Status of BEPCII
(Mar, 2012)

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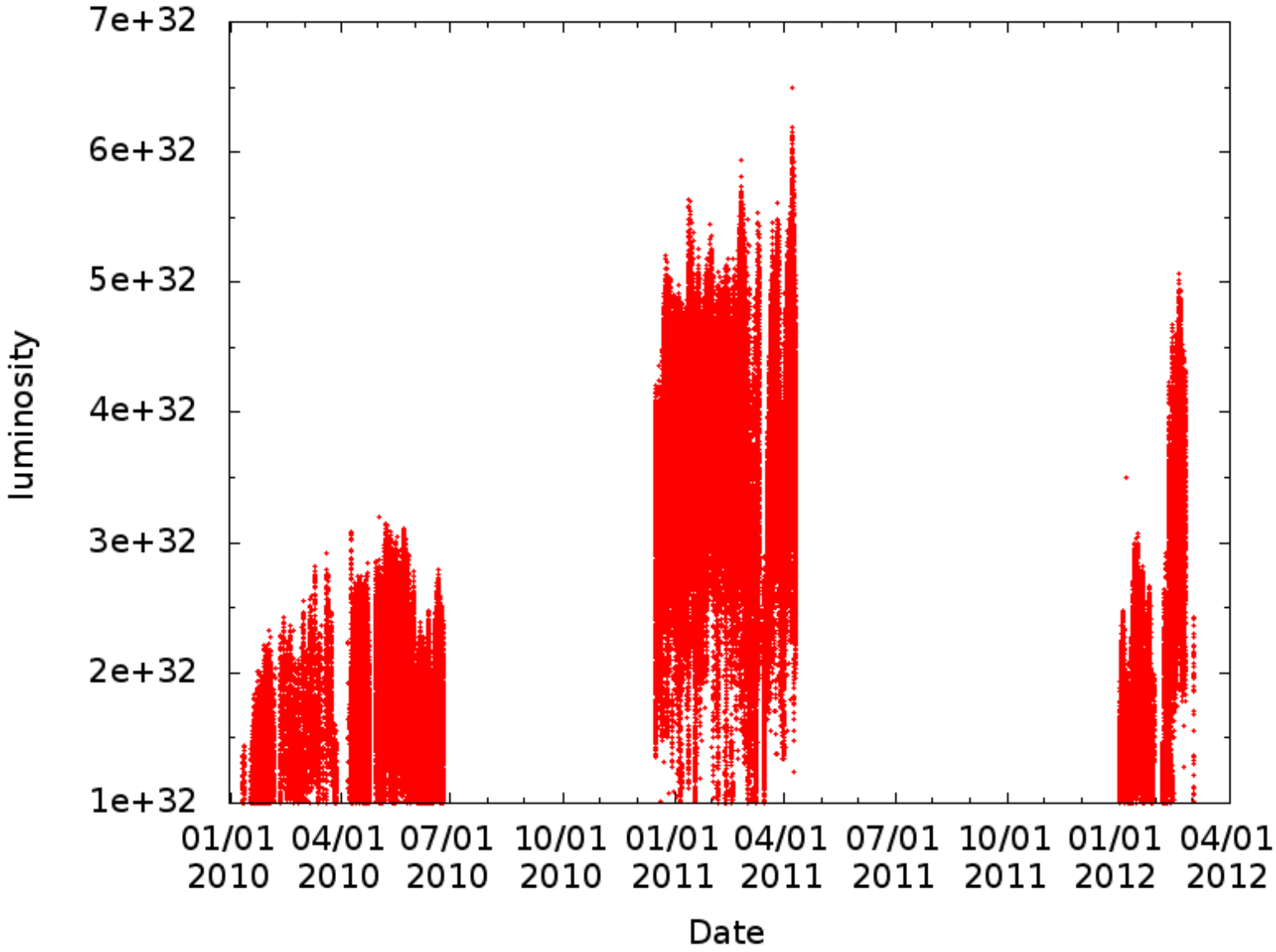
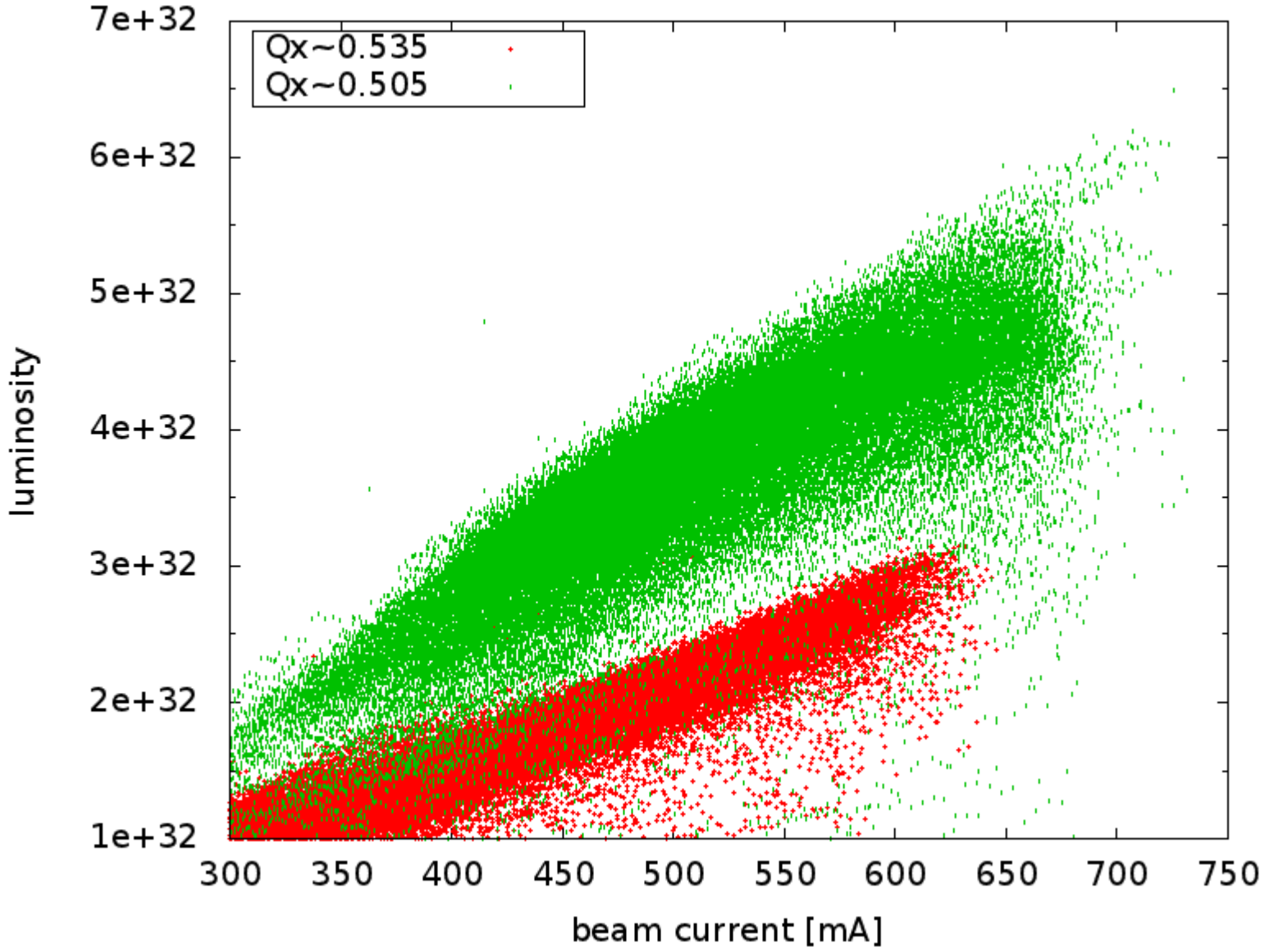
Outline

- Performance
- Optics Correction
- Beam-Beam Limit
- Hardware fault

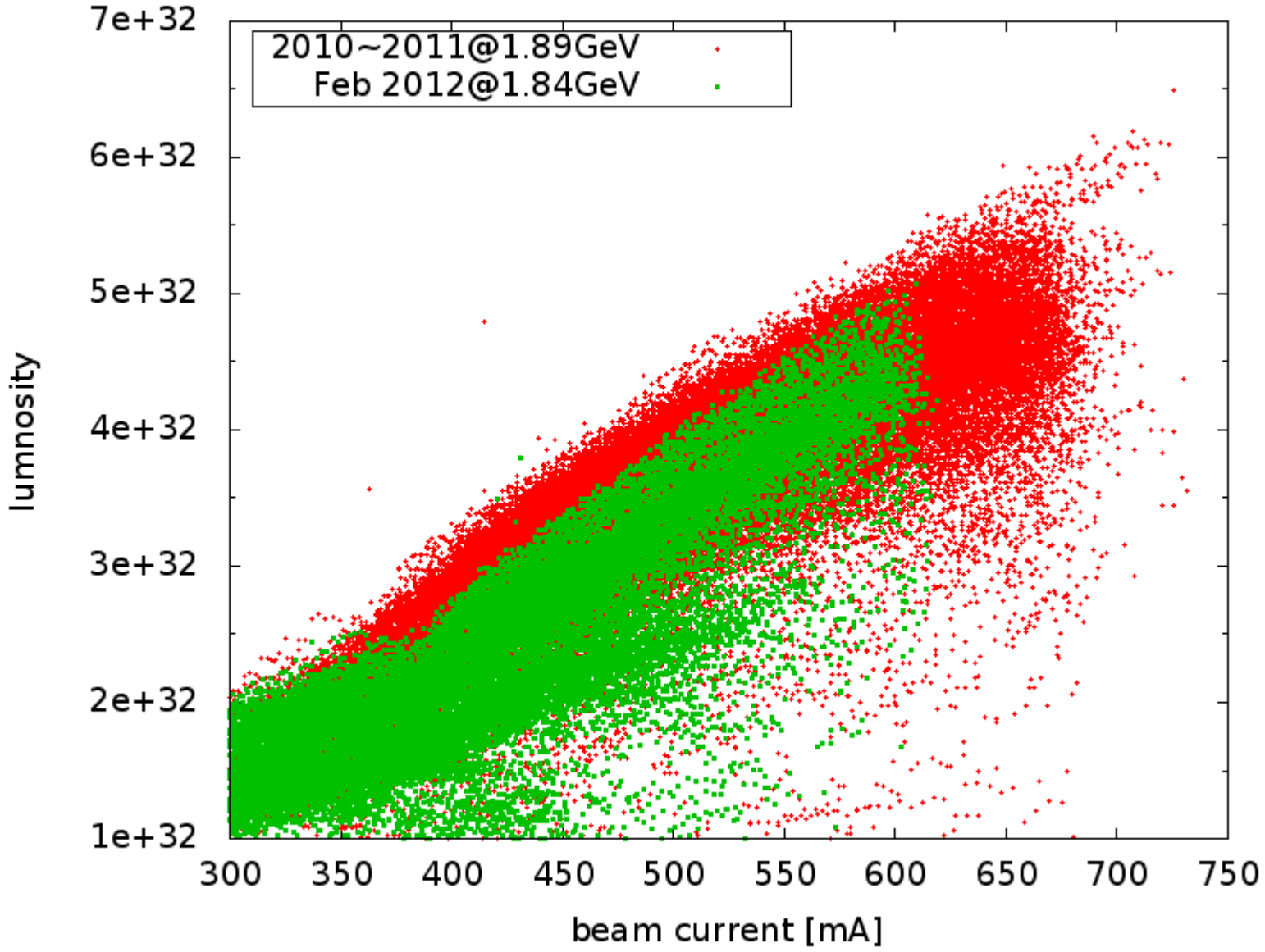
Luminosity History



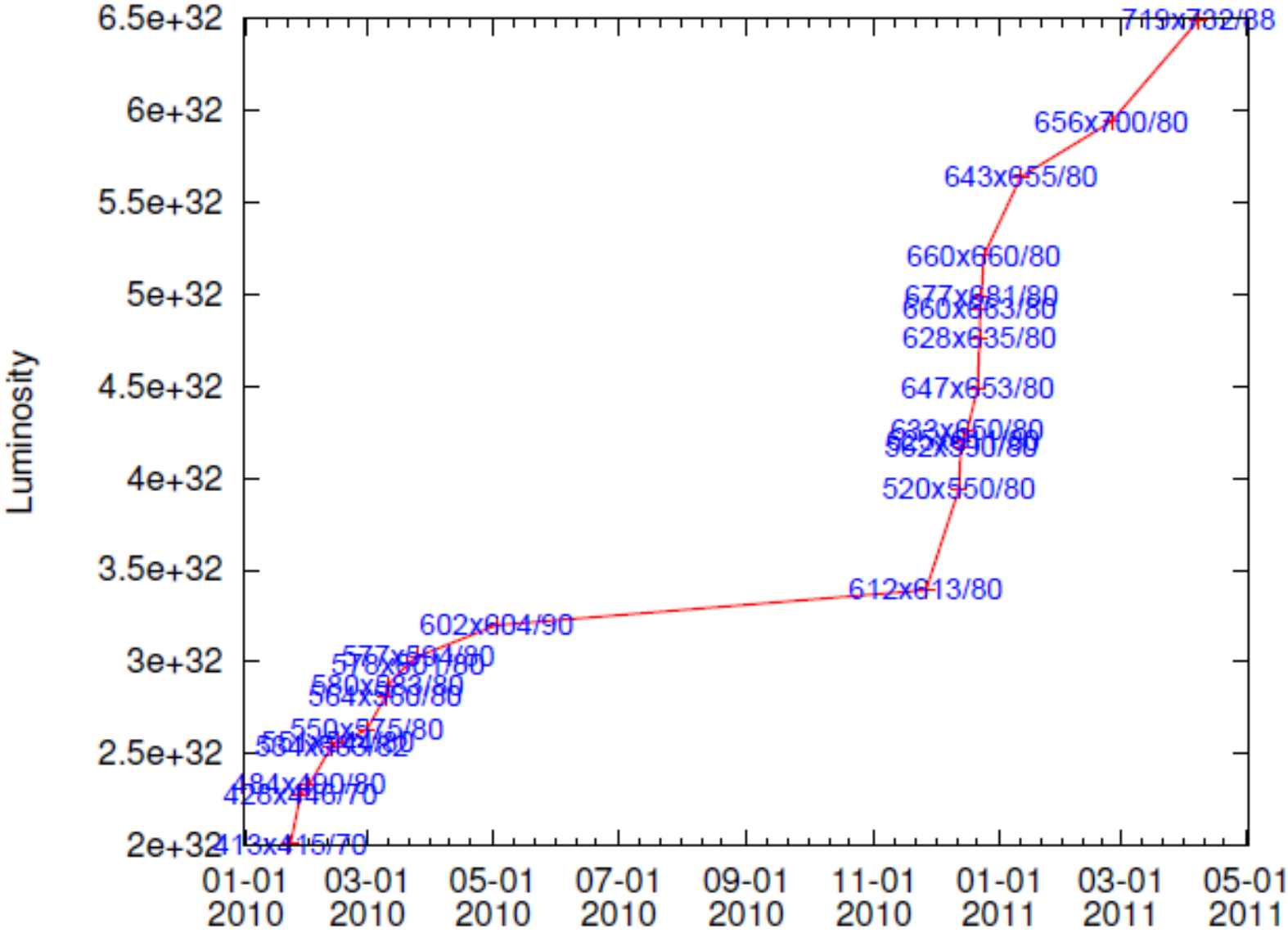
Luminosity versus Beam Current



2011 vs 2012


2010~2011@1.89GeV
Feb 2012@1.84GeV
lumnosity
7e+32
6e+32
5e+32
4e+32
3e+32
2e+32
1e+32
300
350
400
450
500
550
600
650
700
750
beam current [mA]

Peak Luminosity Records



Beam-Beam Parameter

- the achieved beam-beam parameter ξ with collision is defined as

$$\xi_u = \frac{N r_e}{2\pi\gamma} \frac{\beta_u^0}{\sigma_u(\sigma_x + \sigma_y)}$$

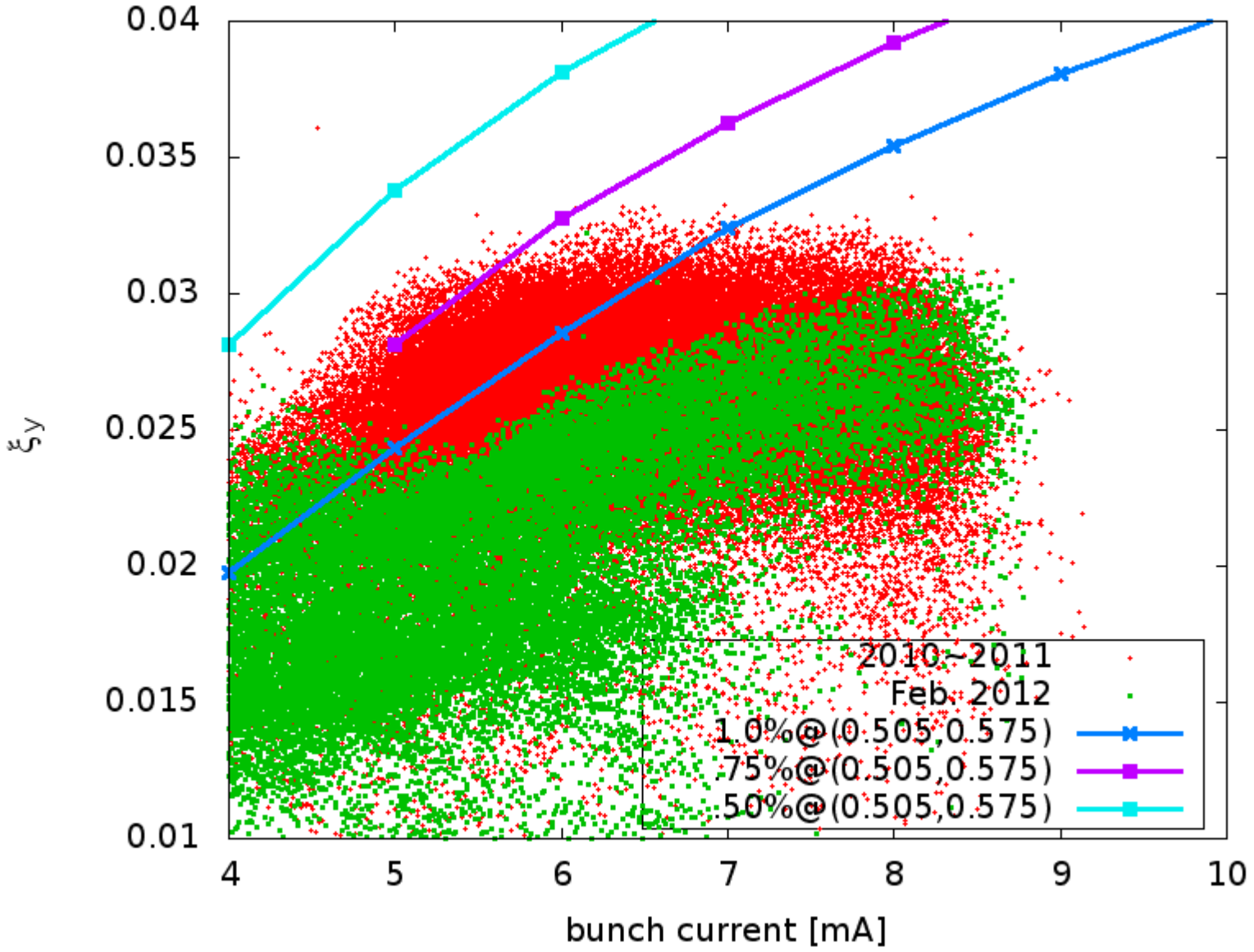
  where β^0 is nominal beta function without collision, and σ is disturbed beam size with collision.
- Do not consider the finite bunch length and finite crossing angle, the bunch luminosity can be represented as

$$L = \frac{N^2 f_0}{4\pi\sigma_x\sigma_y}$$

  where σ is disturbed beam size with collision.
- when beam $\sigma_y \ll \sigma_x$, the achived ξ_y can be represented by lum,

$$\xi_y = \frac{2 r_e \beta_y^0}{N\gamma} \frac{L}{f_0}$$

Beam-Beam Performance



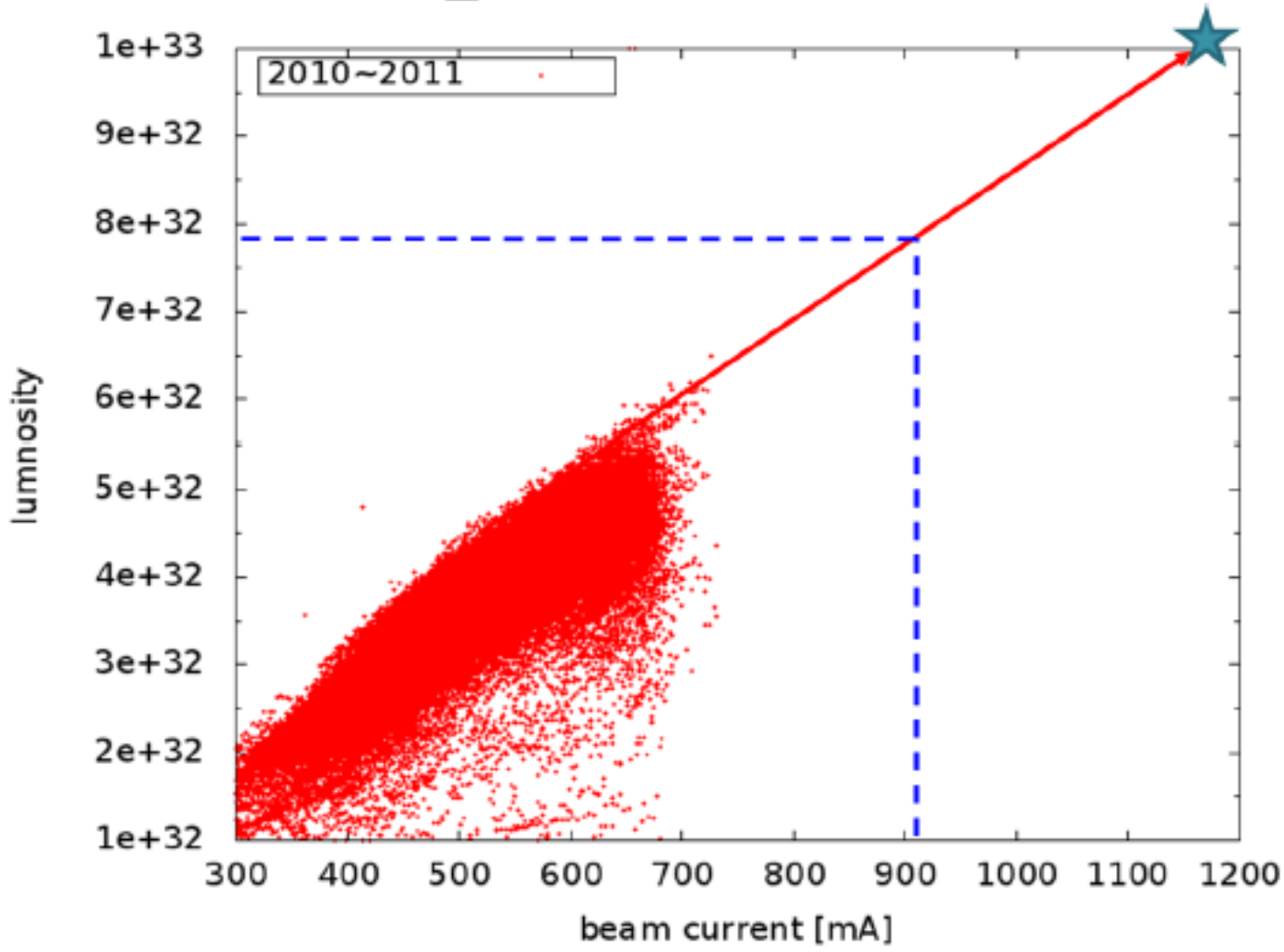
Luminosity Tuning Knobs

Most Frequently Used Knobs:

- transverse collision orbit: x,x',y,y'
- transverse tunes: it seems that it is easier to optimize luminosity when the horizontal tune is closer to half integer, since the high luminosity tune region is much narrower near $\nu_x \sim 0.508$ that that 0.535 :)
- local coupling @IP: four skew quadrupoles in the arc where is dispersion free
- another coupling knob: vertical local bump in some sextupoles (not dispersion free)
- yet another coupling knob: global vertical orbit tuning to minimize the vertical emittance by reduce $\overline{C}_{12}$ at BPMs
- we've to change the horizontal orbit during the decay of beam current in most cases but not all. the maximum offset is about 0.1mm. the causes is not known :(

If we want to achieve 1.0e33 for peak luminosity

- I_b=8.2mA, N_b=140, $\sum I$ = 1150mA, $\mathscr{L} = 1.03 \times 10^{33} cm^{-2} s^{-1}$



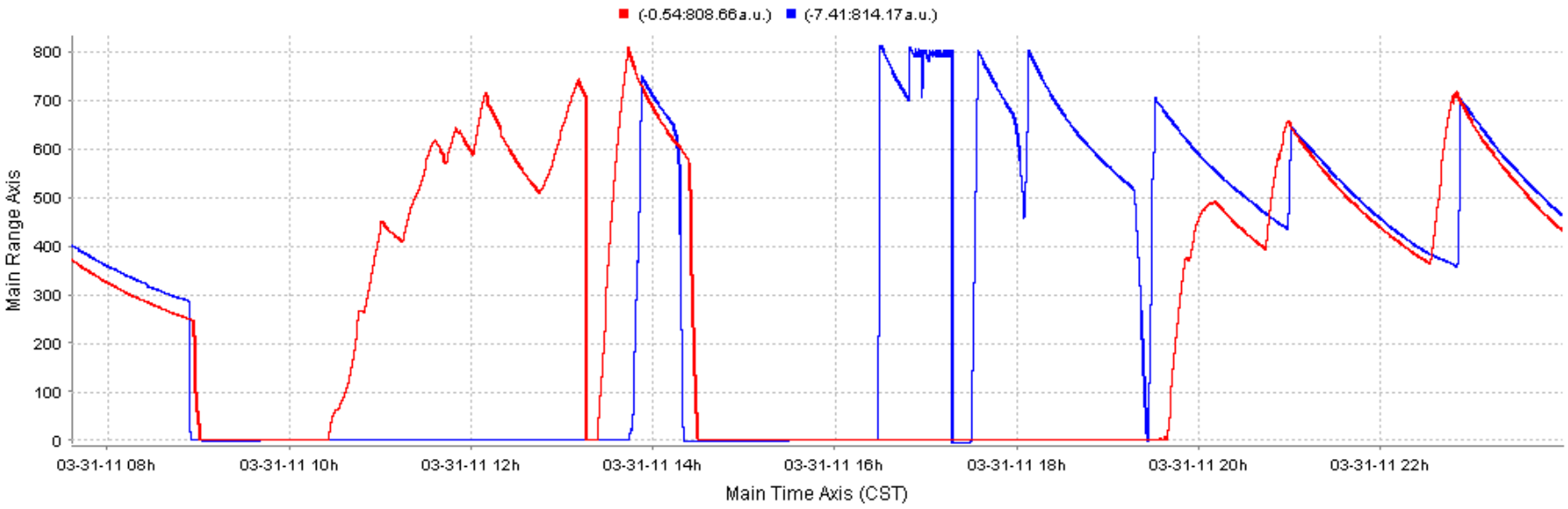
If we want to achieve 1.0e33 for peak luminosity (cont.)

- smaller β_y^*, shorter bunch length
  (smaller α_p, RF maybe also help), $\xi_y = 0.0325$

$$\mathscr{L}[cm^{-2}s^{-1}] = 2.17 \times 10^{34}(1+r)\xi_y \frac{E[GeV]k_b I_b[A]}{\beta_y^*[cm]}$$

	Coupling	β_y^* (cm)	I_b(mA)	N_b	ΣI(mA)	Lum. ($cm^{-2}s^{-1}$)
Case 1	0.01	1.5	8.2	140	1150	1.03×10^{33}
Case 2	0.01	1.3	8.2	120	980	1.02×10^{33}
Case 3	0.01	1.2	8.2	110	900	1.01×10^{33}

High Beam Current in 2011



- Highest beam current is 800mA/88bunches in both rings
- 750mA/88 bunches collide
- 600mA with 93/4, 124/3, 160/4 achieved

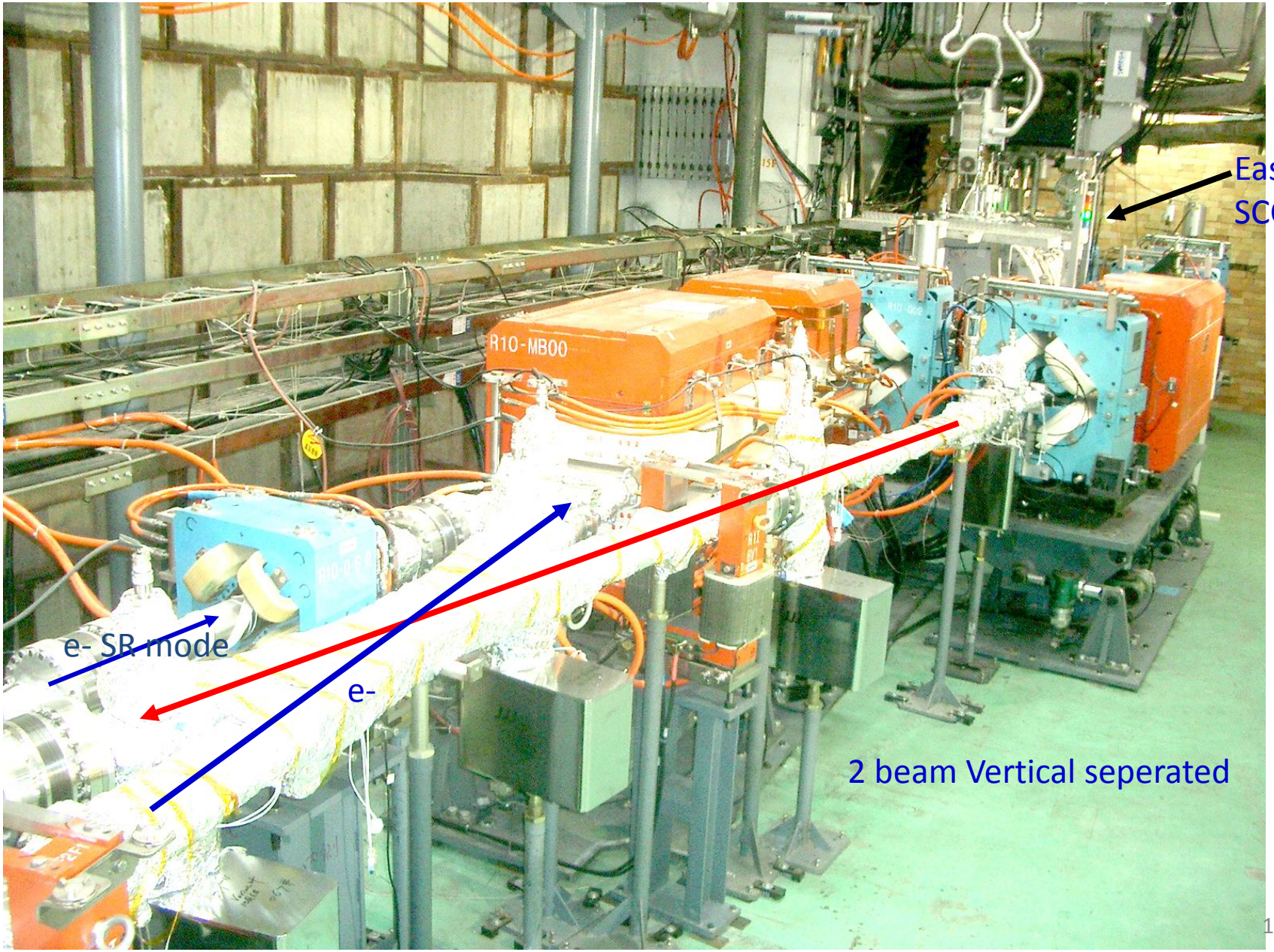
Helium gas pressure increasing with e-beam current of East SC under collision mode operation is still a serious problem!

East cavity	SR mode run	Collision mode	note
e- beam (mA)	480@2.0GeV	750@1.89GeV	West cav. no problem
Bunch number	160	88 Or 160	
Helium gas pressure (bar)	1.217	1.2510	Unknown heat of ~ 60W(collision)
RF power (kw)	~90	~100	
Vc (MV)	1.6	1.6	
GHe flow (g/s)	4.5	6.5	

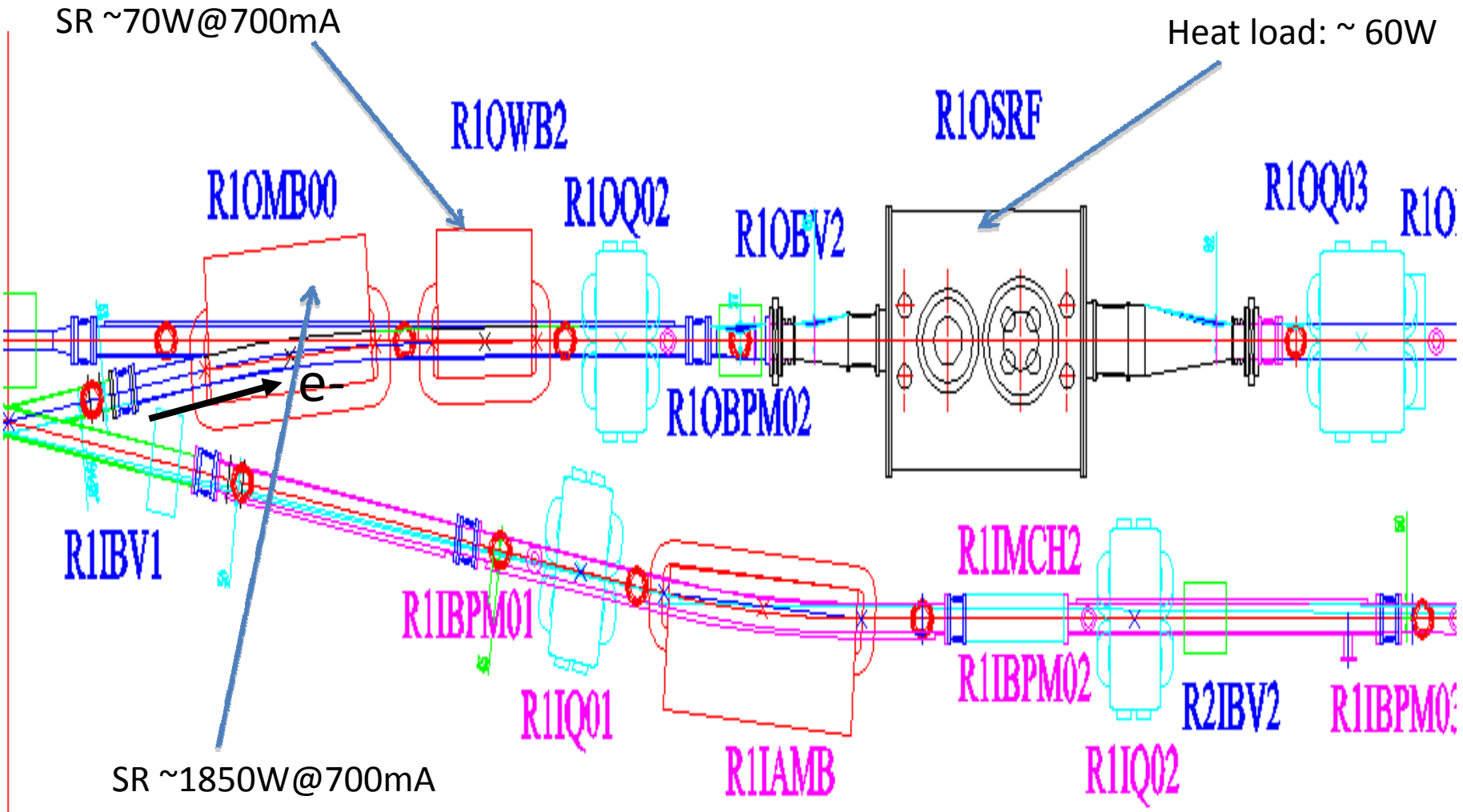
- There is no GHe pressure increasing during SR mode operation of East SC
- At collision mode : 1.21bar –300mA, 1.25bar—750mA

  GHe pressure is increased with beam current, no matter 80 or 160bunches

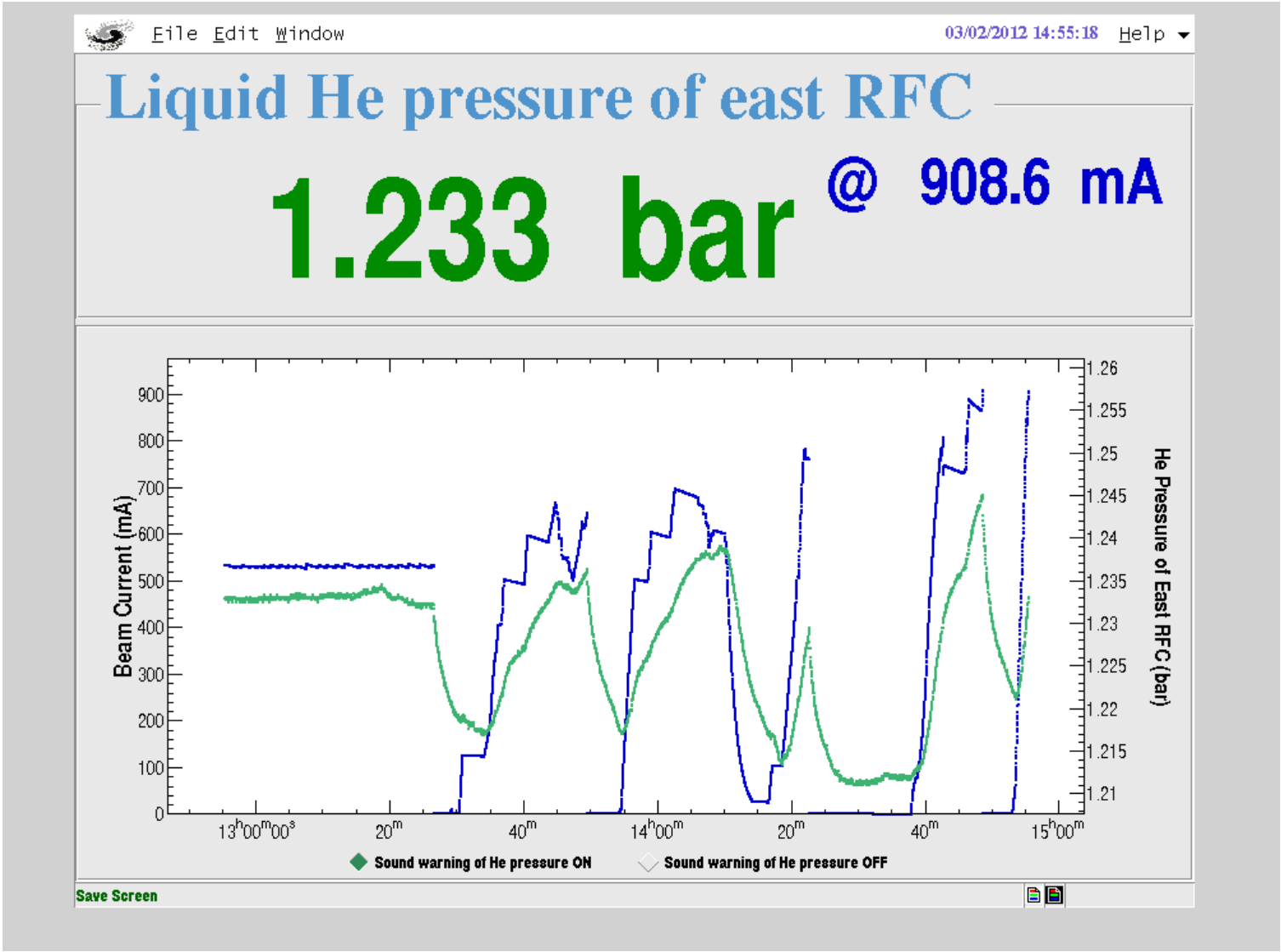
e+/e- Ring crossing point and East SCC in BEPCII tunnel



e- beam SR light may be the heat source?



High Beam Current in 2012

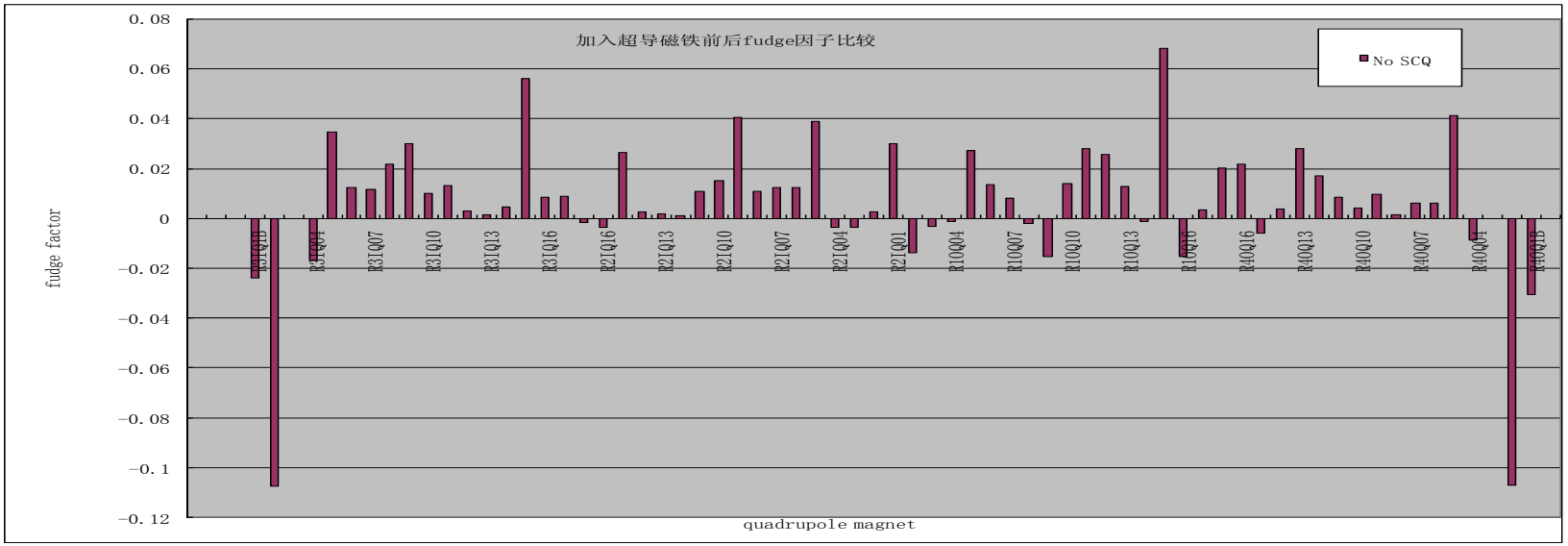


Optics Corection with LOCO before 2011

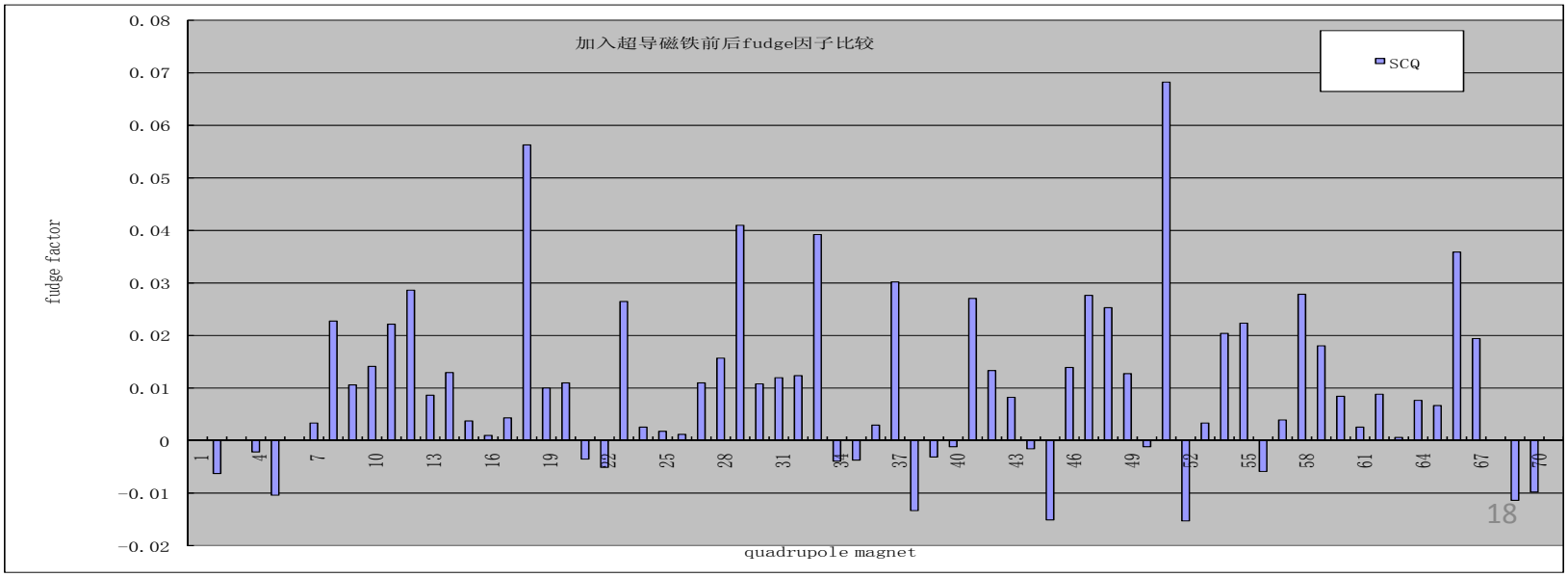
- B_y@IP is about 1.3cm, less than the model value 1.5cm
- “Error” of Q02 near IR is about 10%
- Chromaticity is 1.3, while the model value is 2.5
- Offline analysis shows that everything can be repeated if the final focus magnet (SCQ) has 0.5% error

Fudge Factor of Q-magnet

w/o SCQ



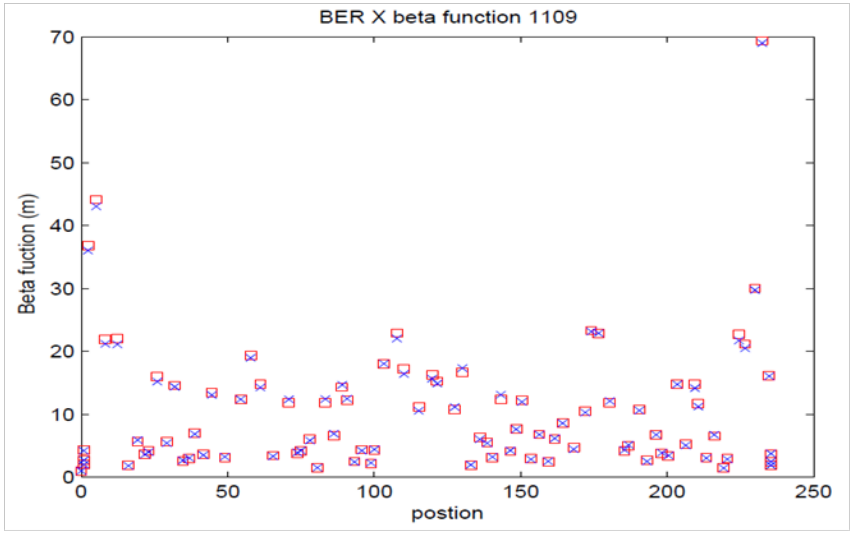
w/ SCQ

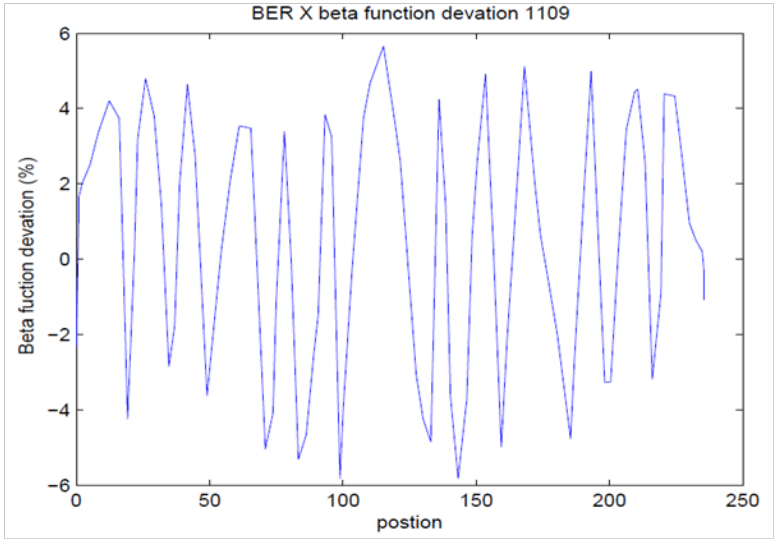


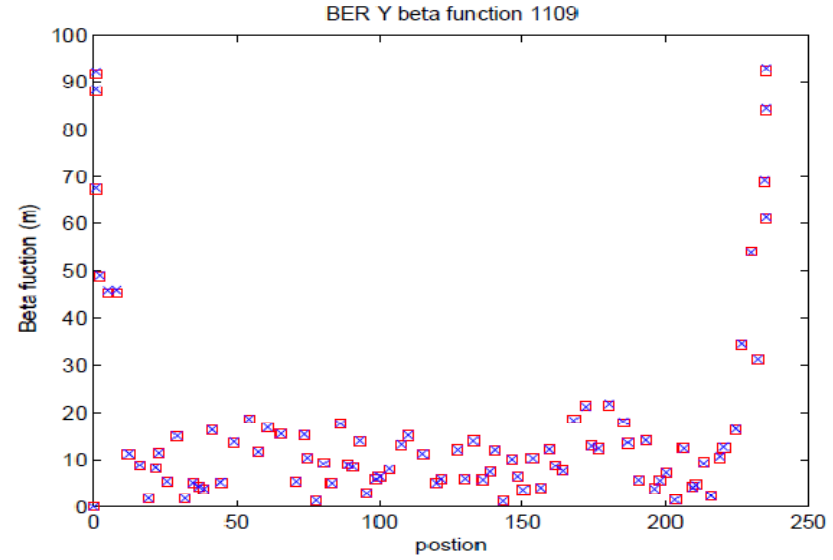
Problems in LOCO

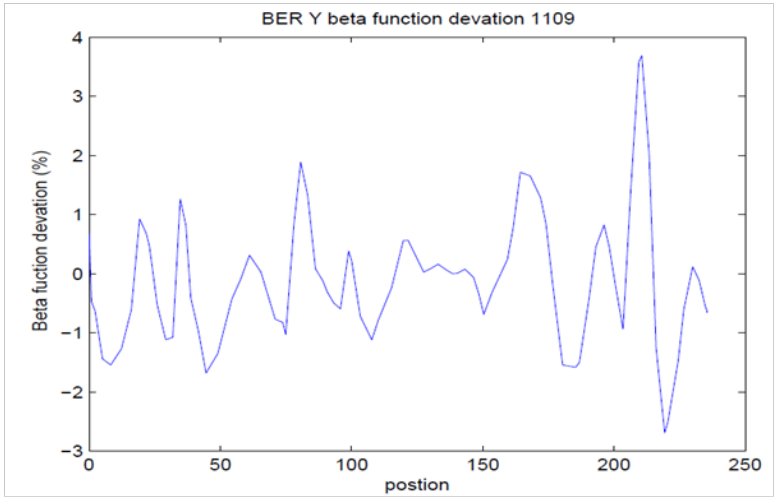
- One time response matrix measurement and optics correction will take about 2~3 hours. It's too long!
- There are about 70 correctors totally in one ring. We adjust all of them during the measurement. We've tried to reduce the number of correctors used. But the offline analysis shows that it really make a difference.
- We read the BPM data 8~10 times. We also tried to reduce the number of BPM readings. And it seems that the error is too big.

β Beating in BER (Q_x~0.53)

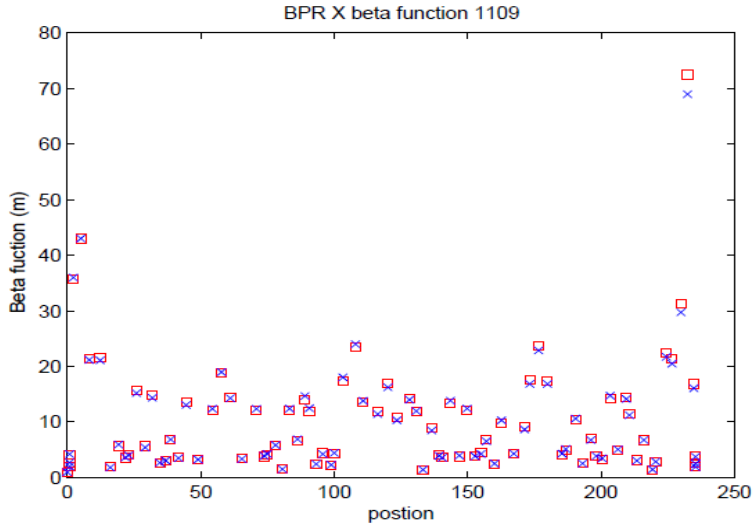


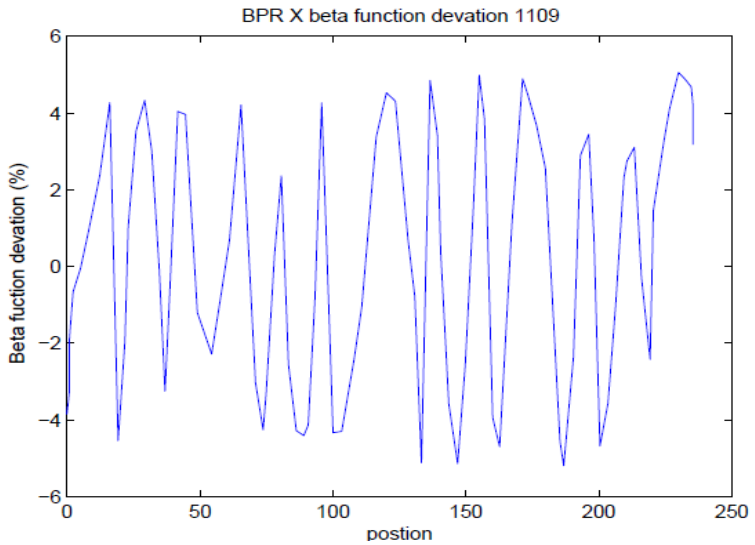


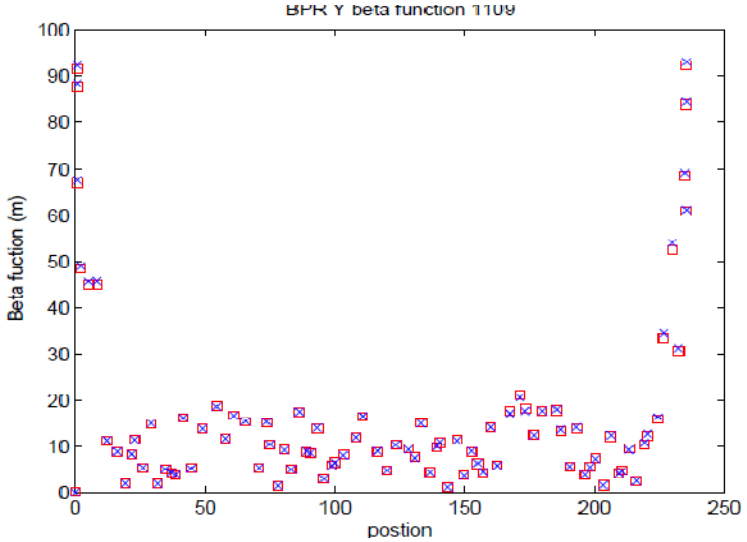


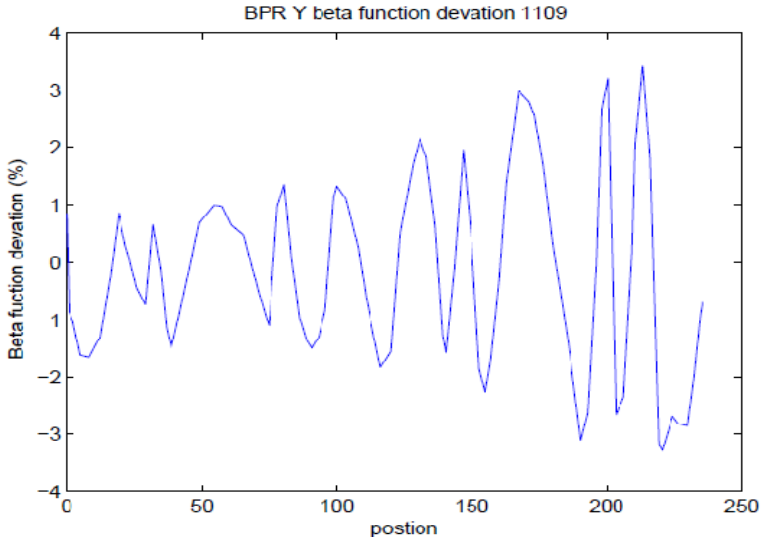


β Beating in BPR (Q_x~0.53)

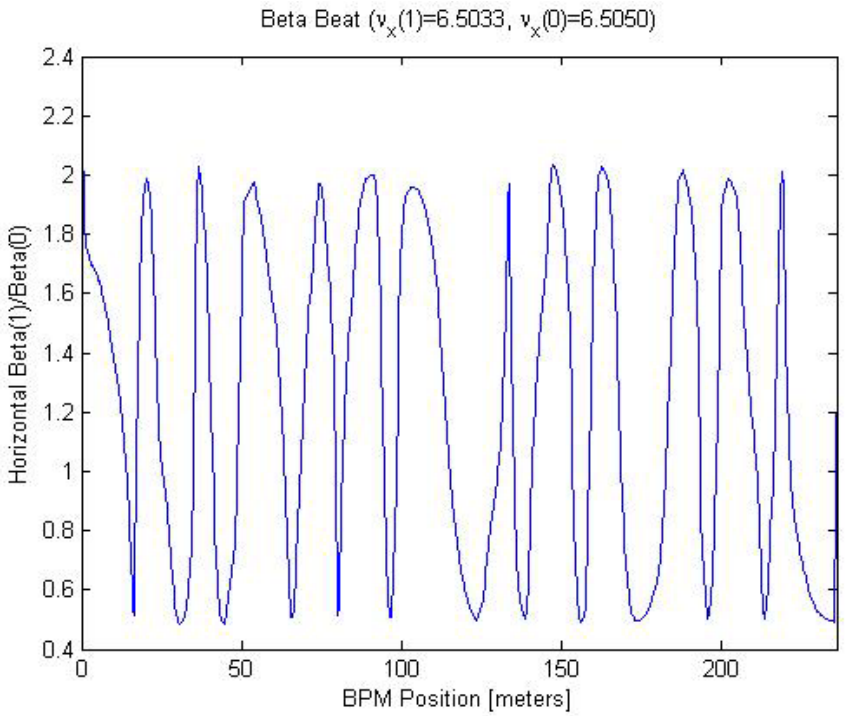


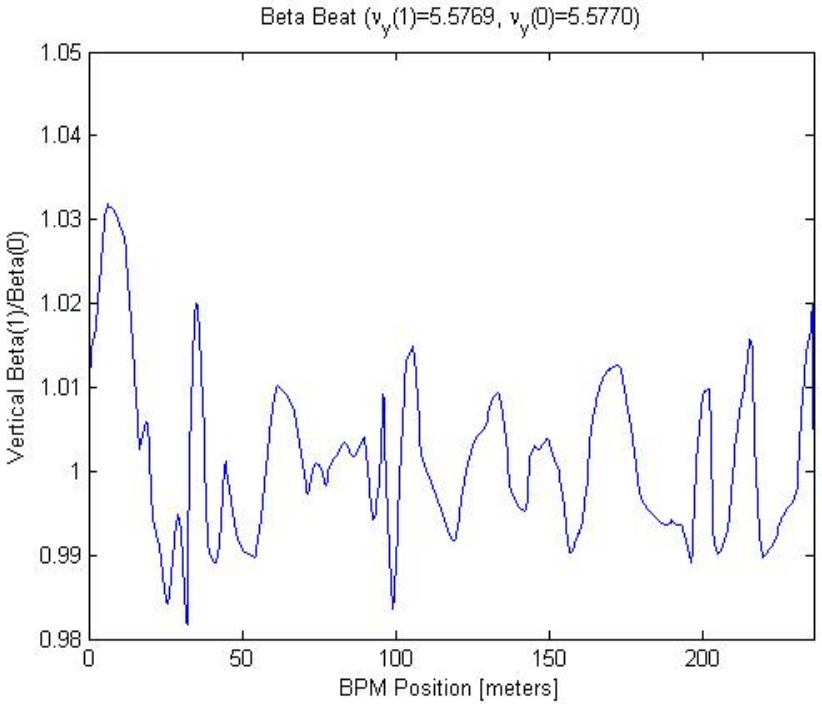




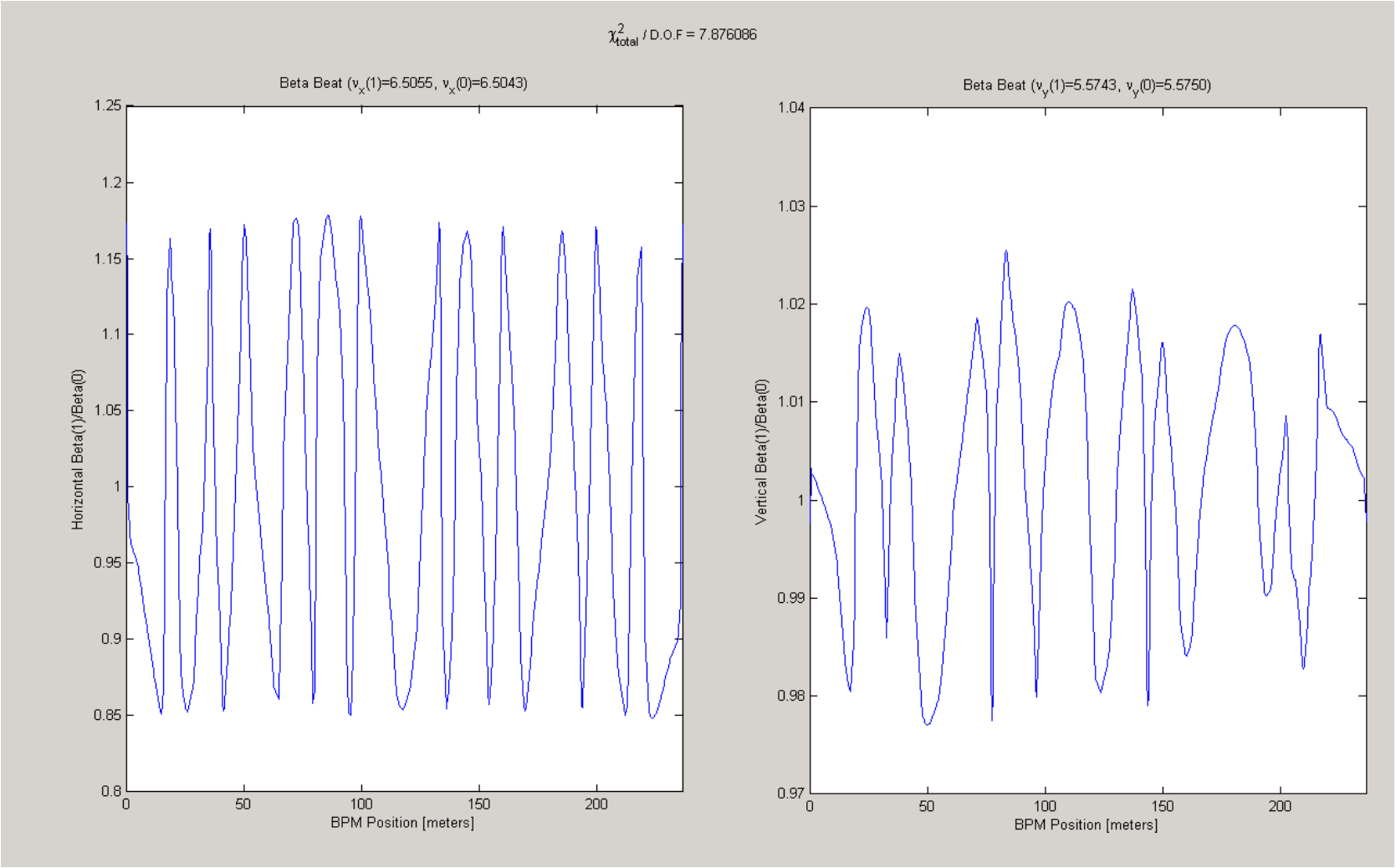


β Beating in BER (Q_x~0.506)

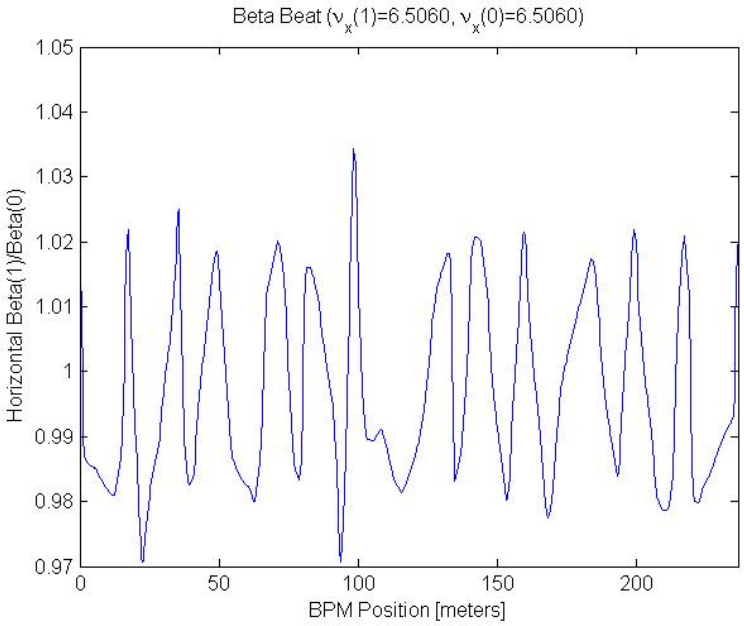


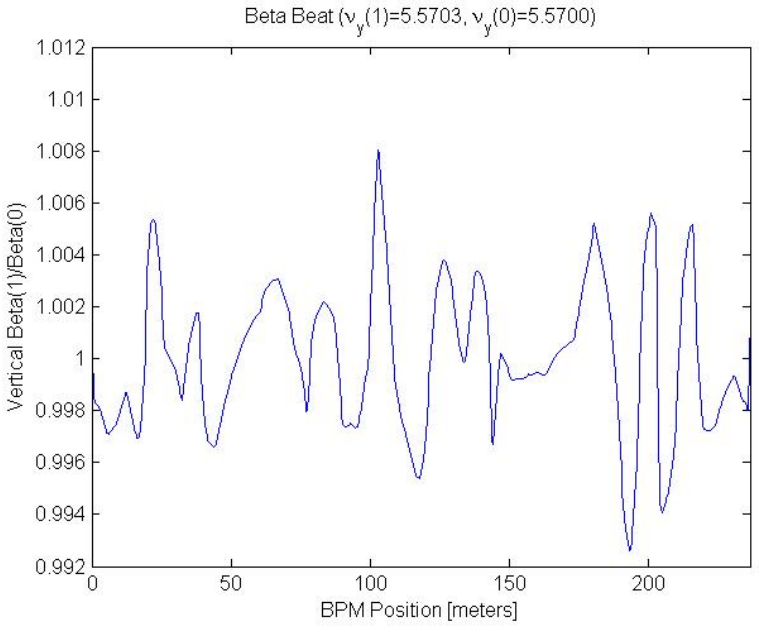


β Beating in BER (Q_x~0.506) Cont.



β Beating in BPR (Q_x~0.506)

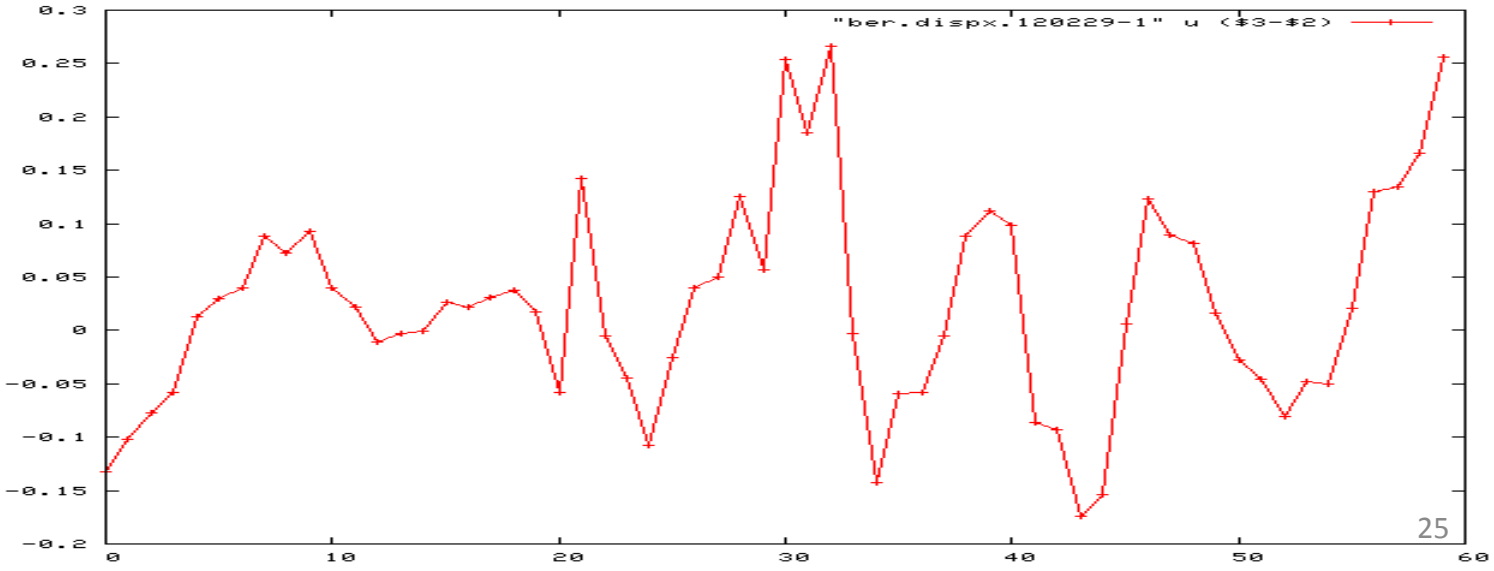




Horizontal Dispersion Error

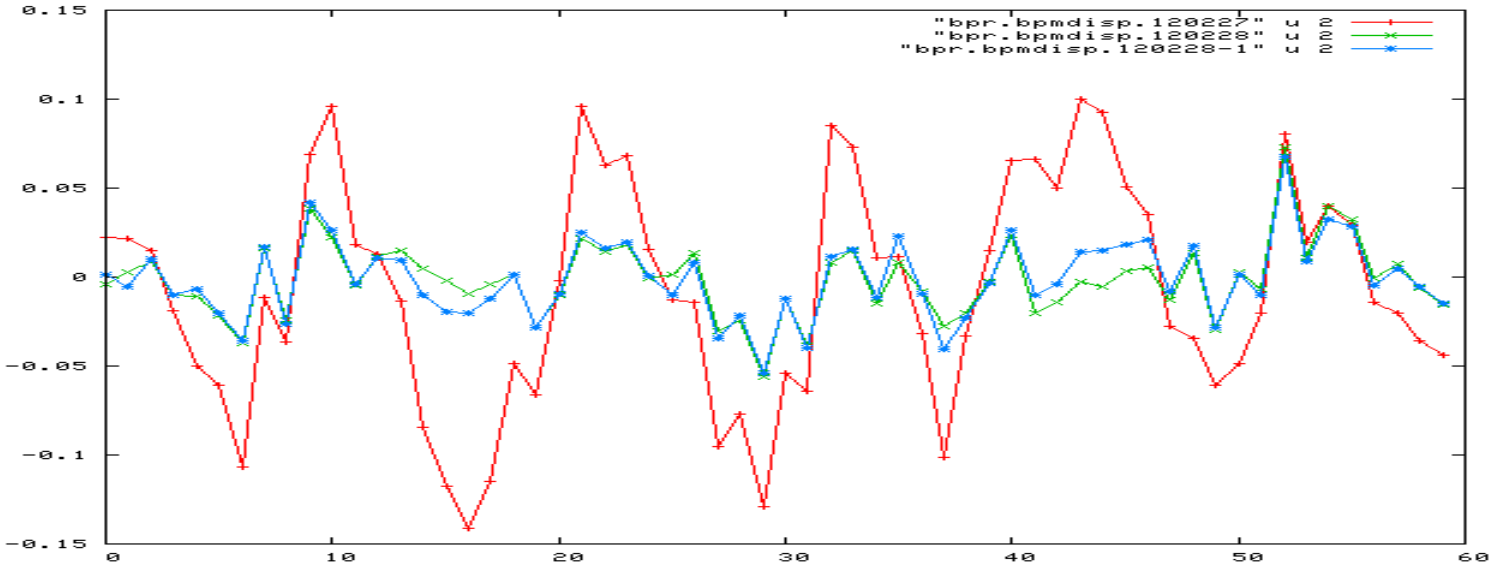
BPR

BER

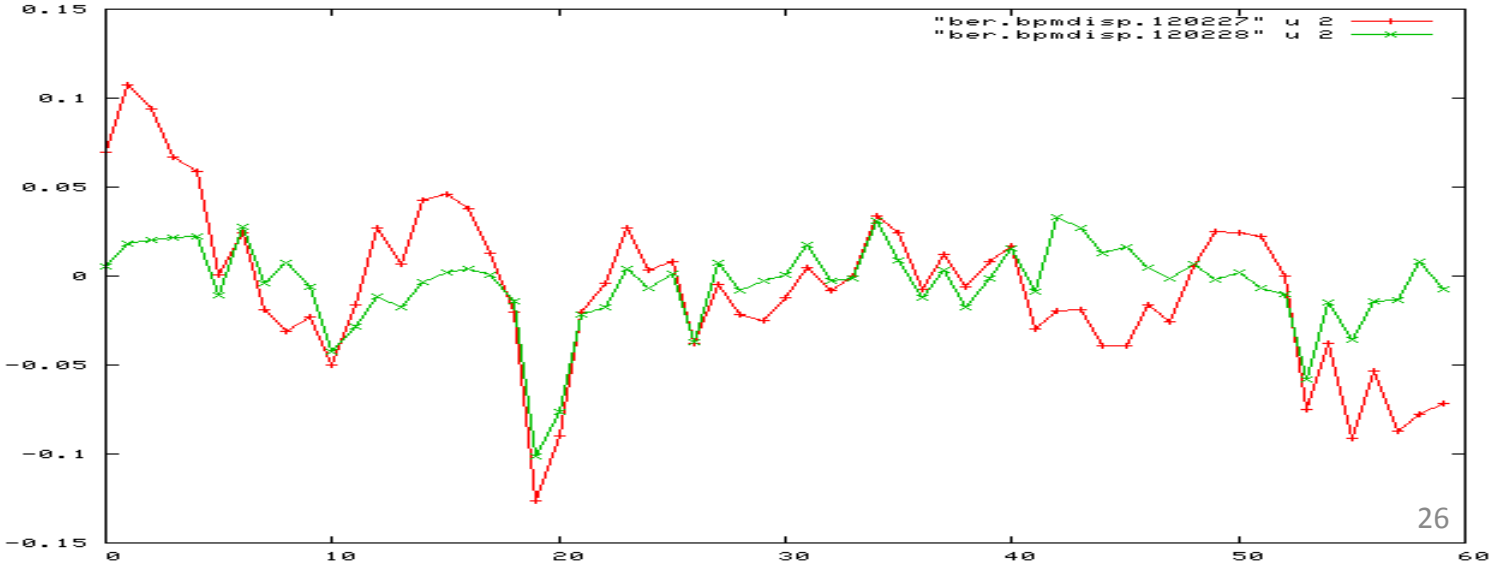


Vertical Dispersion

BPR

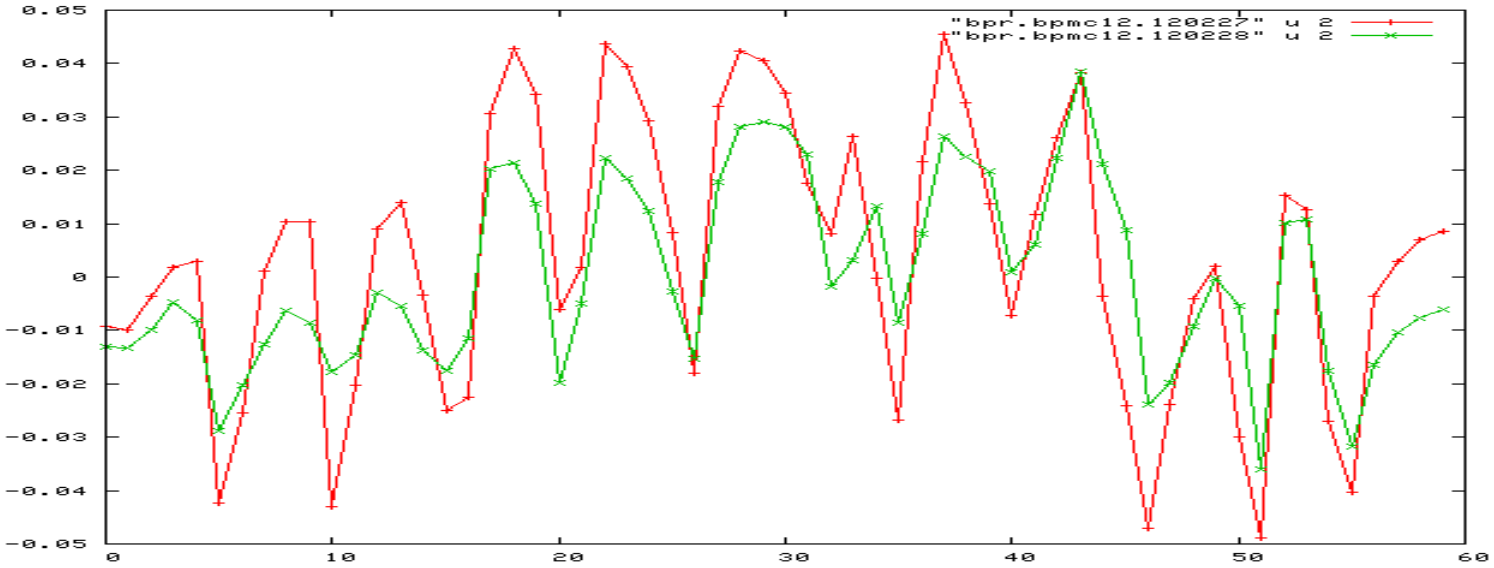


BER

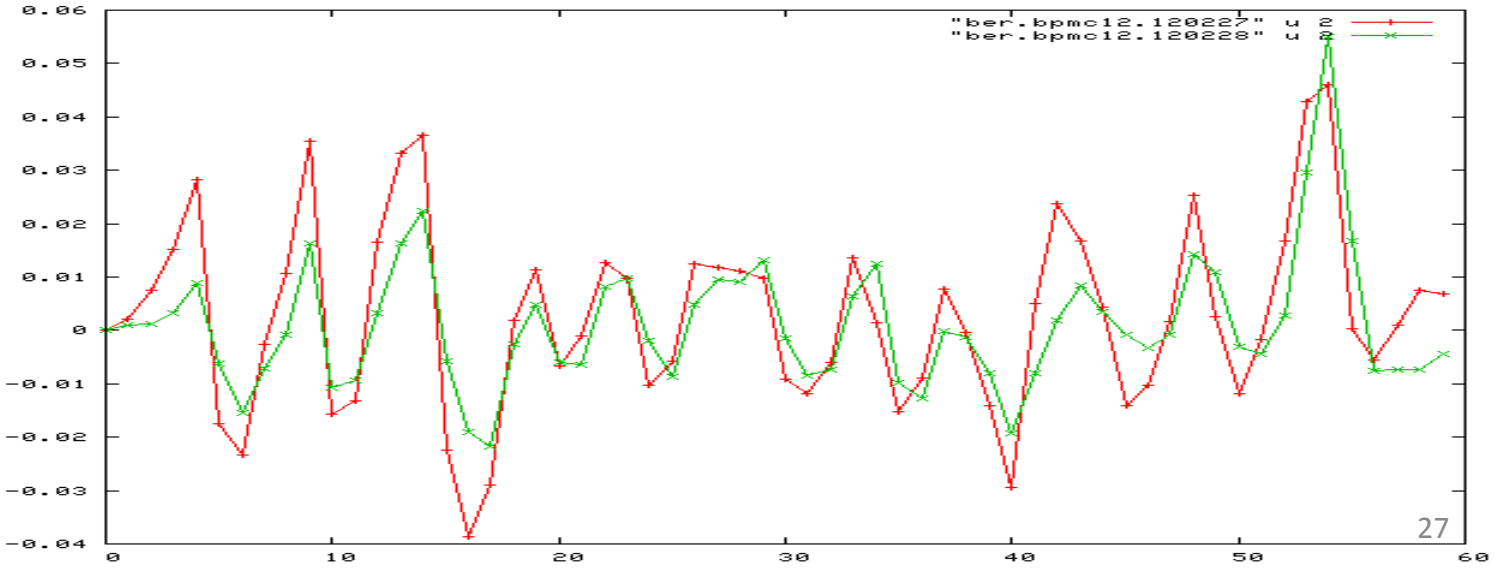


Local Coupling $\overline{C}_{12}$ Distribution

BPR

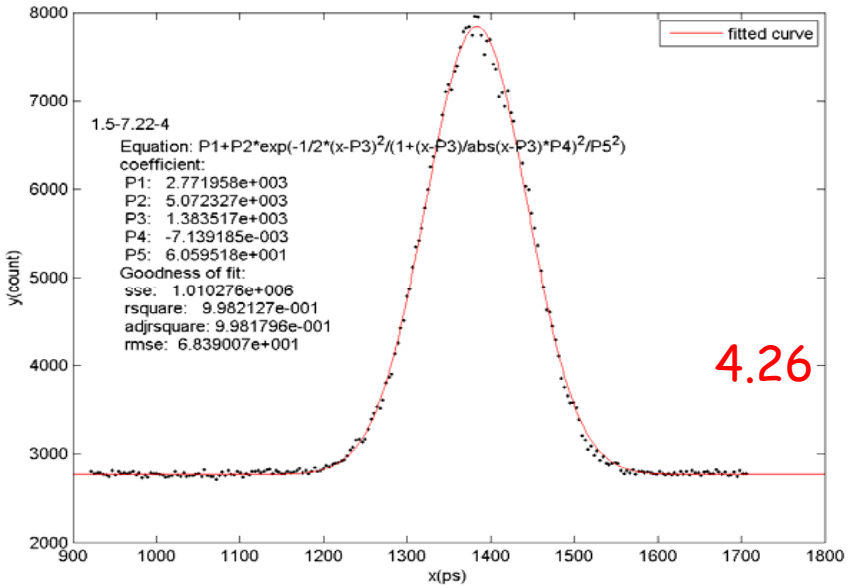


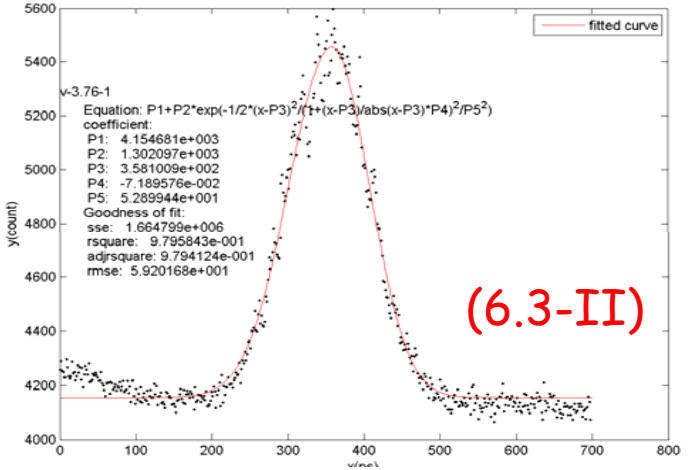
BER

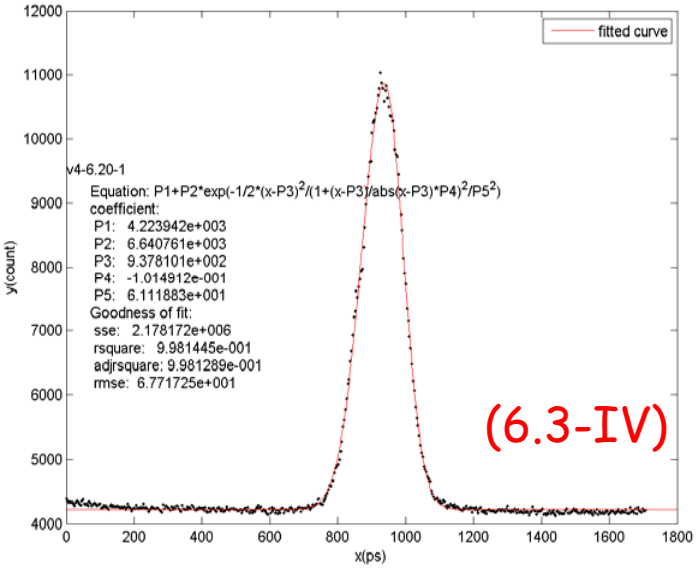


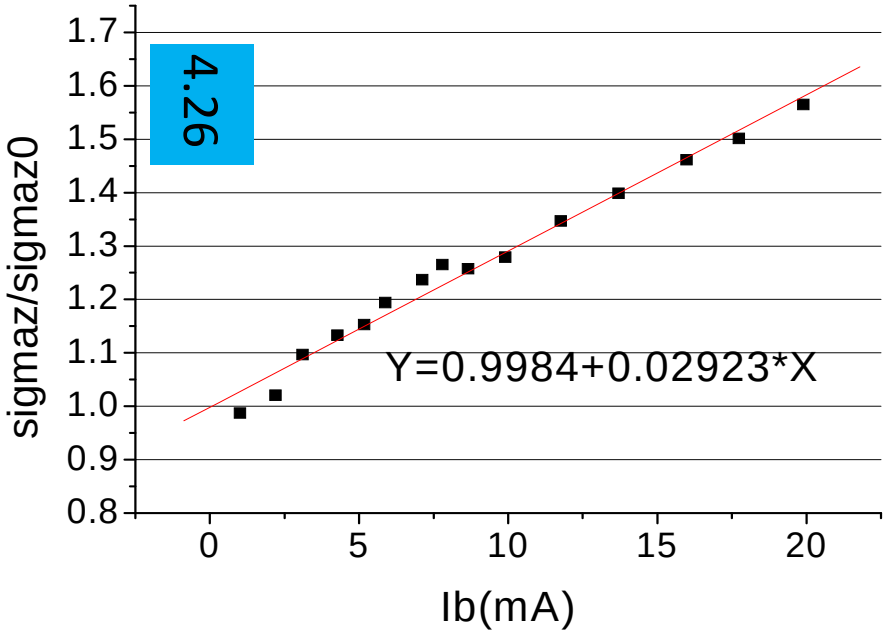
Bunch length fitting

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

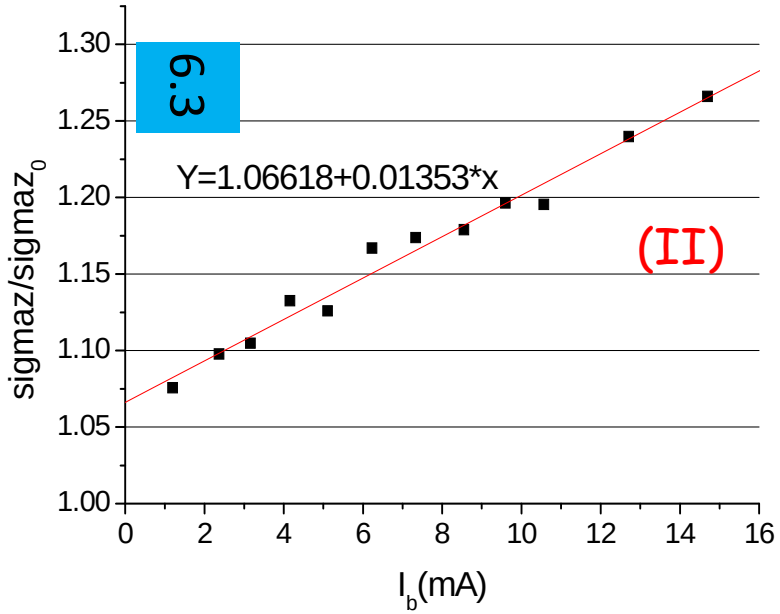




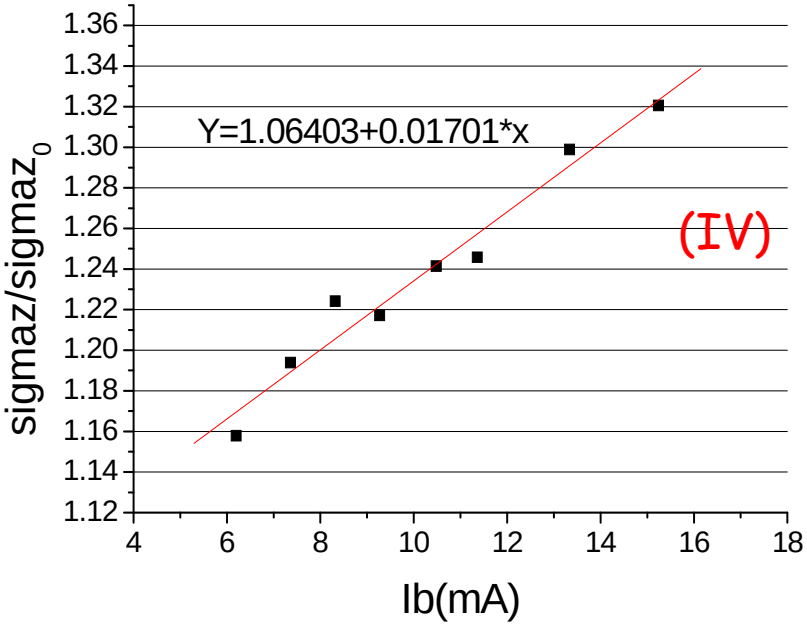




L_{ave} = 287nH



L_{ave} = 209nH



L_{ave} = 211nH

Comparison of impedance

- Taking the experiment in 6.3 for example:

L_{ave} ≈ 210nH（measured）

L_{ave} ≈ 29nH （design）

Measured value ≈ 7×Design value

Review of Inductive Impedance

- longitudinal feedback Kicker（PEPII） which was installed in 2008

$$L_{ave} \approx 20\ \text{nH}$$

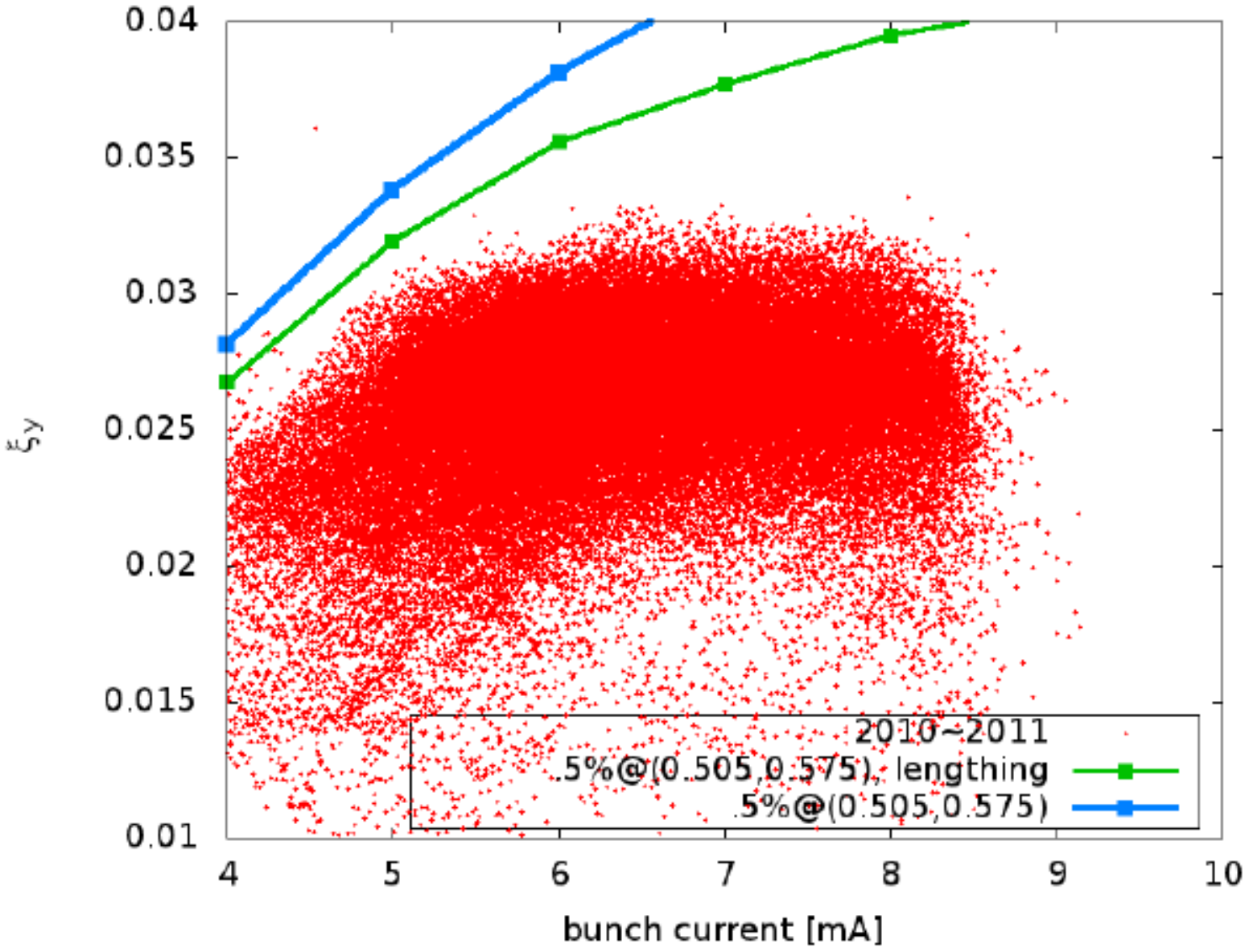
- cavity shape structure of injection kicker (only considering the two tapers in old budget, MODEL OF KICKER IS DIFFERENT?!)

$$L_{ave} \approx 11\ \text{nH} \times 2$$

- $L_{total} \approx 69\ \text{nH}$

Measured ≈3×Calculated

Beam-Beam Parameter (consider Bunch Lengthing, 06-03)



Weak-Strong Model Simulation

Beam Beam Interaction

Use Hirata's BBC [a] as a pass method in Accelerator Toolbox [b]

Matlab + C + Fortran

[a] K. Hirata, Phys. Rev. Lett., 1995, 74, 2228-2231
[b] A.Terebilo, SLAC-PUB-8732, 2001

Element-by-Element Tracking in Arc

symplectic pass method implemented in AT

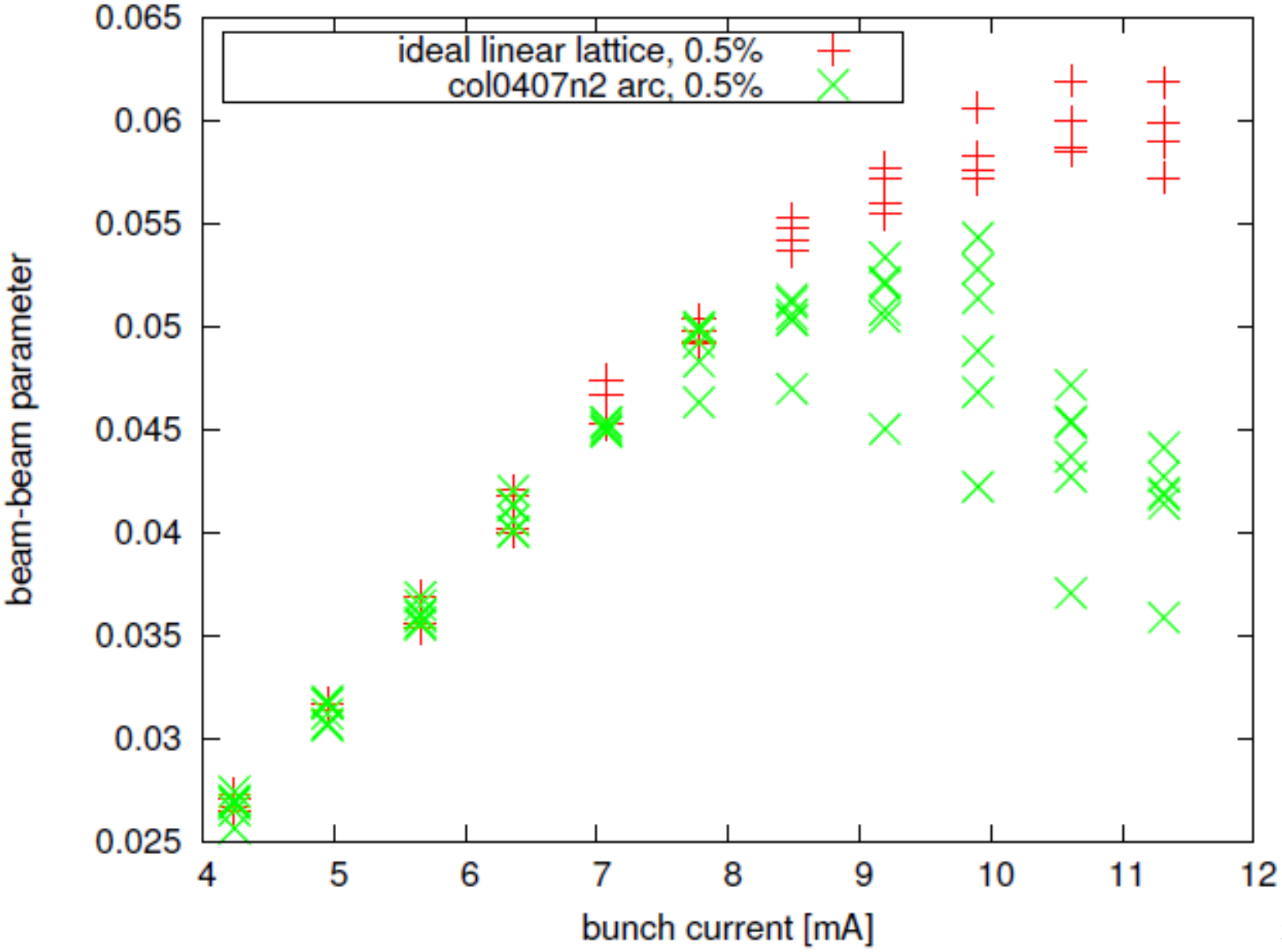
Synchrotron Oscilation

RF on

Radiation Damping and Quantum excitation

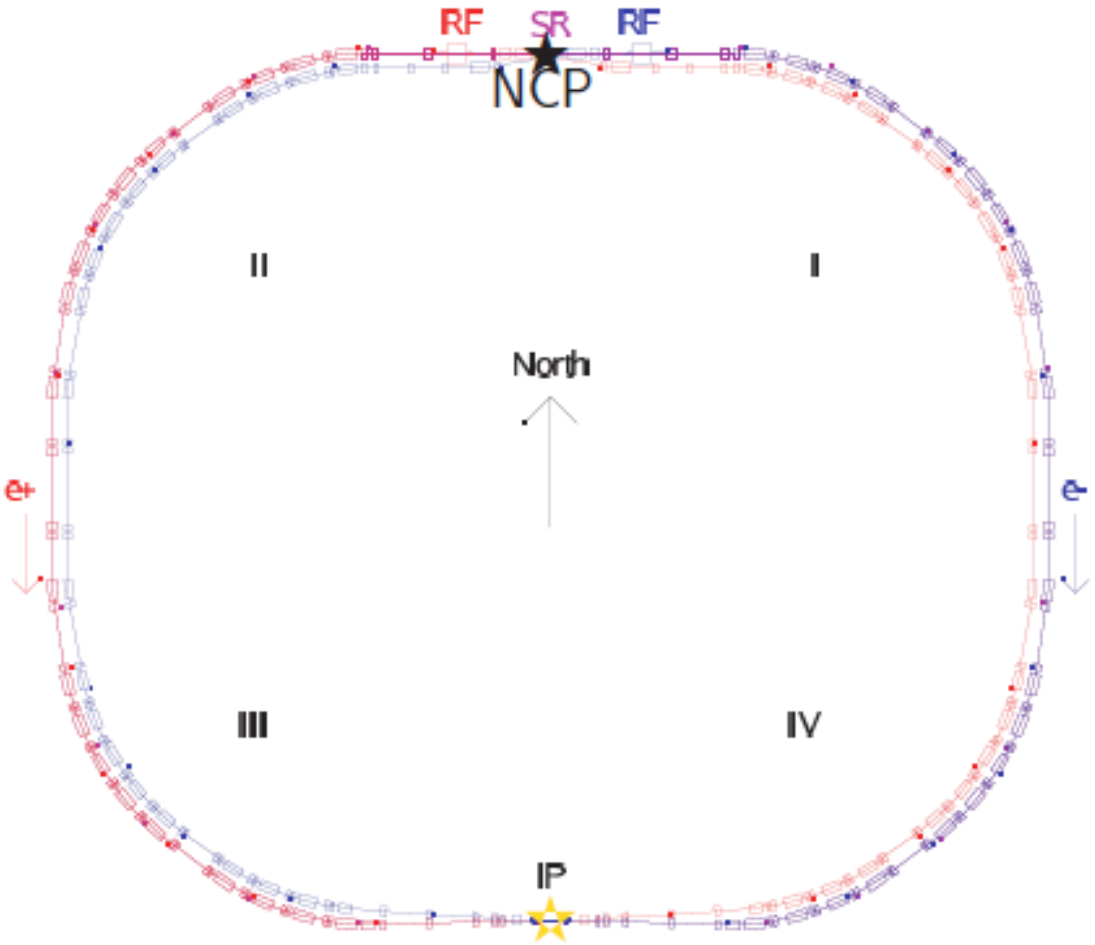
same as that in a strong-strong code

Luminosity Reduction due to Nonlinear Arc



Parasitic Beam-Beam Interaction

There is another crossing point(NCP) in the north of the two rings, where the beams are separated vertically about 5mm and the full horizontal angle is about 2×0.155rad ($17.7°$).

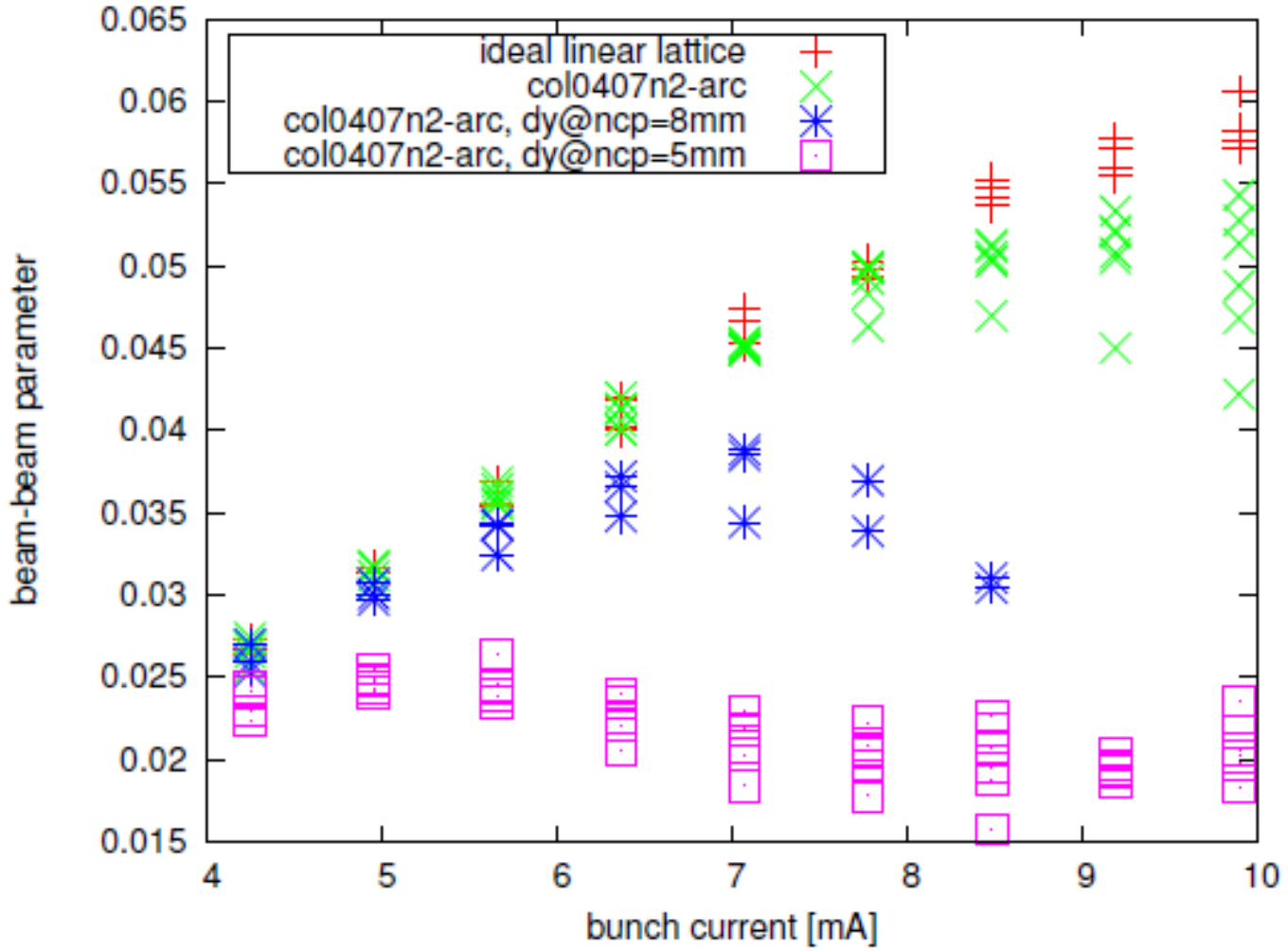


$\beta_x = 12/\beta_y = 8.5$ @ NCP,

- I_b=8mA, 1.0% coupling, $\xi_x/\xi_y = 0.03/0.26$@NCP, $\xi_x/\xi_y = 0.03/0.04$@IP
- vertical separation [5mm]: $\sim 4\sigma_x/\sim 50\sigma_y$
- Piwinski Angle: $\frac{\sigma_z \tan(\theta)}{\sigma_x} = 1.8$@NCP$/0.4$@IP

Nonlinear Arc + NCP

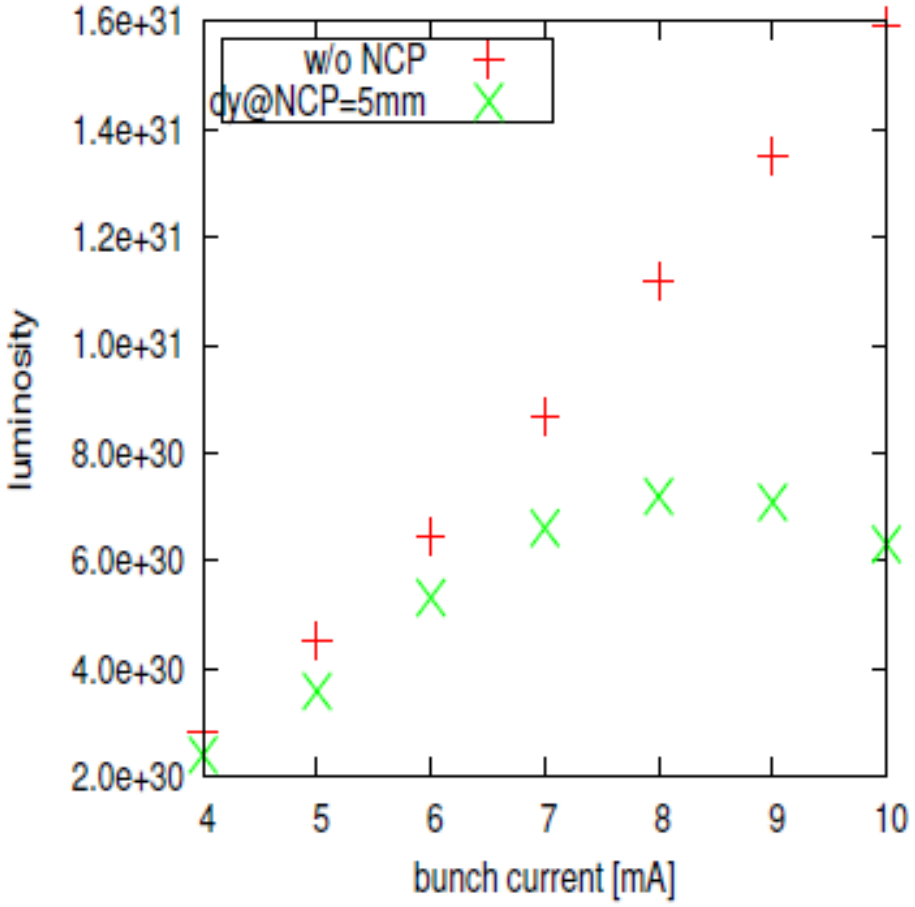
- AT + bbc(by Hirata)

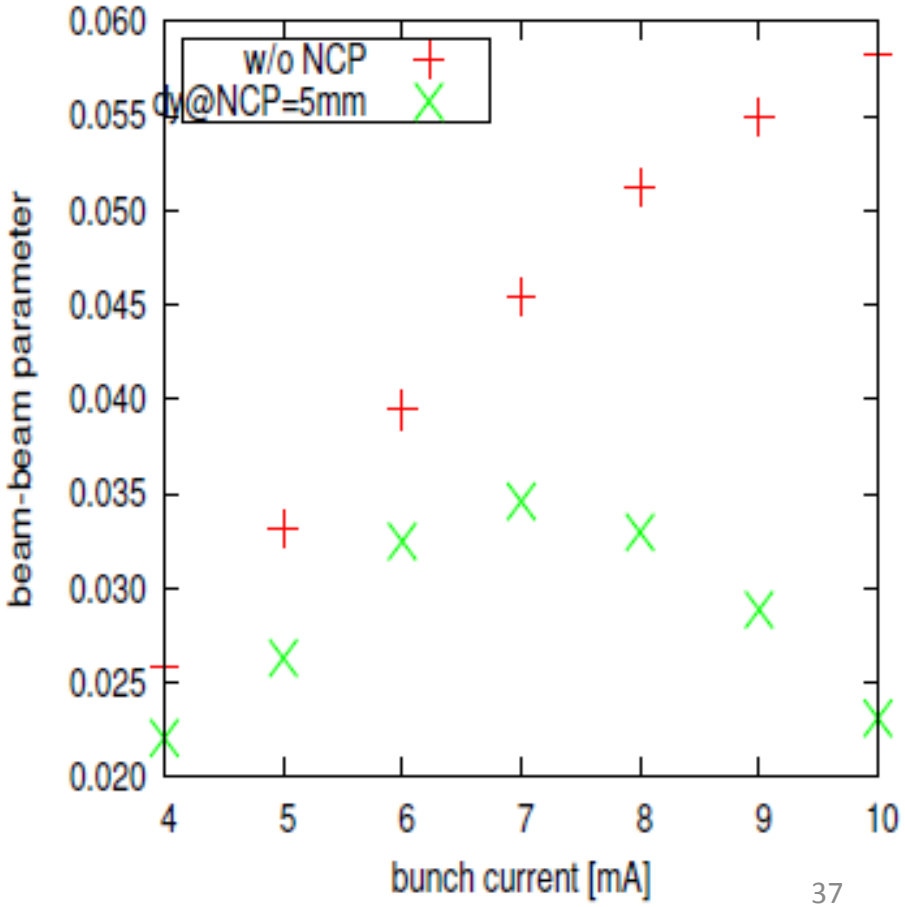


The luminosity loss is over estimated?

Luminosity Loss due to Parasitic Effect@NCP

- **LIFETRAC** by Shatilov is used, Vertical separation is assumed 5mm
- lum@8mA: 11.2e30 $\longrightarrow$ 7.20e30, loss: 35%. SUPPRISE!
- maximum beam-beam parameter achieved at 7mA with parasitic effect@NCP



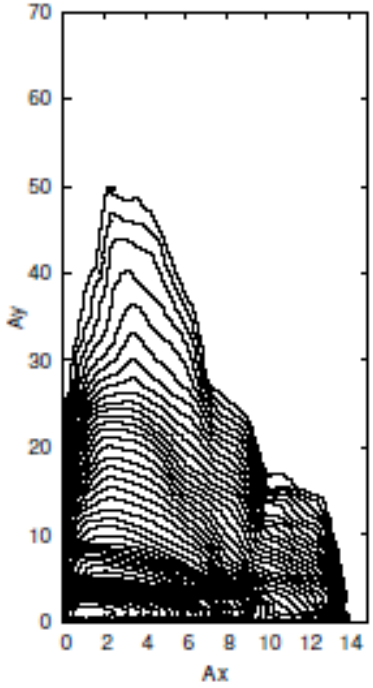


Beam-Beam lifetime (by lifetrac)

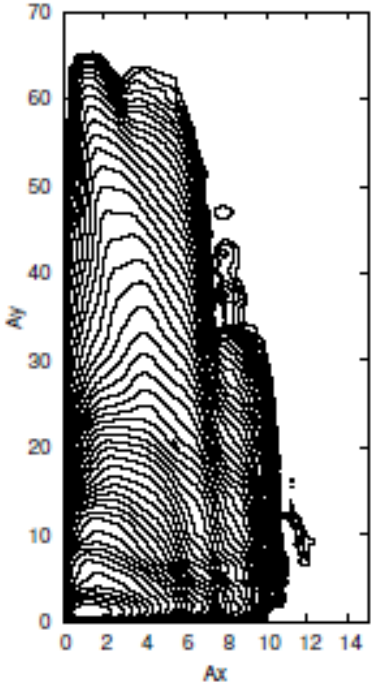
(0.505,0.575), 0.5% coupling, dy@ncp=6mm

I_b	lifetime	lifetime-ncp	ξ_y(W-S)	ξ_y(W-S+ncp)	ξ_y(S-S)
7mA	$>$ 66H	$>$ 66H	0.046	0.039	0.041
8mA	$\sim$ 0.2H	$\sim$ 66H	0.051	0.036	0.044
9mA	$\sim$ 0.6H	$\sim$ 46H	0.055	0.035	
10mA	$\sim$ 0.03H	$\sim$ 6H	0.058	0.029	

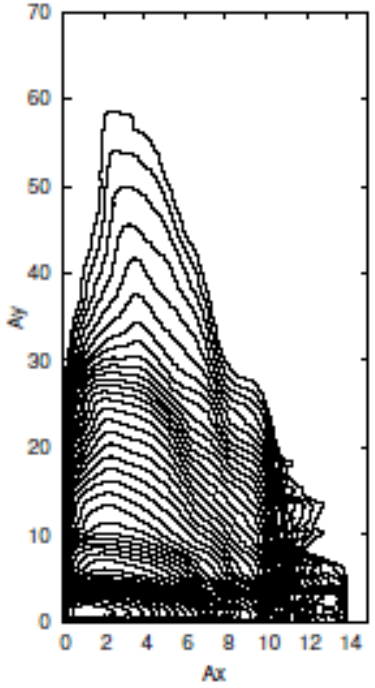
I_b = 7mA



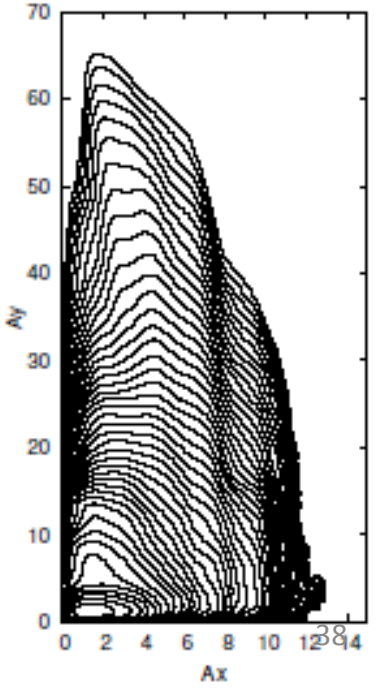
I_b = 7mA+ncp



I_b = 8mA

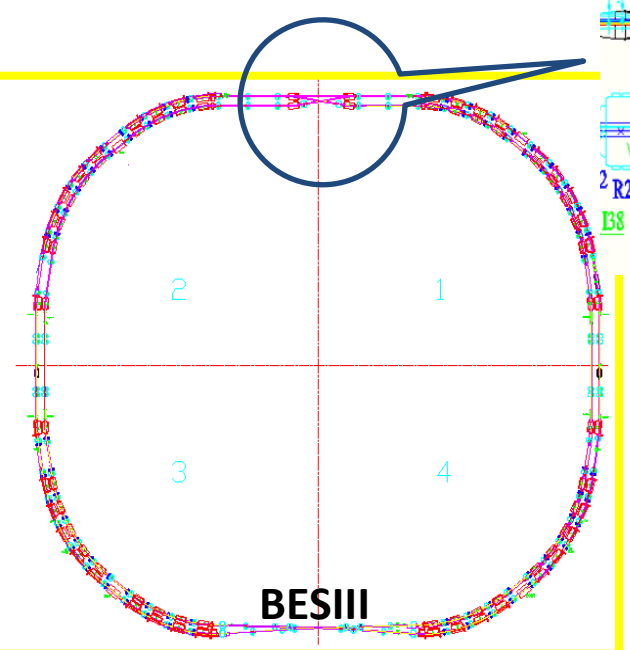


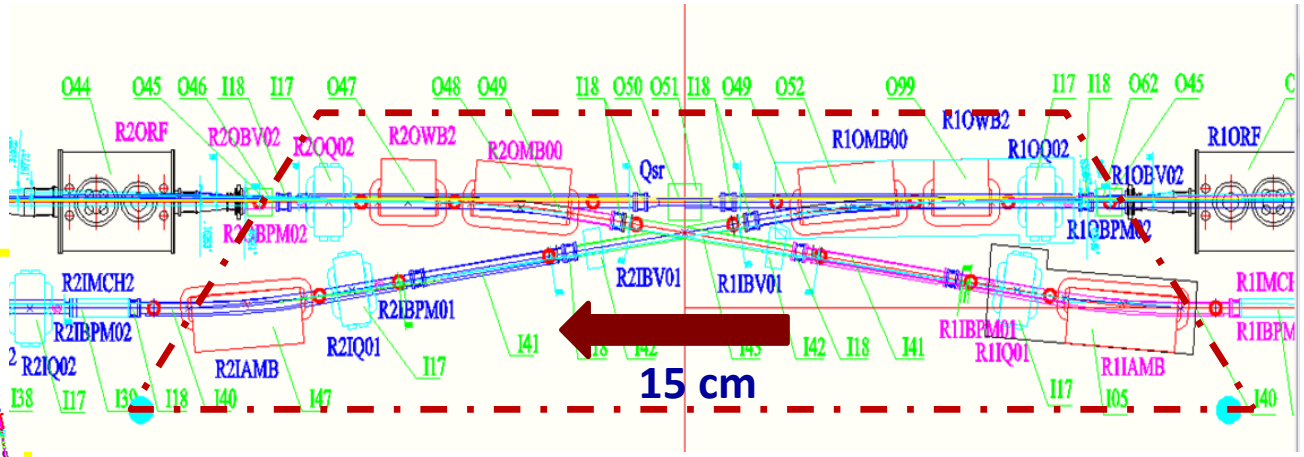
I_b = 8mA+ncp



Collision in 2011~2012

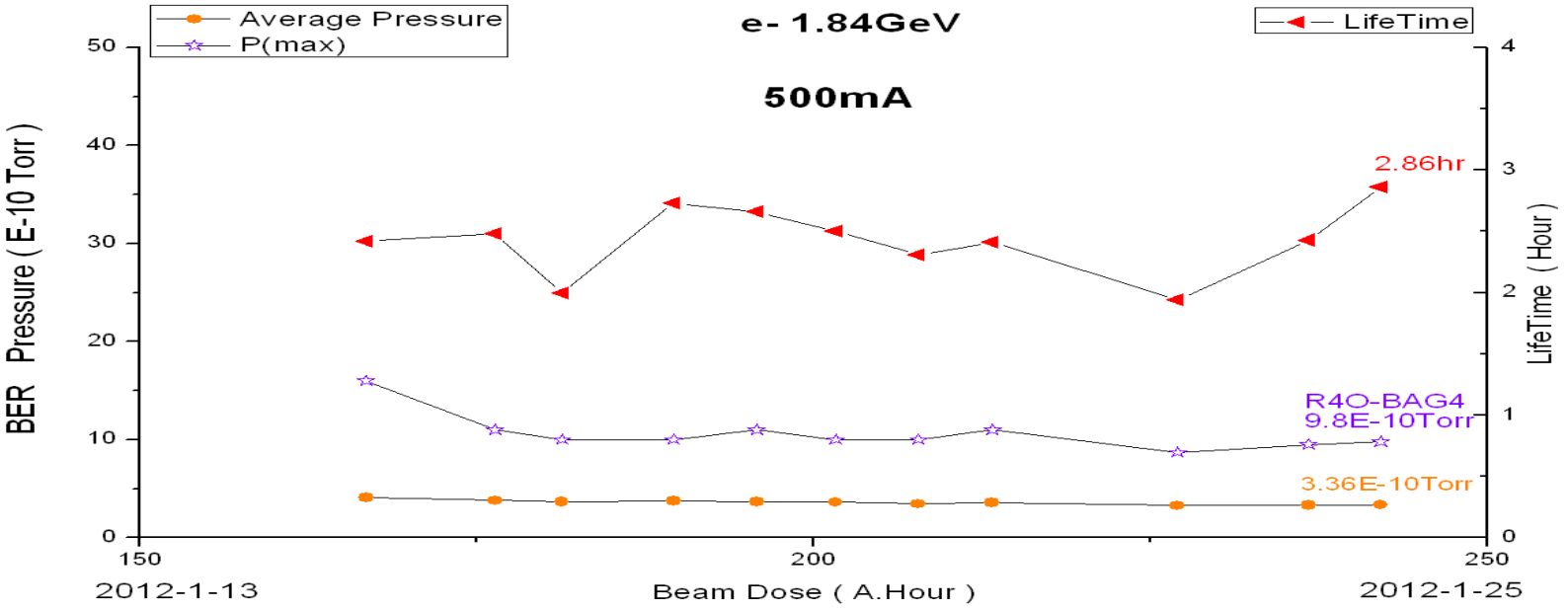
- A big movement of the North Crossing Point (NCP) region due to the beam-beam interaction studies
- The NCP of the chambers of two rings was moved for 15 cm, ¼ of the space of two successive rf buckets.

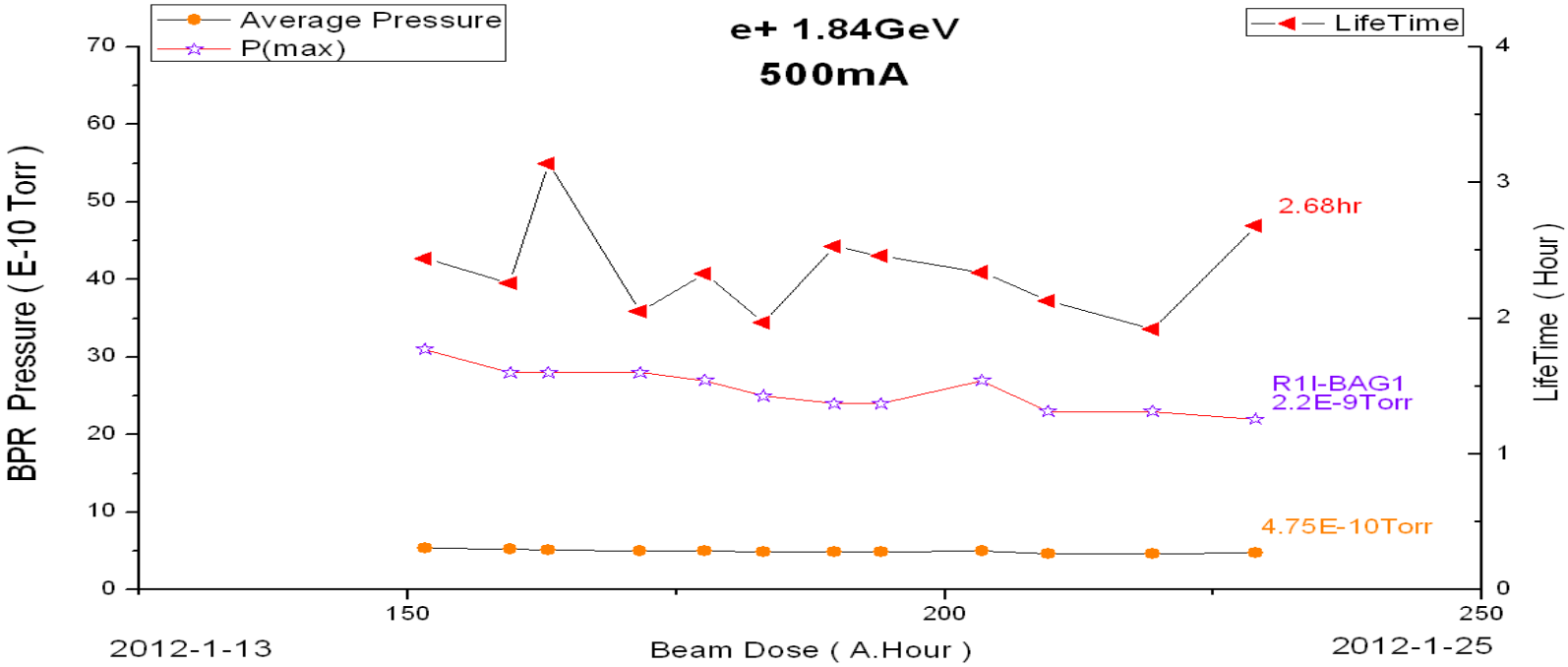




The EMS @ NCP region was moved by 15 cm too

- Beams injected to the rings smoothly after all the hardware is ok. (Dec. 5 & 6, 2011)
- Optics correction was done at τ energy
- BEMS tuning, together with the beam commissioning
- Vacuum was improved very slowly, especially in the e^+ ring.


Average Pressure
P(max)
e- 1.84GeV
500mA
LifeTime
2.86hr
R4O-BAG4
9.8E-10Torr
3.36E-10Torr
BER Pressure (E-10 Torr)
LifeTime (Hour)
Beam Dose (A.Hour)
2012-1-13
2012-1-25


Average Pressure
P(max)
e+ 1.84GeV
500mA
LifeTime
2.68hr
R1I-BAG1
2.2E-9Torr
4.75E-10Torr
BPR Pressure (E-10 Torr)
LifeTime (Hour)
Beam Dose (A.Hour)
2012-1-13
2012-1-25

Hardware problems in 2011~2012

- Three kinds of hardware problem:

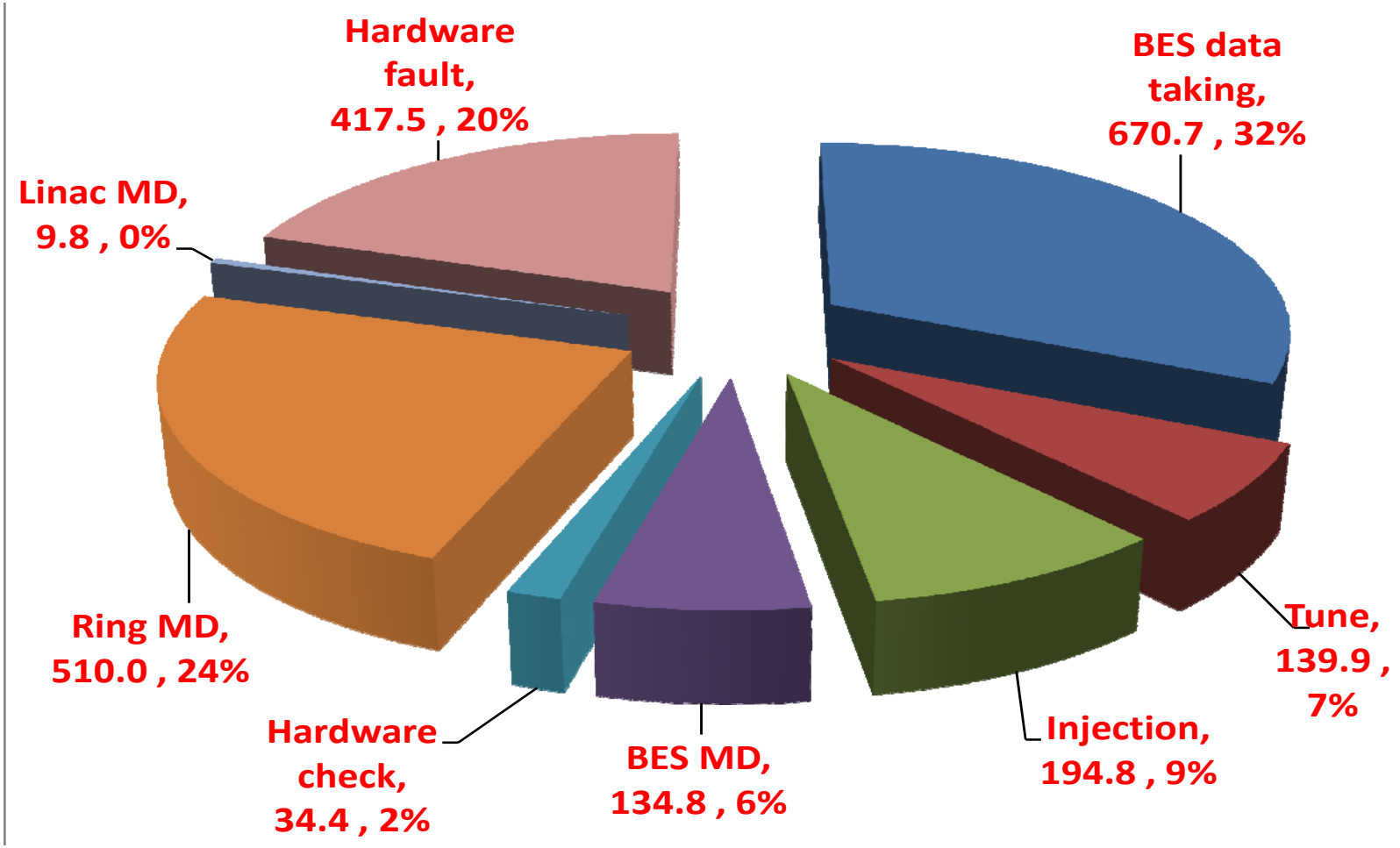
✓ Problems due to long-time maintenance/shutdown in summer --- vacuum near RF cavity in e+ ring, vacuum in the acceleration section of linac, etc.

✓ New-found problems after operation started --- amplifier fault of the longitudinal feedback system, cryogenics system(UPS power supply broken, turbine aging, unclean He/N_2 gas, etc.)

✓ Other occasional problems --- PSI of magnet PS, SHB of linac, etc.

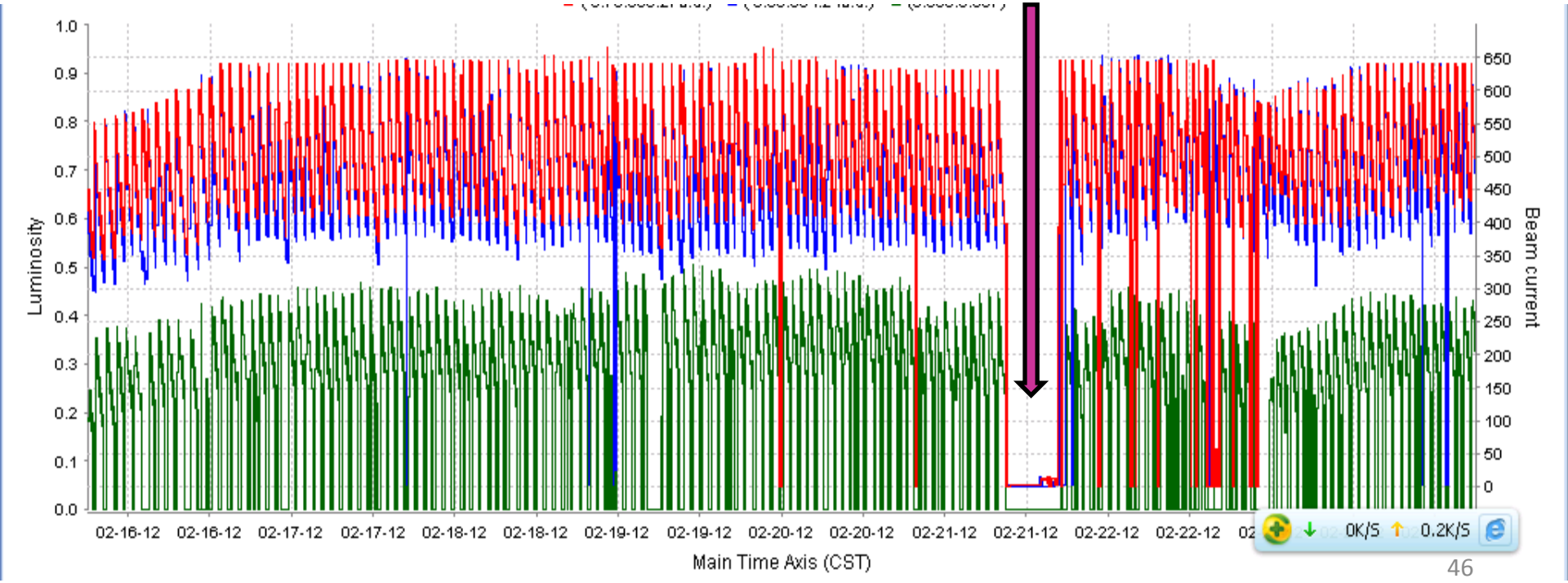
- Some hardware problems happened in series, which influenced the operation seriously.
- Slowly improved vacuum caused the τ mass scan paused --- far from fulfilled.

- Among the total time (from Dec. 1 to Feb. 27, 2112 hr)

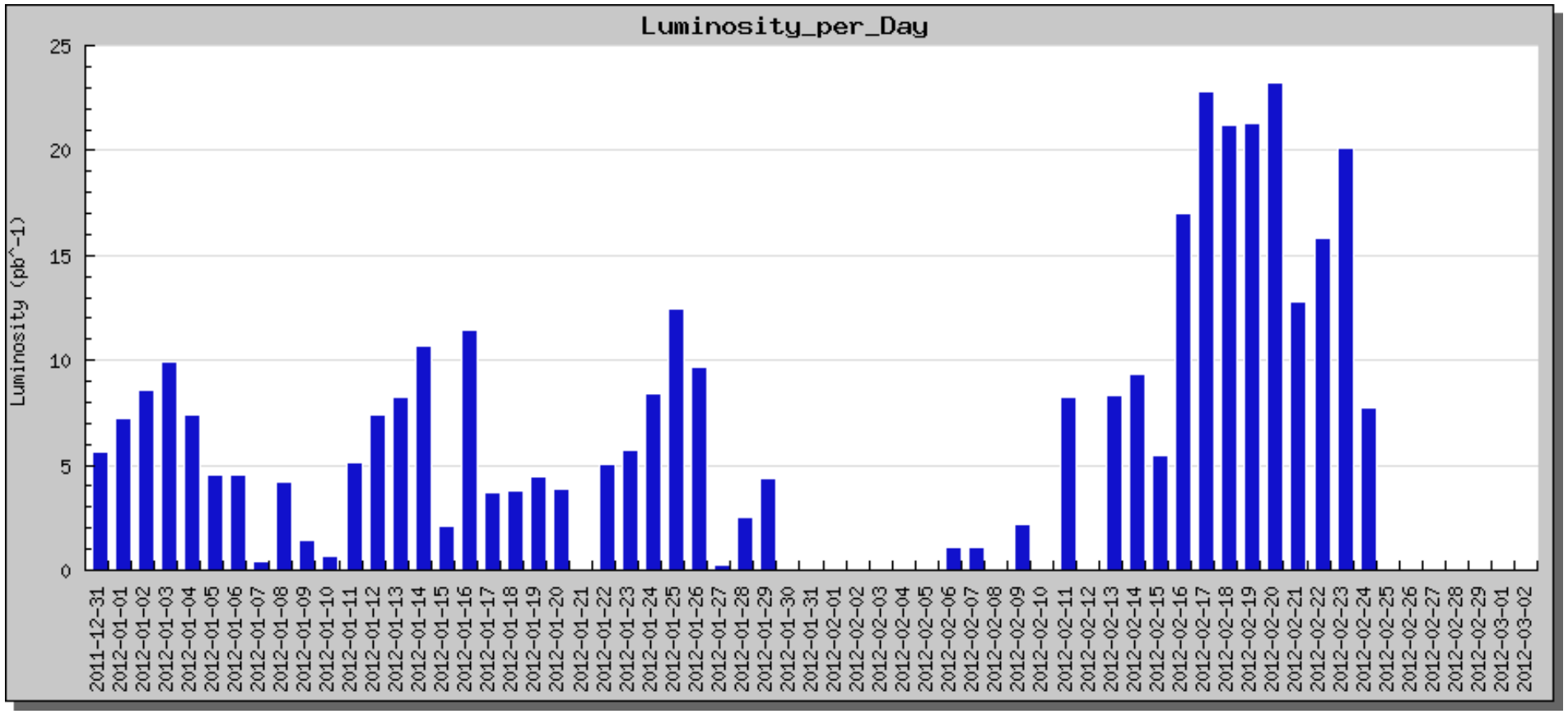


- New problem --- Noise to the detector
- Different from the noise we had before this run
- Electron beam-dependent
- Higher noise in low beam current (<100mA), but clean at high beam current (>400mA), strange!

- Linac reached its best status from Jan. 22, with a positron beam injection rate of 60 – 80mA /min.
- Everything seems good enough after Feb. 14, beam and luminosity run smoothly.



Daily Integrated Luminosity



Summary

- 2011~2012 is a hard year for us
- More detailed optics measurement & correction is being done
- We still not obtain some luminosity improvement by suppressing the parasitic beam-beam interaction
- We'll try to achieve higher luminosity by more detailed optimization, higher beam current and lower β_y (smaller α_p).