Brief Introduction to HEPS BPM Electronics Development

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September 14-18 2020

IBIC2020, Brazil

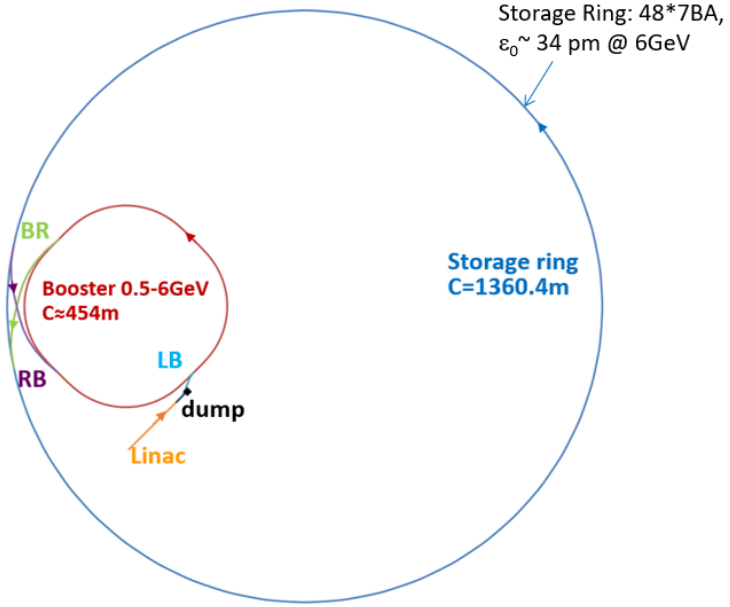
Outline

1. The HEPS Storage Ring BPM requirement
2. BPM electronics design of HEPS project
3. BPM electronics upgrading work in BEPCII project
4. The plan of Pilot Tone Hardware used in HEPS
5. Summary and Acknowledgement

1. The HEPS Storage Ring BPM requirement

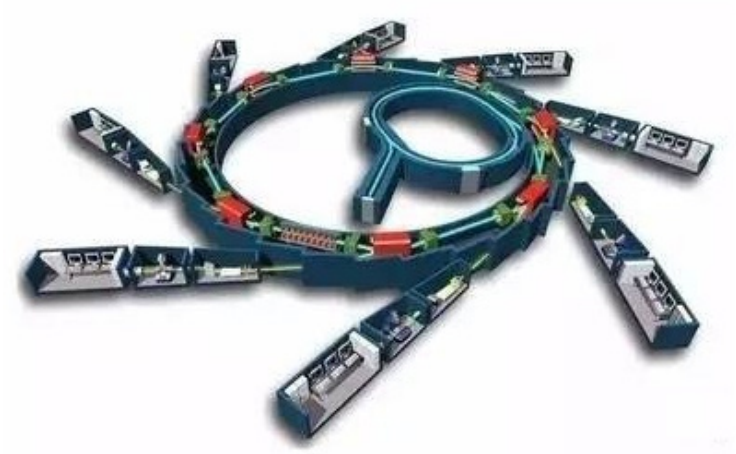
A quick introduction to the HEPS project

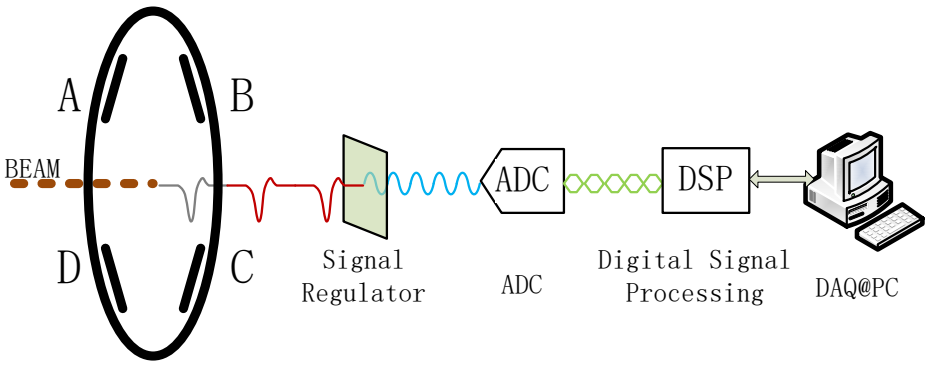
- The **High Energy Photon Source (HEPS)** is designed as an ultra-low emittance ring-based synchrotron radiation light ;
- About fourteen beamlines will be constructed in Phase I of the project;
  - Storage ring circumference: 1360m， 48*7BA
  - Energy: 6GeV
  - Emittance: 60pm.rad
  - Current: >200mA



Schematic of HEPS Complex

The Digital BPM requirement of HEPS project





■ HEPS BPM quantities

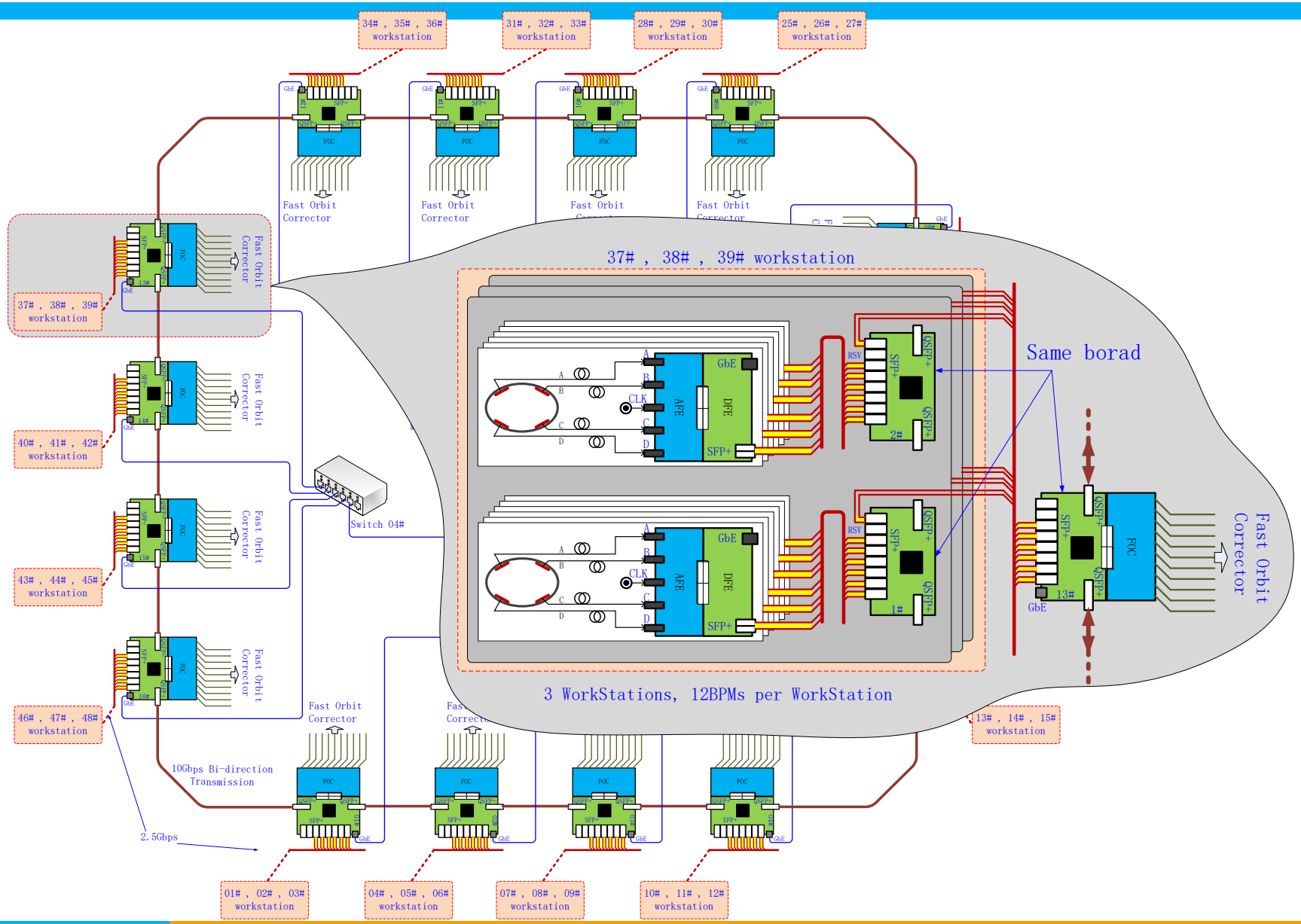
	BPM Quantities
Linac	7
Transfer Line	3*10=30
Booster	80
Storage Ring	48*12+2=578
SUM	695

■ Storage ring BPM Parameters

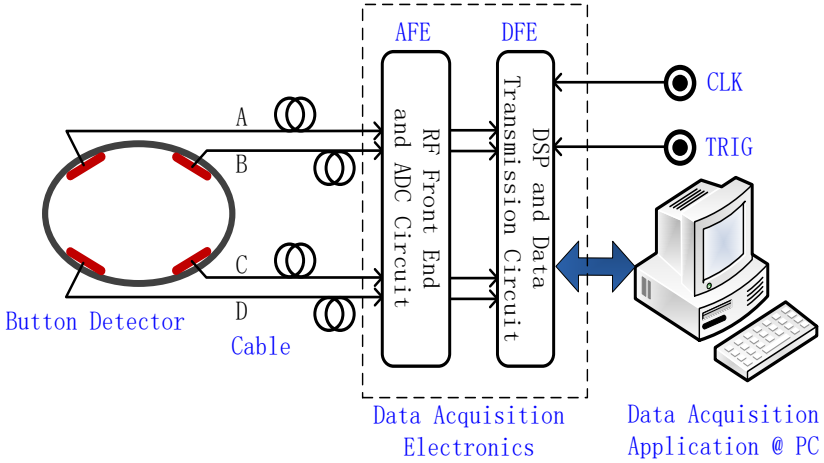
	DBPM@HEPS
Turn by Turn Data	1μm @220kHz
FA data	0.3μm @22KHz
COD data	0.1μm @10Hz

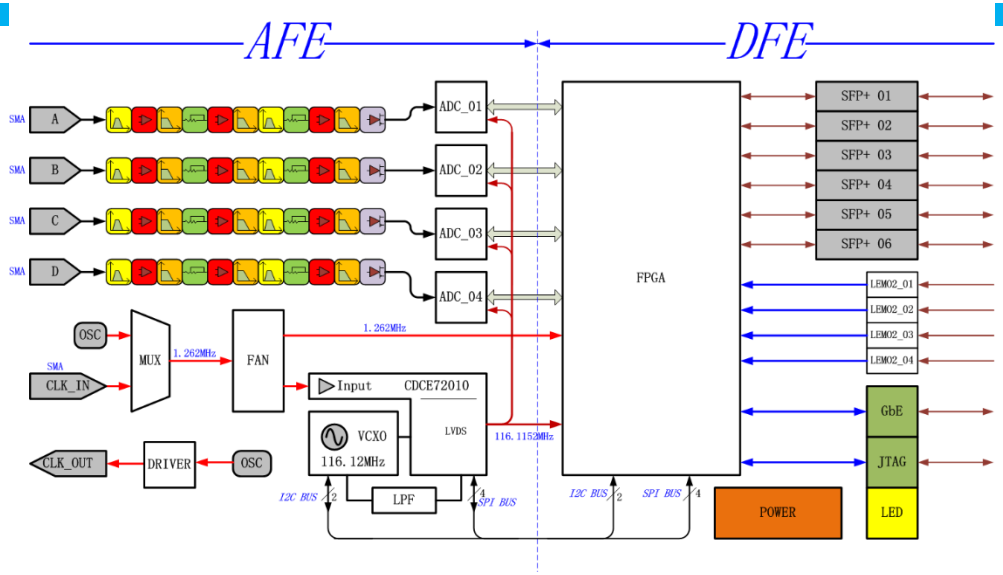
2. BPM electronics design of HEPS project

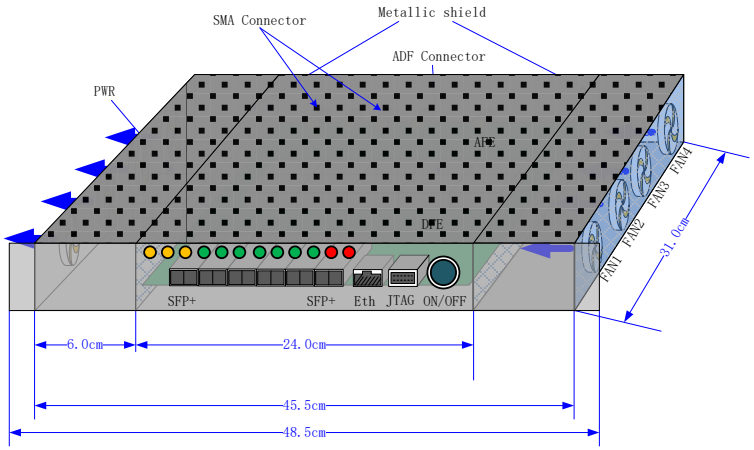
2.1 FOFB Framework and DBPM architecture



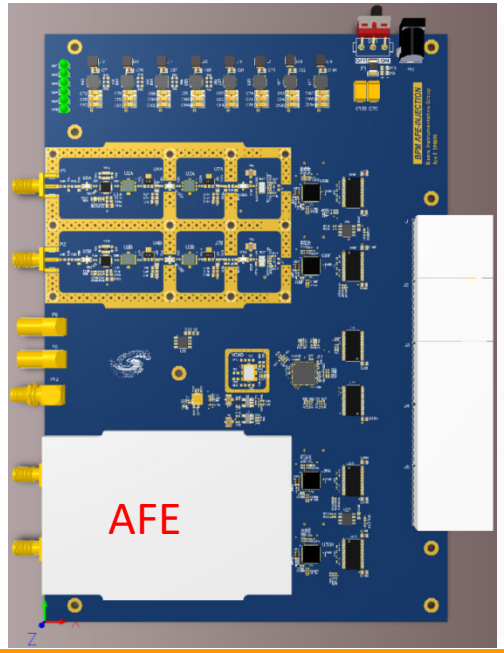
2.2 DBPM Electronics design

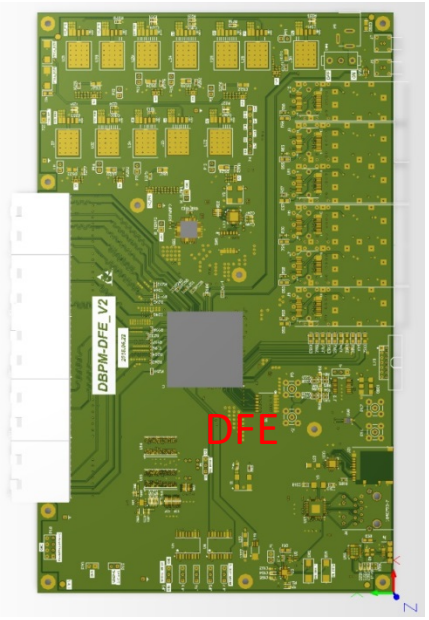




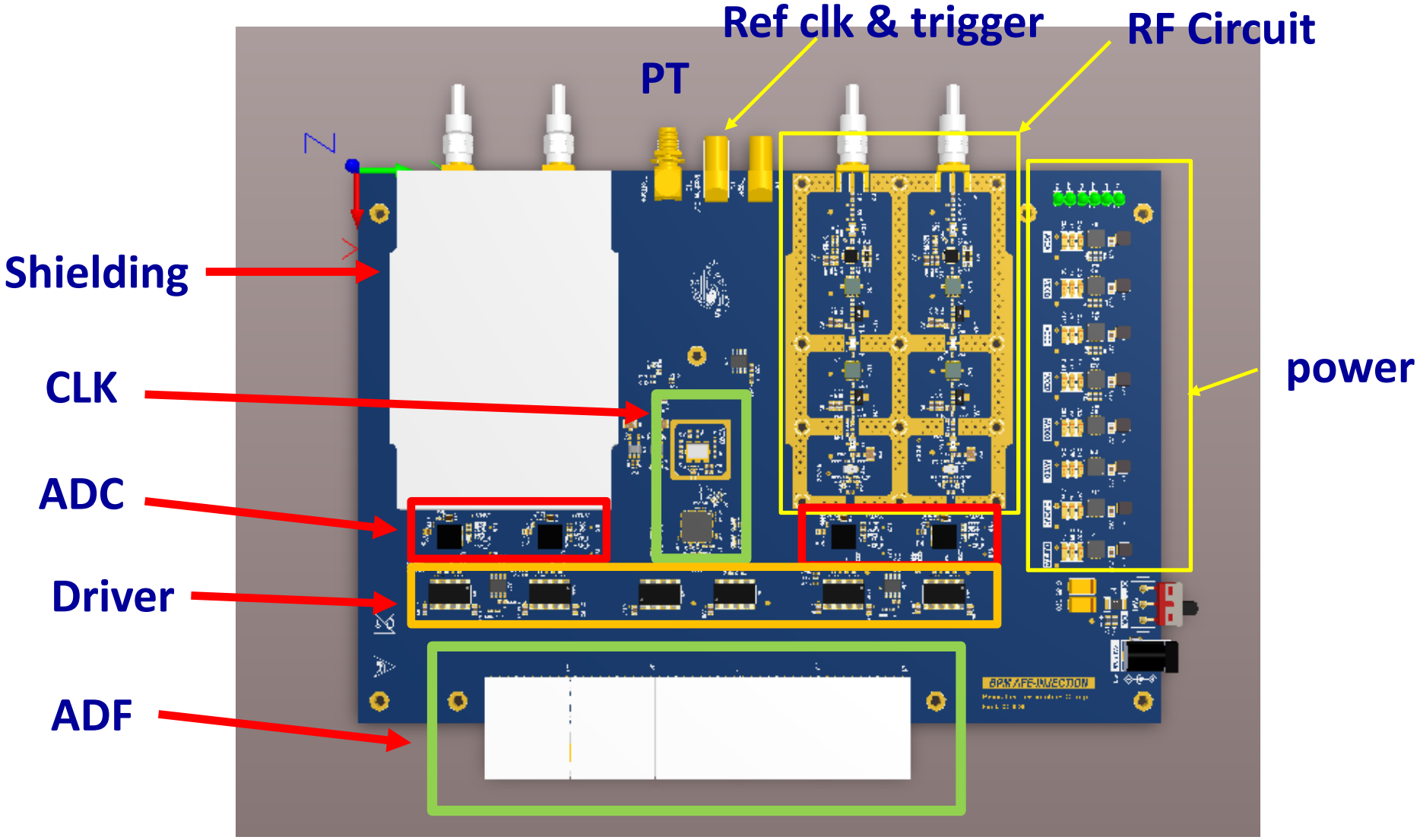


(By HuiZhou Ma)

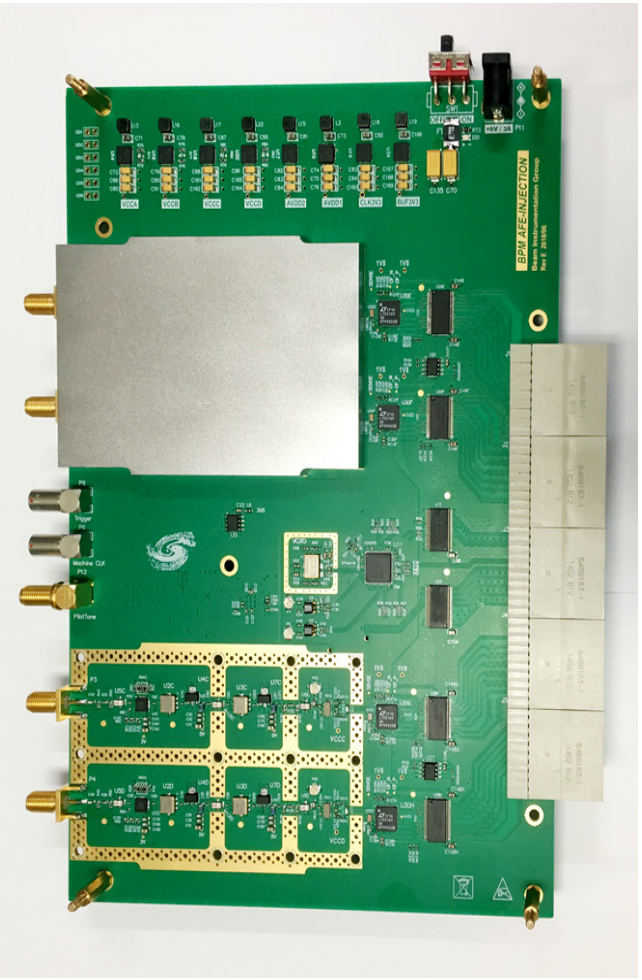


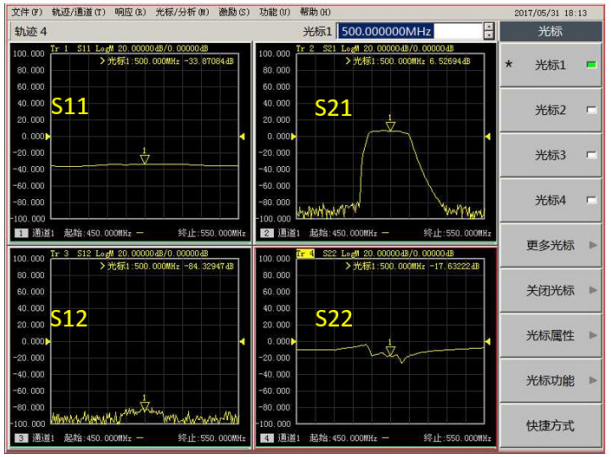


AFE electronic Design

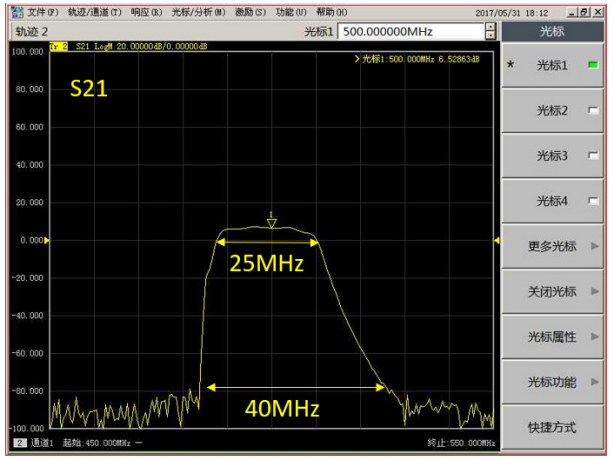


AFE Analog logic Testing



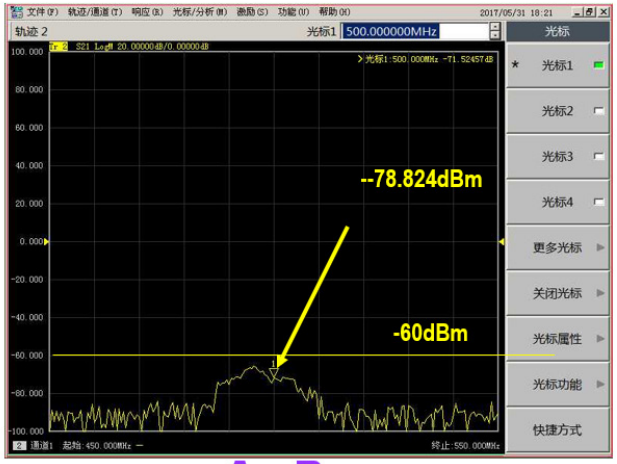


Receiver S-Parameter Characterization



S21-Parameter Characterization

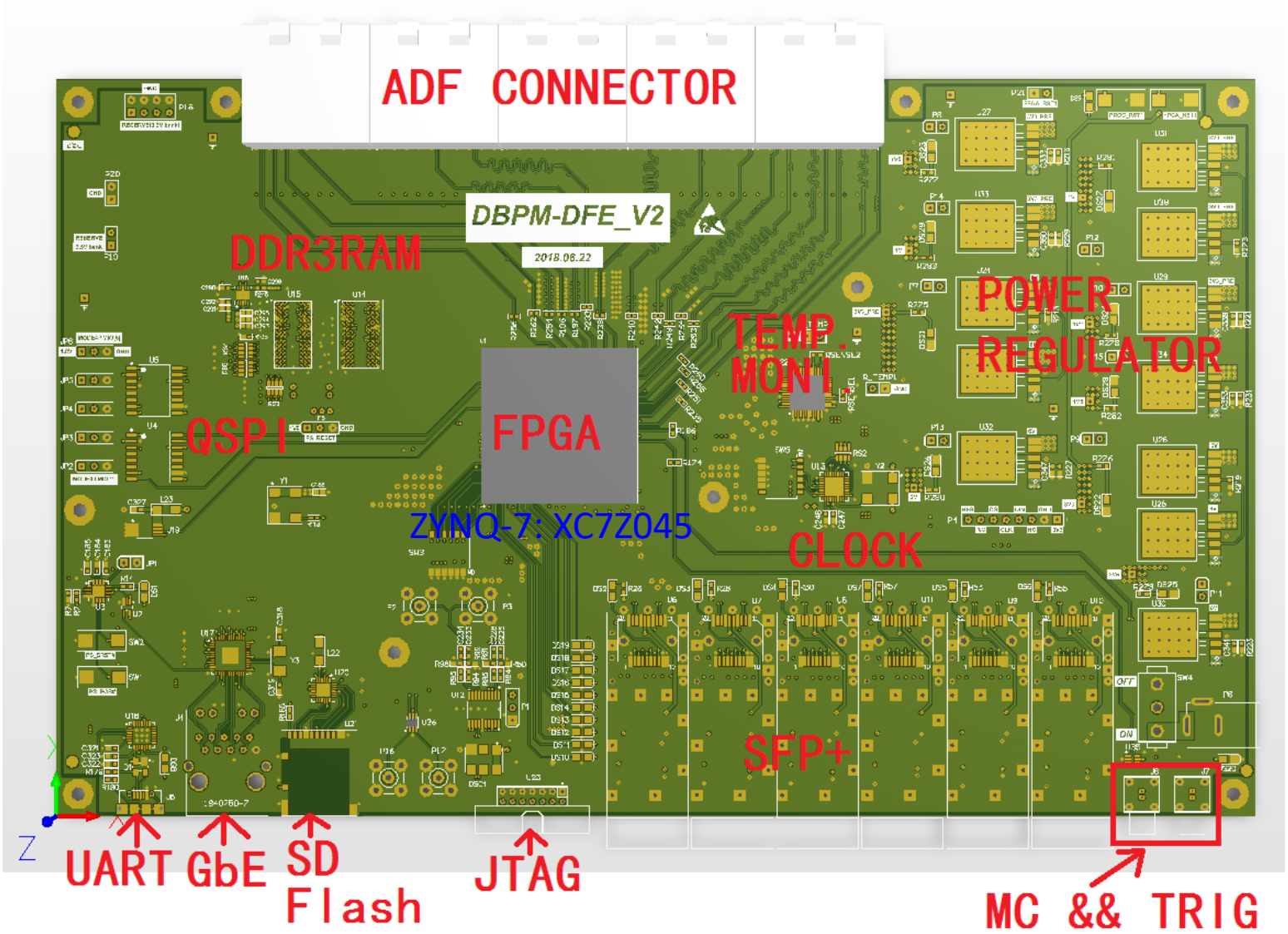
Channel to Channel Isolation > 60dB



A→B

B→A

DFE electronic Design

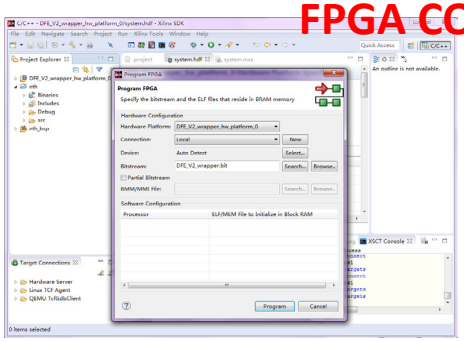


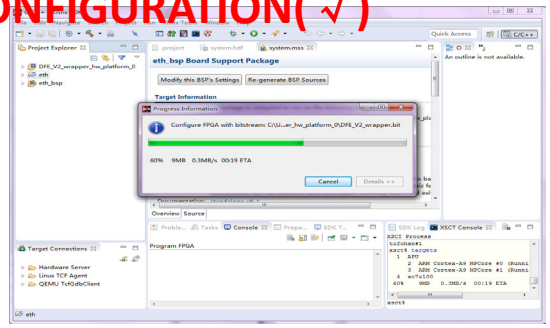
DFE Hardware Testing

DFE POWER(√)

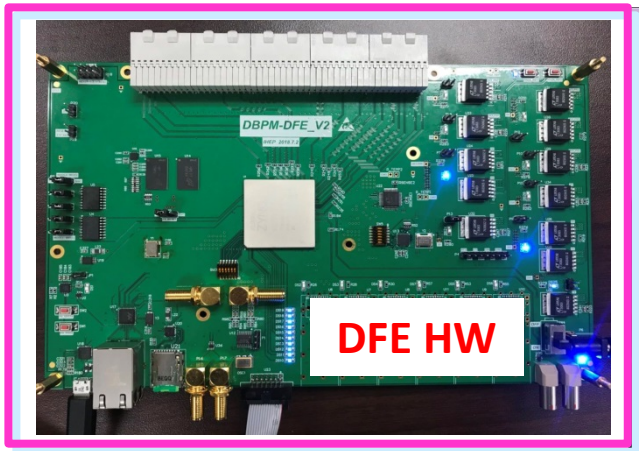
设计电压（V）	实测电压（V）	用电引脚
1	1.006	VCCINT, VCCPINT, VCCBRAM, ETH,
1	1.003	MGTAVCC
1.2	1.213	GTX_MGTAVTT
1.5	1.494	VCCO, DDR3
1.8	1.780	VCCPAUX, VCCPLL, VCCOMIO, VCCAUX, MGTAVCCAUX, UART, SD, I2C
2	1.998	VCCAUX_IO
2.5	2.513	VCCO
3.3	3.315	VCCO, ETH, JTAG, QSPI, POR,
3.3_pre	3.295	1.5V, 1.2V, 1V

FPGA CONFIGURATION(√)



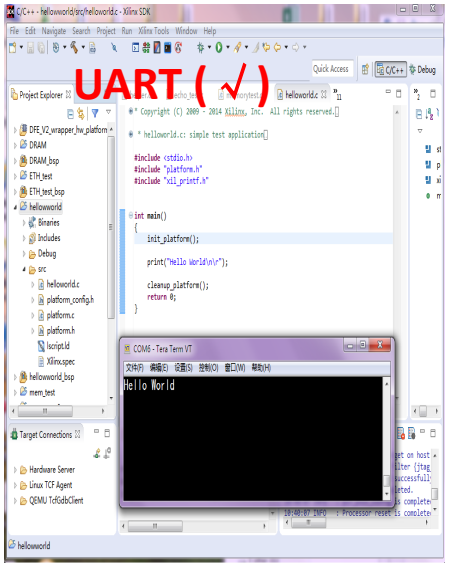


I2C BUS(√)

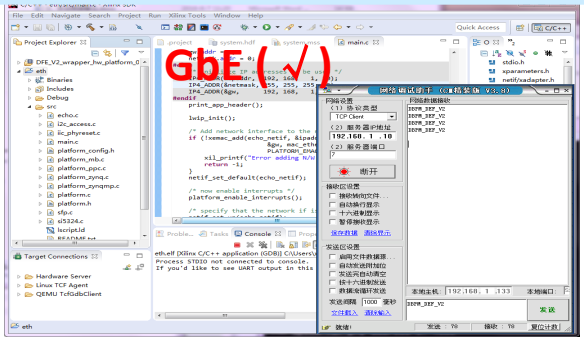


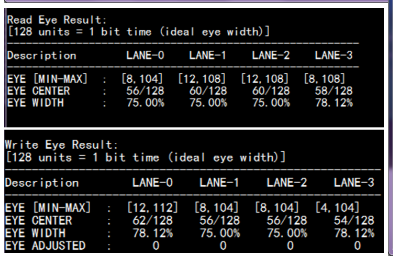
DDR3 (√)

UART (√)

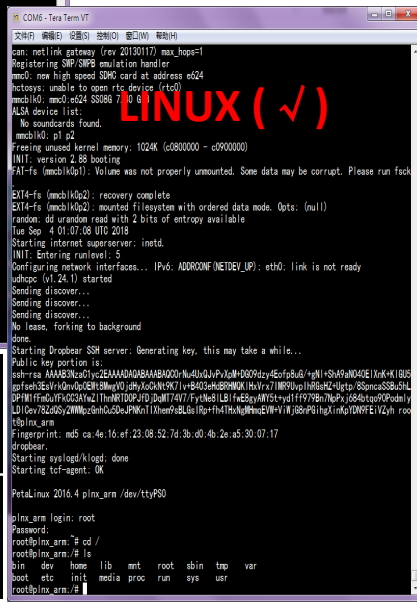


GbE (√)





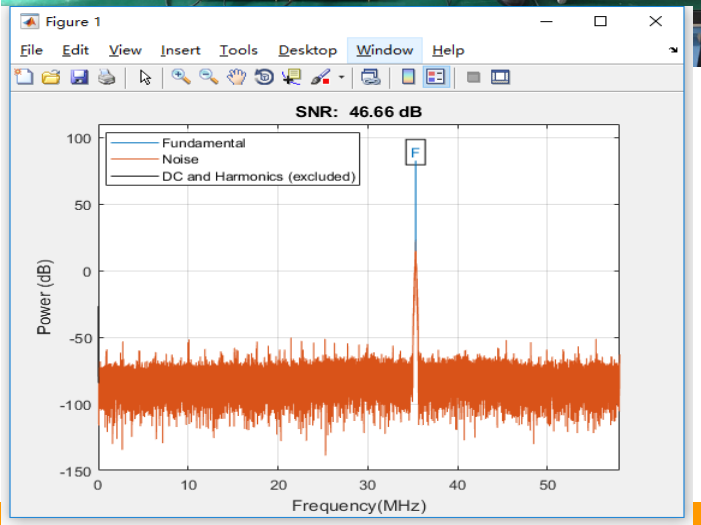
LINUX (√)



2.3 The HEPS BPM electronics Integration Testing

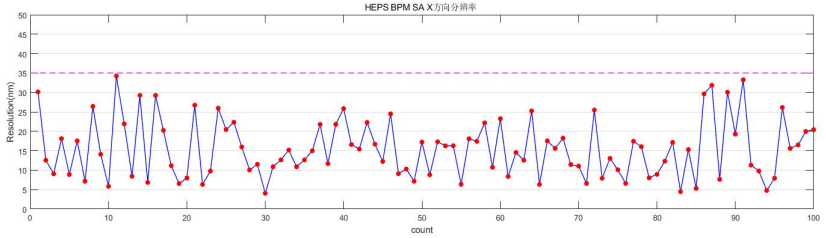
- ADC Clock testing
  - <1ps RMS Jitter
- RAW Data testing in laboratory
  - RAW data SNR: ~46.6dB
  - Process (RAW data to TBT) gain from digital BPF:~20dB

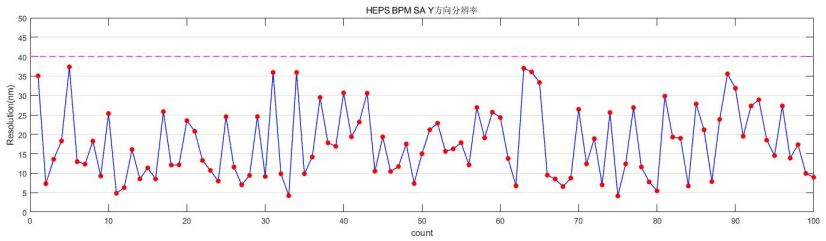
** FFT Process gain is not included !*

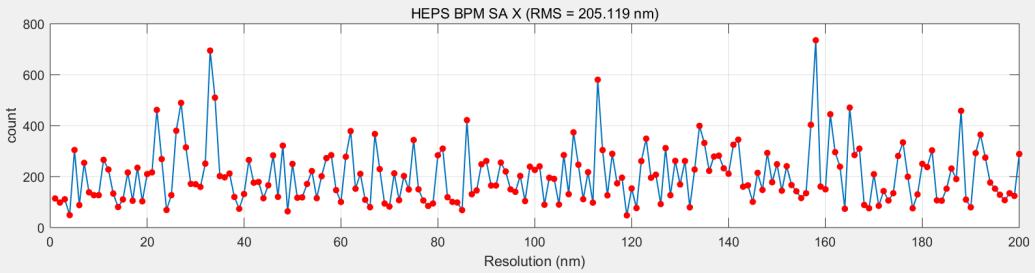


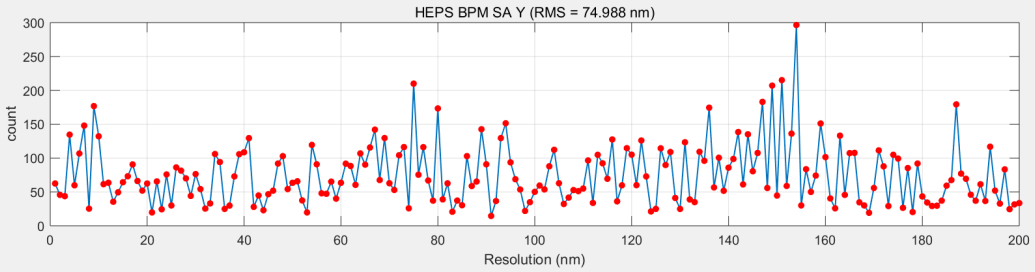
The HEPS BPM electronics Performance Testing

- SA data resolution STD testing (Kx=Ky=8.26mm)
  - Better than 50nm@Laboratory
  - Better than 100nm@ BEPCII Real beam









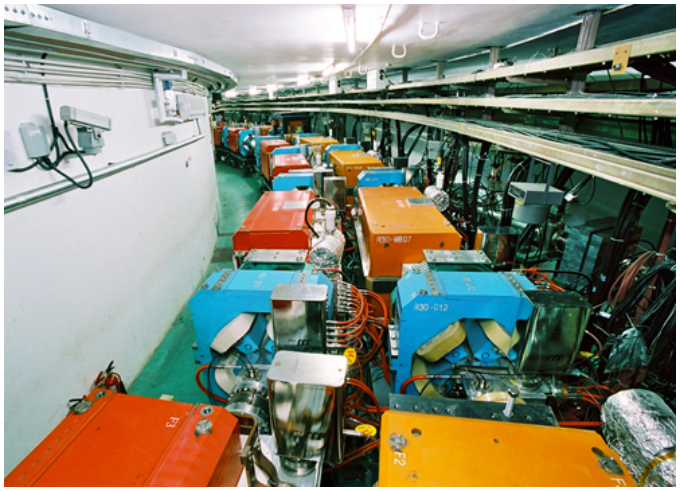
3. BPM electronics upgrading work in BEPCII project

Why we do the BEPCII BPM electronics upgrading work, and why is it important.

- The Bergoz BPM electronics in BEPCII have been worked more than 10 years, some of them broke down now.
- The work can bring benefit to the HEPS' BPM building.
  - The main function and performance of HEPS' BPM electronics can be proofed.
  - Any design flaws in BPM electronics can be found and solved during BEPCII BPM upgrading job.
  - The long-term stability of BPM electronics will be examined.
  - The mass production capacity of BPM electronics will be verified.

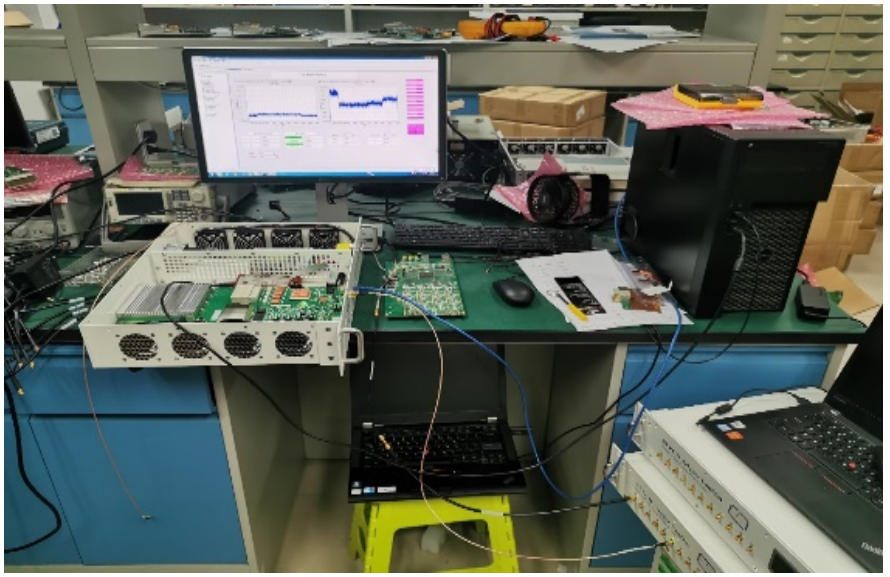
What we have done and what we are about to be done in our upgrading job

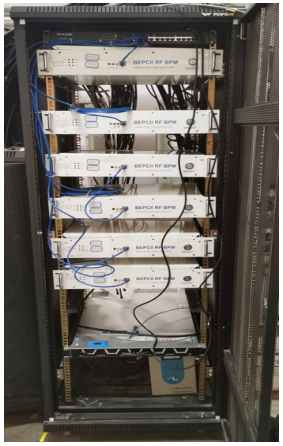
- BEPCII Linac BPM electronics upgrading work have been finished in 2019.
- Storage Ring BPM electronics upgrading work of BEPCII will be completed in 2021



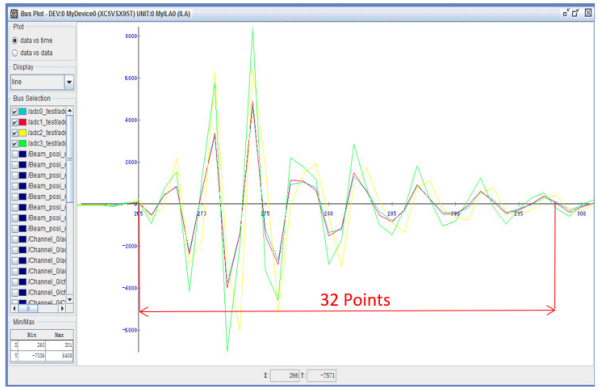
BEPCII Linac BPM electronics upgrading work

- About 20 Linac BPM electronics upgrading were completed in 2019

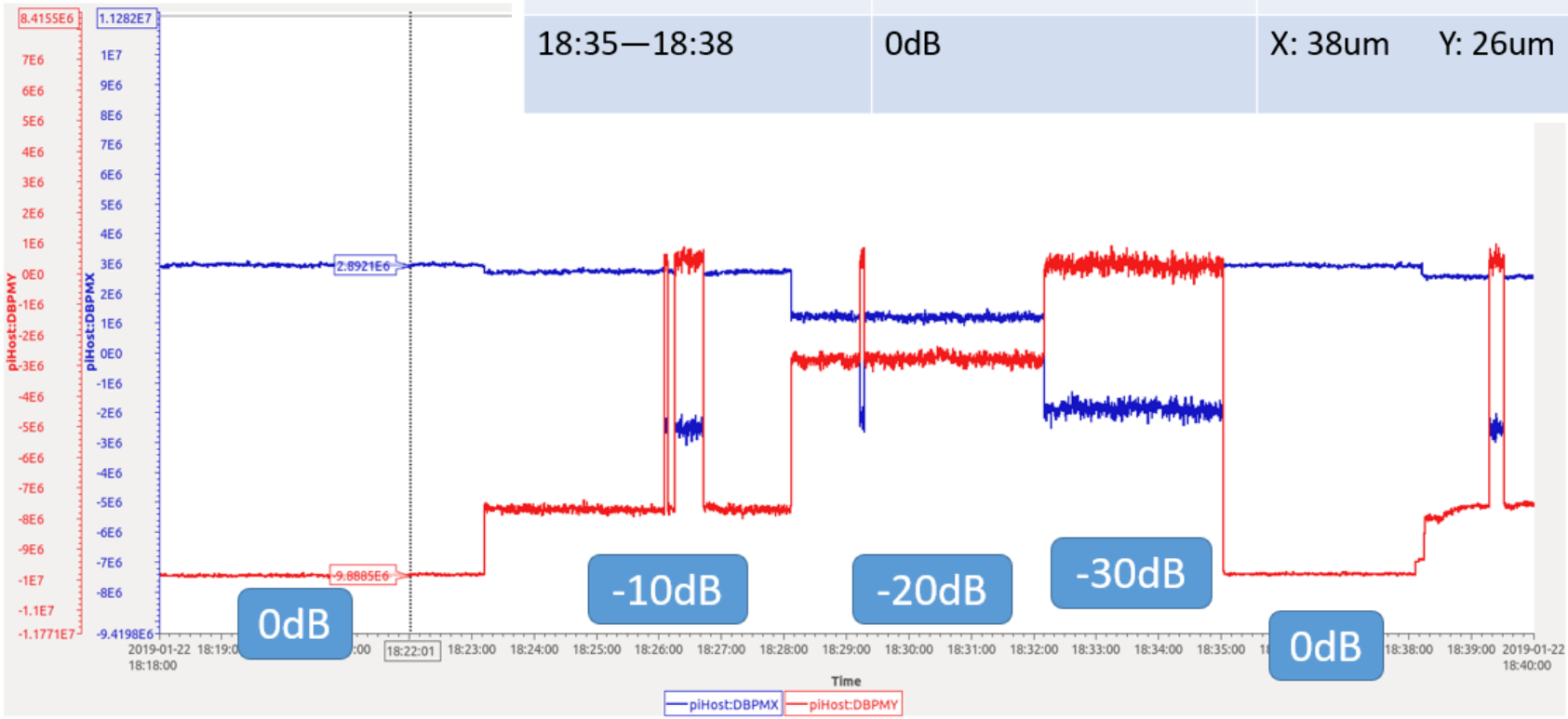




Resolution testing with real beam in BEPCII LINAC

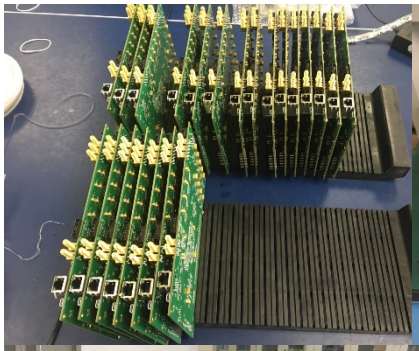


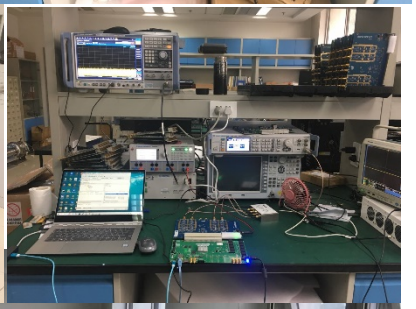
TIME	ATTENUATION SETTING	RESOLUTION
18:18—18:23	0dB	X: 38um Y: 26um
18:23—18:28	-10dB	X: 55um Y: 40um
18:28—18:32	-20dB	X: 85um Y: 70um
18:32—18:35	-30dB	X: 120um Y: 100um
18:35—18:38	0dB	X: 38um Y: 26um



BEPCII SR BPM electronics upgrading work

- All BEPCII Storage Ring BPM electronics will be upgraded within 2 years. Half of the total , about 50 BPM electronics, will complete the installation in 2020. And the rest will be installed in 2021.



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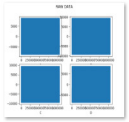
Figure_1.png

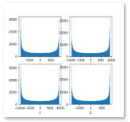
Figure_2.png

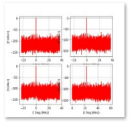
Figure_3.png


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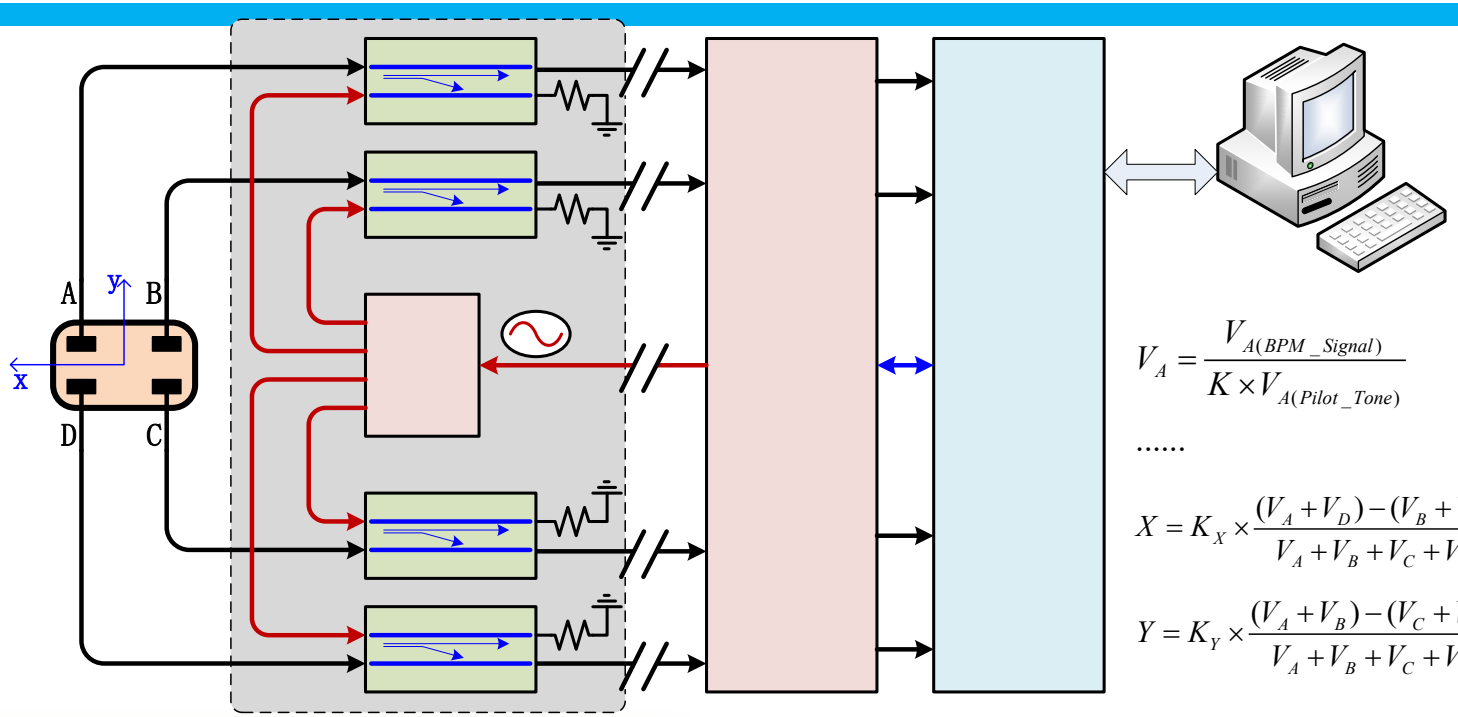
4. The plan of Pilot Tone HW used in HEPS

Pilot-Tone scheme and hardware

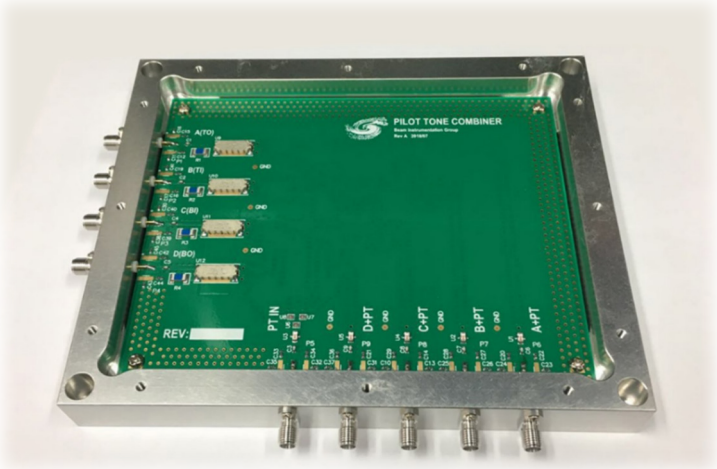


$$V_A = \frac{V_{A(BPM\_Signal)}}{K \times V_{A(Pilot\_Tone)}}$$

.....

$$X = K_X \times \frac{(V_A + V_D) - (V_B + V_C)}{V_A + V_B + V_C + V_D} + X_{offset}$$

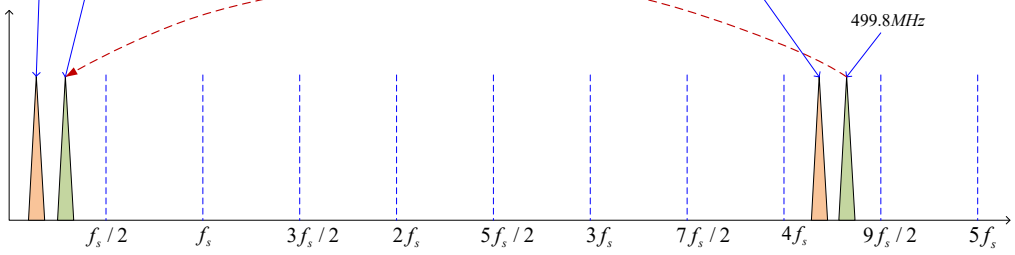
$$Y = K_Y \times \frac{(V_A + V_B) - (V_C + V_D)}{V_A + V_B + V_C + V_D} + Y_{offset}$$



$$f_{Pilot\_Tone\_sample} = \frac{499.8MHz}{396} \times 98 \times 4 - \frac{499.8MHz}{396} \times 92 \times 4 = 30.2909MHz$$

$$f_{Data\_sample} = 499.8MHz - \frac{499.8MHz}{396} \times 92 \times 4 = 35.339495MHz$$

$$f_{Pilot\_tone} = \frac{499.8MHz}{396} \times 98 \times 4 = 494.7515MHz$$



$$f_{Sample} = \frac{499.8MHz}{396} \times 92 = 116.11515152MHz$$

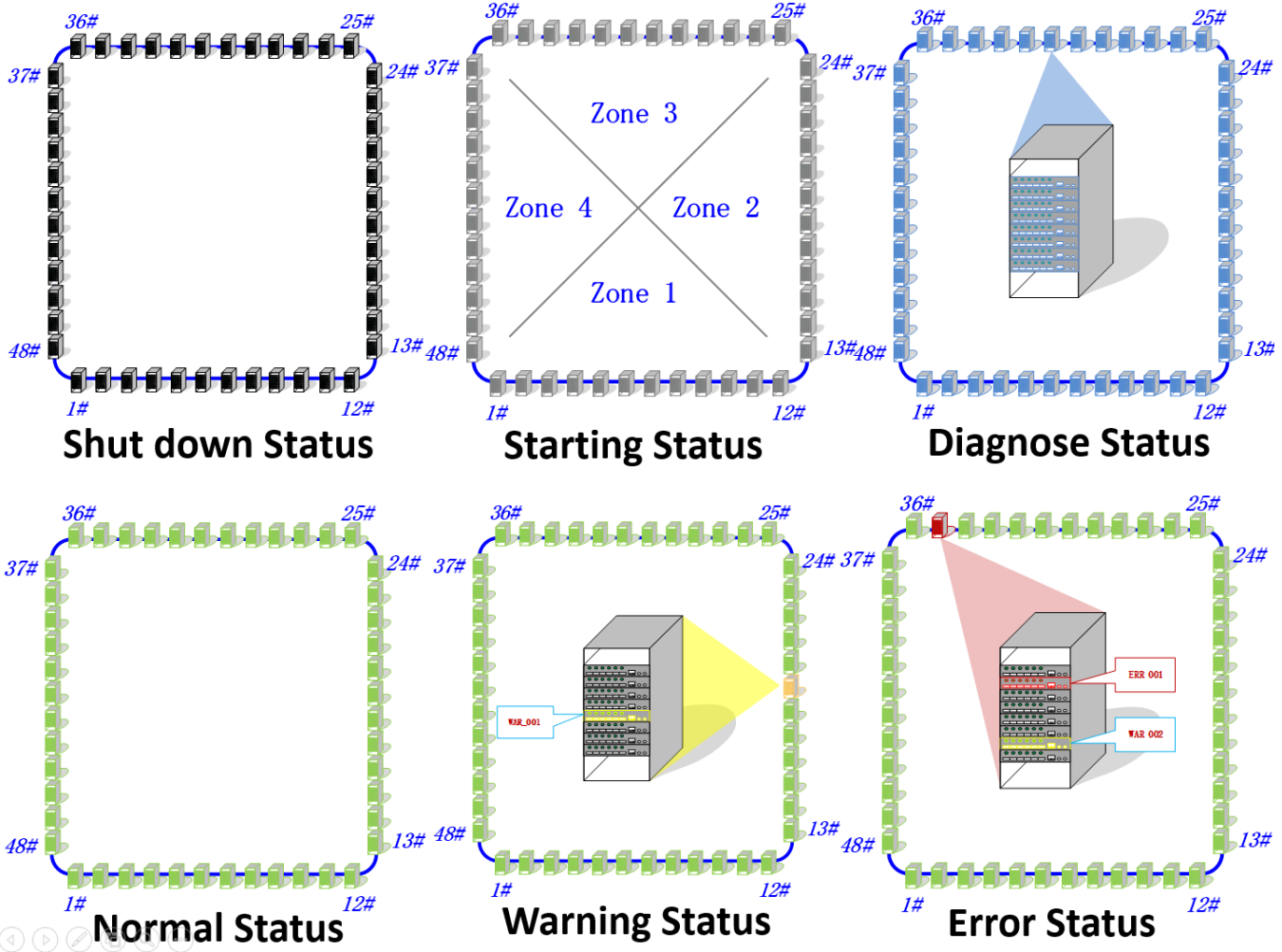
$$f_{NCO} = \frac{499.8MHz}{396} \times 27.5 = 34.7083333MHz$$

The expected functions of Pilot tone logic in HEPS project.

- BPM system self-testing without beam.
- BPM electronics channels on-line calibration.
- BPM electronics on-line diagnosis.
- *The on-line correction measurement is our long-term target.*

Prospective monitor interface in workstation

- Different colors for different operating states



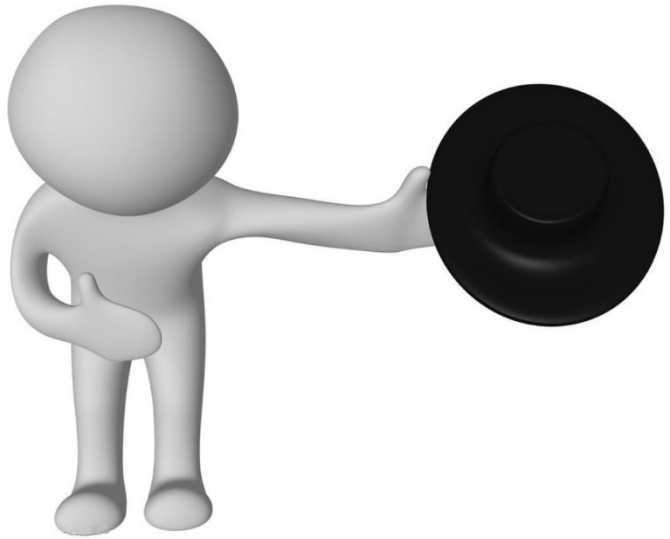
5. Summary and Acknowledgement

Summary

- Digital BPM Electronics hardware and algorithm has been designed carefully and had been tested in laboratory;
- The digital BPM electronics have been tested with the real beam on BEPCII.
- The digital BPM electronics have been used to replace the BEPCII's old Bergoz BPM electronics.
- Pilot Tone hardware will be built in HEPS project and used in special purpose.

Acknowledgement

- During our Digital BPM electronic development, we got many experts help, and I would like to take this opportunity to express my sincere appreciation to those experts.
  - SIRIUS
  - SSRF
  - HLS
  - I-Tech
  - …



Thanks for your attention