Status and Performance of BEPCII

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- Linac Status and New Upgrades
- Commissioning of Storage Rings
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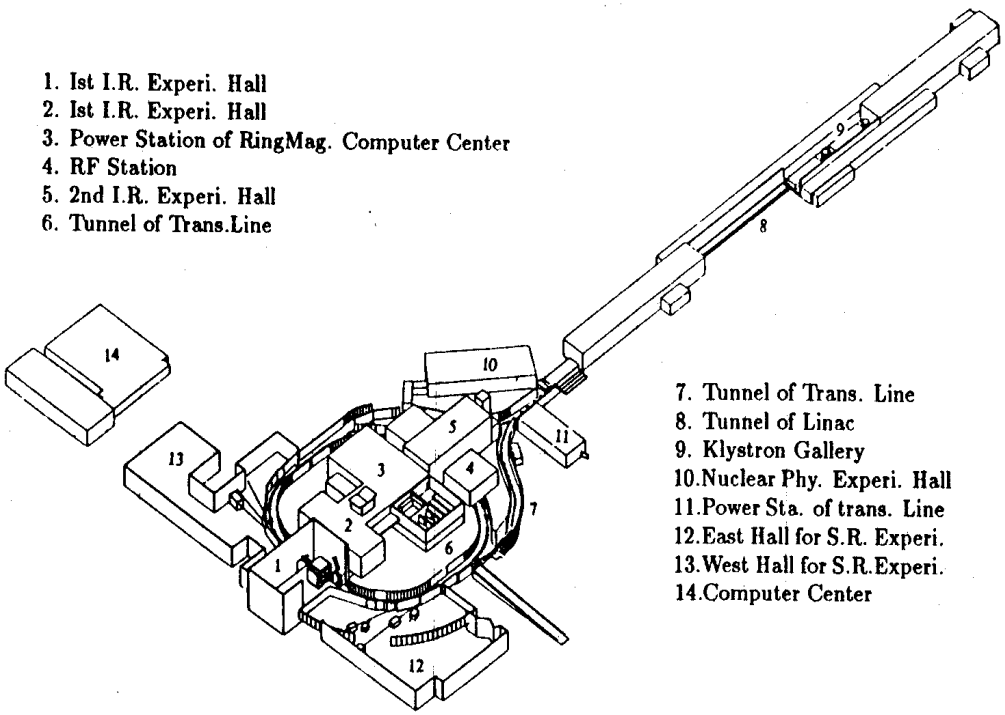
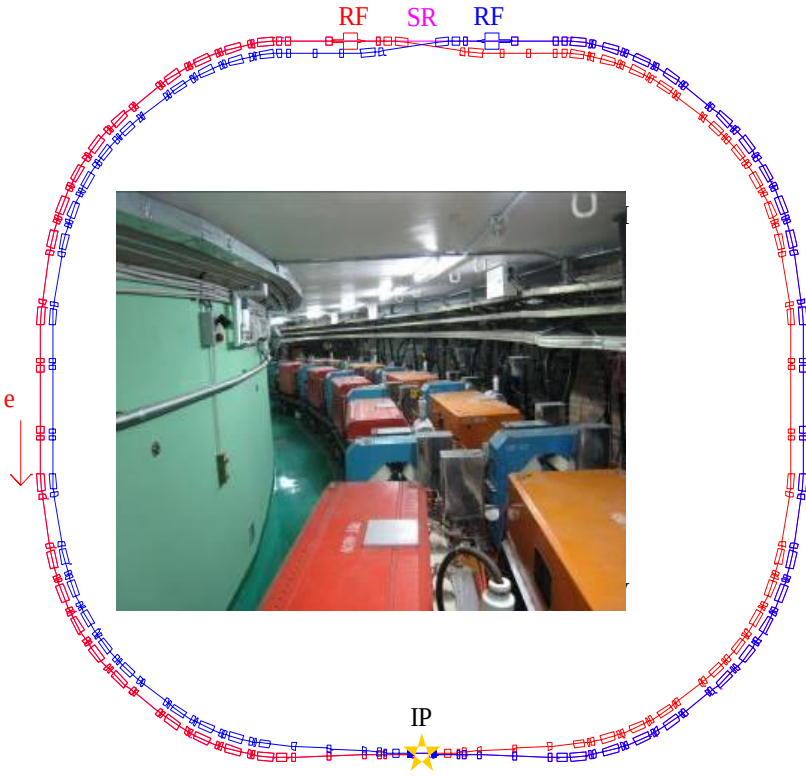
- Discussions and Summary

1. Introduction of BEPCII

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





Strategy of luminosity upgrade

DR: multy-bunch k_{bmax}~400, k_b=1 → 93

Choose large ε_x & optimum param.: I_b=9.8mA, ξ_y=0.04

$$L(\mathrm{cm^{-2}s^{-1}}) = 2.17\times10^{34}(1+R)\xi_y \frac{E(\mathrm{GeV})k_b I_b(\mathrm{A})}{\beta_y^*(\mathrm{cm})}$$

Micro-β: β_y^* =5cm → 1.5 cm
SC insertion quads

Reduce impedance +SC RF
σ_z =5cm → <1.5cm

$(L_{BEPCII}/ L_{BEPC})_{D.R.}=(5.5/1.5)\times93\times 9.8/35=96$

$L_{BEPC}=1.0\times10^{31}$ cm^{-2}s^{-1} → $L_{BEPCII}=1\times10^{33}$ cm^{-2}s^{-1}

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Design Goals of BEPCII

❑ Collision Mode

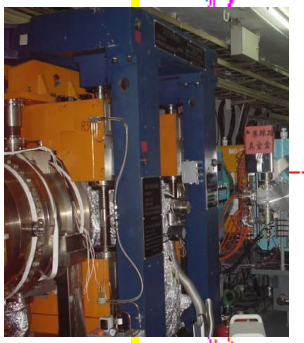
- **Beam energy range** — **1-2.1 GeV**
- **Optimized beam energy** — **1.89 GeV**
- **Luminosity** — **1×10^{33} $cm^{-2}s^{-1}$ @1.89 GeV**
- **Full energy injection** — **1-1.89 GeV**

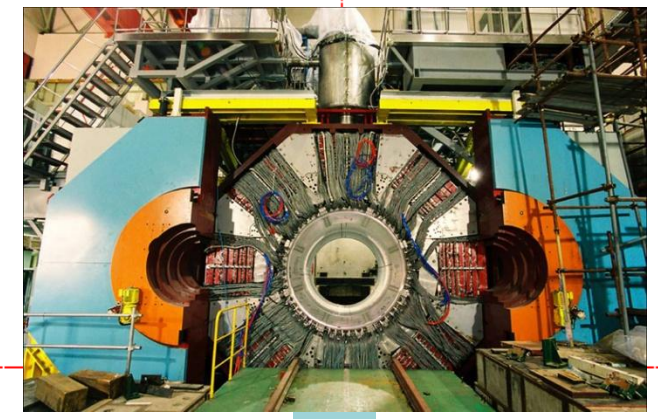
❑ SR Mode

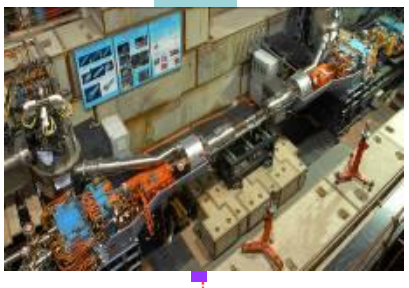
- **Beam energy** — **2.5 GeV**
- **Beam current** — **250 mA**
- **Keep the present beam lines useable**

Upgrade of BEPC: One machine, two purposes (HEP, SR)

Accelerator--Three Rings Structure

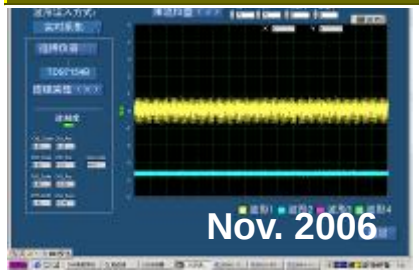


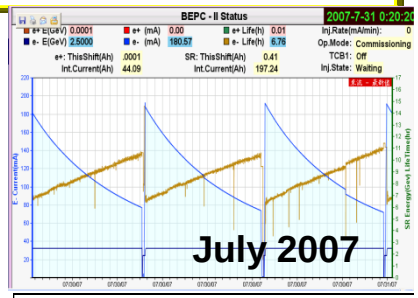


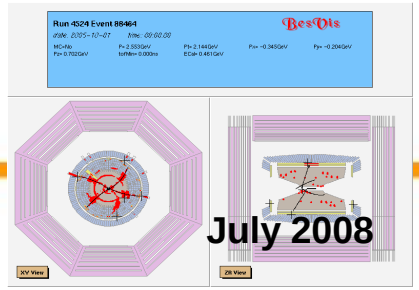


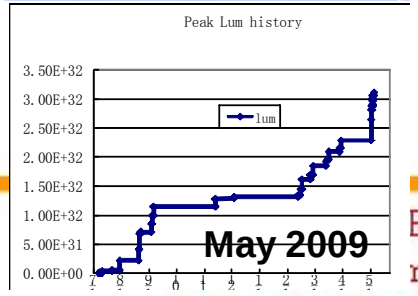
The Milestones

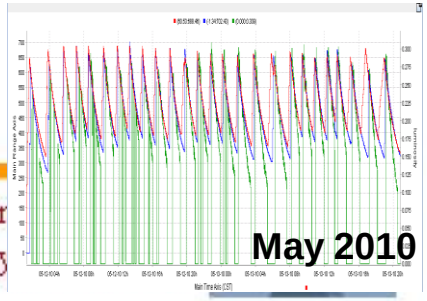
January 2004	Construction started
May. 4, 2004	Dismount of 8 linac sections started
Dec. 1, 2004	Linac delivered e^- beams for BEPC
July 4, 2005	BEPC ring dismount started
Mar. 2, 2006	BEPCII ring installation started
Nov. 13, 2006	Phase 1 commissioning started
Aug. 3, 2007	Shutdown for installation of IR-SCQ's
Oct. 24, 2007	Phase 2 commissioning started
Mar.28, 2008	Shutdown for installation of detector
June 24, 2008	Phase 3 commissioning started
July 19, 2008	First hadron event observed
May 19, 2009	Luminosity reached $3.3\times10^{32}cm^{-2}s^{-1}$





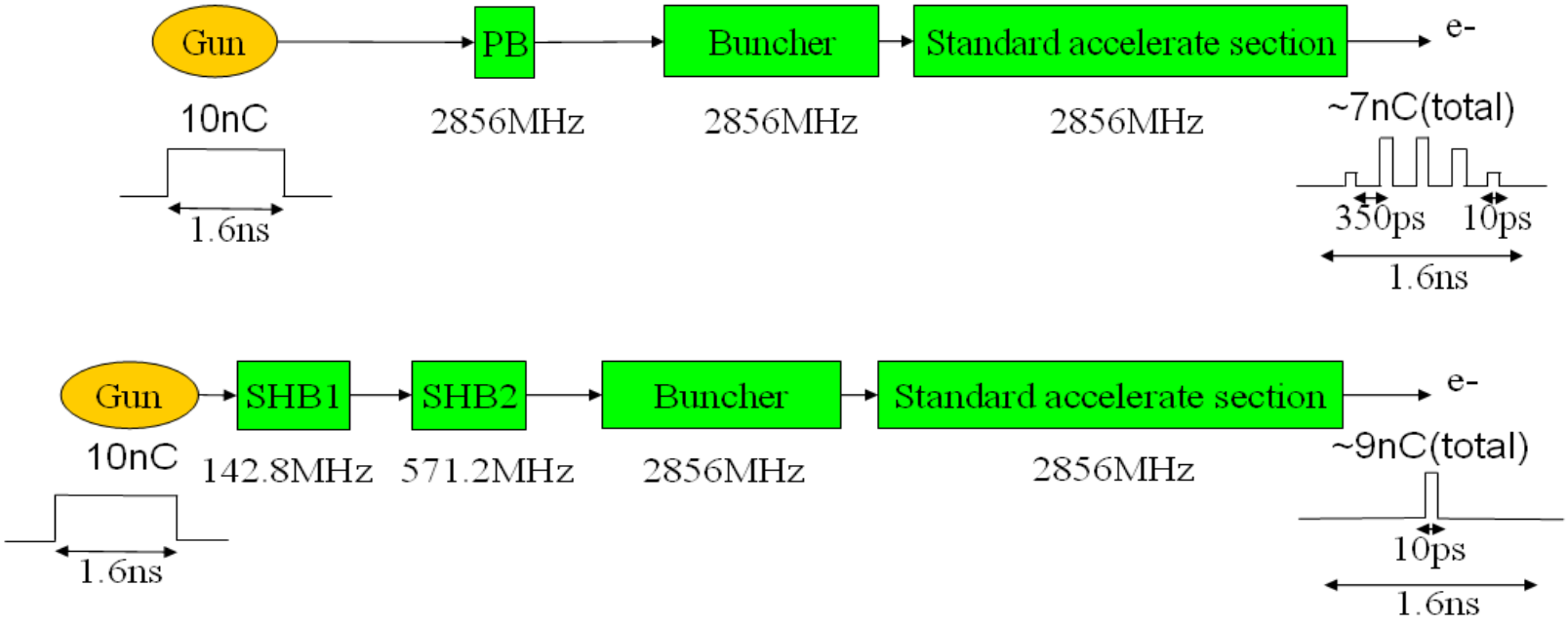




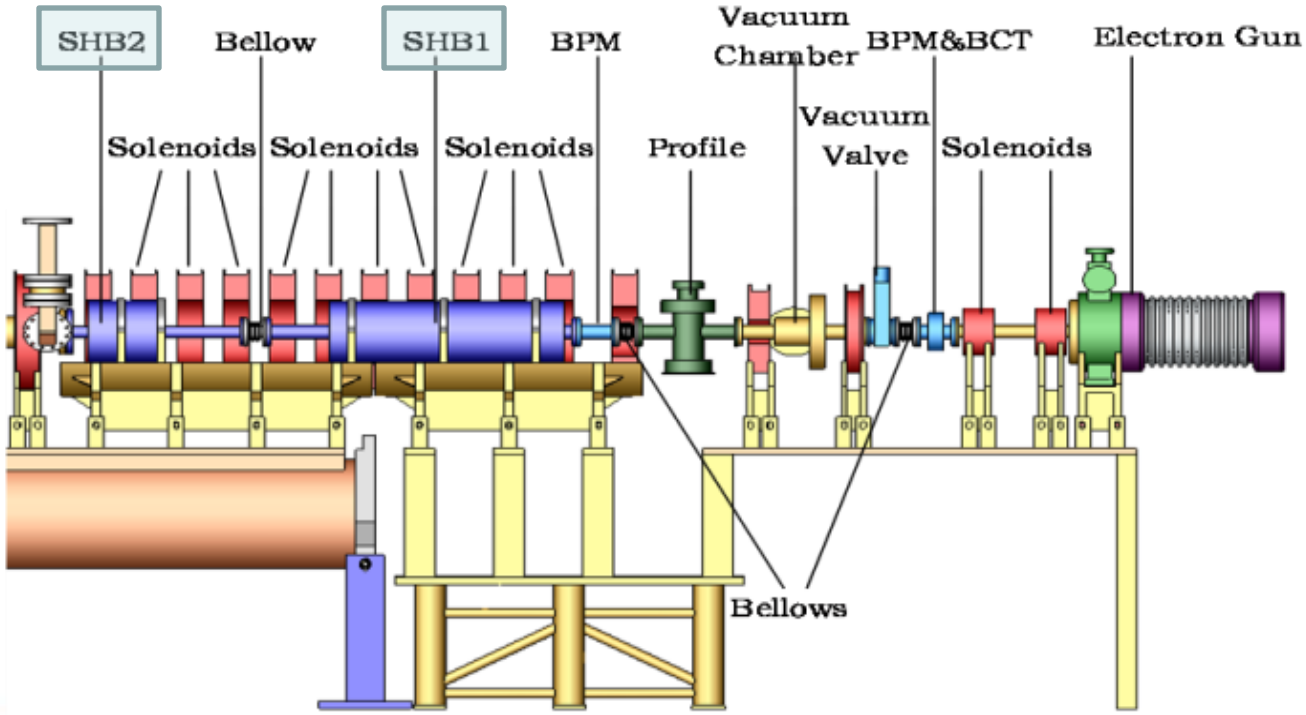


2. Linac Status and New Upgrades

- **Sub-harmonic buncher system installed**



- **Two sub-harmonic bunchers, SHB1 and SHB2, in 142.8MHz and 571.2MHz, respectively**



- **Output of one bunch**

- **Problems exist:**

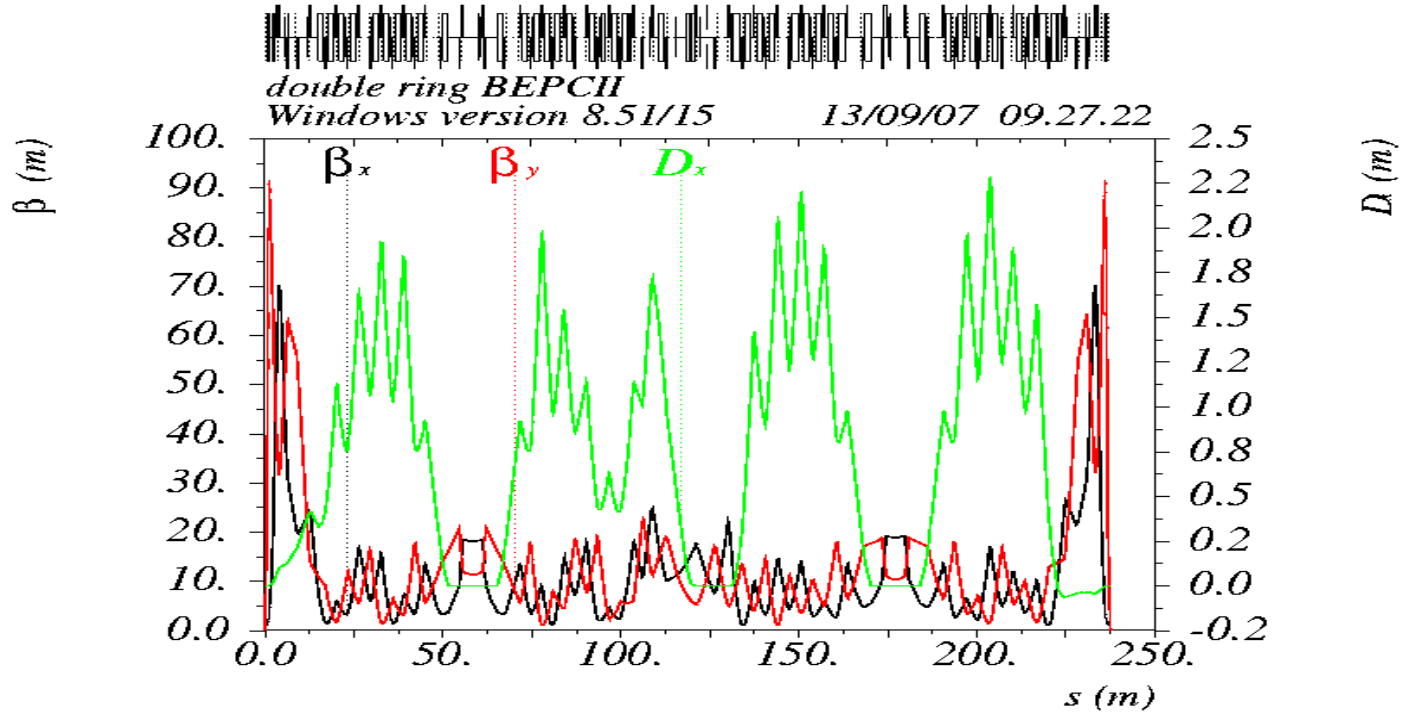
✓ **Phase drift from the SHB's frequency signal generator**

✓ **Temperature control of the thermostatic chamber of the signal generator**

- **Further improvement is needed.**

3. Commissioning of Storage Rings

- **Beam optics and its realization**

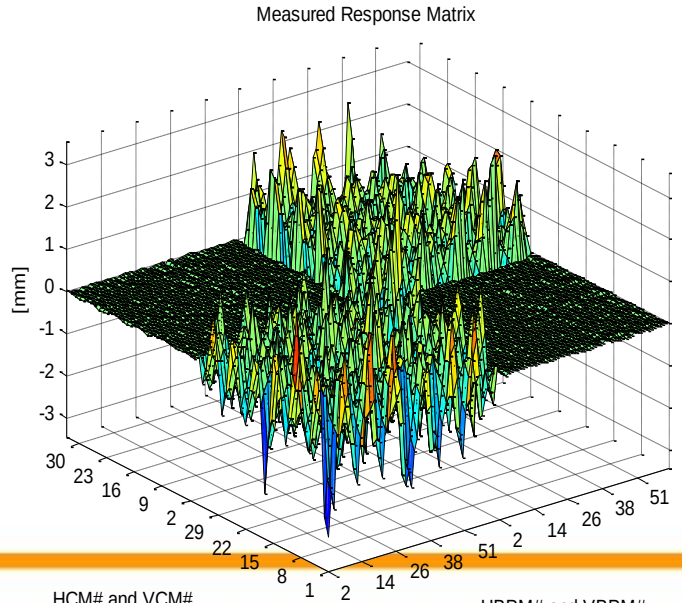


Design Parameters of Ring (Col. Mode)

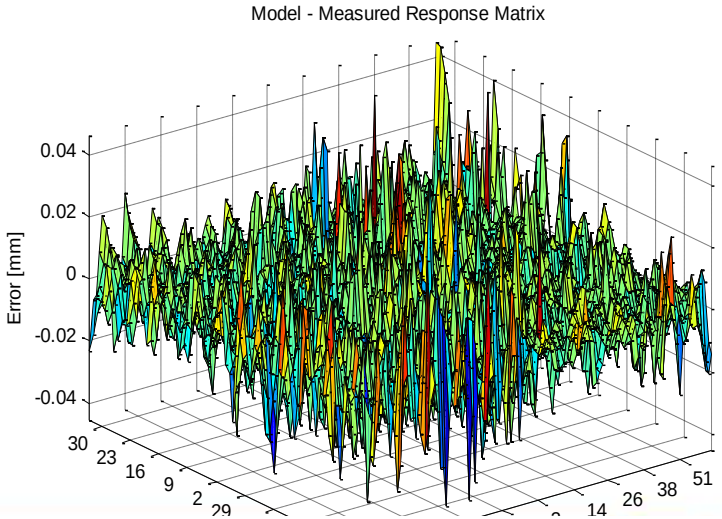
Energy	GeV	1.89
Circumference	m	237.53
Beam current	A	0.91
Bunch number		93
Bunch current	mA	9.8
Bunch spacing	m	2.4
Bunch length	cm	1.5
RF frequency	MHz	499.80
Harmonic number		396
Emittance (x/y)	nm·rad	144/2.2
β function at IP (x/y)	m	1.0/0.015
Crossing angle	mrad	$\pm$11
Design luminosity	$cm^{-2}s^{-1}$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

• Optics Correction

- Beam based alignment to get BPM offset
- Orbit distortion correction based on the measurement of response matrix
- LOCO applied to get fudge factors of quadrupoles



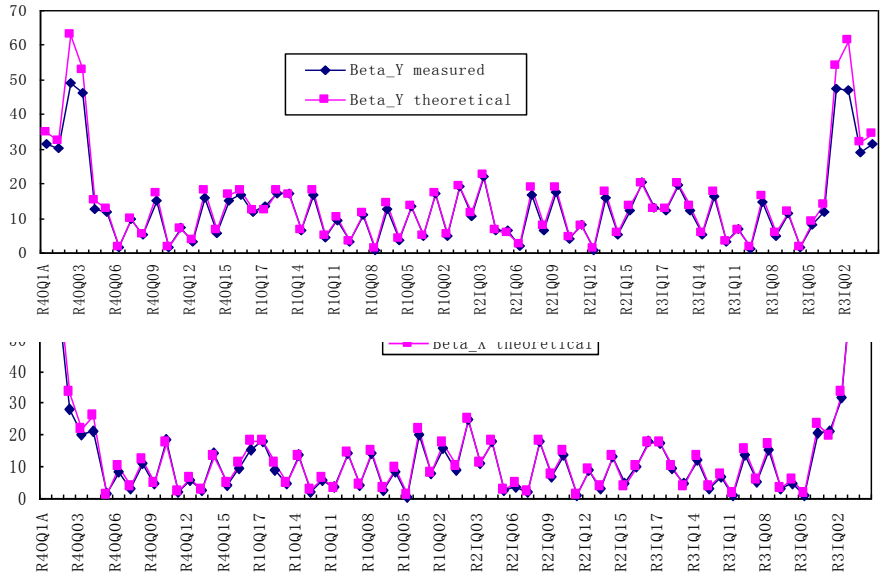
Measured response matrix

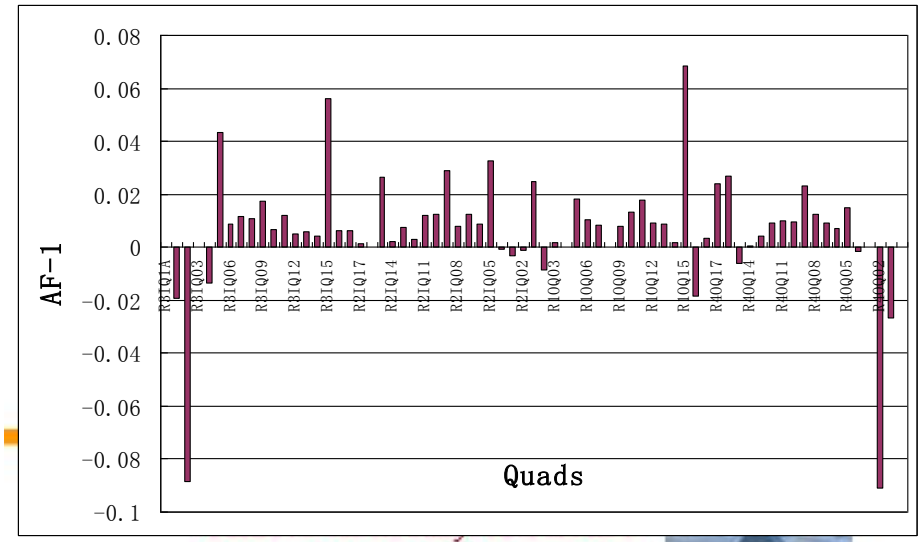


Difference between the measured and the model response matrices with LOCO

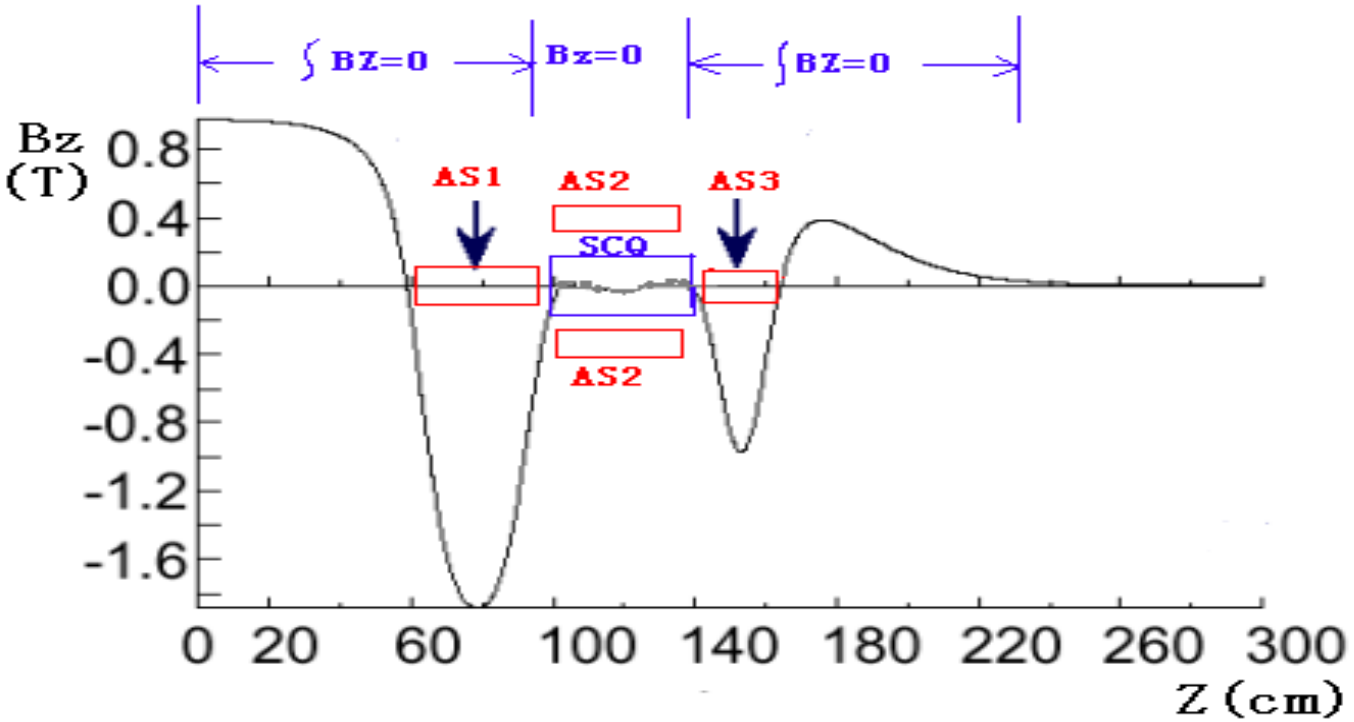
• Optics Correction (cont'd)

- ✓ Measured beam optics functions are in good agreement with theoretical prediction with discrepancy within ±10% at most quadrupoles,
- ✓ Design ν_x/ν_y= 6.54, 5.59， measured ν_x/ν_y= 6.544, 5.559
- ✓ Quadrupole strengths systematically 1~2% lower than design set:
  1) Interference between adjacent Quadrupole and sextupole
  2) fringe field effect.
  3) Other origin of these errors is still pursued.



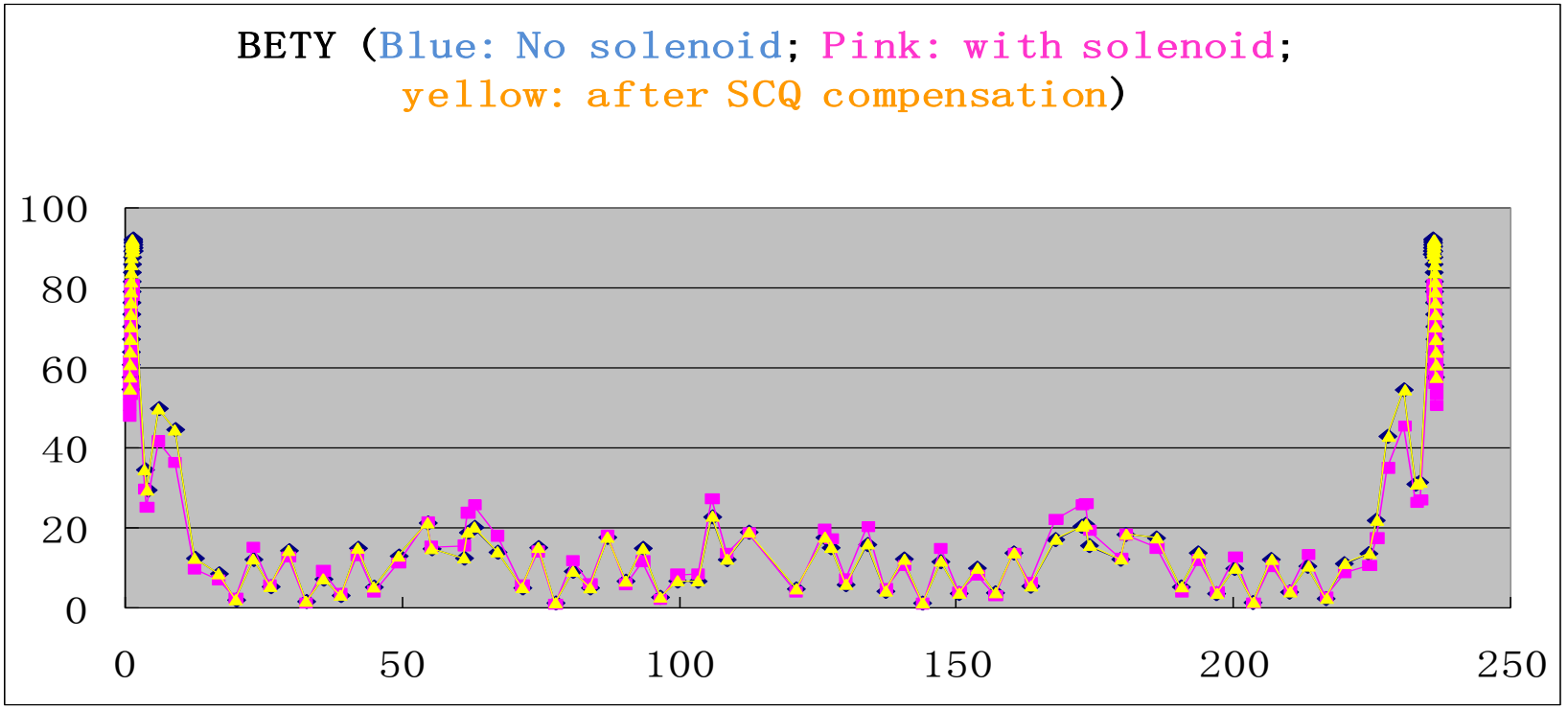


- **In phase 3 of commissioning, the detector solenoid effect was compensated.**



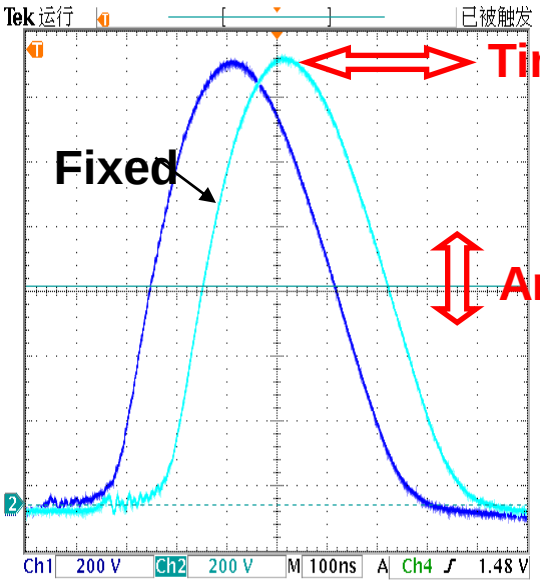
AS1 – 3 are connected in series, but AS2 and AS3 have trims

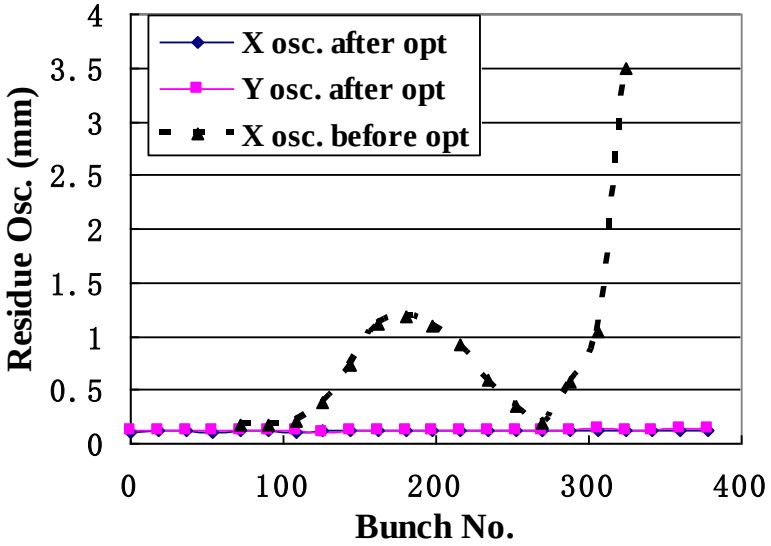
- **Local correction to the SCQs near IP.**



• Beam Injection

To reduce the residual orbit oscillation of the stored beam
=>set the right timing and amplitude of the two kickers.





⇒ After optimization with on bunch, the residual orbit oscillation of all the bunches during injection reduced to around 0.1mm/0.1$\sigma_{x.}$

⇒ Injection on collision possible

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

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

• Beam Injection

To reduce the residual orbit oscillat
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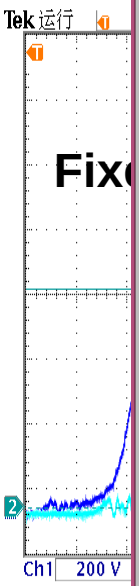

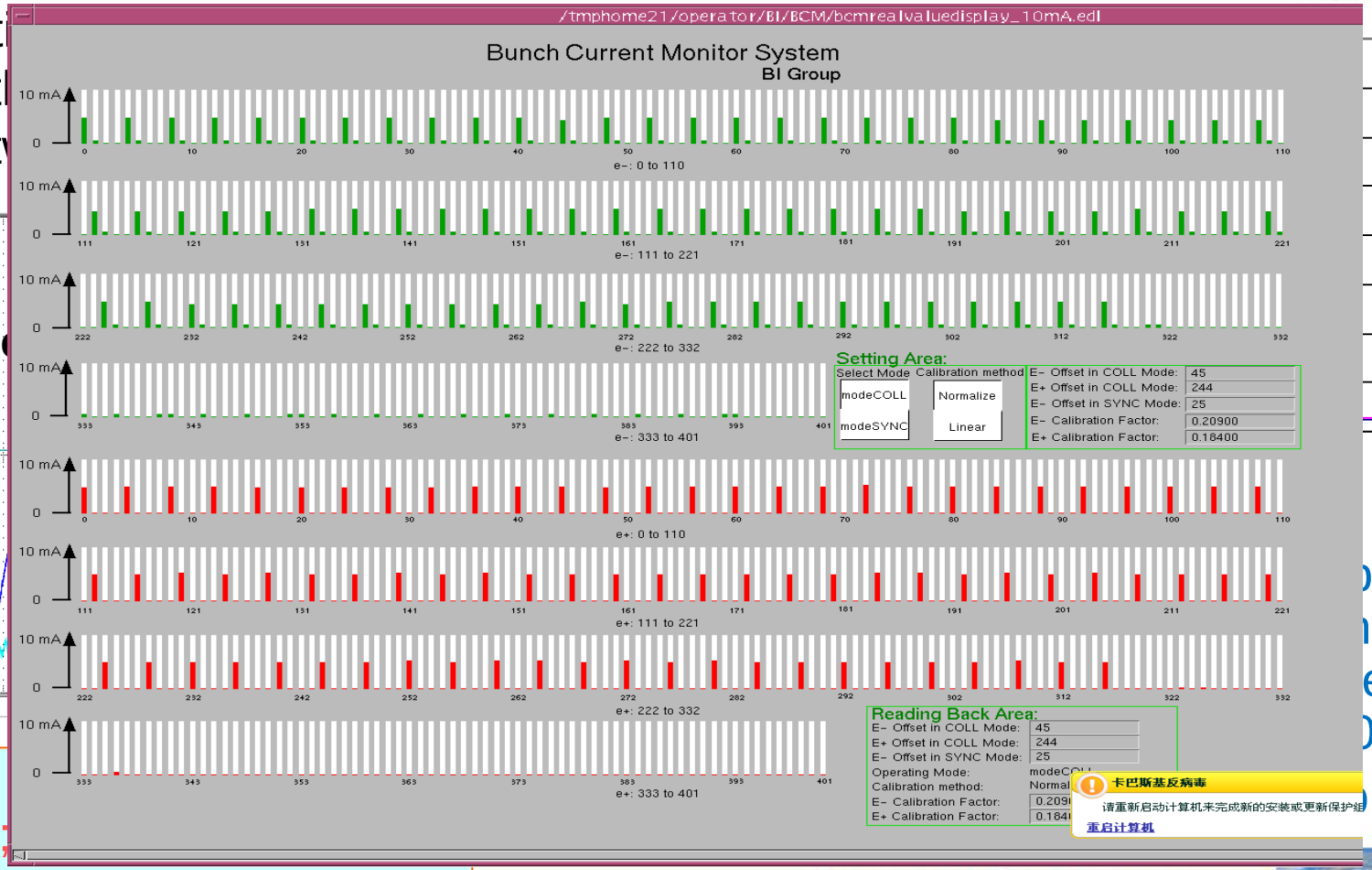

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$0.1\sigma_x$.
le

=>For
k2 ;

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

Luminosity commissioning

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

↓

Set vertical bump at NCP（$4\sim5\sigma_x$）

↓

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

↓

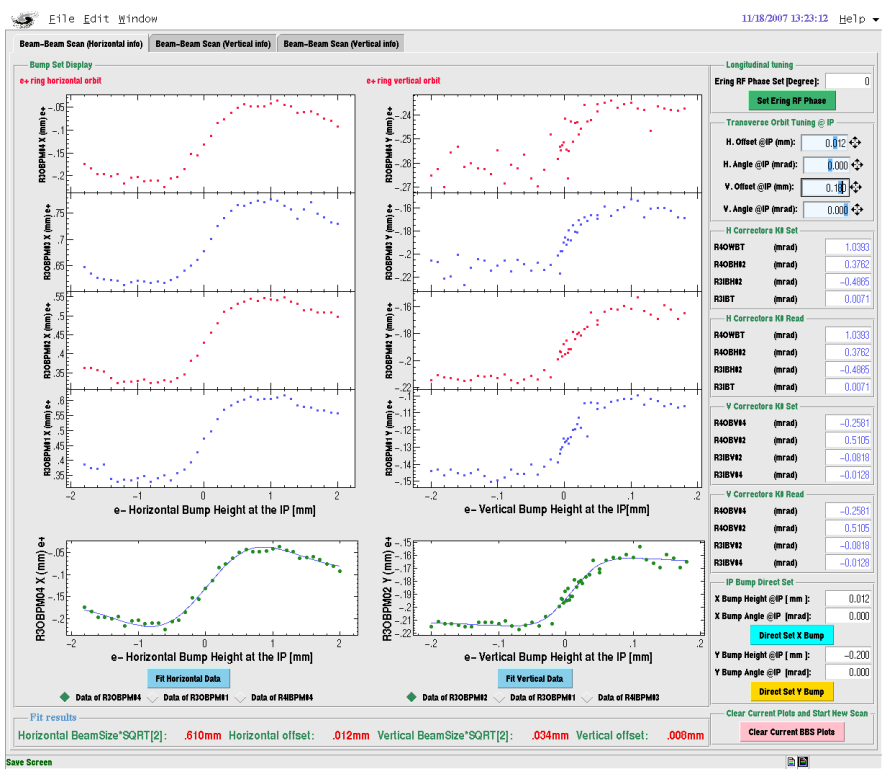
Multi-bunch injection and collision (BCM to watch the uniform injection)

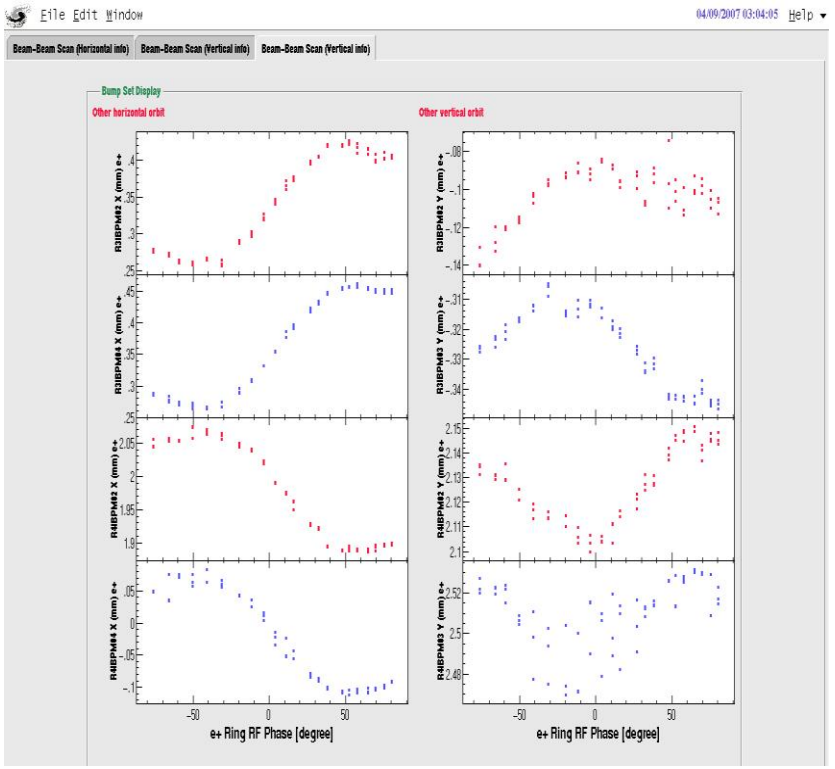
↓

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

↓

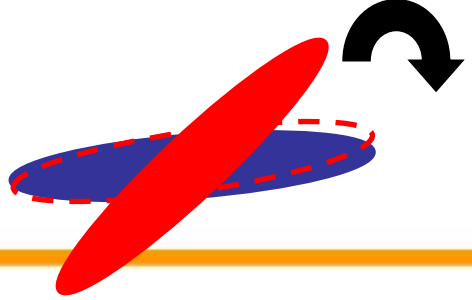
Luminosity with multi-bunch



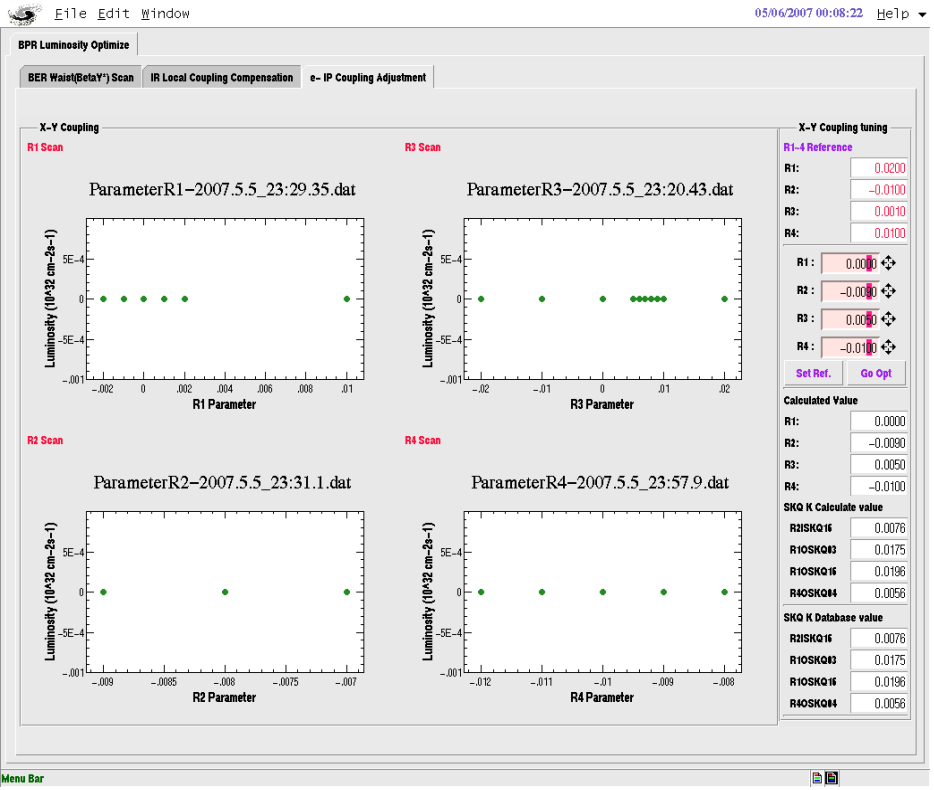


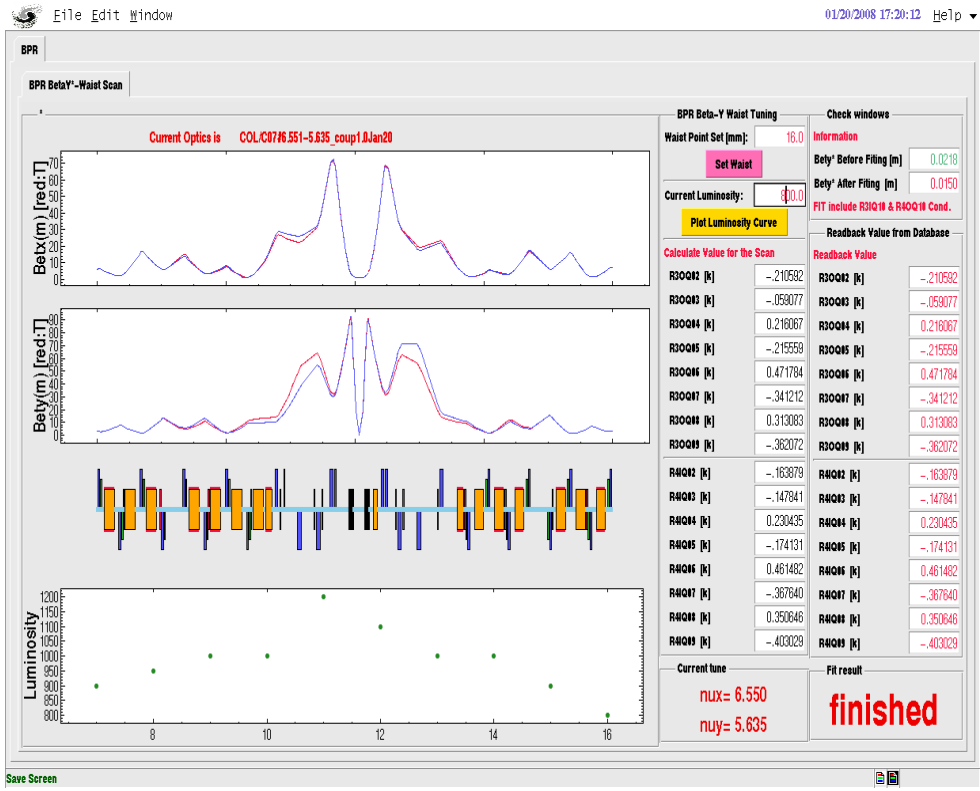
Scan e^-/e^+ orbit
Step for tuning orbit < 1μm

Scan RF phase to get the vertical crossing angle



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



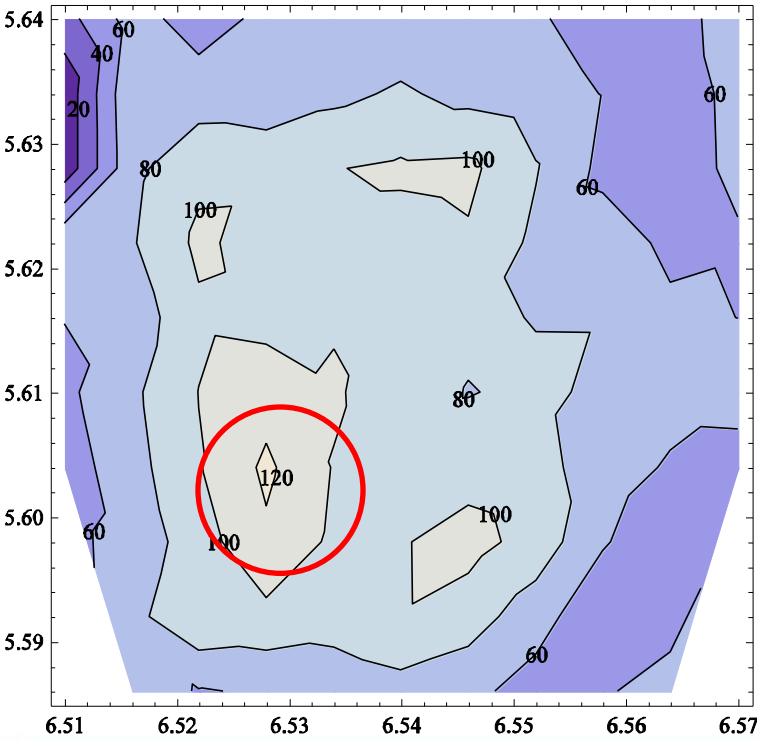


Angle tuning at IP

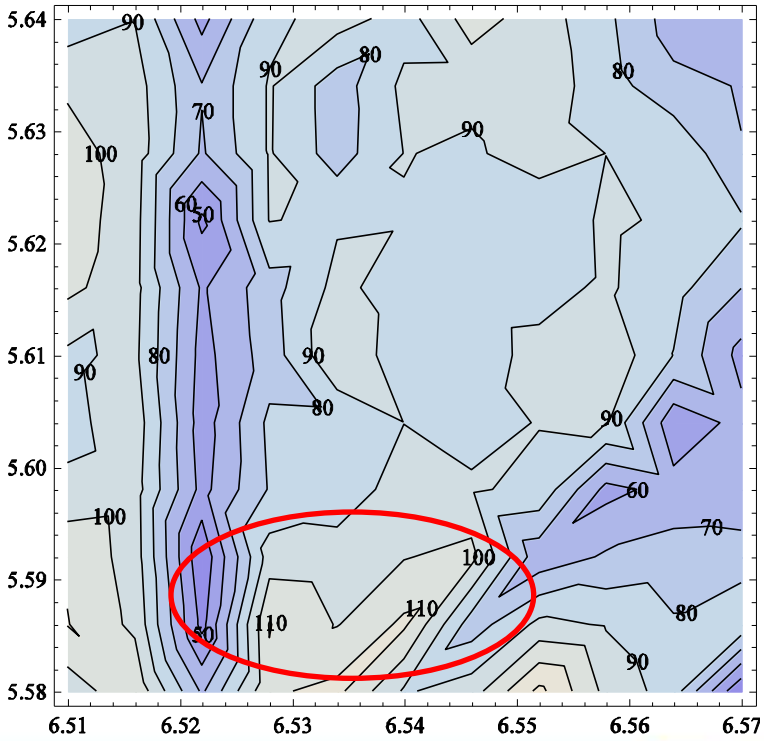
β*-waist tuning

On-line tune scan for two rings

Scan BPR

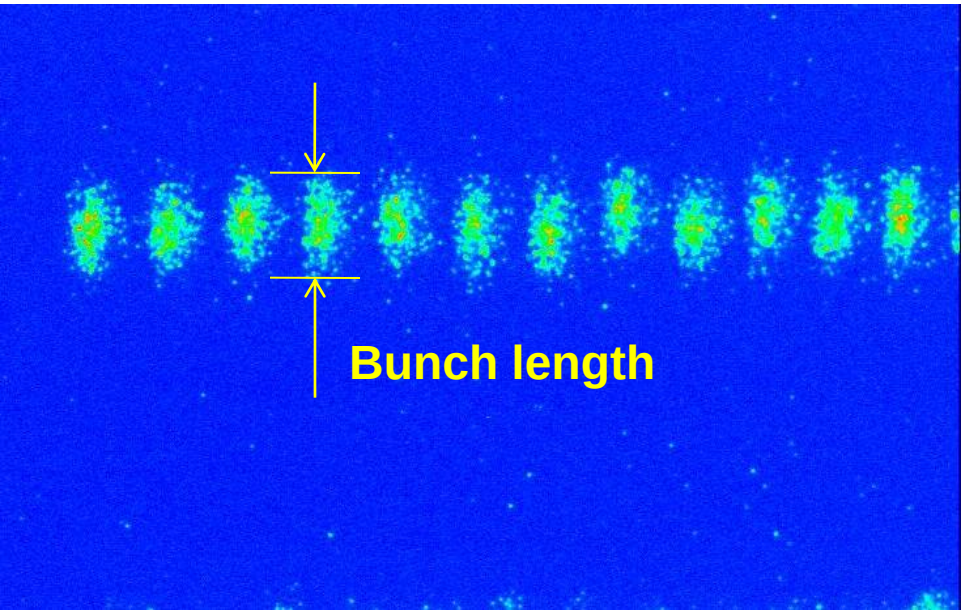


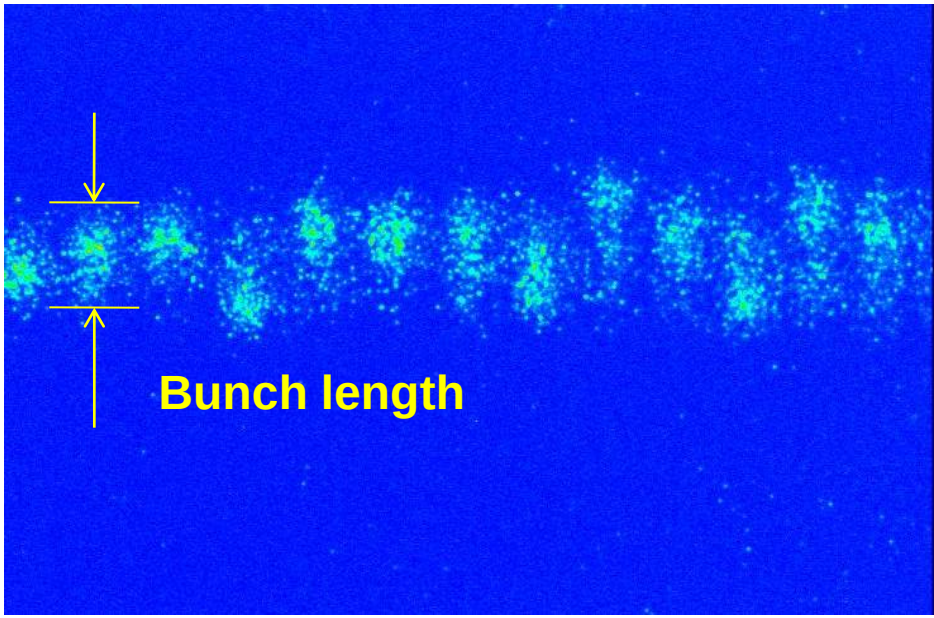
Scan BER



Instability Issues

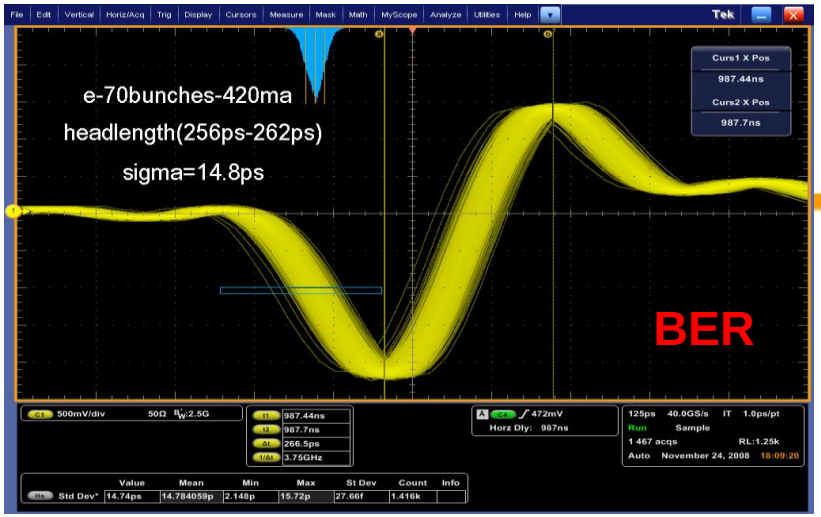
A bunch-by-bunch "lengthening" in BPR observed

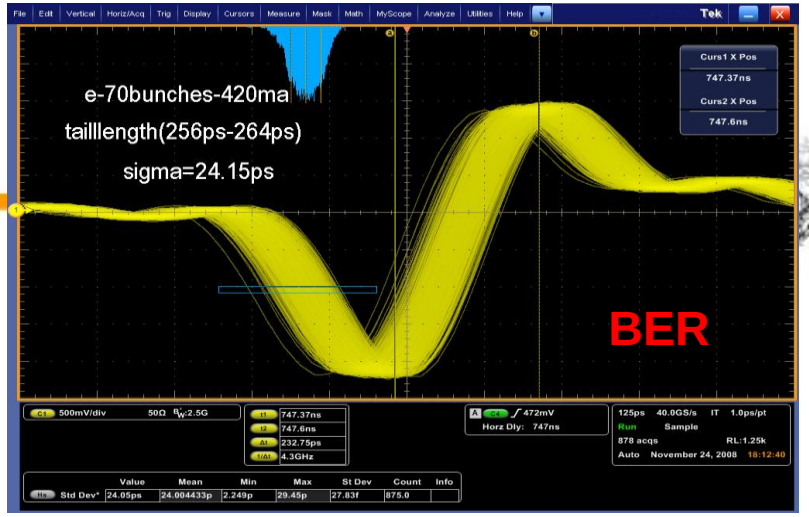


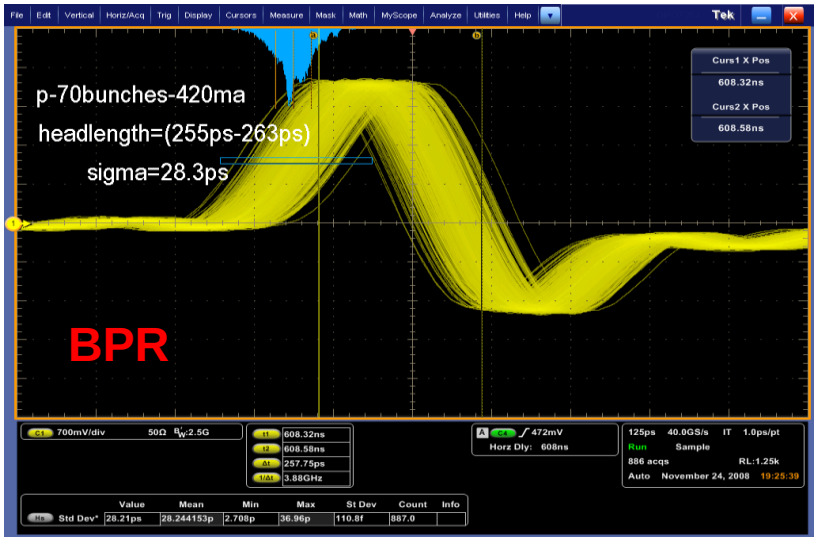


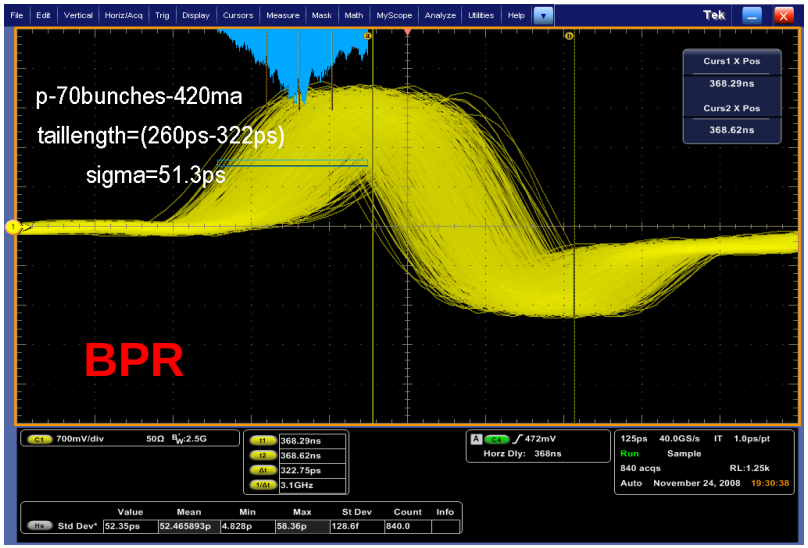
BER: 420mA/70 bunches

BPR: 386mA/70 bunches









Quadrupole oscillations of head and tail of e- and e+ bunch train

2010-05-26

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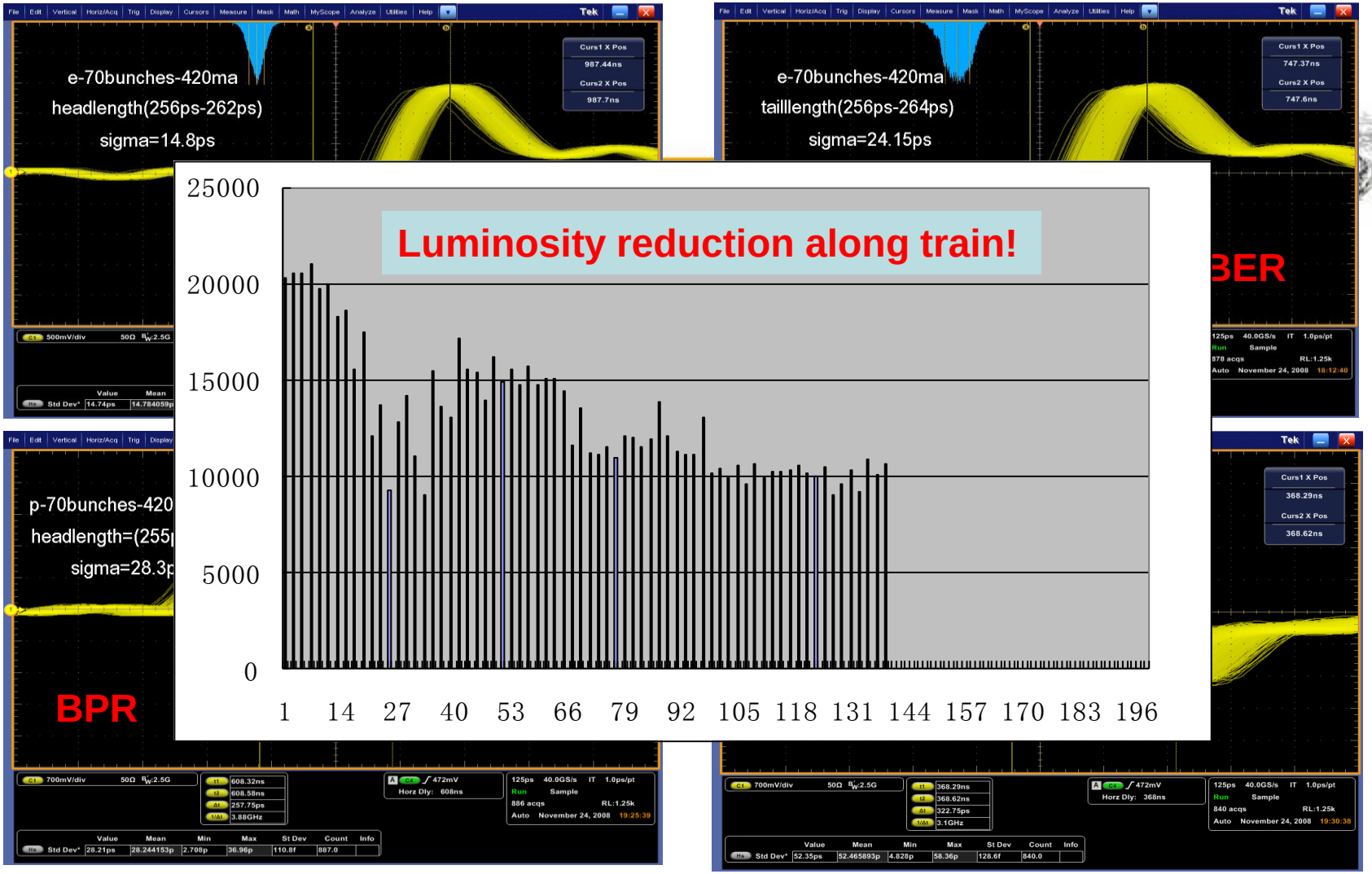

Quadrupole oscillations of head and tail of e- and e+ bunch train

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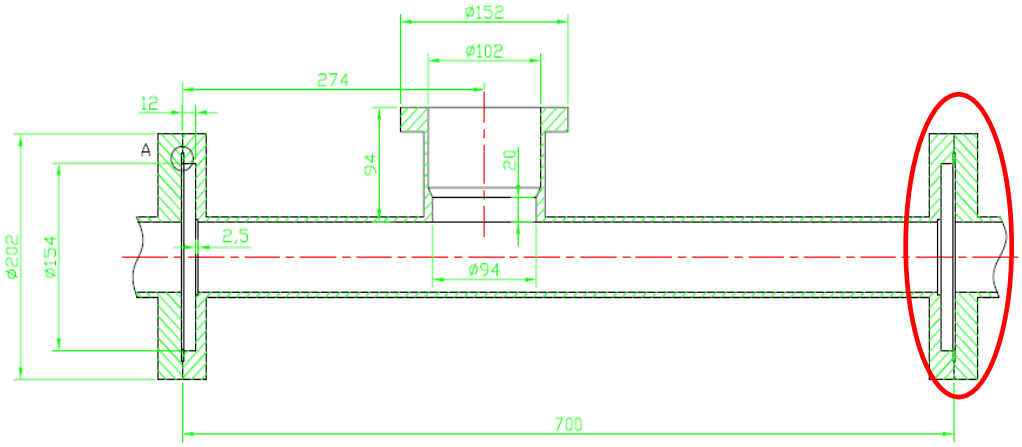
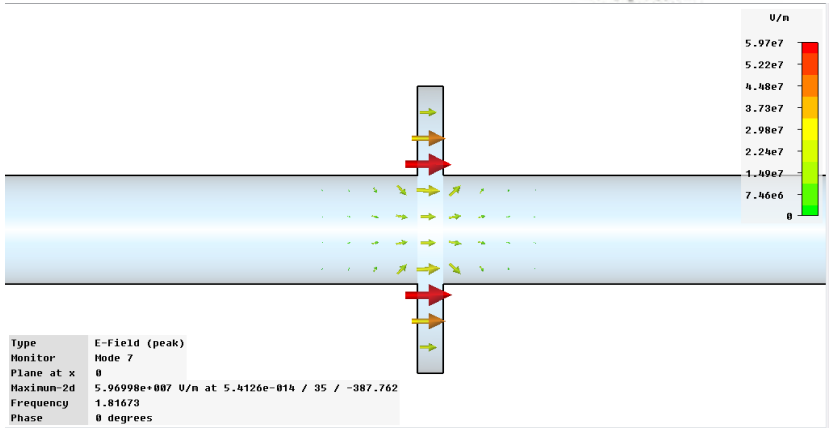
Source of the impedance: the temporary screen monitor in BPR



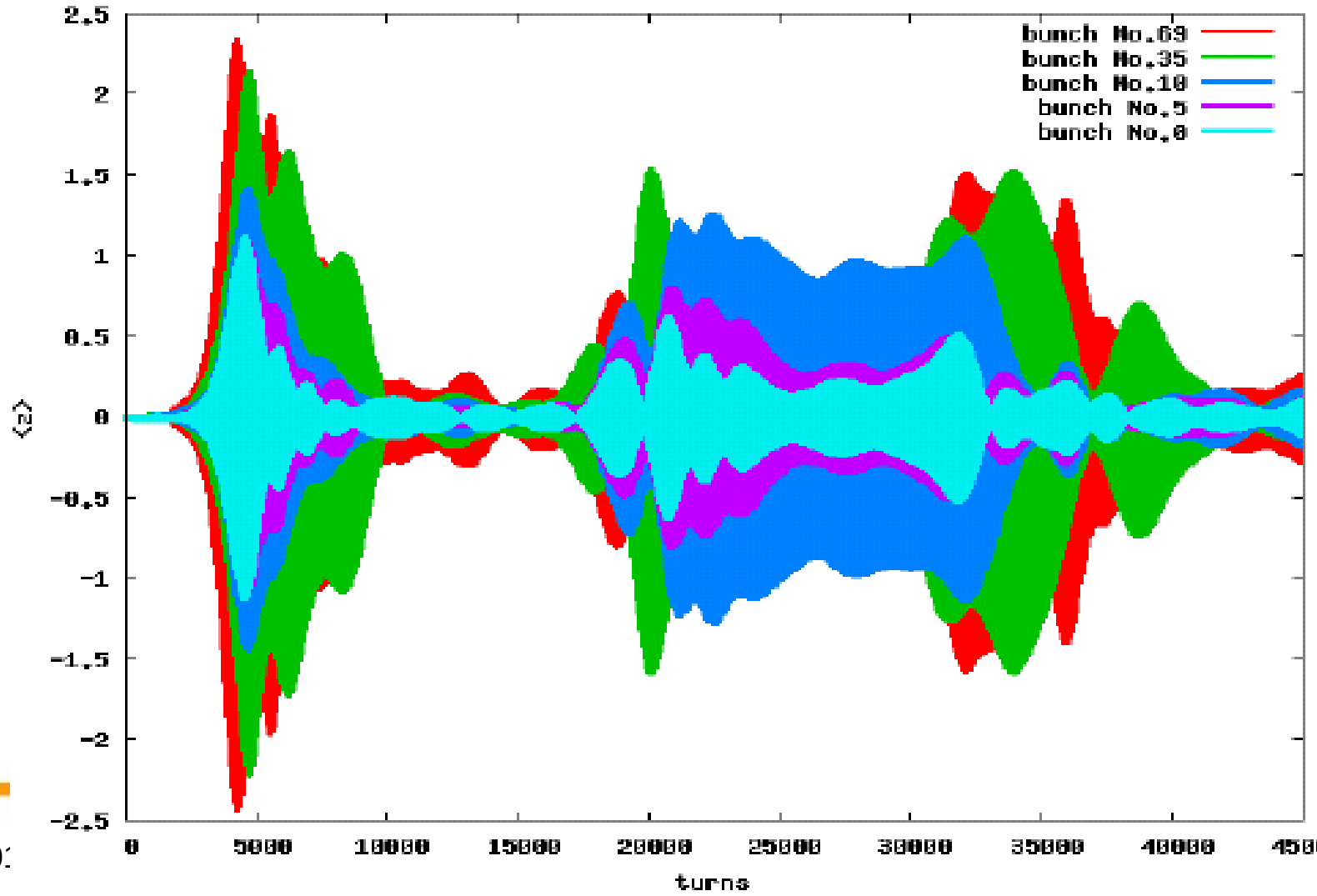


(Courtesy T.M. Huang)

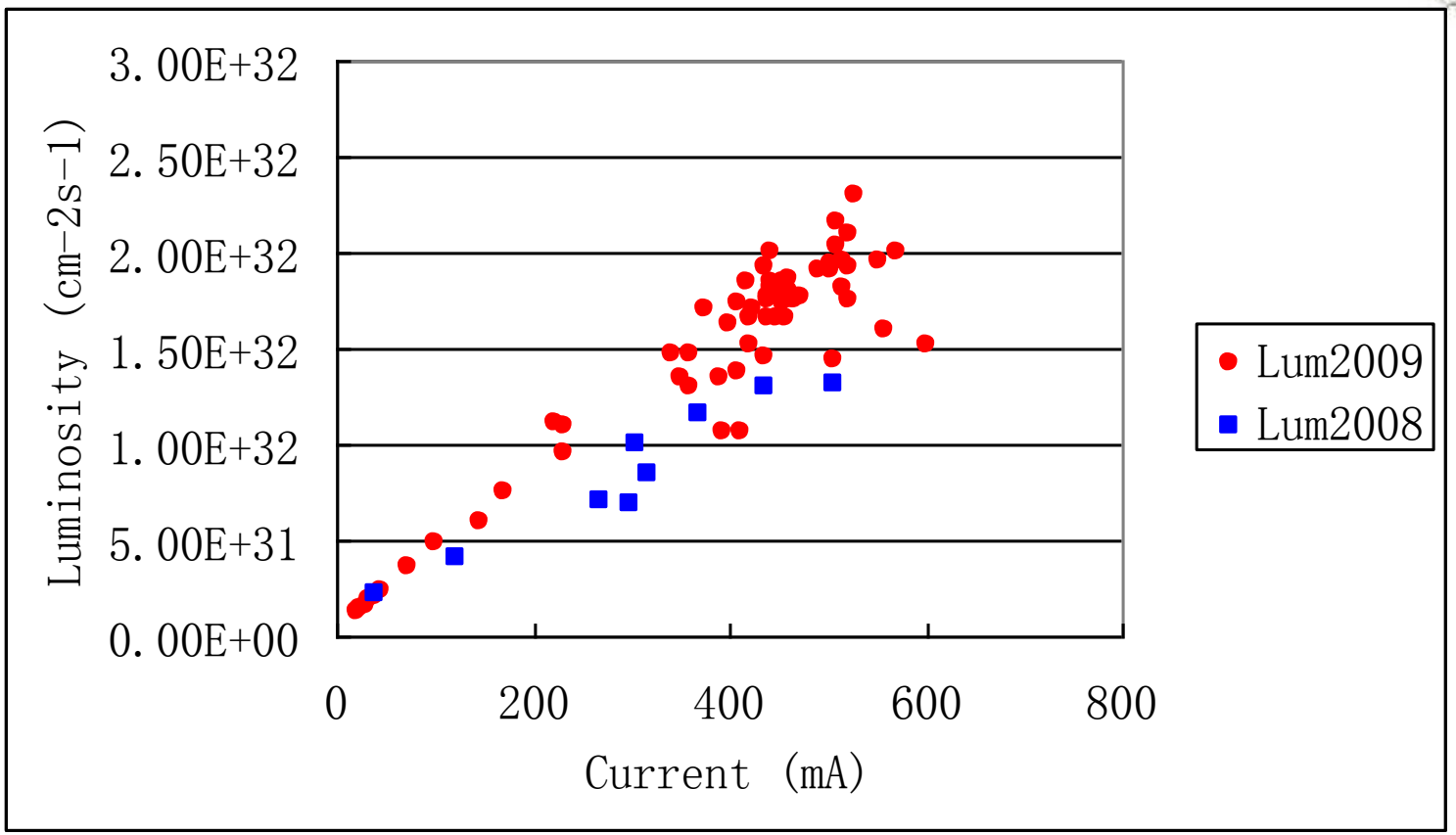
Model	Frequency (GHz)	Q	R	R/Q	Field decay time (ns)
Small cavity	1.8171	2256.9	86160	38.1774	198
Vacuum pump	2.3432	8335.6	4579	0.54933	556

Difference from the BER and BPR!

Simulation on beam oscillation in longitudinal



Luminosity recovery after removing the SM



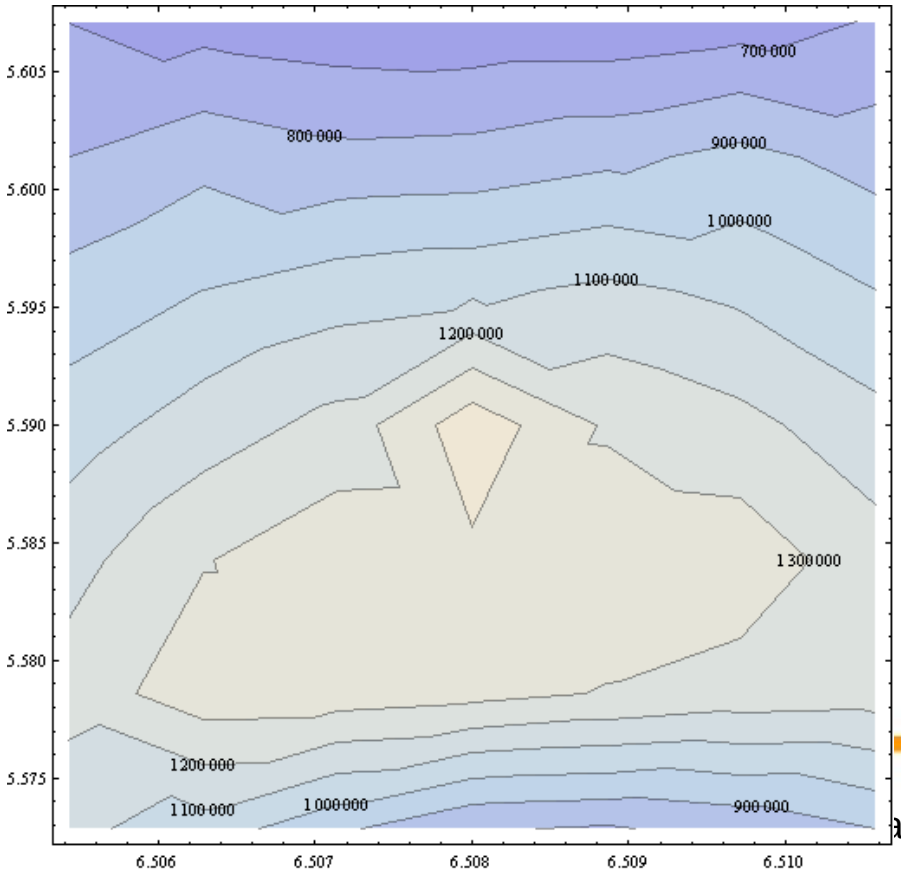
Moving tunes close to half integers

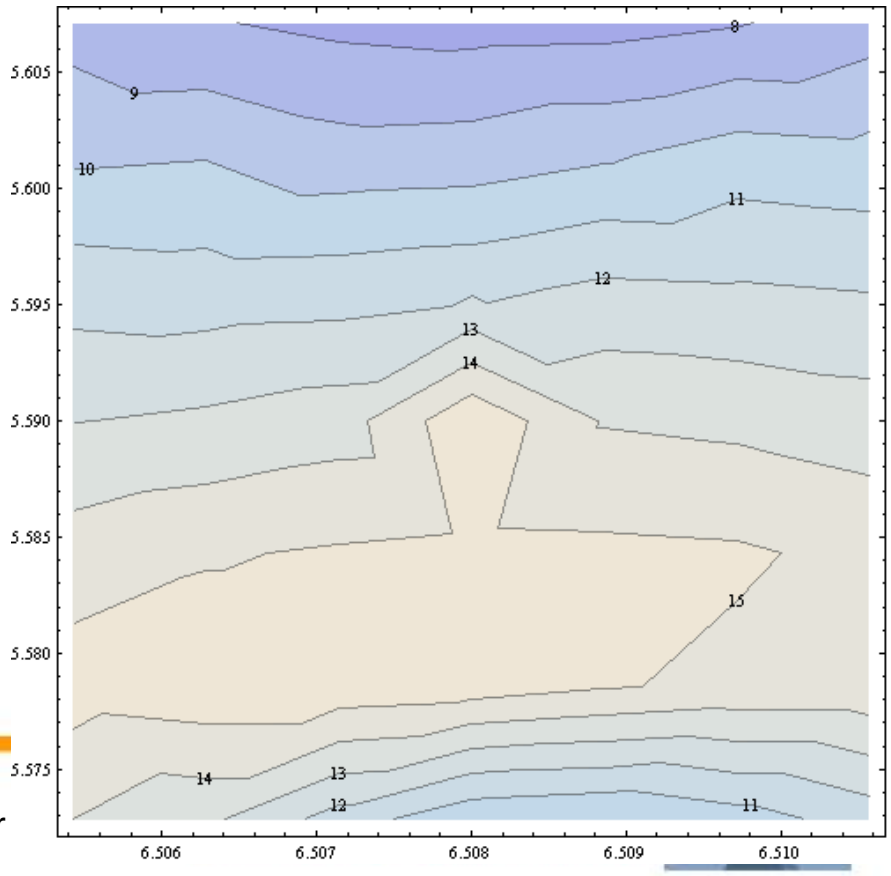
ν_x → 6.51(nominal)，6.508(meas.)

ν_y → 5.58(nominal)，5.587(meas.)

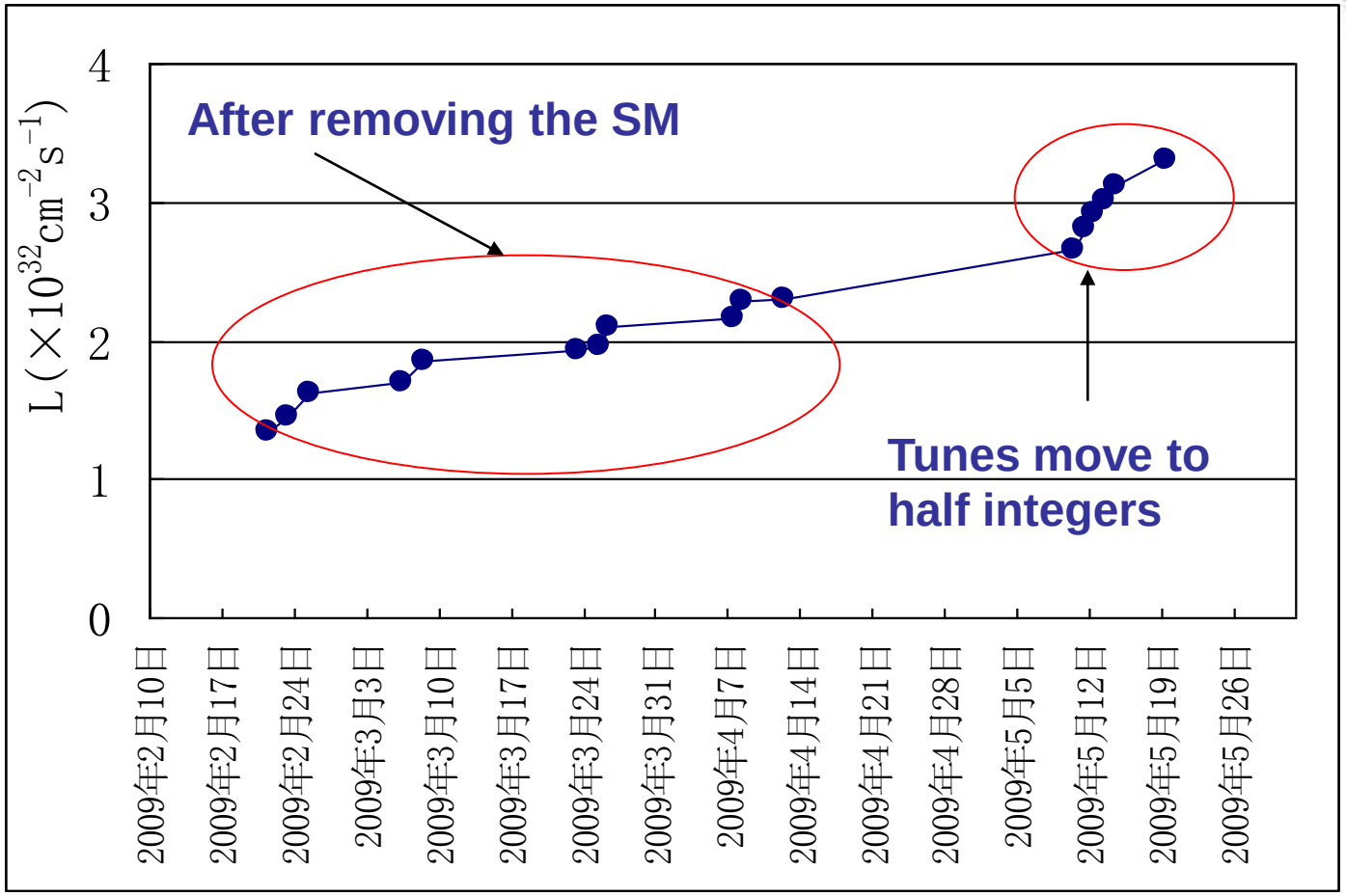
BPR: β_y* ~1.38 cm (measured)

BER: β_y* ~1.33 cm (measured)





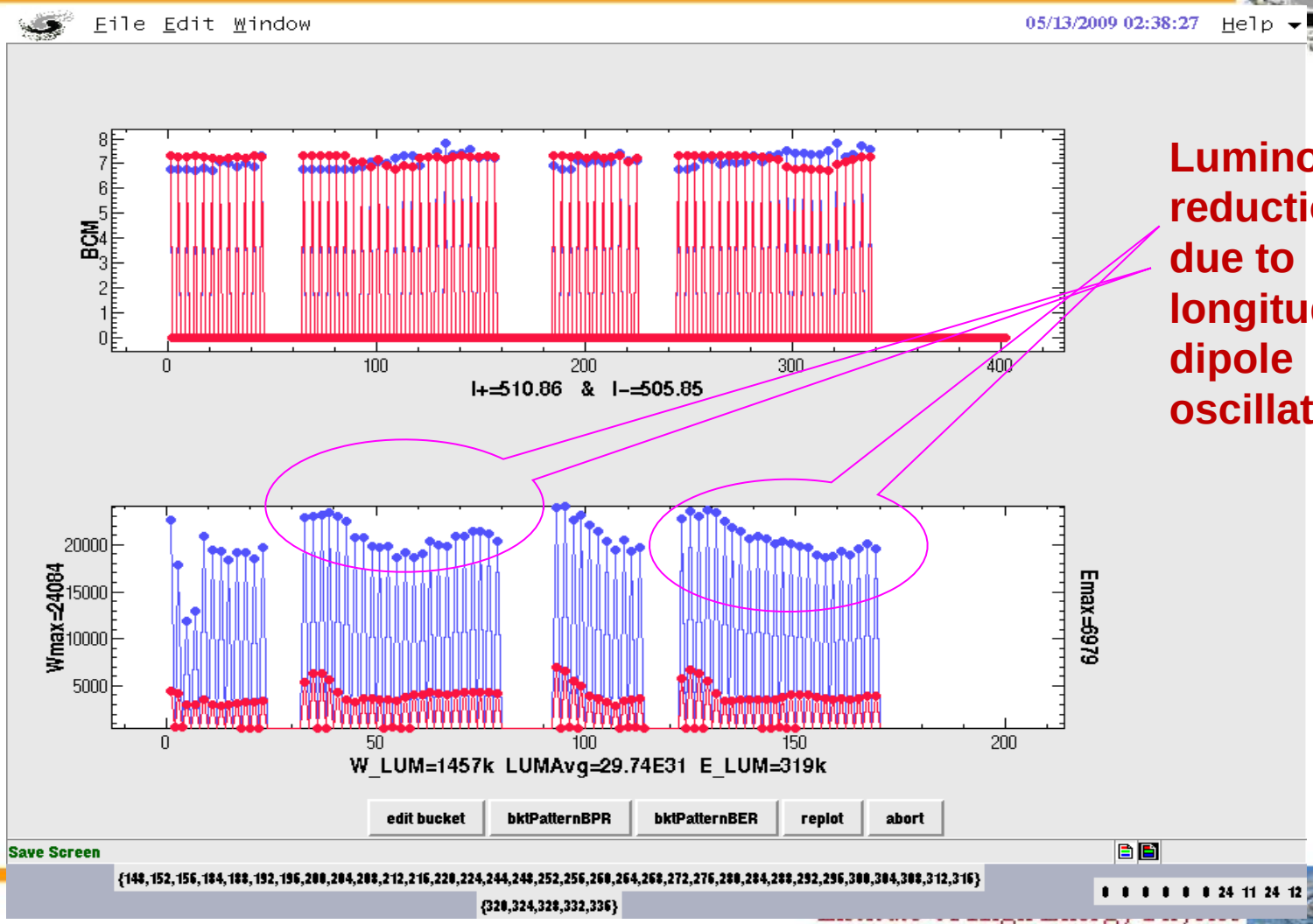
$L_{peak} = 3.3\times10^{32}cm^{-2}s^{-1}$!



Main parameters achieved in collision mode

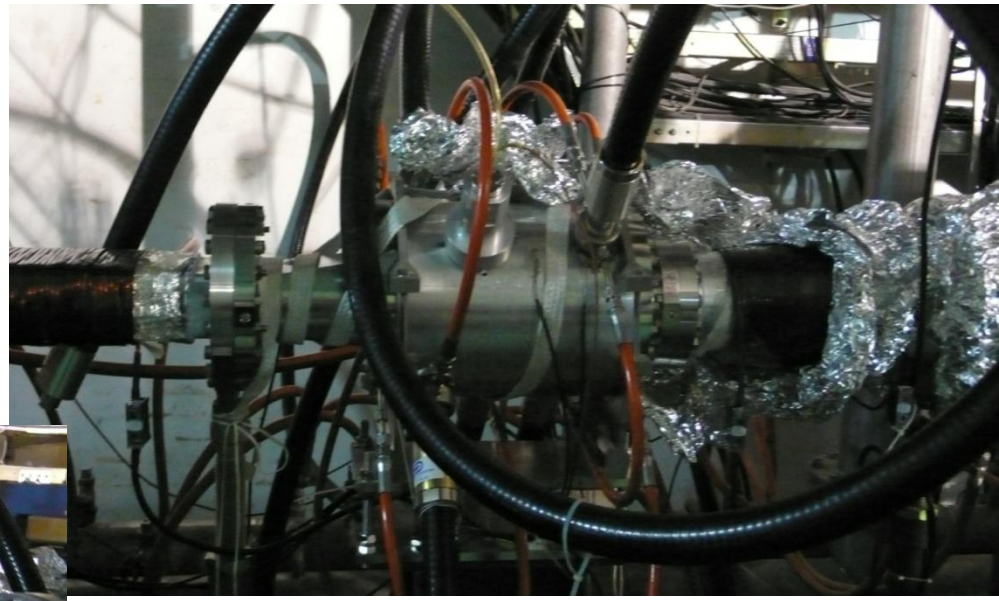
parameters	design	Achieved	
		BER	BPR
Energy (GeV)	1.89	1.89	1.89
Beam curr. (mA)	910	650	700
Bunch curr. (mA)	9.8	>10	>10
Bunch number	93	93	93
RF voltage	1.5	1.5	1.5
* ν_s @1.5MV	0.033	0.032	0.032
β_x^*/β_y^* (m)	1.0/0.015	~1.0/0.0135	~1.0/0.0135
Inj. Rate (mA/min)	200 e^-/ 50 e^+	>200	>50
Lum. ($\times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

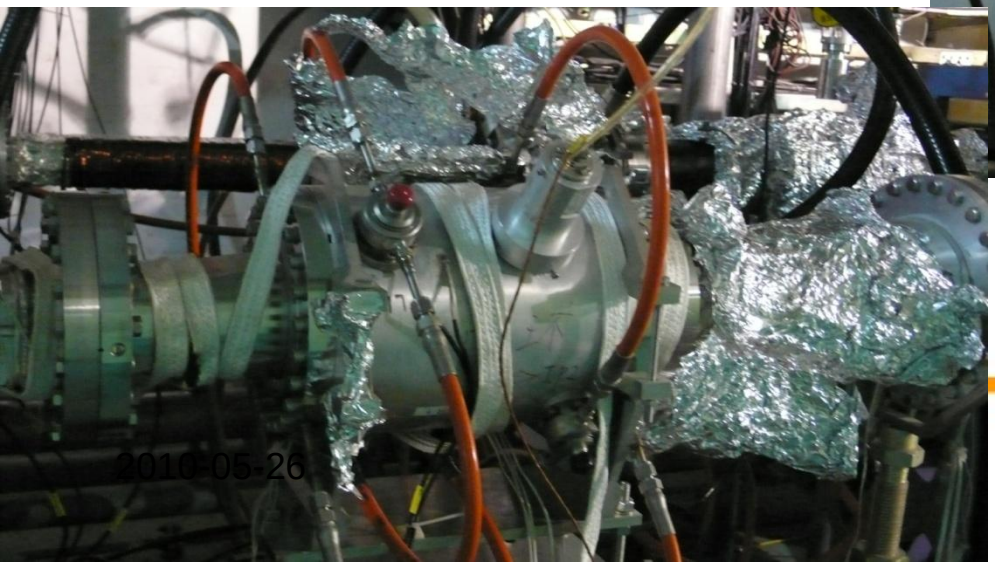
Luminosity with 80 bunches collision

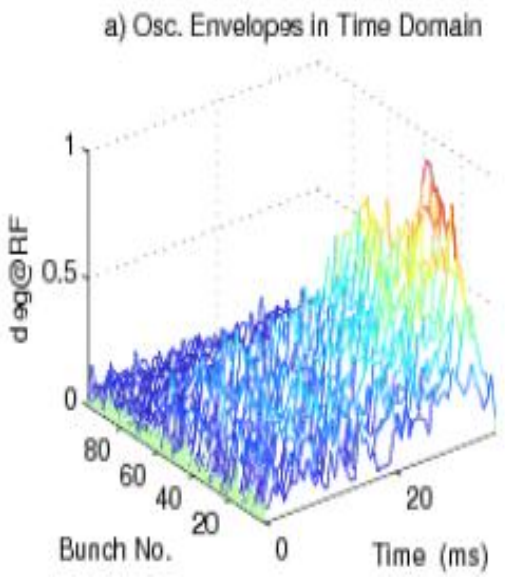


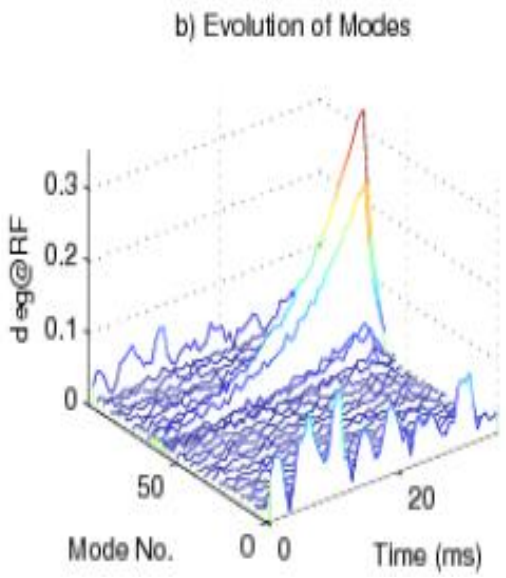
Luminosity reduction due to longitudinal dipole oscillation

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



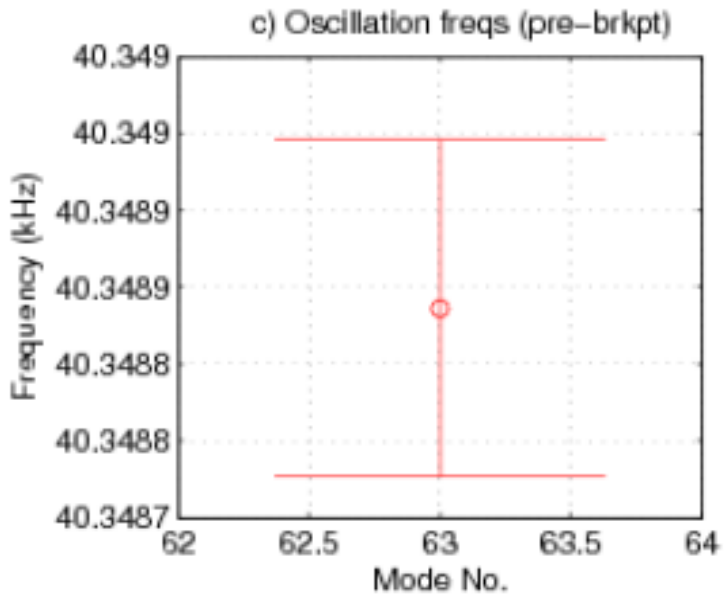


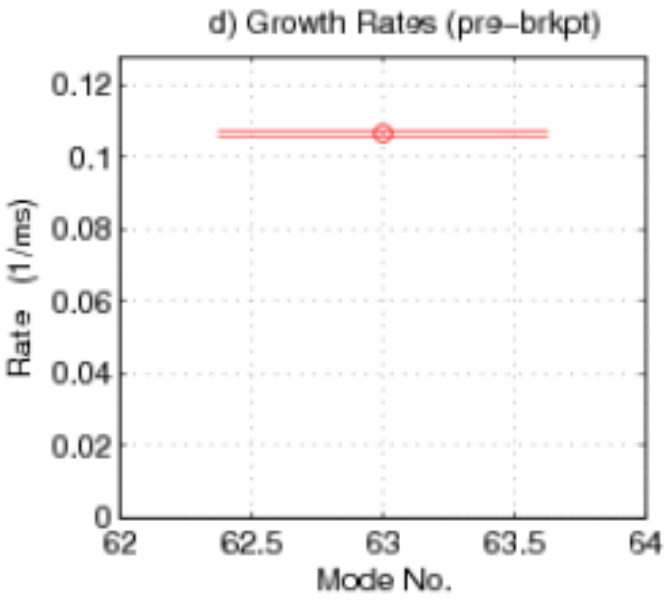


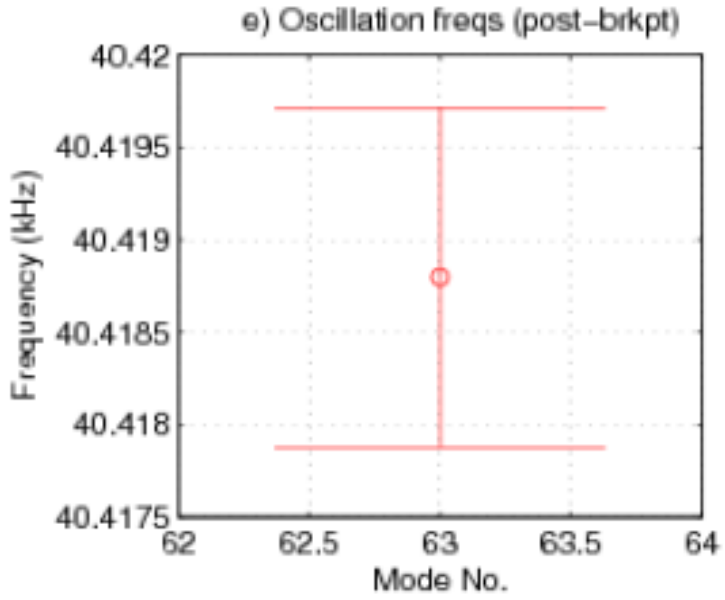


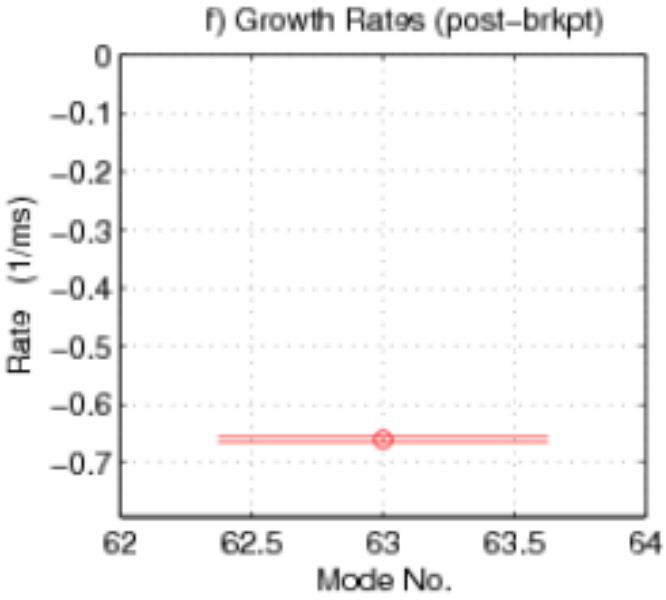
- Grow/damp at 182.4 mA;
- Growth rate of 0.1 ms^{-1} — growth time of 10 ms;
- Fast damping of 0.66 ms^{-1} (1.5 ms damping time);
- Eigenmode 63 is unstable;
- 50+ data sets to analyze at currents from 135 to 182 mA.

Courtesy J.H. Yue and D. Teytelman



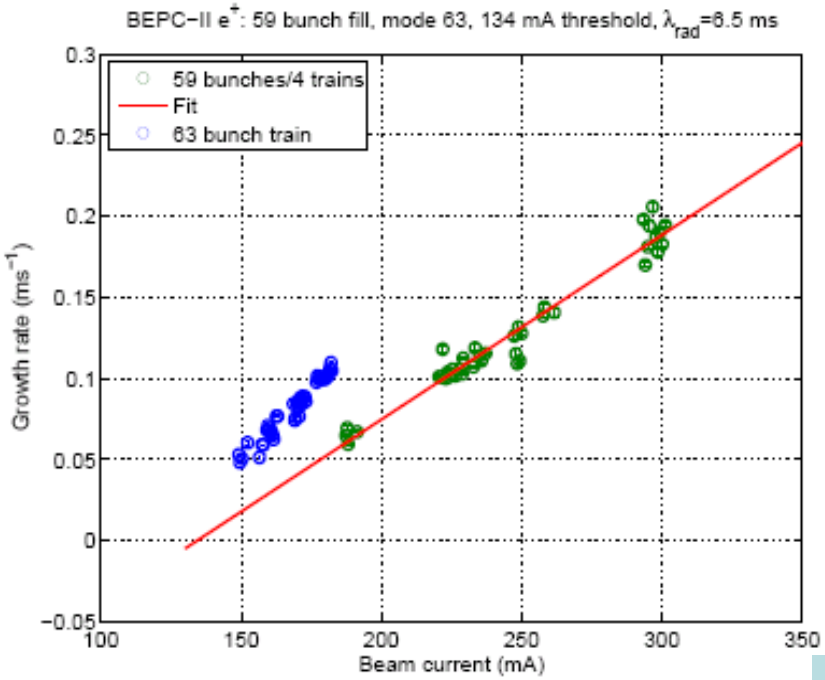






Courtesy J.H. Yue and D. Teytelman

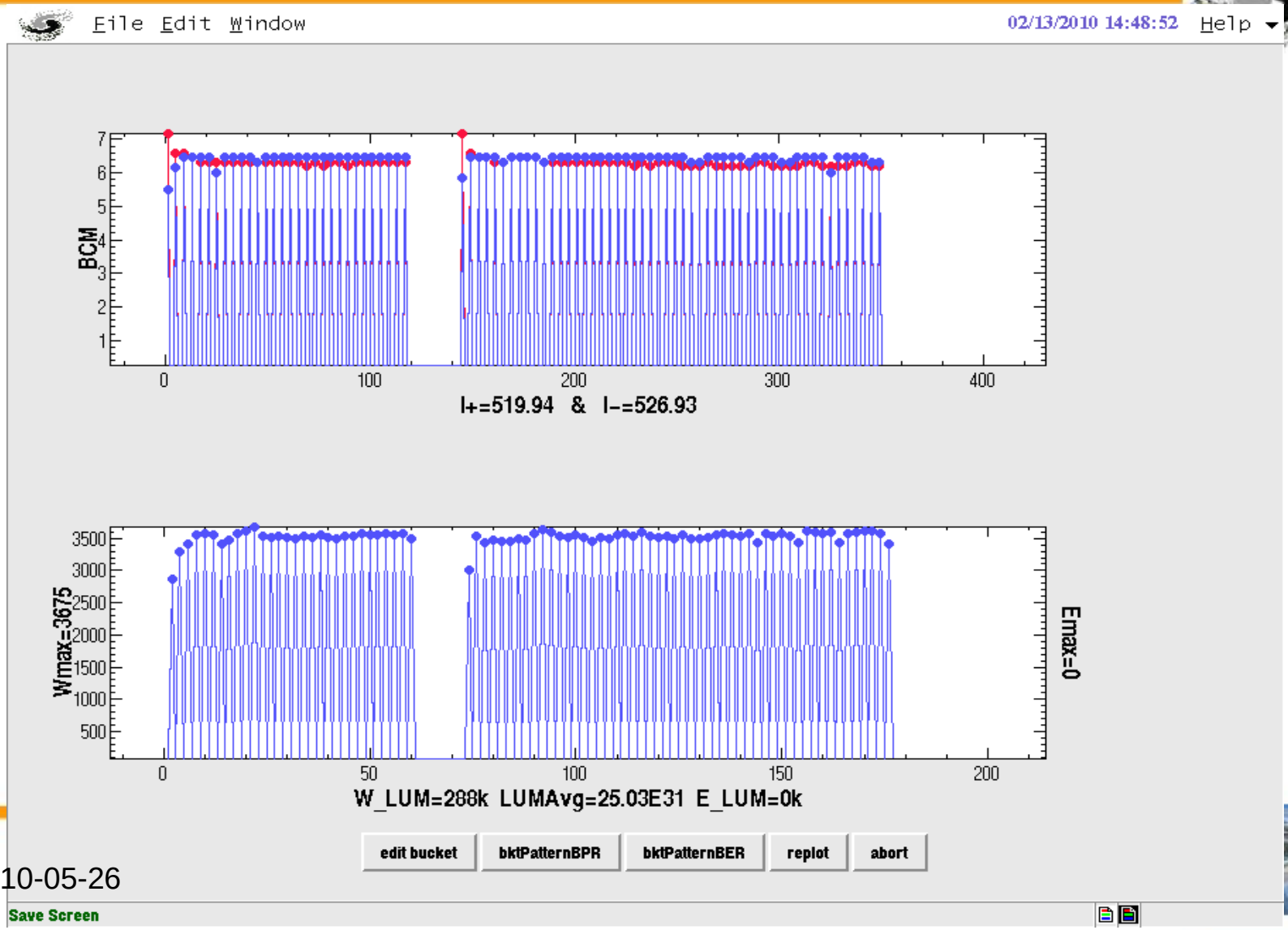
Growth Rates: e^+ (Continued)



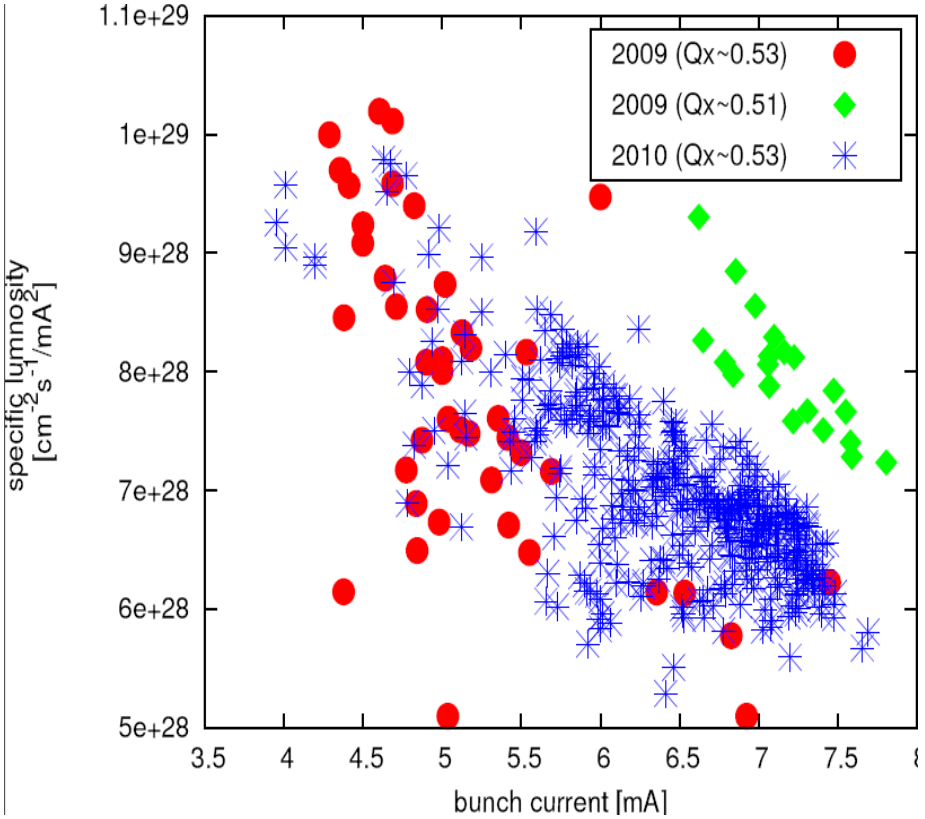
- Four trains, 59 bunches total;
- Threshold estimated quite nicely;
- Extrapolate to 0.98 ms^{-1} at 1 A;
- Clear difference from one train fill pattern.

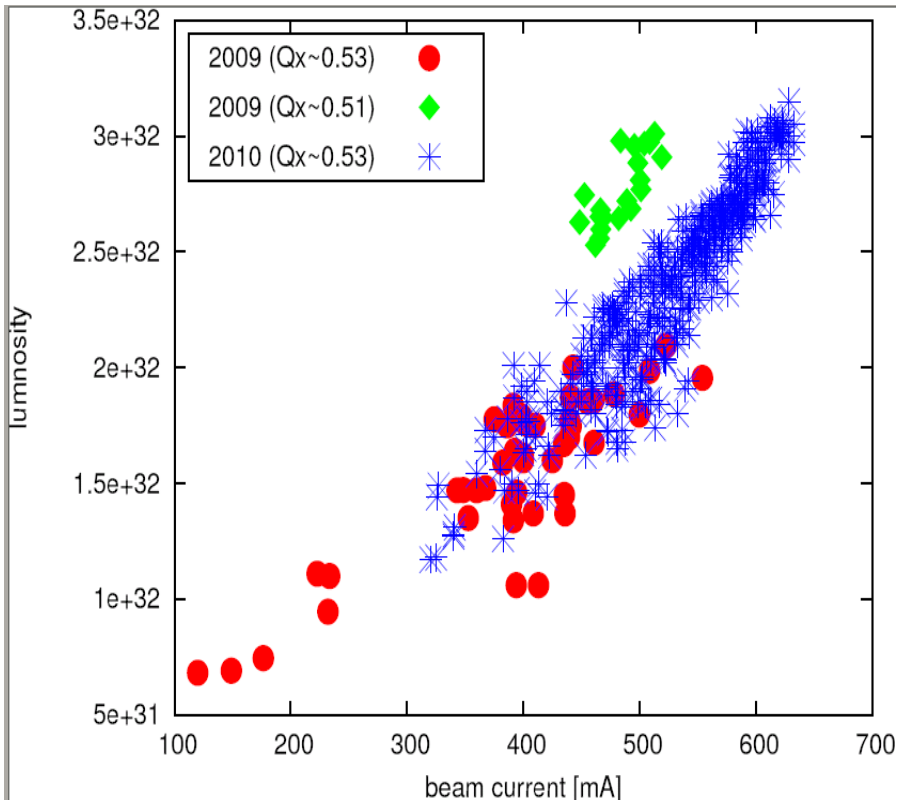
Courtesy J.H. Yue and D. Teytelman

Effect of longitudinal feedback

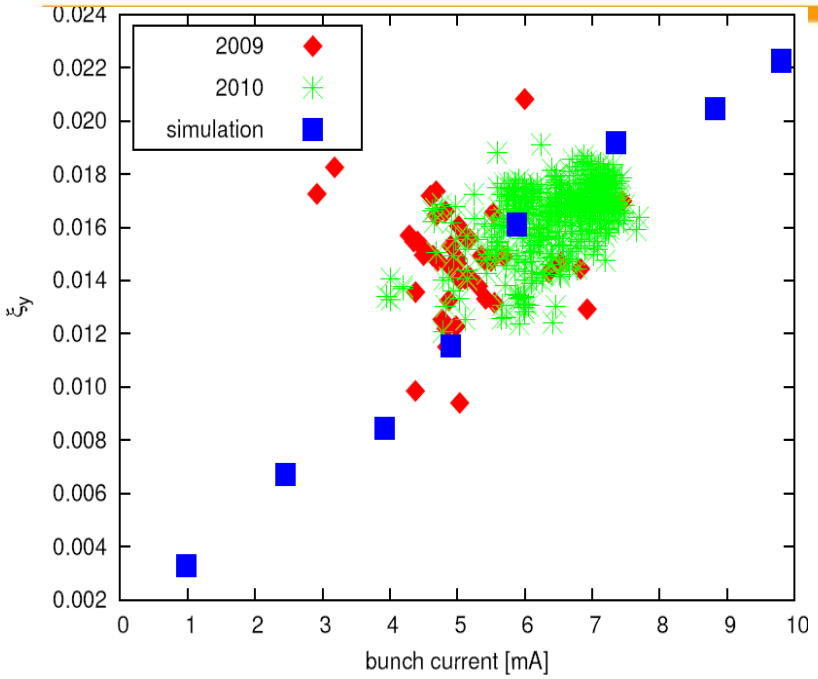


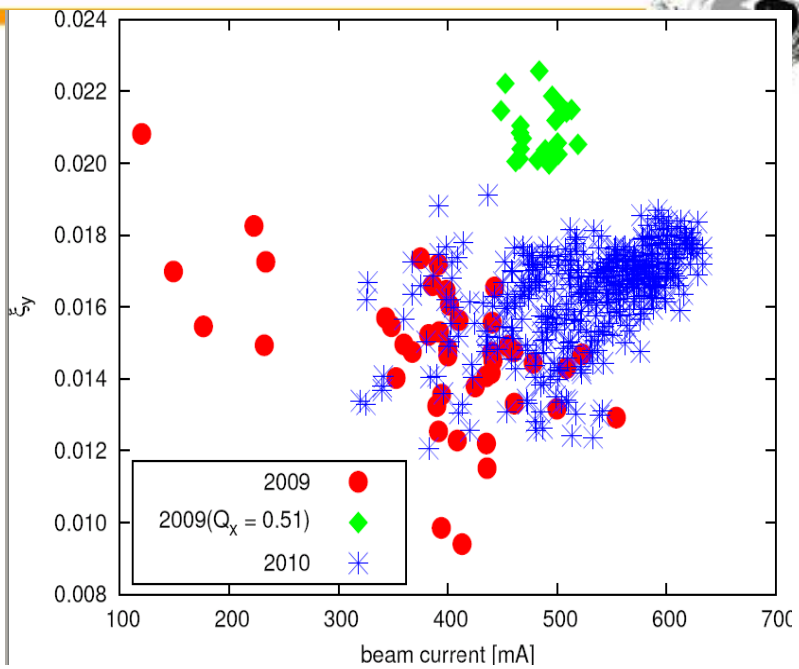
Beam-beam Issue





Achieved beam-beam limit





Reasons of beam-beam limit:

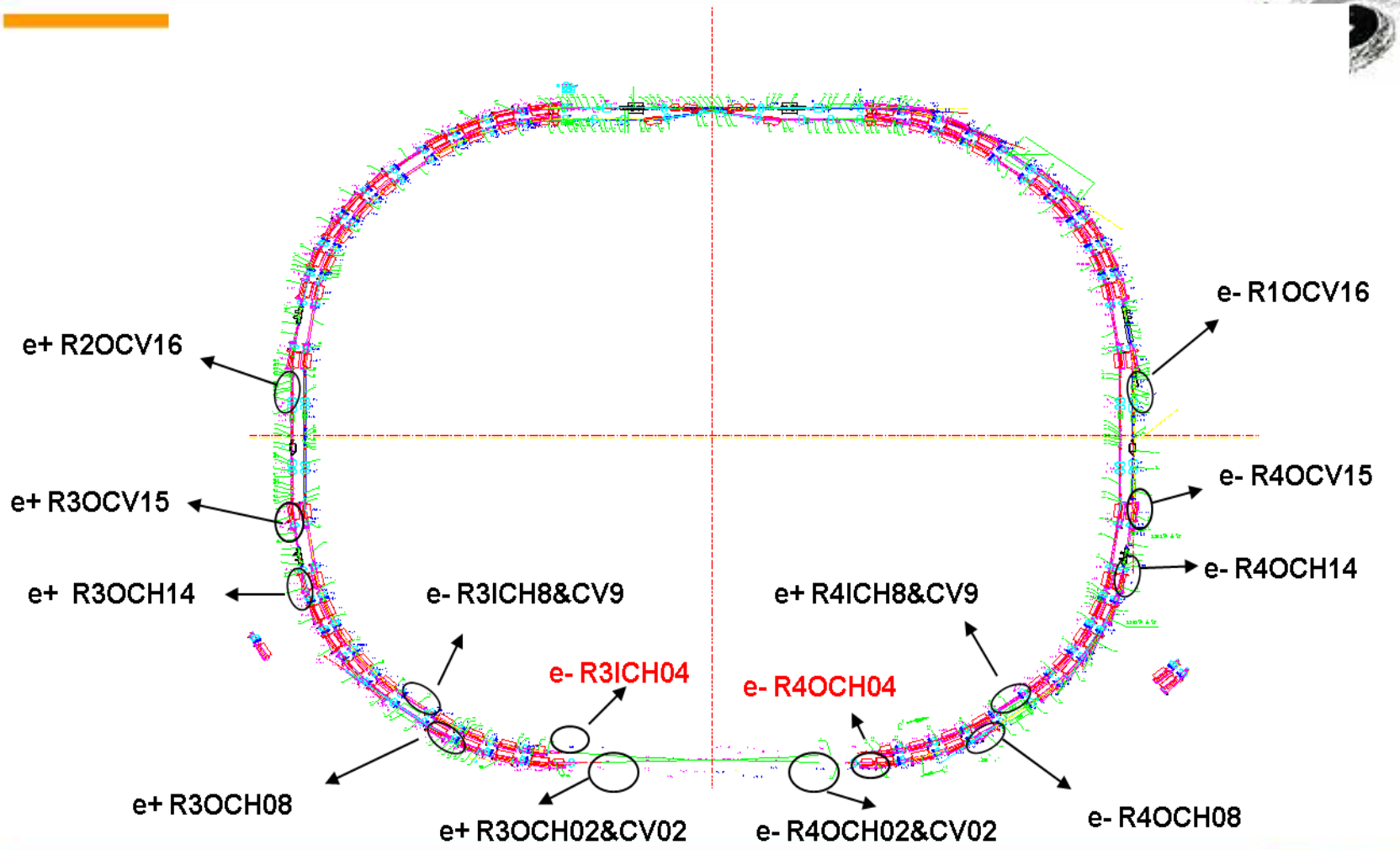
- **Crossing angle at the IP (11mrad×2)**
- **Not high bunch current (9.8mA in design)**

Problems met during luminosity commissioning

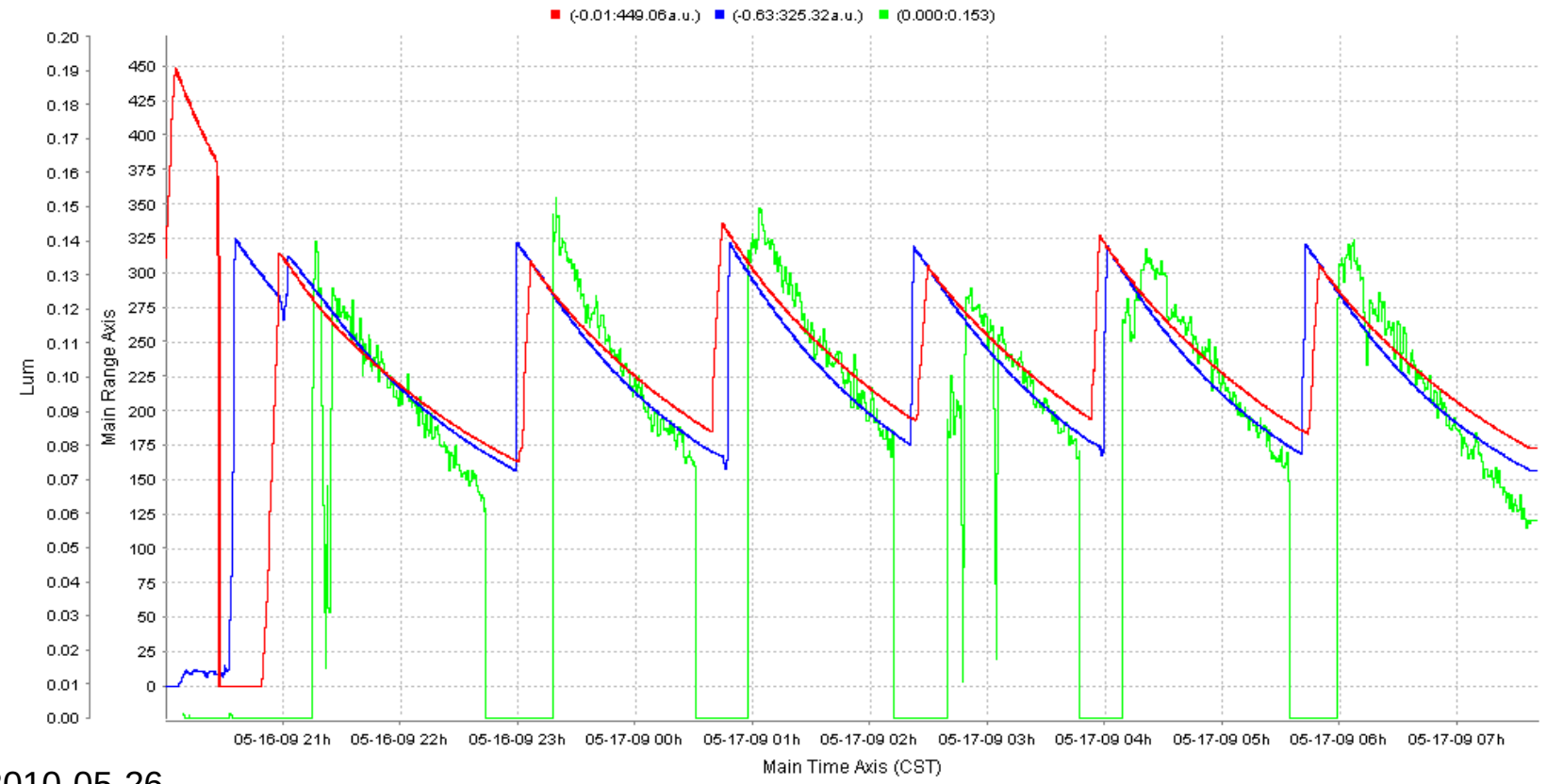
Background of detector

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

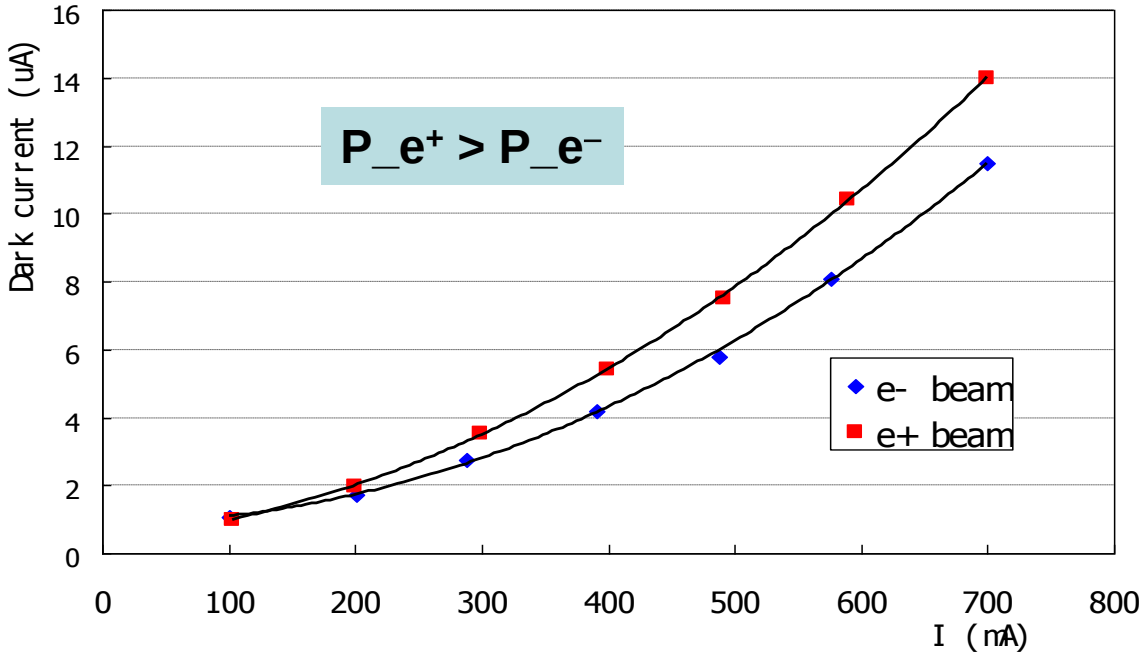
New masks installed last summer to reduce background



- **Data taking @ E=1.84GeV, ψ(s)**
- **Higher dark current for high beam current @ ν_x~0.51**



Detector dark current measurement

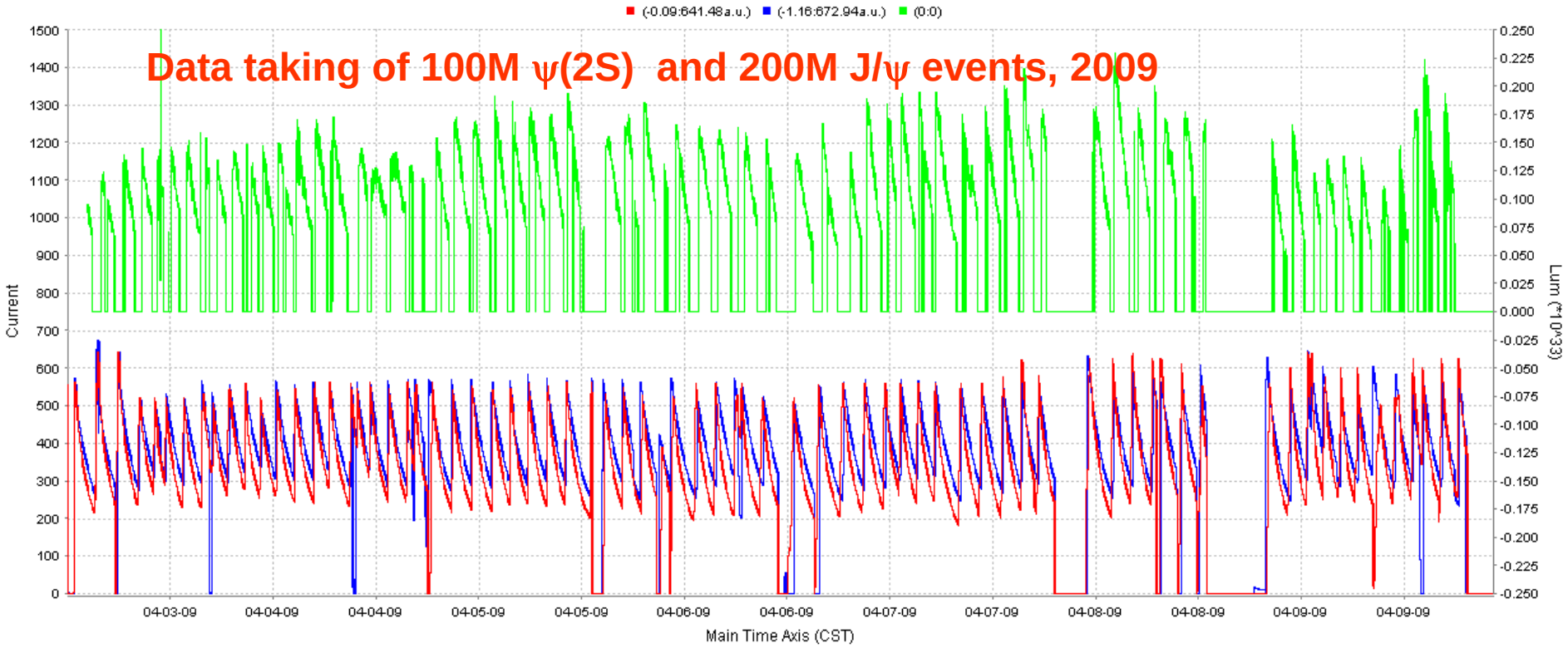


Source of background:

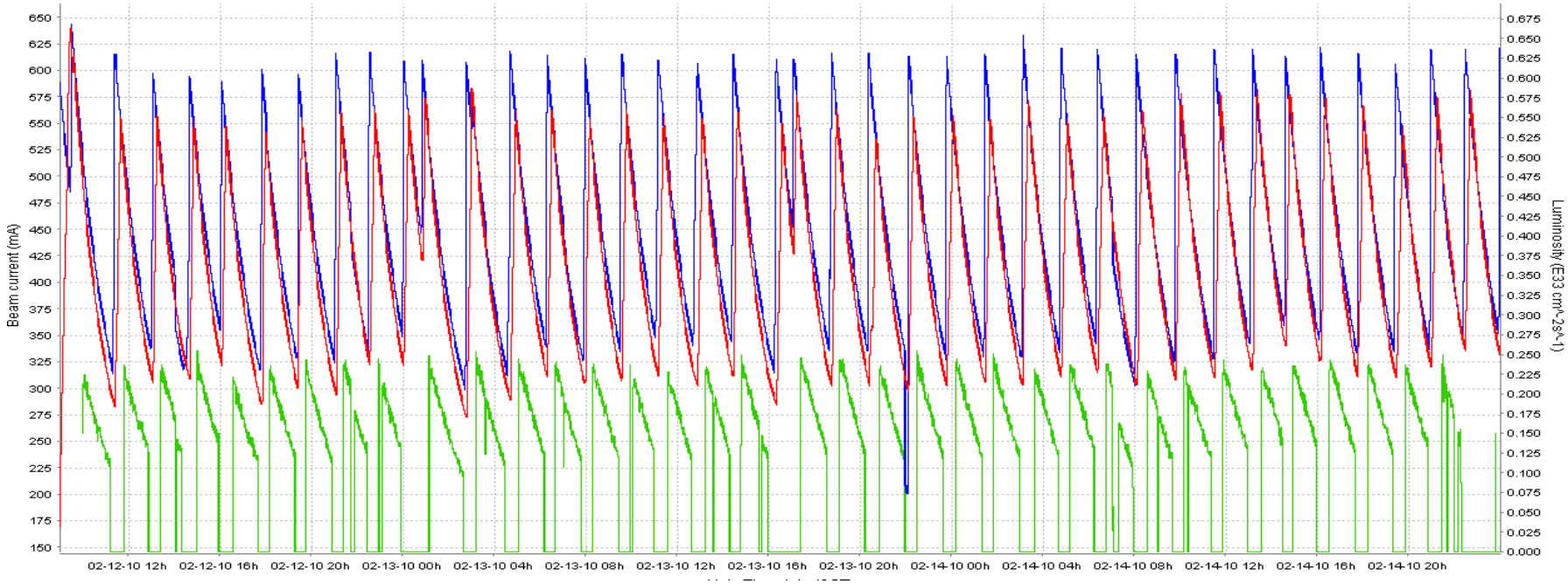
- **Beam-gas scattering --- vacuum needs to be improved**
- **Touschek scattering --- beam optics needs to be modified**
- **Other sources?**

4. Operation of BEPCII

- **Running for HEP (ψ(2S) , J/ψ, ψ(3770))**



Running at ψ(3770) in 2010, aiming at 1 fb^{-1}



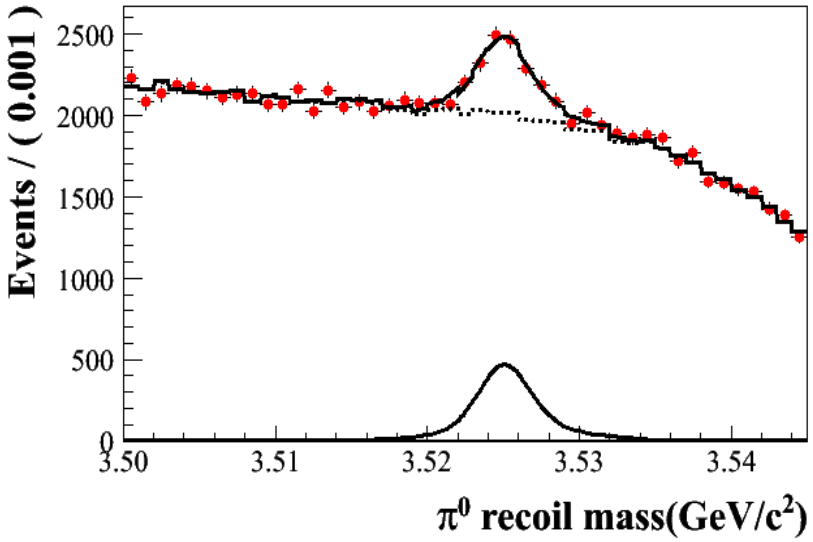
Primary physics results of BESIII

- **Confirmation of BESII results**
  - threshold enhancement γppbar, γωϕ, X(1835), …
- **New improved measurements**
  - h_c, η_c, χ_{cJ}, , …
- **New observations**
  - χ_{cJ} decays
  - h_c decays
  - Light hadrons, …

Three papers published

Many in memo stage

Observation of h_c in $\psi(2S)\rightarrow\pi^0 h_c, h_c\rightarrow\gamma\eta_c$



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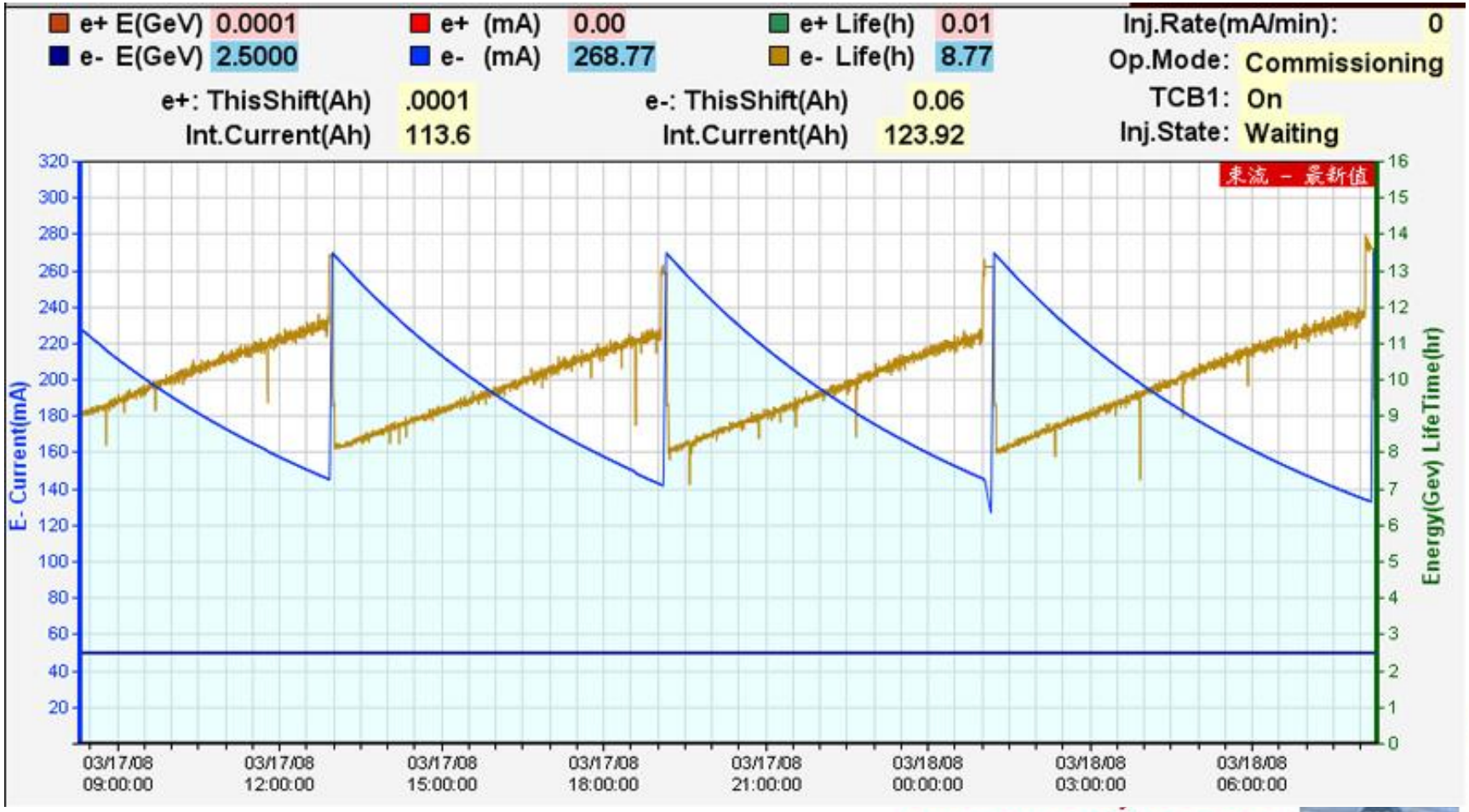
Courtesy Y.F. Wang

- **Running for SR**

➢ **Dedicated SR mode**



- **Running with parasitic mode**

➢ Beam collision with a wiggler on

➢ Luminosity tuning with the wiggler on

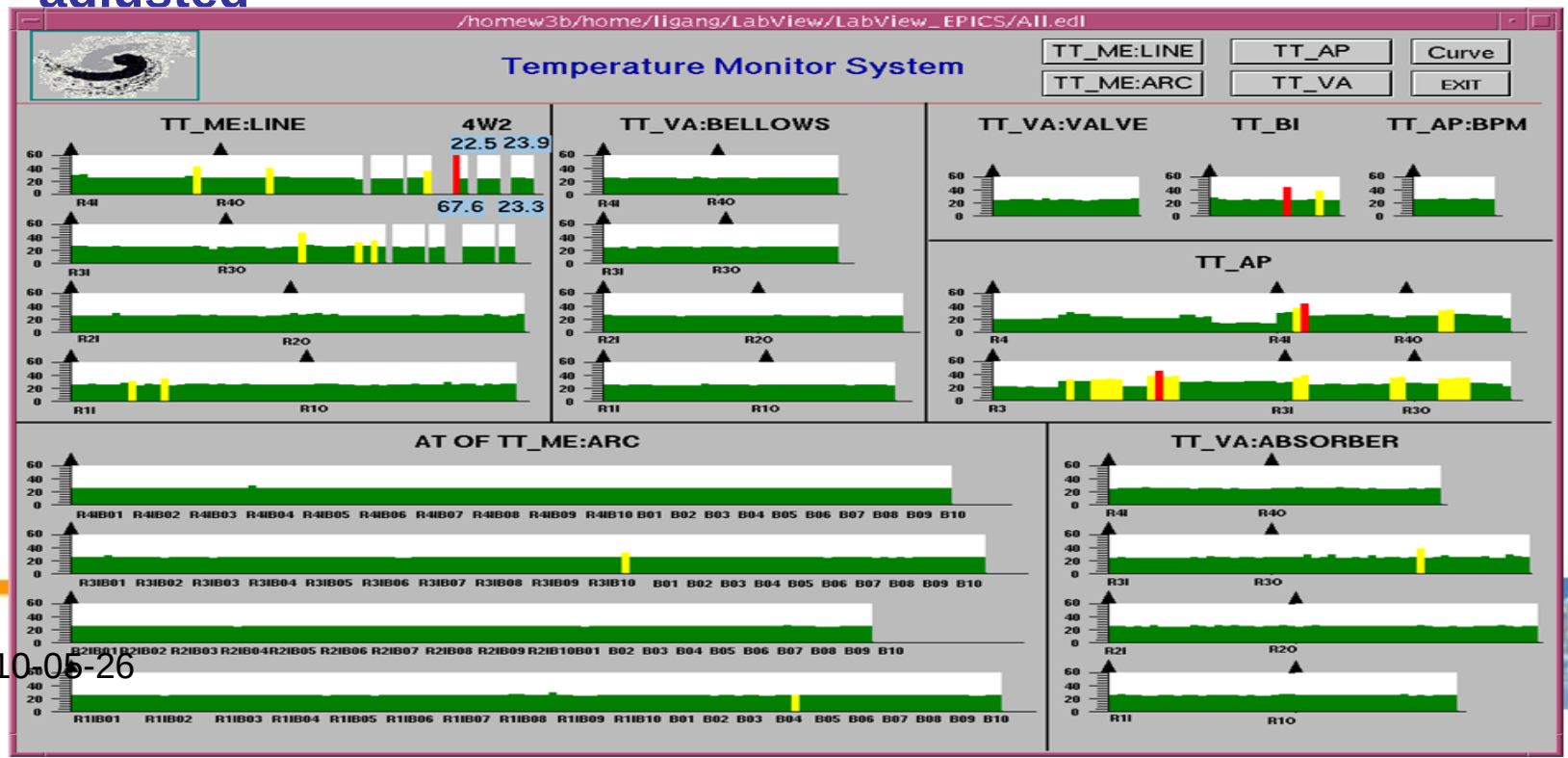
➢ **Deliver beam to HEP and SR users simultaneously!**

HOMs heating problem

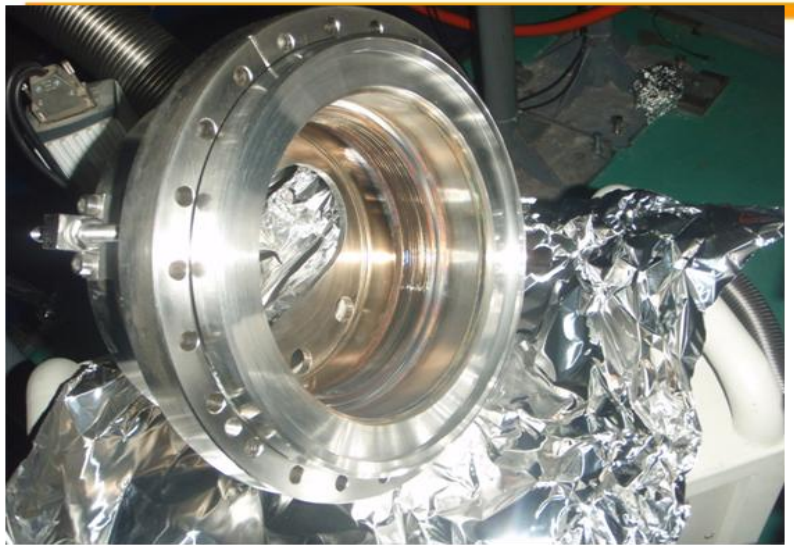
1) More than 1000 thermal couplers used

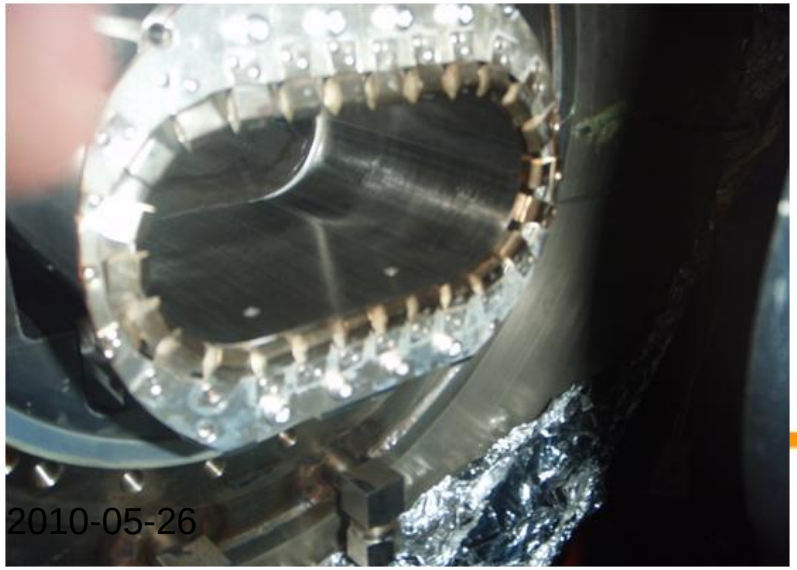
2) Display in colour according dangerousness: green, yellow and red.

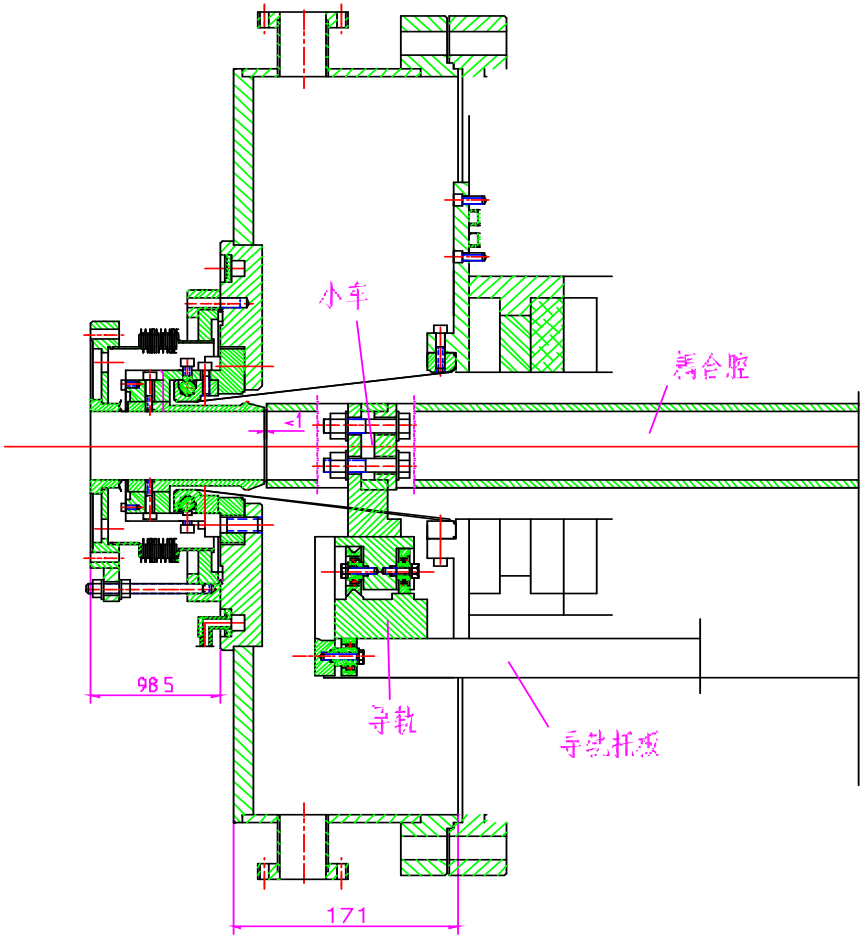
3) In most case, the temperature rise (SR) => flux of cooling water adiusted



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



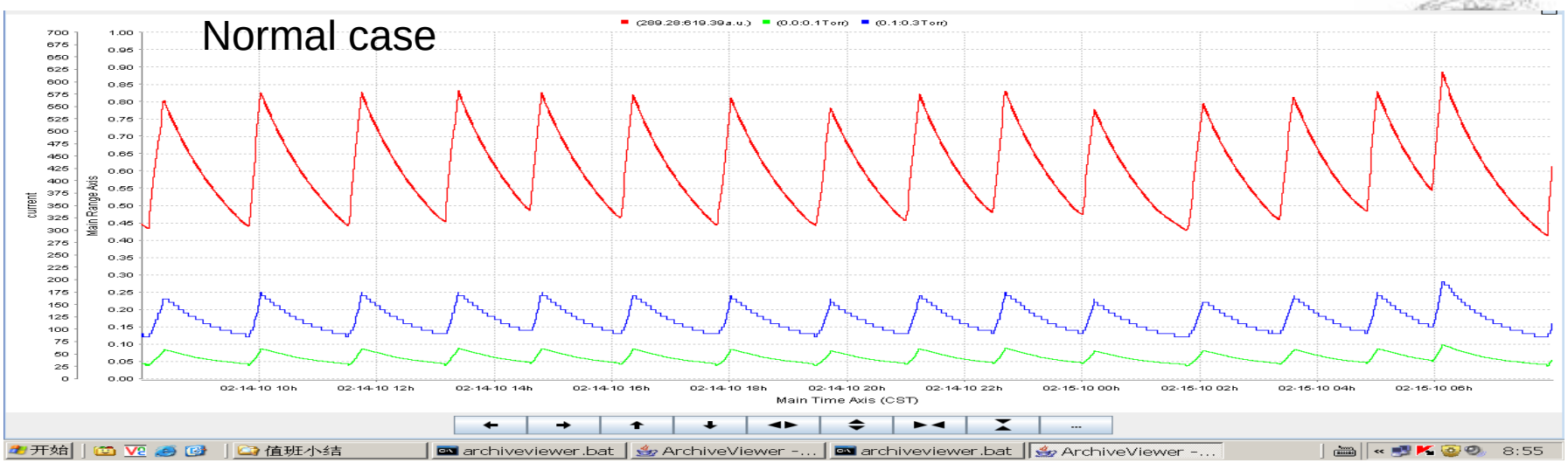


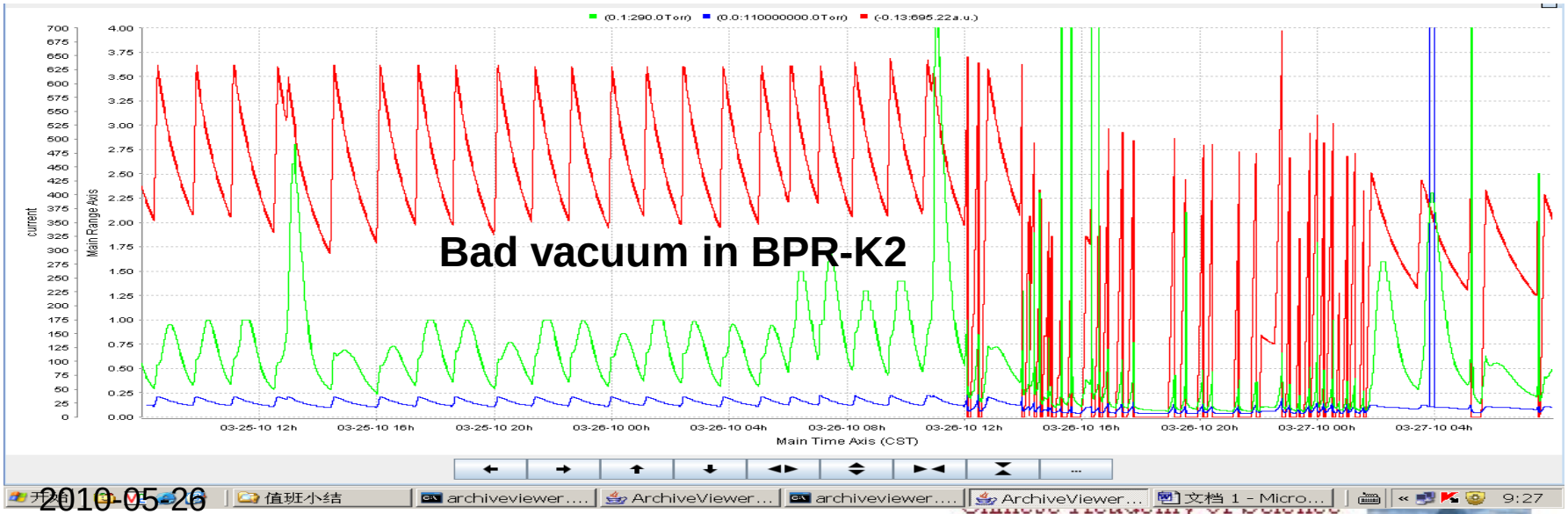


2010-05-26

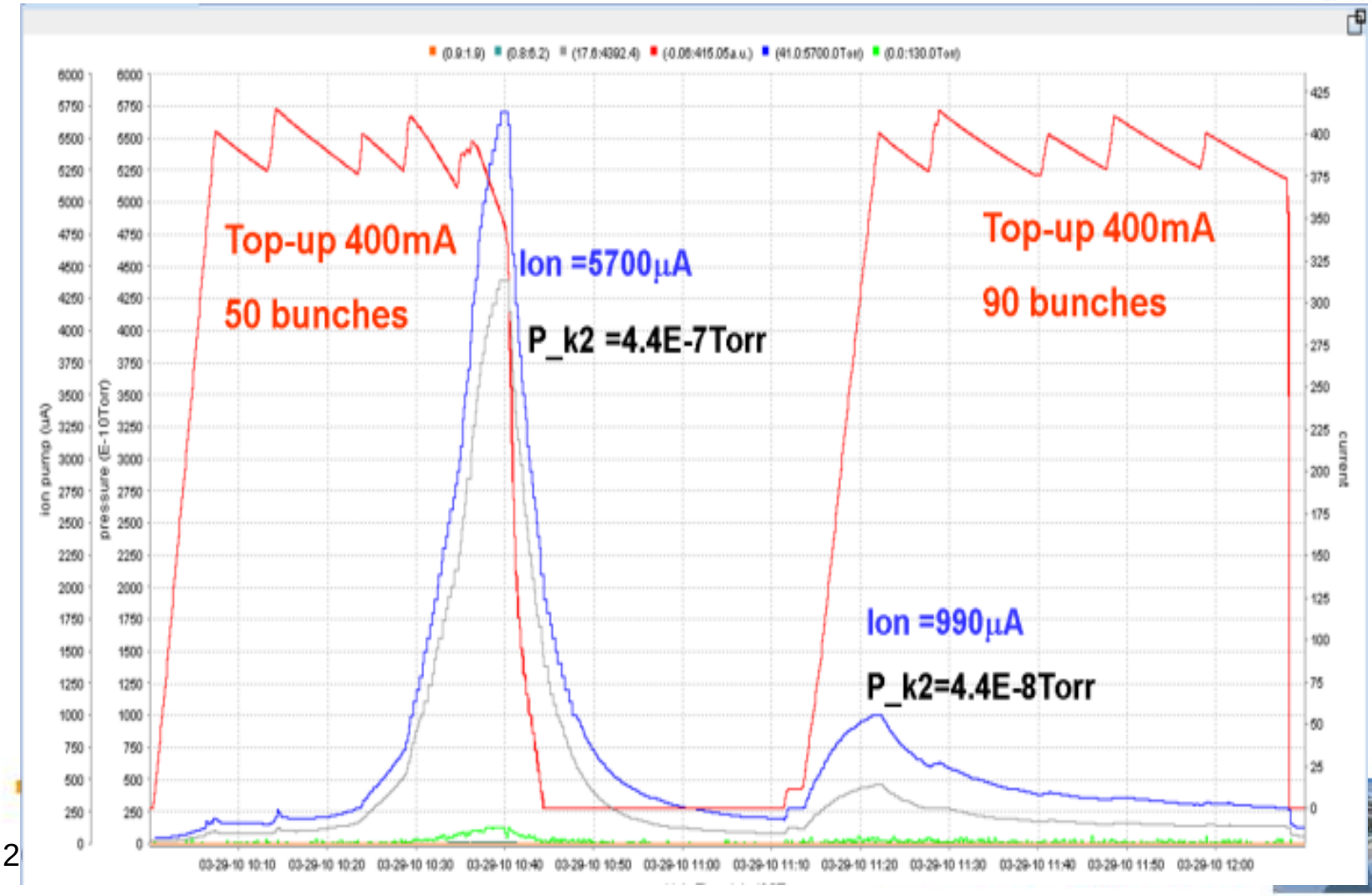
- Replace the new bellows
- Re-design the RF fingers of the shielding
- Cooling water and wind for the new bellows
- Restrain the bunch current and beam current (I_b<6mA, ΣI < 550mA)

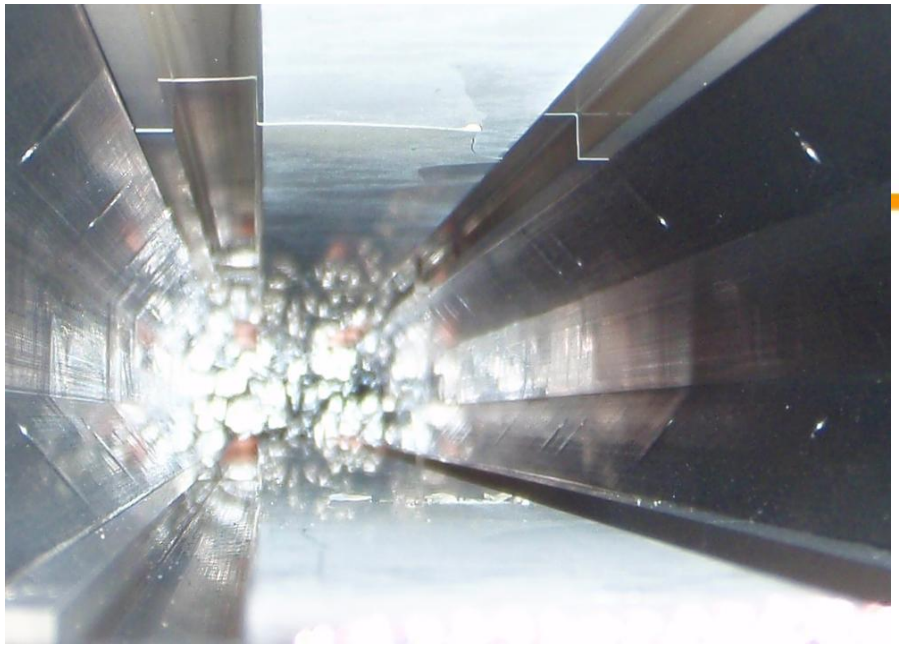
Kicker problem (ceramic board broke in Mar. 2010)

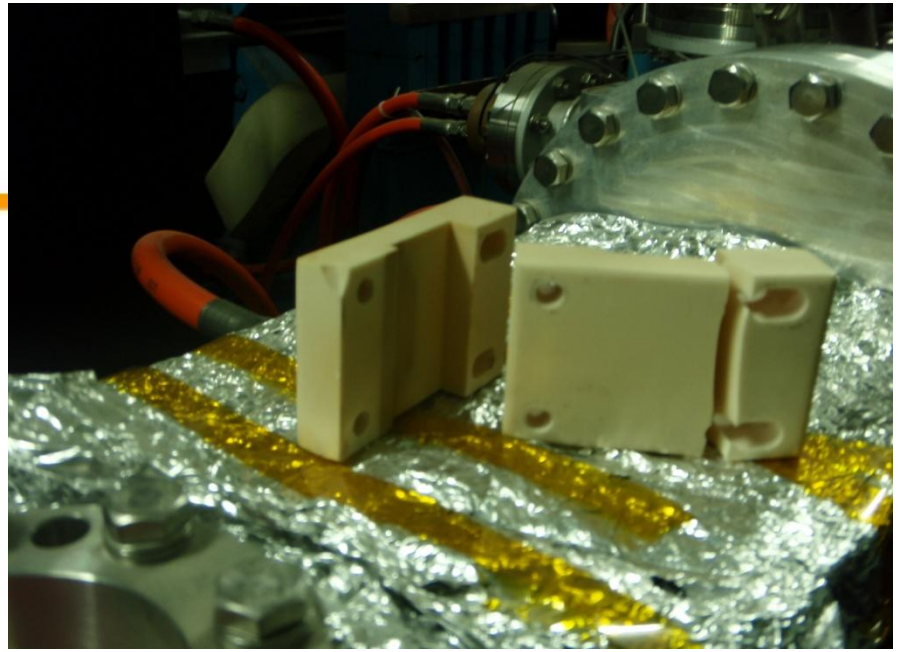


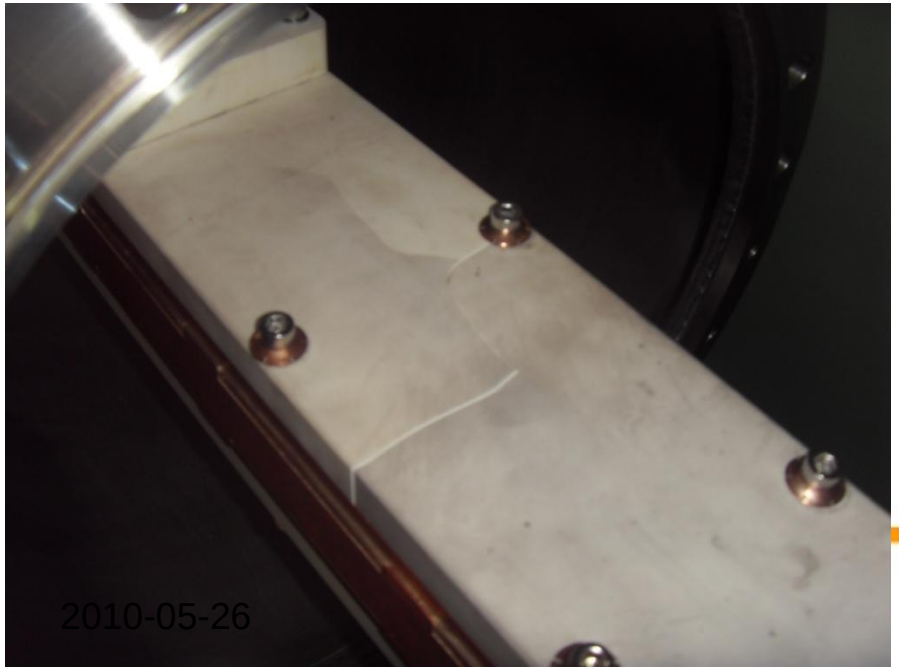


- Beam experiment to determine the problem








2010-05-26

5. Discussions and Summary

- **Commissioning and more stable running of Linac are necessary.**
- **1/3 of the design luminosity reached, further studies are needed.**
- **The dark current of detector limits the beam current right now, and needs to be improved.**

◆ To enhance luminosity

- **Normal measures:**

✓ **Increase bunch current, beam current**

✓ **Shorten bunch spacing, to get more bunches**

✓ **Squeeze β_y***

✓ **Tunes closer to half integers**

Possible peak luminosity: L ~ 4 – 5×10^{32}cm^{-2}s^{-1}

Issues on the ways 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? Other solutions?)**

✓ **Budget**

✓ **Other problems…**

Acknowledgement

- Commissioning team of BEPCII
- Colleagues from BNL, LBNL, INFN-LNF, KEK, and SLAC
- All others from labs around world…

Thanks for your attentions!