中国科学院近代物理研究所
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中国科学院
CHINESE ACADEMY OF SCIENCES

LLRF commissioning of 25 MeV Proton SC Linac and design for 500 MeV CW Linac

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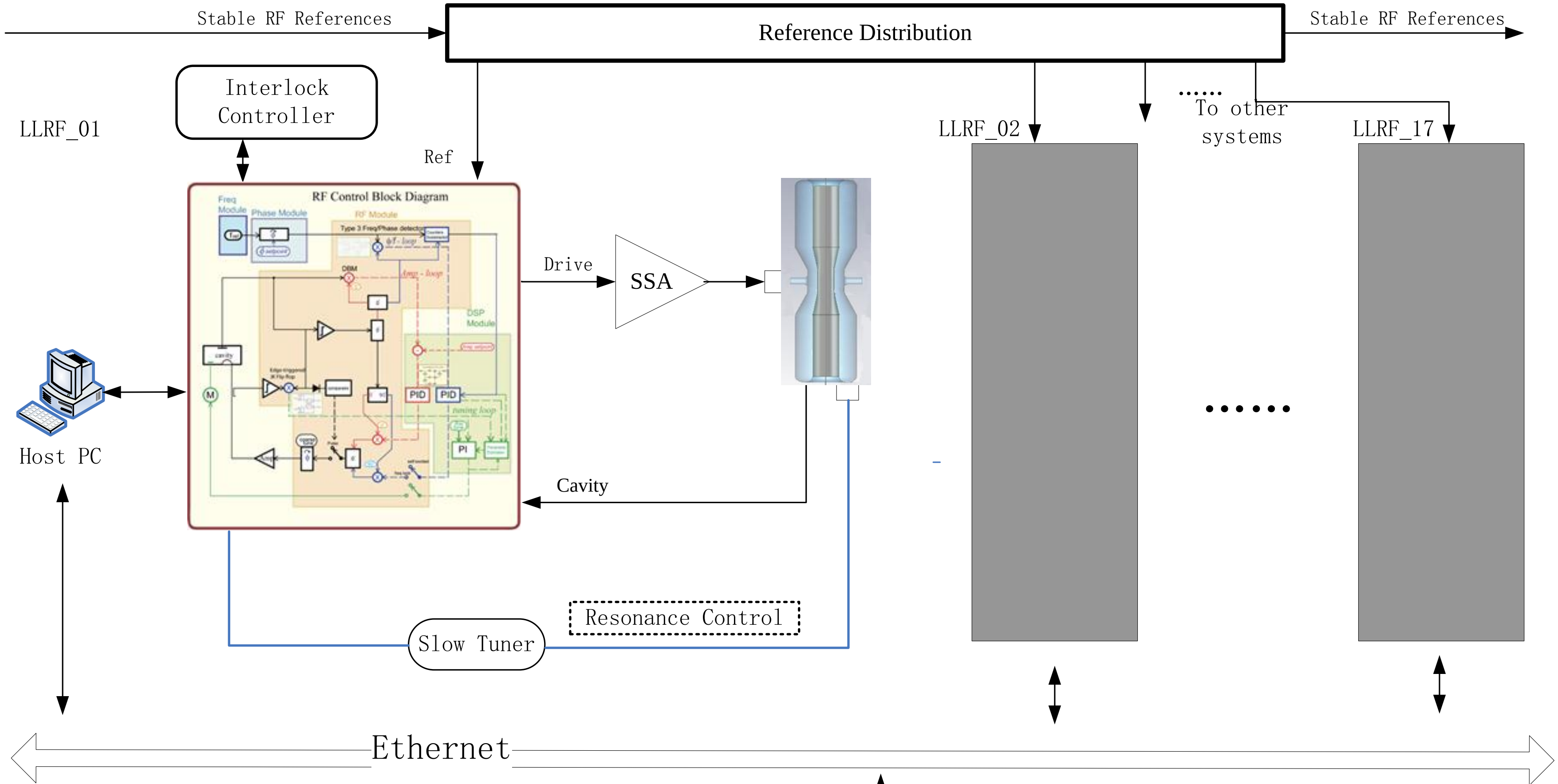
On behalf of IMP Linac group

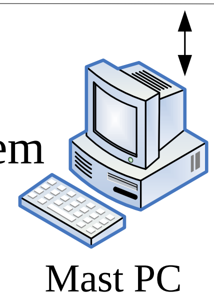
Institute of Modern Physics, CAS

Outlines

- **Introduction of ADS 25 MeV SC linac LLRF system**
- **The problem encountered during LLRF commisioning**
- **The LLRF design for CiADS SC linac**

The LLRF Control System of CM1 to CM3

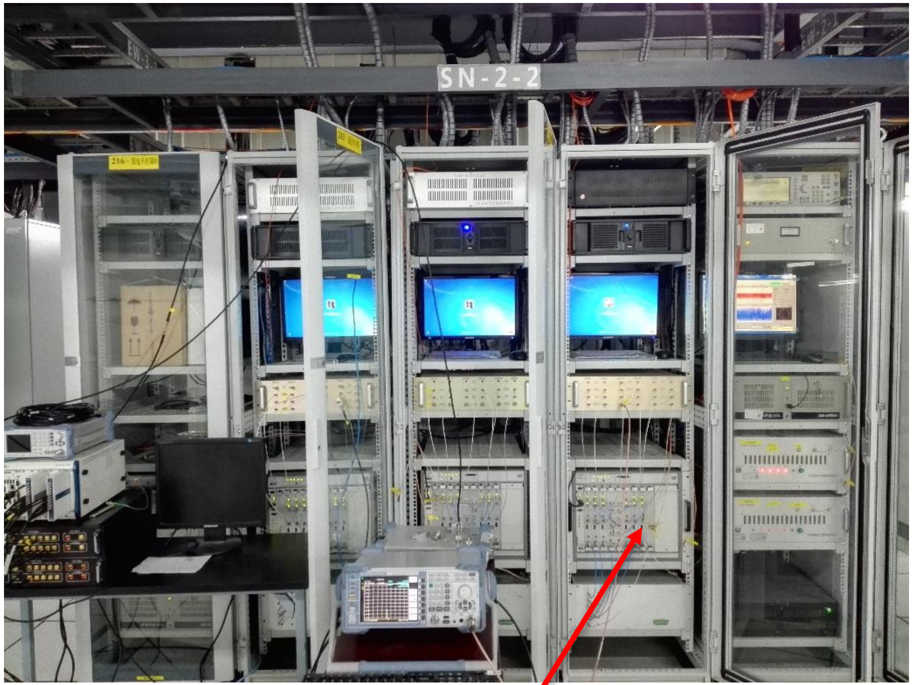




✓ The architecture of HWR SC LLRF system

- 162.5 MHz RF frequency.
- Seventeen controllers.
- Solide state amplifier.
- EPICS communication.

The HWR SC LLRF control system

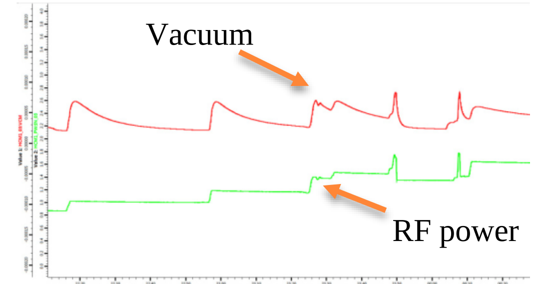


- The 162.5 MHz Phase Reference Distribution System is based on coaxial cable distribution
- The reference distribution system serving as the phase alignment line for all cavities with high phase stability
- Harmonic suppression is better than 90 dB

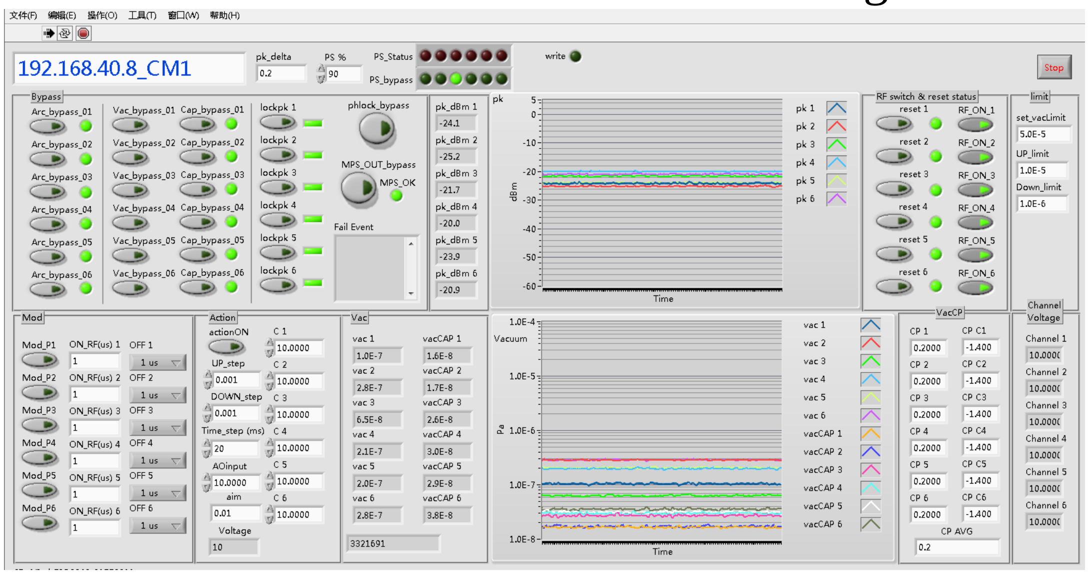
- VXI backplane
- Analog and digital hybrid
- Digital controller based on DSP
- Self-excited close loop
- C++ GUI
- Triumf Design

The SC RF Interlock and integrated auto RF conditioning functionality

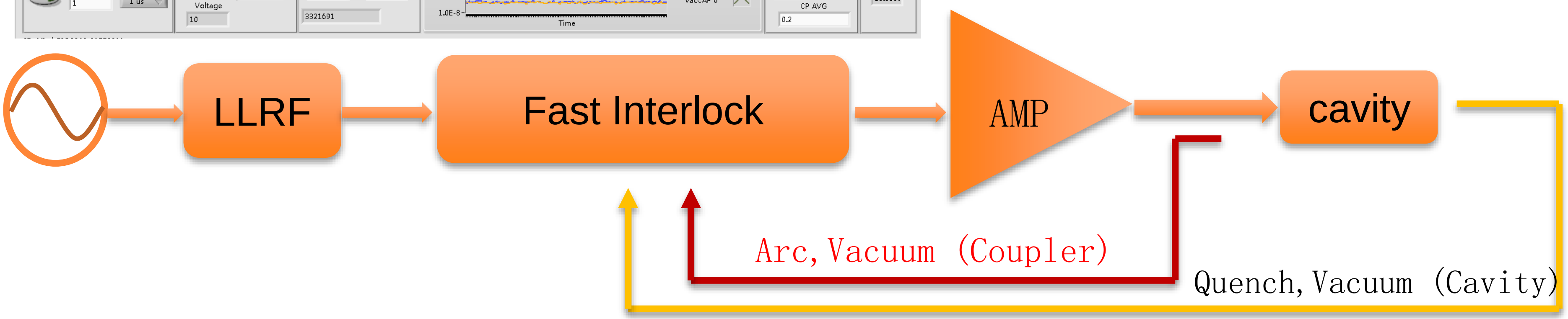
- Shutdown RF in the us time scale.
- Based on the fast logic in FPGA.
- EPICS IOC integrated.
- Auto RF conditioning.



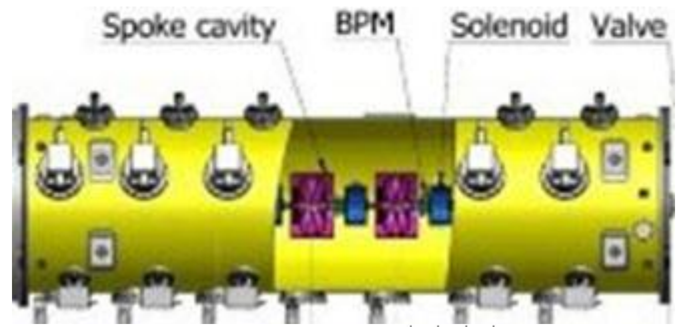
Vacuum changing with power during conditioning



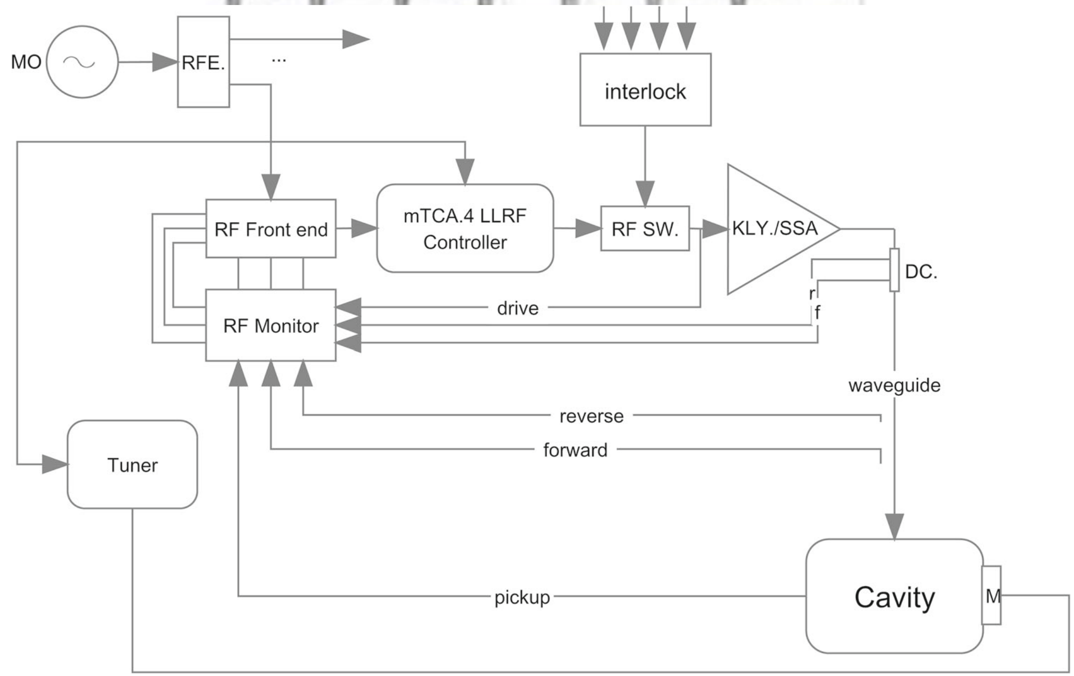
✓ The SC RF interlock system interface



The LLRF system of CM4 (from IHEP)

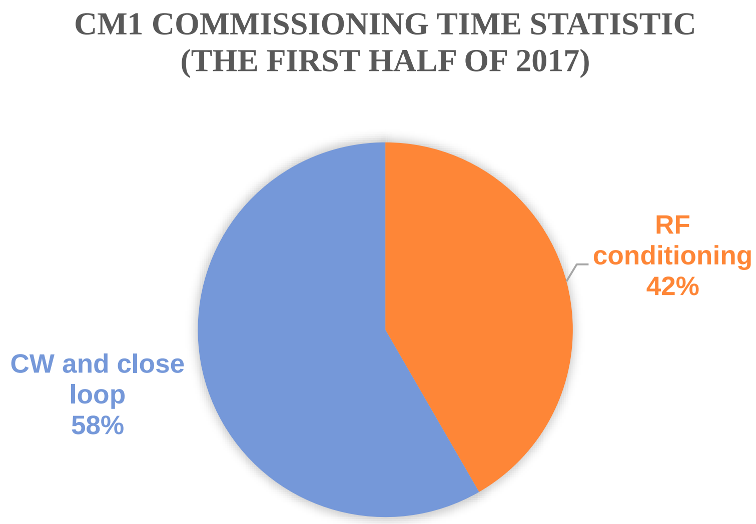


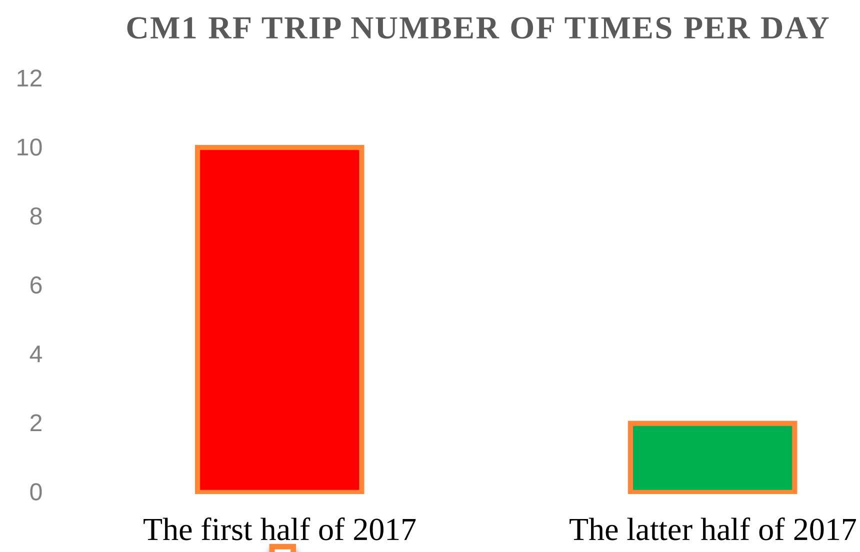
- ✓ CM4

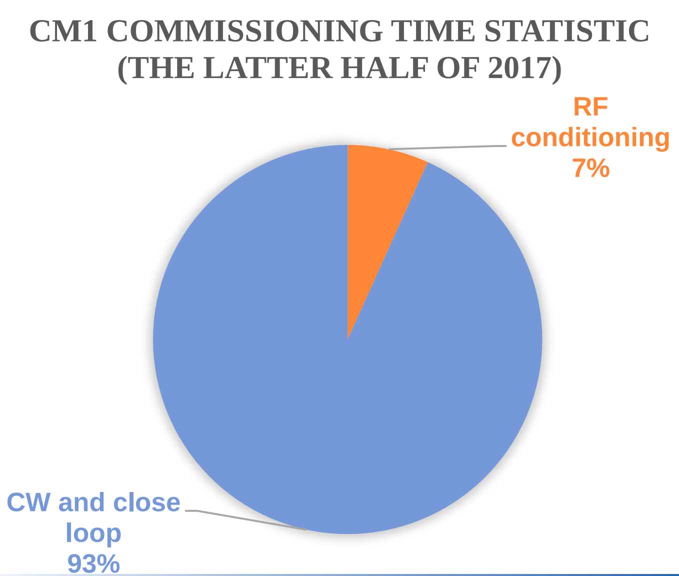


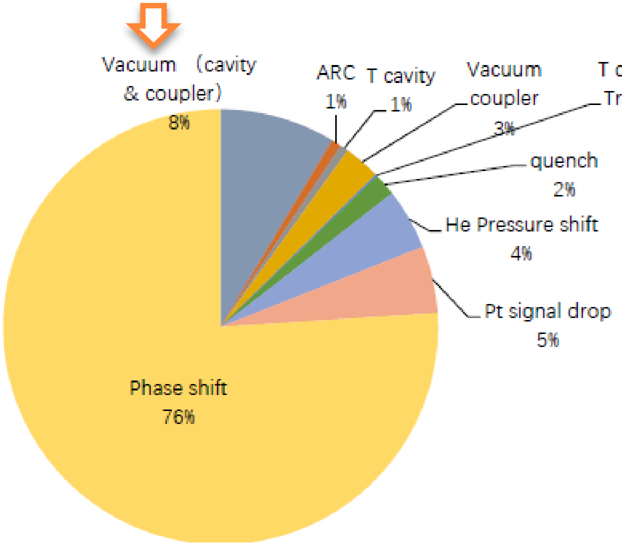
- ✓ The CM4 LLRF system chassis
- ✓ Schematic of typical LLRF controller for one RF system

The HWR SC LLRF operation statistics





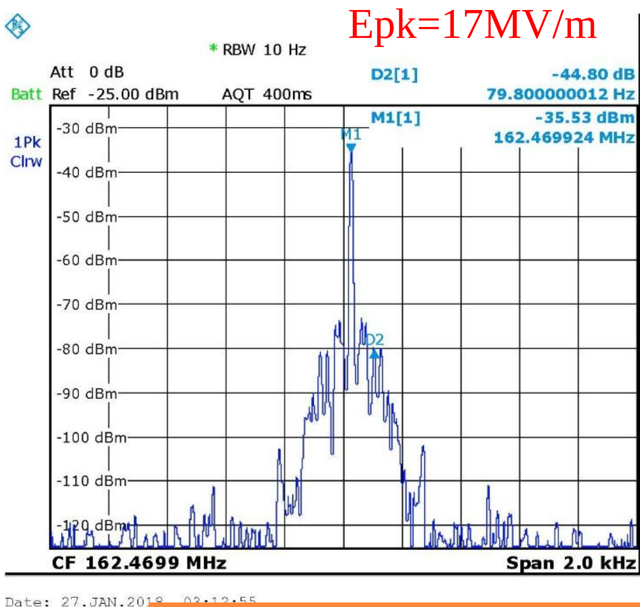




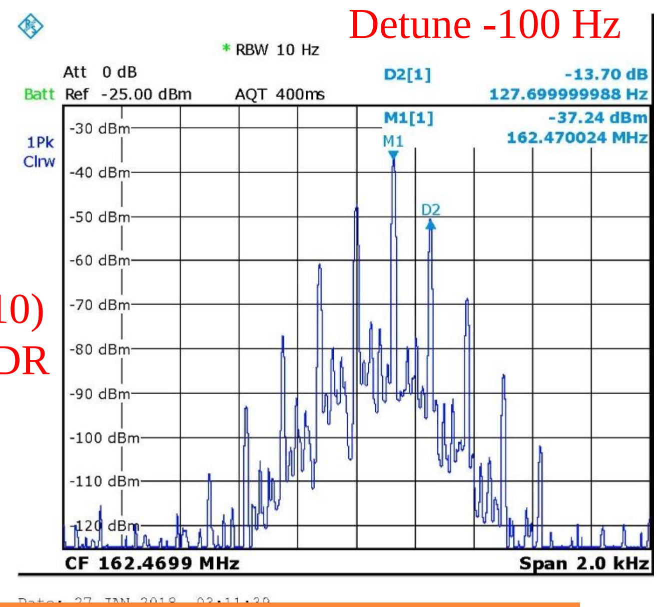
The problem encountered during LLRF commisioning

- **The electromagnetic-mechanical vibration**
- **The microphonics**
- **The thermal acoustic oscillation**

The electromagnetic-mechanical vibration of HWR



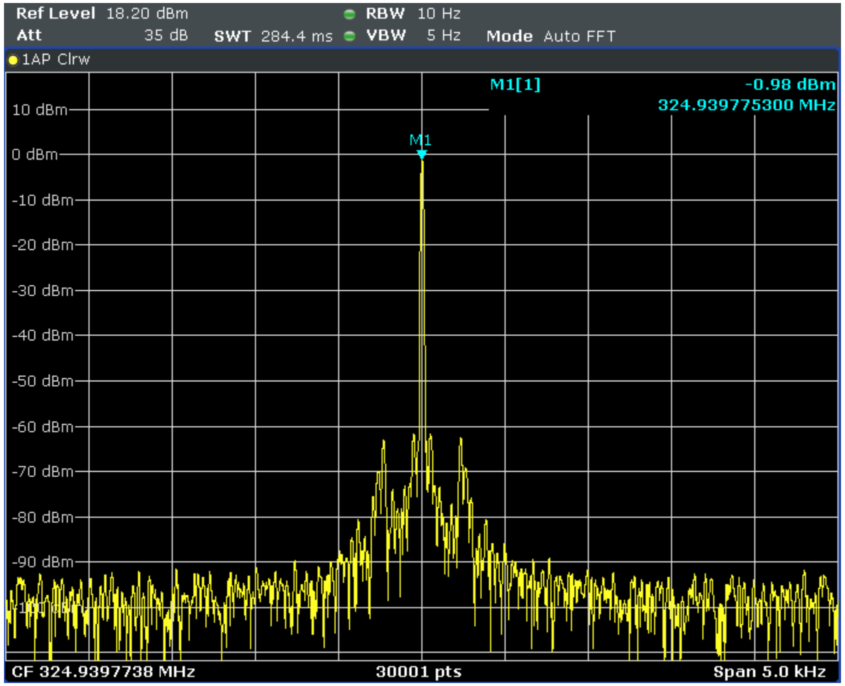
CM1-6
(HWR010)
Under GDR

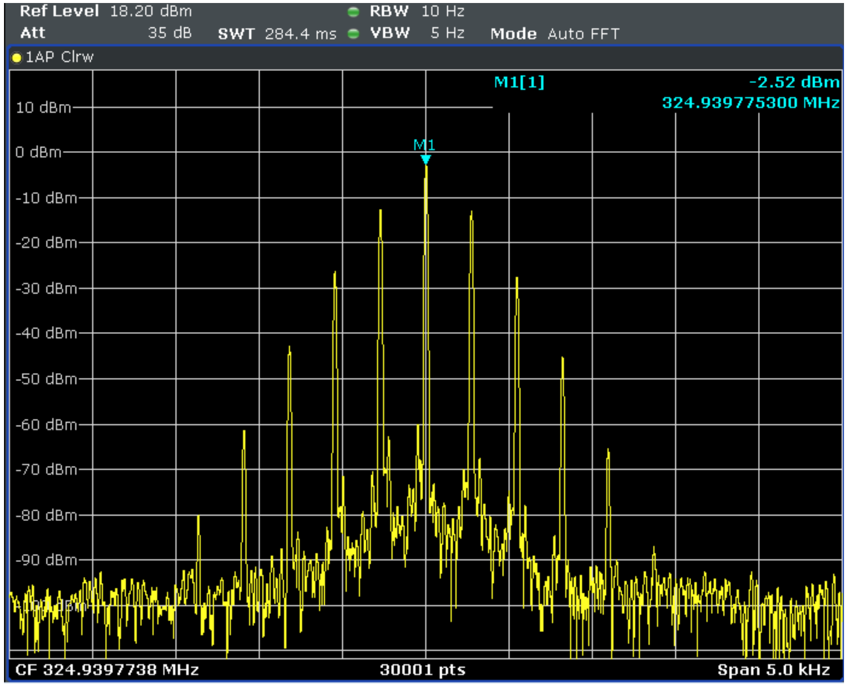


Cavity	Epk (MV/m)	Helium P (Pa)	Detune (Hz)	Threshold (MV/m)
CM1-1	17	111950	-40	10
CM1-2	17	112540	-50	9
CM1-3	20	105004	-50	*
CM1-4	17	112770	-40	12
CM1-5	17	112950	-40	9
CM1-6	17	105010	-100	15

The electromagnetic-mechanical vibration of Spoke021

Epk=28MV/m

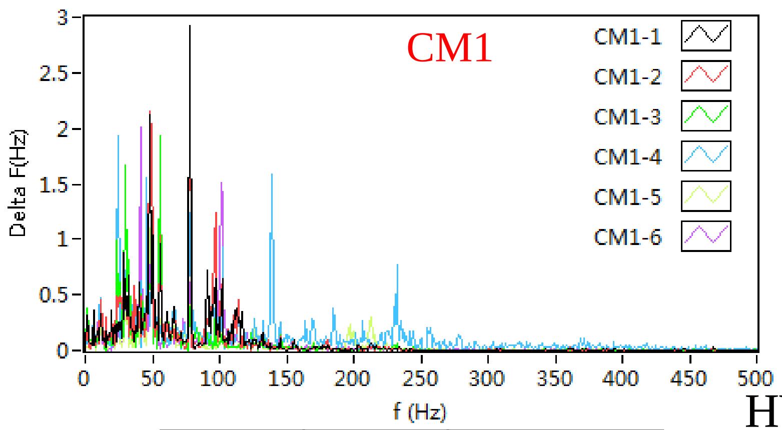


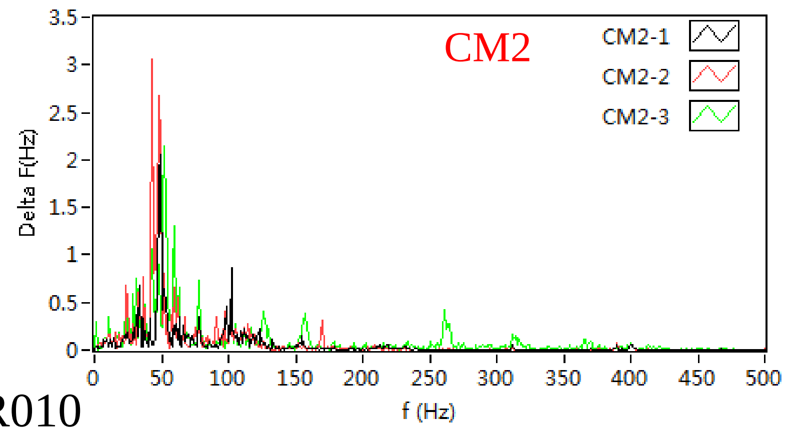


- ✓ CM4-6 (Spoke cavity) operated on GDR mode

The 325 MHz spoke cavities of CM4 also have the same electromagnetic-mechanical vibration problem, more than that, the CM4 operated under generator driven mode, the electromagnetic-mechanical vibration is the main reason which cause unstability.

The microphonics of CM1 to CM3

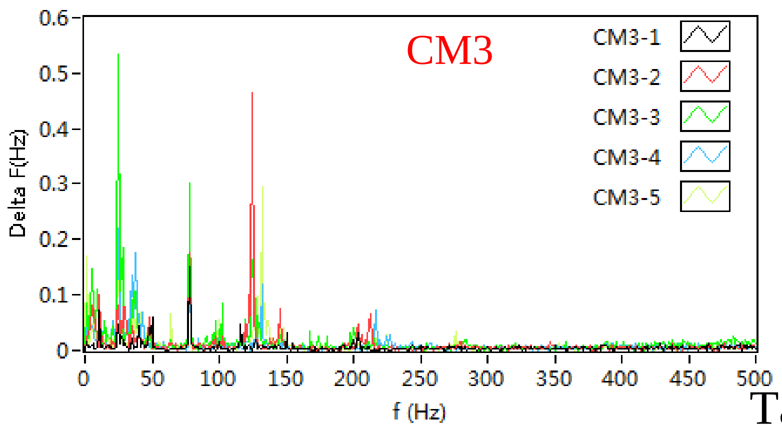


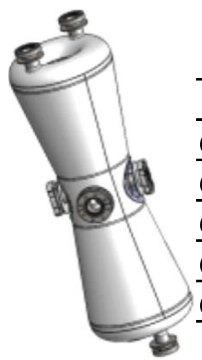


	1 σ(Hz)	pk to pk(Hz)
CM1-1	*6*	*38*
CM1-2	*6*	*41*
CM1-3	*6*	*39*
CM1-4	*5*	*32*
CM1-5	*5*	*30*
CM1-6	*6*	*40*

HWR010

	1 σ(Hz)	pk to pk(Hz)
CM2-1	*7*	*41*
CM2-2	*6*	*33*
CM2-3	*5*	*39*



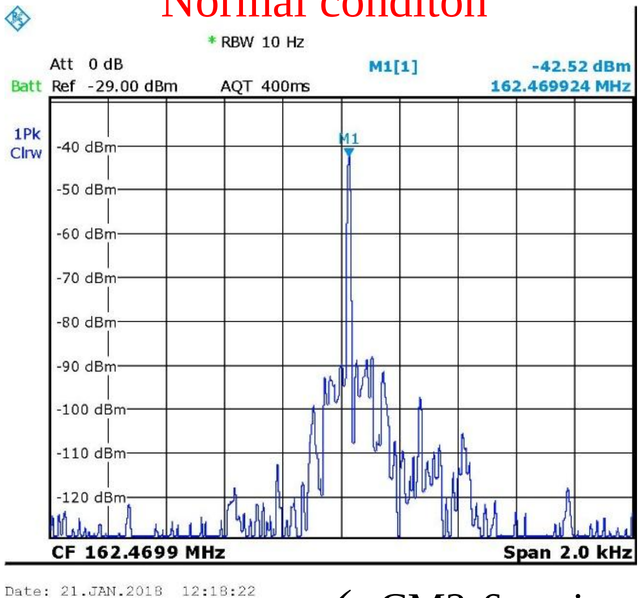


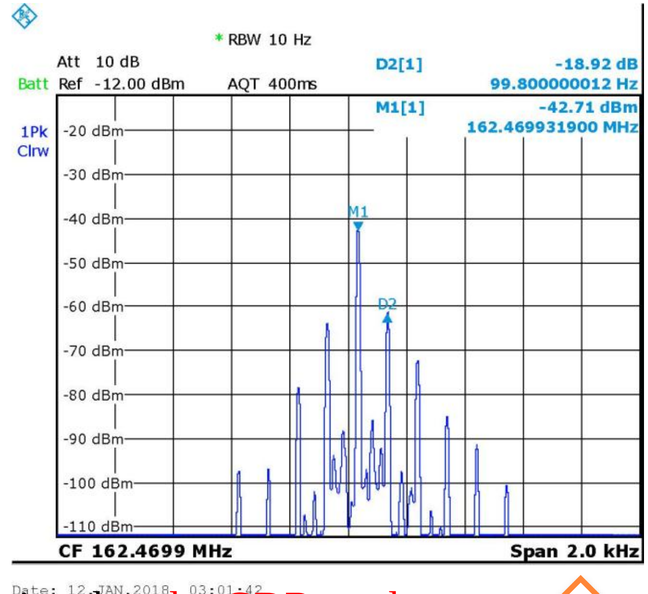
	1 σ(Hz)	pk to pk(Hz)
CM3-1	*5*	*27*
CM3-2	*4*	*25*
CM3-3	*4*	*26*
CM3-4	*4*	*27*
CM3-5	*3*	*20*

Taper HWR015

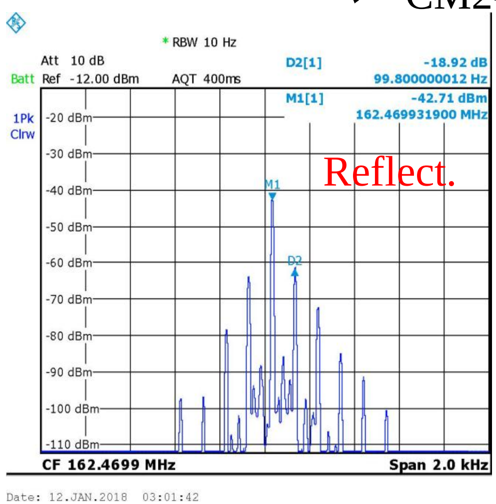
The microphonics of CM2-6

Normal conditon





- ✓ CM2-6 cavity pick up signal under GDR mode

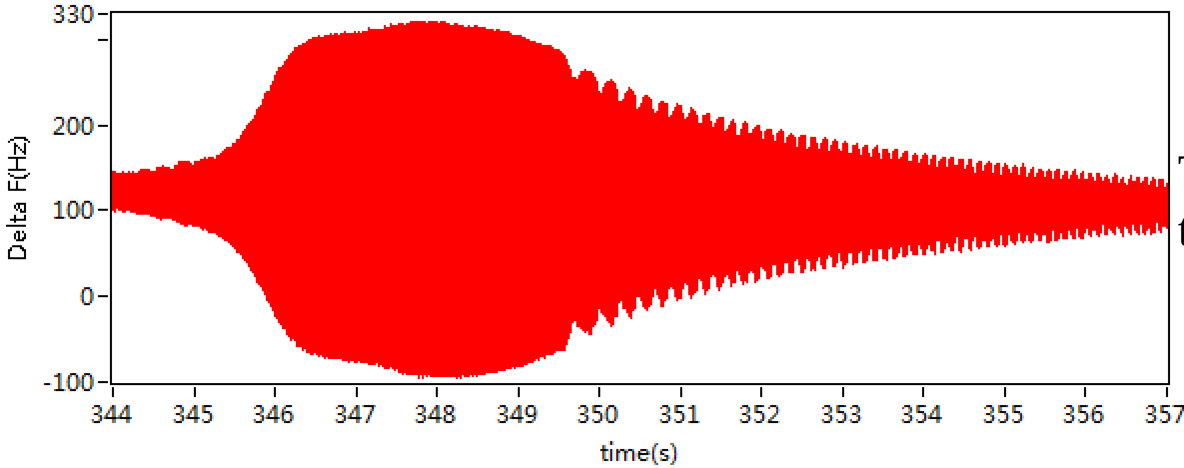


The sideband of reflected signal from coupler appeared when the RF drive signal of solide state amplifer set to -30 dBm (0.001 mW).

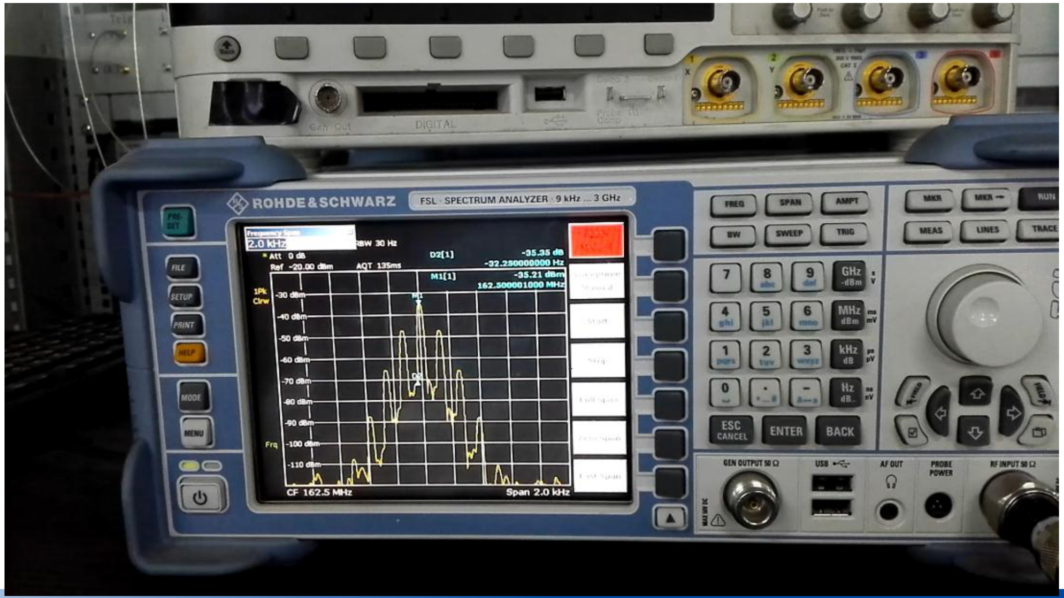
After a careful examination, the mechanical pump was identified to be the reason, It touched the RF waveguide of coupler.

The thermal acoustic oscillation?

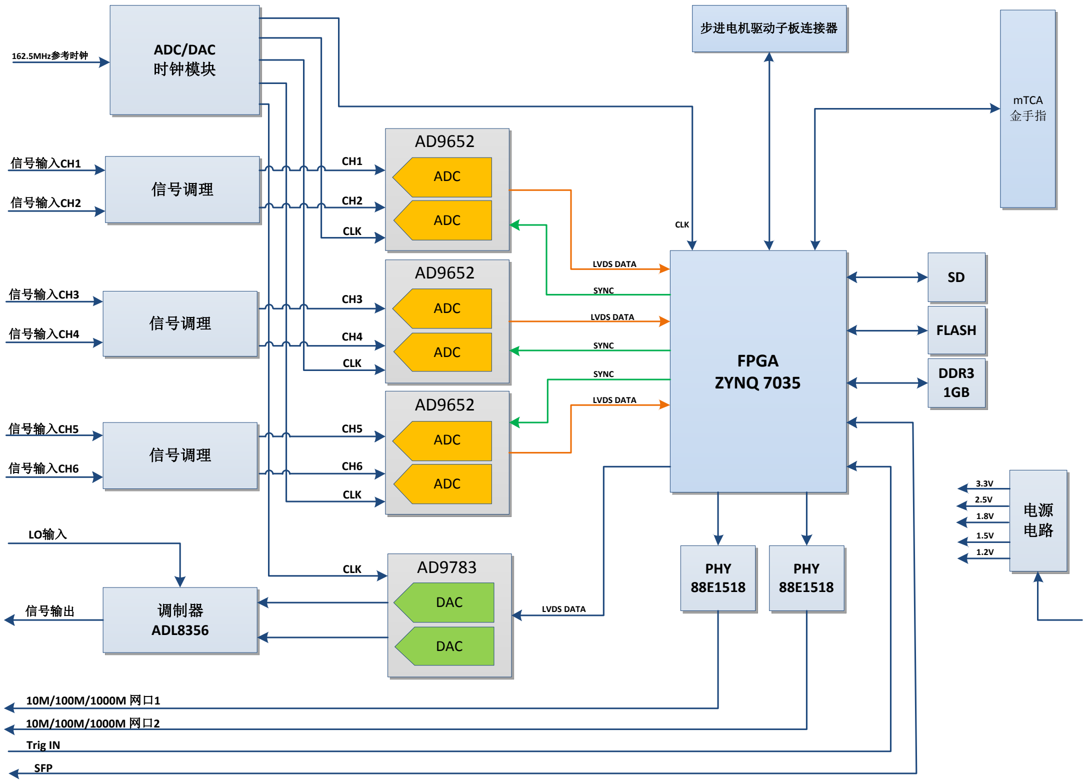
CM3-1
Taper HWR

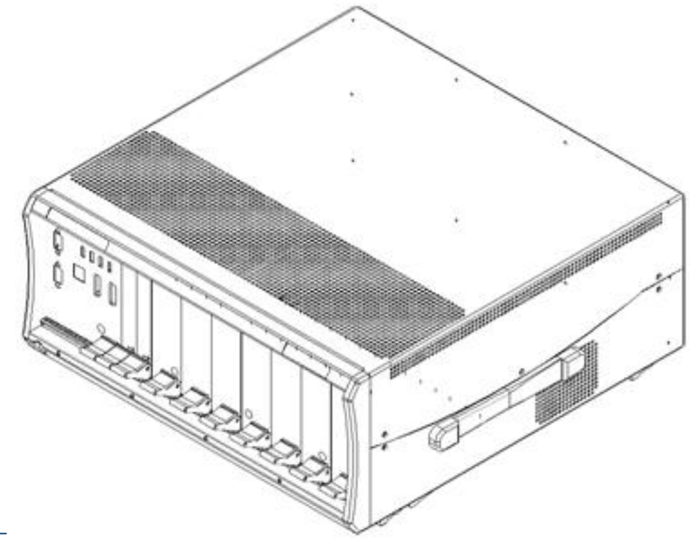


The half bandwidth of this cavity is 55 Hz.

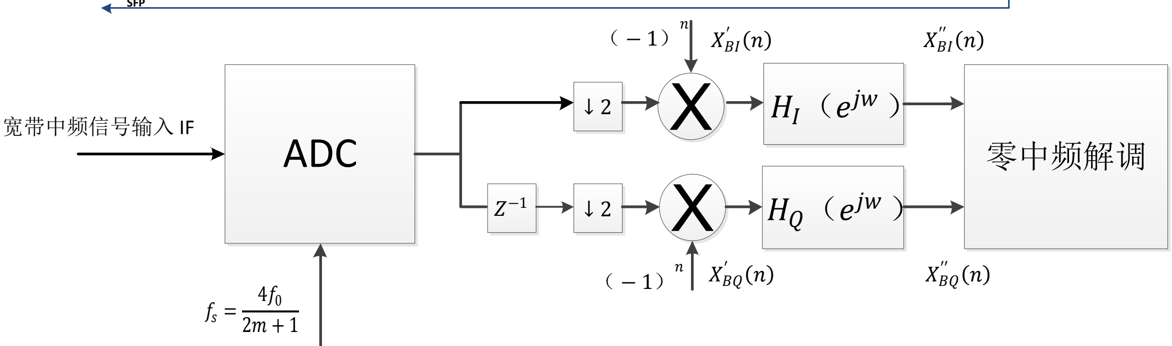


The LLRF design for CiADS SC linac





✓ 4U LLRF crate



The llrf control system conceptual design is implementing, the under-sampling technique will be tested and as a altenative choice of replacing the analog RF downconverter architecture.

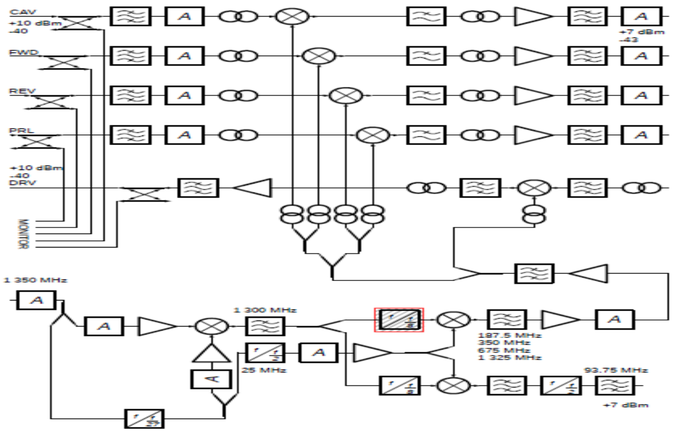
The LLRF design for CiADS SC linac

On the other hand, the analog RF front-end is being designed, and the cooperation with company is implementing to find the final solution.

✓ 162.5 MHz analog RF front-end

Self designing

✓ Analog RF front-end PCB



✓ The block diagram of RF front-end

Summary

1. After a year of commissioning of the 25 MeV SC proton linac, some significant progress for long-term operation has been made, and the CW prototype SC linac successfully accelerated CW beam for a long time on Jan. 1th and Jan. 2th again.
2. But the long-term stability of this demo facility still need to face the tests of electromagnetic-mechanical vibration, thermal acoustic vibration, and some other challenges.
3. With the arrival of the new CiADS project, the initial design phase of LLRF system is starting.

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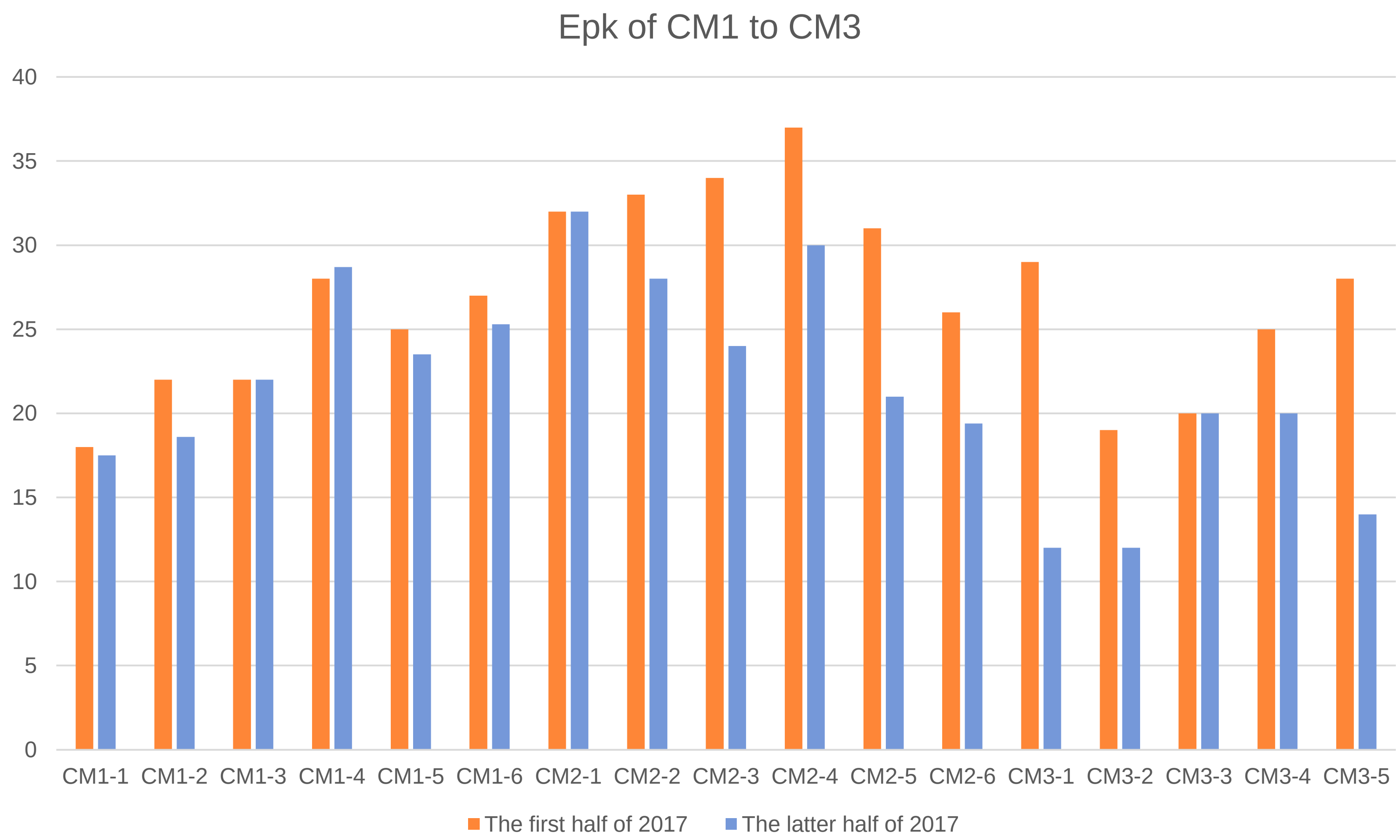
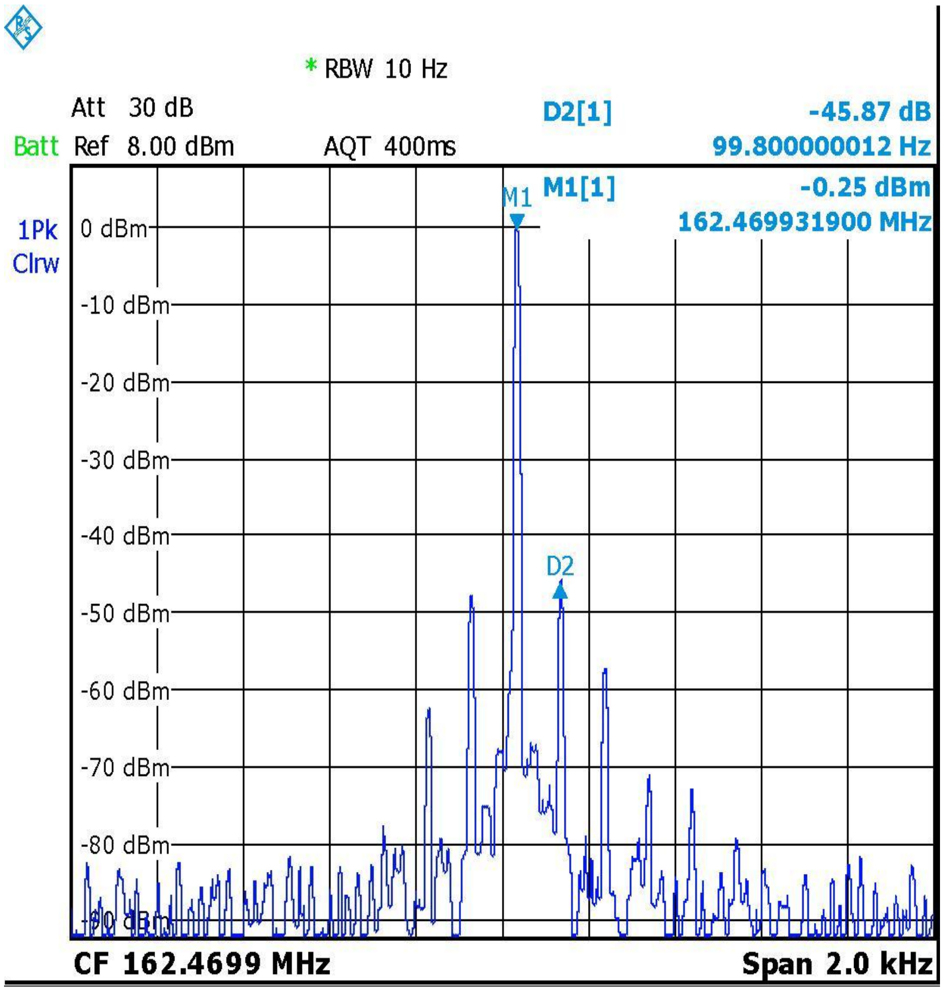
HIT, PKU, IHEP,SINAP,……

Back up slides



Epk of CM1 to CM3
40
35
30
25
20
15
10
5
0
CM1-1
CM1-2
CM1-3
CM1-4
CM1-5
CM1-6
CM2-1
CM2-2
CM2-3
CM2-4
CM2-5
CM2-6
CM3-1
CM3-2
CM3-3
CM3-4
CM3-5
The first half of 2017
The latter half of 2017



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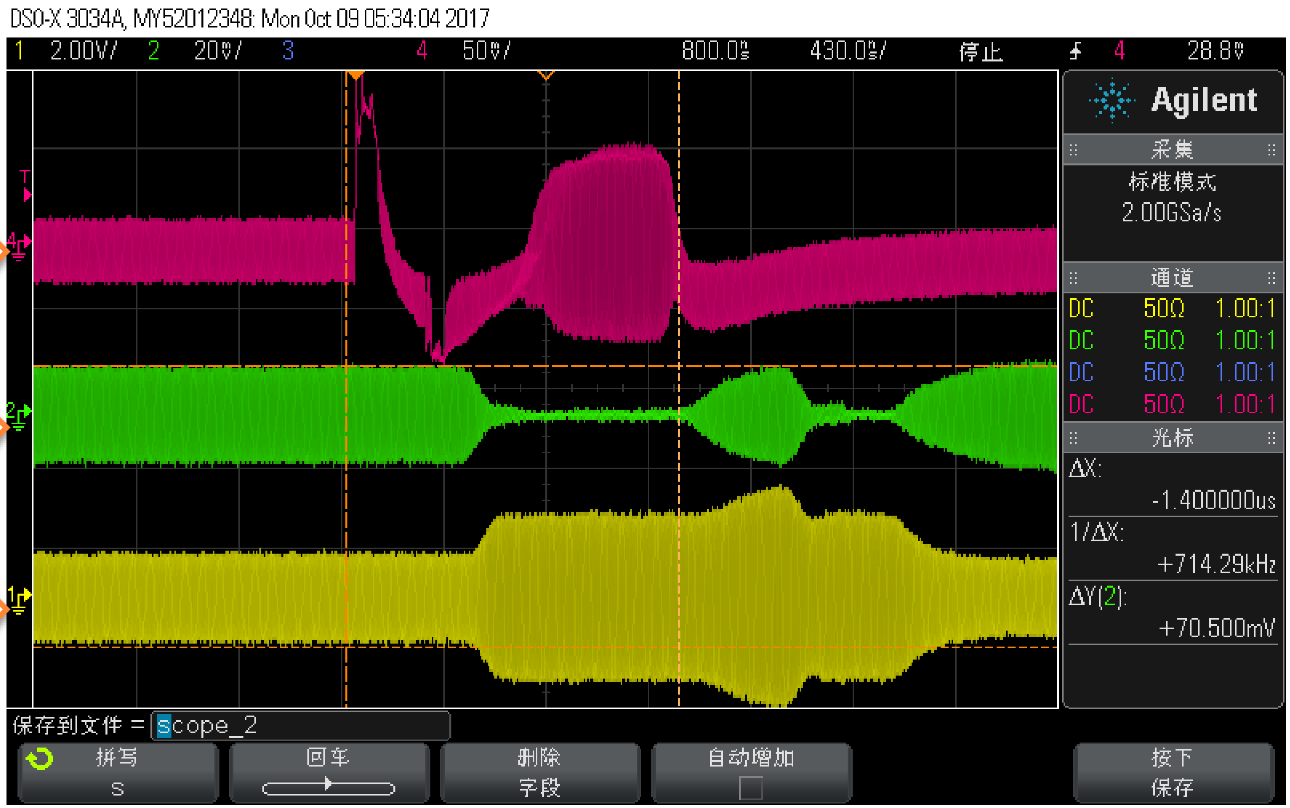
The Puzzle

The pick up signal of SC is varied very strangely!

Pick up from cavity

Forward RF signal

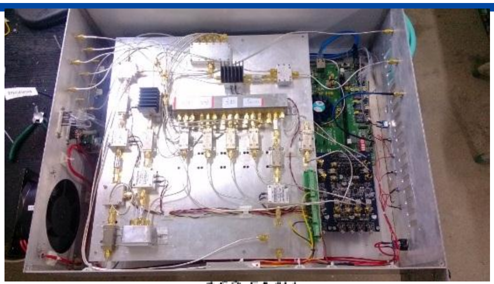
Reflected RF signal



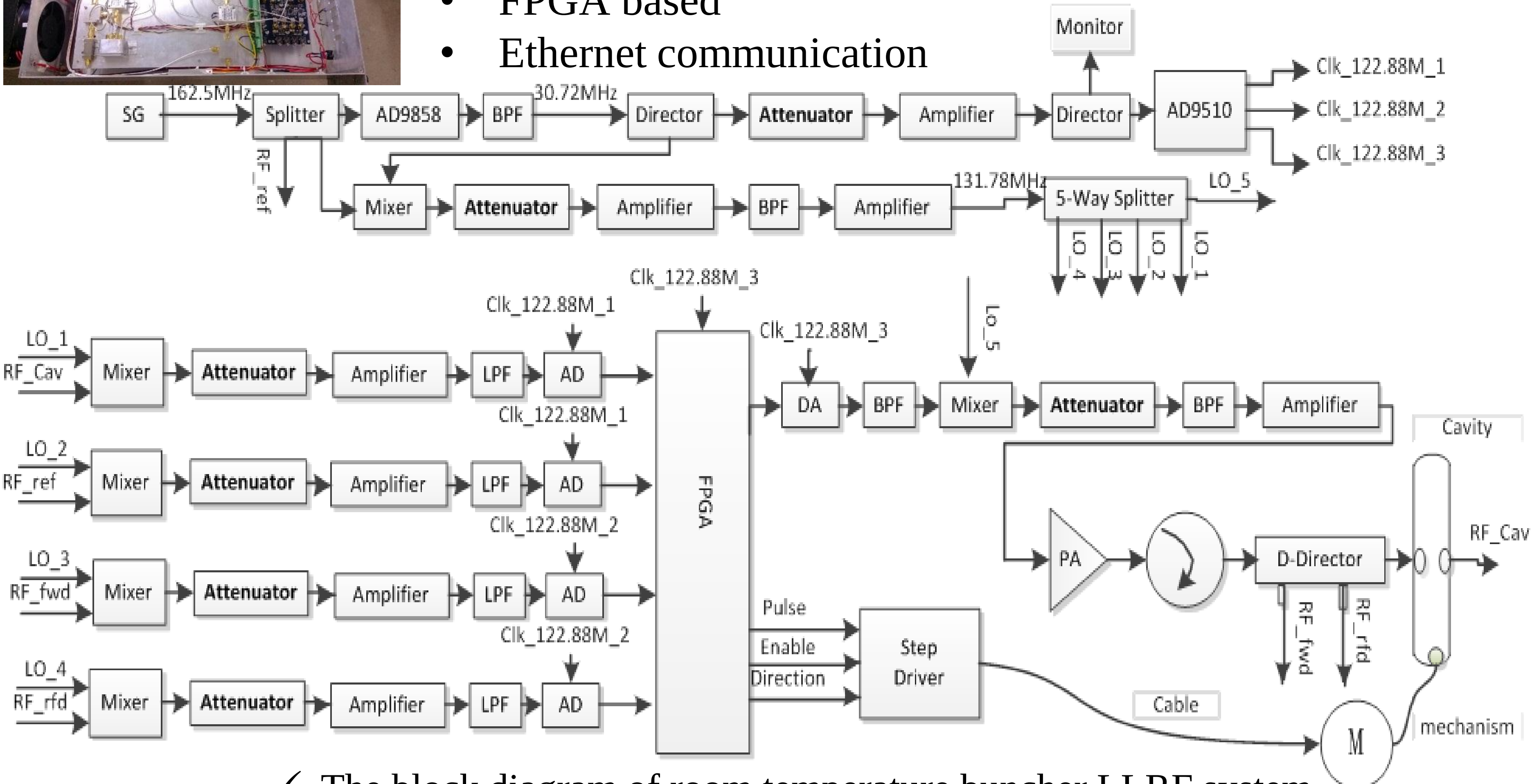
Assumptions:

1. Arc on pick antenna?
2. Multipacting?
3. Connector problem?

The Buncher LLRF control system



- Stand-alone
- Self developing
- FPGA based
- Ethernet communication



✓ The block diagram of room temperature buncher LLRF system

Table 1. 162.5MHz frequency distributor specification

Frequency（MHz）	162.5±1
Output power（dBm）	10
Phase noise(typical value dBc/Hz）	-85dBc @100Hz -100dBc@1kHz -110dBc@10kHz -120dBc@1MHz -130dBc@10MHz
Frequency stabilization	$\pm 1\times 10^{-8}$ （-40～50℃）
harmonic suppression	＞60dB
clutter suppression	＞70dB
Distribution of phase error	<0.1°