First application of MTCA.4 on HEPS

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- Outline

--HEPS project

--LLRF of HEPS Linac

--Timing of HEPS Linac

HEPS High Energy Photon Source

2019/06 Civil starts
2022/02 Linac&Booster start install
2023/01 Linac first beam
2023/08 Booster commissioning completed
2023/10 Storage ring starts commissioning
2024/04 First X-ray
2025/12 Project completed and operation

2021-05-28

2022-05-19

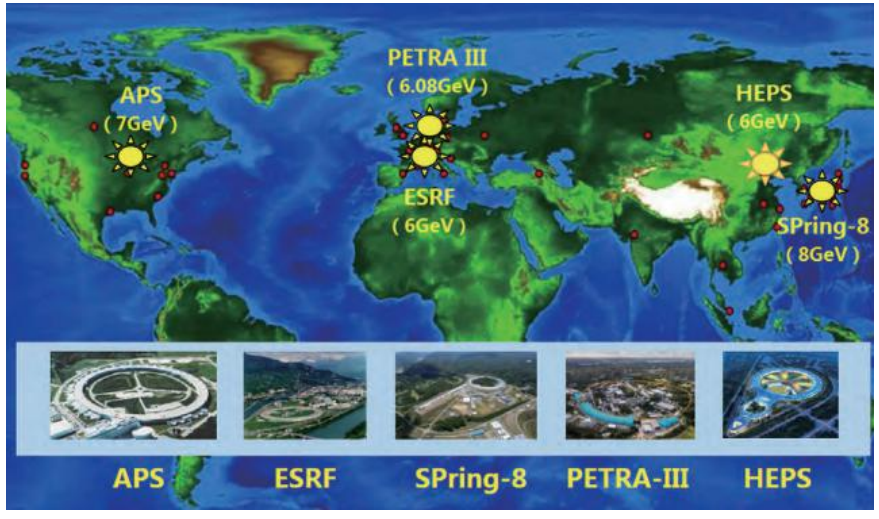
Northeast 70km away from IHEP campus/Beijing

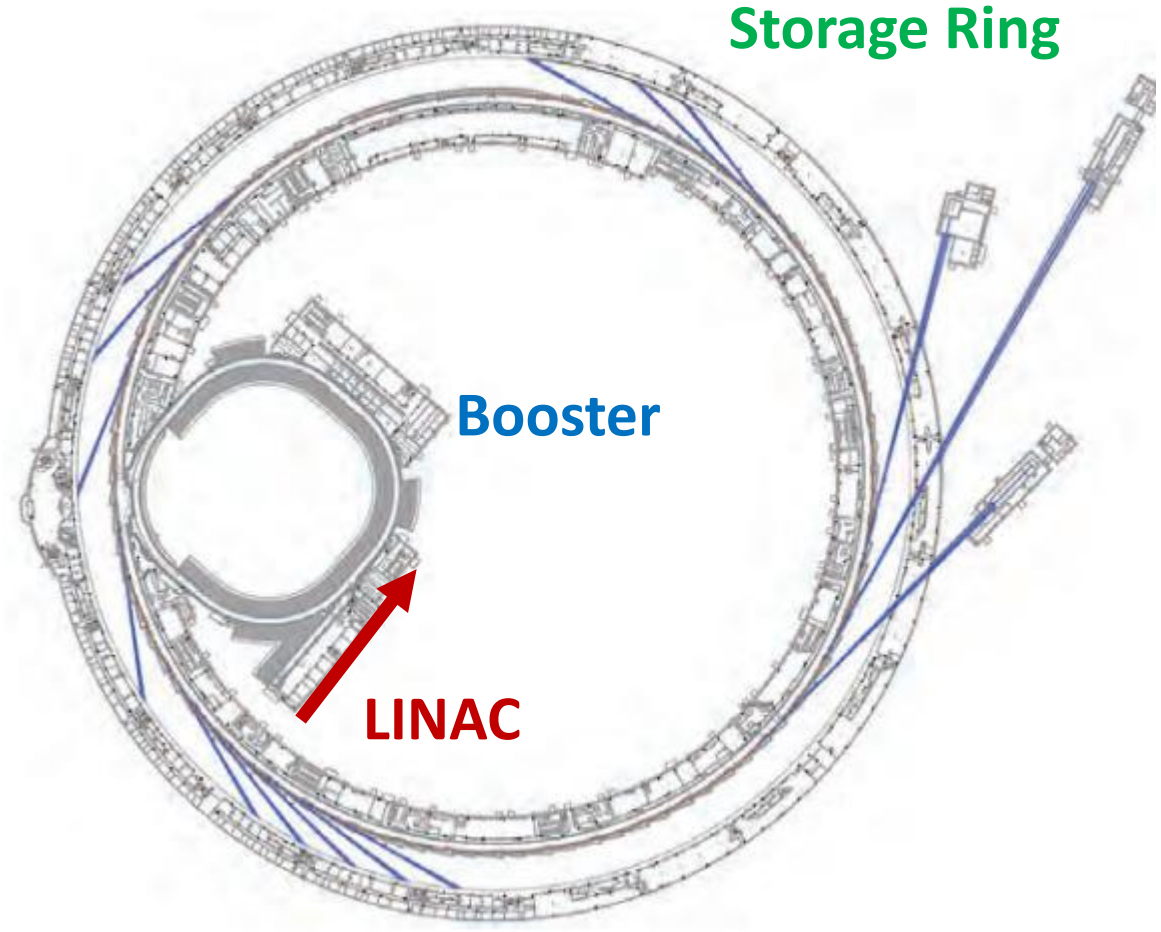
HEPS website - http://english.ihep.cas.cn/heps/

HEPS

new designed and constructed, first high-energy 4th gen SR in China

Main parameters of HEPS	
Beam energy [GeV]	6
Circumference [m]	~1360
Emittance [nm.rad]	0.06
Beam current [mA]	200
Cell units	48
Injection	Top-up
Brightness [phs/s/mm²/mrad²/ 0.1%BW]	>10^{22}



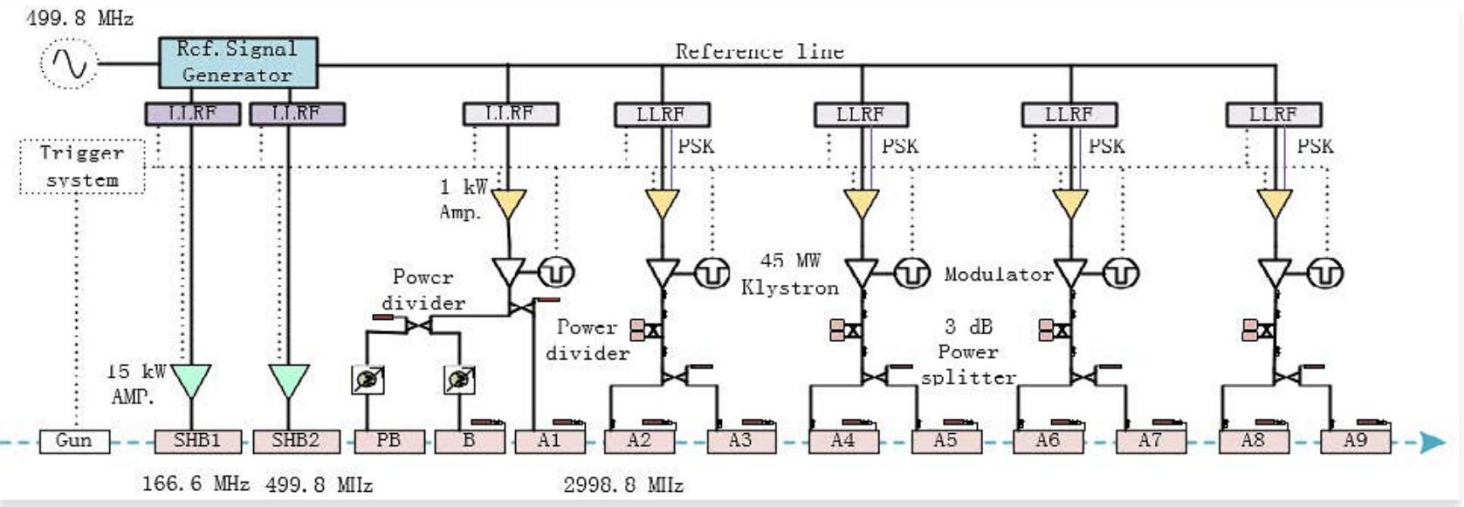


existed 'high energy' ≥6GeV, APS-U/ESRF-EBS/Spring-8 II/PETRA-IV ...

LLRF of HEPS Linac

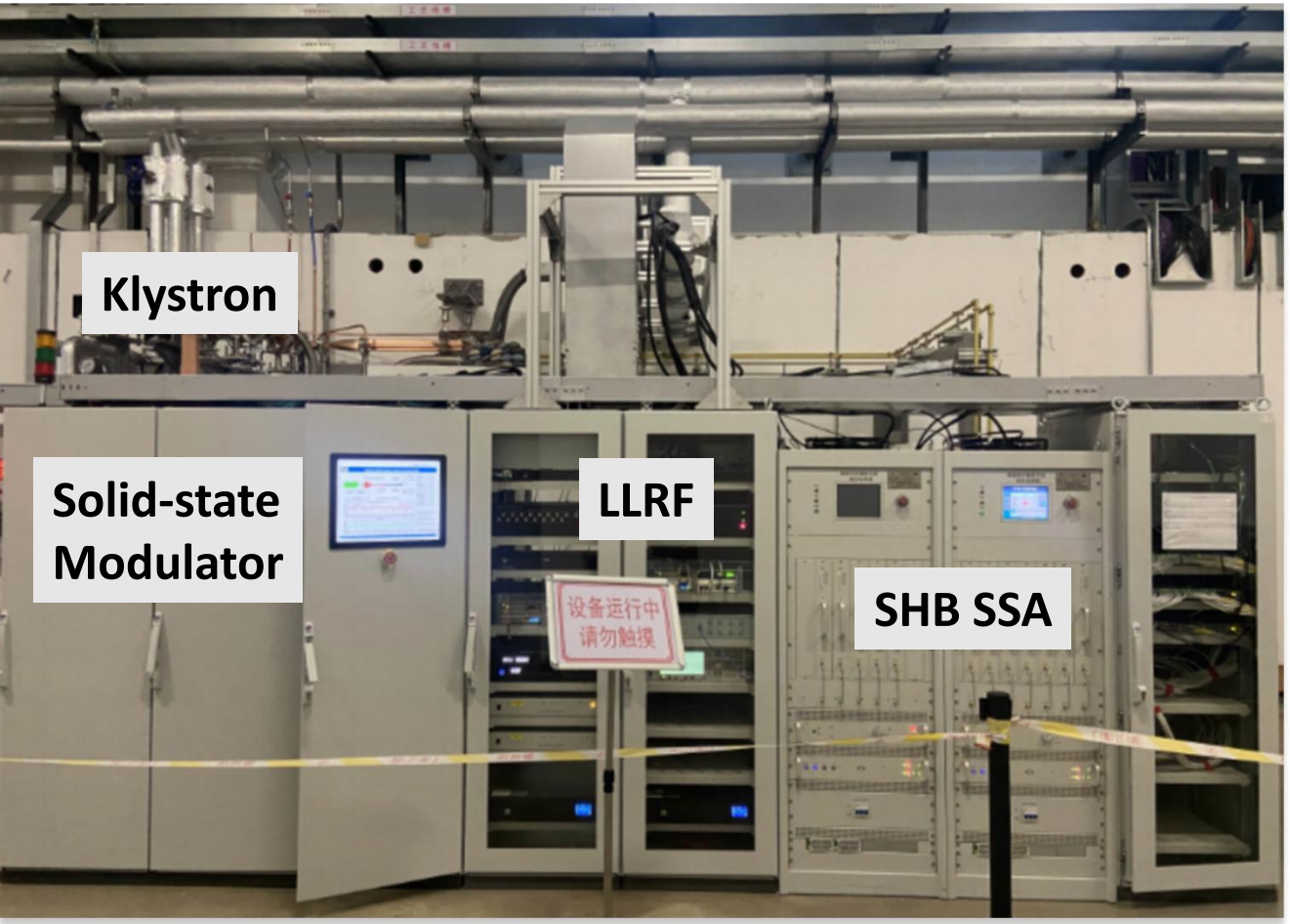
HEPS Linac

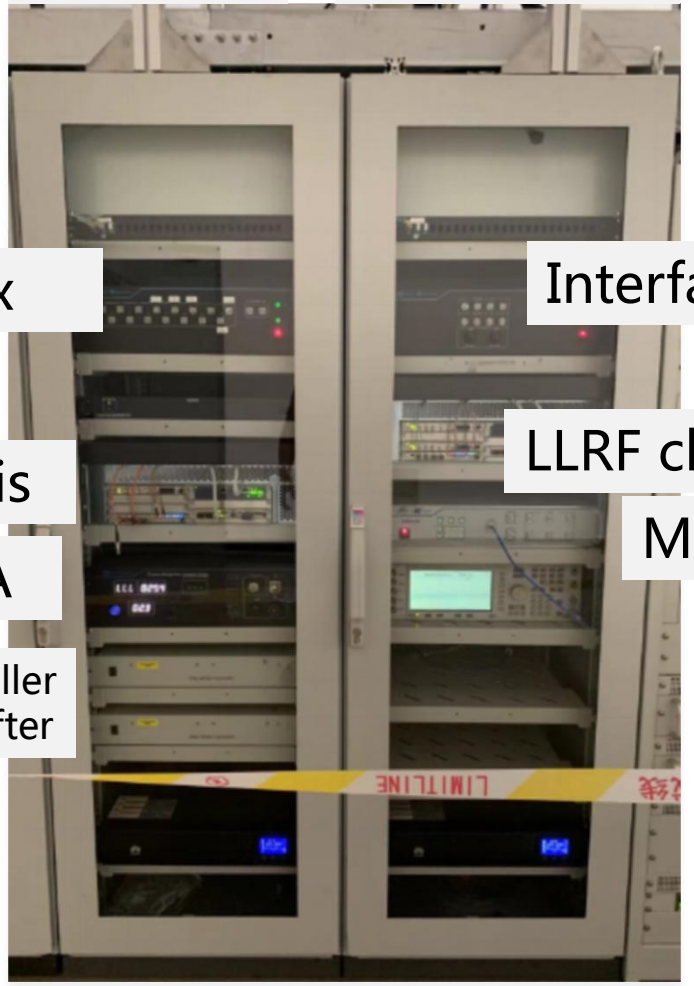
- 500MeV pulsed E- accelerator;
- 1x166.6MHz, 1x499.8MHz SHB bunchers, 5x2998.8MHz 45MW klystrons for 9 accel. tubes;
- Rep Rate: 1-50Hz;



LLRF of HEPS Linac

- 6 LLRF cabinets

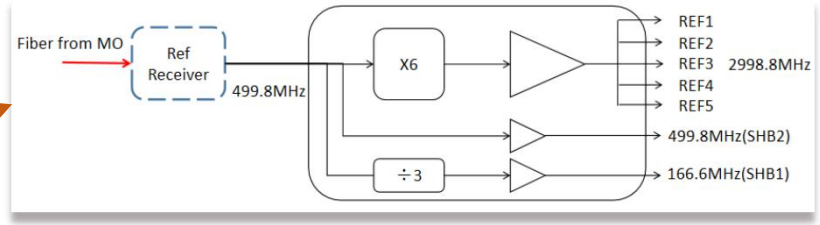




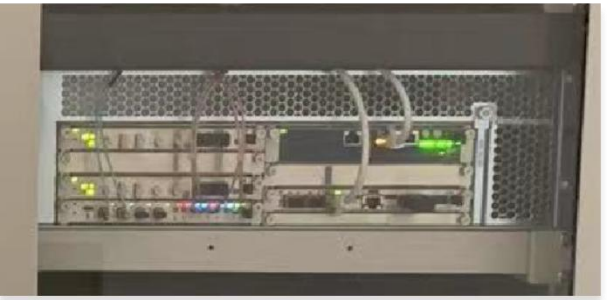
LLRF of HEPS Linac

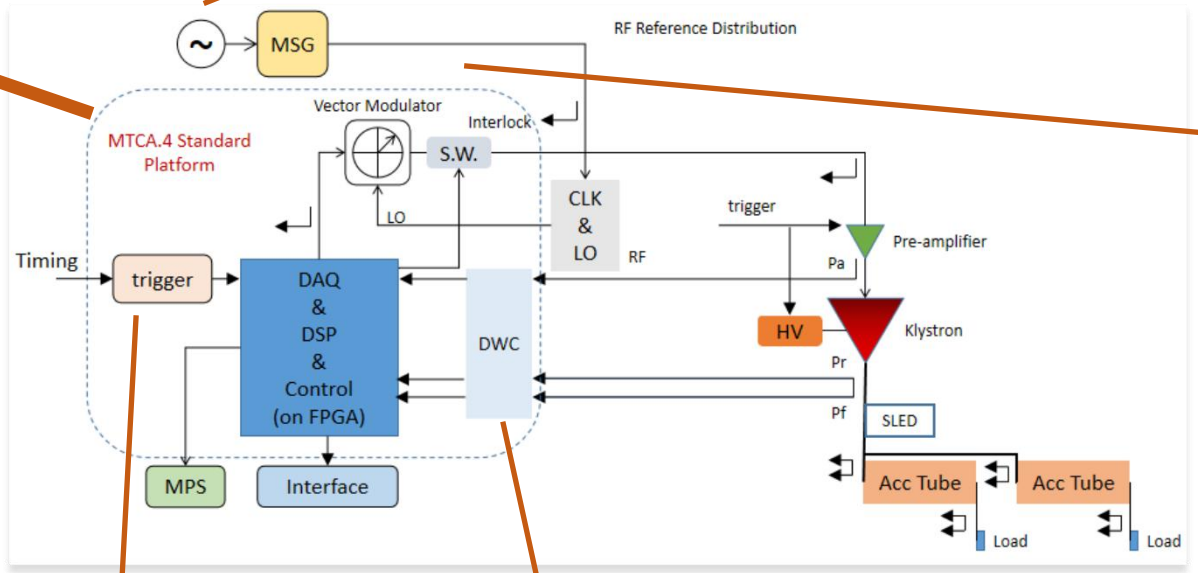
HPRF & LLRF for S-band NC

Multi-Signals Generator

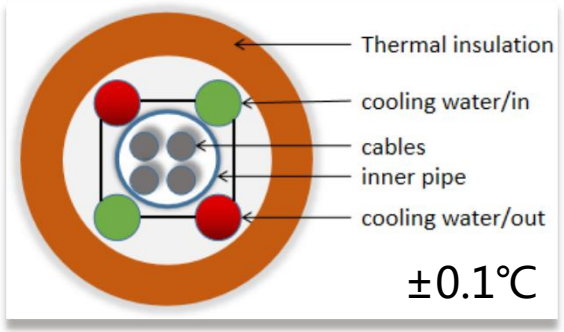


LLRF chassis

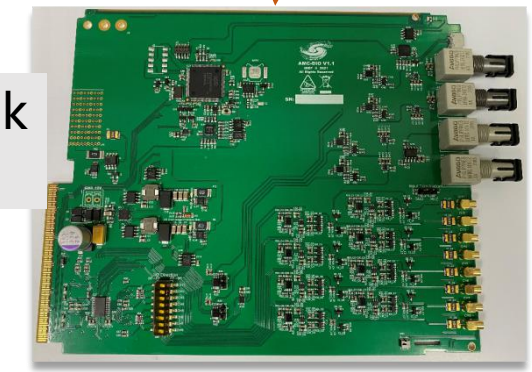




phase reference duct



Timing and interlock AMC

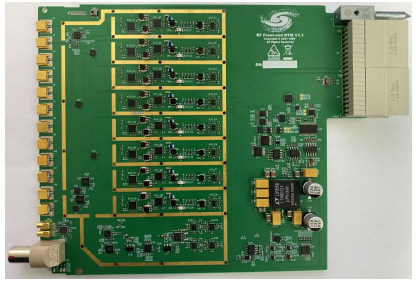


DWC RTM

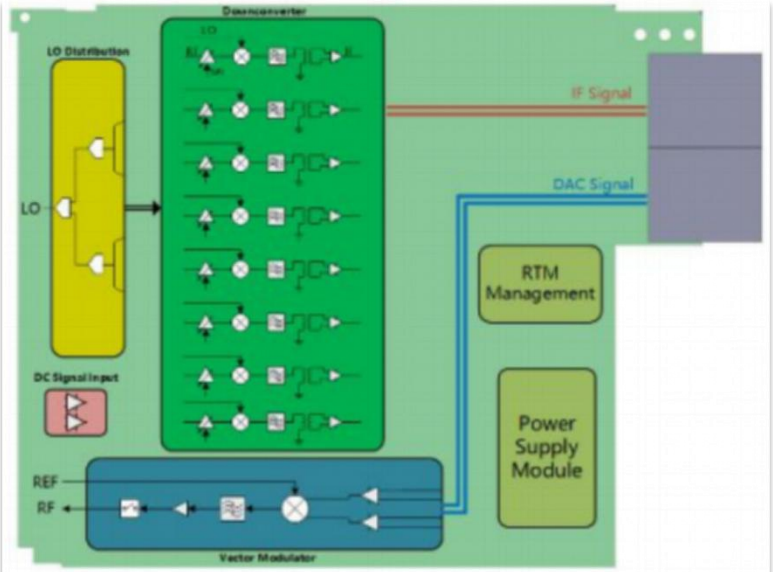
LLRF of HEPS Linac

- MicroTCA.4 RTM;
- with downconverters and vector modulator;
- work with Struck SIS8300L2;
- 8 channels ADC, 2 channels DAC;
- first 20 boards have been in production;

Bandwidth	300–6000 MHz
DWC Linearity (RF@3GHz IF@25MHz)	>55 dB
IF SFDR (RF@3GHz IF@25MHz)	75 dBc



In-house Downconverter RTM

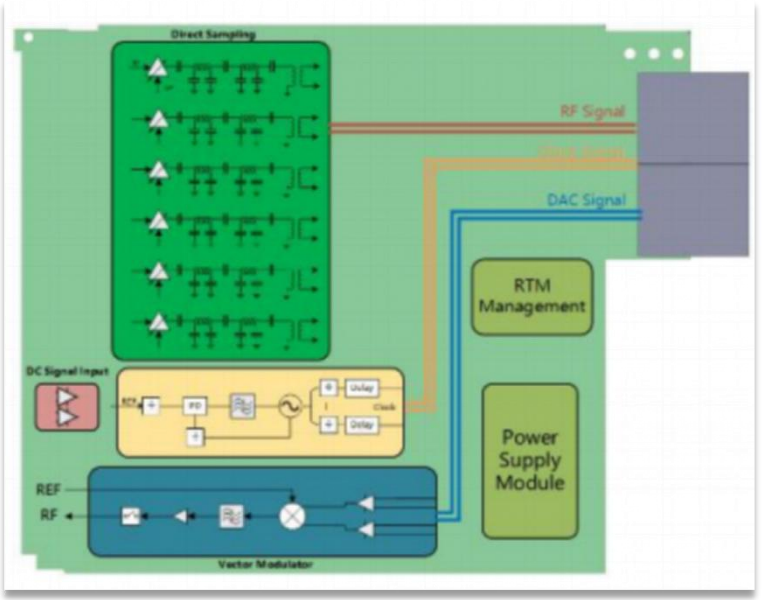


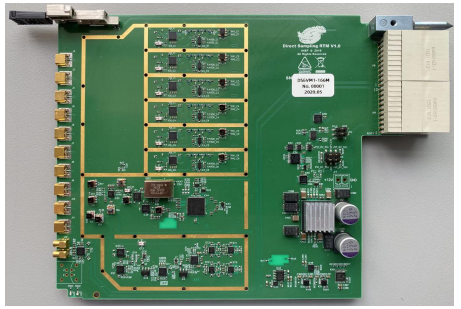
LLRF of HEPS Linac

- MicroTCA.4 RTM;
- bandwidth 0-650MHz;
- tested with Struck SIS8300L2;
- 6 channels ADC, 2 channels DAC;
- first 10 boards have been in production;

Clock Jitter (10 Hz-10 MHz)	**88 fs** @104 MHz
SNR (@500MHz)	**69.51 dBc**

In-house Direct-sampling RTM

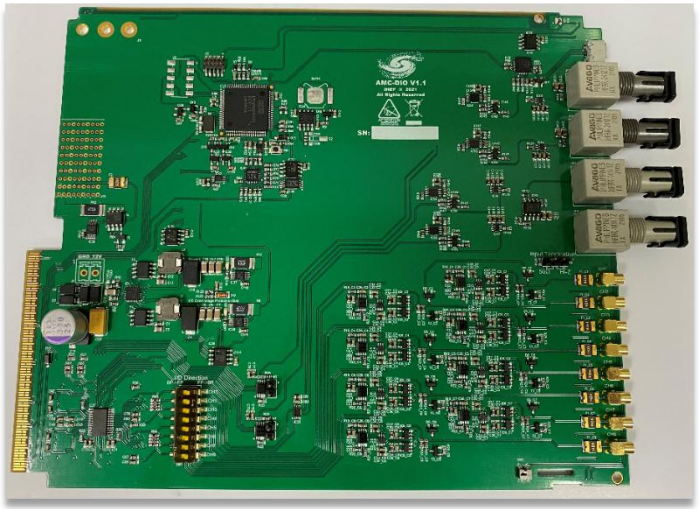




LLRF of HEPS Linac

MTCA.4 digital board

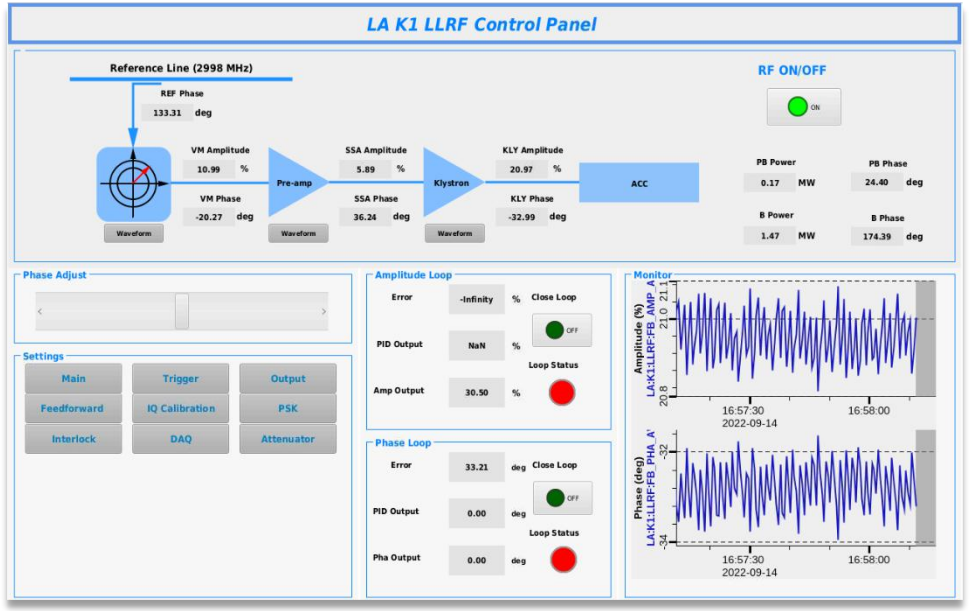
- 2 version digital fanout AMC with openmmc
- support 4 optical in/out;
- 8 channels TTL/LVTTL/CMOS/LVCMOS in/out;
- Impedance&direction controlled by IPMI command;
- Fanout through backplane to each slots;
- part/standalone of MPS and timing system;
- Todo:replace MMC NXP MCU with GigaDevice - in China

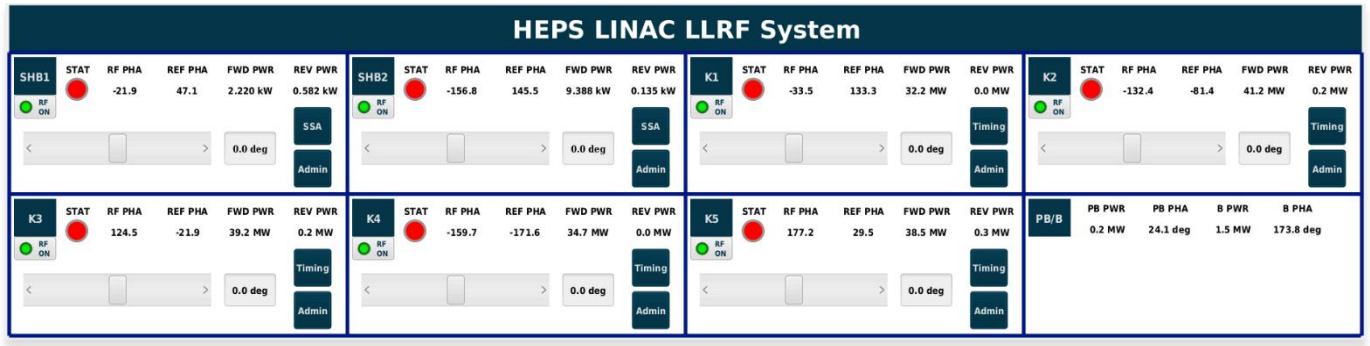


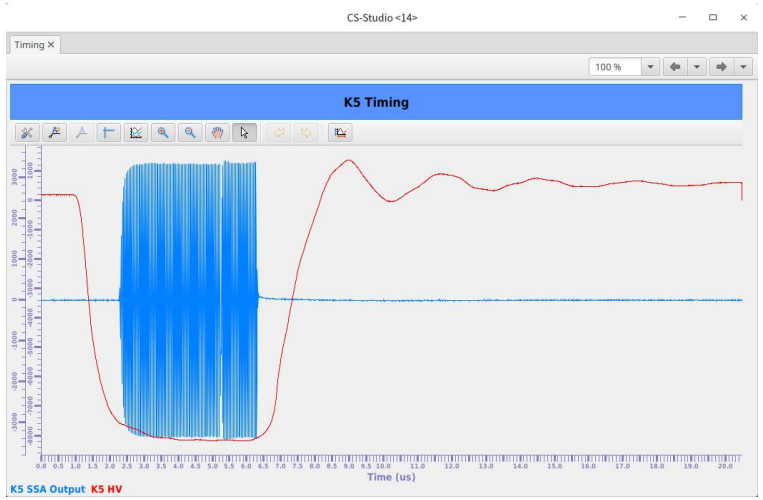
LLRF of HEPS Linac

Phase stability

	Freq (MHz)	Phase (RMS)	Require (RMS)
SHB1	166.6	0.02°	0.5°
SHB2	499.8	0.05°	0.5°
K1-K5	2998.8	0.05°	0.3°

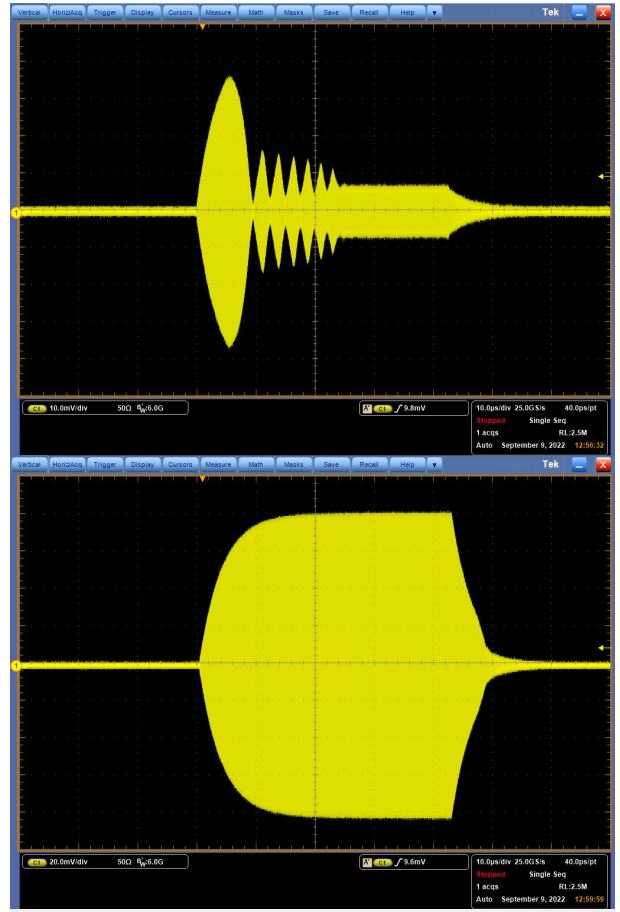


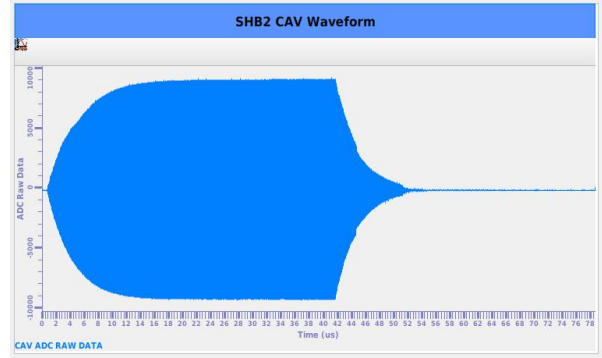




LLRF of HEPS Linac

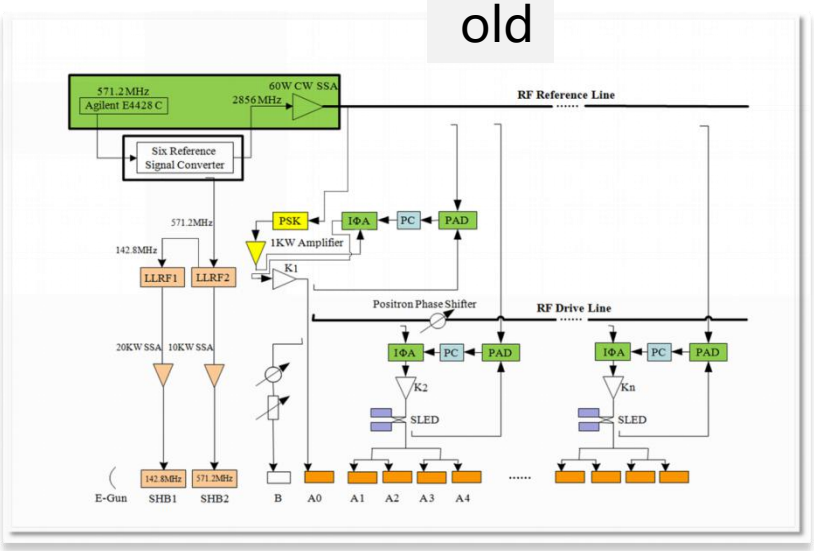
22/03-07, installation
22/07-10,conditioning completed…
22/12- beam commissioning?



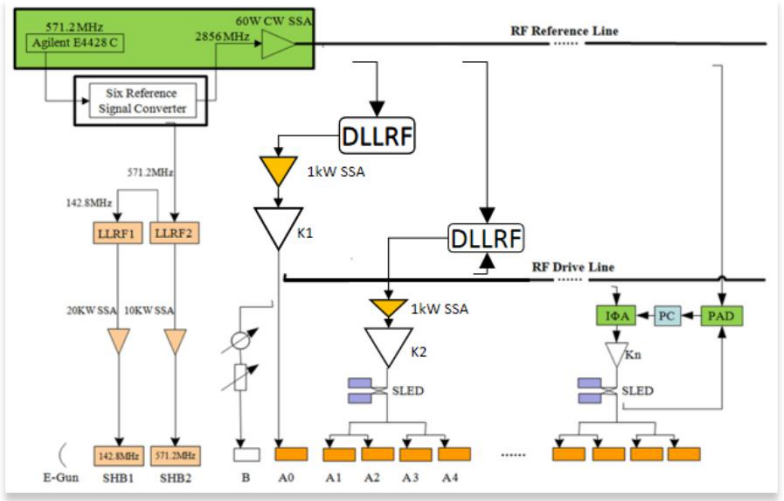


The same LLRF on BEPCII Linac

old



now

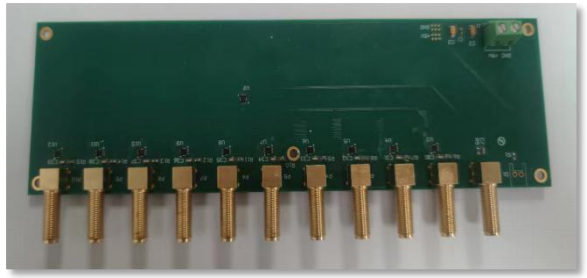


- BEPCII Linac LLRF share similar system from HEPS LLRF, except freq: 2856MHz and 142.8MHz SHB1, 571.2MHz SHB2
- 9 LLRF upgraded in the last two years

Timing of HEPS Linac

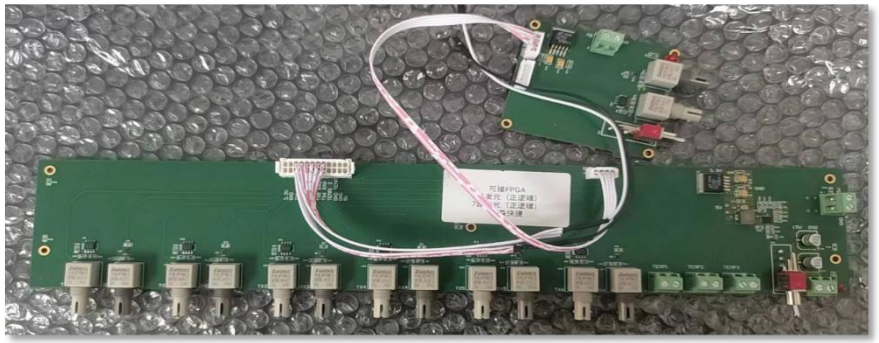
Timing of HEPS Linac

Phase I: 3 chassis installed for timing of the Linac;
MRF MTCA.4 mostly adopted: EVG/EVR;
Also many self-made boards for distribute triggers;
Benefit from different vendors;



Signals: TTL fandout
rise time：500ps
delay between channels：10-600ps
jitter between channels：7ps

Signals: Optical fanout
rise time：1ns
delay between channels：10ps-1ns
jitter between channels：600ps



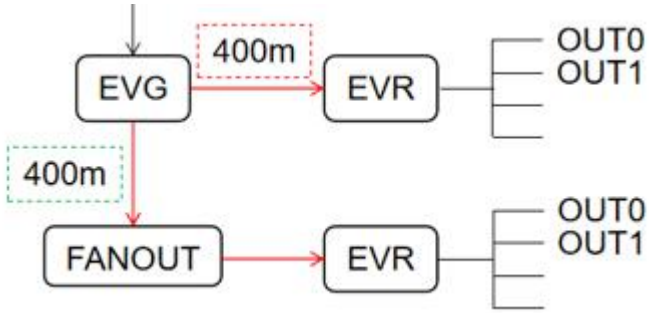
Signals: adjustable delay fanout
rise time：1ns
RMS jitter < 5ns
pulse width and delay configurable

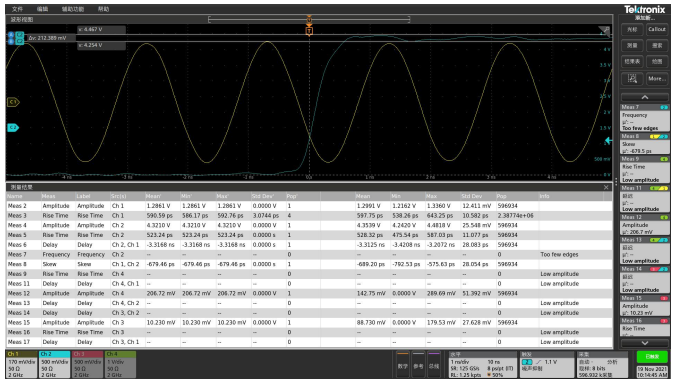
Timing of HEPS Linac

MTCA.4 MRF debugged & final tested on-site;

Jitter (rms) < 24ps;

Timing system serves stable for conditioning of Linac;

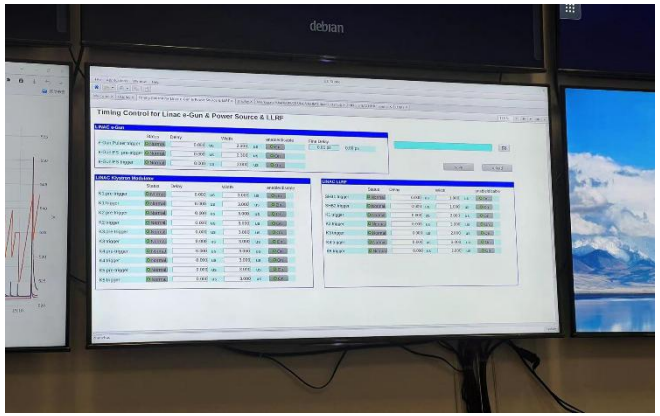


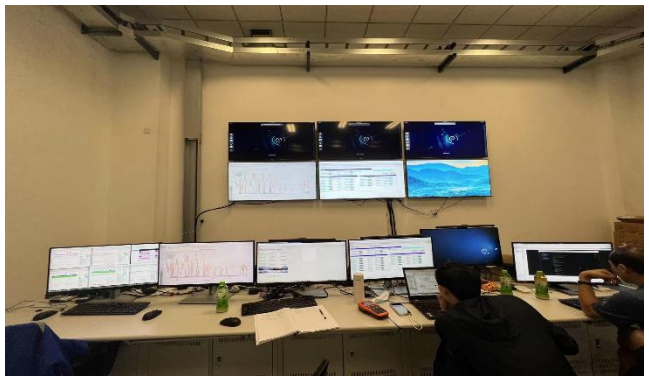


Timing of HEPS Linac

- Serveral more for test bench and other timing system;

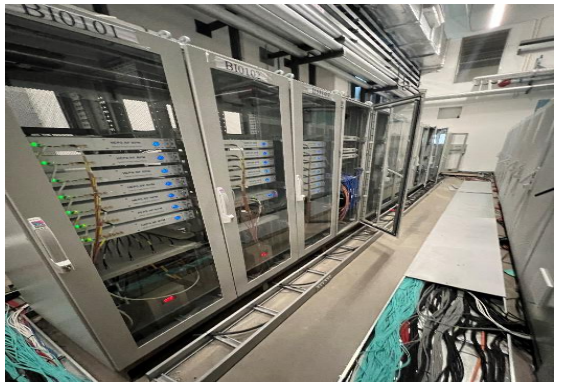
Timing of HEPS Linac





Temporary Linac Control Room and timing use interface

Temporary Main Timing Station for Linac LLRF and High Power Source



Linac BI Timing Station

Summary

- First application on HEPS Linac of MicroTCA.4 platform
  - successful.
- Still many dev/app in China, like new boards, new contributions.
- MicroTCA.4 next year:

- upgrade LLRF hardware with in-house made board;
- More work needed to be done on timing system of HEPS;
- support local vendor grow due to long dilivery time;

Thank you!