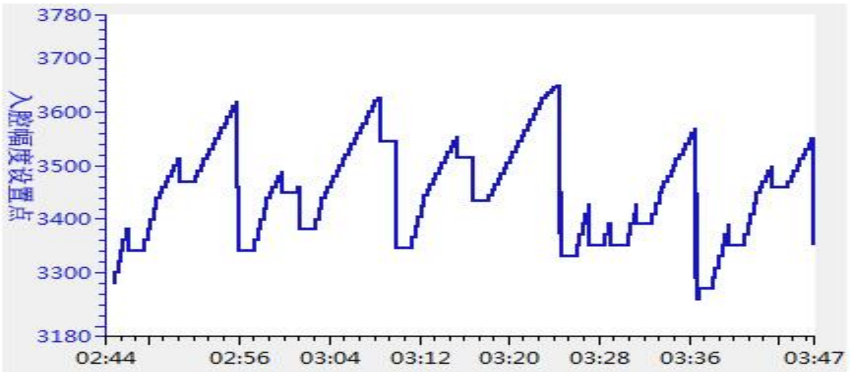
- A auto cavity conditioning program is developed base on VSWR protection times.
- Shorter response time than vacuum base conditioning.
- Vacuum response time more than 10ms.



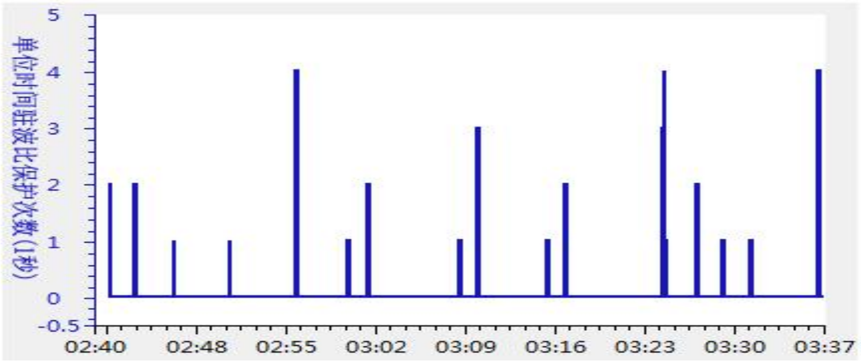


Block diagram of conditioning algorithm

Normal conducting cavity LLRF-Auto cavity conditioning program(2)



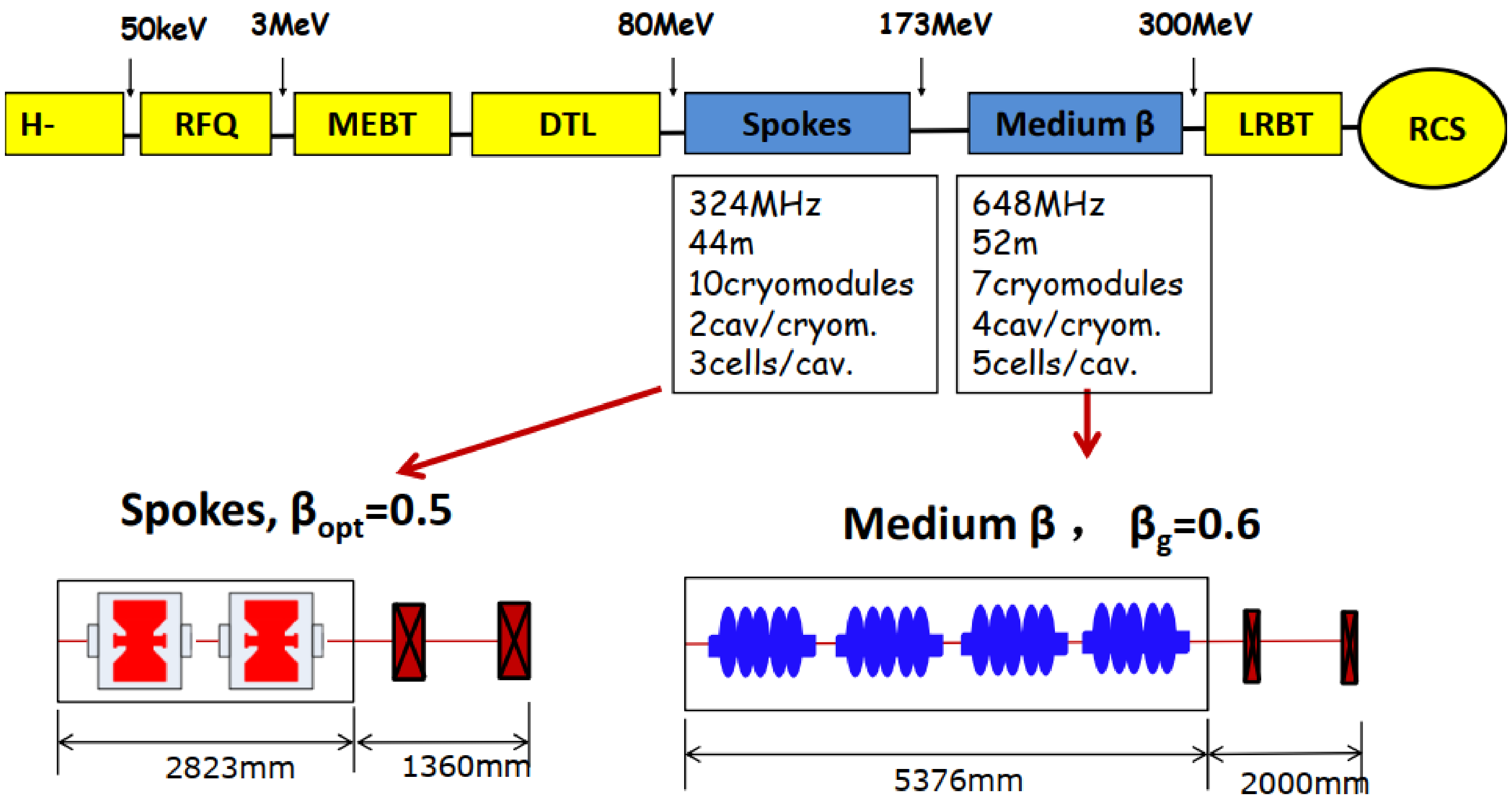
Forward power
increases and decreases with VSWR protection

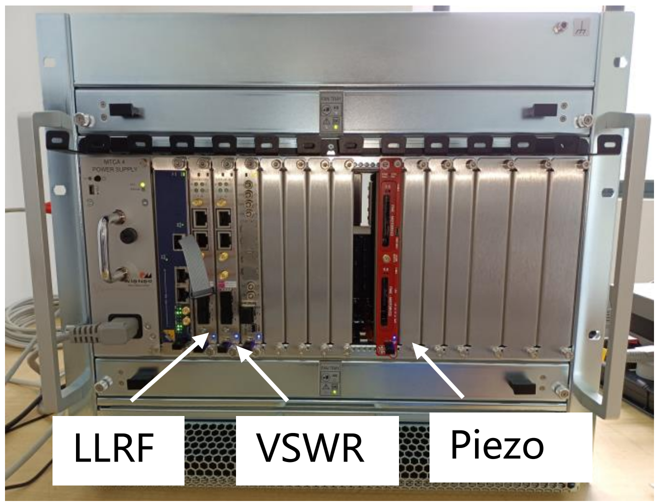


VSWR protection times

Superconducting cavity LLRF-Overview

Parameter	Value
Length (m)	97
Peak Beam Cur (mA)	50
Cutting ratio (%)	60
Energy(MeV)	300

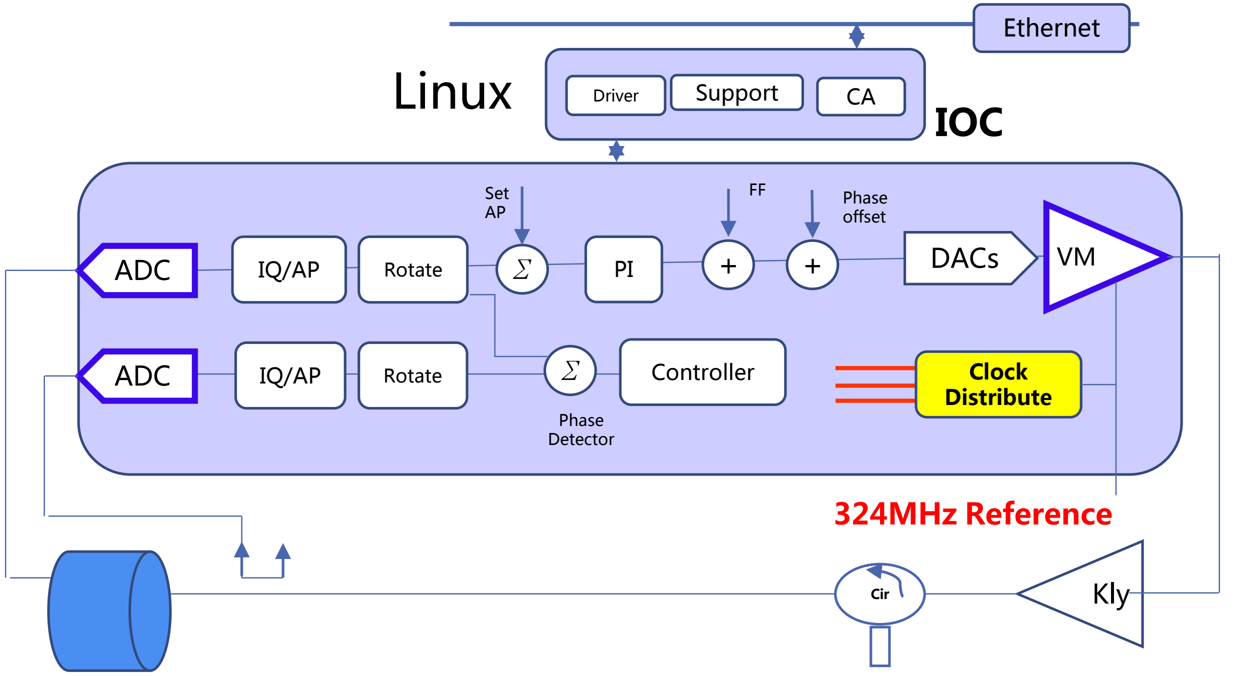


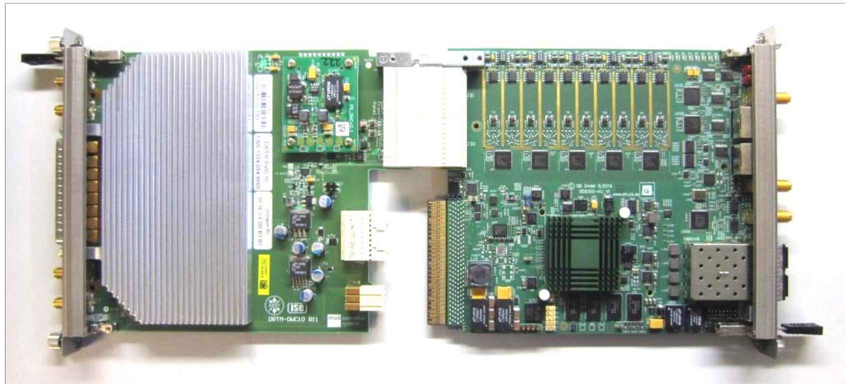


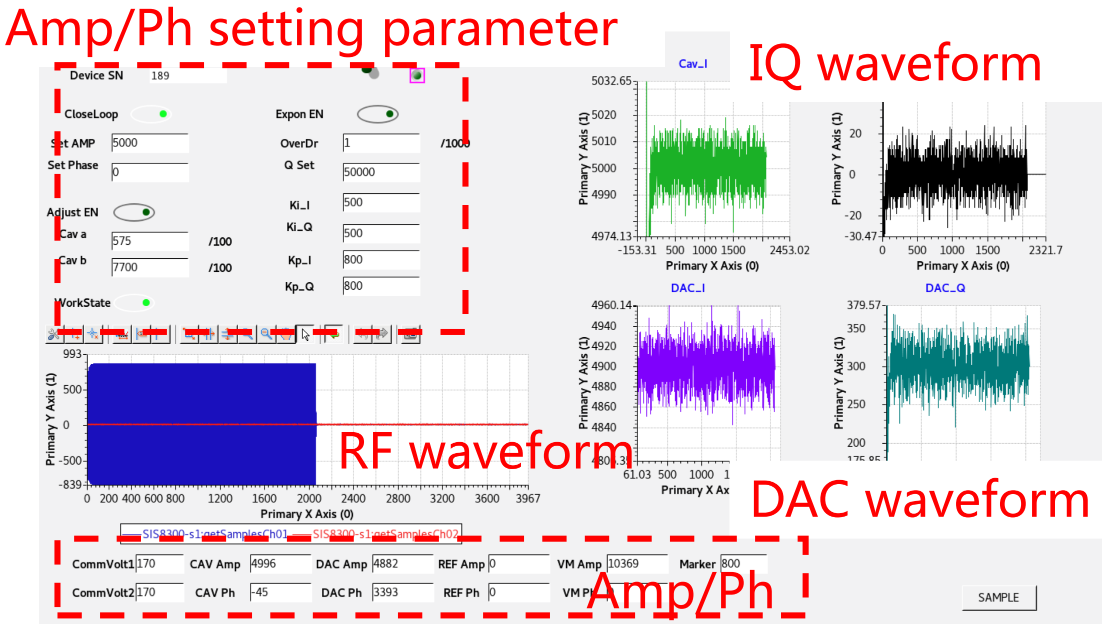
Micro TCA LLRF

Superconducting cavity LLRF-Normal conducting LLRF development

- A normal conductor LLRF is developed: to familiar MicroTCA system and verify its stability.





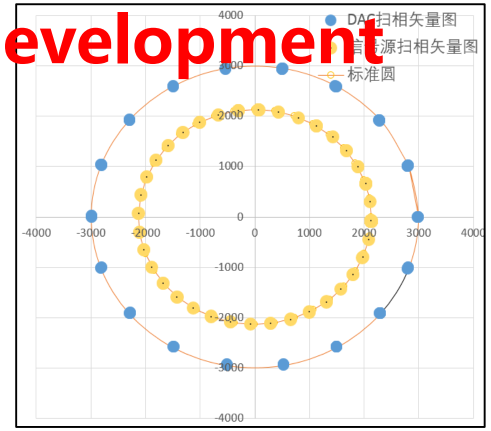


- Direct Sample
- The internal clock chip is used to synchronize the reference and provide ADC sampling clock.

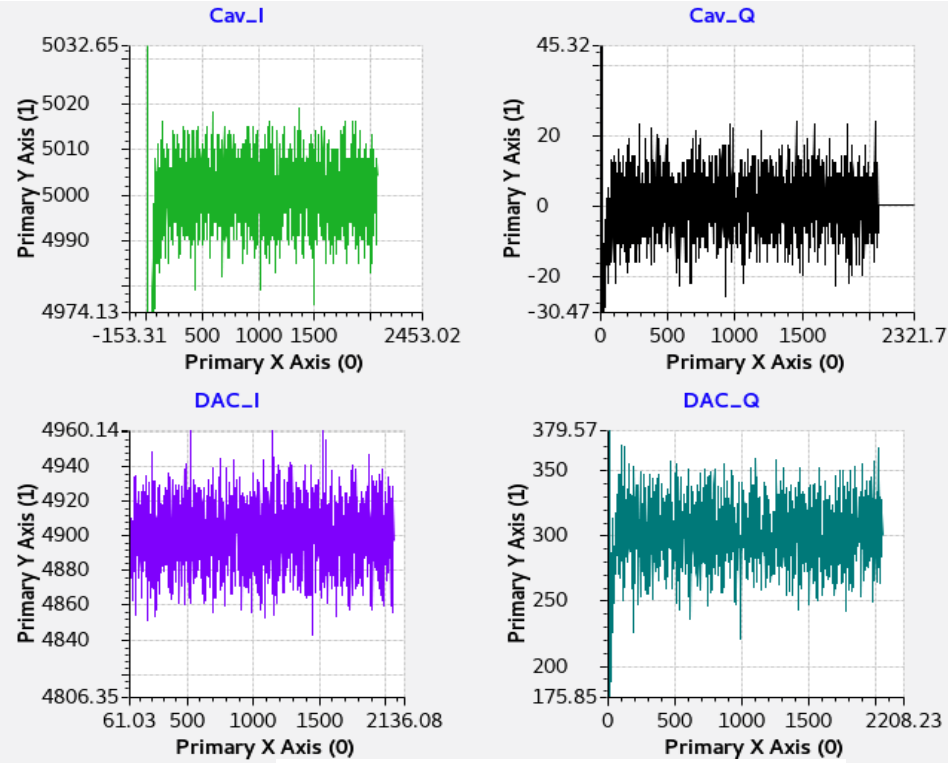
Superconducting cavity LLRF-Normal conducting LLRF development

□ Performance

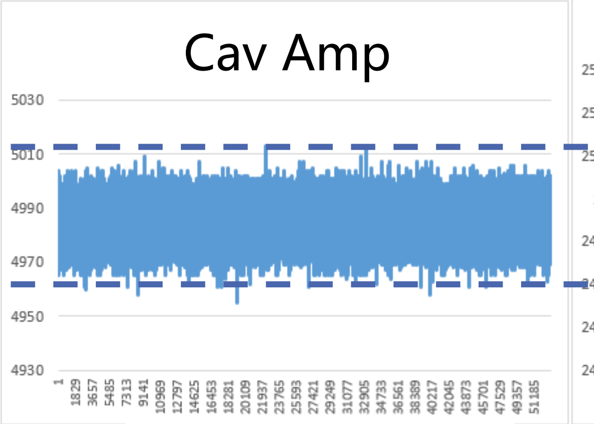
- □ **Short : ±0.4% , ±0.2°**
- □ **Long : ±0.5% , ±0.3°(12 hours)**
- □ **CSNS requirement : ±1% , ±1°**

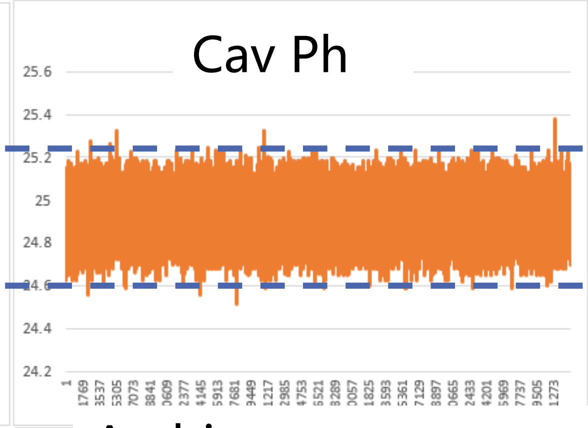


RF source 360° phase scan vs ADC sample data

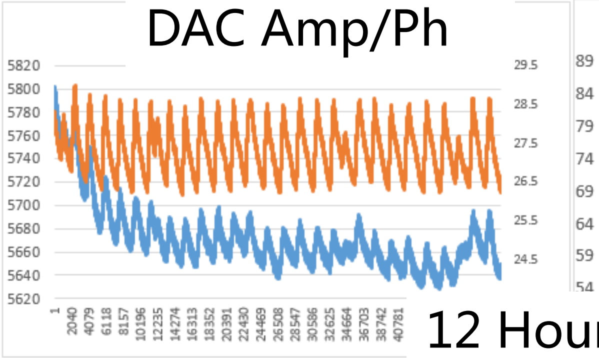


CAV/DAC IQ waveform

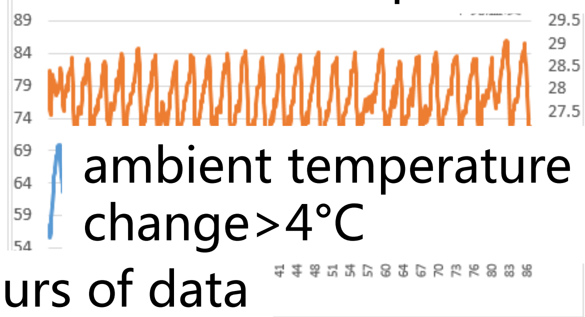




±0.5%
±0.3°



Ambient temperature



ambient temperature change>4°C

12 Hours of data

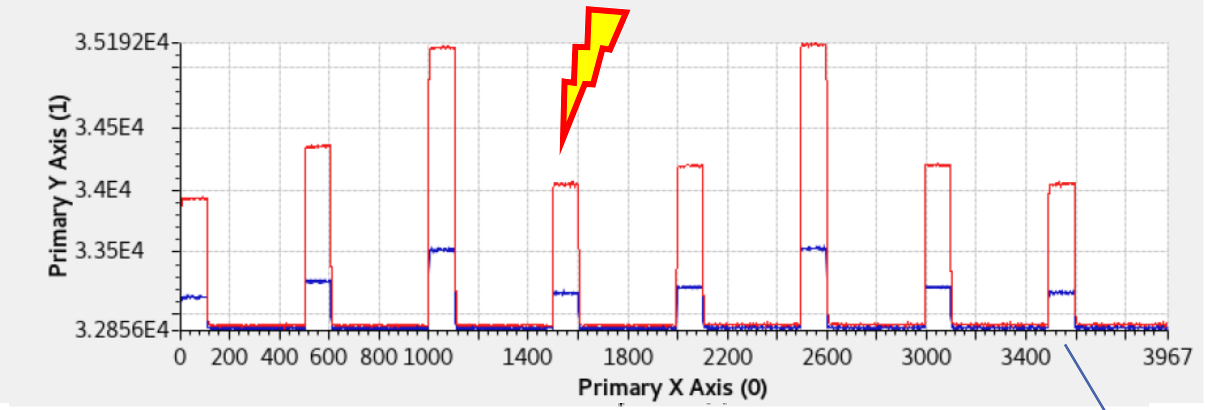
Superconducting cavity LLRF-Data cache

- The data cache can better locate the fault source of the accelerator and distinguish the sequence of events.

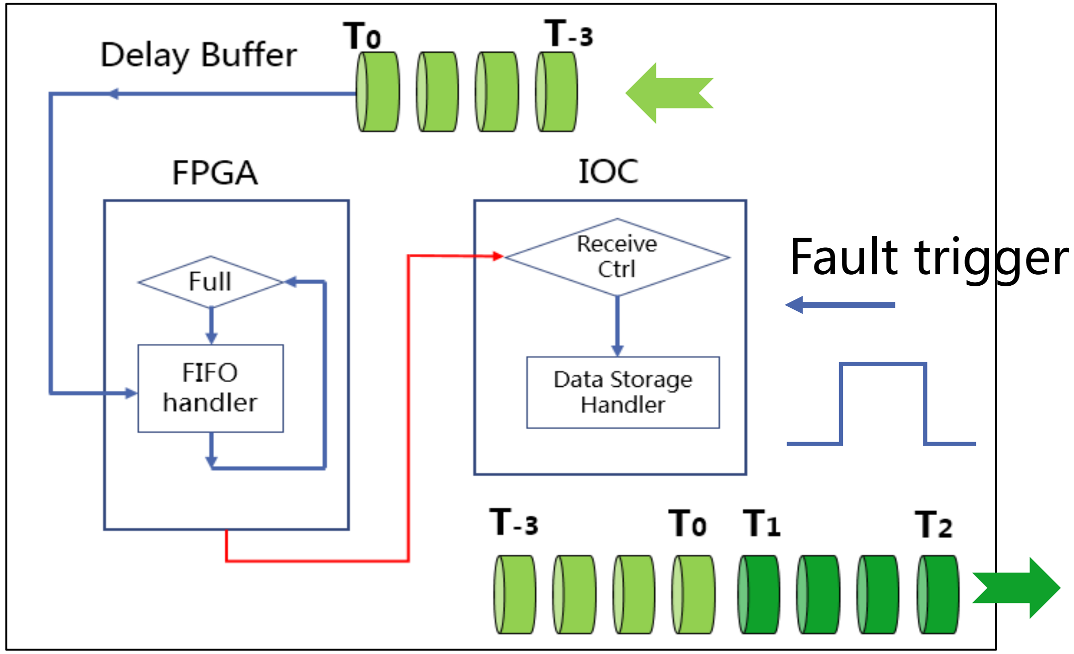
Pulses before fault

Fault

Pulses after fault



Continuous pulse waveform display



Data cache principle

700us Pulse

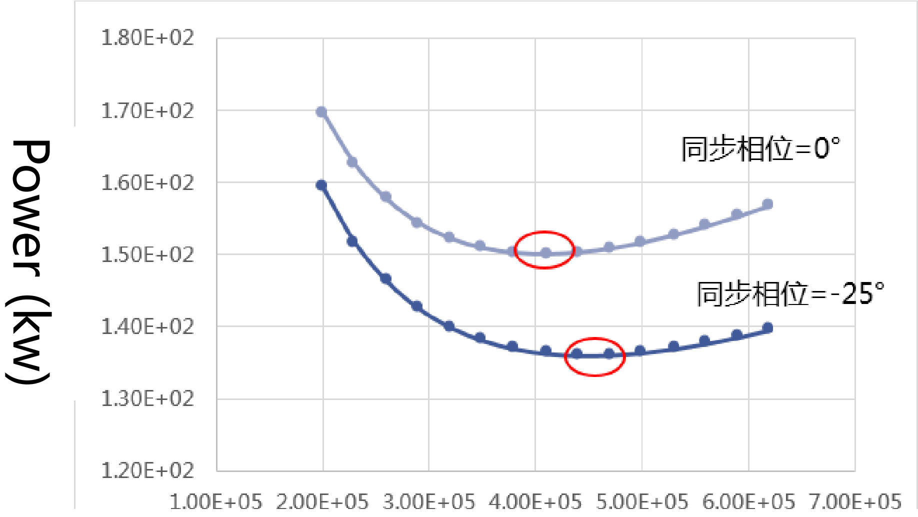
Superconducting cavity LLRF- Theory Learning and Simulation

Goal

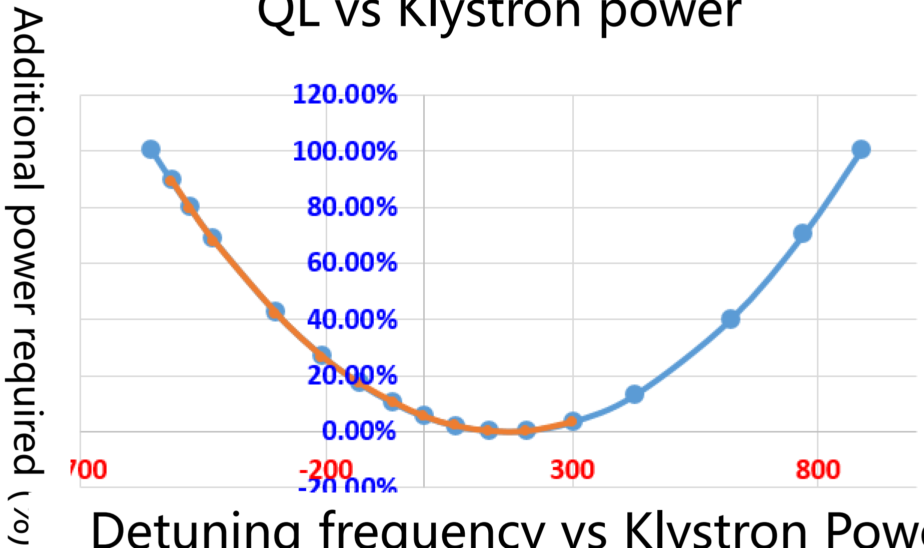
- Provides theoretical guidance for the development of superconducting LLRF

To Know the parameter calculation likes

- Cavity field rising time
- Beam inject time
- Power estimate
- Pre-tuning
- Optimal QL
- Tuner control method
- 。。。



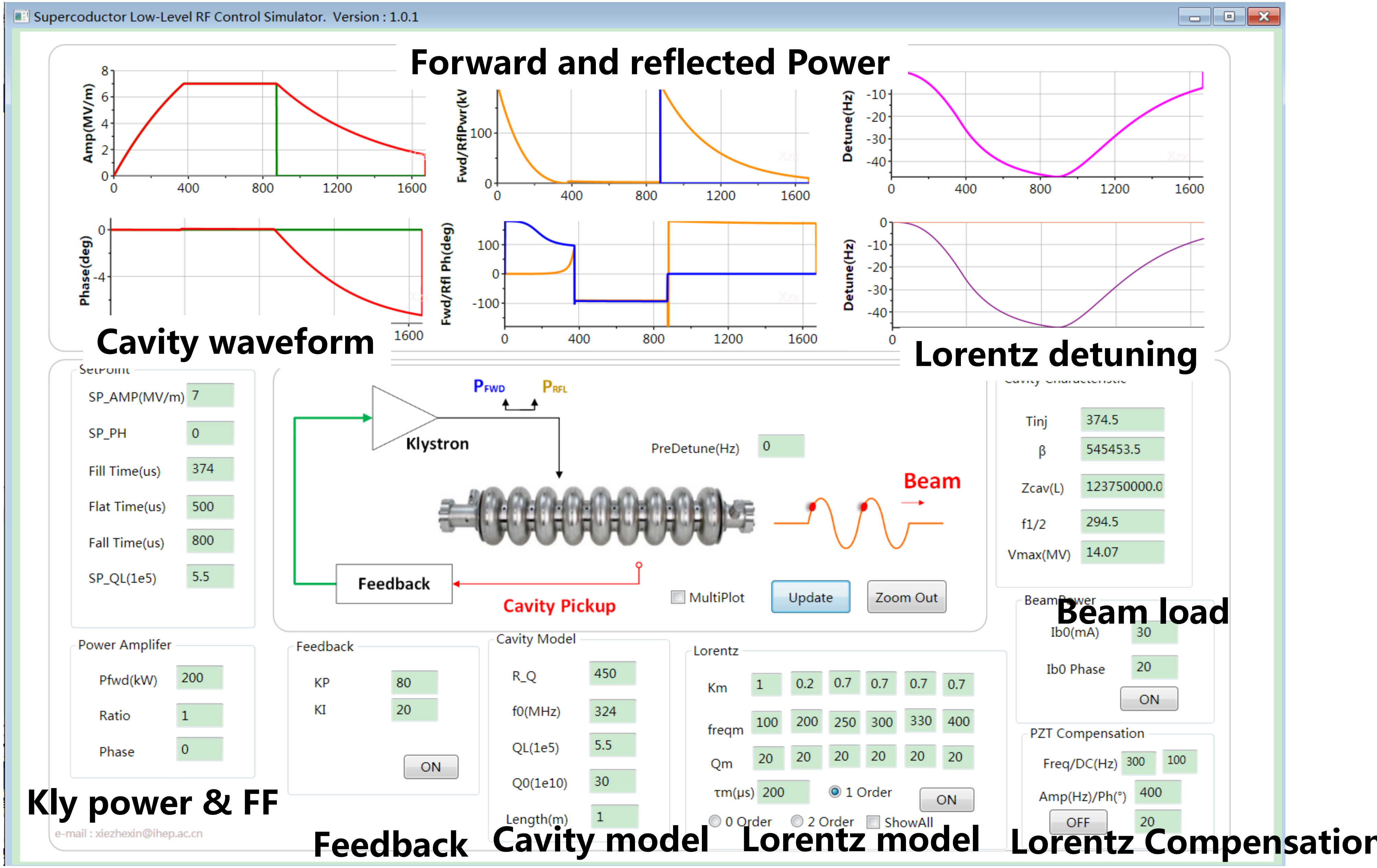
QL vs Klystron power



Detuning frequency vs Klystron Power

Superconducting cavity LLRF- Simulation Software

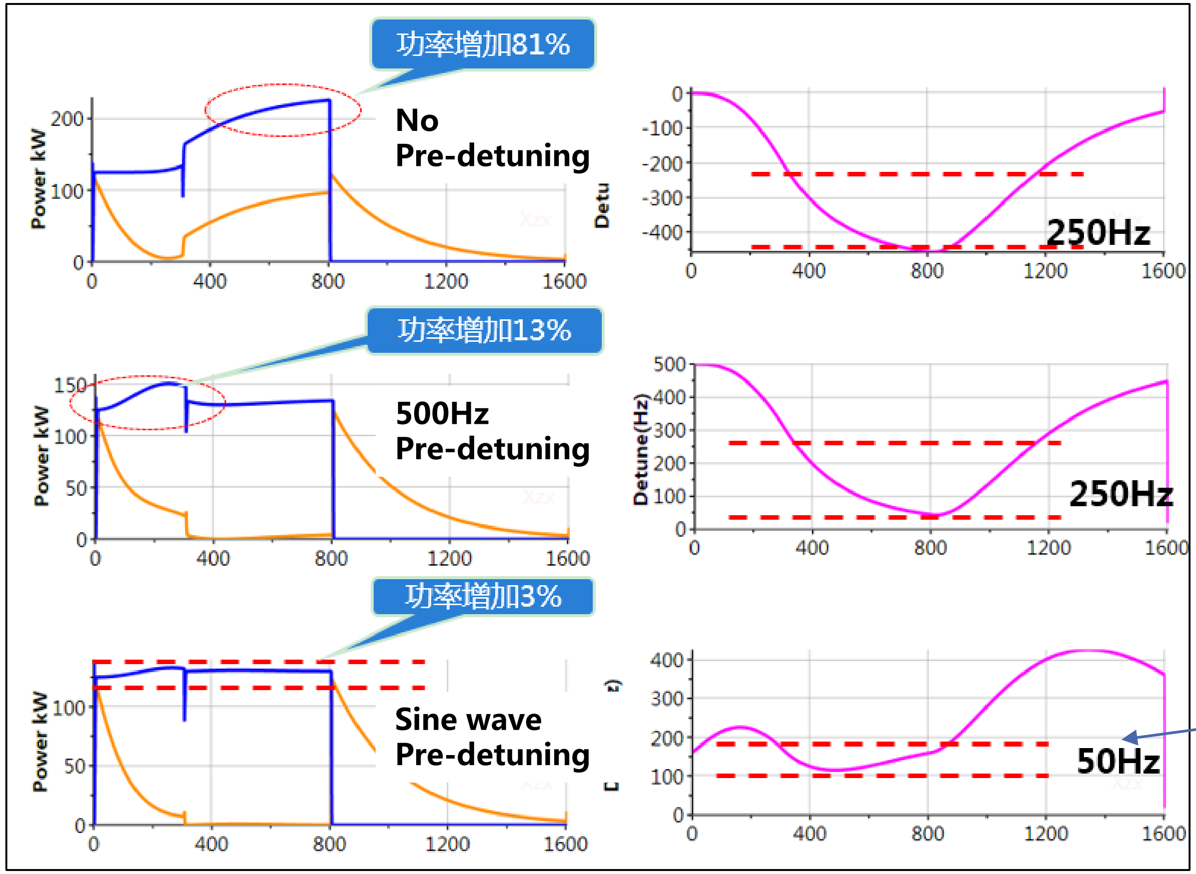
- Base on C# luggage and Windows operating system

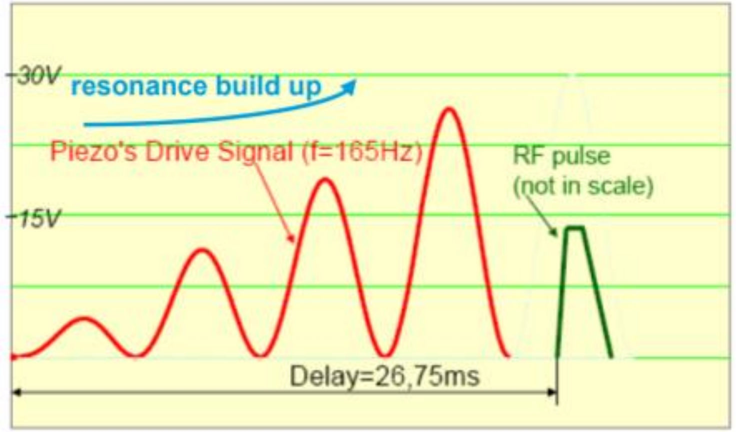


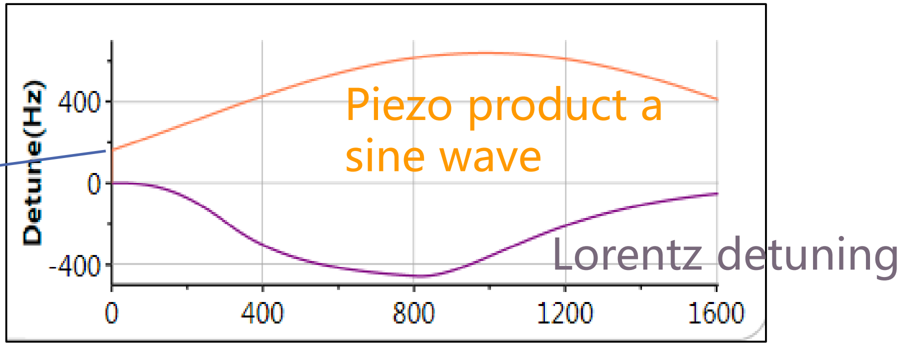
Shared online:
https://github.com/happsky123/Superconductor-Cavity-control-Simulator-

Superconducting cavity LLRF- Piezo Tuning

- The superconducting cavity piezo tuning mode is studied by using the simulation software.







Conclusion

- The llrf of normal conductive cavity is running well at present;
- SRF llrf based on MicroTCA is under development.
- Thanks to the following people for their technical help.
  - Ma xinpeng, Gan nan in IHEP/Beijin
  - Liu Rong and Struck Innovative Systeme
  - …

WORK REPORT

Thank you for your attention!