Novel Accelerator Methods and Technologies for KEKB Upgrade

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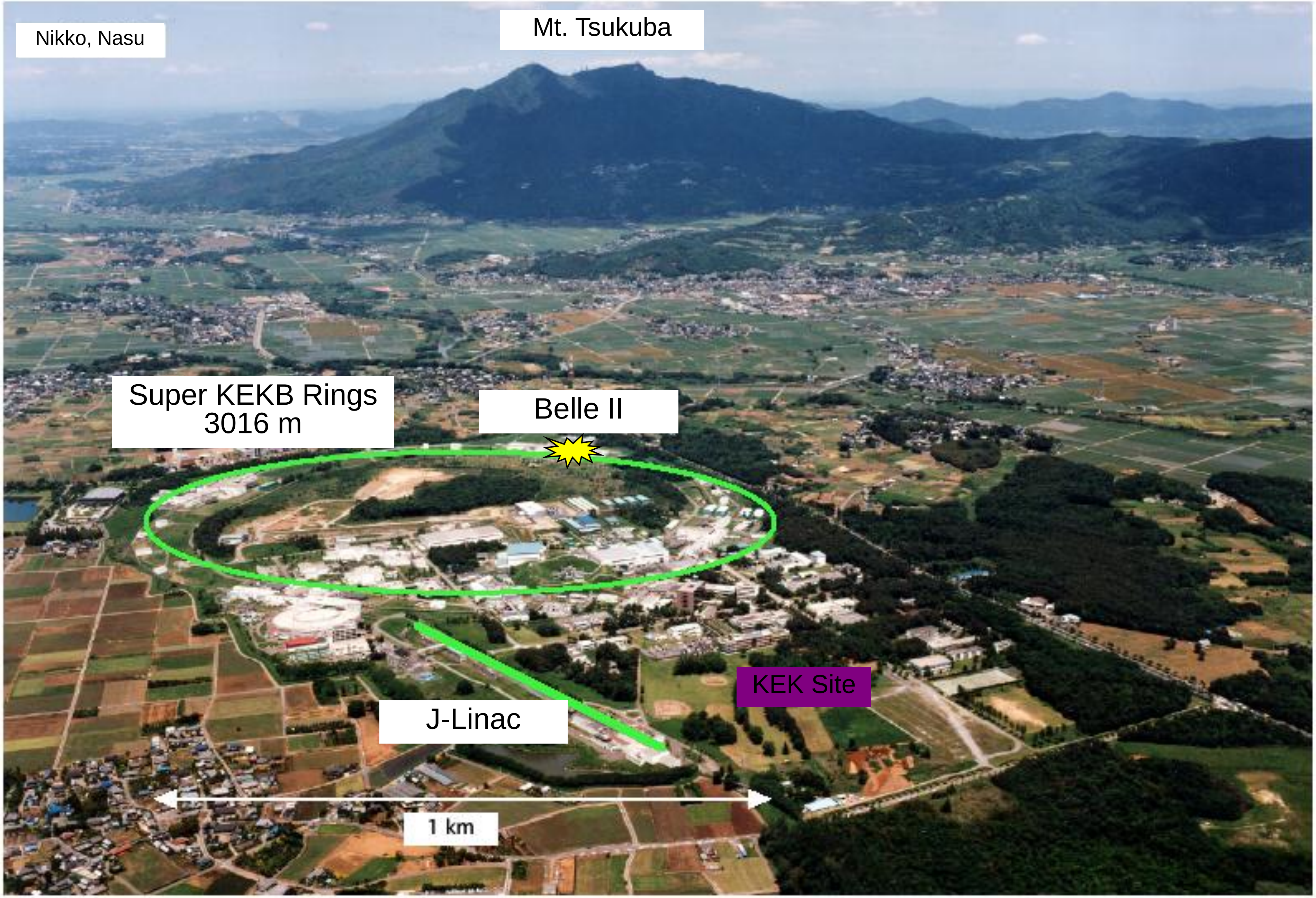
2011.8.11

DPF2011

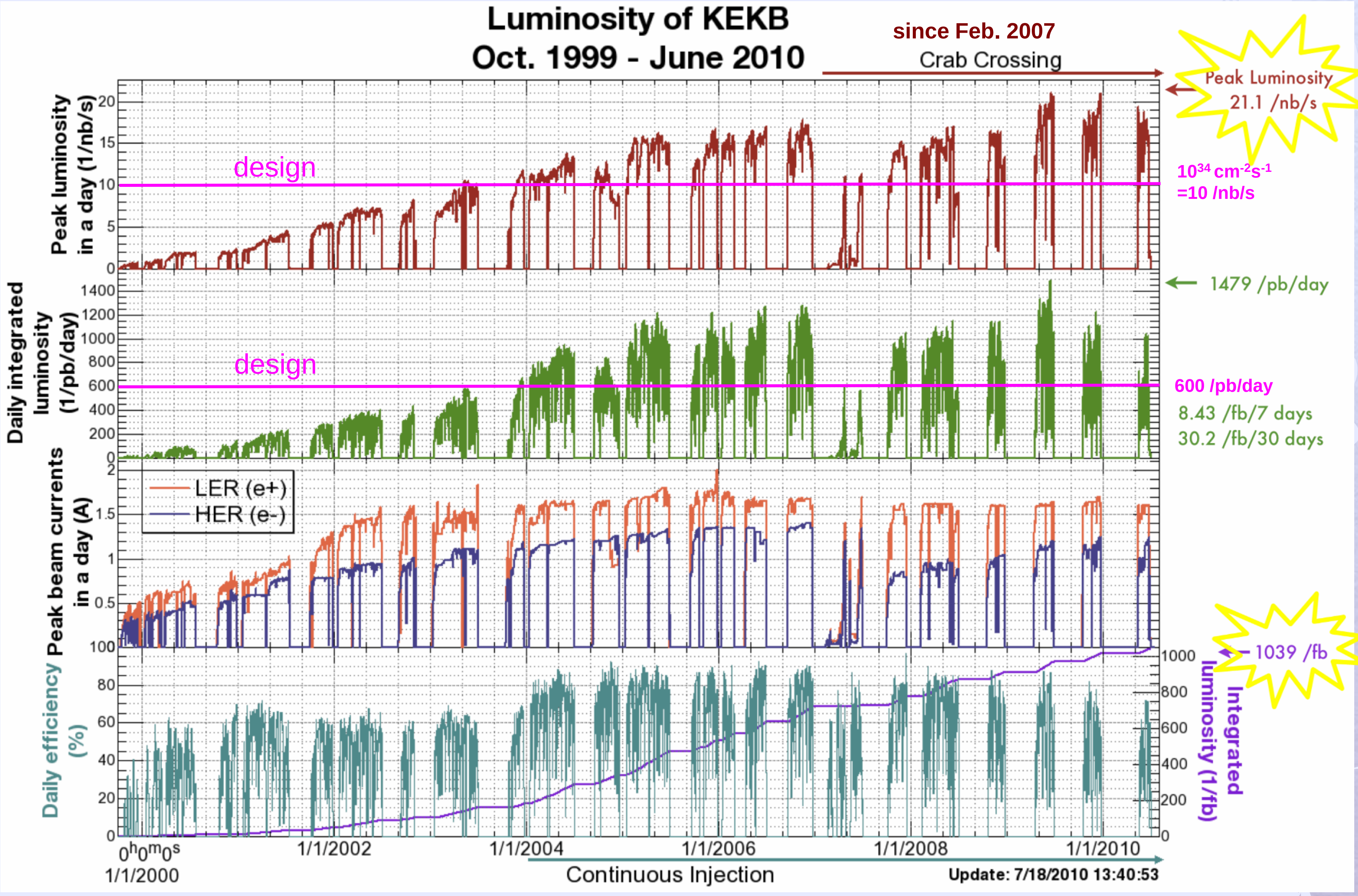
Outline

- Machine Design Overview
- Particular Challenges
  - IR
  - Vacuum
  - Injector
  - Instrumentation
  - Alignment & Stabilization
- Construction & Commissioning

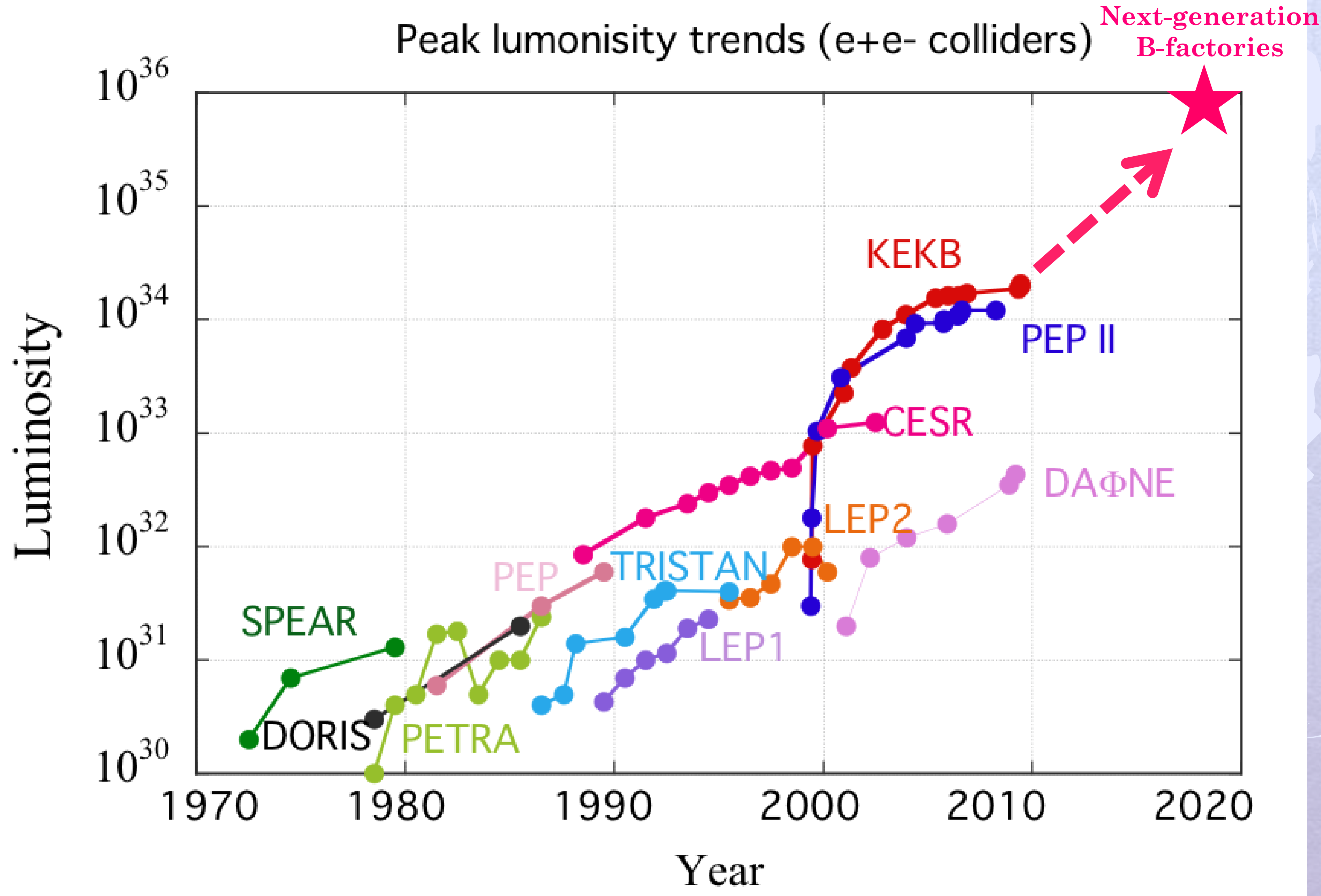
Machine Design Overview

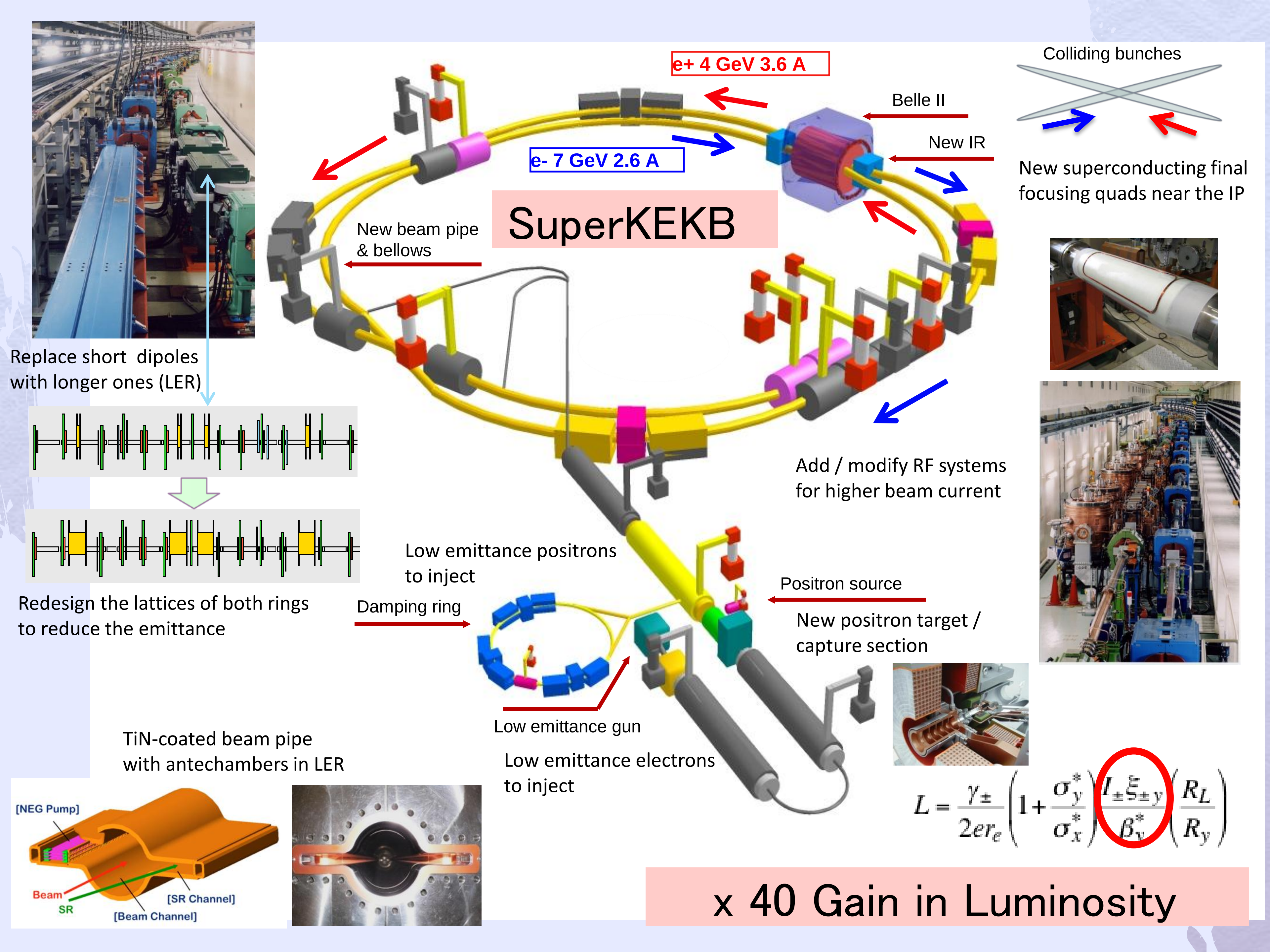


KEKB History



e^+-e^- Colliders




SuperKEKB
e+ 4 GeV 3.6 A
e- 7 GeV 2.6 A
Belle II
New IR
Colliding bunches
New superconducting final focusing quads near the IP
New beam pipe & bellows
Replace short dipoles with longer ones (LER)
Redesign the lattices of both rings to reduce the emittance
Add / modify RF systems for higher beam current
Low emittance positrons to inject
Damping ring
Positron source
New positron target / capture section
Low emittance gun
Low emittance electrons to inject
TiN-coated beam pipe with antechambers in LER
[NEG Pump]
Beam
SR
[SR Channel]
[Beam Channel]
$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$
x 40 Gain in Luminosity

Design Concept of SuperKEKB

- Increase the luminosity by 40 times based on "Nano-Beam" scheme, which was first proposed for SuperB by P. Raimondi.

Luminosity Gain

- Vertical β function at IP: 5.9 → 0.27/0.30 mm (× 20)
- Beam current: 1.7/1.4 → 3.6/2.6 A (× 2)
- Beam-beam parameter: .09 → .09 (× 1)

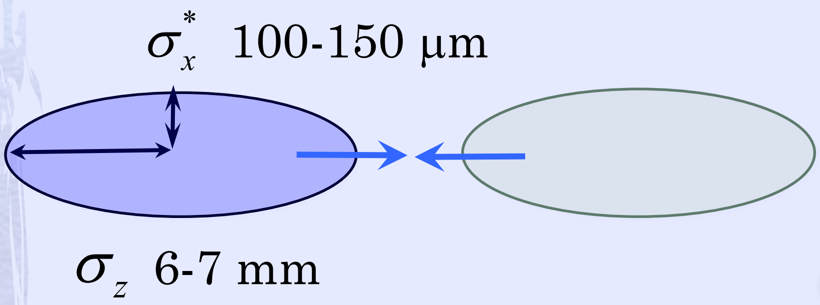
$$L = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right) = 8 \times 10^{35}\ \mathrm{cm^{-2}s^{-1}}$$

- Beam energy: 3.5/8.0 → 4.0/7.0 GeV

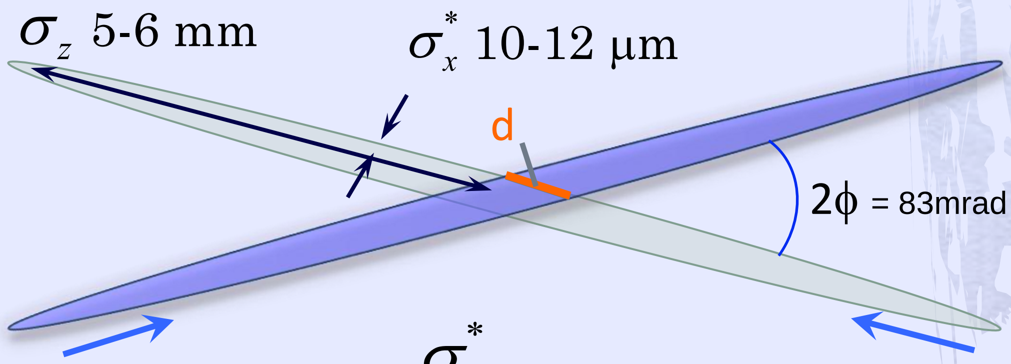
  LER : Longer Touschek lifetime and mitigation of emittance growth due to the intra-beam scattering
  HER : Lower emittance and lower SR power

Collision Scheme

KEKB head-on (crab crossing)



Nano-Beam SuperKEKB



$$d = \frac{\sigma_x^*}{\phi}$$

Half crossing angle: ϕ

overlap region = bunch length

overlap region << bunch length

Hourglass requirement

$$\beta_y^* \geq \sigma_z \quad \sim 6 \text{ mm}$$

$$\beta_y^* \geq \frac{\sigma_x^*}{\phi} \quad \sim 300 \ \mu\text{m}$$

Vertical beta function at IP can be squeezed to ~300μm.
Need small horizontal beam size at IP.
→ low emittance, small horizontal beta function at IP.

Y. Ohnishi et al.

Comparison of Parameters

	KEKB Design	KEKB Achieved : with crab	SuperKEKB Nano-Beam
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	4.0/7.0
β_y^* (mm)	10/10	5.9/5.9	0.27/0.30
β_x^* (mm)	330/330	1200/1200	32/25
ε_x (nm)	18/18	18/24	3.2/5.3
$\varepsilon_y/\varepsilon_x$ (%)	1	0.85/0.64	0.27/0.24
σ_y(μm)	1.9	0.94	0.048/0.062
ξ_y	0.052	0.129/0.090	0.09/0.081
σ_z (mm)	4	6 - 7	6/5
I_{beam} (A)	2.6/1.1	1.64/1.19	3.6/2.6
$N_{bunches}$	5000	1584	2500
Luminosity (10^{34} cm^{-2} s^{-1})	1	2.11	80

Y. Ohnishi et al.

Design Concept of SuperKEKB

- Re-use the KEKB tunnel.
  - We have no option for polarization at present.
    - Not demanded by Belle II.
- Re-use KEKB components as much as possible.
  - Preserve the present cells in HER.
  - Replace dipole magnets in LER, re-using other main magnets in the LER arcs.

Major Items to Upgrade

- Rebuild IR
- Optics improvements:
  - Tsukuba straight section
  - Arcs
  - Wiggler sections
- Magnets
  - Build or rearrange many magnets
  - Survey and alignment
- New LER beam pipes for electron-cloud suppression
- Beef-up RF system
  - Rearrange cavities
  - Increase number of klystrons: 1/2 kly/cav to 1/1 kly/cav
- Improve speed and resolution of beam monitor and control system:
  - Position: BPMs, digital Bunch-by-bunch feedback
  - Size: (SRM, X-ray)
  - Collision monitors: Large Angle Beamstrahlung Monitor (G. Bonvicini)
- Upgrade the injector linac and beam transport system
- Install a 1.1 GeV positron damping ring
- Increase capacity of cooling system for the magnets and vacuum system

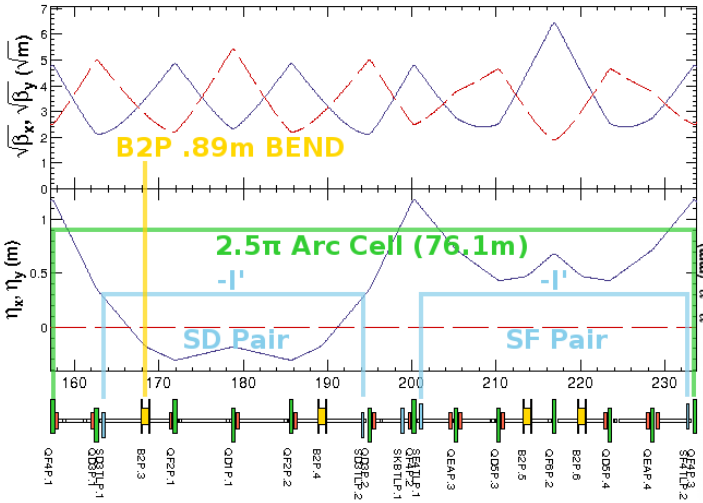
RF

- Beam power requirements at SuperKEKB:
  - HER: 1.5 times
  - LER: 2.5 times higher

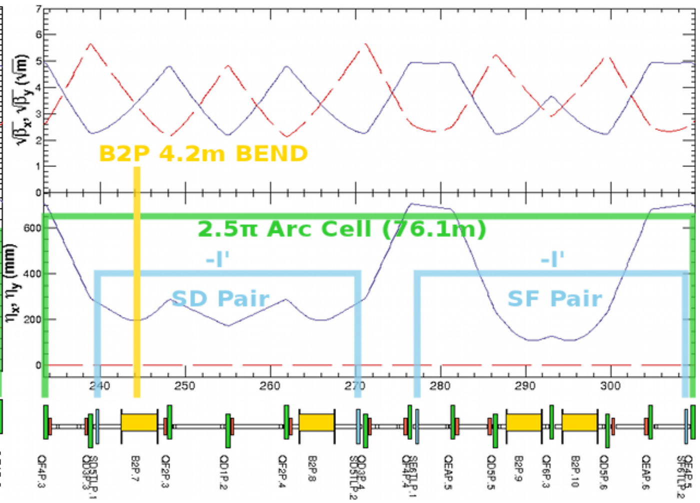
    ↓
- Need to increase the beam power per cavity for both rings, and the number of RF stations where one klystron feeds one ARES cavity with RF power up to 800kW.
- Start with low beam current. At T=0 the maximum current is lower than the design value (maybe 60~70%). Increase to the design current will take two years or more.
  - Start by rearranging cavities
  - Add klystrons in stages as beam currents increase

Optics

LER Arc Cell Changes



KEKB LER



SuperKEKB LER

ε_x = 32.0nm α_c = 4.53 x 10^{-4}
U_0 = 27.1keV

ε_x = 2.48nm α_c = 4.94 x 10^{-4}
U_0 = 10.6keV

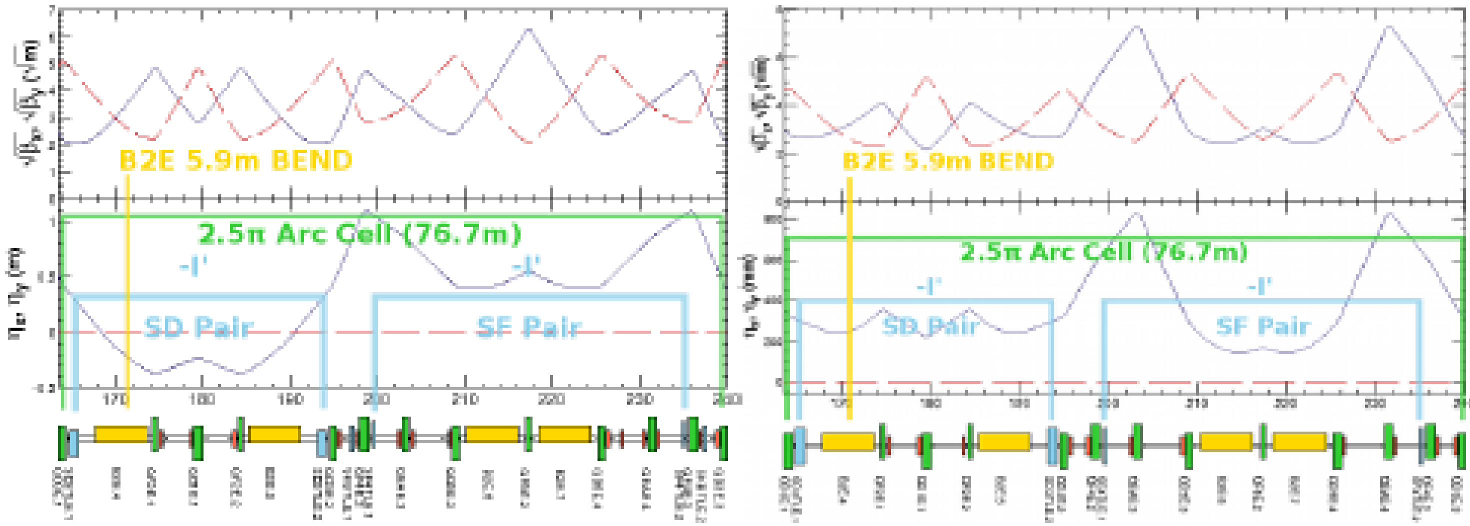
- Keep cell length and focusing structure
  - 2.5π cell & non-interleave chromaticity correction
- Replace main bend(B2P) with 4.2m long bending magnet
- Optimize quadrupole strength to minimize emittance
- Increase beam energy from 3.5GeV to 4GeV to reduce intra beam scattering effect

+Wiggler period shortened, new wigglers added

A.Morita

Optics

HER Arc Cell Changes



KEKB HER

$\varepsilon_x = 24.7\text{nm}$ $\alpha_c = 3.75 \times 10^{-4}$
$U_0 = 120\text{keV}$

SuperKEKB HER

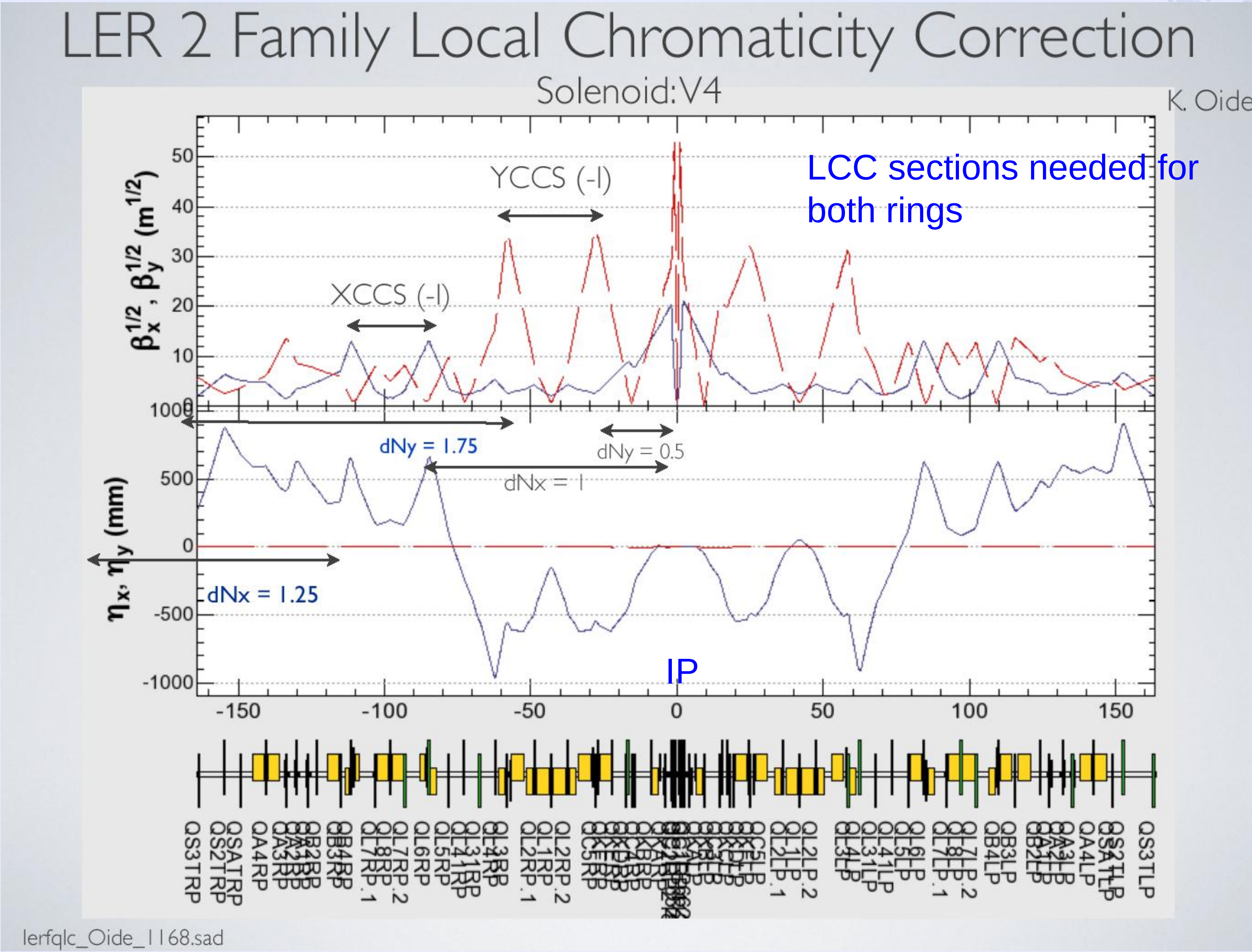
$\varepsilon_x = 4.96\text{nm}$ $\alpha_c = 6.36 \times 10^{-4}$
$U_0 = 70.7\text{keV}$

- Keep arc regular cell structure
  - 2.5π cell & non-interleave chromaticity correction
- Optimize quadrupole strength to minimize emittance
- Decrease beam energy from 8GeV to 7GeV to keep Υ(4s) resonance

+Wigglers added

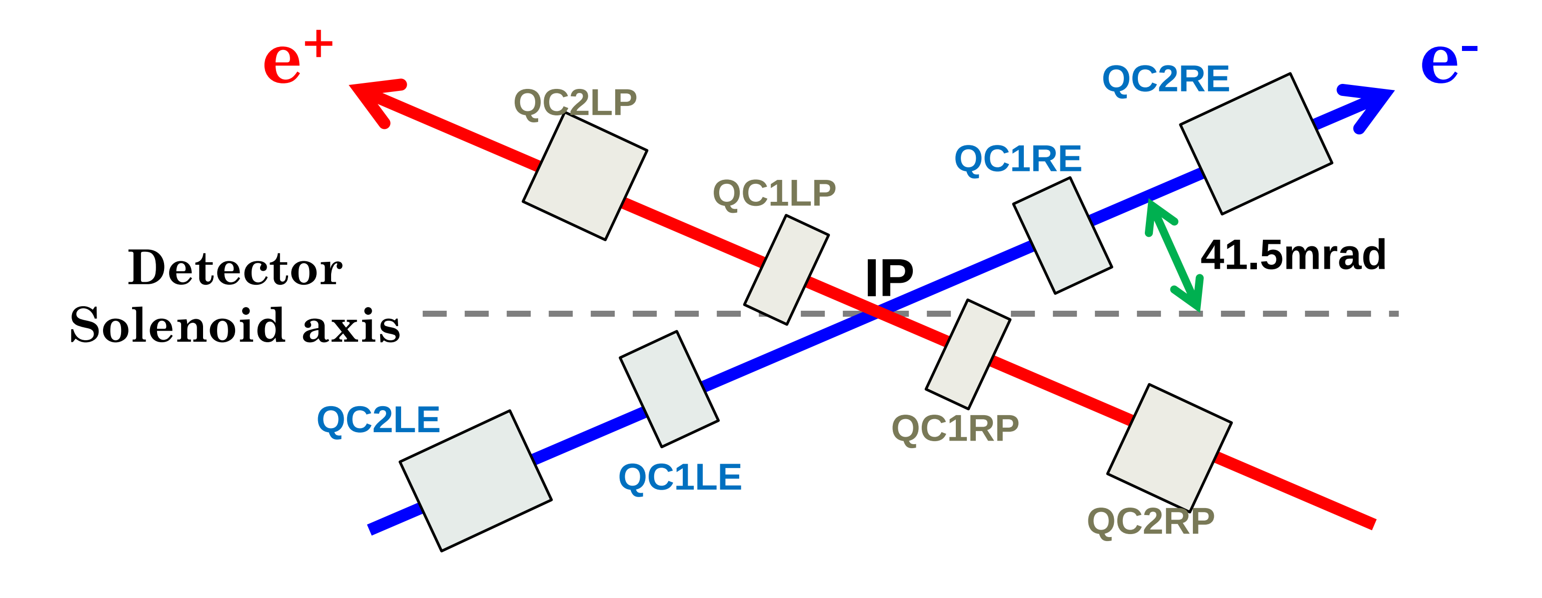
A.Morita

IR with local chromaticity correction



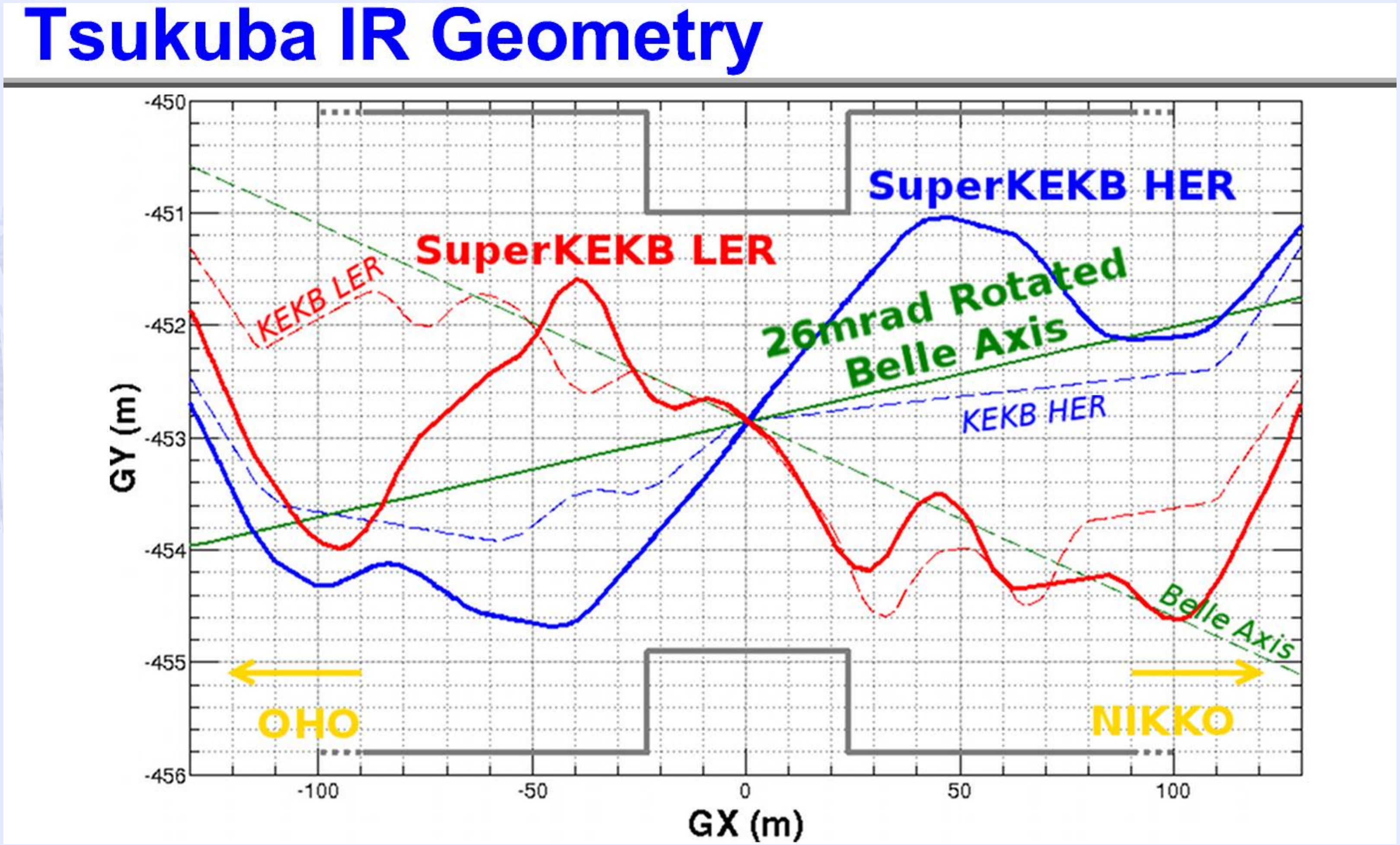
IR layout

- New final focusing system based on the nano-beam scheme has been designed.
  - Consists of **8 superconducting magnets**
  - Final focusing Q-magnets **for each beam**
  - **Crossing angle 83 mrad** to bring the FF magnets closer to IP



N.Ohuchi

IR

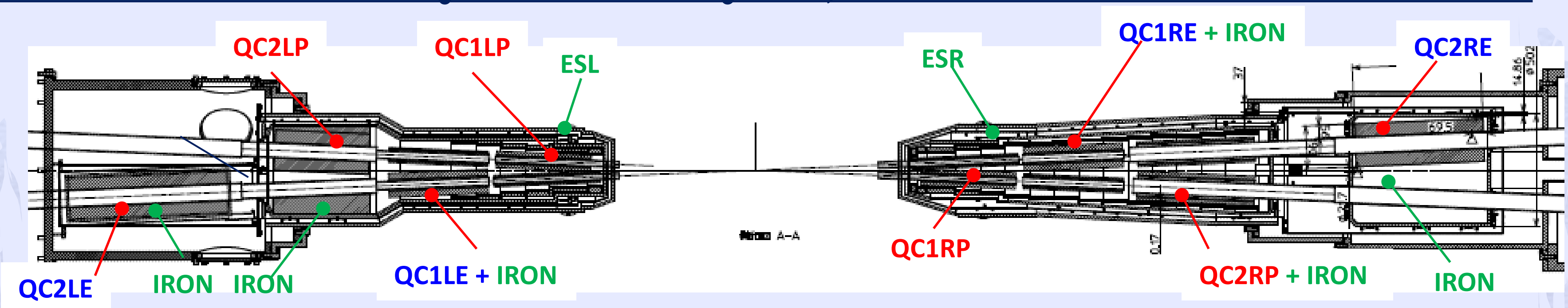


- Need Belle rotation of 26 mrad
  - Need to fit to the existing tunnel.

A.Morita

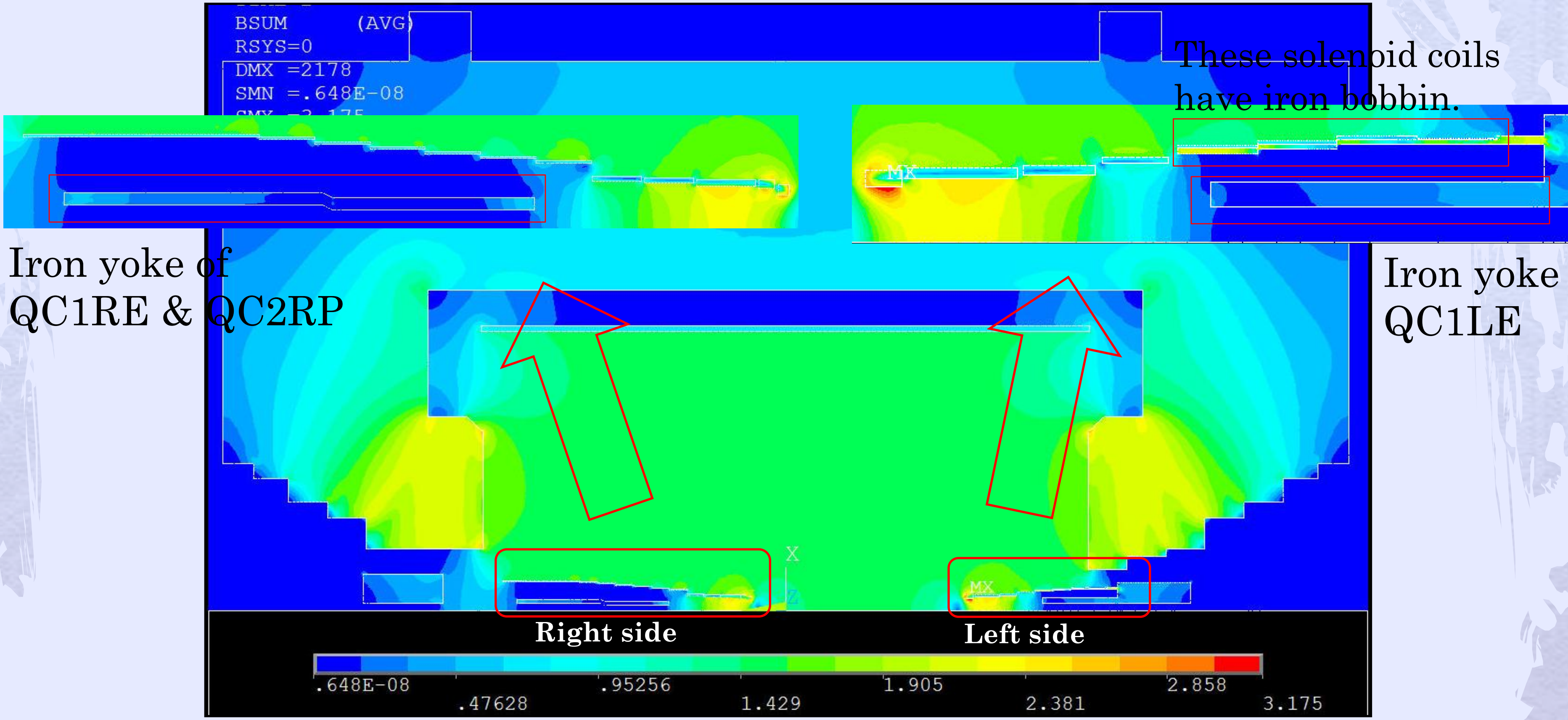
SuperKEKB IR
SC Magnet Configuration

IRON YOKEs for QC1Es and QC2s, and IRON BOBBIN for ESL.

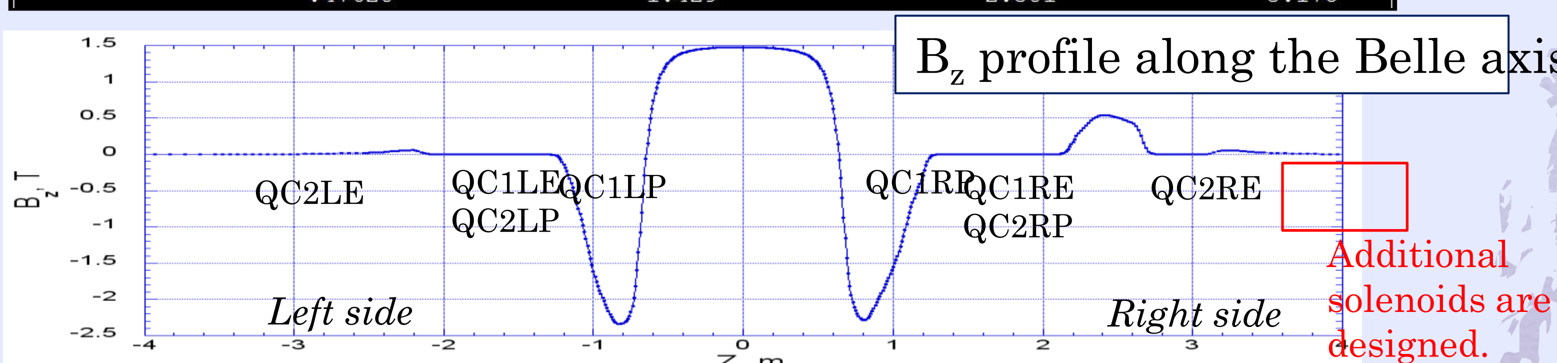


	Magnet type	Integral field gradient, (T/m)·m Solenoid field, T	Corrector	Leak field cancel coil
QC2RE	S.C. Quad. + Iron Yoke	12.91 [34.9 T/m × 0.37m]	a_1, b_1, a_2, b_4	
QC2RP	S.C. Quad. + Iron Yoke	10.92 [30.3 × 0.36]	a_1, b_1, a_2, b_4	
QC1RE	S.C. Quad. + Iron Yoke	26.22 [79.03×0.36]	a_1, b_1, a_2, b_4	
QC1RP	S.C. Quad.	22.43 [66.52×0.337]	a_1, b_1, a_2, b_4	b_3, b_4, b_5, b_6
QC1LP	S.C. Quad.	22.91 [67.94×0.337]	a_1, b_1, a_2, b_4	b_3, b_4, b_5, b_6
QC1LE	S.C. Quad. + Iron Yoke	26.03 [82.75×0.36]	a_1, b_1, a_2, b_4	
QC2LP	S.C. Quad. + Iron Yoke	10.96 [30.4 × 0.36]	a_1, b_1, a_2, b_4	
QC2LE	S.C. Quad. + Iron Yoke	14.13 [20.2×0.70]	a_1, b_1, a_2, b_4	
ESR	S.C. Solenoid	2.6 T [in the Belle solenoid field]		
ESL	S.C. Solenoid + Iron Bobbin	3.0 T [in the Belle solenoid field]		

Solenoid field profile with iron components in 2D



Iron yoke of QC1LE

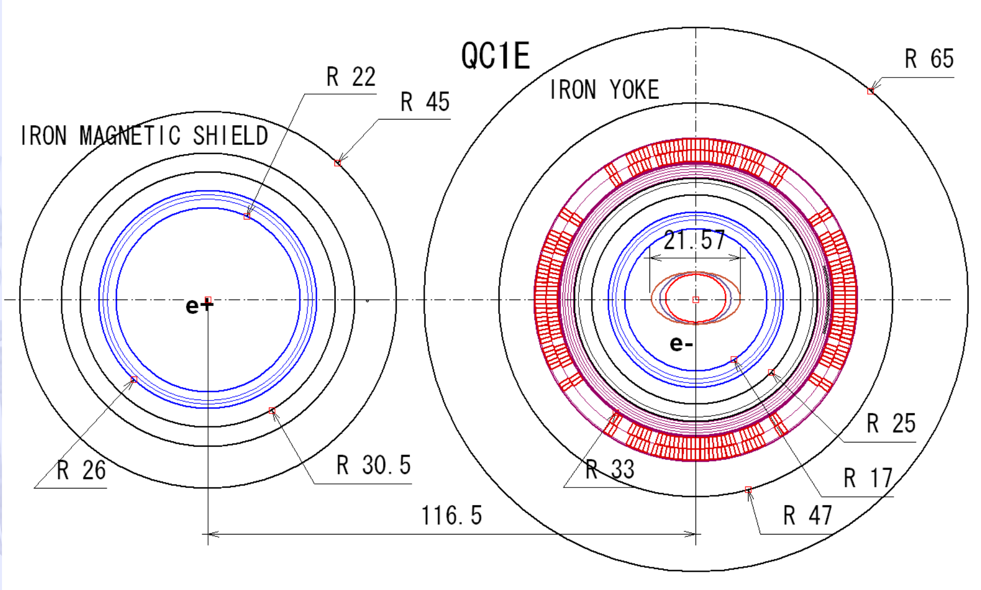


Additional solenoids are designed.

3D calculation model is now being constructed.

QC magnets with iron yoke

QC1E Magnet cross section

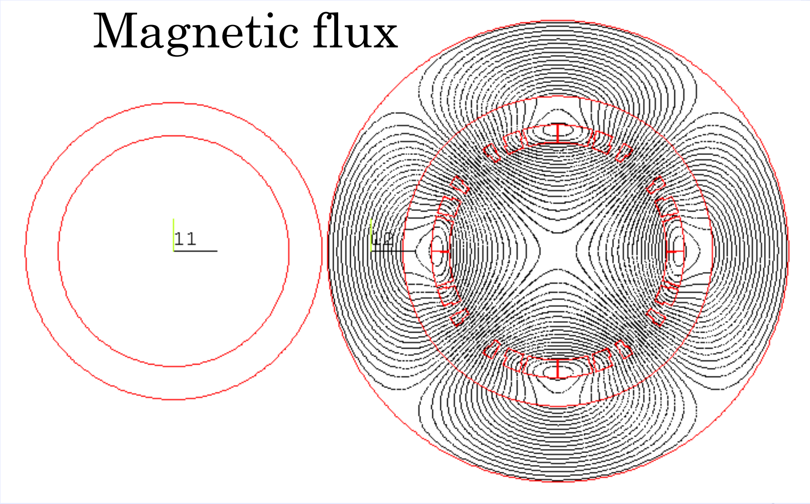


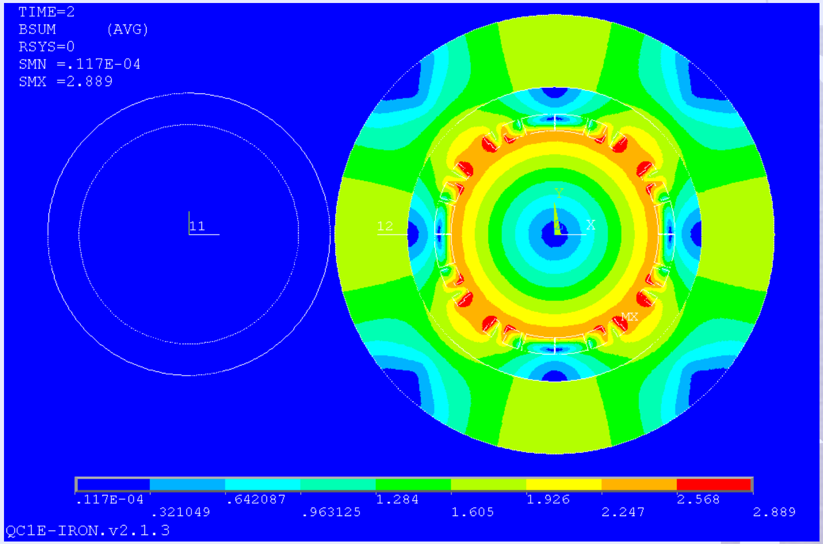
The leak field from QC1E is shielded with the iron yoke of QC1E and the iron pipe on the e- beam line

QC1E magnet design parameter

- Field gradient ＝70.68 T/m
- Maximum field in the coil ＝2.69 T
- Design current＝1559A
  - Current density in the coil＝599.6 A/mm^2
- Operating point w.r.t the critical point = 67.2 %

Magnet field calculation in 2D





3D calculation model is now being constructed.

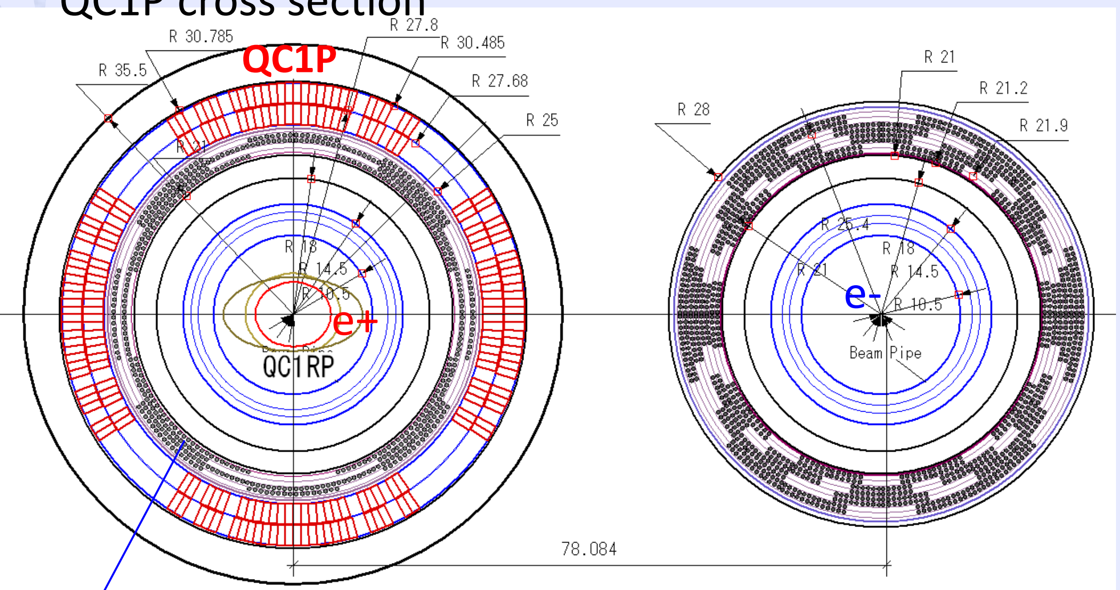
Field strength in QC1E

QC1P (No iron yoke)

QC1Ps are operated in the solenoid fields at the peak fields of 2.34 T and 2.29 T in the left and right sides of IP, respectively.

No iron components
The leak field of QC1P is canceled by the SC coils of b_3, b_4, b_5 and b_6

QC1P cross section



QC1P magnet design parameter

- Field gradient ＝67.98 T/m
- Maximum field in the coil ＝3.93 T
- Design current＝1609A
  - Current density in the coil＝819.6 A/mm^2
- Operating point w.r.t the critical point = 79 %

SC correctors: a_2, b_1, a_1, b_4

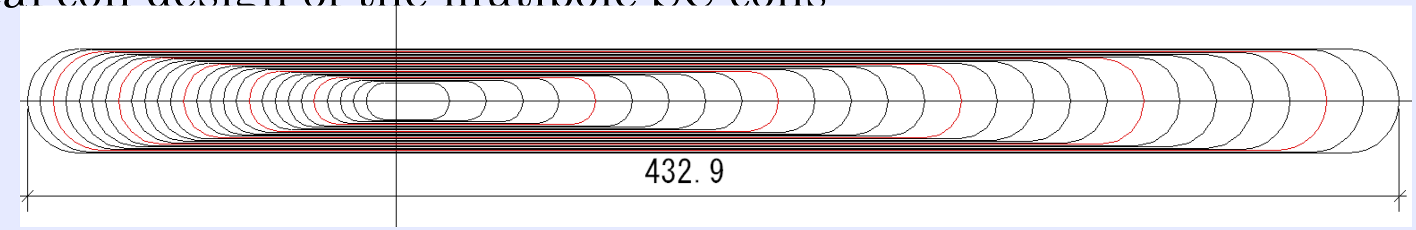
Leak field cancel coils: b_3, b_4, b_5, b_6

R&D of corrector coils (Octupole)

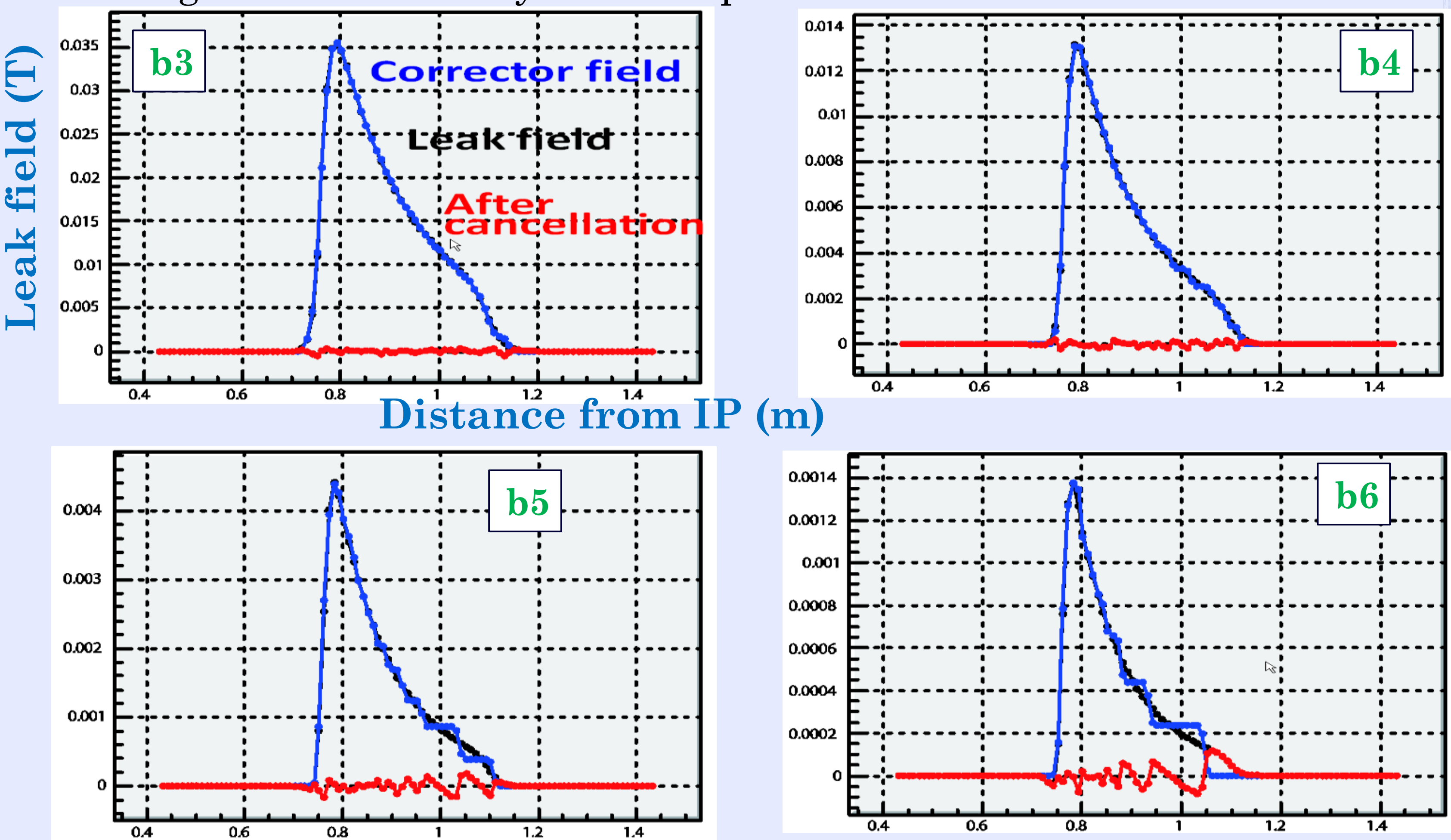
The 1st R&D QC1P magnet with correctors will be tested in October.

QC1P leak field cancellation coil

Typical coil design of the mutipole SC coils

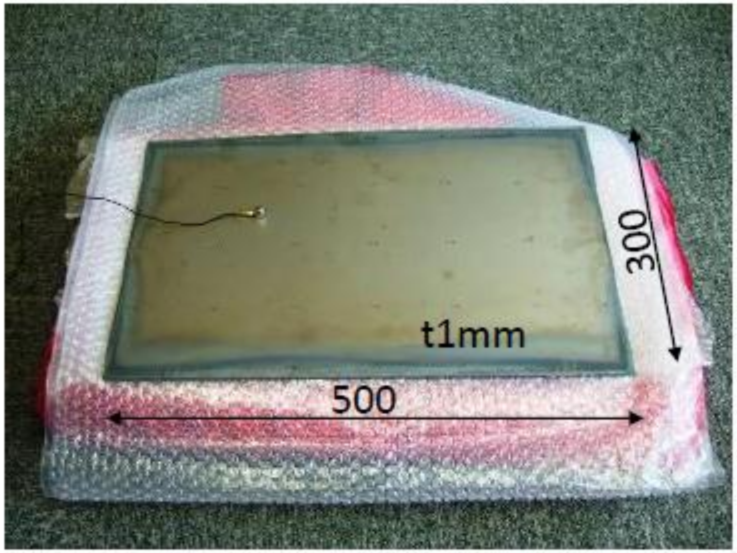


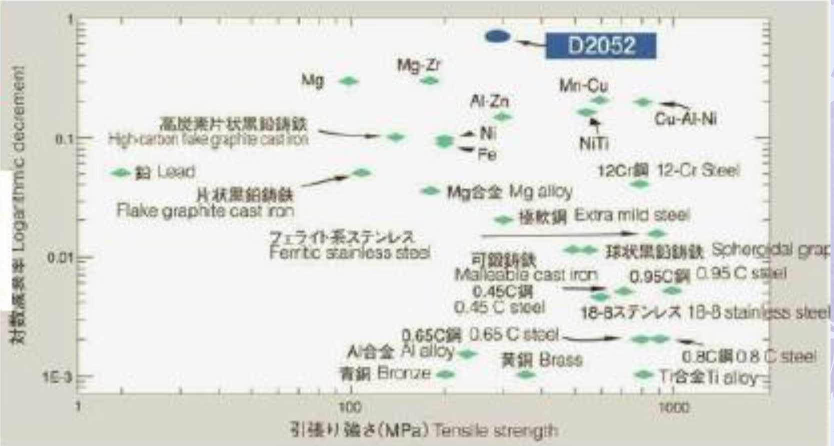
Cancelling the leak fields by SC multipole coils



R&D : Cryostat vibration

- High vibration dumping material test

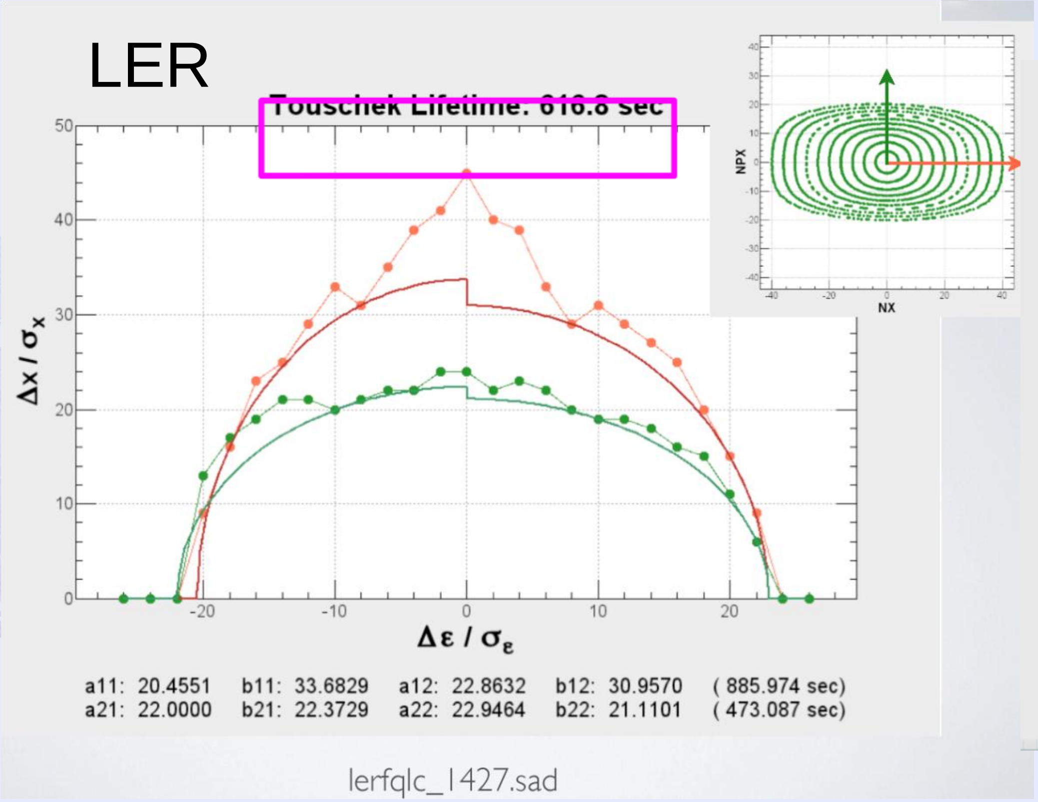


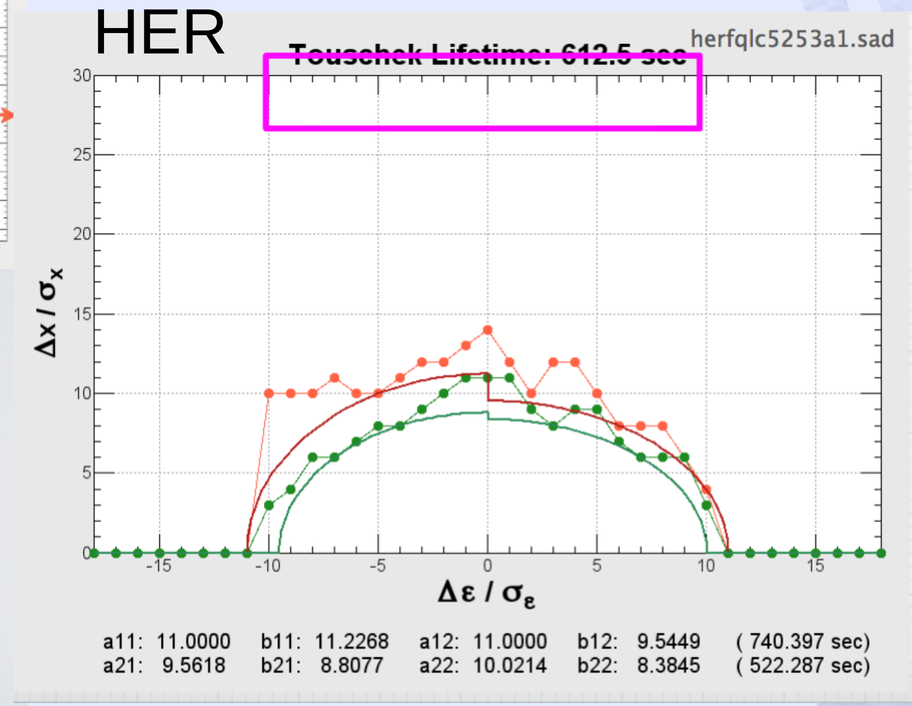


Mn	Cu	Ni	Fe	単位 Unit
Bal.	22.4	5.2	2.0	wt%
Bal.	20.0	5.0	2.0	at%

N. Ohuchi

IR optics





- **Dynamic apertures of both rings are limited by nonlinear leakage fields of IR magnets for counter-rotating beams. More serious in LER.**
- Recent tuning of IR compensation fields
    - => **Beam lifetimes>600 sec**
    - More than sufficient to maintain maximum beam currents
        - Maximum injection rates:
            - LER: 4 nC/bunch, 2 bunches/pulse, 25 Hz
            - HER: 5 nC/bunch, 2 bunches/pulse, 25 Hz

K. Oide, Y. Ohnishi, A. Morita, N. Ohuchi

Orbit Control at IP

- $1/10\sigma_y$ vertical offset causes ~ 2% luminosity loss.
- The offset mainly comes from the mechanical vibration of IR quadrupoles.
- Simulation of vibration of QC1 is going on based on data of floor vibration at Tsukuba. Main component appears near 50Hz.

- The vertical orbit change at IP due to simulated QC1 vibration is estimated to be $\sim 5\sigma_y^*$. Faster IP orbit feedback than used at KEKB is needed.
- Simulation study of the IP orbit feedback has just started to determine specification of the feedback system.
- Measures to reduce the vibration of IR quadrupoles such as improved support structures will be studied further.

Y.Funakoshi

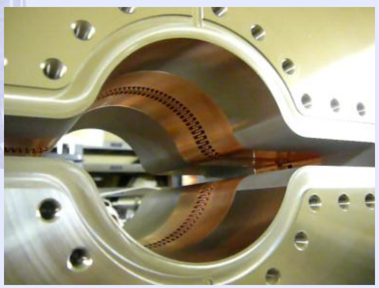
Vacuum System

- To cope with the electron cloud issues and heating problems, ante-chamber type beam pipes will be adopted in the LER with a combination of TiN coatings, grooved shape surfaces, and clearing electrodes.
- Upgrade of vacuum system for SuperKEKB is underway.
- Most design and R&D for key components is finished.
- Further studies are required for movable masks.
  - May borrow PEP-II design
- Baking and TiN coating facilities will be ready this year.
- Manufacturing of beam pipes and bellows chambers for LER wiggler sections started last year.
- For LER arc and straight sections, they will start this year.
- Remaining parts of LER and HER will follow.

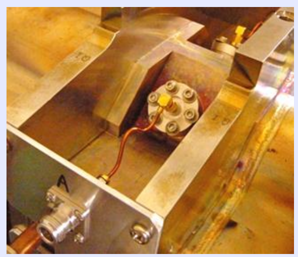
Vacuum Components

- Beam pipes:
  - Antechambers for reduced photoelectron density, low beam impedance, low SR power density
  - Aluminum alloy for for LER arc section . Copper is required for wiggler section (and HER).
  - Fabricate by cold-drawing technique (copper) or extrusion technique (aluminum)
  - Copper beam pipes have been tested in KEKB.

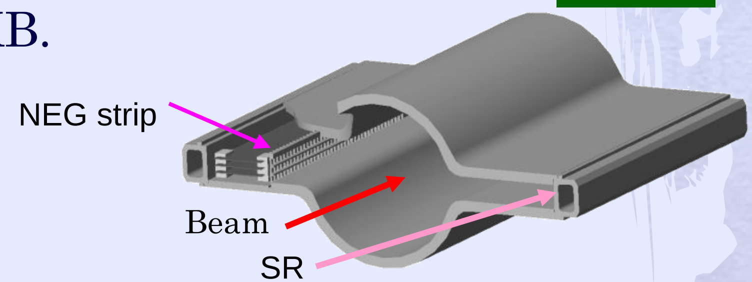
Gate valve



BPM



Concept

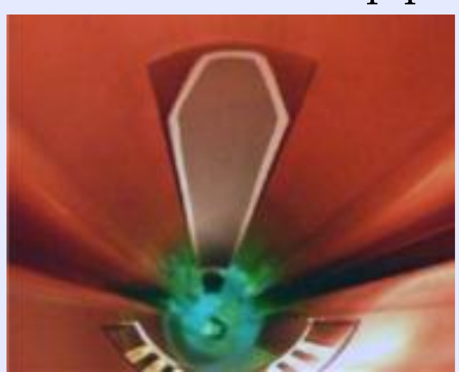


Gate valve

Bellows chamber

Electrode

Suppress electrons inside the beam pipe



Grooves

Suppress secondary electron emission

Y. Suetsugu

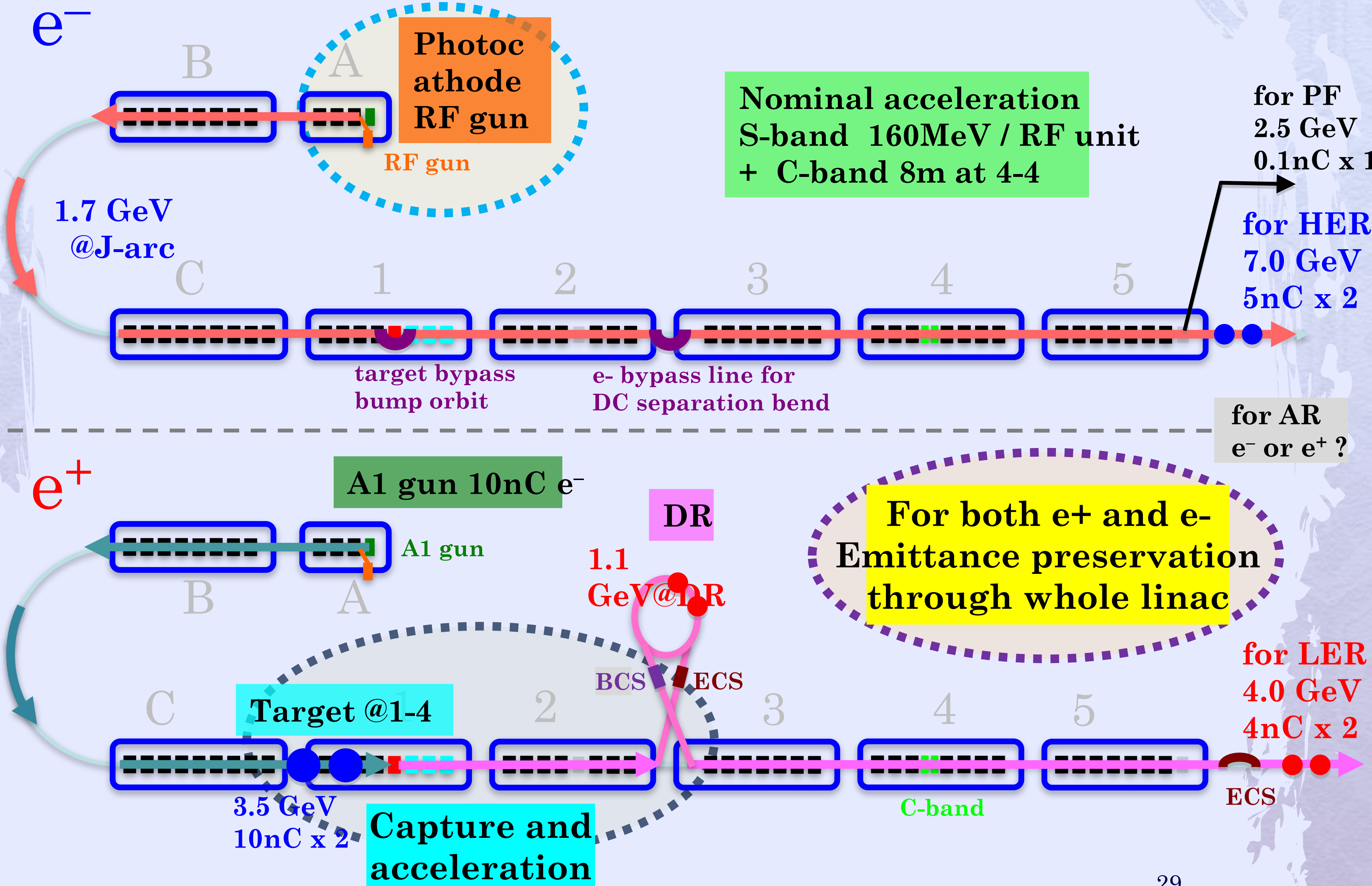
Injector Linac

- High charge positron source and low-emittance RF electron gun are designed to improve the rate and quality of injected beams to deliver the required beams with increased injection efficiencies.

	KEKB obtained (e+ / e-)	SuperKEKB required (e+ / e-)
Beam energy	3.5 GeV / 8.0 GeV	4.0 GeV / 7.0 GeV
Bunch charge	e- → e+ / e- 10 → 1.0 nC / 1.0 nC	e- → e+ / e- 10 → 4.0 nC / 5.0 nC
Beam emittance (γε)[1σ]	2100 μm / 300 μm	6 μm / 20 μm

- e^- :
  - High Charge
  - Low emittance ⇒ Photo RF gun
- e^+:
  - High Charge ⇒ Adiabatic matching device + Large aperture accel.
  - Low emittance ⇒ Damping Ring
- Emittance preservation ⇒ **Alignment**, dispersion, wake, CSR
- Simultaneous injection
  - Pulse-to-pulse optics ⇒ Pulse magnet

Injector Linac



T.Higo

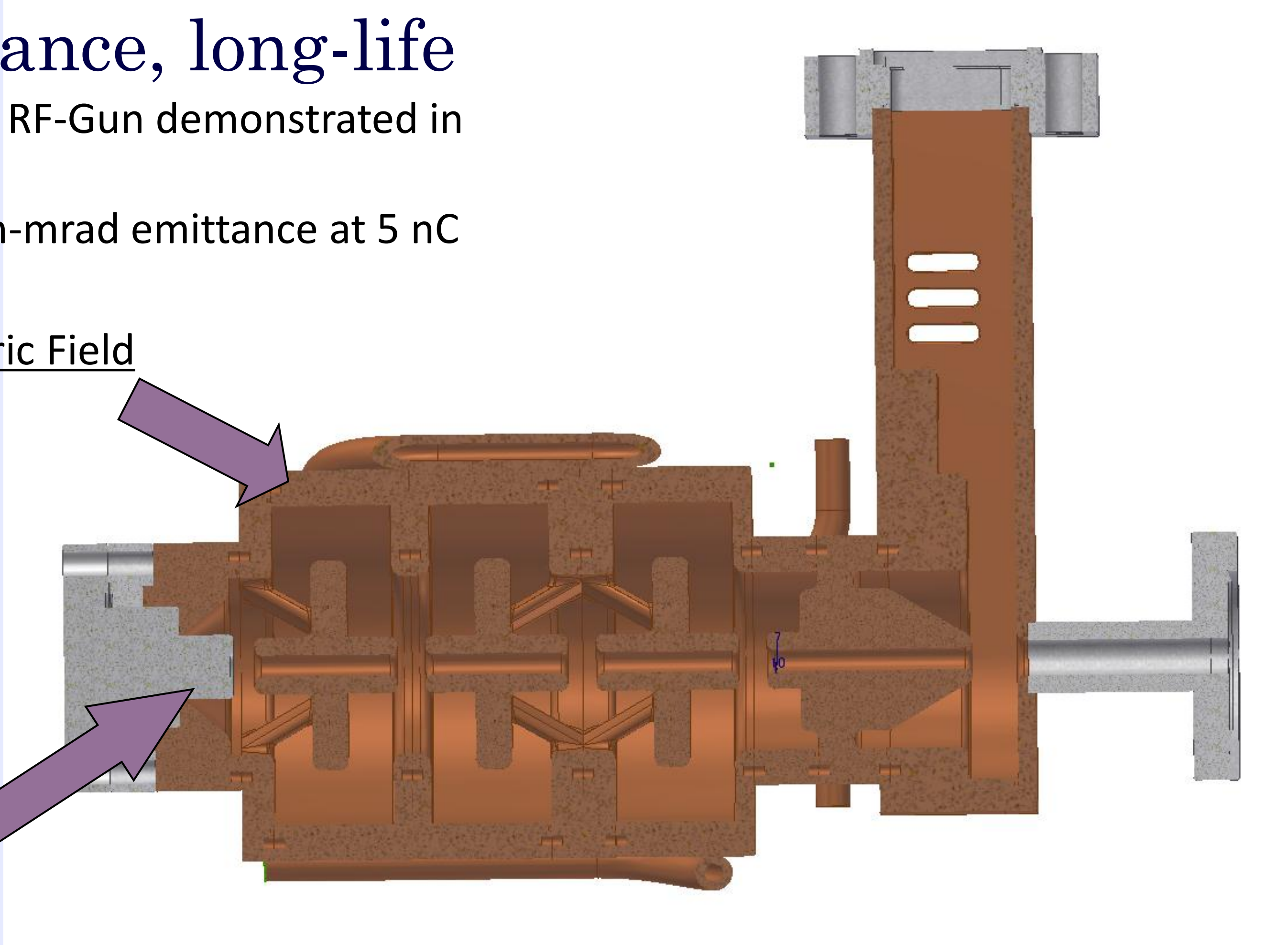
DAW + LaB_6 (or Ir_5Ce)

- Low-maintenance, long-life

LaB_6 hot cathode DAW RF-Gun demonstrated in 2008 at Rika U.
Simulations show 6 mm-mrad emittance at 5 nC bunch charge

Cavity : Lower Electric Field

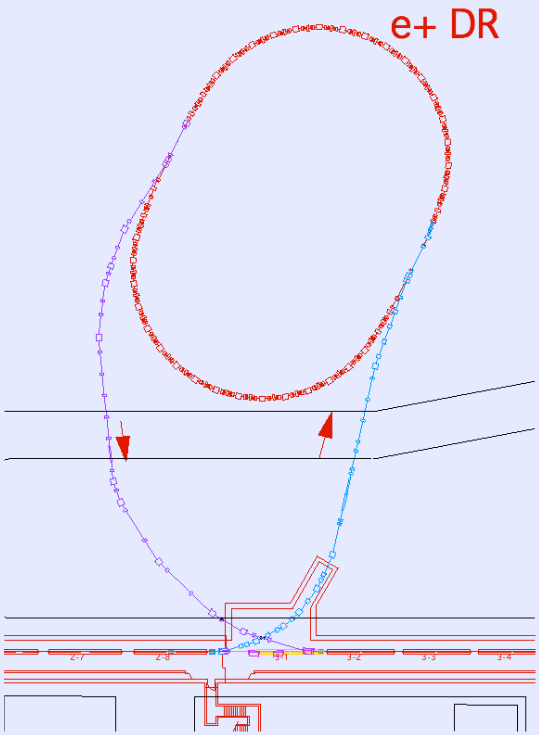
- Stable operation
- Short Aging Time



Stable cathode : LaB_6 or Ir_5Ce

- Inactive, Solid (no thin film), High Melting Temperature : life time >> Cs_2Te
- Work function ϕ =2.8 eV(LaB_6), 2.57 eV(Ir_5Ce) : laser power << metal

Damping Ring



Energy	1.1	GeV
No. of bunch trains/ bunches per train	2 / 2	
Circumference	135.5	m
Maximum stored current*	70.8	mA
Energy loss per turn	0.091	MV
Horizontal damping time	10.9	ms
Injected-beam emittance	1700	nm
Equilibrium emittance(h/v)	41.4 / 2.07	nm
Coupling	5	%
Emittance at extraction(h/v)	42.5 / 3.15	nm
Energy band-width of injected beam	± 1.5	%
Energy spread	0.055	%
Bunch length	6.5	mm
Momentum compaction factor	0.0141	
Number of normal cells	32	
Cavity voltage for 1.5 % bucket-height	1.4	MV
RF frequency	509	MHz
Inner diameter of chamber	32	mm
Bore diameter of magnets	44	mm

* 8 nC/bunch

- Requirements:
  - Injection aperture of LER = 0.7 μm
    - ⇒emittance of injected beam < 14.5 nm
  - lifetime of LER = 600 sec
    - ⇒ intensity of injected beam = **4 nC/bunch** (30% injection efficiency)
- Lattice parameters optimized to suppress microwave instability due to CSR.
- Electron cloud density is below instability threshold.
- Chamber design employing antechamber has been proposed. Fabrication of chambers is scheduled for FY2012.

M.Kikuchi

Beam Instrumentation

- BPM and feedback systems for higher currents and resolution.
- Photonic instrumentation:
  - SR monitors
    - Interferometer (transverse size)
    - Streak camera (bunch length)
  - X-ray monitors
    - Bunch-by-bunch vertical size
  - Beamstrahlung monitor
    - Beam collision monitoring

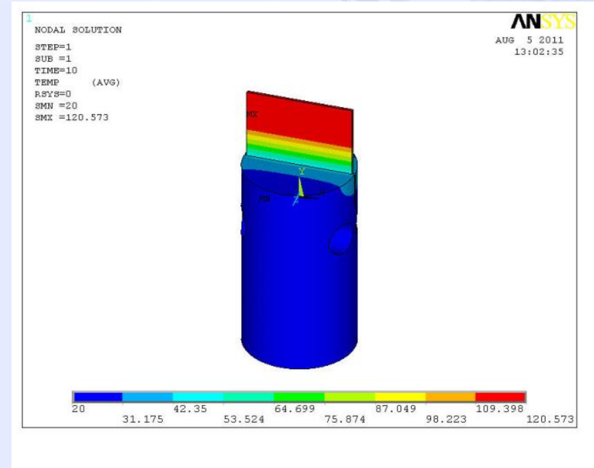
SRM Extraction Mirror

- Heat load on extraction mirrors a problem at high currents
  - Causes deformation of mirror, and change in apparent beam size.

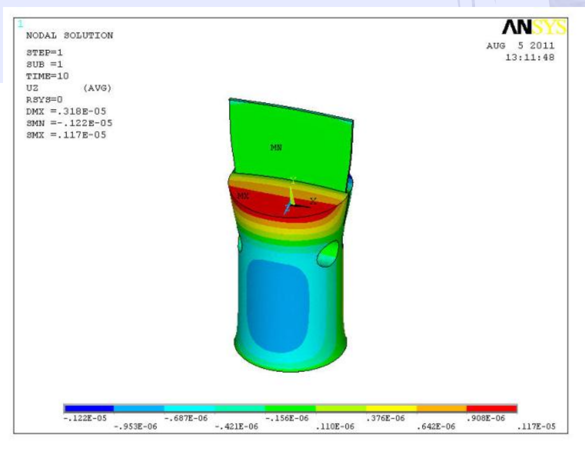
	LER (BSWFRP)		HER (BSWOLE)	
	SuperKEKB	KEKB	SuperKEKB	KEKB
Energy(GeV)	4	3.5	7	8
Current(A)	3.6	2	2.6	1.4
Bending radius(m)	177.4	85.7	580	580
Power(W/mrad)	72	48	149	136
Distance to mirror (m)	11	11	13	13
Mirror width (mm)	35	35	35	35
Total incident power(W)	161	109	283	260

SRM: Diamond Mirrors

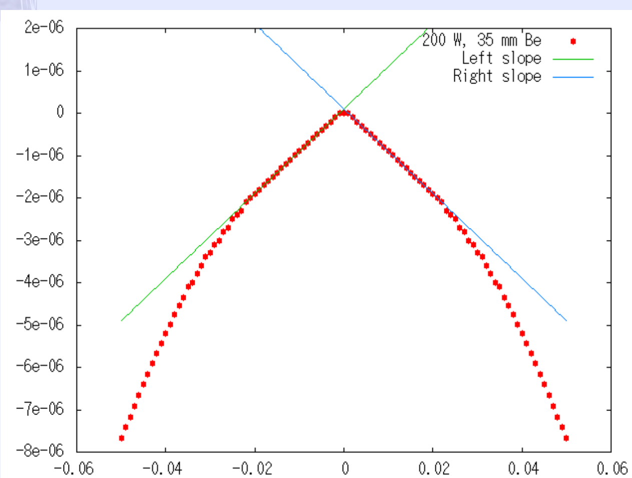
- Monocrystalline diamond
  - Thickness 500 µm
    - 10 mm x 20 mm mirror prototype made
    - 20 mm x 20 mm needed, now possible
  - 3 micron Au surface coating
  - Monocrystalline diamond makes for good surface flatness (<~λ/50)
  - Better heat transfer and thermal expansion coefficients than the beryllium used at KEKB:
    - Berylllium: δmagnification = 43% @ HER full current
    - Diamond: δmagnification = ~7% @ HER full current



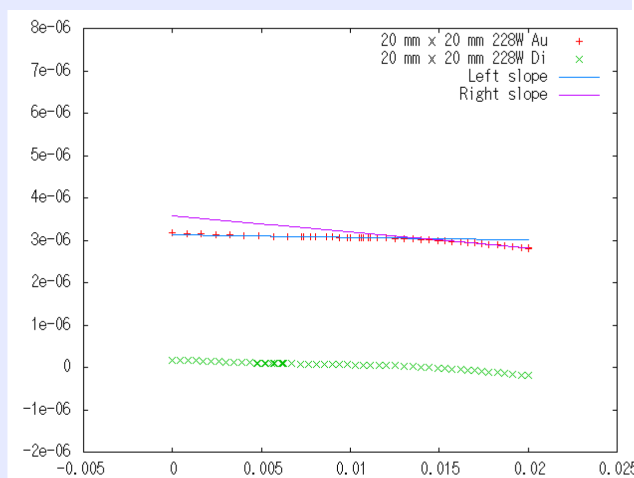
Diamond mirror temperature distribution w/ 228W of SR



Diamond mirror surface distortion w/ 228W of SR



Mirror surface distortion due to 200W of SR power at center of Be mirror



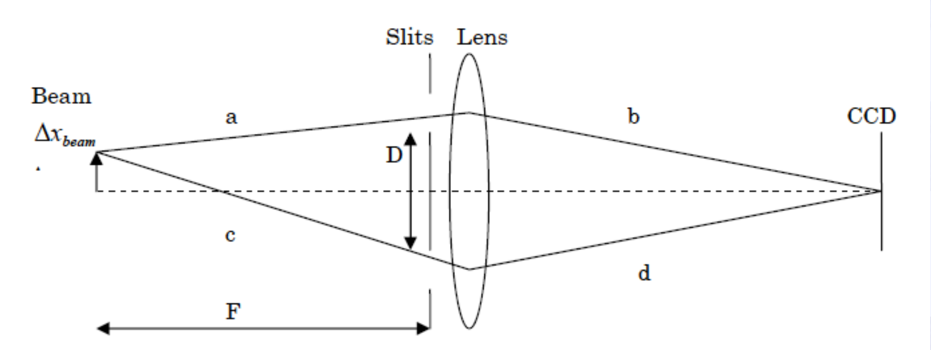
Mirror surface distortion due to 228W of SR power at center of Au+Dia mirror

ANSYS simulations: M. Arinaga

SRM: Interferometers

SR Source Bend Parameter	S-LER1 (BSWFRP)	S-HER (BSWOLE)	Units
ε_x	3.20E-09	4.60E-09	m
κ	0.27%	0.24%	
ε_y	8.64E-12	1.10E-11	m
β_y	29.98	32.49	m
σ_y	16.1	18.9	μm
Beam Energy	4	7	GeV
Bend effective length	0.89	2.90	m
Bend angle	5.04	5.00	mrad
Bend radius ρ	179.0	580.0	m
Observation wavelength λ	4.00E-07	4.00E-07	m
SR Opening angle θ_c (λ)	1.0	0.7	mrad
Slits opening angle D/F	0.7	0.7	mrad
Max. Visibility (fringe depth) γ_{max}	99%	99%	
Min. measurable beam size $\sigma_{y\ min}$	12.8	13.5	μm

- Resolution fundamentally limited by measurement wavelength and opening angle between slits from beam (D/F).
- Max. slit separation determined by beam spread and mechanical considerations.

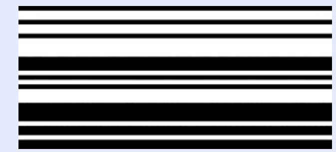


- Vertical beam size measurement is possible with interferometers, though is near the limit of the interferometer resolution.
- Measurement wavelength needs to be lowered to fit beam size into dynamic range.

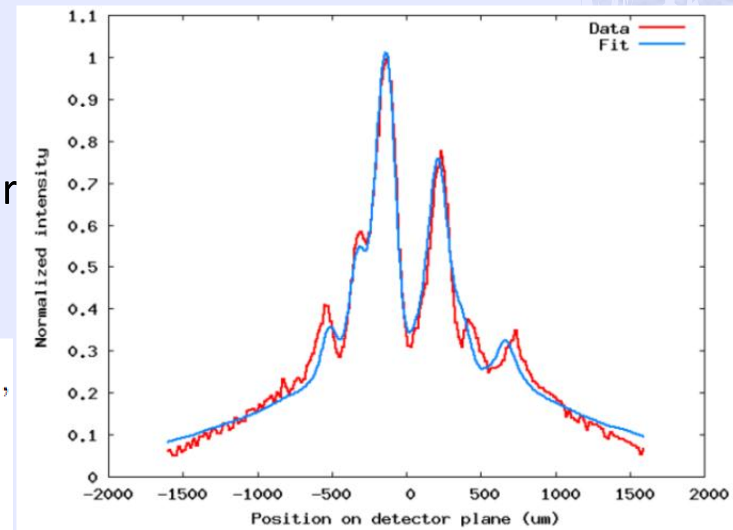
  Also need to be able to measure 99% visibility. (Very difficult!)
- Limitation on slit separation is due to antechamber height (14 mm).
  - ◊Extraction mirror will be in antechamber for reduced impedance.

X-ray monitor using Coded Aperture Imaging

Technique developed by x-ray astronomers using a mask to modulate incoming light. Resulting image must be deconvolved through mask response (including diffraction and spectral width) to reconstruct object. Open aperture of 50% gives high flux throughput for bunch-by-bunch measurements. Heat-sensitive and flux-limiting monochromator not needed.



We need such a wide aperture, wide spectrum technique for shot-by-shot (single bunch, single turn) measurements.



Measured slow-scan detector image (red) at CesrTA, used to validate simulation (blue)

Source distribution:

$$\begin{bmatrix} A_\sigma \\ A_\pi \end{bmatrix} = \frac{\sqrt{3}}{2\pi}\gamma\frac{\omega}{\omega_c}\left(1+X^2\right)(-i)\begin{bmatrix} K_{2/3}(\eta) \\ \frac{iX}{\sqrt{1+X^2}}K_{1/3}(\eta) \end{bmatrix},$$

where

$$X = \gamma\psi,$$

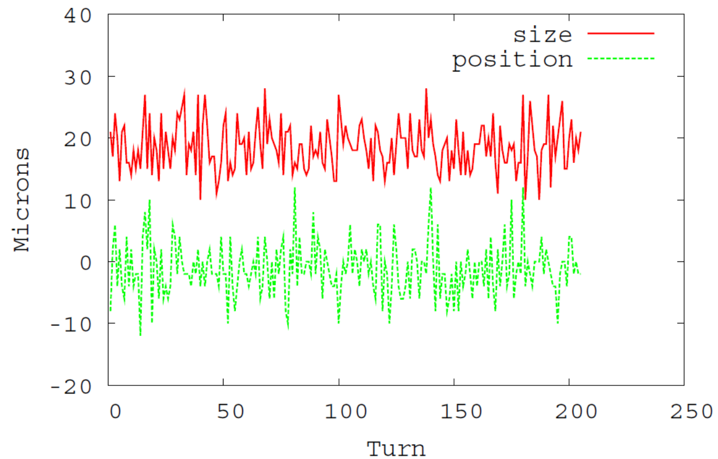
$$\eta = \frac{1}{2}\frac{\omega}{\omega_c}\left(1+X^2\right)^{3/2},$$

+

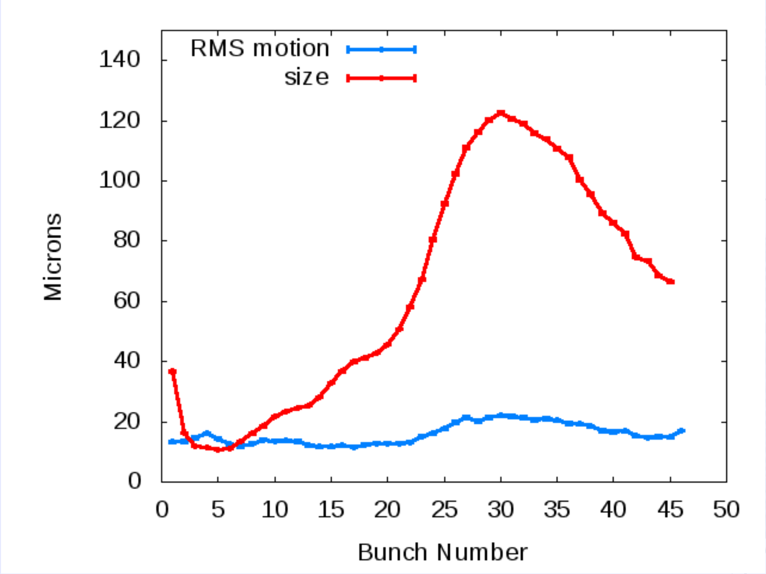
Kirchhoff integral over mask
(+ detector response)
→ Detected pattern:

$$A_{\sigma,\pi}(y_d) = \frac{iA_{\sigma,\pi}(\text{source})}{\lambda}\int_{\text{mask}}\frac{t(y_m)}{r_1 r_2}e^{i\frac{2\pi}{\lambda}(r_1+r_2)} \times \left(\frac{\cos\theta_1+\cos\theta_2}{2}\right)\mathrm{d}y_m,$$

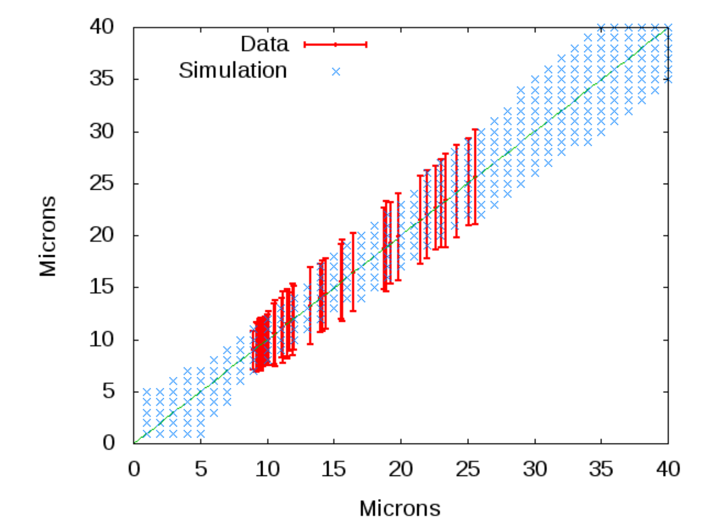
XRM: Coded Aperture tests at CesrTA



Example of turn-by-turn size and position data (one bunch out of

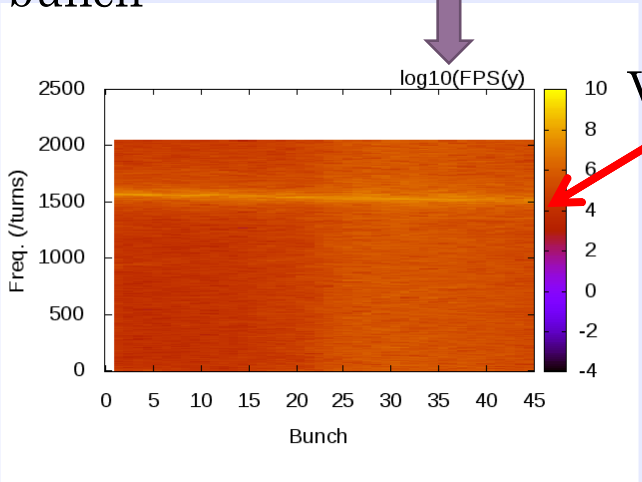


Example of bunch-by-bunch data (electron-cloud blow-up study data)
Single-shot data average for each bunch



Single-shot resolution (simulation + measured spread)

Bunch-by-bunch position spectra

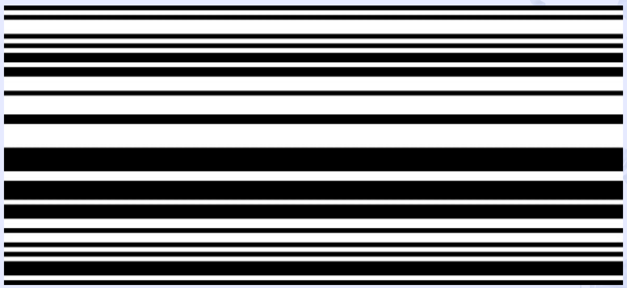


V. tune

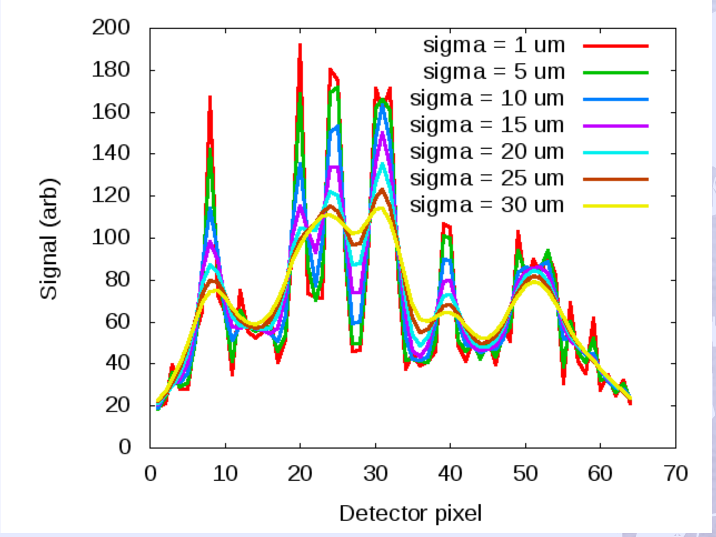
SuperKEKB x-ray monitor

Xray Source Bend Par.	S-LER (BS2FRP.1)	S-HER (BS2E.82)	Units
ε_x	3.20E-09	4.60E-09	m
κ	0.27%	0.24%	
ε_y	8.64E-12	1.10E-11	m
β_y	50.0	11.5	m
σ_y	20.8	11.3	μm
Beam Energy	4	7	GeV
Effective length	0.89	5.9	m
Bend angle	28.0	55.7	mrad
ρ	31.7	105.9	m
Critical Energy	4.4	7.1	keV

- Mask:
  - 59-element, 10 μm/element URA
  - High-power design
    - 10 μm Au mask
    - Substrate:
      - 625 μm Si
      - 300 μm diamond
    - Test at CesrTA
- Detector:
  - 64-channel, 50 μm pitch



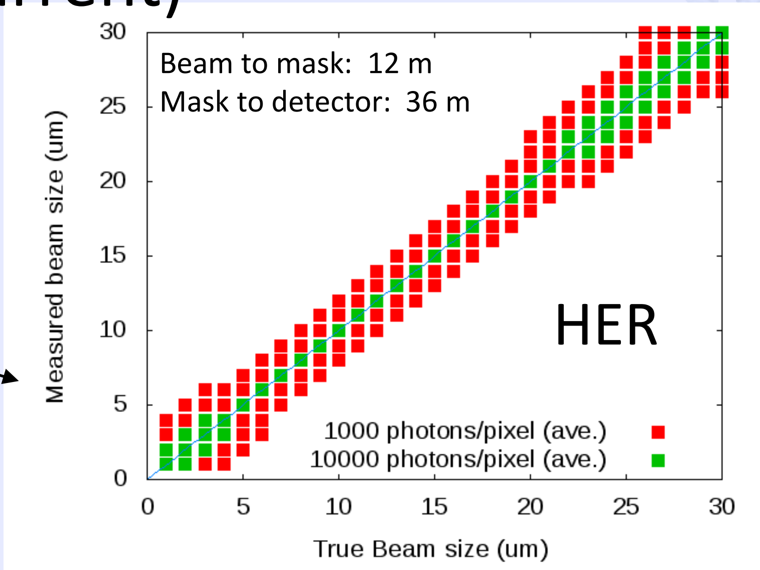
Uniformly Redundant Array (URA) for x-ray imaging to be used at SuperKEKB

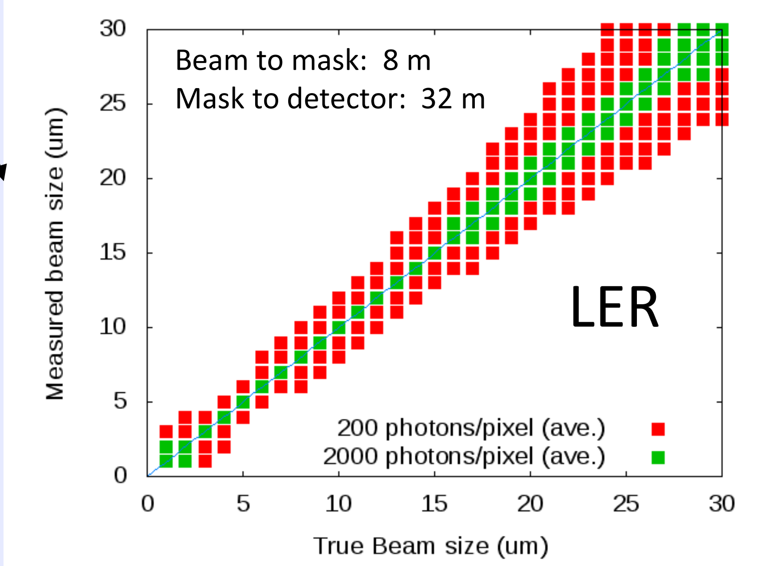


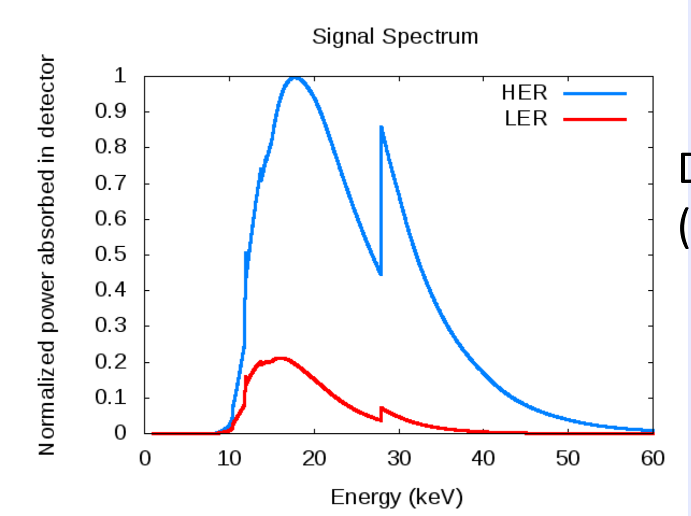
Simulated detector response for various beam sizes at SuperKEKB LER

SuperKEKB Estimated single-shot resolutions (SuperKEKB full current)

- Red points: using 64-pixel detector of same type as at CesrTA
- Green points: using detector with improved photon detection efficiency at higher x-ray energies
  - Deep pixel designs being pursued.



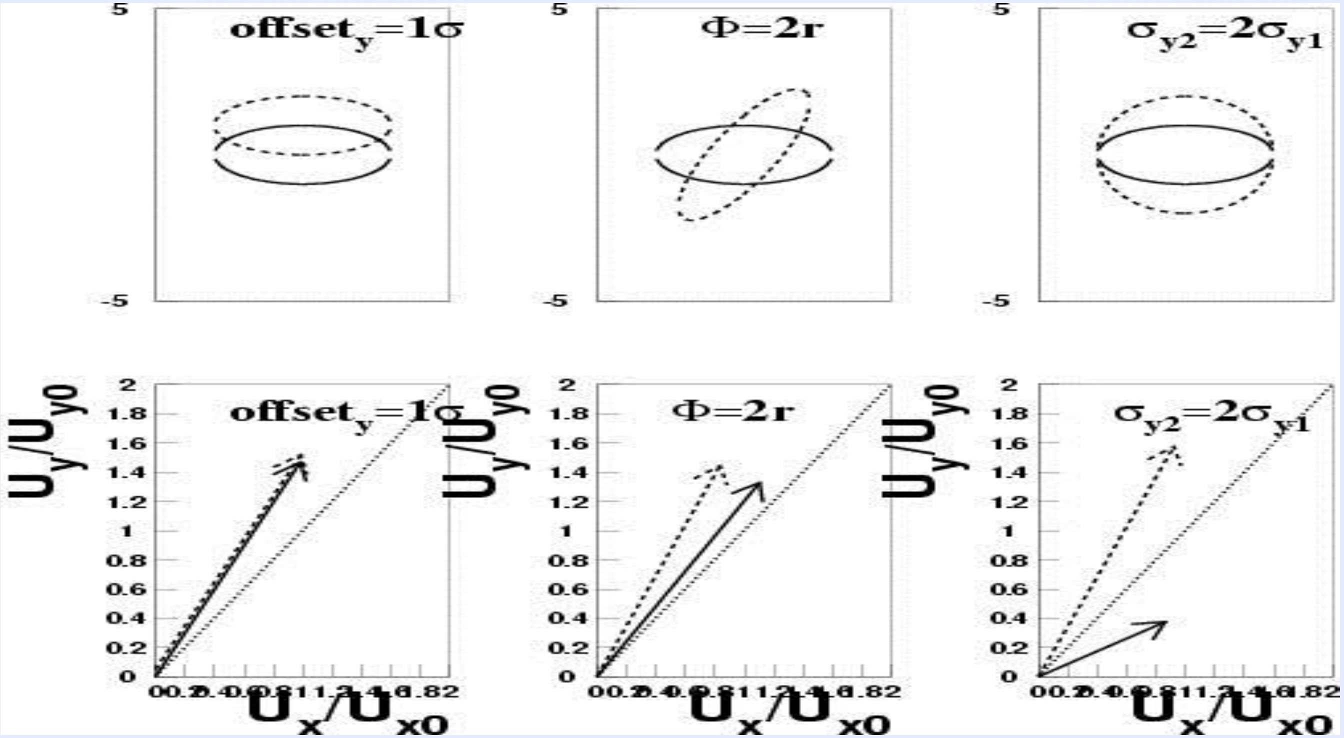




Detected spectrum (Fermionics detector)

LABM: Large Angle Beamstrahlung Monitor

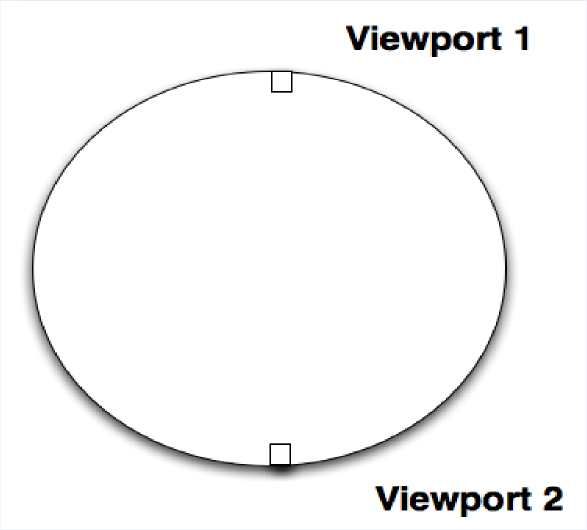
- The radiation of the particles of one beam due to the bending force of the EM field of the other beam
- Beamstrahlung POLARIZATION at specific azimuthal points provides unique information about the beam-beam geometry.

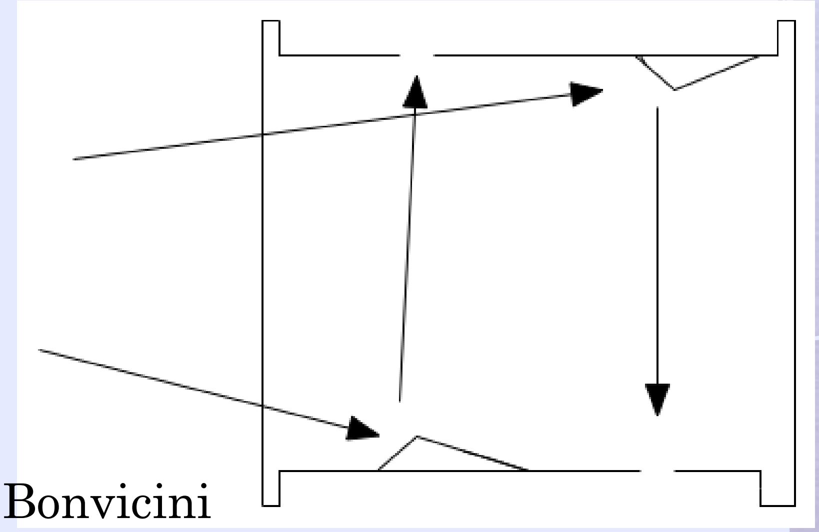


G. Bonvicini

LABM: Beam pipe insert

- View port location at ±90 degrees minimizes backgrounds, polarization measurement errors, and provides redundancy against beam orbit errors
- Located 4.8 m downstream of IP in HER, 3.7 m downstream in LER.
- Mirror and window sizes: 2.83X2 mm^2 and 2.1X2.1 mm^2





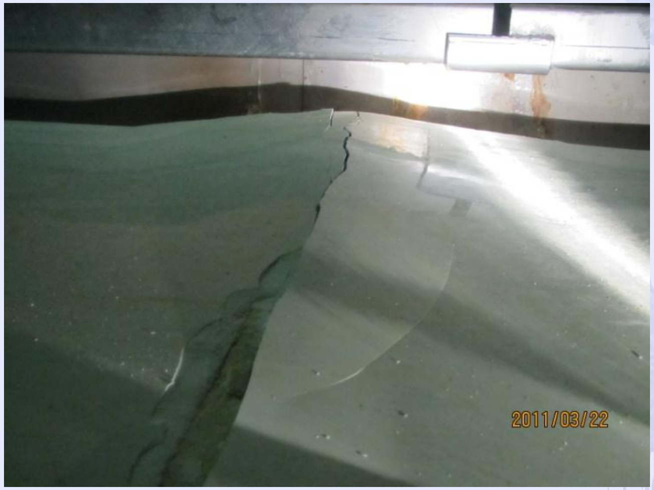
G. Bonvicini

Magnets

- A large number of magnets need to be rearranged, replaced, and added to reduce the horizontal emittance of both beams to one-fifth to one-tenth of their present values.
- LER magnets largely removed from KEKB tunnel.
- HER magnets and vacuum chambers left in place
- Earthquake has highlighted alignment and stabilization issues

KEKB Tunnel

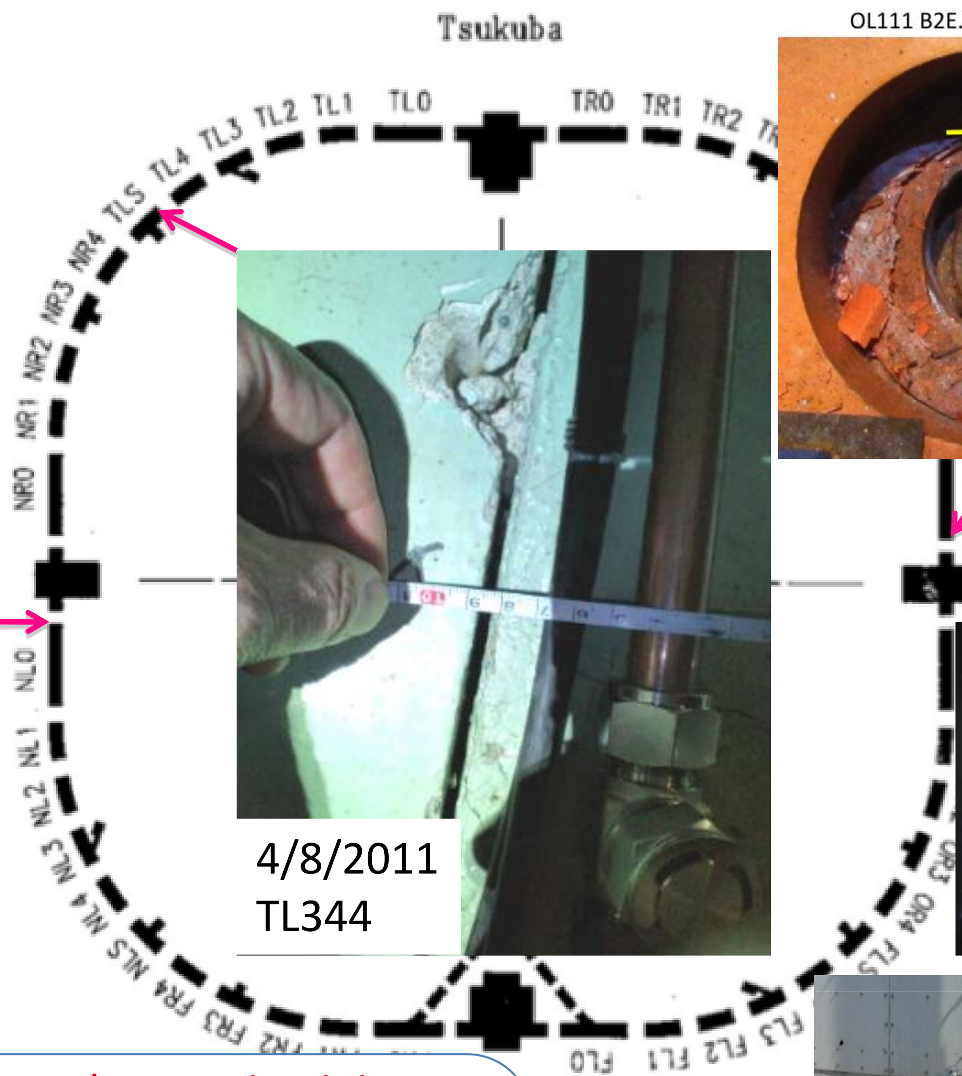
Floor sections at expansion joints pulled apart in some places, pushed together at others

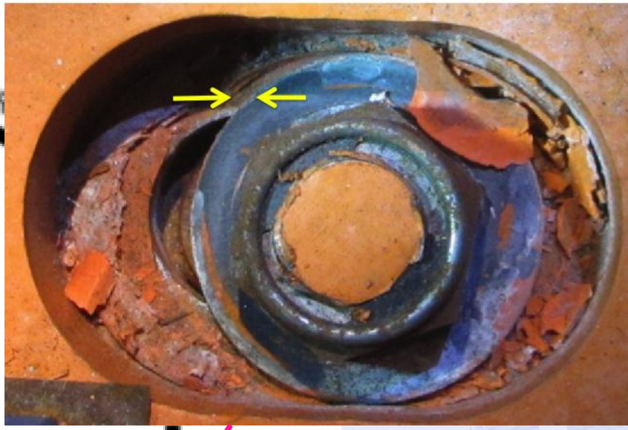


Some level shifts also detected, especially around Oho area. Tunnel around Oho experimental hall has sunk relative to Oho.

Signs of subsidence can also be seen outside Oho. Crack in driveway in front of D4 loading dock door:

KEKB Tunnel





- Damage centered around expansion joints
- Evidence that magnets moved up to 10 mm at interface between experimental halls and arc sections

⇒Tunnel movement requires quantitative measurement

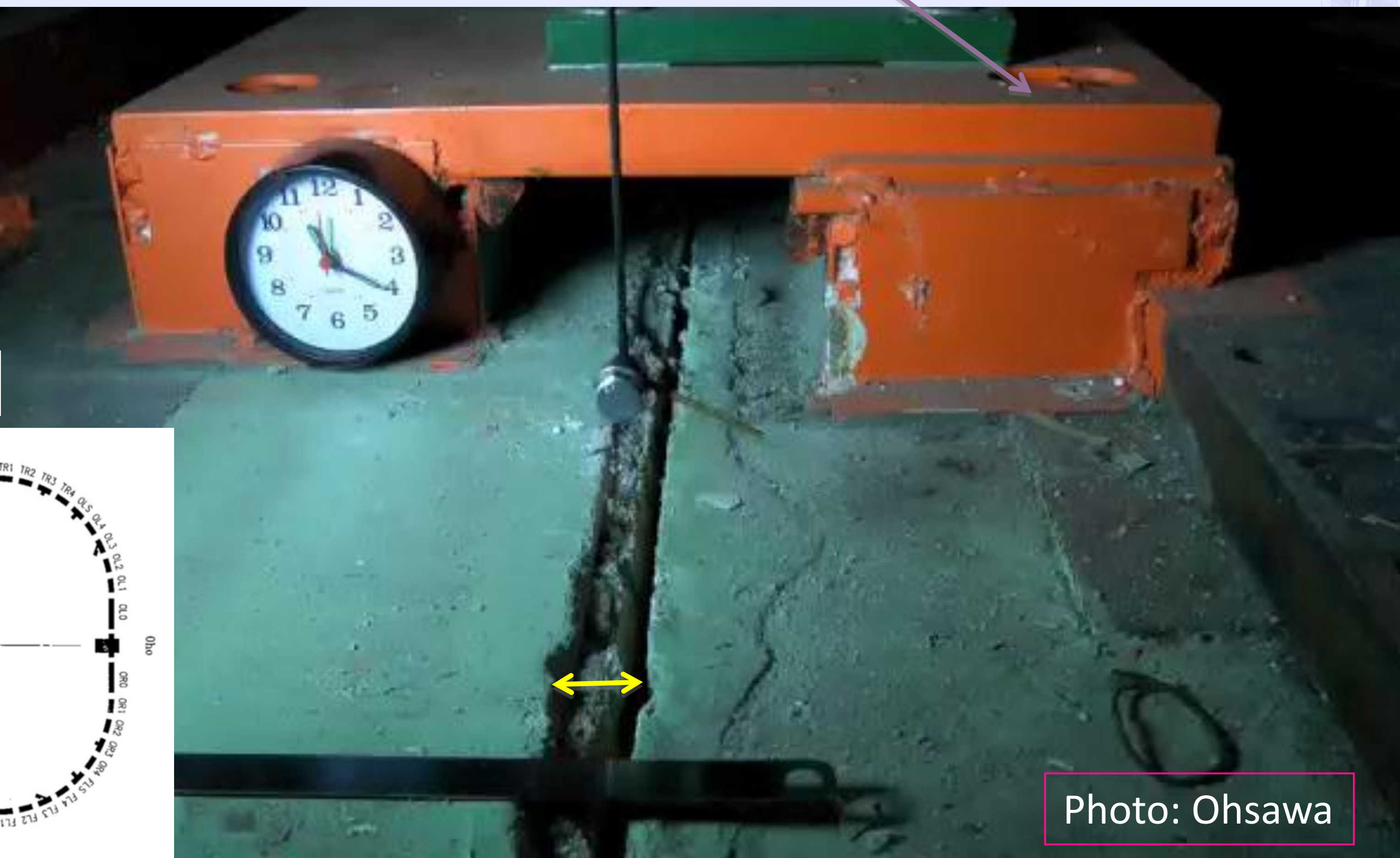
Masuzawa

BL3LP.5
Movement of magnet footing

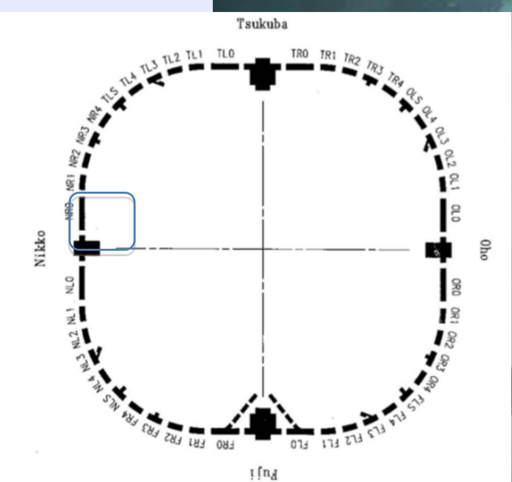
Expansion joint movement

Joint had already opened up on 3/11

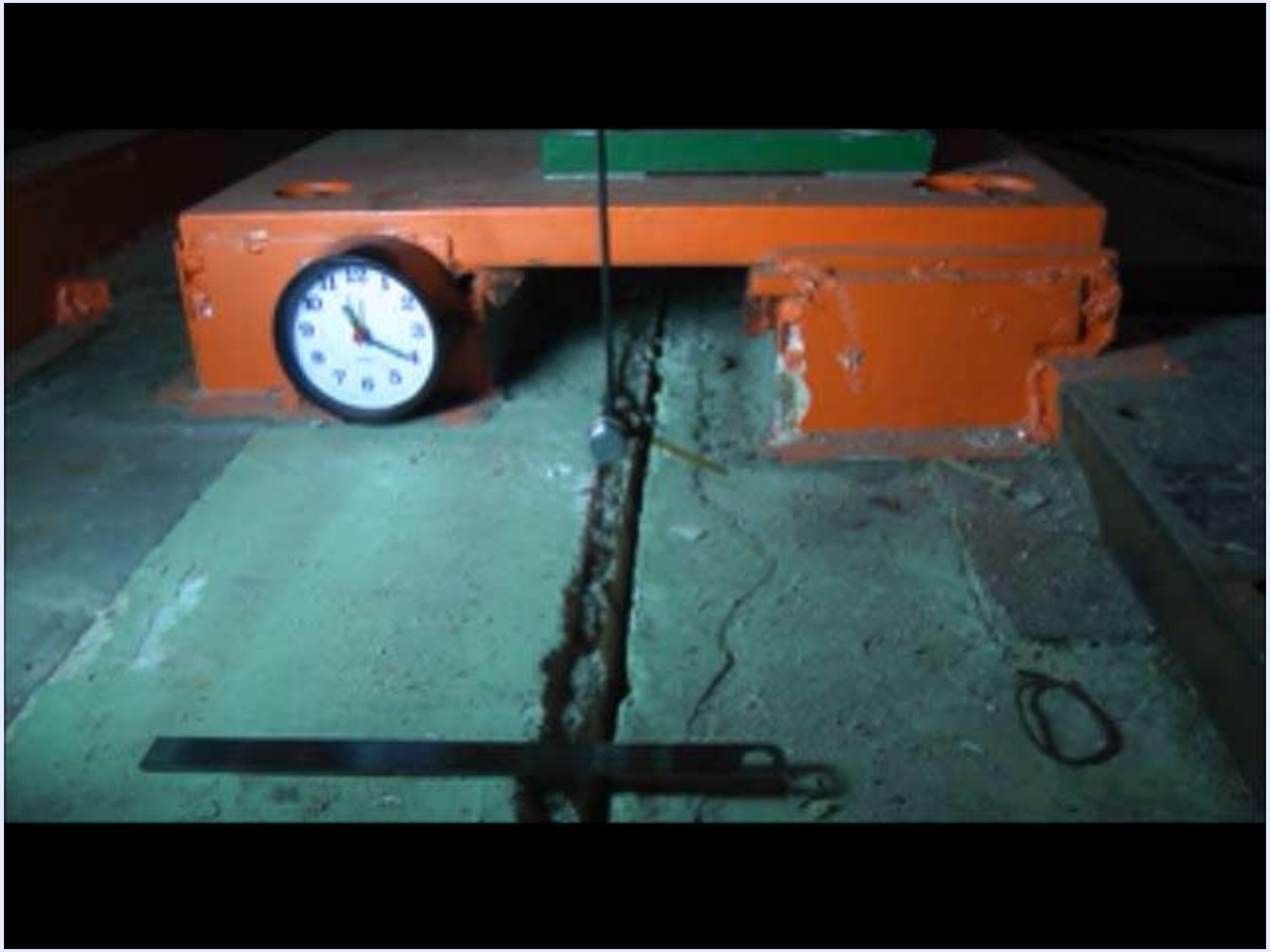
Bolt hole designed to slide to accommodate thermal expansion/contraction



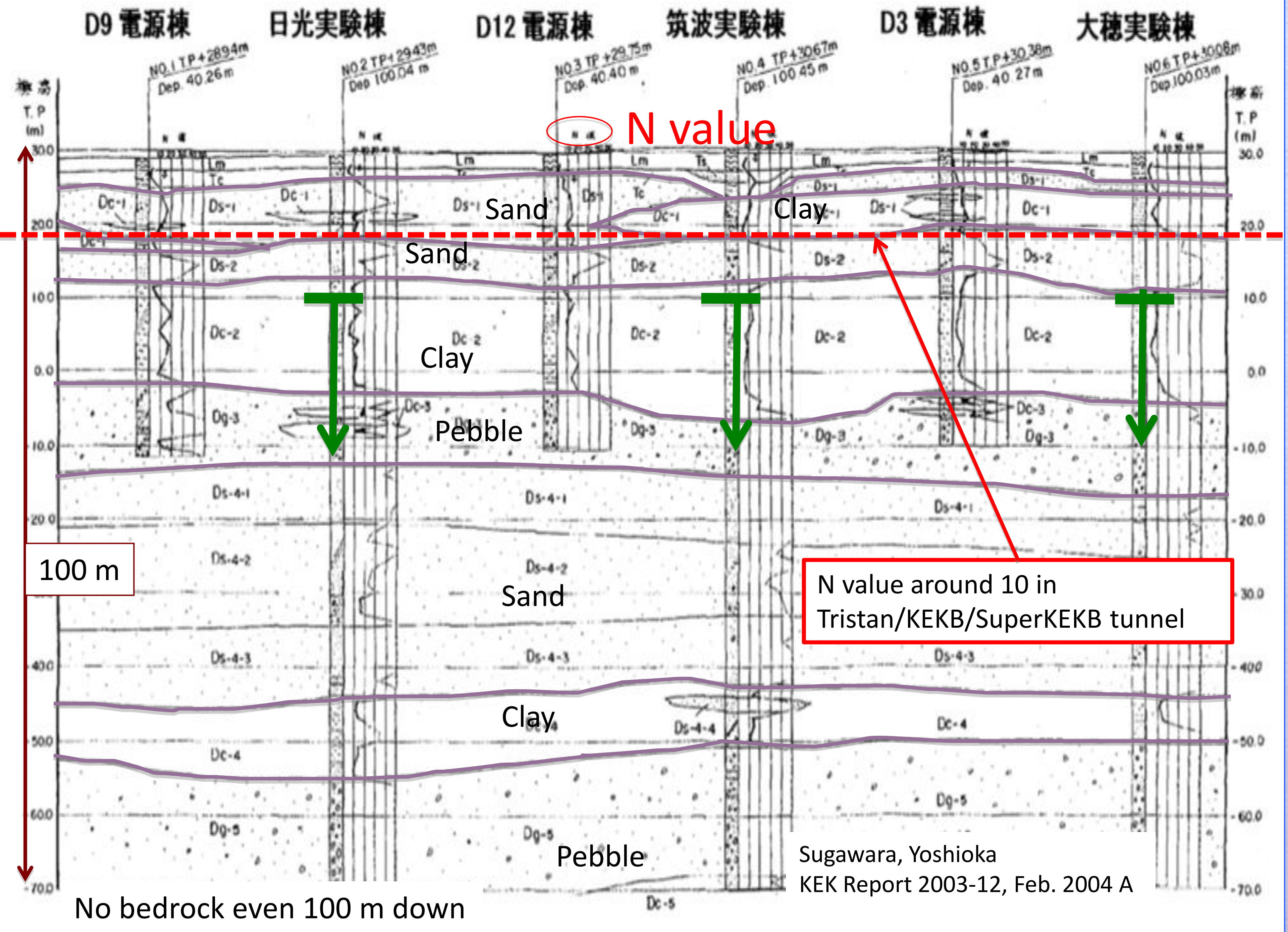
Camera location



4/16 aftershock (Shindo 4 in Tsukuba)

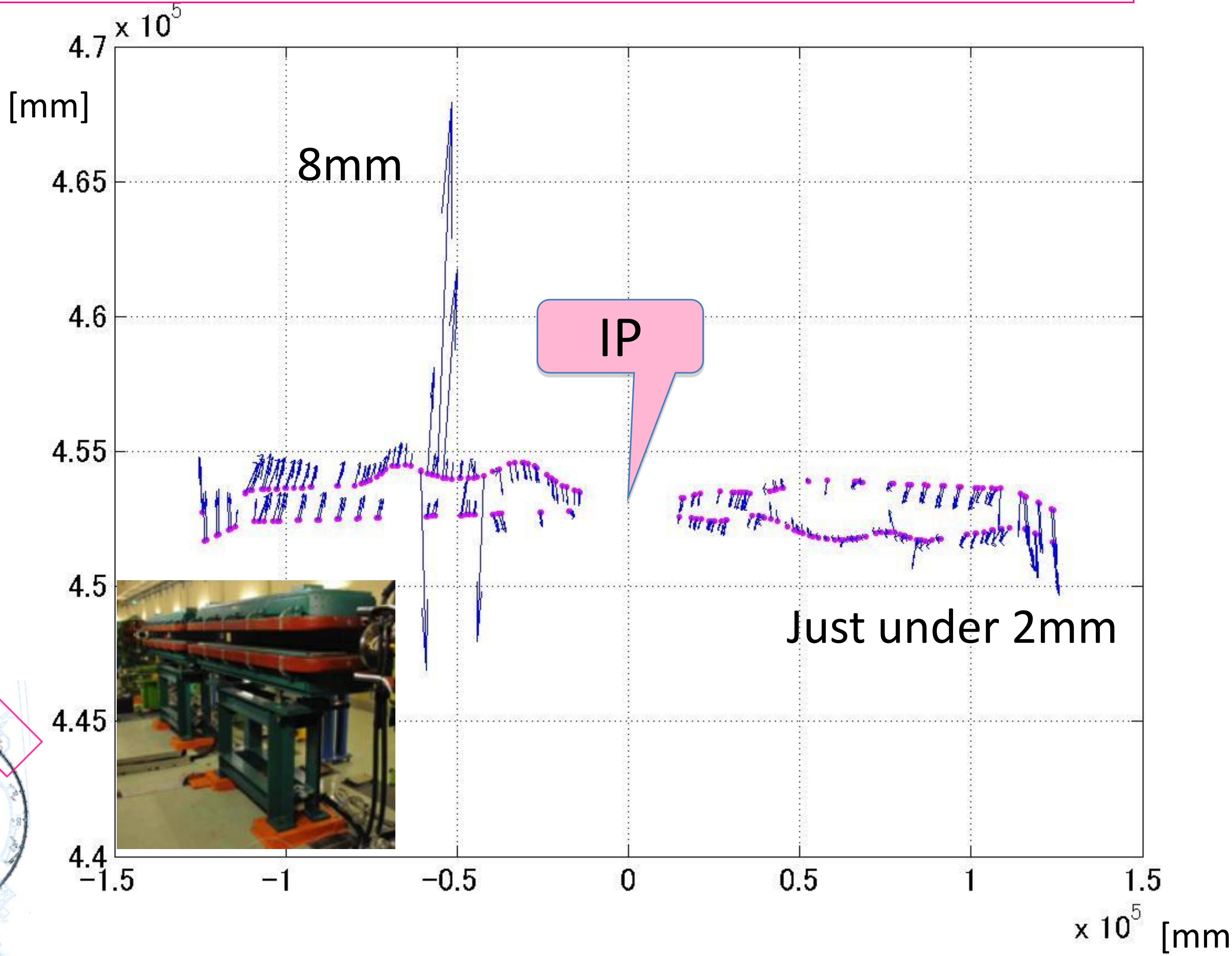


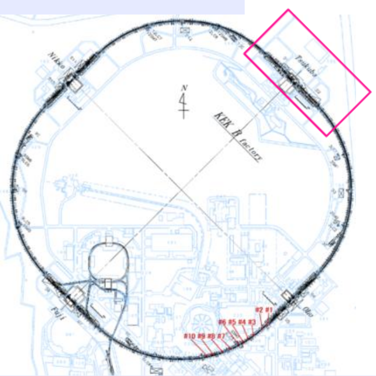
Video: Ohsawa



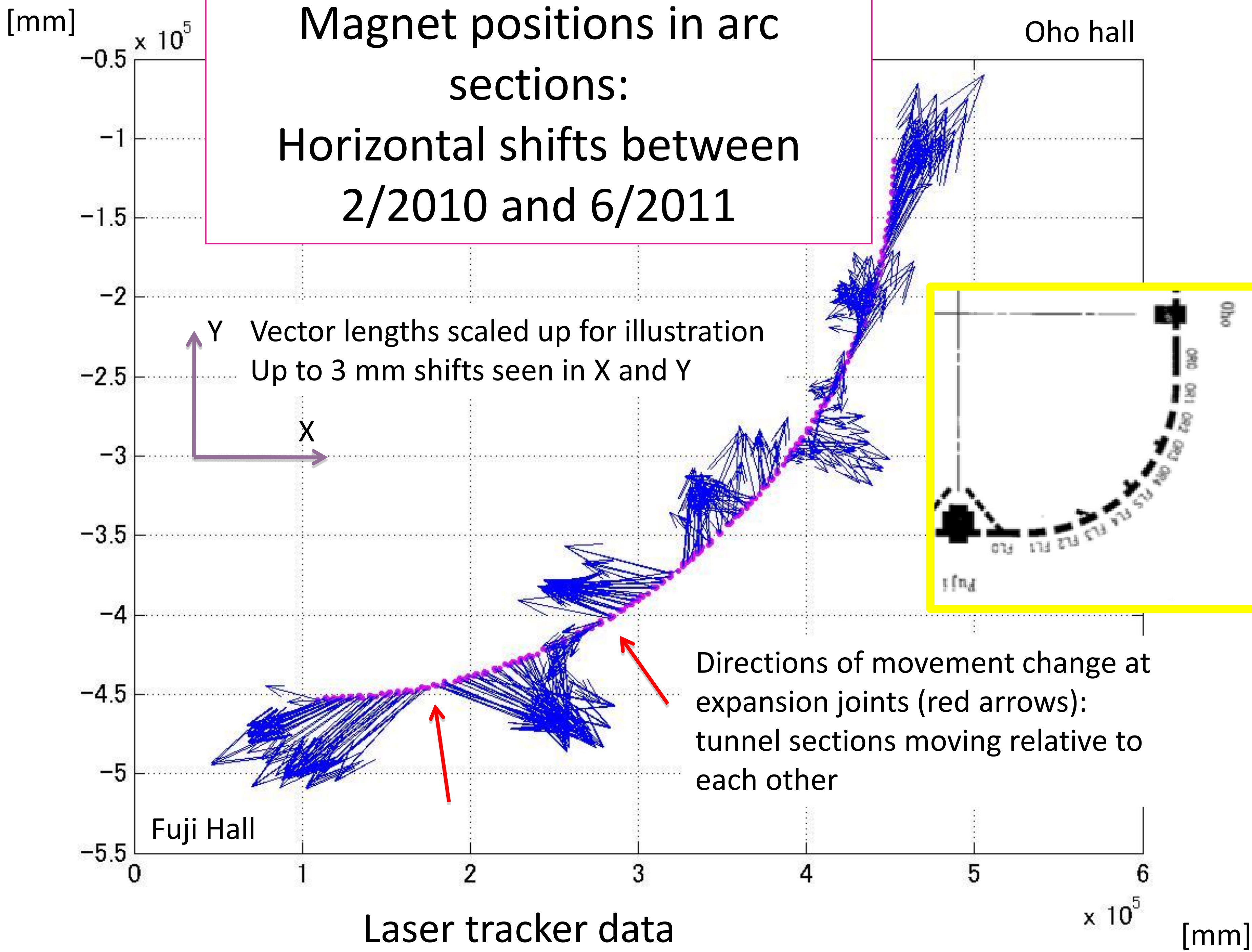
Sugawara, Yoshioka
KEK Report 2003-12, Feb. 2004 A

Magnet positions on either side of IP: Horizontal shifts between 11/2010 and 5/2011



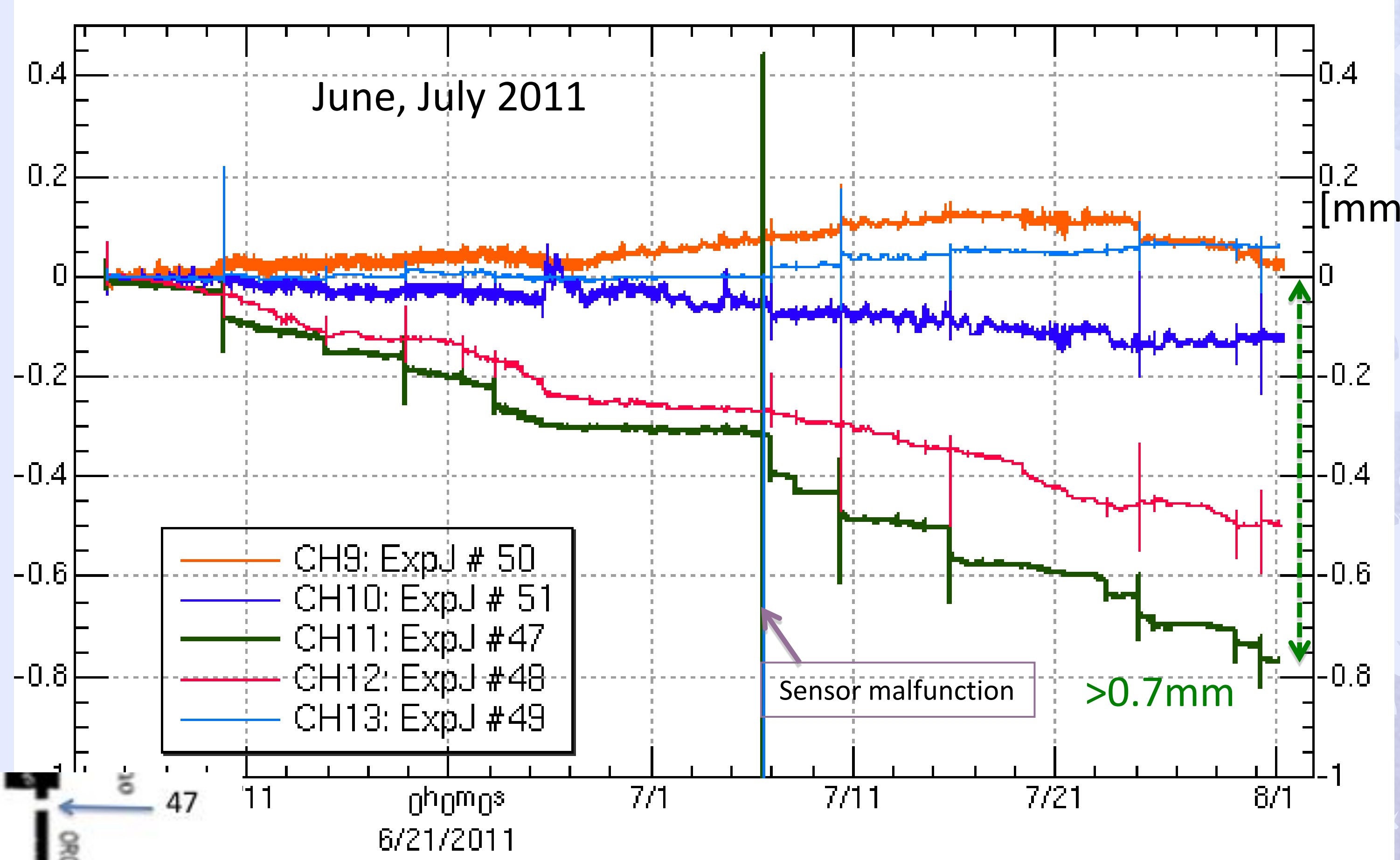


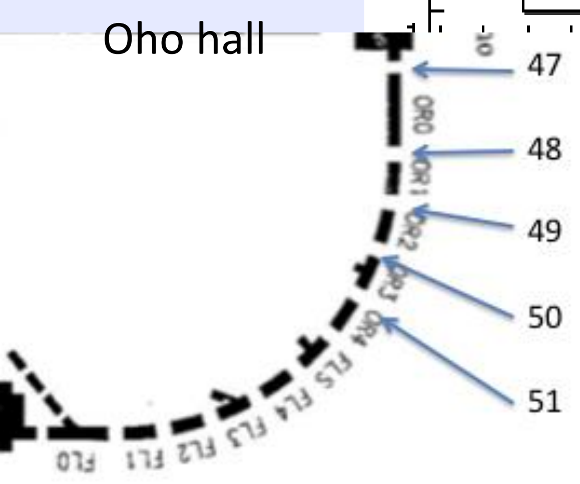
Magnet positions in arc sections: Horizontal shifts between 2/2010 and 6/2011



Laser tracker data

Movement of expansion joints measured by Hydrostatic Leveling System





Small variations due to temperature fluctuations

Spikes due to earthquakes (after-shocks)

Permanent level shifts observed at each after-shock, up to 0.7 mm over the span of two months.

Behavior prior to measurement unknown.

Continuous monitoring will be needed.

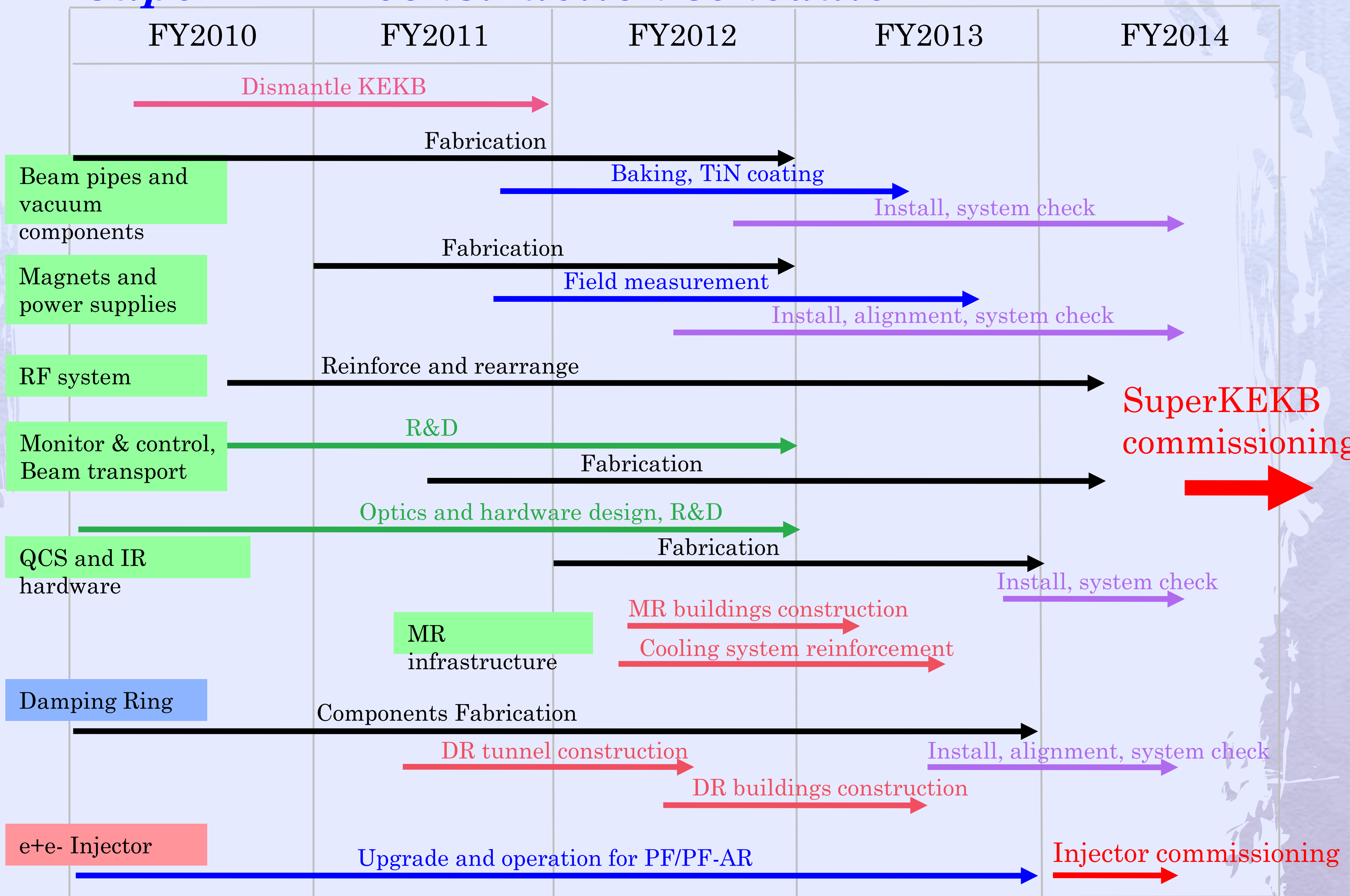
Commissioning plan

- Machine commissioning start
  - Main Ring and Damping Ring commissioning planned to start in the second half of FY2014.
  - Linac is in operation for PF and PF-AR during the construction period. Test operation for the upgrade will be performed in parallel. Commissioning of Linac for SuperKEKB will start in FY2014.
- Detector
  - The detector people prefer that machine operation start without Belle II.
  - Initial commissioning will be in “BEAST” mode:
    - No SVD
    - Belle solenoid may or may not be rolled in at the time
      - Under discussion.

(K. AKAI)

SuperKEKB construction schedule

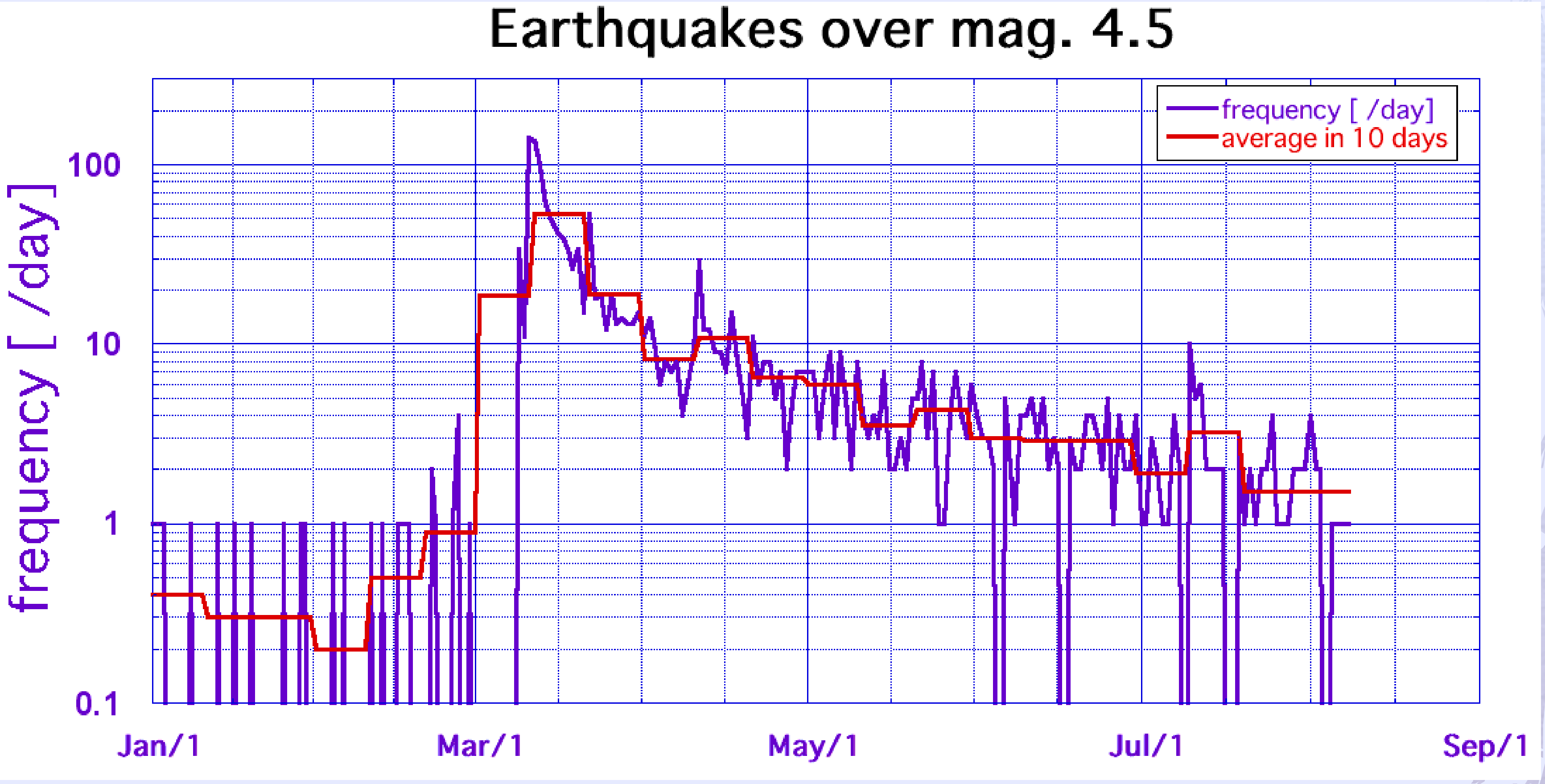
Revised on July 23, 2011



K. Akai

Summary

- SuperKEKB construction has started. Dismantling of KEKB is well underway. Mass fabrication of magnets, beam pipes, etc. has commenced.
- R&D advancing on new components.
- Commissioning scheduled to start in the second half of FY2014.


Earthquakes over mag. 4.5
frequency [/day]
average in 10 days
frequency [/day]
100
10
1
0.1
Jan/1
Mar/1
May/1
Jul/1
Sep/1

XRM Single-shot resolution estimation

- Want to know, what is chance that a beam of a certain size is misfit as one of a different size?
- Tend to be photon statistics limited. (Thus coded aperture.)
- So:
  - Calculate simulated detector images for beams of different sizes
  - "Fit" images pairwise against each other:
    - One image represents true beam size, one the measured beam size
    - Calculate χ^2/ν residuals differences between images:

N = # pixels/channels
n = # fit parameters (=1, normalization)
S_i = expected number of photons in channel i

$$\frac{\chi^2}{\upsilon} = \frac{1}{N-n-1}\sum_{i=1}^{N}\frac{[s_i' - s_i]^2}{\sigma_i^2},$$

    - Weighting function for channel i:

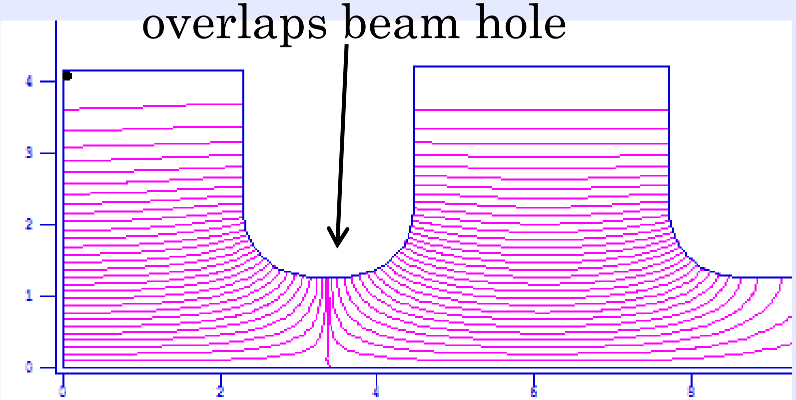
$$\sigma_i = \sqrt{s_i}\,.$$

  - Value of χ^2/ν that corresponds to a confidence interval of 68% is chosen to represent the 1-s confidence interval

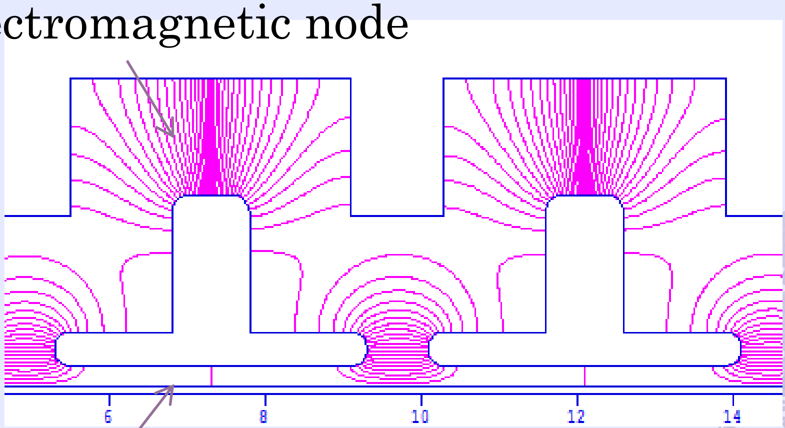
RF gun VS DC gun

	RF gun	DC gun
Electric Field	~ 100 MV/m	~ 10 MV/m
Voltage	Several MV	100 kV ~ 500 kV
Bunching	Shaped internally	Buncher needed
Electron density	High	Low

Pillbox or Disk and Washer (DAW) type



Pillbox type



DAW type

No electromagnet nodes on beam axis, so DAW type has more design freedom in cavity

Spares

Abstract

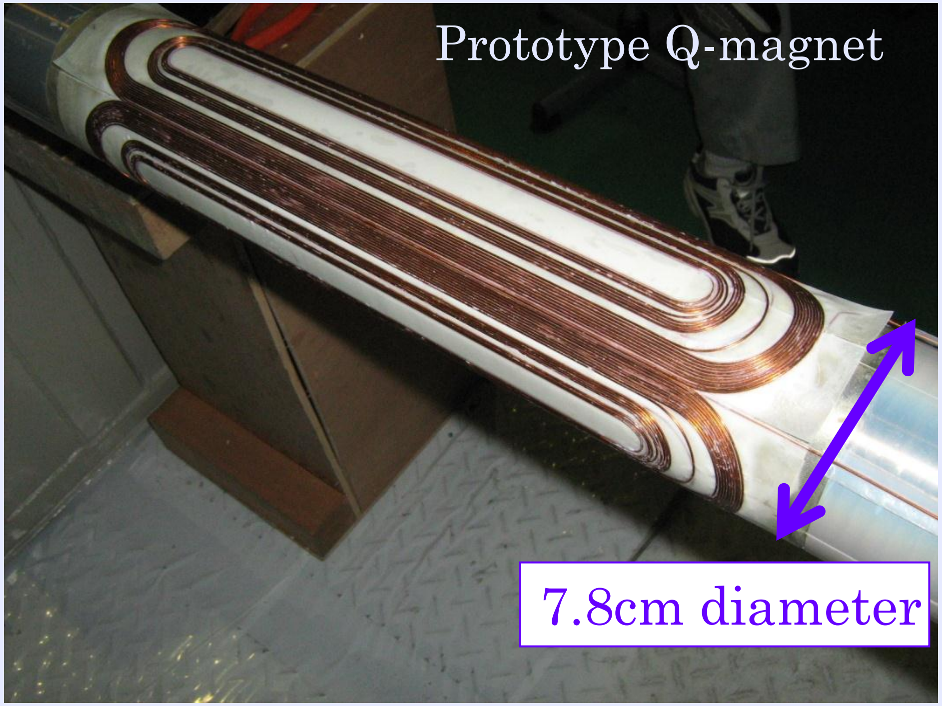
- The KEKB B factory is being upgraded to search for physics beyond the Standard Model, with a target luminosity of 8x10^35 cm^-2 s^-1, a factor of 40 times greater than the world record luminosity achieved at KEKB. To achieve this target luminosity the upgraded machine, SuperKEKB, will require the use of new advances in accelerator technology, among them the development of a low-emittance, high-bunch-charge injector system, a high-beam-current vacuum system incorporating the latest electron-cloud mitigation techniques, an interaction region design that provides a low beta function at the collision point while minimizing emittance growth due to fringe fields and maximizing the dynamic aperture, and beam diagnostics and feedback for monitoring and controlling low-emittance beams and their collisions. This talk will discuss the design challenges facing SuperKEKB, and the technologies that are being developed to meet them.

Collaborations

- Discussions have been held with some US institutions regarding possible participation on the accelerator side. Some possible areas identified:
  - Low-emittance RF gun, mask design, linac alignment and damping ring commissioning (SLAC)
  - Electron-cloud related issues (Fermilab)
  - Large Angle Beamstrahlung Monitor (Wayne State, PNNL)
    - Wayne already a member of Belle
- Outside the US, BINP (flux concentrator) + INFN (FB, beam dynamics, crab waist sims.)

Ground subsidence

IR

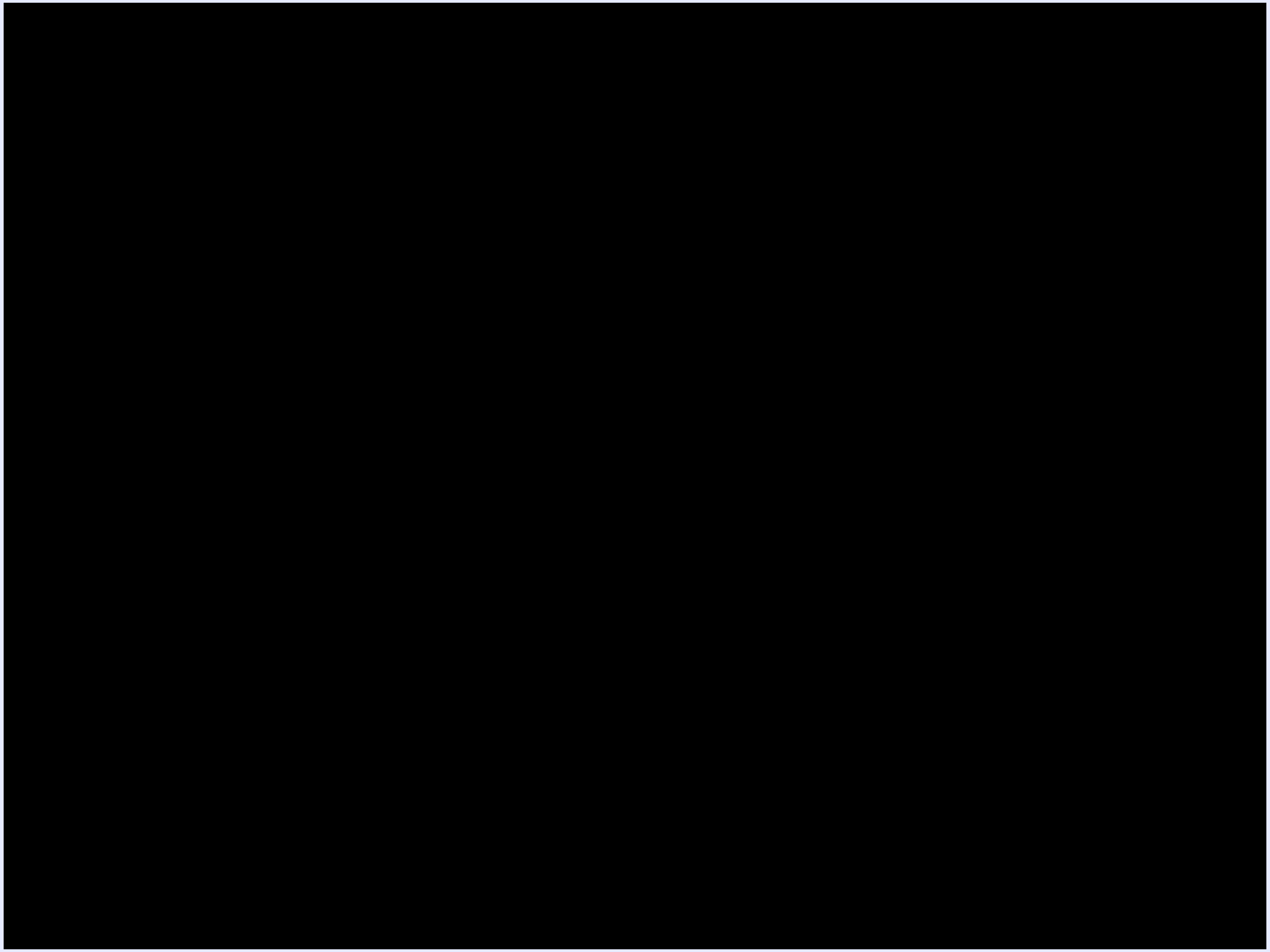


Very compact superconducting magnets for final focusing system

N.Ohuchi

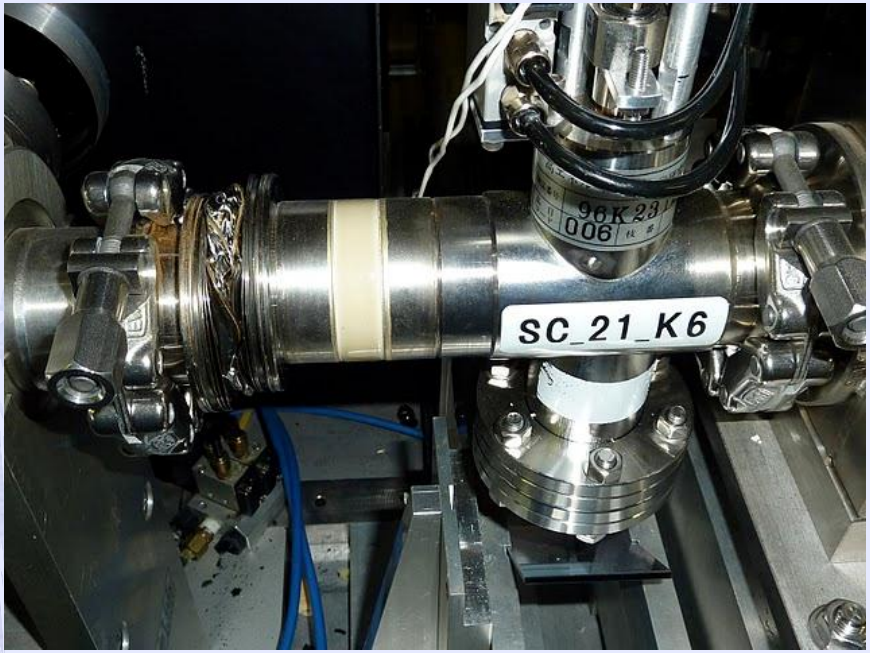
Linac

https://picasaweb.google.com/acc.cont/LinacMar2011?authkey=Gv1sRgCMfDgePDrcfWeA&feat=directlink# K.Suzuki, K.Furukawa (KEK)



Linac

K. Suzuki, K. Furukawa



Belle

- Belle broke free of its anchor and moved on its rails ~20 cm, coming to rest 6 cm from initial position.
- Many snapped cable ties, no other obvious damage visible from outside.
- Awaiting detailed inspection of internal detector components.