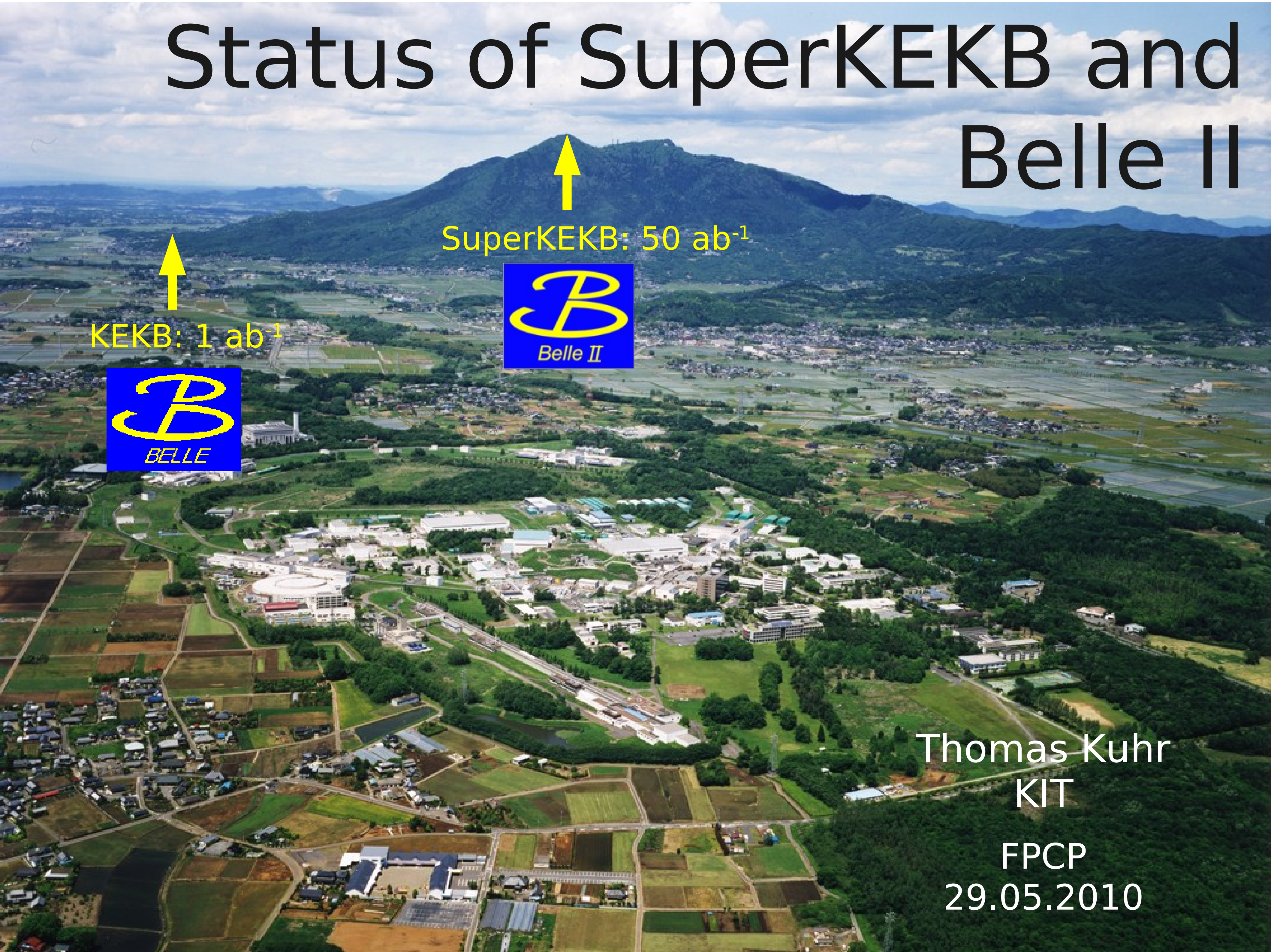
Status of SuperKEKB and Belle II

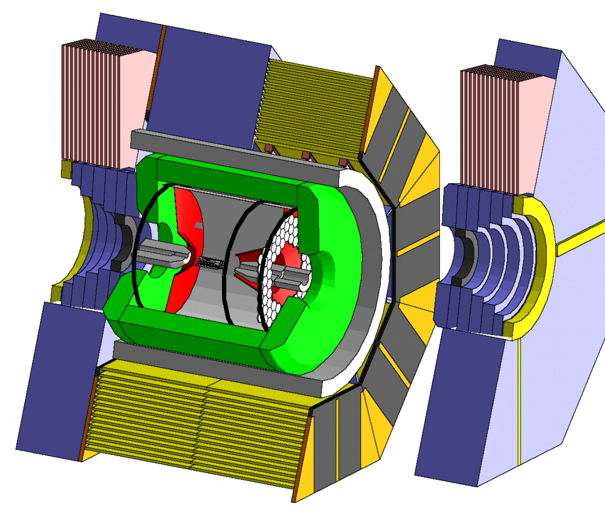


Thomas Kuhr
KIT

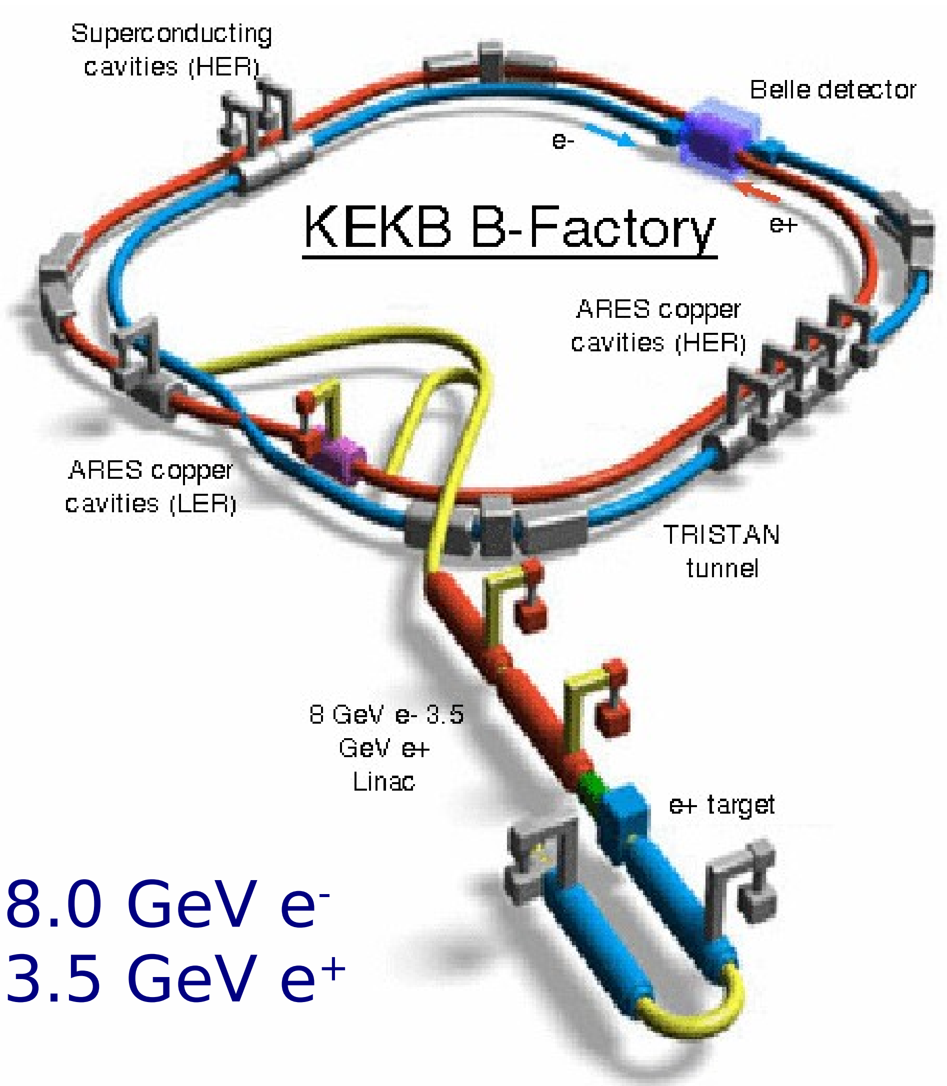
FPCP
29.05.2010

Outline

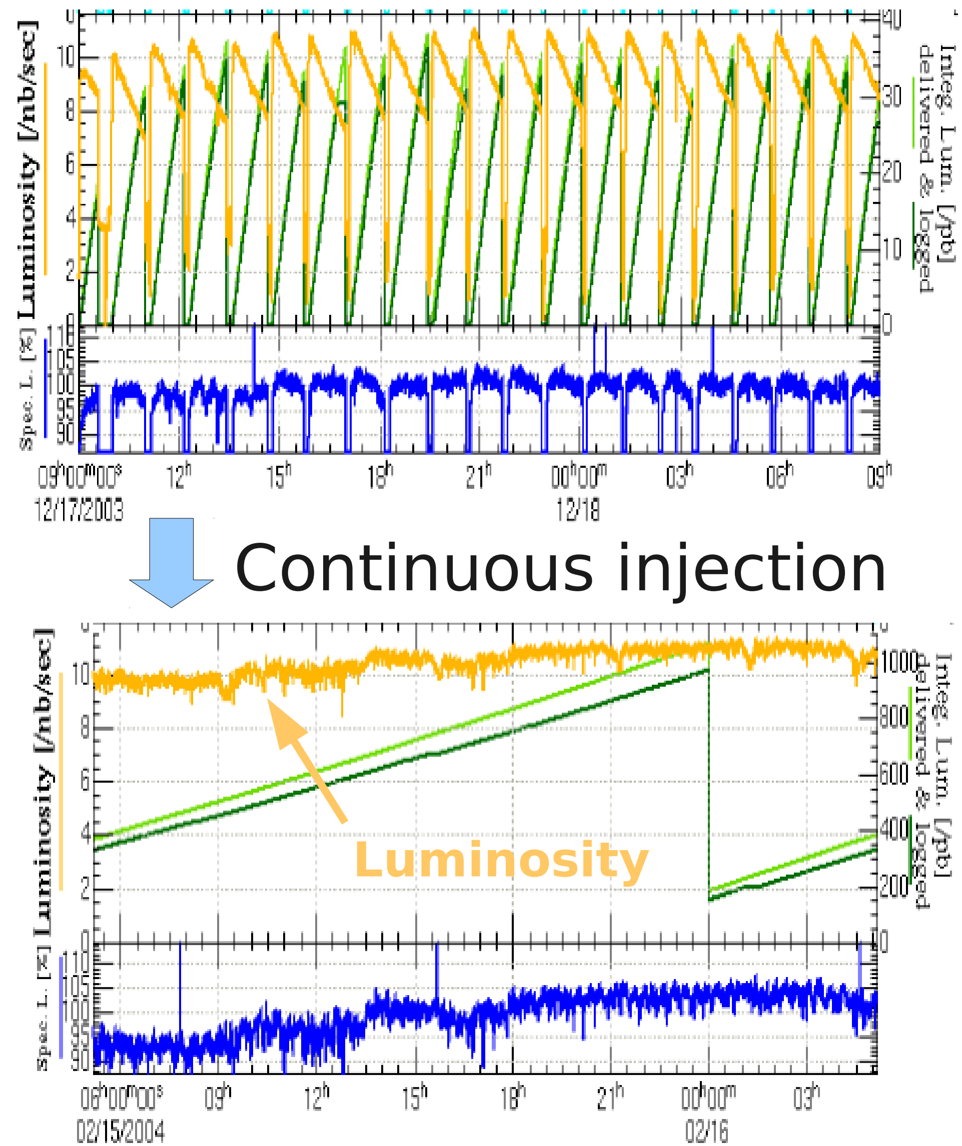
- KEKB and Belle
- Physics at a Super Flavor Factory
- Accelerator Upgrade: SuperKEKB
- Detector Upgrade: Belle II
- Summary



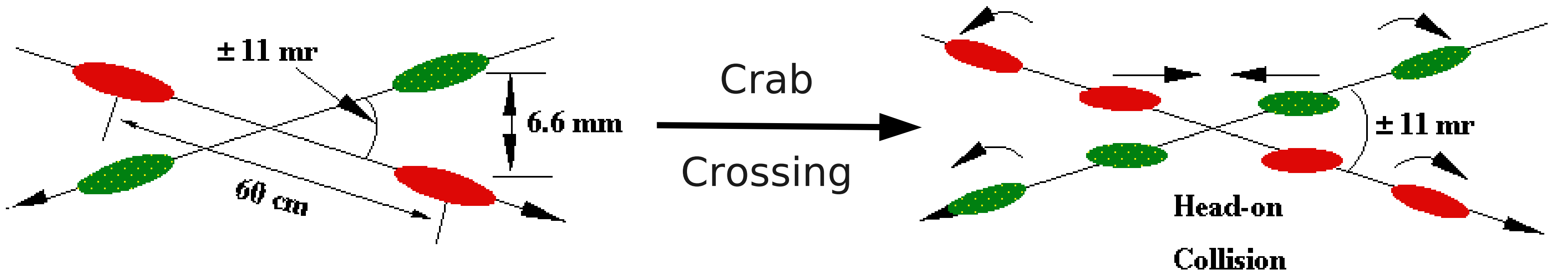
KEKB Accelerator

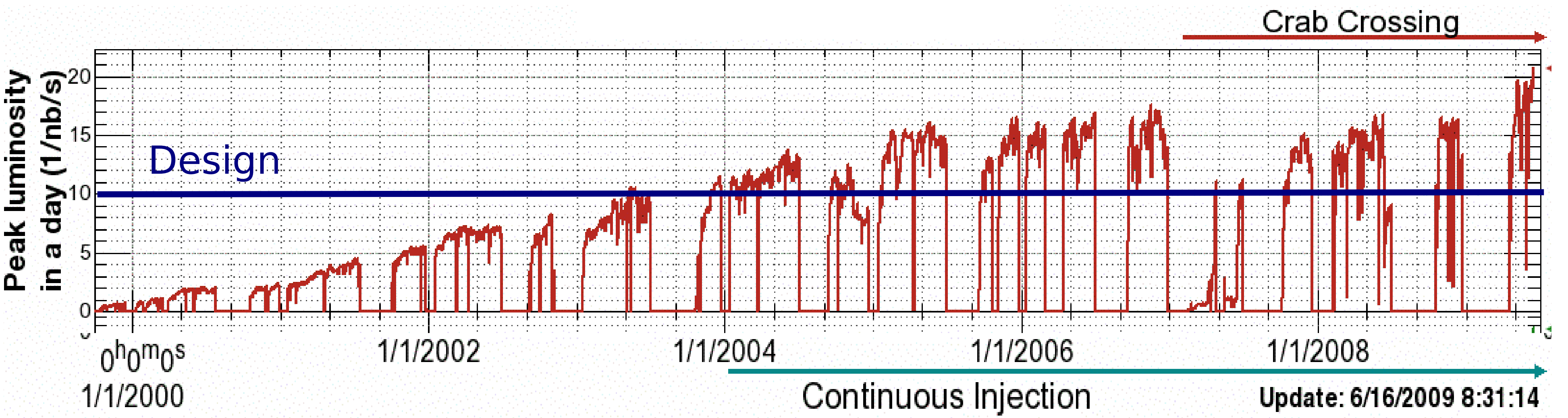


8.0 GeV e^-
3.5 GeV e^+



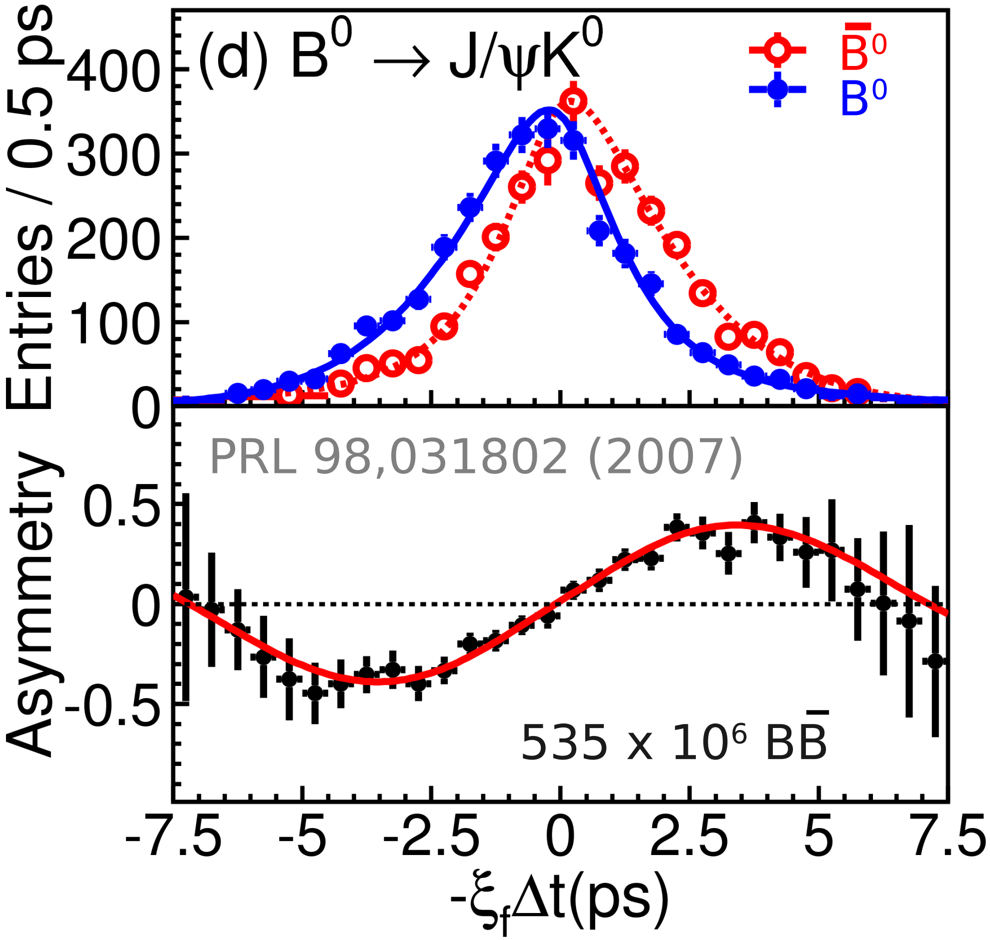
KEKB Performance

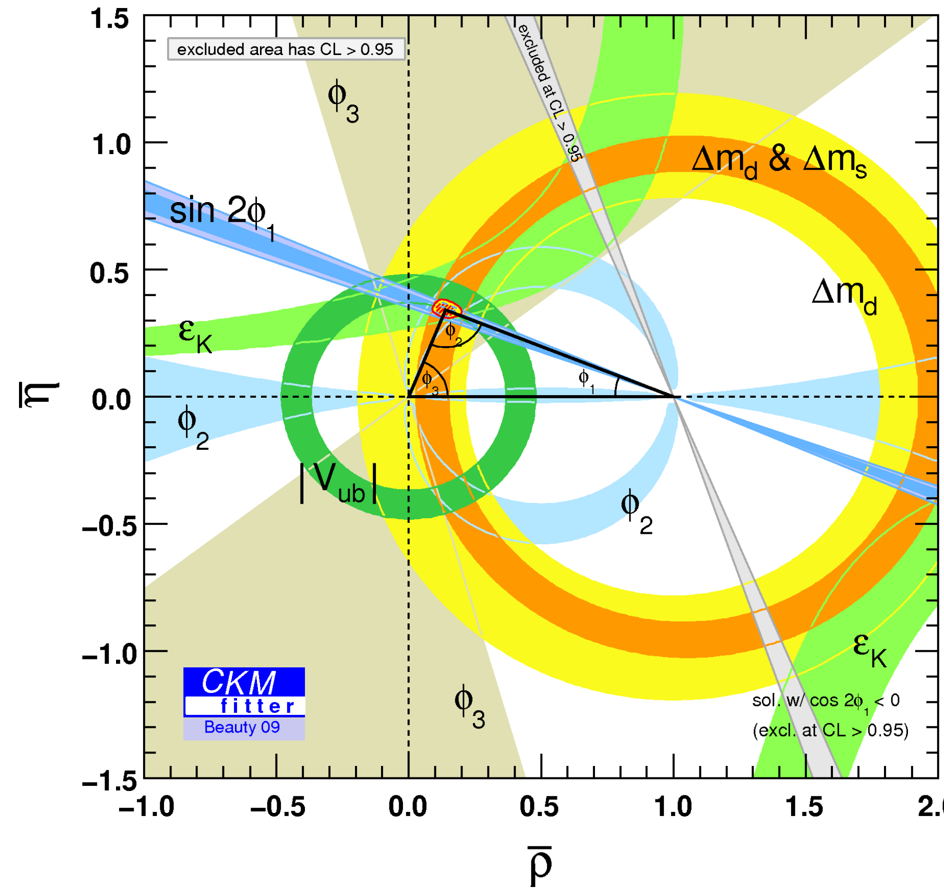




- World record luminosity: 2.1 x 10^{34} $cm^{-2}s^{-1}$ → Twice design
- 1 ab^{-1} of integrated luminosity

Physics Objective of Belle

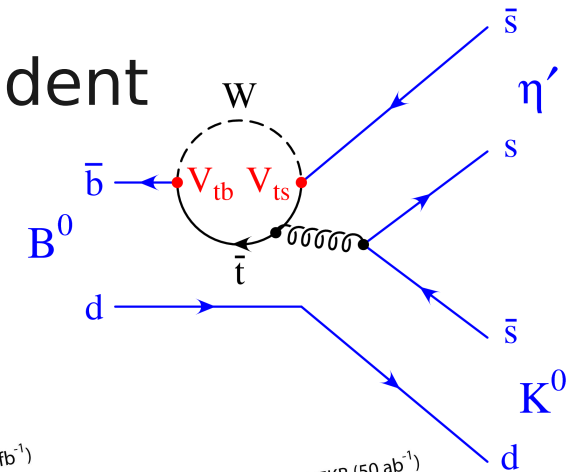


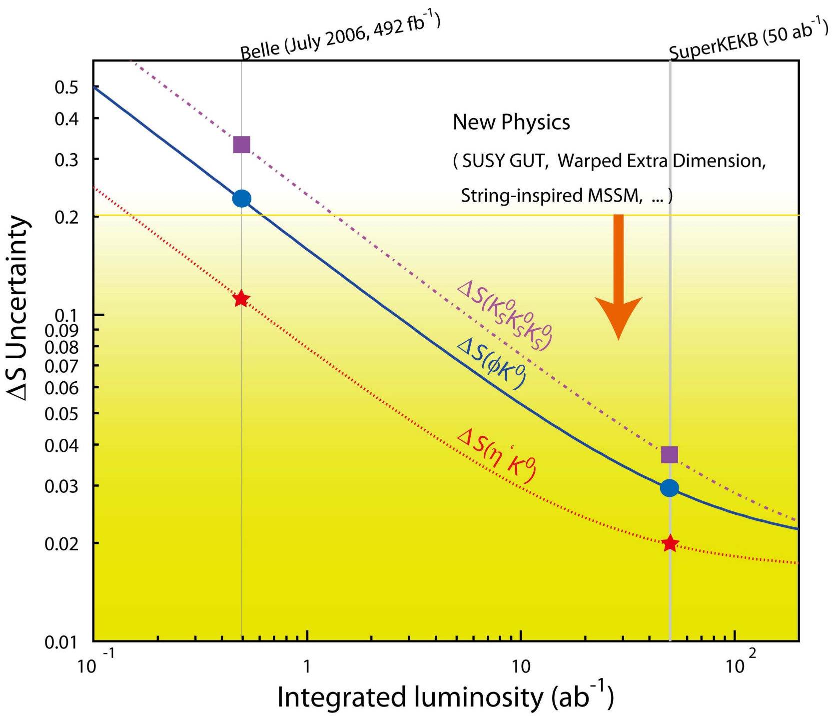


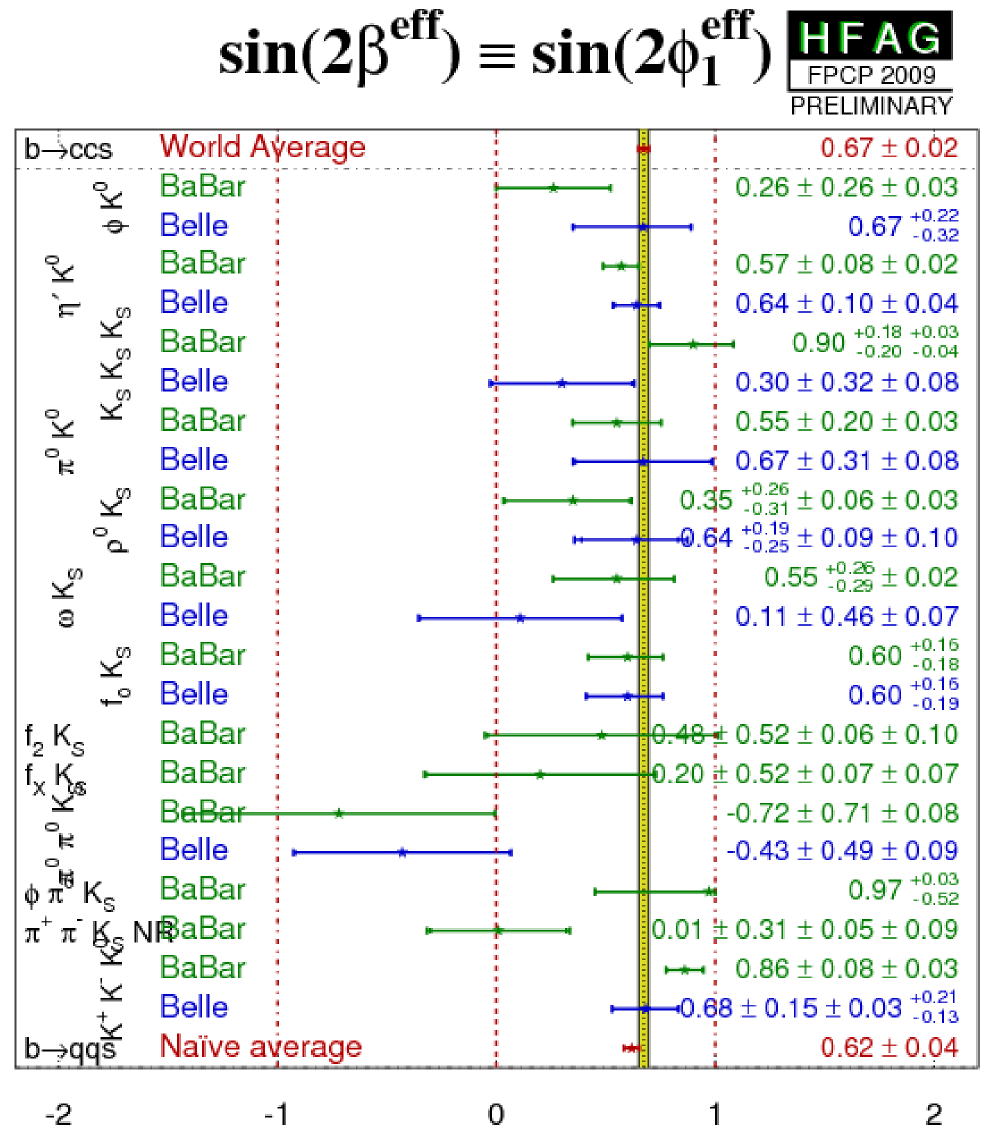
- Confirmation of KM mechanism of ~~CP~~ in the Standard Model

Places to Look for New Physics

Time dependent CP violation in b → q$\bar{q}$s decays



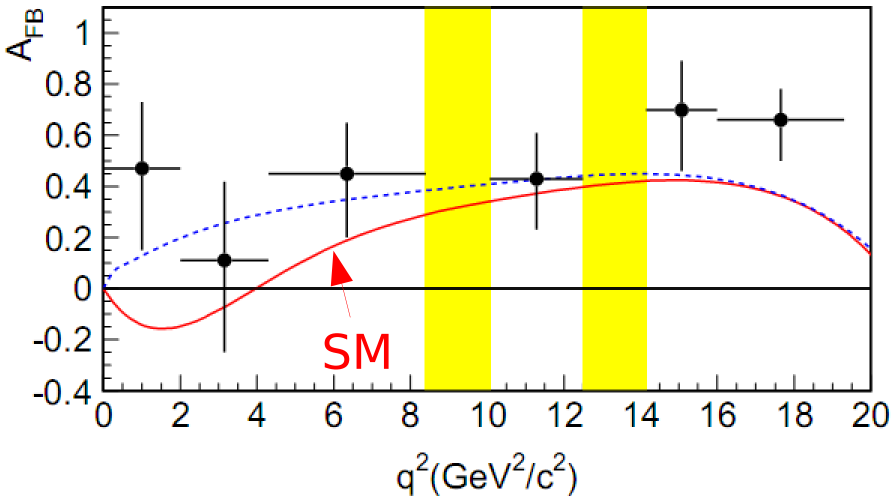




More Places to Look for New Physics

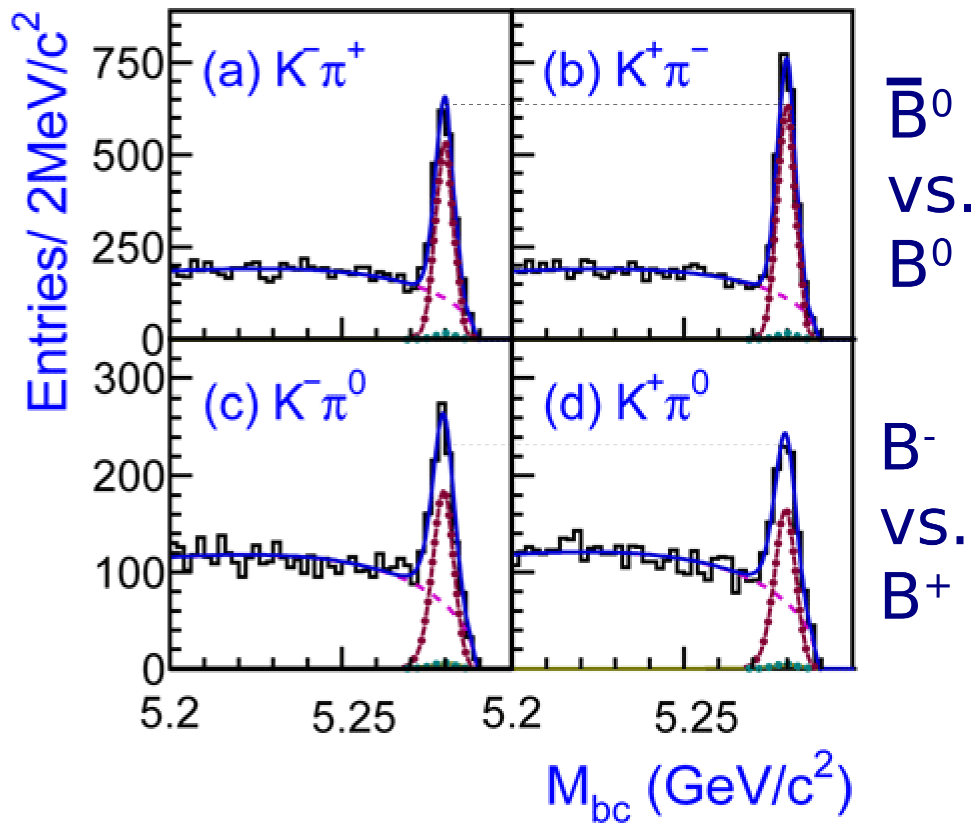
$B \to K^{(*)} l^+ l^-$ FB asymmetry

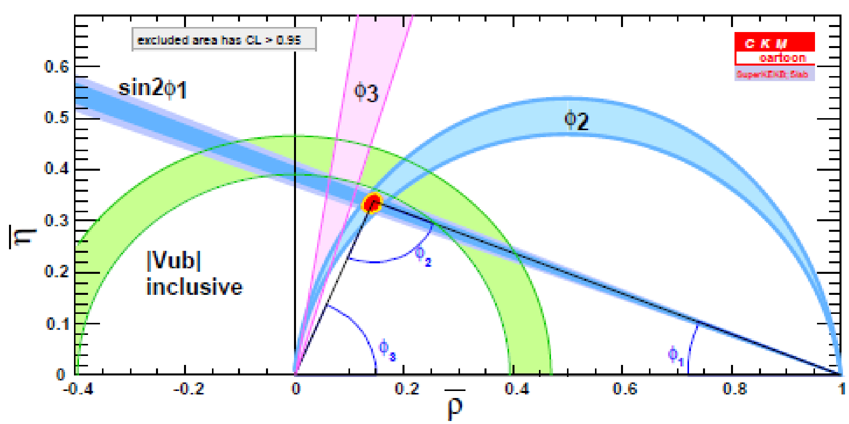
→ Zero crossing with 5% precision at 50 ab^{-1}



Direct CP violation

$\Delta A(K^0\pi^0)$: 0.15 (~0.5 ab^{-1})
→ 0.042 (50 ab^{-1})



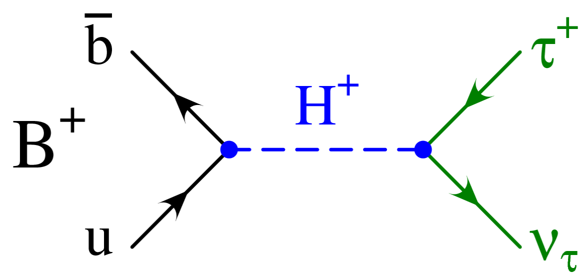


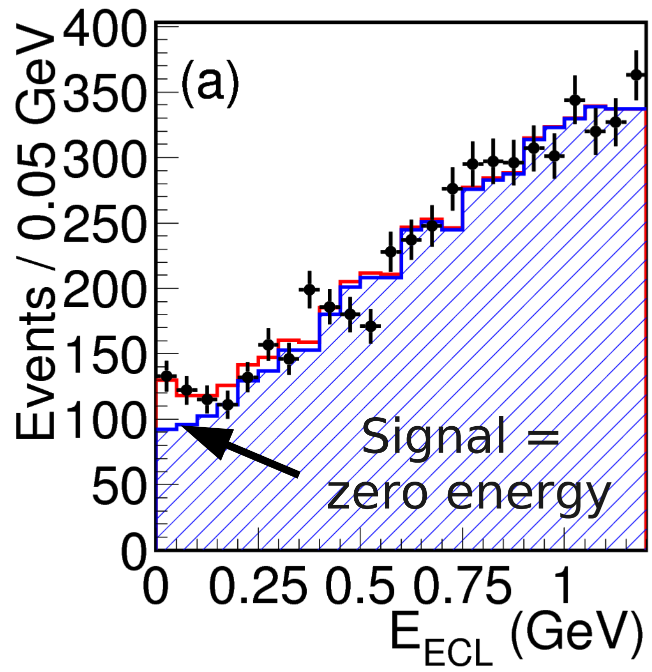
Precision angle measurements

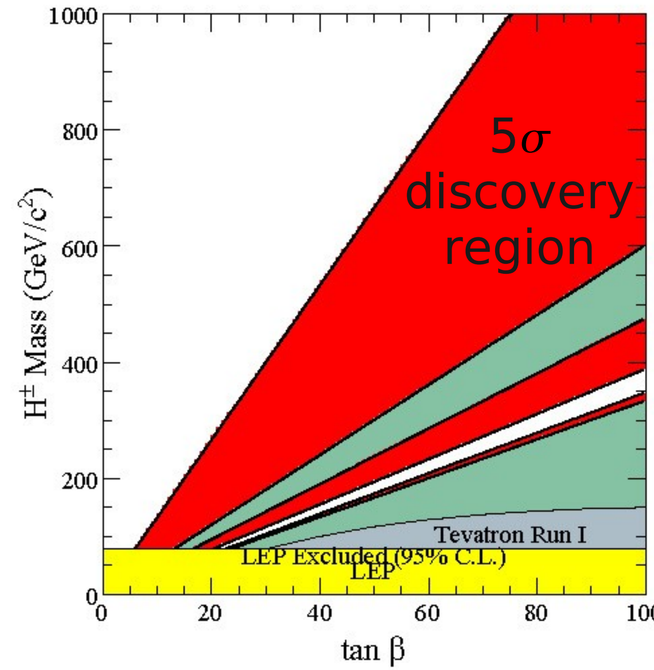
→ Precision at 50 ab^{-1}: $\varphi_2 \simeq 1°$, $\varphi_3 = 1.5°$

Even More Places to Look for New Physics

Charged Higgs:
$B \to \tau\nu$

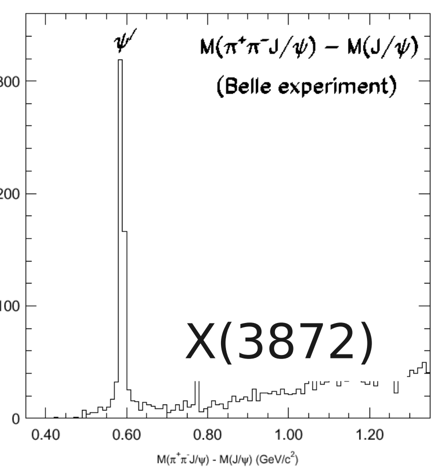






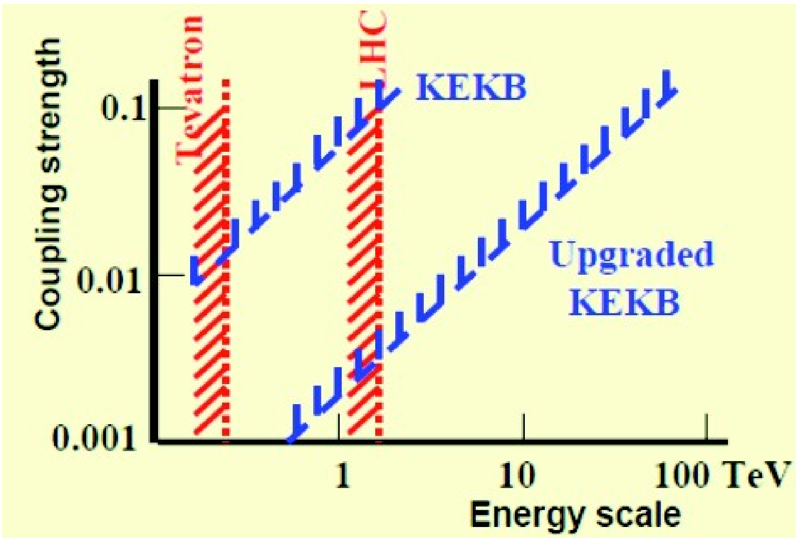
Lepton flavor violation
$B(\tau \to \mu\gamma)$ 90% CL UL [10^{-9}]: 45 (~0.5 ab^{-1}) → 5 (50 ab^{-1})

The unexpected



CP violation in D^0 mixing
Precision of |q/p|: 0.16 (~0.5 ab^{-1}) → 0.05 (50 ab^{-1})

Flavor Physics in the LHC Era



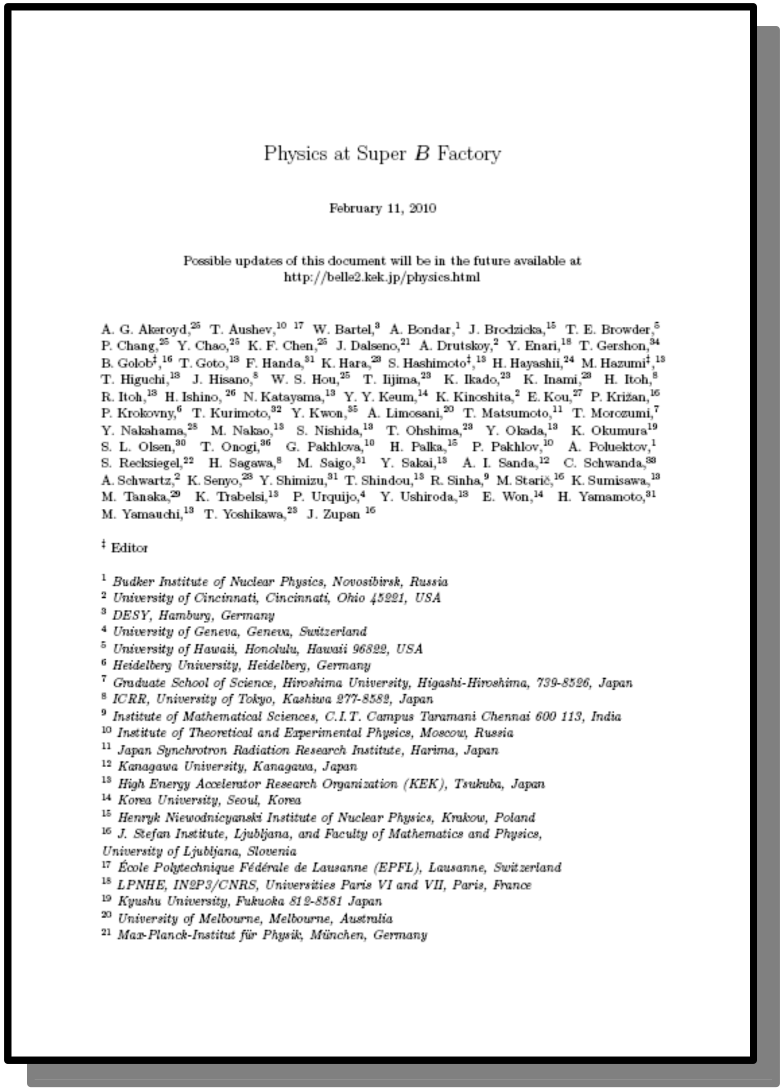
- Complementary to direct search for NP at LHC

→ "DNA test" of NP

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS
$D^0-\bar{D}^0$	★★★	★	★	★	★	★★★	?
ϵ_K	★	★★★	★★★	★	★	★★	★★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?
$A_{\rm CP}(B\to X_s\gamma)$	★	★	★	★★★	★★★	★	?
$A_{7,8}(B\to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?
$A_9(B\to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?
$B\to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★
$B_s\to\mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★
$K^+\to\pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$K_L\to\pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★
$\mu\to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau\to\mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★
$\mu+N\to e+N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★
d_e	★★★	★★★	★★	★	★★★	★	★★★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?

Altmannshofer, Buras, Gori, Paradis and Straub
Nucl.Phys.B830, 17-94, 2010

Physics at Super B Factory



Physics at Super B Factory

February 11, 2010

Possible updates of this document will be in the future available at
http://belle2.kek.jp/physics.html

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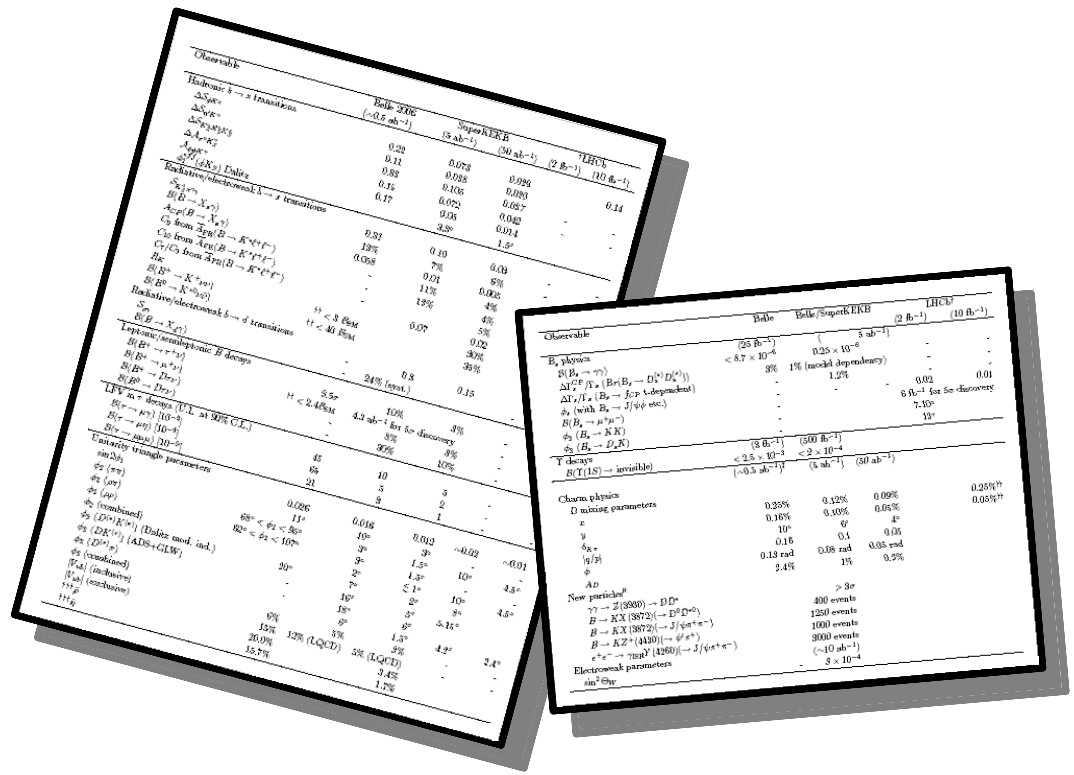
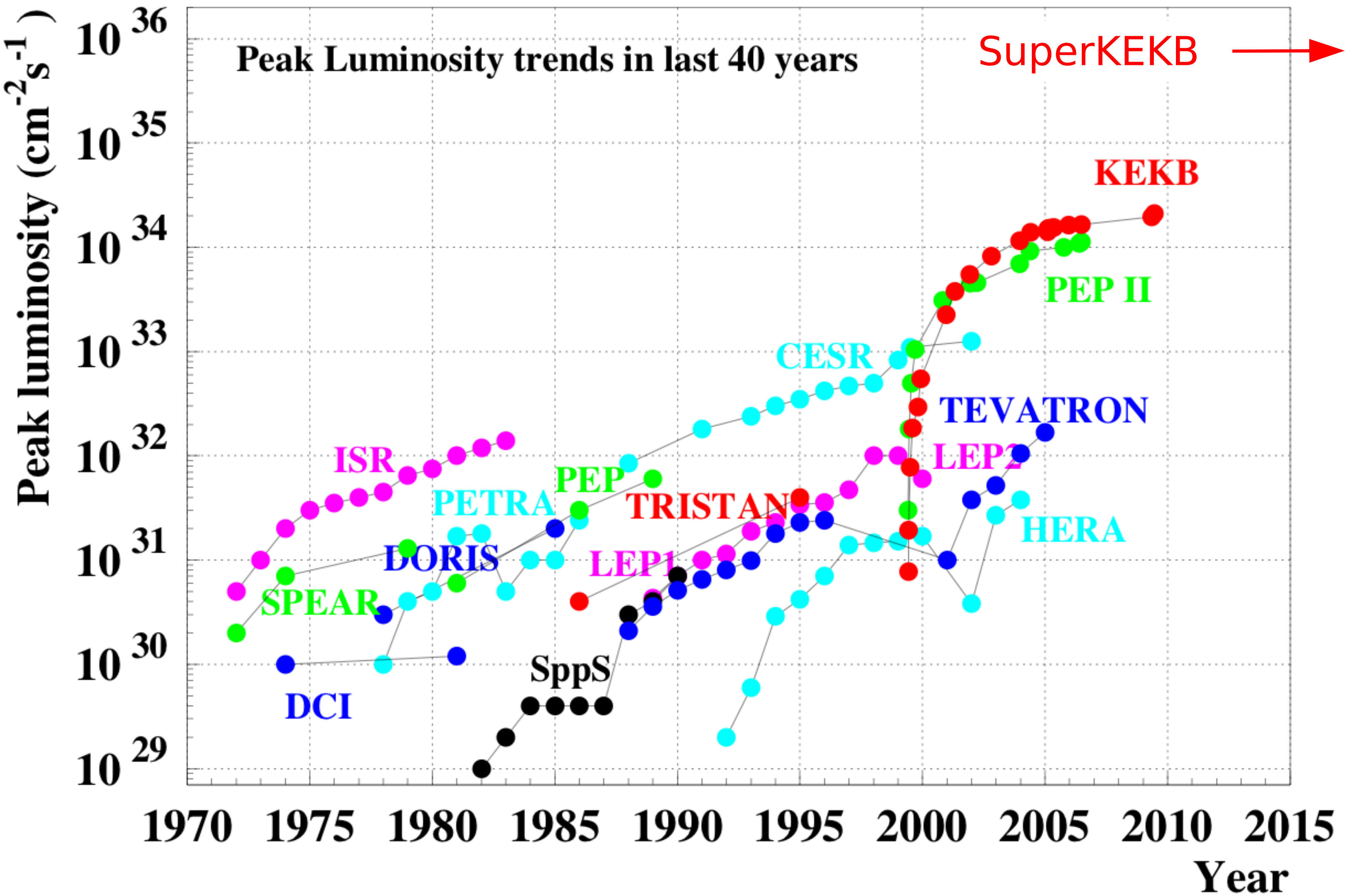
A. G. Akeroyd et al.
KEK-REPORT-2009-12, Feb 2010,
arXiv:1002.5012 [hep-ex]



Aim For 50 ab^{-1}



8×10^{35} cm^{-2} s^{-1}

Accelerator Design: Nano Beam Scheme

Lorentz factor

Beam current

Beam-Beam parameter $\xi_y \propto \sqrt{(\beta_y^*/\varepsilon_y)}$

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

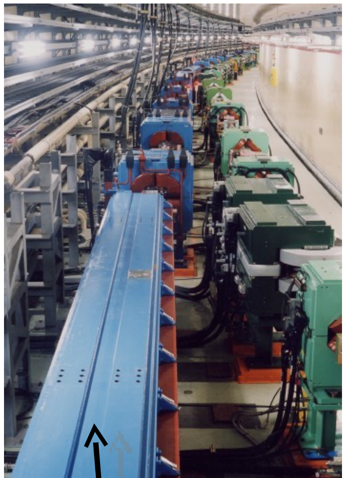
Geometrical reduction factors (crossing angle, hourglass effect)

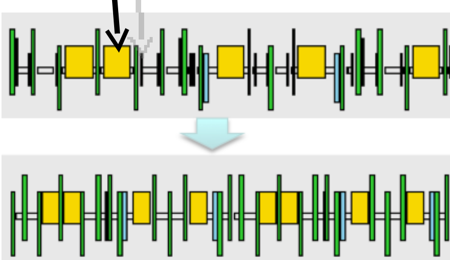
Beam aspect ratio at IP

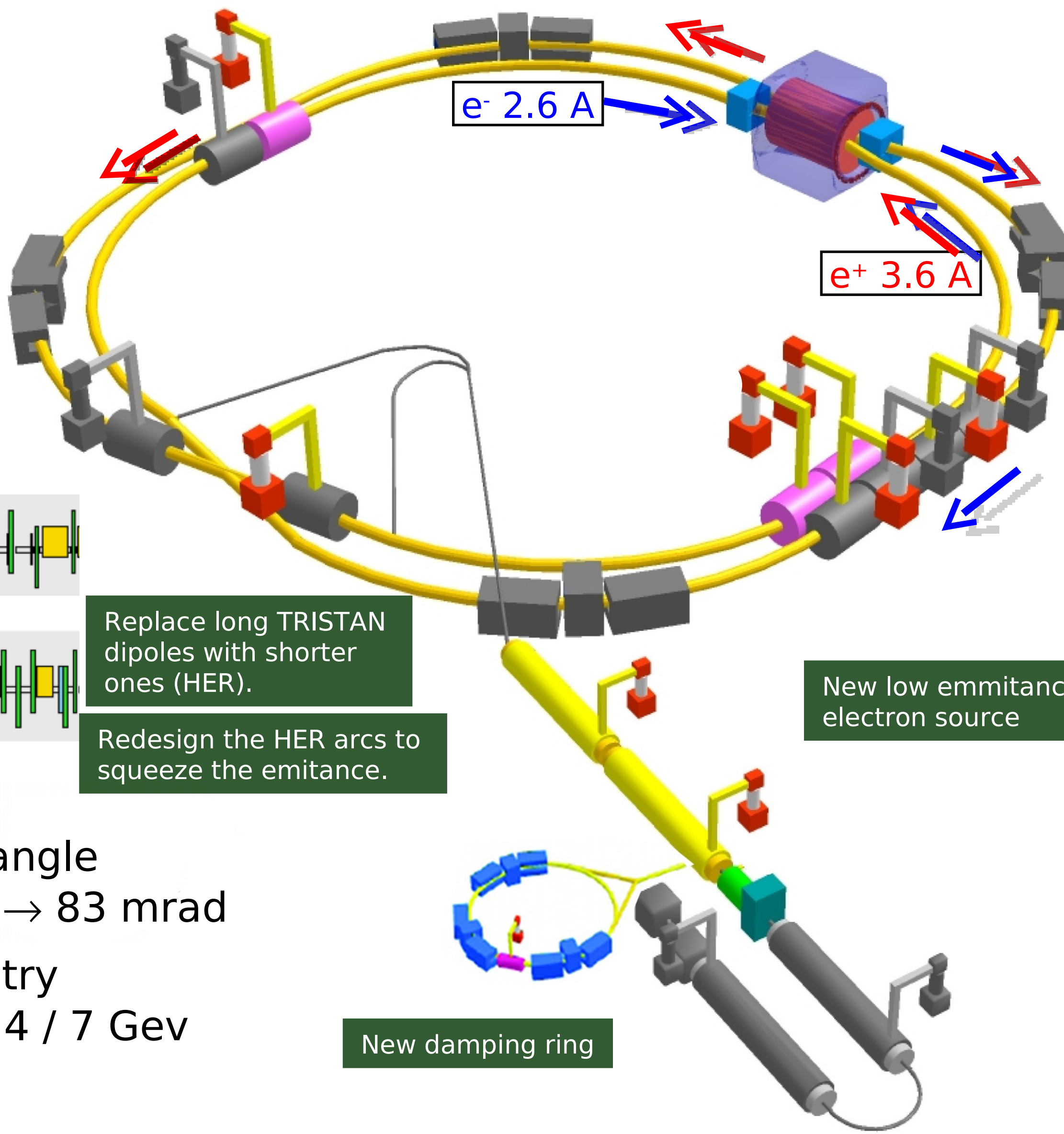
Vertical beta function at IP

	β_x^* (cm)	β_y^* (mm)	ξ_y	ϵ_x (nm)	I_{beam} (A)	L (cm^{-2} s^{-1})
KEKB w/ crab	120/120	5.9/5.9	0.13/0.09	18/24	1.6/1.2	2.11×10^{34}
SuperKEKB	3.2/2.5	0.27/0.42	0.09/0.09	3.2/1.7	3.6/2.6	**80×10^{34}**

SuperKEKB Upgrade







Belle II

New IR

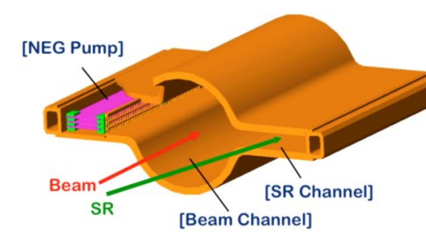
New Superconducting / permanent final focusing quads near the IP

Replace long TRISTAN dipoles with shorter ones (HER).

Redesign the HER arcs to squeeze the emitance.

New low emmitance electron source

TiN coated beam pipe with antechambers



Larger crossing angle

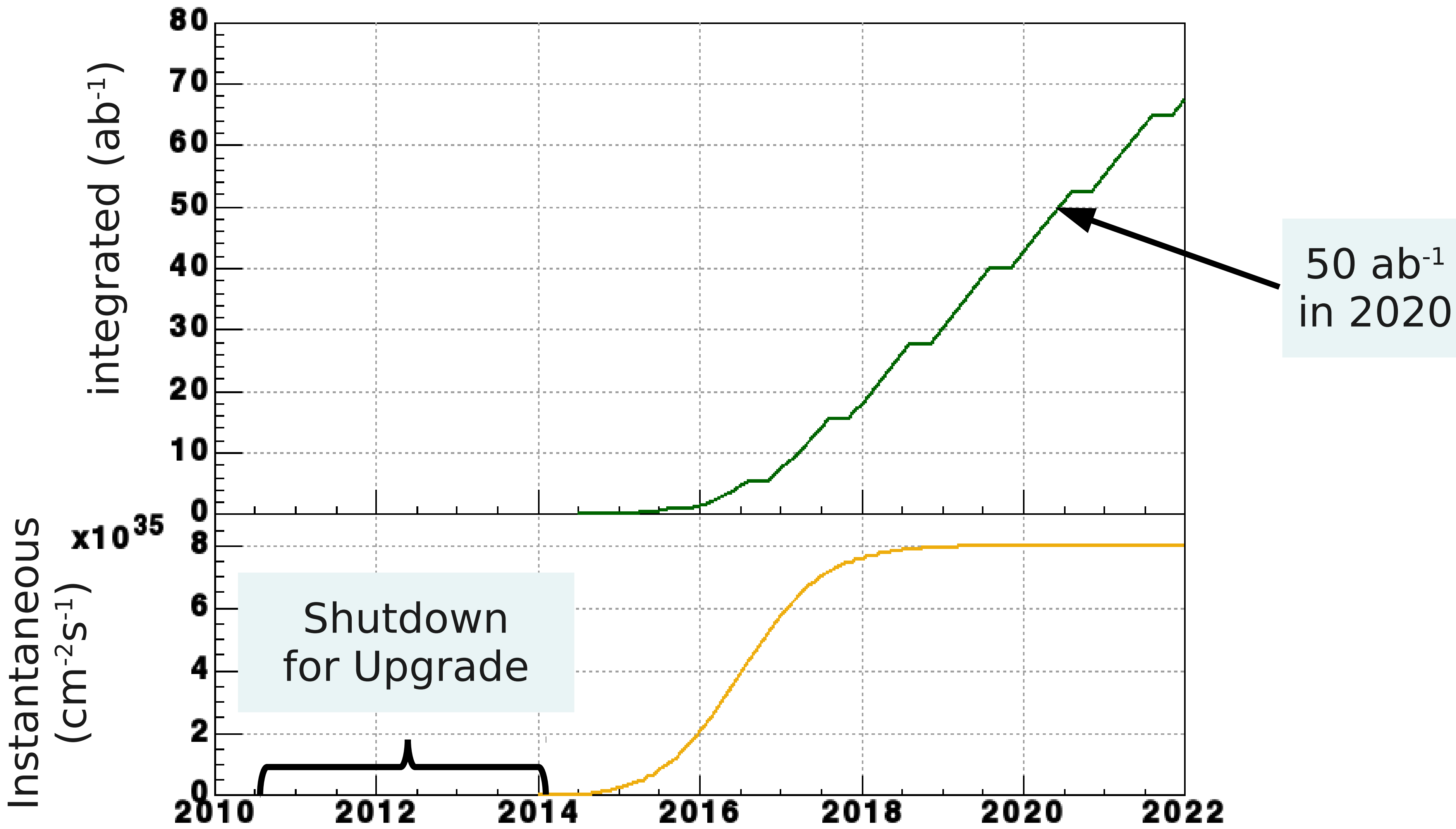
2ϕ = 22 mrad → 83 mrad

Smaller asymmetry

3.5 / 8 GeV → 4 / 7 Gev

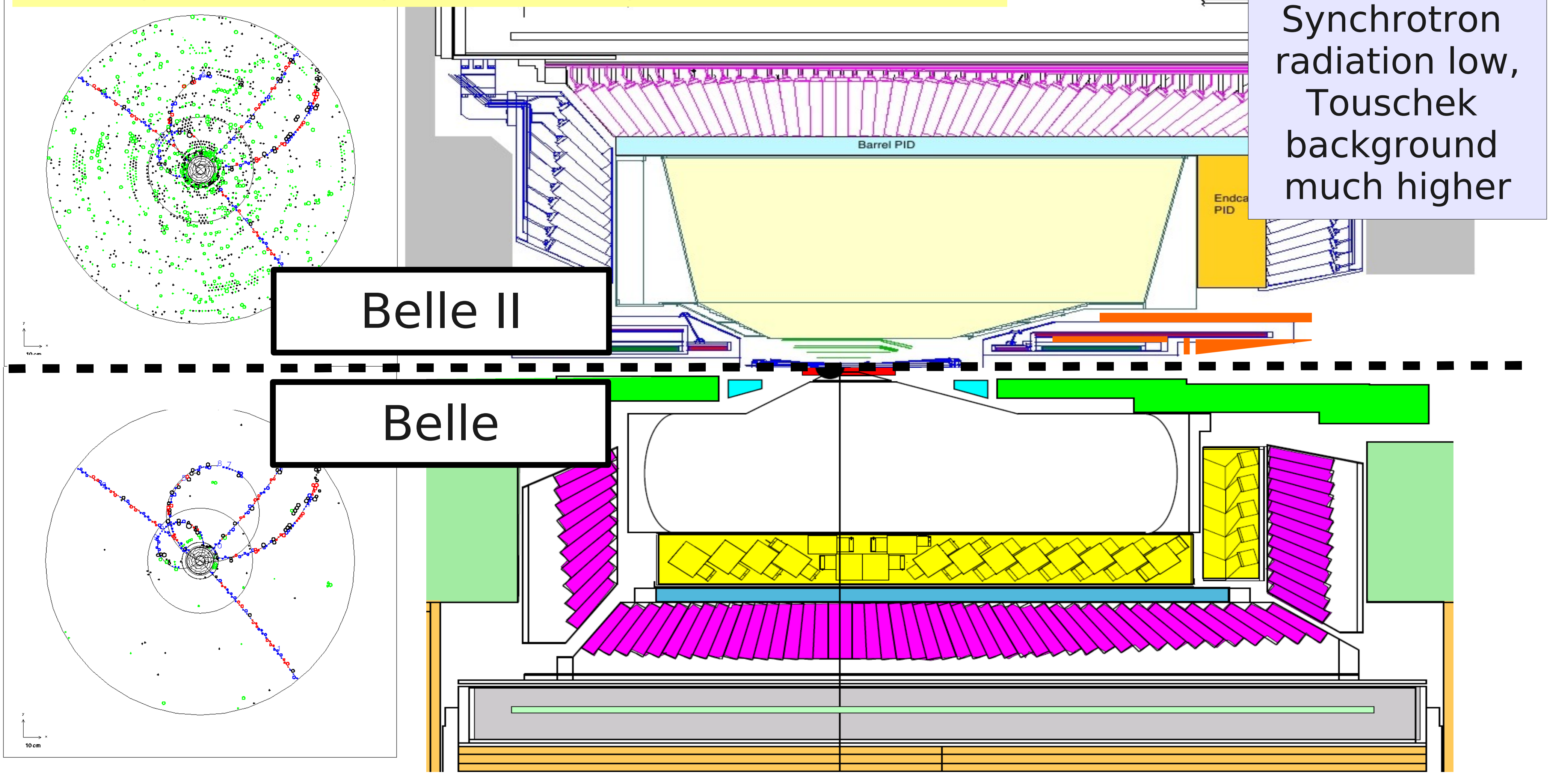
New damping ring

Projection of Luminosity



Belle II Detector

- ➔ Higher background, higher event rate

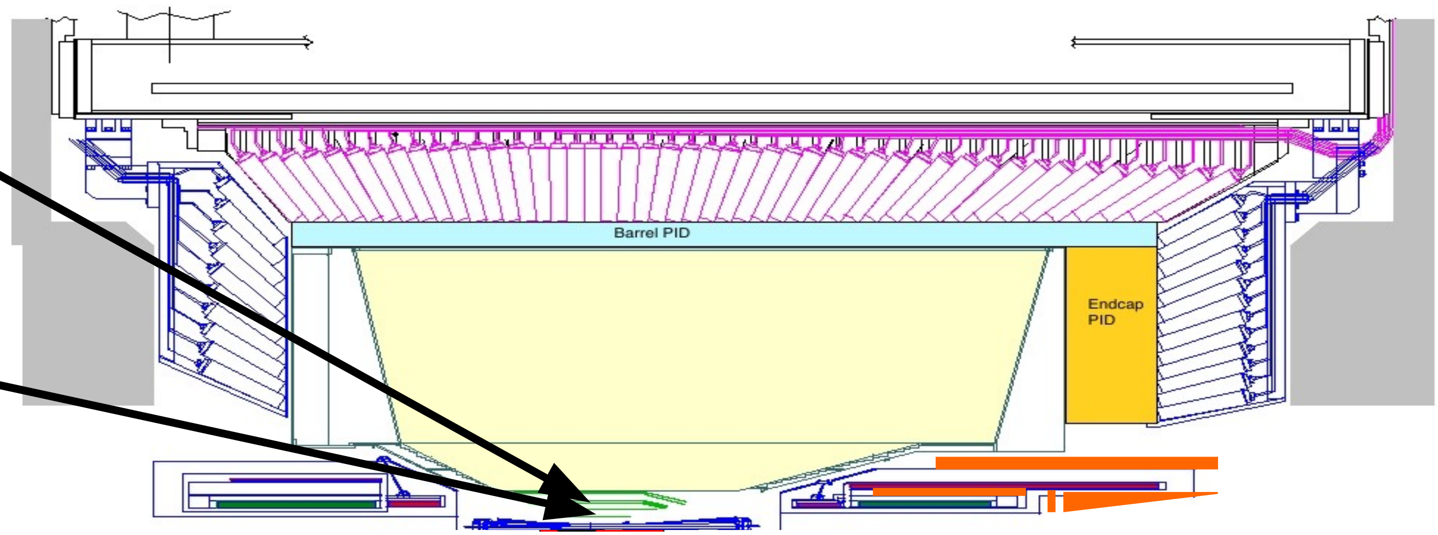


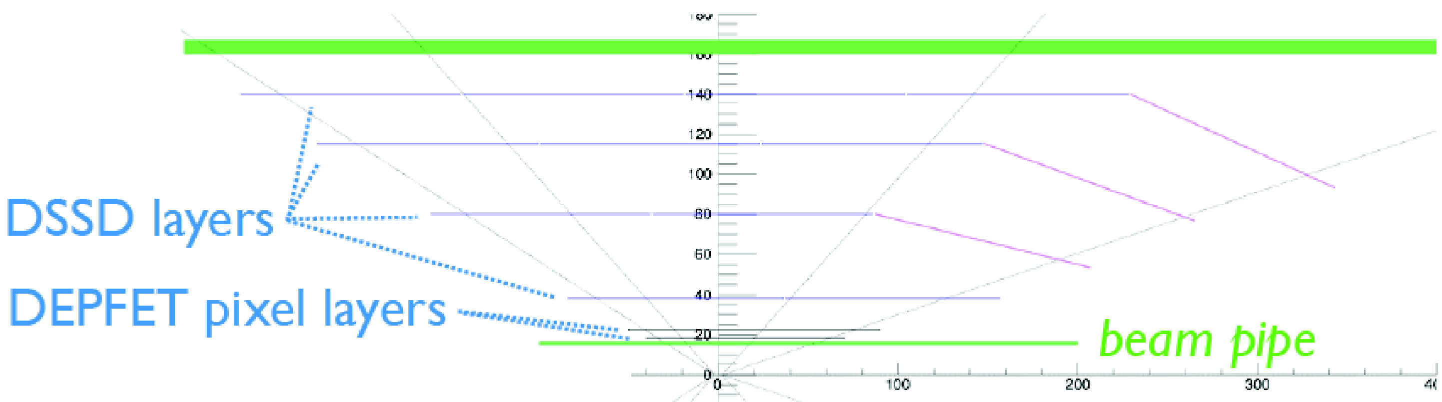
Nano beam: Synchrotron radiation low, Touschek background much higher

Belle II Detector

4 layer silicon strip detector

2 layer DEPFET pixel detector

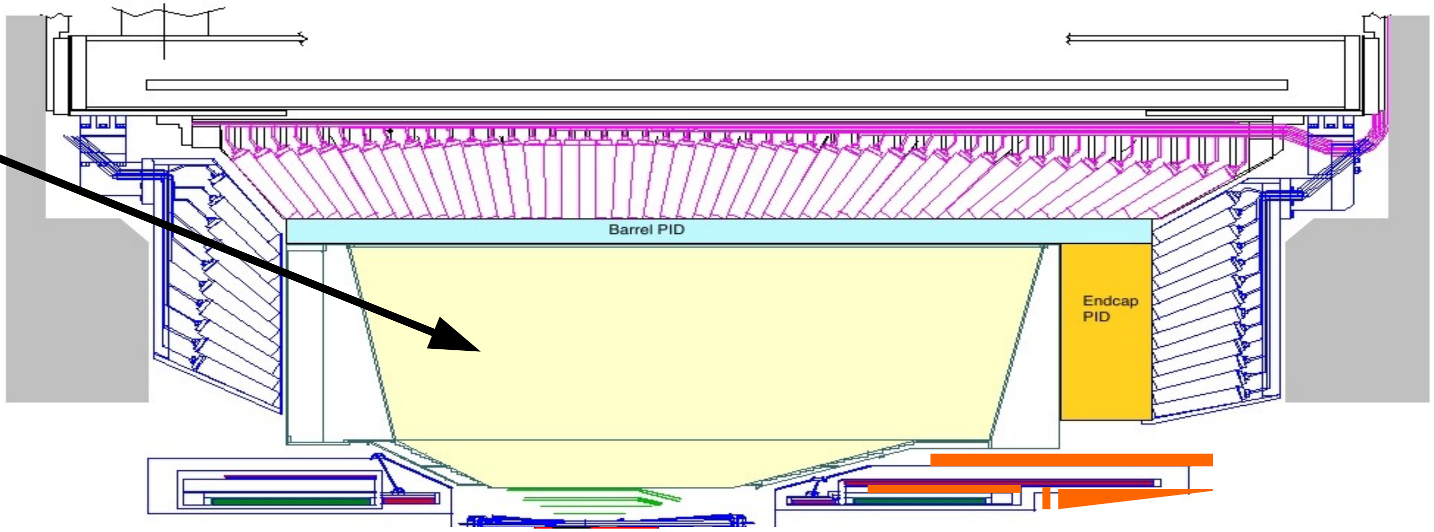


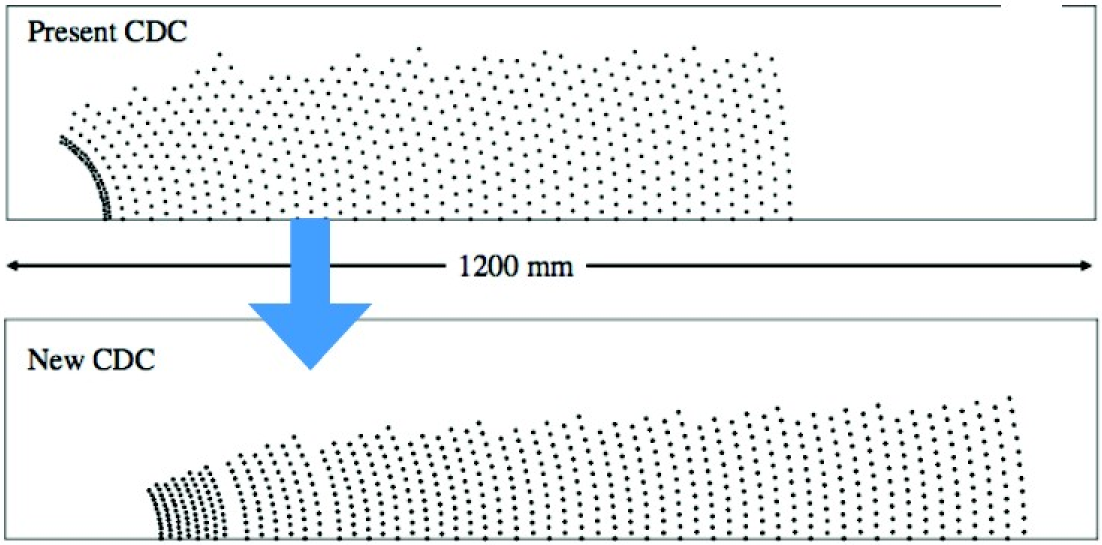


- ➔ Improved vertex resolution
- Larger radius
- ➔ Better K_S efficiency

Belle II Detector

Drift chamber





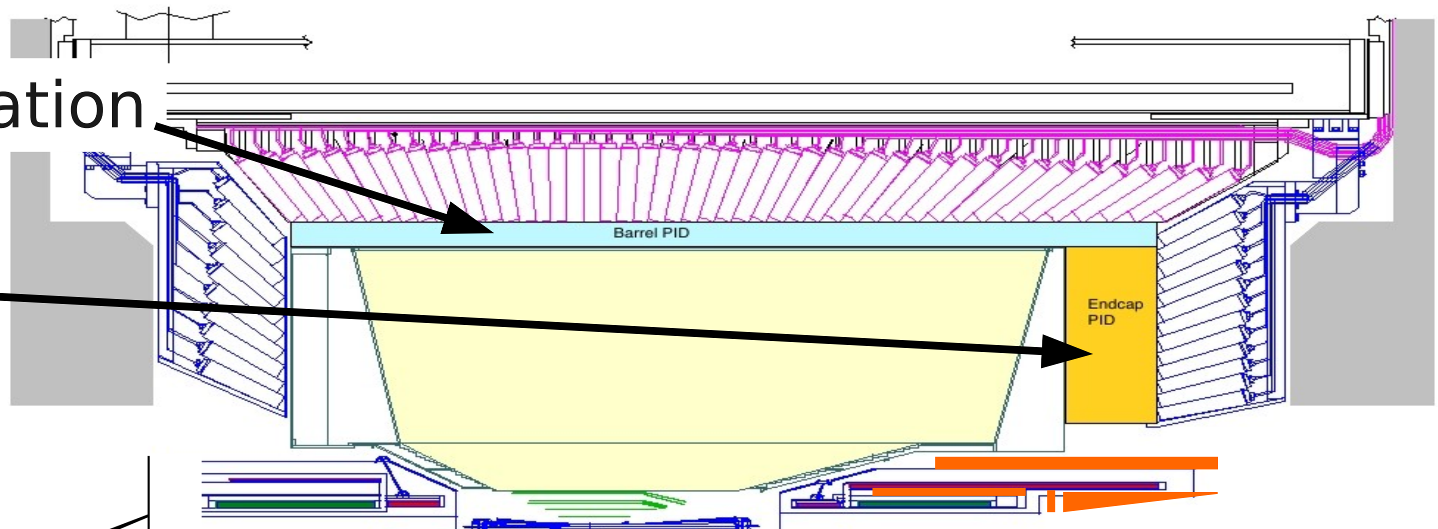
- Smaller cells
- Larger radius

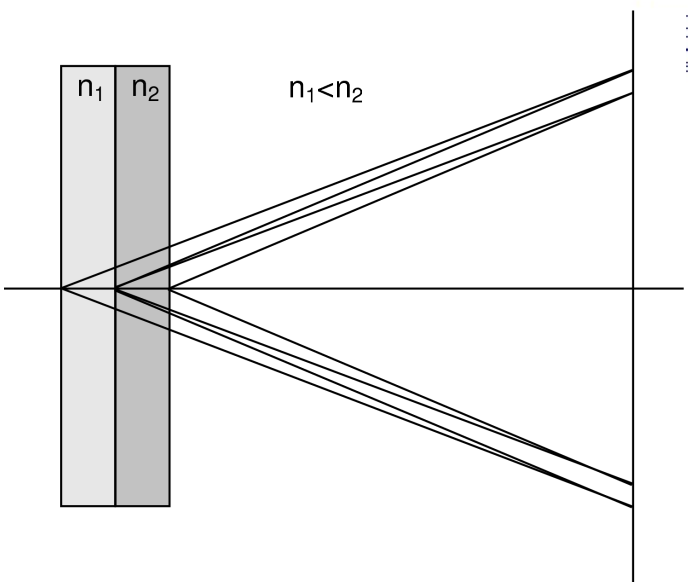
→ Better momentum resolution

Belle II Detector

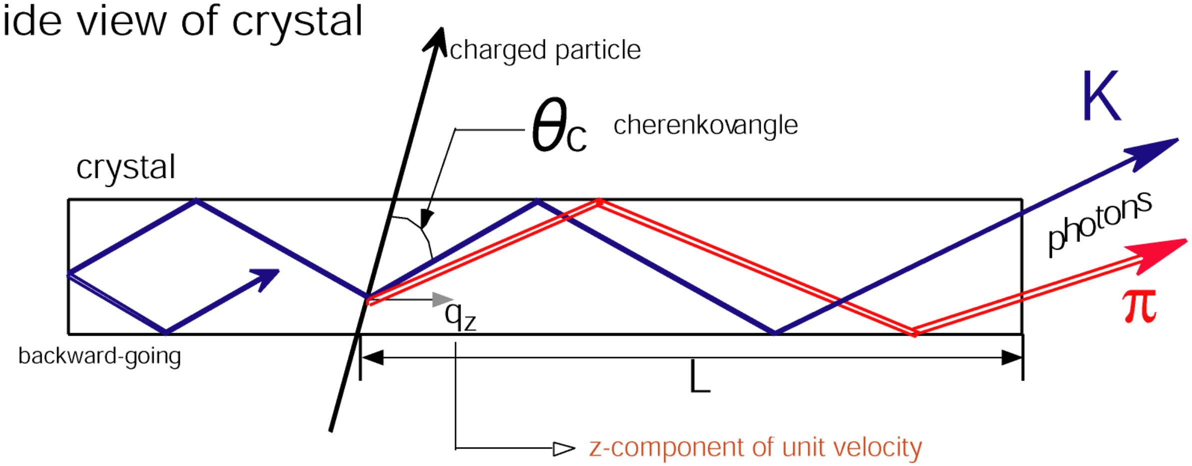
Time of propagation

“Focusing” RICH





Side view of crystal



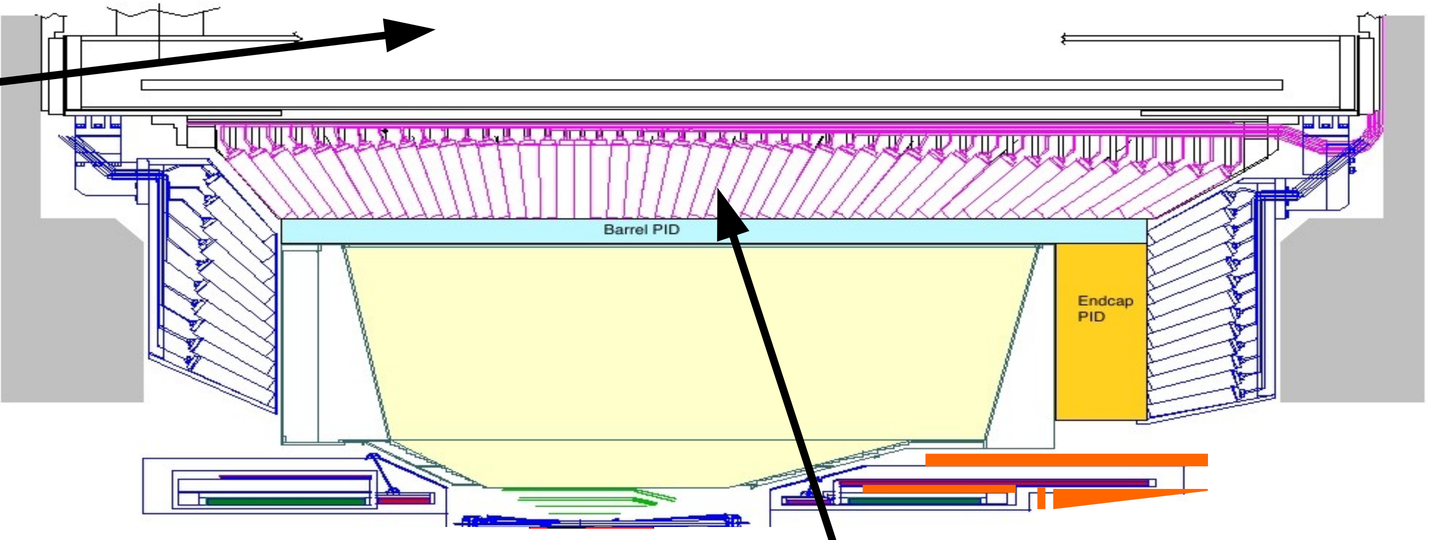
➔ Improved particle identification

Belle II Detector

K_L and μ Detector

- Scintillators in end-caps

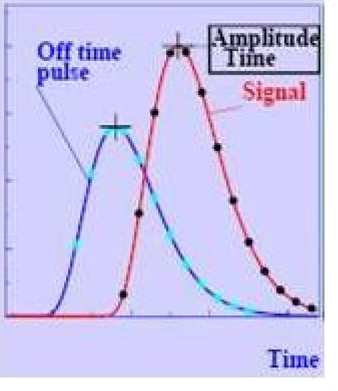
→ Improved beam background tolerance



Electromagnetic Calorimeter

- Wave form sampling

→ Better signal to background separation

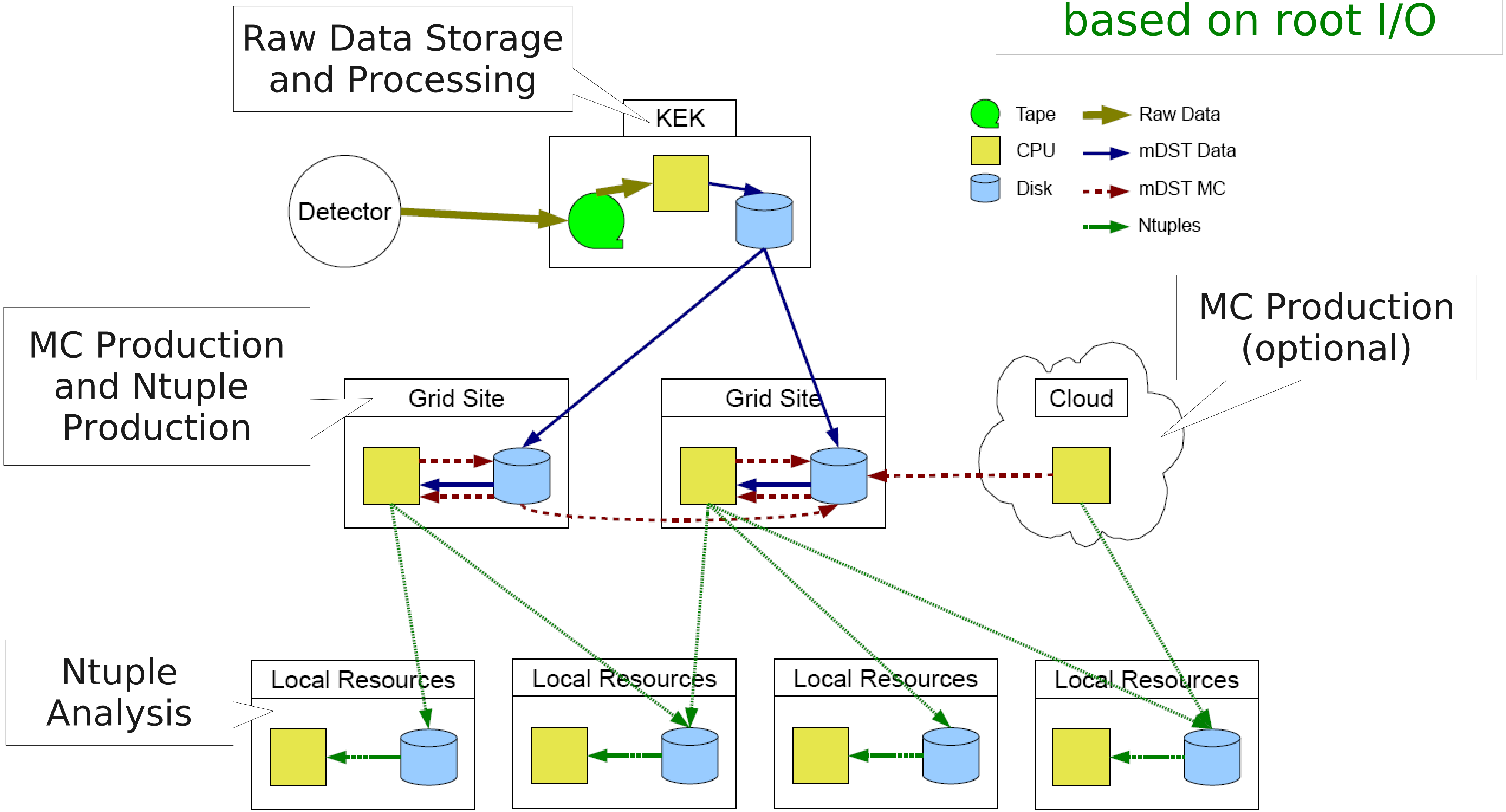


DAQ

- Upgrade to cope with higher rate

Belle II Computing Model

Common framework for DAQ and offline based on root I/O



Belle II Collaboration

- June 2004: Letter of Intent
- March 2008: First proto collaboration meeting
- December 2008: New collaboration founded

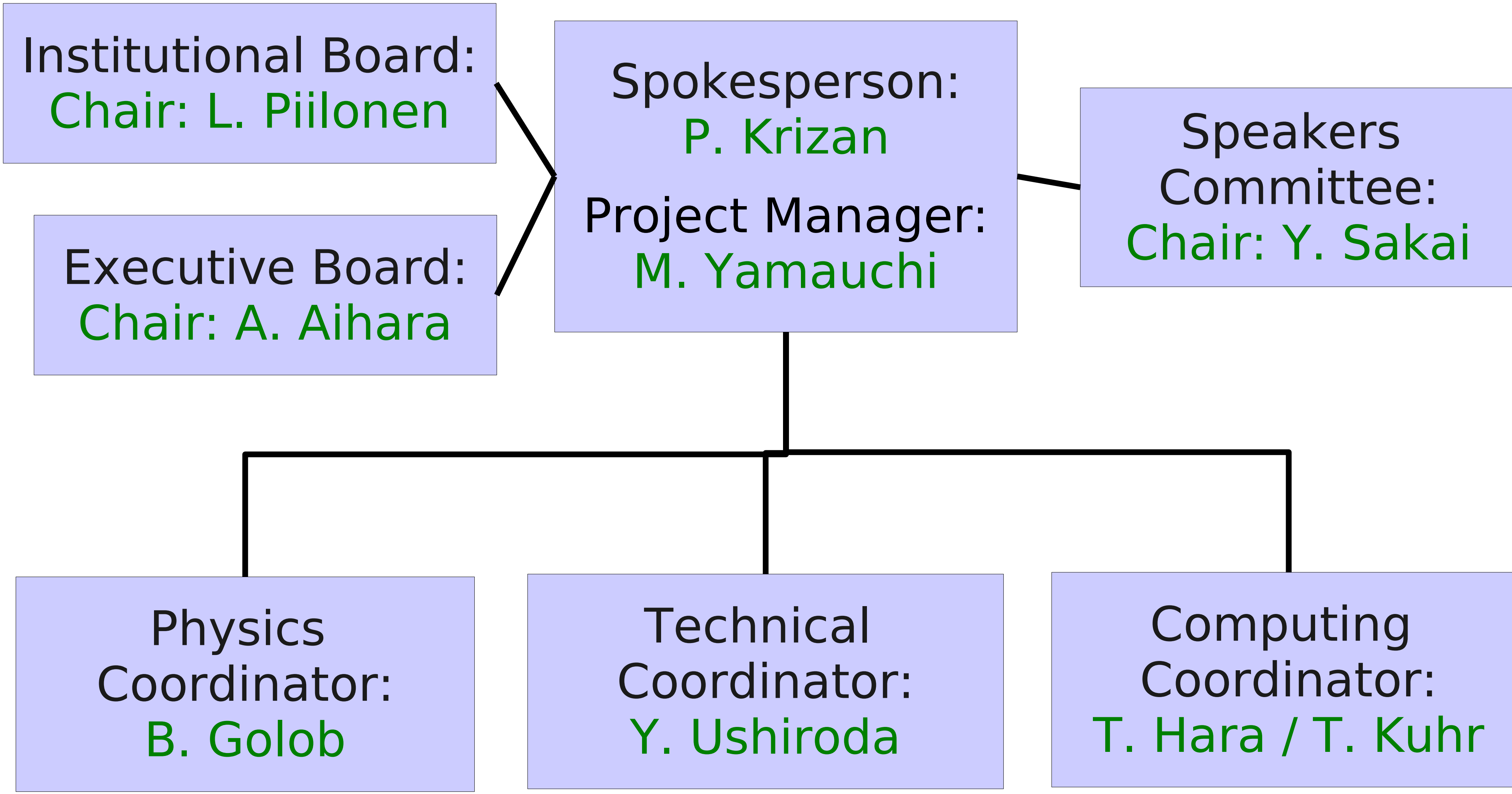
- ~300 members
  47 institutes from 13 countries

Belle II

International Collaboration

You are welcome to join!

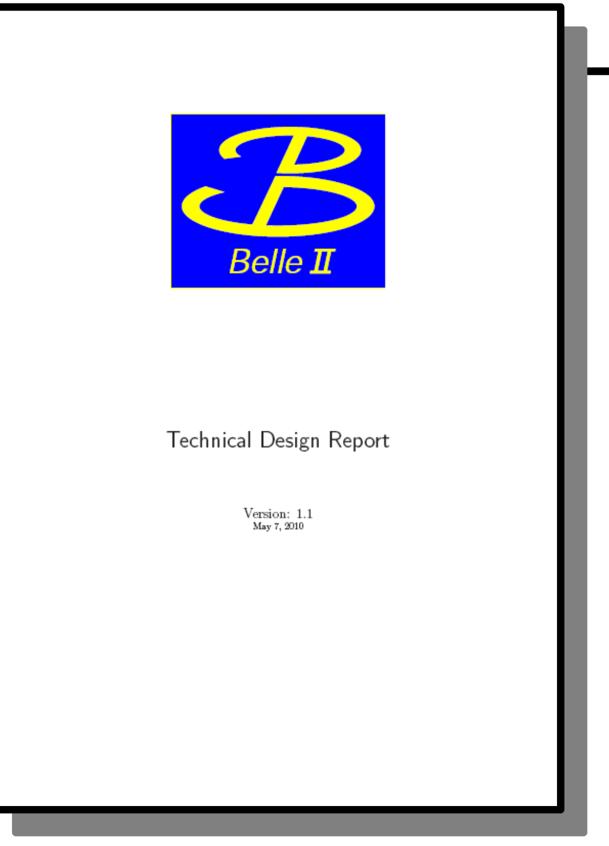
Belle II Organization



Project Status

- ✔ Preliminary approval by Japanese government in January
- Final decision expected soon

- ✔ TDR is written (~480 pages)
  - ➔ Reviewed last weekend
  - ➔ To be published in July

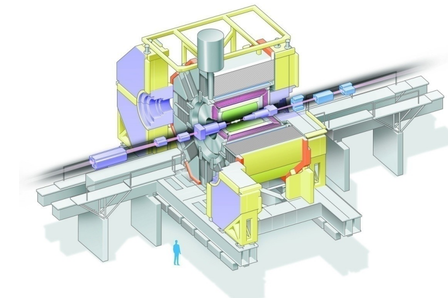


- Belle data taking ends in June
- ➔ Then upgrade work can start

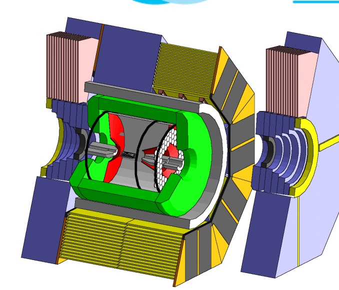
- ➢ Well on track to start data taking in 2014

Summary

- There are still many places where NP or “the unexpected“ can hide



- Need much more data to discover, identify or exclude this NP
- ✔ 50 ab^{-1} in 2020 possible with nano-beam scheme at SuperKEKB
- ✔ Belle II detector is designed for conditions at next generation B factory
- ✔ 6th Open Belle II Meeting July 5-7
  - *You are welcome to attend*

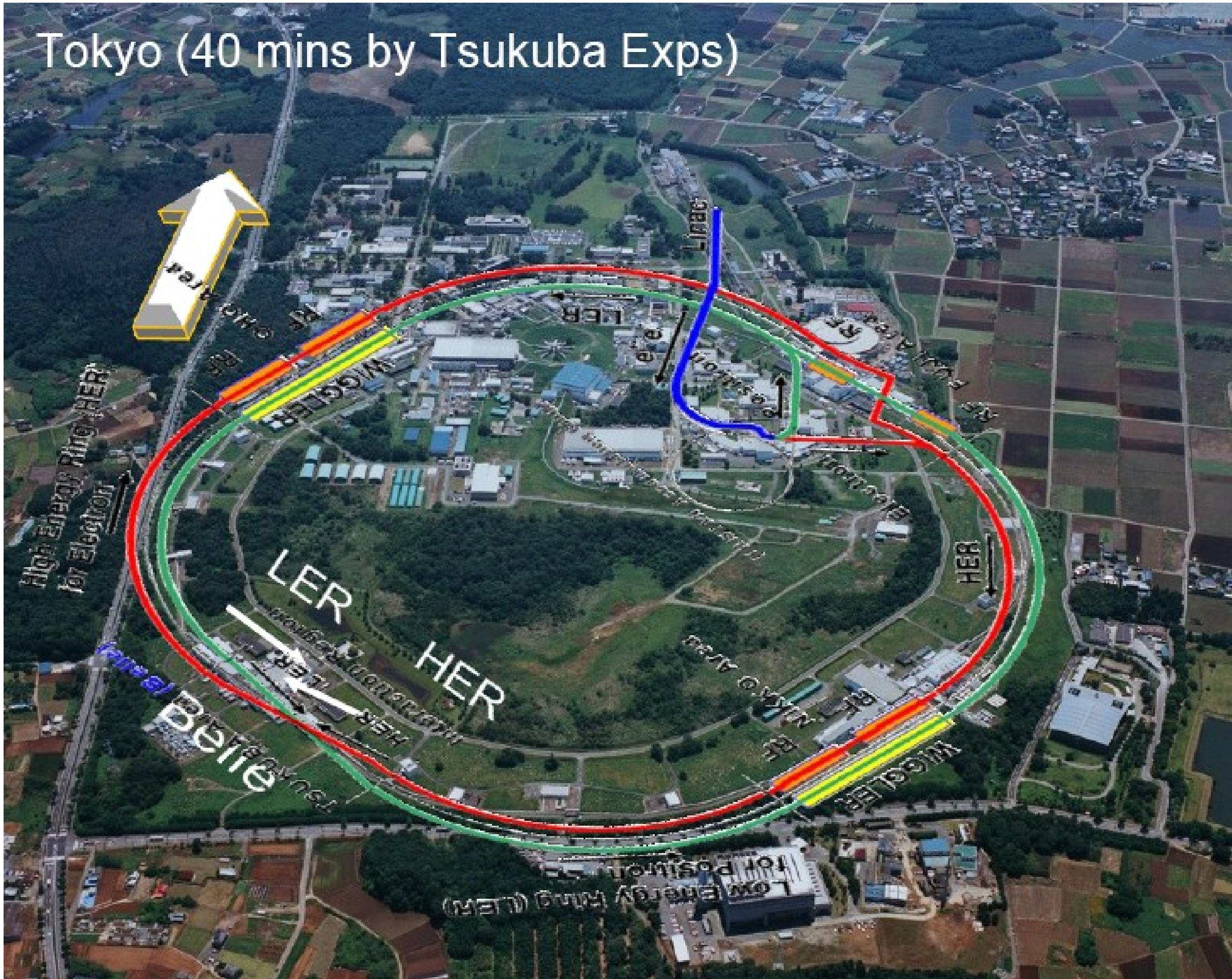


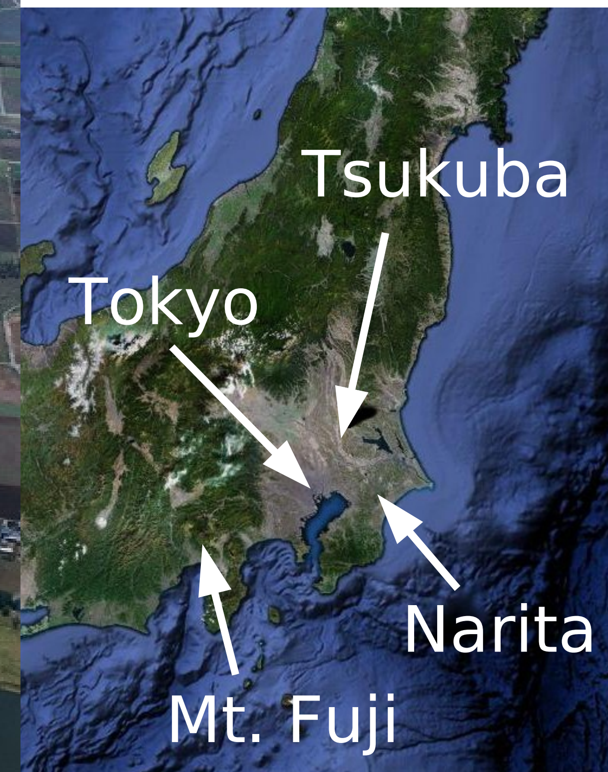
- Looking forward to friendly competition with SuperB and LHCb

http://belle2.kek.jp

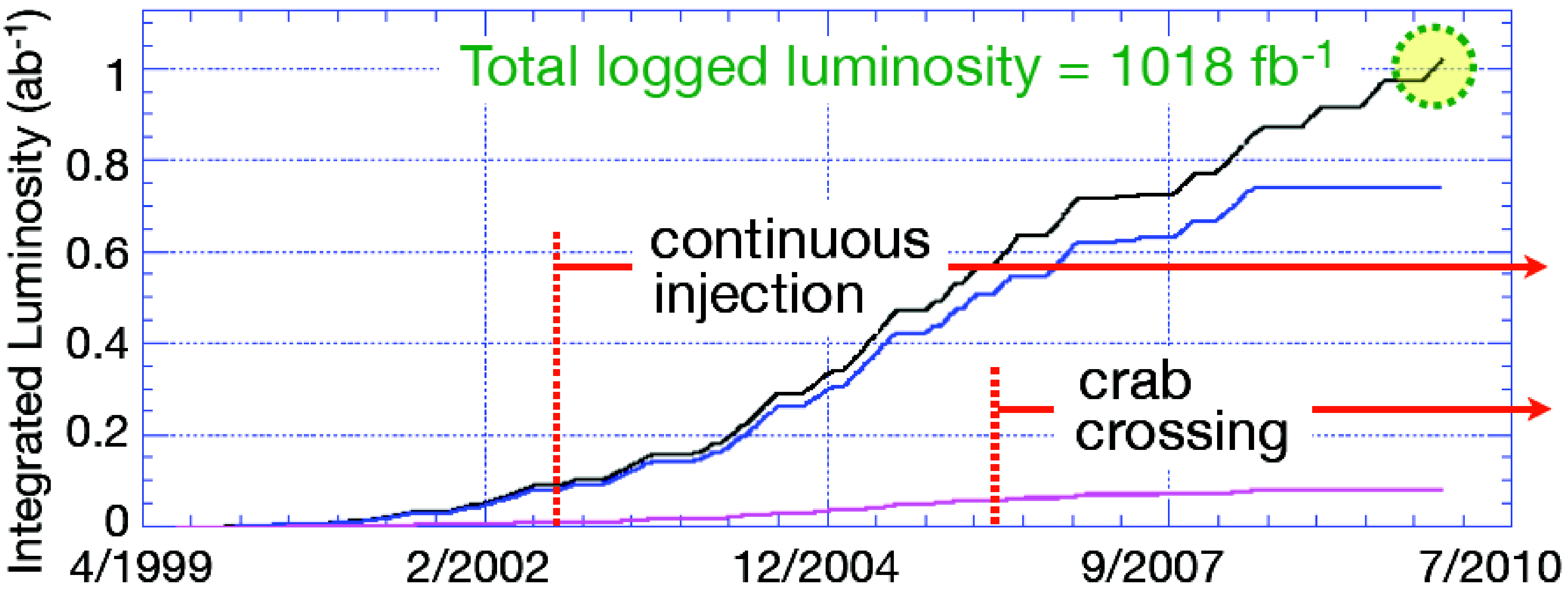
Backup

KEK Site

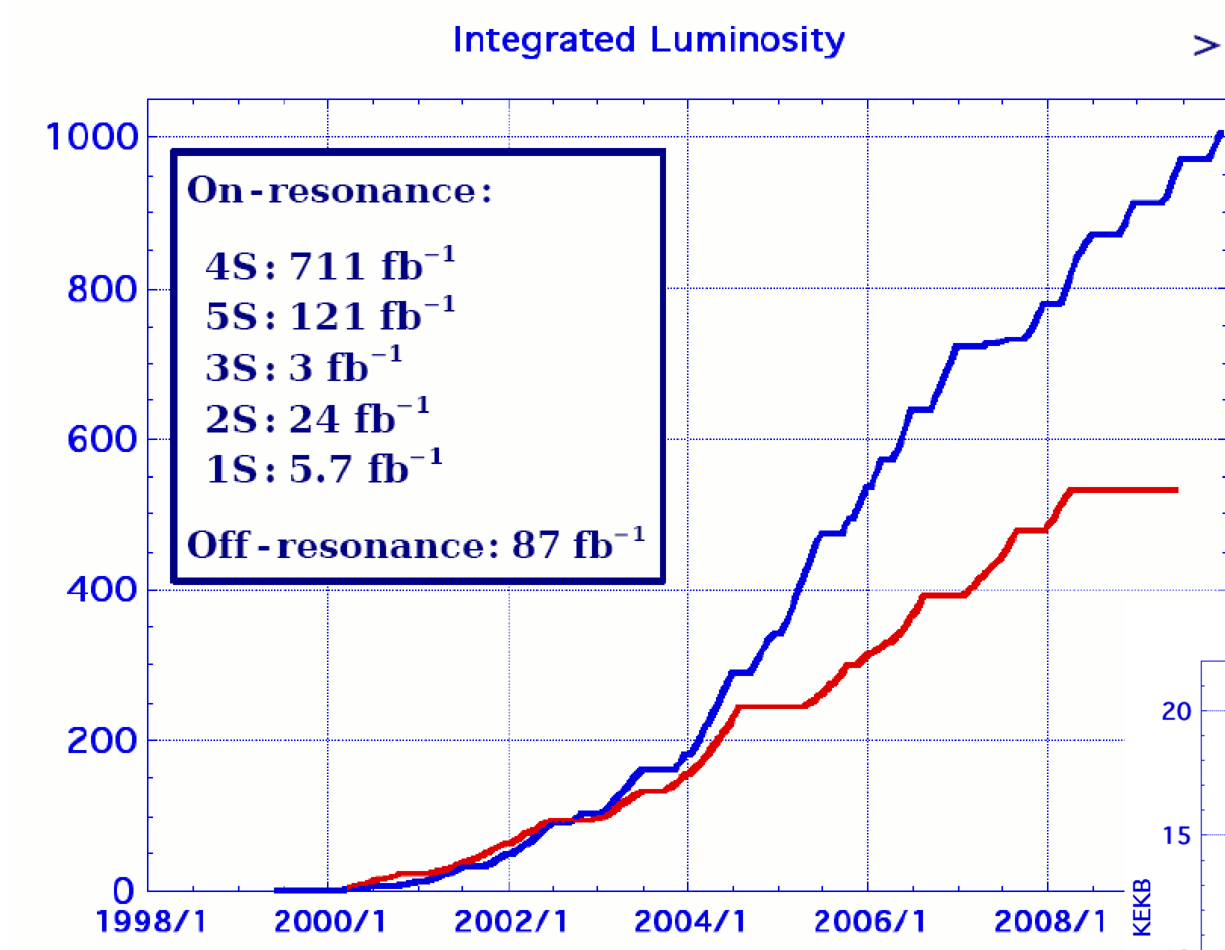

Tokyo (40 mins by Tsukuba Exps)
LER
HER
Belle
Linac
WIGGLER
RF


Tsukuba
Tokyo
Narita
Mt. Fuji

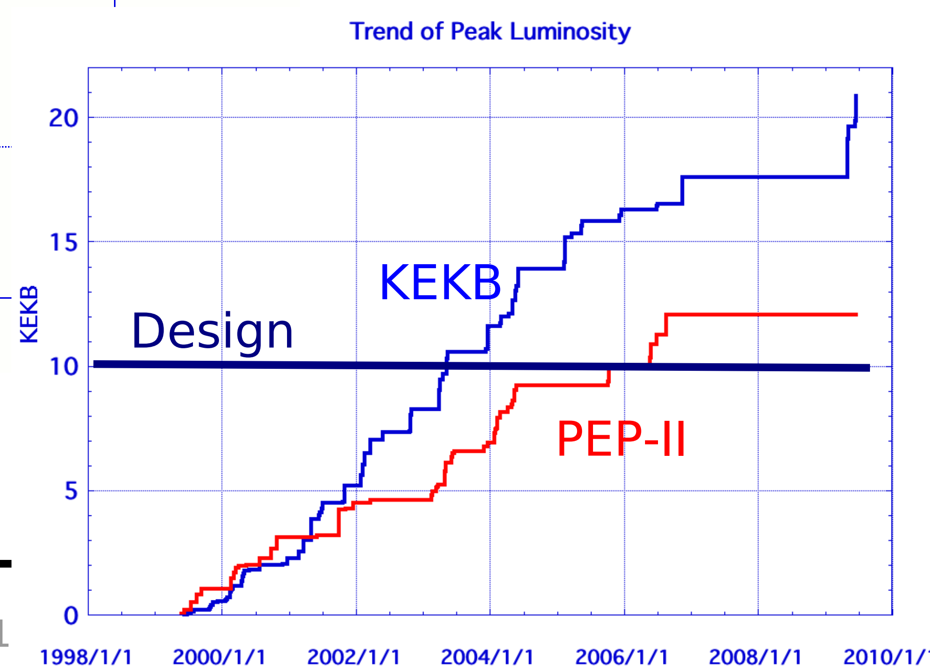
Integrated Luminosity



Comparison KEKB/PEP-II



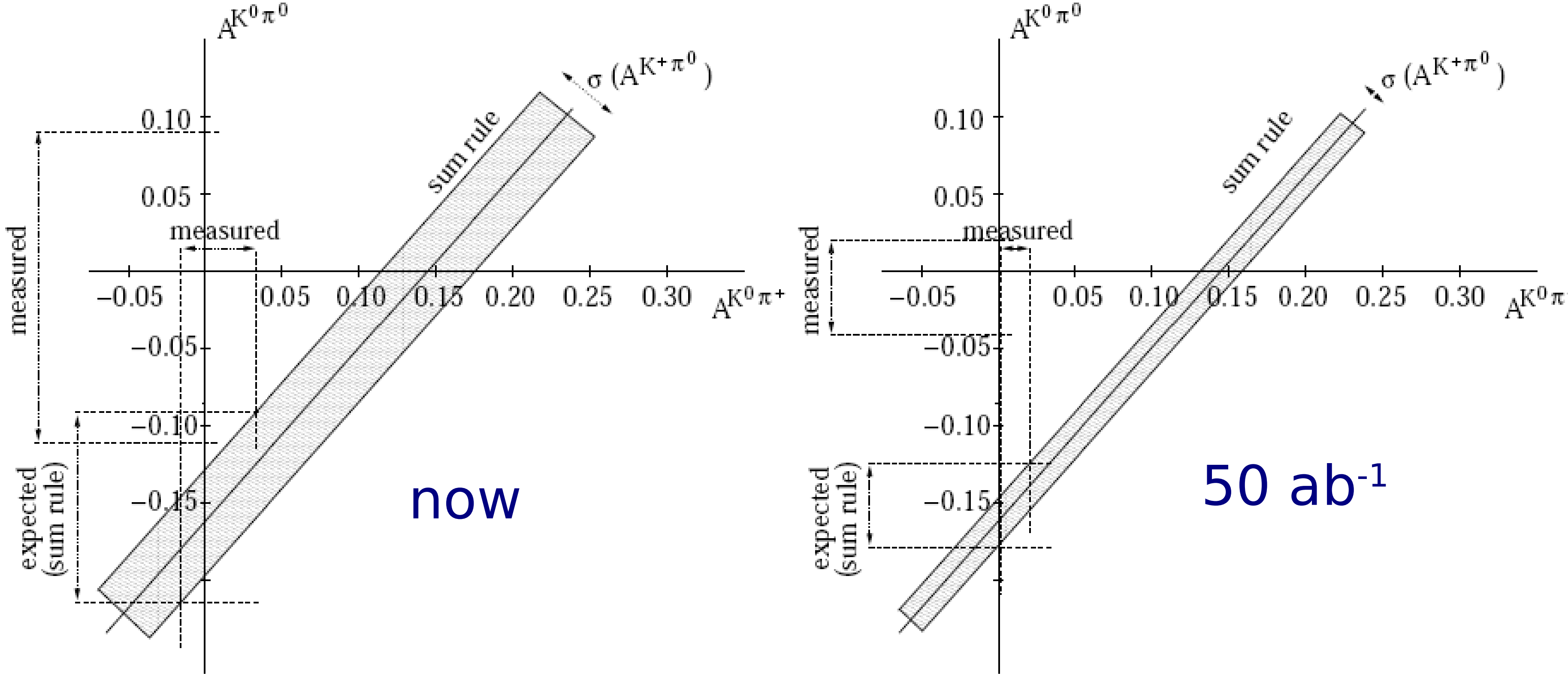
> 1 ab^{-1} !



Direct CP Violation in B → Kπ

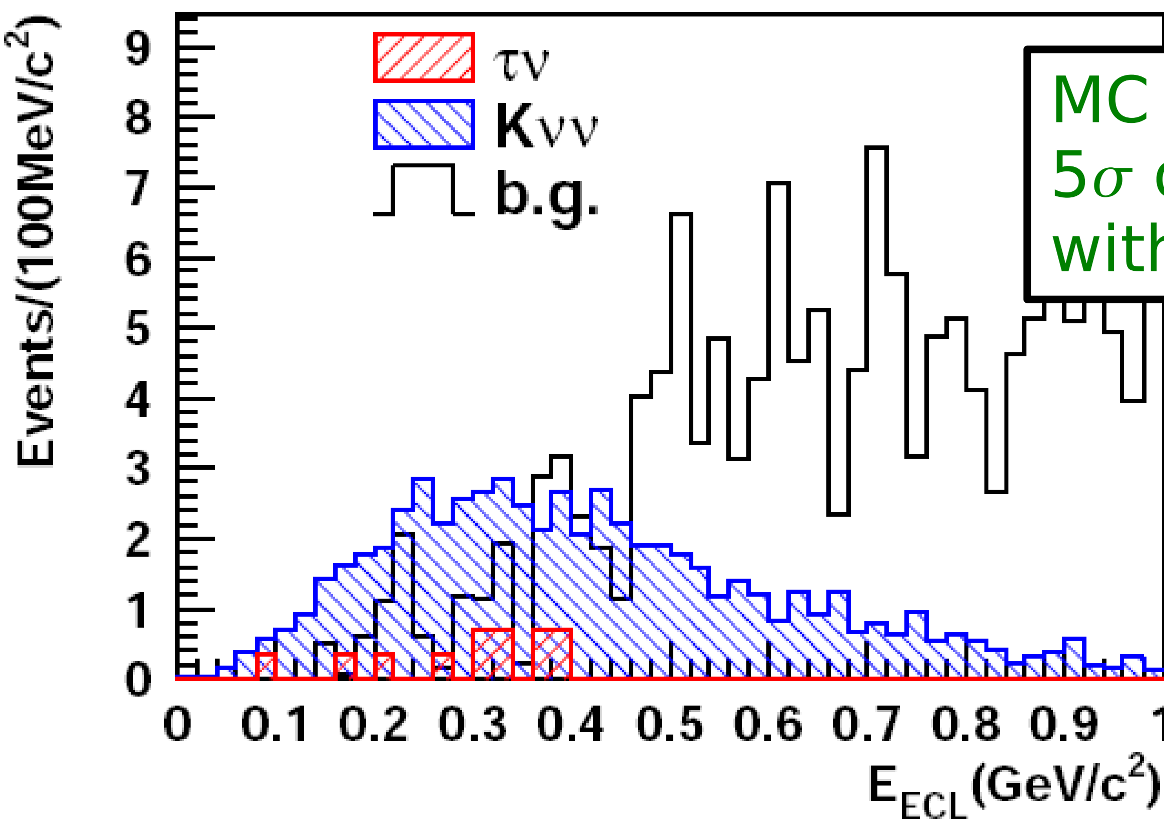
Sum rule:

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



B → K$\nu\nu$

- Theoretically clean mode
  - SM: $B(B^+ \to K^+\nu\nu) = (3.8 ^{+1.2}_{-0.6}) \times 10^{-6}$

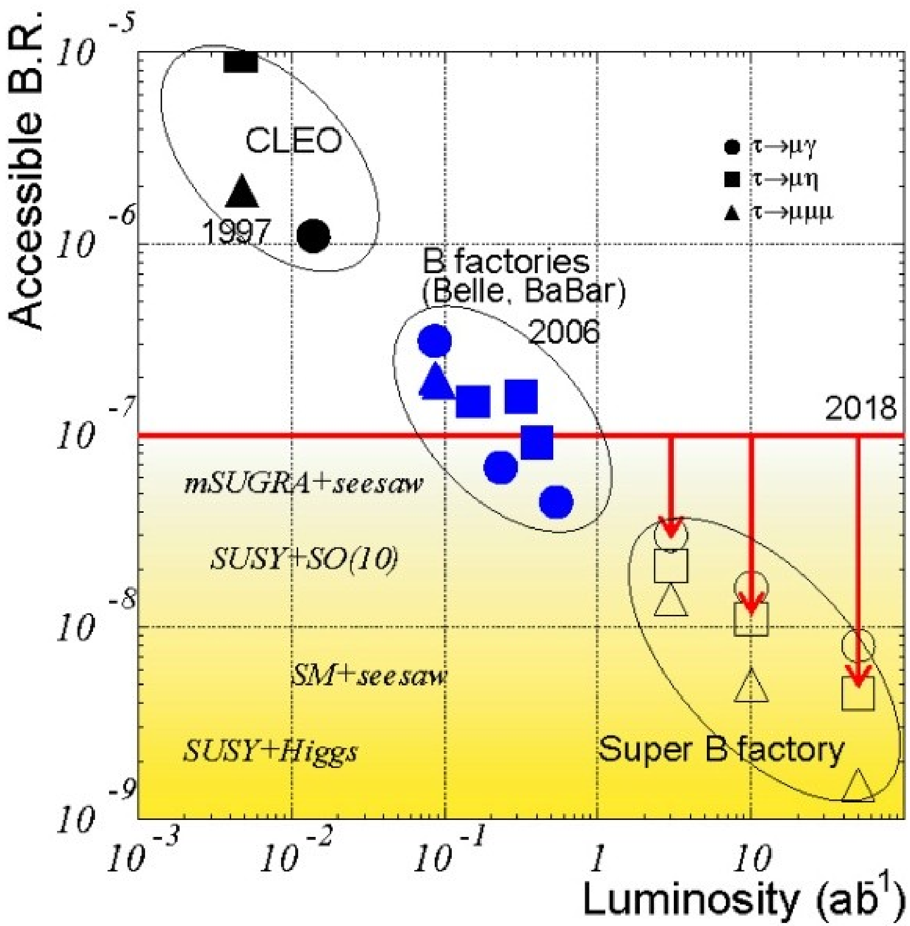


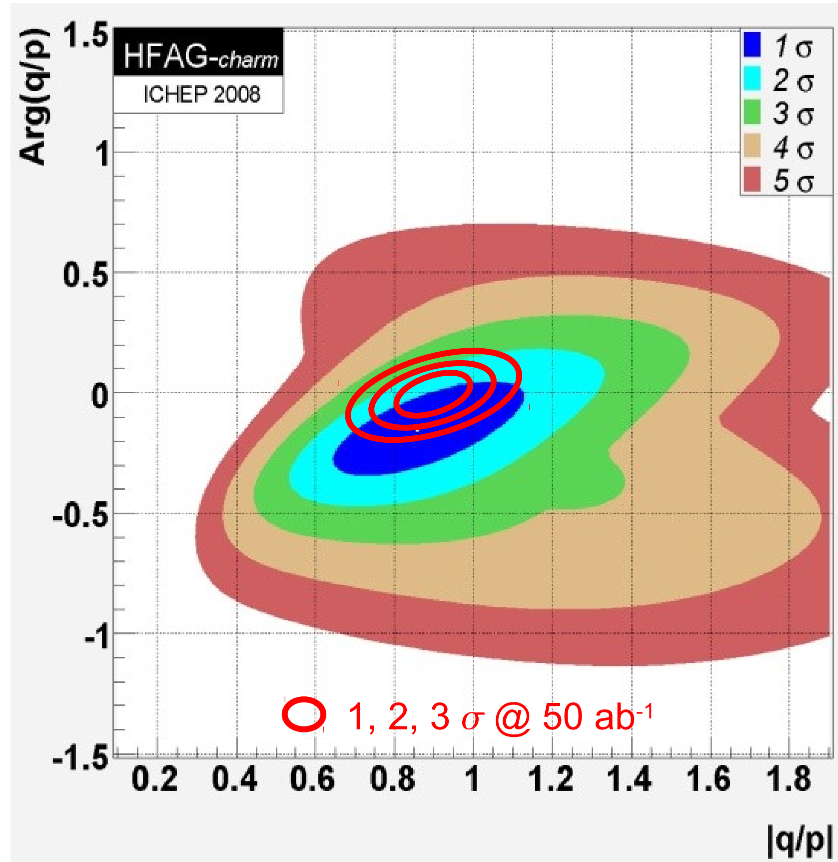
MC study:
5σ observation
with 50 ab^{-1}

Signature
sensitive to
light dark matter

Physics at Belle II

Lepton flavor violation





CP violation in D^0 mixing

Physics at Belle II

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		
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°		
Radiative/electroweak $b \to s$ transitions					
$\mathcal{S}_{K_S^0 \pi^0 \gamma}$	0.32	0.10	0.03	-	-
$\mathcal{B}(B \to X_s \gamma)$	13%	7%	6%	-	-
$A_{CP}(B \to X_s \gamma)$	0.058	0.01	0.005	-	-
C_9 from $\overline{A}_{\mathrm{FB}}(B \to K^* \ell^+ \ell^-)$	-	11%	4%		
C_{10} from $\overline{A}_{\mathrm{FB}}(B \to K^* \ell^+ \ell^-)$	-	13%	4%		
C_7/C_9 from $\overline{A}_{\mathrm{FB}}(B \to K^* \ell^+ \ell^-)$	-		5%		7%
R_K		0.07	0.02		0.043
$\mathcal{B}(B^+ \to K^+ \nu\nu)$	$^{\dagger\dagger} < 3\ \mathcal{B}_{\mathrm{SM}}$		30%	-	-
$\mathcal{B}(B^0 \to K^{*0} \nu\bar{\nu})$	$^{\dagger\dagger} < 40\ \mathcal{B}_{\mathrm{SM}}$		35%	-	-
Radiative/electroweak $b \to d$ transitions					
$\mathcal{S}_{\rho\gamma}$	-	0.3	0.15		
$\mathcal{B}(B \to X_d \gamma)$	-	24% (syst.)		-	-

Observable	Belle 2006	SuperKEKB		†LHCb	
	($\sim$0.5 ab^{-1})	(5 ab^{-1})	(50 ab^{-1})	(2 fb^{-1})	(10 fb^{-1})
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 ab^{-1} for 5σ discovery		-	-
$\mathcal{B}(B^+ \to D\tau\nu)$	-	8%	3%	-	-
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%	-	-
LFV in τ decays (U.L. at 90% C.L.)					
$\mathcal{B}(\tau \to \mu\gamma)$ $[10^{-9}]$	45	10	5	-	-
$\mathcal{B}(\tau \to \mu\eta)$ $[10^{-9}]$	65	5	2	-	-
$\mathcal{B}(\tau \to \mu\mu\mu)$ $[10^{-9}]$	21	3	1	-	-
Unitarity triangle parameters					
$\sin 2\phi_1$	0.026	0.016	0.012	$\sim$0.02	$\sim$0.01
ϕ_2 $(\pi\pi)$	11°	10°	3°	-	-
ϕ_2 $(\rho\pi)$	$68^\circ < \phi_2 < 95^\circ$	3°	1.5°	10°	4.5°
ϕ_2 $(\rho\rho)$	$62^\circ < \phi_2 < 107^\circ$	3°	1.5°	-	-
ϕ_2 (combined)		2°	$\lesssim 1^\circ$	10°	4.5°
ϕ_3 $(D^{(*)}K^{(*)})$ (Dalitz mod. ind.)	20°	7°	2°	8°	
ϕ_3 $(DK^{(*)})$ (ADS+GLW)	-	16°	5°	5-15°	
ϕ_3 $(D^{(*)}\pi)$	-	18°	6°		
ϕ_3 (combined)		6°	1.5°	4.2°	2.4°
$\lvert V_{ub}\rvert$ (inclusive)	6%	5%	3%	-	-
$\lvert V_{ub}\rvert$ (exclusive)	15%	12% (LQCD)	5% (LQCD)	-	-
$^{\dagger\dagger\dagger}\bar{\rho}$	20.0%		3.4%		
$^{\dagger\dagger\dagger}\bar{\eta}$	15.7%		1.7%		

Observable	Belle	Belle/SuperKEKB		LHCb†	
				(2 fb^{-1})	(10 fb^{-1})
B_s physics	(25 fb^{-1})	(	5 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 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 fb^{-1})	(500 fb^{-1})			
$\mathcal{B}(\Upsilon(1S) \to$ invisible)	$< 2.5 \times 10^{-3}$	$< 2 \times 10^{-4}$			
	($\sim$0.5 ab^{-1})‡	(5 ab^{-1})	(50 ab^{-1})		
Charm physics					
D mixing parameters					
x	0.25%	0.12%	0.09%		0.25%††
y	0.16%	0.10%	0.05%		0.05%††
$\delta_{K\pi}$	10°	6°	4°		
$\lvert q/p \rvert$	0.16	0.1	0.05		
ϕ	0.13 rad	0.08 rad	0.05 rad		
A_D	2.4%	1%	0.3%		
New particles$^\aleph$					
$\gamma\gamma \to Z(3930) \to D\bar{D}^*$		$> 3\sigma$			
$B \to KX(3872)(\to D^0\bar{D}^{*0})$		400 events			
$B \to KX(3872)(\to J/\psi\pi^+\pi^-)$		1250 events			
$B \to KZ^+(4430)(\to \psi'\pi^+)$		1000 events			
$e^+e^- \to \gamma_{\rm ISR} Y(4260)(\to J/\psi\pi^+\pi^-)$		3000 events			
Electroweak parameters		($\sim$10 ab^{-1})			
$\sin^2\Theta_W$	-	3×10^{-4}			

Comparison Belle II / LHCb

e^+e^- has advantages in…	LHCb has advantages in…
CPV in $B \rightarrow \phi K_S$, $\eta' K_S$,…	CPV in $B \rightarrow J/\psi K_S$
CPV in $B \rightarrow K_S \pi^0 \gamma$	Most of B decays not including ν or γ
$B \rightarrow K \nu\nu$, $\tau\nu$, $D^{(*)}\tau\nu$	Time dependent measurements of B_S
Inclusive $b \rightarrow s \mu\mu$, *see*	$B_{(s,d)} \rightarrow \mu\mu$
$\tau \rightarrow \mu\gamma$ and other LFV	B_c and bottomed baryons
$D^0 \overline{D^0}$ mixing	

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