Super KEKB
Quest for BSM

Superb prospects: Belle & KEKB upgrades (Detectors II)

DPF 2009

motivation
plan
status

July 26-31, 2009

Kay Kinoshita
University of Cincinnati
Belle Collaboration

B-factories (1999-2009)

Primary goal: establish unitarity & complex phase of CKM matrix

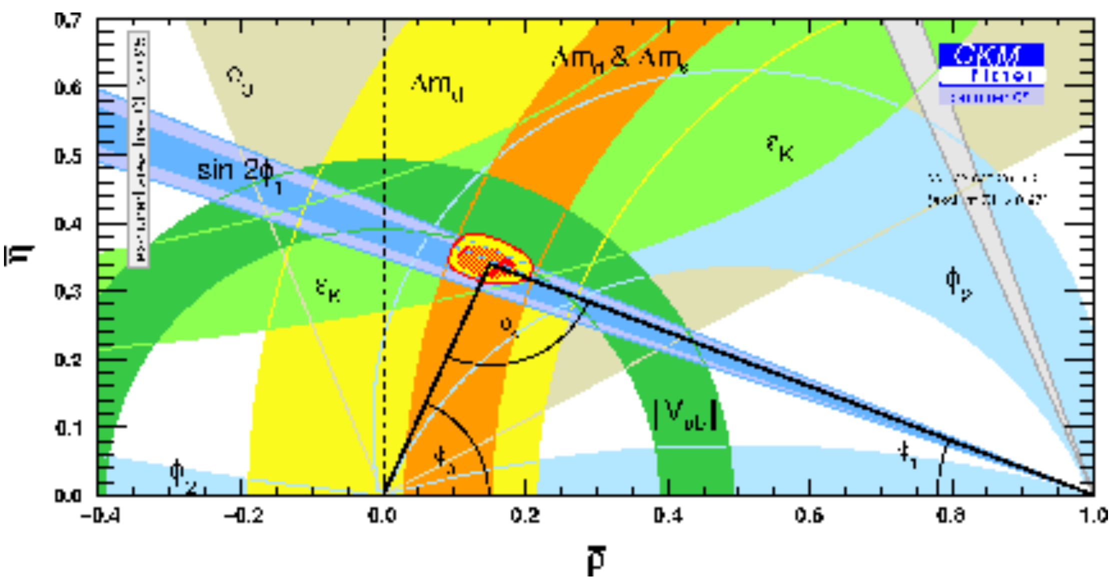
Kobayashi & Maskawa (1973)

- proposed 3rd generation of particles
- Explain CP violation in K, predict for B

Experiments (-2009)

- CP asymmetry manifested in diverse processes in B decay

-> many measurements, (over)constrain CKM



found consistent with unitarity

B-factories (1999-2009)

- … + many other successes

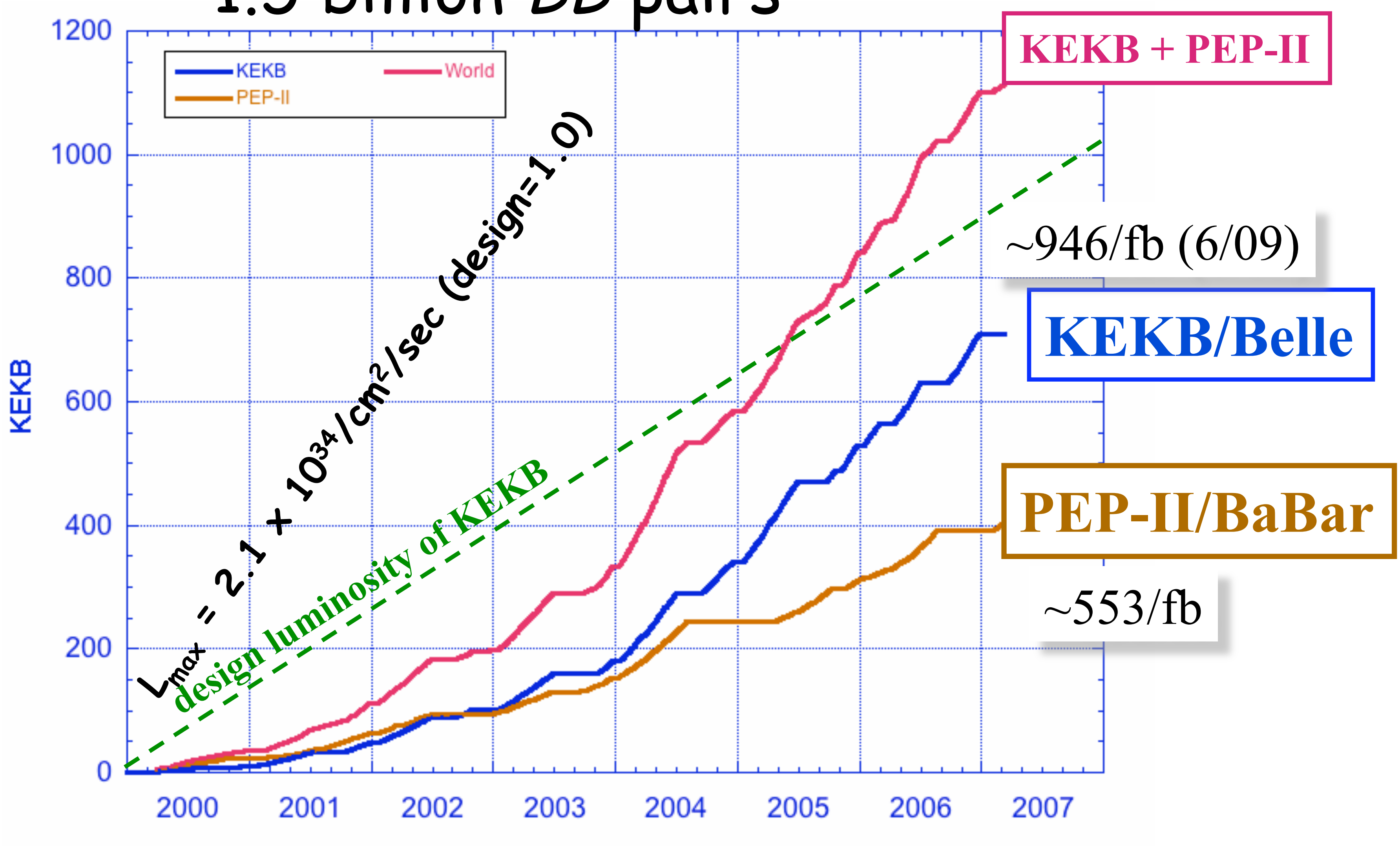
Headliners
- new charmonia, charmonium-like states, ISR, D_{sJ}, many B decays
- D^0 mixing
- limits on/hints of New Physics

\+ 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, …

B pairs world sample

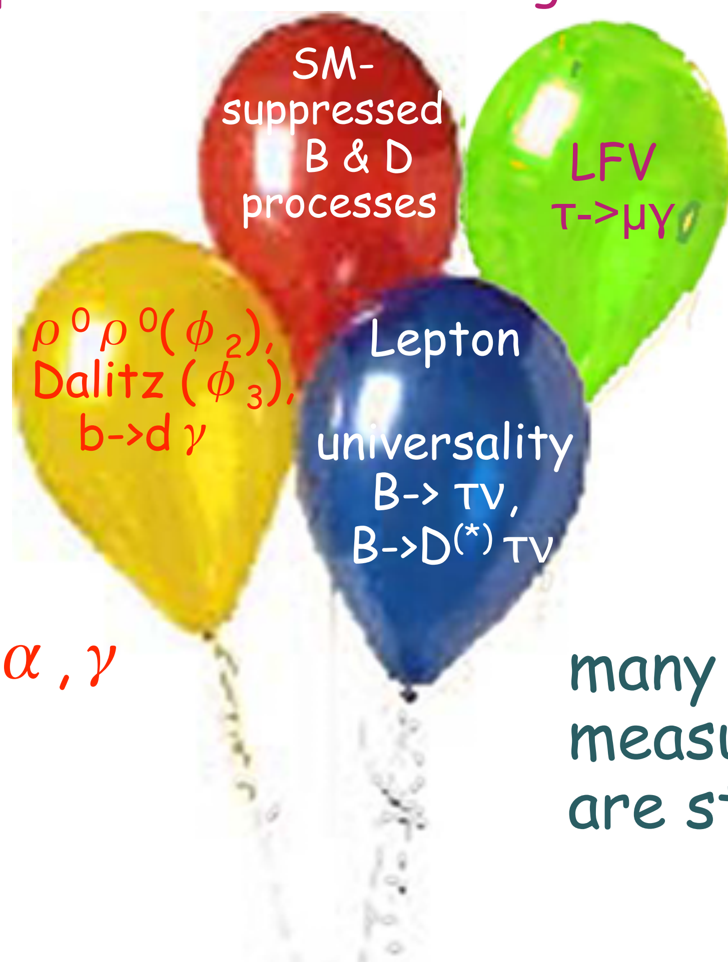
~ 1.5 billion $B\bar{B}$ pairs



Why collect more?

With 1.5G Bpairs (+similar #'s of c, tau) at Belle+Babar

many best measurements:
testing CKM unitarity,
exploring SM-suppressed/forbidden regions



$\varphi_1, \varphi_2, \varphi_3 \Leftrightarrow \beta, \alpha, \gamma$

many of these measurements/limits are statistically limited furthermore ...

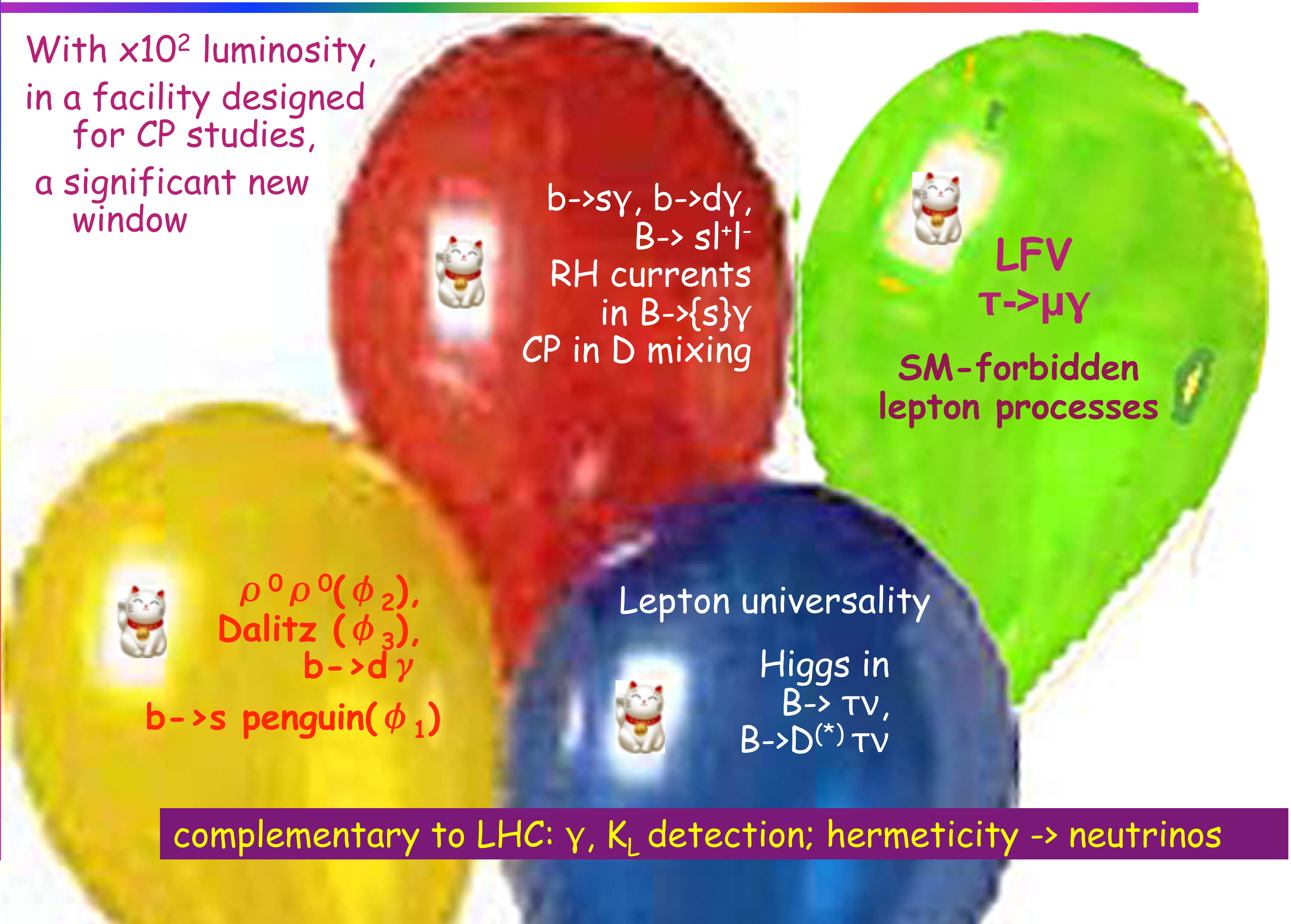
NEED other source(s)
of CP violation

to account for
baryon asymmetry
of universe...

Why collect more?

SuperKEKB Quest for BSM

With x10^2 luminosity,
in a facility designed for CP studies,
a significant new window



b->sγ, b->dγ,
B-> sl$^+$l$^-$
RH currents in B->{s}γ
CP in D mixing

LFV
τ->μγ

SM-forbidden lepton processes

$\rho^0\rho^0(\phi_2)$,
Dalitz (ϕ_3),
b->dγ

b->s penguin(ϕ_1)

Lepton universality

Higgs in
B-> τν,
B->D$^{(*)}$ τν

complementary to LHC: γ, K_L detection; hermeticity -> neutrinos

Sensitivity to New Physics: an example

SM: "golden" vs "other" $\sin 2\varphi_1$ ($\sin 2\beta$)

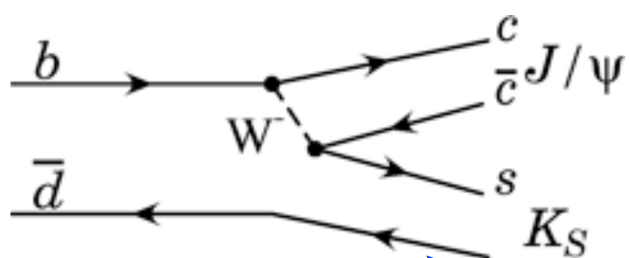
"golden" $B \to J/\psi\, K_s$

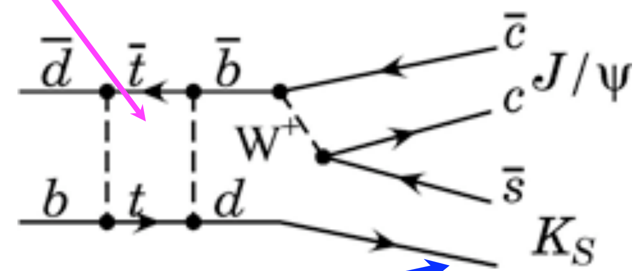
tree (real V_{ij}) $\propto V_{cb}^{*} V_{cs}$

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

well-measured rate

phase = $\arg(V_{tb}^{*2} V_{td}^{2}) = 2\varphi_1$





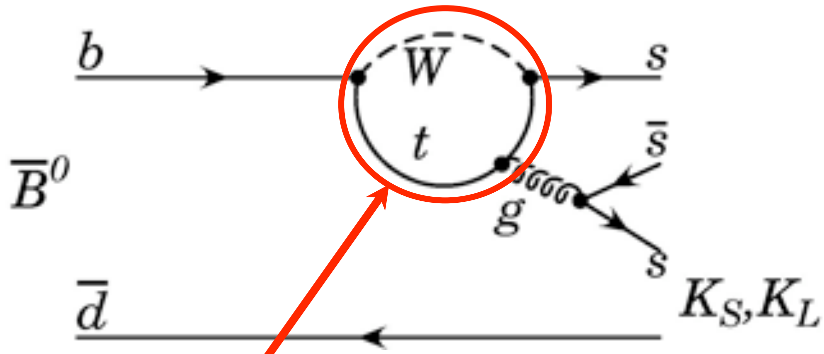
identical hadronic processes -> same |Amplitude|

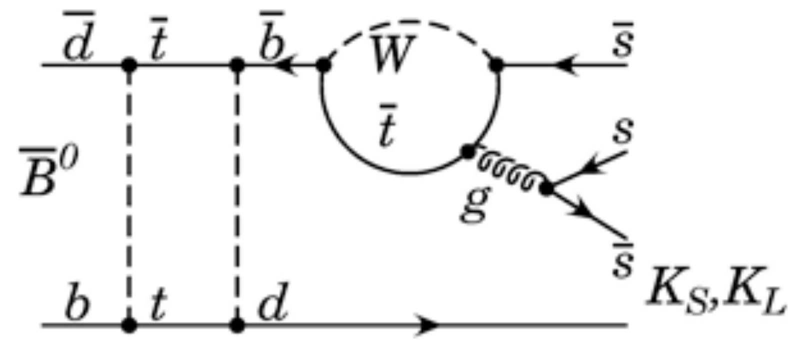
$V_{cb}^{*} V_{cs}$ real => zero phase difference

=> relative phase = $2\varphi_1$, CP asymmetry ~ $\sin 2\varphi_1$

b -> $s\bar{s}s$: identical reasoning

penguin (real V_{ij}) $\propto V_{tb}^* V_{ts}$ mixing+penguin $\propto V_{tb}^{*2} V_{td}^2 V_{tb} V_{ts}^*$





$V_{tb}^* V_{ts}$ real => zero phase difference

=> relative phase = $2\varphi_1$, CP asymmetry ~ $\sin 2\varphi_1$

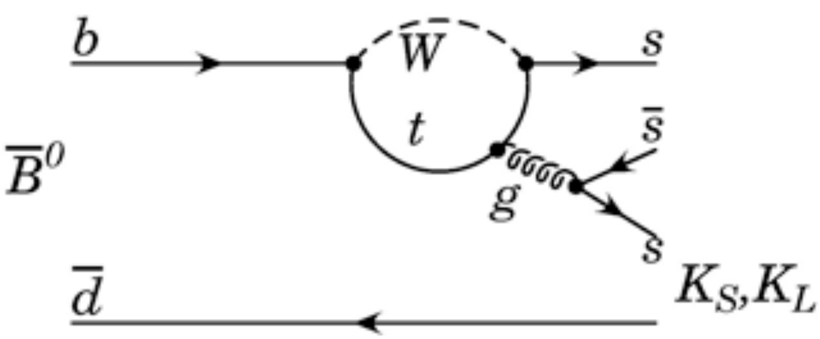
"New Physics" w complex phase φ_{new}

---> CP asymmetry ≠ $\sin(2\varphi_1)$

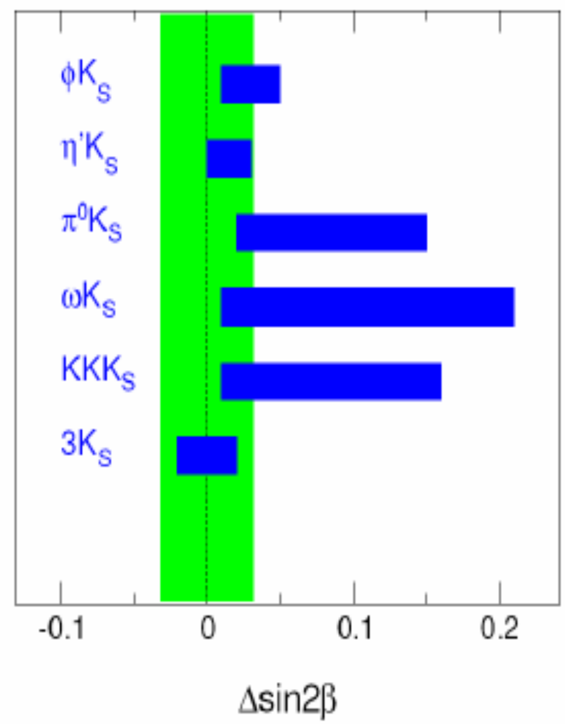
Standard Model: "other" $\sin 2\varphi_1$

b -> $s\bar{s}s$: identical reasoning

penguin (real V_{ij}) $\propto V_{tb}^* V_{ts}$



some of recent QCDF estimates
$\sin 2\beta^f_{eff} - \sin 2\beta$



caveat:
(small) theory correction -> mostly >0

Average "sin2φ_1" from $b \to s$ penguins

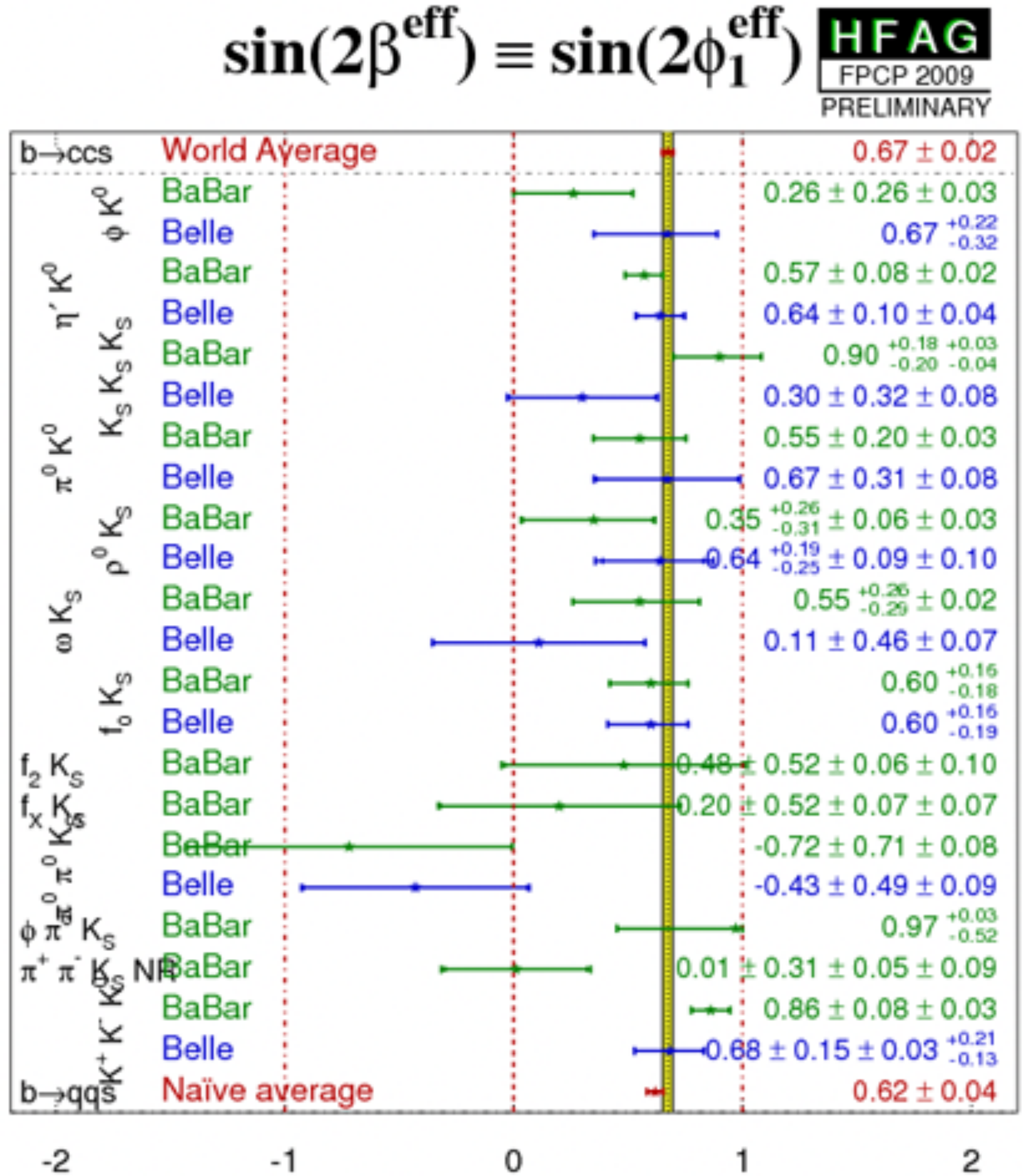
Heavy Flavor Averaging Group

Naïve World Average
$\sin 2\varphi_1(b \to sq\bar{q}) = 0.62 \pm 0.04$

Compare to $c\bar{c}s$:
$\sin 2\varphi_1(b \to c\bar{c}s) = 0.672 \pm 0.024$

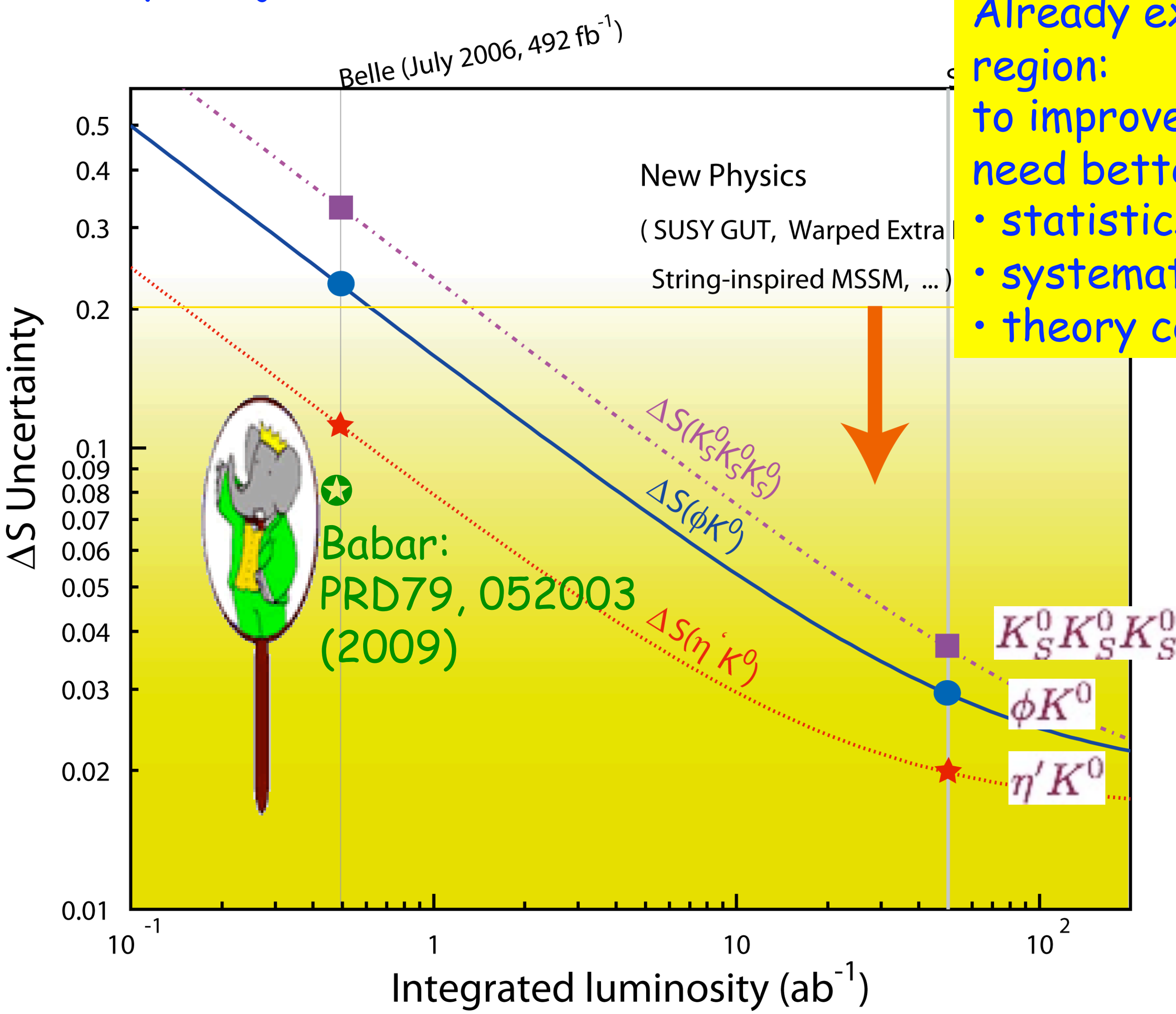
CL = 0.19 (1.3σ)

difference is < 0



"$\sin 2\varphi_1$" sensitivity to New Physics

(Luminosity Projections)



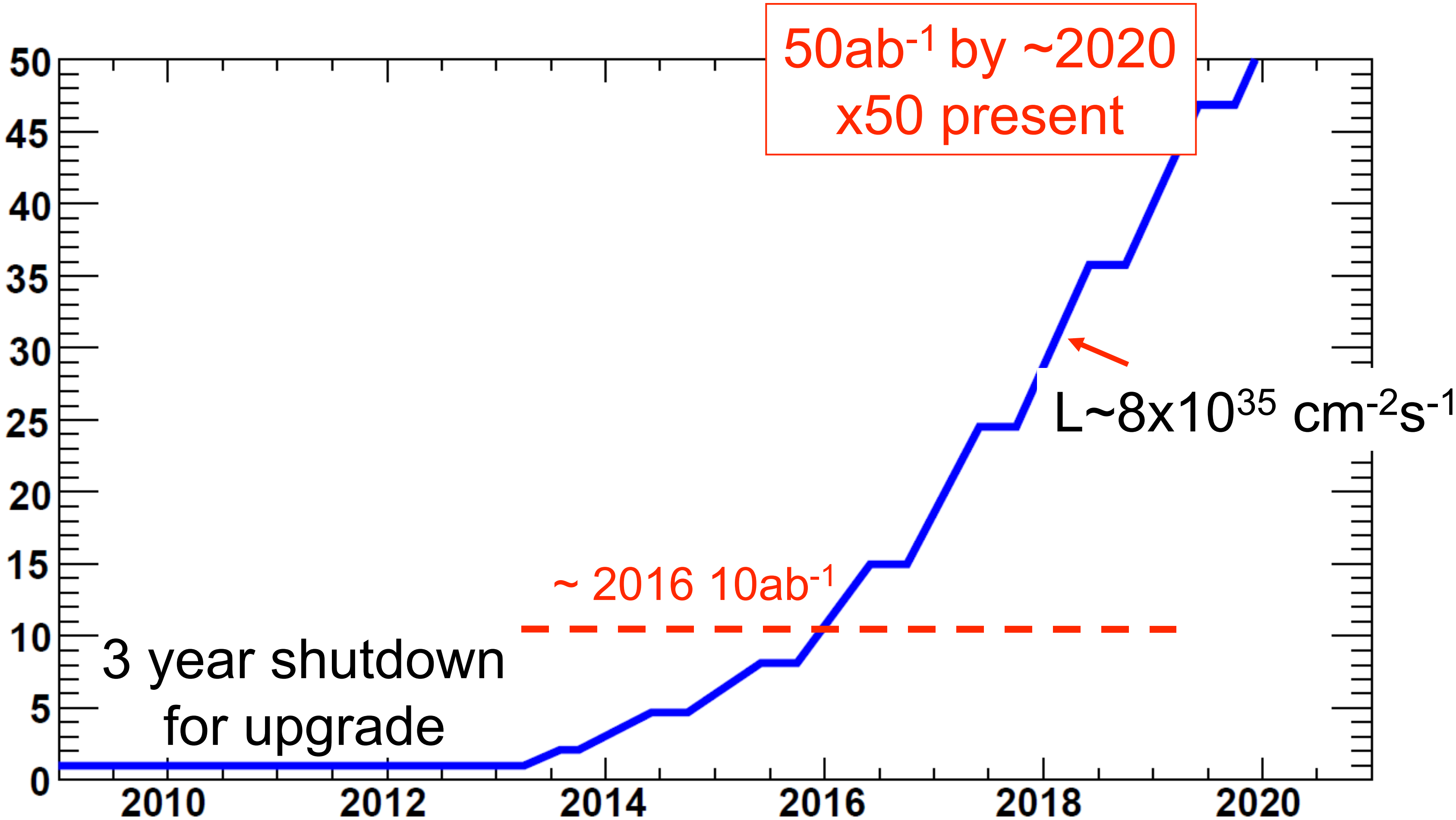
Already exploring "New" region:
to improve sensitivity, need better
- statistics
- systematics
- theory corrections

=> what we need is

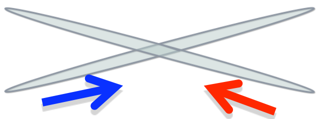
Billions
and
Billions

of B's

Super KEKB Luminosity projection



KEKB luminosity upgrade strategy



"nano-beam" scheme (proposed by P. Raimondi for Italian Super B factory)

1.8A(LER)/1.45(HER)→ 3.8A/2.2A

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

- Lorentz factor
- Beam current
- Beam-Beam parameter
- Geometrical reduction factors (crossing angle, hourglass effect)
- Beam aspect ratio at IP
- Vertical beta function at IP

6.5(LER)/5.9(HER) →0.26/0.26

Minimum value is limited by hourglass effect

KEKB luminosity upgrade strategy

Tentative machine parameters

New lattice: still under study

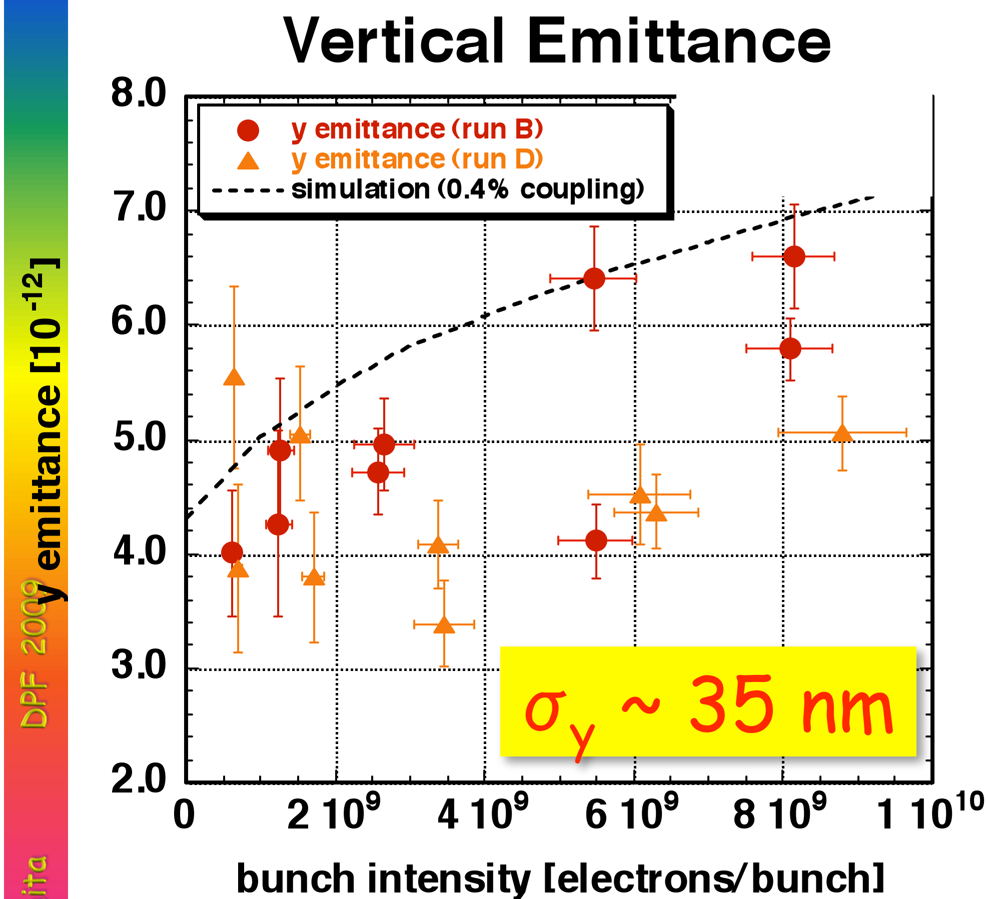
		LER	HER	
Emittance	ε_x	2.8	2.0	nm
Coupling	$\varepsilon_y/\varepsilon_x$	0.74	1.80	%
Horizontal beta at IP	β_x^*	17.8	25.0	mm
Vertical beta at IP	β_y^*	0.26	0.26	mm
Horizontal beam size	σ_x^*	7.06	7.07	μm
Vertical beam size	σ_y^*	0.073	0.097	μm
Bunch length	σ_z	5		mm
Half crossing angle	ϕ	30		mrad
Beam Energy	E	3.5	8.0	
Beam Current	I	3.84	2.21	A
Number of bunches	n_b	2252		
Beam-beam parameter	ξy	0.079	0.079	
Luminosity	L	8×10^{35} (8.5×10^{35} with CW)		$cm^{-2}s^{-1}$

0.073	0.097

<100 nanometers

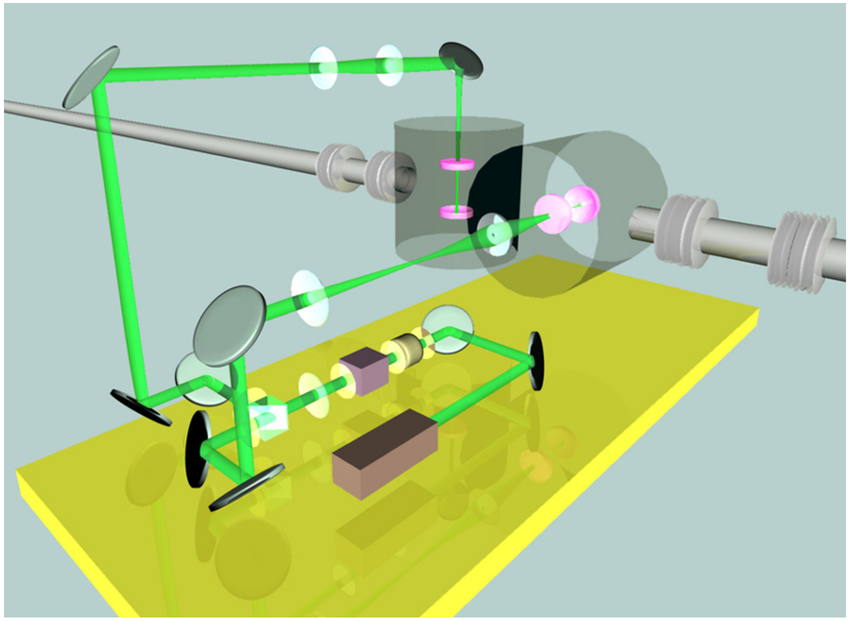
KEK has achieved low ε

Accelerator Test Facility (ATF)
(linear collider damping ring)



Linear collider R&D

Laser wire beam size monitor

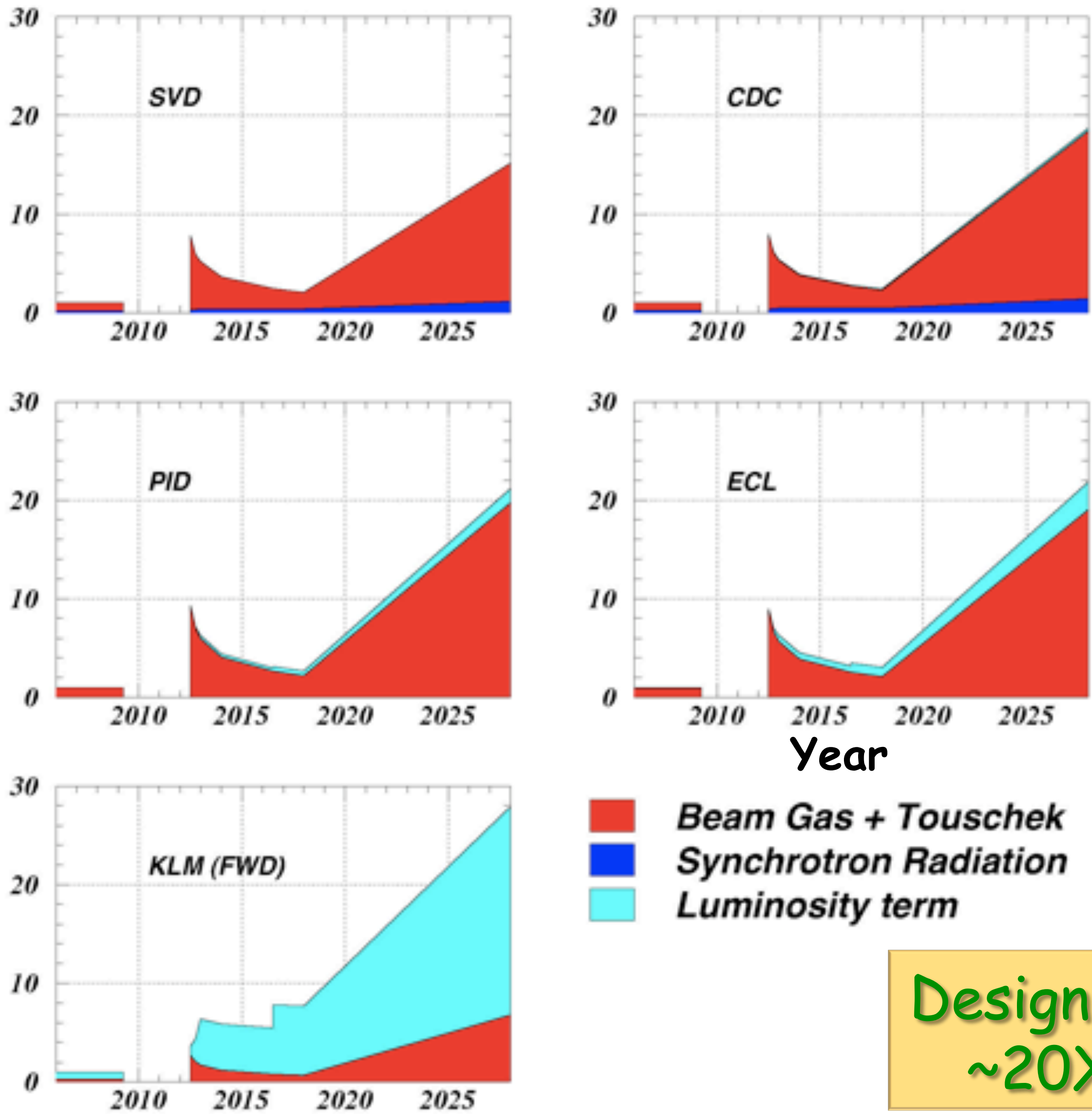


300mW 532nm Solid-state Laser
Fed into optical cavity

Position resolution: 2μm

PRL 92, 054802 (2004)

Detector: Background projections



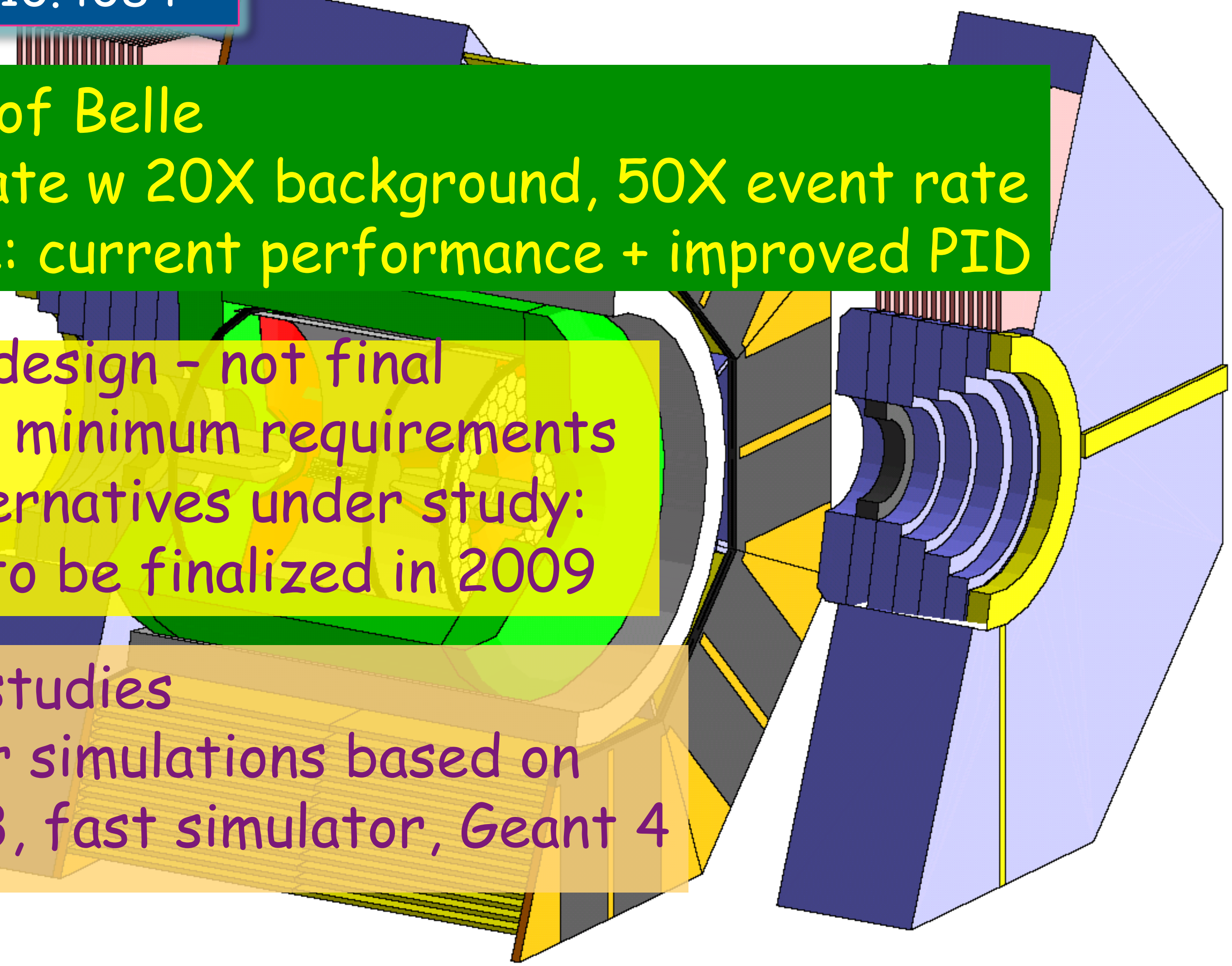
Belle detector
SuperKEKB
(hi-current design)
normalized to
current rates

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

Design upgrade to tolerate ~20X at full luminosity

Detector: Belle II

Design Study Report
arXiv: 0810.4084

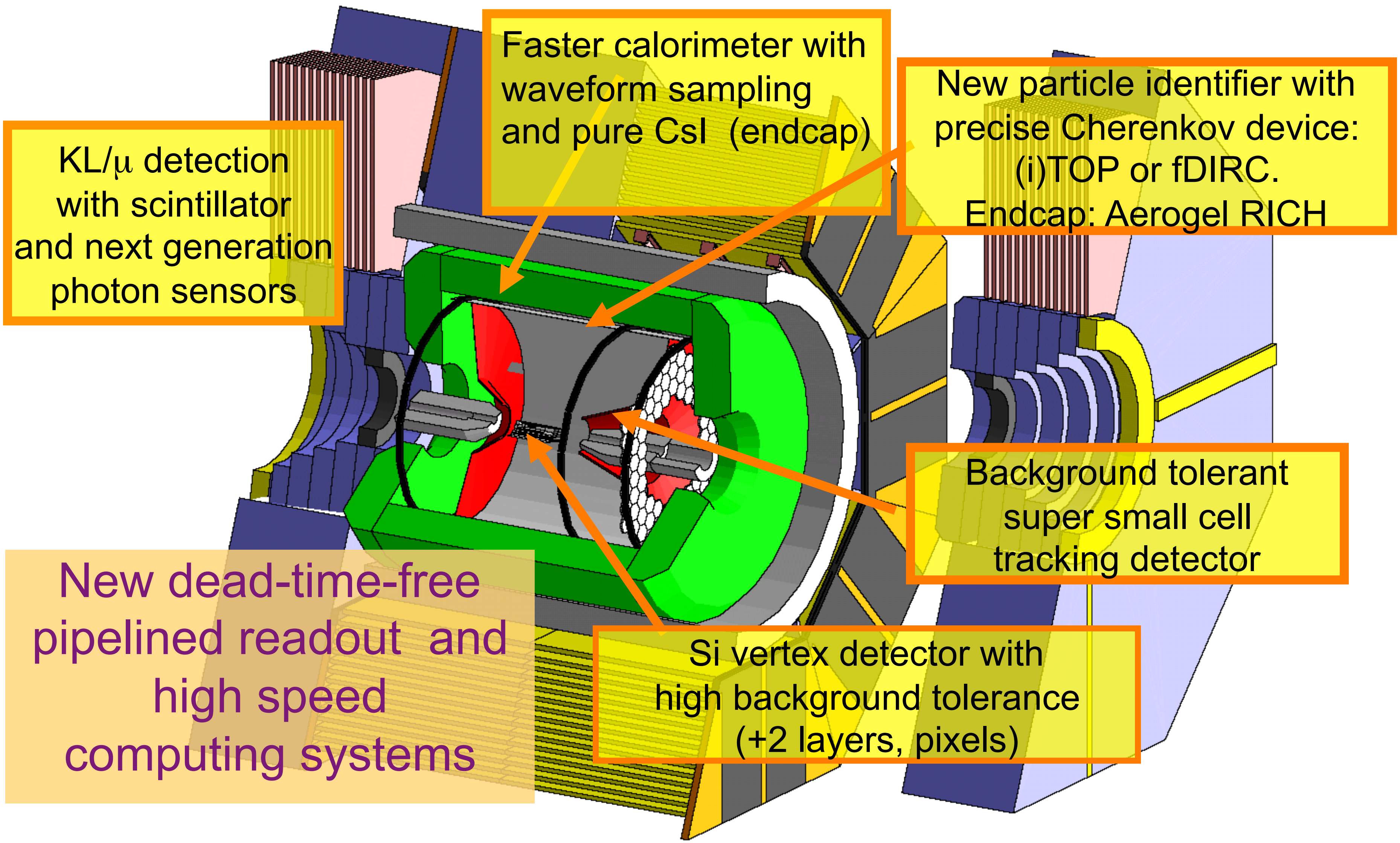


Upgrade of Belle
- to operate w 20X background, 50X event rate
- baseline: current performance + improved PID

Baseline design – not final
Satisfies minimum requirements
Many alternatives under study:
- Design to be finalized in 2009

Physics studies
Detector simulations based on
- Geant 3, fast simulator, Geant 4

Belle II baseline



New dead-time-free pipelined readout and high speed computing systems

Baseline design

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

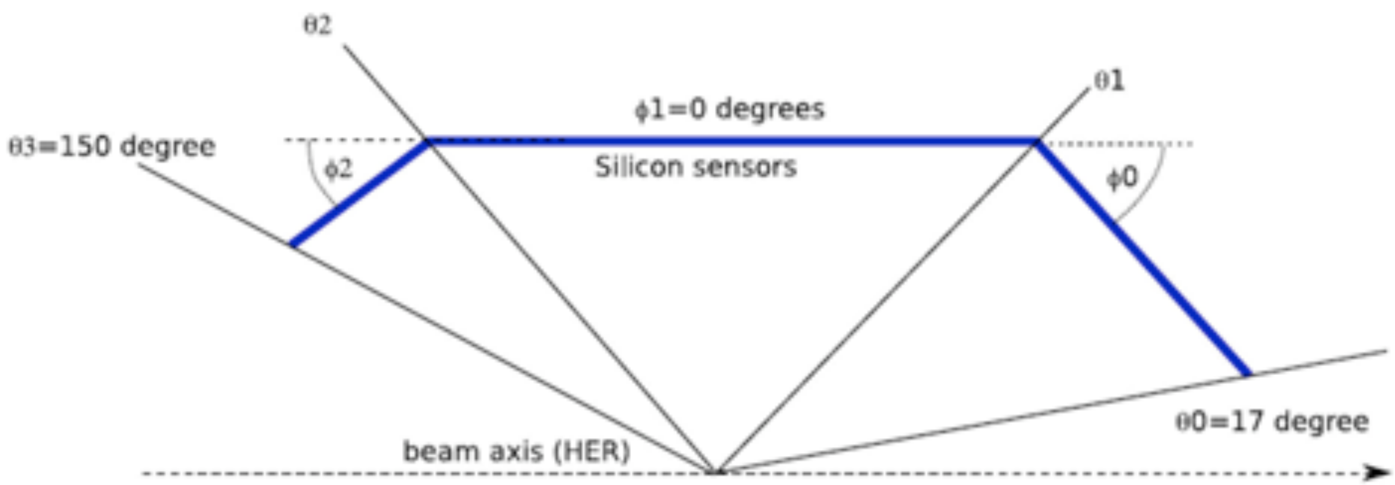
+ standalone tracking, dE/dx

	Belle	sBelle
Detector type	4-DSSD	2-DEPFET pixel + 2-DSSD + 2-DSSD (short strips/angled) chip-on-sensor lyr 5&6
Inner radius	15 mm	10 mm
Outer radius	70 mm	120 mm
DSSD readout	Hold 3μs/ readout 27μs	pipelined
Readout time	800 ns	50 ns

Baseline design

Silicon inner tracker

Layers 5 and 6
- shorten strips
- angle to reduce total area



	θ_1	θ_2	ϕ_0	ϕ_2	V_1	V_2	$S(cm^2)$
LoI	34	---	–15		28	33	5018

Baseline design

Drift chamber

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

	Belle	Belle II (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

Baseline design

Particle ID

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

	Belle	Belle II (t>0)
Barrel	Aerogel TOF dE/dx in CDC	Cerenkov time-of-propagation (TOP)
Endcap	(dE/dx)	Aerogel RICH

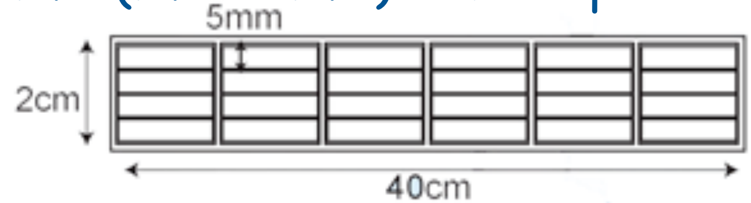
Baseline design

Particle ID

Barrel

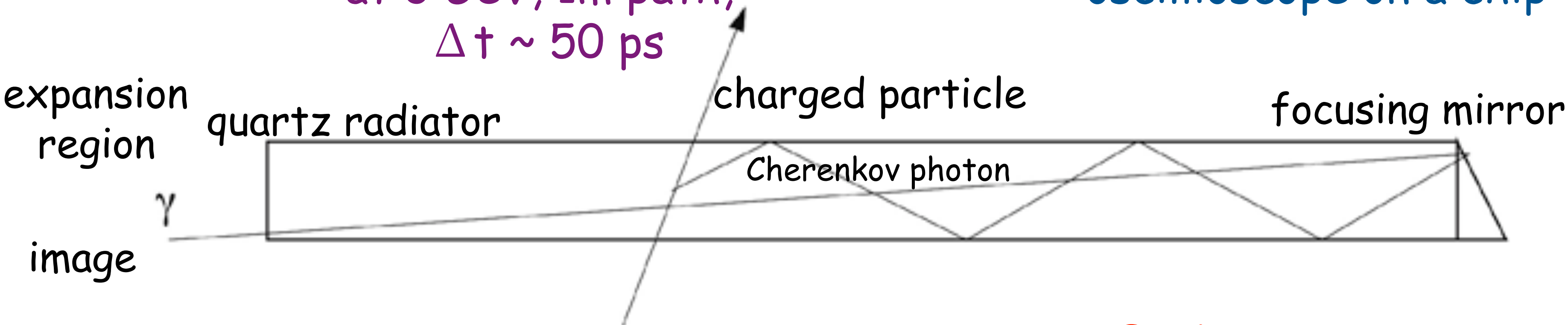
TOP counter with imaging

Photon detection
Multi-anode Microchannel plate
PMT (MCP-PMT) Δt<40 ps



Readout
BLAB3 ASIC
"oscillioscope on a chip"

π/K time-of-flight;
at 3 GeV, 1m path,
$\Delta t \sim 50$ ps



Photon time-of-propagation
due to θ_c difference;
at 3 GeV, 1m path, $\Delta t \sim 75$ ps

Options
2-pc (double readout)
1-pc, time only
1-pc, with standoff, imaging

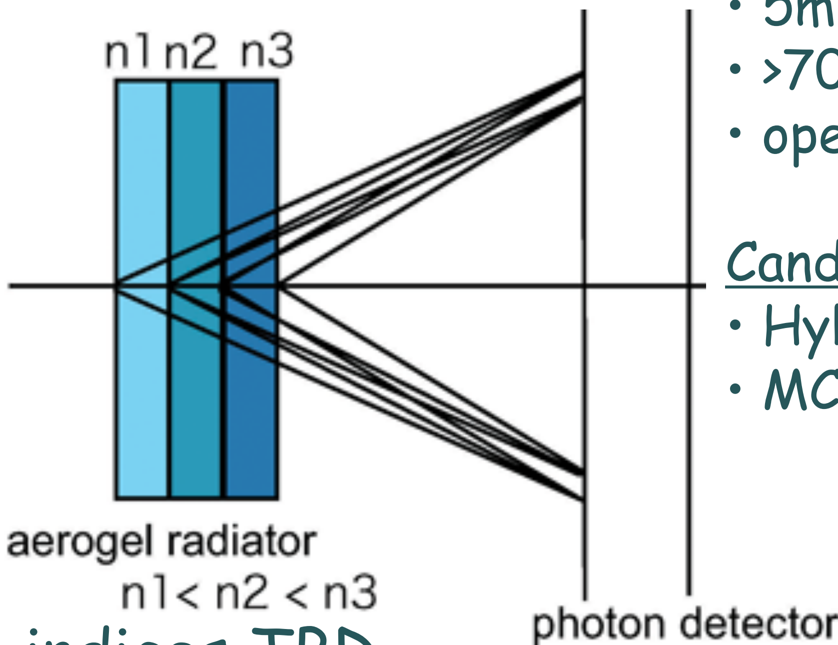
Baseline design

Particle ID

Endcap

Proximity focusing Aerogel RICH

Multi-index to minimize ring width
n = 1.045-1.055



indices TBD

Photon detector requirements
- high QE, >20%
- high gain
- 5mm x 5 mm segmentation
- >70% coverage
- operate in B=1.5 T

Candidates
- Hybrid APD
- MCP-PMT (includes TOF)

Baseline design

Electromagnetic calorimeter

- reduce background without loss of resolution

	Belle	Belle II (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

Alternatives under study

Bismuth silicate (BSO)

Lead Tungstate ($PbWO_4$)

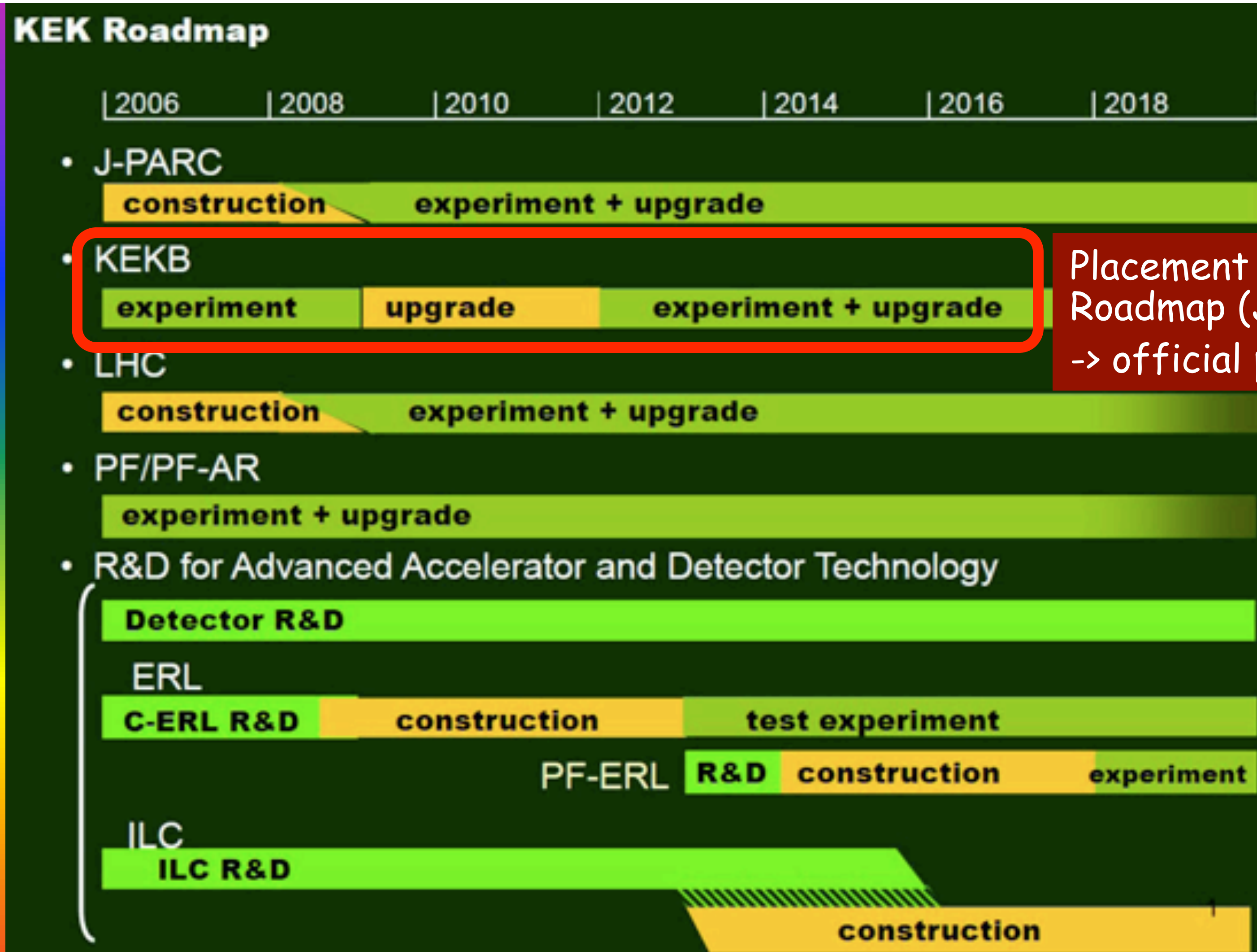
Baseline design

K_L/muon detector

- reduce background in endcap

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

Status of project



Placement of KEKB upgrade on Roadmap (Jan. 2008)
-> official priority of KEK

- 3-year upgrade: 2010–2
- $L \sim 8 \times 10^{35}\ cm^{-2}s^{-1}$
- Funding: 3.2×10^9 ¥ (~$32M) for FY 2009
  request for construction (2010-): $350M

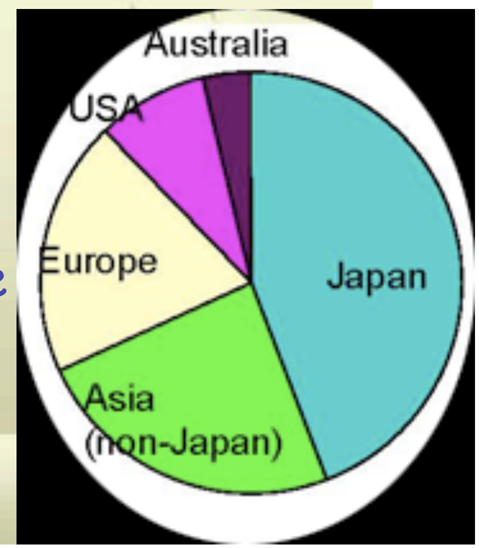
Belle II Collaboration

- New international collaboration (not extension of present Belle)
  http://superb.kek.jp

- First meeting December 2008
- next meeting Nov. 18-9, 2009
- Spokesperson: P. Krizan (Ljubljana)

US institutions
University of Cincinnati
University of Hawaii
Virginia Tech
Wayne State

Belle



Summary

- B-factories 1999-2009, >1.4x10^9 B pairs:
  - firmly established CKM as main source of CP asymmetry
    - at low energy
  - placed multiple constraints on CKM unitarity
    - high precision -> probe for New Physics
  - rare processes as windows to New Physics
    - incl. D mixing, tau decays

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