KEKB Status (before crab)

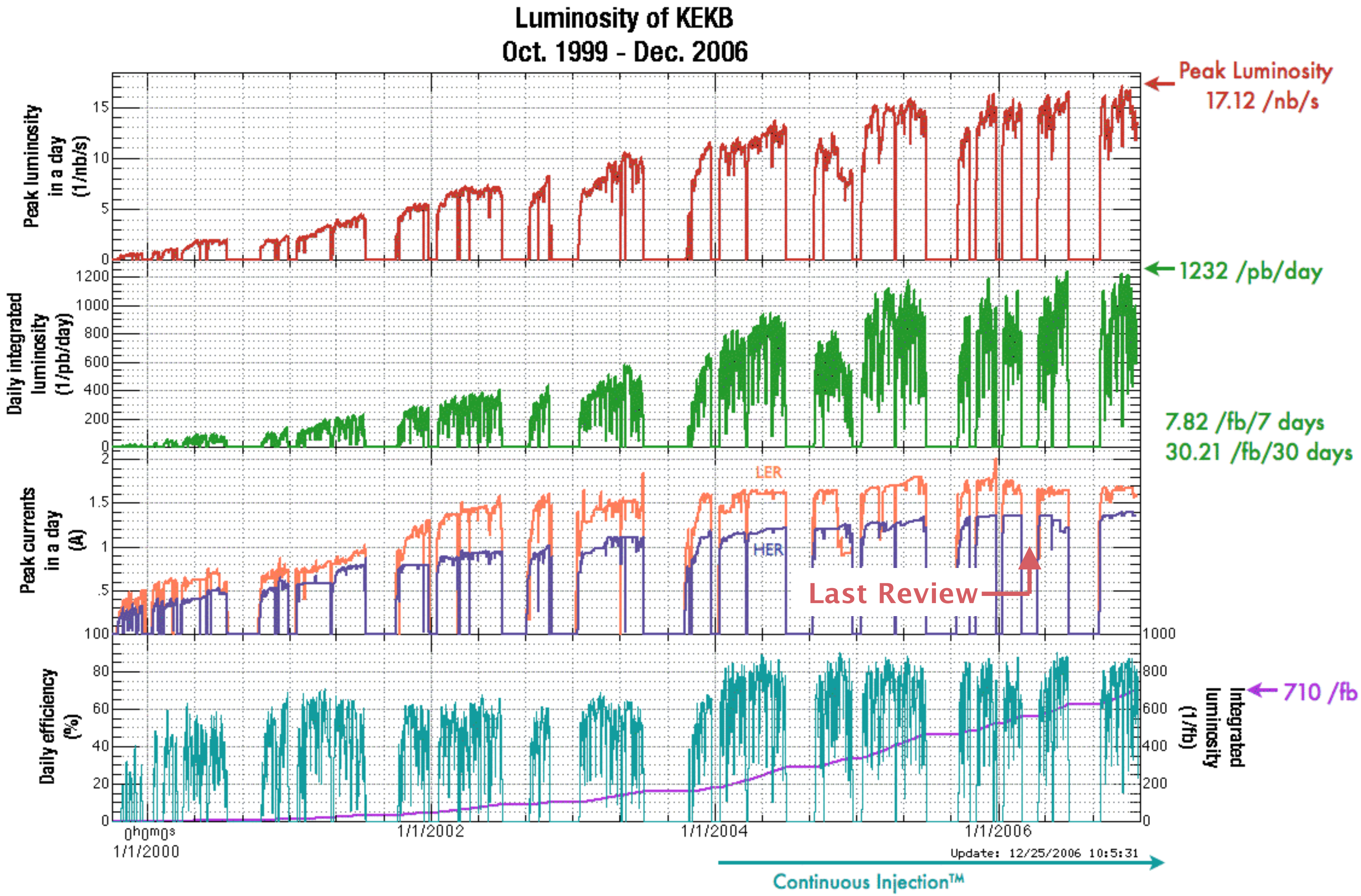
since March 2006

Y. Funakoshi

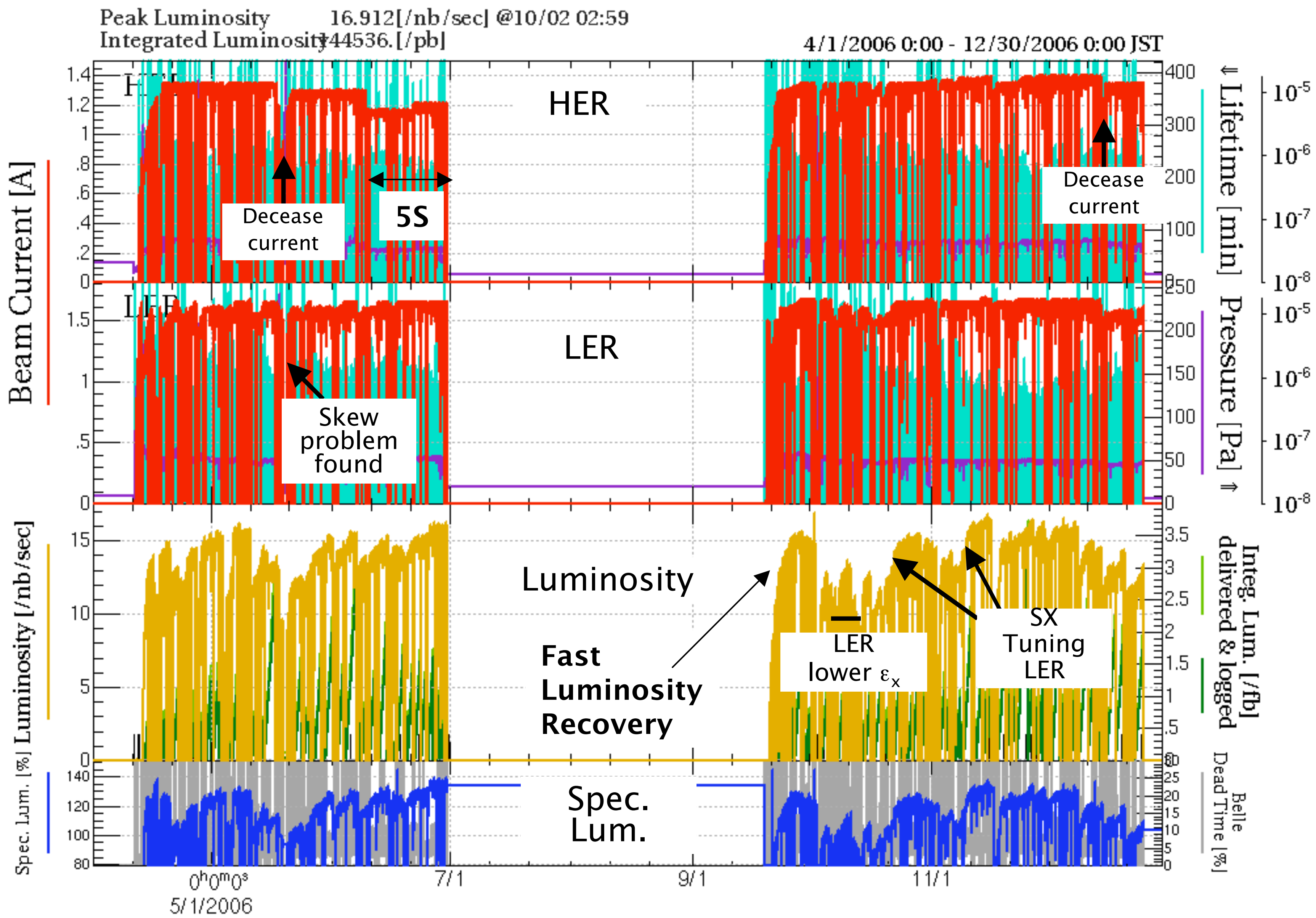
March 19, 2007 @ KEKB Review

KEKB Performance

KEKB History



KEKB Performance Apr. 2006 - Dec. 2006



Luminosity Performance

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

  L_{peak}= *16.27* → *17.12/nb/s*

  ∫L/day, /7days, /30days

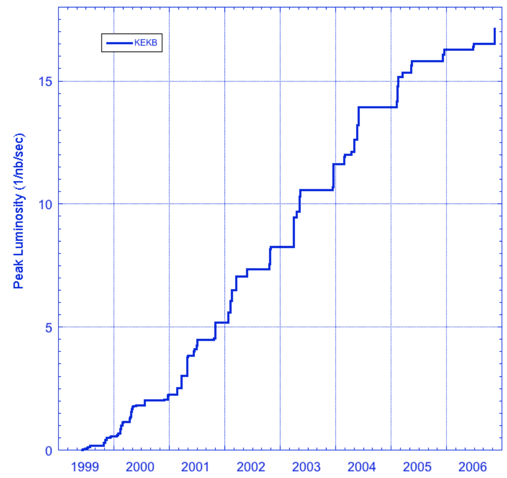
  = *1183/7358/29018* → *1232/7809/30208 /pb*

- **Annual integrated luminosity**

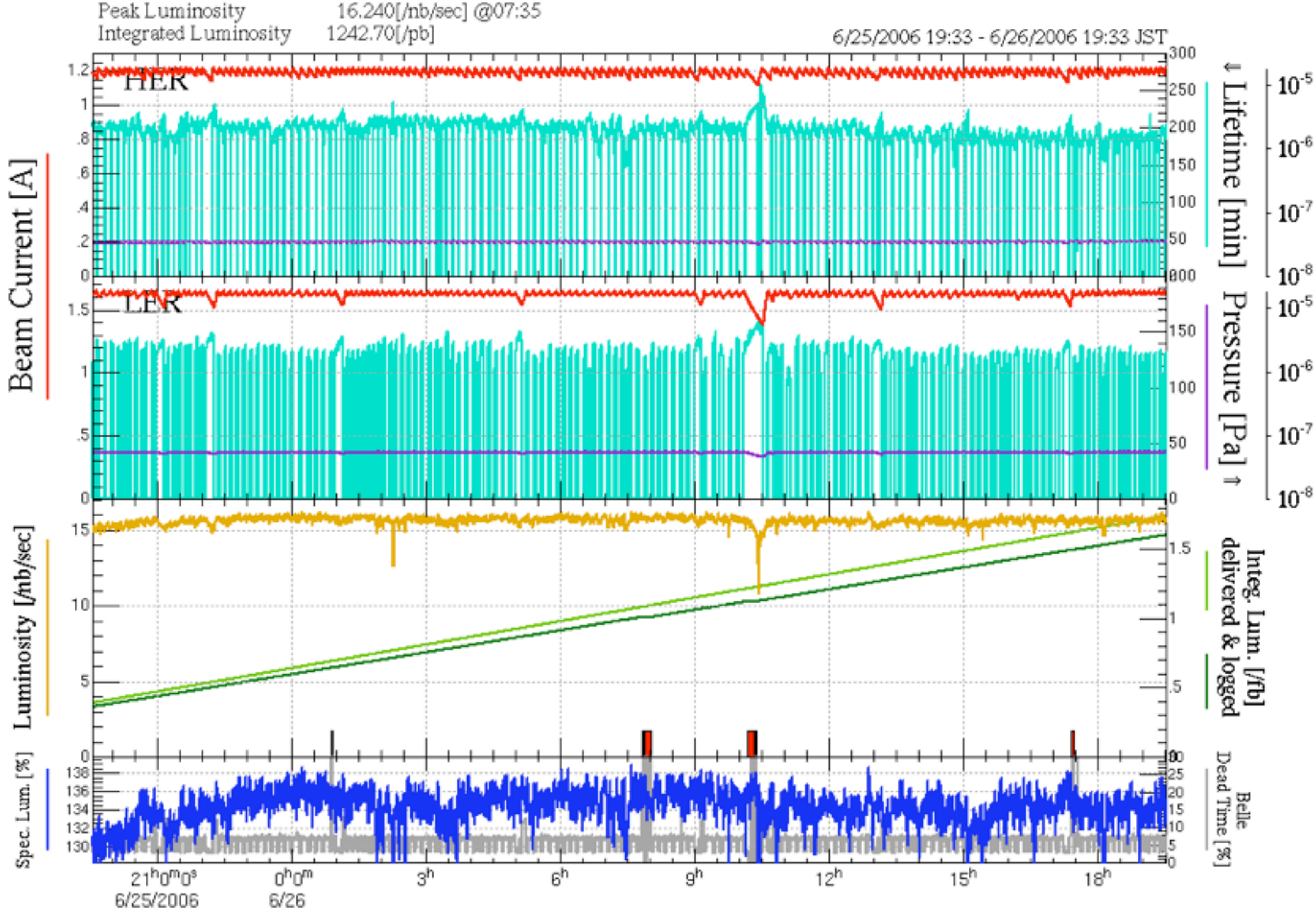
  188.7(2005: 274days) /fb/year

  → *180.8(2006: 227days) /fb/year*

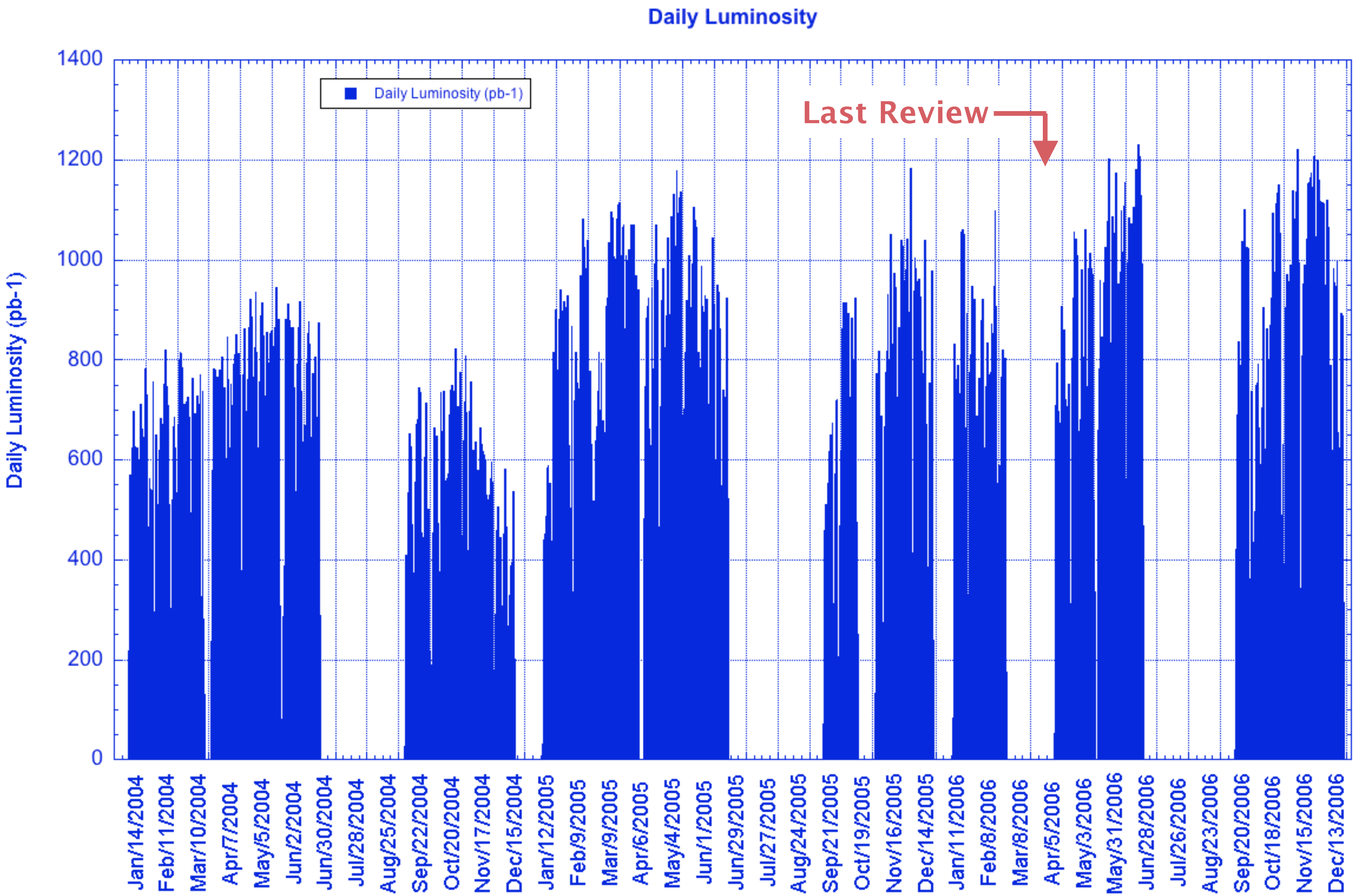
- **Total luminosity** *563.3* → *710.3/fb*



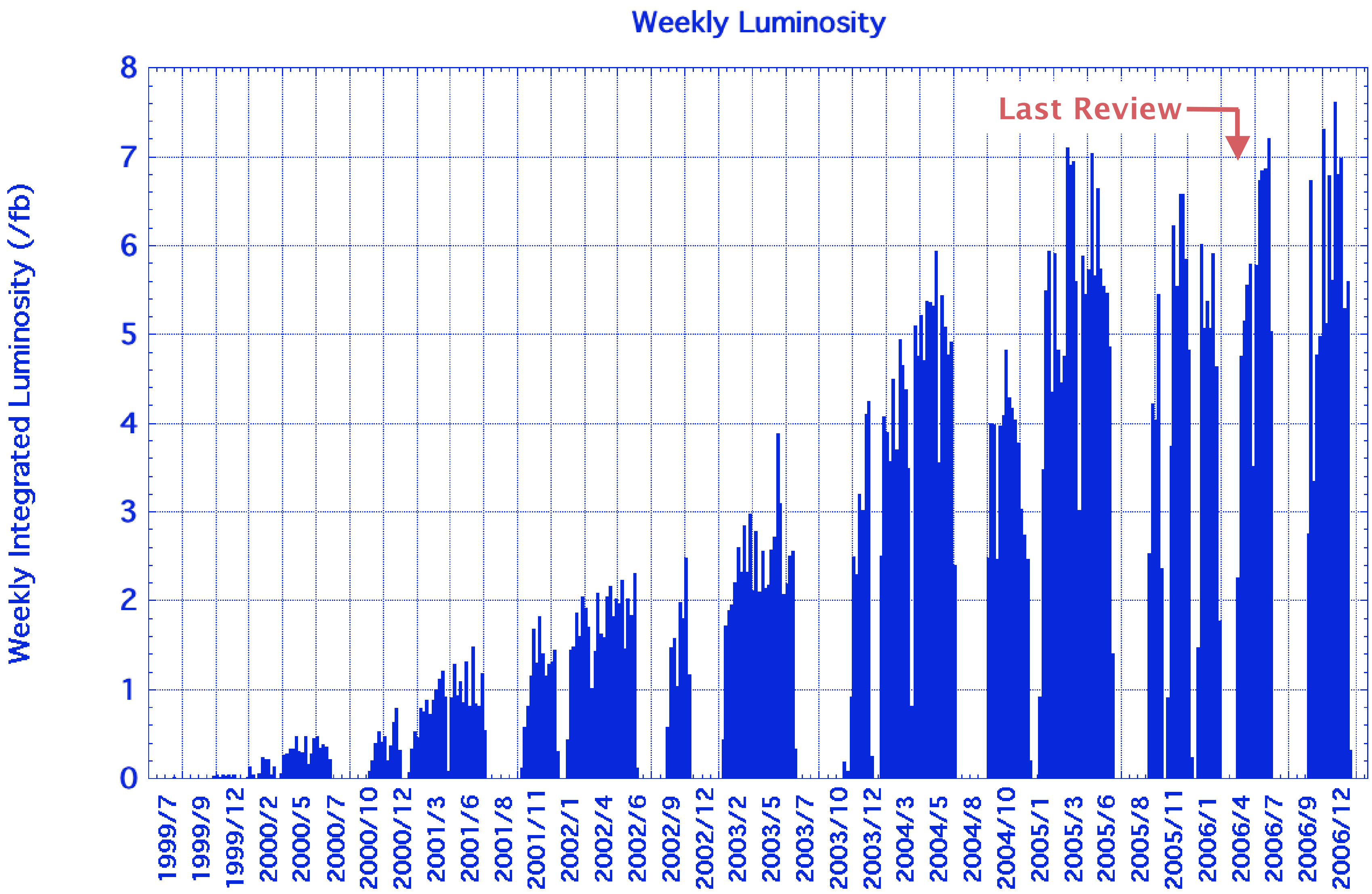
The Best Day 1242.7/pb



History of Daily Luminosity



History of Weekly Luminosity



Machine parameters

Date	Nov/15/2006		Dec/19/2005		
Ring	LER	HER		LER	HER
Horizontal Emittance	18	24	18	24	nm
Beam current	1662	1340		1719	1347
Number of bunches	1388		1388		
Bunch current	1.20	0.965		1.23	0.970
Bunch spacing	1.8 or 2.4 (3.5sp)		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	1.9	1.9	2.1	2.1	μm
Betatron tune ν_x/ν_y	45.505/43.534	44.509/41.565	45.506/43.531	44.512/41.578	
β^*_x/β^*_y	59/0.65	56/0.59	59/0.65	56/0.62	cm
Beam-beam parameters ξ_x/ξ_y	0.117/0.105	0.070/0.056	0.117/0.096	0.073/0.055	
Beam lifetime at collision	110 @1600 mA	180@1340mA	135@1719mA	222@1347mA	min
Luminosity (Belle CsI)	17.12		16.27	/nb/s	
Luminosity records per day/7 days/30 days	1232/7809/30208 (710/fb)	(total)	1183/7358/29018 (560/fb)	/pb	

Machine Parameters (cont'd)

- Bunch fill pattern/bunch spacing
  - 3.5 (49/14) : physics run same as last KEKB review
  - 3.27 (49/15) Test run in Dec. 2006
- Stored currents
  - LER ~<1700 mA
  - HER 1350 → 1400 mA → 1350 mA world's highest with SCC
- RF Voltage
  - LER 8 MV
  - HER 15 MV

Υ(5S) Run

	Υ(4S)	Scan Lower Limit	Υ(5S)	Scan Upper Limit	Note
Center of mass energy [GeV]	10.5800± 0.0035	10.825	10.865± 0.008	10.905	Physics
Energy Ratio	1	1.0232	1.0269	1.0307	Instability Beam-Beam
HER [GeV]	8.0	8.185	8.216	8.246	Linac margin? BT? Ring steering?
LER [GeV]	3.5	3.581	3.594	3.608	BT? Ring steering?
(E/E0)^4	1	1.0959	1.1122	1.1287	Radiation Loss
(E/E0)^3	1	1.0711	1.0830	1.0950	Damping Rate
(E/E0)^(-2)	1	0.9552	0.9483	0.9413	Bhabha Cross Section

HER current was decreased by 11% to keep the radiation power same as at Y(4S).
Shorter damping time may have boosted the luminosity.

Luminosity Records (as of Jun. 30 2006)

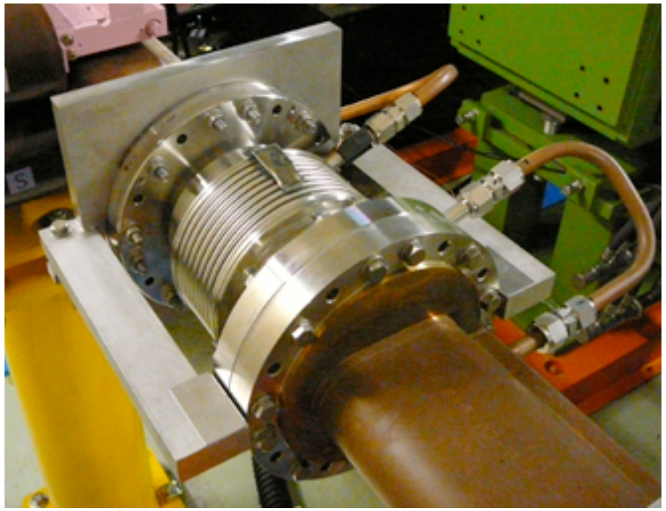
		2005	2006 4S	2006 5S
peak	$nb^{-1}s^{-1}$	16.270 05.12.19 5:01		16.517 06.6.30 2:31
shift	pb^{-1}	401.8 05.12.6E	402.6 06.5.31M	426.4 06.6.28M
day	pb^{-1}	1182.5 05.12.6	1201.7 06.5.31	1231.5 06.6.26
24 hrs	pb^{-1}	1206.6 05.12.7 7:15		1243.7 06.6.27 10:42
week	fb^{-1}	7.096 05.3.14–3.20		7.206 06.6.19–6.25
7 days	fb^{-1}	7.358 05.3.17–3.23		7.819 06.6.22–6.28
month	fb^{-1}	27.887 05.5		29.388 06.6
30 days	fb^{-1}	29.018 05.3.10–4.9		30.208 06.6.22–6.28

Operational difficulty

Troubles of standard bellows in HER

- Frequent breaks of HER arc bellows
  - three times before summer
  - downstream of bending magnets (high power of SR)
- Deformation of bellows
  - Large offsets of bellows (relative movement of upstream and downstream flanges) were observed in hor. direction. (Δx: 1.5 ~2.5 mm)
  - Those offset may bring the breaks.
- Countermeasures (during summer)
  - Supports which prevent the offsets (80 bellows) -> (Δx: <1 mm)
  - Two spare bellows with a revised design

D03 broken bellows



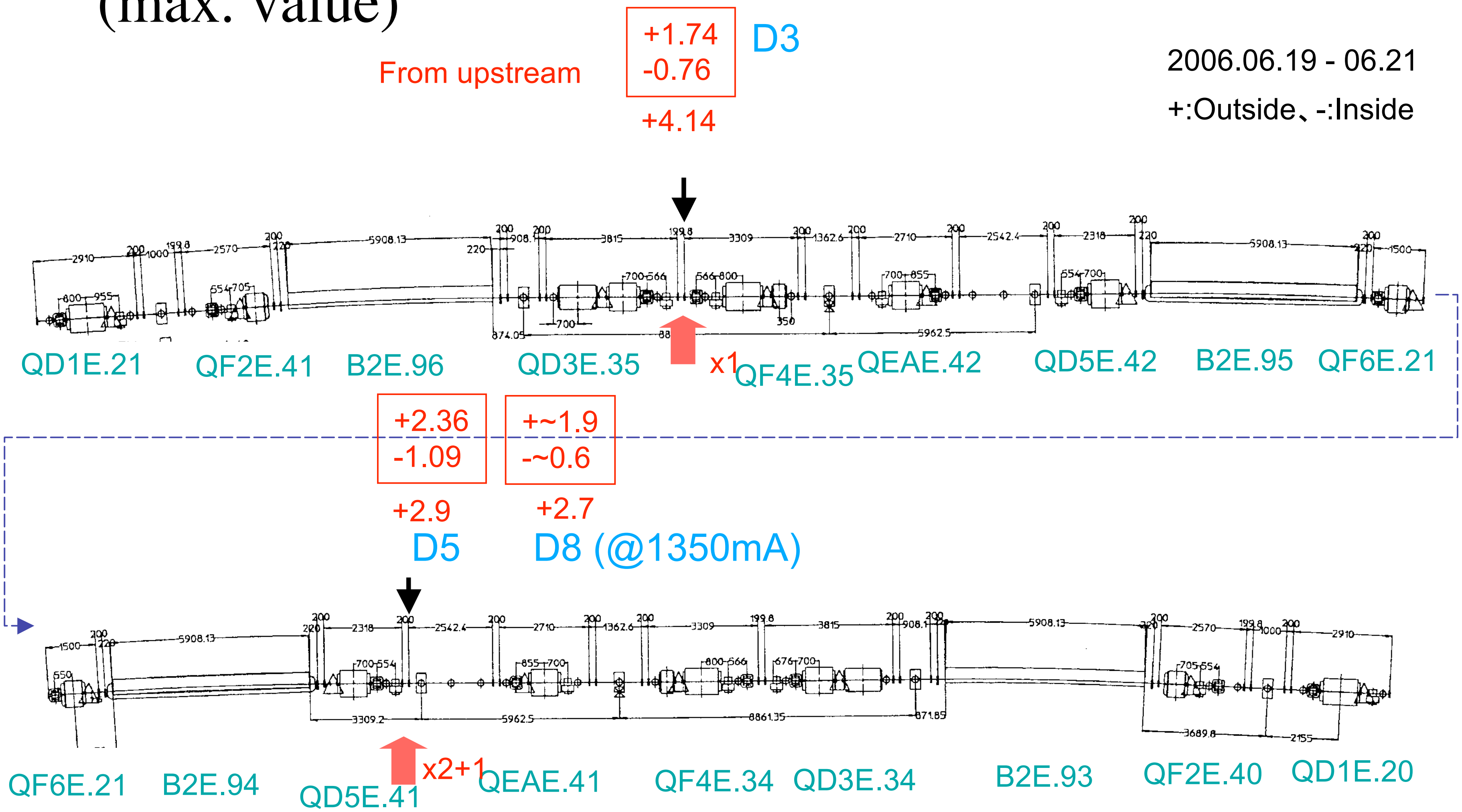
Y. Suetsugu

Measurements with dial-gauge

- Relative movement of up and downstream flanges (max. value)

2006.06.19 - 06.21

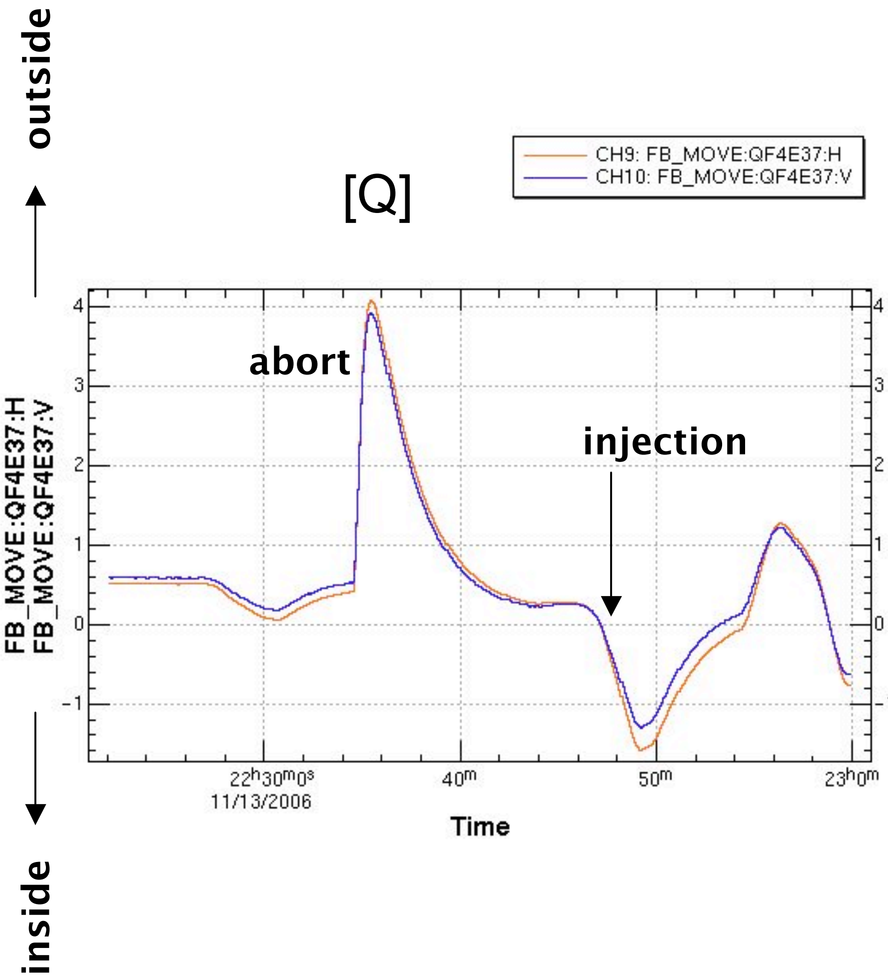
+:Outside、-:Inside

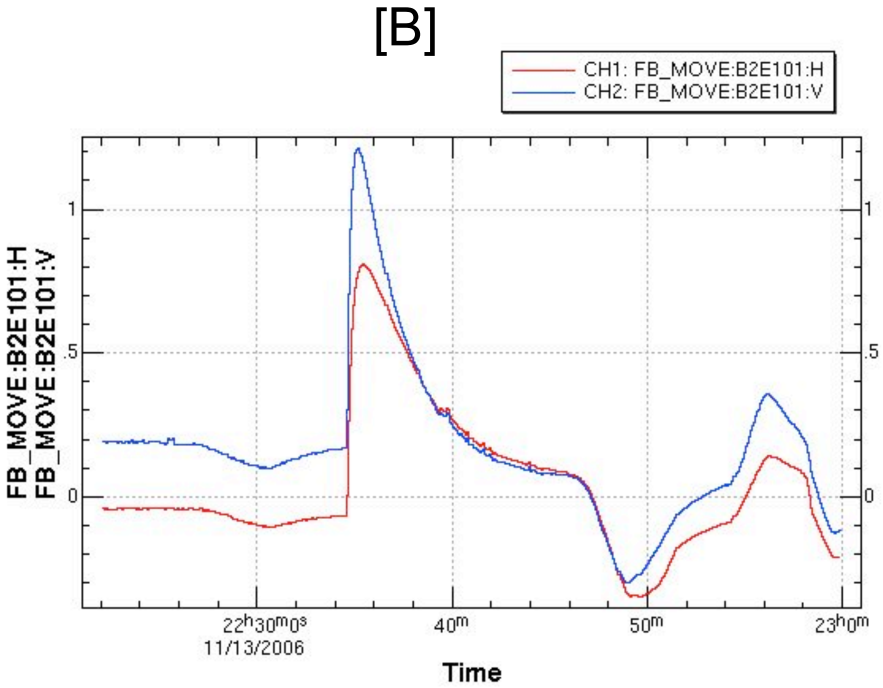


Broken Bellows：Large movement

Y. Suetsugu

Realtime measurements with displacement meters





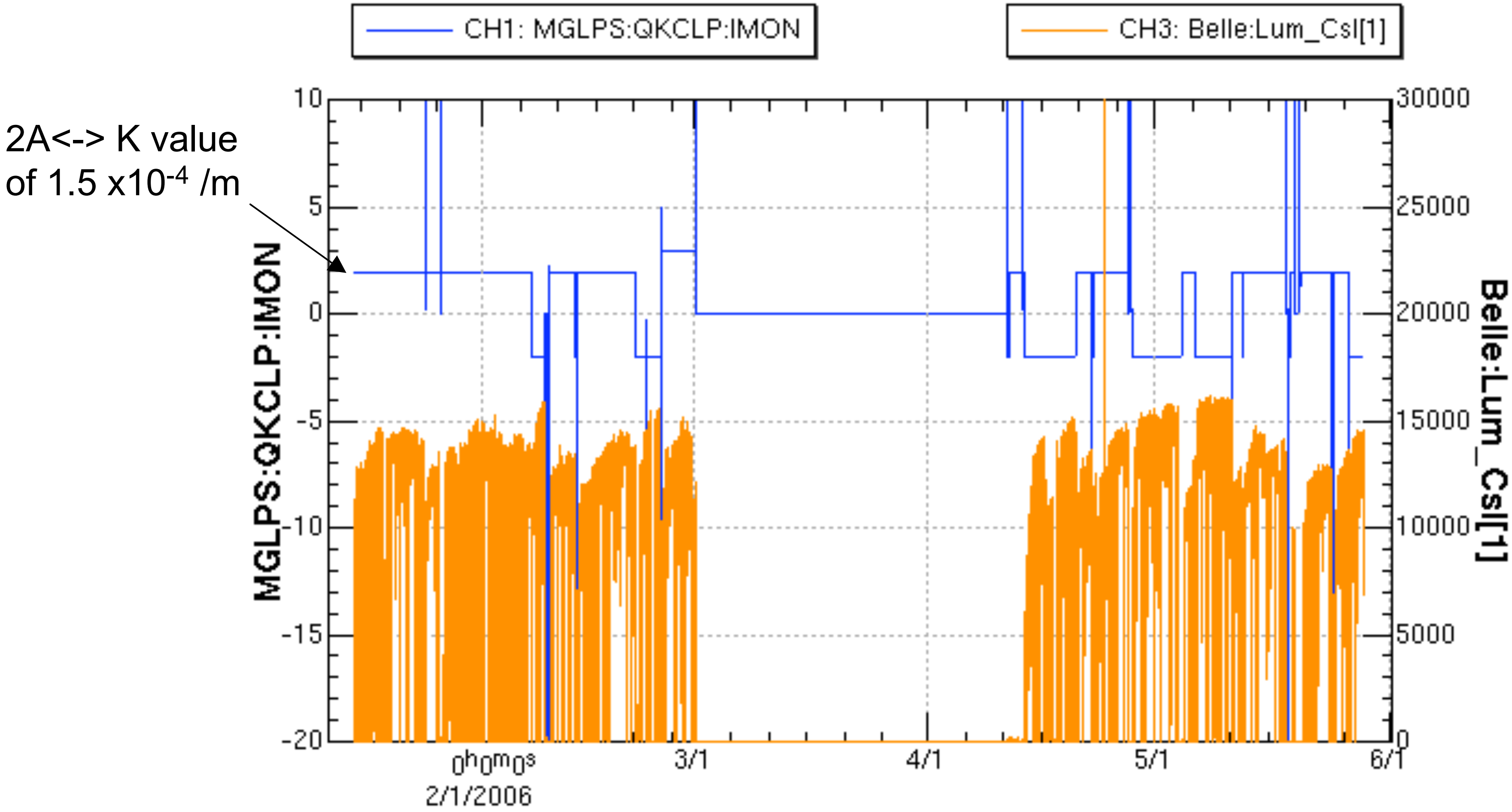
H: upstream
V: downstream

Y. Suetsugu

Reproducibility of luminosity

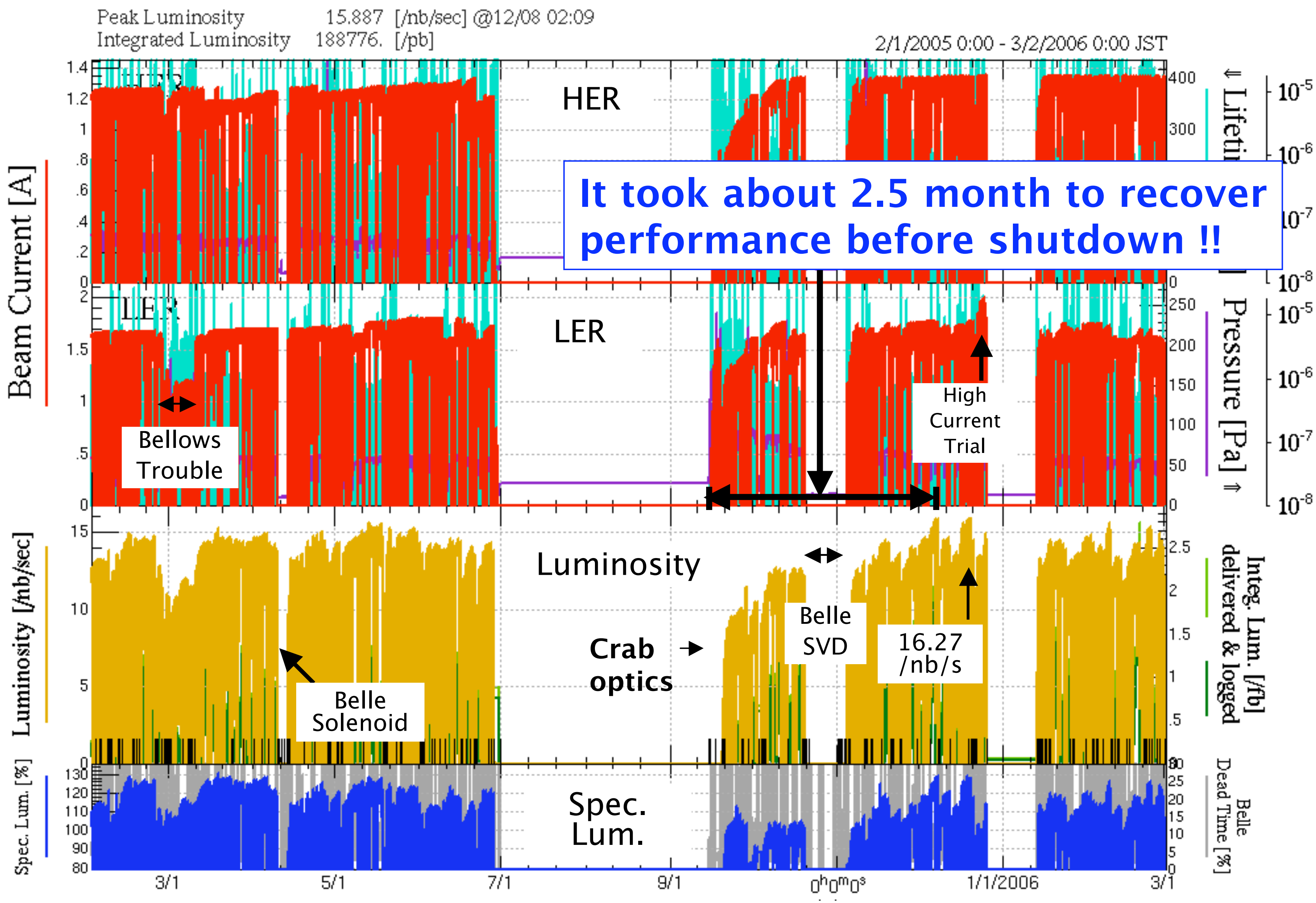
- Integrated luminosity
  - Recovery of luminosity after long-shutdown
  - Recovery of luminosity after short operation break (such as regular maintenance)
    - **It deprives us of opportunities of other trials for a higher luminosity.**
    - **In May last year, we found out one of sources which bring bad luminosity recovery.**

Strong correlation between the achieved peak luminosity and the polarity of one of skew-Q magnet(QKCLP) in LER

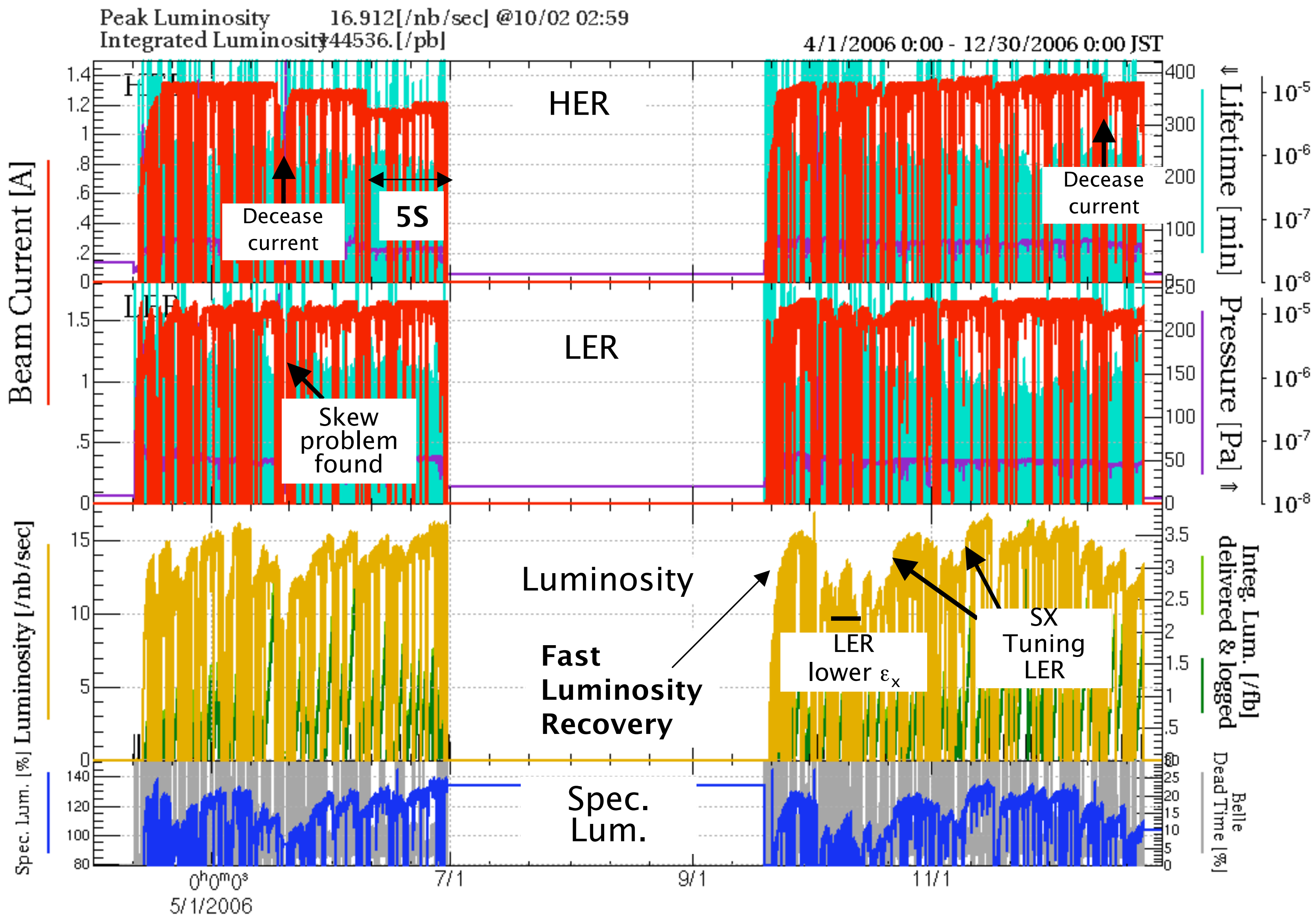


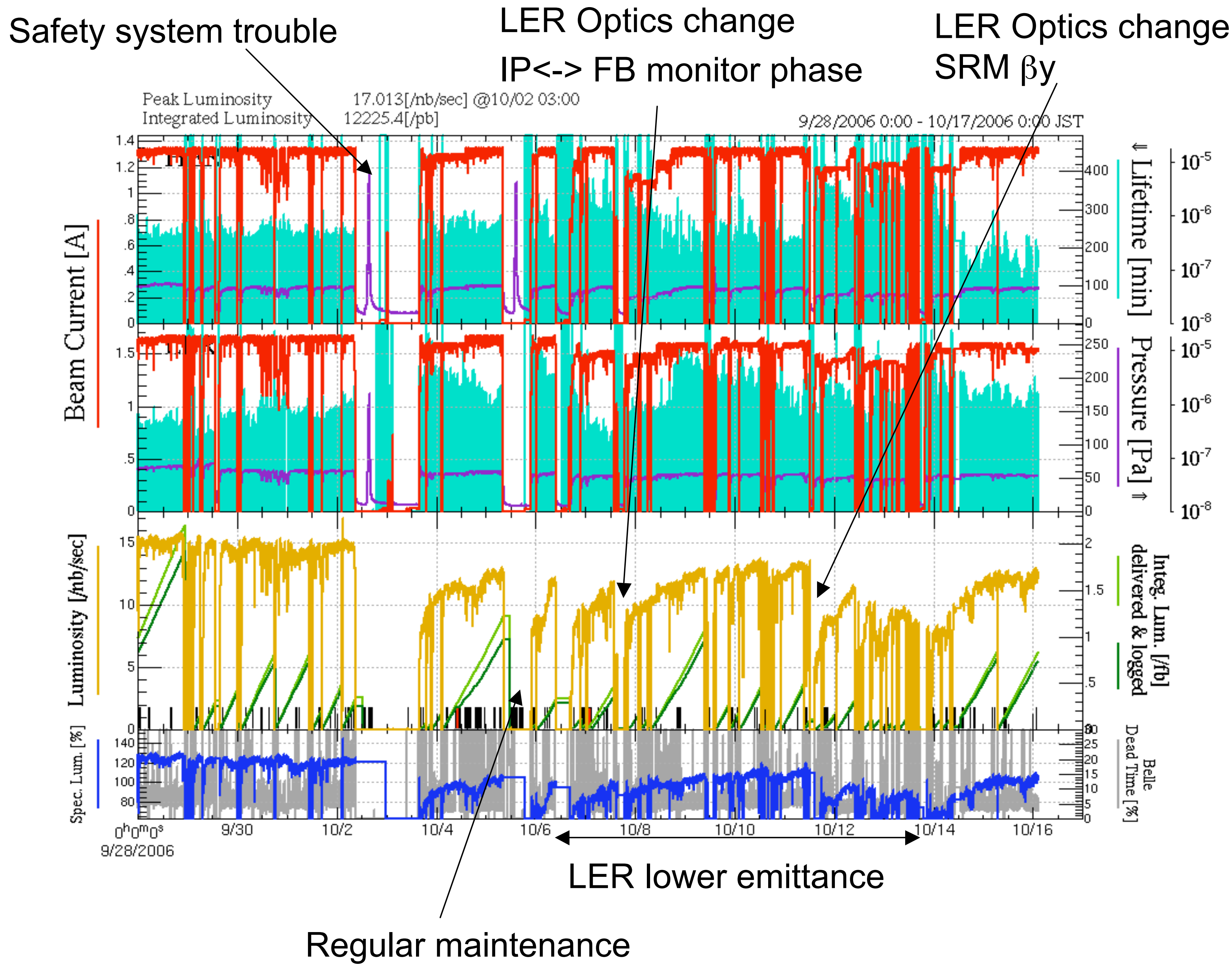
This skew-Q magnet is very weak. In the process of the optics correction, the polarity was easily changed, although the precision of the optics measurement is not enough to distinguish their difference. Since the magnet current between -2A and +2A could not be set due to a software problem, the actual magnet current was set either at around -2A or around + 2A.

KEKB Performance Feb. 2005 - Mar. 2006



KEKB Performance Apr. 2006 - Dec. 2006



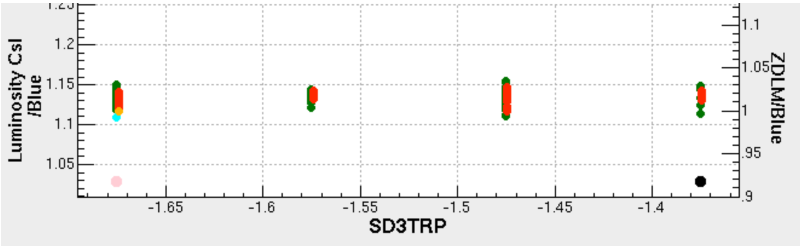


Safety system trouble
LER Optics change
IP<-> FB monitor phase
LER Optics change
SRM βy
Peak Luminosity 17.013[/nb/sec] @10/02 03:00
Integrated Luminosity 12225.4[/pb]
9/28/2006 0:00 - 10/17/2006 0:00 JST
Beam Current [A]
Lifetime [min]
Pressure [Pa]
Luminosity [/nb/sec]
Integ. Lum. [/fb] delivered & logged
Spec. Lum. [%]
Belle Dead Time [%]
0h0m0s 9/28/2006
9/30
10/2
10/4
10/6
10/8
10/10
10/12
10/14
10/16
LER lower emittance
Regular maintenance

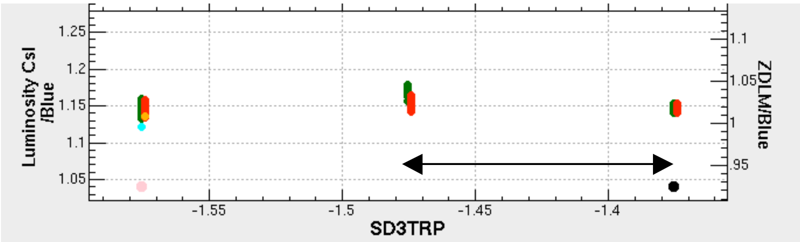
LER SX Tuning

- Methods of tuning
  - Strength of each pair of sextupole magnets
  - Scan R and Twiss parameters by changing strength of all sextuple magnets
- Effectiveness of this tuning
  - almost 30% difference in luminosity
- Mystery
  - What is the difference from the usual IP knob tuning?
- Key issue related to the luminosity reproducibility problem?
  - BPM displacement sensors may be important.

Scan of one of SX pair

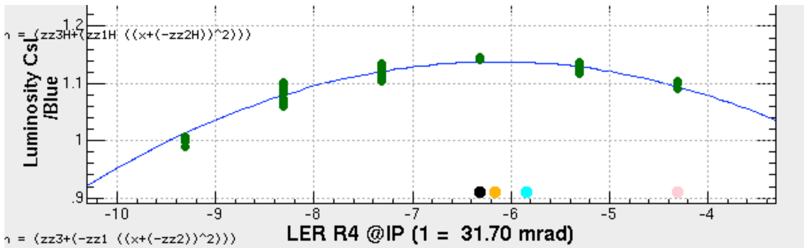


Scan of strength of SD3TRP with all constraints for R and Twiss parameters



R4 4.3units

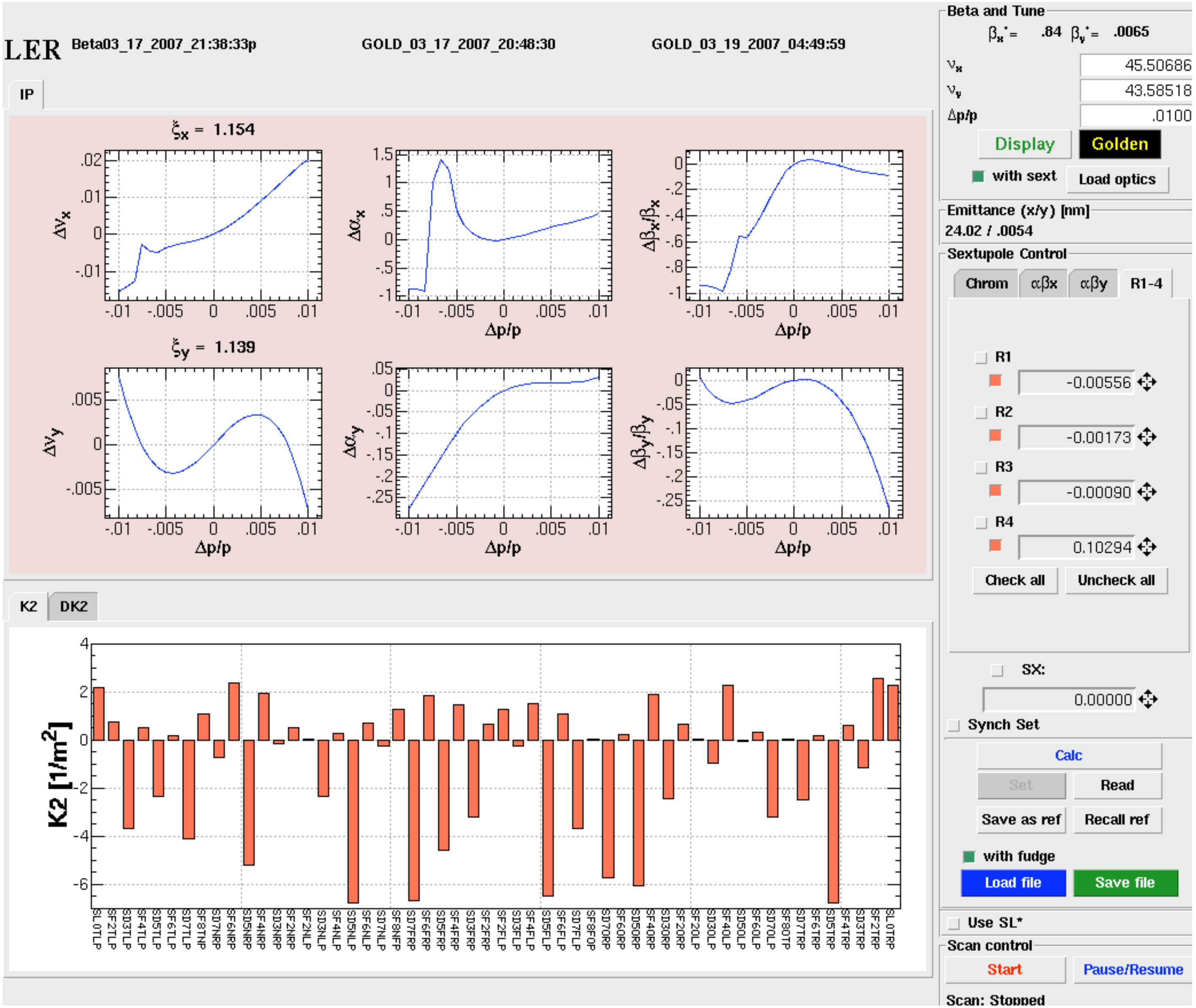
without constraint for R4

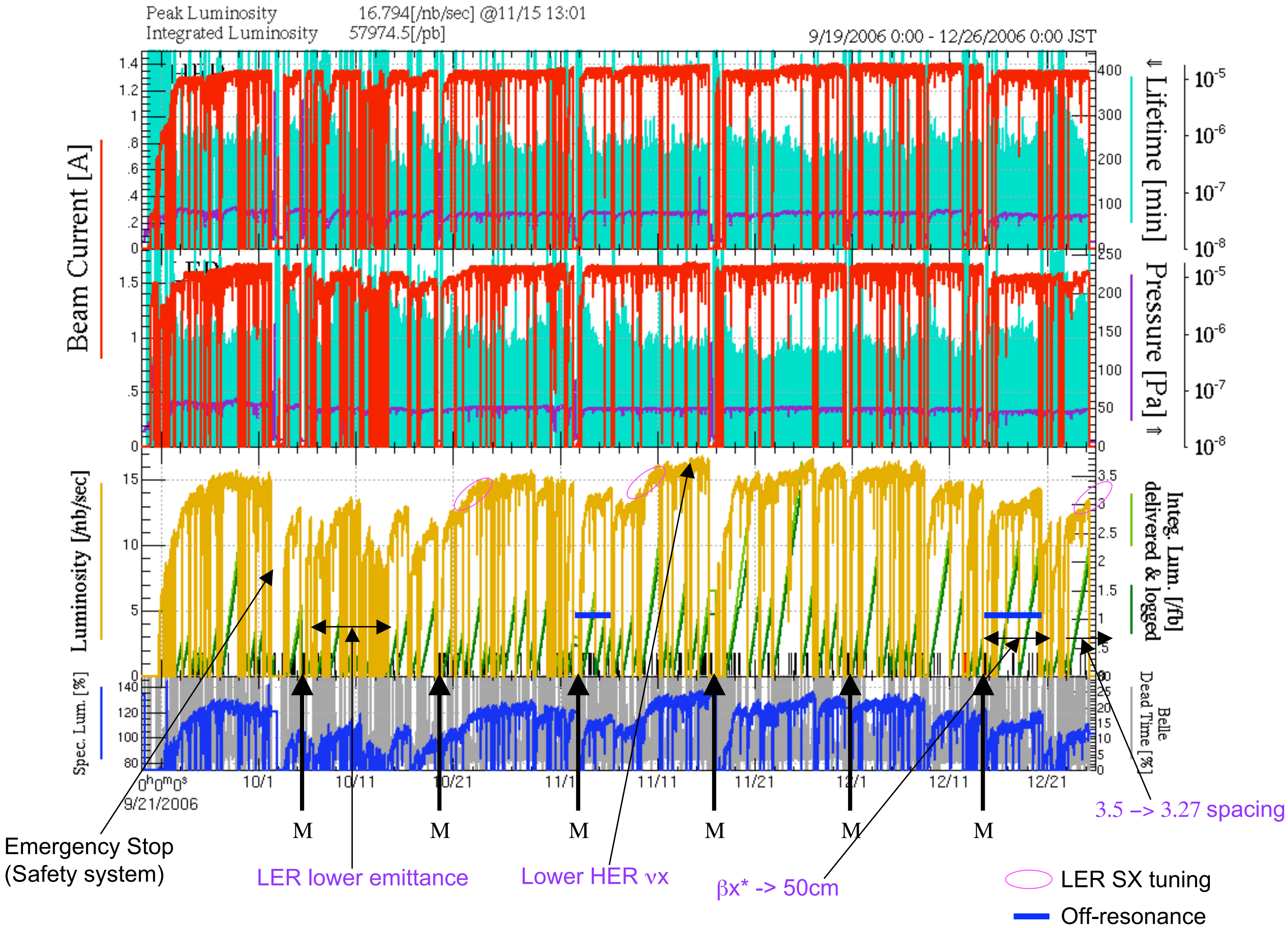


Scan of usual IP knob

Luminosity is sensitive to the strength of sextupole magnets.
The effect can not be reproduced by the usual IP knob.

New Sextupole Tuning panel



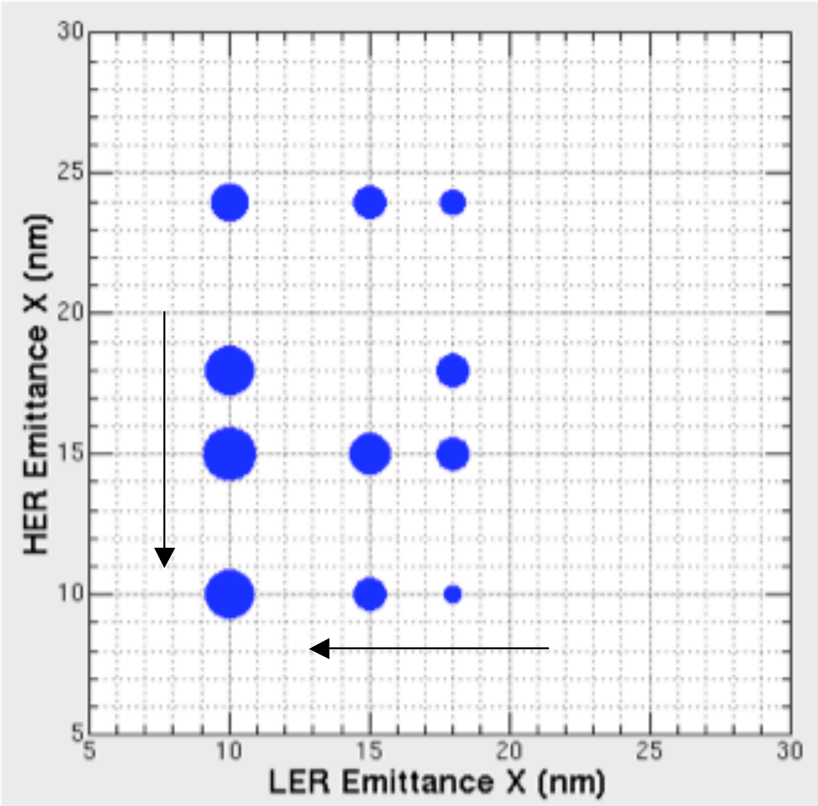


Peak Luminosity 16.794[/nb/sec] @11/15 13:01
Integrated Luminosity 57974.5[/pb]
9/19/2006 0:00 - 12/26/2006 0:00 JST
Beam Current [A]
Lifetime [min]
Pressure [Pa]
Luminosity [/nb/sec]
Integ. Lum. [/fb] delivered & logged
Spec. Lum. [%]
Belle Dead Time [%]
9/21/2006
10/1
10/11
10/21
11/1
11/11
11/21
12/1
12/11
12/21
M
Emergency Stop (Safety system)
LER lower emittance
Lower HER νx
βx* -> 50cm
3.5 –> 3.27 spacing
LER SX tuning
Off-resonance

Search for better machine parameters

Predicted luminosity by beam-beam simulations

Horizontal emittance



This trial   original

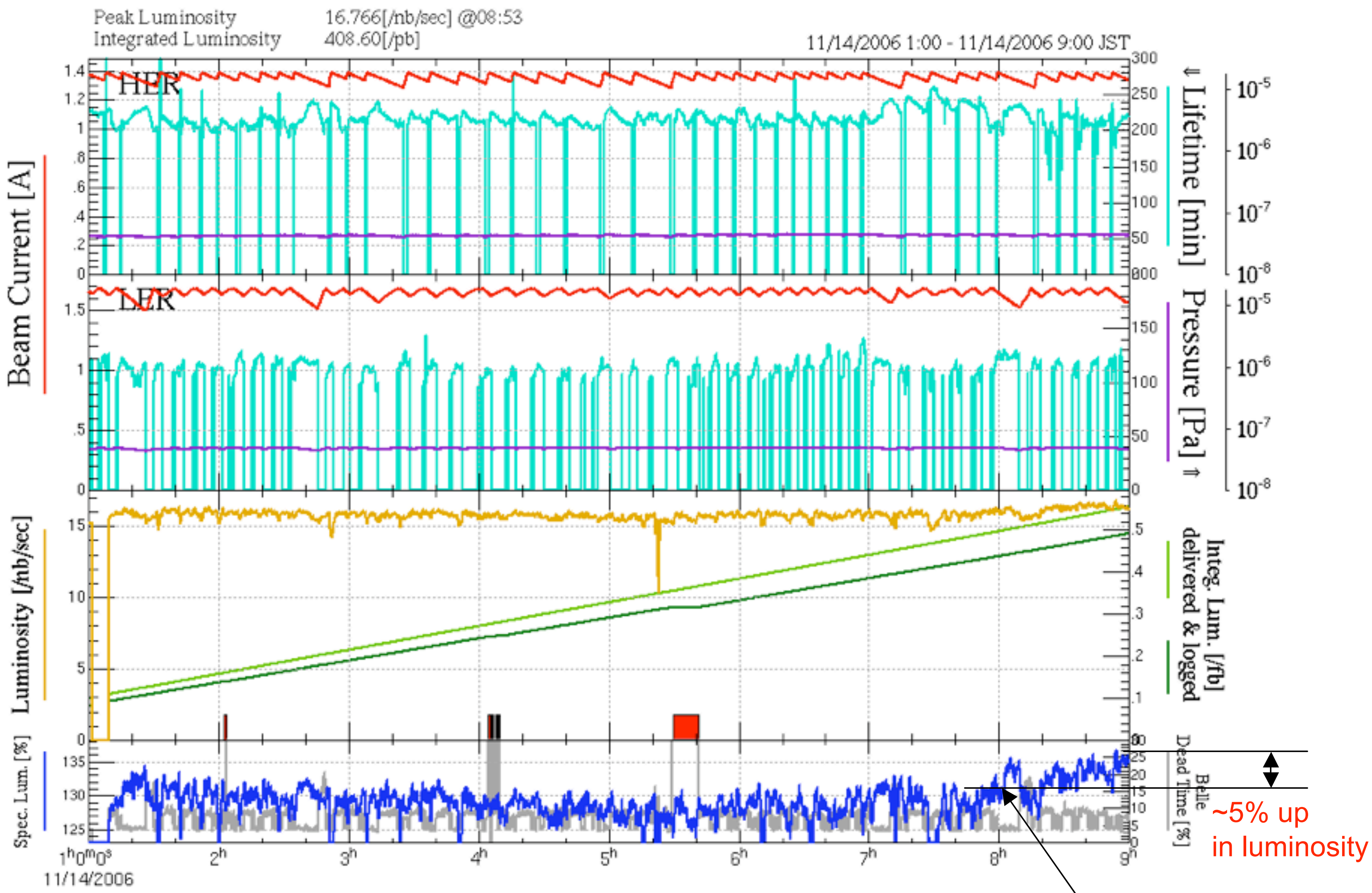
εx(nm) H\L	10	15	18
24	1.469 1.0770	1.414 1.0367	1.364 1
18	1.621 1.1884		1.420 1.0411
15	1.643 1.2045	1.505 1.1034	1.424 1.0440
10	1.595 1.1694	1.433 1.0506	1.249 0.9157

HER Tune

(νx, νy) = (.511, .568) -> (.509, .563)
L=1.381e31 -> 1.451e31 (5% up)

βx*

βX=56(HER) βX=59(LER) L=1.381e31
βX=50(HER) βX=50(LER) L=1.466e31 <- 6% up
βX=40(HER) βX=40(LER) L=1.326e31
βX=30(HER) βX=30(LER) L=1.217e31



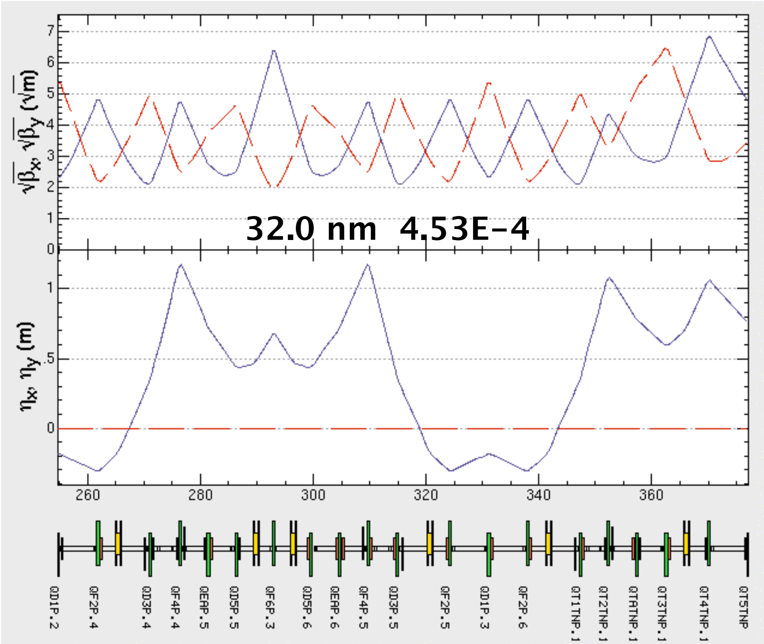
We succeeded to lower the HER horizontal tune by tuning HER sextupole magnets.

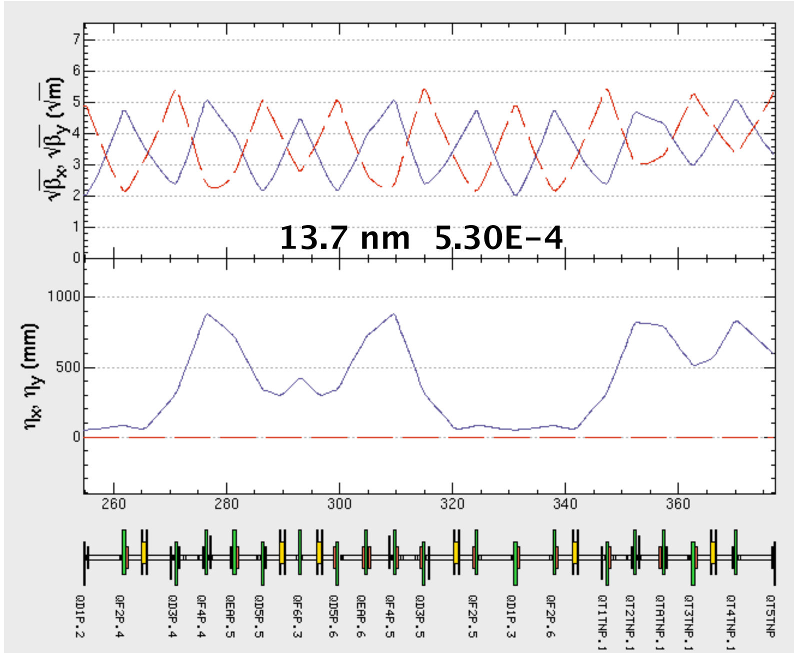
Trial of LER lower emittance optics

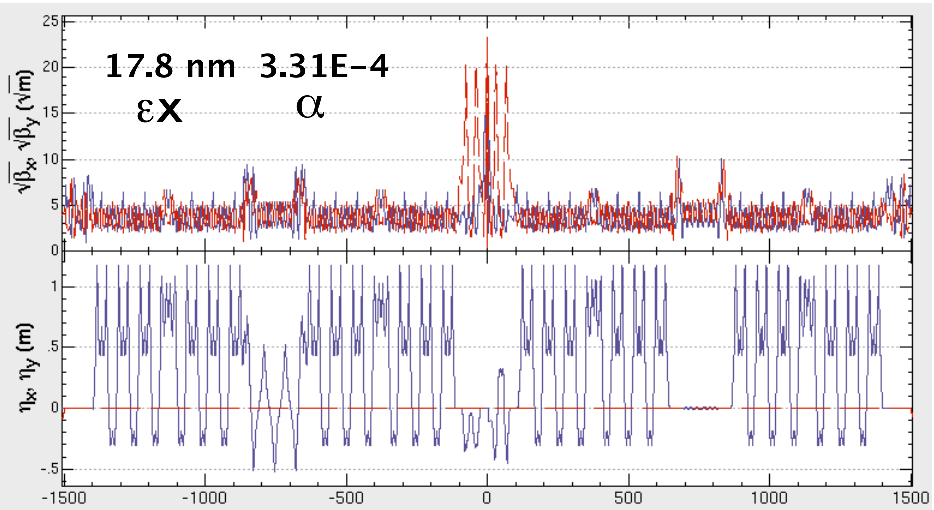
- LER emittance
  - 18nm -> 10nm
- Motivation
  - 7.7% increase of luminosity was predicted by the beam-beam simulation.
- Unexpected difficulty
  - We retreated from the trial due to frequent beam aborts accompanied by horizontal oscillations of both beams.
  - Beam-beam simulations showed that coherent synchro-beta oscillations due to the beam-beam effect tend to be excited with smaller emittances and tunes close to the half integer (Ohmi). More simulations are under way.
- Achieved luminosity
  - L_{peak} = 13.972 /nb/s (cf. 15.845 /nb/s with ex=18nm)
  - After returning to the original optics, the recovery of the luminosity was very slow.
  - It is not easy to make a critical comparison of 18 and 10nm optics with the short-term trial.

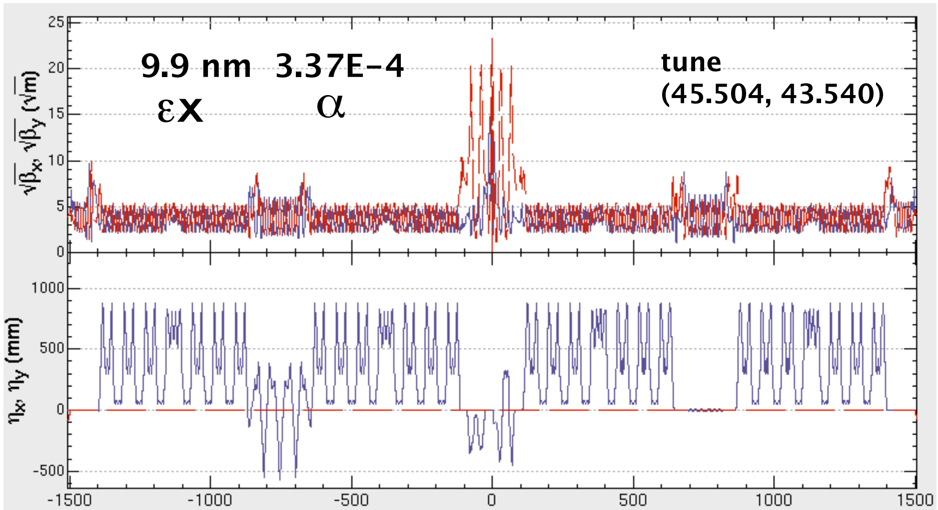
LER low emittance *Emit x =10* nm

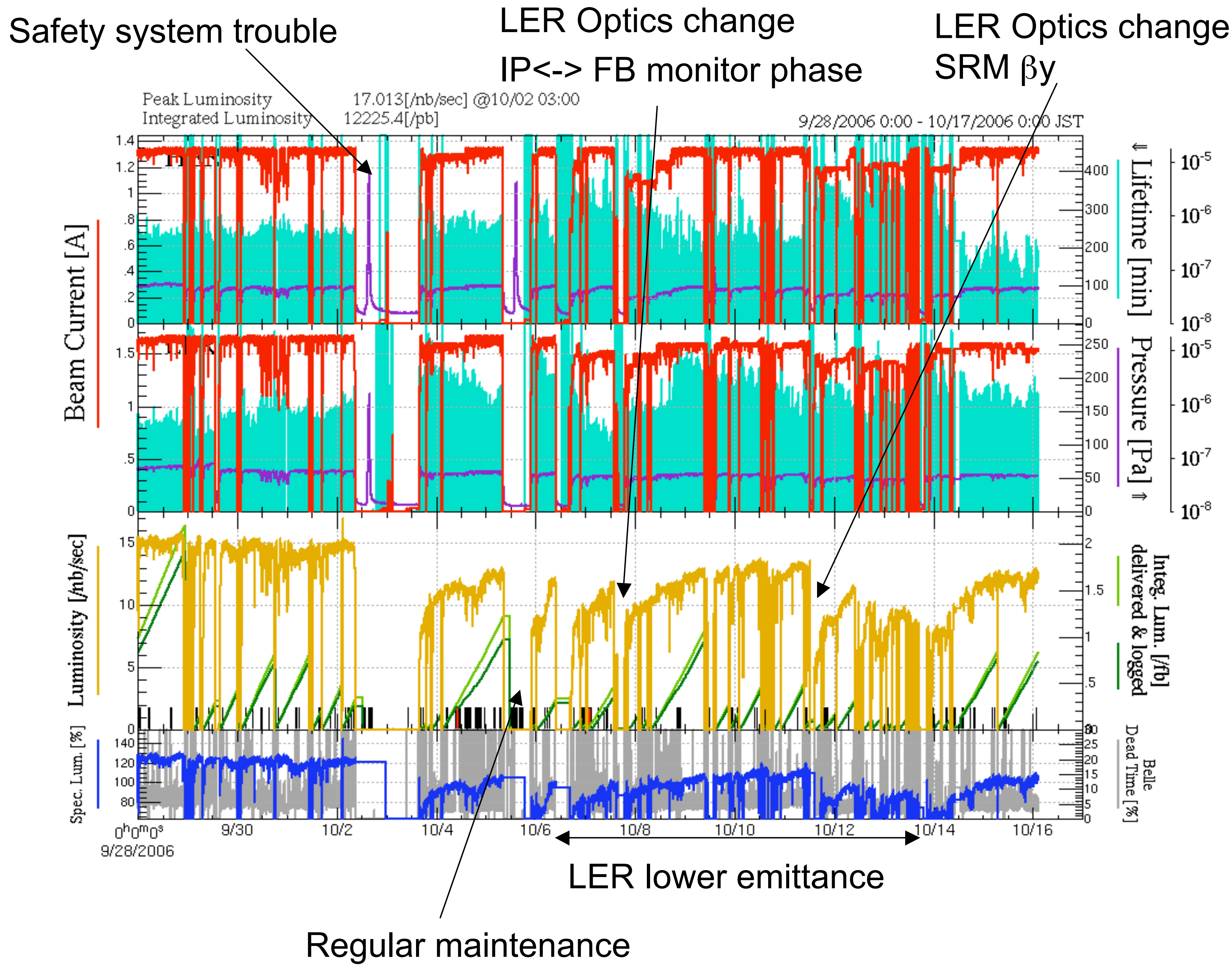
A. Morita











Safety system trouble
LER Optics change
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SRM βy
Peak Luminosity 17.013[/nb/sec] @10/02 03:00
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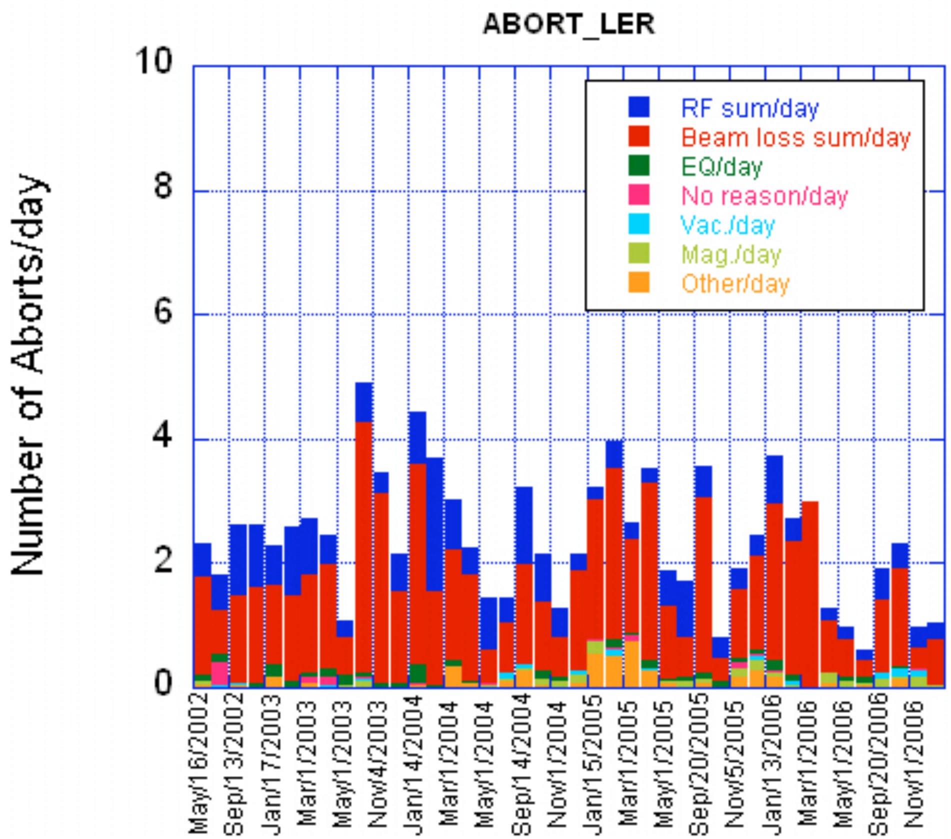
Integ. Lum. [/fb] delivered & logged
Spec. Lum. [%]
Belle Dead Time [%]
9/28/2006
9/30
10/2
10/4
10/6
10/8
10/10
10/12
10/14
10/16
LER lower emittance
Regular maintenance

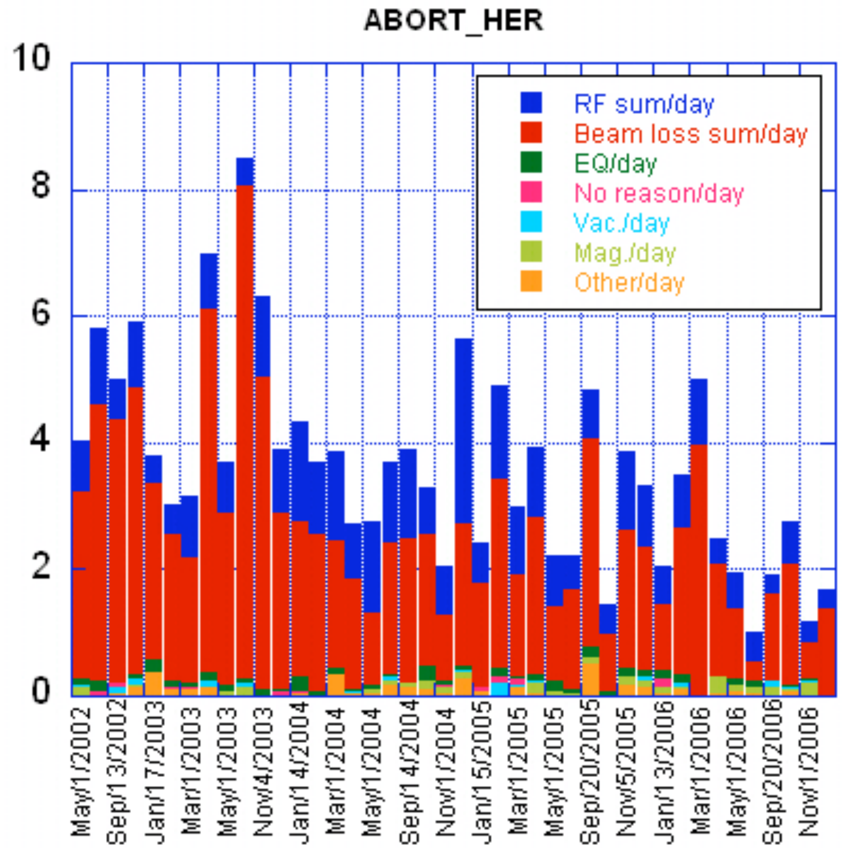
Other trial

- New power supplies of solenoid coils
  - In summer 2006, we replaced 50 power supplies of solenoids in straight sections.
  - With the power supplies, the currents of 1452 solenoids were increased from 3A to 5A.
  - However, the effectiveness of the new power supplies was not observed.
- Smaller β_x^*
  - (β_x^*(LER), β_x^*(HER))= (59cm, 56cm) -> (50cm, 50cm)
  - We could not go to the operating points which give a good luminosity due to bad beam lifetime.
  - It was not easy to test performance with limited tuning time due to the luminosity reporducibility problem.

Machine Operation Statistics

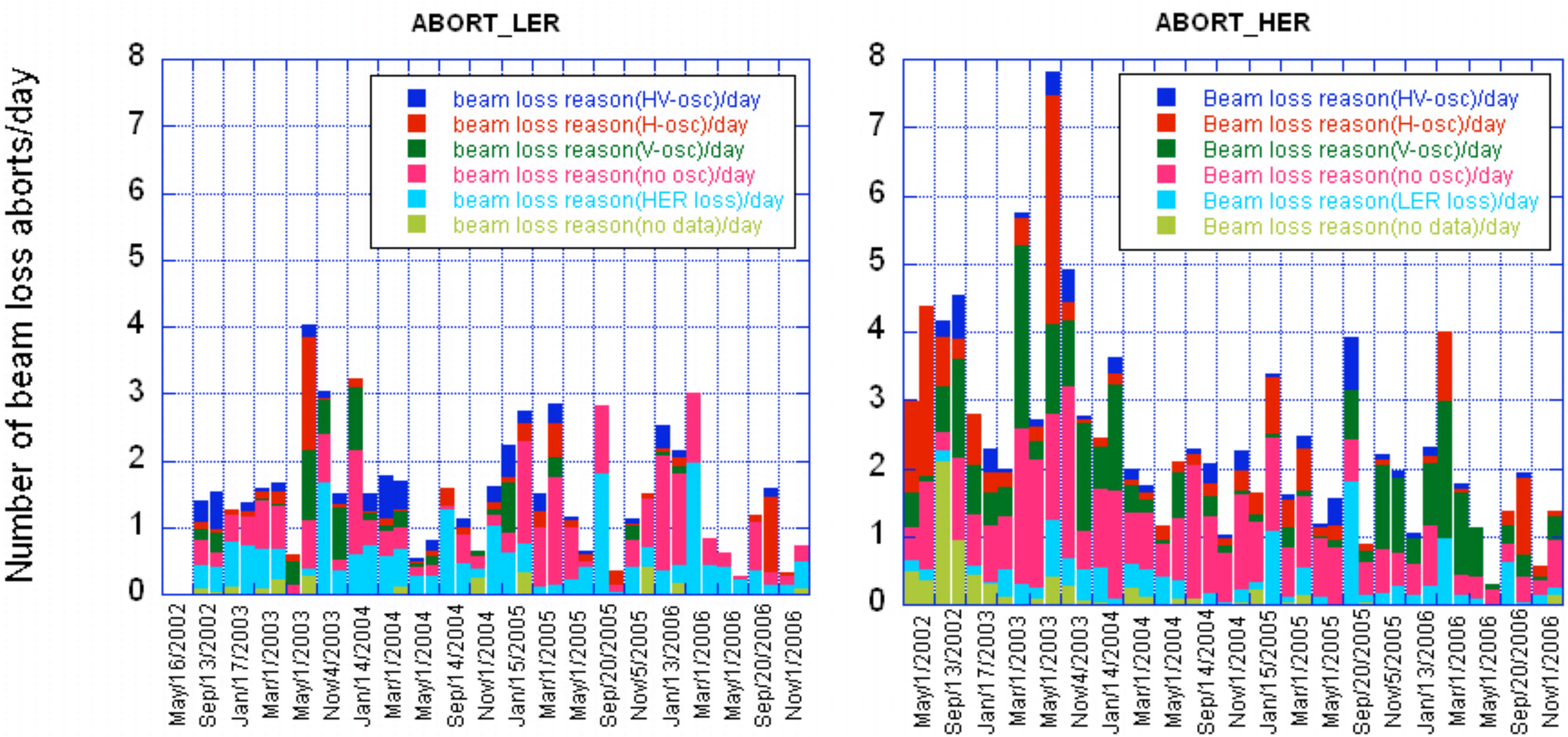
Abort statistics (total)





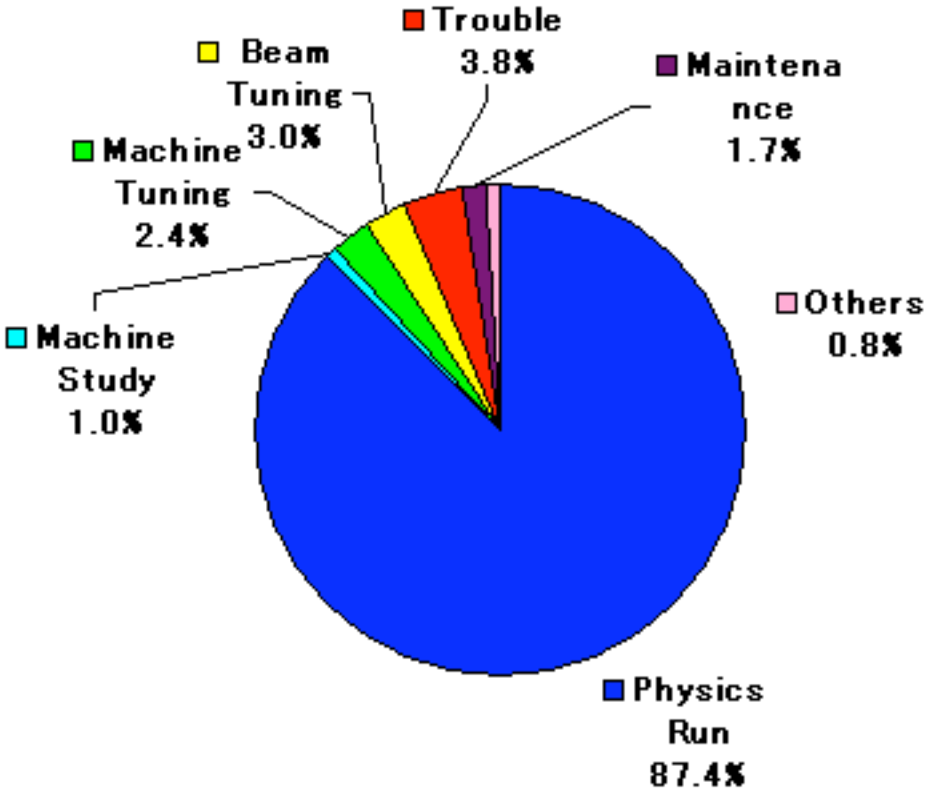
H. Ikeda and M. Tanaka

Abort statistics (beam loss aborts)

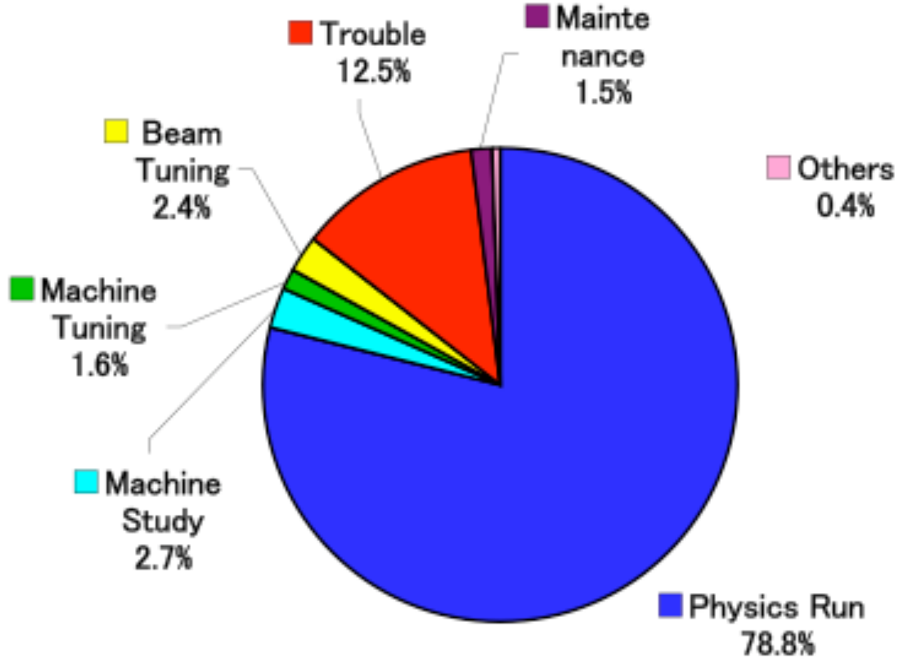


- **Causes of beam loss aborts**
  - **failure of tune control**
  - **coupled bunch instability**
    - **Fast ion, electron clouds, beam-beam, RF cavities**
  - **vacuum troubles such as bellows breaks**

Operation Statistics



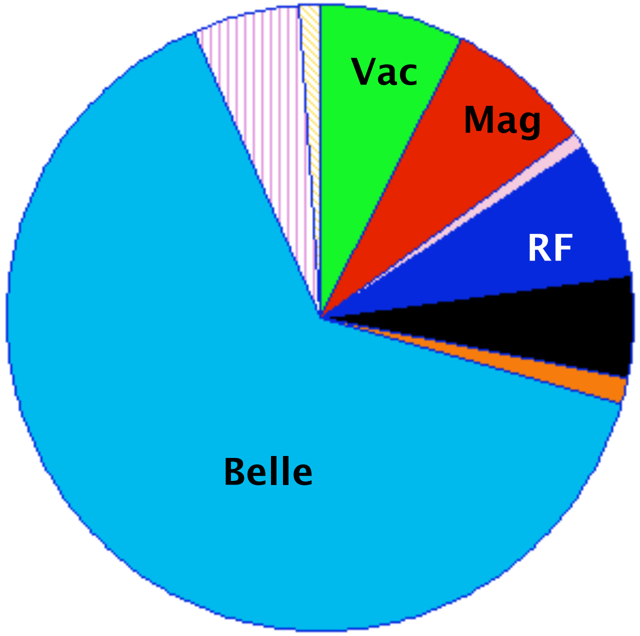
FY 2006 (Apr. 2006 ~ Dec. 2006)



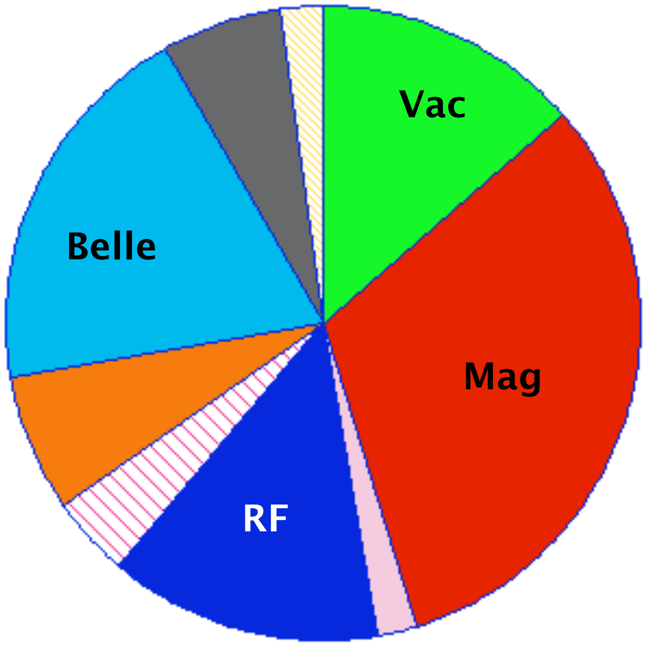
FY 2005

T. Kawasumi

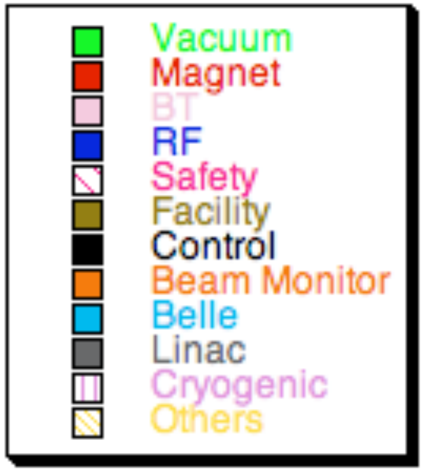
Operation Statistics (Troubles)



FY 2005

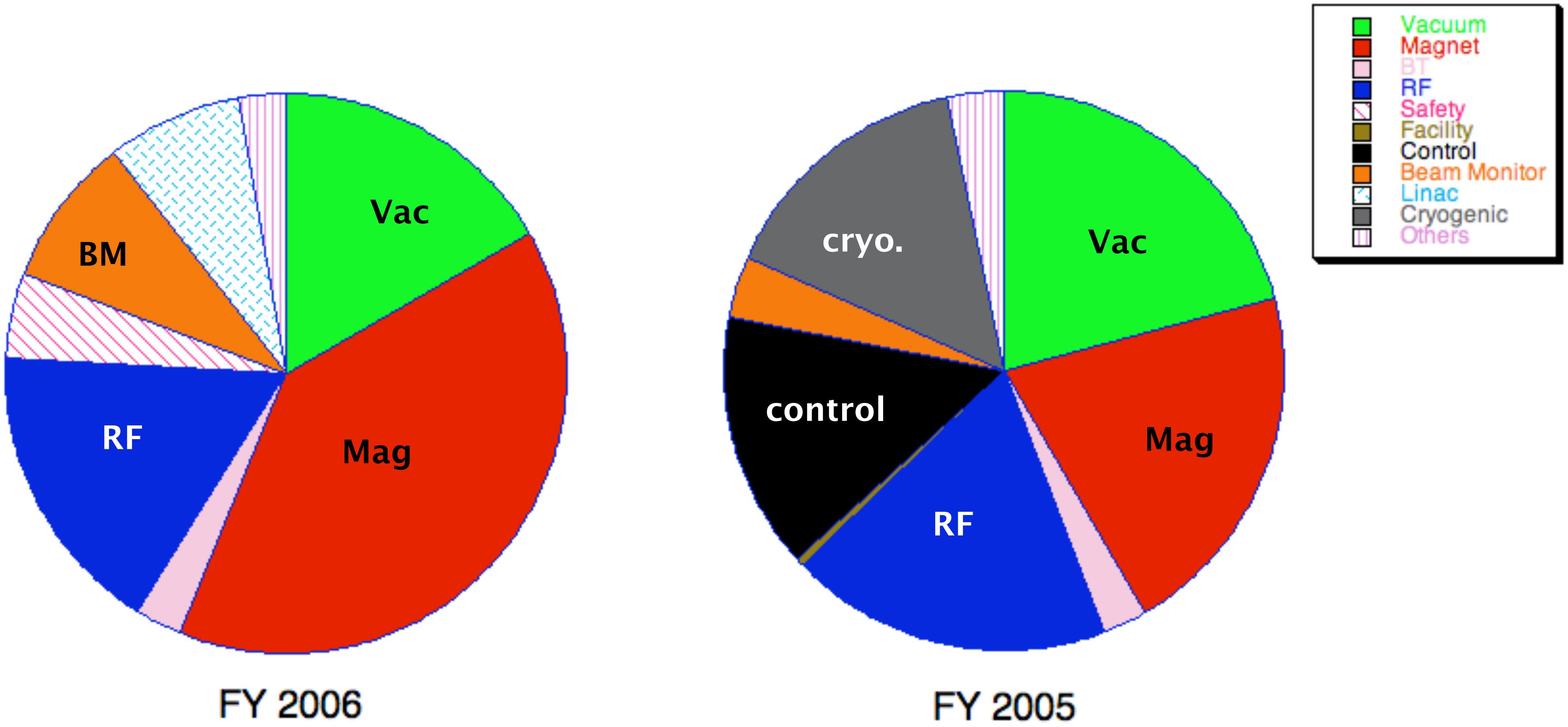


FY 2006 (Apr. 2006 ~ Dec. 2006)



T. Kawasumi

Trouble Statistics (except Belle)

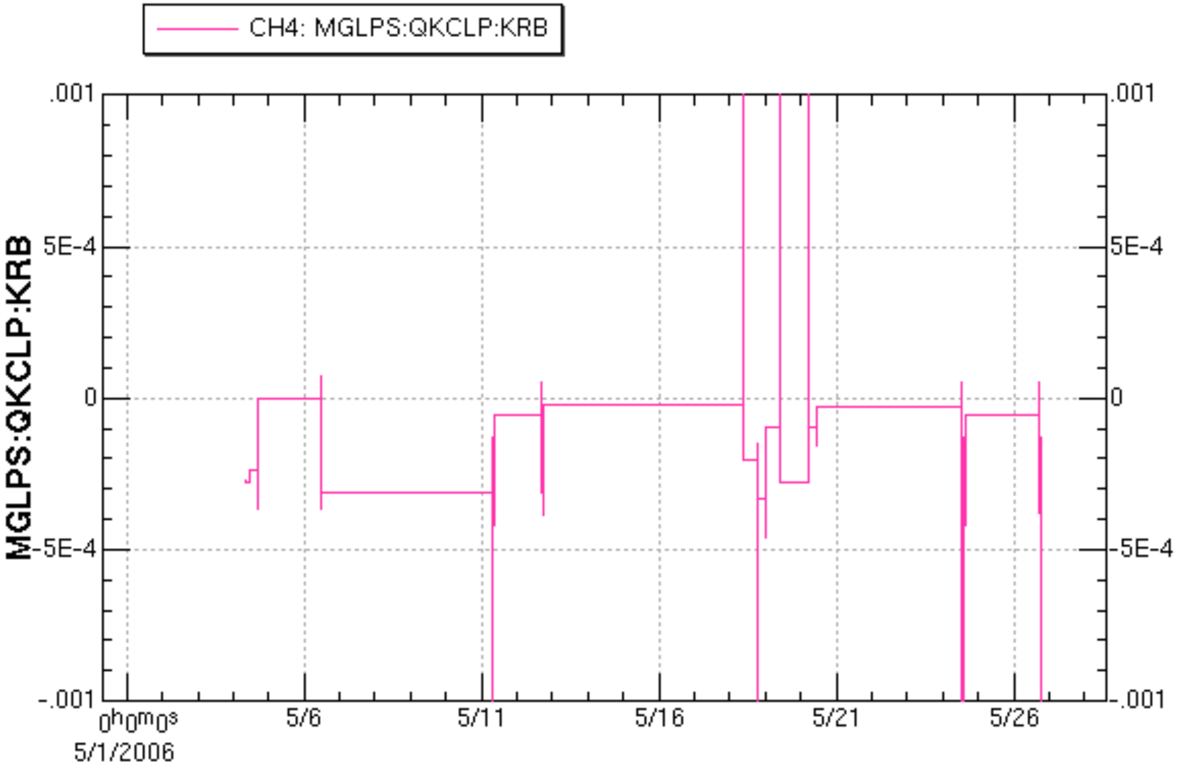


	FY 2006 (~Dec.2006)	FY 2005
Total operation Time [h]	4247.5	4527.5
Trouble Total except Belle [h]	128.5	258.5
Trouble Rate [%]	3.0	5.7

Future plans

- To see results of the crab crossing experiment

spare slides



R1 @IP (1 = 3.25 mrad)

R2 @IP (1 = 0.28 mm)

R3 @IP (1 = 126.30 km^{-1})

R4 @IP (1 = 23.75 mrad)

```
 In[90]:= K1o=Element["K1","QKCLP"]
Out[90]:= -1.5692027453E-4
 In[91]:= Twiss[{R1,R2,R3,R4},"IP"]
Out[91]:= {-3.79720241333E-15,1.286156554319E-13,5.236906695158E-12,-7.47076444381E-11}
 In[92]:= Element["K1","QKCLP"]=K1o+3e-4
Out[92]:= 1.4307972547E-4
 In[93]:= Twiss[{R1,R2,R3,R4},"IP"]
Out[93]:= {-3.79720241333E-15,1.286156554319E-13,5.236906695158E-12,-7.47076444381E-11}
 In[94]:= calc;
 Matched. (  0.000    ) DP = 0.02500  DP0 = 0.00000  ExponentOfResidual = 2.0  OffMomentumWeight =   1.000
IP.1        f AX     #######  #     .017280 IP.1        f BX     #######  #    .571844 IP.1        f AY     #######  #  -1.152E-6
IP.1        f BY     #######  #     .006500 PQD1C.1       AX     #######  #   -.021142 PQD1C.1       AY     #######  #  -2.502E-6
PQD1C.1/PQD BX     #######  #    5.278687 PQD1C.1/PQD BY     #######  #  29.429921 PMID          AX     #######  #   -.020426
PMID          BX     #######  #   14.567634 PMID          AY     #######  #  -1.631E-6 PMID          BY     #######  #  14.999941
KICKER2/KIC NX     #######  #     .500000 INJECTIO      BX     #######  #  52.588222 PQD1C.5       AX     #######  #   -.035736
PQD1C.5       AY     #######  #   -8.615E-7 PQD1C.5/PQD BX     #######  #   5.427029 PQD1C.5/PQD BY     #######  #  29.430052
$$$           AX     #######  #     .017280 $$$           BX     #######  #    .571844 $$$           NX     #######  #  45.501257
$$$           AY     #######  #   -1.152E-6 $$$           BY     #######  #    .006500 $$$           NY     #######  #  43.547252
$$$           LENG   #######  #   3016.2426
 In[95]:= Twiss[{R1,R2,R3,R4},"IP"]
Out[95]:= {1.3021830040284E-4,-5.921150897078E-4,.17612624426585,-.395099218273478}
 In[96]:= Twiss[{R1,R2,R3,R4},"IP"]/{3.25e-3,0.28e-3,126.3e-3,23.75e-3}
Out[96]:= {.04006716935472,-2.114696748956598,1.394507080489707,-16.635756558883329}
```

ΔK1=+3E-4

Definition of R matrix

- Definition in the SAD code

$$\begin{pmatrix} u \\ p_u \\ v \\ p_v \end{pmatrix} = T \begin{pmatrix} x \\ p_x \\ y \\ p_y \end{pmatrix}$$

$$T(s) = \begin{pmatrix} \mu I & S R^t S \\ R & \mu I \end{pmatrix} = \begin{pmatrix} \mu & 0 & -R4 & R2 \\ 0 & \mu & R3 & -R1 \\ R1 & R2 & \mu & 0 \\ R3 & R4 & 0 & \mu \end{pmatrix}$$

Normal (uncoupled) coordinate

Usual coordinate

R matrix

$$S = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$$

$$\mu^2 + \det R = 1$$