Future B Physics Program at KEK

March 25, 2008

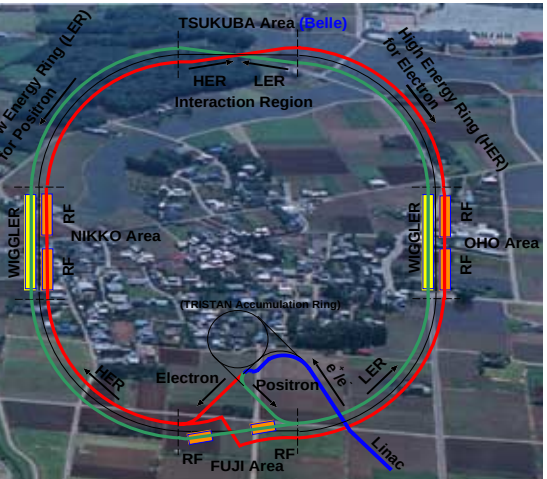
Seminar at IHEP, Protvino

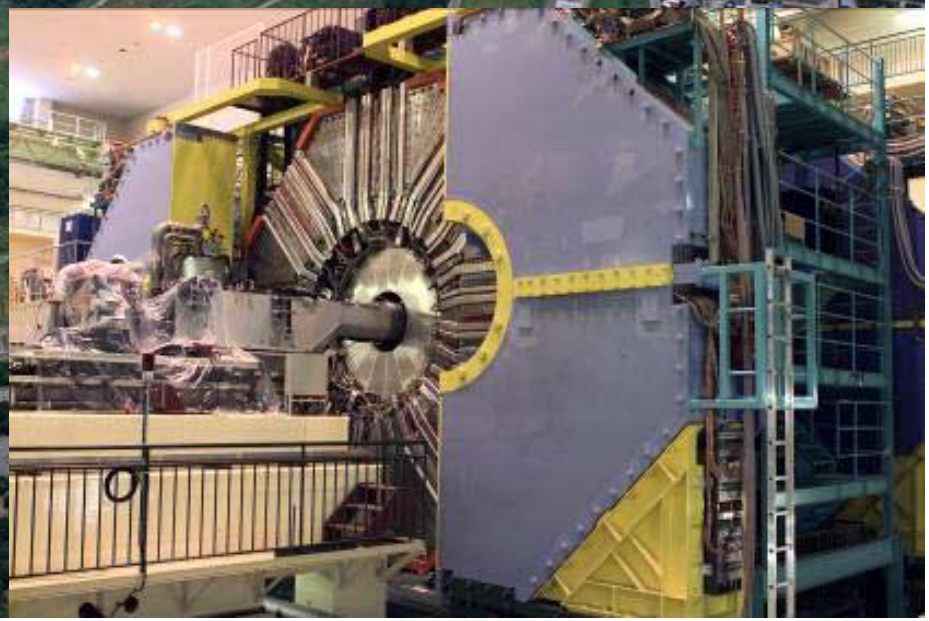
Masa Yamauchi
KEK

Outline

- Introduction: KEKB and Belle
- Achievements of Belle
- Physics case for KEKB/Belle upgrade
- KEKB upgrade plan → Oide's talk
- Detector issues
- Long term strategy
- Summary

KEKB and Belle



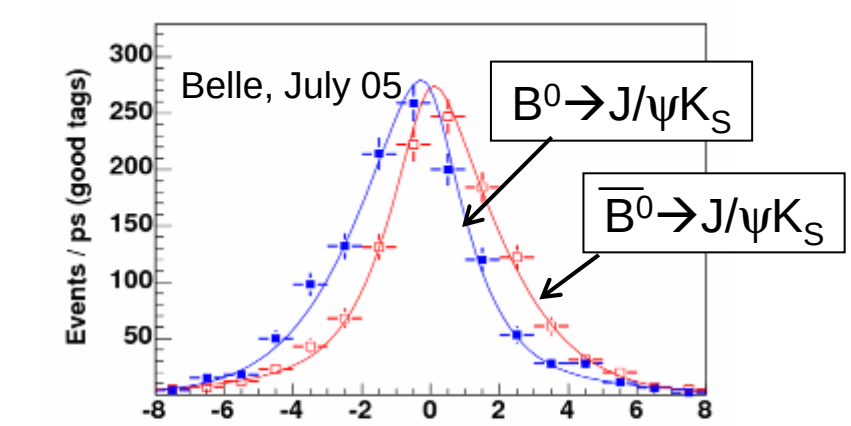


Belle Collaboration

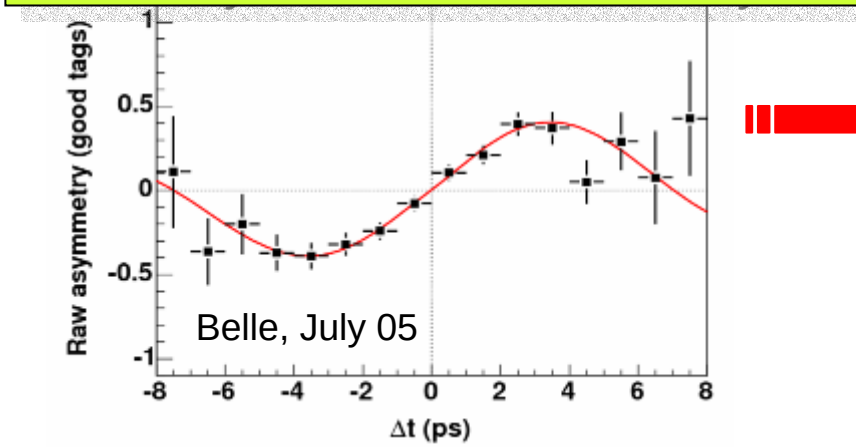
BINP
Chiba U.
Hanyang U.
U. of Cincinnati
Ewha Women's U.
Fu-Jen U.
Giessen U.
Gyeongsang Nat'l U.
U. of Hawaii
Hiroshima Tech.
HEPHY, Vienna
IHEP, Protvino
IHEP, Beijing
INFN, Torino
ITEP
Kanagawa U.
KEK
Korea U.
Krakow Inst. of Nucl. Phys.
Kyoto U.
Kyungpook National U.
U. of Lausanne
Jozef Stefan Inst.
U. of Melbourne
Nagoya U.
Nara Women's U.
National Central U.
National United U.
National Taiwan U.
Nihon Dental College
Niigata U.
Nova Gorica U.
Osaka U.
Osaka City U.
Panjab U.
Peking U.
Princeton U.
Illinois U. - Riken
Saga U.
USTC
Seoul National U.
Shinshu U.
Sungkyunkwan U.
U. of Sydney
Tata Institute
Toho U.
Tohoku U.
Tohuku Gakuin U.
U. of Tokyo
Tokyo Inst. of Tech.
Tokyo Metropolitan U.
Tokyo U. of A and T.
Toyama Nat'l College
U. of Tsukuba
VPI
Yonsei U.

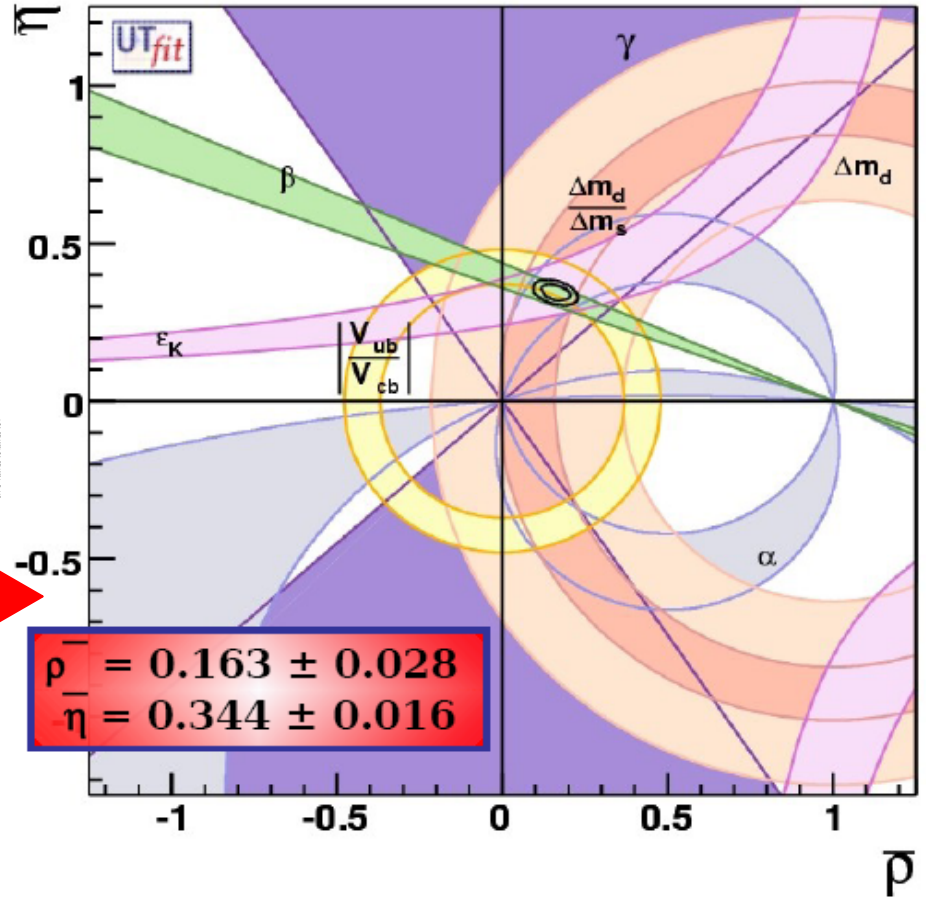
Achievement of the *B* Factories

Quantitative confirmation of the KM model



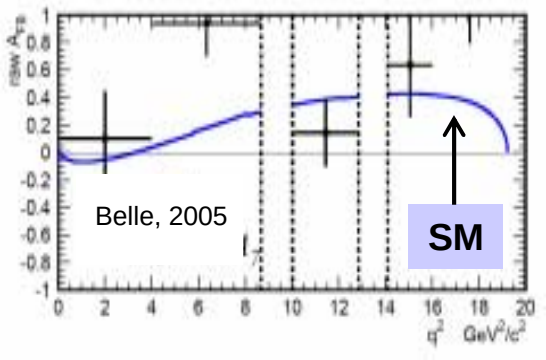
Discovery of CP violation in $B\overline{B}$ system



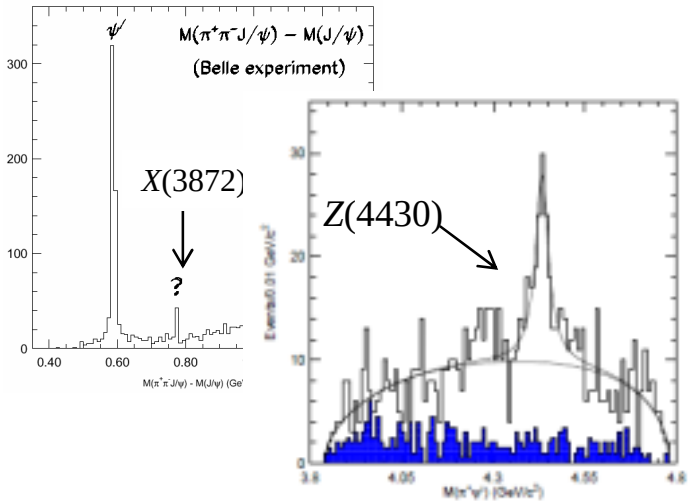


Other highlights

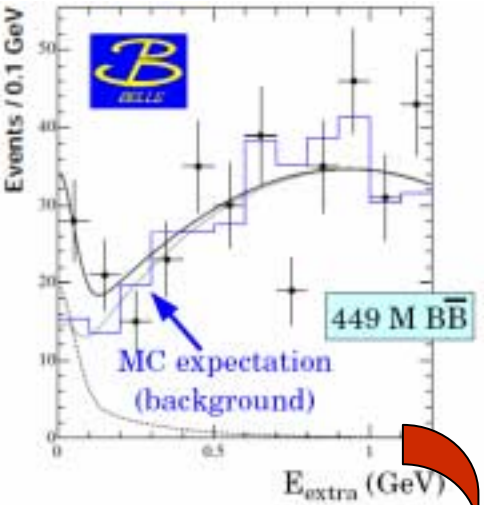
A_{FB} in $B \to K^* l^+ l^-$



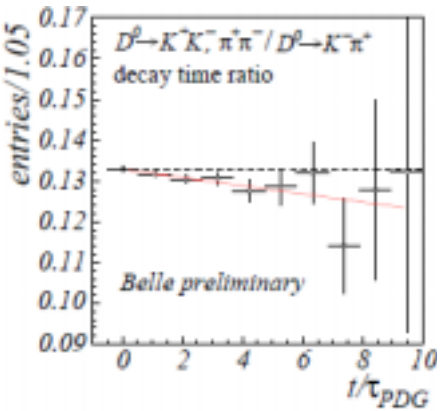
Many new resonances



Evidence for $B \to \tau\nu$

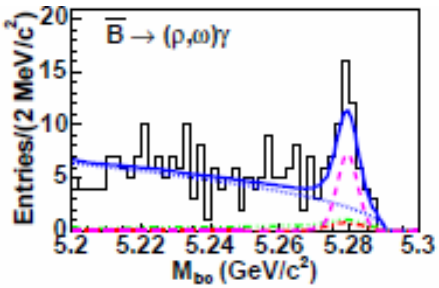


D^0-$\overline{D^0}$ mixing

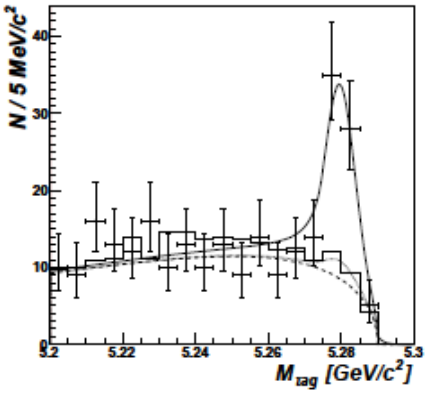


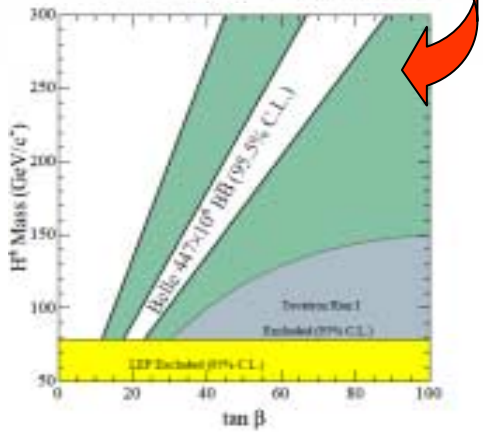
$y_{CP} = 1.31 \pm 0.32 \pm 0.25$ %

$b \to d\gamma$ transition



$B \to D^* \tau\nu$

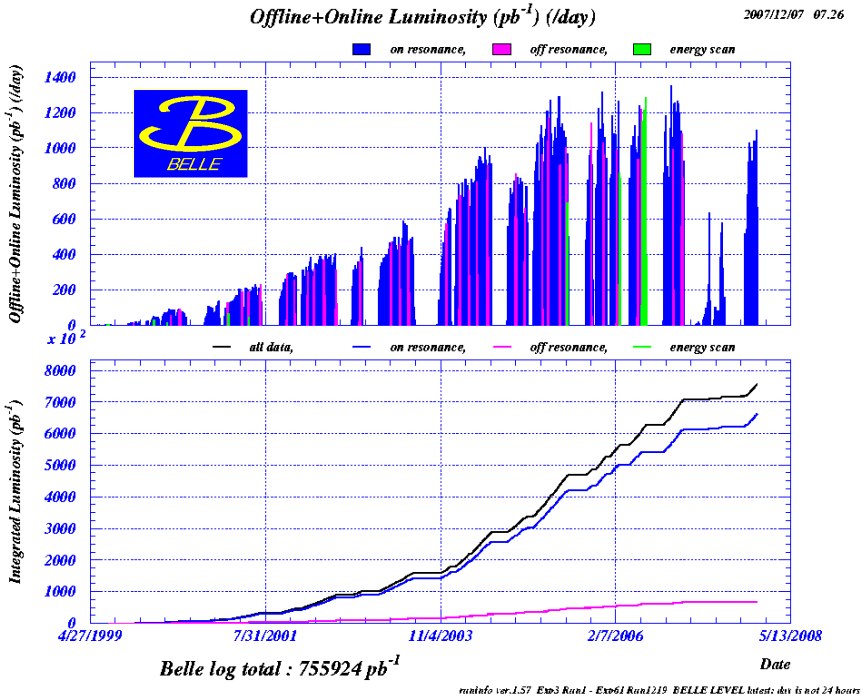


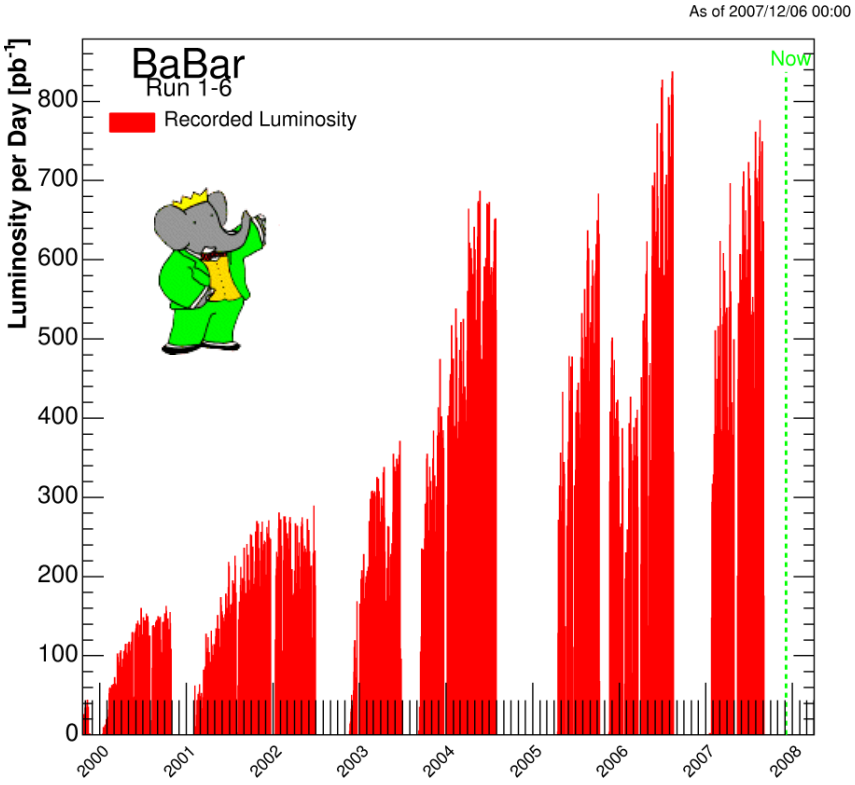


and more…

Another important achievement

Asymmetric e^+e^- collider with $L > 10^{34}$





- Success of KEKB and PEP-II enabled us to design a new e^+e^- *B* factory with much higher L_{peak}.

What is next with flavour physics?

- If new physics at O(1)TeV…
  - It is natural to assume that the effects are seen in $B/D/\tau$ decays.
  - Flavour structure of new physics?
  - CP violation in new physics?
  - These studies will be useful to identify mechanism of SUSY breaking, if NP=SUSY.

- Otherwise…
  - Search for deviations from SM in flavor physics will be one of the best ways to find new physics.

KEKB Upgrade Plan

- ***Asymmetric energy e^+e^- collider at E_{CM}=m(ϒ(4S)) to be realized by upgrading the existing KEKB collider.***
- ***Initial target: 10×higher luminosity*** **≅ 2×10^{35}/cm²/sec** **after 3 year shutdown**
  → 2×10^9 $B\bar{B}$ and $\tau^+\tau^-$ per yr.
- ***Final goal: L=8×10³⁵/cm²/sec and ∫L dt = 50 ab⁻¹***

Crab cavity

8GeV e^-

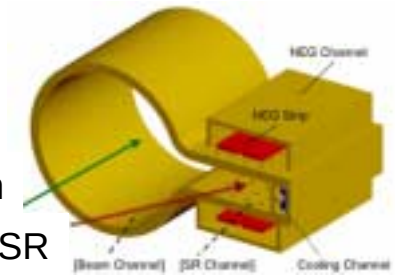
New IR with crab crossing and smaller β_y^*

3.5GeV e^+

New beam-pipes with ante-chamber

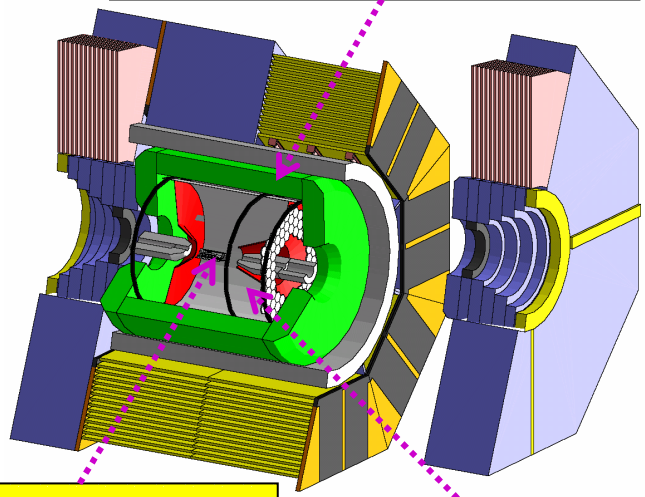
More RF for higher beam current

Damping ring for e^+



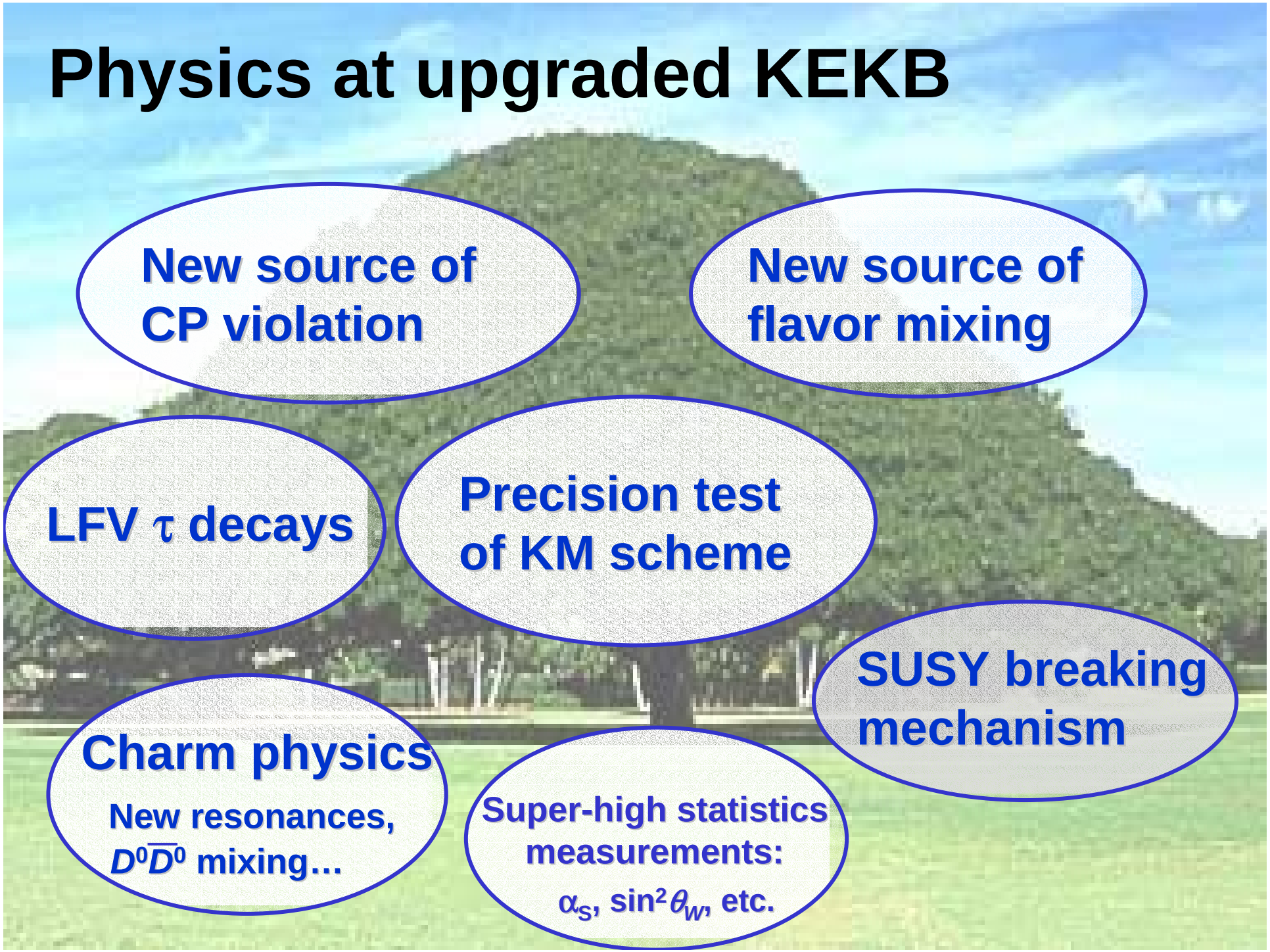
Belle with improved rate immunity

Faster calorimeter with wave form sampling and pure CsI



Si vertex detector with very short strips

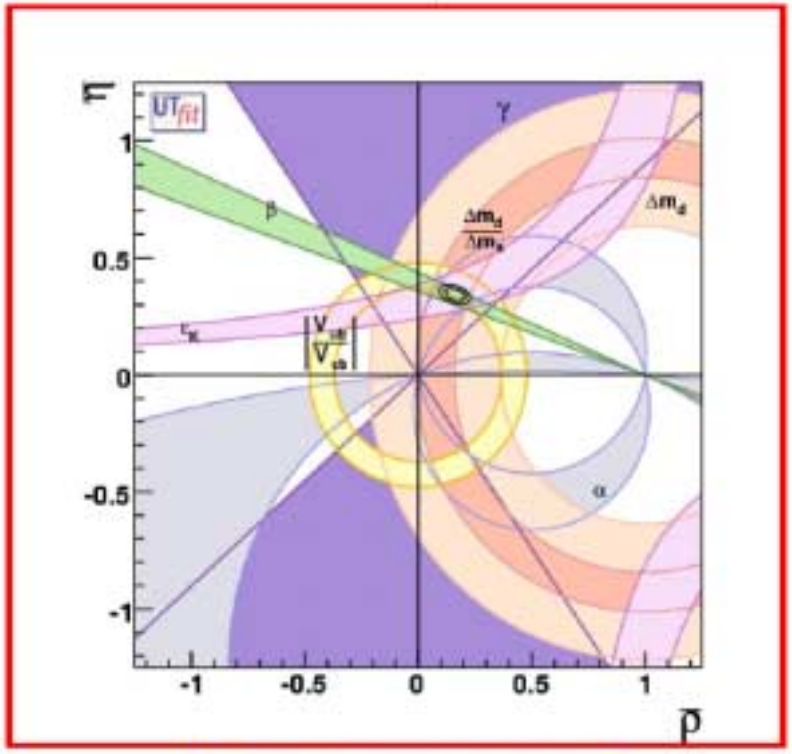
Background tolerant small cell drift chamber


Physics at upgraded KEKB
New source of CP violation
New source of flavor mixing
LFV τ decays
Precision test of KM scheme
SUSY breaking mechanism
Charm physics
New resonances, $D^0\overline{D}^0$ mixing…
Super-high statistics measurements:
α_S, $\sin^2\theta_W$, etc.

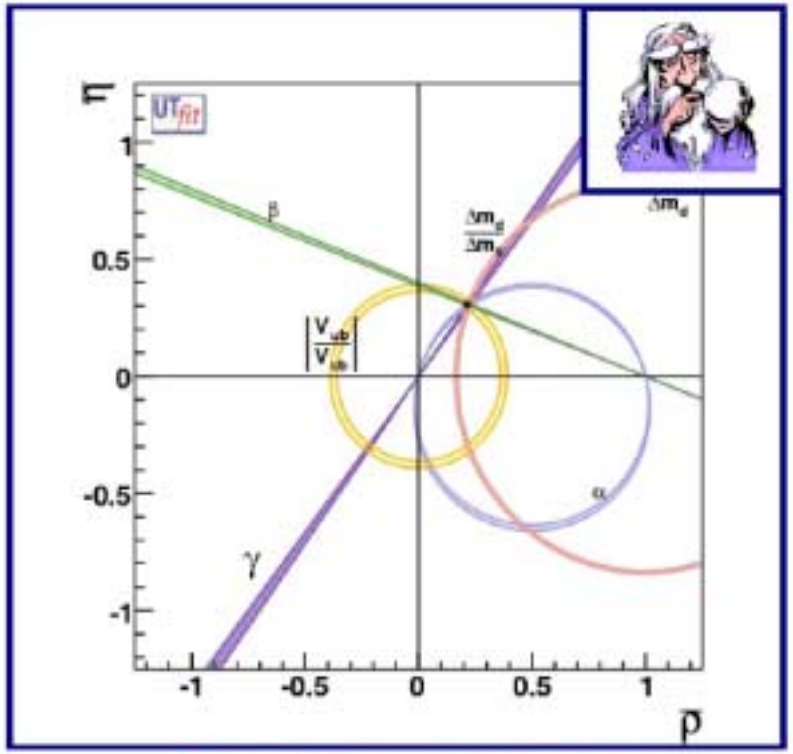
Precision test of KM scheme

UTfit in the SM: 2006 vs.2015

M.Pierini
CKM2006



$\bar{\rho} = 0.163 \pm 0.028$
$\bar{\eta} = 0.344 \pm 0.016$



$\bar{\rho} = 0.2226 \pm 0.0028$
$\bar{\eta} = 0.3052 \pm 0.0024$

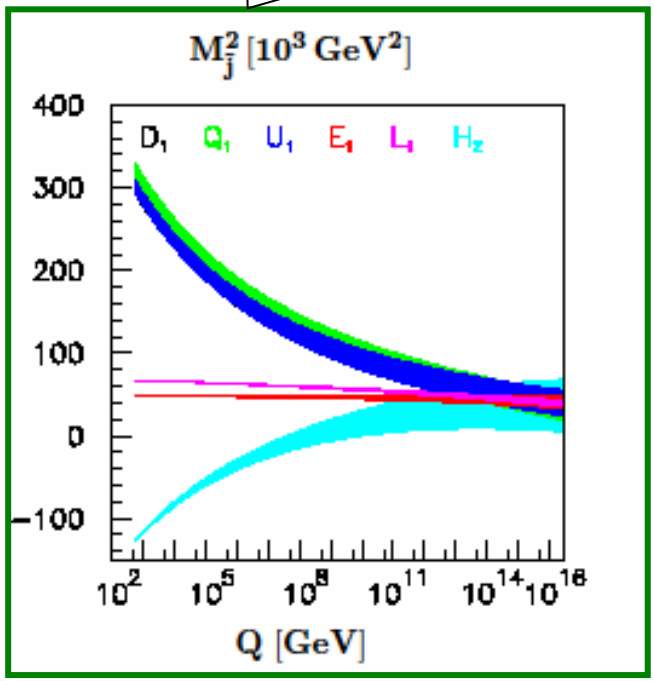
SUSY flavour physics: mass matrix of squark and slepton will be determined by their direct production at the energy frontier and flavour physics measurements.

$$(m^2_{\tilde{q}})_{ij} = \begin{pmatrix} m^2_{11} & m^2_{12} & m^2_{13} \\ m^2_{21} & m^2_{22} & m^2_{23} \\ m^2_{31} & m^2_{32} & m^2_{33} \end{pmatrix}$$

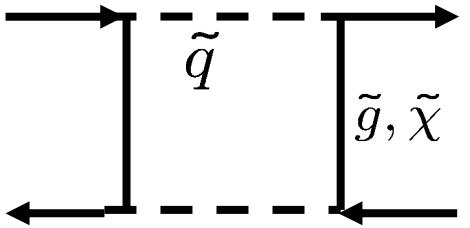
Diagonal

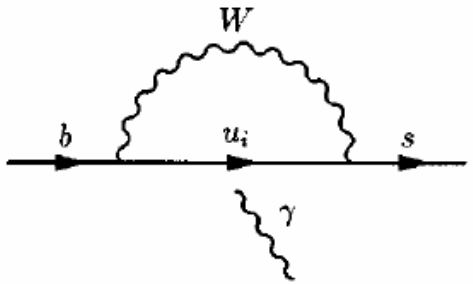
Off-diagonal

LHC/ILC
SUSY mass spectrum

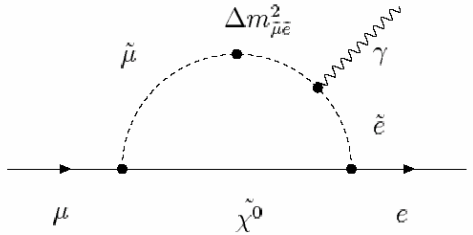


Quark flavor changing processes



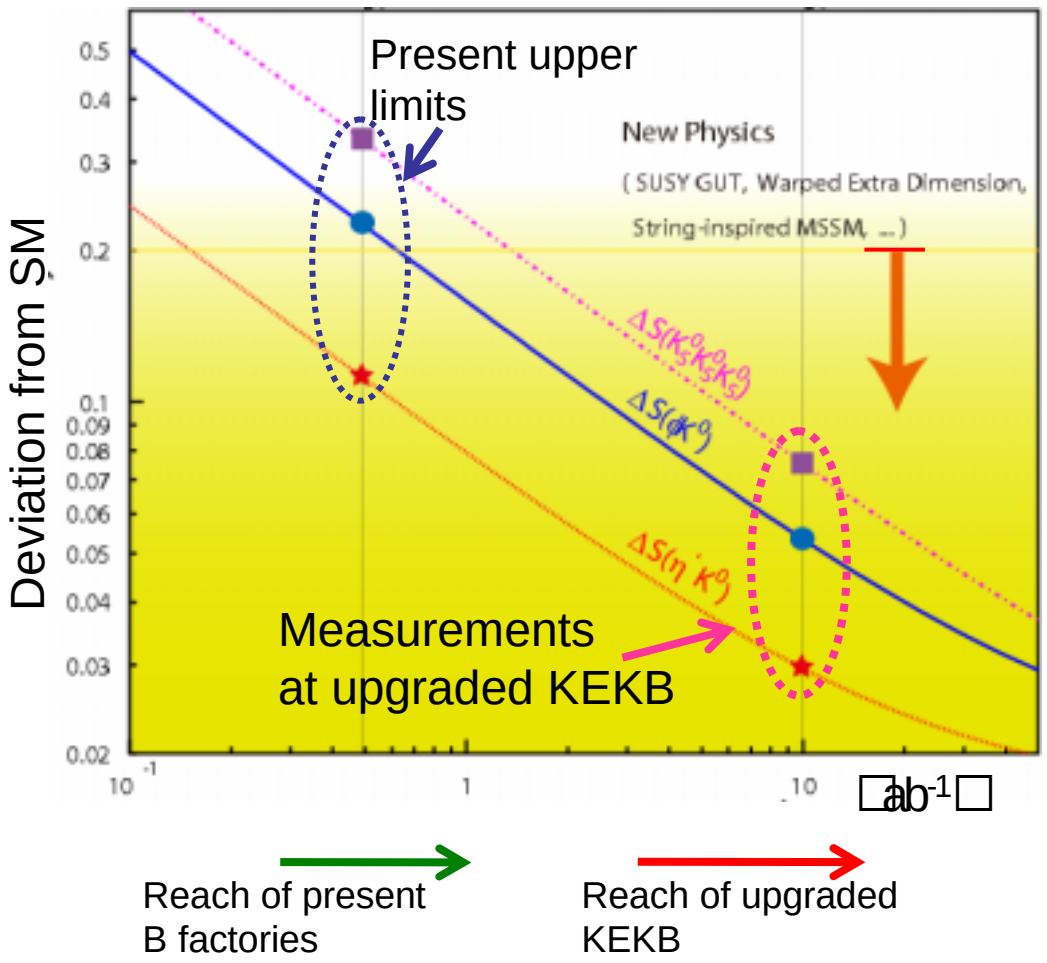


Lepton flavor violation



Y.Okada, Nov. 2007

CP asymmetries of penguin dominated B decays



Deviation from SM

↓

New source of CP violation

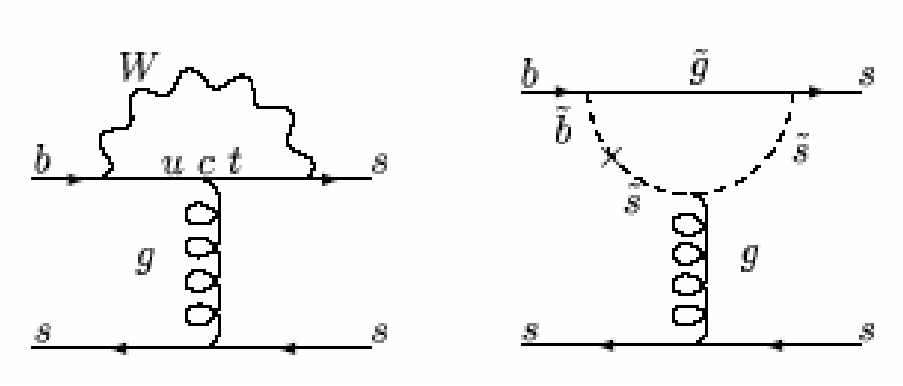
↓

Relevant to baryogenesis?

Search for new CP phases

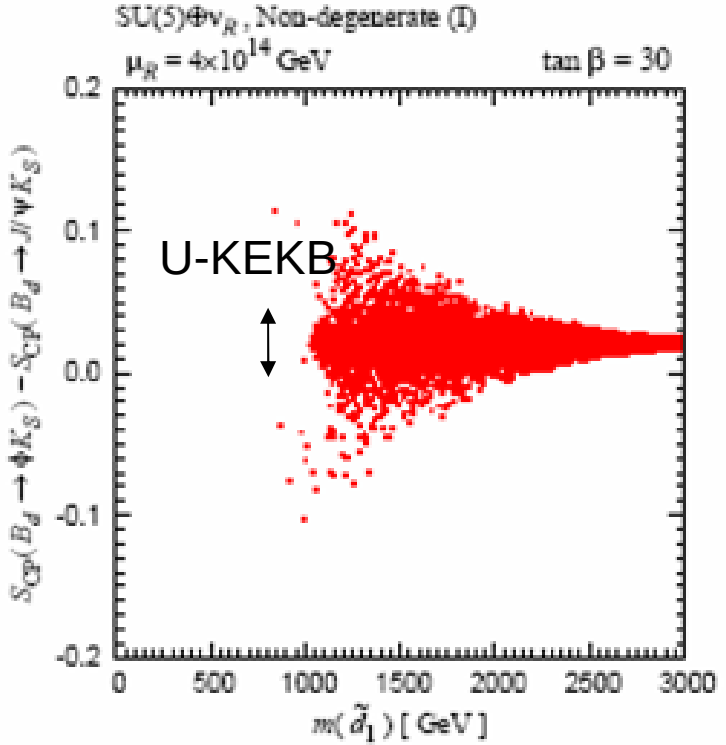
In general, new physics contains new sources of flavor mixing and CP violation.

- In SUSY models, for example, SUSY particles contribute to the $b \to s$ transition, and their CP phases change CPV observed in $B \to \phi K$, $\eta' K$ etc.



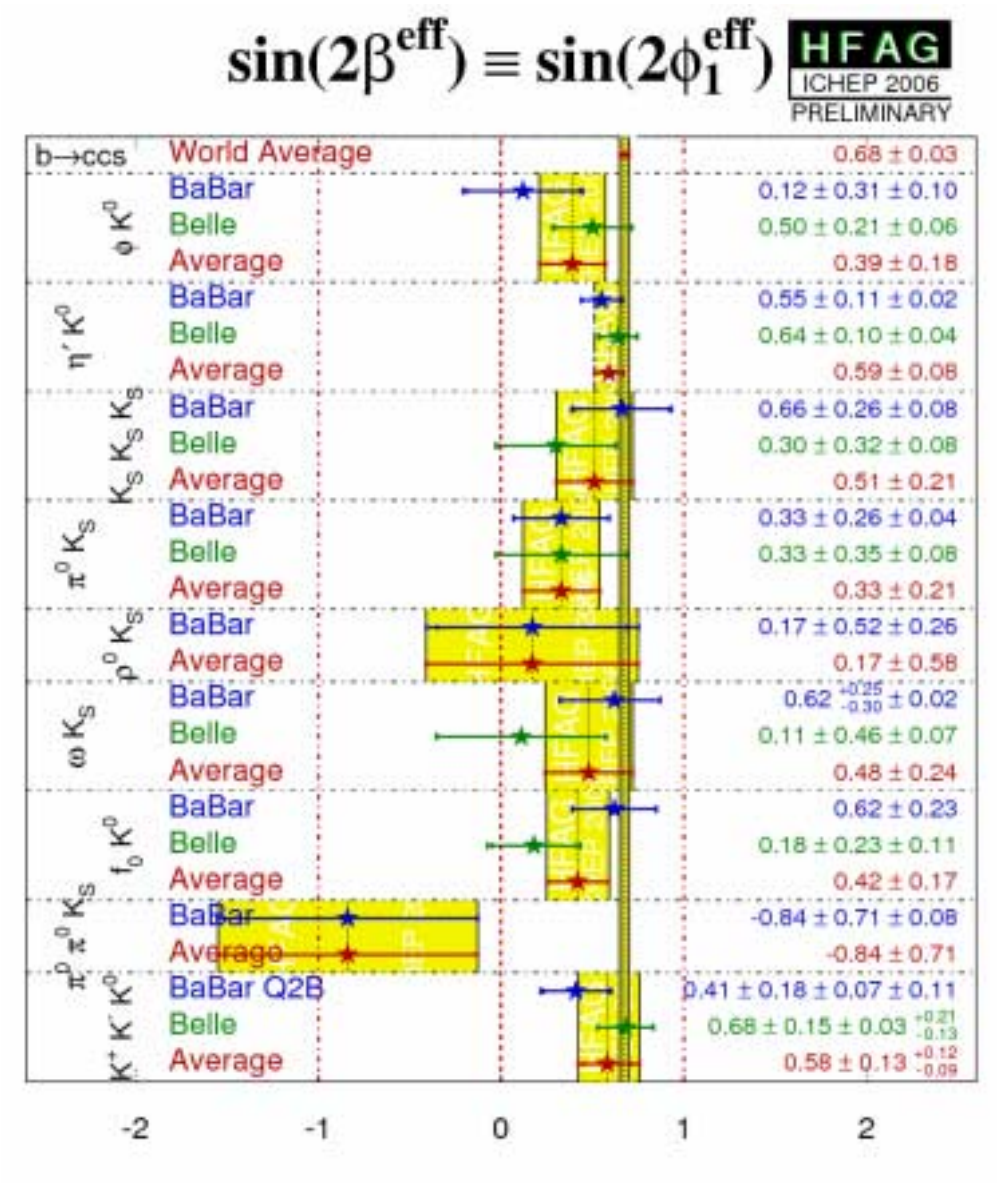
SM SUSY contribution

In general, if SUSY is present, the *s*-quark mixing matrix contains complex phases just as in the Kobayashi-Maskawa matrix.



T.Goto et al., 2007

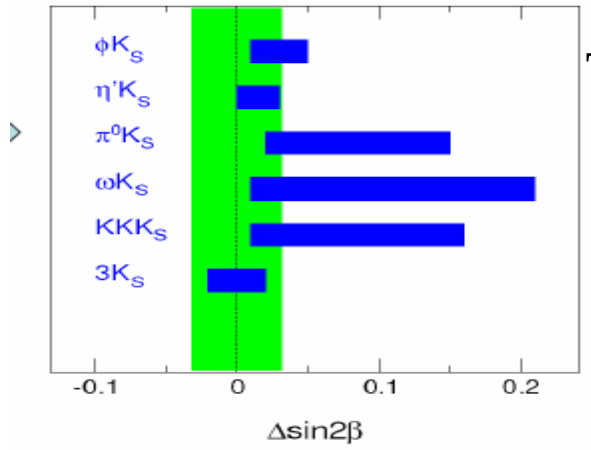
A possible hint for NP: $b \to s q\bar{q}$



Smaller than $b \to c\bar{c}s$ in all of 9 modes

some of recent QCDF estimates

$\sin2\beta^f_{eff} - \sin2\beta$



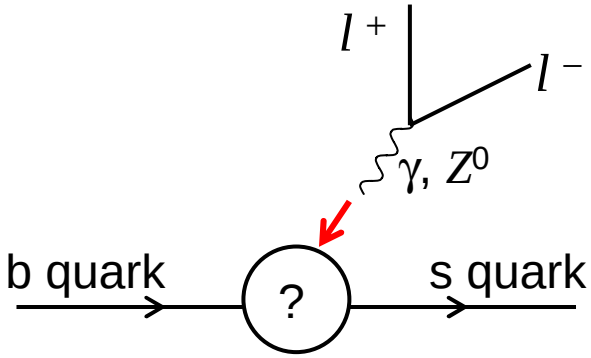
Theory : tends to positive shifts

Naïve average of all b → s modes

$\sin2\beta^{eff} = 0.52 \pm 0.05$

2.6 σ deviation from SM

Search for new flavor mixing



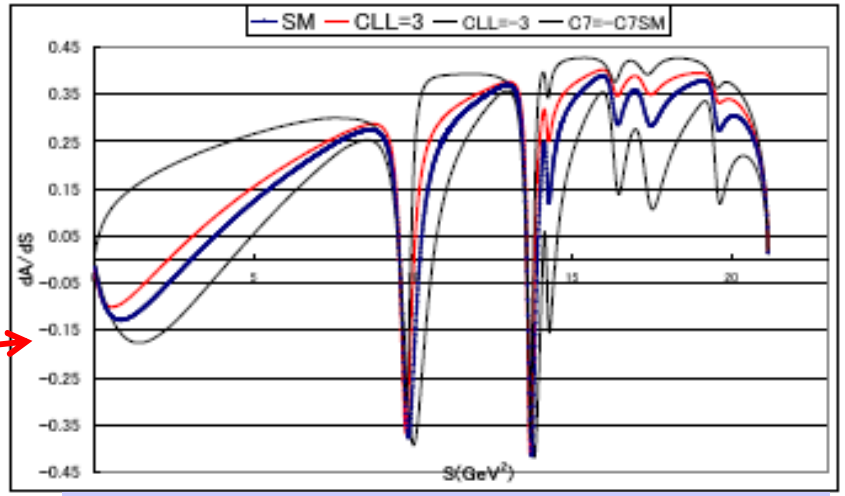
: Probe the flavor changing process with the “EW probe”.

This measurement is especially sensitive to new physics such as SUSY, heavy Higgs and extra dim.

Possible observables:

- Ratio of branching fractions
- Branching fraction
- CP asymmetry
- q^2 distribution
- Isospin asymmetry
- Triple product correlation
- Forward backward asymmetry
- Forward backward CP asymmetry

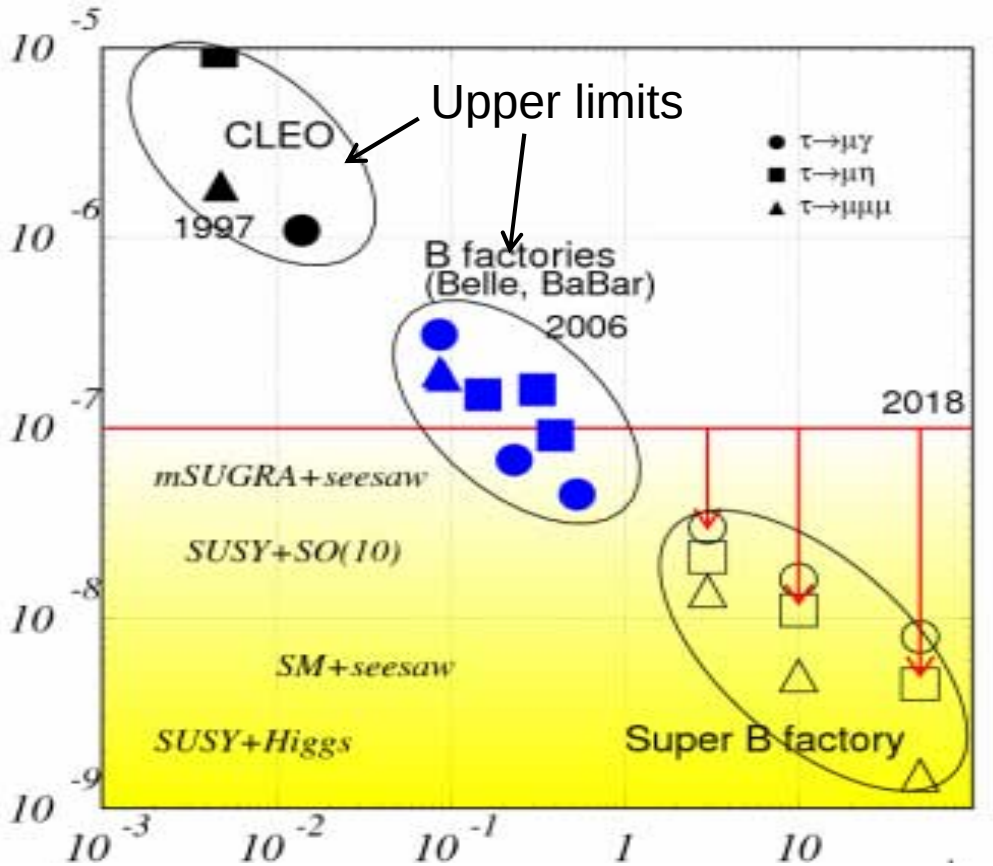
Theoretical predictions for l^+l^- forward-backward charge asymmetry for SM and SUSY model with various parameter sets.

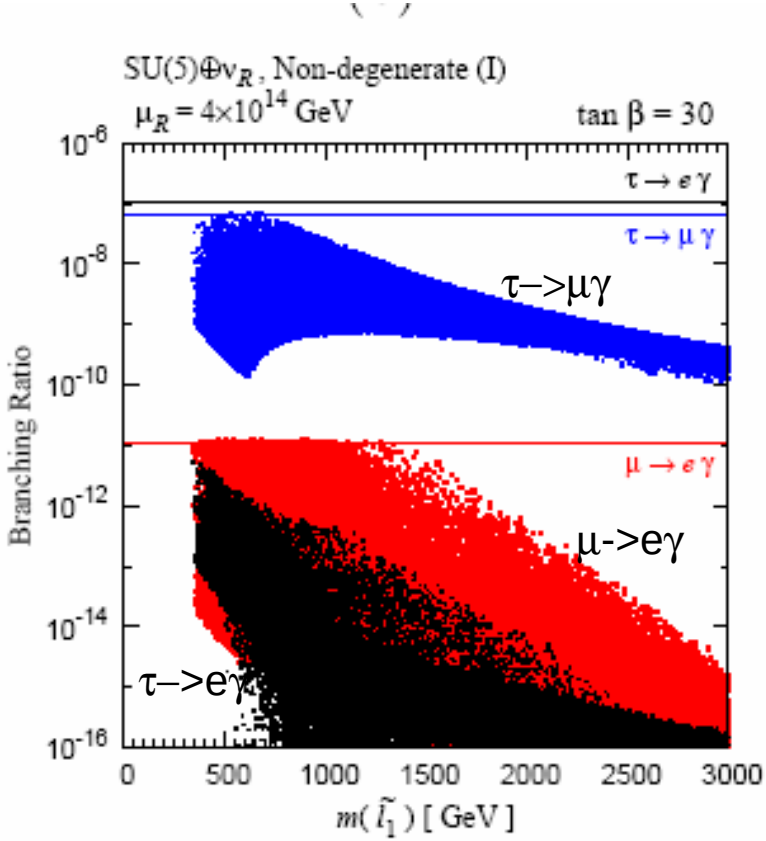


The F/B asymmetry is a consequence of γ-Z^0 interference.

Precise measurements of τ decays

LFV violating τ decay?

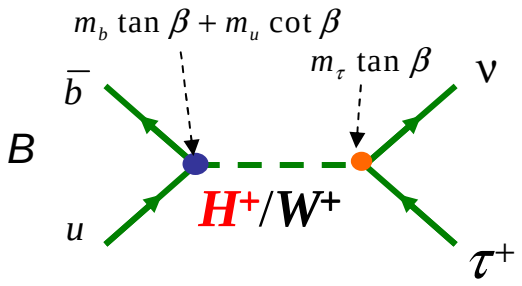




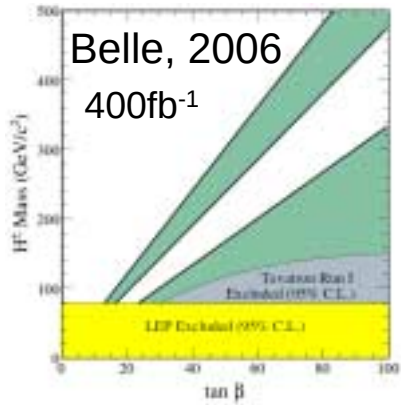
T.Goto et al., 2007

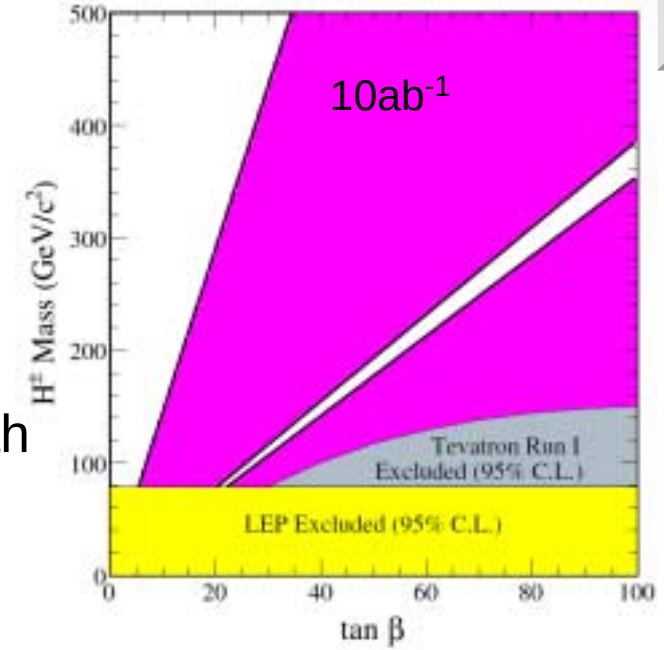
B decays with more than one ν

Interactions of $H^{\pm}$

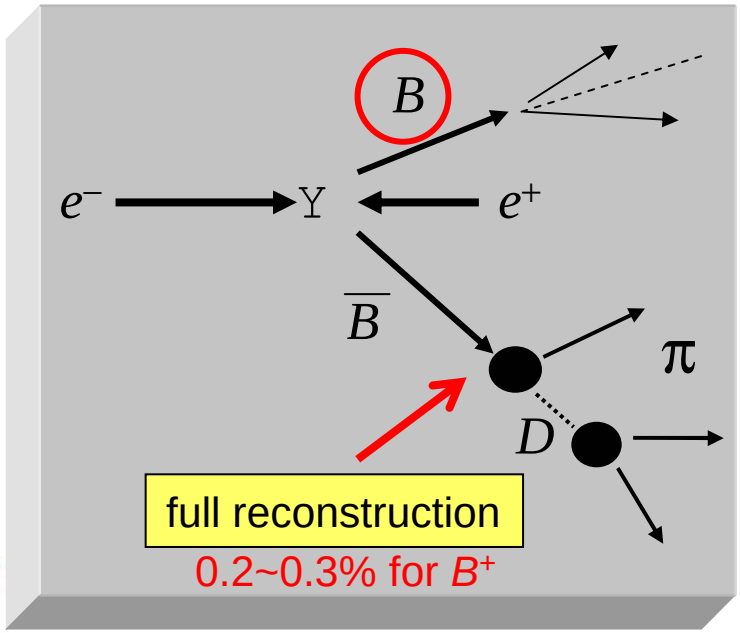


$B\to\tau\nu$ decays





Search region with
$B\to\tau\nu$ decays



Provides a unique method to measure b-$H^{\pm}$-u and b-$H^{\pm}$-c coupling strength.

Identification of SUSY breaking scenario

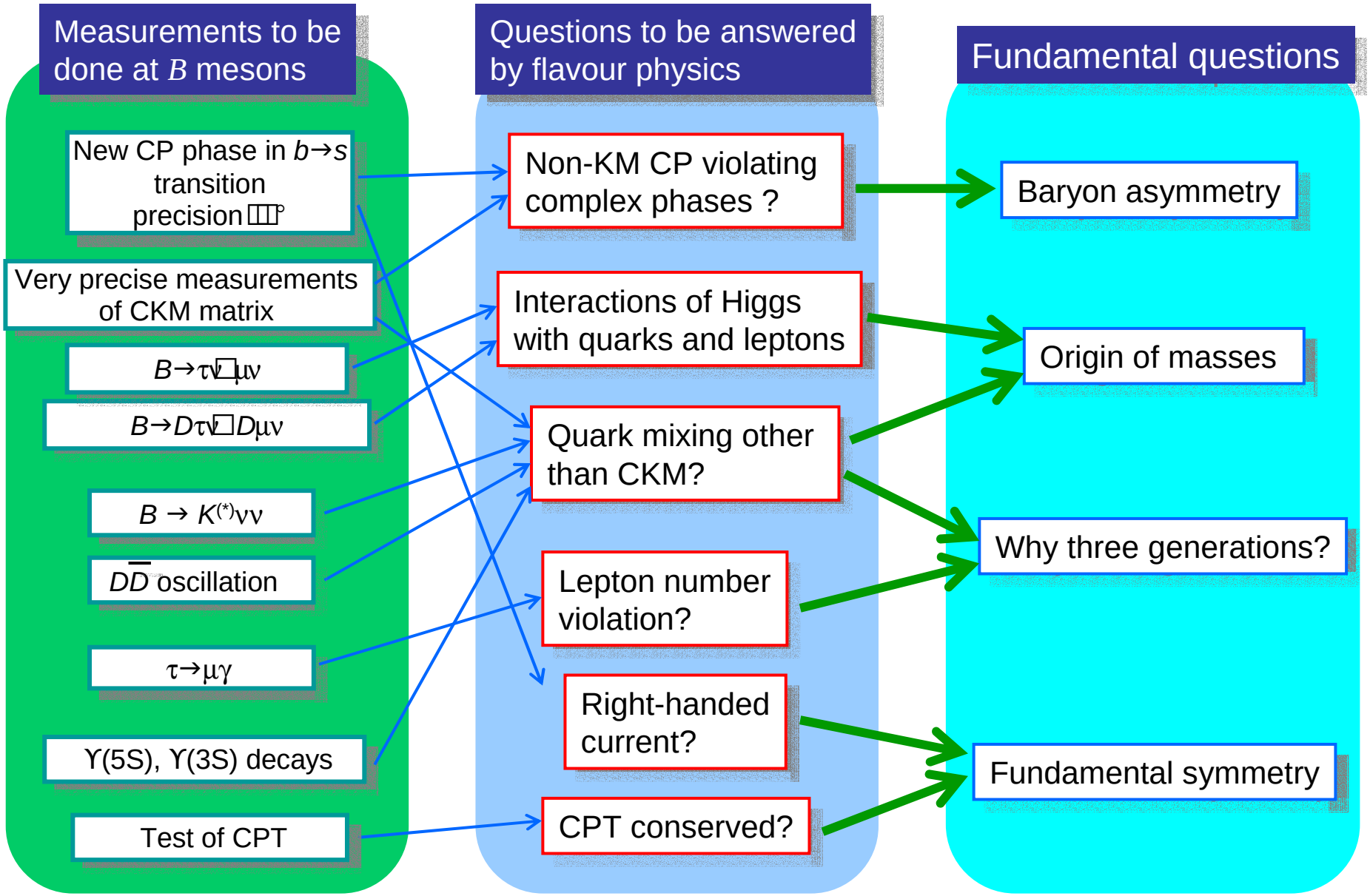
Pattern of deviations from the Standard Model

Y.Okada

Observ-ables / SUSY models	Unitarity triangle	$B \to \phi K_S$	$\to \gamma$ Indirect CPV	$\to \gamma$ Direct CPV	$\tau \to \mu\gamma$
mSUGRA	–	–	–	–	–
SU(5) SUSY GUT + ν_R (degenerate)	–	–	+	–	–
SU(5) SUSY GUT + ν_R (non-degenerate)	+	+	+ +	–	+ +
U(2) Flavor symmetry	+	+	+ +	+	

+ +: large + : sizable – : small

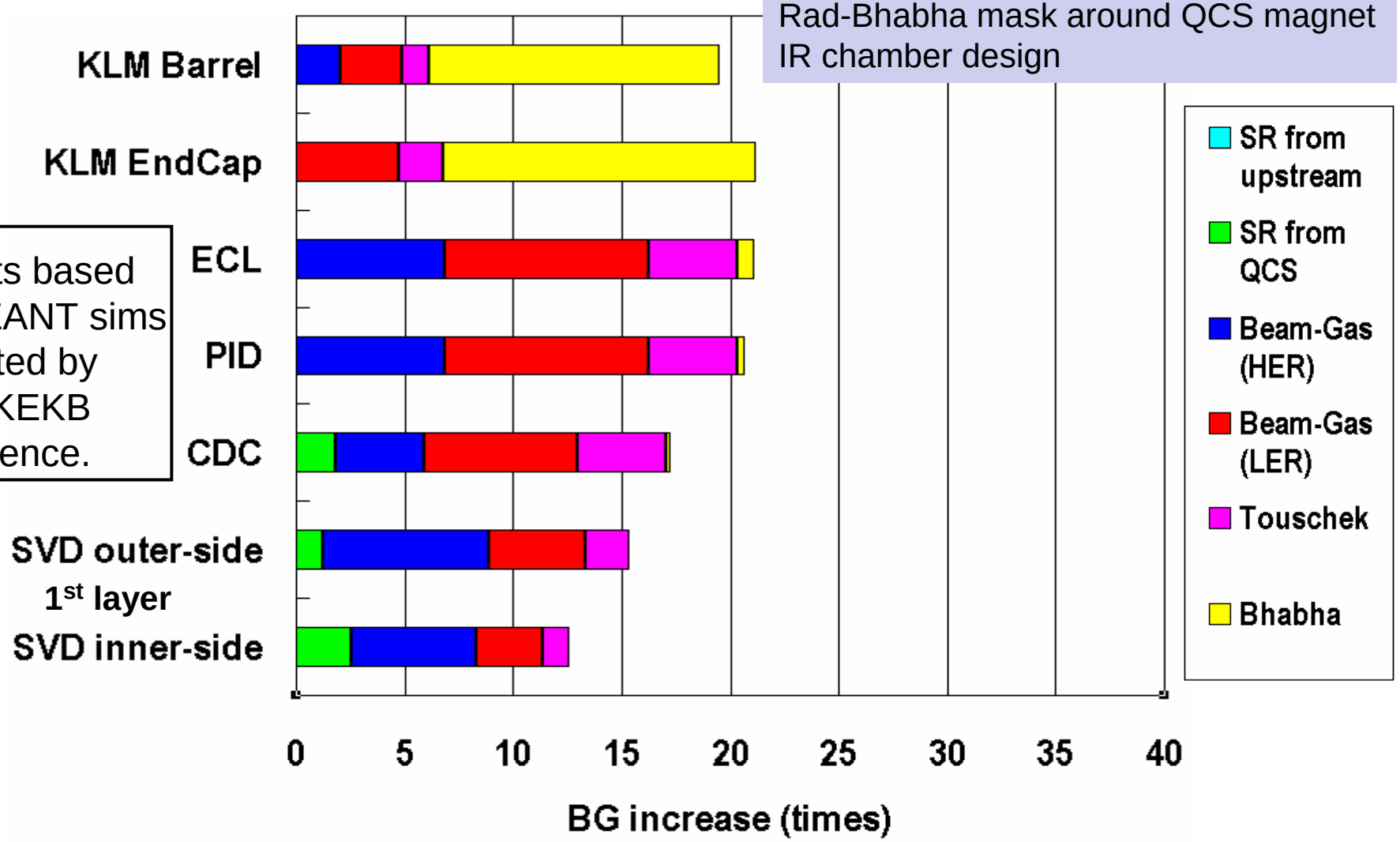
B physics' approach to the fundamental questions



Beam Background (after 1st optimization)

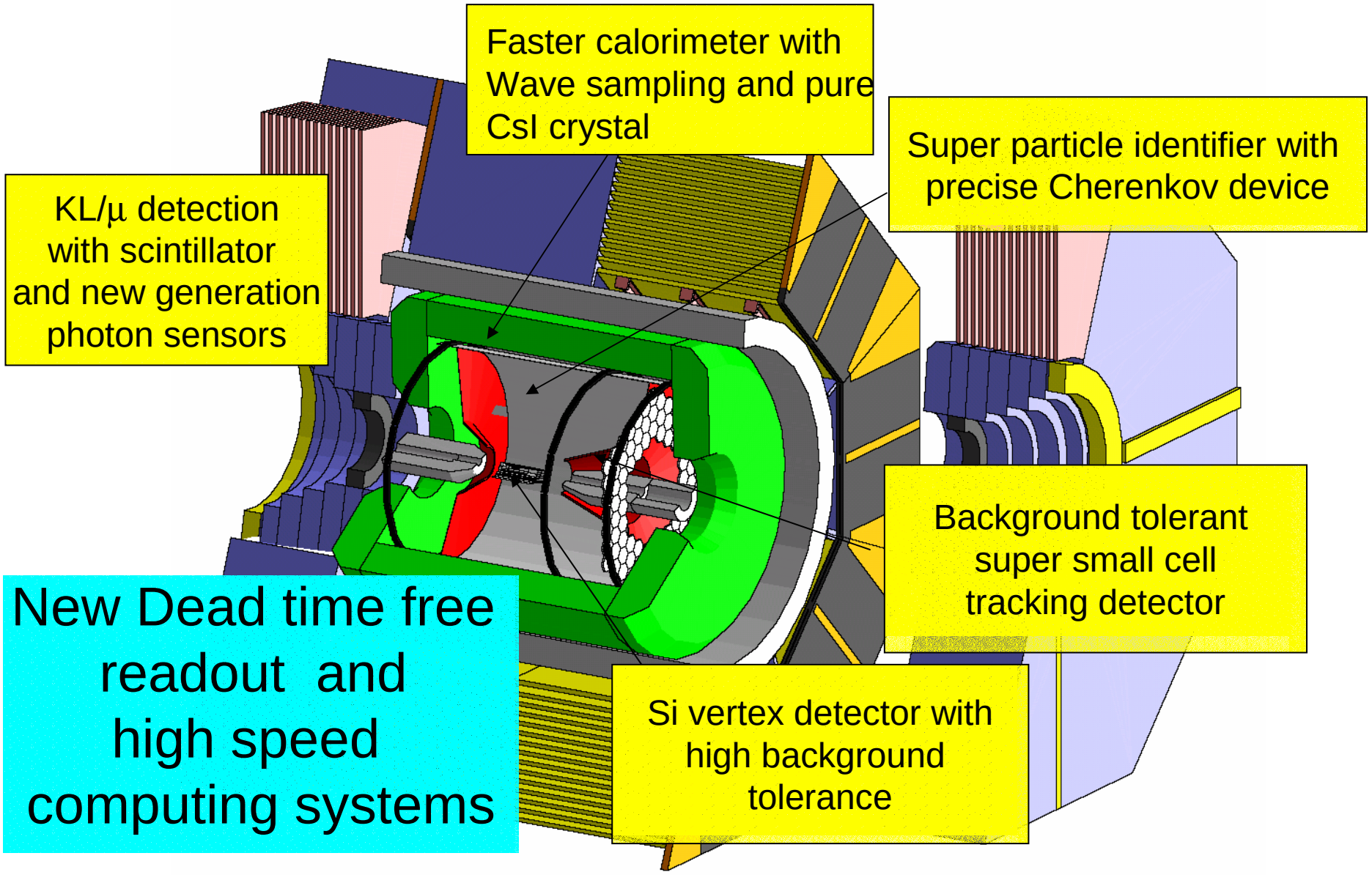
Rad-Bhabha mask around QCS magnet
IR chamber design

Results based on GEANT sims validated by Belle/KEKB experience.



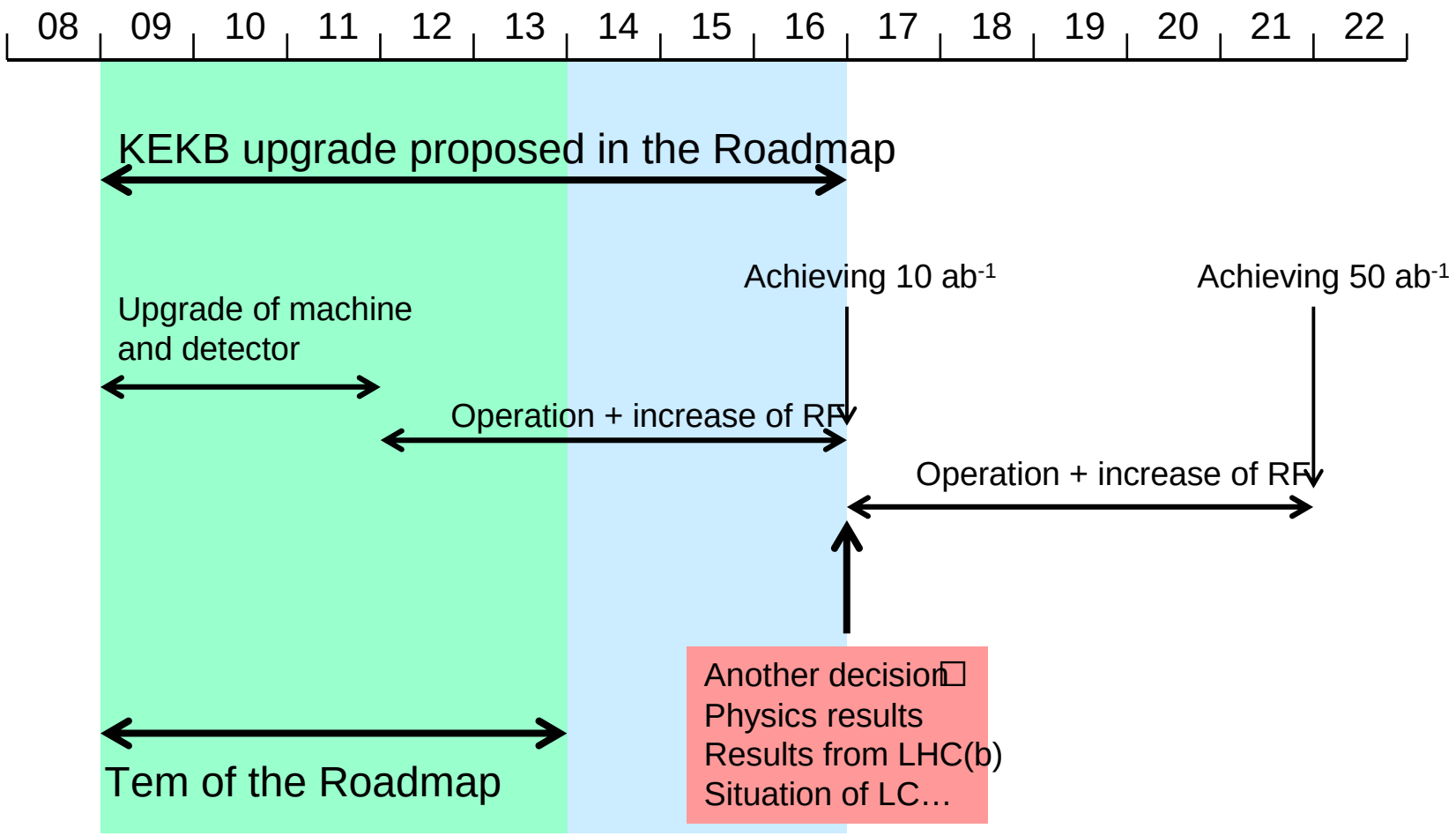
Conservative, robust detector should be handle up to 20 times more background

Belle upgrade



Long term strategy

- Assumption: Crab scheme works as expected.
- 10 ab^{-1} Initial target 50 ab^{-1} Final goal



Summary

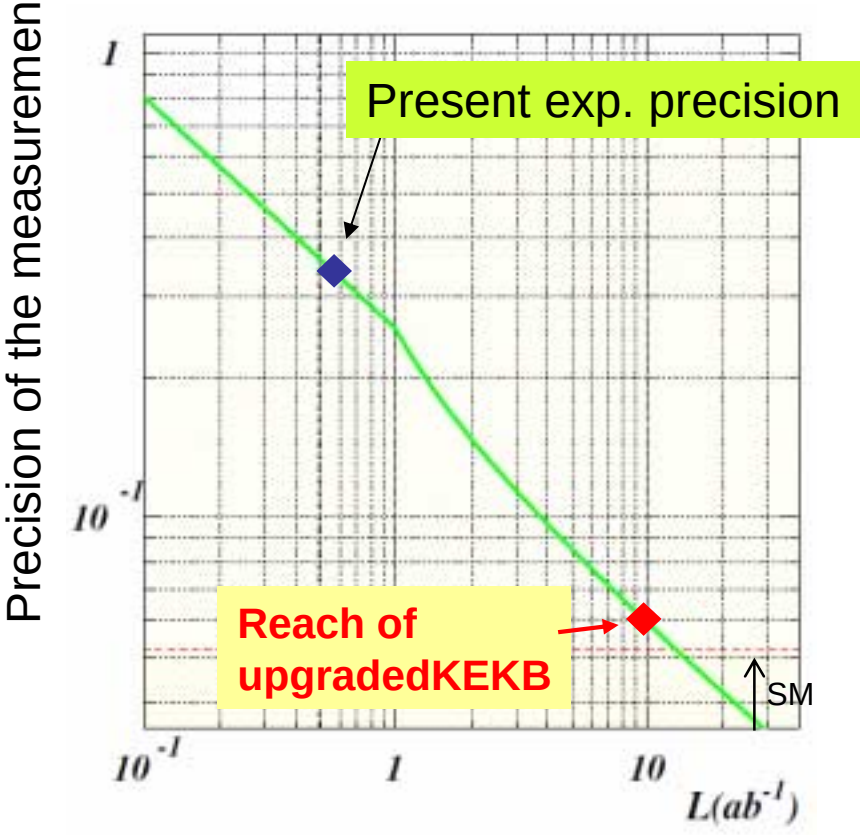
- KEKB/Belle and PEP-II/BaBar have been running very successfully, and brought important scientific and technical achievements.
- Next generation e^+e^- B factory with $L\sim10^{36}$ will be very useful to study the new sources of flavor mixing and CP violation.
  - Search for new CPV in $b\to s$ transition
  - Very precise test of CKM scheme
  - Search for lepton flavor violating τ decays
  - Studies of $H^{\pm}$ interactions with fermions
  - Very precise measurements of α_S(@10GeV), $\sin^2\theta_W$(@10GeV)…
- KEKB machine upgrade plan → Oide's talk
- Detector upgrade necessary to improve BKG/rate immunity.
- New collaboration to be formed soon.

BACK UP SLIDES

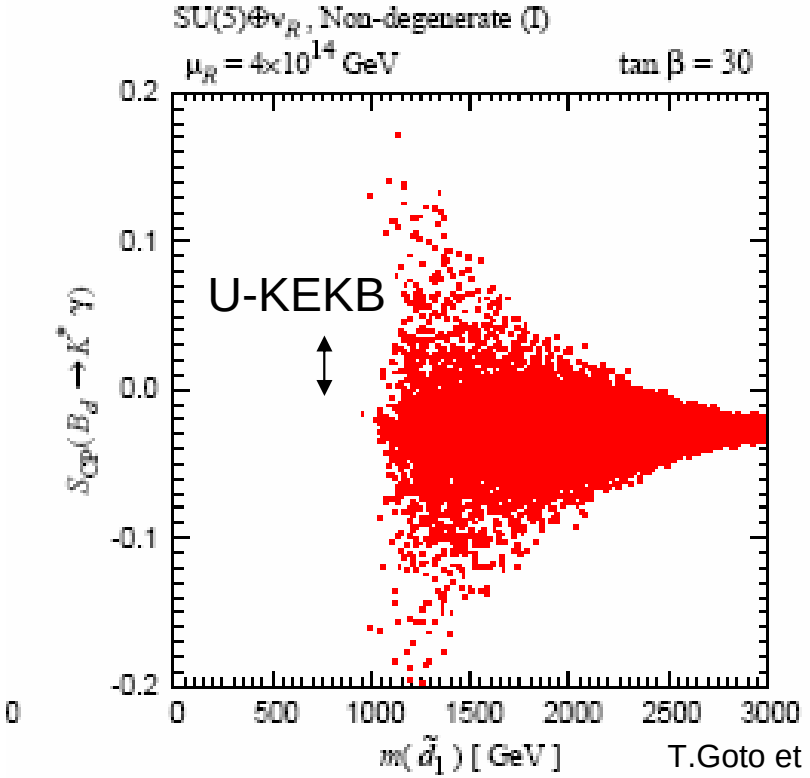
Search for right handed interaction

Left-right summetry in new physics?

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



Sizable CP asymmetry is expected in $B^0 \to X\gamma$ decay, if right-handed interaction exists in new physics.

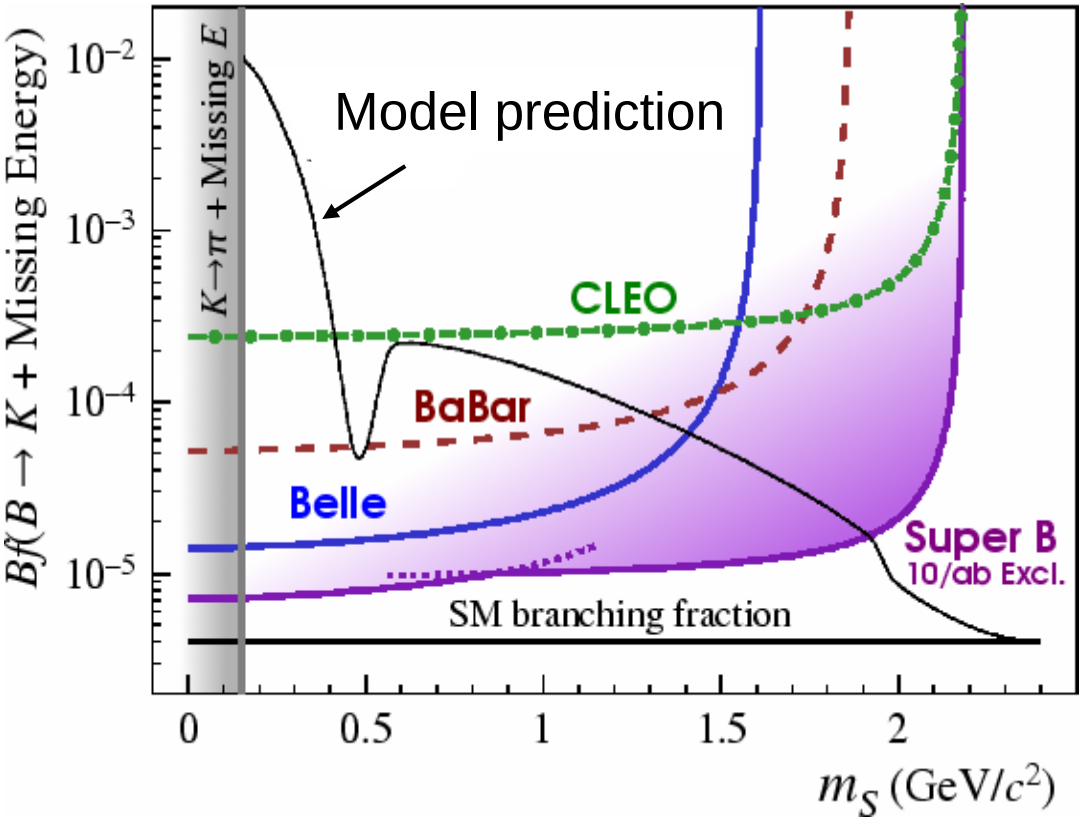


T.Goto et al., 2007

B decays into invisible particles?

Light dark matter?

$$B \to K^{(*)} \nu\bar{\nu} \; [\text{or } \chi\chi]$$

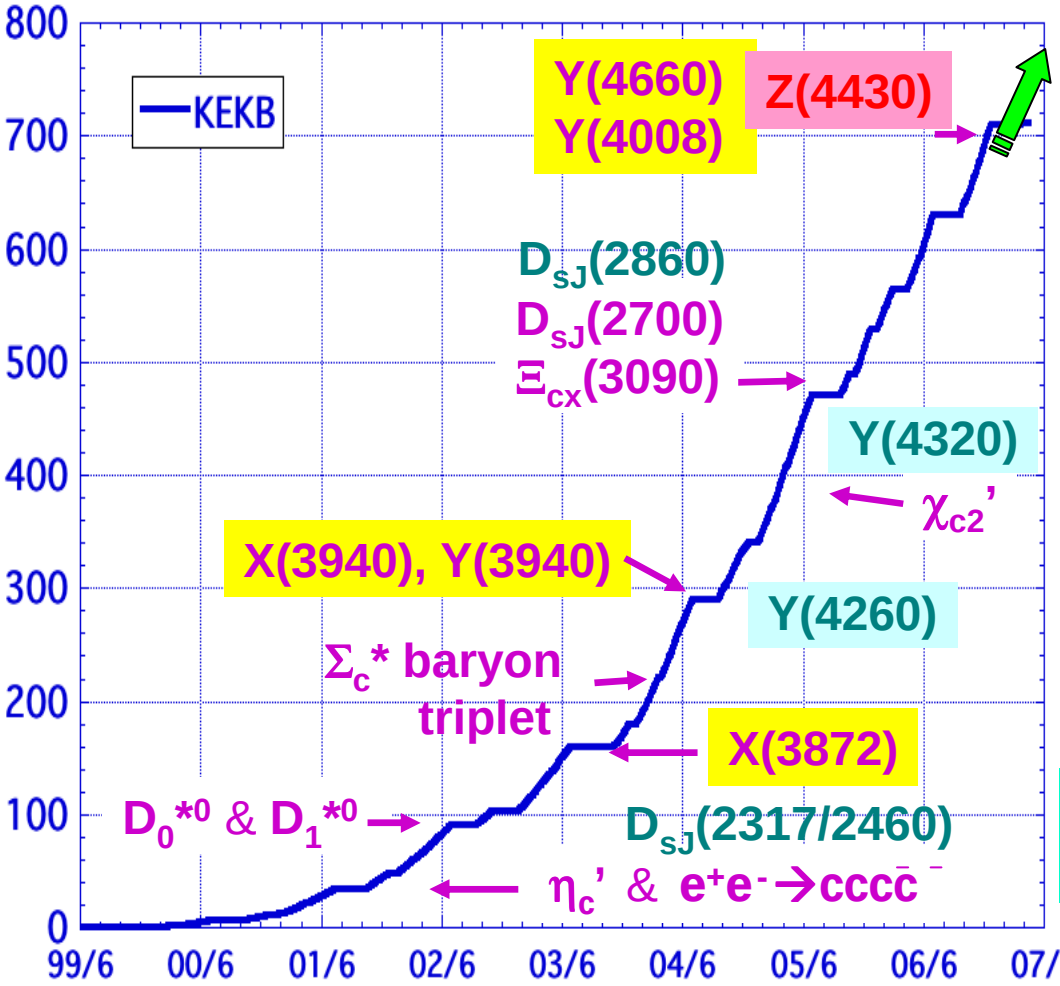


Heavy darm matter is being searched for in direct detection experiments.

Light dark matter can be Searched for in the upgraded KEKB.

New resonances

New resonances found at Belle

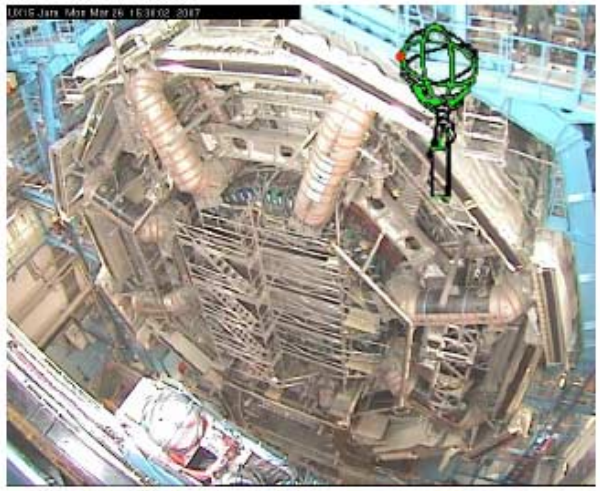


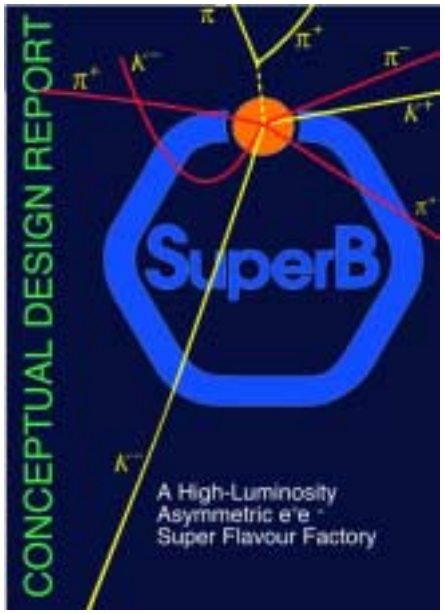
More than 10 new resonances have been found at Belle

Among them X(3872) and Z(4430) are considered to be "exotic" states.

More and more exotic states will be Observed by the upgraded KEKB.

Strong competitors





Comparison with LHCb

e^+e^- is advantageous in…	LHCb is advantageous in…
CPV in $B\to\phi K_S$, $\eta' K_S$,…	CPV in $B\to J/\psi K_S$
CPV in $B\to K_S\pi^0\gamma$	Most of B decays not including ν or γ
$B\to K\nu\nu$, $\tau\nu$, $D^{(*)}\tau\nu$	Time dependent measurements of B_S
Inclusive $b\to s\mu\mu$, *see*	$B_{(s,d)}\to\mu\mu$
$\tau\to\mu\gamma$ and other LFV	B_c and bottomed baryons
$D^0\overline{D^0}$ mixing	

These are complementary to each other !!