A_RD_08:
Collaboration on fast luminosity measurements and MDI questions for super B meson factories

S.Uehara(KEK)

FKPPL-TYL(FJPPL) Workshop,

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A_RD_08 Members

LAL/IN2P3, France:

Philip Bambade

Cécile Rimbault

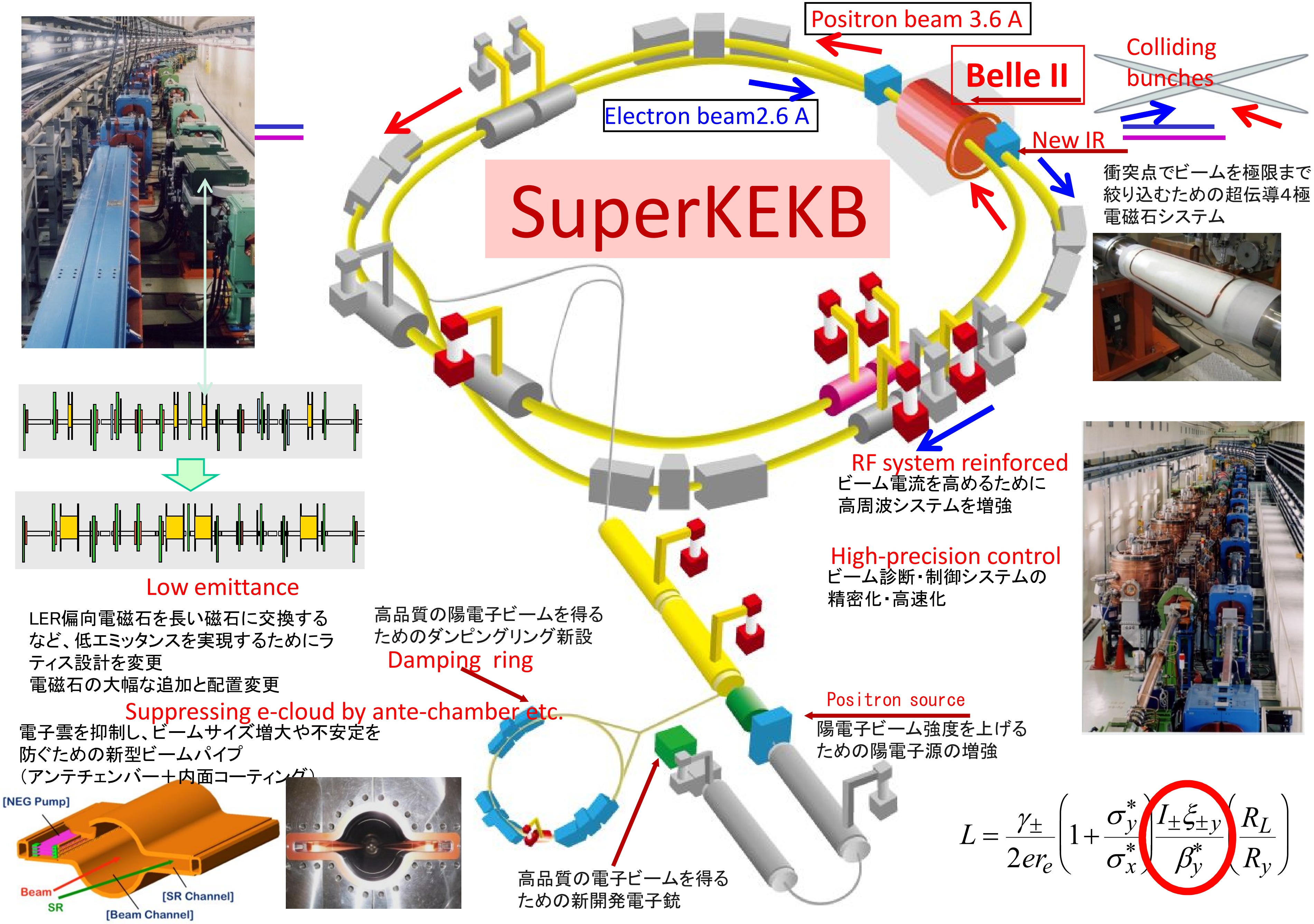
PhD student (funded)

KEK, Japan:

Sadaharu Uehara

Yoshihito Funakoshi

Masako Iwasaki



$$L = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

Upgrade to SuperKEKB : Aiming for the luminosity 40xKEKB

IP machine parameters and schedule

	KEKB		SuperKEKB	
	LER	HER	LER	HER
ε_x	18nm	24nm	3.2	5.0
ε_y	0.15nm	0.15nm	8.6pm	13.5pm
κ	0.83 %	0.62%	0.27%	0.25%
β_x*	120cm	120cm	32mm	25mm
β_y*	5.9mm	5.9mm	0.27mm	0.31mm
σ_x*	150μm	150μm	10μm	11μm
σ_x'*	120μrad	120μrad	450μrad	320μrad
σ_y*	0.94 μm	0.94μm	48nm	56nm
σ_y'*	0.16mrad	0.16mrad	0.18mrad	0.22mrad
iBump horizontal offset		+/- 500μm		+/- 30μm?
iBump vertical offset		+/- 150μm		+/- 7.5μm?
iBump vertical angle		+/- 0.4mrad		+/- 0.4mrad?

~1/4 (ε_y)

~1/4.5 (β_y*)

~1/20 (σ_y*)

First beam : Jan. 2015

First collision – luminosity tuning – physics run --- 2016

Luminosity measurement by ZDLM

Zero **D**egree **L**uminosity **M**onitor

detects the very-forward Radiative Bhabha events

$e^+ e^- \rightarrow e^+ e^- \gamma$

Each of the final-state particles goes to

0-degree for either of incident beams

(The photon is collinear with either of the incident e^+ or e^-,

even in lab. with the finite-angle crossing).

Cross section at $\sqrt{s}$ = M(Υ(4S))

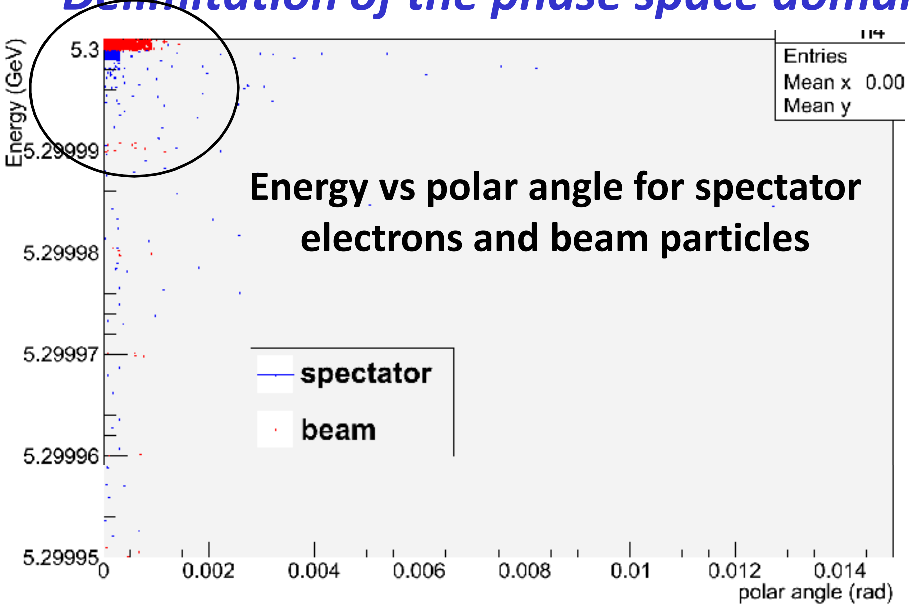
σ = ~10^{-25} cm^2 for E_γ>10MeV

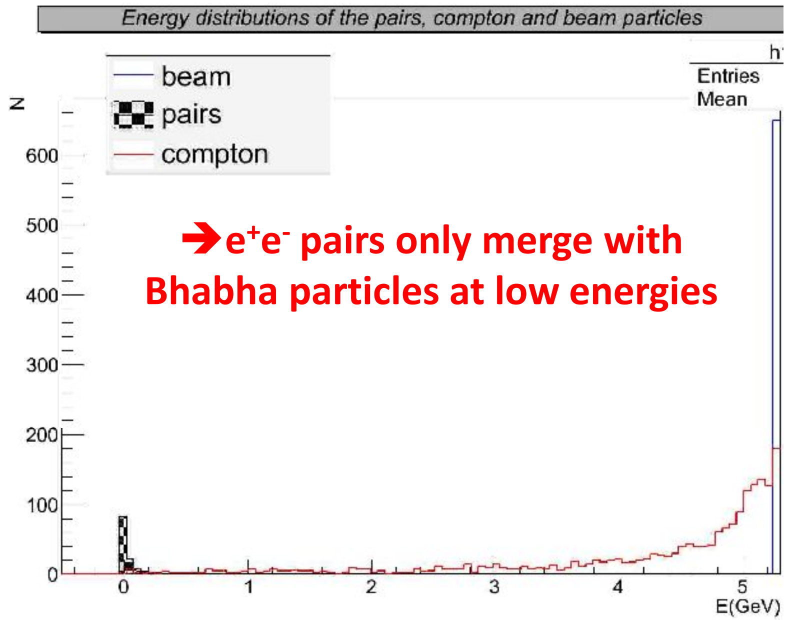
very high (sometimes too high) rate for L~$10^{35}/cm^2/s$

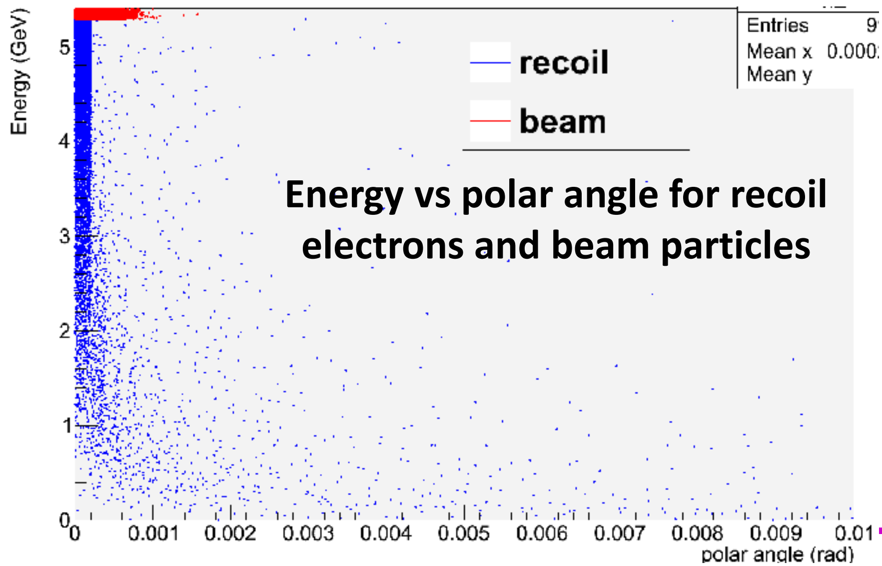
rate ~10 GHz > bunch-collision rate (max. 0.509 GHz)

Simulation of the radiative Bhabha (for Super B)

Delimitation of the phase space domain useful to our luminosity measurements

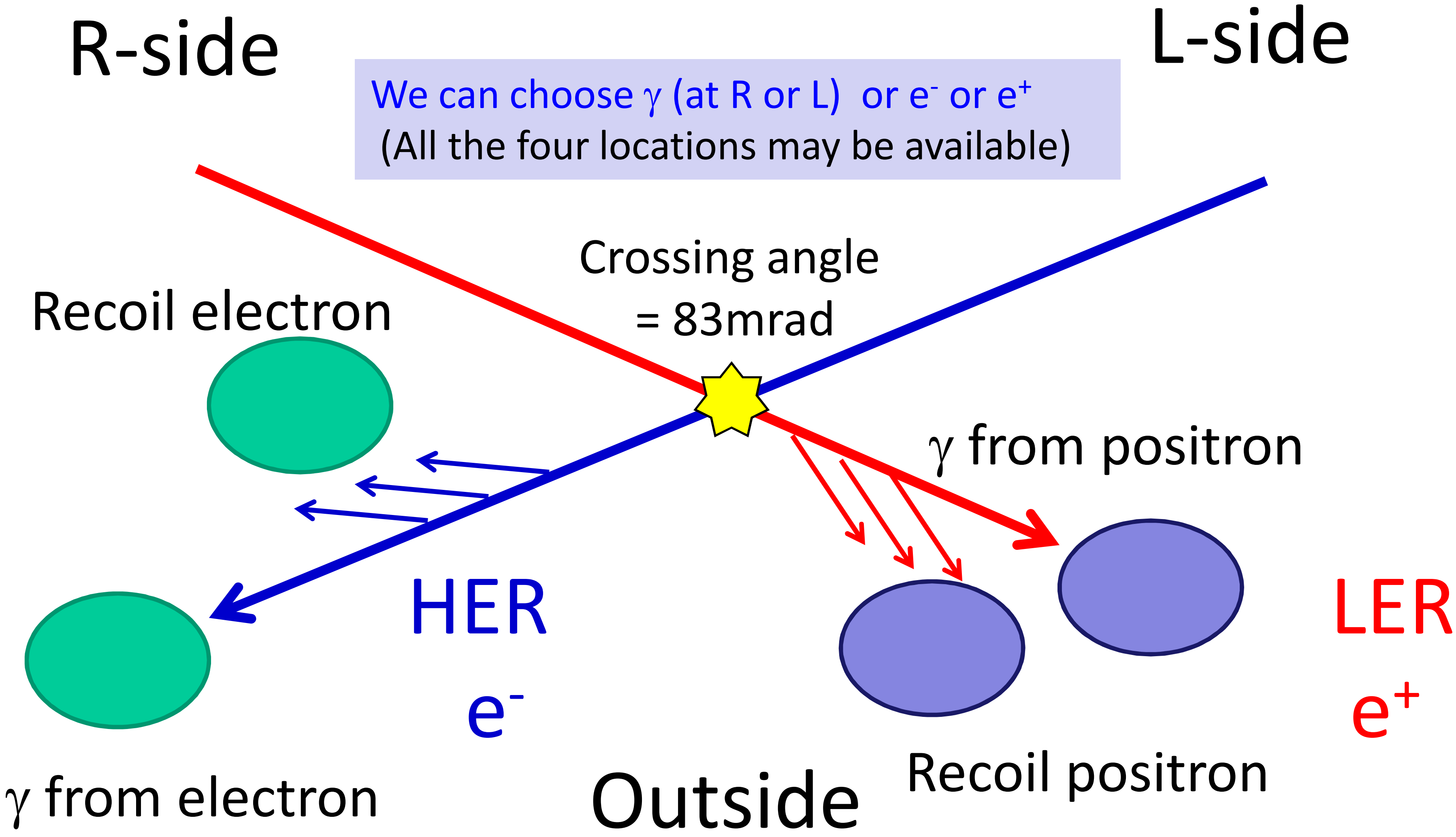






➔Spectator electrons: merged with beam particles
Recoil electrons: large energy spectrum but those with low energy are too much deflected

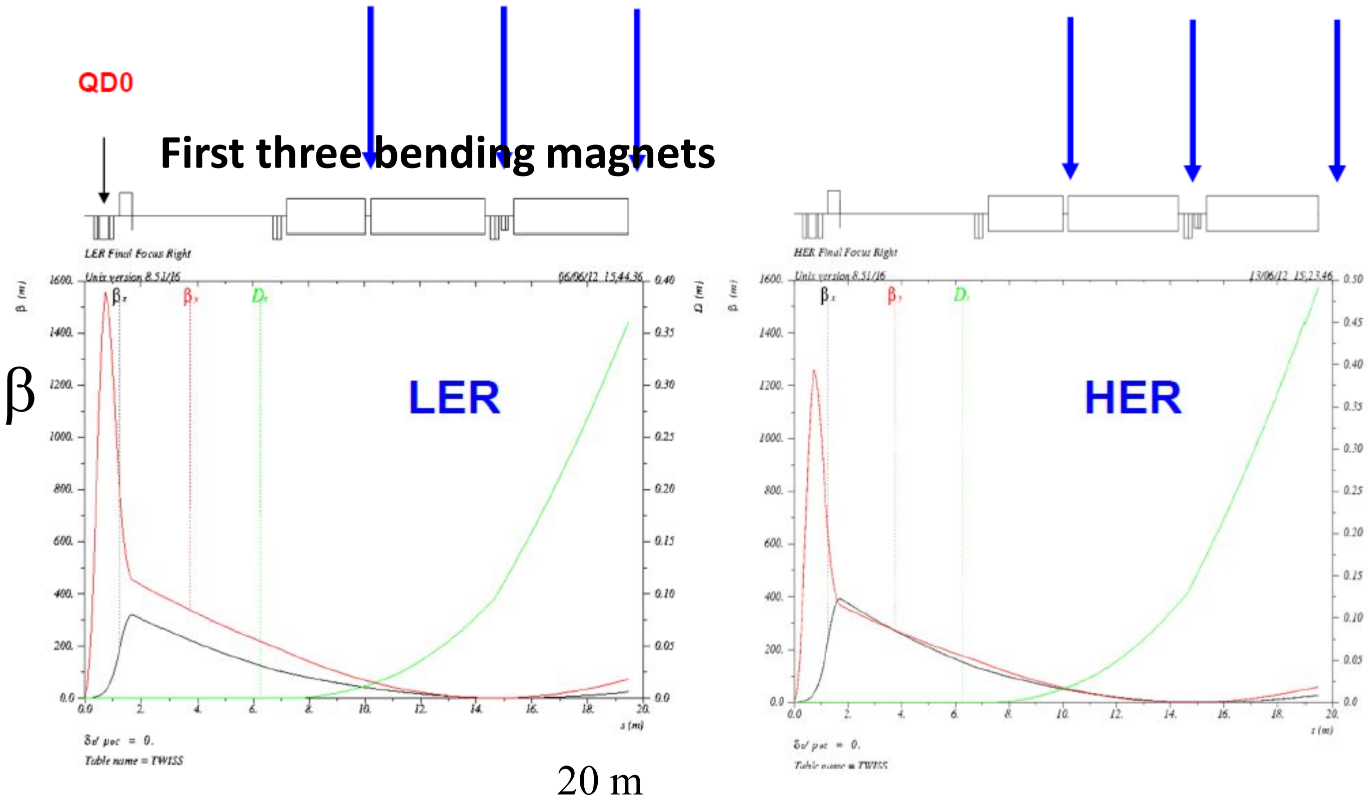
Where are the signals?



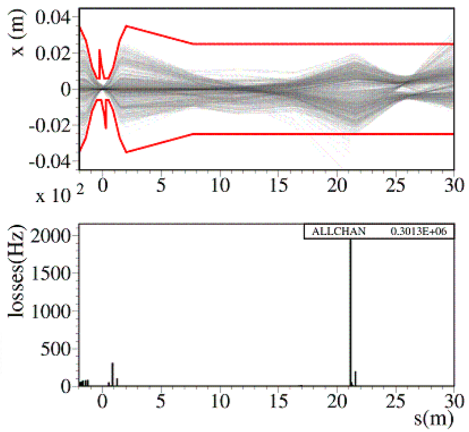
Optimize the setting locations (simulation for Super B)

Transportation of Bhabha in the IP region by MAD simulation program

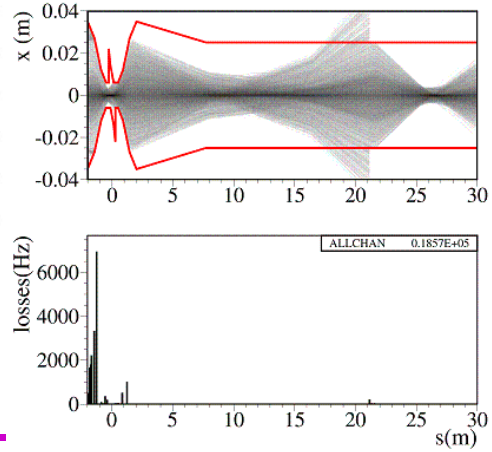
Best locations to maximise Bhabha / Touschek & beam gas rates



Loss by Touschek



Loss by beam-gas



ZDLM@SuperKEKB/Belle II

(1) Analog integration or discrimination by threshold:

Rate (multiple-event) problem for simple counting

(detection rate vs. intersecting rate)

or Integrate pulse size/shape (Capable to the higher rate)

(2) High-precision timing measurements:

- bunch-by-bunch (every ~1s, with Δt = 2ns separation)

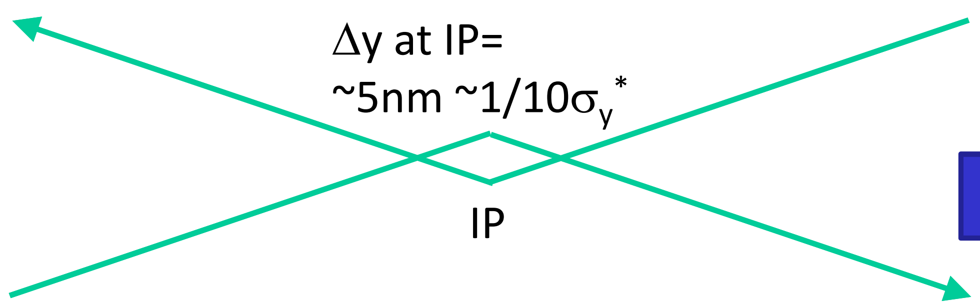
  high-freq. vibration (every ~ 1ms)

like as at Belle

Aiming for a 100% duty factor and a quick online analysis

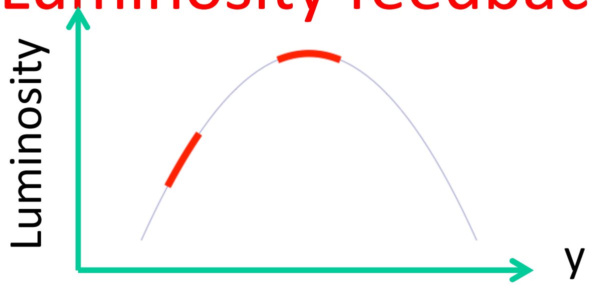
Orbit feedback at IP :Algorithm

- Beam-beam deflection (SLC, KEKB vertical)



SuperKEKB vertical offset

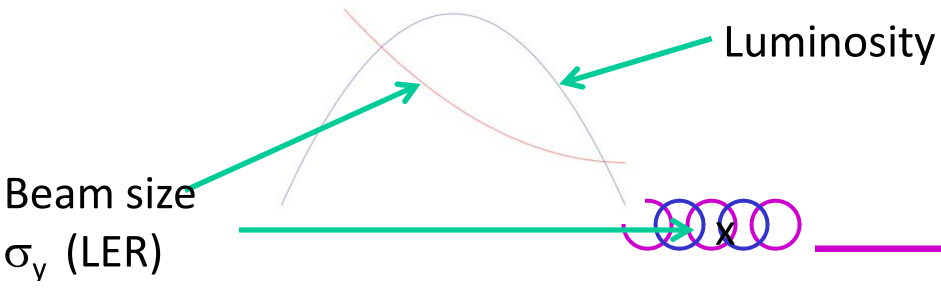
- Luminosity feedback (dithering)(PEP-II)



When we shake the beam at around the peak of the luminosity, there appears twice of the frequency of the dithering frequency.

Collaboration with SLAC experts is under way **for SuperKEKB**

- Beam size feedback (KEKB horizontal)

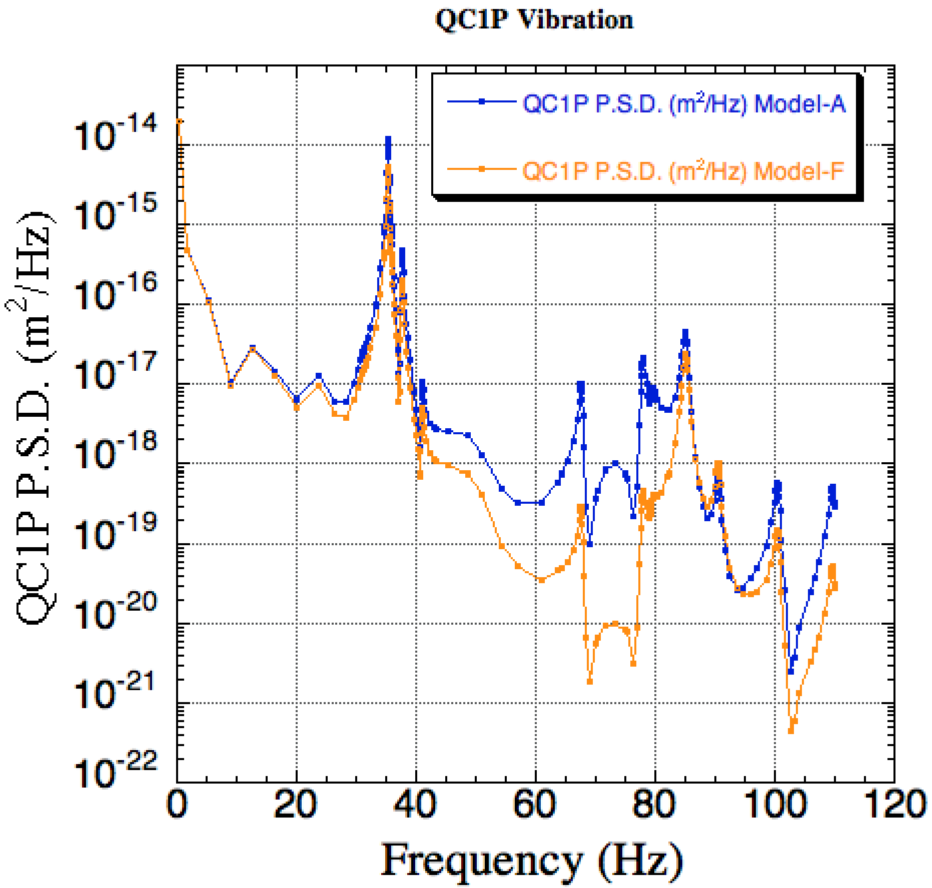


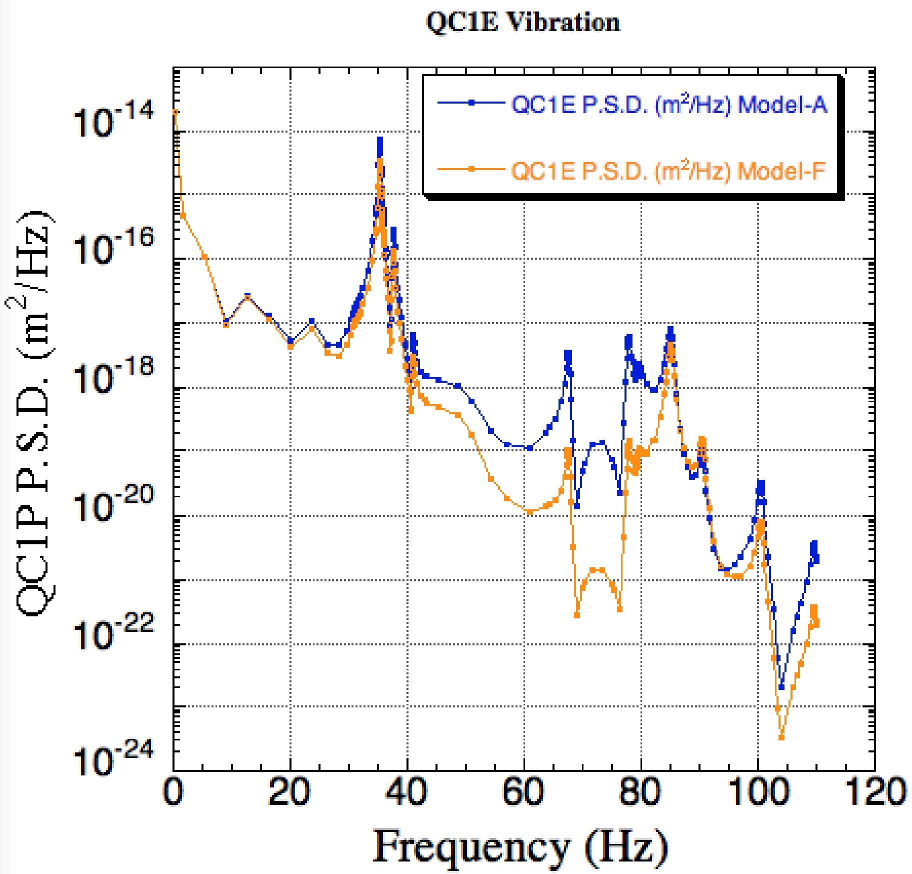
At KEKB before installation of crab cavities, the vertical beam of LER was used for the horizontal orbit feedback at IP.

Recent progress for IP of SuperKEKB

- We have finalized the locations of steering magnets
  - HER (for fast feedback)
    - 12 steering magnets (8 for vertical and 4 for horizontal)
    - Vacuum chamber: SUS(thickness: 6mm) , Vacuum group is now in design.
  - LER (for dithering)
    - 8 air-core Helmholtz coils (Length: ~ 0.25m)
      - Three kinds of bump orbits: h-offset, v-offset, v-angle
      - Steering kick max: ~ 50mrad
    - Vacuum chamber: SUS (thickness: 6mm) , Vacuum group is now in design.
- QCS vibration
  - QCS group is preparing new simulation results.
  - I will have to update the simulation on orbit changes with the data.

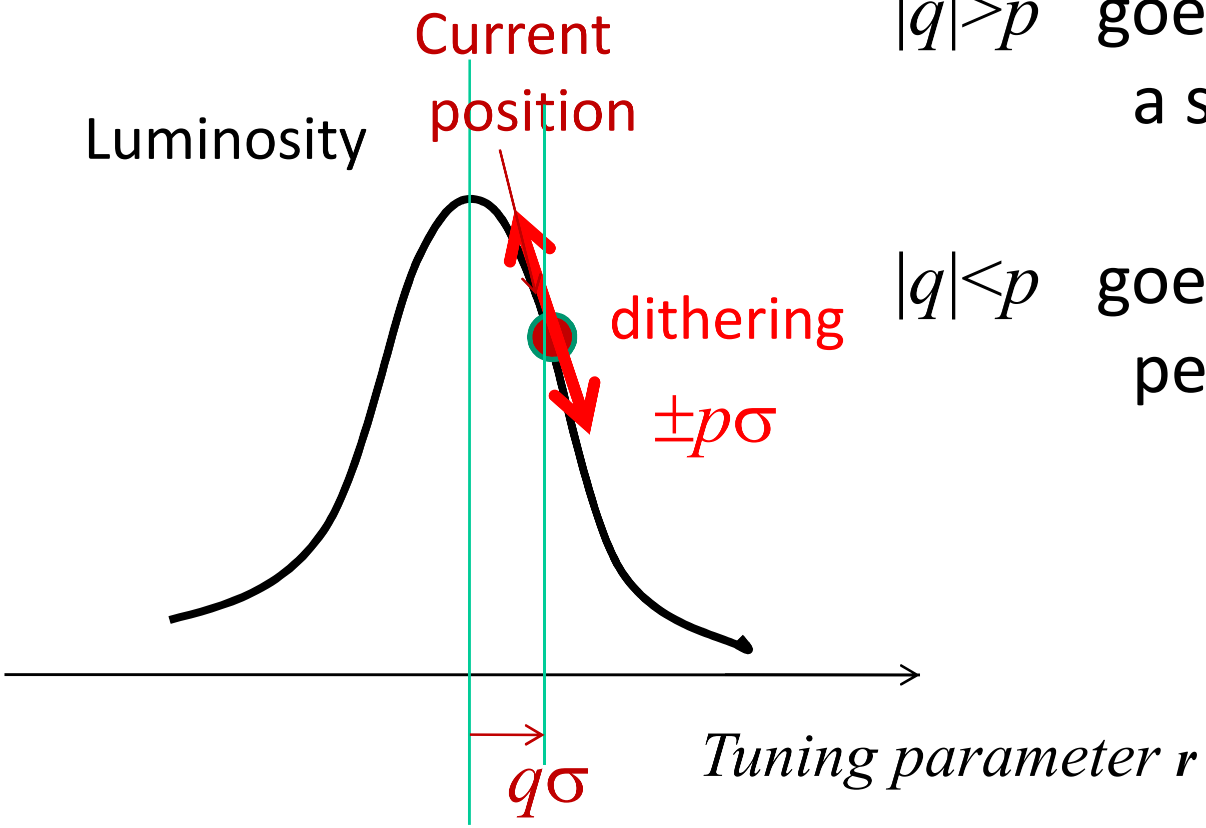
Simulation results of QC1L vibrations in the vertical direction





The 3 Hz ground motion is excluded from the simulation.

Illustrating the dithering quantities



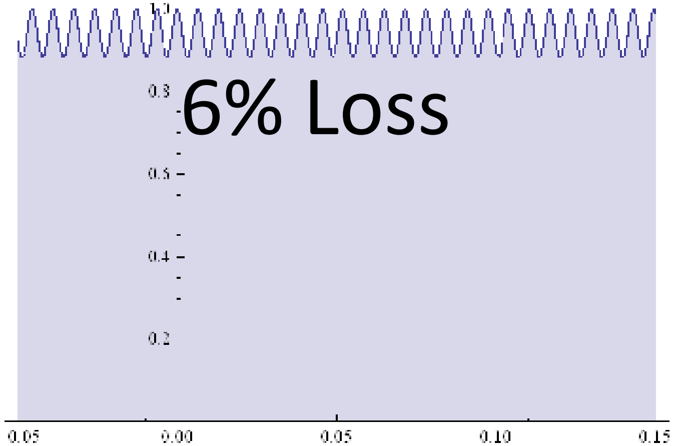
$|q|>p$ goes up and down on a side of slope

$|q|<p$ goes over across the peak

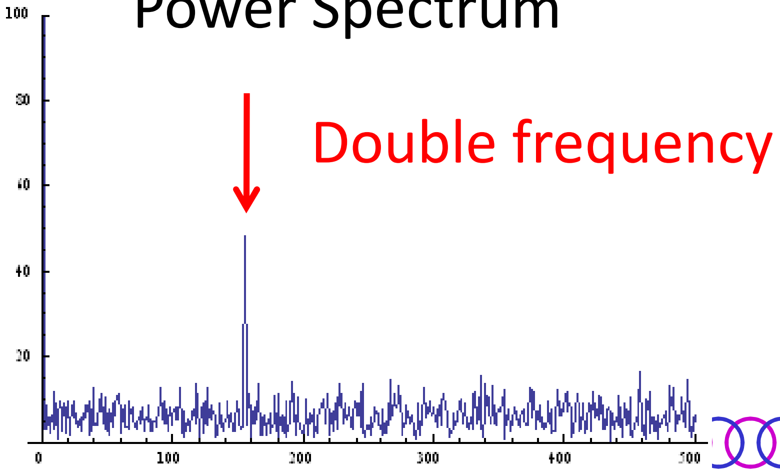
Artificial vibration of luminosity

Simulations for p =0.5, q=0, 50kHz

Luminosity



Power Spectrum



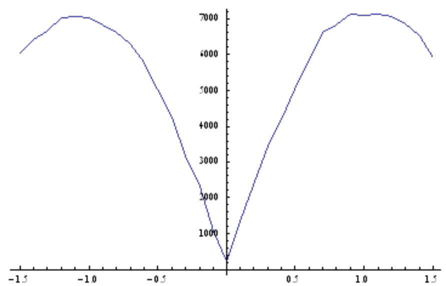
Lock-in Amplifier

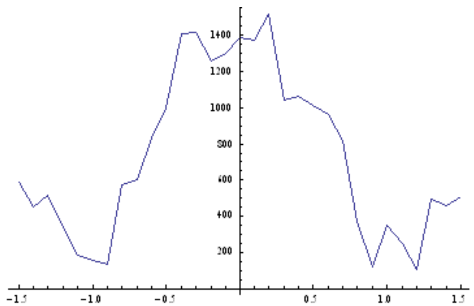
C = S cos 2p$f_0 t_i$ t_i : time of each event

S = S sin 2p$f_0 t_i$ S: summation for one measurement

f_0 : Same as the dithering frequency and twice the frequency

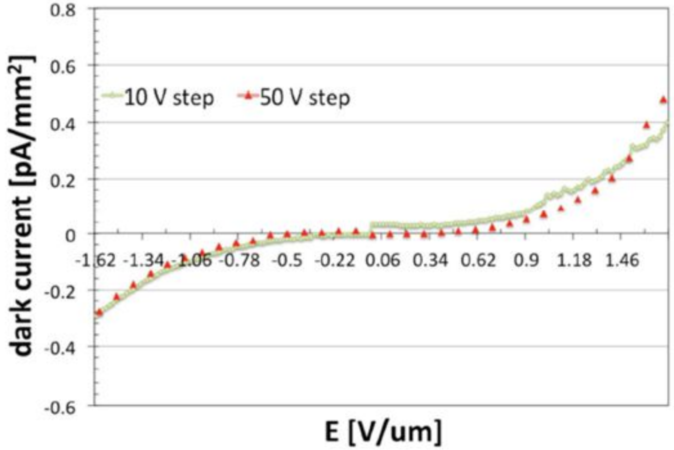
Base freq. Double freq.



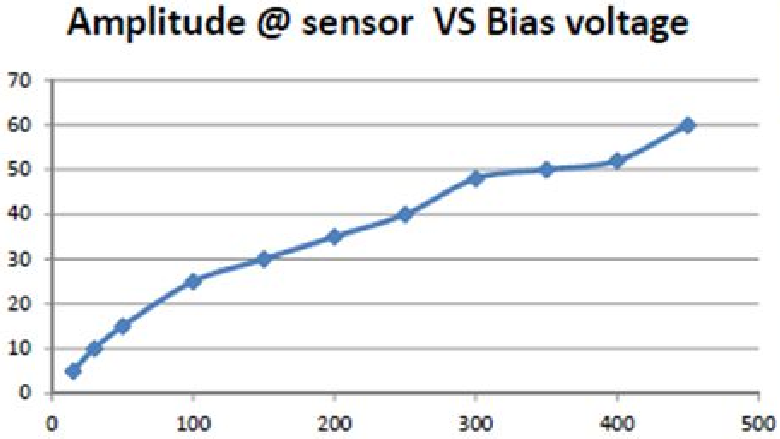


Diamond Sensors for beam diagonostics

Diamond sensor studies started at LAL in context of ATF2



First test results @ PHIL, LAL



Filter	Total Charge	Amplitude @sensor
100%	180pC	65V
62%	130 pC	55V
31%	95pC	45V
3%	14pC	7V
0.1%	≈0.1pC?	40mV

Plan for 2013: install 1st prototype @ ATF2 at year end

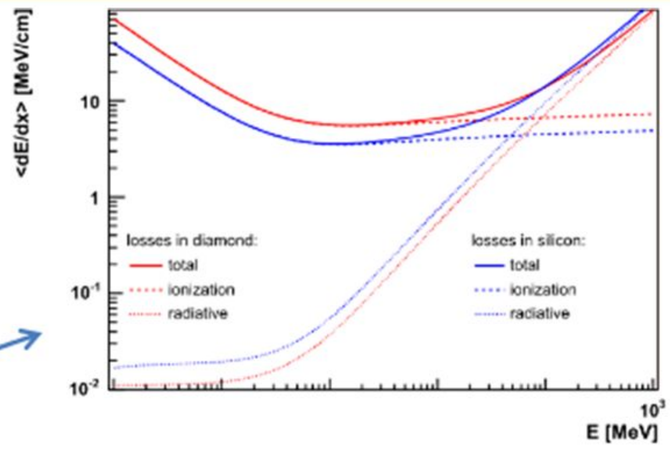
Diamond detector characteristics

Property	Diamond	Silicon
Density (g m^{-3})	3.5	2.32
Band gap (eV)	5.5	1.1
Resistivity (Ω cm)	>10^{12}	10^5
Breakdown voltage (V cm^{-1})	10^7	10^3
Electron mobility (cm^2 V^{-1} s^{-1})	1800	1500
Hole mobility (cm^2 V^{-1} s^{-1})	1200	500
Saturation velocity (μm ns^{-1})	220	100
Dielectric constant	5.6	11.7
Neutron transmutation cross-section(mb)	3.2	80
Energy per e-h pair (eV)	13	3.6
Atomic number	6	14
Av.min.ionizing signal per 100 μm (e)	3600	8000

ADVANTAGES

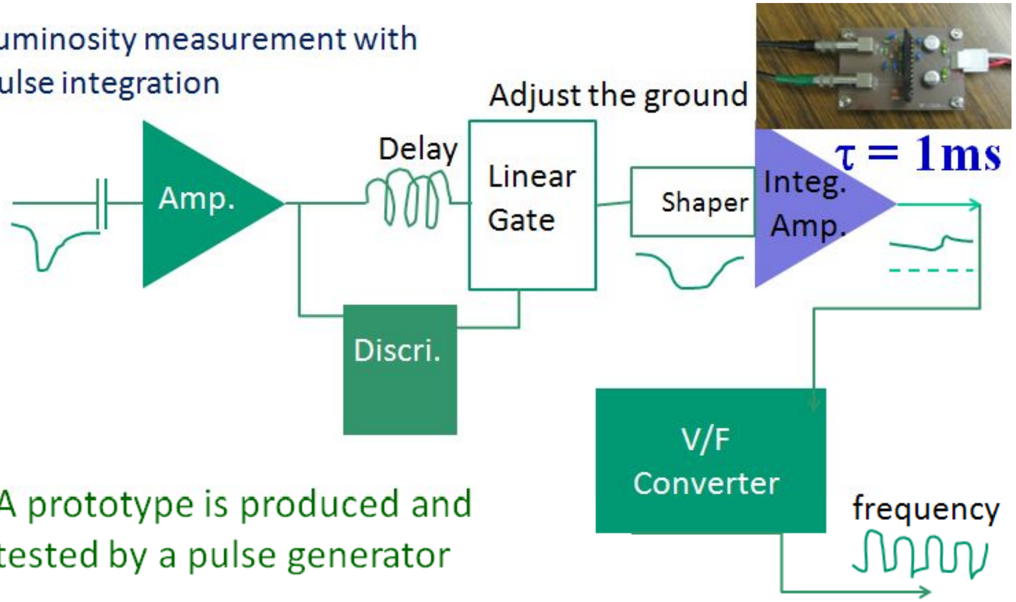
- *Large band-gap ⇒ low leakage current*
- *High breakdown field*
- *High mobility ⇒ fast charge collection*
- *Large thermal conductivity*
- *High binding energy ⇒ Radiation hardness*
- *Fast pulse ⇒ < 1 ns*

Energy loss of an electron in **diamond** & **silicon**



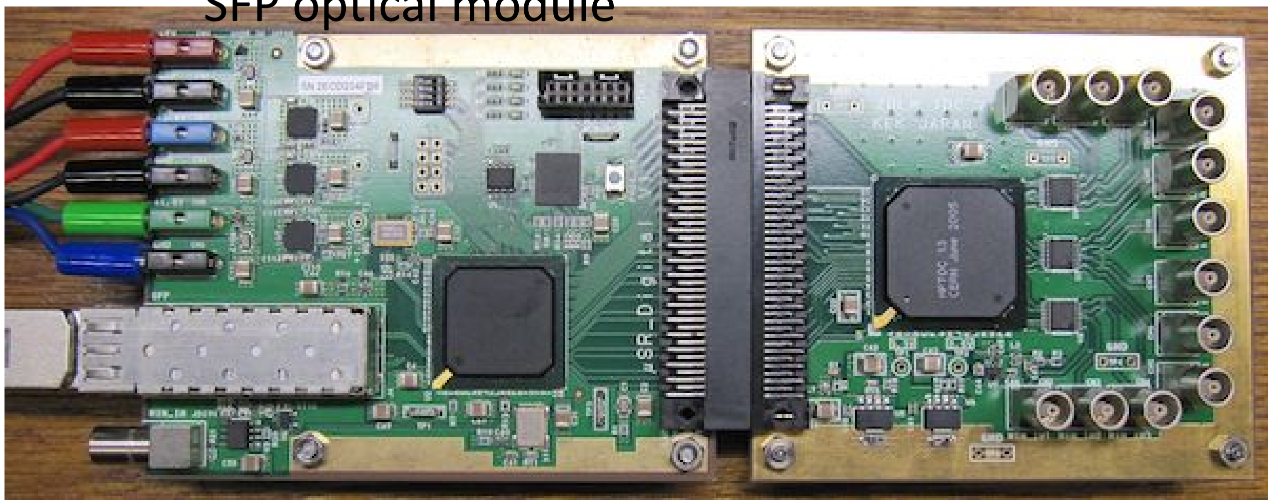
Circuits for signal processing

Luminosity measurement with pulse integration



A prototype is produced and tested by a pulse generator

TDC Module for precise timing measurement



Communicate with 1Gbps

Activity at KEK in 2013

- Development and Test of signal-processing circuits

    Lock-in amplifier

- Developments of detectors

    Cherenkov/scintillator

    its implementation plan

- Simulations for the accelerator

    QCS vibration

    Vertical feedback (for magnet etc.)

    Dithering

Activity at LAL in 2013

- Investigation on best location for the positioning of the luminosity monitors
- Study of secondaries induced by interactions with the beam pipe

- Study of particle loss mechanisms as background to luminosity measurements (Touschek, Beam gas scattering, beam-beam effects)

- Design of diamond sensor instrumentation and suitable electronics readout (in collaboration with the ATF2 diamond sensor project).

- Discussion for integration of the planned prototype among the instrumentation for the early commissioning a of SuperKEKB

Summary

Machine – detector interface through luminosity measurement at a luminosity-frontier machine

Accelerator

- Beam/background simulations
- Feedback/control simulations
- Design and construction of the IP (SuperKEKB @ KEK)

Detectors

- Diamond sensors
- Other sensors
- Electronics for measurement and communications

Readout Circuit at KEK

Counting rate -- proportional to Luminosity

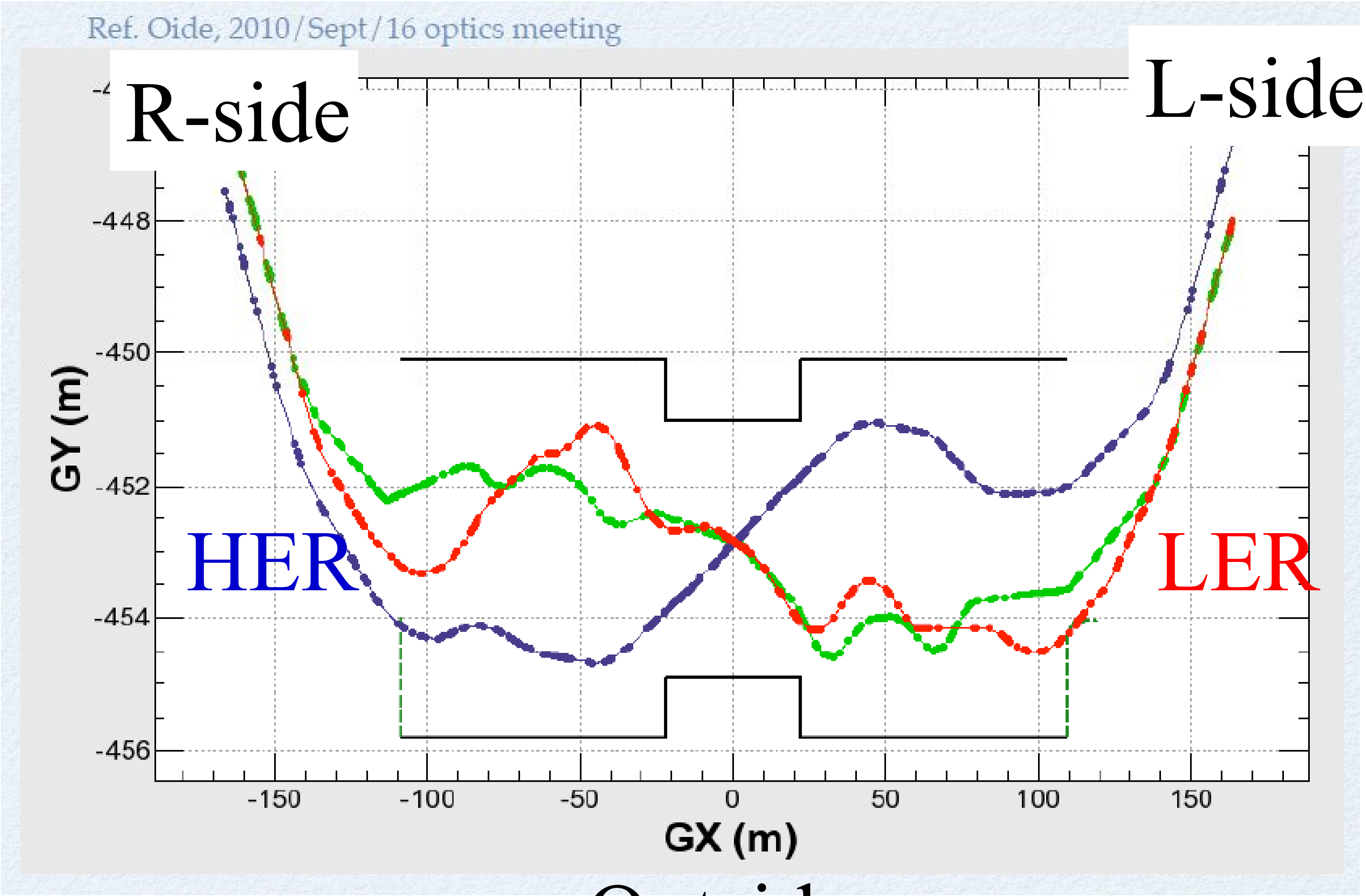
~10^{35} >O(1MHz) --- 1% stat. accuracy in 100Hz readout
~10^{34} >O(100kHz) --- 3% stat. accuracy in 100Hz readout
Tune depends on Luminosity

Cf. Collision rate (2-bucket spacing) 250MHz

Charge amp (Makes slow change) → V/F conversion (1MHz max)
for Feedback @ SuperKEKB

Analog input (with pulse overlaps) is also OK in this scheme
Capable for >=2 events per bunch collision
when we use analog sum

Central Orbits near IR



Outside

Expected ZDLM rate

- Funakoshi-san's simulation
  for the Recoil e- or e+

0.1mA/s -> 6.2GHz

- The rate should be proportional to luminosity
  10^{35} luminosity --- ~ O(1GHz/m/s)

- Effective detector length --- ~ 0.1m
- Efficiency --- 10% (conservative, may be more)
  (angular coverage and shower loss)

Expected Rate --- 0.1mA/s → 10 MHz

LER 4 m point (upstream BLC1LP) ~ 2MHz @10^{35}
9 m point (downstream BLC1LP) ~ 8MHz @10^{35}
13 m point (downstream QKBLP) ~ 30MHz @10^{35}
HER 11 m point (downstream BLC1RE) ~ 2MHz @10^{35}

Expected ZDLM acceptance

- Spread from HER ~±30deg

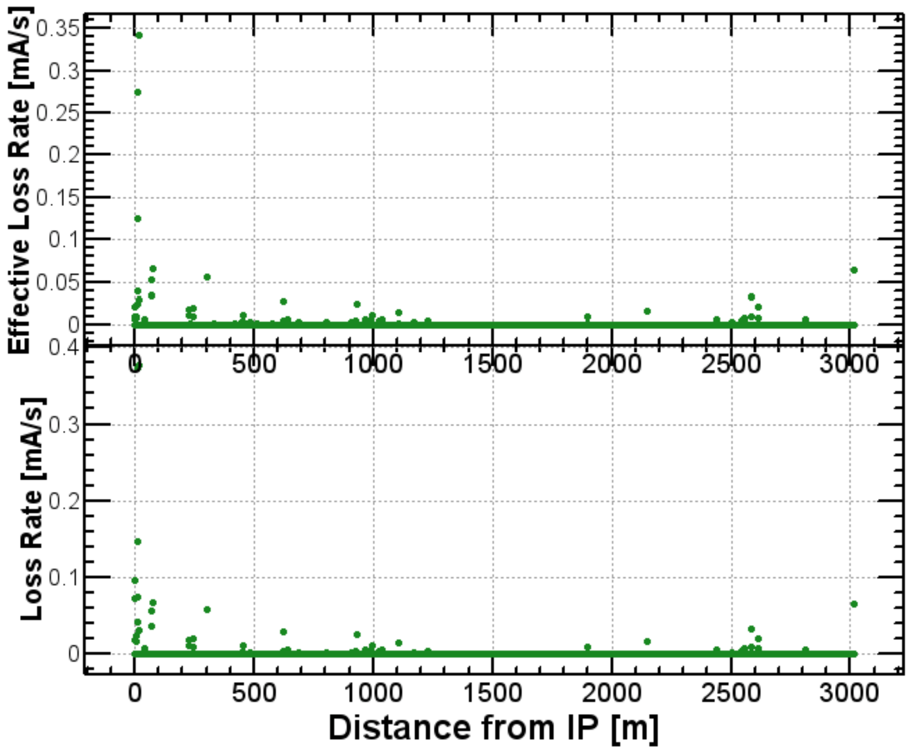
There may be efficiency loss

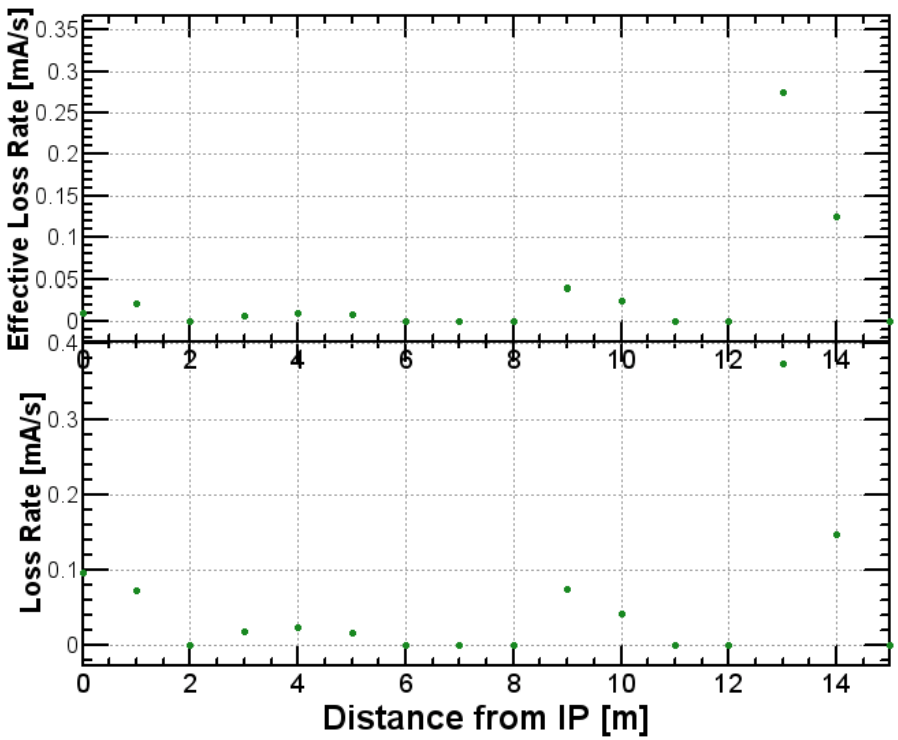
Larger counter:

robust for an orbit change

worse time resolution

LER Loss Position & Rate





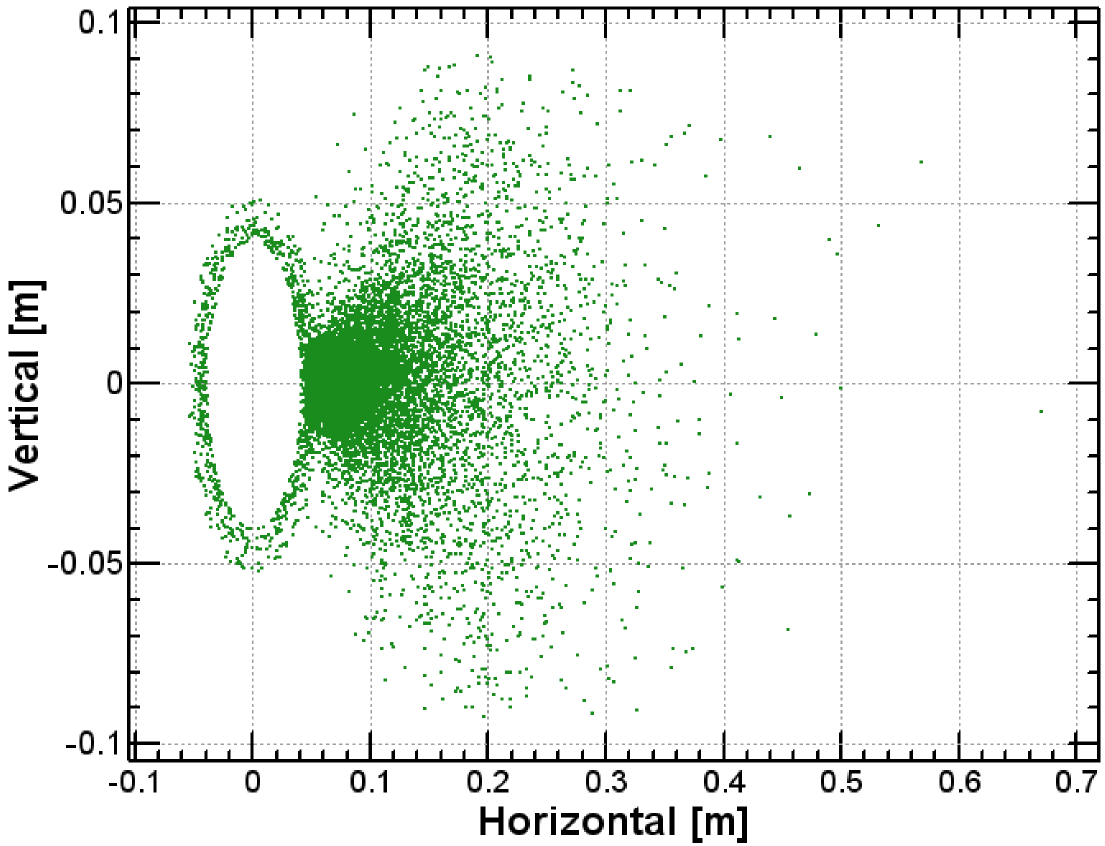
Loss rate: R_{Loss} [mA/s] = $1000N$ [partices/s] $e\ f_0$

$e = 1.602 \times 10^{-19}$ [C]

$f_0 \cong 100$ [kHz]

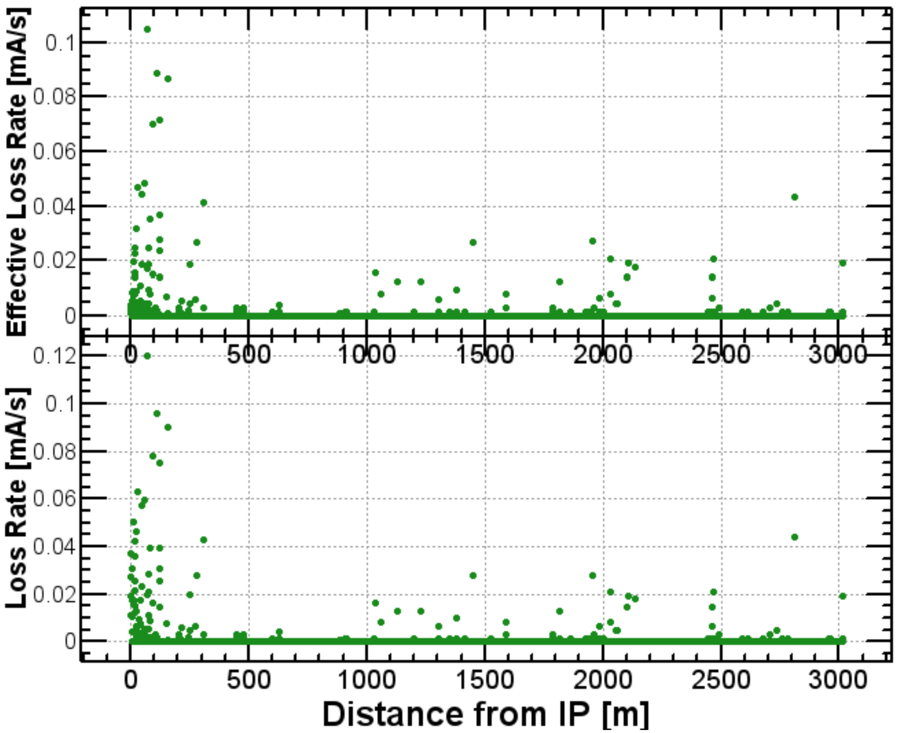
0.1mA/s -> 6.2GHz

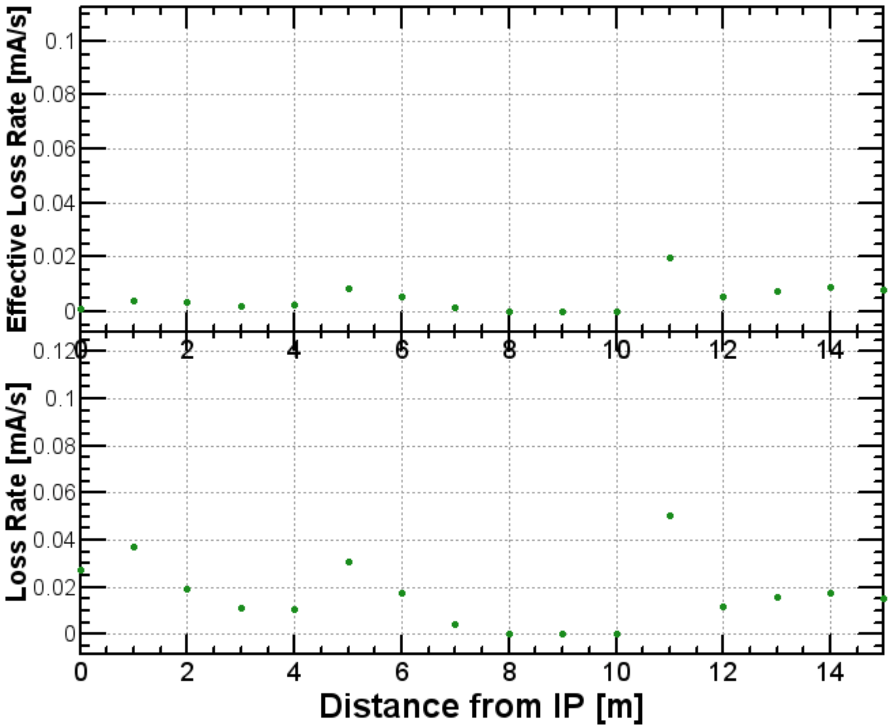
Loss point（transverse）



4m < s < 16m (sはIPからの距離)

HER Loss Position & Rate





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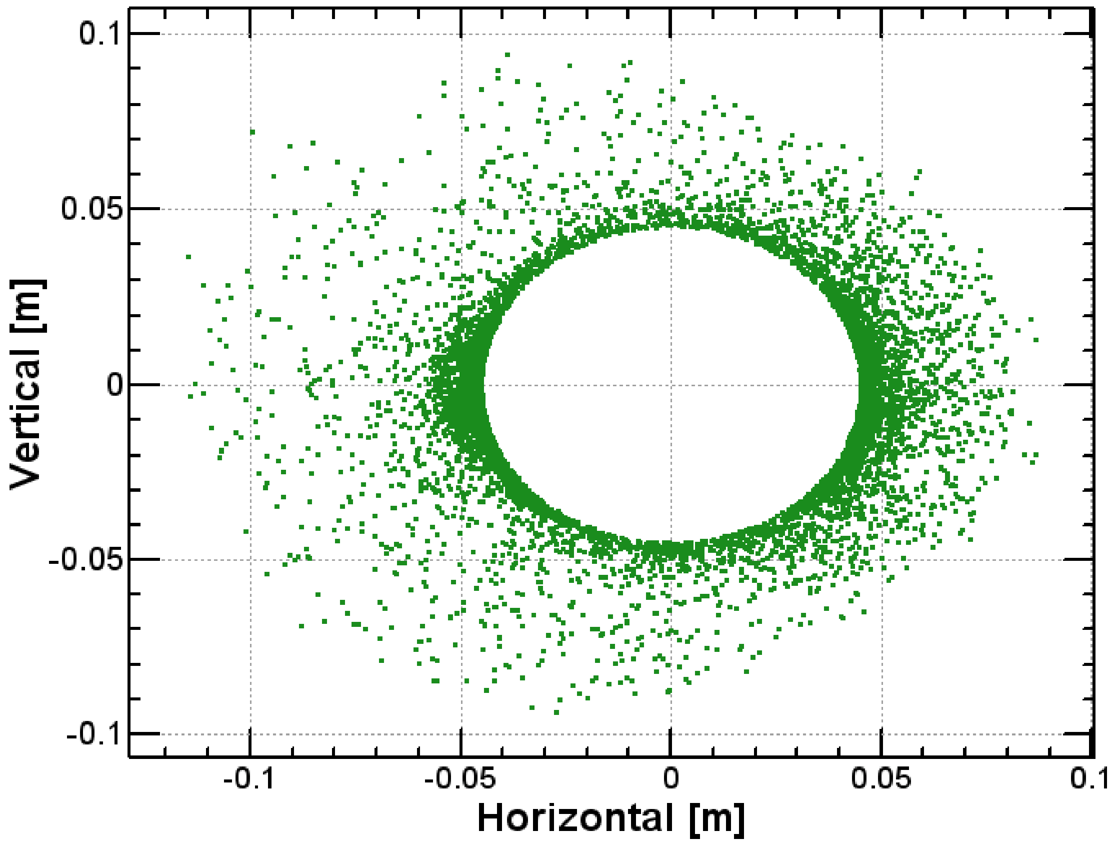


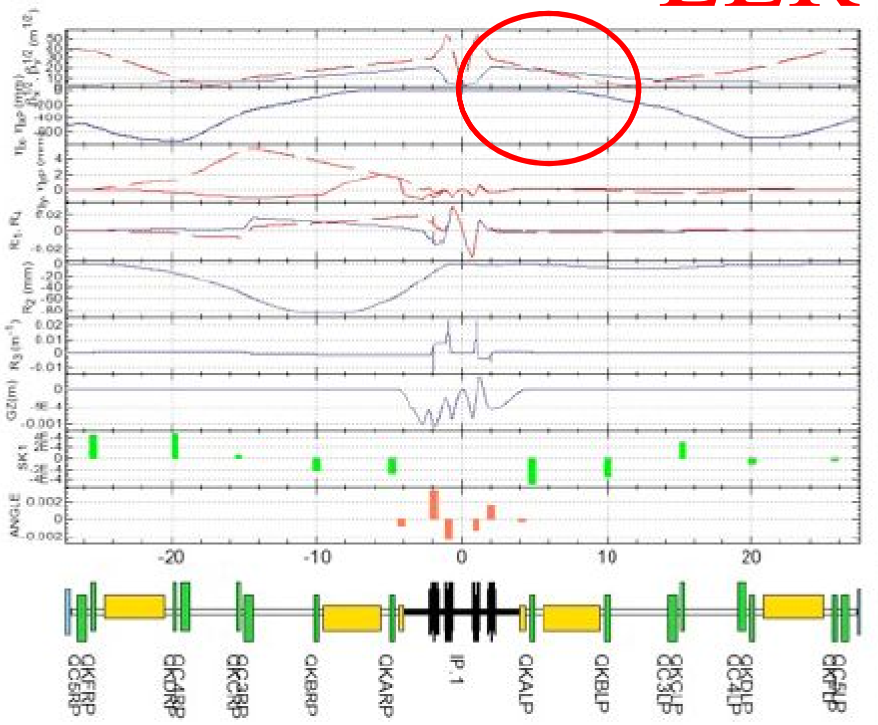
4m < s < 16m

IR Optics,
~~Horizontal dispersion parameters~~

Simultaneous correction of X-Y coupling and vertical dispersion

lerfqlc_1354.sad

LER



Separation of X-Y coupling and vertical dispersion correction

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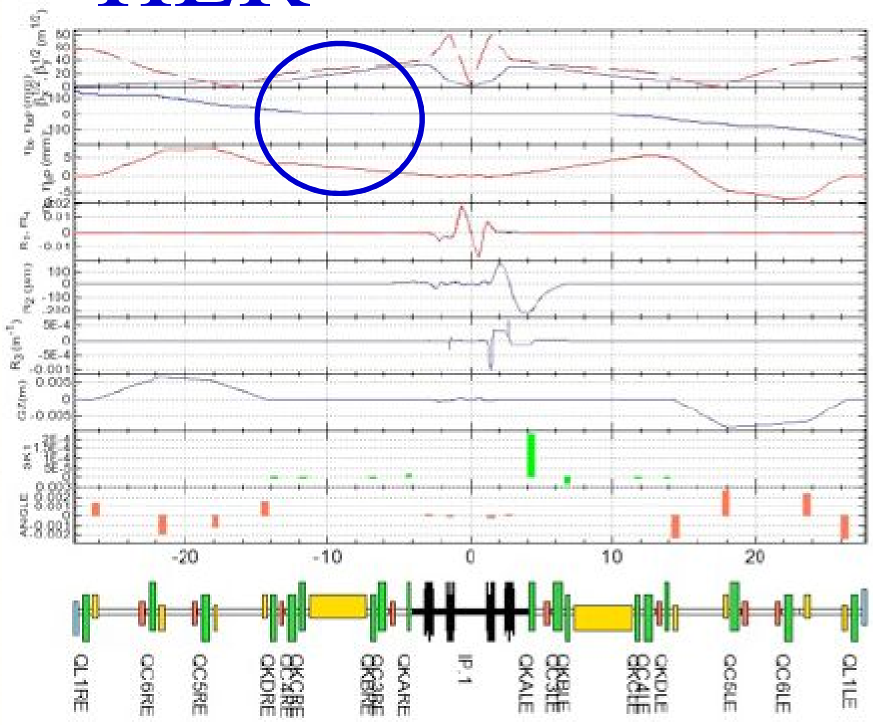
HER



Assumption of simulation

. Measure the rate of ZDLM during 1 sec (1 second for 1 measurement)

- Sampling rate = 1024 Hz (Counting rate every 0.977 ms)
- Dithering frequency at accelerator

$f = 77\text{Hz}$ Vibrate a certain tuning parameter r

$$r \sim \sin 2\pi f t$$

We assume the luminosity depends of this parameter with a Gaussian function:

$$L(t) \sim \mathrm{Exp}[-(q + p \sin 2\pi f t)^2/2]$$

q : Shift of the operation point from the luminosity peak

p : Amplitude of the dithering

f : Dithering frequency (taken to be 77Hz, here)

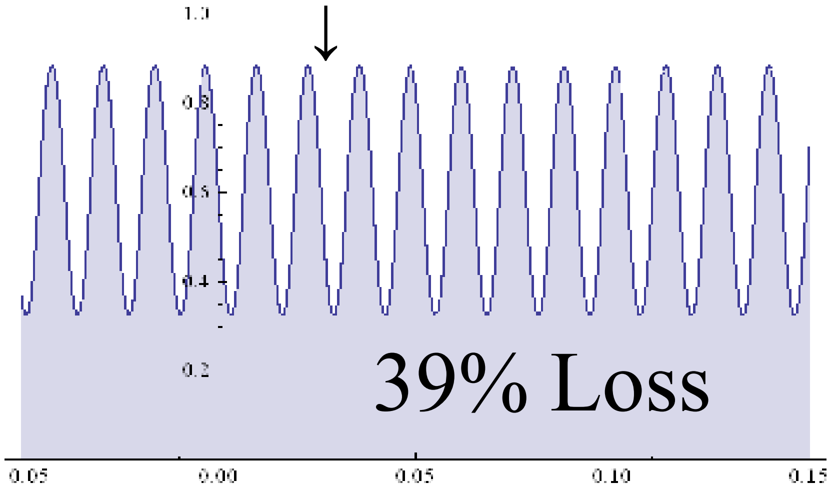
Some calculation results

Mathematica8 is used

p =0.5, q=1.0、10kHz

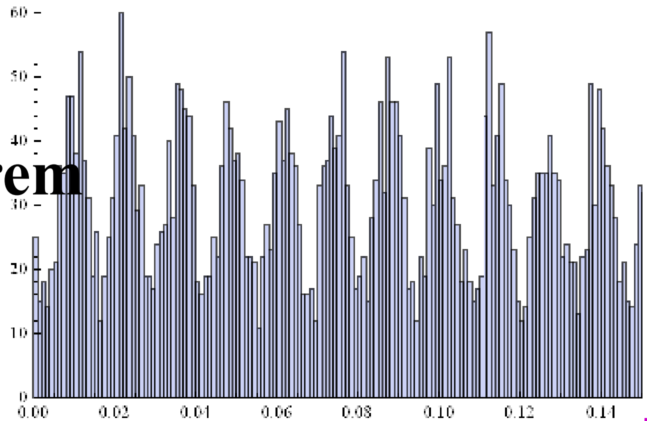
Luminosity (input)

↓

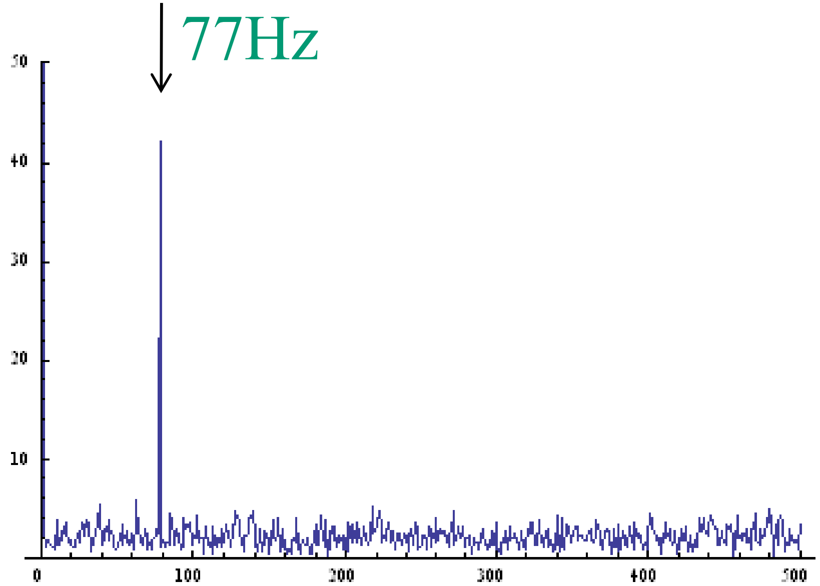


Measurement (MC)

→

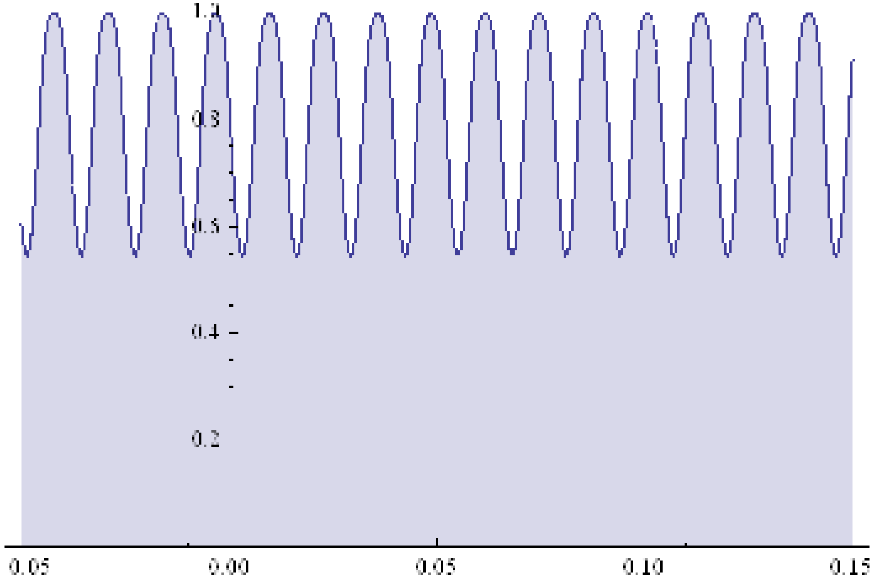


Sqrt of the
Power Spectrum
Absolute value of the Fourier coefficient

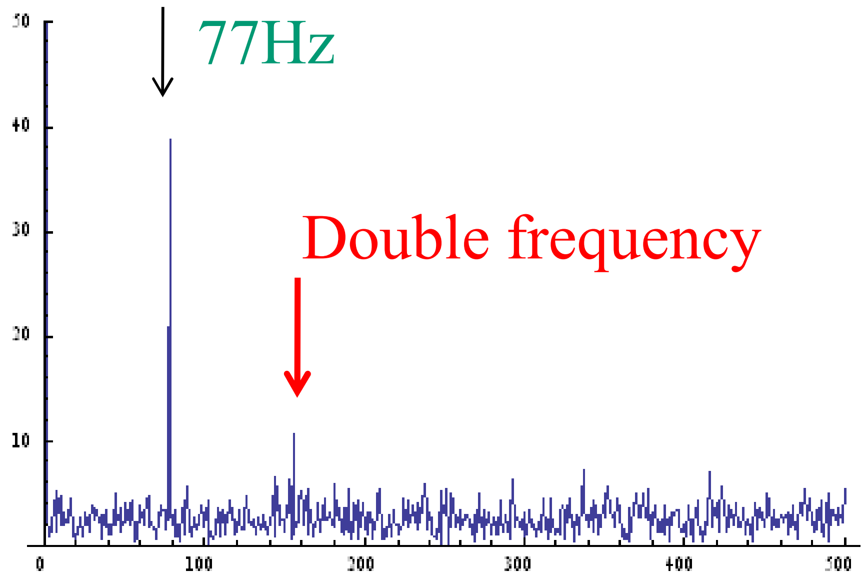


p =0.5, q=0.6、10kHz

Luminosity



Power Spectrum



20% Loss

A model of Lock-in Amp.

- Modulated Amplification

Output(t) ~ Input(t)*cos($2\pi f_0 t + \phi$)

Two phases cos $2\pi f_0 t$ and sin $2\pi f_0 t$

Measuring signal size

$C = \Sigma \cos 2\pi f_0 t_i$ t_i : time of each event

$S = \Sigma \sin 2\pi f_0 t_i$ Σ: summation for one measurement

Size: $\sqrt{C^2 + S^2}$, Phase = atan2(S, C)

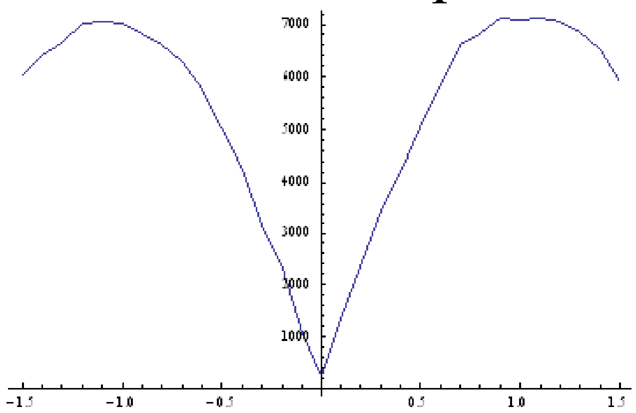
Dithering frequency: f_0=77Hz

doubled: f_0=154Hz

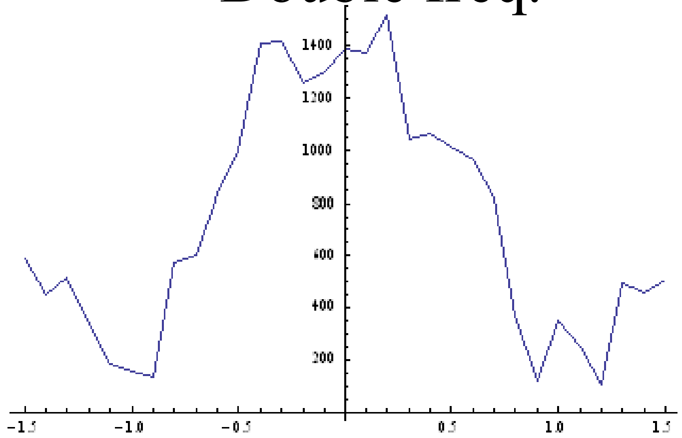
Simulation (Mathematica8)

p= 0.5, Rate=50kHz, Measurement in 1 sec
Horizontal axis: q = -1.5 ～ +1.5,
Vertical axis: Size (arbitrary)

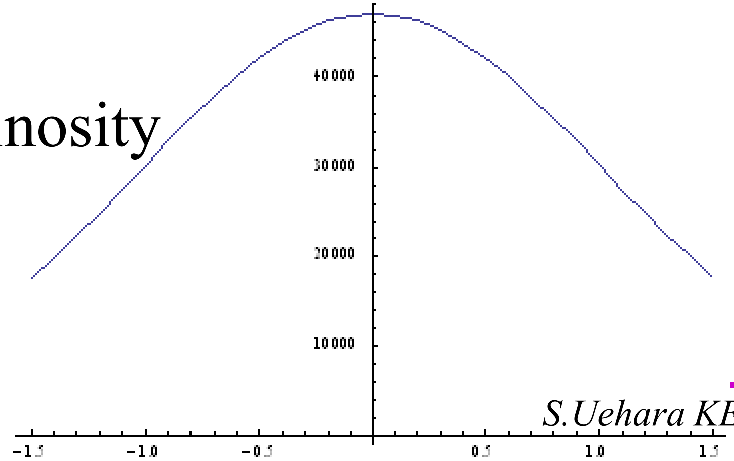
Base freq.



Double freq.



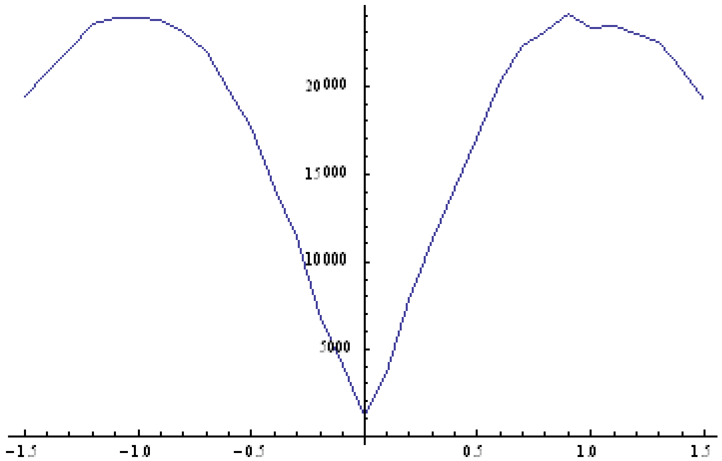
Luminosity



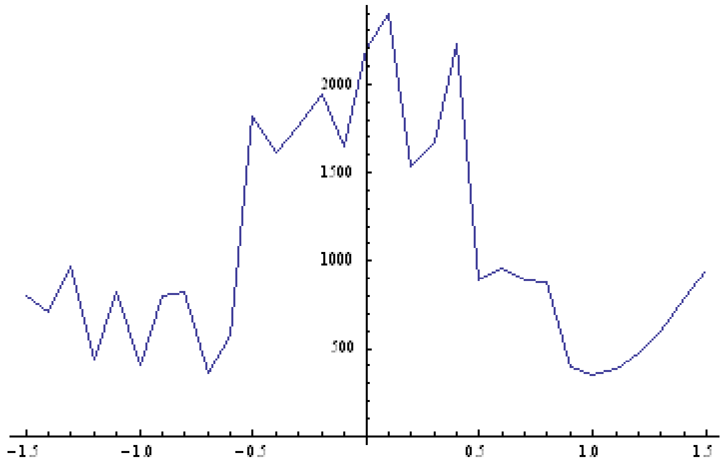
Simulation

p= 0.2, Rate=400kHz

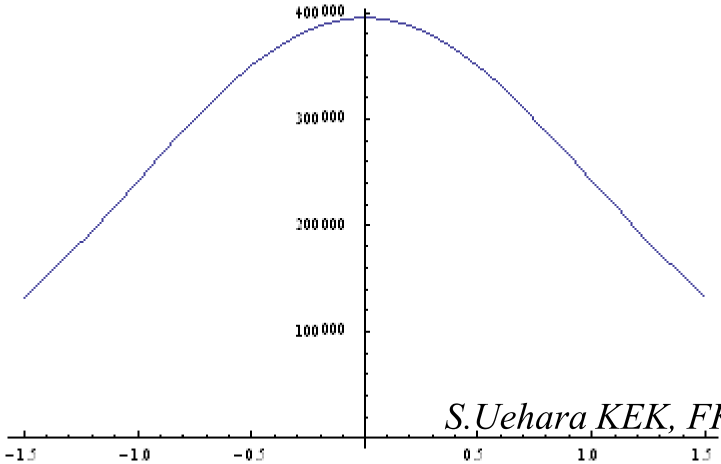
Base Freq.



Double Freq.



Luminosity



Not good

Observation with the base frequency is the most sharp.