Status and Prospect of sKEKB

May 30, 2008

Yutaka Ushiroda (KEK)

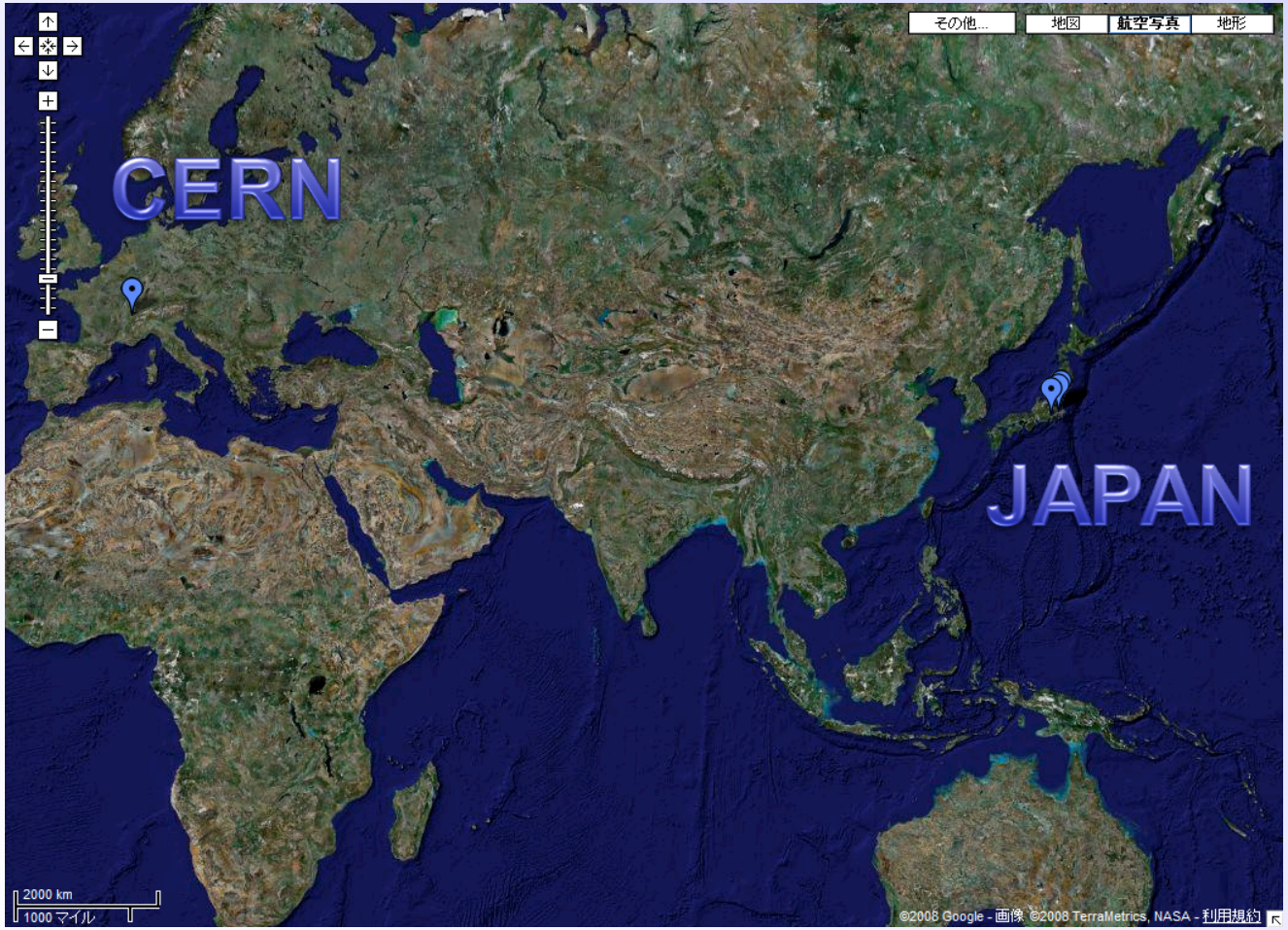
Flavour as a Window to New Physics at the LHC

Focus Week “B@LHC”

Outline

- Introduction
- Accelerator status and prospect
- Detector status and prospect
- Political situation
- Summary

KEK and KEKB


CERN
JAPAN
その他...
地図
航空写真
地形
2000 km
1000 マイル
©2008 Google - 画像 ©2008 TerraMetrics, NASA - 利用規約

KEK and KEKB


その他...
地図
航空写真
地形
Tsukuba
Tokyo
Mt. Fuji
50 km
20 マイル
©2008 Google - 画像 ©2008 TerraMetrics - 利用規約

KEK and KEKB


その他...
地図
航空写真
地形
KEK
2 マイル
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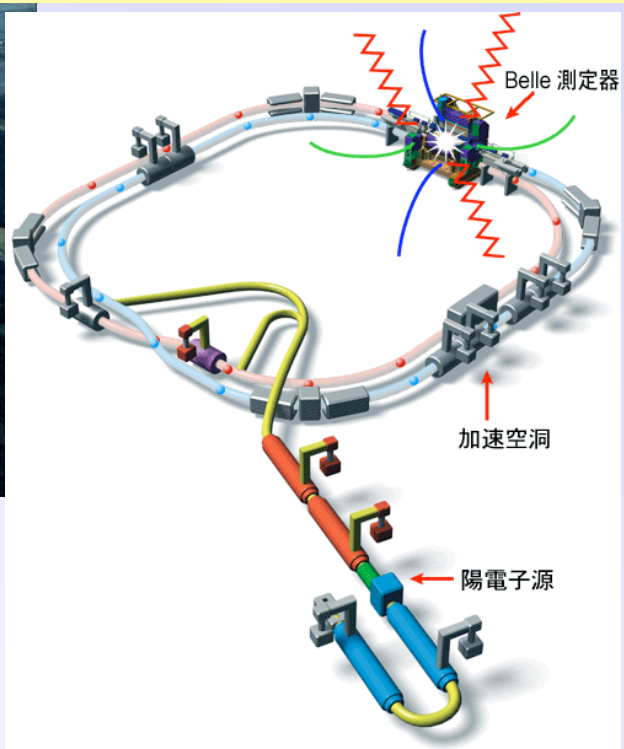
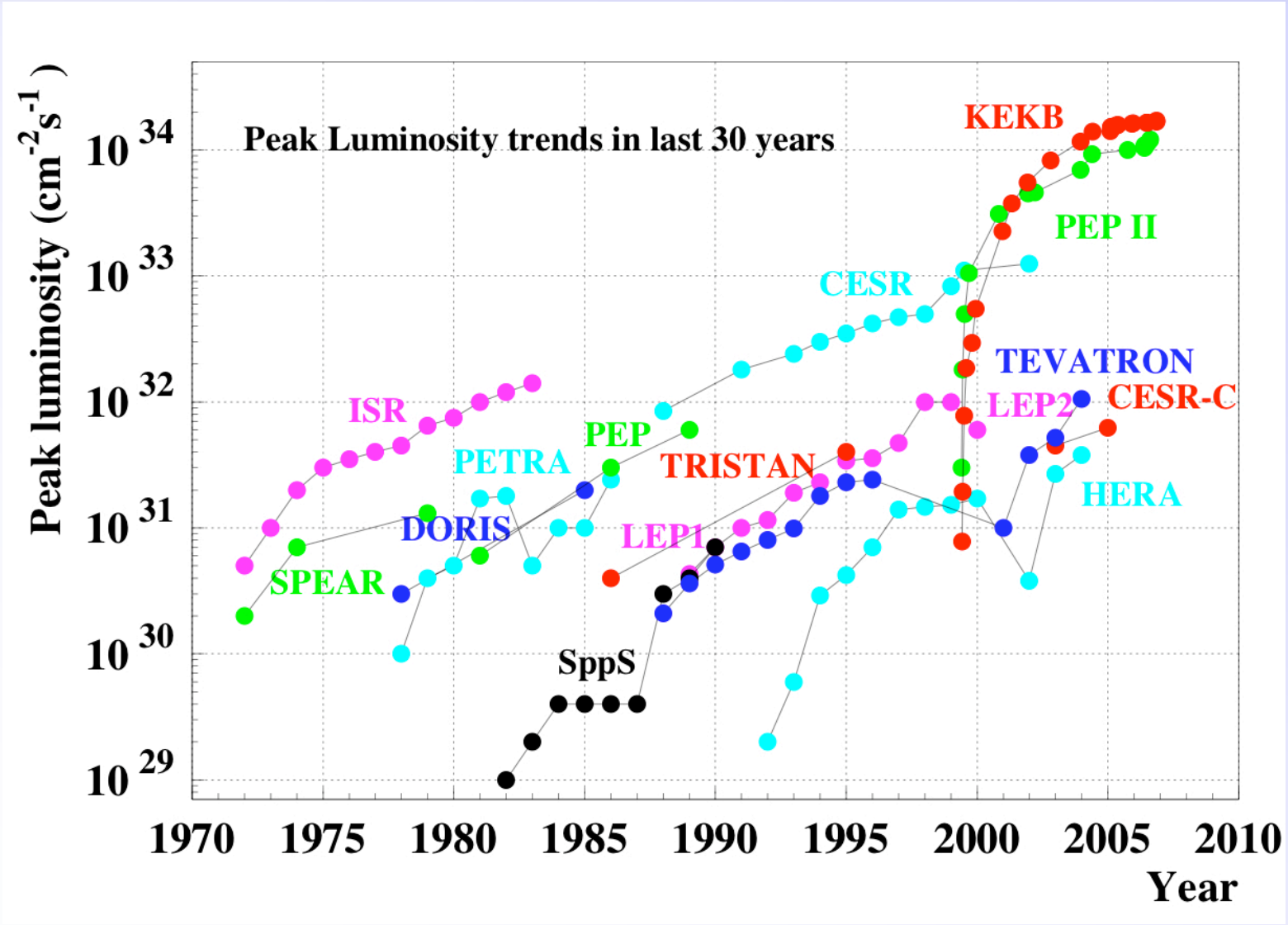
KEK and KEKB

3.5 GeV e^+ X 8.0 GeV e^-
crossing angle = ±11 mrad.

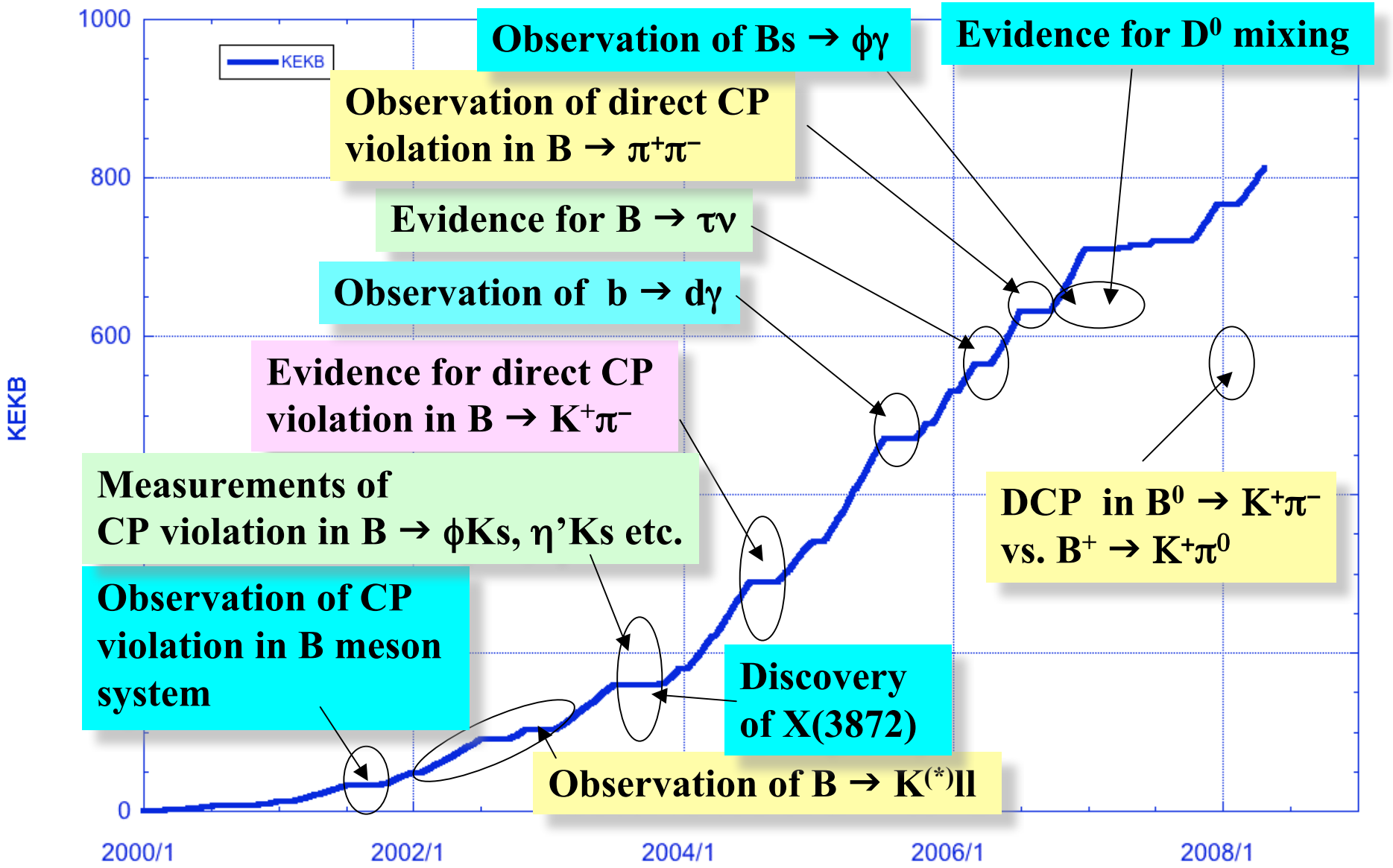


The Luminosity Frontier



Main results from Belle

L>830/fb



Five key measurements

- Non-SM CP phase: High precision $b \to s$ penguin studies
- Charged Higgs: searches in $B^+ \to \tau^+\nu$ and $B \to D^{(*)}\tau^+\nu$
- Non-SM right-handed current: $B \to K^*\gamma$ CPV
- Loop vs tree: high precision unitarity triangle measurement
- Lepton flavor violation: searches in high statistics τ decays

+ Bonus

- NP search in up-quark sector: CPV in D-D mixing
- Hunt for new particles: 4-quark states and more?
- Endless list: Many rare B decays, $A_{FB}(B \to K^*\ell^+\ell^-)$, B_s at $\Upsilon(5S)$, more D decays, continuum, $\gamma\gamma$, ISR...
- Jackpot?: anything not thought of yet...

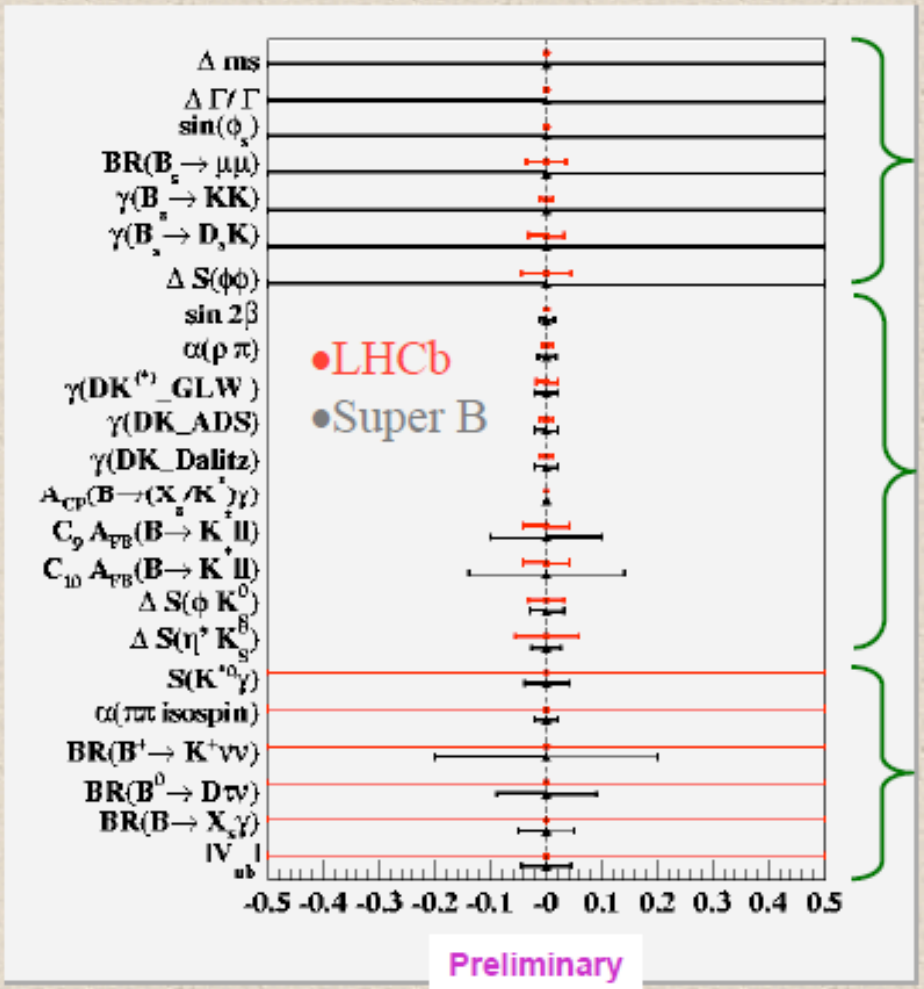
S. Stone

Super B factory and Super-LHCb

Sensitivity Comparison ~2020

Super-LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}

SuperB numbers from M Hazumi - Flavour in LHC era workshop; LHCb numbers from Muheim



B_s

Common

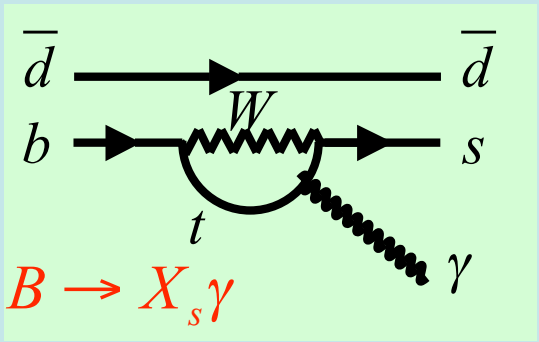
No IP
Neutrals, ν

•This plot is made by our LHCb friend.
LHCb: 10/fb
Super-LHCb: 100/fb

Quite complementary to each other !

B→K*(→$K_S\pi^0$) γ TCPV

SM prediction

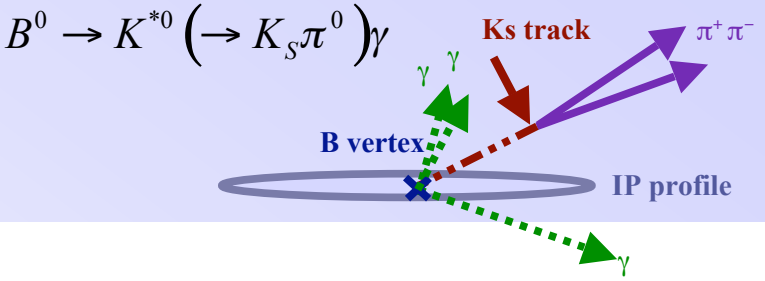


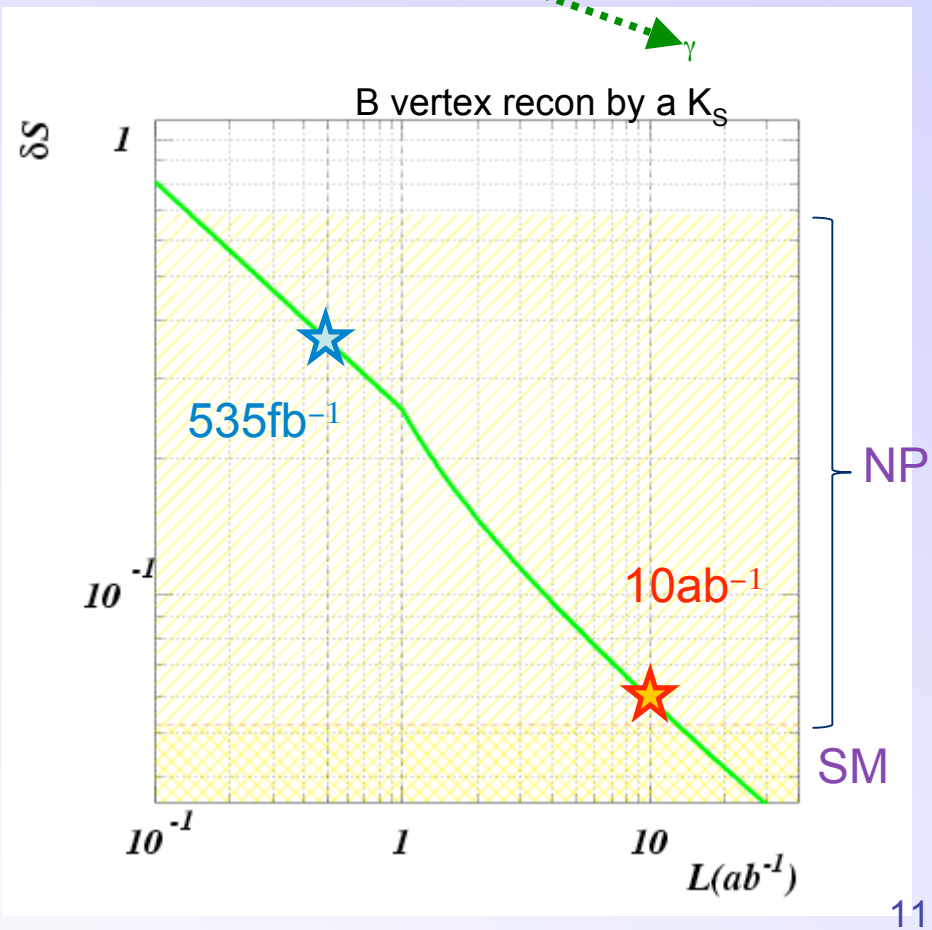
The decay is almost flavor specific because photon is highly polarized

$$b \to s\gamma_L$$
$$\bar{b} \to \bar{s}\gamma_R$$

$$|S| \approx \frac{2m_s}{m_b}\sin 2\phi_1 \approx 0.04$$

AGS [Phys.Rev.Lett. **79**, 185 (1997)]
AGHS [Phys. Rev. D 71, 076003 (2005)]



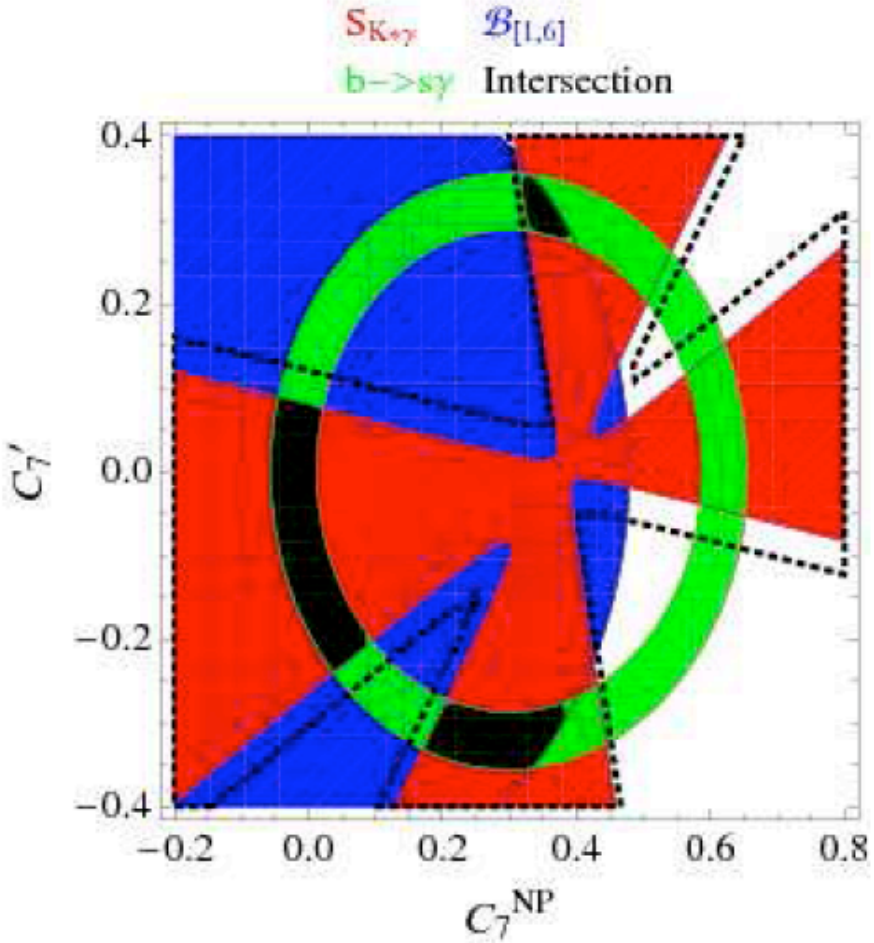


talk by M. Misiak

Constraints in the $(C_7^{\rm NP} \equiv C_7 - C_7^{\rm SM}, C_7')$ plane from

C. Bobeth, G. Hiller and G. Piranishvili, **arXiv:0805.2525**

Fig. 2a



Assumptions for the above plot:

(i) $C_7^{\rm NP}$ and C_7' are real.

(ii) All the other Wilson coefficients are fixed at their SM values.

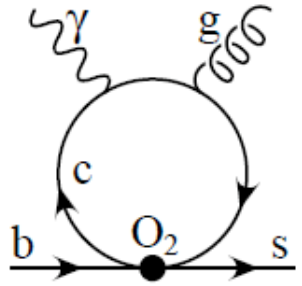
Green: $\bar{B} \to X_s\gamma$,

Blue: $\bar{B} \to X_s l^+ l^-$

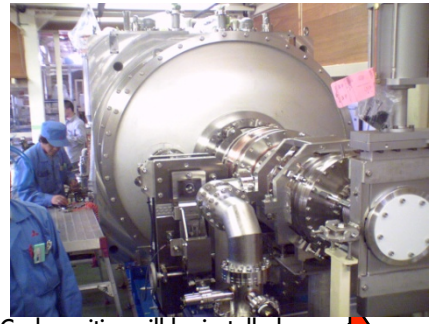
$q^2_{\rm dilept} \in [1,6]\ {\rm GeV}^2$,

Red: $S_{K^*\gamma}$

Black dotted lines: Effect of enlarging the uncertainty in the SM prediction for $S_{K^*\gamma}$ due to the $\mathcal{O}(\Lambda/m_b)$ fraction of right-handed photons originating from:



B. Grinstein, Y. Grossman, Z. Ligeti and D. Pirjol, Phys. Rev. D 71 (2005) 011504.



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

SuperKEKB

SuperBelle

New IR

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

Crab cavities

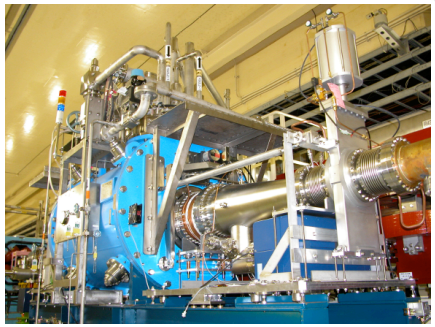
New beam pipe & bellows

e- 9.4 A

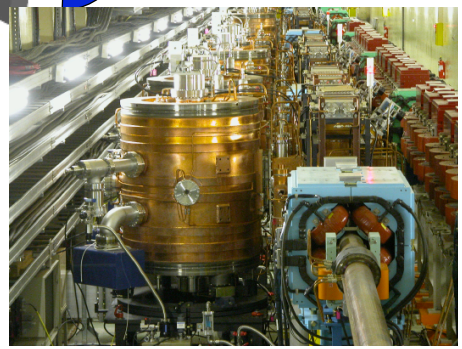
e+ 4.1 A

More RF sources

More RF cavities



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

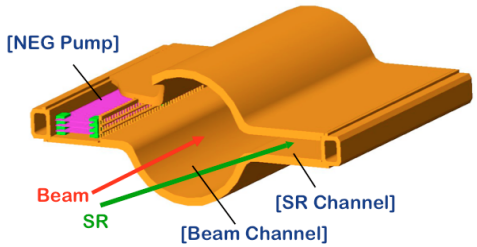


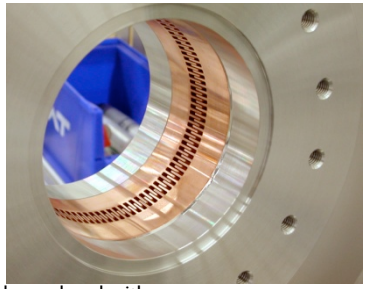
The state-of-art ARES coppe cavities will be upgraded with higher energy storage ratio t support higher current.

Energy exchange C-band

Damping ring

Positron source





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

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma^*_y}{\sigma^*_x}\right)\frac{I_\pm \xi_{\pm y}}{\beta^*_y}\left(\frac{R_L}{R_y}\right)$$

will reach 8×10^{35} cm^{-2}s^{-1}.

Machine parameters

Slide from Y. Ohnishi

		LER	HER	
Energy	E	3.5	8.0	GeV
Current	I_b	9.4	4.1	A
#particles/bunch	N	1.18×10^{11}	5.13×10^{10}	
#bunches	n_b	5018		
Emittance	ε_x	12		nm
Coupling	$\varepsilon_y/\varepsilon_x$	0.5		%
Beta at IP	β_x^*	20		cm
	β_y^*	3		mm
Bunch length (0A)	σ_z	3		mm
Crossing angle	θ_x	30→**0** (crab crossing)		mrad
Bean-beam	ξ_x	0.272		
	ξ_y	0.295		
Luminosity reduction	R_L	0.86		
Beam-beam	$R_{\xi x}$	0.98		
reduction	$R_{\xi y}$	1.11		
Luminosity	L	5.5×10^{35}		$cm^{-2}s^{-1}$

Improve Luminosity

KEKB
PEPII

sKEKB

- Increase beam current
- Squeeze beam size (a little)

Brute force, but adiabatic and steady

Super*B*

- Squeeze beam size

New sophisticated approach

Improve Gas Mileage

Gasoline Car

Hybrid

TOYOTA Prius

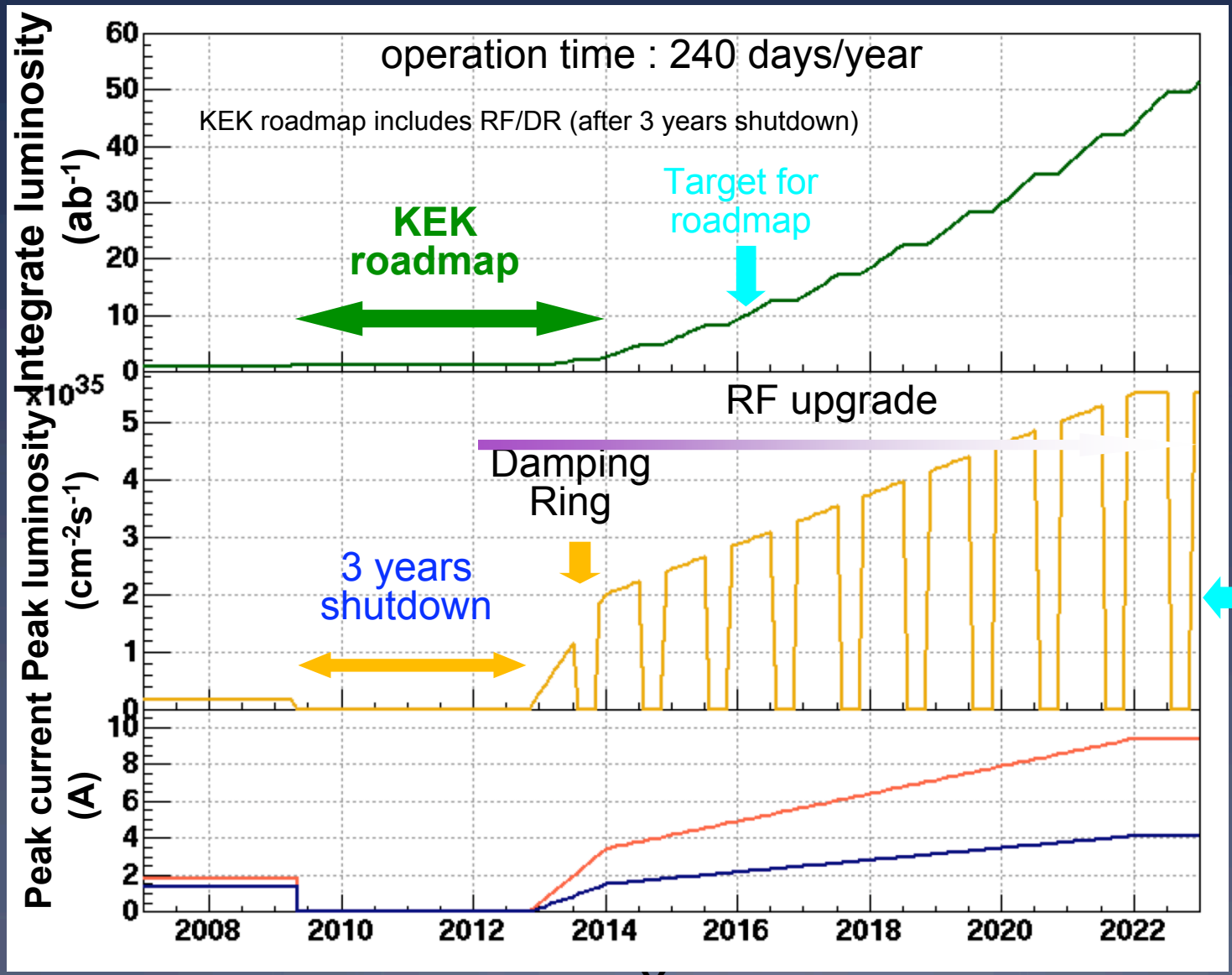
Plug-in Hybrid

Hydrogen

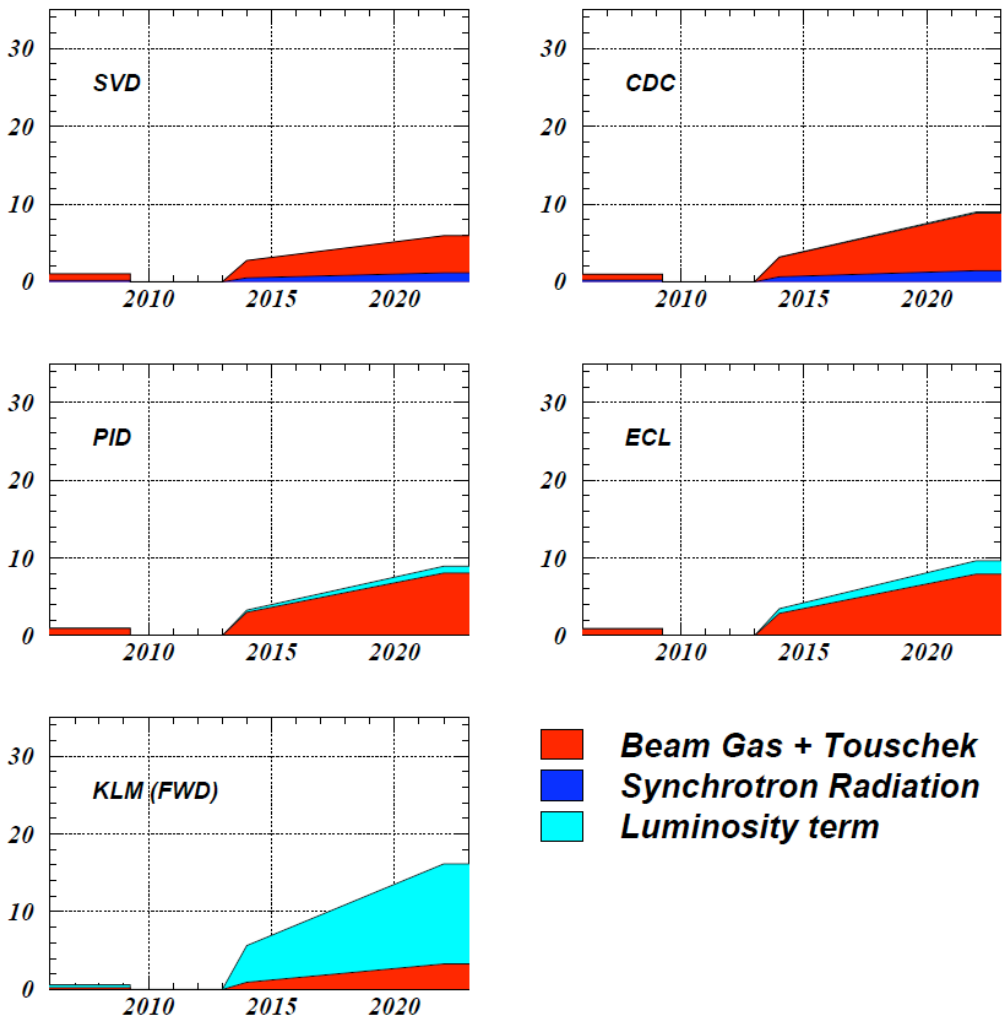
FIAT Panda Hydrogen

Slide from Y. Ohnishi

Projected Luminosity (preliminary)



Beam Background (extrapolation)

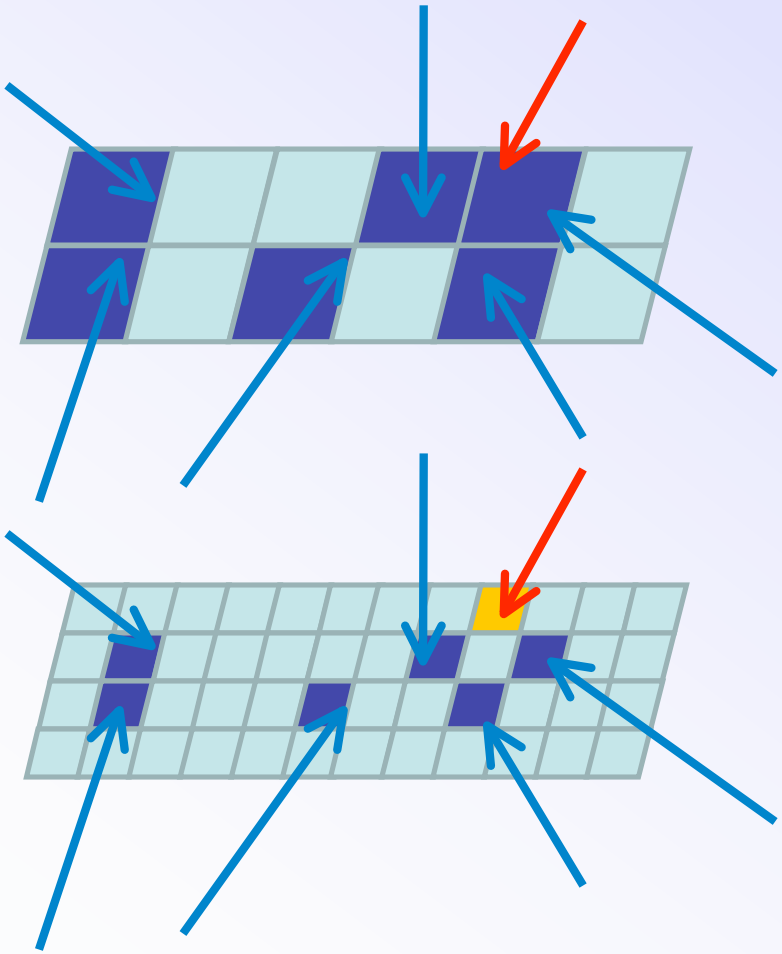


Prepare against 20x

Ideas to reduce background:
- Neutron shield for KLM
- Improve vacuum
- Cu chamber near IR
- Careful IR design

Against high background (1)

Finer segmentation of sensors



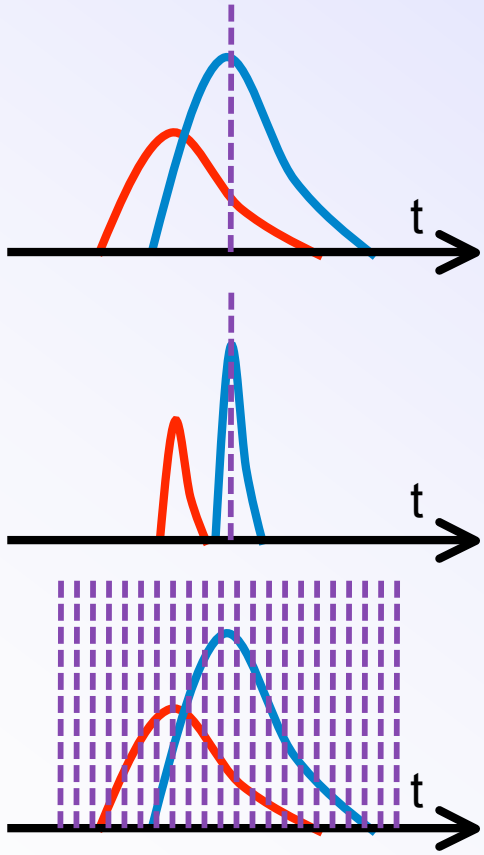
Large cell
Occupancy = 6/12 = 50%
Hits overlap

Small cell
Occupancy = 7/48 = 14.5%
Hits separated

Hit rate per cell can be reduced

Against high background (2)

Finer segmentation in time



Long-tailed signals overlap each other

Short signals are separated

Even when we cannot shorten the peaking time, waveform sampling will help to discriminate two signals

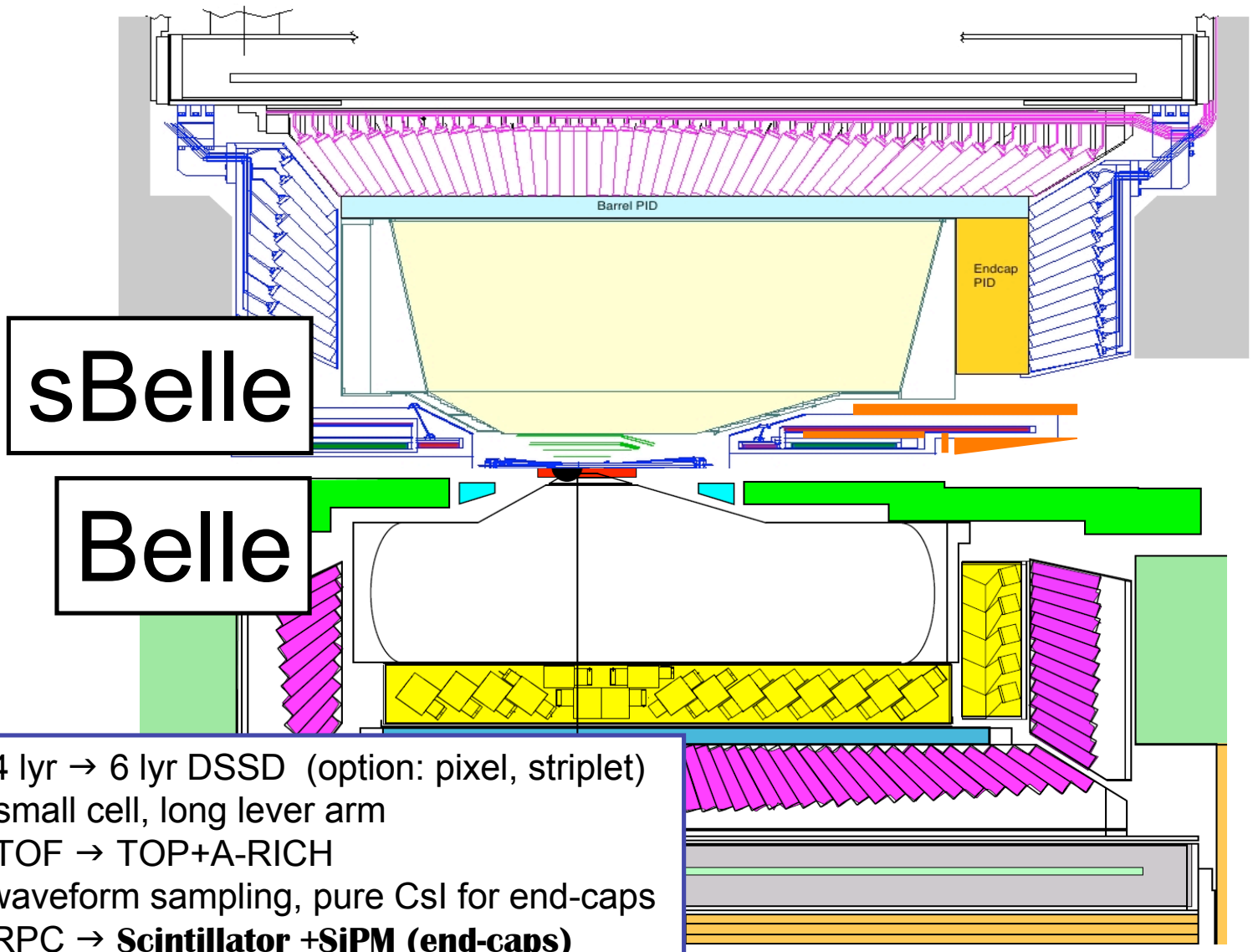
“effective” background with new hardware

	How to cope with	Reduction factor	bkg
SVD	Shorter t_p	50/800 = 1/16	0 ~ 1
CDC	Smaller cell	<2/3	4 ~ 13 (*)
PID	Brand new device	Good enough	0 ~ 1
B-ECL	Waveform fitting	1/7	1 ~ 2
E-ECL	Pure CsI (shorter τ)	1/200	0 ~ 1
KLM	Faster detector, finer segment	Under control	0 ~ 1

(*) Software efforts needed for CDC

We know how to deal with high background

sKEKB: Baseline Design



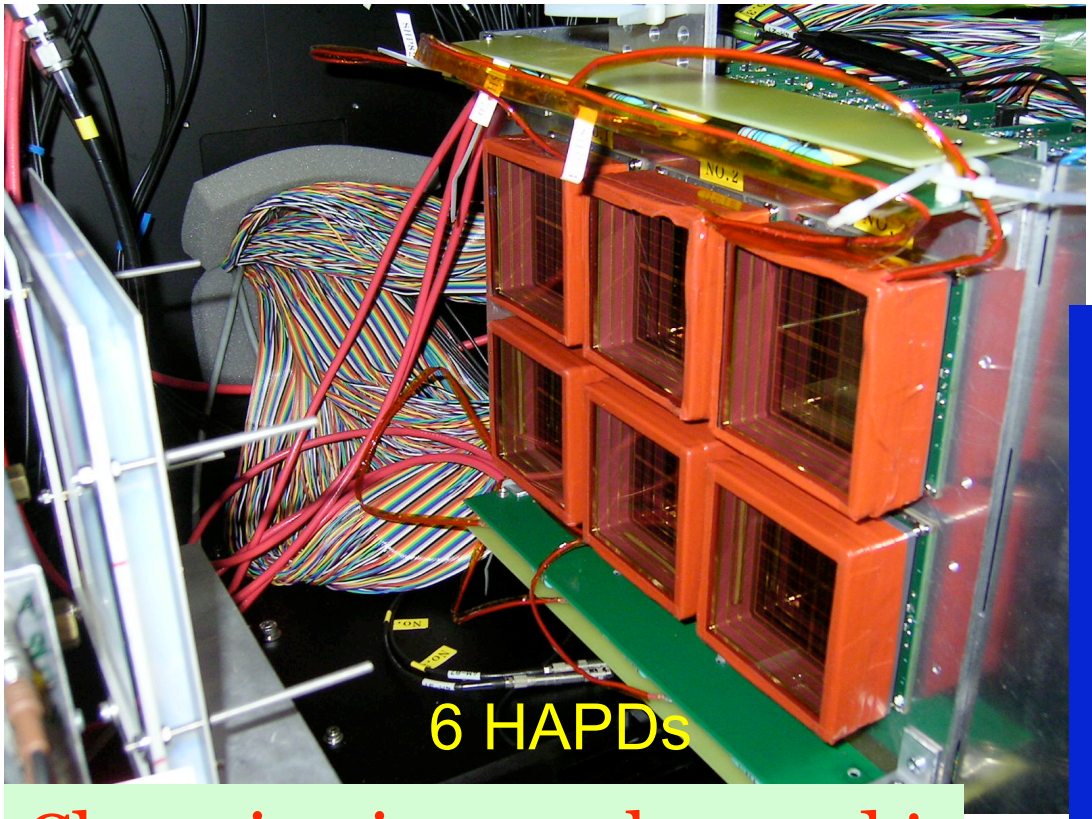
SVD: 4 lyr → 6 lyr DSSD (option: pixel, striplet)
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → **Scintillator +SiPM (end-caps)**

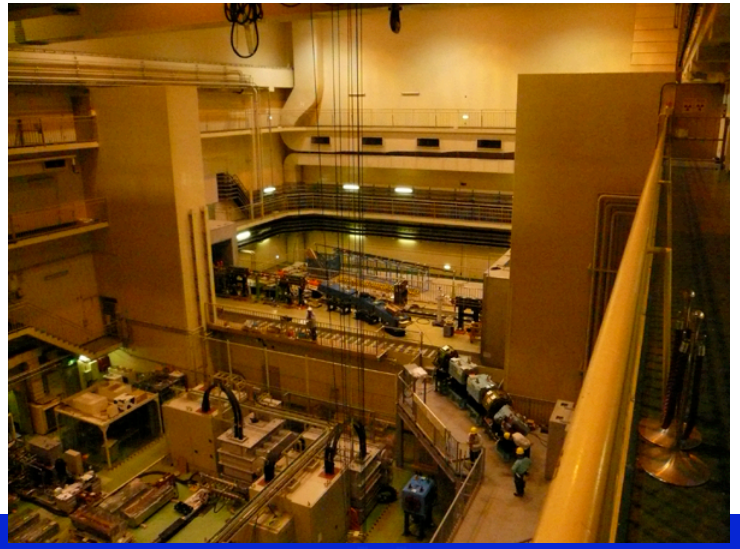
To be improved

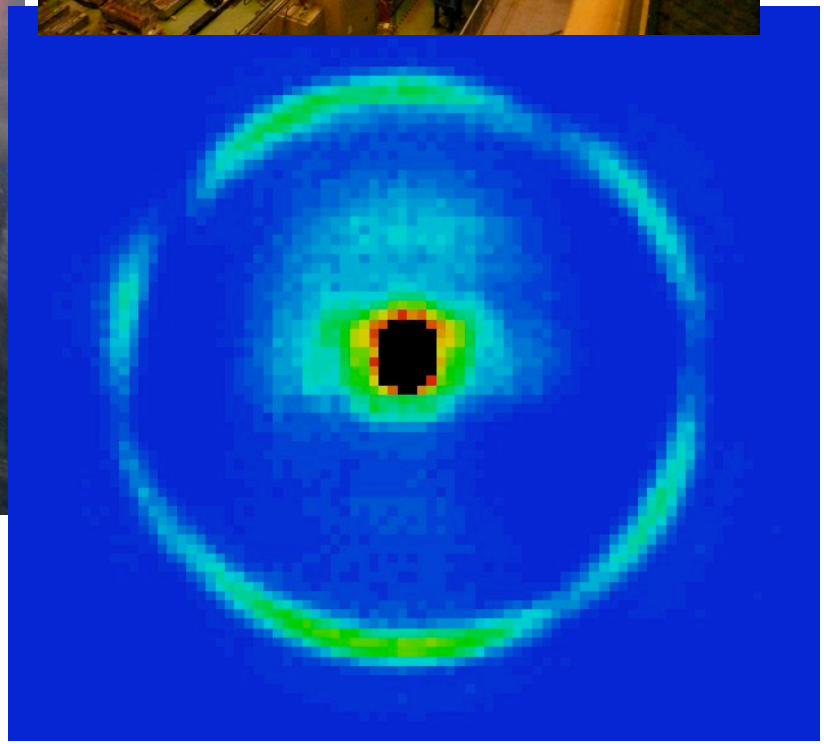
- Larger radial size of vertex detector to accept more K_S
- Innermost sensor closer to the IP to improve Δz resolution
- More hermetic detector to help reconstruction of *invisible* modes (w/ ν)
- Better Particle Identification
- Better K_L reconstruction
- …

End-cap PID (A-RICH)
Test beam result

March 2008 at KEK Fuji electron beam line
p_e = 2 GeV/c

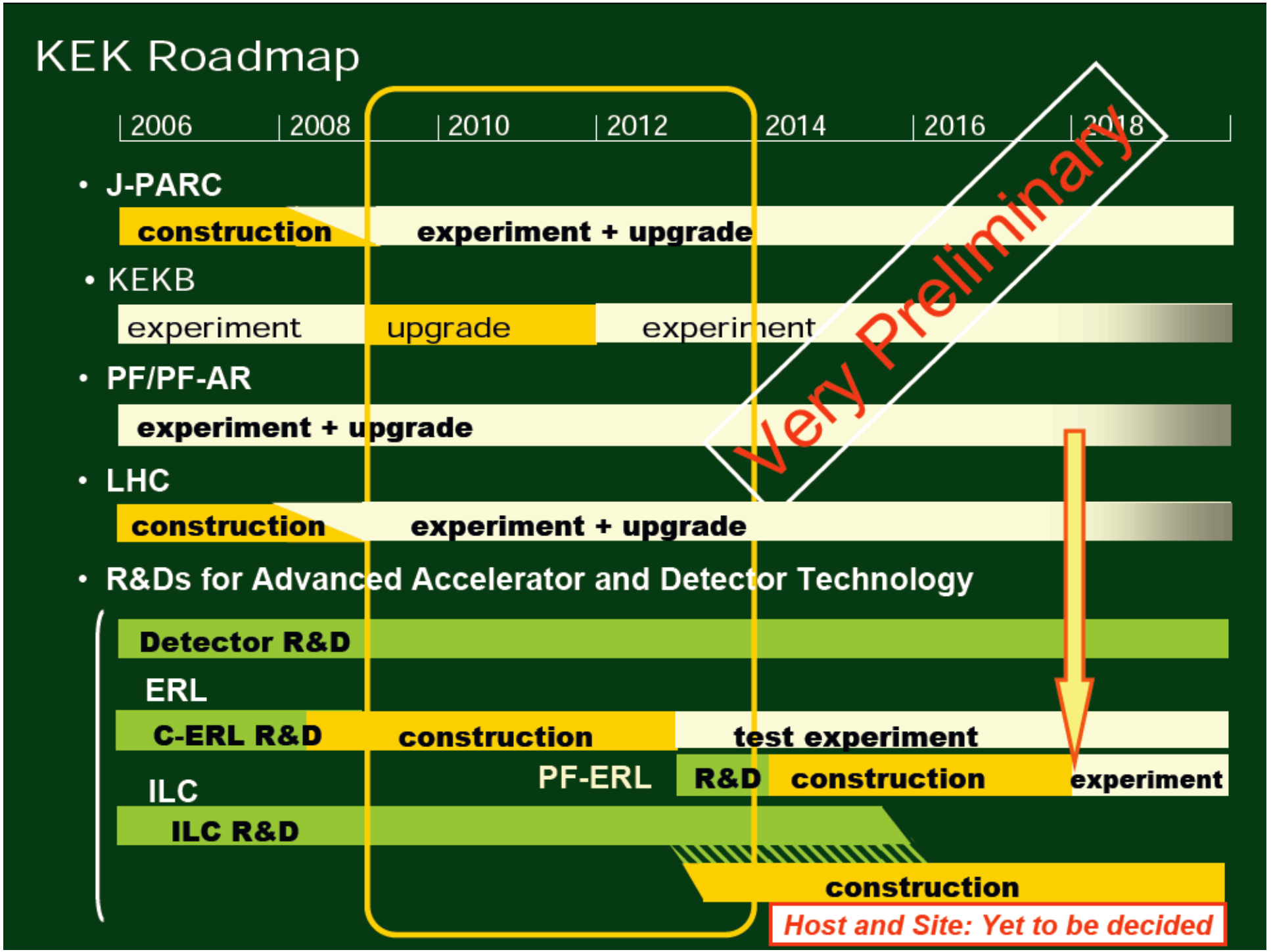






Clear ring image observed !

σ ~ 12mrad, $N_{p.e.}$ ~ 4


KEK Roadmap
2006
2008
2010
2012
2014
2016
2018
Very Preliminary
• J-PARC
construction
experiment + upgrade
• KEKB
experiment
upgrade
experiment
• PF/PF-AR
experiment + upgrade
• LHC
construction
experiment + upgrade
• R&Ds 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
Host and Site: Yet to be decided

External Reviews

Belle PAC, Feb. 25,26, 2008

BPAC report, 6 March 2008

BELLE Programme Advisory Committee
Review Summary Report
2nd meeting, 25-26 February 2008 at KEK

I. Bigi (Notre Dame), A. Buras (TU München), A. Golutvin (ITEP),
S. Kim[1)] (Tsukuba), T. Nakada[*)] (CERN and EPFL), T. Skwarnicki (Syracuse) and
T. Yamanaka (Osaka)
[*)] *Chair*
[1)] Partially attended
Apology received from J. Butler (FNAL)

http://belle.kek.jp/hot/Review_report-bis.pdf

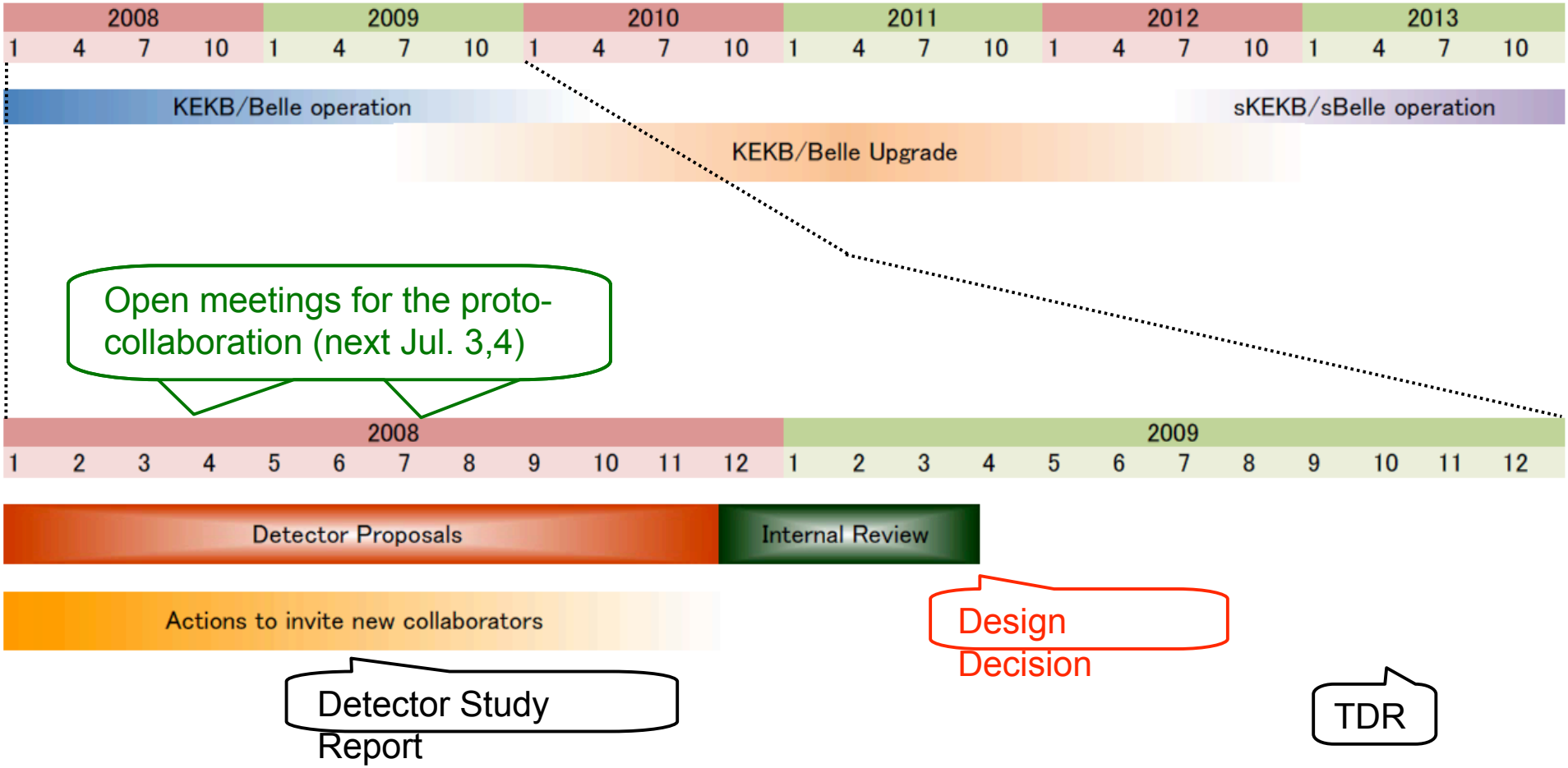
KEKB Review, Nov.-Dec., 2007

KEK Roadmap Review Committee, Mar. 9,10, 2008

and one more Belle review in July by Japanese key figures

Necessary approvals to start a new big project at KEK

Tight Schedule Toward Upgrade



Summary

- We plan to upgrade KEKB/Belle in a sure and steady method.
- We have ideas to make the accelerator and the detector, and continuing R&Ds.
- We will make a budget request to the government *soon*.
- Hopefully, we will start the operation in late 2012 and accumulate 10-50ab^{-1} by 202x depending on the budget.
- Hope you will put this talk not in the 'Long-term future' session from the next time.

KEK's 5 year Roadmap

- Official 20 page report released on January 4, 2008 by director A. Suzuki and KEK management
- KEKB's upgrade to $2x10^{35}$ /cm^2/sec in 3+x years is *the central element in particle physics.* (Funding limited: Final goal is 8 x 10^{35} and an integrated luminosity of 50 ab^{-1})
  - Will be finalized after recommendations by the Roadmap Review Committee (March 9-10).
    - Membership: Young Kee Kim, John Ellis, Rolf Heuer, Andrew Hutton, Jon Rosner and reviewers from other fields

Super-Belle (and Super KEKB) is an open international project that covers the next two orders of magnitudes at the luminosity frontier. A special opportunity for high impact international collaboration

Three factors to 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 repipeion factors due to crossing angle and hour-glass effect

Luminosity:

0.17×10^{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)

Costs & Effects

Preliminary

Item	Object	Oku-yen = 1.0 M$	Luminosity
New beam pipes	Enable high current Reduce e-cloud	178 (incl. BPM, magnets, etc.)	x1.5
New IR	Small β^*	31	x2
e+ Damping Ring	Allow injection with small increase e+ capture	40 incl. linac upgrade	if not, x0.75
More RF and cooling systems	High current	179 (incl. facilities)	x3
Crab Cavities	Higher beam-beam param.	15	x2 - x4

Items are interrelated.

Time schedule is restricted.

Baseline is “HIGH current scheme”.

Alternative is low beta+low emittance+crab waist scheme

Luminosity upgrade

Luminosity gain and upgrade items (preliminary)

Item	Gain	Purpose
beam pipe	x 1.5	high current, short bunch, electron cloud
IR($\beta^*_{x/y}$=20cm/3 mm)	x 1.5	small beam size at IP
low emittance(12 nm) & $\nu_x \rightarrow 0.5$	x 1.3	mitigate nonlinear effects with beam-beam
crab crossing	x 2	mitigate nonlinear effects with beam-beam
RF/infrastructure	x 3	high current
DR/e^+ source	x 1.5	low β^* injection, improve e^+ injection
charge switch	x ?	electron cloud, lower e^+ current

Machine parameters

		LER	HER	
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Current	I_b	9.4	4.1	A
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#bunches	n_b	5018		
Emittance	ε_x	12		nm
Coupling	$\varepsilon_y/\varepsilon_x$	0.5		%
Beta at IP	β_x^*	20		cm
	β_y^*	3		mm
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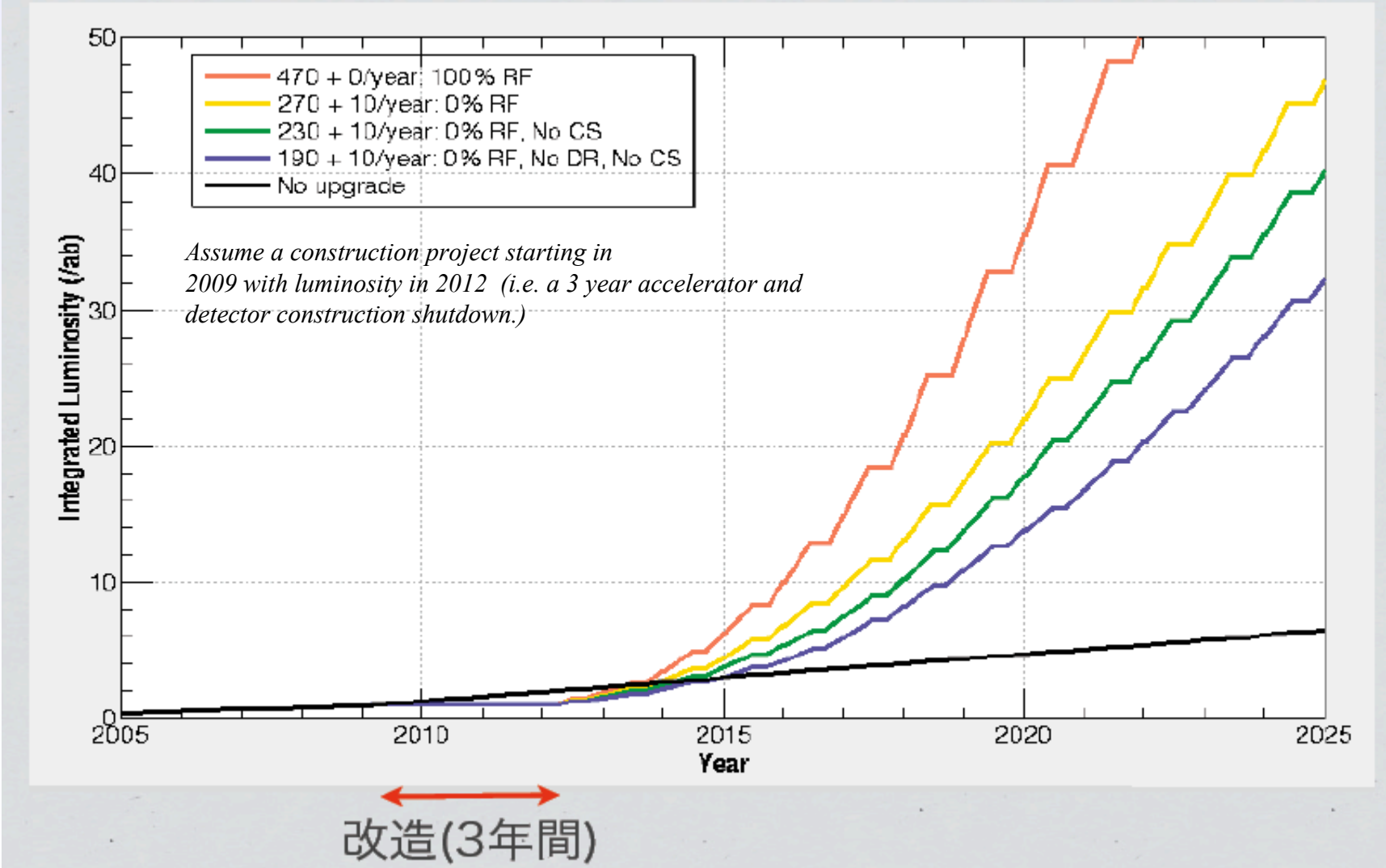
reduction	$R_{\xi y}$	1.11		
Luminosity	L	5.5×10^{35}		$cm^{-2}s^{-1}$

Slide from K. Oide

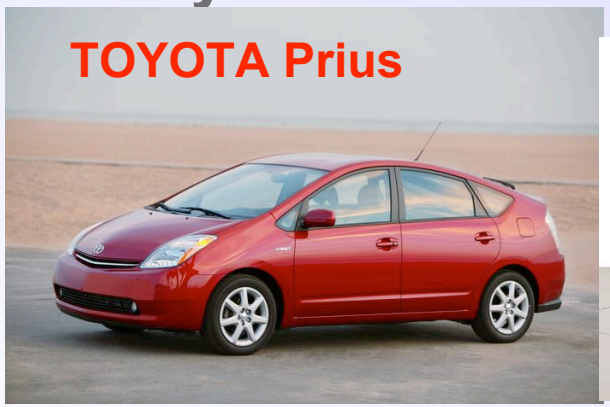
sKEKB: Accelerator Luminosity is funding-limited



Luminosity ⇨ Gas mileage

Hybrid

TOYOTA Prius



Plug-in Hybrid

Hydrogen

MAZDA RX8

Girasole = Street2008

EV

FIAT Panda

Hydrogen