


Univerza v Ljubljani

# Super B factory at KEK

Peter Križan

*University of Ljubljana and J. Stefan Institute*

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- Physics case for the Super B factories
- KEKB accelerator upgrade
- Belle detector upgrade
- Summary

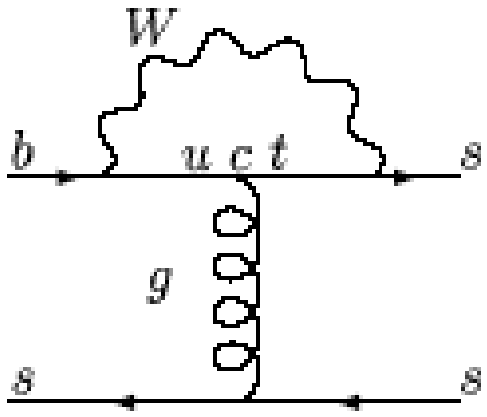
# B factories: a success story

- Observation of CP violation in $B^0$ decays
- Measurements of CKM matrix elements and angles of the unitarity triangle
- Measurements of rare decay modes (e.g., $B \to \tau\nu$, $D\tau\nu$) by fully reconstructing the other B meson
- Observation of D mixing
- CP violation in $b \to s$ transitions remains bellow SM expectation, but statistically limited.
- Forward-backward asymmetry ($A_{FB}$) in $b \to s l^+ l^-$ has become a powerfull tool to search for physics beyond SM.

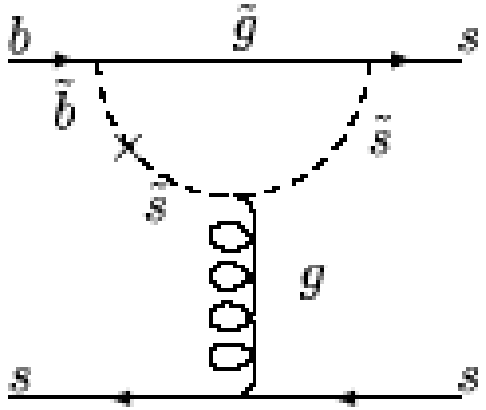
# A possible hint for NP: $b \to s\bar{q}q$

In general, physics beyond SM 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.



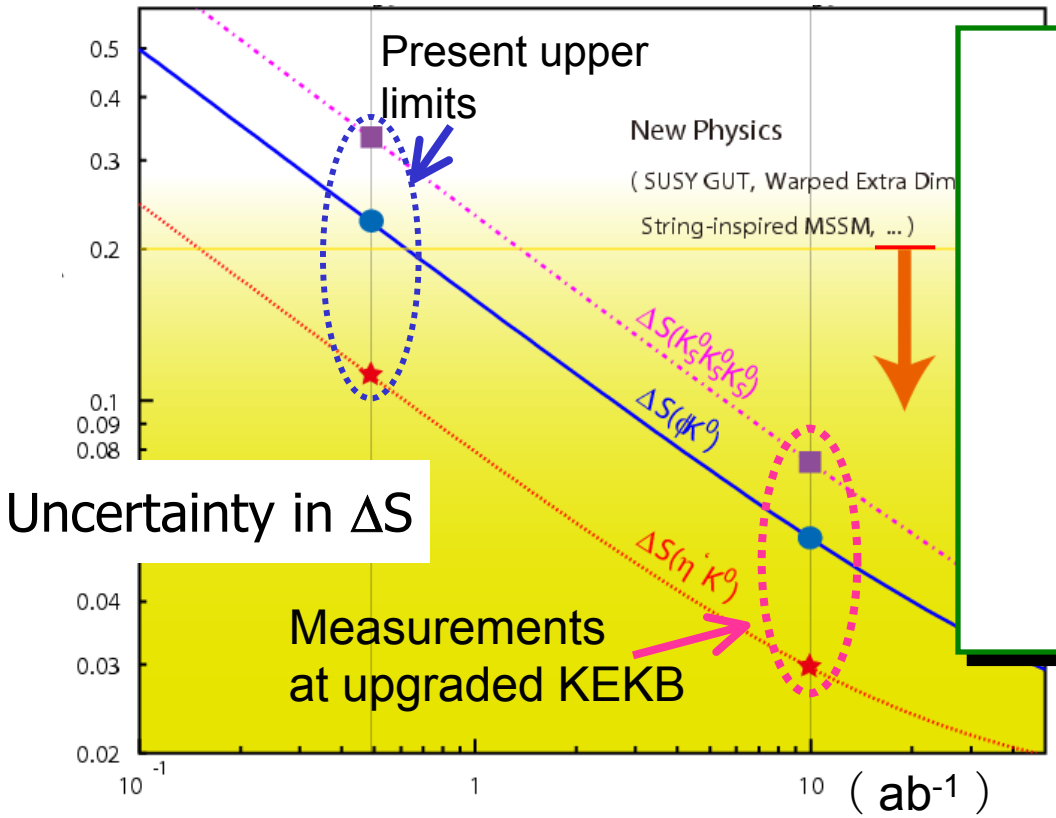

SM



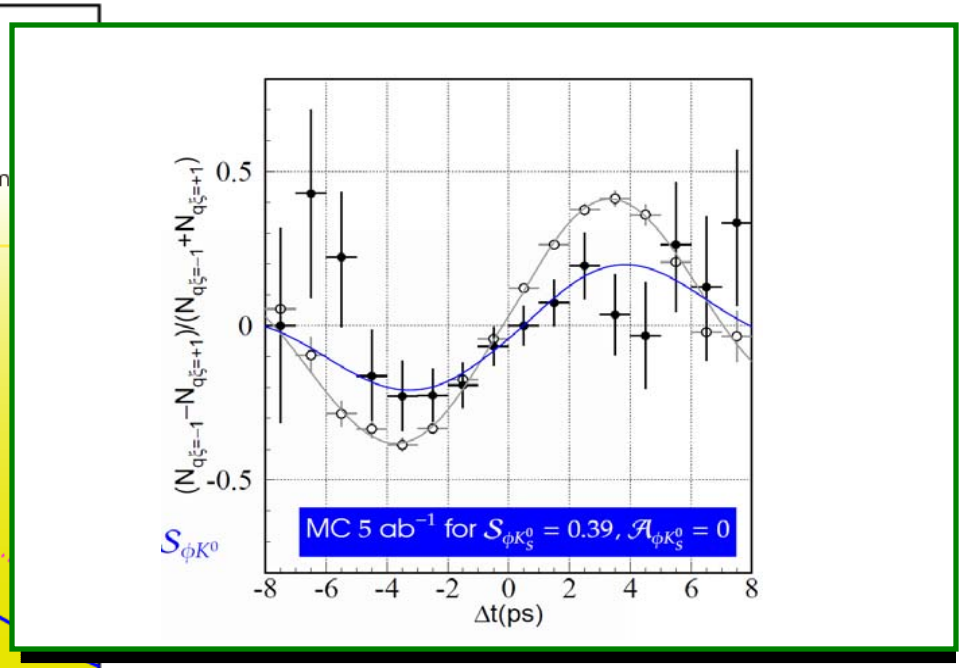

SUSY contribution

# Searches for new sources of quark mixing and CP violation

## CP asymmetries of penguin dominated B decays




Uncertainty in $\Delta S$

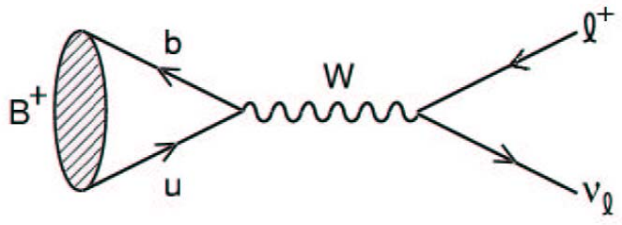



**Reach of present B factories**

**Reach of upgraded KEKB**

# Purely leptonic decay B→τ ν

- Challenge: B decay with at least two neutrinos
- Proceed via W annihilation in the SM.



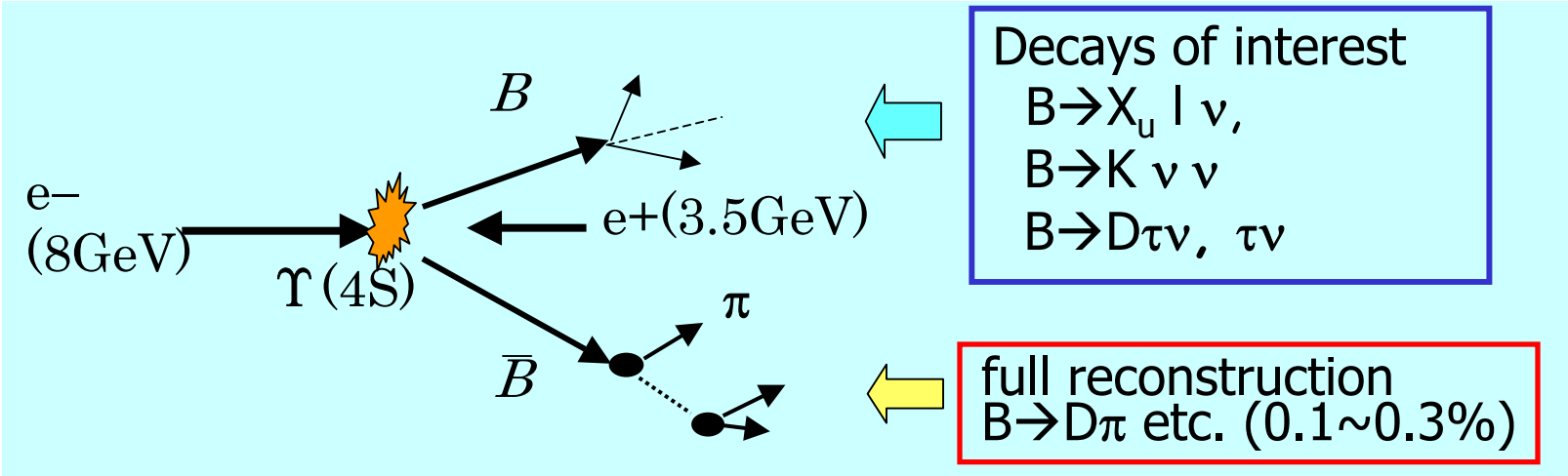

- Branching fraction

$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

- Provide information of $f_B|V_{ub}|$
  - $|V_{ub}|$ from $B \to X_u\, l\, \nu$ ➡ $f_B$ ⟺ cf) Lattice
  - $Br(B \to \tau\nu)/\Delta m_d$ ➡ $|V_{ub}| / |V_{td}|$
- Limits on charged Higgs

# Full Reconstruction Method

- Fully reconstruct one of the B's to
  - Tag B  flavor/charge
  - Determine B momentum
  - Exclude decay products of one B from further analysis

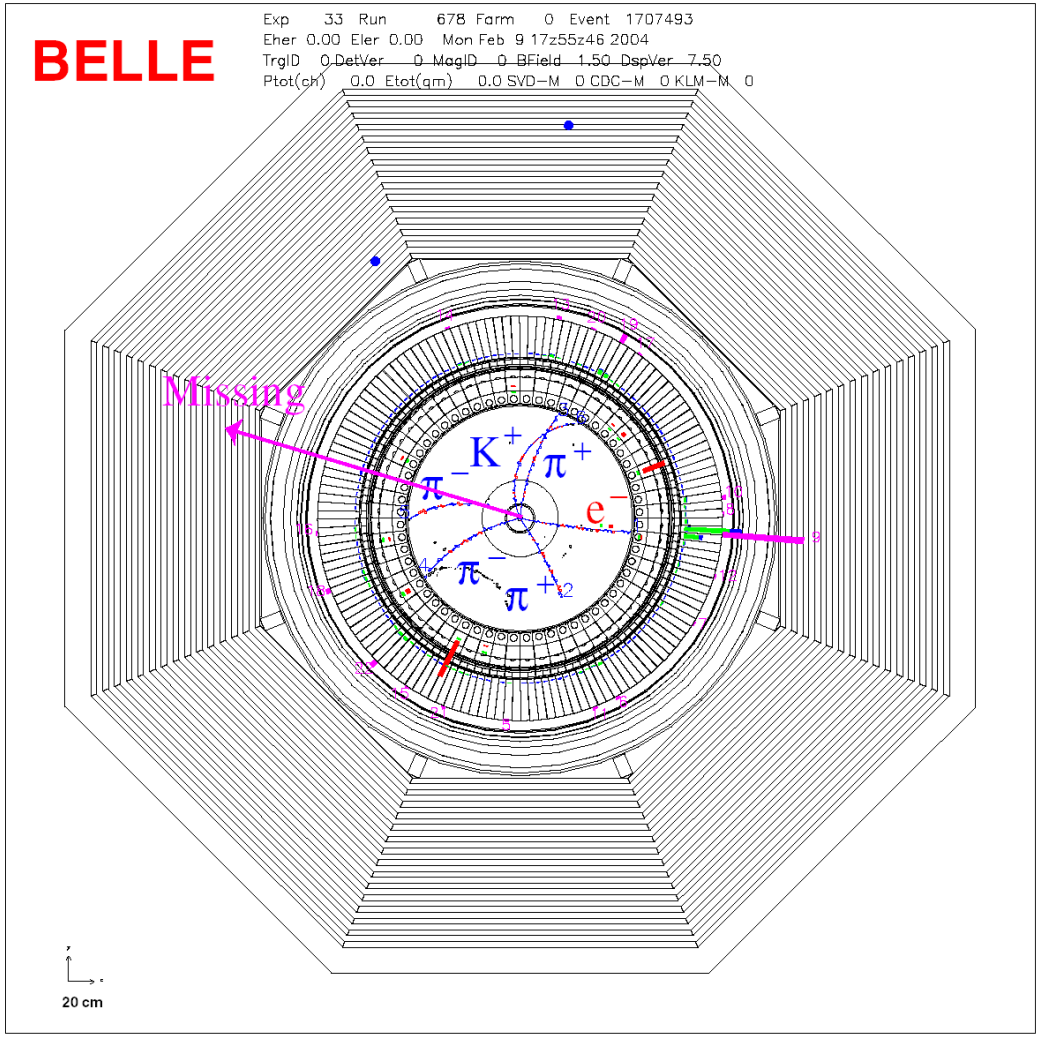



Offline B meson beam!

Powerful tool for B decays with neutrinos

# Event candidate $B^- \rightarrow \tau^- \nu_\tau$

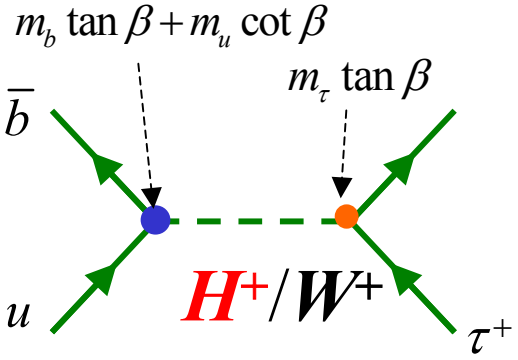
$$B^+ \rightarrow D^0 \pi^+$$
$$(\rightarrow K\pi^-\pi^+\pi^-)$$
$$B^- \rightarrow \tau(\rightarrow e\nu\bar{\nu})\nu$$

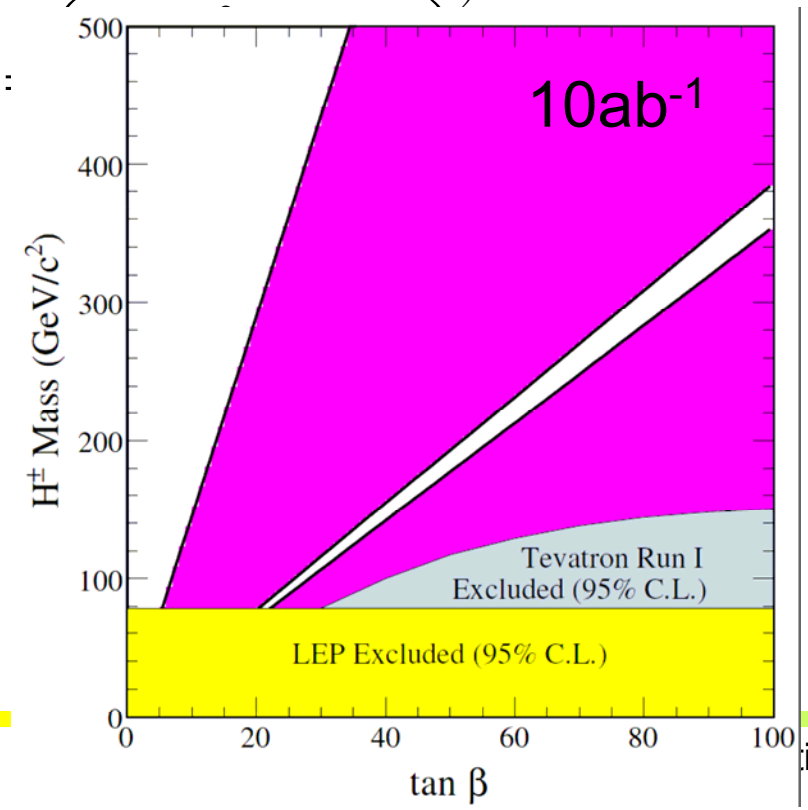


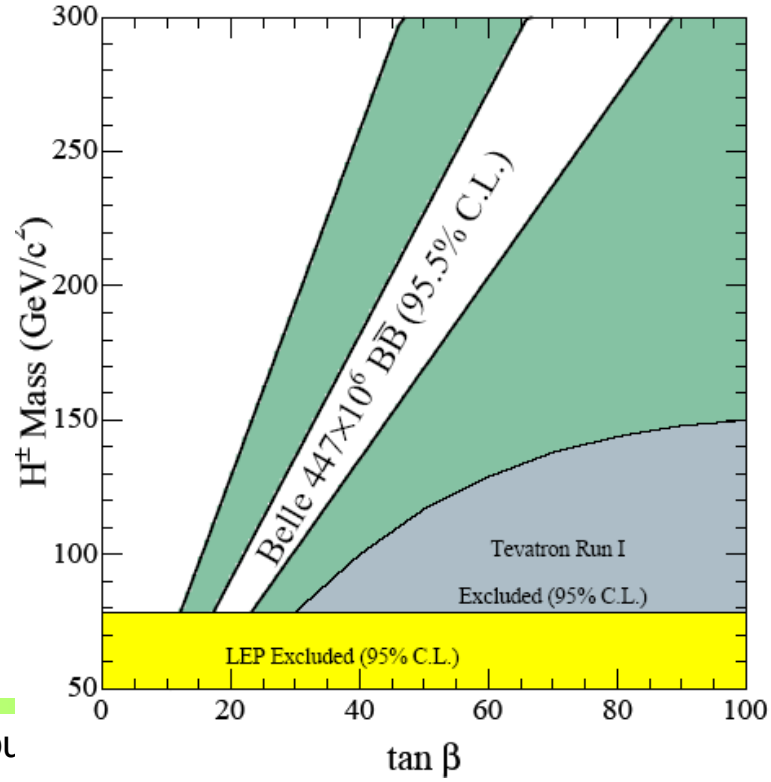
# Charged Higgs limits from $B^- \to \tau^- \nu_\tau$

If the theoretical prediction is taken for $\mathbf{f_B}$
→ limit on charged Higgs mass vs. tanβ

$$r_H = \frac{BF(B \to \tau\nu)}{BF(B \to \tau\nu)_{SM}}$$

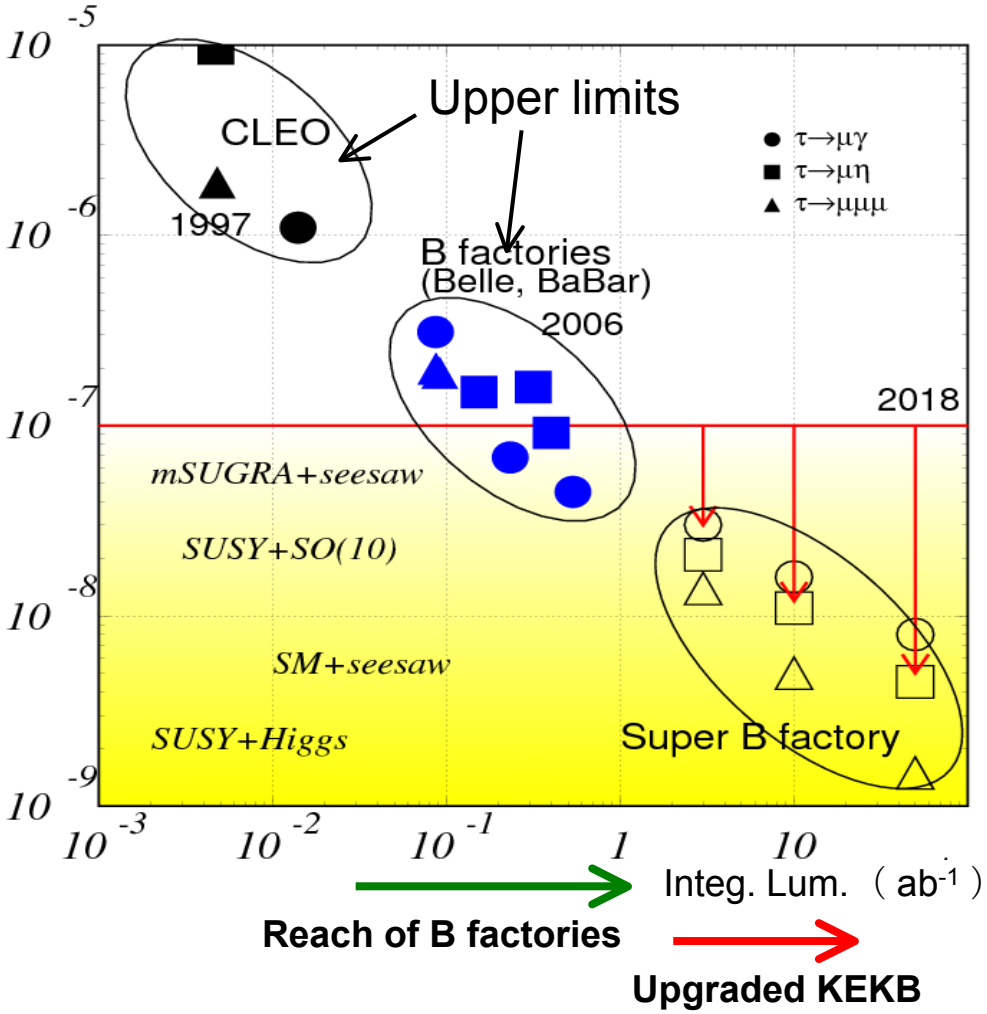


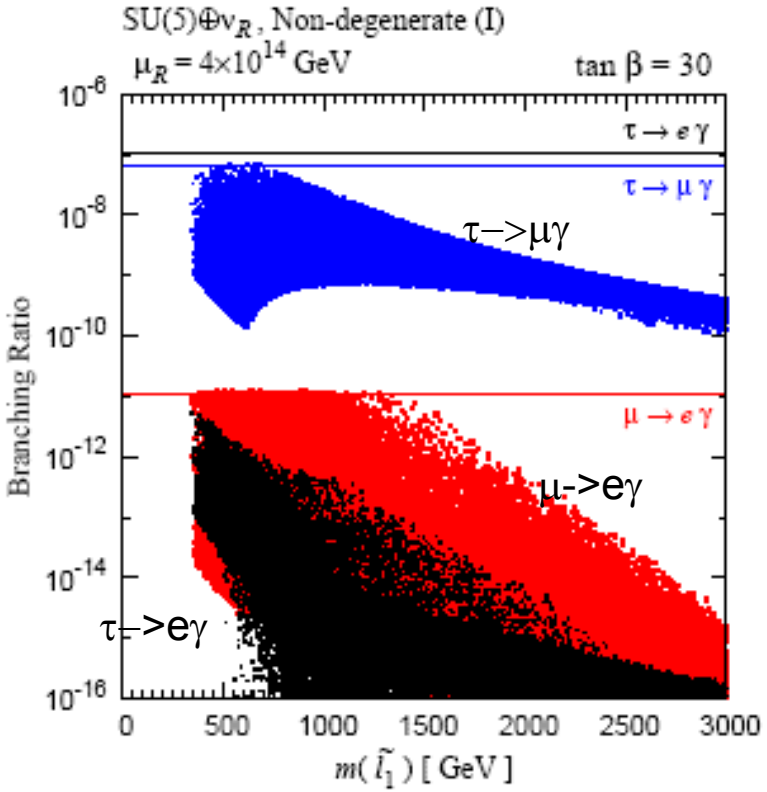



# Precision measurements of τ decays

## LF violating τ decay?



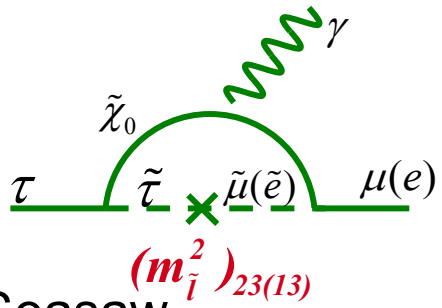

Theoretical predictions compared to present experimental limits




T.Goto et al., 2007

# LFV and New Physics

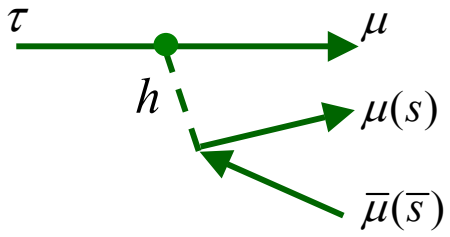
## $\tau \to l\gamma$




- SUSY + Seasaw
- Large LFV $Br(\tau \to \mu\gamma) = O(10^{-7\sim9})$

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

## $\tau \to 3l, l\eta$




- Neutral Higgs mediated decay.
- Important when $M_{SUSY}$ >> EW scale.

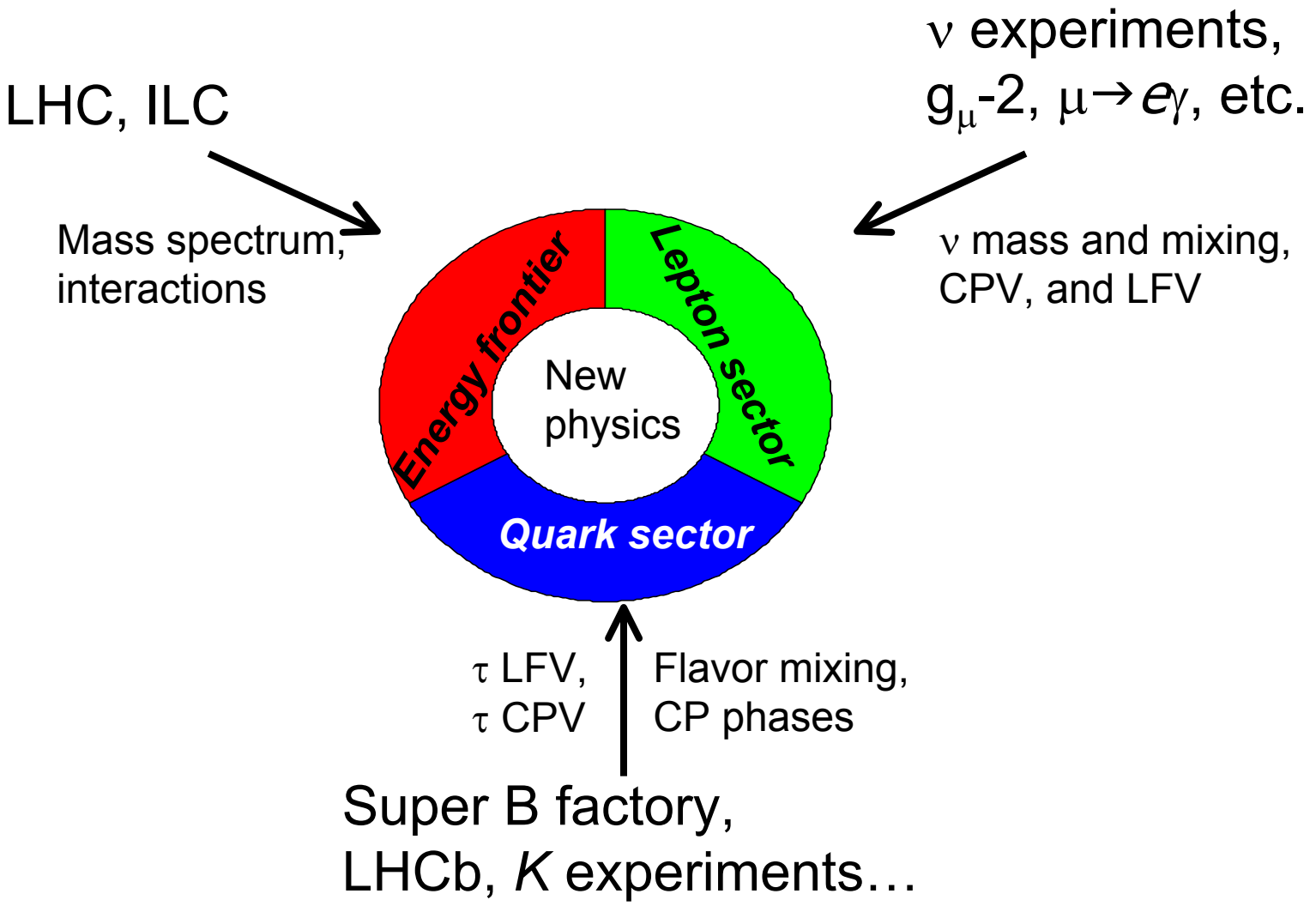
$$Br(\tau \to 3\mu) = 4\times10^{-7} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}}\right)\left(\frac{\tan\beta}{60}\right)^6\left(\frac{100GeV}{m_A}\right)^4$$

| model | $Br(\tau \to \mu\gamma)$ | $Br(\tau \to lll)$ |
|---|---|---|
| mSUGRA+seesaw | $10^{-7}$ | $10^{-9}$ |
| SUSY+SO(10) | $10^{-8}$ | $10^{-10}$ |
| SM+seesaw | $10^{-9}$ | $10^{-10}$ |
| Non-Universal Z' | $10^{-9}$ | $10^{-8}$ |
| SUSY+Higgs | $10^{-10}$ | $10^{-7}$ |

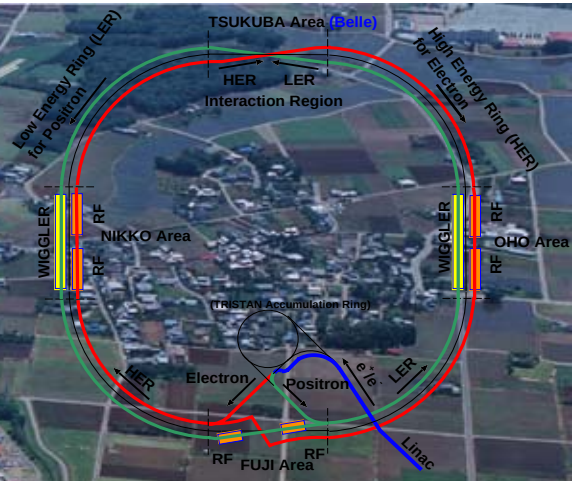
# Physics at Super B Factories

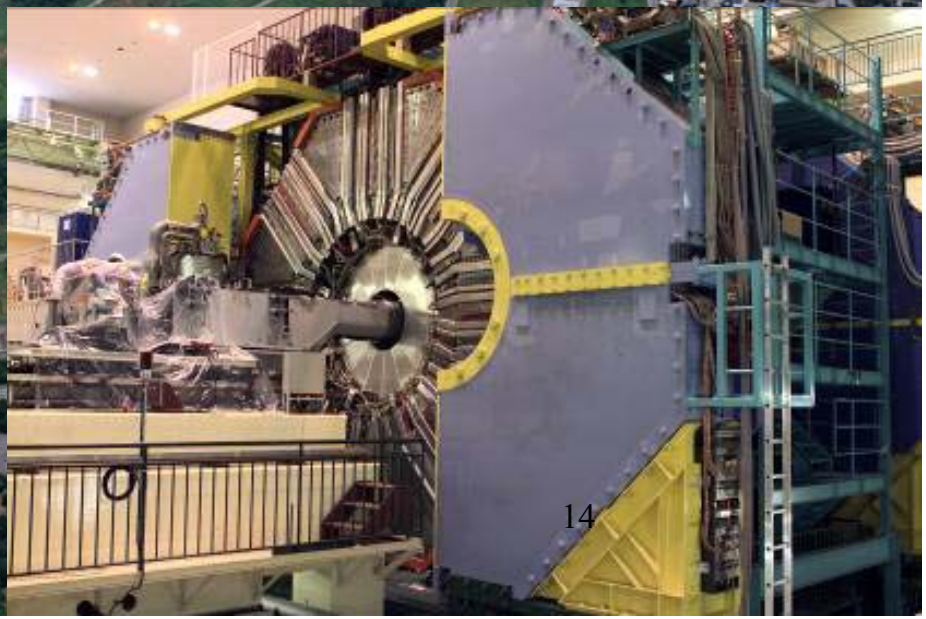
- There is a good chance to see new phenomena;
  - **CPV in B decays from the new physics (non KM).**
  - **Lepton flavor violations in $\tau$ decays.**
- They will help to diagnose (if found) or constraint (if not found) new physics models.
- Even in the worst case scenario (such as MFV), $B \rightarrow \tau\nu$, $D\tau\nu$ can probe the charged Higgs in large $\tan\beta$ region.
- **Physics motivation is independent of LHC**.
  - If LHC finds NP, precision flavour physics is compulsory.
  - If LHC finds no NP, high statistics B/$\tau$ decays would be an unique way to search for the TeV scale physics.
- There are many more topics: CPV in charm, new hadrons, …

# Super B factory: an important part of a broad unbiased approach to New Physics

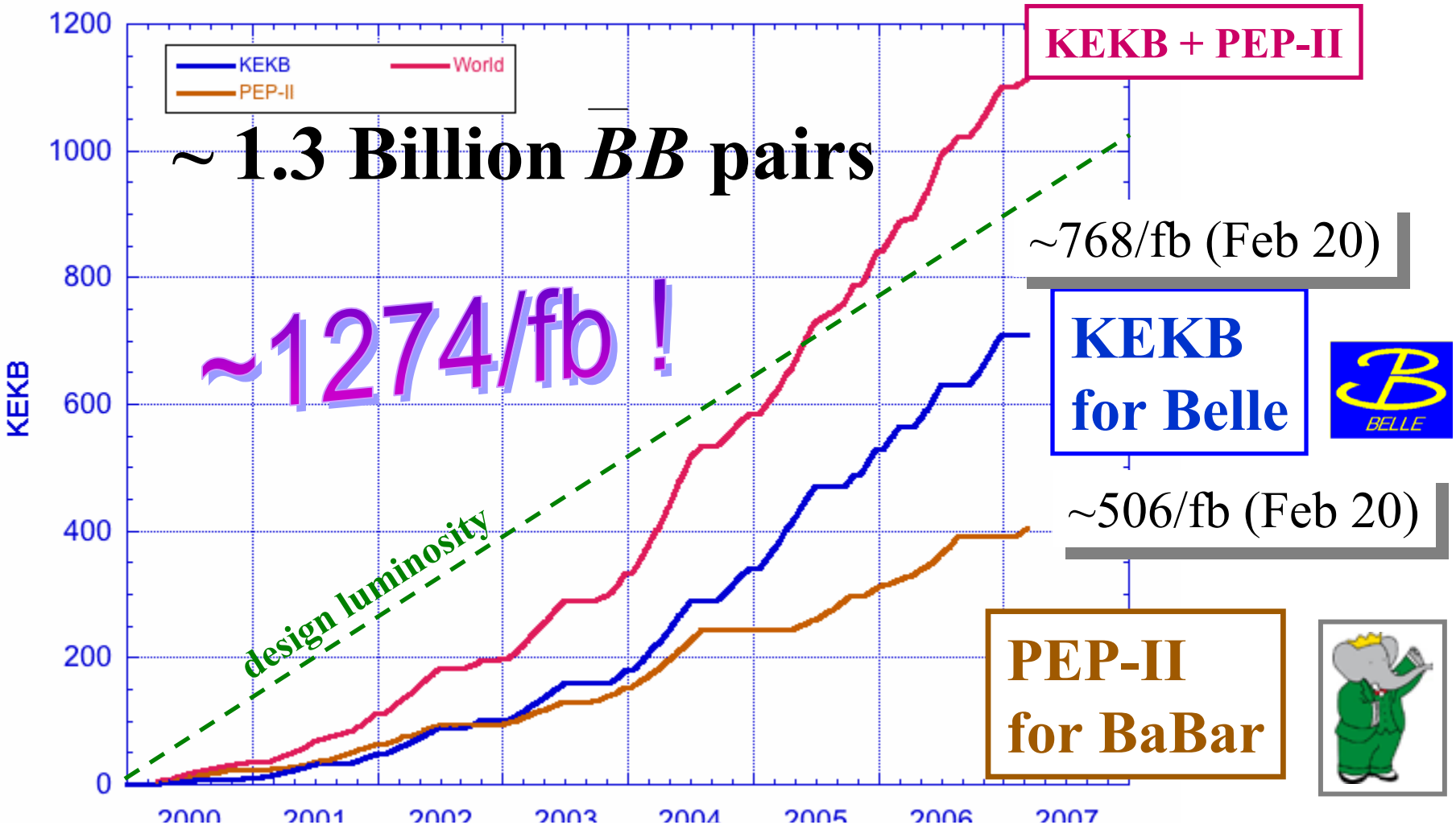


# How to do it?
# → upgrade KEKB and Belle



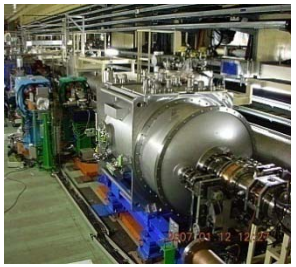
# KEKB's Track Record




$L_{peak}$ (KEKB) = 1.7 x $10^{34}/cm^2/sec$ (design 1.0)

# KEKB Upgrade Plan : Super-B Factory at KEK

- *Asymmetric energy $e^+e^-$ collider at $E_{CM}$=m(ϒ(4S)) to be realized by upgrading the existing KEKB collider.*
- *Initial target: 10×higher luminosity* ≅ $2\times10^{35}$/cm$^2$/sec after 3 year shutdown
  → $2\times10^9$ $BB$ and $\tau^+\tau^-$ per yr.
- *Final goal: L=8×10$^{35}$/cm$^2$/sec and* $\int L\,dt$ = 50 ab$^{-1}$



*Crab cavity*

8GeV $e^-$

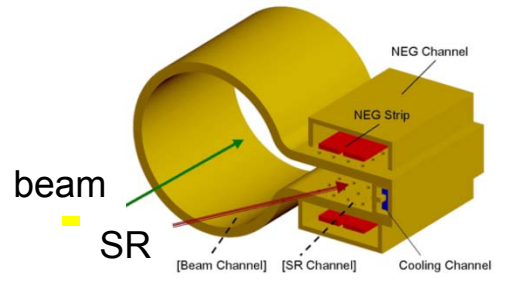
*New IR with crab crossing and smaller $\beta_y^*$*

3.5GeV $e^+$

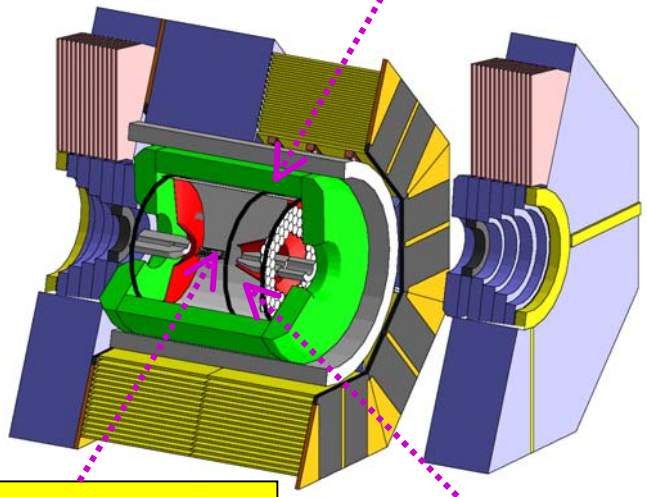
*New beam-pipes with ante-chamber*

*More RF for higher beam current*

*Damping ring for e$^+$*




Faster calorimeter with wave form sampling and pure CsI



Si vertex detector with very short strips

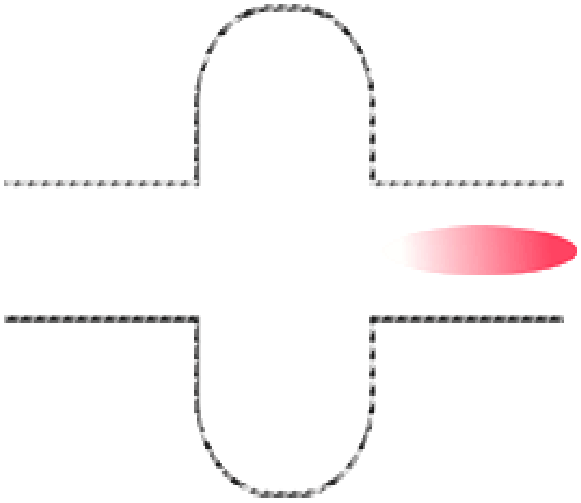
Background tolerant small cell drift chamber

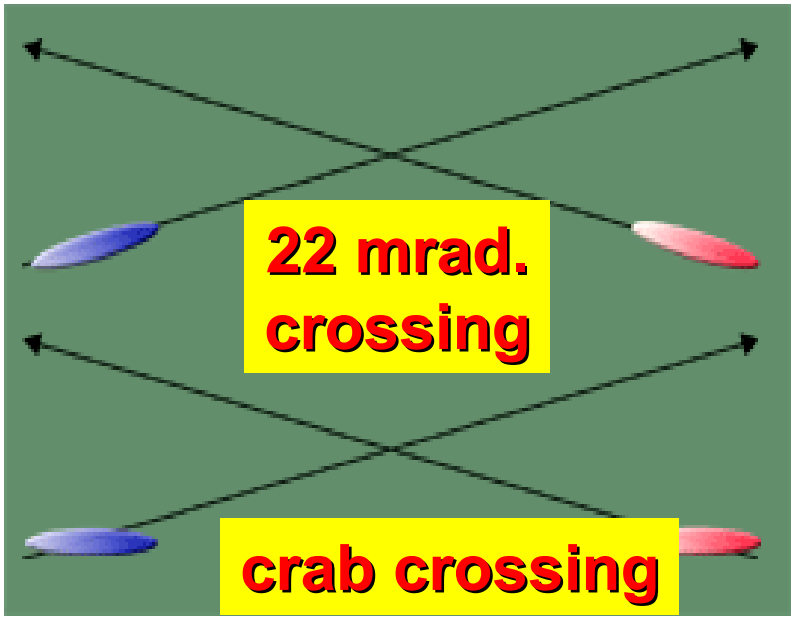
# Luminosity gain and upgrade items (preliminary)

3 years shutdown

| 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 $\beta^*$ injection, improve $e^+$ injection |
| charge switch | x ? | electron cloud, lower $e^+$ current |

# *Crab cavity commissioning*

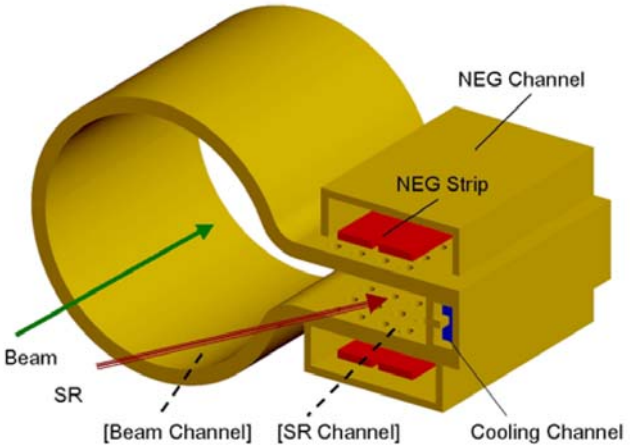


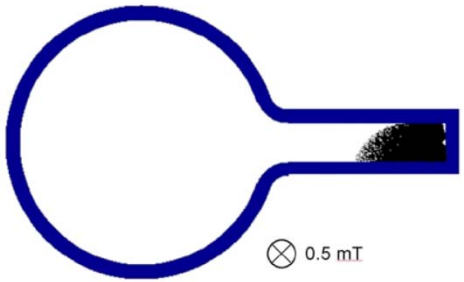



Installed in the KEKB tunnel
(February 2007)


# Super-KEKB (cont'd)

- Ante-chamber /solenoid for reduction of electron clouds




Ante-chamber
with solenoid field

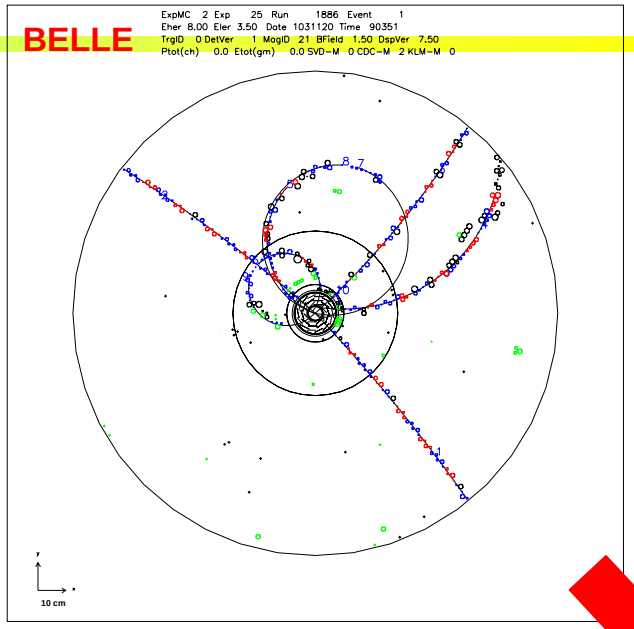
# Requirements for the Super B detector

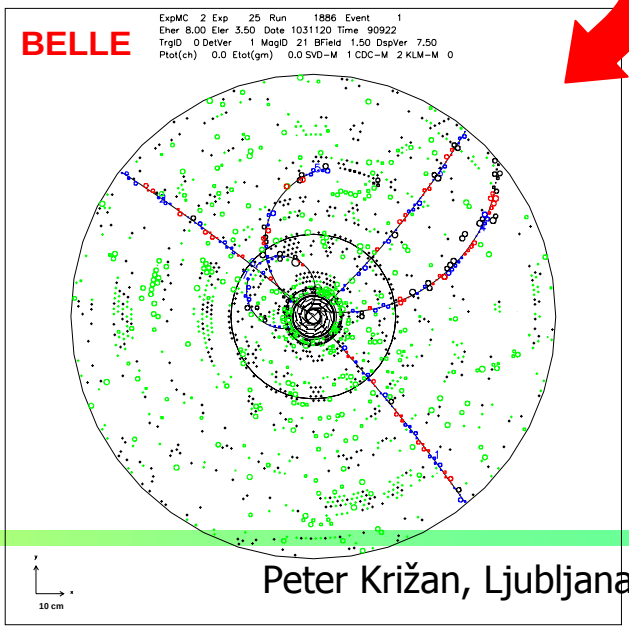
Critical issues at L= 4 x $10^{35}$/cm$^2$/sec

- **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"

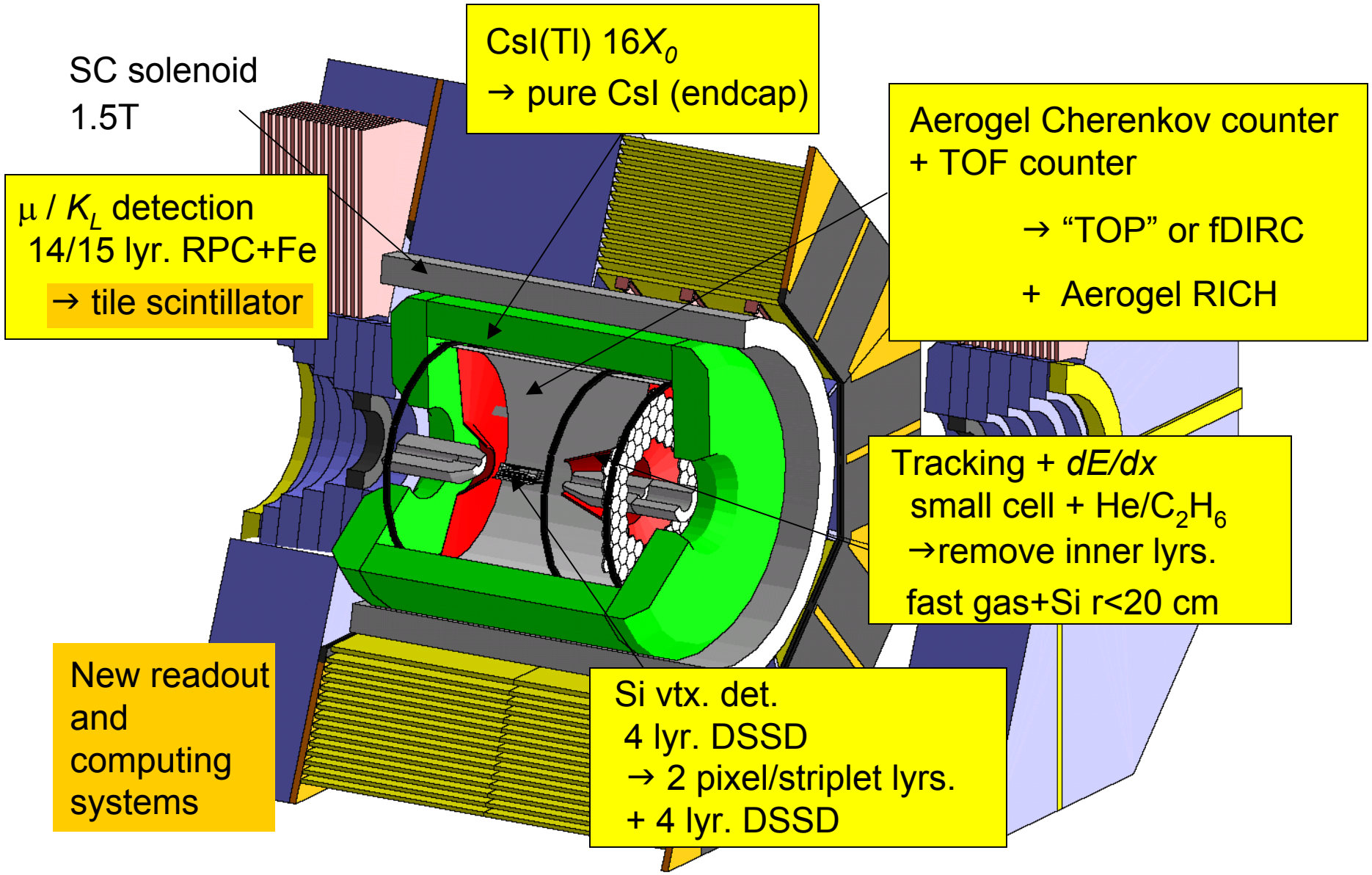
Possible solution:

- Replace inner layers of the vertex detector with a silicon striplet or pixel 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.



# Belle Upgrade for Super-B

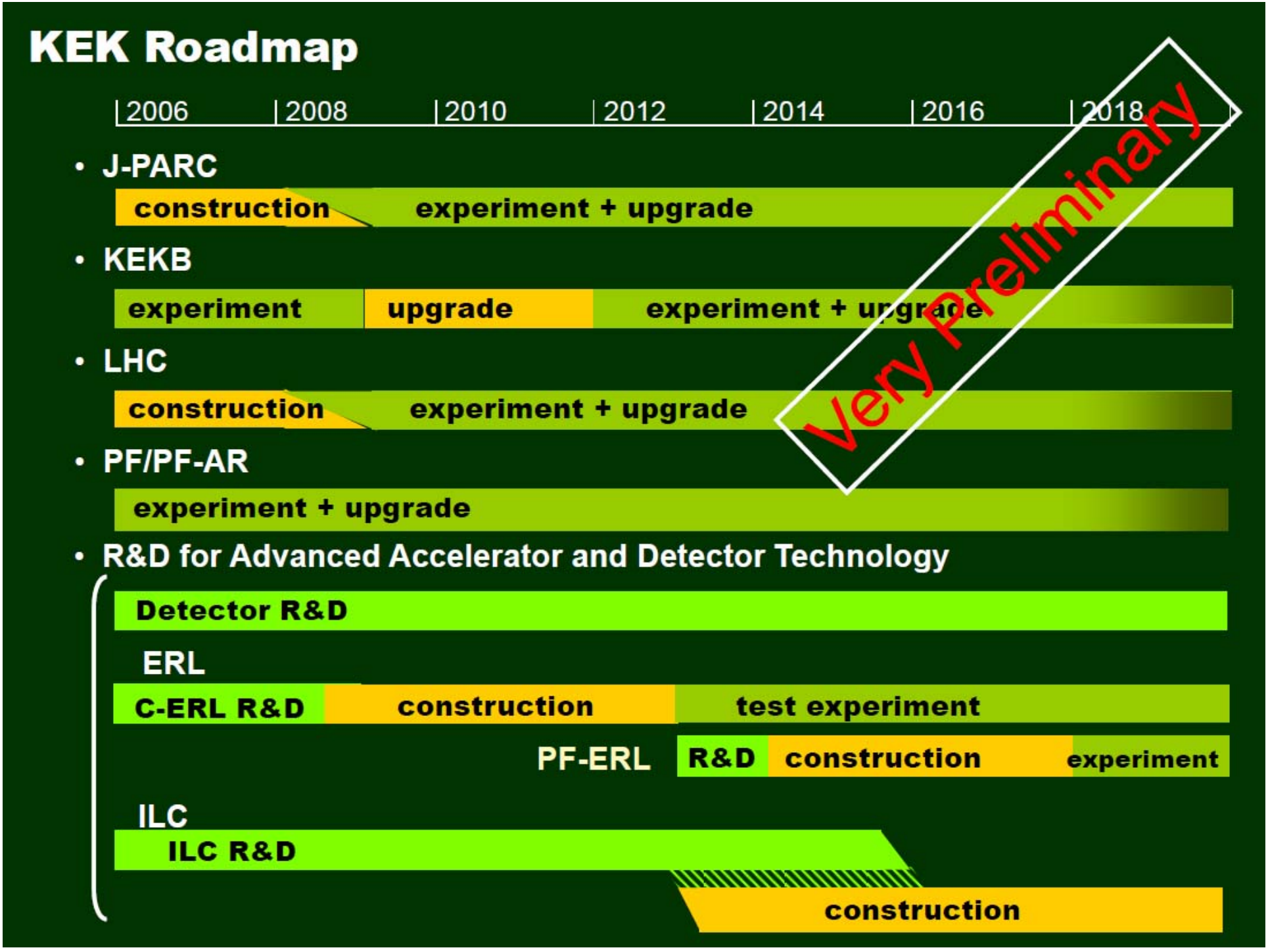


# KEK's 5 year Roadmap

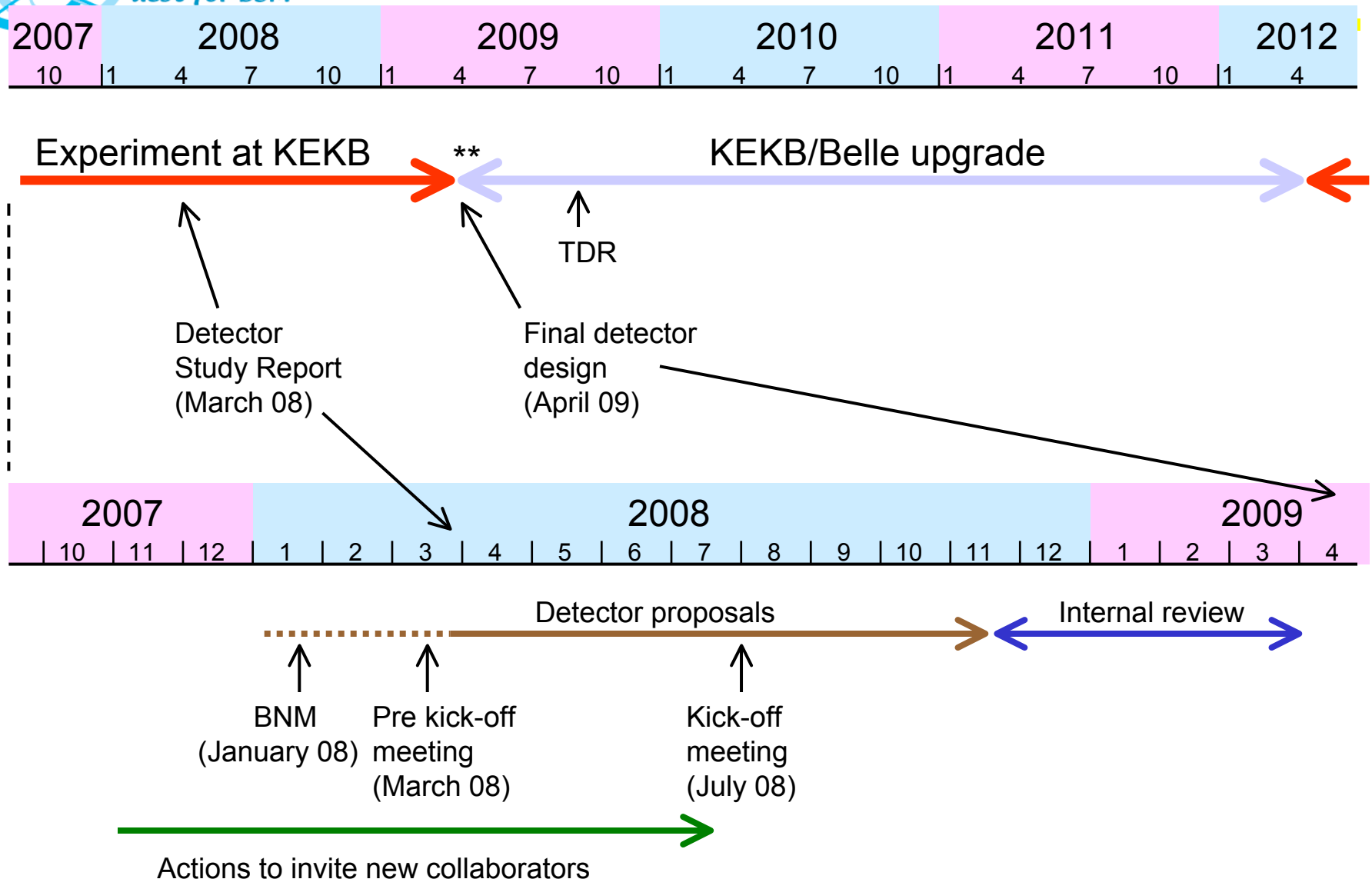
- Official 20 page report released on January 4, 2008 by director A. Suzuki and KEK management
- KEKB's upgrade to $2x10^{35}$ /cm$^2$/sec in 3+x years is *the central element in particle physics.* (Funding limited: Final goal is $8 \times 10^{35}$ and an integrated luminosity of 50 ab$^{-1}$)
  - Will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

# KEK Roadmap


2006
2008
2010
2012
2014
2016
2018
Very Preliminary
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

# *Tight Schedule for the Super KEKB Collaboration*




** Possible 6-month shift to the right

# Summary

- B factories have proven to be an excellent tool for flavour physics
- Reliable long term operation, constant improvement of the performance.
- Major upgrade in 2009-12 → Super B factory, L x10→40
- Essentially a new project, all components have to be replaced, plans exist (LoI), nothing is frozen...
- Expect a new, exciting era of discoveries, complementary to LHC
- Do not miss the chance to be part of it...