The progress of BEPCII storage ring diagnostics system

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May 4, 2008, 13th BIW
Lake Tahoe, CA., USA

Outline

- Introduction
- Libera BPM
- MX_BPM
- Bunch Current Monitor
- Transverse Feedback System
- Beam Loss Monitor
- Tune Measurement
- SLM and DCCT
- Summary

Introduction

The BEPCII continues to serve the purposes of both high energy physics experiments and synchrotron radiation applications.

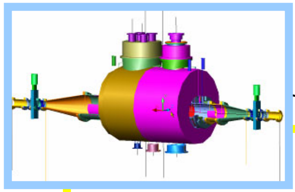
Design Goals of BEPCI I

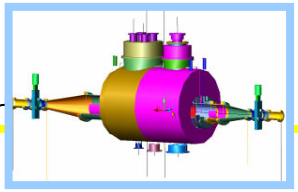
Beam energy	**1-2.1 GEV**
Optimum energy	**1.89 GEV**
Luminosity	**1×10^{33} $cm^{-2}s^{-1}$ @1.89 GeV**
Linac Injector	**Full energy inj.: 1.55-1.89GeV** **Positron inj. rate > 50 mA / min**
Dedicated SR	**250 mA @ 2.5 GeV**

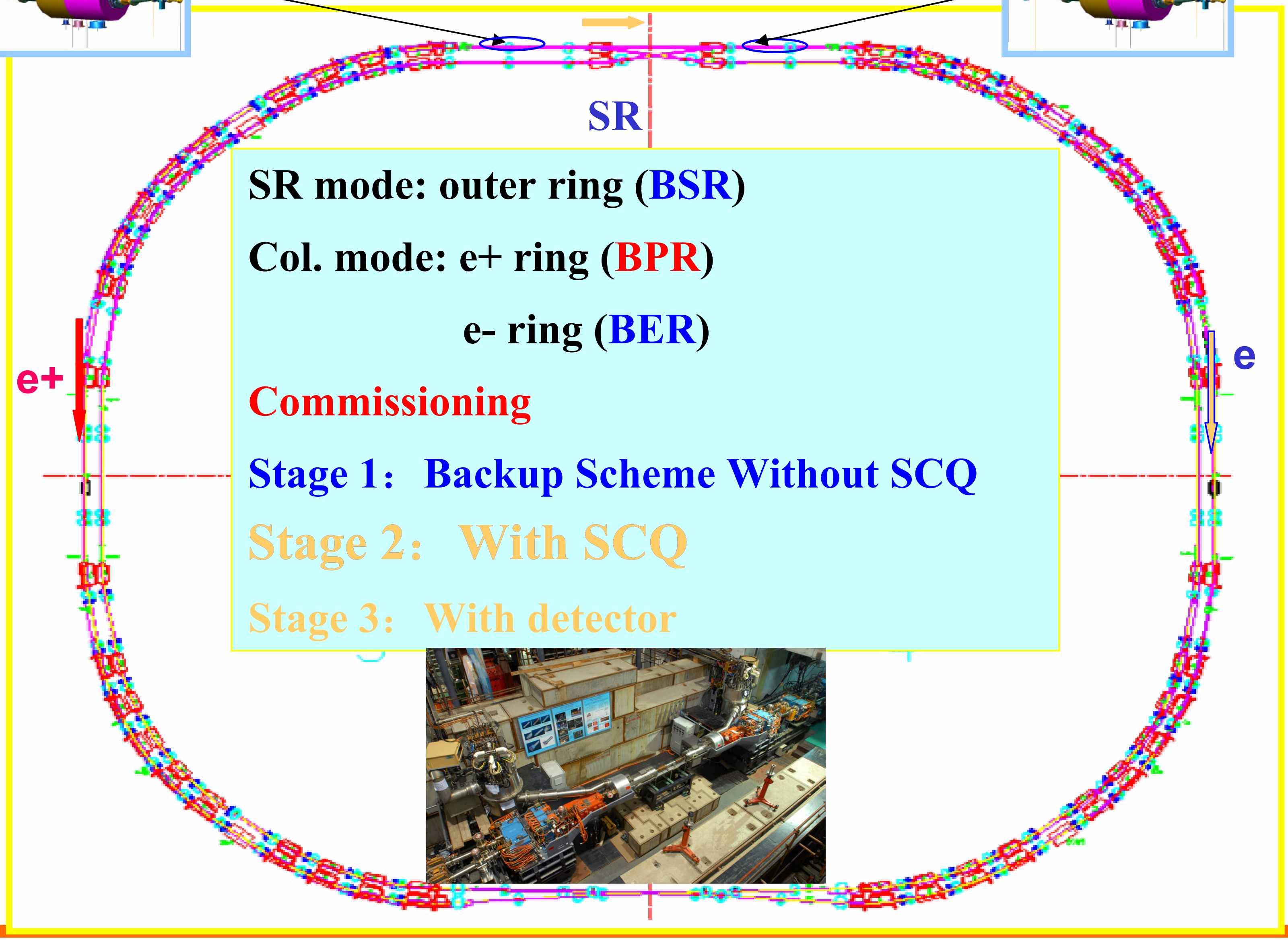
Main Parameters of BEPCII

Parameters		Unit	BEPCII	BEPC
Operation energy (E)		GeV	1.0–2.1	1.0–2.5
Injection energy (E_{inj})		GeV	1.55–1.89	1.3
Circumference (C)		m	237.5	240.4
β^*-function at IP (β_x^*/β_y^*)		cm	100/1.5	120/5
Tunes ($\nu_x/\nu_y/\nu_s$)			6.57/7.61/0.034	5.8/6.7/0.02
Hor. natural emittance (ε_{x0})		mm·mr	0.14 @1.89 GeV	0.39 @1.89 GeV
Damping time ($\tau_x/\tau_y/\tau_e$)			25/25/12.5 @1.89 GeV	28/28/14@1.89 GeV
RF frequency (f_{rf})		MHz	499.8	199.533
RF voltage per ring (V_{rf})		MV	1.5	0.6–1.6
Bunch number (N_b)			93	2×1
Bunch spacing		m	2.4	240.4
Beam current	Colliding	mA	910 @1.89 GeV	~2×35 @1.89 GeV
	SR		250 @2.5GeV	130
Bunch length (cm) σ_l		cm	~1.5	~5
Impedance $\|Z/n\|_0$		Ω	~ 0.2	~4
Crossing angle		mrad	±11	0
Vert. beam-beam param. ξ_y			0.04	0.04
Beam lifetime		hrs.	2.7	6–8
luminosity@1.89 GeV		$10^{31}cm^{-2}s^{-1}$	100	1

BEPCII Storage rings







SR mode: outer ring (BSR)

Col. mode: e+ ring (BPR)

e- ring (BER)

Commissioning

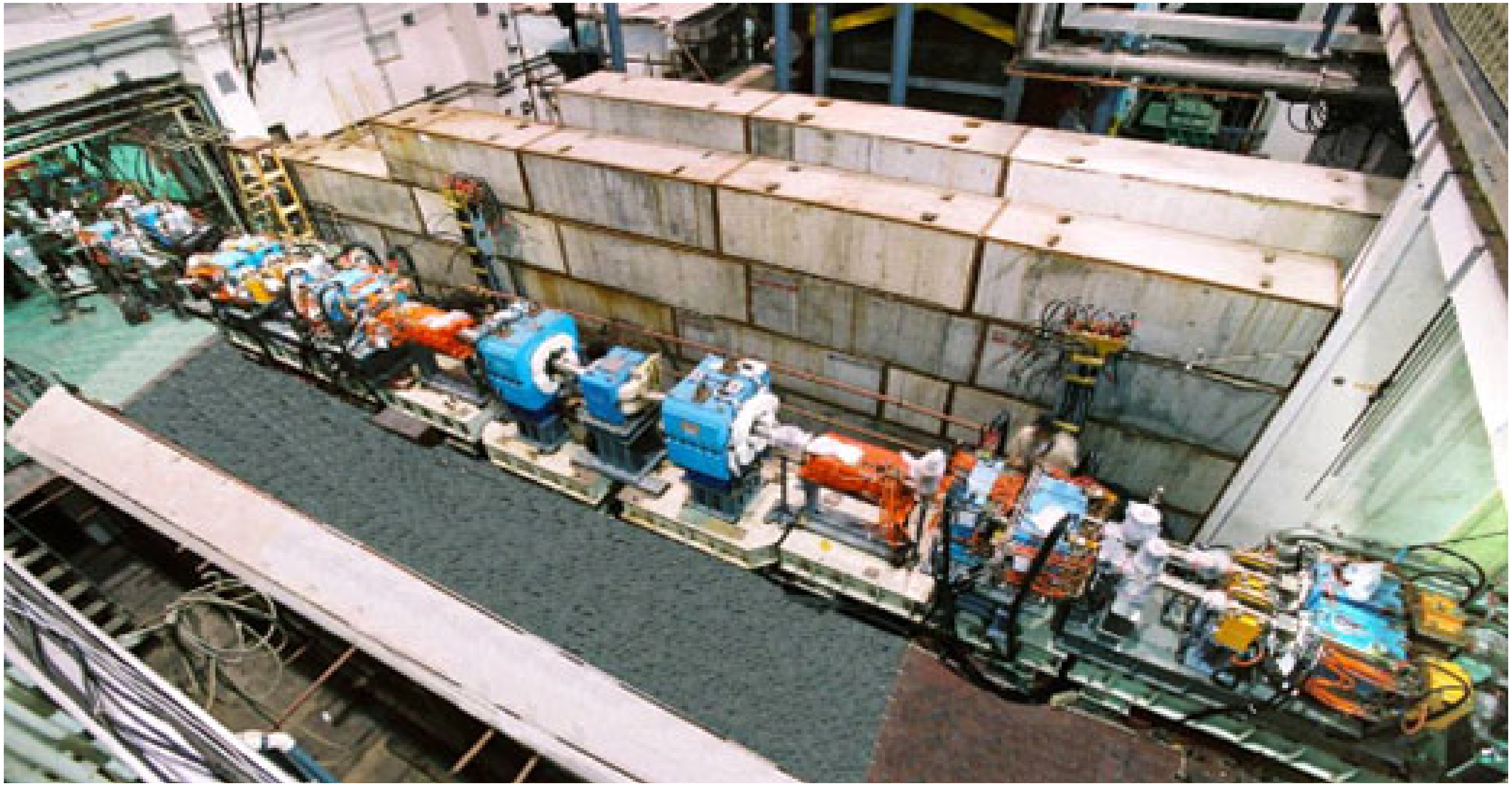
Stage 1: Backup Scheme Without SCQ

Stage 2: With SCQ

Stage 3: With detector

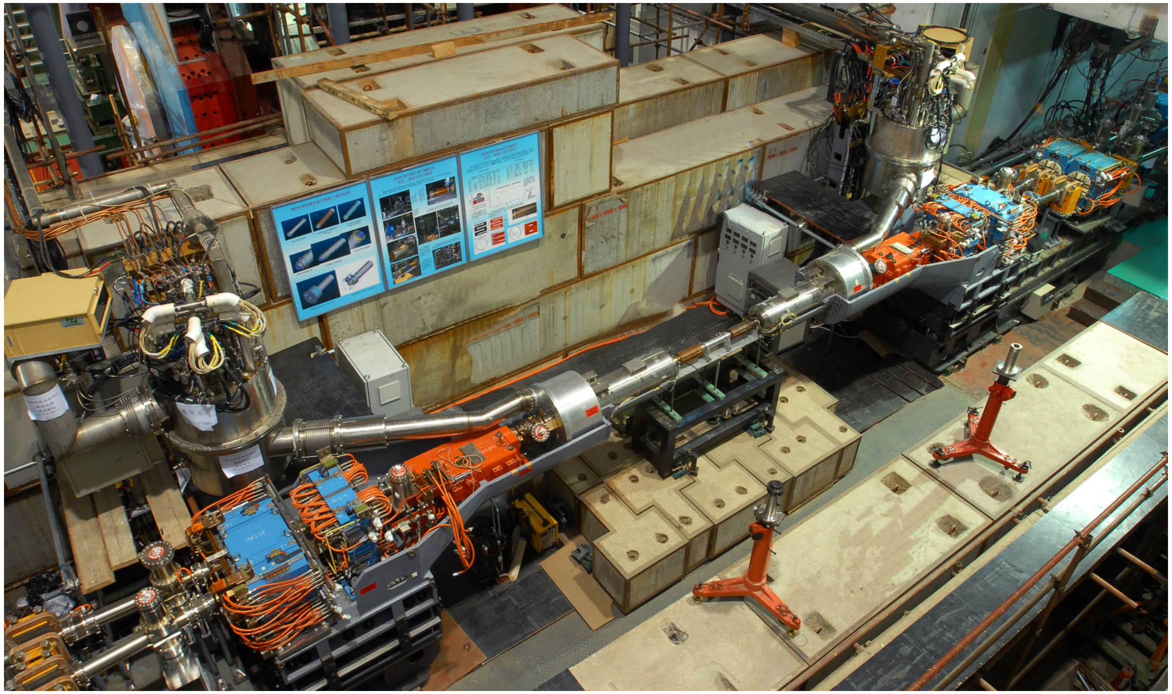
Backup scheme without SCQ

It took about 16 months to complete the installation of BEPCII rings (except the superconducting IR magnets and IR chambers)

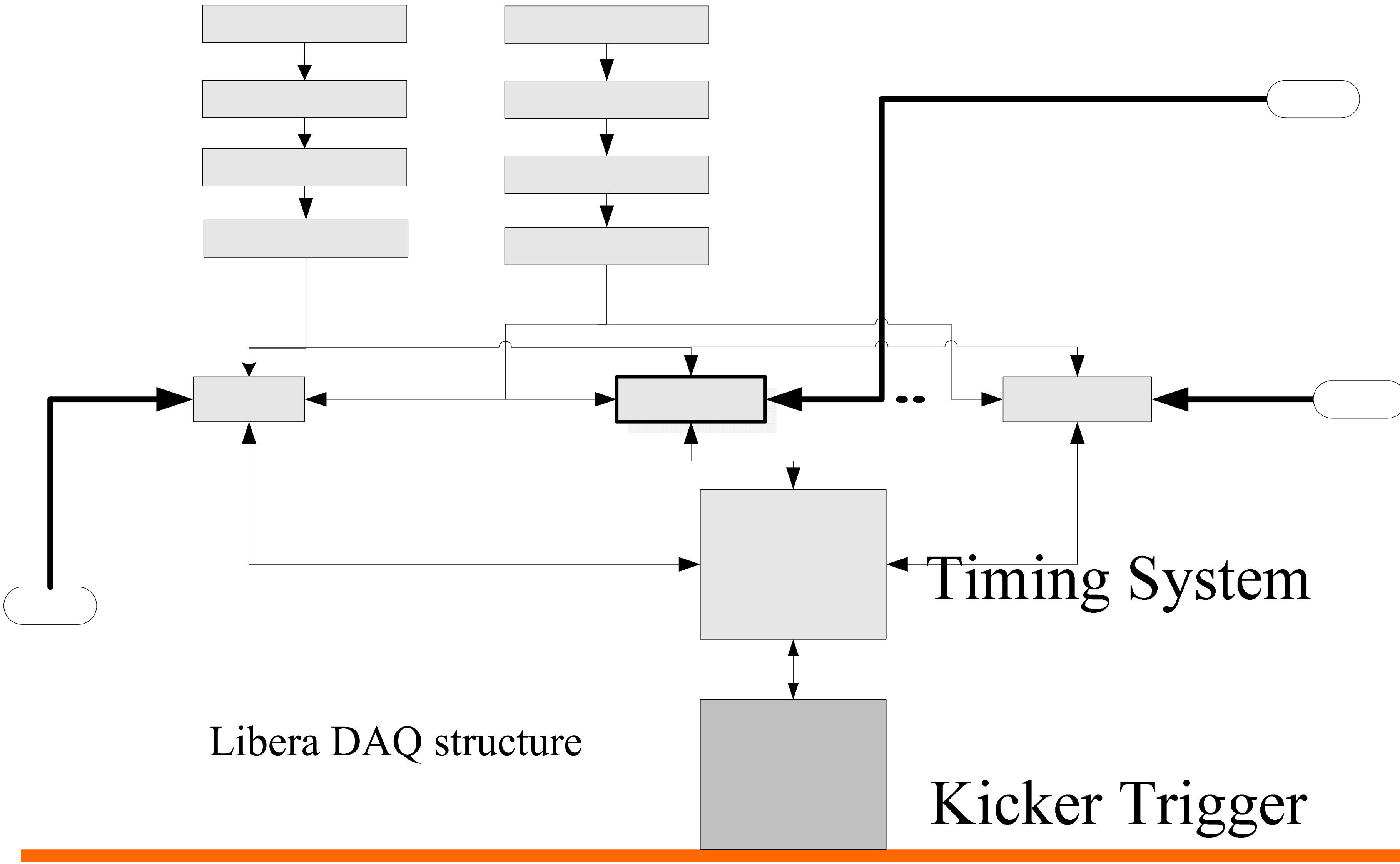


Phase two commissioning with SCQ

The phase two commissioning started from Oct. 24, 2007 by using SC magnets and without BESIII detector. Shut down on March 28, 2008. We realized the 500×500mA collision on Jan. 29. The luminosity over $1\times10^{32}cm^{-2}s^{-1}$ achieved. And also realized the full energy injection (2.5GeV) for SR mode.



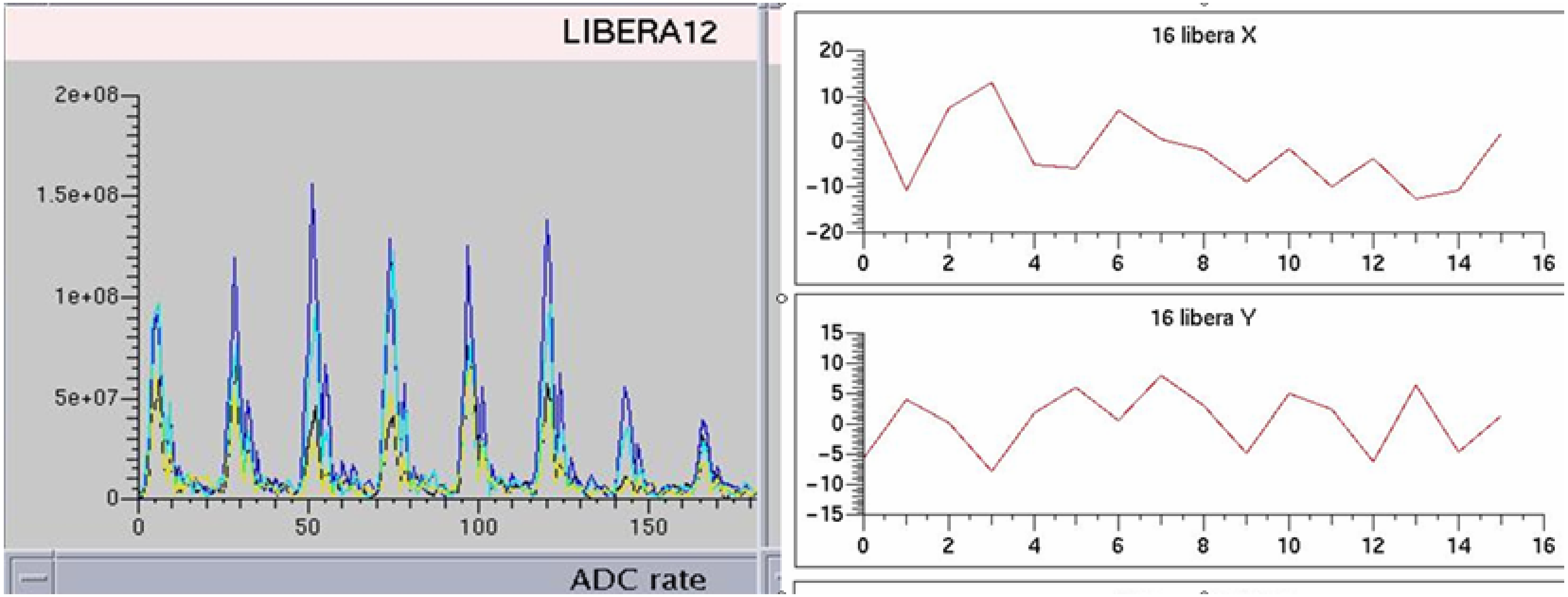
Libera



Libera DAQ structure

Libera—first turn

Libera BPM system was used for first turn beam tuning in BER and BPR commissioning. According to the measurement results of Libera BPM, on axis injection was soon realized by properly adjusting the kicker strength and the correctors along the ring.



Libera BPM signal for first several turns of beam in BER

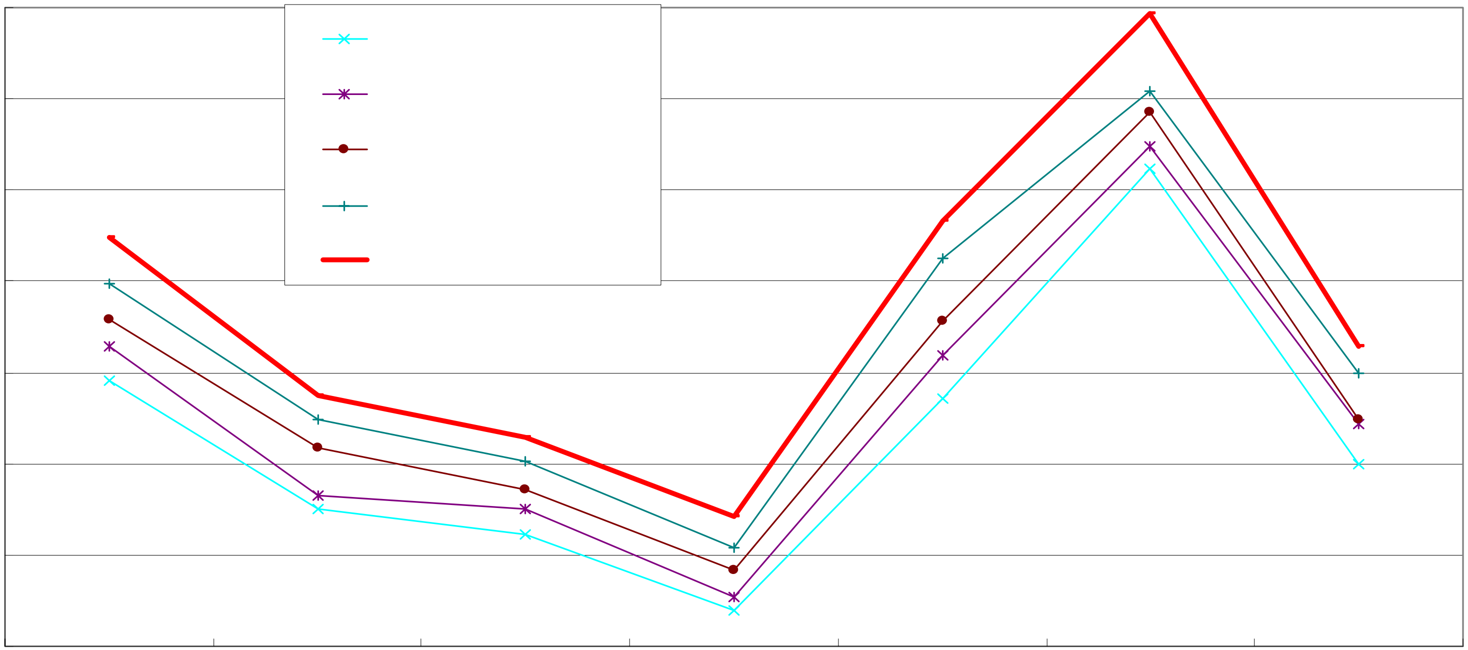
Libera—residual orbit study

Another important role Libera played is the optimization of timing delay of injection kickers and minimization of residual orbit oscillation in BER.

The BEPCII includes two injection kickers and a Lambertson magnet for each ring. The injection layout of two rings is the same. Both two kickers would kick the beam in horizontal plane. The phase advance in the horizontal plane between two kickers is designed exactly 180° which is in order to decrease the disturbance to the circulating beams during the injection.

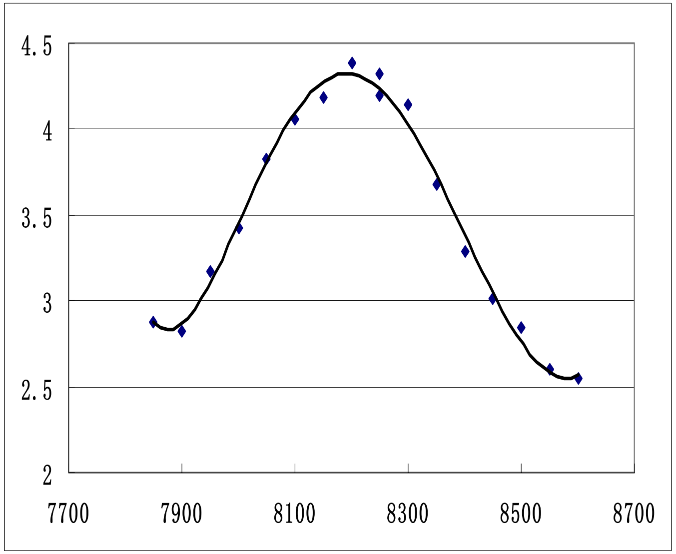
Libera BPM

During the beam injection in BER, we found the injection kickers frequently make beam loss when the voltage intensity of two kickers set at almost same.

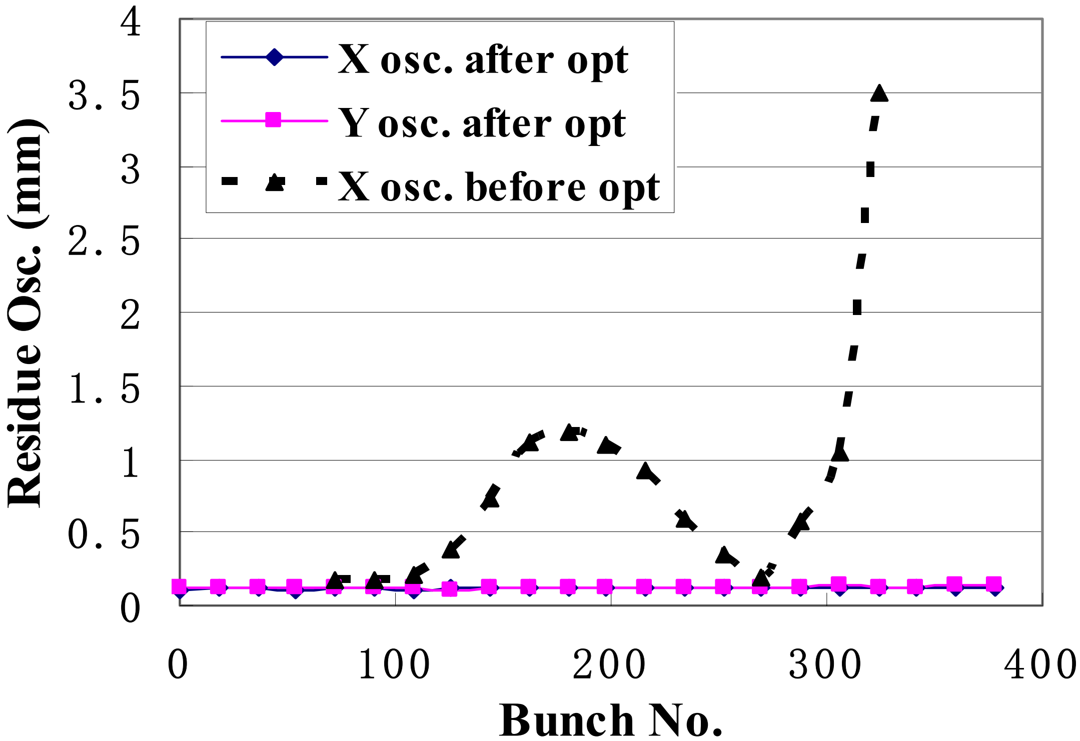


Libera BPM

By optimizing the timing delay and the voltage intensity of two injection kickers, we can reduce the residual orbit oscillation in BER.



K1 Timing delay



Libera —in the future

- Libera has also been used for the on_line tune measurement. But more functions we hope to develop from Libera, such as Post Mortern Data. Also, more information we hope to get from libera, such as beam phase measurement ad so on.

Post Mortem Data

After the Post Mortem Trigger, the data is acquired from history before the trigger occurred. It allows reviewing the causes of critical events, such as a sudden beam loss for example.

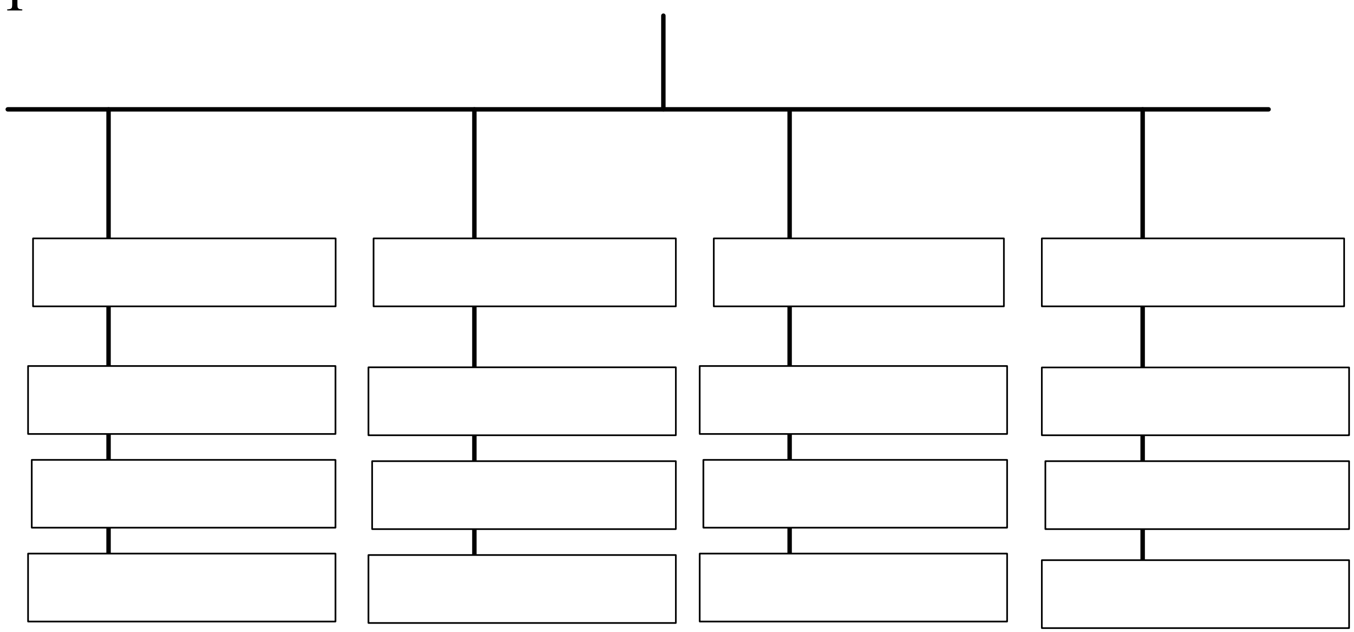
MX_BPM—COD

The main parameters of BPM

Parameters	Unit	Design Value
BPM Accuracy	mm	0.1
BPM Resolution	mm	< 0.01
RF Frequency	MHz	499.8
Harmonic Number	Colliding mode	396
Harmonic Number	SR mode	402
Bunch Current	mA	9.8
Total Beam Current	mA	910
Tunes (ν_x, /ν_y)		6.57 / 7.61

MX_BPM—COD

There are 67 BPMs in each ring (total 132 BPMs, two are for common) for the COD measurement and correction. The system consists of Bergoz MX_BPM, VME64x and ADC boards. Among various analog signals from a MX_BPM board, only the beam position (x and y), Σ and A, B, C, D (four buttons) signals are digitized for regular operational database.

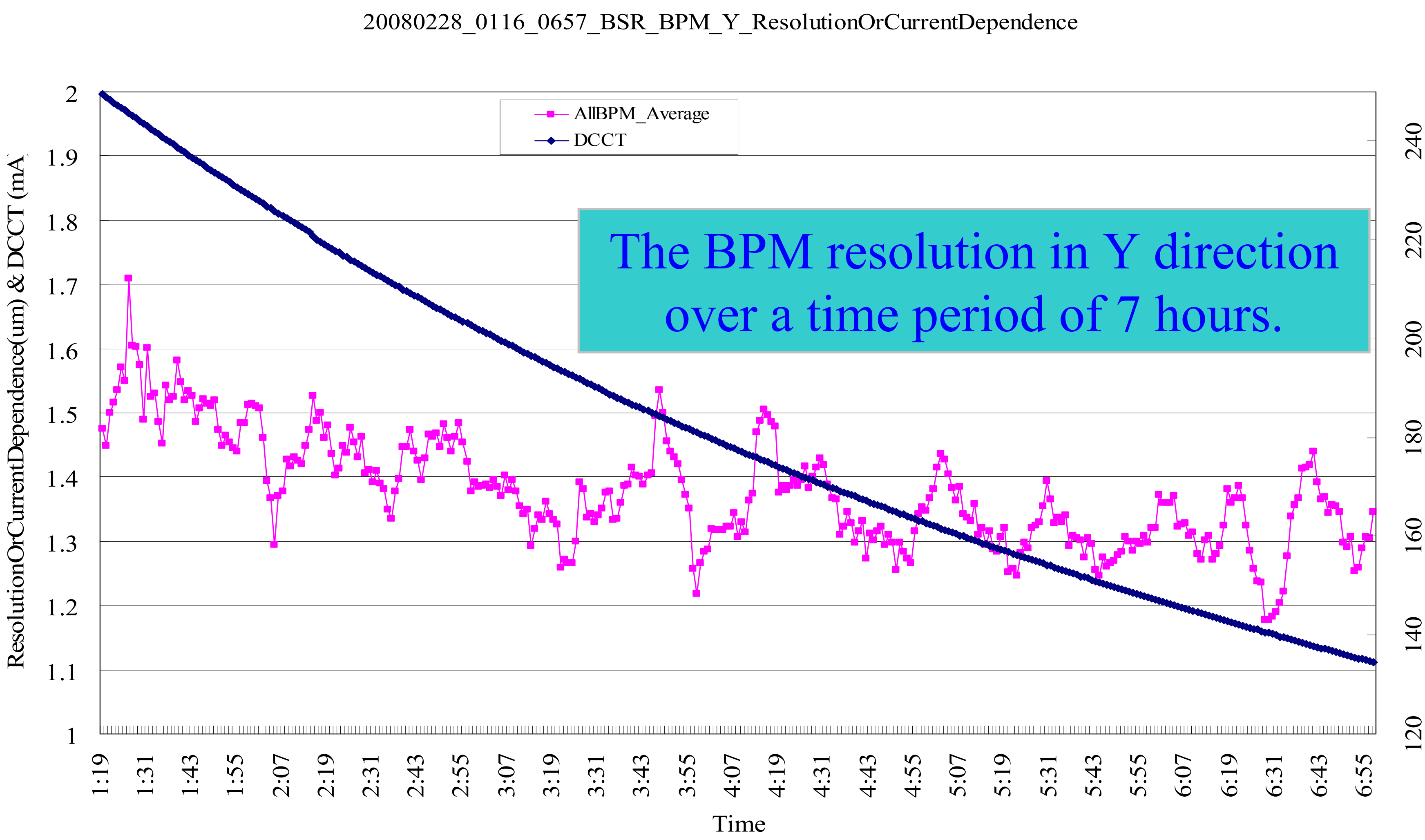


MX_BPM—COD

There are twenty 32-channel 60-kHz 16-bit ADC boards in each ring. The resolution of the position measurement is improved by averaging 30 raw BPM data in the microprocessor. It gives the 2Hz data refreshing rate for double rings.

By taking 16-bit ADC and averaging the raw BPM data, the system resolution is less than 2μm in Y direction within a measuring range of ±5mm and 4μm in X direction within a measuring range of ±10mm, respectively.

MX_BPM—COD



20080228_0116_0657_BSR_BPM_Y_ResolutionOrCurrentDependence
AllBPM_Average
DCCT
The BPM resolution in Y direction over a time period of 7 hours.
ResolutionOrCurrentDependence(um) & DCCT (mA)
Time

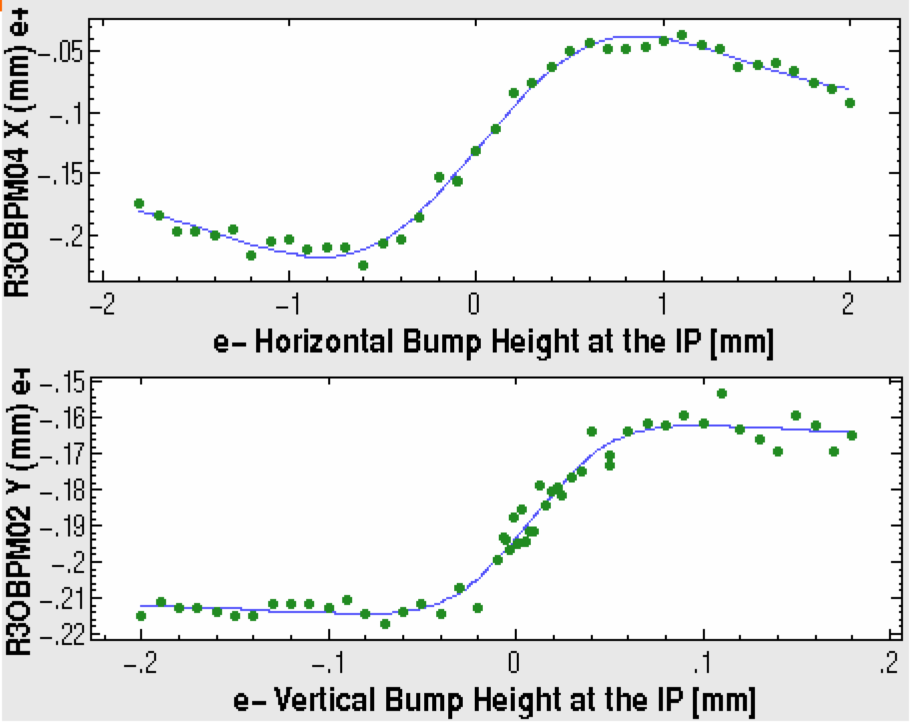
MX_BPM—BBS

For Beam-beam Scan

The vertical β function at IP is one of the key parameters for luminosity. The small beam size means that the BPM system should have a good resolution to satisfy the requirement for beam-beam scan (BBS) on collision tuning. The first beam-beam scan with SCQ at IP was done by 2 μm step on Nov. 18, 2007. For this purpose, an orbit bump around the IP in one ring is used to scan the beam position at the IP, while observing the beam orbit variation in the other ring due to the beam-beam deflection.

MX_BPM—BBS

Positron beam orbit variation due to beam-beam deflection. The lines are the fitted curves for Gaussian bunches.



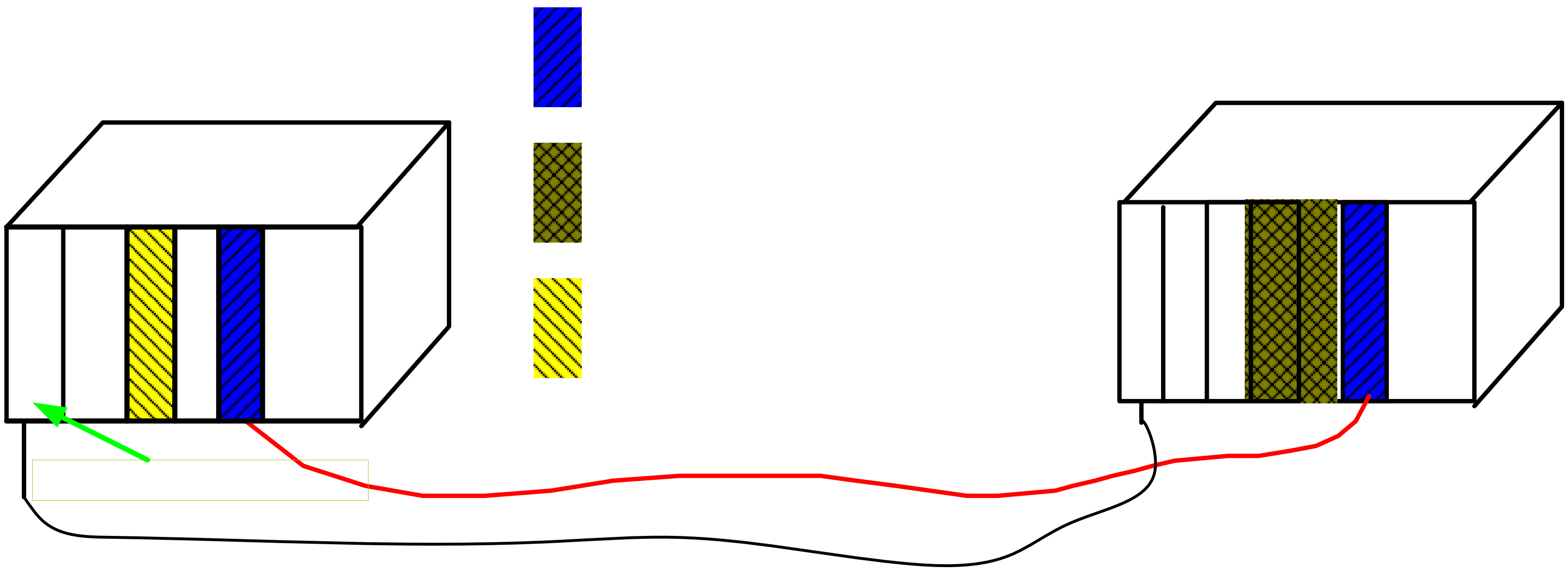
After the various parameters of the two rings being optimized, the electron and positron beams collided successfully on Nov. 18, 2007, with the collision beam currents of 5.2 mA * 5.2 mA. As a milestone of the commissioning, it was the first time for the BEPCII to collide at the designed vertical beta function of 1.5 cm at the IP.

BCM

The bunch current monitor (BCM) system consists of three parts in the hardware layer: the front-end circuits, the DAQ and the bucket selection system. The front-end circuits is located near the storage rings.

The key component of DAQ is a FADC board with model of ECAD-1-081500-1 (1.5GSPS, 8-bit VME board).

BCM



The bucket selection system located in the central control room firstly reads the bunch current data from the shared memory board and then controls the beam pulse from the linac to be injected into the required bucket within 20 ms, which is the repetition period of the linac.

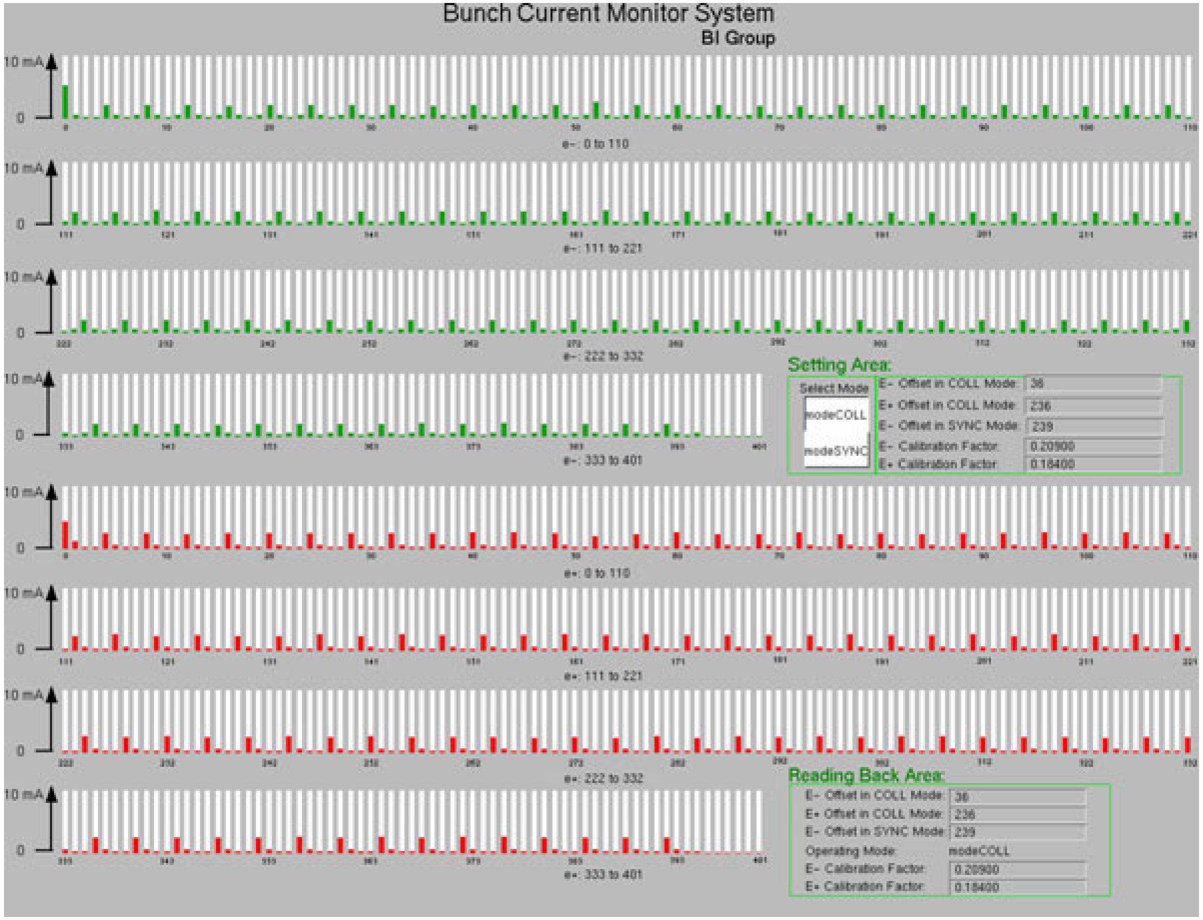
Central control room

BCM

In the software layer, the VME computer MVME5100-0163 in the local station of beam instrumentation runs real-time VxWorks program for the DAQ, while the same type VME com-puter in the central control room runs program based on standard EPICS I/O.

For an 8-bit ADC with maximum input of 500mV, the resolution of BCM system can reach up to 50 pC for an injection beam pulse.

BCM



BCM measurement result on 300mA×300mA multi-bunch collision.

Transverse Feedback

Specifications of the TFB system

RF frequency	MHz	499.8
Bunch spacing	ns	8
Feedback damping time	ms	0.5
Detection frequency	GHz	1.5
Kicker shunting impedance (at 125 MHz)	kΩ	4.0
Total damping voltage per turn	V	800
Kicker power for 800 V	w	106
Bandpass of power amplifier	MHz	250

The growth time of most dangerous coupled bunch modes

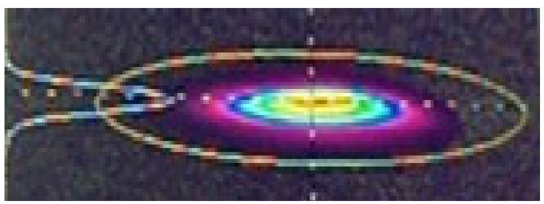
	HOMs	Resistive wall	ECI
Transverse (ms)	26.6	4.3	0.5

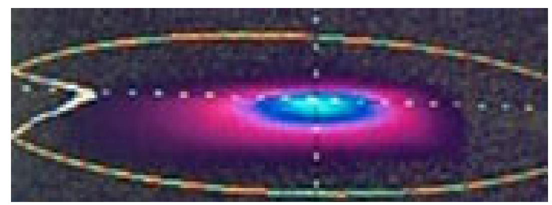
Transverse Feedback System

Because the BEPCII storage rings are small and the limited budget, the transverse feedback system (TFB) was designed by adopting analog system.

Transverse Feedback System

The TFB system successfully operated at the phase two commissioning of BEPCII. In most cases of without TFB, a threshold of beam current often appeared for beam injecting into rings to over 200mA.



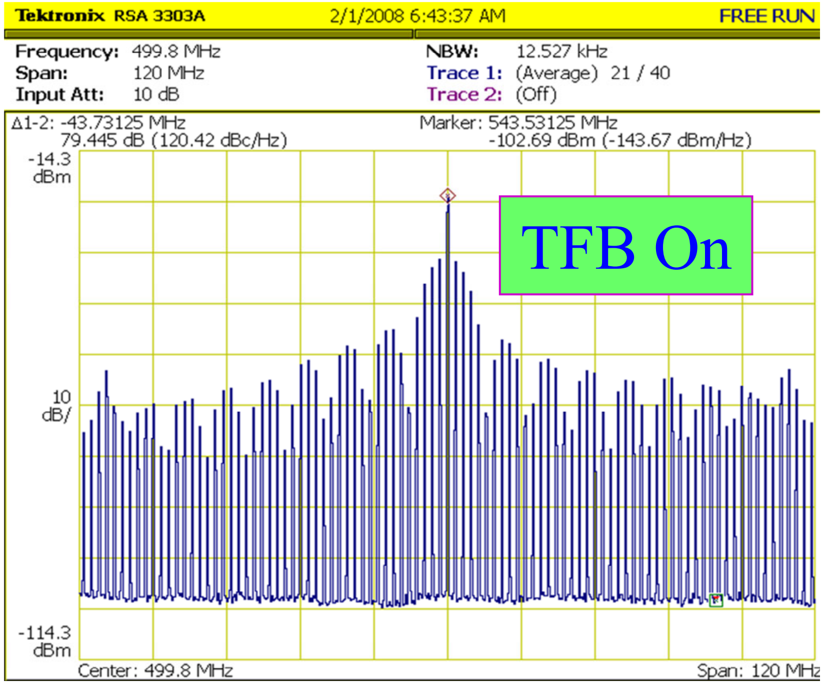


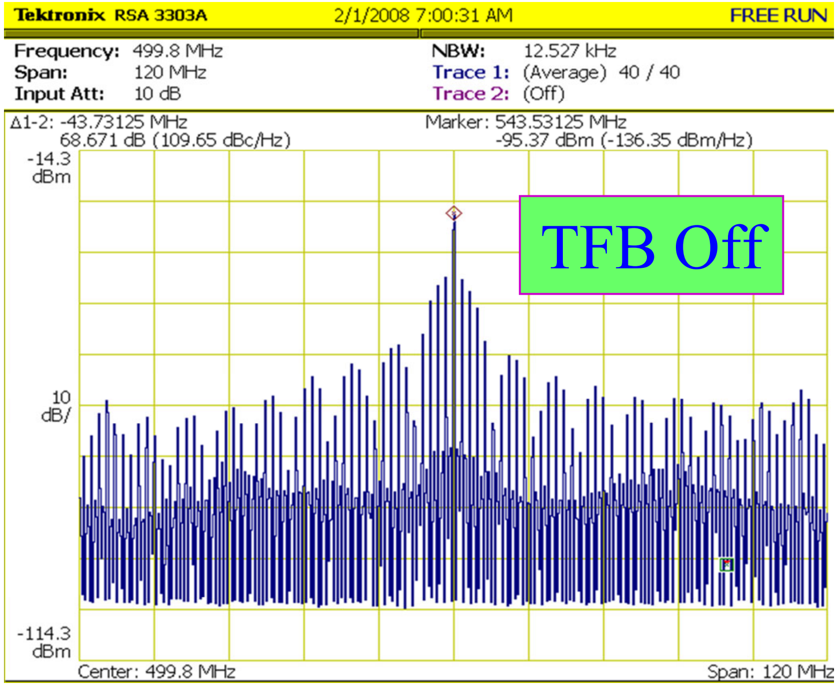
TFB turn on (left) and turn off (right)

The measurement results of SLM with the TFB turning on and off during BEPCII operated on the SR mode.

Transverse Feedback System

The capability of suppressing betatron sidebands can reach to 40dB in both horizontal and vertical directions in designed 125MHz system bandwidth.

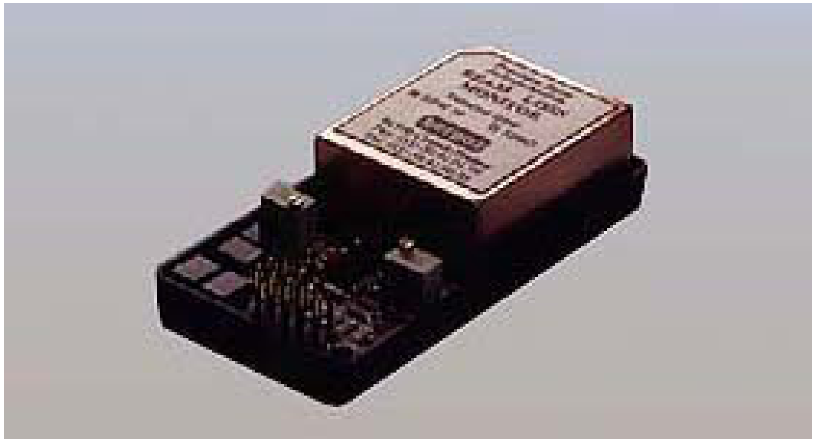


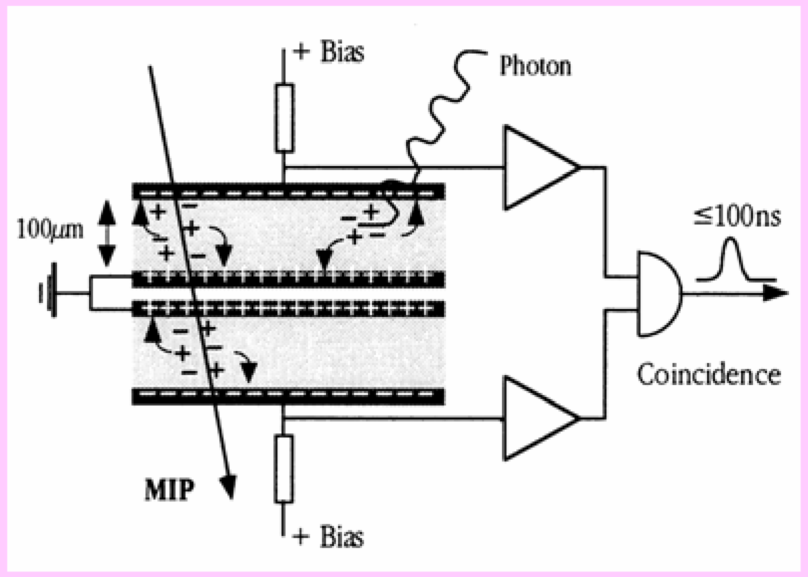


The spectrum measurement results in BPR when BEPCII operated on the colliding mode with 93 bunches and 243mA beam current.

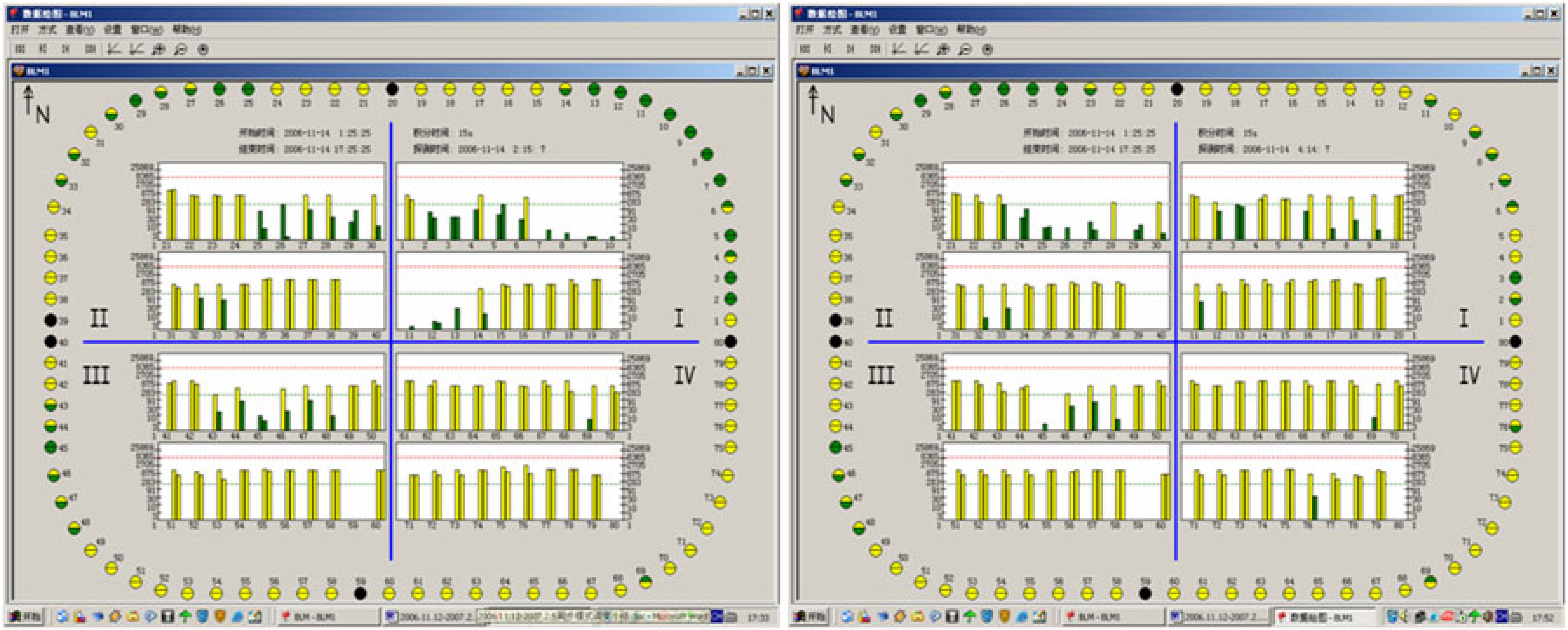
Beam loss monitor

- Sensitive to MIPs (minimum ionizing particles) produced when a particle hits the vacuum chamber.
- Consist of two PIN-diodes mounted face to face. An AND-gate detects the coincidence of pulses from the two PIN-diodes.
- MIPs cause ionizations in both PIN-diodes, a coincidence occurs and an output pulse is generated.
- Not sensitive to photons.
- Maximum count rate: 10MHz





Beam loss monitor



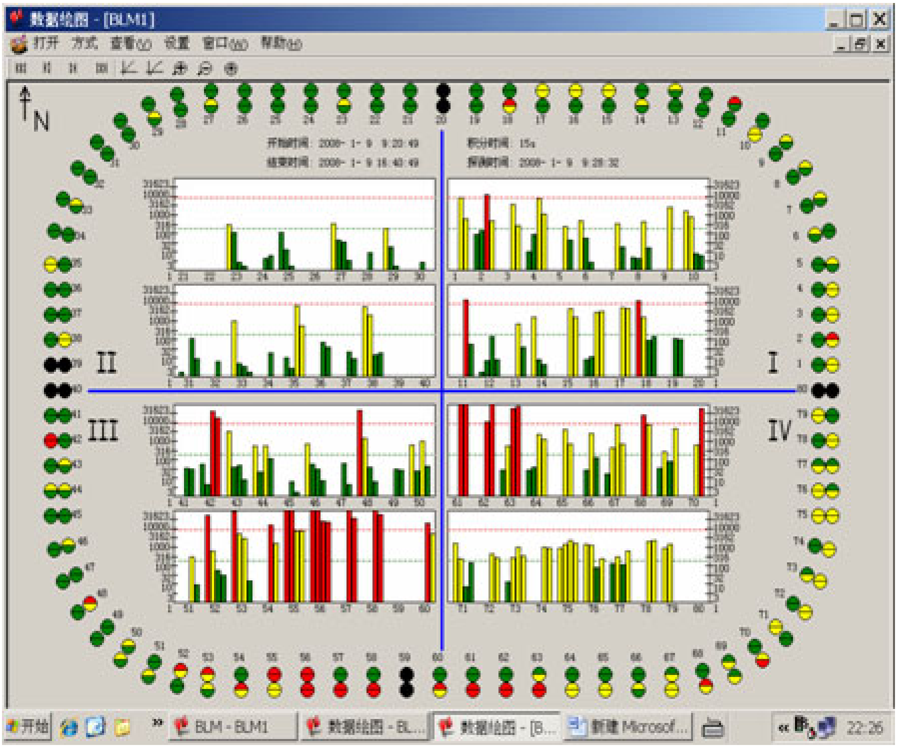
By using BLM and BPM, we found a wrong connection of a power supply to R1OQ09 quadrupole magnet during the first beam circulating in the outer ring for the dedicated SR mode (BSR) at the phase one commissioning.

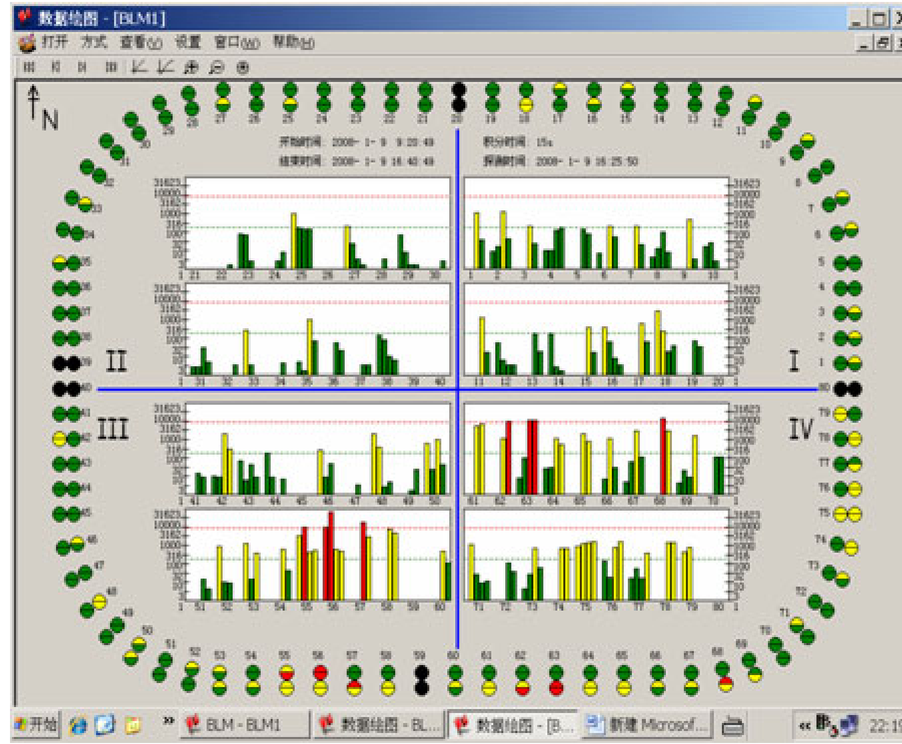
Beam loss monitor

We try to use the BLM system for the BESIII detector background study. From the BLM measurement results, we found that:

- The electron beam injection brings more beam loss than positron beam injection.
- The collimators at present locations in the electron ring didn’t show obvious effects to reduce the background, but the collimators at transport line show obvious effects to reduce the background during the electron beam injection.
- On the SR mode, the beam loss in IR is small.

Beam loss monitor





Aperture $8\sigma_x$
Energy spread ±0.8%

Aperture $5\sigma_x$
Energy spread ±0.5%

Dose measurement with BLM in the rings during e^- injection

Beam loss monitor

Because BEPCII doesn't have a dedicated abort system for dumping the beam, so the beam abort became a problem. Similarly, according to the BLM measurement results, the new abort method was decided by using injection kickers and local orbit bump.

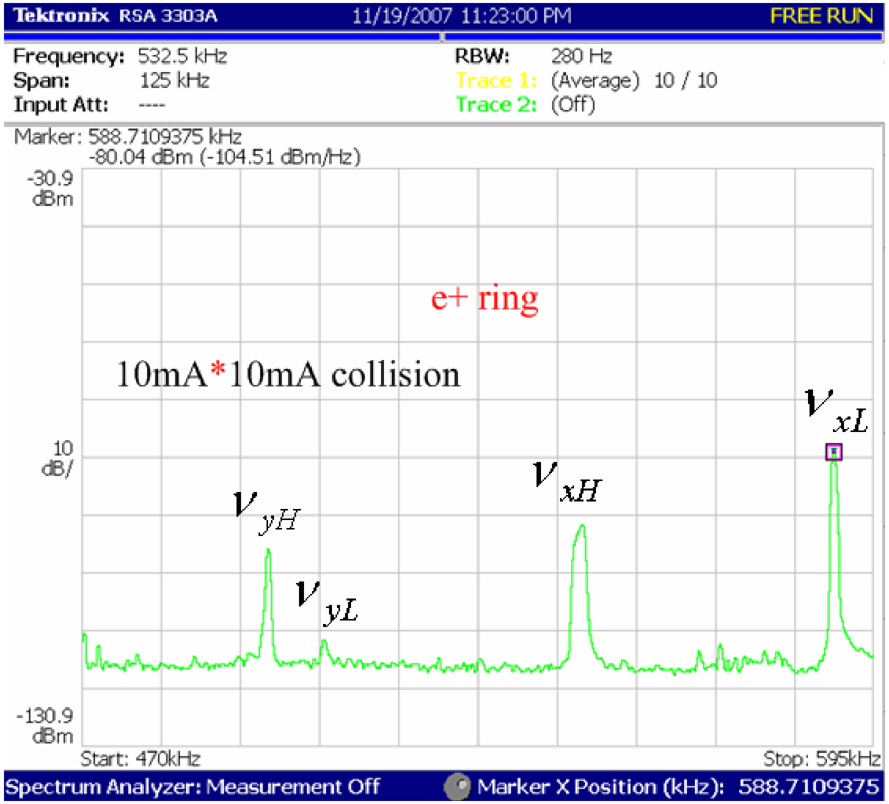
- Setting the collimator for energy spread ±0.3% and emittance aperture with ±3mm, namly ±1.7σ in the e^- transport line.
- By using injection kickers and a local bump.

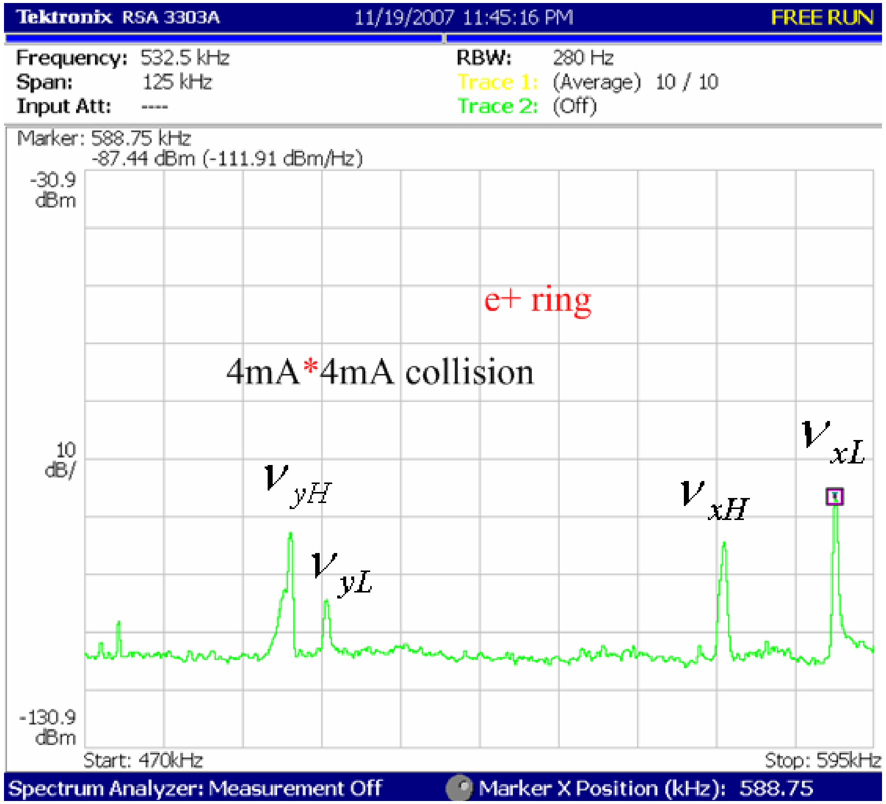
The dose rate in the IR is reduced to an acceptable level!

Tune measurement

The beam-beam tune shift can be used to evaluate the collision luminosity. Before the dedicated luminosity detector can offer the measured luminosity data for the accelerator commissioning, the sweep frequency method was used for the tune measurement while the transverse feedback kicker serving as the shaker to excite the beam oscillation. The perturbed tunes of each ring corresponding to the so called high tune (H) and low tune (L) modes have been observed with spectrum analyzer.

Tune measurement



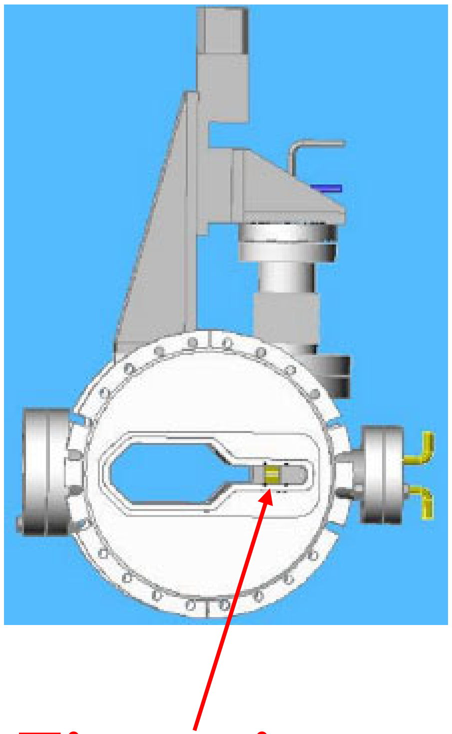


Measured tunes due to beam-beam effects

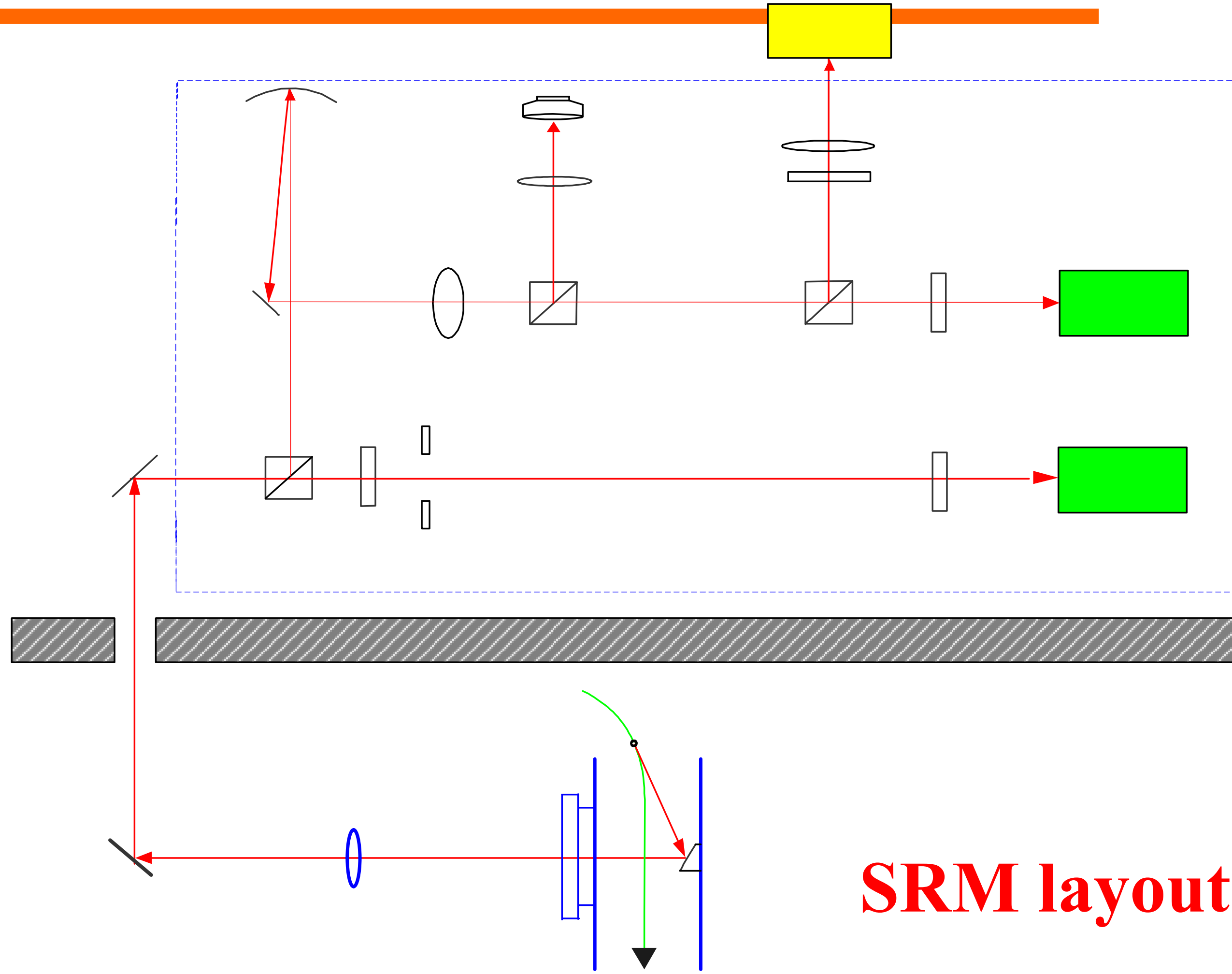
Synchrotron Light Monitor

Synchrotron light monitors (SLM) just keep the same optics structure with BEPC used, only first mirror and its vacuum chamber were replaced by new one.

Synchrotron Light Monitor

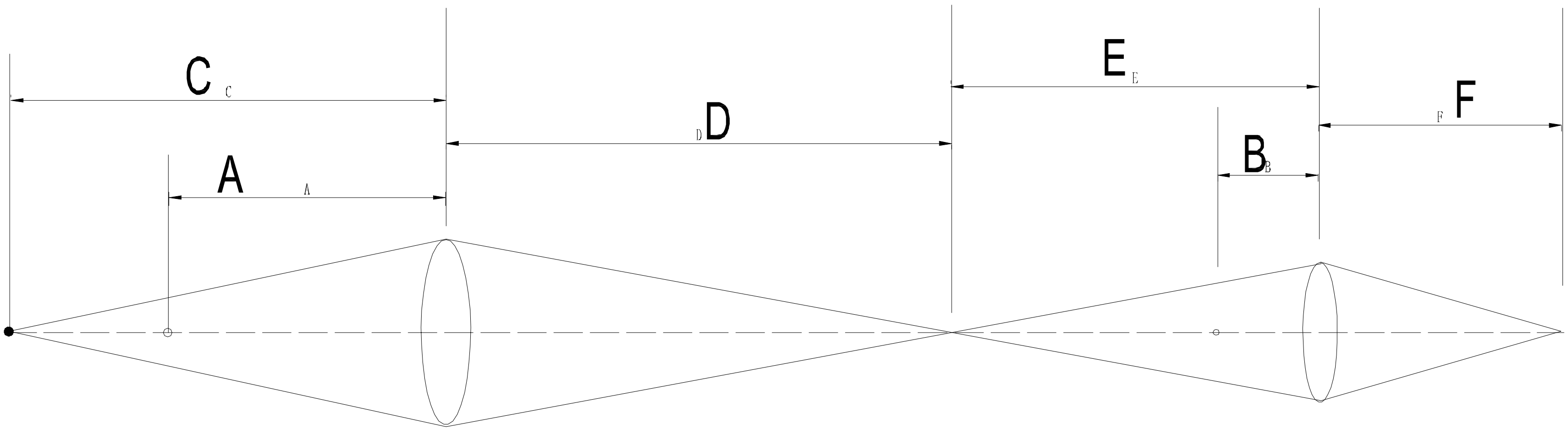


First mirror



SRM layout

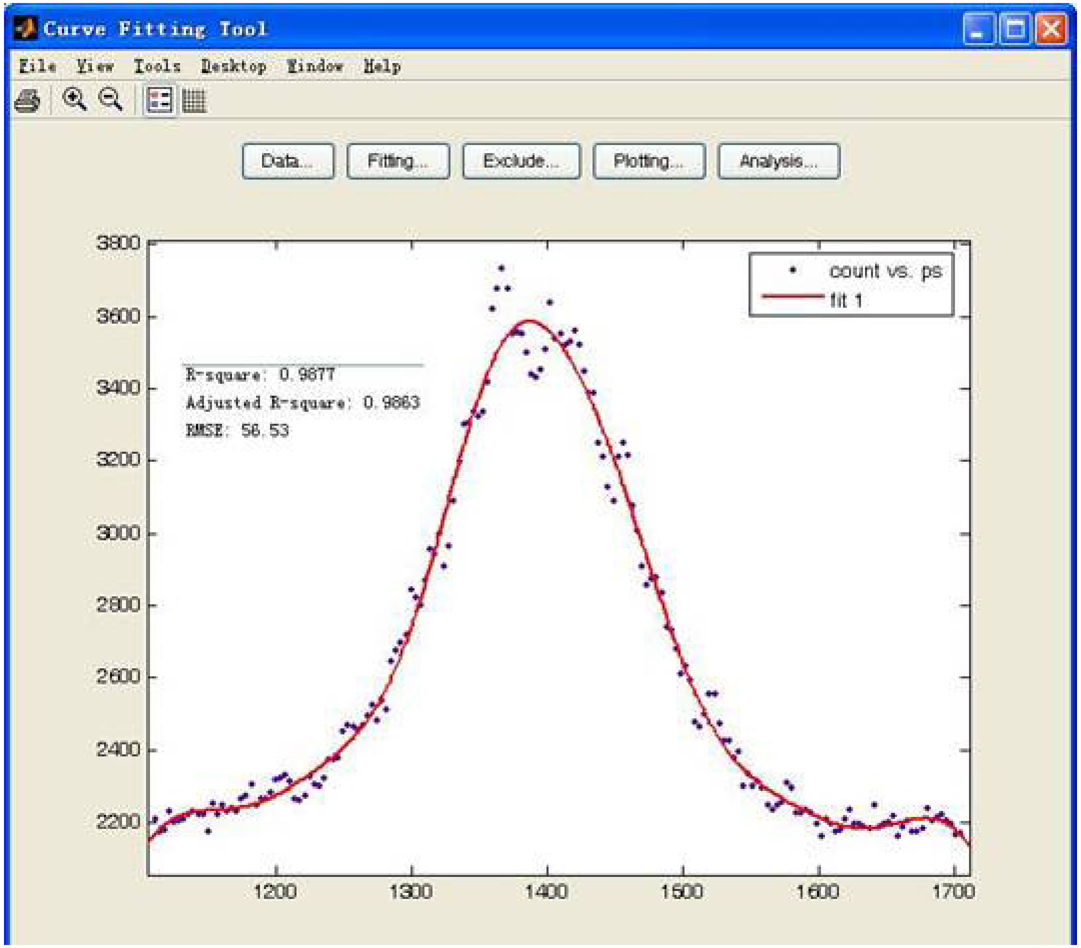
Synchrotron Light Monitor



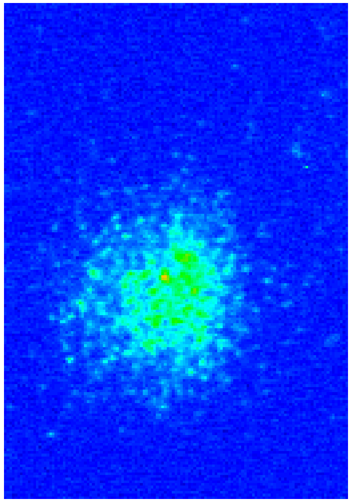
The calibration of the transverse magnification of the imaging optics had been done with beam by using the method of sliding the lens. The measurement error of beam size including chromatic error, depth of field error, diffraction error and curvature error are also analyzed.

Synchrotron Light Monitor

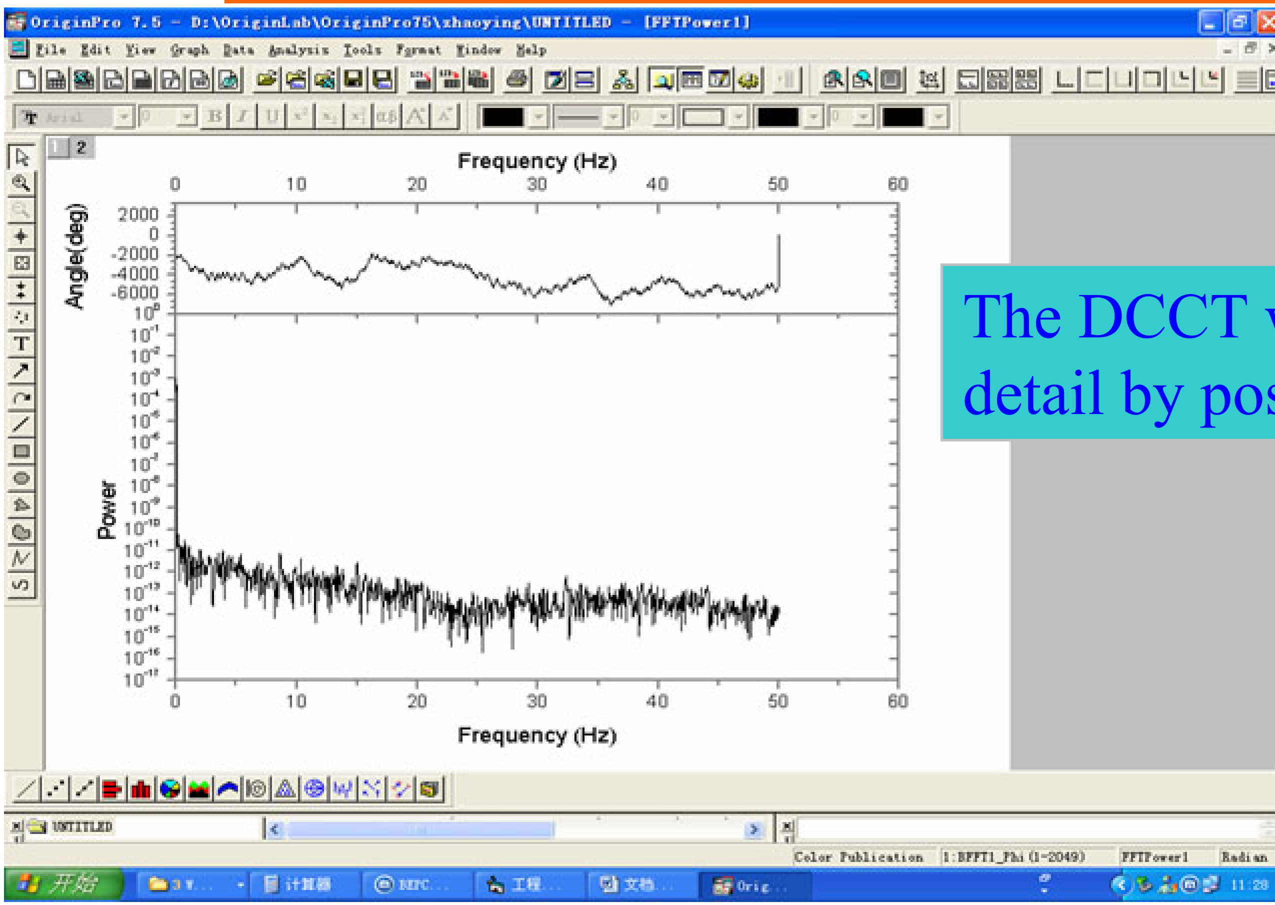
Example of bunch length measurement results of electron ring



When the current of single bunch is 10mA and RF voltage is 0.8MV, the bunch length is about 59ps.



DCCT



The DCCT will be introduced in detail by poster in this workshop.

Noise over 50Hz, -110dB， 0.002mV (RMS),
In 2A ~ 10V range 0.4uA (RMS) in 2 second

DCCT

Here only introduces the issues related to the high beam current. Along with beam intensity growth, particularly when the beam current is higher than 500mA on colliding mode, the heating effect due to HOM clearly appeared in the DCCT, with the temperature rising shows the feature of sensitive to the bunch current. Though this problem had been considered on the shielding design, such as the RF shielding of copper layer to bridge the image current rerouting on the ceramic gap was adopted, but its capacity seems not big enough for some low frequency parts of the image current. So, some capacitors will be connected to improve the RF shielding in machine shut down.

Summary

Two phases BEPCII commissioning have been completed. Various beam instrumentation system played important roles during the each commissioning stages. However, there are still much works to do, such as to eliminate the jitter happened in BCM, to carefully tuning the phase to keep the TFB working stable, to solve the heating problem in DCCT, more functions developed for Libera in order to get more beam information and so on.

Acknowledgement

We appreciate many people from SLAC, LBNL and KEK for their continuous help.

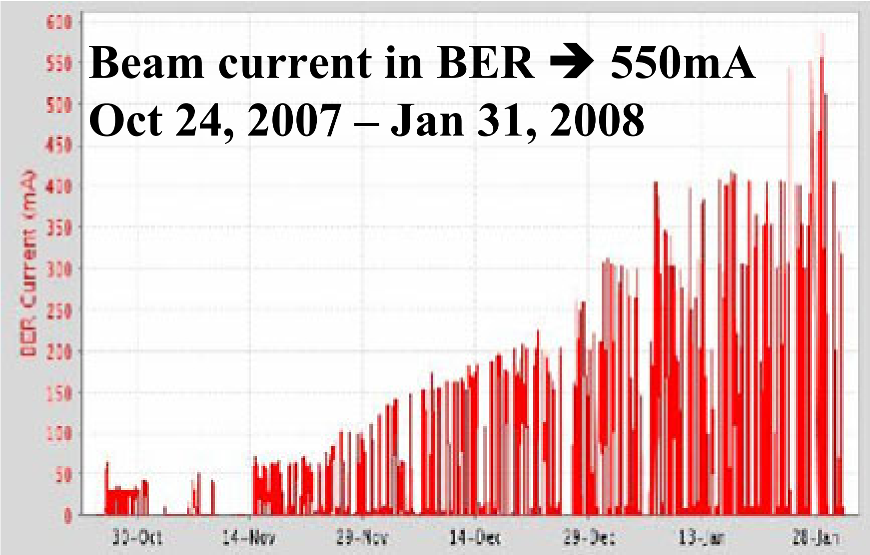
- Dr. Alan S. Fisher joined the first week of BSR commissioning, giving helpful advices.
- Dr. Tobiyama and Dr. John byrd give us help on the transverse feedback system commissioning.
- Dr. Michael Abbott gives help on the code of Libera system.
- The companies of Bergoz and Instrumentation Technologies also give technical supports on the application of their products.
- Thanks also go to R. Hettel, the BEPCII IMAC member.

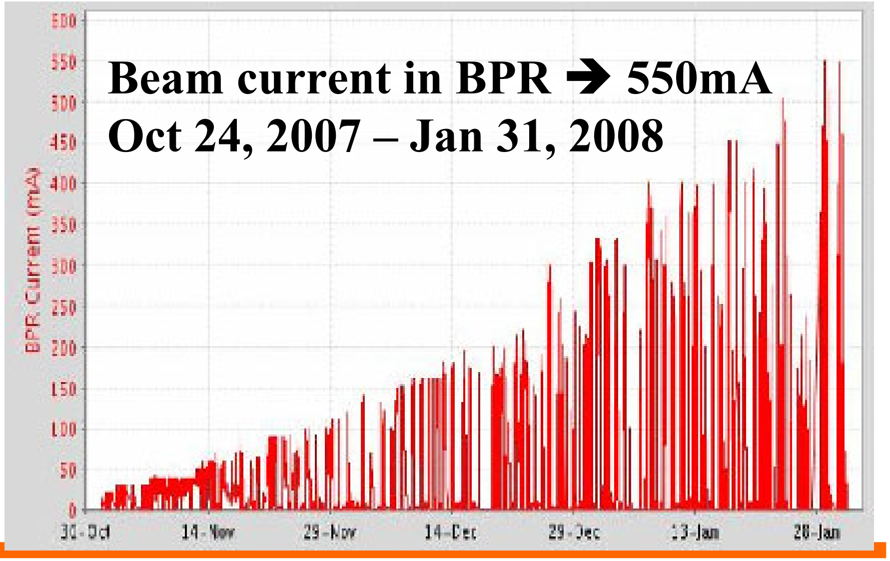
Thank You for Attention

The road to high beam current

- Optics optimization： Twiss parameter corrected to design velues, orbit correction, etc.
- High beam current: Beam dose cleaning vacuum, RF conditioning, bunch-by-bunch feedback, etc.
- High luminosity： tune scan, collision optimization, single bunch current, more bunches ， etc.

As the result, the beam current in collision get higher than 530mA.





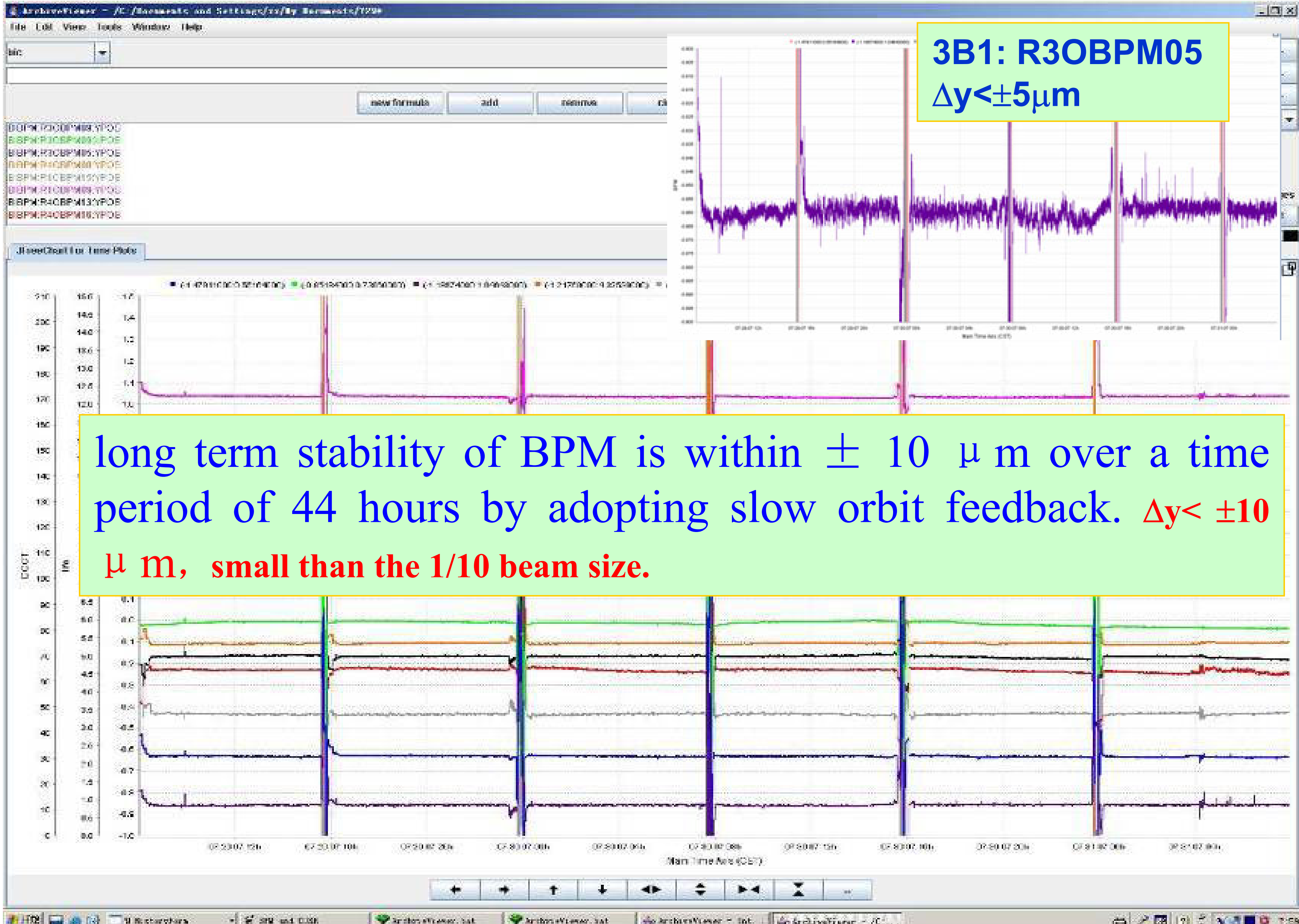
The phase one highlight

Nov. 18, 2006, First e- beam stored in BSR.
Dec. 25, 2006, SR user experiment started (Beam over 100mA @ 2.5GeV)
Feb. 02, 2007, First run of SR mode completed

Feb. 6, 2007, BER commissioning started. 3 hours later, beam stored.
Mar. 3, 2007, BPR commissioning started. Took one day, beam stored.
Mar. 25, 2007 First collision of BEPCII realized on
May 14, 2007, 100mA* 100mA collision with luminosity over BEPC

July 28, 2007, realized the long term orbit stability within ± 10 μm over a time period of 44 hours by adopting slow orbit feedback.

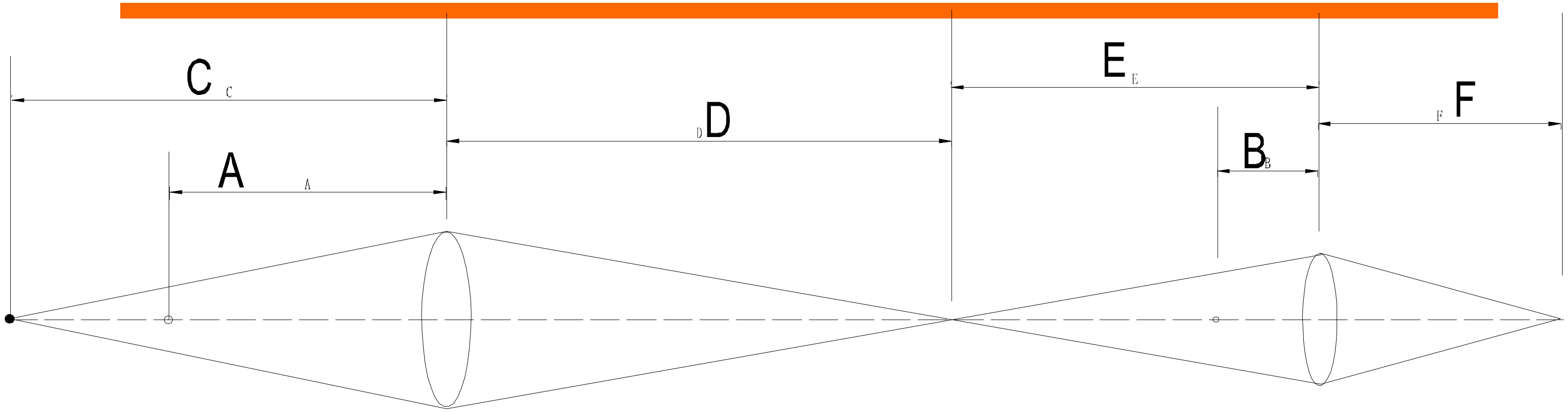
July 31, 2007, SR mode reached up the design goal (Beam over 250mA @ 2.5GeV).



3B1: R3OBPM05
Δy<±5μm

long term stability of BPM is within ± 10 μ m over a time period of 44 hours by adopting slow orbit feedback. **Δy< ±10 μ m， small than the 1/10 beam size.**

Synchrotron Light Monitor

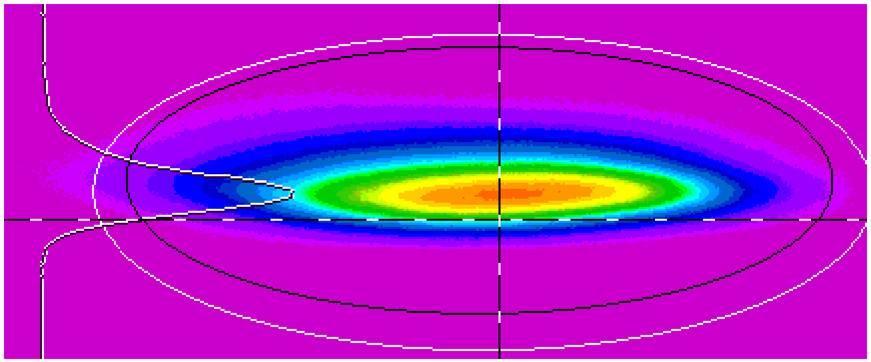


UV AND VISIBLE LIGHT DIAGNOSTICS FOR THE ESRF STORAGE RING

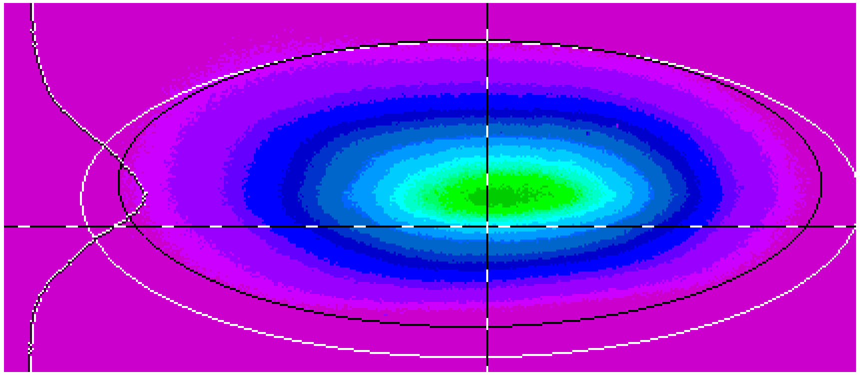
K.Scheidt, Machine Division, ESRF,France

The calibration of the transverse magnification of this imaging system is needed to obtain measurements of absolute dimensions. This is done in a very efficient, simple and inexpensive way by using individual tranverse m-metric slides for each of the three components (2 lenses + CCD camera). Displacing each of these components a precise value in one plane represents a transverse source point displacement of the same value (but of the opposite sign) and a displacement of the beam spot on the CCD matrix of that value multiplied by the total-magnification.

Synchrotron Light Monitor



7.3mA*7.3mA, no colliding



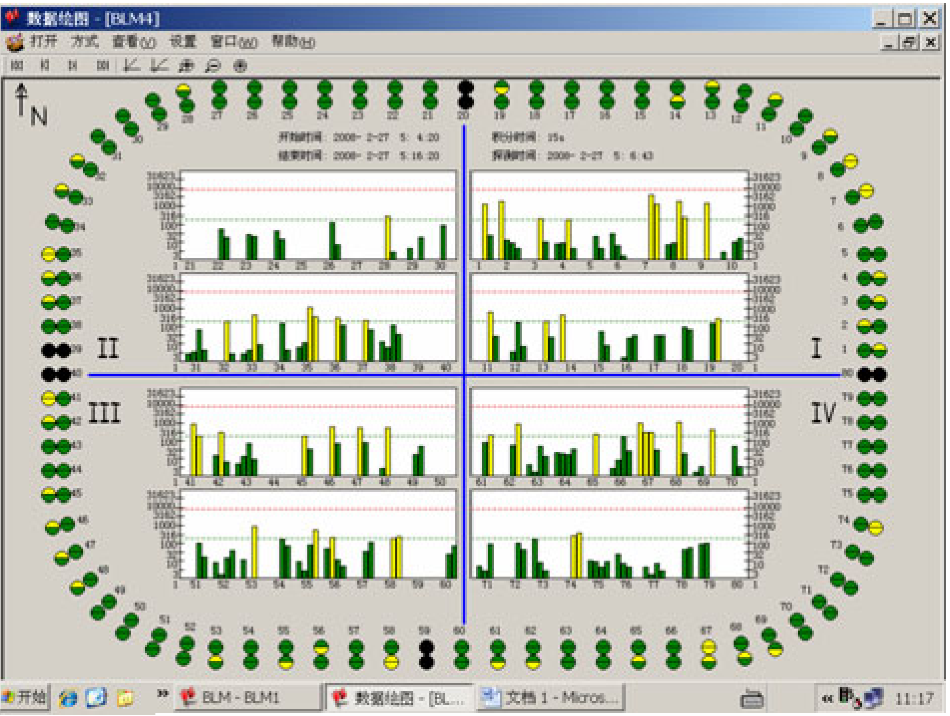
7.3mA*7.3mA, colliding

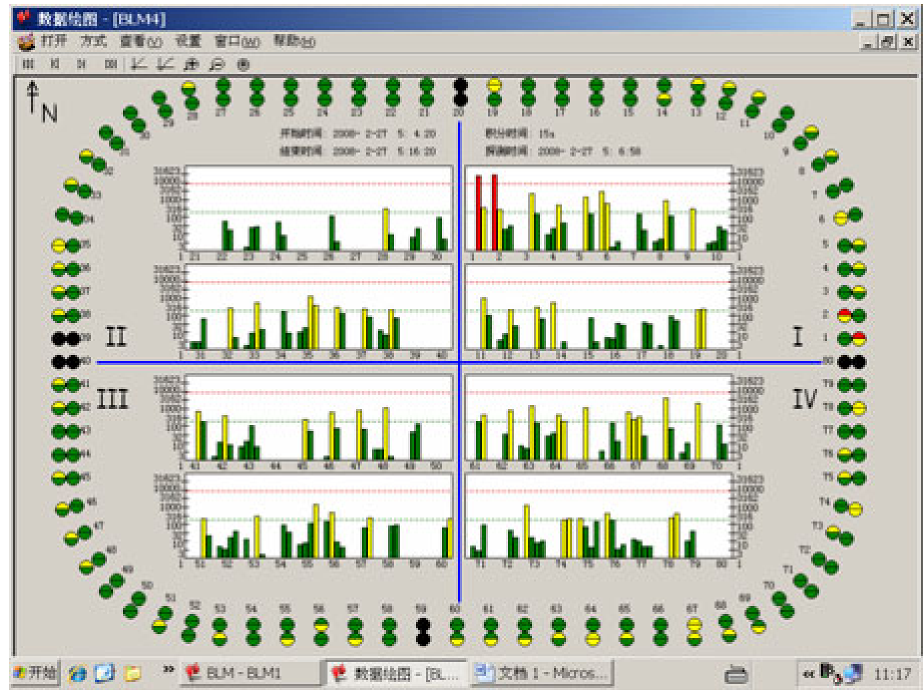
Transverse Feedback System

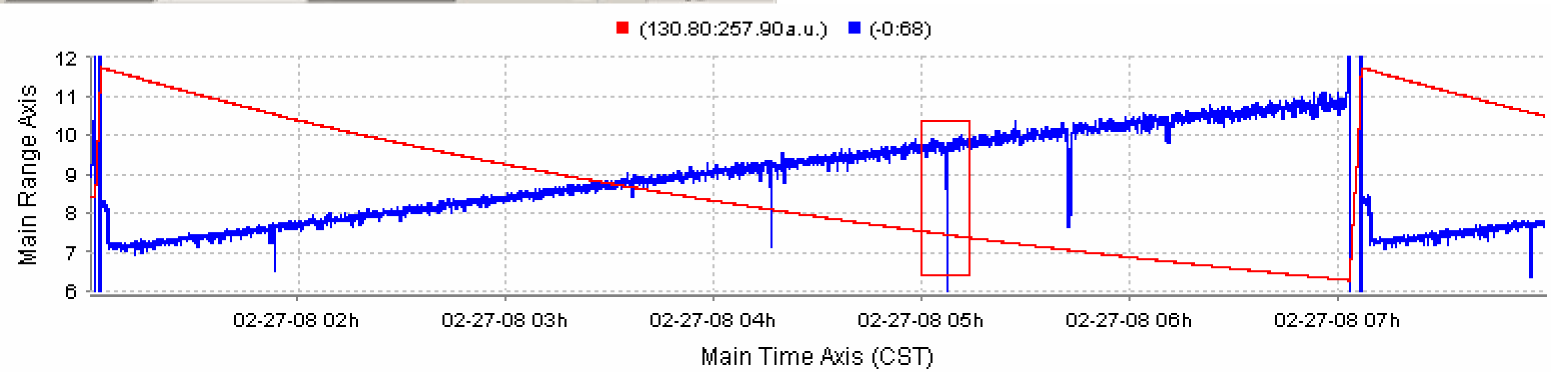
BEPCII designs for operating with every other 4-bucket filled with a bunch spacing of 8 ns (62.5-MHz bunch frequency) and high beam current of about 1 A on the colliding mode. The number of bunches in each ring is 93 and 99 with and without a small ion clearing gap, respectively. According to estimations of the growth time of most dangerous coupled bunch modes (4.3 ms for resistive wall and 0.5 ms for electron cloud) are shorter than the radiation damping time of 25 ms in the transverse direction. The design goal of the feedback damping time is set to 0.5 ms in the transverse directions.

In order to increase the shunting impedance, the length of damping kicker was selected to match 125-MHz bunch frequency.

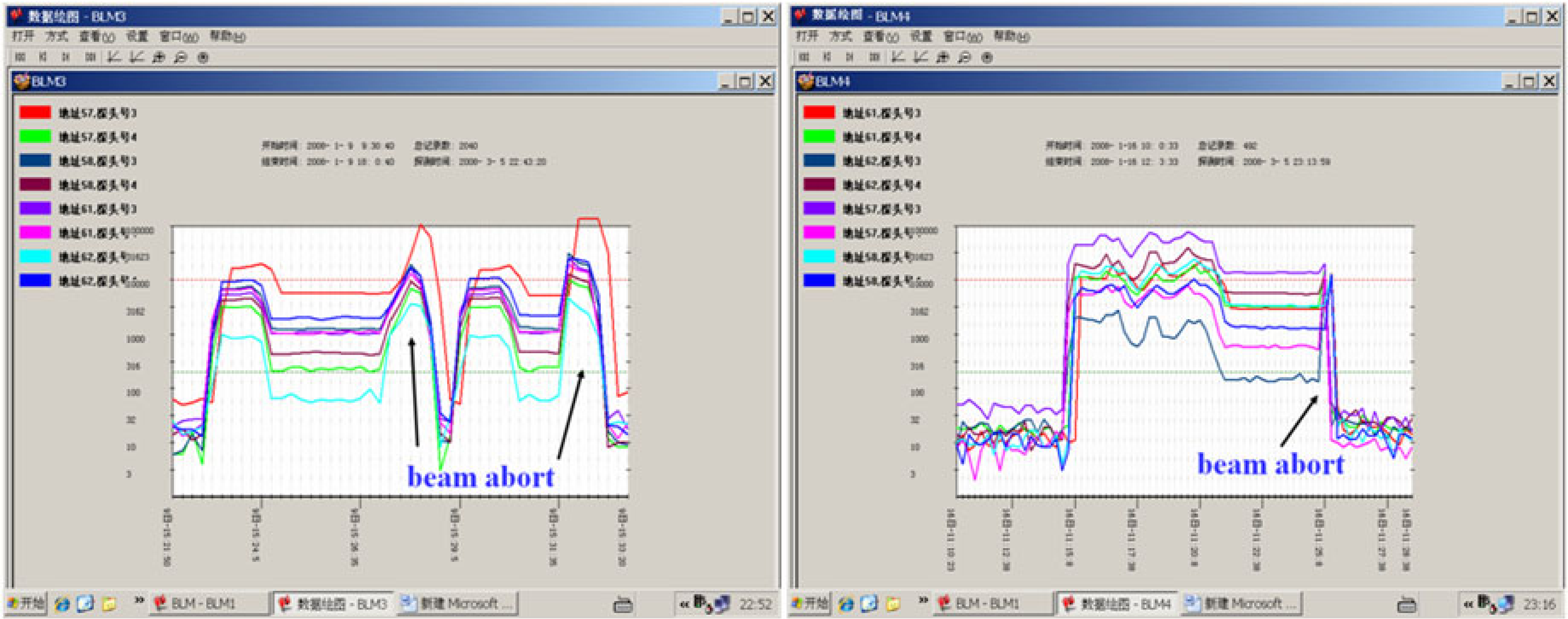
Beam loss monitor







Beam loss monitor



Dose measurement with BLM at IR