News on SuperKEKB Physics Reach

Masashi Hazumi (KEK)
for
SuperKEKB physics study group

CERN Flavour Workshop

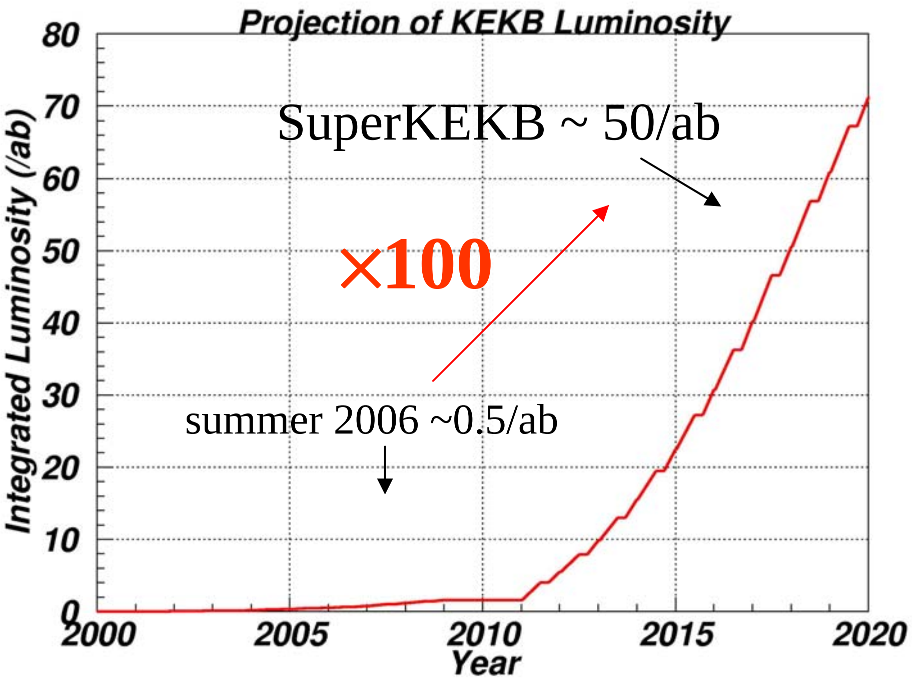
Oct. 9, 2006

Recap: SuperKEKB overview

- Super-high luminosity ≅ 8×10^{35} cm^{-2}s^{-1}

50 × present world record (recorded at KEKB)

- Natural extension of KEKB
- 8×10^{35} cm^{-2}s^{-1} with technologies proven at KEKB, together with a few modifications



- Letter of Intent (LoI) in 2004
  - ➢ 276 authors from 61 institutions
  - ➢ available at http://belle.kek.jp/superb/loi
  - ➢ "Physics at Super B Factory" hep-ex/0406071

- HEP community in Japan is now discussing the Grand Lepton Collider plan to accommodate both SuperKEKB and ILC.

Changes since SuperKEKB LoI

- New results from Belle/BaBar with improved analyses
  - Better background rejection lead to evidence for $B \rightarrow \tau\nu$
  - Time-dependent CP violation meas. also improved
  - Isospin analysis for ϕ_2 proven with $\pi\pi$, $\rho\pi$, $\rho\rho$
- New results from other experiments
  - Bs mixing from CDF/D0
- Progress in theory, proposals for new measurements

Need to update physics studies done for LoI. Need to include new studies.

↓

Workshop held at KEK in September. Interim reports given.
BNM2006 (B Factories and New Measurements)
http://www-conf.kek.jp/bnm/2006/

More than 100 participants: Many new ideas proposed. Very fruitful !

New results (not in LoI)

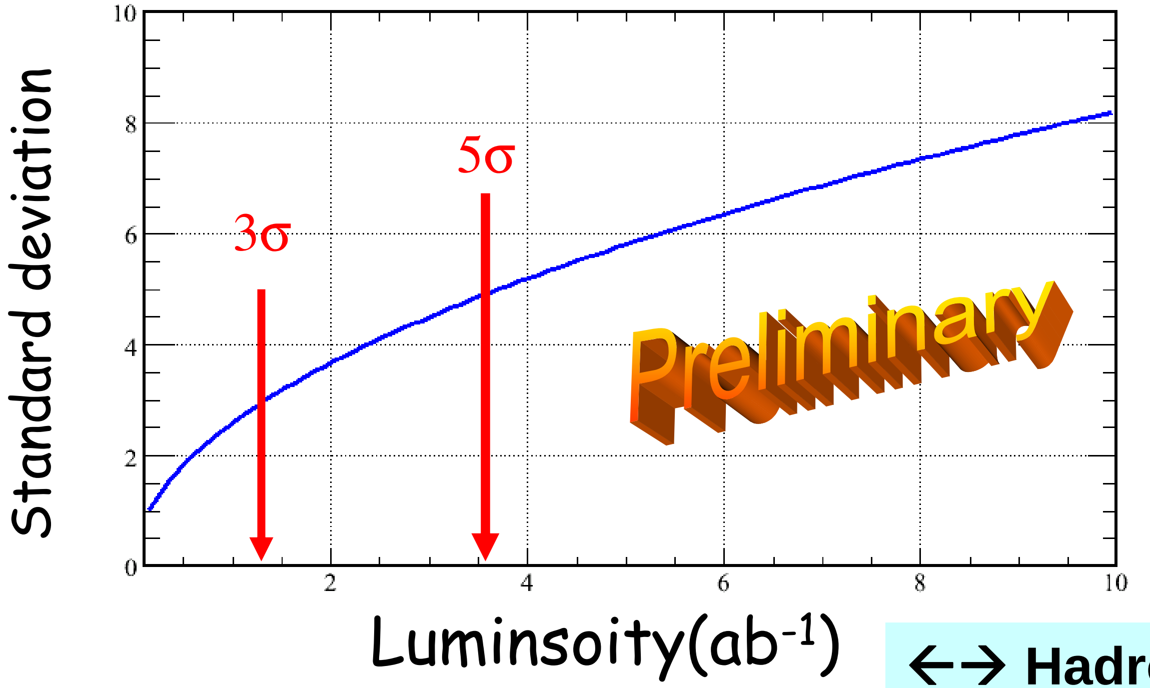
- Modes with neutrinos
  - $B \rightarrow \mu\nu$ (1 ν)
  - $B \rightarrow \tau\nu$ (>1 ν)
- New ideas
  - Use of conversion photons
    - $\mathcal{S}(B^0 \rightarrow \pi^0\pi^0)$ measurements with vertices from $\gamma \rightarrow ee$
    - $B \rightarrow K^*\gamma$ with $\gamma \rightarrow ee$
  - Direct CP violation in $B^0 \rightarrow K_S\pi^0$ vs. $B \rightarrow K\pi$ sum rule: $\Delta\mathcal{A}(K_S\pi^0)$
  - Upsilon(5S) and other energies
  - Ambitious detectors (not covered in this talk)
- Estimations based on new measurements at Belle
  - $Br(B \rightarrow X_d\gamma)$
  - $\mathcal{S}(B^0 \rightarrow \rho^0\gamma)$
  - TPC (triple product correlations) with $B \rightarrow VV$
- Progress in theory side

Ikado

$B \to \mu\nu$

- Highly energetic muon
- Accompanied B reconstructed with the remaining particles (neutrino reconstruction technique)
- $Br(B \to \mu\nu)$ upper limit measurement :
  significance is about 1.3σ from the current Belle results ($250fb^{-1}$)

Assuming that significance depends on luminosity in the following plot



sigma	Lum (ab^{-1})
3σ	1.3
5σ	3.7

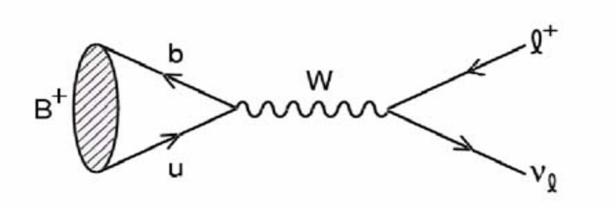
Cf. 5σ @ $5.8ab^{-1}$ with SM branching ratio

←→ Hadronic-tagging : Need $15ab^{-1}$ for the 3σ sensitivity

$H^{\pm}$ constraints from B → τν: SuperKEKB projections

$$\mathcal{B}(B \to \tau\nu) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

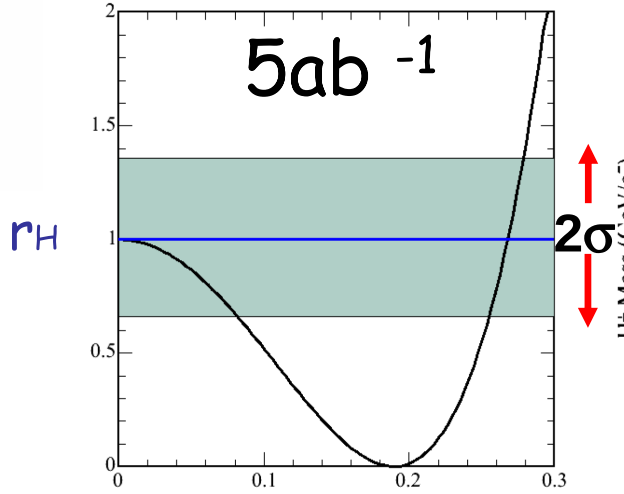
95.5%C.L.
exclusion regions

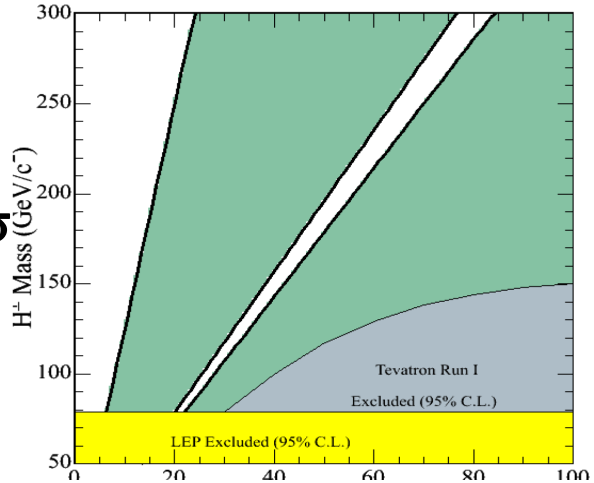


Use known f_B and $|V_{ub}|$

Ratio to the SM BF.

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

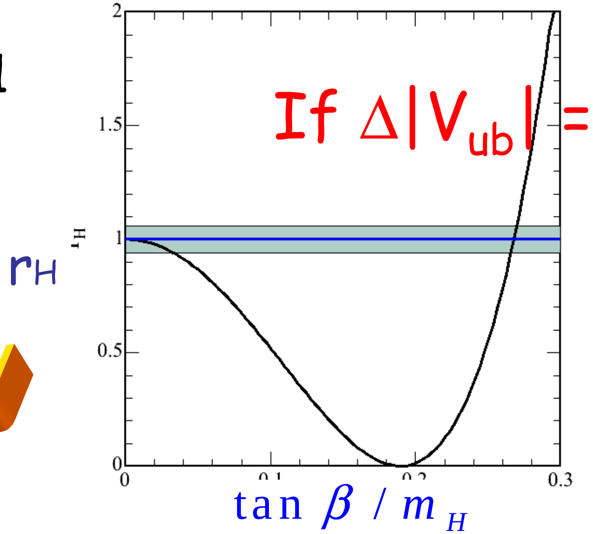


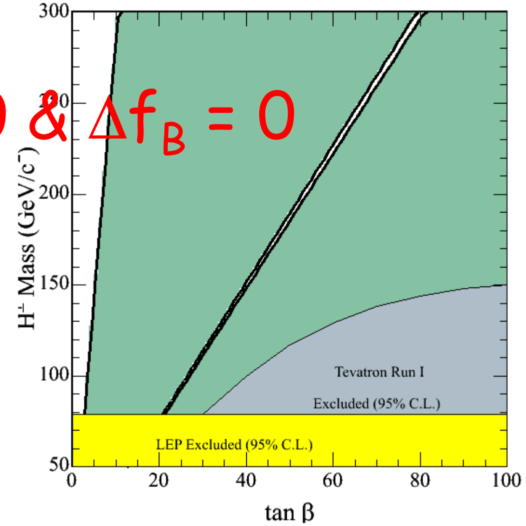


50ab -1

Δf_B(LQCD) = 5%

If $\Delta|V_{ub}| = 0$ & $\Delta f_B = 0$

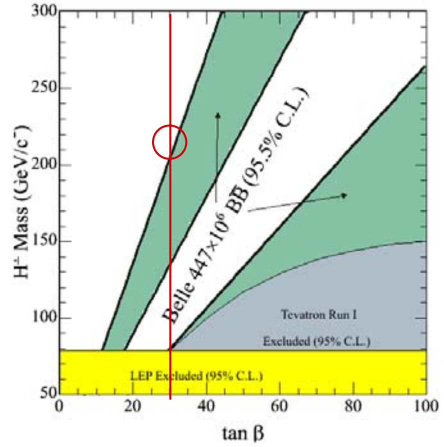


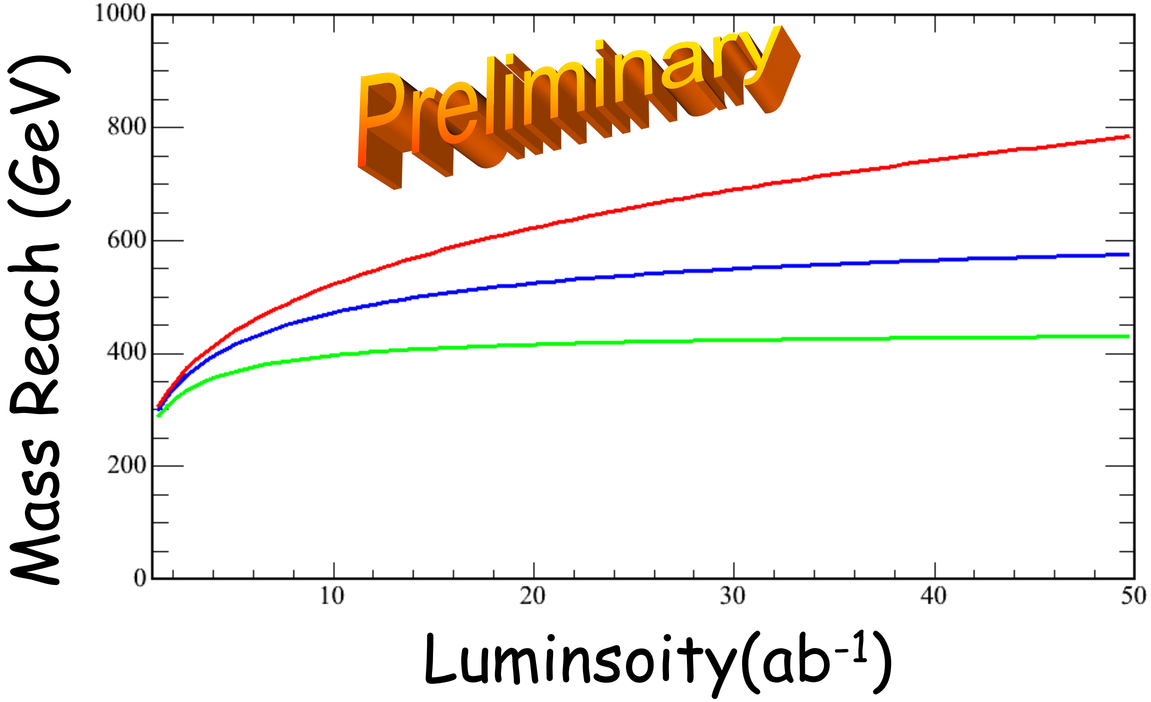


Preliminary

Constraints at Super-B (cont.)

Charged Higgs Mass Reach
(95.5%CL @ tanβ=30)





Only exp. error
(ΔV_{ub}=0%, Δf_B=0%)

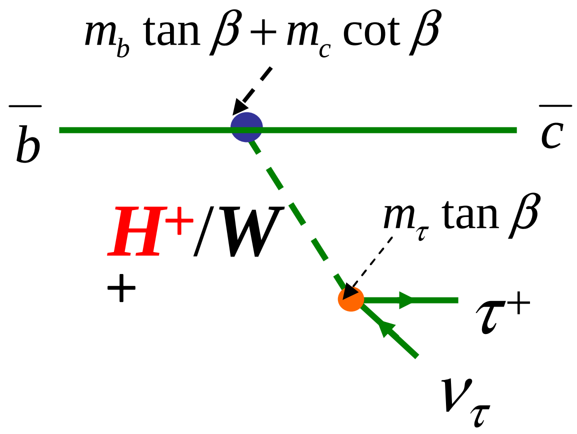
ΔV_{ub}=2.5%, Δf_B=2.5%

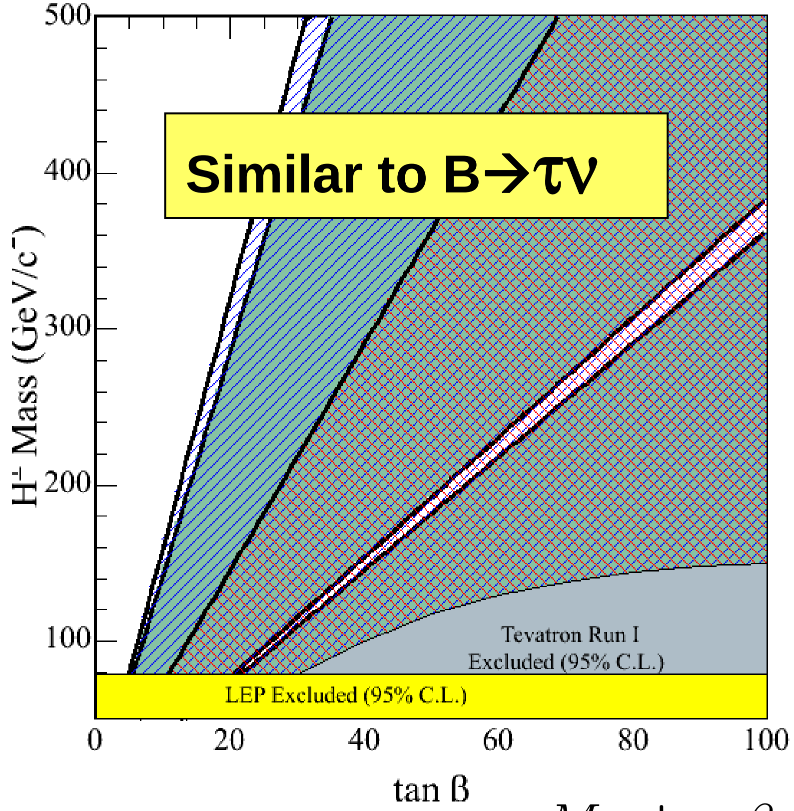
ΔV_{ub}=5%, Δf_B=5%

Constraints at Super-B from B→Dτν

(no update from LoI yet)

$H^{\pm}$ search in **B→Dτν**





- $5\ \mathrm{ab}^{-1} \rightarrow M_H > \dfrac{M_W \tan\beta}{11}$
- $50\ \mathrm{ab}^{-1} \rightarrow M_H > \dfrac{M_W \tan\beta}{5}$

Full reconstruction modes

Int. Lumi (ab-1)

0 5 10 20 30 40 50

Preliminary

B→τν 5σ 10% 3%

similar sensitivity from B → Dτν → M(H+)>400GeV (2σ) at tanβ = 30

B→μν 5σ@3.7ab-1 with present central value

5σ@5.8ab-1 with SM branching ratio

B→K+νν 5σ@33ab-1

updated New !

Very important progress on these theoretically clean modes !

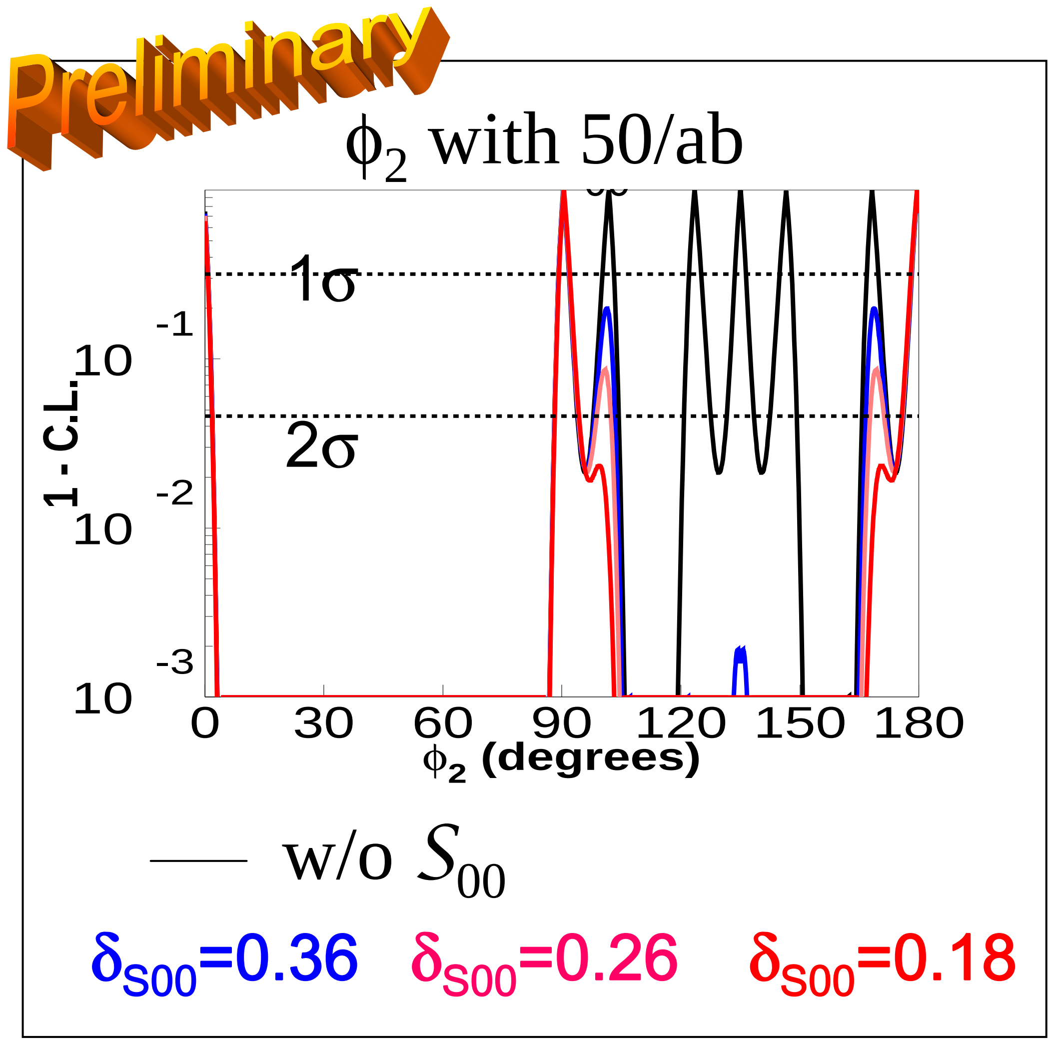
Need to work on B → K*νν, Ksνν

Need to work on Bd → μ+μ–, e+e-

Ishino, Hazumi, Yoshikawa

Isospin analysis w/ or w/o S_{00} (S term for $B^0 \to \pi^0\pi^0$)

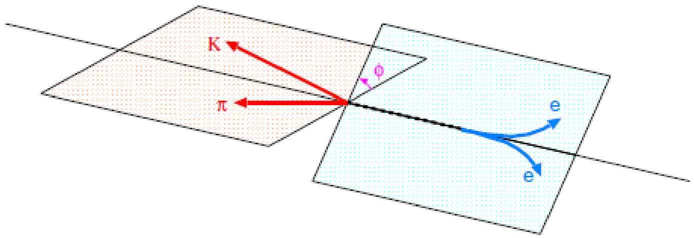
- Reconstruction efficiency w/ vertexing: 1.3%
- How many signal events w/ 50/ab data?: 850 events.
- Toy MC
  - # of signal =850
  - three cases: signal fraction = 100%, 50%, 25%.
  - resolution function obtained from Geant MC
  - tagging efficiency 30%.
- RMS of fitted S_{00}
  - δS_{00} = 0.18 (for sig. frac.=100%), 0.26 (50%) and 0.36 (25%)

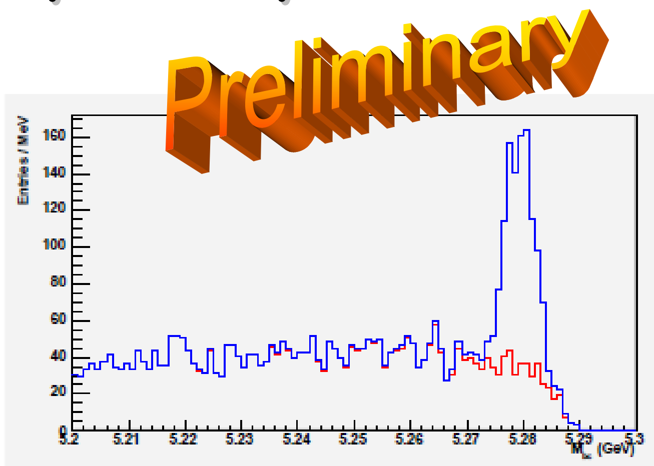


Cf. Larger vtx detector → larger conversion eff
Detector optimization → large improvement

Photon polarization in B → K*γ with γ → e⁺e⁻

- $B \to K^*\gamma$ with $\gamma \to e^+e^-$ in the detector could be used to measure the left- and non-SM right-handed components (A_L and A_R) (Grossman-Pirjol JHEP 0006,029(2000))





- If $A_R \neq 0$, phi modulation in the form:

$$1 + \xi(E_e, q^2)\frac{|A_R||A_L|}{|A_R|^2 + |A_L|^2}[\cos(2\phi + \delta)],$$

[ξ: efficiency factor average $\xi \sim 0.3$]

- Very clear signal
- Signal should be already visible with current data

- A full-MC test for 5 ab^{-1} (with loosened cuts for background)
- Fit with $N(1 + A\cos(2\phi + \delta)) \Rightarrow A = 0.085 \pm 0.067$
- Given that $\xi \sim 0.3$, $A_R \sim A_L$ is needed for $> 3\sigma$ at 5 ab^{-1}, and
  - Need to evaluate ξ in a boosted CM system
  - Need to evaluate detector effects/bias
  - Need to separate conversion and low-q^2 $B \to Ke^+e^-$

$\Delta\mathcal{A}(B^0 \rightarrow K_S\pi^0)$

Sum rule

$$A_{CP}(K^+\pi^-)+A_{CP}(K^0\pi^+)\approx A_{CP}(K^+\pi^0)+A_{CP}(K^0\pi^0)$$

M. Gronau, Phys. Lett. B627 (2005) 82.

- Diff. between experiment and sum rule
  - ΔAcp($K_S\pi$0)=0.10 (Belle only), 0.03 (HFAG Avg.)
- Uncertainty on the sum rule
  - $\delta A \approx \pm 0.002$ @5/ab, $\approx \pm 0.001$ @50/ab
- Uncertainty on the experimental measurement
  - $\delta A \approx \pm 0.072$ @5/ab, $\approx \pm 0.050$ @50/ab

Preliminary

can be improved by optimizing flavor tagging

Upsilon(5S) and other energies

- Upsilon(5S)

Drutskoi, Pierini

  - Belle results with engineering runs (1.86/fb) at ICHEP2006
  - Belle recorded 21.7/fb (June 9-31, 2006). Results expected in the winter conferences
    - Branching fractions for semileptonic Bs decays: 5~10% accuracy
    - Br[Bs → $Ds^{(*)+}Ds^{(*)-}$]: ~30% accuracy

$$\frac{\Delta\Gamma_{CP}^{s}}{\Gamma_s} \approx \frac{Bf(B_s \to D_s^{(*)+} D_s^{(*)-})}{1 - Bf(B_s \to D_s^{(*)+} D_s^{(*)-}) / 2}$$

  - ~100/fb to reach SM Br for Bs → γγ
  - Need more studies on ΔΓ/Γ with Bs → sensitive to cosine of a new phase

Tajima, Hazumi

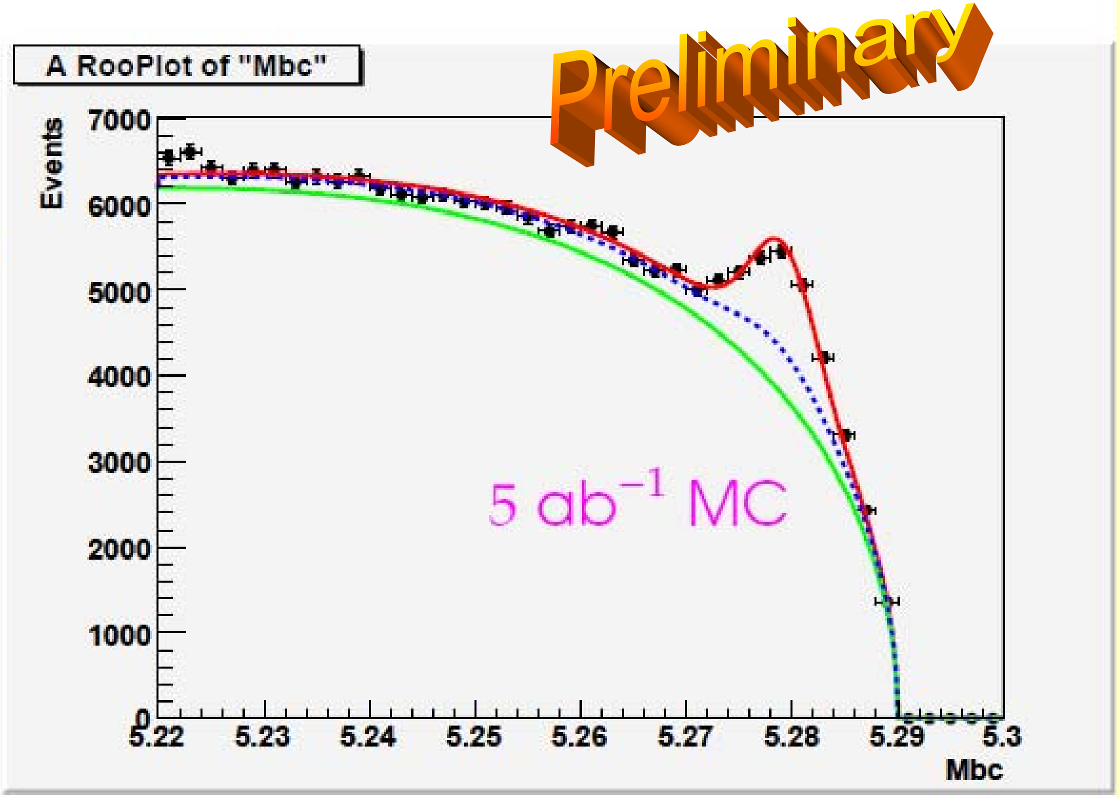
- Upsilon(3S): best place to search for light dark matter candidates
- Upsilon(1S-4S): test of lepton universality

Sanchis-Losano

O(1) month running at SuperKEKB enough for ~1/ab

B → $X_d\gamma$ at 5/ab

- A fit result:
  $\Rightarrow Y = 6432 \pm 298 \pm 800$
- Error sources:
  Stat.: 5%
  Fit.: 13%
  Model: 10%
  Total: 17%



$B \to X_d\gamma$ seems to be possible with 5 ab^{-1}!
(still challenging, systematic error could be quite different in reality)

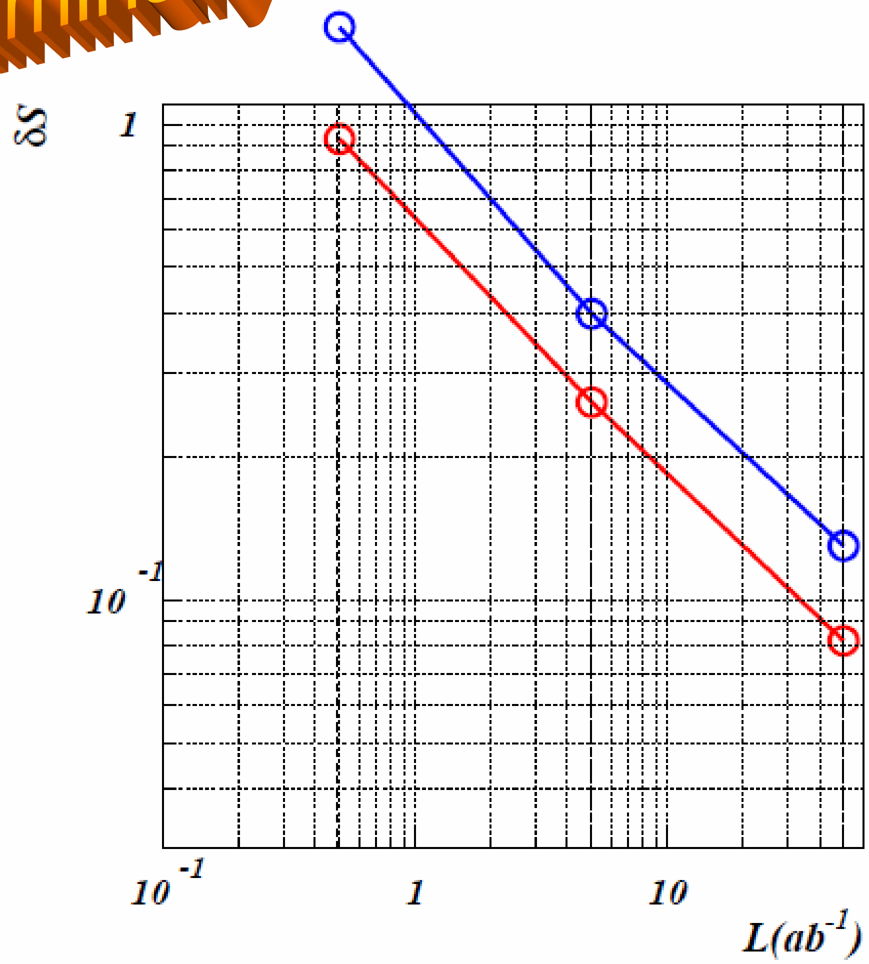
$S(B^0 \to \rho^0\gamma)$

Sumisawa

- Toy MC study based on Belle's and SM-like $\overline{B}^0 \to \rho^0\gamma$ rate

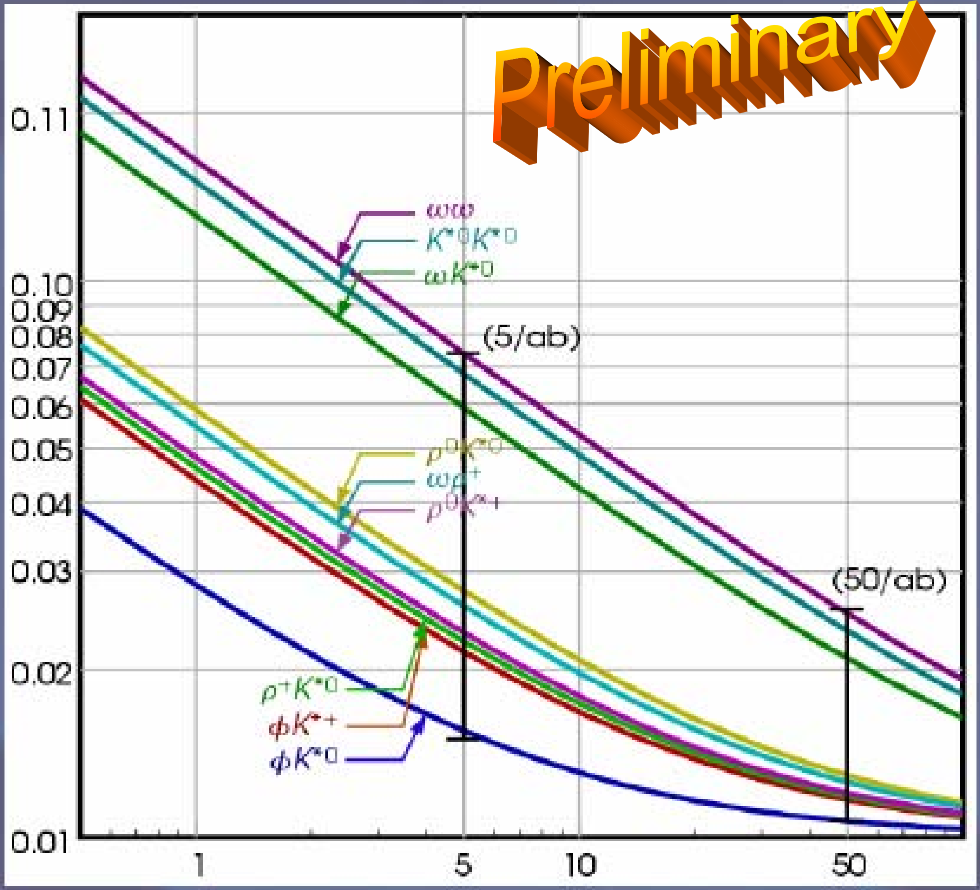
Preliminary

- Vertexing efficiency
  $\sim 87\%$ (a la ϕK^0_S)
- All background PDF
  $B \to K^*\gamma$, $X_s\gamma$, $\rho\pi^0$, other B decays, continuum
- Background Δt PDF from $K^0_S\pi^0\gamma$ analysis



Need 50 ab^{-1} for $\sim$ 10% error

Expected Errors on f_L



- Scaling from Belle or BaBar results.
- $K^{*0}K^{*0}$ is estimated with Bf ~ 0.5 x 10^{-6} and an efficiency of 3.6%.
- An 1% systematic uncertainty limitation is assumed (dominated by the uncertainty on detector acceptance).

And many other sensitivity numbers → how to use them for new physics studies ?

b → s/d precision summary

Int. Lumi (ab-1)

0 5 10 20 30 40 50

R_K	0.07	0.02
$A_{CP}(b\to s\gamma)$	0.01	0.005
A_9	11%	4%
A_{10}	13%	4%
$B\to X_d\gamma$	**7.5σ**	
$S(K_S\pi^0\gamma)$	0.1	0.03
$S(\rho^0\gamma)$	0.3	0.1
A_R w/ γpol	3σ if A_R~A_L	
S(KsKsKs) S(φK0) S(η'K0)	0.105 0.073 0.038	0.037 0.029 0.020
$\Delta A(K_S\pi^0)$	0.072	0.050

Preliminary

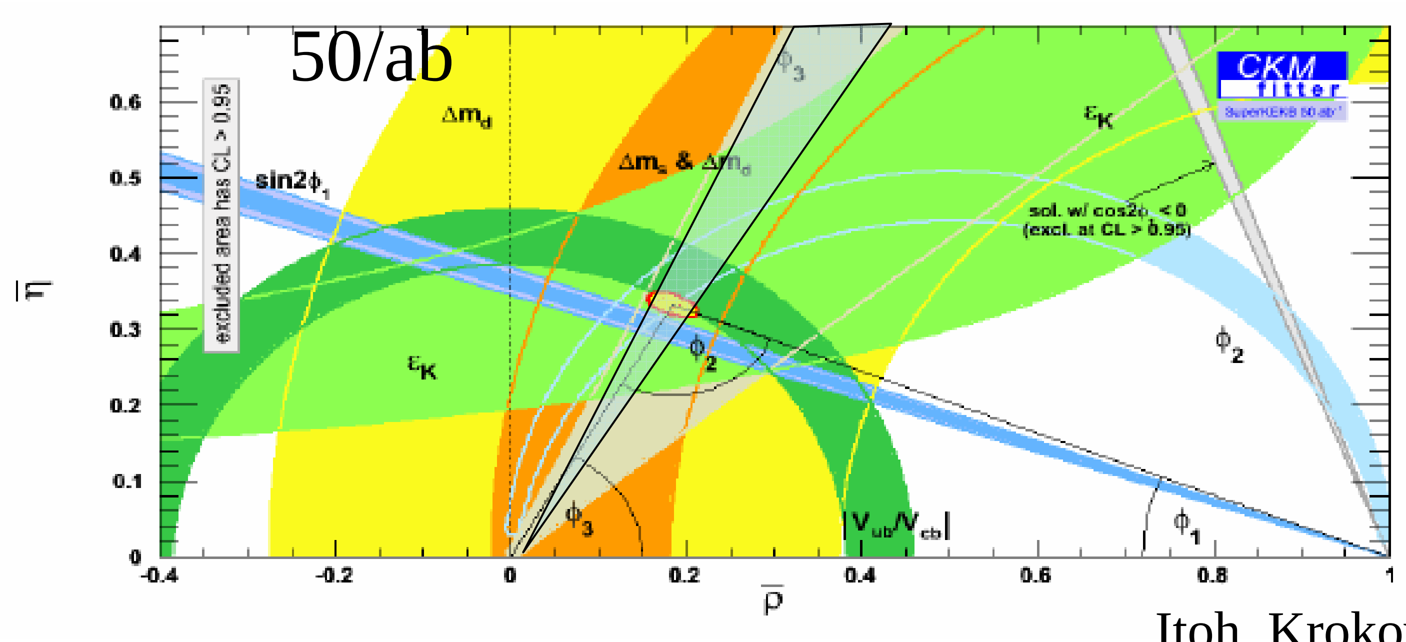
no update | updated | New !

CKM fit at SuperKEKB

Int. Lumi (ab-1): 0, 5, 10, 20, 30, 40, 50

$\phi1$	0.016	0.012
$\phi2$		2deg*.
$\phi3$		<2deg**.
Vub(inclsv)	6.6%	6.1%
Vub(exclsv)	~12%	~5%

Preliminary



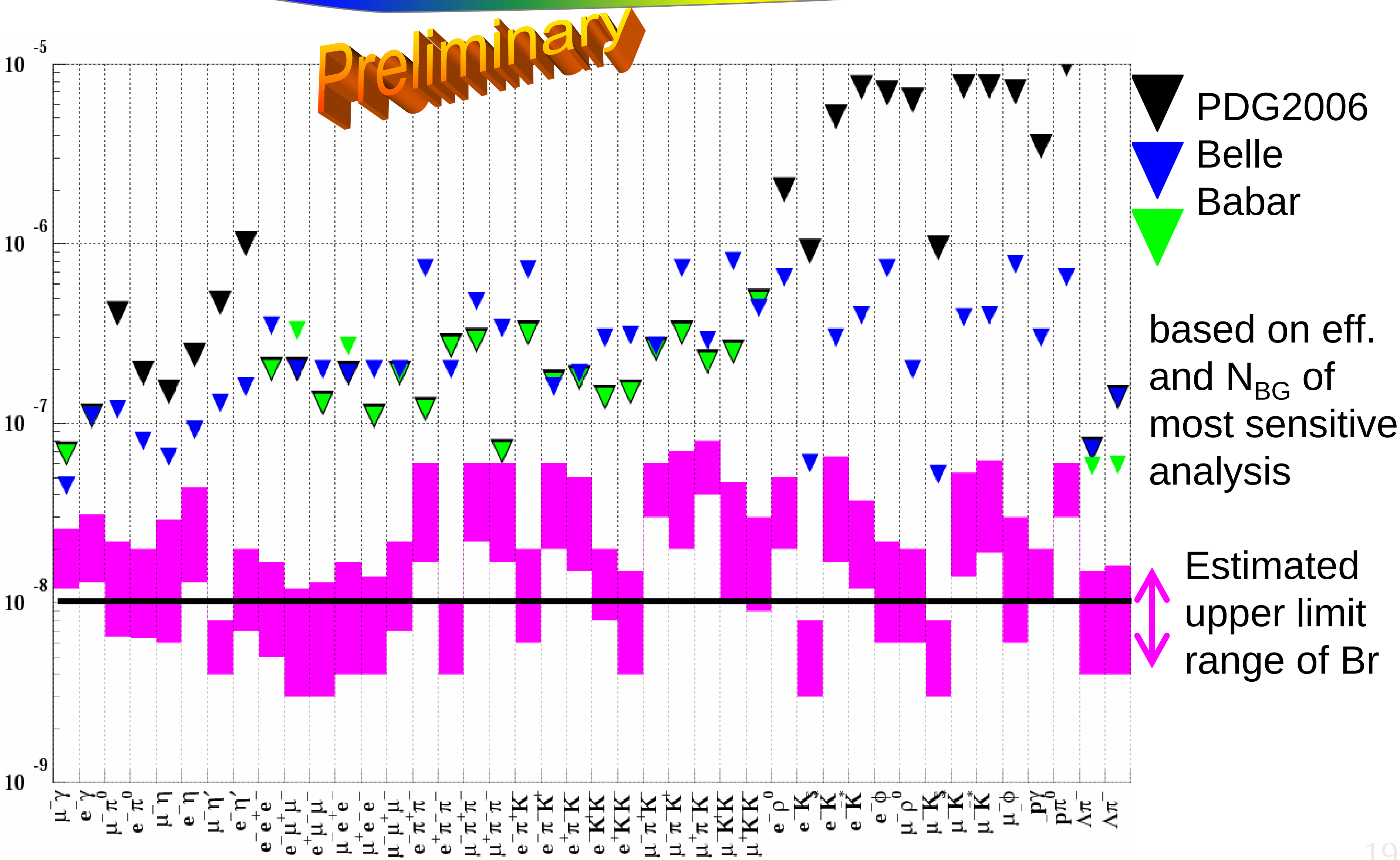
*ϕ_2 theory error will be an issue.

**$\phi3$ assumes ~10/fb $\psi(3770) \rightarrow$ DD for theory-uncertainty-free measurements

Itoh, Krokovny, Kusaka, Limosani

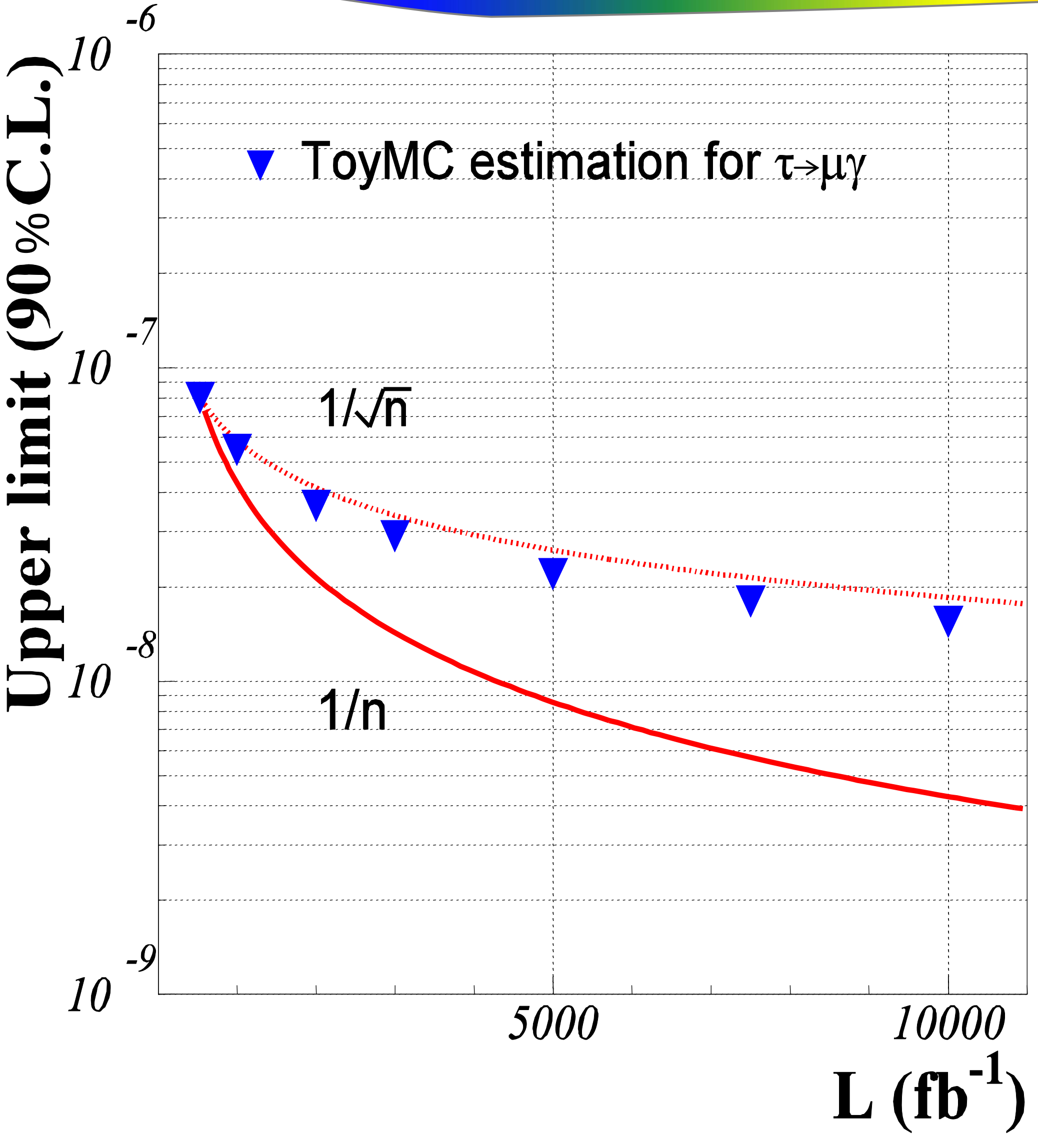
Hayasaka

τ LFV: Estimated ULs at $5ab^{-1}$

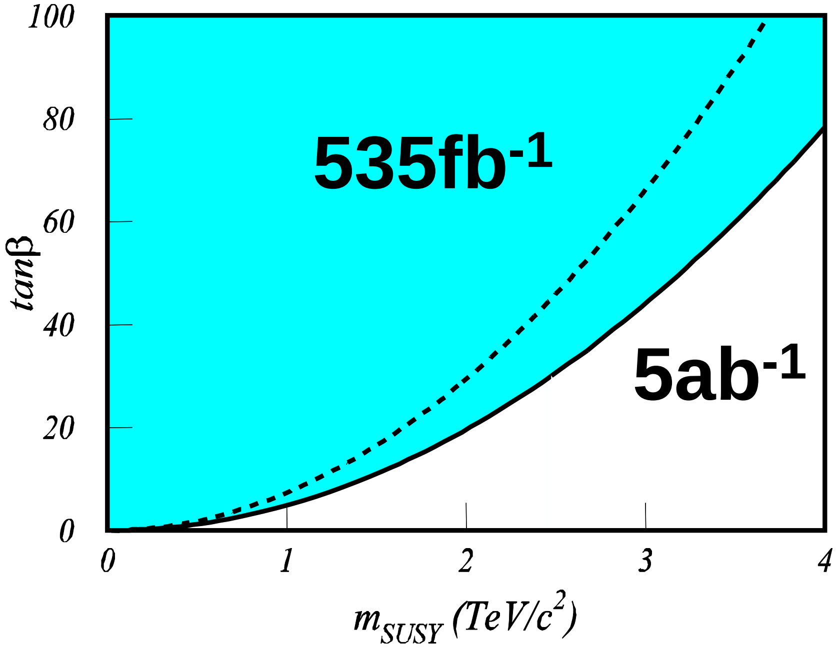


Hayasaka

SuperKEKB projections for τ→μγ



MSSM+Seesaw



~proportional to sqrt(N)
with $3ab^{-1}$ data sample
UL will reach $9x10^{-9}$.

Theory: Super KEKB LoI update

- Update the SUSY case study as an example of new physics models, including the Bs mixing.
- Add new measurements

  e.g. Triple product correlations.

  New ideas on right-handed current search in radiative B decays.

  → new idea also covered by A.Soni's talk today
- More discussions on B leptonic decays, semi-tauonic decays, and tau LFV decays.
- Add theoretical motivations and phenomenological introduction to Bs physics.

Schedule

- BNM2006-II
  - December 18, 19 in Nara
    - after CKM2006 in Nagoya (Dec.12-16)
  - Finalize sensitivity studies
- Revised SuperKEKB physics book by the end of 2006
  - Aim for publication
- Include the results in the yellow report

Backup Slides

Three factors to determine luminosity:

Stored current:

1.36/1.75 A (KEKB)

→ 4.1/9.4 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:

0.16×10^{35} cm^{-2}s^{-1} (KEKB)

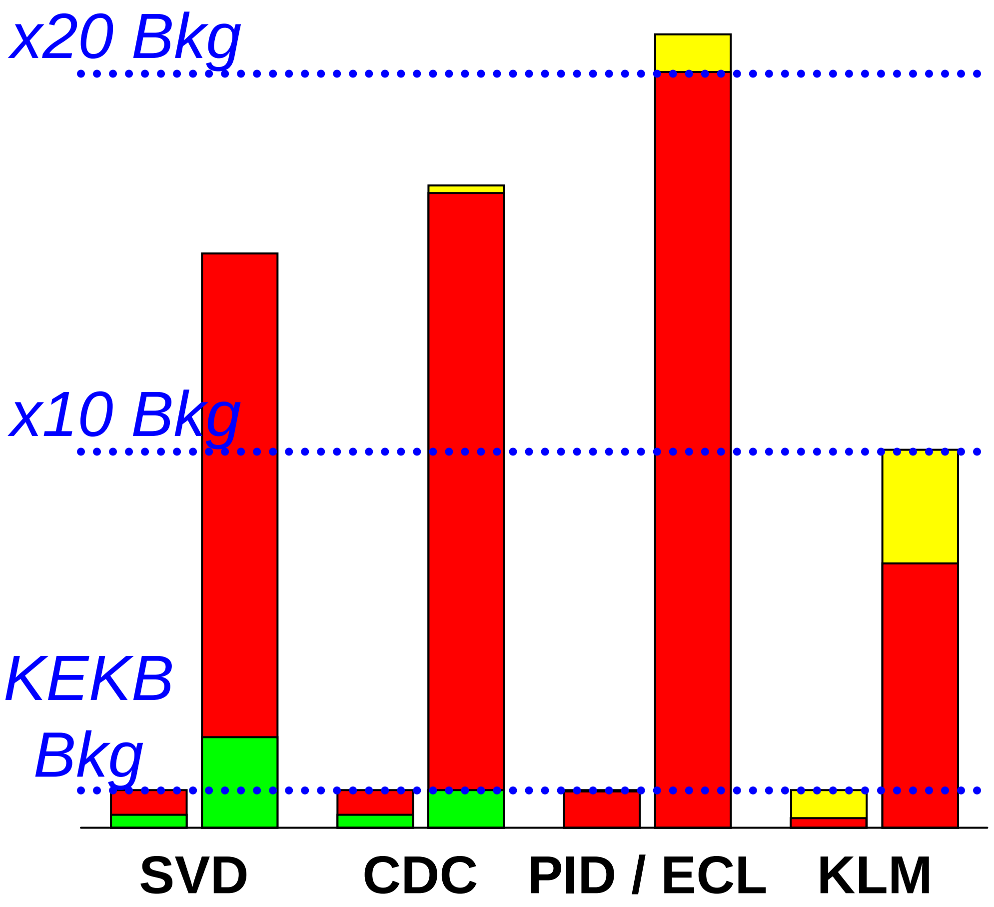
8×10^{35} cm^{-2}s^{-1} (SuperKEKB)

Vertical β at the IP:

6.5/5.9 mm (KEKB)

→ 3.0/3.0 mm (SuperKEKB)

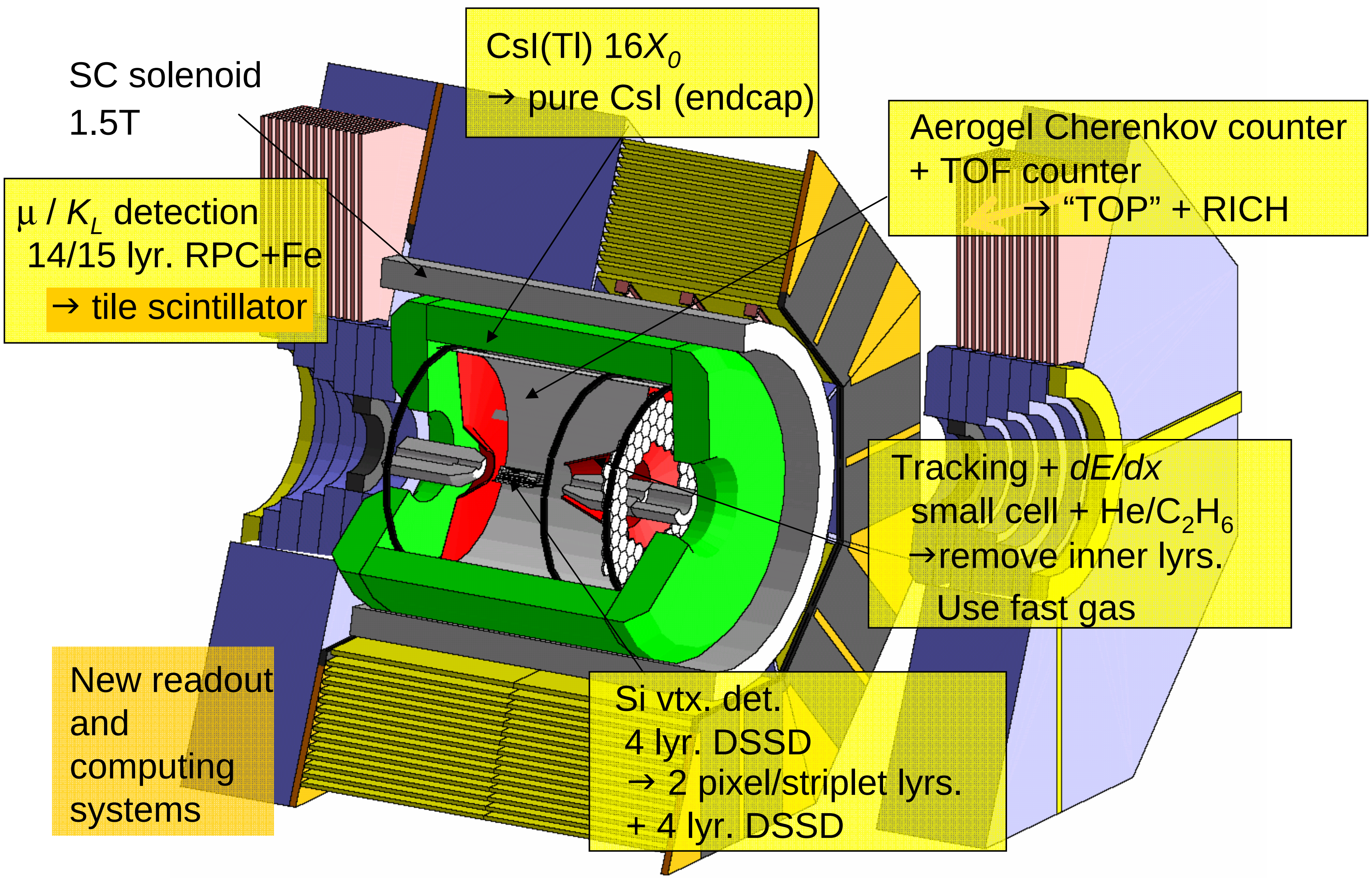
Bkg & TRG rate in future



	KEKB	SuperB
Luminosity ($10^{34}cm^{-2}sec^{-1}$)	~1	80
HER curr. (A)	1.2	4.1
LER curr. (A)	1.6	9.4
vacuum (10^{-7}Pa)	~1.5	5
Bkg increase	-	x 20
TRG rate (kHz)	0.4	14
phys. origin	0.2	10
Bkg origin	0.2	4

Synchrotron radiation
Beam-gas scattering (inc. intra-beam scattering)
Radiative Bhabha

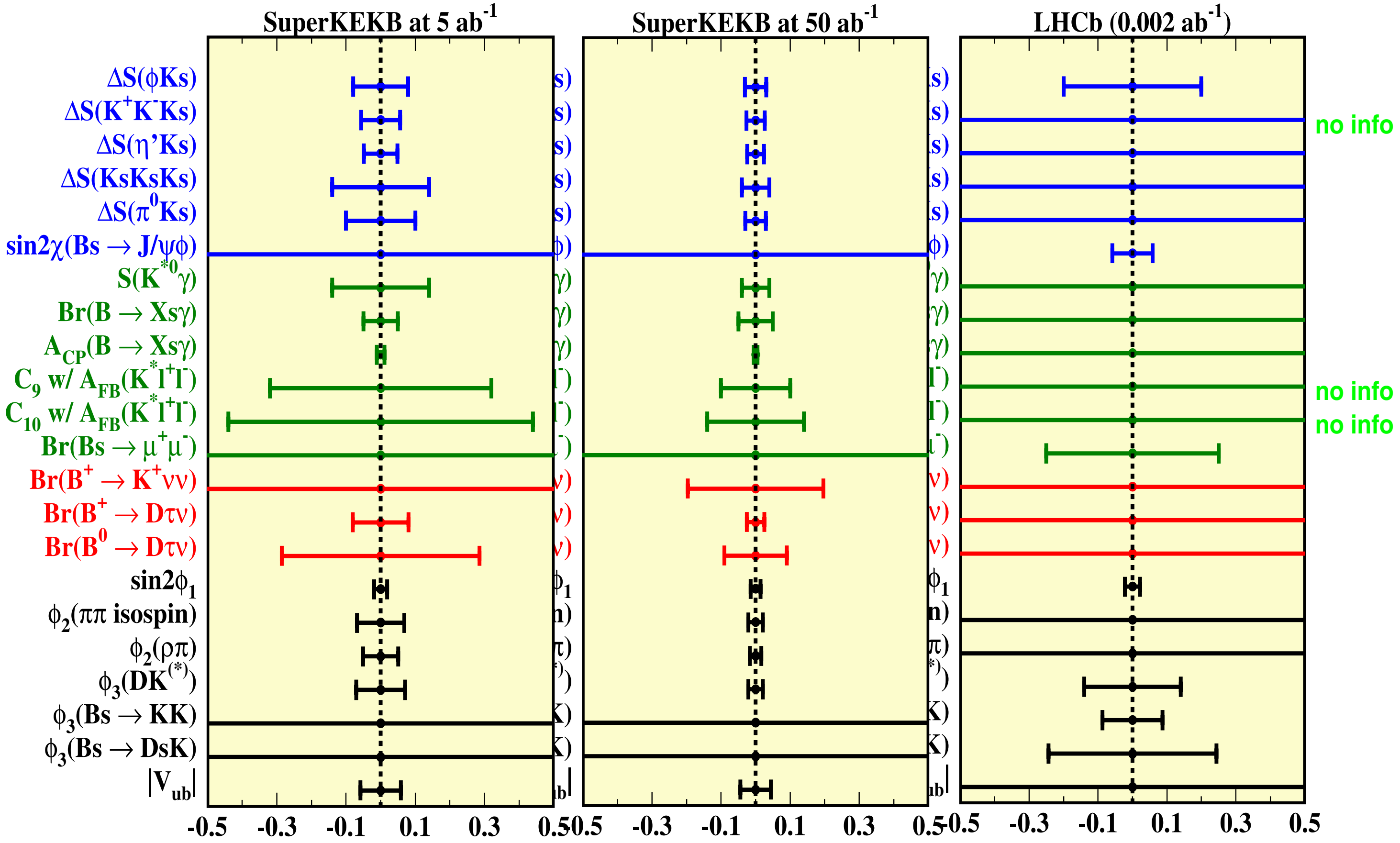
SuperBelle detector



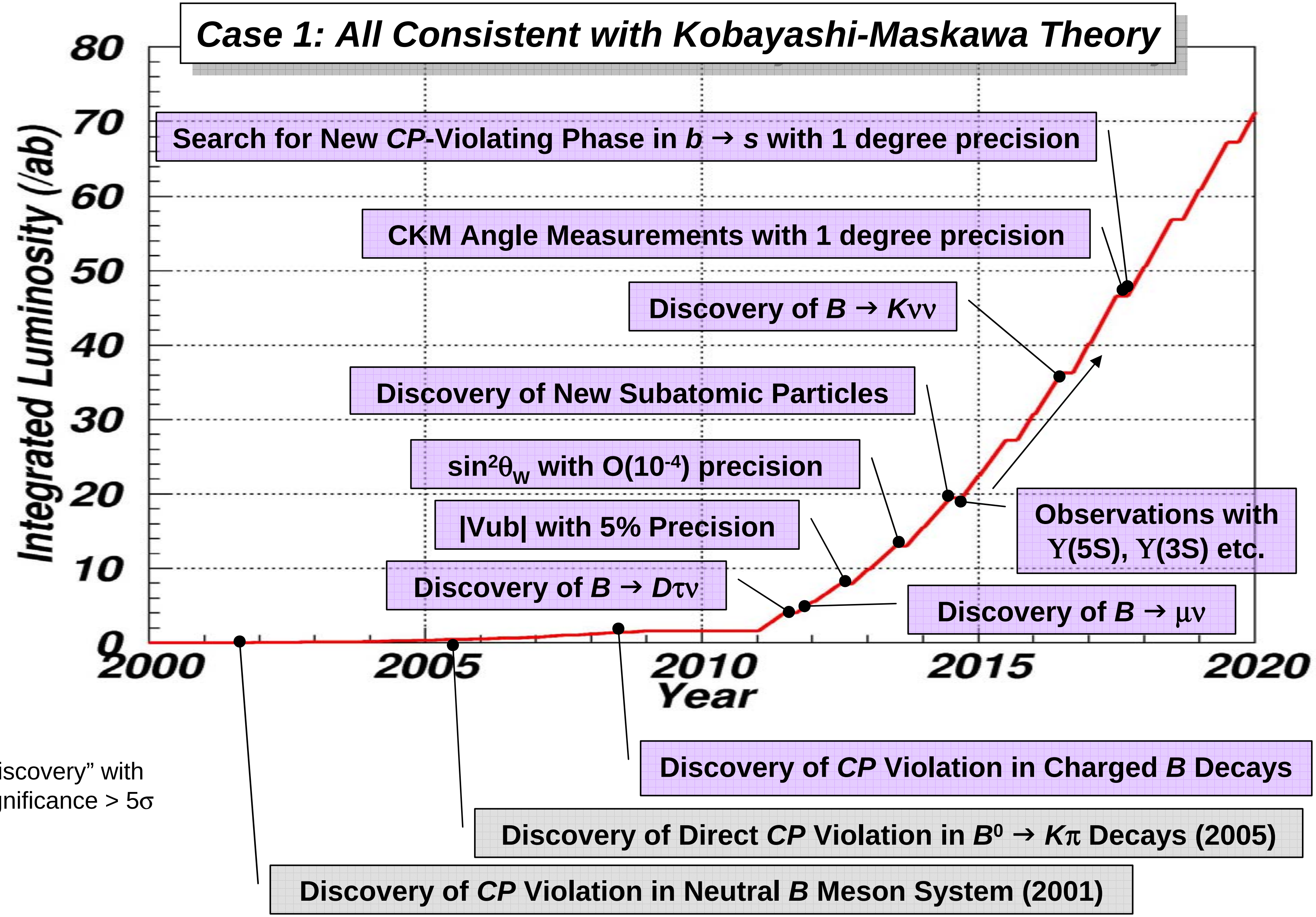
In general, requirements less severe than those for LHC

Recap: Sensitivities (SuperKEKB LoI)

SuperKEKB 5ab^{-1} 50ab^{-1} LHCb 2fb^{-1}

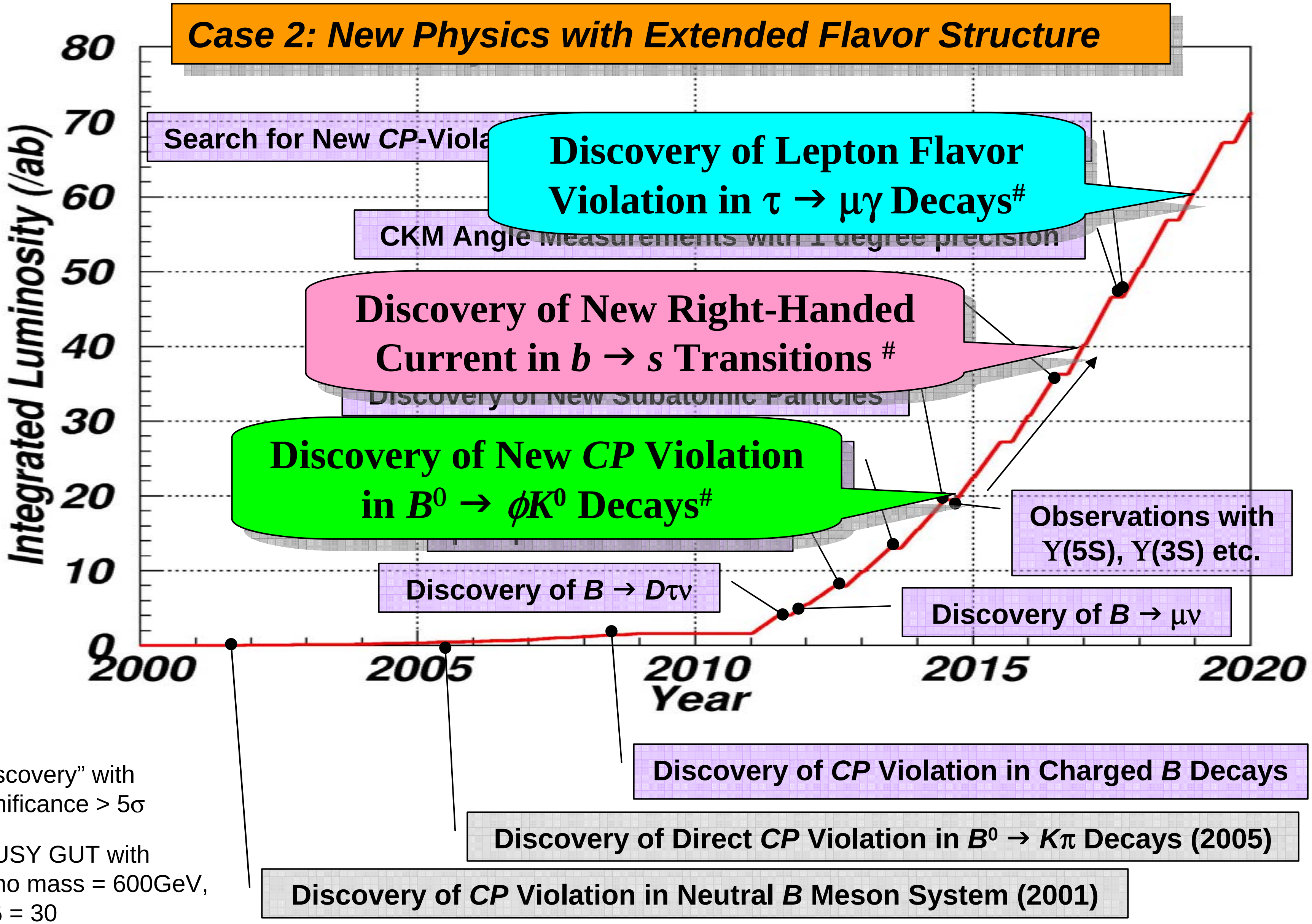


Major Achievements Expected at SuperKEKB



"Discovery" with significance > 5σ

Major Achievements Expected at SuperKEKB



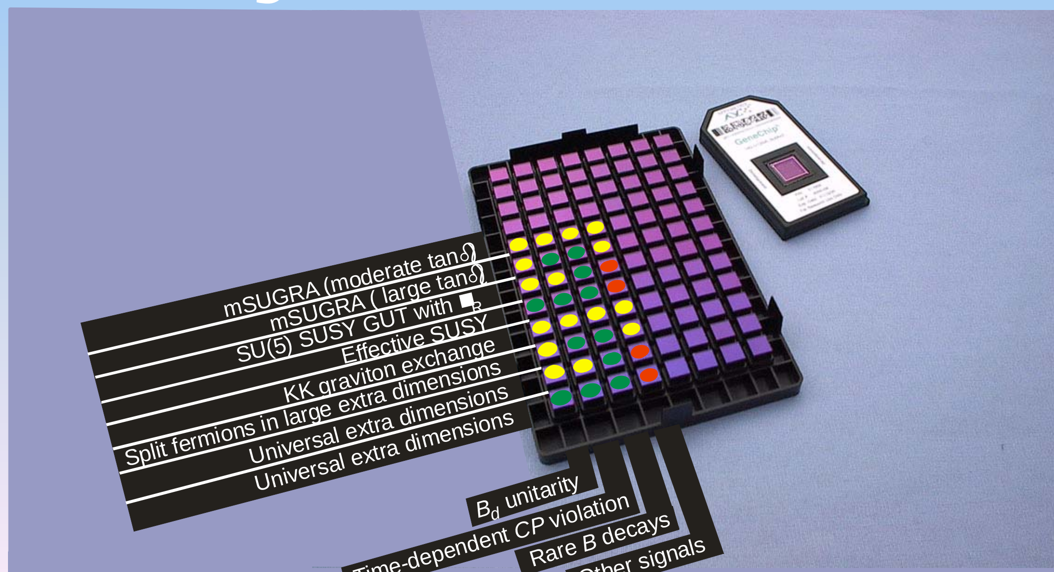
“Discovery” with significance > 5σ

SUSY GUT with gluino mass = 600GeV, tanβ = 30

Which is the correct description of Nature ?

No Super B factory,
no answer.

Physics at SuperKEKB is "DNA Identification of New Physics".



The future plan of Japanese Higher Energy Physics Community is under discussion and not yet concluded. This is not more than a material for the discussion.

dai - leputong - keikaku

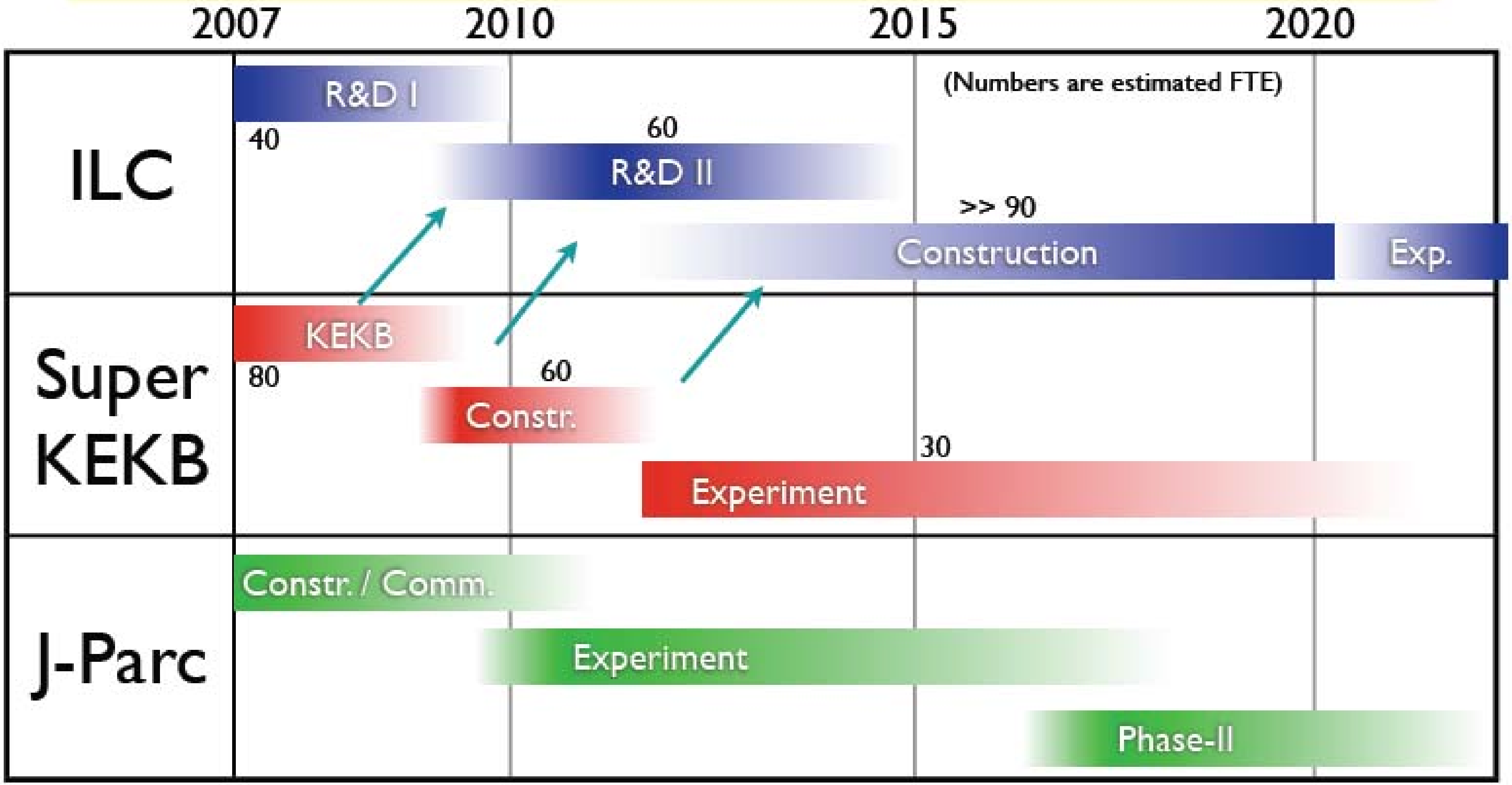
「大レプトン計画」

Grand Lepton Collider Project

K. Oide for HEC

Aug. 17 & Sep. 9, 2006

We will do everything: ILC, SuperKEKB, J-Parc.



- All members of KEK-ACCL will have both duties for ILC and SuperKEKB.
- The weight between SuperKEKB and ILC is subject to change, depending on the readiness of ILC.
- The individual role and weight in the two projects should be flexibly managed by considering time, speciality, and occasion.

- In the 2010s decade, while producing physics by SuperKEKB, utilize KEKB accelerator's material and human resources to the R&D of ILC.
- Upgrade KEKB to SuperKEKB, and do experiment.
- R&D of ILC for industrization and construction.
- Items of utilization of KEKB for ILC R&D:
  - positron sources, flux concentrator
  - orbit and emittance control in linac
  - low-emittance operation of KEKB-LER
  - electron cloud、 test of beam pipes and coatings
  - effect of wigglers
  - development of ring rf system with ILC spec, development of ring klystrons
  - next generation of bunch-by-bunch feedback、 ring BPM
  - Detector Components

Outline of SuperKEKB physics book

- Basic structure remains the same.
- Some more descriptions about why a Super B factory is essentially important.
  - TeV new physics introduces new flavor mixing and CP violation.
    - Mixing is often large as history tells.
  - Measurements needed to uncover the flavor structure.
  - 50/ab sufficient to study couplings of TeV particles
    - 30/fb for observation of CP violation from top-quark coupling
    - LHC energy 7 times higher than Tevatron → New physics effect: $1/7^2 \sim 1/7$
    - Sufficient statistics: 30/fb x $[7^2 \sim (7^2)^2]$ → 1.5/ab ~ 75/ab
  - Theoretically clean measurements with experimentally clean environments; some key measurements carried out only at a Super B.