SuperKEKB

February 8, 2007

KEK Topical Conference

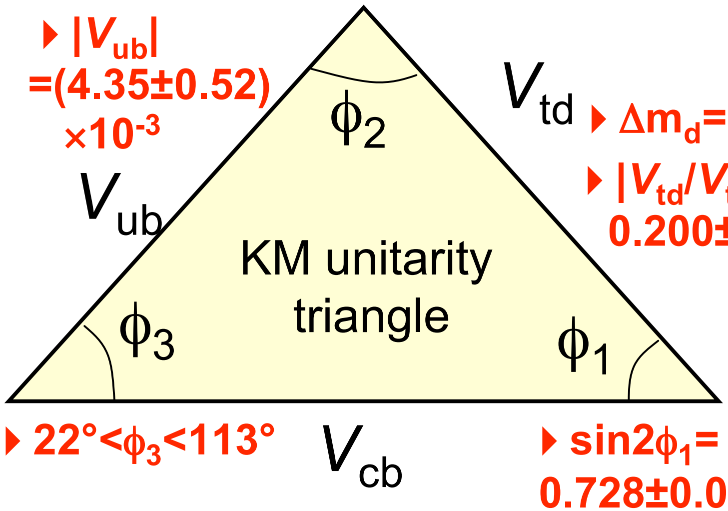
Masa Yamauchi
KEK

Outline

- Introduction
- Achievements of the *B* factories and the next step
- Physics at SuperKEKB
- Two possible approaches to achieve $L \sim 10^{36}$
  - High current approach: SuperKEKB
  - Low β and low ε approach: LC inspired SuperB
- Schedule and funding status
- Detector issues
- Summary

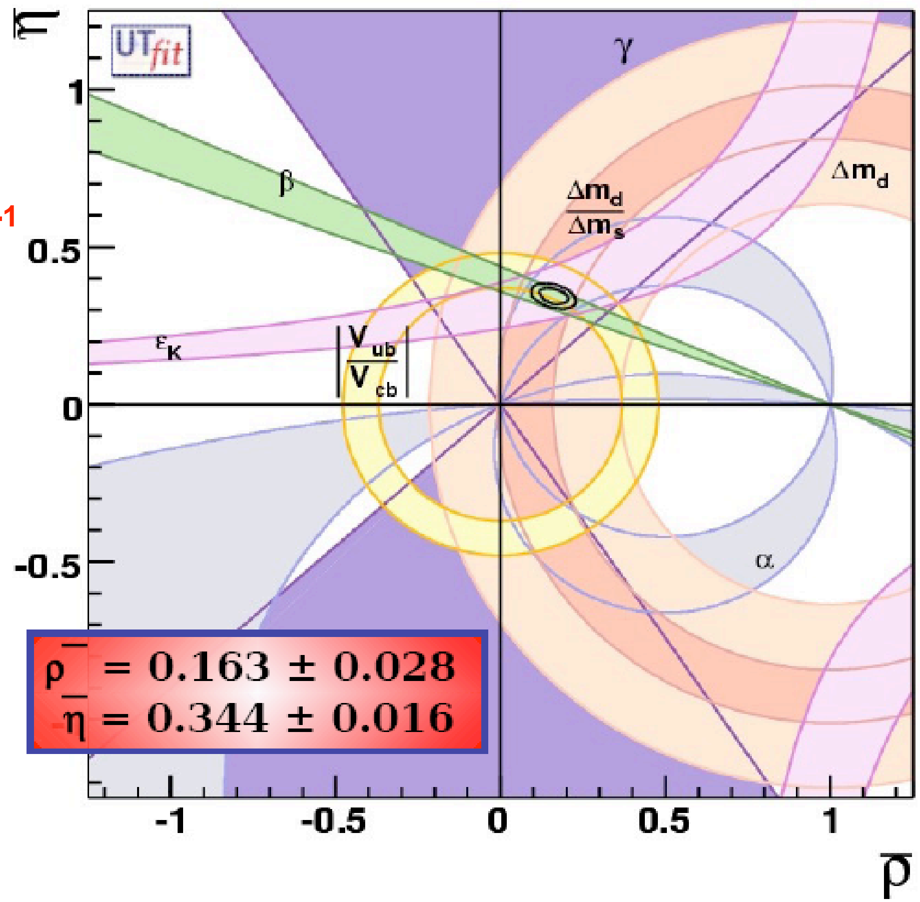
Achievements of the *B* Factories

Quantitative confirmation of the KM theory



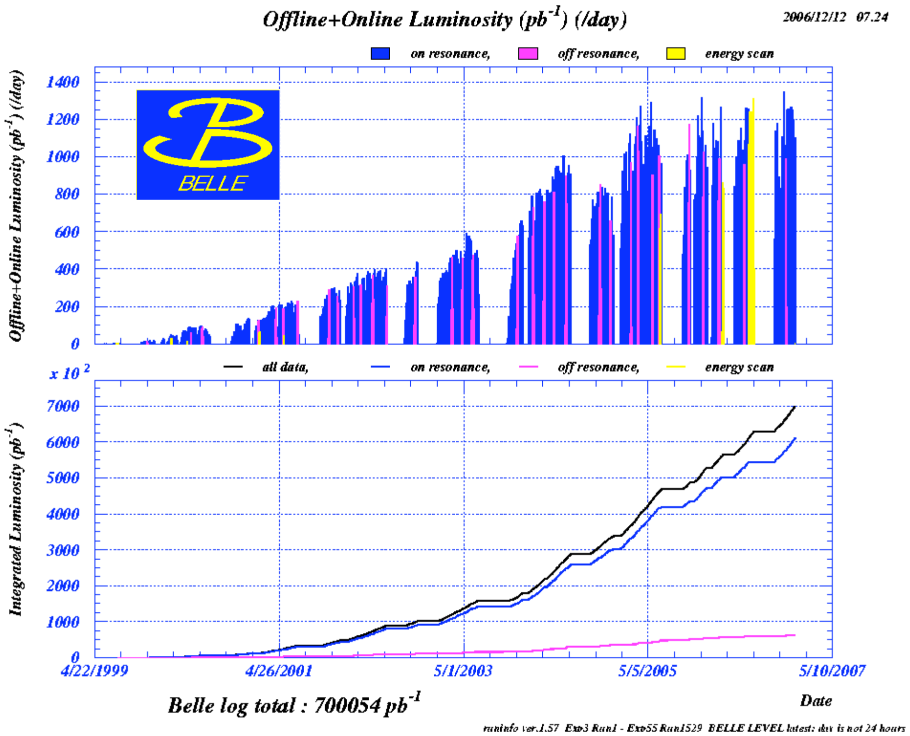
- $75° < \phi_2 < 113°$
- $|V_{ub}| = (4.35 \pm 0.52) \times 10^{-3}$
- $\Delta m_d = 0.511 ps^{-1}$
- $|V_{td}/V_{ts}| = 0.200 \pm 0.046$
- $22° < \phi_3 < 113°$
- $\sin 2\phi_1 = 0.728 \pm 0.061$
- $|V_{cb}| = (4.08 \pm 0.27) \times 10^{-2}$

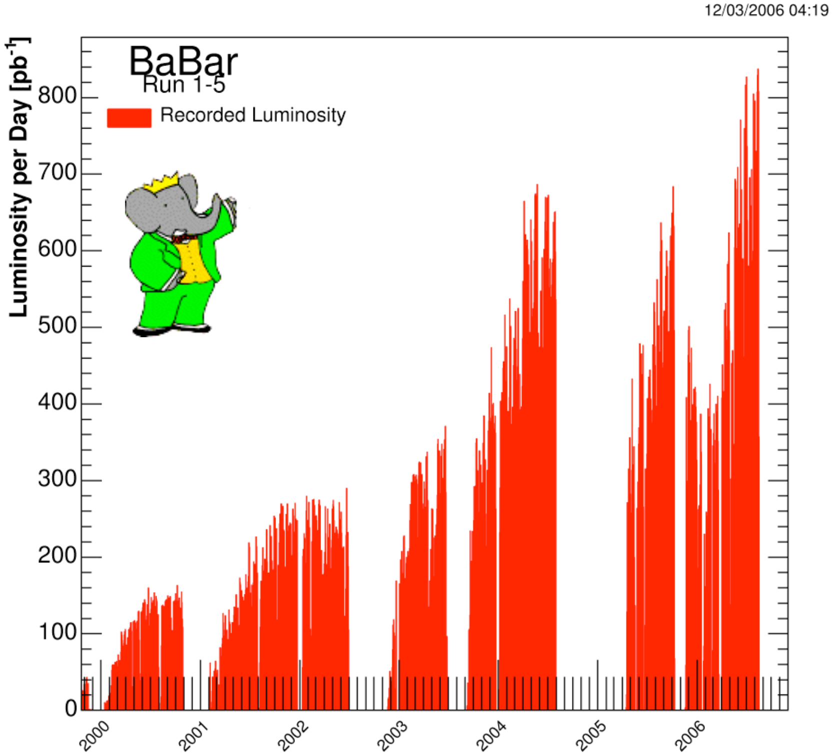
(Belle, ~2006)



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}.

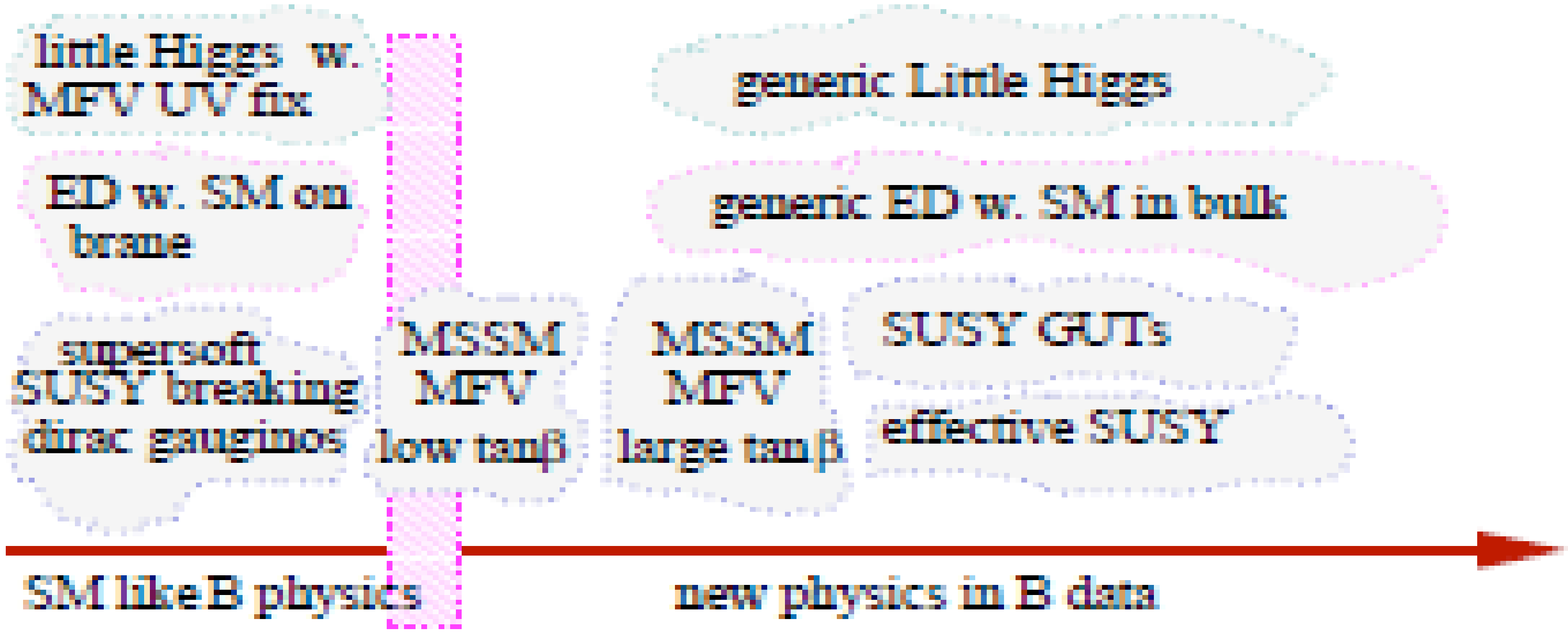
What is next with *B* physics?

- If new physics at O(1)TeV…
  - It is natural to assume that the effects are seen in *B*/*D*/τ 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.

New physics effect in *B* decays

G.Hiller

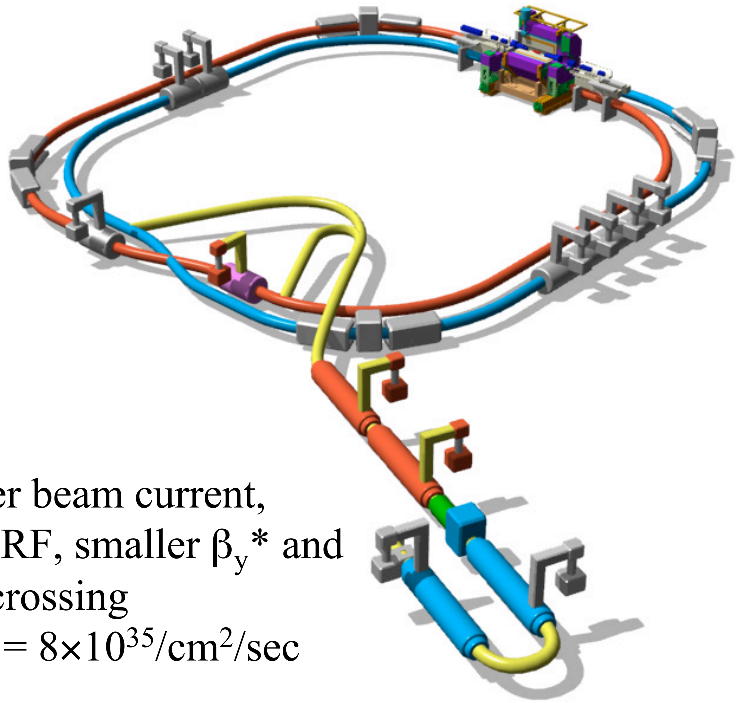


Likelihood for the effects of new physics to be seen in *B* decays.

SuperKEKB

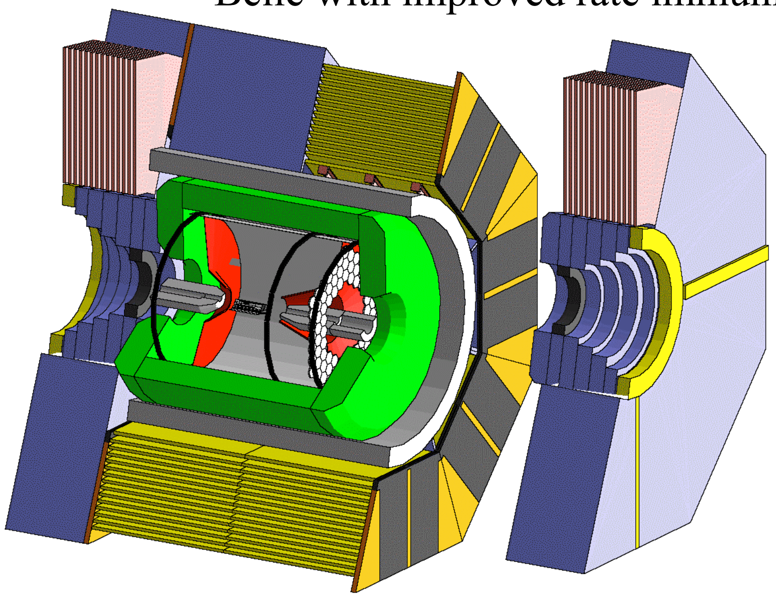
- *Asymmetric energy e^+e^- collider at $E_{CM}=m(\Upsilon(4S))$ to be realized by upgrading the existing KEKB collider.*
- *Super-high luminosity* ≅ 8×10^{35}/cm²/sec → 1×10^{10} *BB per yr.*

  → 8×10^{9} $\tau^+\tau^-$ *per yr.*



Higher beam current, more RF, smaller β_y^* and crab crossing
→ $L = 8\times10^{35}$/cm²/sec

Belle with improved rate immunity



http://belle.kek.jp/superb/loi

Physics at SuperKEKB

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…

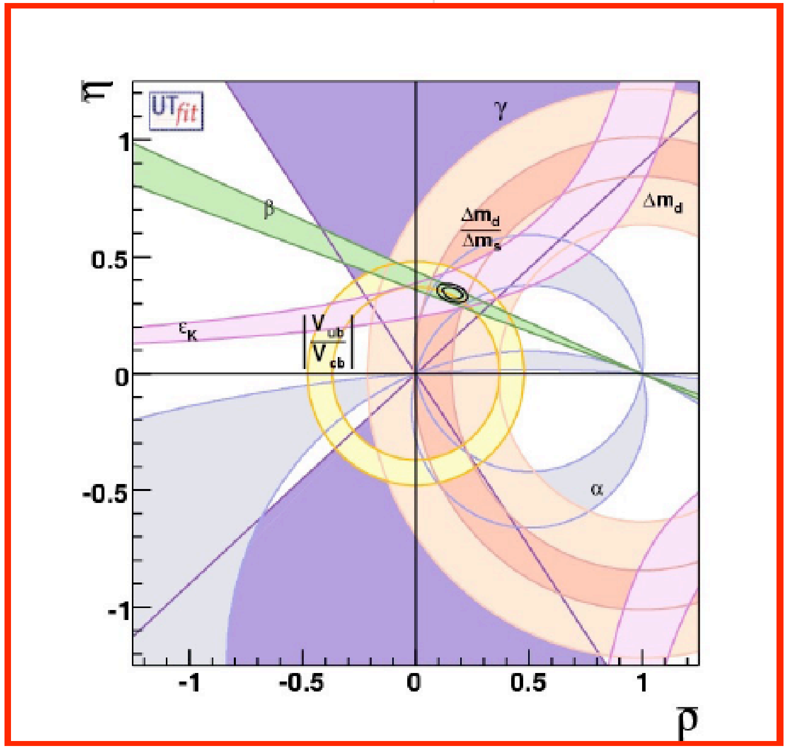
Super-high statistics measurements:

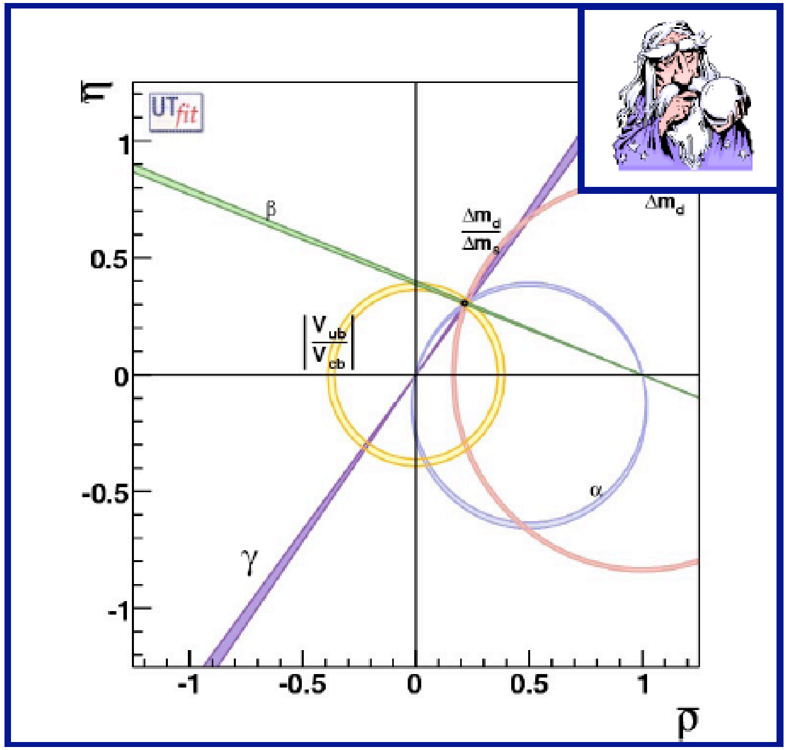
α_S, $\sin^2\theta_W$, etc.

Precision test of KM scheme

UTfit in the SM: 2006 vs. 2015

M.Pierini
CKM2006





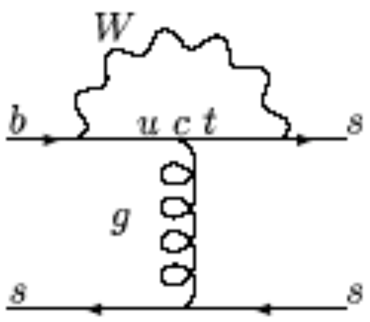
$\bar{\rho} = 0.163 \pm 0.028$
$\bar{\eta} = 0.344 \pm 0.016$

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

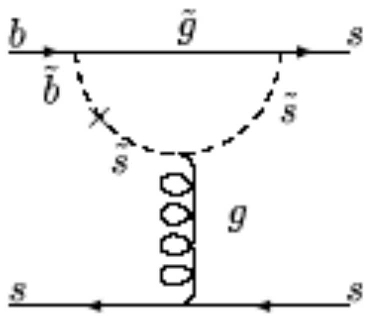
Search for new CP phases

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.

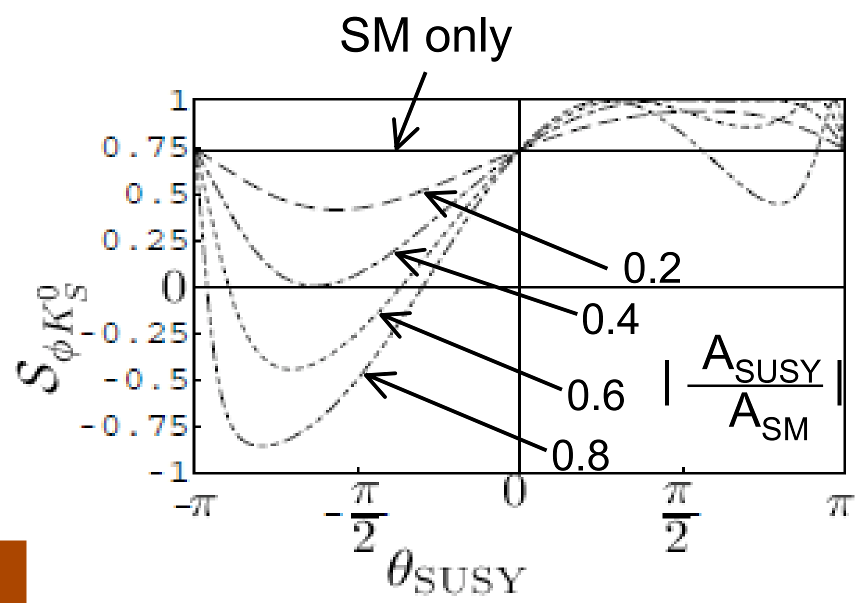


SM



SUSY contribution

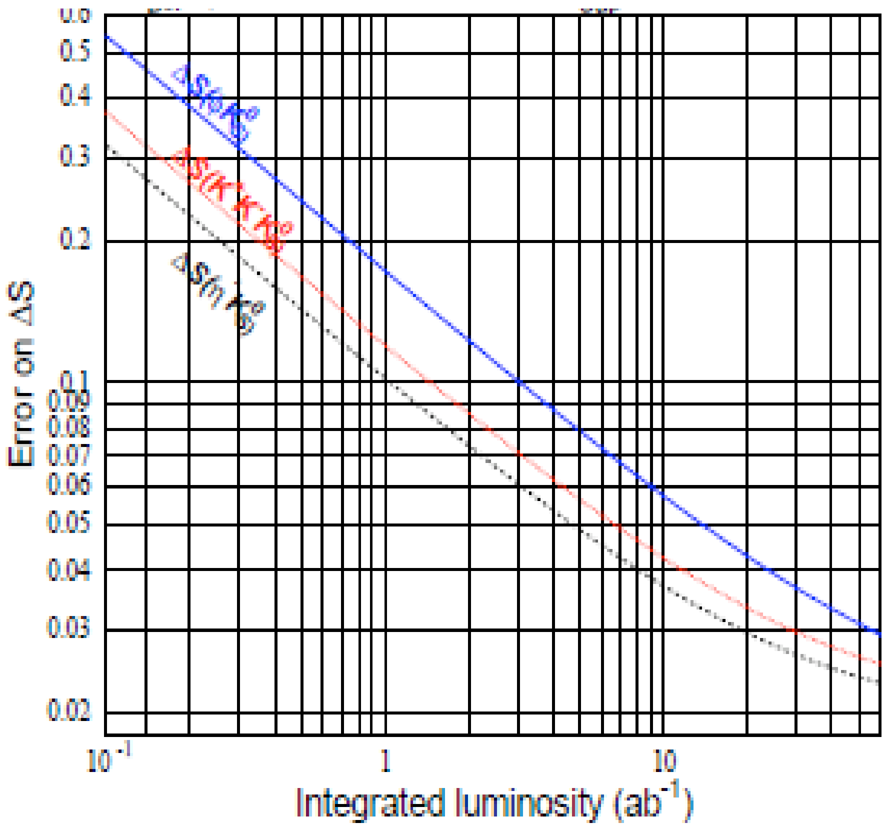
In general, if SUSY is present, the *s*-quark mixing matrix contains complex phases just as in the Kobayashi-Maskawa matrix.



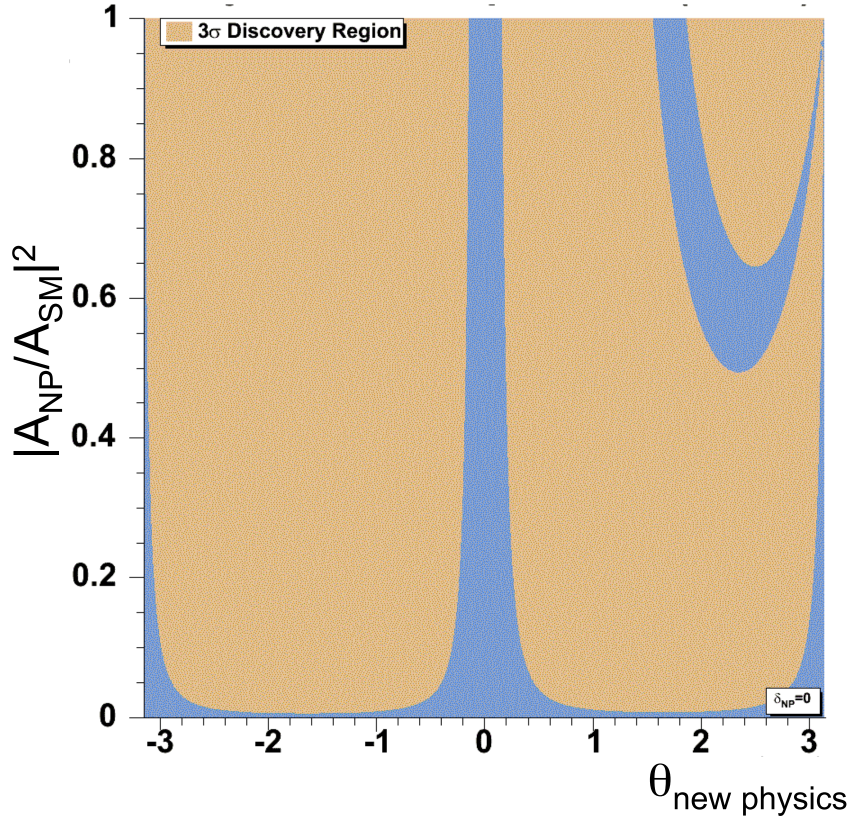
Effect of SUSY phase θ_{SUSY} on CPV in $B \to \phi K$ decay

Sensitivity to new CP phases

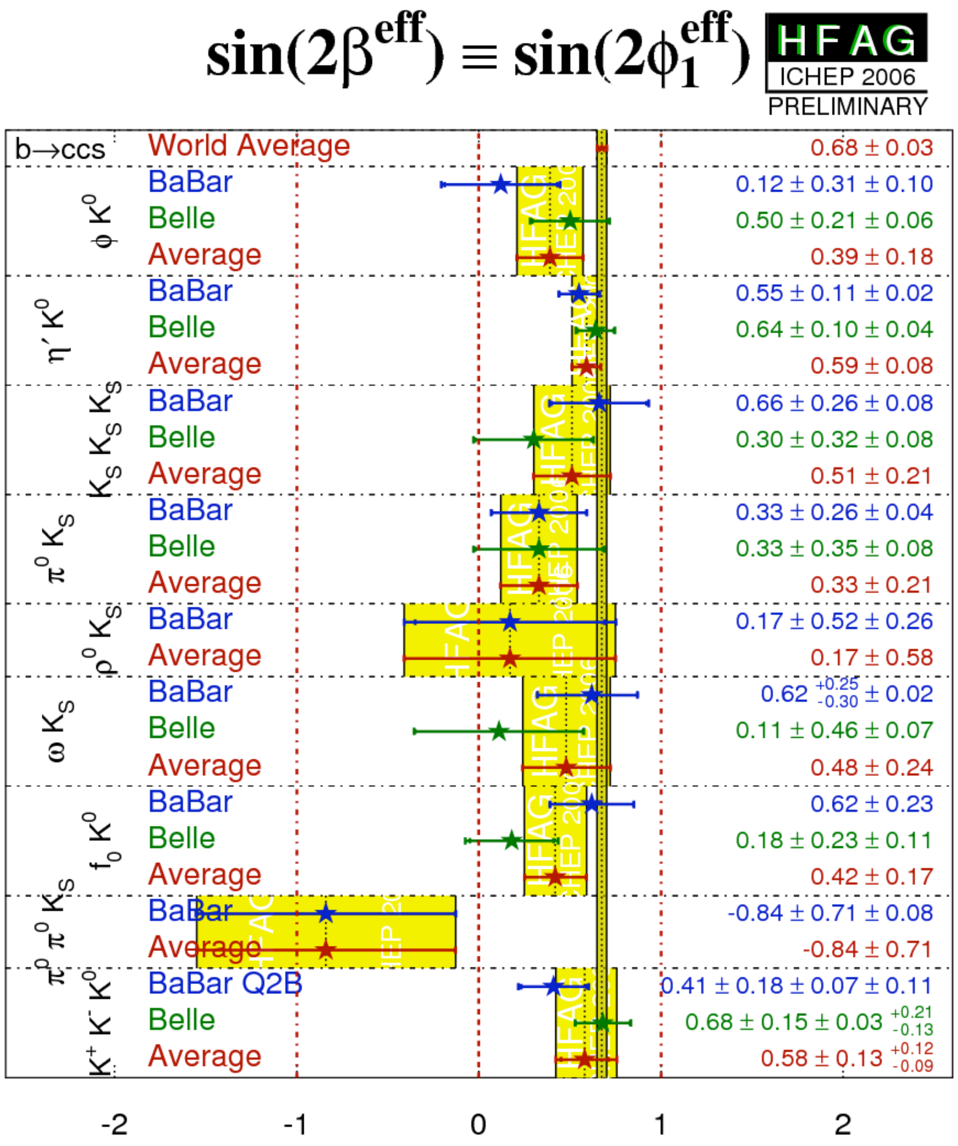
Estimated error in the measurement of time dependent CP violation



Discovery region with 50 ab^{-1}

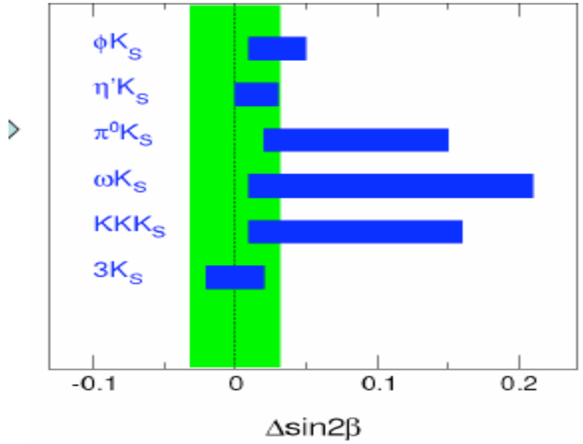


A possible hint for NP: $b \to s\bar{q}q$



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

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



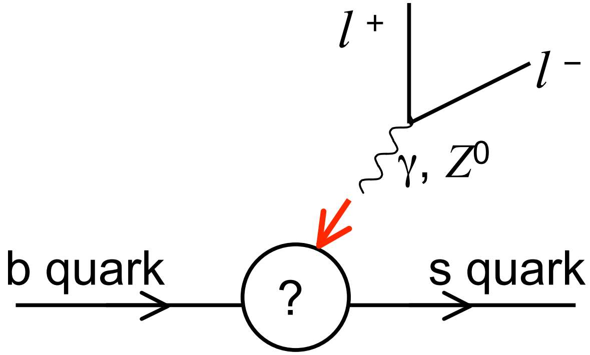
Theory : tends to positive shifts

Naïve average of all $b \to s$ modes

$\sin 2\beta^{eff} = 0.52 \pm 0.05$

$2.6\,\sigma$ deviation from SM

Search for new flavor mixing



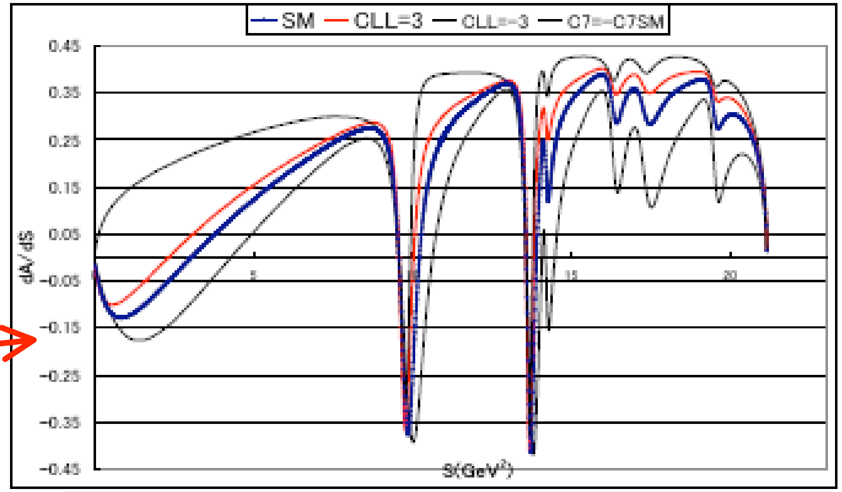
: Probe the flavor changing process with the "EW probe".

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.

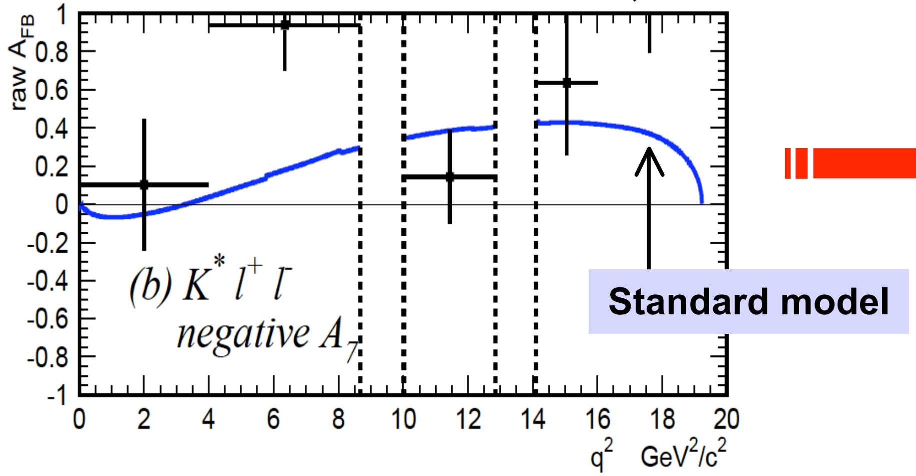


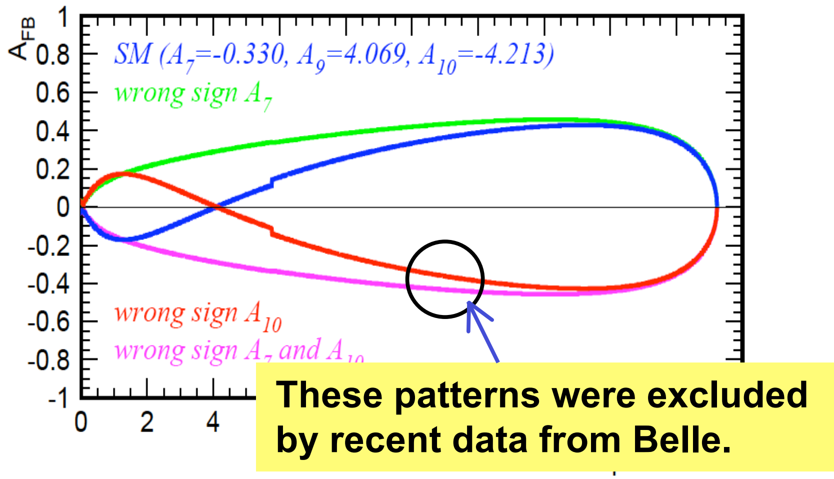
The F/B asymmetry is a consequence of γ-Z^0 interference.

Sensitivity to new flavor mixing

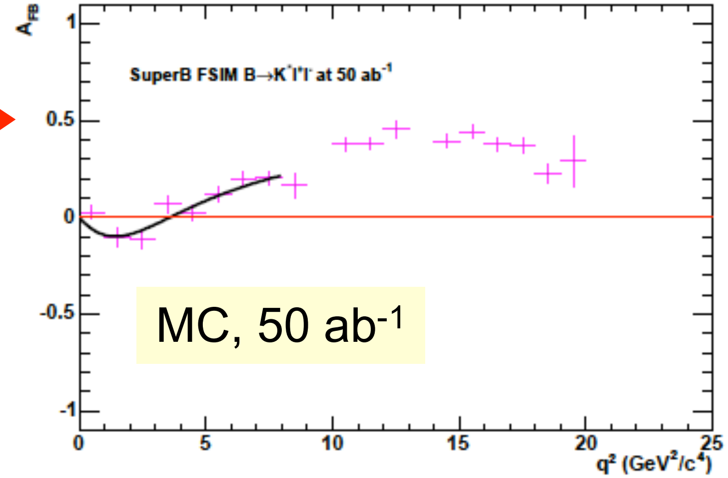
Experimental result with 0.35 ab^{-1}

Belle, 2005



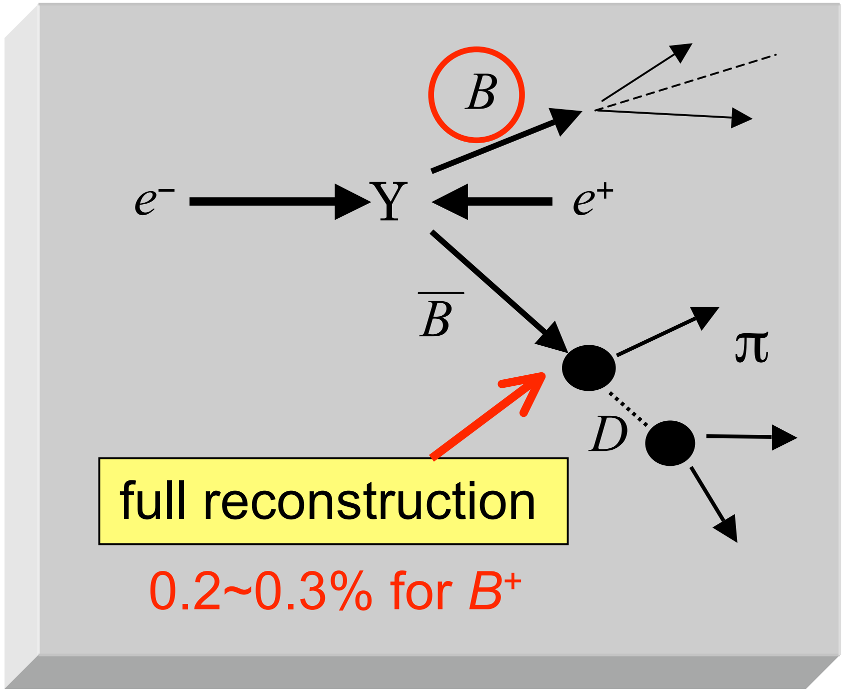


Sensitivity at Super KEKB

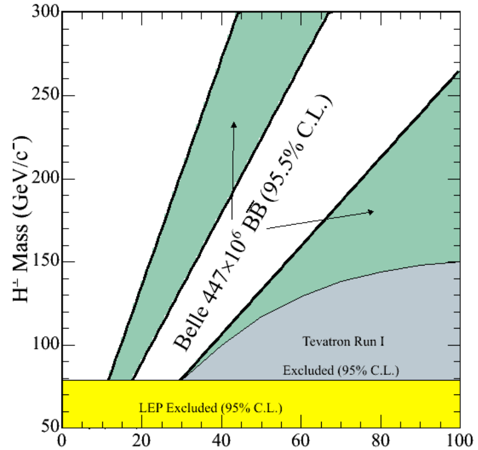


- Zero-crossing q^2 for A_{FB} will be determined with 5% error with 50ab^{-1}.

"*B* meson beam" technique



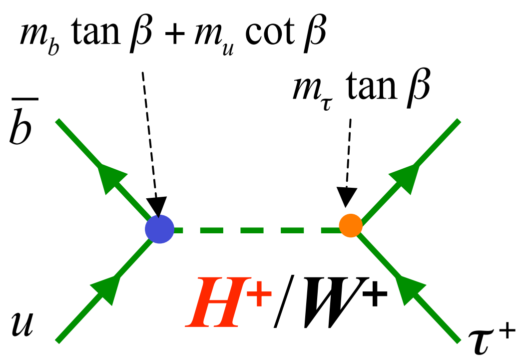
95.5%C.L. exclusion boundaries



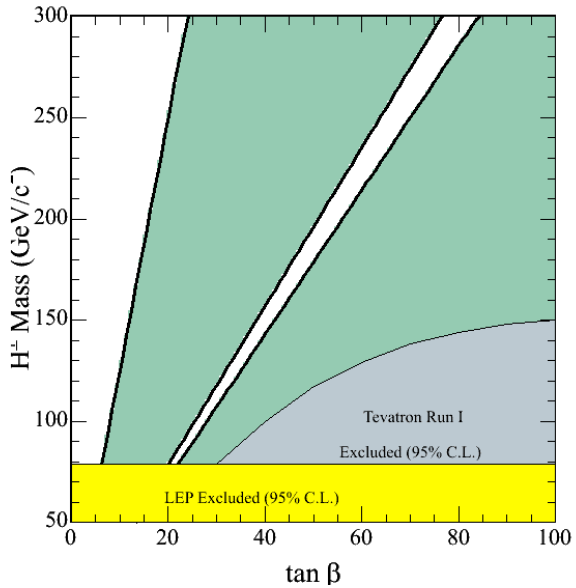
Belle, 2006

Application

$H^{\pm}$ search in $B \to \tau\nu$

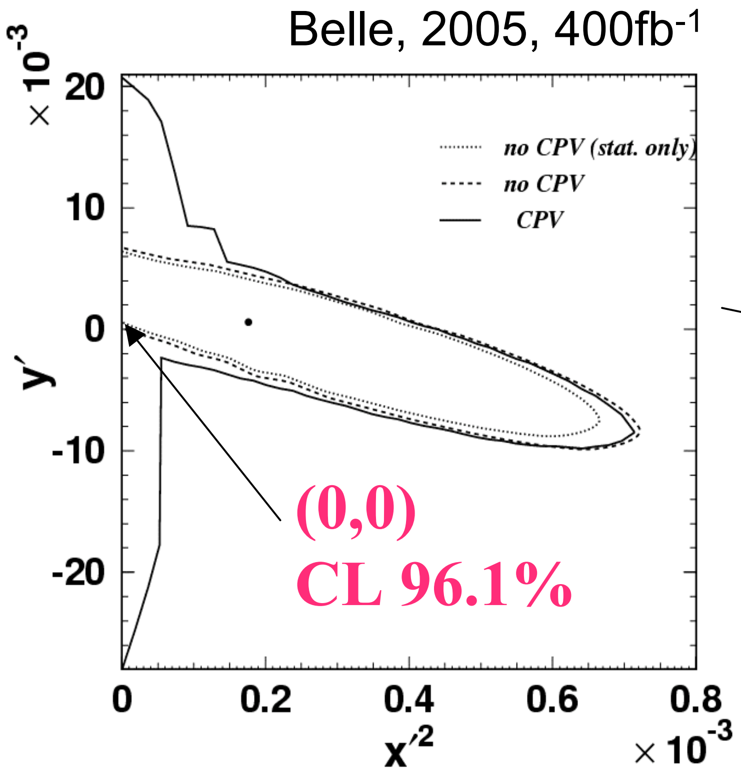


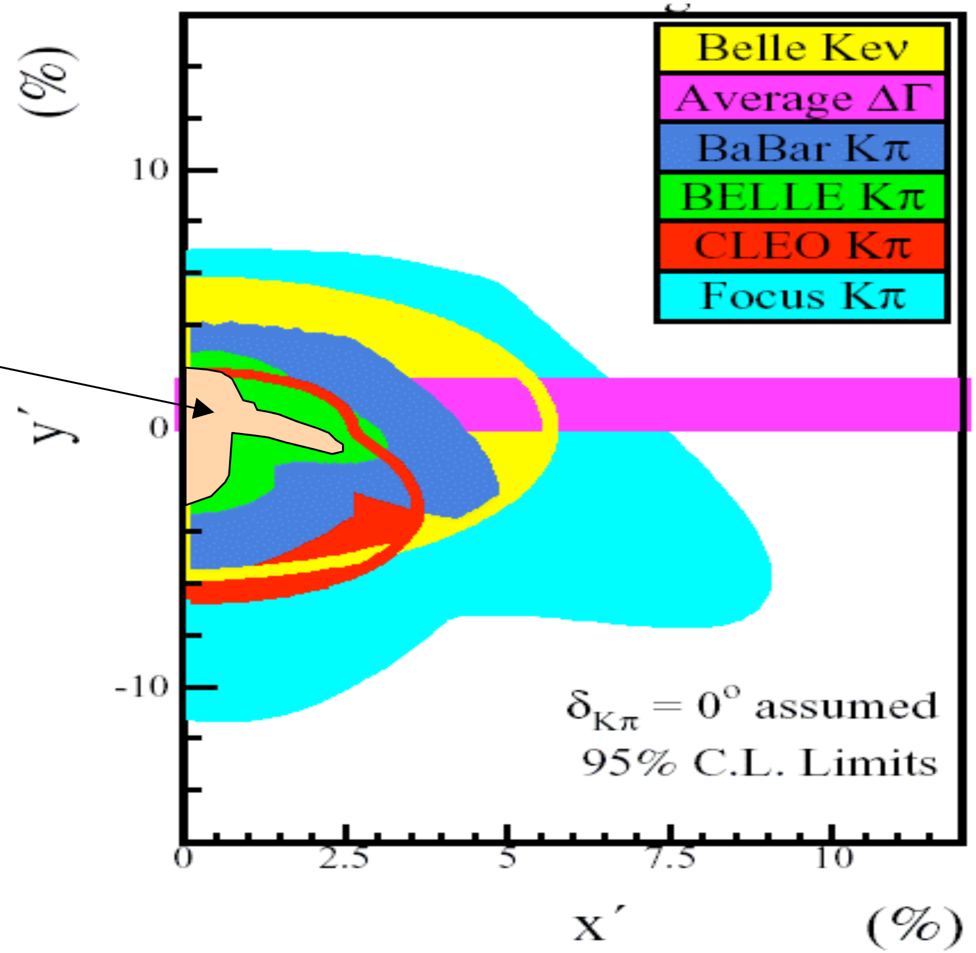
5ab^{-1} assumed



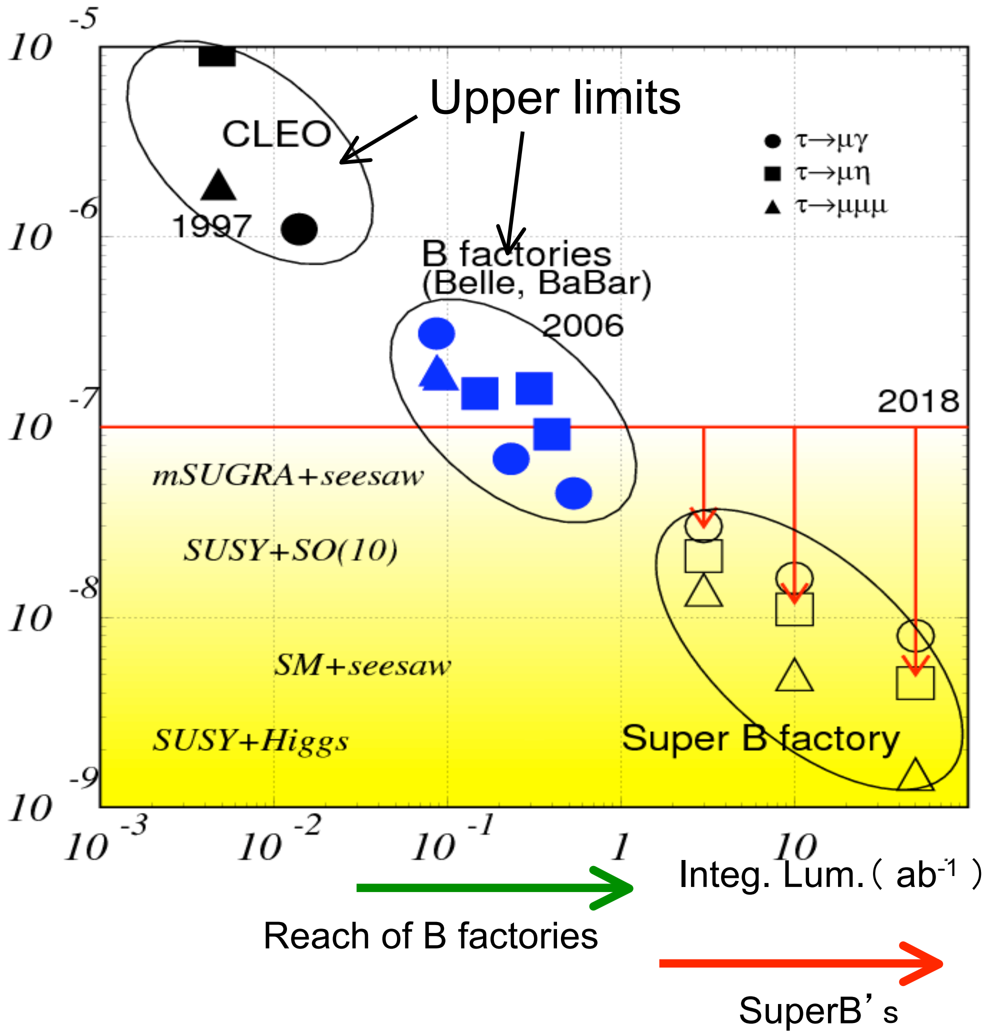
Charm physics at *B* factories

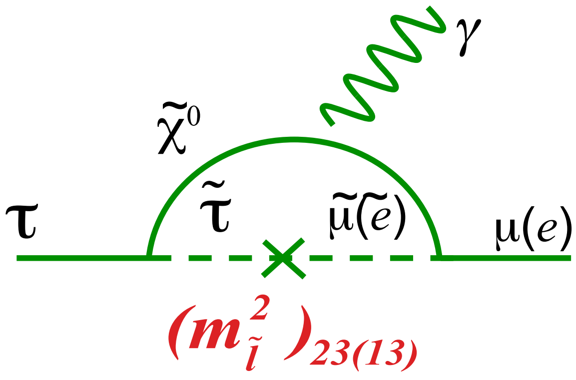
$D^0\overline{D^0}$ mixing may be observed at *B* factories with higher L.





Search for flavor-violating τ decay





Comparison with LHCb

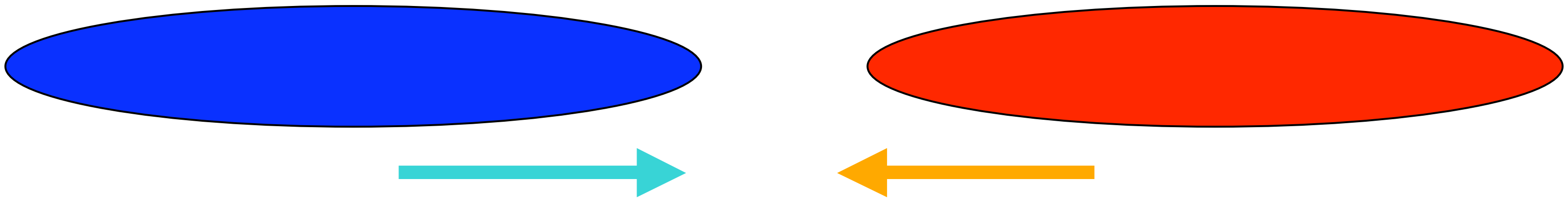
e^+e^- is advantageous in…	LHCb is advantageous in…
CPV in $B \to \phi K_S$, $\eta' K_S$,…	CPV in $B \to J/\psi K_S$
CPV in $B \to K_S \pi^0 \gamma$	Most of B decays not including ν or γ
$B \to K \nu\nu$, $\tau\nu$, $D^{(*)}\tau\nu$	Time dependent measurements of B_S
Inclusive $b \to s\mu\mu$, *see*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

These are complementary to each other !!

Two approaches to achieve L~10^{36}

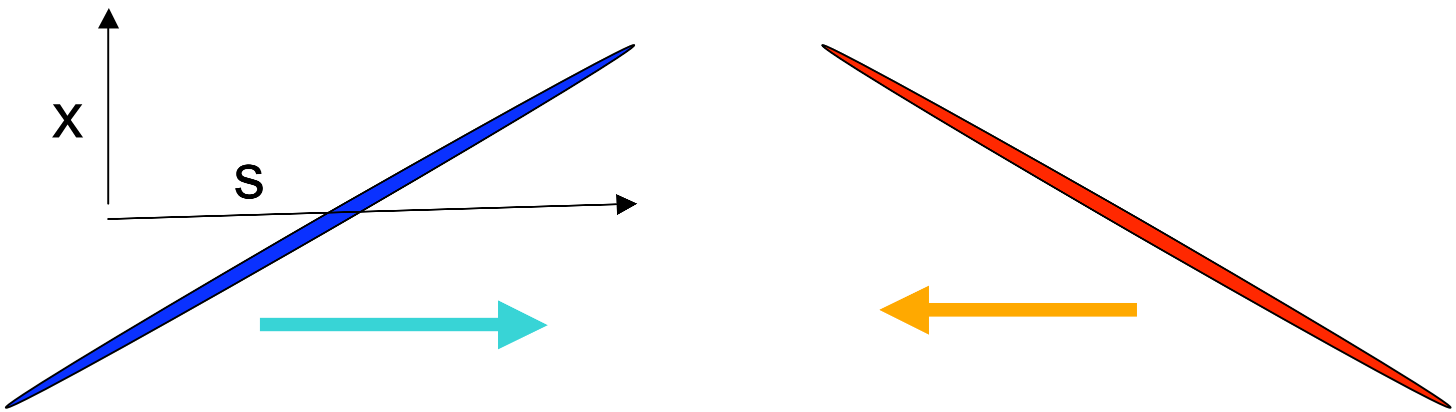
- High current, high beam-beam parameter

= SuperKEKB



- Low emittance, low beta, low current

= LC SuperB



High current approach – Technical challenge

- Powerful RF system needed to store high current
  - Larger wall-plug power
- High beam-beam parameter with head-on collision
- Highly nonlinear system
- Sensitive for noise and error due to high beam-beam parameter
- Limit of bunch length, instability and coherent synchrotron radiation

Low emittance approach
-Technical challenge

- Low emittance lattice design needed.
- Low beta and the strongly focusing IR will limit dynamic aperture.
- Single turn injection is required due to the narrow aperture. High speed kicker (~2ns), low emittance damping ring and high precision injection will be needed.
- Very sensitive to the alignment error and stability of the land(!) due to the very low emittance.
- The main ring is similar to ILC damping ring equip with the final focus system of ILC.

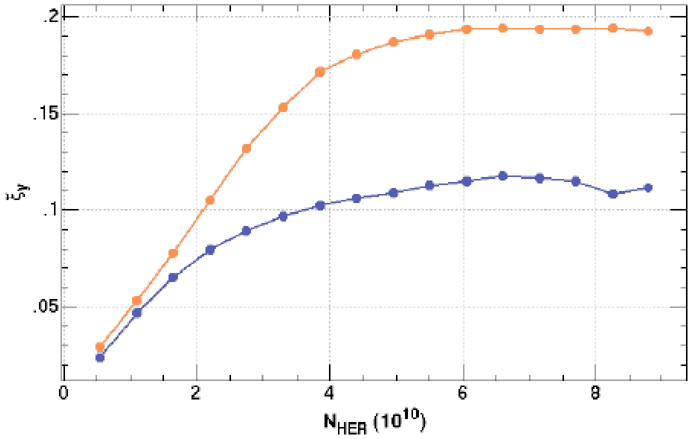
Parameter sets for SuperB

	KEKB	SuperKEKB	LC-SuperB
εx	18(L)/24(H) $\times 10^{-9}$	9.0×10^{-9}	0.8×10^{-9}
εy	18(L)/24(H) $\times 10^{-11}$	4.5×10^{-11}	2×10^{-12}
βx (mm)	560	200	9
βy (mm)	6	3	0.133
σz (mm)	7	3	6
νs	0.025	0.025	0.012/0.026
ne	(1388×) 5.5×10^{10}	(5000×) 5.5×10^{10}	(5000×) 1.9×10^{10}
np	(1388×) 7.5×10^{10}	(5000×) 1.26×10^{11}	(5000×) 3.3×10^{10}
$\theta/2$ (mrad)	11	0 (crab crossing)	25
ξx	0.1	0.397	
ξy	0.06	0.794->0.24	
Lum.	1.7×10^{34}	8×10^{35}	1×10^{36}

Crab cavity

●Crab crossing will boost the beam-beam parameter up to 0.19!

K. Ohmi



Head-on(crab)

(Strong-strong simulation)

crossing angle 30 mrad

(at the optimum tune)

●Superconducting crab cavities are under development, and will be installed in KEKB in 2006.

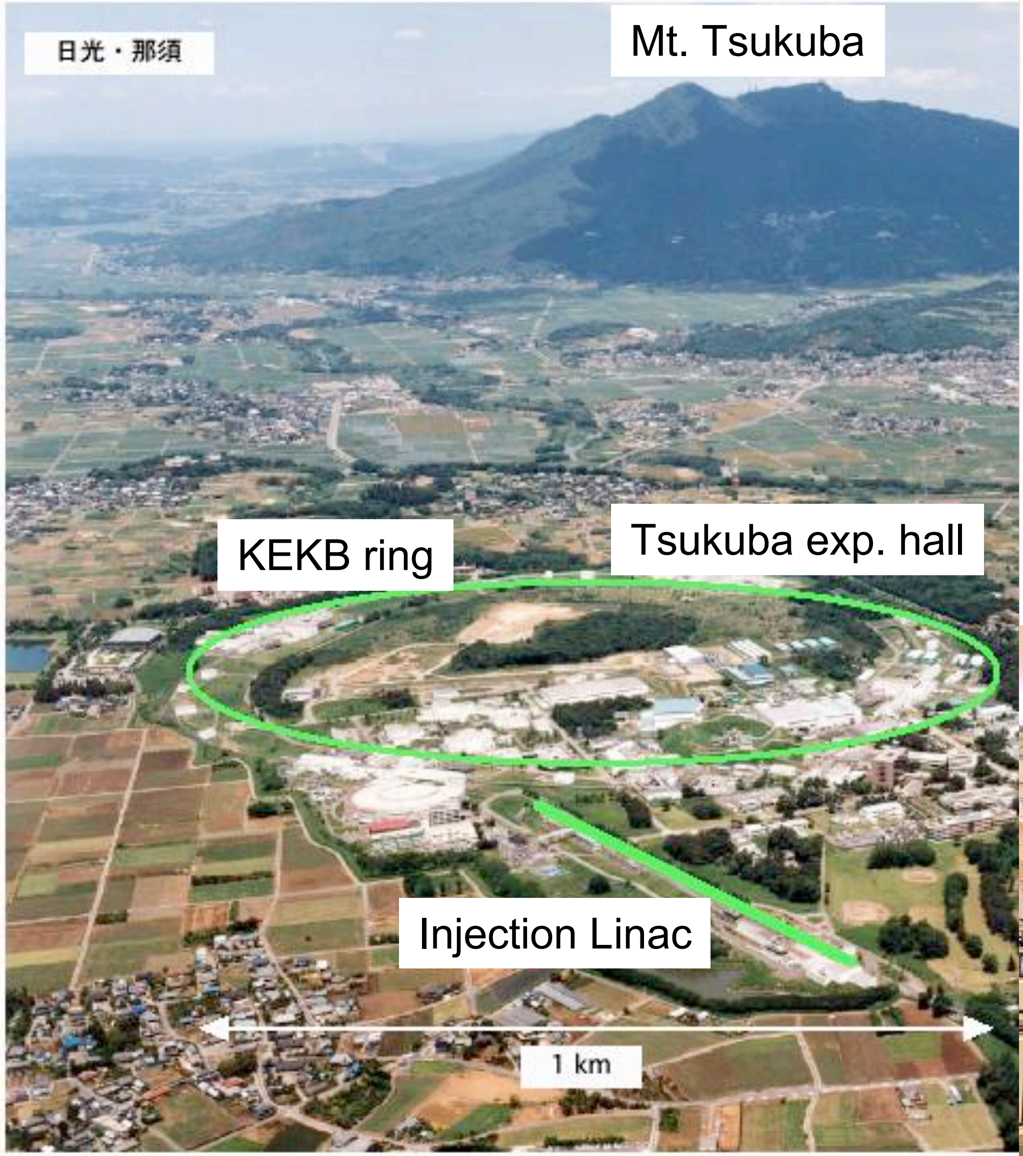
A pair of crab cavities will be installed in KEKB in Jan. 07.

KEKB's approach

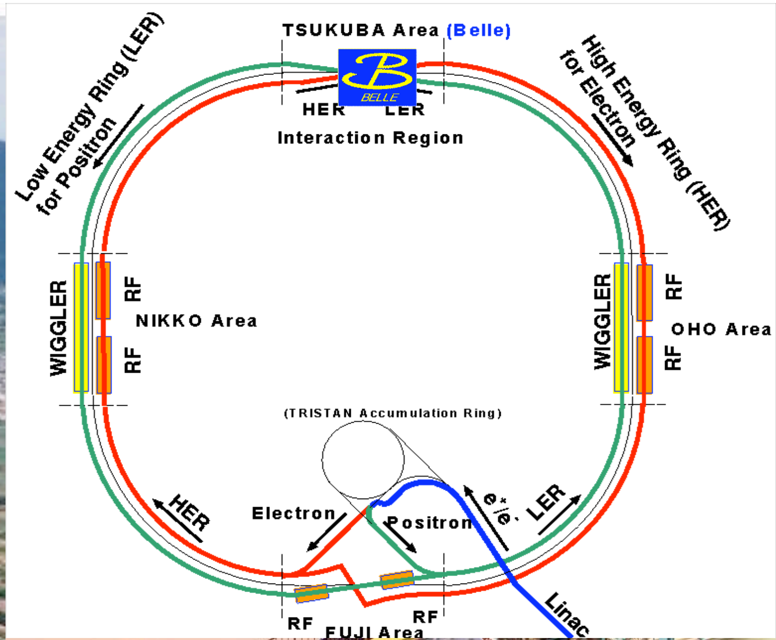
- We keep high current approach until finding a solution to dynamic aperture and injection scheme in the low emittance scheme.

- Both crab crossing and crab waist scheme will be tested in the KEKB ring soon.

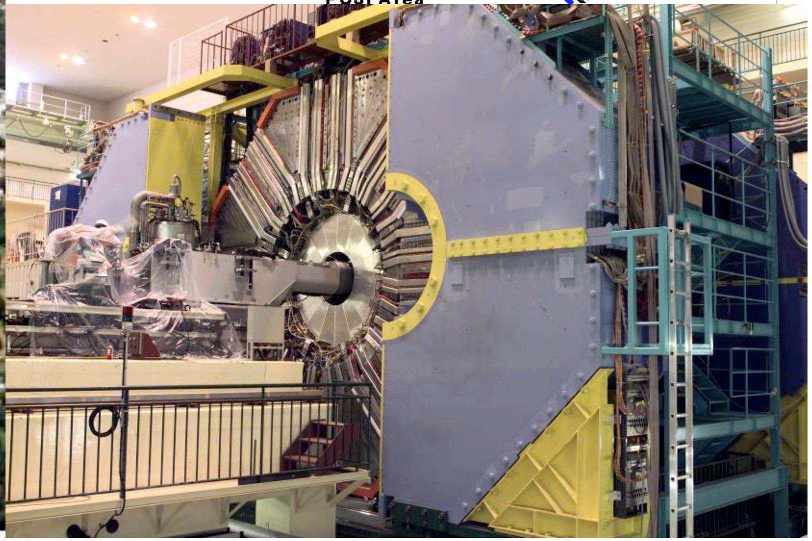
KEKB

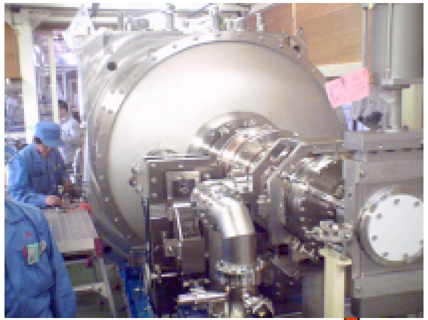


日光・那須
Mt. Tsukuba
KEKB ring
Tsukuba exp. hall
Injection Linac
1 km

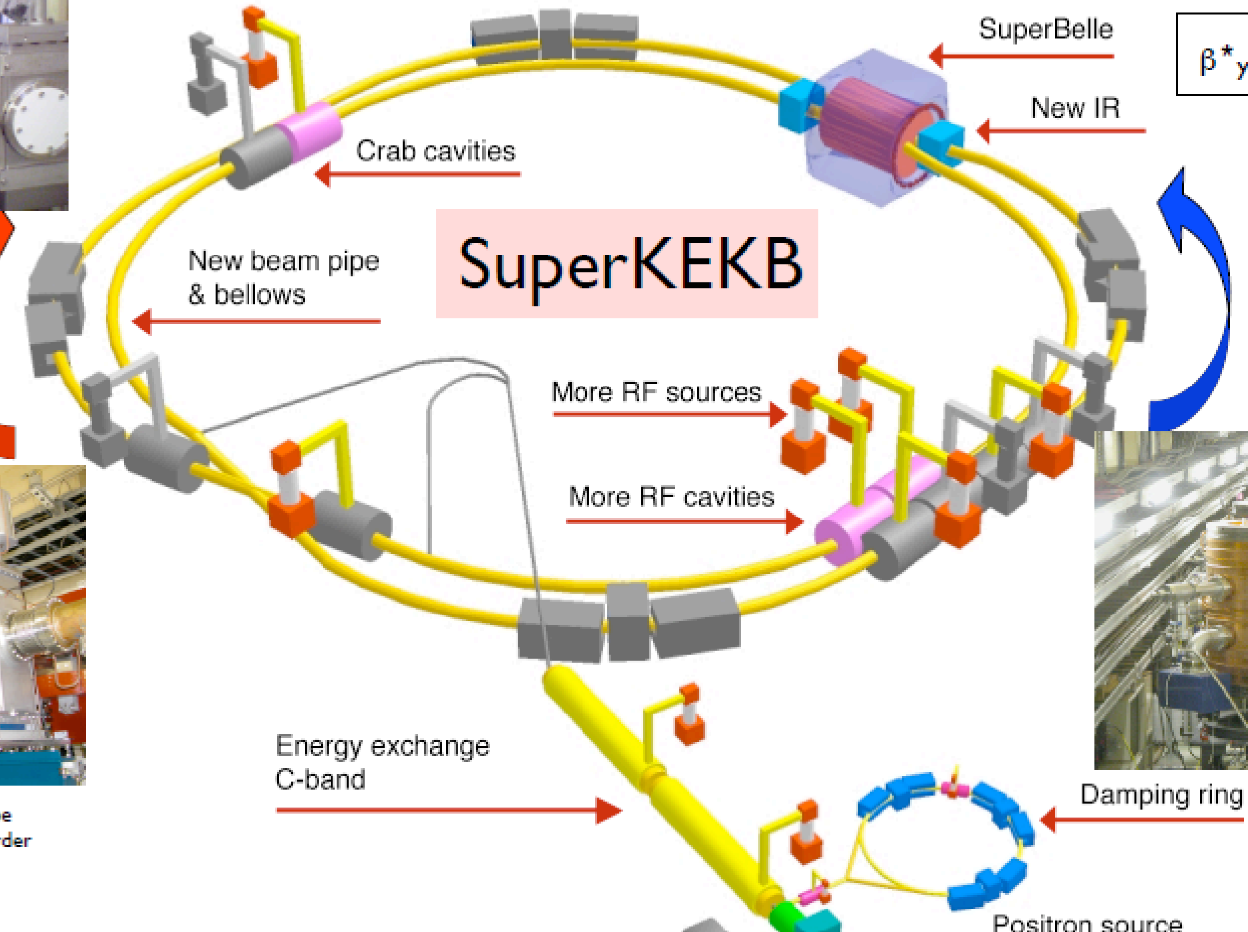


TSUKUBA Area (Belle)
Low Energy Ring (LER) for Positron
High Energy Ring (HER) for Electron
BELLE
HER
LER
Interaction Region
WIGGLER
RF
NIKKO Area
OHO Area
(TRISTAN Accumulation Ring)
HER
Electron
Positron
e+/e-
LER
Linac
RF
FUJI Area





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



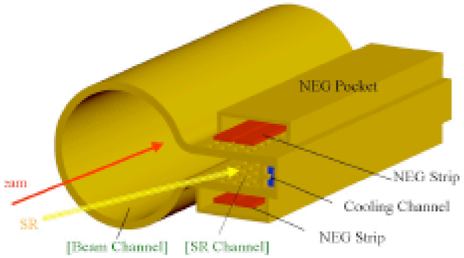
$\beta^*_y = \sigma_z = 3$ mm

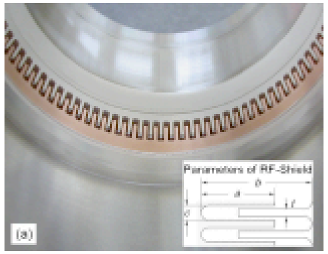
e- 9.4 A

e+ 4.1 A

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.



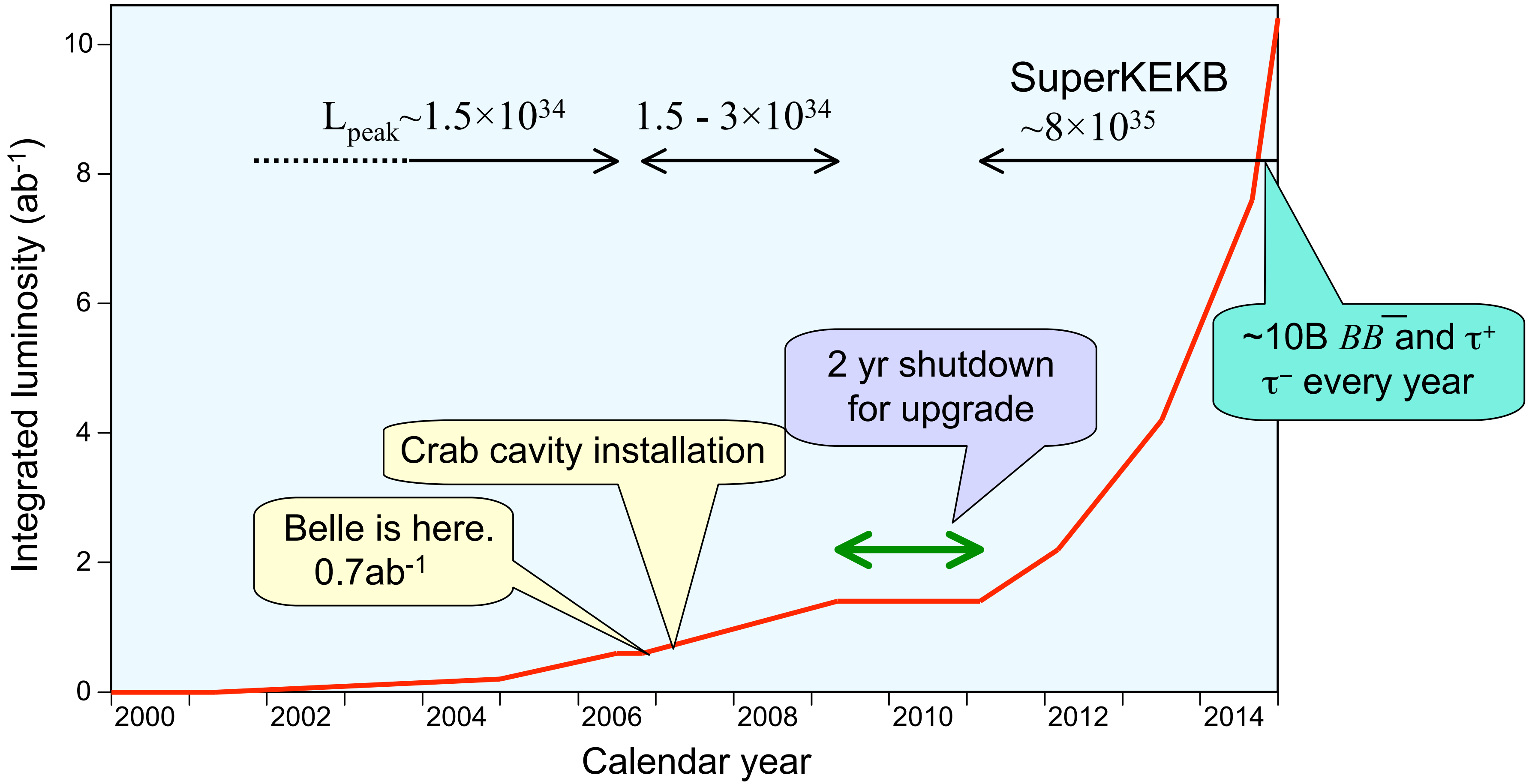


The beam pipes and all vacuum components will be replaced with higher-current-proof design.

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

will reach 8×10^{35} cm^{-2}s^{-1}.

Proposed schedule

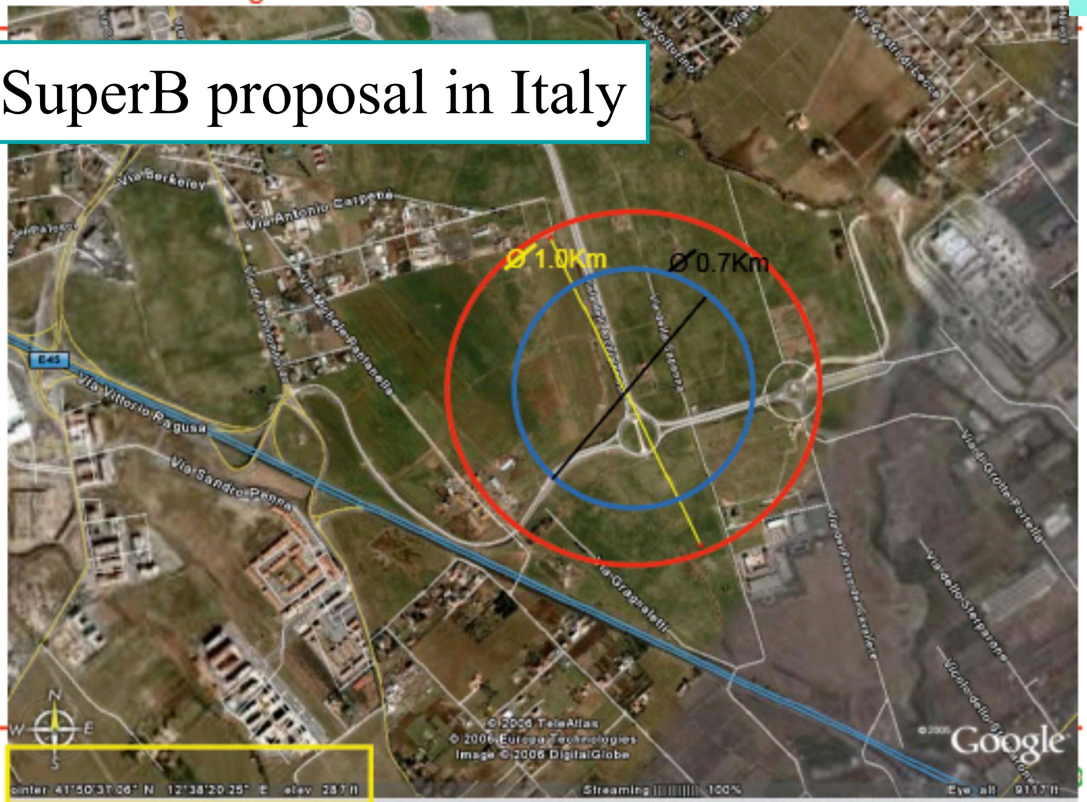


A.Roodman
BNM2006, Sep.06

Location?

Tor Vergata site between 3.0 Km and 2.2 Km

One more SuperB proposal in Italy



Marcello Giorgi

Site of SuperB is not defined and will remain undefined for quite a while. The machine can stay in an existing tunnel of 6 Km, 3 Km and perhaps 2 Km. Any offer will be welcome, providing is within a true international spirit of cooperation between partners with equal dignity.

However INFN is a strong supporter in this enterprise.

INFN will try to gain the support of italian government for such an international project.

Conclusion 2

Only one Super B Factory will be built if one.

Site decision should be open

Lumi as high as possible

(> 10^{36} better 10^{43} !!)

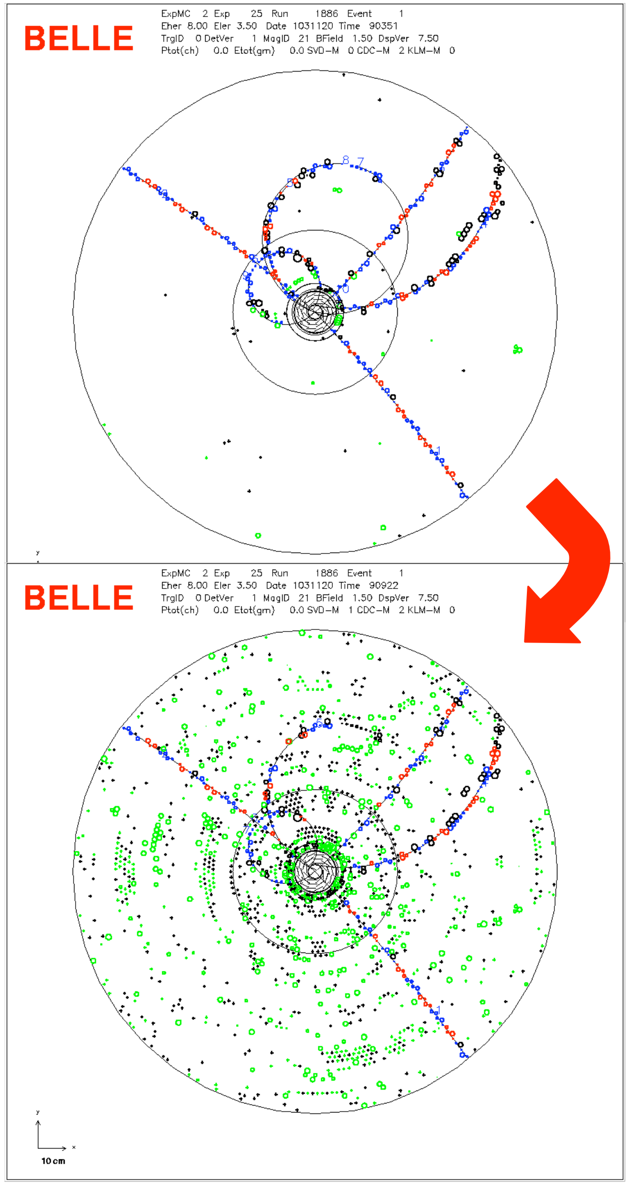
We have set up an International Group

Collaboration between SuperB and SuperKEKB is needed and welcome!

Requirements to the detector

Issues

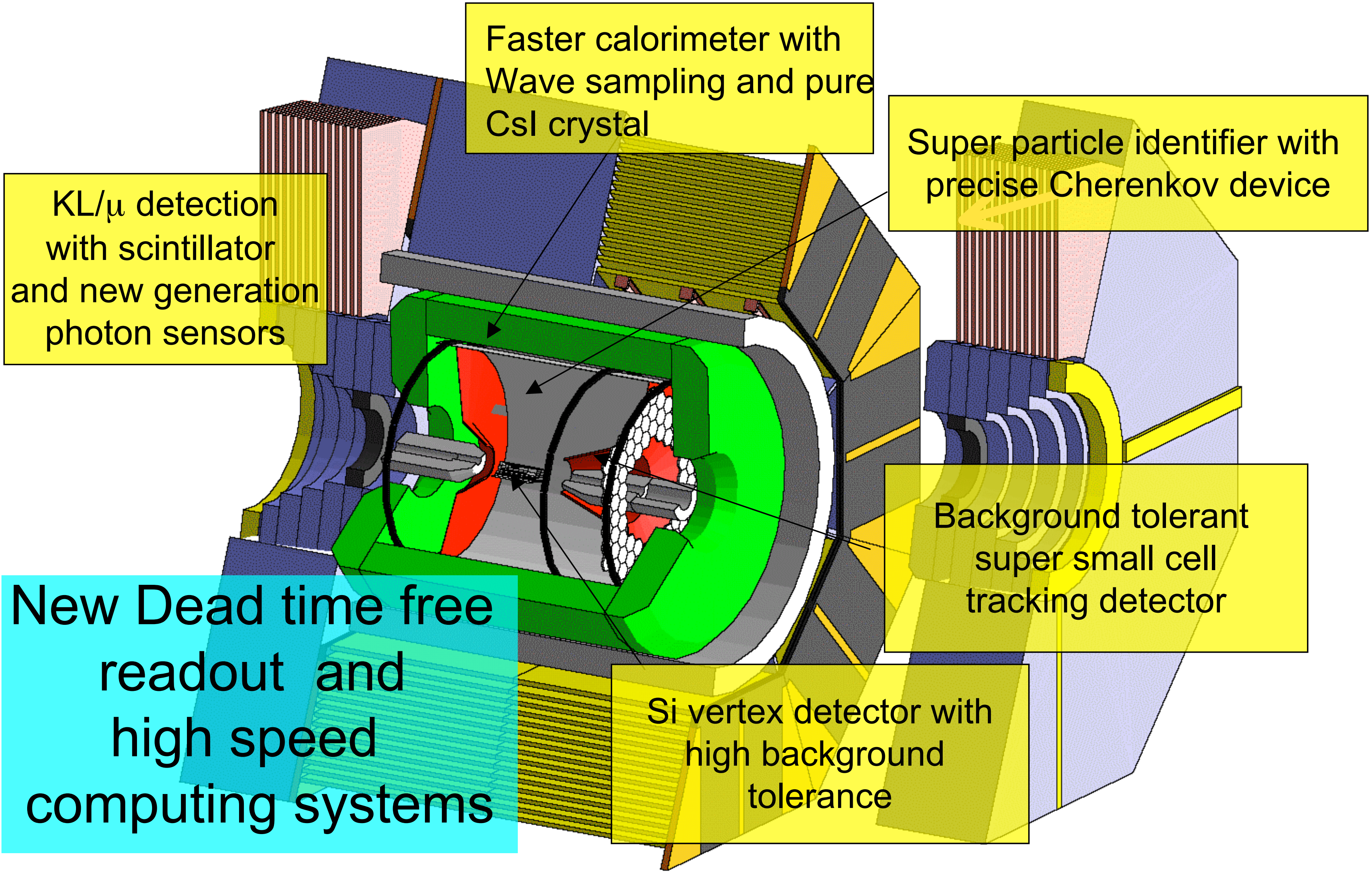
- **Higher background ($\times$20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate ($\times$50)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low p μ identification ← $s_{\mu\mu}$ recon. eff.
  - hermeticity ← ν "reconstruction"

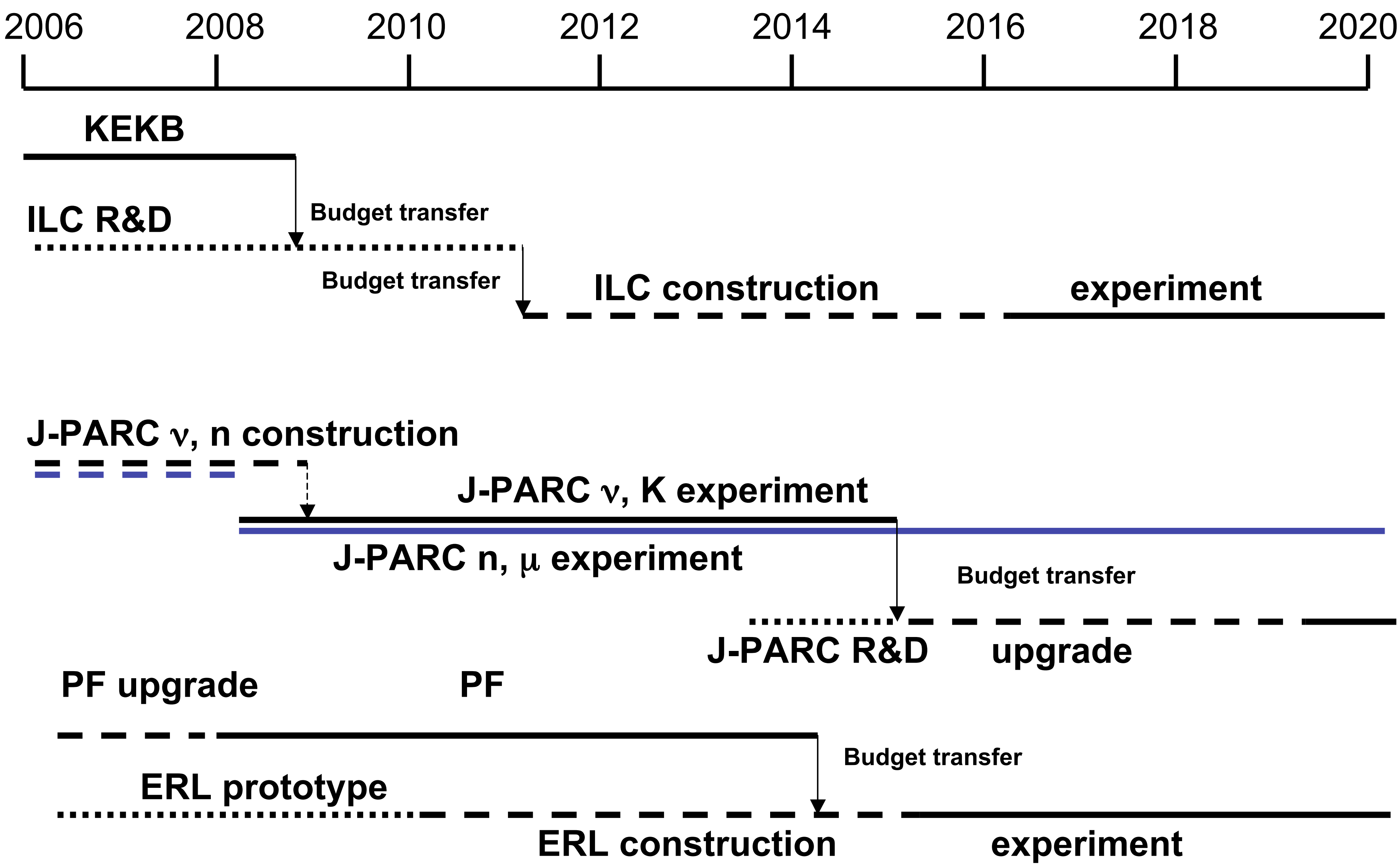


Possible solution:

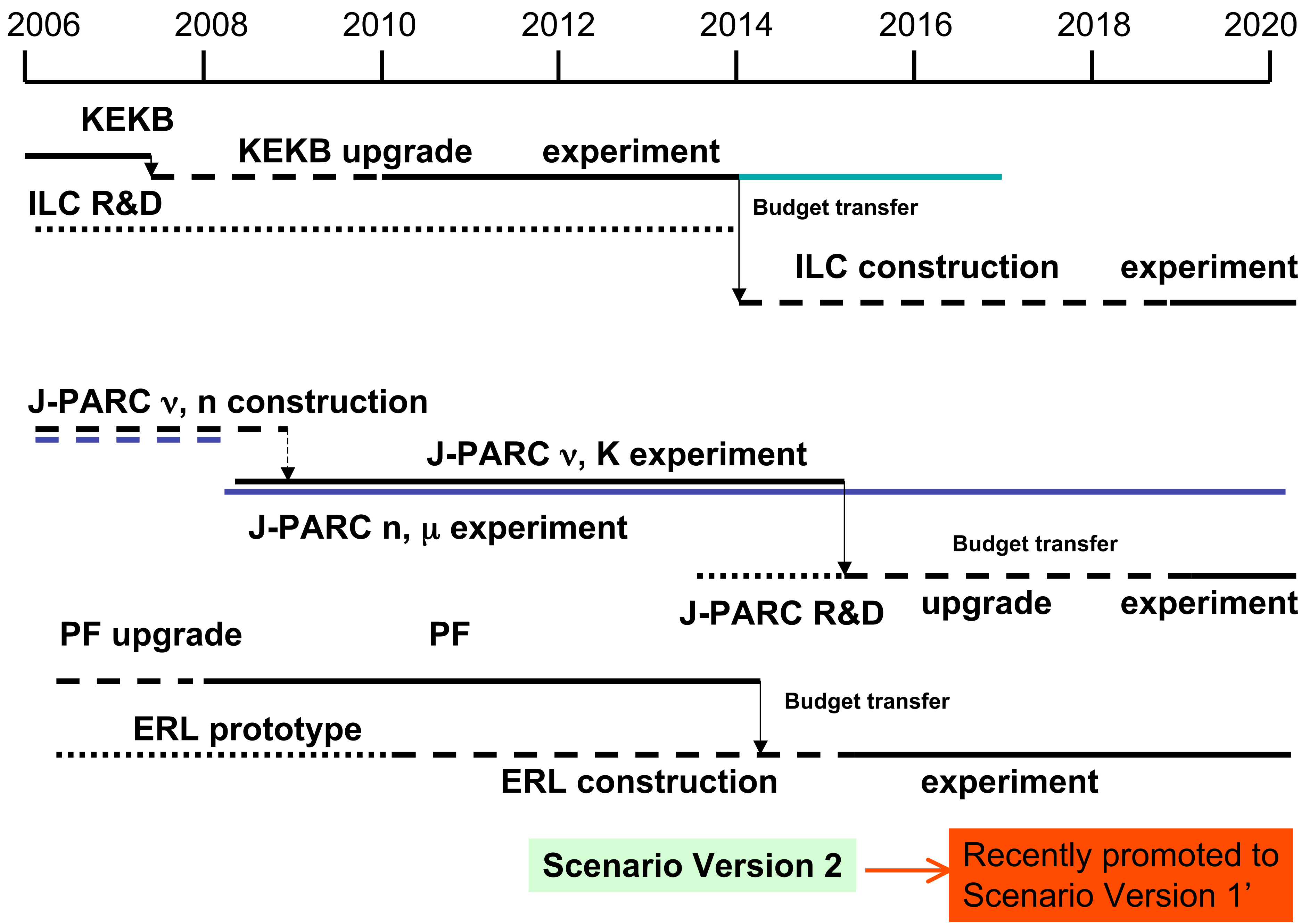
- Replace inner layers of the vertex detector with a silicon striplet detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter by pure CsI.
- Faster readout electronics and computing system.

Super Belle


Faster calorimeter with Wave sampling and pure CsI crystal
Super particle identifier with precise Cherenkov device
KL/μ detection with scintillator and new generation photon sensors
Background tolerant super small cell tracking detector
Si vertex detector with high background tolerance
New Dead time free readout and high speed computing systems



Scenario Version 1


2006
2008
2010
2012
2014
2016
2018
2020
KEKB
KEKB upgrade
experiment
Budget transfer
ILC R&D
ILC construction
experiment
J-PARC ν, n construction
J-PARC ν, K experiment
J-PARC n, μ experiment
Budget transfer
J-PARC R&D
upgrade
experiment
PF upgrade
PF
Budget transfer
ERL prototype
ERL construction
experiment
Scenario Version 2
Recently promoted to Scenario Version 1’

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 $L \sim 10^{36}$ 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)…
- Two possible approaches:
  - High current + crab crossing → SuperKEKB
  - Low β and low ε + crab waist → LC SuperB
- SuperKEKB upgrade and LC inspired SuperB have been proposed.

Goal: $\int L\, dt$ = 50-100 ab^{-1}

- Most of the interesting measurements will be limited by unavoidable systematics when we reach 50-100 ab^{-1}.

Obs.	δ_{stat} with 50ab^{-1}	δ_{syst} with 50ab^{-1}	Theory err.
sin2ϕ_1	0.004	0.014	~0.01
ϕ_2	1.2^o	a few ^{o}	
ϕ_3	1.2^o	O(1) ^{o}	
$\lvert V_{ub}\rvert$	1%	~1%	~5 %
$S_{\phi Ks}$	0.023	0.020	
$A_{\phi Ks}$	0.016	0.018	
$S_{\eta' Ks}$	0.013	0.020	
$A_{\eta' Ks}$	0.009	0.017	
DCPV in $b \to s\gamma$	0.003	0.002	0.003

High current approach

$$\frac{\sqrt{\varepsilon_x \beta_x}}{\theta \sigma_z} > 1 \text{ or } \theta = 0$$

$$L \sim \frac{N^2}{\sqrt{\varepsilon_x \beta_x \varepsilon_y \beta_y}}$$

$$\xi_x \sim \frac{N}{\varepsilon_x}$$

$$\xi_y \sim N \sqrt{\frac{\beta_y}{\varepsilon_x \beta_x \varepsilon_y}}$$

$$\beta_y > \sigma_z$$

Keep ε_x, β_x and $\sqrt{\frac{\beta_y}{\varepsilon_y}}$.

$$\varepsilon_y \beta_y \to 0$$

$$L \to \infty$$

$\beta_y > \sigma_z$ limits luminosity

- High current, Small coupling
- Choice of operating point

$$\nu_x \to +0.5 \quad \xi_y \to \infty \quad N \to \infty$$

$$L \to \infty$$

Low emittance approach

$$\frac{\sqrt{\varepsilon_x \beta_x}}{\theta \sigma_z} < 1$$

$$L \sim \frac{N^2}{\theta \sigma_z \sqrt{\varepsilon_y \beta_y}}$$

$$\xi_x \sim \frac{N}{\theta \sigma_z} \sqrt{\frac{\beta_x}{\varepsilon_x}}$$

$$\xi_y \sim \frac{N}{\theta \sigma_z} \sqrt{\frac{\beta_y}{\varepsilon_y}}$$

$$\beta_y > \frac{\sqrt{\varepsilon_x \beta_x}}{\theta}$$

Keep $\sqrt{\frac{\beta_y}{\varepsilon_y}}$, $\sqrt{\frac{\beta_x}{\varepsilon_x}}$ and $\frac{\sqrt{\varepsilon_x \beta_x}}{\beta_y}$.

$$\varepsilon_y \beta_y \rightarrow 0$$

$$L \rightarrow \infty$$

- Bunch length is free.
- Small beta and small emittance are required.

Crab crossing and crab waist

- Head-on collision is effectively realized by crab cavity, while crab waist control nonlinear interaction induced by crossing angle.
- For high current approach, either scheme will work(, but not both at once).
- For low emittance approach, only crab waist scheme is applicable.

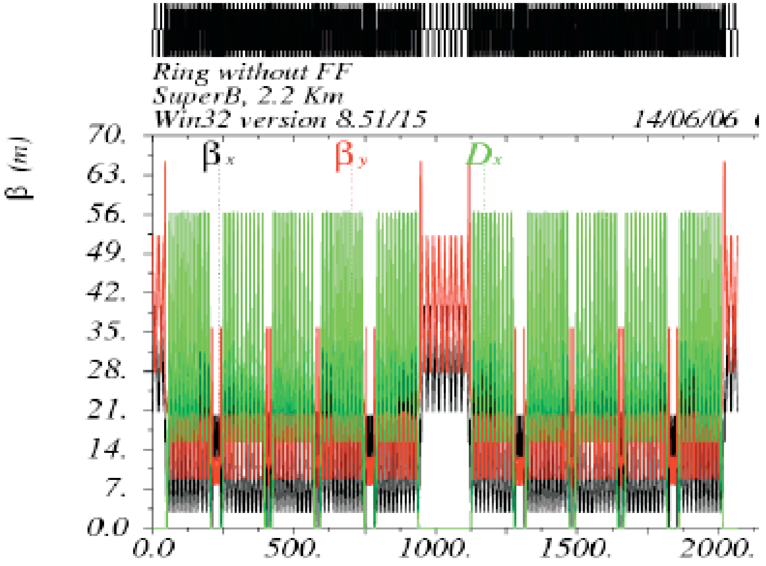
Beam-beam parameter
becomes too high

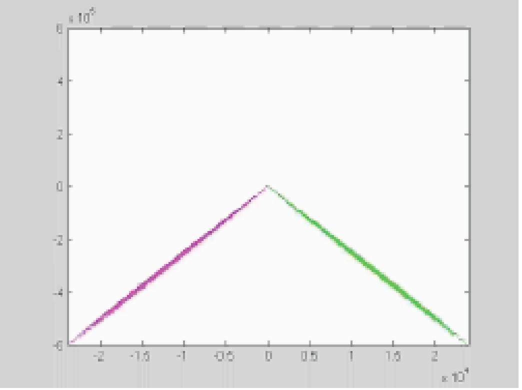
Consensus in J-HEP community

- First priority is to realize ILC, and its R&D should be boosted. On the other hand, flavor physics programs (SuperKEKB and ν at J-PARC) should be carried out as physics program before ILC (i.e., 2010's).

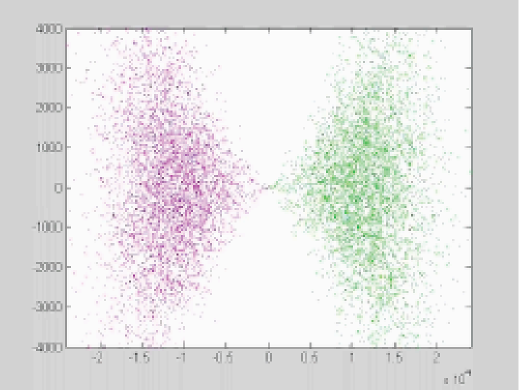
Ongoing Work

Biagini, Koop, Novohatski, Ohmi, Seeman, Seryi, Shatilov, Sullivan, Raimondi, Wienands, Wolsky, Zobov etc...

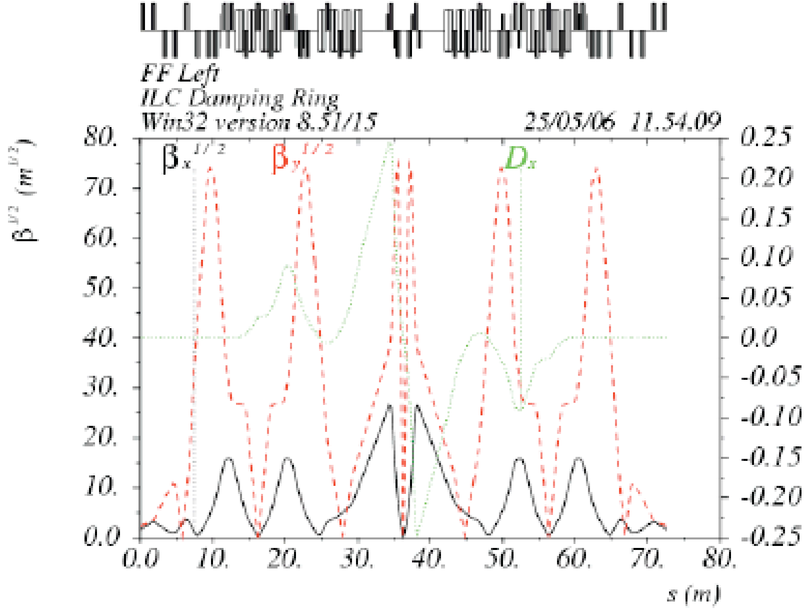


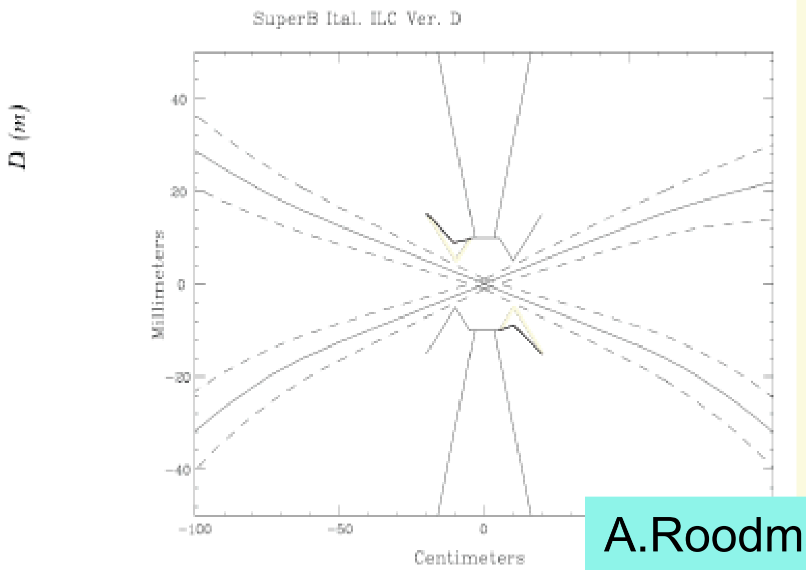


Horizontal Plane



Vertical Plane



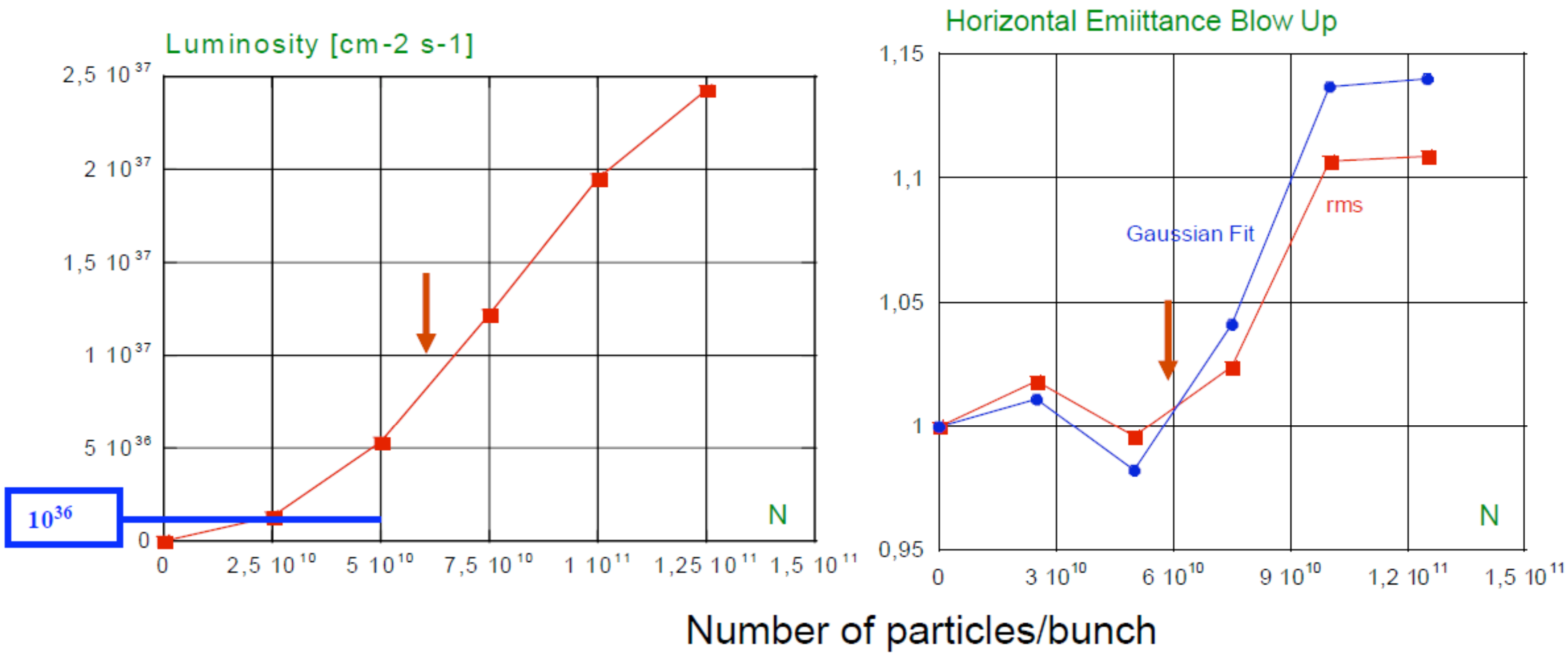


A.Roodman
BNM2006, Sep.06

More

- **Low background. Lower than in Babar**
- Wall power less than 50 MW(goal 25MW)
- Low beam energy spread for best background rejection as inPEPII or KEKB.
- Upgradable to higher performance
- Possibiliy of reusing existing machine components
- High level of Synergy with other machine projects as ILC.
- “ To be studied the possibility to run down to Φ ”

Upgradeable



M. Zobov, D. Shatilov

INFN Process

- Workshops
  - Nov 2005 Frascati
  - March 2006 Frascati
  - June 2006 SLAC
  - November 13-15 Rome
- Documents
  - INFN Roadmap Dec 2005
  - INFN Roadmap & CERN Strategy Mar 2006
- INFN Roadmap
  - SuperB identified as research direction
  - next step is a CDR-type document ~ at end of 2006
- see Web site http://www.pi.infn.it/SuperB

INFN-AE-05-08
SLAC-PUB-11676
physics/0512235

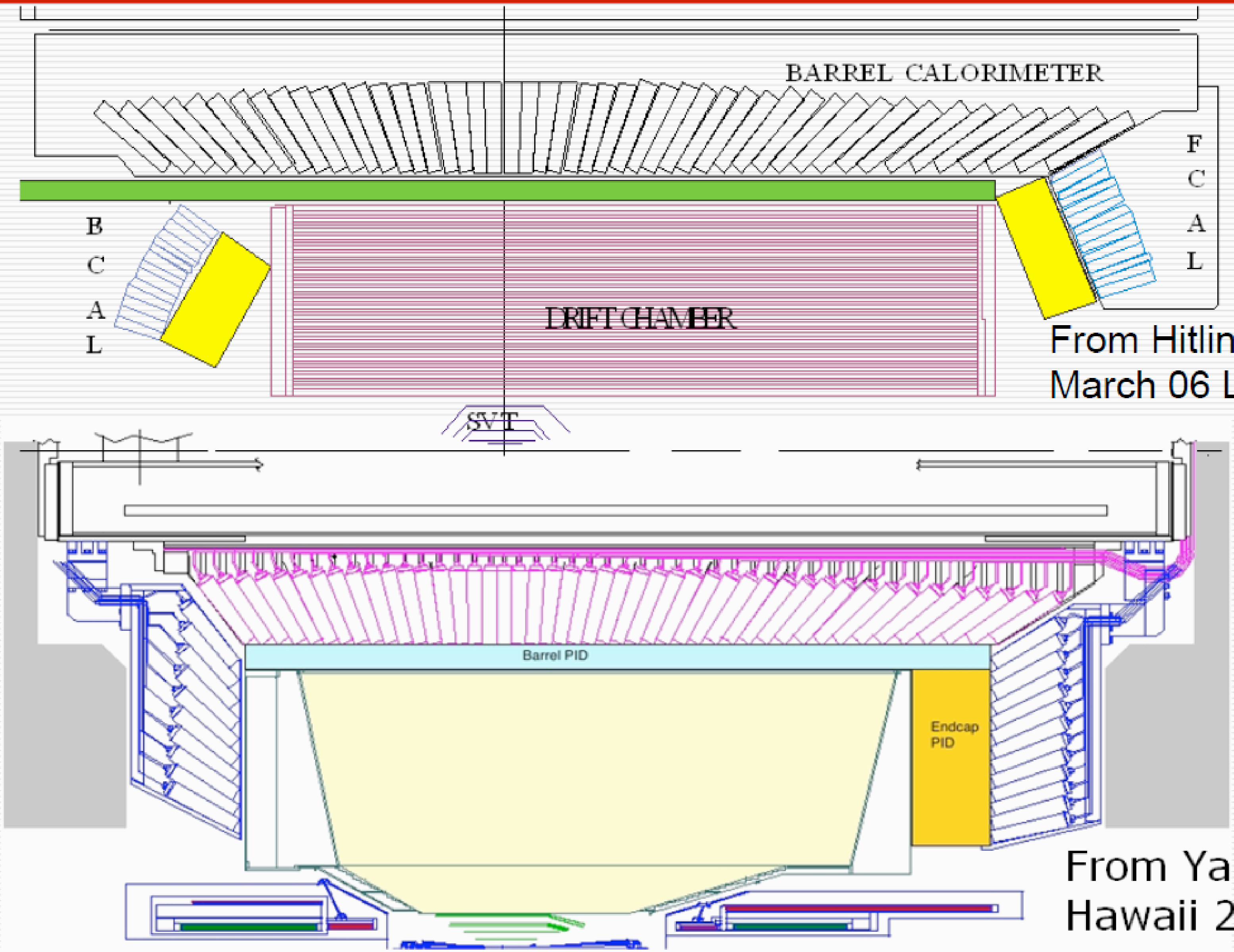
INFN Roadmap Report

***SuperB*: a linear high-luminosity *B* Factory**

INFN Roadmap Report

SuperB: a High Luminosity Flavour Factory

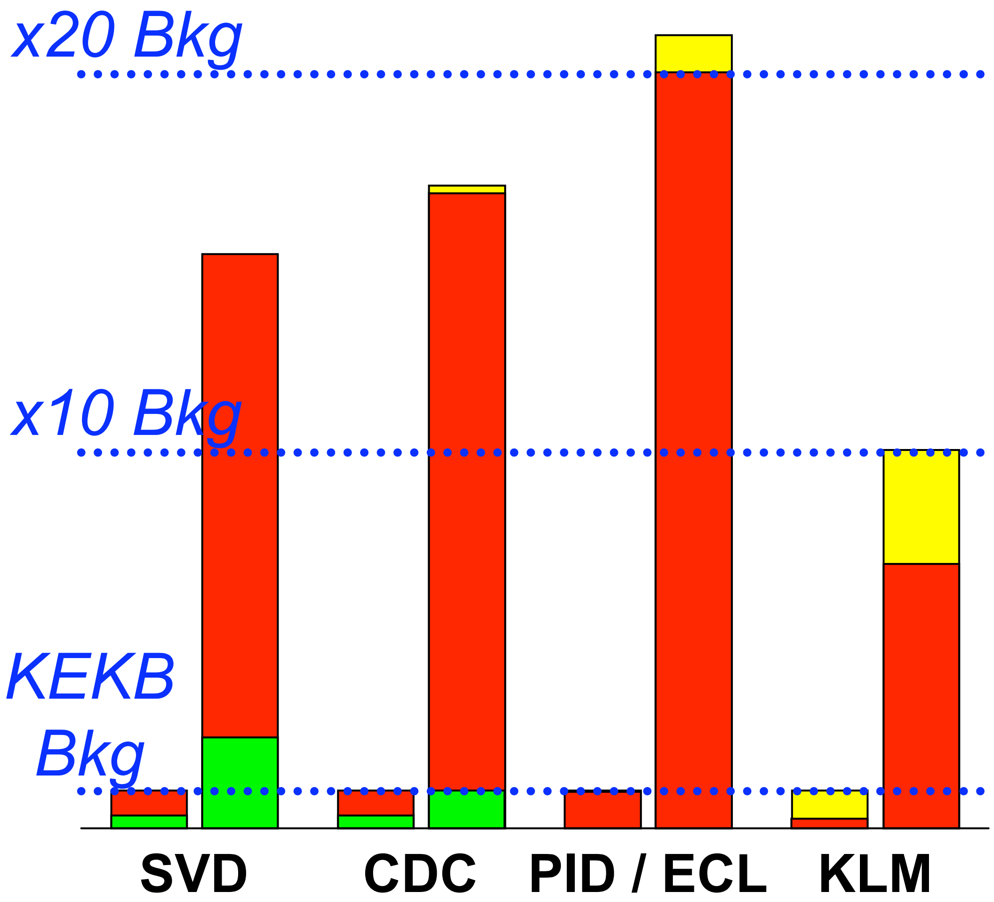
Comparison – *BABAR* and Belle for *SuperB*



From Hitlin's talk at March 06 LNF

From Yamauchi's Hawaii 2005 talk

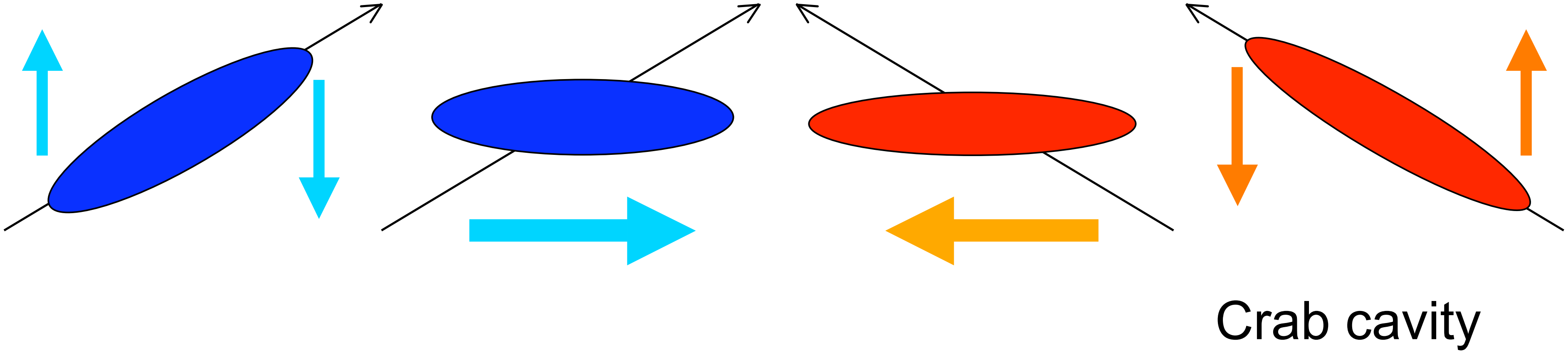
Detector issue: background



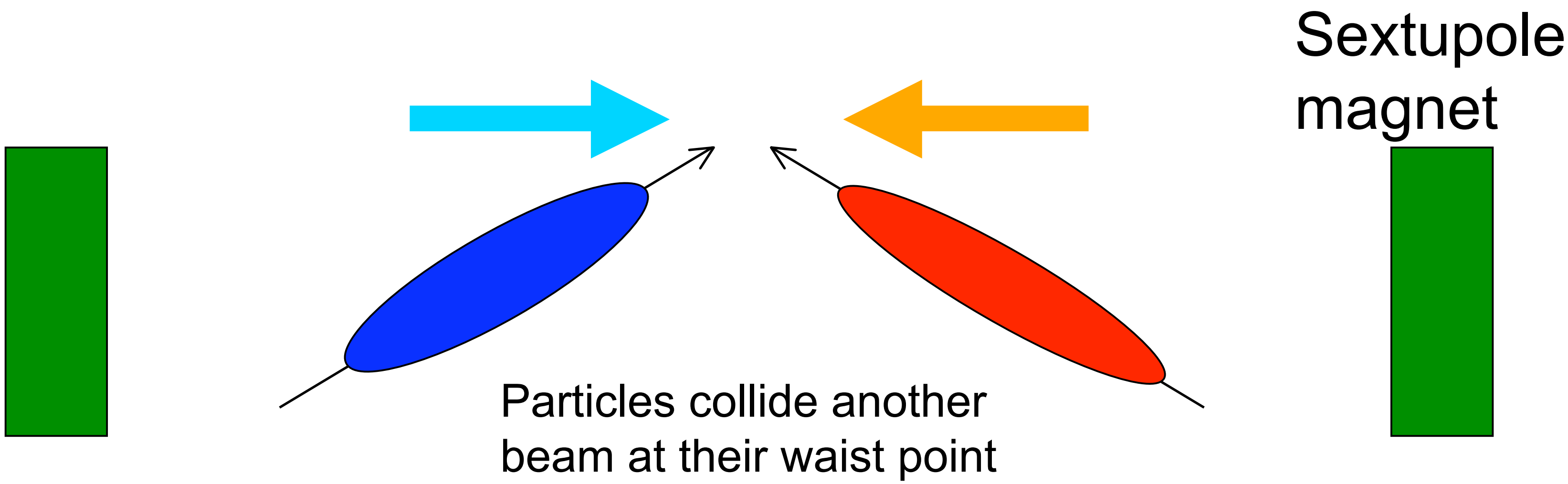
Shynchrotoron radiation
Beam-gas scattering (inc. intra-beam scattering)
Radiative Bhabha

	KEKB	SuperB
Luminosity ($10^{34}cm^{-2}sec^{-1}$)	1.7	80
HER curr. (A)	1.2	4.1
LER curr. (A)	1.6	9.4
vacuum (10^{-7}Pa)	~1.5	5
Bkg increase	-	
TRG rate (kHz)	0.4	
phys. origin	0.2	
Bkg origin	0.2	

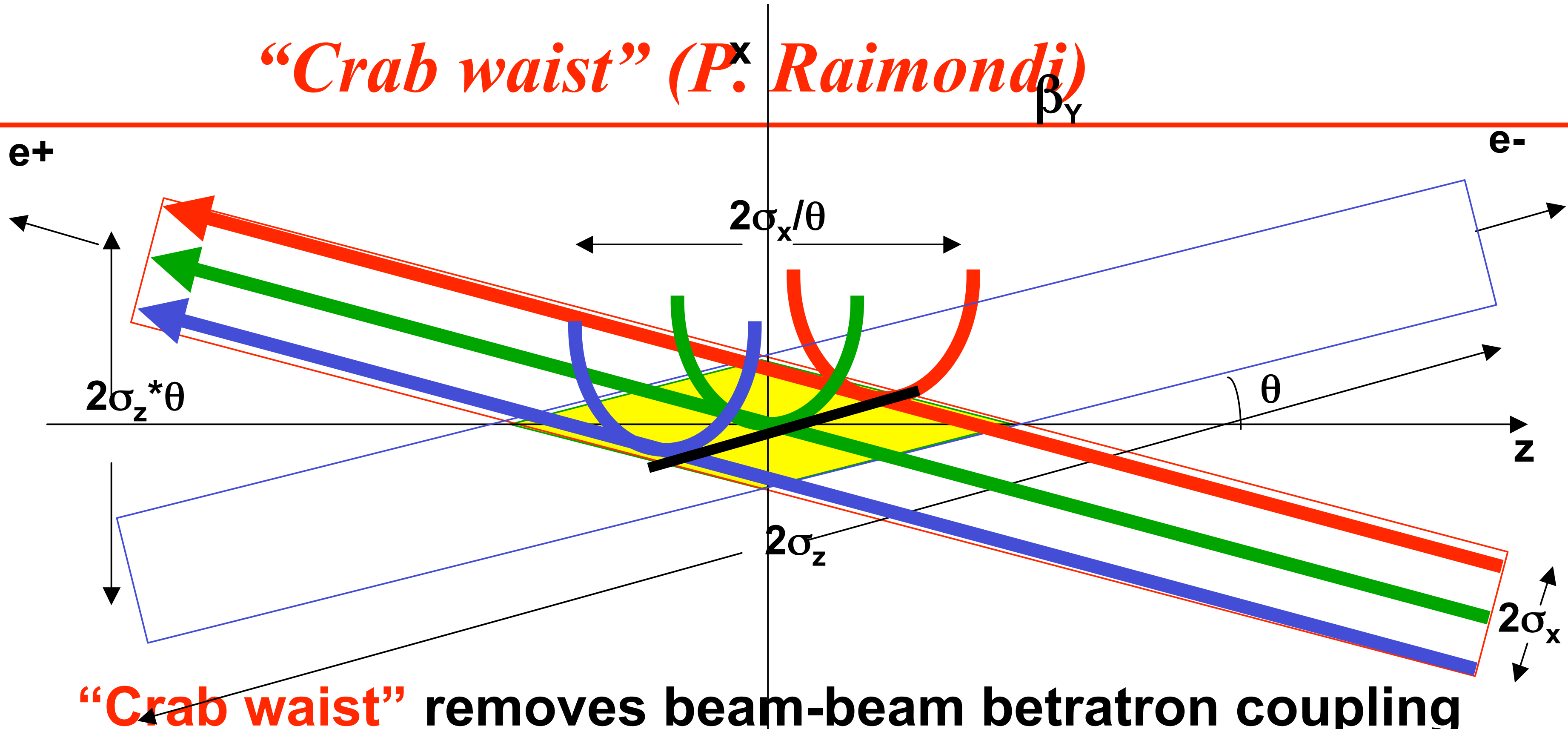
- Crab crossing



- Crab waist



“Crab waist” (P. Raimondi)



“Crab waist” removes beam-beam betratron coupling Introduced by the crossing angle

Vertical waist has to be a function of x:

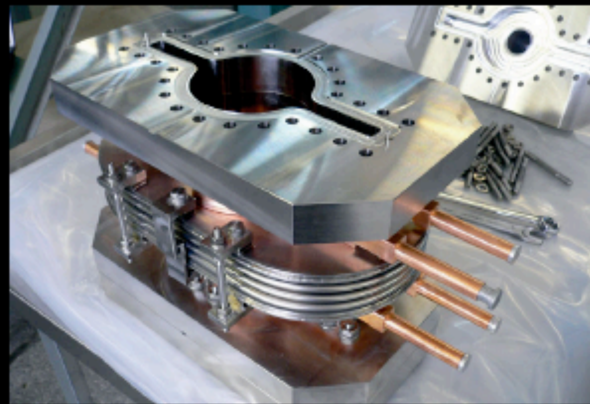
Z=0 for particles at $-\sigma_x$ ($-\sigma_x/2\theta$ at low current)

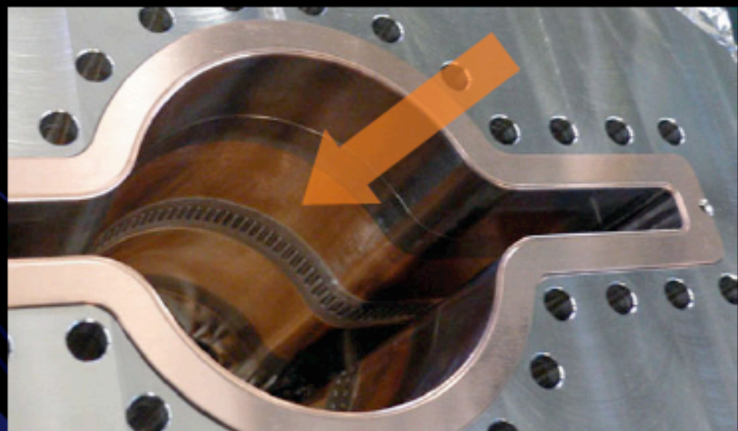
Z= σ_x/θ for particles at $+\sigma_x$ ($\sigma_x/2\theta$ at low current)

Crabbed waist realized with a sextupole in phase with the IP in X and at $\pi/2$ in Y

2. Bellows Chamber and Gate Valve

- Application of Ver.2 to antechamber-type bellows
  - Manufactured at BINP (2005)
  - Copper cooling channel
    - Improve cooling of teeth
  - Two bellows chamber were installed into LER wiggler (2005).
  - No problem was found up to 1.7 A.





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

$$L = \frac{\gamma_{\pm}}{2 e r_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

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)