Ring commissioning

2015.2.24

SuperKEKB Review

Y. Funakoshi for the SuperKEKB commissioning group and IP orbit FB group

Injection time (question by F. Zimmerman to Kamitani-san)

- Injection time
  - Linac beam charge: 1nC
  - Repetition rate: 50Hz
  - To accumulate 1A, it takes about 5 min.
  - In Kamitani-san's talk, he mentioned e+ charge of 0.66nC/bunch at the end of Linac. In this case, it takes about 2.5 min. to store 1A in phase 1.
- Actual injection time depends on the injection efficiency and the beam lifetime.
- At KEKB, a typical injection time for storing the operation beam current (~1.0A e-, ~1.6A e+) was ~30min at 50Hz (sum of e- and e+ injection).

Beam lifetime

	KEKB (design)		KEKB (operation)		SuperKEKB Design	
	LER	HER	LER	HER	LER	HER
Radiative Bhabha	21.3h	9.0h	6.6h	4.5h	28min.	20min.
Beam-gas	45h[a)]	45h[a)]			24.5min.[b)]	46min. [b)]
Touschek	10h	-			10min.	10min.
Total	5.9h	7.4h	~133min.	~200min.	6min.	6min.
Beam current	2.6A	1.1A	1.6A	1.1A	3.6A	2.6A
Loss Rate	0.12mA/s	0.04mA/s	0.23mA/s	0.11mA/s	10mA/s	7.2mA/s

4nC@25Hz 2.9nC@25Hz

a) Bremsstrahlung
b) Coulomb scattering, sensitive to collimator setting

As for loss rate, beam loss accompanied with the beam injection should be added.

Contents

- Update of commissioning scenario
- Operation tools
- Update of dithering system for beam collision
- Collaboration with other laboratories

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Update of commissioning scenario

- Time of commissioning
  - Phase 1: start from Jan.-Mar. 2016
  - Damping ring commissioning: start before phase 2
  - Phase 2: start from spring 2017?
- Period of commissioning
  - Damping ring commissioning
    - 3 weeks (old estimation) -> ~3 months (recent more realistic estimation)
- More precise consideration of each step
  - Beast study
    - Emittance control bump system will be required sometime in phase 1.
    - We have discussing with Belle II group on the slow control system.
      - Which kinds of information are needed on both sides as the EPICS records.
        - » How fast? and Time preciseness of the data?
    - Belle II people wanted to know the history of vacuum pressure change from the beginning of KEKB commissioning.
    - Required machine time for Beast: ~ 1 week (phase 1), ~2 weeks (phase 2)

SuperKEKB Commissioning Meeting
2011.11.08 *Kikuchi, M.*

DR Commissioning

- LTR commissioning 2 days
- BPM commission
- First turn 1 day
- COD meas. and correction 2 day
- BPM commission
- Optics meas. 2 days
- RTL commissioning 2 days
- Injection to LER
- 25 Hz operation
- SR commission
- Vacuum scrubbing ~14 days

~ 9 days

~ 3 weeks

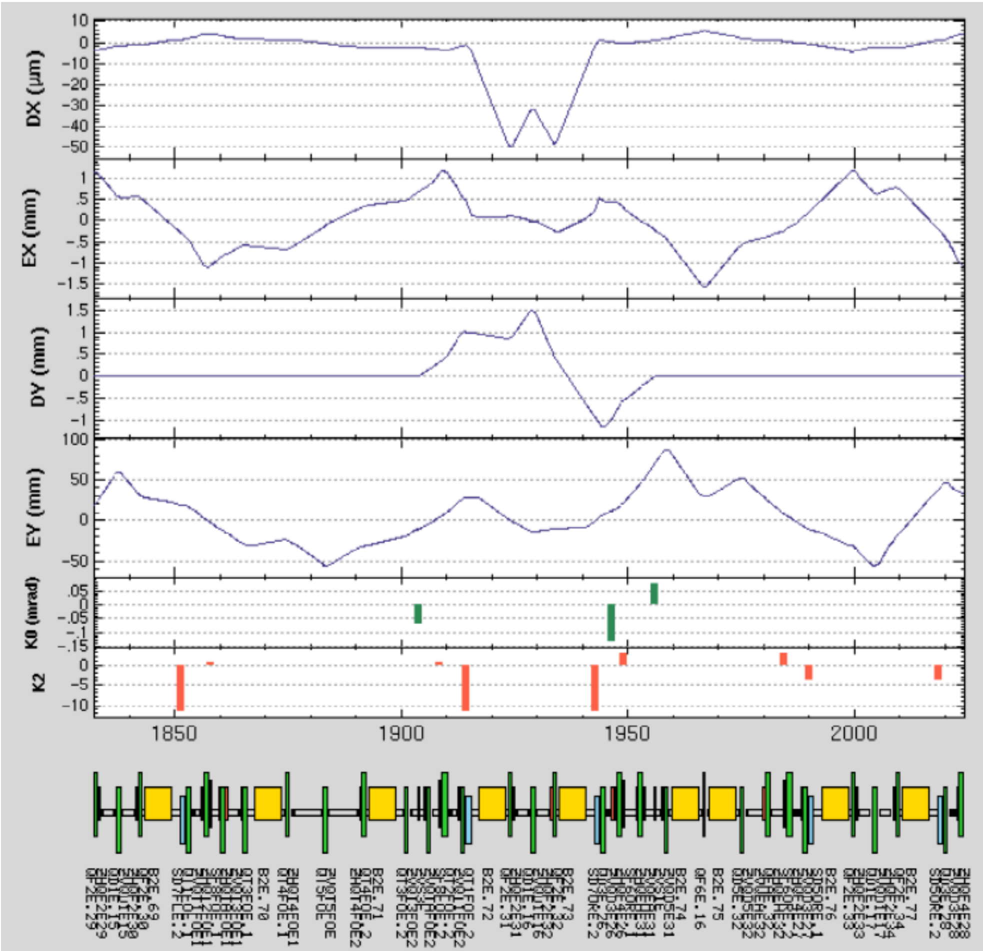
by wishful thinking

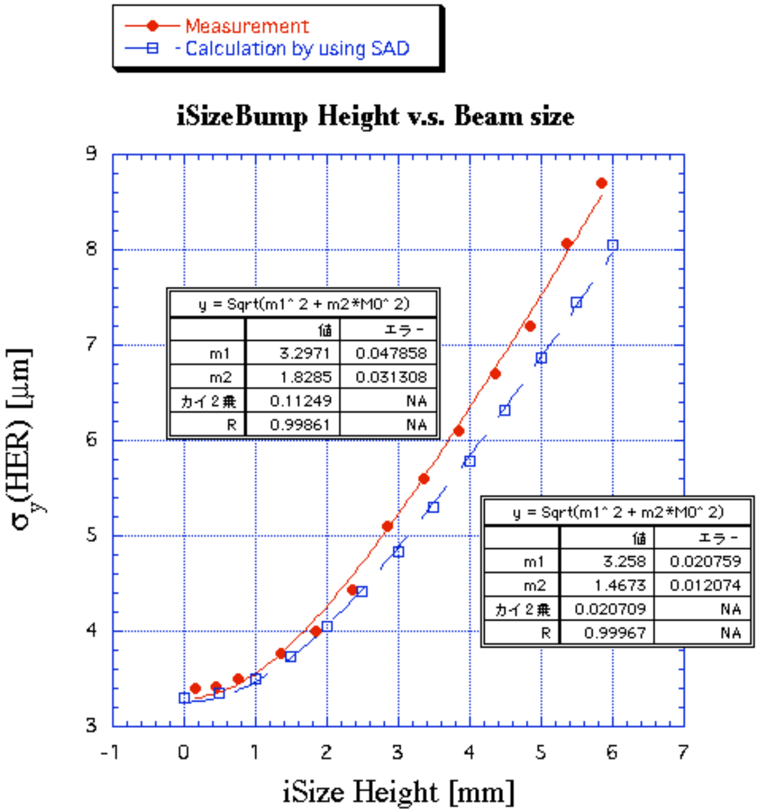
M. Kikuchi

Commissioning phase 1 (updated) (~5 months)

- Machine condition
  - No QCS, No solenoid (no Belle II), No beam collision
- Tuning items (We assume ~1A beam current)
  - Linac tuning (if necessary)
  - Basic commissioning of machine (~ 1.5 month)
    - Injection tuning, Hardware check and bug fix, software bug fix
  - Vacuum scrubbing (>~3 months) <- important goal of Phase1
    - Belle II people request enough vacuum scrubbing in this stage (before Belle II roll-in). At least one month with beam currents of 0.5 ~ 1 A.
  - Detector beam background
    - Study with Beast detectors, check of collimator system (two new-type collimators in LER)
      - For beam background machine study, emittance control bump system should be ready to be used sometime in phase 1.
  - Some optics tuning
    - With day-1 optics
    - Low emittance tuning w/o Belle-II solenoid
  - Study of beam instability (FII, e-cloud, TMC)
    - Tuning on bunch-by-bunch feedback

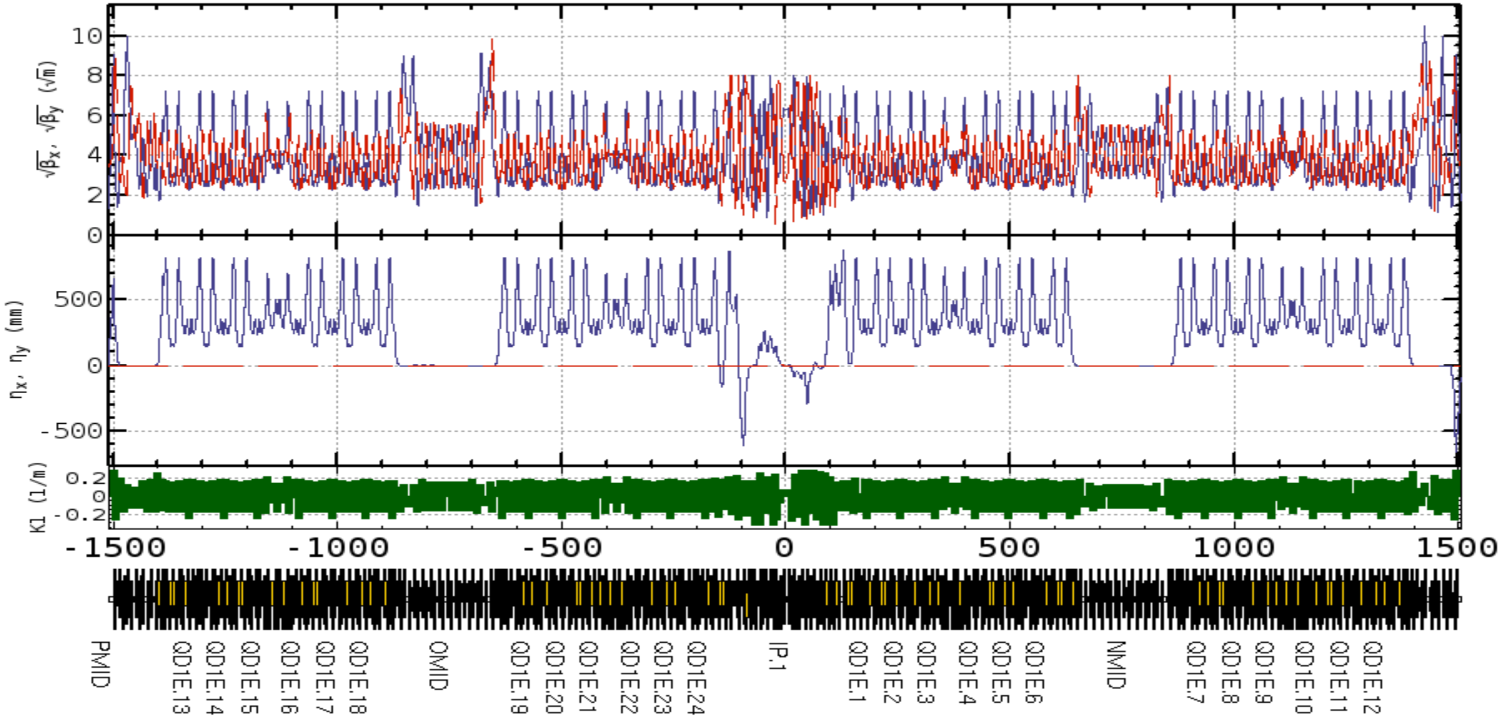
Emittance control bump system at KEKB HER (iSize bump system)

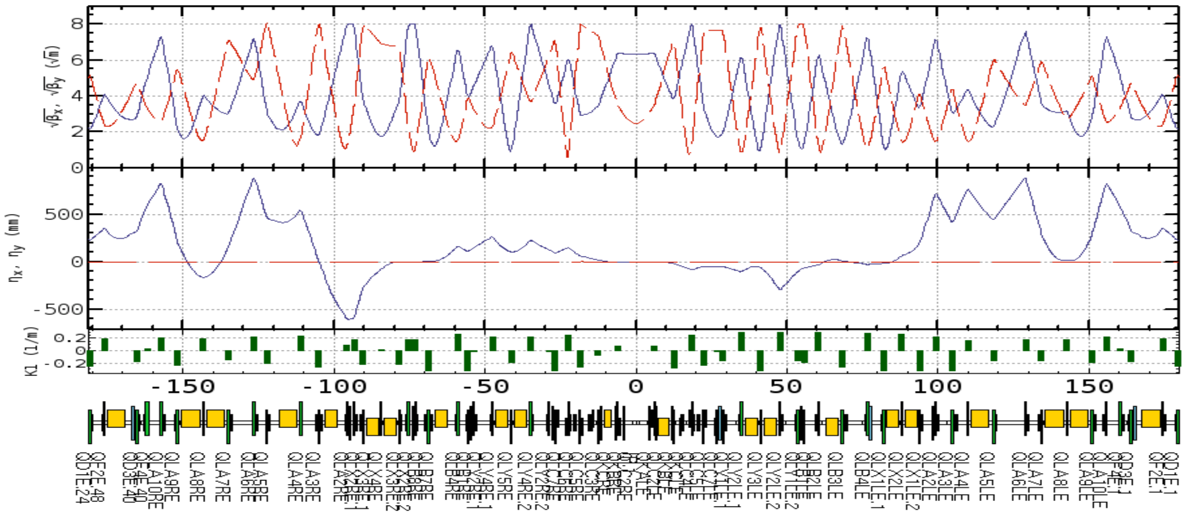




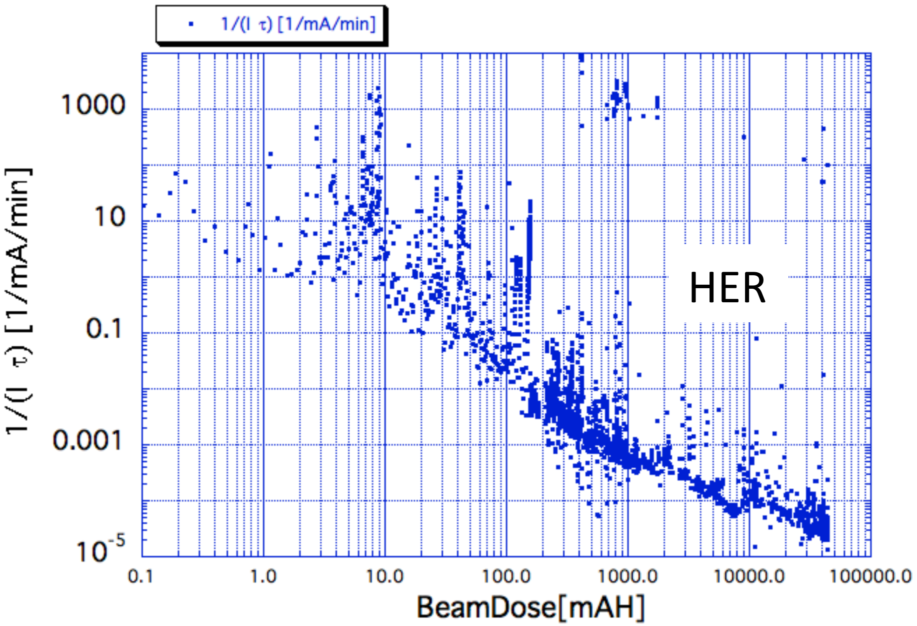
We need to reconfigure the emittance control bump systems for both ring to be used sometime in phase 1.

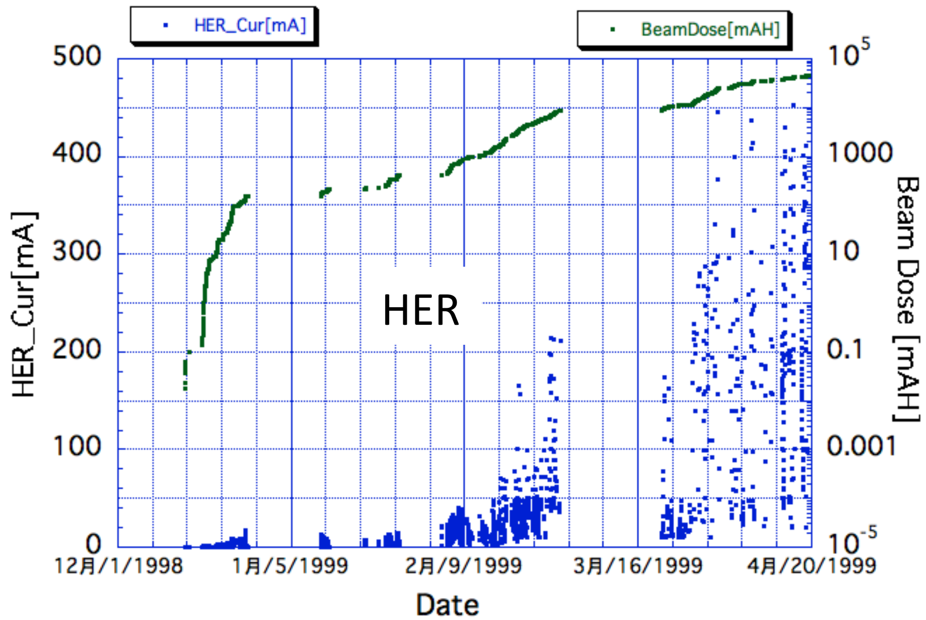
Phase 1 optics (HER)

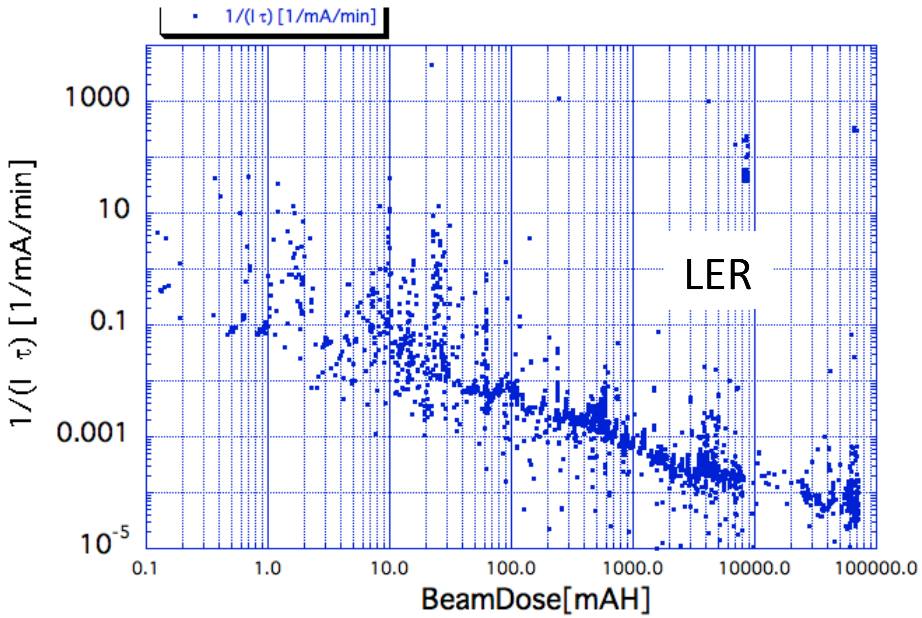


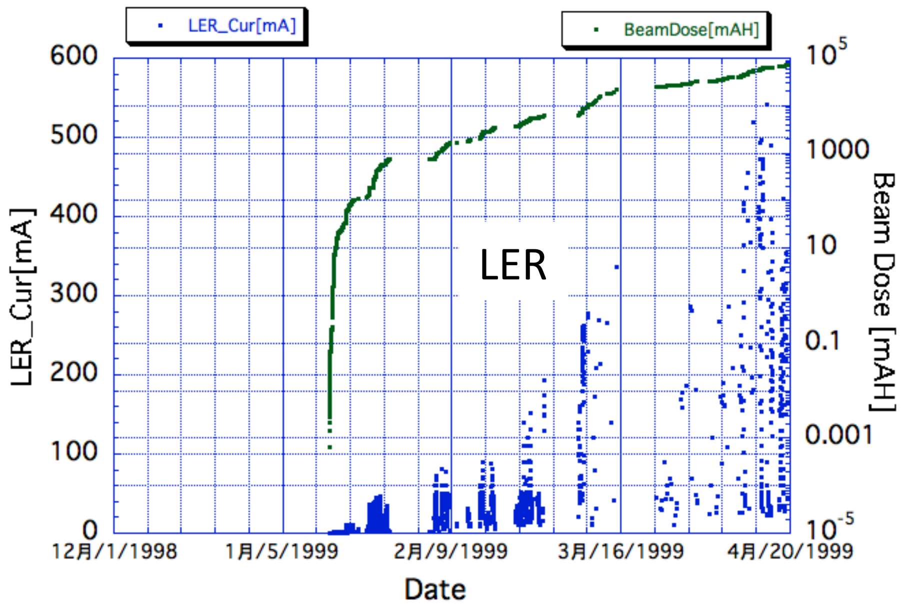


Vacuum scrubbing at KEKB (HER/LER)



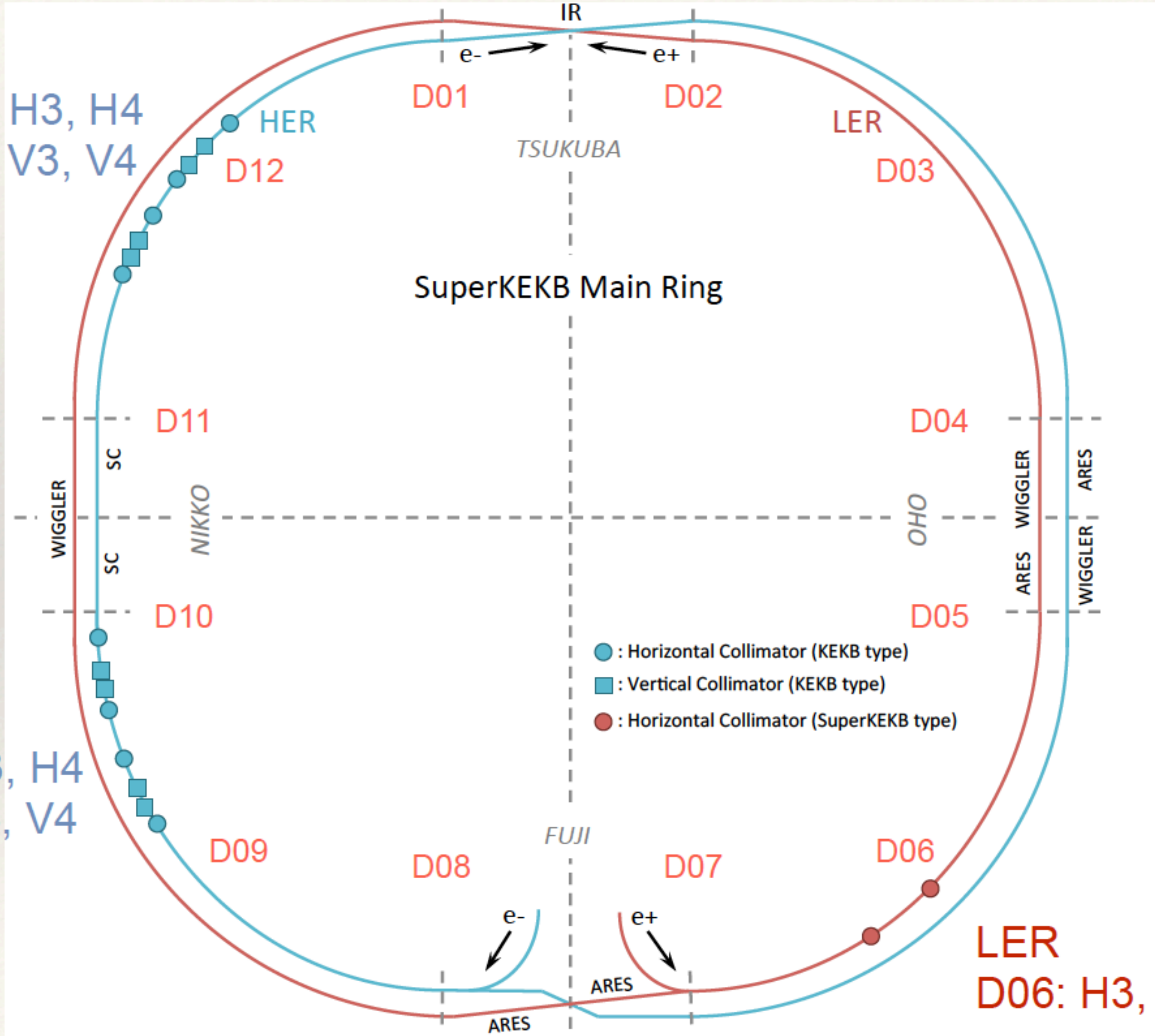






Collimators Location (Phase-I)

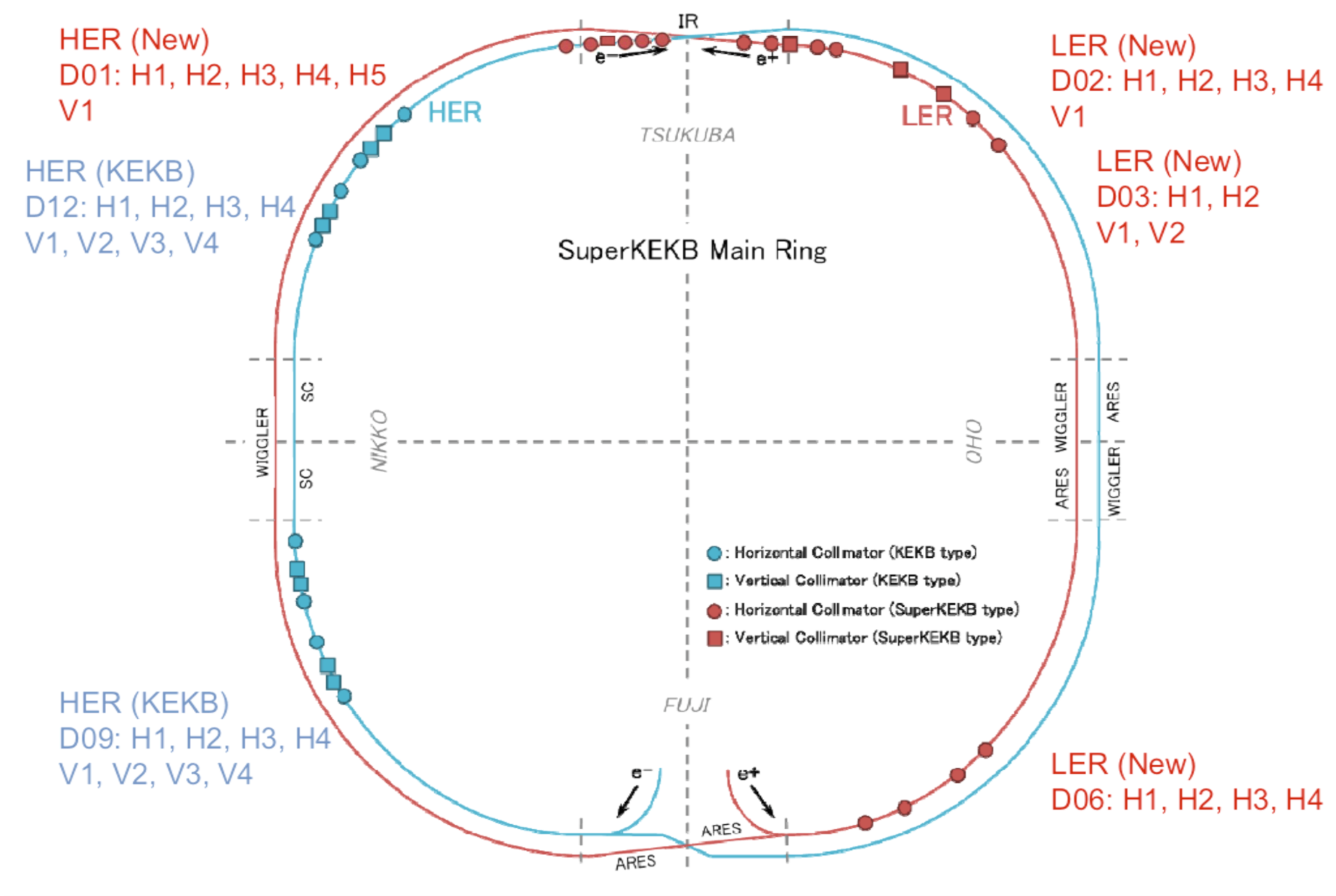
HER
D12: H1, H2, H3, H4
V1, V2, V3, V4



HER
D09: H1, H2, H3, H4
V1, V2, V3, V4

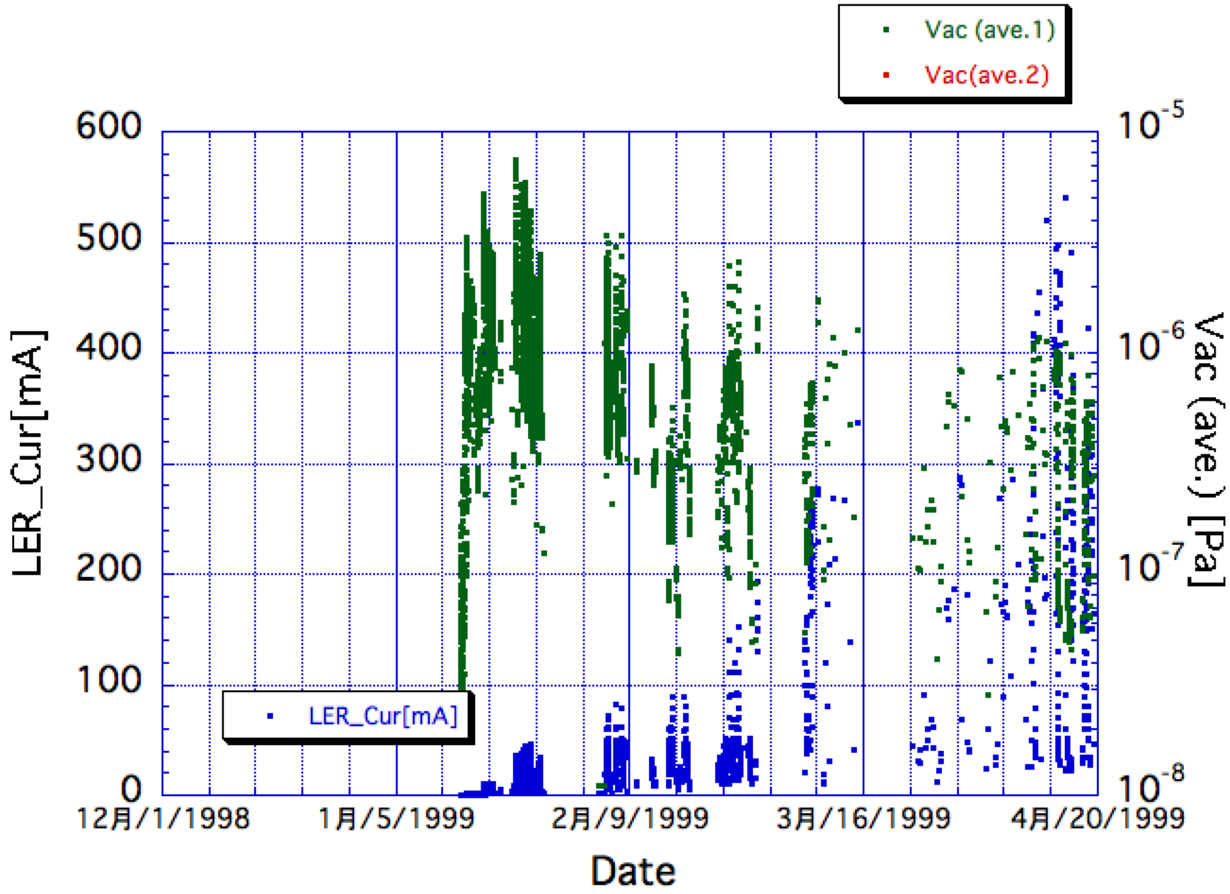
LER
D06: H3, H4

Collimators location (phase 2)



Suetsugu

Vacuum pressure (LER)
KEKB commissioning phase



Commissioning phase 2 (~5 months)

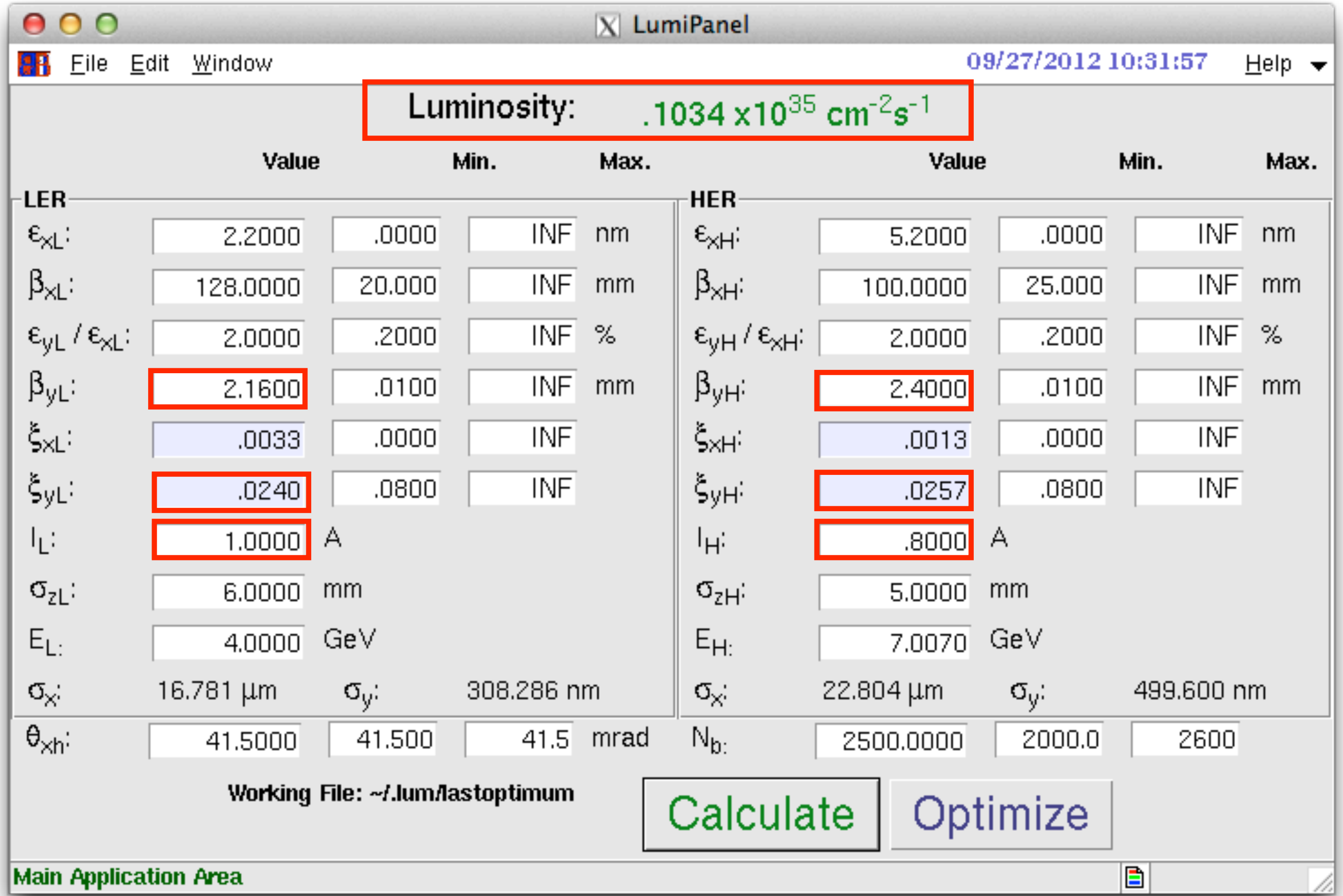
- Machine condition
  - w/ QCS, w/ Belle II (w/o VXD),TOP detectors partially installed, full accelerator tuning, no physics experiment
- Tuning items
  - Optics tuning
    - Tentative target values of IP beta's: β_x^*: x4, β_y^*: x8
    - Optics tuning with QCS and Belle II solenoid
    - Low emittance tuning w/ Belle II solenoid
    - Optics tuning w/ beam collision
  - Detector beam background
    - Study with Belle II detector, test of continuous injection (BEAST)
  - Increase of beam currents (instability, RF power, vacuum issues)
    - Detector background may possibly give some restriction.
    - Continue upgrade for RF system (support ~70% of design beam currents)
  - Beam collision tuning
    - Orbit feedback (fast feedback, dithering system)
    - Collision tuning w/ "Nano-Beam" scheme
  - Luminosity tuning
    - Tuning knobs (x-y coupling at IP etc.)
    - Target luminosity: 1 x 10^{34} cm^{-2} s^{-1} (design of KEKB)

Luminosity prospect in phase 2

- Three parameters to determine the luminosity
  - Beam currents
    - RF system can support 70% of design currents.
    - We experienced many troubles to increase the beam currents at KEKB.
  - Beam-beam parameters
    - Our experience is that the beam-beam parameters were increased very slowly by the many trial-and-errors most of which were unsuccessful.
    - "Nano-beam scheme" is a new scheme. Maybe we will need a lots of trial-and-errors before we find effective tuning methods with this scheme.
  - IP beta functions
    - There is big uncertainty as to how low values of IP beta functions in phase 2.
    - I think that we have to make many efforts to squeeze the beta functions by making optics corrections (not easy task).
    - We may need hard time of many years until we approach the design IP beta functions.
- The target luminosity in phase 2 is $1x10^{34}$ $cm^{-2}s^{-1}$.
  - There is big uncertainty whether we can achieve this luminosity.
  - My feeling is that exceeding the KEKB record luminosity (2.1 $x10^{34}$ $cm^{-2}s^{-1}$) in phase 2 is very difficult, although it is worthwhile to challenge of course.

Detuned Optics (4x8)

Example of machine parameters for 10^{34} $cm^{-2}s^{-1}$



β_x^*: x4, β_y^*: x8, x-y coupling =2 %, $\xi_y \sim 0.025$, I_{LER} = 1 A.

To do list for commissioning scenario

- More concrete plan of each step
  - We have started discussion also for damping ring
  - Procedures of optics corrections in main ring and other tools related to the beam optics
  - Belle II and Beast related issues
    - Tools for collimator control
- Operation energy in phase 2
- Requirement to Belle II in phase 2
- Beam operation mode from the viewpoint of radiation safety
- others…

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- Update of commissioning scenario
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Operation tools

- Commissioning group asked control group to develop operation tools
  - Alarm system
    - At KEKB, a member of commissioning group (K. Oide) developed the system.
  - Injection control system
  - Data logging system
    - KBLog system (upgrade the system used at KEKB)
    - CSS archiver system (backup)
  - Task launcher
    - SAD based system (KEKB) -> CSS based system (SuperKEKB)

New Alarm system for SuperKEKB

- In KEKB, we used SAD-based alarm system.
- In SuperKEKB, we are going to construct the CSS-based alarm system.

CSS-based Alarm System

Used at PF-AR from 2011 fall. ← operated with no problem so far
Recently installed at Linac.
(J-PARC is also considering to install the system.)

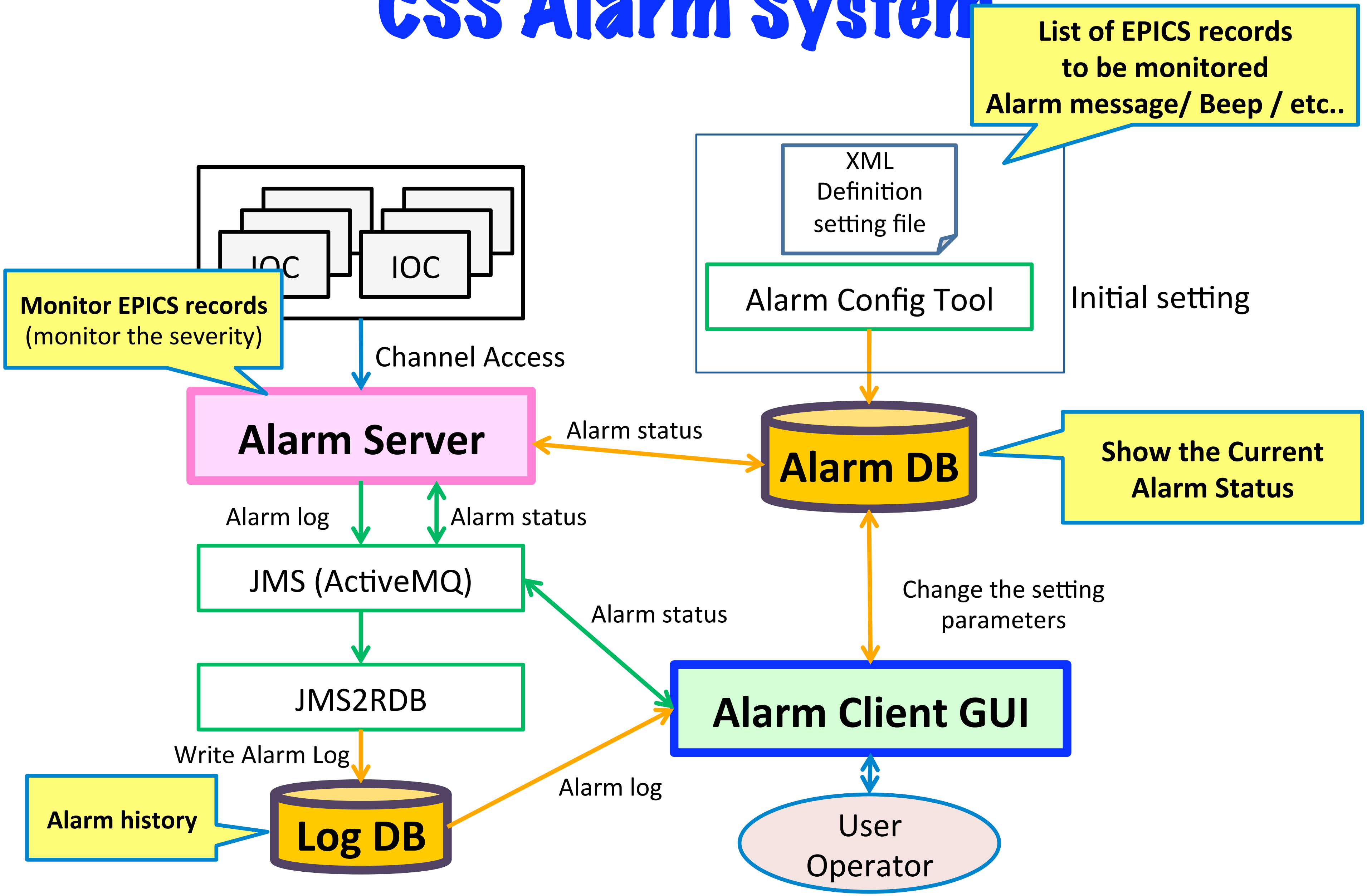
To apply the CSS-based alarm system to SuperKEKB

1） We must make sure that It stably operates under the several 10 thousands alarm data points. (~25,000 in KEKB)
→ We did load tests.

2） We must develop the software tools to meet our accelerator operation system.

M. Iwasaki

CSS Alarm System



M. Iwasaki

Test of the CSS Alarm System

- By generating 50,000 test records, we did CSS alarm system load test.
  → Our Alarm system can stably operates.
- We also measured the start up time of the system.

Initial setting

Alarm Config Tool → Software IOC (50,000 record) → Alarm Server / JMS2RDB → Alarm Client GUI

10-15minutes

Directly edit RDB
7minutes

2.5 minutes

20-30 seconds

20-30 seconds

~~**Total 13.5 to 18.5 minutes**~~
8-10 minutes if we directly edit RDB

Without the initial parameter setting

Software IOC (50,000 records) → Alarm Server / JMS2RDB → Alarm Client GUI

2.5 minutes

20-30 seconds

20-30 seconds

Total

→ To change the alarm configuration during the operation, it takes 3-4 minutes.

Plan: We develop 1) the software IOC to take care of the records which cannot be directly monitored , and 2) user interface tools.

Takuya Nakamura (Mitsubishi Electric SC) and K. Asano (KIS)

M. Iwasaki

Contents

- Update of commissioning scenario
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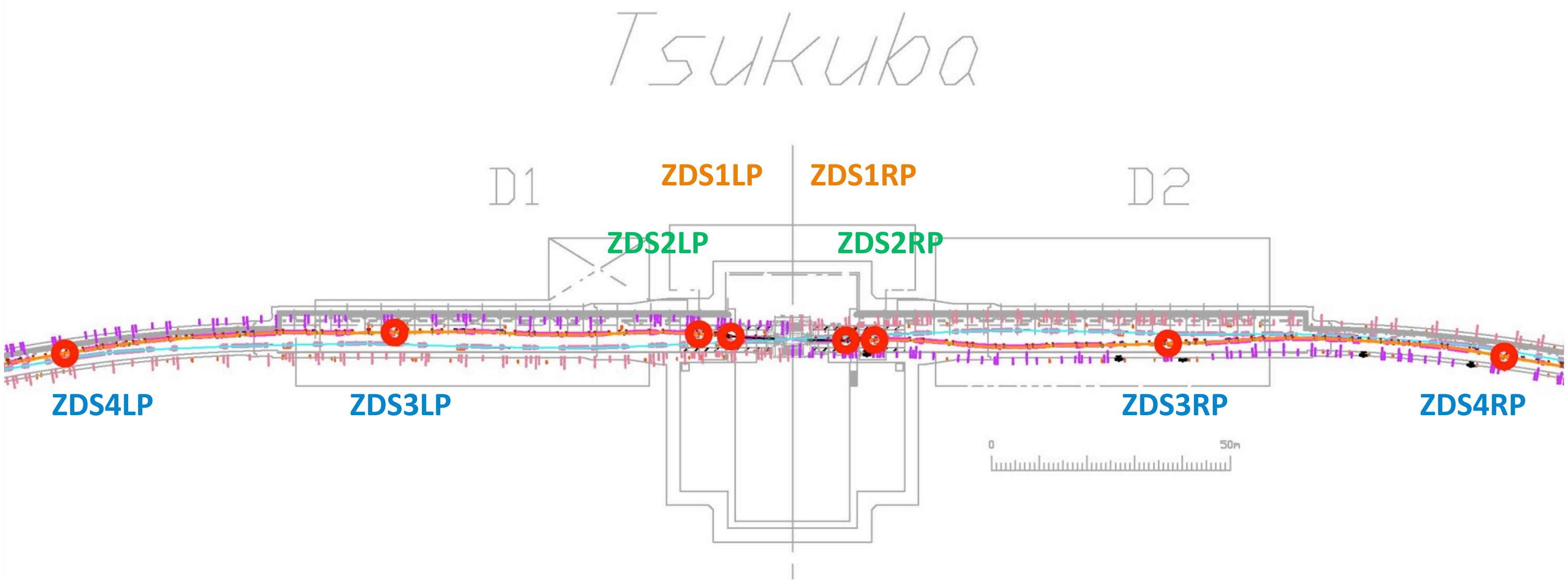
Update of dithering system for beam collision

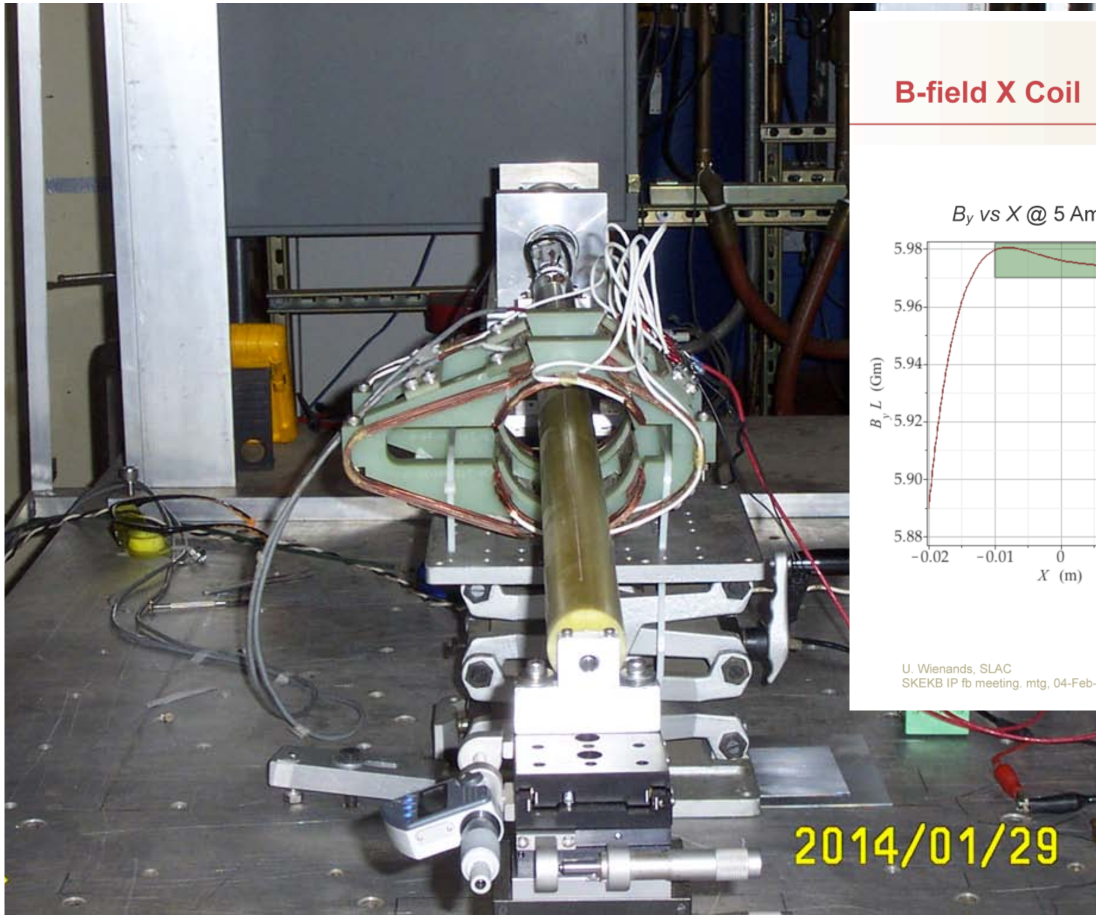
- Orbit feedback system at IP
  - Vertical direction: system based on beam-beam deflection (observables: BPM orbit measurement)
  - Horizontal direction: dithering system (observables: luminosity)
    - For redundancy, dithering of IP vertical offset and angle can be done.
- System layout
  - We will start with an analog system, which is a copy of PEP-II system, due to a lack of human resources. We will upgrade to a digital system, if necessary.
  - Components
    - Fast luminosity monitor, lock-in amps, coils for dithering, dither circuits (drive amps, amplitude and phase adjustment), actuators (slow bump systems which is commonly used for fast vertical feedback), control system (actual feedback algorithm which will be run in an IOC), Power supplies
- Collaborations
  - SLAC
    - Fabrications of dither coils (2013) and dither circuits (2014)
    - Simulations (U. Wienands)
  - LAL-Orsay
    - Fast luminosity monitor

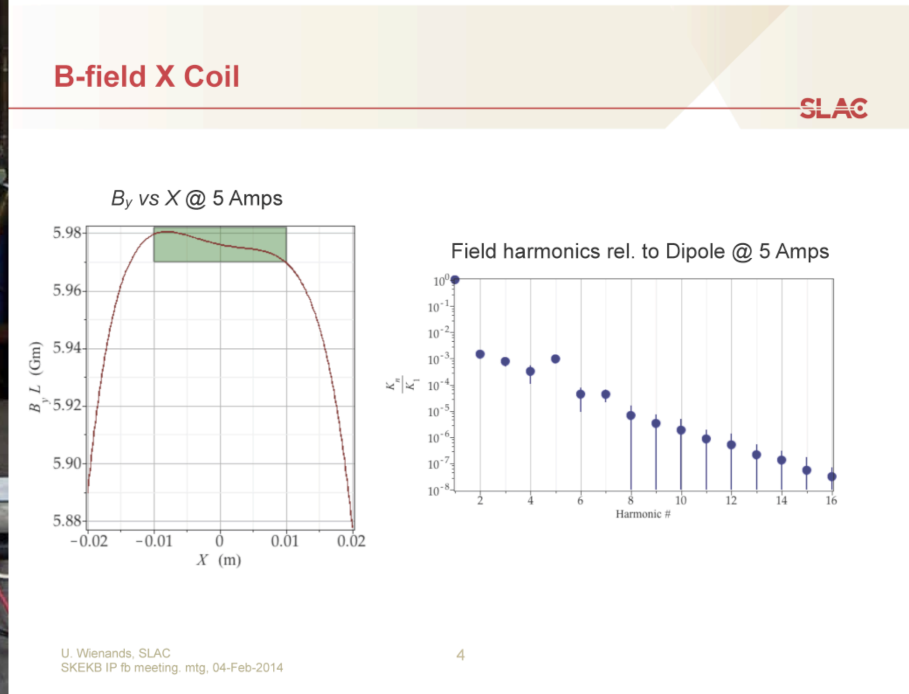
Locations for the dithering coils

8 locations for the dithering coils in LER around IP.



Dither coils: Fabrication and field measurement



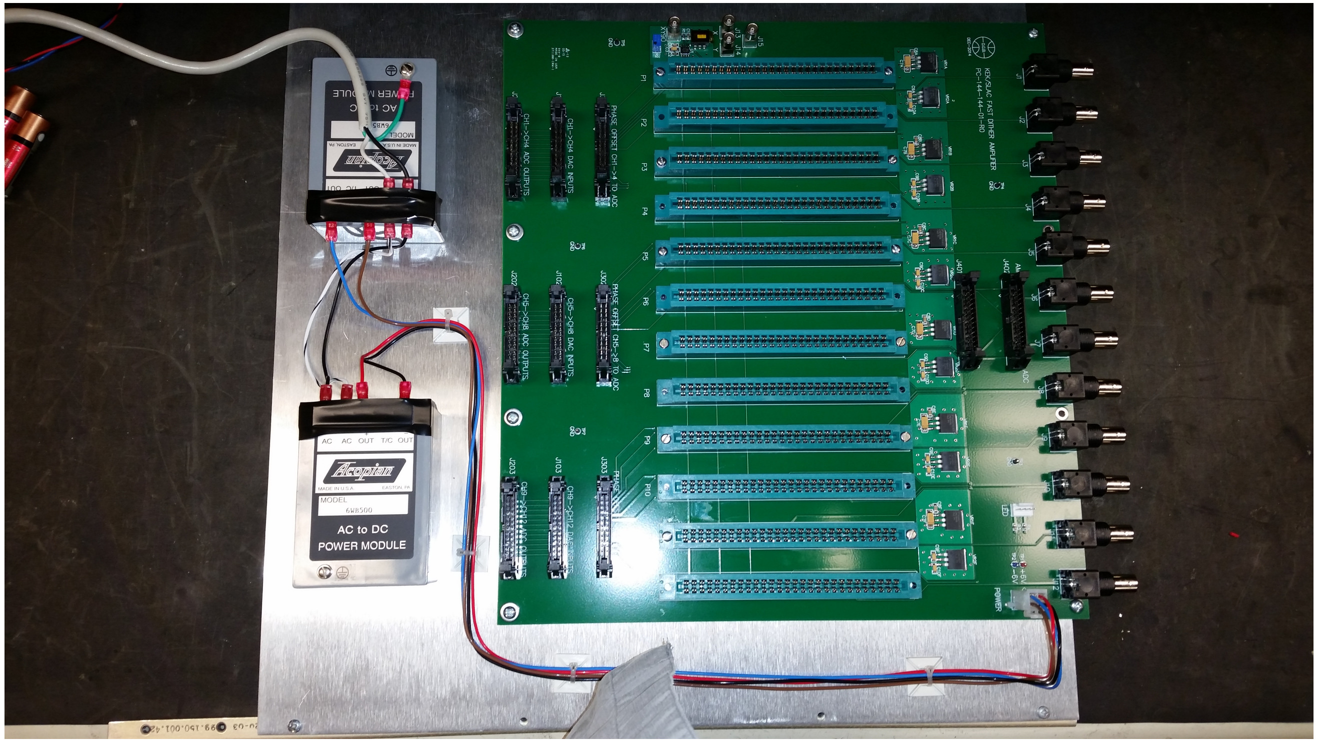


Fabrication and measurement were done last year.
All sets of dither coils have been delivered to KEK and will be installed in LER ring in coming spring.

U. Wienands, S.D. Anderson, MFD Metrology, SLAC

Dither Circuit

- An amplifier board has been being fabricated at SLAC and will be completed within this fiscal year.



U. Wienands and D.Brown SLAC

Simulations on dithering system

- U. Wienands (SLAC) has been doing the simulations by modifying a code used for PEP-II.
- Input data for the simulations
  - Orbit dependence of the luminosity (K. Ohmi)
  - Information on accuracy of fast luminosity monitors (P. Bambade(LAL), S. Uehara(KEK))
  - QCS vibrations in the horizontal direction (H. Yamaoka)

Parameters for dither simulation

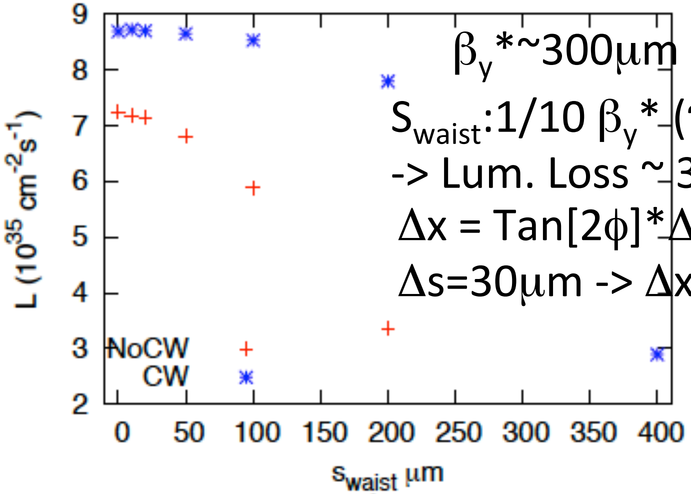
	initial		First milestone		Design	
Luminosity	1×10^{34} cm^{-2} s^{-1}		1×10^{35} cm^{-2} s^{-1}		8×10^{35} cm^{-2} s^{-1}	
	LER	HER	LER	HER	LER	HER
I_{beam} [A]	1.0	0.8	2.7	1.95	3.6	2.6
# of bunches	2500		2500		2500	
$\varepsilon_x/\varepsilon_y$ (nm/pm)	2.2/44	5.2/104	3.2/51.84	4.6/77.28	3.2/8.64	4.6/12.88
β_x^*/β_y^* (mm)	128/2.16	100/2.4	128/1.08	100/1.2	32/0.27	25/0.30
σ_x^*/σ_y^* (μm/nm)	16.8/308	22.8/500	20.2/237	21.4/305	10.1/48	10.7/59
$\sigma_{x\ \mathrm{eff}}^*$ (μm)	249	208	249	208	249	208
ξ_x/ξ_y	0.0033/0.024	0.0013/0.0257	0.0083/0.049	0.0052/0.046	0.0028/0.0881	0.0012/0.0807
Δx (lumi:20% drop)	~110μm		~55μm		~10μm	
Lumi. meas.	1kHz		1kHz		1kHz	
accuracy	$\sim 5 \times 10^{-3}$ (w/ radiator)		1.3×10^{-3}(w/o radiator)		$< 1 \times 10^{-3}$	

$$\sigma_{x\ \mathrm{eff}}^* = \sigma_z \sin\phi$$

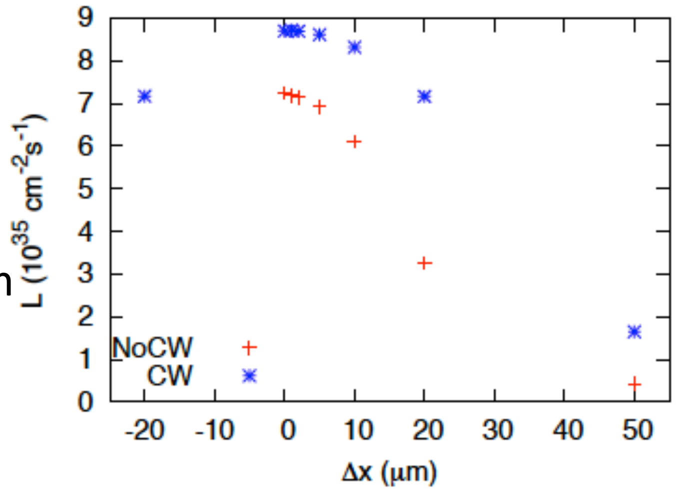
K. Ohmi

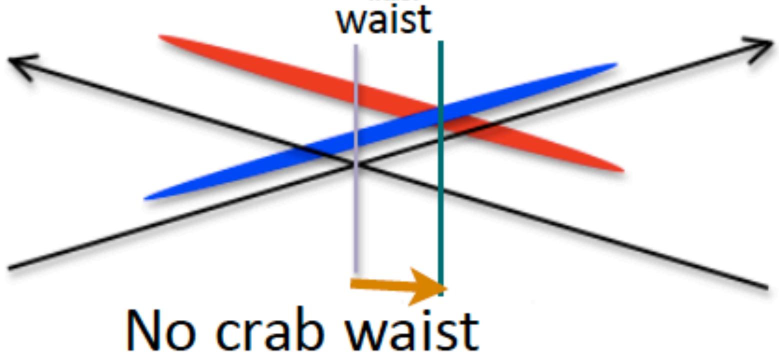
Tolerance of collision condition Horizontal collision offset and waist

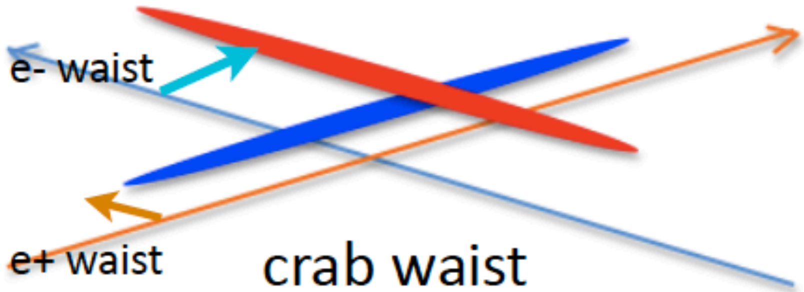
- Horizontal offset and waist are related to each other.
- The cross point of the waist is only one in x-z plane for the crab waist scheme.

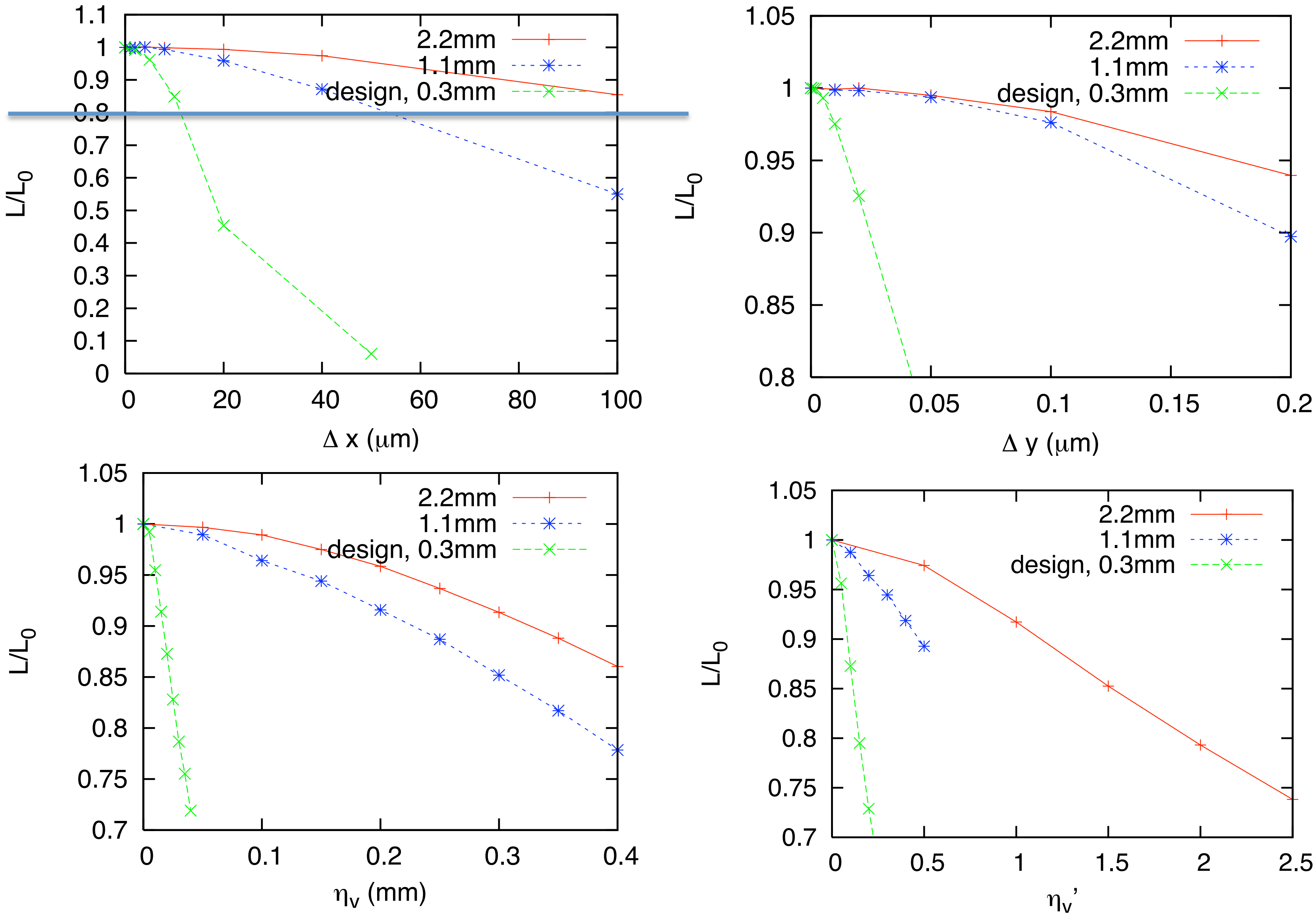


β_y*~300μm
S_{waist}:1/10 β_y* (~30μm)
-> Lum. Loss ~ 3.5%
$\Delta x = \mathrm{Tan}[2\phi]*\Delta s$
Δs=30μm -> Δx = =2.5μm

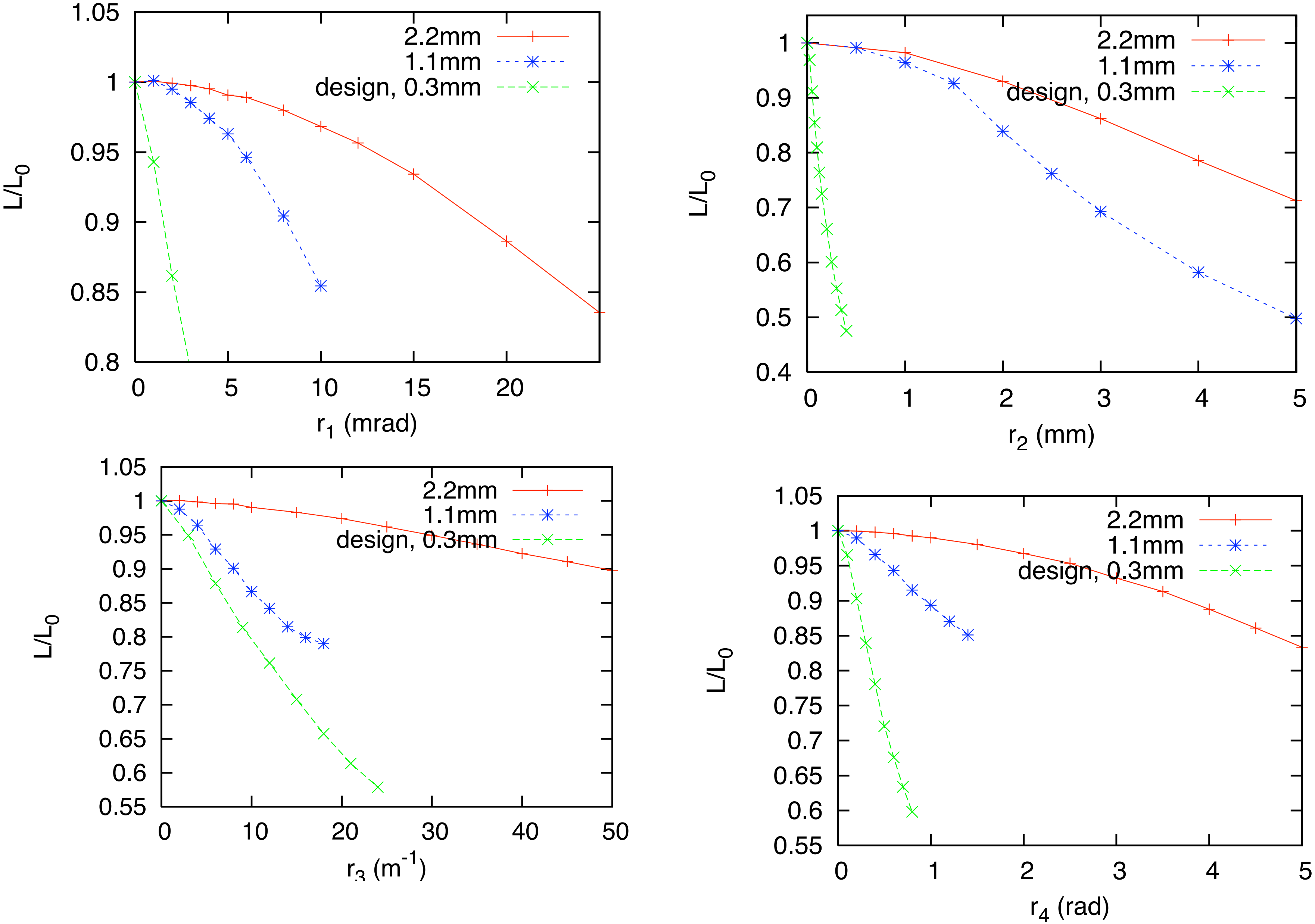








2.2mm
1.1mm
design, 0.3mm
L/L0
Δ x (μm)
Δ y (μm)
ηv (mm)
ηv'



2.2mm
1.1mm
design, 0.3mm
L/L0
r1 (mrad)
r2 (mm)
r3 (m-1)
r4 (rad)

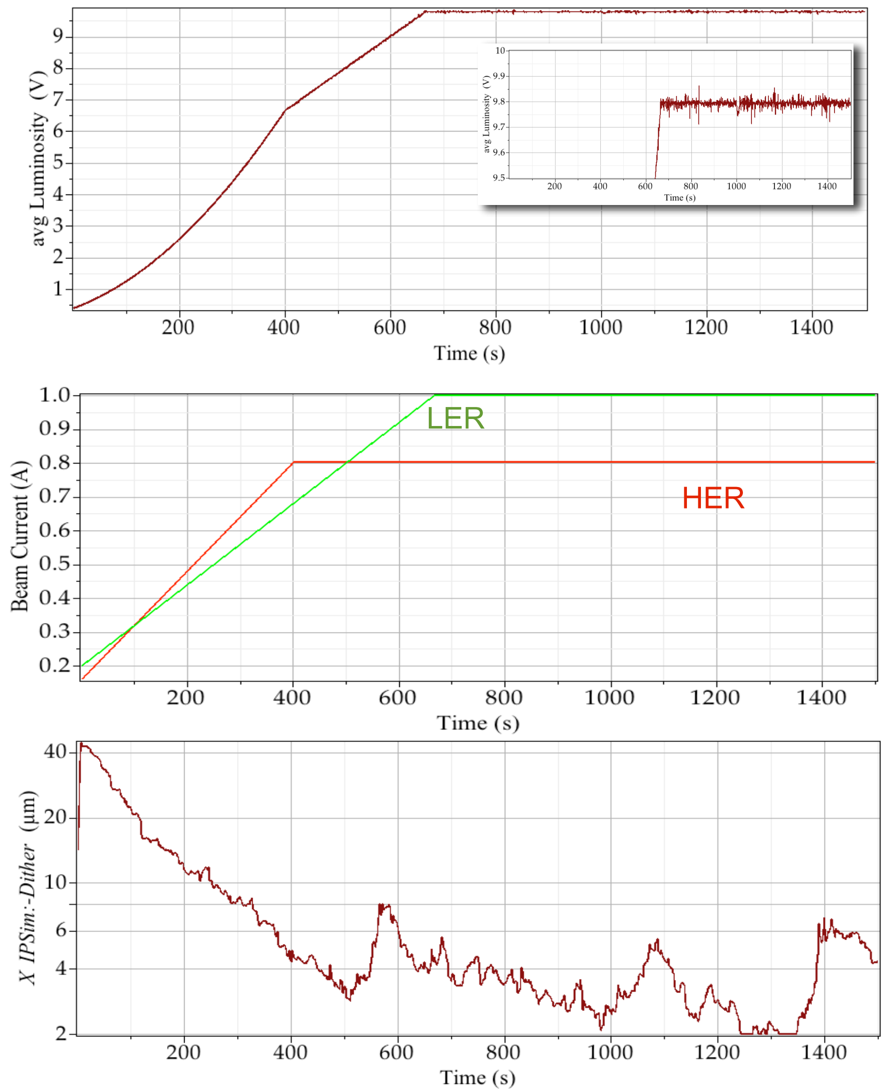
Fast Dither Feedback Algorithm

- ≈ 100-Hz excitation of small local orbit bump in LER
- Lock-in amps measure dL/dx; used to servo dc bump to keep beams centered (dL/dx ≈ 0). Integrating feedback.
- Simulator extends Gierman's IPSim03 code for PEP-II:
  - 6-d luminosity model for SuperKEKB
  - orbit vibrations from IR quads or similar (modal spectrum)
  - counting noise of luminosity monitor
  - adaptive servoing of key parameters (∑, dither, lock-in gain)
  - can dither in all planes (plan for X plane only so far)
- Many effects seen at PEP-II also seen in simulator
  - lock-ups, necessity to adjust dither sizes and lock-in gains
  - "harden" the algorithm against lock-up,
  - automatically adjust dither and lock-in gains.

U. Wienands

Typical IPSim Run

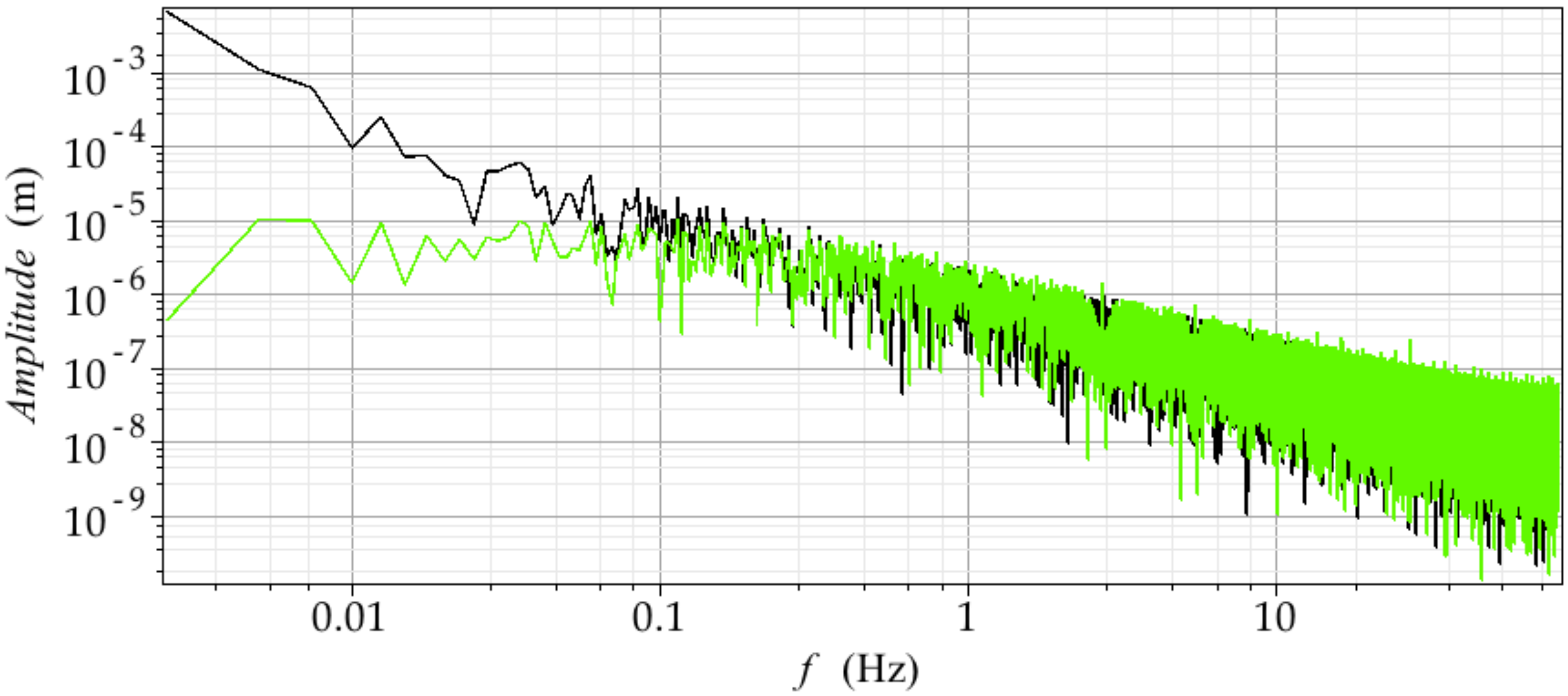
- Commissioning config $1 \times 10^{34}/cm^2/s$
- ≈ 25 min. real time
- 40 MHz lumon count rate @ $1 \times 10^{34}/cm^2/s$
- 1% “dither penalty”
- 1/3 sec cycle time
- X plane only



U. Wienands

Spectrum of orbit (black) and orbit difference (green)

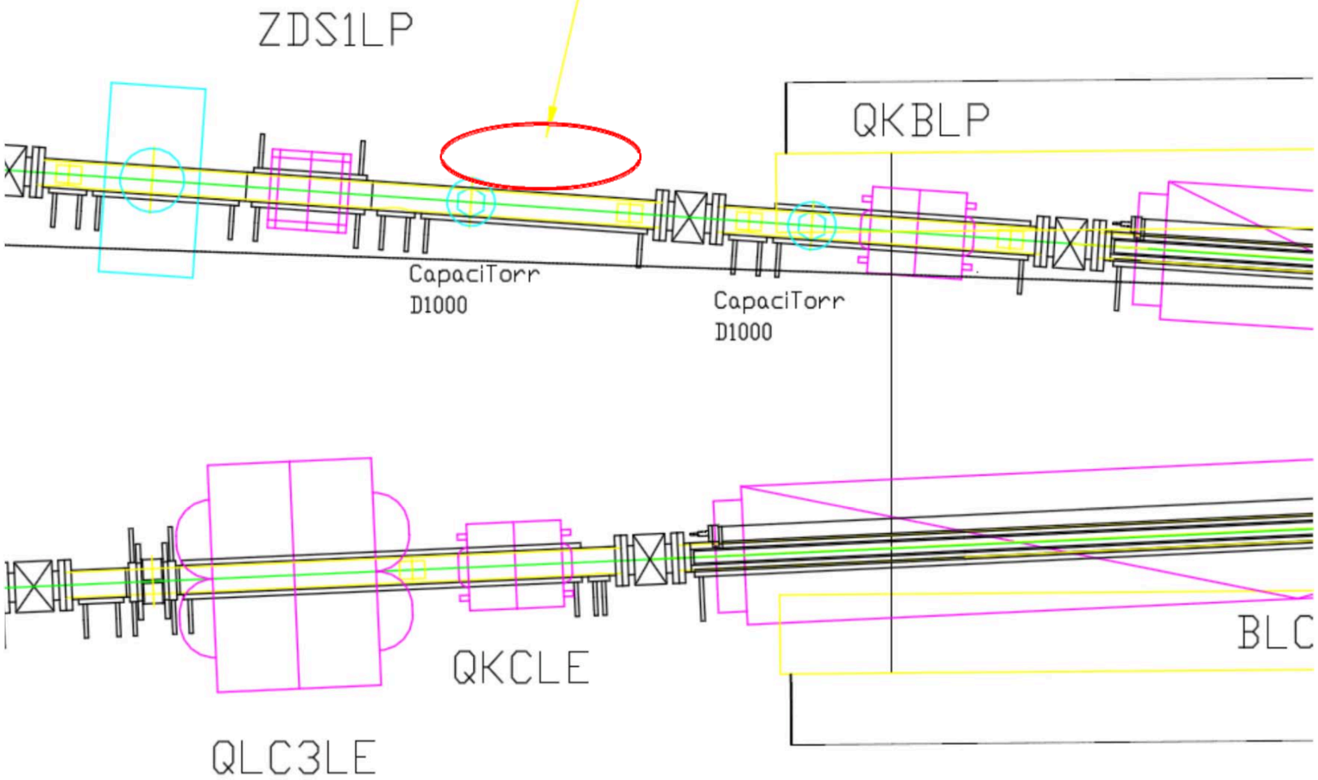
SLAC



U. Wienands

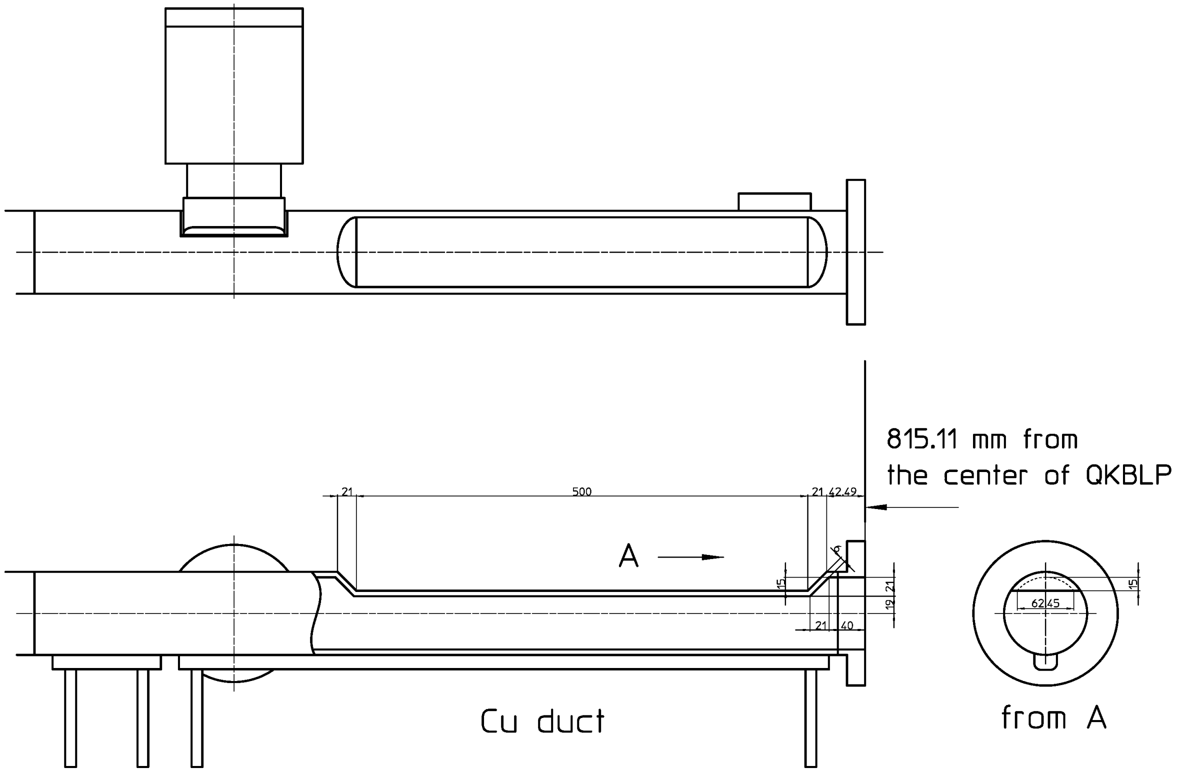
Location of fast luminosity monitor

12m downstream of IP
Monitor detects lost positrons



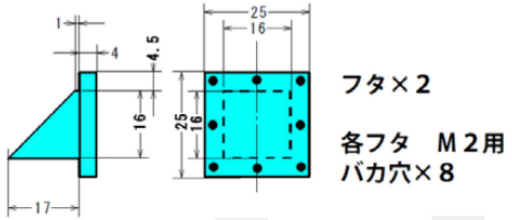
As a backup, another fast luminosity monitor will be installed in 28m downstream of HER, which detects photons from Radiative Bhabha scatterings.

Proposed vacuum chamber modification for fast luminosity monitor by LAL

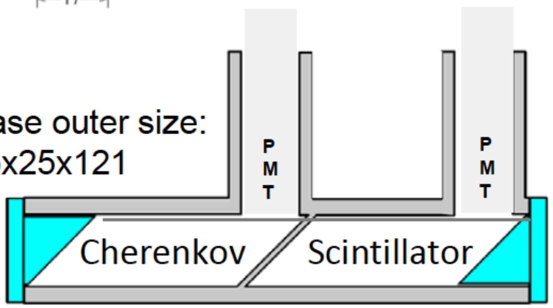


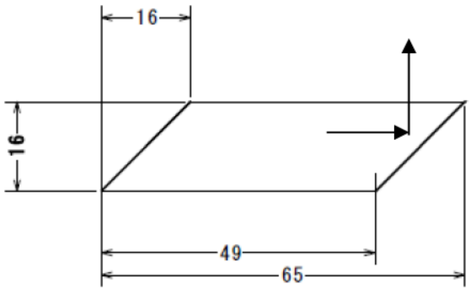
Kanazawa-san is considering the design for this chamber. Impedance issues have been studied by Shibata-san. The chamber is considered to install for phase 2 operation.

ZDLM for SuperKEKB of the counter type



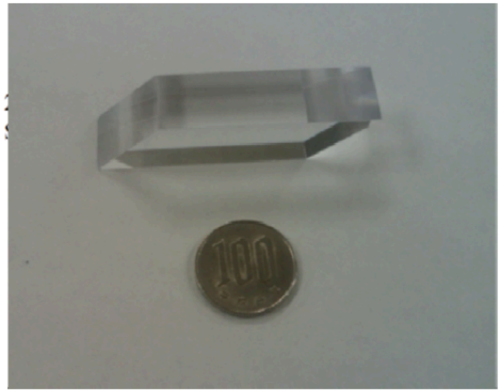
Case outer size:
25x25x121





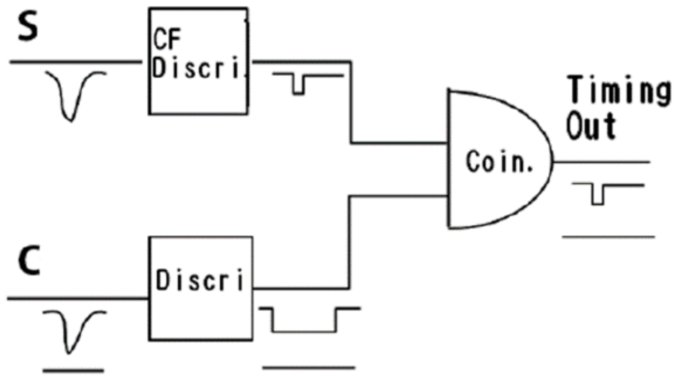
15x15x64(full length) cut with 45 deg at the two ends
Scintillator is covered by an Al-foil

Hamamatsu PMT H3165-11 (1/2”)
for each



LGSO non-organic scintillator
and ES-crystal (quartz)
Both no-color and fully transparent

Scintillator vs Cherenkov



Cf. Diamond sensor type (LAL)

Scintillator:

Larger pulse size

better photon-quanta statistics

safer even in a weak magnetic field degrading PMT

Cherenkov:

Not sensitive to low-energy photon backgrounds

rejection with the coincidence

Time resolution

Better at Cherenkov when its pulse size is large enough

Better at Scintillator when Cherenkov's pulse size is small

S. Uehara

Contents

Collaboration with other laboratories

- Japan/US Cooperation Program
  - Coordinator: M. Tobiyama
- TYL-FJPPL
- Others
  - Collaboration with NLF, IHEP, BINP…
- Very important for SuperKEKB

US-Japan collaboration

- **Collaboration with SLAC, FNAL, BNL, Cornell …**
  - Draws on deep experience base of US accelerator laboratories to solve these challenging problems.
  - Utilizes existing facilities and outstanding human resources of US laboratories to assist in constructing SuperKEKB accelerator components.
  - Develops and tests SuperKEKB components using working accelerators.

- **Both KEK and US laboratories have much to gain from collaboration.**
- **Achieve high luminosity faster!**

Project overview

- **Development and fabrication of accelerator components important to the construction and operation of the SuperKEKB accelerator**
  - Collaborate with SLAC to develop
    - IP collision feedback systems (4,500k JPY, to US 4,000k JPY)
    - Fast luminosity monitor
    - Beam collimators (7,500k JPY)
    - Beam background, Machine Detector Interface
    - Accelerator Physics
      - Main Ring commissioning
      - Damping Ring commissioning
      - Linac commissioning
    - BPM for Linac/BT
    - X-band deflecting cavity
    - Stripline kicker for high beam current
    - X-ray detector
    - Flux Concentrator to increase capture efficiency of positrons
    - Beam energy calibration using laser Compton scattering

M. Tobiyama

Project overview (cont)

- **R&D on accelerator technology important for the next generation of high luminosity colliders.**
  - Development of general purpose bunch-by-bunch feedback systems (KEK, SLAC) (3,000k JPY, to US 2,000k JPY)
  - Development of bunch-by-bunch X-ray beam size monitor using coded aperture mask (KEK, Univ. Hawaii, Cornell Univ., SLAC) (8,900k JPY, to US 8,900k JPY)
  - Development of Large Angle Beamstrahlung Monitor for collision monitoring (KEK, Wayne State U.) (1,100k JPY: to US 1,100k JPY)
  - Study of electron cloud instability and its cure (KEK, SLAC, LBNL, Cornell Univ., FNAL) (5,000k JPY)
  - Simulation of beam-beam interactions on various accelerators (KEK, SLAC, LBNL, Cornell Univ., FNAL) Total budget 30,000k JPY
  - R&D of injector components(KEK, SLAC) Travel 4,500k + 700k JPY
- **Supported by US-Japan Collaboration since FY2003**

Collaboration with LAL-Orsay

- Framework
  - Collaborative work in the framework of TYL-FJPPL (Toshiko Yuasa Laboratory, France Japan Particle Physics Laboratory)
    - LAL: P. Bambade, C. Rimbault, D. E. Khechen, D.Jehanno
    - KEK: S. Uehara, Y. Funakoshi, M. Iwasaki
  - Budget (300kYen(KEK), ~7000€(LAL) in FY 2014)
- Status
  - Fast luminosity monitor system based on diamond sensor has been being developed at LAL.
  - To determine the location of the monitor, beam loss simulations have been done using SAD and GEANT4.

SuperKEKB-LNF collaboration

- Proposal by the LNF scientists (December 2013)
  - 1) Feedbacks implementation (collaboration started already, Contact Person: Dr. Alessandro Drago),
  - 2) Optics studies, in particular the problem of the “crab waist” sextupoles (Contact Person: Dr. Maria Enrica Biagini),
  - 3) Lifetimes and backgrounds studies (Contact Person: Dr. Manuela Boscolo),
  - 4) Rings injection studies (Contact Person: Dr. Susanna Guiducci).
- Status
  - Things seem to have been delayed in Director General/Trustee-level communication between both labs.
  - We have received official endorsement from a Trustee (Okada-san) and have begun discussing and writing a rough draft of collaboration agreement.

7. Future plan

➤ **Detailed analysis of lattice nonlinearity under an international collaboration program**

- **Cornell Univ.: D. Sagan (Bmad+PTC)**
- **SLAC: Y. Cai**
- **IHEP: Y. Zhang**
- **KEK: E. Forest, A. Morita, K. Ohmi, Y. Ohnishi, K. Oide, H. Sugimoto, D. Zhou, etc.**

➤ **Collaboration with CEPC/FCC-ee teams**

➤ **High-priority tasks:**

- **Global or local correction schemes for latt. nonlin.**
- **SC compensation schemes**
- **Better understand beam-beam physics for nano-beam scheme**
- **More benchmark studies for SAD**
- **… …**

➤ **Recommendations are welcome!**

D. Zhou in this MAC

Remarks

- The collaborative works with other laboratories have been very helpful for the construction of SuperKEKB.
- The beam commissioning will start next year and the collaborations will be increasingly important, since SuperKEKB is very difficult machine for achieving the design performance.
- Recommendations from the committee members are very important as the past recommendations.

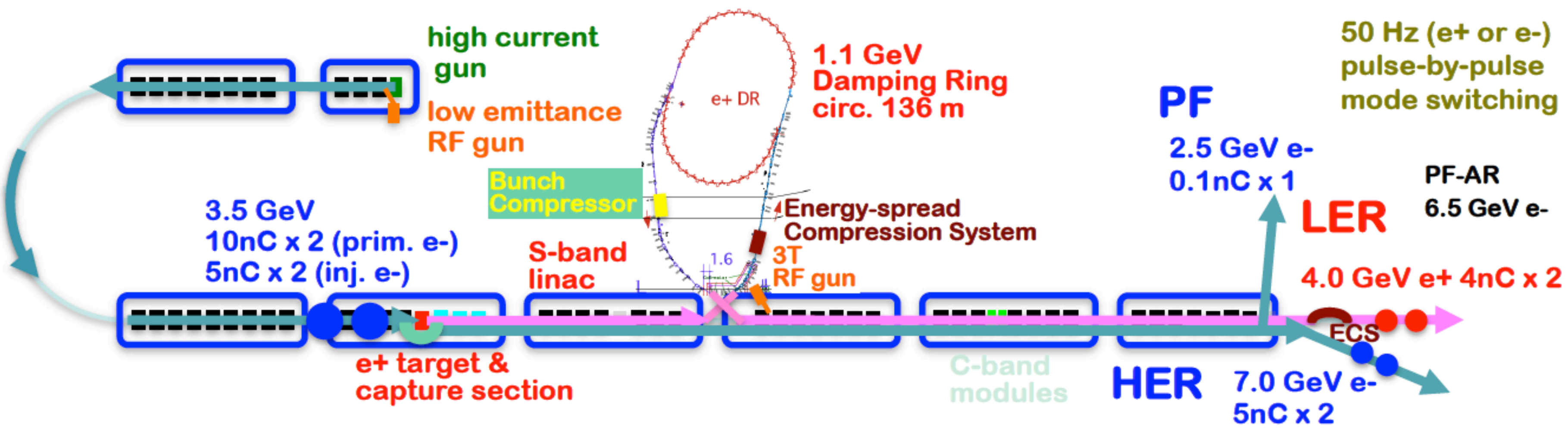
Congratulations on the 20th anniversary of the KEKB Accelerator Review Committee!!!

The KEKB accelerator members really appreciate your pertinent recommendations that we have got a lot of benefit from and the continuous encouragements and supports.

We wish to celebrate a great success of SuperKEKB in the 30th anniversary of the review committee!

backup slides

Linac



Positron capture section 920 kVA, 900 lit/min	Damping ring BT (LTR, RTL) 310 kVA	Switch yard (3SY) 300 kVA, 460 lit/min

- RF low-emittance gun for 5 nC
- Improve positron source for 4 nC
- Low-emittance transport
  - alignment error tolerance is 0.1 mm locally (0.3 mm global).
- Simultaneous and top-up injection (accompany PF and PF-AR)

SuperKEKB requirements (tentative)

	KEKB (e+/e-)	SuperKEKB (e+/e-)
Charge [nC]	1/1	4/5
Normalized emittance[μm]	2100/300	100/50 (H)
		20/20 (V)

09:50 **Injector commissioning and issues** *30'*
Speaker: Masanori Satoh (KEK)

K. Furukawa, M. Satoh, M. Yoshida, T. Kamitani