Univerza v Ljubljani

Prospects of the KEK-B/Belle upgrade

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KAON'07

Laboratori Nazionali di Frascati dell'INFN

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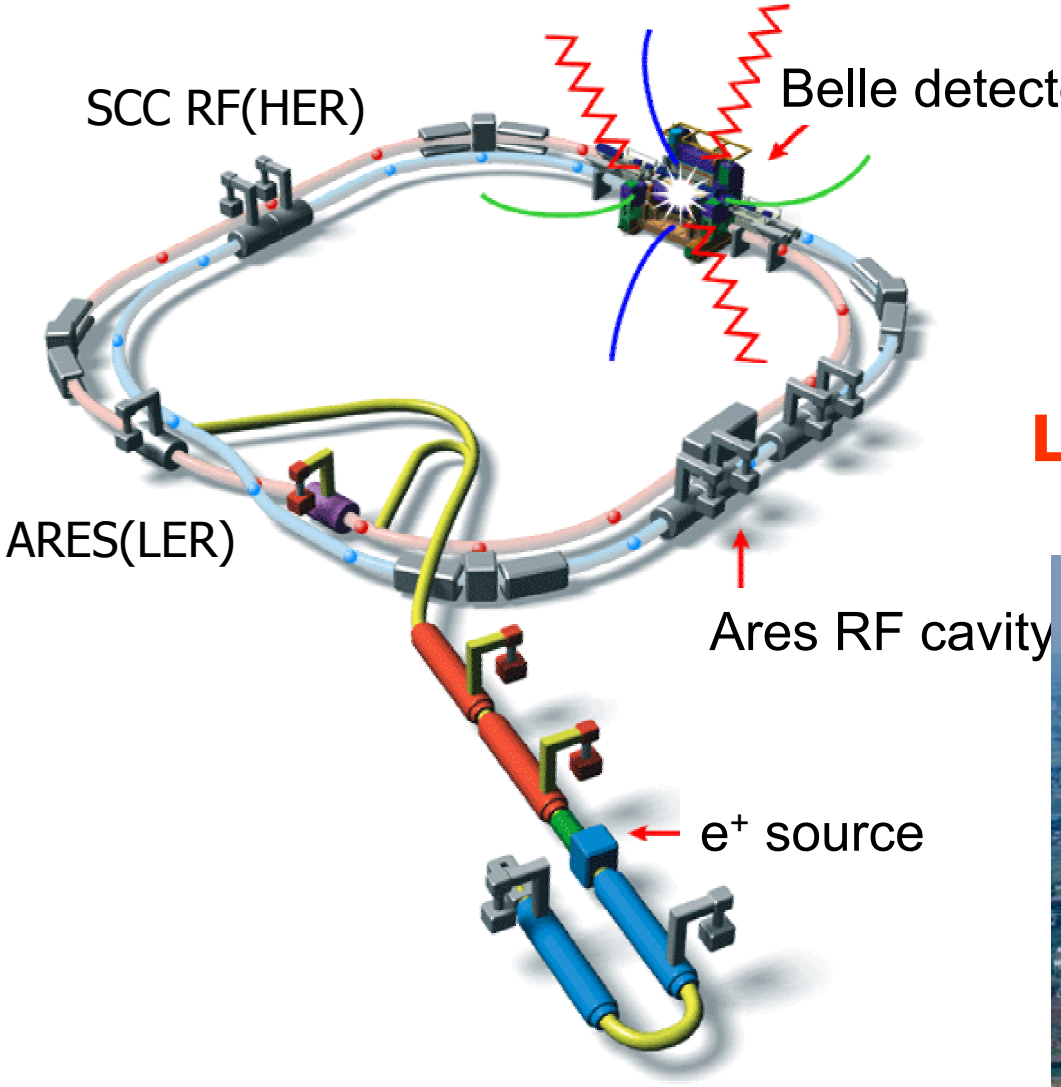
The KEKB Collider

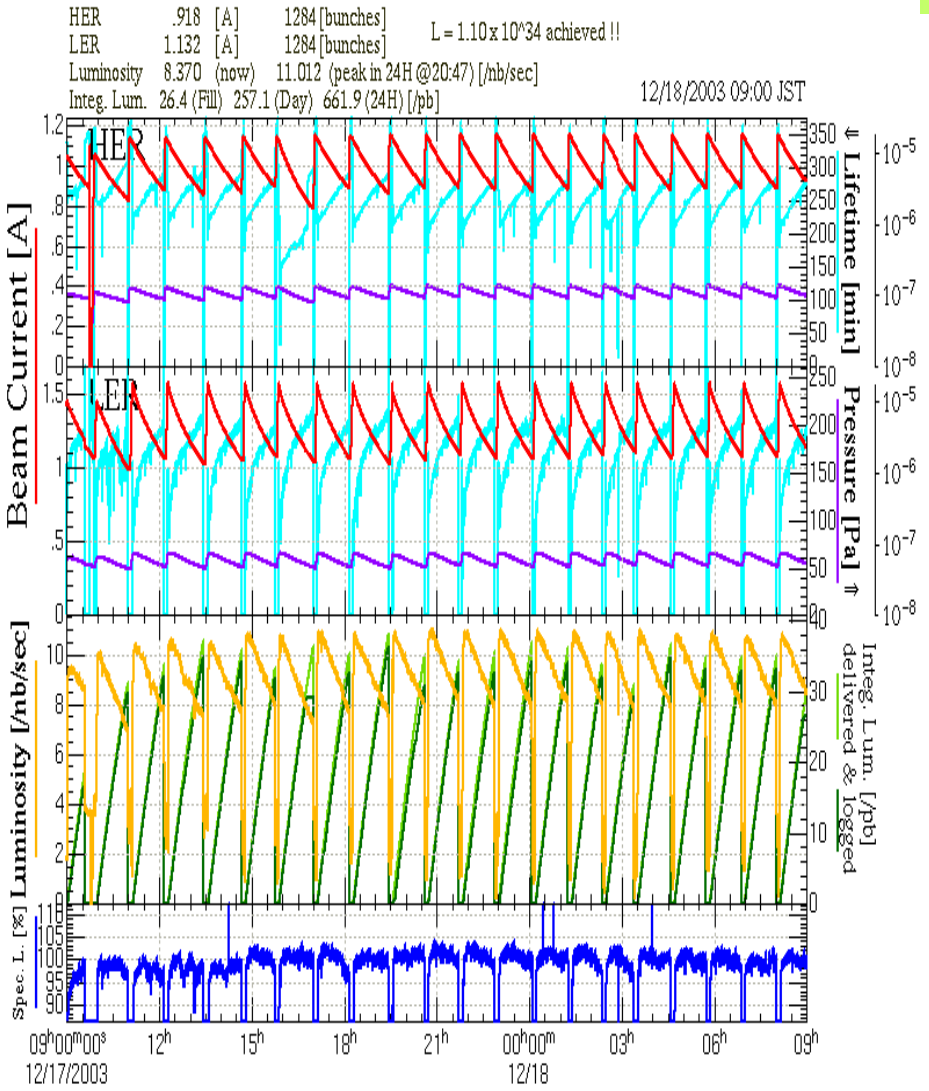


8 x 3.5 GeV
22mrad crossing angle

World record:

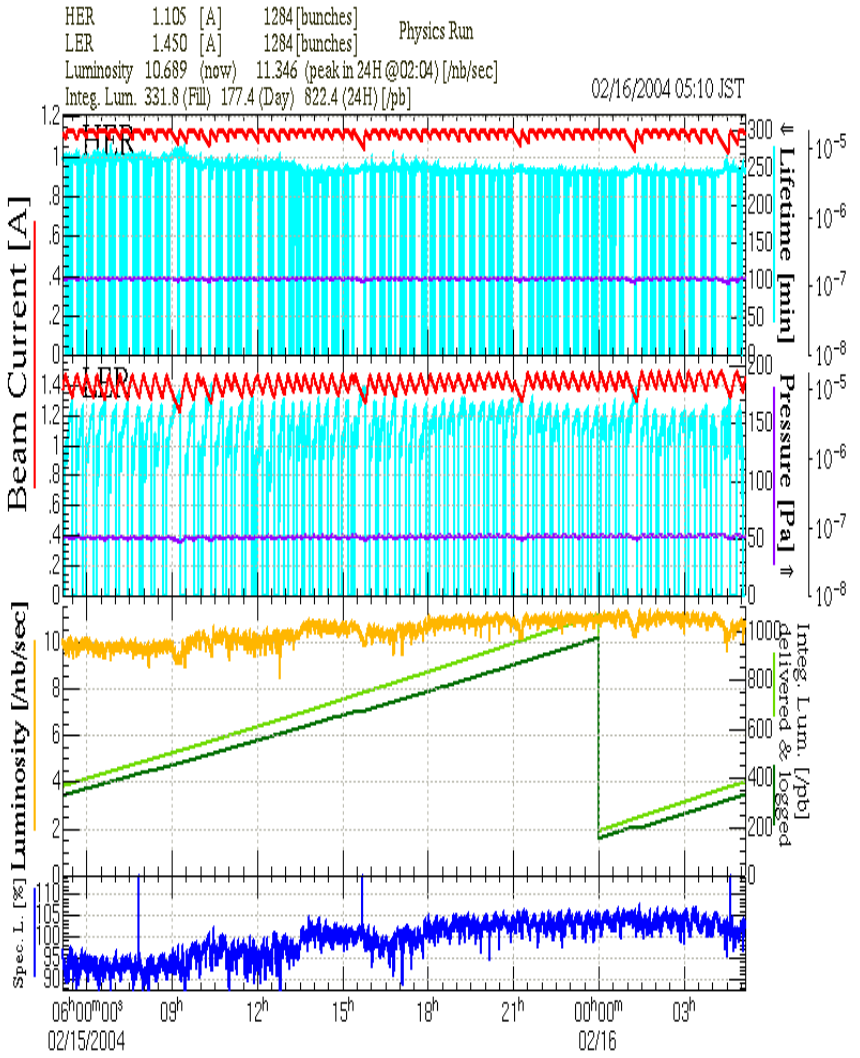
$L = 1.7 \times 10^{34}/cm^2/sec$

Normal injection



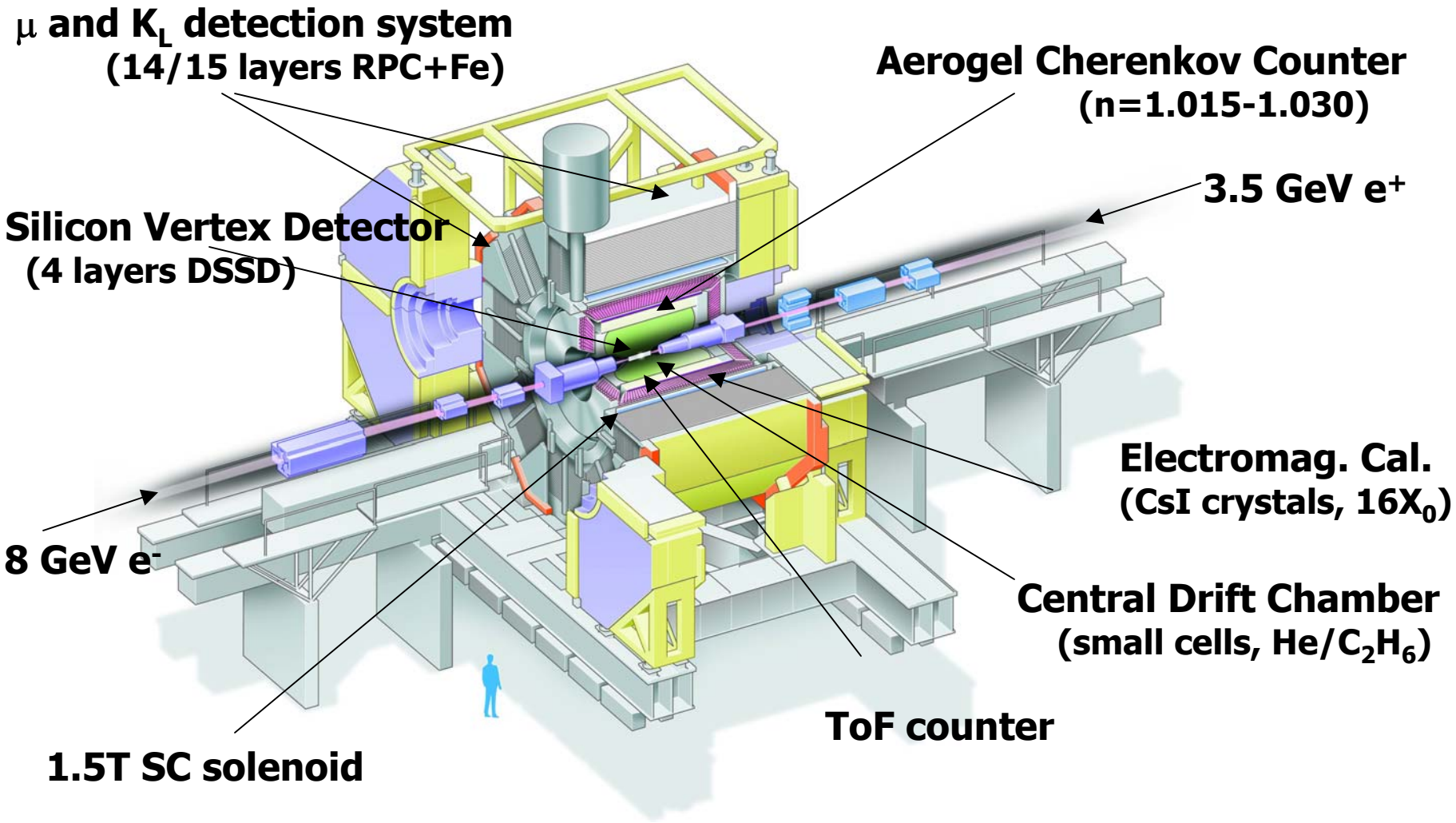
661/pb/day

Continuous injection



→1182/pb/day

Belle spectrometer at KEK-B

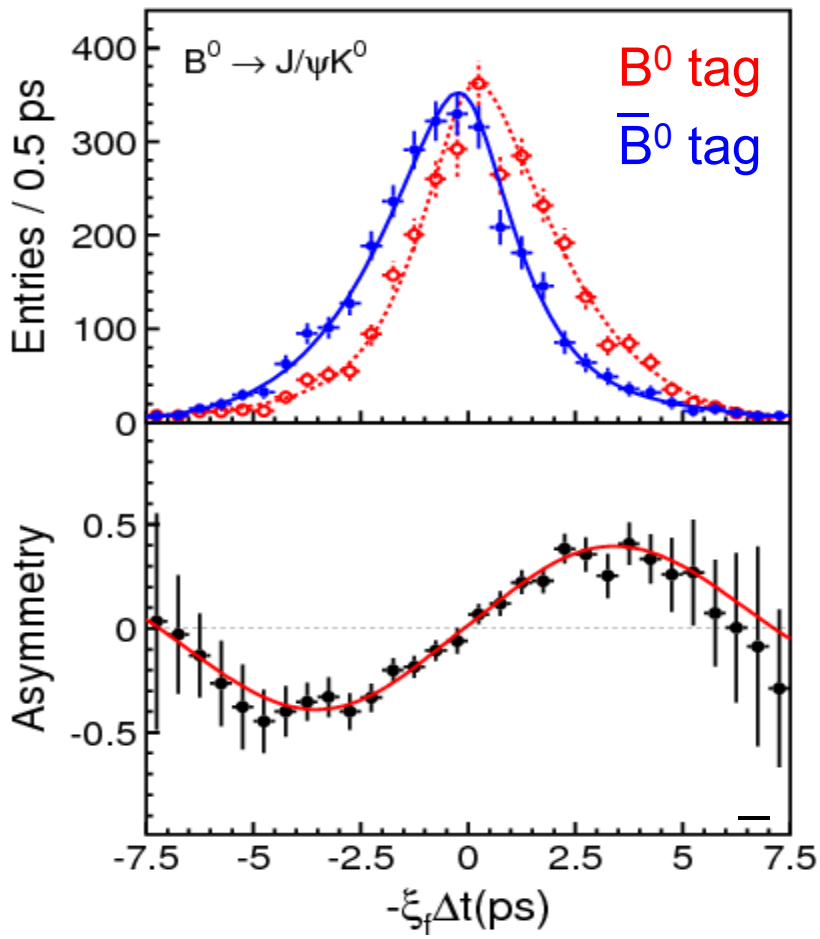


B factories Belle and BaBar: a fantastic physics harvest

CP violation in B system: from the discovery (2001) to a precision measurement (2006)

$\sin 2\phi_1 = \sin 2\beta$ from $b \to ccs$

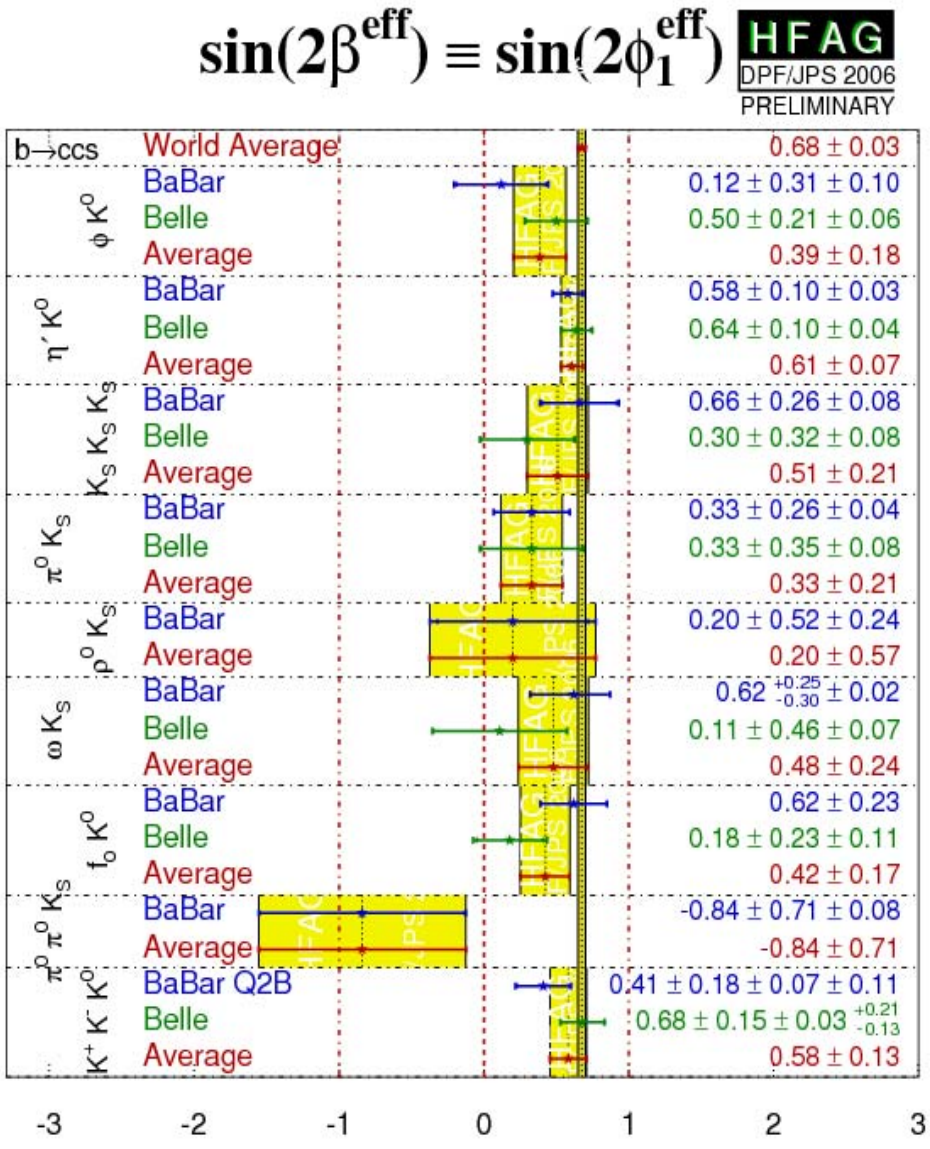
535 M $B\bar{B}$ pairs



$\sin 2\phi_1 = 0.642 \pm 0.031$ (stat) ± 0.017 (syst)

$A = 0.018 \pm 0.021$ (stat) ± 0.014 (syst)

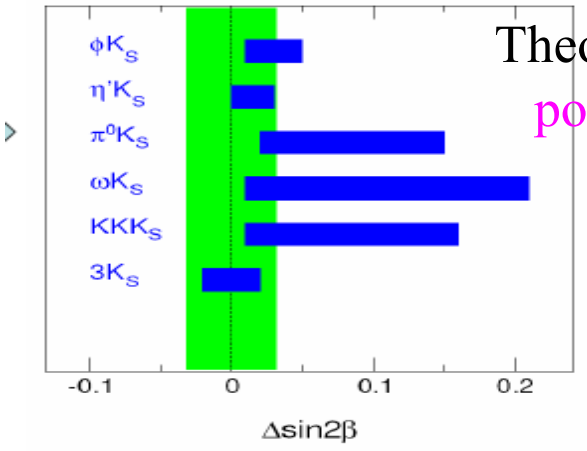
2006: Hints of NP in $b \to s$ Penguins ?



Smaller than b→cc̄s in all of 9 modes

some of recent QCDF estimates

$\sin2\beta^f_{\rm eff} - \sin2\beta$



Theory predicts positive shifts

Naïve average of all b → s modes

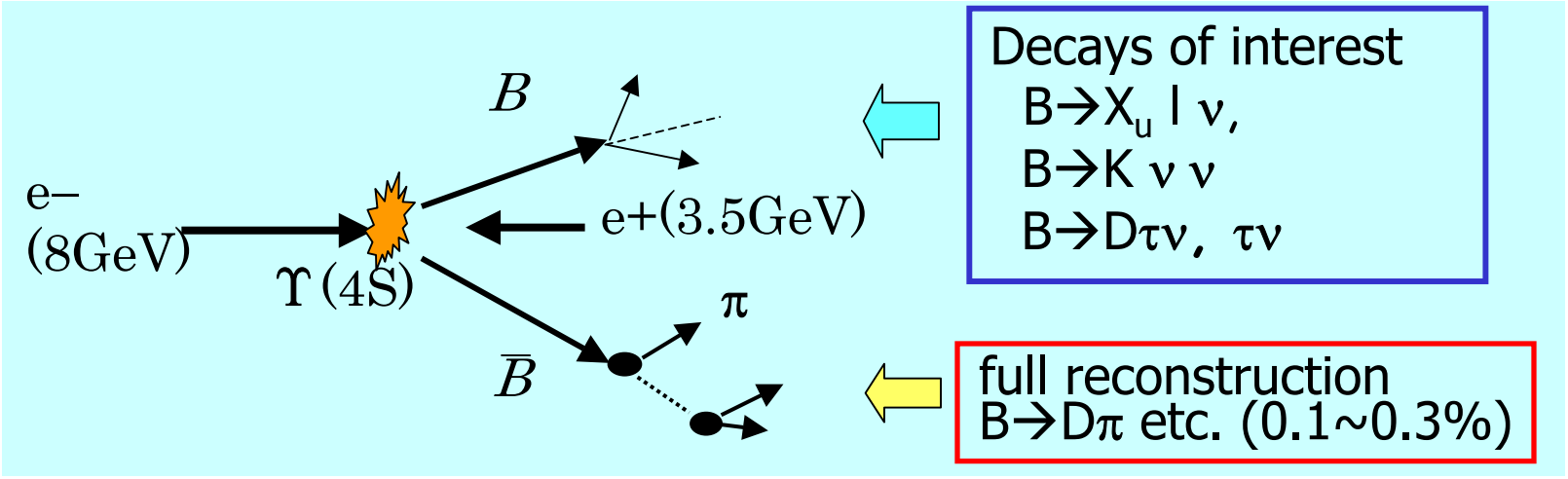
$\sin2\beta^{\rm eff} = 0.52 \pm 0.05$

$2.6\,\sigma$ deviation from SM

B factories Belle and BaBar: new techniques

Fully reconstruct one of the B's to:

- Tag B flavor/charge
- Determine B momentum
- Exclude decay products of one B from further analysis



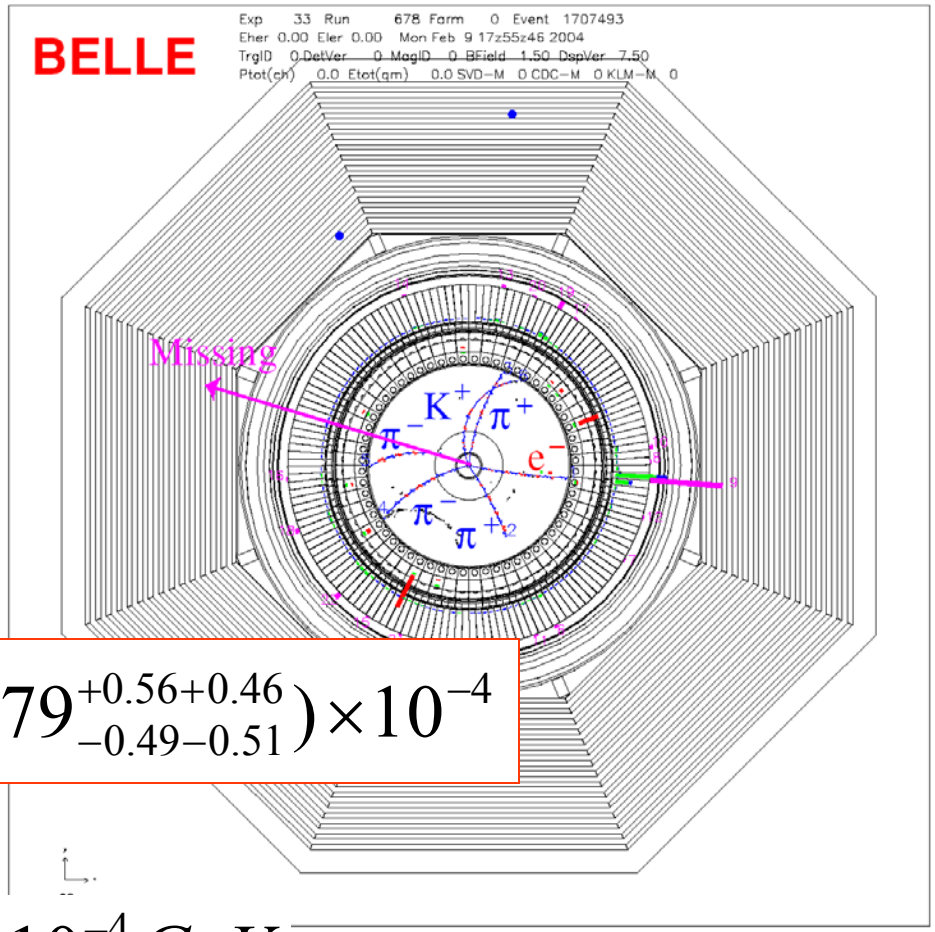
Offline B meson beam!

Powerful tool for B decays with neutrinos

$B^- \to \tau^- \nu_\tau$

Event candidate

$$B^+ \to D^0\pi^+ \quad (\to K\pi^-\pi^+\pi^-)$$
$$B^- \to \tau(\to e\nu\bar{\nu})\nu$$



$$\text{BF}(B^+ \to \tau^+\nu_\tau) = (1.79^{+0.56+0.46}_{-0.49-0.51}) \times 10^{-4}$$

$$f_B \times V_{ub} = \left(10.1^{+1.6+1.3}_{-1.4-1.4}\right) \times 10^{-4}\, GeV$$

$$f_B = 229^{+36+34}_{-31-37}\, MeV$$

Fundamental Questions in Flavor Physics

Are there New Physics Phases and New sources of CP Violation Beyond the SM ?

Experiments: b→s CPV, compare CPV angles from tree and loops

Are there new operators with quarks enhanced by New Physics ?

Experiments: $A_{FB}(B \to K^* l\, l)$, $B \to K\, \pi$ rates and asymmetries

Are there right-handed currents ?

Experiments: b→s γ CPV, B→V V triple-product asymmetries

Are there new flavor changing neutral currents ?

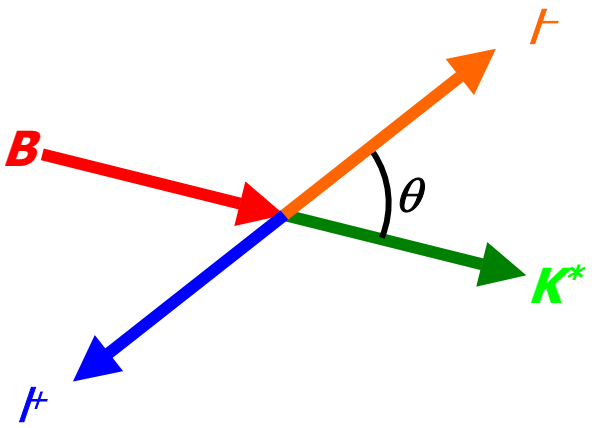
Experiments: b→s $\nu\ \bar{\nu}$, D–$\bar{D}$ mixing+CPV+rare, $\tau \to \mu\, \gamma$

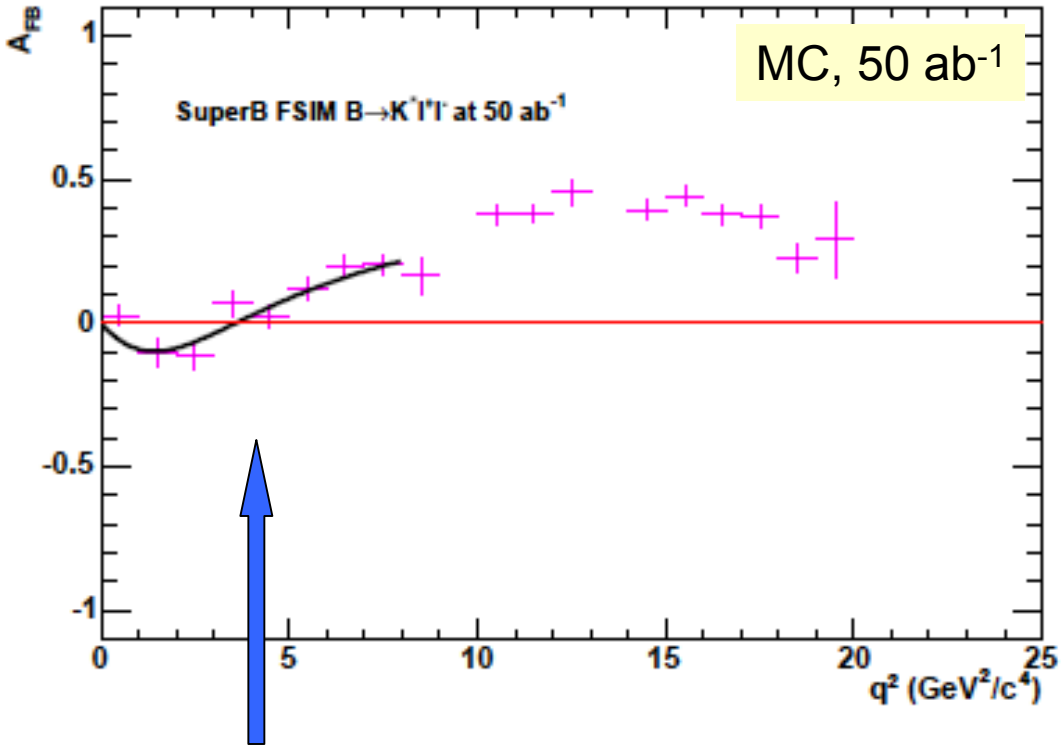
These questions can only be answered at a Super B Factory.

$A_{FB}(B \to K^* l^+ l^-)[q^2]$ at Super B Factory

Sensitivity at Super KEKB

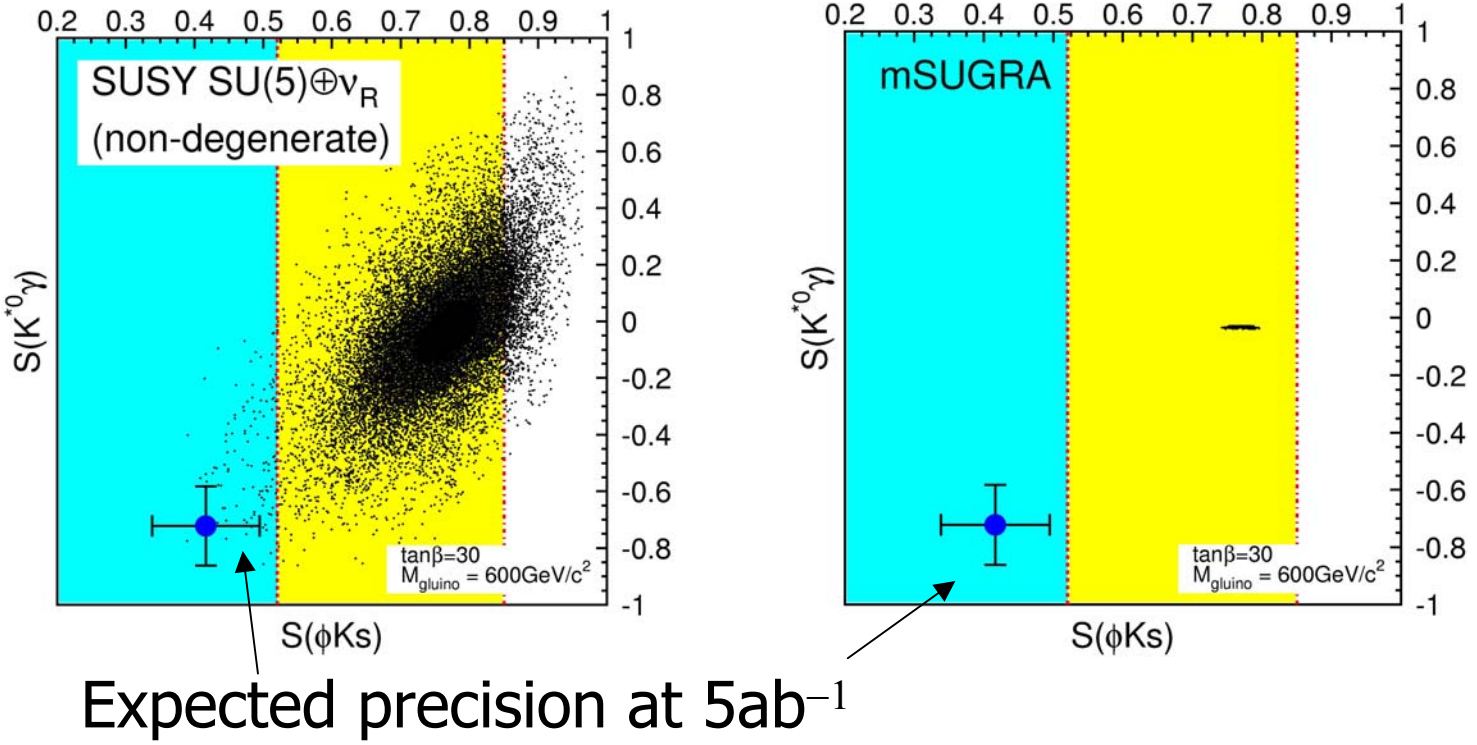
Forward-backward asymmetry





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

CPV in b → s and diagnosis of new physics



Expected precision at 5ab^{-1}

Example: CP asymmetry parameters $S(\phi K_S)$ vs $S(K^{*0}\gamma)$

Many other examples of using correlations to distinguish new physics scenarios have been examined.

T.Goto, Y.Okada, Y.Shimizu,T.Shindou, M.Tanaka (2002, 2004) + SuperKEKB LoI

Super B factory strong points

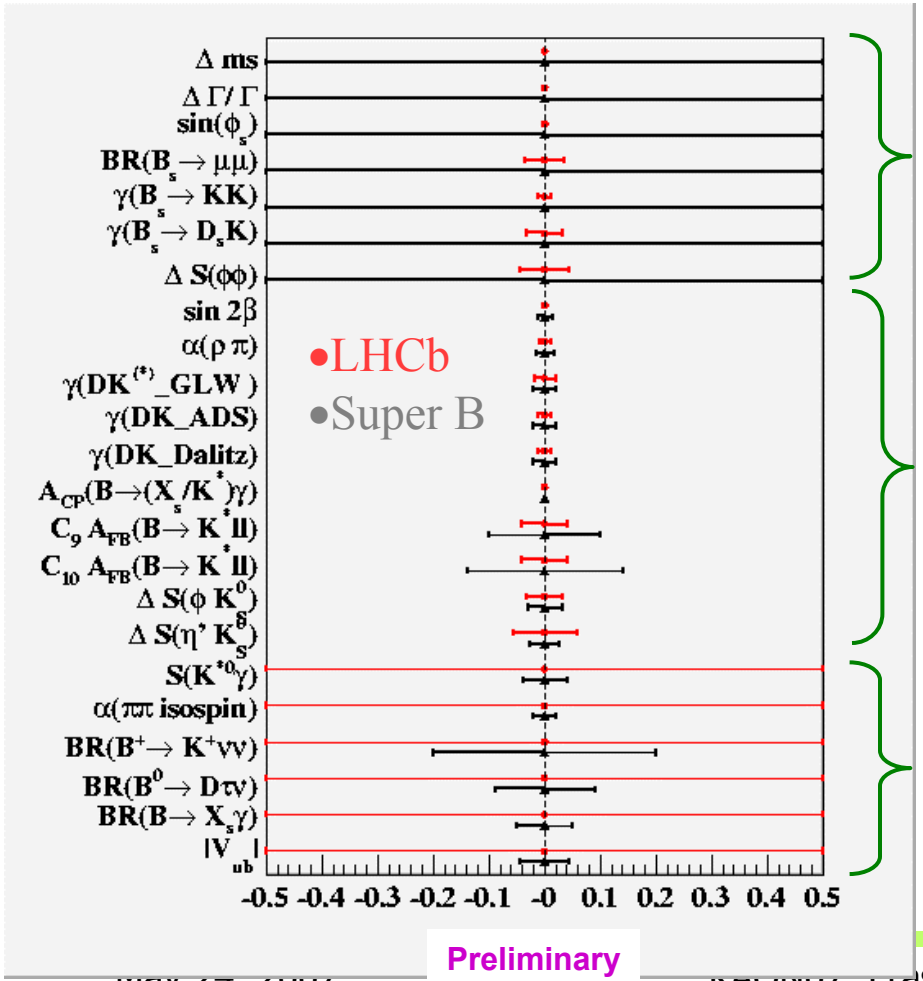
- Clean environment → measurements that no other experiment can perform. Examples: CPV in $B \to \phi K^0$, $B \to \eta' K^0$ for new phases, $B \to K_S \pi^0 \gamma$ for right-handed currents.
- "*B*-meson beam" technique → access to new decay modes. Example: discover $B \to K \nu\bar{\nu}$.
- Measure new types of asymmetries Example: forward-backward asymmetry in $b \to s\mu\mu$, *see*
- Rich, broad physics program including *B*, τ and charm physics. Examples: searches for $\tau \to \mu\gamma$ and *D*-$\bar{D}$ mixing with unprecedented sensitivity.

Super B factory and LHCb: complementary

S. Stone

Sensitivity Comparison ~2020

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



B_s

Common

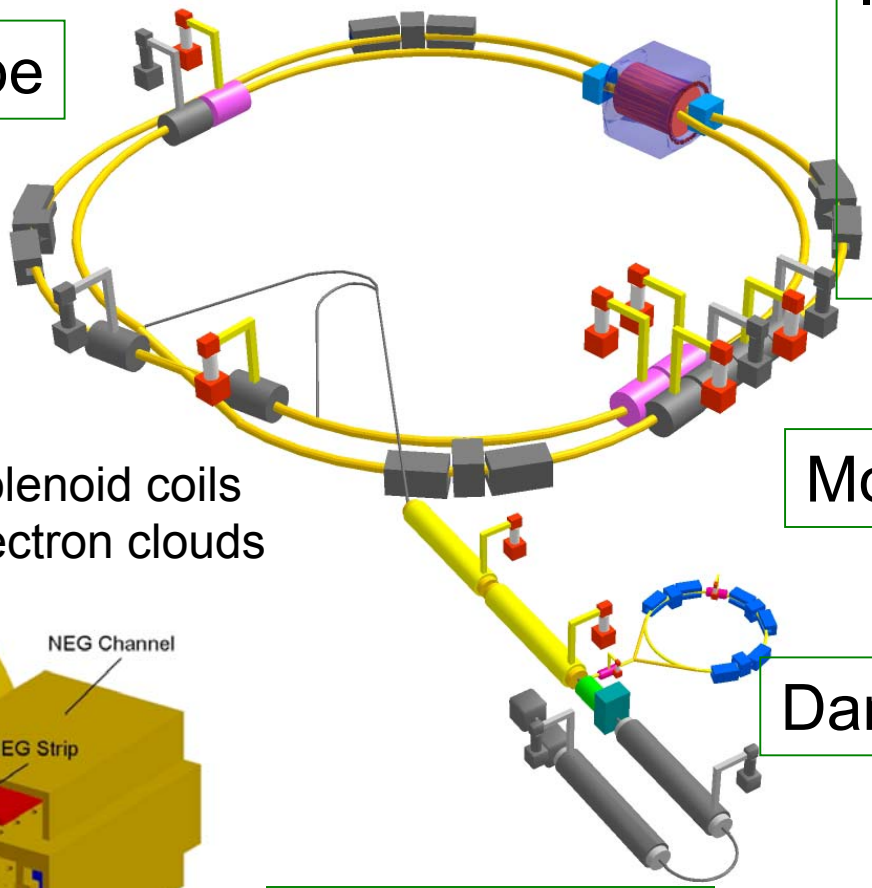
No IP
Neutrals, ν

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

Super B Factory at KEK

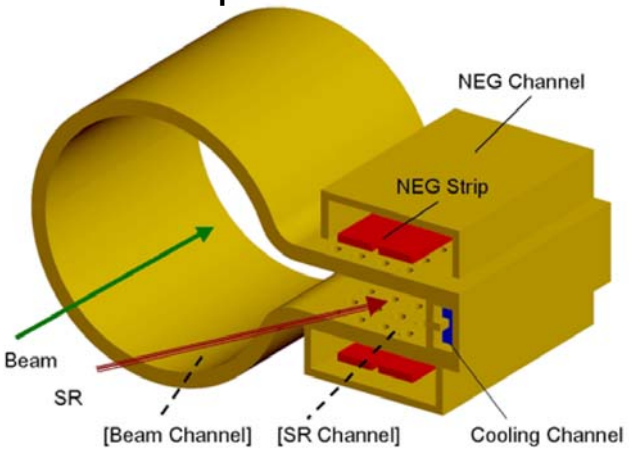
New Beam pipe

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



More RF power

Ante-chamber & solenoid coils
to reduce photo-electron clouds



Damping ring

Linac upgrade

$L = 8\times10^{35}/cm^2/s$

Upgraded Components for SuperKEKB

Movable mask

New QCS
(Final focus system)
Crossing angle
22 mrad (KEKB)
→ 30 mrad (SuperKEKB)

SuperBelle

New IR

Crab cavities

8 GeV
4.1 A

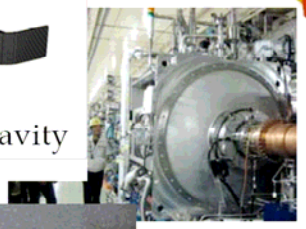
New beam pipe
& bellows

Ante-chambers,
comb-type bellows, HOM absorbers

3.5 GeV
9.4 A

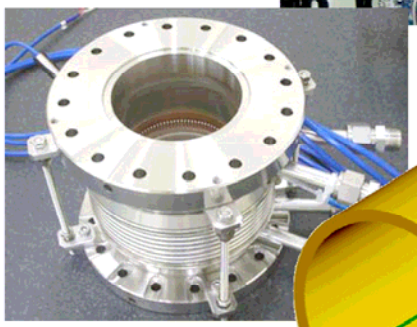
More RF sources

More RF cavities



Energy exchange
C-band

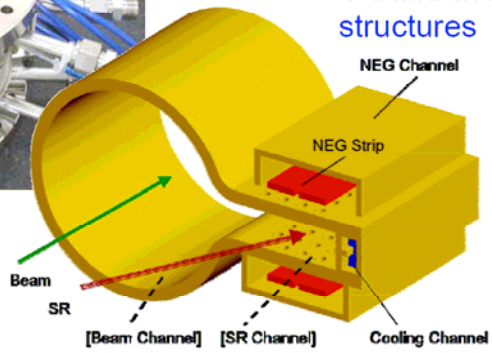
C-band accelerating
structures



Damping ring

Flux concentrator+L-band

Positron source



Electric power consumption
45 MW (KEKB)
→ 83 MW (SuperKEKB)

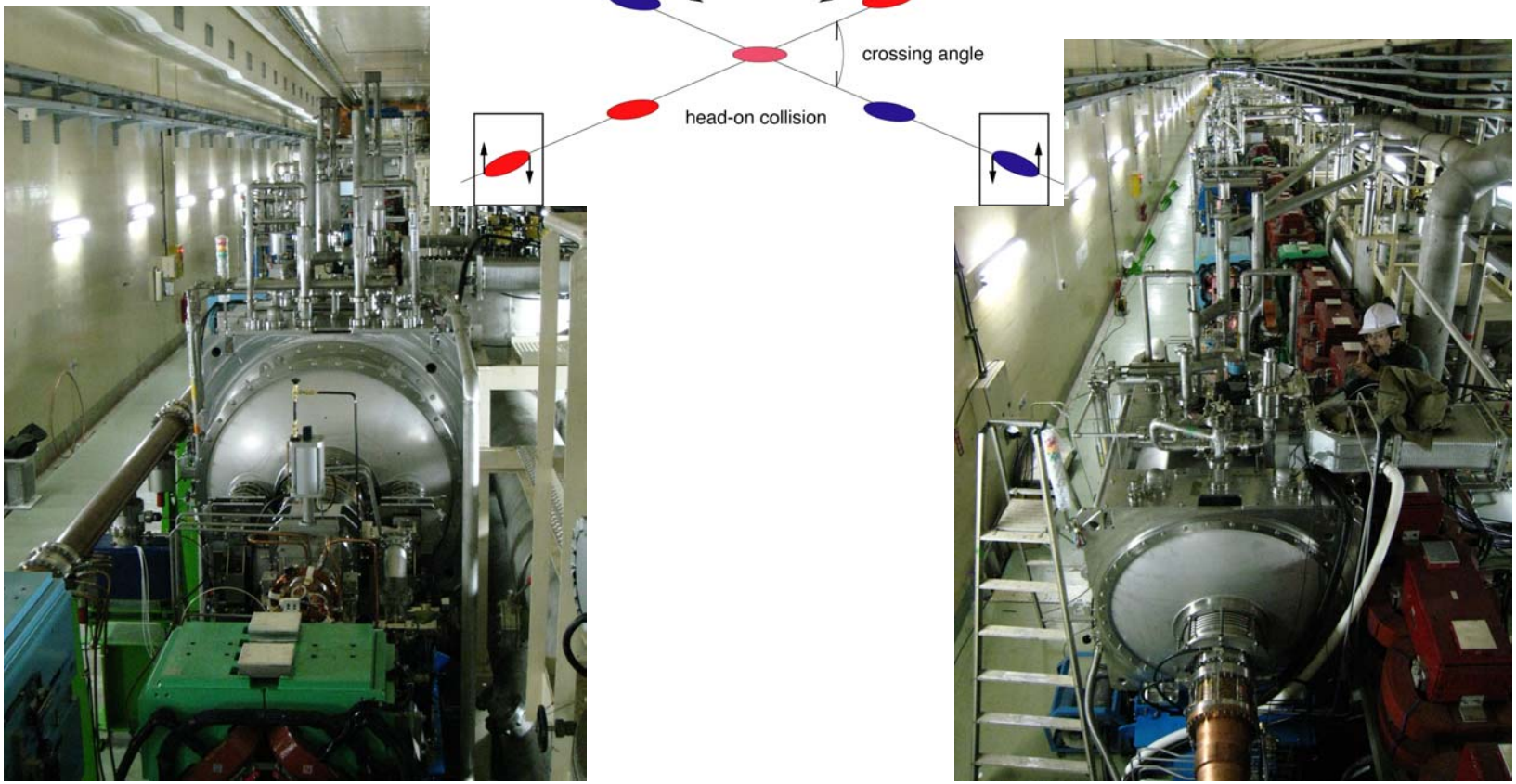
SuperKEKB strategy

- Target luminosity is 8×10^{35} $cm^{-2}s^{-1}$.
- Use components of KEKB as much as possible: magnets, klystrons, tunnel, existing facilities, ...
- Continuous injection and a powerful injection system is necessary: considerable experience with the continuous injection, operated successfully at KEKB.
- Ultra-High beam current: 9.1 A(LER) and 4.1 A(HER).
- Low beta function at IP to improve luminosity

– Interaction region(IR) should be designed to satisfy requirements of low beta at IP, physical and dynamic aperture, SR, detector backgrounds, etc.

- Finite crossing and crab crossing scheme is needed for a ultra-high beam-beam parameter.

Crab Cavities have been installed in the KEKB tunnel (1 cavity per ring)



LER (3.5 GeV, positron)

HER (8 GeV, electron)

Summary of current KEKB Status

- The crab cavities were successfully assembled and have been operated at KEKB with beam. No serious problem has been found so far, at least at low current.
- The first crab crossing was done at KEKB.

(~30 years after the idea was first proposed by Bob Palmer)

Head-on collision with a crossing angle was achieved. Highest beam-beam tune shift 0.08 (before 0.052).

Large gains in physics luminosity will require more time for tuning and development of method to optimize the machine since a higher beam-beam parameter is very sensitive to machine errors.

SuperKEKB R+D status

A technically feasible design of SuperKEKB has been made with 8×10^{35} $cm^{-2}s^{-1}$ luminosity.

SuperKEKB R&D is in the engineering phase for the ultra-high current scheme.

- Realistic lattice design, dynamic aperture is OK.
- Crab cavity, ante-chamber, new bellows, C-band structures, upgraded ARES, development of powerful BxB feedback system, new QCS, ...
- These items have already been or will be tested at KEKB.
- More in "Letter of Intent for KEK Super B Factory", June 2004. (numbers should be updated.)

Having such a baseline design, KEKB group is working on the design with lower beam current + lower emittance under close communication with the SLAC/Frascati SuperB team.

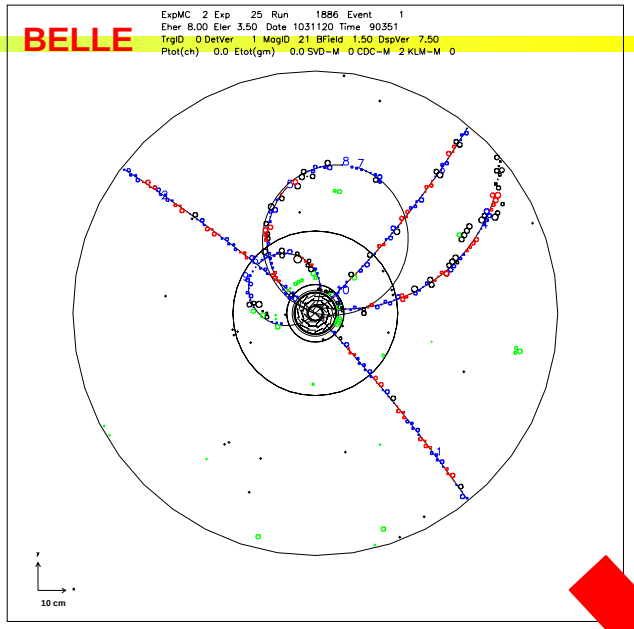
Requirements for the Super B detector

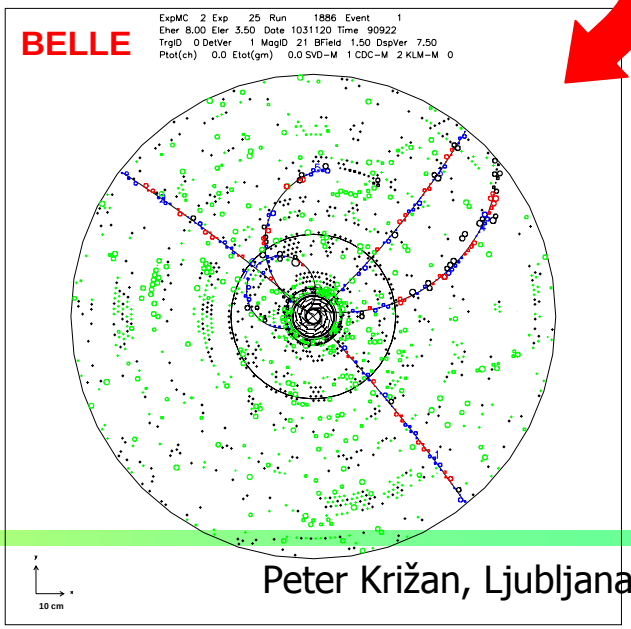
Critical issues at L= 4 x 10^{35}/cm^2/sec

- **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"

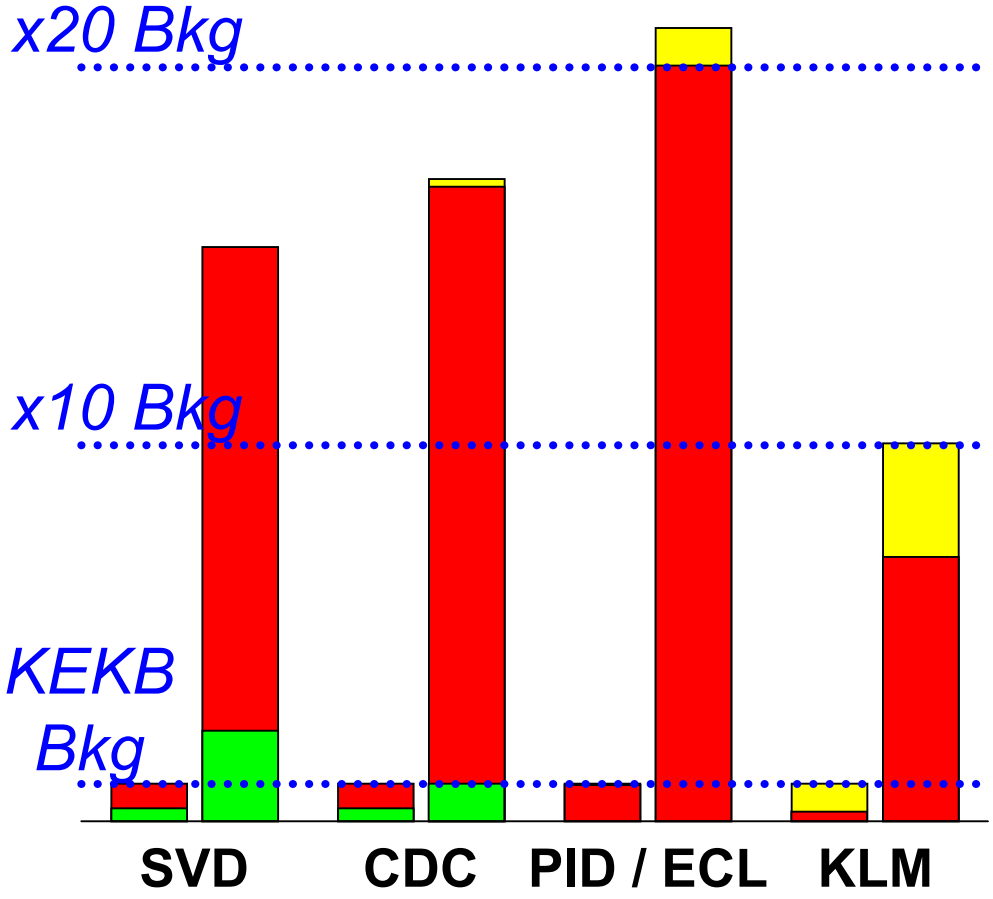
Possible solution:

- 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.





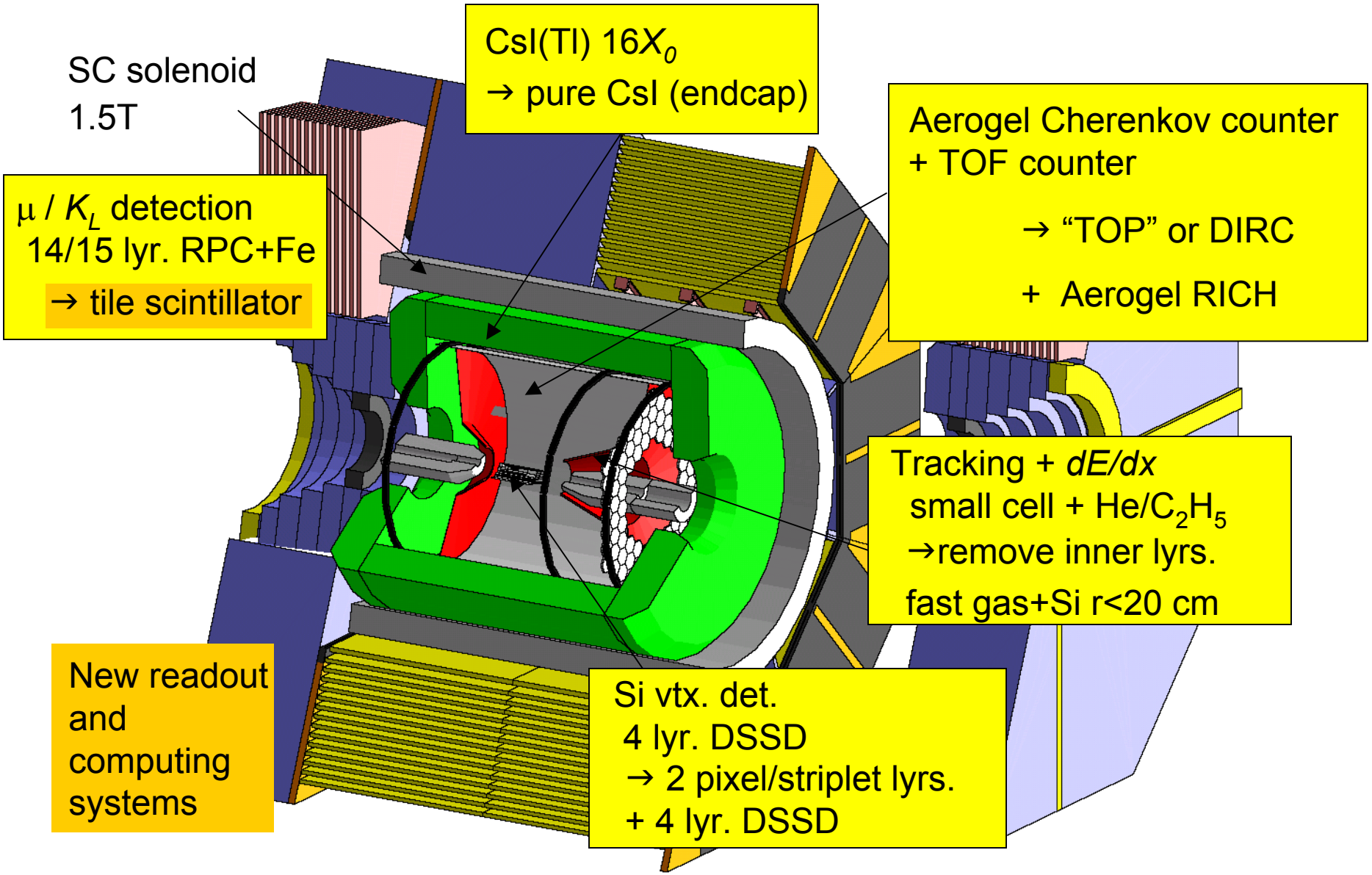
Detector issue: backgrounds



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

	KEKB	SuperB
Luminosity ($10^{34}cm^{-2}sec^{-1}$)	1.7	80
HER curr. (A)	1.2	4.1
LER curr. (A)	1.6	9.4
vacuum ($10^{-7}Pa$)	~1.5	5
Bkg increase	-	~ 20
TRG rate (kHz)	0.4	
phys. origin	0.2	
Bkg origin	0.2	

Belle Upgrade for Super-B



http://www.jahep.org/hec/doc/jahep_tenbou_eng_final.pdf

Prospects for Elementary Particle Physics

The Japan Association of High Energy Physicists (JAHEP)

October 25, 2006

(An excerpt)

We, the Japanese HEP community, recognize that physics at the energy frontier is of primary importance. With this understanding, we give the highest priority to the realization of the ILC. Before the ILC experiment commences, we will also promote flavor physics that is complementary to physics at the energy frontier. We should pursue the above two goals as a single master plan.

....

Based on these achievements, we will endeavor to make neutrino and kaon experiments at J-PARC successful, and promote an upgrade of the B factory to achieve a significant breakthrough in luminosity in order to explore new physics that emerges in the phenomena of b, c and τ decays.

Recommendation by Belle-PAC

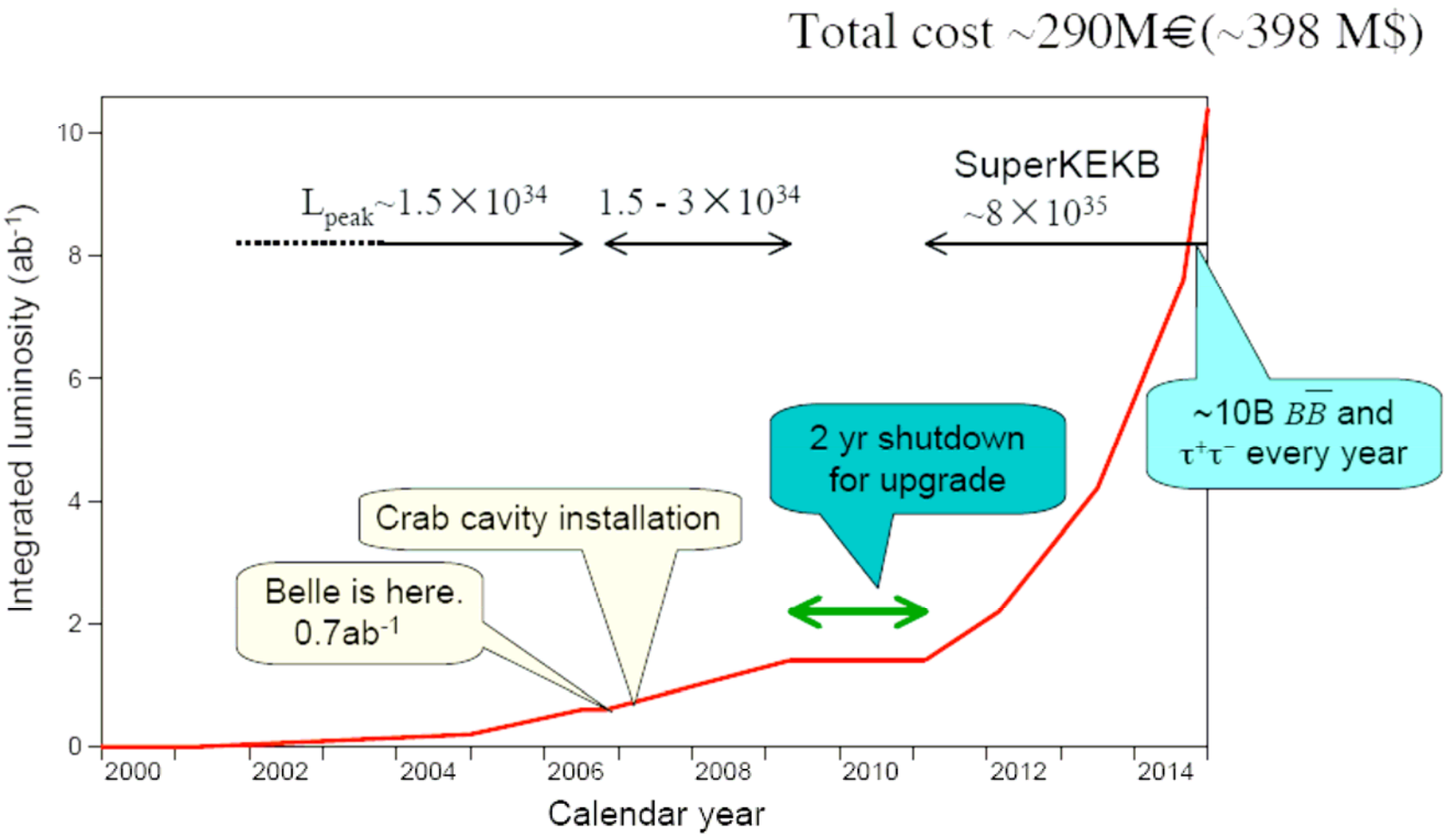
- The committee provided a strong endorsement for SuperKEKB at the meeting in April 2007.

In summary, the committee reached the following conclusions:

1) We endorse strongly the realization of a very high luminosity e^+e^- B meson factory for its potential to investigate physics beyond the Standard Model and improve our understanding of electroweak and strong dynamics.
2) We think that a timely realisation of such a facility is important so that several tens of ab^{-1} of $\Upsilon(4S)$ data can be collected by the middle of the next decade.
3) We think that KEK is an ideal laboratory to realise such a project by upgrading the existing KEK-B accelerator. It has a proven record in producing high performance e^+e^- machines and a successful and highly motivated experimental group, which could act as a catalyst for the new collaboration. Having the kaon and neutrino programme at JPARC, KEK would become a unique place in the world to explore flavour physics that is a complementary and, in some areas, more sensitive approach to investigate physics beyond the Standard Model than the experiments at the high energy frontier.

- This is also an important support from the int'l community.

Proposed schedule for SuperKEKB



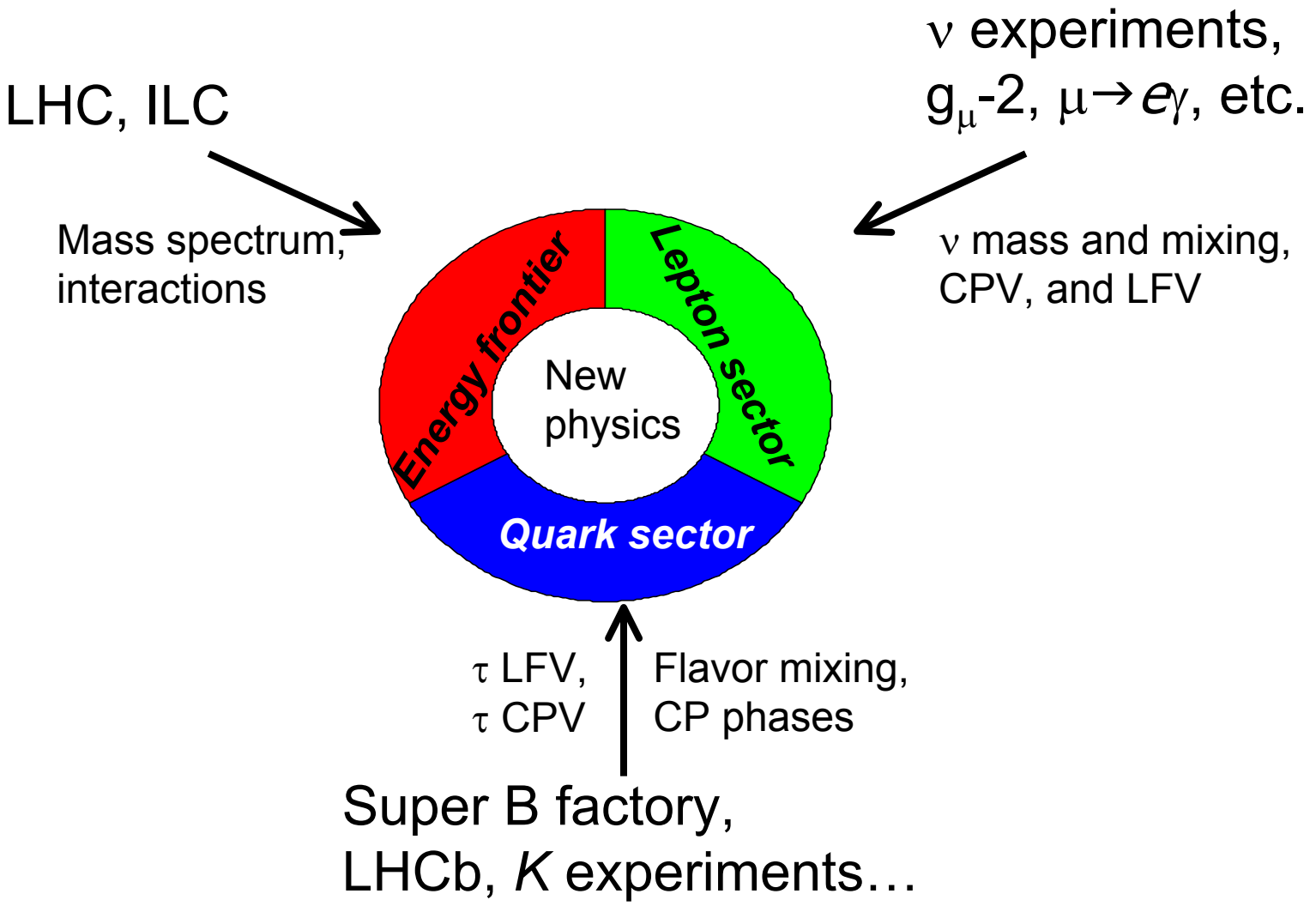
Y. Ohnishi, FPCP07, Bled, May 16, 2007

Summary

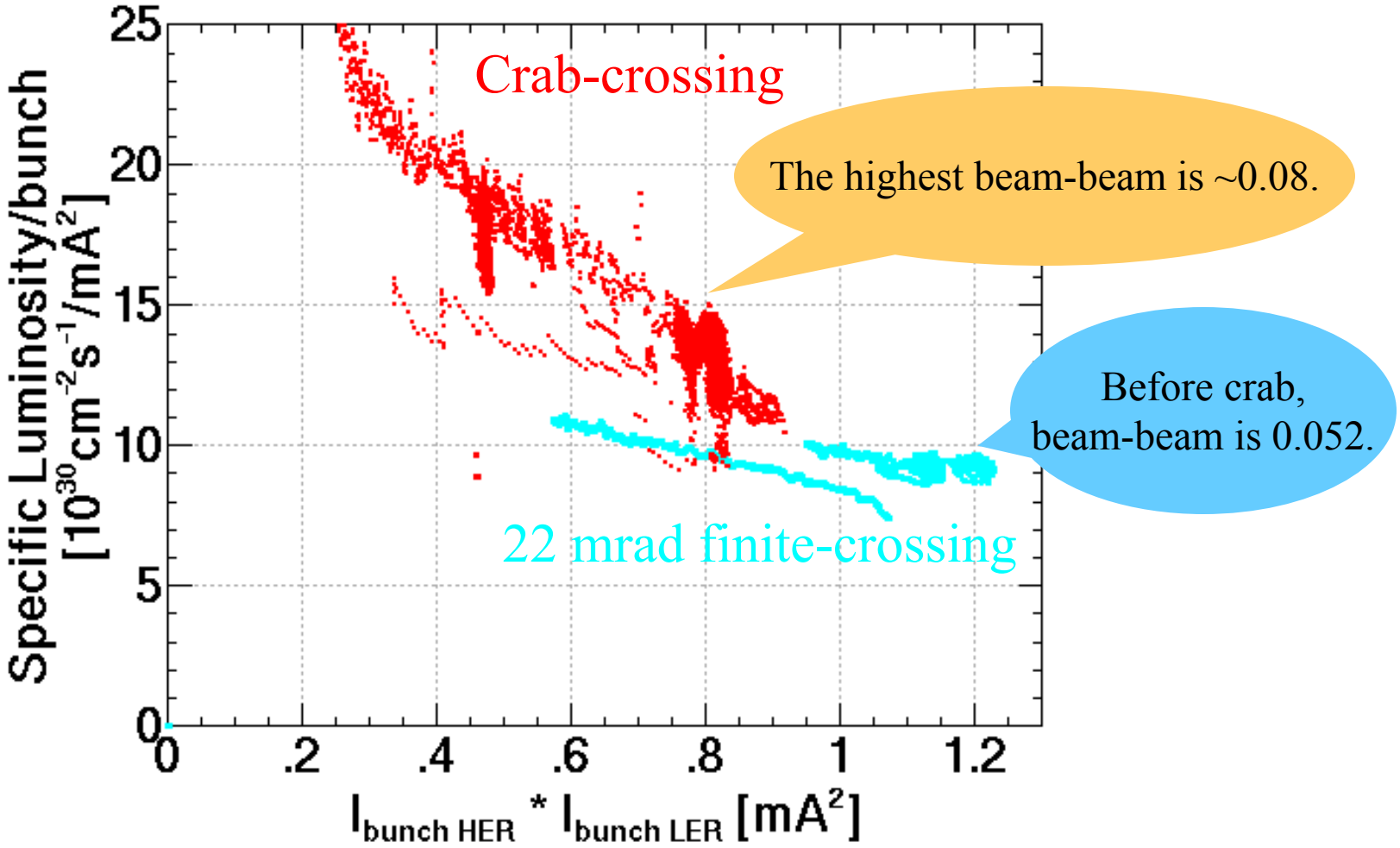
- B factories have proven to be an excellent tool for flavour physics
- Reliable long term operation, constant improvement of the performance.
- Short term plan at KEK: increase luminosity x2 by a crab cavity
- Major upgrade in 2009-10 -> Super B factory, L x50
- Essentially a new project, all components have to be replaced, plans exist (LoI), nothing is frozen... ←→ close collaboration to the SuperB project
- Expect a new, exciting era of discoveries, complementary to LHC
- Do not miss the chance to be part of it...

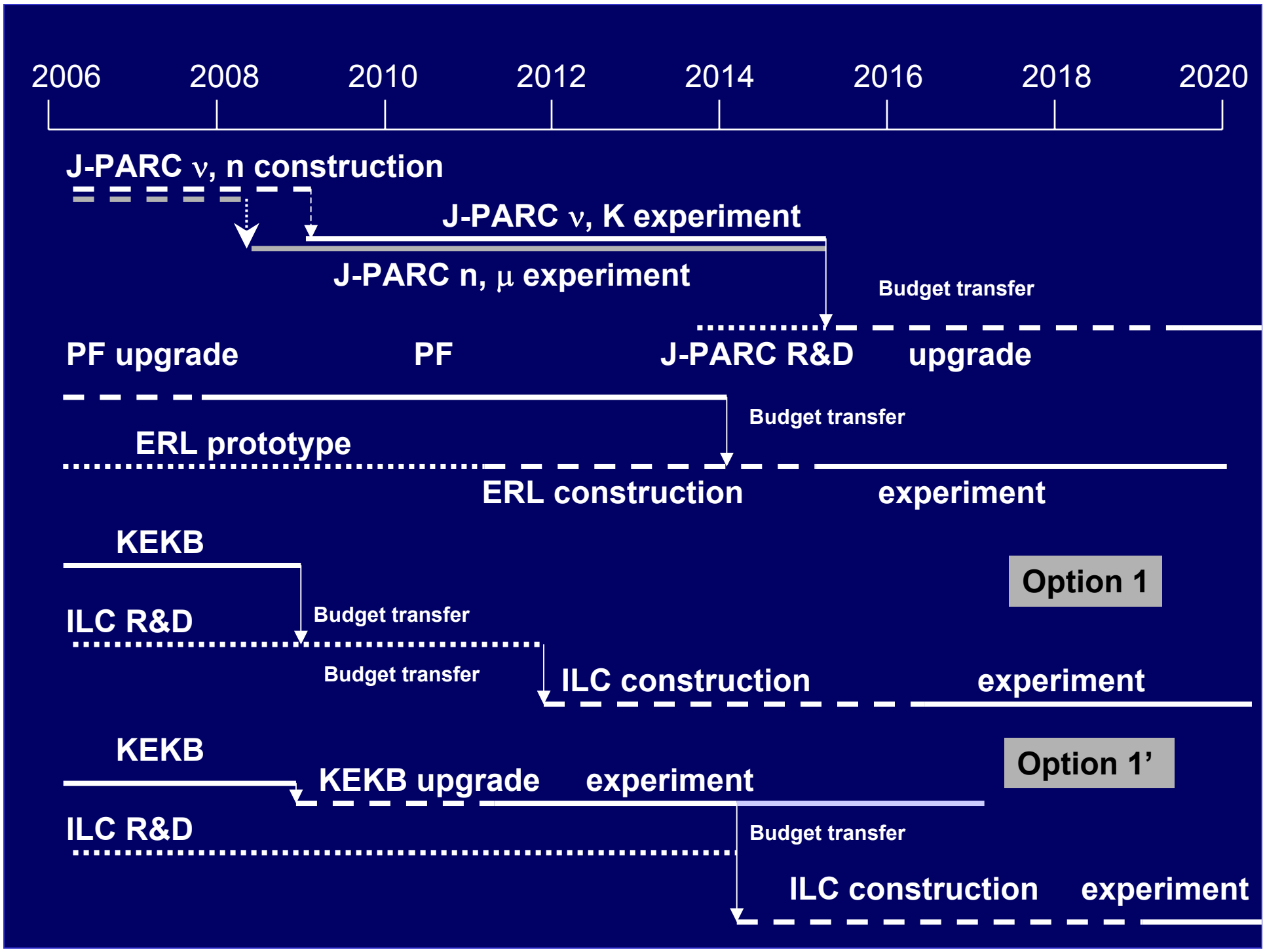
Additional slides

A Broad Unbiased Approach to New Physics



Specific Luminosity at KEKB




2006
2008
2010
2012
2014
2016
2018
2020
J-PARC ν, n construction
J-PARC ν, K experiment
J-PARC n, μ experiment
Budget transfer
PF upgrade
PF
J-PARC R&D
upgrade
Budget transfer
ERL prototype
ERL construction
experiment
KEKB
Option 1
ILC R&D
Budget transfer
Budget transfer
ILC construction
experiment
KEKB
Option 1'
KEKB upgrade
experiment
ILC R&D
Budget transfer
ILC construction
experiment

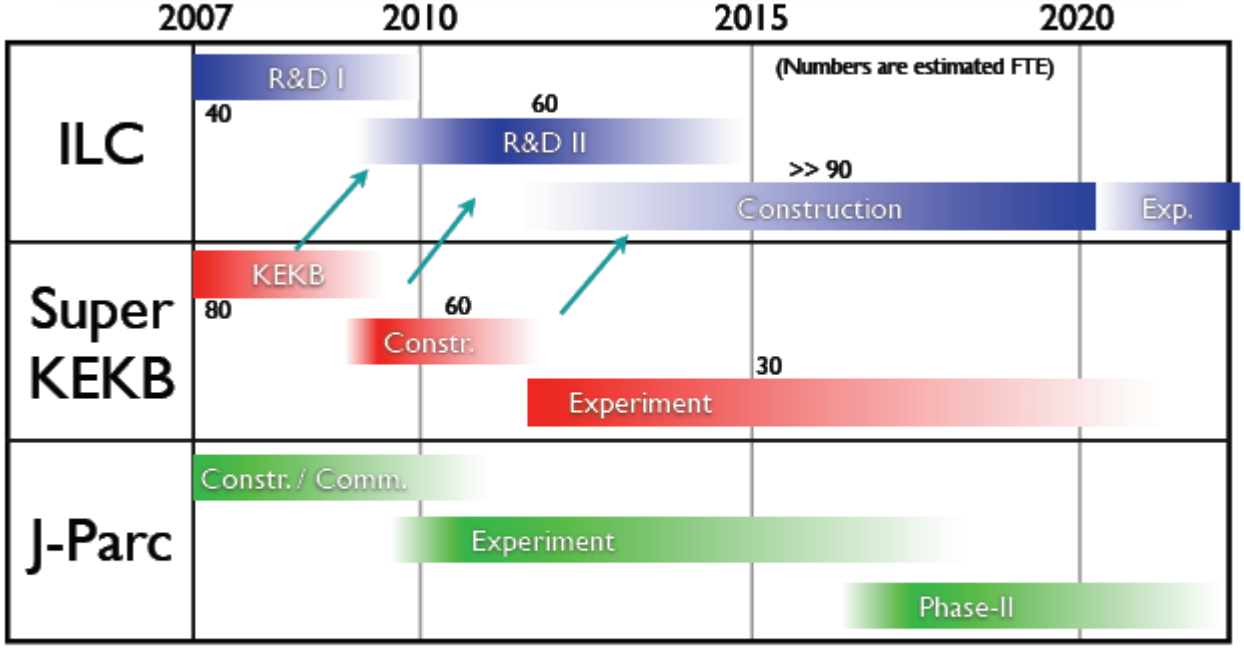
K. Oide (Leading Japanese Accelerator Physicist)

「大レプトン計画」

Grand Lepton Collider Project

"Dai-repoton keikaku"

We will do everything: ILC, SuperKEKB, J-Parc.



- All members of KEK-ACCL will have both duties for ILC and SuperKEKB.
- The weight between SuperKEKB and ILC is subject to change, depending on the readiness of ILC.
- The individual role and weight in the two projects should be flexibly managed by considering time, speciality, and occasion.

Budget of Japanese accelerator physicists

Official Announcement from KEK director A. Suzuki on Super B expected in 2007

Milestones toward approval