Super KEKB/Belle

Toru Iijima

Nagoya University

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New Hadrons with Various Flavors

BELLE

KEKB Quest for CPV kekb.jp

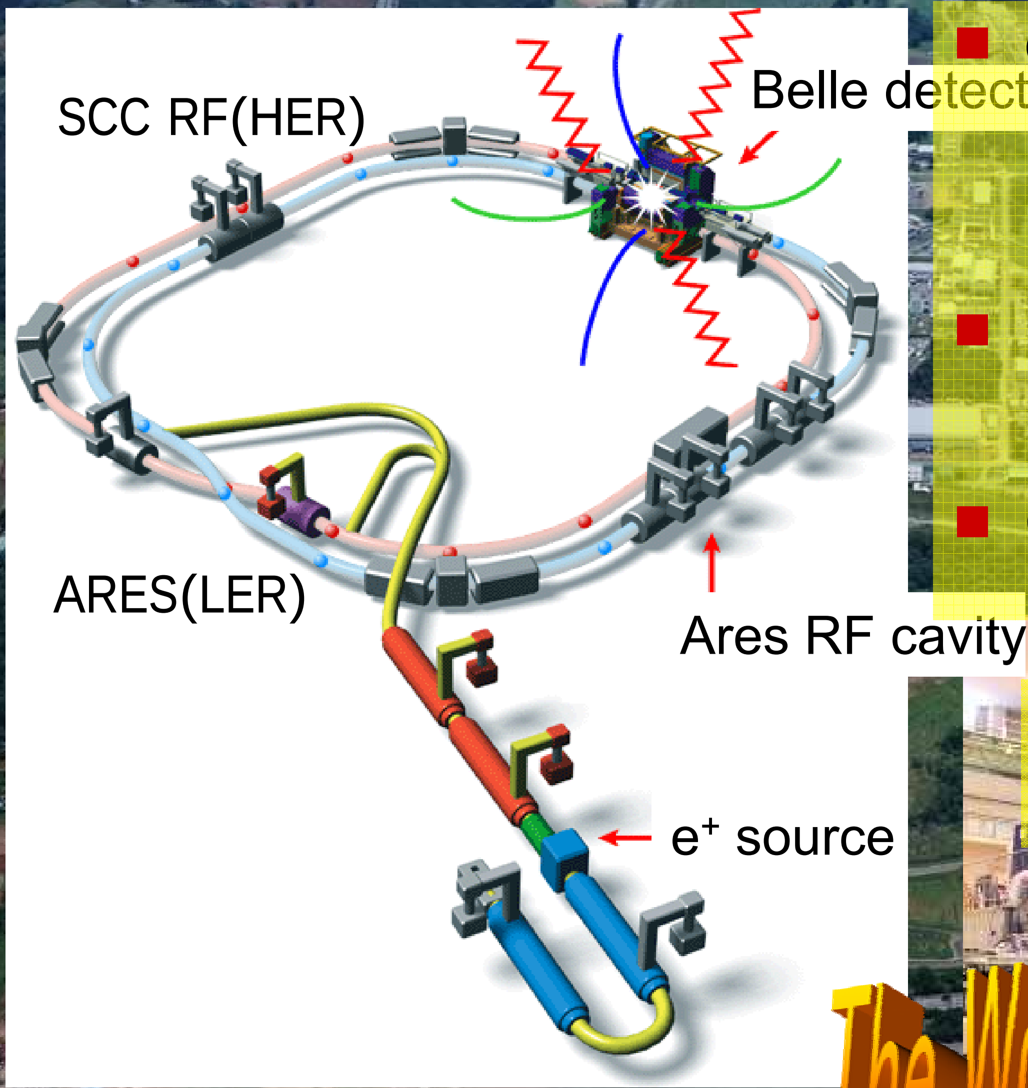
LAB

Nagoya University タウ・レプトン物理研究センター Tau Lepton Physics Research Center

Talk Outline

- KEKB & Belle
- Super KEKB & Belle
  - – Physics target
  - – KEKB upgrade
  - – Belle upgrade
- Plan / New Collaboration
- Summary

KEKB & Belle



- e^- (8.0GeV) × e^+ (3.5GeV)
  - $\Rightarrow \Upsilon(4S) \rightarrow B\bar{B}$
  - $\Rightarrow$Lorentz boost: $\beta\gamma = 0.425$
- Finite crossing angle
  - 11mrad ×2
- Operation since 1999.

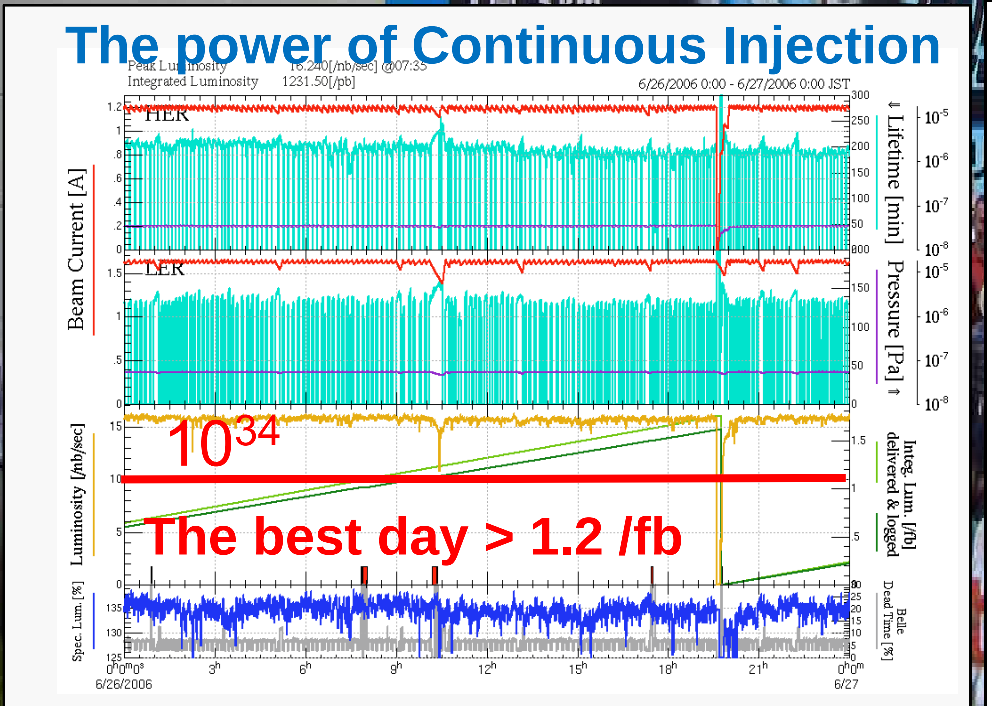
Peak luminosity

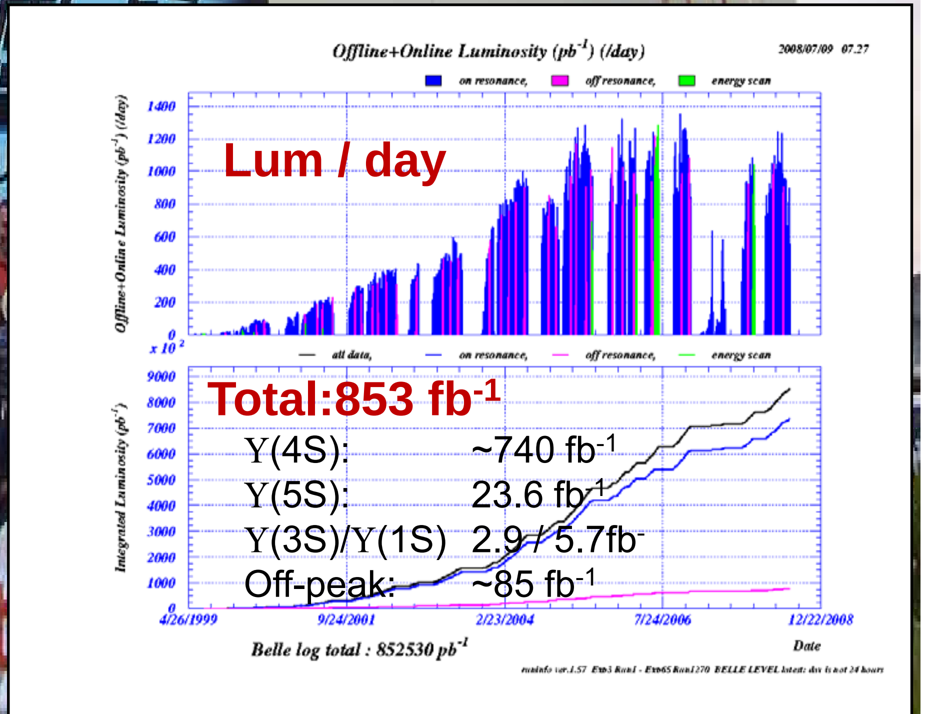
1.71×10^{34} $cm^{-2}s^{-1}$!

KEKB Performance

Luminosity Records;

- L peak = $1.71 \times 10^{34} cm^{-2} s^{-1}$ 70% higher than the design
- L day = $1232 pb^{-1}$/day double the design
- L int = $855 fb^{-1}$ as of Oct.28, 2008

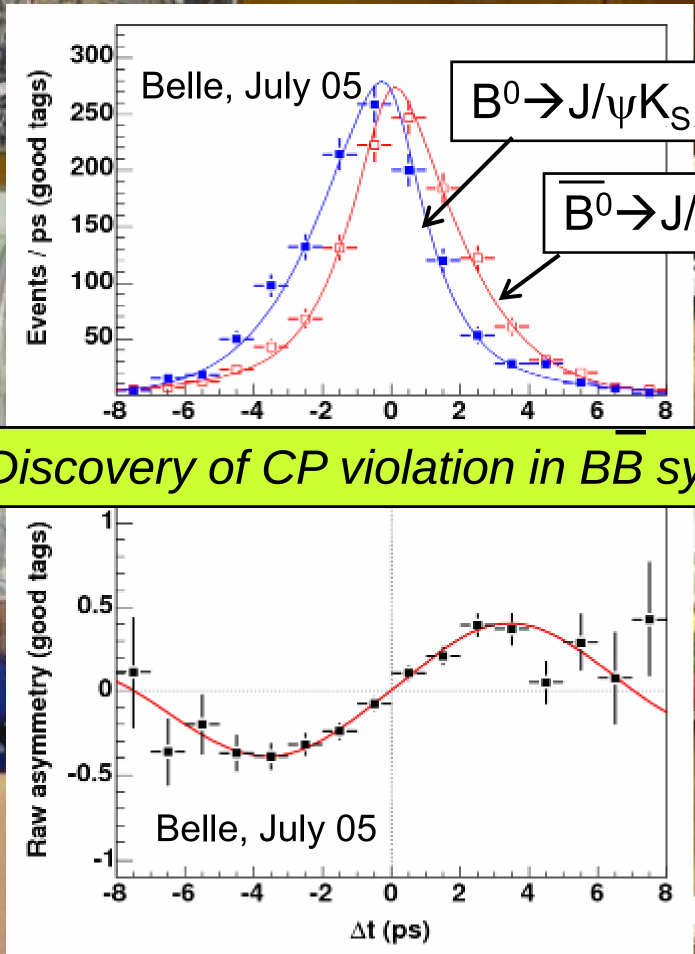




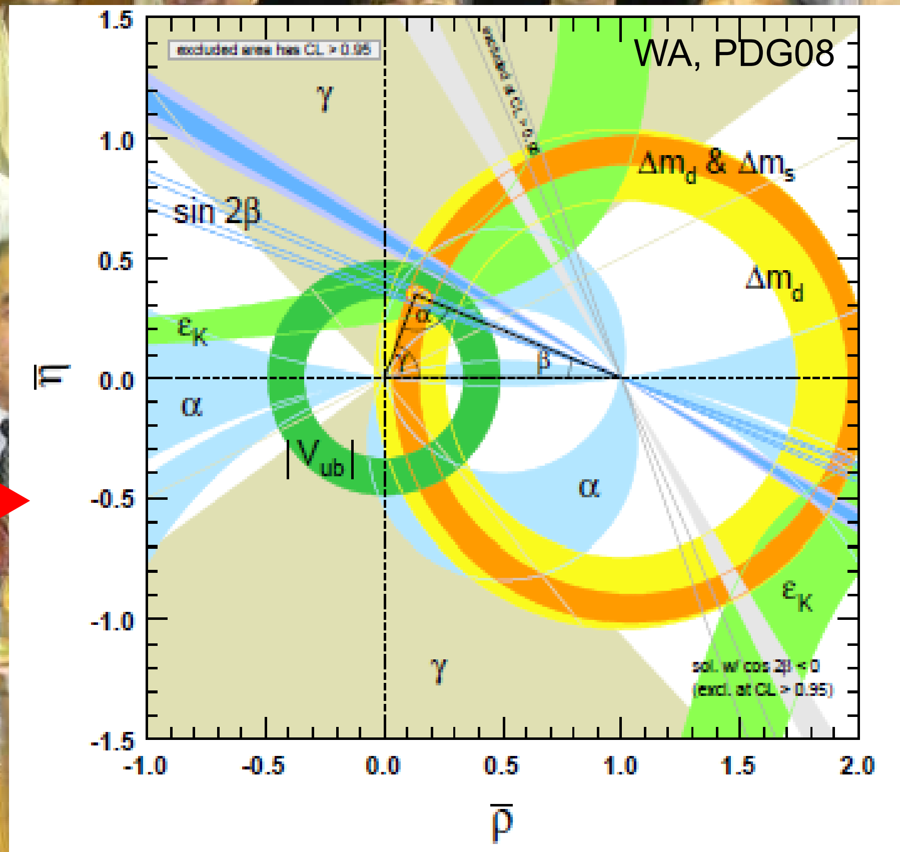
Achievement of the *B* Factories

Quantitative confirmation of the KM model

Discovery of CP violation in $B\bar{B}$ system

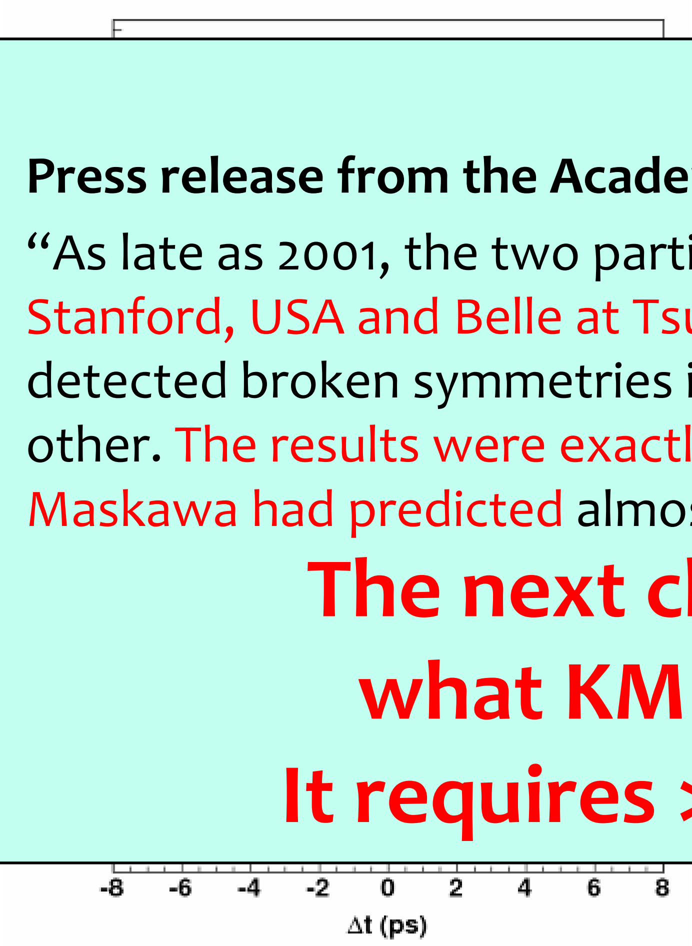


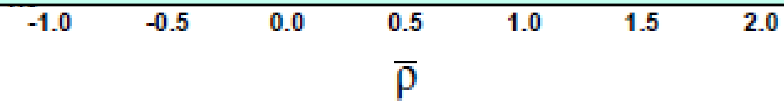
Confirmation of Kobayashi-Maskawa model



Achievement of the *B* Factories

Quantitative confirmation of the KM model





Press release from the Academy

"As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier. "

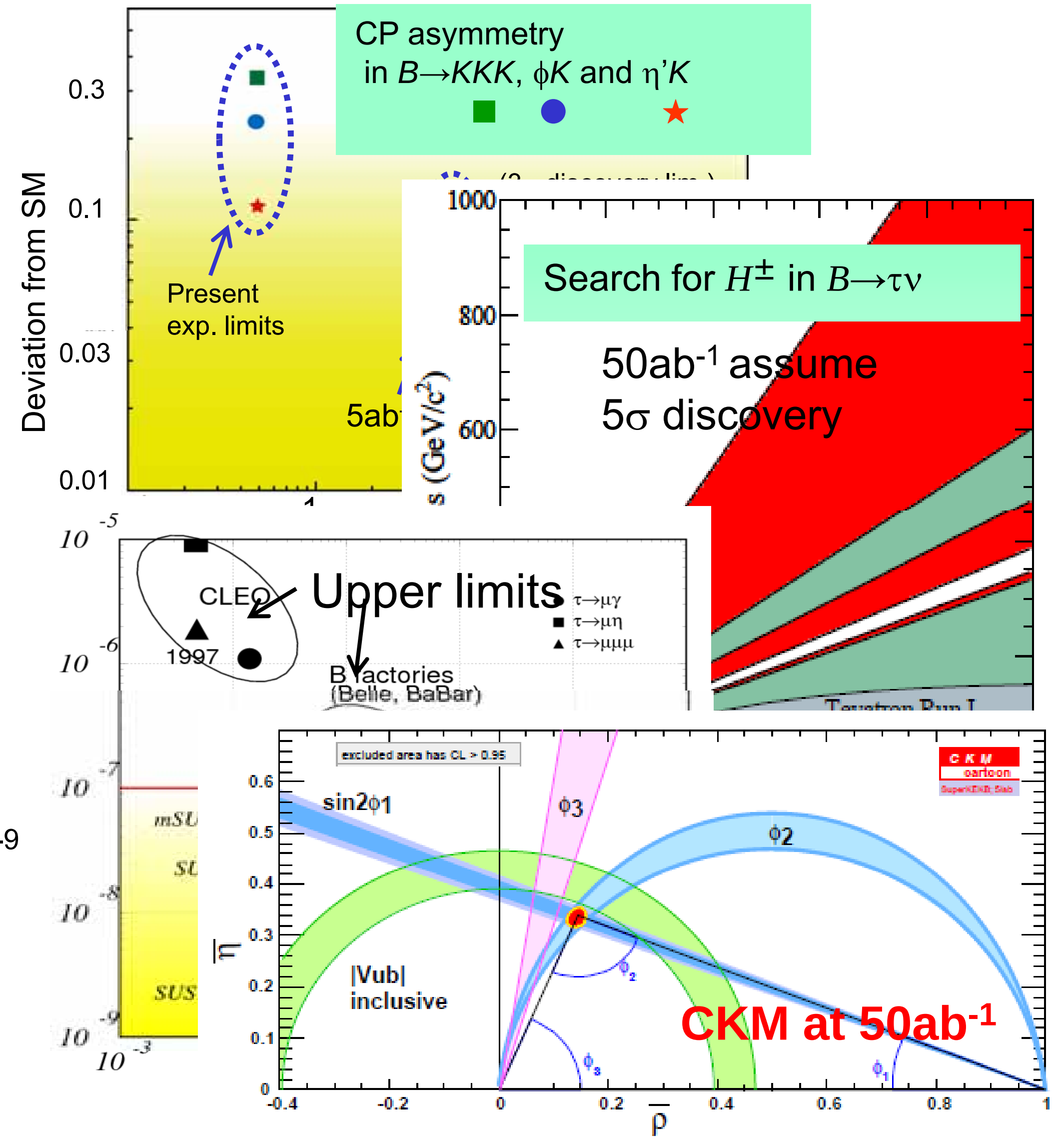
The next challenge is to find what KM cannot explain !

It requires >10^{10} B and τ pairs !

Physics Reach at Super-KEKB/Belle

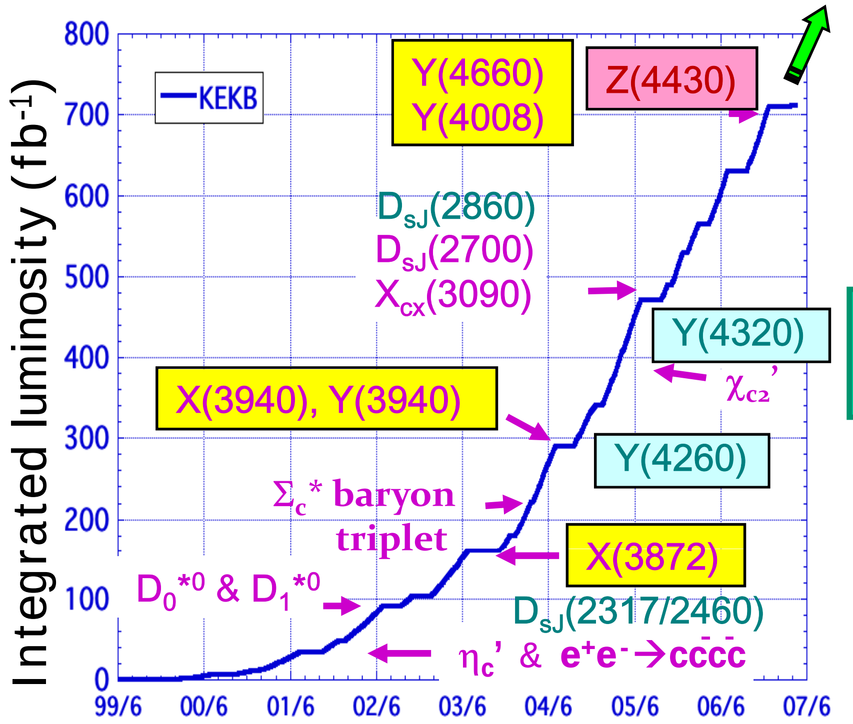
	Belle'06 (~0.5ab^{-1})	5ab^{-1}	50ab^{-1}
$\Delta S(\phi K^0)$	0.22	0.073	0.029
$\Delta S(\eta' K^0)$	0.11	0.038	0.020
$\Delta S(K_S K_S K_S)$	0.33	0.105	0.037
$\Delta S(K_S \pi^0 \gamma)$	0.32	0.10	0.03
$Br(X_s \gamma)$	13%		
$A_{CP}(X_s \gamma)$	0.058	0.01	0.005
C_9 [$A_{FB}(K^*ll)$]	---	11%	4%
C_{10} [$A_{FB}(K^*ll)$]	---	13%	4%
$Br(B^+ \to K^+ \nu\nu)$	<9Br(SM)	33ab^{-1} for 5σ discovery	
$Br(B^+ \to \tau\nu)$	3.5σ	10%	3%
$Br(B^+ \to \mu\nu)$	<2.4Br(SM)	4.3ab^{-1} for 5σ discovery	
$Br(B^+ \to D\tau\nu)$	---	7.9%	2.5%
$Br(\tau \to \mu\gamma)$	<45	<30	<8
$Br(\tau \to \mu\eta)$	<65	<20	<4
$Br(\tau \to 3\mu)$	<209	<10	<1
$\Delta \sin 2\phi_1$	0.026	0.016	0.012
$\Delta\Phi_2$ ($\rho\pi$)	68 ° —95 °	3 °	1 °
$\Delta\Phi_3$(Dalitz)	20 °	7 °	2.5 °
ΔV_{ub} (incl.)	7.3%	6.6%	6.1%

$\}$ X10^{-9} (for the three τ rows)



From Hadron Physics Point of View

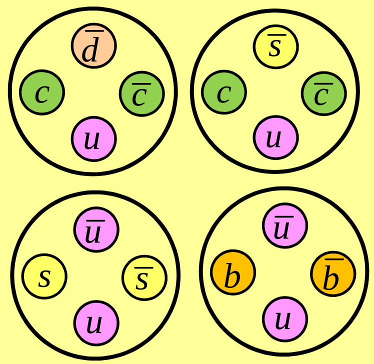
Discoveries of new resonances at Belle



Tau decays is also unique tool to study QCD.

- Study of detailed properties; J^{PC}, production & decay.
- More states;
  - Decaying to $c\bar{c}$ and K
  - $s\bar{s}$ counter-part
  - $b\bar{b}$ counter-part

    by quick energy scan.



Super-KEKB Strategy

Three factors that determine luminosity

Stored current:
1.7 / 1.4 A (e^+/ e^- KEKB)
→ 9.4 /4.1 A (SuperKEKB)

Beam-beam parameter:
0.059 (KEKB)
→ >0.24 (SuperKEKB)

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

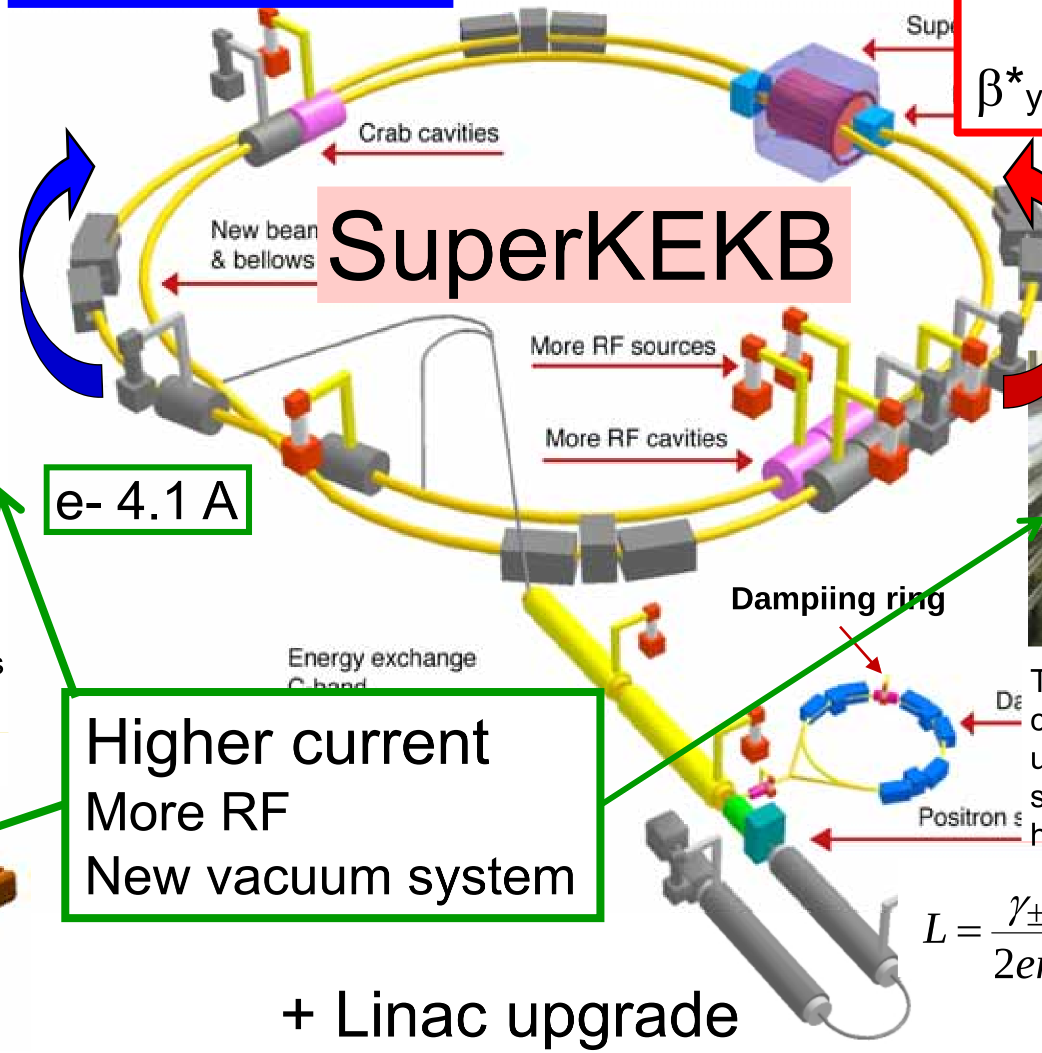
Geometrical reduction factors due to crossing angle and hour-glass effect

Luminosity:
0.17 ×10^{35} $cm^{-2}s^{-1}$ (KEKB)
5×10^{35} $cm^{-2}s^{-1}$ (SuperKEKB)

Vertical β at the IP:
6.5 / 5.9 mm (KEKB)
→ 3.0 / 3.0 mm (SuperKEKB)

Crab crossing

Crab cavities installed and undergoing testing in beam



SuperKEKB

New IR

$\beta^*_y = \sigma_z = 3$ mm

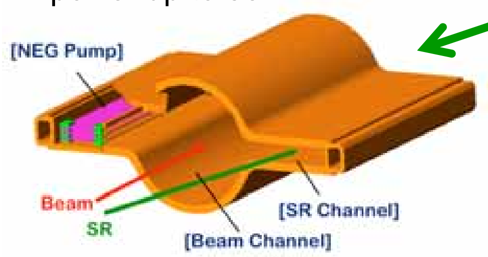
e+ 9.4 A

e- 4.1 A

The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.

The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.

Higher current
More RF
New vacuum system



The beam pipes and all vacuum components will be replaced with higher-current design.

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

+ Linac upgrade

will reach 8 × 10^{35} $cm^{-2}s^{-1}$

Major components: Cost & Effects

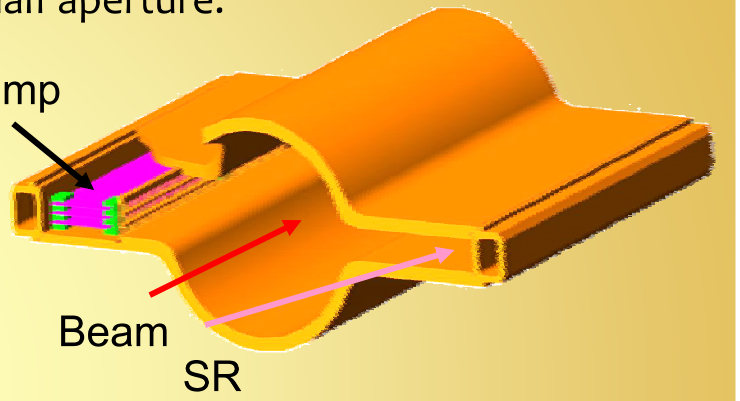
Item	Object	Oku-yen = 1.0 M$	Luminosity
New beam pipes	Enable high current Reduce e-cloud	178 (incl. BPM, magnets, etc.)	x1.5
New IR	Small β*	31	x2
e+ Damping Ring	Allow injection with small increase e+ capture	40 incl. linac upgrade	if not, x0.75
More RF and cooling systems	High current	179 (incl. facilities)	x3
Crab Cavities	Higher beam-beam param.	15	x2 - x4

Items are interrelated.

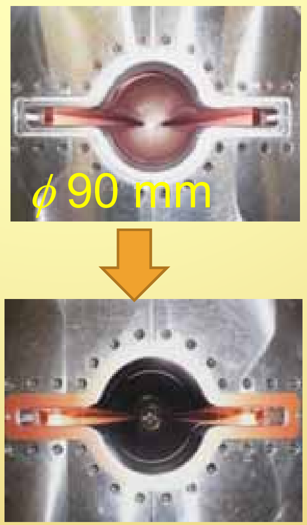
- Tunnel already exists.
- Most of the components (magnets, klystrons, etc.) will be re-used.

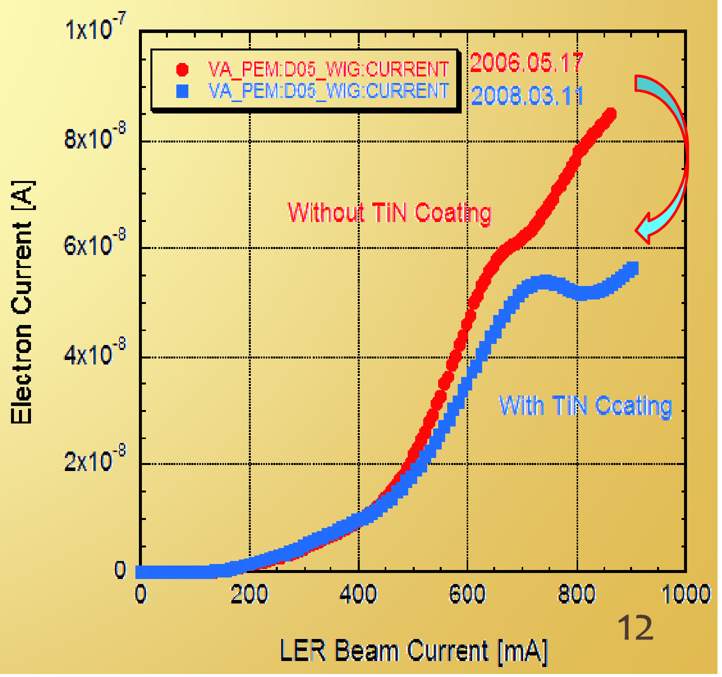
Vacuum System

- High currents (9.4/4.1A) & short bunch (σ_z=3mm) lead to;
  - Intense SR power
    - Max. power density of 28kW/m (40W/mm^2) even at half aperture.
  - High Photon density
    - ~1x10^{19} photons/m/s in average.
  - Intense HOM power
    - For a loss factor of 1V/pC, loss power is ~200kW.



- Copper beam duct w/ ante-chamber
- TiN coating on inner surface
  - to decrease secondary electron yield (SEY); max.SEY~0.9
- Clearing electrode
  - A possible measure even inside of magnets

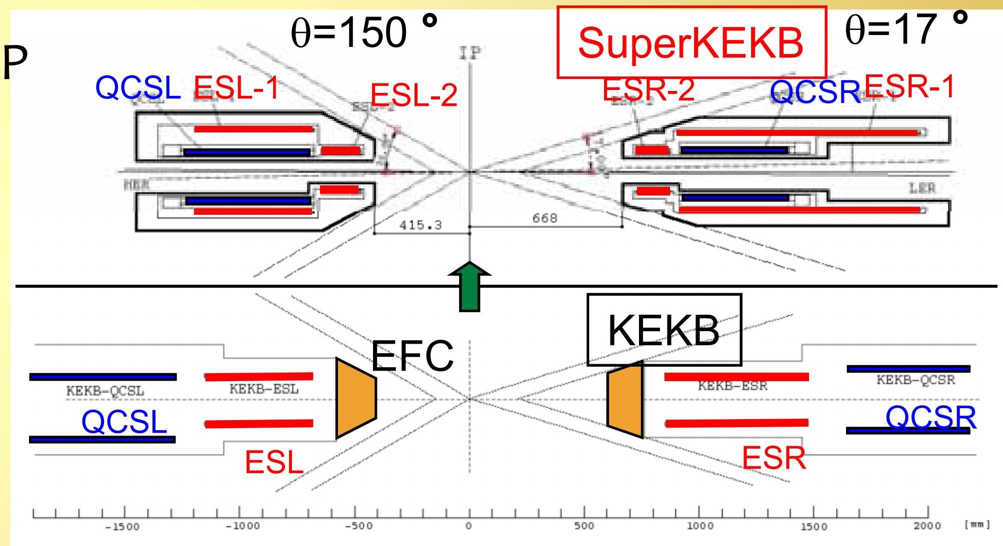




Interaction Region

		Achieved	KEKB design	SuperKEKB	unit
Beta (hor.) at IP	β_x^*	~60	33	20	cm
Beta (ver.) at IP	β_y^*	~6.5	10	3	mm
Bunch length	σ_z	~7	5	3	mm
Crossing angle	θ_x^*	±11	±11	±15	mrad

- Move final focus quad. closer to IP for lower beta functions at IP.
- Preserve current machine-detector boundary.
- Rotate LER 8 mrad.
- ➡ Crossing angle: 22-> 30 mrad
- QCS and solenoid compensation magnets overlap in SuperKEKB.



Issues	Causes
Physical aperture around IP	Lower β at IP
Dynamic aperture	Lower β at IP
Detector background	Higher beam current
Heating of IP components	Higher beam current & shorter bunch length

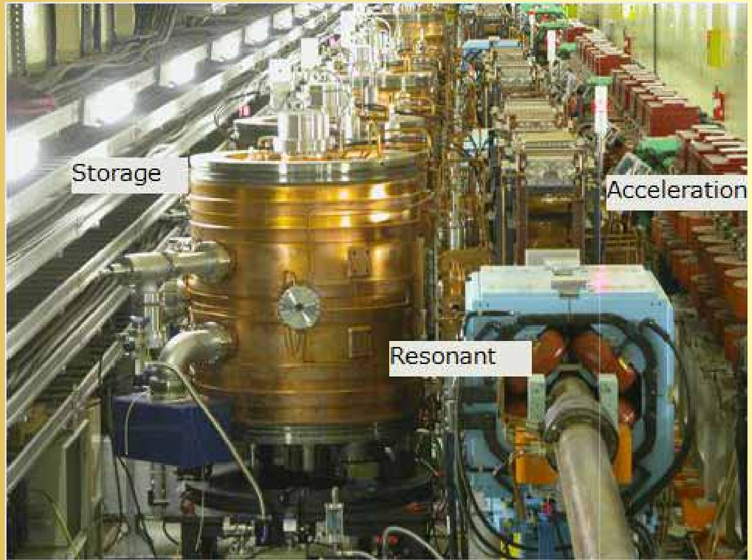
(Physical aperture, Dynamic aperture, Detector background) ➡ **Damping Ring**

RF Systems

- Adopt the same RF frequency as KEKB and use the existing RF system as much as possible, with improvements as necessary to meet the requirements for SuperKEKB.

→ Construction cost is greatly reduced.
Technical uncertainties are relatively small.

ARES Normal conducting cavity

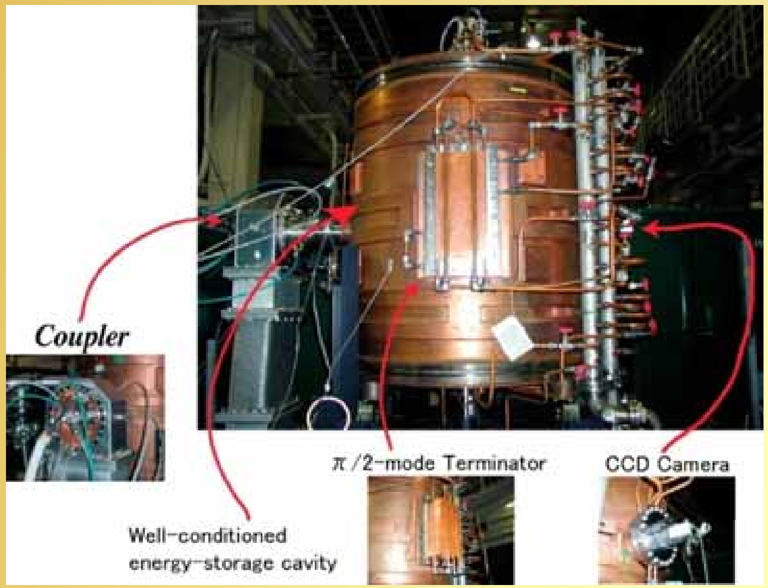


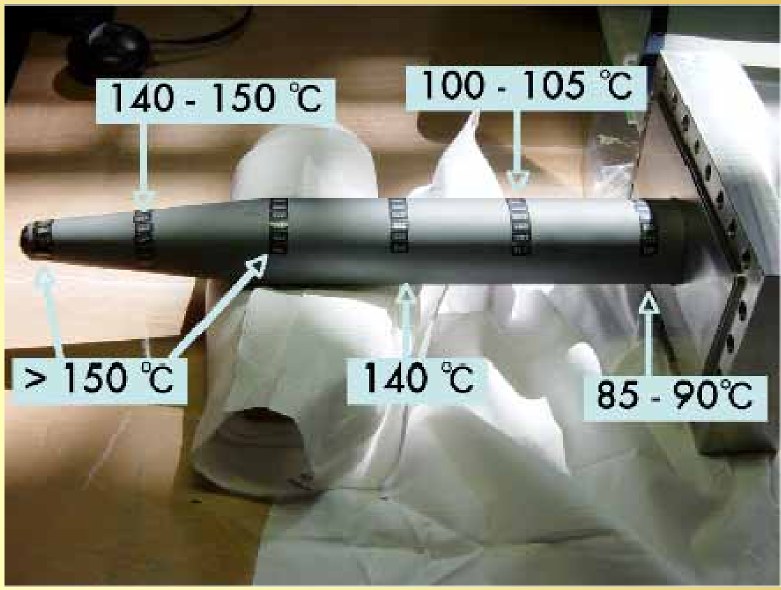
Normal-conducting ARES cavity: LER + HER
Passive stabilization with huge stored energy.
T. Kageyama et al.

Superconducting cavity

Superconducting cavity: HER
S. Mitsunobu et al.

High Power RF R&D

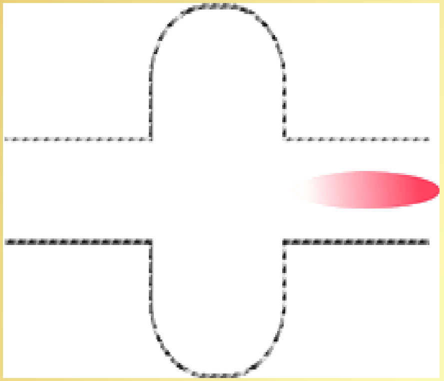


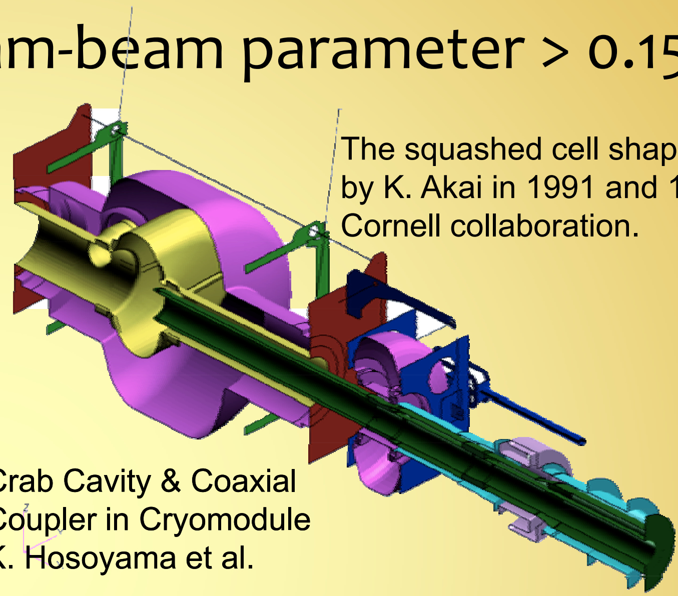


- Normal Conducting cavities (ARES):
  - Upgrade of ARES with higher energy storage ratio. (left)
  - High power rf input couplers.
  - SiC dummy load with higher power capability (right).
- Superconducting cavities:
  - The expected power load to the HOM absorber is 50 kW/cavity at 4.1 A, (even) with a larger beam pipe of 220 mmφ.
  - HOM damper upgrade may be needed.

Crab Crossing at KEKB

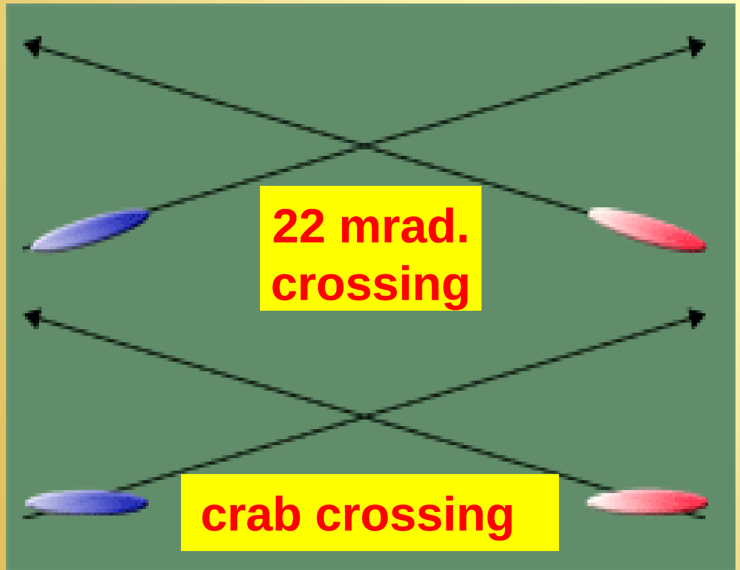
- Crab Crossing can boost the beam-beam parameter > 0.15 .

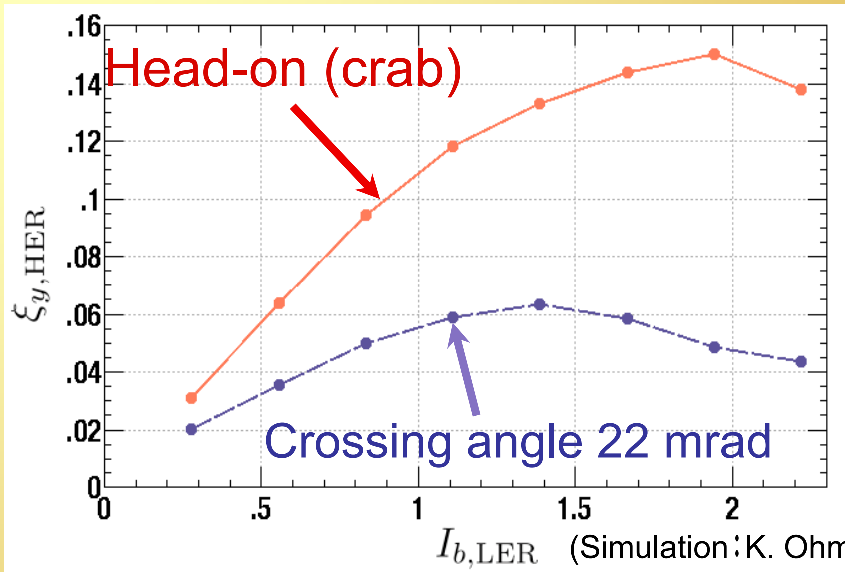




The squashed cell shape cavity studied by K. Akai in 1991 and 1992 under KEK-Cornell collaboration.

Crab Cavity & Coaxial Coupler in Cryomodule
K. Hosoyama et al.





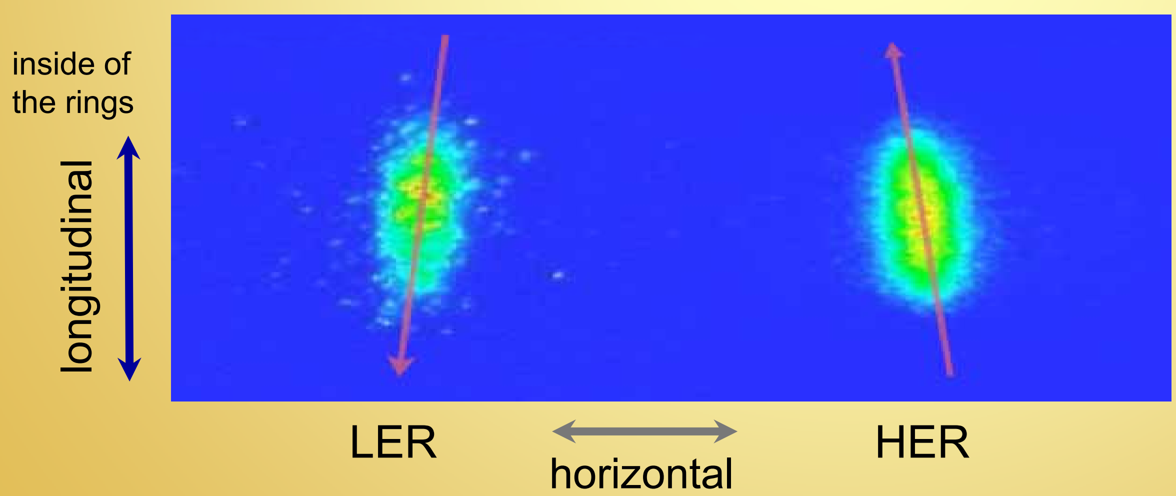
(Simulation：K. Ohmi)

Test of Crab Crossing

- Two crab cavities were installed in KEKB in January 2007.

one for each ring

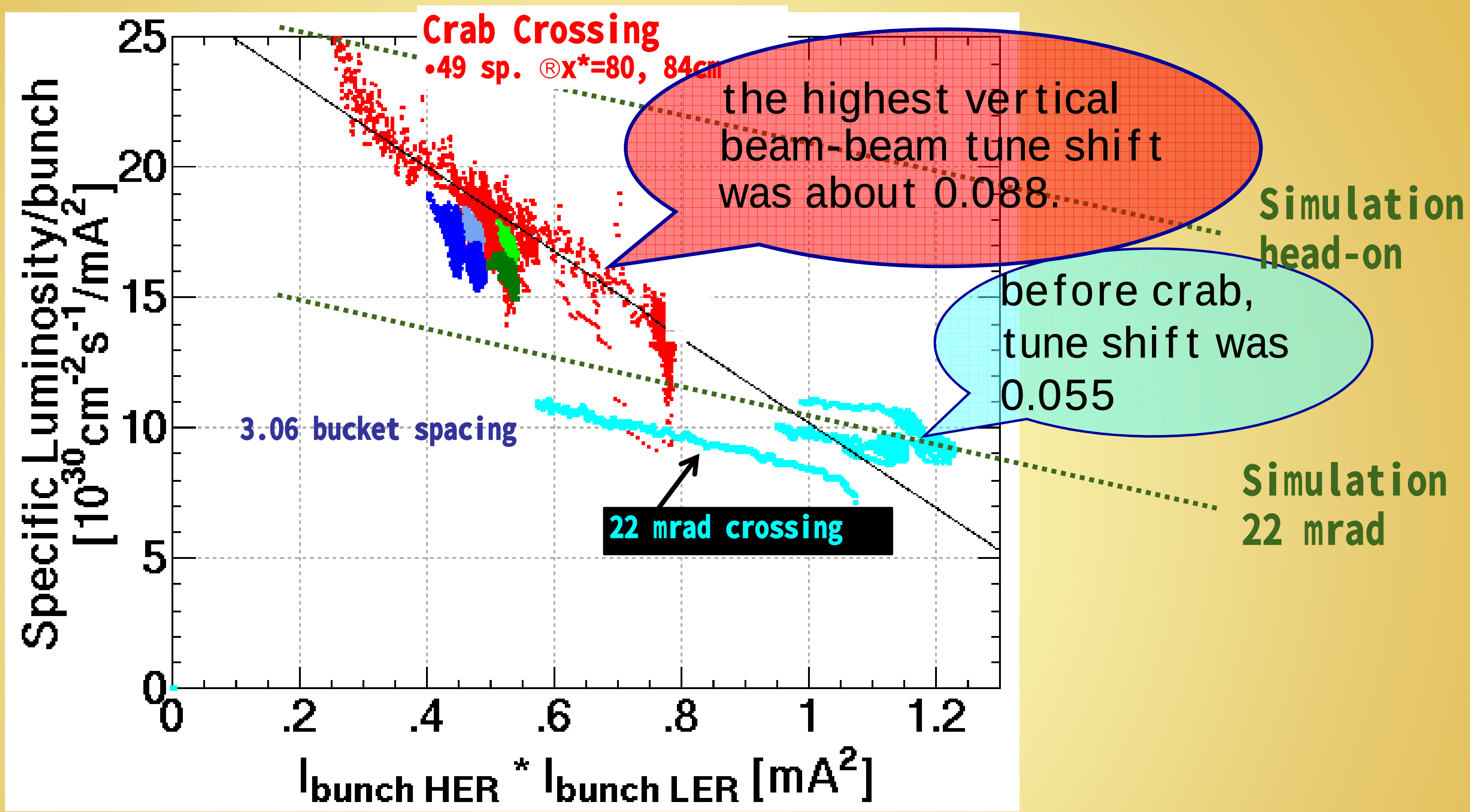
- Beams have been indeed tilted !



outside of the rings

Observation with streak cameras (H. Ikeda et al, PAC07 FRPMN035)

Specific Luminosity With Crab Crossing

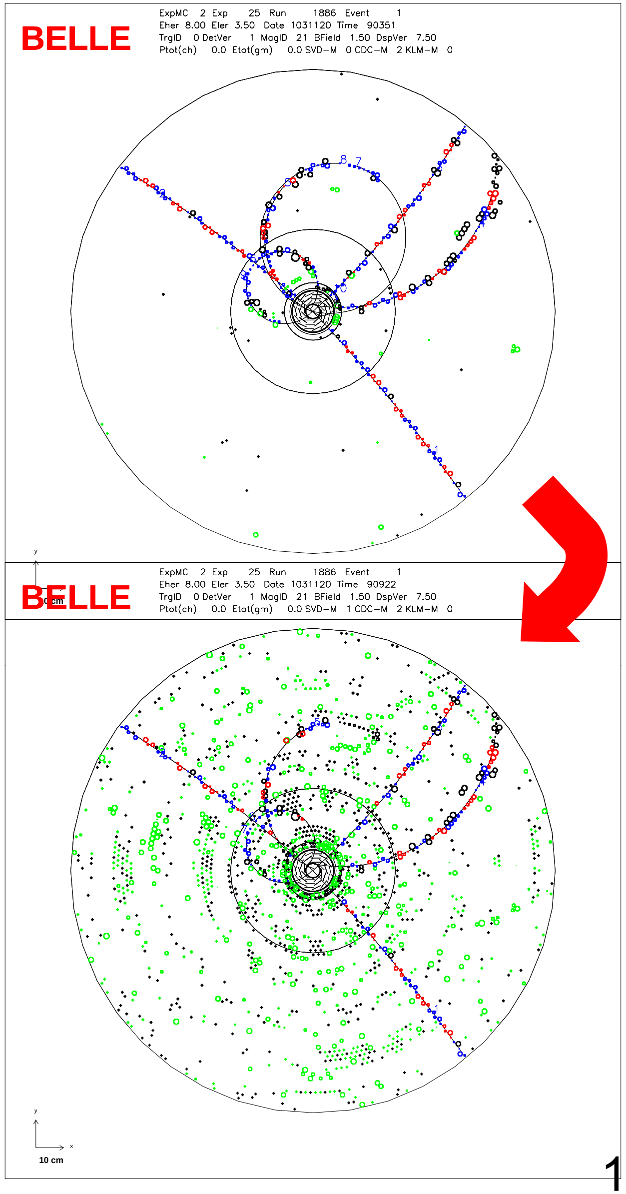


- A number of measurements indicate effective head-on collision.
- The vertical tune shift went from 0.055 to 0.088.
- The specific luminosity/bunch improved by more than just the geometrical gain, by about 15%.
- Need more time to achieve the goal (X2 specific luminosity).

Super-Belle Strategy

Issues

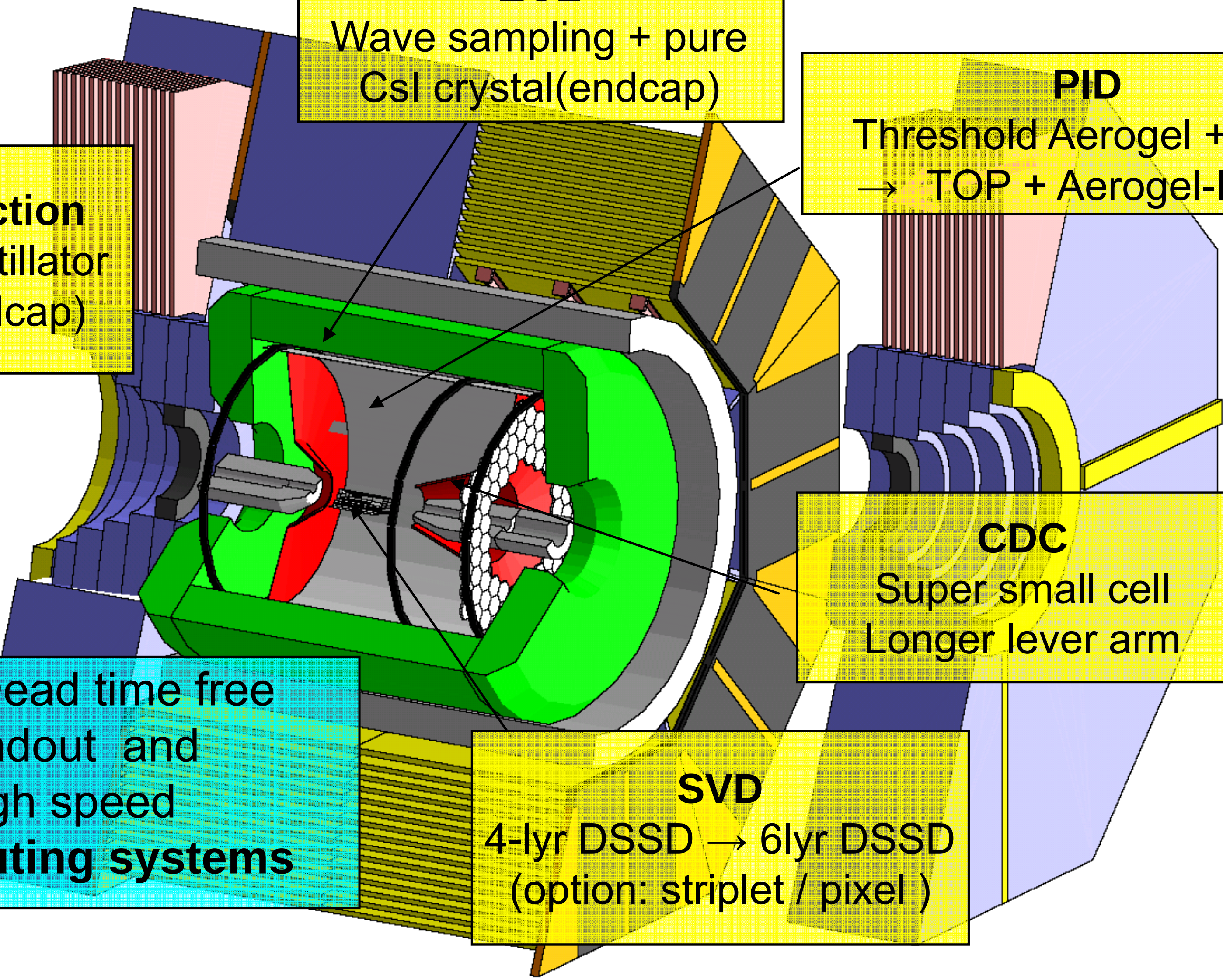
- **Higher background (×20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low *p* μ identification ← sμμ recon. eff.
  - hermeticity ← ν “reconstruction”



Possible solution:

- Replace inner layers of the vertex detector with a silicon striplet/pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter by pure CsI.
- Faster readout electronics and computing system.

Super-Belle (Baseline)



Background Effects

"sBelle Detector Study Report" posted as arXiv: 0810.4084

New

- Effective background with new hardwares

	How	Reduction factor	Effective bkg
SVD	Shorter t_p	50/800=1/16≈1/12.5	0 ~ 1
CDC	Smaller cell	<2/3	4 ~ 13 (*)
PID	Brand new device	Good enough	0 ~ 1
B-ECL	Waveform fitting	1/7	1 ~ 2
E-ECL	Pure CsI (shorter t)	1/200	0 ~ 1
KLM	Faster detector, finer segment	Under control	0 ~ 1

(*) Software efforts needed for CDC

- Background effects on tracking

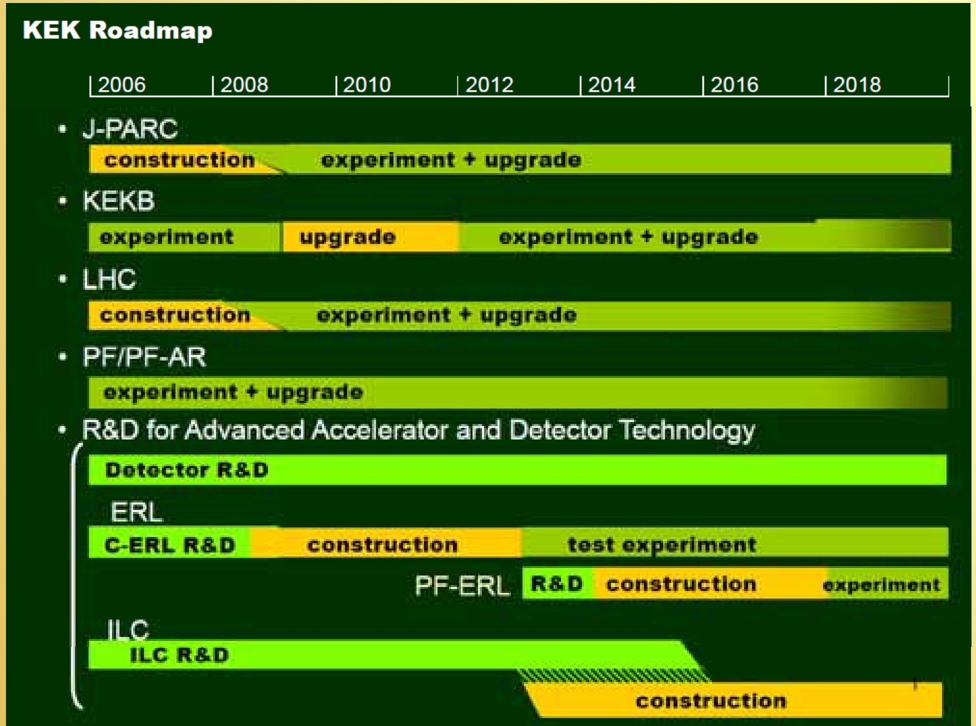
Gain in reconstruction efficiency of $B \to D^* D^* (D^* \to D\pi_s, D \to K3\pi)$

	Present Belle	Software update	+SVD tracker
Present	ε=4.3%	ε=7.1% (+65%)	ε=11.9% (+177%)
×5 BG		ε=6.3% (+47%)	ε=11.2% (+160%)
×20 BG		ε=3.8% (–12%)	ε=8.8% (+105%)

We know how to handle the background.

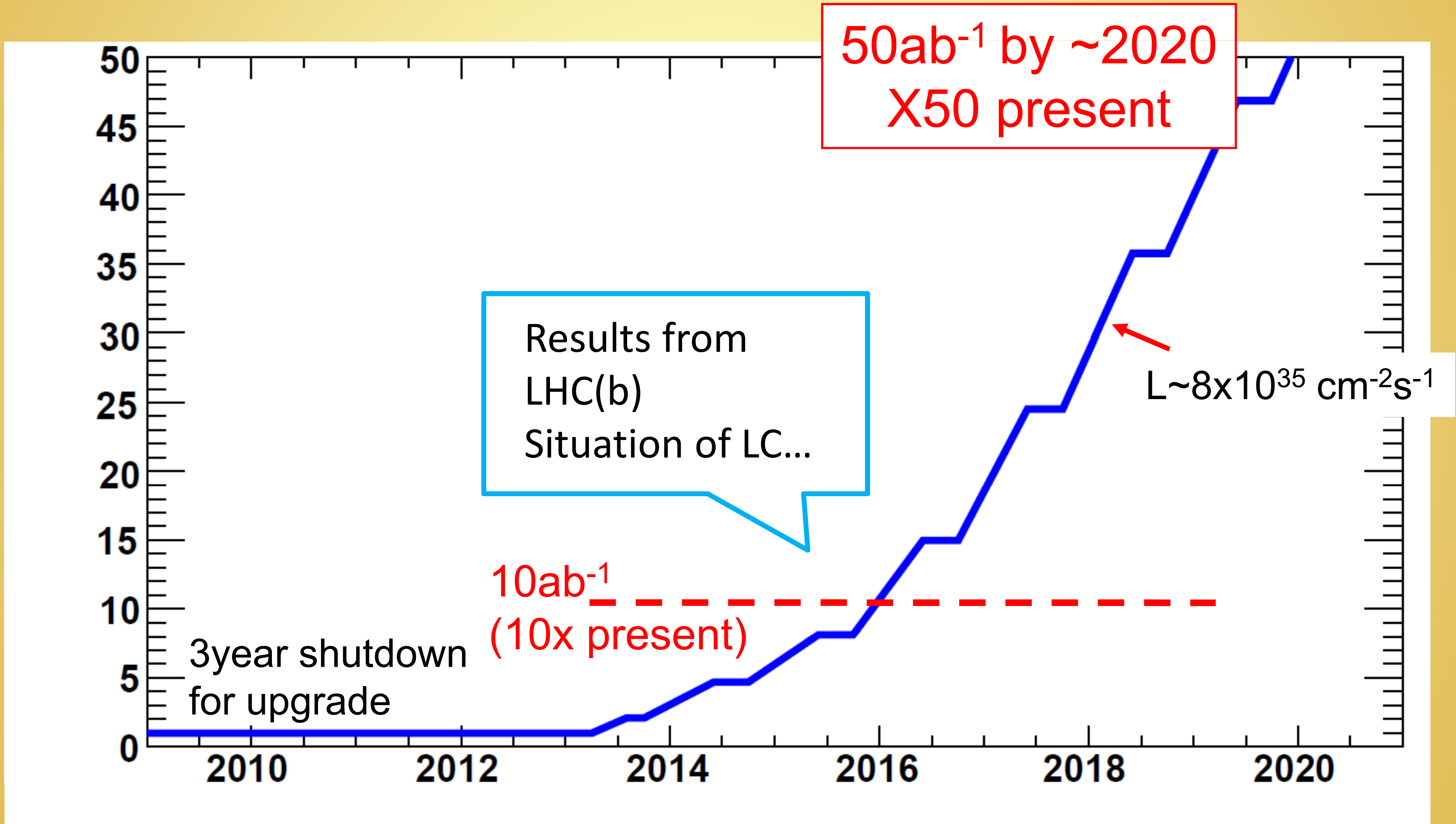
KEK Roadmap

- KEK's 5-year roadmap.
- 3-year shutdown for KEKB upgrade
  - 0.5-1 year delay, KEKB will run in FY2009
- KEK management in close contact with MEXT.
  - "Investigation money" requested in FY2008.



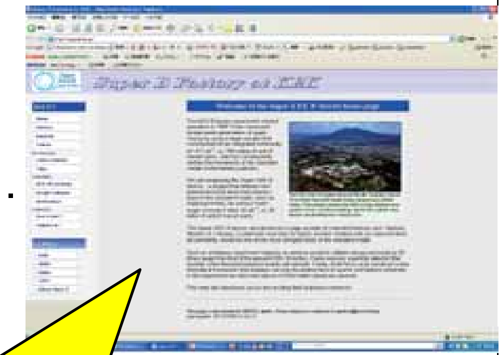
Hope
Positive effects from the Nobel Prize ...

Luminosity Prospect



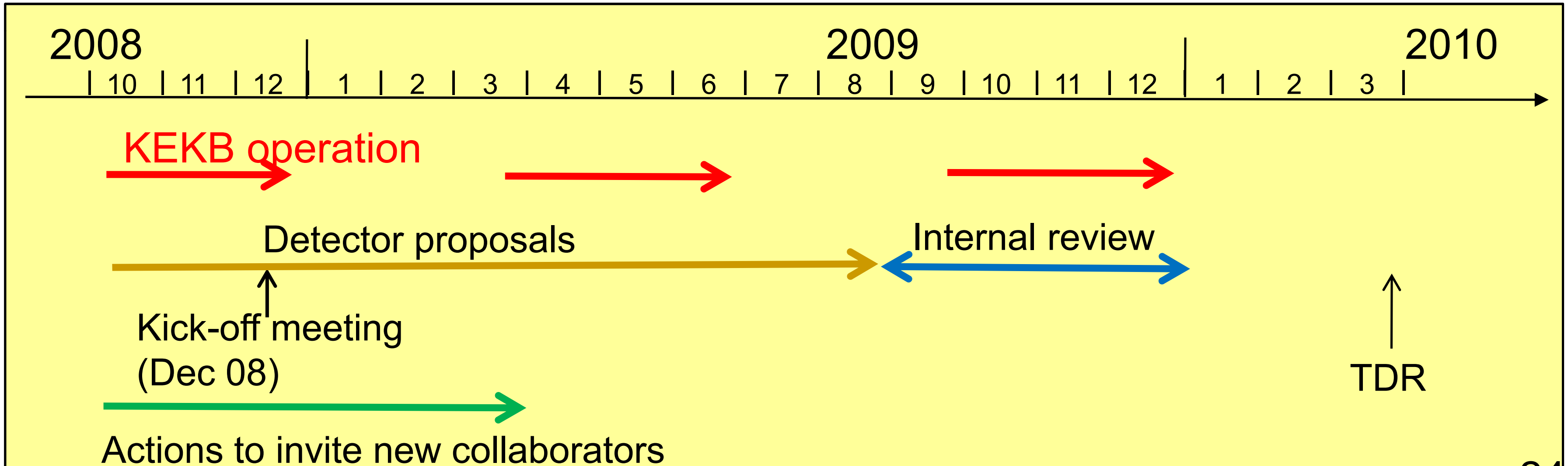
New collaboration

- Super-Belle will be a new international collab.
  - Two proto-collaboration meetings in Mar&Jul, 2008
    - Participation of new people from Germany, India, U.S., Japan,… .
  - Kick-off of the new collaboration: Dec.10-12, 2008.
    - Still many sessions will be open.



Super-Belle webpage
http://superb.kek.jp/
ML subscription is available.

- Near-term plan (preliminary)
  - Detector study report has been completed.
  - Detector proposals (by summer 2009).
  - The final detector design by Dec. 2009.



Summary

- KEKB/Belle has been running successfully, and brought important scientific and technical achievements.
- Next generation e^+e^- *B* factory with L~10^{36} will be very useful to study the new sources of flavor mixing and CP violation.
- It must be very interesting also from hadron physics point of view.
- Super-KEKB: the target luminosity is 8 x 10^{35}cm^{-2}s^{-1}, based on existing or tested technologies (mostly), which enables us to accumulate 10ab^{-1} by 2016, and 50ab^{-1} by 2020.
- Super-Belle: detector upgrade studies are in progress, and will be finalized in 2009.
- New collaboration is being formed; the kick-off meeting on Dec.10-12 at KEK (many sessions will be open).

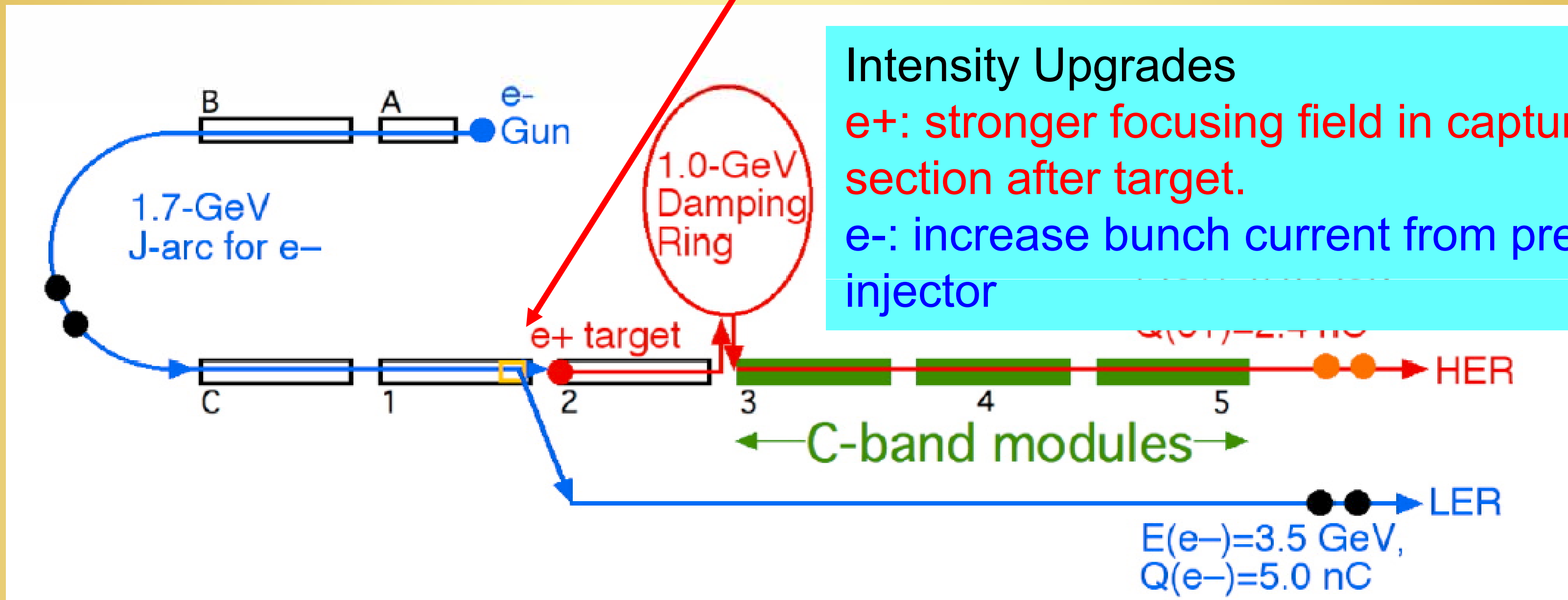
We are trying to get ready soon. **Stay Tuned !**

Backup

Linac Upgrade

Pulse beam kicker for quick beam switching (50 Hz).

→ **Start testing this Fall**



Intensity Upgrades

e+: stronger focusing field in capture section after target.

e-: increase bunch current from pre-injector

Energy Upgrade (Positrons)

Replace S-band (2856 MHz) with C-band (5712 MHz) RF system to double field gradient in downstream section of linac.

C-band linac:

- completed a single section in the linac with 4 structures
- Performance was satisfactory with beam.

Damping Ring

- Positron emittance needs to be damped, to pass reduced aperture of C-Band section and to meet IR dynamic aperture restrictions.
  - Electron DR may also be considered later to reduce injection backgrounds in physics detector, but for now only positron DR considered.
- Damping ring located downstream of positron target, before C-Band accelerating section.