The BEPCII: Status and Early Commissioning

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Outline

1. Introduction
2. Progress on accelerator
3. Early Commissioning of Rings
4. Beam performance
5. Progress on Cryo. & SCQ
6. Plan & Schedule
7. Concluding Remarks
8. Acknowledgement

1. Introduction--Upgrade project of BEPC

BEPC--Constructed in 1984 –1988; Operation 1988-2005

Single Ring collider, Beam energy: 1 – 2.8 GeV

Physics Run：Lum. $10^{31}cm^{-2}s^{-1}$ @ 1.89GeV, 5 month/year

Syn. Rad. Run：140mA @ 2.2 GeV, 3 month/year

Design Goals of BEPCII

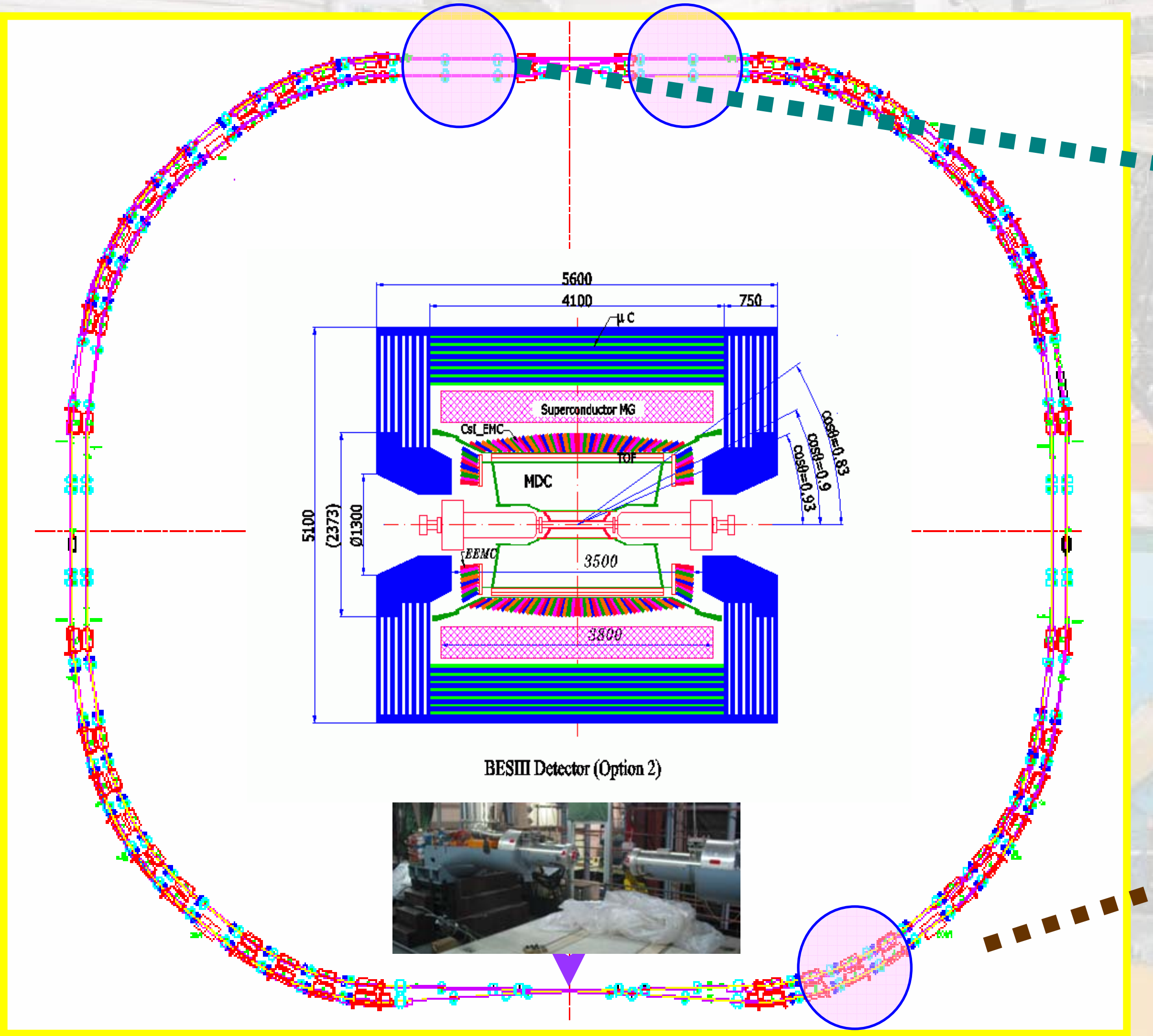
The BEPCII continues to serve the purposes of both high energy physics experiments and synchrotron radiation applications.

Beam energy range	1–2.1 GeV
Optimized beam energy region	1.89GeV
Luminosity @ 1.89 GeV	1×10^{33} $cm^{-2}s^{-1}$
Injection from linac	Full energy injection: E_{inj}=1.55–1.89GeV
Dedicated SR operation	250 mA @ 2.5 GeV

Main Parameters

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

Accelerator--Three Rings Structure



Main Milestones of BEPCII Accelerator

January 2004	Construction started
May. 4, 2004	Dismount of 8 linac sections started
Dec. 1, 2004	Linac delivered e^- beams for BEPC
Mar. 19, 2005	First e^+ beam of 50mA obtained
July 4, 2005	BEPC ring dismount started
Mar. 2, 2006	BEPCII ring installation started
Nov. 13, 2006	BEPCII ring commissioning started
Nov. 18, 2006	First e^- beam stored in the ring
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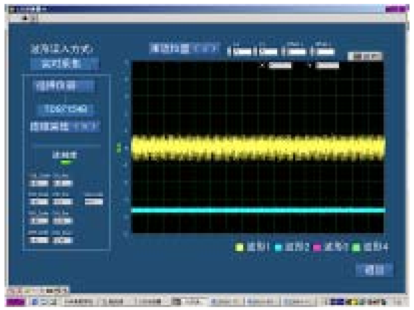
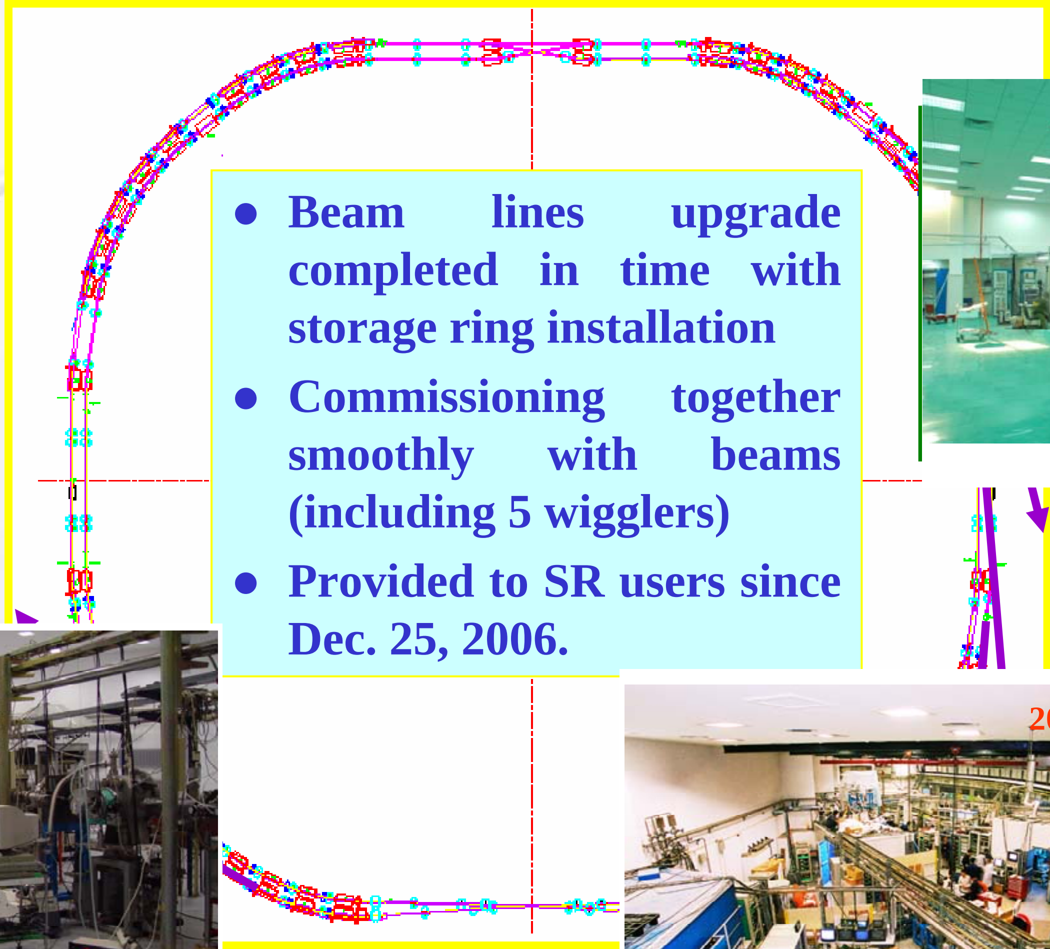


Progress of BESIII Detector

- Most sub-detectors completed and under commissioning
- Field mapping of SSM will be started soon
- EMC installation planned in Sep.

  …
- Roll in scheduled in Mar. 2008

Progress BSRF



- Beam lines upgrade completed in time with storage ring installation
- Commissioning together smoothly with beams (including 5 wigglers)
- Provided to SR users since Dec. 25, 2006.

15 # Experimental Hall

13 # Experimental Hall

12# Experimental Hall

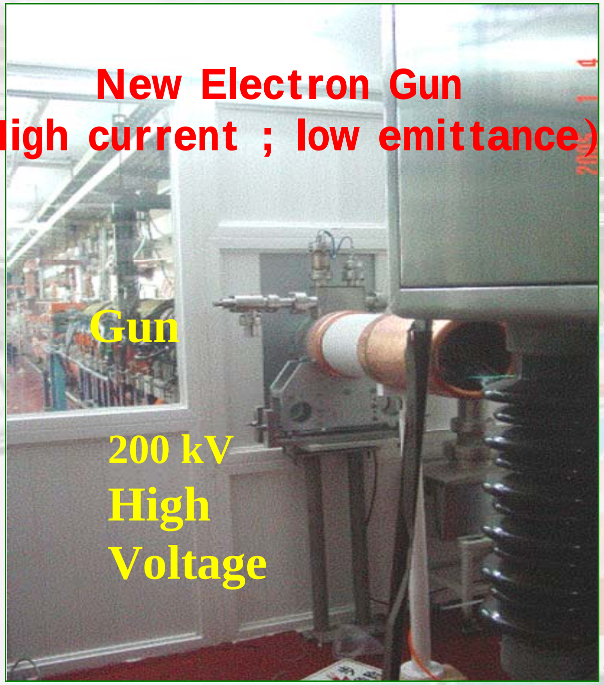
2. Progress of Accelerators

- Injector Linac
- Storage Rings

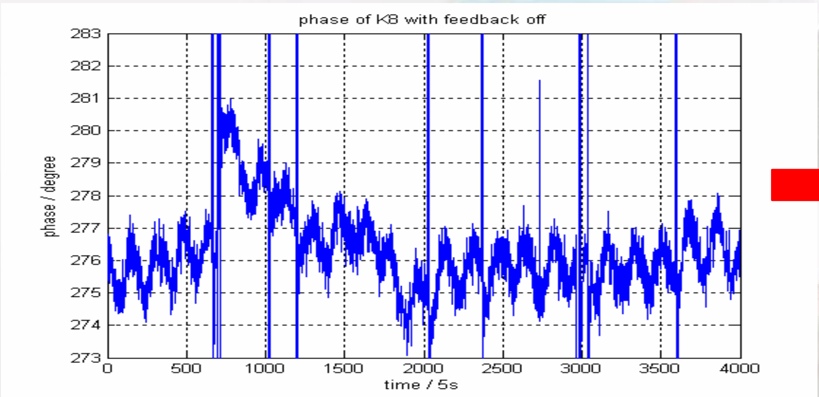
2.1 The Injector Linac

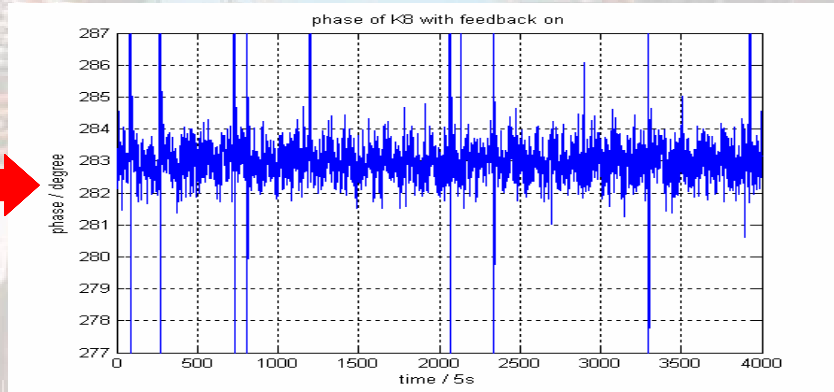
- Upgrade was done in the summer 2004: including the electron gun, 40MeV pre-injector, 200MeV booster section and the positron source of the linac.
- Commissioned in 2005 and optimized in the first half year of 2006. Its main parameters have reached the designed value at least for short term.
- The linac is well operated for both e- and e+ injection in the commissioning of collision mode either at 50Hz or 12.5Hz.
- A phase loop has been put into operation, with phase stability better than 2°. A one button operation has been developed to fast switch between e+ and e- mode which improved the efficiency.

New Electron Gun
(High current ; low emittance)



New Positron Source
（High e+ yield;Large capture acceptance）





Phase stability better than 2°

BEPCII-Linac Beam Performance

	Design	Measured	BEPC
Energy (e+ / e-) (GeV)	1.89	1.89	1.30-1.55
Current (e+) (mA)	37	61	~ 5
Current (e-) (mA)	500	> 500	~300
Emittance（e+）(1 σ , mm-mrad）	0.40 (37 mA)	0.39~0.41 (40~46 mA)	----
Emittance (e-) (1 σ , mm-mrad）	0.10 (500 mA)	0.09~0.11 (600 mA)	----
Pulse Repe. Rate （Hz）	50	50	12.5
Energy Spread (e-) （%） **	± 0.50 (500 mA)	± 0.44 (600 mA)	± 0.80
Energy Spread (e+) （%） **	± 0.50 (37 mA)	± 0.50 (⩾37 mA)	± 0.80

Beam Stability measurement

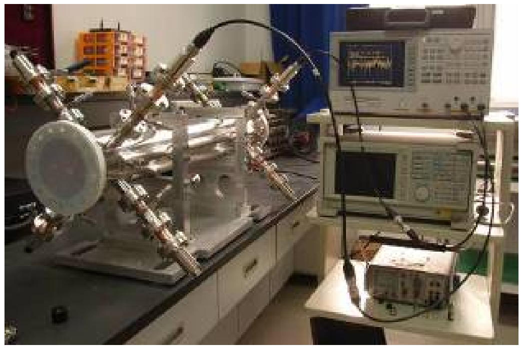
	Design	Measured
Beam orbit instability (BPMs @ Linac exit)	$\pm$ 0.20 mm	$\pm$ 0.16 mm
Beam energy instability (BPM downstream energy analyzer)	$\pm$ 1.0 mm	$\pm$ 1.0 mm
Gun trigger timing jitter	35 ps (1σ)	39 ps (1σ) 27 ps (rms)*

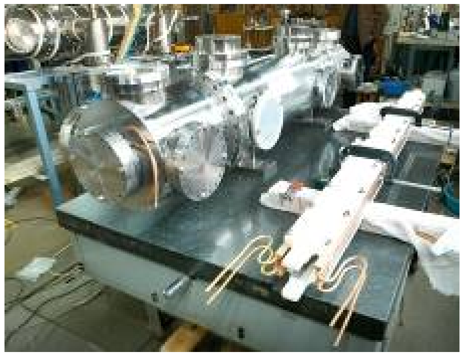
- **Efforts still being done to improvement on the long term stability of orbit and energy, as well as repeatability.**
- **A new SHB bunching system is being constructed to further enhance the e+ injection rate roughly by a factor of 2.**

2.2 Storage Rings

- RF System
- Injection Kickers
- Magnet System
- Power Supply
- Vacuum System
- Beam Diagnosis
- Control System
- Cryogenics
- Interaction Region
- Installation

Sub-systems of the Storage Rings



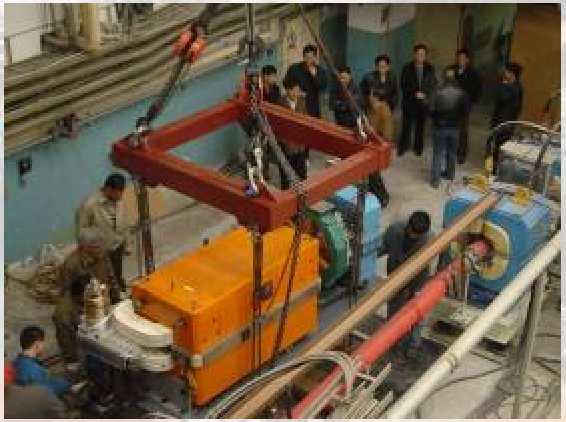


Installation of Storage Rings

2006/03/02	Start installation of the first magnet unit in the ring tunnel.
2006/07/18	Start PS test & commissioning with magnets and control, in parallel with installation.
2006/09/10	Complete installation of last magnet raft in the ring tunnel
2006/10/29	Complete installation of all chambers and vacuum components
2006/11/05	Complete cable connections and chamber baking
2006/11/09	Complete fine alignment of the ring magnets
2006/11/12	Start ring commissioning

Installation

Preassembly and pre-alignment



A unit placed into the tunnel

Superconducting cavity

Wiggler in the tunnel

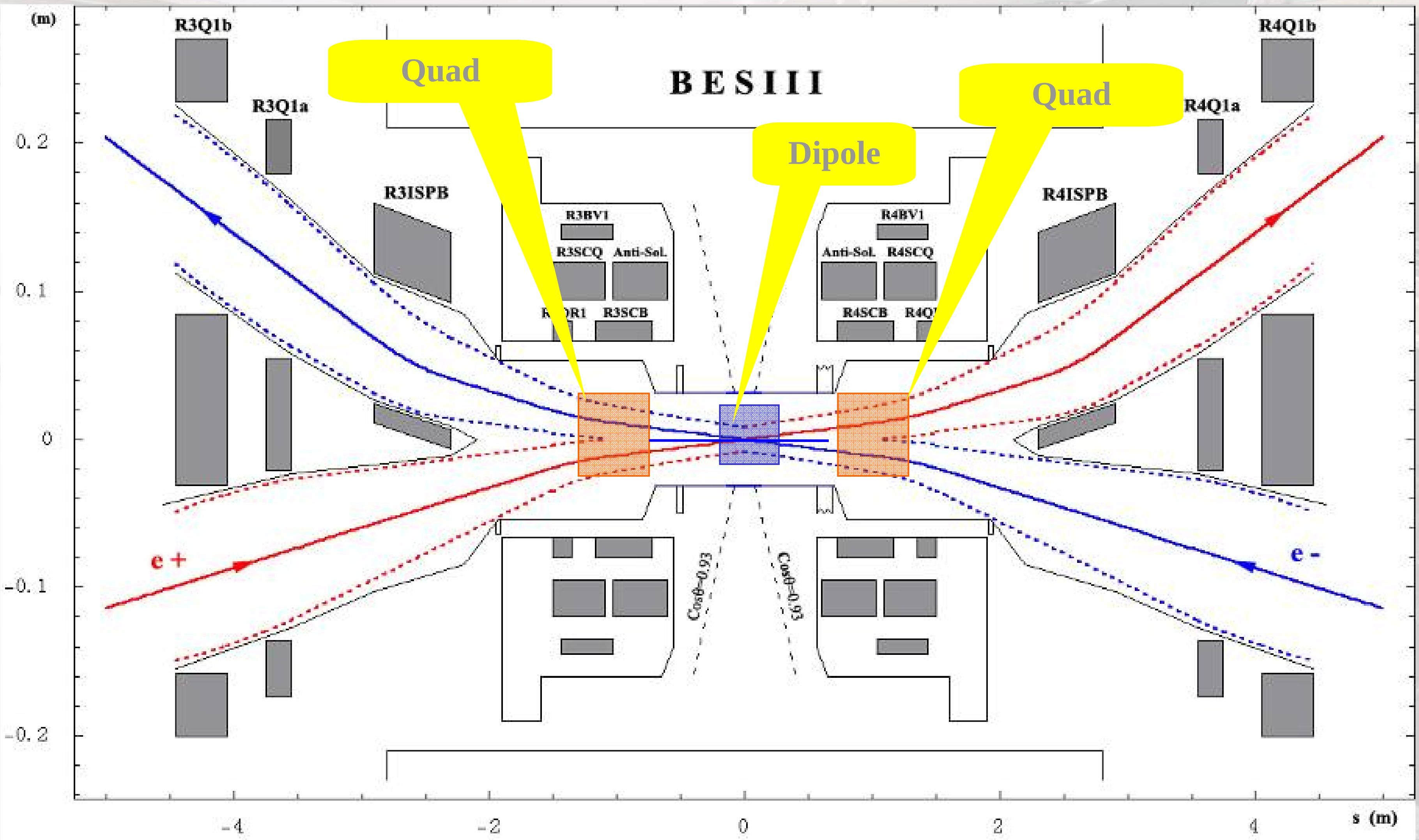
Installation of bellows

Aligning and adjusting

It took about 16 months to complete the installation of BEPCII rings (except the superconducting IR magnets and IR chambers) after the BEPC ring shut-down in July 4,2005.

Backup scheme without SCQ

- **The backup scheme with conventional magnets in the IR was decided in early 2006 in order to:**
  - **Provide beam to SR users as early as possible, and to accumulate experience on beam commissioning of double-ring collider.**
  - **In parallel, on the BESIII offline location, take full use of the time about 6 months for the modification of the valve boxes of SCQ and the following field measurement with detector solenoid (SSM) as well as the field mapping of the SSM.**
- **The backup scheme has a similar lattice with the original design except that in collision mode the β_y at IP is 5cm instead of 1.5cm.**



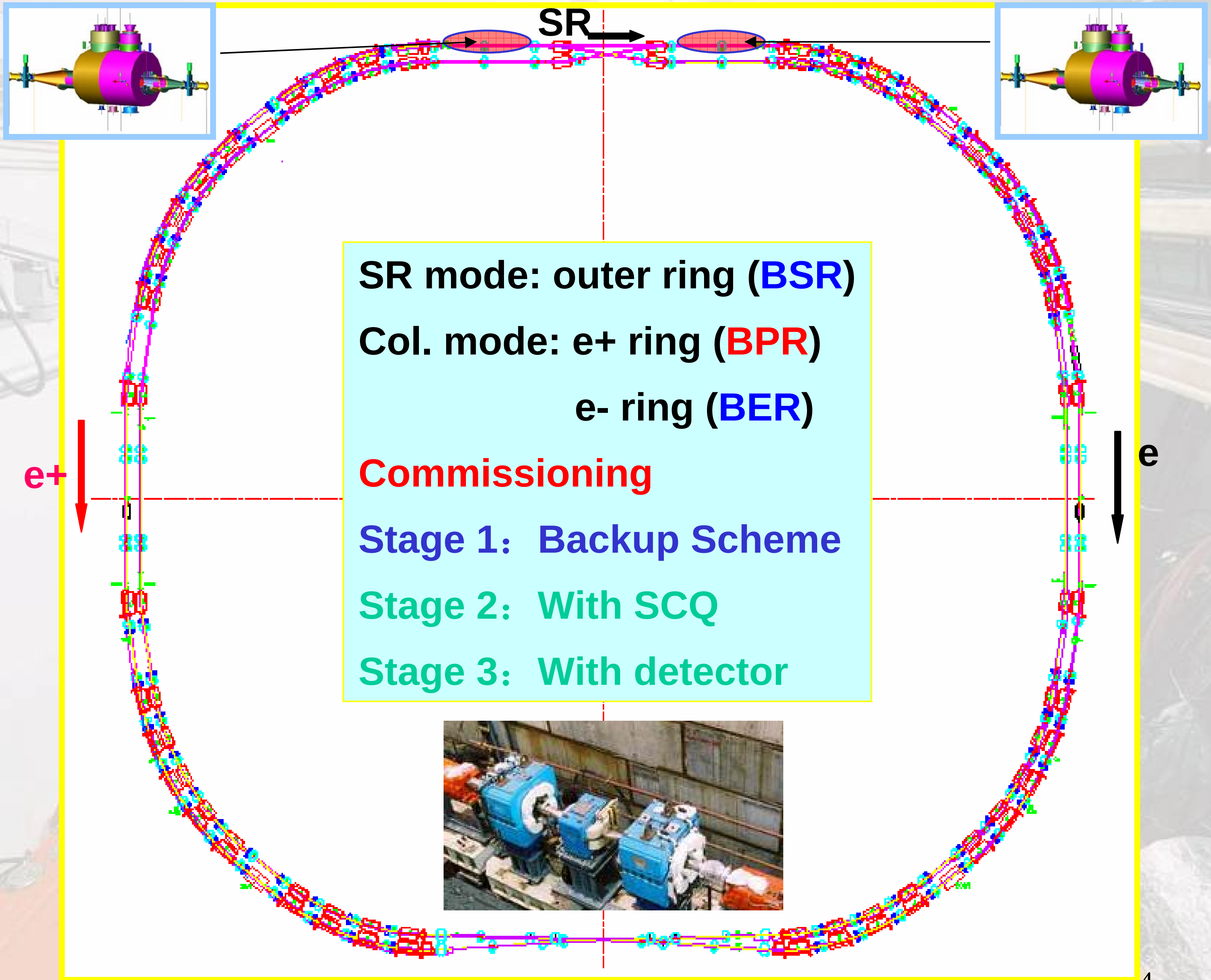
Beam orbit in IR for the backup scheme

1st IR: Backup scheme

2rd IR

3. Commissioning of Storage ring

- **Beam commissioning of the back-up scheme started out after installation finished in Nov. 2006.**



SR mode: outer ring (BSR)

Col. mode: e+ ring (BPR)

e- ring (BER)

Commissioning

Stage 1：Backup Scheme

Stage 2：With SCQ

Stage 3：With detector

Time table of beam commissioning with back-up scheme

- BSR commissioning (06/11.13-06/12.25)
- BSR user operation(06/12.25-07/02.02)
- BER commissioning (07/02.01-07/02.16)
- BPR commissioning (07/02.25-07/03.20)
- BER and BPR optimization (07/03.20-07/03.25)
- Collision (07/03.25-07/05.25)
- BSR optimization (07/5.25-07/6.15)
- Second run for SR user experiment (07/06.15-07/07.15)
- …

3.1 BSR commissioning（2006）

Nov. 12, Commissioning of beam transport line

Nov. 14, First turn in the ring

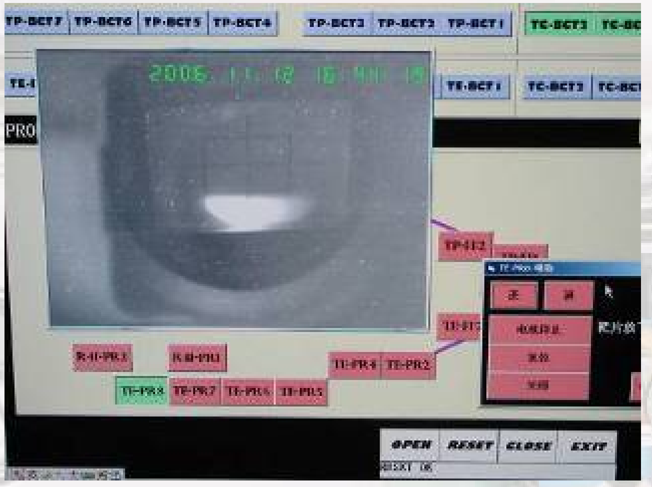
Nov. 18, Beam stored in the ring

Dec. 09, Beam energy ramp to 2.5GeV

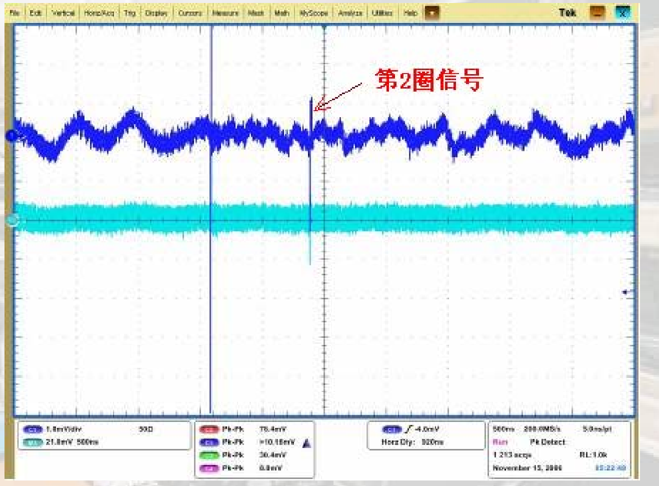
Dec. 25, SR user experiment started

Dec. 27, Beam over 100mA @ 2.5GeV

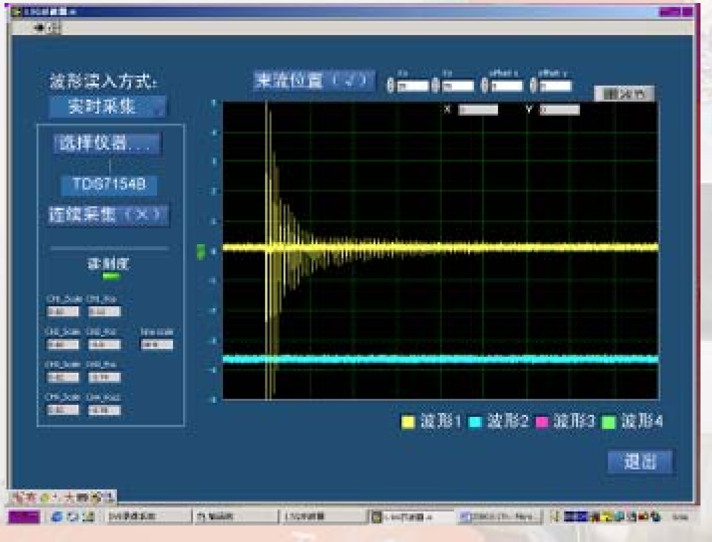
Feb. 02, 2007, First run of SR mode completed



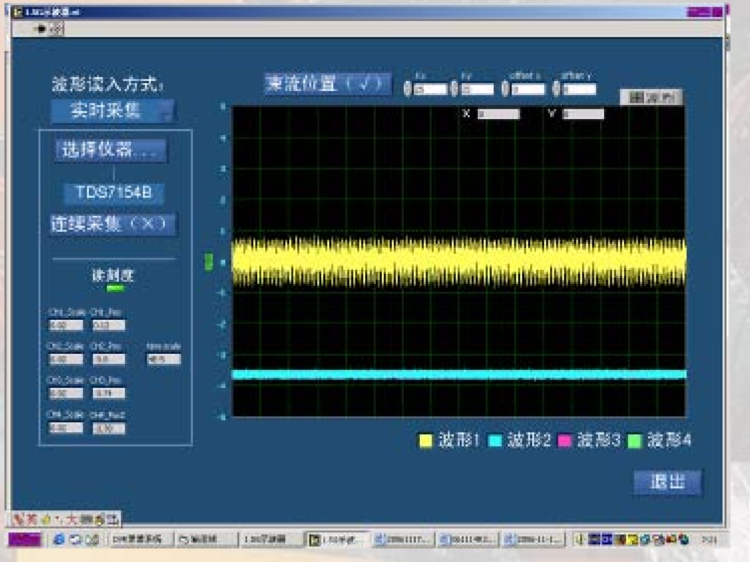
Beam profile at the exit of transport line on Nov. 12



First turn on Nov. 14



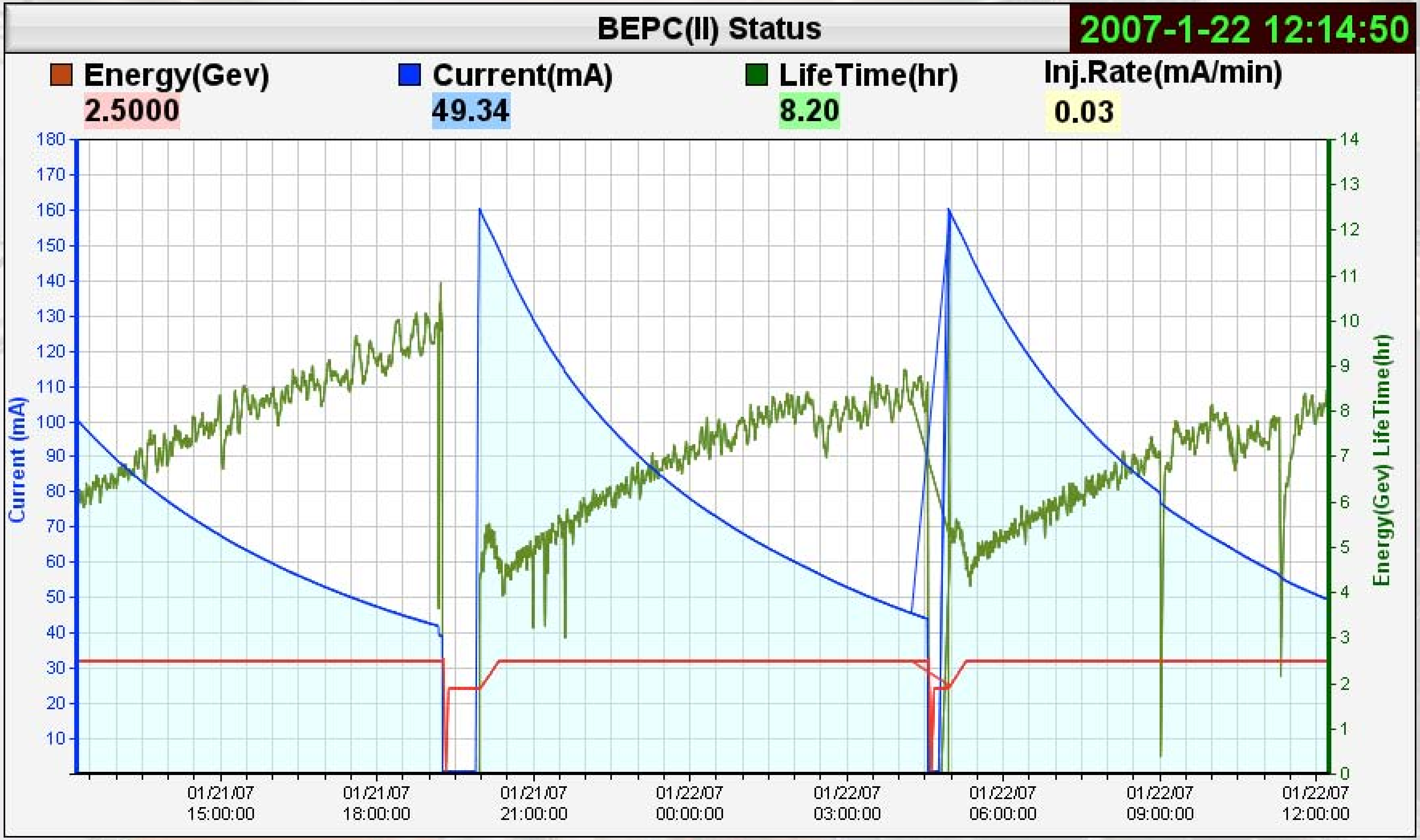
10s turns on Nov. 18



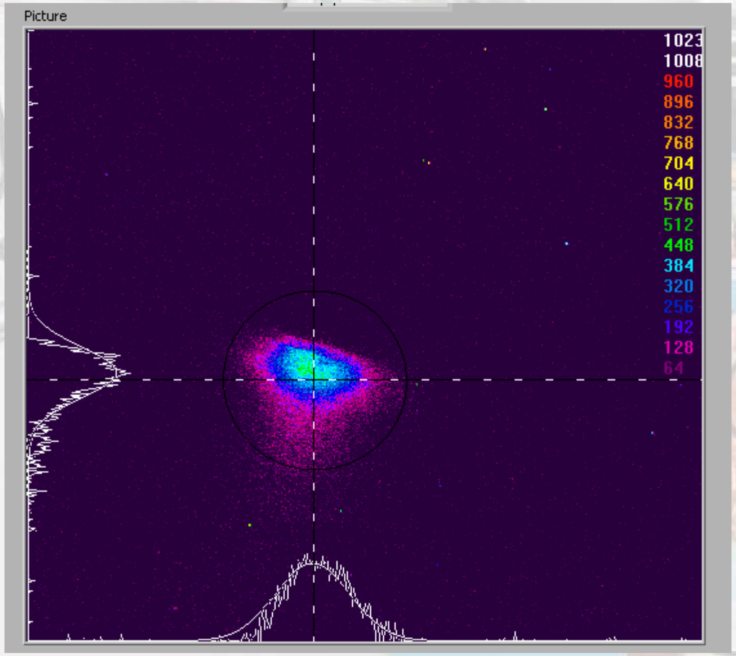
Beam stored on Nov. 18

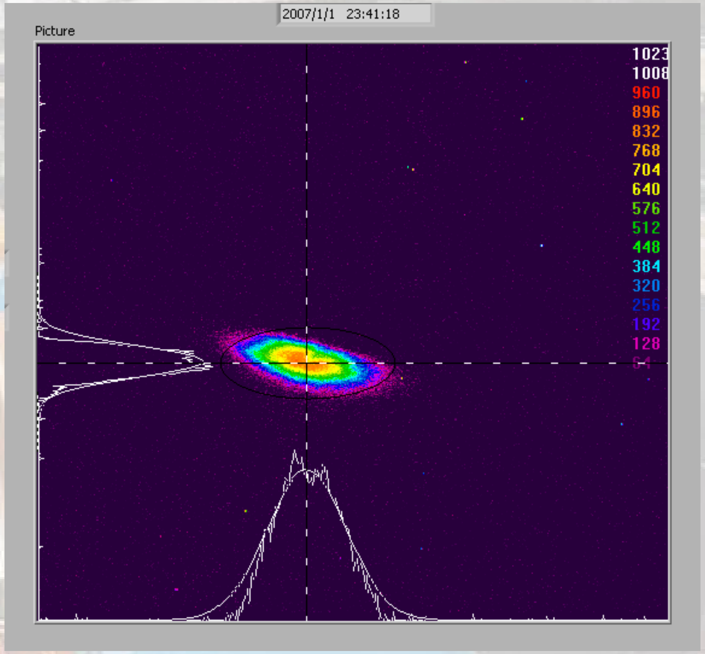
BSR Performance

- The first run of SR operation was from Dec. 25, 2006 to Feb. 2, 2007. The commissioning procedure and the beam performance of BSR were reported on the APAC07 [2].
- For first run:
  - 500 hrs of beam time to users;
  - 11 beamlines and experimental stations in operation
  - 92 experiments carried out.
- Second run from June 15--July 15, 2007. Now is in operation.



Typical beam history of SR user operation





- **R4OOCT4:I=0**

R4OOCT4:I=-1.5A

Octupole was used to damp the beam oscillation at high current

3.2 Commissioning of Collision mode

Electron ring commissioning (2007)

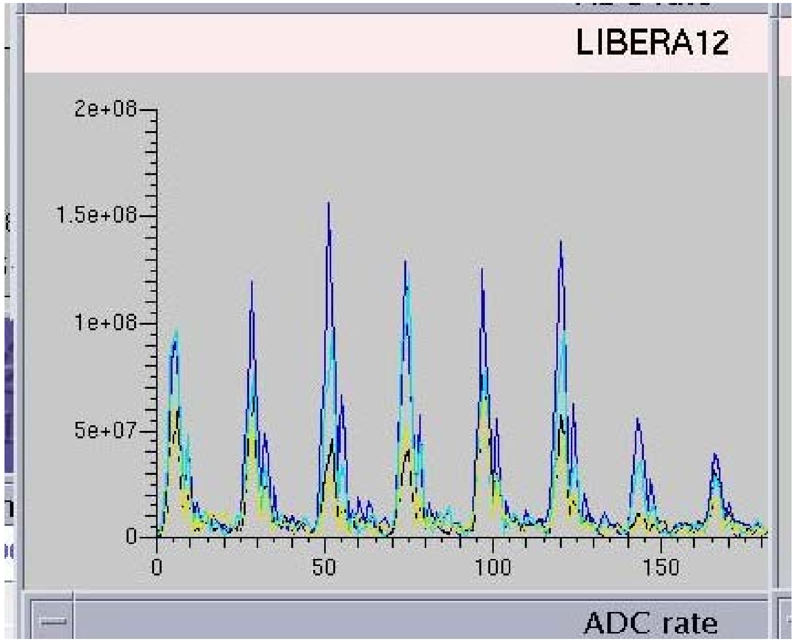
Feb. 6, Beam commissioning started
Feb. 7, Beam stored
Feb. 9, Beam accumulated

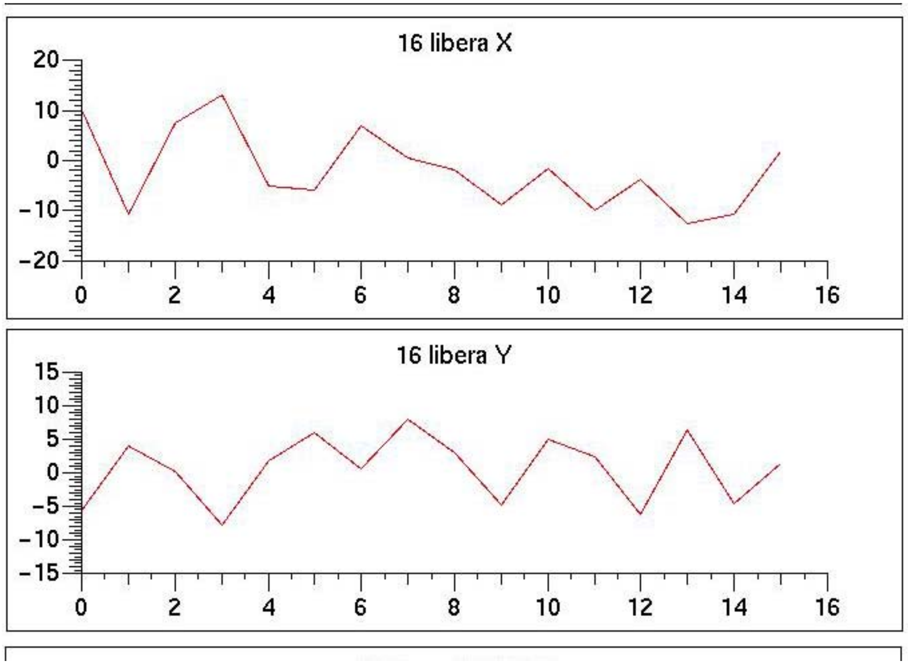
Positron ring commissioning (2007)

Mar.2-3, Use BSR to optimize the transport line of positron and kickers for injection.
Mar. 3, Beam commissioning started
Mar. 4, Beam stored and accumulated

Commissioning of first turns

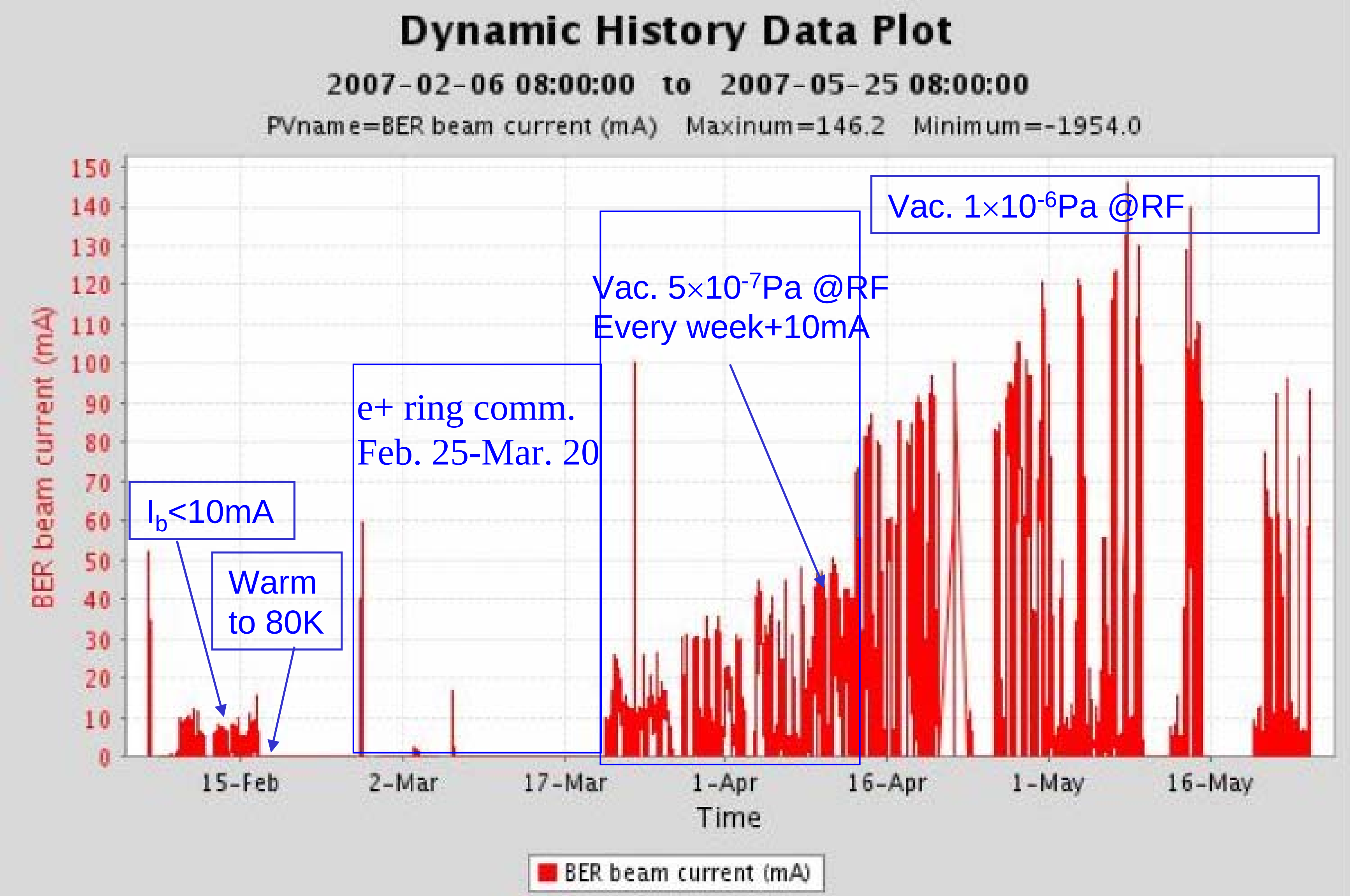
➢For easy tuning: β_x/β_y*=2.5/0.1m, ν_x/ν_y~6.77/5.81 Libera BPM system was used for first turn tuning. On axis injection was soon realized by properly adjusting the kicker strength and the correctors along the ring.



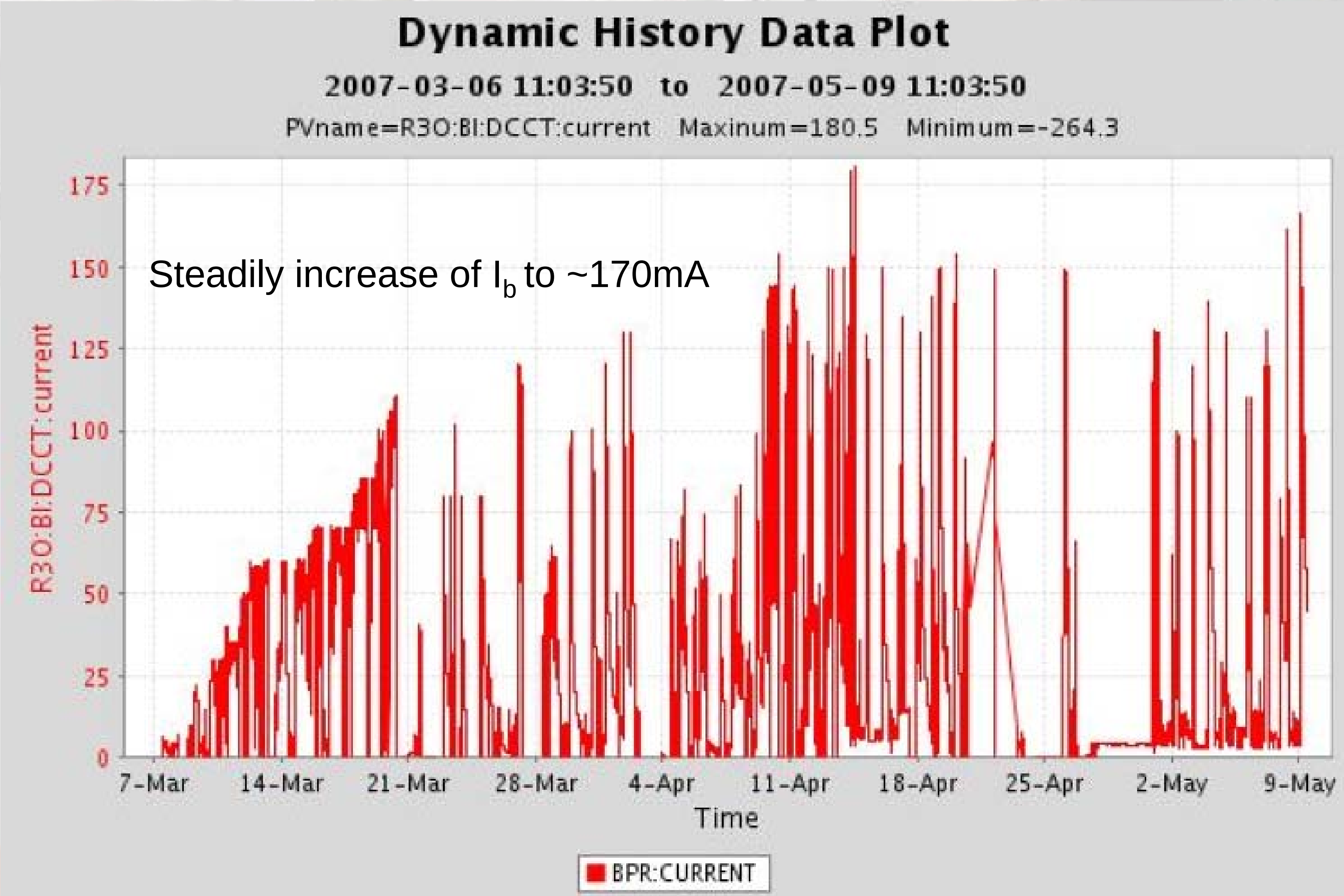


Libera BPM signal for first several turns of beam in BER

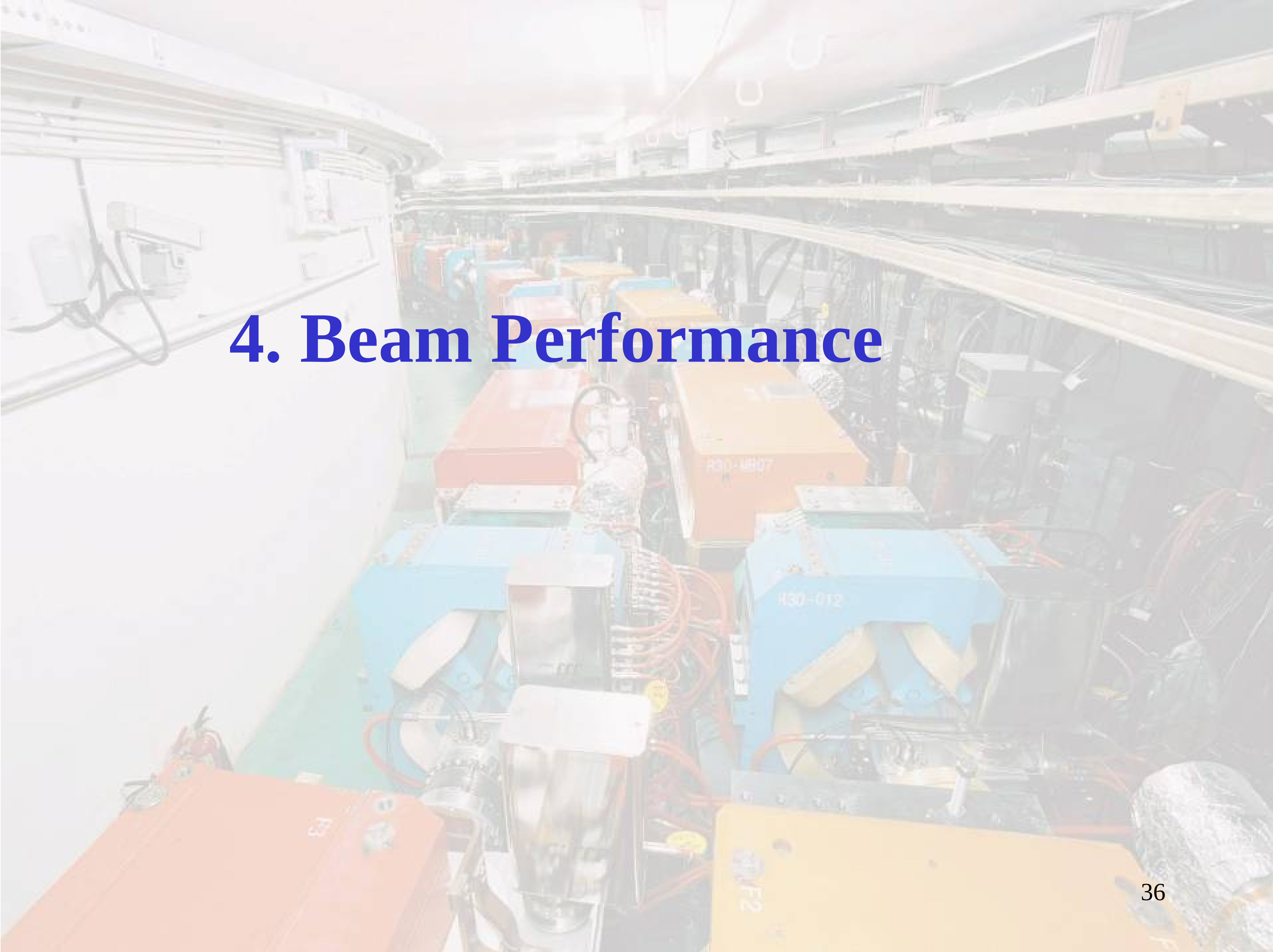
Beam current history for E-



Beam current history of E+

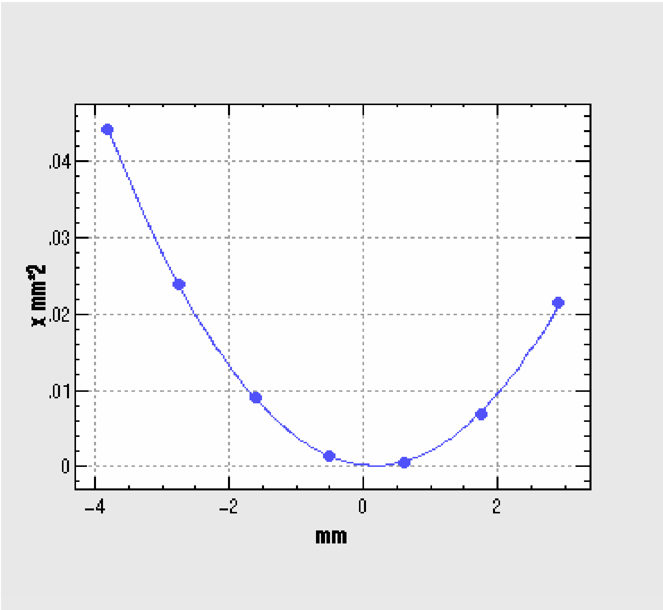


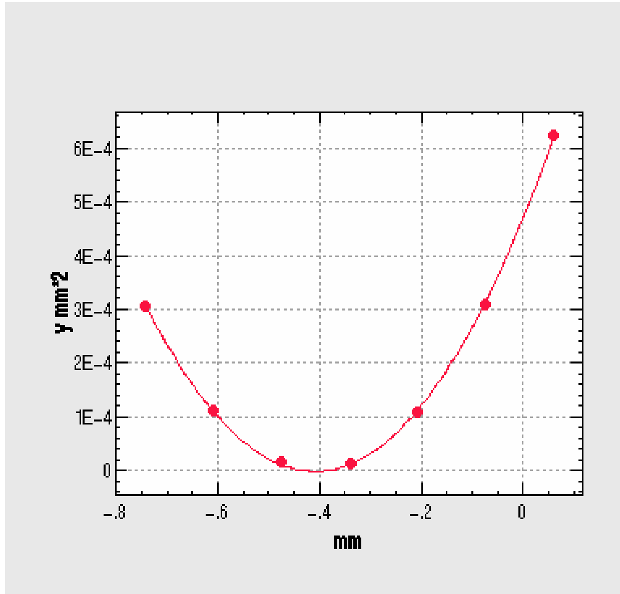
4. Beam Performance



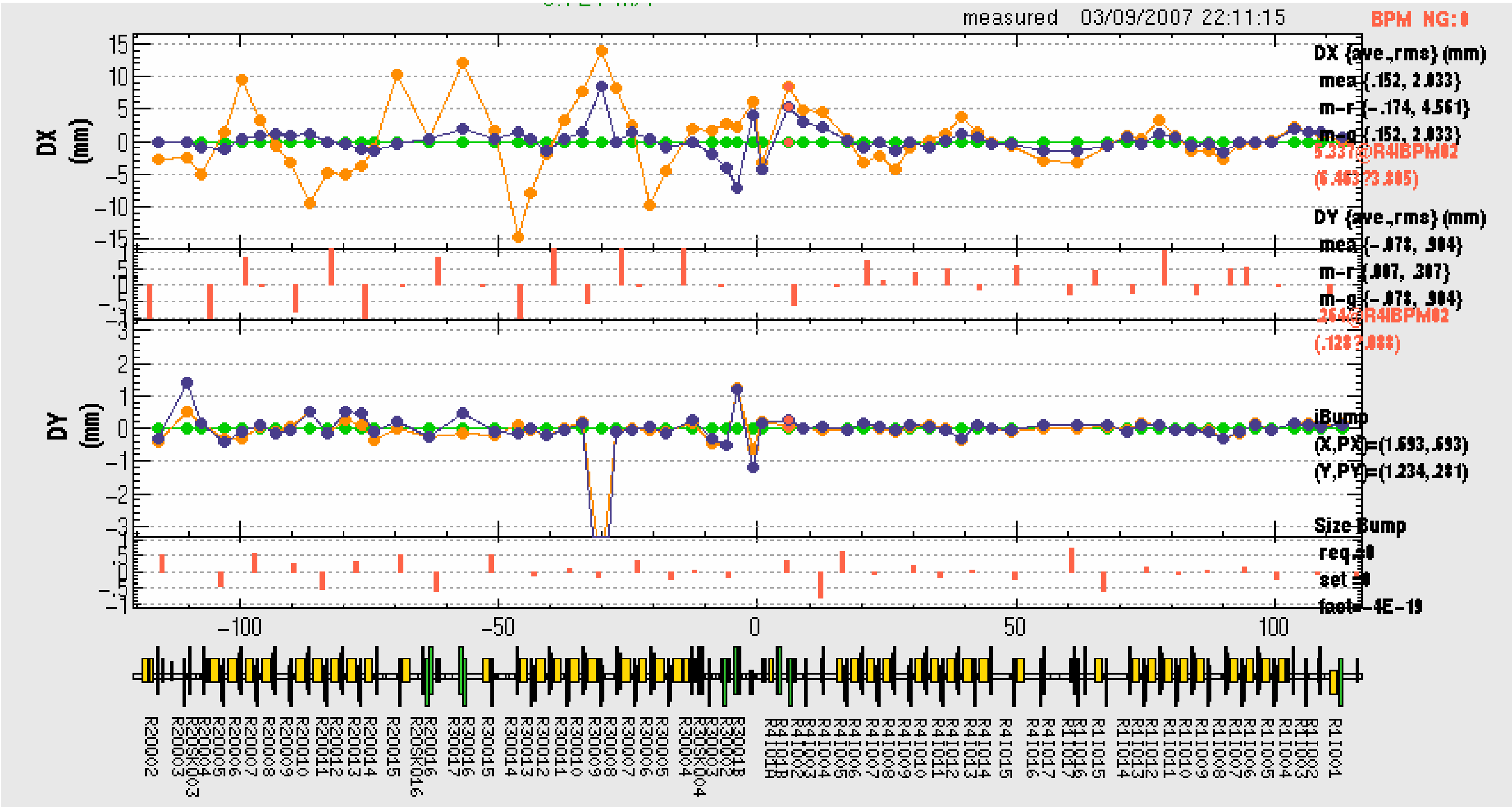
4.1 Orbit Correction

BPM offsets were determined with beam-based alignment (BBA) and COD correction was done based on the measured response matrix between BPMs and correctors..





Beam Based alignment to determine all the BPM- to-quadrupole offsets

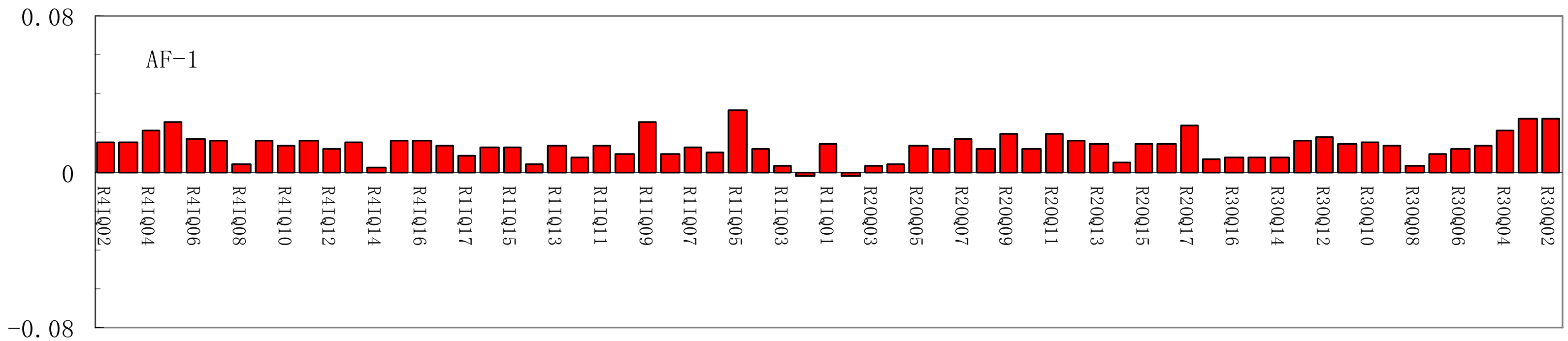


BPR orbit correction before (orange) and after (blue)

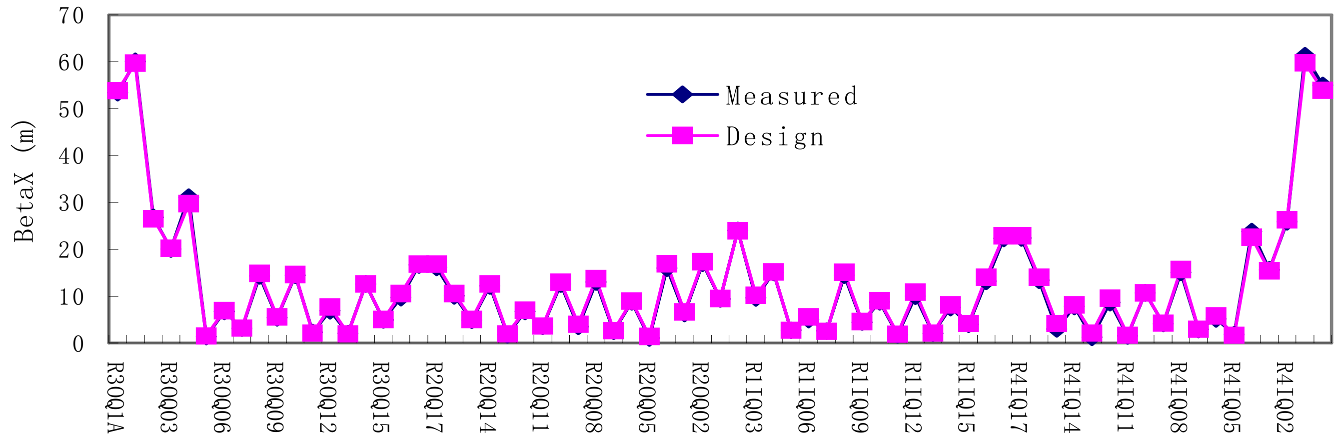
After COD correction the average orbit deviation is about 0.2mm/0.08mm in horizontal and vertical planes,

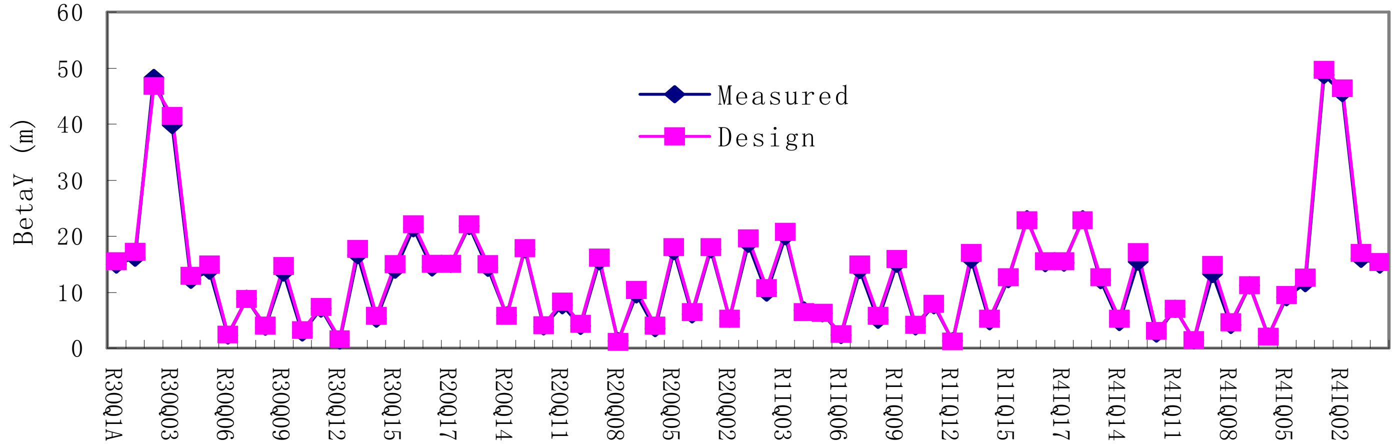
4.2 BPR optics analysis and correction

- LOCO (Linear Optics from Closed Orbits) method [3] was applied to analyze and restore the optics functions of the BSR, BPR and BER
- A fudge factor AF was used to describe the correction of each quadrupole strength to restore the optics, i.e., k=k0*AF, where k is the quadrupole strength after correction and k0 is the original one set for the theoretical lattice

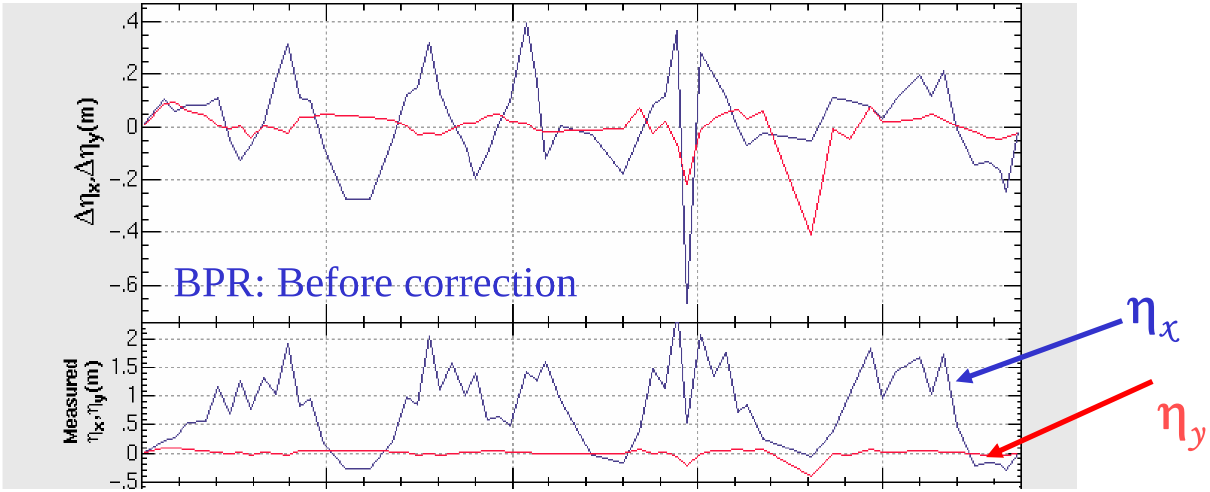


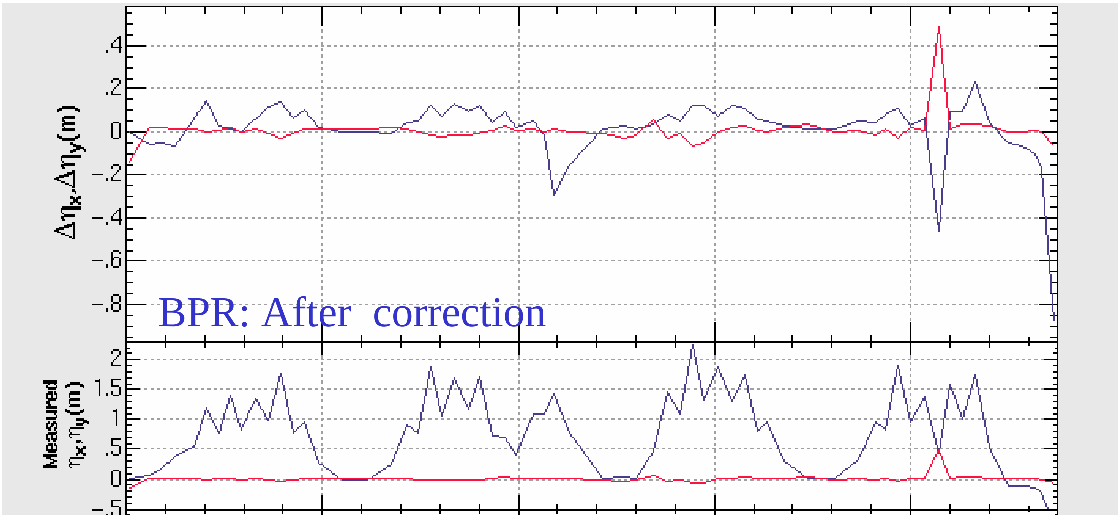
The fudge factors of quadrupole are mostly within 1.01~1.02, One possible cause of this systemic component may come from the short distance between the quadrupole and its adjacent sextupole. Other origin of these errors will be also pursued.





When the fudge factors were applied to the storage rings, it led to good agreement between theoretical and measured beam optics functions with $\Delta\beta/\beta<\pm10\%$, at most quadrupoles, for tune: $\Delta\nu<0.002$.



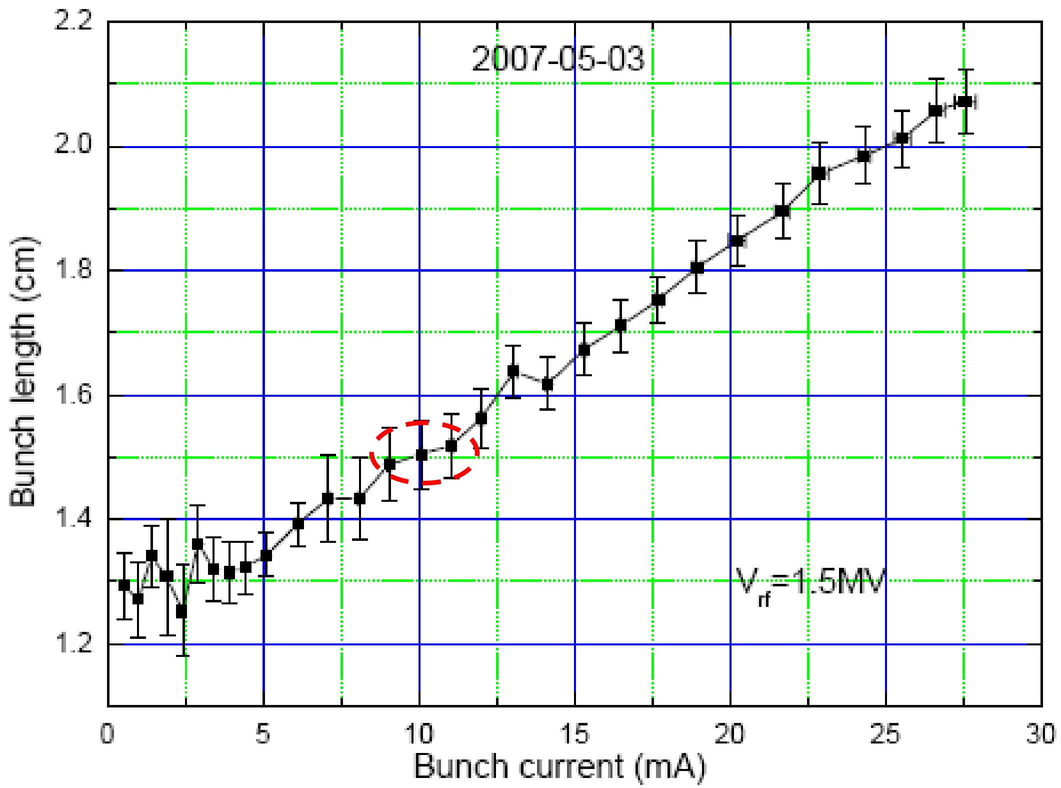


The deviation of measured dispersion function from the design is also small.

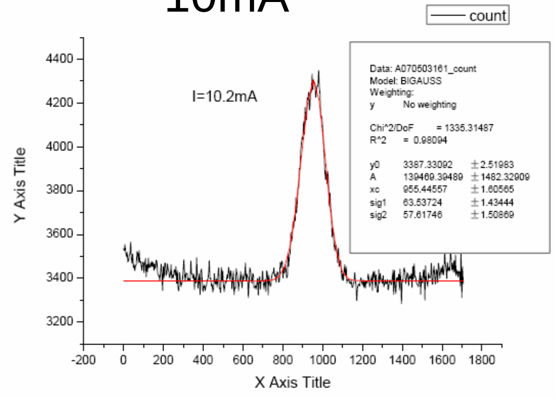
4.3 Beam Instabilities

- Single bunch current of both rings > 40mA with no disastrous instability.
- The bunch lengthening effect was measured with streak camera:

  ~1.3cm@ 0mA, 1.5cm@10mA, which is consistent with the design.
- Energy spread was measured from the quantum beam lifetime, no significant increase when I_b <10mA.
- Long. broadband impedance was deduced from the tune shift with bunch current.
  - For both rings: <1Ω, corresponding to the microwave instability threshold. Difference between the BER (0.43) and BPR (0.80), more studies needed.
- Sudden beam lifetime drop was observed in electron rings (BSR& BER). Possible explanation is dust trapping or ion trapping.
- ECI not yet observed in the BPR >100mA, much weaker than BEPC. This indicates that the antechamber with TiN coating is effective to reduce the photo electron and SEY=>ECI in high beam current should be carefully studied later.



10mA



0.6mA

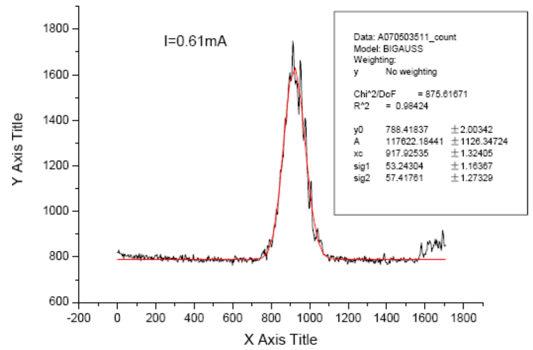


图 5 平均束长随流强变化

Bunch length vs current was measured @1.5MV:

Ib=0mA, ~1.3cm;

Ib=10mA, ~1.5cm

4.4 Injection

- Efforts were mainly paid to improve the injection rate of positron beam.

  @ 12.5Hz : 15-20 mA/min. (BEPC ~3-5mA/min)

  @ 50Hz: > 40mA/min.

  This gives confidence to reach the design value of 50mA/min.

- ➢ The Injection rate was not so stable:

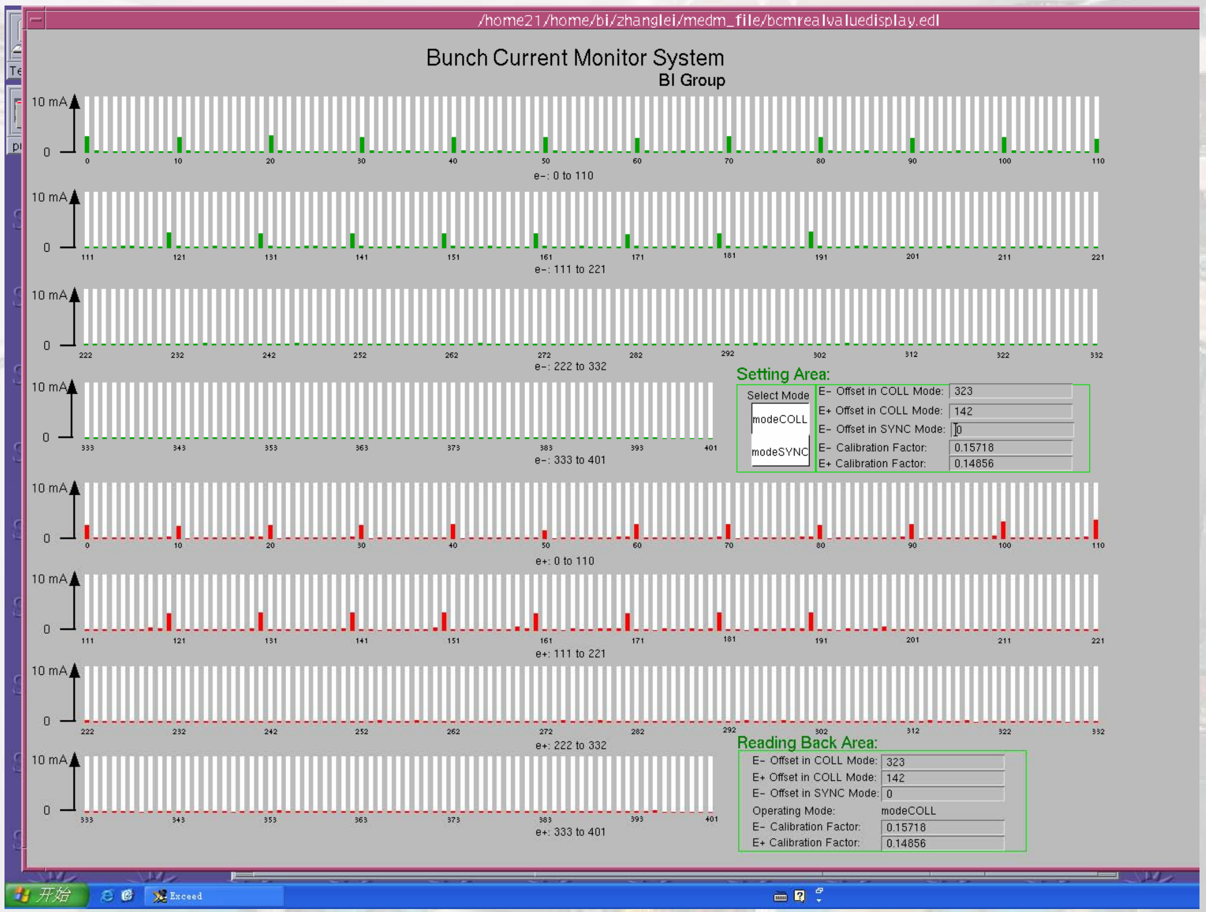
  May be owing to the unstable performance of the linac

  Mismatch of optics along transfer line: wire scanner being developed

- For multi-bunch operation, BCM system used to control uniformity and EVG/EVR timing system provides enough flexibility on the filling pattern.

- ➢ Difficult to get uniform bunches-- mismatch on the timing and amplitude of kicker or some beam instability caused by the injection oscillation.

- Optimizing the injection process and improving the injection efficiency are under way.

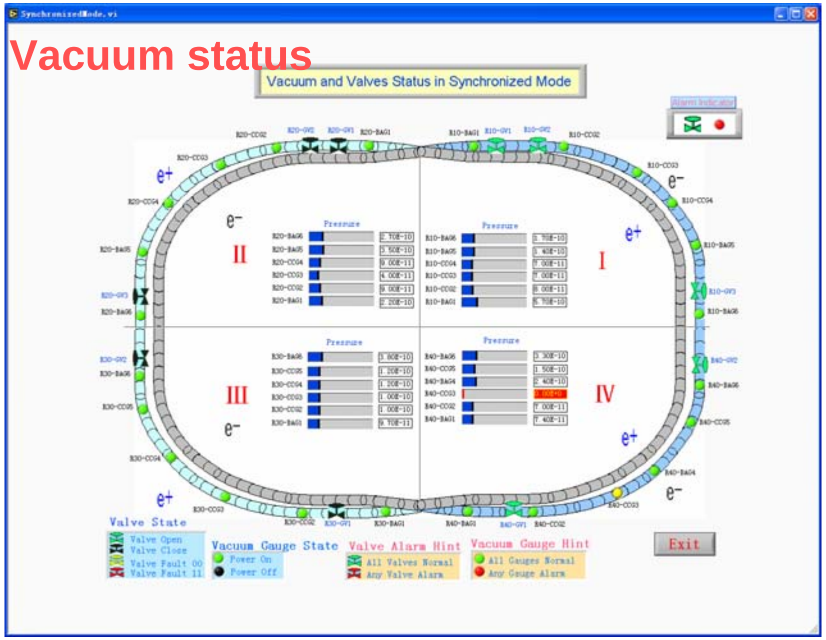


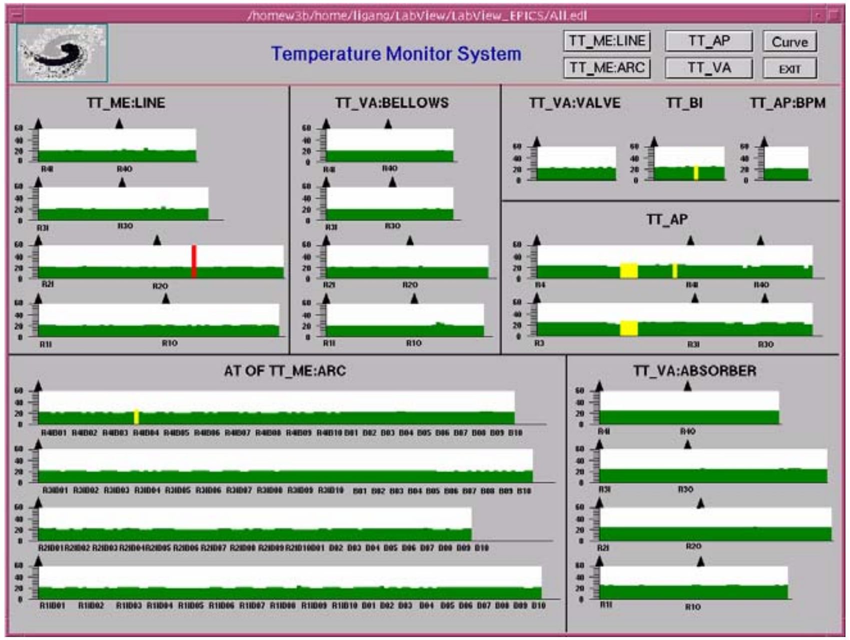
Filling pattern on BCM

The main parameters of the BER and BPR

parameters	design	Achieved	
		BER	BPR
Energy (GeV)	1.89	1.89	1.89
Beam curr. (mA)	910	145	180
Bunch curr. (mA)	9.8	>40	>40
Bunch number	93	93	93
RF voltage	1.5	1.6	1.6
Tunes (ν_x/ν_y)	6.54/5.59	6.538/5.590	6.539/5.589
Chromaticity ξ_x/ξ_y	1.0/1.0	1.79/0.95	1.35/1.37
∗ν_s @1.5MV	0.033	0.0308	0.0309
β_x^*/β_y^* (m)	2.0/0.05	1.19/0.056	1.13/0.057
Inj. Rate (mA/min)	200 e^-/ 50 e^+	500	46
Energy spread(10^{-4})	5.26	5.12	5.21
$\lvert Z/n \rvert_0$ (Ω)	0.23	0.43	0.80

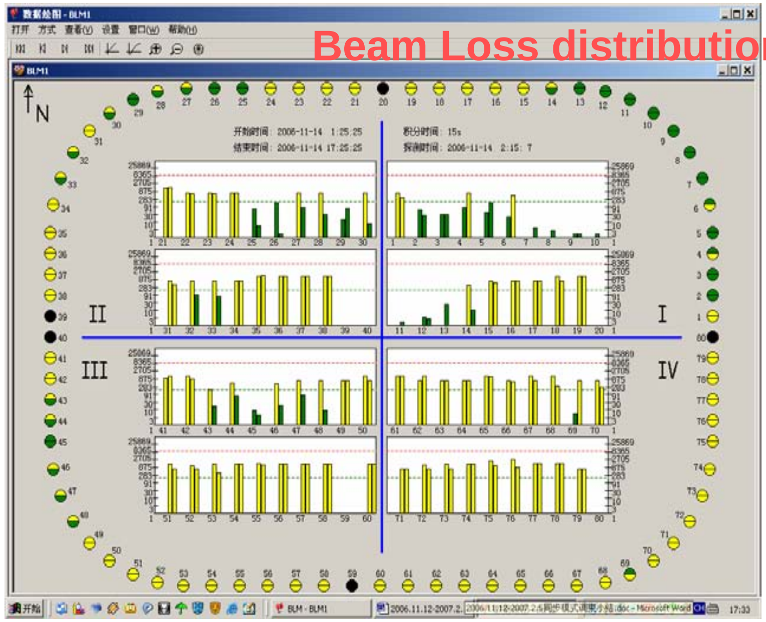
Vacuum status

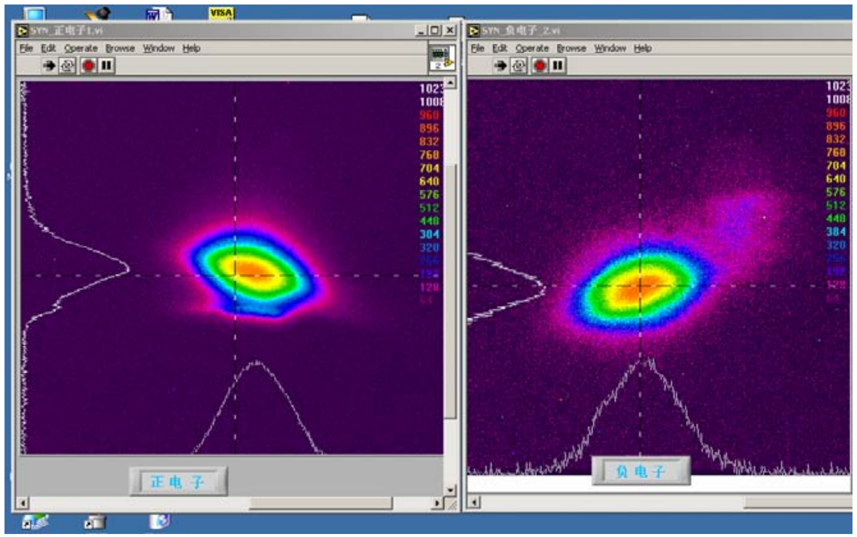




Temperature of vacuum componets

Beam Loss distribution





Beam Profile in Collision

4.5 Collision Tuning

Beam-Beam Scan

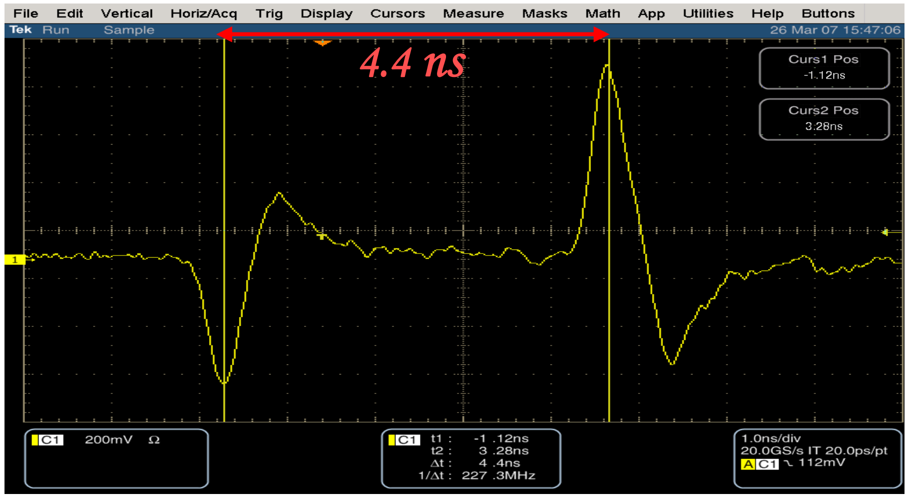
- The first Beam-Beam Scan (BBS) for collision at IP was done on Mar. 25.
- The BBS in sequences: longitudinal, horizontal and vertical directions.
- First collision of BEPCII realized on Mar. 25, 2007

Longitudinal Position Tuning

A BPM (R4CBPM00) located on the common beam pipe of two rings near IP was used to measure the difference on the arrival time of two beams to IP. By properly adjusting the RF phase in either ring, the two beams can be brought to the nominal IP at the same time.

Distance from the IP to R4CBPM00 is 0.6587m, corresponding to time arrival difference of 4.4 ns. Adjustment accuracy of 3mm (or 10ps)

.



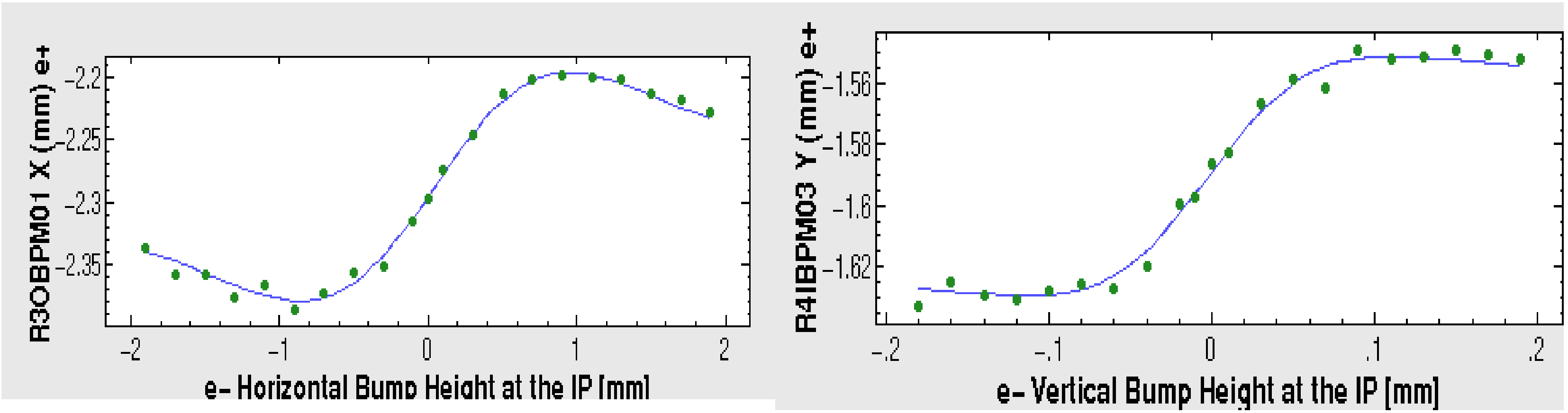
e+ and e- signals on R4CBPM00

Transverse position tuning

=> Eliminate Hor. offset and vert. beam offset @ IP

- **Transverse BBS done with local 4-bump. Adjust an orbit bump around the IP in one ring, while observing the beam orbit variation in the other ring due to the beam-beam deflection.**

Example) Scan: e- IP bump height Monitor: e+ IR BPM

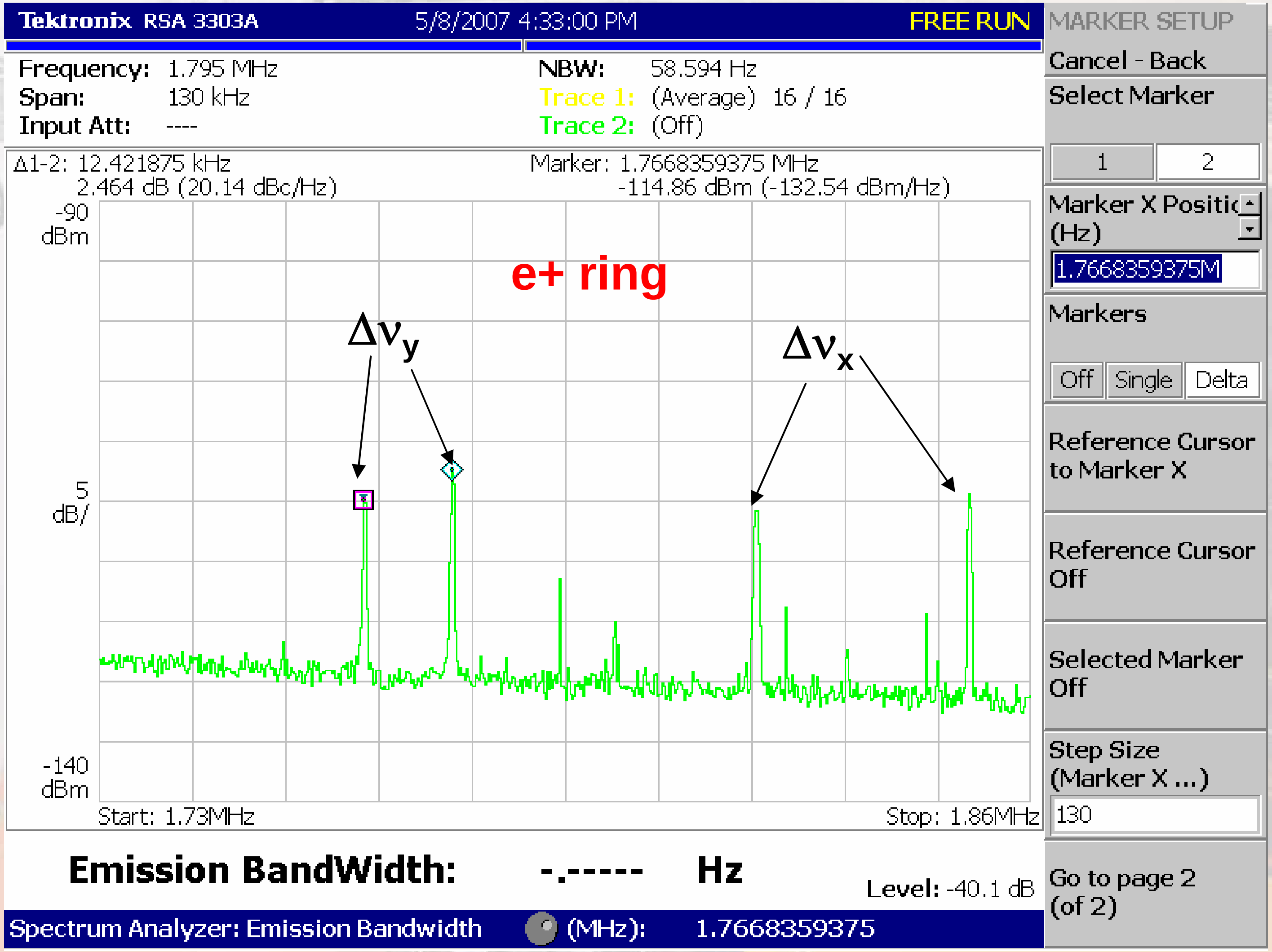


The beam size and IP position can be obtained by fitting the BBS data.

For one scan, beam size fitted: $\sigma x^*/\sigma y^*$=0.5mm/0.016mm

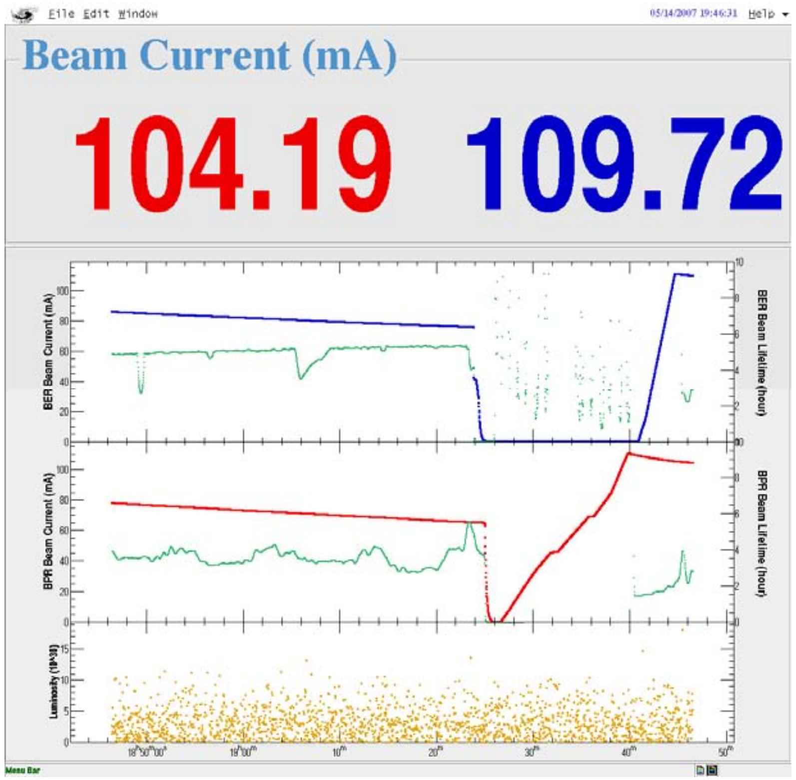
Comparable to design value: $\sigma x^*/\sigma y^*$=0.5mm/0.012mm.

Tune shift measurement



Multi-bunch Collision

100mA×100mA beam collision has been achieved with multi-bunches (20, 50 bunches for each beam).



100mA×100mA on Mar. 14

Estimation of luminosity

For single bunch

Estimate from tune shift:

Lum ~5-10×10^{29} $cm^{-2}s^{-1}$ @ I_b=5mA

Estimated from beam size:

sigmaX＝489um，sigmaY＝16um,

Lum~ 7.8×10^{29} $cm^{-2}s^{-1}$ @ I_b=5mA

For multi-bunch

K_b=20, I_b=5mA,

Lum. > 1.0×$10^{31}$$cm^{-2}s^{-1}$, which is the record of BEPC

Issues to be further studied

- Ring commissioning goes smoothly, and the systems show good performance.
- However, due to the short period, lot of issues need much more studies:
    - Beam instabilities & component heating issues at high current
    - The fine tuning of the collision conditions to improve luminosity such as tunes, orbit, beam sizes (coupling), etc
    - Steadily high injection rate and efficiency
    - Limitation & improvement on the beam lifetime
    - Background issues

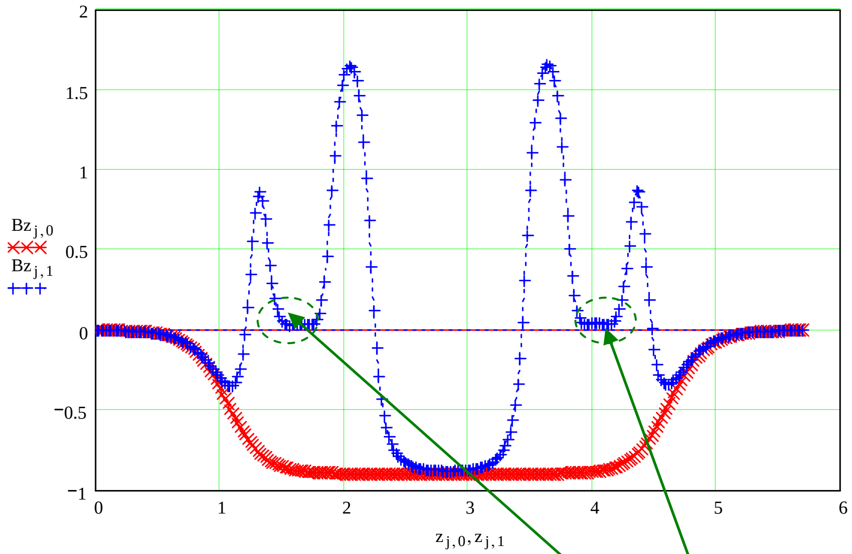
    ….

A very long way to go to meet the design luminosity

5. Progress of Cryogenic & SCQ

- In parallel with the beam commissioning, the improvement of the cryogenic system and test of superconducting IR magnets (SCQ's) were pushed on.
- An insulation vacuum section was added to the neck of 1000L Dewar to reduce the heat loss and the valve boxes were rebuilt with new power leads, helium route and improved structure.
- After these modifications, the two SCQs and the superconducting solenoid magnet (SSM) for detector were successfully cooled down together in May. Then the power supplies and quench protection systems of SCQs were tested.
- On June 11, the two SCQs and the SSM were successfully excited to their full design currents at the same time. This condition was kept for more than 10 hours and the whole system worked stably.
- The combined magnetic field measurement of SCQ's and SSM is being carried out.

SCQ with detector soloenoid



Preliminary result :

Integral zero

Field at SCQ's zero nearly fullfilled

Measurements of the combined field of BES III and BEPC II Solenoid Magnets using the Salamander System (by DESY)

The preliminary results show that design of using 3 Anti-Solenoids AS1 AS2 AS3 to compensate Detector Solenoid Field works very well.

Plan & Schedule

July. 2007 BSR operation &

SCQ field mapping off-line

Aug. 2007 SCQ installation on-line

Sept. 2007 SCQ field measurement on-line

Oct. 2007 Commissioning BER&BPR with SCQ

Beam collision tuning with SCQ

Mar. 2008 Detector move in, collision tuning

Dec. 2008 Lum. $(1.0 \sim 3.0) \times 10^{32} cm^{-2}s^{-1}$

Concluding Remarks

- Significant progress has been made since the project started construction in the beginning of 2004;
- Commissioning of BSR, BER and BPR with backup scheme was carried out on schedule with milestones:
  - 29 Oct. 2006 Installation complete
  - 12 Nov. 2006 Beam commissioning started
  - 18 Nov. 2006 BSR beam first stored
  - 09 Feb. 2007 BER beam first stored
  - 04 Mar 2007 BPR beam first stored
  - 25 Mar 2007 First collision
  - 14 May 2007 100mA*100mA collision with luminosity over BEPC

Concluding Remarks (cont.)

- **Cryogenic system for SCQ has been completed. The field measurement of SCQ& SSM is under way.**
- **Beam commissioning with SCQ planed in Oct. 2007**
- **Beam commissioning with Detector planned in Mar. 2008**
- **However, there is still a long way to reach high beam current and luminosity as design…**

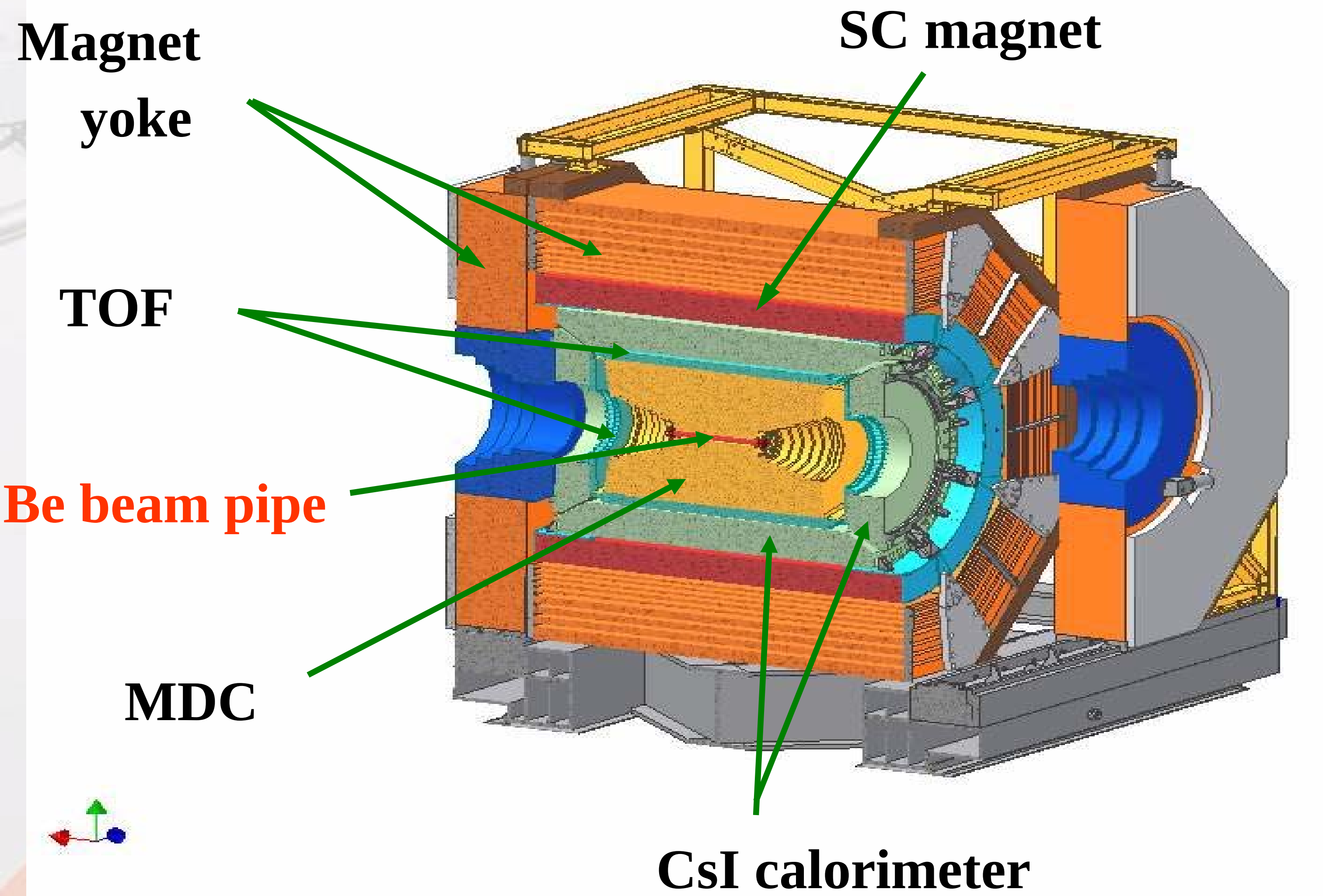
Acknowledgement

- For the construction of SCQ and cryogenic system, we appreciate the many help from BNL, DESY and KEK.
- For SCRF operation, Drs. Furuya, Mitsunobu and Akai from KEK help a lot.
- For beam commissioning and lattice analysis, SAD was transplanted from KEK and LOCO from SLAC is used.
- Dr. Fisher from SLAC joined the first days of BSR commissioning, giving helpful advices.
- Thanks also go to the BEPCII IMAC members.

Thank you very much

for your attention!

The BESIII Detector



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