Further Luminosity Upgrade

Y. Funakoshi (KEK)

Contents

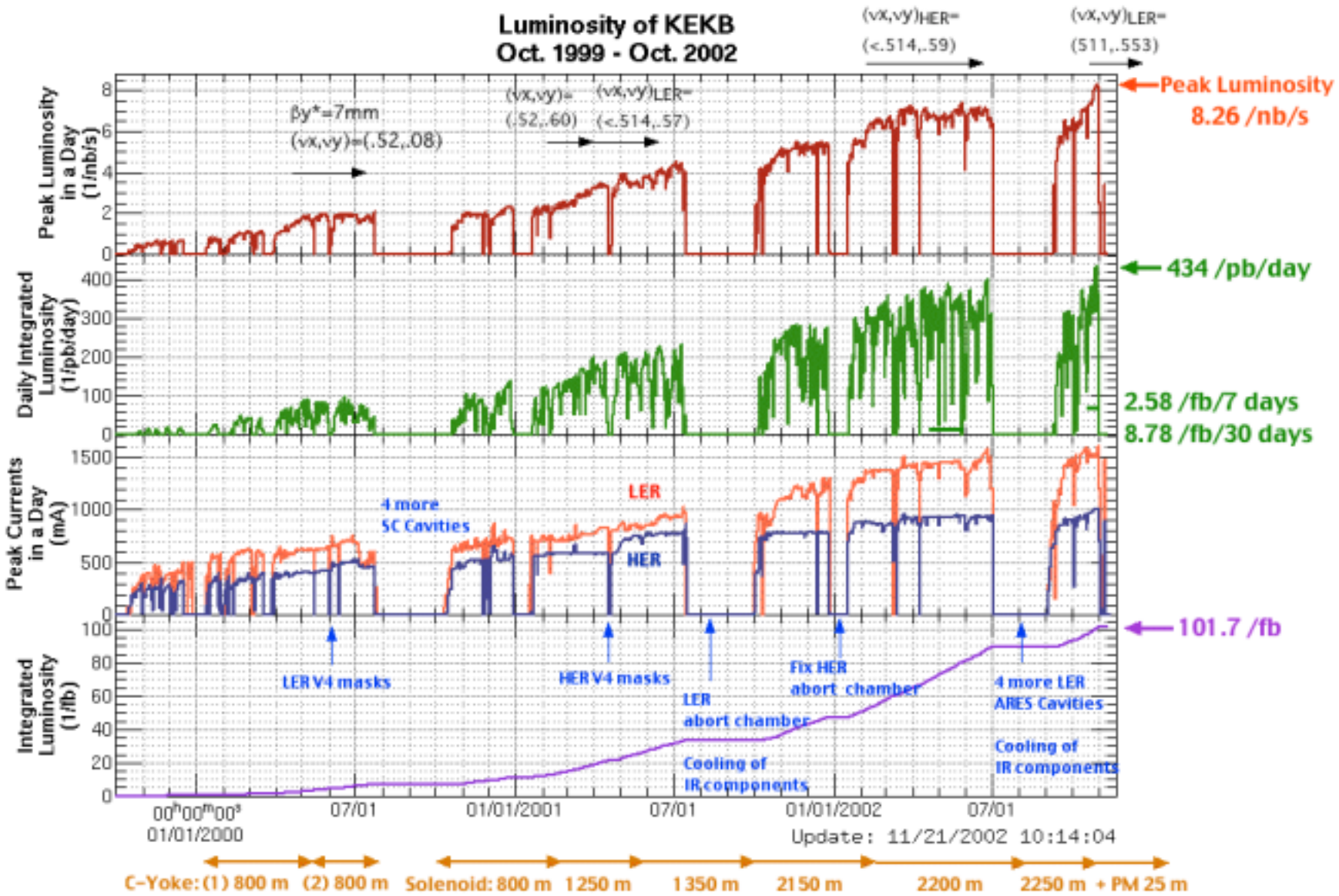
- Three ways of considering luminosity upgrade
  - Comparison with the design
  - History of luminosity improvements
  - Luminosity limiting issues
- Summary

Comparison with design

		LER	HER
Horizontal emittance	nm	18 (18)	24 (18)
Total beam current	mA	1454 (2600)	949 (1100)
Number of bunches		1184 (~5000)	
Bunch current	mA	1.23 (0.52)	0.801 (0.22)
Bunch spacing	nsec	8 (2)	
Synchrotron tune		-0.0236	-0.0207
Betatron tunes νx/νy		45.511/43.553 (45.52/45.08)	44.513/41.582 (47.52/43.08)
Beta's at IP βx/βy	cm	59/0.62 (33/1)	61/0.7 (33/1)
Beam-beam parameters ξx/ξy		0.090/0.053 (0.039/0.052)	0.078/0.045 (0.039/0.052)
Peak luminosity	/cm^2/sec	$8.26*10^{33}$ ($1*10^{34}$)	

( ): design values

History of Luminosity improvements



Luminosity limiting issues

- Luminosity formula

$$L = \frac{\gamma_k}{2er_e}\frac{R_L}{R_{\xi y}}\frac{I_k\xi_y}{\beta_y^*}$$

Three key parameters for higher luminosity

- Beam currents
- Vertical beta function at IP
- Vertical Beam-Beam parameter

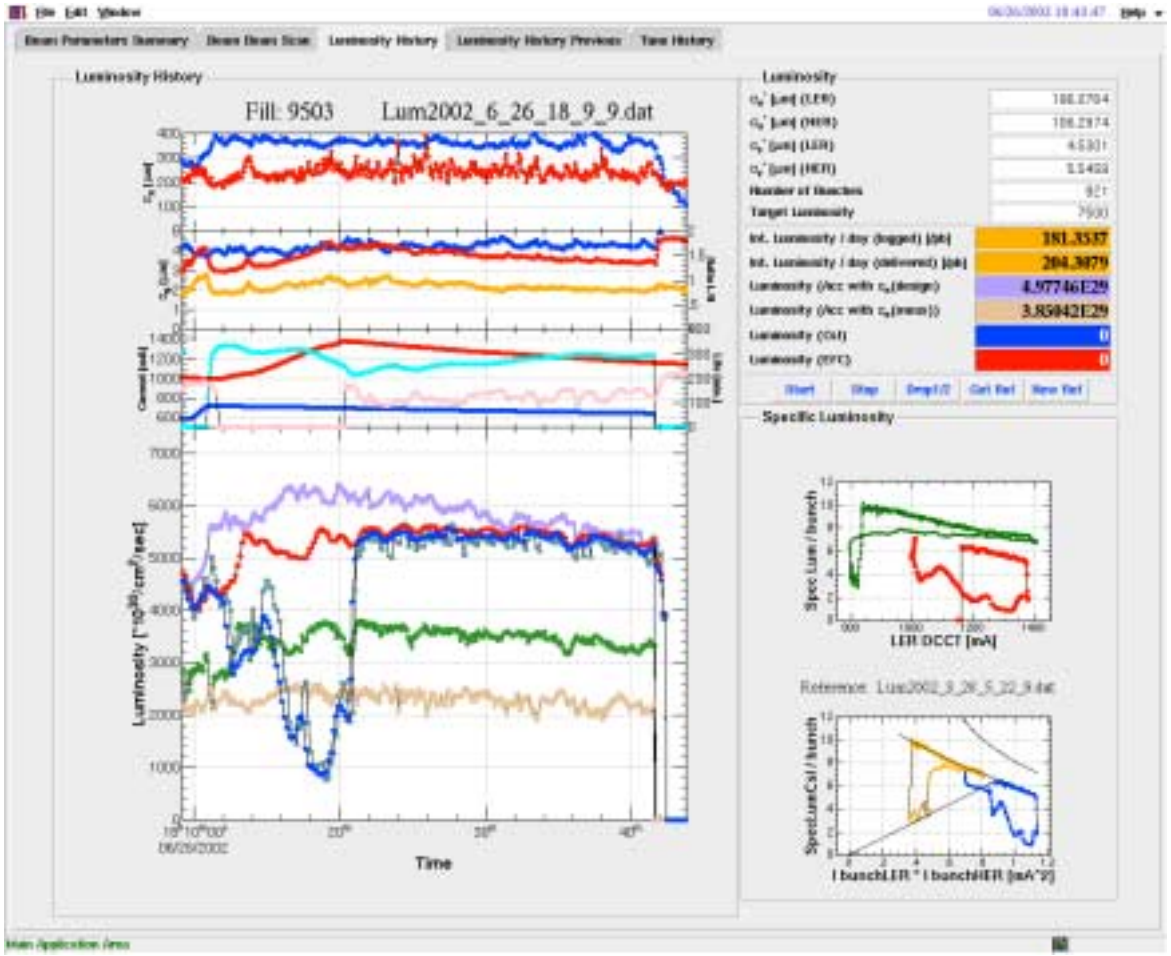
Beam currents

- Record values at KEKB
  - HER 1006mA(record) cf. 1100mA(design)
  - LER 1650mA(record) cf. 2600mA(design)
- Issues
  - Effect on luminosity
  - Hardware tolerance
  - Bunch spacing problem
  - RF power

Effect of higher beam currents on luminosity

- Machine study on June 26 2002
  - Method
    - Decreased number of bunches by 33% (with the same bunch spacing)
    - Increased bunch currents
    - Observed achieved luminosity (times 1.33)
  - Results
    - Increase of LER beam current did not result in a higher peak luminosity. -> due to ECI ?
    - Increase of beam currents in both rings resulted in a higher peak luminosity.
- Increase LER beam current in actual physics run
  - Result
    - Higher LER current did not bring a higher peak luminosity.

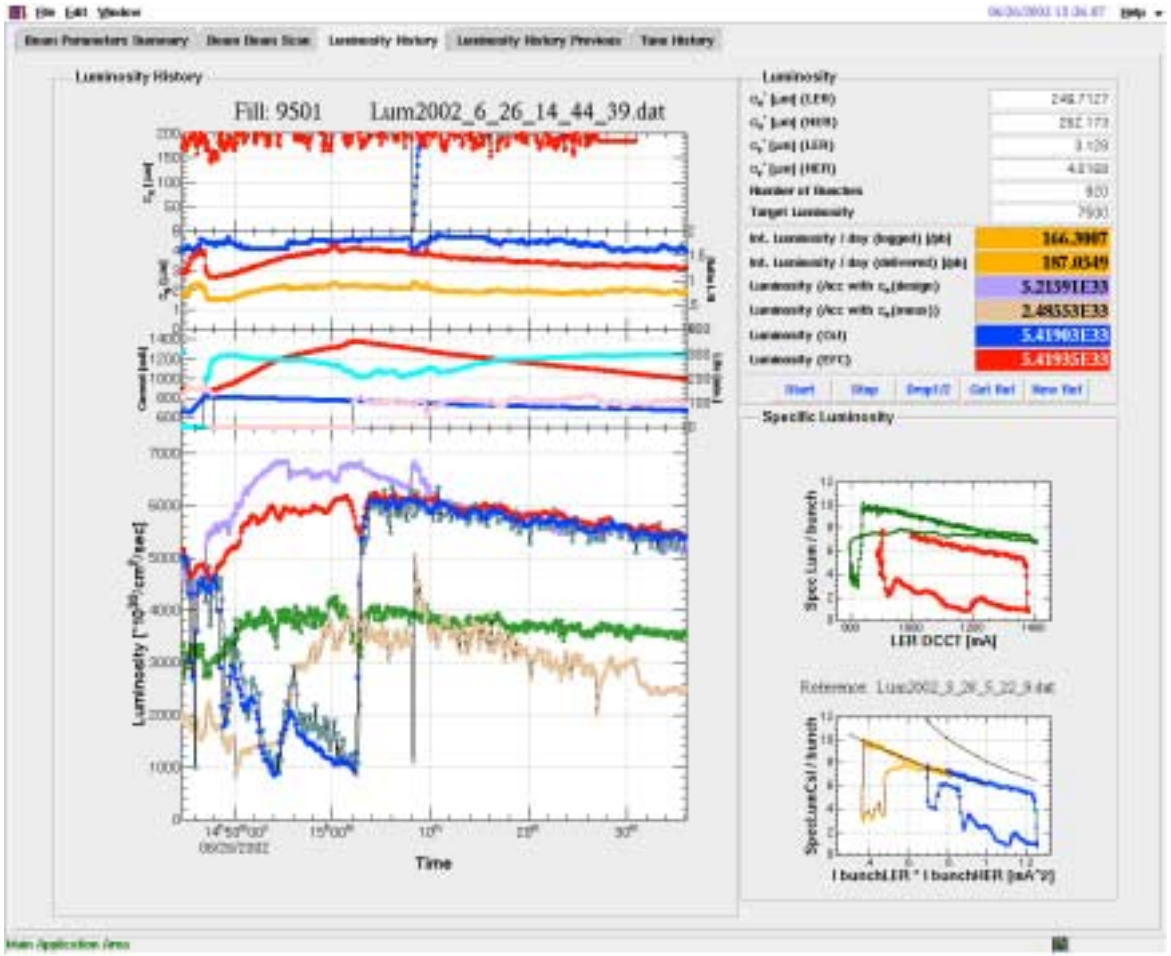
Increase LER beam current Machine Study (June 2002)



Machine Study:
I_{LER} (max) = 1380mA
-> 1835mA
I_{HER} (max) = 720mA
-> 958mA
L_{peak}= 5.58 /nb/sec
-> 7.42 /nb/sec

Physics Run:
I_{LER} (max) = 1380mA
I_{HER} (max) = 950mA
L_{peak}= 7.3 /nb/sec

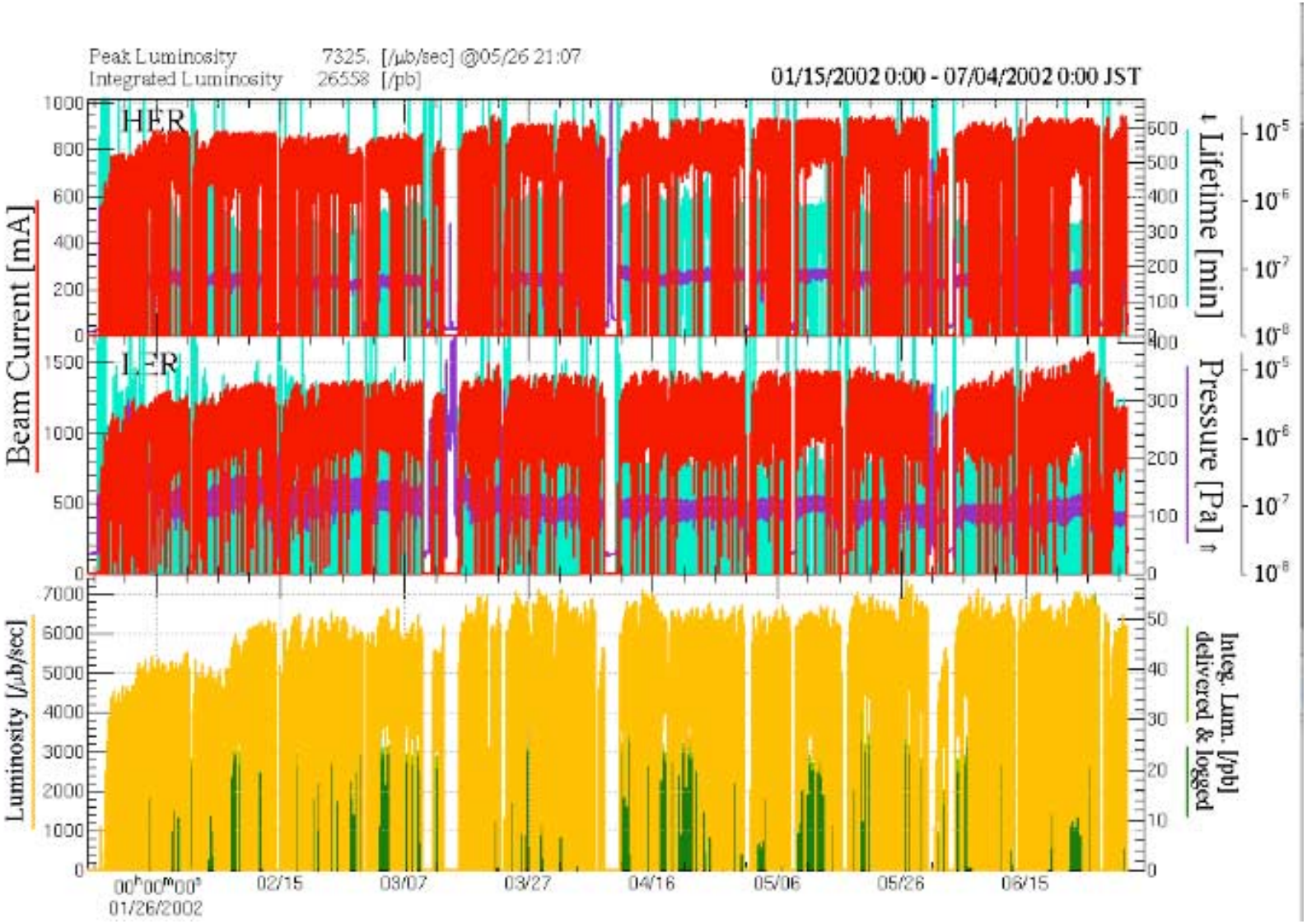
Increase beam currents of both rings
Machine Study (June 2002)



Machine Study:
I_{LER} (max) = 1380mA
-> 1835mA
I_{HER} (max) = 815mA
-> 1084mA
L_{peak}= 6.16 /nb/sec
-> 8.19 /nb/sec

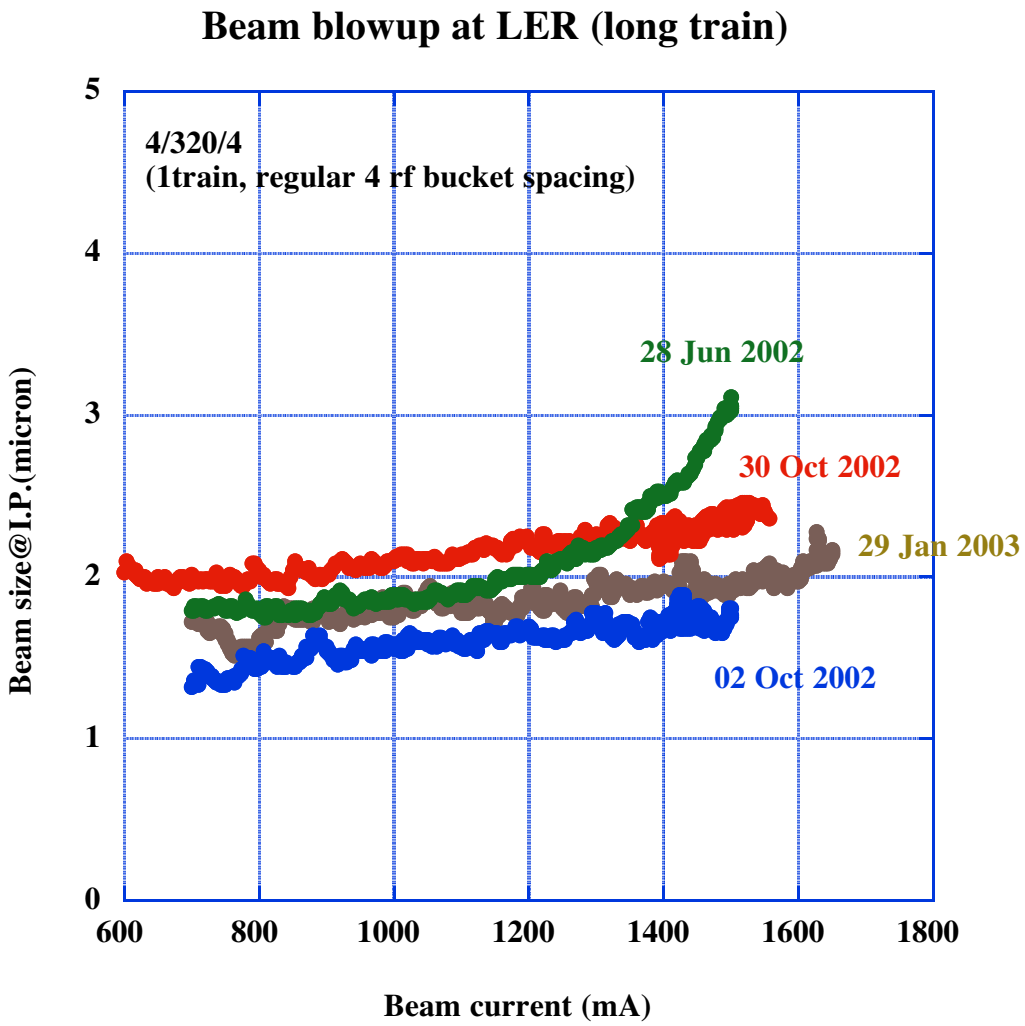
Physics Run:
I_{LER} (max) = 1380mA
I_{HER} (max) = 950mA
L_{peak}= 7.3 /nb/sec

Increase of LER beam current in actual physics run (June 2002)



LER single beam blowup

From Fukuma



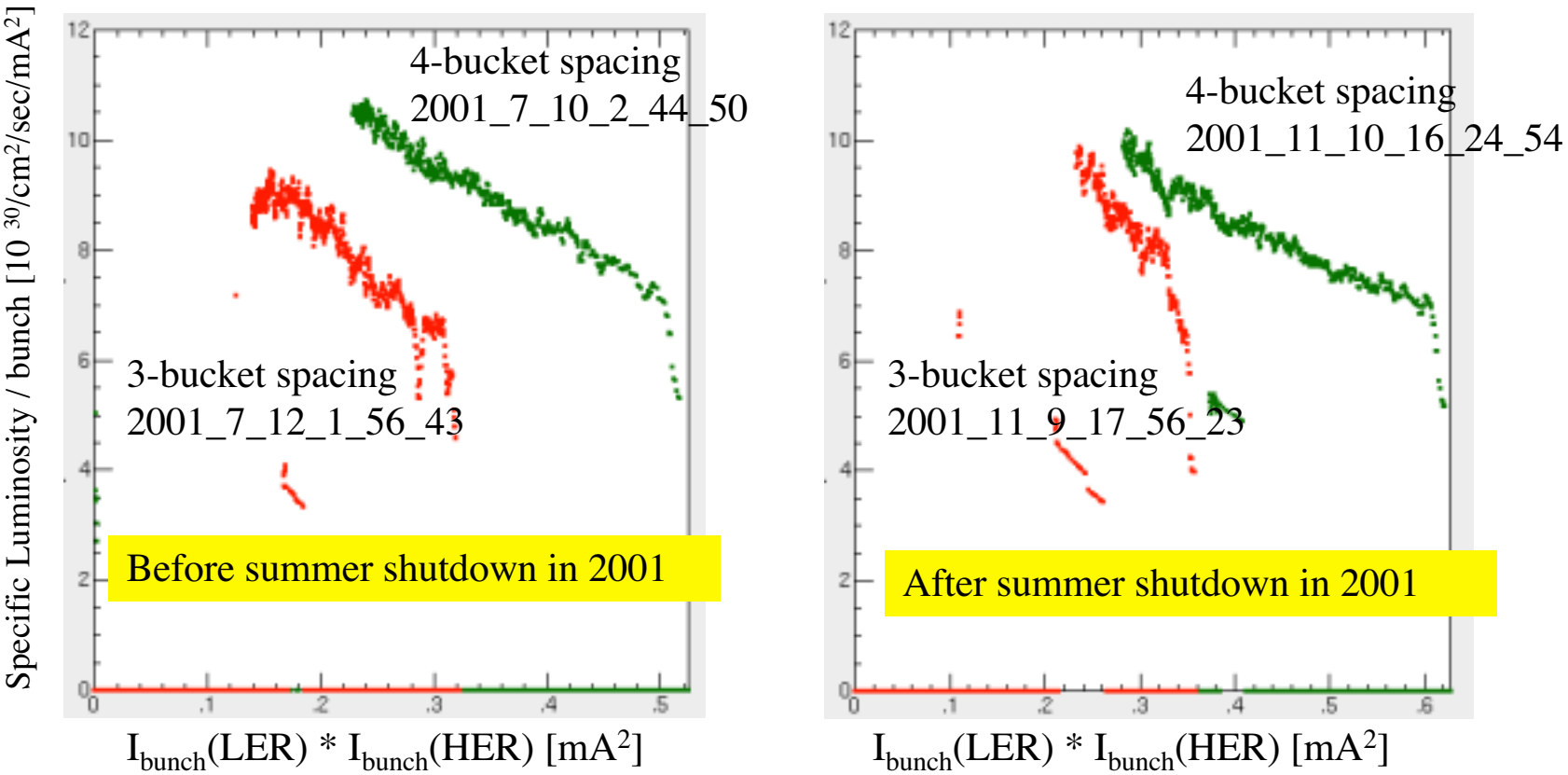
Hardware tolerance to high beam currents

- IP beam chamber
  - Present restriction: 2200mA in the sum of the two beams
  - Investigation on the cause of the vacuum leak, Temperature rise of IP chamber -> more currents?
- Other hardware components
  - We experienced a lot of troubles due to high beam currents.
  - No substantial difficulty at the present level of beam currents.
  - HOM heating issues
    - It is desirable to decrease bunch currents by increasing the number of bunches. -> Bunch spacing problem
  - Next target
    - 1.1A (HER), 2.0A (LER)

Bunch spacing problem

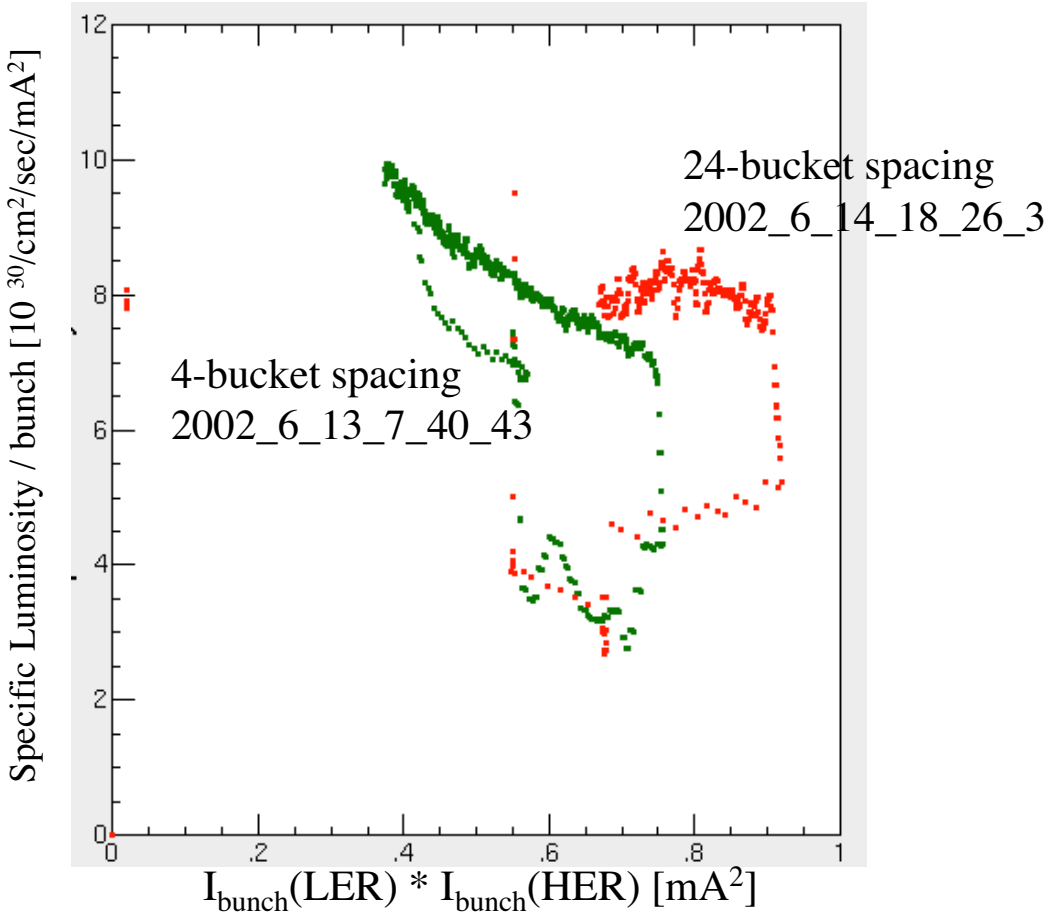
- Observations
  - The specific luminosity depends on bunch spacing.
  - Longer bunch spacing gives a higher specific luminosity.
- Cause of the problem
  - This problem can not be attributed to the beam-beam effect.
  - The LER single beam blowup does not explain this problem, since the problem occurs even below the threshold of the blowup.
  - No conclusive cause for this problem has not been found yet.
    - A synergistic effect of the beam-beam and the ECI might be relevant to this problem.

Comparison of specific luminosity with 3 and 4 bucket spacing



Specific Luminosity / bunch = $L/N_{bunch}/I_{bunch}(LER)/I_{bunch}(HER)$

Comparison of specific luminosity with 4 and 24 bucket spacing



RF Power

- LER
  - We already have a full set of RF (ARES) cavities.
  - We are ready to store a design beam current of 2.6A from the viewpoint of RF power.
- HER
  - 2 ARES cavities are lacking for a full set.
    - The design beam current of 1.1 A is maybe possible to stored.
  - In summer 2003, 2 ARES cavities will be installed.
    - We will be able to store 1.2 A in autumn.

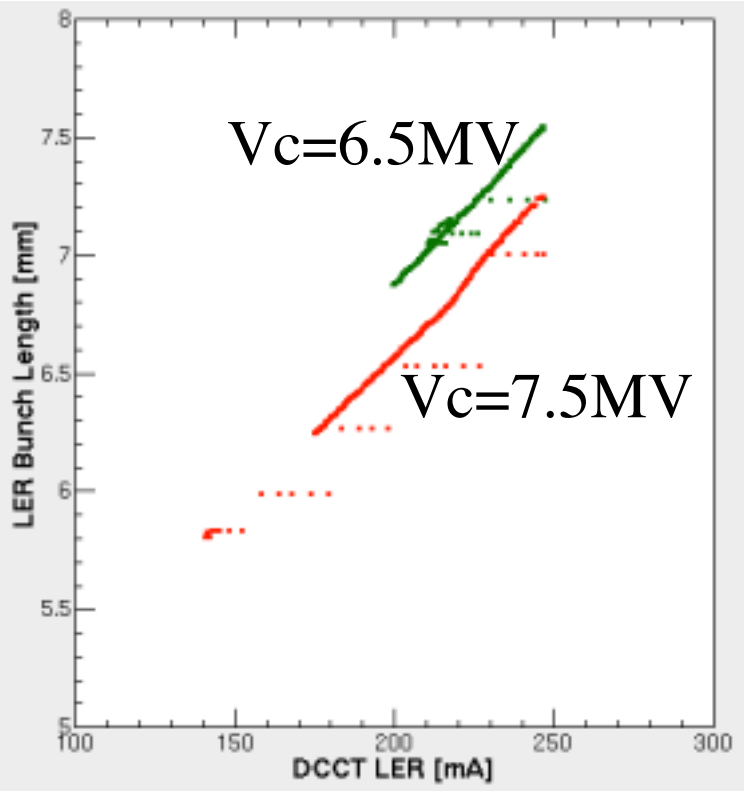
β_y^* (vertical beta function at IP)

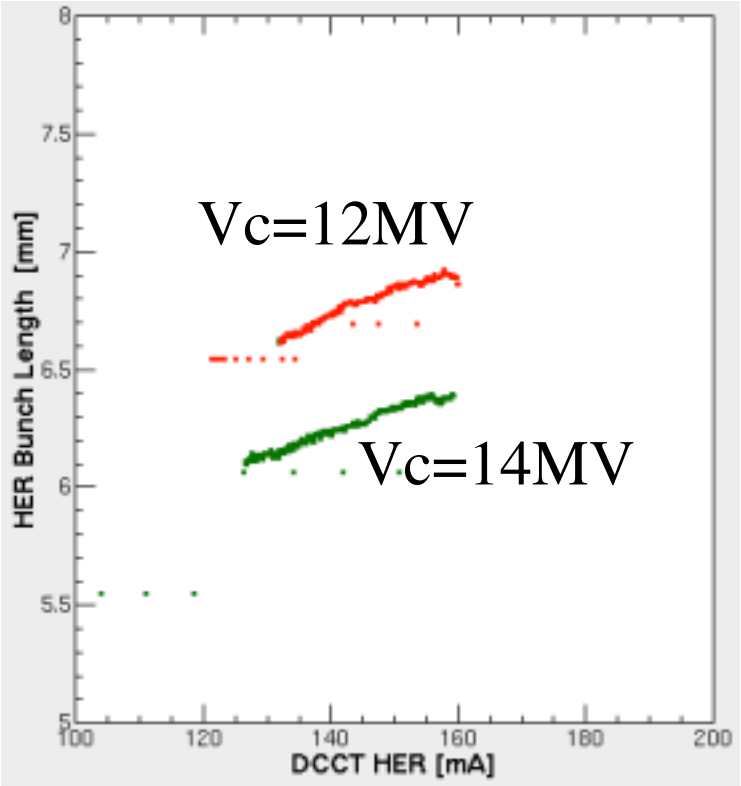
- Record values at KEKB
  - HER 7.0mm (present) cf. 10mm (design)
  - LER 6.2mm (present) cf. 10mm (design)
- Issues
  - Dynamic and physical aperture
    - There may be small room for squeezing the vertical beta function further.
  - Bunch length
    - The bunch length in the usual physics run is already comparable with the vertical beta function.

Luminosity with shorter bunch length Machine Study June 14 2002

- Vc (RF voltage)
  - HER: 12MV -> 14MV
  - LER: 6.5MV -> 7.5MV
- Bunch length (measured by bunch spectrum monitor)
  - HER: ~6.9mm -> ~6.3mm
  - LER: ~7.7mm -> ~7.3mm
- Luminosity
  - No significant improvement in the luminosity was observed with the higher Vc operation.
    - Tuning time was insufficient?
  - A beam-beam simulation predicts a higher luminosity with the measured bunch length by 6.5%.

Bunch Length with higher Vc





204 bunches: 24 bucket spacing

ξ_y (Vertical Beam-Beam parameter)

- Record values at KEKB
  - HER 0.045 (record) cf. 0.052 (design)
  - LER 0.053 (record) cf. 0.052 (design)
- Issues
  - Tune survey
  - ECI
  - Bunch spacing problem
  - Crab cavity system

ECI (Electron Cloud Instability)

- Solenoid coils
  - If we switched off all the solenoids, the luminosity would be less than half or we would not be able to store the present beam current.
- Does ECI limit the KEKB performance still now?
  - The single beam blowup does not appear up to around 1800mA in the usual fill pattern.
  - The bunch spacing problem has something to do with ECI?
  - A higher LER beam current brings a higher luminosity?
  - We need more data…

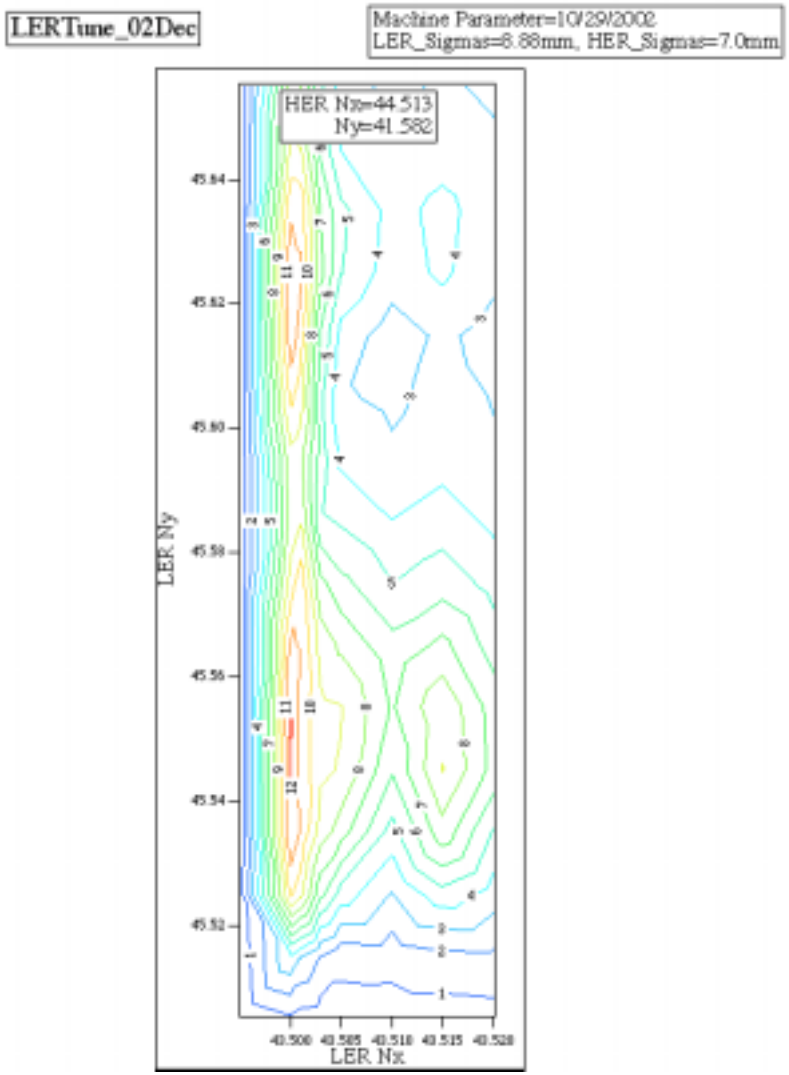
ECI [cont'd]

- Effect of more solenoid
  - There remains very small room for installation of solenoids.
  - However, there is some indications that a small amount of solenoids has effects than was expected.

Tune Survey

- An enormous amount of efforts have been devoted to the tune survey since the beginning of the KEKB commissioning.
- At present there is almost no more promising tune region than the present position.
- In Factories 2001 workshop, I found that the fractional part of tune at CESR (.53,.58) is similar to ours.

Tune Survey
(Simulation by Tawada)

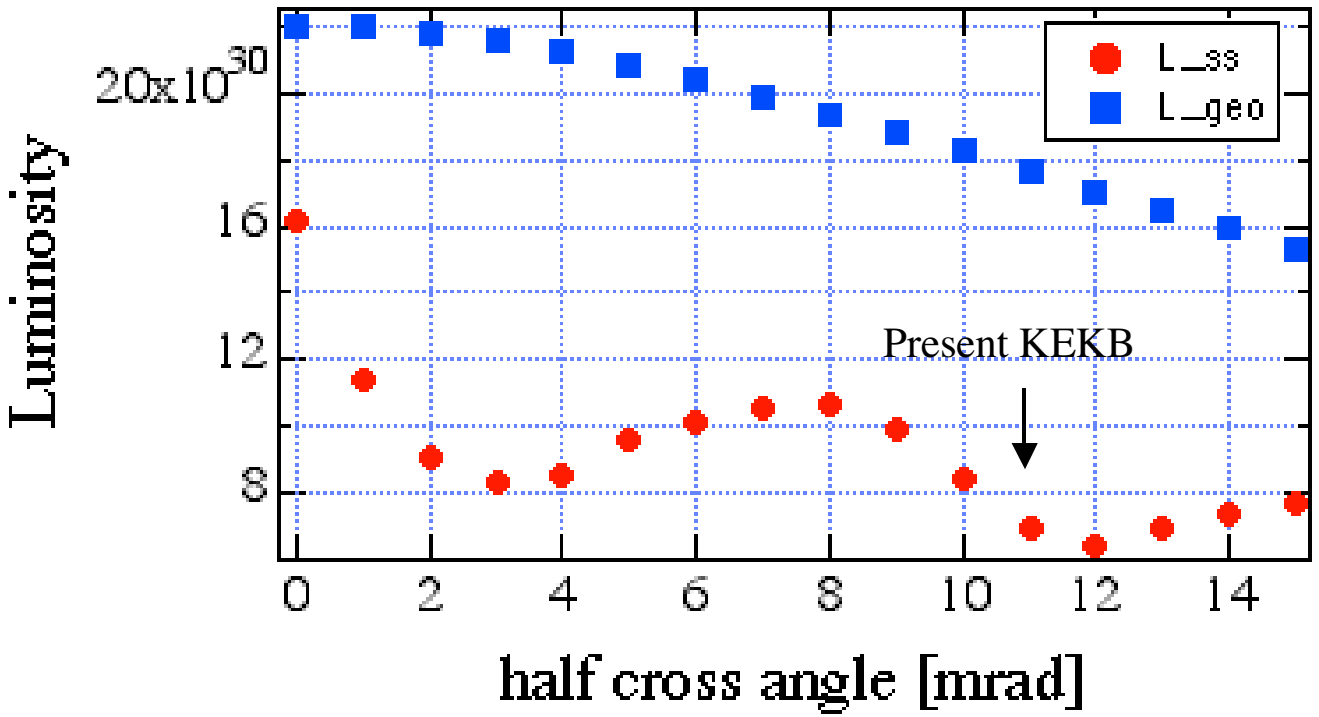


Crab cavity

- Beam-Beam simulation by using Ohmi's code (Tawada)
  - Luminosity will be doubled with the present machine parameters, if the crossing angle becomes zero.
    -> ξ_y^* ~0.1
- Beam test of crab cavity system
  - Present Plan: 1 cavity at Nikko section in HER (2005 or 2006)
  - My opinion: 1 cavity at Nikko section in both rings (2005 or 2006)

Effect of crab cavity system (simulation by Tawada)

Crab_03Jan



Summary [1/3]

- An introduction of the crab cavity system is the most promising way of raising the luminosity, if the simulation is correct.
  - We should introduce it in both rings.
- Increasing the HER beam current is effective for a higher luminosity.
- Increasing the LER beam current might be effective for a higher luminosity. -> We need more study.
- To mitigate HOM related problems, it is desirable to increase the number of bunches by reducing bunch spacing. -> bunch spacing problem?

Summary [2/3]

- There is an indication that ECI has some effects on the machine performance even below the threshold of the single beam blowup .
  - We maybe need more solenoids.
- The next target of beam currents are:
  - HER: 1.1A, LER:2A.
- The present beam current limitation comes from the issue on the IP beam pipe.
  - Study on this problem is one of the most important issues at the present KEKB.

Summary [3/3]

- There is some (maybe small) room to get a higher luminosity by shortening bunch length and/or squeezing β_y^* further.