Commissioning of the Shanghai Light Source

Zhentang Zhao for the SSRF Team
Shanghai Institute of Applied Physics, CAS, China

PAC09, Vancouver, May 04, 2009

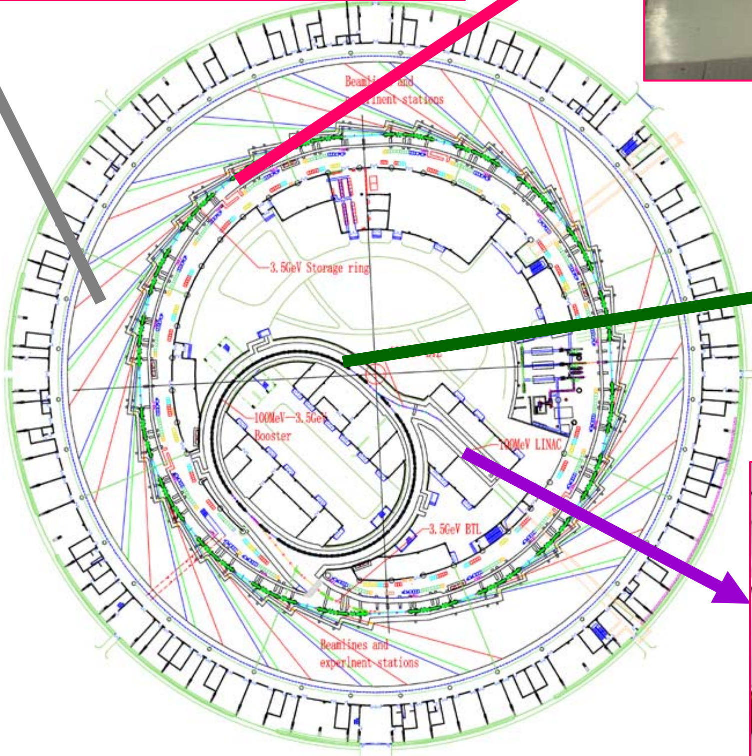
SINAP
中国科学院上海应用物理研究所
Shanghai Institute of Applied Physics, Chinese Academy of Sciences

Shanghai Synchrotron Radiation Facility

- SSRF is an intermediate energy 3rd generation light source funded by Chinese Academy of Sciences (CAS), Shanghai local government and central government of China;
- The SSRF project was initiated in 1995, and then its R&D program was carried out from January 1999 to March 2001. This project was finally launched in 2004 with the ground breaking made on Dec.25, 2004;
- The SSRF linac, booster and storage ring started their commissioning in May, September and December 2007 respectively. The first stored and accumulated beam in the ring was achieved on Dec. 24, 2007, the machine now is operating at 3.5GeV with 200mA beam current and seven phase-I beamlines are ready for user experiments.

The SSRF Complex

Storage Ring
3.5GeV, C=432m



Booster
3.5GeV, C=180m

Electron Linac
150MeV

The First SSRF Beamlines

- ☐ Macromolecular Crystallography (In-Vac Und.)
- ☐ High-Resolution X-ray Diffraction (Bend)
- ☐ X-ray Absorption Fine Structure Spectroscopy (Wiggler)
- ☐ Hard X-ray Micro-focus and Application (In-Vac Und.)
- ☐ X-ray Imaging and Biomedical Application (Wiggler)
- ☐ Small Angel X-ray Scattering (Bend)
- ☐ Soft X-ray Microscopy (EPU)

The SSRF Construction Schedule

- ☐ Dec. 2004 ~ May 2007: Building construction
- ☐ Jun. 2005 ~ Jun. 2008: Accelerator equipment and components manufacture and assembly
- ☐ Dec. 2005 ~Dec. 2008: Beamline construction and assembly
- ☐ May. 2007 ~ Jul. 2007: Linac commissioning
- ☐ Oct. 2007 ~ Dec. 2007: Booster commissioning
- ☐ Dec. 2007 ~ Dec. 2008: Storage ring commissioning
- ☐ May 2008 ~ Mar. 2009: Beamline commissioning
- ☐ May 2009: The SSRF pre-user operation begins

The SSRF Accelerator Complex

- The SSRF accelerator complex consists of a 150MeV Linac, a full energy booster and 3.5GeV storage ring
- The energy selected higher than 3GeV for getting higher photon energy;
- High brightness and high flux optimized for photon energy range of 0.1 - 40keV;
- High beam position stability requirement @ the long, medium and short terms;
- Top-up considered as one of the normal operation mode;

The SSRF Storage Ring

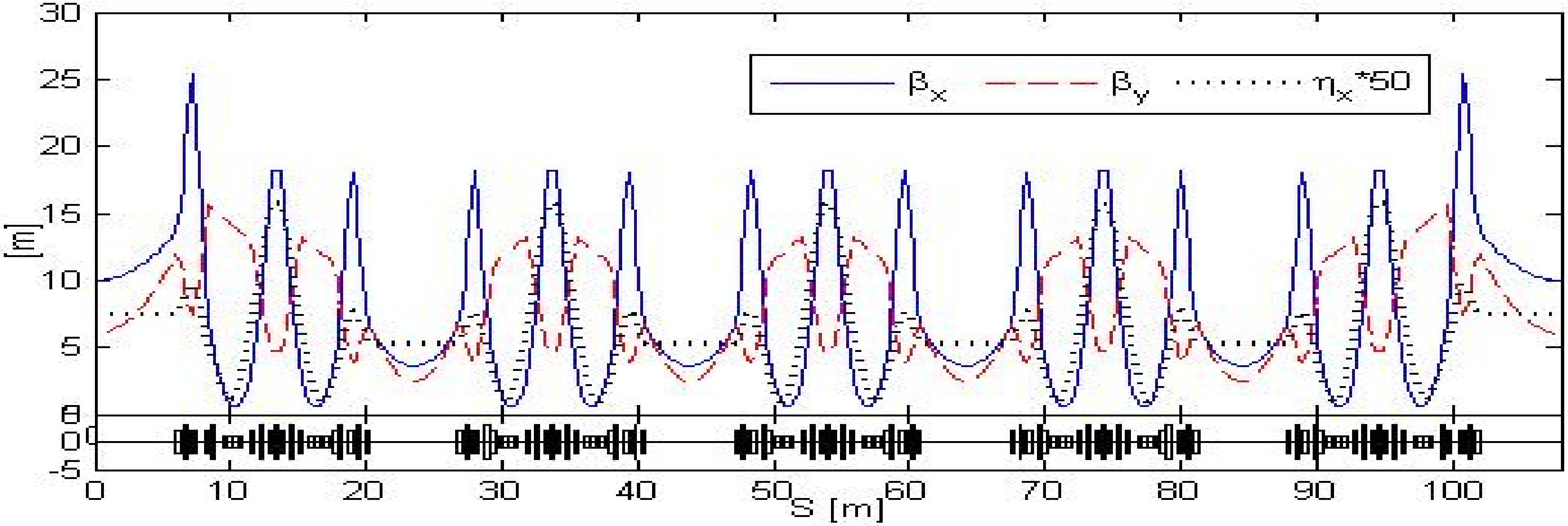
- ❑ A 20-cell double bend ring lattice structure with a circumference of 432 m and a natural emittance of 3.9nm-rad;
- ❑ 4 fold configuration with two types of straight sections (16x6.5m and 4x12m);
- ❑ One 12m straight for accommodating all injection elements, another one for SRF cavities and other 18 for various IDs;
- ❑ Reasonable beam sizes, beta functions and dispersion at straight sections;

Main Parameters of the SSRF Storage Ring

	DBA	Low-emittance mode	Normal Mode
Energy	GeV	3.5	3.5
Circomference	m	432	432
Natural Emittance	nm· rad	3.9	11. 2
Current：Multi-bunch（Single）	mA	200~300(5)	200~300(5)
Number of Cells		20/4	20/4
Straights: Length×Number	m	12×4、6.5×16	12×4、6.5×16
$\beta_x/\beta_y/\eta_x$ in middle of 12m straight	m	10.0/6.0/0.15	10.0/6.0/0.0*
$\beta_x/\beta_y/\eta_x$ in middle of 6.5m straight	m	3.6/2.5/0.10	3.6/2.5/0.0*
Betatron Tune Q_x/Q_y		22.22/11.29	22.22/11.29
Chromaticity ξ_x/ξ_y		-55/-17	-55/-17
RF Voltage	MV	4.0~6.0	4.0~6.0
Energy Loss Per Turn (Dipole)	MeV	1.448	1.448
Bunch Length	mm	4.0	4.0

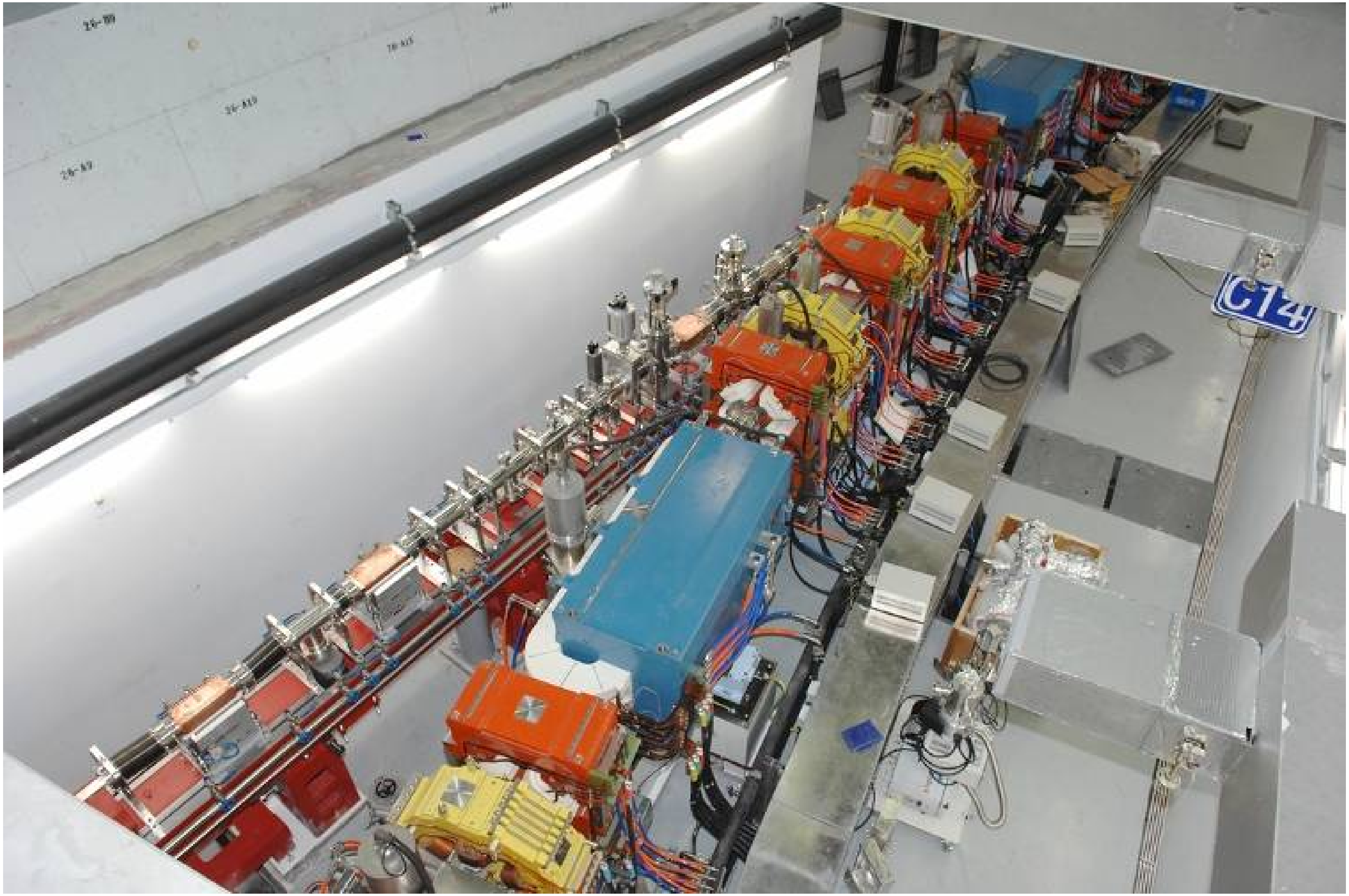

C05

Lattice Functions for One Super-Period



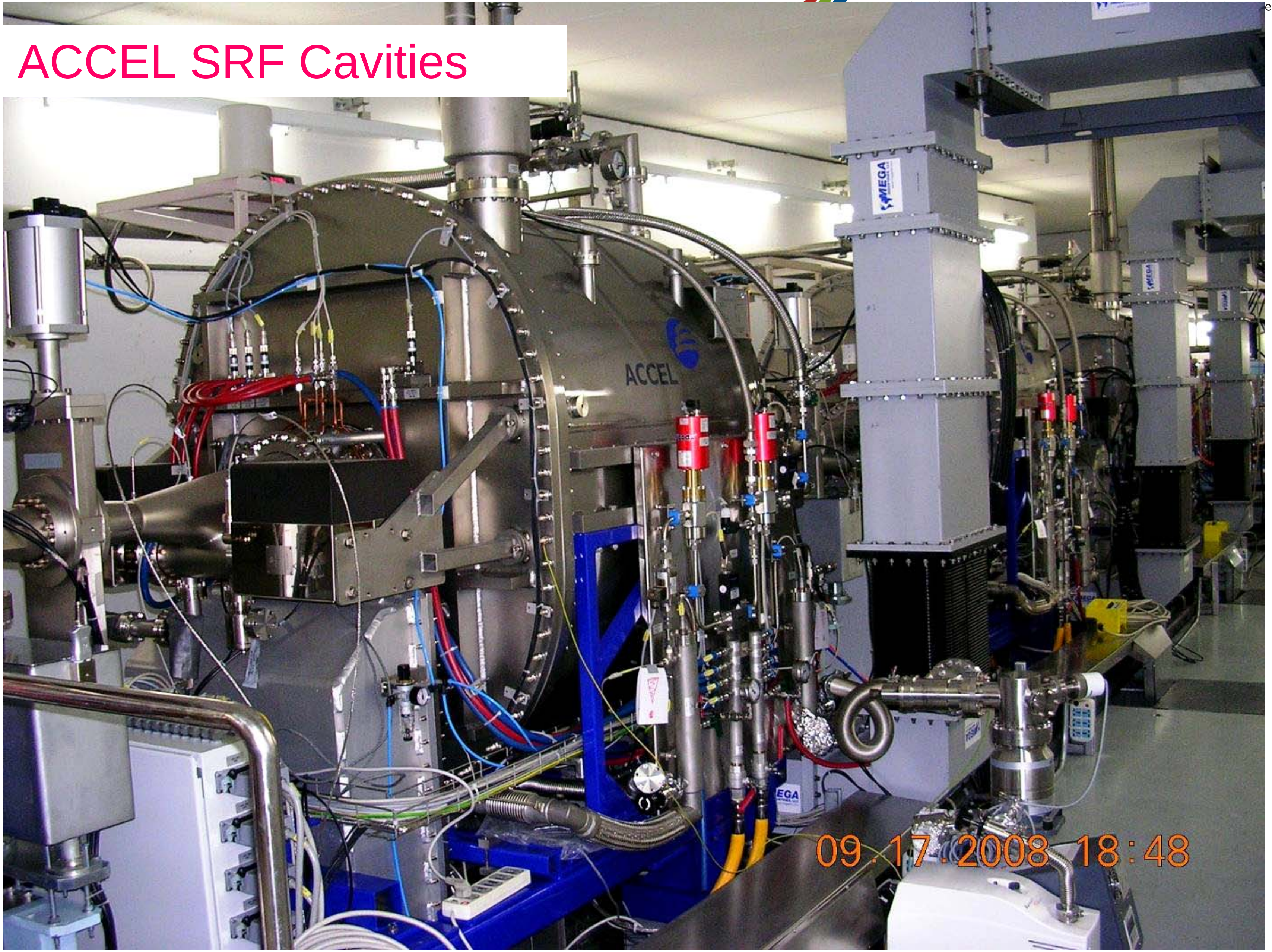
SSRF Beam Sizes at Source Points

Source Point	σ_x (μm)	σ_x' (μrad)	σ_y (μm)	σ_y' (μrad)
Standard Straight (6.5m)	158	33	9.9	3.95
Long Straight (12.0m)	247	20	15	2.55
1°@upstream of SS	70	114	22	1.97
3.1°@upstream of SS	53	94	22	1.97
1°@upstream of LS	77	116	23	1.79
3.1°@upstream of LS	56	96	23	1.79

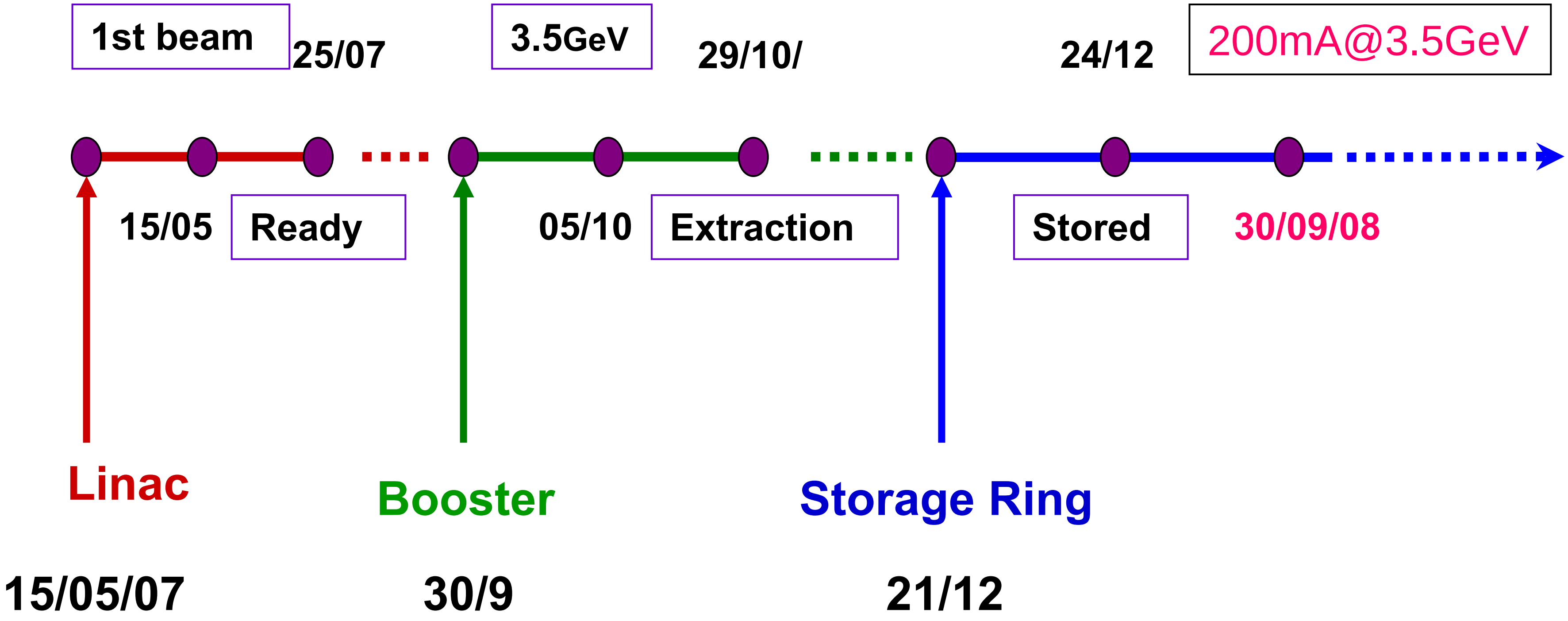

C14


Ring Injection
BTS Line

ACCEL SRF Cavities



Key Dates of the SSRF Commissioning



1st beam 25/07

3.5GeV 29/10/

24/12 200mA@3.5GeV

15/05 Ready

05/10 Extraction

Stored 30/09/08

Linac

15/05/07

Booster

30/9

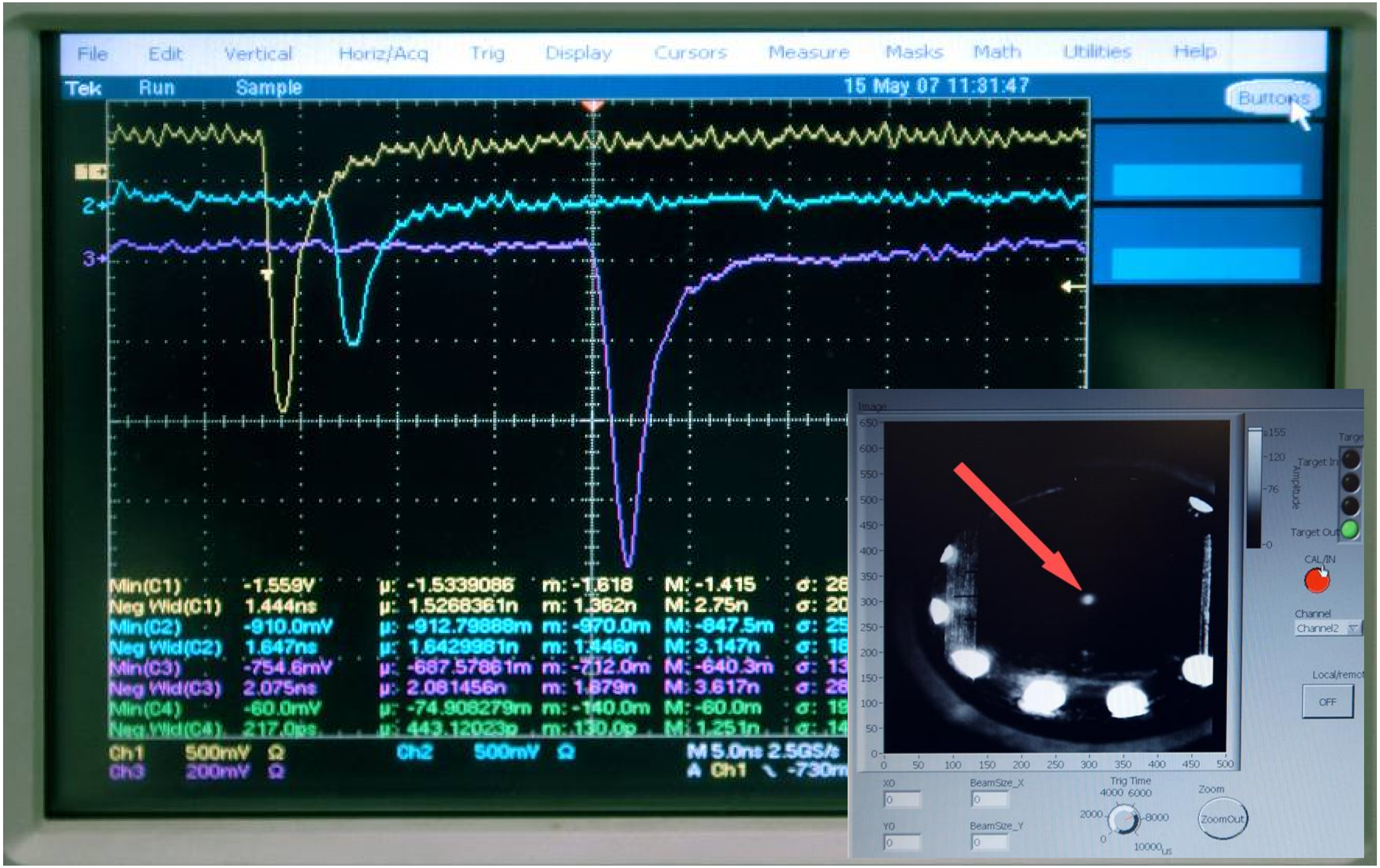
Storage Ring

21/12

The SSRF Linac and its Commissioning

- A dedicated 150MeV Linac for top-up operation and the working frequency of 2998MHz chosen to have harmonic relation with the storage ring RF frequency;
- Main components include two 45MW klystrons, four 2998MHz/3m long accelerating sections, a 500MHz sub-harmonic buncher and a fundamental buncher;
- 100kV thermionic gun with single bunch (1nC/1ns) and multi bunch (3nC/200ns) operation modes;
- The linac commissioning started on May 15, 2007 and beam with energy more than 100MeV was obtained on the first day. The design specifications were achieved in July 2007.

First beam from Linac on May 15, 2007



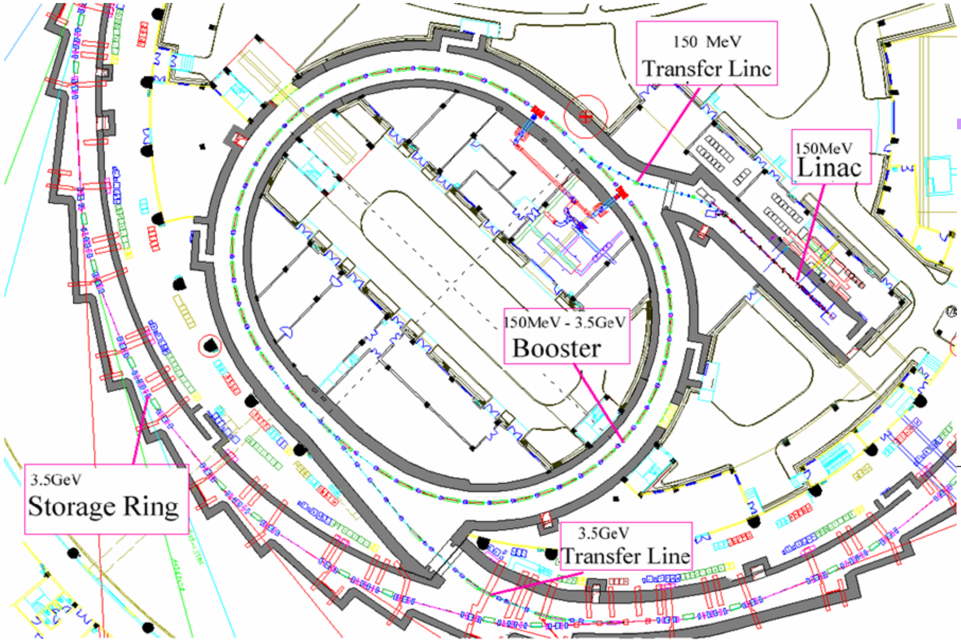
```
Min(C1)        -1.559V     μ: -1.5339086    m: -1.618    M: -1.415    σ: 28
Neg Wid(C1)    1.444ns     μ: 1.5268361n    m: 1.362n    M: 2.75n     σ: 20
Min(C2)        -910.0mV    μ: -912.79888m   m: -970.0m   M: -847.5m   σ: 25
Neg Wid(C2)    1.647ns     μ: 1.6429981n    m: 1.446n    M: 3.147n    σ: 16
Min(C3)        -754.6mV    μ: -687.57861m   m: -712.0m   M: -640.3m   σ: 13
Neg Wid(C3)    2.075ns     μ: 2.081456n     m: 1.879n    M: 3.617n    σ: 28
Min(C4)        -60.0mV     μ: -74.908279m   m: -140.0m   M: -60.0m    σ: 19
Neg Wid(C4)    217.0ps     μ: 443.12023p    m: 130.0p    M: 1.251n    σ: 14
Ch1    500mV  Ω          Ch2    500mV  Ω          M 5.0ns 2.5GS/s
Ch3    200mV  Ω                                   A Ch1  \  -730m
```

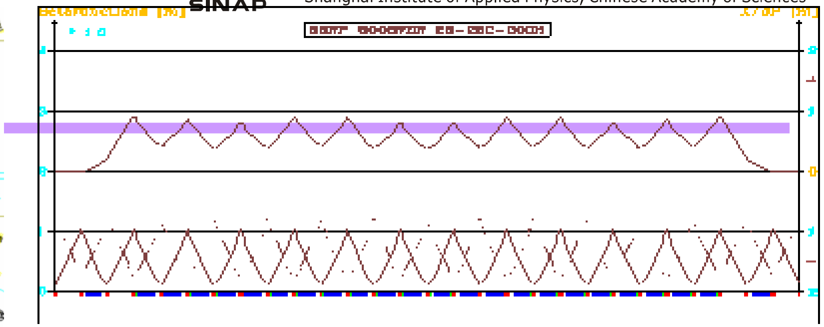
The Achieved Performance of the SSRF Linac

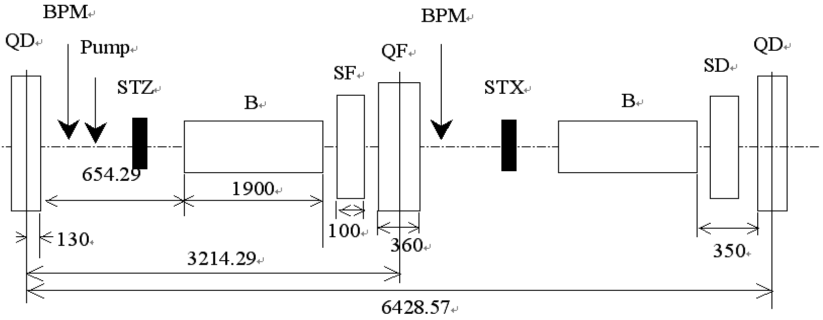
	Designed	Measured
Energy (MeV)	150	152 – 162
Single bunch charge (nC)	1.0	1.06
Multi-bunch charge (nC)	5.0	6.0 – 6.6
Energy stability	0.5% (rms)	0.1 – 0.4%
Relative energy spread	0.5% (rms)	0.2 – 0.4%
Normalized emittance (x)	50 mm-mrad	37- 46 mm-mrad
Normalized emittance (y)	50 mm-mrad	32 – 49 mm-mrad
Linac Frequncey (MHz)	2997.924	2997.924
Rep. Rate (Hz)	2	2

The SSRF Booster and its commissioning

- ☐ A full energy booster optimized for top-up injection;
- ☐ Two fold Lattice configuration to accommodating 28 FODO cells with 8 missing dipole magnets;
- ☐ Extraction beam emittance designed at ~100 nm-rad for getting a clean top-up operation;
- ☐ A circumference of 180m and a injection energy of 150MeV;
- ☐ Repeat rates up to 2Hz;


150 MeV
Transfer Line
150MeV
Linac
150MeV - 3.5GeV
Booster
3.5GeV
Storage Ring
3.5GeV
Transfer Line




BPM
BPM
QD
Pump
STZ
B
SF
QF
STX
B
SD
QD
654.29
1900
130
100
360
350
3214.29
6428.57


C15 C16

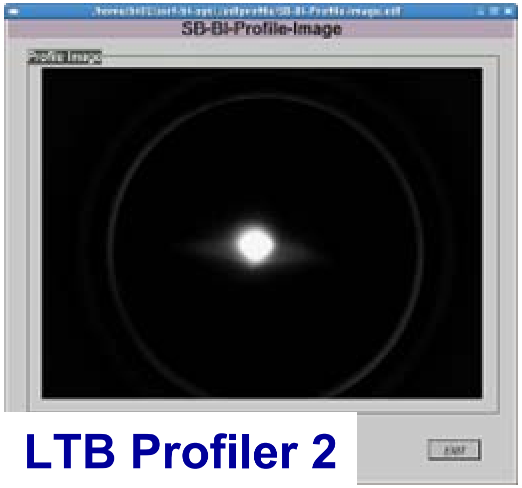

C21 C22

Booster Commissioning Milestones

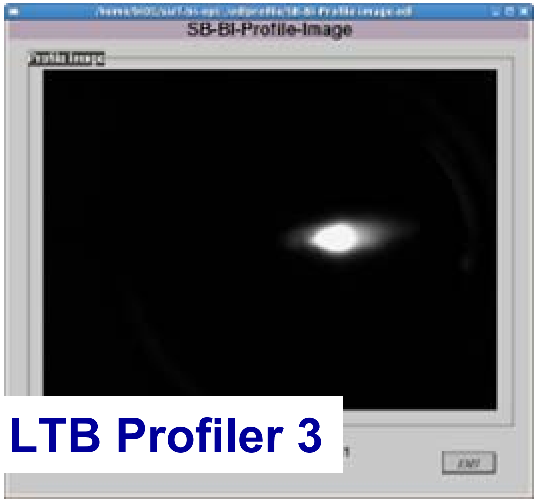
- ☐ Sept. 30: Commissioning started at 20:30, and beam arrived at the booster entrance at 21:58;
- ☐ Oct. 01: First turns of the circulating beam in booster achieved at 17:00;
- ☐ Oct. 02: First stored beam in the booster obtained at 4:30;
- ☐ Oct. 05: Within 60 effective commissioning hours, first ramped beam (3.5GeV) obtained at 4:25;
- ☐ Oct. 29: First extract beam from the booster achieved;

Beam passed LTB transport line on Sept.30, 23:00

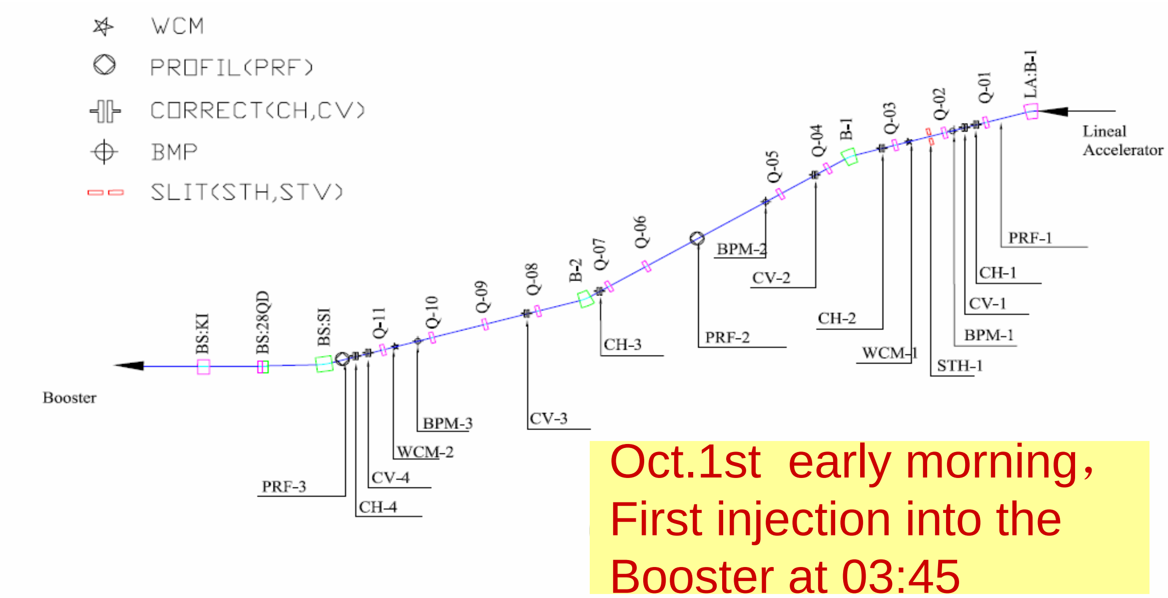
LTB Profiler 1



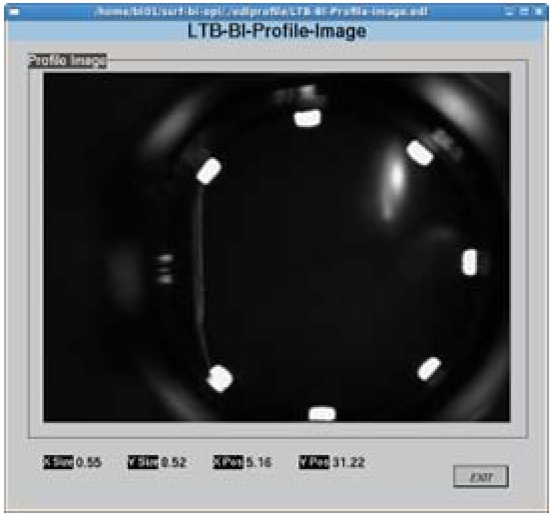
LTB Profiler 2



LTB Profiler 3



Oct.1st early morning，
First injection into the
Booster at 03:45



First turns (Oct. 1, 17:00)

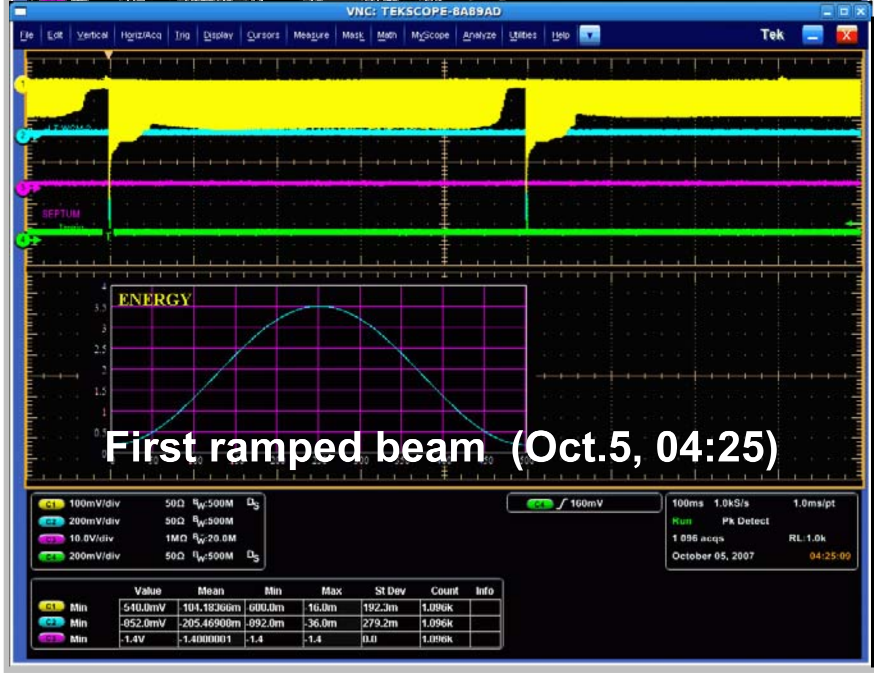
First stored beam (Oct.2 04:30)

C1 100mV/div 50Ω BW:500M DS
C4 200mV/div 50Ω BW:500M DS

C4 ∫ 324mV

200ms 50.0kS/s 20.0μs/pt
Run Pk Detect
3 acqs RL:100k
October 02, 2007 04:32:32

	Value	Mean	Min	Max	St Dev	Count	Info
C1 Min	>-886.0mV	-886.00001m	-886.0m	-886.0m	0.0	3.0	⚠
C2 Min	-1,000.0mV	-999.99995m	-1,000.0m	-1,000.0m	0.0	3.0	
C3 Min	-1.4V	-1.4	-1.4	-1.4	0.0	3.0	



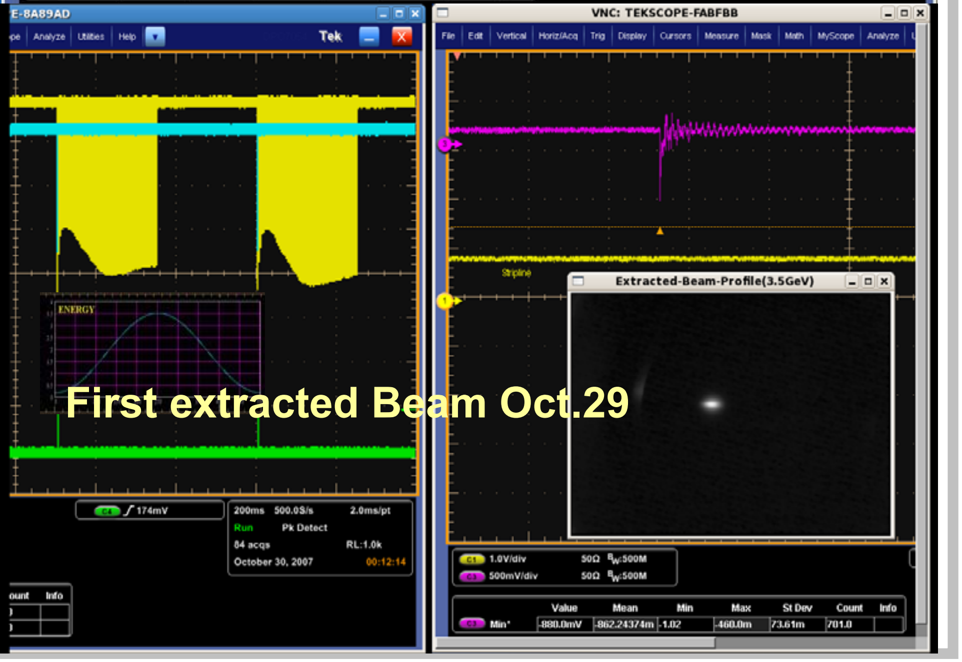
First ramped beam (Oct.5, 04:25)

C1 100mV/div 50Ω BW:500M DS
C2 200mV/div 50Ω BW:500M
C3 10.0V/div 1MΩ BW:20.0M
C4 200mV/div 50Ω BW:500M DS

C4 ∫ 160mV

100ms 1.0kS/s 1.0ms/pt
Run Pk Detect
1 096 acqs RL:1.0k
October 05, 2007 04:25:09

	Value	Mean	Min	Max	St Dev	Count	Info
C1 Min	540.0mV	104.18366m	600.0m	16.0m	192.3m	1.096k	
C2 Min	-052.0mV	-205.46900m	-092.0m	-36.0m	279.2m	1.096k	
C3 Min	-1.4V	-1.4000001	-1.4	-1.4	0.0	1.096k	



First extracted Beam Oct.29

C4 ∫ 174mV

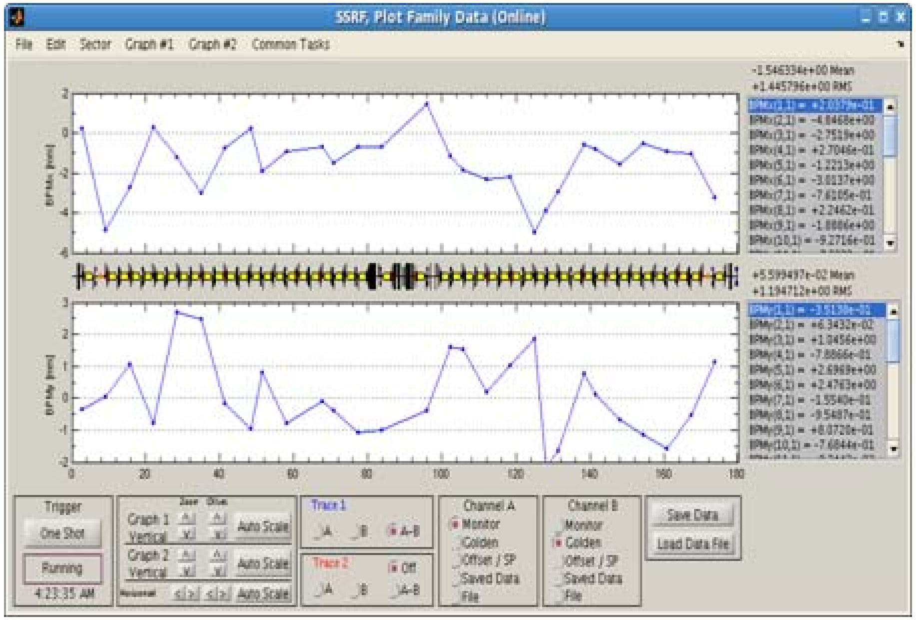
200ms 500.0S/s 2.0ms/pt
Run Pk Detect
84 acqs RL:1.0k
October 30, 2007 00:12:14

C1 1.0V/div 50Ω BW:500M
C3 500mV/div 50Ω BW:500M

	Value	Mean	Min	Max	St Dev	Count	Info
C3 Min'	-880.0mV	-862.24374m	-1.02	-460.0m	73.61m	701.0	

Tune and COD measurement

Tune: 8.251(h)/ 5.317(v). COD: The maximum COD is less than 3mm (h)/1mm (v) without any correctors, thanks to the very good magnet alignment.

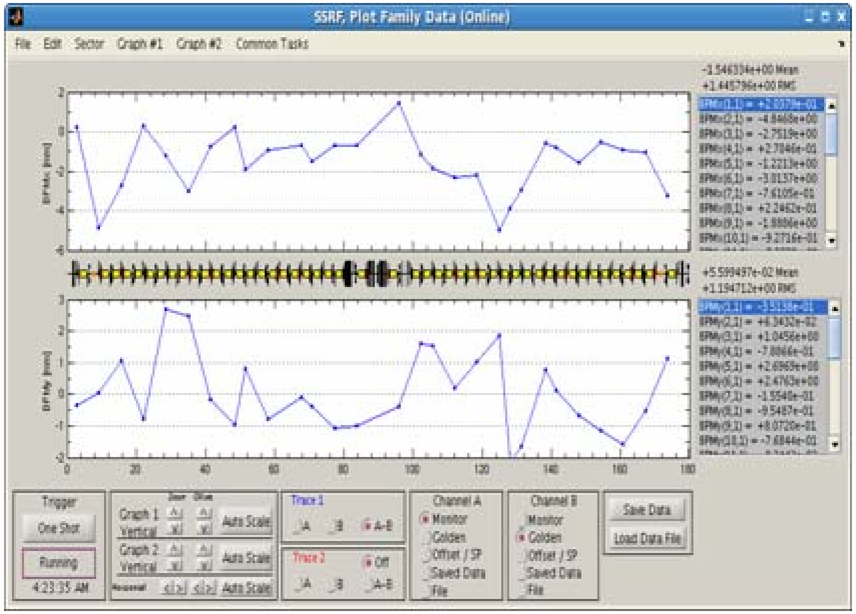


-1.546334e+00 Mean
+1.445796e+00 RMS

BPMx(1,1) = +2.0379e-01
BPMx(2,1) = -4.8468e+00
BPMx(3,1) = -2.7519e+00
BPMx(4,1) = +2.7046e-01
BPMx(5,1) = -1.2213e+00
BPMx(6,1) = -3.0137e+00
BPMx(7,1) = -7.6105e-01
BPMx(8,1) = +2.2462e-01
BPMx(9,1) = -1.8886e+00
BPMx(10,1) = -9.2716e-01

+5.599497e-02 Mean
+1.194712e+00 RMS

BPMy(1,1) = -3.5138e-01
BPMy(2,1) = +6.3432e-02
BPMy(3,1) = +1.0456e+00
BPMy(4,1) = -7.8866e-01
BPMy(5,1) = +2.6969e+00
BPMy(6,1) = +2.4763e+00
BPMy(7,1) = -1.5540e-01
BPMy(8,1) = -9.5487e-01
BPMy(9,1) = +8.0720e-01
BPMy(10,1) = -7.6844e-01



-1.546334e+00 Mean
+1.445796e+00 RMS

BPMx(1,1) = +2.0379e-01
BPMx(2,1) = -4.8468e+00
BPMx(3,1) = -2.7519e+00
BPMx(4,1) = +2.7046e-01
BPMx(5,1) = -1.2213e+00
BPMx(6,1) = -3.0137e+00
BPMx(7,1) = -7.6105e-01
BPMx(8,1) = +2.2462e-01
BPMx(9,1) = -1.8886e+00
BPMx(10,1) = -9.2716e-01

+5.599497e-02 Mean
+1.194712e+00 RMS

BPMy(1,1) = -3.5138e-01
BPMy(2,1) = +6.3432e-02
BPMy(3,1) = +1.0456e+00
BPMy(4,1) = -7.8866e-01
BPMy(5,1) = +2.6969e+00
BPMy(6,1) = +2.4763e+00
BPMy(7,1) = -1.5540e-01
BPMy(8,1) = -9.5487e-01
BPMy(9,1) = +8.0720e-01
BPMy(10,1) = -7.6844e-01

Achieved Performance of the SSRF Booster

Parameter	Designed	Measured
Energy (GeV)	3.5	3.51
Circumference (m)	180	180
Bunch charge Single/multi (nC)	1.0/5.0	~1.2 / >6.0
Tunes	8.42/5.39	8.41/5.27
Emittance (nm-rad)	108	90 - 107
Rep. rate (Hz)	2	2

In addition:

The SSRF booster transmission efficiency from the LTB transport line to the BTS transport line is larger than 85%;

The SSRF Storage Ring Commissioning

☐ The SSRF storage ring commissioning, started on Dec. 21, 2007, four months ahead of its original schedule, has been carried out in three phases:

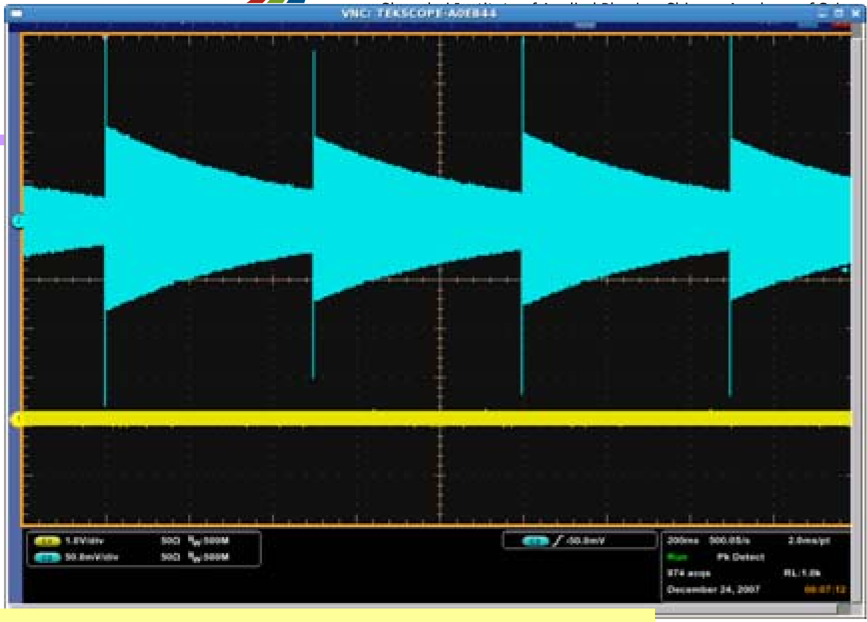
- Phase I (Dec. 2007 to June 2008): Commissioning with normal conducting cavity at 3GeV@100mA and 2 bend beamlines;
- Phase II (from Aug. to Sept. 2008): Commissioning with superconducting cavity at 3.5GeV@200-300mA;
- Phase III (Oct. 2008 to Apr. 2009): Commissioning with 5 IDs (1EPU, 2 In-vac undulators, 2 wigglers) and their corresponding beamlines;

Storage Ring Commissioning Milestones

- ❑ Dec. 21, 2007: commissioning started at 18:20, one turn beam achieved at 21:08 and multi-turn beam at 21:18;
- ❑ Dec.24, 2007: first stored beam obtained at 06:54 (in~60hrs)
- ❑ Jan.03, 2008: 100mA stored beam achieved at 20:20;
- ❑ Mar. 16, 2008: Both horizontal and vertical closed orbit corrected to <50um rms with 80 correctors (137BPMs);
- ❑ June 2008: orbit stability at a few of microns level achieved;
- ❑ Sept. 30, 2008: 200mA at 3.5GeV achieved;
- ❑ April 30, 2009: integrated current of 468 Ahrs obtained.

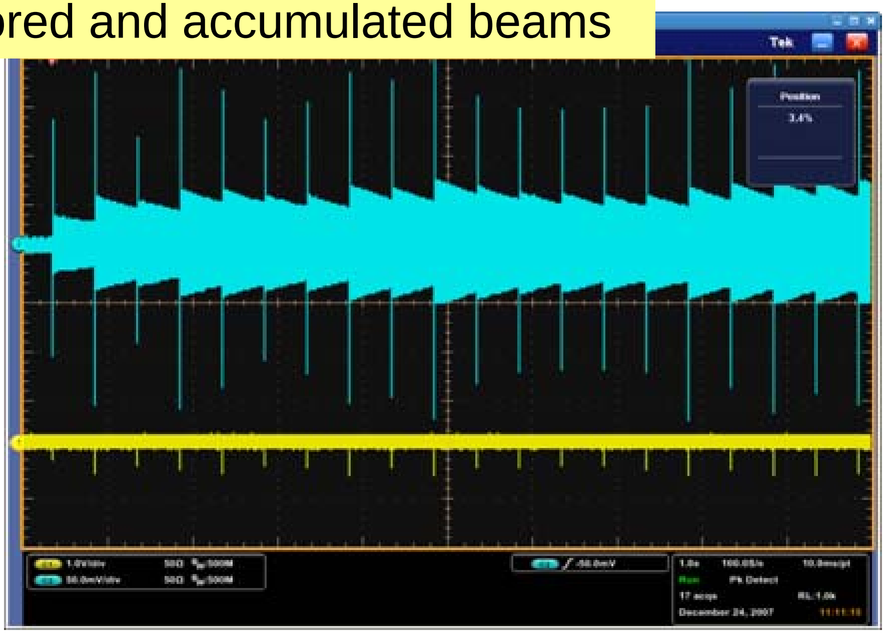
Machine Calibration and Characterization

- Achieving first turn, multi-turn, stored and accumulated beam in storage ring;
- Orbit correction
  - Correct orbit with the most effective corrector (MICADO);
  - BBA and response matrix measurements;
  - Closed orbit corrections based on BBA and RM;
- Linear optics calibrations
  - Beta function restoration with beatings within ±1%;
  - Dispersion restoration with beating within ±1%;
  - LOCO and MIA calibration (based turn by turn BPM data);



Circulated, Stored and accumulated beams

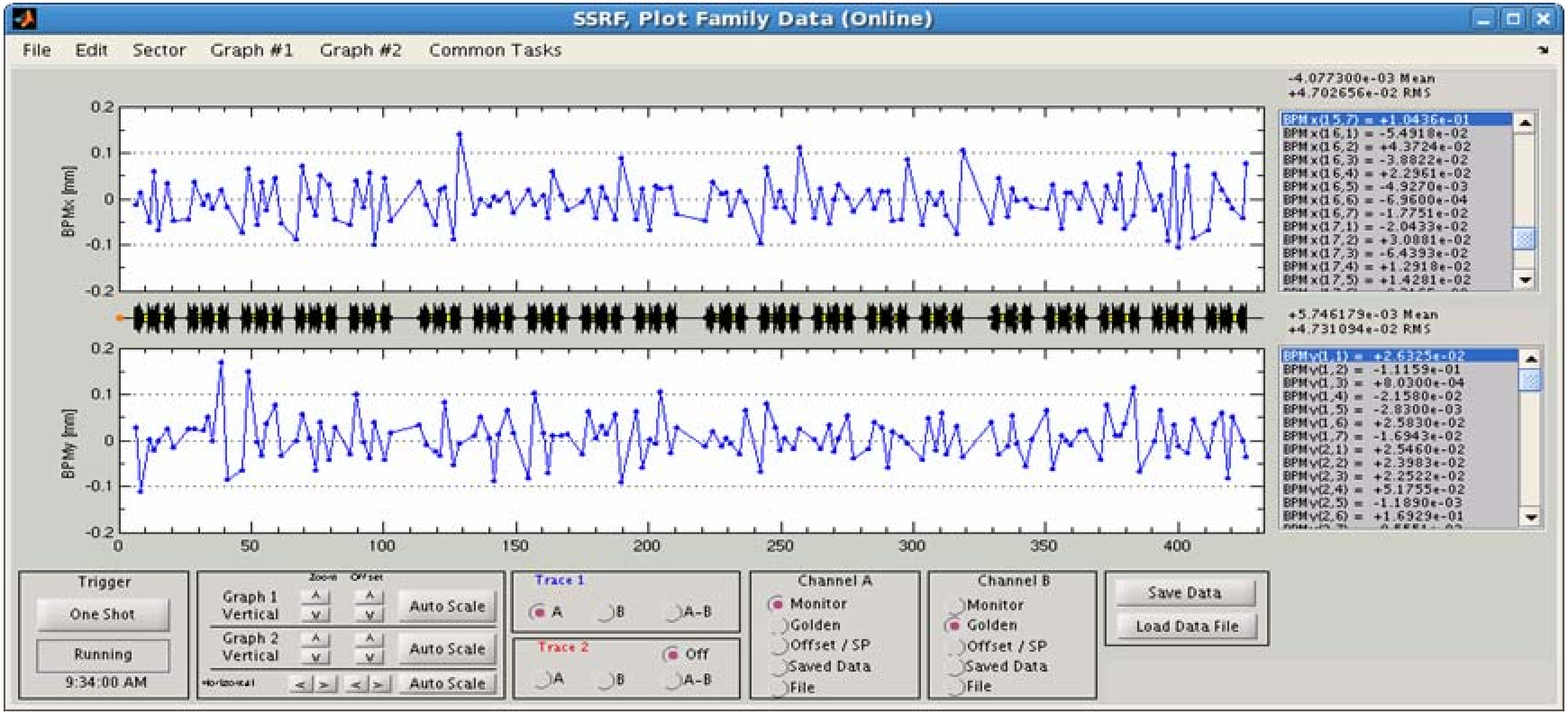
First Light



Celebrating the Stored Beam 06:54, Dec.24, 2007

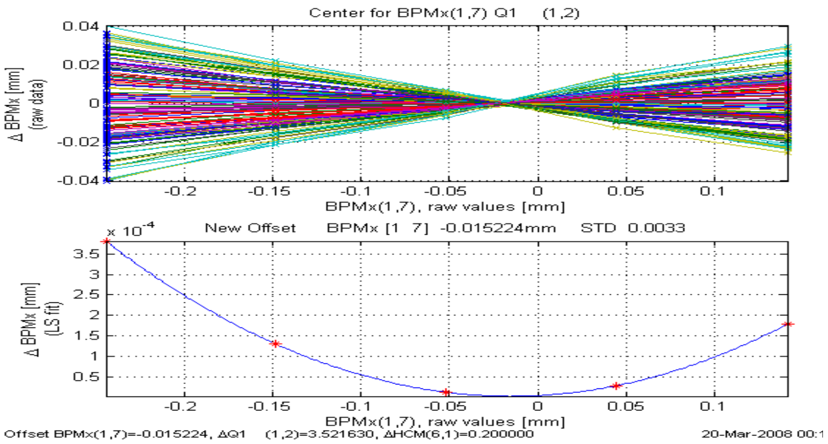
Residual closed orbit at 3GeV@100mA: <50um rms

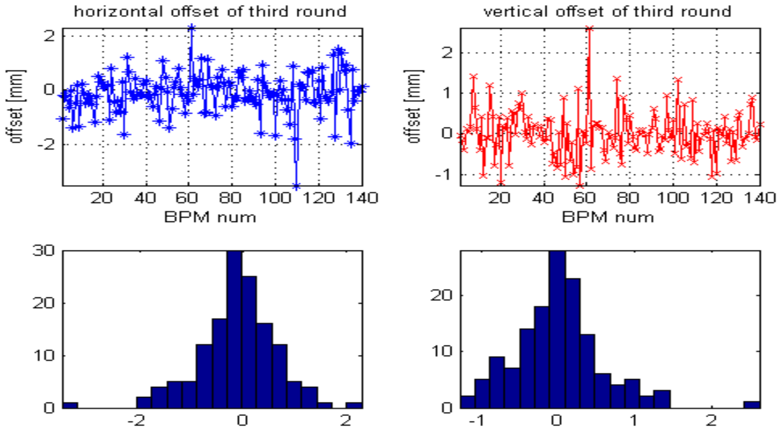
- With 137BPMs and 80 correctors for each of the horizontal and vertical planes
- Closed orbit was corrected to (rms): 47um (horizontal) and 47 um (vertical)
- Maximum corrector strengths are: 0.17mrad (horizontal) and 0.18mrad (vertical)

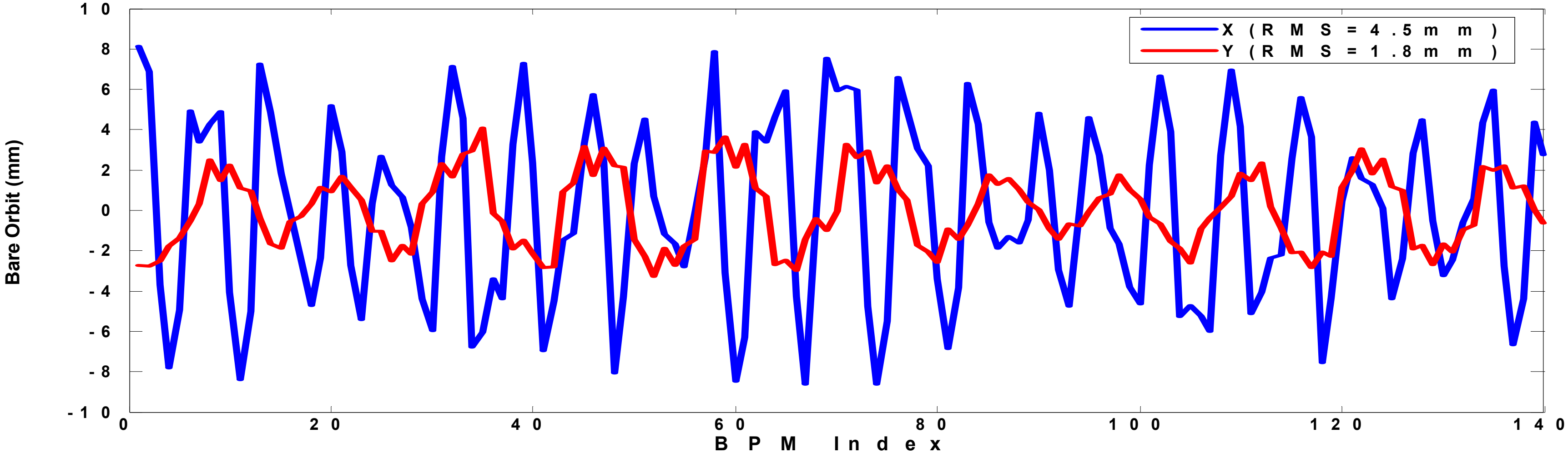


```
-4.077300e-03 Mean
+4.702656e-02 RMS

BPMx(15,7) = +1.0436e-01
BPMx(16,1) = -5.4910e-02
BPMx(16,2) = +4.3724e-02
BPMx(16,3) = -3.8822e-02
BPMx(16,4) = +2.2961e-02
BPMx(16,5) = -4.9270e-03
BPMx(16,6) = -6.9600e-04
BPMx(16,7) = -1.7751e-02
BPMx(17,1) = -2.0433e-02
BPMx(17,2) = +3.0081e-02
BPMx(17,3) = -6.4393e-02
BPMx(17,4) = +1.2918e-02
BPMx(17,5) = +1.4281e-02

+5.746179e-03 Mean
+4.731094e-02 RMS

BPMy(1,1) = +2.6325e-02
BPMy(1,2) = -1.1159e-01
BPMy(1,3) = +8.0300e-04
BPMy(1,4) = -2.1580e-02
BPMy(1,5) = -2.8300e-03
BPMy(1,6) = +2.5830e-02
BPMy(1,7) = -1.6943e-02
BPMy(2,1) = +2.5460e-02
BPMy(2,2) = +2.3983e-02
BPMy(2,3) = +2.2522e-02
BPMy(2,4) = +5.1755e-02
BPMy(2,5) = -1.1890e-03
BPMy(2,6) = +1.6929e-01
```

Bare Orbit in the SSRF Storage Ring (all correctors off)







consistent with quads positioning tolerance

Designed Lattice Configurations

	Mode I	Mode II	Mode III	Mode IV
Tune	22.22/11.29	22.22/11.29	23.32/11.23	19.22/7..32
emittance	3.92	11.4	3.36	5.42

LOCO Calibration results for different lattice mode

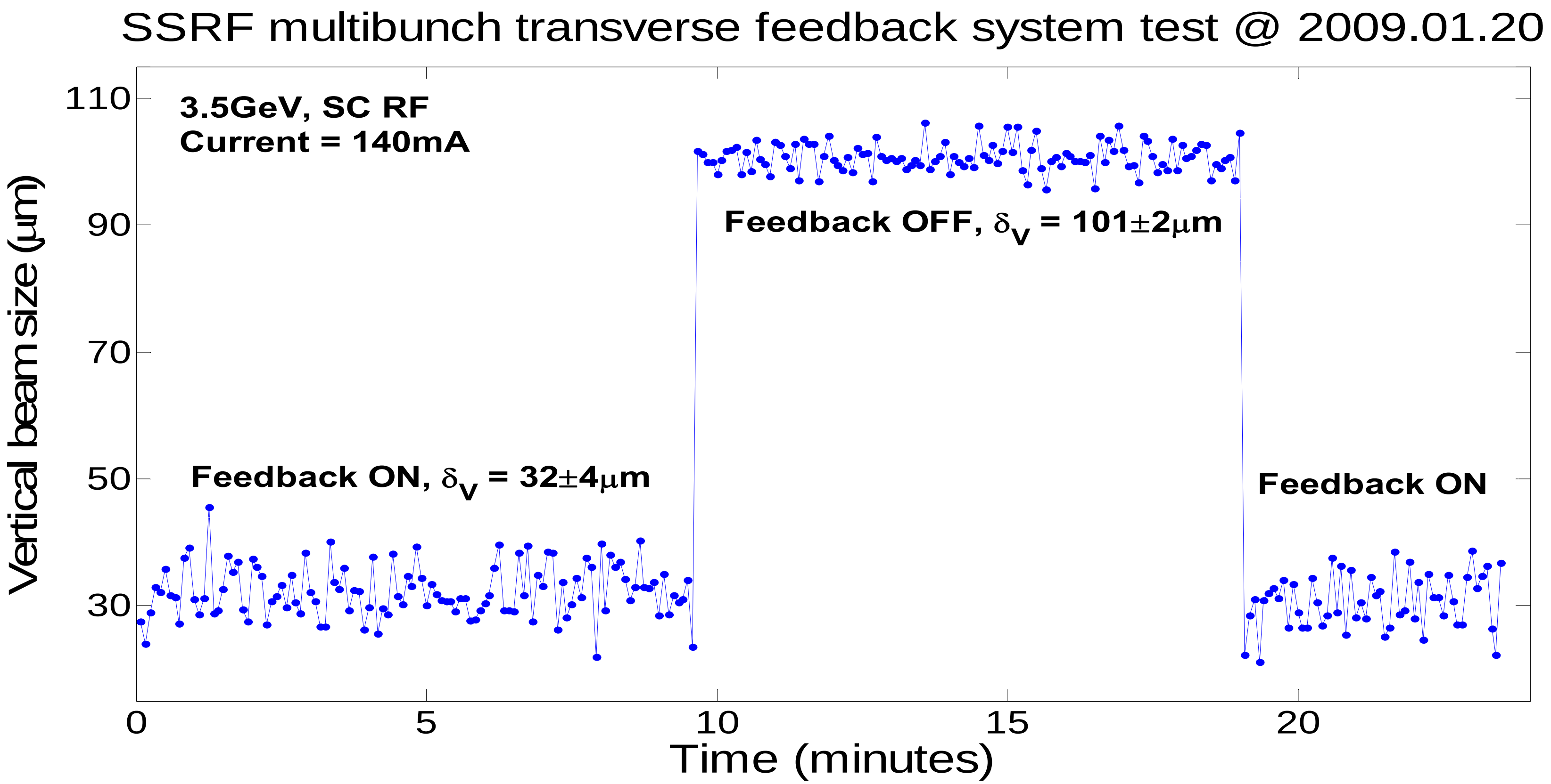
rms	Mode I	Mode II	Mode III	Mode IV
Beta function distortion before LOCO	3.9~5.8%	7.8~4.1%	6.1~4.1%	4.4~4.9%
Beta function distortion After LOCO	0.50~0.52%	0.52~0.87%	0.48~0.71%	0.81~0.36%
Calibrated dK/K	0.29%	0.43%	0.33%	0.23%

Calibration results of main optical parameters @3.0GeV

Parameters	Designed Mode	LOCO Model	Measurement
Tune Q_x/Q_y	22.22/11.29	22.2231/11.2916	~22.2213/11.2905
$\beta_x/\beta_y/\eta_x$(m) in the centers of straight sections	10/6.0/0.15 3.6/2.5/0.10	10.02/6.06/0.15	
Natural emittance (nm-rad) @3.0GeV	2.86	2.86	~2.8
Natural chromaticity ξ_x/ξ_y	-55.70/-17.94	-55.68/-17.93	~-50/-17
Momentum compaction factor	4.27×10^{-4}	4.27×10^{-4}	
RF frequency (MHz)	499.654	499.674660	499.674640

Transverse Beam Feedback and Beam Size

- ☐ Transverse multi-bunch beam feedback
- Beam size blow up is effectively suppressed;



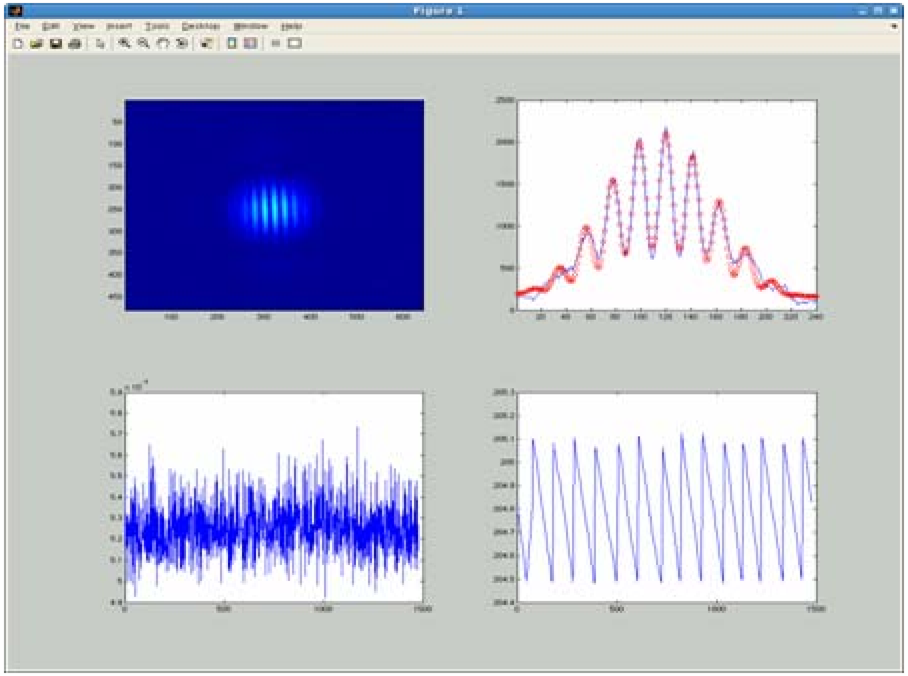
Beam Size and Emittance Measurements

- Beam size measurements with SR interferometer
  - Beam size measurements at different currents and ID gaps);
  - Emittance is determined from the measured beam size and the beta function from LOCO calibration;

Natural emittance is:

~3.8 nm-rad with ~10% measurement errors

@ beam current up to 200mA;



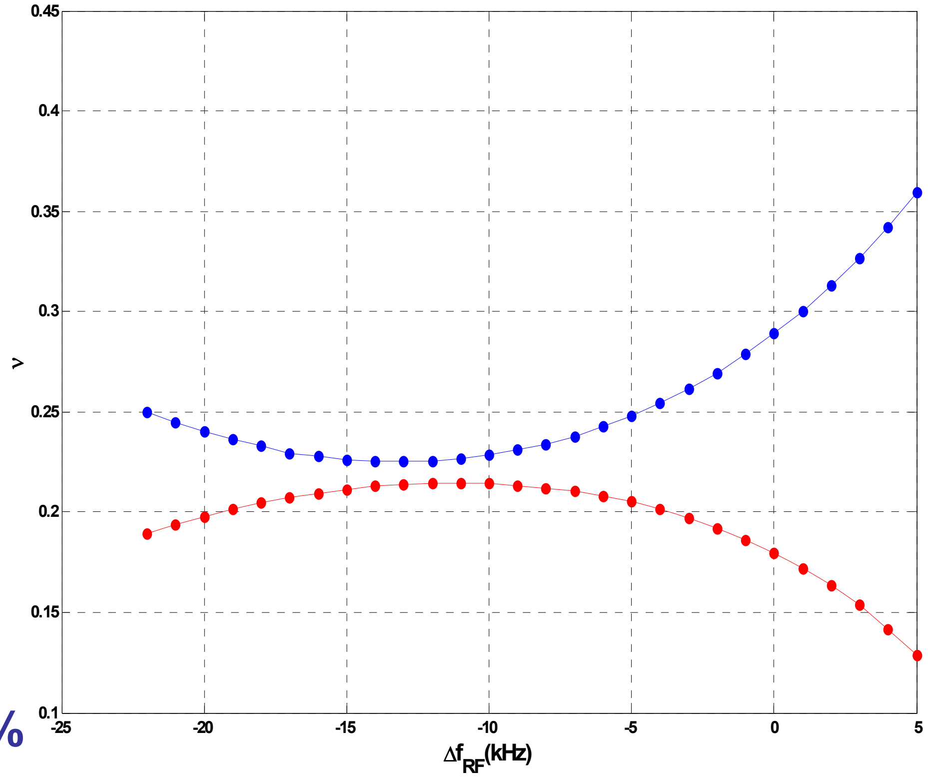
Emittance Coupling of the Storage Ring

- Coupling coefficient measurement
- Measurement of the tune change vs the RF frequency;

$$(\nu_x - \nu_y)_{\min} = 2|\kappa|$$

$$\Delta_r = \nu_x - \nu_y - N$$

$$\frac{\varepsilon_y}{\varepsilon_x} = \frac{|\kappa|^2}{|\kappa|^2 + \Delta_r^2 / 2}$$



The measured coupling is 0.69%

Beam Lifetime and Bunch Current

☐ Beam lifetime

- Beam lifetime at 3.5GeV with 200mA in 600 bunches are:

  31.1 hours @ 5 IDs is opened and average vacuum pressure is 0.54 nTorr, &
  18.3 hours @ 5 IDs is closed and average vacuum pressure is 0.68 nTorr
- Beam lifetime of a 5mA single bunch at 3.5GeV is 4.7hours;
- The measured Touschek lifetime is 51.3hours at 3.5GeV with 0.3mA per bunch and the theoretical one is 53.5 hours;
- The measured beam scattering lifetime at 3.5GeV is 51.7h / nTorr;

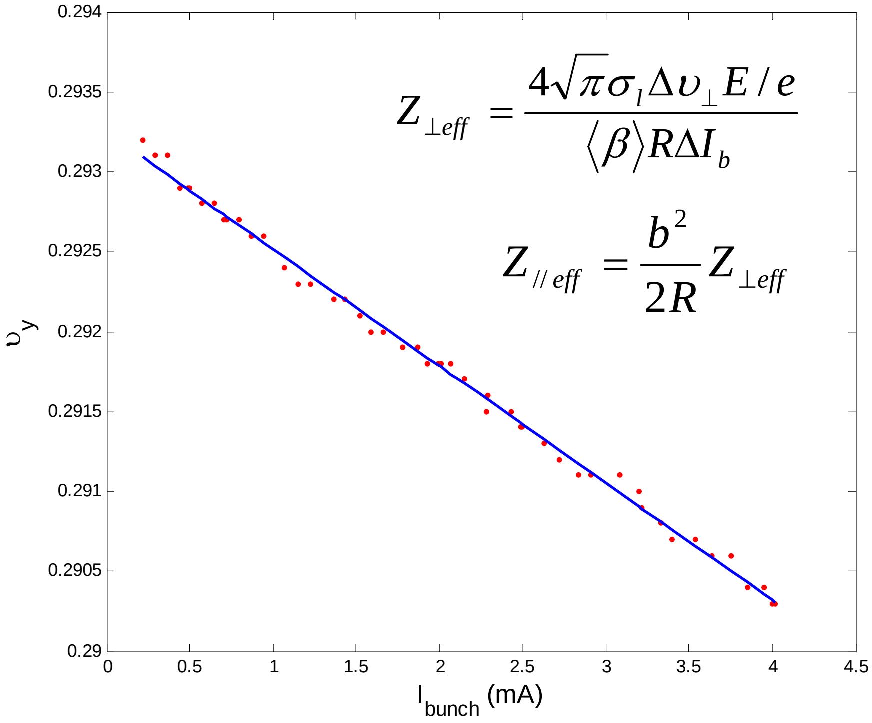
Top-up Operation

☐ High current and top-up operation

- Beam current of 200mA at 3.5GeV in 600 bunches is often used in the storage ring operation;
- Top-up operation has been often performed during machine studies, the beam current can be controlled with 0.3%
- Top-up operation can maintain the ring beam at high orbit stability level because of it avoids the current dependence;
- Optimizations of kickers have been performance to reduce the orbit disturbances during injection, and <100um (H) and <30um (V) have been obtained;

Impedance of the Storage Ring

- Impedance
- Impedance was measured before the installation of IDs and with different in-vacuum undulator gaps;



$$Z_{\perp eff} = \frac{4\sqrt{\pi}\sigma_l \Delta\upsilon_\perp E/e}{\langle\beta\rangle R\Delta I_b}$$

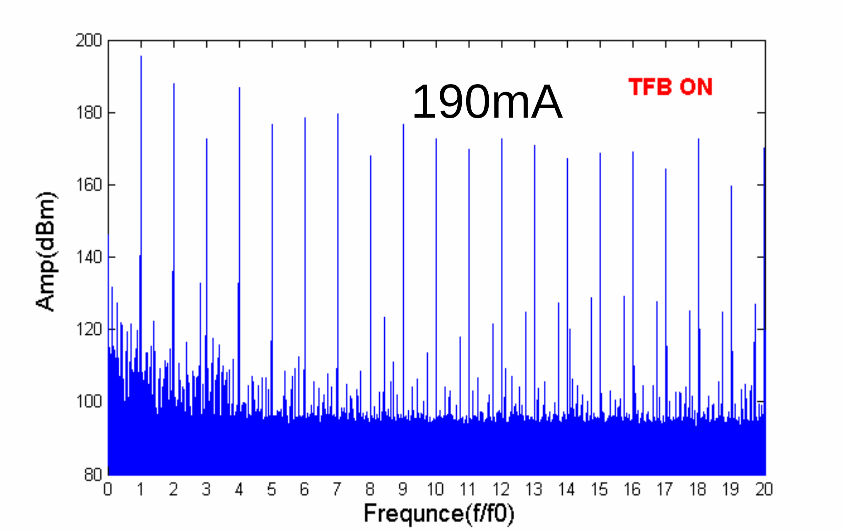
$$Z_{// eff} = \frac{b^2}{2R} Z_{\perp eff}$$

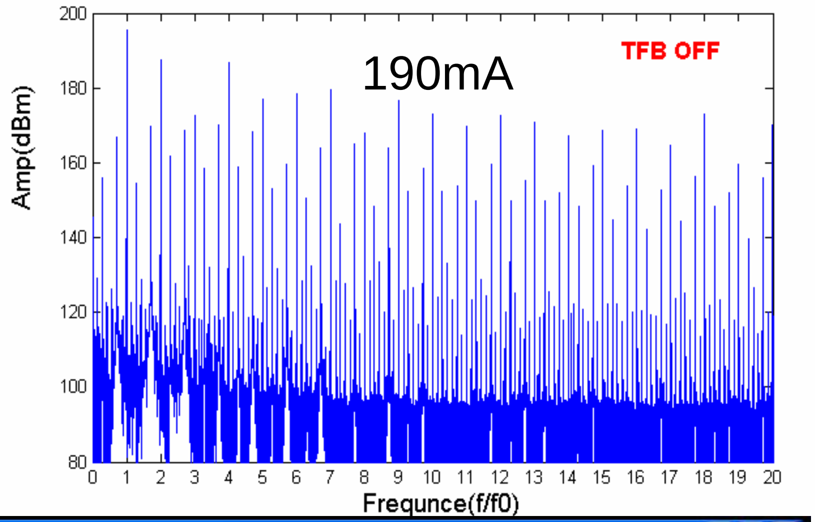
Before ID installation $Z_{//eff}$=0.34 Ω

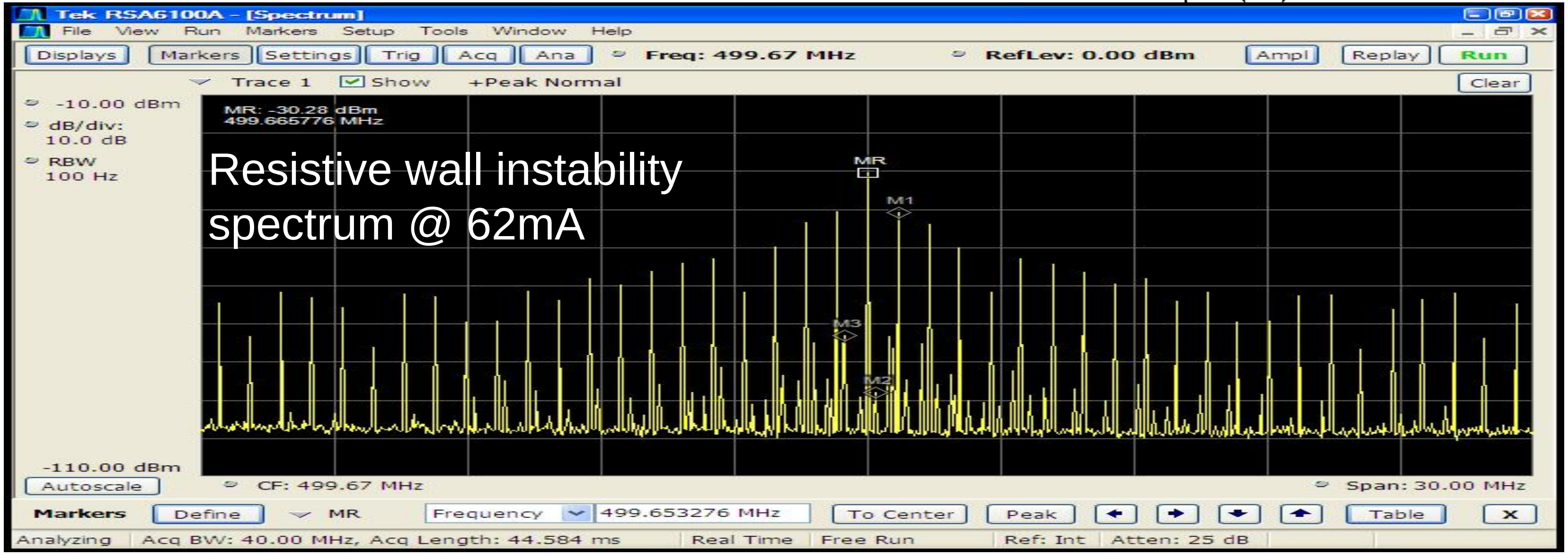
With 2 In-Vacuum undulators

IDs gap(mm)	$Z_{//eff}$(Ω)
30	0.39
12	0.40
10	0.43
8	0.45
7	0.48

Resistive Wall Instability and Transverse Feedback





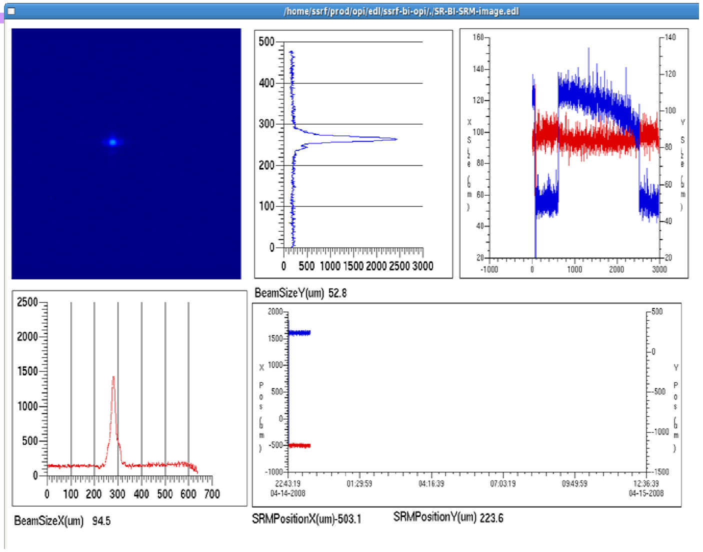


Freq: 499.67 MHz
RefLev: 0.00 dBm
Trace 1 ☑ Show +Peak Normal
-10.00 dBm
dB/div: 10.0 dB
RBW 100 Hz
MR: -30.28 dBm
499.665776 MHz
-110.00 dBm
CF: 499.67 MHz
Span: 30.00 MHz
MR Frequency 499.653276 MHz
Analyzing | Acq BW: 40.00 MHz, Acq Length: 44.584 ms | Real Time | Free Run | Ref: Int | Atten: 25 dB

Resistive wall instability spectrum @ 62mA

Bunch Length and Single Bunch Instability

- ☐ Sawtooth beam blowup occurs at bunch current above 6mA;
- ☐ Bunch lengthening occurs at bunch current above 0.5mA;

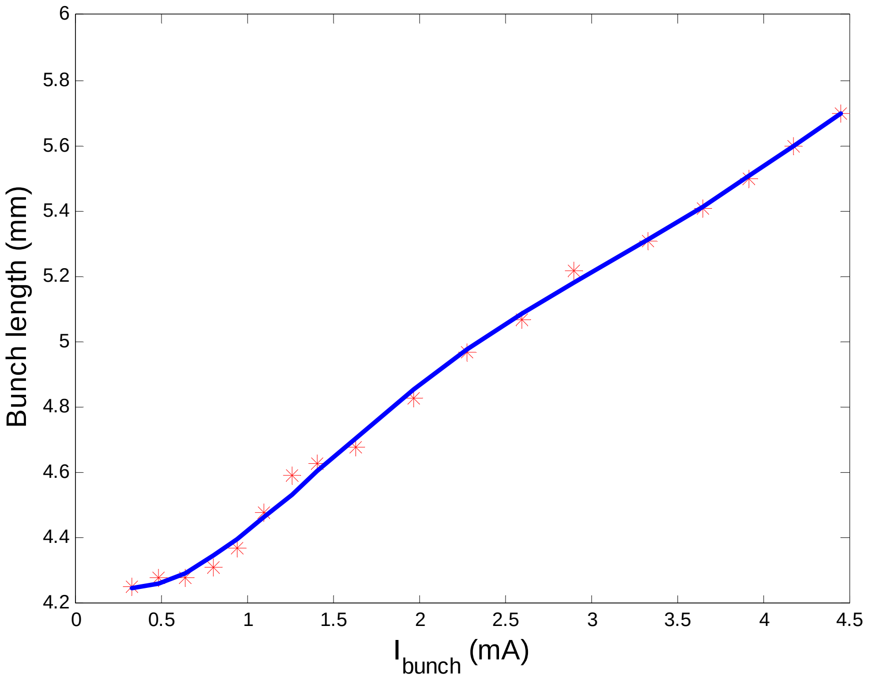

/home/ssrf/prod/opi/edl/ssrf-bi-opi/../SR-BI-SRM-image.edl

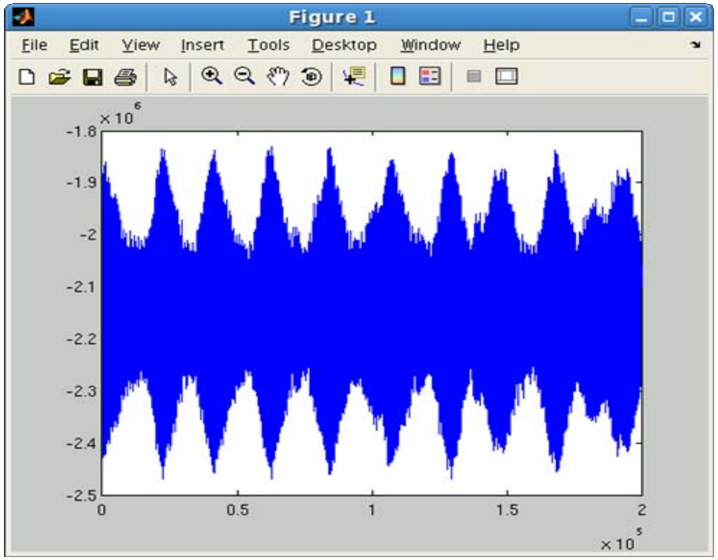
BeamSizeY(um) 52.8

BeamSizeX(um) 94.5

SRMPositionX(um)-503.1

SRMPositionY(um) 223.6

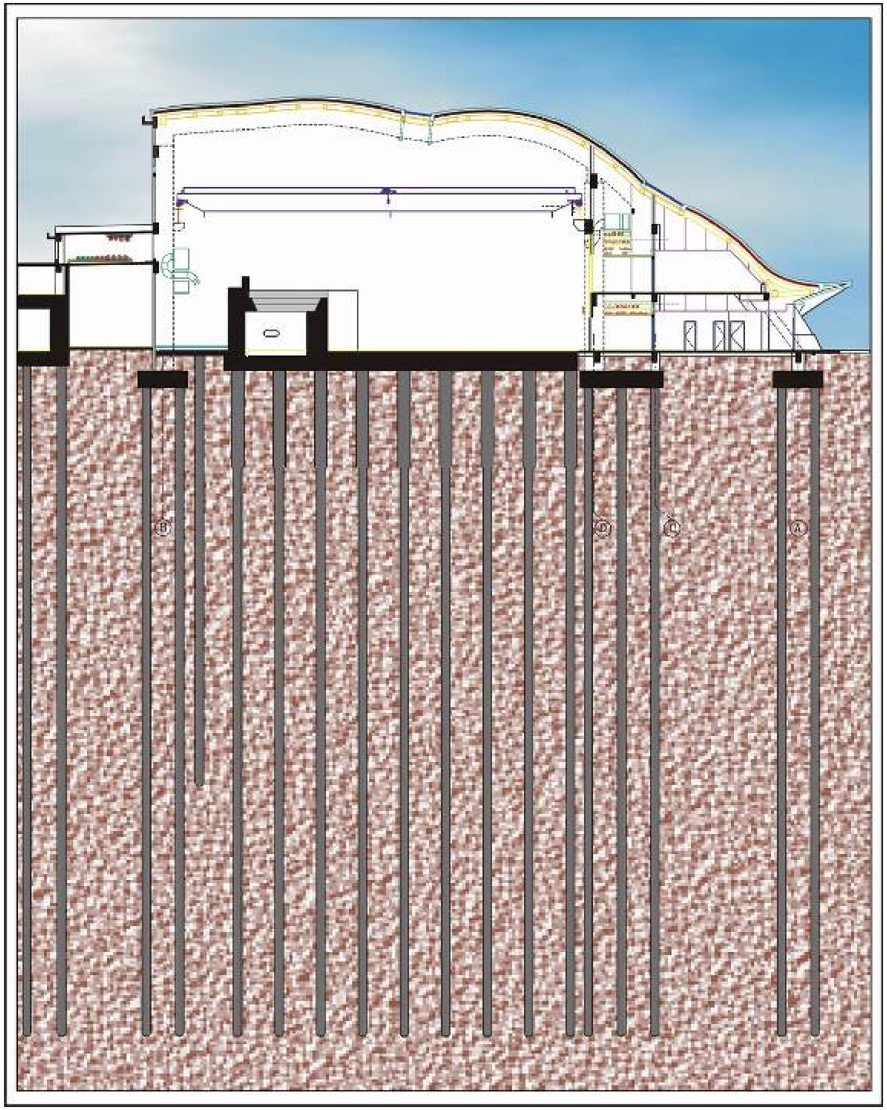




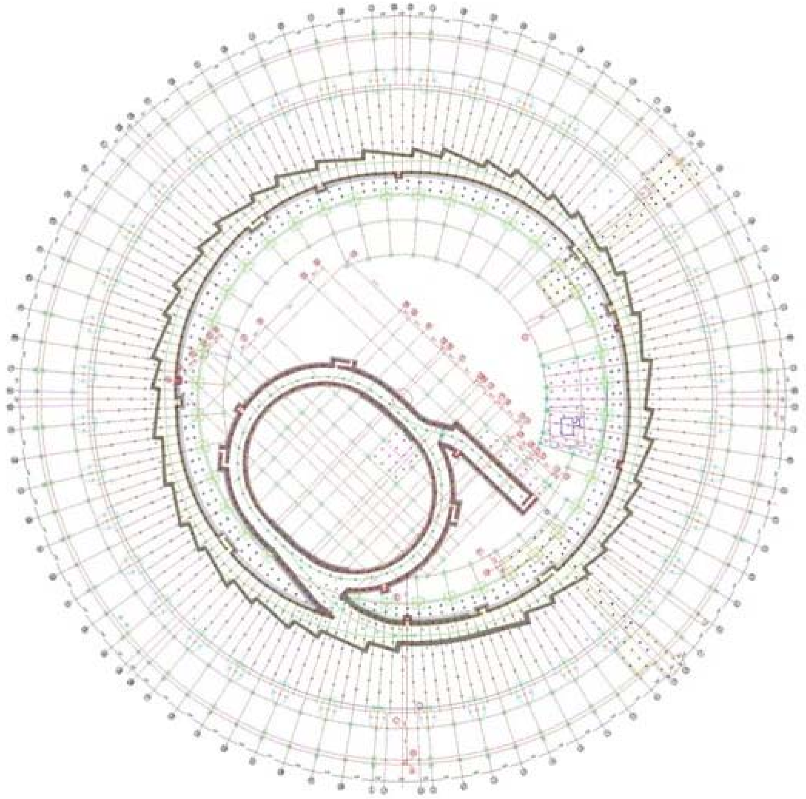
Beam Orbit Stability Situation

- Reduce disturbances to short term orbit stability
  - Make a solid foundation onto the soft soil ground;
  - Locate utility system far from storage ring;
  - Limit the vehicles with load above 2.5 tons
- Control the middle term effects
  - Tunnel air temperature stability within 0.2 ^{0}C;
  - Cooling water temperature stability within 0.1 ^{0}C
- Using feedbacks
  - RF frequency feedback in operation
  - Slow orbit feedback in operation
  - Fast orbit feedback in commissioning

Solid Foundations

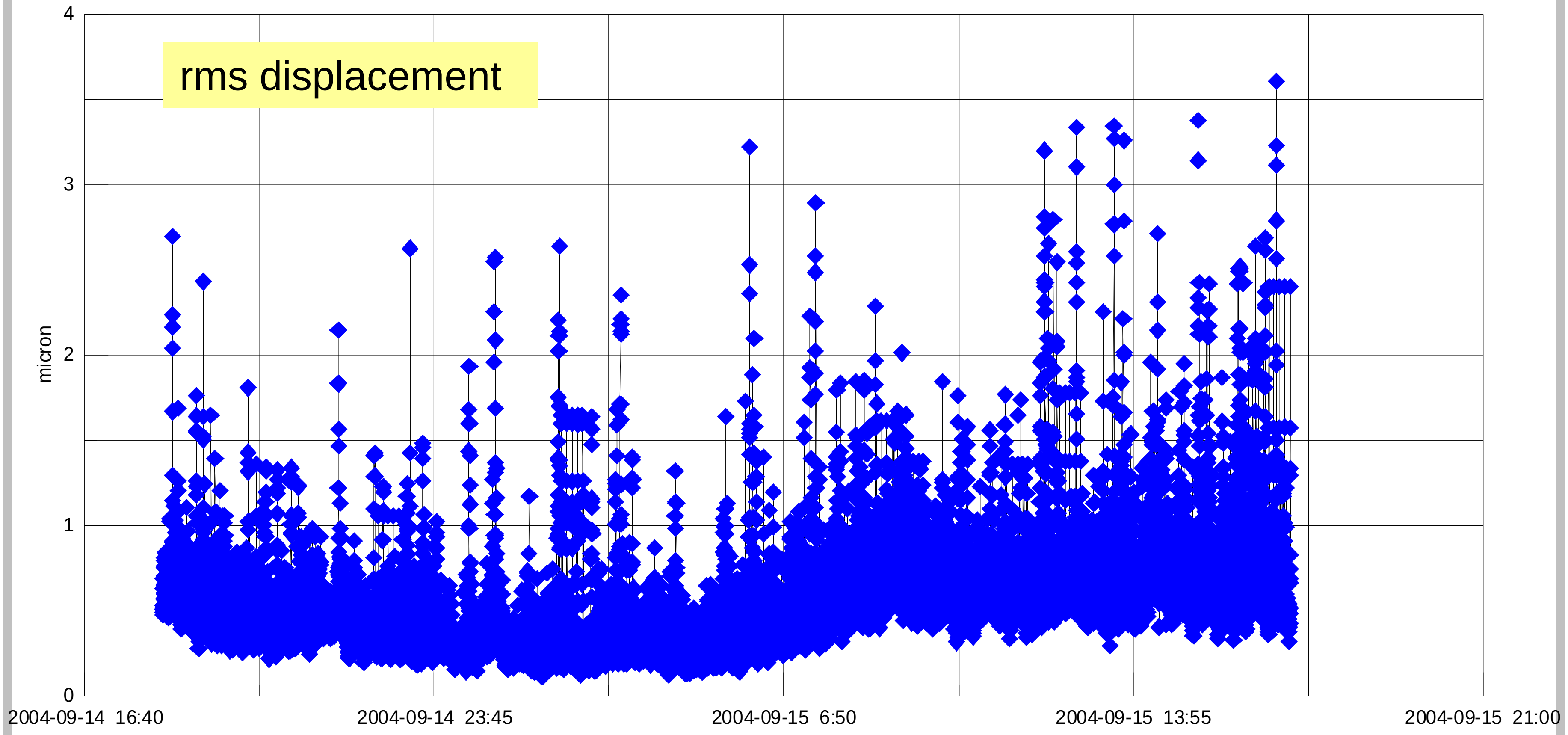


- 1000 piles in 0.6m diameter down to 48m underground under experimental hall and the storage ring tunnel
- Slab of 1.45m thick for the storage ring tunnel and SR experiment hall；



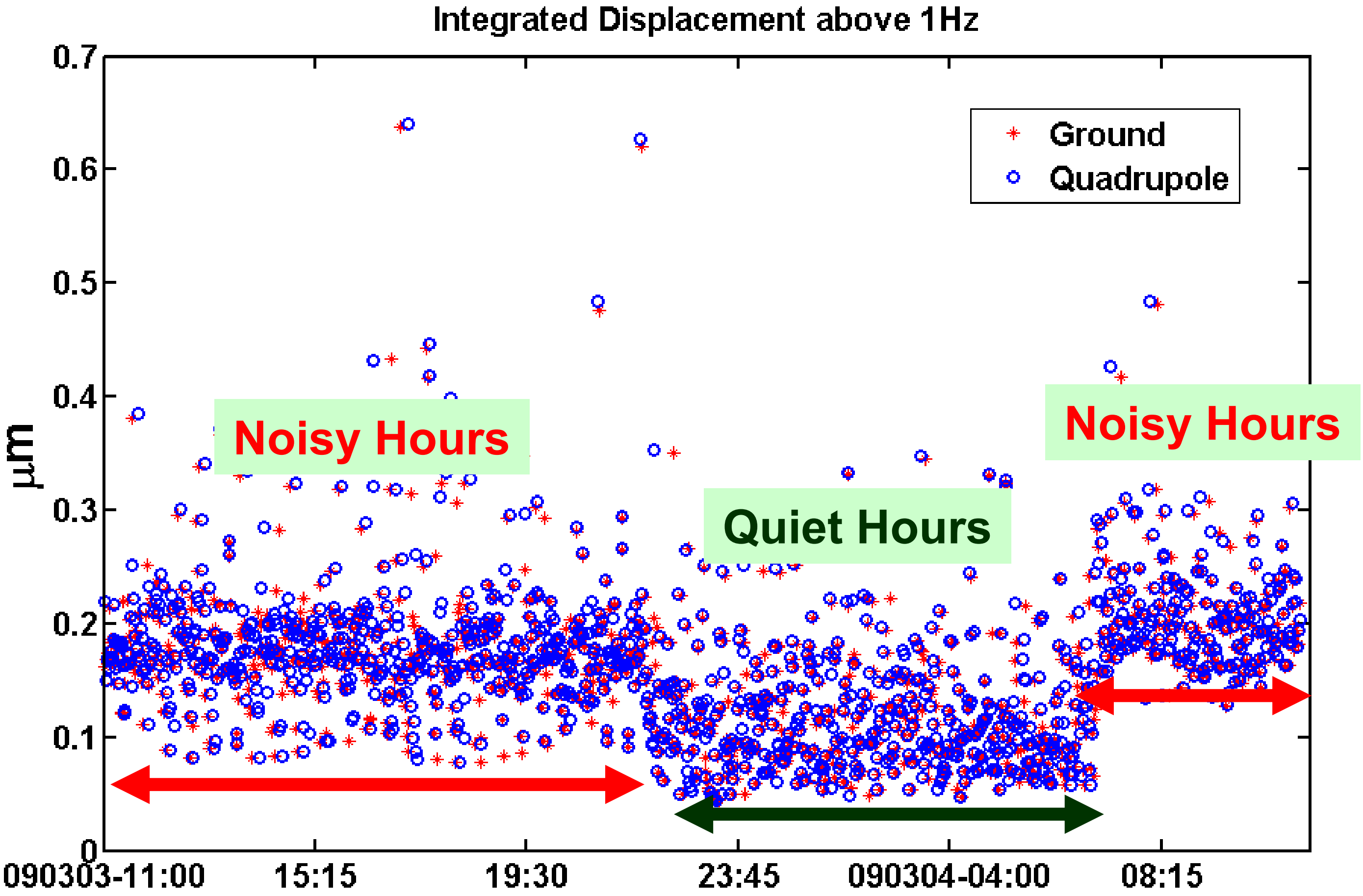
First Measurement of Ground Vibrations

(Bare site)

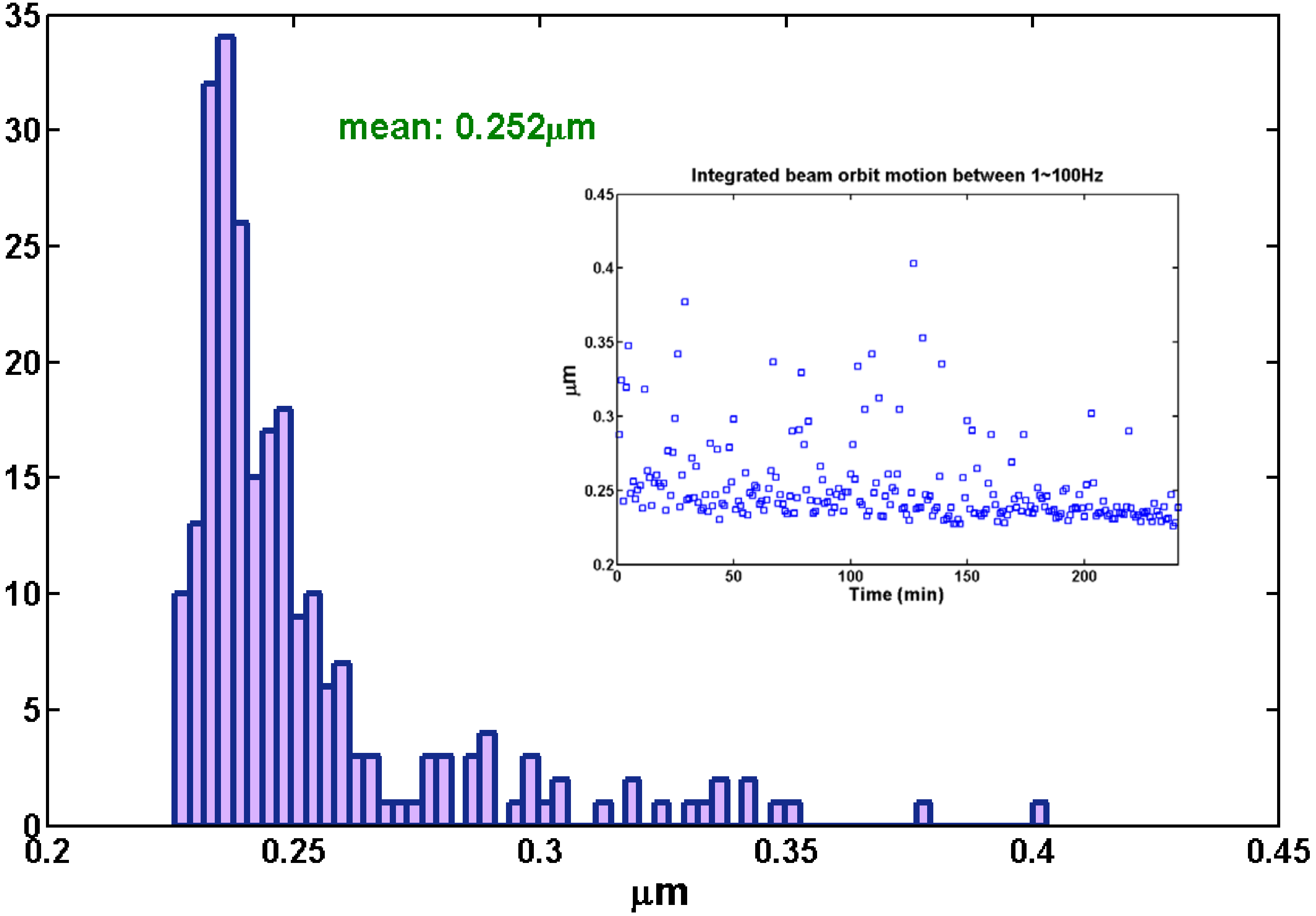


Zhangjiang, SSRF bare site, September 14-15, 2004

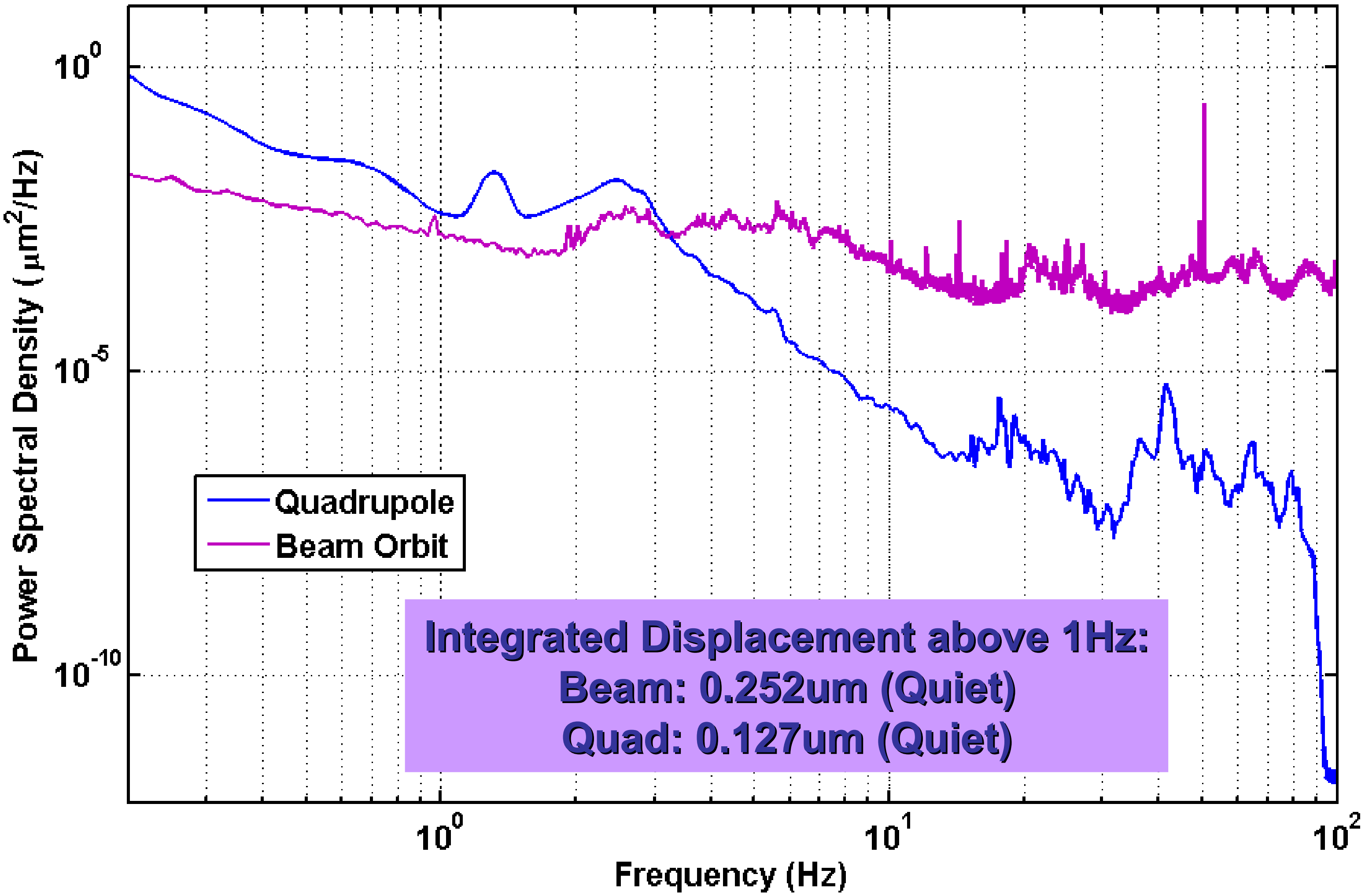
Floor and Magnet Vibrations @ Ring tunnel



Beam Orbit Motion @ Quiet Hours



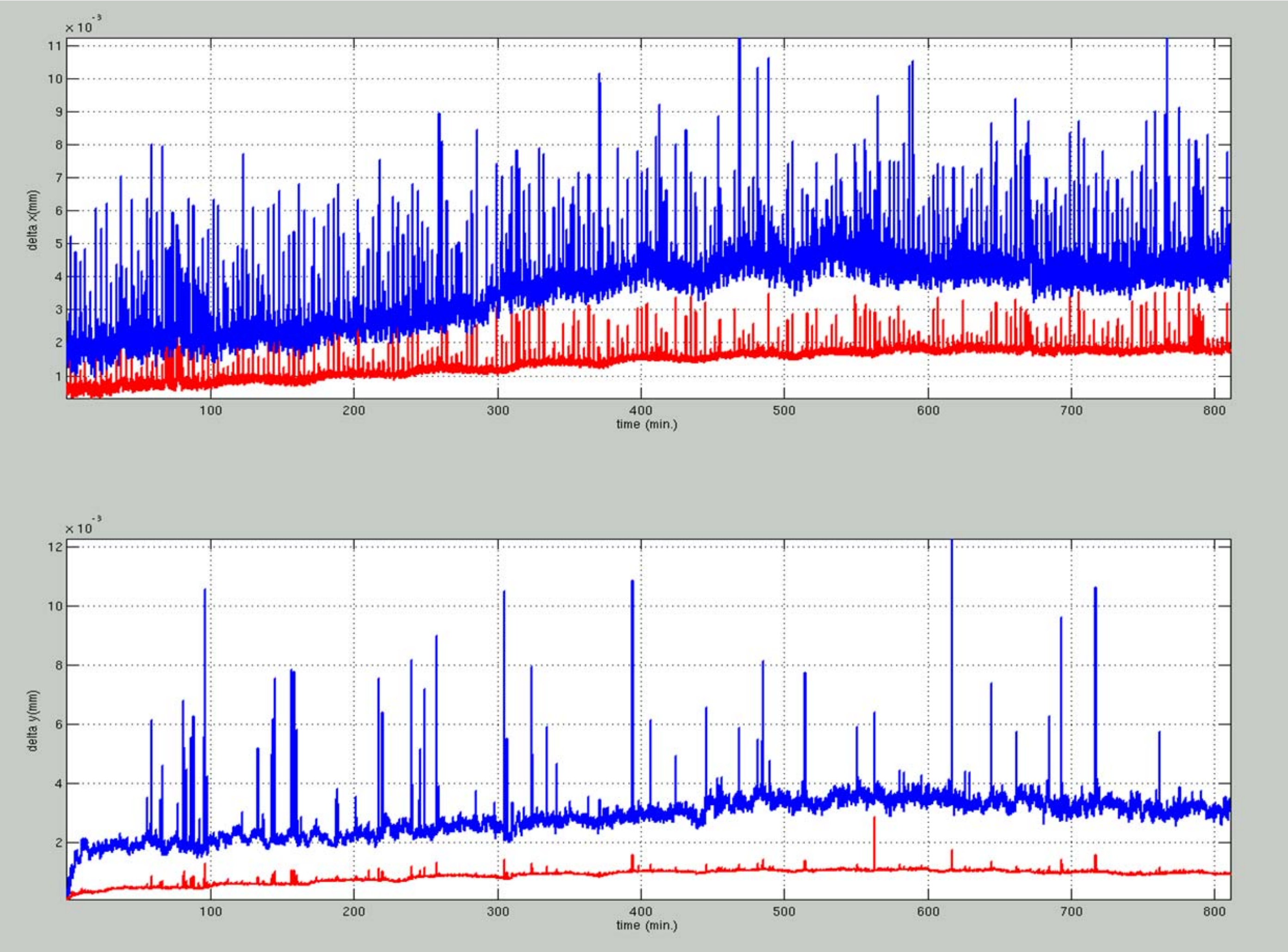
Beam vs. Quad PSD



Integrated Displacement above 1Hz:
Beam: 0.252um (Quiet)
Quad: 0.127um (Quiet)

Orbit stability at 3.5GeV with SOFB

（Top-up operation for14 hours with SOFB）



80 BPM

Eigen values

H : 40

V : 60

Upper : H

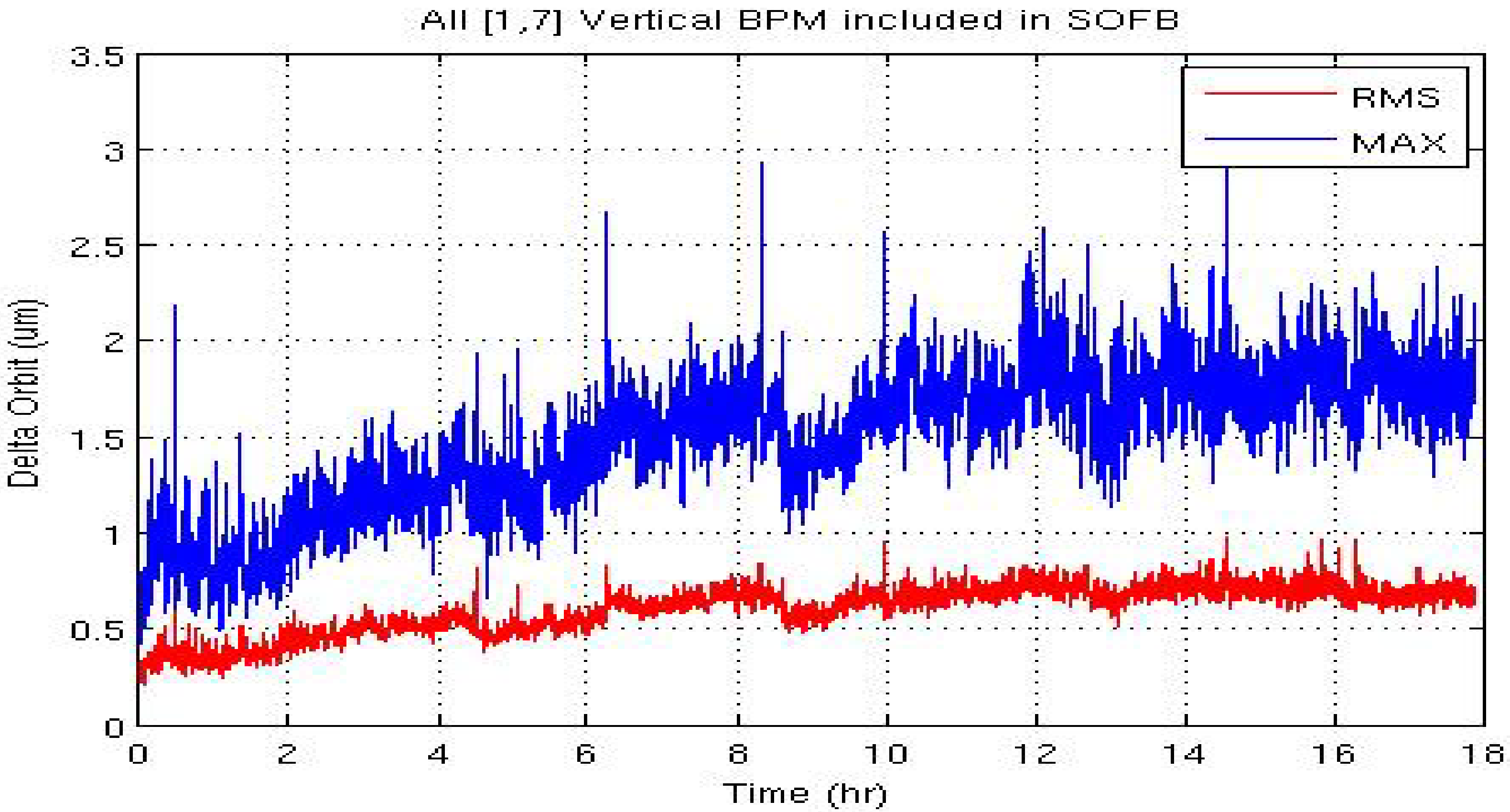
Lower : V

Blue : Max.

Red : RMS.

Orbit stability at Straight Section Ends

Top-up operation @204-205mA with SOFB



The SSRF Phase-I Insertion Devices

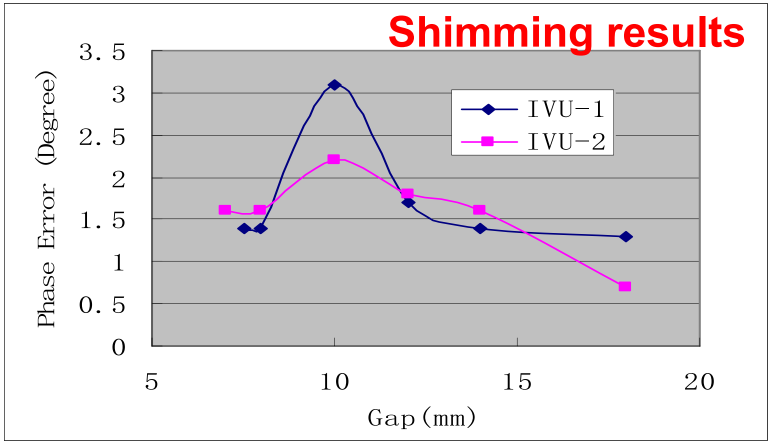
☐ Commissioning of the first SSRF insertion devices

- Two wigglers, one EPU and two in-vacuum undulators;
- The tunes change too small to be corrected;
- The orbit perturbations are corrected for each ID, the rms values of ~5um in horizontal and ~4um in vertical have been achieved;
- The maximum orbit perturbation of 0.2mm comes from EPU, and it is corrected to less than 10 microns;
- The corrections are performed against the ID gaps;

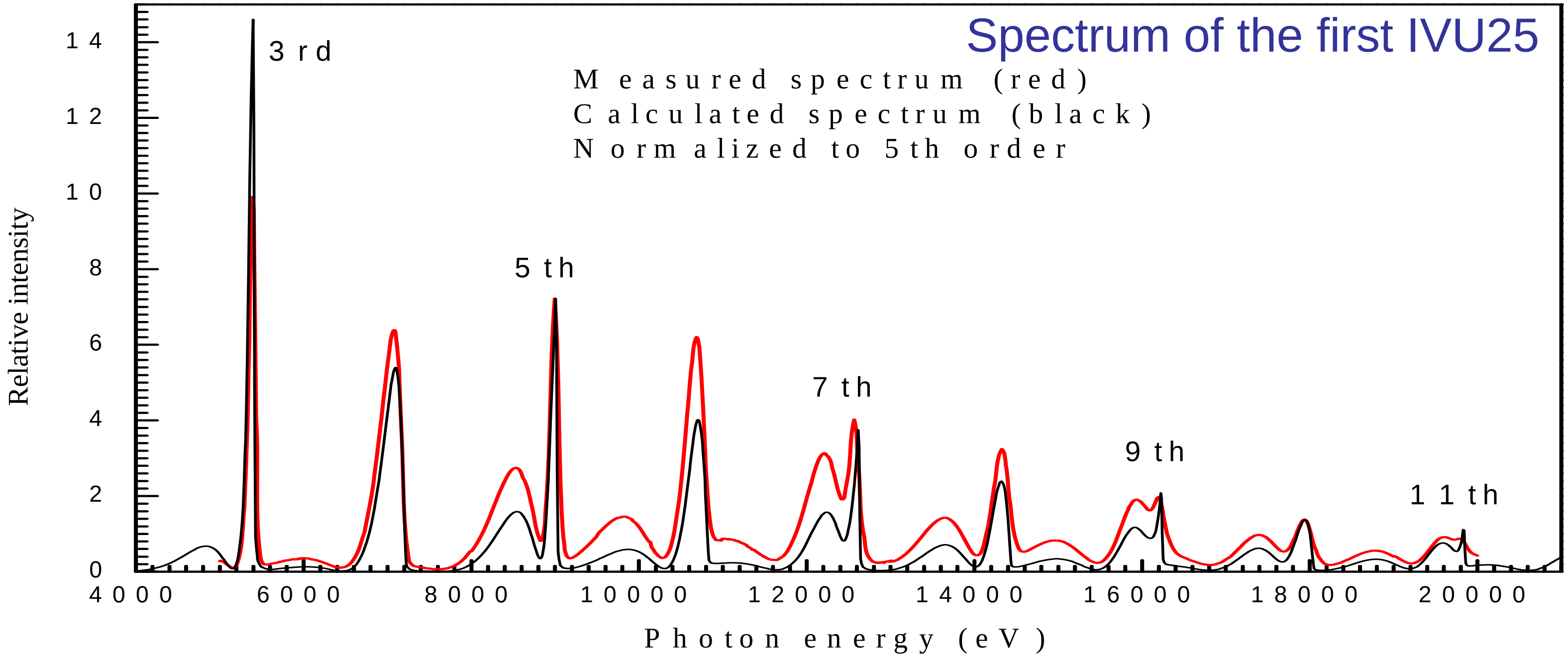
The SSRF Phase-I Insertion Devices

	Beam Line	λ_u (mm)	Nu	Kmax	ε_n (keV)
W80	XAFS	80	19	8.9	3.5～50
W140	XI	140	8	25.4	8～75
EPU100	STXM	100	42	5.6 (H.P.) 3.2 (V.P.) 2.8 (C.P.)	0.07～2 0.2～2 0.13～1
IVU25-1	HXM	25	80	2.2	3.5～22.5
IVU25-2	MC	25	80	2.2	5～20

In-vacuum undulator Commissioning results



Shimming results



Spectrum of the first IVU25

Achieved Performance of the Storage Ring

Parameter	Designed	Measured
Beam energy (GeV)	3.5	3.5008
Circumference (m)	432	432
Beam current (mA)		
Multi-bunch	200 – 300	>200
Single bunch	5	6.5
Natural Emittance (nm-rad)	3.9	~3.8
Natural energy spread	0.098%	~0.1%
Coupling	1%	~0.3%
Betatron tunes	22.22/11.29	22.223/11.293
RF voltage (MV)	4.0	>4.2
Beam lifetime (hours)	>10@200-300mA	>15@200mA
Coupling	1%	<1%
Orbit stability rms x/y(μm)	10/1	top-up @ ~10hrs
@straight section	10/5 (Phase-I)	2/1

Transport efficiency is larger than 95% (from the booster DCCT to the ring DCCT)

Commissioning of Phase-I beanlines

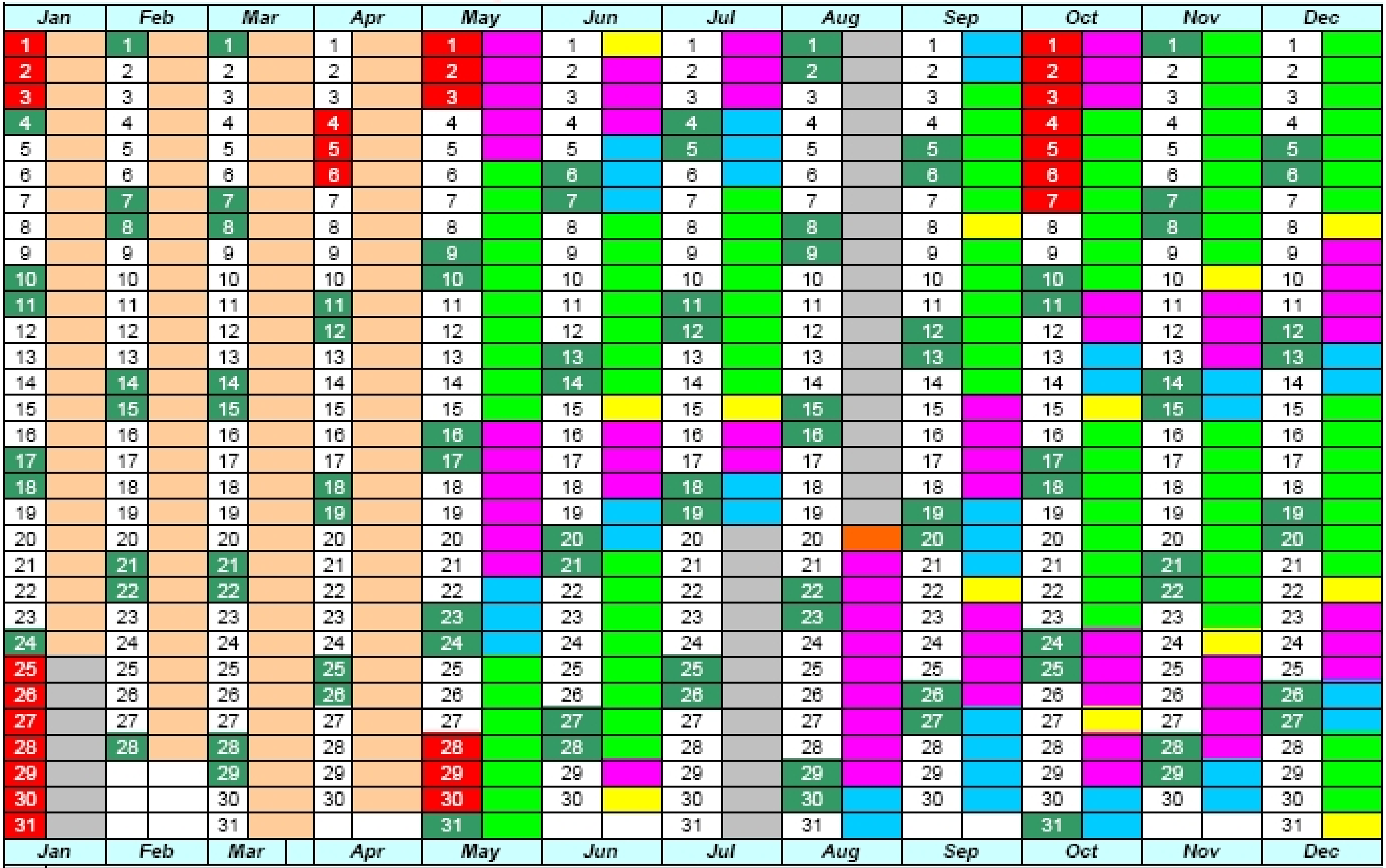
- Commissioning of the first SSRF beamlines started from the small angle X-ray scattering beamline on May 9, 2007, and the macromolecular crystallography beamline is the last one starting the commissioning on March 7,2009; all of them have been commissioned to their acceptance specifications;
- Test experiments have been carried out at each beamline to verify its performance and capabilities for user operation;
- The pre-user experiment will start on May 6, 2009, and all the phase-I beamlines are over booked;

Operation Plan for 2009

❑ The SSRF project needs to proceed the acceptance of the central government, it will take plenty time to go the whole procedure and do the performance measurements against the design specifications; from May 6, 2009, there will be

- 2000~2400 hrs for user operation;
- 744 hrs for summer shutdown;
- 2400 hrs for machine and beamline developments and acceptance tests;
- 336 hrs for maintenance;

SSRF Operation Schedule （2009）



Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
🟥 1	🟫	■ 1	🟫	■ 1	🟫	1	🟫	🟥 1	🟪	1	🟨	1	🟪	■ 1	▨	1	🟦	🟥 1	🟪	■ 1	🟩	1	🟩
🟥 2	🟫	2	🟫	2	🟫	2	🟫	🟥 2	🟪	2	🟪	2	🟪	■ 2	▨	2	🟦	🟥 2	🟪	2	🟩	2	🟩
🟥 3	🟫	3	🟫	3	🟫	3	🟫	🟥 3	🟪	3	🟪	3	🟪	3	▨	3	🟩	🟥 3	🟪	3	🟩	3	🟩
■ 4	🟫	4	🟫	4	🟫	🟥 4	🟫	4	🟪	4	🟪	■ 4	🟦	4	▨	4	🟩	🟥 4	🟩	4	🟩	4	🟩
5	🟫	5	🟫	5	🟫	🟥 5	🟫	5	🟪	5	🟦	■ 5	🟦	5	▨	■ 5	🟩	🟥 5	🟩	5	🟩	■ 5	🟩
6	🟫	6	🟫	6	🟫	🟥 6	🟫	6	🟩	■ 6	🟦	6	🟦	6	▨	■ 6	🟩	🟥 6	🟩	6	🟩	■ 6	🟩
7	🟫	■ 7	🟫	■ 7	🟫	7	🟫	7	🟩	■ 7	🟦	7	🟩	7	▨	7	🟩	🟥 7	🟩	■ 7	🟩	7	🟩
8	🟫	■ 8	🟫	■ 8	🟫	8	🟫	8	🟩	8	🟩	8	🟩	■ 8	▨	8	🟨	8	🟩	■ 8	🟩	8	🟨
9	🟫	9	🟫	9	🟫	9	🟫	■ 9	🟩	9	🟩	9	🟩	■ 9	▨	9	🟩	9	🟩	9	🟩	9	🟪
■ 10	🟫	10	🟫	10	🟫	10	🟫	■ 10	🟩	10	🟩	10	🟩	10	▨	10	🟩	■ 10	🟩	10	🟨	10	🟪
■ 11	🟫	11	🟫	11	🟫	■ 11	🟫	11	🟩	11	🟩	■ 11	🟩	11	▨	11	🟩	■ 11	🟪	11	🟪	11	🟪
12	🟫	12	🟫	12	🟫	■ 12	🟫	12	🟩	12	🟩	■ 12	🟩	12	▨	■ 12	🟩	12	🟪	12	🟪	■ 12	🟪
13	🟫	13	🟫	13	🟫	13	🟫	13	🟩	■ 13	🟩	13	🟩	13	▨	■ 13	🟩	13	🟦	13	🟪	■ 13	🟦
14	🟫	■ 14	🟫	■ 14	🟫	14	🟫	14	🟩	■ 14	🟩	14	🟩	14	▨	14	🟩	14	🟦	■ 14	🟦	14	🟦
15	🟫	■ 15	🟫	■ 15	🟫	15	🟫	15	🟩	15	🟨	15	🟨	■ 15	▨	15	🟪	15	🟨	■ 15	🟦	15	🟩
16	🟫	16	🟫	16	🟫	16	🟫	■ 16	🟪	16	🟪	16	🟪	■ 16	▨	16	🟪	16	🟩	16	🟩	16	🟩
■ 17	🟫	17	🟫	17	🟫	17	🟫	■ 17	🟪	17	🟪	17	🟪	17	▨	17	🟪	■ 17	🟩	17	🟩	17	🟩
■ 18	🟫	18	🟫	18	🟫	■ 18	🟫	18	🟪	18	🟪	■ 18	🟦	18	▨	18	🟪	■ 18	🟩	18	🟩	18	🟩
19	🟫	19	🟫	19	🟫	■ 19	🟫	19	🟪	19	🟦	■ 19	🟦	19	▨	■ 19	🟦	19	🟩	19	🟩	■ 19	🟩
20	🟫	20	🟫	20	🟫	20	🟫	20	🟪	■ 20	🟦	20	▨	20	🟧	■ 20	🟦	20	🟩	20	🟩	■ 20	🟩
21	🟫	■ 21	🟫	■ 21	🟫	21	🟫	21	🟪	■ 21	🟩	21	▨	21	🟪	21	🟦	21	🟩	■ 21	🟩	21	🟩
22	🟫	■ 22	🟫	■ 22	🟫	22	🟫	22	🟦	22	🟩	22	▨	■ 22	🟪	22	🟨	22	🟩	■ 22	🟩	22	🟨
23	🟫	23	🟫	23	🟫	23	🟫	■ 23	🟦	23	🟩	23	▨	■ 23	🟪	23	🟪	23	🟩	23	🟩	23	🟪
■ 24	🟫	24	🟫	24	🟫	24	🟫	■ 24	🟦	24	🟩	24	▨	24	🟪	24	🟪	■ 24	🟪	24	🟨	24	🟪
🟥 25	▨	25	🟫	25	🟫	■ 25	🟫	25	🟩	25	🟩	■ 25	▨	25	🟪	25	🟪	■ 25	🟪	25	🟪	25	🟪
🟥 26	▨	26	🟫	26	🟫	■ 26	🟫	26	🟩	26	🟩	■ 26	▨	26	🟪	■ 26	🟪	26	🟪	26	🟪	■ 26	🟦
🟥 27	▨	27	🟫	27	🟫	27	🟫	27	🟩	■ 27	🟩	27	▨	27	🟪	■ 27	🟦	27	🟨	27	🟪	■ 27	🟦
🟥 28	▨	■ 28	🟫	■ 28	🟫	28	🟫	🟥 28	🟩	■ 28	🟩	28	▨	28	🟪	28	🟦	28	🟪	■ 28	🟪	28	🟩
🟥 29	▨			■ 29	🟫	29	🟫	🟥 29	🟩	29	🟪	29	▨	■ 29	🟪	29	🟦	29	🟪	■ 29	🟦	29	🟩
🟥 30	▨			30	🟫	30	🟫	🟥 30	🟩	30	🟨	30	▨	■ 30	🟦	30	🟦	30	🟦	30	🟦	30	🟩
🟥 31	▨			31	🟫			■ 31	🟩			31	▨	31	🟦			■ 31	🟦			31	🟨
Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	

🟩 Operation for user
🟪 Mechine Study
🟦 Operation for Beamline Study
🟧 Machine Warm-up
🟨 Inspection & Maintenance, no Beam
▨ Shutdown
■ Weekend
🟥 National Holiday
🟫 Commissioning

Conclusions

- The commissioning of Shanghai light source was carried out rapidly, smoothly and successfully;
  - The SSRF injector (linac and booster) commissioning was completed and it has been operating reliably since Dec.2007;
  - The storage ring commissioning started at 3GeV using KEK PF retired copper cavities, and with SRF cavities it is quickly commissioned to its design performance;
  - The commissioning of the SSRF phase-I beamlines has been completed by middle of April 2009;
- The pre-user operation will start on May 6, 2009.

Acknowledgement

Thank all of the members of the SSRF team for their dedications and contributions to the design, construction, installation and commissioning of the SSRF complex.

Thanks to the experts and colleagues of SLAC, LBL, ANL, BNL and CLS in America, KEK, Spring-8, PLA, NSRRC, SSLS, IHEP and NSRL in Asia, ELETTRA, SLS, ESRF, SOLEIL, DIAMOND, ALBA, ANKA, DESY and BESSY in Europe, and many others for their great helps and supports to the SSRF design and construction over passed years.

Thank you for your attention