Status of Belle II Project

Boštjan Golob
University of Ljubljana, Jožef Stefan Institute & Belle Collaboration

University
of Ljubljana

"Jožef Stefan"
Institute

Interplay of Collider and Flavour Physics,
CERN, December 14-16, 2009

Outline

1. KEKB ⇨ SuperKEKB

2. Belle ⇨ Belle II
   - vertexing
   - PID
   - EM Calorimeter

   examples of physics reach
   "on the fly"

3. Organizational issues

Introduction

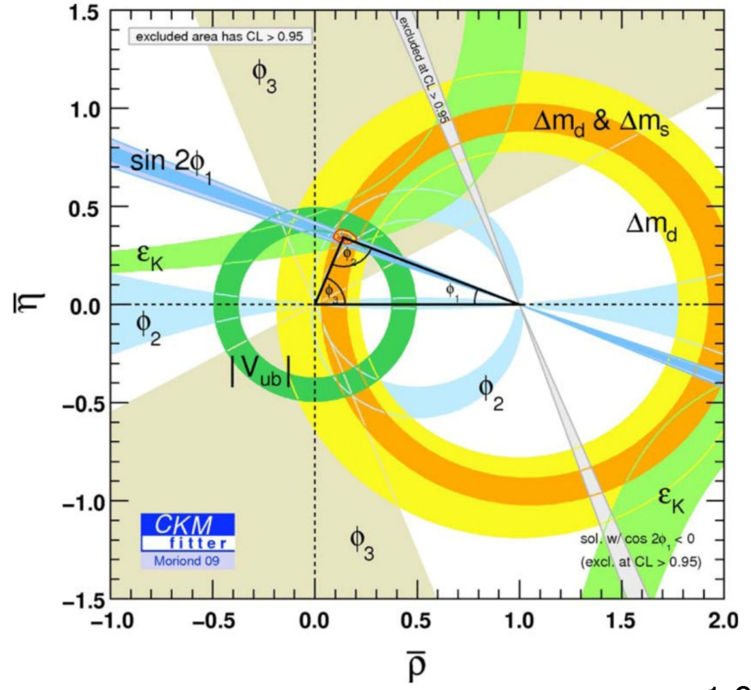
B-factories: success story

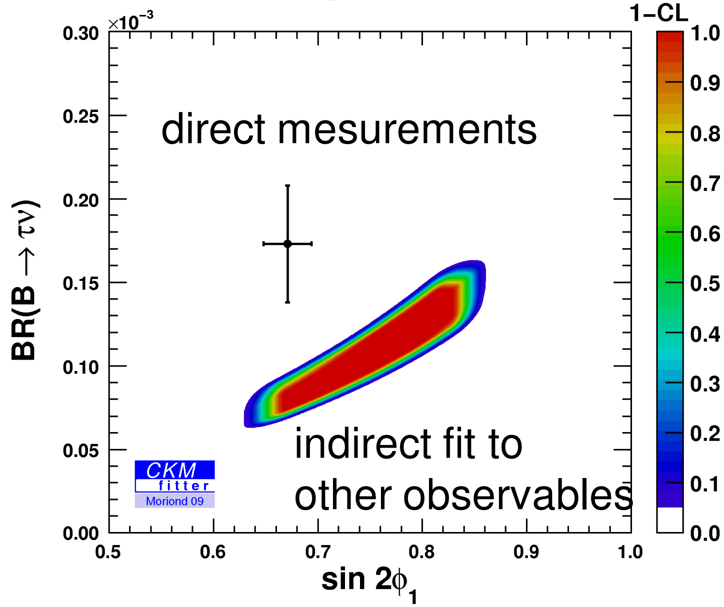
CKM mechanism confirmed at 1st order;
small discrepancies exist.

Can we do better
(in complement to LHC)?

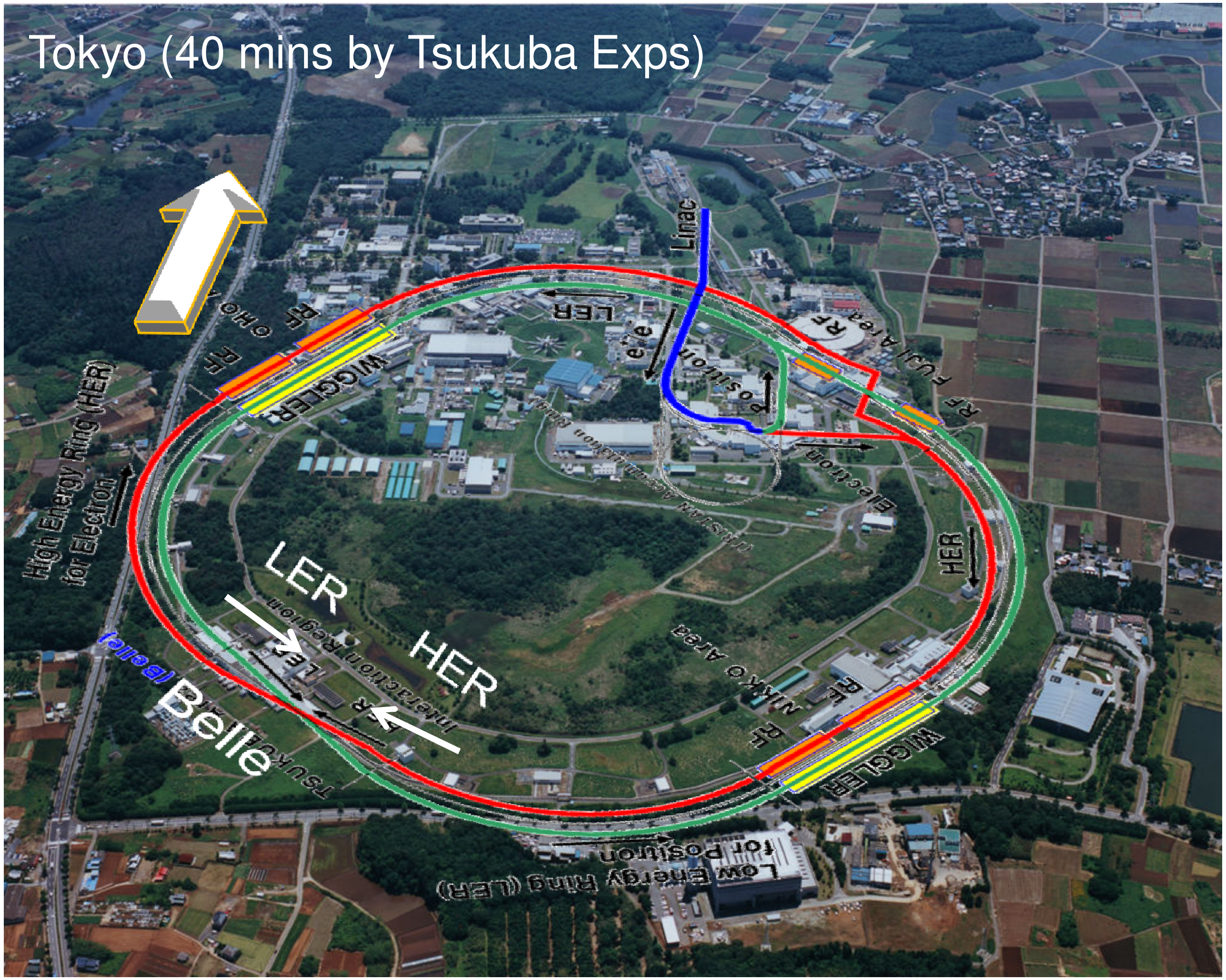
⇒ Super B-factory

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





KEKB



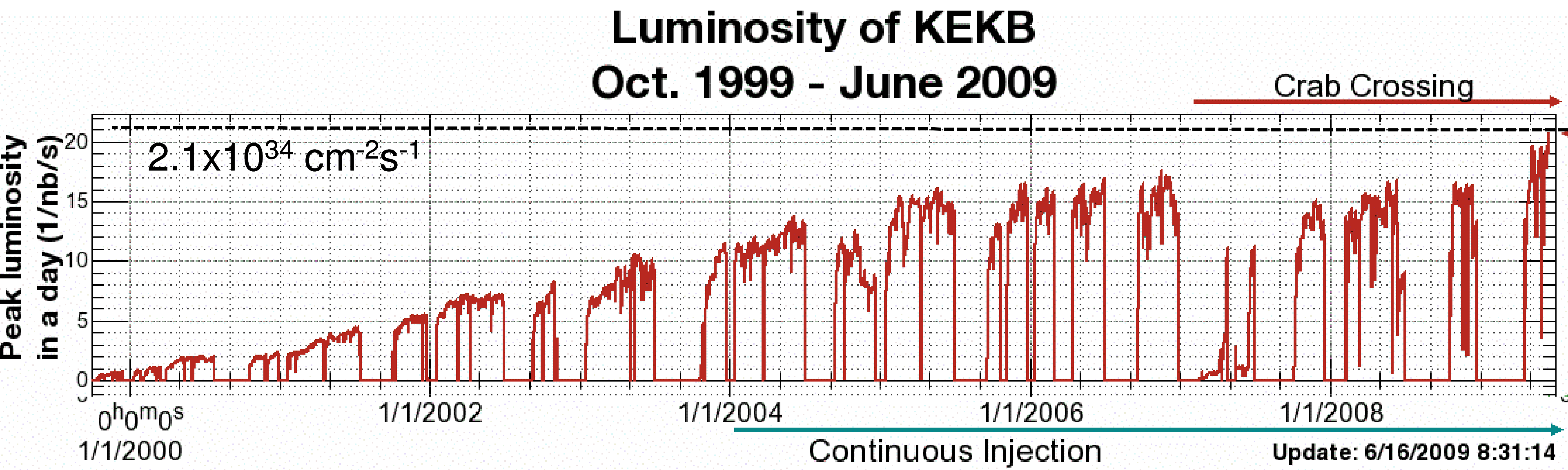
KEKB:

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

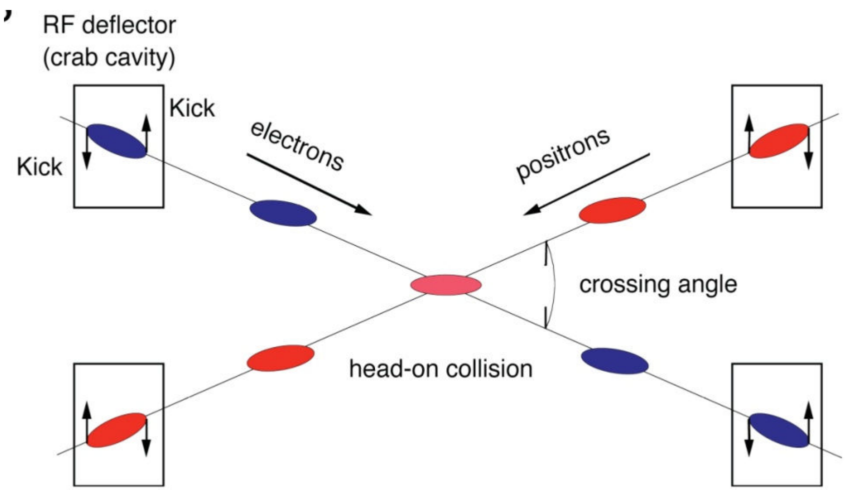
$E_{CMS}=M(\Upsilon(4S))$
$\beta\gamma=0.425$

$\int_{1999}^{2009} \mathcal{L}dt = 977\ \mathrm{fb}^{-1}$

KEKB



Crab-crossing:



SuperKEKB

Luminosity:

Lorentz factor — Beam current — Beam-Beam parameter

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

Geometrical reduction factors (crossing angle, hourglass effect)

Beam aspect ratio at IP

Vertical beta function at IP

Minimum value is limited by hourglass effect

high-current: large I

nano-beam: small β_y^*

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

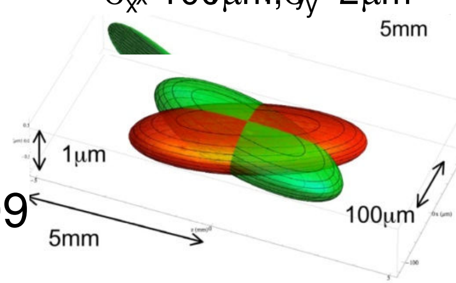
hourglass effect $\Rightarrow$ small β_x^*

(more in additional slides)

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

σ_x~10μm, σ_y~60nm

σ_x~100μm, σ_y~2μm

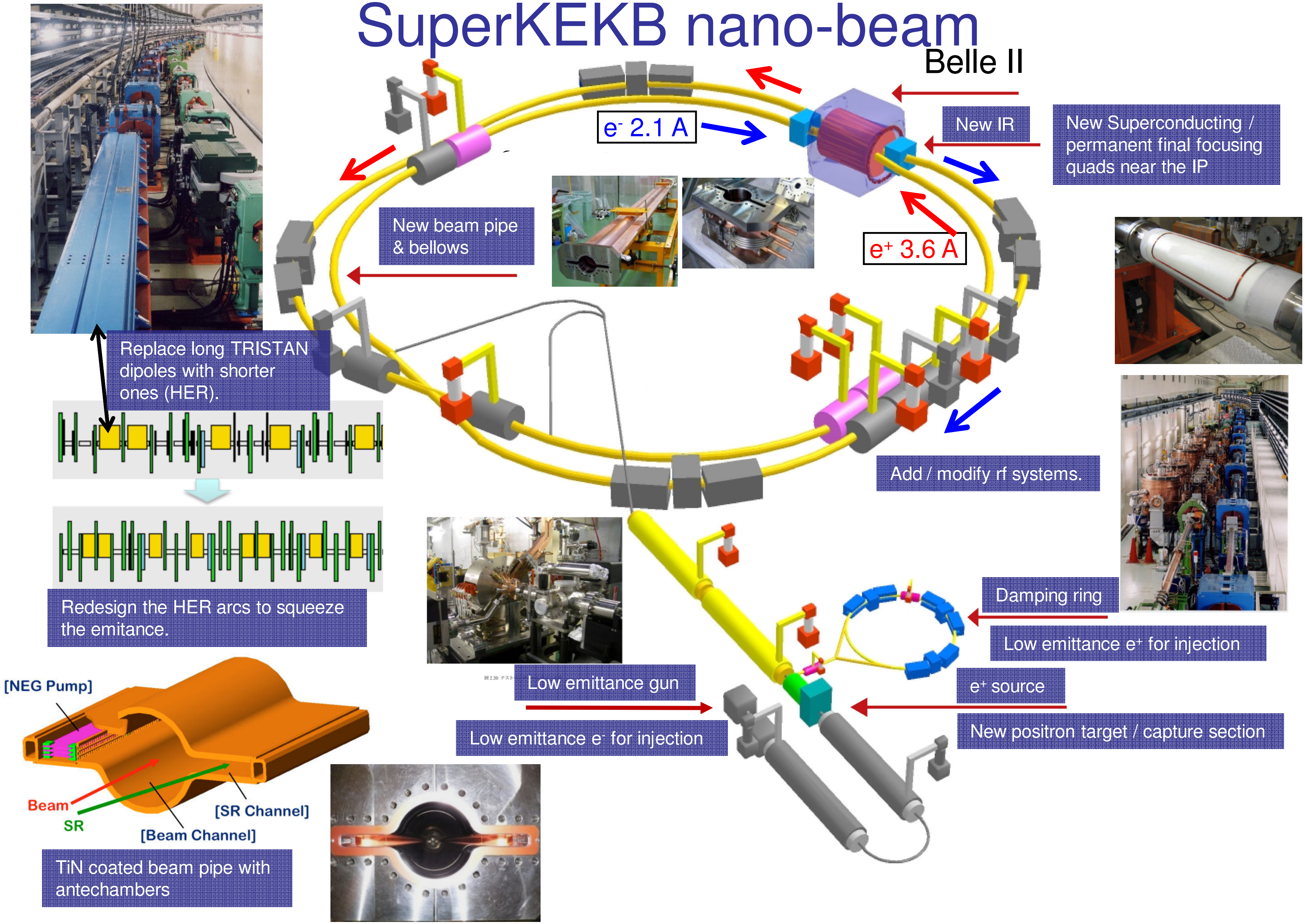


small β_y^*[mm]: 5.9(LER)/5.9(HER)→ 0.21/0.37
small β_x^*[mm]: 1200(LER)/1200(HER)→ 32/25
small ε_y: keep current ξ_y 0.101(LER)/0.096(HER) → 0.09/0.09
increase I [A]: 1.8(LER)/1.45(HER) → 3.6/2.1

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}

dynamic aperture: phase space volume of acceptable trajectories;
Touschek effect: Coulomb scattering causing transfer of transverse to longitud. momentum between particles in a bunch; if transfer is too large particles are lost (more in additional slides)

SuperKEKB nano-beam



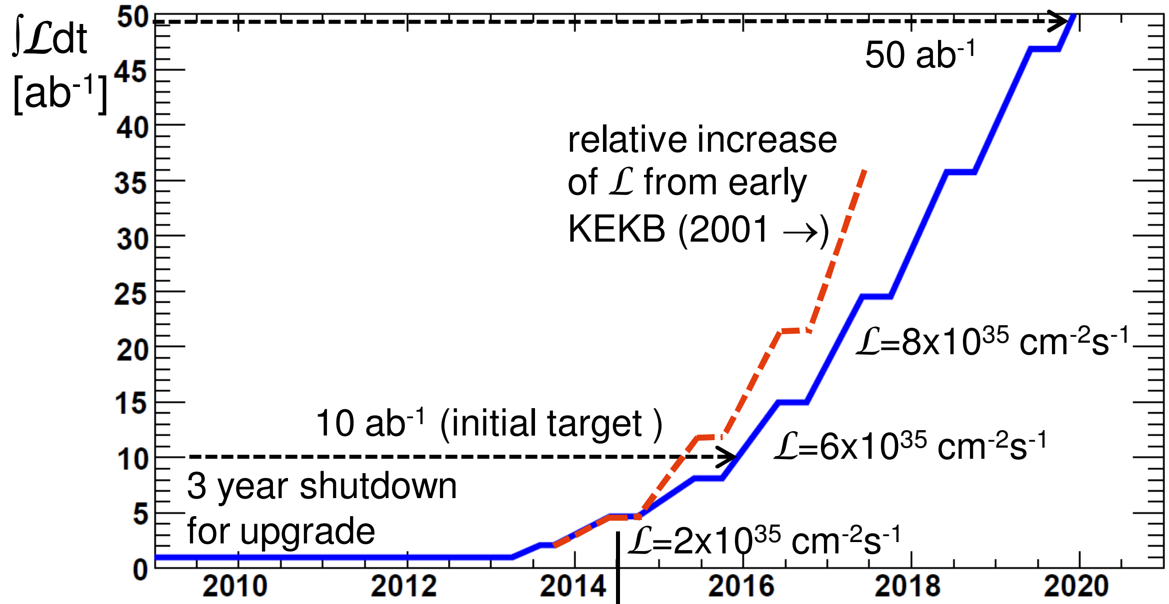
SuperKEKB

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)

with mentioned upgrade

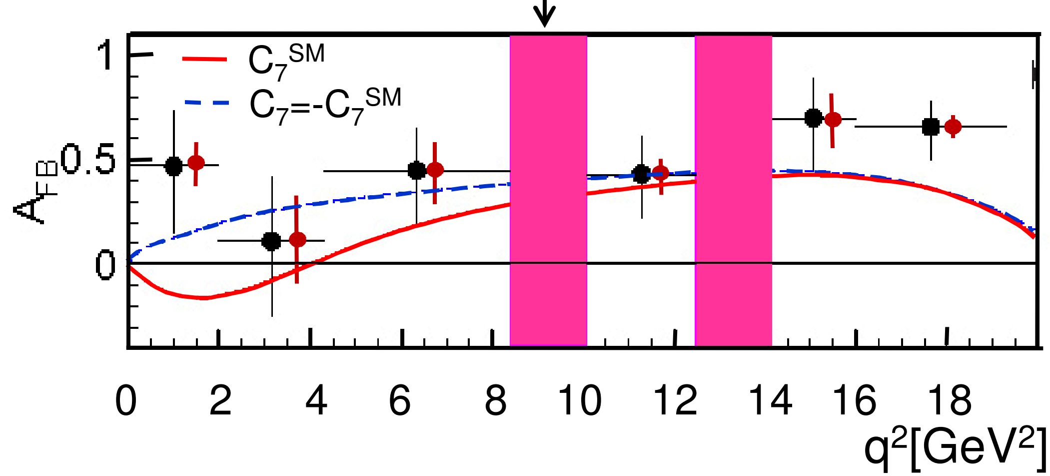
$\mathcal{L} = 8 \times 10^{35}$ cm^{-2} s^{-1}



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

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

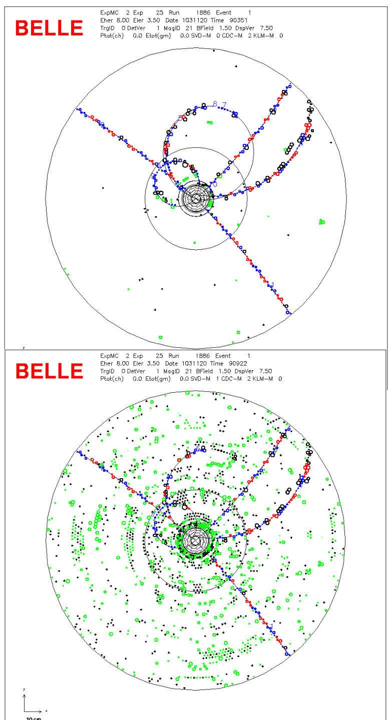
Belle, PRL103, 171801 (2009), 657M BB



Belle II

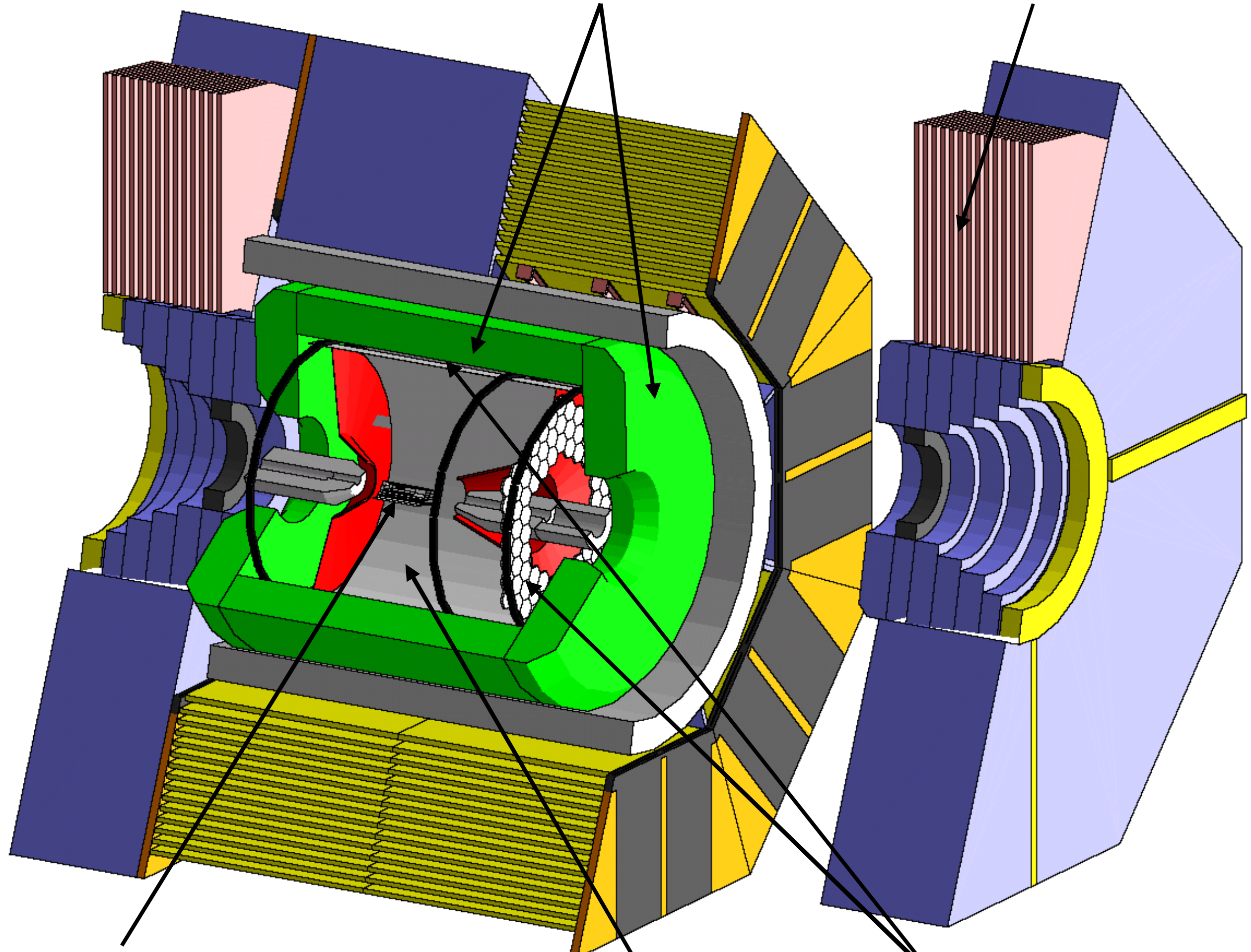
have to deal with:

- higher background
  - radiation damage,
  - higher occupancy
- higher event rates
  - DAQ
- 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

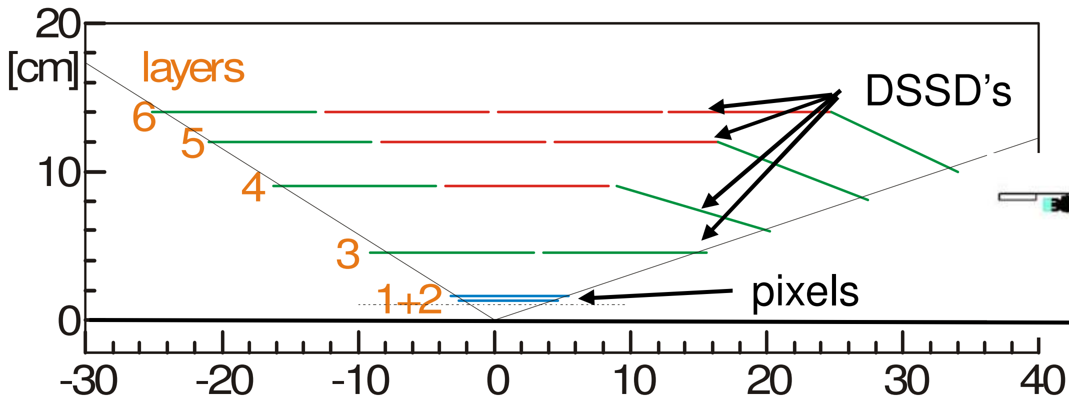
PID:
TOP barrel
ARICH forward

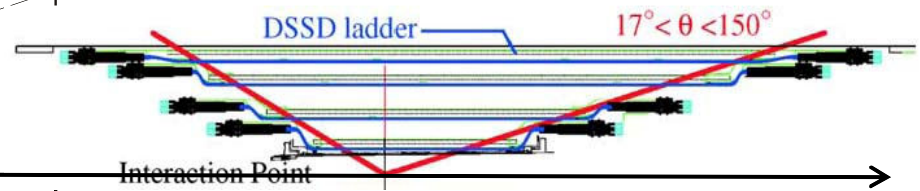
Belle II vertexing

to scale

r [cm] PXD+SVD Belle II

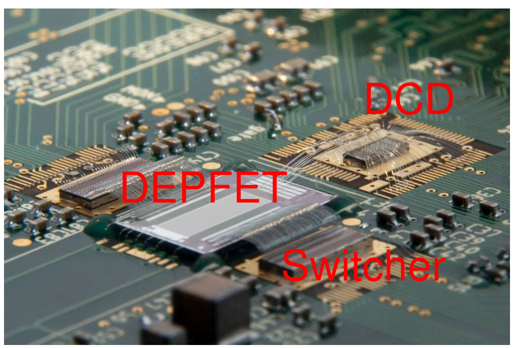
SVD Belle





z [cm]

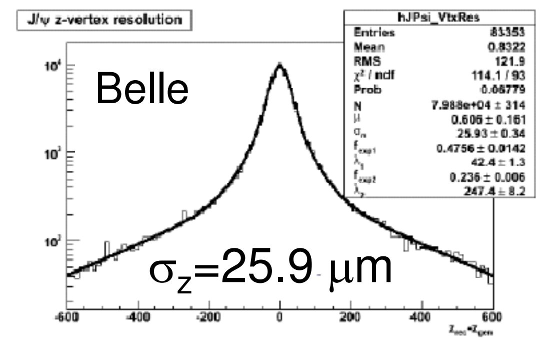
sBelle Design Group, KEK Report 2008-7



sensor
thickness
50 μm

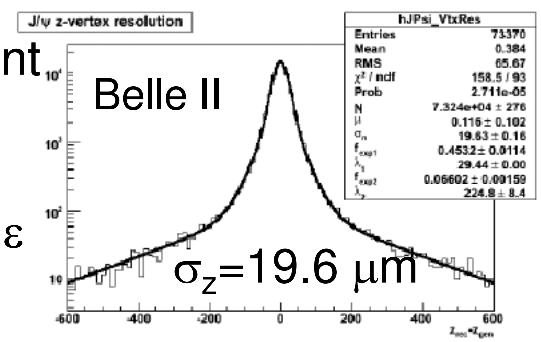
prototypes June 2010
4-5 months testing
production starts January 2011

$B \to J/\psi K_S$ MC
$J/\psi \to \mu^+\mu^-$
vertex resol.



25% improvement
in vtx resol.

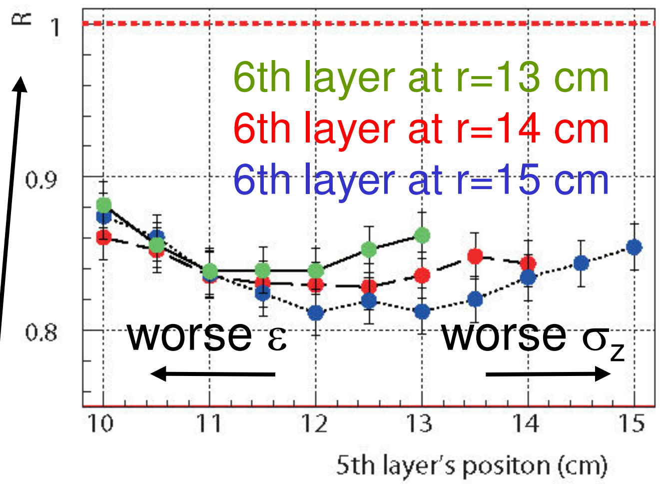
~30% improved ε
for $K_S \to \pi^+\pi^-$
(larger radius)



z_{rec}-z_{gen}

Belle II vertexing

MC study of SVD layers positioning:



evts needed for given sensitivity relative to Belle

example: b→ s γ decays

t-dependent CPV

HFAG, Winter'09

$S_{CP}(K_s\pi^0\gamma)$ = -0.15 ±0.20

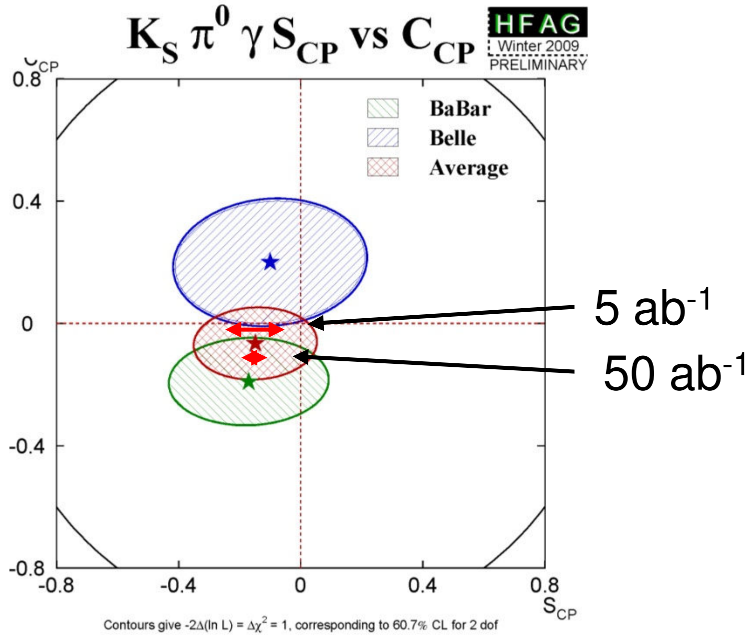
$C_{CP}(K_s\pi^0\gamma)$ = -0.07 ±0.12

B decay vtx from K_s and IP;

$\sigma(S_{CP}(K_s\pi^0\gamma))$= 0.09 @ 5 ab^{-1}

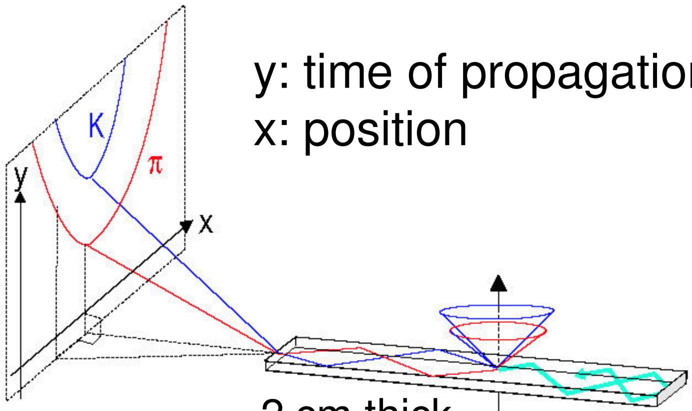
0.03 @ 50 ab^{-1}

(~SM prediction)



Belle II PID

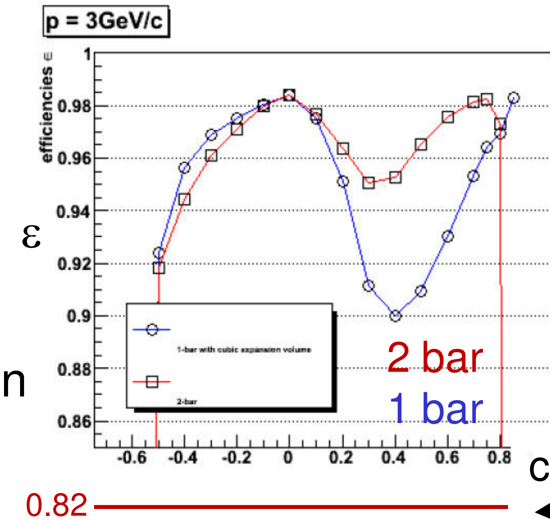
barrel:
Time-Of-Propagation counter (TOP)
principle:

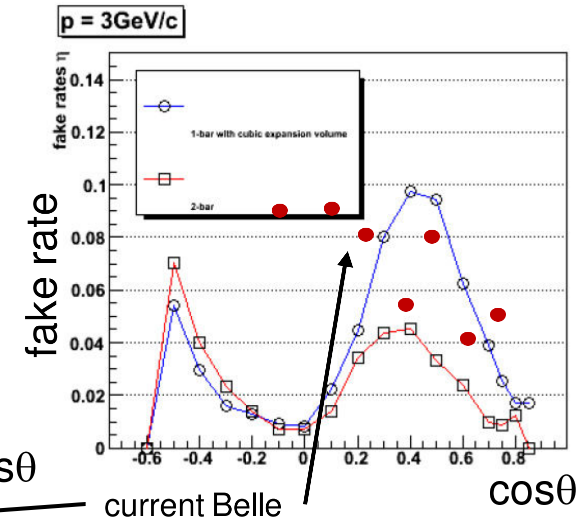


y: time of propagation
x: position

2 cm thick
quartz bar

MC ε/fake rate $K^{\pm}$



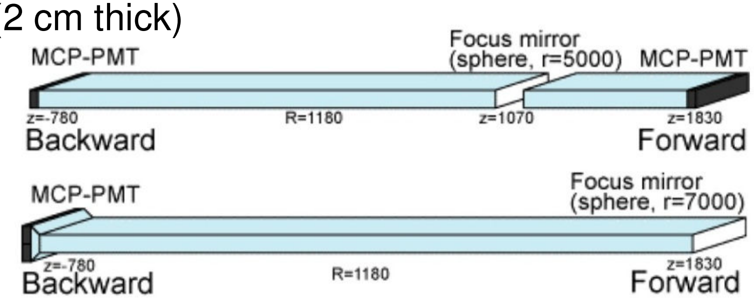


current Belle

options:

quartz bar
(2 cm thick)

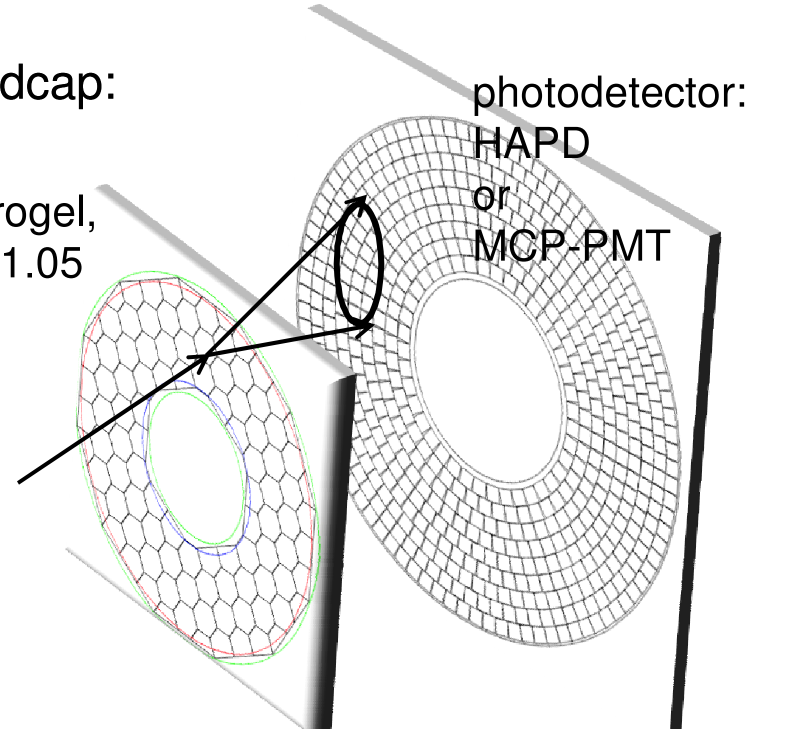
photodetector:
microchannel plate PMT



endcap:

aerogel,
n ≈1.05

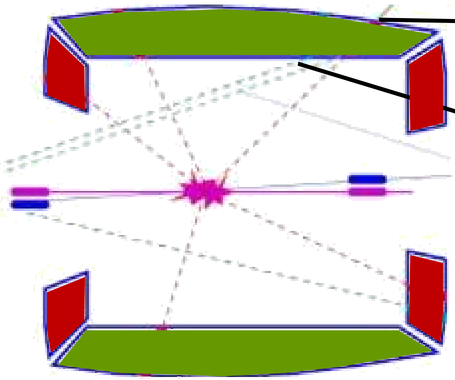
photodetector:
HAPD
or
MCP-PMT

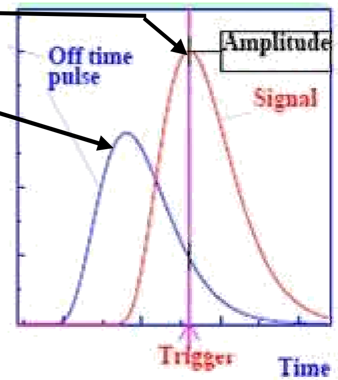


Belle II EM Calorimeter

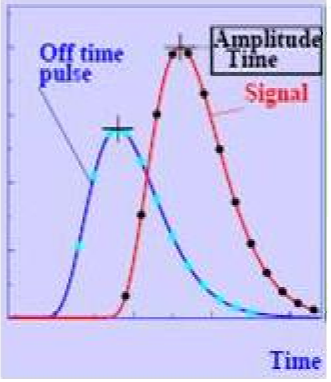
wave form sampling:

currently only amplitude measured





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



endcaps:
replace CsI(Tl) with pure CsI

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

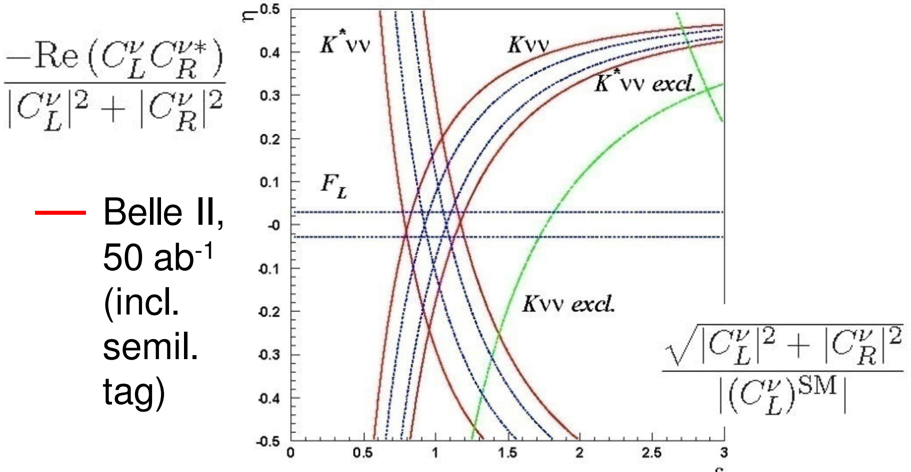
effect of PID & ECL upgrade (and other improvements) on
$B \to K^{*0}\nu\nu$

ε_{Btag}, +20%
(modes including neutrals)
ε_{PID}, +15%, $K\pi$ +30%

$Br(B \to K^{*0}\nu\nu) < 3.4 \times 10^{-4}$ @90% C.L.

Belle, PRL99, 221802 (2007), 490 fb^{-1}

3 σ significance @ 45 ab^{-1}
($B_{tag} \to$ hadron only)



W. Altmannshofer et al., arXiv:0902.0160

Organizational issues

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

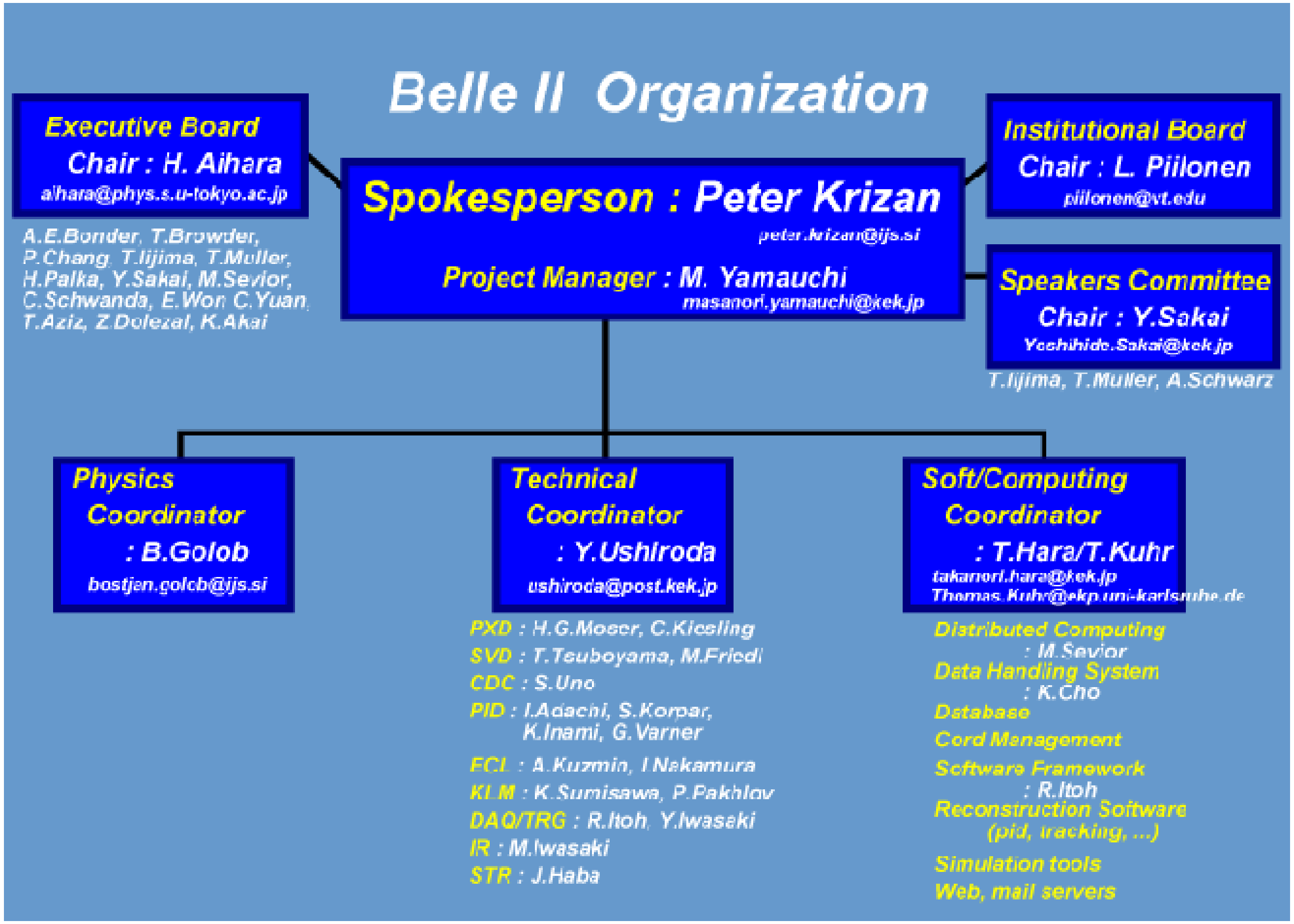
Taiwan — Fu Jen Catholic Univ.; National Central Univ.; National United Univ; National Taiwan Univ.

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

293 members
43 institutions
13 countries

Organizational issues



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

Organizational issues funding situation

- SuperKEKB and Belle II are priorities of KEK
- 32 oku-¥ for upgrade R&D in fiscal year 2009

1 oku-¥ = 1M US $

- Significant funds available to collaborating institutes
- Request for 2010 and beyond: 350 oku-¥
  KEK → MEXT → Ministry of finance
- Government change in Japan in September 2009
  revision of all major projects
- "Scrutiny and classification" panel of Japanese government
  recommendation to government re budget allocation for FY 2010
  (already made recommendations of severe budget cuts in science)
  Nov 25th: SuperKEKB discussed with other projects
  the project was passed, specific recommendation not public
- Governmental decision expected end 2009/early 2010
- So far all the news support our optimism
  - SuperKEKB and Belle II well on the way

Additional material

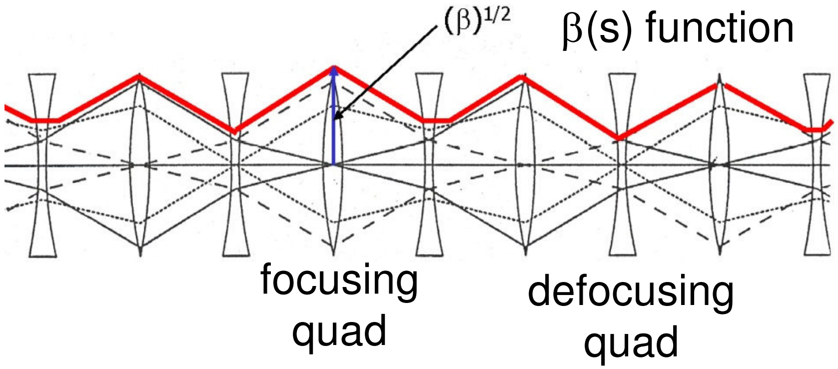
SuperKEKB more hourglass effect

slac-pub-8699

naive luminosity formula: $\mathcal{L} = \frac{N_1 N_2}{2\pi \Sigma_x^* \Sigma_y^*}$

$\Sigma_{x,y}^*$: $\sqrt{(\sigma_{x,y1}^{*2}+\sigma_{x,y2}^{*2})}$
horiz., vertical bunch size @ IP

valid if $\sigma_z << \beta^*_{x,y}$;
if not $\Rightarrow \sigma_{x,y}$ depending on $\beta^*_{x,y} \Rightarrow$ reduction of luminosity;



effect: more involved formula

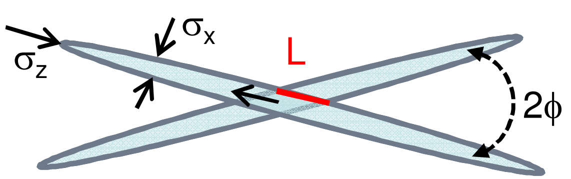
$$\sigma_{xi}^2 = \sigma_{xi}^{*2}\left(1+\frac{z^2}{\beta_{xi}^{*2}}\right) \qquad \frac{1}{u_x^2} = \frac{\Sigma_z^2}{2\Sigma_x^{*2}}\left(\frac{\sigma_{x1}^{*2}}{\beta_{x1}^{*2}}+\frac{\sigma_{x2}^{*2}}{\beta_{x2}^{*2}}\right)$$

$$\sigma_{yi}^2 = \sigma_{yi}^{*2}\left(1+\frac{z^2}{\beta_{yi}^{*2}}\right) \qquad \frac{1}{u_y^2} = \frac{\Sigma_z^2}{2\Sigma_y^{*2}}\left(\frac{\sigma_{y1}^{*2}}{\beta_{y1}^{*2}}+\frac{\sigma_{y2}^{*2}}{\beta_{y2}^{*2}}\right)$$

$$\mathcal{L}_0 = \frac{N_1 N_2}{2\pi\Sigma_x^*\Sigma_y^*}\int_{-\infty}^{\infty}\frac{du}{\sqrt{\pi}}\frac{e^{-u^2}}{\sqrt{1+u^2/u_x^2}\sqrt{1+u^2/u_y^2}}$$

to avoid large hourglass effect (reducing $\mathcal{L}$):

head-on: $\beta_y^* \geq \sigma_z$ crossing-angle: $\beta_y^* \geq L = \sigma_x/\phi$



SuperKEKB more
machine parameters

crossing-angle: 2ϕ = 22 mrad → 83 mrad
asymmetry: 3.5 GeV/ 8 GeV → 4 GeV / 7 Gev

	KEKB Design	KEKB Achieved (): with crab	SuperKEKB High-Current Option	SuperKEKB Nano-Beam Scheme
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
κ(%)	1	0.8-1	1/0.5	1.0/0.7
σ_y(μm)	1.9	1.1	0.85/0.73	0.084/0.072
ξ_y	0.052	0.108/0.056 (0.101/0.096)	0.3/0.51	0.09/0.09
σ_z (mm)	4	~ 7	5(LER)/3(HER)	5
I_{beam} (A)	2.6/1.1	1.8/1.45 (1.62/1.15)	9.4/4.1	3.6/2.1
$N_{bunches}$	5000	~1500	5000	2119
Luminosity (10^{34} cm^{-2} s^{-1})	1	1.76 (2.08)	53	80

SuperKEKB more Touschek effect

In Coulomb scattering between particles in a bunch transverse momentum is transfered to longitudinal one (multiplied by γ);
if the longitudinal momentum transfer exceeds accelerator momentum acceptance particles are lost;
beam current decreases exponentially:

$$\frac{1}{\tau} = -\frac{1}{N_{bunch}} \frac{dN_{bunch}}{dt}$$

H. Wiedemann, Particle Accelerator Physics, Springer

$$\tau = \frac{8\pi\sigma_x\sigma_y\sigma_z}{r_c^2 c N_{bunch}} \gamma^2 \left(\frac{\Delta p}{p_0}\right)^3_{acc} \frac{1}{D(\varepsilon)} \qquad \varepsilon = \left(\frac{\Delta p \beta_x}{mc\gamma^2\sigma_x}\right)$$

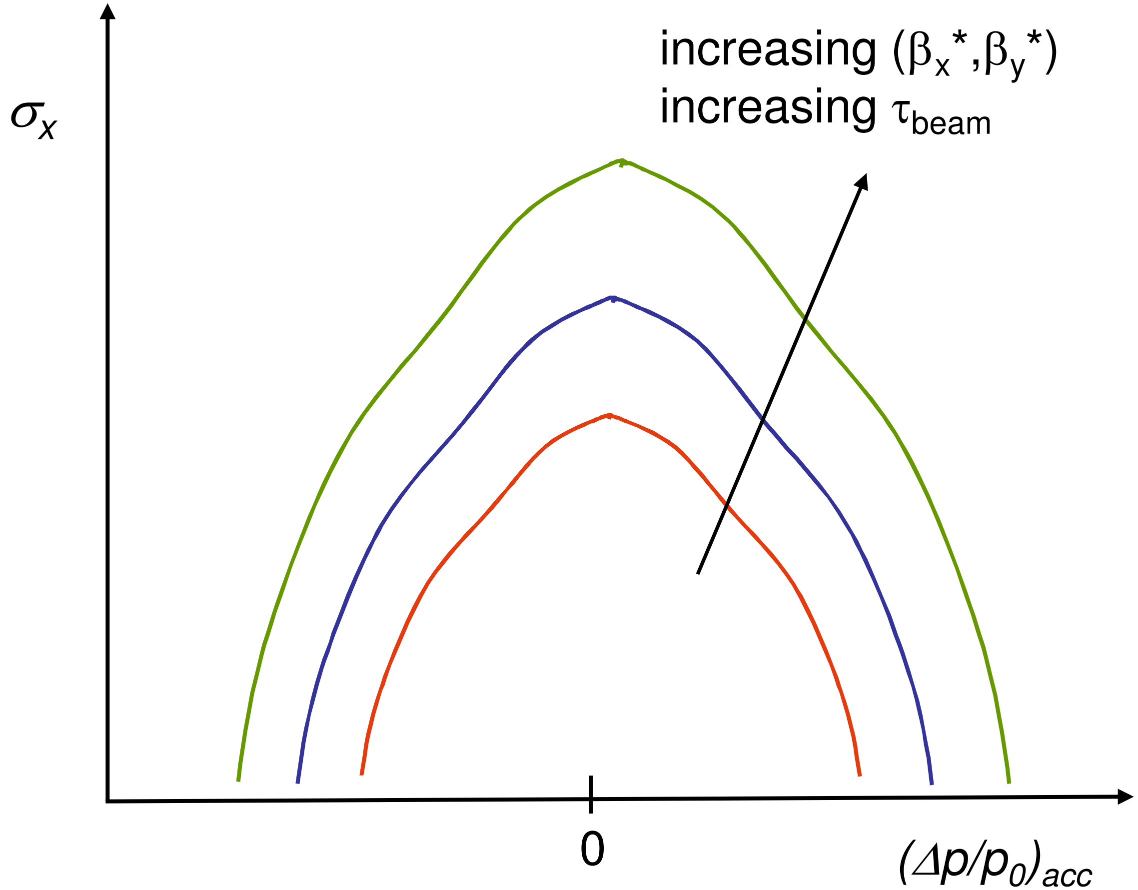
effect more important for LER

$N_{bunch}/\sigma_x\sigma_y\sigma_z$: particle density in bunch
$(\Delta p/p_0)_{acc}$: momentum acceptance
r_C: orbit radius

for large τ: increase $(\Delta p/p_0)_{acc}$; this also reduces $\sigma_x\sigma_y\sigma_z$ but the overall effect on τ is positive

SuperKEKB more
dynamic aperture,
high current

dynamic aperture:



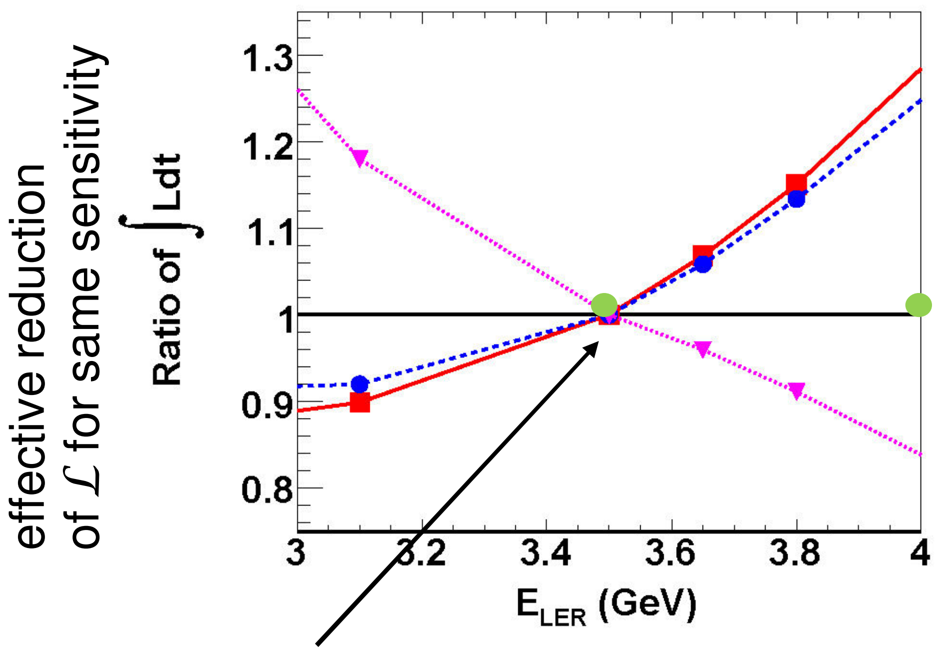
high current option:

- high operation costs
- too low beam-beam parameter
- CSR prevents squeezing the beam
- difficult to find solution for IR with low enough β^*

SuperKEKB more effect of energy asymmetry

larger asymm.: larger boost, better relative decay time resolution,
better continuum bkg. rejection
smaller asymm.: more isotropic events, better hermeticity

sBelle Design Group, KEK Report 2008-7



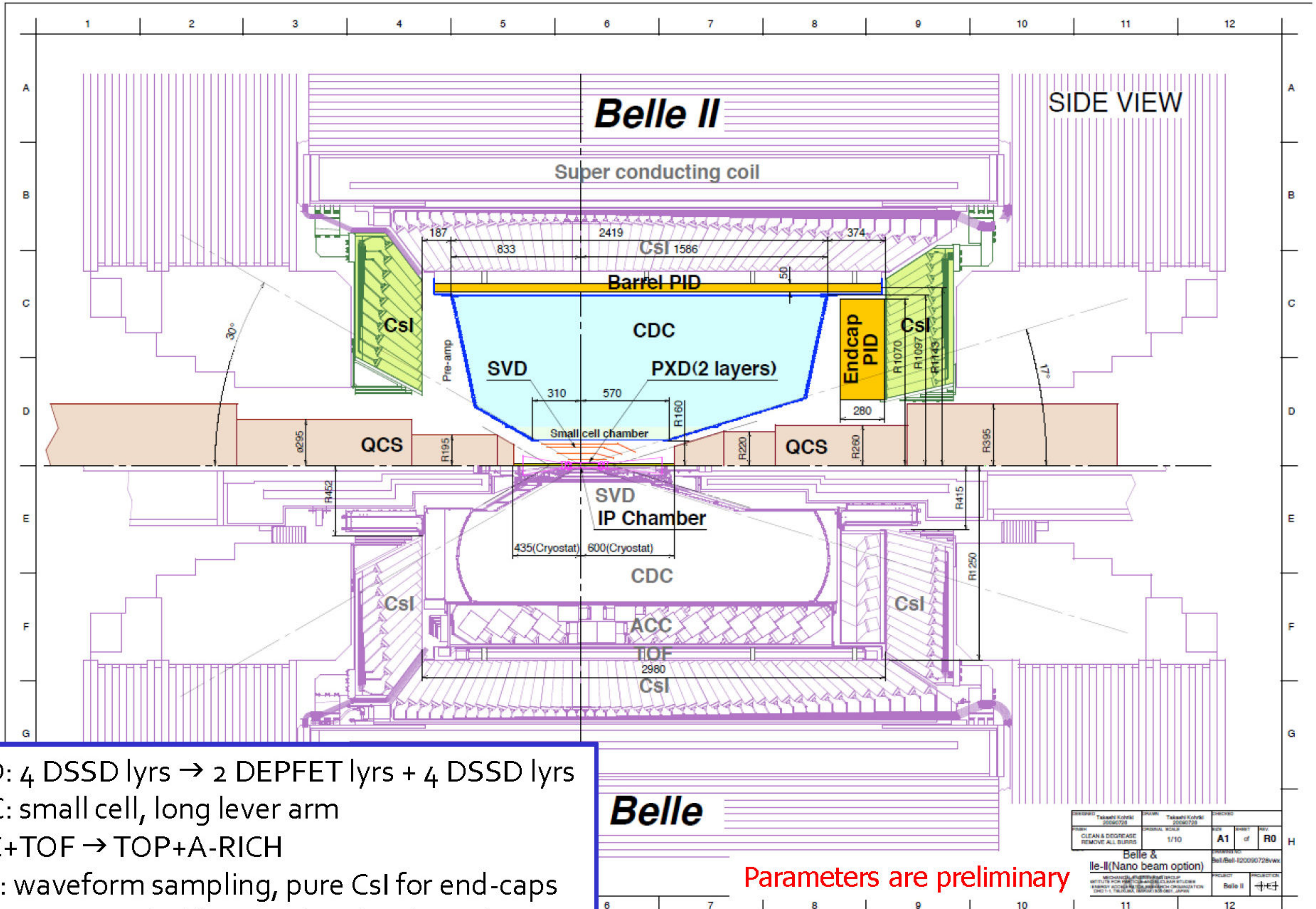
$\sigma_{\Delta z}$ = 180 μm, $\beta\gamma$=0.425 → $\sigma_{\Delta t}$=1.4 ps

t-dependent:
- $B \to J/\psi K_S$
- $B \to \phi K_S$
- $D^* \to D^0\pi$, $D^0 \to K^+K^-$

t-independent:
- $B \to \tau\nu$

not including improved resol. of upgraded PXD+SVD!
if $\sigma(\Delta z)$ improved by 10%-15% →
σ(t-dependent) improved by 5%-10%
→ effective $\int\mathcal{L}dt$: ↓10%-20%

Belle II more



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

Parameters are preliminary

Belle II more DEPFET pixel

p-channel FET on a completely depleted bulk

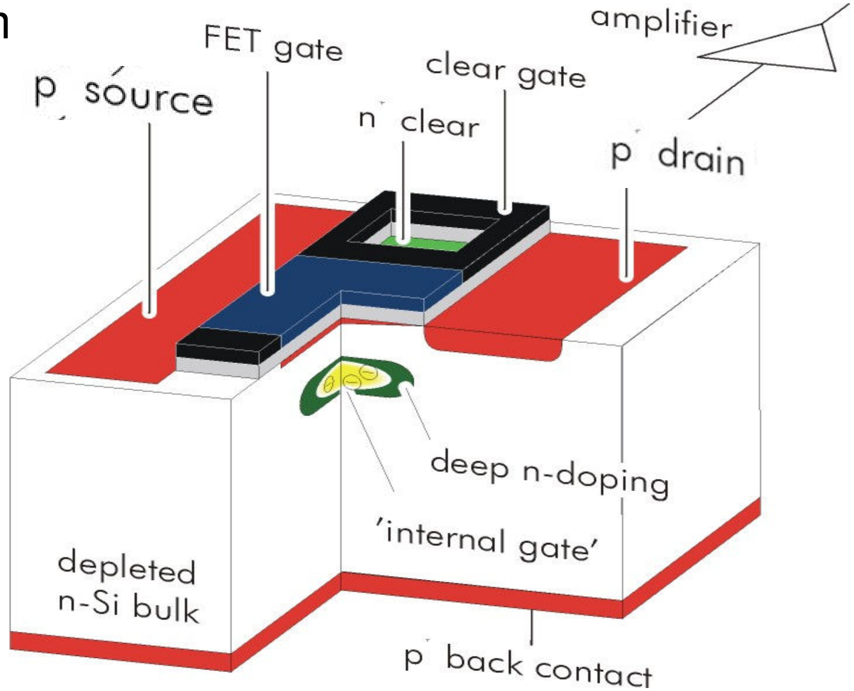
A deep n-implant creates a potential minimum for electrons under the gate ("internal gate")

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

Belle II DEPFET pixel

Belle II DEPFET Collaboration

University of Barcelona, Spain
Universitat Ramon Llull, Barcelona, Spain
Bonn University, Germany
Heidelberg University, Germany
Giessen University, Germany
Goettingen University, Germany
Karlsruhe University, Germany
IFJ PAN, Krakow, Poland
MPI Munich, Germany
Charles University, Prague, Czech Republic
IGFAE, Santiago de Compostela University, Spain
IFIC, CSIC-UVEG, Valencia, Spain

with important help from Hawaii, KEK, Vienna

C. Kiesling, 3rd Open Meeting of the Belle-II Collaboration, KEK, July 7-9, 2009

DEPFET@Belle-II

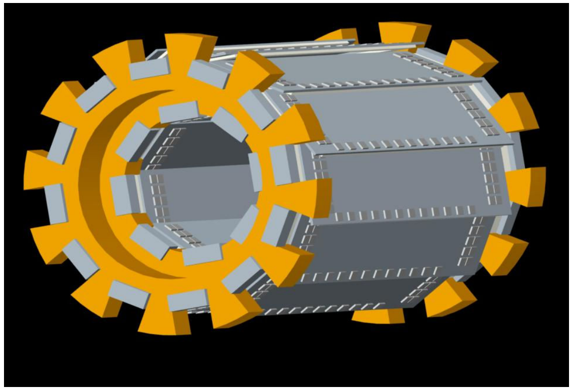
New management:

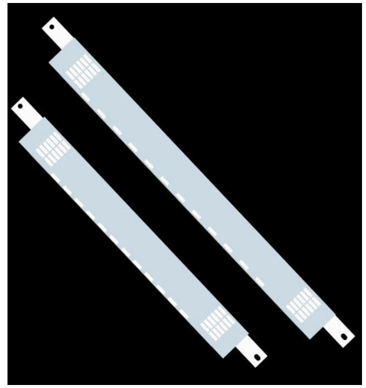
- IB- Board
- Project Leader
  C. Kiesling
- Technical Coord.
  H.-G. Moser
- „Integration Coord.“
  (Liaison @ KEK)

: full member of Belle II coll.

Belle II more DEPFET pixel

Overall geometry & support



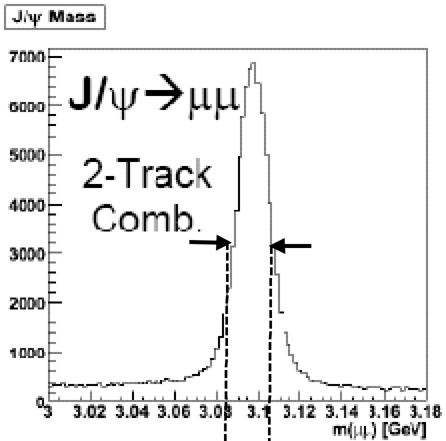


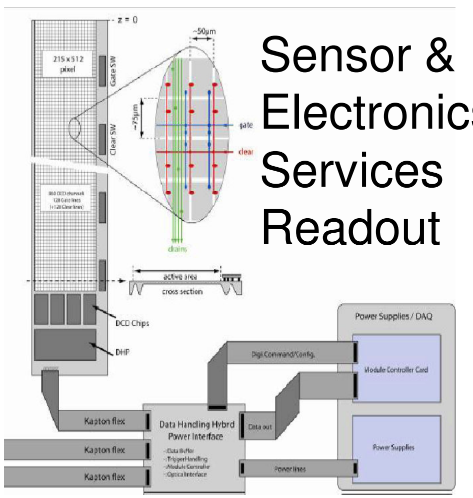
Ladder-
Layout

Mounting

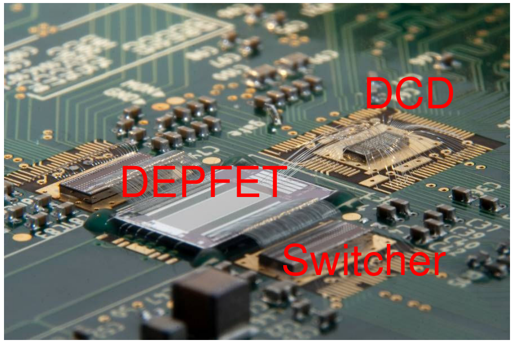
Local cooling

Belle config. tracking

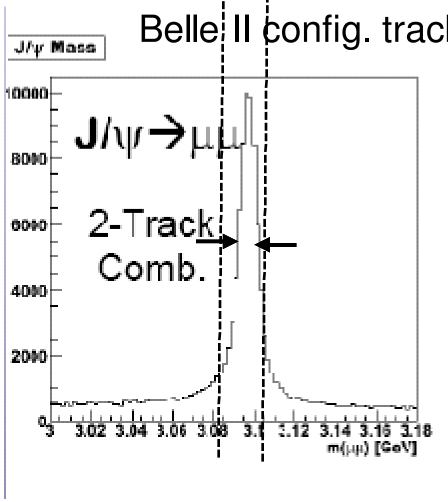




Sensor &
Electronics
Services
Readout

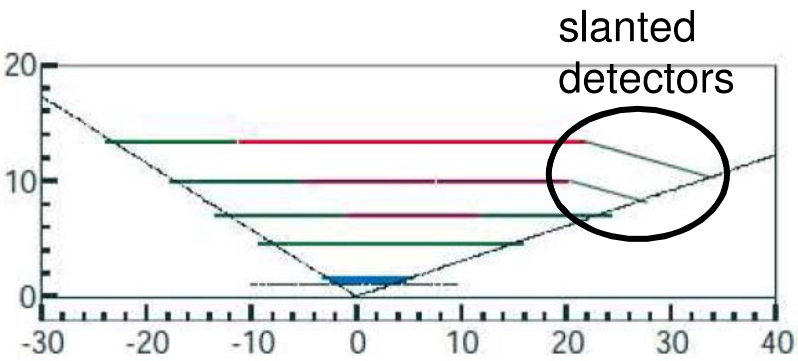


Belle II config. tracking

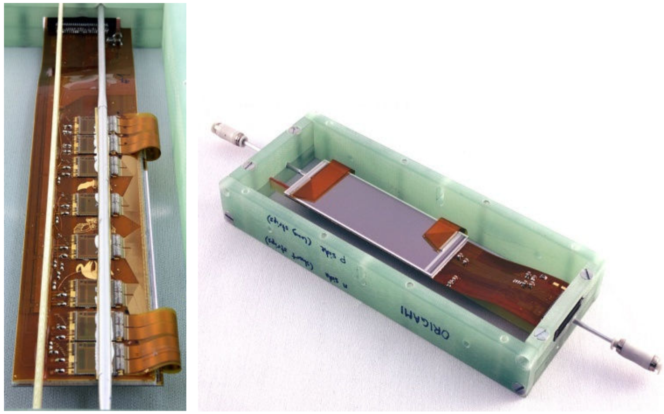


wafers finished June 2010
4-5 months testing
production starts January 2011

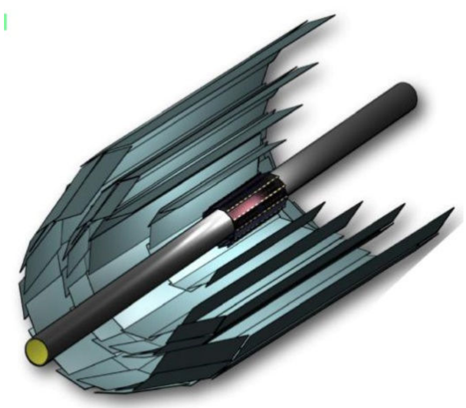
Belle II more SVD

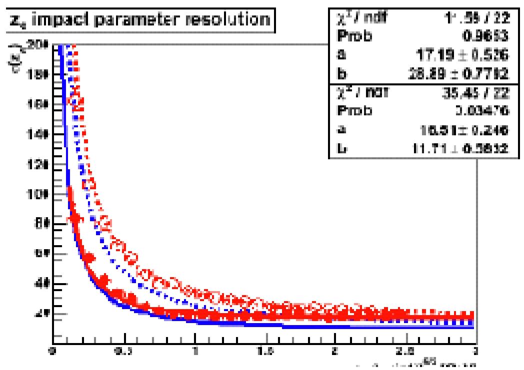


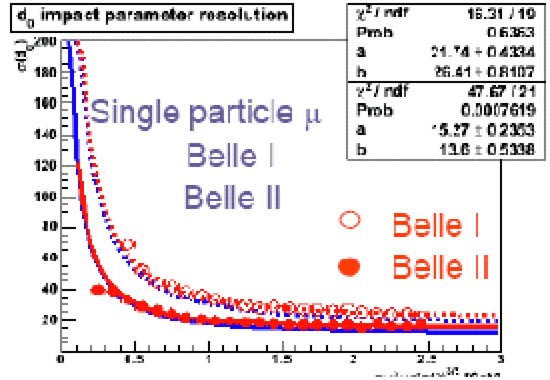
Beam Pipe	**r = 1cm**
DEPFET	
Layer 1	**r = 1.3cm**
Layer 2	**r = 2.2cm**
DSSD	
Layer 3	**r = 3.8cm**
Layer 4	**r = 8.0cm**
Layer 5	**r = 11.5cm**
Layer 6	**r = 14.0cm**



tests until June 2010
DSSD production until 2012







Belle II more vertexing, $b \to s\gamma$

in SM: helicity structure H_{eff}

$b_R \to s_L\gamma_L \quad \propto m_b$

or

$b_L \to s_R\gamma_R \quad \propto m_s$

CPV in SM $\propto m_s/m_b$

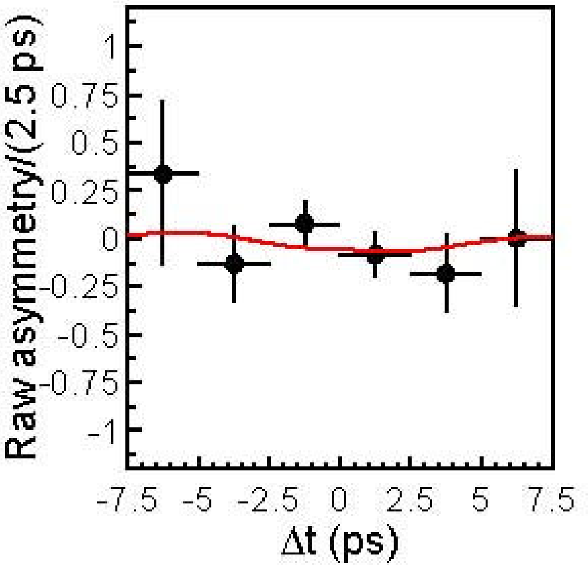
t-dependent CPV:

$S_{CP}(K_s\pi^0\gamma)$ = -0.10 ±0.31 ±0.07

$A_{CP}(K_s\pi^0\gamma)$ = -0.20 ±0.20 ±0.06

for $m(K_s\pi^0)$ < 1.8 GeV (mainly $K^*\gamma$)

Belle, PRD74, 111104 (2006), 535M BB



B decay vtx from K_s and IP;

additional improvement with

upgraded SVD; sBelle Design Group, KEK Report 2008-7

$\sigma(S_{CP}(K_s\pi^0\gamma))$ = 0.09 @ 5 ab^{-1}

0.03 @ 50 ab^{-1}

similar sensitivity for $K_s\rho^0\gamma$

(dilution from $K^*\pi\gamma$)

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

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

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

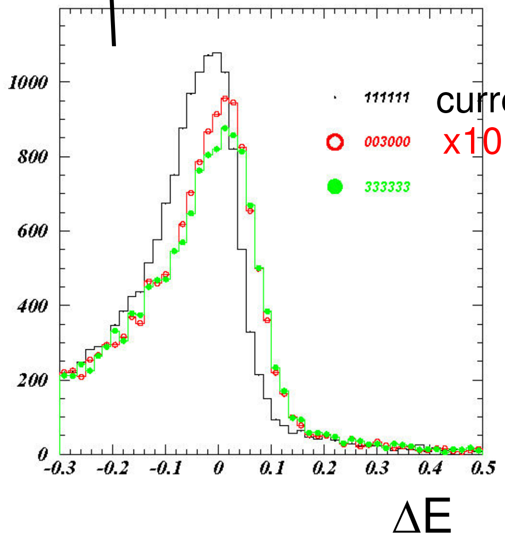
Belle II more vertexing, $b \to s\gamma$

t-dependent CPV

expectation:

- main syst. scales with luminosity
- +30% increase in K_s acceptance with upgraded vertexing
- -10% decrease due to 10x higher background in upgraded ECL

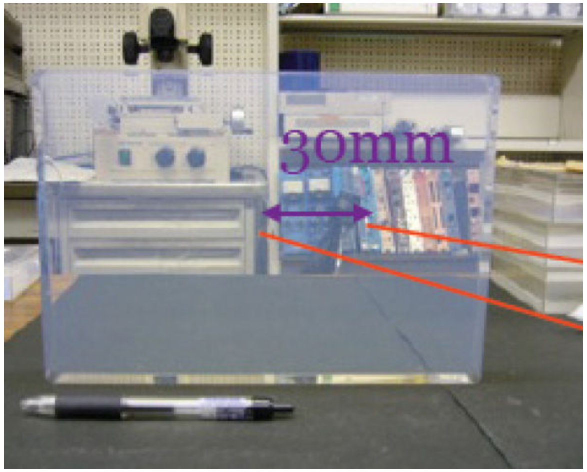
$\sigma(S(K_s\pi^0\gamma))=0.09$ @5 ab^{-1}
0.03 @50 ab^{-1} (~SM value)



MC $B \to K_s\pi^0\gamma$

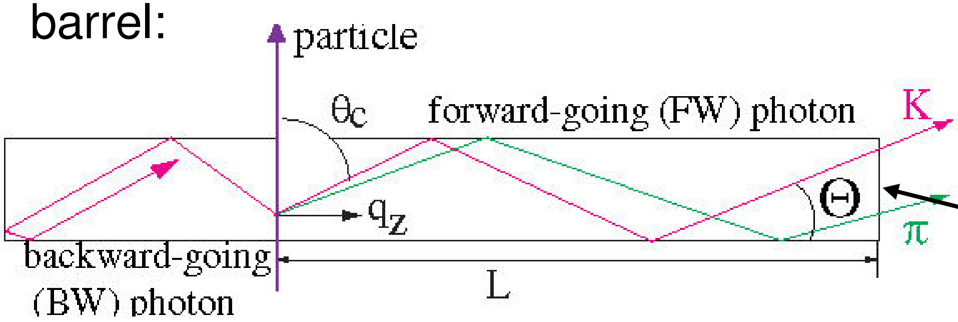
Belle II more PID

endcap:



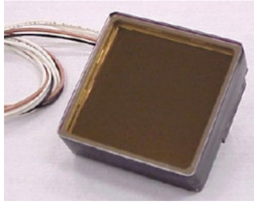
aerogel

barrel:

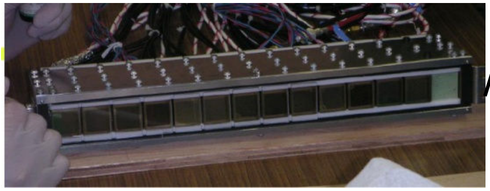


photodetector options:
(multichannel plate PMT):

Hamamatsu SL10
27.5x27.5 mm^2, 4x4 ch

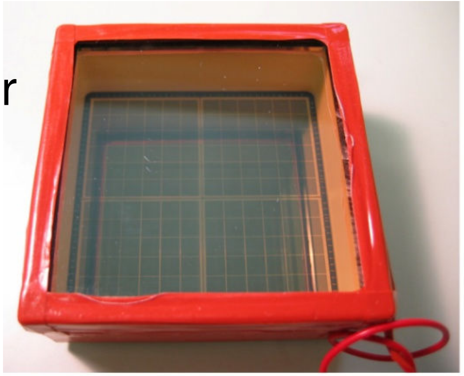


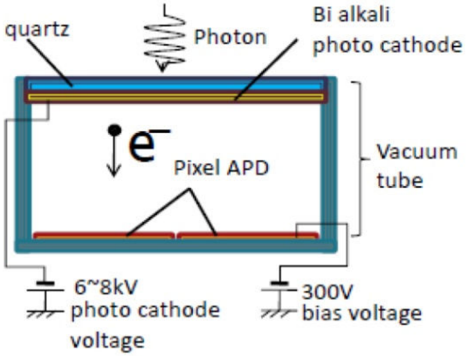
Photonis
59x59 mm^2, 8x8 ch



photodetector options:

Hybrid
Avalanche
Photo
Diode
(Hamamatsu)

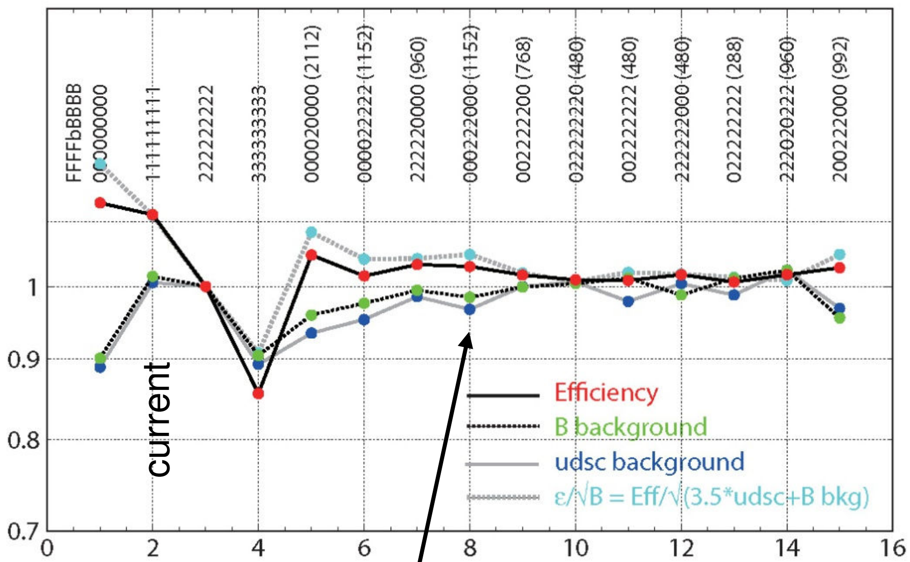




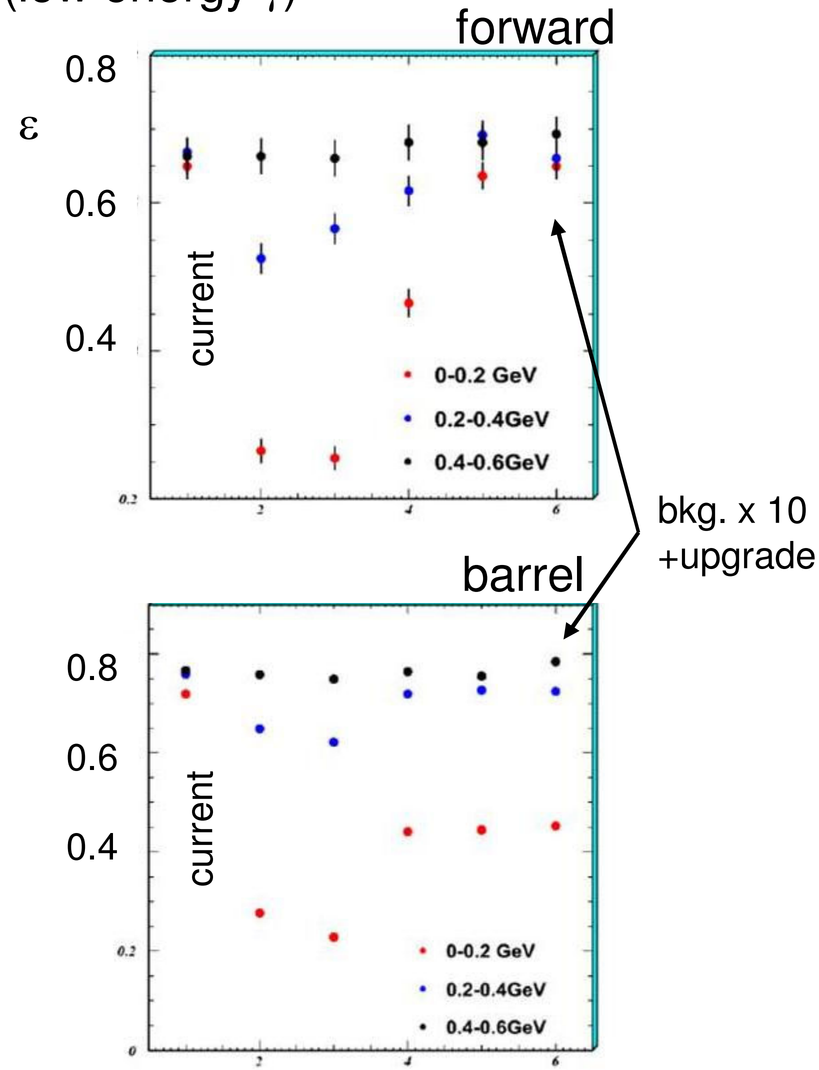
(or
MCP-PMT)

Belle II more EM Calorimeter

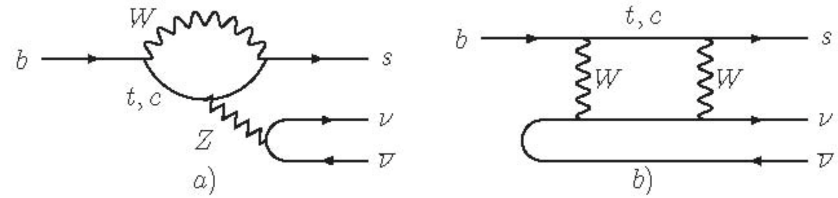
effect of upgrade on full B recon.



MC: $B \to J/\psi\ \omega$, $\omega \to 3\pi$, $\pi^0 \to \gamma\gamma$ (low energy γ)



Belle II more ECL, B $\to K^{*0}\nu\nu$



FCNC with lower hadronic uncertainties compared to $b \to s\ell\ell$

Br($B \to K^{*0}\nu\nu$)$<3.4\times10^{-4}$ @90% C.L.

Belle, PRL99, 221802 (2007), 490 fb^{-1}

similar method as $B \to \tau\nu$

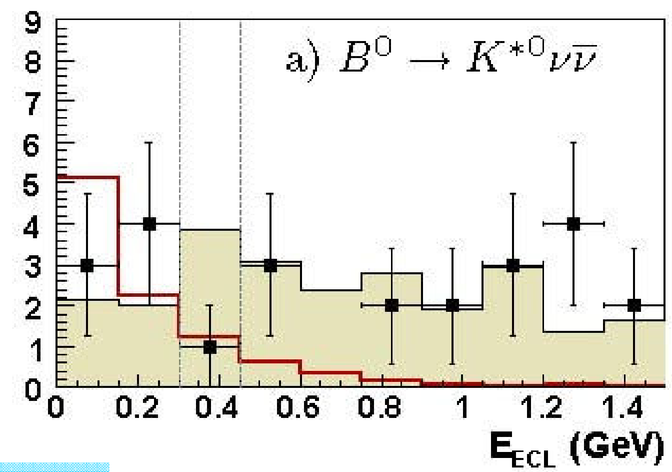
full recon. B_{tag}, K^{*0} on signal side,

signal in E_{ECL};

expected N_{sig}=0.37

(Br=1.3×10^{-5}) G. Buchalla et al., PRD63, 014015 (2001)

N_{bkg}=3.15



improvements assumed

ε B_{tag}: 20% (similar ECL performance, more inclusive + neutral modes) sBelle Design Group, KEK Report 2008-7

ε_{PID}: 15% (30% for $K^{*0} \to K\pi$)(barrel TOP + dE/dX);

Σ: 50% increase of ε (hadr. tag only)

$B_{tag} \to$ semil.: comparison for $B \to \tau\nu$ (both tag methods used)

3 σ significance @ 45 ab^{-1}

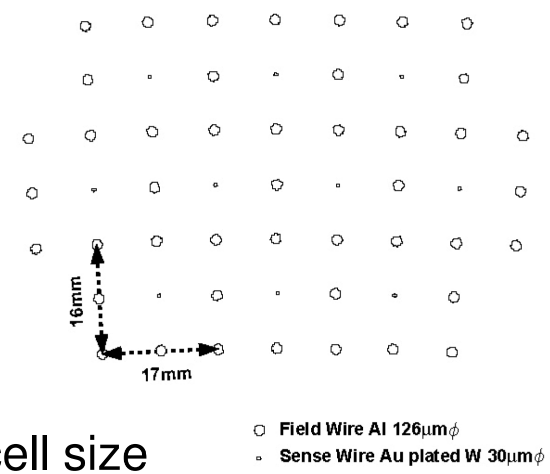
3 σ significance @ 8 ab^{-1}

5 σ significance @ 25 ab^{-1}

Belle II more CDC

read-out:
dead time 800 ns – 2200 ns
→ 200 ns

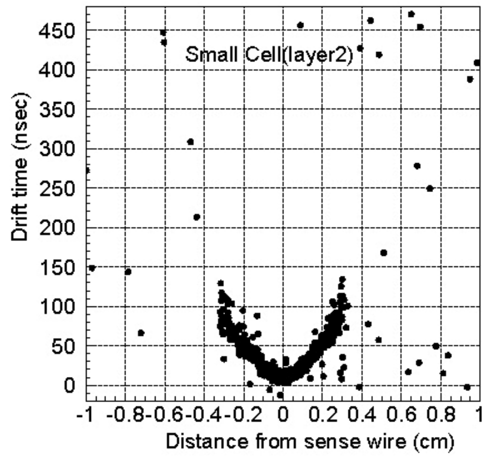
Central Drift Chamber

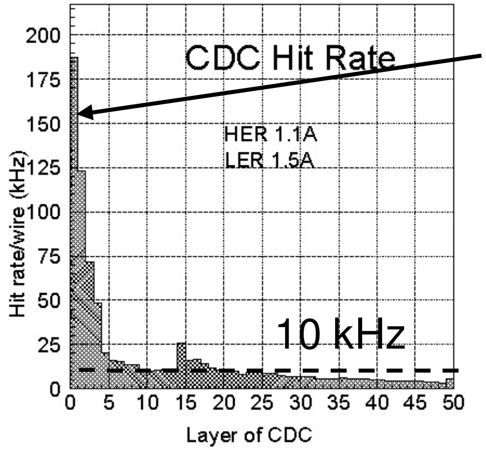


cell size

smaller cells (5x5 mm²)
installed in 2003 in two
inner layers;

drift time
decreased
≤100 ns;





inner-most layer
operating well
@200 kHz;

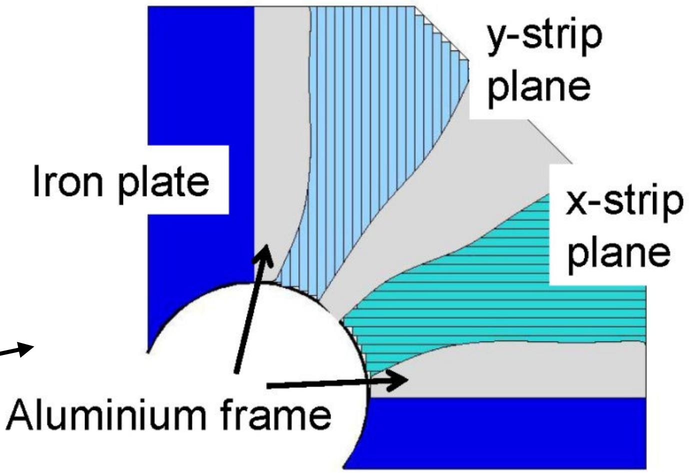
if 20x bkg. for other layers
⇒ no problem

expected performance
(20x bkg w.r.t. Belle):
$B \to J/\psi\, K_S$:
ε +2%
$\sigma_{\Delta E}$ +6%
$B \to D^{*+}D^{*-}$:
ε +30%
$\sigma_{\Delta E}$ +11%

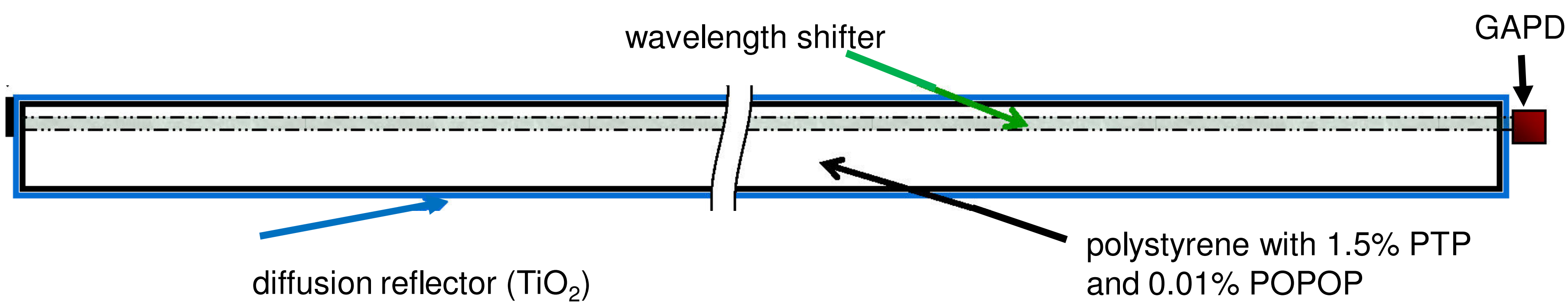
Belle II more KLM

endcap:
- scintillators, two orthogonal directions in one super-layer, WLS read-out
- avalanche photo-diode in Geiger mode (GAPD)

super-layer:
iron
Al frame
x-strips
y-strips



single strip:



Belle II more physics sensitivity

Observable	Belle 2006	SuperKEKB		[†]LHCb	
	($\sim$0.5 ab^{-1})	(5 ab^{-1})	(50 ab^{-1})	(2 fb^{-1})	(10 fb^{-1})
Hadronic $b \to s$ transitions					
$\Delta\mathcal{S}_{\phi K^0}$	0.22	0.073	0.029		0.14
$\Delta\mathcal{S}_{\eta' K^0}$	0.11	0.038	0.020		
$\Delta\mathcal{S}_{K_S^0 K_S^0 K_S^0}$	0.33	0.105	0.037	-	-
$\Delta\mathcal{A}_{\pi^0 K_S^0}$	0.15	0.072	0.042	-	-
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014		
Radiative/electroweak $b \to s$ transitions					
$\mathcal{S}_{K_S^0 \pi^0 \gamma}$	0.32	0.10	0.03	-	-
R_K		0.07	0.02		0.043
$\mathcal{B}(B \to X_s\gamma)$	13%	7%	6%	-	-
$A_{CP}(B \to X_s\gamma)$	0.058	0.01	0.005	-	-
C_9 from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-	11%	4%		
C_{10} from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-	13%	4%		
C_7/C_9 from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-		5%		7%
$\mathcal{B}(B^+ \to K^+\nu\nu)$	[††] $< 3\ \mathcal{B}_{\rm SM}$	?	30%	-	-
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	[††] $< 40\ \mathcal{B}_{\rm SM}$	?	35%	-	-
Radiative/electroweak $b \to d$ transitions					
$\mathcal{S}_{\rho\gamma}$	-	0.3	0.1		
$\mathcal{B}(B \to X_d\gamma)$	-	24%		-	-

preliminary

(blue text are just edits, no special emphasize)

Belle II more physics sensitivity

Leptonic/semileptonic B decays					
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%	-	-
$\mathcal{B}(B^+ \to \mu^+\nu)$	$^{\dagger\dagger} < 2.4\mathcal{B}_{\rm SM}$	4.3 $\rm ab^{-1}$ for 5σ discovery		-	-
$\mathcal{B}(B^+ \to D\tau\nu)$	-	7.9%	2.5%	-	-
$\mathcal{B}(B^0 \to D\tau\nu)$	-	28.5%	9.0%	-	-
LFV in τ decays					
$\mathcal{B}(\tau \to \mu\gamma)$ $[10^{-9}]$	< 45	< 30	< 8	-	-
$\mathcal{B}(\tau \to \mu\eta)$ $[10^{-9}]$	< 65	< 20	< 4	-	-
$\mathcal{B}(\tau \to \mu\mu\mu)$ $[10^{-9}]$	< 209	< 10	< 1	-	-
Unitarity triangle parameters					
$\sin 2\phi_1$	0.026	0.016	0.012	~0.02	~0.01
ϕ_2 $(\pi\pi)$	11°	10°	3°	-	-
ϕ_2 $(\rho\pi)$	$68^\circ < \phi_2 < 95^\circ$	3°	1°	10°	4.5°
ϕ_2 $(\rho\rho)$	$62^\circ < \phi_2 < 107^\circ$	3°	1°	-	-
ϕ_2 (combined)		2°	1°	10°	4.5°
ϕ_3 $(D^{(*)}K^{(*)})$ (Dalitz)	20°	7°	2.5°	8°	
ϕ_3 $(DK^{(*)})$ (ADS+GLW)	-	16°	5°	5-15°	
ϕ_3 $(D^{(*)}\pi)$	-	18°	6°		
ϕ_3 (combined)		6°	2°	4.2°	2.4°
$\|V_{ub}\|$ (inclusive)	6%	5%	3%	-	-
$\|V_{ub}\|$ (exclusive)	15%	12% (LQCD)	5% (LQCD)	-	-
$^{\dagger\dagger\dagger}\bar{\rho}$	20.0%		3.4%		
$^{\dagger\dagger\dagger}\bar{\eta}$	15.7%		1.7%		

preliminary

(blue text are just edits, no special emphasize)

Belle II more physics sensitivity

Observable	Belle	Belle/SuperKEKB		LHCb†	
				$(2\ \mathrm{fb}^{-1})$	$(10\ \mathrm{fb}^{-1})$
B_s physics	$(25\ \mathrm{fb}^{-1})$	(	$5\ \mathrm{ab}^{-1}$)		
$\mathcal{B}(B_s \to \gamma\gamma)$	$< 8.7 \times 10^{-6}$	0.25×10^{-6}		-	-
$\Delta\Gamma_s^{CP}/\Gamma_s$ $(Br(B_s \to D_s^{(*)} D_s^{(*)}))$	3%	1% (model dependency)		-	-
$\Delta\Gamma_s/\Gamma_s$ $(B_s \to f_{CP}$ t-dependent)	-	1.2%		-	-
ϕ_s (with $B_s \to J/\psi\phi$ etc.)	-	-	-	0.02	0.01
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-			$6\ \mathrm{fb}^{-1}$ for 5σ discovery	
ϕ_3 $(B_s \to KK)$	-			7-10°	
ϕ_3 $(B_s \to D_s K)$	-			13°	
Υ decays	$(3\ \mathrm{fb}^{-1})$	$(500\ \mathrm{fb}^{-1})$			
$\mathcal{B}(\Upsilon(1S) \to$ invisible)	$< 2.5 \times 10^{-3}$	$< 2 \times 10^{-4}$			
	$(\sim 0.5\ \mathrm{ab}^{-1})$‡	$(5\ \mathrm{ab}^{-1})$	$(50\ \mathrm{ab}^{-1})$		
Charm physics					
D mixing parameters					
x	0.25%	0.10%	0.07%		0.25%††
y	0.18%	0.08%	0.05%		0.05%††
$\delta_{K\pi}$	11°	6°	4°		
$\|q/p\|$	0.16	0.07	0.05		
ϕ	0.13 rad	0.07 rad	0.04 rad		
A_D	2.4%	1%	0.3%		
New particles					
Electroweak parameters		$(\sim 10\ \mathrm{ab}^{-1})$			
$\sin^2\Theta_W$	-	3×10^{-4}			

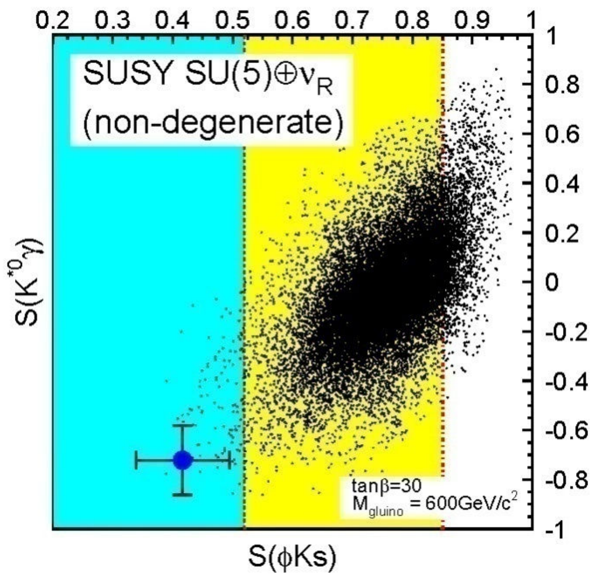
preliminary

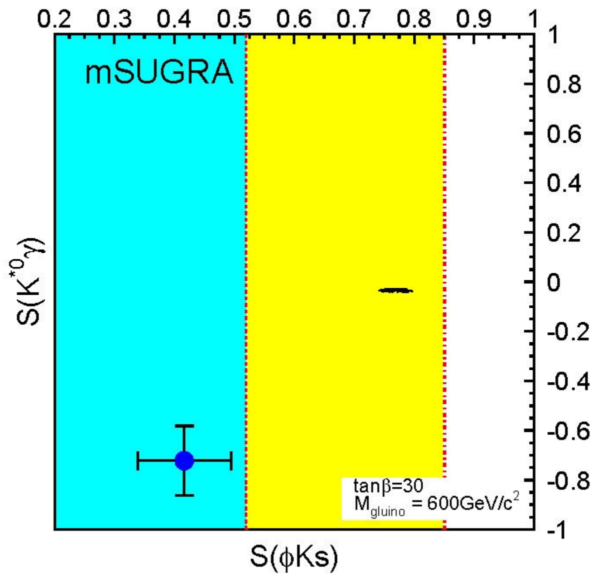
(blue text are just edits, no special emphasize)

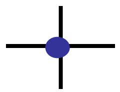
Belle II more example scenario

Possibilities of Super B-factory:

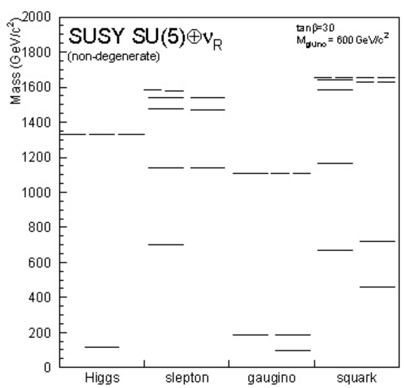
- can identify nature of NP - example

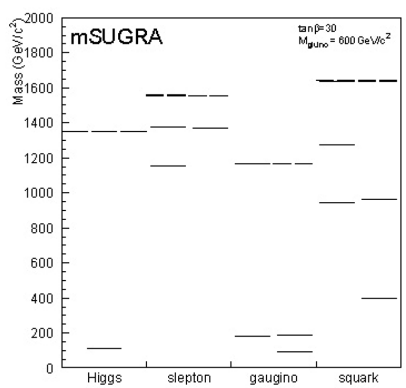






expected sensitivity of SuperBelle 5 ab^{-1}





particle mass spectra similar

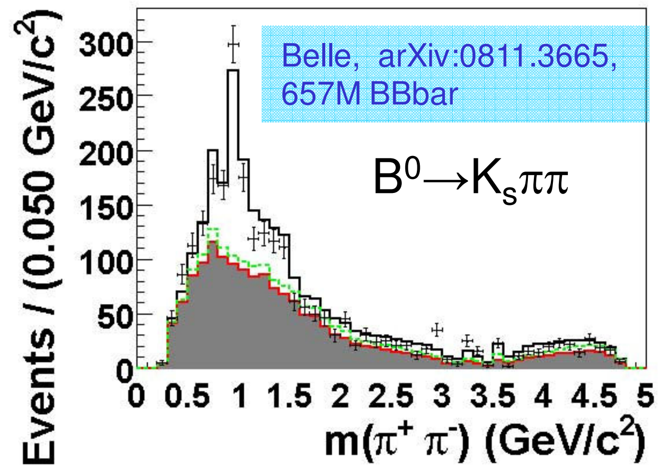
Belle II more $b \to sqq$

quasy two-body states

⇩

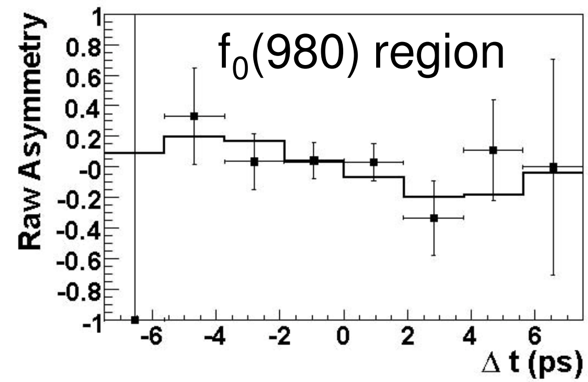
t-dependent Dalitz analyses

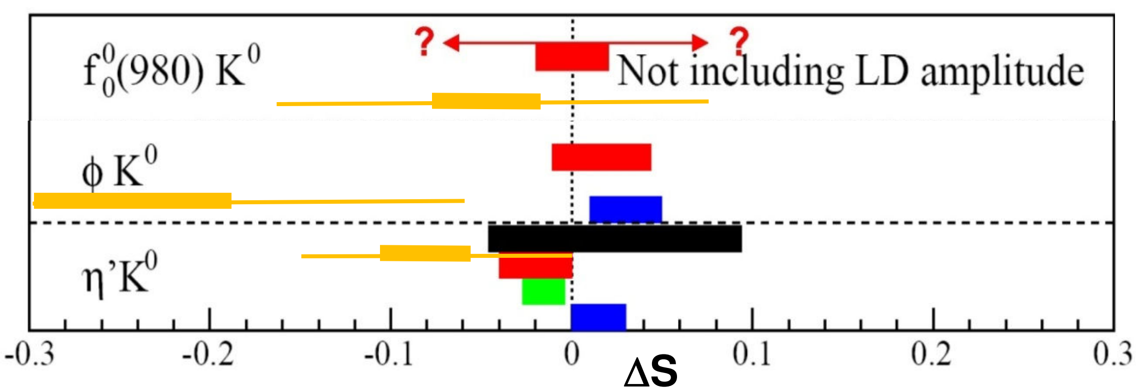
measure ϕ_1^{eff} associated with individual amplitudes (ϕK_s, f_0K_s,...)



$5\, ab^{-1}$: $$\sigma(\Delta S) \approx \begin{cases} 0.05 & f_0 K_s \\ 0.10 & \varphi K_s \\ 0.05 & \eta' K_s \end{cases}$$

$50\, ab^{-1}$: $$\sigma(\Delta S) \approx \begin{cases} 0.03 & f_0 K_s \\ 0.05 & \varphi K_s \\ 0.02 & \eta' K_s \end{cases}$$





- Belle II, 50 ab^{-1}
- range allowed with current HFAG central values

determine possible new phase with $\sigma \leq \sigma_{th}$(current)

Belle II more $B \to K\pi$

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

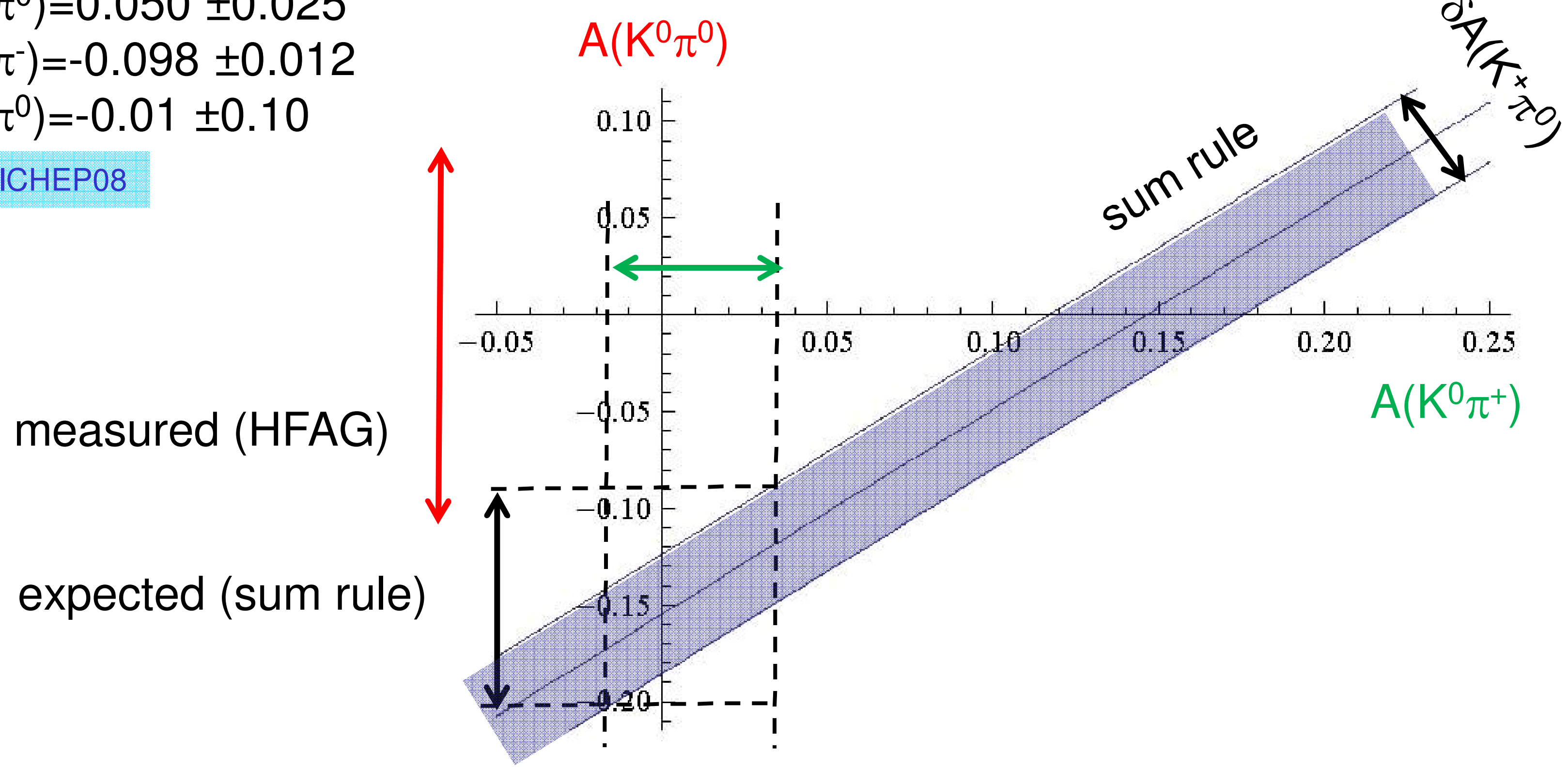
$B \to K\pi$

sum rule

$A(K^0\pi^+)=0.009 \pm 0.025$
$A(K^+\pi^0)=0.050 \pm 0.025$
$A(K^+\pi^-)=-0.098 \pm 0.012$
$A(K^0\pi^0)=-0.01 \pm 0.10$

HFAG, ICHEP08

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



Belle II more $B \to K\pi$

$B \to K\pi$

sum rule

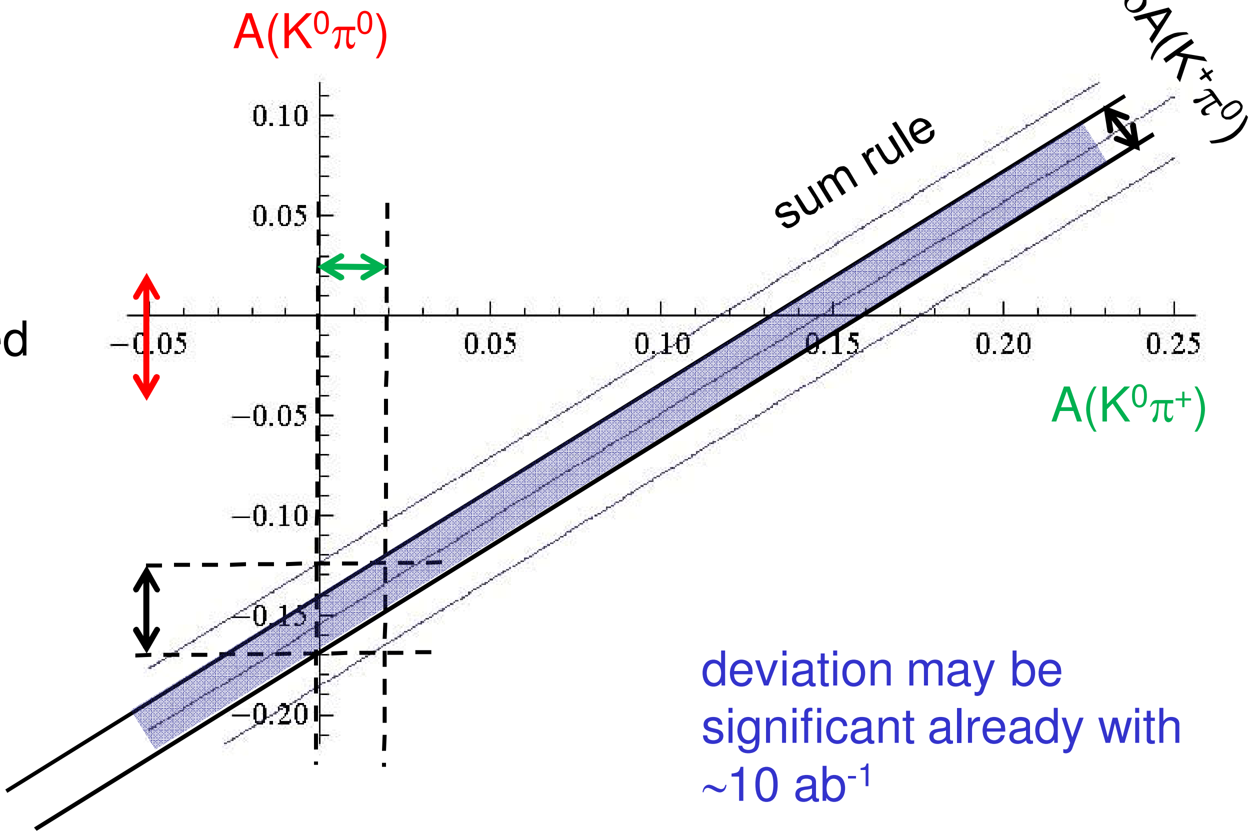
$B \to K^0\pi^0$:

main syst. uncertainty from tag side interf.; can be reduced by measuring Δt with semil. B_{sig} decays

$B \to K^0\pi^+, K^+\pi^0$:

full systematics treated as non-scaling

Belle, 50 ab^{-1}



deviation may be significant already with ~10 ab^{-1}

Belle II more $B \to \tau\nu$

H± discovery region:

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

for 50 ab^{-1}

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

similar results arise from expectations for semileptonic $B \to D\tau\nu$

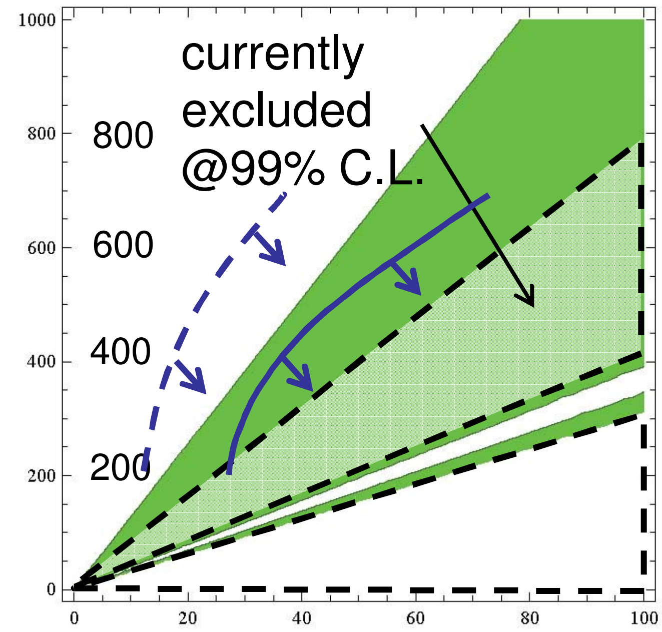
Γ/Γ^{SM} indpendent of m_ℓ in type-II 2HDM

$$R_{\tau\mu} = \frac{Br(B^+ \to \tau\nu)}{Br(B^+ \to \mu\nu)} \sim \frac{m_\tau^2}{m_\mu^2}$$

deviations in R̸ SUSY;

$B \to \mu\nu$: 4.3 ab^{-1} for 5 σ discovery (SM Br);

5 σ discovery from $B \to \tau\nu$



LHC $H^\pm \to \tau\nu$; exploting helicity effects

LHC discovery potential, 100 fb^{-1}

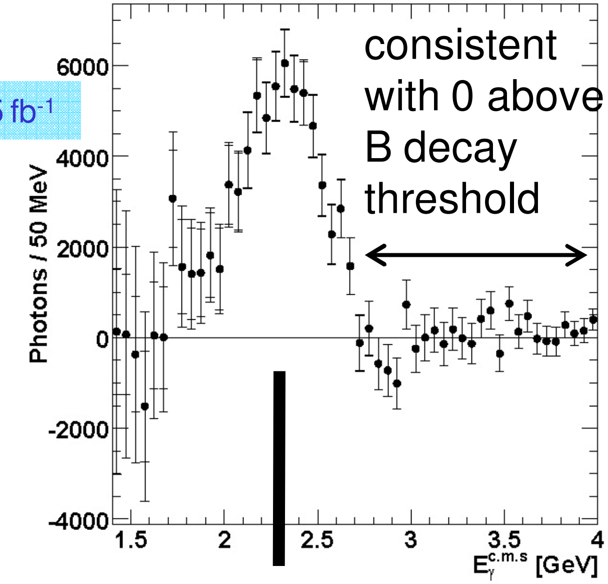
LHC discovery potential, 30 fb^{-1}

D.P. Roy, cHarged2006

(+ effect of trigger simul., mentioned to increase the discovery limits in tanβ by 25%)

Belle II more $B \to s\gamma$

Belle, arXiv:0804.1580,605 fb^{-1}



$m_b^{1S}/2$~2.3 GeV

Inclusive measurement

E_γ spectrum

$Br(B \to X_s\gamma)$

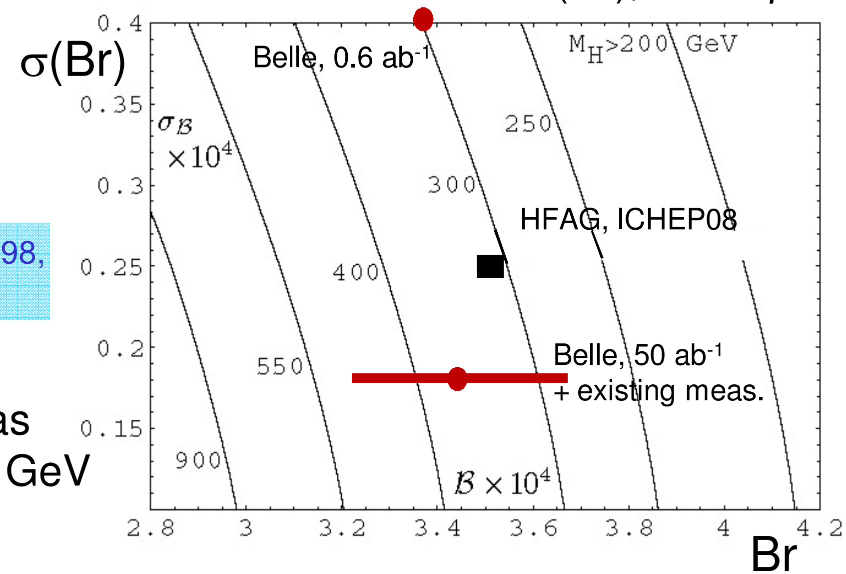
deconvolution of E_γ ($E_\gamma^{meas} \to E_\gamma^{true}$; using radiative di-muon evts);
boost to B rest frame;
$b \to d\gamma$ contrib. (4%);

$$Br(B \to X_s\gamma; 1.7 < E_\gamma < 2.8\, GeV) = (3.31 \pm 0.19 \pm 0.37 \pm 0.01)\cdot 10^{-4}$$

last uncertainty due to boost;
largest system.: corr. factors in off-data subtraction ; assumed scaling bkg. γ's from B (other than π^0, η) -> assumed non-scaling ($0.24\text{x}10^{-4}$), rest of syst. scaling

M. Misiak et al., PRL98, 022002 (2007)

95% C.L. lower limit on m($H^\pm$), all tanβ



L.L. can get as high as ~500 GeV