Prospects for upgrades of KEKB and Belle

Super KEKB uest for BSM

BEACH 2008
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Belle and beyond: physics, collider, detector

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University of Cincinnati
Belle Collaboration

Belle (1999-present)

- RICH physics in the Upsilon region

Headliners
- CKM, including $\sin 2\varphi_1$, constraints on φ_2, φ_3
- new charmonia, charmonium-like states in continuum, ISR, D_{sJ}, B decays
- D^0 mixing
- probes of New Physics

+ many more measurements on
B, charm, tau, 2-photon, $\Upsilon(4S)$, $\Upsilon(10860)$, B_s, $\Upsilon(3S)$, $\Upsilon(1S)$, ...

Addressing
CP, CKM, QCD, HQ spectroscopy, LFV, NP, Dark Matter, ...

265 journal articles published/submitted

http://belle.kek.jp/bdocs/b_journal.html

Why continue in flavor physics?

- CKM: highly constrained pattern of CC couplings w CP violation manifested in diverse processes in B decay
  -> many measurements, (over)constrain CKM
- statistics limited on $\rho^0\rho^0(\varphi_2)$, Dalitz analyses (φ_3), b->dγ, τ->μγ,...
- SM extensions likely to have new sources of CPV & flavor couplings
  -> precision CKM as window to New Physics
- in 1.4 ab^{-1} at Belle+Babar: hints of New Physics?

-> to open the window, X10^2 luminosity at B-factory
pro's vis-a-vis LHCB: γ, K_L detection; hermeticity -> neutrinos

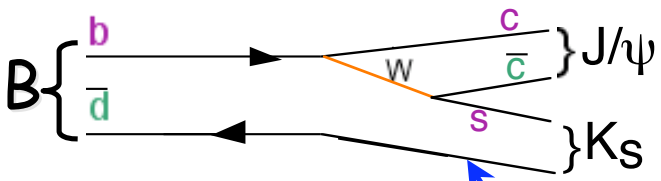
- CP asymmetry in b->s penguin -> non-SM contributions
- Lepton universality B-> τν, B->$D^{(*)}$ τν
- Right-handed currents CP asymmetry of B->{s}γ
- Inclusive b->sγ, b->dγ, B-> sl^+l^-
- CP asymmetry in D mixing -> NP

... + many B-factory measurements are not yet systematics limited

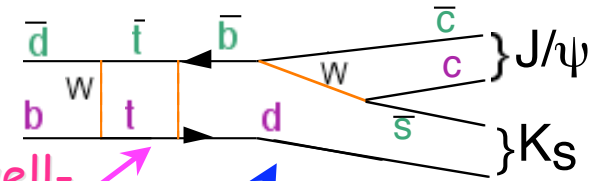
CP asymmetry in B->ssbar: sin2φ1 in SM

for B -> J/ψ Ks

tree (real V_{ij}) $\propto V_{cb}^* V_{cs}$



mixing+tree $\propto V_{tb}^{*2} V_{td}^2 V_{cb} V_{cs}^*$



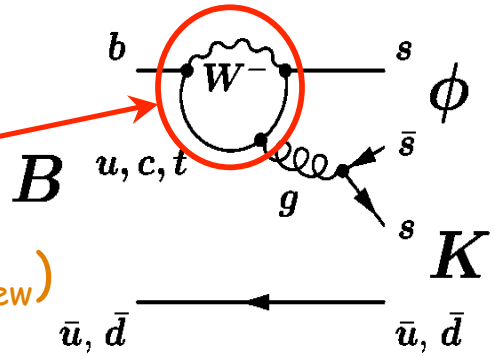
well-measured

identical hadronic processes -> same |A|

Phase of mixing $(V_{tb}^{*2} V_{td}^2) = 2\varphi_1$, $V_{cb}^* V_{cs}$ real -> asym ~ sin $2\varphi_1$

for b -> sbar s s

- similarly, penguin & mixing+penguin
  - due to loop cancellation, large m_t -> $\propto V_{tb}^* V_{ts}$ real -> asym ~ sin $2\varphi_1$
  - NP w complex phase φ_{new} -> asym ~ sin $(2\varphi_1 \pm 2\varphi_{new})$



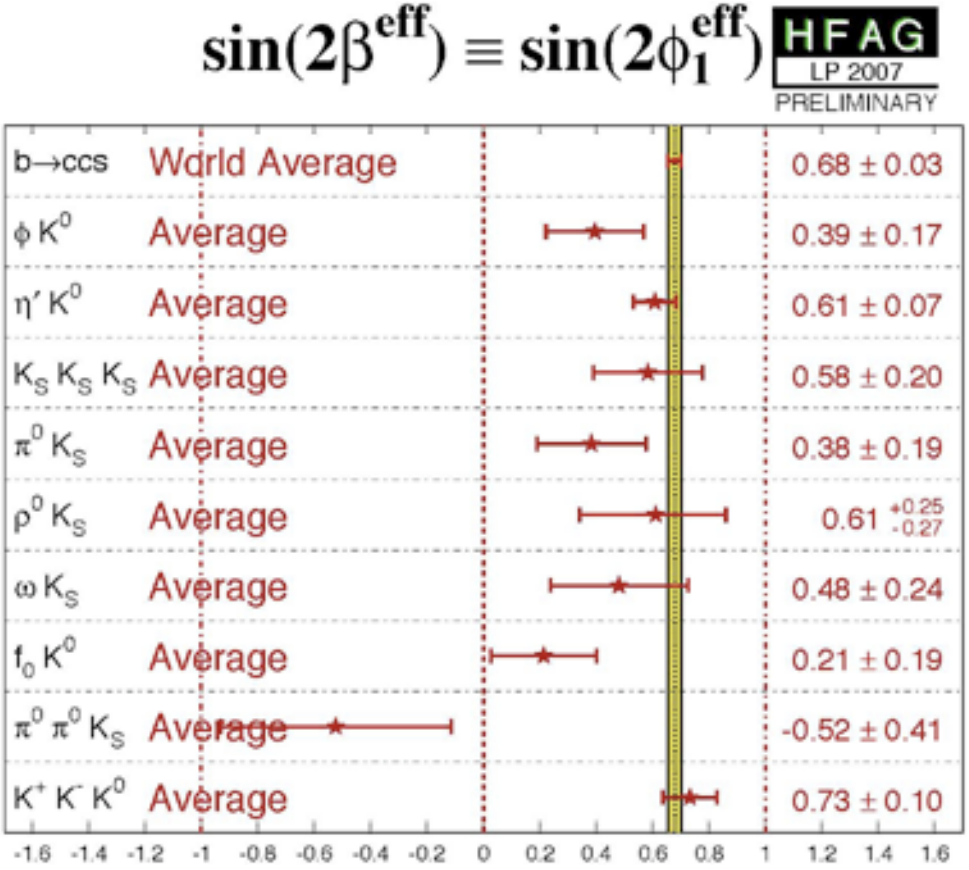
Average "sin2φ_1" from *b->s* penguins

Naïve World Average
sin2φ_1(*b->sqq̄*)= 0.56 ± 0.05

Compare to *cc̄s*:
sin2φ_1(*b->cc̄s*) = 0.680 ± 0.025

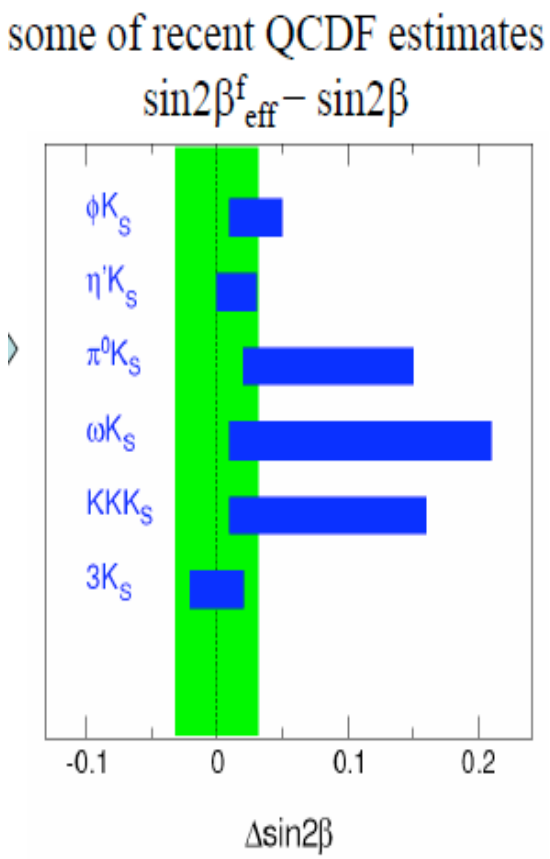
CL = 0.03 (2.2σ)

- statistics?
- experimental systematics?
- theory corrections?
- new physics?

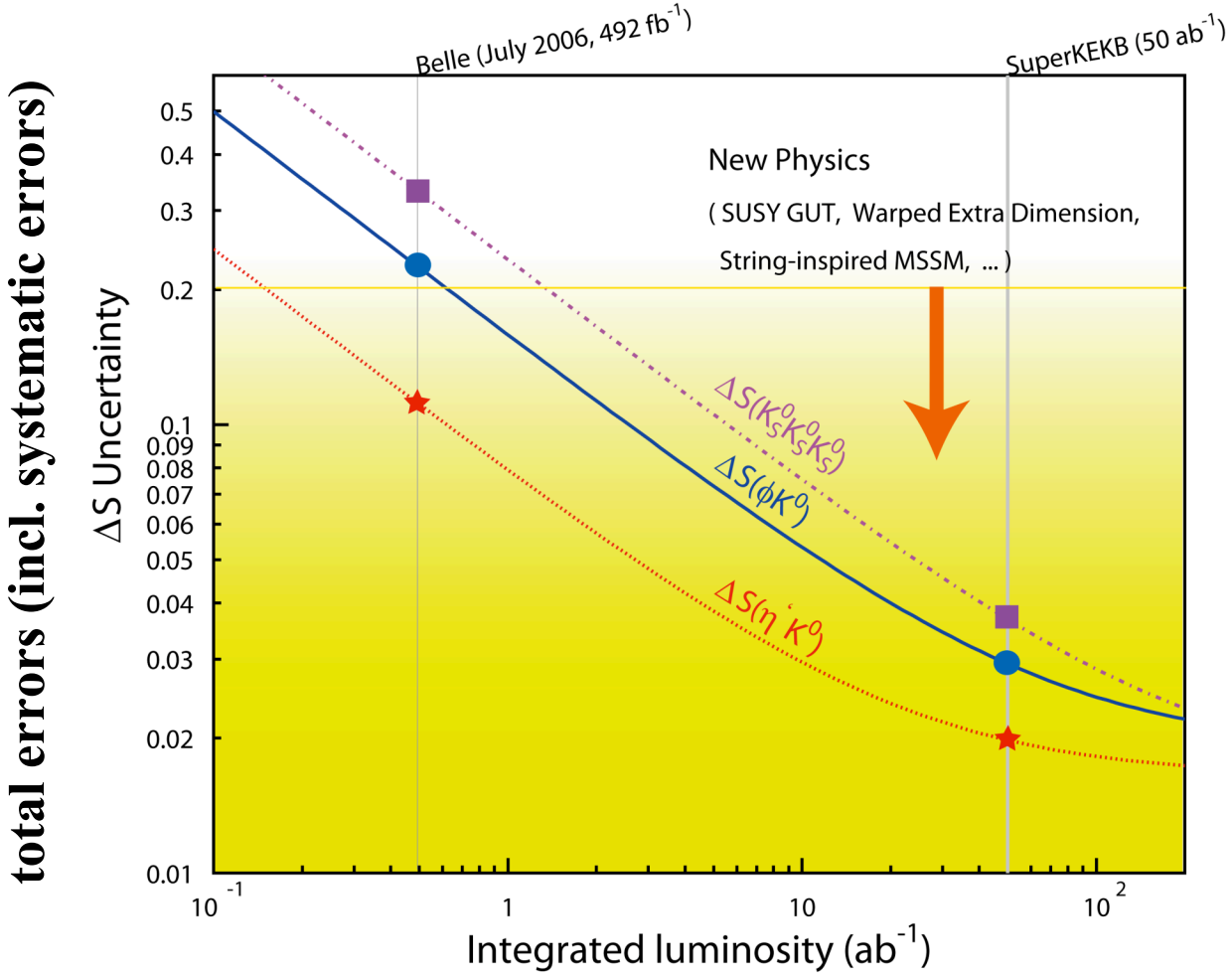


CP asymmetry in b → s: SuperKEKB sensitivity

SM prediction



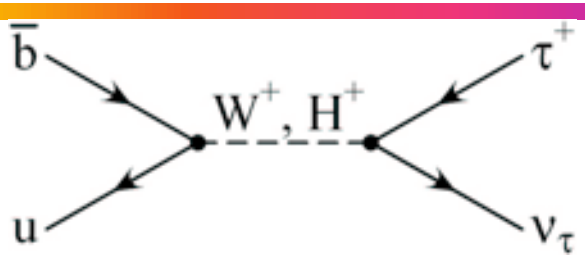
$B \to \phi K^0$, $\eta' K^0$, $K_S K_S K_S$ projection for SuperKEKB



$B^+ \to \tau^+ \nu_\tau$: constraints on charged Higgs

$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{SM} \times r_H$$

$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2\beta)^2$$

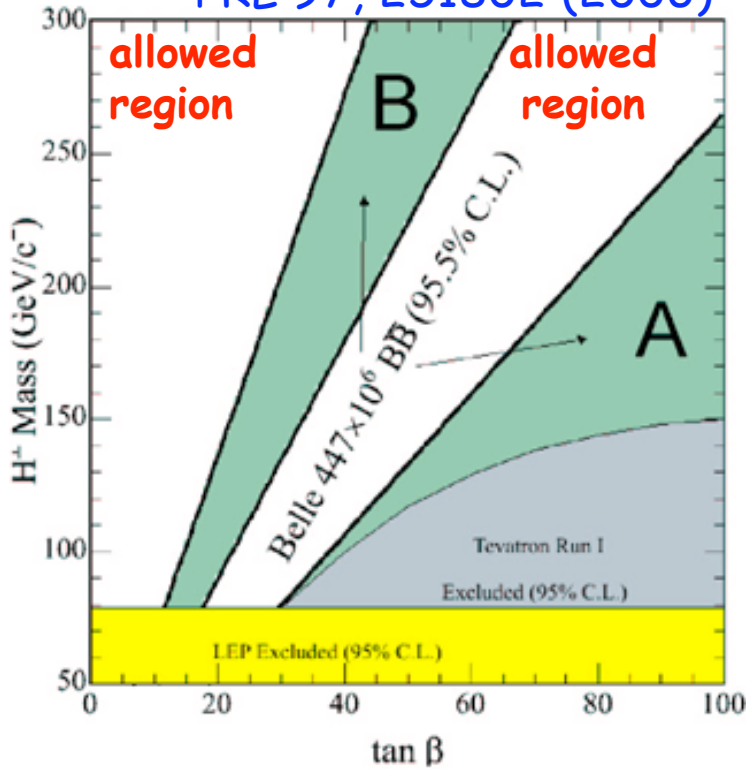


{WS Hou, PRD 48, 2342 (1993)}

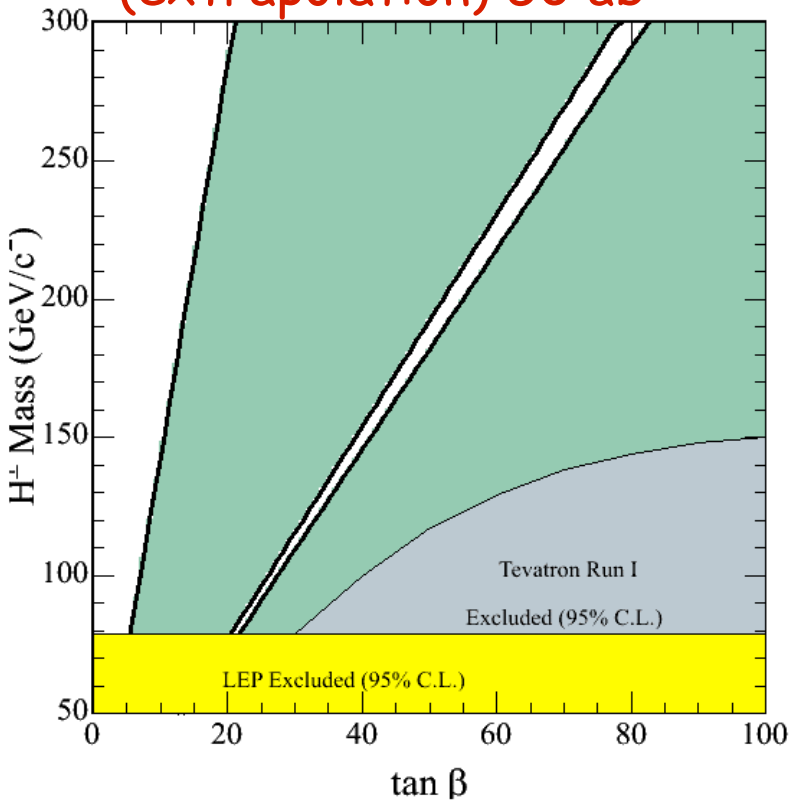
(Belle) 0.41 ab^{-1}

$\mathcal{B}(B \to \tau\nu) = (1.8 \pm 0.5 \pm 0.5) \times 10^{-4}$

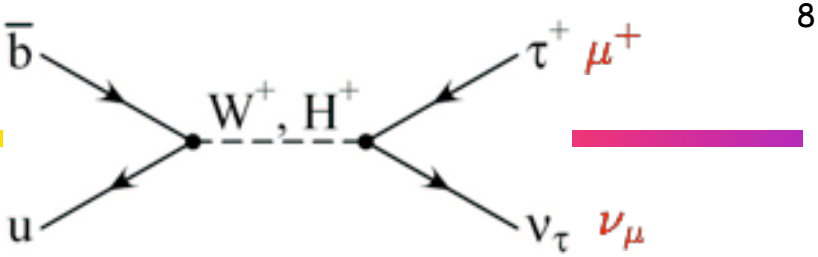
PRL 97, 251802 (2006)



(extrapolation) 50 ab^{-1}



Lepton universality: B→μν



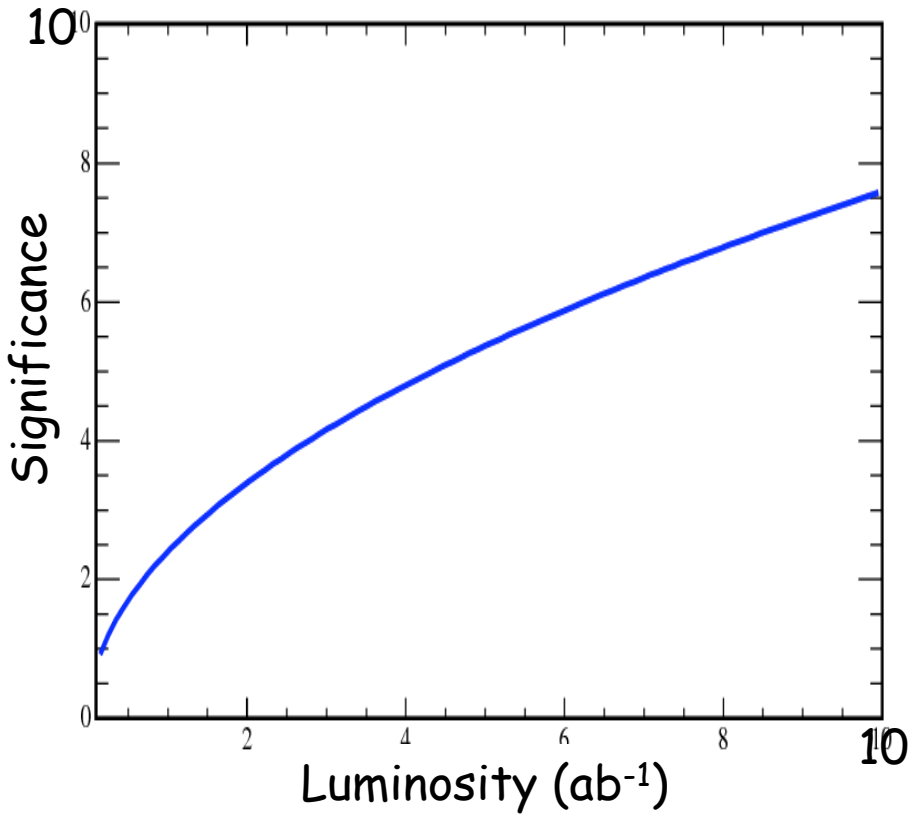
SM:

B(B->τν) = 1.6×10^{-4}

B(B-> μν) = 7.1×10^{-7}

B(B-> eν) = 1.7×10^{-11}

expect observation within few ab^{-1}

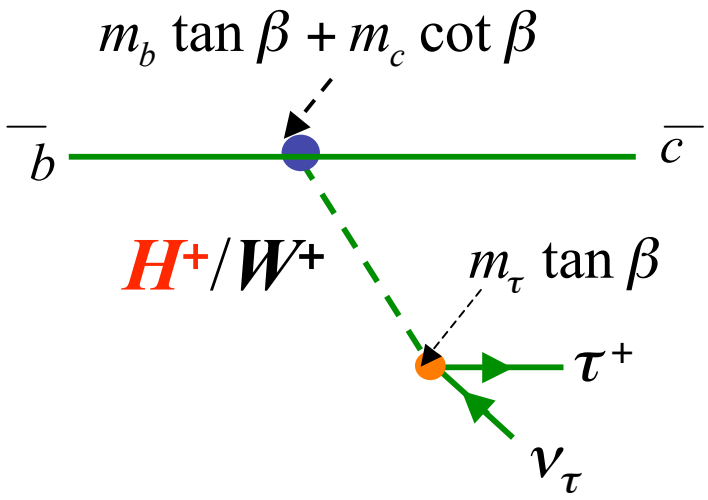


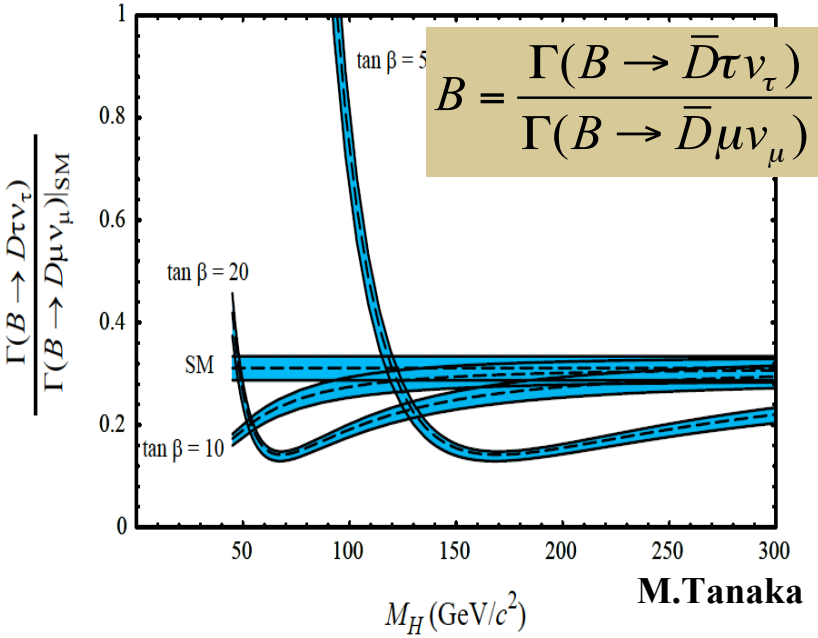
B->τν / B-> μν

deviations from SM sensitive to NP

$B \to D^{(*)} \tau \nu$

- Lepton universality via semileptonic decays





$B(B^0 \to D^{*-}\tau\nu) = (2.0 \pm 0.4 \pm 0.4)\%$
[PRL 99, 191807 (2007)]

- Ratio (τ/μ) is sensitive to charged Higgs (similar to $B \to \tau\nu$)

$B \to \tau$ X decays probe NP in different ways:

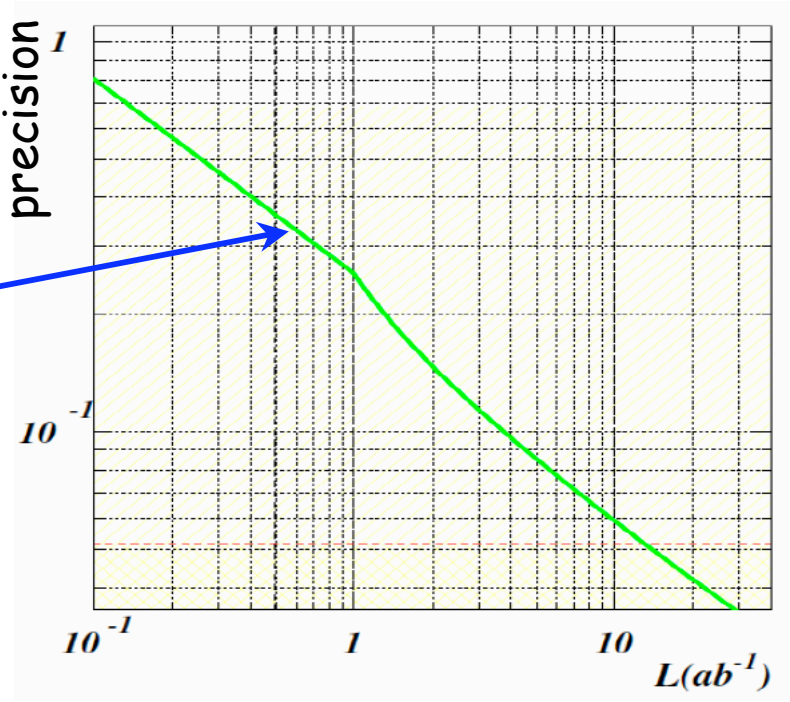
- $B \to \tau\nu$: H-b-u vertex
- $B \to D\tau\nu$: H-b-c vertex

Right-handed currents

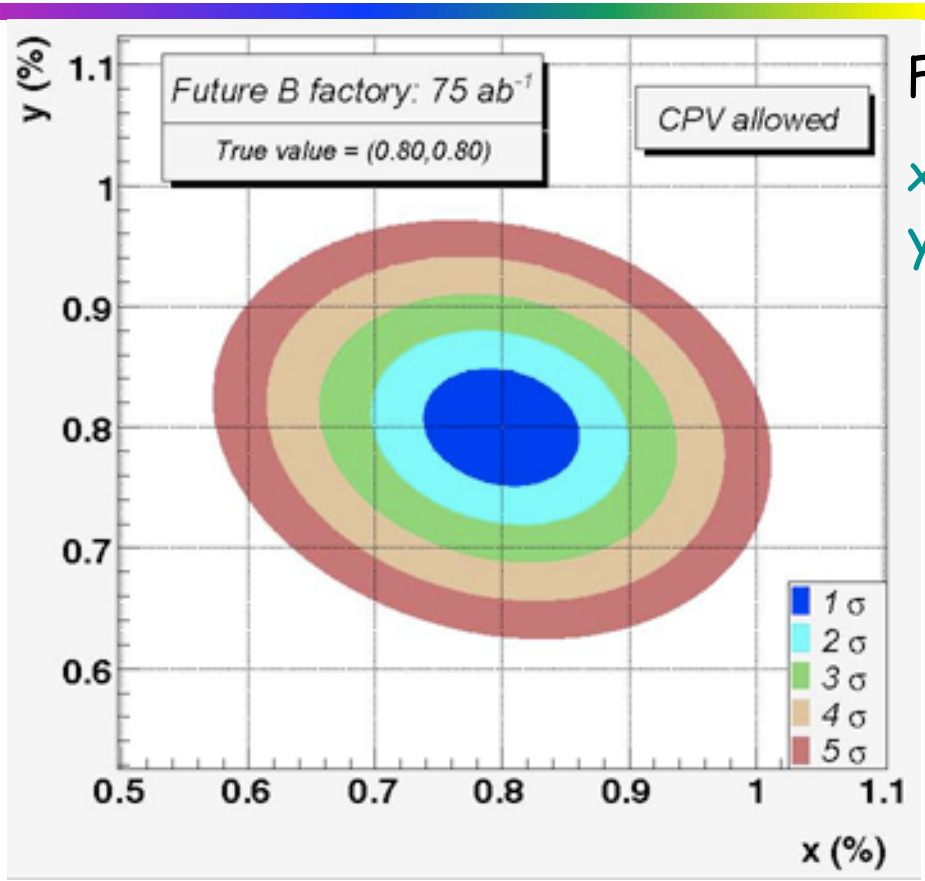
Sizable CP asymmetry expected in $B^0 \to X_s\gamma$
if NP includes right-handed current

CP asymmetry in $B \to K_S\pi^0\gamma$

PRD 74, 111104(R) (2006)



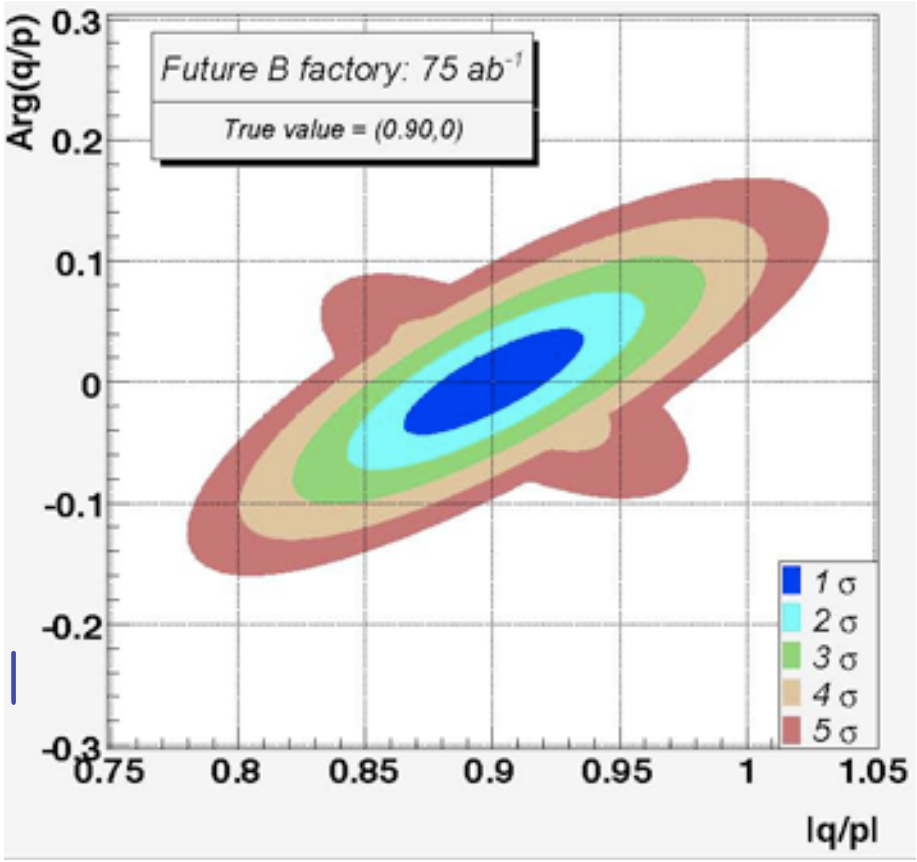
D mixing/CP violation



For 75 ab^{-1}

x=0.8 >4σ significance on x

y=0.8 >5σ significance on y



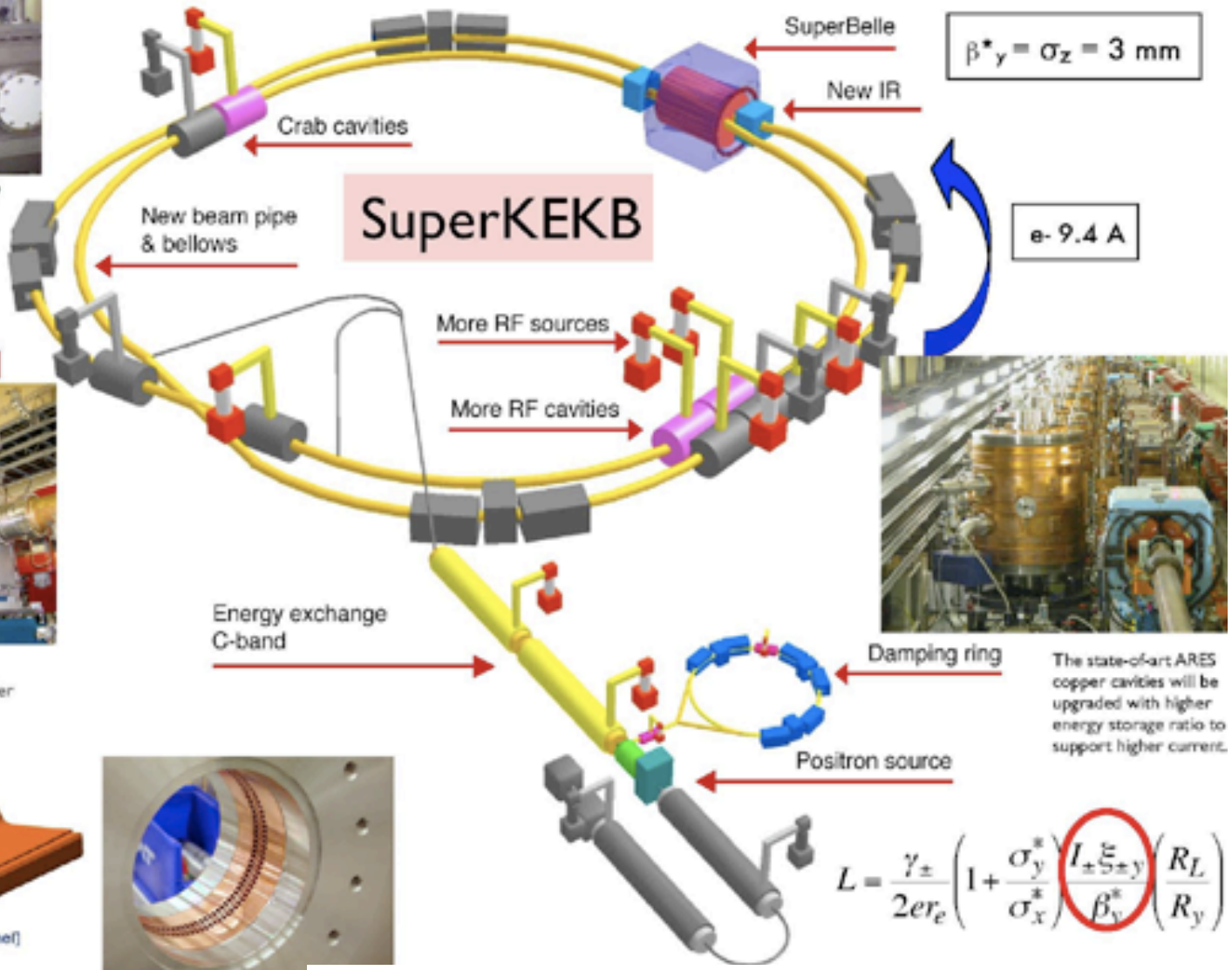
|q/p|=0.9

~4σ significance on 1-|q/p|

KEKB Upgrade plan

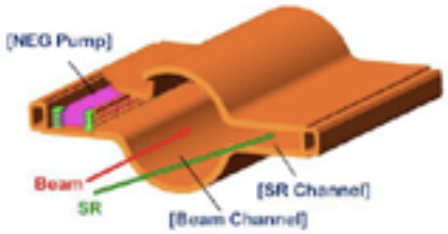
- *upgrade existing KEKB collider*
- *Final goal: $L=8\times10^{35}/cm^2/sec$ and $\int L\,dt = 50\ ab^{-1}$*

Crab cavities will be installed and tested with beam in 2006.



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.

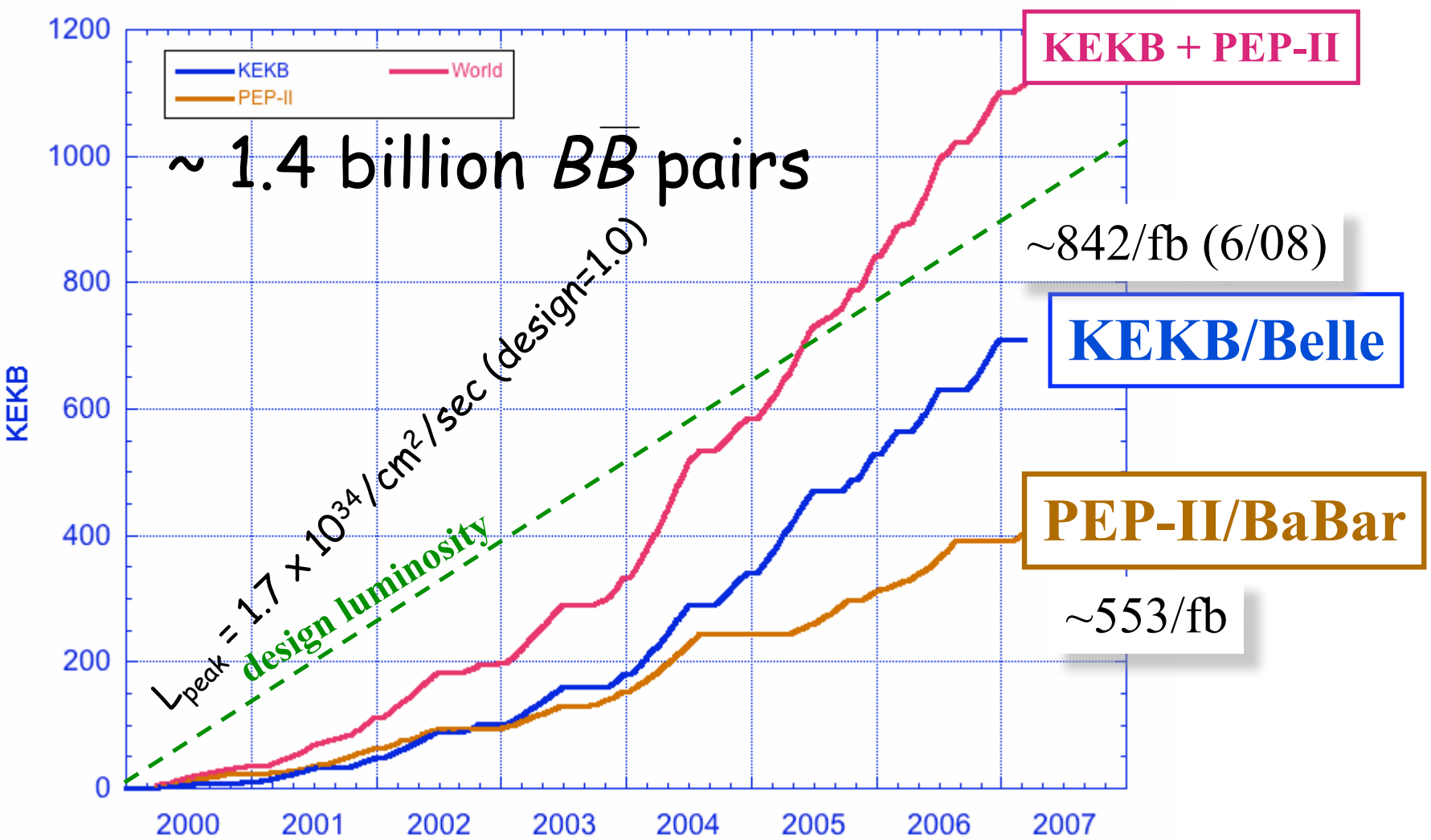


The beam pipes and all vacuum components will be replaced with higher-current-proof design.

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma^*_y}{\sigma^*_x}\right)\frac{I_\pm \xi_{\pm y}}{\beta^*_y}\left(\frac{R_L}{R_y}\right)$$

"adiabatic" - test/install in existing machine

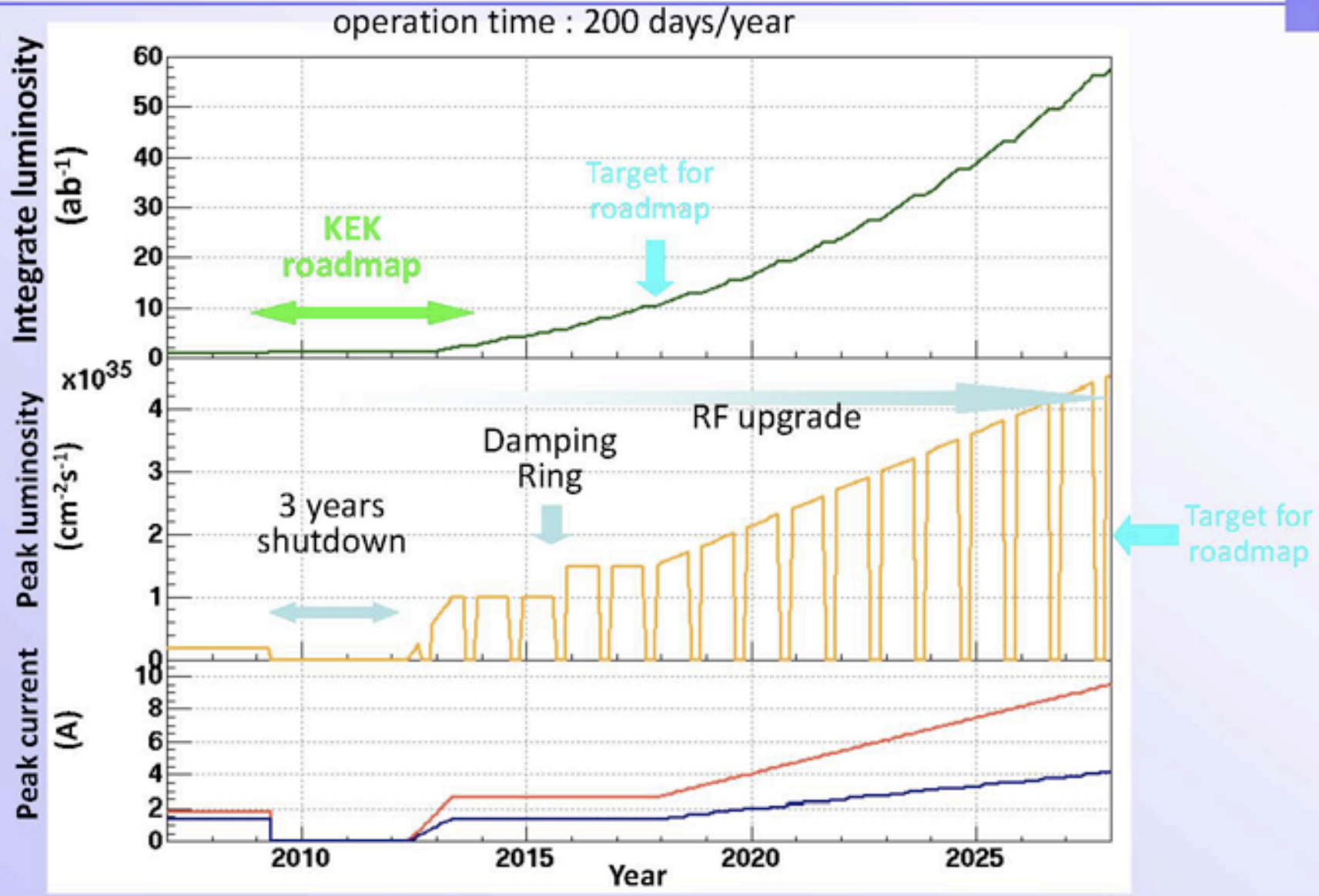
KEKB track record (although past performance does not guarantee future results...)



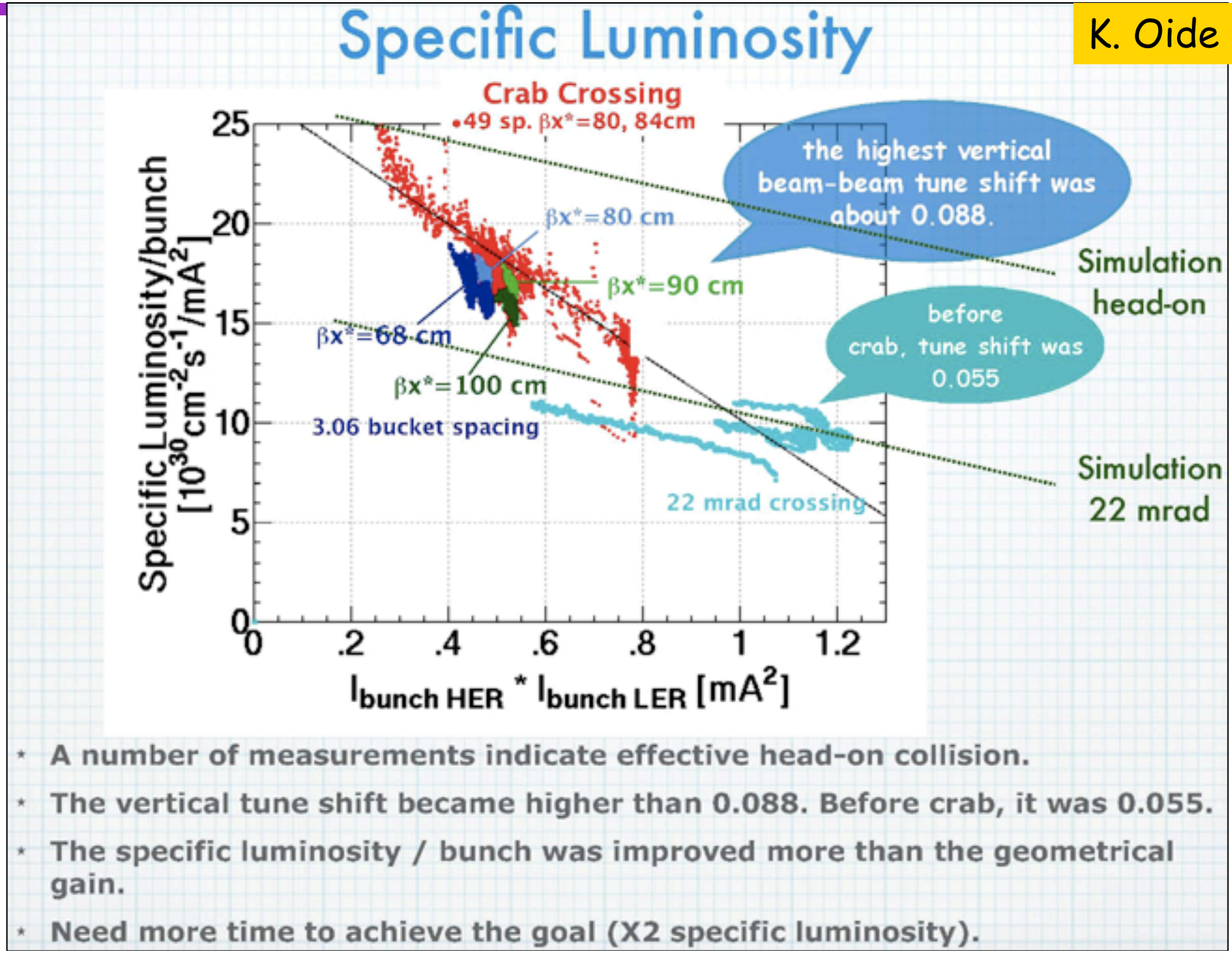
Super KEKB

Luminosity Projection (preliminary)

Y. Ohnishi



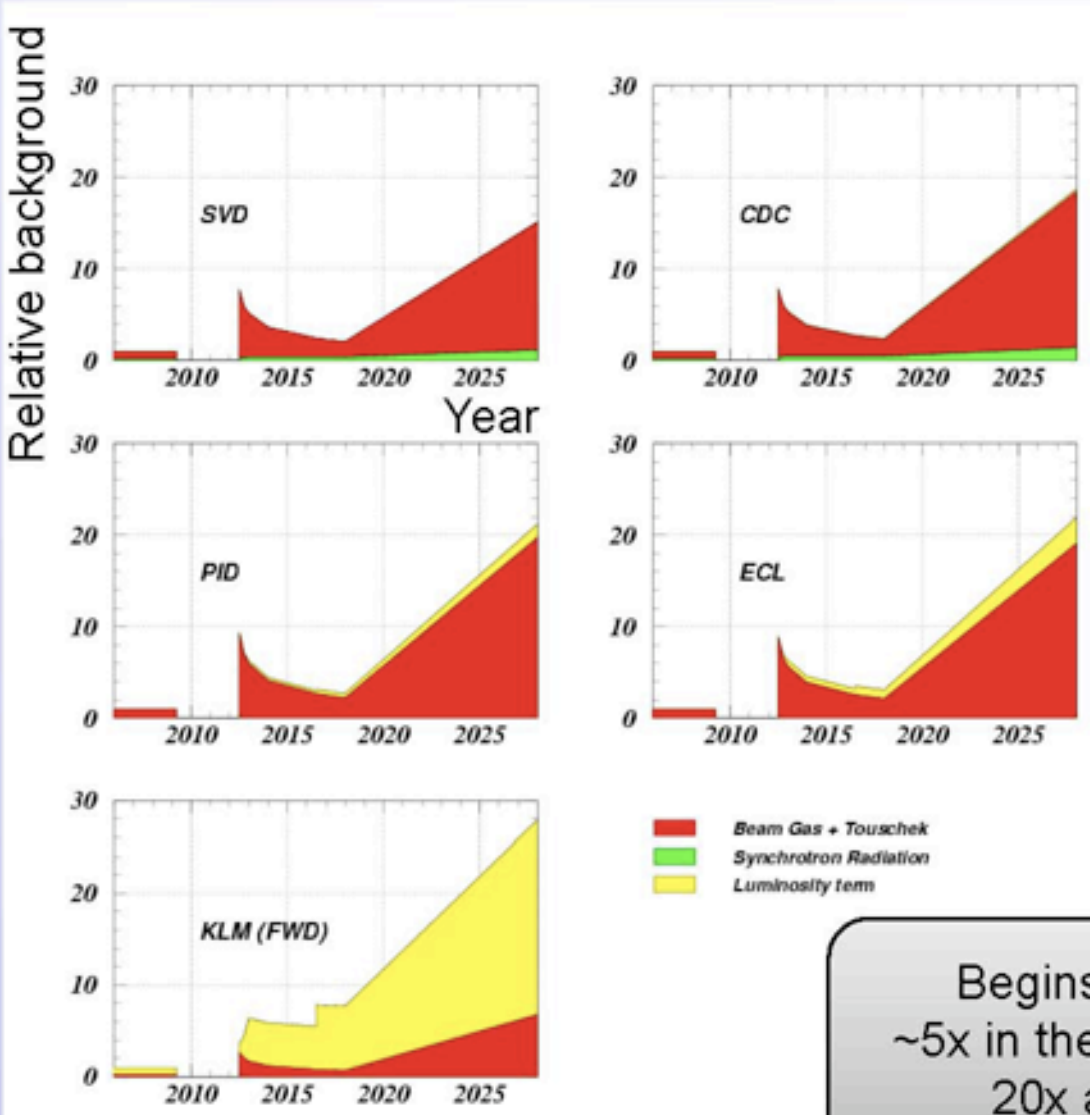
Crab cavities: as of June 08, L_{max} = 1.61 x 10^{34} $cm^{-2}s^{-1}$



Super KEKB: detector requirements and strategy

Background projection (preliminary)

O. Tajima

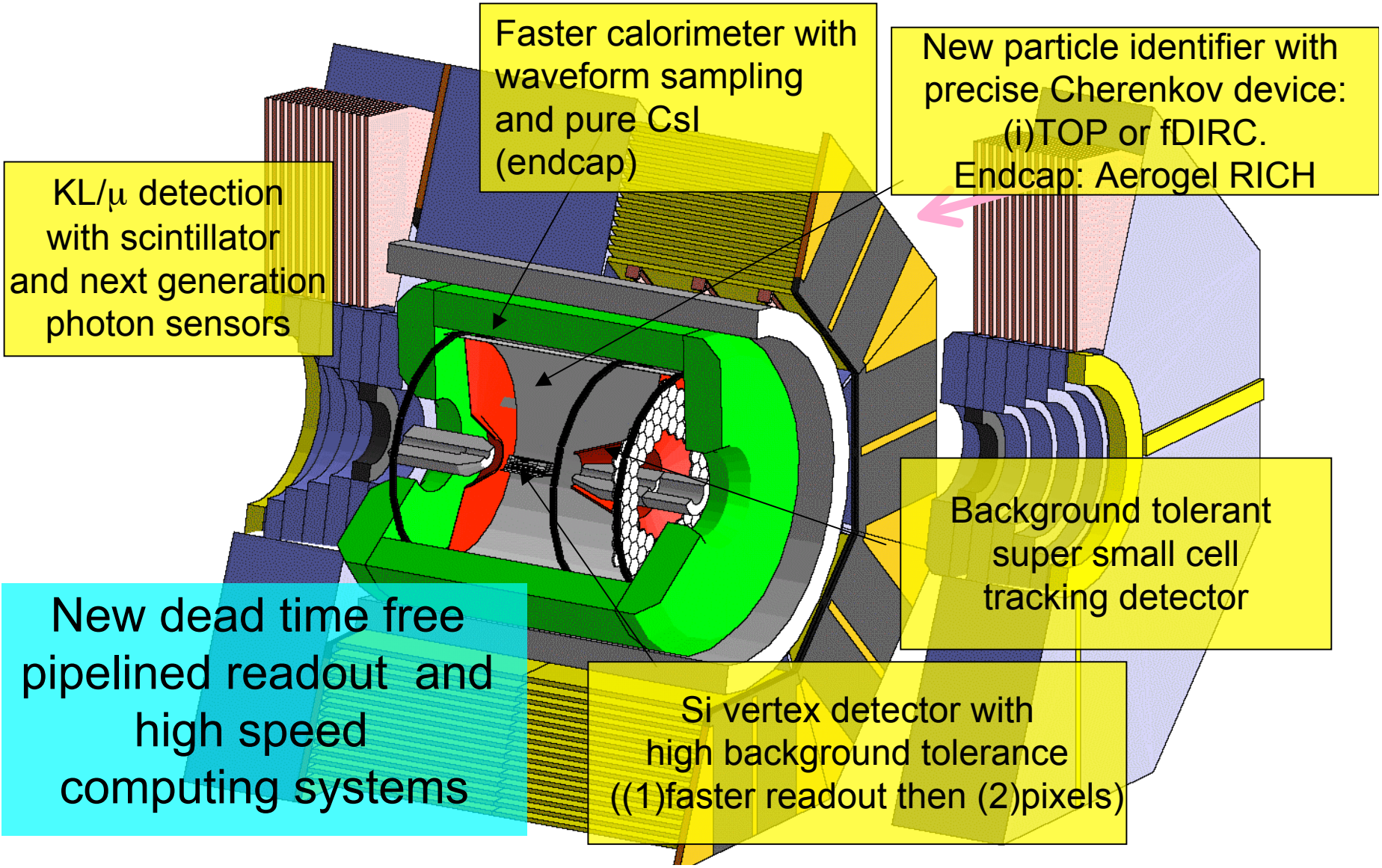


Issues
Radiation damage
Occupancy
Fake hits, pile-up
Event rate

Begins with 7~10x
~5x in the first few years
20x at full spec

(the detector temporarily known as) sBelle

[upgrade Belle to operate w 20X background, 50X event rate]



Current concepts

Silicon inner tracker

- improve vertexing -> thin innermost 2 layers, reduce inner radius
- improve K_S acceptance -> increase outer radius
- background/occupancy -> striplets, pixels, pipelined readout

	Belle	sBelle (t=0)	sBelle (t>>0)
Detector type	4 X DSSD	4X DSSD + 2 X DSSD (short strips)	2 X pixel + 4 X DSSD
Inner radius	15 mm	15 mm	10 mm
Outer radius	70 mm	120 mm	120 mm
DSSD readout	Hold/readout	pipelined	pipelined
Readout time	800 ns	50 ns	50 ns

Current concepts

Drift chamber

- improve momentum resolution -> increase outer radius
- improve dE/dx -> longer radial path
- background/occupancy -> smaller cells

	Belle	sBelle (t>0)
Inner radius	77 mm	160 mm
Outer radius	880 mm	1140 mm
Inner layer cell size	12 mm	8 mm
# sense wires	8400	15140

Current concepts

Particle ID

- improve K/π for b->s vs b->d, etc.
- add endcap PID
- reduce material in front of calorimeter

	Belle	sBelle (t>0)
Barrel	Aerogel TOF	Cerenkov time-of-propagation (TOP) [imaging TOP] [focusing DIRC]
Endcap	none	Aerogel RICH

Current concepts

Electromagnetic calorimeter

- reduce background without loss of resolution

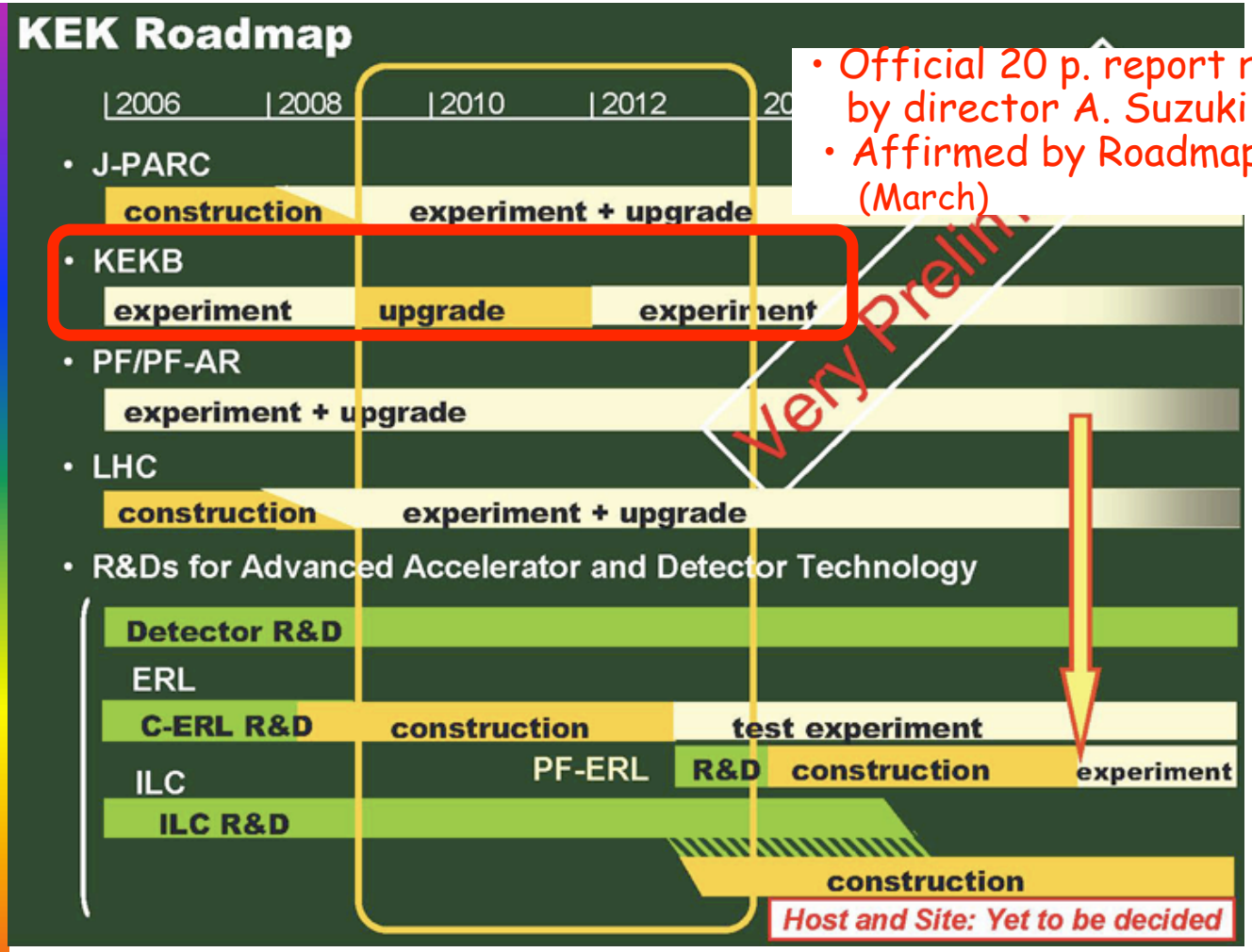
	Belle	sBelle (t>0)
Barrel	CsI (Tl)	CsI(Tl) +waveform sampling/fitting
Endcap Rise time Photodetector	CsI(Tl) 1000 ns Si photodiode	Pure CsI 30 ns PMT +waveform sampling/fitting

Current concepts

K_L/muon detector

- reduce background in endcap

	Belle	sBelle (t>0)
Barrel	Glass RPC, streamer mode	Same RPC (avalanche mode?)
Endcap	Glass RPC, streamer mode	Plastic scintillator x-y strips



- Official 20 p. report released Jan 4, 2008 by director A. Suzuki & KEK mgmt
- Affirmed by Roadmap Review Committee (March)

Placement of KEKB upgrade on roadmap is **significant**

- 3-year KEKB upgrade ('09–'11) with constant annual budget (KEKB operations → construction)
- Staging RF cavities etc, initial $L \sim 2 \times 10^{35}$ cm^{-2}s^{-1}
- Funding: KEK management in discussions w agency (MEXT)

International group for sBelle

- New experimental group being formed (not an extension of present Belle collaboration): name TBD
- New participants are welcome, will have equal opportunities to work on detector construction and physics

Interim Steering Committee:
Hiroaki Aihara (Tokyo/IPMU), Alex Bondar (BINP), Tom Browder (Hawaii), Paoti Chang (NTU), Toru Iijima (Nagoya), Peter Krizan (Chair, Ljubljana), Thomas Muller (Karlsruhe), Henryk Palka (Crakow), Christoph Schwanda (Vienna), Martin Sevior (Melbourne), Eunil Won (Korea), Changzheng Yuan(IHEP, China), Yutaka Ushiroda, Yoshi Sakai(KEK), Masa Yamauchi (KEK)

Summary

- B-factories 1999-2009, >1.4x10^9 B pairs:
  established CKM as source of CP asymmetry in weak interaction
  multiple measurements on CKM with increasing precision:
  φ_1, φ_2, φ_3, $|V_{ub}|$,
  -> probe New Physics:
  discoveries: D mixing, new hadronic states
  studies of tau
  a few unresolved effects: Kπ CP asymmetry, imperfect CKM fit

- ~10^2X luminosity will probe significantly into >1 TeV mass scale
  precision CKM, CP, lepton universality, LFV
- KEKB upgrade for L=2-8 x 10^{35} included in KEKB Roadmap
- KEKB/Belle upgrade plans well underway
  new international collaboration forming