KEK, High Energy Accelerator
Research Organization

Future flavour physics program at KEK

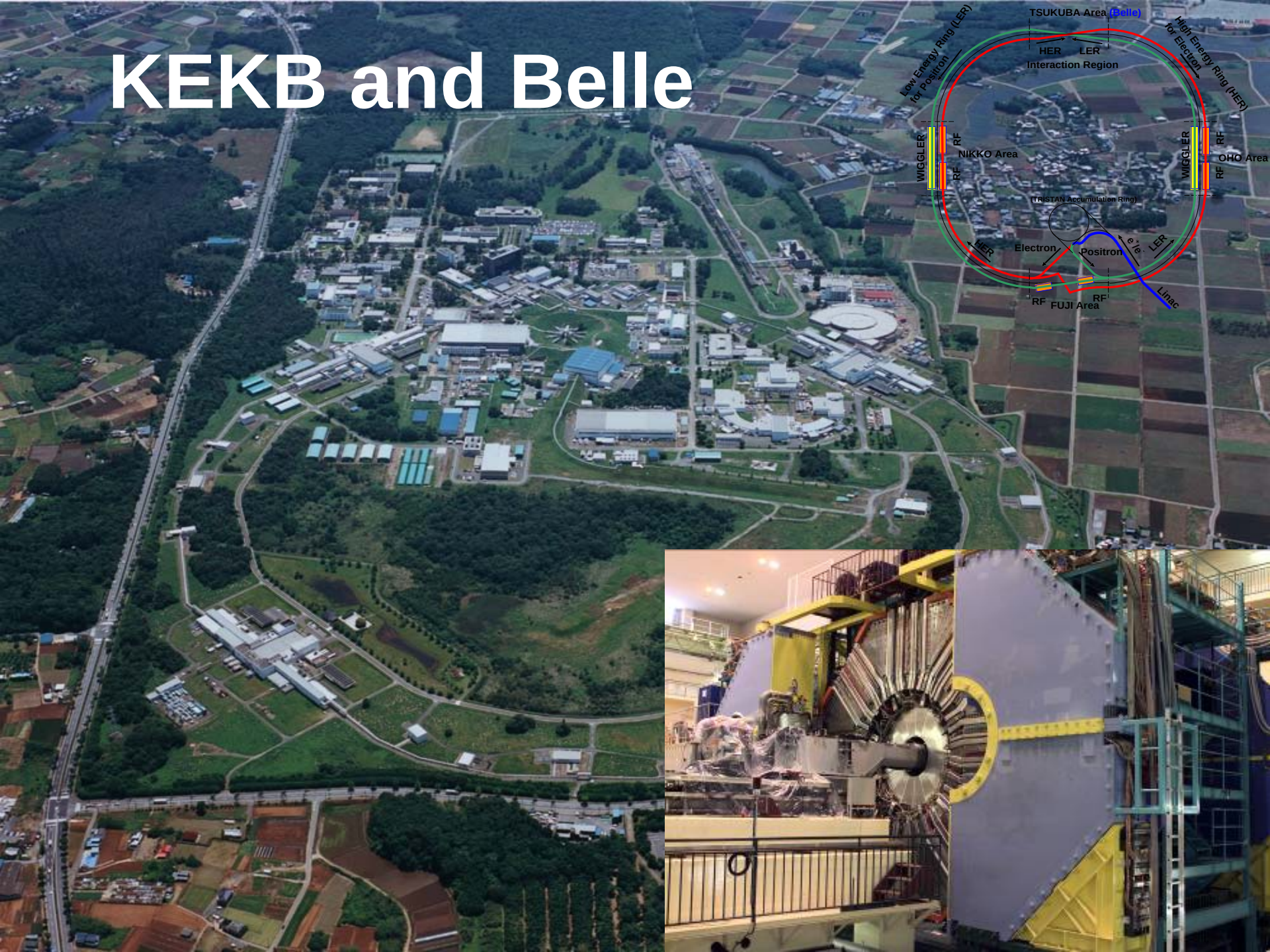
Seminar at BNL
November 13, 2008

Masa Yamauchi
KEK

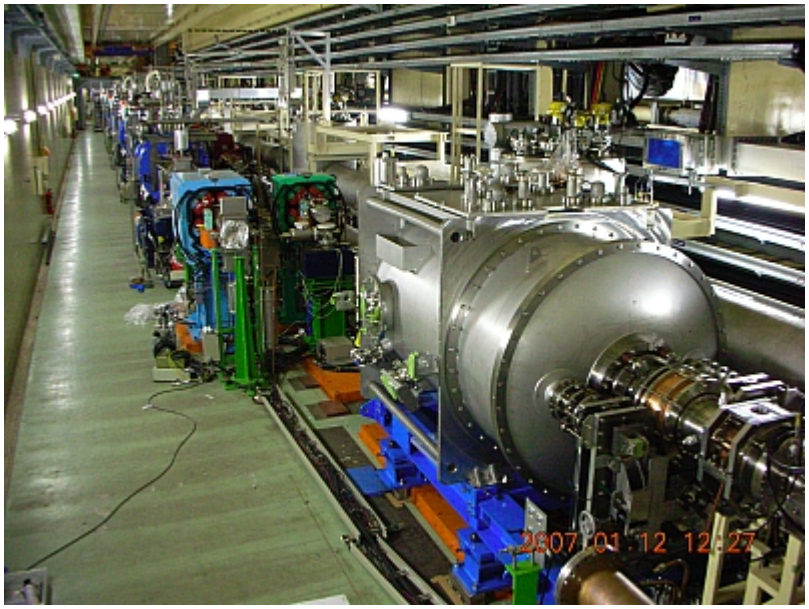
Outline

- Introduction: KEKB and Belle
- Physics case for KEKB/Belle upgrade
- KEKB upgrade plan
- Detector upgrade plan
- Schedule and funding status
- Summary

KEKB and Belle



KEKB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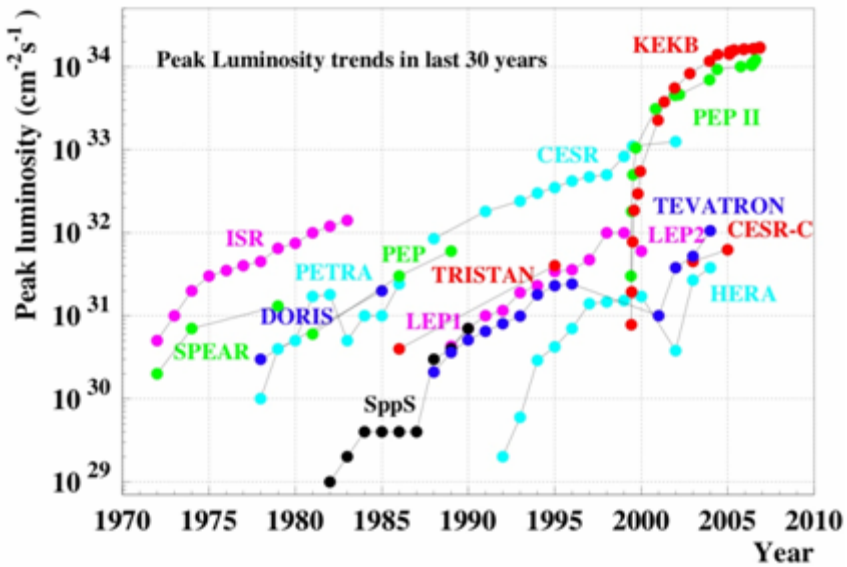
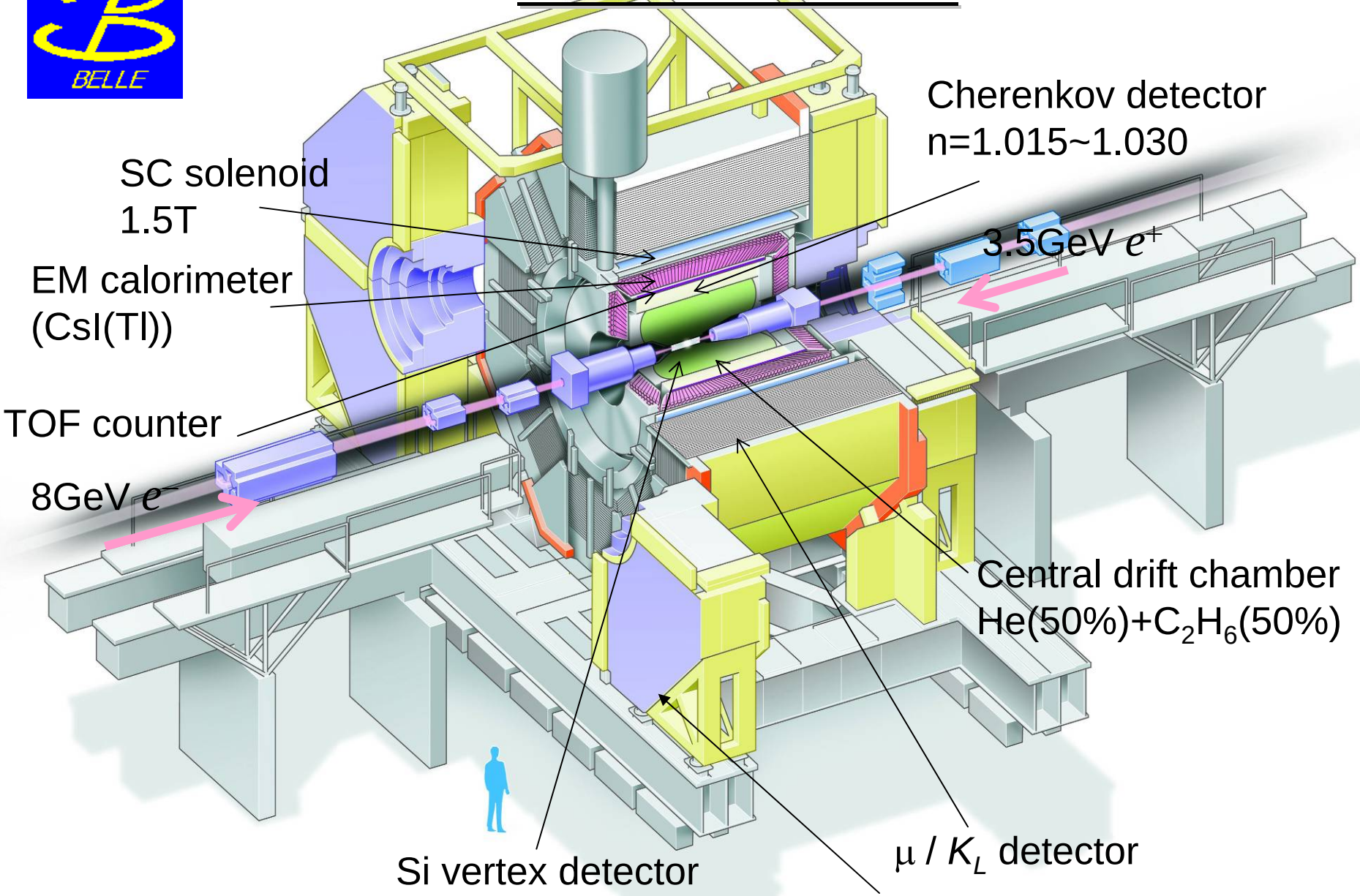

Peak Luminosity trends in last 30 years
Peak luminosity (cm^{-2}s^{-1})
10^{34}
10^{33}
10^{32}
10^{31}
10^{30}
10^{29}
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
KEKB
PEP II
CESR
TEVATRON
LEP2
CESR-C
HERA
ISR
PEP
PETRA
TRISTAN
DORIS
LEP1
SPEAR
SppS

Belle Detector

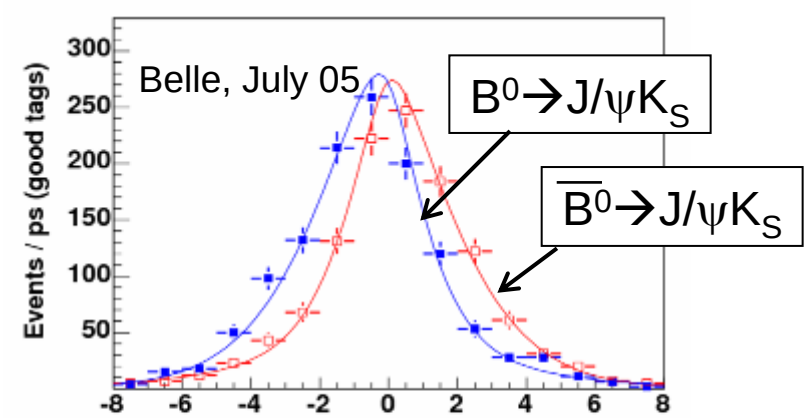


Belle Collaboration

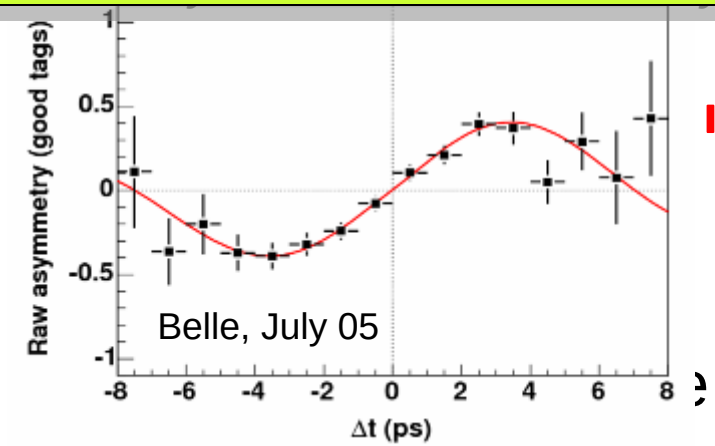
BINP
Chennai
Chiba U.
Hanyang U.
U. of Cincinnati
Fu-Jen U.
Giessen U.
Gyeongsang Nat'l U.
U. of Hawaii
Hiroshima Tech.
HEPHY, Vienna
IHEP, Protvino
IHEP, Beijing
INFN, Torino
ITEP
Kanagawa U.
Karlsruhe
KEK
Korea U.
Krakow Inst. of Nucl. Phys.
Kyoto U.
Kyungpook National U.
U. of Lausanne
Jozef Stefan Inst.
MPI, Munich
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.

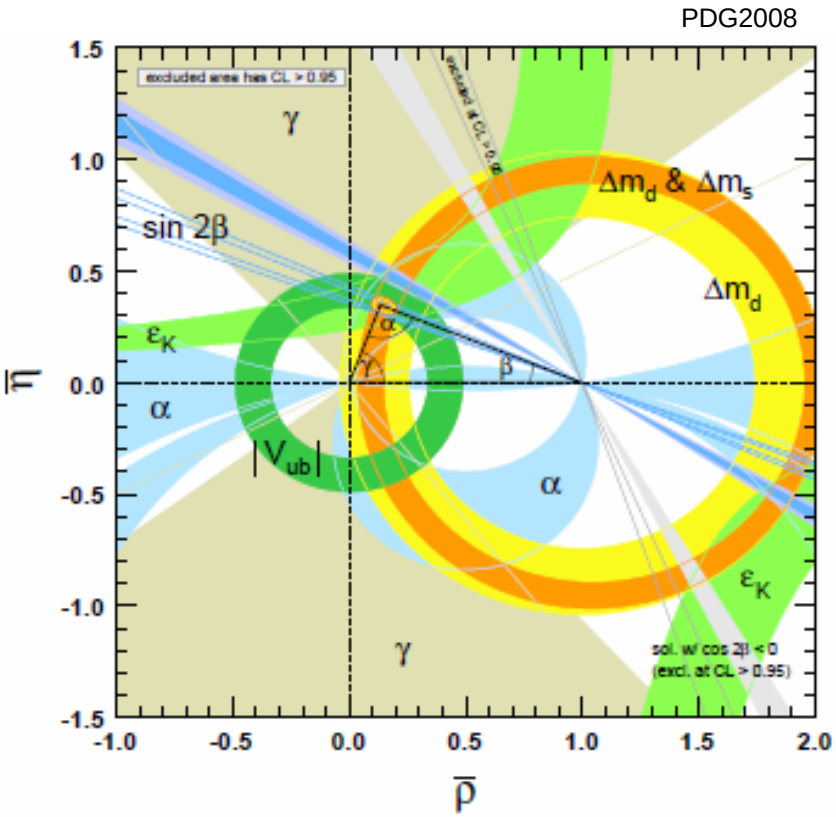
Achievement of the *B* Factories

Quantitative confirmation of the KM model



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

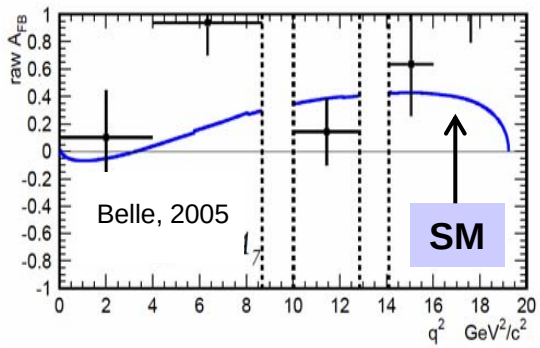


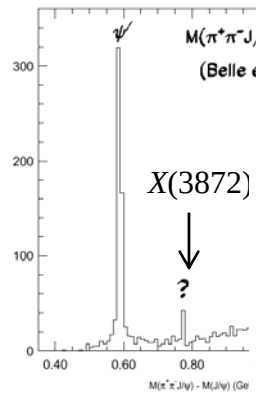


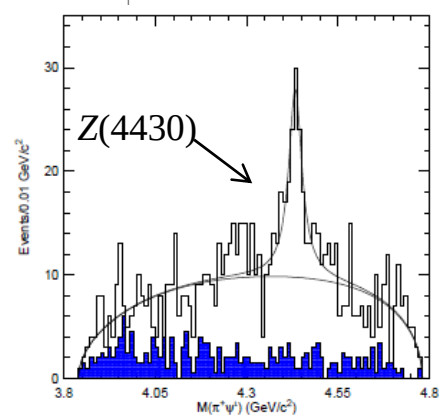
Other highlights

Many new resonances

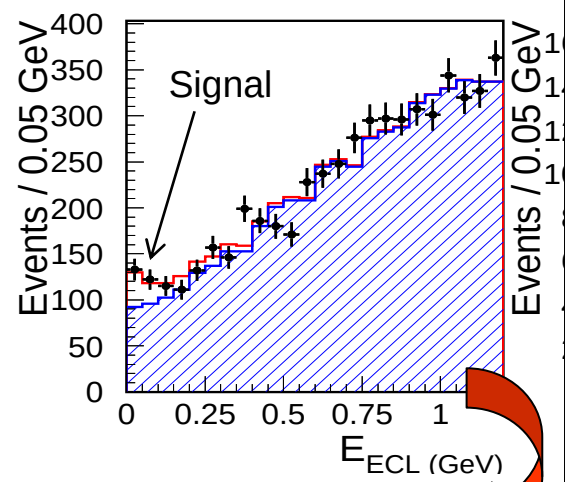
A_{FB} in $B \to K^* l^+ l^-$



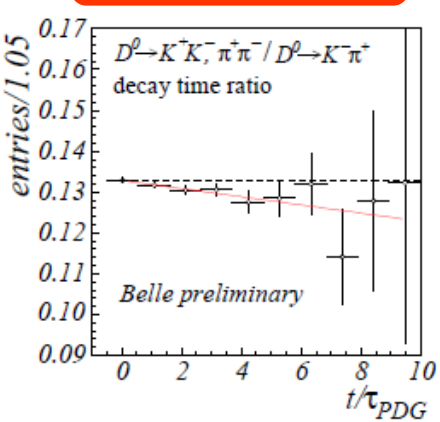




Evidence for $B \to \tau\nu$

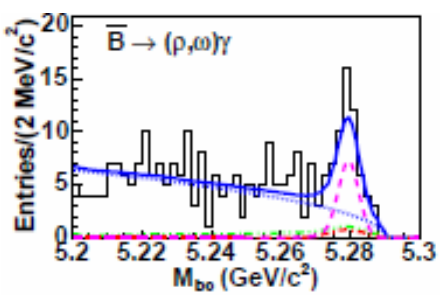


D^0-$\overline{D^0}$ mixing

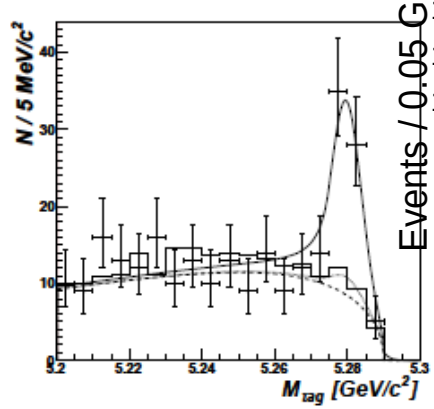


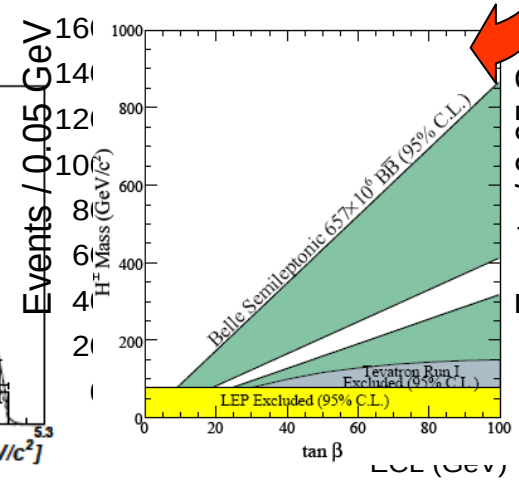
$y_{CP} = 1.31 \pm 0.32 \pm 0.25$ %

$b \to d\gamma$ transition



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

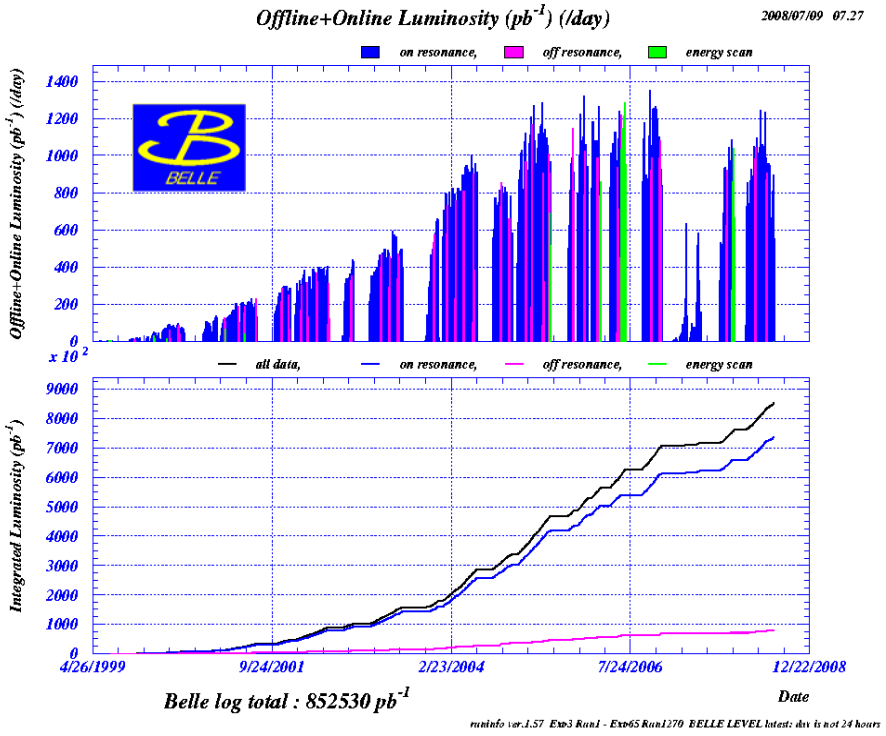


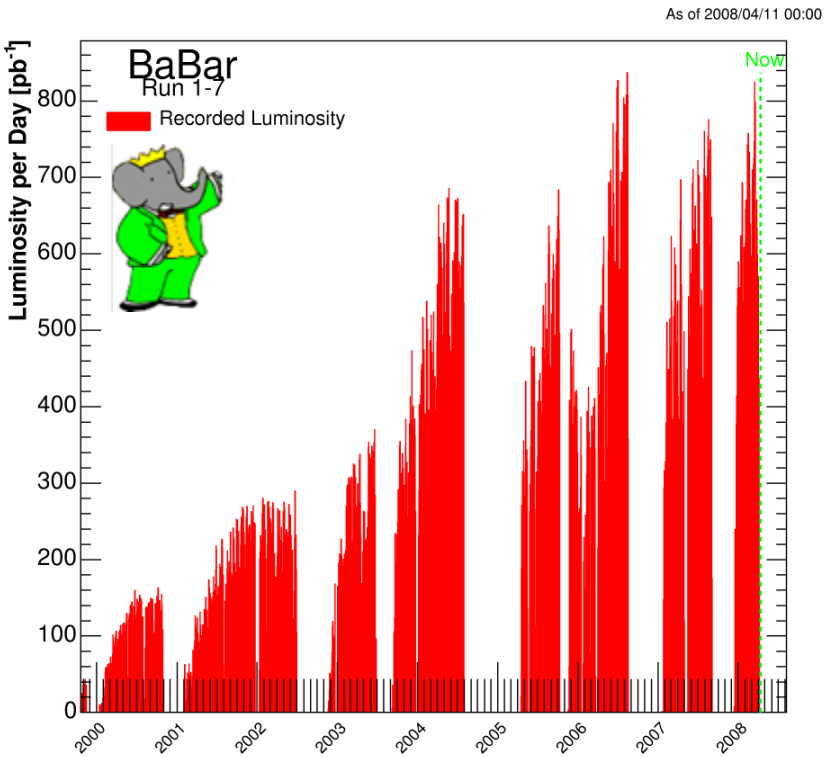


and more…

Another important achievement

Asymmetric e^+e^- colliders 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?

- LHC will start soon to explore the TeV region, which is the scale of the electroweak symmetry breaking, and most probably related to the "New Physics" scale.
  - It is natural to assume that the NP 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.

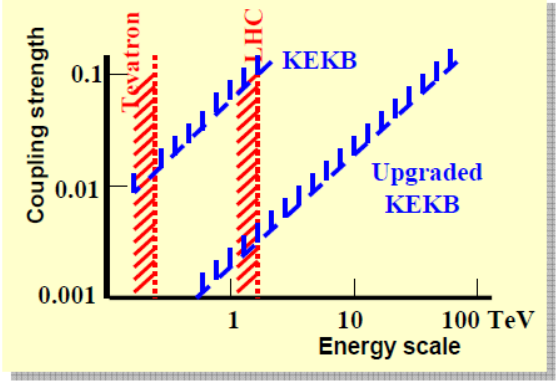
Pattern of deviations from the Standard Model

Y.Okada

SUSY models \ Observ-ables	Unitarity triangle	$B \to \phi K_S$	$b \to s\gamma$ Indirect CPV	$b \to s\gamma$ 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

Search for New Physics in precision meas.

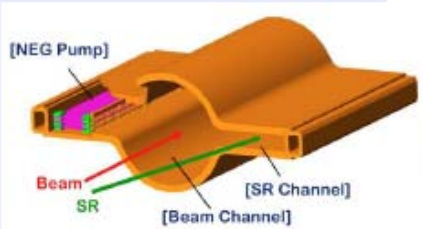


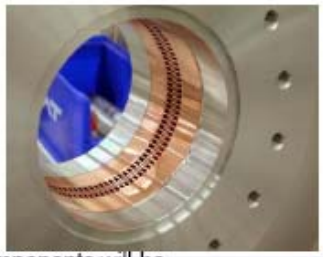
In order for the flavor physics to be useful in the coming LHC era, the precision of various flavor measurements must be significantly improved, both in terms of experimental reach and understanding of theoretical uncertainty.

From KEKB to SuperKEKB

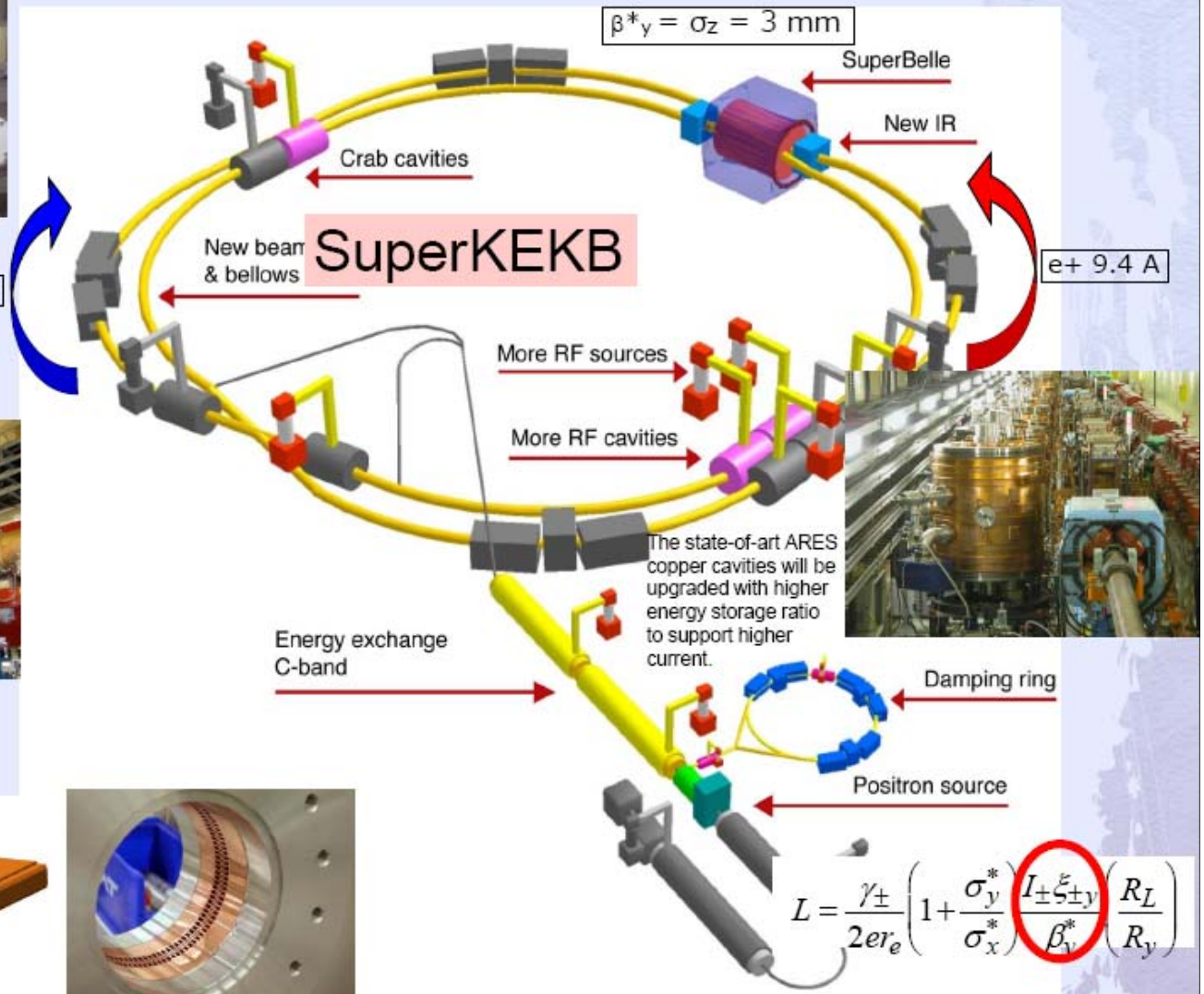
Crab cavities installed and undergoing testing in beam

The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.





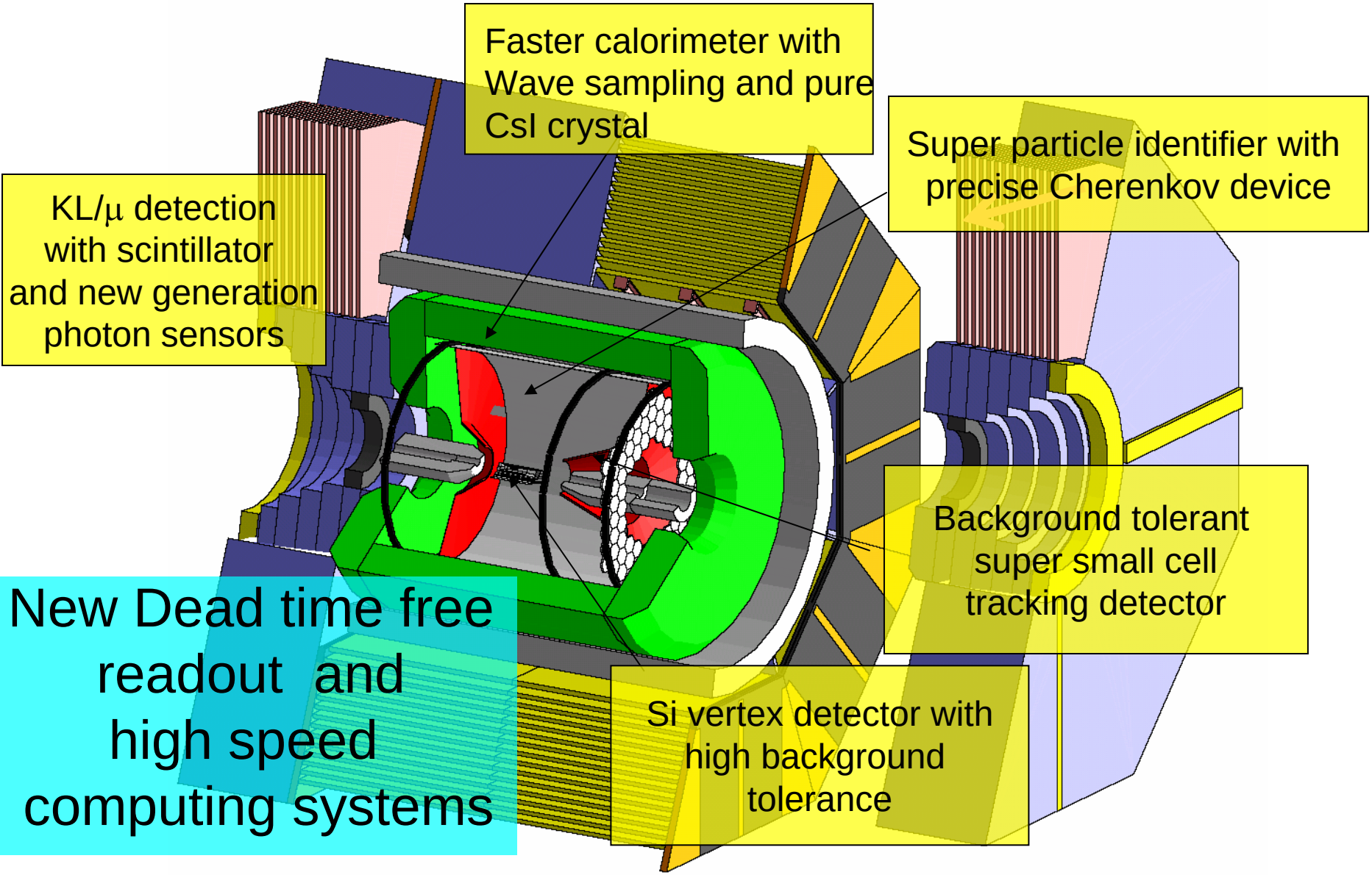
The beam pipes and all vacuum components will be replaced with higher-current design.



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

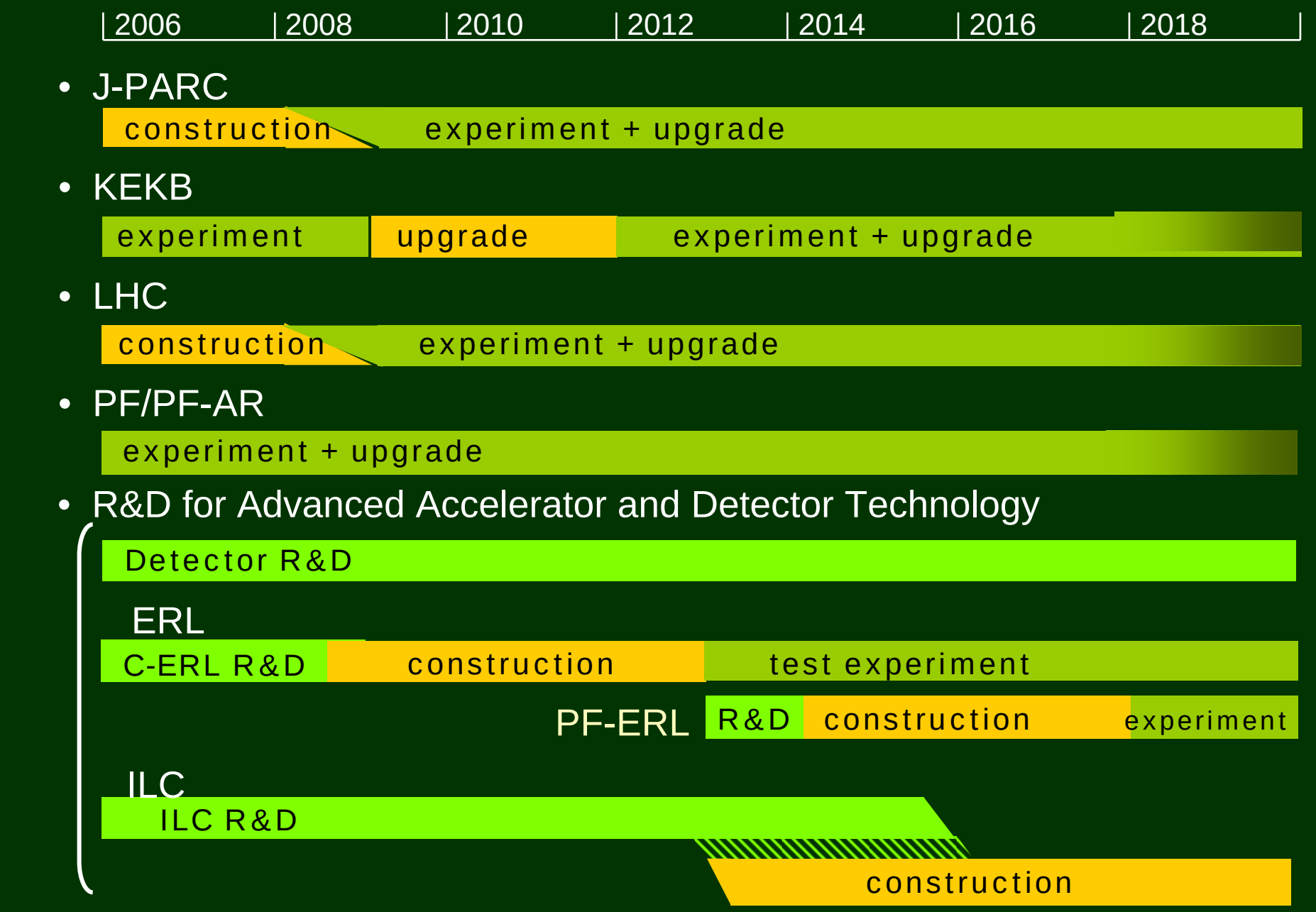
will reach 8×10^{35} cm^{-2}s^{-1}.

Belle upgrade



New Dead time free readout and high speed computing systems

KEK Roadmap


2006
2008
2010
2012
2014
2016
2018
J-PARC
construction
experiment + upgrade
KEKB
experiment
upgrade
experiment + upgrade
LHC
construction
experiment + upgrade
PF/PF-AR
experiment + upgrade
R&D for Advanced Accelerator and Detector Technology
Detector R&D
ERL
C-ERL R&D
construction
test experiment
PF-ERL
R&D
construction
experiment
ILC
ILC R&D
construction

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…

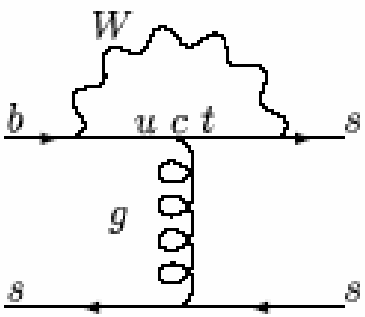
Super-high statistics measurements:

α_S, $\sin^2\theta_W$, etc.

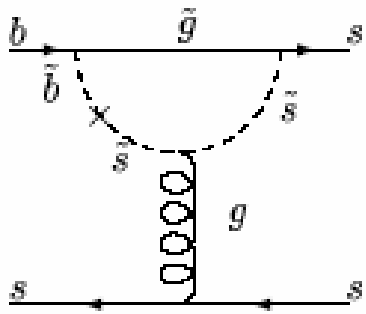
Search for new CP phases

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.

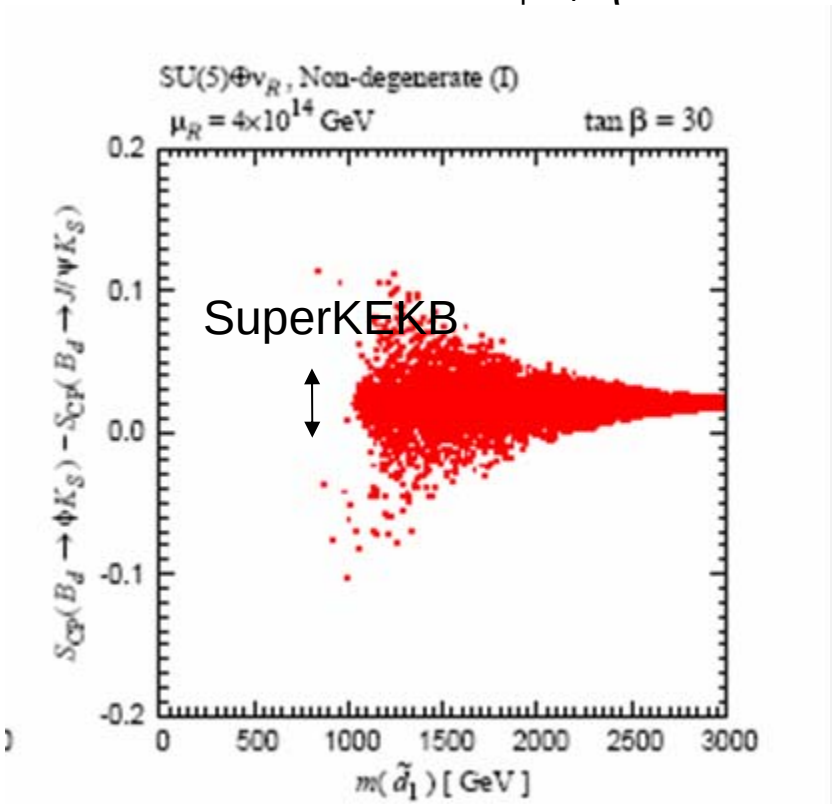


SM



SUSY contribution

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



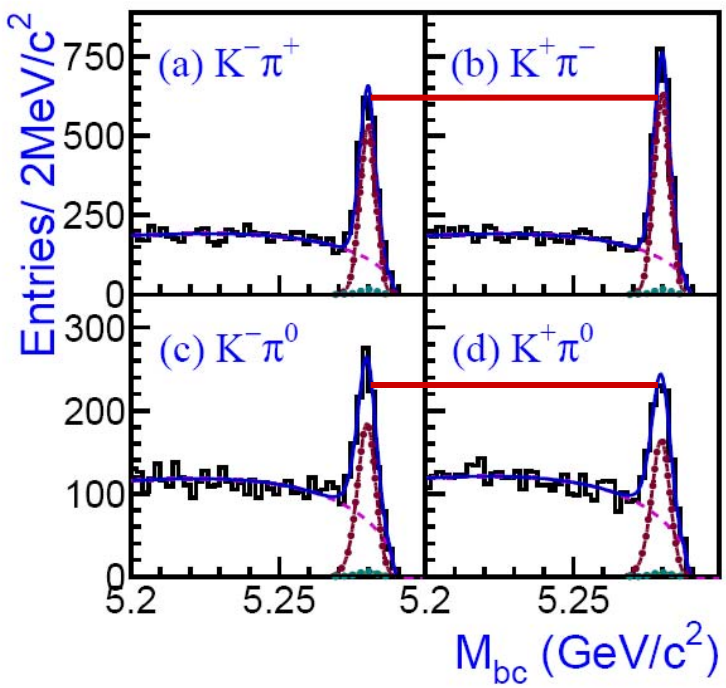
T.Goto et al., 2007

Direct CP Violation in $B \to K\pi$ Decays

P.Chang, ICHEP2008

$$\mathcal{A}_{CP}(B \to f) = \frac{|\overline{A}|^2 - |A|^2}{|\overline{A}|^2 + |A|^2} \propto \sum_{i,j} A_i A_j \sin(\delta_i - \delta_j) \sin(\phi_i - \phi_j)$$

Belle Results: Nature 452, 332 (2008)



New Update

$A_{cp}(K^+\pi^-) =$

$-0.107 \pm 0.016\ ^{+0.006}_{-0.004}$		**BaBar**
$-0.094 \pm 0.018 \pm 0.008$		**Belle**
$-0.086 \pm 0.023 \pm 0.009$		**CDF**
$-0.04 \pm 0.16 \pm 0.02$		**CLEO**
$\Rightarrow -0.098\ ^{+0.012}_{-0.011}$	@ 8.1σ	**AVG**

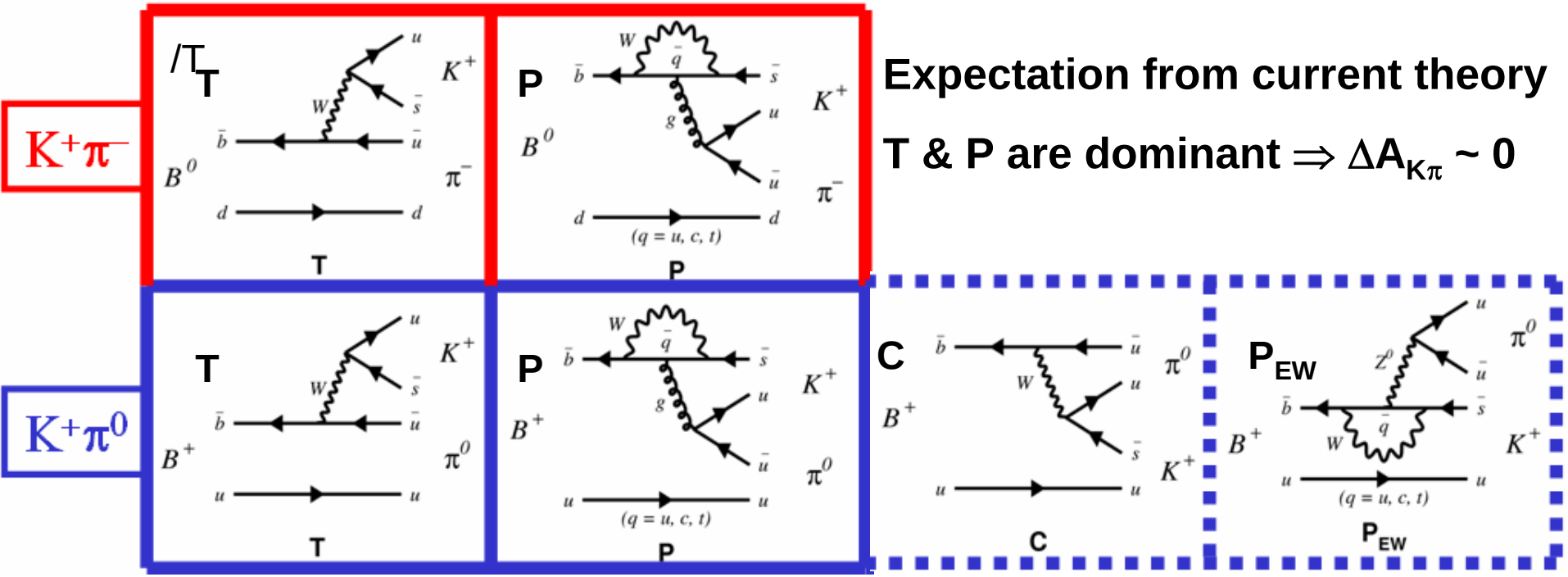
$\mathbf{A_{cp}(K^+\pi^0)} =$

$+0.030 \pm 0.039 \pm 0.010$		**BaBar**
$+0.07 \pm 0.03 \pm 0.01$		**Belle**
$-0.29 \pm 0.23 \pm 0.02$		**CLEO**
$\Rightarrow +0.050 \pm 0.025$	@**2.0**σ	**AVG**

$\Delta \mathbf{A_{K\pi}} = A_{cp}(K^+\pi^-) - \mathbf{A_{cp}(K^+\pi^0)}$
$= -0.147 \pm 0.028$ @ **5.3**σ

$\Delta A_{K\pi}$ Puzzle

P.Chang, ICHEP2008



Expectation from current theory

T & P are dominant ⇒ $\Delta A_{K\pi}$ ~ 0

- **Enhancement of large C with large strong phase to T ⇒ strong inter. !?**

Chiang et. al. 2004
Li, Mishima & Sanda 2005

- **Enhancement of large P_{EW} ⇒ New physics**

Yoshikawa 2003; Mishima & Yoshikawa 2004; Buras et. al. 2004, 2006; Baek & London 2007; Hou et. al. 2007; Feldmann, Jung & Mannel 2008

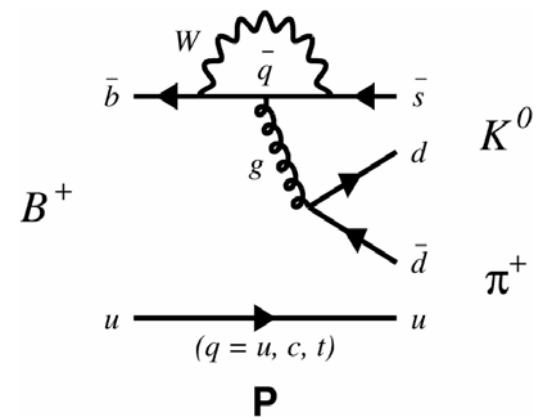
Model independent checks for NP

P.Chang, ICHEP2008

M. Gronau, PLB 627, 82 (2005); D. Atwood & A. Soni, Phys. Rev. D 58, 036005(1998).

$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} = \mathcal{A}_{CP}(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

$B^+ \to K^0\,\pi^+$



P dominants. $\Rightarrow$ **$A_{cp}(K^0\pi^+) \sim 0$**

World Average

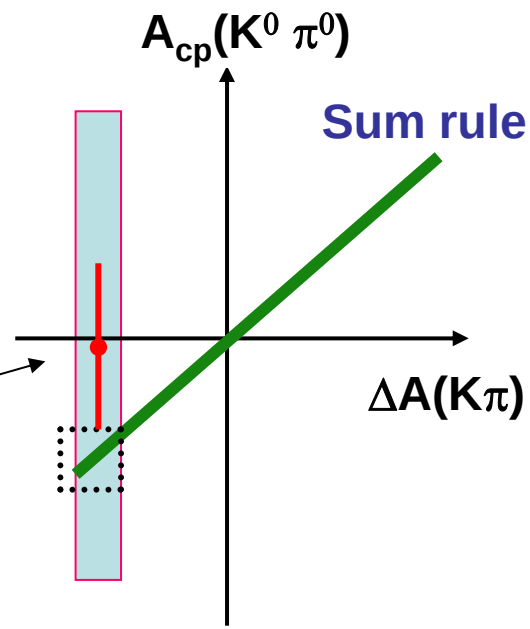
$A_{cp}(K^0\pi^+) = 0.009 \pm 0.025$

$B^0 \to K^0\,\pi^0$ **New**

A = –0.13 ± 0.13 ± 0.03

A = +0.14 ± 0.13 ± 0.06

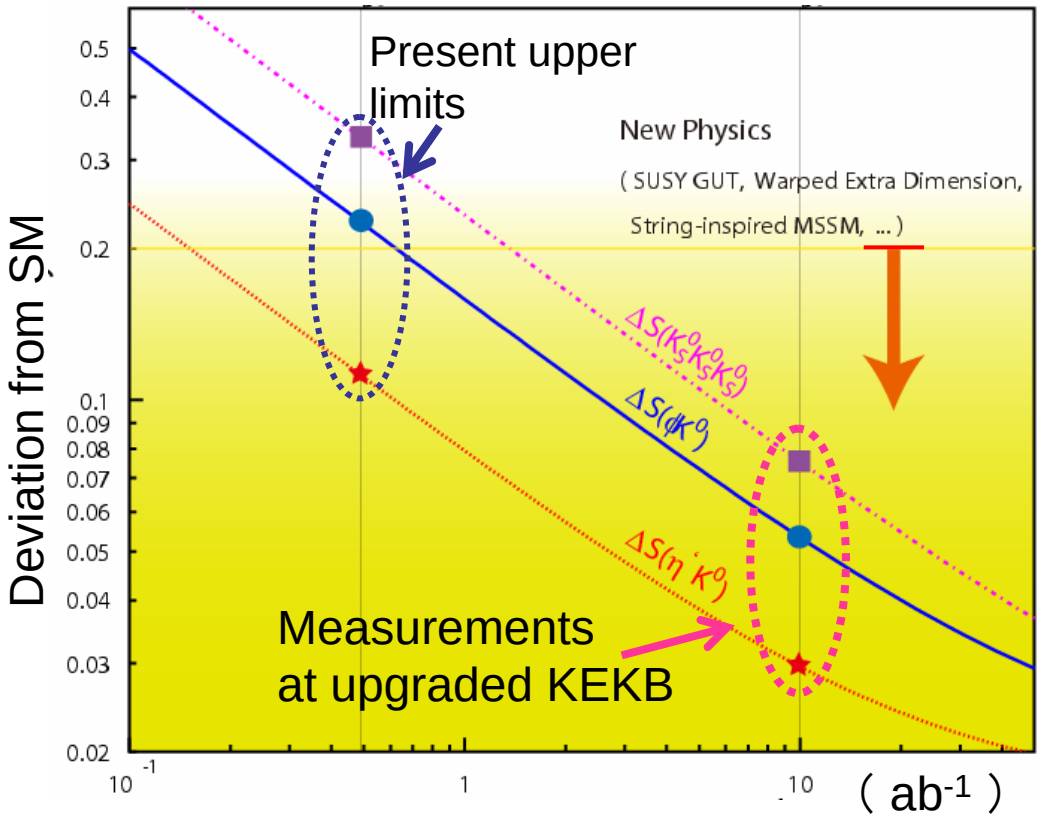
HFAG AVG: –0.01 ± 0.10



Important topic for Super B factory

Sum rule predicts
$A_{cp}(K^0\pi^0) = -0.151 \pm 0.043$

CP asymmetries of penguin dominated B decays



Reach of present B factories

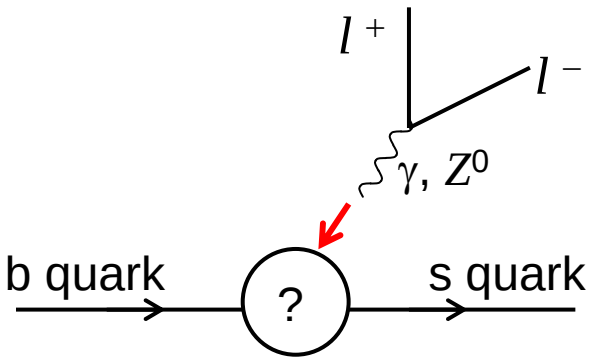
Reach of upgraded KEKB

Deviation from SM

New source of CP violation

Relevant to baryogenesis?

Probing $b \rightarrow s$ transition with $l^+ l^-$



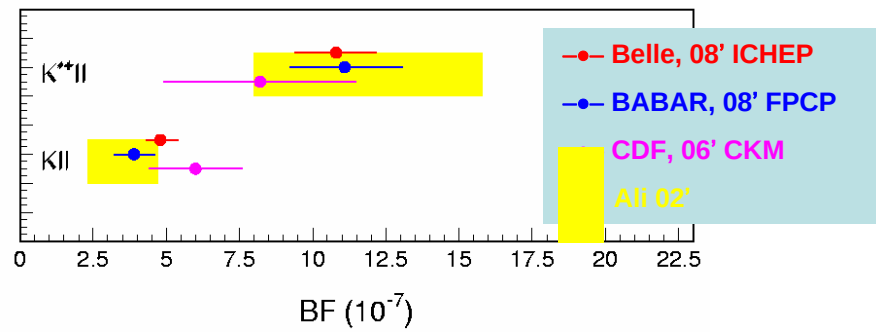
: Probe the flavor changing process with the "EW probe".

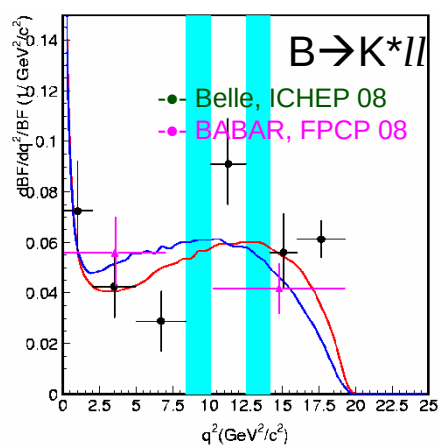
This measurement is especially sensitive to new physics such as SUSY, heavy Higgs and extra dim.

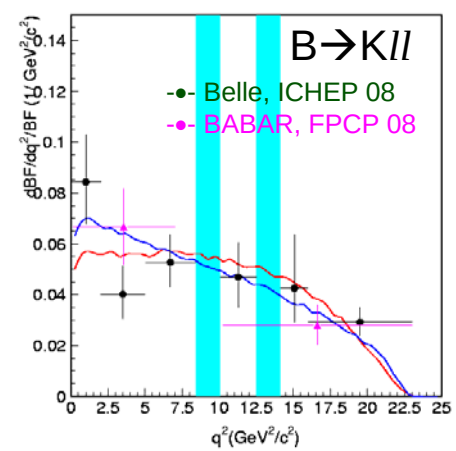
Possible observables:

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

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



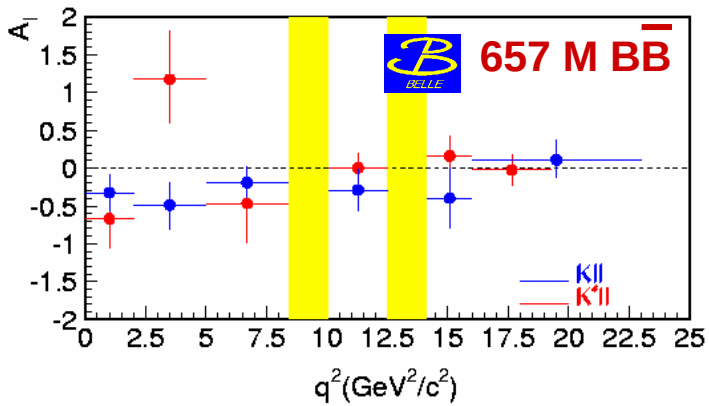


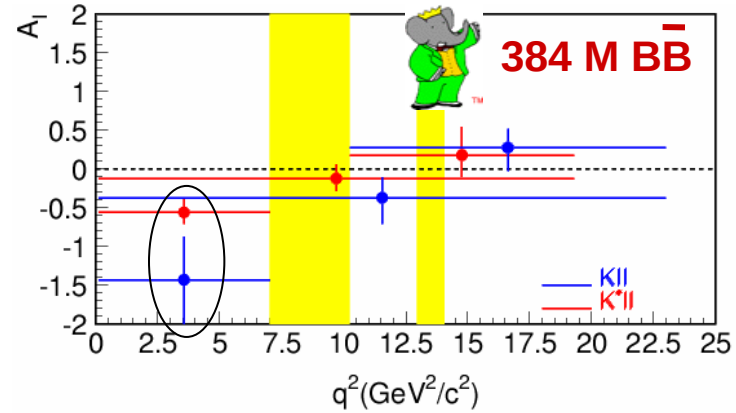


Probing $b \to s$ transition with $l^+ l^-$

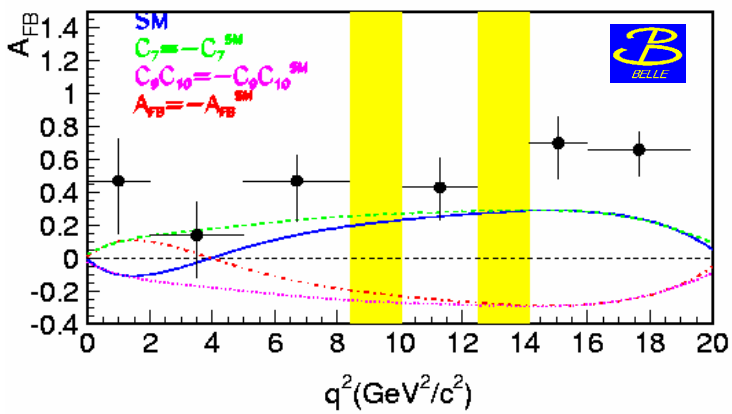
$$A = \frac{1.071 \times BF(B^0 \to K^{(*)0} ll) - BF(B^\pm \to K^{(*)\pm} ll)}{1.071 \times BF(B^0 \to K^{(*)0} ll) + BF(B^\pm \to K^{(*)\pm} ll)}$$

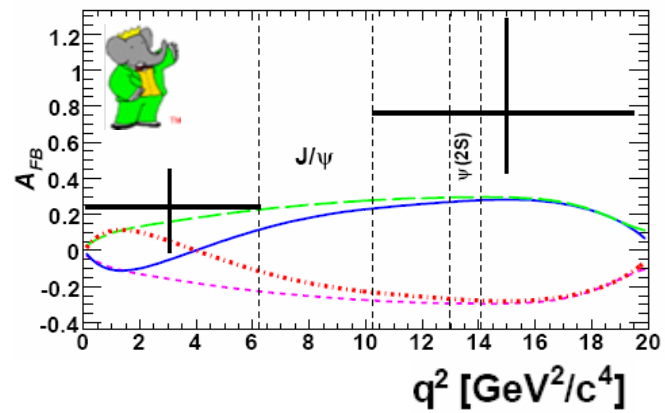
Isospin symmetry
$A_I \neq 0$??





Forward-backward charge asymmetry as a consequence of γ-Z^0 interference

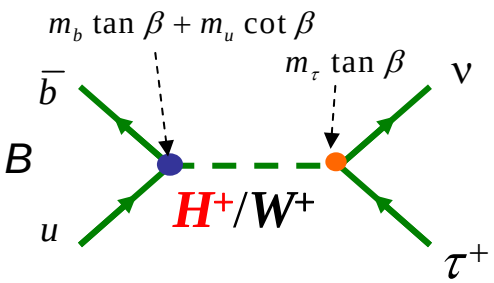


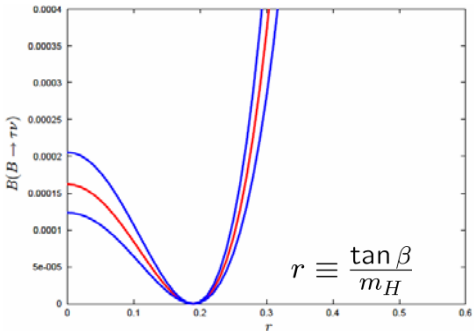


Data show positive A_{FB} at low q^2, while the SM predicts negative A_{FB}.

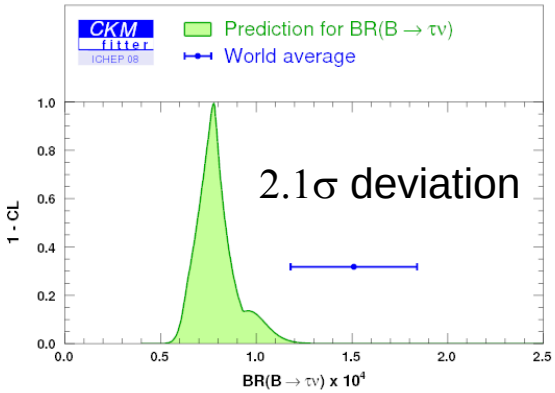
At high q^2, data above the SM expectation.

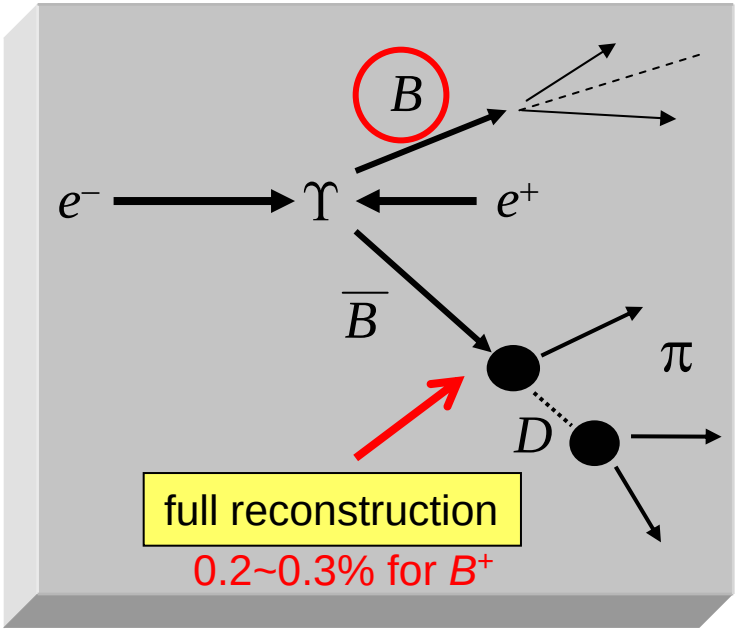
B to τ decays

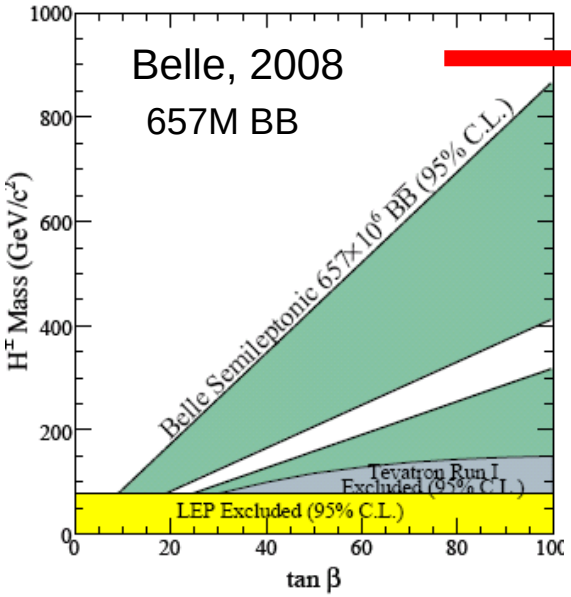


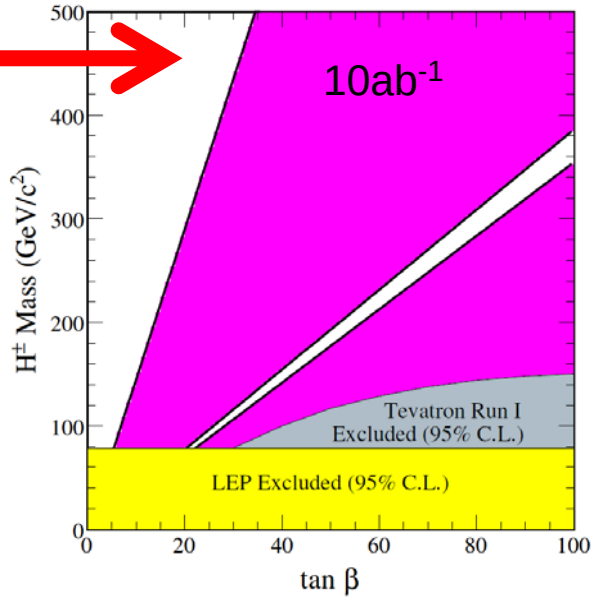


$\mathcal{B}(B \to \tau\nu) = (1.51 \pm 0.33) \times 10^{-4}$



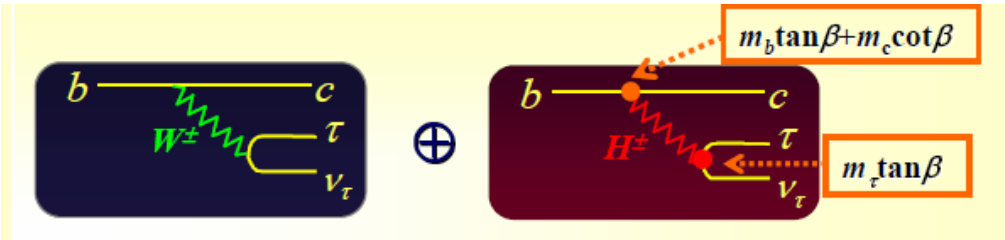




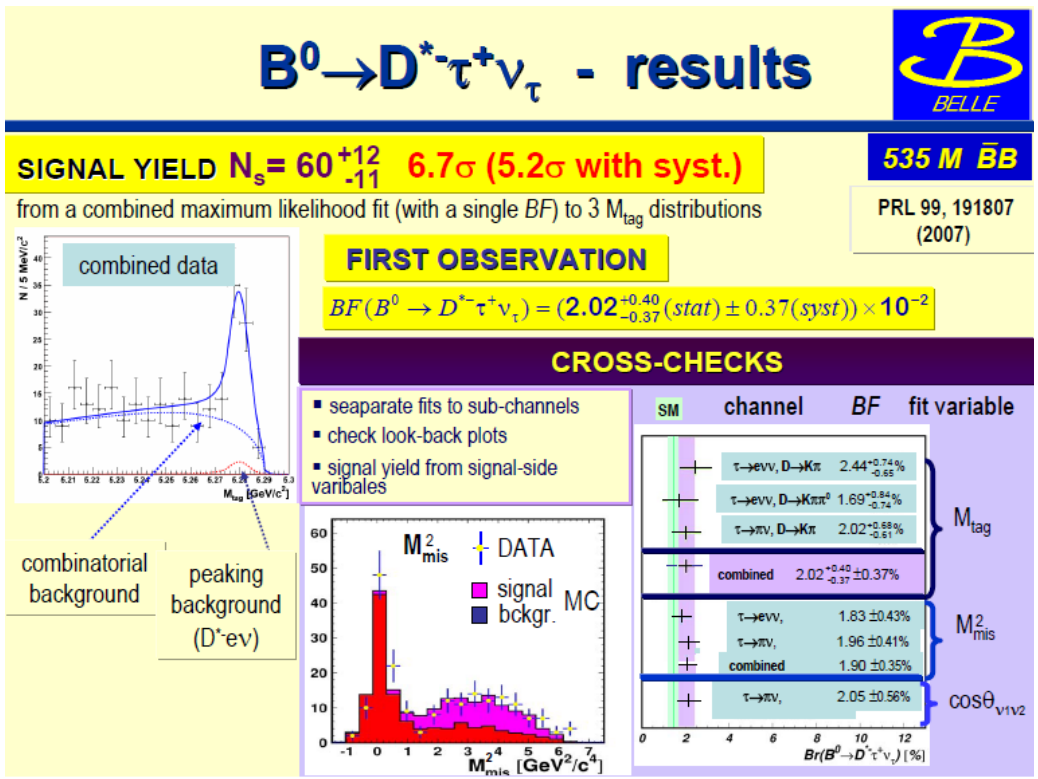


Provides a unique method to measure b-$H^\pm$-u and b-$H^\pm$-c coupling strengths.

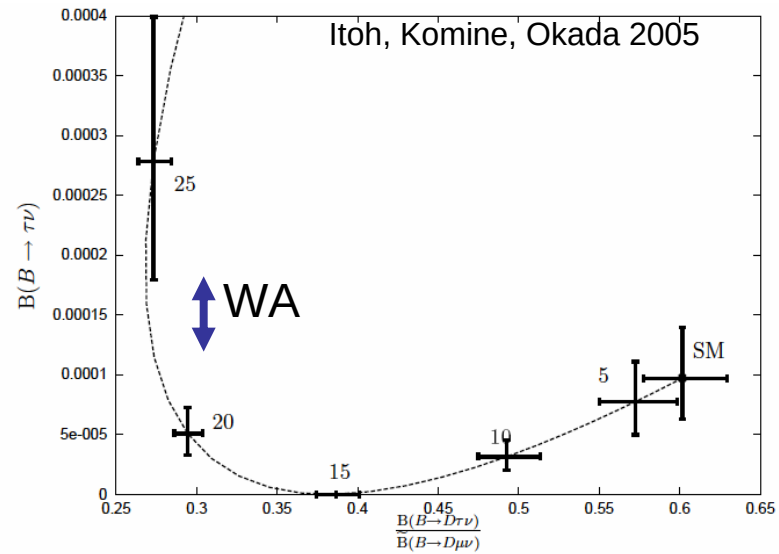
B to τ decays



$B \to D^* \tau \nu$ has been measured.



Two-fold ambiguity is resolved by the two measurements.

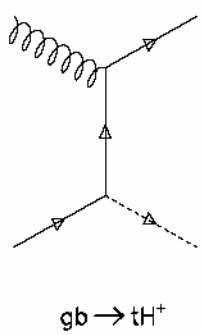


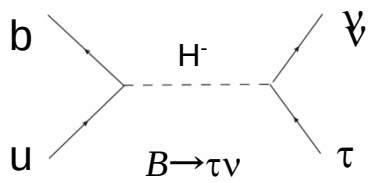
A.Bozek at Tau08

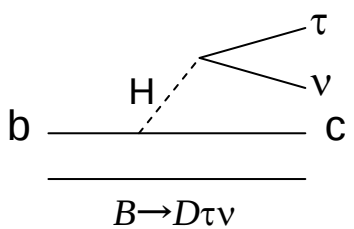
Comparison with $H^{\pm}$ production at LHC

- The parameter region covered by B decays and the charged Higgs production overlaps.
- If both experiments find positive effects, we can perform Universality Test of the charged Higgs couplings.

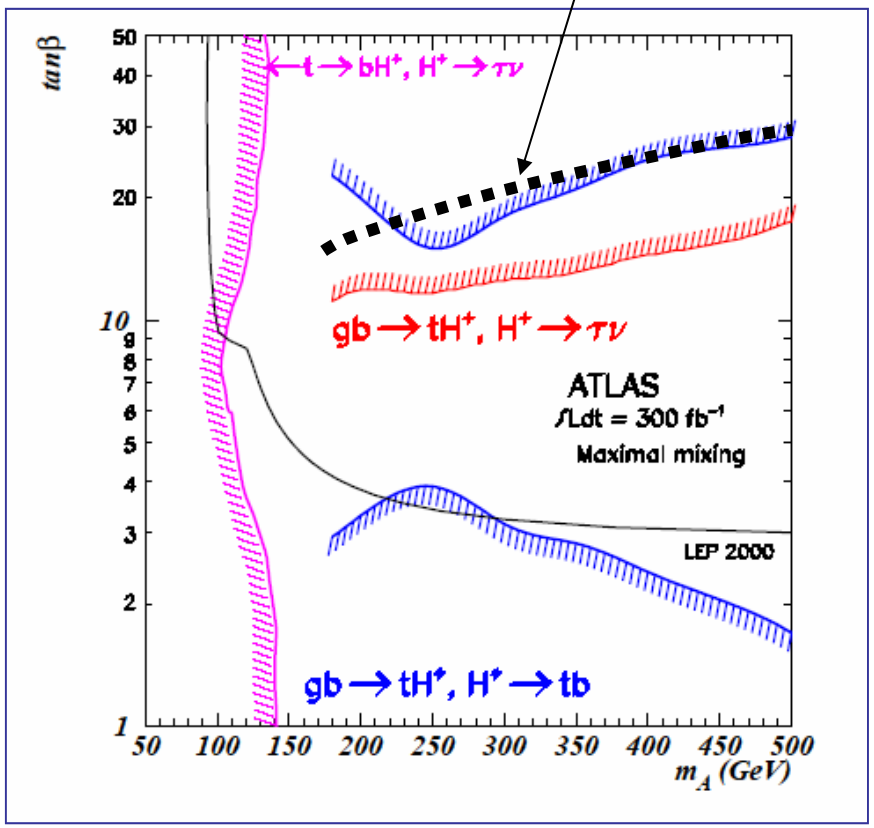
B->τν:	H-b-u coupling
B->Dτν :	H-b-c coupling
gb->tH:	H-b-t coupling







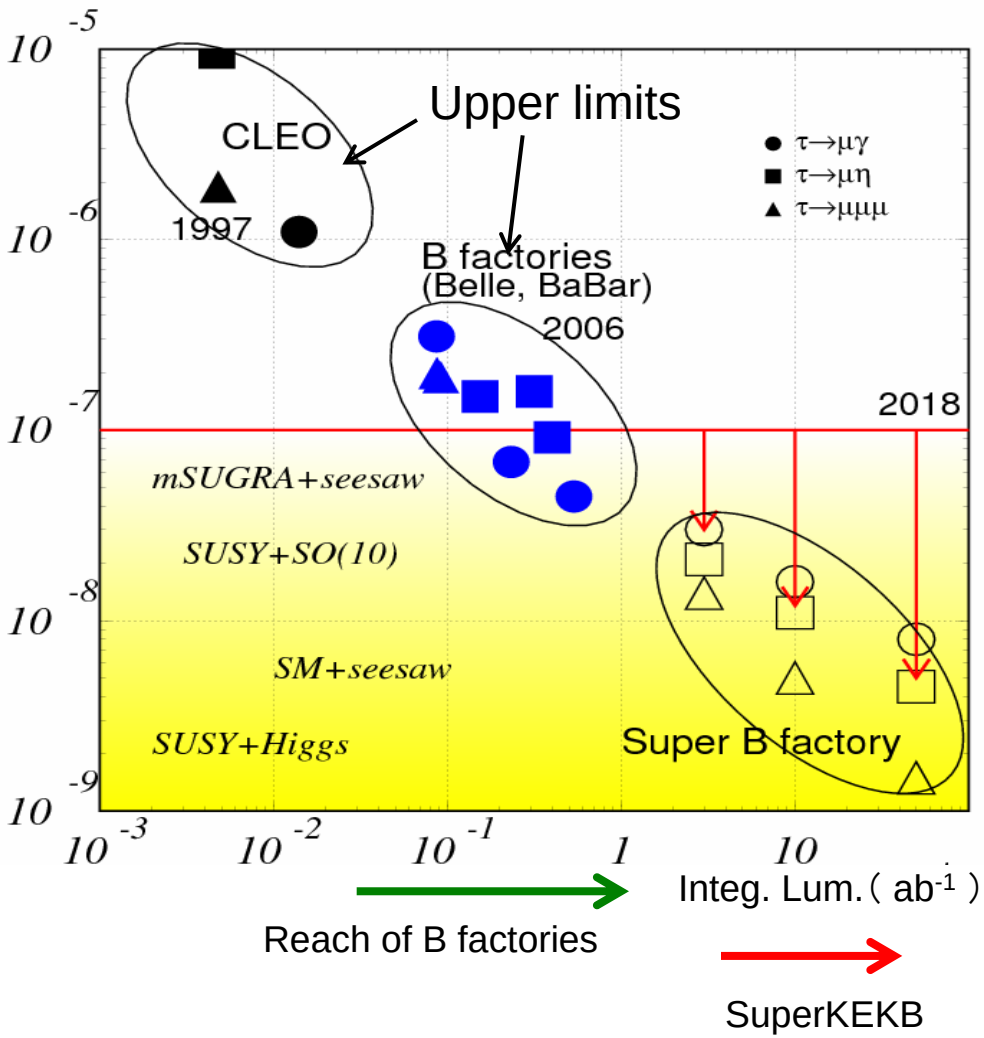
B->Dτν 50ab^{-1}

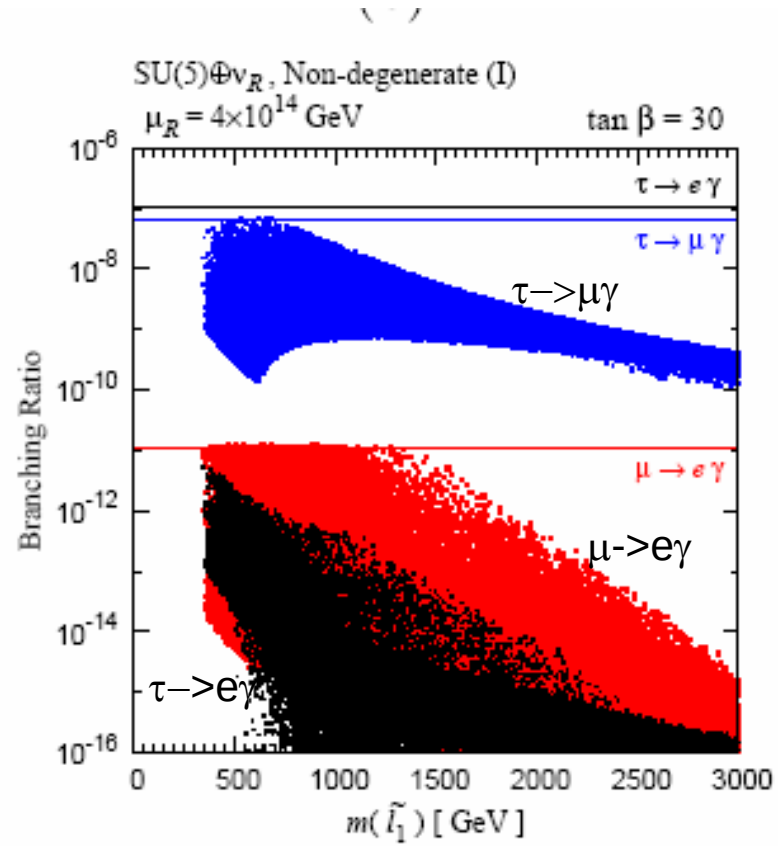


K.A.Assamagan, Y.Coadou, A.Deandrea 2002

Precise measurements of τ decays

LFV violating τ decay?

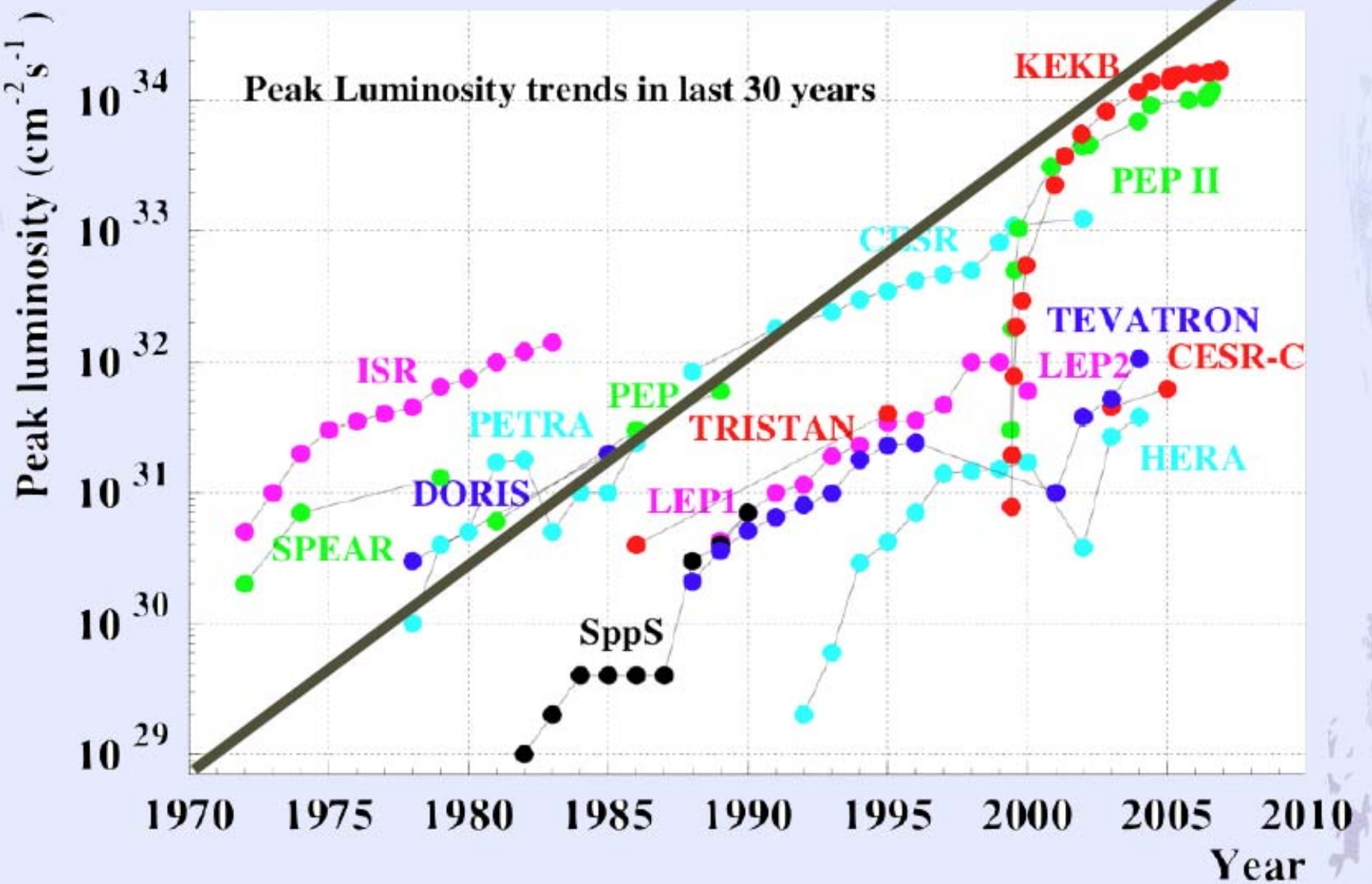




T.Goto et al., 2007

In Context:

Target: 8×10^{35} cm^{-2}s^{-1}
= 50 x World Record (KEKB)



Three factors that determine the luminosity:

Stored current:

1.7 / 1.4 A (e^+/ e^- KEKB)

→ 9.4 /4.1 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:

0.17 $\times 10^{35}$ $cm^{-2}s^{-1}$ (KEKB)

8 $\times 10^{35}$ $cm^{-2}s^{-1}$ (SuperKEKB)

Vertical β at the IP:

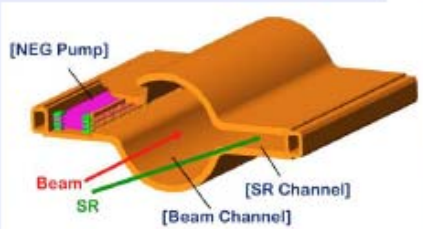
6.5/5.9 mm (KEKB)

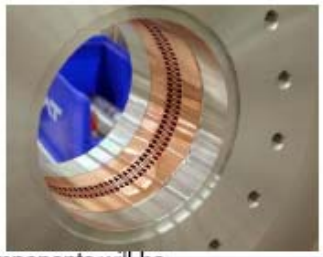
→ 3.0/3.0 mm (SuperKEKB)

From KEKB to SuperKEKB

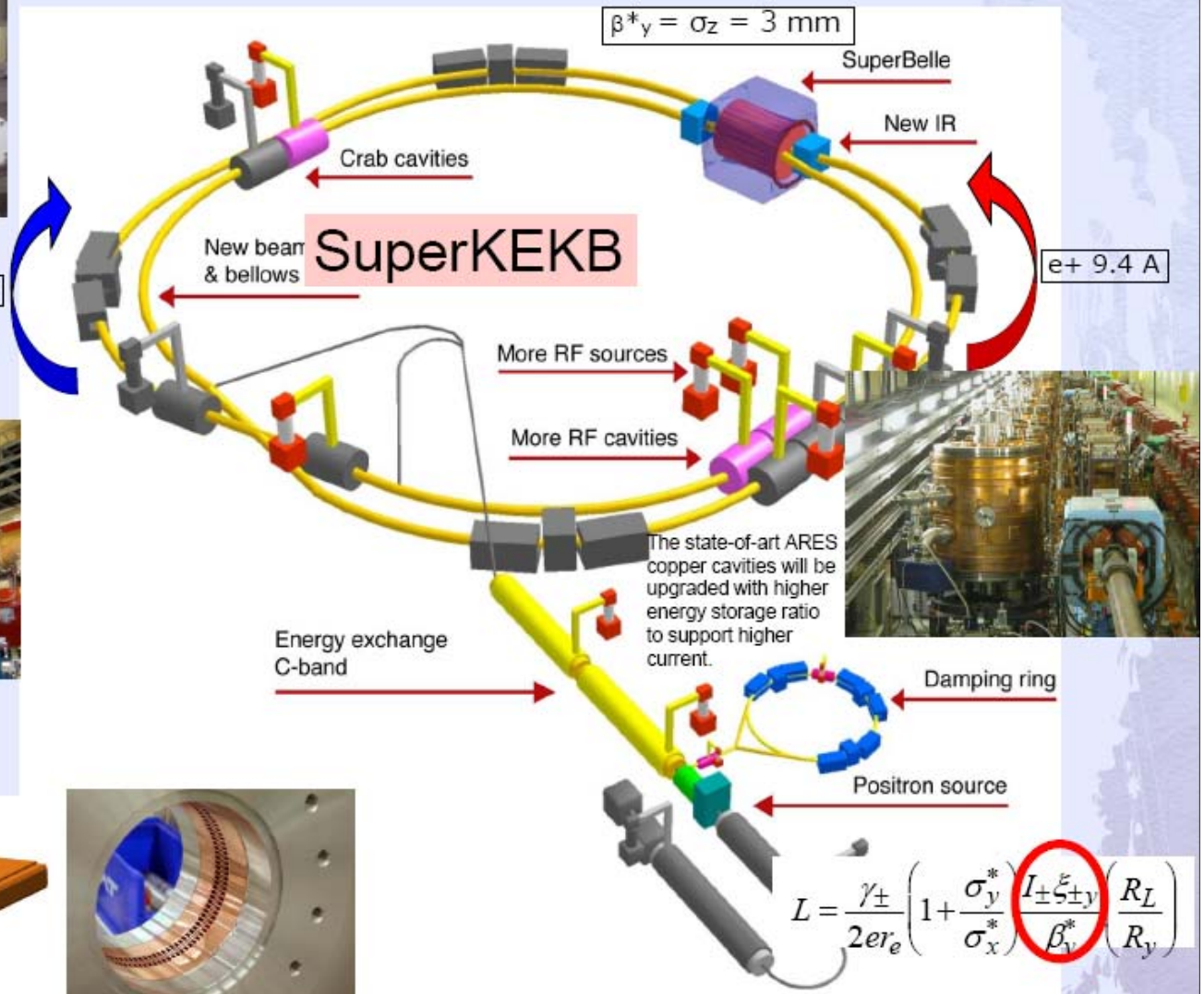
Crab cavities installed and undergoing testing in beam

The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.





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



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

will reach 8×10^{35} cm^{-2}s^{-1}.

Machine Parameters of SuperKEKB

	symbol	LER	HER	unit
Beam Energy	E	3.5	8.0	GeV
Beam current	I	9.4	4.1	A
Circumference	C	3016		m
Number of bunches	n_b	5018		
Number of particles	N/bunch	11.8	5.1	$\times 10^{10}$
Emittance	ε_x	9		nm
Emittance ratio	$\varepsilon_y/\varepsilon_x$	0.5		%
Beta (hor.) at IP	β_x^*	200		mm
Beta (ver.) at IP	β_y^*	3		mm
Bunch length	σ_z	3		mm
Crossing angle	θ_x^*	30 to 0		mrad
Beam-Beam (hor.)	ξ_x	0.36		
Beam-Beam (ver.)	ξ_y	0.43		
RF AC plug power	P_{AC}	73		MW
Luminosity	L	8.0		$\times 10^{35}$ cm^{-2}s^{-1}

Strategy for Achieving Higher Luminosity

- Higher Currents
- Smaller Bunches
- Electron-cloud suppression
- Crab Cavities

Challenges for vacuum system

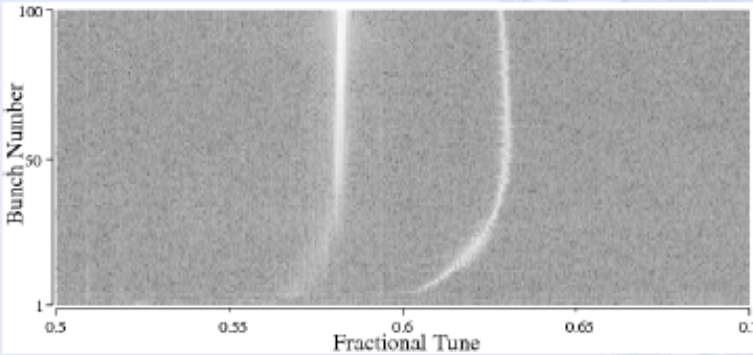
Key parameters for vacuum system:

- High current (LER:9.4 A, HER:4.1 A)
- Short bunch (σ_z = 3 mm)

- Intense SR power
  - Max. power density of 28 kW/m (40 W/mm^2) even a half aperture of 110 mm, for example.
- High photon density
  - Photon density ~1x10^{19} photons/m/s in average
  - Large gas desorption
    - Gas load ~ 5x10^{-8} Pa m^3/s/m (for η = 1x10^{-6} molecules/photon)
    - Average pressure ~ 5x10^{-7} Pa for S ~ 0.1 m^3/s/m
  - Electron Cloud Instability (ECI) becomes a big issue in positron ring
- Intense HOM (higher order mode) power
  - For a loss factor of 1 V/pC, loss power ~ 200 kW

The Problem of Electron Clouds

- Photo-electrons produced at the beam pipe wall by synchrotron radiation, and secondary electrons produced by electron-wall collisions, are trapped in the region of the beam orbit in the positron ring (LER).
- The KEKB LER has suffered beam blow-up and luminosity loss due to interactions with these electron clouds, which cause a fast head-tail instability.
- Bunch-current blowup threshold can be raised by the use of solenoids around the beam pipe.



Bunch spectral signature of e-cloud instability observed at KEKB LER.
J.W. Flanagan et al., PRL 94, 054801 (2005).

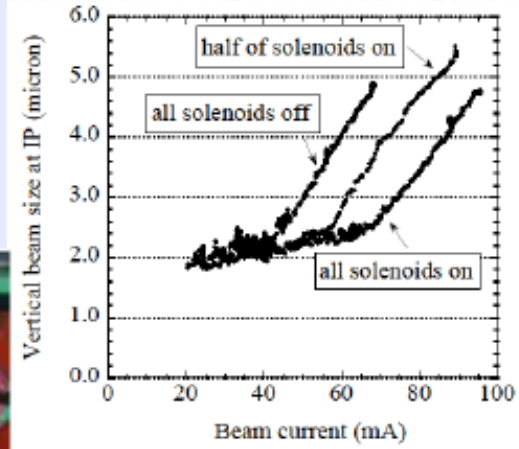


Figure 2: Vertical beam size as a function of the beam current. In the measurement two trains were injected on opposite sides in the ring. Each train contained 60 bunches. Bunch spacing was 4 rf buckets.

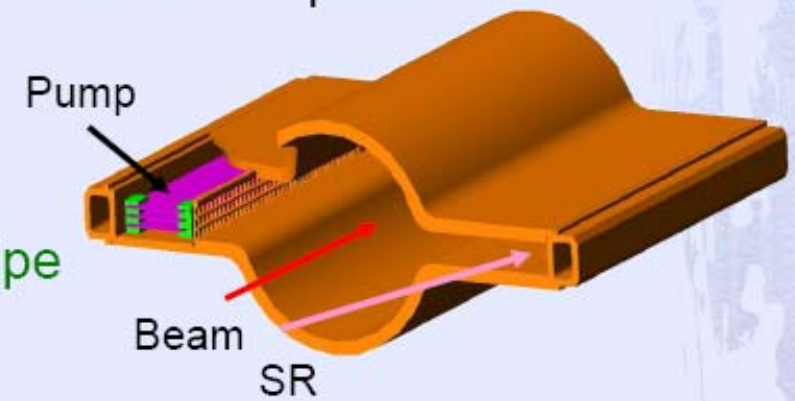
Fukuma et al., "Study of Vertical Beam Blow-up in KEKB LER," HEAC01 proceedings

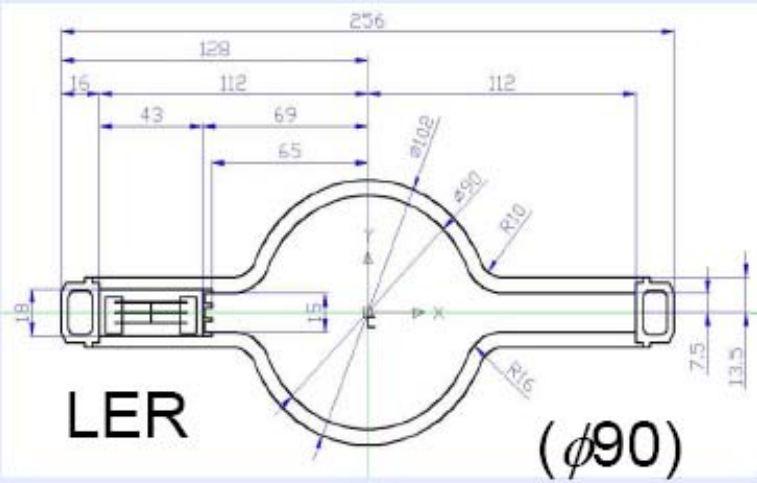
Figure 1: Solenoids in the LER tunnel. The three solenoids on the right side are those installed in bellows-NEG pump sections. The long solenoid on the left side was installed in the first installation.

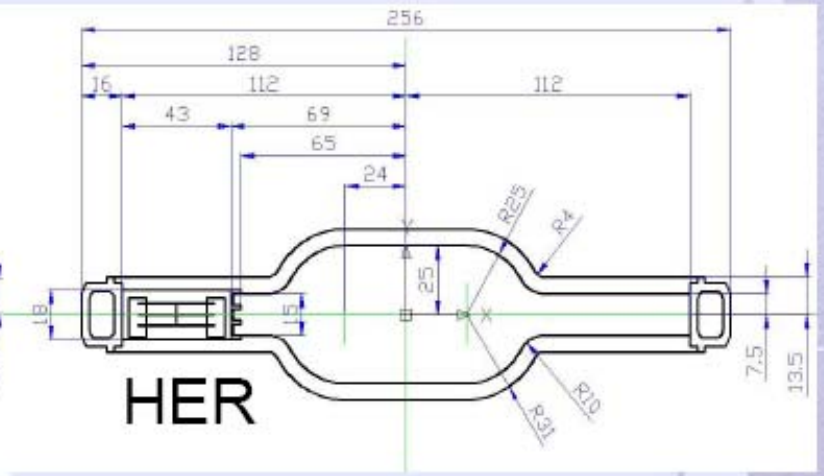
However, KEKB performance is still limited by electron clouds.

Beam duct

- Copper beam duct with ante-chambers
  - Copper is required to withstand intense SR power
- Features (compared to simple pipe):
  - Low SR power density
  - Low photoelectrons in beam pipe
  - Low beam impedance
  - Expensive

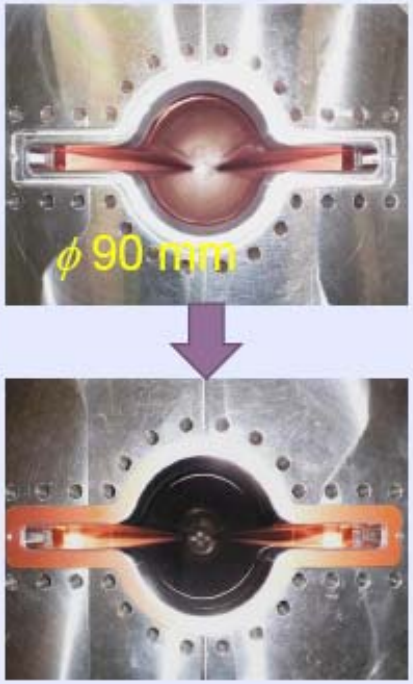


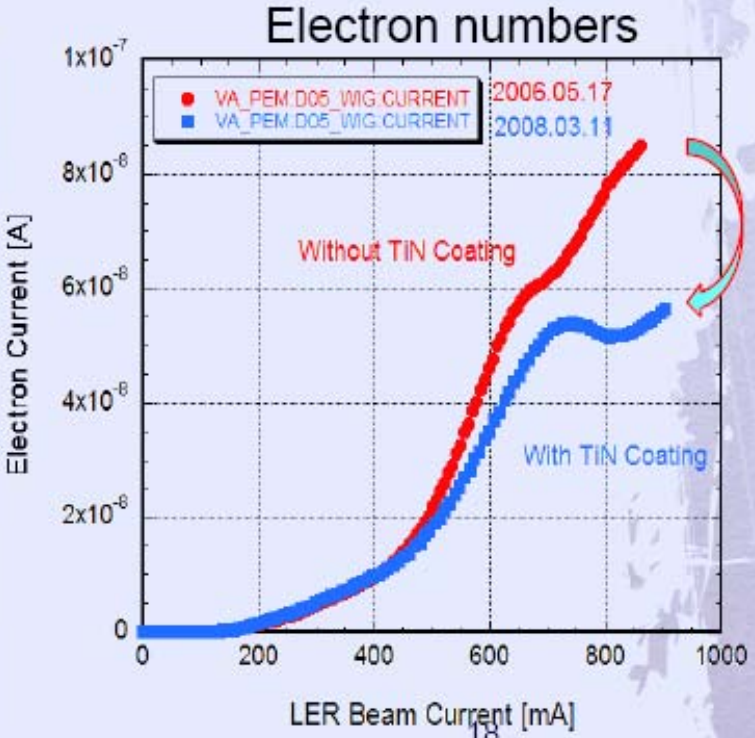




Cure for Electron Clouds (1)

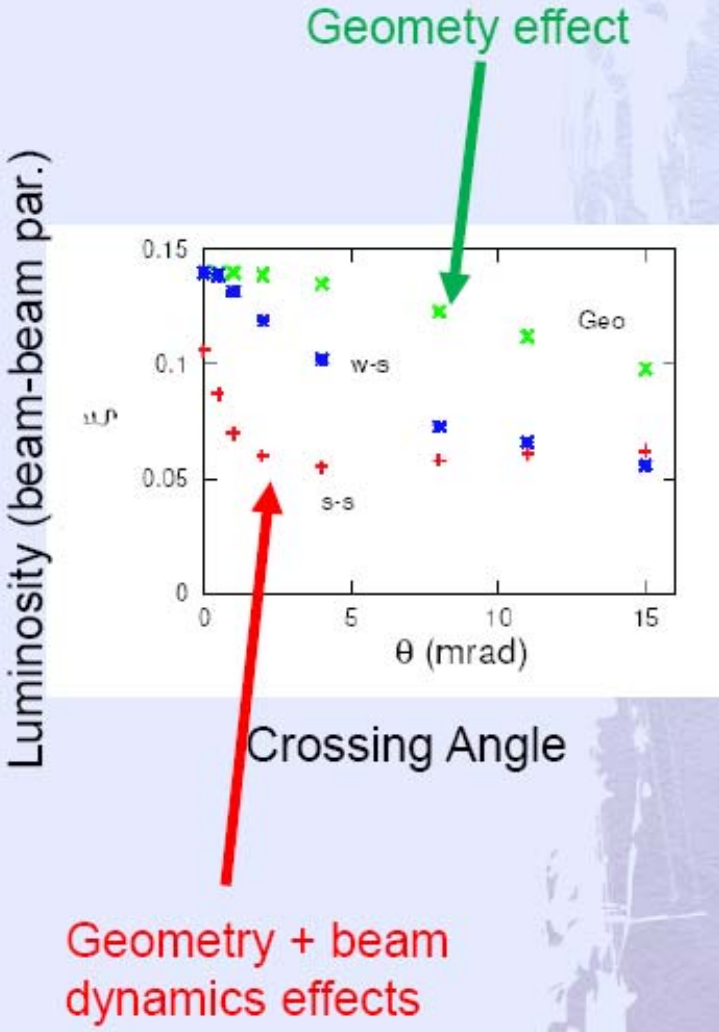
- A critical issue for positron ring
- TiN coating on inner surface
  - Decrease secondary electron yield (SEY): Max. SEY ~0.9
  - A test stand for the coating was built in KEK, and applied to a test duct with ante-chambers.
    - Decrease of electrons at high current region was demonstrated.





Beam-beam limit

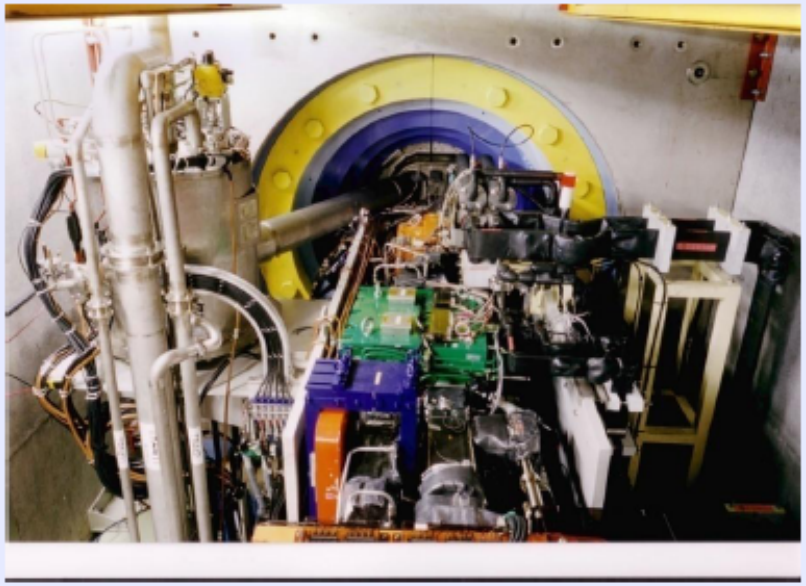
- Beam-beam parameter up to 0.059 has been achieved with a finite crossing angle at KEKB.
- Beam-beam simulations say:
  - A head-on collision greatly improves the luminosity, for two reasons:
    - Geometrical cross-section improvement
    - Improved beam dynamics (reduce non-Gaussian tails)
  - Crab crossing scheme (finite crossing angle but with crab cavity) effectively creates a head-on collision.
- The crab crossing scheme is being tested now.

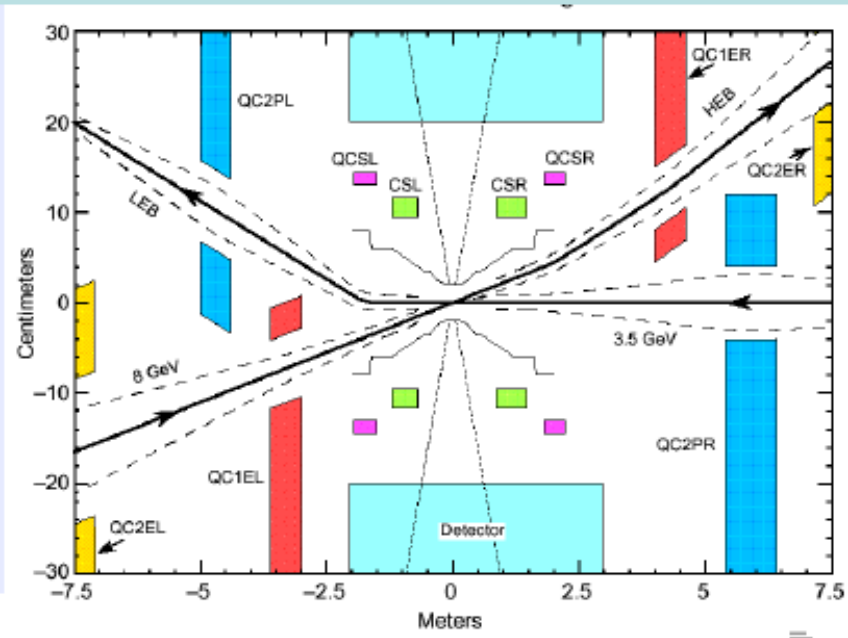


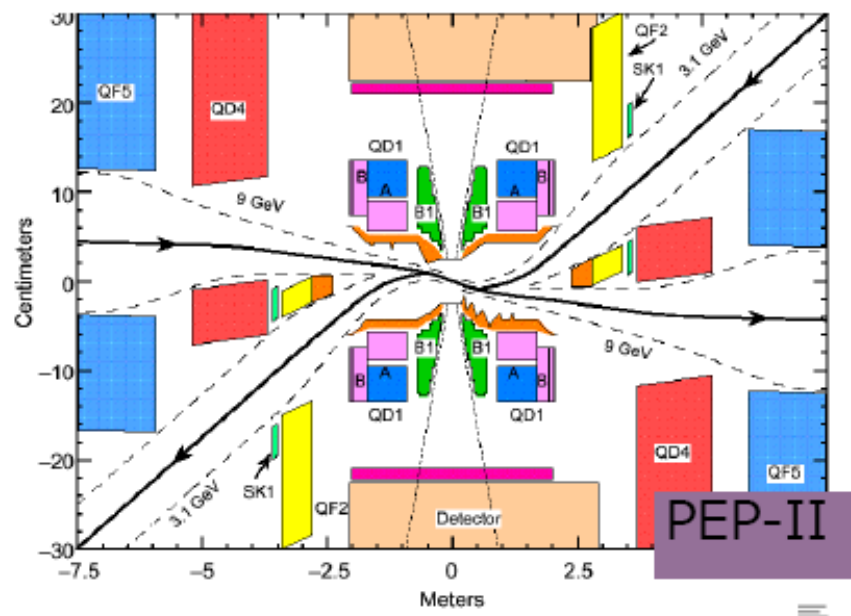
Crab Crossing

KEKB has 22 mrad horizontal crossing angle at the IP:

- Easier beam separation
- Simpler design around the IP.
- Less number of components.
- Less synchrotron radiation.
- Less luminosity-dependent background.
- Space for compensation solenoid, etc.





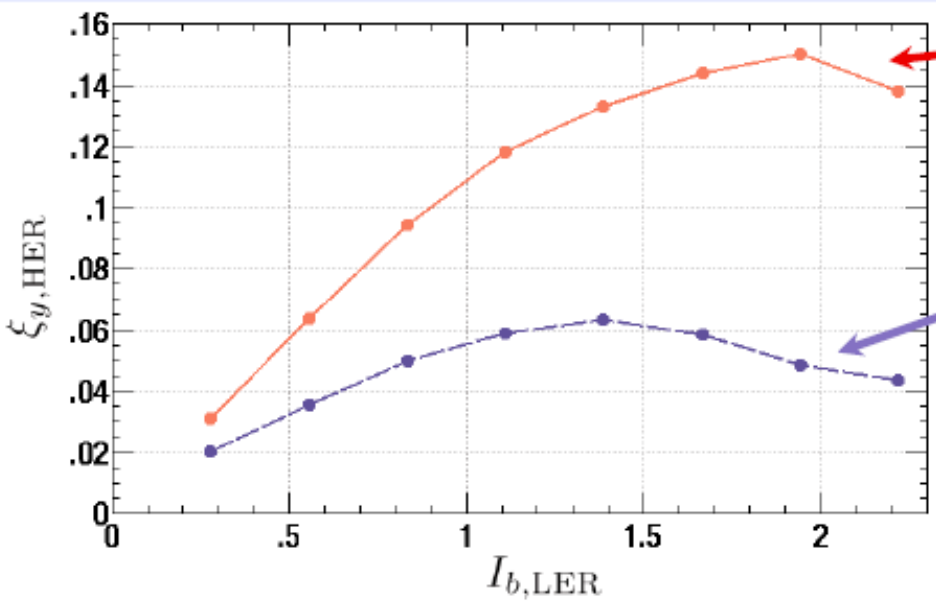


PEP-II

Crab Crossing @ KEKB

- Crab Crossing can boost the beam-beam parameter higher than 0.15 !

K. Ohmi

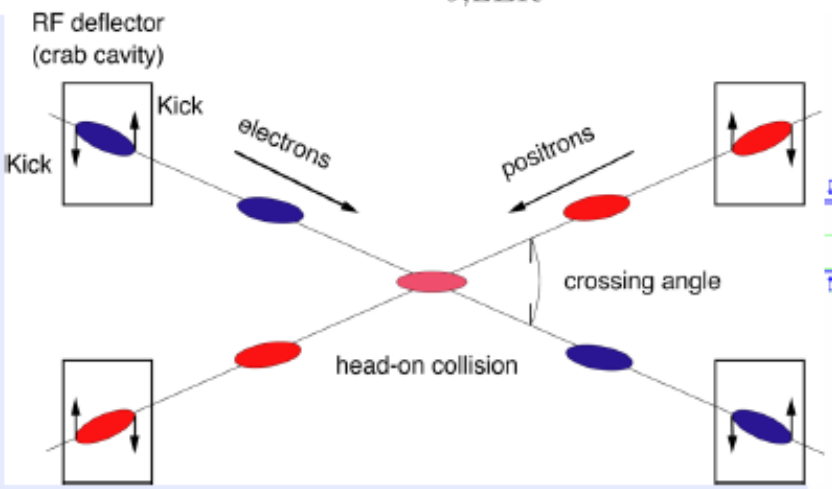


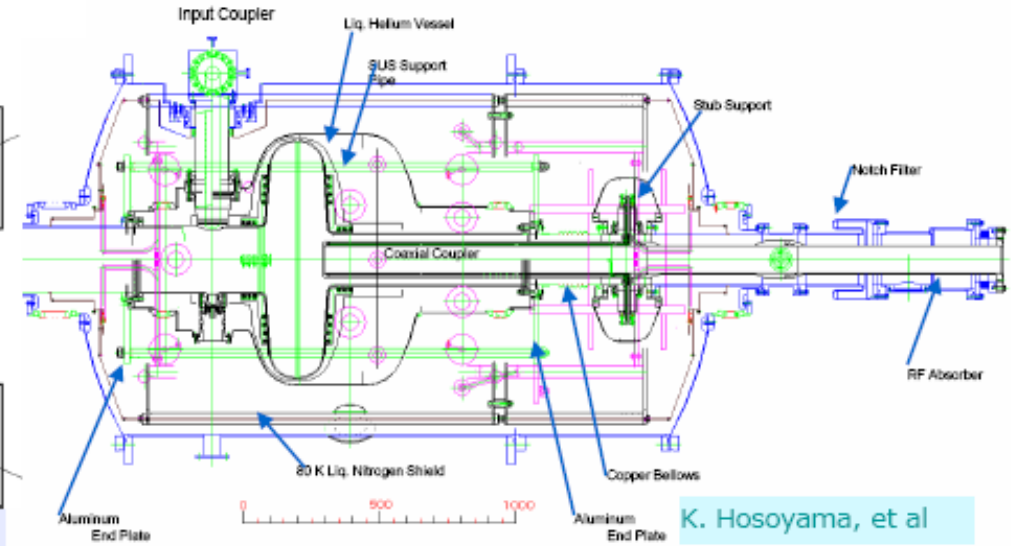
Head-on (crab)

(Strong-strong simulation)

Crossing angle 22 mrad

- Crab cavities were successfully produced and beam study started in Feb. 2007.



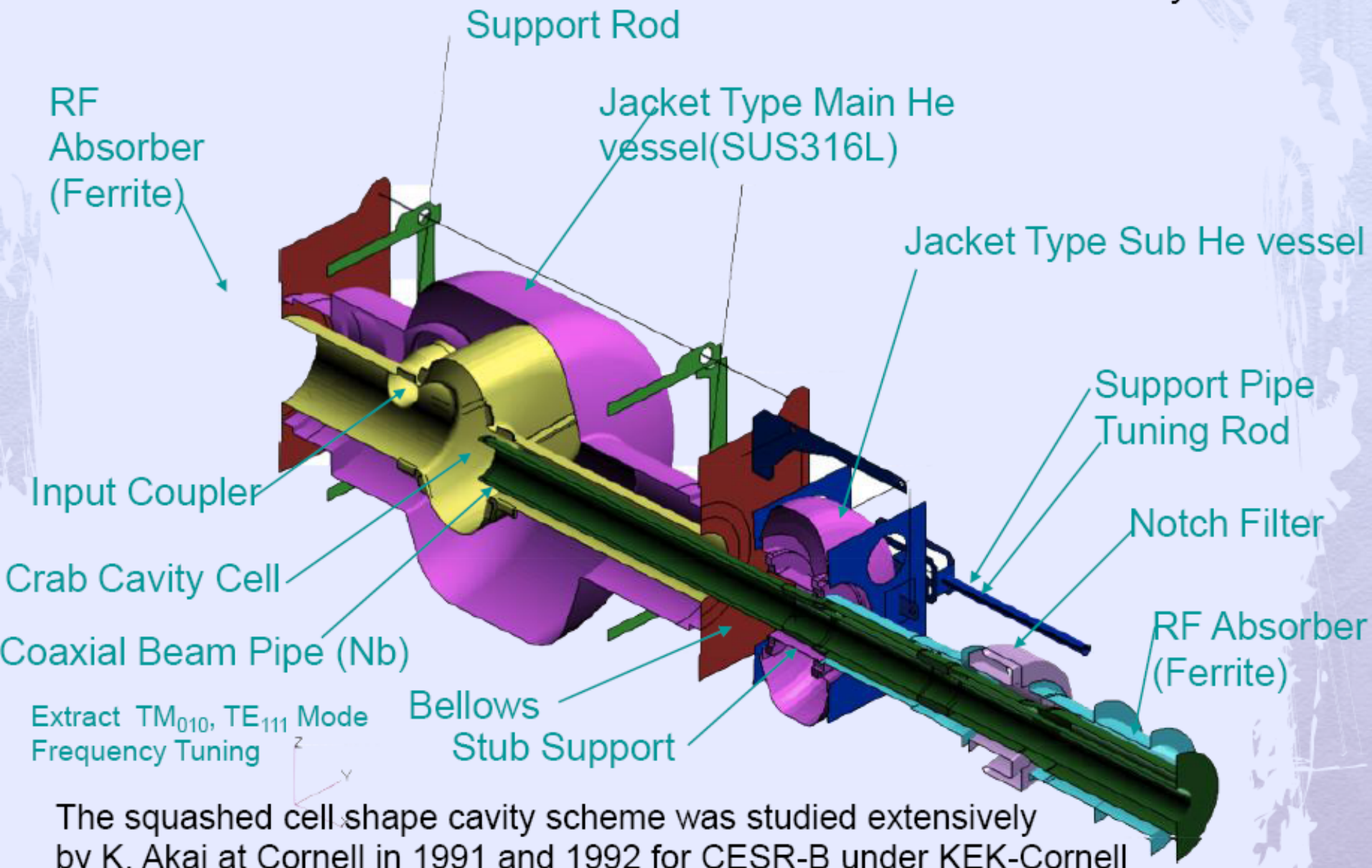


K. Hosoyama, et al

First proposed by R. B. Palmer in 1988 for linear colliders.

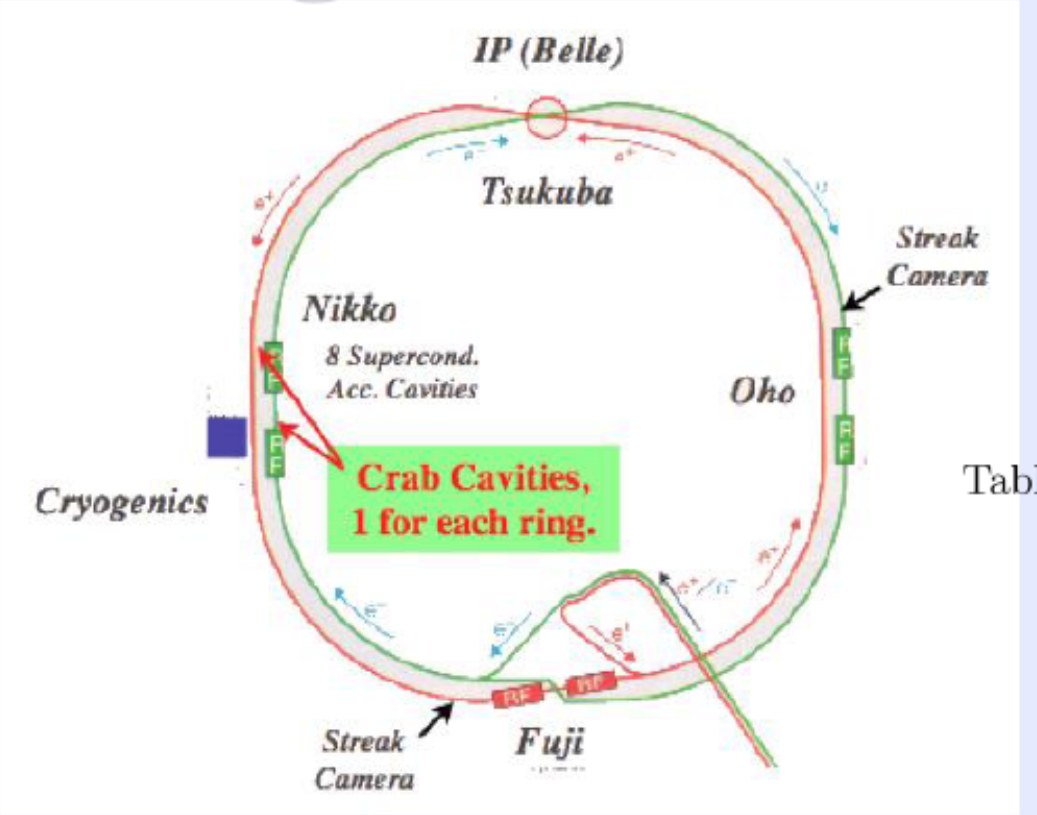
Crab Cavity & Coaxial Coupler in Cryomodule

K. Hosoyama et al



The squashed cell shape cavity scheme was studied extensively by K. Akai at Cornell in 1991 and 1992 for CESR-B under KEK-Cornell collaboration. We adopted this design as “base design.”

Single Crab Cavity Scheme



- Beam tilts all around the ring.
- z-dependent horizontal closed orbit.
- tilt at the IP:

$$\frac{\theta_x}{2} = \frac{\sqrt{\beta_x^C \beta_x^*}\cos(\psi_x^C - \mu_x/2)}{2\sin(\mu_x/2)} \frac{V_C \omega_{\rm rf}}{Ec}$$

Table 1: Typical parameters for the crab crossing.

Ring	LER	HER	
θ_x	22		mrad
β_x^*	80	80	cm
β_x^C	73	162	m
$\mu_x/2\pi$	0.505	0.511	
$\psi_x^C/2\pi$	~ 0.25	~ 0.25	
V_C	0.95	1.45	V
$\omega_{\rm rf}/2\pi$	509		MHz

- 1 crab cavity per ring.
- saves the cost of the cavity and cryogenics.
- avoids synchrotron radiation hitting the cavity.

Finally two crab cavity was installed in KEKB, one for each ring in January 2007.

HER (e-, 8 GeV)

LER (e+, 3.5 GeV)

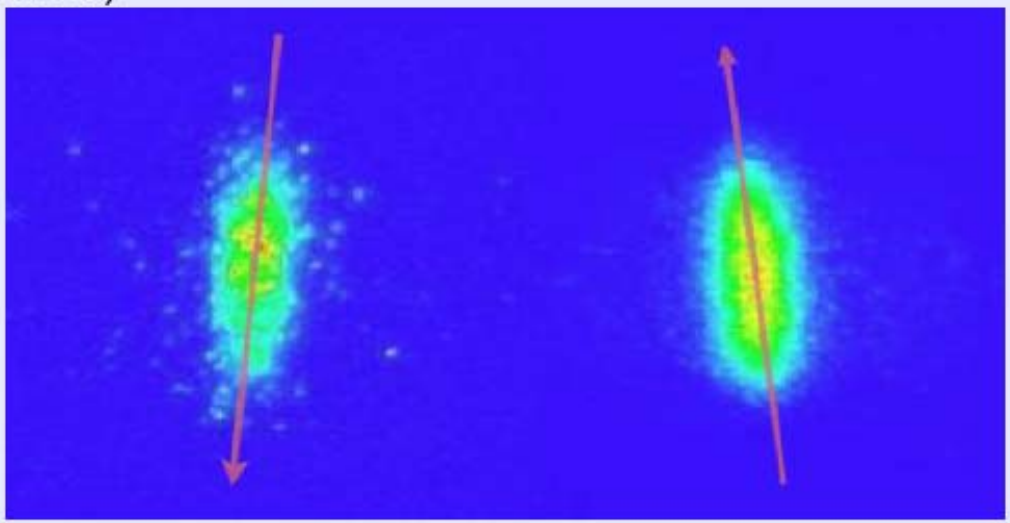
Beams has indeed tilted!

- Observation with Streak Cameras (H. Ikeda et al, FRPMN035)

inside of the rings

outside of the rings

longitudinal

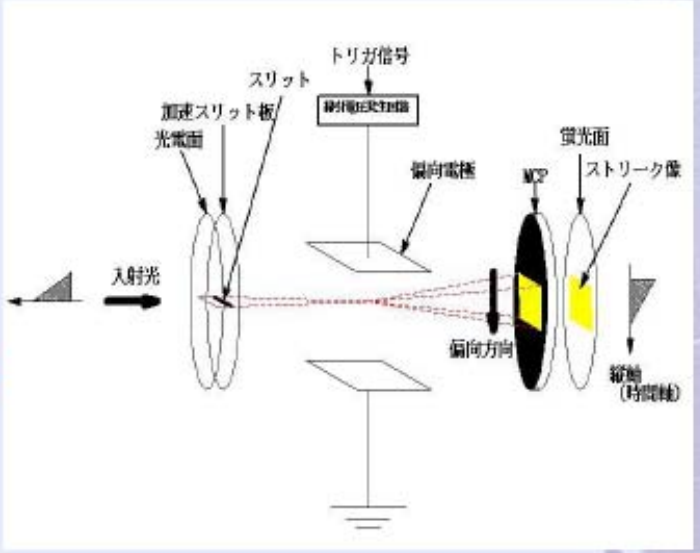


LER

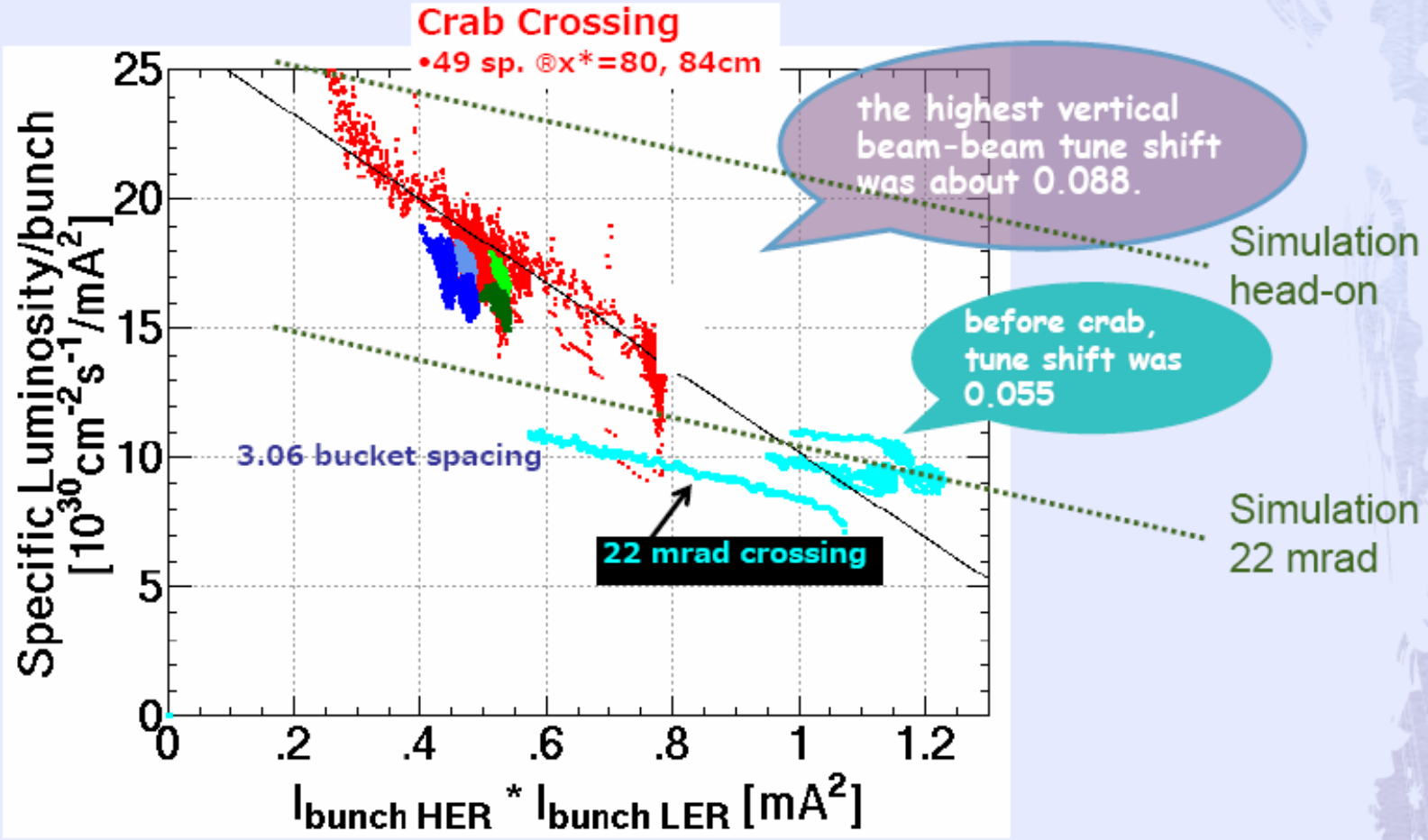
HER

horizontal

The streak camera



Specific Luminosity With Crab Crossing



- A number of measurements indicate effective head-on collision.
- The vertical tune shift went from 0.055 to 0.088.
- The specific luminosity/bunch improved by more than just the geometrical gain.
- Need more time to achieve the goal (X2 specific luminosity).

Detector Study Report

Detector Study Report as “Year 2008 supplemental update to the LoI detector part”
Quick studies in one year including software development
To be replaced with full simulation studies in TDR

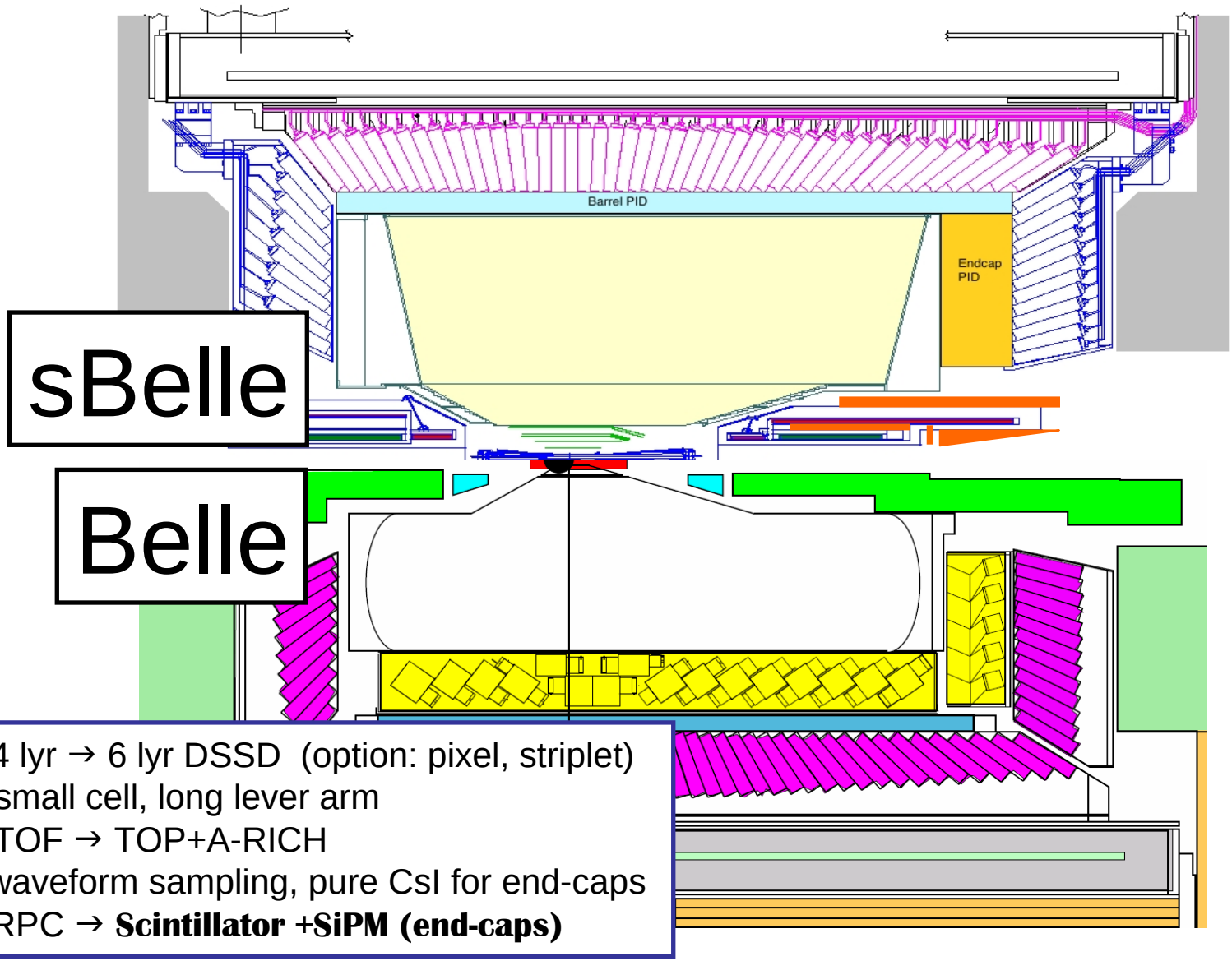
Dated: June 20, 2008

sBelle Design Study Report

Year 2008 Supplemental Update to the LoI Detector Part

http://belle.kek.jp/~ushiroda/private/cgi-bin/sBN/dl.cgi?id=0001

Baseline Design ≈LoI (2004)

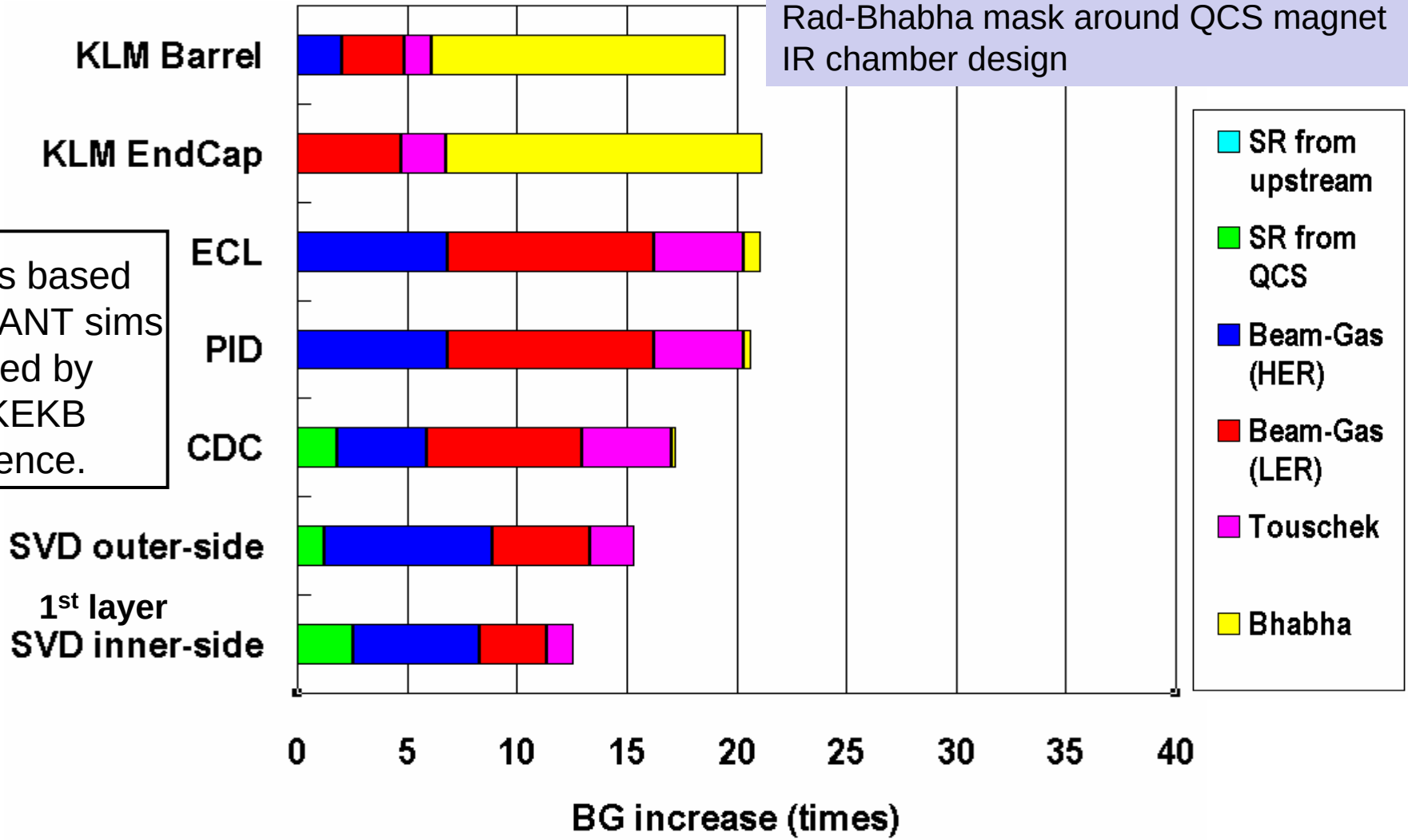


SVD: 4 lyr → 6 lyr DSSD (option: pixel, striplet)
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → **Scintillator +SiPM (end-caps)**

Beam Background

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

Keys of PID upgrade

K/π separation

- Smaller K contamination in π candidate helps a lot in e.g. B→ργ analysis

Forward end-cap

- No dedicated PID in end caps for high momentum tracks → (A-RICH)

Material

- Less material, and material closer to ECL is preferred

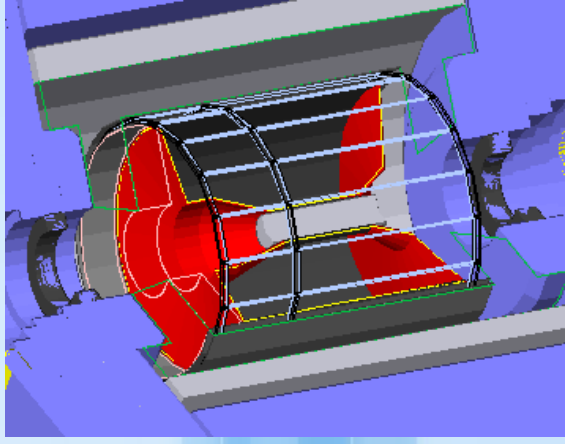
Charge asymmetry

- PID efficiency depends on particle charge (a source of systematic error) → quartz bar?!

Background tolerance

- TOF will not work under high background → Cherenkov detector (TOP)

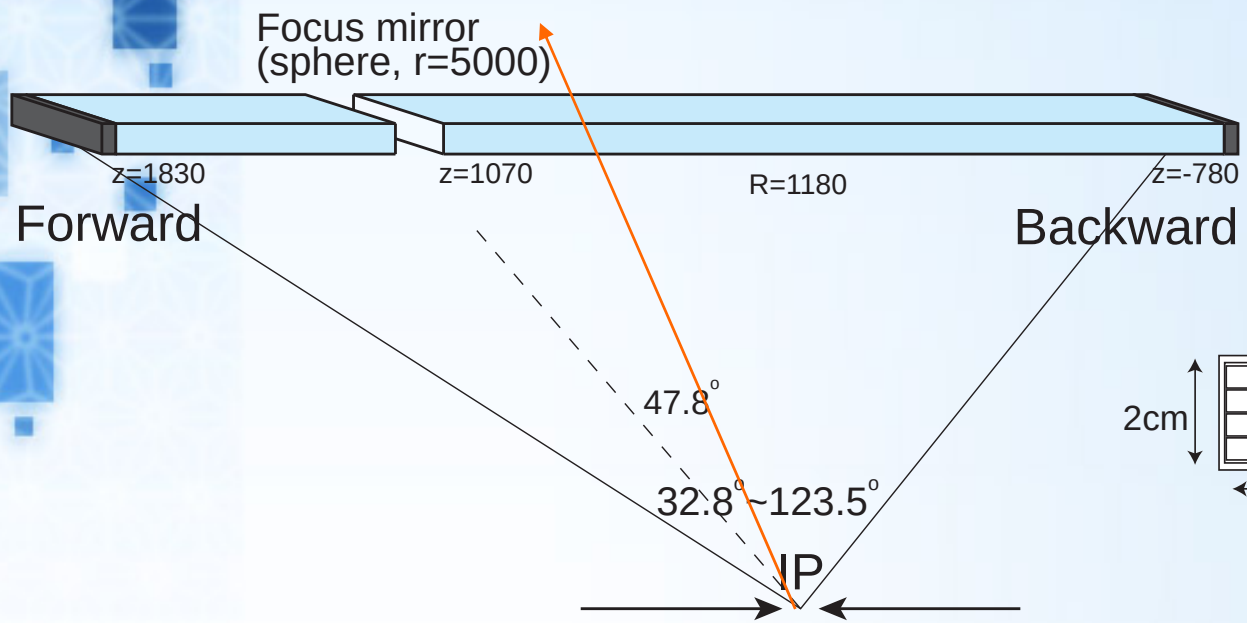
Barrel PID (TOP)

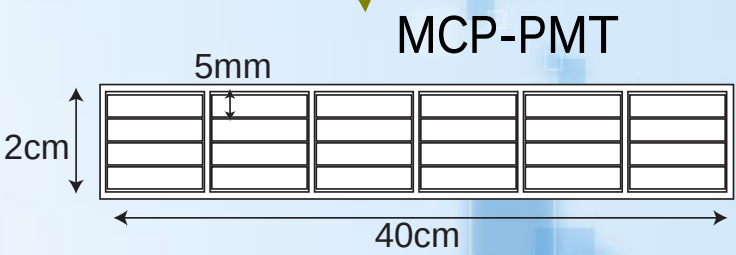


- Quartz: $255cm^L$ x $40cm^W$ x $2cm^T$
  - Focus mirror at 47.8deg.
    angle(λ) → y(λ); correct chromatic dispersion t(λ)
- Multi-anode (GaAsP) MCP-PMT
  - Linear array (5mm pitch), Good time resolution (<~40ps)

re-polishing going on

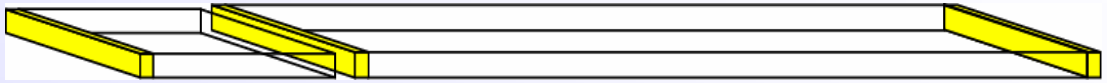
lifetime to be checked



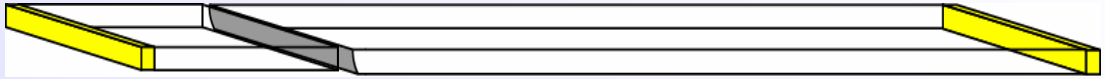


Possible options for B-PID w/ TOP

3 readout type



Focusing type

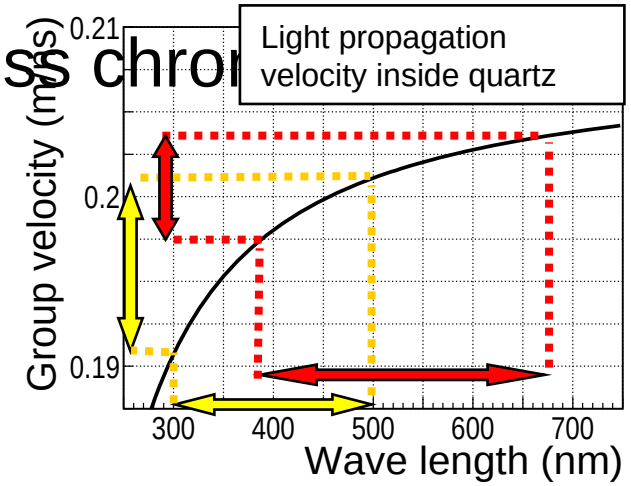


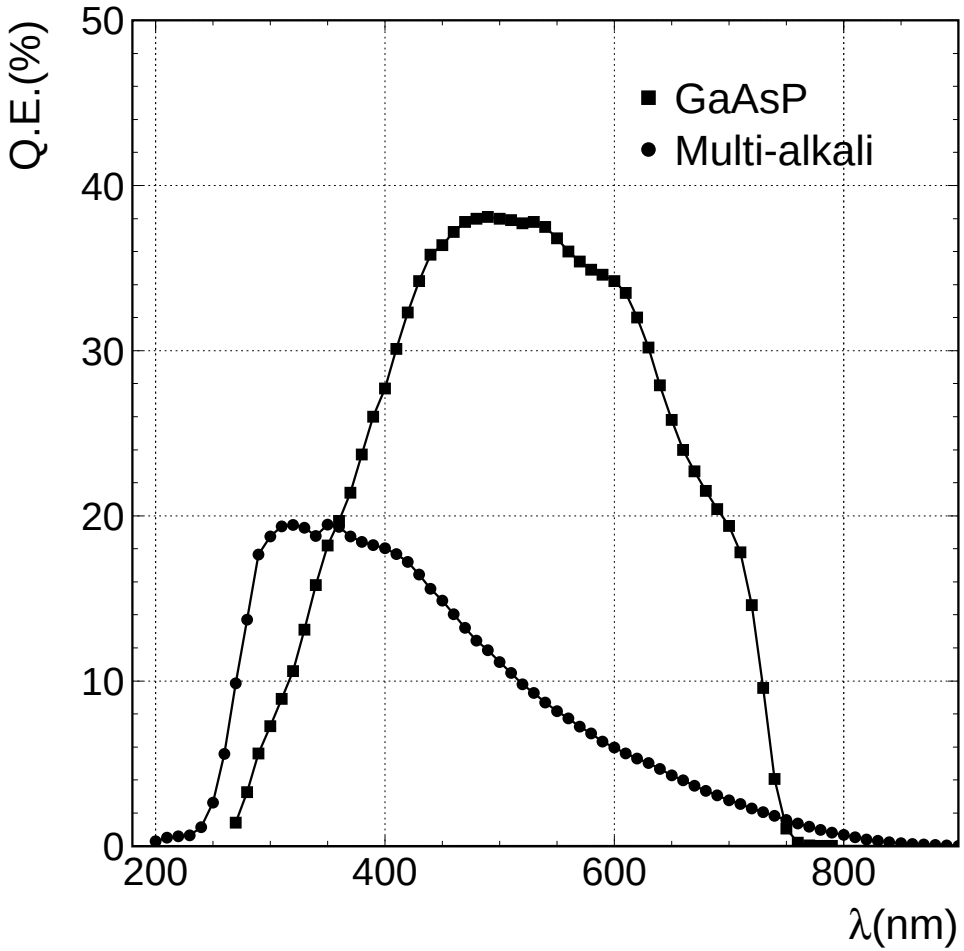
Focus Mirror

	Option 0 **3 readout** **+ multi-alkali MCP-PMT**	**Option 1** **Focusing** **+ multi-alkali MCP-PMT**	**Option 2** **Focusing** **+ GaAsP MCP-PMT**
4GeV K/π	2.8σ	2.5σ→ 4.0σ	4.2σ
comment	Principle established	C.E. to be improved	GaAsP under development

GaAsP MCP-PMT; QE distribution

- Better QE
  - >35% at 500nm
- Less chrom



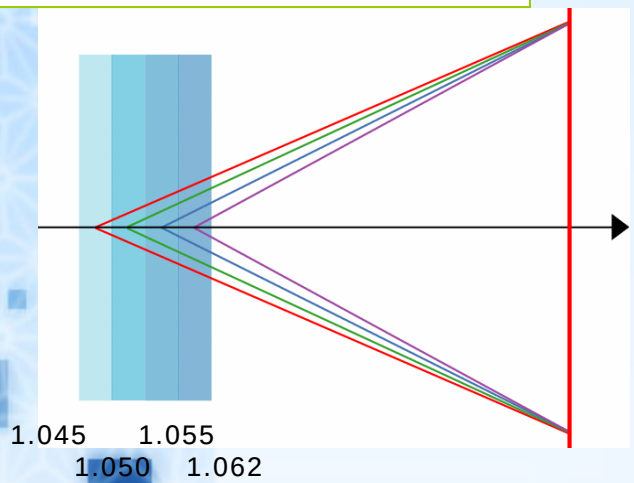


- Lifetime test has started.
  - Need to check the QE degradation

Endcap PID (A-RICH)

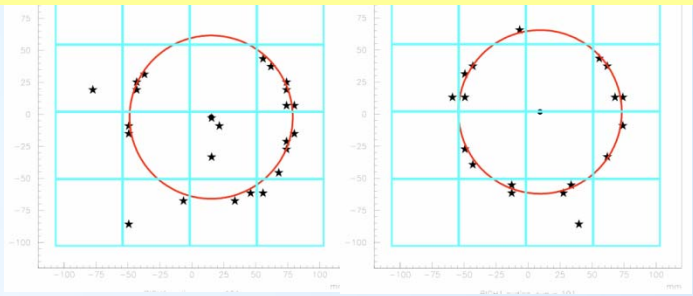
S. Korpar's talk for details

"Focusing" Aerogel radiator



N_{pe} = 9.1, σ(track) = 4.2 mrad achieved

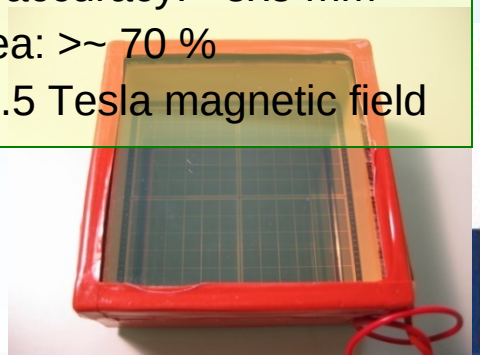
~5.5σ separation for 4 GeV/c K/π

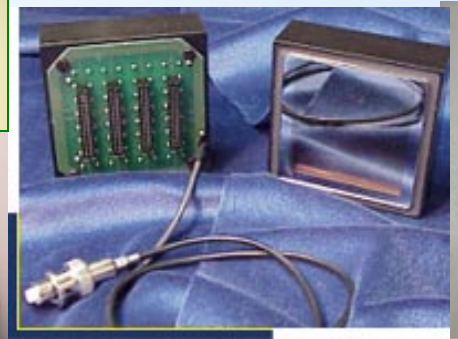


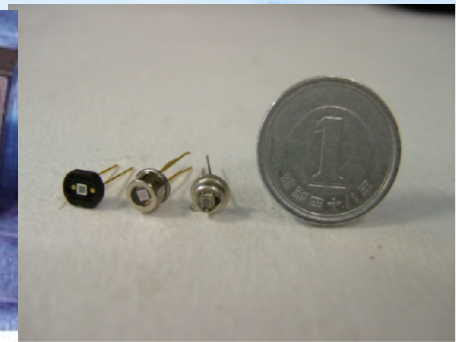
Photon Sensors

- Sensitive to single photon
  - High QE >~ 20 %
  - High gain
- Position detection accuracy: ~5x5 mm^2
- Large effective area: >~ 70 %
- Operational with 1.5 Tesla magnetic field

Hybrid (Avalanche) Photon Detector
MCP (Micro Channel Plate) PMT
Si-PM/MPPC





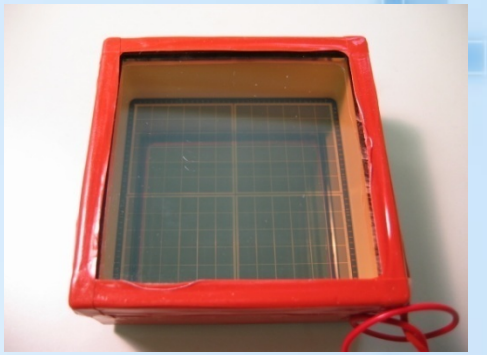


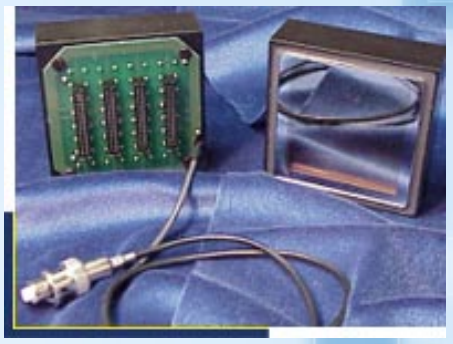
Photon Detectors

Basic requirements

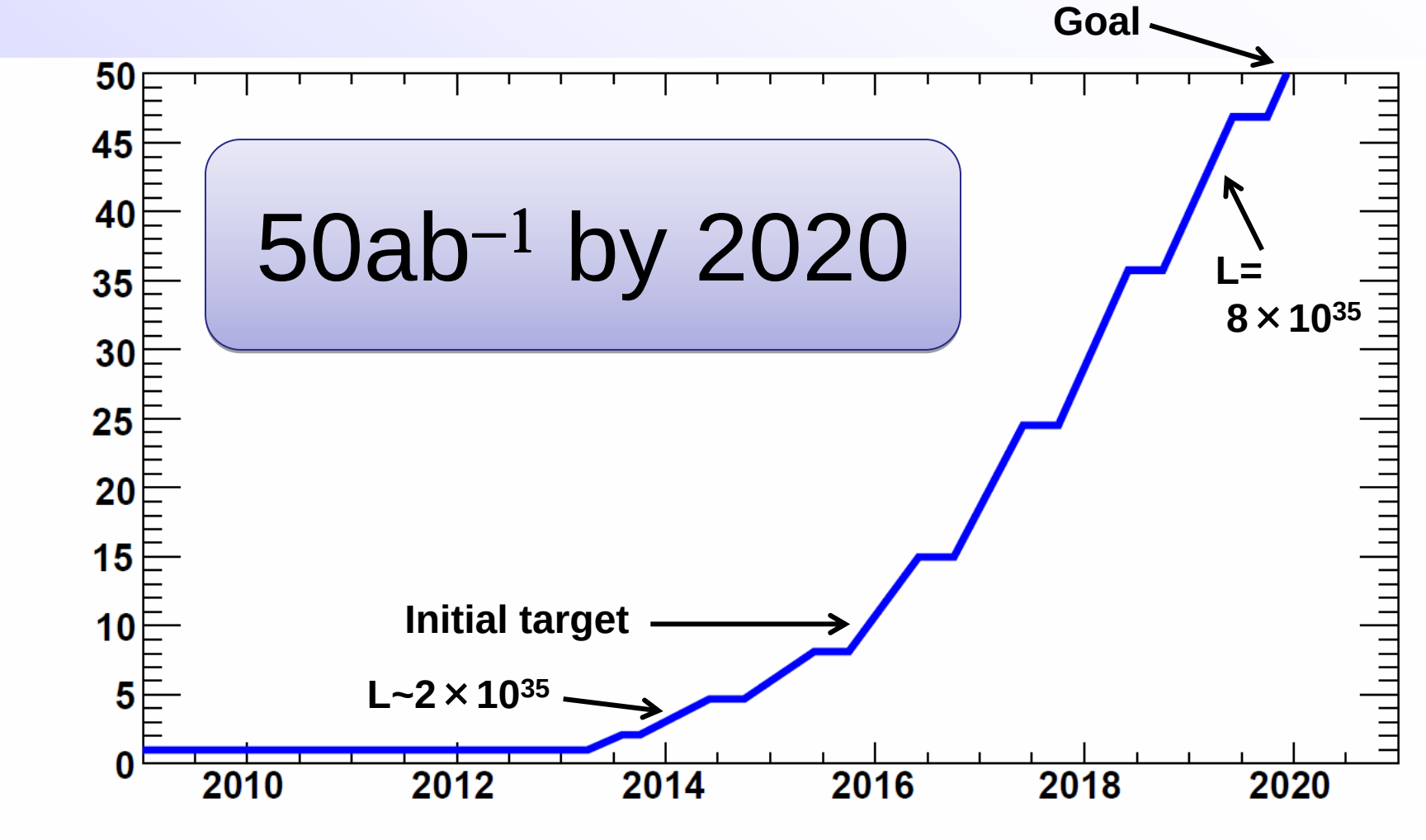
- Sensitive to single photon
  - High QE >~ 20 %
  - High gain
- Position detection accuracy: ~5x5 mm^2
- Large effective area: >~ 70 %
- Operational with 1.5 Tesla magnetic field

1. Hybrid (Avalanche) Photon Detector
   dedicated detector for A-RICH
2. MCP (Micro Channel Plate) PMT
   good timing resolution
3. Si-PM/MPPC ?
   high QE

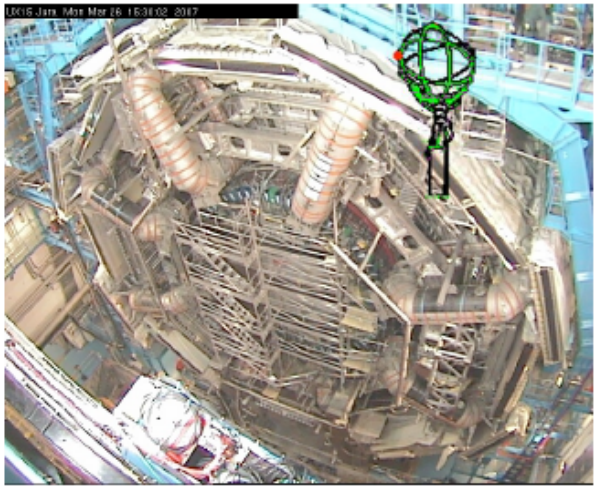


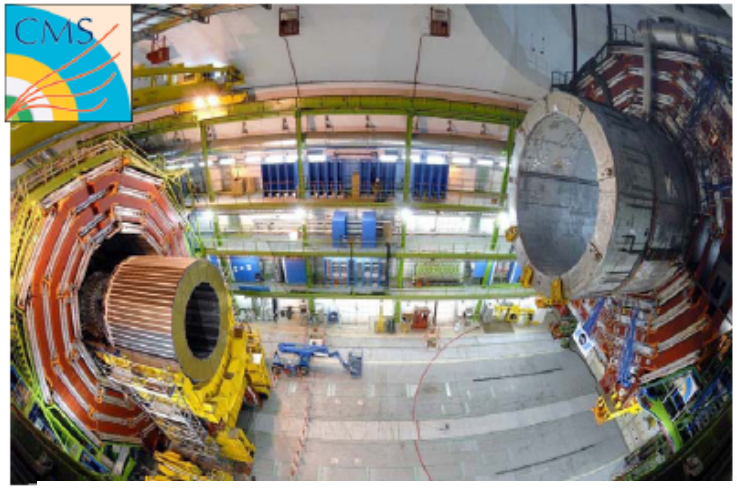


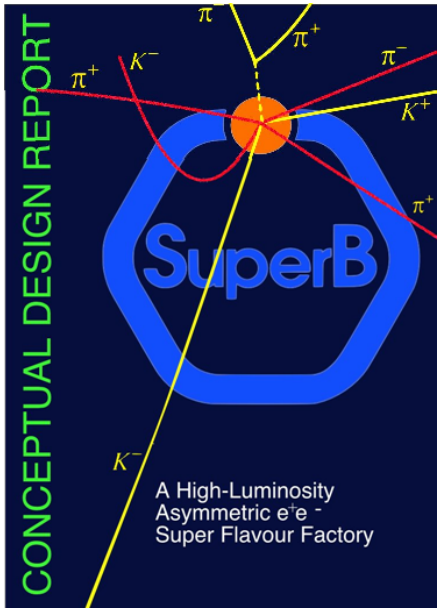
Luminosity prospect



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 !!

Summary

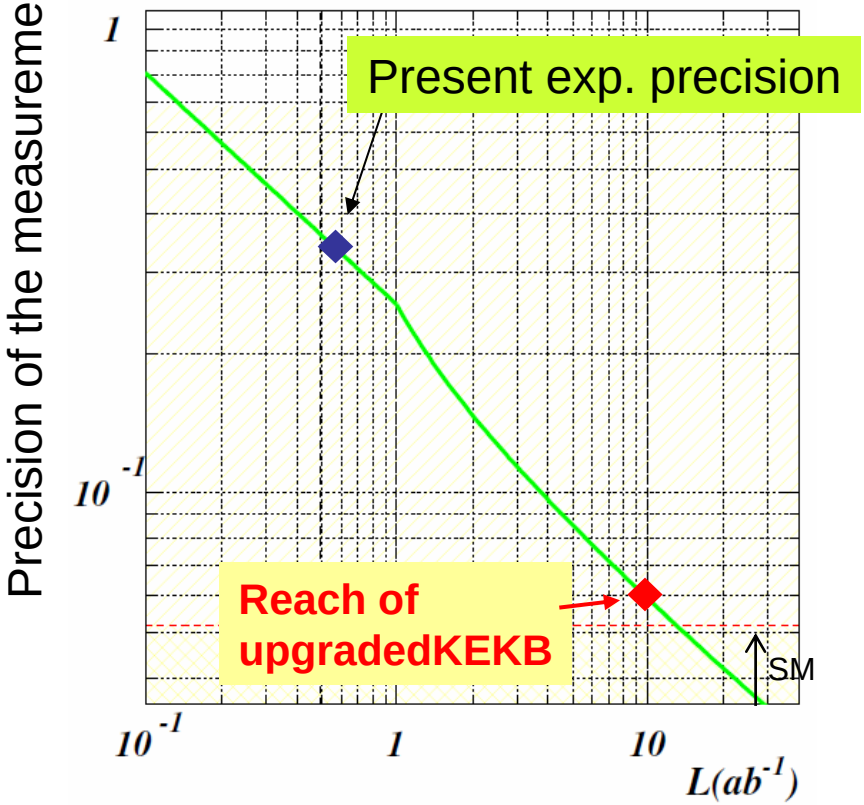
- KEKB/Belle and PEP-II/BaBar have been running successfully, and brought important scientific and technical achievements.
- Next generation e^+e^- *B* factory with L~10^{36} will be very useful to study the new sources of flavor mixing and CP violation.
  - Search for new CPV in $b \to s$ transition
  - 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)…
- KEKB machine upgrade plan
- Detector upgrade necessary to improve BKG/rate immunity.
- New collaboration to be formed soon. Third open meeting is scheduled on December 10-12 at KEK.

BACK UP SLIDES

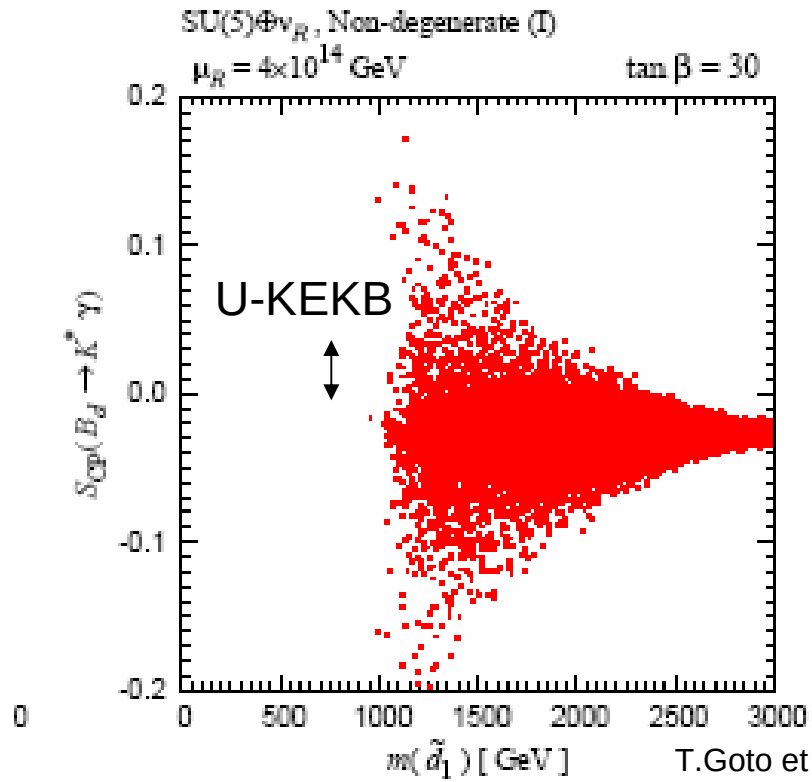
Search for right handed interaction

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.

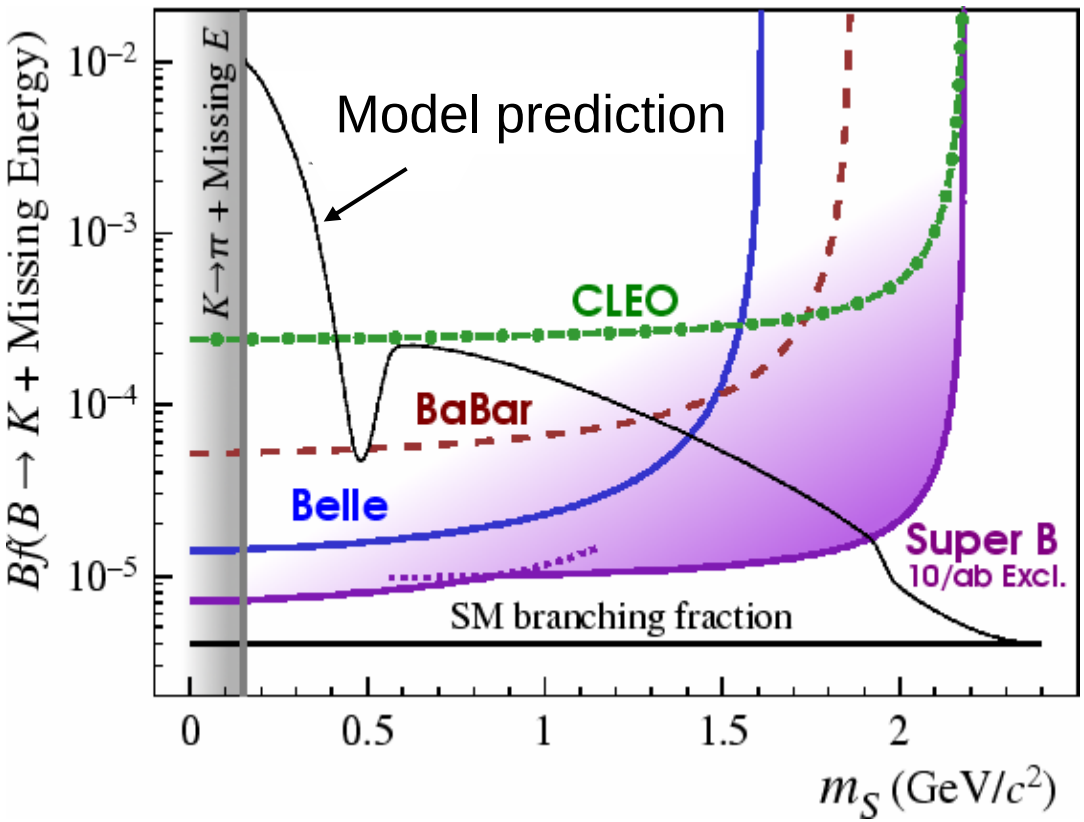


T.Goto et al., 2007

B decays into invisible particles?

Light dark matter?

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

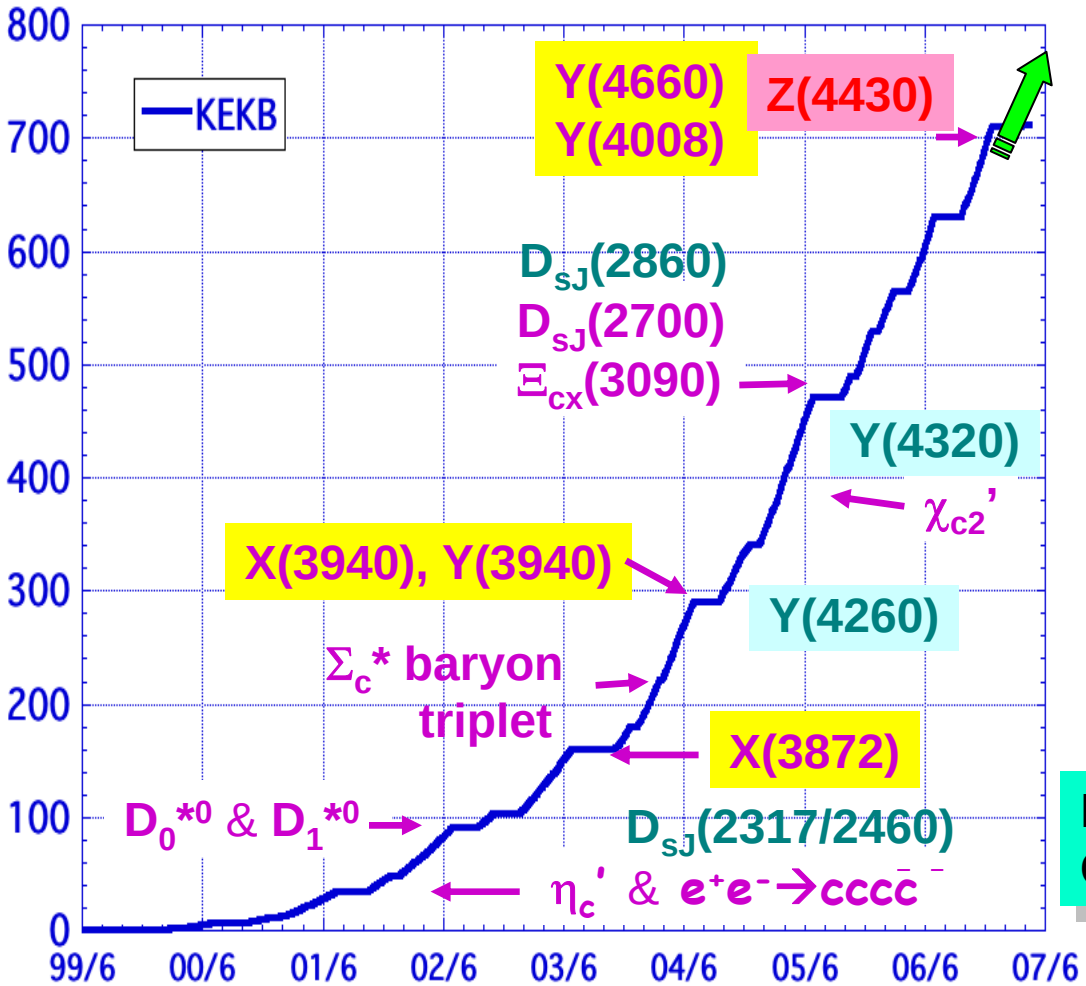


Heavy darm matter is being searched for in direct detection experiments.

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.

Keys of SVD upgrade

Vertex Resolution

- 1st layer closer to the IP (BP r=15mm → 10mm) *later* with pixel

Vertex efficiency for K_S

- Enlarge radial volume (r_{N-1}=70mm → 120mm or more)
  - 20% more K_S for TCPV studies w/ 120mm
- Detector capacitance is an issue

↓

Chip-on-sensor

↓

Material effect is an issue

Background tolerance

- Current readout chip (VA1TA) dies 3μs/hold, 27μs/readout → analog pipelined chip (APV25)
- Shaping time 0.8μs (VA1TA) → 50ns (APV25)
- Monolithic Pixel detector in the end

Other

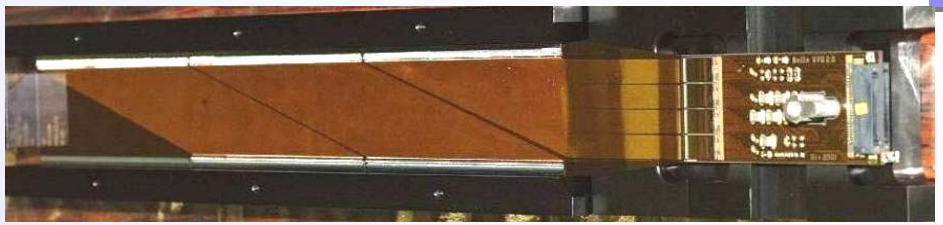
- Standalone tracking to increase slow track efficiency
- dE/dx measurement in SVD
- Better alignment

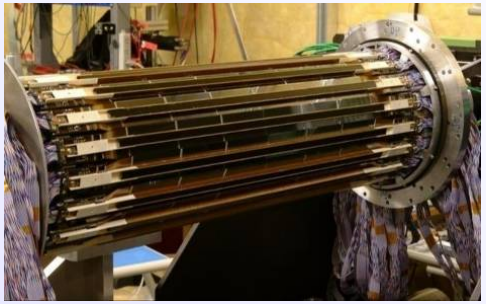
Baseline option

- Inner layers
  - Pixel detector

    MAPS,**DEPFET**,SOI
  - Or striplet?
- Outer layers

  DSSD +
  - **APV25**
    - t_p = 50ns, pipelined, weak at C_d
  - VA1TA (currently used)
    - t_p = 800ns, hold & readout

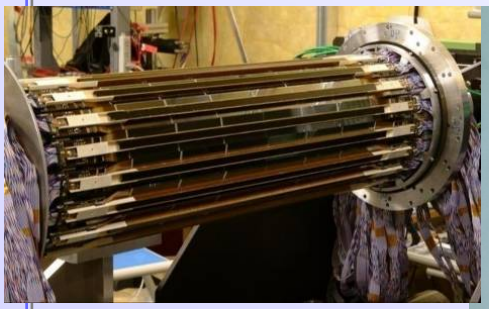


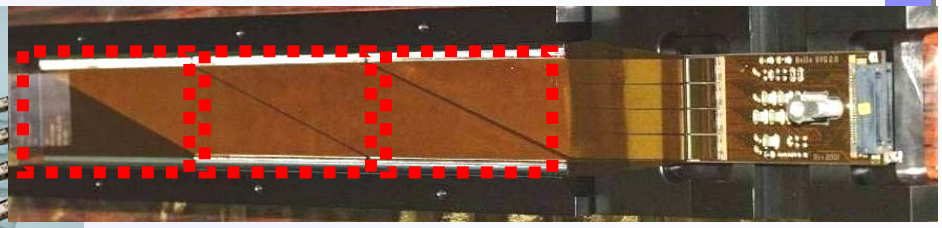


Open questions:

1. Inner radius
2. Outer radius
3. Material budget
4. Readout pitch of outer layers
5. Slant angle

Conventional *ladders* do not help





Belle

VA1 @ Tp=1μs

enc [e^-]= 180+ 7.5/Cd[pF]

3DSSD:~60pF 630e^-

sBelle

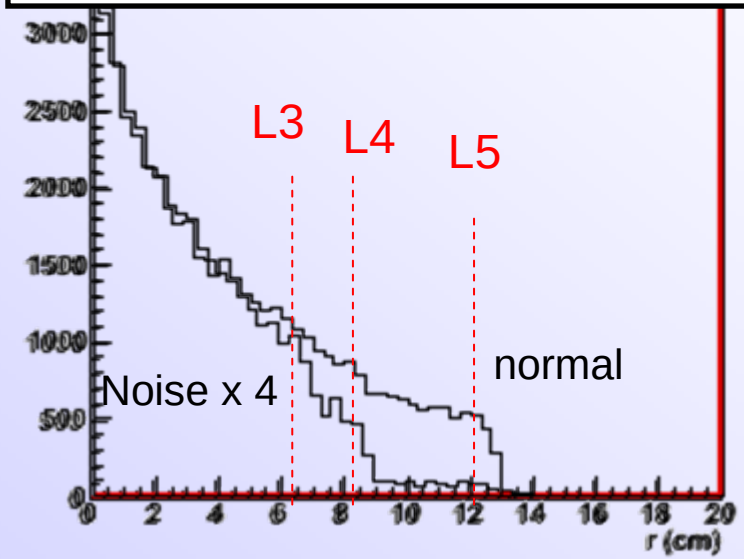
APV25 @ Tp=50ns

enc [e^-]= 246 + 36/Cd[pF]

2500e-

4 times larger Noise

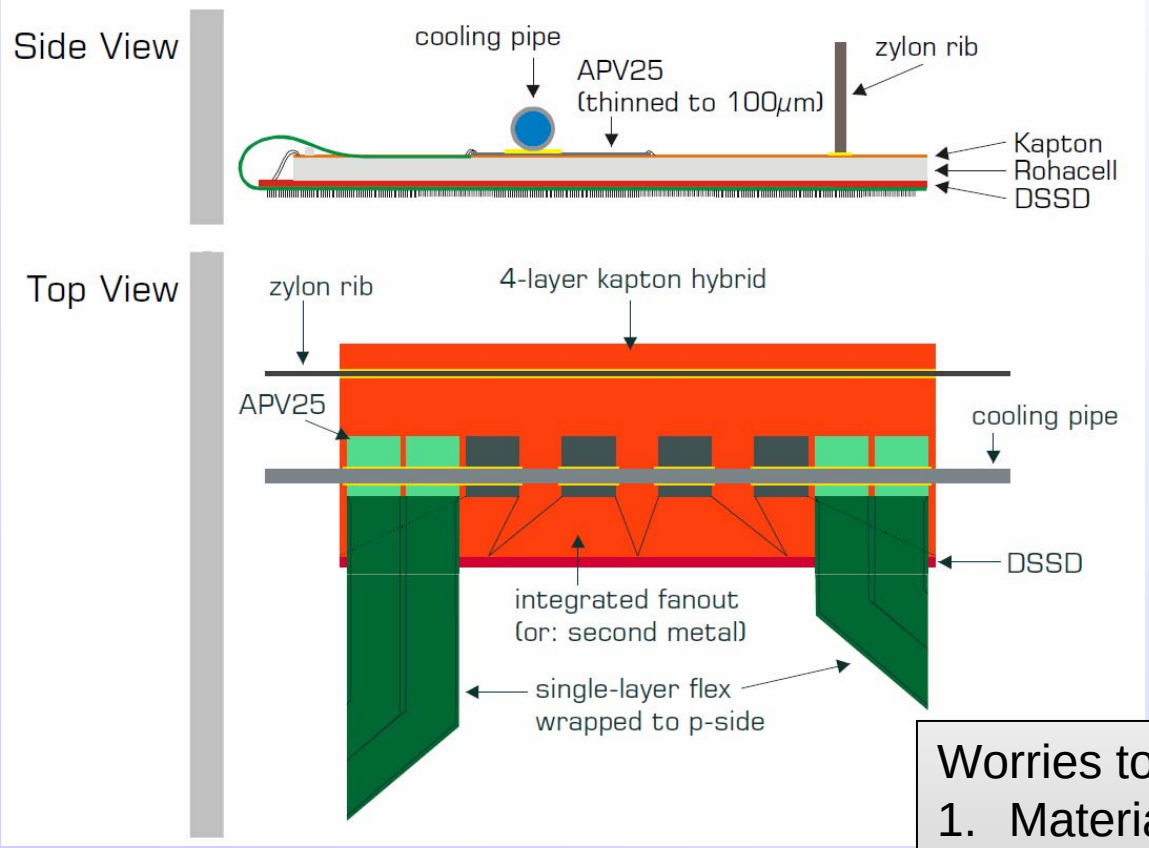
Cannot associate SVD hits and loose 20% of events



r of Ks decay vertex

sKEKB: Chip on sensor !?

The only possibility, so far, to use APV25 chips for the outer layers



Worries to be cleared away:

1. Material inside det. acceptance
2. Heat cycle
3. Coolant leak, clog
4. …

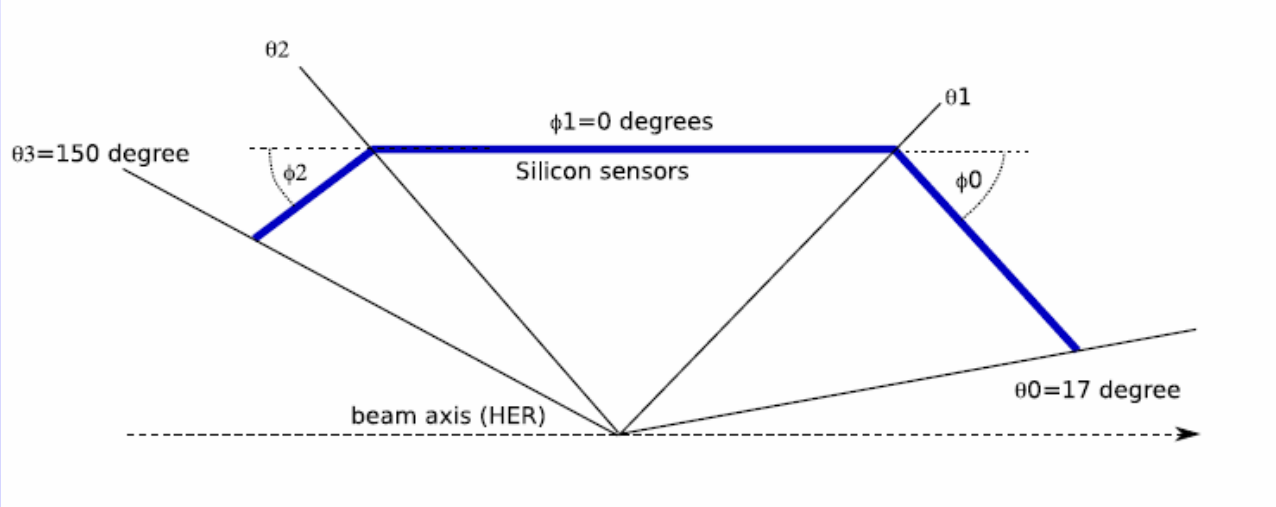
Vertex Detector (inner layers)

- Start with DSSD at t=0
- Upgrade with Monolithic pixel later (hybrid pixel too thick for us)
  - CAPS in Hawaii (since 2002)
  - SOI in KEK (since 2005)

    will take 2~3 years

DEPFET is now a promising option.

Slant angle



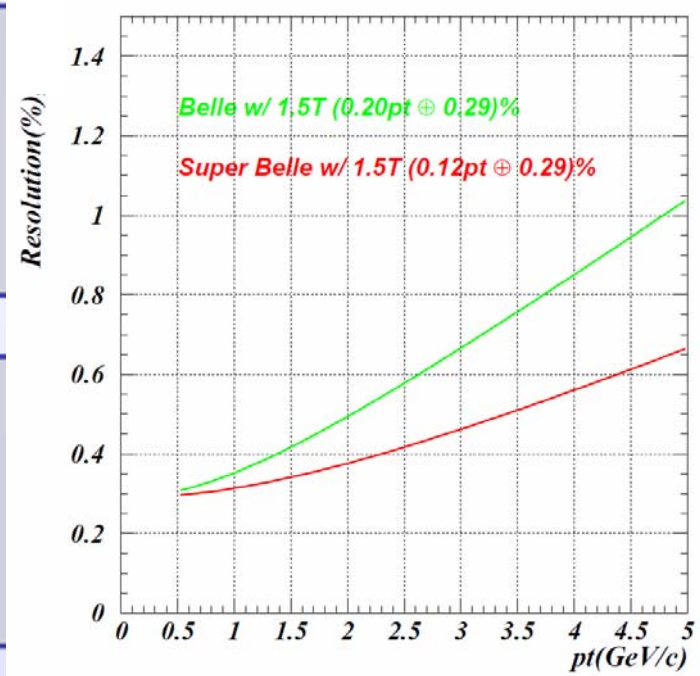
	θ_1	θ_2	ϕ_0	ϕ_2	V_1	V_2	S(cm^2)
No slant	---	---	---	---	29	34	6161
LoI	34	---	–15		28	33	5018
Disk	45	135	–90	90	24	28	3431
Optimized	70	108	–41	36	11	13	2419

Total sensor area can be half of LoI design in a spherical design
Lose K_S → should go even outer if we take this option

Keys of CDC upgrade

pt resolution

- Longer lever arm to improve momentum resolution



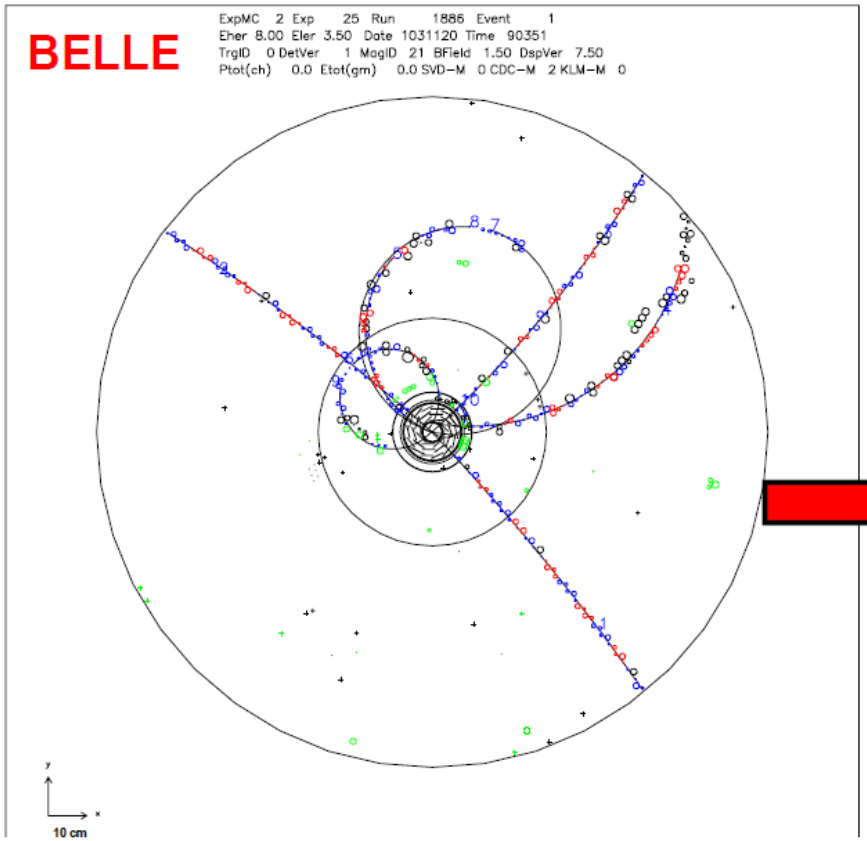
dE/dx

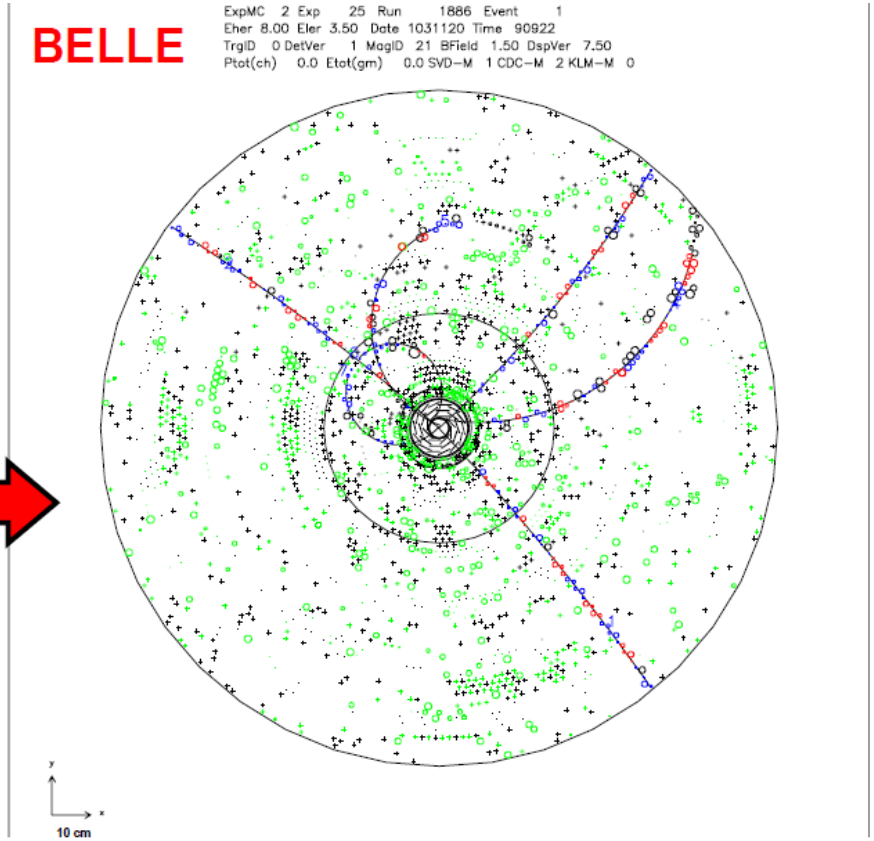
- Larger radial volume for better dE/dx measurement (752mm → 978mm)

Background tolerance

- Smaller cell size
  - innermost 12mm, 64cells → 8mm, 160cells
- Gas (current one is the best)

Tracks under x20 background





Background effect on tracking

Checked with the old Gold-plated mode ($J/\psi K_S$) and the severest mode (D^*D^*) for tracking that contains many slow tracks in the final state

	Efficiency(%) / Relative(%)		ΔE width(MeV) / Relative(%)	
	$J/\psi K_S$	D^*D^*	$J/\psi K_S$	D^*D^*
Belle 1x bkg	52.7 / ≡±0	3.3 / ≡±0	8.8 / ≡±0	7.1 / ≡±0
sBelle 1x bkg	58.7 / +11.3	7.3 / +119	8.9 / +1	7.2 / +1
sBelle 5x bkg	57.7 / +9.4	6.7 / +99	8.9 / +1	7.5 / +6
sBelle 20x bkg	53.6 / +1.5	4.4 / +30	9.1 / +3	7.9 / +11

Efficiency drops drastically with increasing the background, but will be better than Belle thanks to the software efforts + SVD track finder.
ΔE resolution will be worse relatively mildly.

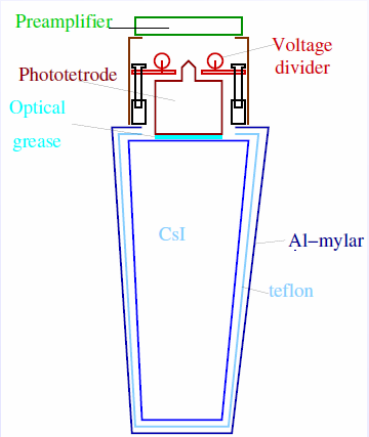
Key points of ECL upgrade

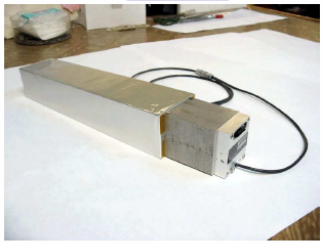
End caps

Background is the biggest issue → Faster crystal CsI(Tl) τ~1μs → pure CsI τ~30ns → Small light yield UV → PMT

Barrel

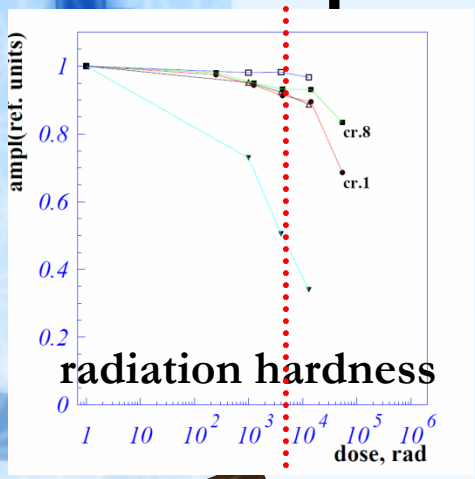
Background is the biggest issue, but not as bad as end caps → Waveform sampling & fitting

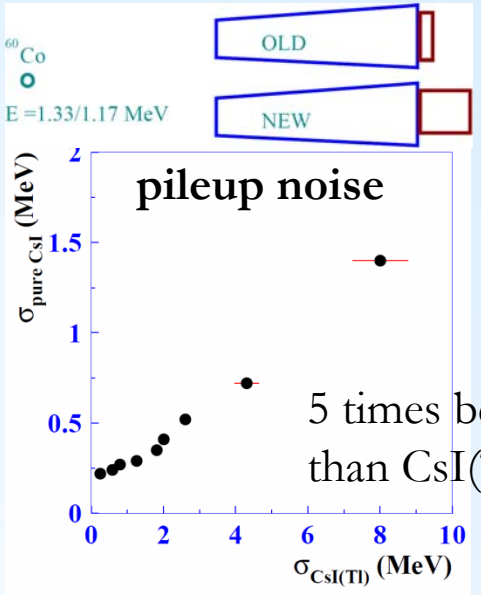


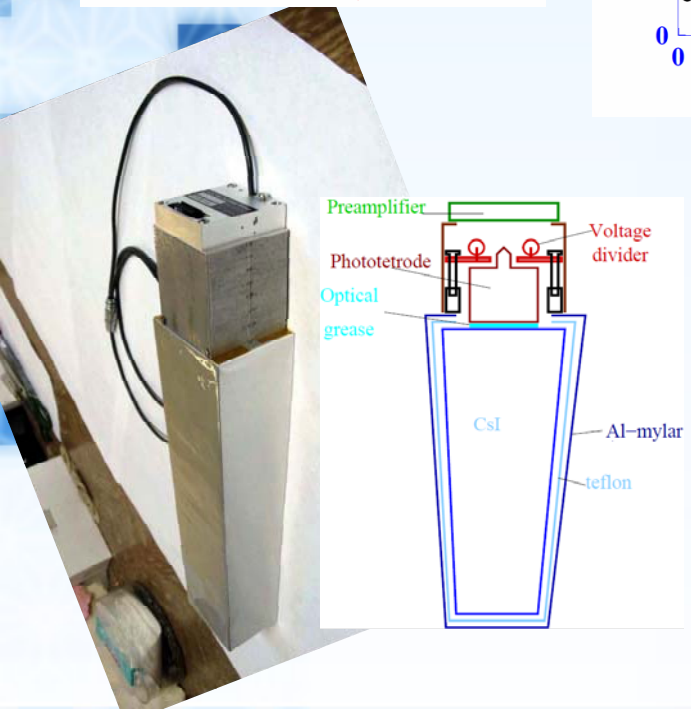


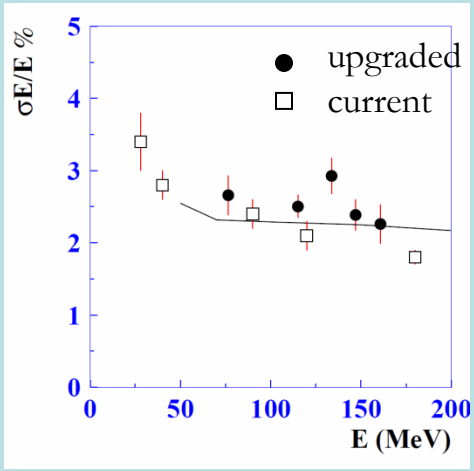
Bonus:
Material inside ECL changes (reduces)

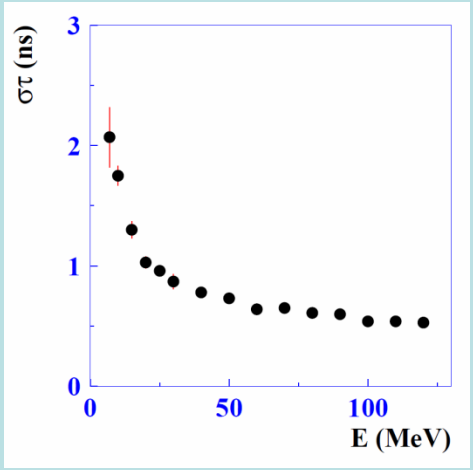
Pure CsI counter performance









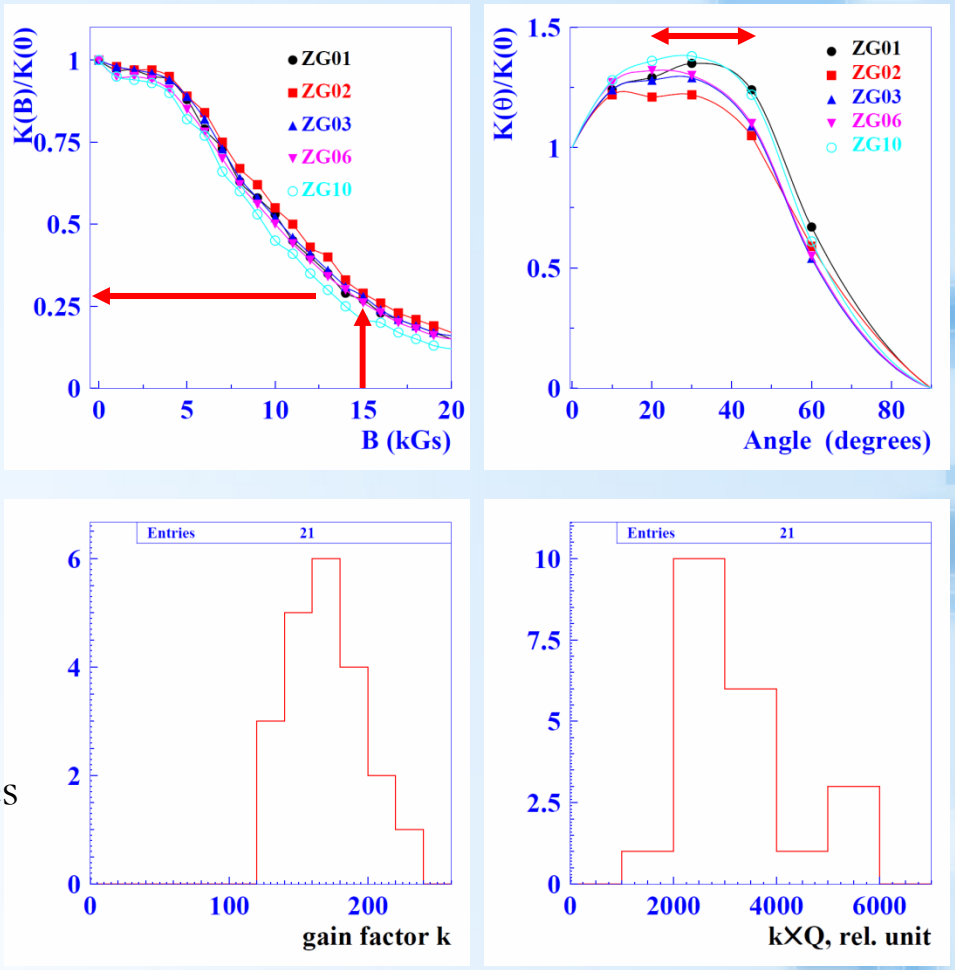


E, t resolution
test beam at BINP

Photon Detector

2' UV sensitive photo pentodes (PP)
by Hamamatsu C ≈ 10pF

our endcap



Gain Factor k = 120-240 for 21 samples
k = 46-92 > 30 @ B=1.5T, endcap
Q ≈ 14%

MPPC, APD will also be tested

Keys of KLM upgrade

End caps

Background is the biggest issue

→ Scintillatior + GAPD(SiPM) $t_{recover}$ = 1s → 500ns

→ Radiation hardness (ok for >5yrs)
temperature dependence of gain

Barrel

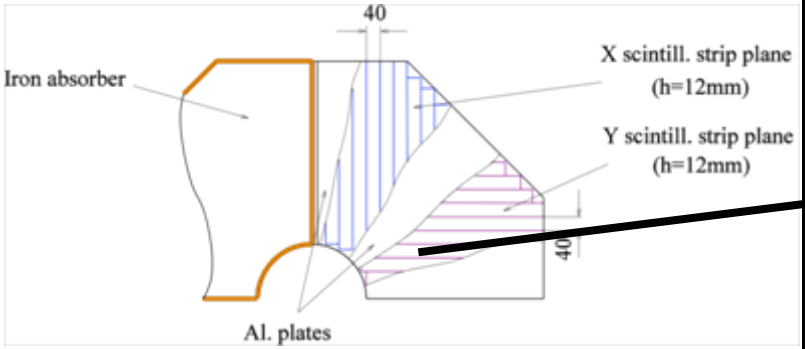
Background will be okay

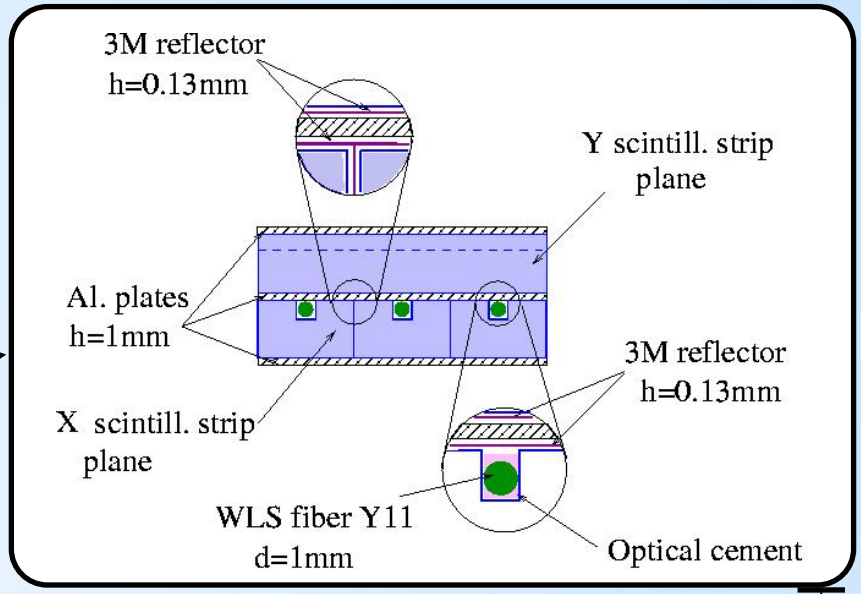
→ RPC in avalanche mode if not

Layer	Barrel(F)	E-cap(F)	E-cap(B)
0	3.6	2.4	3.4
1	2.3	2.4	2.9
2	1.6	2.4	2.8
3	1.1	2.0	2.8
4	0.7	2.2	2.8
5	0.6	2.7	2.9
6	0.6	2.7	1.5
7	0.4	3.3	2.6
8	0.7	3.1	3.0
9	0.5	3.9	2.8
10	0.3	4.7	3.5
11	0.4	5.3	3.0
12	0.4		
13	0.4		
14	0.5		

Scintillator + SiPM

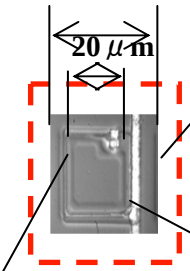
~17k scintillator strips
with WLS fiber readout.

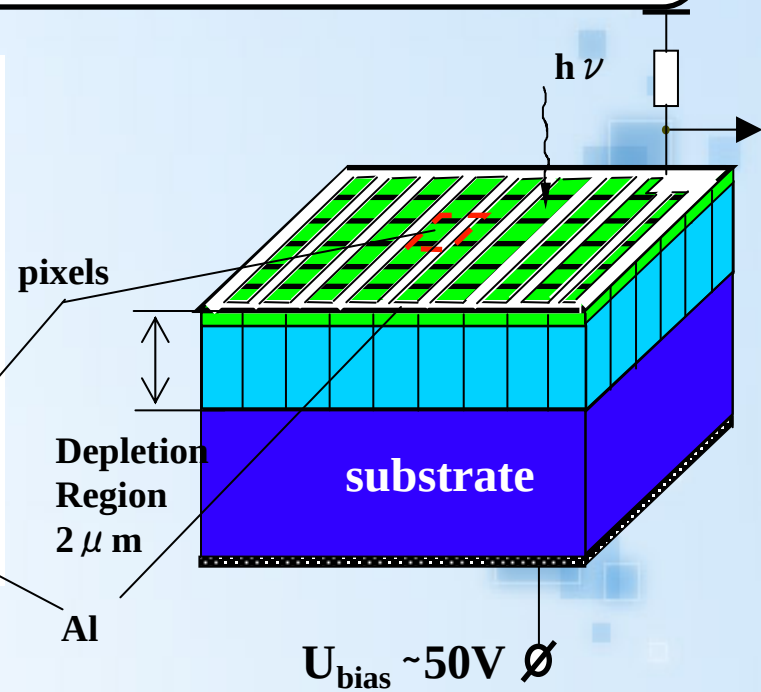




SiPM main features:

- Sensitive size 1x1mm^2 on chip 1.5x1.5 mm^2
- Gain $2 \cdot 10^6$
- U_{bias}~50V
- Recovery time ~ 100 ns/pixel
- Number of pixels: 576-1024
- Insensitive to magnetic field
- Dynamic range ~10^3/mm^2



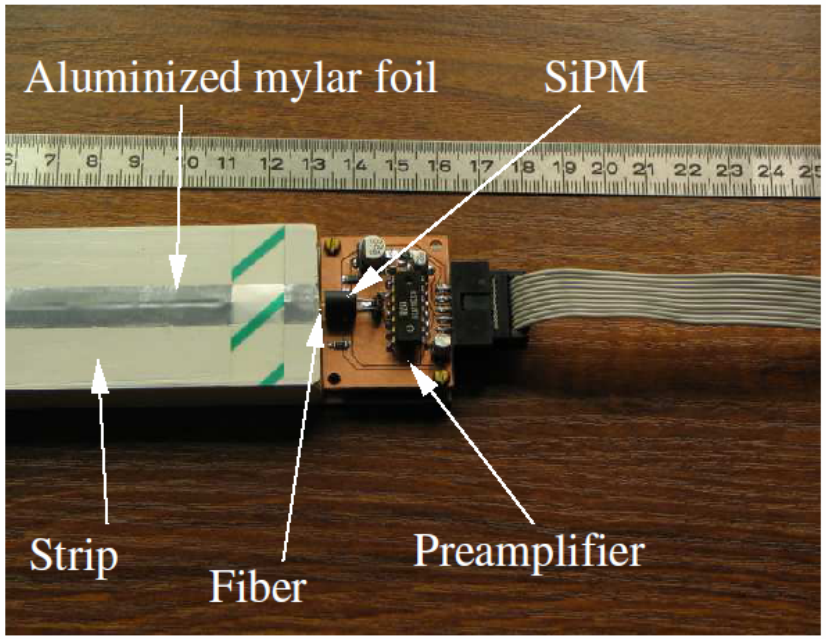


— ITEP scintillator 1m × 1m test module (96 readout ch.)

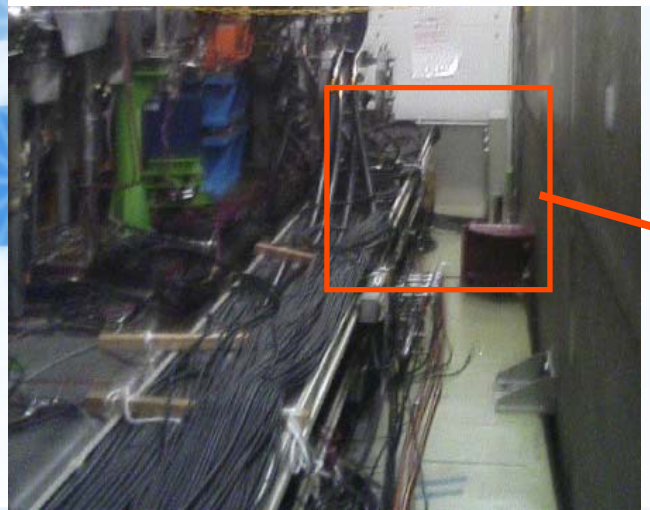
Test Module

Housed in an aluminum box.

Scintillator Strip with SiPM



These modules will be installed in Oho side

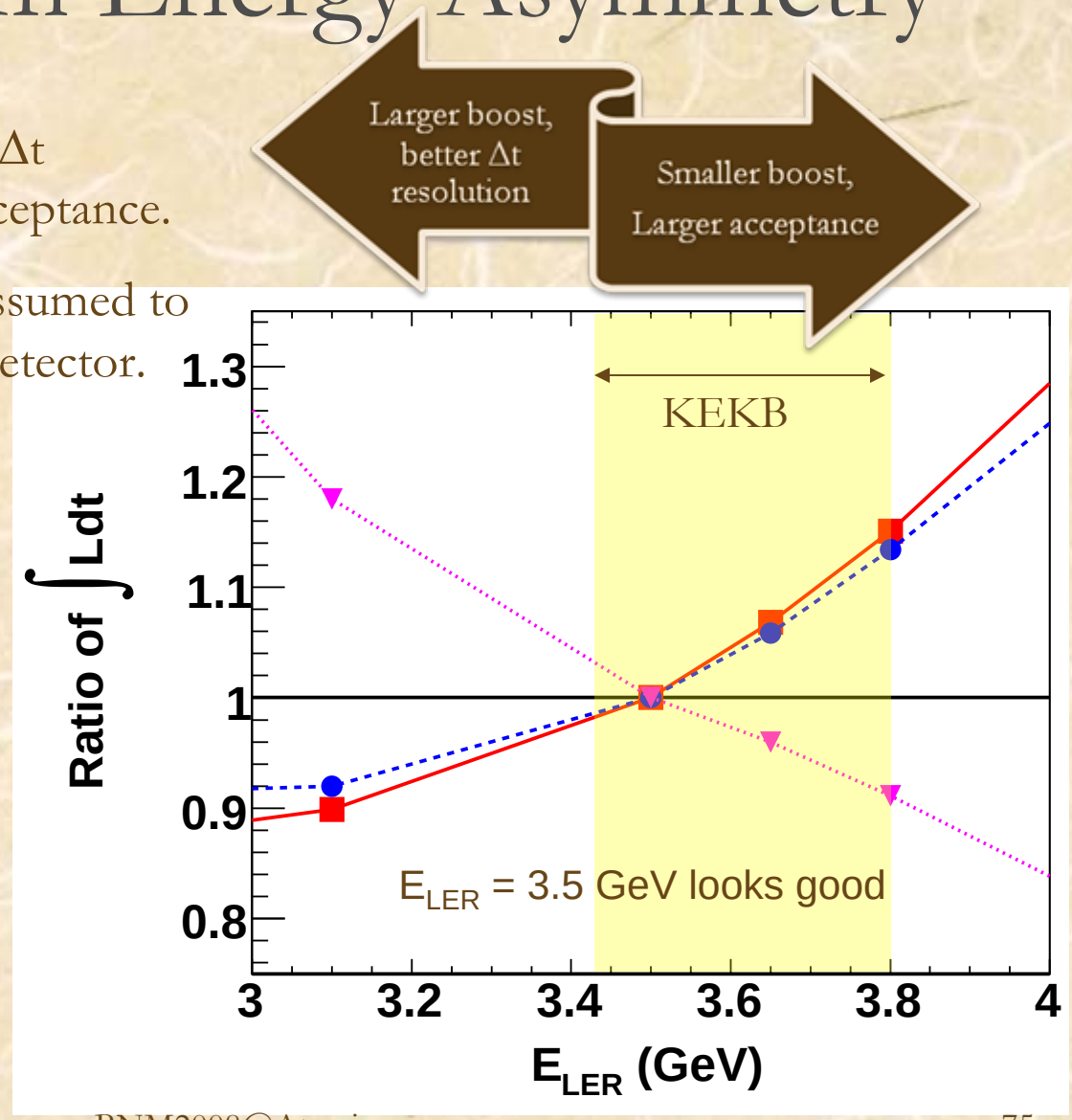


sKEKB: Beam Energy Asymmetry

- Toy MC results considering Δt resolution and geometrical acceptance.
- Geometrical acceptance is assumed to be same as the current Belle detector.

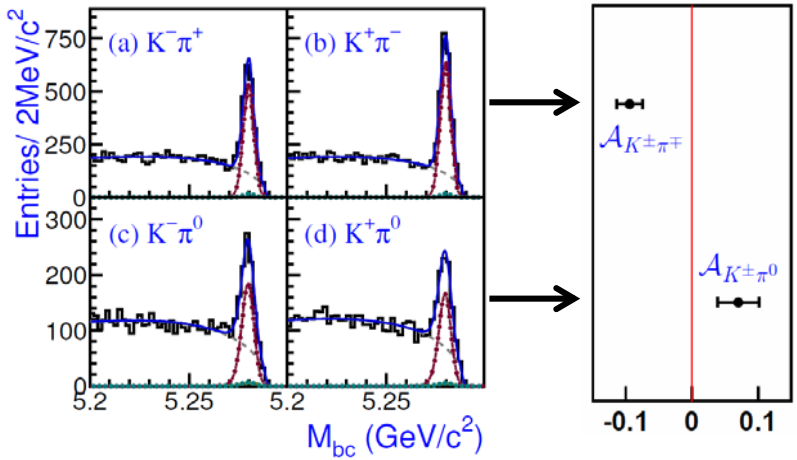
– $J/\psi K^0$ tCPV
– ϕK^0 tCPV
– $B \rightarrow \tau\nu$ BF

worse ↓ better

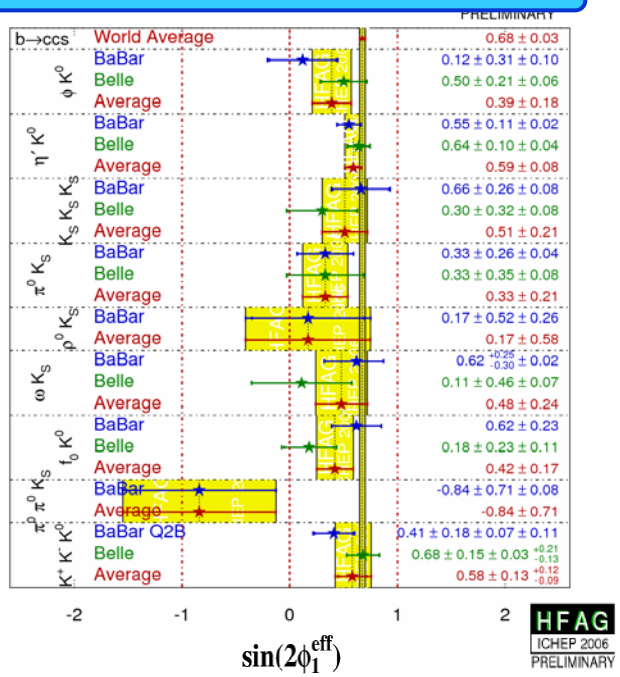


Possible Hints for New Physics in Flavor Decays

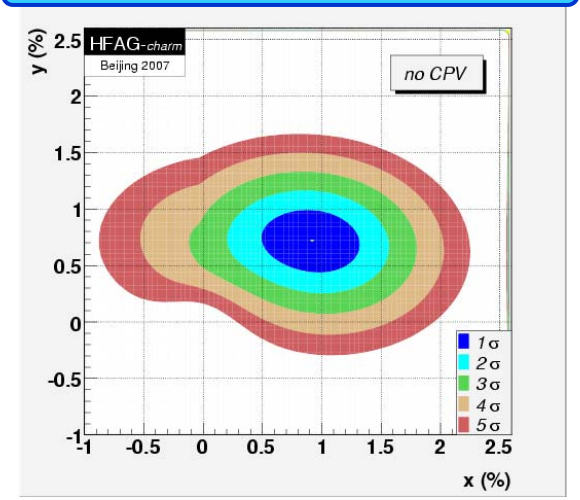
Opposite CP asymmetry between B^0 and $B^\pm$



Anomalous CPV in $b \to s$ transition?

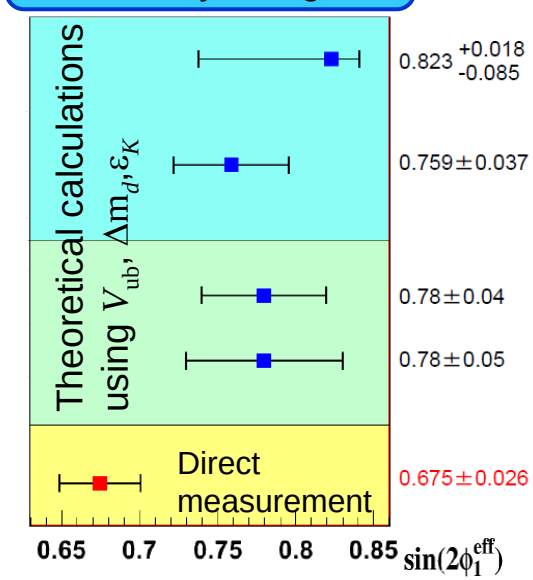


Unexpectedly large $D^0\overline{D}^0$ mixing



x=(0.97±0.29)%, y=(0.78±0.19)%

Small inconsistency in the unitarity triangle?



RF systems

Need RF systems which can store high beam currents and handle shorter bunches.

ARES (normal-conducting cavity) for LER
ARES + SCC (Single-cell Superconducting cavity) for HER

- Adopt the same RF frequency as KEKB and use the existing RF system as much as possible, with improvements as necessary to meet the requirements for SuperKEKB.

→Construction cost is greatly reduced.

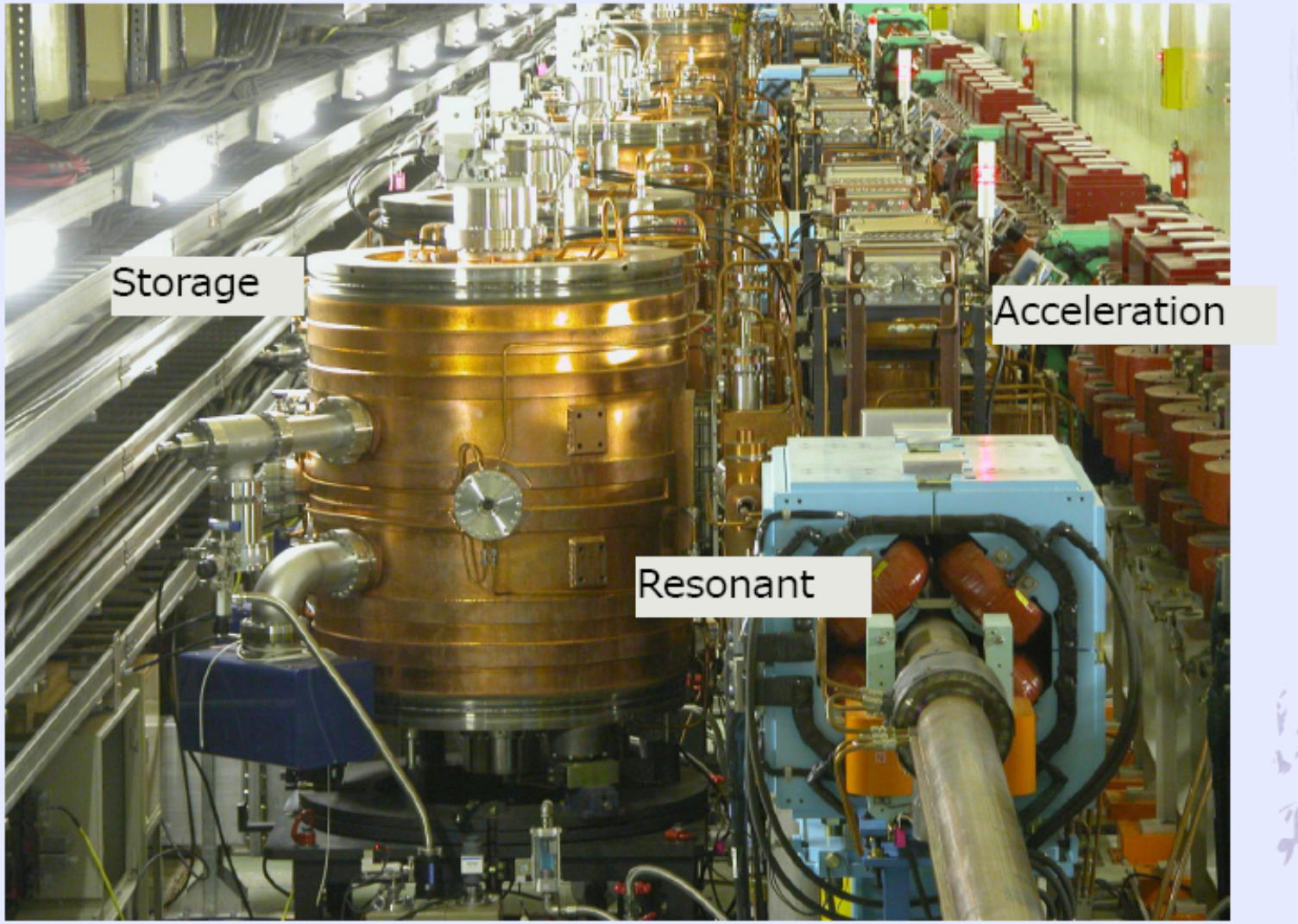
→Technical uncertainties are relatively small.

The ARES Cavity

Accelerator Resonantly-coupled Energy Storage

T. Kageyama, et al

- Passive stabilization with huge stored energy.
- Eliminate unnecessary modes by coupling of 3 cavities.
- Higher order mode dampers and absorbers.
- No need for longitudinal bunch-by-bunch feedback.
- No transverse instability arises from the cavities.



Superconducting Cavity

SuperKEKB challenges:
The expected power load to the HOM absorber is 50 kW/cavity at 4.1 A, (even) with a larger beam pipe of 220 mm).

HOM damper upgrade may be needed.

S. Mitsunobu, et al

Main Ring Magnets

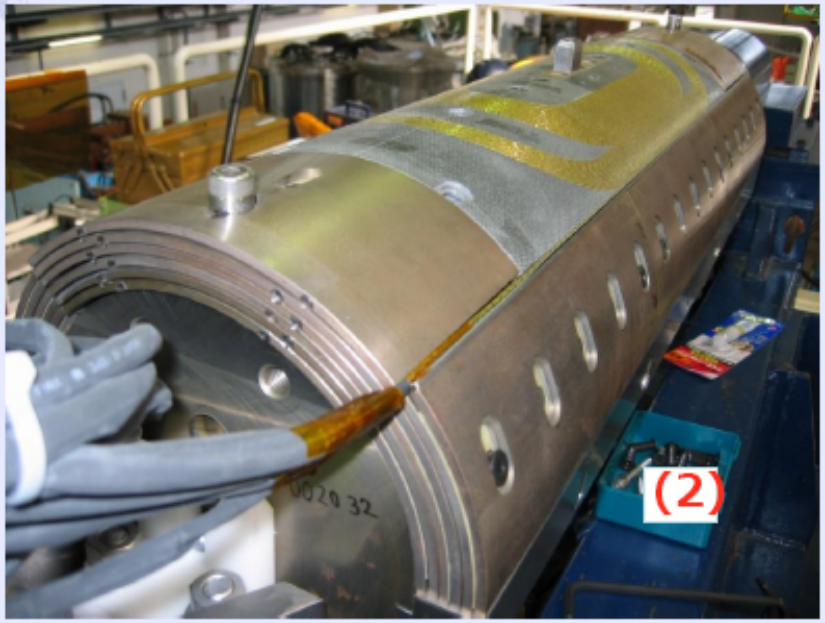
- Outside of the IR, will largely reuse present KEKB magnets & power supplies.
- The following magnets (& some power supplies) will have to be newly designed and fabricated.
- Magnet re-assembling due to the beam pipe replacement.

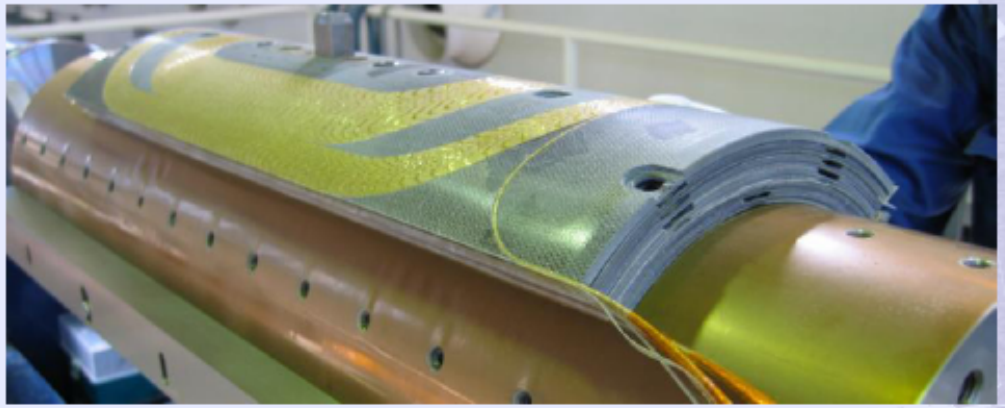
Magnet type	# of magnets	comments
HER Quad. (RF section)	19+1	Larger bore radius 80→120mm
LER Quad. (RF section)	2	The same type as the present LER Q
HER Sext.	49	~50% stronger field
V dipole corrector	~450	Ante-chamber

Construction of QCS R&D Magnet

N. Ohuchi

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

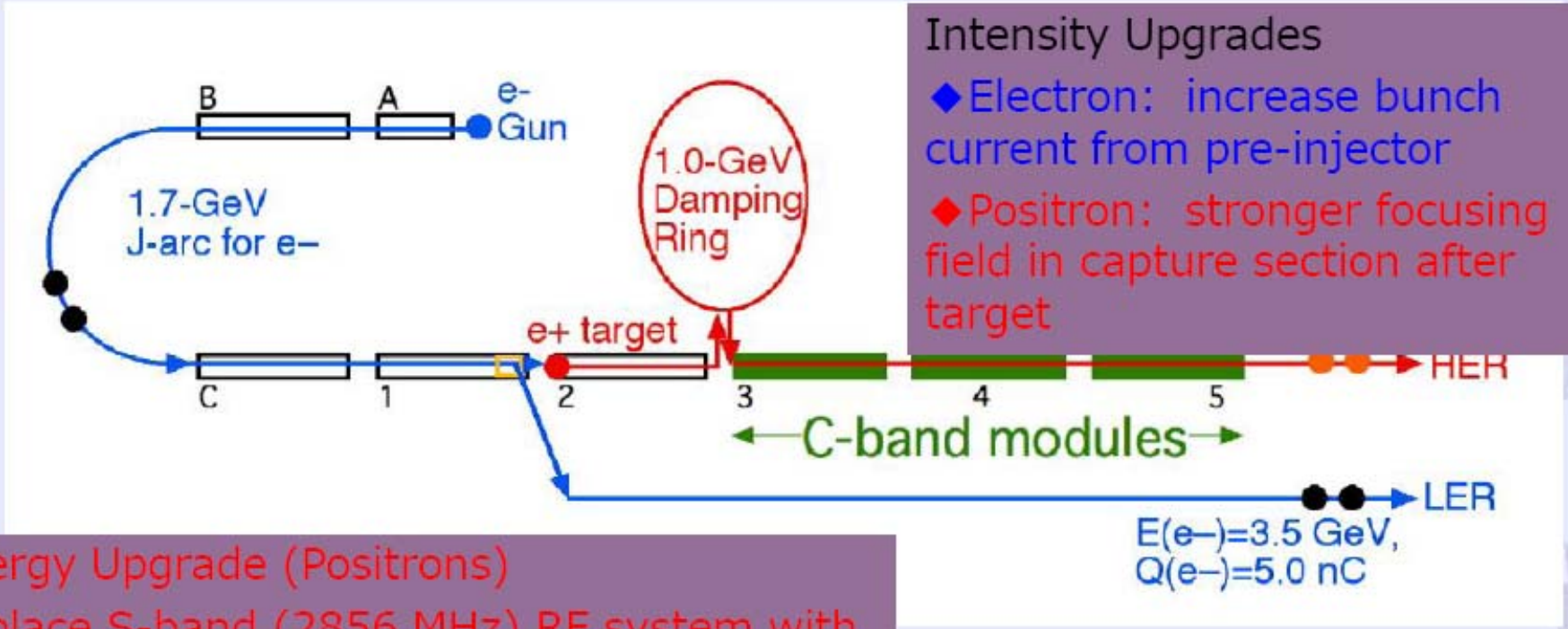




(1) 12 cured double pan-cake coils.

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

Linac Upgrade



Intensity Upgrades

- Electron: increase bunch current from pre-injector
- Positron: stronger focusing field in capture section after target

Energy Upgrade (Positrons)

Replace S-band (2856 MHz) RF system with C-band (5712 MHz) system to double field gradient in downstream section of linac. (The present max. energy gain is 4.8 GeV)

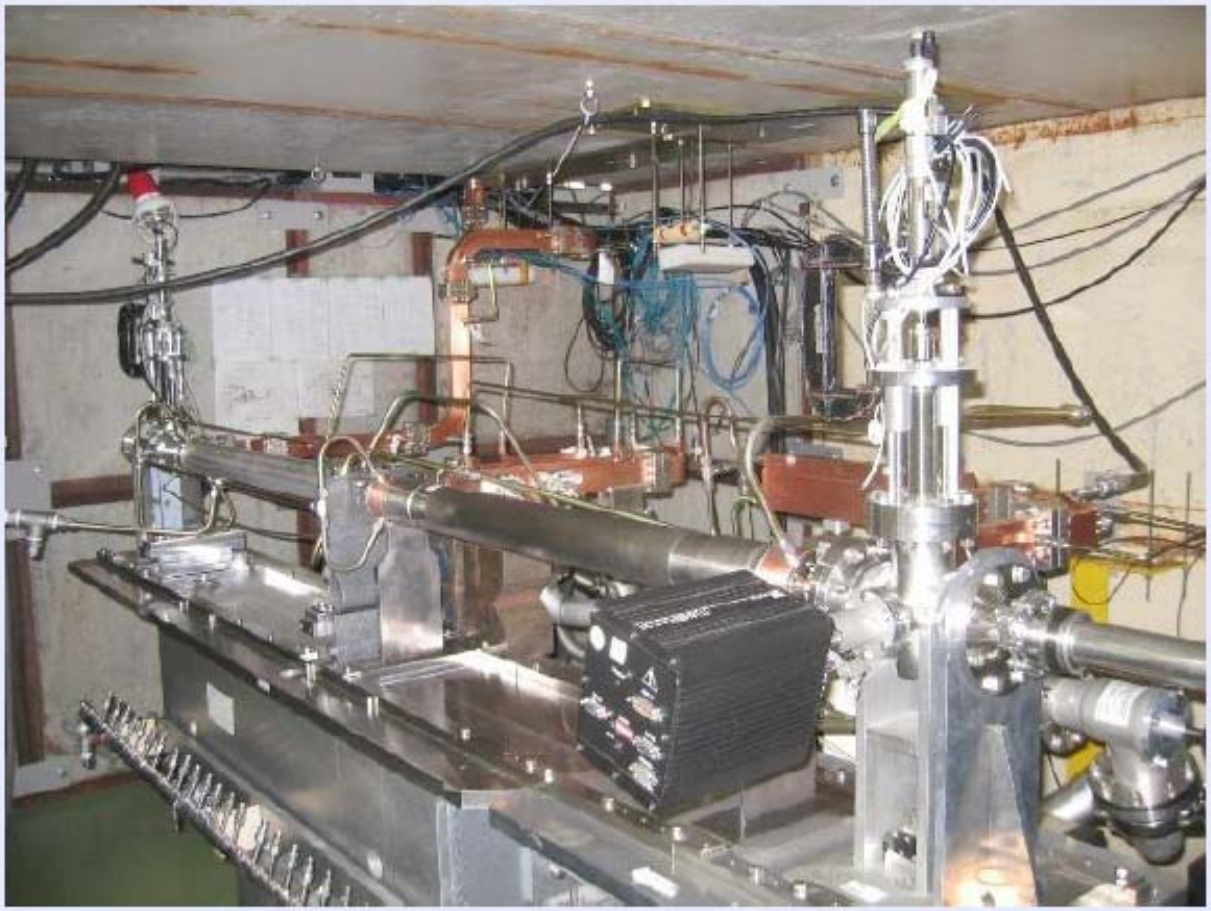
Pulse beam kicker installed before positron target for quick switching between beams (50 Hz).

Start testing this Fall

Talks by Michizono, Akemoto, Kamitani, Satoh

- C-band linac: completed a single section in the linac with 4 structures.
- Performance was satisfactory with the beam.

T. Kamitani, et al



Damping Ring

- Positron emittance needs to be damped, to pass reduced aperture of C-Band section and to meet IR dynamic aperture restrictions.
  - Electron DR may also be considered later to reduce injection backgrounds in physics detector, but for now only positron DR considered.
- Damping ring located downstream of positron target, before C-Band accelerating section.

M. Kikuchi