SuperKEKB B factory

July 7th, 2006

BEACH2006@Lancaster University

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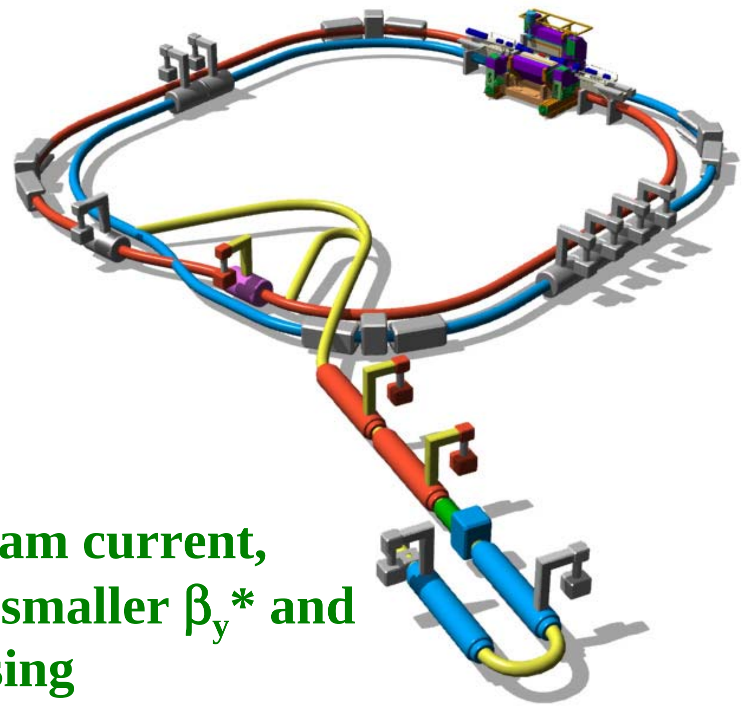
Outline

- Physics cases at Super KEKB
- Accelerator parameters and R&D status
- Detector R&D status

Super KEKB

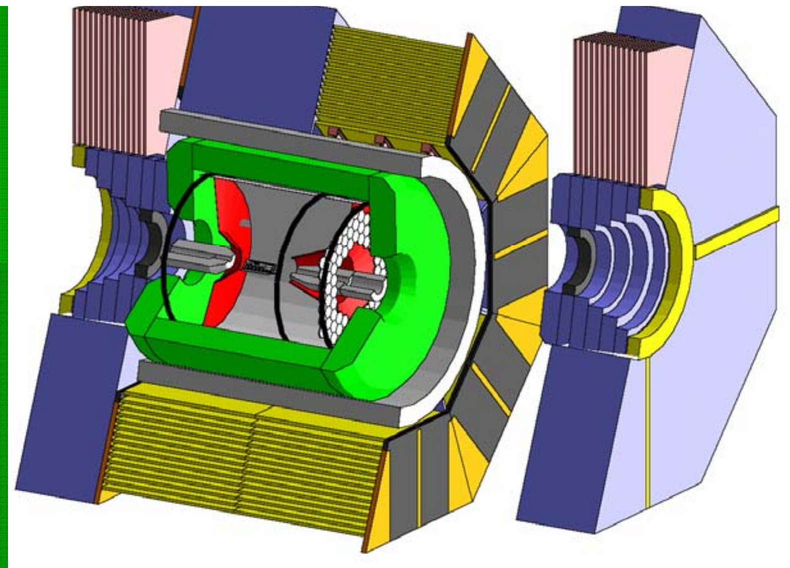
- ***Asymmetric energy e^+e^- collider at $E_{CM}=m(\Upsilon(4S))$ to be realized by upgrading the existing KEKB collider.***
- ***Super-high luminosity $\cong 8\times10^{35}$/cm²/sec $\rightarrow$ 1×10^{10} BB per yr.***

  $\rightarrow 8\times10^{9}\ \tau^+\tau^-$ per yr.



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

Belle with improved rate immunity

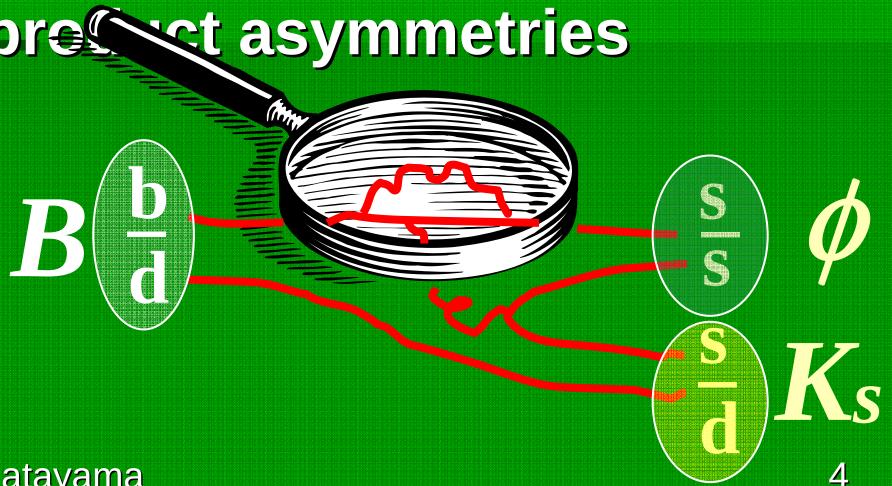


http://belle.kek.jp/superb/loi

More questions in flavor physics

- ***Are there New Physics phases and new sources of CP violation beyond the SM ?***
  - **Compare CPV angles from tree and loops.**
- ***Are there new flavor-changing interactions with b, c or τ ?***
  - **$b \to s\nu\nu$bar, D-Dbar mixing+CPV+rare, $\tau \to \mu\gamma$**
- ***Are there right-handed currents ?***
  - **$b \to s\gamma$ CPV, $B \to V\,V$ triple-product asymmetries**

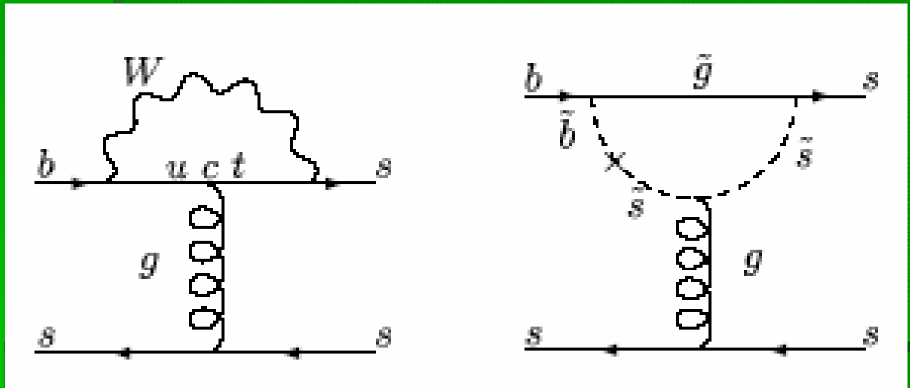
Can we answer such questions at a Super B Factory?



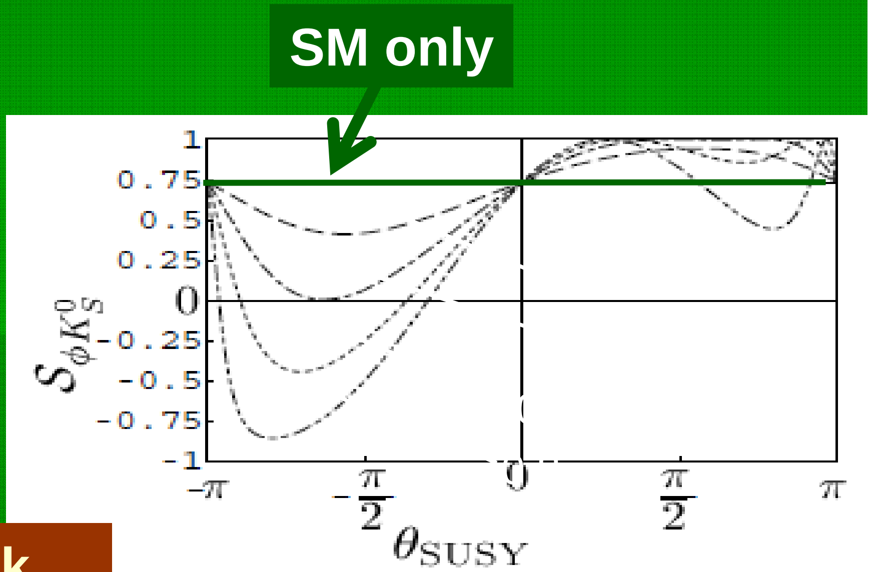
Search for new CP phases

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**

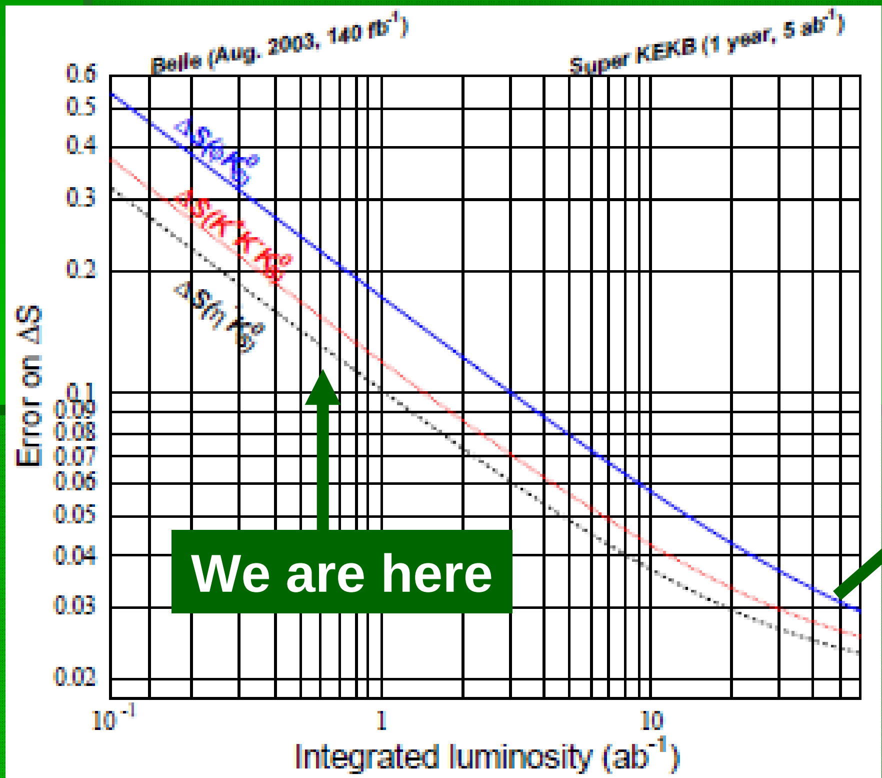


In general, if SUSY is present, the *s*-quark mixing matrix contains complex phases just as in the Kobayashi-Maskawa matrix.

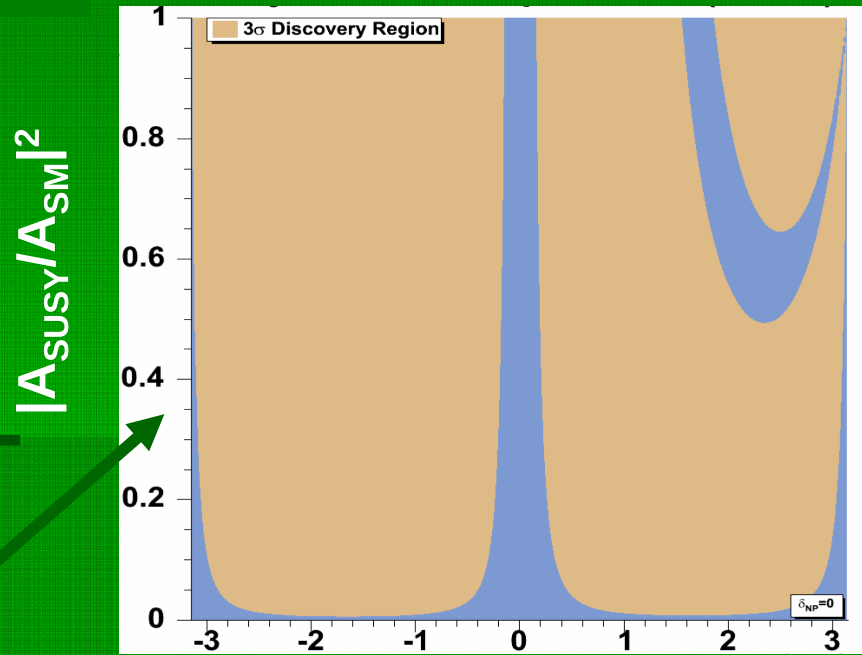
Effect of SUSY phase θ_{SUSY} on CPV in $B \to \phi K$ decay

Sensitivity to new CP phases

Estimated error in the measurement of time dependent CP violation

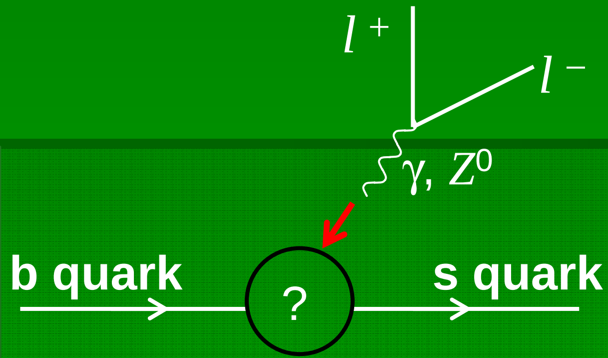


Discovery region with 50 ab^{-1}



(For a particular set of SUSY model/parameters)

Search for new flavor mixing



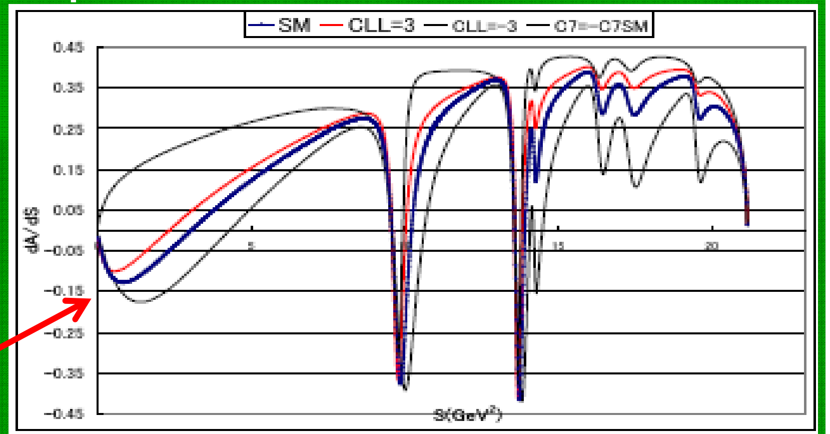
: Probe the flavor changing process with the "EW probe".

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**

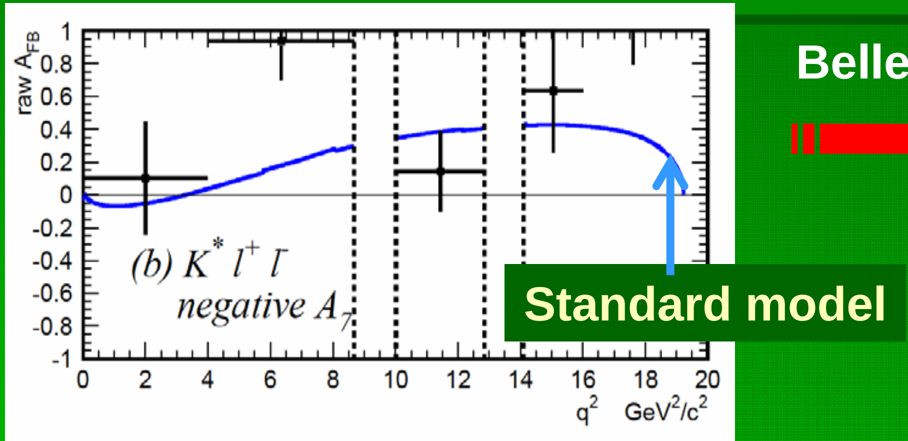
Theoretical predictions for l^+l^- forward-backward charge asymmetry for SM and SUSY model with various parameter sets.



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

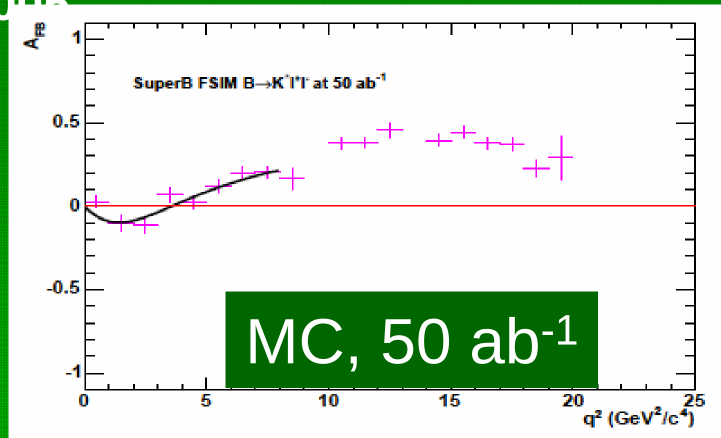
Sensitivity to new flavor mixing

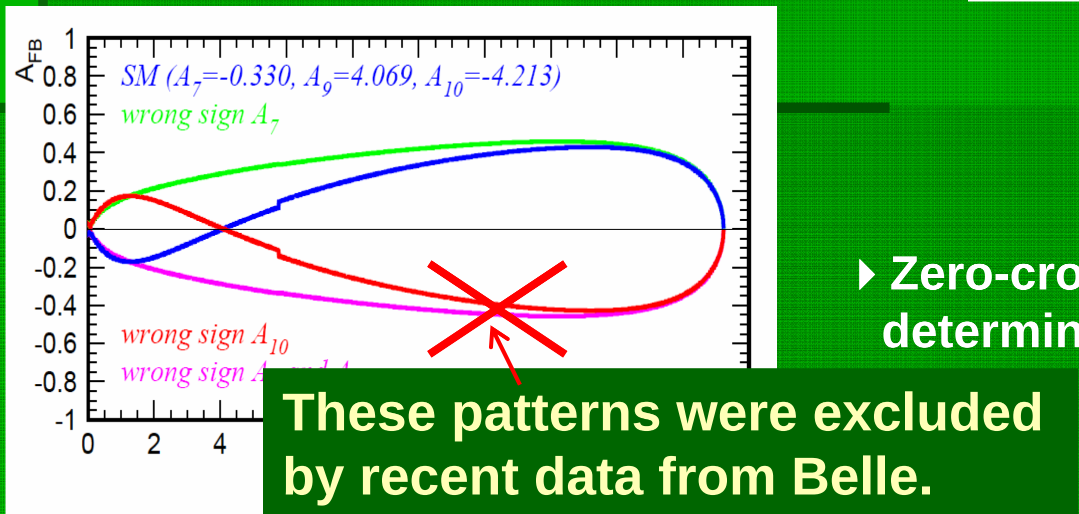
Experimental result with 0.35 ab^{-1}



Sensitivity at Super KEKB

Belle, 2005

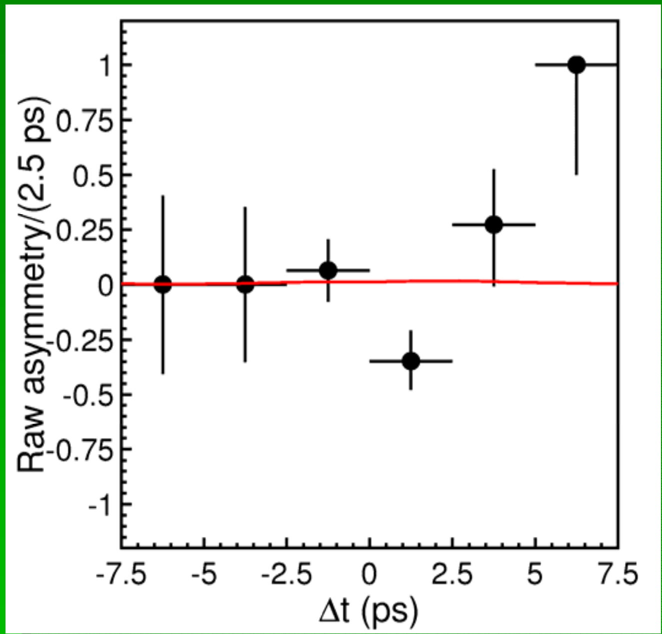


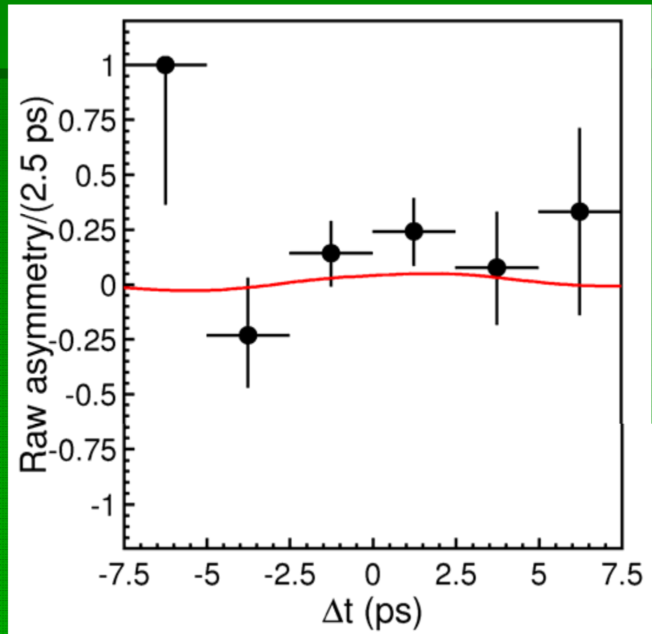


- **Zero-crossing q^2 for A_{FB} will be determined with 5% error with 50ab^{-1}.**

Belle Update 2005 (386×10^6 B pairs):

Search for Right-Handed Currents in $B \rightarrow K_S \pi^0 \gamma$





Use the K_S to determine the vertex.

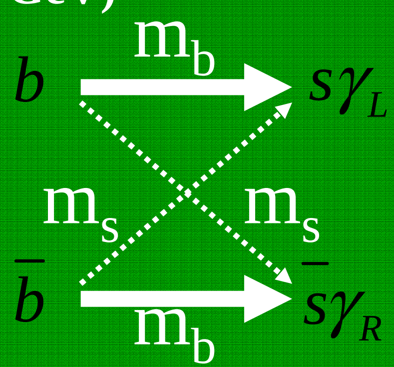
hep-ex/0507059

$$S(B \rightarrow K_S \pi^0 \gamma) = 0.08 \pm 0.41 \pm 0.10$$ **(M_X<1.8 GeV)**

In the SM, S should be close to zero (<0.10).

SM: γ is polarized, the final state almost flavor-specific.

$$S(B \rightarrow K_S \pi^0 \gamma) = -2 m_s / m_b \sin(2\phi_1)$$



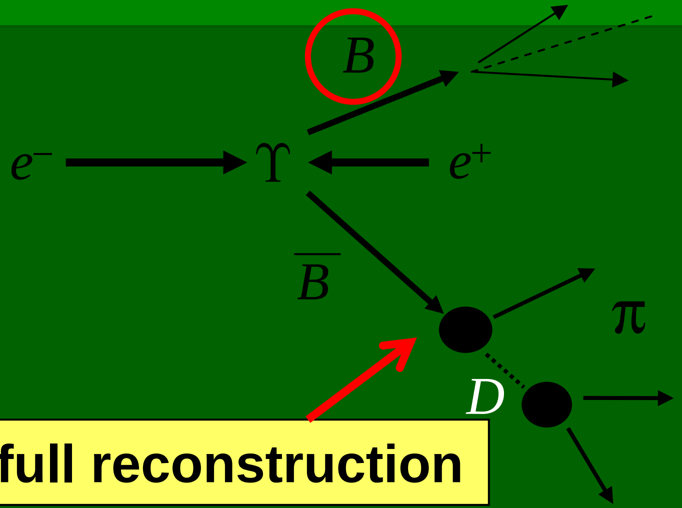
NP and Right-handed currents in $b \to s\gamma$

D.Atwood, M.Gronau, A.Soni (1997)
D.Atwood, T.Gershon, M.Hazumi A.Soni (2004)

- tCPV in $B^0 \to K_S \pi^0 \gamma$
  - m_{heavy}/m_b enhancement for right-handed currents in many NP models
    - LRSM, SUSY, Randall-Sundrum (*warped extra dimension*) model
  - LRSM: $SU(2)_L \times SU(2)_R \times U(1)$
    - Right-handed amplitude $\propto \zeta m_t/m_b$: ζ is W_L -W_R mixing parameter
    - for present exp. bounds ($\zeta < 0.003$, W_R mass > 1.4TeV) $|S(K_S\pi^0\gamma)| \sim 0.5$ is allowed.
  - *Here an asymmetry does not require a new CPV phase*

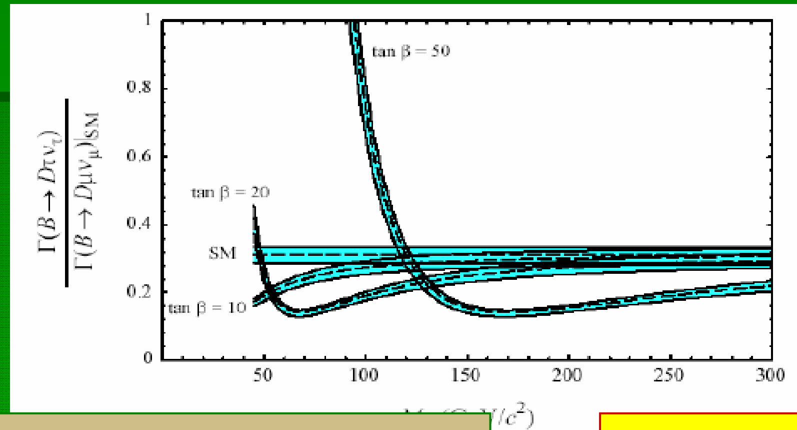
	Present Belle (stat.) ⇒	$5ab^{-1}$ ⇒	$50ab^{-1}$
$S(B \to K^*\gamma, K^* \to K_S\pi^0)$	0.52	0.14	0.04

"*B* meson beam" technique



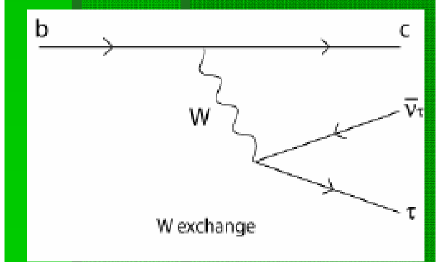
0.2~0.3% for B^+

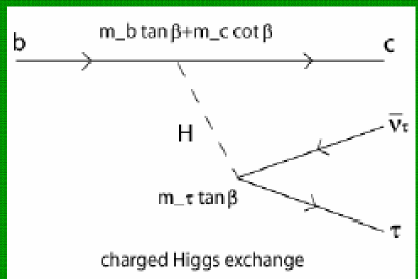
$\delta(Br)/Br$ = 2.5% at 50 ab^{-1}

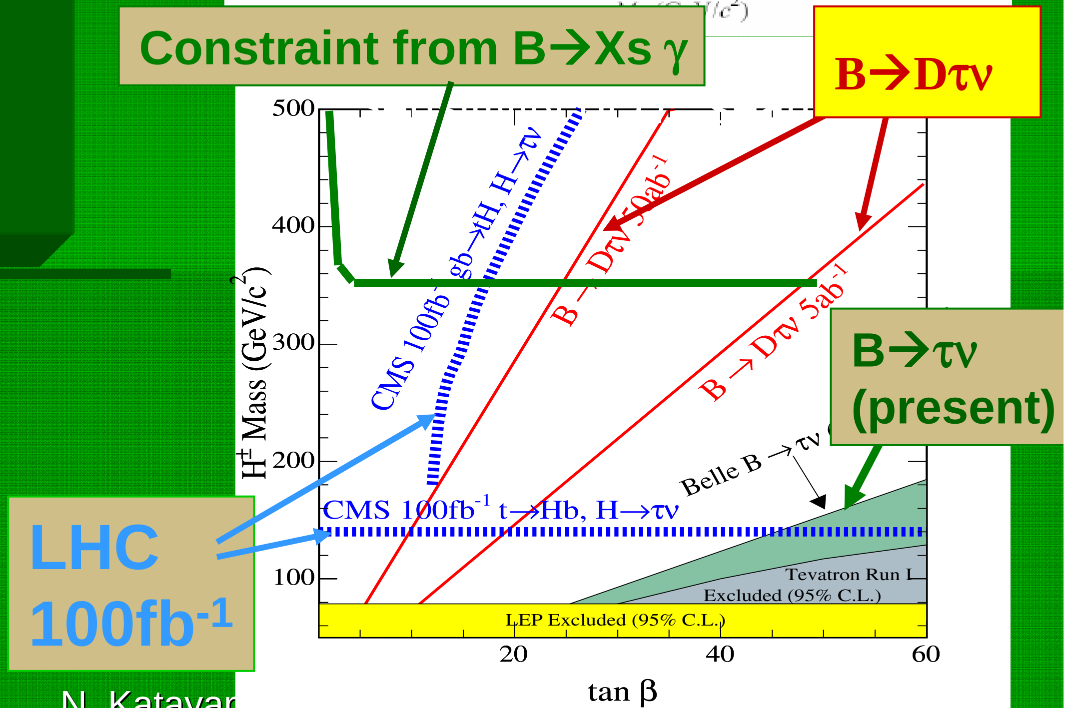


Application

$H^{\pm}$ search in $B \to D^{(*)}\tau\nu$





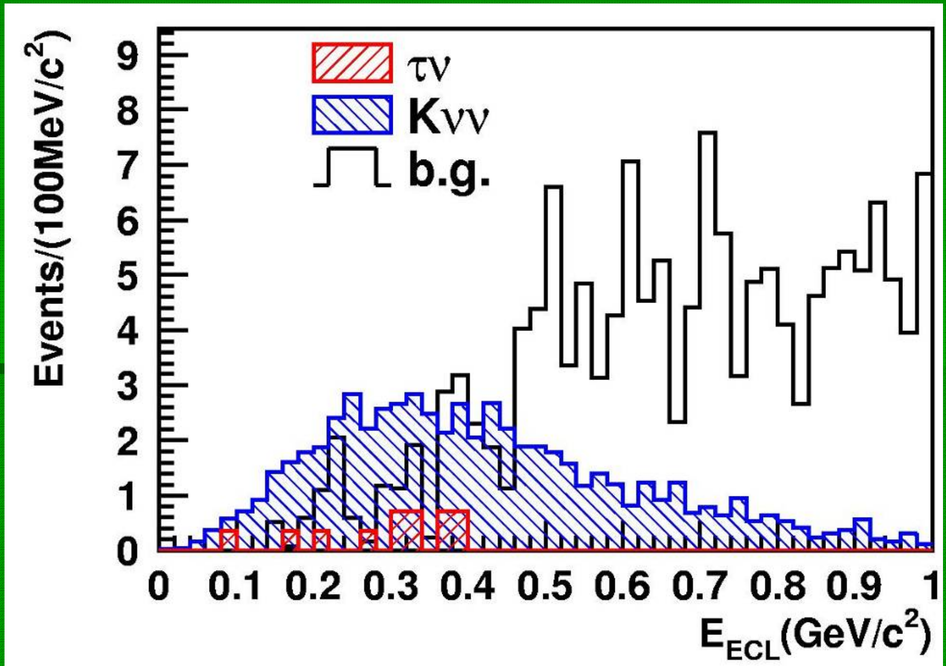


B tagging provides a "B-meson beam"

MC extrapolation to 50 ab^{-1}

5σ Observation of $B^{\pm} \rightarrow K^{\pm} \nu \nu$

(compare to $K^{+} \rightarrow \pi^{+} \nu \nu$ and $K_L \rightarrow \pi^0 \nu\nu$)



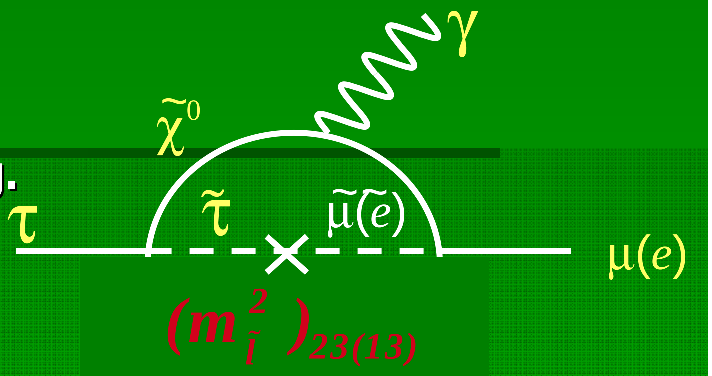
Extra EM calorimeter energy

A Super B Factory is also a powerful τ-charm Factory

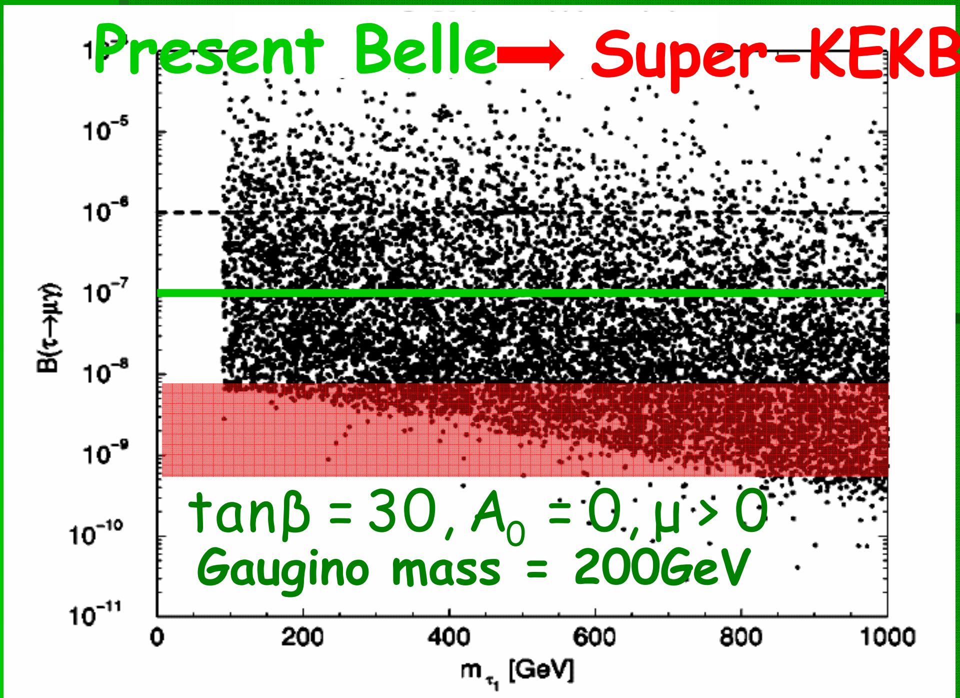
- **Rich, broad physics program that covers *B*, τ and charm physics.**
- **Examples:**
  - **examination of rare charm modes**
  - **D^0-D^0*bar* mixing**
  - **searches for $\tau \to \mu\gamma$ with unprecedented sensitivity.**

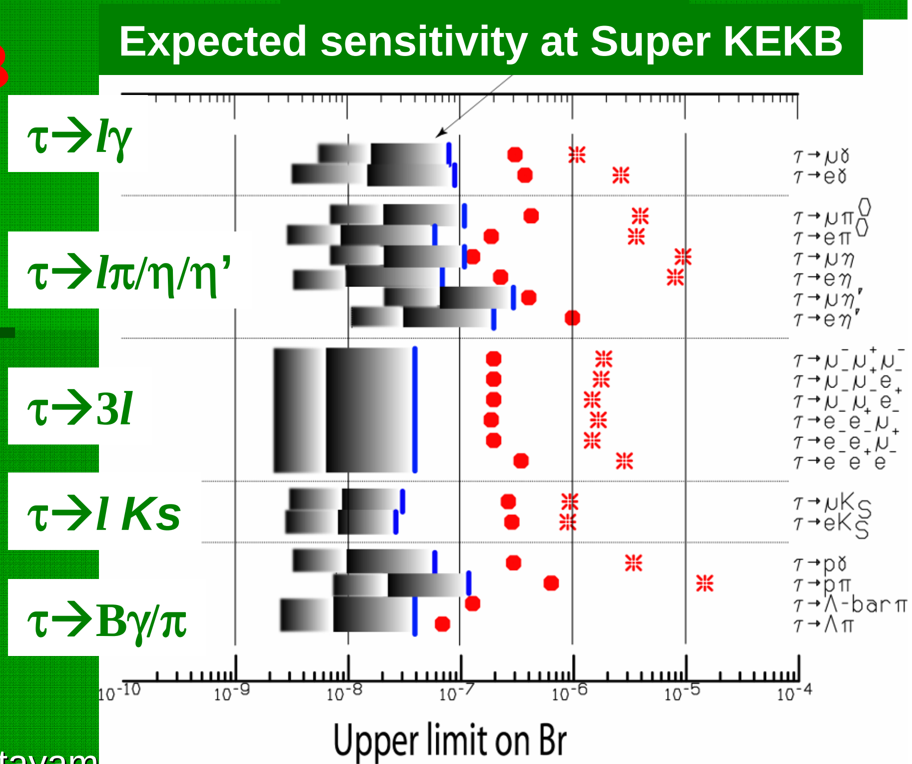
Search for flavor-violating τ decay

- **SUSY + Seesaw**
  - **Flavor violation by ν-Yukawa coupling.**
  - **Large LFV** $Br(\tau \to \mu\gamma) = O(10^{-7\sim 9})$



$$BR(\tau \to \mu\gamma) \sim 10^{-6} \times \frac{(m_{\tilde{L}}^2)_{32}}{\bar{m}_{\tilde{L}}^2} \left(\frac{1\ \mathrm{TeV}}{m_{SUSY}}\right)^4 \tan^2\beta$$





Search for New Physics in the Charm Sector

c – the only heavy up-like quark experimentally accessible;
New Physics Mechanisms may be different for u- and d-like quarks;

⇒ *Rare Charm Decays, D-Dbar Mixing and CP Violation*

Exp.	Int.lum.	# recon. $D^0 \to K^-\pi^+$	Comments
Belle	500 fb^{-1}	1.4 x 10^7	1.5 x 10^6 in $D^{*+} \to D^0\pi^+$ p*(D*)>2.5 GeV
Cleo-c	3 fb^{-1} @ ϕ (3770)	5.5 x 10^5	3 x 10^4 CP-tagged
CDF Run II	4.4 fb^{-1}	3 x 10^7	7 x 10^6 in $D^{*+} \to D^0\pi^+$, p_t>2 GeV
BESIII	30 fb^{-1}	5.5 x 10^6	
Super B Factory	5 ab^{-1}~ 50 ab^{-1}	1.4 x 10^8~ 1.4 x 10^9	1.5 x 10^7 (10^8) $D^{*+} \to D^0\pi^+$ with p*(D*)>2.5 GeV

e.g. $D^0 \to \gamma\gamma$; $D^{0(\pm)} \to H^{0(\pm)}\, l^+l^-$; $D^0 \to l^+l^-$; $D^{0(\pm)} \to V^{0(\pm)}\gamma$

Why $\int L\,dt = 50ab^{-1}$ is a goal?

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

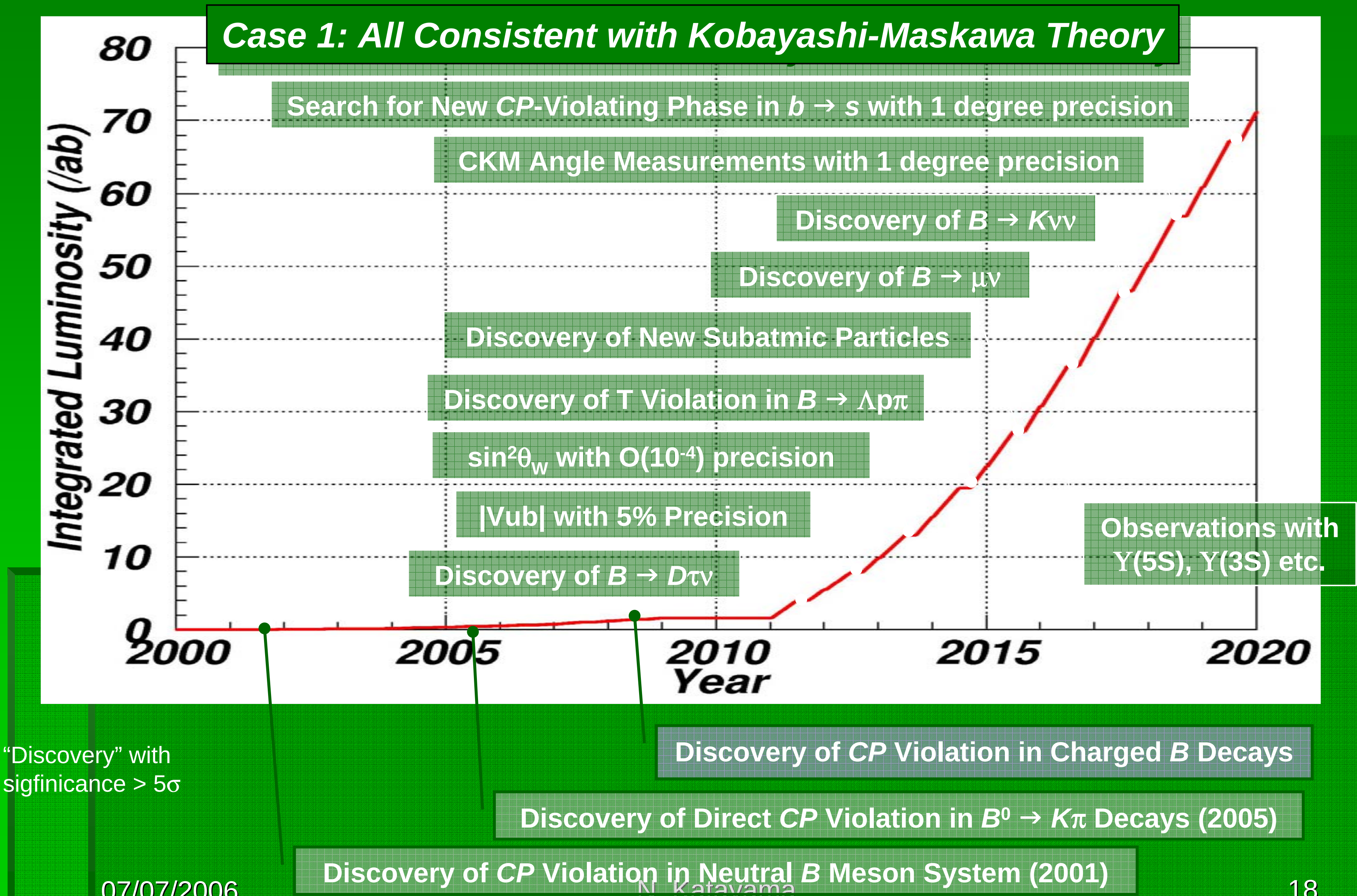
Obs.	δ_{stat} with $50ab^{-1}$	δ_{syst} with $50ab^{-1}$	Theory err.
$\sin 2\phi_1$	0.004	0.014	~0.01
ϕ_2	1.2°	a few °	
ϕ_3	1.2°	O(1) °	
$\lvert V_{ub}\rvert$	1%	~1%	~5 %
$S_{\phi Ks}$	0.023	0.020	
$A_{\phi Ks}$	0.016	0.018	
$S_{\eta' Ks}$	0.013	0.020	
$A_{\eta' Ks}$	0.009	0.017	
DCPV in $b \to s\gamma$	0.003	0.002	0.003

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	

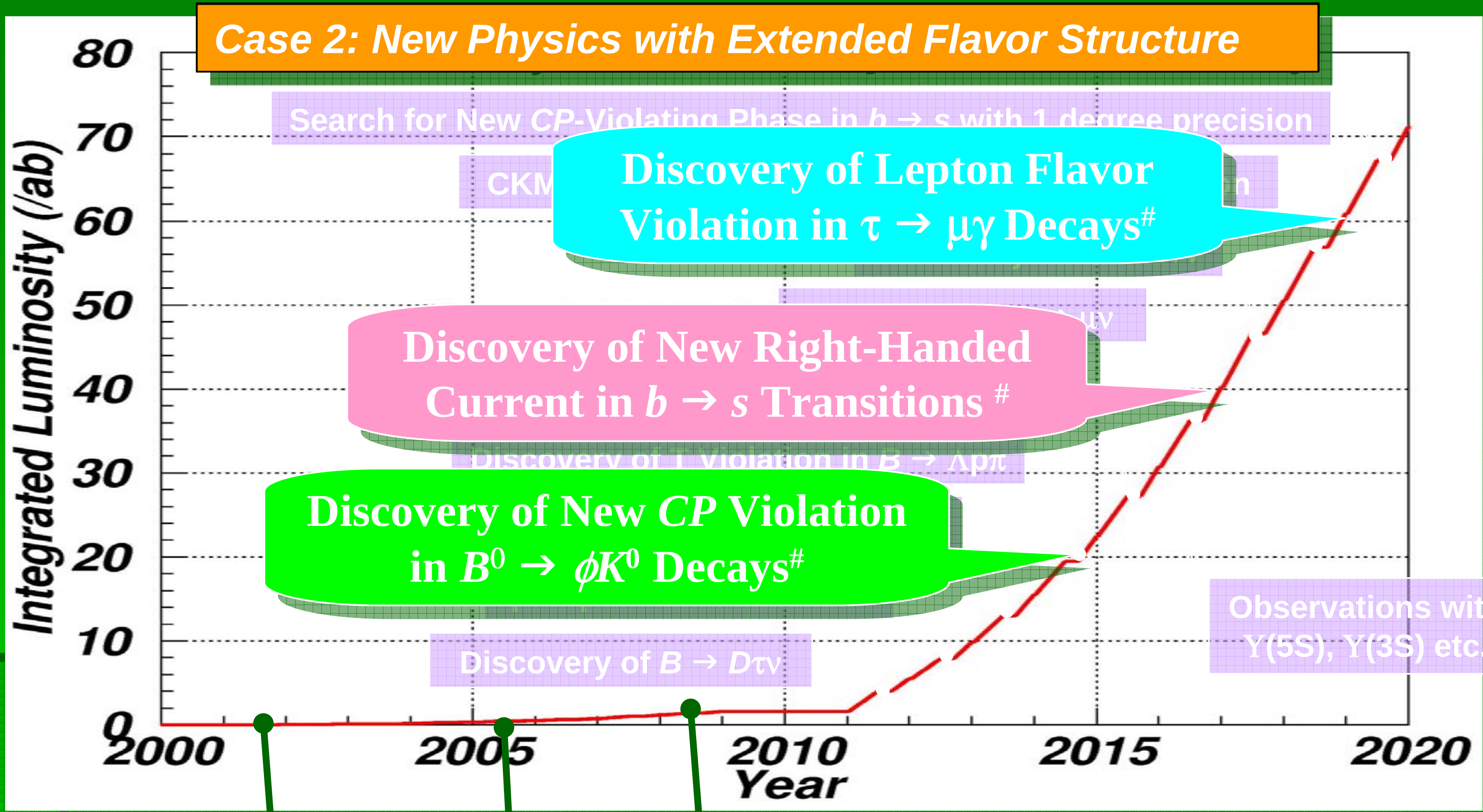
They are complementary to each other !!

Major Achievements Expected at SuperKEKB



"Discovery" with sigfinicance > 5σ

Major Achievements Expected at SuperKEKB



Discovery of *CP* Violation in Charged *B* Decays

Discovery of Direct *CP* Violation in $B^0 \rightarrow K\pi$ Decays (2005)

Discovery of *CP* Violation in Neutral *B* Meson System (2001)

"Discovery" with sigfinicance > 5σ

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

Super KEKB accelerator

How to achieve the super-high luminosity

Stored current:

1.36/1.75 A (KEKB)

→ 4.1/9.4 A (SuperKEKB)

Beam-beam parameter:

0.059 (KEKB)

→ >0.24 (SuperKEKB)

Crab cavity

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)

New parameter set for 8×10^{35}

	SuperKEKB	Crab waist			
εx	9.00E-09	6.00E-09	6.00E-09	6.00E-09	6.00E-09
εy	4.50E-11	6.00E-11	6.00E-11	6.00E-11	6.00E-11
βx (mm)	200	100	50	100	50
βy (mm)	3	1	0.5	1	0.5
σz (mm)	3	6	6	4	4
νs	0.025	0.01	0.01	0.01	0.01
ne	5.50E+10	5.50E+10	5.50E+10	3.50E+10	3.50E+10
np	1.26E+11	1.27E+11	1.27E+11	8.00E+10	8.00E+10
φ/2 (mrad)	0	15	15	15	15
ξx	0.397	0.0418	0.022	0.0547	0.0298
ξy	0.794→0.24	0.1985	0.179	0.178	0.154
Lum (W.S.)	8E+35	6.70E+35	1.00E+36	3.95E+35	4.80E+35
Lum (S.S.)	8E35	4.77E35	5.65E36	3.94E35	4.27E35

What' new in the param. set?

- **8×10^{35} cm^{-2}s^{-1} is achievable with the same beam currents, beta and bunch lengths as before (4×10^{35} cm^{-2}s^{-1})**
- **The beam-beam simulation was improved by using more longitudinal slices to reduce numerical noises and instabilities on a new super computer at KEK**
- **A new choice of emittance (ratio or horizontal emittance)**
- **Crab crossing (head on collision) is necessary**
- **Crab waist, traveling focus may help lifetimes but not essential at this moment**

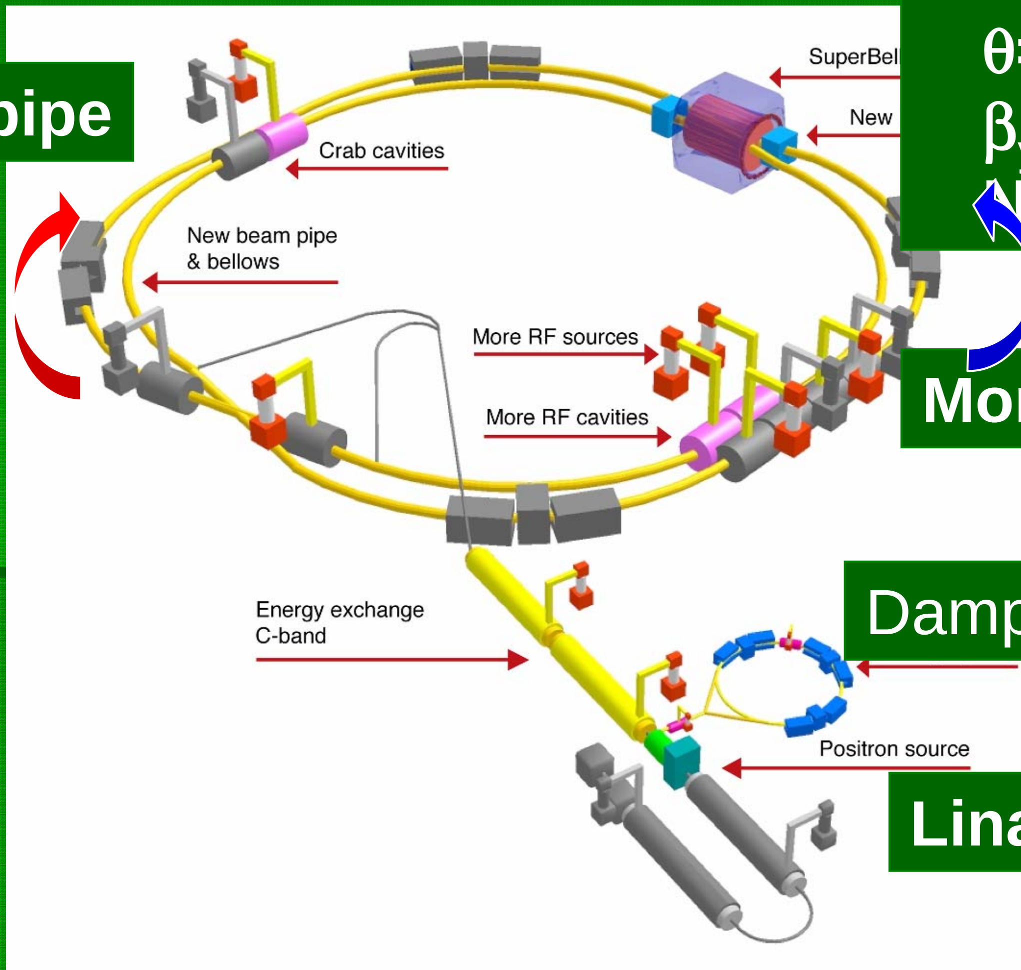
Accelerator R&D

- Vacuum components for higher current
  - Antechambers, coating, bellows, collimetors,,
- Superconducting quadrupoles
- High power RF components
- Bunch-by-bunch feedback system
- C-band linac
- Beam diagnostics
- Crab cavities

Components to be upgraded

New Beam pipe

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

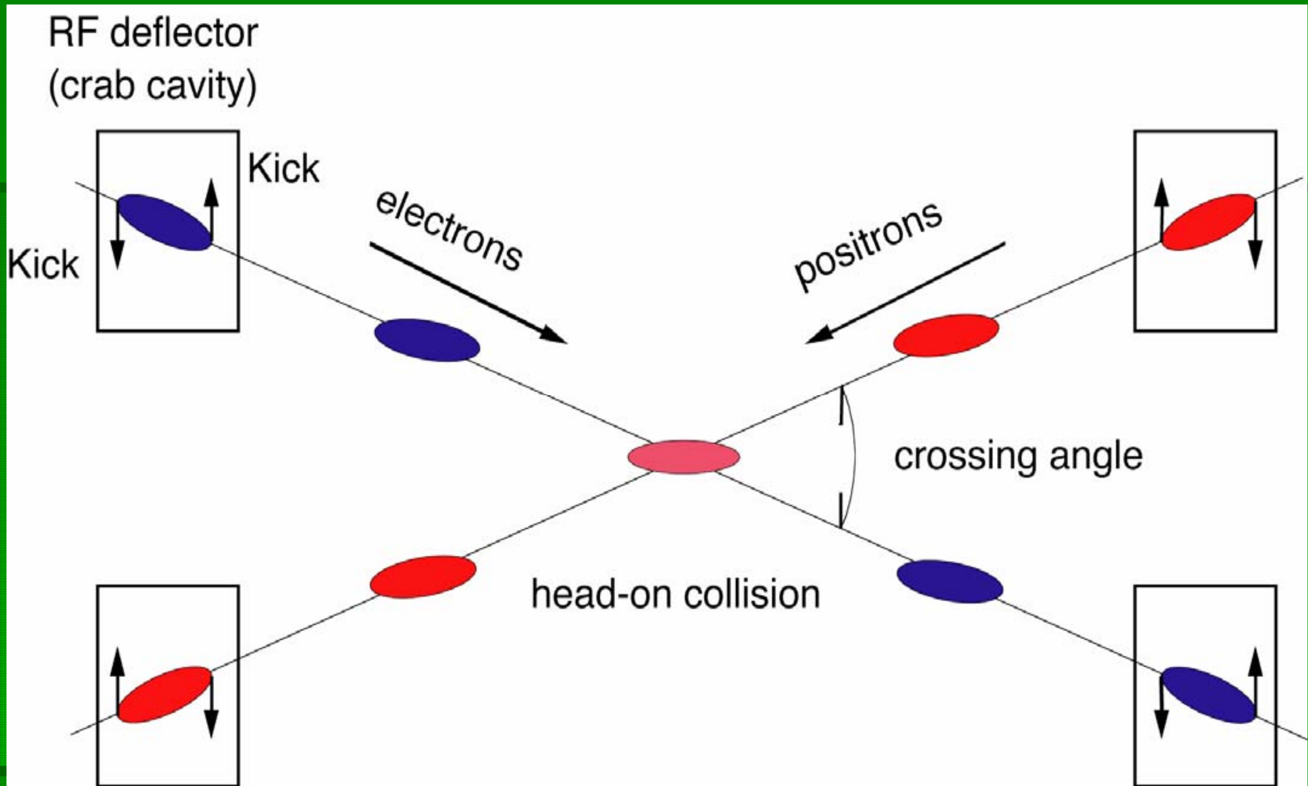


More RF power

Damping ring

Linac upgrade

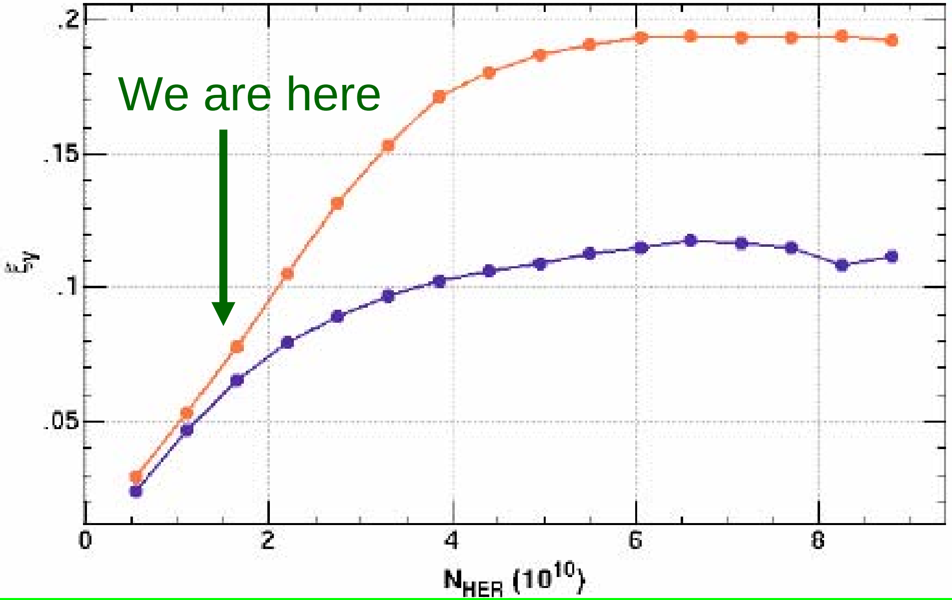
Crab cavity: a new idea for higher luminosity



- **Head-on collisions with finite crossing angle !**
  - **avoid parasitic collisions**
  - **collisions with highest symmetry → large beam-beam parameter**

Crab crossing is coming soon!

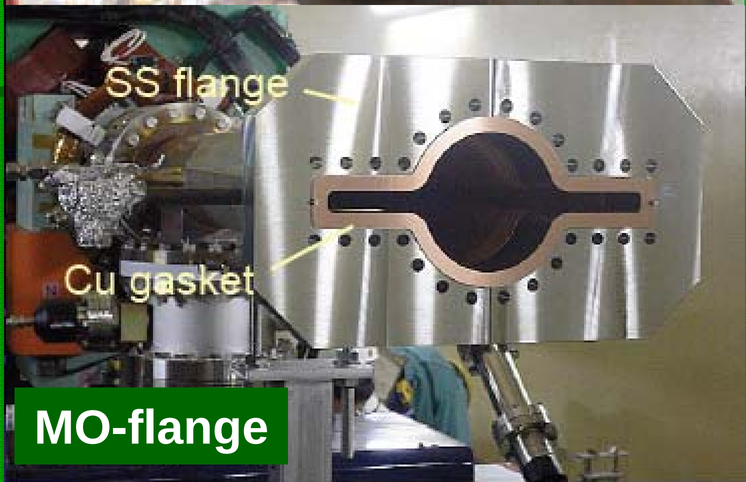
● Crab crossing will boost the beam-beam parameter up to 0.24 K. Ohmi

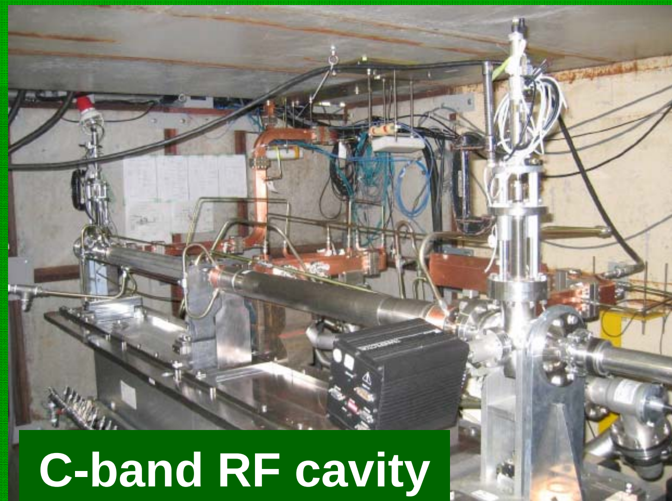


● Superconducting crab cavities are under development, will be installed in KEKB in end of 2006.

- **First performance report expected in early 2007**
- **Factor ~2 gain in $\mathcal{L}_{peak}$ may be expected within ~2 yrs**
  - **~3×10^{34}cm^{-2}s^{-1} within our reach**

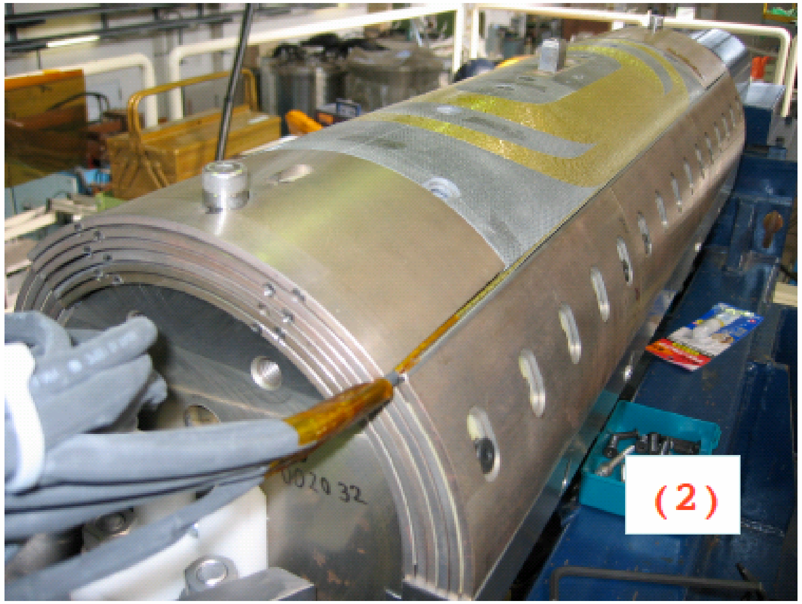
Super KEKB components

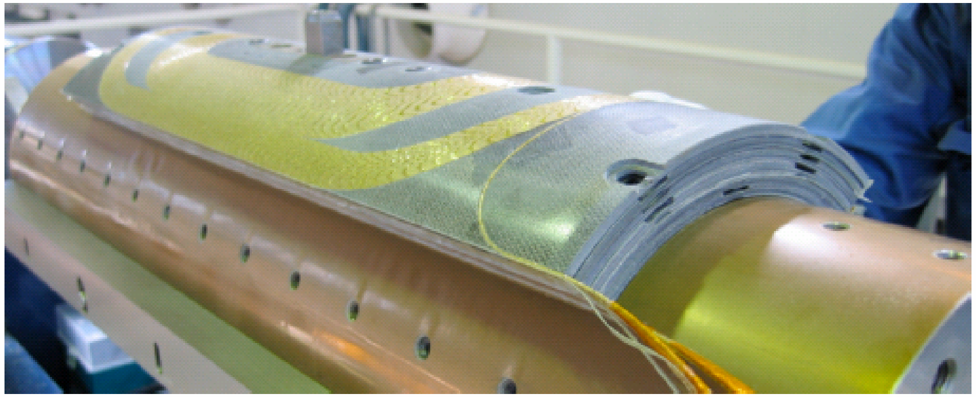




Construction of QCS R&D Magnet

(2-4) 12 Cured Coils and curing 6 layer coils all at once





(1) 12 cured double pan-cake coils.

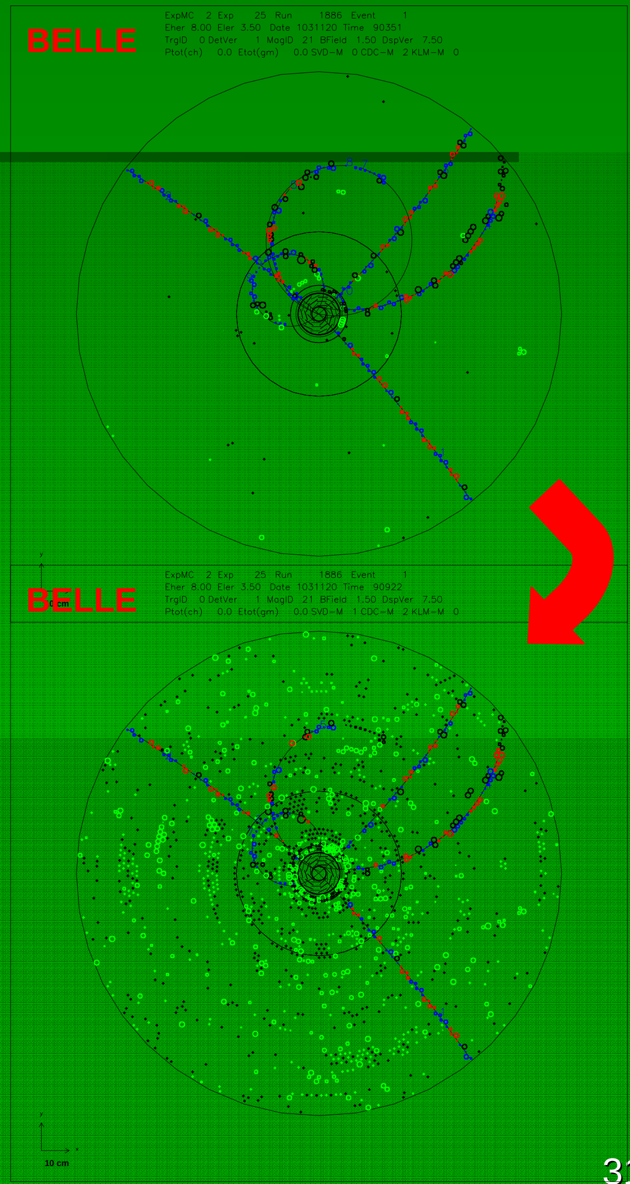
(2) Curing process of 6 layer coils. This process is necessary for improving the field quality in the

Detector requirements and R&D status

Requirements for the detector

Issues

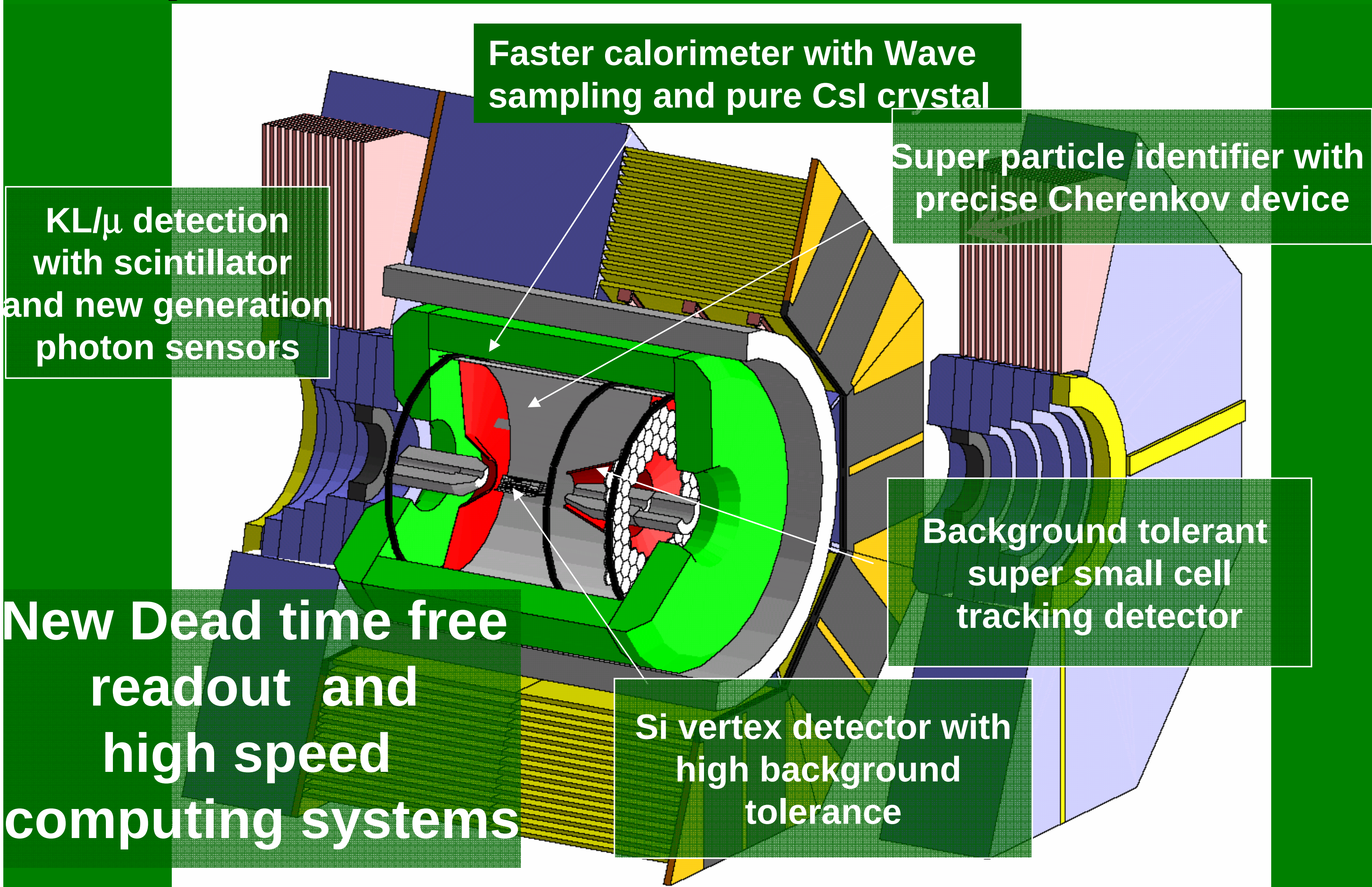
- Higher background (×20)
  - **radiation damage and occupancy**
  - **fake hits and pile-up noise in the EM**
- Higher event rate (×10)
  - **higher rate trigger, DAQ and computing**
- Require special features
  - **low *p* μ identification ← sμμ recon. eff.**
  - **hermeticity ← ν “reconstruction”**



Possible solution:

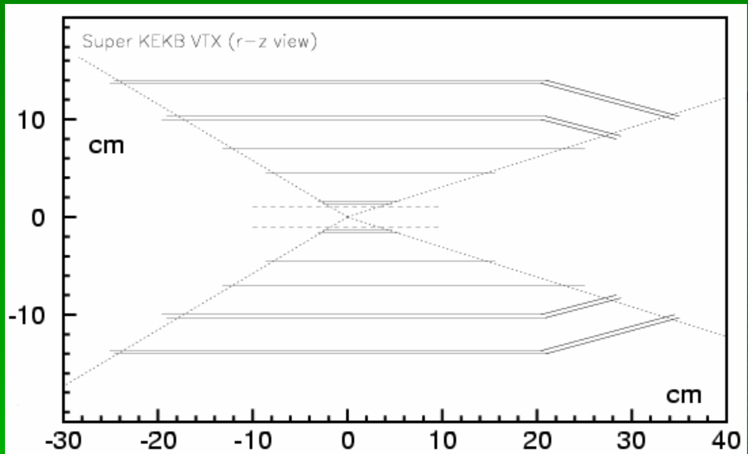
- **Replace inner layers of the vertex detector with a silicon striplet detector.**
- **Replace inner part of the central tracker with a silicon strip detector.**
- **Better particle identification device**
- **Replace endcap calorimeter by pure CsI.**
- **Faster readout electronics and computing system.**

Super Belle

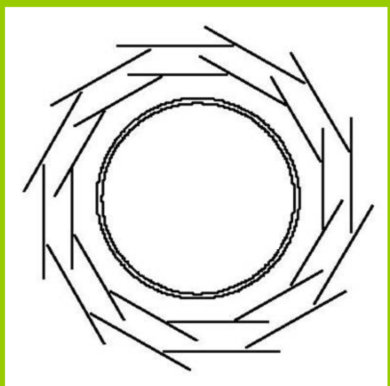

Faster calorimeter with Wave sampling and pure CsI crystal
Super particle identifier with precise Cherenkov device
KL/μ detection with scintillator and new generation photon sensors
Background tolerant super small cell tracking detector
Si vertex detector with high background tolerance
New Dead time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

Si vertex det. & Tracker

SVD



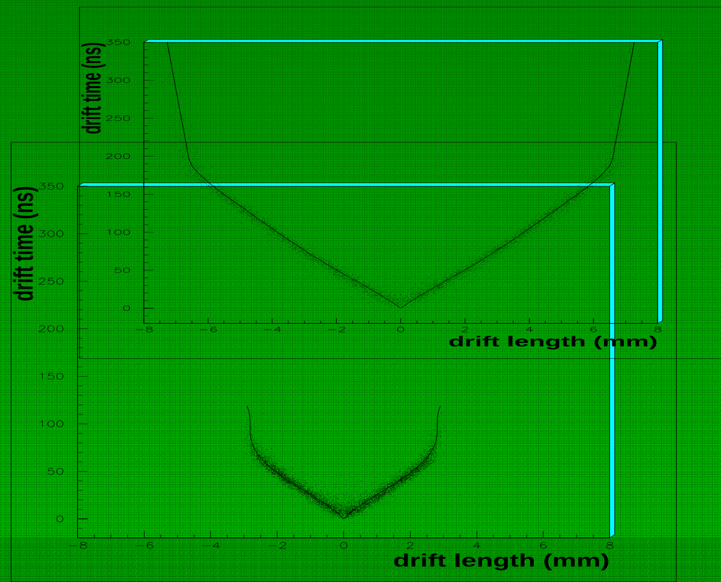
- 6 or more Layers
- Large area Si tracker



2-layer sensors at inner layer for robust vertexing

- Self tracking of low momentum tracks.
- Dead time less readout at the luminosity of $5x10^{35}$/ cm^2/sec.
- Rejection of beam background that is 30 times severer than that in KEKB.

CDC



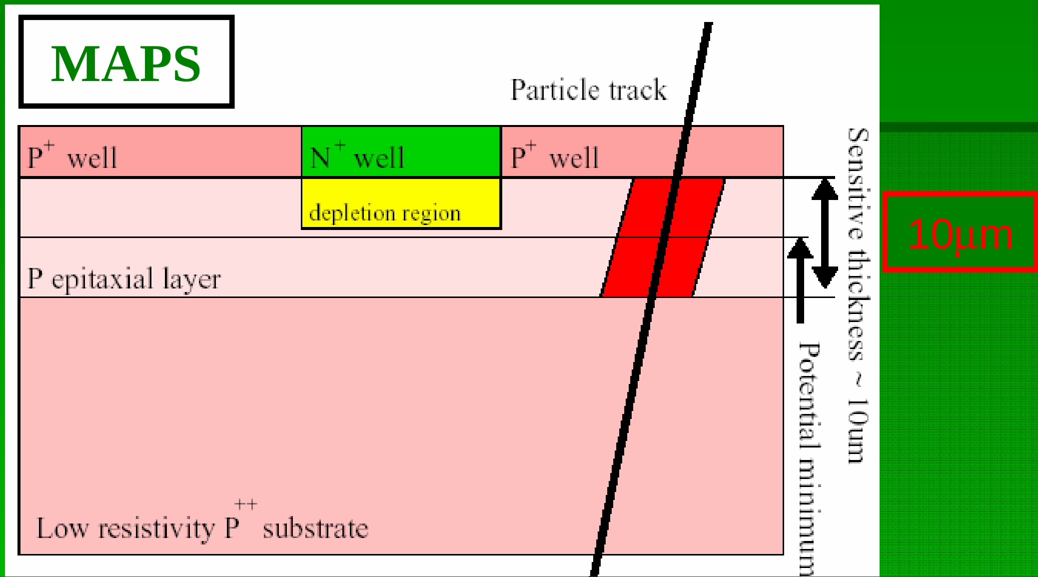
- Smaller cell size

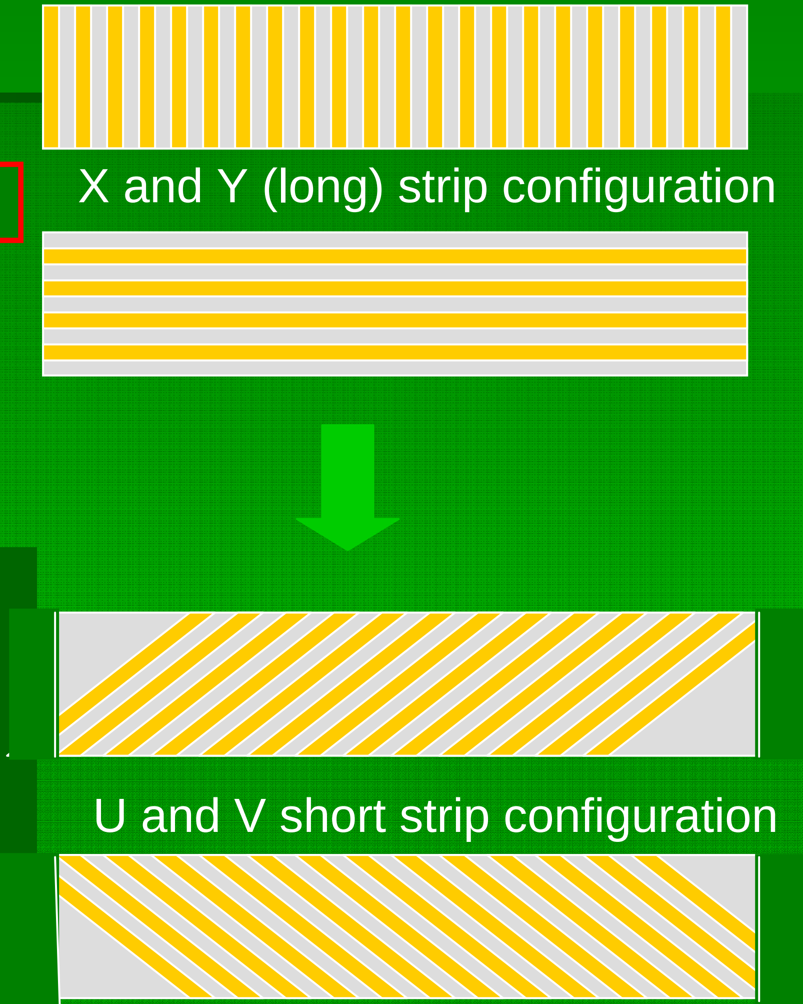
  Lower hit rate for each wire.

  Shorter maximum drift time.
- Faster drift velocity

  Shorter maximum drift time

Monolithic Active Pixel Sensor (MAPS) and Silicon striplet



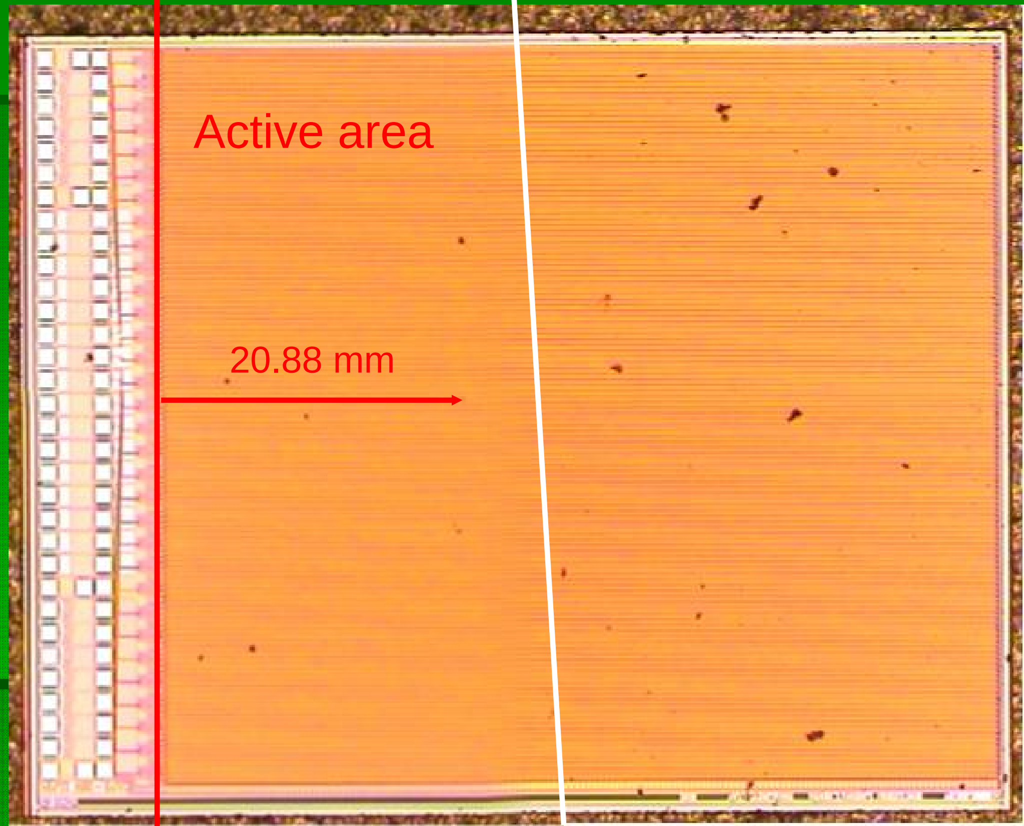


Key Features

- Thermal charge collection (no HV)
- Thin - reduced multiple-scattering, γ conversion, background γ target
- NO bump bonding – fine pitch possible (8000x geometrical reduction)
- Standard CMOS process - "System on Chip" possible

CAP3 – full-sized!

21 mm



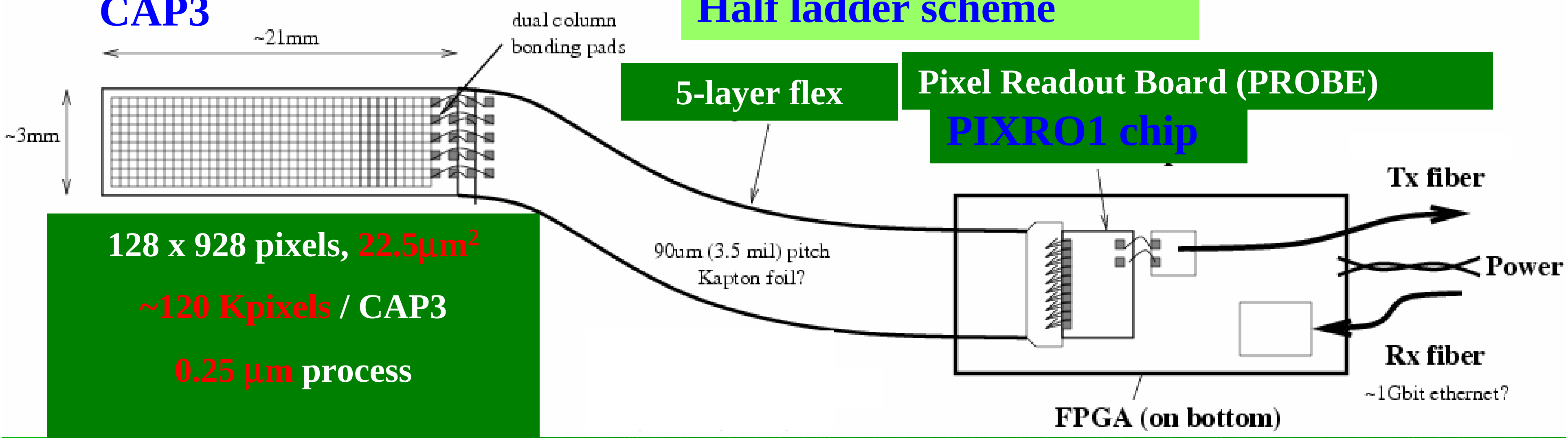
928 x 128 pixels = 118,784

~4.5M transistors !

>93% active without active edge processing

CAP3: Full-size Detector

Half ladder scheme

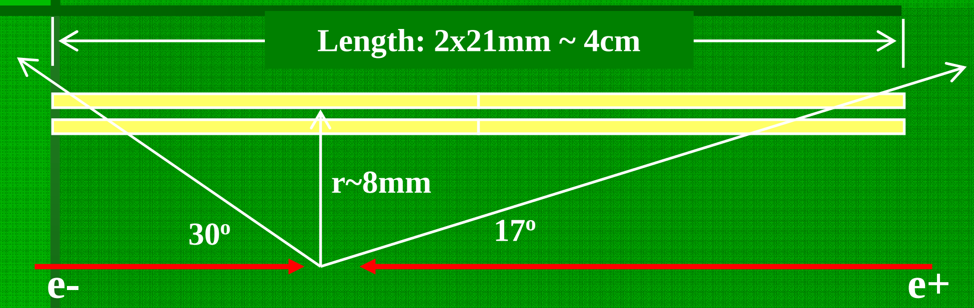


128 x 928 pixels, $22.5\mu m^2$

~120 Kpixels / CAP3

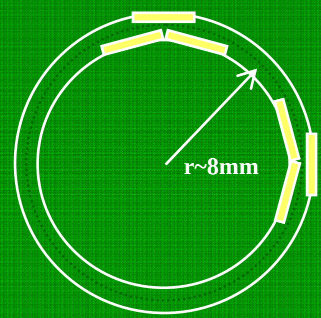
0.25 μm process

Side view



End view

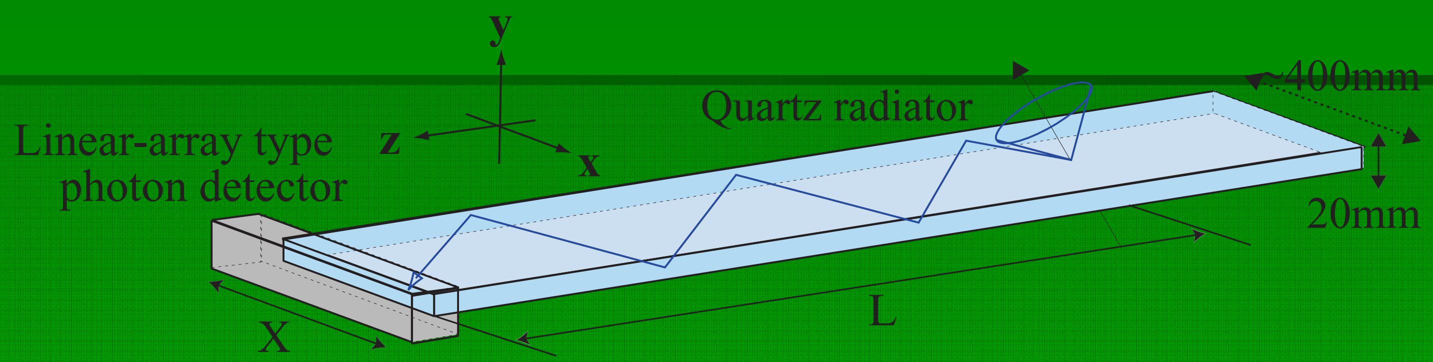
Double layer, offset structure

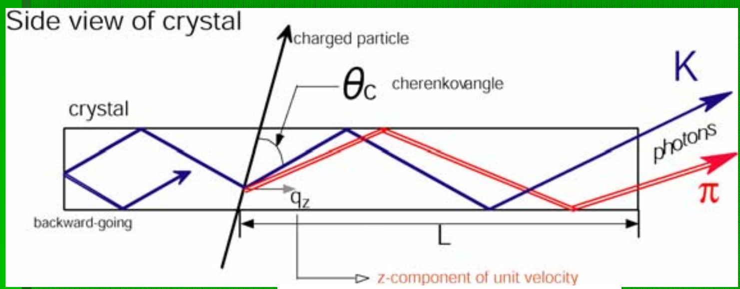


# of Detector / layer ~ 32

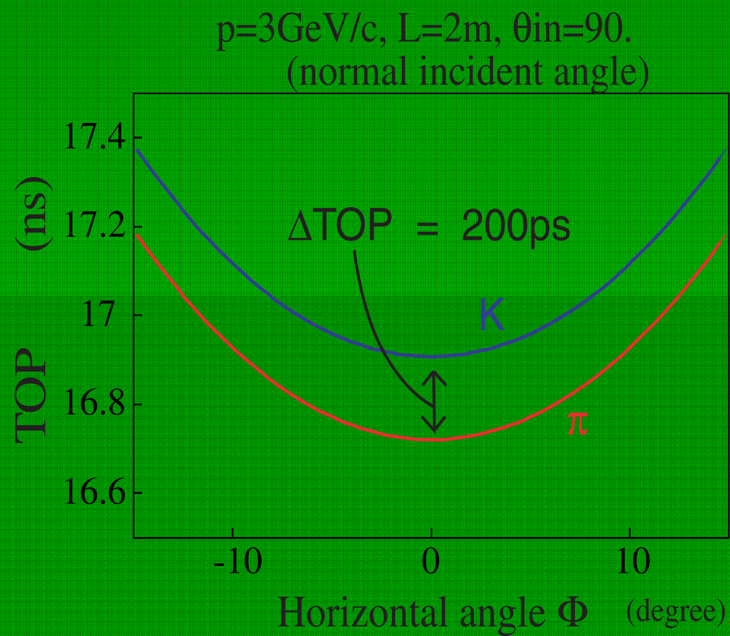
TOP counter

- **Cherenkov ring imaging using timing information**





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



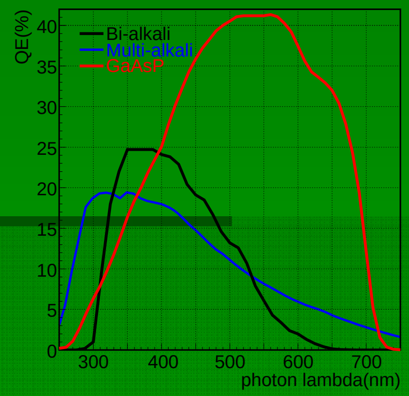
Difference of path length

→ Difference of time of propagation (TOP)

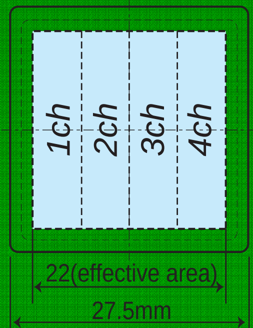
(+ TOF from IP)

With precise time resolution (σ~40ps)

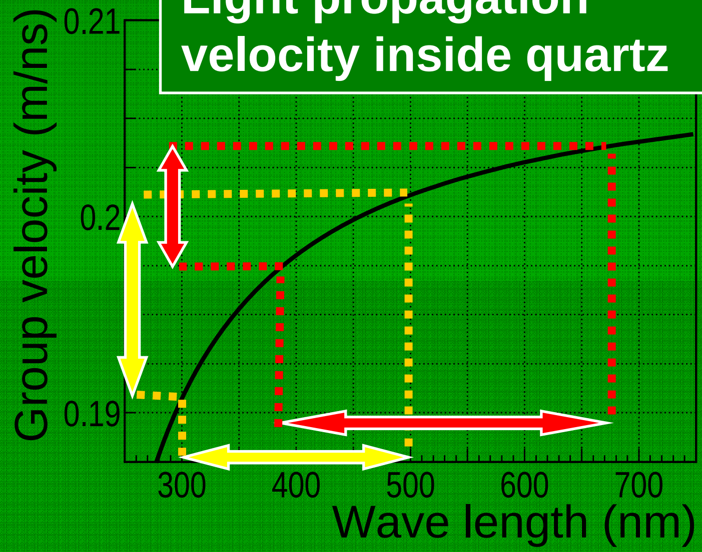
MCP-PMT with GaAsP



- **GaAsP photo-cathode**
  - **Higher Q.E.**
  - **at longer wavelength → less chromatic error**
- **3.5s K/p at 4GeV/c, q=70° (1s improvement)**
- **Square-shape MCP-PMT with GaAsP photo-cathode is developing with Hamamatsu**



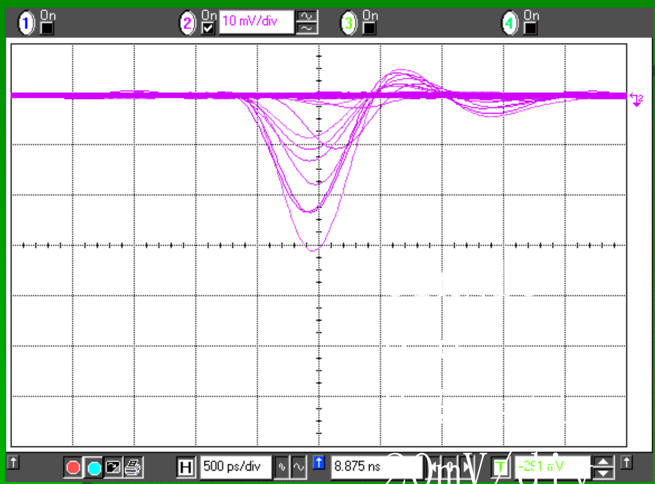
Light propagation velocity inside quartz

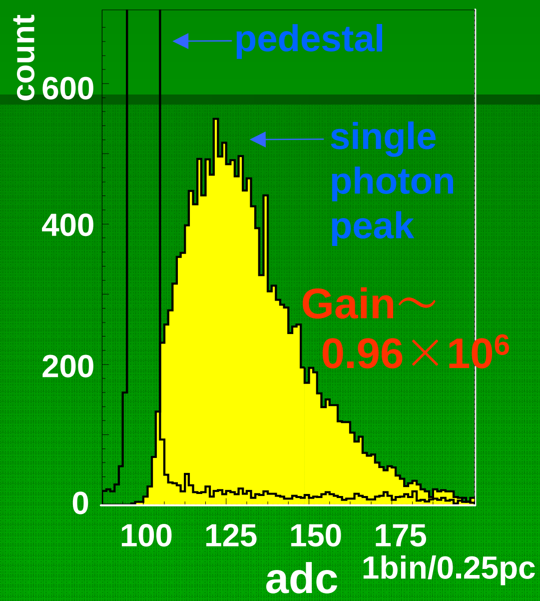


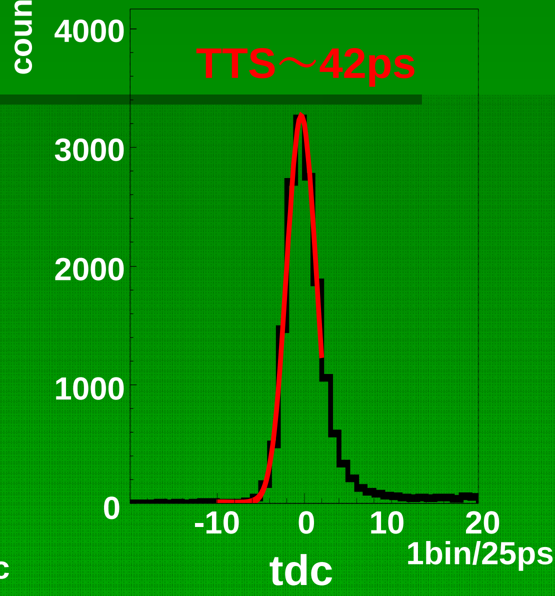
Photon sensitivity at longer wave length shows the smaller velocity fluctuation.

GaAsP MCP-PMT performance

- Wave form, ADC and TDC distributions







- Enough gain to detect single photo-electron
- Good time resolution (TTS=42ps) for single p.e.
  - Slightly worse than single anode MCP-PMT (TTS=32ps)
- Next
  - Check the performance in detail
  - Develop with the target structure

Summary of Super KEKB upgrade

- **Why? – Search for new sources of flavor mixing and CP violation**
- **How? – Increase N_B, decrease β_y*, and crab crossing: L=8$\times$10^{35}/cm^2/s**
  - **New beam pipe, crab cavity, new injector with damping ring**
  - **Belle will also be upgraded**
- **Ideas for even higher luminosity and better detector are desperately needed**
  - **Please join and help!**