Super B factories

Shoji Uno （KEK）

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WIN05 Delphi, Greece

Contents

1. Physics motivation
2. Accelerator design
3. Proposed detector
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References

- Letter of Intent for KEK Super B Factory
  (KEK-Report 2004-4, http://belle.kek.jp/superb/)
- Physics at Super B Factory(hep-ex/0406071)

- The Discovery Potential of a Super B Factory
  (SLAC-R-709)

Roadmap of B physics

Tevatron (m~100GeV) → LHC (m~1TeV)
B Factory (~10^{34}) → Super B Factory(4-7×10^{35})
Concurrent program

Better understanding for New Physics

Anomalous CPV in $b \to s\bar{s}s$

sin2ϕ_1, CPV in $B \to \pi\pi$, ϕ_3, V_{ub}, V_{cb}, $b \to s\gamma$, $b \to sll$, new states etc.

Study of NP effect in B and τ decays

Precise test of SM and search for NP

Yes!!

Discovery of CPV in B decays

time or integrated luminosity

~50 ab^{-1}

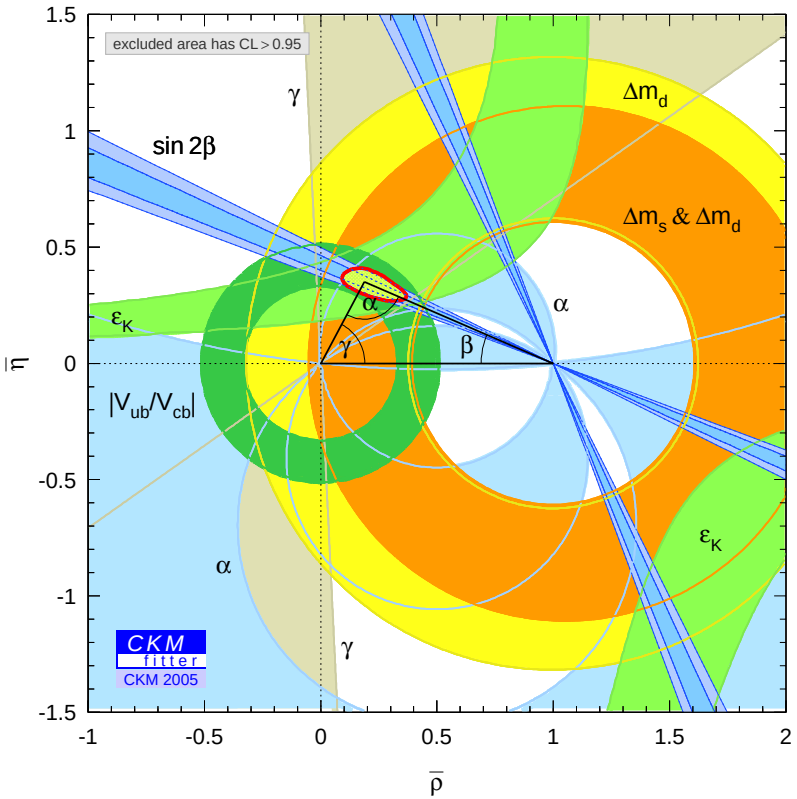
NP discovered at LHC (2010?)

~1 ab^{-1}

Now
~0.5 ab^{-1}

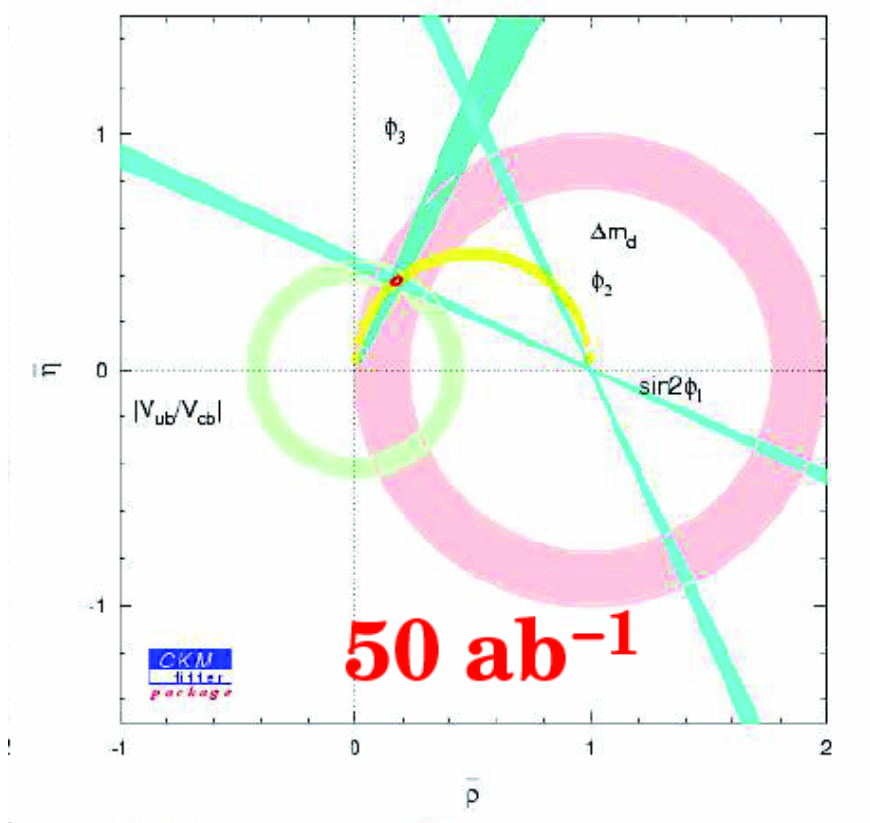
CKM Unitarity Triangle

Present



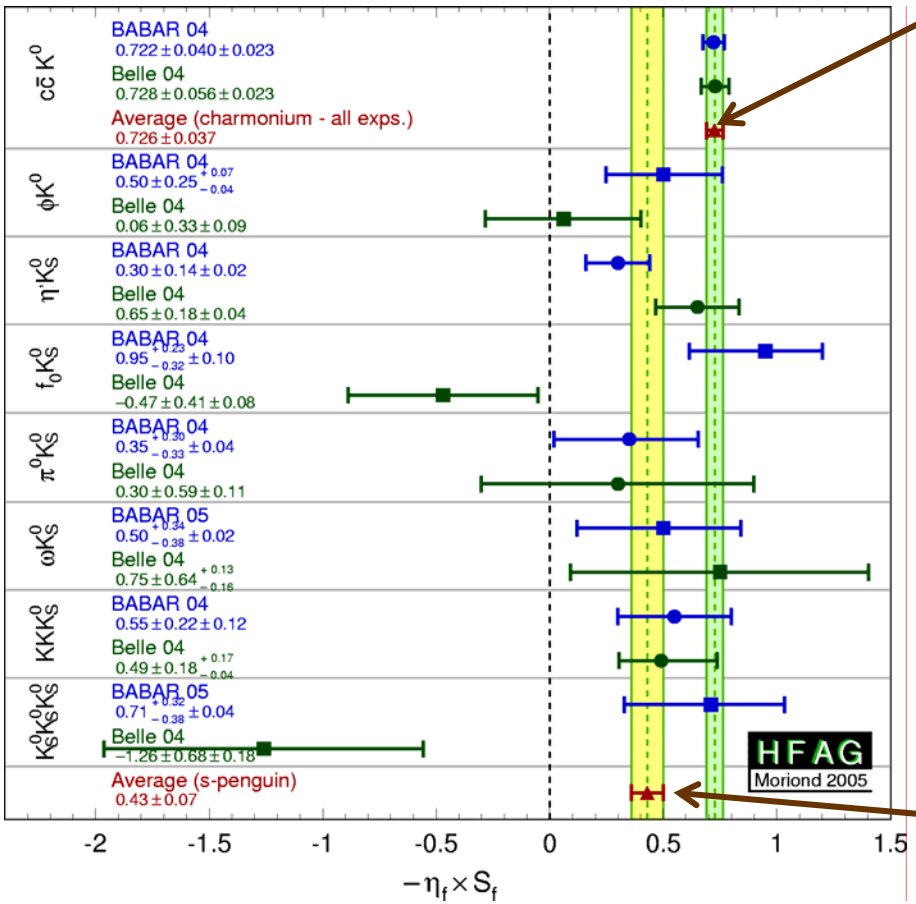
HFAG
hep-ex/0505100

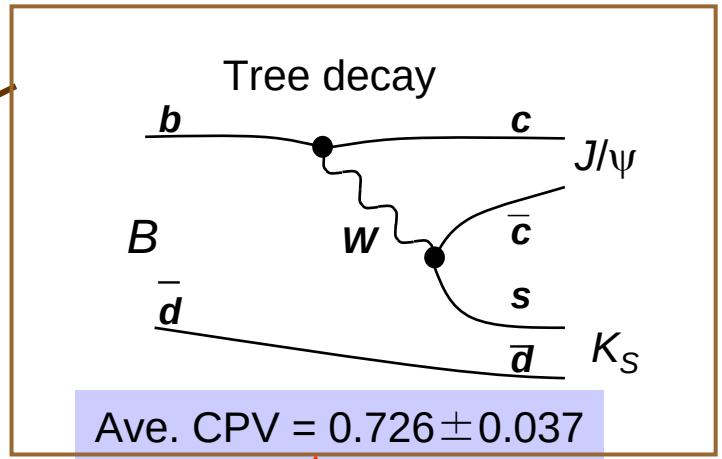
Super B Factory



Anomalous CPV hints new physics?

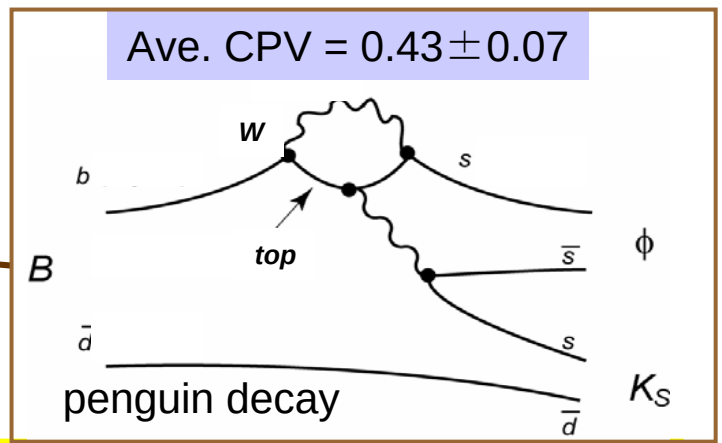
hep-ex/0505100





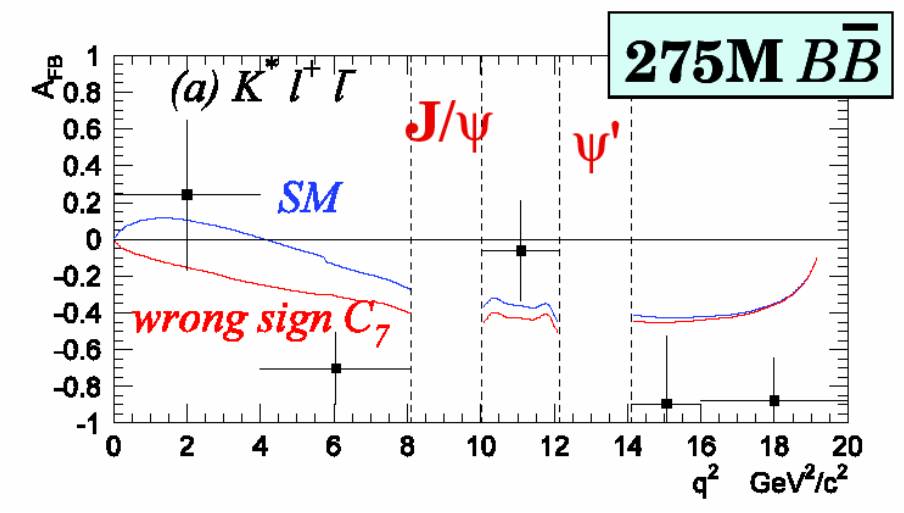
equal if only SM

3.7σ deviation observed



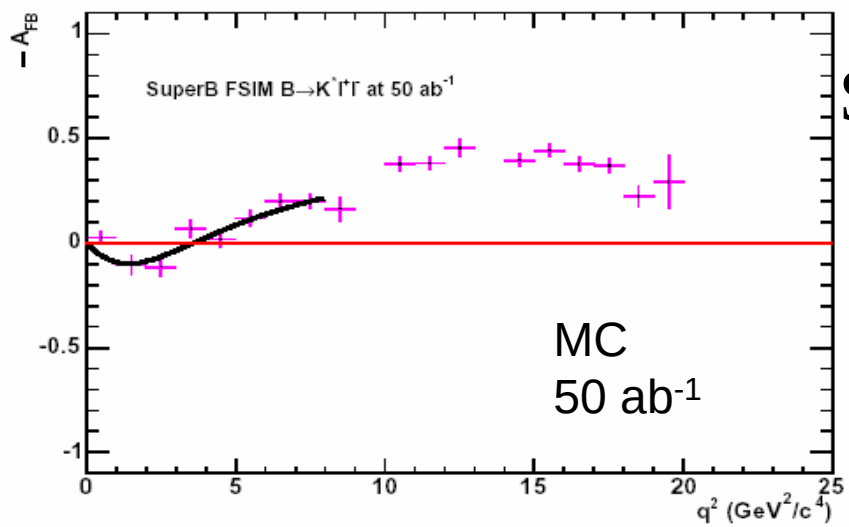
$B \to K^* l^+ l^-$ FB Asymmetry

- Sensitive test of new physics
- Can determine sign of C7
- Can measure C9 and C10



Belle

hep-ex/0410006

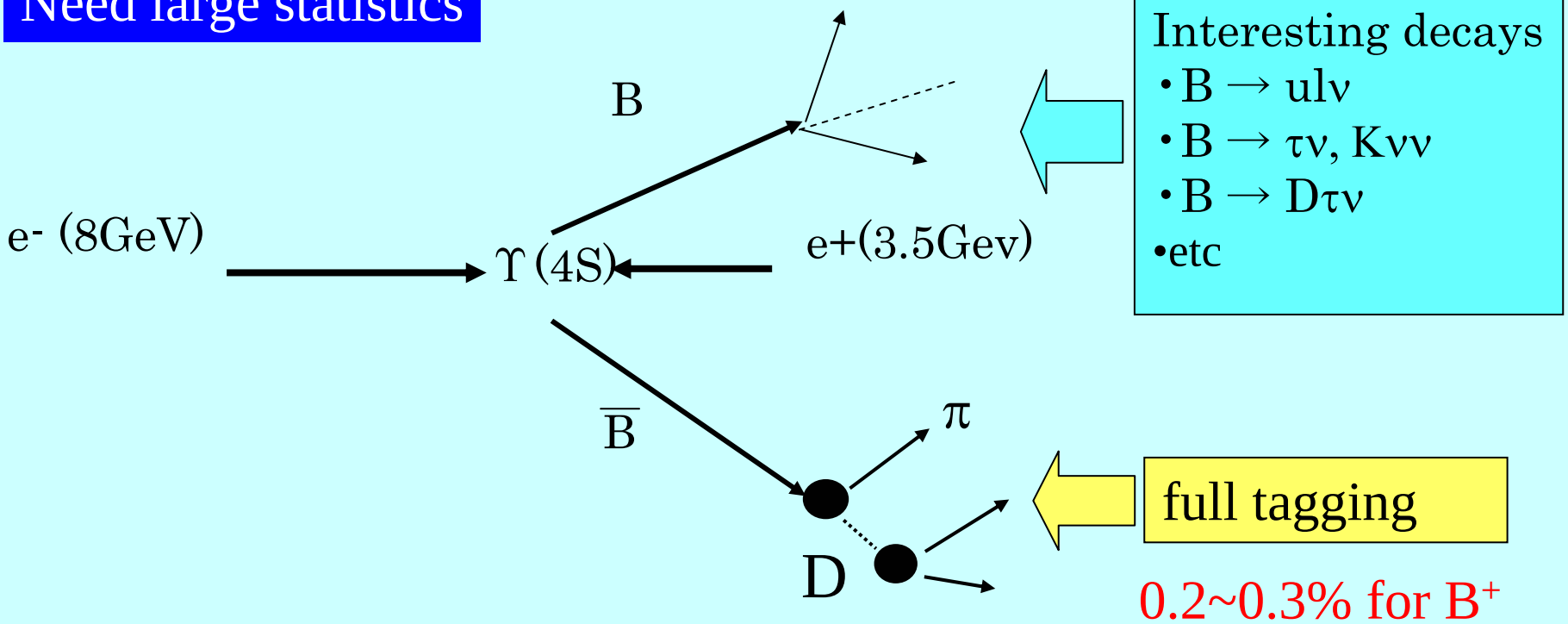


Super B factory

Opposite sign

“B-meson beam” with full reconstruction

Unique at Υ(4S)
Need large statistics



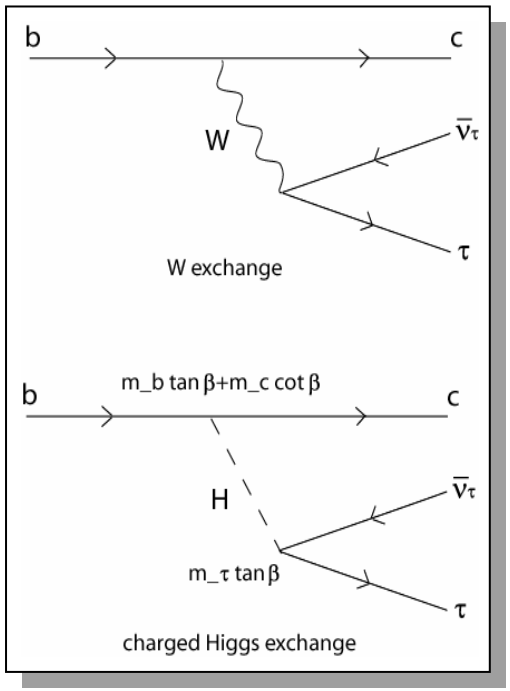
Interesting decays
- B → ulν
- B → τν, Kνν
- B → Dτν
- etc

full tagging

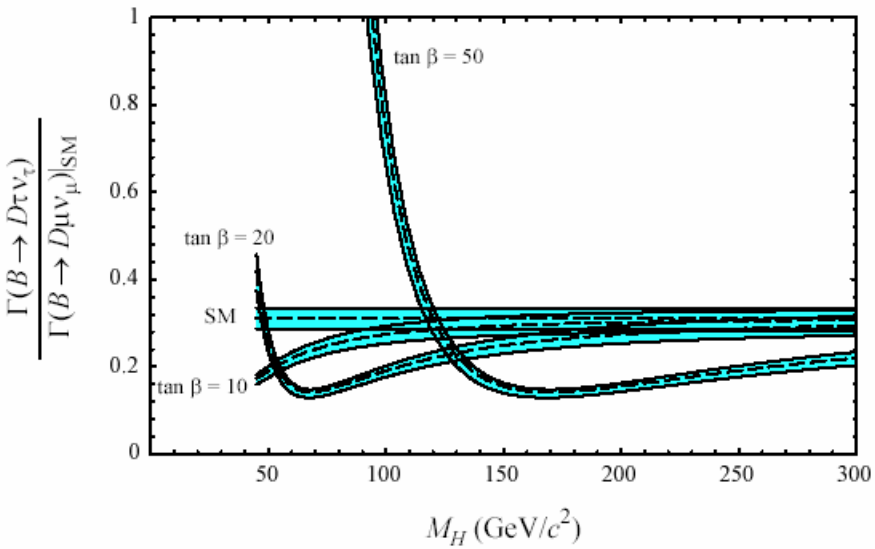
0.2~0.3% for B^+

Charged Higgs in tree decay

$B \to D^{(*)}\tau\nu$ vs. $D^{(*)}\mu\nu$



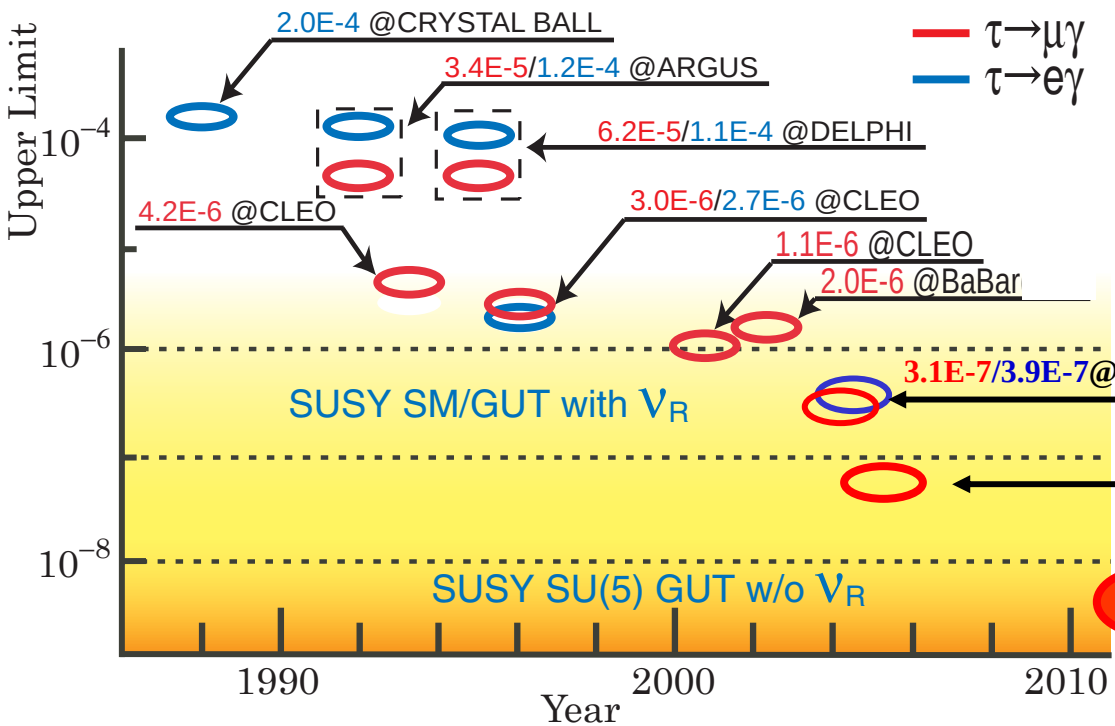
- Large BF of $O(1)$%
- Uncertainty in form factor cancels in the ratio $\Gamma(B \to D\tau\nu)/\Gamma(B \to D\mu\nu)$.
- τ polarization is more sensitive to $H^{\pm}$.



$\delta(Br)/Br = 2.5\%$ at 50 ab^{-1}

τ physics

- ~5×10^{10} τ pairs with 50ab^{-1} → Super τ factory!



$\sigma(\tau^+\tau^-) \sim \sigma(BB)$

Search for LFV

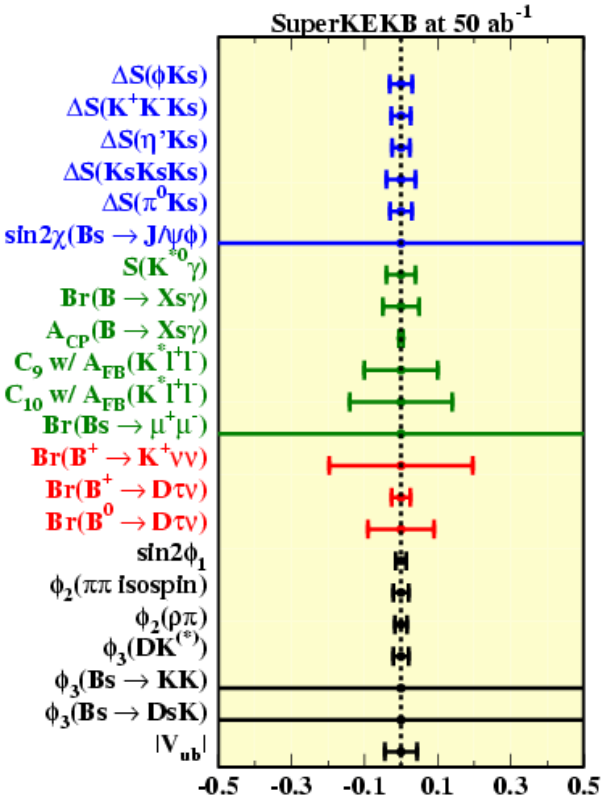
Recent BaBar result
hep-ex/0502032
$Br(\tau\rightarrow\mu\gamma) < 6.8\times10^{-8}$

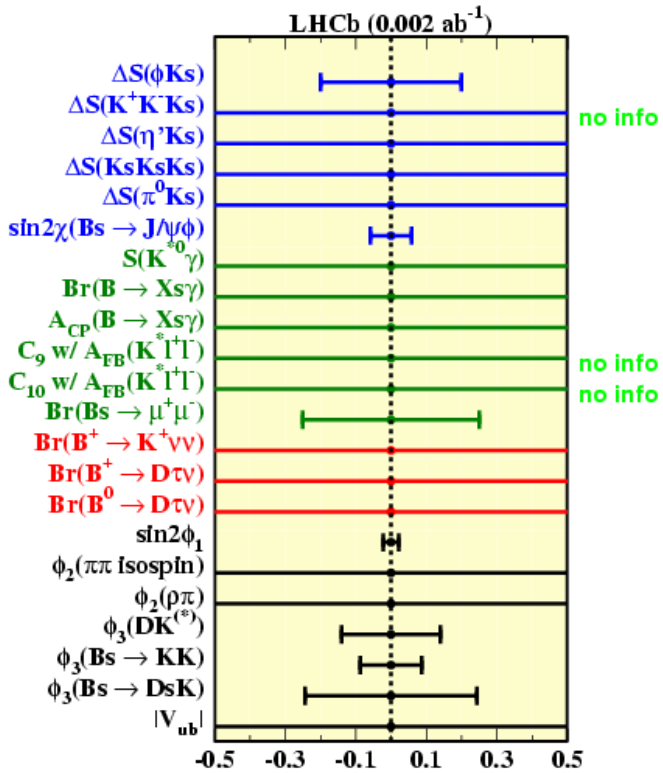
Super B Factory

Super B factory has a chance to find these decay modes.
If not, the upper limit will reach to O(10^{-9}).

Comparison with LHCb

LoI Executive Summary Table 1

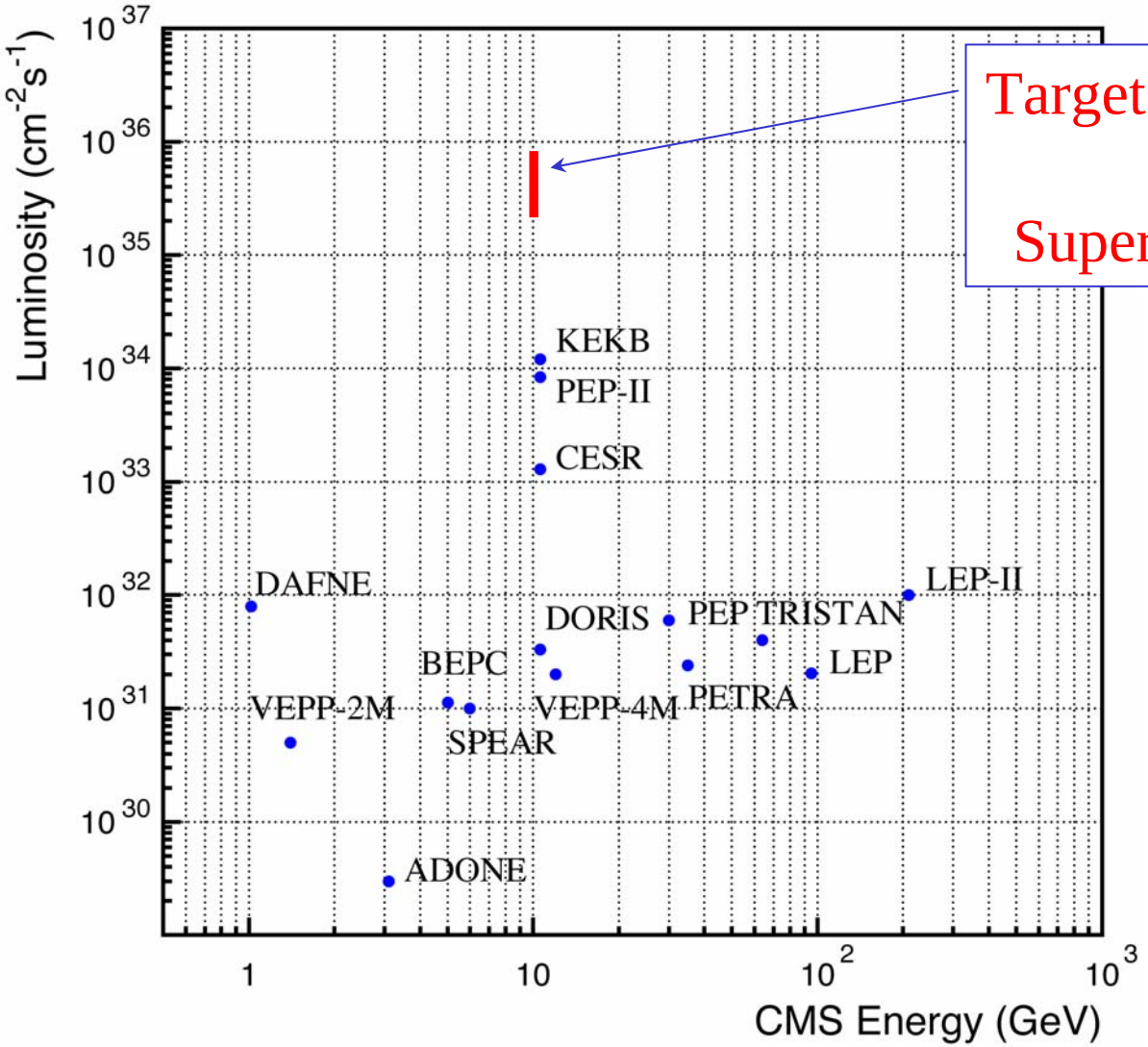




Super B factory
- All decay modes except for Bs
- Decay modes including $\pi^0/\gamma/\nu$

LHCb
- Bs decay
- Decay modes including leptons

Target Luminosity



Target Luminosity
for
Super B Factory

Super B factory Parameters

Stored current:
1.30/1.80A(KEKB)
1.55/2.45A(PEPII)
→ 4.1/ 9.4A(SuperKEKB)
→ 6.8/15.5A(SuperPEPII)
×4-7

Beam-beam parameter:
0.056(KEKB)
0.046(PEPII)
→ 0.22(SuperKEKB)
→ 0.11(SuperPEPII)
×2-4

Lorentz factor

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

Classical electron radius

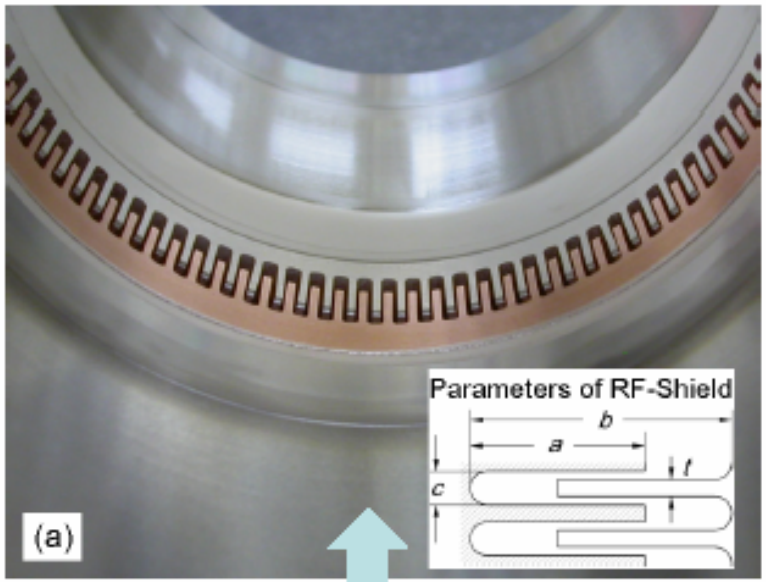
Beam size ratio

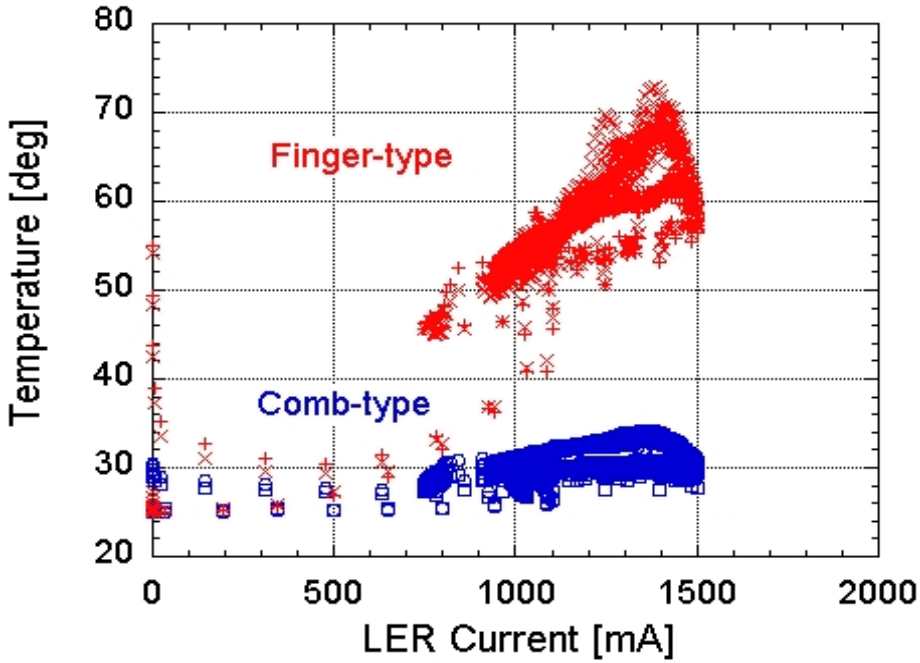
Geometrical reduction factors due to Crossing angle and hour-glass effect

Luminosity:
1.58×10^{34} $cm^{-2}sec^{-1}$(KEKB)
0.92×10^{34} $cm^{-2}sec^{-1}$(PEPII)
→ 4×10^{35} $cm^{-2}sec^{-2}$(SuperKEKB)
→ 7×10^{35} $cm^{-2}sec^{-2}$(SuperPEPII)
×30-80

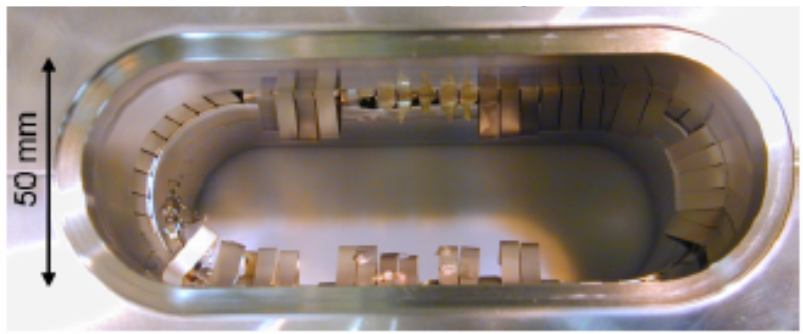
Vertical β* at the IP:
6.2/6.5 mm(KEKB)
11/11 mm(PEPII)
→ 3.0/3.0(SuperKEKB)
→ 1.5/1.5(SuperPEPII)
×2-7

Fight for Higher Beam Current



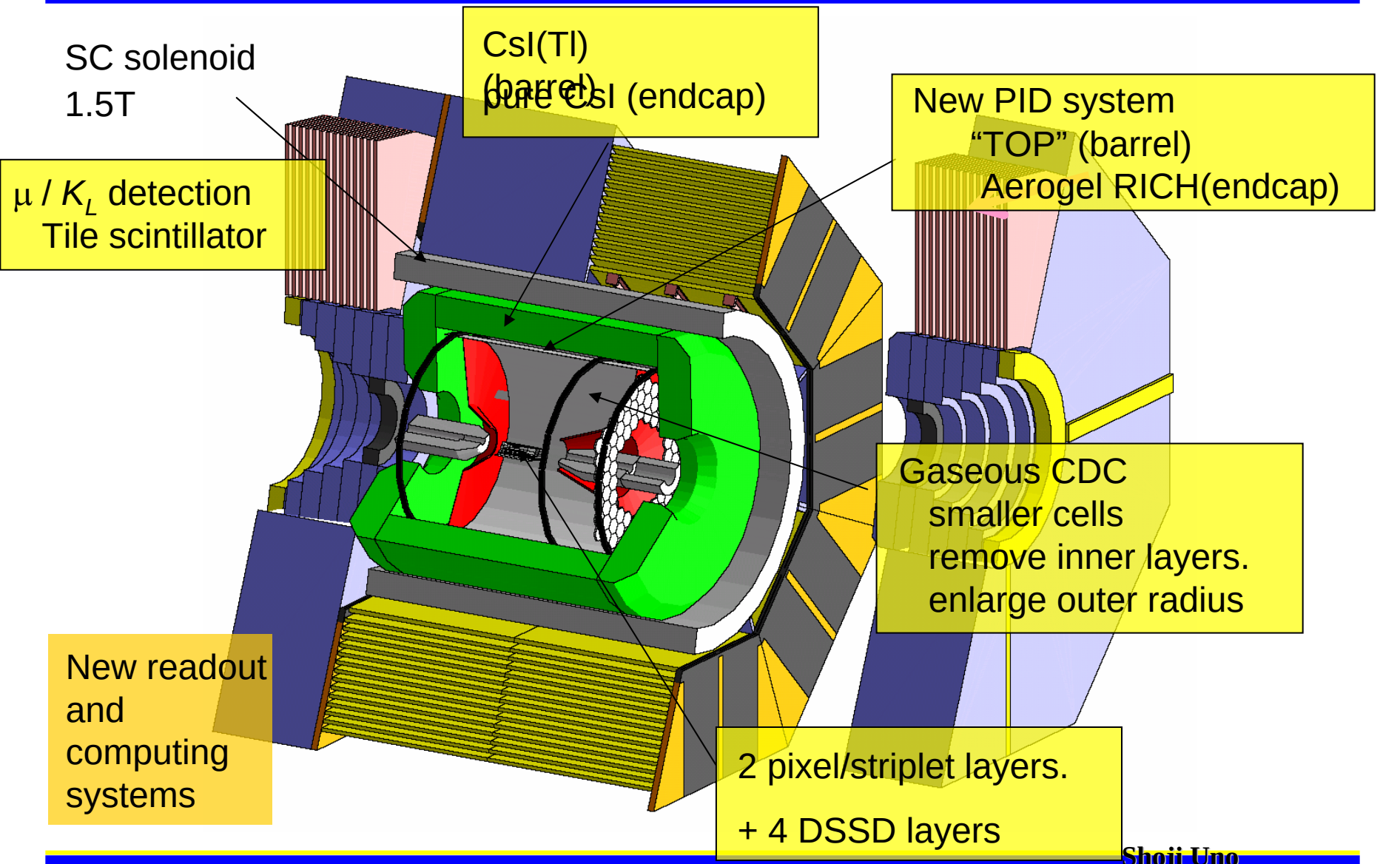


- High thermal strength
- Low impedance
- No sliding contact on the surface facing the beam



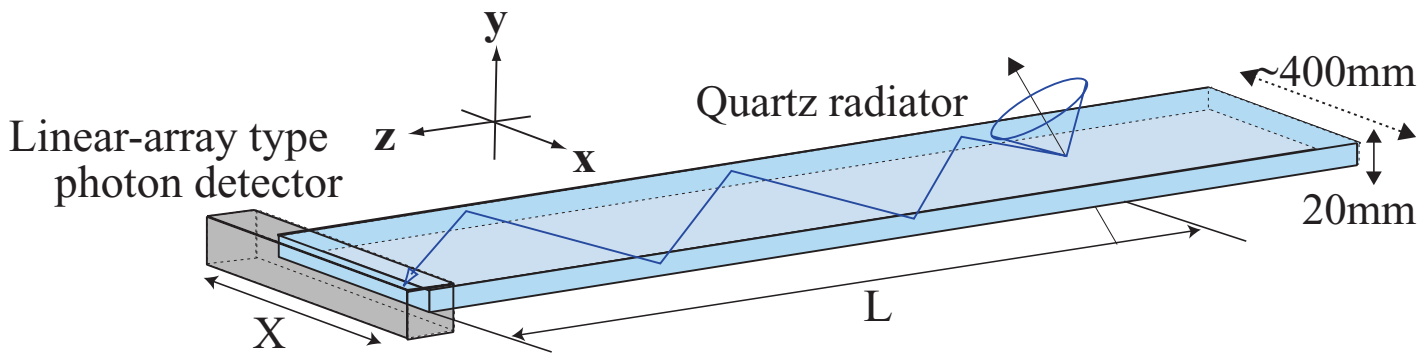
Comb-type bellows were installed in the LER (2004).

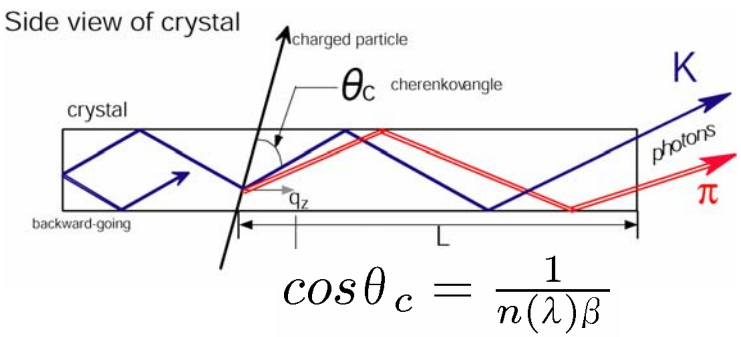
SuperBelle


SC solenoid
1.5T
CsI(Tl) (barrel)
pure CsI (endcap)
New PID system
"TOP" (barrel)
Aerogel RICH(endcap)
μ / K_L detection
Tile scintillator
Gaseous CDC
smaller cells
remove inner layers.
enlarge outer radius
New readout and computing systems
2 pixel/striplet layers.
+ 4 DSSD layers

New PID "TOP"

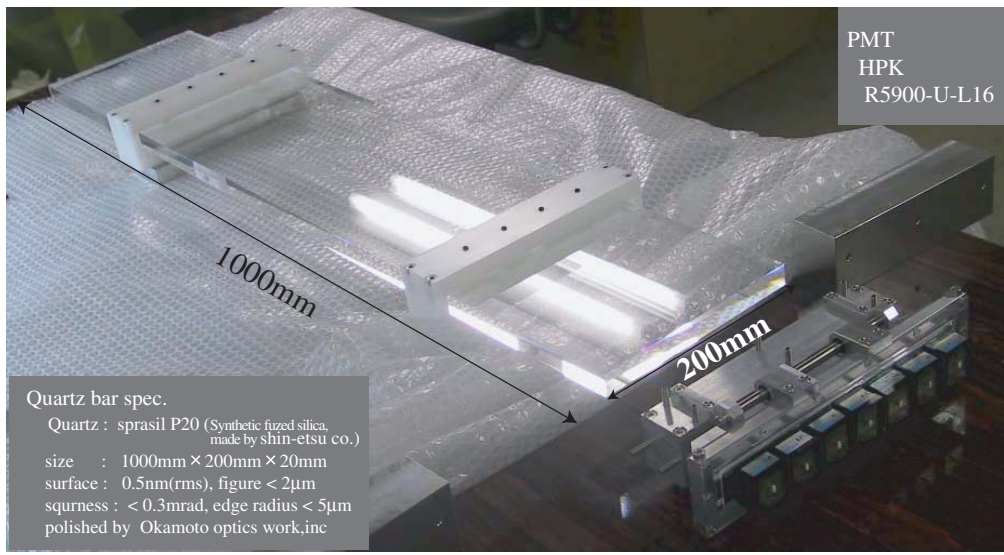
- Cherenkov ring imaging using detected time.



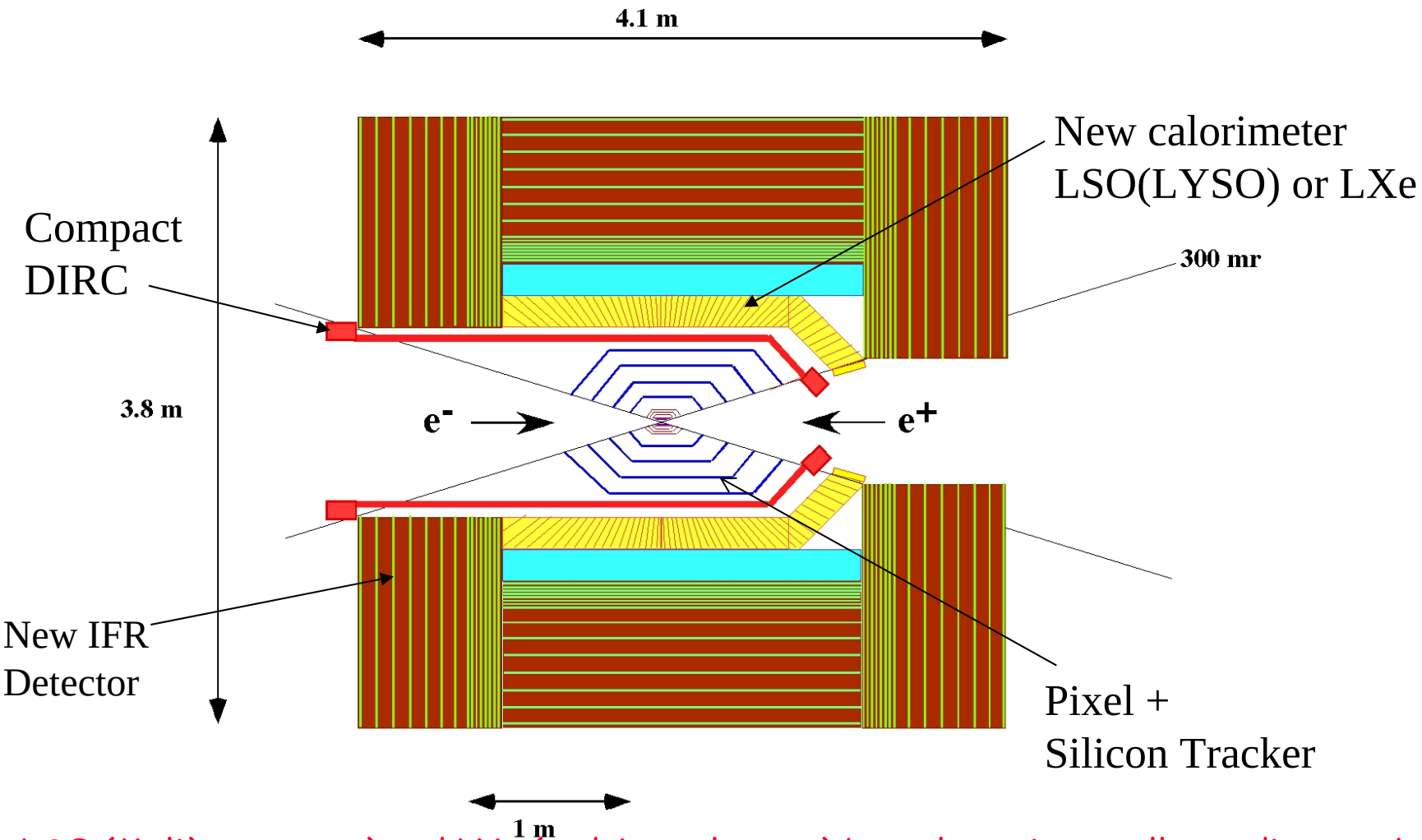


$$cos\theta_c = \frac{1}{n(\lambda)\beta}$$

Difference of path length
→Difference of
time of propagation (TOP)
(+ TOF from IP)

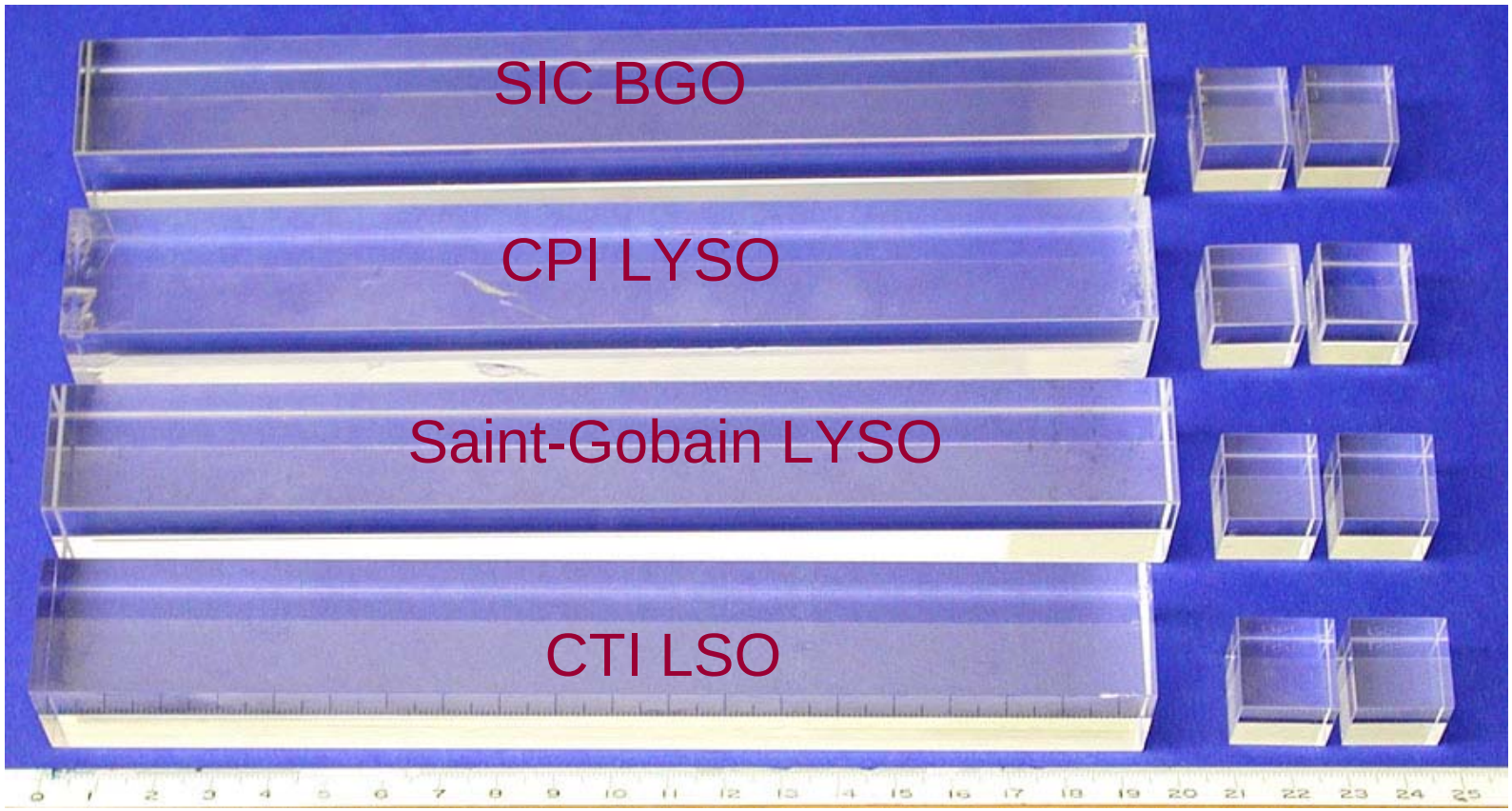


SuperBaBar



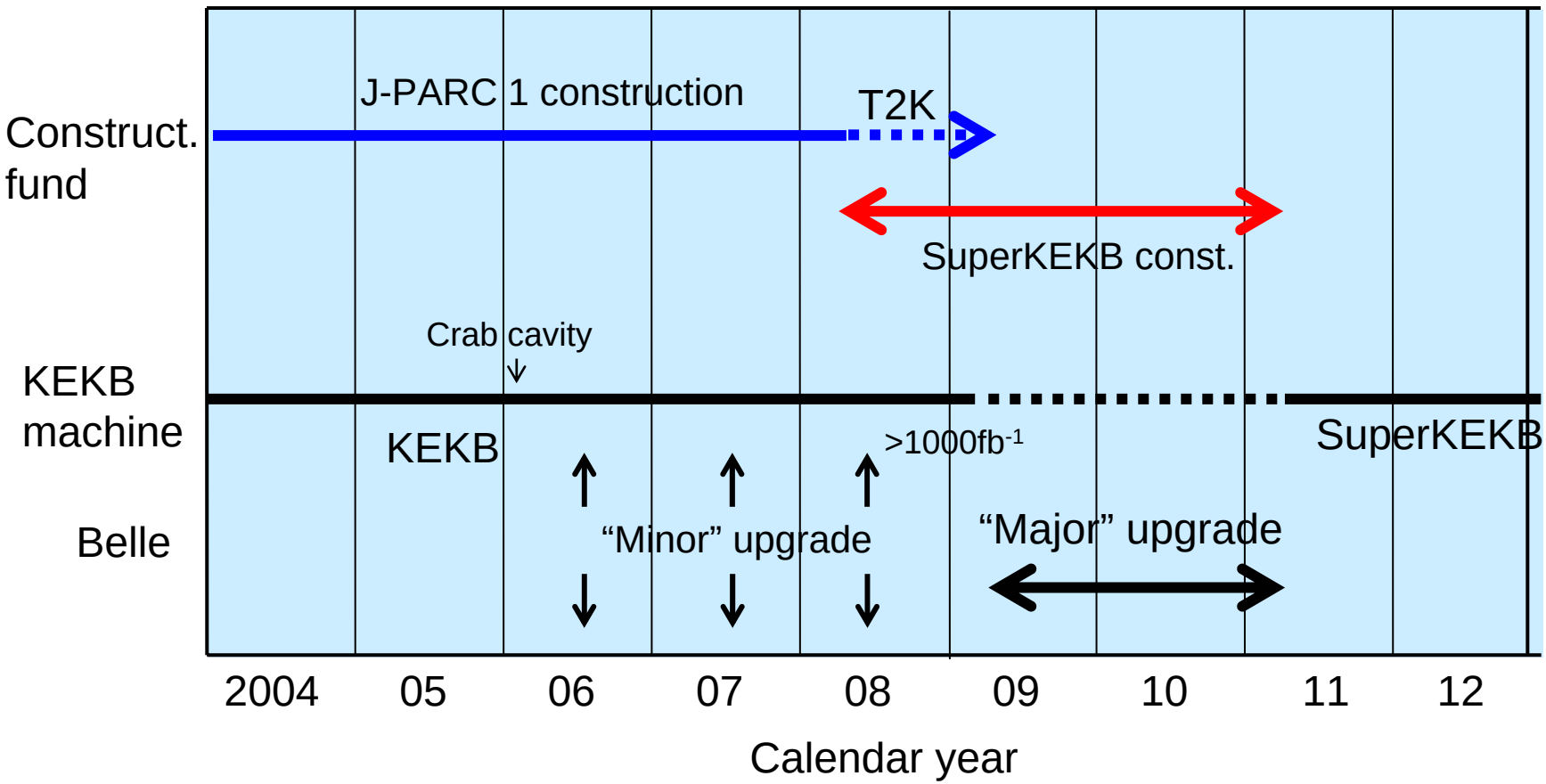
Both LSO (Molière r., cost) and LXe (rad. Length, cost) barrel require smaller radius tracker
A new detector would be smaller than *BABAR*/Belle; can, of course, fit into existing detectors

Tests of large crystals at Caltech



There is LSO/LYSO Mass Production Capability (PET)

Proposed Schedule



Possible Timeline for SuperPEPII

Super-B Program

R&D, Design, Proposals and Approvals → **Construction of upgrades to L = 5-7x10^{35}** → **Super B Operation**

$\int L dt \sim 10\ ab^{-1}/yr$

2001 2003 2005 2006 2008 2010 2011 2012

Construction

Installation

Commission

LOI **CDR**

P5

Planned PEP-II Program

$\int L dt = 140\ fb^{-1}$ (June 30, 2003)

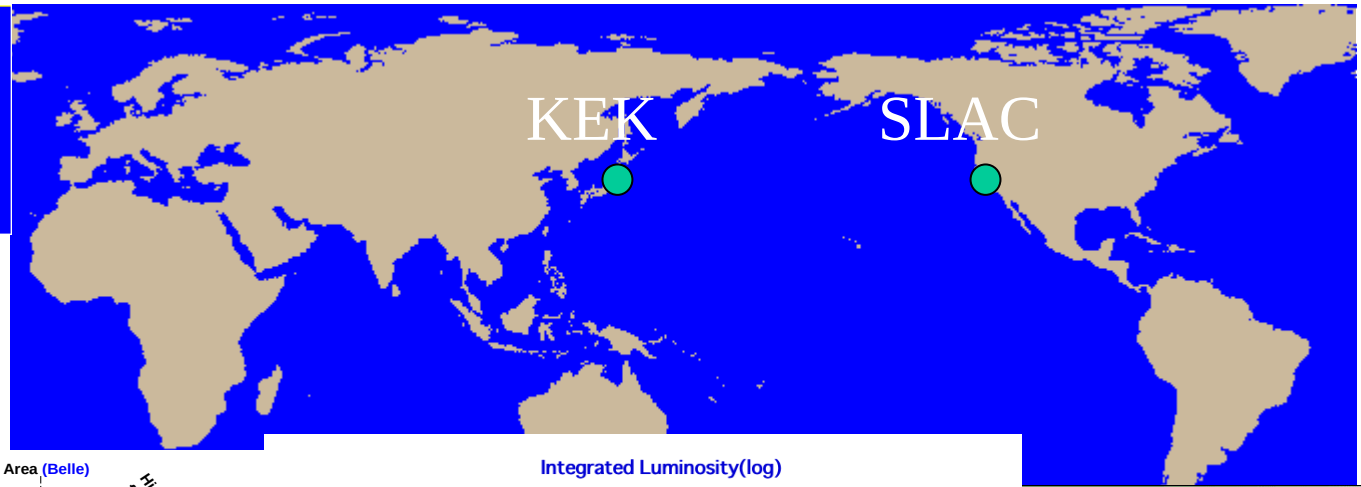
$\int L dt = 500\ fb^{-1}$ (End 2006)

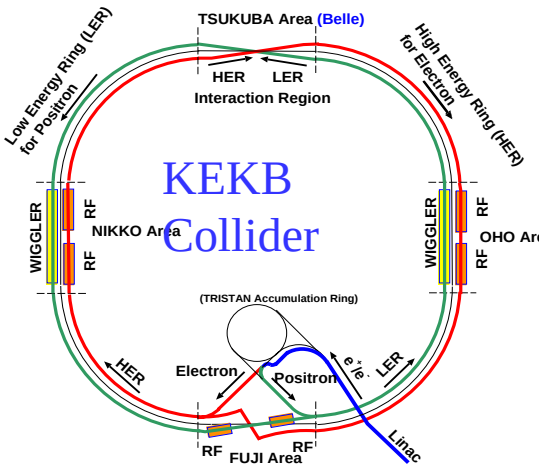
$\int L dt \sim 1-2\ ab^{-1}$ (PEP-II ultimate)

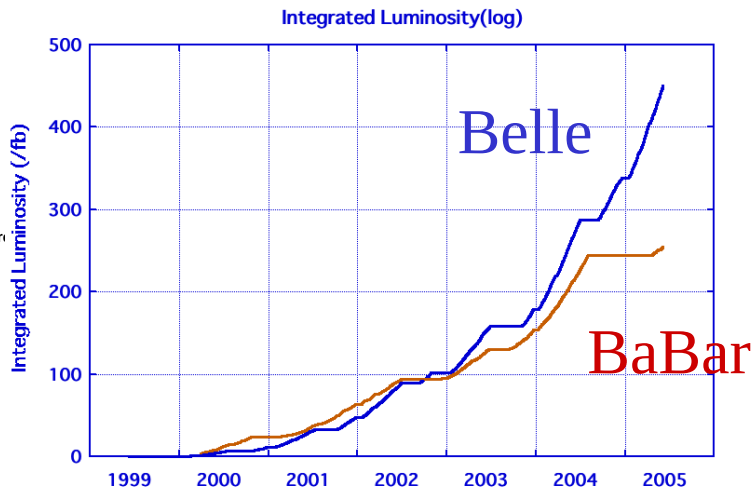
Severe match race since 1999

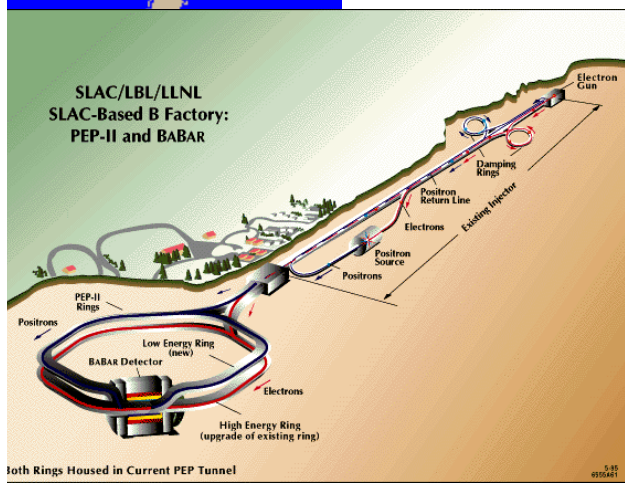
KEKB collider for Belle

PEPII collider for BaBar









Joint effort

- We(Belle and BaBar) think only one Super B factory will be realized in the world.
  - Not two.

- Joint effort has been made by Belle and BaBar to construct better accelerator and better detector for Super B factory.
  - Two Belle/BaBar joint workshops were held.
    - 2004, Jan in Hawaii
    - 2005, April in Hawaii
  - One joint group is working to understand the beam background each other.

Summary

- Aiming : Search for new origin of flavor mixing and CP violation
  - Many other fruitful physics topics
  - Concurrent program with LHC and also LHCb.
- Target luminosity : $L=4-7\times10^{35}/cm^2/s$
  - Accelerator and detector are upgraded.
- Proposed schedule for construction :
  - In 2008-2010
  - Data taking will resume from 2011.
- Please join us!

Backup

Better and more components

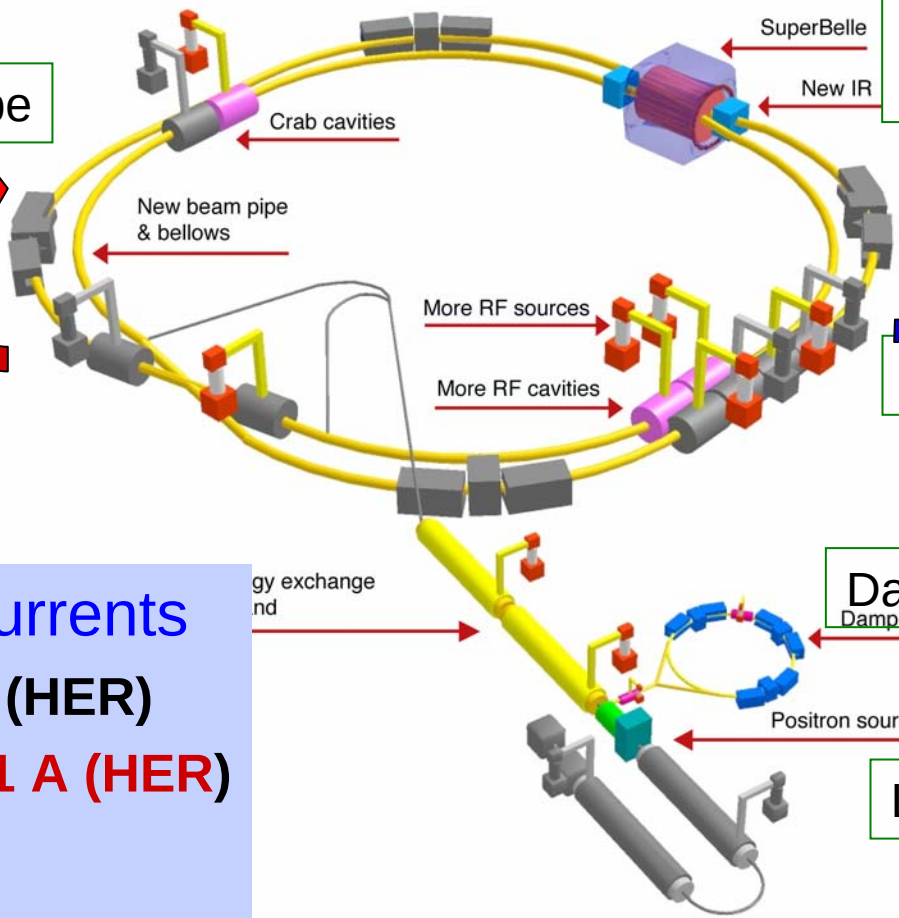
- Common approach for SuperKEKB and SuperPEPII
  - Ante-chamber with solenoid winding(PEPII)
    - To reduce electron clouds
  - Finite angle crossing at IP(KEKB)
    - To remove the separation bending magnet and to reduce the beam background
  - Crab cavity(will be installed at KEKB in next year.)
    - To get higher beam-beam parameter
  - Super-conducting final focus magnet(KEKB)
    - To squeeze the beam efficiently
  - Damping ring(PEPII)
    - To reduce emittance for injection beam
  - More RF cavities
    - To store higher beam current
    - Normal-conducting with stored cavity(KEKB) and/or super-conducting(KEKB)
- One big difference → Frequency of RF system
  - SuperKEKB : ~500MHz : It is same as present.
    - Present system is usable for super KEKB. → low cost
  - SuperPEPII : ~1GHz
    - More bunches → higher beam current
    - New system : needs more time, more man power and more money.

SuperKEKB Design

Interaction Region
- Crab crossing
- θ=30mrad.
- βy*=3mm
- New QCS

New Beam pipe

8GeV (e+, 4.1A)



3.5GeV (e-, 9.6A)

More RF power

Damping ring

Linac upgrade

$$L \approx \frac{\gamma_\pm}{2er_e}\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\frac{R_L}{R_y}$$

Increase beam currents

- **1.6 A (LER) / 1.2 A (HER)**
  → **9.6 A (LER) / 4.1 A (HER)**

Smaller β_y^*

- **6 mm→3 mm**

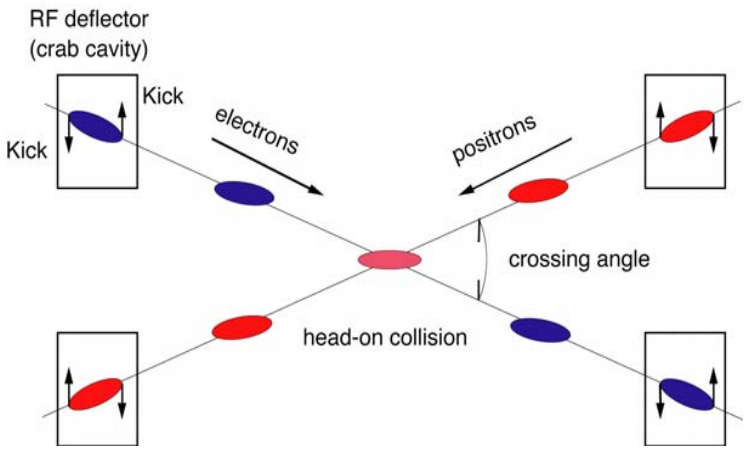
Increase ξ_y

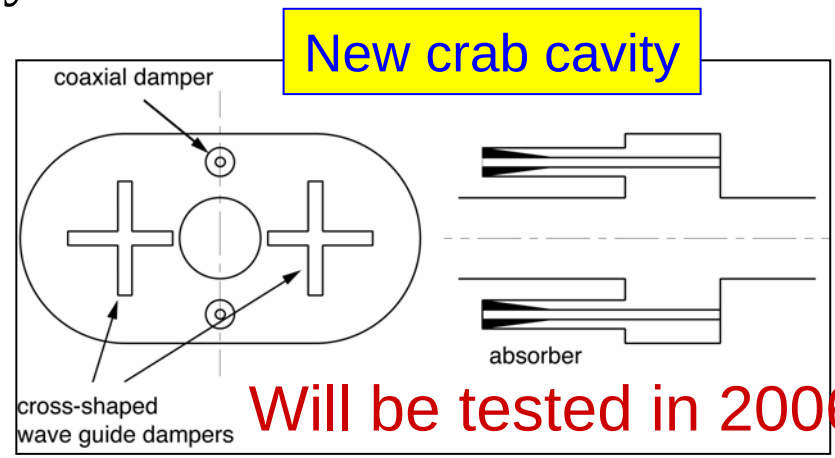
- **0.05→0.22(S-S)**

$L=4.0\times10^{35}cm^{-2}s^{-1}$

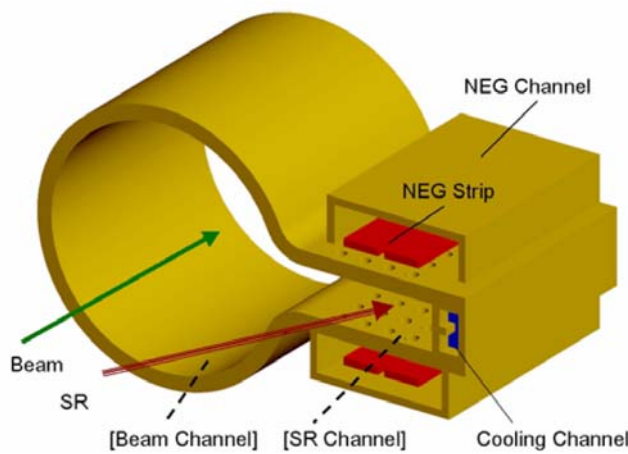
Super-KEKB

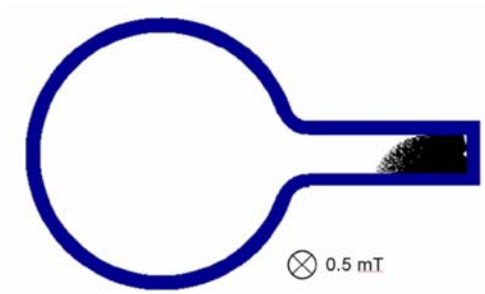
- Head-on collision w/ Crab cavity





- Ante-chamber /solenoid for reduction of electron clouds

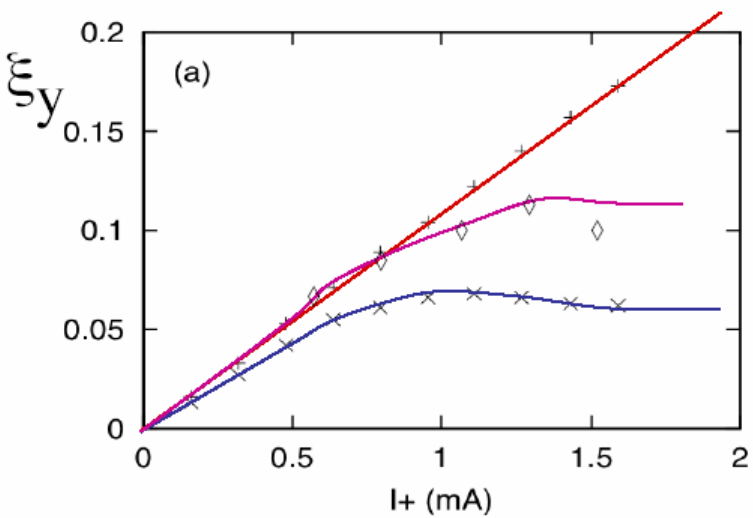




Ante-chamber
with solenoid field

Crab Cavity

- Crab crossing will boost the beam-beam parameter up to 0.17!



(Strong-weak simulation)

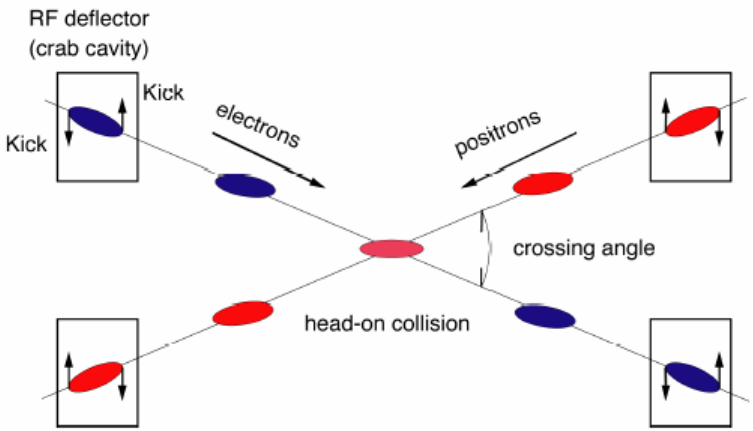
K. Ohmi

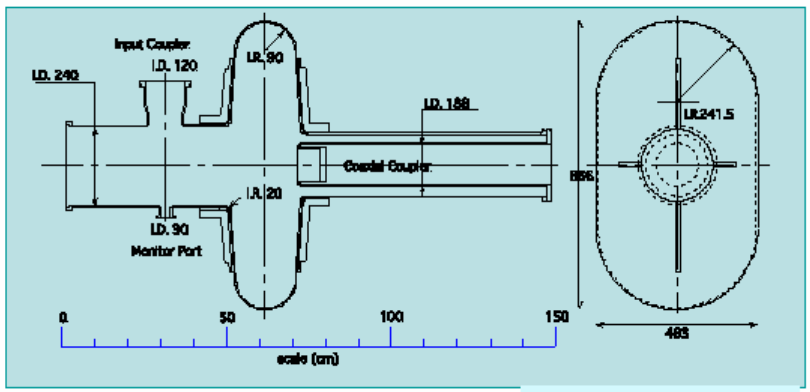
Head-on(crab)

(Strong-strong simulation)

crossing angle 22 mrad

- Superconducting crab cavities are under development, will be installed in KEKB in early 2006.





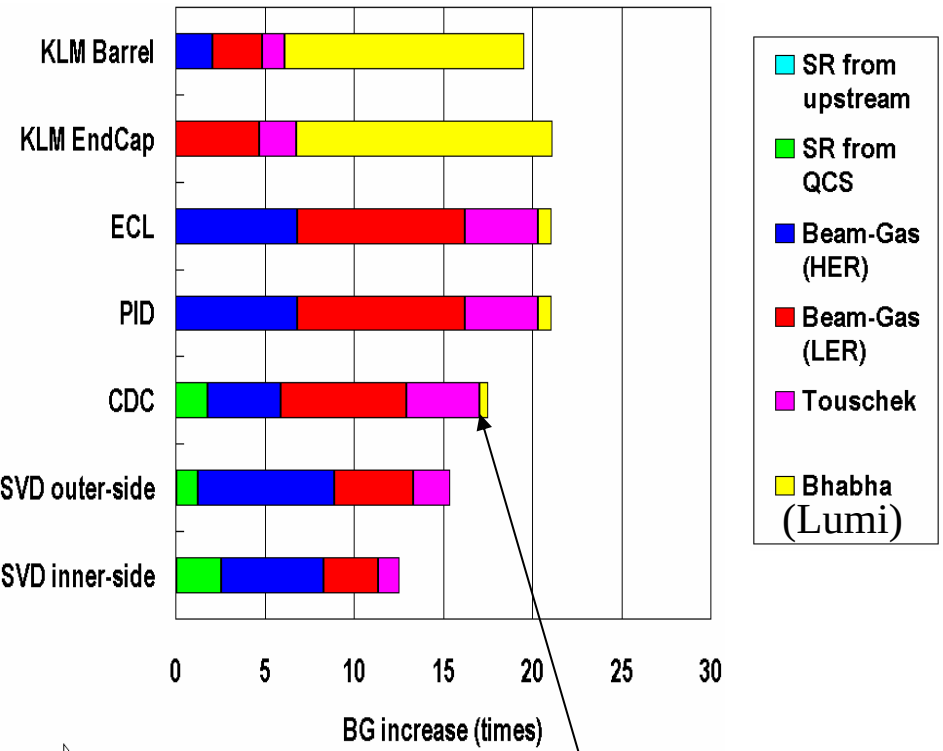
K. Hosoyama, et al

Consideration about Detector upgrade

- Different approach for consideration about detector upgrade between Belle and BaBar
  - Estimated beam background : SuperBelle << SuperBaBar
    - Present beam background : Belle < BaBar
    - Luminosity term : Belle < BaBar
    - Design luminosity and beam current : SuperKEKB < SuperPEPII
- Design concept
  - SuperBelle : Upgrade
    - CDC : Gaseous drift chamber with smaller cells
    - Present barrel calorimeter : CsI(Tl) with new electronics
  - SuperBaBar : Complete new detector
    - Silicon tracker
    - New calorimeter with shorter decay time

Beam background estimation

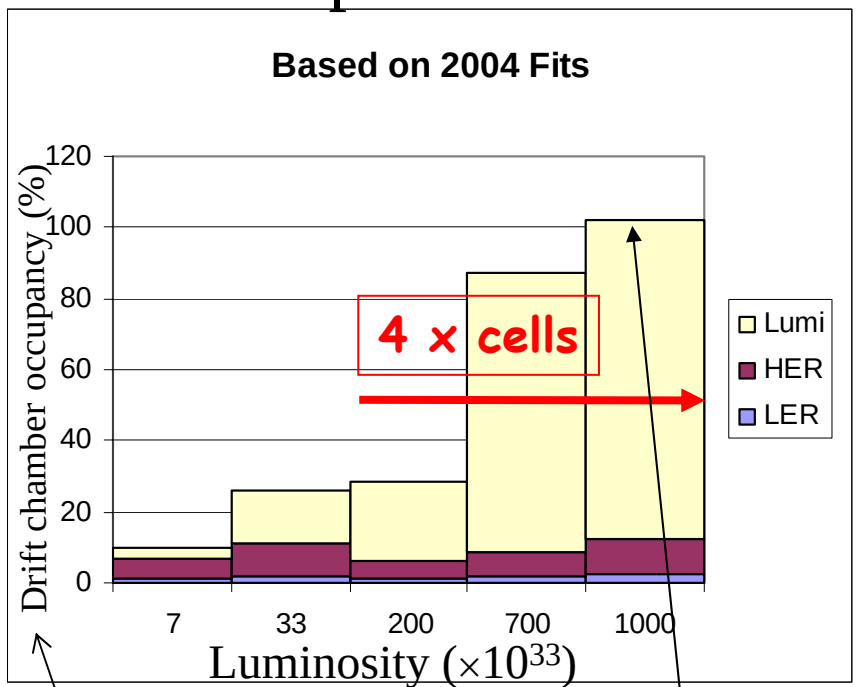
SuperBelle



Small luminosity term

5% occupancy

SuperBaBar



Raw occupancy

30% occupancy