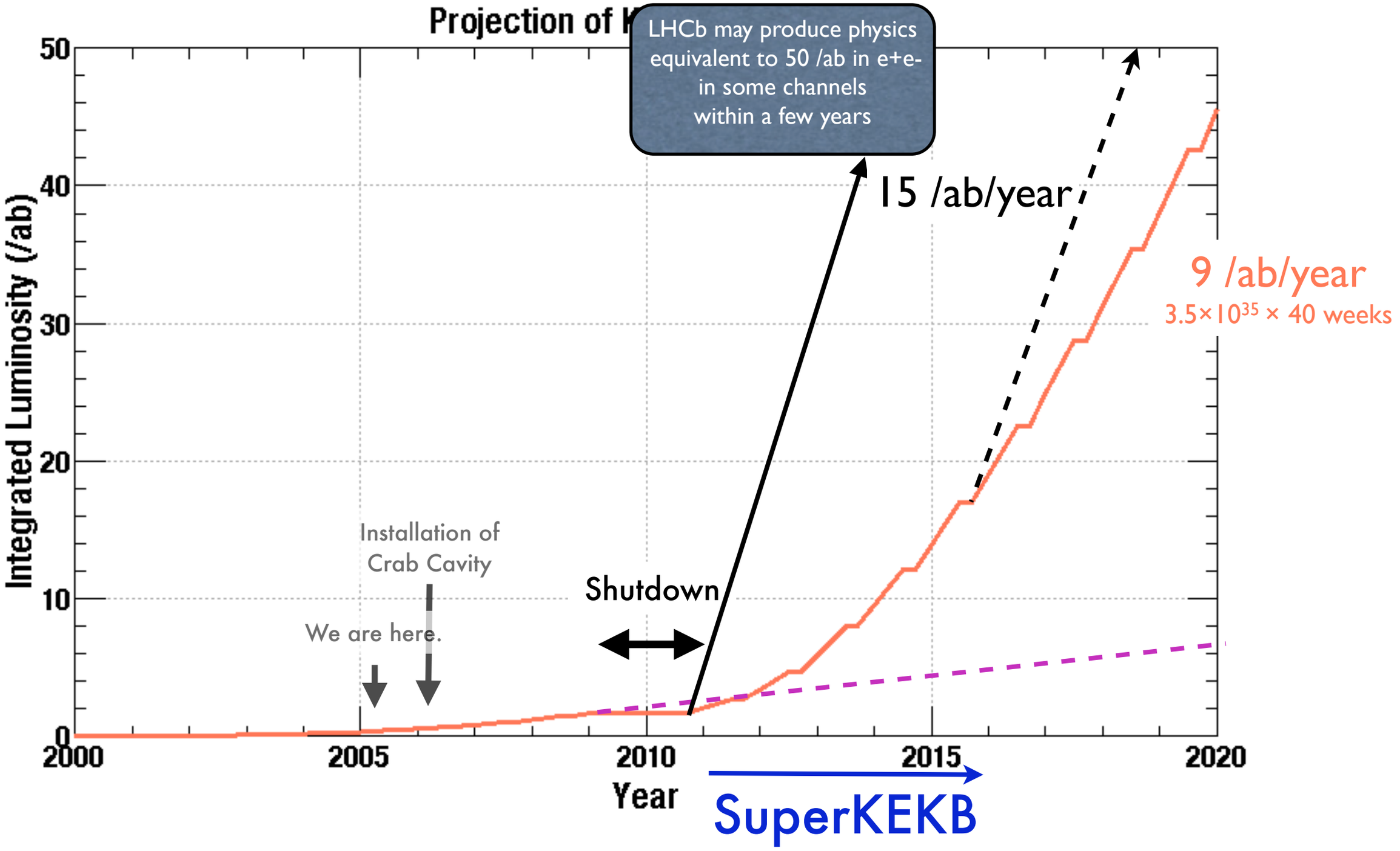
10^{36} ???

20 Apr. 2005

K. Oide (KEK) @ Super B Workshop



- Shutdown for 18-26 months in 2009-2010 for the upgrade.
- 0.9 /ab/month in 2020.

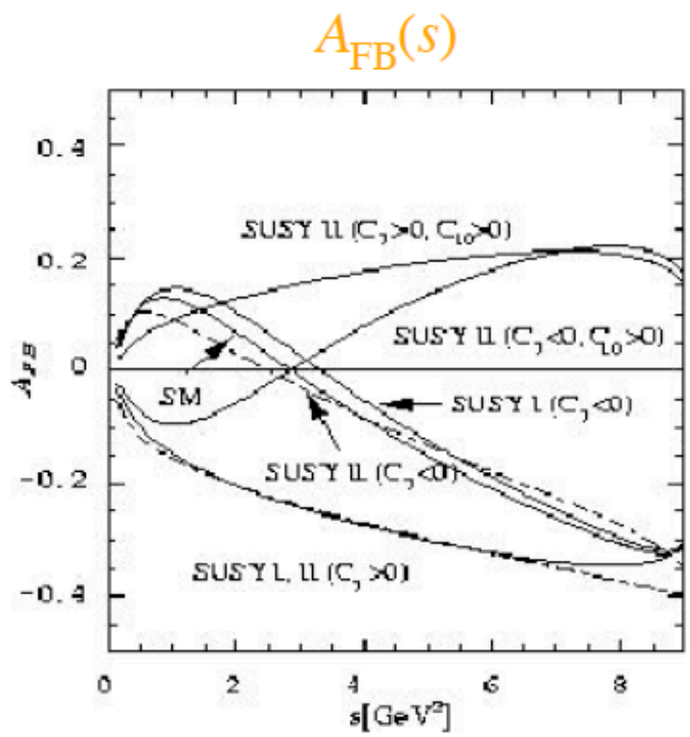
An example why you need 10^{36} ..... (giving a lecture to Buddhas)

http://ckm2005.ucsd.edu/agenda/thu1/forty.pdf

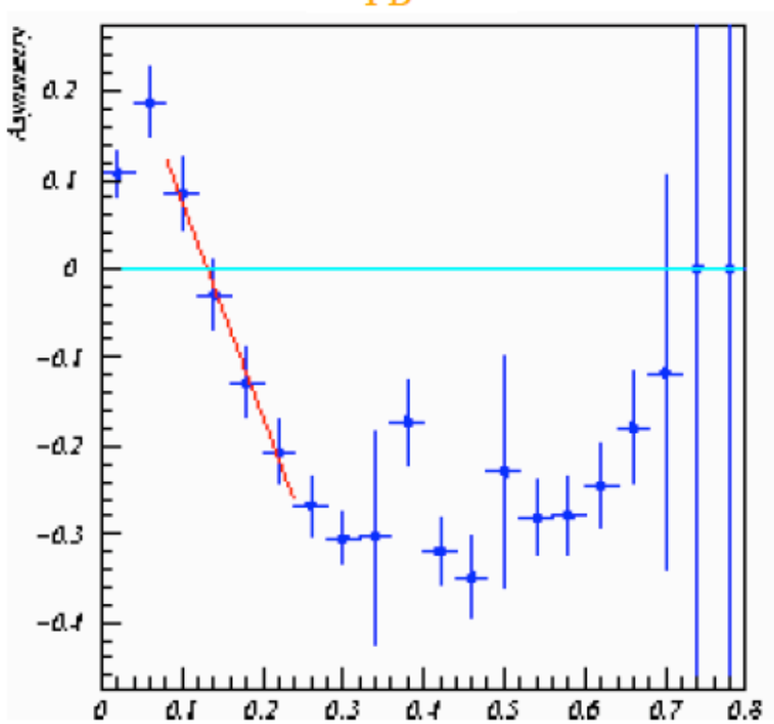
$$B^0 \rightarrow K^{*0}\mu^+\mu^-$$

- Suppressed decay ($\Delta B = 1$ FCNC), BR ~ 10^{-6}
- Forward-backward asymmetry in the μμ rest-frame $A_{FB}(s)$ is sensitive probe of new physics [Ali *et al*]

$A_{FB}(s)$



$A_{FB}(\hat{s})$



$\hat{s} = (m_{\mu\mu}/m_B)^2$

LHCb: 4400 events/year, S/B > 0.4

$A_{FB}(\hat{s})$ reconstructed using toy MC
(two years data, background subtracted)
Zero point located to ±0.04

ATLAS: 2000 events, S/B = 7 (30 fb^{-1})

Three factors to determine the luminosity:

Stored current:

1.27/1.7 A (KEKB)

→ 4.1/9.4 A (SuperKEKB)

Beam-beam parameter:

0.057 (KEKB)

→ 0.19 (SuperKEKB)

Limited
by beam-beam effect

Lorentz factor

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

Classical electron radius

Beam size ratio

Geometrical reduction factors due to crossing angle and hour-glass effect

Luminosity:

0.15 $\times 10^{35}$ $cm^{-2}s^{-1}$ (KEKB)

4 $\times 10^{35}$ $cm^{-2}s^{-1}$ (SuperKEKB)

Vertical β

5.2/6.5 m

→ 3.0/3.0 mm (SuperKEKB)

Limited
by bunch length
by HOM & CSR

SuperKEKB Machine Parameters

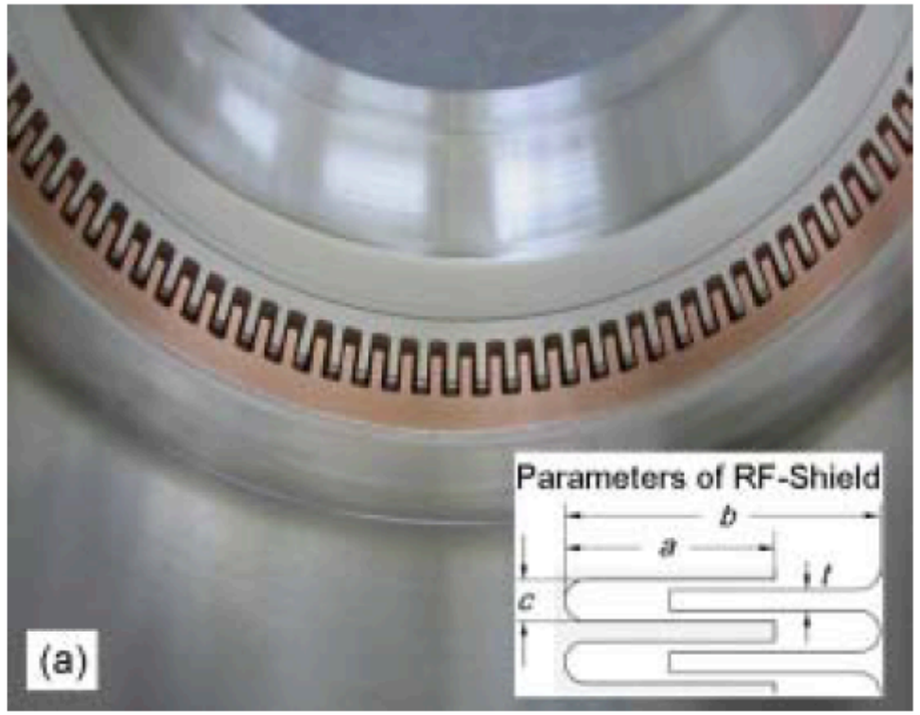
		bare lattice	with beam-beam	unit
Beam current (LER/HER)	I	9.4/4.1		A
Beam energy (LER/HER)	E	3.5/8.0		GeV
Emittance	ϵ_x	24	128	nm
Horizontal beta at IP	β_x^*	20	2.3	cm
Vertical beta at IP	β_y^*	3	2.4	mm
Horizontal beam size	σ_x^*	69	dynamical effects	μm
Vertical beam size	σ_y^*	0.73	1.23	μm
Beam size ratio	$r = \sigma_y^*/\sigma_x^*$	1.1	2.3	%
Crossing angle (30 mrad crab crossing)	θ_x	0		mrad
Luminosity reduction	R_L	0.86	0.82	
ξ_x reduction	$R_{\xi x}$	0.99	0.97	
ξ_y reduction	$R_{\xi y}$	1.11	1.16	
Reduction ratio	$R_L/R_{\xi y}$	0.78	0.72	
Horizontal beam-beam (estimated with S-S simulation)	ξ_x	0.152	0.041	
Vertical beam-beam (estimated with S-S simulation)	ξ_y	0.215	0.187	
Luminosity	L	4.0×10^{35}		$cm^{-2}s^{-1}$

Higher Order Mode Loss (K. Shibata, Y. Suetsugu)

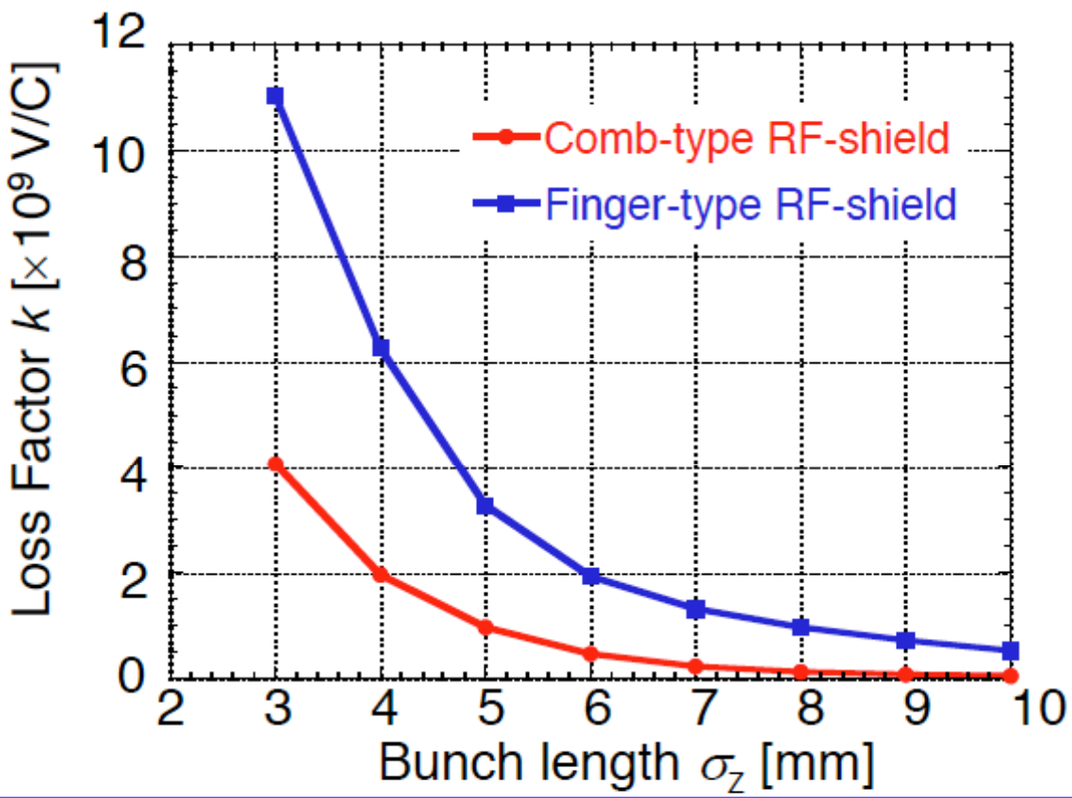
http://www-kekb.kek.jp/MAC/2005/Report/Shibata.pdf

Bellows - SuperKEKB

- Bellows chamber with a comb-type RF shield
  - Features
    - RF shield : nested comb teeth
      Length: 10 mm, Width: 1 mm
      Radial thickness: 10 mm,
    - High thermal strength
    - No radial step on the inner surface



  - Loss Factor (estimated by MAFIA T3)



- k(3 mm) = 4.1×10⁹ [V/C]
- × 1000

Total : k(3 mm) = 4.1 [V/pC]

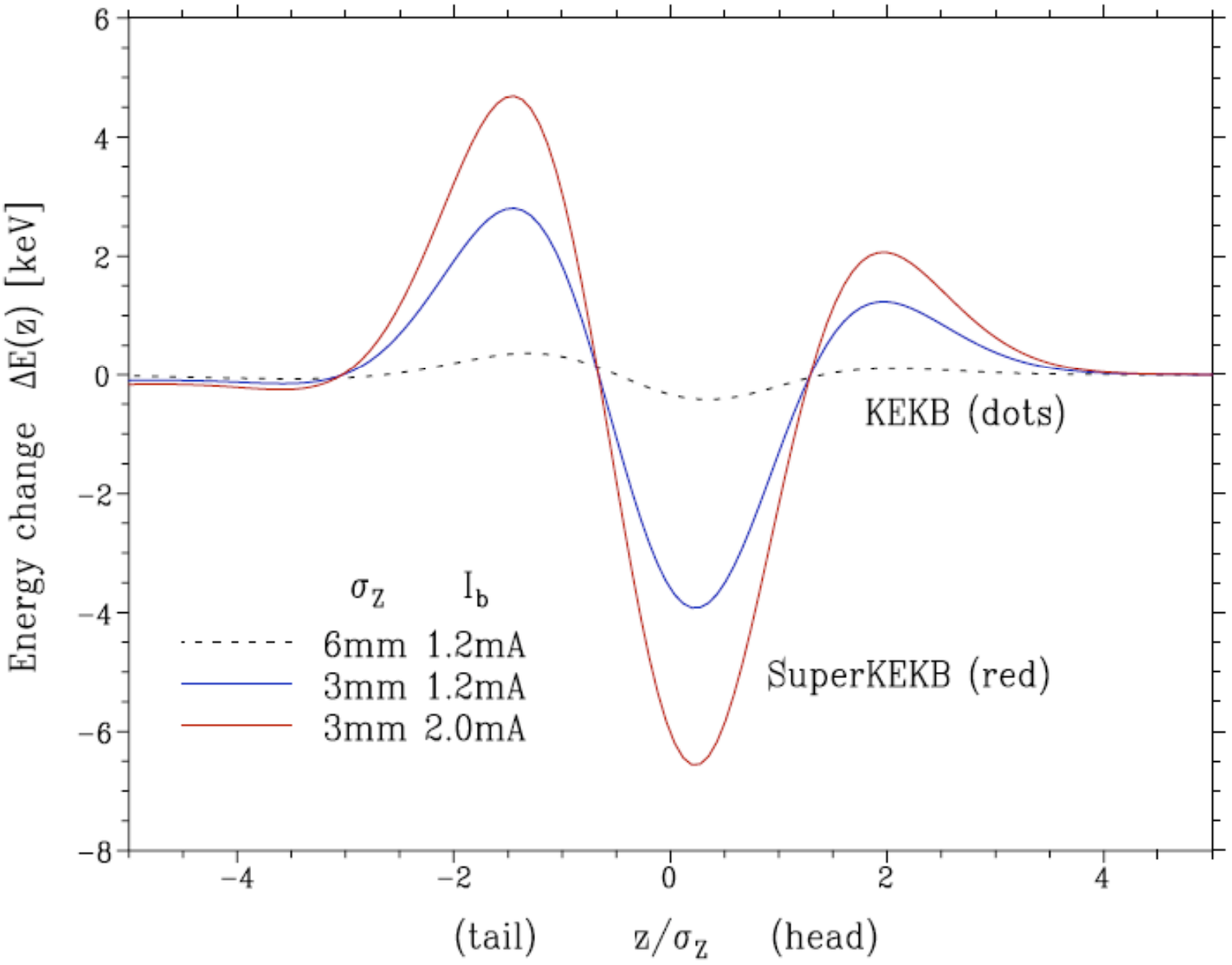
P_{HOM} = 707 [kW]

k(3mm) reduces to ~40 %.

Coherent Synchrotron Radiation (T. Agoh)

http://www-kekb.kek.jp/MAC/2005/Report/Agoh.pdf

	KEKB		SuperKEKB
Bunch Length :	$\sigma_z = 6$mm	$\Rightarrow$	3mm
Bunch Current :	$I_b = 1.2$mA	$\Rightarrow$	2mA (≈ 20nC)



⇐ Energy change by CSR
for one particle,
for one bend.

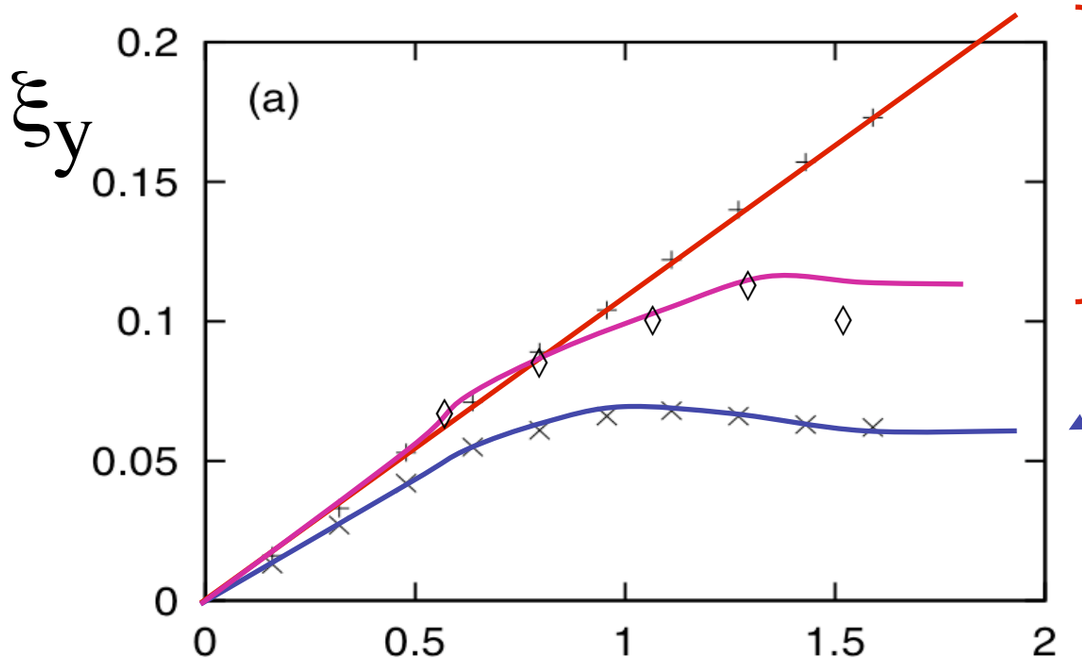
SuperKEKB (red line)
14 times larger ΔE
than KEKB (dotted line)

Square pipe
$r = 47$mm
(half height)

Crab crossing in the near future

- Crab crossing will boost the beam-beam parameter up to 0.19!

K. Ohmi & M. Tawada

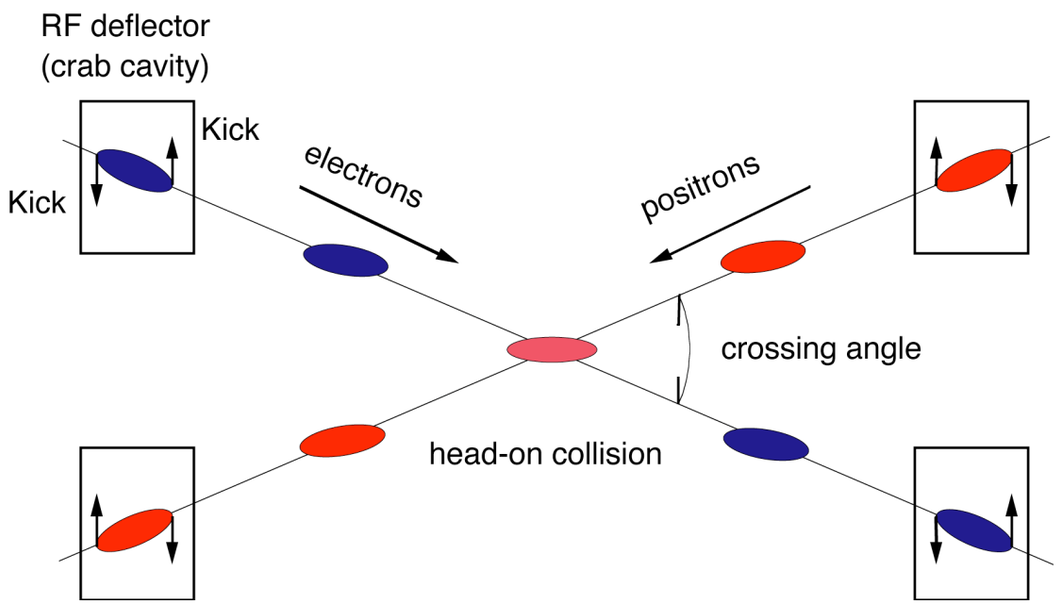


(Strong-weak simulation)

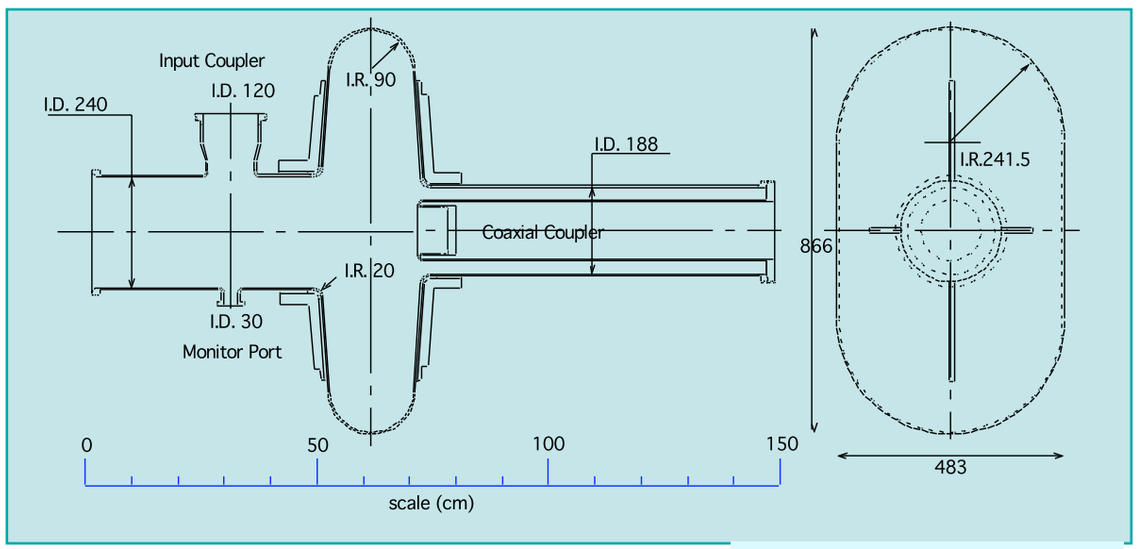
Head-on(crab)

(Strong-strong simulation)

crossing angle 22 mrad



- Superconducting crab cavities are under development, will be installed in KEKB in early 2006.



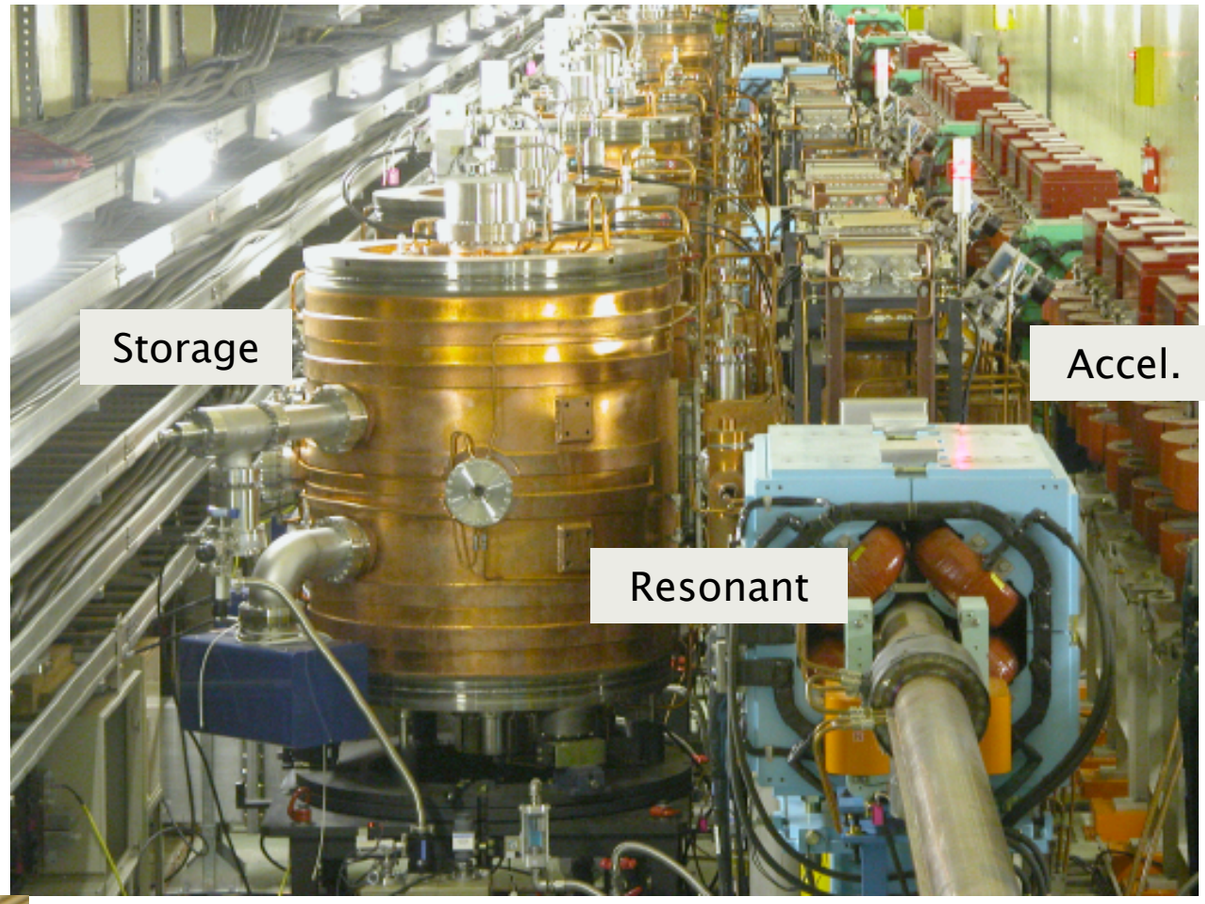
K. Hosoyama, et al

Can we increase the stored current?

- Bunch current has been already limited by HOM and CSR.
- More bunches are necessary: more RF buckets: 1–1.5 GHz.
- Completely new RF system:
  - Discard all the existing 500 MHz system, which has been developed for 25 years since TRISTAN.
  - Develop klystrons, power supplies, cavities at a new frequency.
  - Superconducting cavity's HOM absorber will be more than difficult.
  - Feasibility of ARES at higher frequency is unknown.
  - 300 – 500 M$, at least 15 FTE × 5 years. (Where are those people?)
  - In parallel with the operation of the existing system.
- Higher current needs different design of the vacuum system, which requires all magnets to be replaced for larger aperture.
- Is the shorter bunch spacing safe with parasitic collision?
- More electricity(150–200 MW!), additional power stations.
- Bad luminosity/cost.

ARES Cavity

- Passive stabilization with huge stored energy.
- Eliminates unnecessary modes by a coupling of 3 cavities.
- Higher order mode dampers and absorbers.
- No need for longitudinal bunch-by-bunch feedback.
- No transverse instability arises from the cavities.



Superconducting Cavity

- World's highest current, 1.3 A.
- Input coupler has been operated up to 380 kW.
- Ferrite HOM absorber working at 12 kW.

ARES upgrade for SuperKEKB

- Larger detuning

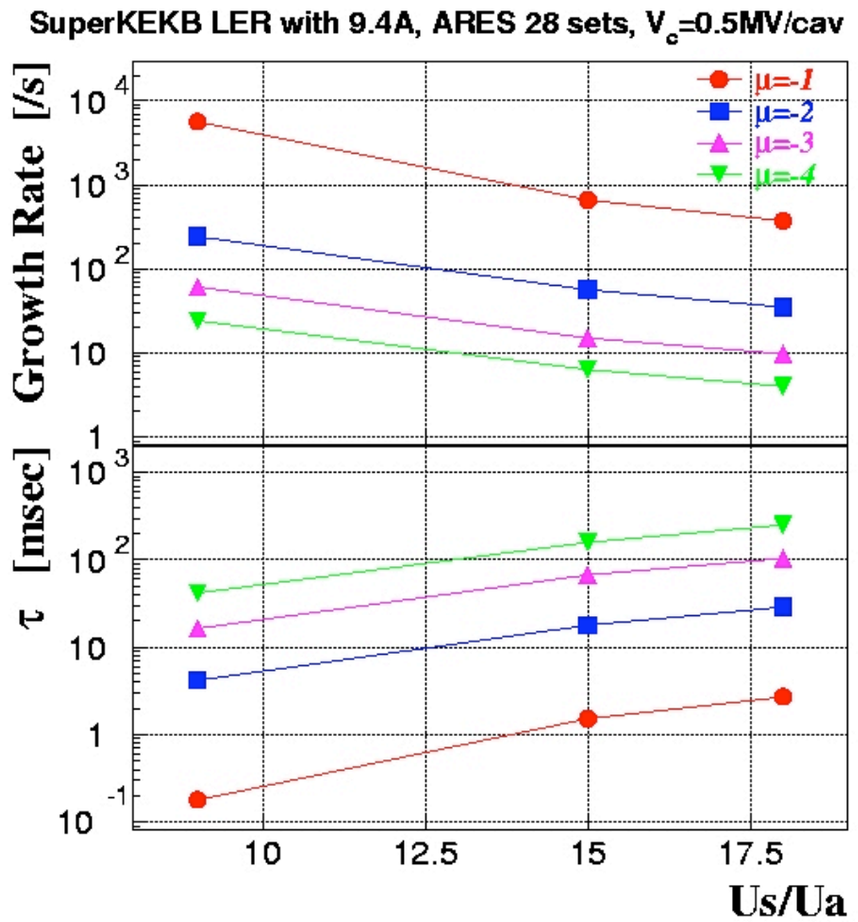
⇒ Change energy ratio : Us/Ua = 9 →15

Small modification on the window size of A-cav

-1 mode growth time :0.3 ms to 1.6 ms.

Then the -1 (and -2) modes related to the fundamental mode will be suppressed by a FB system in the RF control system.

(need bunch-by-bunch FB to suppress ARES HOM & 0/π mode instability)



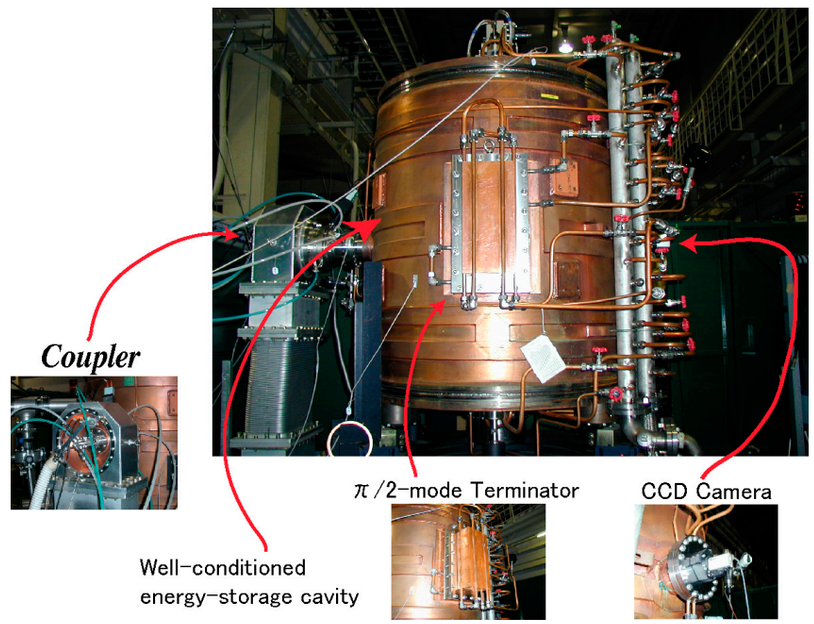
- Higher HOM power

Upgrade of HOM damper

- Higher input RF power

400 kW/cavity -> 800 kW/cavity

R&D of input coupler using new test-stand.

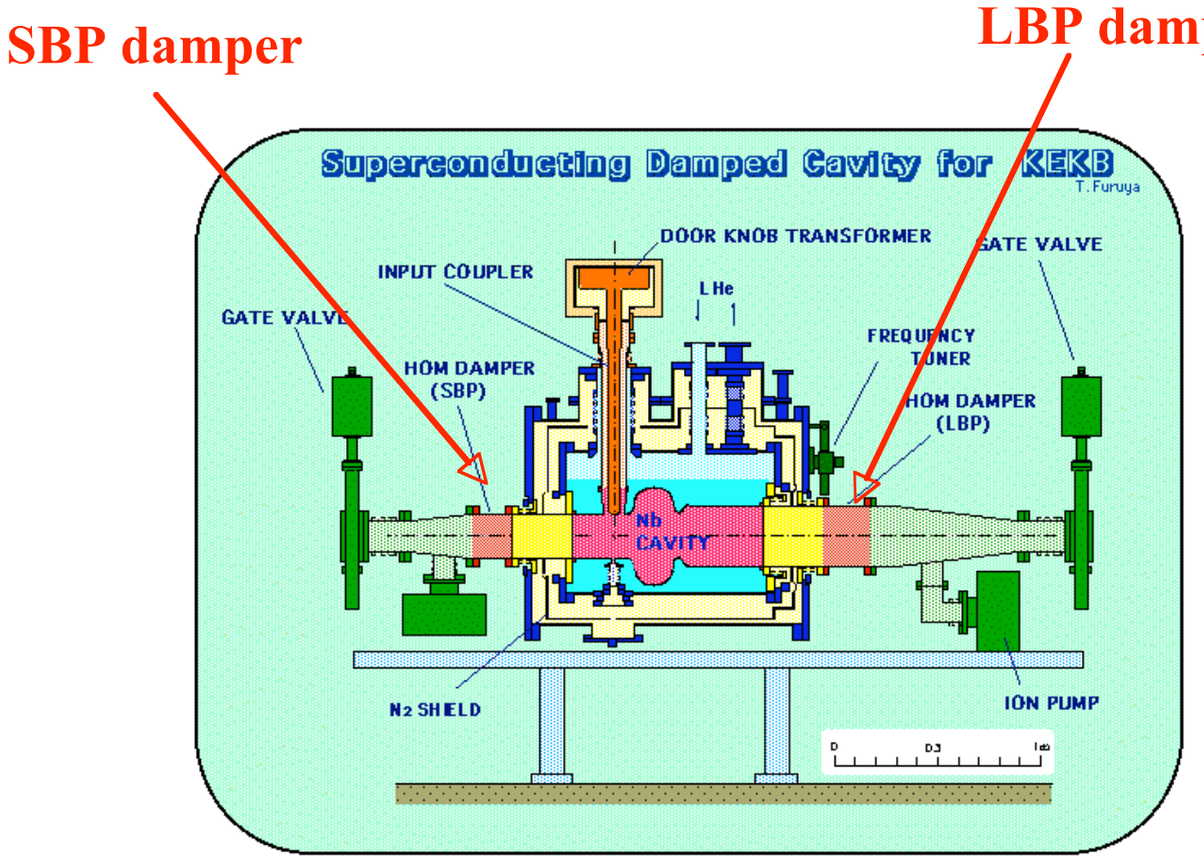


T. Kageyama

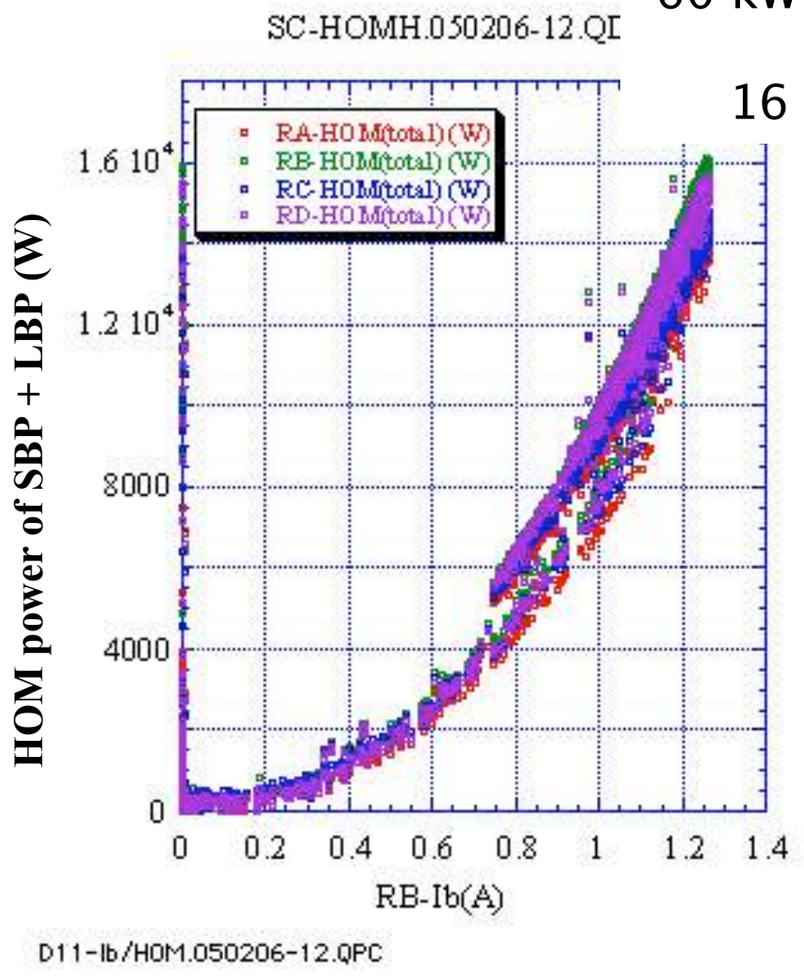
Achievements of KEKB-SC

RF power absorbed by HOM dampers at 1.27 A

- A beam of 1.27 A in 1293 bunches induces the HOM of 14 - 16 kW for each module. (σ_z=7mm)
- The ratio of SBP / LBP is 7 kW / 9 kW.



↑
60 kW (SuperKEKB)
↑
16 kW(KEKB)



HOM of D11 cavities

Summary

- Present design of SuperKEKB hits fundamental limits in the beam-beam effect and the bunch length (HOM & CSR).
- Higher current is the only way to increase the luminosity.
- Many technical and cost issues are expected with a new RF system.
- We need a completely different collider scheme.....

Construction schedule of SuperKEKB RF system

Ver. 1.4 2004.12.22

Fiscal Year		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
KEKB		KEKB operation					KEKB shut down						
SuperKEKB				New buildings		SuperKEKB construction			SuperKEKB commissioning				
Operating stations (cavities)	D1								2 (Crabs)	→	→	→	→
	D2								2 (Crabs)	→	→	→	→
	D4	3 (6A)	→	→	→	→			10 (10AH)	→	→	→	14 (14AH)
	D5	3 (6A)	→	4 (6A)	→	→			2 (2AH)	→	6 (2H+4L)	→	10 (2H+8L)
	D7	5 (10A)	→	→	→	→			10 (10AL)	→	→	→	→
	D8	5 (10A)	→	→	→	→			10 (10AL)	→	→	→	→
	D10	4 (4S)	→	→	→	→			6 (6SH)	→	→	→	→
	D11	4 (4S)	→	6 (4S+2C)	→	→			6 (6SH)	→	→	→	→
	DR							1(1A)	→	→	→	→	→
Total number of operating stations		24	→	27	→	→			49	→	53	→	61
ARES-AC modify 1set			Design	Prototype	Beam Test								
ARES-AC modify 20 sets						Fabricate		Install					
ARES new full set				1st S-cav		S-cavity only			Fabricate		Install 4		Install 5
Move ARES from D5 to D4							Move 4						
Install spare ARES							Install 1@DR						Install 3
4 additional SCC						Fabricate		Install					
Enlarge beam pipe for existing SCC								Beam pipe					
Crab RF system @Nikko		Constuct											
Crab RF system @Tsukuba							Constuct						
RF system for Damping Ring						Constuct							
Klystron fabrication		1	3	4	4	5	4	4	3	3	3	3	
Power supply for 2 klystrons					3	3	3	2		1	2	2	
High-power and cooling system			2	1		8	8	8			2	4	4
Low-level RF system			2	1		8	8	8			2	4	4
Reinforce vapor cooling system					D4	D7	D8		D5				
R&Ds		R&D of HOM damper, Coupler, Control, etc.											