Prospects of Super KEKB and Belle II Experiment

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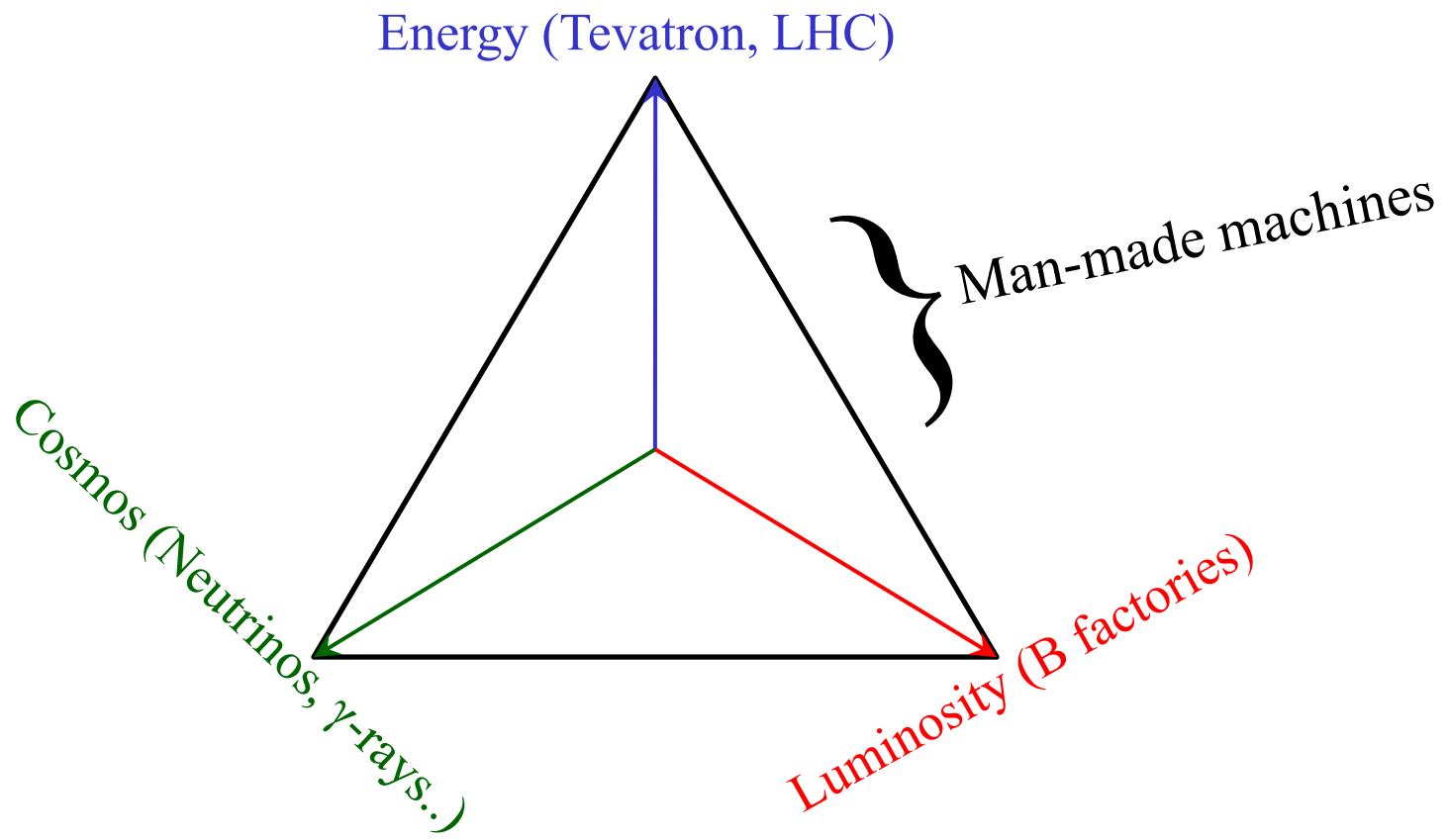
Talk outline

- Physics case
- Accelerator
  - Super KEKB in Japan
- Detector upgrade
  - Belle → Belle II
- Current status of the project
  - Timeline, collaboration, funding
- Closing remarks

Threefold Way

- Today, breakthroughs in elementary particle physics are made possible through the advances in three complementary directions



- I shall concentrate on the right-most corner, i.e., luminosity frontier

Now: 10 years after the B factories

Kobayashi, Maskawa, PTP 49 (1973) 2

In a framework of the renormalizable theory of weak interaction, problems of *CP*-violation are studied. It is concluded that no realistic models of *CP*-violation exist in the quartet scheme without introducing any other new fields. Some possible models of *CP*-violation are also discussed.

Step1

Discovery of CPV in B decays ← **2001 summer !**

Step2

Precision test of KM paradigm

Step3

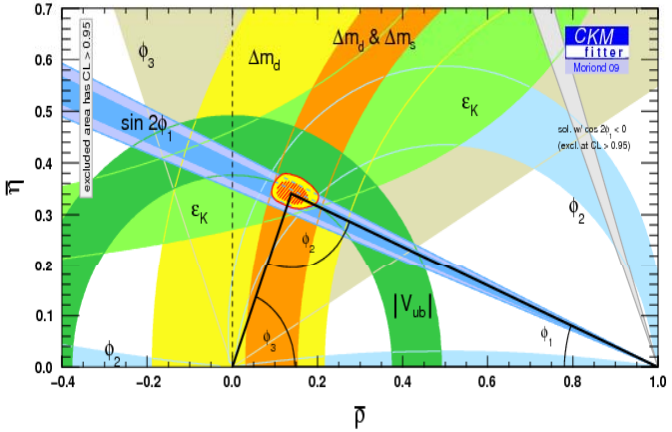
Look for new physics (NP) signature

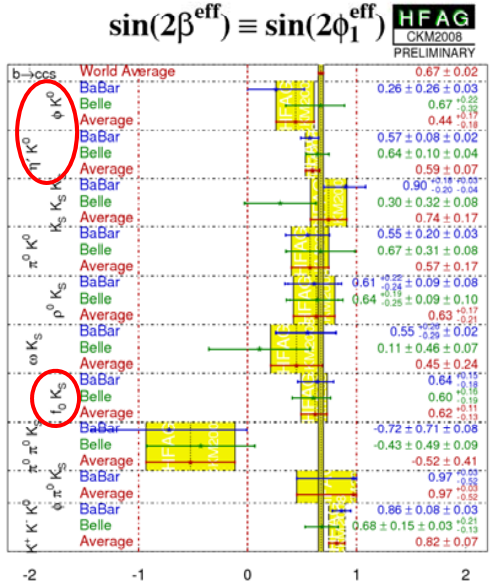
- Need more than 50 times the data (50 ab^{-1}) we have at present to decipher NP effects

What is so special about 50?

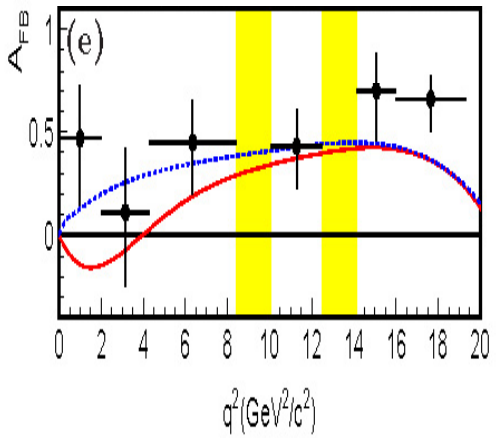
CKM UT triangle

Now

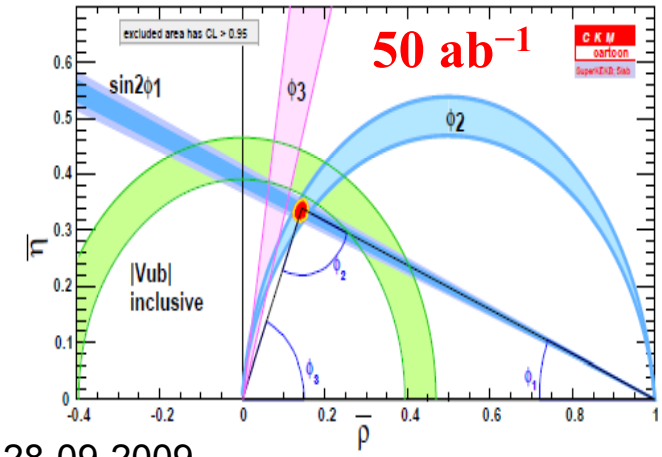




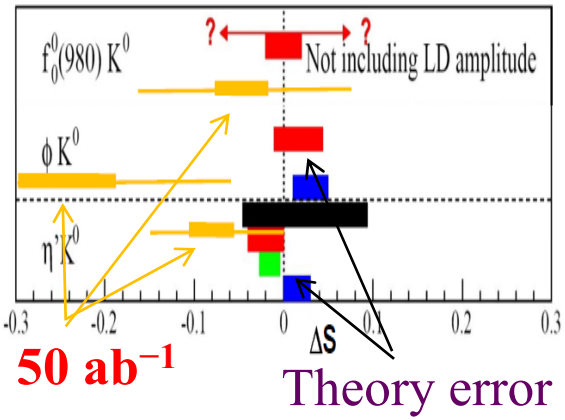
$B \to K^{(*)} l^+ l^-$: A_{FB}



⬇ NP effect

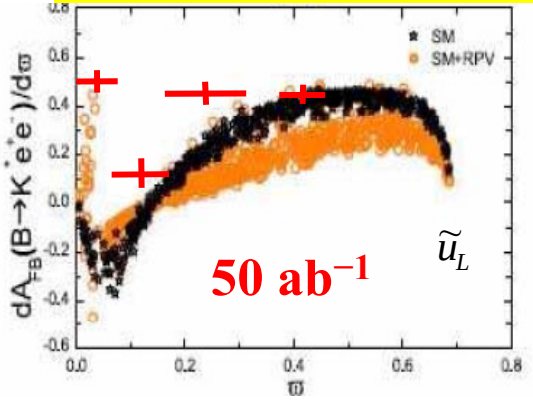


⬇ New CP phase



⬇ Flipped C_7

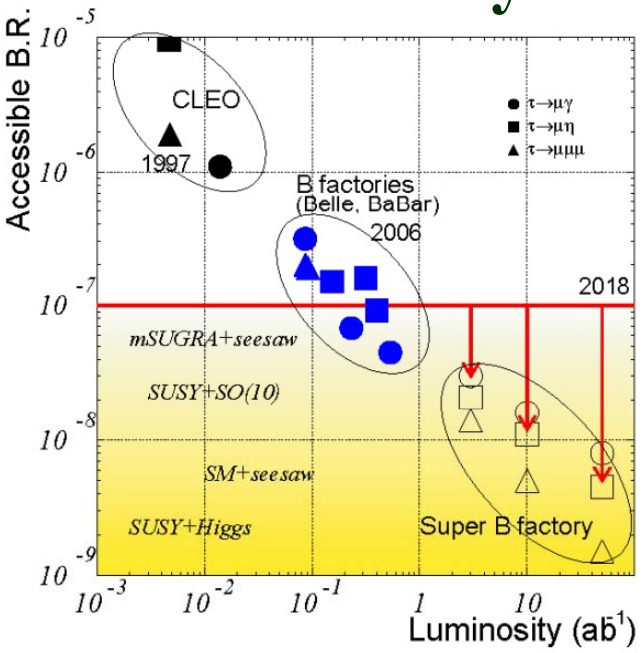
Xu et al., PRD 74 (2006) 114019



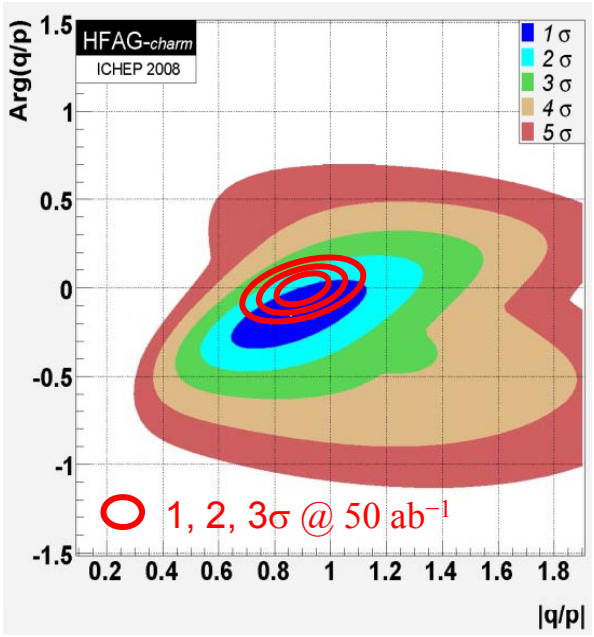
Is that all?

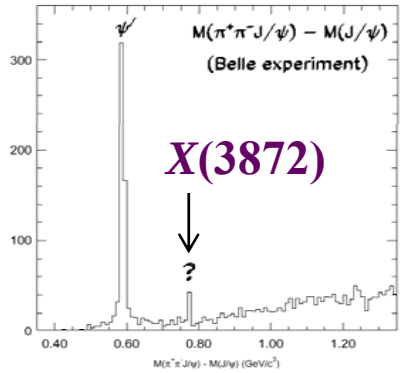
Super B factories are really super flavor factories

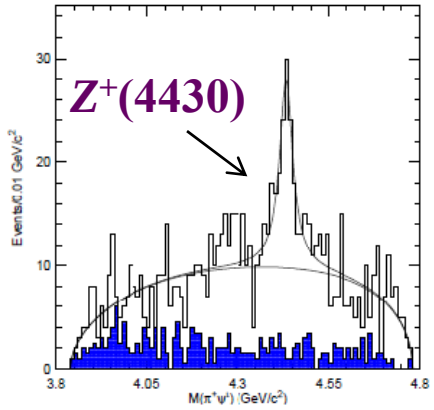
τ LFV decays



$D^0\bar{D}^0$ mixing







- LFV in tau decays, CPV in D-mixing would be unambiguous signatures of NP – beam polarization, operating @ threshold further benefit the cause
- Good detector, huge data in a clean environment ➡ Rest assured

In fact a “treasure chest”

Δm_K ϵ_K ϵ'/ϵ_K $B(K_L \to \pi^0 \nu\bar{\nu})$ $B(K^+ \to \pi^+ \nu\bar{\nu})$

Δm_d $A_{SL}(B_d)$ $S(B_d \to J/\psi K_S)$ $S(B_d \to \phi K_S)$

$\alpha(B \to \pi\pi, \rho\pi, \rho\rho)$ $\gamma(B \to DK)$ CKM fits

Δm_s $A_{SL}(B_s)$ $S(B_s \to J/\psi \phi)$ $S(B_s \to \phi\phi)$

$B(b \to s\gamma)$ $A_{CP}(b \to s\gamma)$ $S(B^0 \to K_S \pi^0 \gamma)$ $S(B_s \to \phi\gamma)$

$B(b \to d\gamma)$ $A_{CP}(b \to d\gamma)$ $A_{CP}(b \to (d+s)\gamma)$ $S(B^0 \to \rho^0 \gamma)$

$B(b \to s l^+ l^-)$ $B(b \to d l^+ l^-)$ $A_{FB}(b \to s l^+ l^-)$ $B(b \to s \nu\bar{\nu})$

$B(B_s \to l^+ l^-)$ $B(B_d \to l^+ l^-)$ $B(B^+ \to l^+ \nu)$

$B(\mu \to e\gamma)$ $B(\mu \to e^+ e^- e^+)$ $(g-2)_\mu$ μ EDM

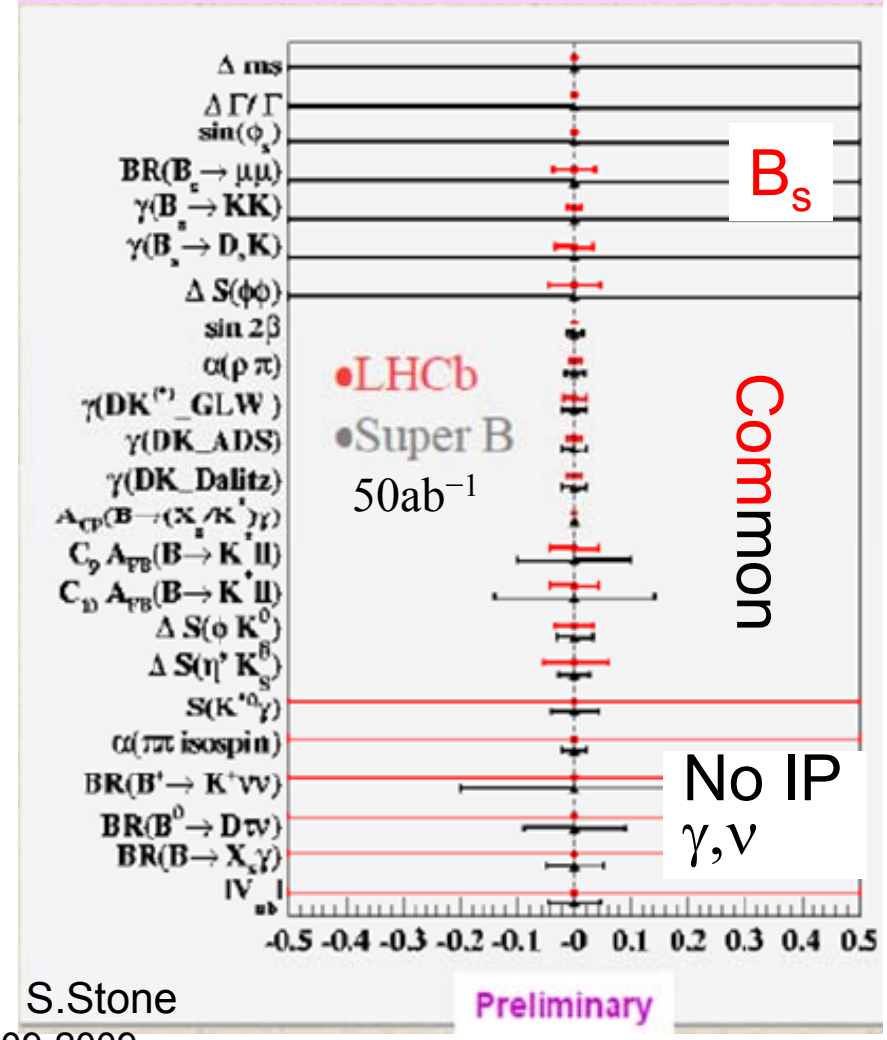
$B(\tau \to \mu\gamma)$ $B(\tau \to e\gamma)$ $B(\tau^+ \to l^+ l^- l^+)$ τ CPV τ EDM

$B(D^+_{(s)} \to l^+ \nu)$ x_D y_D charm CPV

Would be possible with a good amount data taken at $\Upsilon(5S)$

Complementary with the LHC

Super flavor factory vs LHCb



S.Stone

NP flavor couplings

$$(m^2_{\tilde{q}})_{ij} = \begin{pmatrix} m^2_{11} & m^2_{12} & m^2_{13} \\ m^2_{21} & m^2_{22} & m^2_{23} \\ m^2_{31} & m^2_{32} & m^2_{33} \end{pmatrix}$$

Diagonal: Energy frontier
(LHC – ATLAS, CMS)

Off-diagonal: Lumi frontier
(super flavor factory, LHCb)

- Settle NP models
- Look for higher scale NP

What about worst-case scenario?

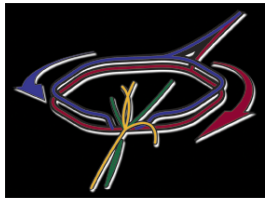
- Imagine the possibility, where NP follows the SM pattern of flavor and CP violation (minimal flavor violation)

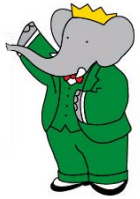
D'Ambrosio et al., NPB 645 (2002) 155

- The model predicts all NP flavor couplings are zero – nature may not be so much unkind to us!
- Even in this most unfavorable scenario, super flavor factories are still sensitive up to NP mass range of 600-1000 GeV
- Going little up, in the next-to-minimal flavor violation, the to-be exploratory scale goes beyond 10 TeV ➡ LHC domain
- For generic flavor violation scenario, super flavor factories are sensitive up to ~1000 TeV

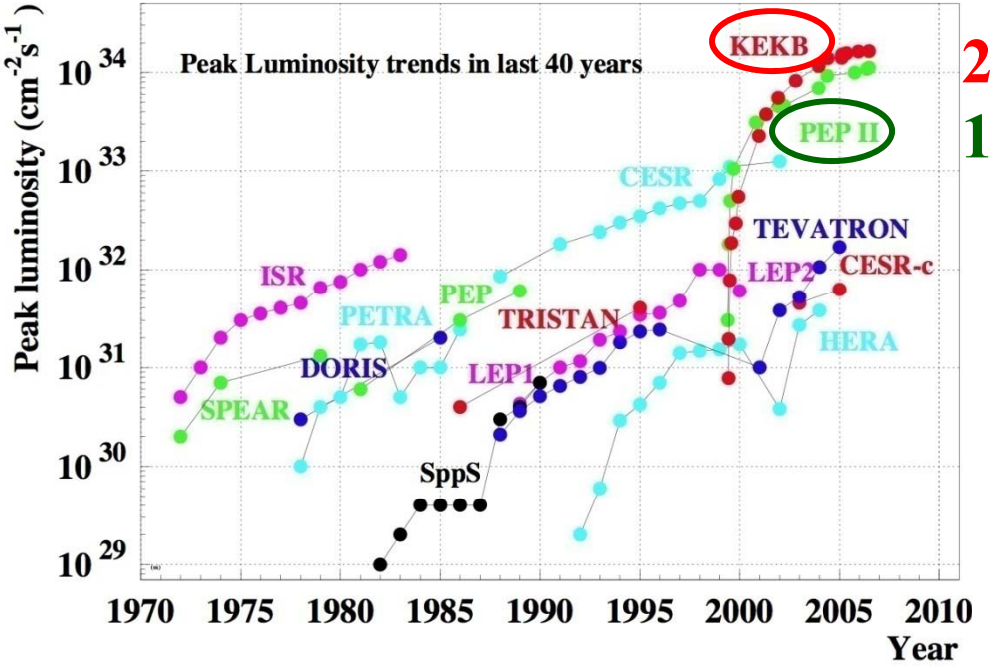
Explore luminosity frontier

KEKB/Belle (Japan)





PEP II/BaBar (US)



2.1×10^{34}

1.2×10^{34}

Super KEKB (Japan)

SuperB (Italy)

Peak luminosity ~10^{36} cm^{-2}s^{-1}

One eqn. – many ways to play around

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

× ~5	• Raise the beam current, ***I***
~5	• Larger beam-beam par, ξ_y
~1/2	• Smaller β^*_y
~50	(short bunch)

< 1/20
+ low emittance
(long bunch)

High current approach

Super KEKB uest for BSM

Brute force
Realizable

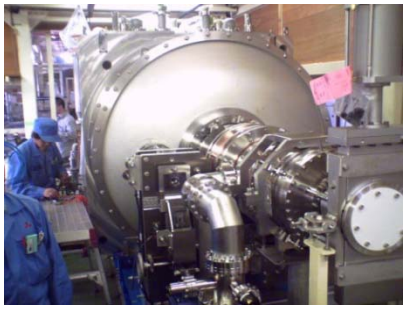
Baseline: **Super KEKB (Japan)**

Nano-beam approach

New scheme
Risk?

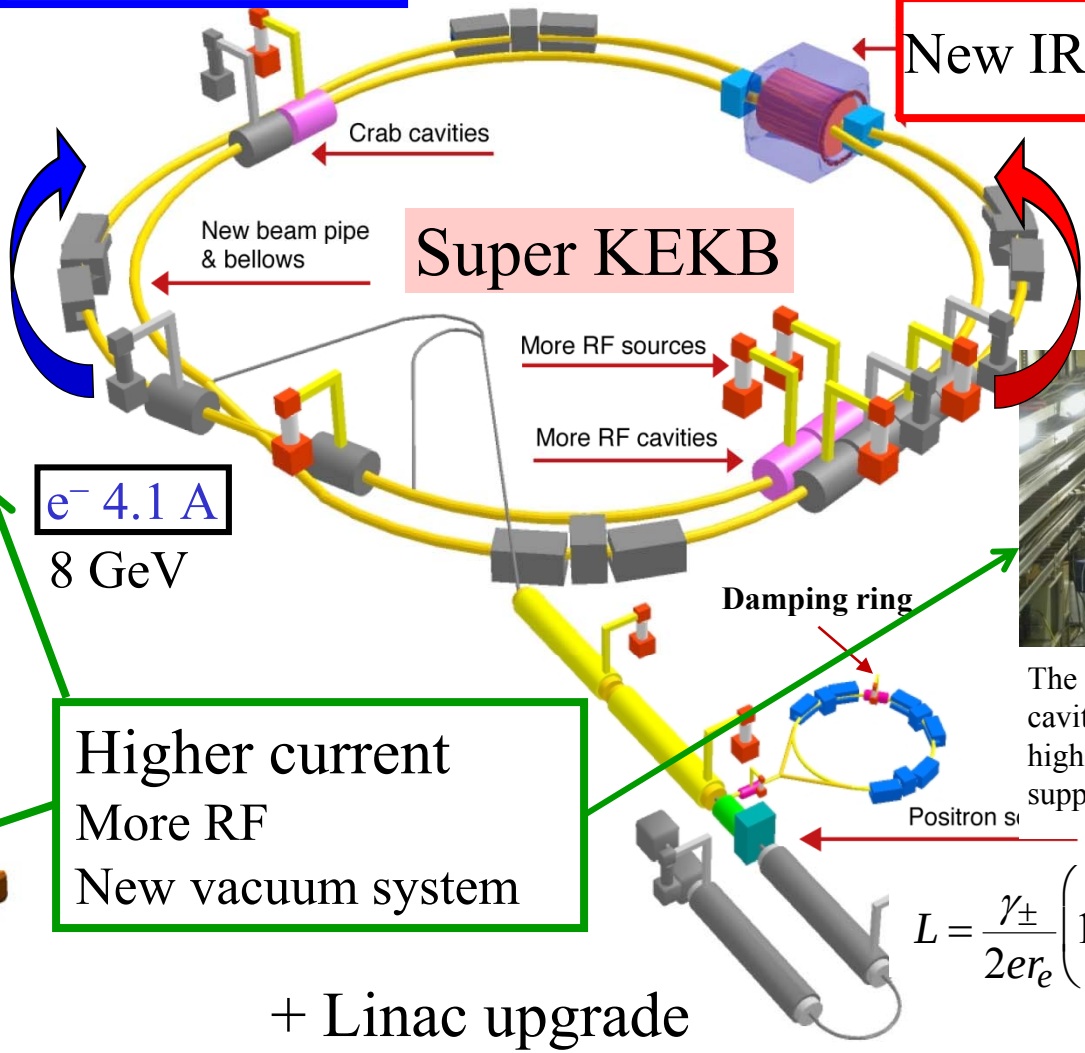
SuperB

SuperB (Italy)



Crab cavities installed and undergoing testing in beam

Crab crossing



New IR: Belle II

3.5 GeV

e^+ 9.4 A

e^- 4.1 A

8 GeV

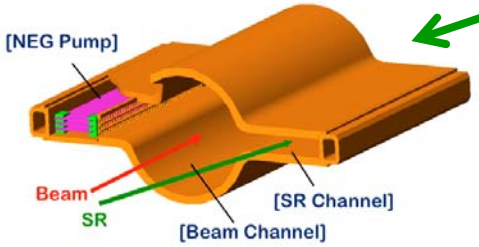
Superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW

The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current

Higher current

More RF

New vacuum system



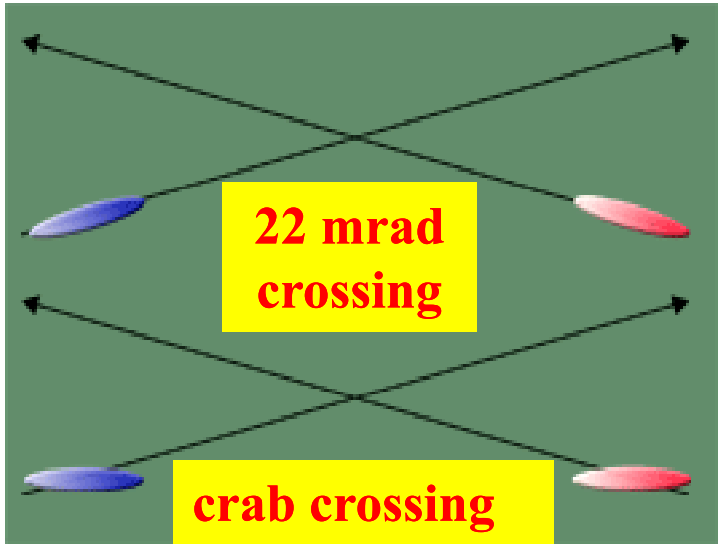
The beam pipes and all vacuum components will be replaced with higher-current design

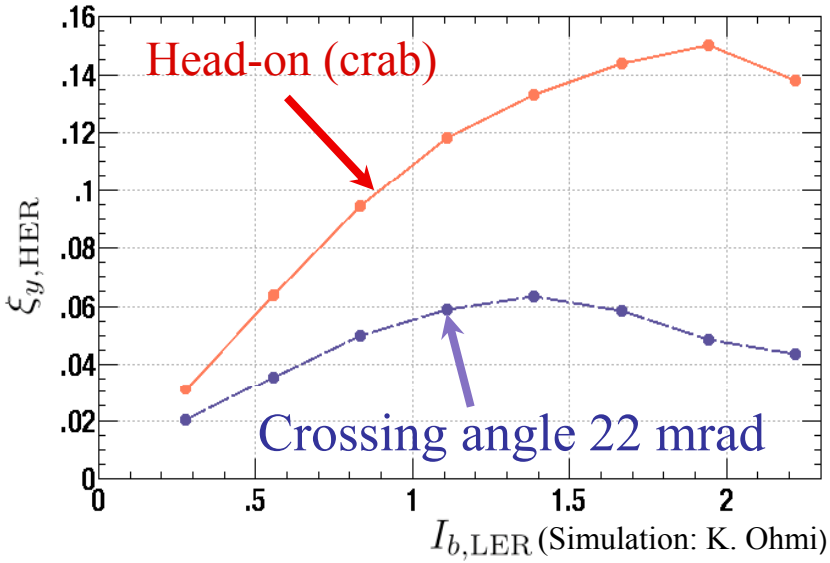
+ Linac upgrade

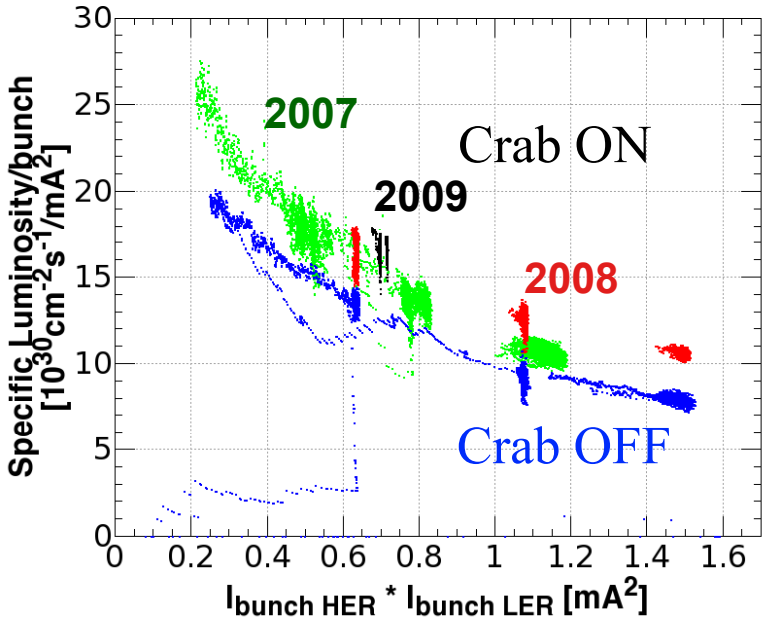
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

High-current option (baseline)

Crab crossing and its impact





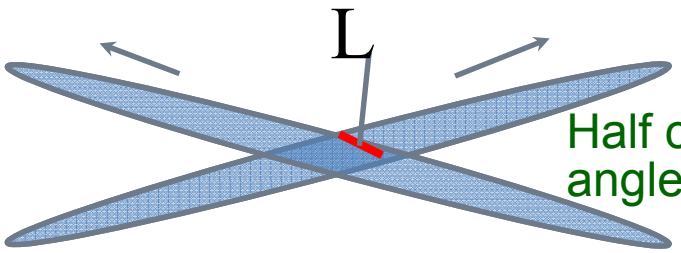


Crabbing: successful!

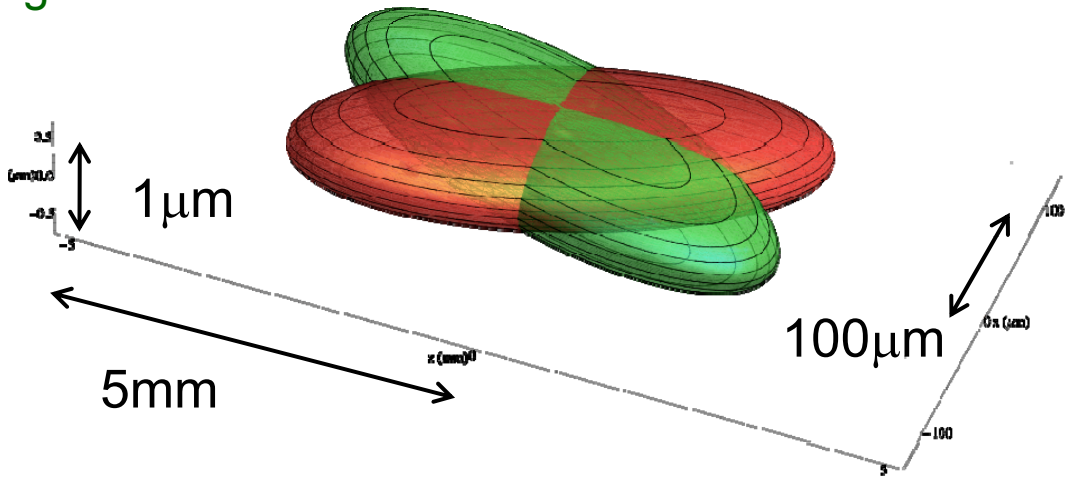
L = 2.11×10^{34} (17 July)
higher than without crab
(new skew sextupoles)

Specific luminosity
has increased ~30%

Nano-beam scheme



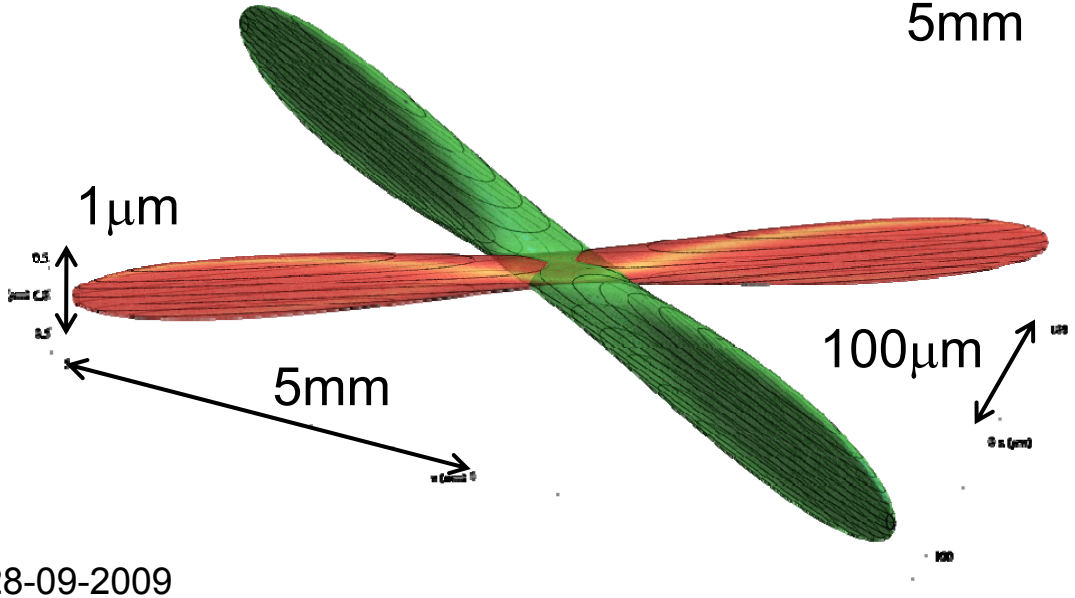
Present KEKB (w/o crab)



Hourglass condition:

$\beta^*_y >\sim L=\sigma_x/\phi$

SuperB

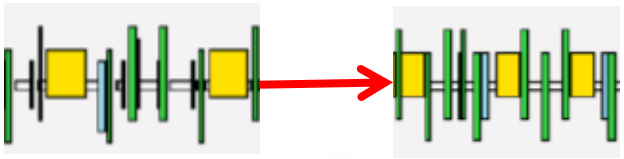


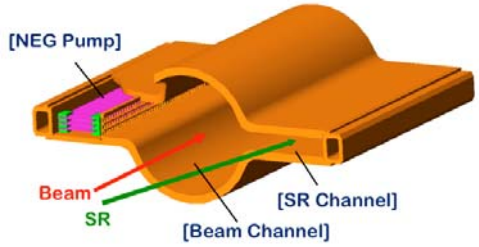
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma^*_y}{\sigma^*_x}\right)\frac{I_\pm \xi_{\pm y}}{\beta^*_y}\left(\frac{R_L}{R_y}\right)$$

$$\Updownarrow$$

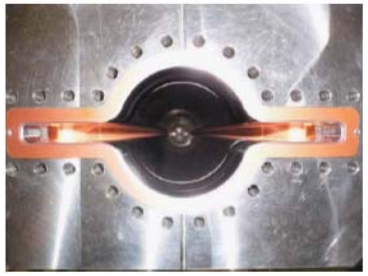
$$L = \frac{N_+ N_- f}{4\pi\sigma^*_x\sigma^*_y}R_L$$

Replace long TRISTAN dipoles with shorter ones





Tin coated beam pipes with antechambers



e^+ 3.7 A

e^- 2.1 A

New IR: Belle II

New superconducting / permanent final focussing quads

New beam pipe & bellows

Super KEKB

Add/modify RF systems

Low emittance positrons to inject

Damping ring

Positron source

Low emittance electrons to inject

New positron target and capture section

Nano-beam option

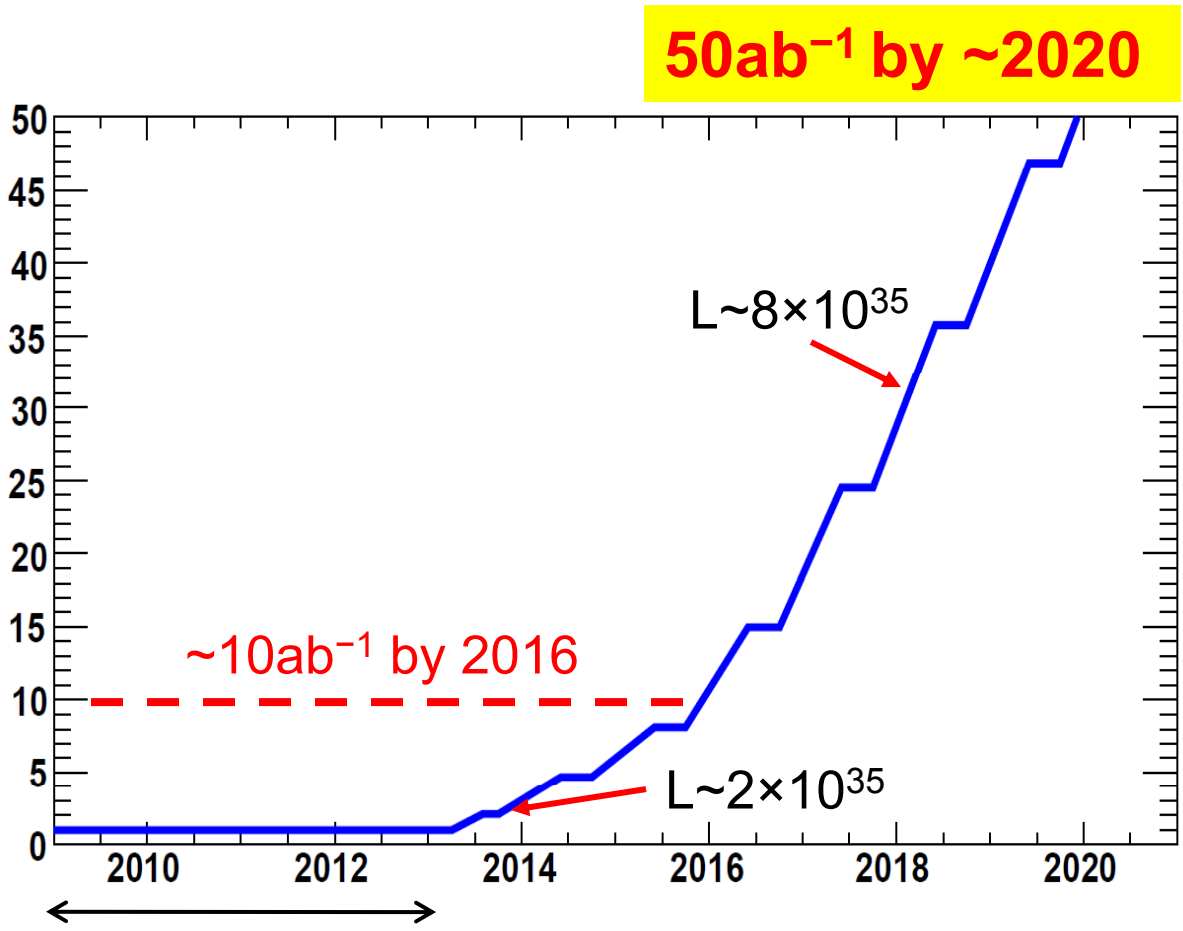
Comparison of parameters

	KEKB design	KEKB achieved (with crab)	Super KEKB high-current option	Super KEKB nano-beam option
β_y^* (mm)(LER/HER)	10/10	6.5/5.9 (5.9/5.9)	3/6	0.24/0.37
ε_x (nm)	18/18	18(15)/24	24/18	2.8/2.0
σ_y (μm)	1.9	1.1 (0.84)	0.85/0.73	0.084/0.072
ξ_y	0.052	0.108/0.056 (**0.101/0.096**)	0.30/0.51	0.09/0.09
σ_z (mm)	4	~ 7	5(LER)/3(HER)	5
I_{beam} (A)	2.6/1.1	1.80/1.45 (1.62/1.15)	9.4/4.1	3.6/2.1
$N_{bunches}$	5000	1387 (1585)	5000	2119
Luminosity (10^{34} cm^{-2} s^{-1})	1	1.76 (2.11)	53	80

under study

High-current option includes crab crossing and travelling focus
Nano-beam option does not include crab waist

Luminosity projection



Requirements for the detector

- Will be built by upgrading the current Belle spectrometer taking the following points into account

1) Higher background
   - Radiation damage, higher occupancy

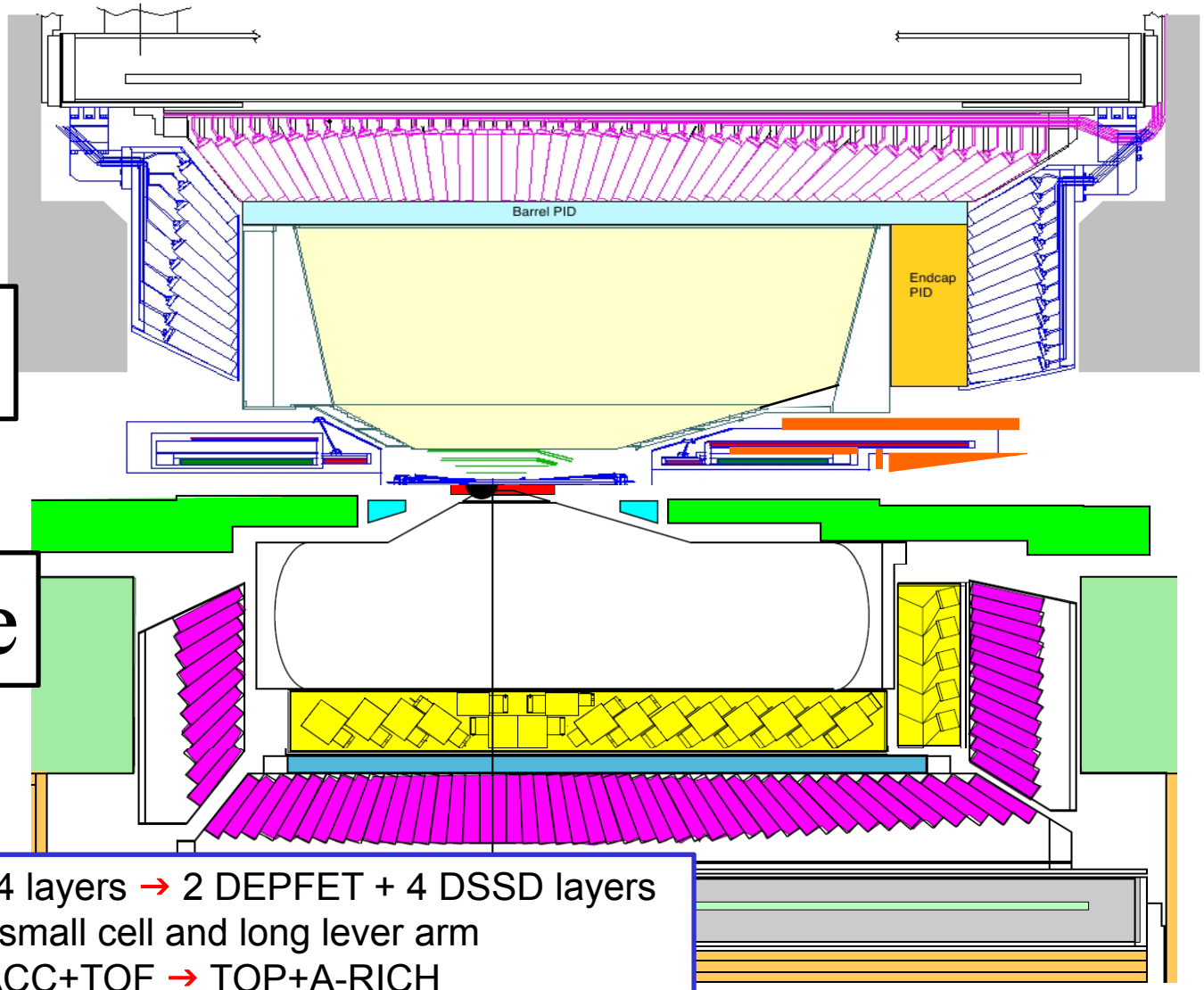
2) Higher event rates
   - Higher DAQ rate

3) New requirements
   - Improved hermiticity for LFV searches and study of final states involving neutrinos

Super KEKB baseline detector

Belle II

Belle

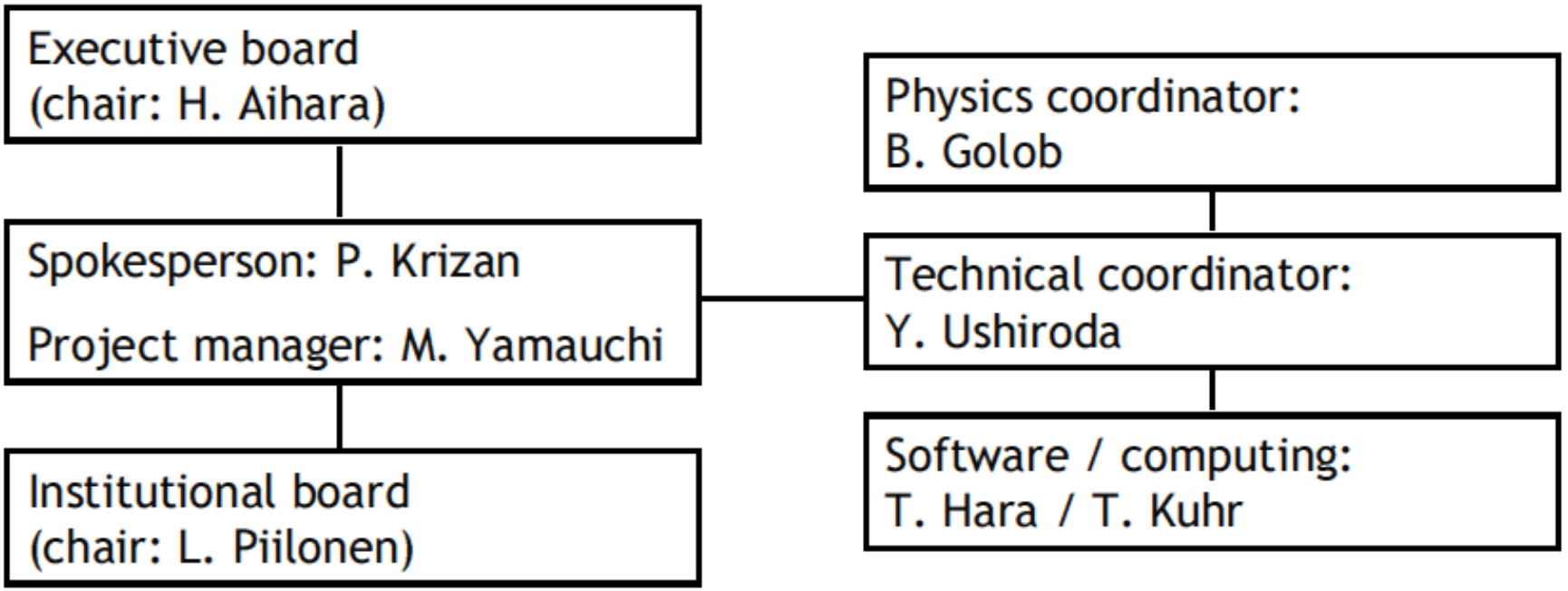


SVD: 4 layers → 2 DEPFET + 4 DSSD layers
CDC: small cell and long lever arm
PID: ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for endcap
KLM: RPC → Scintillator+SiPM (endcap)

Progress and plan

Jun 2004: LoI for Super KEKB
Jan 2008: KEK Roadmap
Super KEKB is identified as high priority
Dec 2008: New collaboration (Belle II) officially formed
13 countries, 43 institutes
Election of the spokesperson
Mar 2009: BPAC (Chair: T.Nakada) endorsement
Mar 2009: FY2008/9 supplemental budget:
~5M$ for the Belle upgrade
May 2009:~27M$ for KEKB upgrade R&D
July 2009: 3rd Open Belle II collaboration meeting

Current organizational setup



Closing Remarks

- Both the B factories – Belle and BaBar – have performed exceptionally well, beyond their original design
- CKM paradigm has been established as the only source of CP violation in the SM
- Proposal for two super flavor factories with *raison d'être* to probe NP effects (complementary to LHC)
- Super KEKB in Japan is one of the candidates
  - Baseline design (high-current option) is finalized, work in progress for the nano-beam option
  - Belle II collaboration is formed
  - Partial funding is already secured

➡ Your active support and participation are most welcome