Libera Hadron test in SESRI

Min LI

Institute of Modern Physics, Chinese Academy of Sciences
limin@impcas.ac.cn

on behalf of the Beam Diagnostics Department

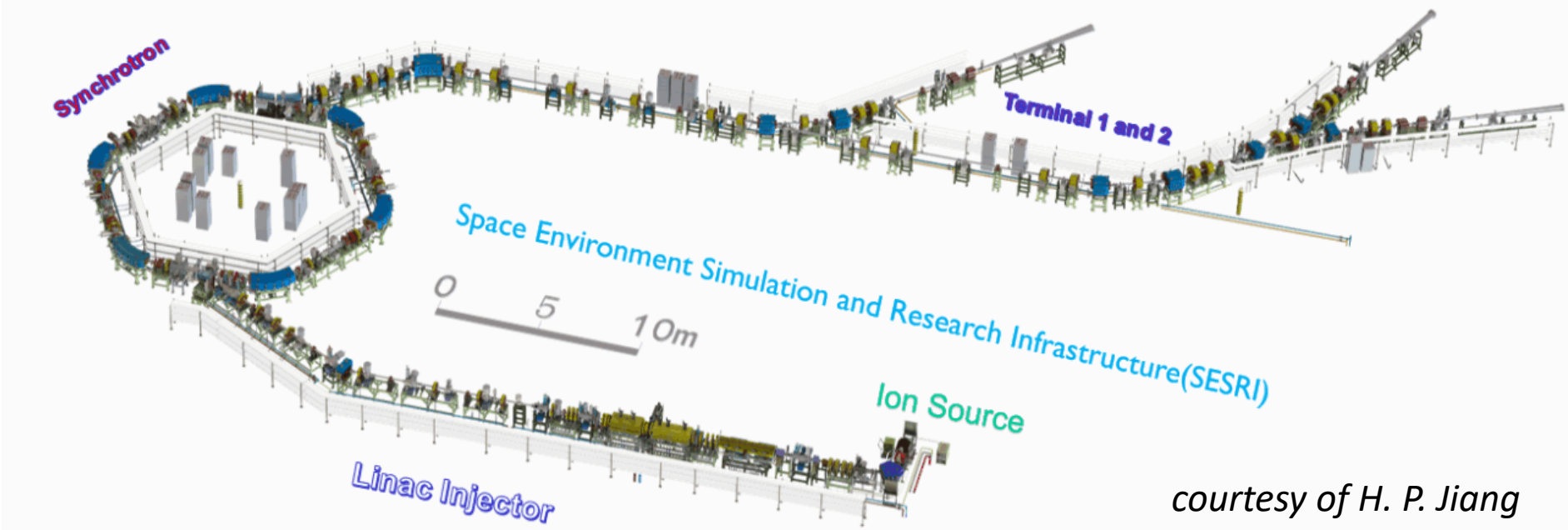
Libera Workshop, June 10th, 2021

Outlines

1. SESRI facility introduction
2. SESRI BPM system and Libera Hadron test
3. Project plan

1 SESRI: layout

- **SESRI** : Space Environment Simulation and Research Infrastructure, aims at the simulation of space environment on the ground.
- **The proton and heavy ion accelerator:** supply 100-300MeV protons and 7-85MeV/u heavy-ions
- **the ECR ion source：** provide all stable nuclide beams from H_2^+ to Bi
- **The linac injector :** supplies 1MeV/u heavy ion beams and 5MeV proton beam
- **The synchrotron:** accelerates heavy ions up to 85MeV/u and proton beam 300MeV



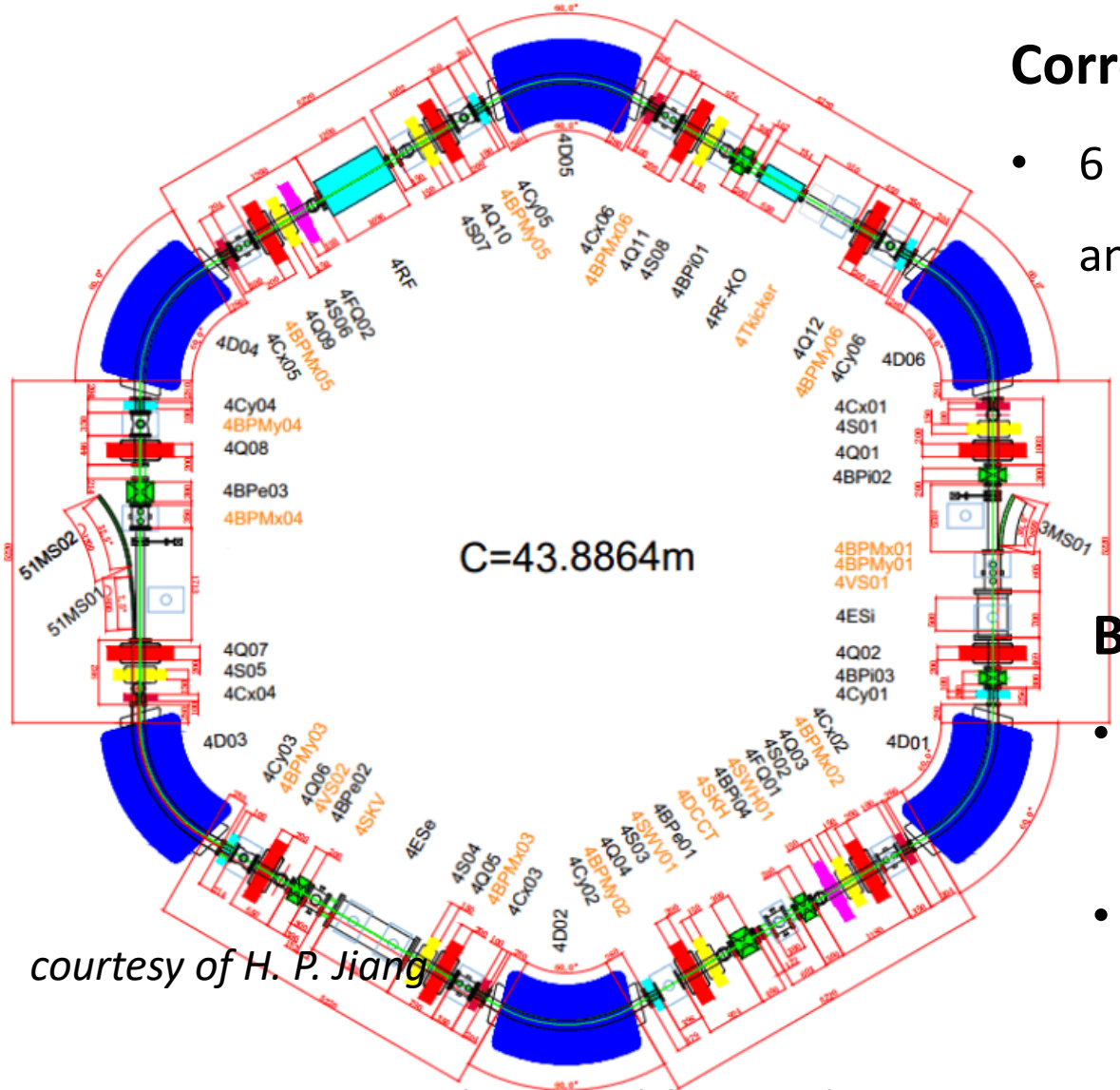
courtesy of H. P. Jiang

1 SESRI：the main parameters of the synchrotron

Main Parameters	Circumference(m)	43.8864
	Magnetic rigidity(T · m)	0.28∼2.8
	Accelerating time(s)	0.53∼0.81
	Period(s)	3∼10
	Repetition frequency(Hz)	0.1∼0.3
Input beam	Energy(MeV/u)	1 ($^{4}He^{2+} \sim {}^{209}Bi^{32+}$), 5(p)
	Momentum dispersion($\Delta P/P$)	$\leqslant \pm 2\times10^{-3}$
	Emittance(πmm · mrad)	$\leqslant$ 13 (6σ)
Beam in synchrotron	Ion:p$\sim{}^{209}Bi^{32+}$	
	Energy(MeV/u)	300(p), 80($^{4}He^{2+}$), 15($^{84}Kr^{18+}$), 7($^{209}Bi^{32+}$)
	Beam intensity(ppp):$^{4}He^{2+} \sim {}^{209}Bi^{32+}$	$1.1\times10^{6} \sim 1.1 \times 10^{7}$(p:$1.1\times10^{9}$)
Beam in terminal	Beam instensity(p/spill)	$1\times10^{6} \sim 1 \times 10^{9}$
	Momentum dispersion ($\Delta P/P$)	2×10^{-3}
	Emittance(πmm · mrad)	$\leqslant$10
Lattice parameters	Super-period	6
	Tune(Q_x/Q_y)	1.72/1.62(Injection), 1.68/1.62(Extraction)
	Acceptance A_h/A_v(π mm · mrad)	200/30($\Delta P/P=\pm0.5\%$)

courtesy of H. P. Jiang

2 layout of the synchrotron



courtesy of H. P. Jiang

injection，horizontal & vertical BPM

Correctors

- 6 correctors in both horizontal and vertical direction respectively

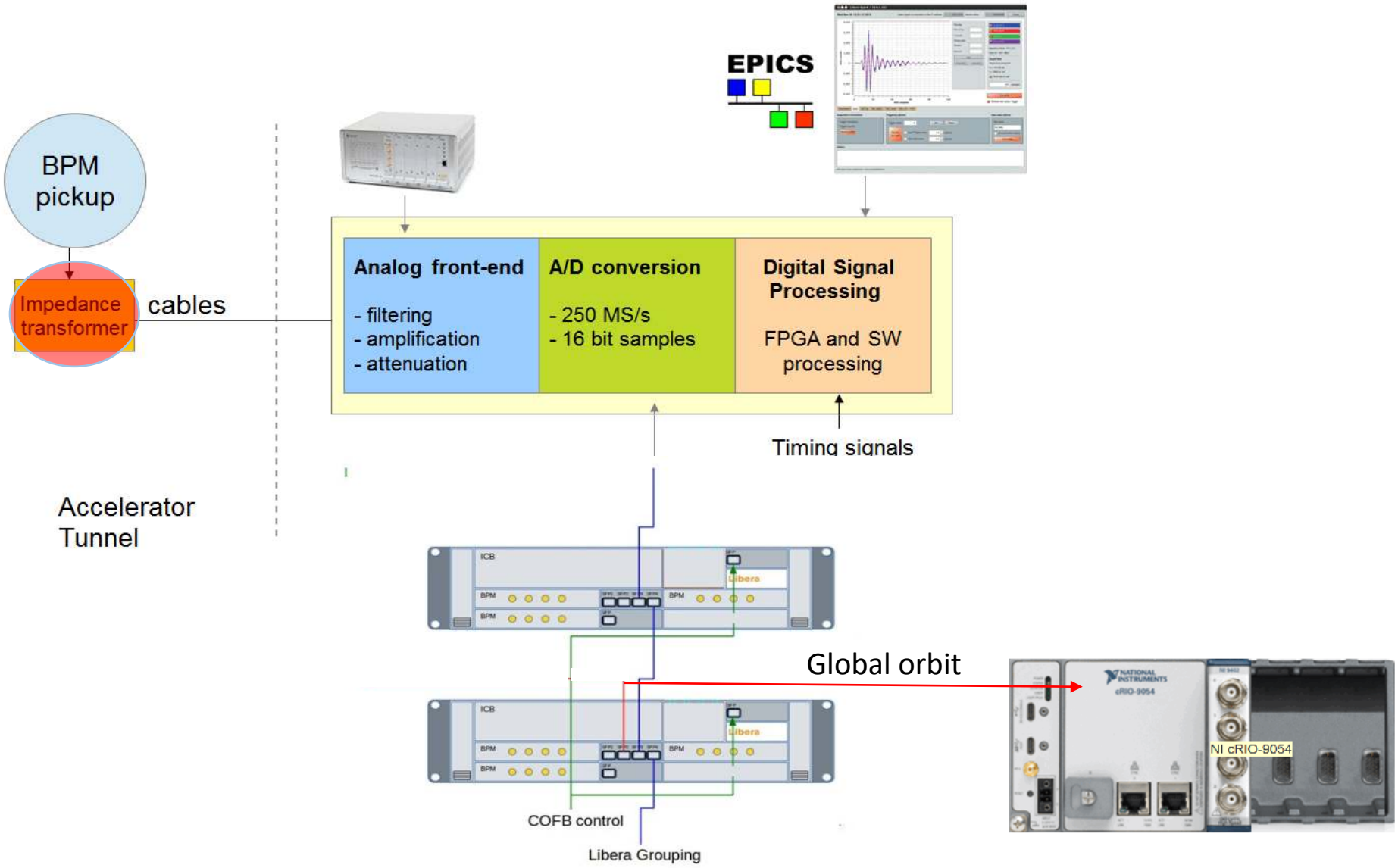
BPMs

- 6 BPMs in both horizontal and vertical direction respectively
- Only one BPM can monitor two direction position

2 BPM measurement requirements

BPM	measurements	notes
Beam current	5 orders	range of front-end electronics
Sample rate	250MHz	
Raw data	2-3ms/second	Multi-turn injection
Bunch-by-bunch position	RF reference signal	RF reference phase
Closed orbit	Averaged orbits	adjustable
resolution	Closed orbit： < 0.1mm	Proton current:1.0×10^{9}
Closed orbit rate	100Hz for orbit feedback 5Hz for orbit monitor	
Abnormal status	Amplitude of sum signal	add an abnormal parameter

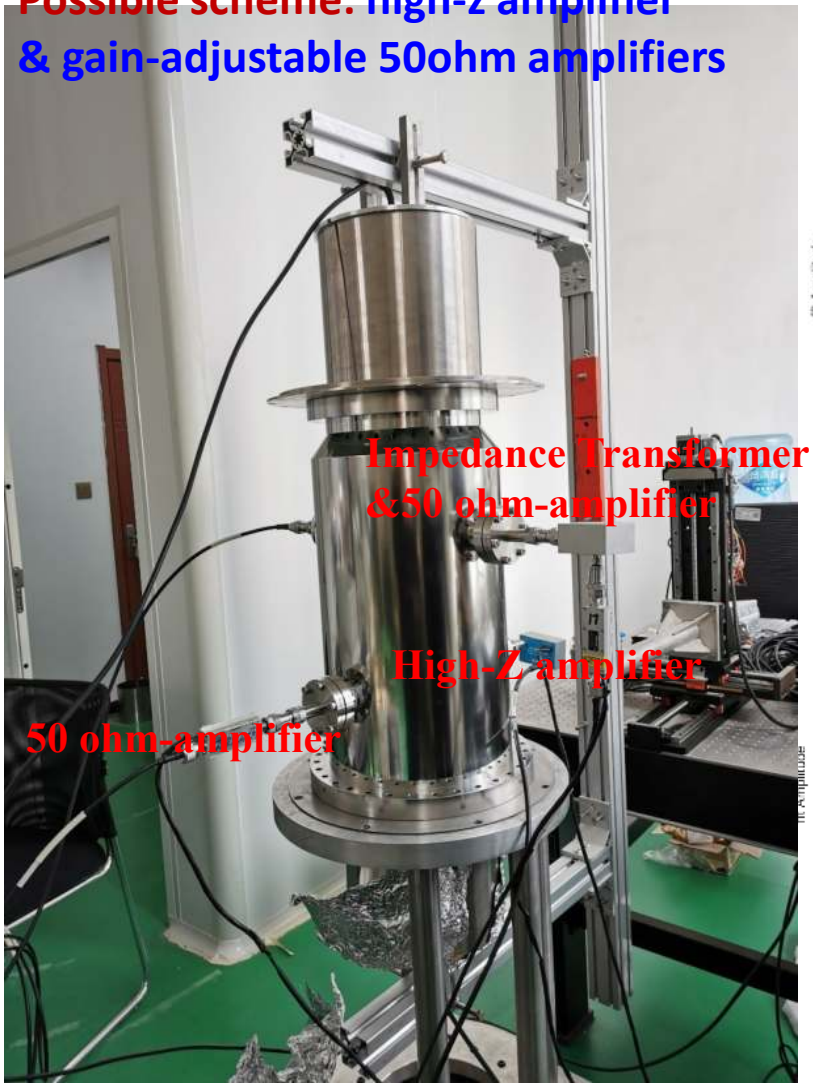
2 BPM measurement system



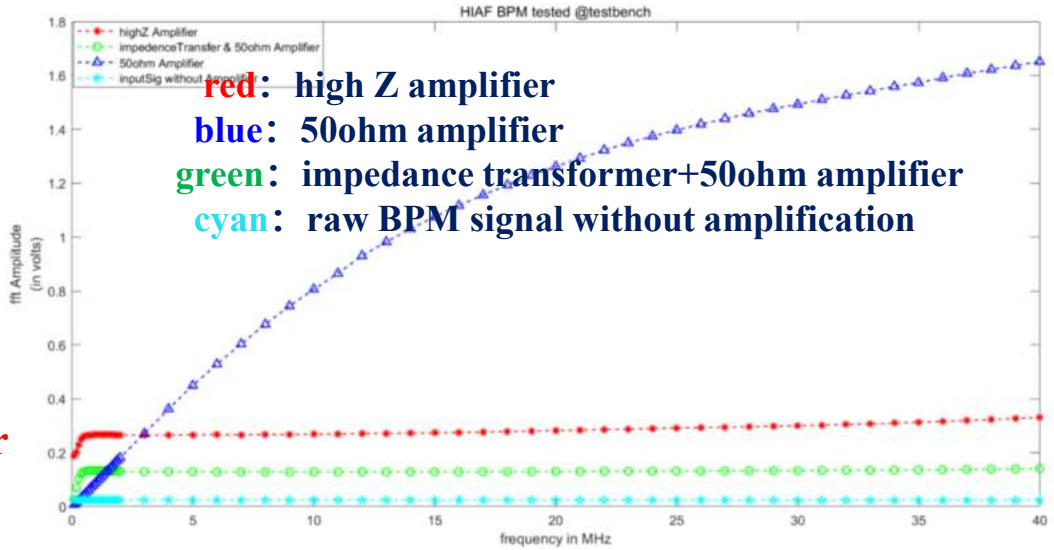
2 BPM measurement system: Impedance transformer

- The developed impedance transformer can be used in heavy-ion accelerator
- However, the signal was attenuated obviously by the impedance transformer & 50 Ohm-amplifier compared with the high-z amplifier scheme

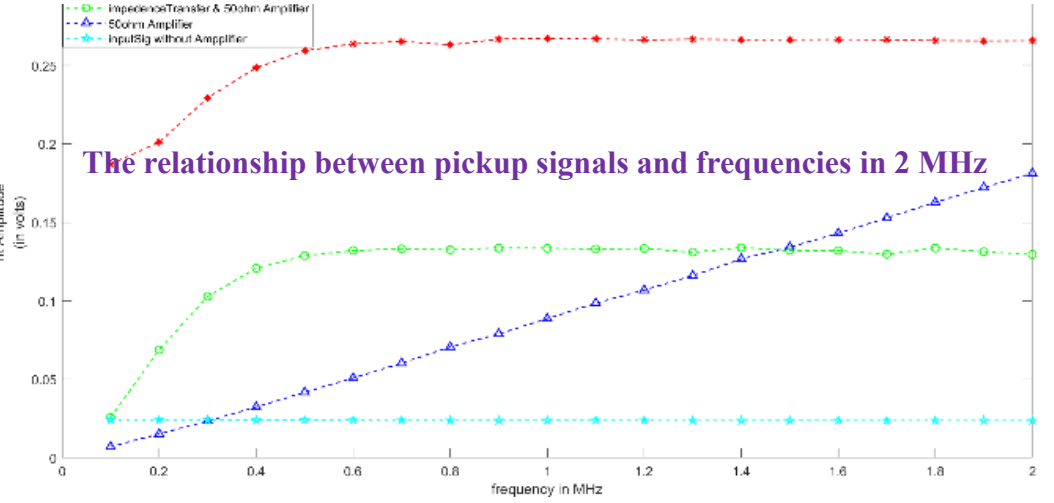
Possible scheme: high-z amplifier & gain-adjustable 50ohm amplifiers



The relationship between pickup signals and frequencies in 40MHz

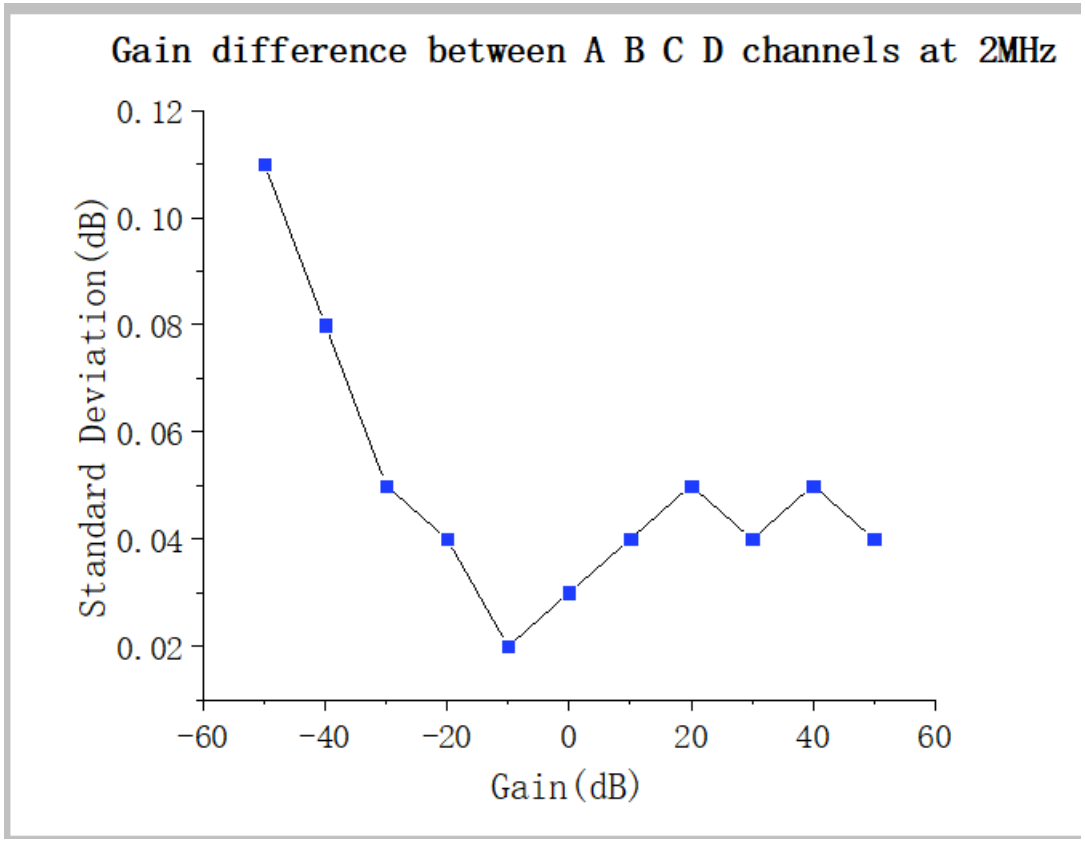


The relationship between pickup signals and frequencies in 2 MHz



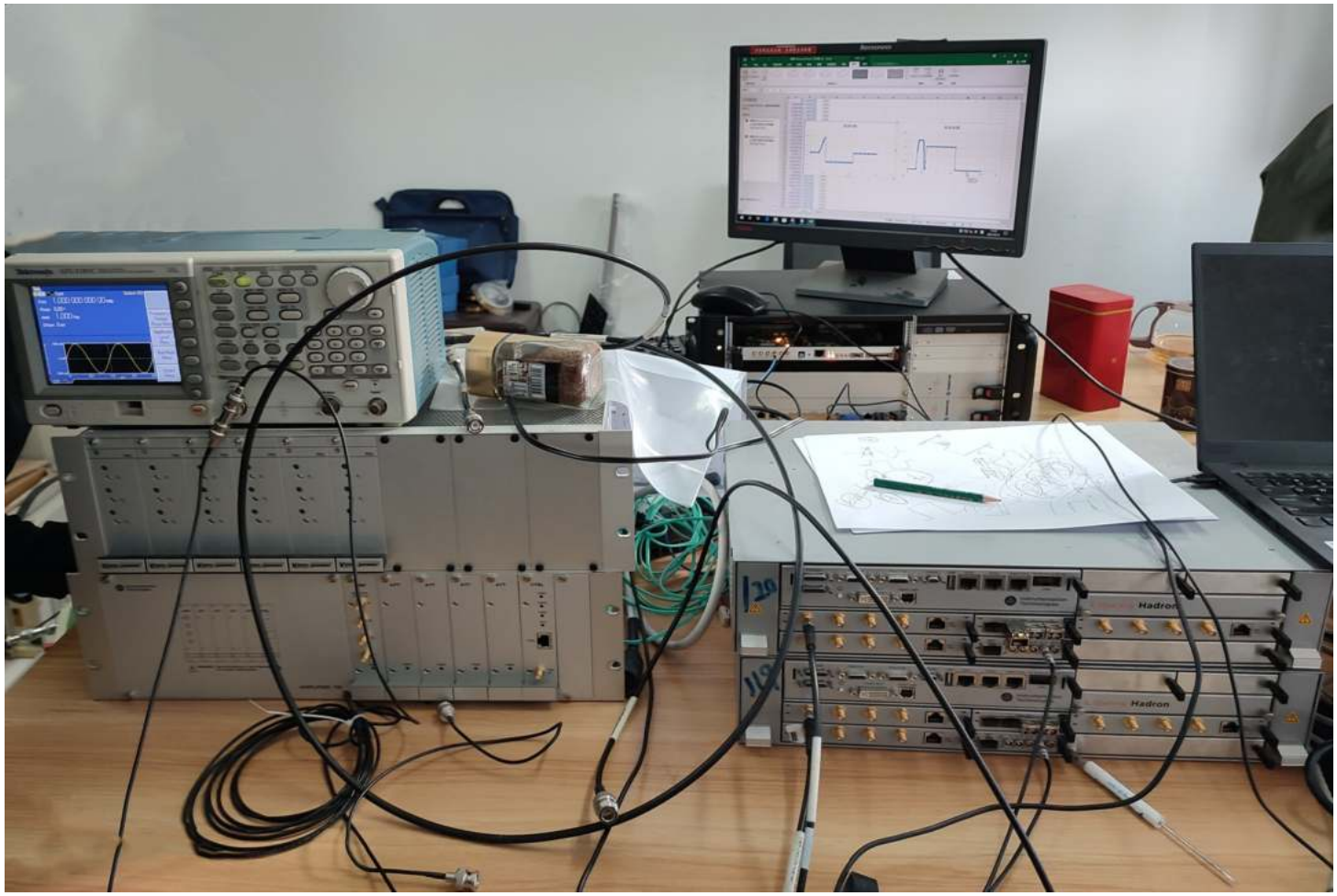
2 Amplifier 110 test

- All the amplifier 110s were calibrated in the lab by a network analyzer
- Good gain consistency between amplifier channels
- Test results are consistent with the factory parameters



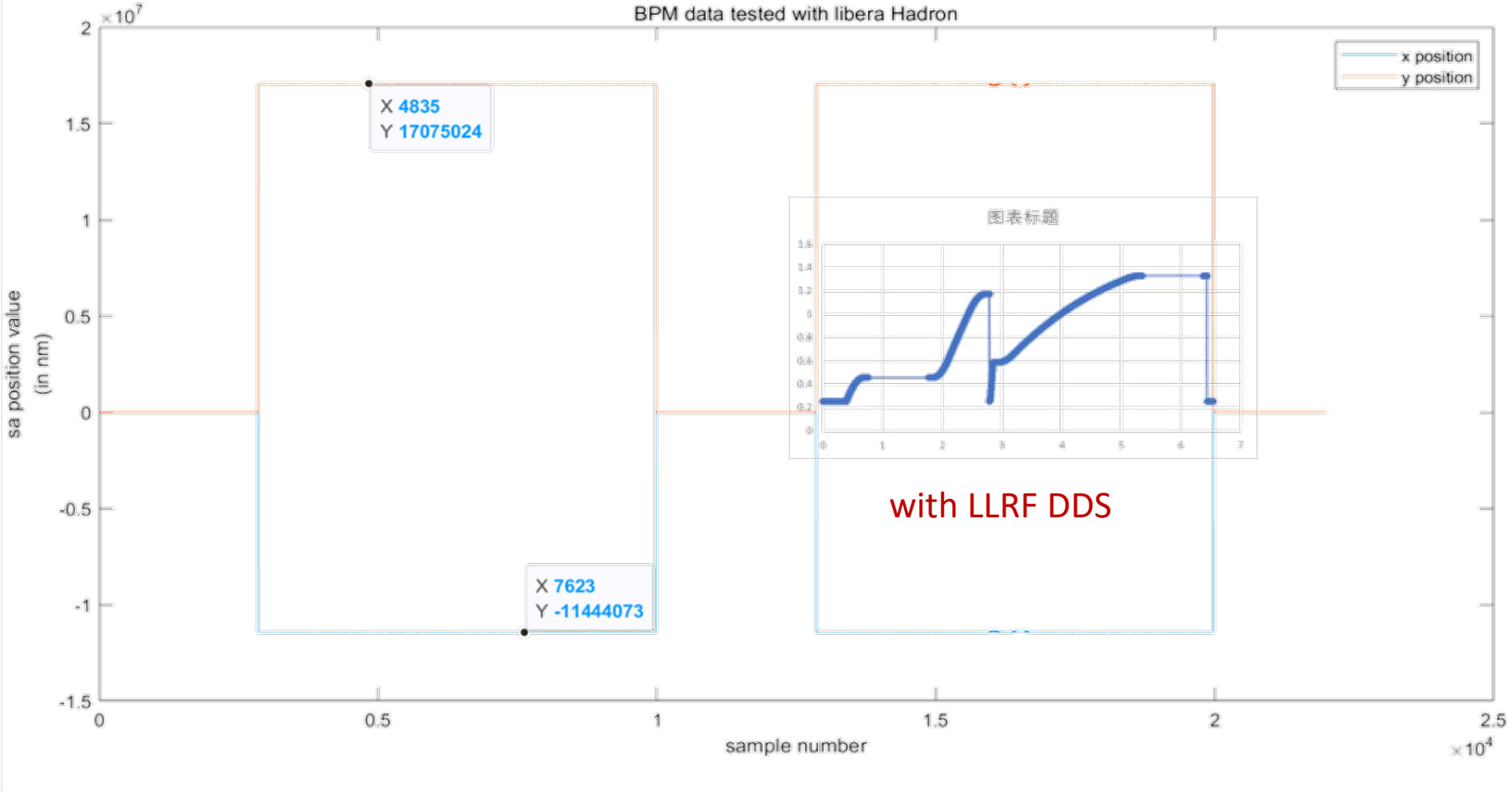
2 Amplifier 110 & Libera Hadron test

- The BPM measurement system was set in the lab with Amplifier 110, libera hadrons, signal generators, LLRF system and so on
- System functions were verified by this test environment



2 Libera Hadron： position measurement

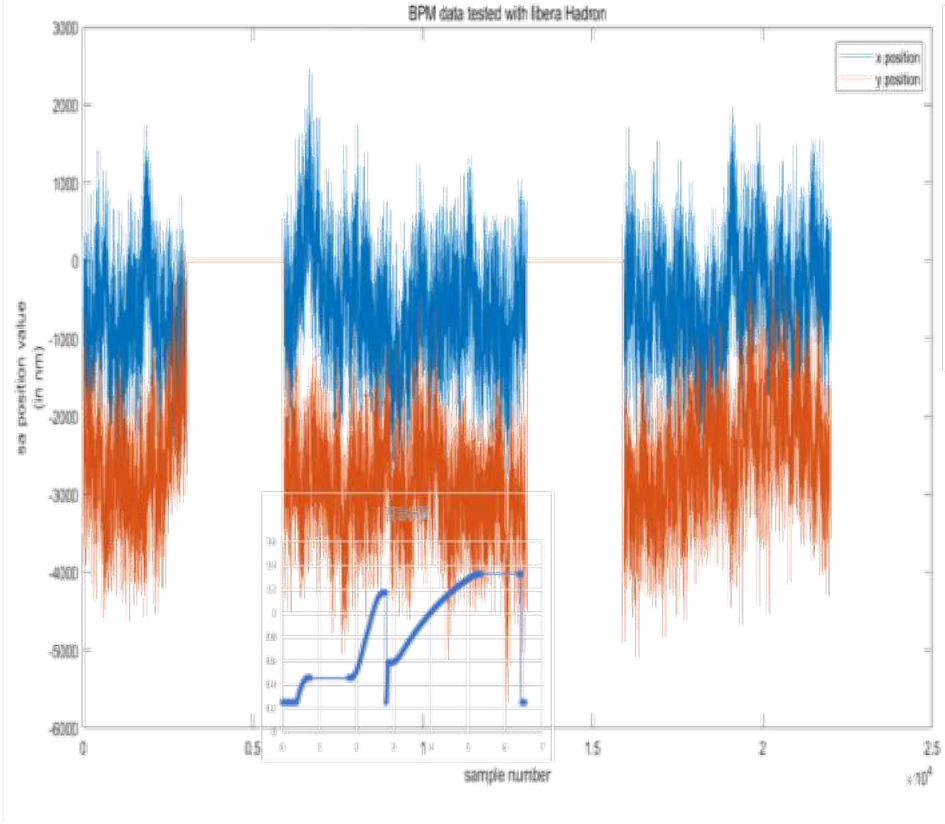
- x-axis: sample No， SA data， 1kHz
- y-axis： X,Y position， unit： nm
- Channel A and D was added 2dB, 3dB attenuation



2 Libera Hadron：position resolution analyzation

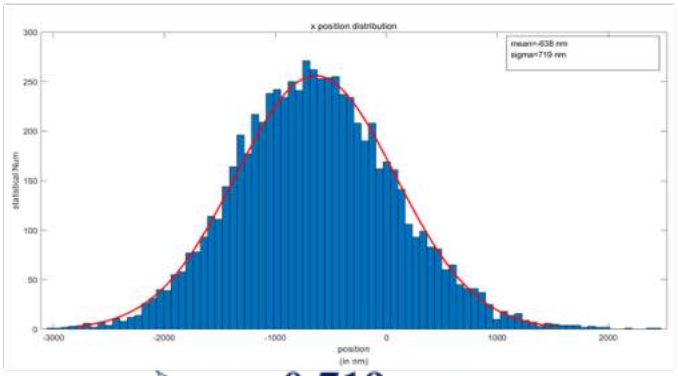
the position resolution performance measurement:

- different number of bunch position, different shapes, and different frequencies of beam signal
- The position resolution is less than 1um, and the position resolution meets the physical requirements

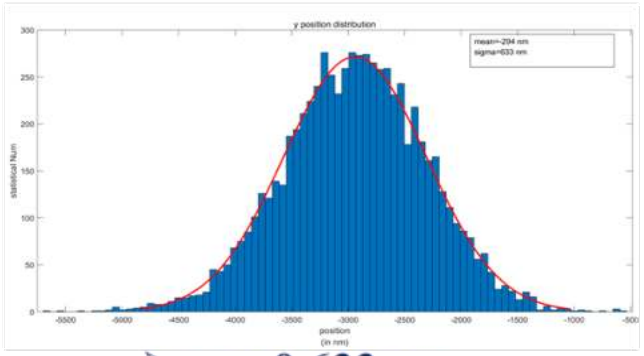


SA：1KHz

Input same signal into the libera hadron



- σx= 0.719 um
- mean x= -0.638 um



- σy= 0.633 um
- mean y= -0.294 um

2 Libera Hadron： position resolution test

Different number of bunches' position are averaged to obtain the position resolution

	σx(nm)	σy(nm)
Bunch	639	622
10 kHz	169(118)	214(106)
1 kHz	64	67
10 Hz	64	63

- Bunch： average and statistic 2000 bunches position resolution
- 10 kHz： position resolution of fa data
- 1 kHz： every 10 points averaged from 10kHz
- 10 Hz： sa data from libera hadron

2 Libera Hadron： position resolution

- Different shapes and frequencies are simulated as beam signal and input into libera hadron

Sine waveform

resolution / Frequency	σx(um)	σy(um)
1 MHz	0.316	0.473
2 MHz	0.222	0.341
3 MHz	0.185	0.291
4 MHz	0.162	0.254
5 MHz	0.127	0.176

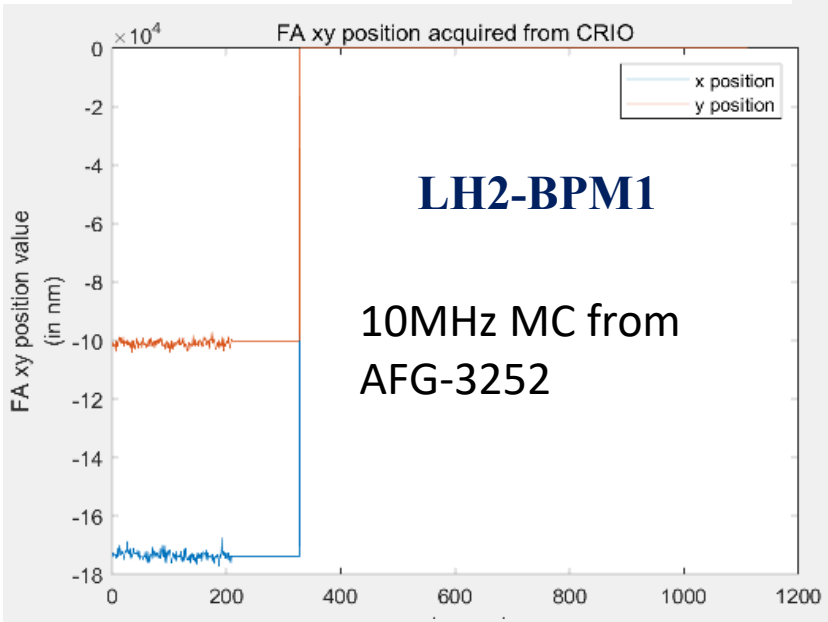
Gaussian waveform

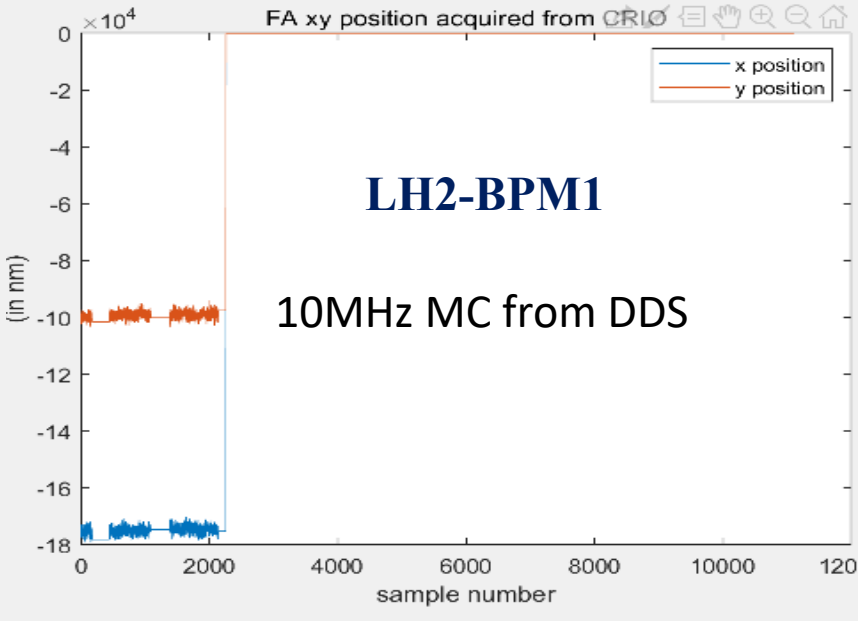
resolution / Frequency	σx(um)	σy(um)
1 MHz	0.322	0.481
1.2 MHz	0.336	0.498
1.5 MHz	0.271	0.424
1.8 MHz	0.249	0.366
2 MHz	0.224	0.338

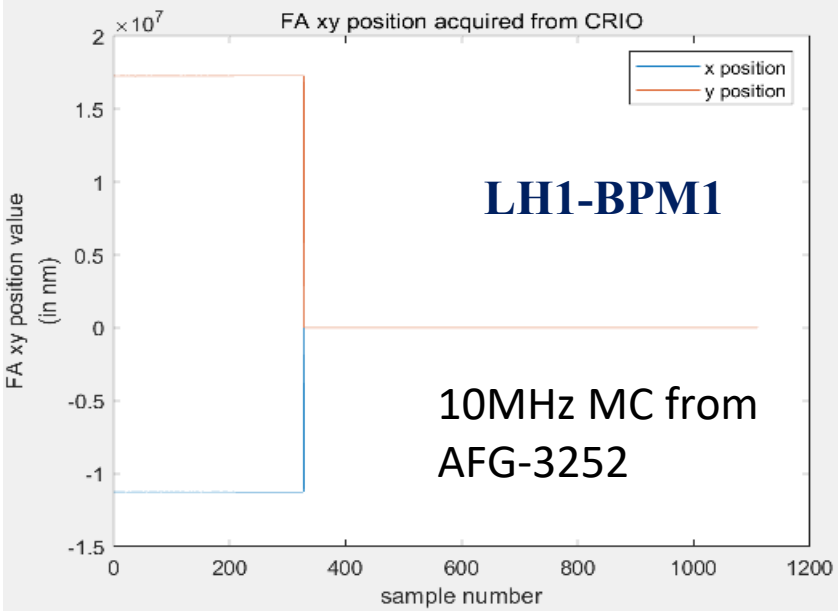
Note： the maximum frequency is 2.4MHz while AFG3252 generates gaussian signal

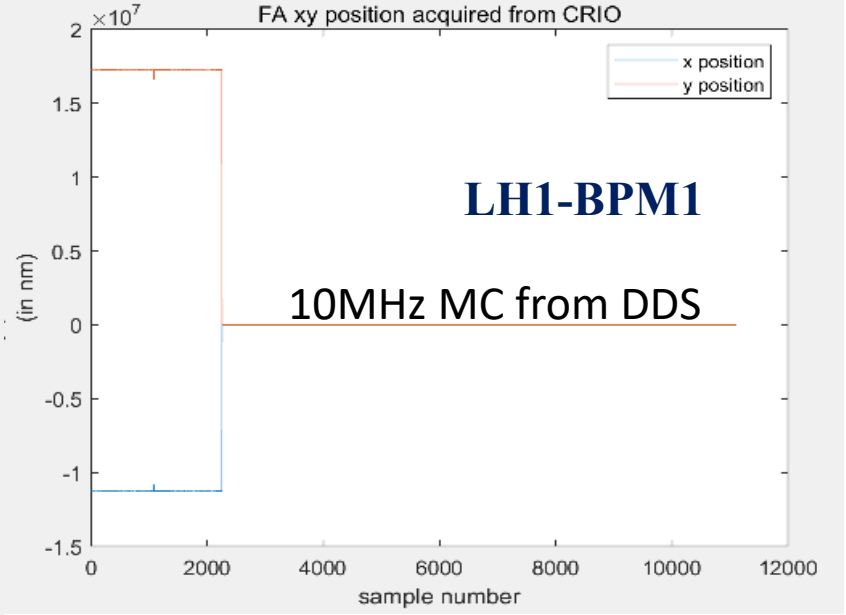
3 Libera Hadron： machine synchronization 10 MHz

Two libera hadron crates were first synchronized by DDS or signal generator



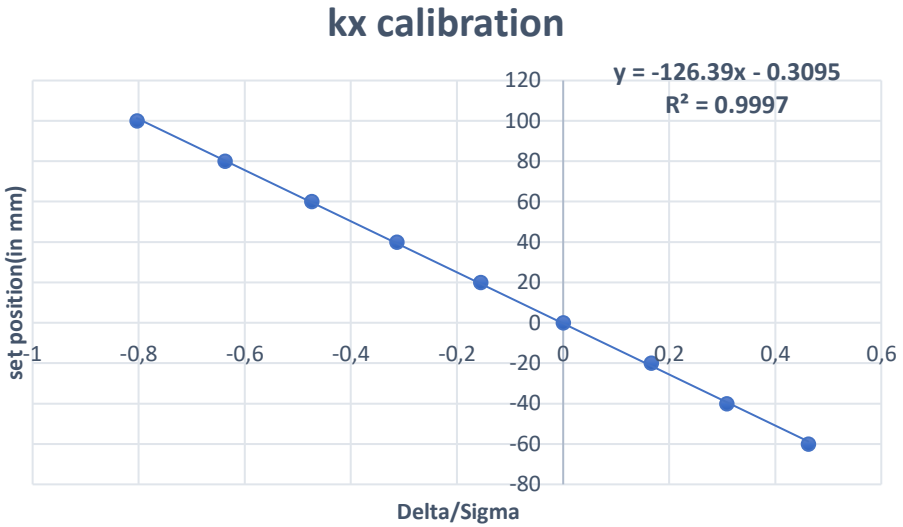


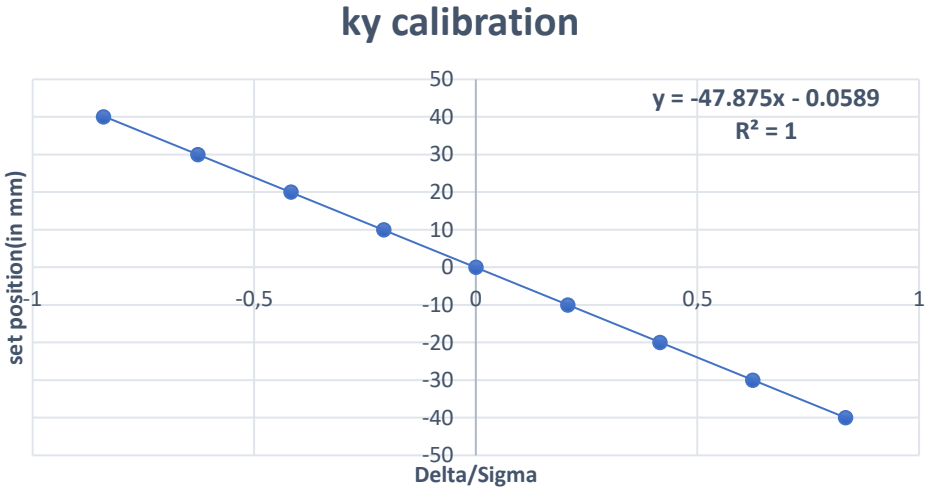




2 BPM calibration in the lab in SESRI

- the BPM which can measure the horizontal and vertical position was calibrated in the lab

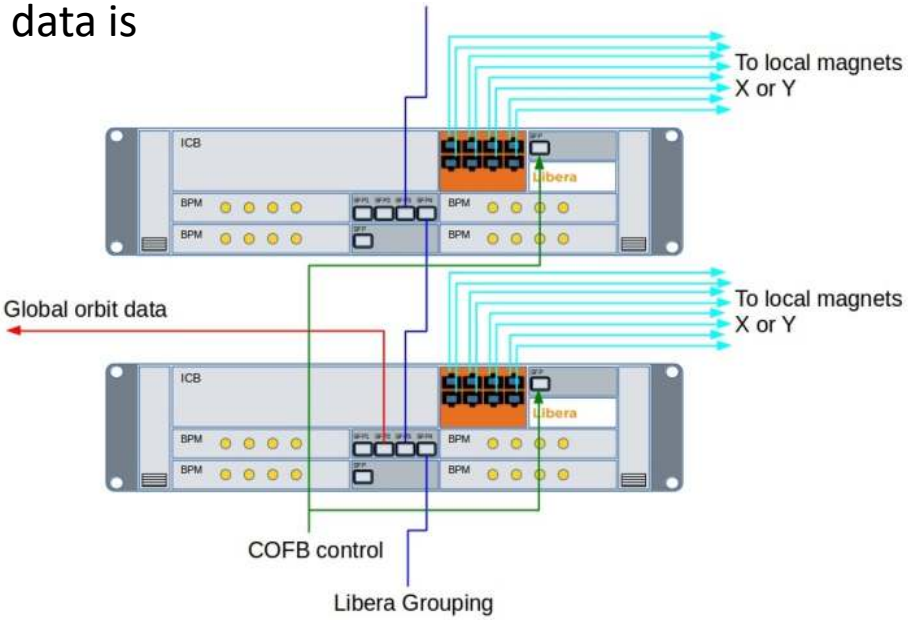


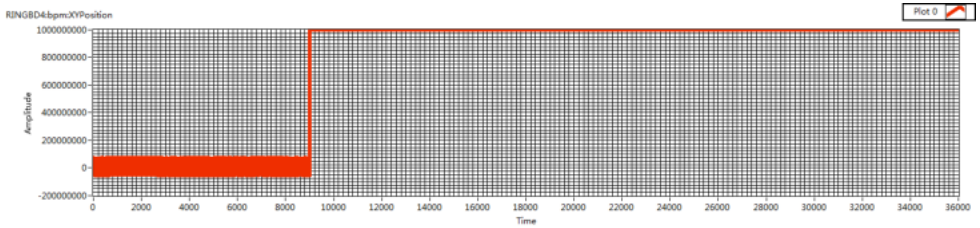


2 Libera grouped data process in SESRI

6 BPM modules interconnected in the closed orbit feedback

- Position data from 12 BPMs is grouped together
- Grouped positions are transferred to a compactRIO NI 9065(real time system&FPGA) by UDP @FPGA, then parsed, processed and rearranged into a big waveform with the length size 36000 in the whole cycle
- The closed orbit of the whole accelerator cycle data is published by a PV @RT target @100 Hz

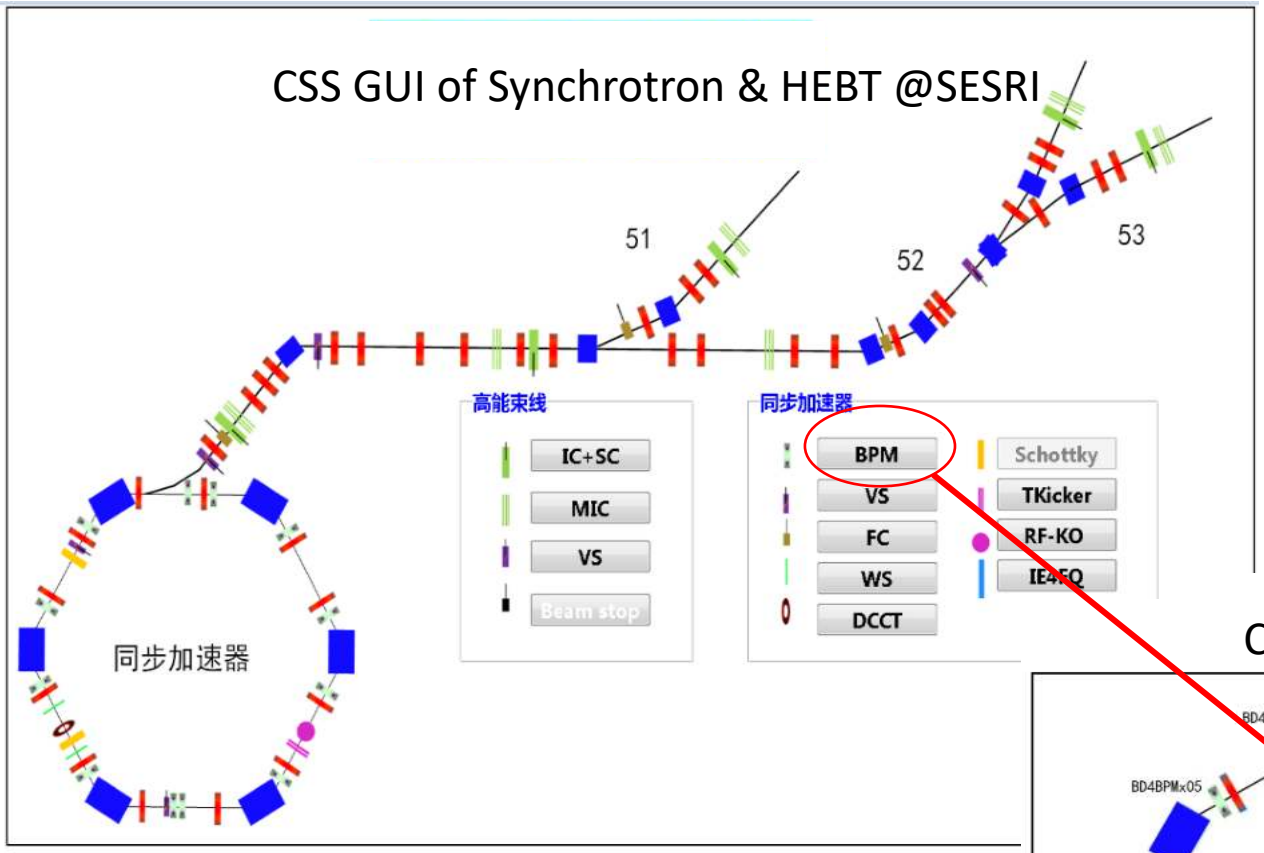


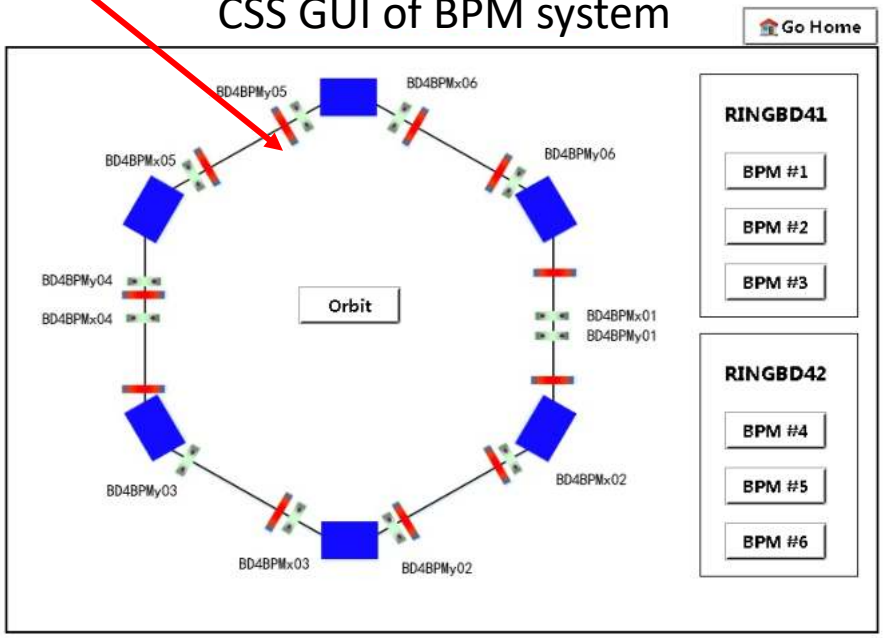


2 Multi-turn raw data monitor

- to monitor the raw BPM data while multi-turn injection
- the data rate should be decimated to 1MHz or 25MHz with a ratio parameter
- the display data length should be 2500
- monitor the data in 2-3ms every 1 second (The sample rate is 250MSa/s fixed, which means the maximum length reaches 750000 samples for each pickup each time
- The sample time can be delayed in the range of 0-5ms and the delay precision is in 1 us, which refers to the T2 trigger signal, this has been completed
- 24 pickups raw data are required to be monitored at the same time

2 BPM control panel in SESRI





3 Project plan

- The beam diagnostics detectors of synchrotron and HEBT are being installed since June
- The Accelerator will be commissioned by the end of this year