Status and plan for Belle II and SuperKEKB

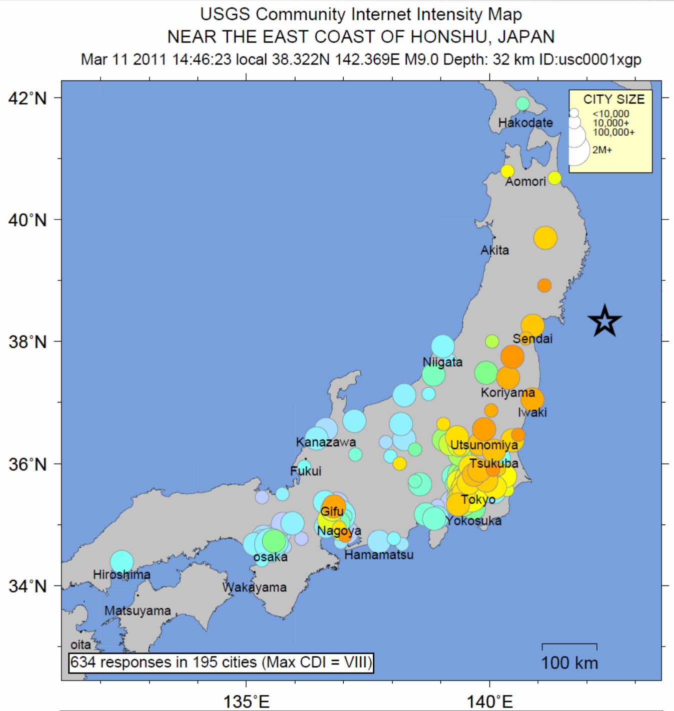
Jolanta Brodzicka (Kraków)
on behalf of BelleII

BEAUTY 2011
4-8 April 2011, Amsterdam

Outline

- Why upgrade?
- Processes sensitive to NP
- KEKB milestones
- Super KEKB design
- Belle II: detector upgrade
- Summary

After the earthquake



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

As is now well known, Japan suffered a terrible earthquake and tsunami on March 11, which has caused tremendous damage, especially in the Tohoku area. Fortunately, all KEK personnel and users are safe and accounted for. The injection linac did suffer significant but manageable damage and repairs are underway. The damage to the KEKB main rings appears to be less serious, though non-negligible. No serious damage has been reported so far at Belle. Further investigation is necessary. We would like to convey our deep appreciation to everyone for your generous expressions of concern and encouragement.

Why to upgrade?

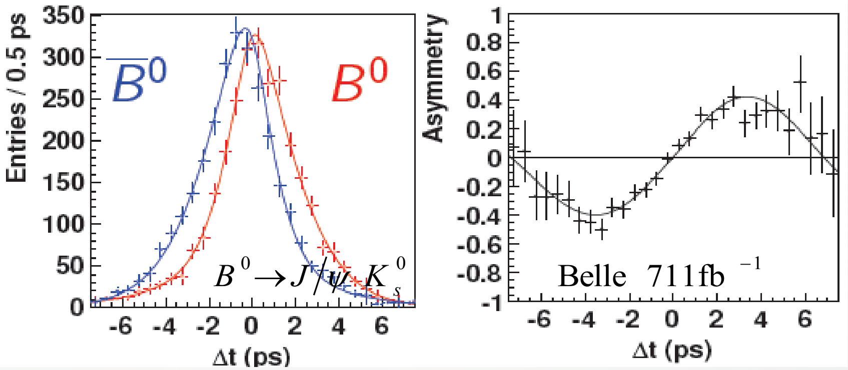
- **Success of B-Factories: confirmation of KM mechanism of CPV**

2001: discovery of CPV in B system

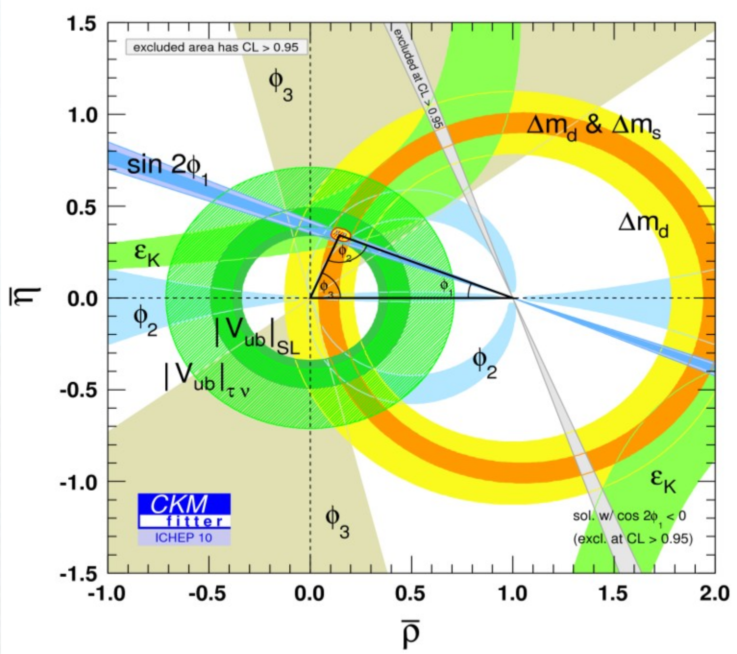
2011: most precise $\sin 2\varphi_1$ from $b\to c\bar{c}s$

$$\boxed{\sin\, 2\phi_1^{B\to(c\bar{c})K^0} = 0.668 \pm 0.023 \pm 0.013}$$

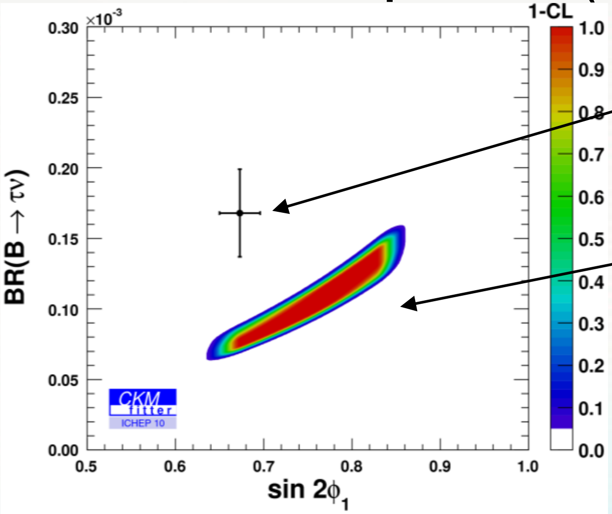
(Belle full data set, preliminary)



- **Standard Model works well in this flavour sector**



2.8σ difference between direct and indirect $\sin 2\varphi_1$ and $BR(B\to\tau\nu)$



experimental measurements

CKM fit w/o these measurements

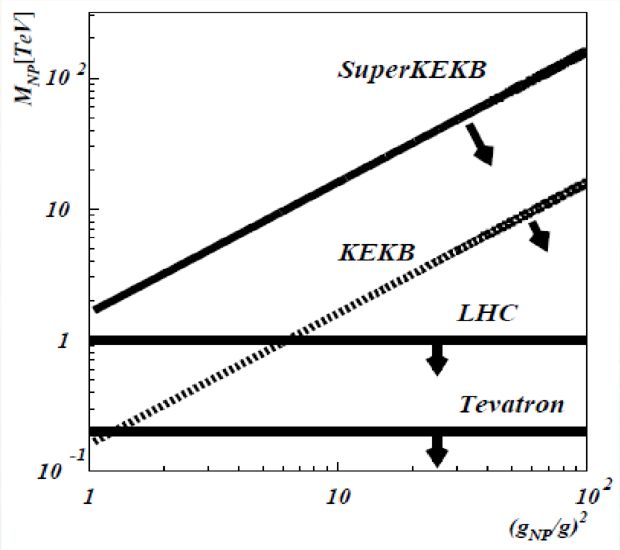
- **Hints of New Physics: some results of B-Factories show tensions with SM**

Physics goals of SuperKEKB

- Still room for corrections from New Physics at *O*(10%)
- Explore NP hints with higher precision

- Approach complementary to hadron colliders
- LHC: energy frontier Direct searches NP up to *O*(1TeV)
- SuperKEKB: rare/precision frontier Search for indirect NP effects
  - ✓ up to *O*(1TeV) if Minimal Flavour Violation assumed
  - ✓ up to *O*(100TeV) if Flavour Violation couplings enhanced
- Observe NP→ overconstrain SM and NP parameters→characterize NP

- New Physics sensitive processes:
  - $b \to sss$ penguins
  - DCPV in $B \to K\pi$
  - $B \to \tau\nu$, $B \to D\tau\nu$
  - A_{FB} in $B \to K^* l^+ l^-$
  - CPV in D decays
  - LFV in τ decays
  - ...

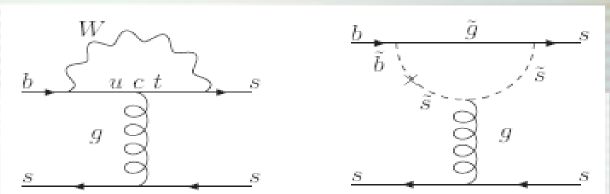


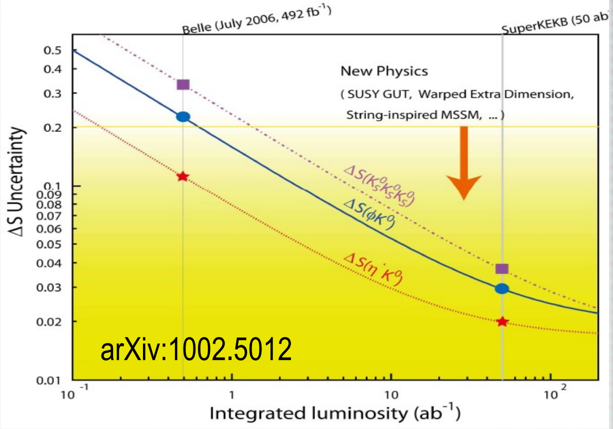
NP-sensitive processes

- **CPV in b → s<u>s</u>s penguin decays**

$$\Delta S \equiv \sin 2\phi_1^{B\to\phi K_s} - \sin 2\phi_1^{B\to J/\psi K_s} = 0.22 \pm 0.17$$

- **ΔS≈0 in SM, NP can change it**
- **Measured via t-dep. Dalitz analysis of $B\to K^+K^-K_s$**
- **Accurate B vertex and good PID required**





- **Puzzling DCPV in B→Kπ**

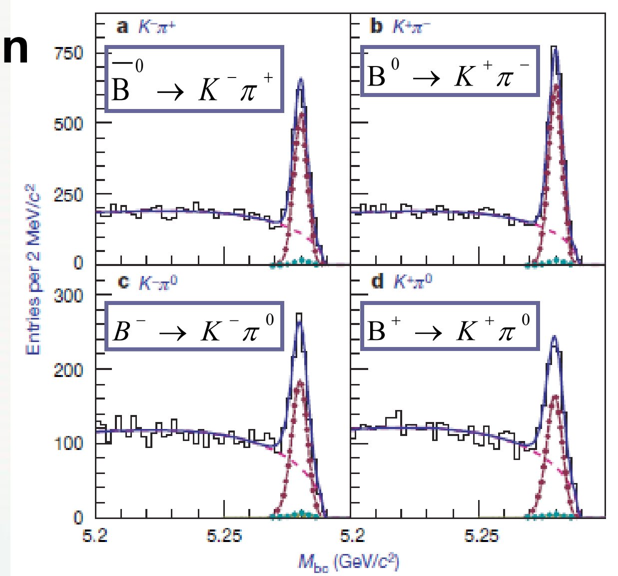
- **DCPV from interference between Tree and Penguin**

$$\Delta A \equiv A_{CP}^{B^0\to K^+\pi^-} - A_{CP}^{B^+\to K^+\pi^0} = -0.147 \pm 0.028$$

- **ΔA≈0 in SM, NP (or hadronic effects) can change it**
- **Model independent sum rule to test SM**

$$A_{CP}^{K^+\pi^-} + A_{CP}^{K^0\pi^+}\frac{\mathcal{B}(B^+\to K^0\pi^+)\tau_{B^0}}{\mathcal{B}(B^0\to K^+\pi^-)\tau_{B^+}} = A_{CP}^{K^+\pi^0}\frac{2\,\mathcal{B}(B^+\to K^+\pi^0)\tau_{B^0}}{\mathcal{B}(B^0\to K^+\pi^-)\tau_{B^+}} + A_{CP}^{K^0\pi^0}\frac{2\,\mathcal{B}(B^0\to K^0\pi^0)}{\mathcal{B}(B^0\to K^+\pi^-)}$$

M. Gronau, PLB627, 82 (2005); D. Atwood, A. Soni, PRD58, 036005 (1998)

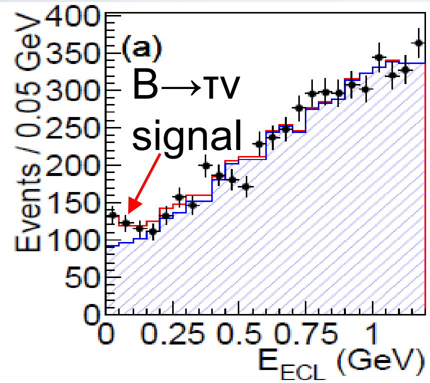


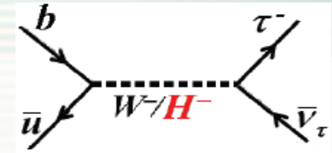
- **Good K_s^0 vertex, good ECL for π^0, good K/π separation**

Belle, Nature 452, 332 (2008)

NP-sensitive processes

❑ B→τν annihilation process

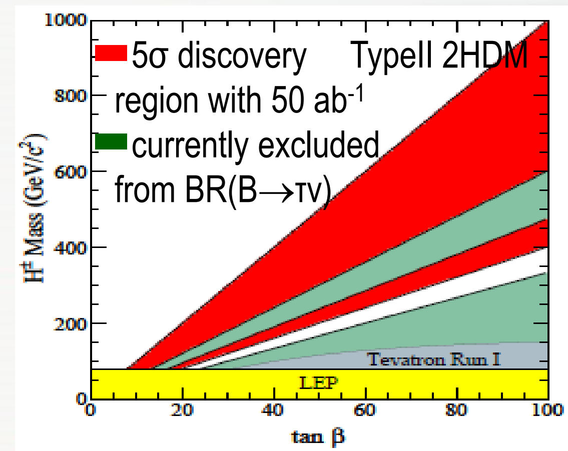




$$BR^{WA}(B \to \tau\nu_\tau) = (1.64 \pm 0.34) \times 10^{-4}$$
$$BR^{SM}(B \to \tau\nu_\tau) = (1.20 \pm 0.25) \times 10^{-4}$$

$$\frac{BR(B \to \tau\nu_\tau)}{BR^{SM}(B \to \tau\nu_\tau)} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

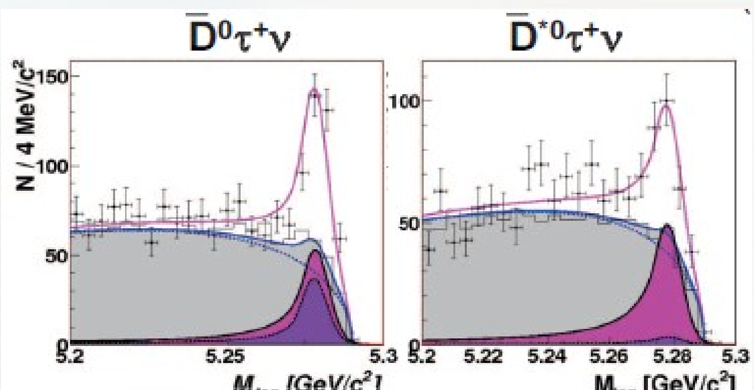
- **Increase of BR observed. Higgs contribution?**

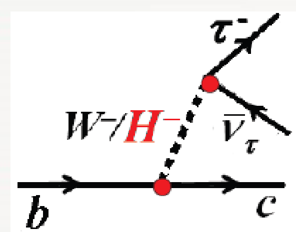


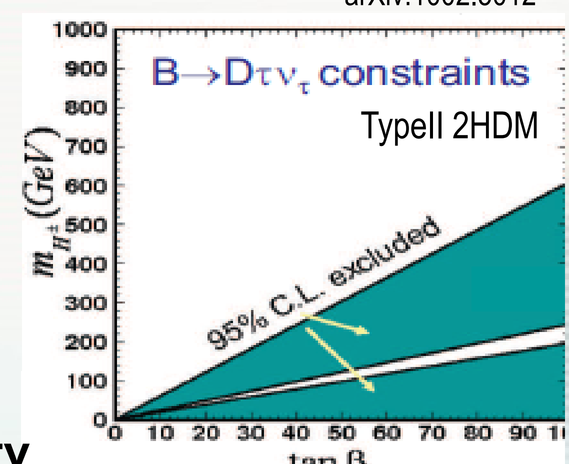
arXiv:1002.5012

- **Signal: null residual energy detected in ECL**
- **Improvement with NeuroBayes tagging**
- **Good performance of ECL needed**

❑ B→Dτν







- **complementary to B→τν and competitive with B →τν**

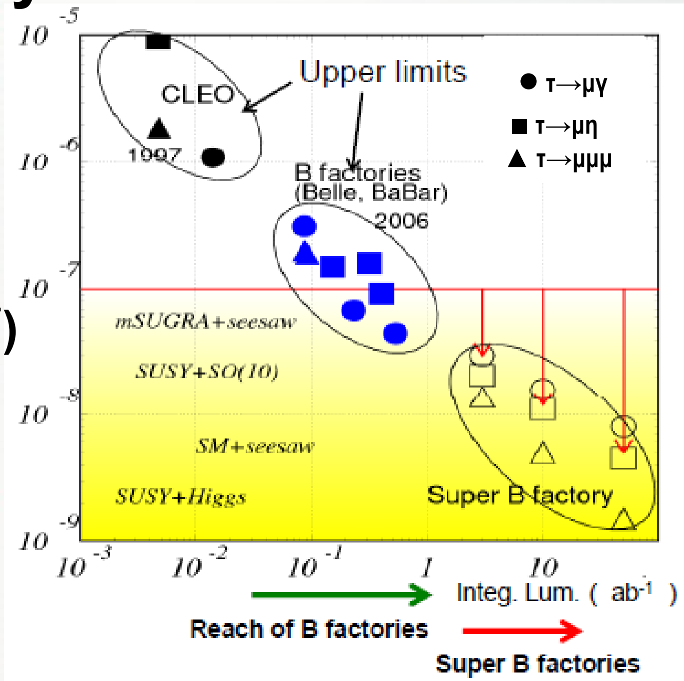
NP-sensitive processes

Lepton Flavour Violation in tau decays

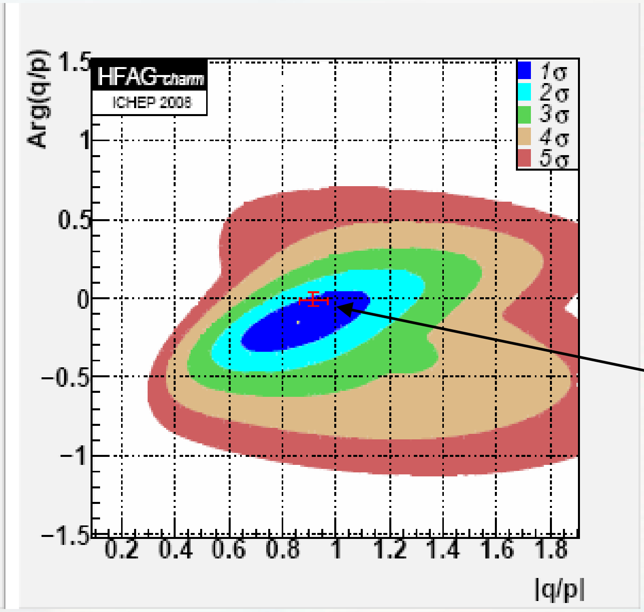
- Strongly suppressed in SM

$$\mathcal{B}(\tau \to l\gamma) = \frac{3\alpha}{32\pi} \left| \sum_i U^*_{\tau i} U_{\mu i} \frac{\Delta^2_{3i}}{m^2_W} \right|^2 \le 10^{-53} \sim 10^{-49}$$

- In BSM (SUSY, little Higgs) LFV up to $O(10^{-9}\text{-}10^{-7})$
- With $50 ab^{-1}$ sensitivity will reach $O(10^{-9})$



CPV in D decays



- CPV in SM: $O(10^{-3})$. Can be enhanced by NP
- With $50 ab^{-1}$: sensitivity of CPV asymmetries $O(10^{-4})$

Expected accuracy with $50 ab^{-1}$

KEKB milestones

06/1999: First physics run

05/2003: Design luminosity of $1\times10^{34}/cm^2/s$ achieved

01/2004: Operating in continuous injection mode

02/2005: $1.52\times10^{34}/cm^2/s$, $1fb^{-1}$ per day accumulated

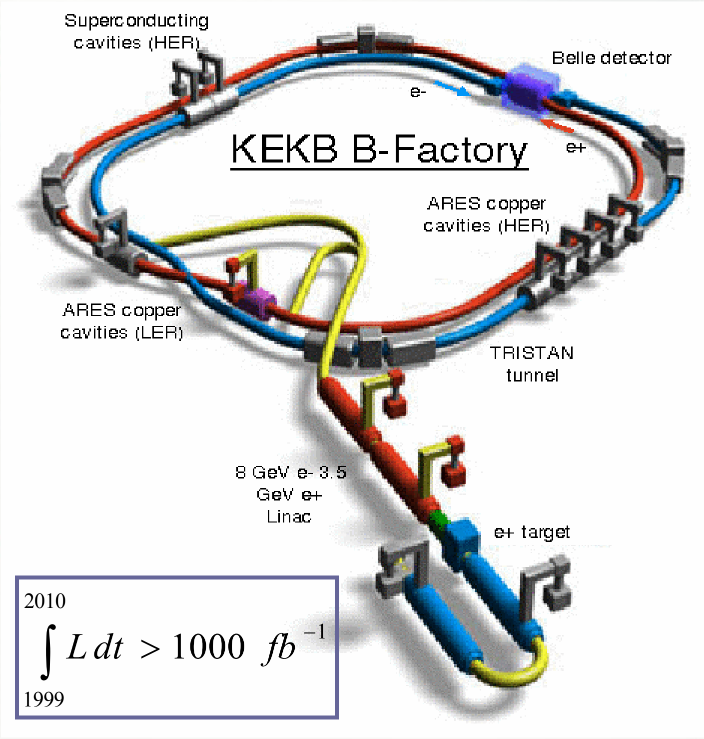
07/2007: First operation of crab cavities

05/2009: World luminosity record $2.1\times10^{34}/cm^2/s$

11/2009: Accumulated luminosity exceeded $1ab^{-1}$

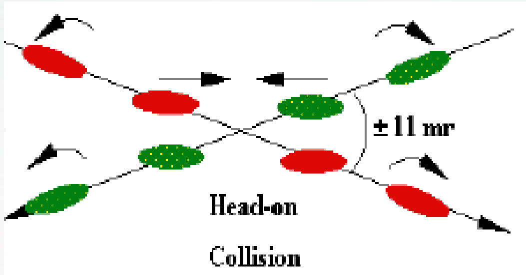
06/2010: Last physics run

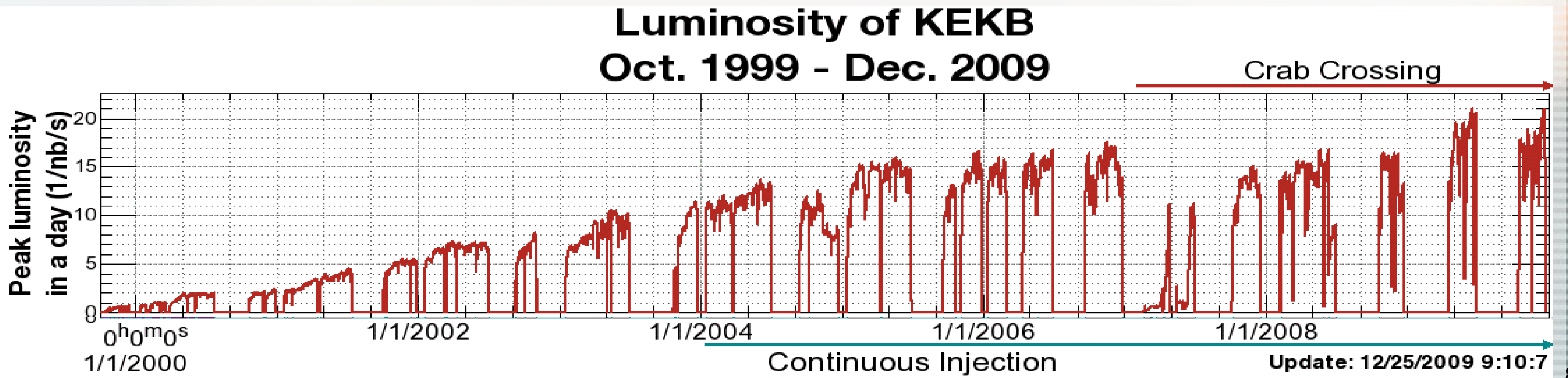
HER: 8.0GeV e^- LER: 3.5GeV e^+



$$\int_{1999}^{2010} L\,dt > 1000\ fb^{-1}$$

Crab cavities

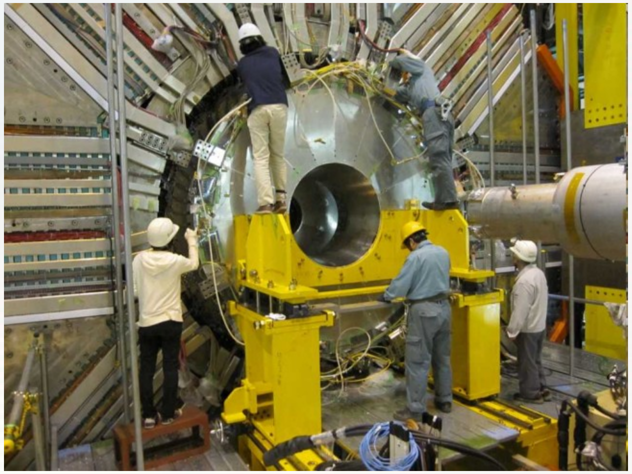


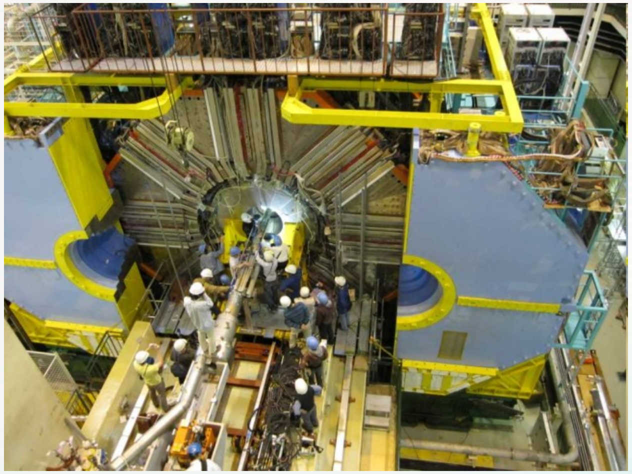


End of KEKB/Belle operation

- 30 June 2010: Last KEKB beam abort

- November 2010 - January 2011: Belle detector partial extraction





- All ready to start construction of SuperKEKB and Belle II

Super KEKB in nano-beam scheme

- To increase luminosity:

→ squeeze beams to nanometer scale and enlarge crossing angle (minimize β^*_y)

→ decrease beam emittance (keep current ξ_y)

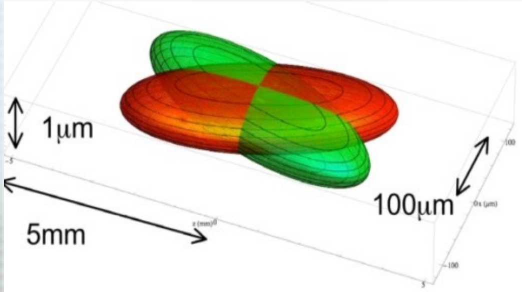
- Squeezing beams in stronger magnetic field saturated by hourglass effect

→ intersect bunches only at highly focused region

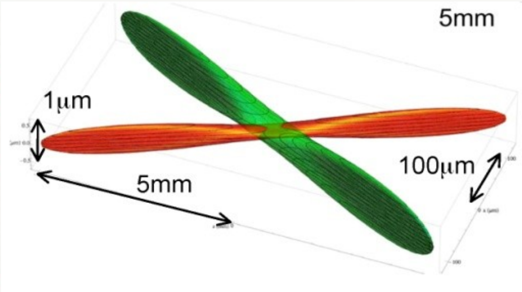
$$L = \frac{\gamma_\pm}{2 e r_e}\left(1 + \frac{\sigma^*_y}{\sigma^*_x}\right)\frac{I_\pm \xi_{y\pm}}{\beta^*_{y\pm}}\frac{R_L}{R_{\xi_y}}$$

I: beam current
β^*: envelope around trajectories at IP
$\xi_y \propto \sqrt{(\beta^*_y/\varepsilon_y)}$ beam-beam parameter
ε: beam emittance
σ^*: beam size $\propto \sqrt{(\beta^* \varepsilon)}$
$R_L, R_{\xi y}$: geometrical reduction factors (crossing angle, hourglass effect)

σ_x~100μm, σ_y~2μm

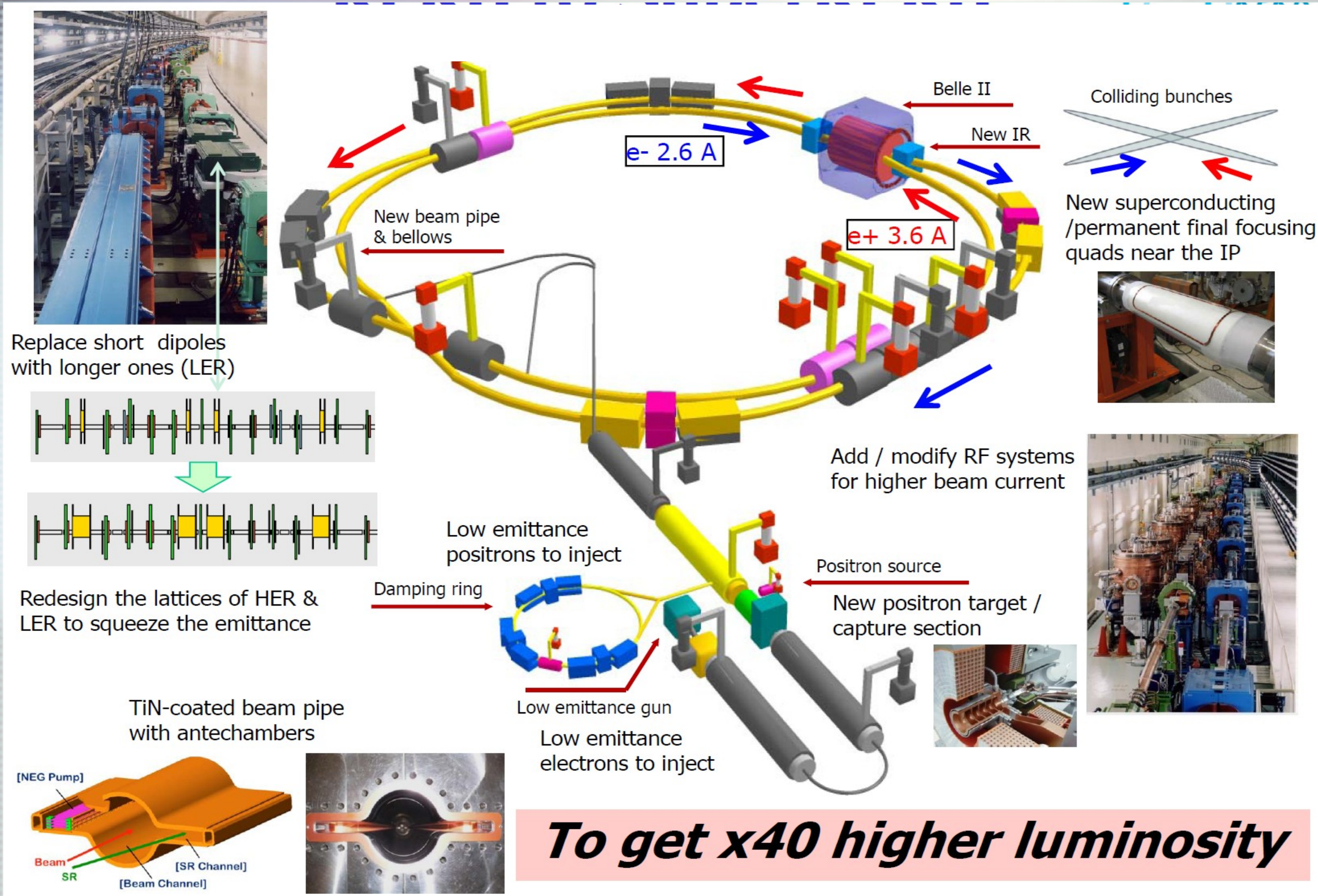


σ_x~10μm, σ_y~60nm

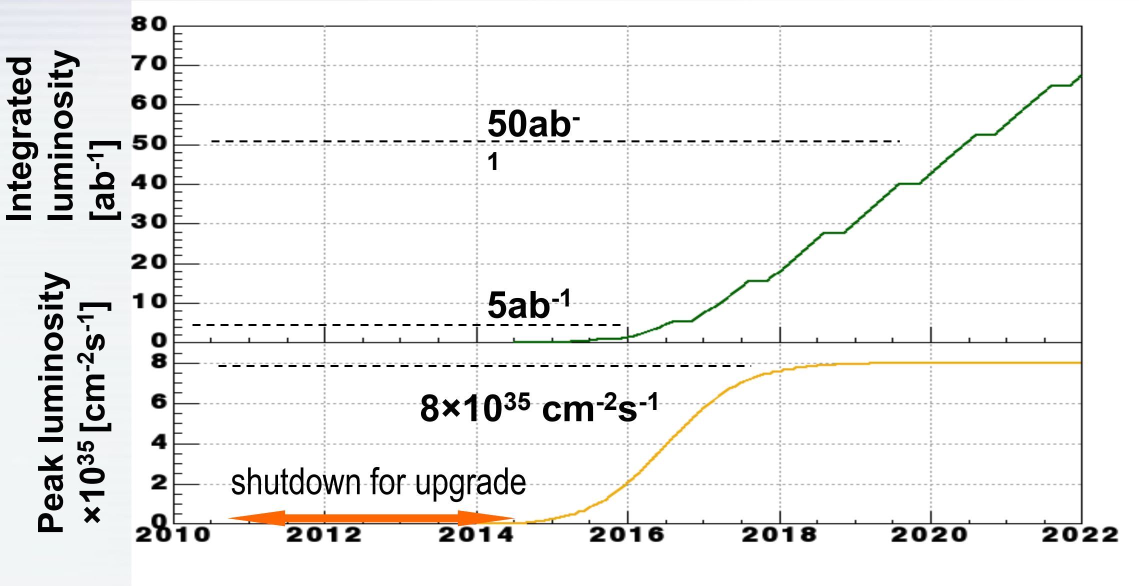


	E (GeV) e+/e-	β^*_y (mm) e+/e-	β^*_x (cm) e+/e-	ε_x (nm) e+/e-	$\varepsilon_y/\varepsilon_x$ e+/e-	φ (mrad)	I (A) e+/e-	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	18/24	0.88/0.66	11	1.6/1.2	2.1 x 10^{34}
Super KEKB	4.0/7.0	0.27/0.31	3.2/2.5	3.2/5.3	0.27/0.24	41.5	3.6/2.6	80x10^{34}

KEKB to SuperKEKB



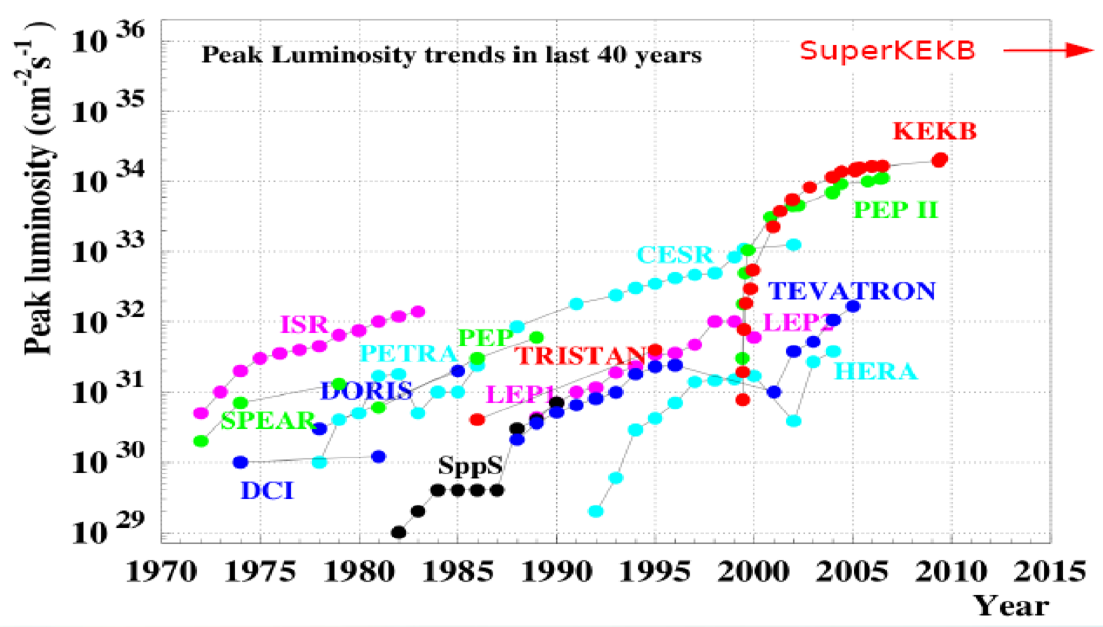
Foreseen luminosity increase



5 ab^{-1} in 2016

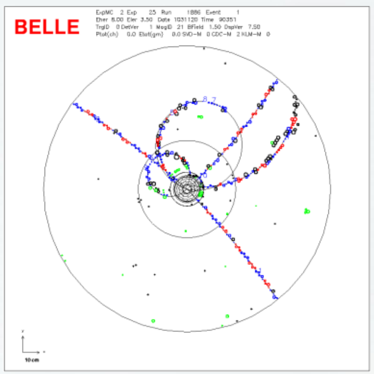
50 ab^{-1} in 2020/2021

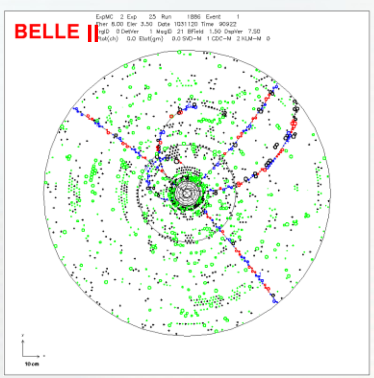
Commissioning will start in 2nd half of FY2014

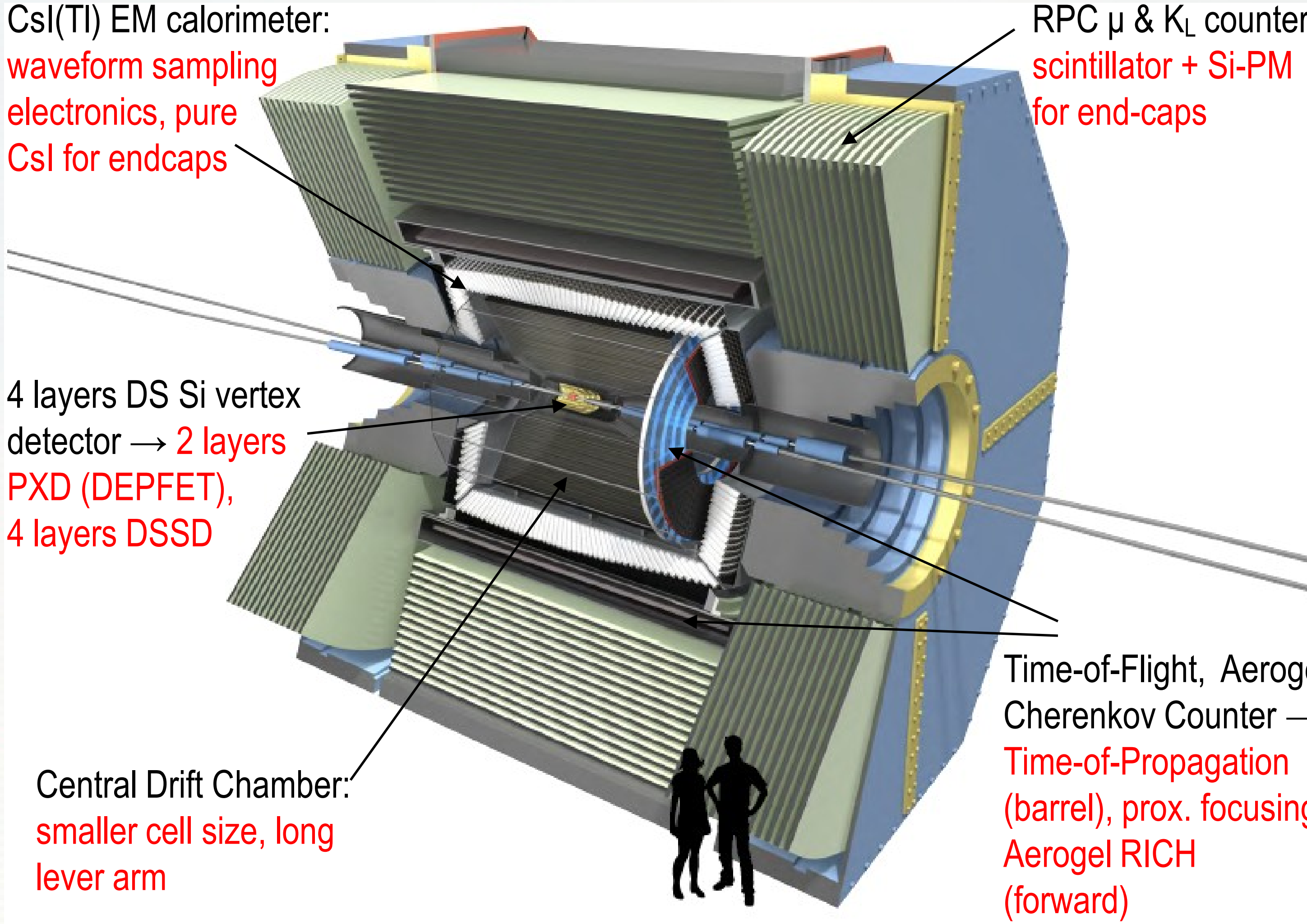


Belle II detector

- Deal with higher background (10-20×), radiation damage, higher occupancy, higher event rates (L1 trigg. 0.5→30 kHz)
- Improved performance and hermeticity

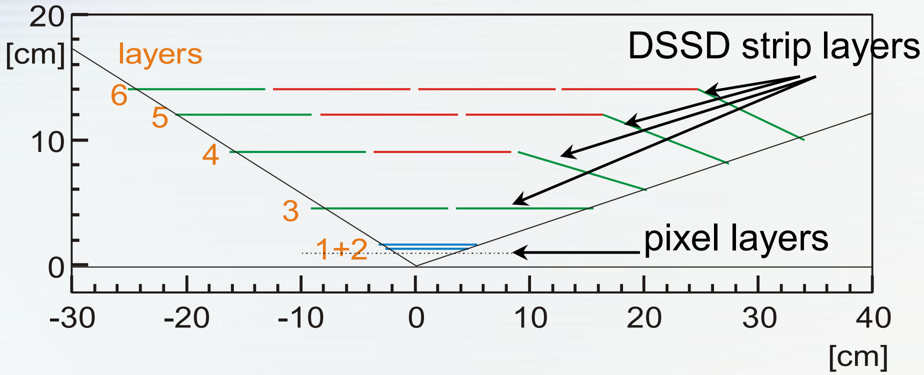


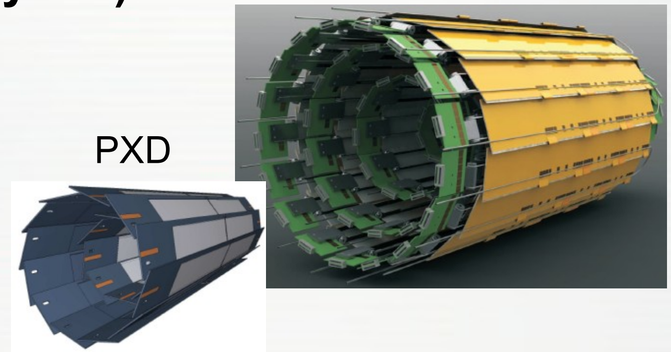




Vertexing with silicon pixels and strips

- PXD + SVD in Belle II (in Belle only strip layers)



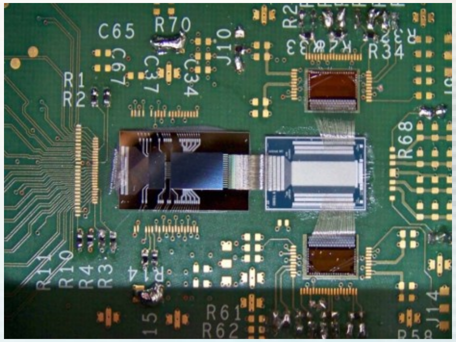


- Pixels based on DEPFET technology: thin (75μm) sensors → little multiple scattering, can deal with high occupancy close to the IP, fast readout
- Strip layers deal with <10% occupancy; useful in reducing bckgd. in PXD
- IP resolution σ_{z0}~50μm, improved reconstruction of p_T<100MeV tracks, 30% larger eff. of $K_s \rightarrow \pi^+\pi^-$ with vertex info

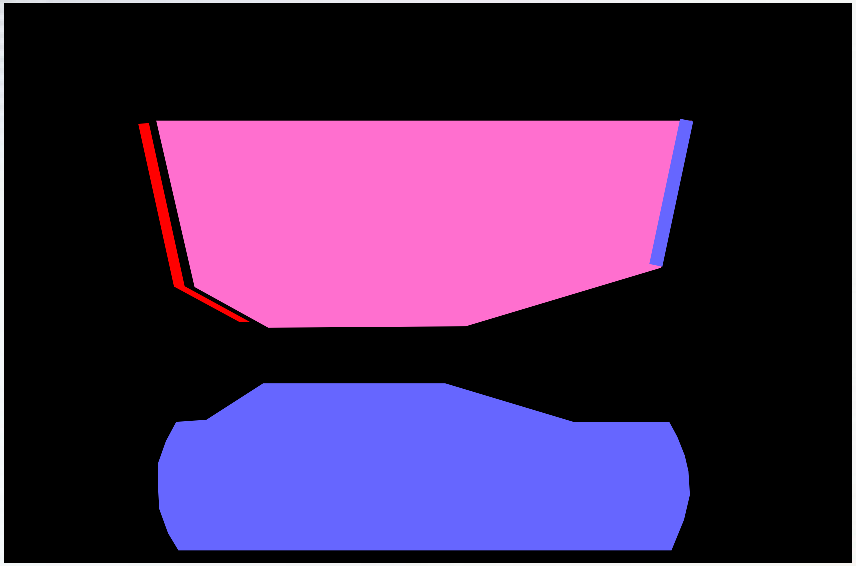
Mechanical mockup of pixel detector

DEPFET sensor

Prototype DEPFET pixel sensor and readout



Tracking with Central Drift Chamber

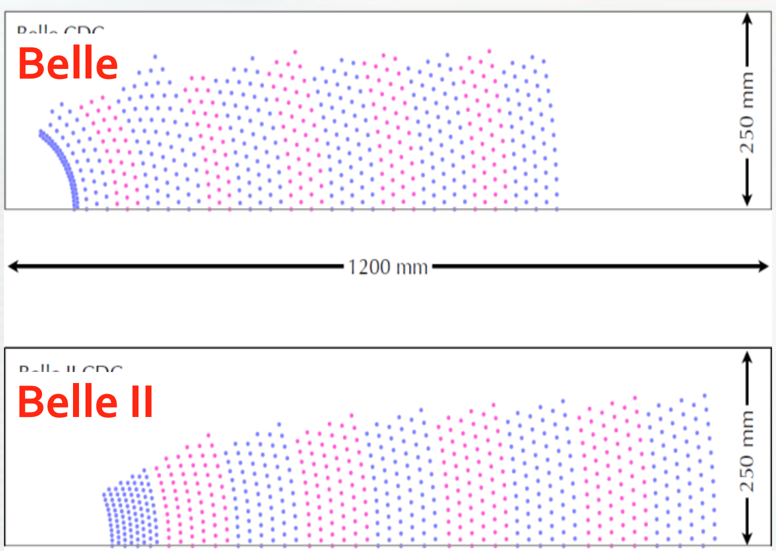


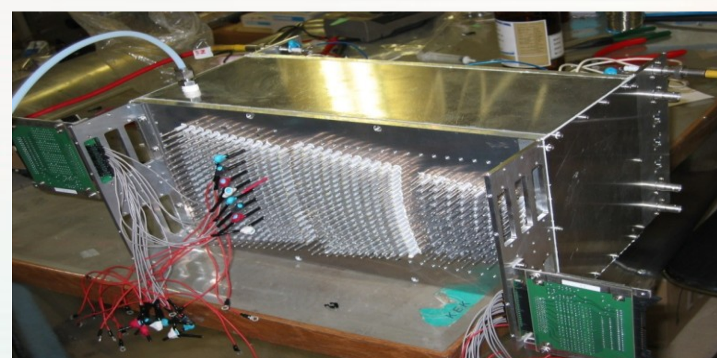
- Extended outer radius, longer lever arm, smaller cells near beampipe, faster readout electronics

- Maintains high efficiency and momentum resolution in spite of higher background

	Belle	Belle II
inner most sense wire	r=88mm	r=168mm
outer most sense wire	r=863mm	r=1111.4mm
Number of layers	50	56
Total sense wires	8400	14336
Gas	$He:C_2H_6$	$He:C_2H_6$
sense wire	W(Φ30μm)	W(Φ30μm)
field wire	Al(Φ120μm)	Al(Φ120μm)

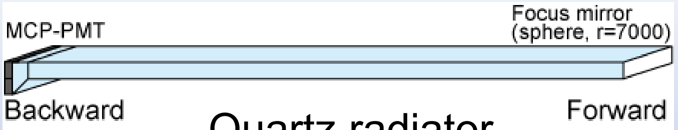
wire configuration





Particle identification

Barrel PID: Time of Propagation Counter



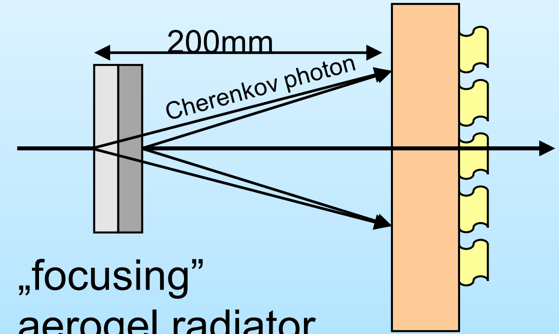
Quartz radiator

Focusing mirror

Small expansion block

Hamamatsu MCP-PMT (measure t, x and y)

Endcap PID: Aerogel RICH

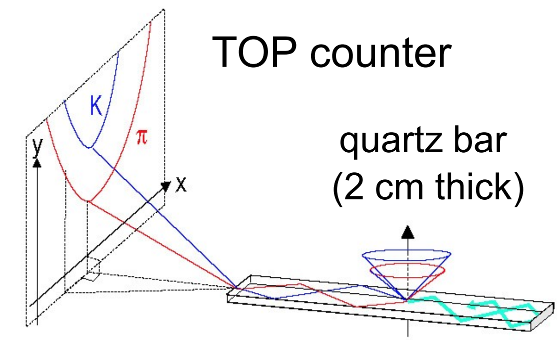


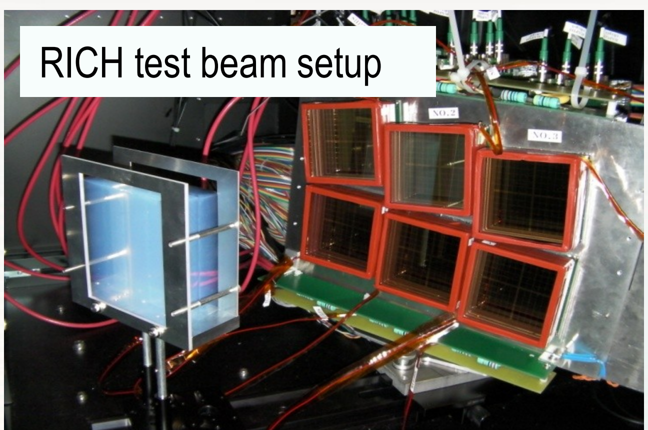
„focusing" aerogel radiator

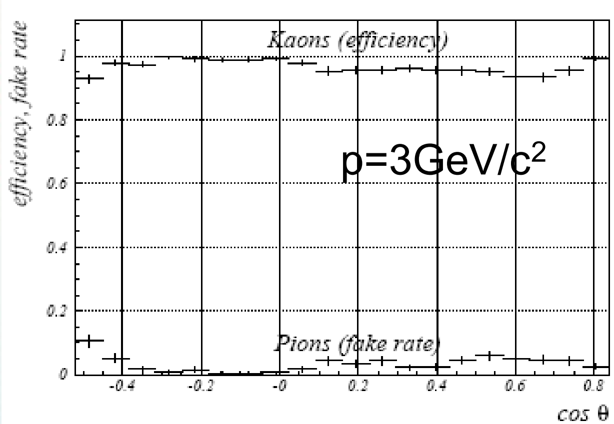
n~1.05

Hamamatsu HAPD + new ASIC

- **TOP: reconstructs Cherenkov rings from 3D info from PMTs: x,y and time of photon propagation (40 ps resolution)**
- **ARICH: measures Cherenkov angle. Inhomogeneous aerogel radiator to improve photon resolution**
- **Improved K/π separation in wide momentum range**

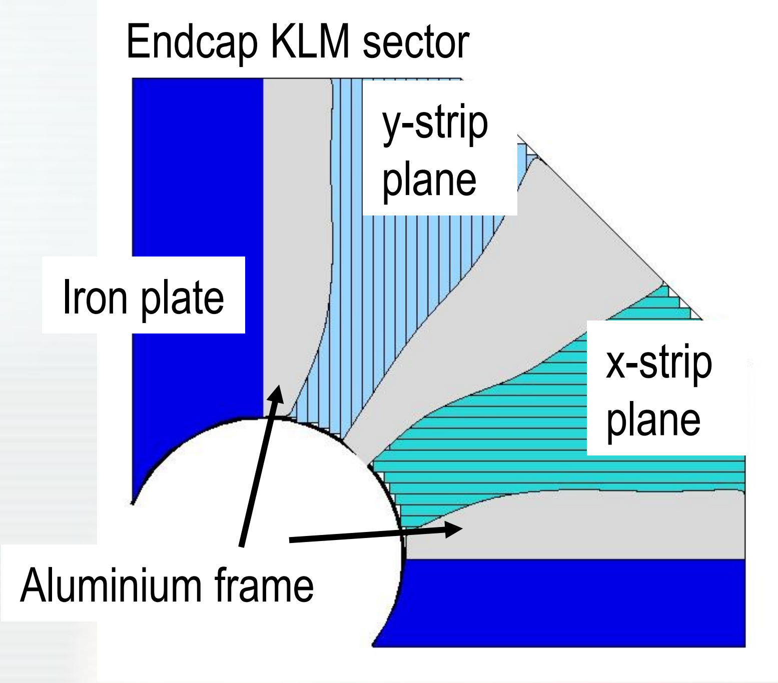


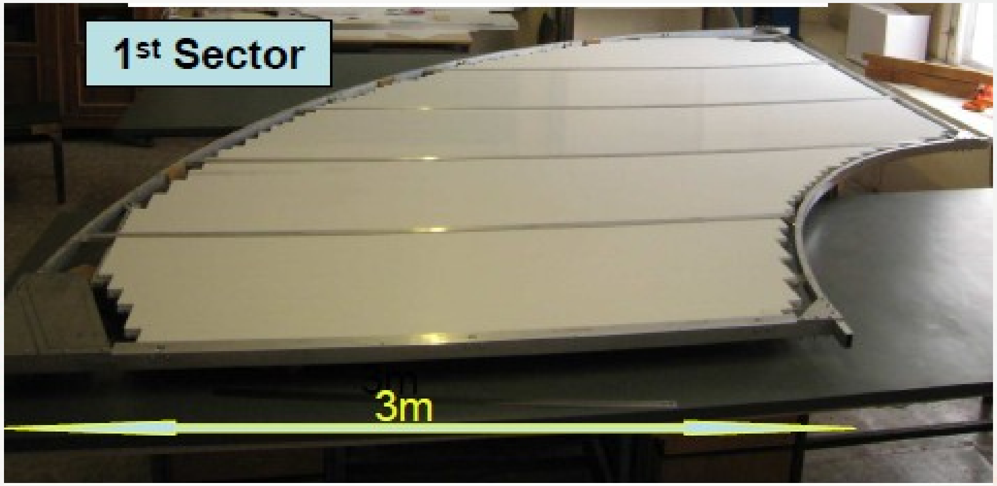


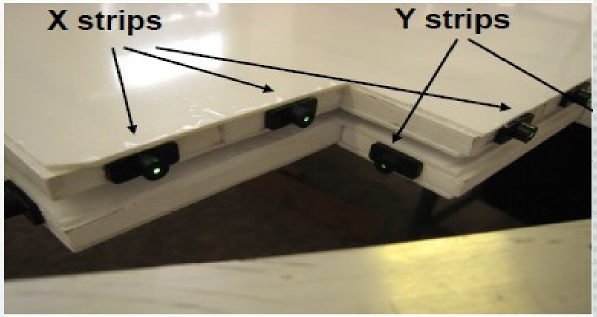


K_L - μ detection with KLM

- End-caps upgrade: Resistive Plate Chambers ⇨ scintillator- based KLM
- 20x background increase in RPCs (worse shielding of neutrons along beams)
- Scintillators + SiPM: better beam-background tolerance
- Barrel KLM: some RPC layers may be replaced as background increases with luminosity







Upgrade approved

一般向けページ >> 研究者向けページ >> English Pages >>

大学共同利用機関法人 KEK 高エネルギー加速器研究機構

Press Release

Top | Access | For Visitors | Map & Guide | Document | Site Map | Search

>Top >PressRelease >this page

last update: 10/06/23

Press Release

KEKB upgrade plan has been approved

June 23, 2010
High Energy Accelerator Research Organization (KEK)

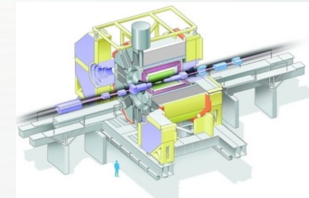
The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government.

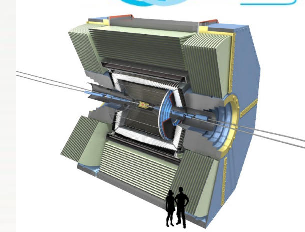
"We are delighted to hear this news," says Masanori Yamauchi, former spokesperson for the Belle experiment and currently a deputy director of the Institute of Particle and Nuclear Studies of KEK. "This three- year upgrade plan allows the Belle experiment to study the physics from decays of heavy flavor particles with an unprecedented precision. It means that KEK in Japan is launching a renewed research program in search for new physics by using a technique which is complementary to what is employed at LHC at CERN."

Summary

- Belle II will search for New Physics in B, D and τ decays with high sensitivity and complementary to LHCb
- Belle II physics in more details: arXiv:1002.5012

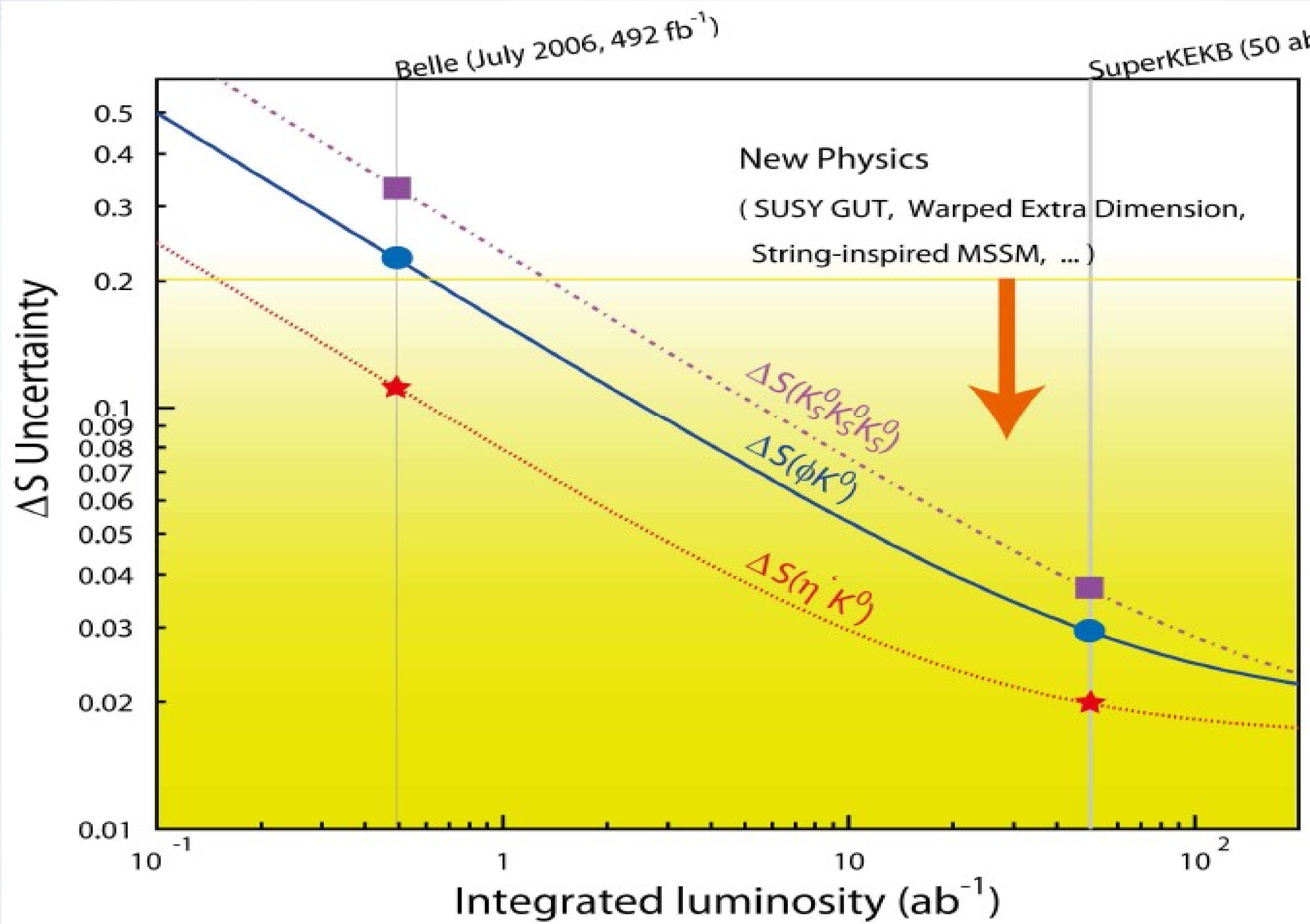
- Upgrade of KEKB and Belle in progress
- TDR published: arXiv:1011.0352v1 [physics.ins-det]
- Belle II will start data taking in JFY2014
- Aim at 50ab^{-1} by 2020/2021





Backup

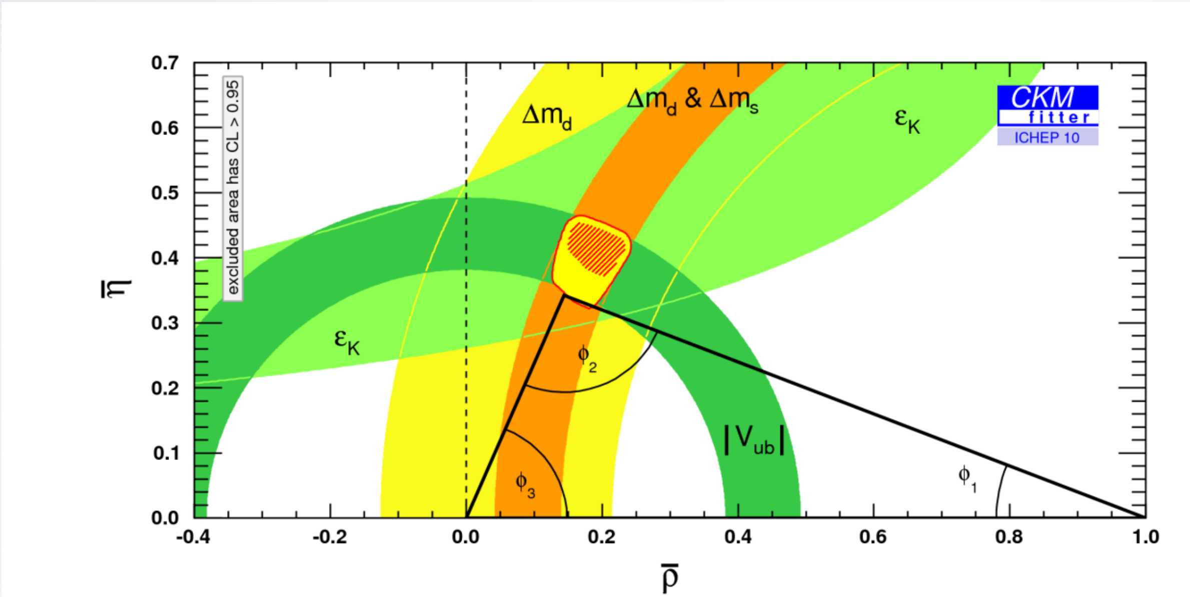
Backup



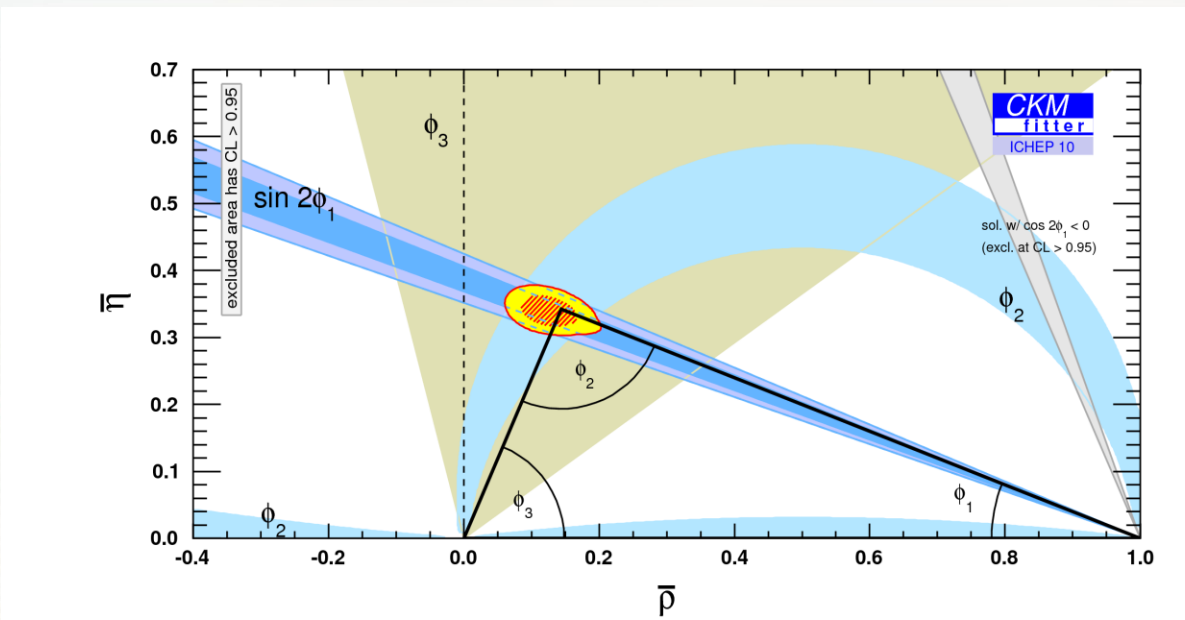
Belle (July 2006, 492 fb^{-1})
SuperKEKB (50 ab
New Physics
(SUSY GUT, Warped Extra Dimension,
String-inspired MSSM, ...)
$\Delta S(K_S^0 K_S^0 K_S^0)$
$\Delta S(\phi K^0)$
$\Delta S(\eta' K^0)$
ΔS Uncertainty
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
10^{-1}
1
10
10^2
Integrated luminosity (ab^{-1})

Unitarity triangle

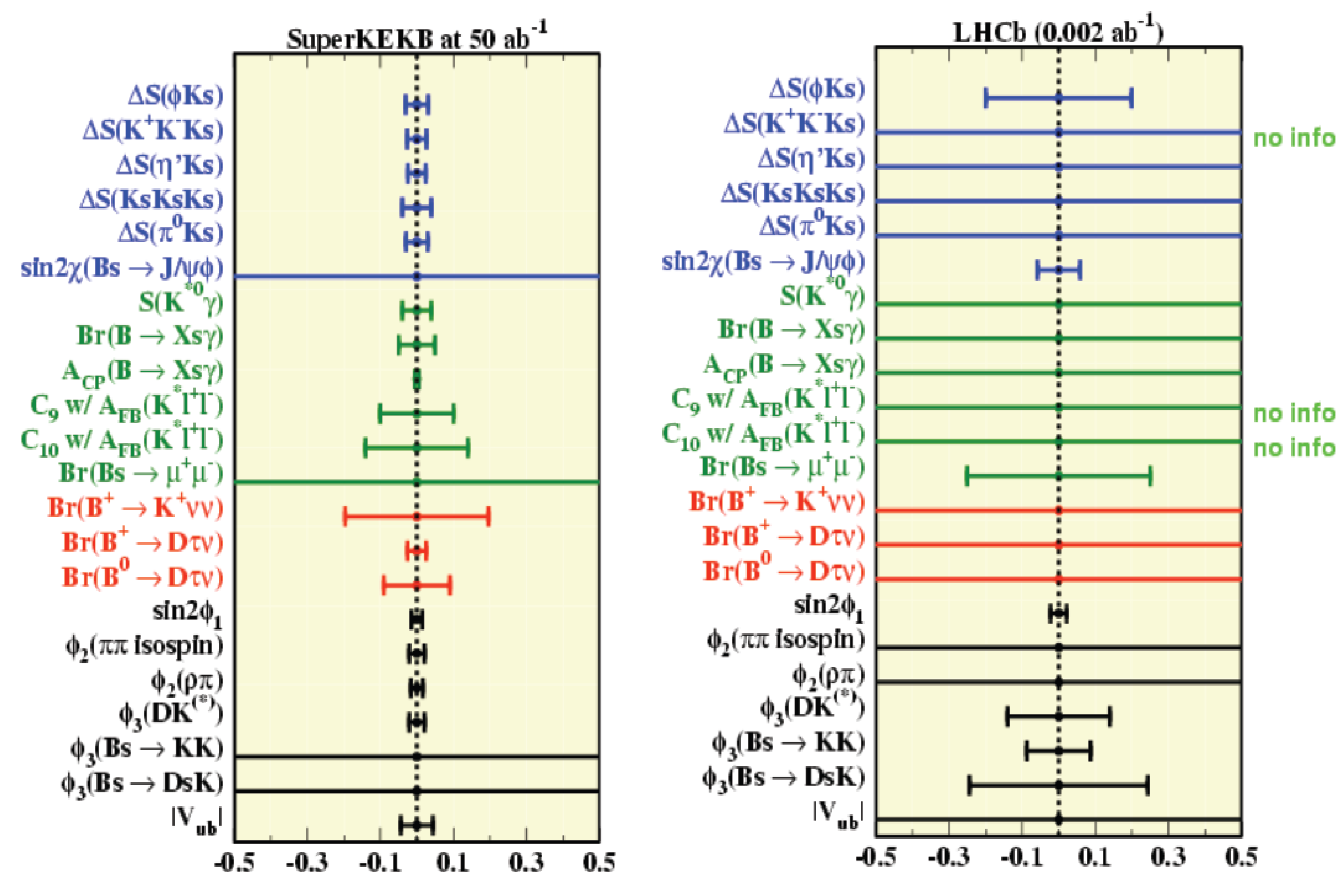
- w/o angles



- only angles



Backup



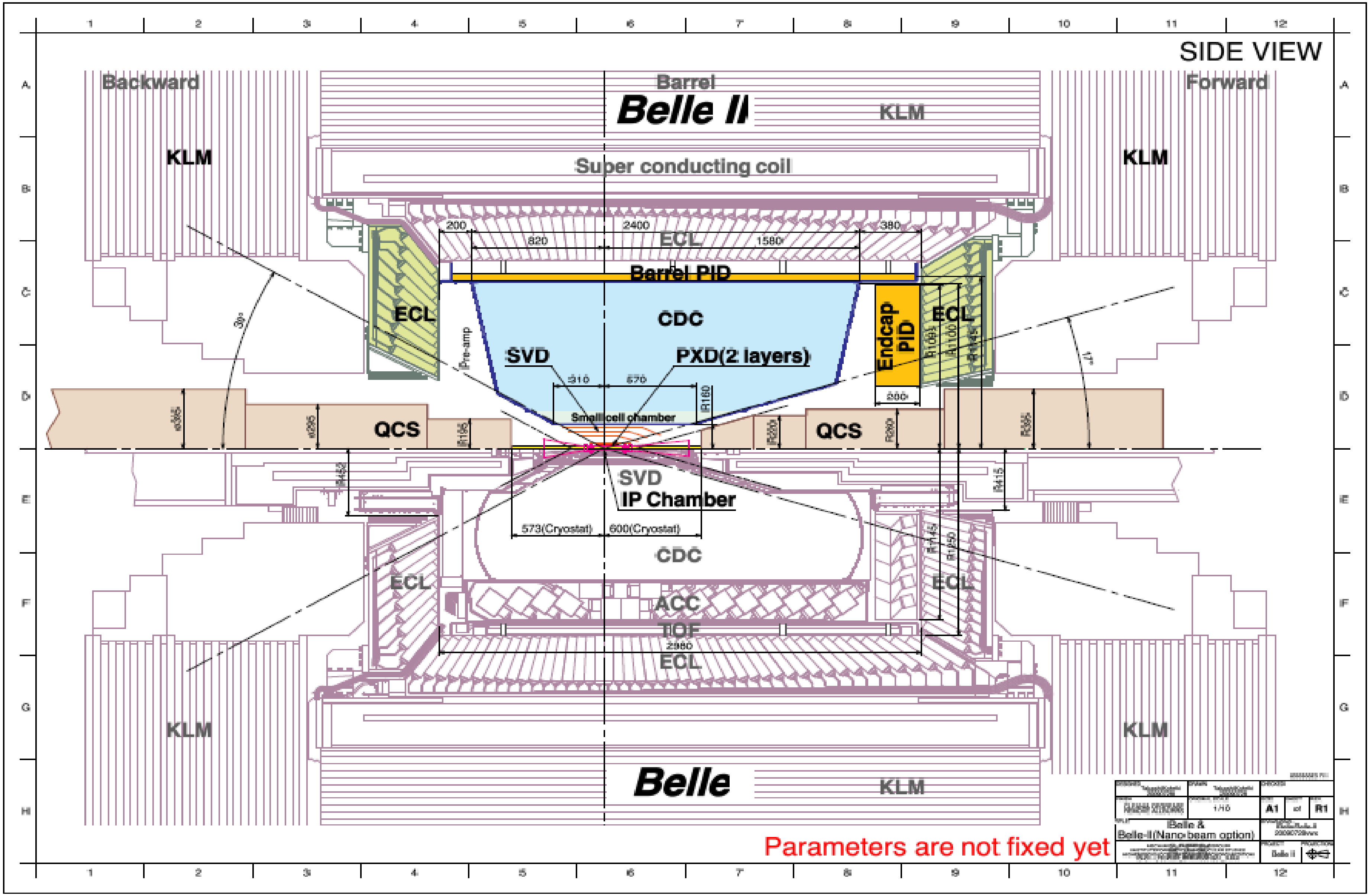
SuperKEKB at 50 ab^{-1}
LHCb (0.002 ab^{-1})
ΔS(φKs)
ΔS(K$^+$K$^-$Ks)
ΔS(η'Ks)
ΔS(KsKsKs)
ΔS(π^{0}Ks)
sin2χ(Bs → J/ψφ)
S(K^{*0}γ)
Br(B → Xsγ)
A$_{CP}$(B → Xsγ)
C$_9$ w/ A$_{FB}$(K*l$^+$l$^-$)
C$_{10}$ w/ A$_{FB}$(K*l$^+$l$^-$)
Br(Bs → μ$^+$μ$^-$)
Br(B$^+$ → K$^+$νν)
Br(B$^+$ → Dτν)
Br(B^0 → Dτν)
sin2φ$_1$
φ$_2$(ππ isospin)
φ$_2$(ρπ)
φ$_3$(DK$^{(*)}$)
φ$_3$(Bs → KK)
φ$_3$(Bs → DsK)
|V$_{ub}$|
-0.5 -0.3 -0.1 0.1 0.3 0.5
no info
no info
no info

Challenges in accelerator design

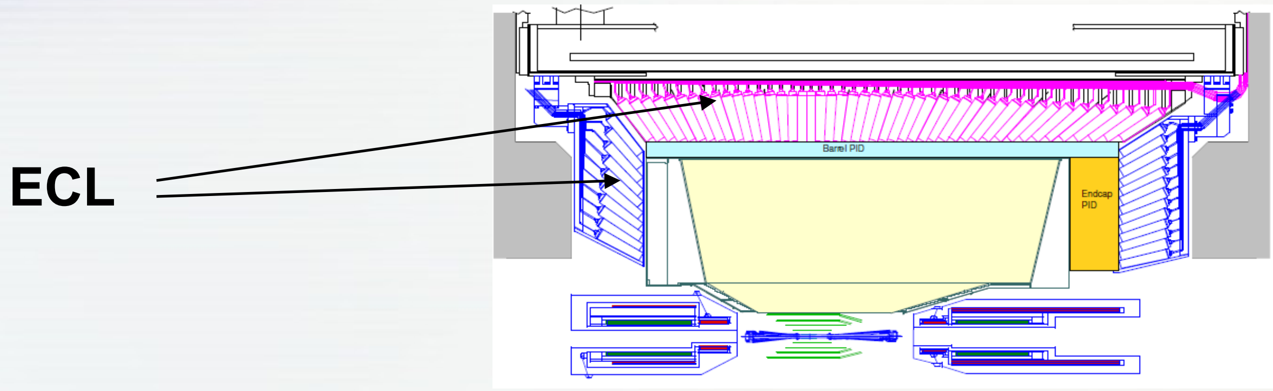
	E (GeV) e+/e-	β^*_y (mm) e+/e-	β^*_x (cm) e+/e-	ε_x (nm) e+/e-	$\varepsilon_y/\varepsilon_x$ e+/e-	φ (mrad)	I (A) e+/e-	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	18/24	0.88/0.66	11	1.6/1.2	2.1×10^{34}
Super KEKB	4.0/7.0	0.27/0.31	3.2/2.5	3.2/5.3	0.27/0.24	41.5	3.6/2.6	80×10^{34}

- Nanometer beams ⇨ special final focus in interaction region
- Low emittance beam ⇨ new design of magnet lattice, better beam source
- Higher beam currents ⇨ deal with vacuum issues
- Increase dynamic aperture and τ_{beam} (target 600 s) ⇨ lower beam asymmetry, final focus closer to IP, chromaticity correction

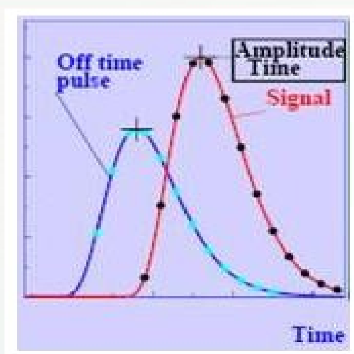
Belle II detector

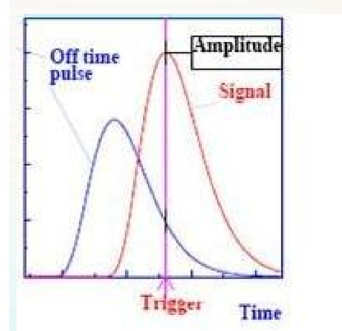


Electromagnetic Calorimeter

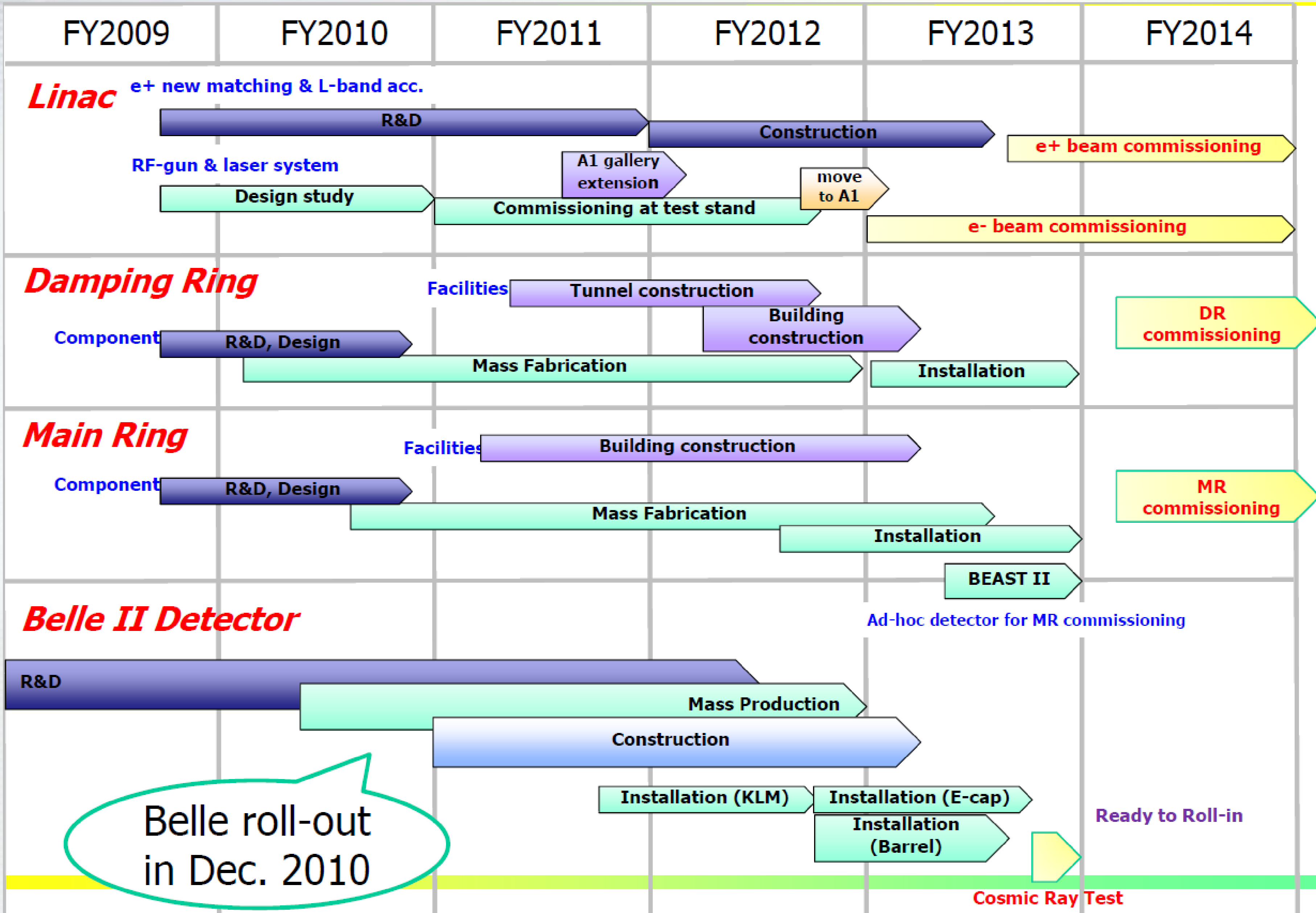


- Background: pile up noise by soft background photons, fake clusters from high energy photons 10 times higher
- Background in endcaps is high due to high radiation dose
  → Replace CsI(TI) with pure CsI in endcaps
- New electronics with waveform sampling to measure time and amplitude: fake clusters suppresed by factor 7
- Expected performance:
  5-10% lower efficiency with similar S/B level

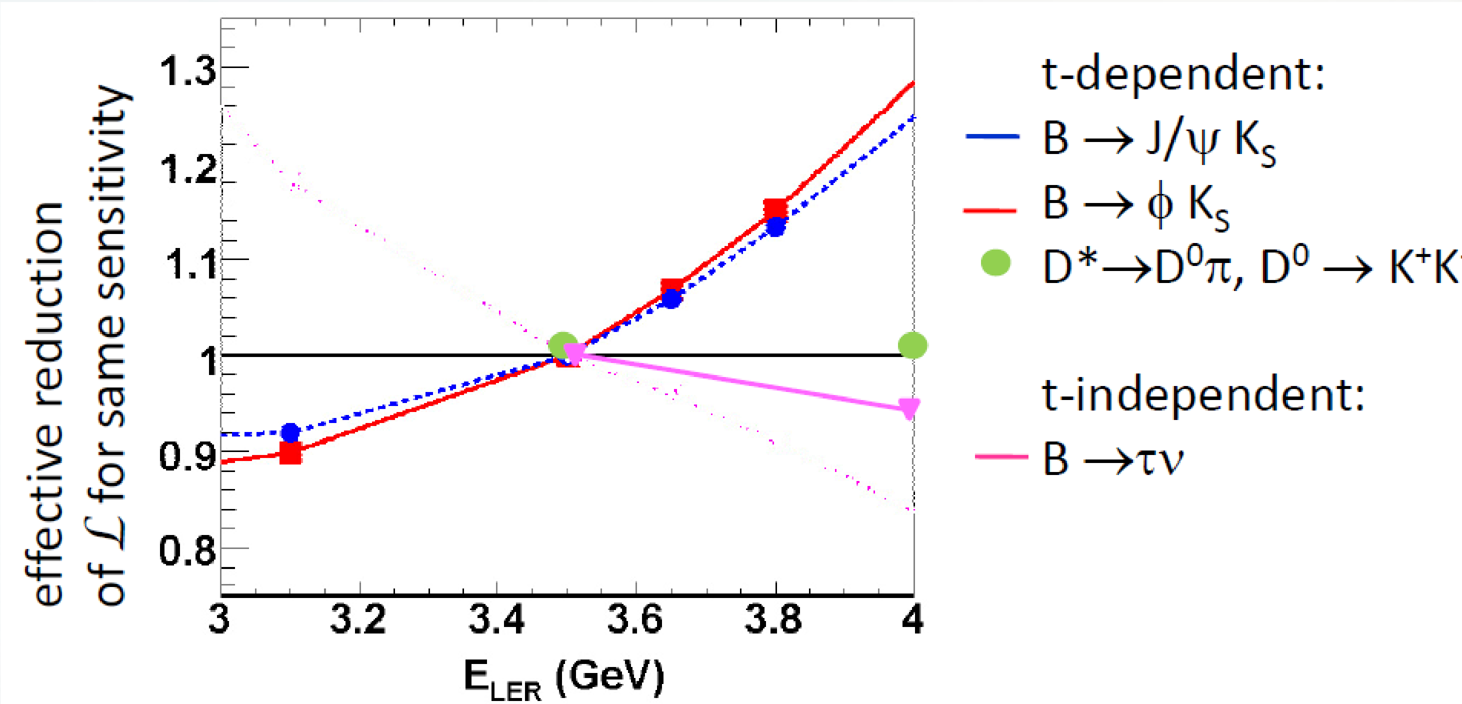




Construction Schedule



Impact of lower boost



Backup

p-channel FET on a completely depleted bulk

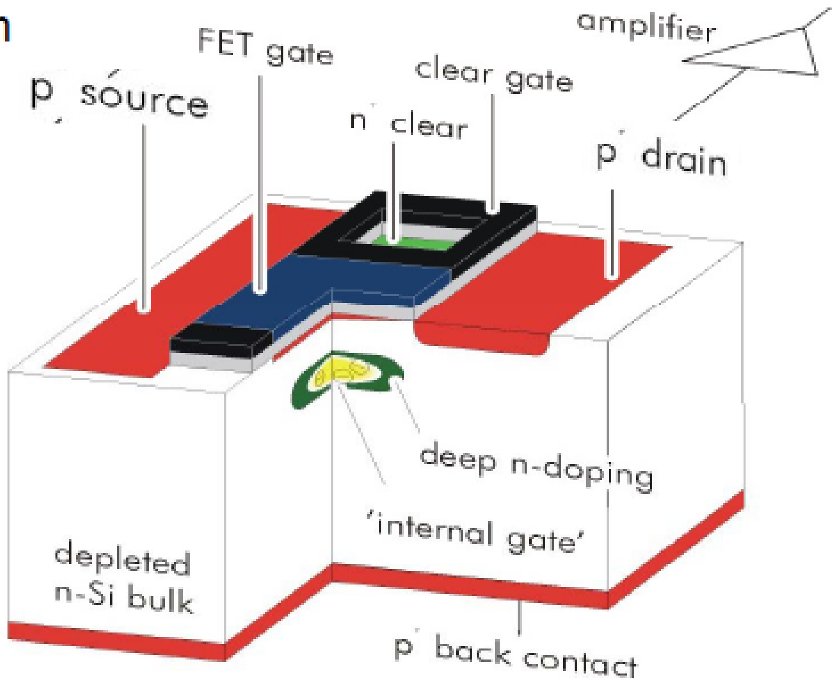
A deep n-implant creates a potential minimum for electrons under the gate ("internal gate")

Signal electrons accumulate in the internal gate and modulate the transistor current (g_q ~ 400 pA/e$^-$)

Accumulated charge can be removed by a clear contact ("reset")

Invented in MPI Munich

Depleted p-channel FET



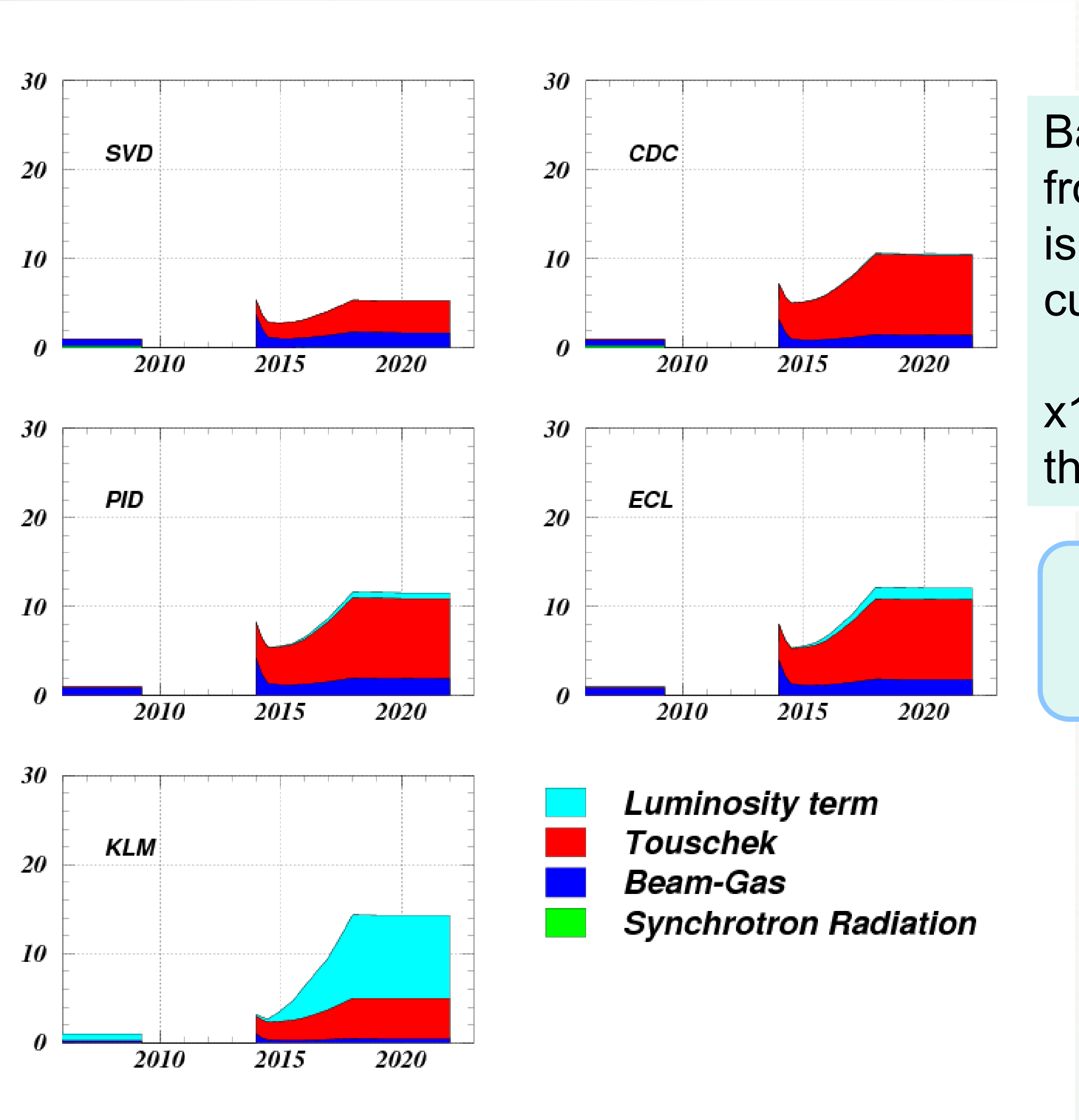
Fully depleted:
→ large signal, fast signal collection

Low capacitance, internal amplification → low noise

Transistor on only during readout: low power

Complete clear → no reset noise

Beam background



Background composition derived from background study data, which is then scaled by Luminosity, beam current etc.

x10 to x20 as large background as that of 2003 conditions (~severest)

Similar or Higher detector performance even under x20 bkg

Title

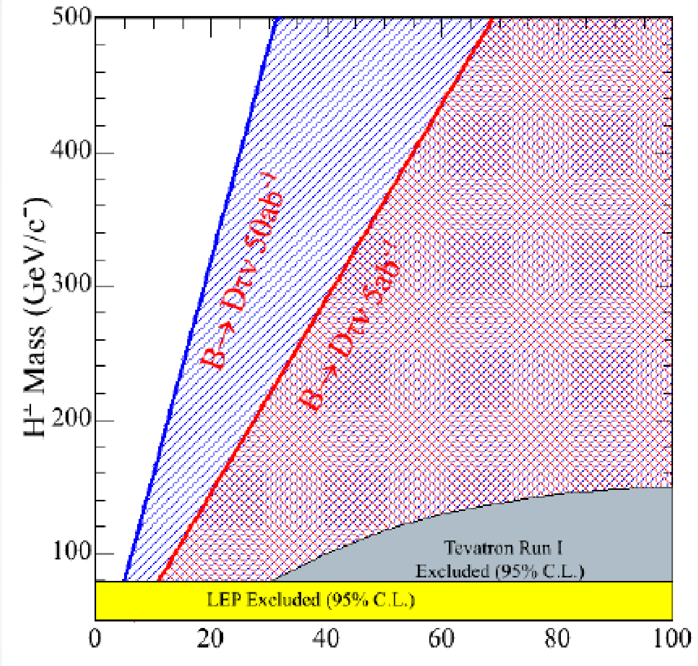
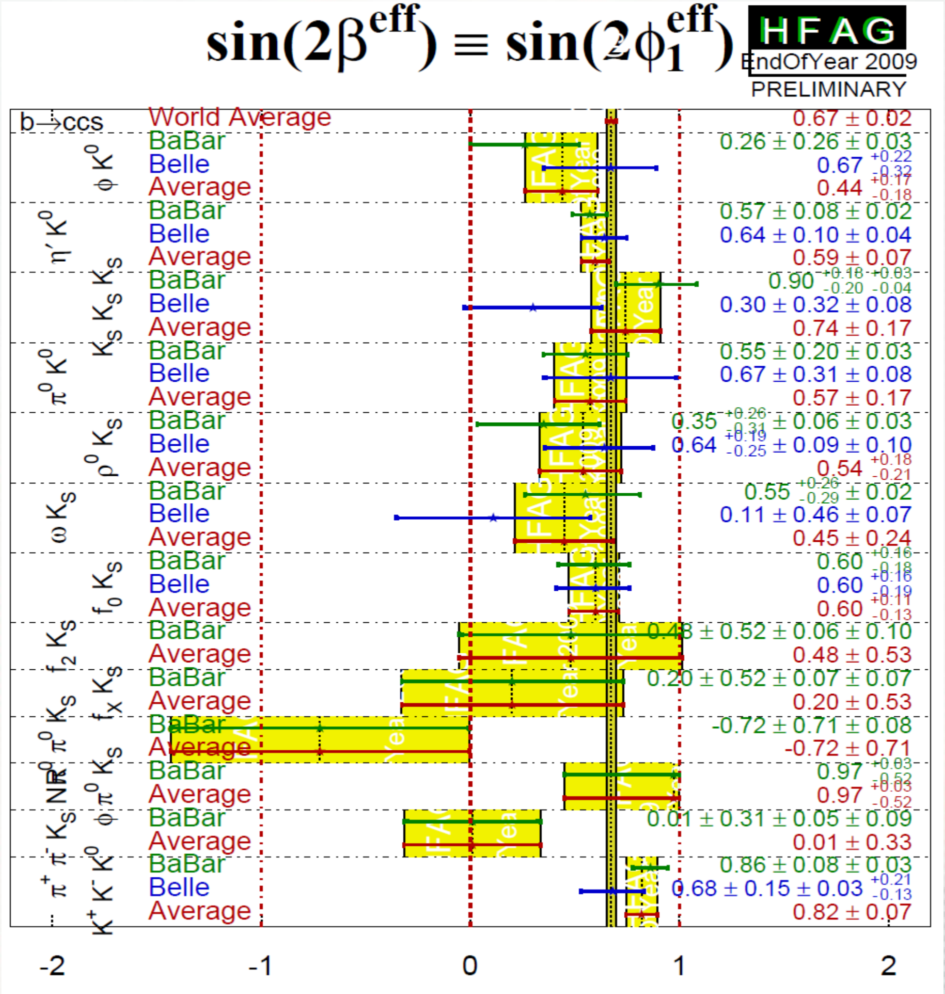
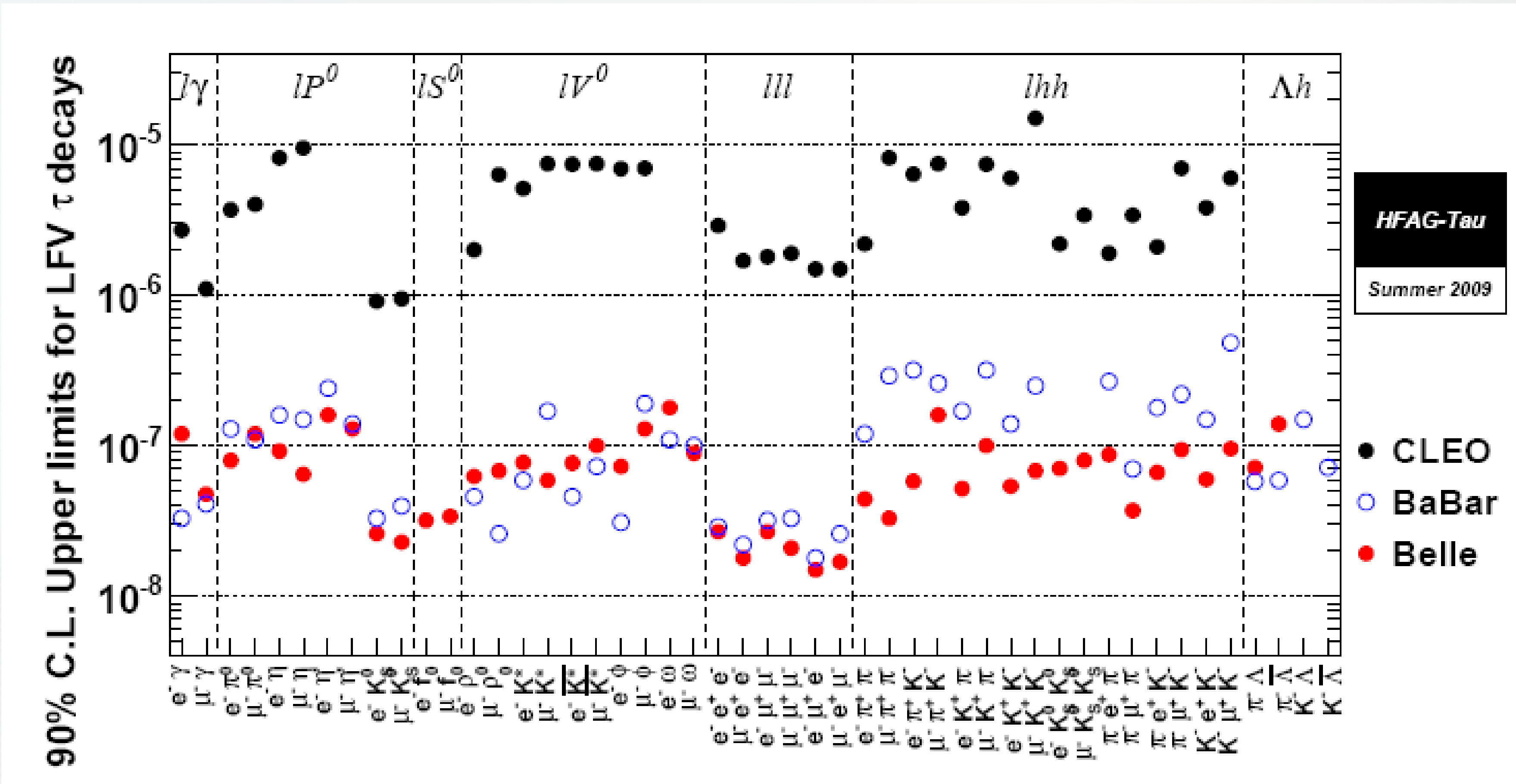


Figure 5.28: Exclusion boundaries in the $[M_{H^+}, \tan\beta]$ plane compared with other experimental searches at LEP and at the Tevatron.

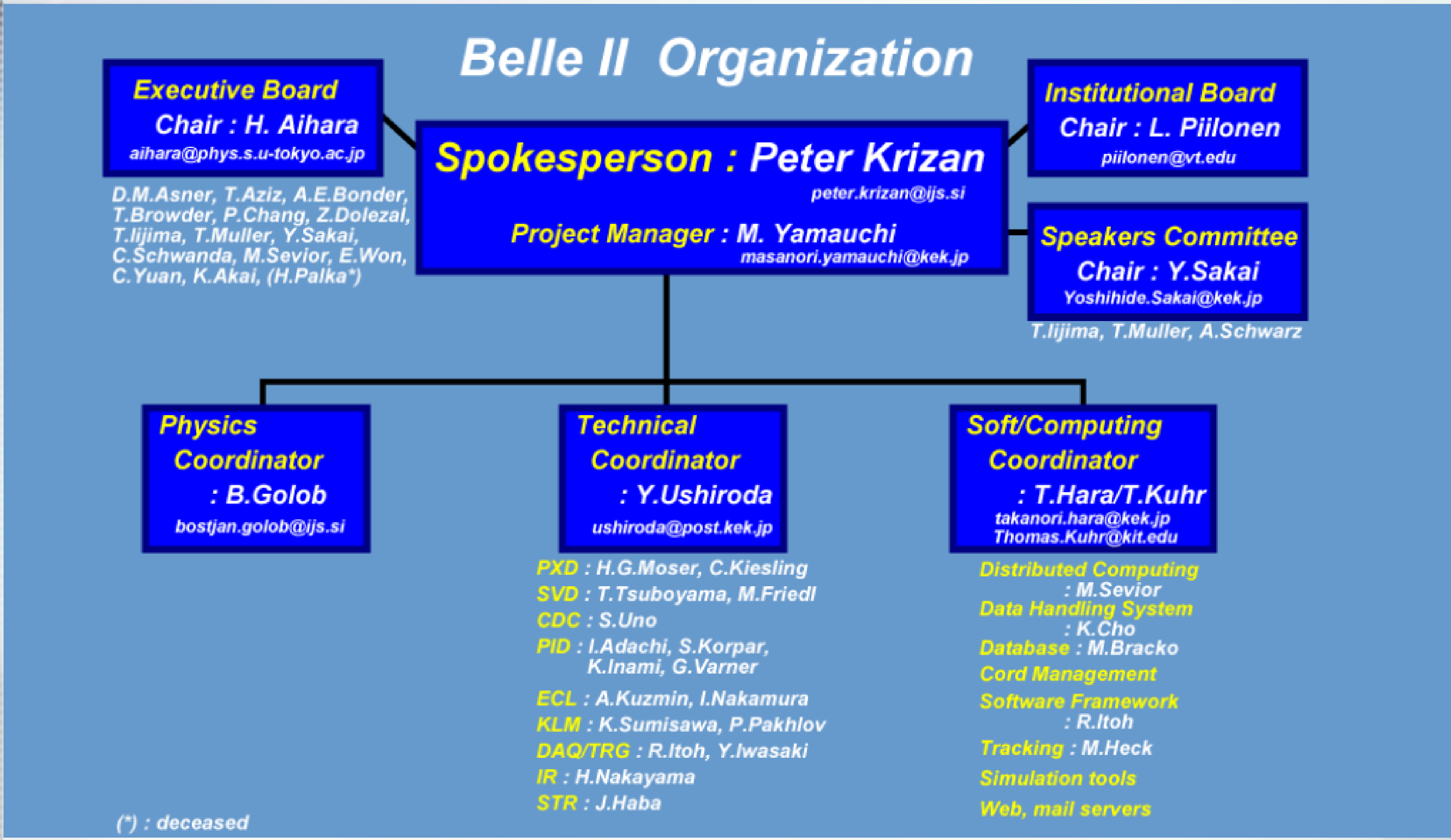


LFV

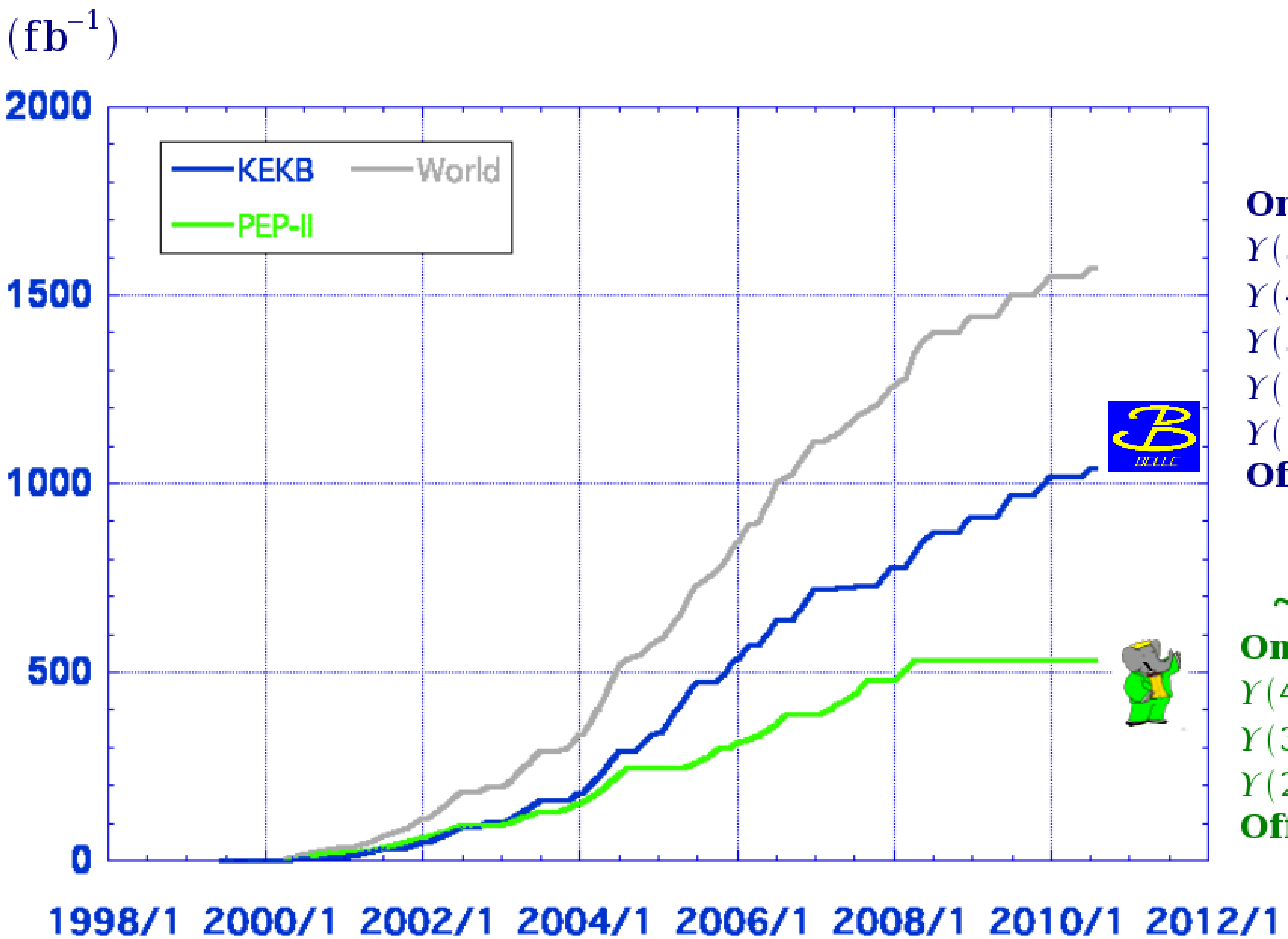


90% C.L. Upper limits for LFV τ decays
lγ
lP0
lS0
lV0
lll
lhh
Λh
10-5
10-6
10-7
10-8
HFAG-Tau
Summer 2009
CLEO
BaBar
Belle

Organization



Luminosity at B Factories



> 1 ab^{-1}

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1}

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 24 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan:

~ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

$\Upsilon(4S)$: 433 fb^{-1}

$\Upsilon(3S)$: 30 fb^{-1}

$\Upsilon(2S)$: 14 fb^{-1}

Off resonance:

~ 54 fb^{-1}