KEKB Status

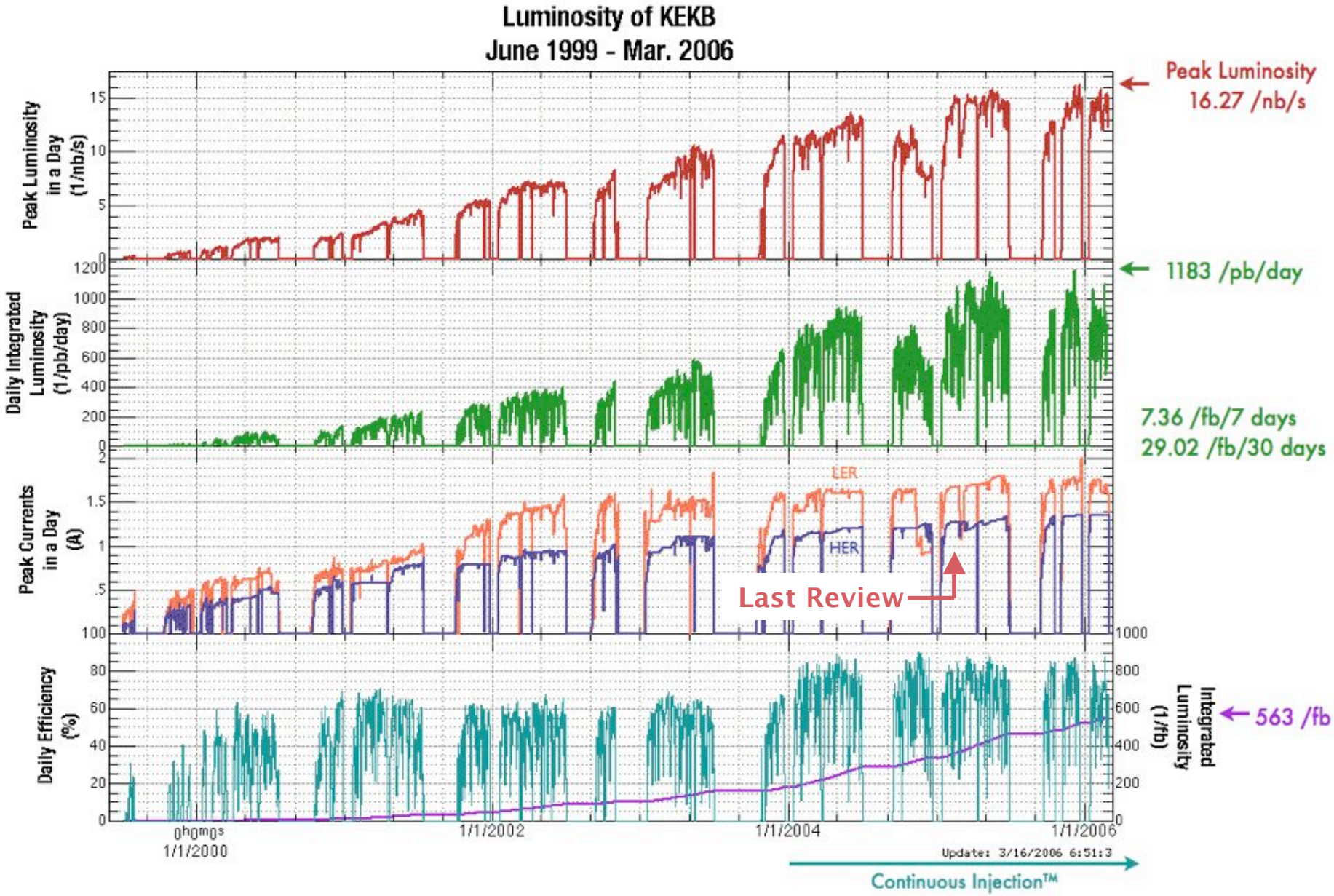
since Feb. 2005

Y. Funakoshi

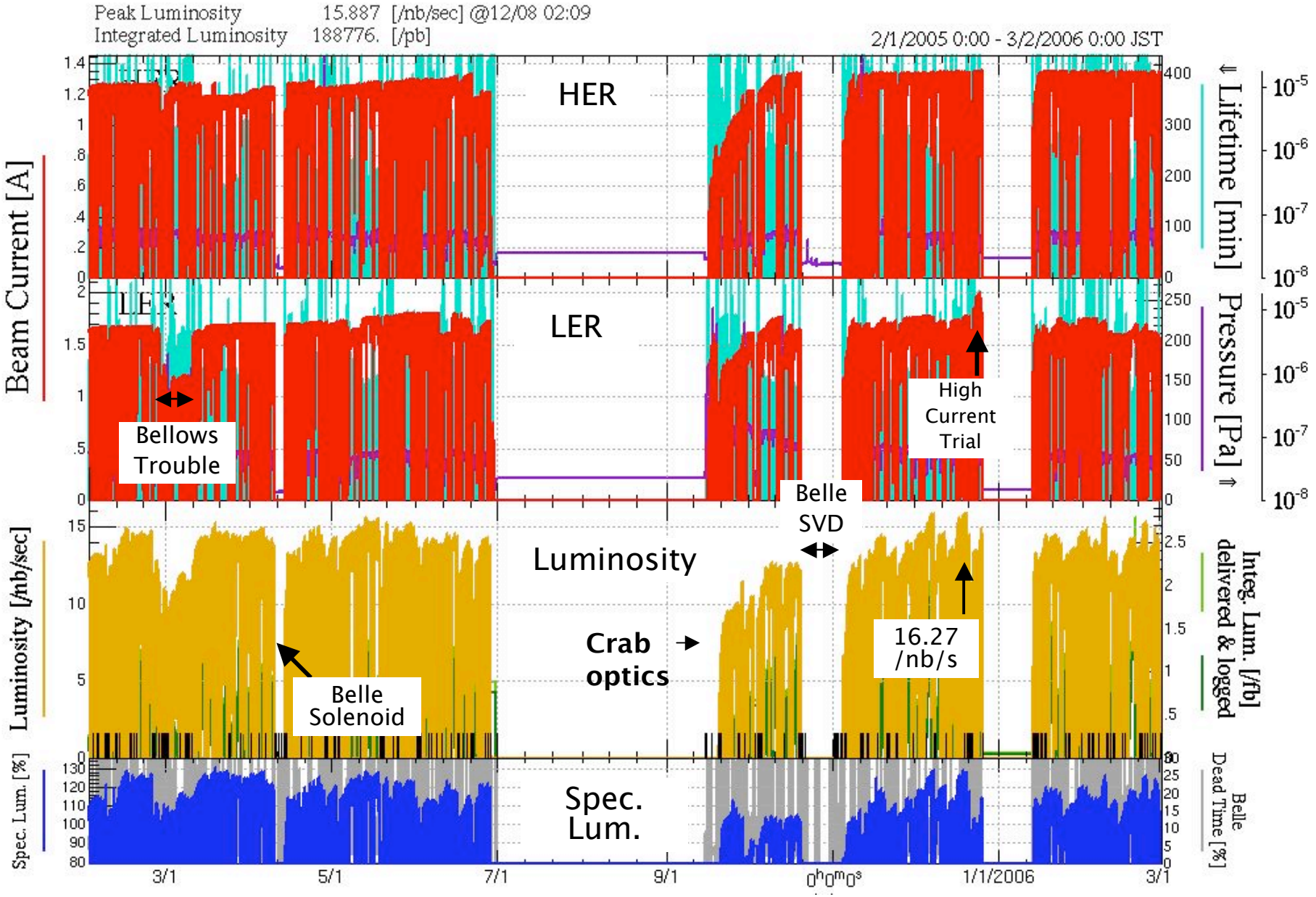
March 21, 2006 @ KEKB Review

KEKB Performance

KEKB History



KEKB Performance Feb. 2005 - Mar. 2006



Luminosity Performance

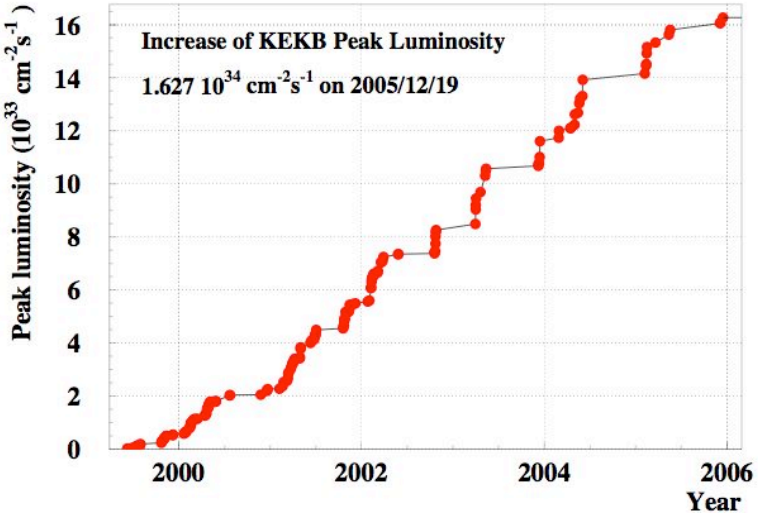
- **Both peak and integrated luminosities have been improved.**

  L_{peak} = *15.16* → *16.27/nb/s*

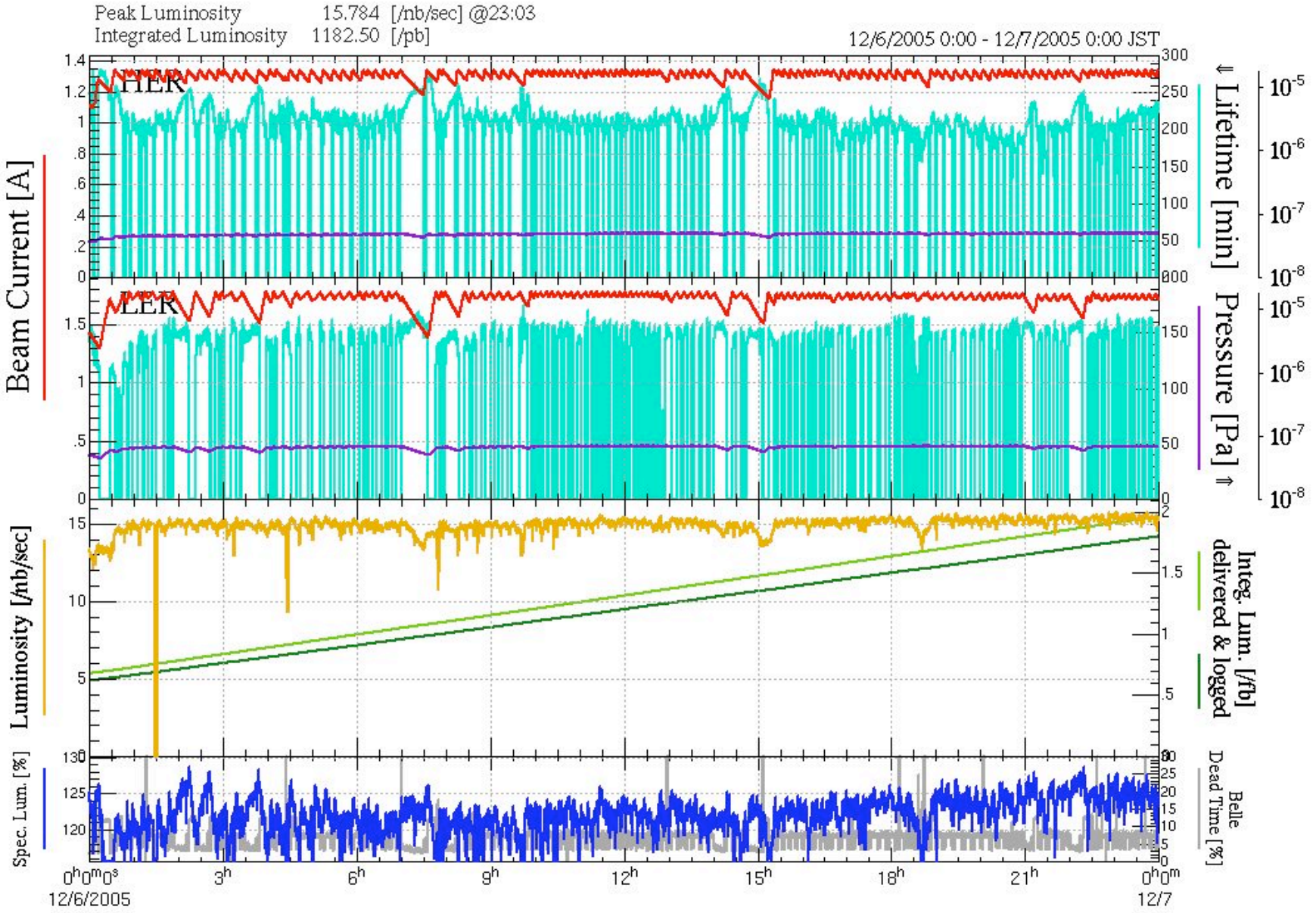
  ∫ L/day, /7days, /30days

  = *1083/6242/23995* → *1183/7358/29018 /pb*

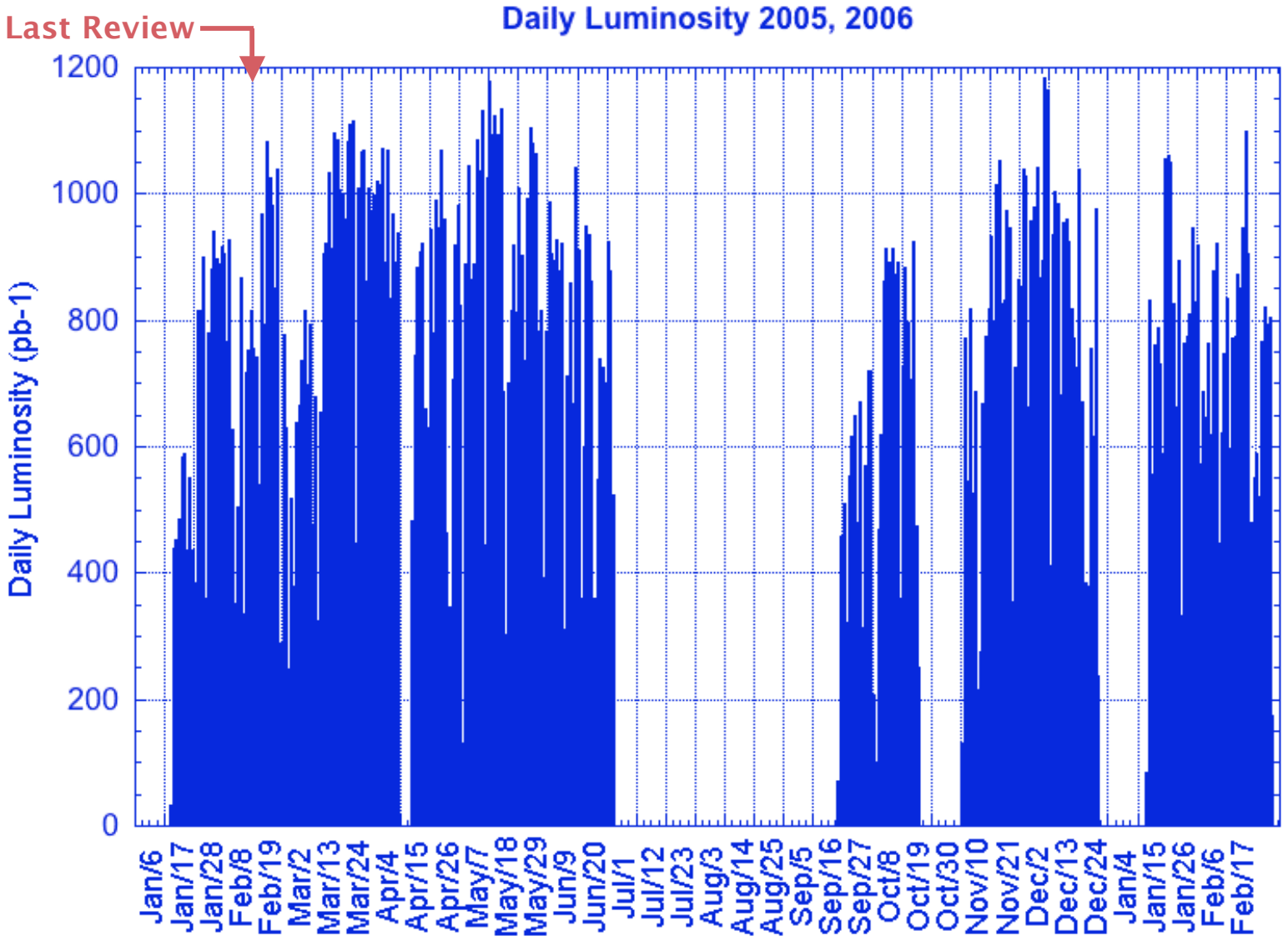
- **Annual integrated luminosity**
  158.9(2004) → *188.7(2005)/fb/year*
- **Total luminosity** *363.4* → *563.3/fb*



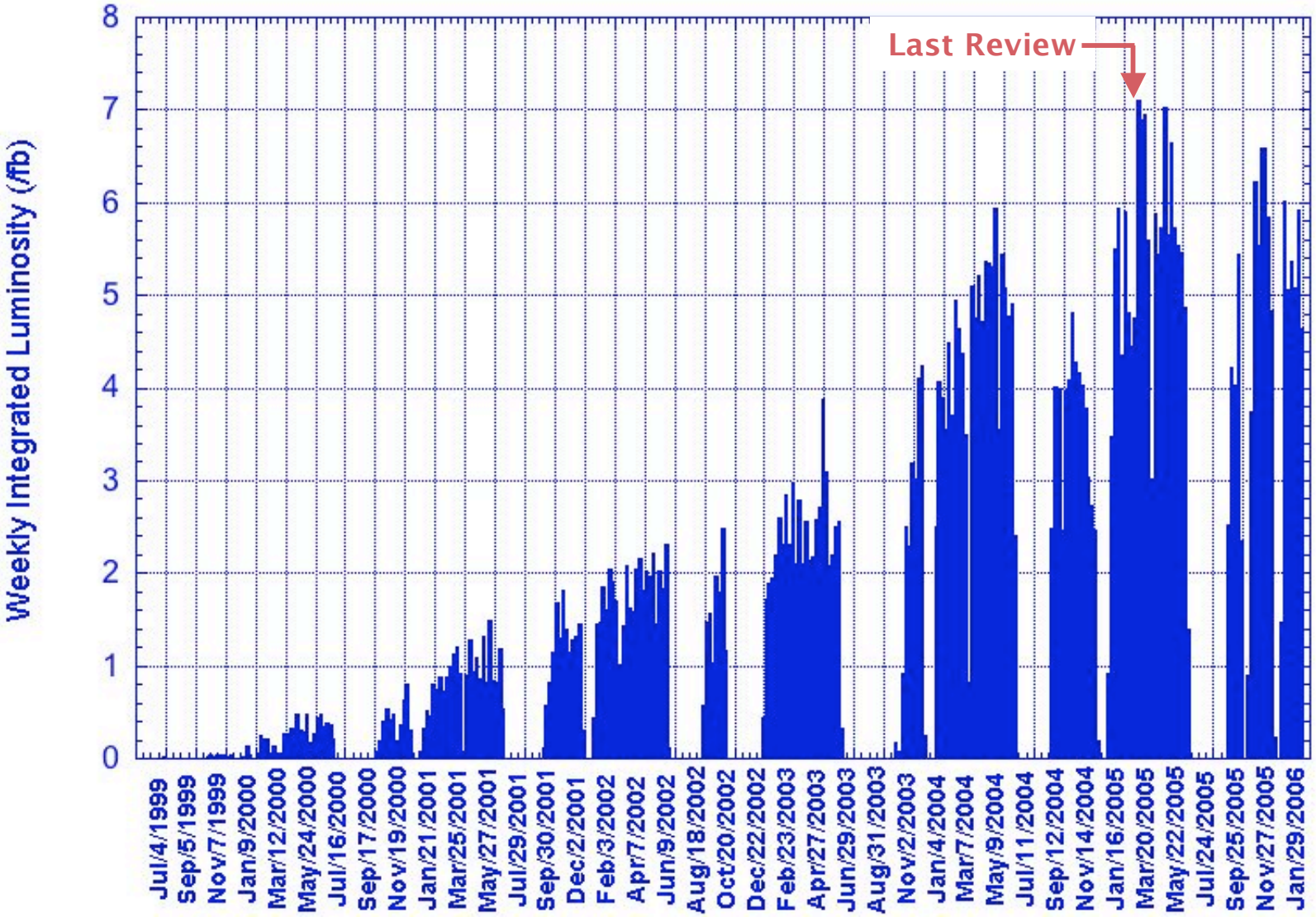
The Best Day 1182.5/pb



History of Daily Luminosity



History of Weekly Luminosity



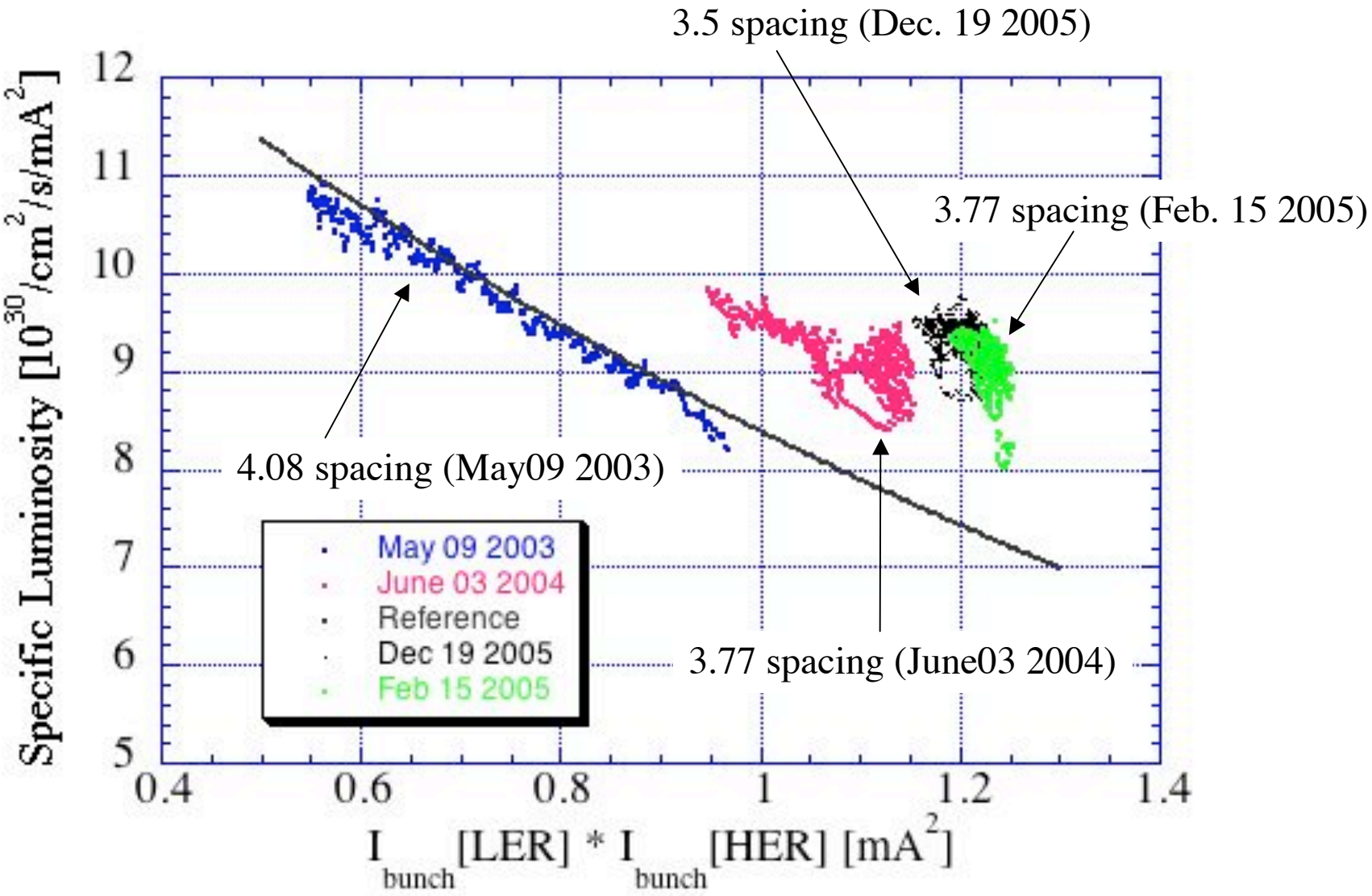
Machine parameters

Date	2/15/2005		12/19/2005		
Ring	LER	HER	LER	HER	
Horizontal Emittance	18	24	18	24	nm
Beam current	1636	1261	1719	1347	
Number of bunches	1293		1388		
Bunch current	1.27	0.975	1.23	0.970	
Bunch spacing	1.8 or 2.4 (3.77sp)		1.8 or 2.4 (3.5sp)		m
Bunch trains	1		1		
Horizontal size at IP σ^*_x	103	116	103	116	
Vertical size at IP σ^*_y	2.1	2.1	2.1	2.1	μm
Betatron tune ν_x/ν_y	45.506/43.535	44.510/41.577	45.506/43.531	44.512/41.578	
β^*_x/β^*_y	59/0.54	56/0.62	59/0.65	56/0.62	cm
Beam-beam parameters ξ_x/ξ_y	0.118/0.081	0.074/0.056	0.117/0.096	0.073/0.055	
Beam lifetime at collision	160 @1503 mA	195@1132 mA	135@1719mA	222@1347mA	min
Luminosity (Belle CsI)	15.16		16.27	/nb/s	
Luminosity records per day/7 days/30 days	1083/6242/23995 (363.4/fb) (total)		1183/7358/29018 (560/fb)	/pb	

Machine Parameters (cont'd)

- **Bunch fill pattern/bunch spacing**
  - 3.77 (49/13) (April 2005~): physics run
  - 3.5 (49/14) (~April 2005): physics run
  - 3.27 (49/13) Test run in June 2005
  - 3.06 (49/16) Test run in Dec. 2005
- **Stored currents**
  - LER ~ 1674 → ~<1750 mA
    ~ 2000mA (short-term trial)
  - HER 1270 → 1350 mA world's highest with SCC
- **RF Voltage**
  - LER 8 MV
  - HER 15 MV

Progress of Specific Luminosity



Methods for higher luminosity

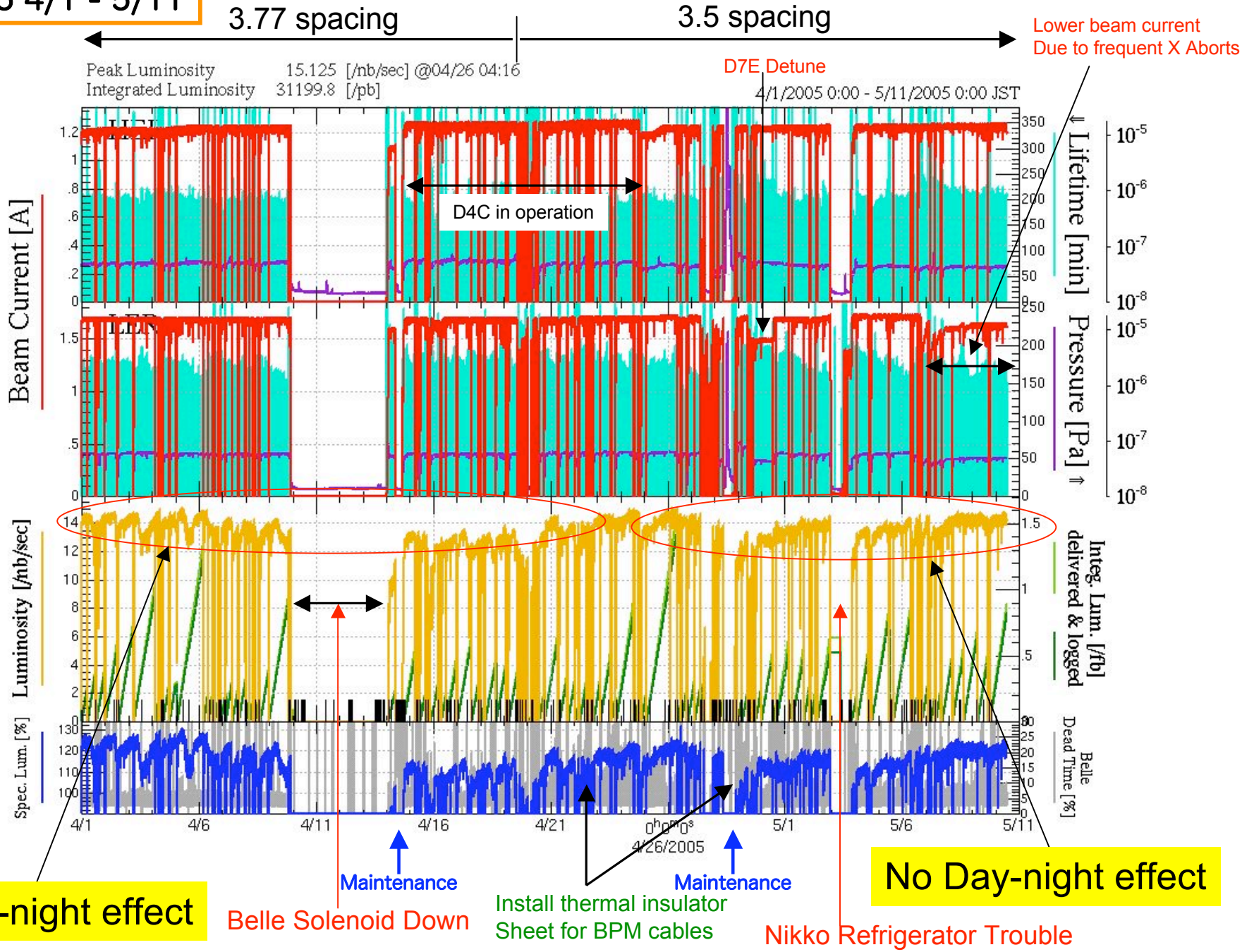
Methods for higher luminosity

Items		Limitations or Methods	
Peak Luminosity	Higher beam currents	HER	Available RF power Tolerance of vacuum components
		LER	Effects of electron clouds Tolerance of vacuum components
	Crab cavities	-> in preparation	
	Search for better machine parameters	Tune	Dynamic aperture
		IP $\beta_{x,y}$	Hourglass effect
		FB Gain	
Integrated Luminosity	Reduction of downtime due to troubles	-> Show statistics	
	Reduction of beam aborts	-> Show statistics	
	Luminosity recovery after breaks	Pursuit for effective tuning procedure	
	Shortening of injection time	Electron 2 bunch injection	
	Other operation stabilities	Countermeasure against day-night effects	

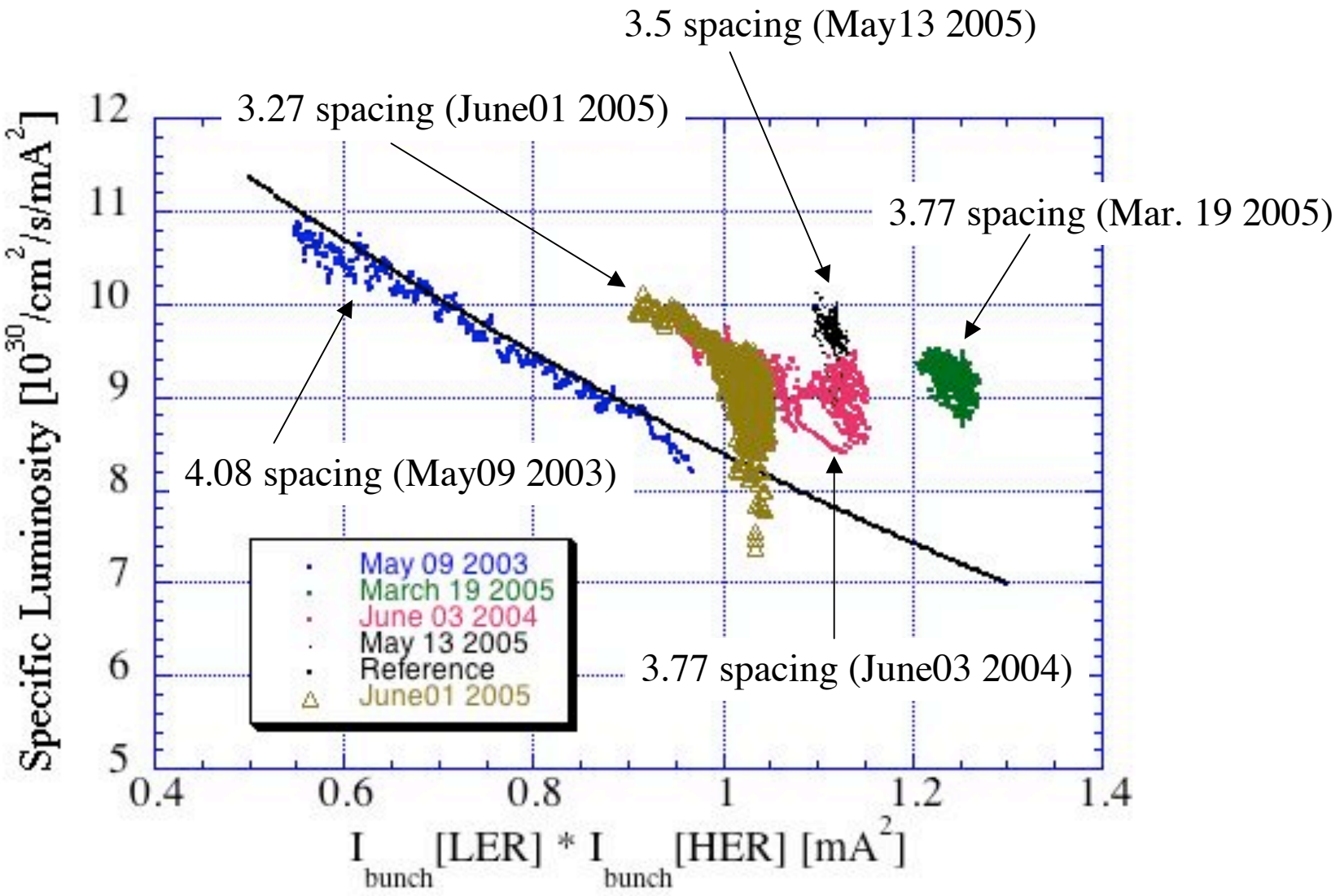
Higher beam currents

- Request from vacuum group
  - When we increase the beam currents, it is strongly requested to increase the number of bunches to protect vacuum components against high HOM power.
  - At KEKB, the increases of the beam currents and the number of bunches are a set of procedures.
- Trial
  - 3.77 -> 3.5
    - Luminosity increased.
  - 3.5 -> 3.27
    - Luminosity decreased.
  - 3.5 -> 3.06
    - LER high current trial. No increase of luminosity.

2005 4/1 - 5/11

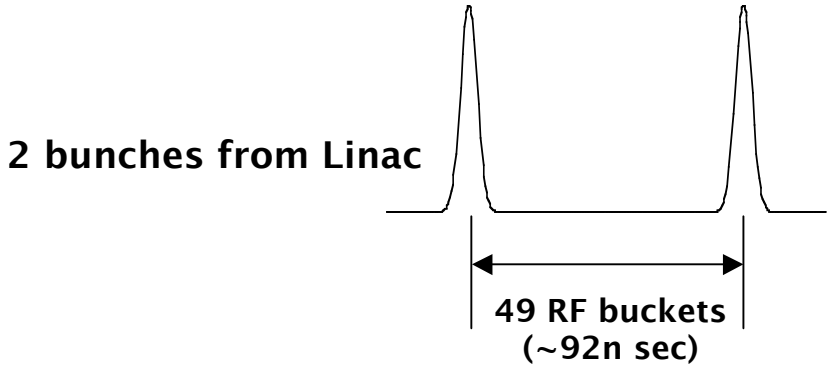

3.77 spacing
3.5 spacing
Lower beam current
Due to frequent X Aborts
Peak Luminosity 15.125 [/nb/sec] @04/26 04:16
Integrated Luminosity 31199.8 [/pb]
D7E Detune
4/1/2005 0:00 - 5/11/2005 0:00 JST
D4C in operation
Beam Current [A]
Lifetime [min]
Pressure [Pa]
Luminosity [/nb/sec]
Integ. Lum. [/fb] delivered & logged
Spec. Lum. [%]
Belle Dead Time [%]
4/1
4/6
4/11
4/16
4/21
4/26/2005
5/1
5/6
5/11
Maintenance
Maintenance
Day-night effect
Belle Solenoid Down
Install thermal insulator
Sheet for BPM cables
Nikko Refrigerator Trouble
No Day-night effect

Comparison of Specific Luminosity



Fill pattern

- Constraint from 2 bunch injection
  - The same fill pattern must be repeated every 49 RF buckets.



- Fill pattern
  - 3.77 (49/13)spacing (4444434443443): Physics Run (~April 2005)
  - 3.5 (49/14)spacing (34343434343434): Physics Run (April 2005~)
  - 3.27 (49/15)spacing(333433343334334): Test pattern
  - 3.06 (49/16)spacing(3333334333333333): Test pattern

Beam current dependence of luminosity (HER)

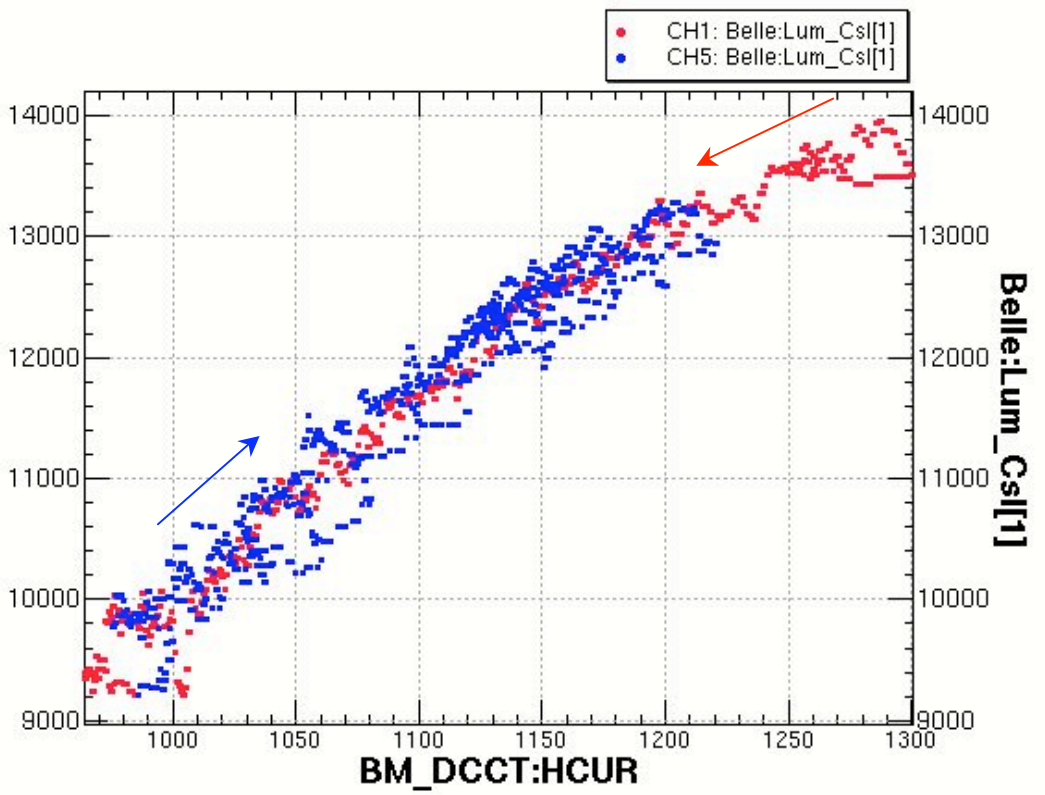
$\mathcal{L}$ vs HER beam current

LER : 1800 mA (fixed)

HER : 1300 → 1000 → 1300 mA

2005 June 08

3.5 bucket spacing



Beam current dependence of luminosity (LER)

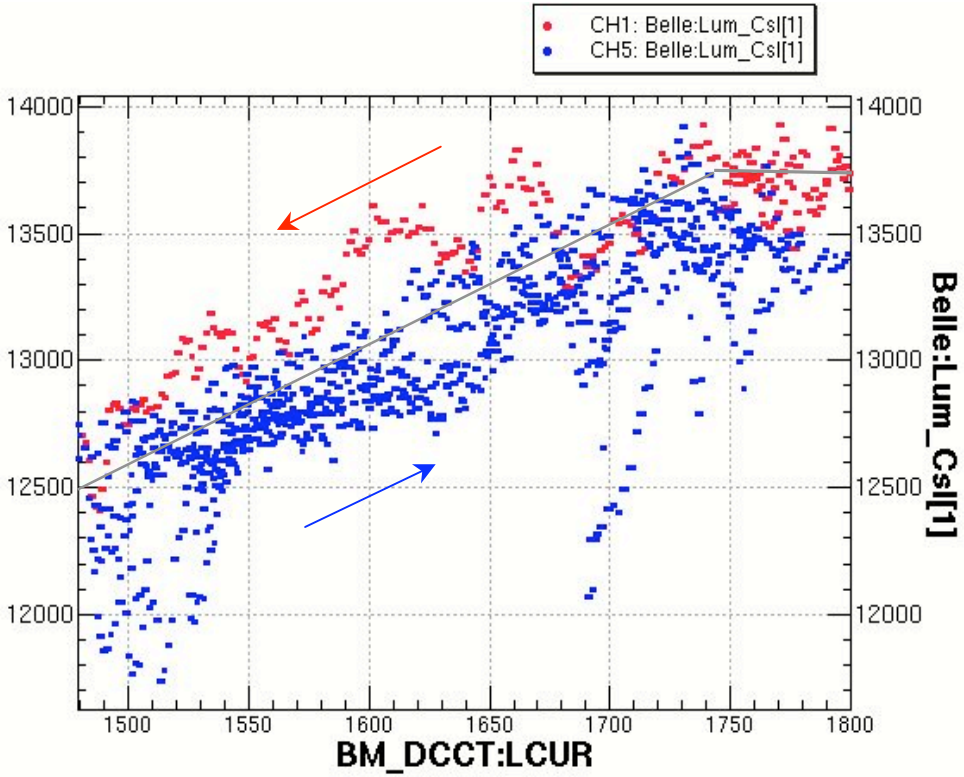
$\mathcal{L}$ vs. LER beam current

LER : 1800 → 1500 → 1800 mA

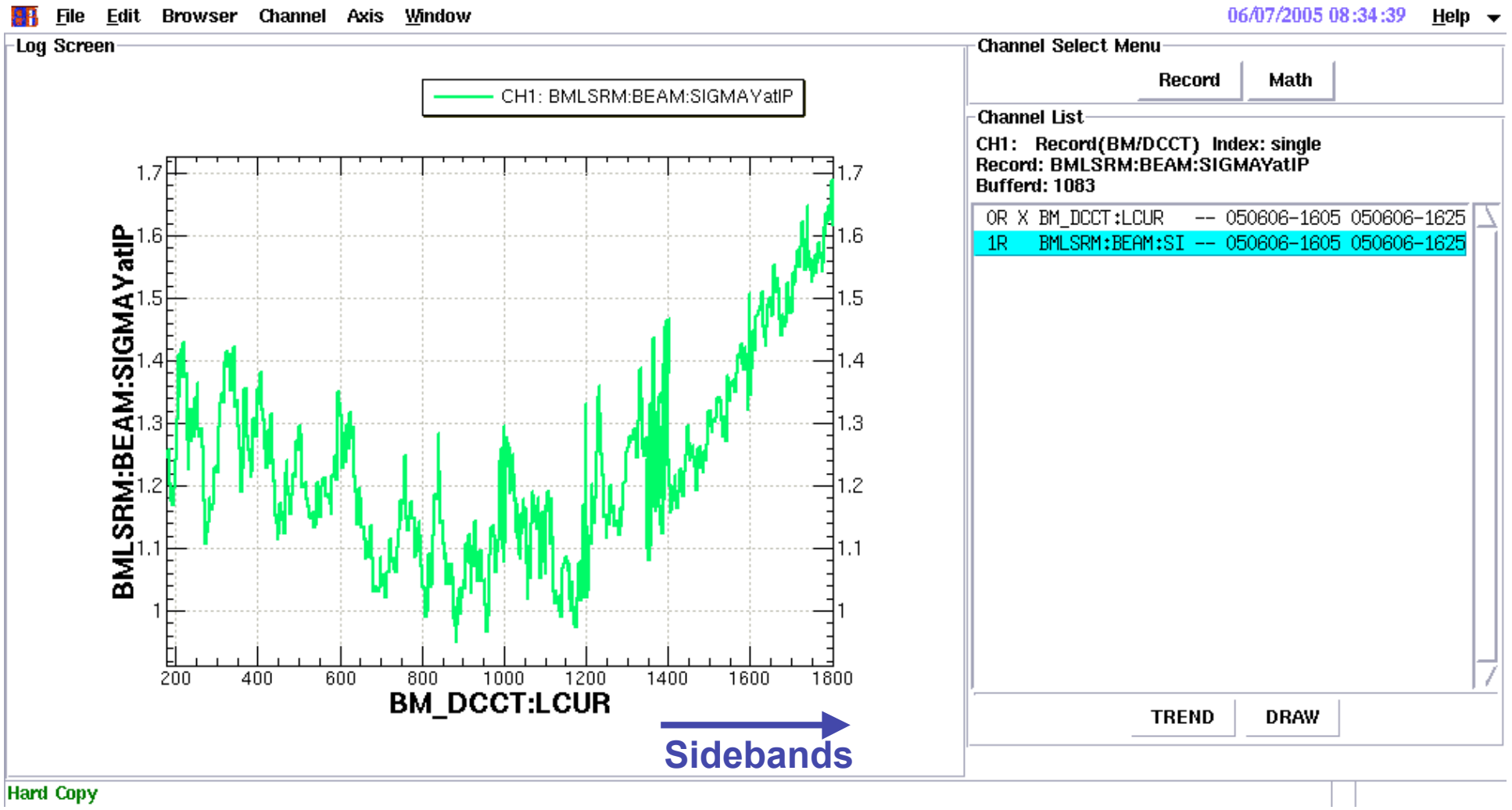
HER : ~1300 mA (fixed)

2005 June 08

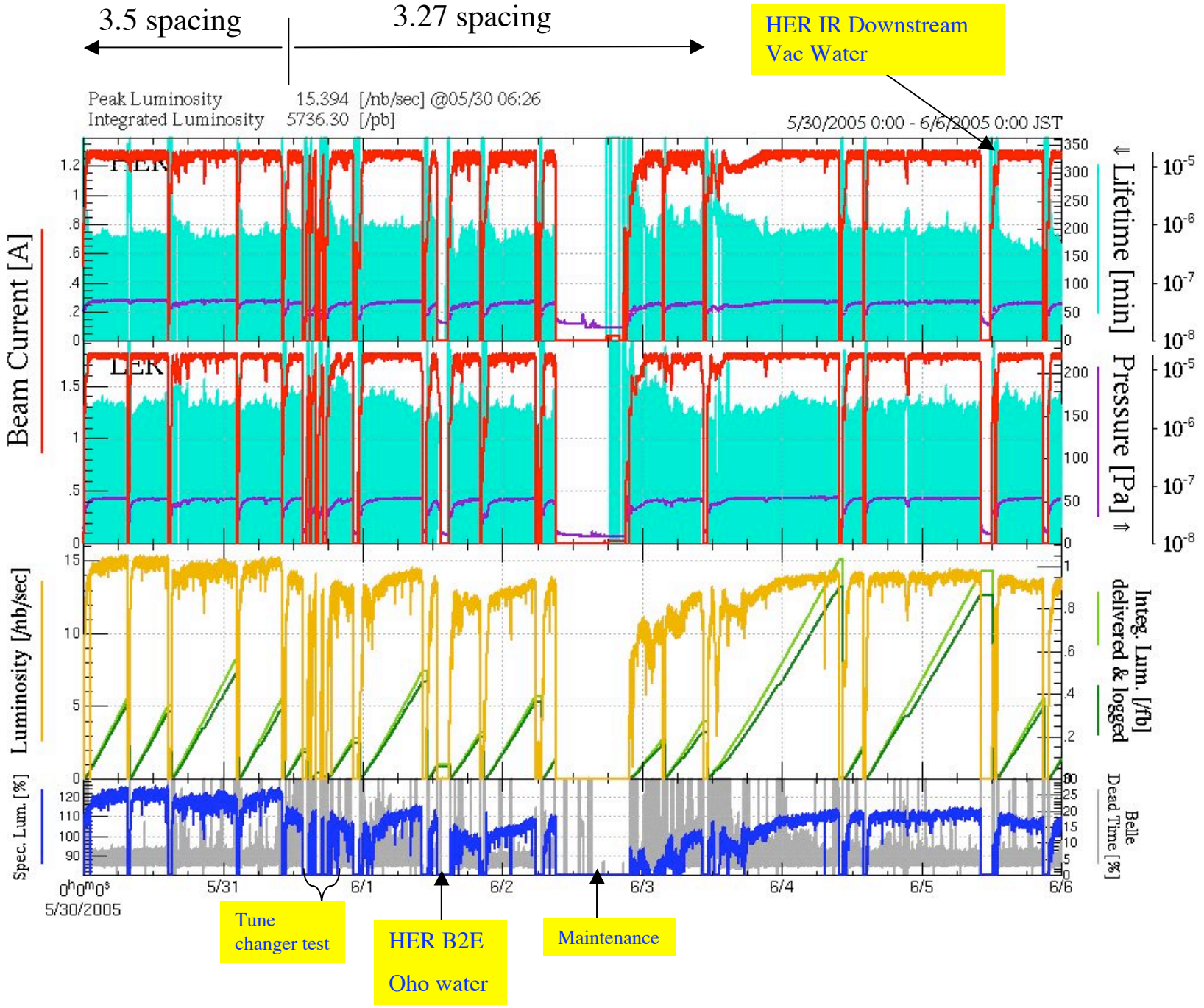
3.5 bucket spacing



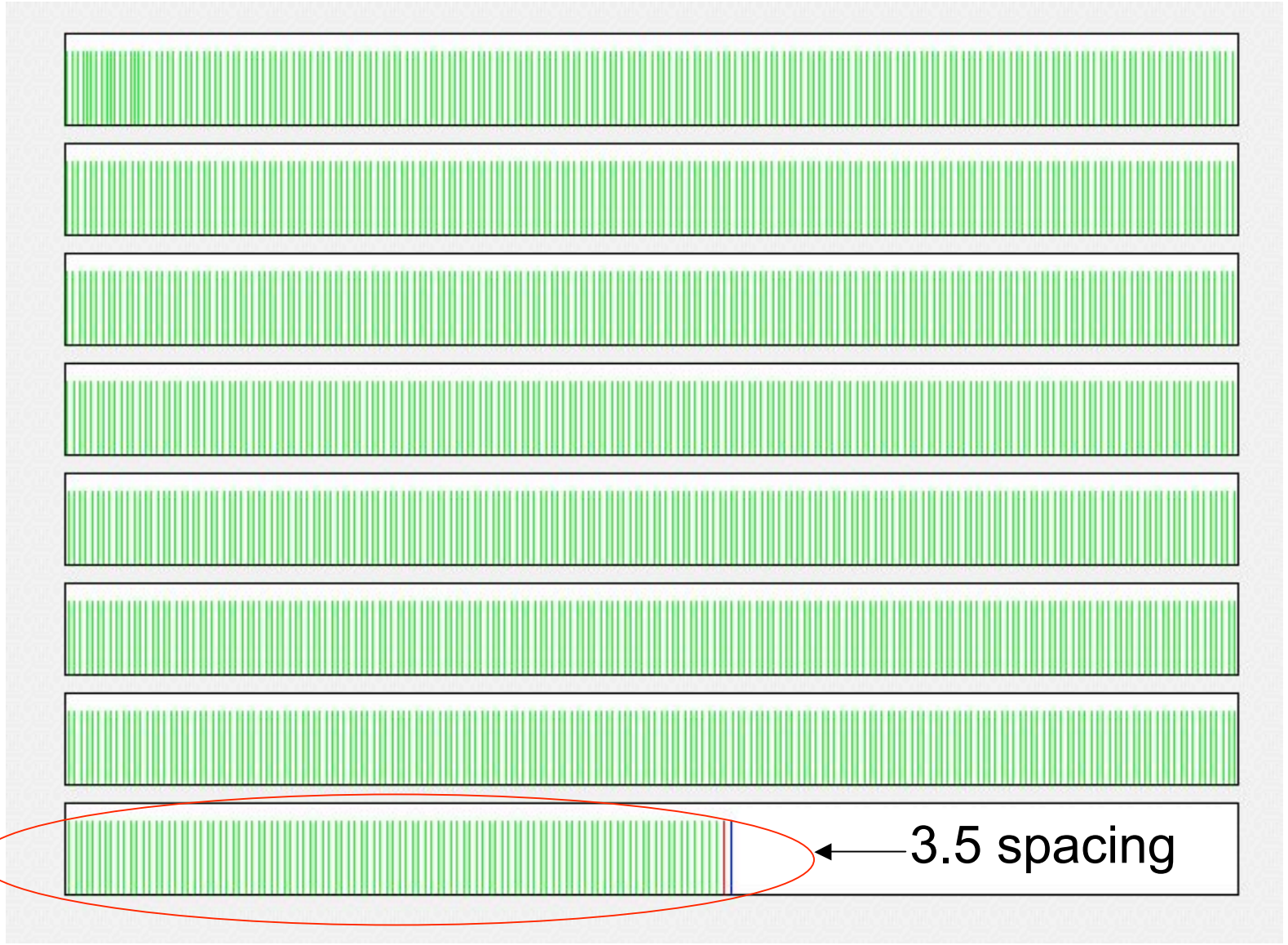
Single beam: current dependence of beam size (LER)



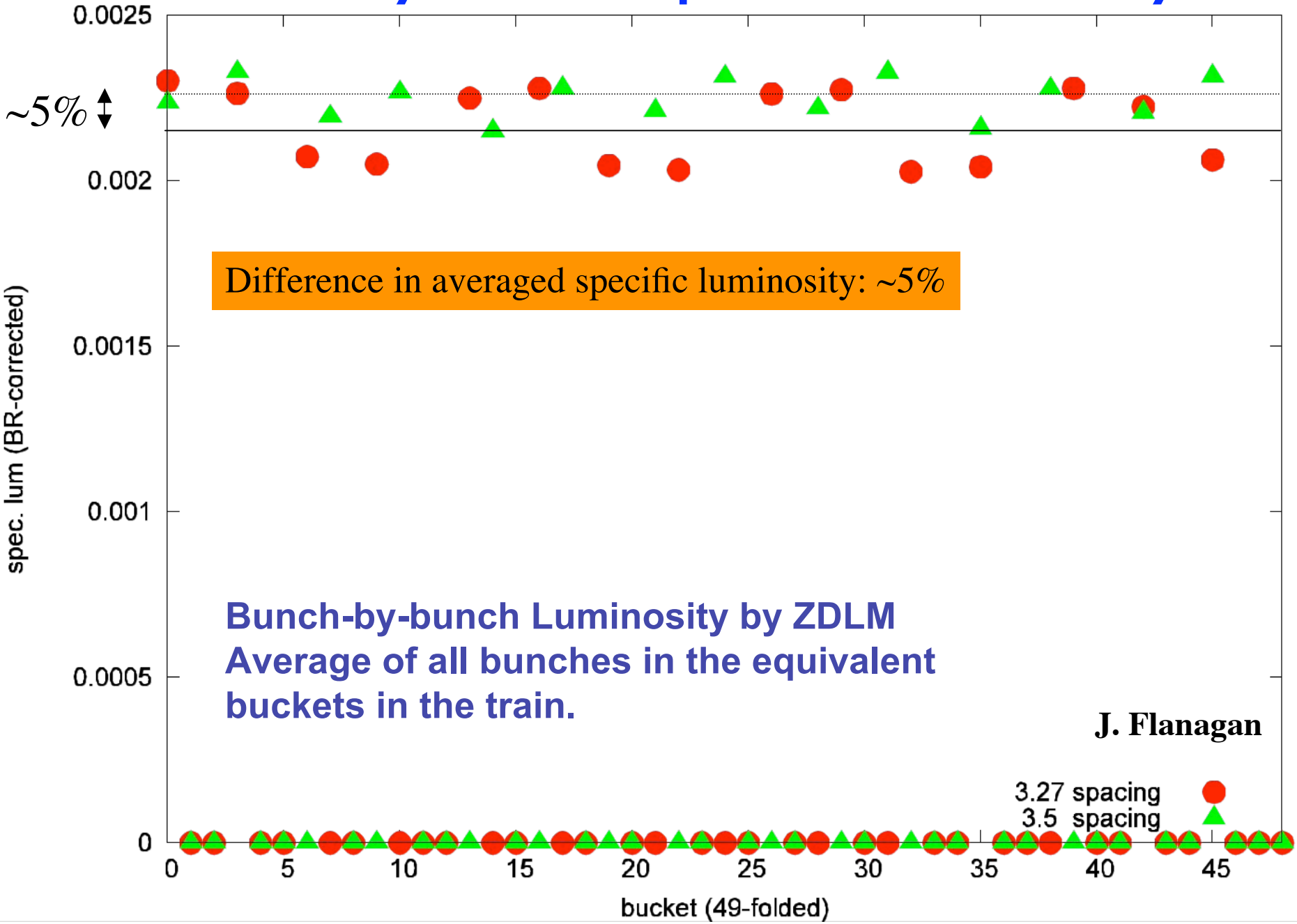
J. Flanagan

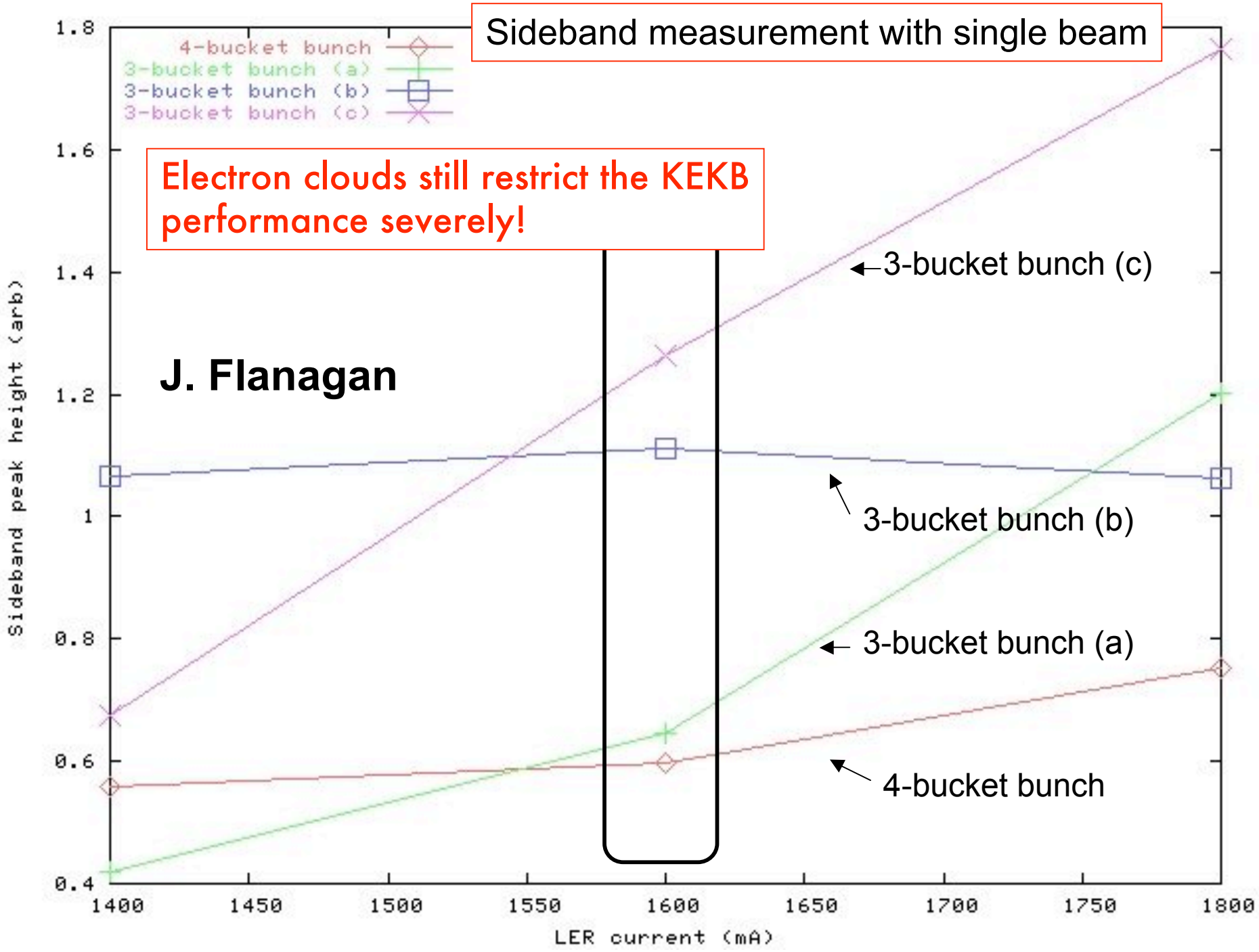

3.5 spacing
3.27 spacing
HER IR Downstream
Vac Water
Peak Luminosity 15.394 [/nb/sec] @05/30 06:26
Integrated Luminosity 5736.30 [/pb]
5/30/2005 0:00 - 6/6/2005 0:00 JST
HER
LER
Beam Current [A]
Lifetime [min]
Pressure [Pa]
Luminosity [/nb/sec]
Integ. Lum. [/fb]
delivered & logged
Spec. Lum. [%]
Belle
Dead Time [%]
0h0m0s
5/30/2005
5/31
6/1
6/2
6/3
6/4
6/5
6/6
Tune
changer test
HER B2E
Oho water
Maintenance

Base fill pattern: 3.27 spacing

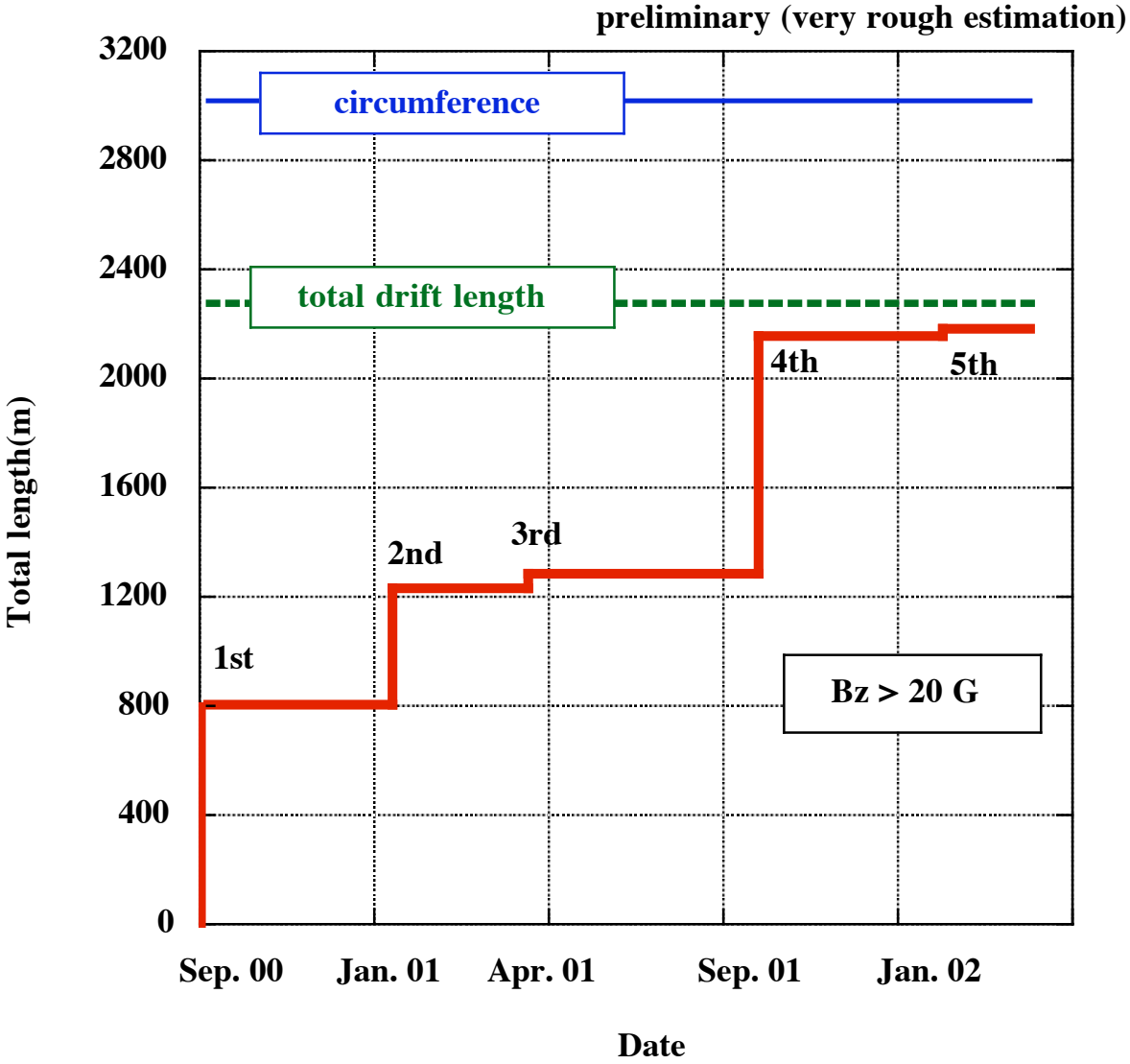


Bunch-by-bunch specific luminosity




Sideband measurement with single beam
4-bucket bunch
3-bucket bunch (a)
3-bucket bunch (b)
3-bucket bunch (c)
Electron clouds still restrict the KEKB performance severely!
J. Flanagan
3-bucket bunch (c)
3-bucket bunch (b)
3-bucket bunch (a)
4-bucket bunch
Sideband peak height (arb)
LER current (mA)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
1400
1450
1500
1550
1600
1650
1700
1750
1800

Total length of solenoid



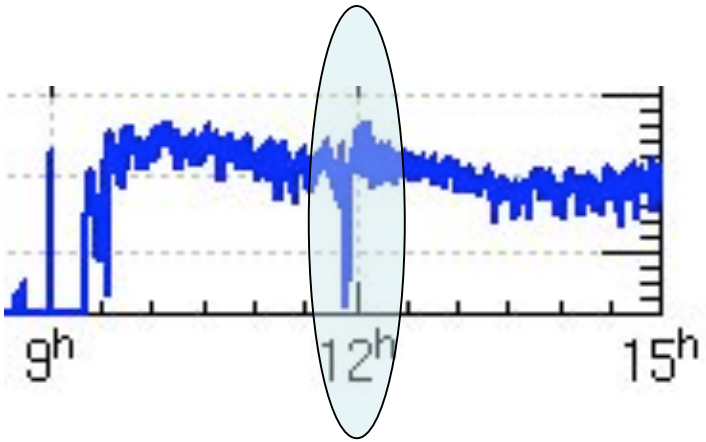
- Almost all parts of the drift space have been covered with solenoids.

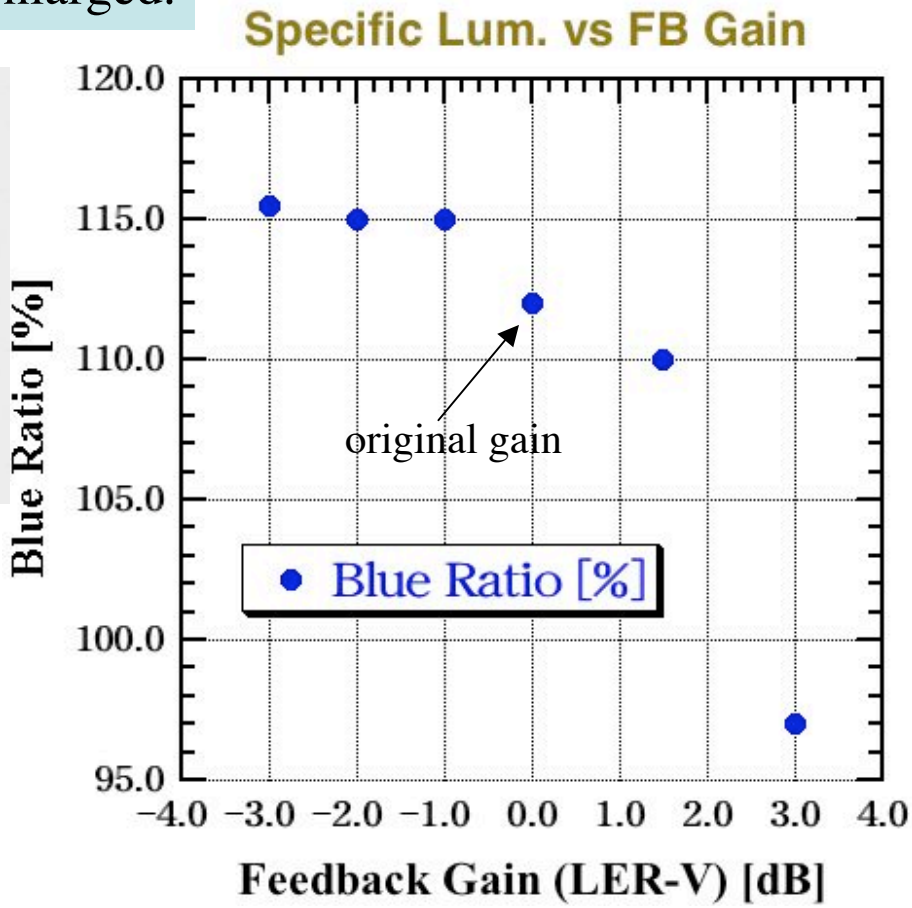
- In summer 2005, we installed solenoids in 88 quadruple magnets out of 461.

- However, the effectiveness of the solenoids was not observed. (-> Fukuma's talk)

Specific Luminosity vs FB Gain

HER vertical size enlarged.

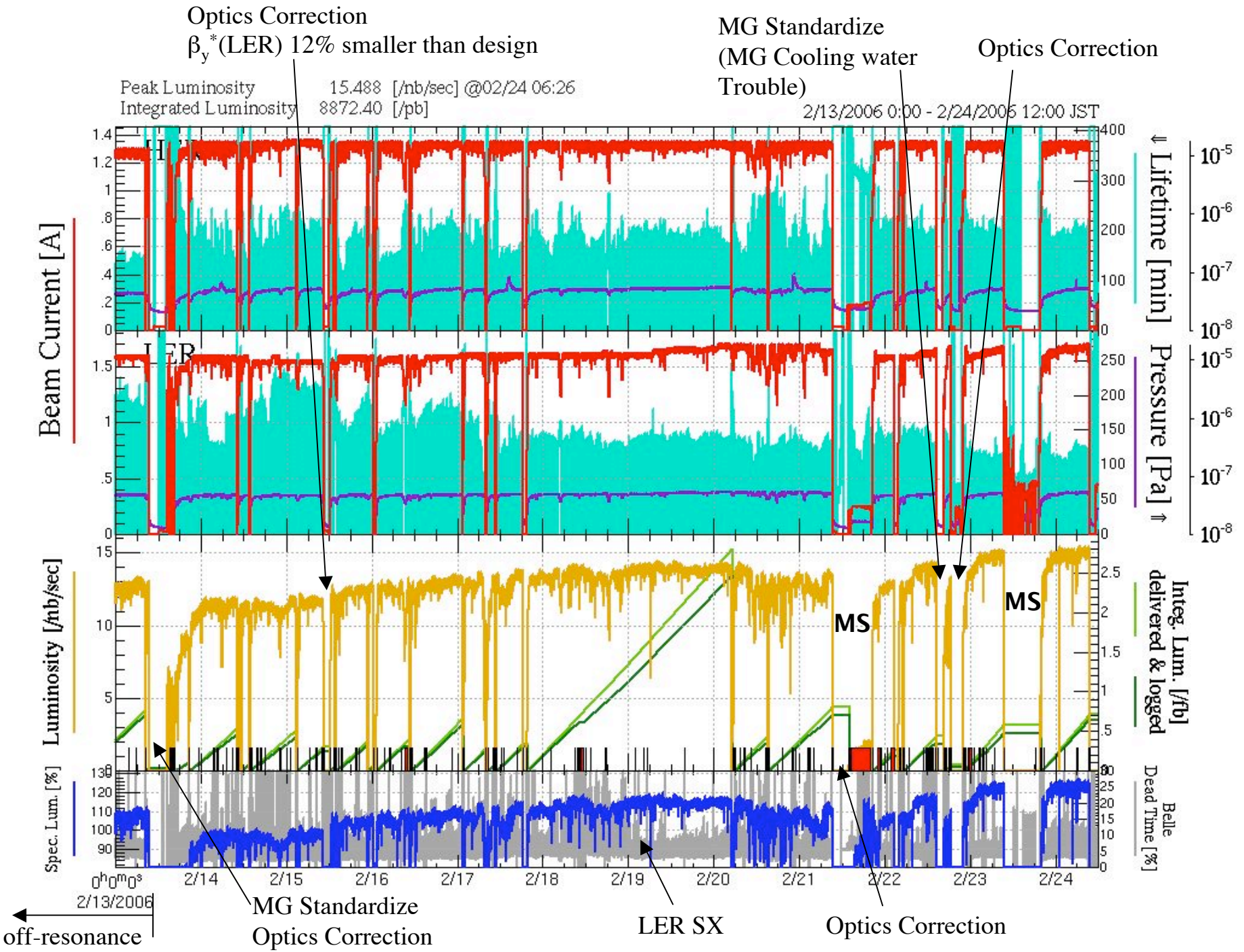




FB gain of the LER vertical affects the specific luminosity.
The other gains (LER H, HER H/V) bring no effects.

Methods of luminosity tuning after regular maintenance

- Magnet standardization (~30min.)
- Optics Correction (~2h)
  - Global x-y coupling
  - Global dispersions
  - Beta beat
- Collision tuning (~30min.)
  - Orbit FB parameters
- Fine tuning(knob tuning) (always during physics run)
  - IP Knobs
  - Tunes
  - SX strength


Optics Correction
β_y^*(LER) 12% smaller than design
MG Standardize
(MG Cooling water
Trouble)
Optics Correction
Peak Luminosity 15.488 [/nb/sec] @02/24 06:26
Integrated Luminosity 8872.40 [/pb]
2/13/2006 0:00 - 2/24/2006 12:00 JST
Beam Current [A]
HER
LER
Lifetime [min]
Pressure [Pa]
Luminosity [/nb/sec]
MS
MS
Integ. Lum. [/fb]
delivered & logged
Spec. Lum. [%]
Belle
Dead Time [%]
2/13/2006
2/14
2/15
2/16
2/17
2/18
2/19
2/20
2/21
2/22
2/23
2/24
off-resonance
MG Standardize
Optics Correction
LER SX
Optics Correction

Recovery of luminosity

- After a short break such as a regular maintenance
  - Optics corrections are important.
  - Knob tunings are also important.
  - However, the best performance is not always reproduced by the above tunings.
    - It seems that there are some unknown sources which affect the luminosity.
    - It is critically important to identify such sources, if there are any.
      - Candidate: mechanical position shift of BPMs due to heating by SR.
- After a long shutdown
  - It takes very long time to recover the best performance before the shutdown.
    - We feel that the recovery time became longer with higher specific luminosity.
  - Usually we don't proceed to other subjects before the recovery of the best performance.

Peak Luminosity

- Beam-Beam Blowup
  - Tune
  - Single beam emittance
  - IP Optical parameters
    - IP knobs (14 parameters)
      - Waist
      - X-Y coupling parameters
      - Vertical dispersion
  - Chromatic parameters
    - Linear chromaticity etc.
  - Feedback Gain
- IP β-functions
- Effects of electron clouds
- Beam Currents

Knob! 1

Tuning in a typical shift

LER

D7 RoomPhase :
-23.64 -> -23.58

Δf_{RF} :
-106.15 -> -94.74

Waist :
0 -> 0

ηy :
0 -> .21

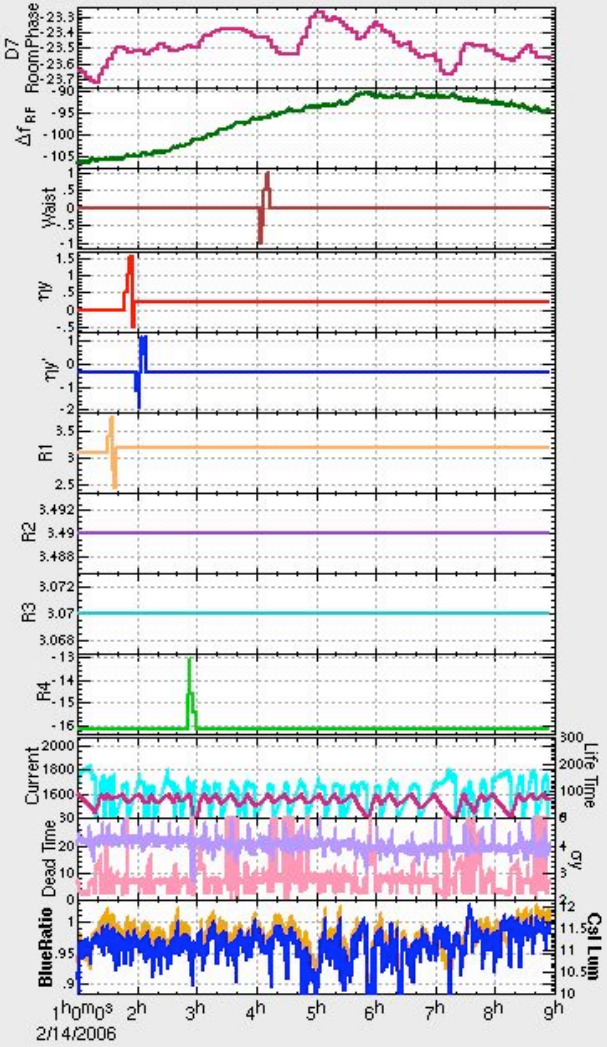
ηy' :
-.38 -> -.38

R1 :
3.1 -> 3.2

R2 :
3.49 -> 3.49

R3 :
3.07 -> 3.07

R4 :
-16.16 -> -16.16



HER

Voffset :
-1.48 -> -1.48

Vangle :
-.65 -> -.67

Waist :
0 -> .2

ηy :
0 -> 0

ηy' :
0 -> .5

R1 :
.25 -> 0

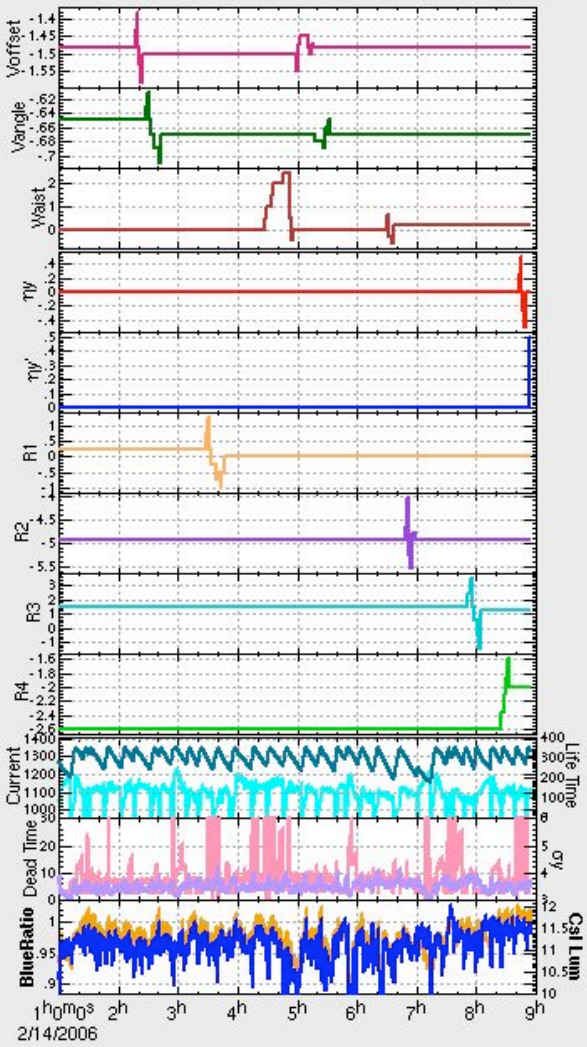
R2 :
-4.95 -> -4.95

R3 :
1.5 -> 1.3

R4 :
-2.6 -> -2

Lum_{Max}:12.037

BR_{Max}:102.69%



The knob tuning is always done during the physics run by operators and/or shift crews.

Knob!2

LER

LER SizeFB(Inj) :
4.2 -> 3.9@1.6A

νx @0A :
.519 -> .515

νy @0A :
.5566 -> .5551

ξx :
1.732 -> 1.732

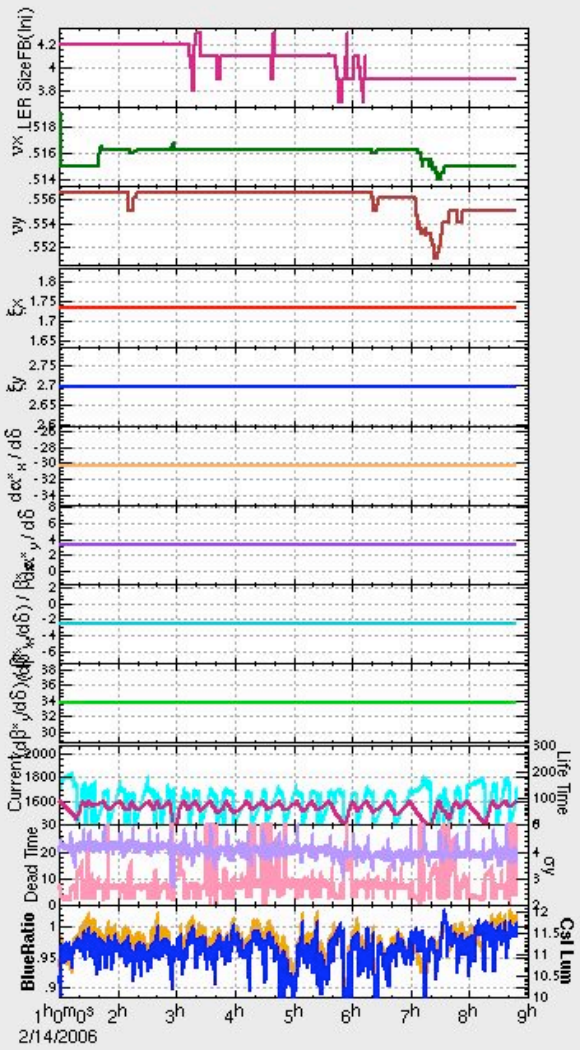
ξy :
2.695 -> 2.695

$d\alpha^*_x / d\delta$:
-30.37 -> -30.37

$d\alpha^*_y / d\delta$:
3.28 -> 3.28

$(d\beta^*_x/d\delta) / \beta^*_x$:
-2.55 -> -2.55

$(d\beta^*_y/d\delta) / \beta^*_y$:
33.7 -> 33.7



HER

LER SizeFB(Col) :
4.2 -> 3.9@1.6A

νx @0A :
.514 -> .514

νy @0A :
.5889 -> .5889

ξx :
-.207 -> -.207

ξy :
2.22 -> 2.22

$d\alpha^*_x / d\delta$:
62.1 -> 62.1

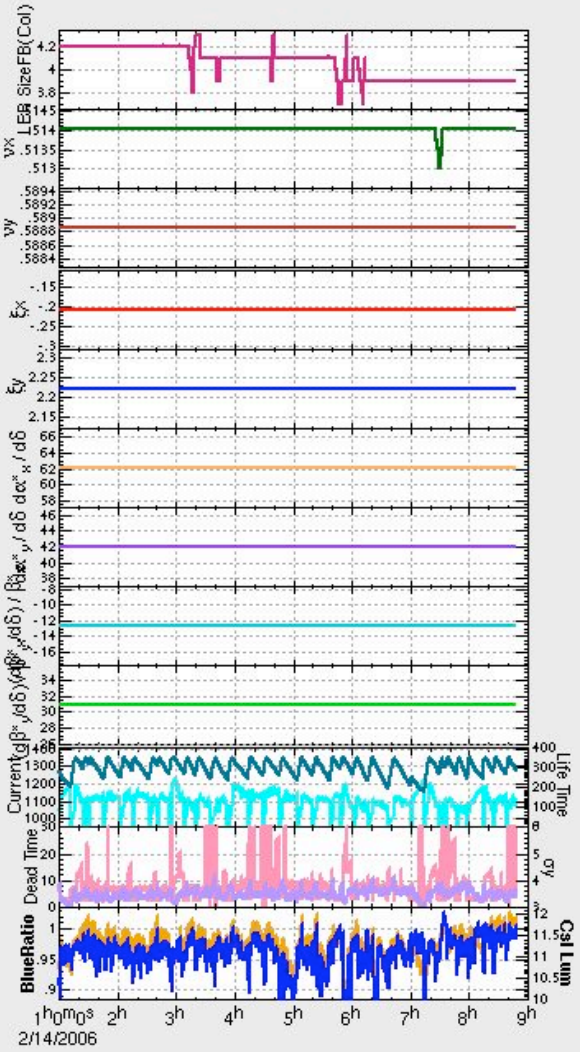
$d\alpha^*_y / d\delta$:
41.96 -> 41.96

$(d\beta^*_x/d\delta) / \beta^*_x$:
-12.68 -> -12.68

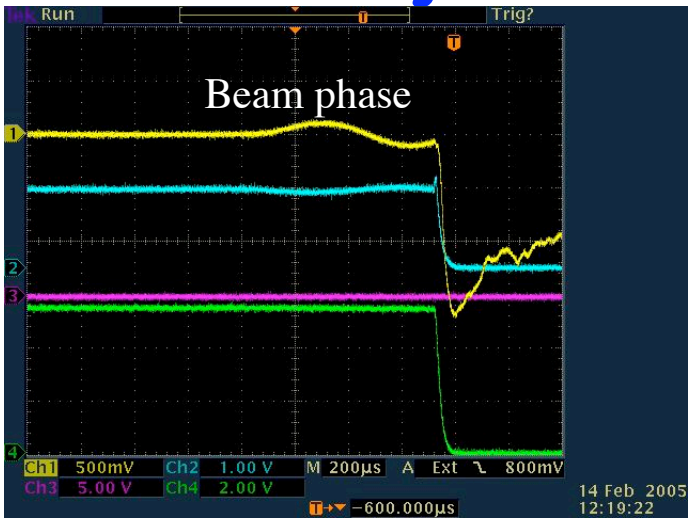
$(d\beta^*_y/d\delta) / \beta^*_y$:
30.88 -> 30.88

Lum_{Max}:12.037

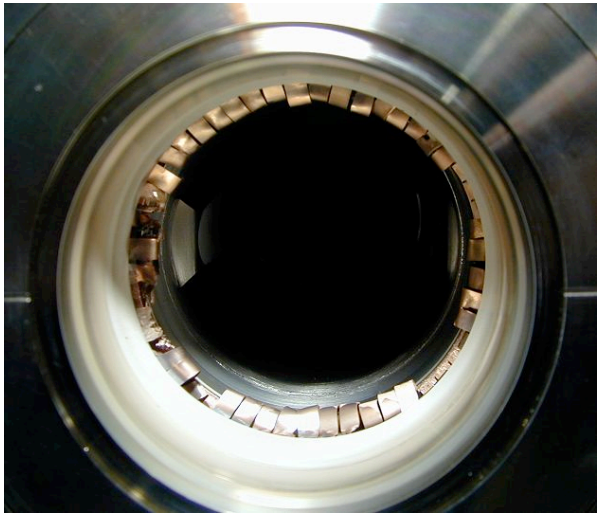
BR_{Max}:102.69%



X-Aborts (Frequent beam aborts due to mysterious beam loss in LER)



- Frequent beam aborts
  - Typically 15 aborts/week
  - Lost more than 1 shift every week!!
- LER Loss Monitor or Belle SVD Abort
- Beam loss of LER is observed.
- Change of beam phase is observed.
  - Energy loss side
- No transverse oscillation
- No vacuum pressure change at the beginning
- We found anomalous behavior of a bellow (temperature and vacuum pressure).
- The beam aborts disappeared after replacing the bellows.

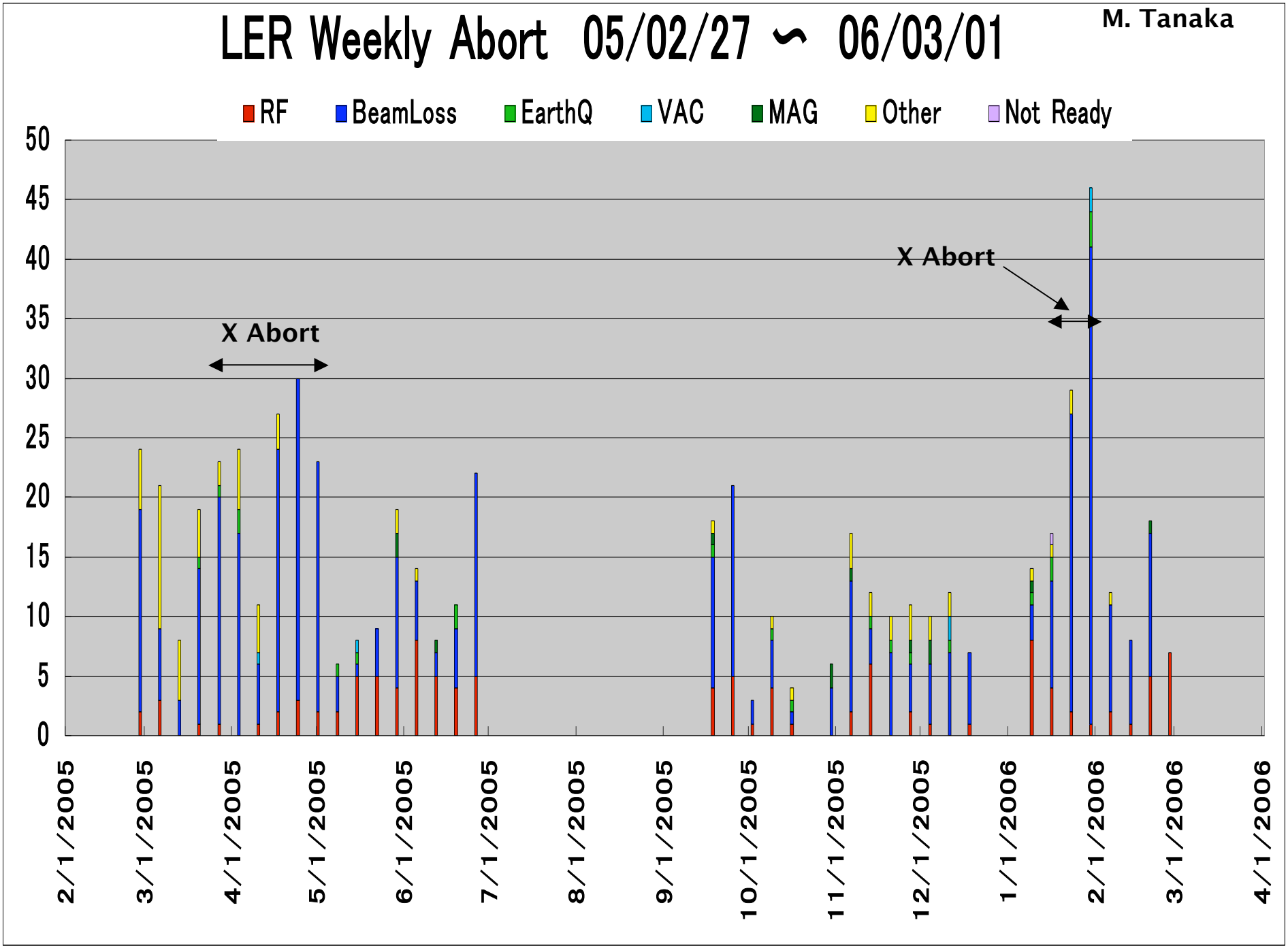


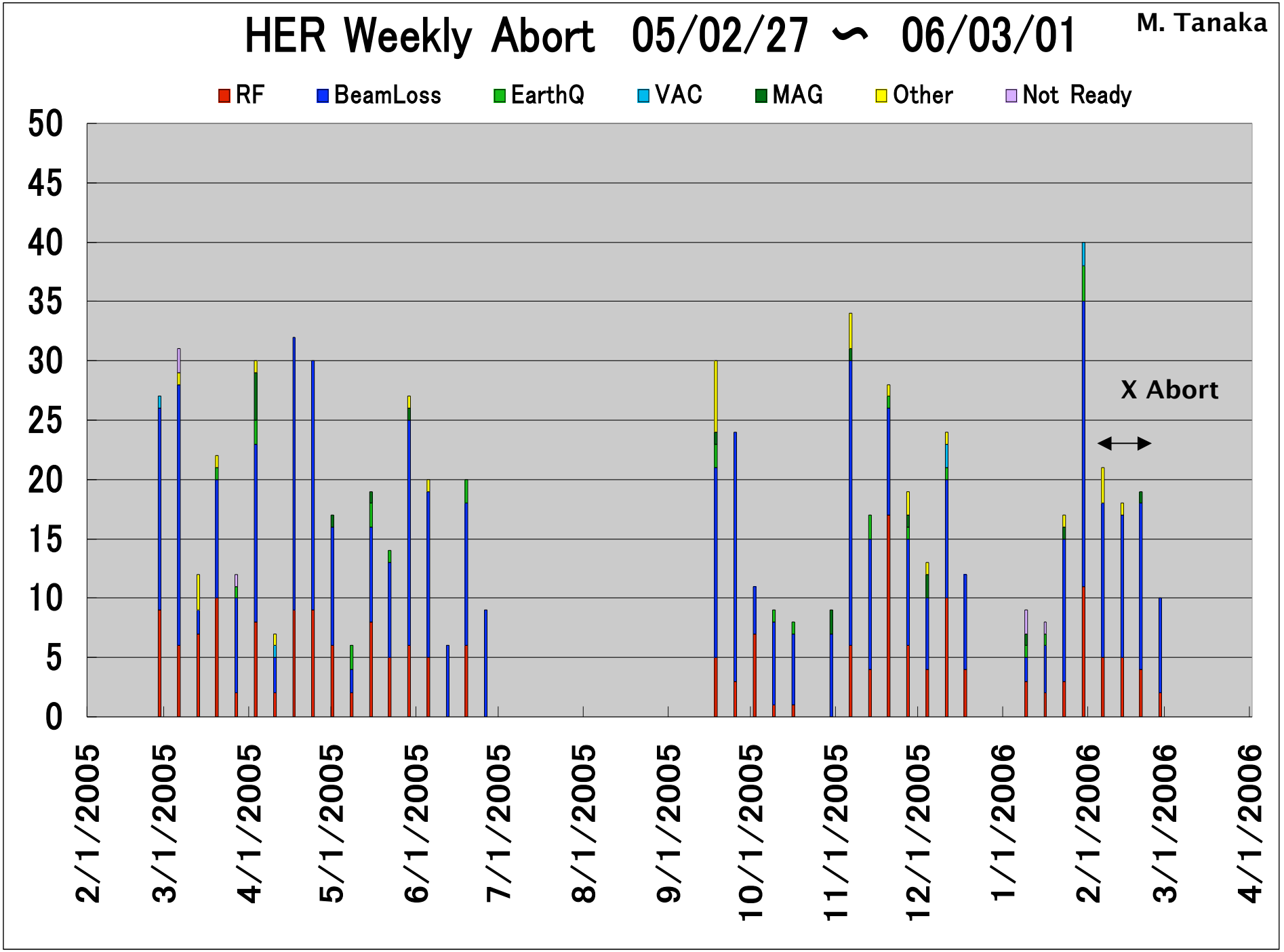
← Broken bellows

We experienced this kind of troubles twice with different bellows (March and May 2005).

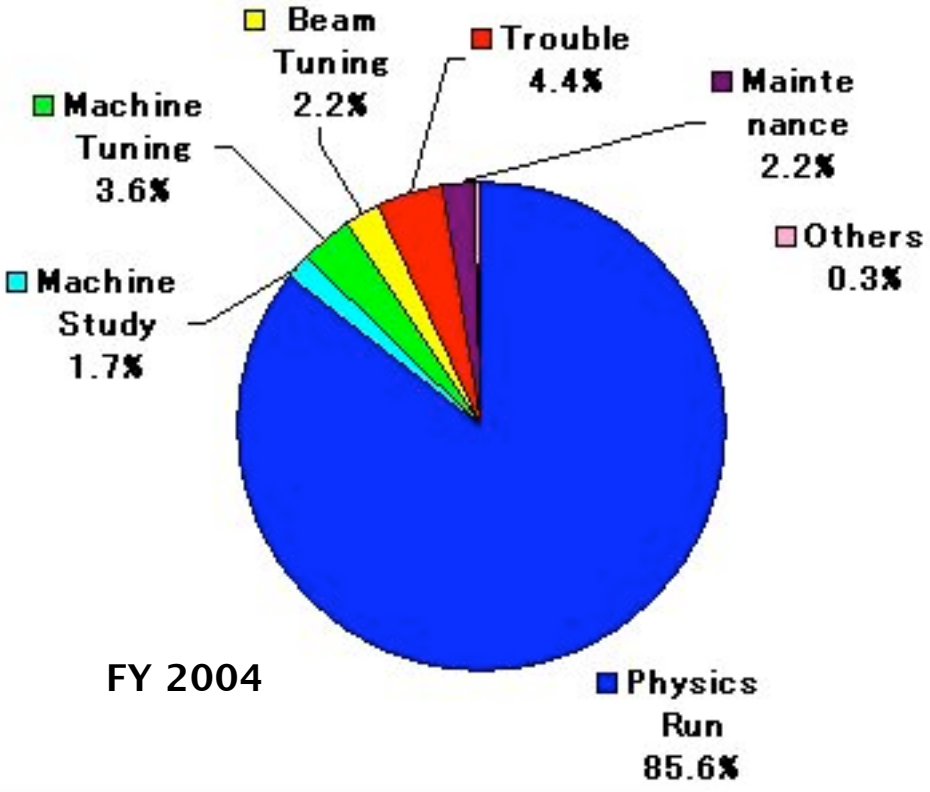
LER Weekly Abort 05/02/27 ~ 06/03/01

M. Tanaka

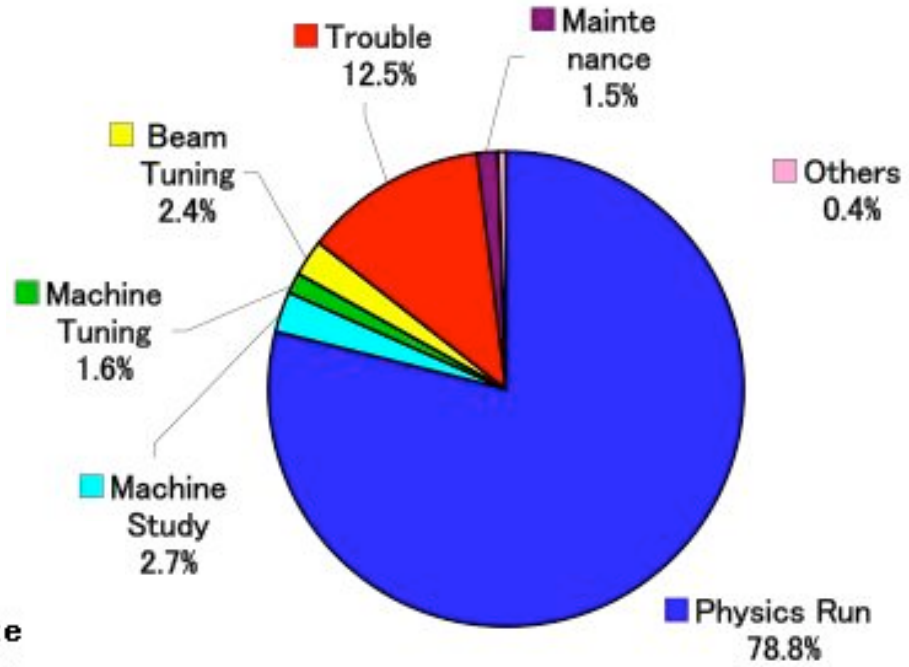



HER Weekly Abort 05/02/27 ~ 06/03/01
M. Tanaka
RF
BeamLoss
EarthQ
VAC
MAG
Other
Not Ready
X Abort
50
45
40
35
30
25
20
15
10
5
0
2/1/2005
3/1/2005
4/1/2005
5/1/2005
6/1/2005
7/1/2005
8/1/2005
9/1/2005
10/1/2005
11/1/2005
12/1/2005
1/1/2006
2/1/2006
3/1/2006
4/1/2006

Operation Statistics



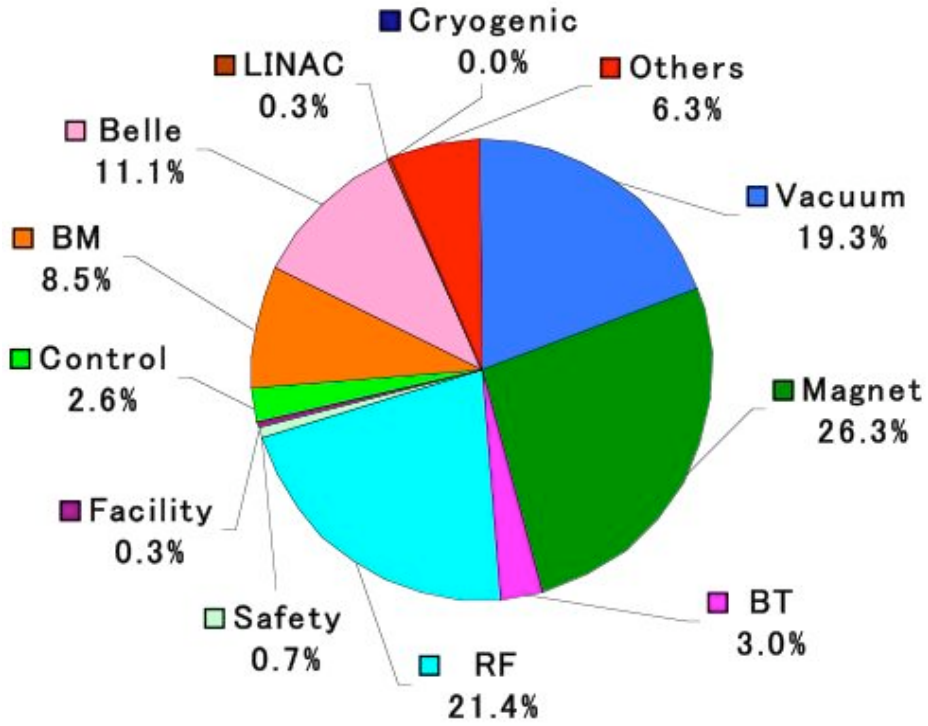
FY 2004



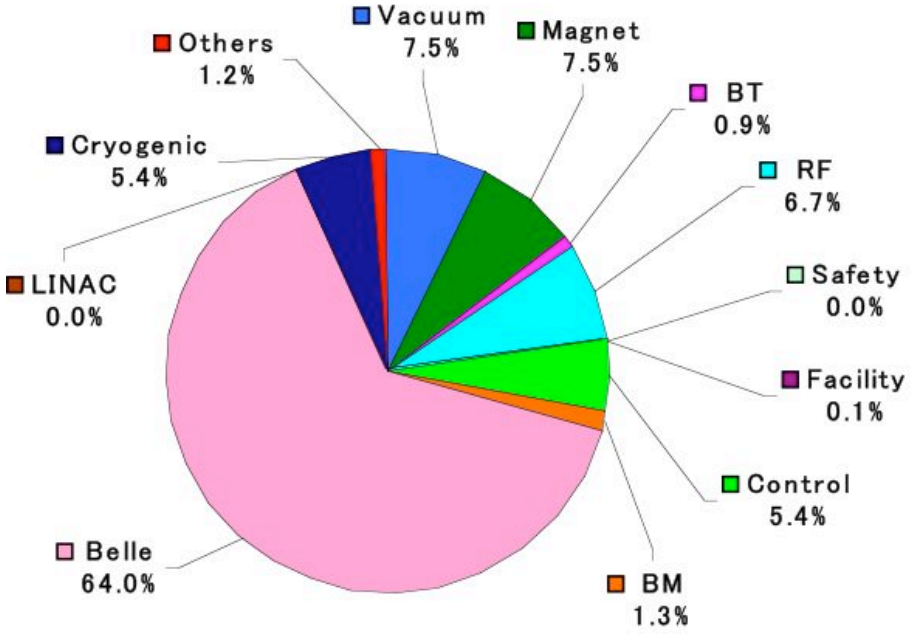
FY 2005

T. Kawasumi

Operation Statistics (Troubles)



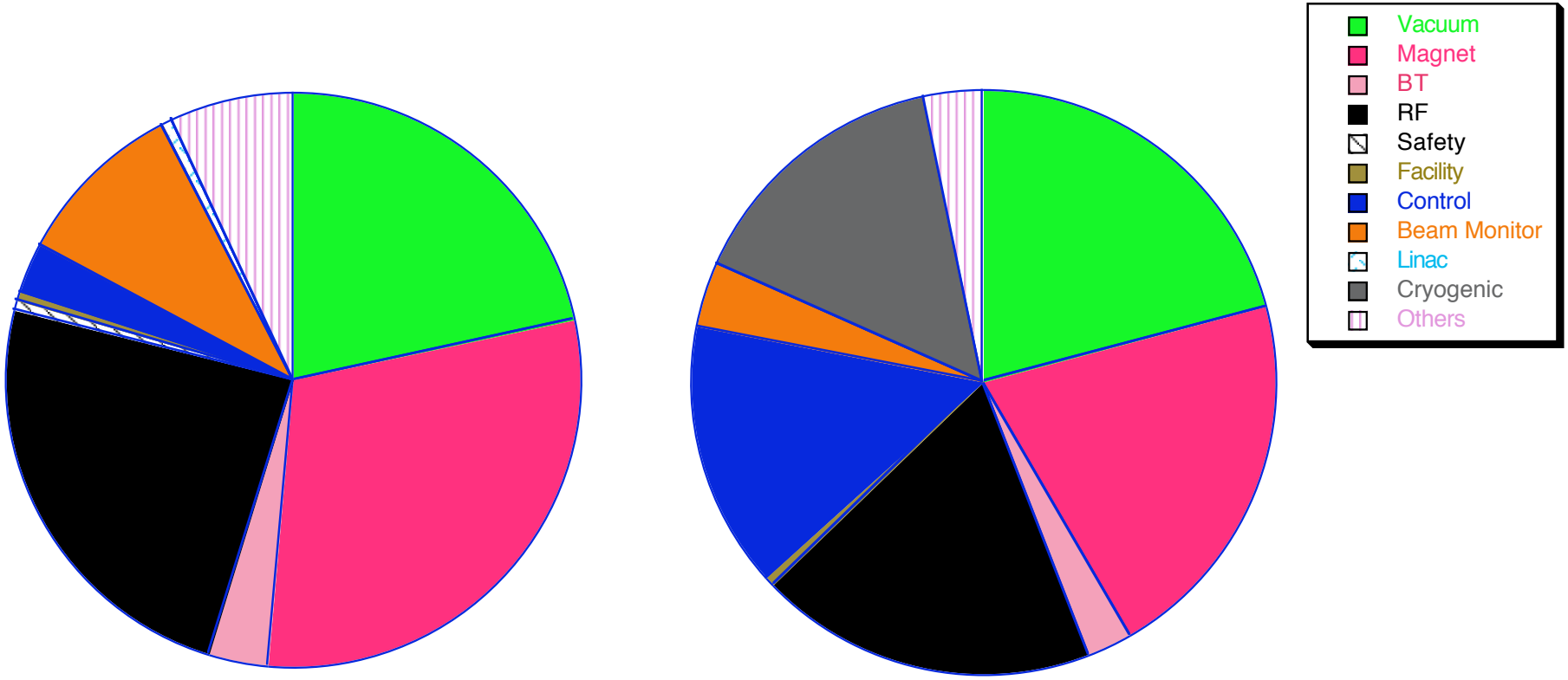
FY 2004



FY 2005

T. Kawasumi

Trouble Statistics (except Belle)



FY 2004

FY 2005

	FY 2004	FY 2005
Total operation Time [h]	5608	4527.5
Trouble Total except Belle [h]	255	258.5
Trouble Rate [%]	4.5	5.7

0 A	1 FY2004	2 FY 2005
Operation Time [h]	5608.0	4527.5
Trouble Total [h]	287.00	717.50
Vacuum	55.000	54.000
Magnet	75.500	54.000
BT	8.5000	6.5000
RF	61.500	48.000
Safety	2.0000	0.0000
Facility	1.0000	1.0000
Control	7.5000	38.500
Beam Monitor	24.500	9.0000
Belle	32.000	459.00
Linac	1.0000	0.0000
Cryogenic	0.0000	39.000
Others	18.000	8.5000

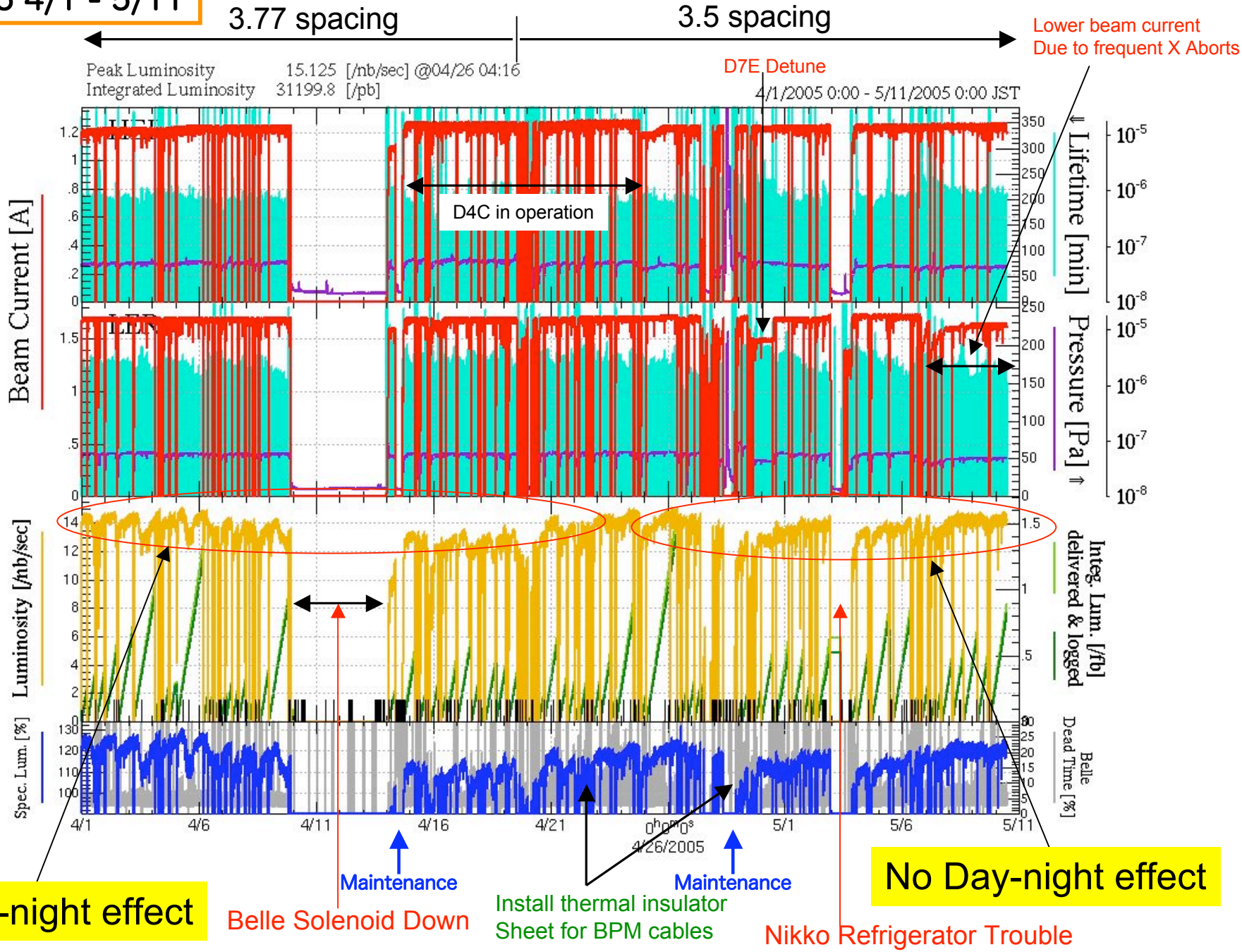
← QCS system is included

← FB is included

More detailed information:

http://accmac-server.kek.jp:8080/kekb/commissioning/statistics/Statistics/Statistics.html

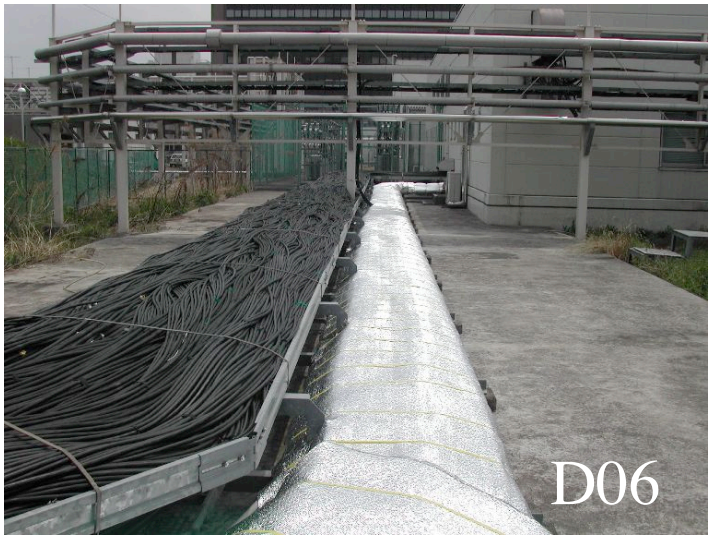
2005 4/1 - 5/11


3.77 spacing
3.5 spacing
Lower beam current
Due to frequent X Aborts
Peak Luminosity 15.125 [/nb/sec] @04/26 04:16
Integrated Luminosity 31199.8 [/pb]
D7E Detune
4/1/2005 0:00 - 5/11/2005 0:00 JST
D4C in operation
Beam Current [A]
Lifetime [min]
Pressure [Pa]
Luminosity [/nb/sec]
Integ. Lum. [/fb] delivered & logged
Spec. Lum. [%]
Belle Dead Time [%]
4/1
4/6
4/11
4/16
4/21
4/26/2005
5/1
5/6
5/11
Maintenance
Maintenance
Day-night effect
Belle Solenoid Down
Install thermal insulator
Sheet for BPM cables
Nikko Refrigerator Trouble
No Day-night effect

Installation of thermal insulator sheets

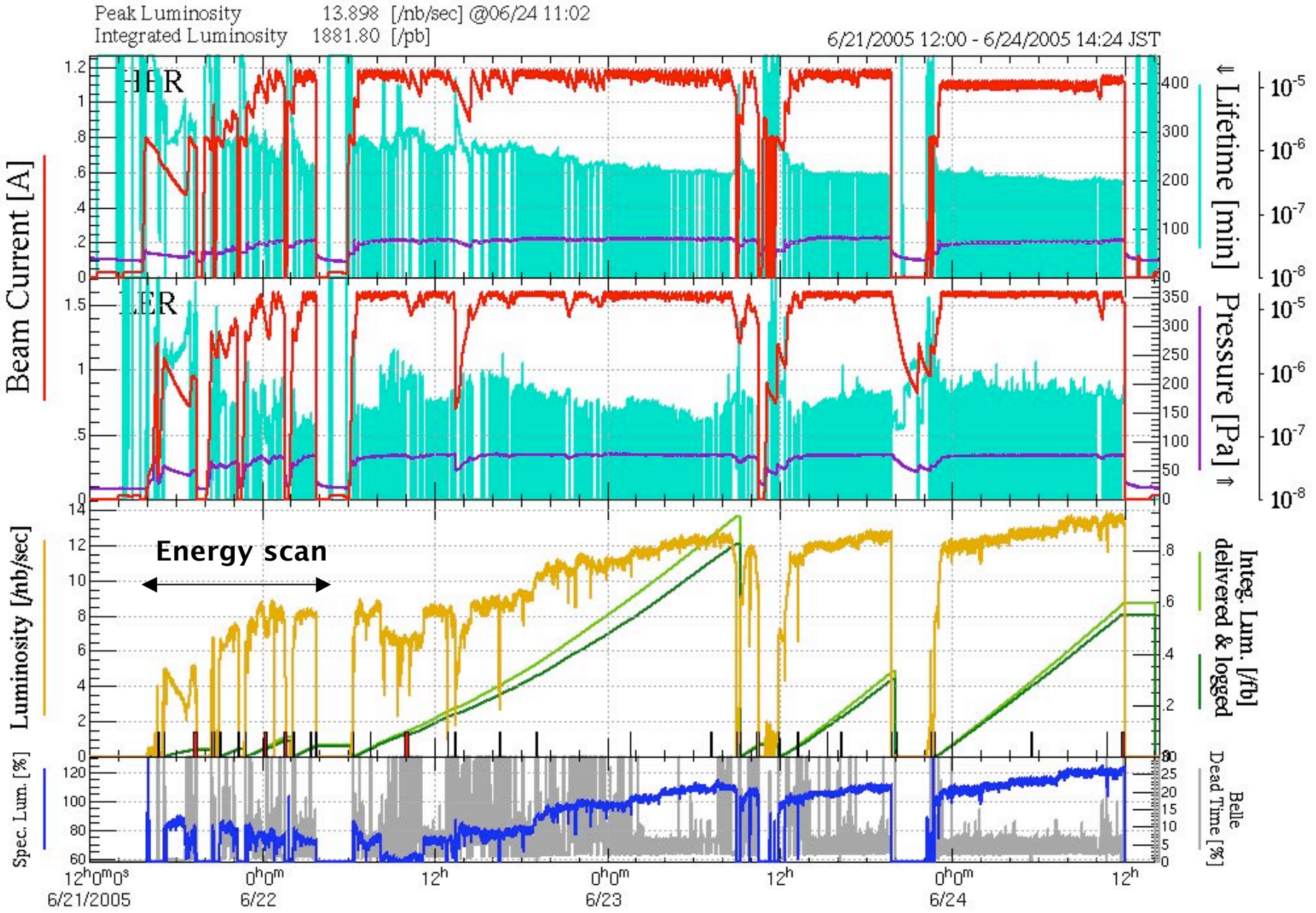
Tejima

2005/04/22



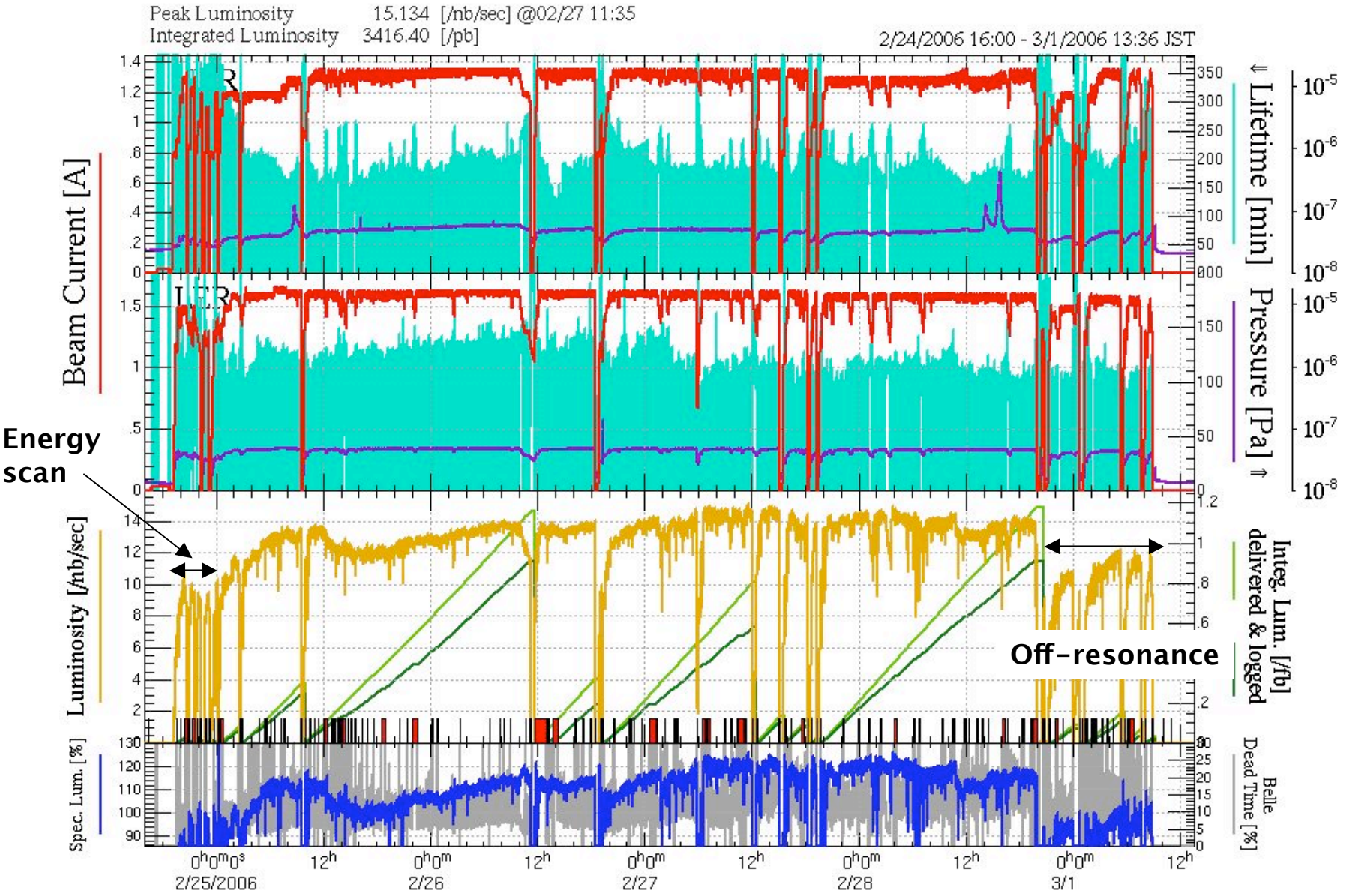
$\Upsilon(5S)$ Luminosity Run@10.87GeV

L_{peak} = 14.66 /nb/s, L_{int} = 1.817 /fb (corrected values)



$\Upsilon(3S)$ Luminosity Run@10.35GeV

L_{peak} = 14.48 /nb/s, L_{int} = 3.279 /fb (corrected values)



Summary and Plans

Electron cloud

- Electron cloud effects still restrict severely the KEKB performance.
- It is important to find where the e clouds exit and how we can remove them.
- In this year,
  - We will buy 16 power supplies of 5A which replace the existing 3A power supplies for the solenoids in the straight sections.

Recovery of luminosity performance after breaks

- To avoid losses of the integrated luminosity and keep the opportunities to go for the other subjects, it is important to identify unknown sources which affect the luminosity.

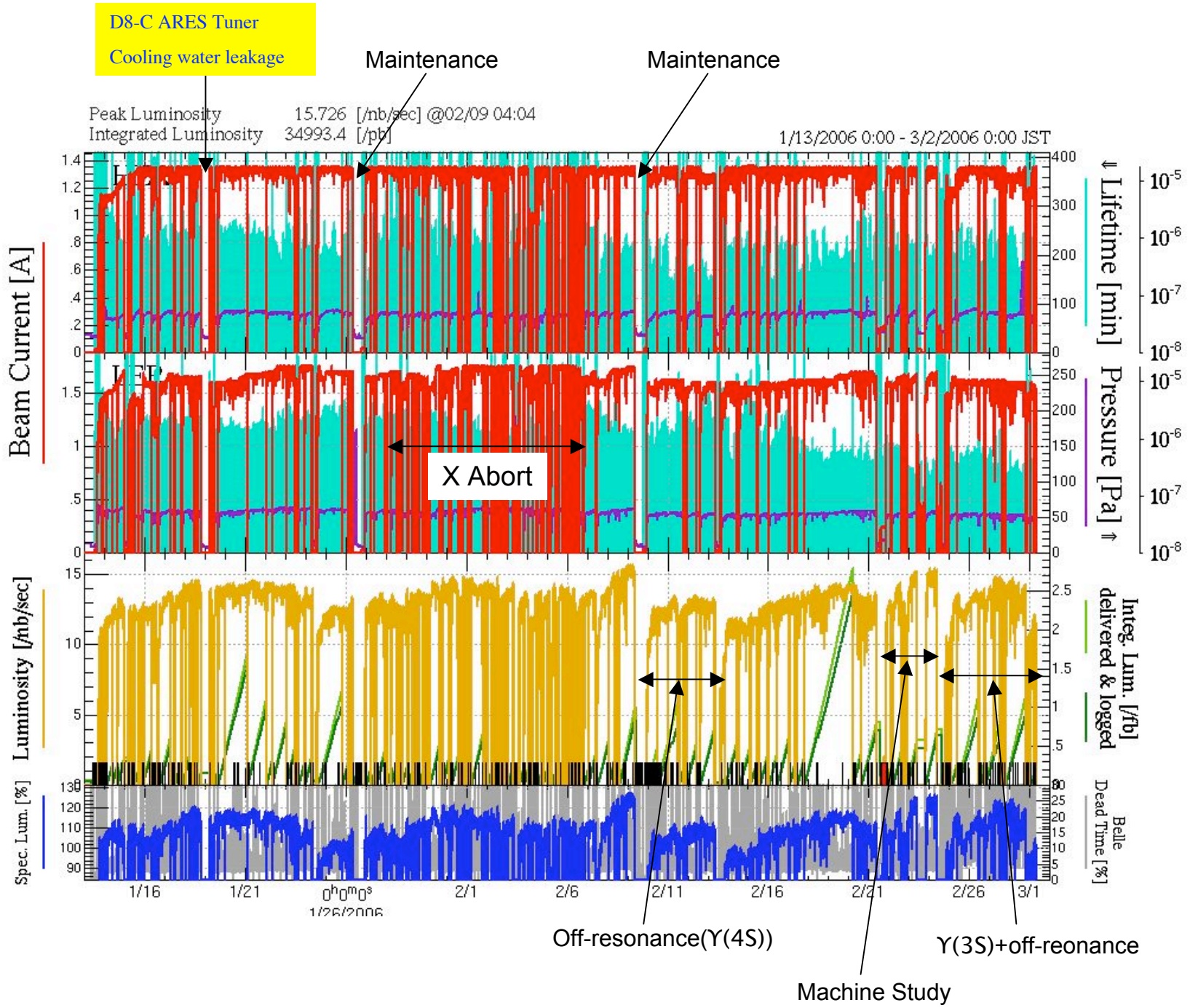
Summary and Plans (cont'd)

Higher luminosity

- Optimization of machine parameters
  - Optimize $\beta_{x/y}^*$ in both rings
  - Better choice of tunes and chromaticity corrections
    - Larger dynamic aperture
    - Weaken the effect of the synchro-betatron resonance
- Higher HER beam currents
  - There remains some room to improve the luminosity with higher HER current and larger number of bunches.

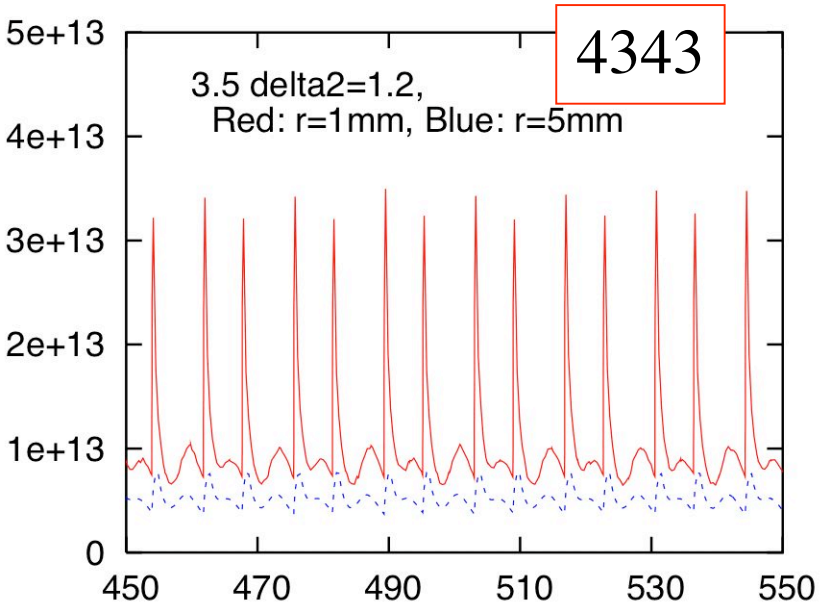
We will install crab cavities in both rings in summer 2006.

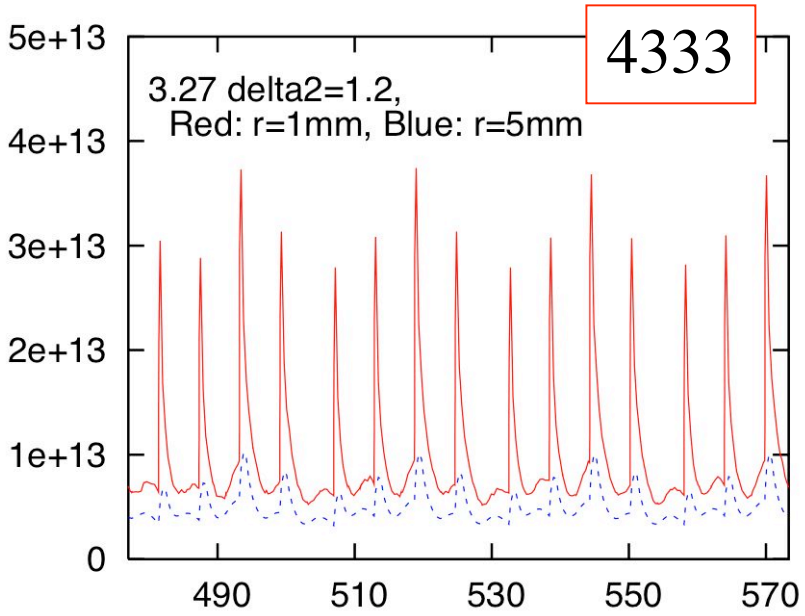
- Achieve $\xi_y > .1$ with crab cavities

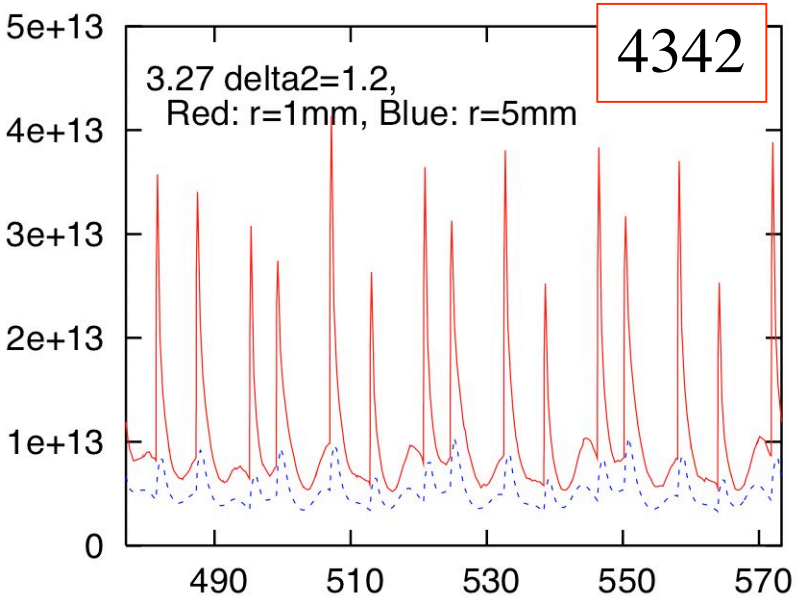

D8-C ARES Tuner
Cooling water leakage
Maintenance
Maintenance
Peak Luminosity 15.726 [/nb/sec] @02/09 04:04
Integrated Luminosity 34993.4 [/pb]
1/13/2006 0:00 - 3/2/2006 0:00 JST
Beam Current [A]
LER
HER
X Abort
⇓ Lifetime [min]
Pressure [Pa] ⇑
Luminosity [/nb/sec]
Integ. Lum. [/fb]
delivered & logged
Spec. Lum. [%]
Belle
Dead Time [%]
1/16
1/21
0h0m0s
1/26/2006
2/1
2/6
2/11
2/16
2/21
2/26
3/1
Off-resonance(Υ(4S))
Machine Study
Υ(3S)+off-reonance

Spare slides

Electron cloud density simulation







K. Ohmi

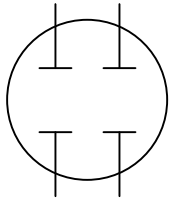
Recent progress

BPM consistency

•3 electrodes -> beam position
-> 4 sets of beam position

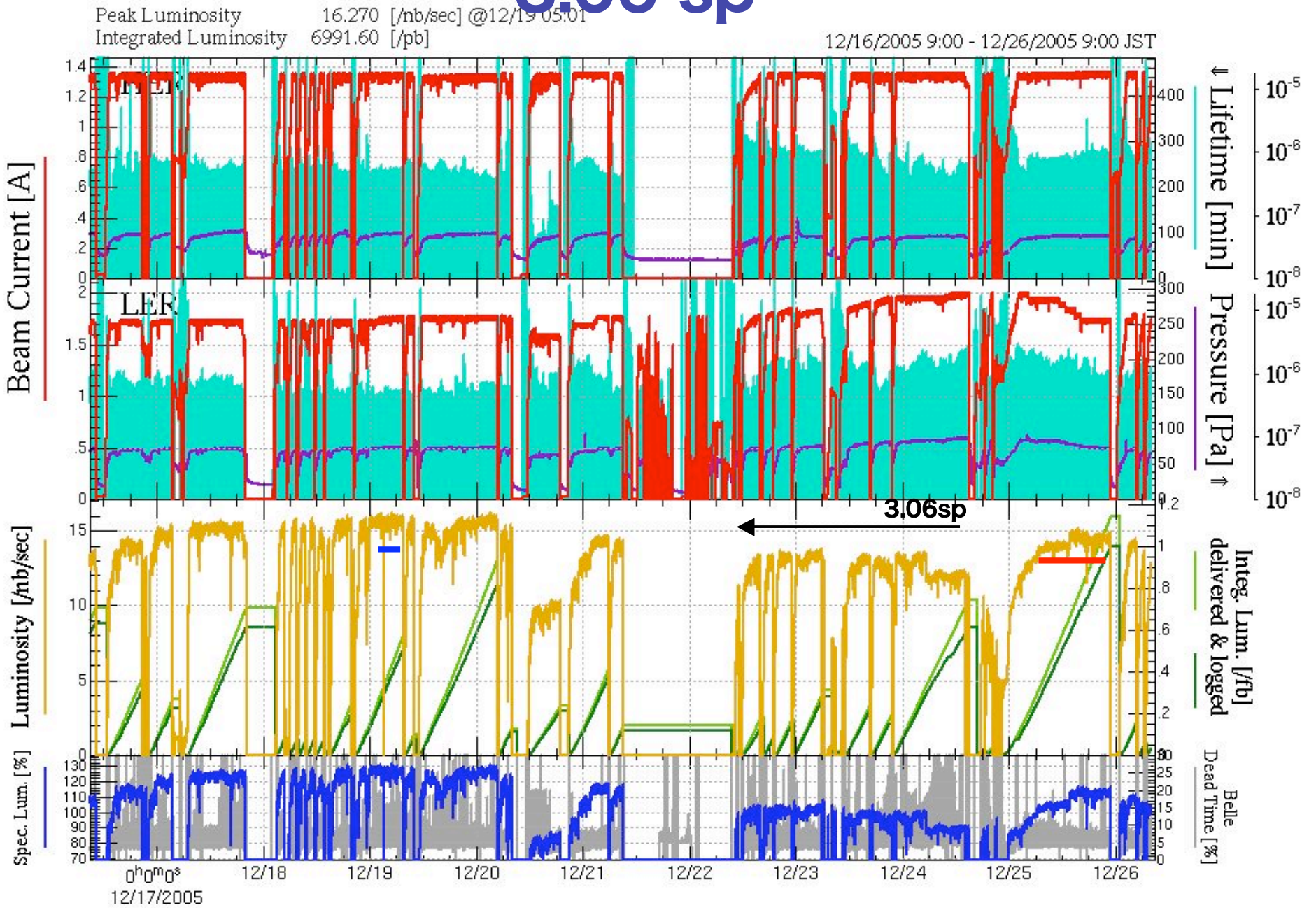
•BPM consistency

•RMS of 4 beam position data



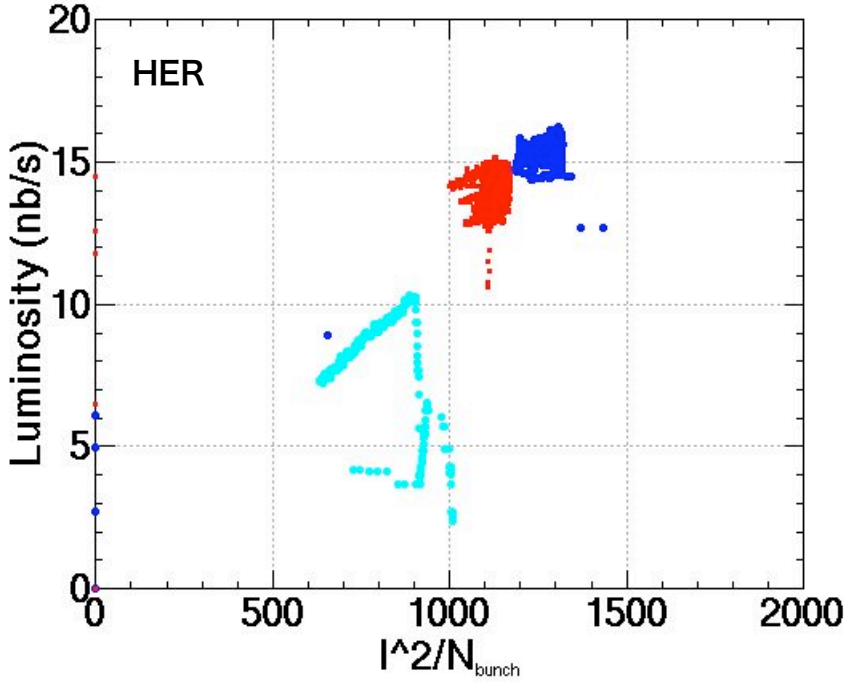
- Recent observations
  - The BPM consistency also shows day-night difference.
  - A part of BPM cables go through the outside of buildings and is affected by the temperature change.
  - Orbit corrections based on inaccurate BPM readings (or changing offset) bring the optics deformation and may result in the luminosity degradation.
- Countermeasure
  - Installation of thermal insulator sheets for the BPM cables in the outside.
  - The BPM consistency error was reduced by 30 or 50 %.
  - The day-night difference in the luminosity almost disappeared.

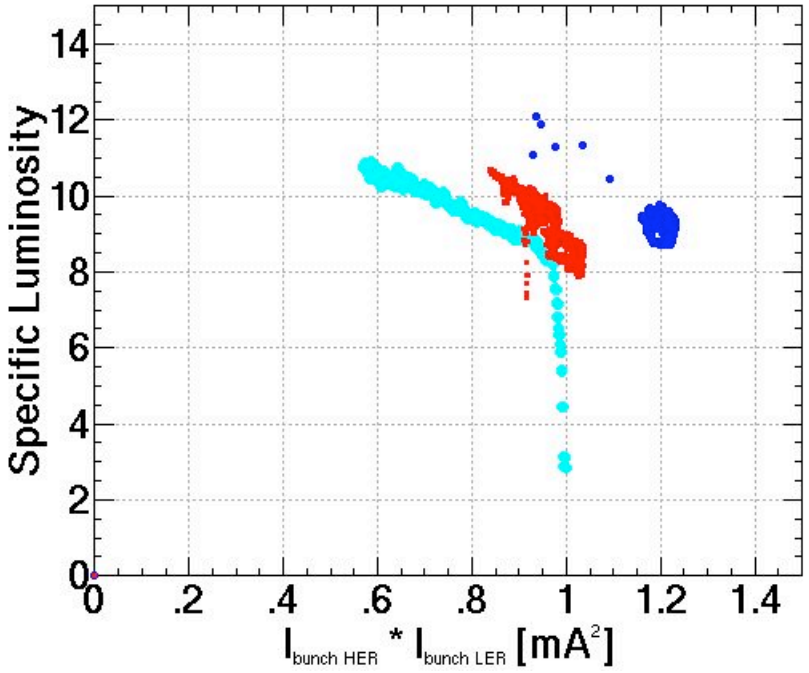
3.06 sp

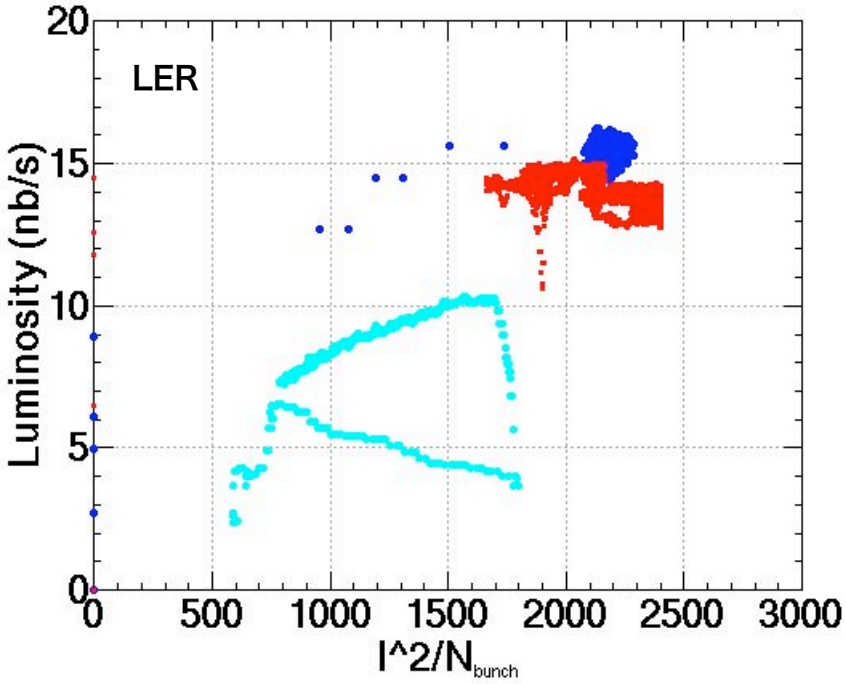

Peak Luminosity 16.270 [/nb/sec] @12/19 05:01
Integrated Luminosity 6991.60 [/pb]
12/16/2005 9:00 - 12/26/2005 9:00 JST
HER
LER
Beam Current [A]
Lifetime [min]
Pressure [Pa]
3.06sp
Luminosity [/nb/sec]
Integ. Lum. [/fb]
delivered & logged
Spec. Lum. [%]
Belle
Dead Time [%]
0h0m0s
12/17/2005
12/18
12/19
12/20
12/21
12/22
12/23
12/24
12/25
12/26

3.5sp v.s. 3.06sp

(blue) 3.5 sp 12/19 4:35 - 7:39
(red) 3.06sp 12/25 5:39 - 23:04
(cyan) reference 2003/5/9



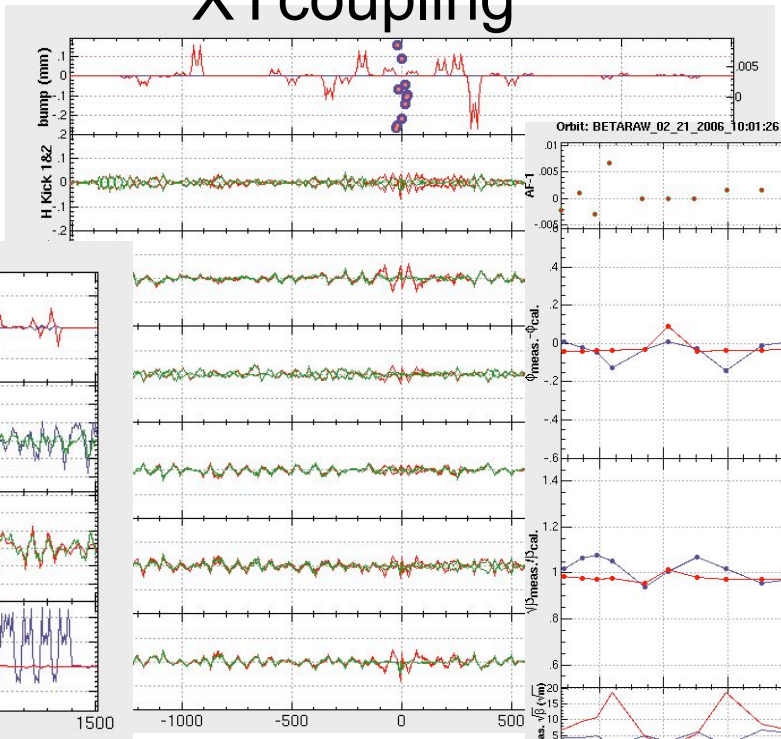




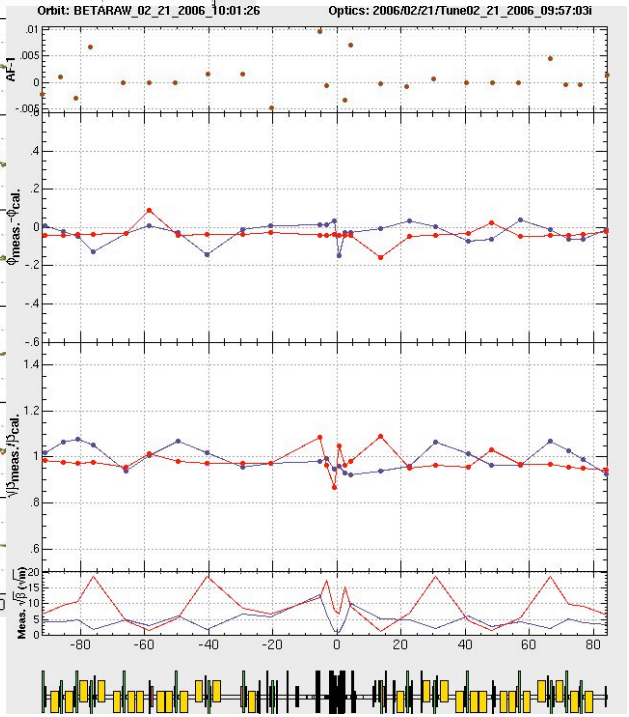
Tuning Items

- Optics Correction
  - 全周にわたってLER dispersion が劣化していた。
  - 衝突点付近のLER XYcoupling が劣化していた。
  - LER βy*少し大きめであった（＋７％）

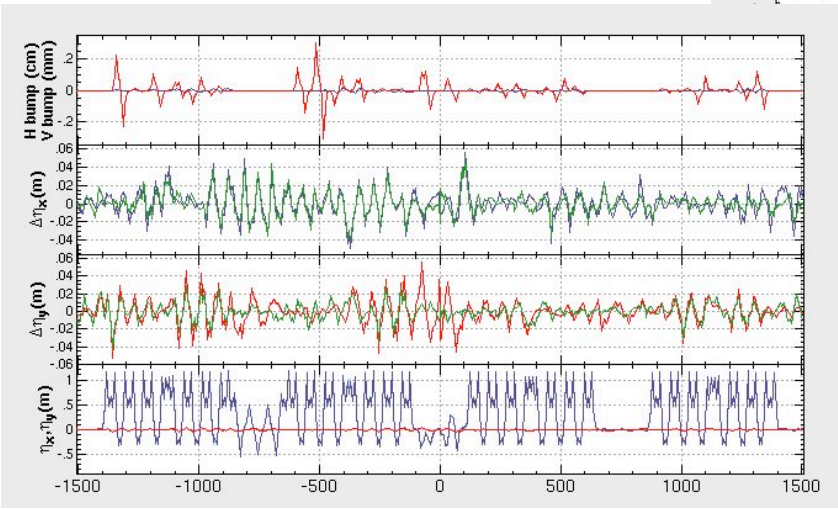
XYcoupling



LERβy*



LERηy

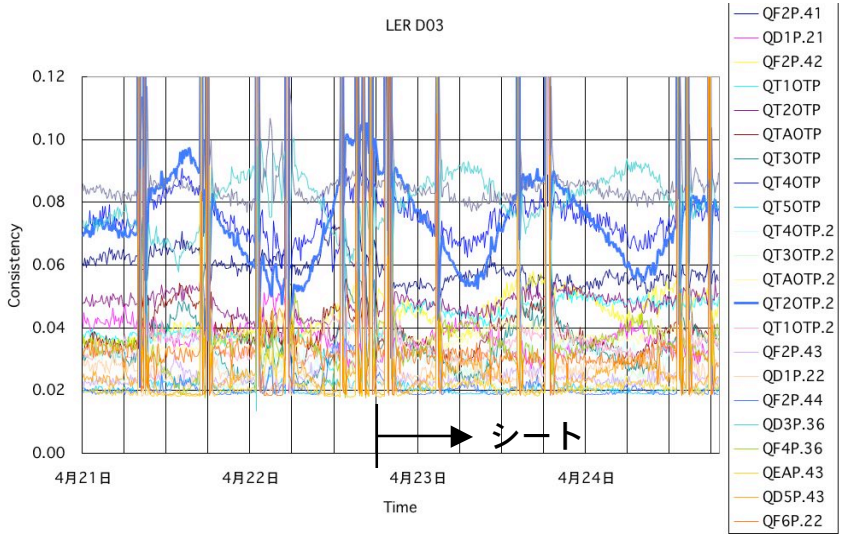


Day-night effect

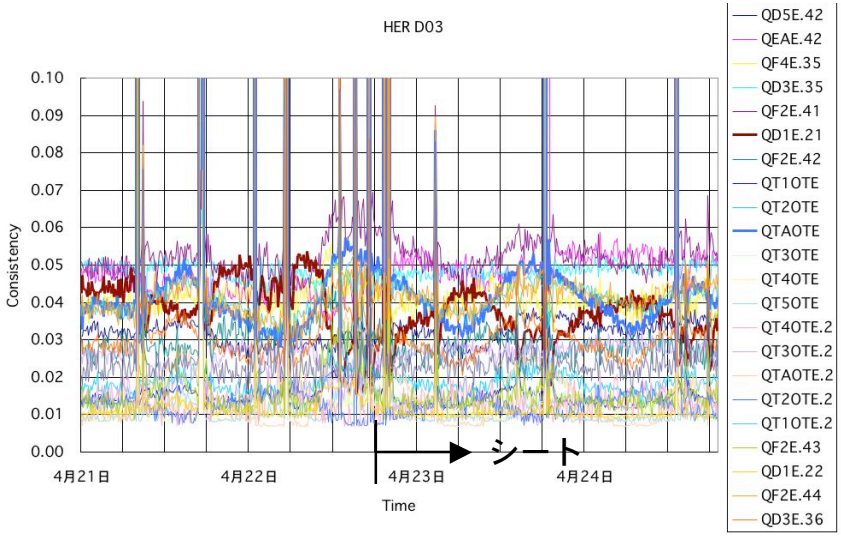
- The KEKB luminosity degrades in the daytime by about 20% at the worst.
- The luminosity degradation seems to depend on temperature difference between day and night.
- The effect is not remarkable in winter or on a rainy day.
- When the luminosity degrades, the HER beam blowup is observed.
- Tuning on the x-y coupling parameters at IP is somewhat effective to mitigate the degradation, although its effectiveness is insufficient.

Effectiveness of thermal insulator sheets

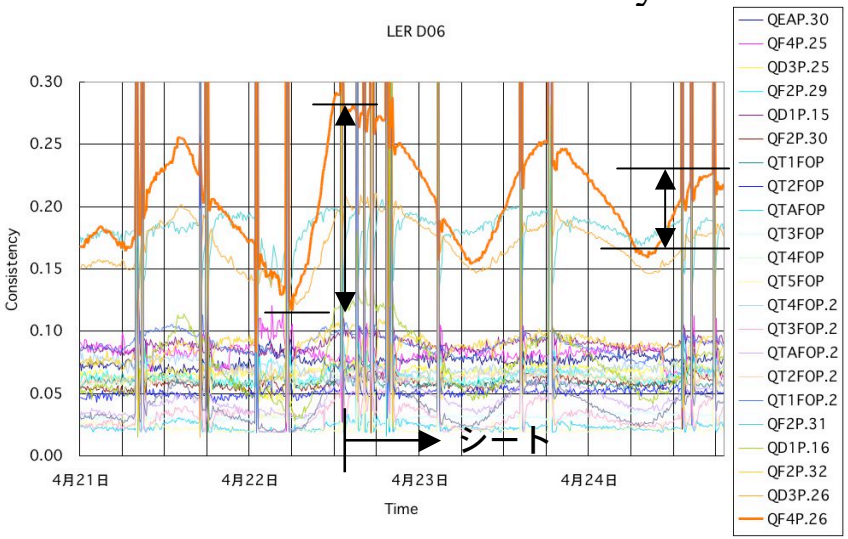
LER D03 BPM consistency



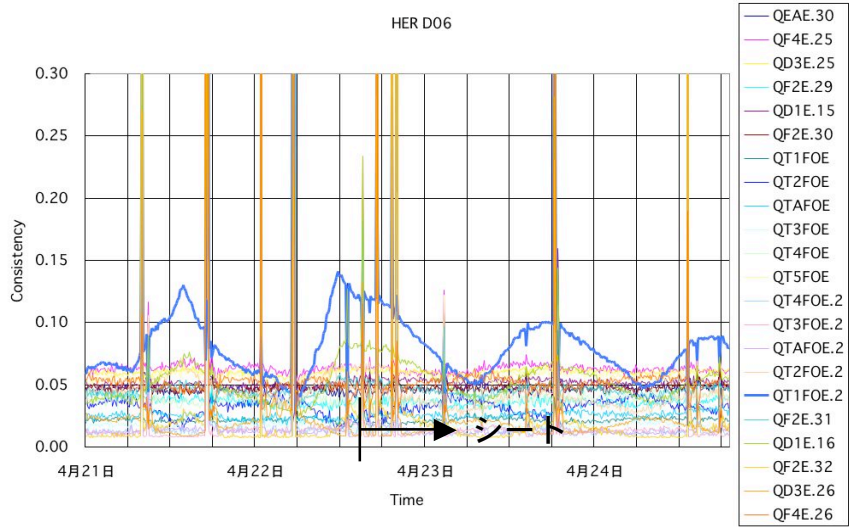
HER D03 BPM consistency



LER D06 BPM consistency



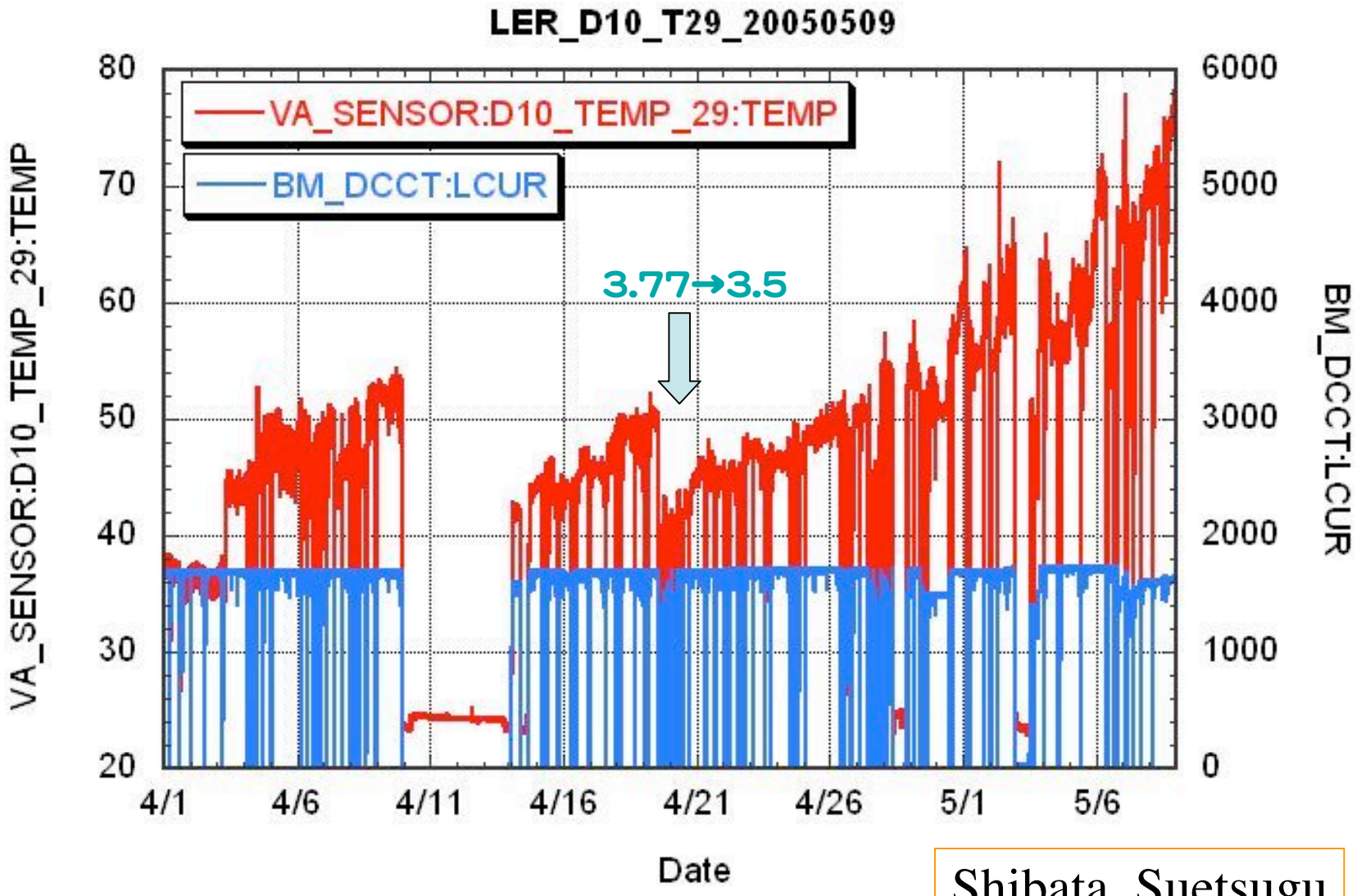
HER D06 BPM consistency



Upgrade plan (short term)

- Before the summer shutdown
  - Target beam currents
    - HER: 1400mA (We need to fix the D4C problem.)
    - LER: 2000mA
  - Target peak luminosity
    - 17 /nb/s
- During the next summer shutdown (2005)
  - Install one more RF station for ARES cavity (a klystron, low level control …) in HER (to be named as D5E)
    - Increase of the HER beam current by about 150mA
    - One RF station costs about 2 Oku-yen.
  - Movable masks in LER: Cu head -> Ti head
  - Solenoids for electron cloud
    - Upgrade the 50 power supplies for solenoid coils (3A -> 5A)
    - Test for winding thin coils inside quadrupole magnets
- Crab cavity
  - A crab cavity for the purpose of raising the beam-beam parameters is scheduled to be installed in each ring at the beginning of 2006.

D10 Chicane bellows temperature



Shibata, Suetsugu