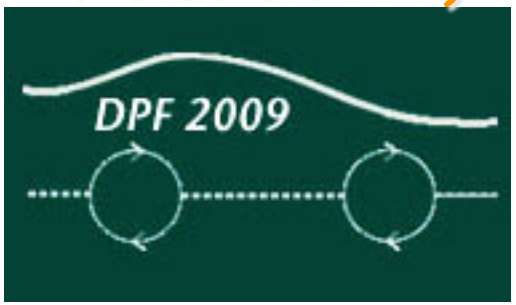
Super KEKB Quest for BSM

Superb prospects: Belle & KEKB upgrades

(CP Violation III)



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

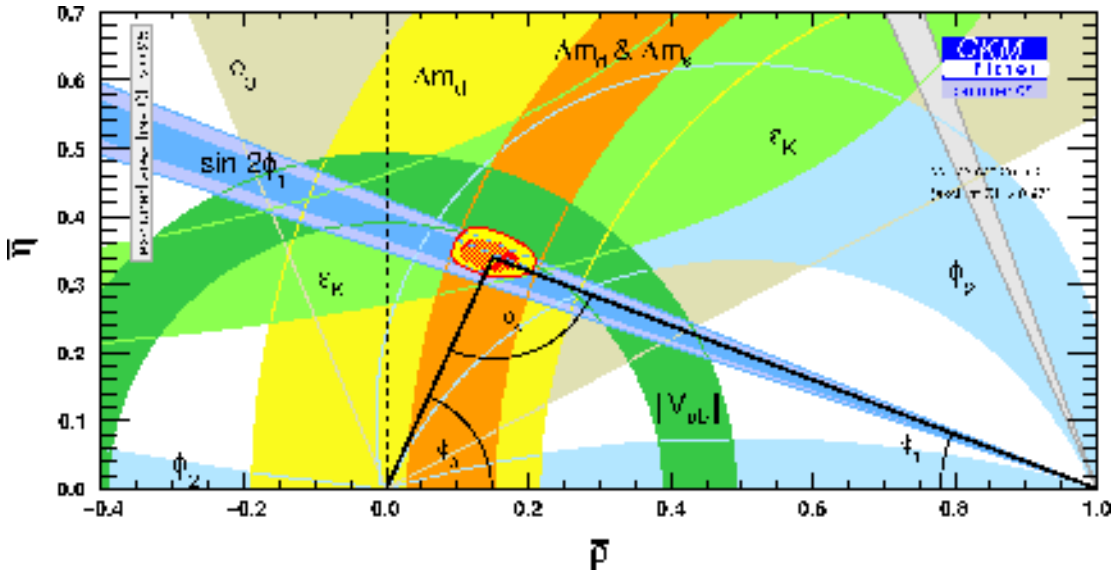
Kobayashi & Maskawa (1973)

- 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

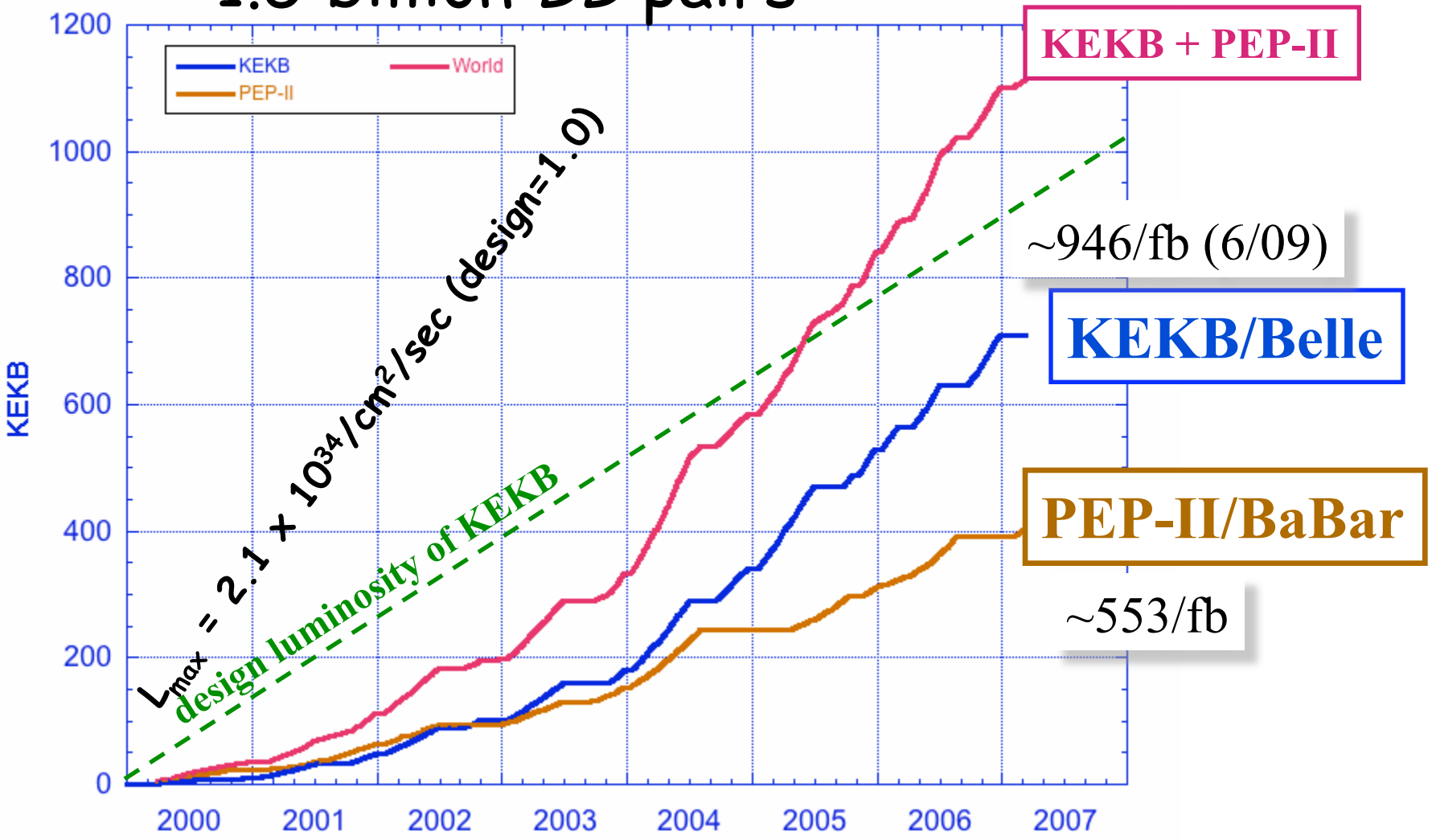
Headliners
- new charmonia, charmonium-like states, ISR, D_{sJ}, many B decays
- D^0 mixing
- limits on/hints of New Physics

+ more measurements, on
B, charm, tau, 2-photon, Υ(4S), Υ(10860), B_s, Υ(3S), Υ(1S), …

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

B pairs world sample

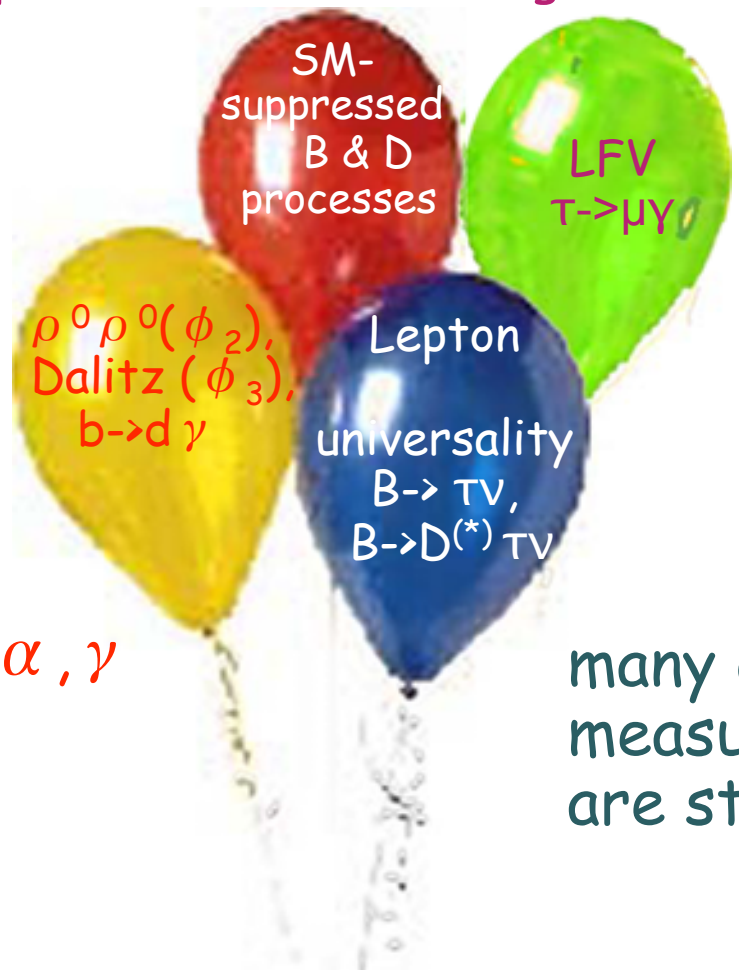
~ 1.5 billion $B\bar{B}$ pairs



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

Why collect more?

furthermore ...

NEED other source(s)
of CP violation

to account for
baryon asymmetry
of universe...

Why collect more?

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

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

Sensitivity to New Physics: some examples

SM: "golden" vs "other" sin2φ_1 (sin2β)

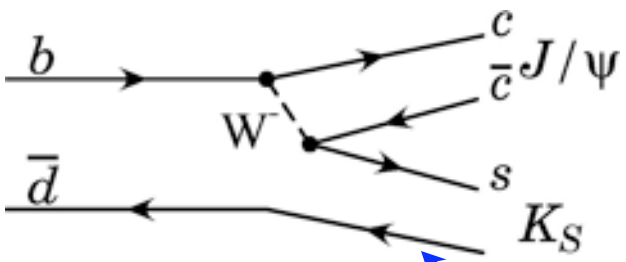
"golden" B -> J/ψ K_s

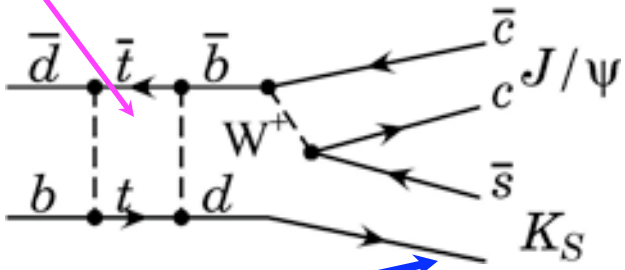
tree (real V_{ij}) $\propto V_{cb}^* V_{cs}$

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

well-measured rate

phase = arg($V_{tb}^{*2} V_{td}^2$)=2φ_1





identical hadronic processes -> same |Amplitude|

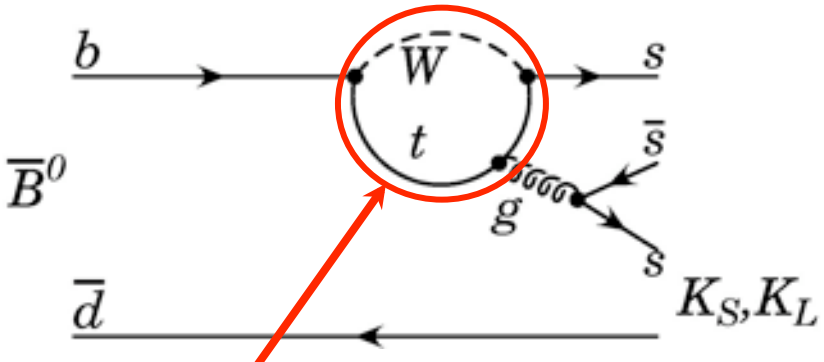
$V_{cb}^* V_{cs}$ real => zero phase difference

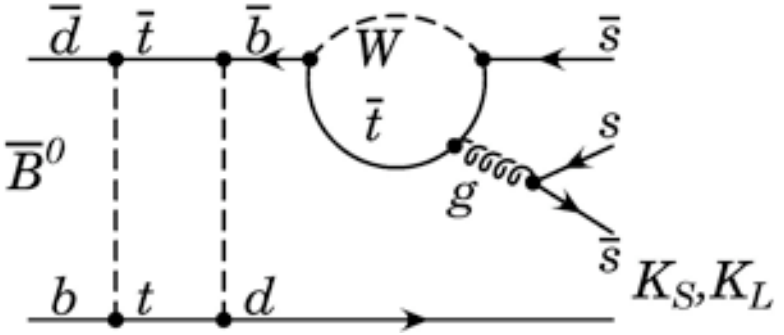
=> relative phase = 2φ_1, CP asymmetry ~ sin 2φ_1

"other" sin2φ_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 = 2φ_1, CP asymmetry ~ sin 2φ_1

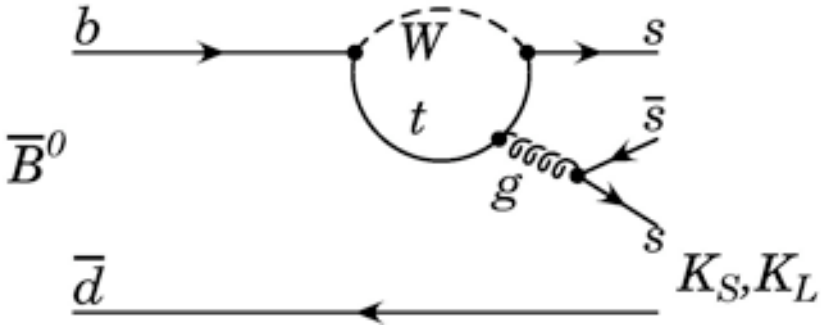
"New Physics" w complex phase φ_{new}

---> CP asymmetry ≠ sin (2φ_1)

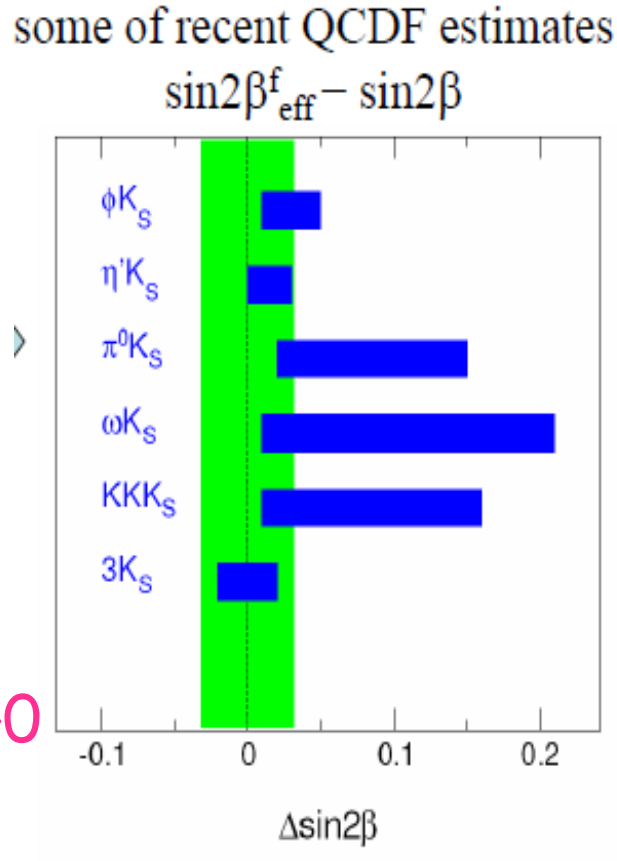
Standard Model: "other" sin2φ_1

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

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



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



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

Heavy Flavor Averaging Group

$$\sin(2\beta^{\text{eff}}) \equiv \sin(2\phi_1^{\text{eff}})$$

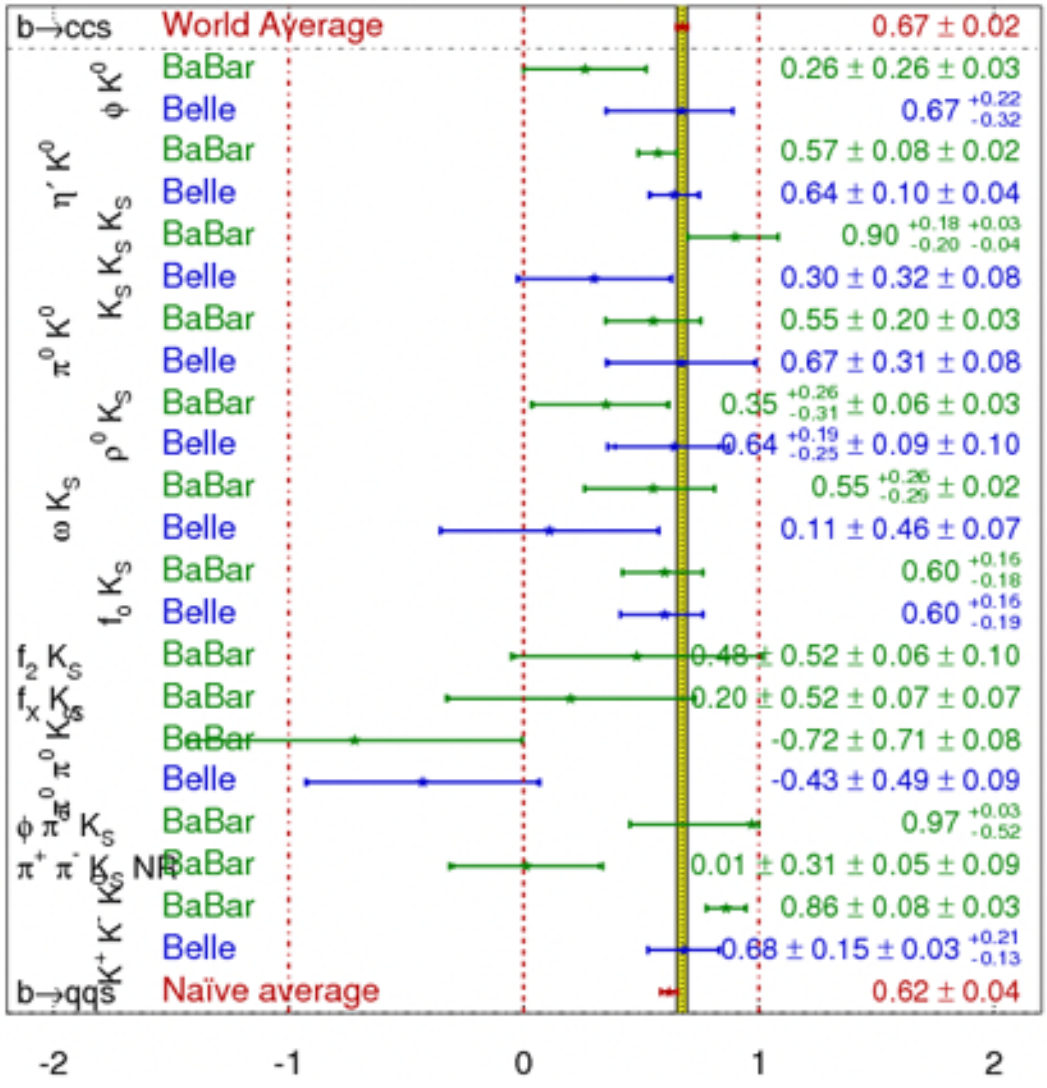
HFAG FPCP 2009 PRELIMINARY

Naïve World Average
sin2φ_1(*b->sqq̄*)= 0.62 ± 0.04

Compare to $c\bar{c}s$:
sin2φ_1(*b->cc̄s*) = 0.672 ± 0.024

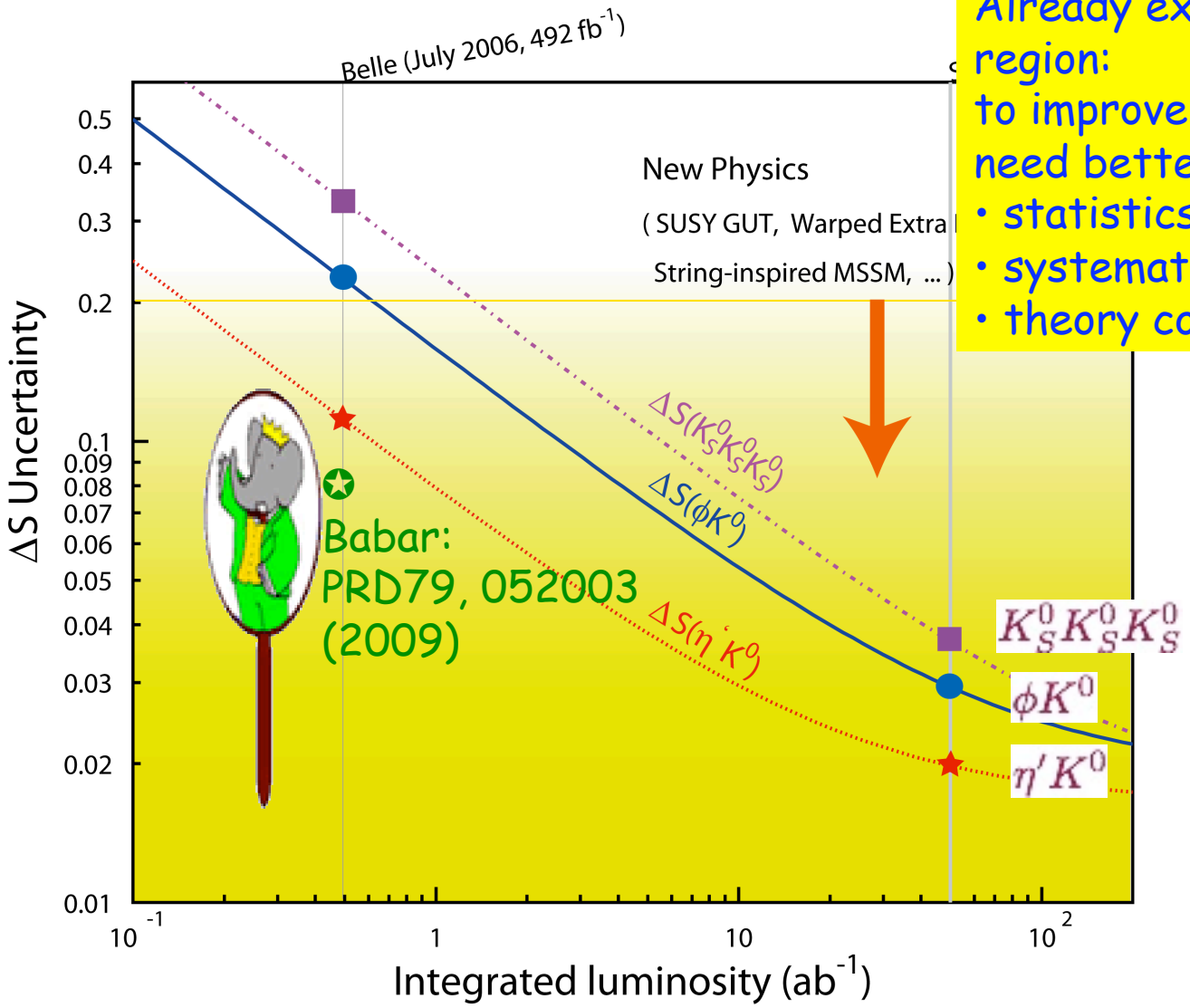
CL = 0.19 (1.3σ)

difference is < 0



"sin2φ_1" sensitivity to New Physics

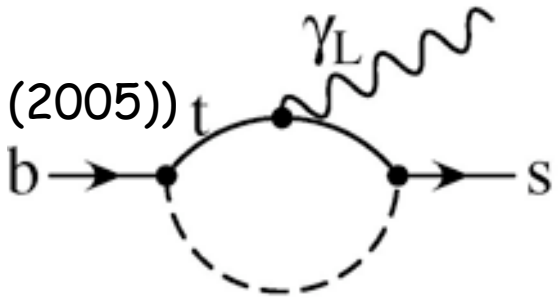
(Luminosity Projections)



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

Right-handed currents

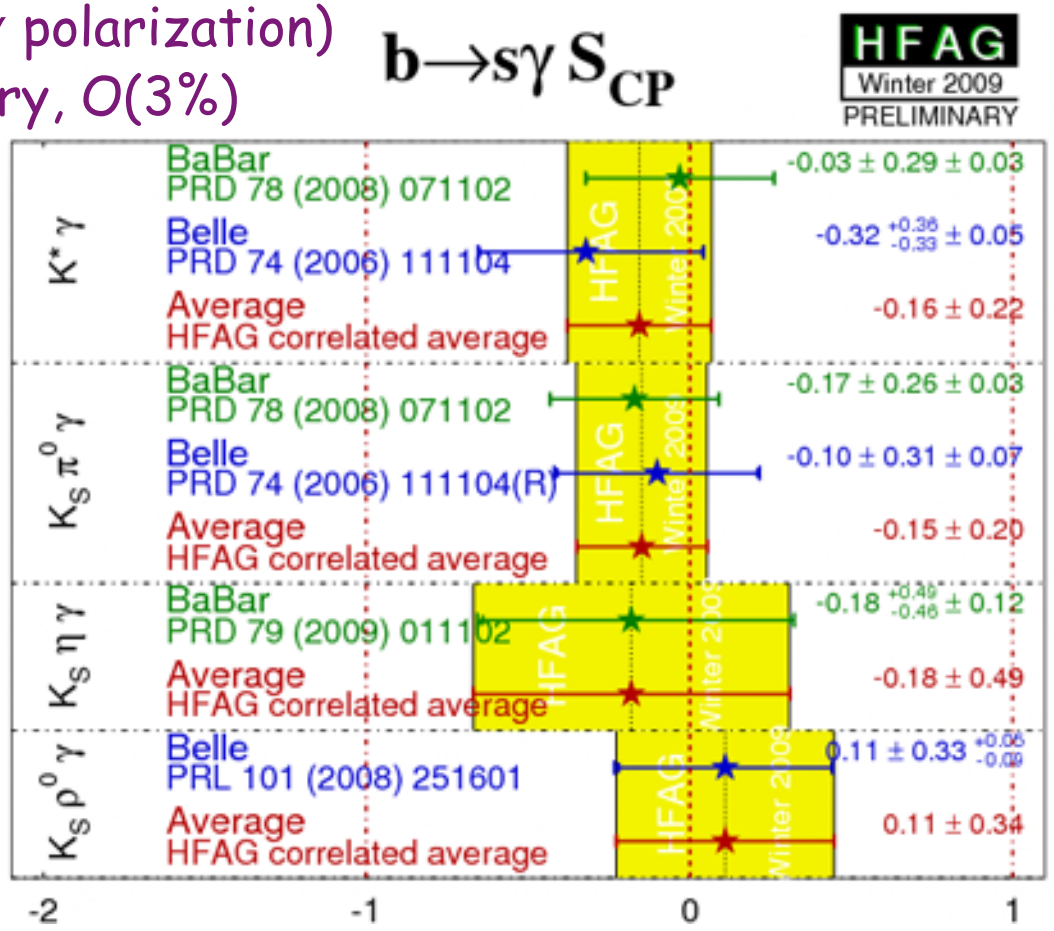
Atwood, Gronau, Soni (PRL 79, 185 (1997))
Atwood, Gershon, Hazumi, Soni (PRD 71, 076003 (2005))



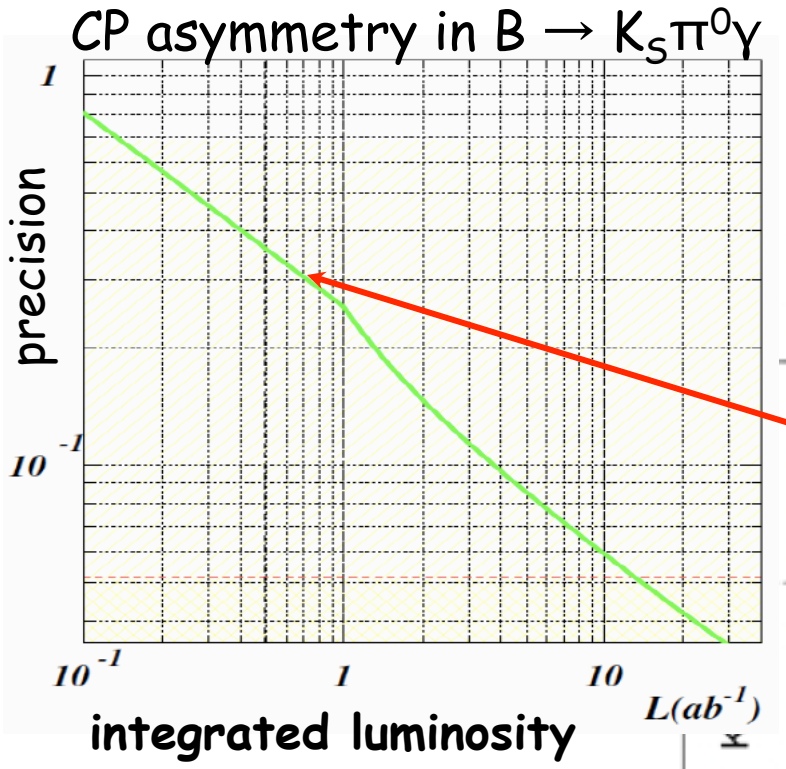
- in SM
- $B^0 \to X_s^{CP}\gamma$ is
- ~flavor-specific (γ polarization)
- -> low CP-asymmetry, O(3%)

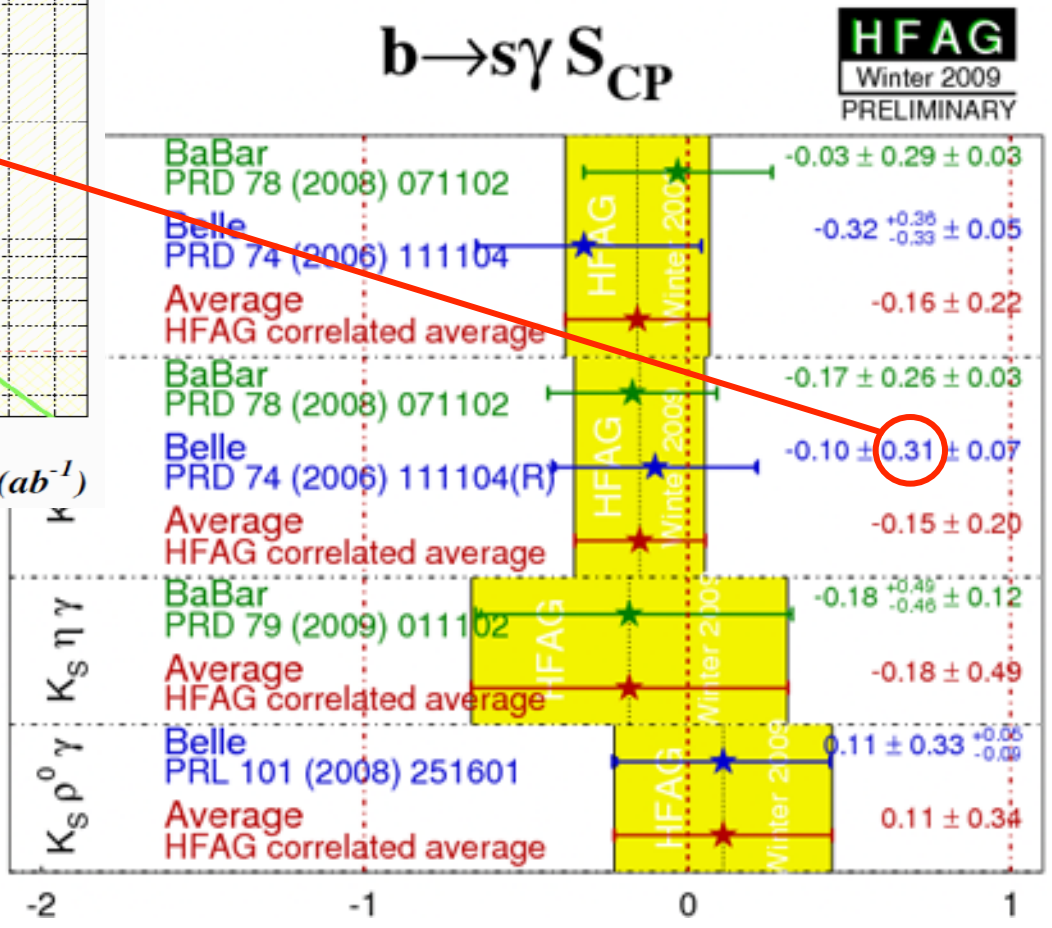
large asymmetry
<->
right-handed current

Currently:
consistent with no
RH currents
(but need more data for
good sensitivity...)



Right-handed currents

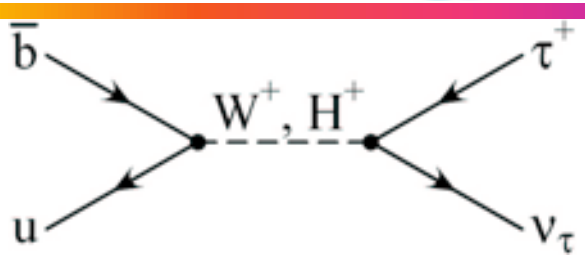




$B^+ \to \tau^+ \nu_\tau$: constraints on charged Higgs

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

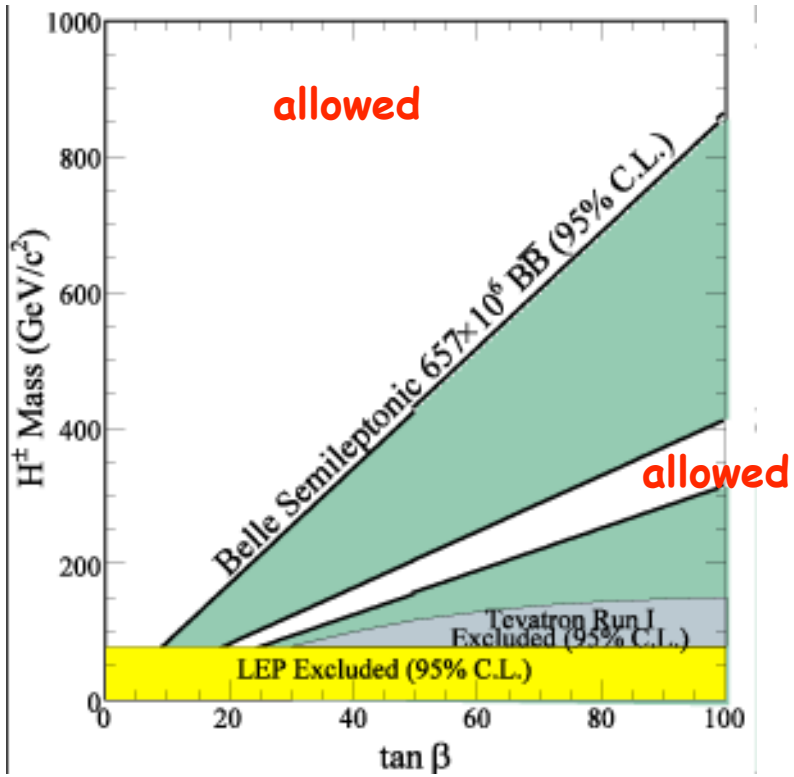
$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2\beta)^2$$



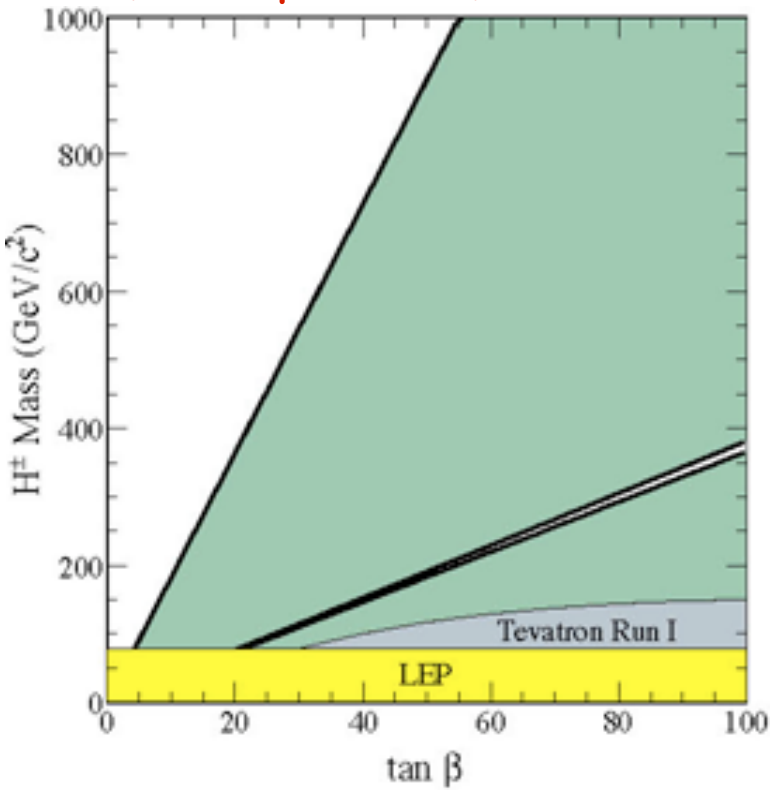
{WS Hou, PRD 48, 2342 (1993)}

(Belle) 0.65 ab^{-1}

$\mathcal{B}(B \to \tau\nu) = (1.7 \pm 0.4 \pm 0.4) \times 10^{-4}$



(extrapolation) 50 ab^{-1}



Lepton universality: B→μν

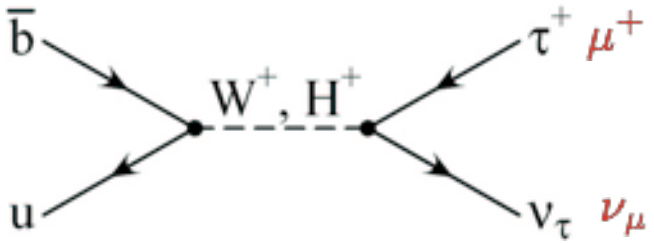
SM:

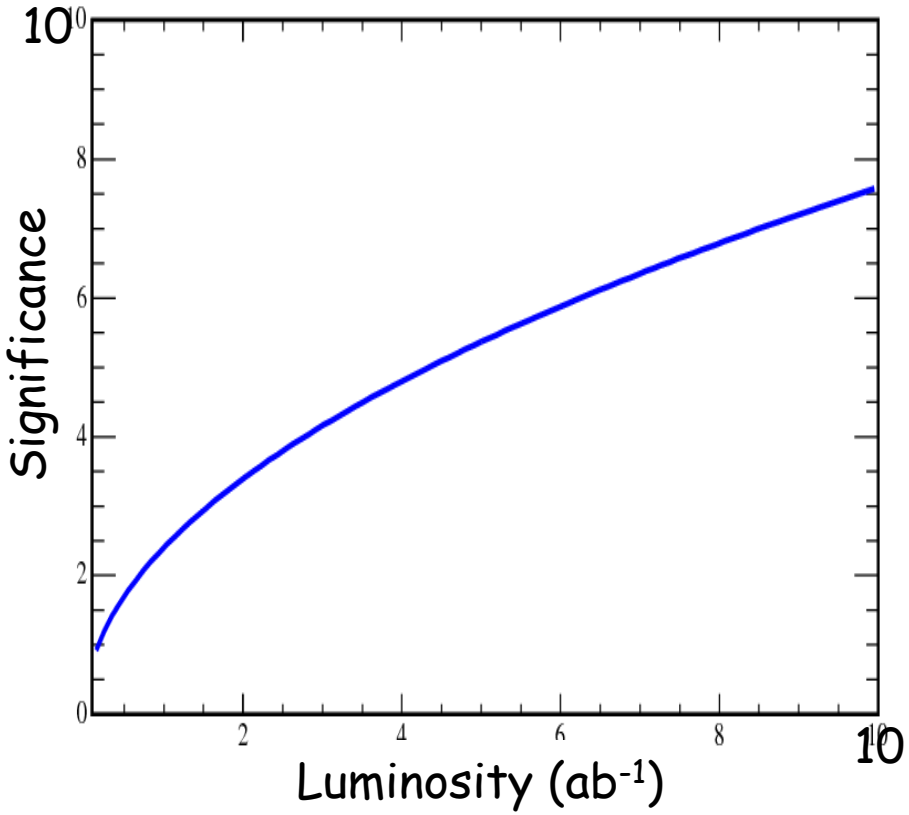
B(B->τν) = 1.6×10^{-4}

B(B-> μν) = 7.1×10^{-7}

B(B-> eν) = 1.7×10^{-11}

expect observation with ~4 ab^{-1}



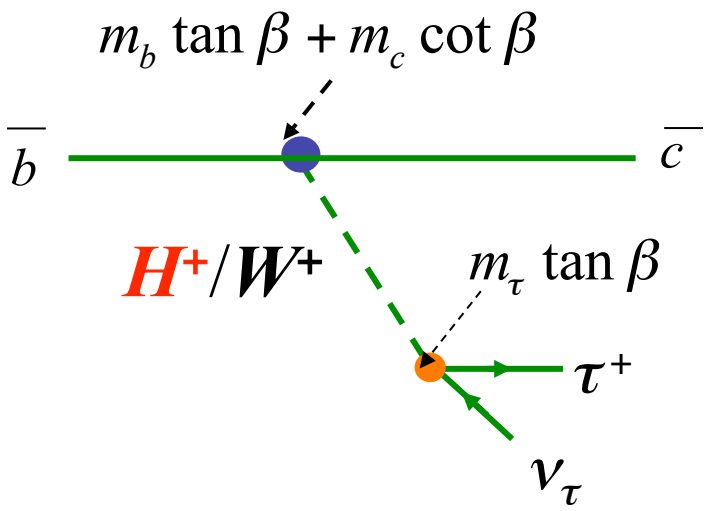


B->τν / B-> μν

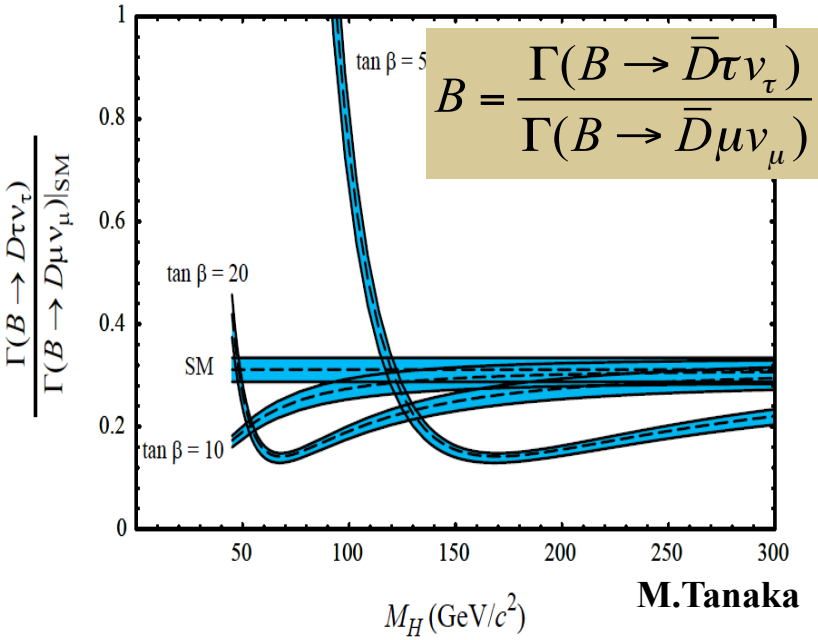
deviations from SM sensitive to NP

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

- universality via semileptonic decays



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

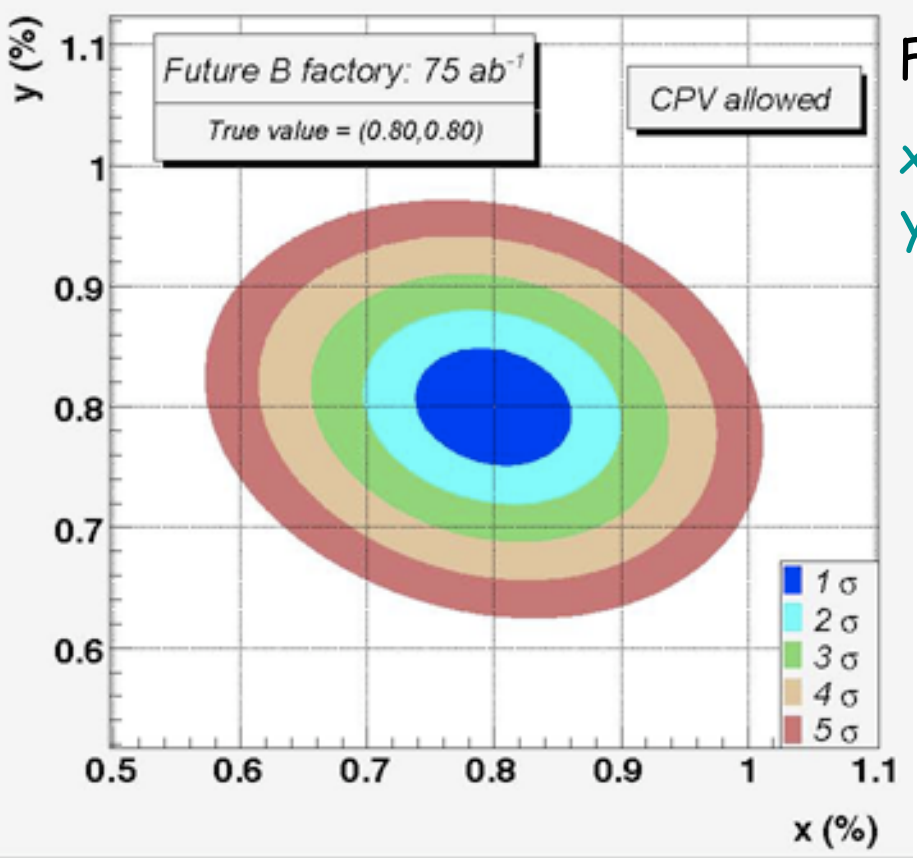


- Ratio (τ/μ) is sensitive to charged Higgs (similar to $B \to \tau\nu$)

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

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

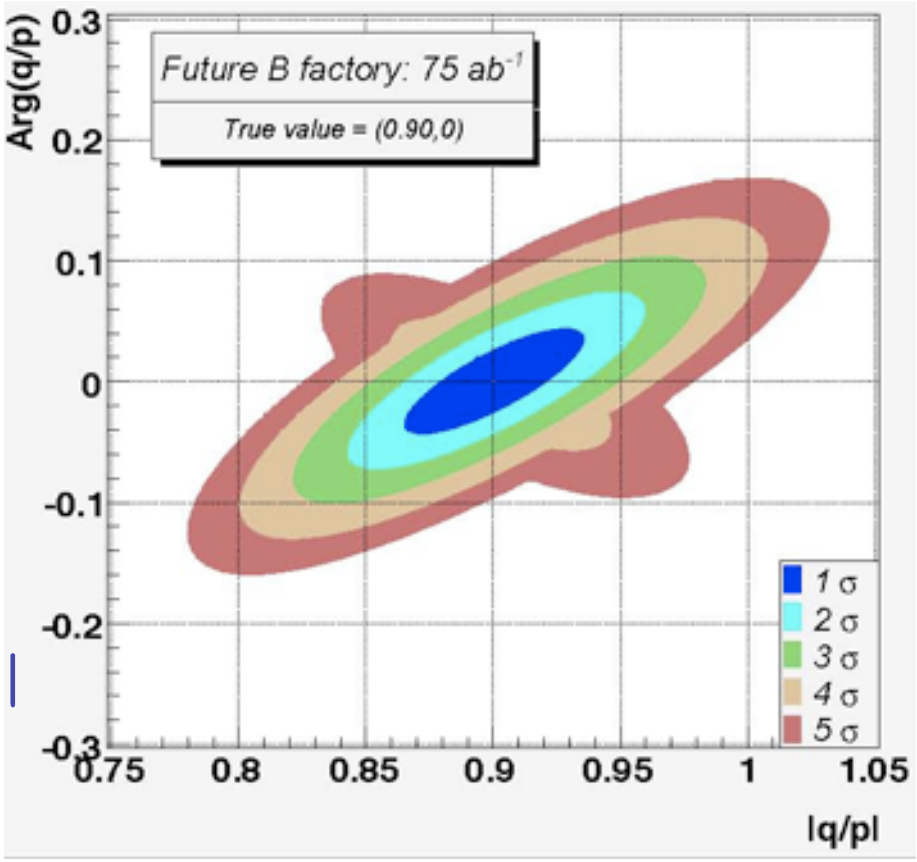
D mixing/CP violation



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|

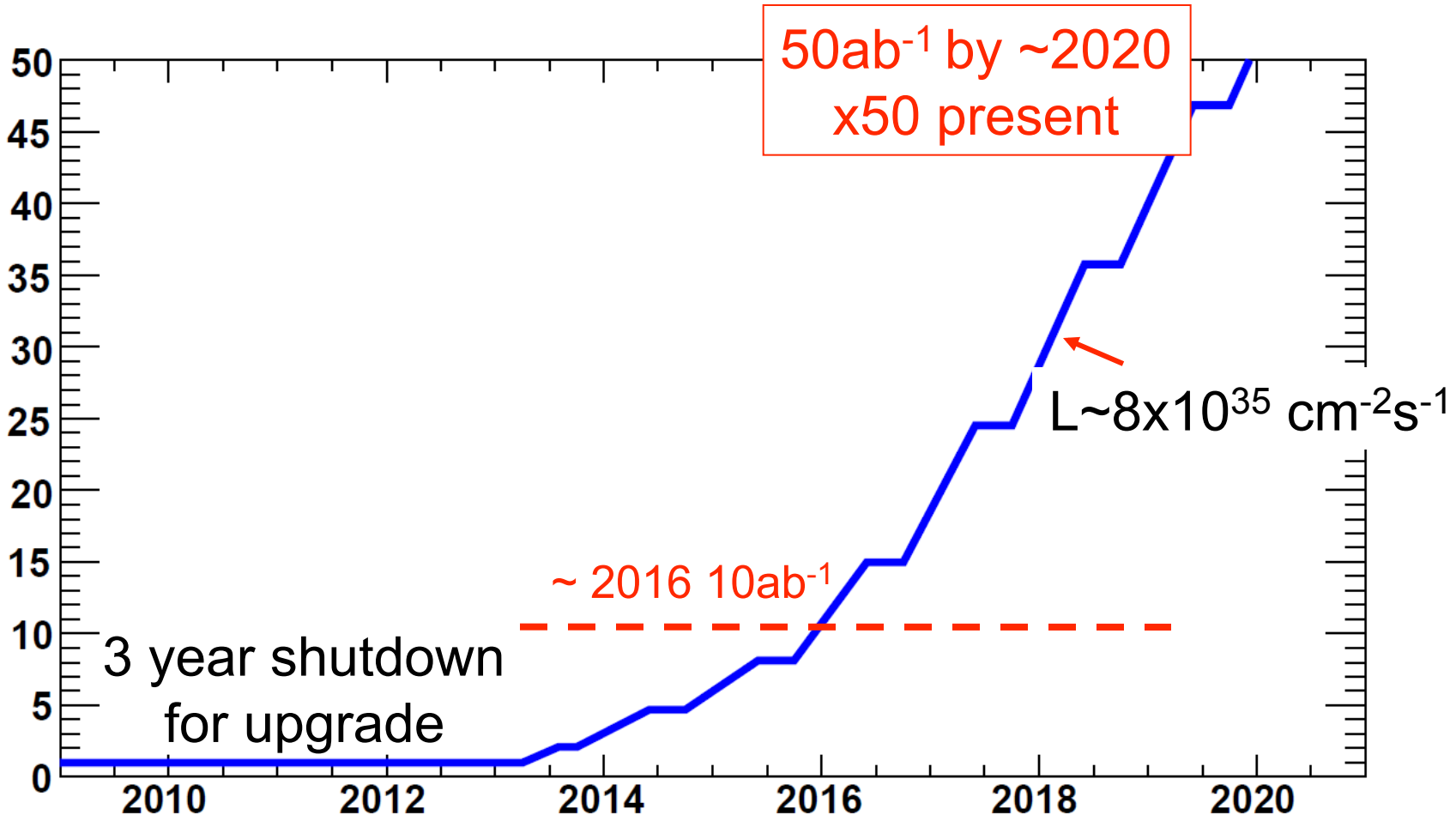
Super KEKB uest for BSM

=> what we need is

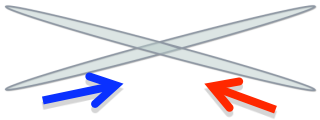
Billions and Billions

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

Lorentz factor

Beam current

Beam-Beam parameter

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

Geometrical reduction factors (crossing angle, hourglass effect)

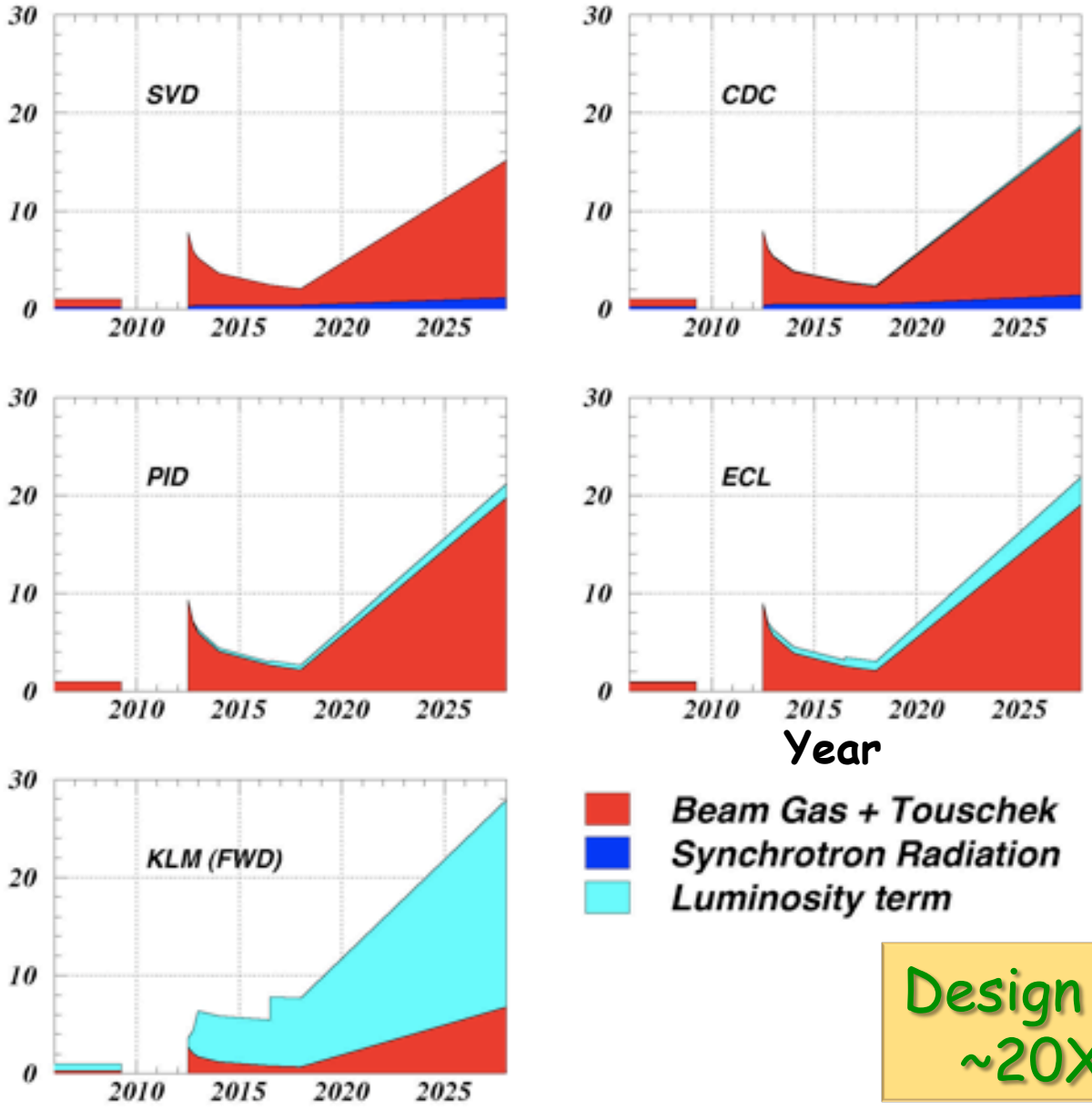
Beam aspect ratio at IP

Vertical beta function at IP

6.5(LER)/5.9(HER) →0.26/0.26

Minimum value is limited by hourglass effect

Detector: Background projections



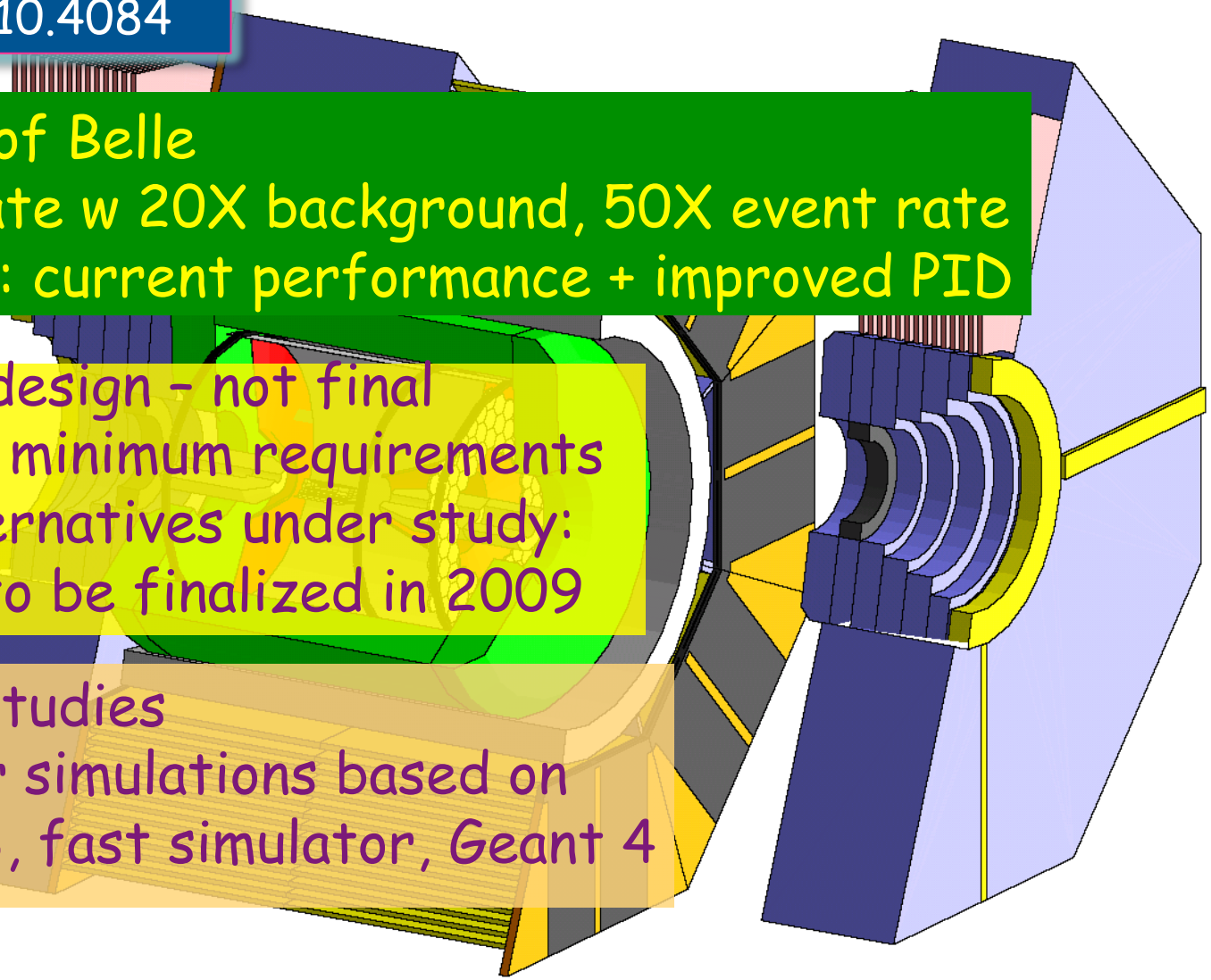
Belle detector
SuperKEKB
(hi-current design)
normalized to
current rates

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

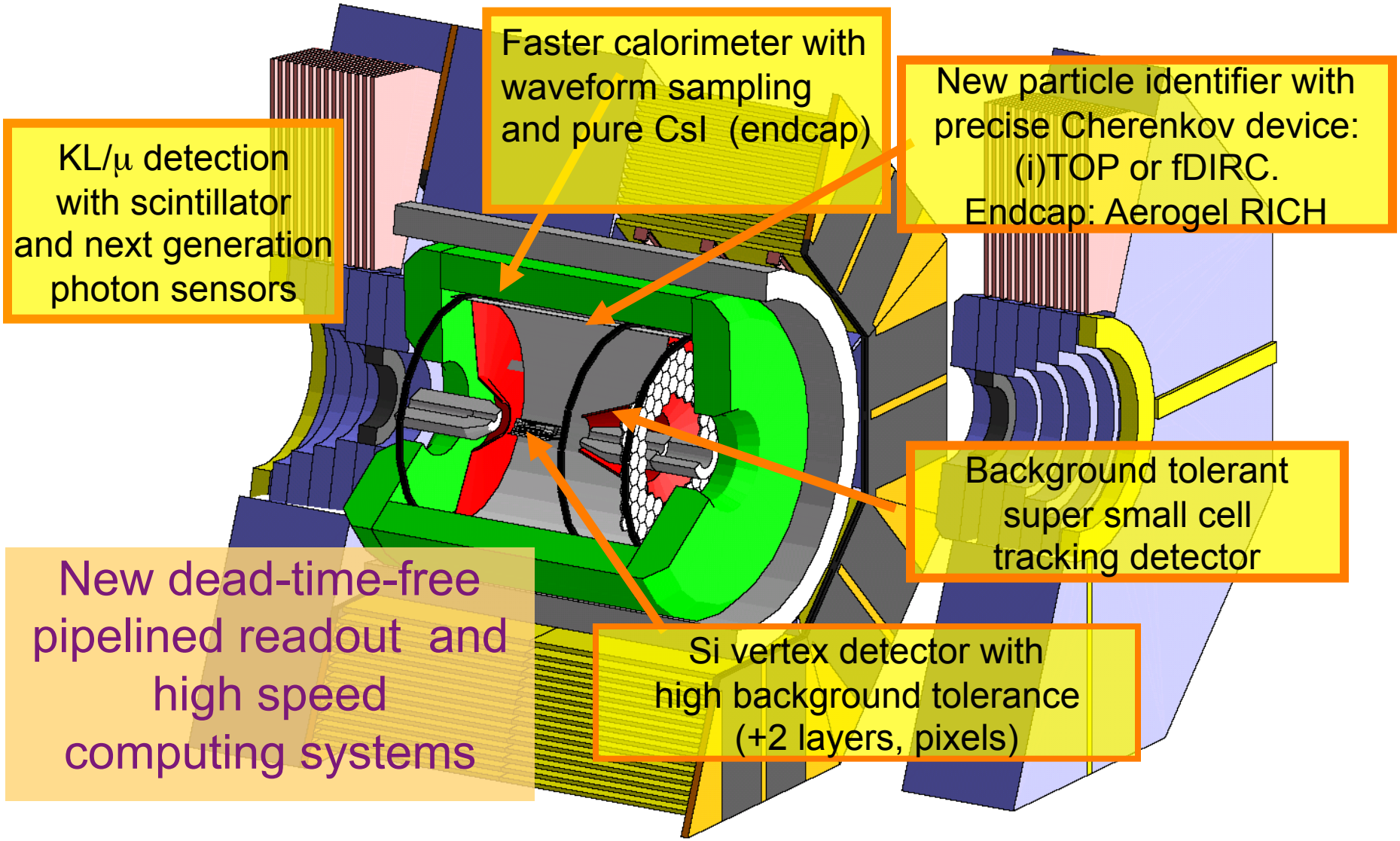


Upgrade of Belle
to operate w 20X background, 50X event rate
baseline: current performance + improved PID

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

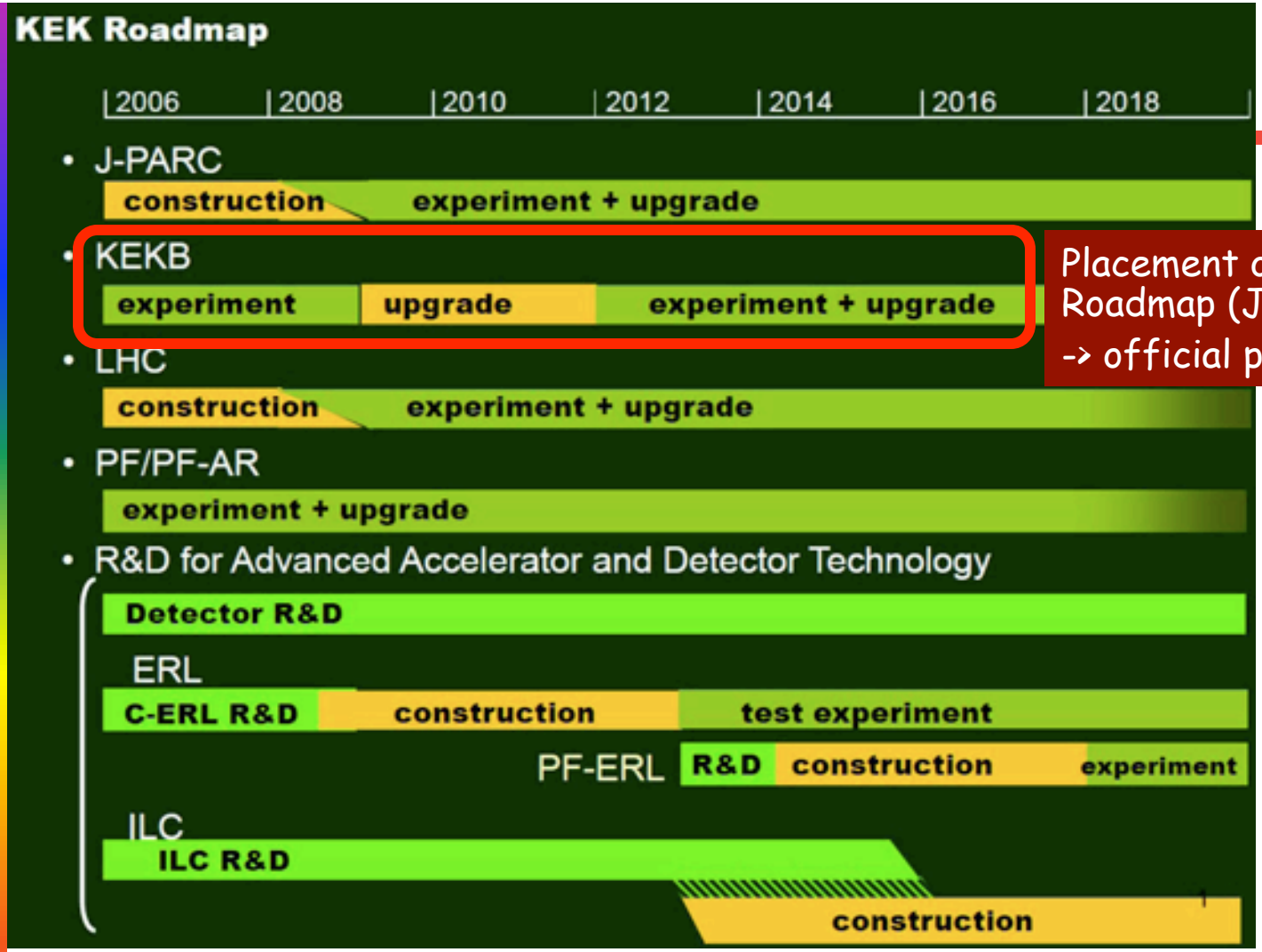
Physics studies
Detector simulations based on
Geant 3, fast simulator, Geant 4

Belle II baseline



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

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