Super KEKB / Belle II Project

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University of Ljubljana
"Jožef Stefan" Institute

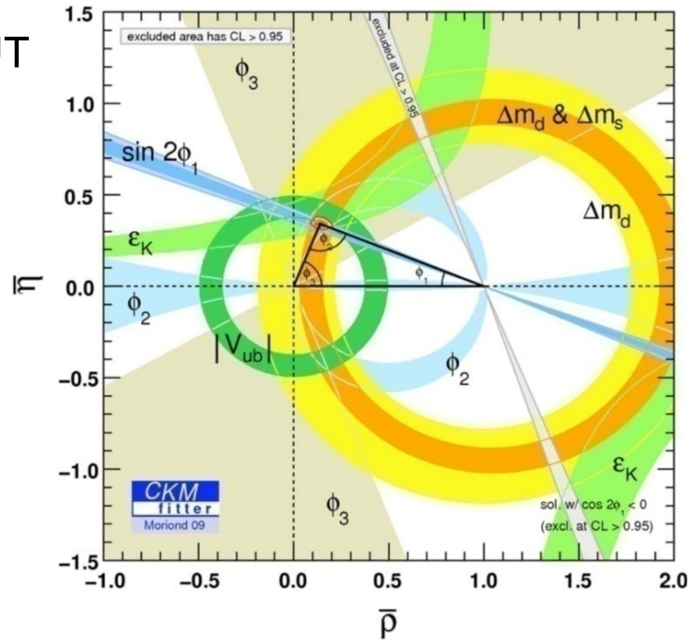
BELLE
Belle II

1. KEKB ⇨ SuperKEKB
2. Belle ⇨ Belle II
   - vertexing
   - PID
   - EM Calorimeter
     - examples of physics
     - reach "on the fly"
3. Summary

Les Recontres de Physique de la Valee d'Aoste,
La Thuile, Feb 28 – Mar 6, 2010

Introduction

global fit to UT



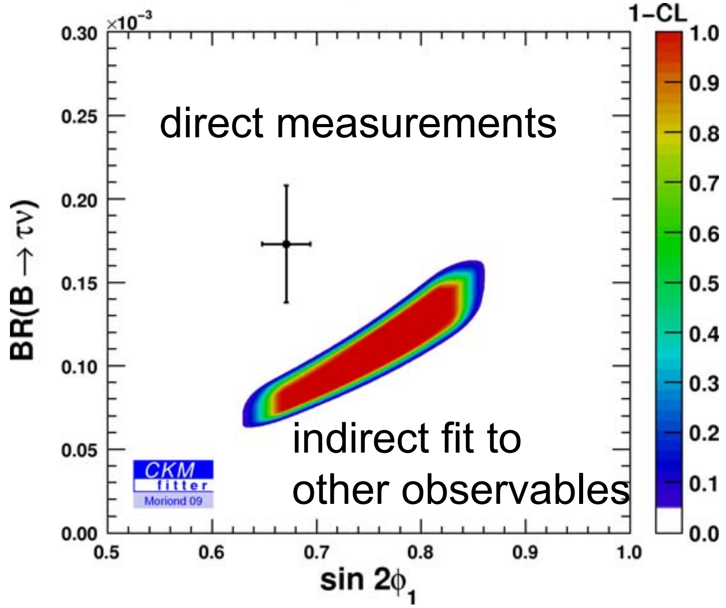
B-factories: success story

CKM mechanism confirmed at "1st order";
small discrepancies exist.

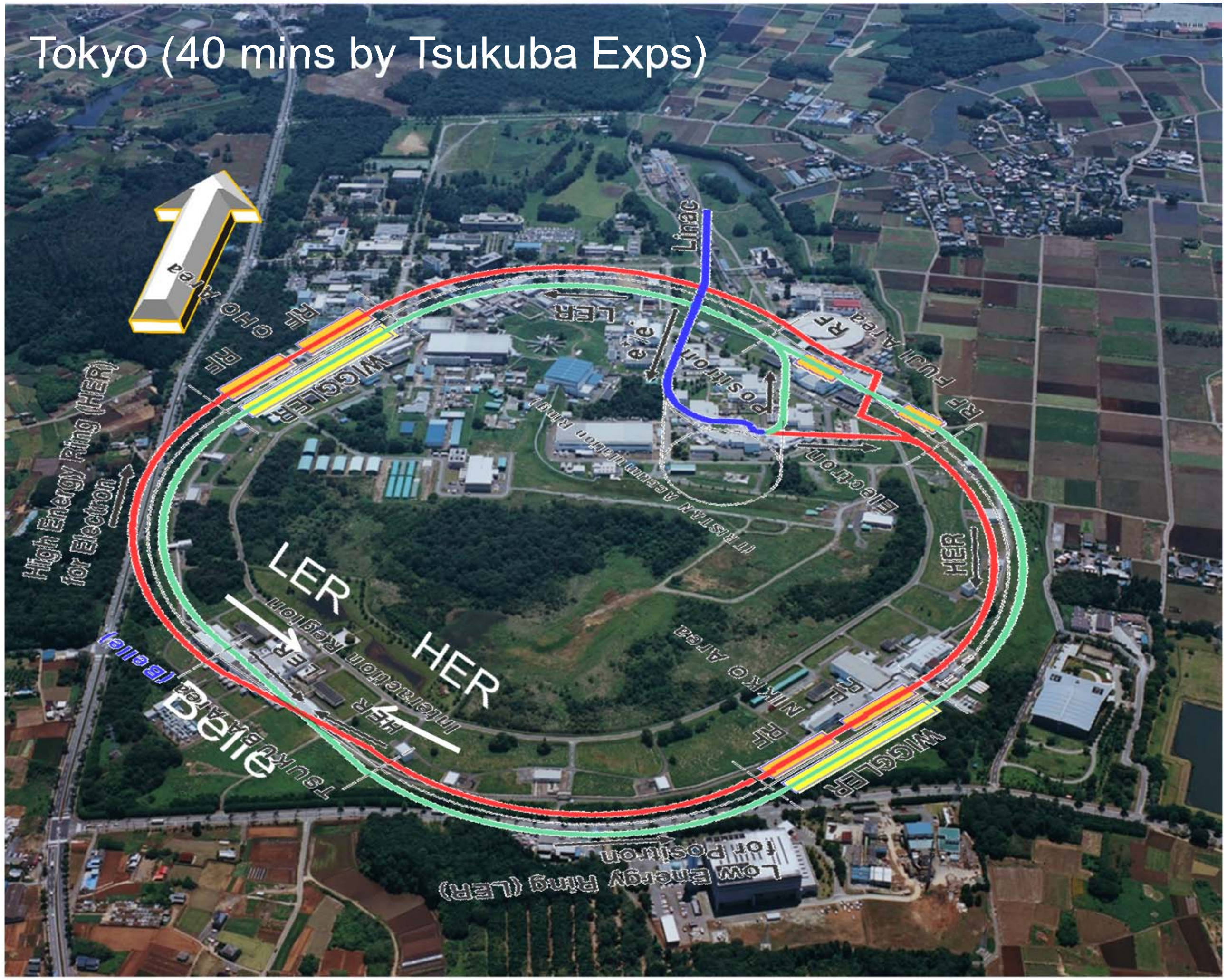
Can we do better
(in complement to LHC)?

⇒ **Super B-factory**

$\mathcal{O}(10^2)$ larger $\int \mathcal{L}dt$



KEKB



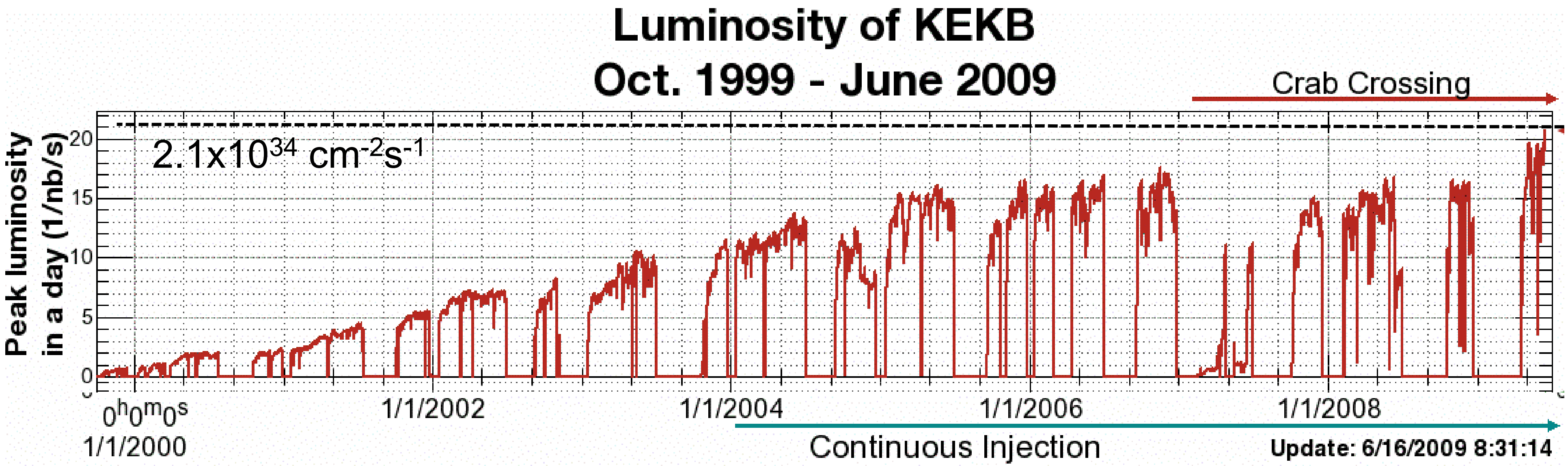
KEKB:

HER: 8.0 GeV
LER: 3.5 GeV
crossing: 22 mrad

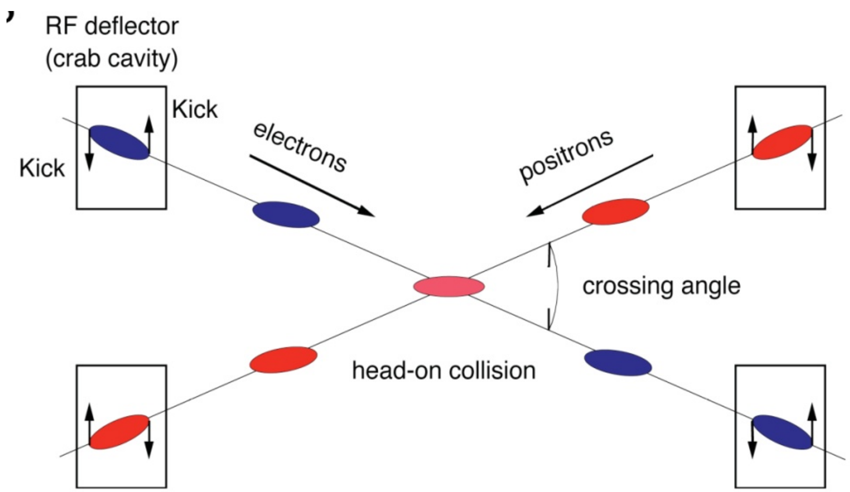
$E_{CMS}=M(\Upsilon(4S))$
$\beta\gamma=0.425$

2009
$\int \mathcal{L} dt > 1000\ fb^{-1}$
1999

KEKB



Crab-crossing:



SuperKEKB

Luminosity:

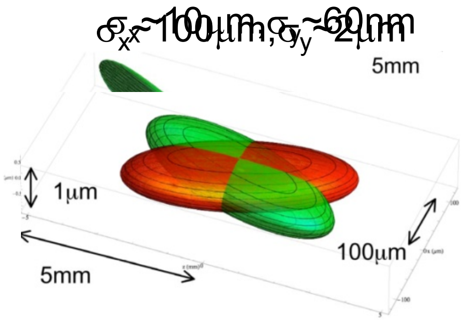
$$L = \frac{\gamma_\pm}{2 e r_e}\left(1 + \frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{y\pm}}{\beta_{y\pm}^*}\left(\frac{R_L}{R_{\xi_y}}\right)$$

- Lorentz factor: $\gamma_\pm$
- Beam current: $I_\pm$
- Beam-Beam parameter: $\xi_{y\pm}$
- Geometrical reduction factors (crossing angle, hourglass effect): R_L / R_{ξ_y}
- Vertical beta function at IP: $\beta_{y\pm}^*$
- Beam aspect ratio at IP: σ_y^*/σ_x^*

nano-beam:

small β_y^*
small β_x^*
large $\xi_y \propto \sqrt{(\beta_y^*/\varepsilon_y)} \Rightarrow$ small ε_y

β^*: beta-function (trajectories envelope) at IP

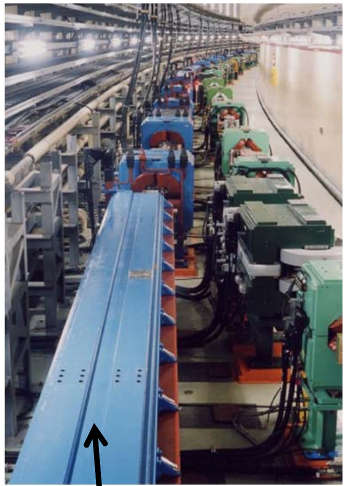


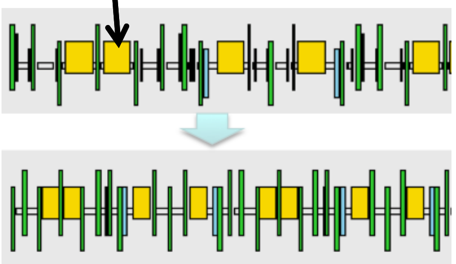
small β_y^*[mm]:
small β_x^*[mm]:

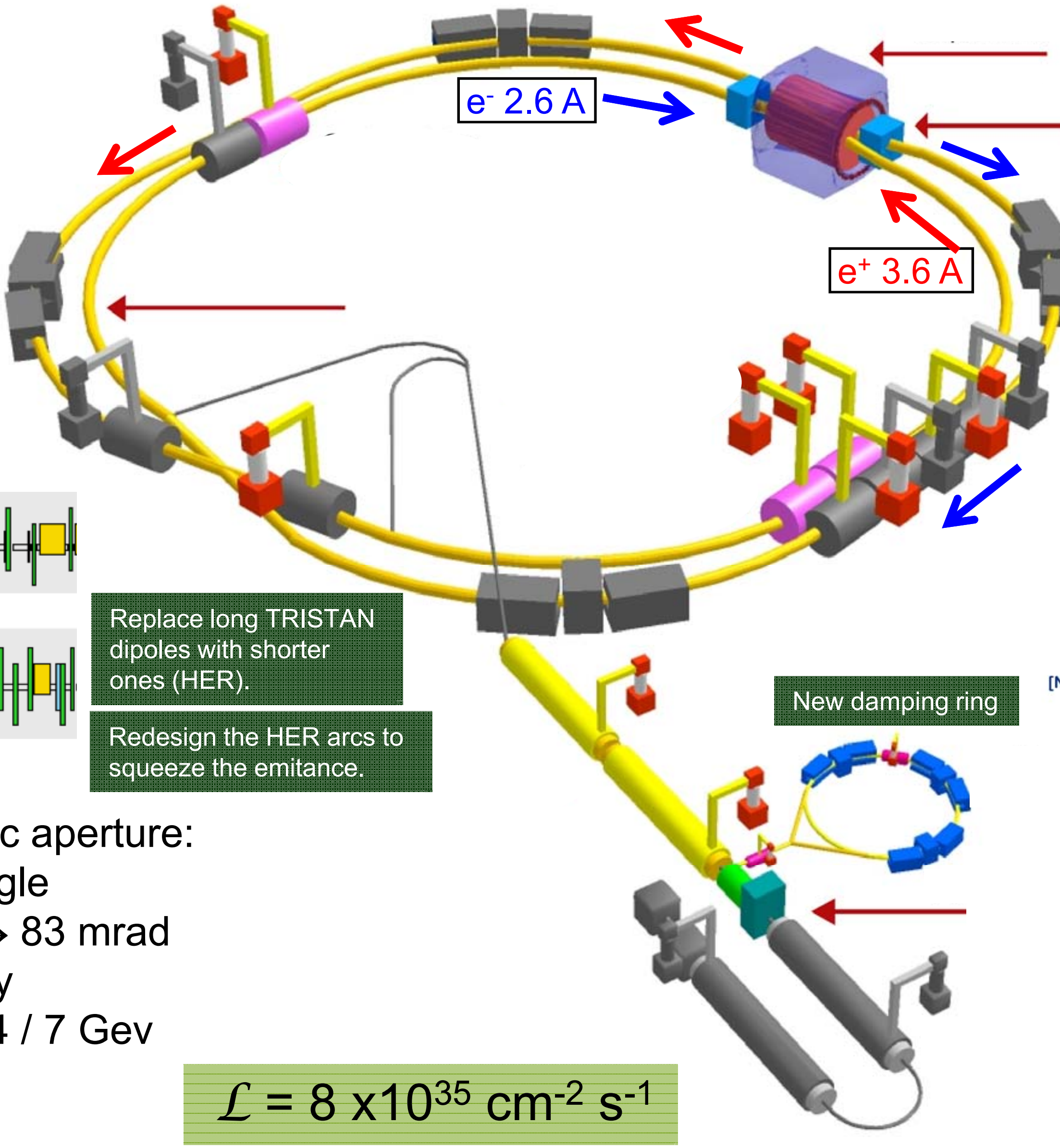
small ε_y: keep current ξ_y 0.101(LER)/0.096(HER) → 0.09/0.09
increase *I* [A]: 1.8(LER)/1.45(HER) → 3.6/2.6

small ε LER: longer bends; HER: more arc cells
small β^*: separate quadrupoles closer to IP
small ε, β^*: small dynamic aperture, larger Touschek background and smaller τ_{beam}

SuperKEKB

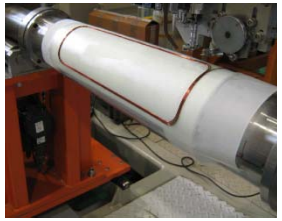






New IR

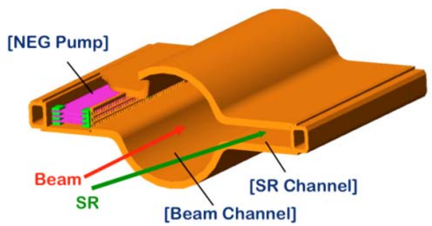
New Superconducting / permanent final focusing quads near the IP



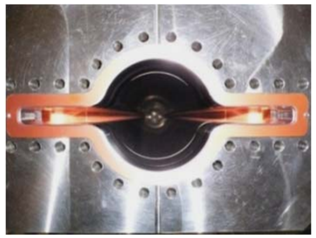
Replace long TRISTAN dipoles with shorter ones (HER).

Redesign the HER arcs to squeeze the emitance.

New damping ring



TiN coated beam pipe with antechambers



increasing dynamic aperture:

larger crossing angle

2ϕ = 22 mrad → 83 mrad

smaller asymmetry

3.5 / 8 GeV → 4 / 7 Gev

optimizing lattice:

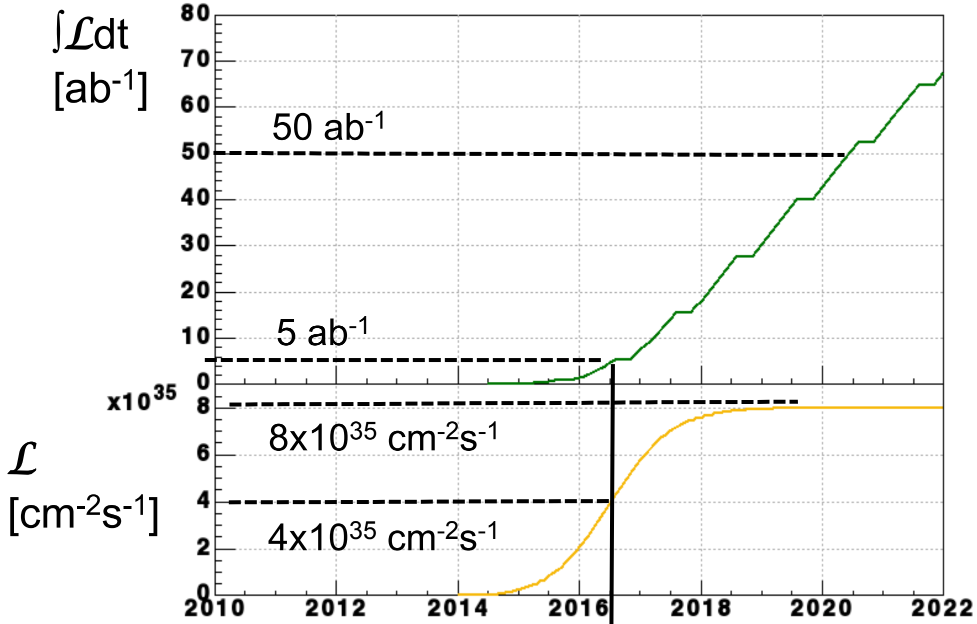
τ_{beam} ~ 400 s

(target 600 s)

$\mathcal{L} = 8 \times 10^{35}$ cm^{-2} s^{-1}

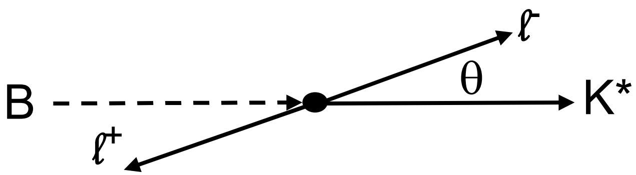
SuperKEKB

Foreseen increase of $\mathcal{L}$:



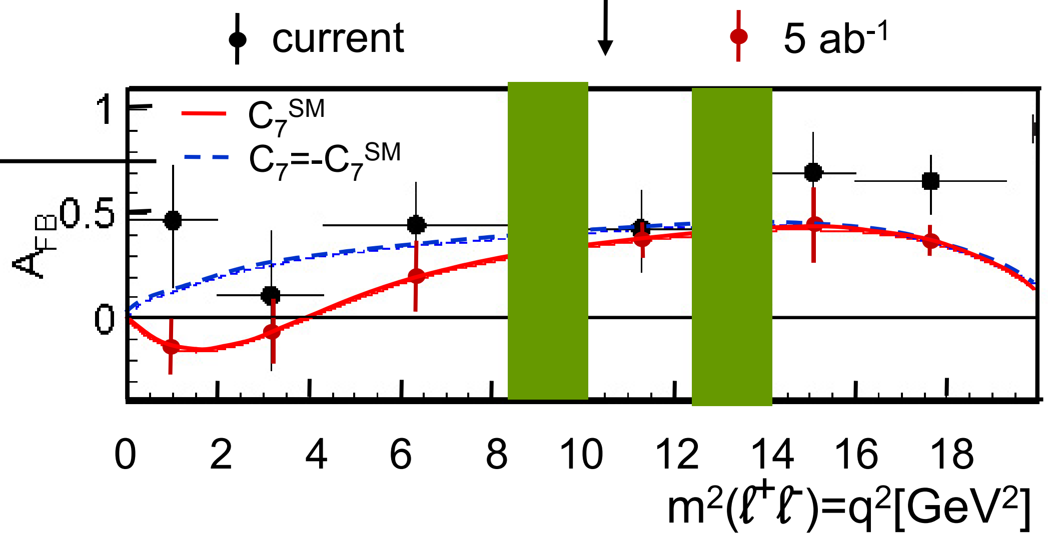
example of physics results with $\mathcal{L}$=5 ab^{-1}

A_{FB} in $B \rightarrow K^* \ell^+ \ell^-$



Belle, PRL103, 171801 (2009), 657M BB

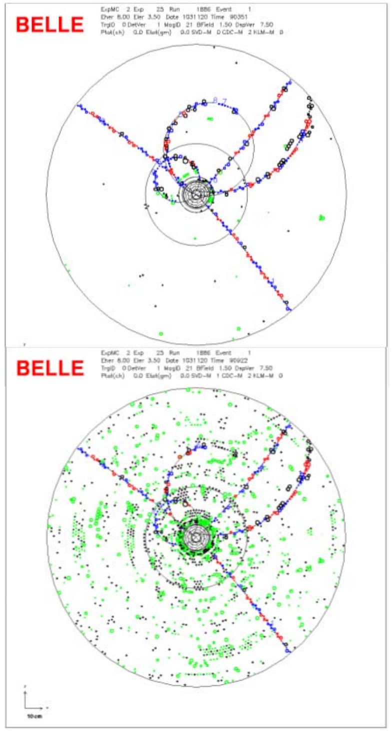
e.g. Supergravity model



Belle II

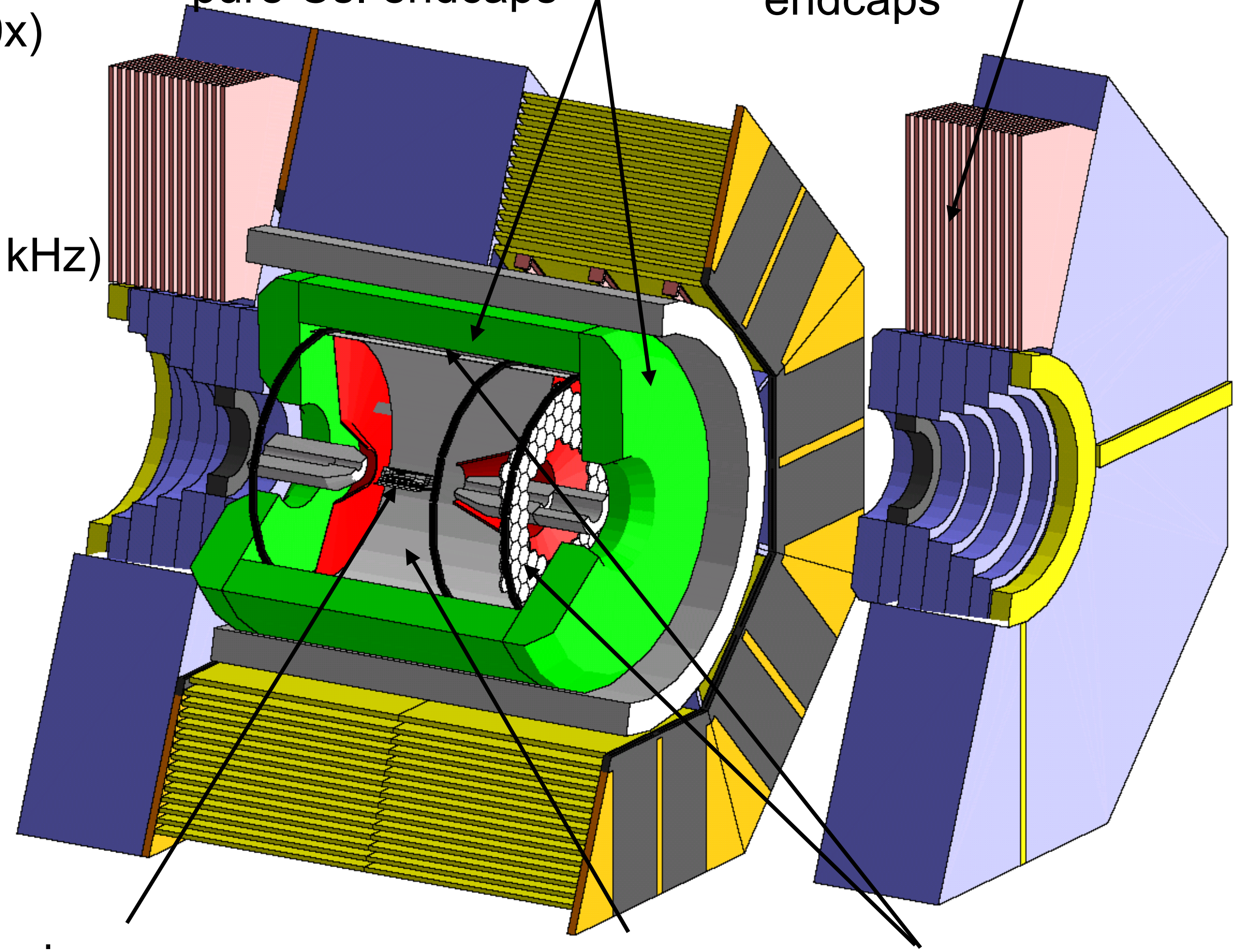
have to deal with:

- higher background (10-20x)
  radiation damage,
  higher occupancy
- higher event rates
  DAQ (L1 trigg. 0.5 →20 kHz)
- improved performance
  hermeticity



ECL: wave form sampling
pure CsI endcaps

μ, K_L: scintillator strips
endcaps



vertexing:
2 lyrs DEPFET pixel
4 lyrs DSSD

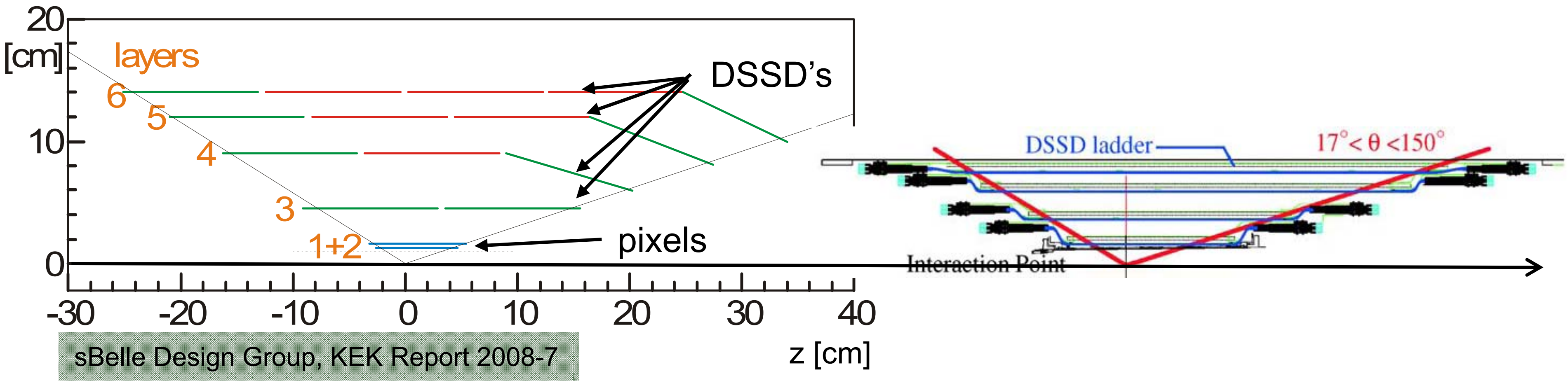
Central Drift Chamber:
smaller cell size
improved read-out

PID:
TOP barrel
ARICH forward

Belle II Vertexing

PXD+SVD Belle II

SVD Belle



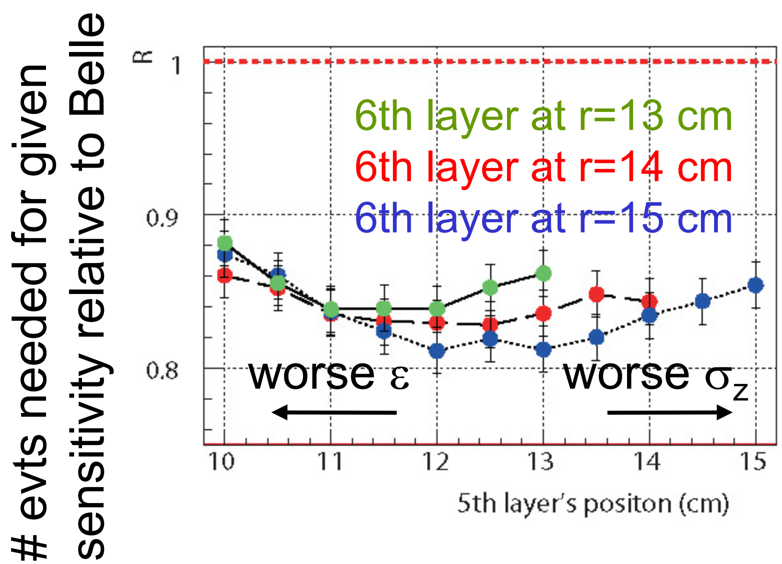
example: b→ s γ decays

B → K*(→ $K_S\pi^0$) γ t-dependent CPV

B decay vtx from K_s and IP;
improved ε($K_s \to \pi^+\pi^-$), better σ(t)

25% improvement in vtx resol.

~30% improved ε for $K_S \to \pi^+\pi^-$ (larger radius)



Belle II Vertexing

B → K*γ t-dependent CPV

SM:
$S_{CP}^{K^*\gamma} \sim (2m_s/m_b)\sin 2\phi_1 \sim 0.04$

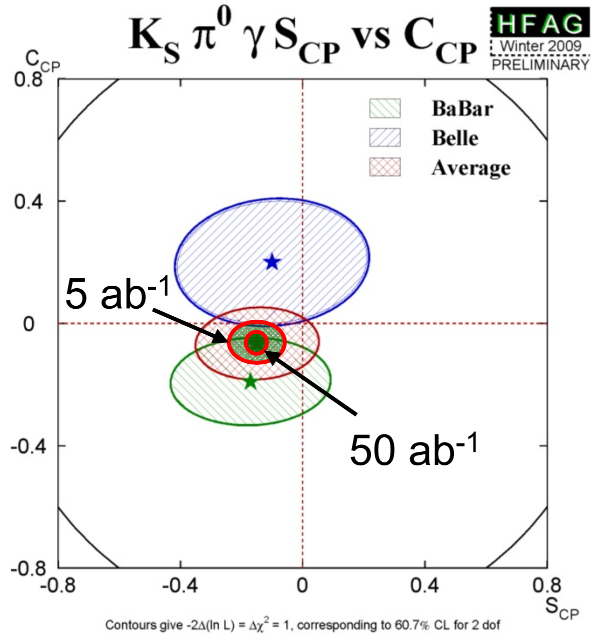
$$P(B^0 \to f;\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}[1 + S_{CP}^f \sin(\Delta m \Delta t) + A_{CP}^f \cos(\Delta m \Delta t)]$$

Left-Right Symmetric Models:
$S_{CP}^{K^*\gamma} \sim 0.67 \cos 2\phi_1 \sim 0.5$

D. Atwood et al., PRL79, 185 (1997)

$S_{CP}^{Ks\pi 0\gamma} = -0.15 \pm 0.20$
$A_{CP}^{Ks\pi 0\gamma} = 0.07 \pm 0.12$

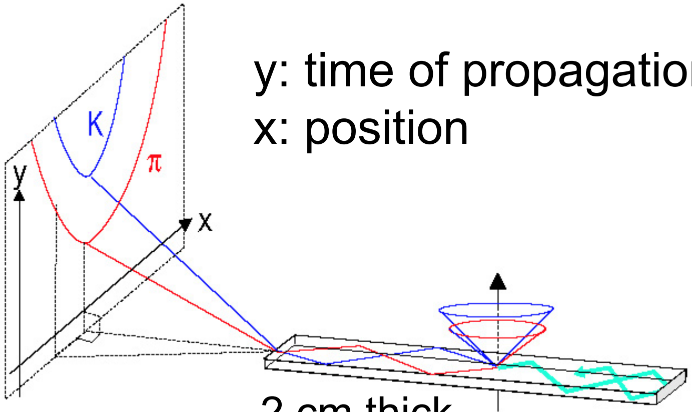
HFAG, Winter'09



$\sigma(S_{CP}^{Ks\pi 0\gamma}) =$ 0.09 @ 5 ab^{-1}
0.03 @ 50 ab^{-1} (~SM prediction)

Belle II PID

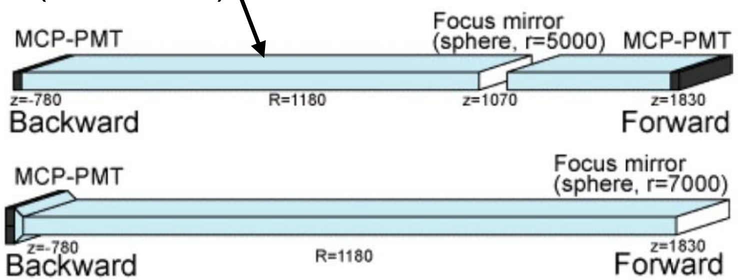
barrel:
Time-Of-Propagation counter (TOP)
principle:



y: time of propagation
x: position

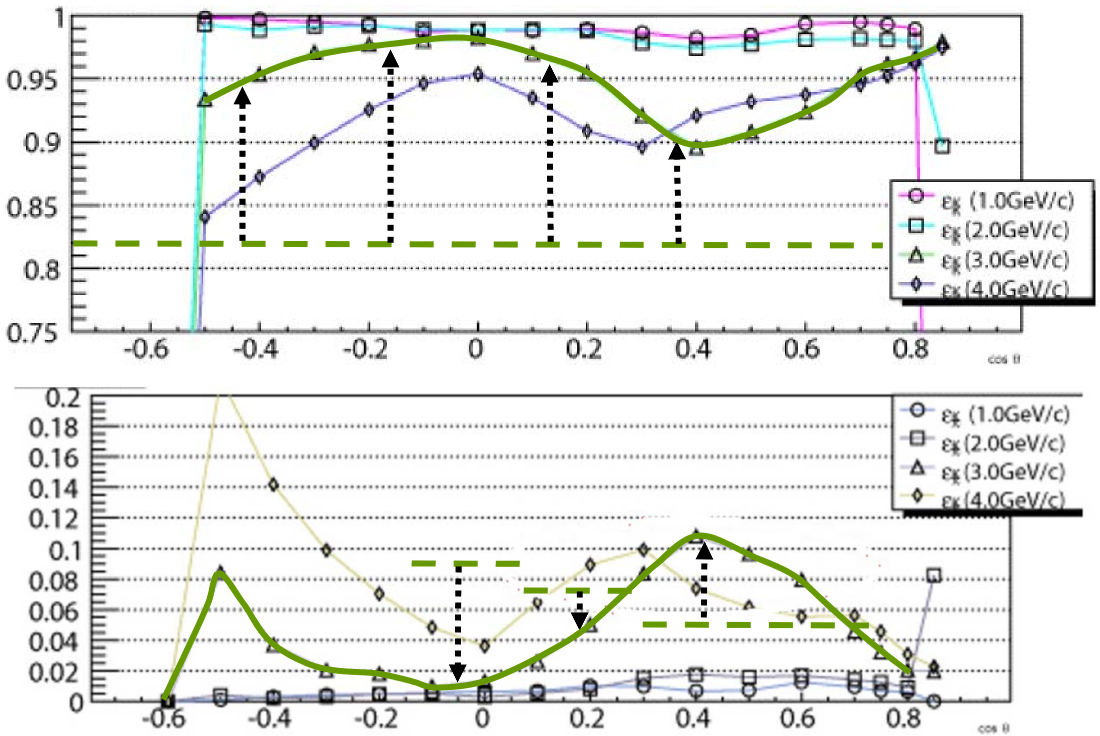
2 cm thick
quartz bar

quartz bar
(2 cm thick)



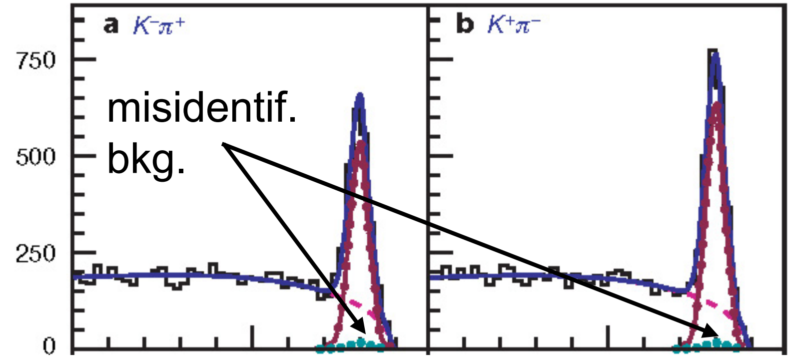
photodetector:
microchannel plate PMT

MC ε/fake rate $K^{\pm}$



~current performance, 3 GeV $K^{\pm}$
expected

Belle II PID



Belle, Nature 452, 332 (2008), 480 fb^{-1}

DCPV puzzle:

tree+penguin processes, B →Kπ

$\Delta A_{K\pi}= A(K^+\pi^-)- A(K^+\pi^0)= -0.147 \pm 0.028$

HFAG, LP'09

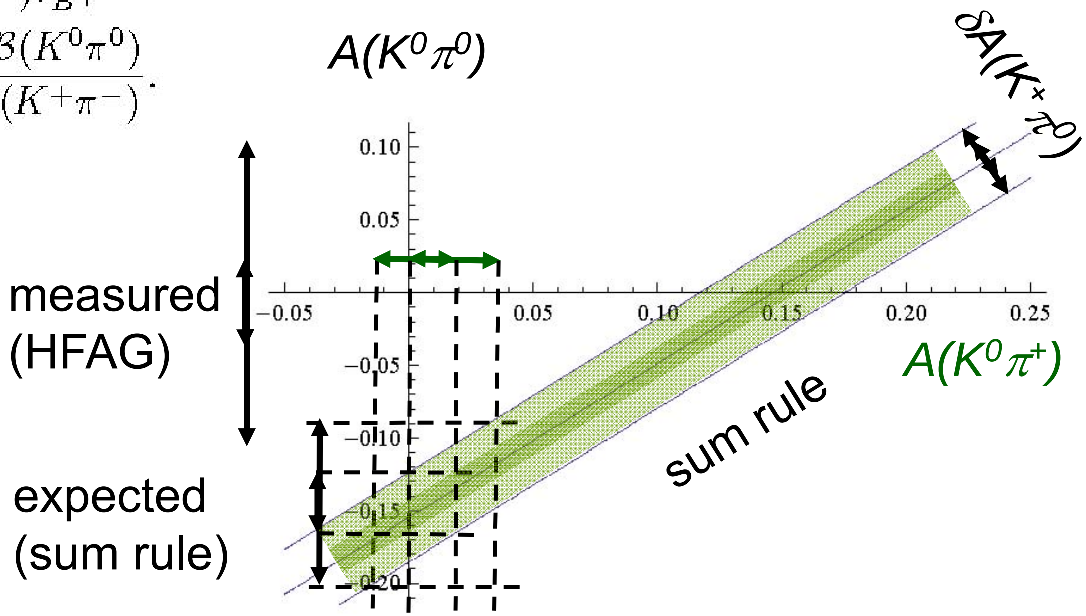
model independent sum rule:

$$\mathcal{A}_f(K^+\pi^-)+\mathcal{A}_f(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)\tau_{B^0}}{\mathcal{B}(K^+\pi^-)\tau_{B^+}}=$$
$$\mathcal{A}_f(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)\tau_{B^0}}{\mathcal{B}(K^+\pi^-)\tau_{B^+}}+\mathcal{A}_f(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}.$$

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

$A(K^0\pi^+)=0.009 \pm 0.025$
$A(K^+\pi^0)=0.050 \pm 0.025$
$A(K^+\pi^-)=-0.098 \pm 0.012$
$A(K^0\pi^0)=0.01 \pm 0.10$
Belle II 50 ab^{-1}

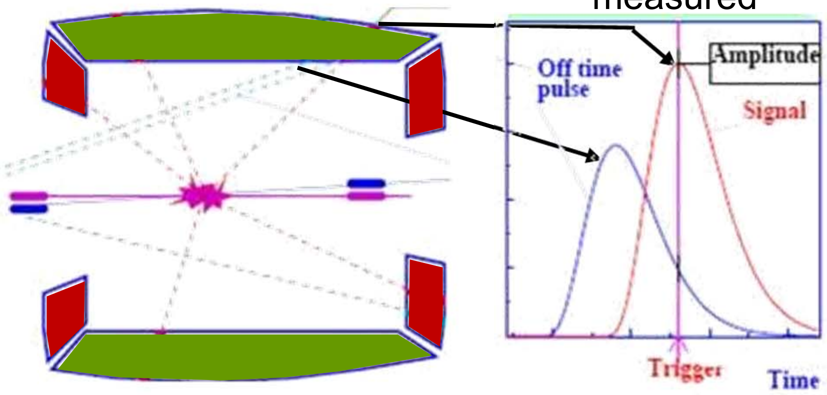
HFAG, LP'09



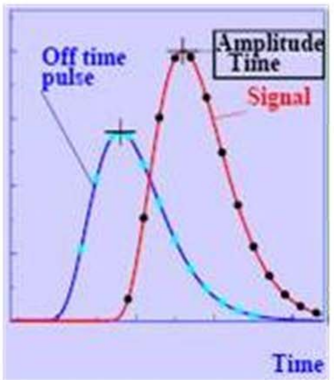
Belle II ECL

wave form sampling:

currently only amplitude measured



new electronics:
16 meas. of time and amplitude;
fake clusters suppressed by 7x;



endcaps:
replace CsI(Tl) with pure CsI (partially)

expected performance @ 10x bkg.
~ 5%-10% lower ε at same bkg. level

Charged Higgs search

$B_{sig}B_{tag} \to (\tau\nu)(X\ell\nu)$
$\to (Y\nu\nu)(X\ell\nu)$

B_{tag}: semi-lept. or hadronic tag

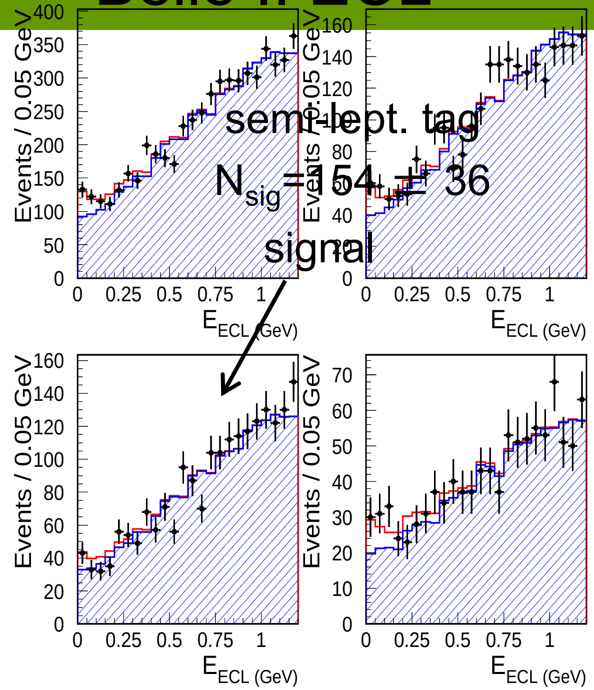
two or more ν in rest of event,
no residual energy in ECL,
signal at $E_{ECL} \sim 0$

$$\Gamma(B^+ \to \tau^+\nu) =$$
$$= \Gamma^{SM}(B^+ \to \tau^+\nu)\cdot\left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

Belle II ECL

$$Br(B^+ \to \tau\nu) = (1.65 \pm {}^{0.38}_{0.37} \pm {}^{0.35}_{0.37}) \cdot 10^{-4}$$

Belle, arXiv: 0809.3834, 600 fb^{-1}

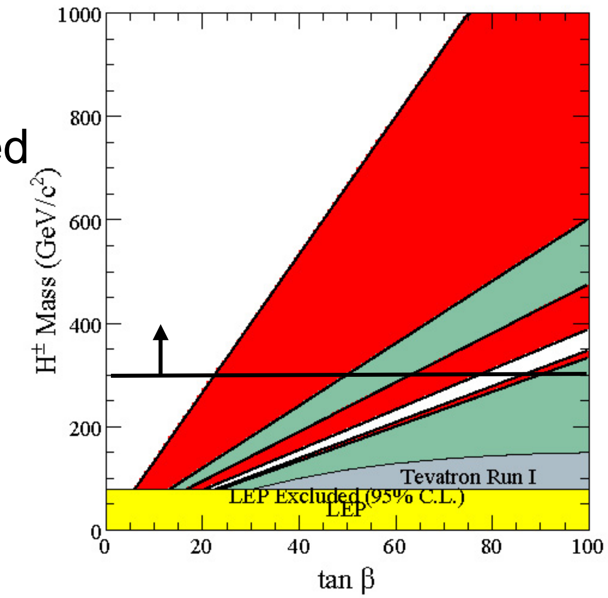


Belle 50 ab^{-1}:
- semil. + hadr. tag;
- main syst. reducible:
  - bkg. ECL shape, ε B_{tag}

V_{ub} ±3%, f_B ±3%

$$\sigma(Br(B^+ \to \tau\nu)) \approx 0.05 \cdot 10^{-4}$$
$$\sigma(\Gamma / \Gamma^{SM}) \approx 0.08$$

- 5 σ discovery region @ 50 ab^{-1}
- currently excluded from Br(B →τν)
- current limit from Br(B → sγ)



Belle II Physics

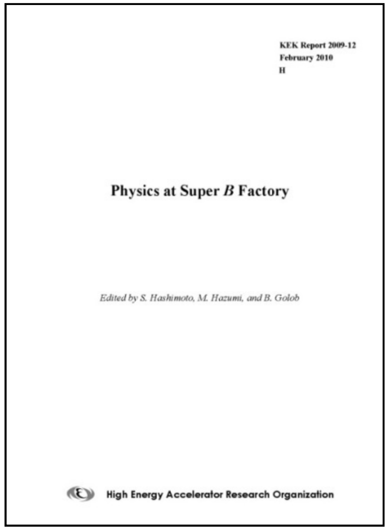
Detailed physics case of Belle II, including expected sensitivities:

A.G. Akeroyd et al., KEK Report 2009-12

in print

arXiv:1002.5012

http://belle2.kek.jp/physics.html


KEK Report 2009-12
February 2010
H

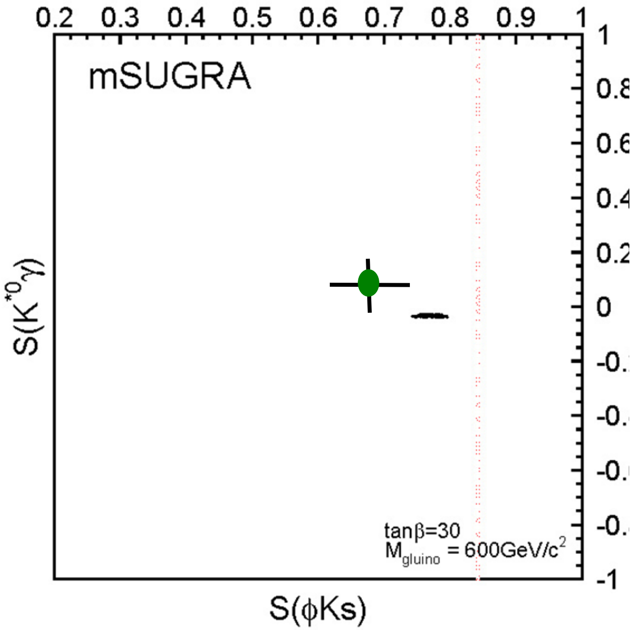
Physics at Super *B* Factory

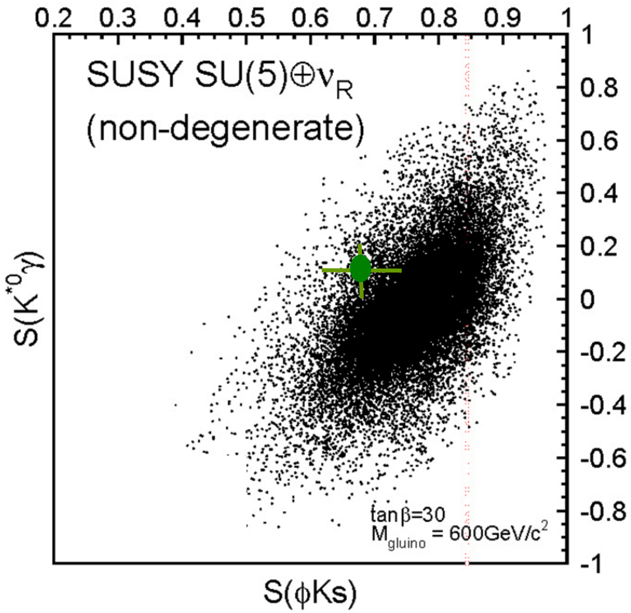
Edited by S. Hashimoto, M. Hazumi, and B. Golob

High Energy Accelerator Research Organization

Belle II: overconstrained measurements to identify nature of NP

sensitivity
@ 5 ab^{-1} shown:





Summary

- Belle II can search for NP with high sensitivity and complementary to LHC experiments
- Correlations among observables → identify nature of possible NP signals
- Upgrade of KEKB and Belle II well on track

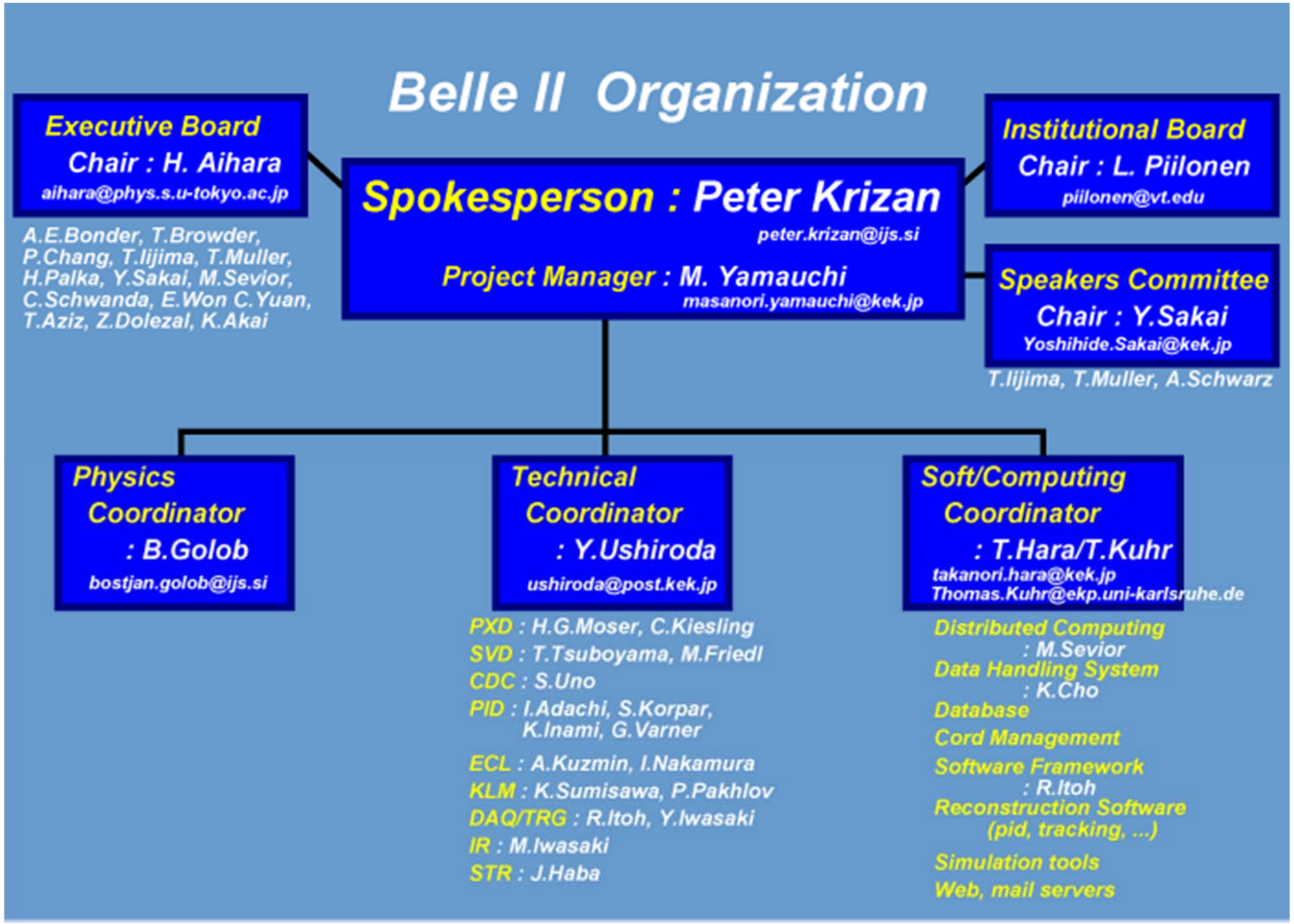
Start data taking in 2014

Belle II Organization more

296 members
44 institutions
13 countries

Australia	Univ. of Sydney Univ. of Melbourne
Austria	Austrian Academy of Sciences (HEPHY)
China	Institute of High Energy Physics, Chinese Academy of Science Univ. of Science and Technology of China
Czech	Charles University in Prague
Germany	Karlsruhe Institute of Technology Max-Planck-Institut fur Physik - MPI Munich Univ. of Giessen Bonn Univ.
India	Indian Institute of Technology Guwahati Indian Institute of Technology Madras Institute of Mathematical Sciences (Chennai) Panjab Univ. Tata Insitute of Fundamental Research
Korea	Gyeongsang National Univ. Korea Institute of Science and Technology Information Korea Univ. Kyungpook National Univ. Seoul National Univ. Yonsei Univ. Hanyang Univ.
Poland	The Henryk Niewodniczanski Institute of Nuclear Physics - Polish Academy of Science
Russia	Budker Institute of Nuclear Physics Institute for Theoretical Experimental Physics
Slovenia	Jozef Stefan Institute (Ljubljana) Univ. of Nova Gorica
Taiwan	Fu Jen Catholic Univ. National Central Univ. National United Univ National Taiwan Univ.
U.S.A.	Univ. of Cincinnati Univ. of Hawaii Virginia Polytechnic Institute and State Univ. Wayne State Univ.
Japan	Nagoya Univ. Nara Women's Univ. Niigata Univ. Osaka City Univ. Toho Univ. Tohoku Univ. Tokyo Metroporitan Univ. Univ. of Tokyo KEK

Belle II Organization more



5th Open Meeting of the Belle II Collaboration
March 31st - April 2nd 2010, KEK