# First application of MTCA.4 on HEPS







#### MA Xinpeng Institute of High Energy Physics, CAS 2022-12-07

The 11th MicroTCA Workshop for Industry and Research, @DESY





#### --HEPS project

#### --LLRF of HEPS Linac

## --Timing of HEPS Linac

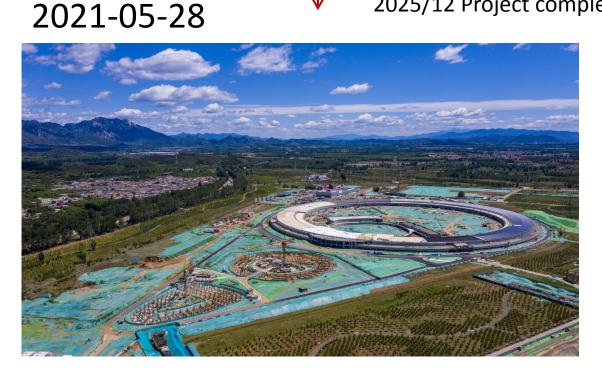
## **HEPS** High Energy Photon Source

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



#### 2022-05-19



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

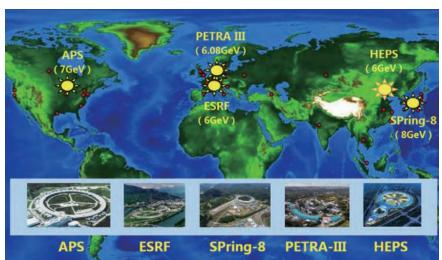
#### \_ \_ \_ \_ \_ \_ \_ \_ \_

HEPS

Northeast 70km away from IHEP campus/Beijing

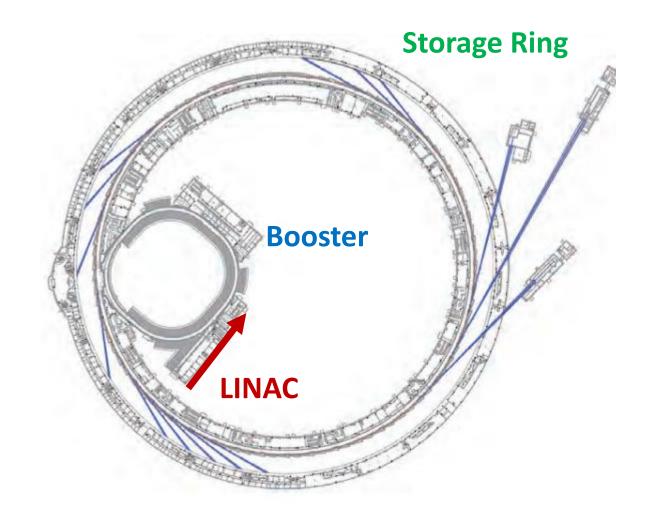


Main parameters	of HEPS
Beam energy [GeV]	6
Circumference [m]	~1360
Emittance [nm.rad]	0.06
Beam current [mA]	200
Cell units	48
Injection	Top-up
Brightness [phs/s/mm²/mrad²/ 0.1%BW]	>1022



## HEPS

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



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



#### **HEPS Linac**

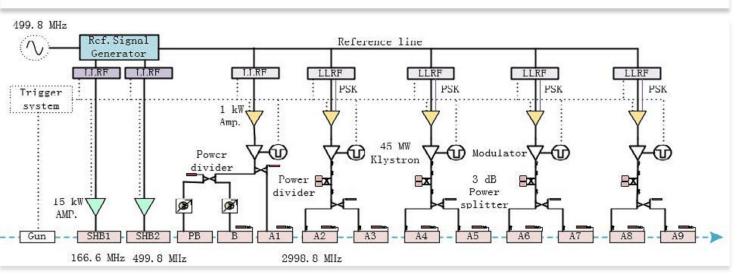
**500MeV** pulsed E- accelerator;

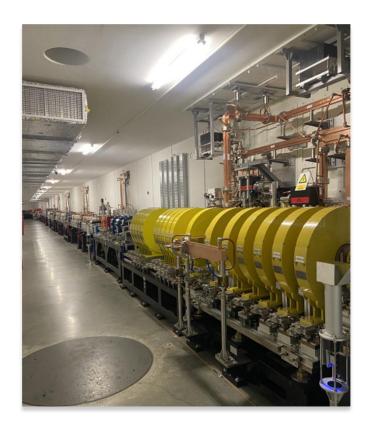
□1x166.6MHz, 1x499.8MHz SHB bunchers,

5x2998.8MHz 45MW klystrons for 9 accel. tubes;

Rep Rate: 1-50Hz;



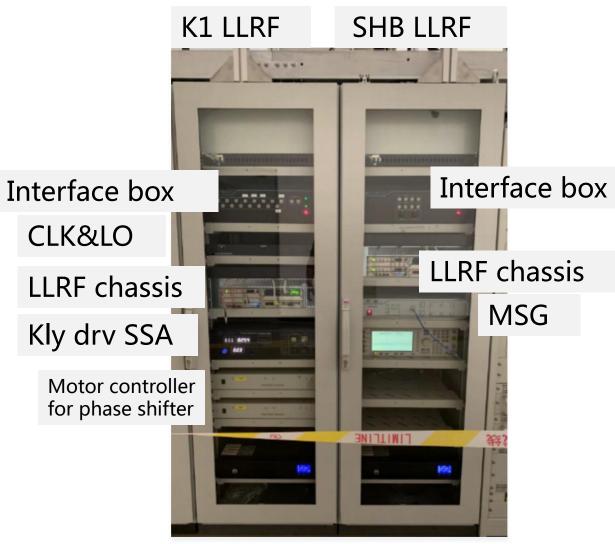






#### 6 LLRF cabinets





# **LLRF of HEPS Linac** HPRF & LLRF for S-band NC

MTCA.4 Standard

Platform

→ trigger →

MPS

Timing

....

MSG

DAQ &

DSP

&

Control

(on FPGA)

Interface

Vector Modulator

Interlock +

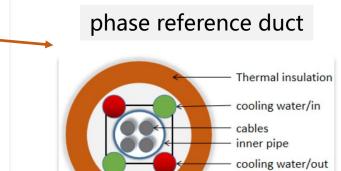
DWC

CLK

&

LO RE

S.W.



±0.1°C

REF1

REF2

REF4

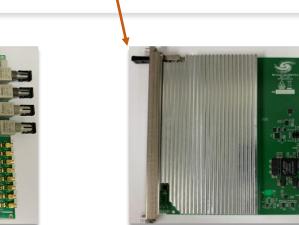
→ REF5

REF3 2998.8MHz

499.8MHz(SHB2)
 166.6MHz(SHB1)

Timing and interlock AMC

LLRF chassis



**RF** Reference Distribution

trigger

Pa

P

Pf

HV

Pre-amplifier

Klystron

Acc Tube

DWC RTM

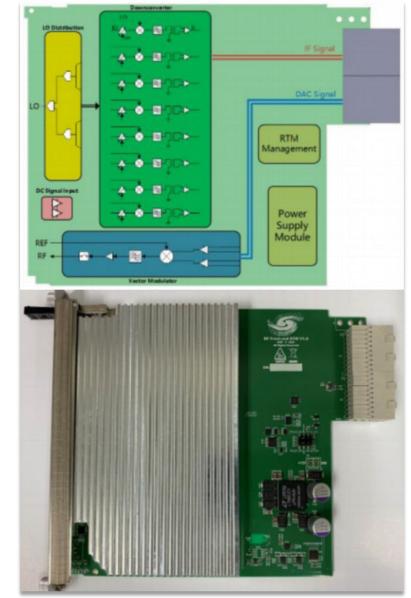
SLED

- □ 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



□MicroTCA.4 RTM;

□bandwidth 0-650MHz;

□tested with Struck SIS8300L2;

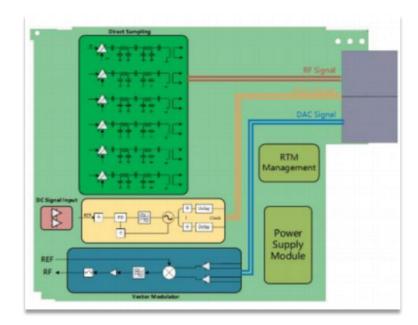
□6 channels ADC, 2 channels DAC;

□ first 10 boards have been in production;

<b>Clock Jitter</b>	<b>88 fs</b>
(10 Hz-10 MHz)	@104 MHz
SNR (@500MHz)	69.51 dBc



#### In-house Direct-sampling RTM





## MTCA.4 digital board

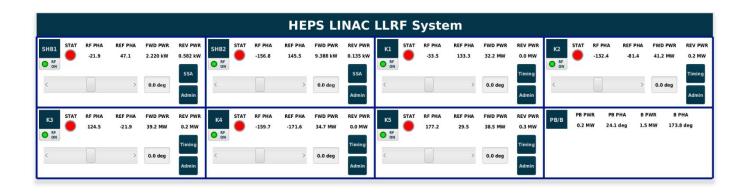
- 2 version digital fanout AMC with openmmc
- support 4 optical in/out;
- 8 channels TTL/LVTTL/CMOS/LVCMOS in/out;
- Impedance&direction controlled by IPMI command;
- Fanout through backplane to each slots;
- part/standalone of MPS and timing system;
- Todo:replace MMC NXP MCU with GigaDevice in China

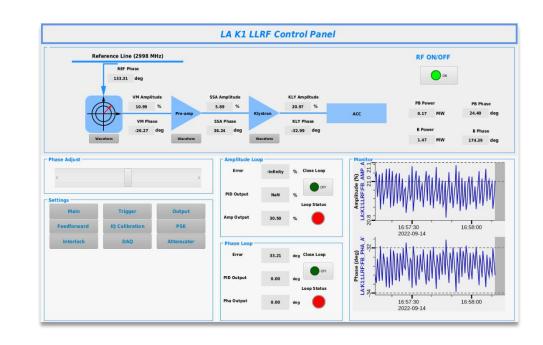


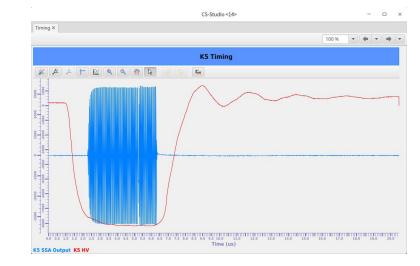


## Phase stability

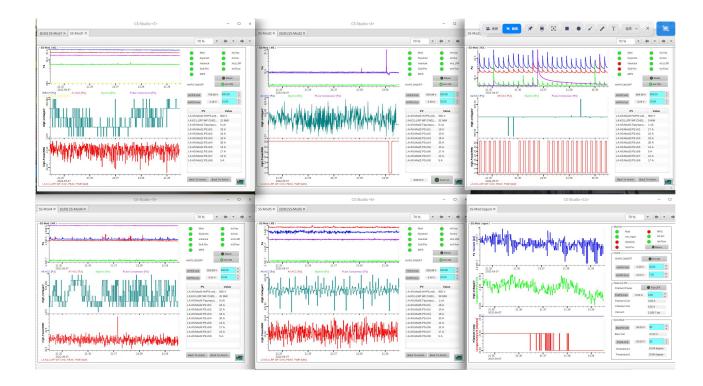
	Freq ( MHz )	Phase ( RMS )	<mark>Require</mark> ( RMS )			
SHB1	166.6	0.02°	0.5°			
SHB2	499.8	0.05°	0.5°			
K1-K5	2998.8	0.05°	0.3°			

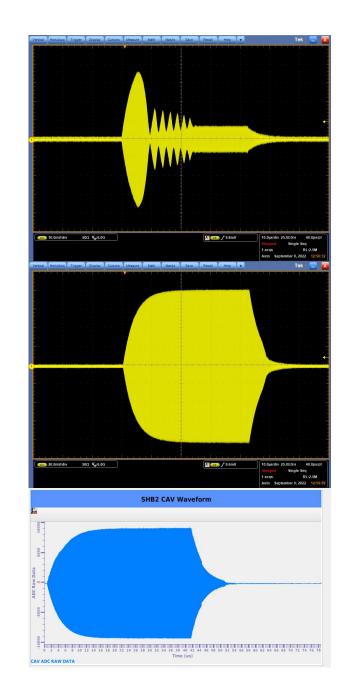




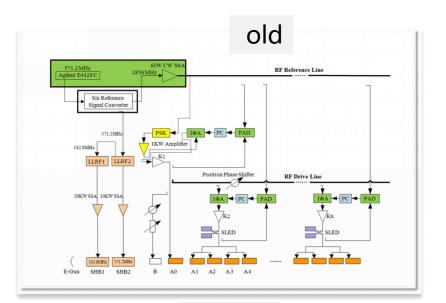


# 22/03-07, installation22/07-10, conditioning completed...22/12- beam commissioning?

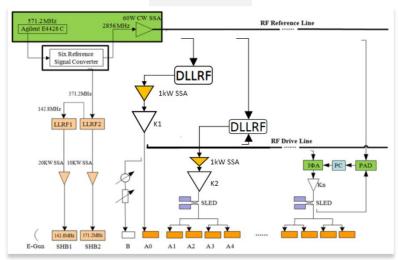




#### The same LLRF on BEPCII Linac



now



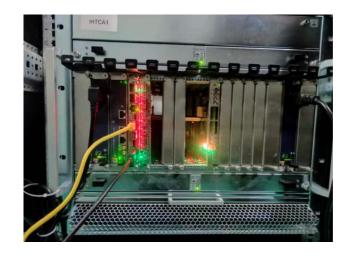
 BEPCII Linac LLRF share similar system from HEPS LLRF, except freq: 2856MHz and 142.8MHz SHB1, 571.2MHz SHB2
 9 LLRF upgraded in the last two years

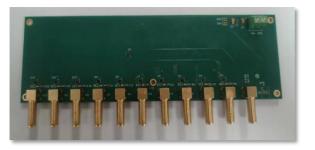






Phase I: 3 chassis installed for timing of the Linac; MRF MTCA.4 mostly adopted: EVG/EVR; Also many self-made boards for distribute triggers; Benefit from different vendors;





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



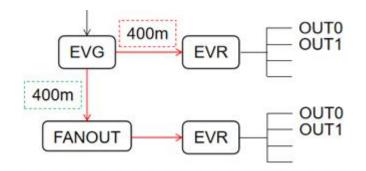


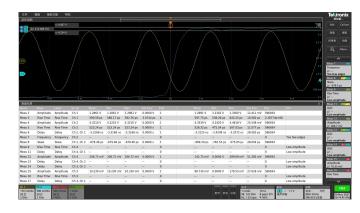
MTCA.4 MRF debugged & final tested on-site;

Jitter (rms) < 24ps;</pre>

Timing system serves stable for conditioning of Linac;







#### Timing Control for Linac e-Gun & Power Source & LLRF

	Status	Delay		Width		enable/disable	Fine Delay						
e-Gun Pulser trigger	<ul> <li>Normal</li> </ul>	0.00	us	2.3	00 us	• On	0.00 ps 0.00 ps						
e-Gun PS pre-trigger	<ul> <li>Invert</li> </ul>	0.00	us	2.3	00 us	• On							
e-Gun PS trigger	<ul> <li>Normal</li> </ul>	0.00	us us	2.3	00 us	0 On					58	PA	reload
INAC Klystron Modu	ilator						LINAC LLRF					_	
	Status	Delay		Width		enable/disable	and the state of t	Status	Delay	Wi	dth		enable/disable
K1 pre-trigger	Invert	0.00	) us	3.0	00 us	• On	SHB1 trigger	<ul> <li>Normal</li> </ul>	0.000	us	1.000	us	0 Dn
K1 trigger	<ul> <li>Normal</li> </ul>	0.00	us	3.0	00 us	• On	SHB2 trigger	• Normal	0.000	us	1.000	US	• On
K2 pre-trigger	• Invert	0.00	) us	4.0	00 uz	• On	K1 trigger	• Normal	0.000	us	2.000	us	• On
K2 trigger	<ul> <li>Normal</li> </ul>	0.00	us.	4.0	00 us	O On	K2 trigger	• Normal	0.000	us	2.000	us	On On
K3 pre-trigger	• Invert	0.00	us us	4.0	00 us	• On	K3 trigger	• Normal	0.000	us	2.000	US	0 On
K3 trigger	• Normal	0.00	us l	4.0	00 us	On .	K4 trigger	<ul> <li>Normal</li> </ul>	0.000	us	2.000	us	• On
K4 pre-trigger	• Invert	0.00	us	4.0	00 Le	• On	K5 trigger	• Normai	0.000	us	2.000	us	• On
K4 trigger	O Normal	0.00	) us	4.0	00 18	On .							
K5 pre-trigger	• Invert	0.00	us	4.0	00 15	• On							
K5 trigger	<ul> <li>Normal</li> </ul>	0.00	us	4.0	00 us	OOn							

Serveral more for test bench and other timing system;









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!