# Commissioning of the BEPC-II Storage Rings

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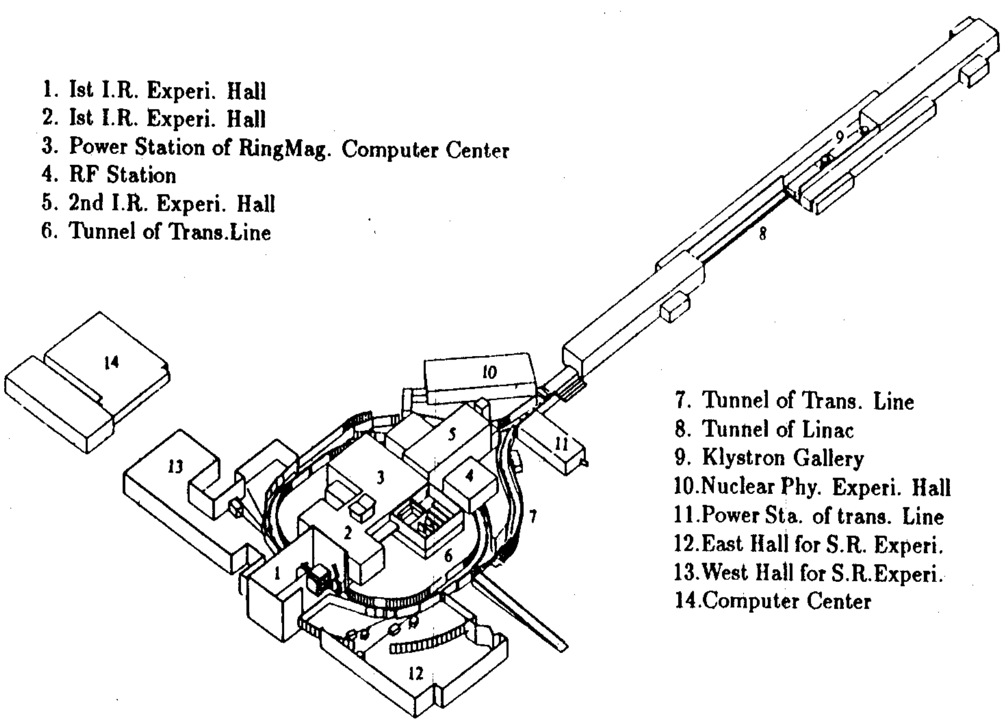
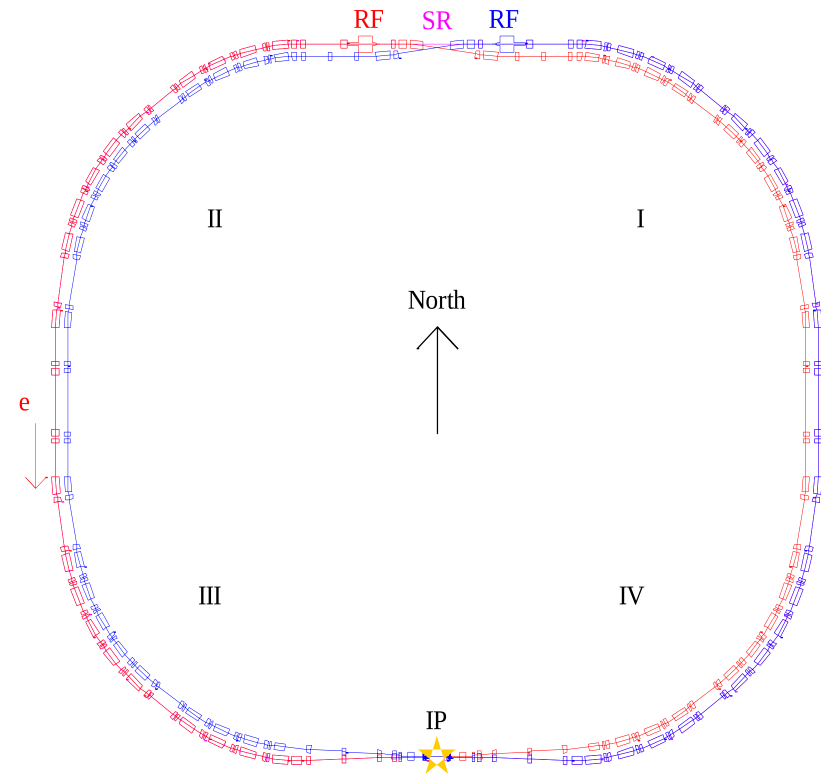
- Brief introduction on the BEPC-II
- Commissioning of the SR and collision modes
- Problems during luminosity commissioning
- Operation for users
- Possible upgrades in the near future
- Summary

# 1. Brief introduction on the BEPC-II

- BEPC-II — An upgrade project of the BEPC
  — A double-ring factory-like machine
  — Deliver beams to both HEP & SR

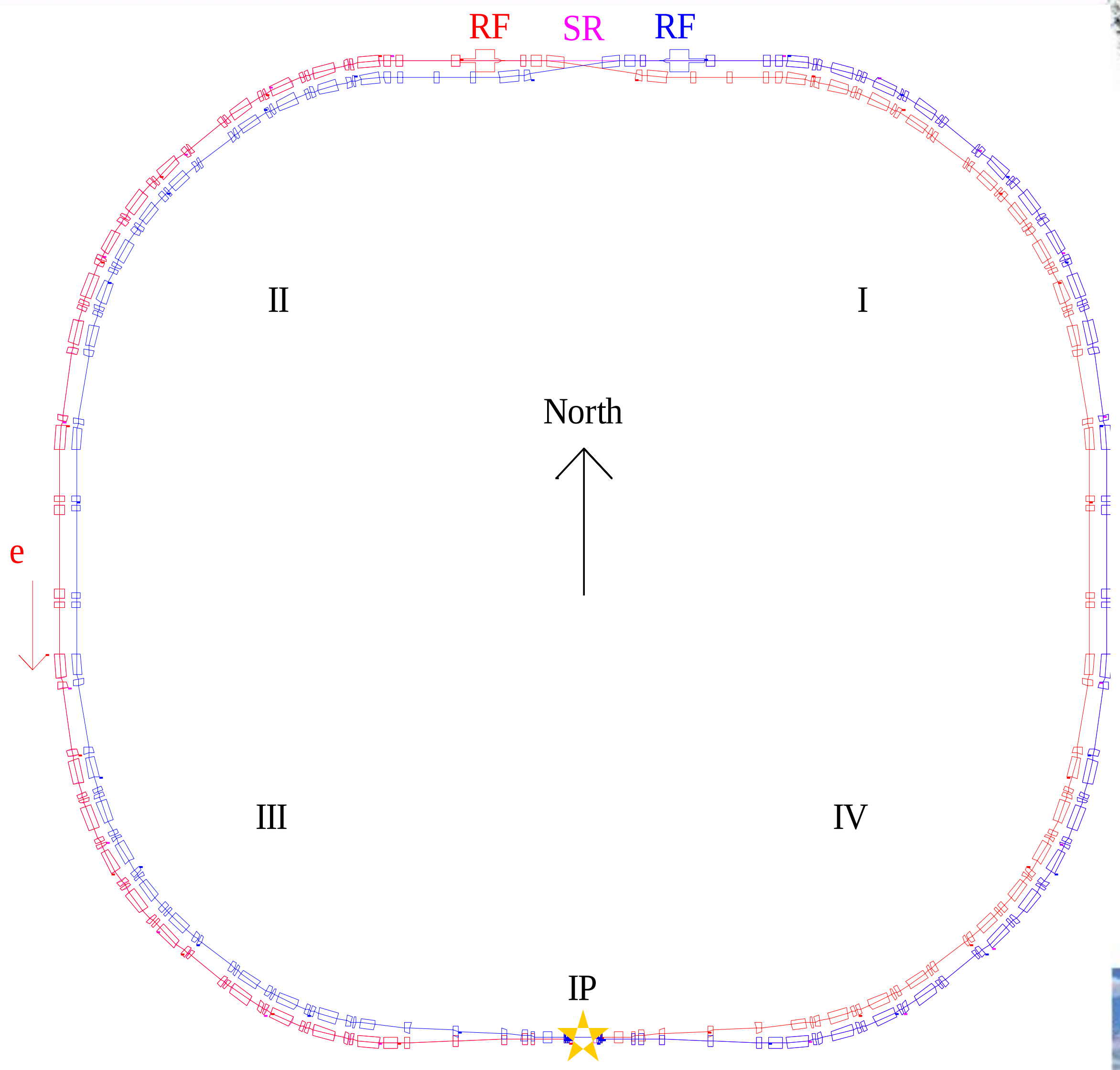


# Milestones of BEPC-II

- July 1997, Proposal on BEPC upgrades (single-ring)
- July 2000, Official approval from government
- Jan. 2001, Double-ring scheme proposed
- Jan. 2004, Construction started
- Nov. 2004, Linac finished upgrade and delivered beam
- July, 2005, BEPC stopped, ring disassembly started
- Nov. 2006, Ring commissioning started
- July 2008, First hadron event collected in BES-III
- May 2009, Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$

# Layout of the Double-ring scheme

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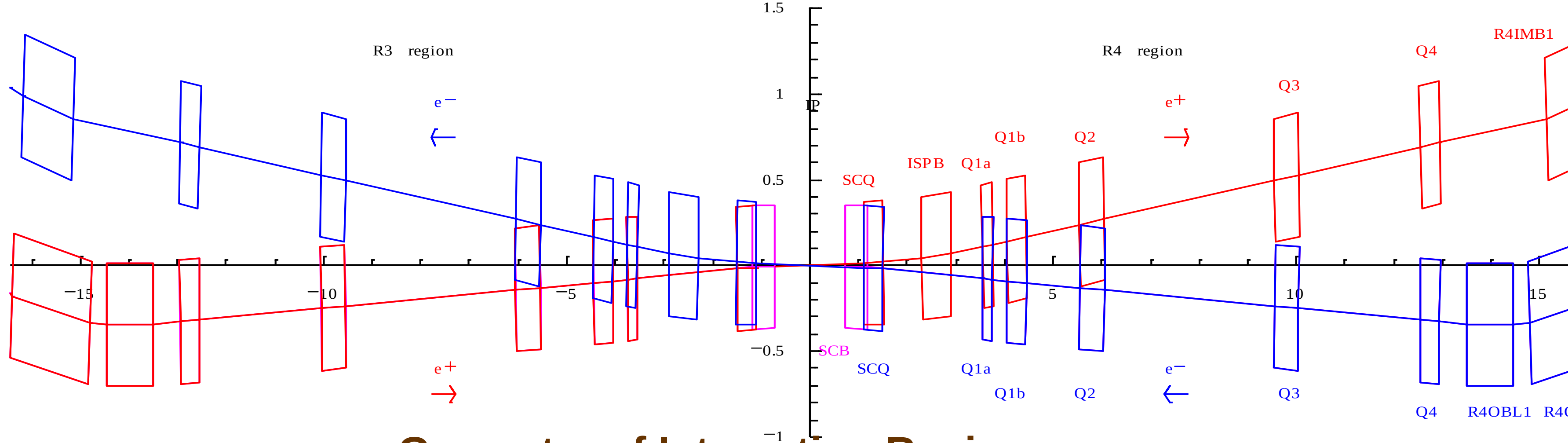
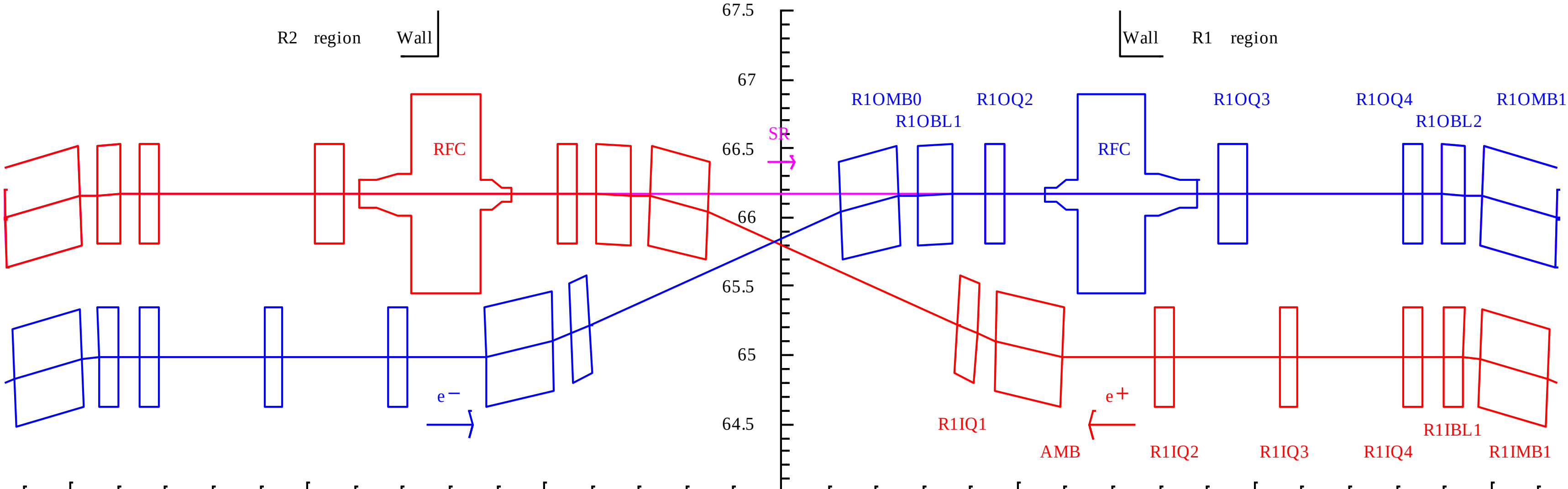
# Goals of the BEPC-II

- **Collision Mode**
  - **Beam energy range** 1-2.1 GeV
  - **Optimized beam energy** 1.89 GeV
  - **Luminosity** $3\text{-}10\times10^{32}$ $cm^{-2}s^{-1}$ @1.89 GeV
  - **Full energy injection** 1-1.89 GeV
- **SR Mode**
  - **Beam energy** 2.5 GeV
  - **Beam current** 250 mA
  - **Keep the present beam lines useable**

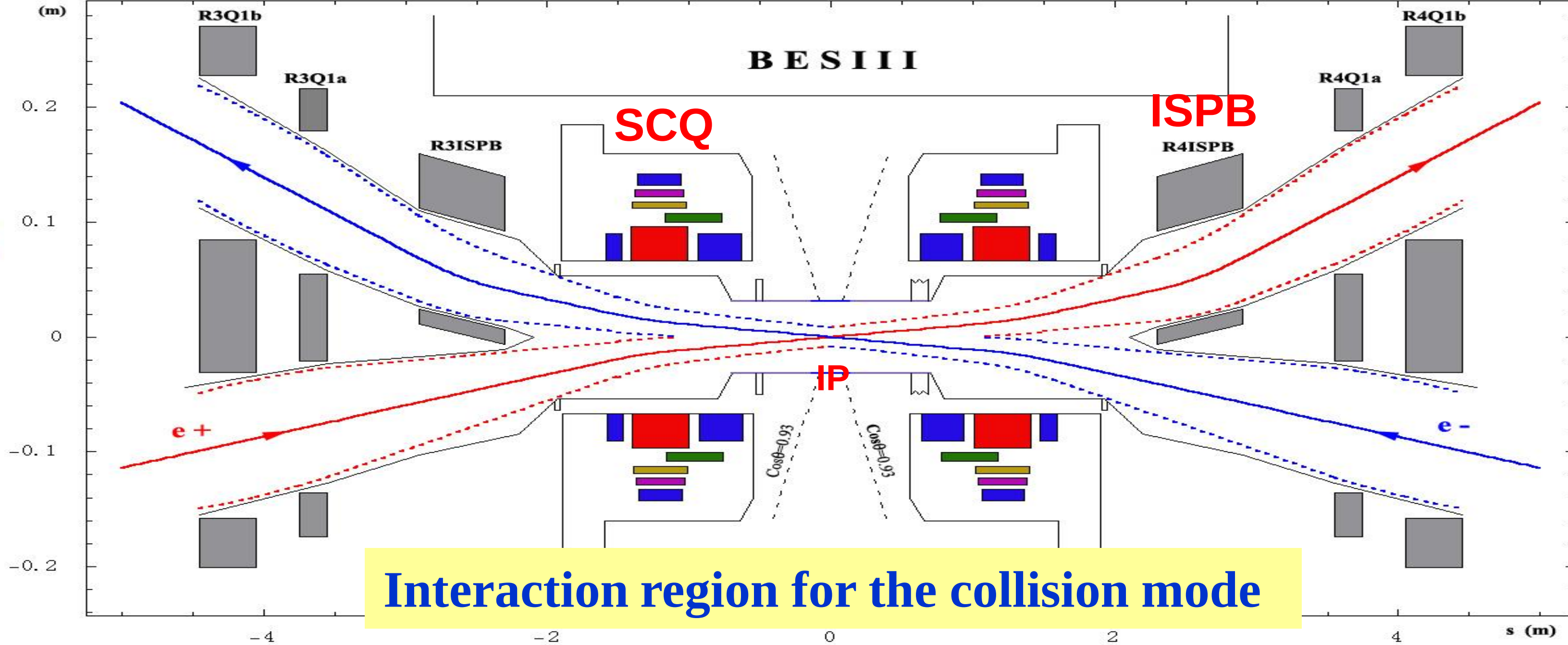
# • Geometry of the IR and RF regions



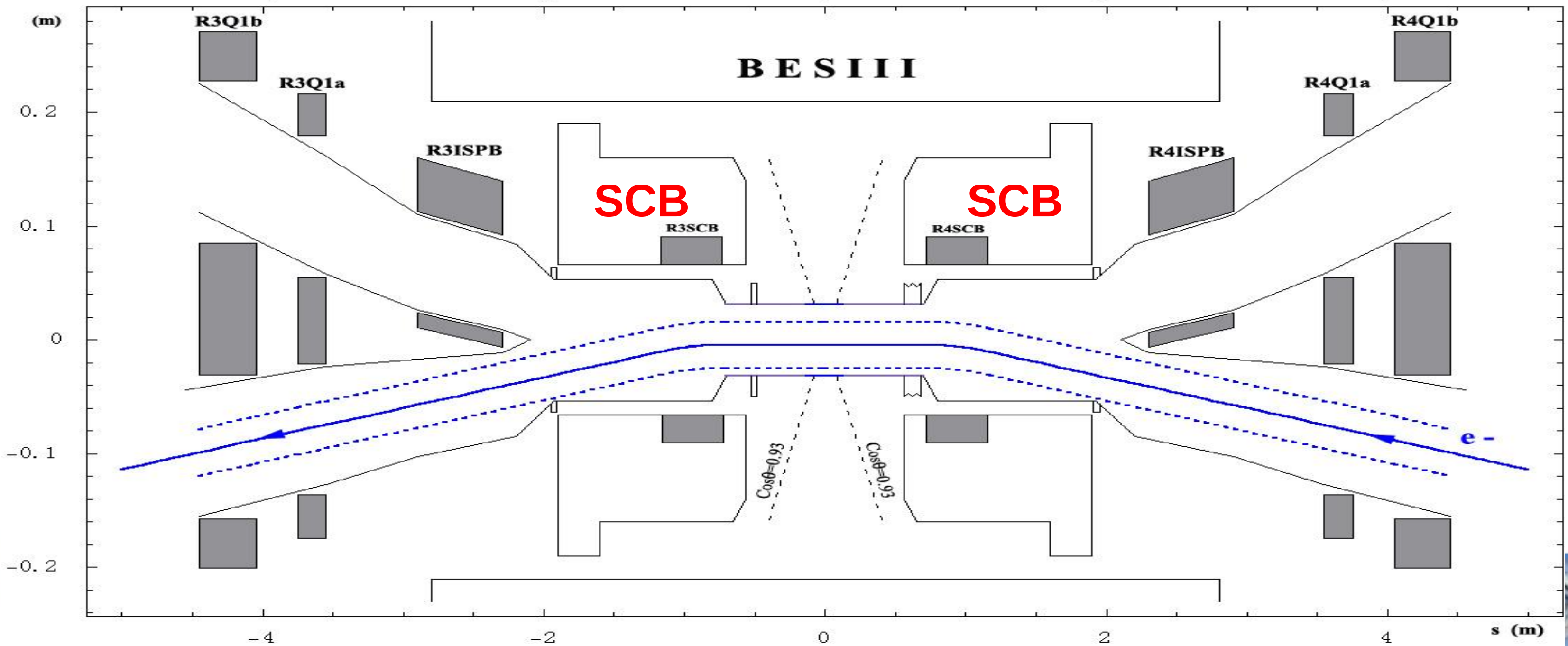

Geometry of Interaction Region




Geometry of RF region




Interaction region for the collision mode




Interaction region for the dedicated SR mode

# Lattice design of the storage rings

- **Design philosophy**
  - **Use the existing BEPC tunnel**
  - **Keep the BEPC SR ports for beam lines**
  - **Use as more BEPC magnets as possible**
  - **Keep the BEPC injection scheme**
  - **Fit 500MHz RF system, and the two-bunch injection scheme in the future**
  - **Luminosity and other requirements from hardware**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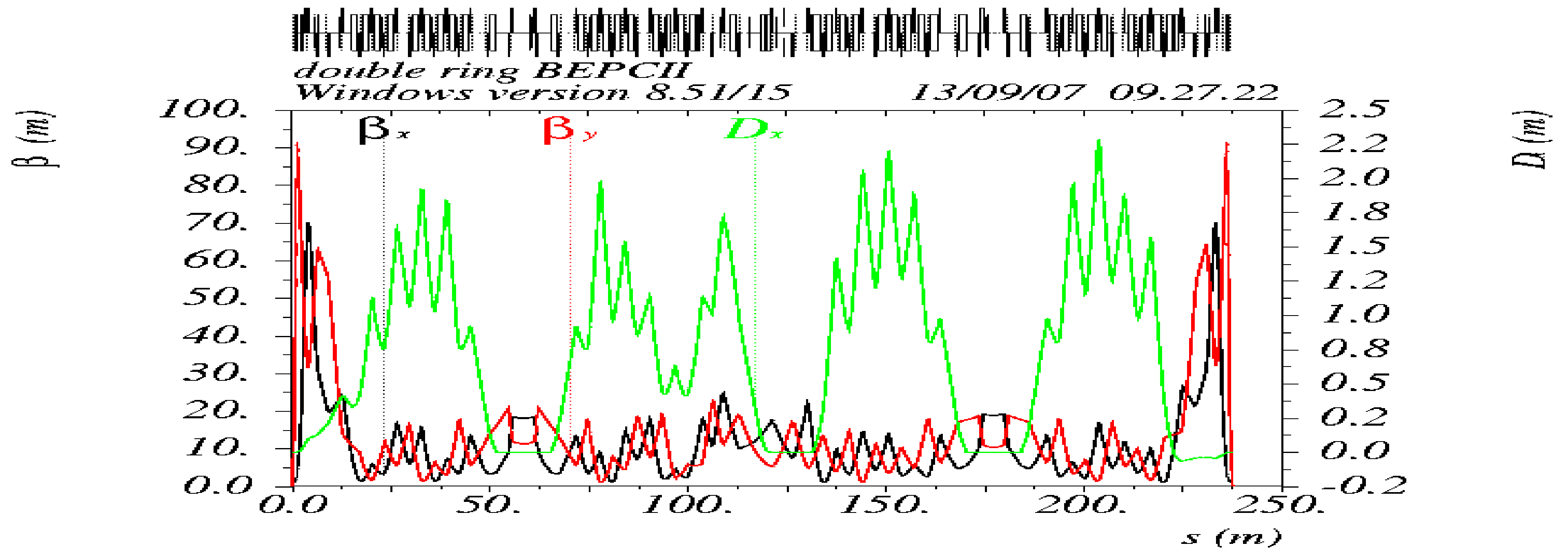
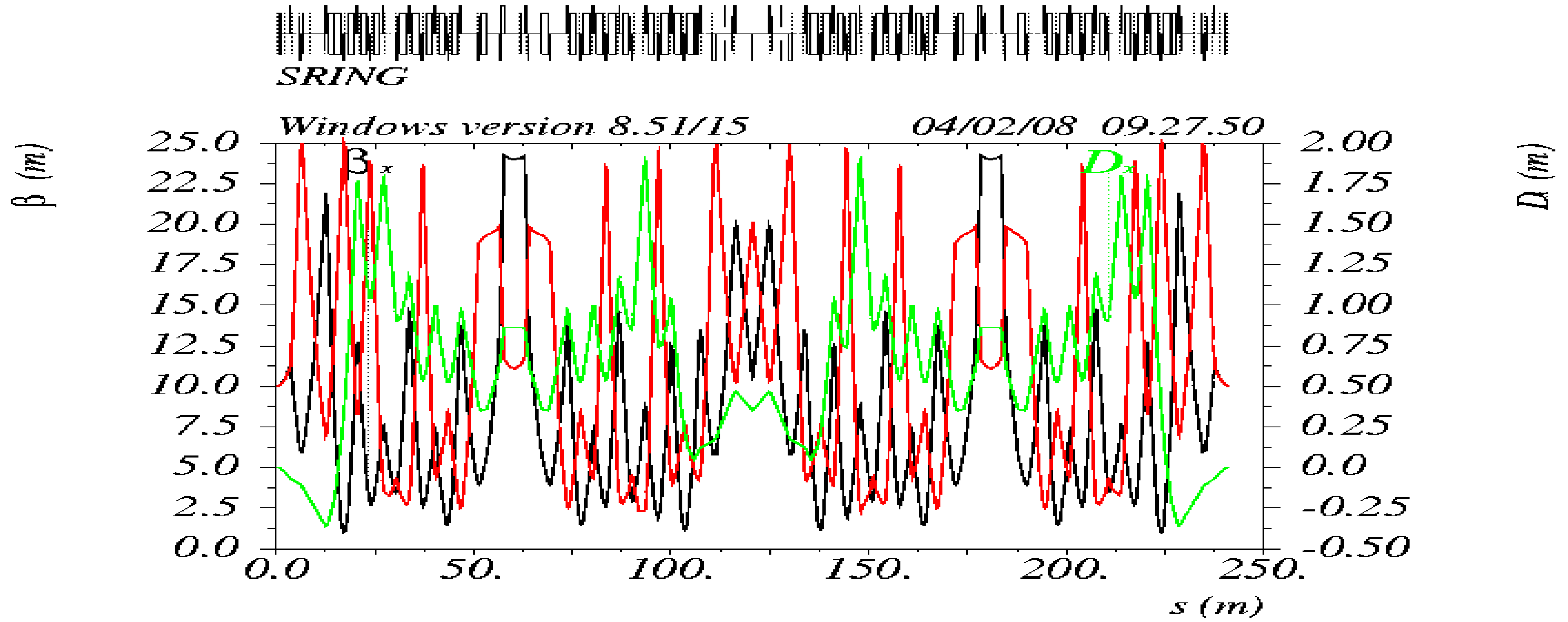

double ring BEPCII
Windows version 8.51/15
13/09/07 09.27.22
β (m)
D (m)
βx
βy
Dx
s (m)
0.0
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.
-0.2
0.0
0.2
0.5
0.8
1.0
1.2
1.5
1.8
2.0
2.2
2.5
0.0
50.
100.
150.
200.
250.


SRING
Windows version 8.51/15
04/02/08 09.27.50
β (m)
D (m)
βx
Dx
s (m)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
-0.50
-0.25
0.0
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
0.0
50.
100.
150.
200.
250.

# Design Parameters of Ring (Col. Mode)

| | | |
|---|---|---|
| **Energy** | **GeV** | **1.89** |
| **Circumference** | **m** | **237.53** |
| **Beam current** | **A** | **0.91** |
| **Bunch number** | | **93** |
| **Bunch current** | **mA** | **9.8** |
| **Bunch spacing** | **m** | **2.4** |
| **Bunch length** | **cm** | **1.5** |
| **RF frequency** | **MHz** | **499.80** |
| **Harmonic number** | | **396** |
| **Emittance (x/y)** | **nm·rad** | **144/2.2** |
| $\beta$ **function at IP (x/y)** | **m** | **1.0/0.015** |
| **Crossing angle** | **mrad** | **±11** |
| **Design luminosity** | **$cm^{-2}s^{-1}$** | **$1 \times 10^{33}$** |

# Design Parameters of Ring (SR Mode)

| | | |
|---|---|---|
| Energy | GeV | 2.5 |
| Circumference | m | 241.13 |
| Beam Current | mA | 250 |
| Natural emittance | nm·rad | 120 |
| RF frequency | MHz | 499.80 |
| Harmonic number | | 402 |
| RF Voltage | MV | 3.0 |
| Energy loss per turn | keV | 335 |
| SR Power | kW | 84 |
| Natural bunch length | cm | 1.2 |
| Momentum compact factor | | 0.016 |
| Tune (x/y/z) | | 7.28/5.18/0.036 |
| SR Damping time (x/y/z) | ms | 12/12/6 |



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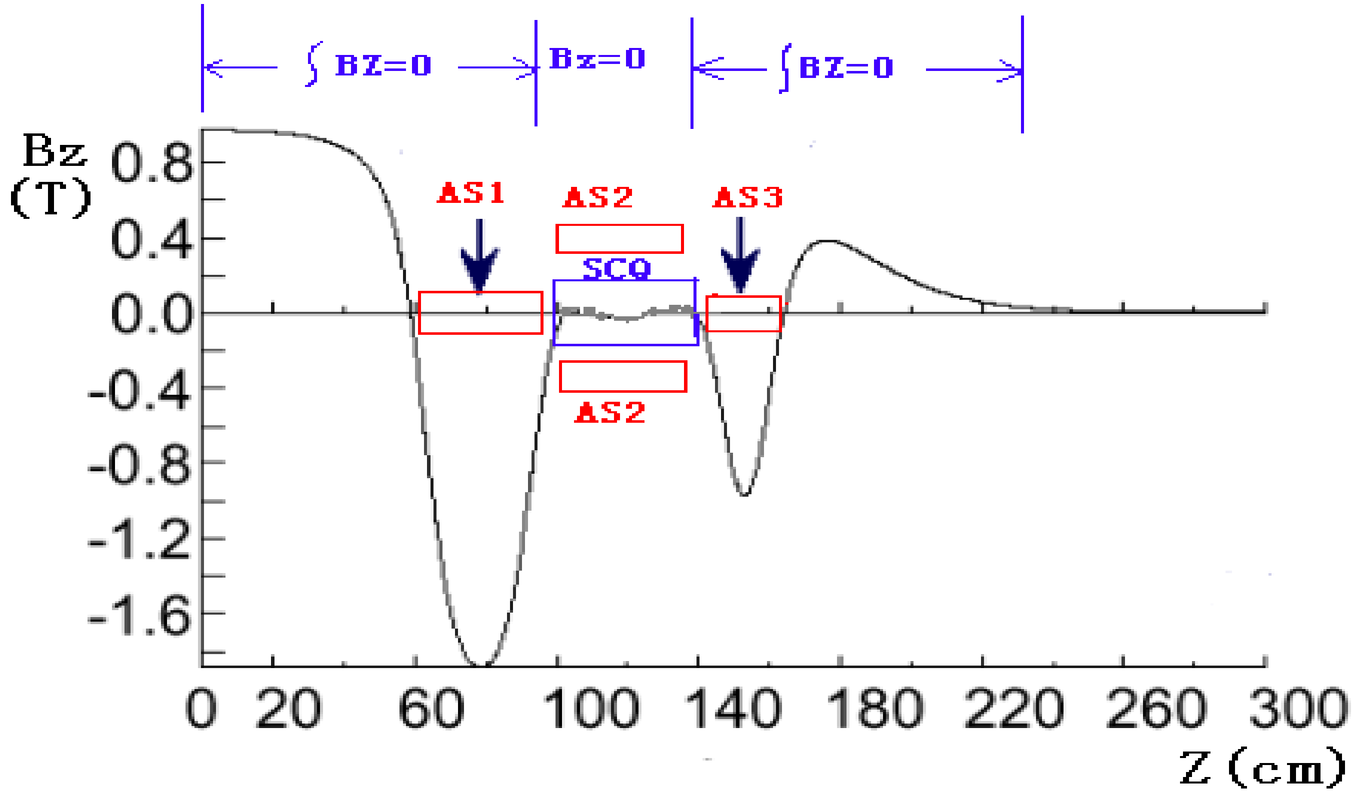
# Parameters of on-line lattice (collision mode)

| | |
|---|---|
| Circumference（m） | 237.53 |
| Beam energy（GeV） | 1.89 |
| RF voltage（MV） | 1.5 |
| Tune（x/y/s） | 6.54/5.59/0.035 |
| Momentum compaction factor | 0.0237 |
| Nature chromaticity（x/y） | –10.8/–20.8 |
| Nature horizontal emittance（nm·rad） | 132 |
| Nature energy spread | $5.16\times10^{-4}$ |
| Nature bunch length（cm） | 1.36 |
| $\beta_{x,y}$ @ IP（m）(x/y) | 1/0.015 |
| $\beta_{x,y,\ max}$ @ IR（m）(x/y) | 70.2/91.4 |
| $\beta_{x,y,\ max}$ @ arc（m）(x/y) | 24.2/23.5 |
| $D_{x,max}$（m） | 2.28 |

# Detector solenoid compensation




**AS1 – 3 are connected in series, but AS2 and AS3 have trims**



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# 3. Commissioning of the SR and collision modes

**2006 Oct. Installation completed with NIM-IR**

**2006 Nov 18 First beam stored**

**2007 Mar 26 First collision**

**2007 May 14 Luminosity reached that of BEPC**

**Phase 1**

**2007 Oct. Installation completed with SIM-IR**

**2007 Oct. 24 First beam stored**

**2007 Nov. 18 First collision**

**2008 Jan. 29 Luminosity >$1\times10^{32}cm^{-2}s^{-1}$**

**Phase 2**

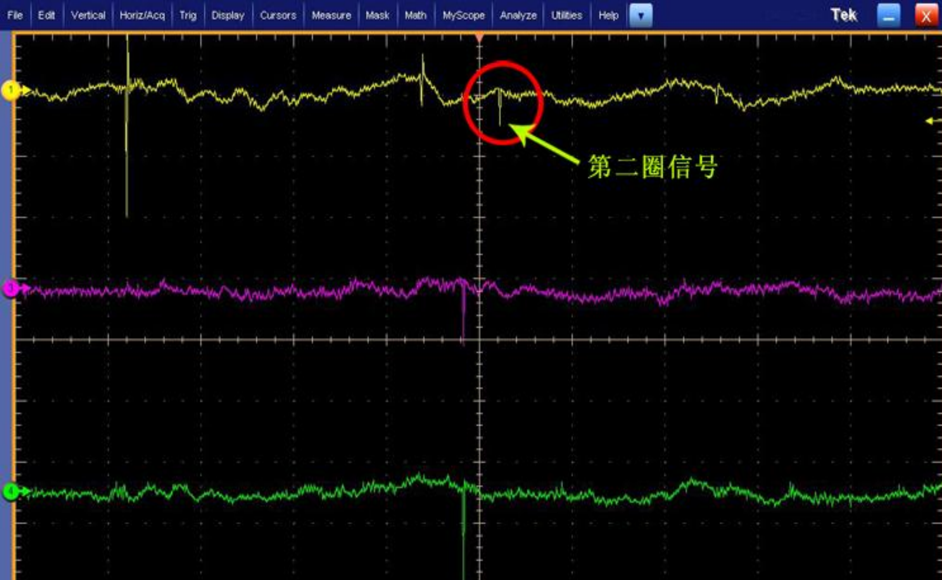
**2008 June. Installation completed with BESIII in the IR**

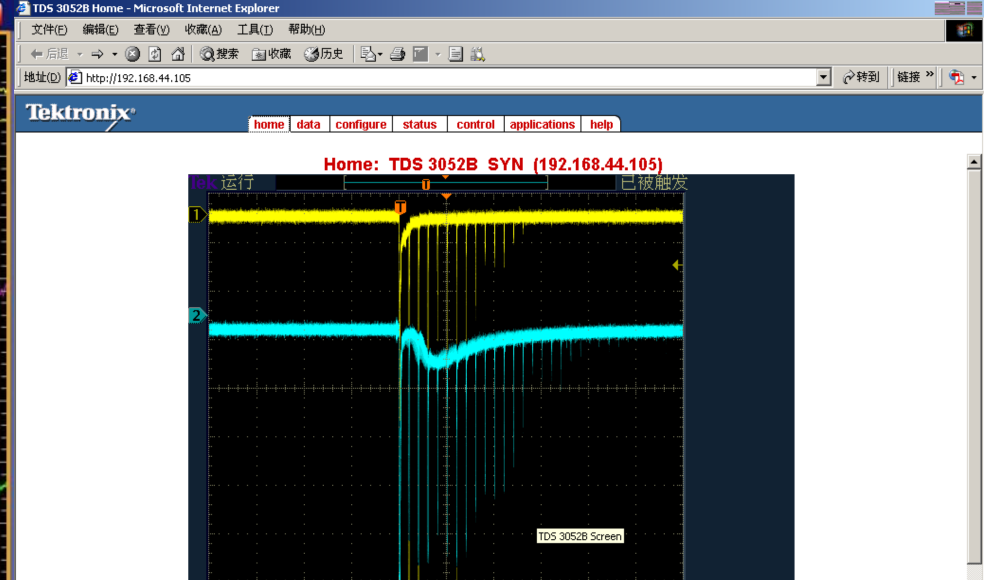
**July 19, 2008 First event detected with BESIII**

**April 8, 2009 Luminosity reached $2.3\times10^{32}cm^{-2}s^{-1}$**

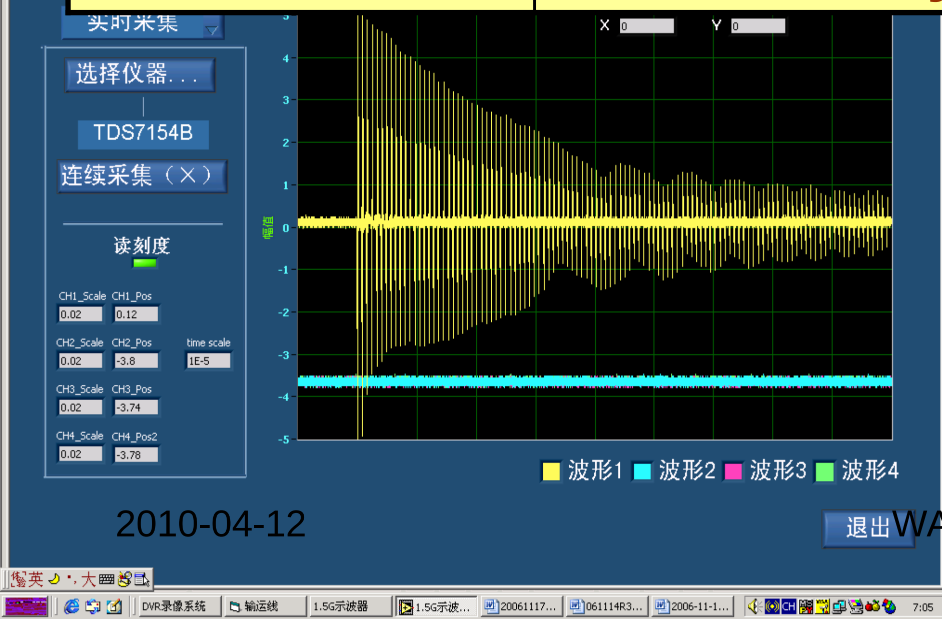
**May19, 2009 Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$**

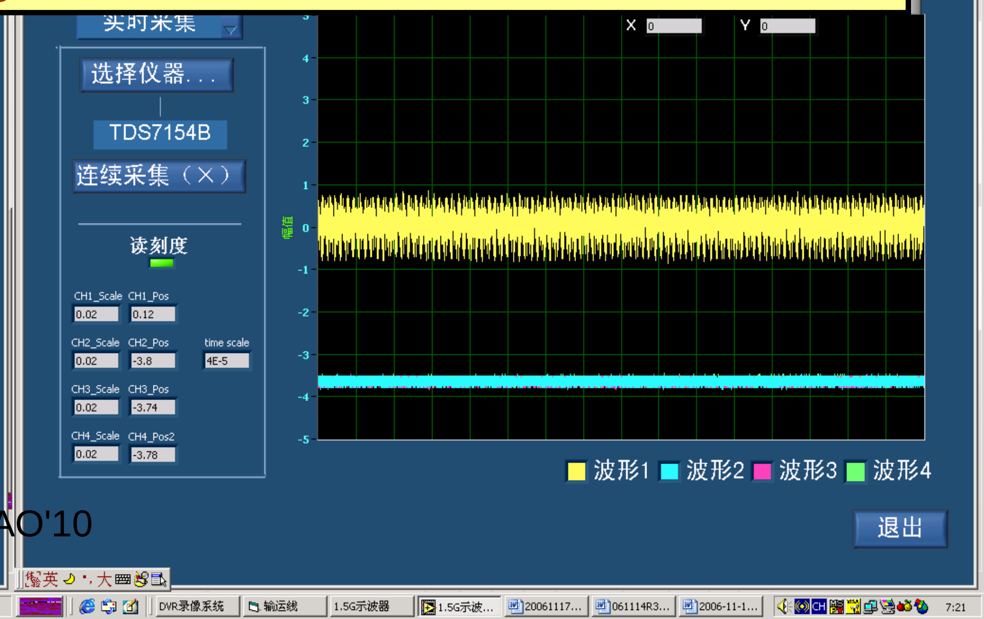
**Phase 3**




| | |
|---|---|
| **Time of beam accumulation** | **BSR: 4.5 days, 11/13/2006 – 11/18/2006**<br>**BER: 2 days, 02/06/2007 – 02/07/2007**<br>**BPR: 1 day, 03/04/2007** |



# Beam optics realization

With LOCO (Linear Optics from Closed Orbits), the parameters of a computing model can be adjusted until the model response matrix fits the measured response matrix well enough.

$$\chi^2 = \sum_{i,j} \frac{(M_{\mathrm{mod},ij} - M_{meas,ij})^2}{\sigma_i^2} \equiv \sum_{i,j} V_{ij}^2$$

Determine the errors by,

$$\Delta V_{ij} = \sum \frac{\partial V_{ij}}{\partial K_q} \Delta K_q + \sum \frac{\partial V_{ij}}{\partial G_i} \Delta G_i + \sum \frac{\partial V_{ij}}{\partial \theta_j} \Delta \theta_j + \sum \frac{\partial V_{ij}}{\partial \delta_j} \Delta \delta_j + \ldots\ldots$$

- $\Delta K_q$ — error of quadrupole strength
- $\Delta G_i$ — error of BPM gain
- $\Delta \theta_j$ — error of corrector strength
- $\Delta \delta_j$ — energy shift when horizontal corrector strength change

# Beam optics analysis

- The change of quadrupole strengths to restore the optics is described by using the amplitude fudge factor.

$$K = K_0 * AF$$

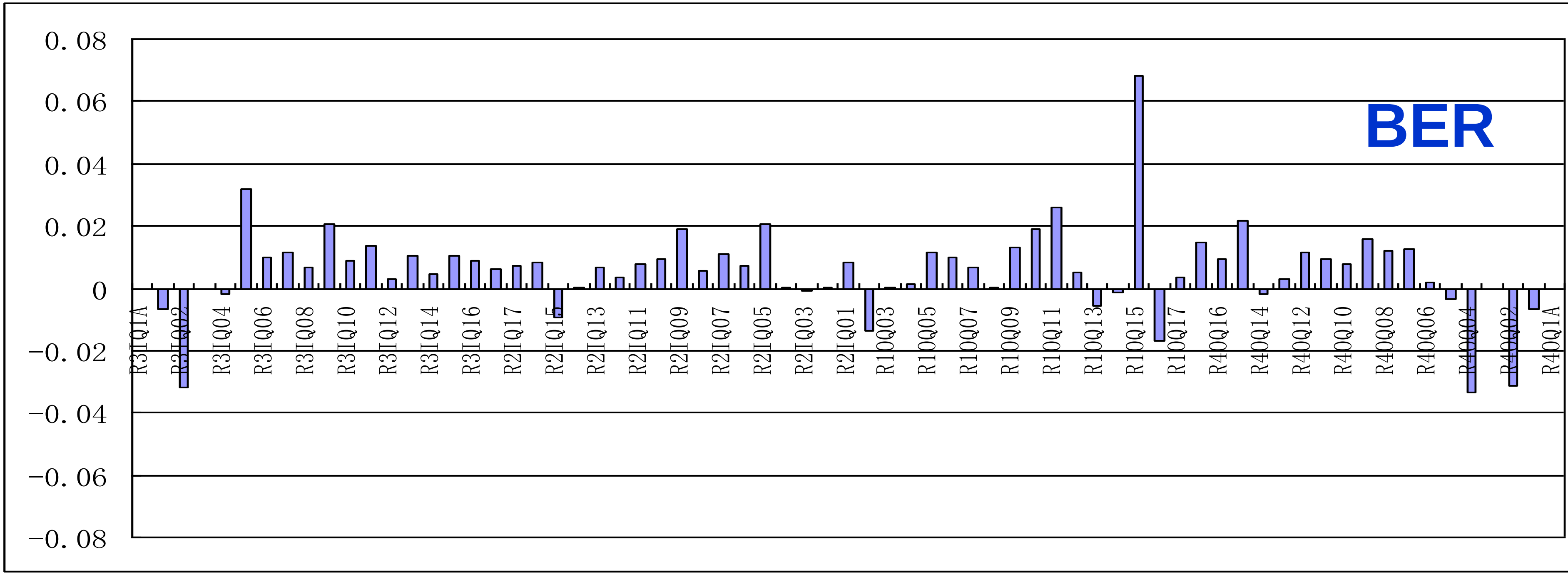
$K_0$ : design strength $K$ : optimized strength

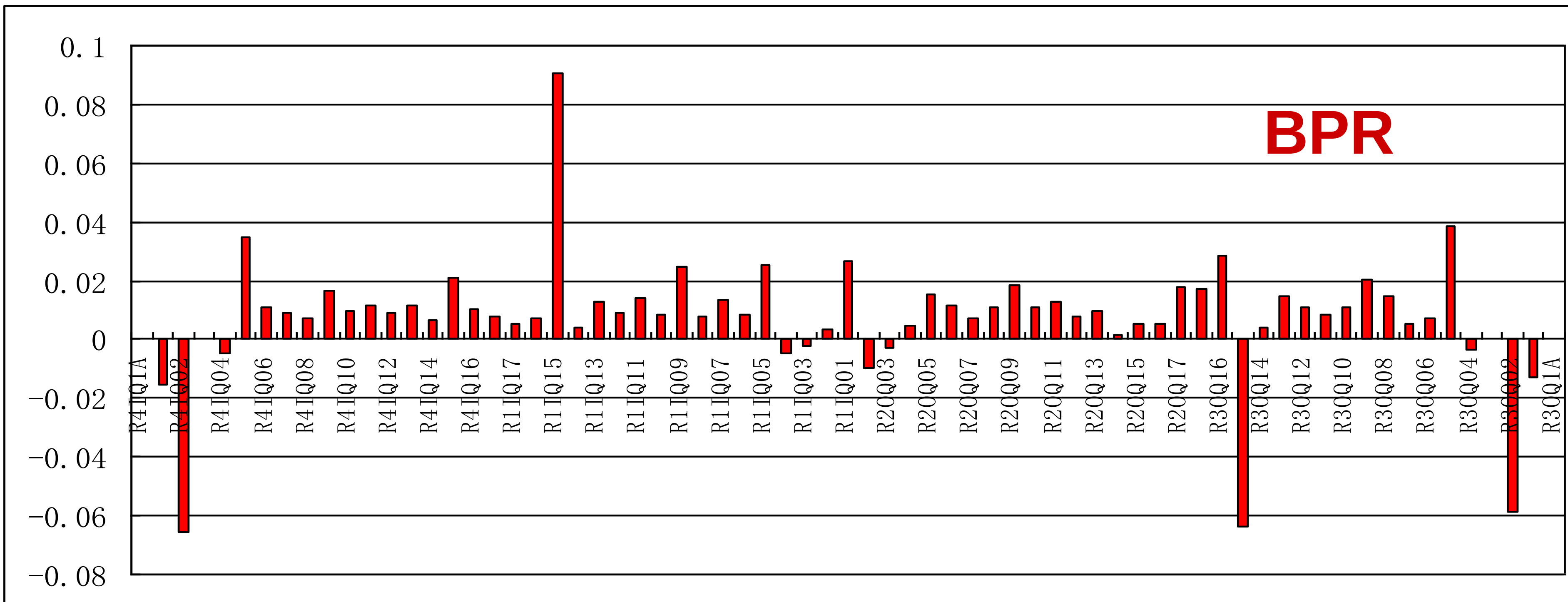
- Most of the quad's fudge factors are within 1%

- Some quads, such as **Q15 and Q02, $\triangle AF$ ~ 6%.**
  Reason: same polarity with the neighbour quads.

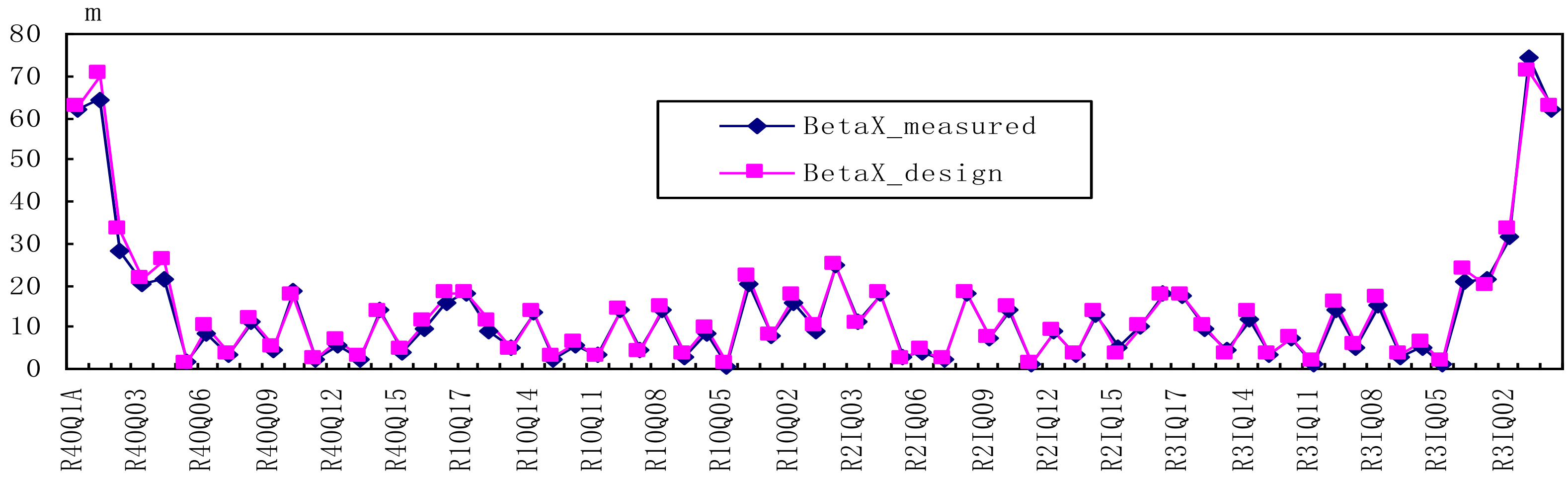
- Problems found from the abnormal *AF* s:

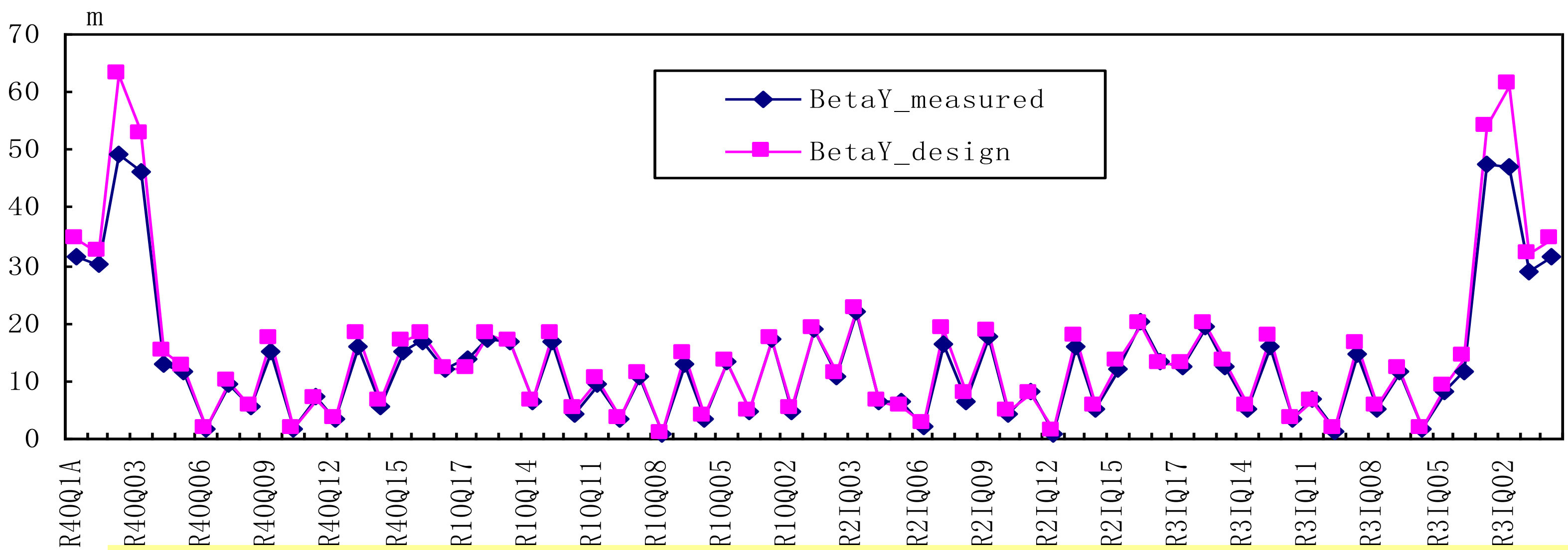
✓ shortcut of magnet poles: R1OQ16 and R2OS7
✓ grounding problem of R3OQ04
✓ fitting method for the SCQs @ IP.


BER
0. 08
0. 06
0. 04
0. 02
0
−0. 02
−0. 04
−0. 06
−0. 08
R3IQ1A
R3IQ04
R3IQ06
R3IQ08
R3IQ10
R3IQ12
R3IQ14
R3IQ16
R2IQ17
R2IQ13
R2IQ11
R2IQ09
R2IQ07
R2IQ05
R2IQ03
R2IQ01
R1OQ03
R1OQ05
R1OQ07
R1OQ09
R1OQ11
R1OQ13
R1OQ15
R1OQ17
R4OQ16
R4OQ14
R4OQ12
R4OQ10
R4OQ08
R4OQ06
R4OQ1A


BPR
0. 1
0. 08
0. 06
0. 04
0. 02
0
−0. 02
−0. 04
−0. 06
−0. 08
R4IQ1A
R4IQ04
R4IQ06
R4IQ08
R4IQ10
R4IQ12
R4IQ14
R4IQ16
R1IQ17
R1IQ15
R1IQ13
R1IQ11
R1IQ09
R1IQ07
R1IQ05
R1IQ03
R1IQ01
R2OQ03
R2OQ05
R2OQ07
R2OQ09
R2OQ11
R2OQ13
R2OQ15
R2OQ17
R3OQ16
R3OQ14
R3OQ12
R3OQ10
R3OQ08
R3OQ06
R3OQ04
R3OQ1A

# Results




**The comparison of measured and design Beta function after optics correction**

- After the optics corrections with response matrix, measured tunes are close to the nominal values.

| | Nominal | Measured (BER) | Measured (BPR) |
|---|---|---|---|
| $\nu_x$ | 6.54 | 6.544 | 6.540 |
| $\nu_y$ | 5.59 | 5.559 | 5.596 |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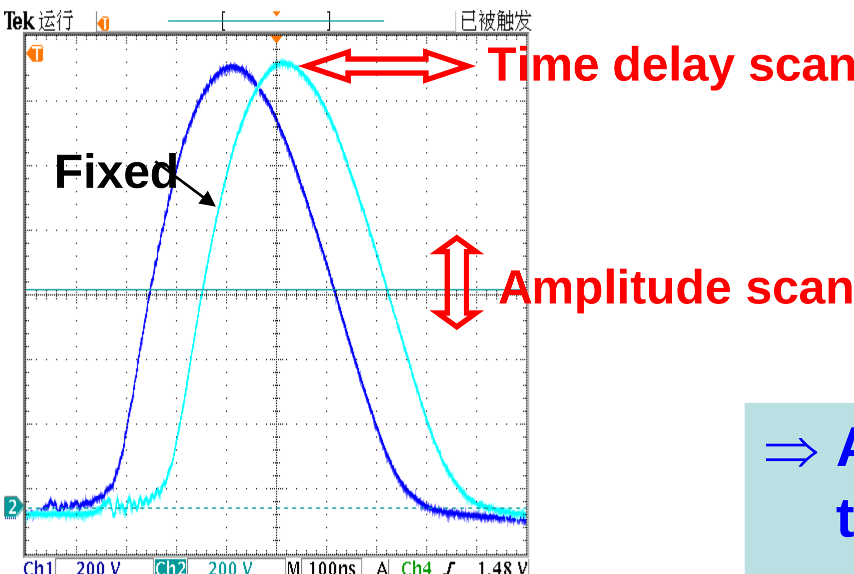
# Understanding the fudge factors

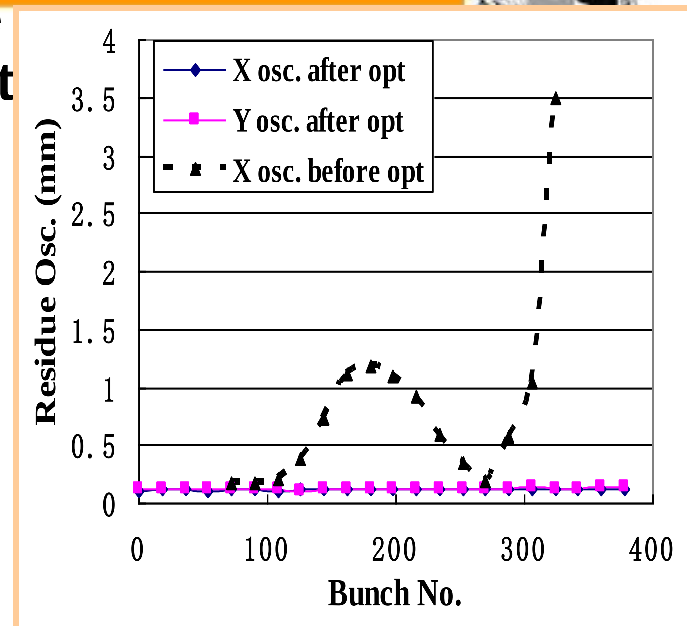
- Large fudge factors --- hardware problems: magnet, PS, database, model of special magnet, etc.
- Small fudge factors --- interaction between quad and sext in arcs, fringe field effect of dipoles and quads.
- Aim --- get fudge factors as small as possible, $K \rightarrow K_0$
- **Experiment performed at BSR, no wiggler and no optics correction, nominal tunes (7.28,5.38)**

| | Design lattice | Increase the strength of Q5~Q13 by 0.6% | Include fringe filed effect of Q and B in model | Both considered |
|---|---|---|---|---|
| Measured tunes νx/νy | 0.1685/0.2834 | 0.1917/0.3174 | 0.2005/0.3413 | 0.225/0.379 |
| Δνx/Δνy | 0/0 | 0.023/0.034 | 0.0315/0.058 | 0.054/0.096 |

# Beam injection

**Set the right timing and amplitude of the two kickers => reduce the residual orbit oscillation of stored beams during injection**



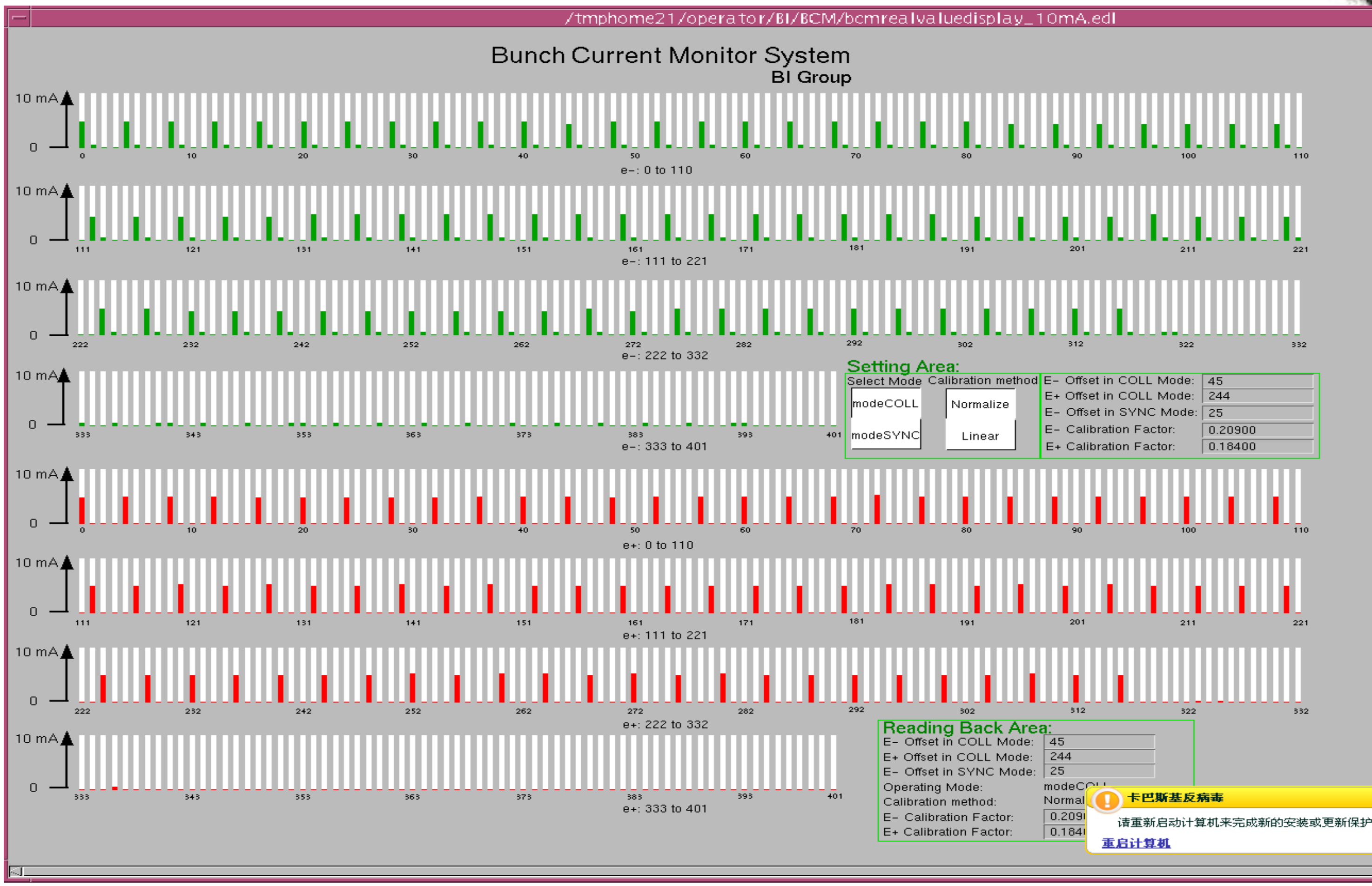

=>For timing: fix k1, scan k2 ; do in turn for k2

=>For amp: fix k1 or k2 amp, scan the other

⇒ **After optimization with on bunch, the residual orbit oscillation of all the other bunches during injection reduced to around 0.1mm/0.1$\sigma_x$.**

⇒ **Injection on collision possible.**

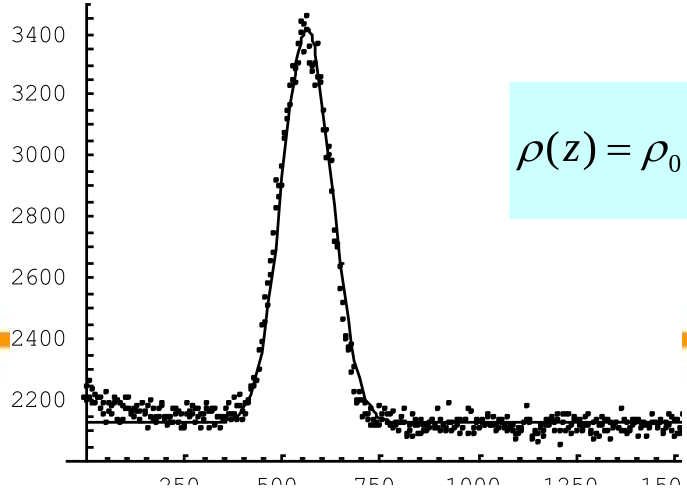
# Result of multi-bunch injection



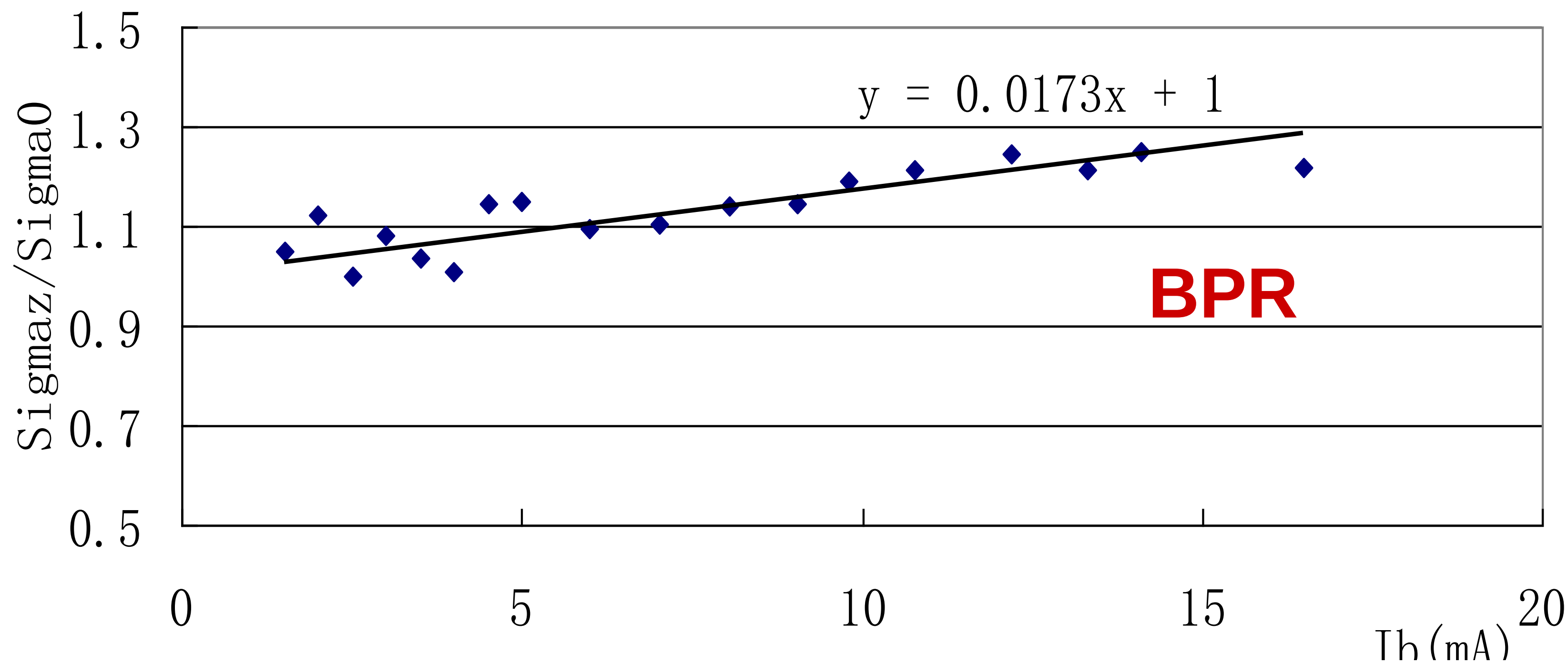
# Impedance and instability issues

## Bunch lengthening

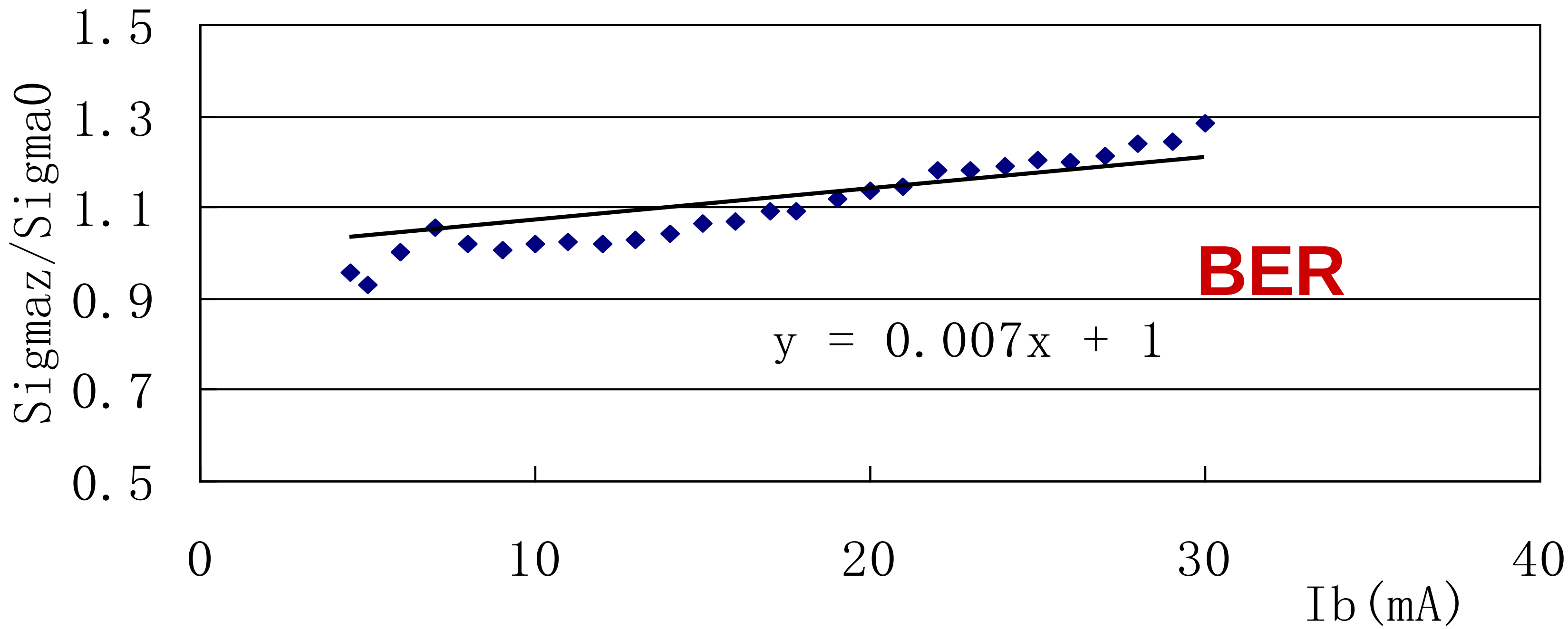
- Measured with streak camera.
- Single bunch case, in the bunch length measurement.
- Keep $V_{rf}$ fixed, measure the bunch length vs. bunch current.




$$\rho(z) = \rho_0 + \rho_1 \exp\left(-\frac{1}{2}\frac{(z-\bar{z})^2}{(1+\mathrm{sgn}(z-\bar{z})A)^2\sigma_z^2}\right)$$



y = 0.0173x + 1
BPR
Sigmaz/Sigma0
1.5
1.3
1.1
0.9
0.7
0.5
0
5
10
15
20
Ib(mA)

BER
y = 0.007x + 1
Sigmaz/Sigma0
1.5
1.3
1.1
0.9
0.7
0.5
0
10
20
30
40
Ib(mA)

# • Tune variation vs bunch current

- Betatron tunes vary with single bunch current
- Effective impedance can be got from the tune variation

$$\frac{d\nu_\perp}{dI} = \frac{R}{4\sqrt{\pi}(E/e)\sigma_l}\overline{\beta}_\perp Z_{\perp,eff}$$

$$Z_{\parallel,0} = \frac{b^2}{2R} Z_{\perp,eff}$$

# • Estimated impedance

- Bunch lengthening ⇒

  BPR: $|Z/n|_0$ =0.94Ω, BER: $|Z/n|_0$ =0.25Ω

- Tune variation ⇒

  BPR & BER: $|Z/n|_0$ ~ 1.0 Ω

# Luminosity optimization

**Optics compensation (β*, β_IR, α*, tune) and Golden orbit**

⬇

Set vertical bump at NCP（4～5$\sigma_x$）

⬇

Longitudinal position tuning（bunch spacing ~ 3.6ns）

⬇

Scan e+/e- orbit to get collision offset

⬇

Scan e+/e- offset at IP, optimize luminosity according to background

⬇

Single bunch luminosity tuning (tune, coupling, β-waist, etc.)

⬇

Scan orbit again to optimize luminosity

⬇

Multi-bunch injection and collision (BCM to watch the uniform injection)

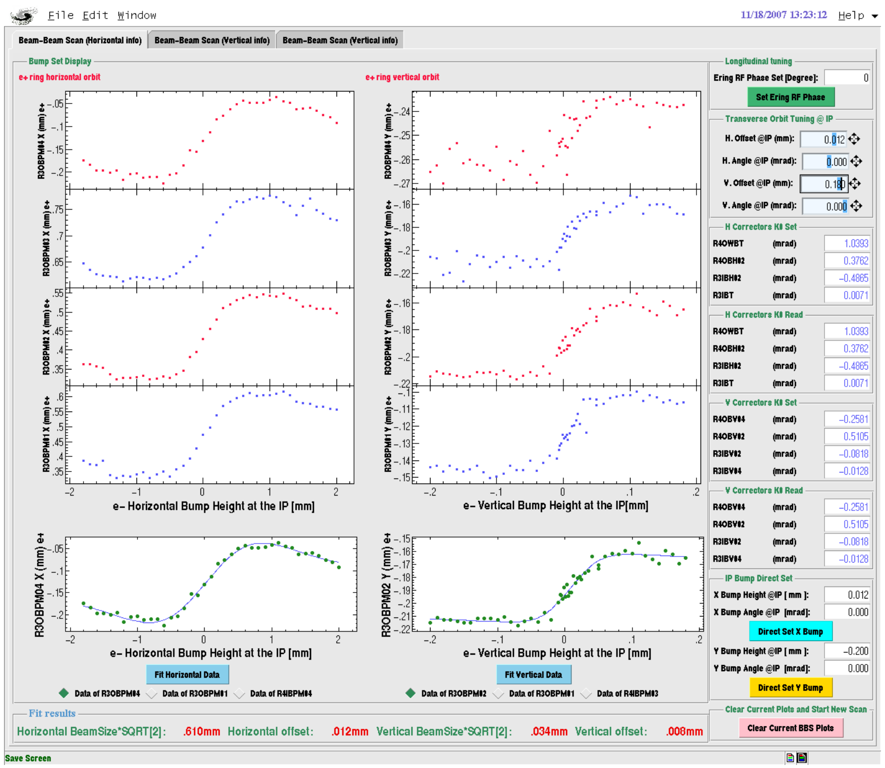
⬇

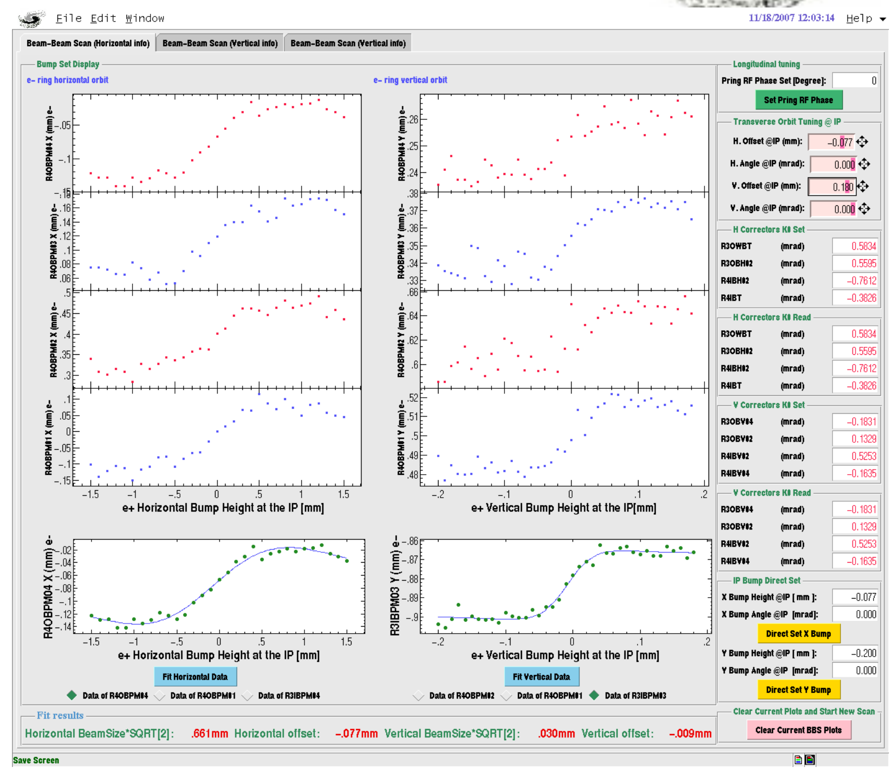
Multi-bunch optimization (instability, filling pattern, background)

⬇

Luminosity with multi-bunch

# Orbit scan for the transverse offset at IP



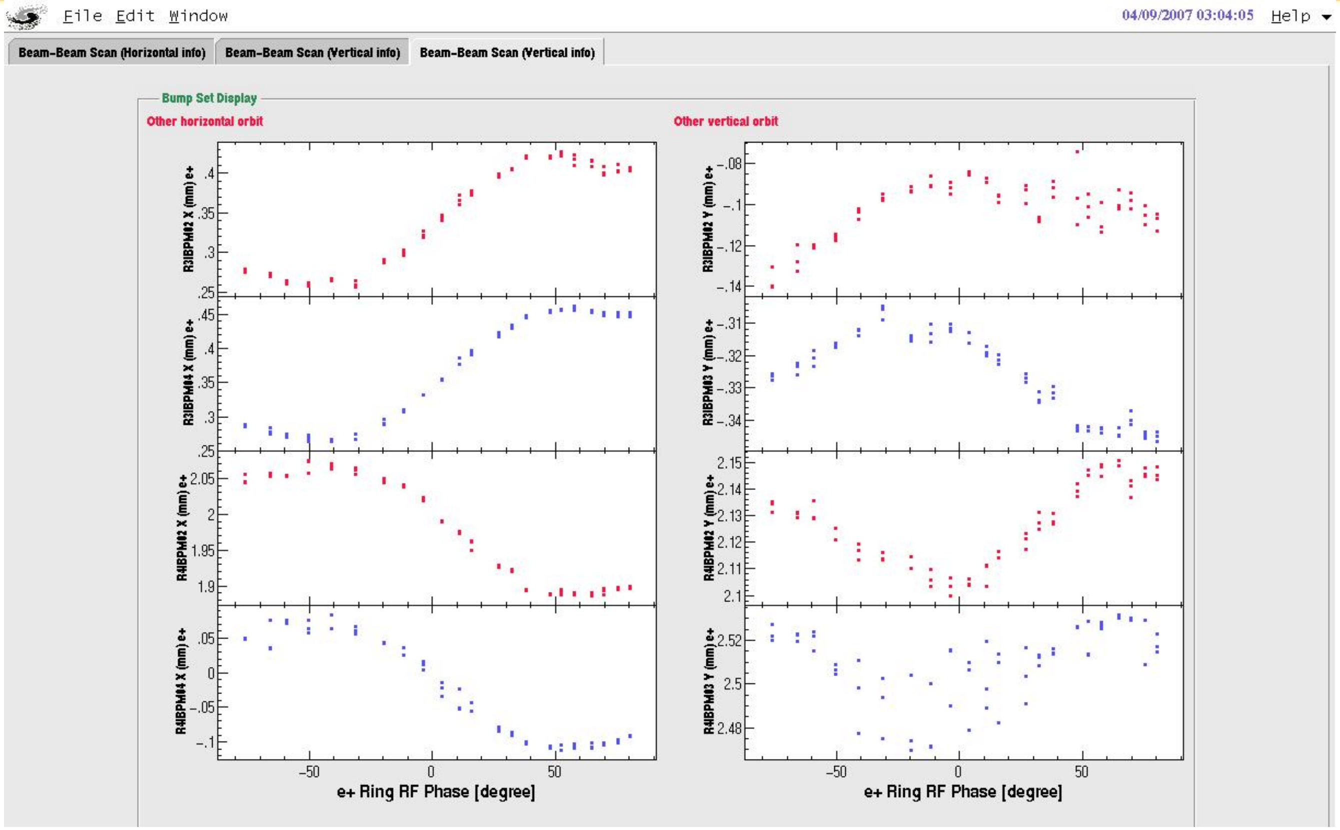




Scan e- orbit

Scan e+ orbit

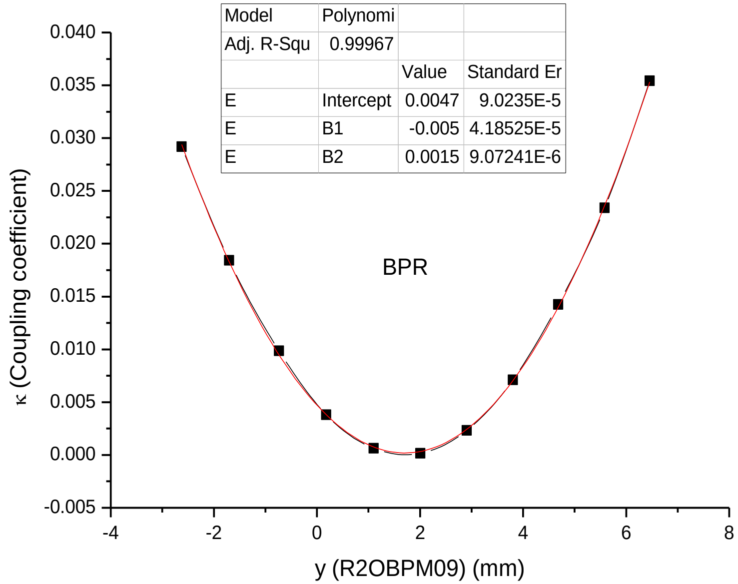
Step for tuning orbit < 1μm

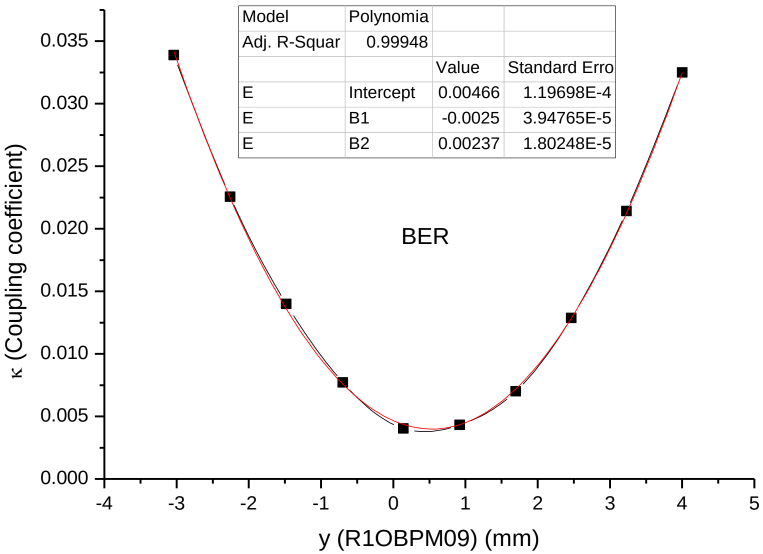
# Tuning vertical crossing angle of two orbits at IP



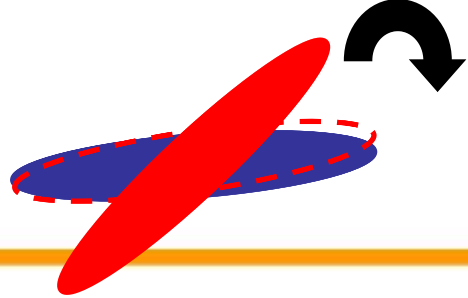

Scan RF phase to get the vertical crossing angle, and reduce it with 4-bump

# Transverse coupling tuning

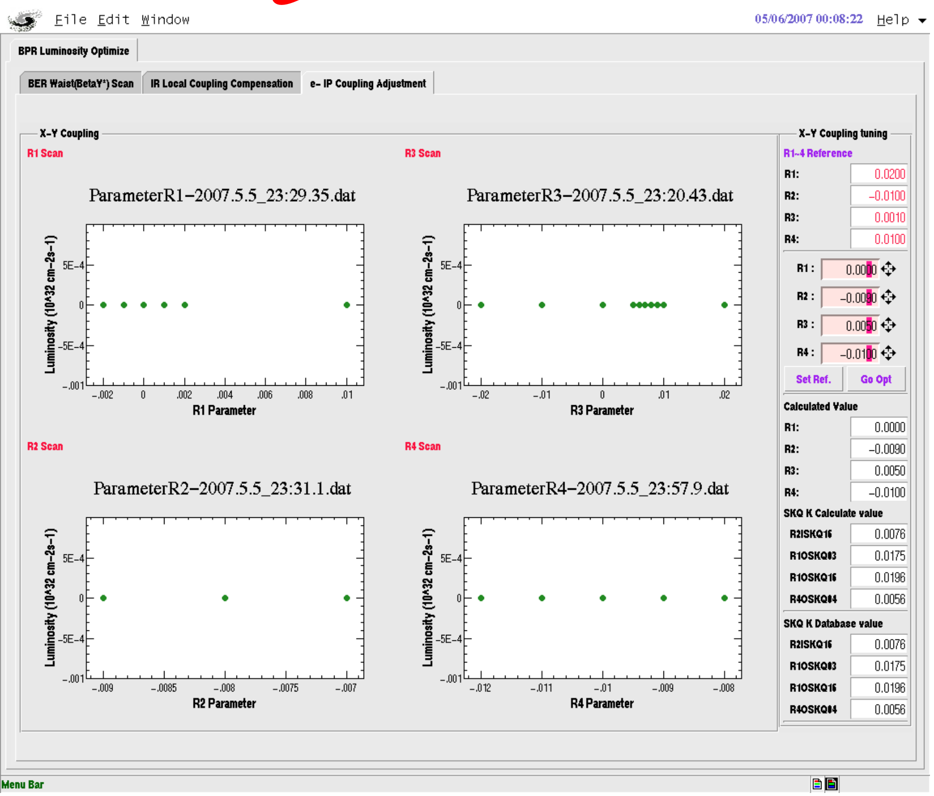


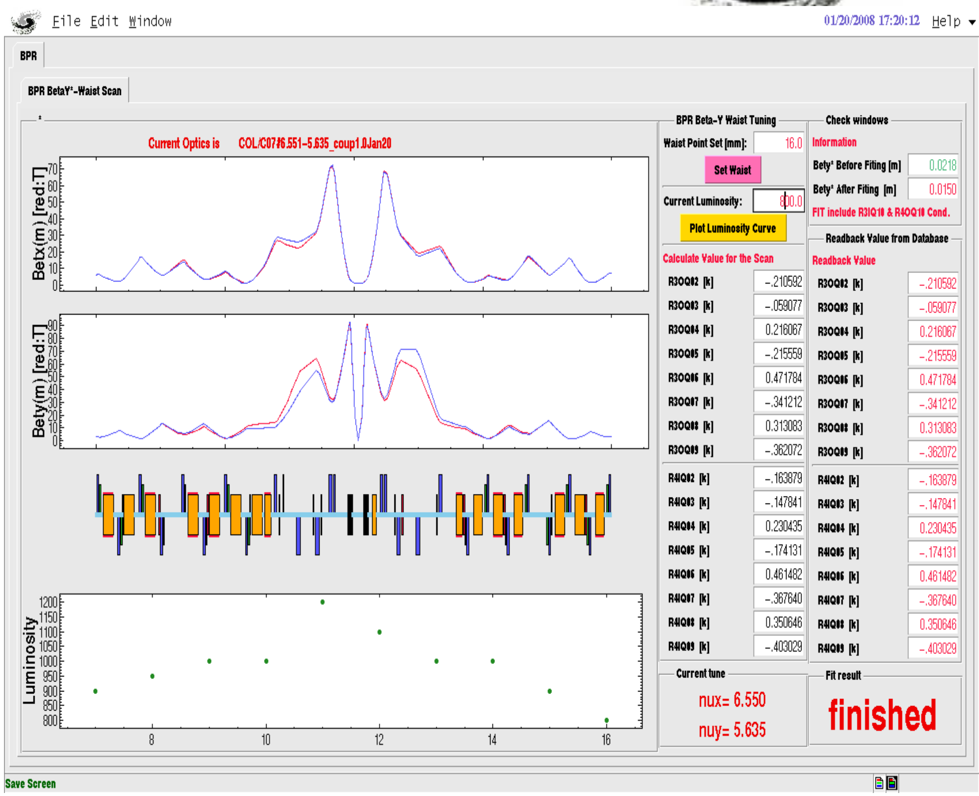




Vertical orbit at one sextupole vs. transverse coupling



$$\beta = \beta^* + \frac{s^2}{\beta^*}$$

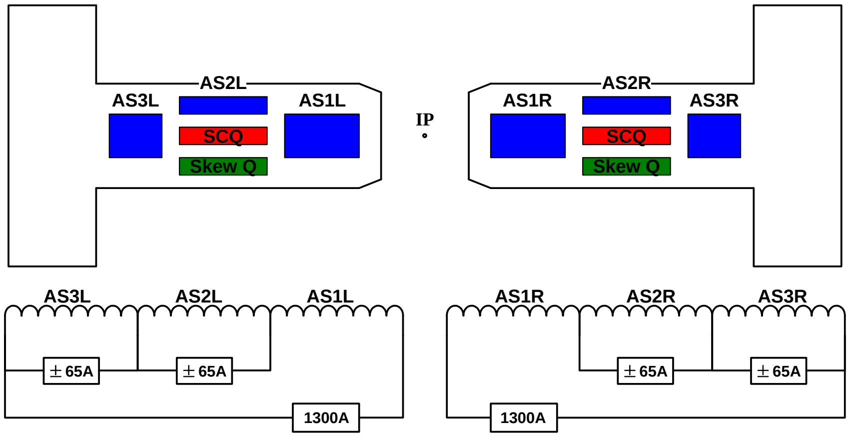


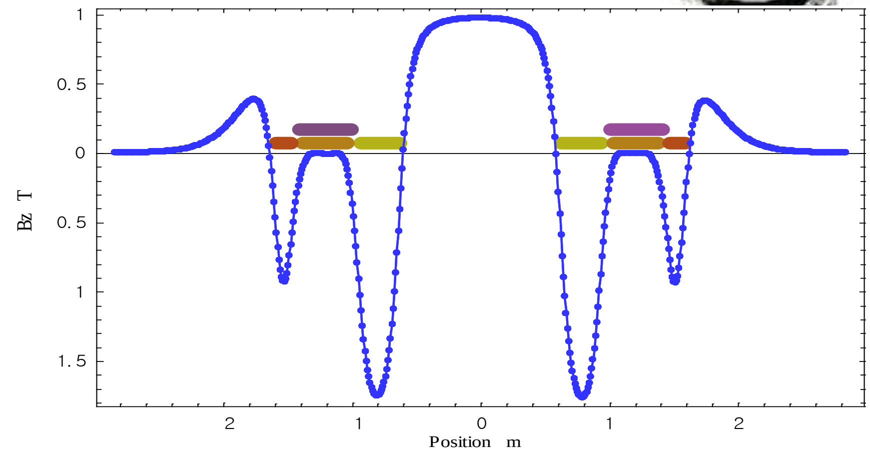



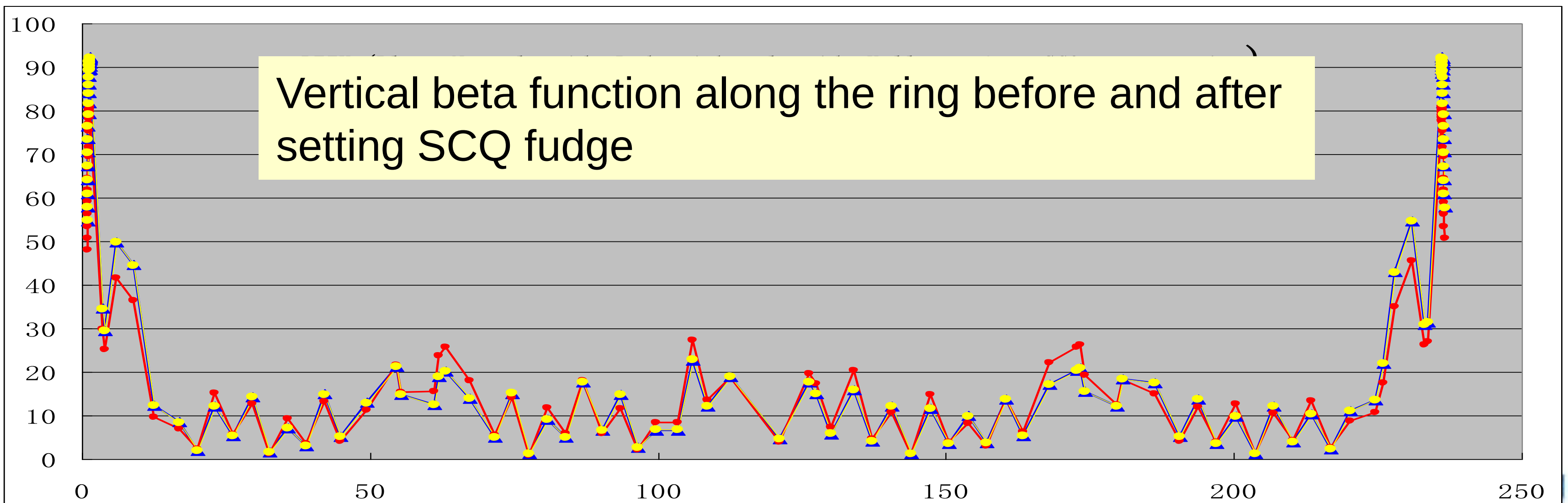

## Angle tuning at IP

## β*-waist tuning

# Detector solenoid compensation

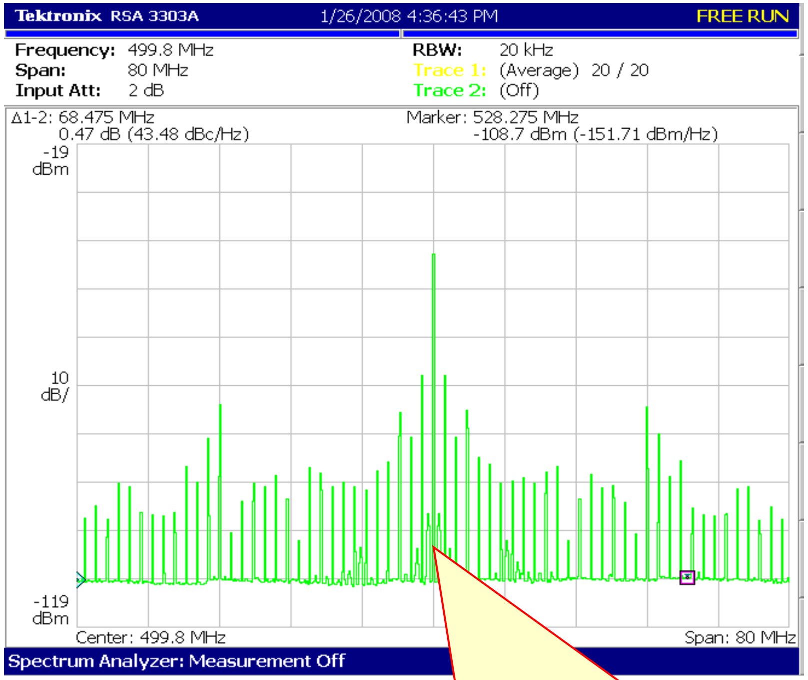


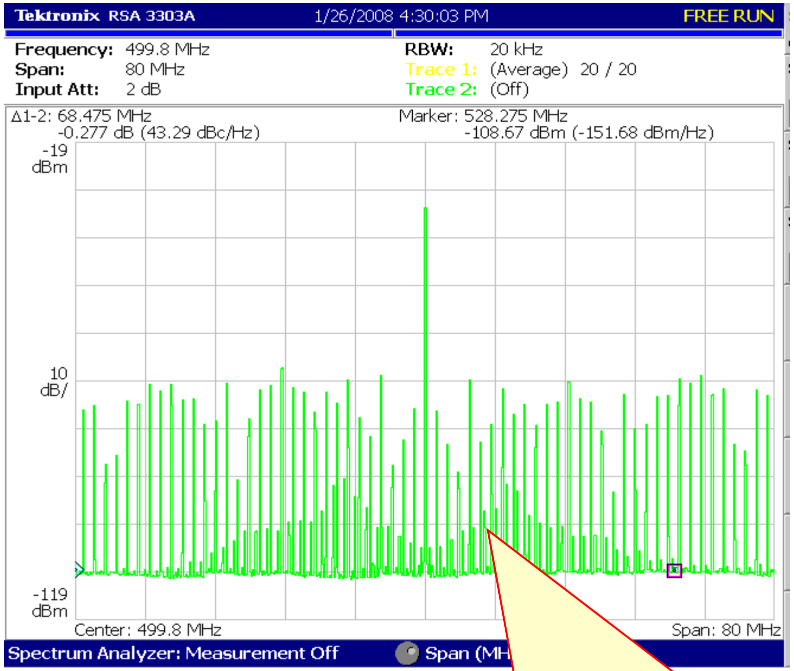



# Instability observation

**BER -- resistive wall, ion**



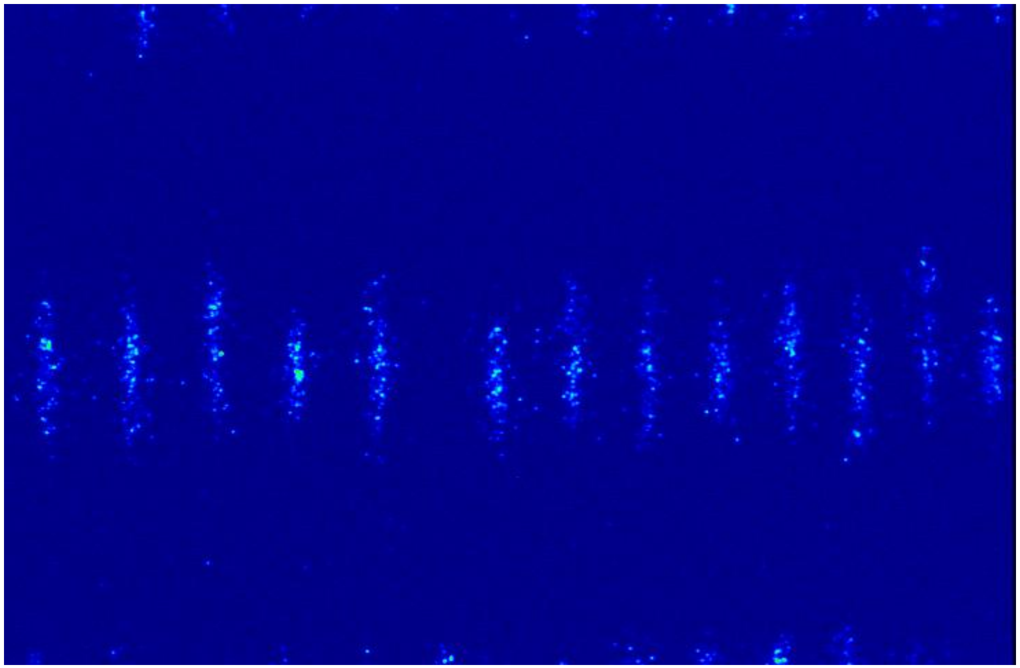

**BPR – ECI or other inst.?**




**Sidebands of the electron beam with 99 bunch, uniform filling, spacing 4 buckets, beam current 40mA.**

**Sidebands of the positron beam with 99 bunch, uniform filling, spacing 4 buckets, beam current 40mA.**

# Observation on e+ bunch transverse sizes

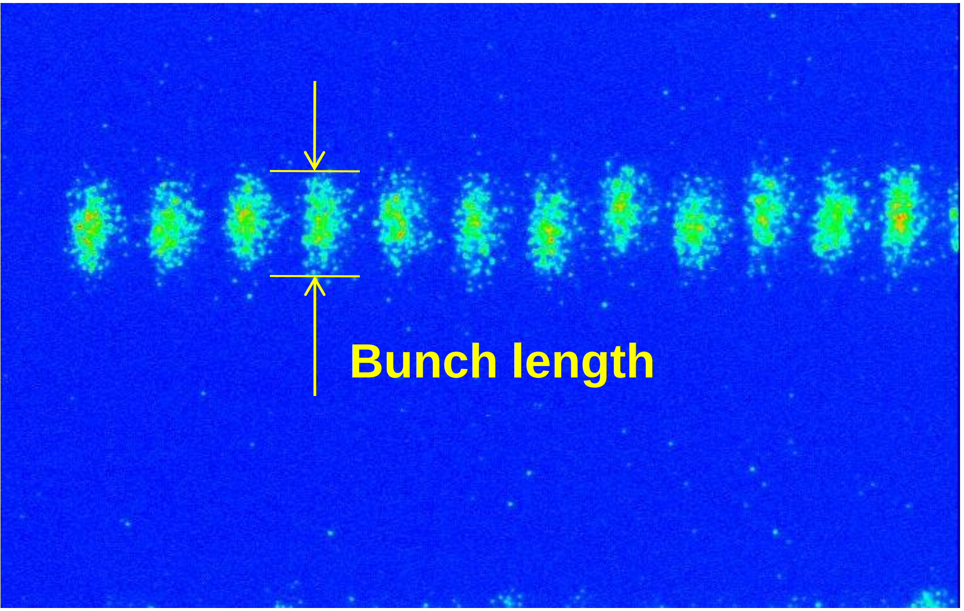


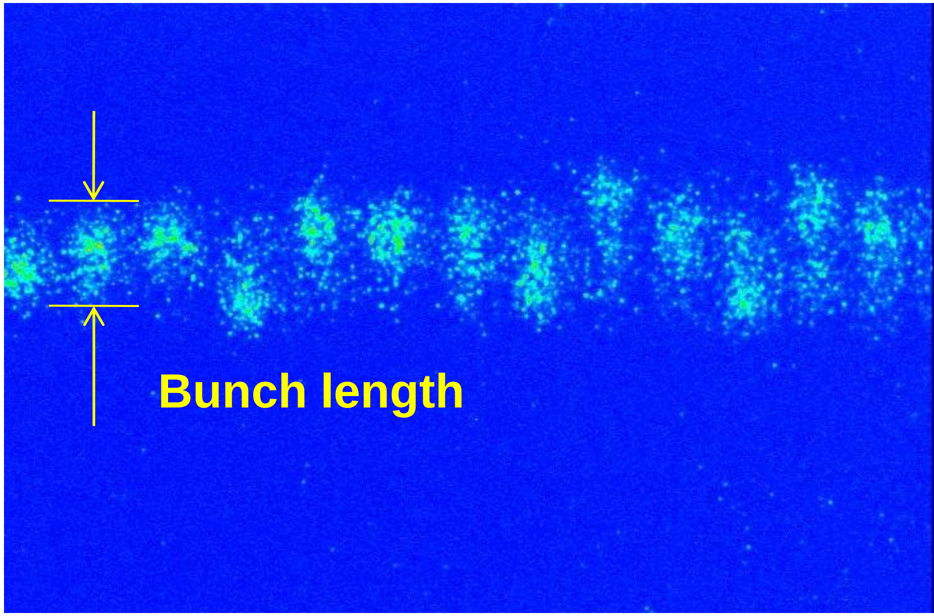
**Sigma_y of head bunch = 90.1**

**Sigma_y of tail bunch = 95.6**

**e+ bunch train**

# A bunch-by-bunch lengthening in e+ ring observed

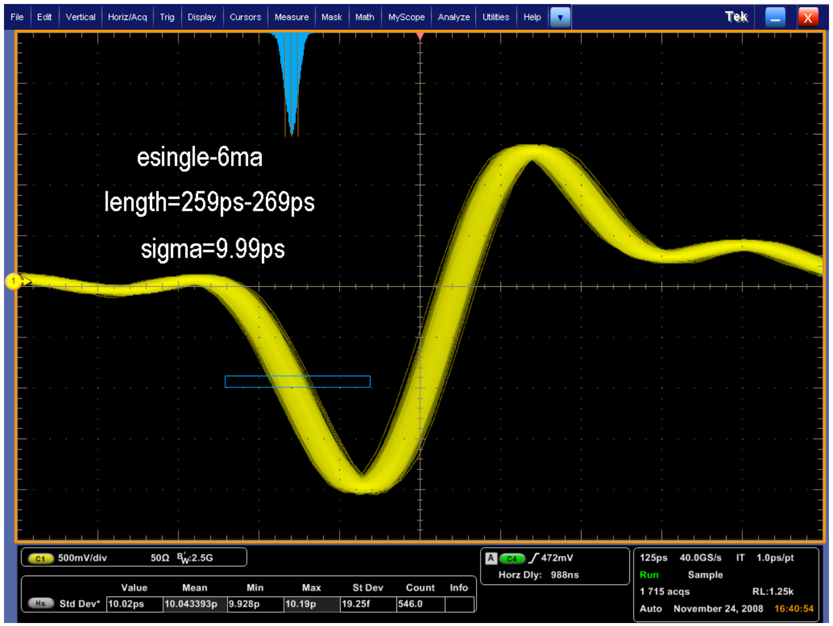


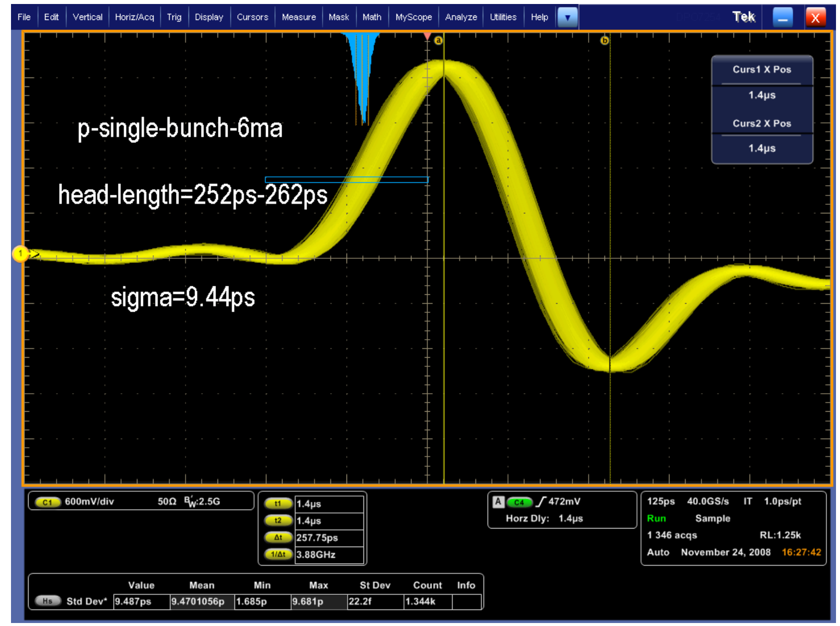




BER: 420mA/70 bunches

BPR: 386mA/70 bunches

# Longitudinal dipolar oscillation observed




Single e- bunch, I = 6mA
Sigma = 9.99 ps

Single e+ bunch, I = 6mA
Sigma = 9.44 ps

Similar in both rings!



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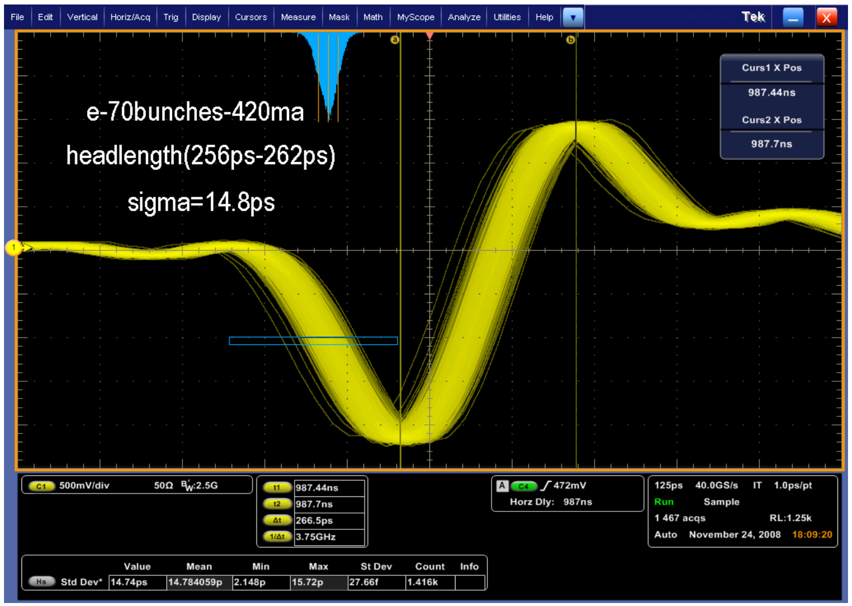
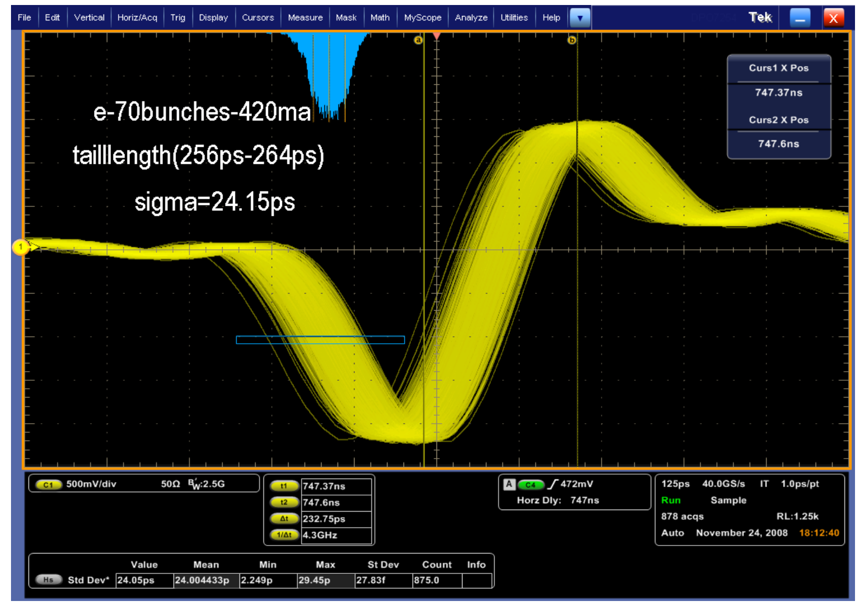
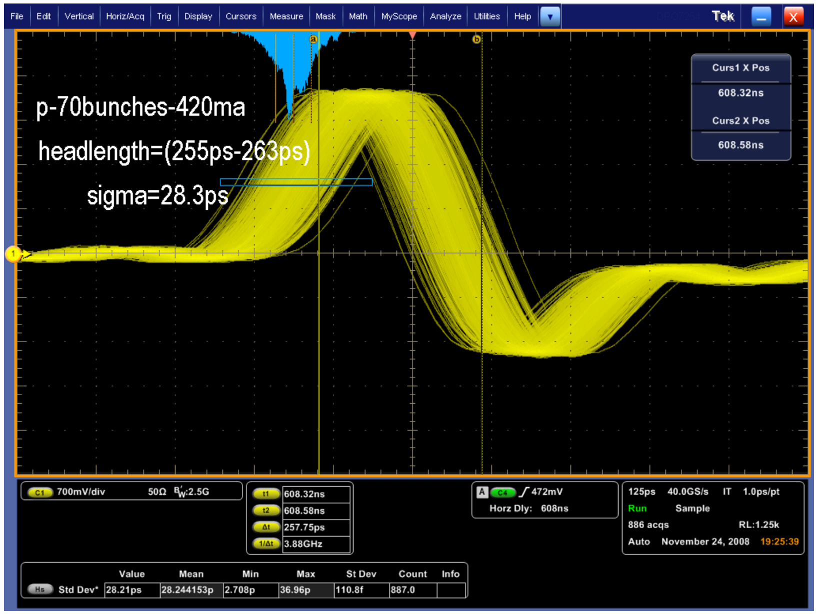
# Longitudinal quadrupolar oscillation observed

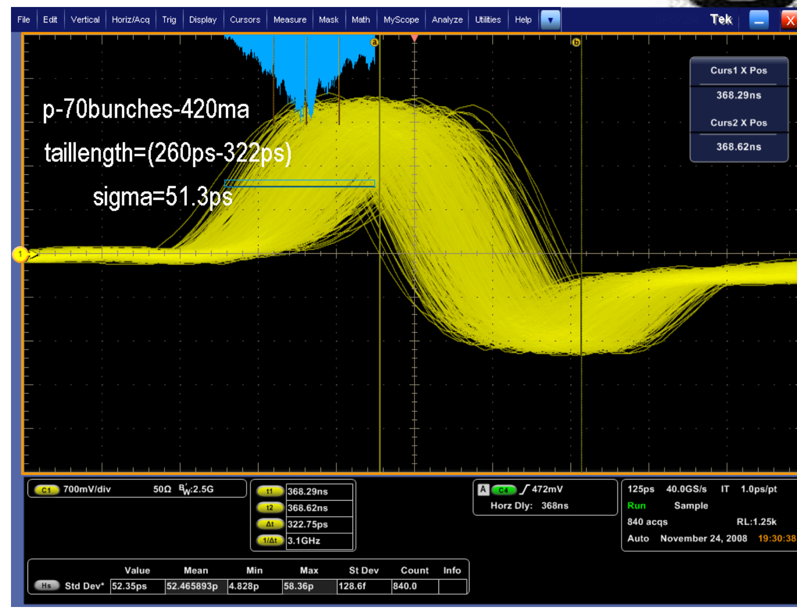



Head of e- bunch train
420mA/70 bunches
Sigma = 14.8 ps




Tail of e- bunch train
420mA/70 bunches
Sigma = 24.2 ps



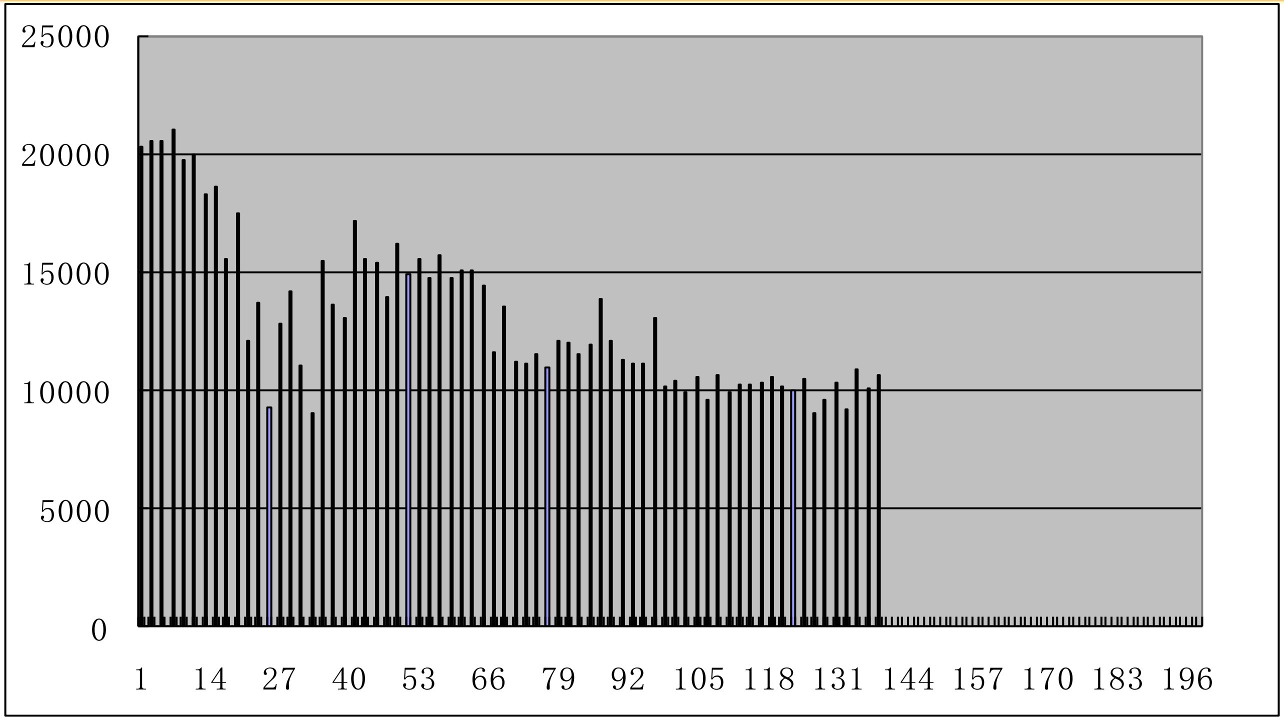




Head of e+ bunch train
420mA/70 bunches
Sigma = 28.3 ps

Tail of e+ bunch train
420mA/70 bunches
Sigma = 51.3 ps

**Much stronger than BER!**

# Luminosity reduction due to long. quad. oscillation



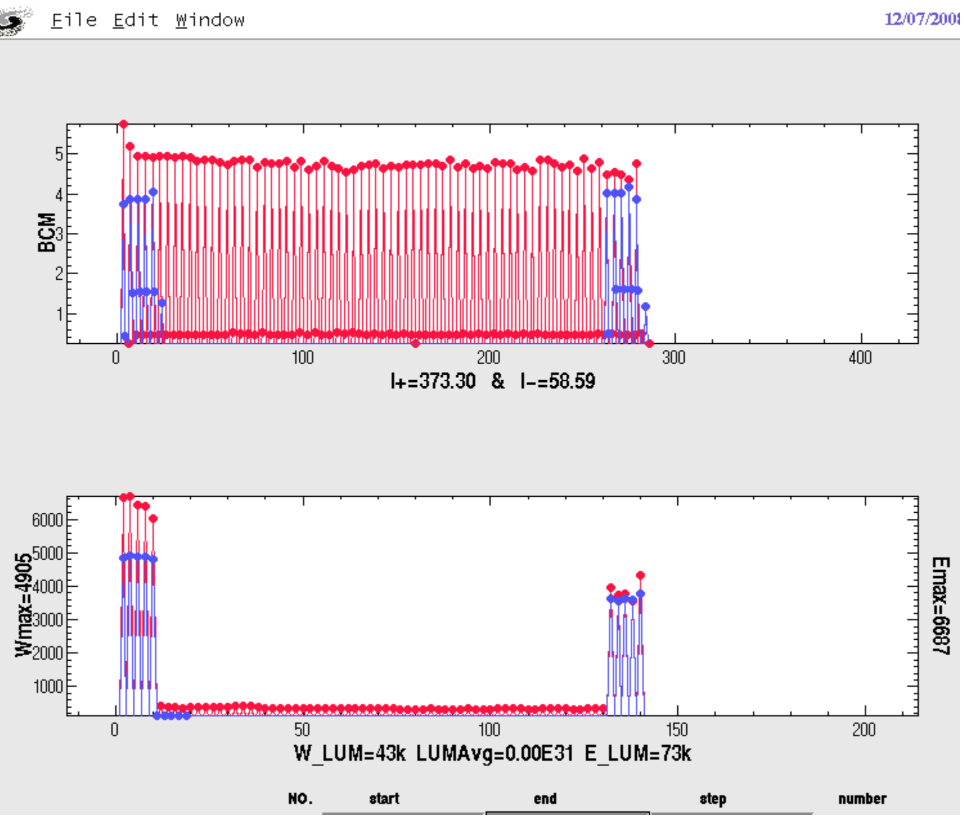

Bunch-by-bunch luminosity

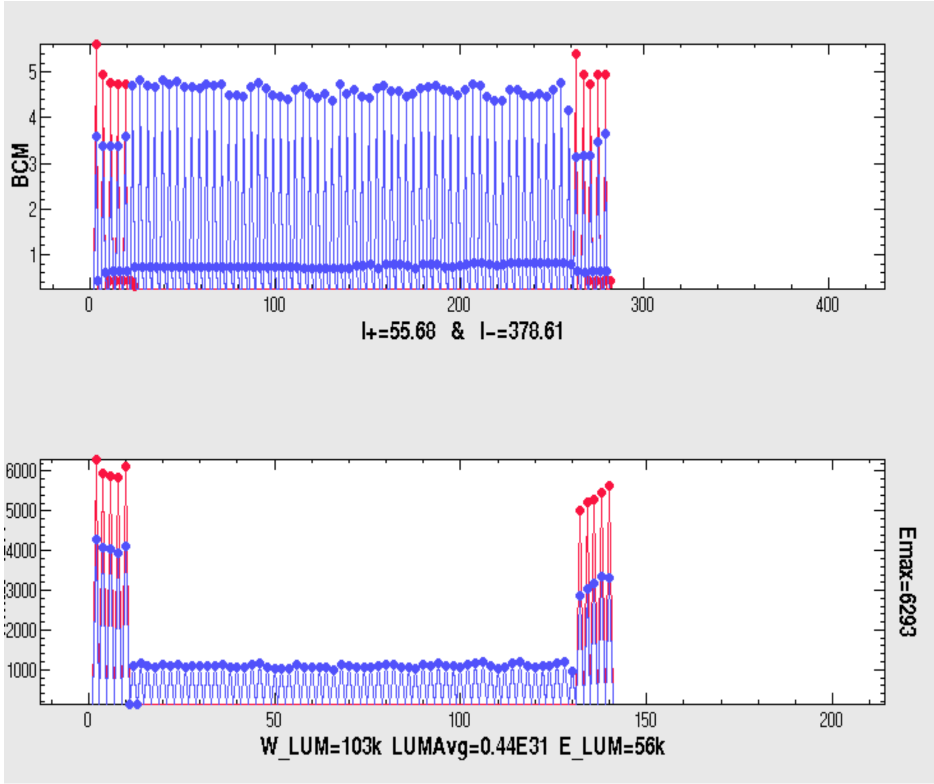
**Single bunch: 5.0mA*5.0mA，Lum_bunch=2.5×10$^{30}$cm$^{-2}$s$^{-1}$**

**Multi-bunch: 93 bunches, 450mA*450mA，Lum_total~1.1×10$^{32}$cm$^{-2}$s$^{-1}$**

**Lum_total~93*lum_bunch/2**

# Luminosity of head and tail bunches from different beams



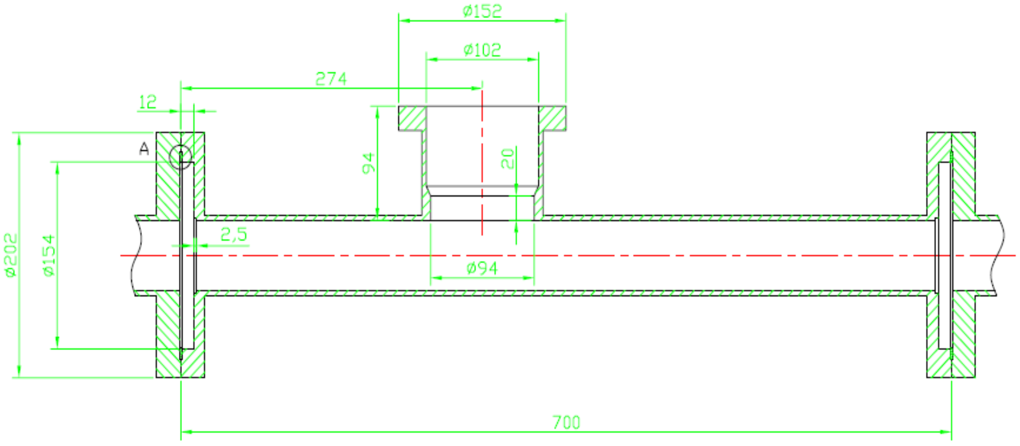



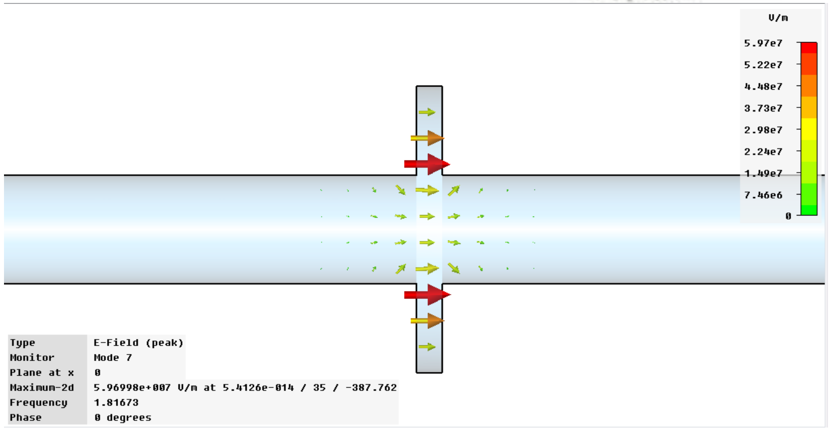

**10 e- bunches vs 70 e+ bunches** **70 e- bunches vs 10 e+ bunches**

# Source of the instability —— ECI? Impedance?

- No strong evidence of ECI effect
- Longitudinal oscillation along bunch train affects luminosity
- Difference of impedance for two rings cause the different oscillation

# Impedance from the annular slot of profile




| Model | Frequency (GHz) | Q | R | R/Q | Field decay time (ns) |
|---|---|---|---|---|---|
| Small cavity | 1.8171 | 2256.9 | 86160 | 38.1774 | 198 |
| Vacuum pump | 2.3432 | 8335.6 | 4579 | 0.54933 | 556 |

**Difference from the BER and BPR!**

# Simulation on the longitudinal instabilities

- Map in longitudinal

$$\begin{pmatrix} \Delta E \\ \Delta t \end{pmatrix} = \begin{pmatrix} 1 - 2\frac{U_0}{E_0}s & 0 \\ \frac{\alpha T_0 s}{E_0} & 1 \end{pmatrix} \begin{pmatrix} \Delta E \\ \Delta t \end{pmatrix} - \begin{pmatrix} U_0 s \\ 0 \end{pmatrix}$$

- Beam – cavity interaction

$V_m$ and $i_m$ : conjugate variables

$$\begin{pmatrix} v_m(t) \\ i_m(t) \end{pmatrix} = \exp(-\alpha_m t)\times$$

$$\begin{pmatrix} \cos(\beta_m t) - \frac{\alpha_m}{\beta_m}\sin(\beta_m t) & -\frac{\omega_m R_{sm}}{\beta_m Q_m}\sin(\beta_m t) \\ \frac{\omega_m Q_m}{\beta_m R_{sm}}\sin(\beta_m t) & \cos(\beta_m t) + \frac{\alpha_m}{\beta_m}\sin(\beta_m t) \end{pmatrix} \begin{pmatrix} v_m(t) \\ i_m(t) \end{pmatrix}$$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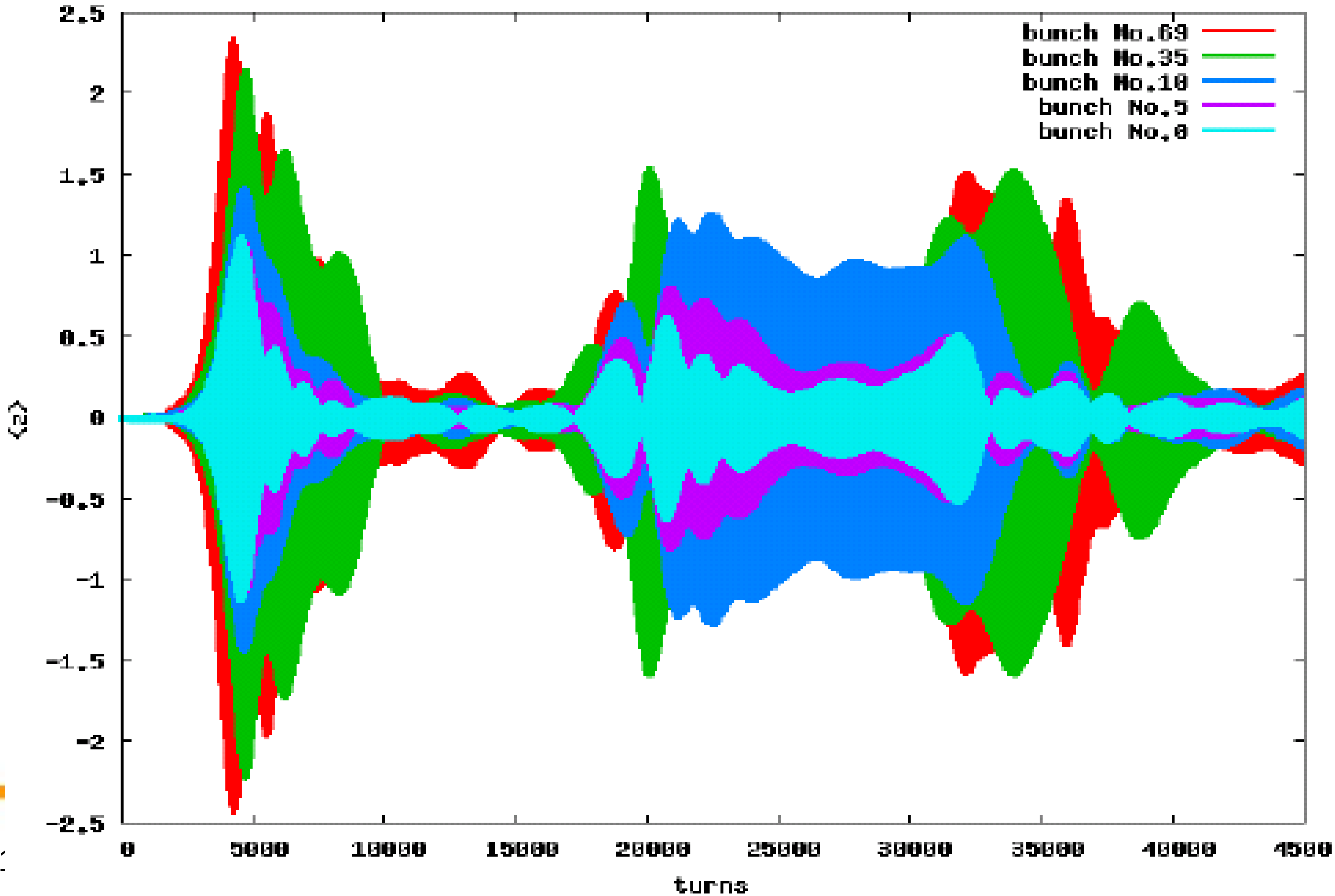
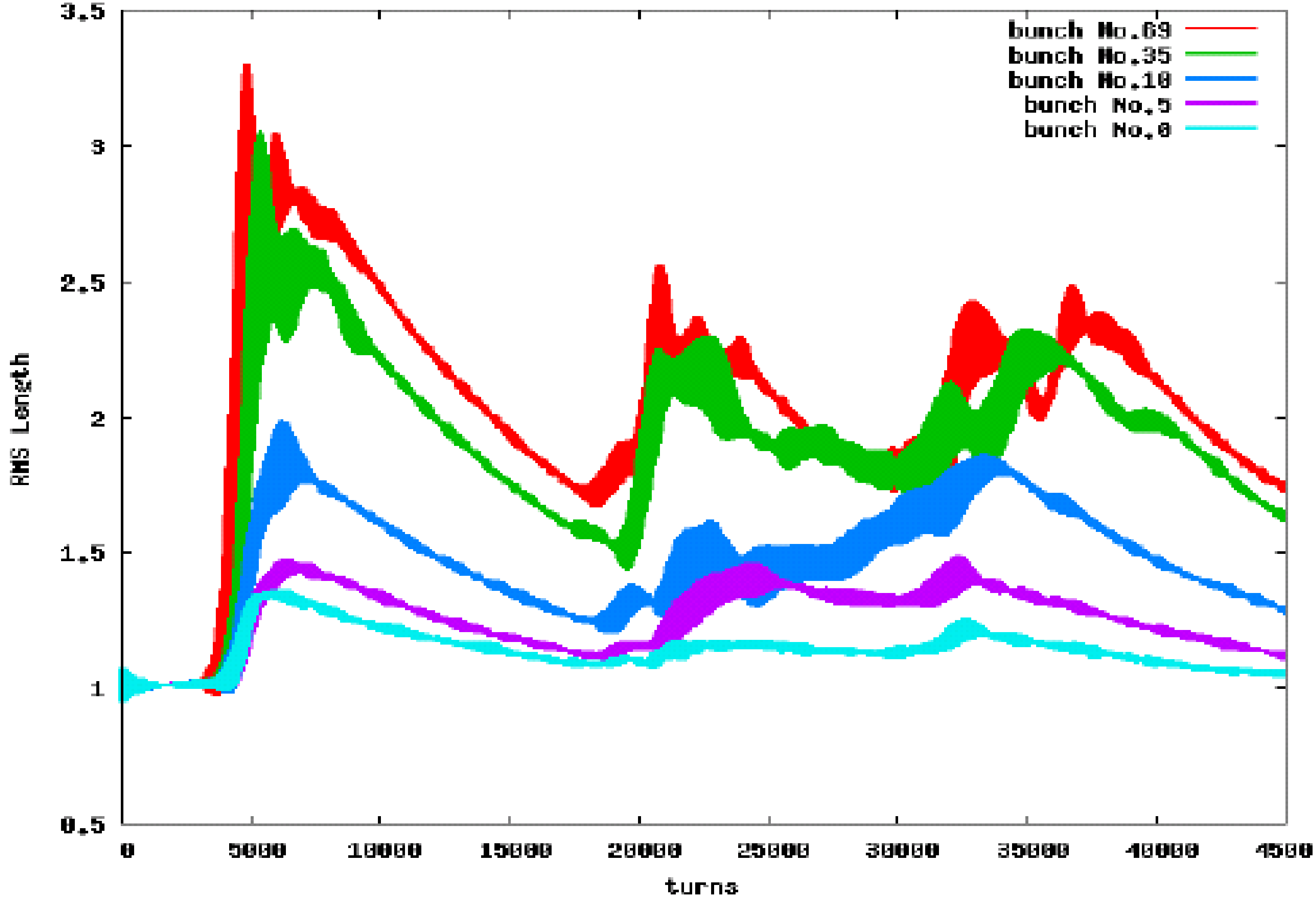
# Results on impedance of Q=1028, R=40000, f=1817MHz

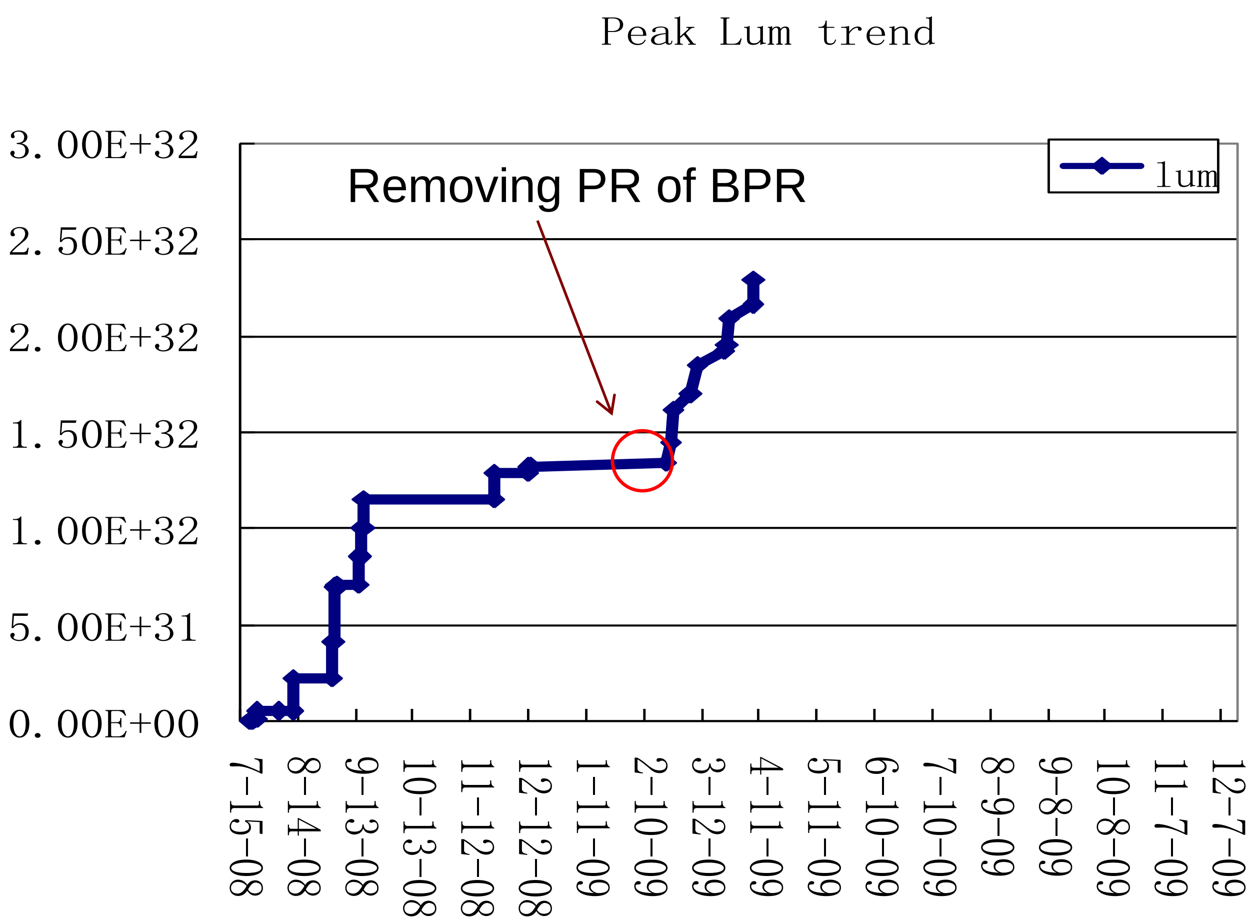


# Evolution of bunch length

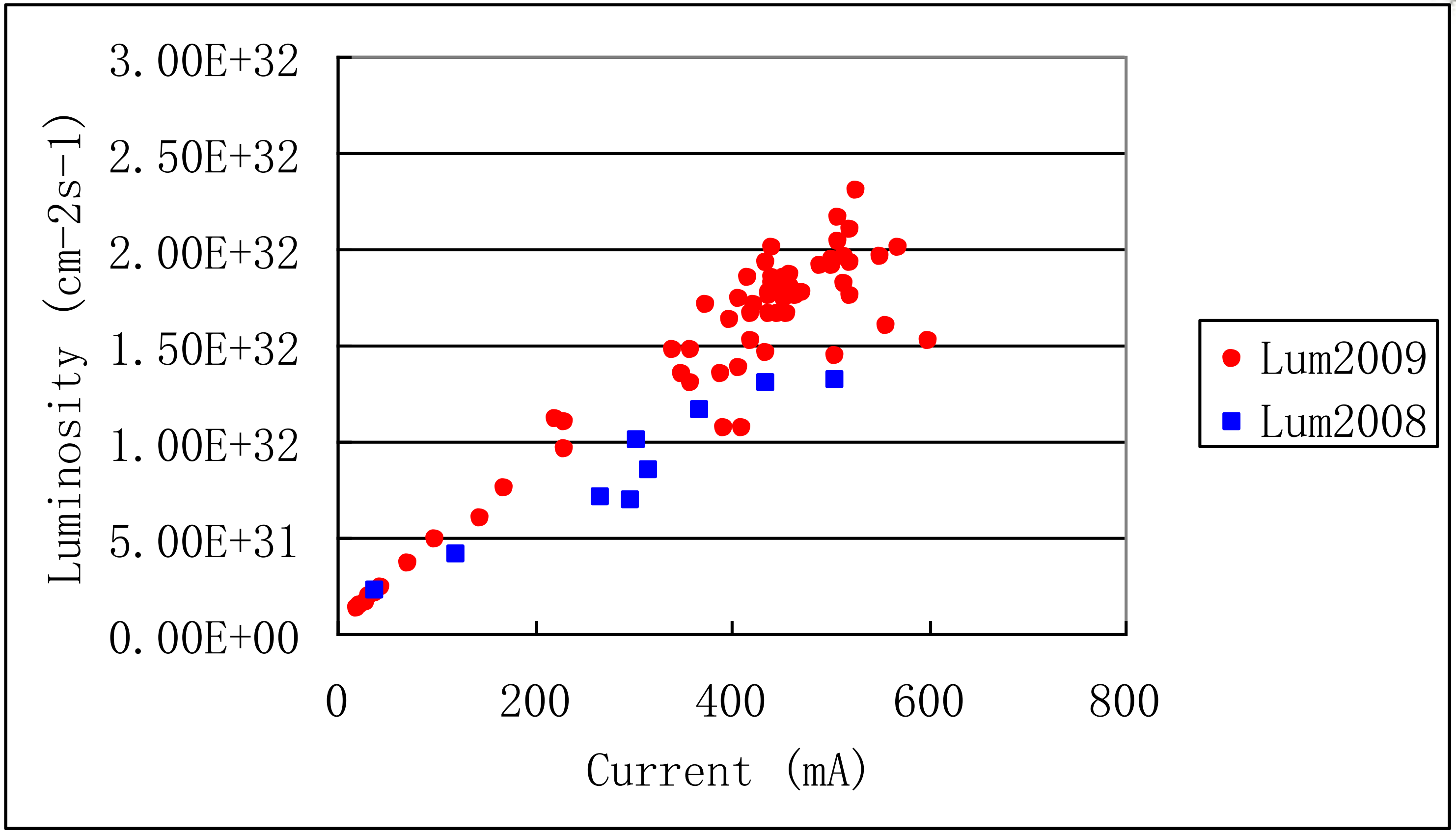


- Remove the PR in e+ ring in Feb. 2009
- Start the new run of luminosity commissioning from March 2009

# Luminosity recovery after removing the PR



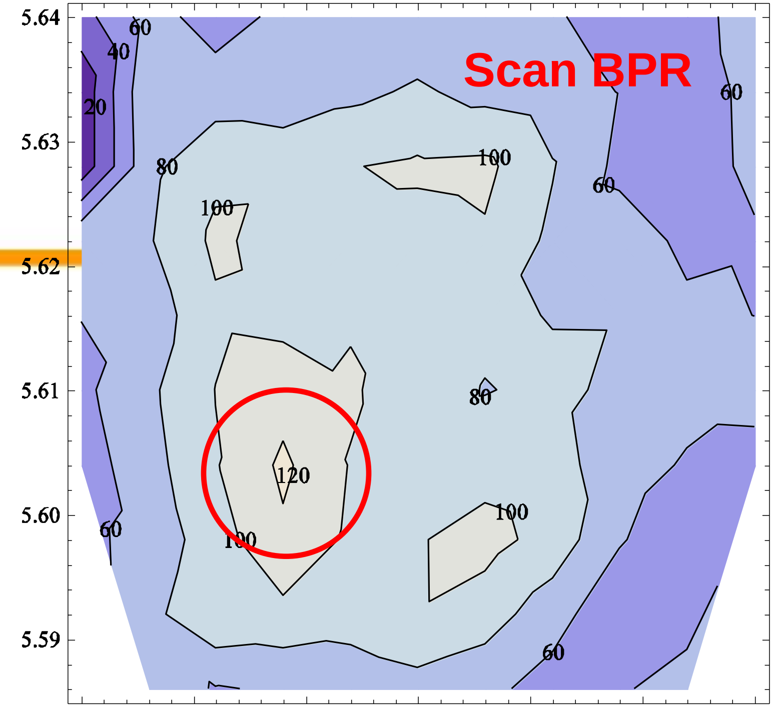
# Luminosity recovery after removing the PR

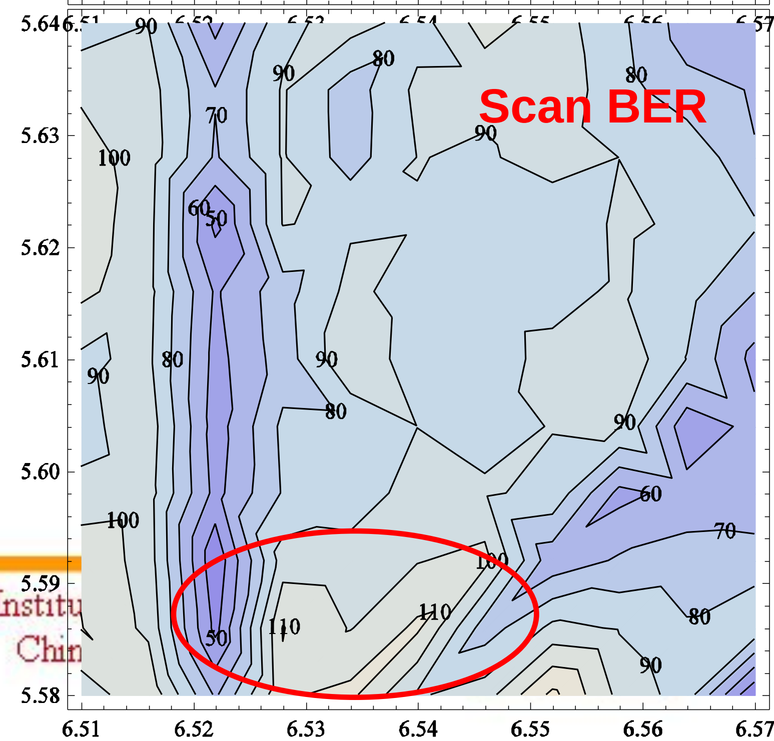


# On-line tune scan for two rings

| BPR | 5.55 | 5.56 | 5.57 | 5.58 | 5.59 | 5.6 | 5.61 | 5.62 | 5.63 | 5.64 | 5.65 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.52 | t 差 | t 差 | t 差 | t 差 | 76.92 | | 丢束 | t 差 | 127.3 | 139.2 | 166.0 |
| 6.53 | 108.6 | 119.3 | 98.8 | 105.4 | 89.7 | 198.6 | 164.9 | 139 | 99.2 | 84.3 | 81.1 |
| 6.54 | 105.7 | 160.8 | 164.8 | 182.4 | 118.5 | 168.7 | 172.5 | 129.9 | 137.8 | 131.8 | 142.8 |
| 6.55 | 82.1 | 101.6 | 109.4 | 96.7 | 125.6 | 150.3 | 117.3 | 164.4 | 157.9 | 149.2 | 155.7 |
| 6.56 | 74.2 | 79.0 | 139.4 | 147.0 | 118.5 | 139.7 | 161.7 | 134.1 | 139.3 | 141.6 | 146.2 |
| 6.57 | 112.9 | 96.1 | 77.1 | 87.2 | 132.5 | 133.4 | 151.2 | 148.4 | 143.4 | 131.8 | 164.8 |
| 6.58 | 93.5 | e+ blow up | | | 185.2 | 102.4 | 114.3 | 128.5 | 171.0 | 136.0 | 146 |
| 6.59 | 113.1 | 101.9 | 158.9 | 75.2 | | 110.5 | 113.7 | | 140.4 | t 差 | |

| BER | 5.55 | 5.56 | 5.57 | 5.58 | 5.59 | 5.6 | 5.61 | 5.62 | 5.63 | 5.64 | 5.65 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.52 | | | | | | | | | | | |
| 6.53 | 131.8 | 167.2 | 141.9 | 111.7 | 139.1 | 146.2 | 145.6 | | | 207.1 | 214.1 |
| 6.54 | t差 119 | 109 | 139.5 | 164.5 | 156.5<br>145.2 | | | | | 218.5 | 224.2 |
| 6.55 | 60.1 | 106.3 | 93.1 | 99.2 | 123 | 143.4 | 142.7 | | | 205.6 | 215.2 |
| 6.56 | | 丢束 | 丢束 | 132.1 | 165.5 | | | | 205.8 | 198.6 | 丢束 |
| 6.57 | 75.2 | 143.3 | 134 | 116.2 | 94.1 | 111.1 | 122.5 | 164.4 | 166.9 | 170.7 | t 差 |
| 6.58 | | | | | | | | | | | |
| 6.59 | 131.9 | 171.8 | 163.2 | 93.0 | 118.2 | 丢束 | 90.1 | | | | |



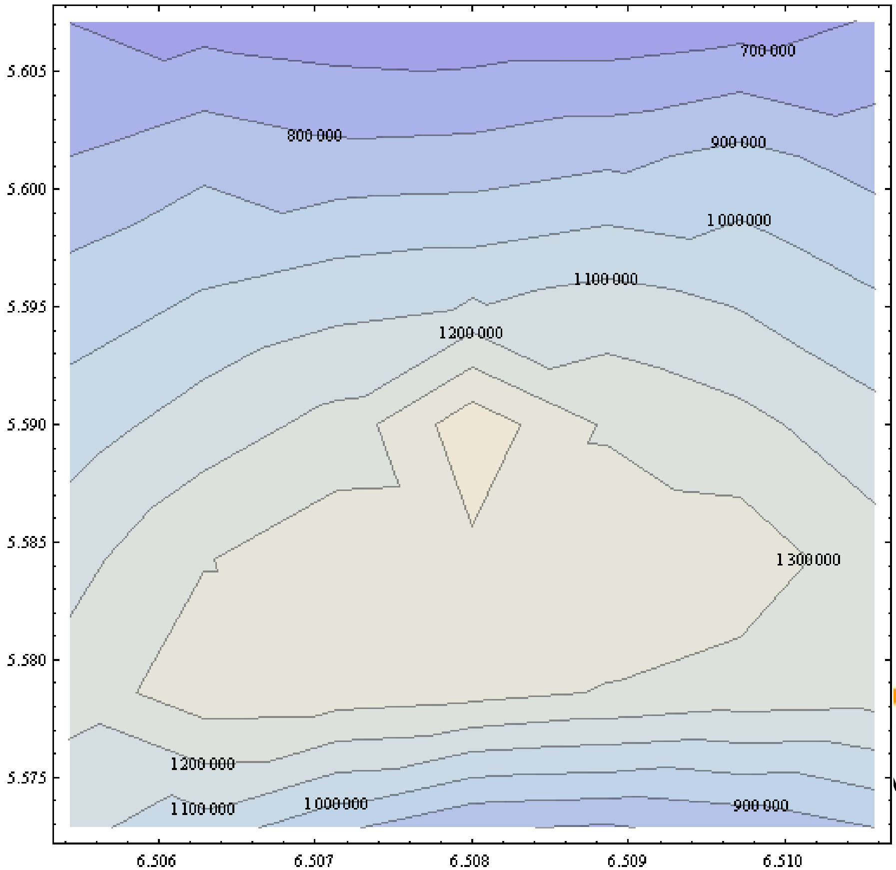
# Moving tunes close to half integers

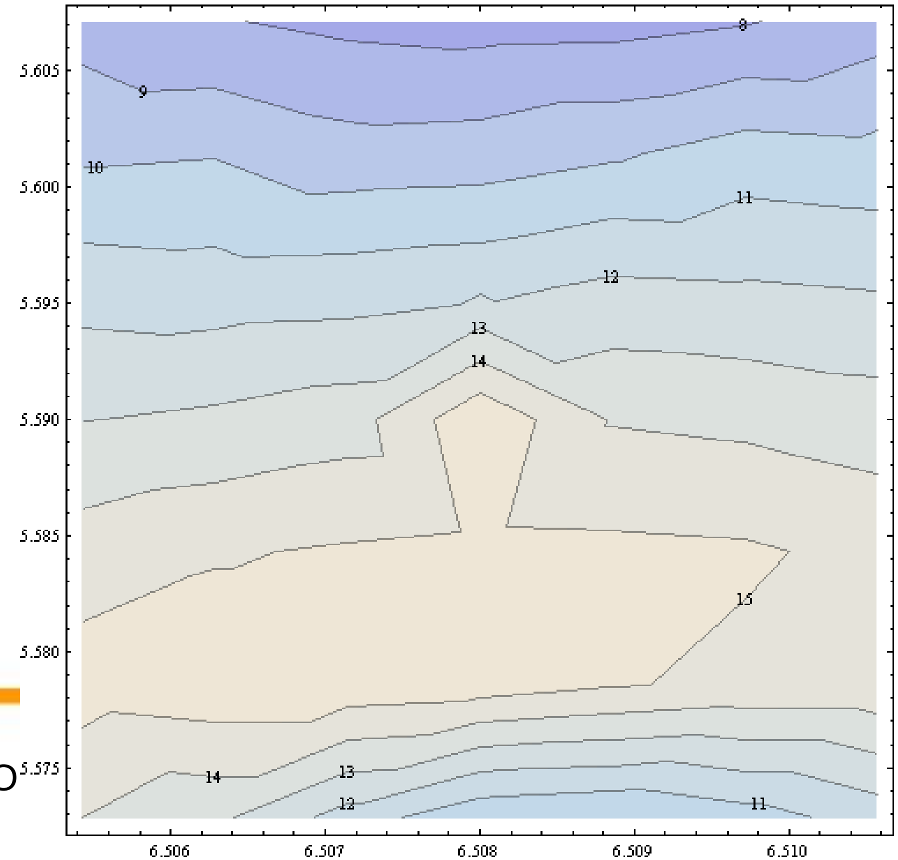
$\nu_x \rightarrow$ **6.51，6.508**

$\nu_y \rightarrow$ **5.58，5.587**

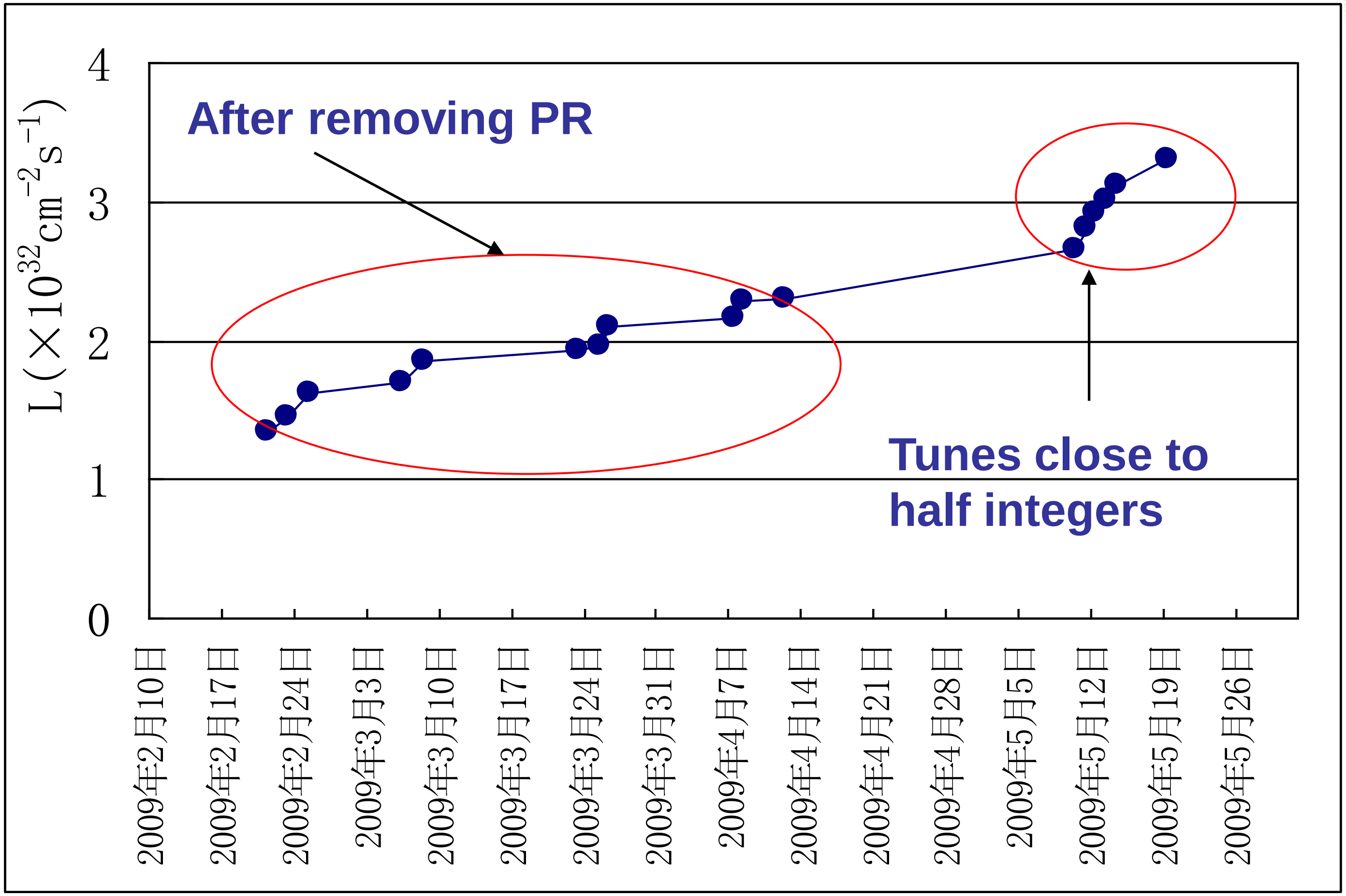
**BPR: $\beta_y^*$ ~1.38 cm (measured)**

**BER: $\beta_y^*$ ~1.33 cm (measured)**

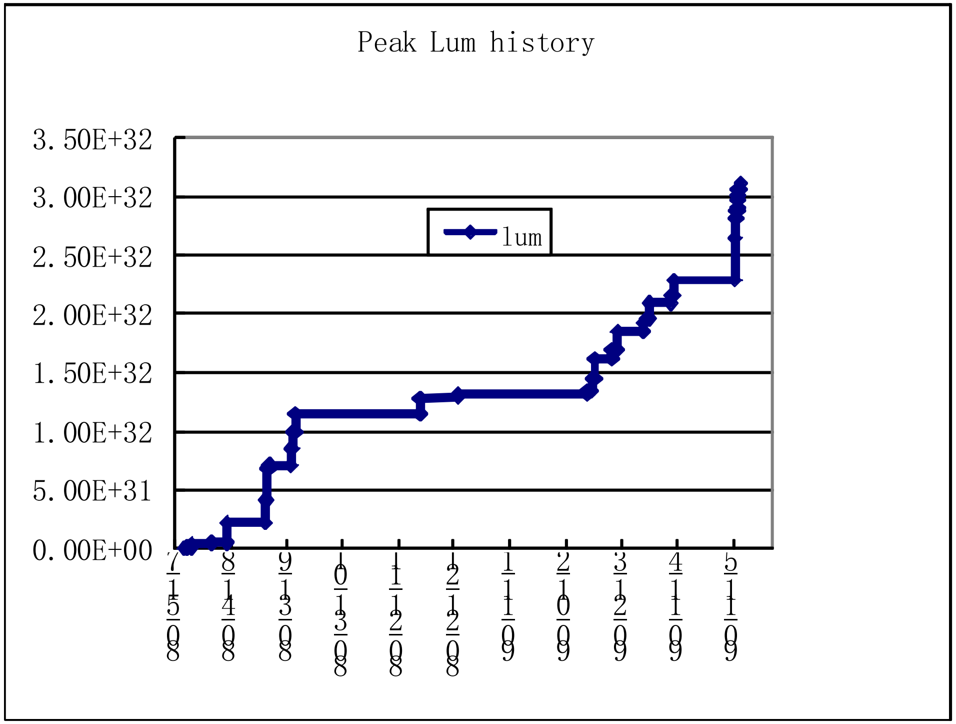


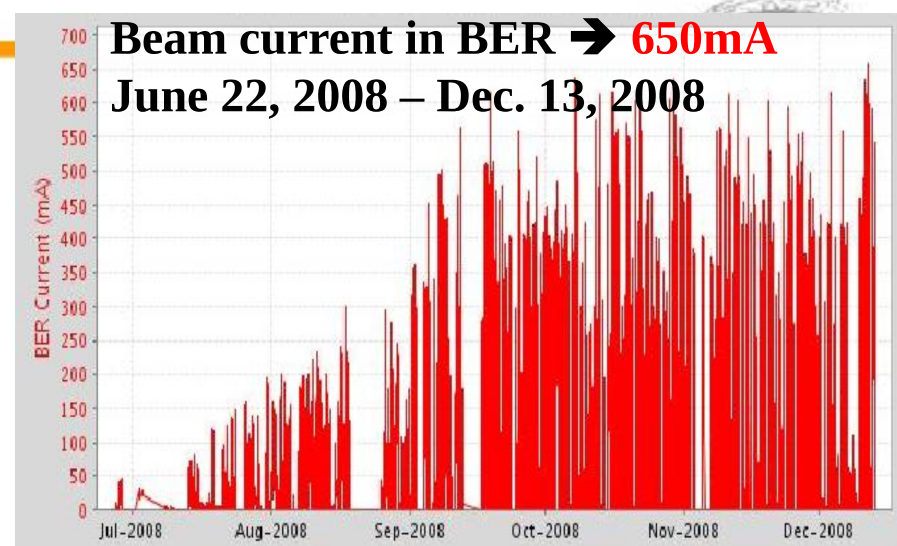



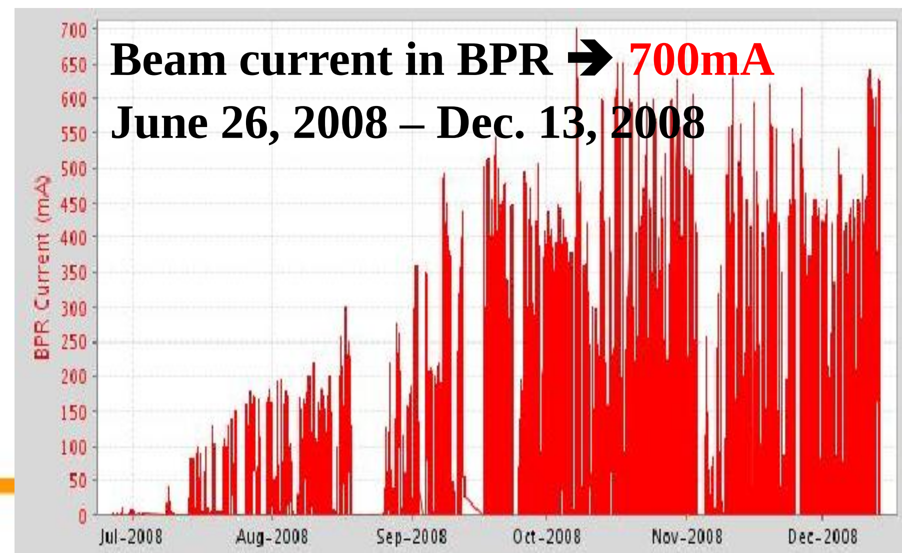
# $L_{peak} = 3.3\times10^{32}cm^{-2}s^{-1}$ !



# Luminosity and beam current trends



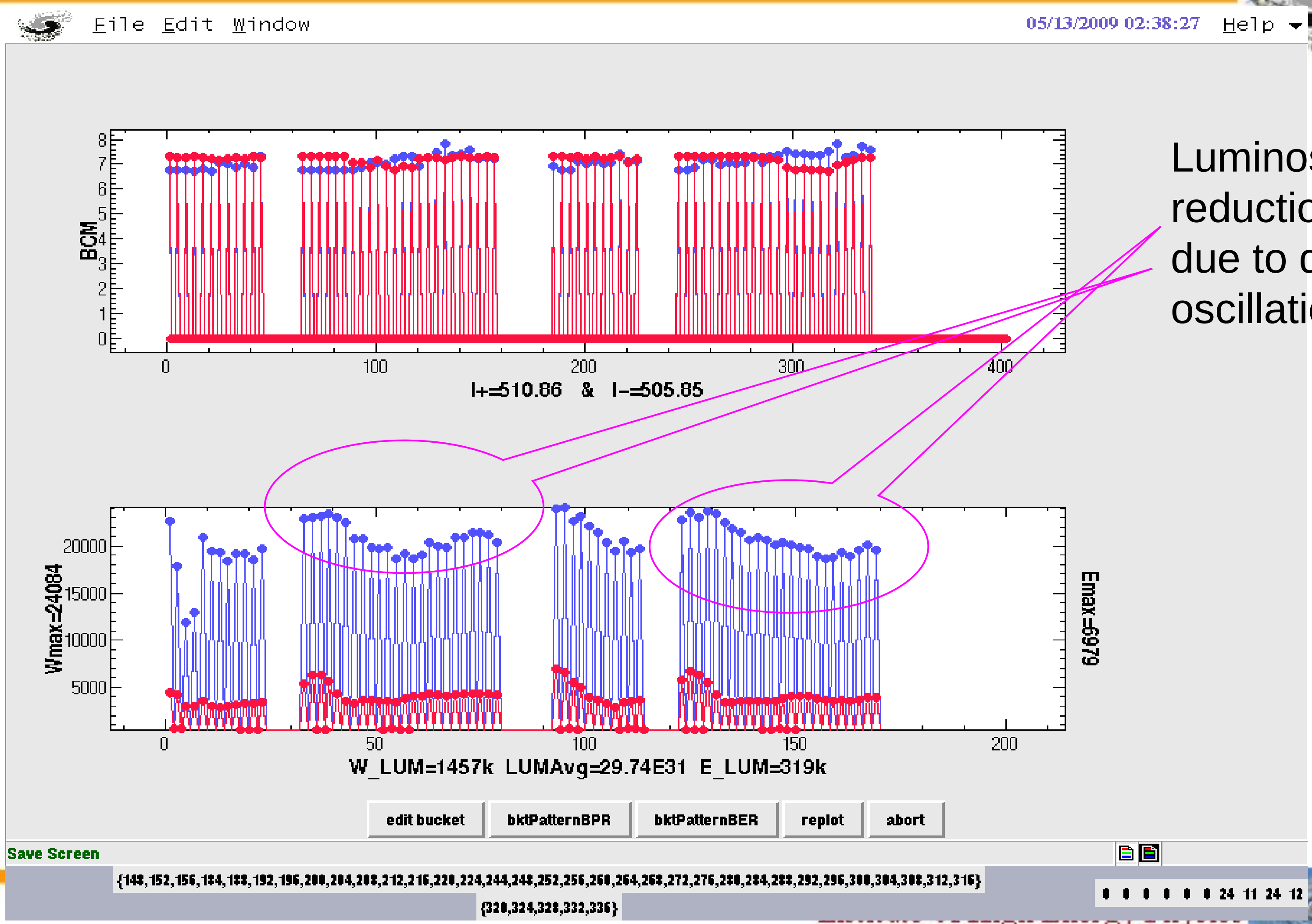




## Got peak luminosity @ ~550*550mA

# Main parameters achieved in collision mode

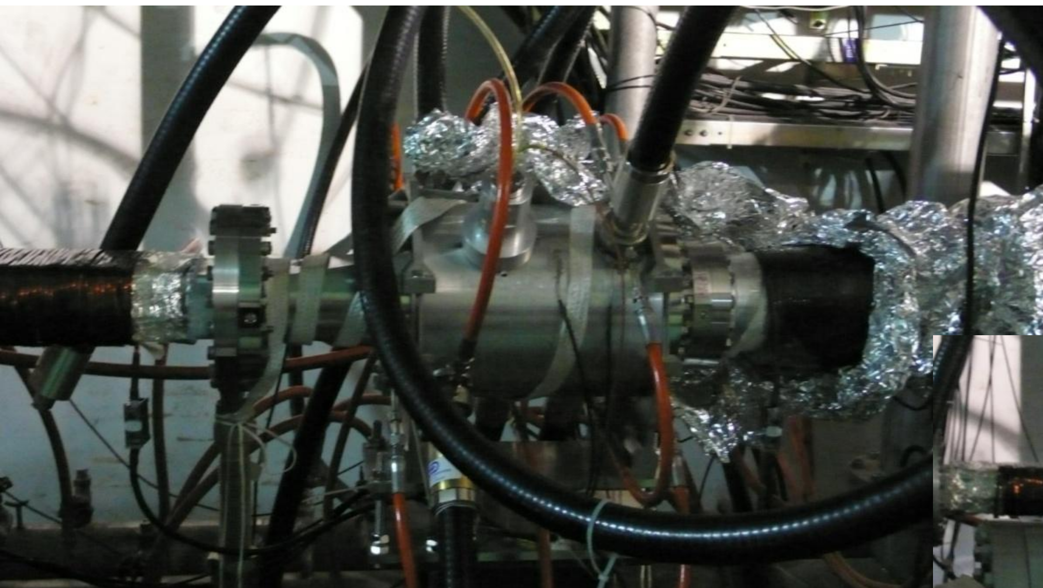
| parameters | design | Achieved | |
|---|---|---|---|
| | | BER | BPR |
| Energy (GeV) | 1.89 | 1.89 | 1.89 |
| Beam curr. (mA) | 910 | 650 | 700 |
| Bunch curr. (mA) | 9.8 | >10 | >10 |
| Bunch number | 93 | 93 | 93 |
| RF voltage | 1.5 | 1.5 | 1.5 |
| * $\nu_s$ @1.5MV | 0.033 | 0.032 | 0.032 |
| $\beta_x^*/\beta_y^*$ (m) | 1.0/0.015 | ~1.0/0.0135 | ~1.0/0.0135 |
| Inj. Rate (mA/min) | 200 $e^-$/ 50 $e^+$ | >200 | >50 |
| Lum. ($\times 10^{33} cm^{-2}s^{-1}$) | 1 | 0.33 | |

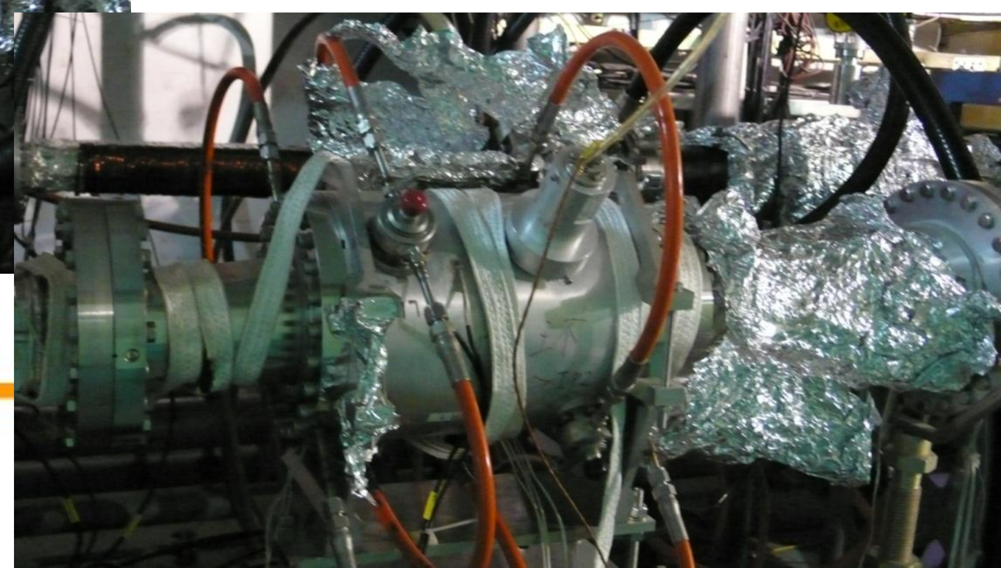
# Luminosity with 80 bunches collision



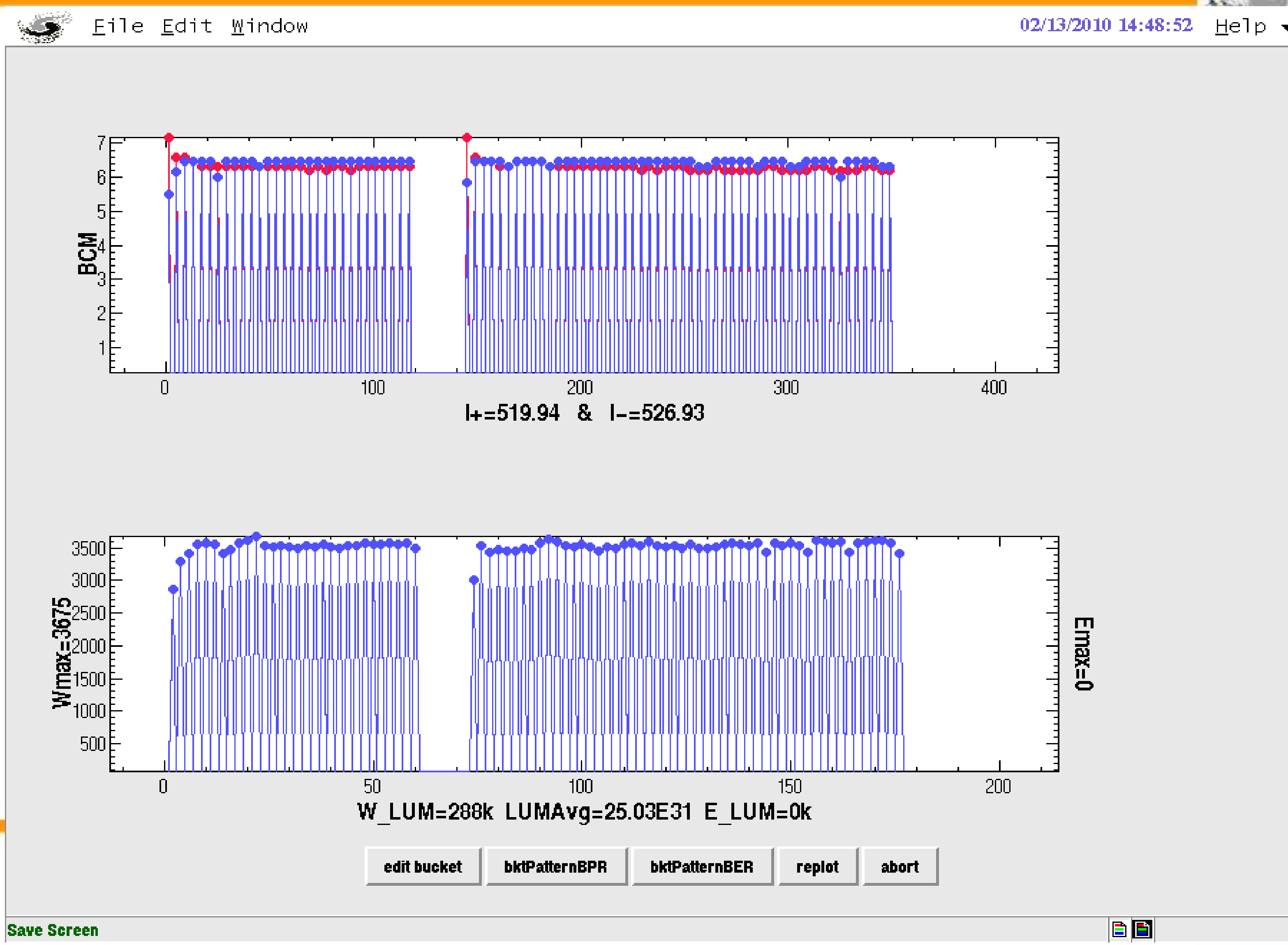

Luminosity reduction due to dipole oscillation

- **Longitudinal feedback system was installed in both rings in last summer to cure the longitudinal dipolar oscillation.**

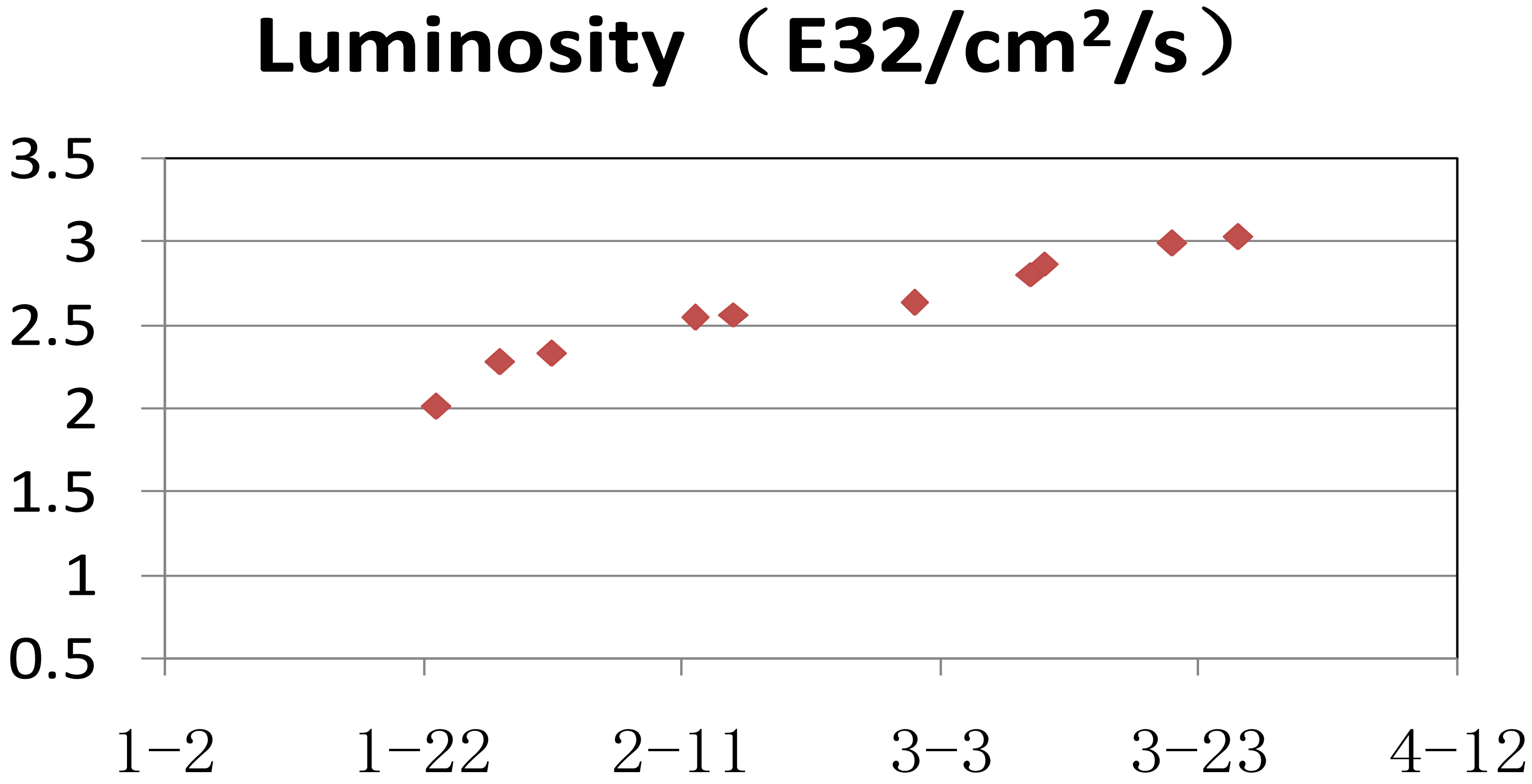


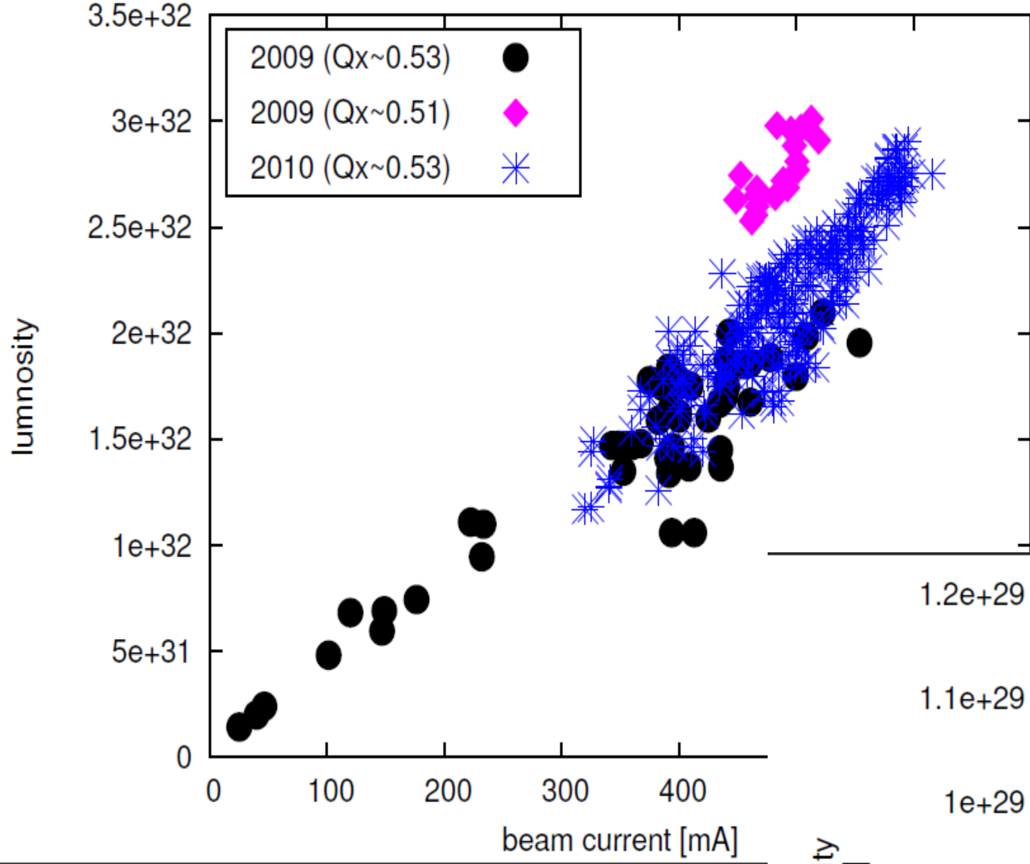


# Result of longitudinal feedback

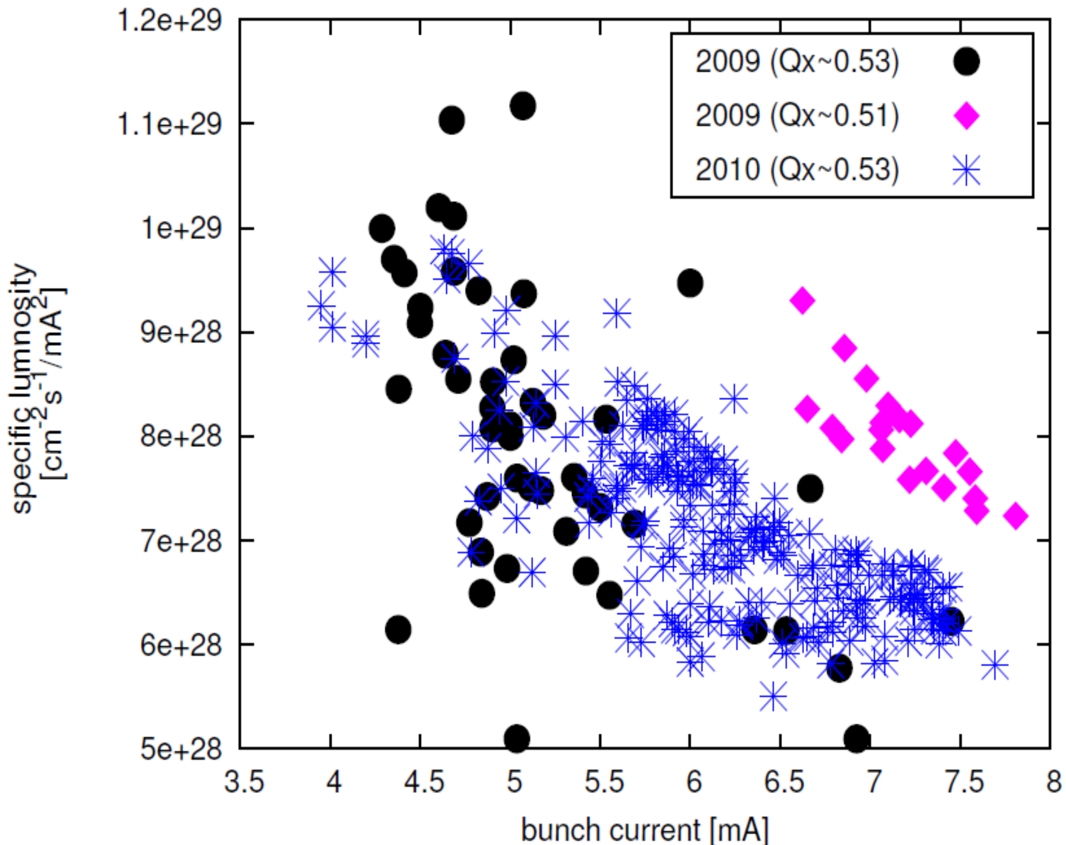


# Luminosity trend in this run



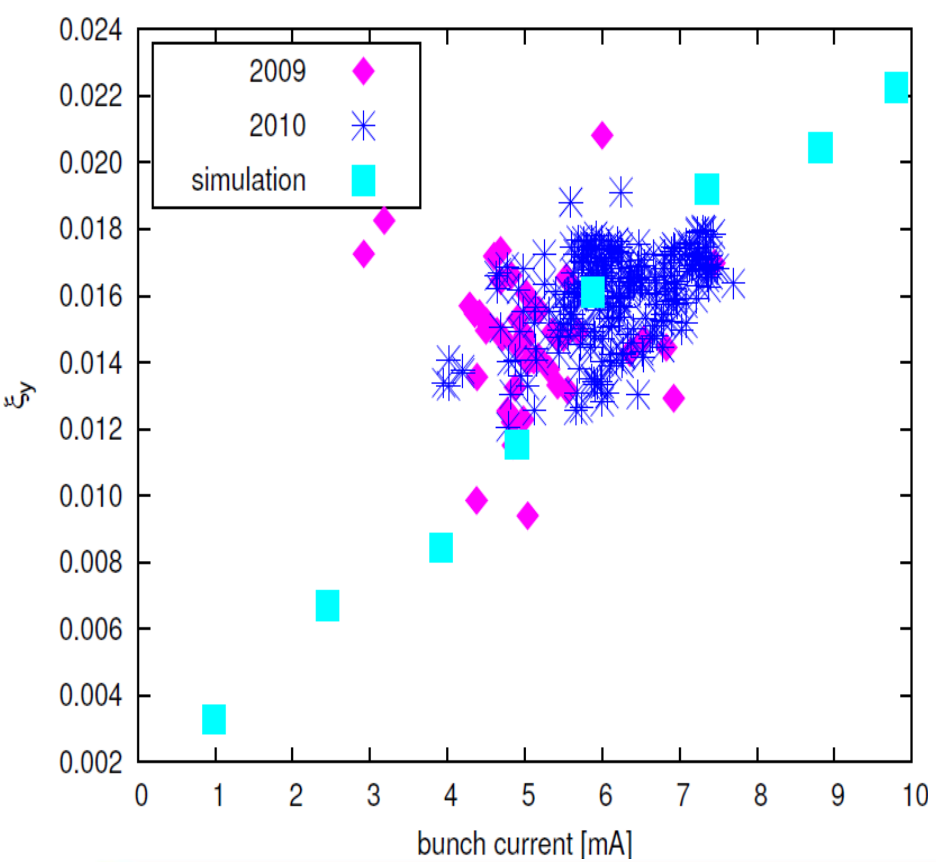


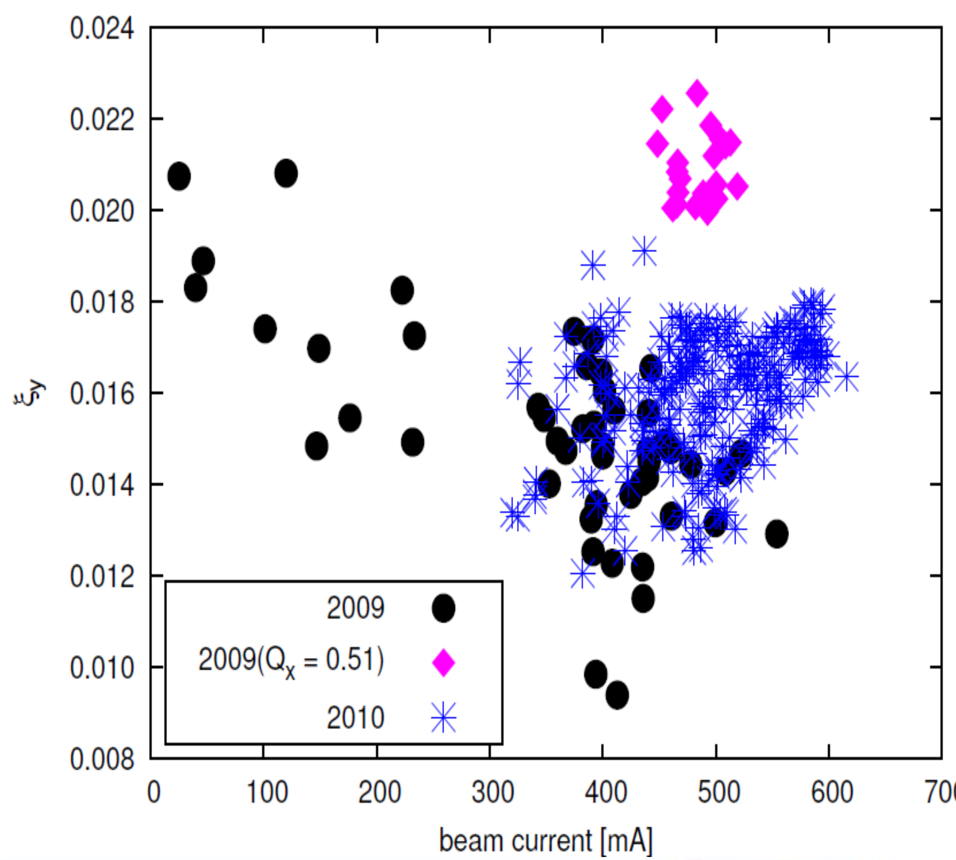
lumnosity
beam current [mA]
3.5e+32
3e+32
2.5e+32
2e+32
1.5e+32
1e+32
5e+31
0
0
100
200
300
400
2009 (Qx~0.53)
2009 (Qx~0.51)
2010 (Qx~0.53)

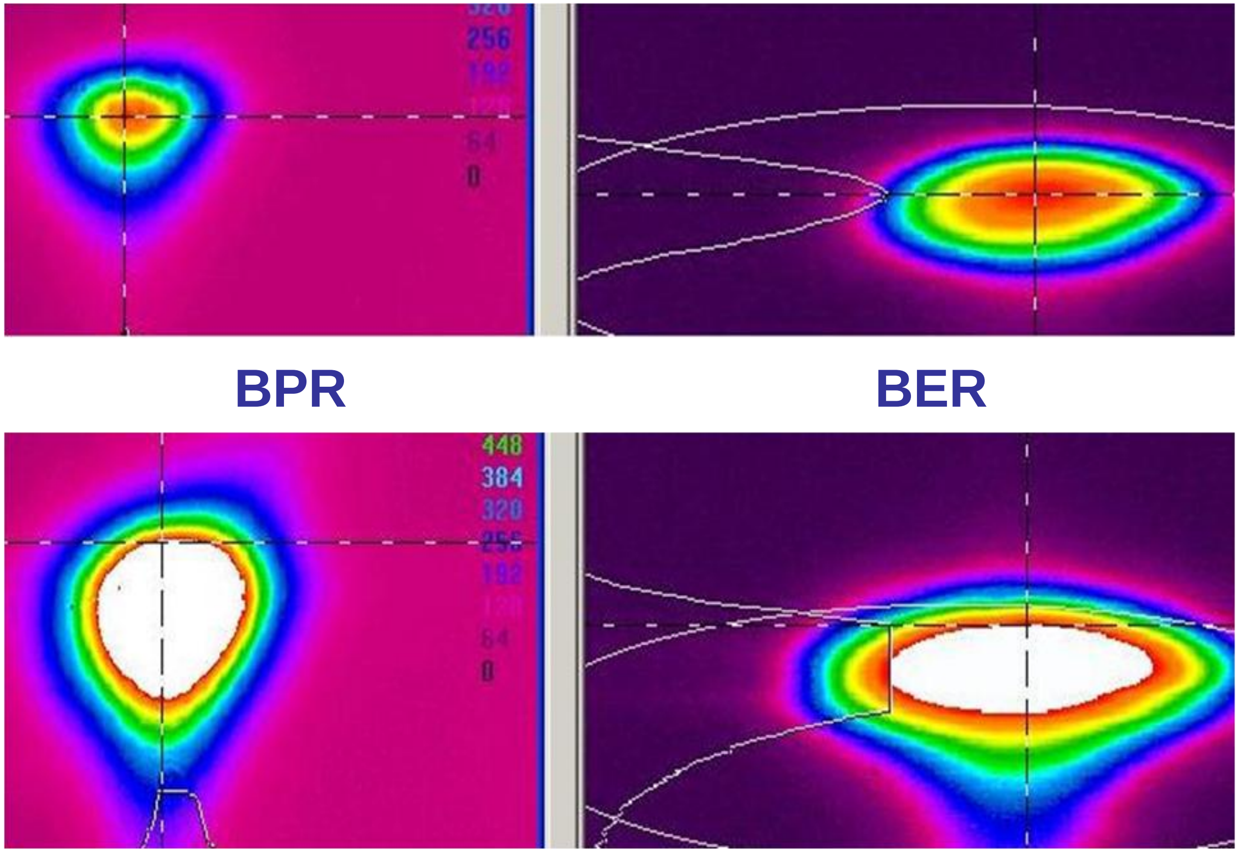
specific lumnosity
[cm^-2s^-1/mA^2]
bunch current [mA]
1.2e+29
1.1e+29
1e+29
9e+28
8e+28
7e+28
6e+28
5e+28
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
2009 (Qx~0.53)
2009 (Qx~0.51)
2010 (Qx~0.53)

# Achieved beam-beam limit



# Blow-up due to beam-beam interaction



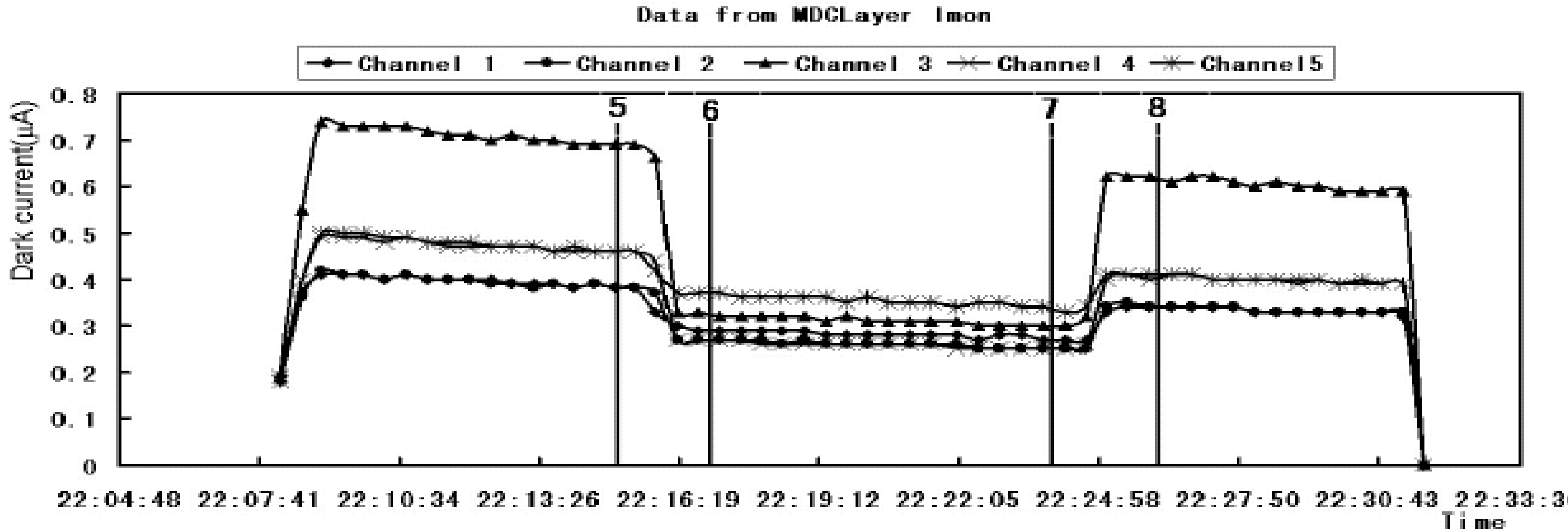

**Single bunch collision**

**Multi-bunch collision**

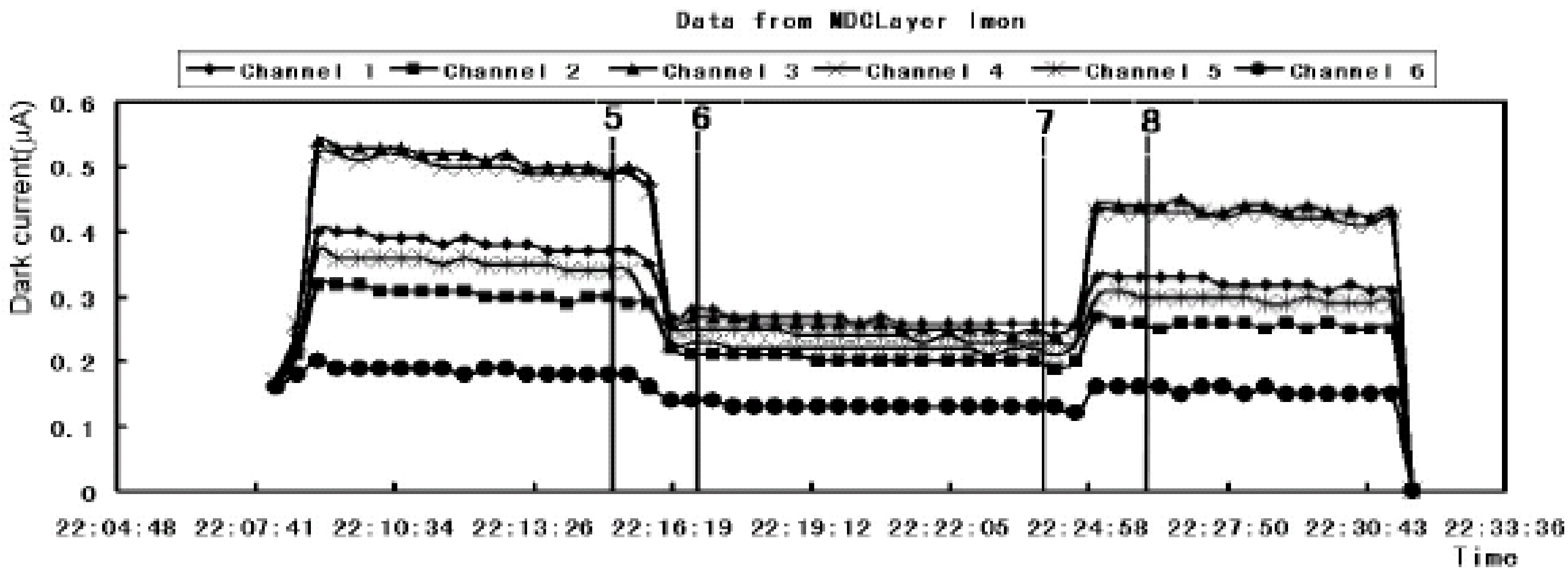
# 3. Problems met during luminosity commissioning

## Background of detector

- 2 horizontal moveable masks installed, each for one ring, ~8m upstream from the IP.
- They reduced ~50% of the beam-related background.

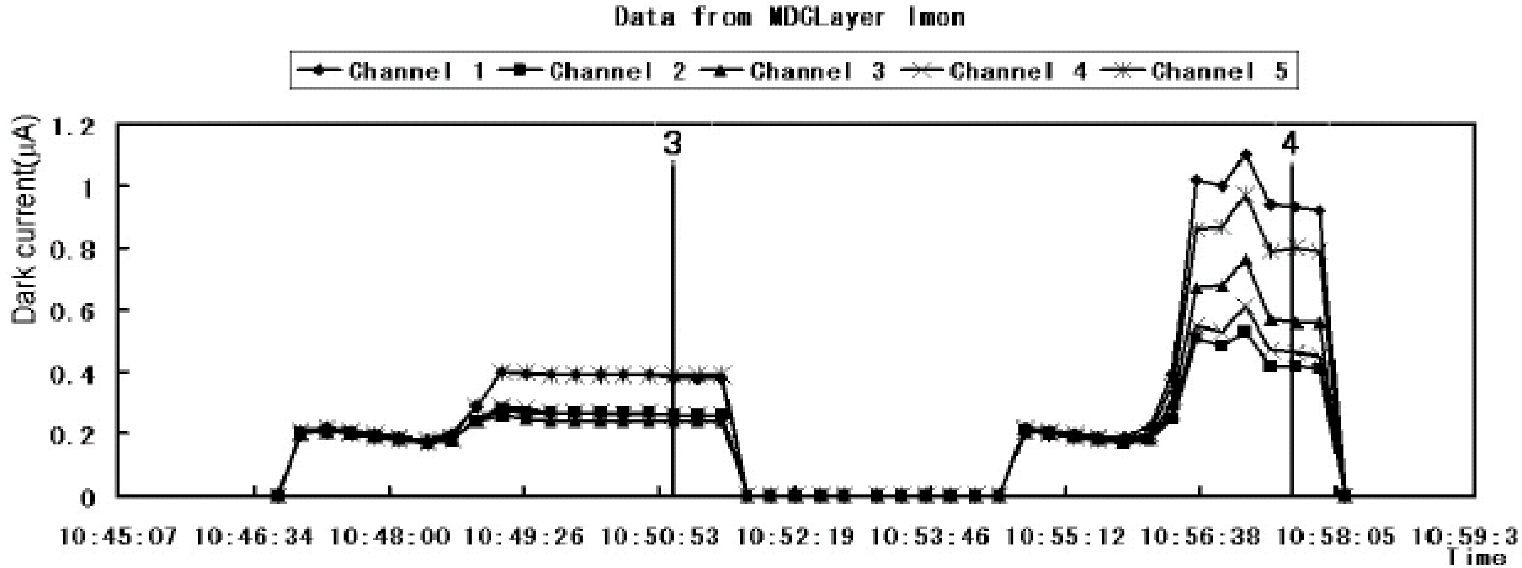



**Dark current variation in MDC layer 1(e+, 6mA/bunch)**

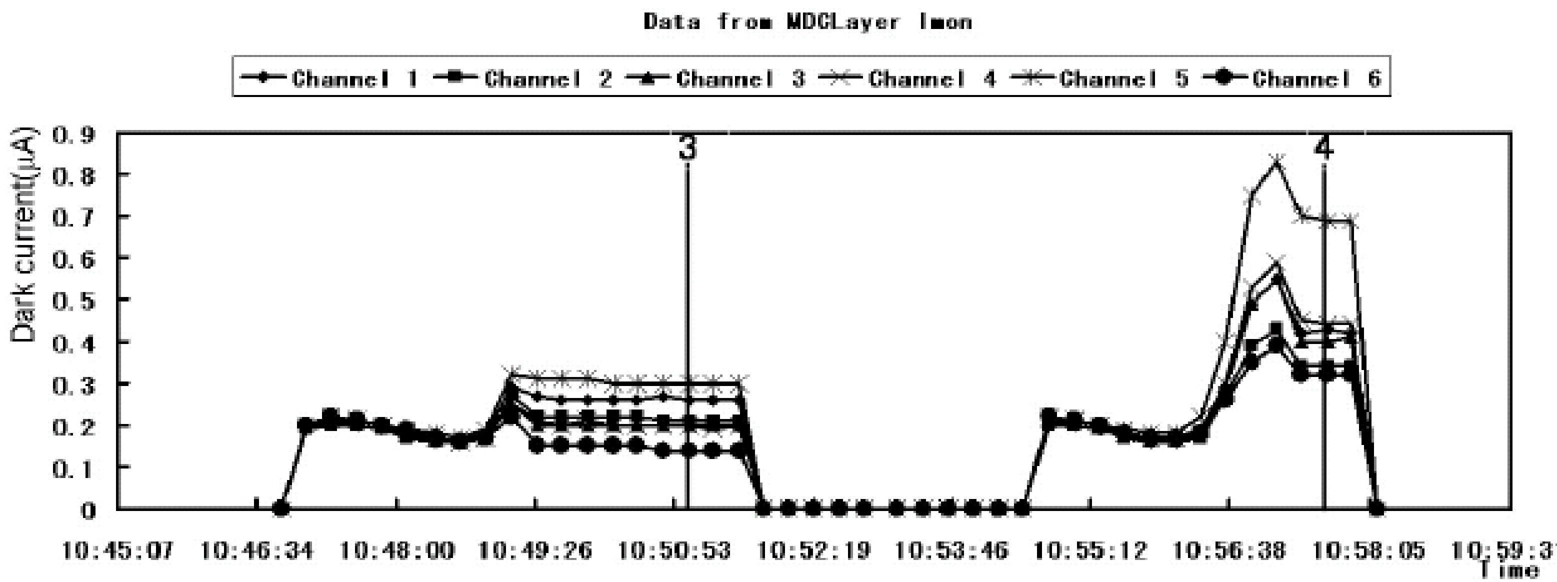





**Dark current variation in MDC layer 2 (e+, 6mA/bunch)**



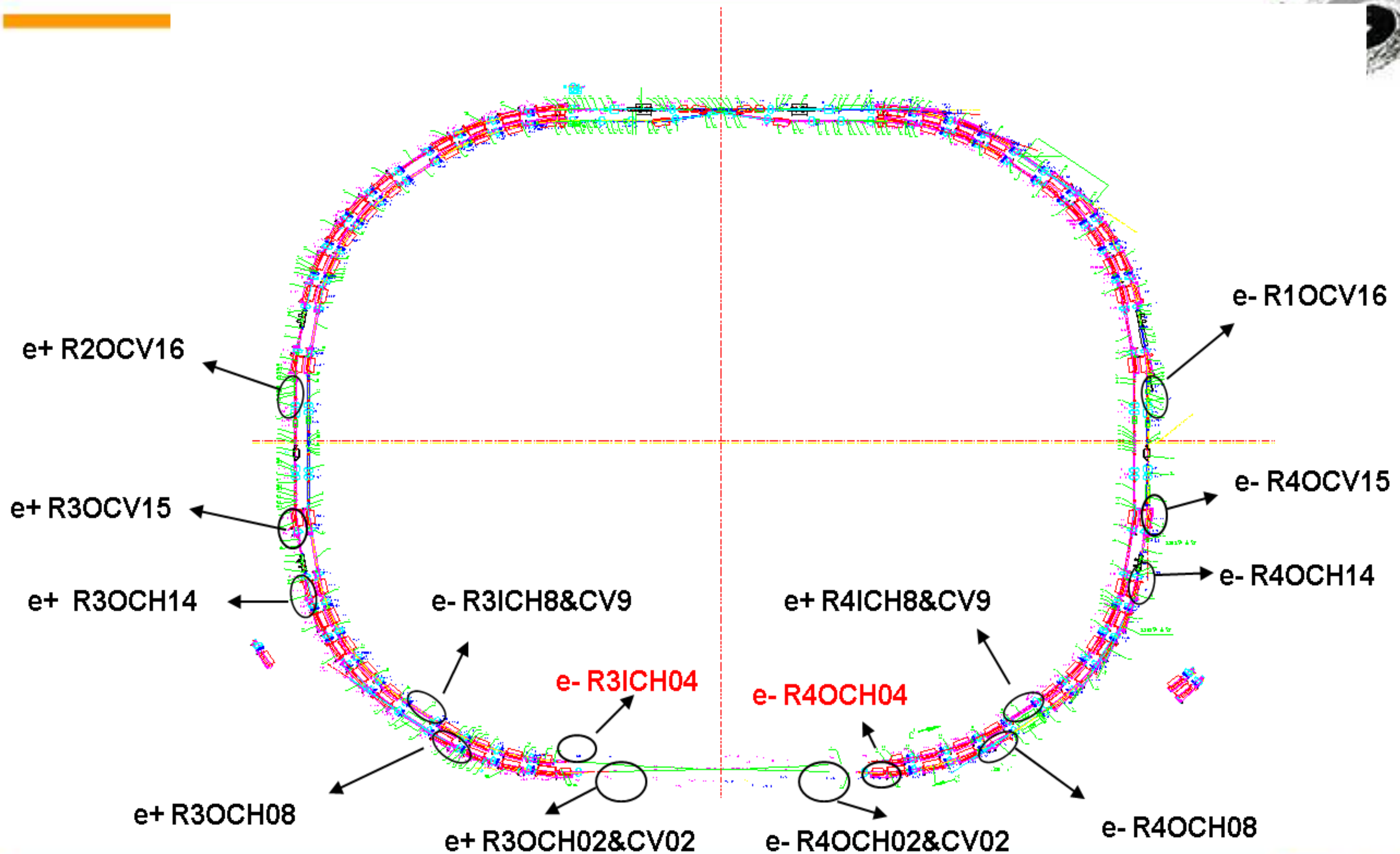

**Dark current variation in MDC layer 1(e-, 6mA/bunch)**






**Dark current variation in MDC layer 2 (e-, 6mA/bunch)**

# New masks installed last summer to reduce background



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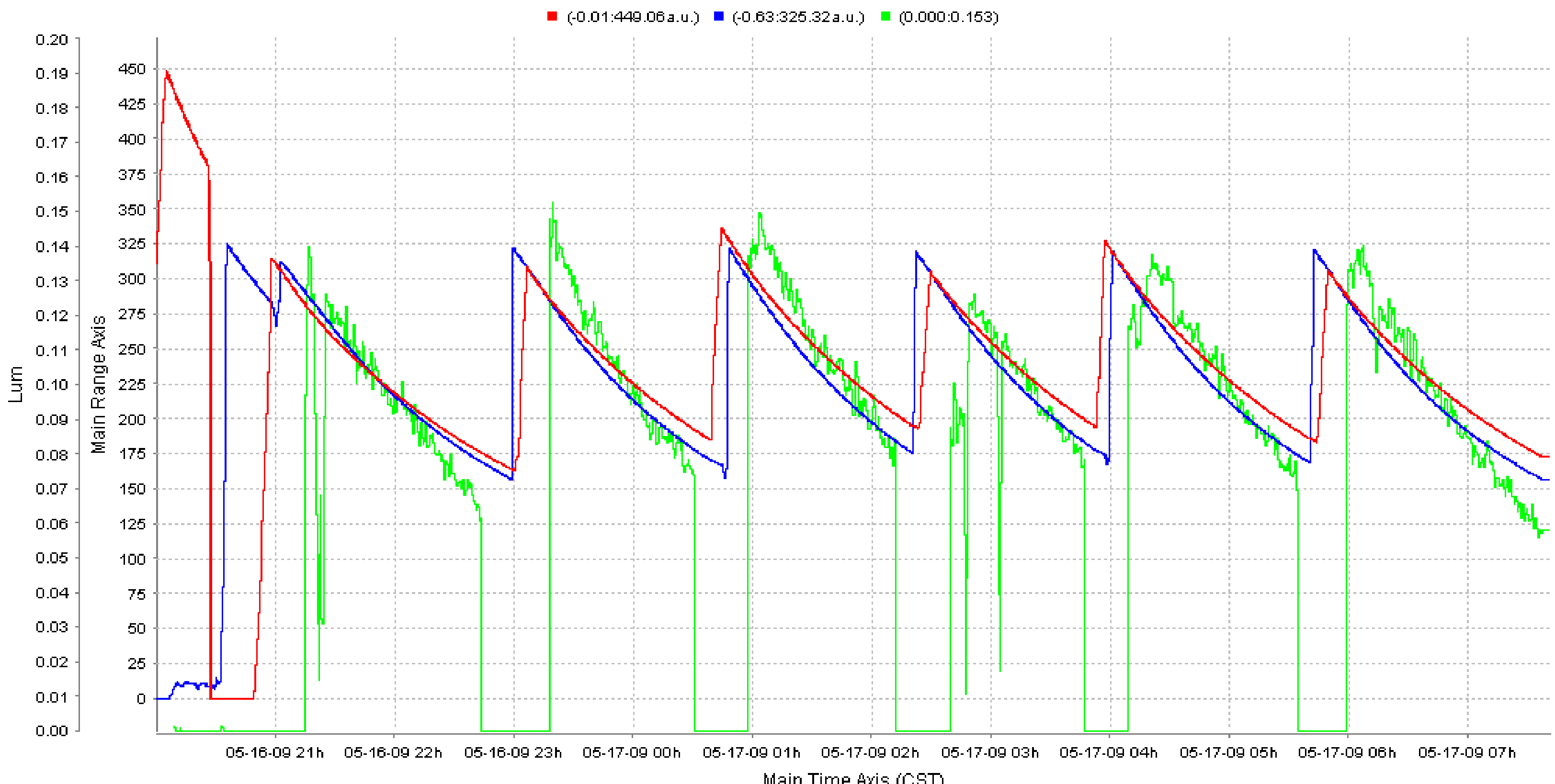
- **Data taking @ E=1.84GeV, ψ(s)**
- **High dark current for higher beam current @ $\nu_x$~0.51**

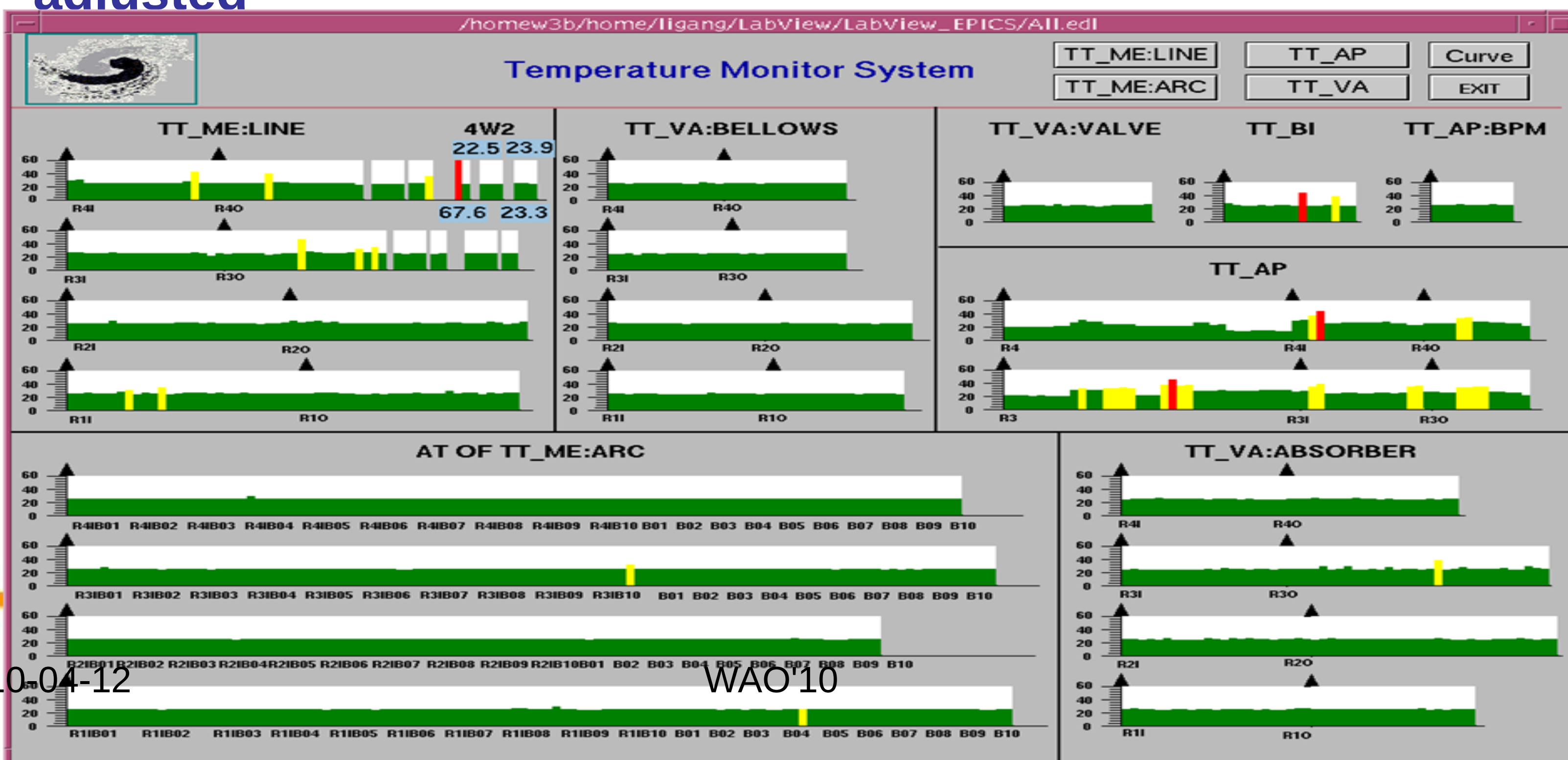


# HOMs heating problem

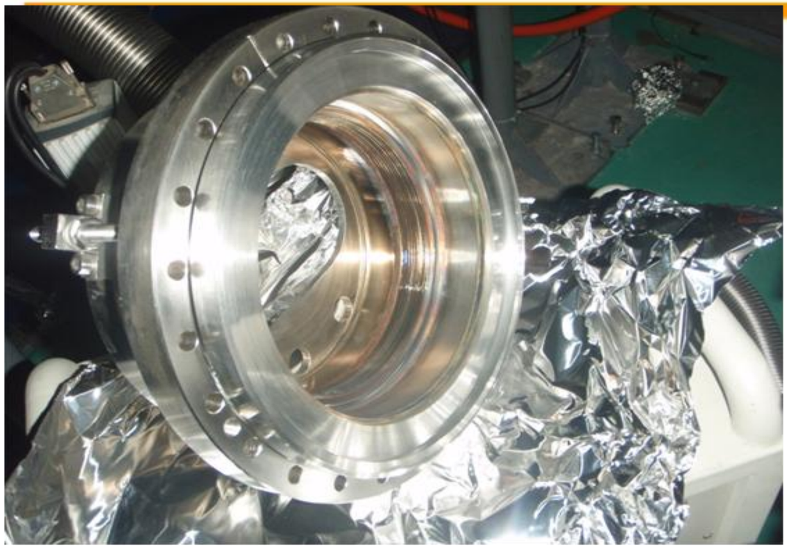
1) More than 1000 thermal couplers used

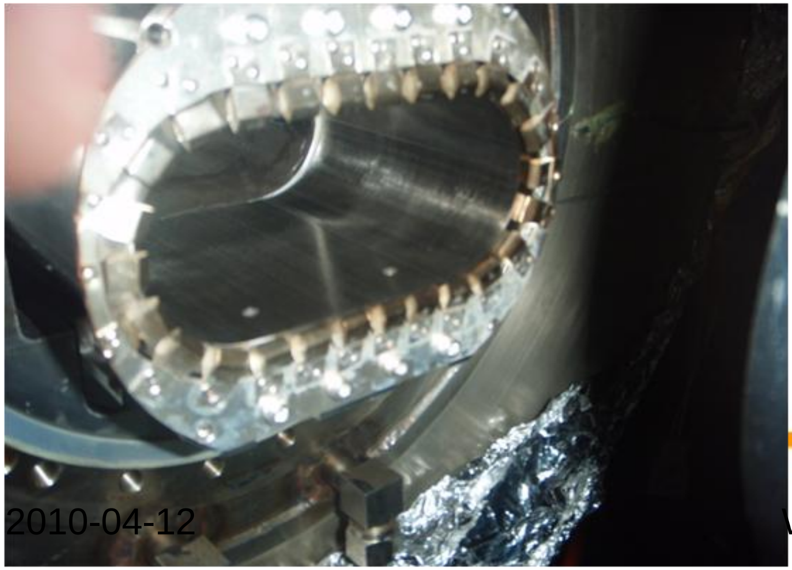
2) Display in colour according  dangerousness: green, yellow and red.

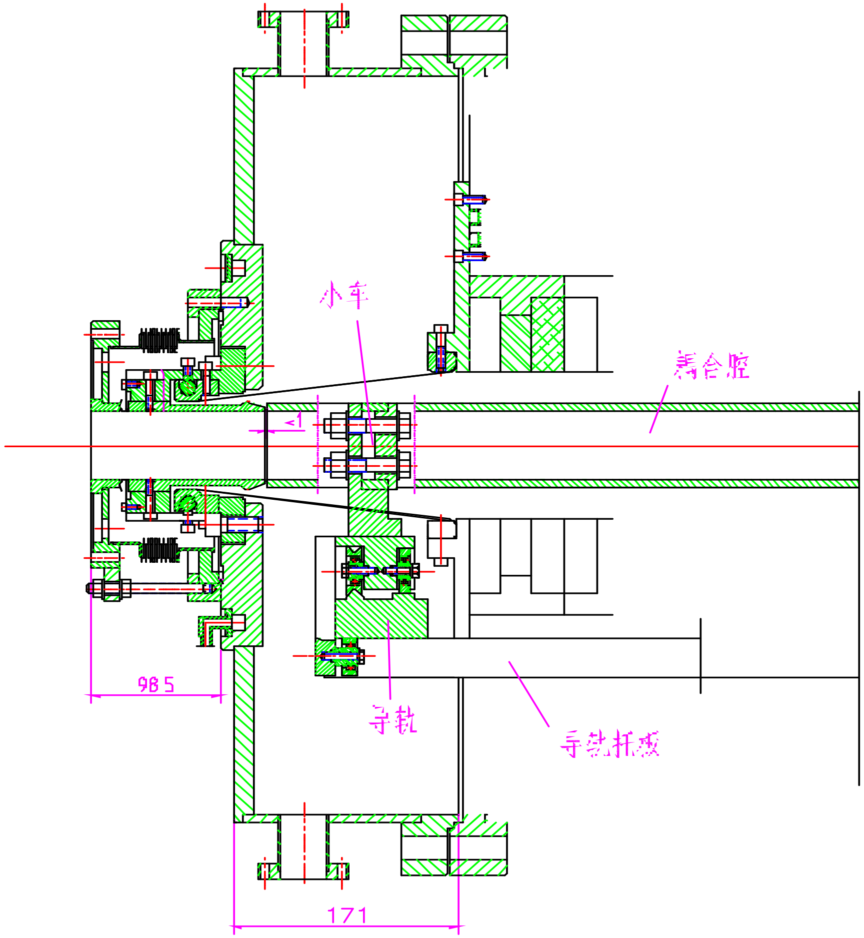
3) In most case, the temperature rise (SR) => flux of cooling water adjusted



# Bad contact of the RF finger in the shielding of bellows caused HOM heating, vacuum leakage in April 2009.







- Replace the new bellows
- Re-design the RF fingers of the shielding
- Cooling water and wind for the new bellows
- Restrain the bunch current and beam current ($I_b$<6mA, $\Sigma I$ < 550mA)



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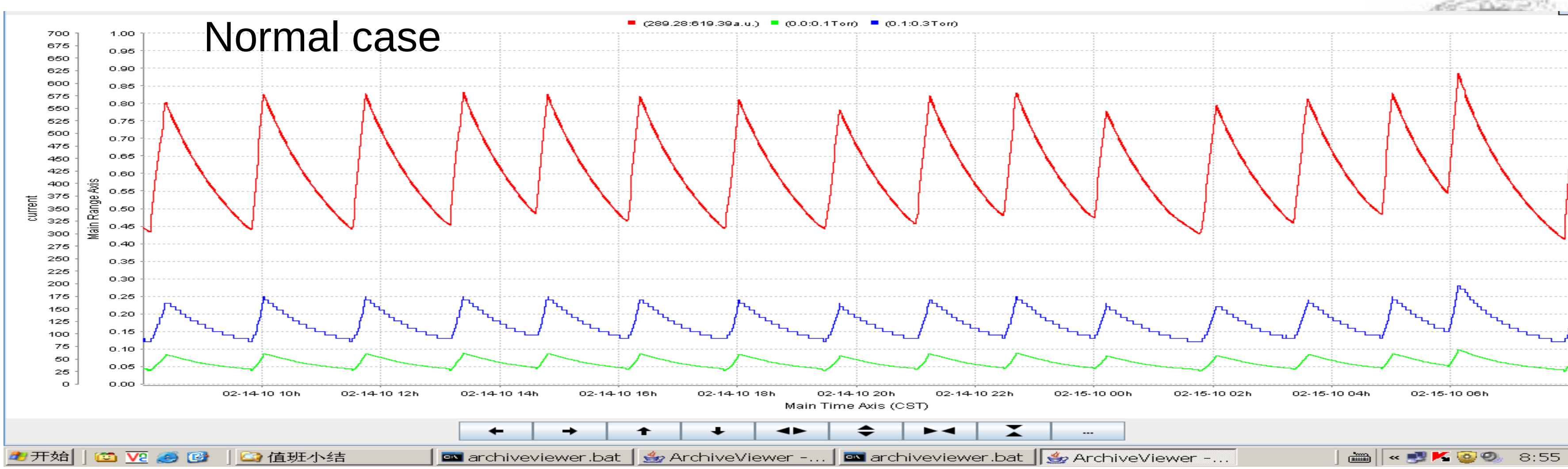
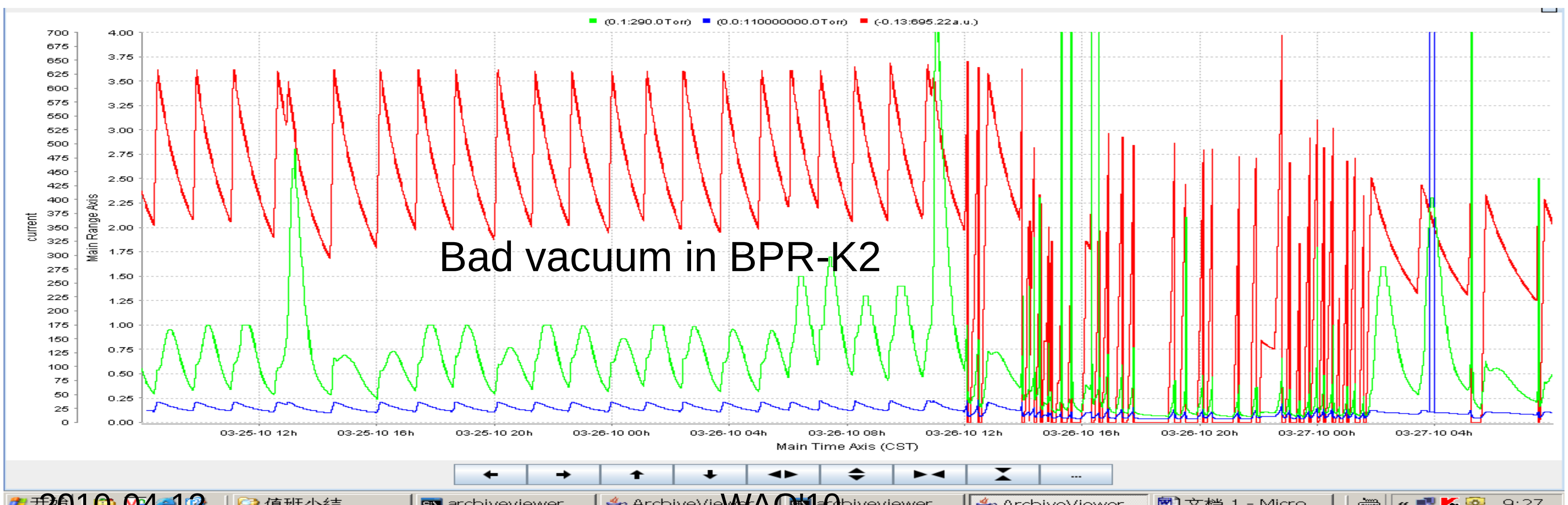
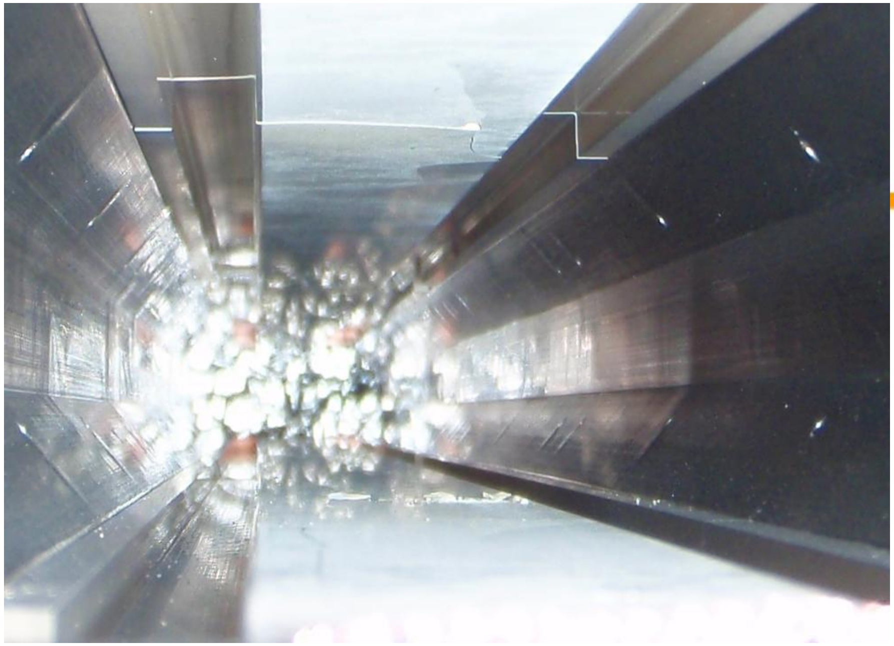
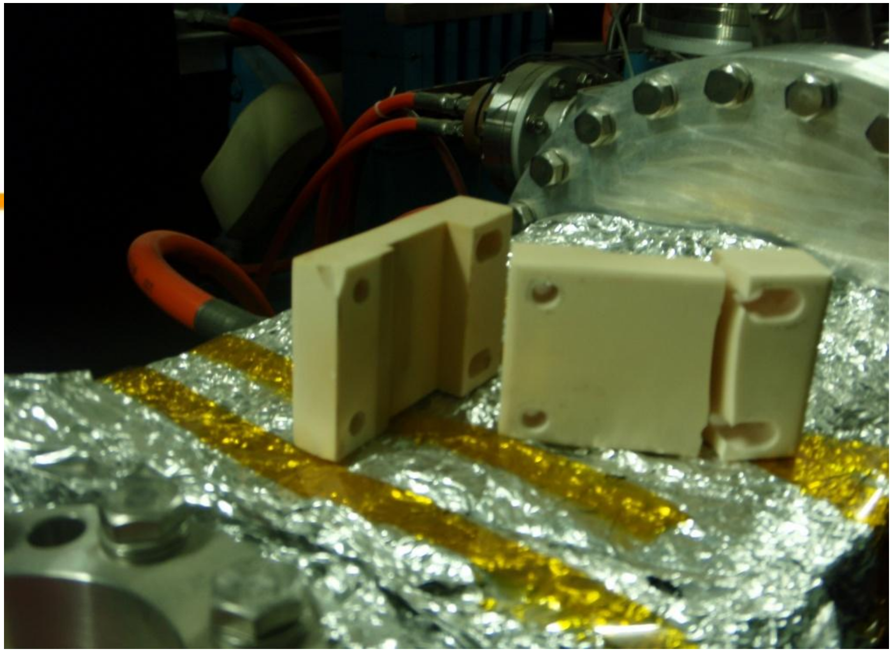
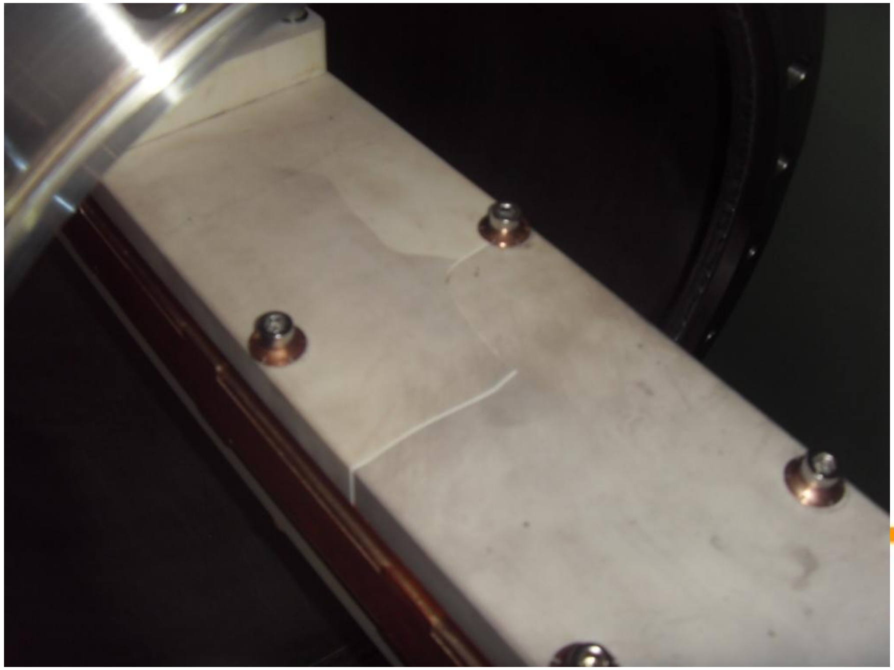
# Kicker problem (ceramic board broken in Mar. 2010)



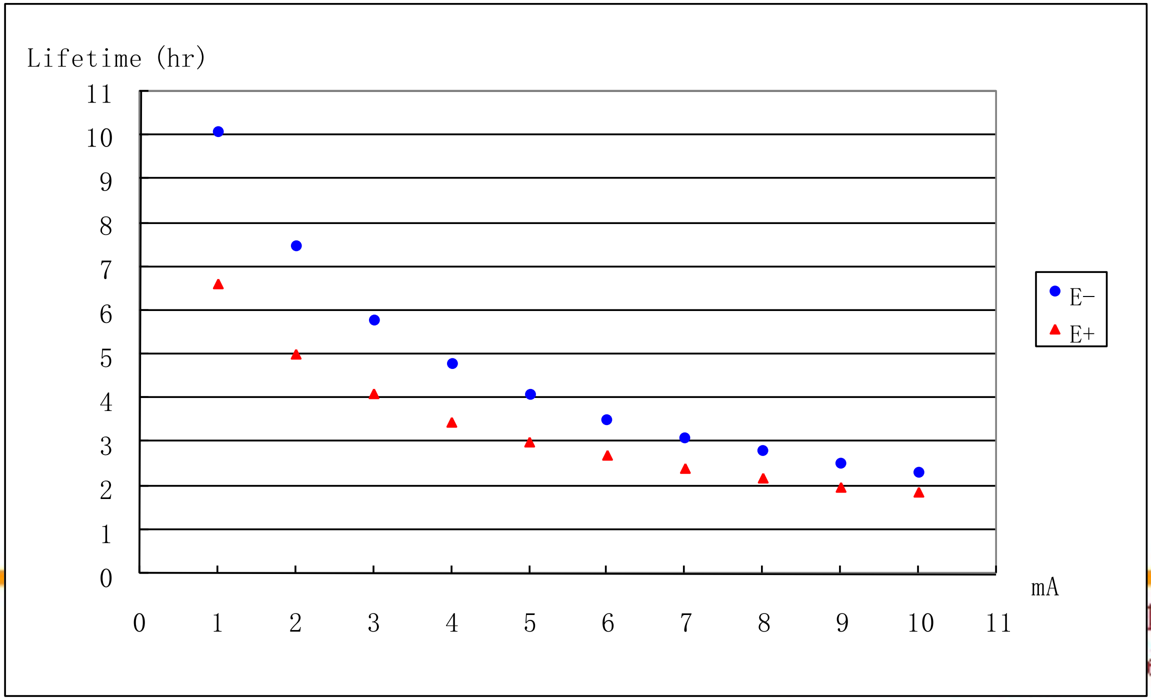



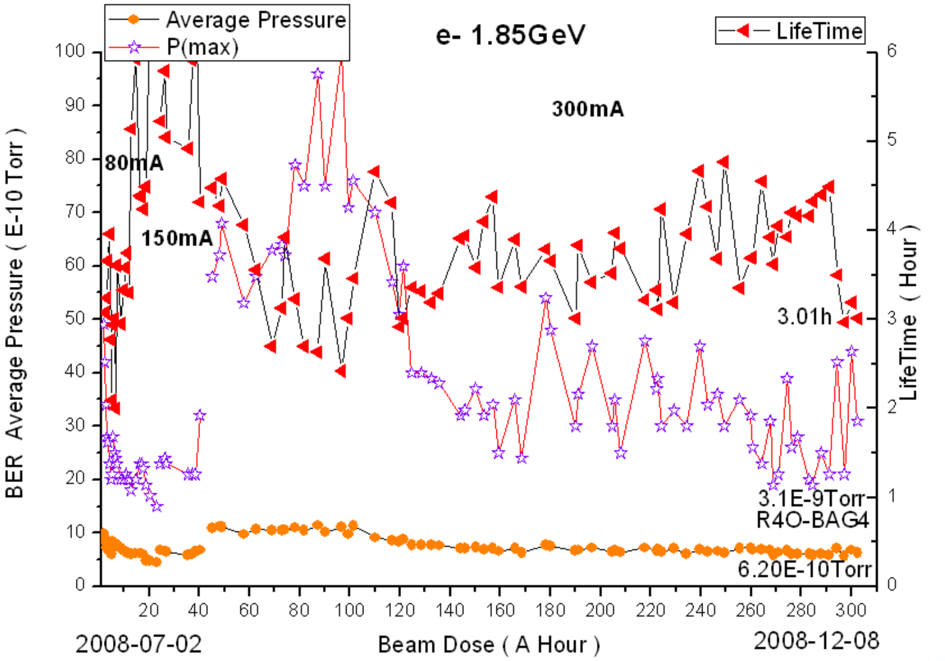

# Beam lifetime

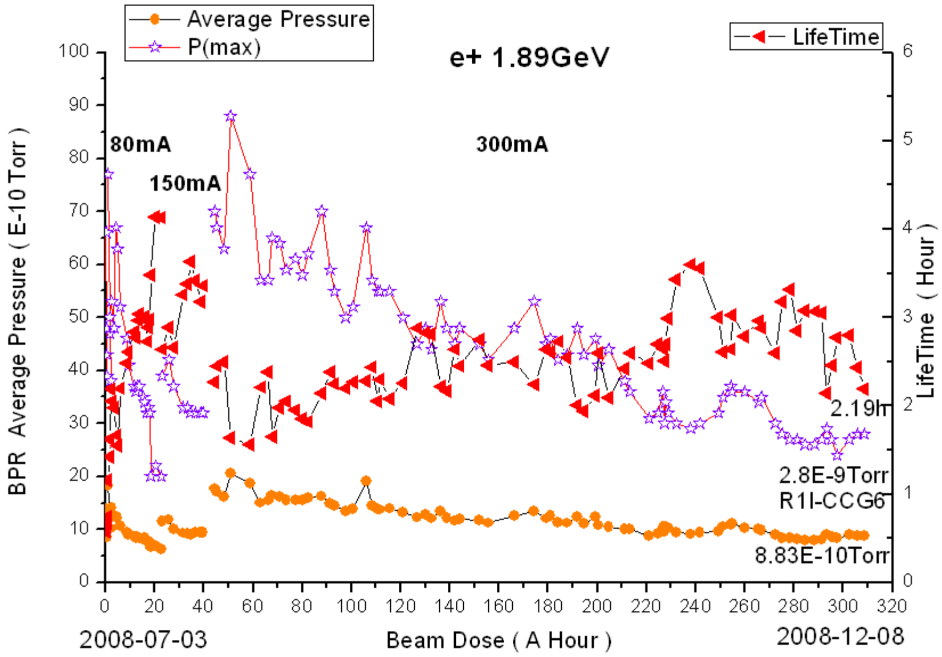
- Real beam lifetime much lower than estimated
- Single bunch: both $\tau_{BER}$ and $\tau_{BPR}$ < calculated value
- $\tau_{BER} > \tau_{BPR}$ at single bunch case.

  Dynamic aperture? Longitudinal acceptance?

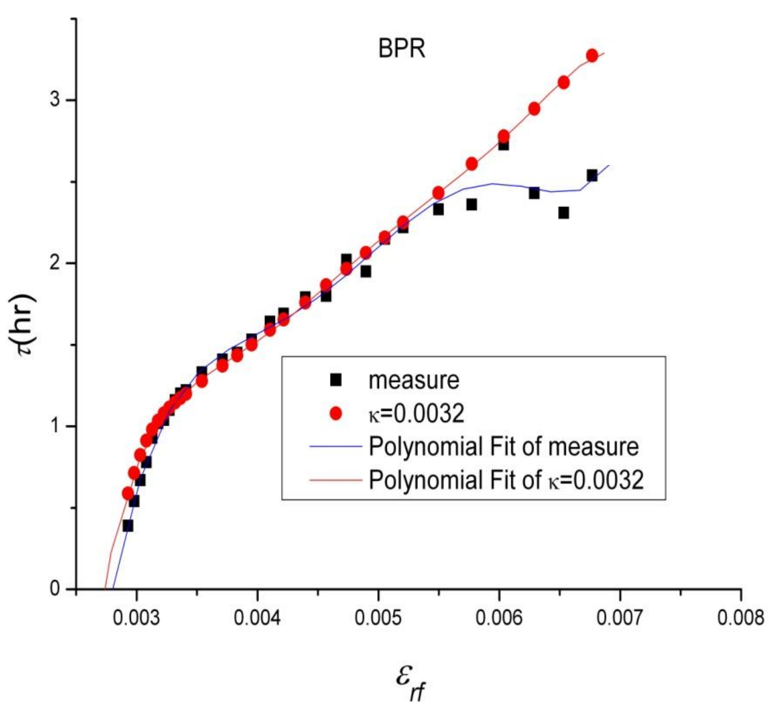


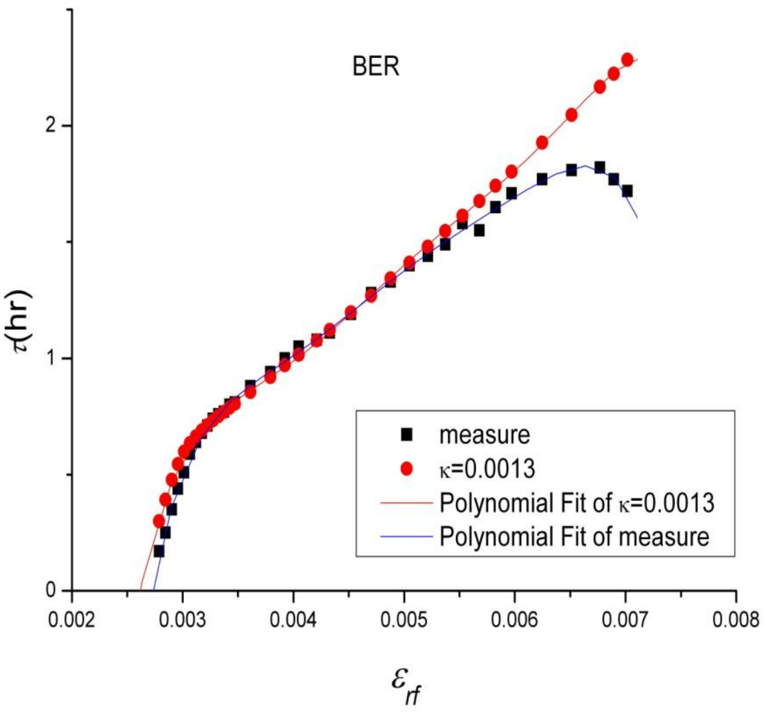
- Multi-bunch: $\tau_{BER} > \tau_{BPR}$
- Possible cause: vacuum, $P_{BPR} > P_{BER}$
- $\tau_{BPR}$ is getting better with vacuum improving.



# Experiment on beam lifetime and long. acceptance



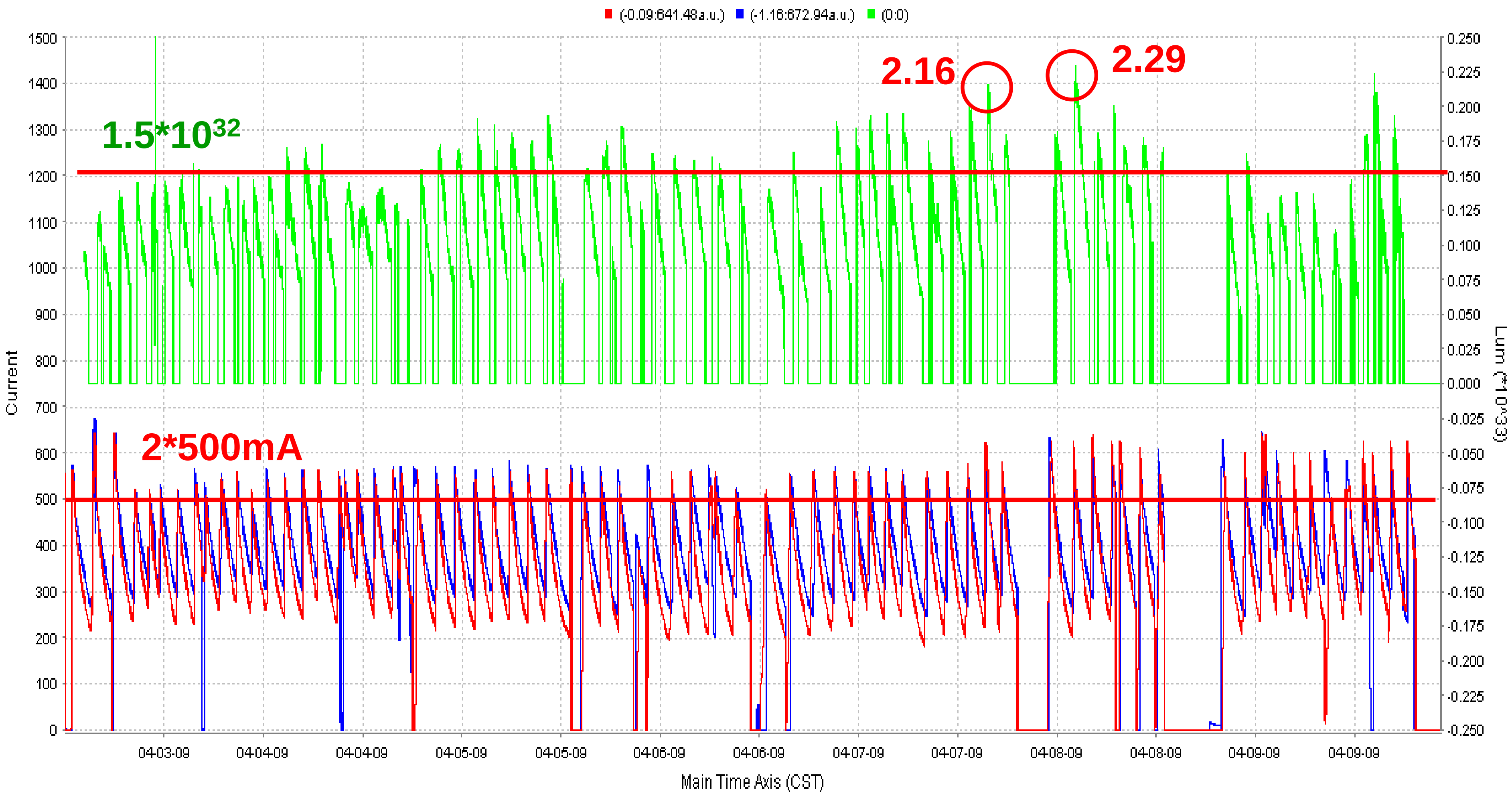




**Effective longitudinal acceptance ~0.0046, smaller than theoretical value 0.007**

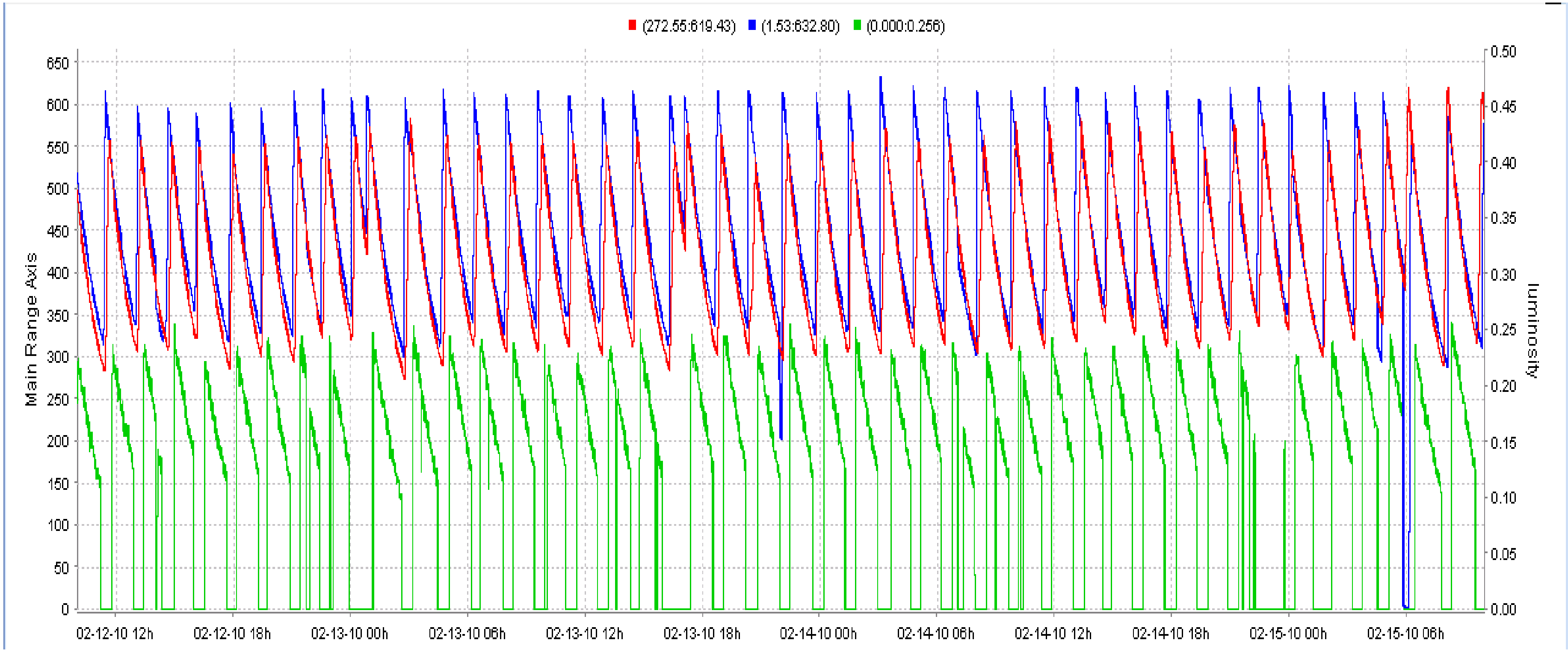
# 4. Operation for users

- Deliver beam to SR users for ~5 months every year
- Run for HEP data taking @ J/$\psi$ energy, getting 200 M events in 2009
- HEP data taking @ $\psi$(s) for 40 days, getting 100 M events in 2009
- Running at $\psi$(2s) now, expecting 1.2 $fb^{-1}$ before this July.

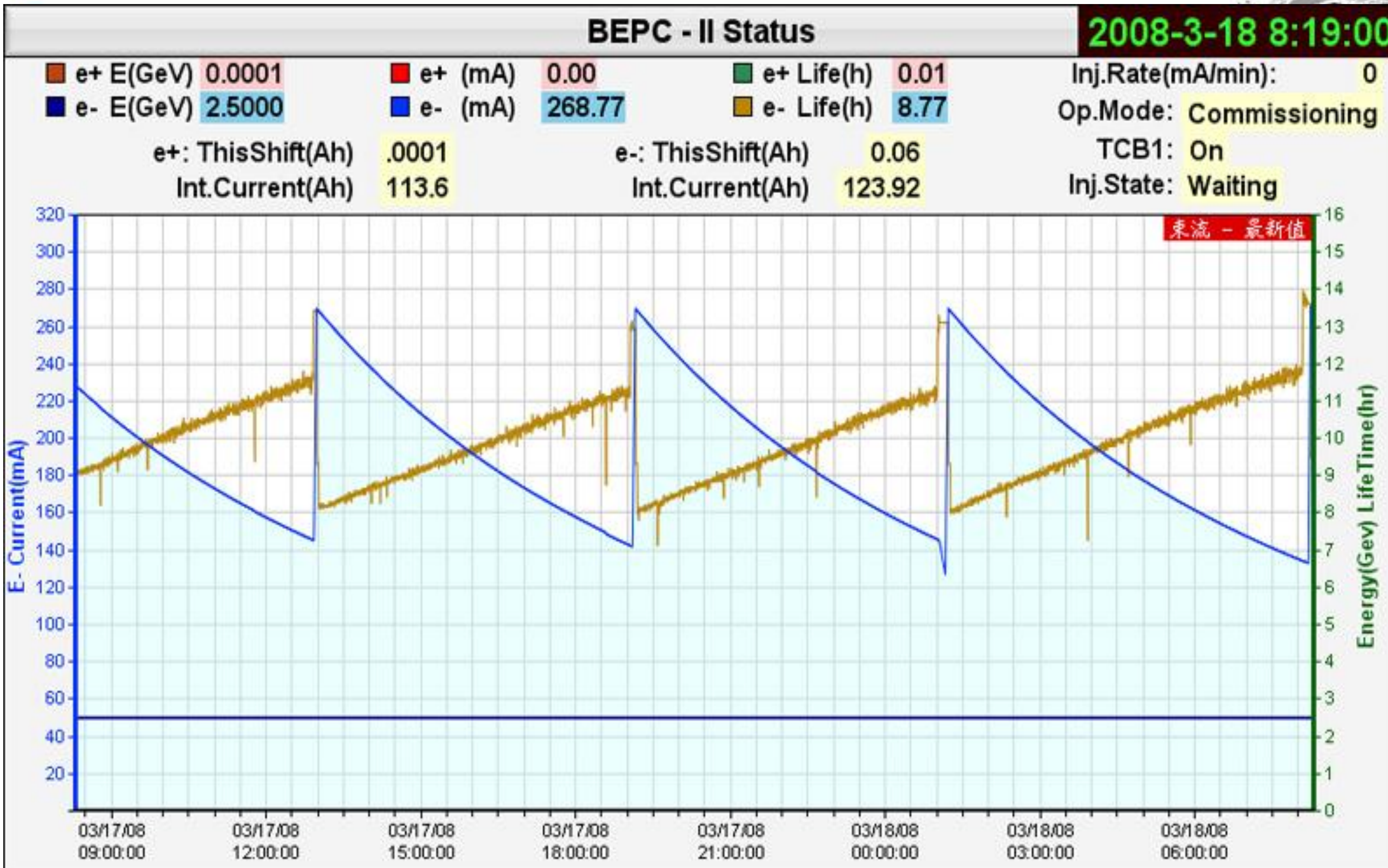
# Luminosity vs beam current during ψ(s) run



# Luminosity vs beam current during ψ(2s) run this year



# Synchrotron radiation operation



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# 5. Possible upgrades for luminosity

- Normal measures:

✓ Longitudinal feedback, installed this summer, to cure the longitudinal dipolar oscillation

✓ Increase bunch current, beam current

✓ Shorten bunch spacing, to get more bunches

✓ Squeeze $\beta_y$*

✓ Tunes closer to half integers

Possible peak luminosity: $L \sim 4 - 5\times10^{32}cm^{-2}s^{-1}$

# Problems on the way of further upgrades

- Heating of bellows, vacuum chamber, etc.
- Background when bunch current increases
- Possible ECI after bunch current increases or bunch spacing shortening
- Longitudinal instabilities after bunch spacing shortening
- Etc, etc.

# Long term upgrade of the BEPC-II

- **Crab-waist for higher luminosity**

- **Collision with polarized beam**

✓ Physics requirement

✓ Possibility of realization (e- beam? Location for rotators?)

✓ Budget limitation

✓ Other problems…

# 6. Summary

- The three rings of the BEPC-II reached their design parameters after 2.5 years' commissioning and operation.
- Luminosity reached the lowest design value after curing the instability due to impedance and moving tunes close to half integers.
- Some problems, low beam-beam parameter, short beam lifetime, high background under strong bunch current, etc, still exist and need to be studied further.
- Further luminosity upgrade is needed.
- Possibilities of crab waist and beam polarization need more studies.

# Acknowledgement

- Commissioning team of the BEPC-II
- People from KEKB, PEP-II and DAFNE
- All others from labs around world…

# Thanks for your attentions!