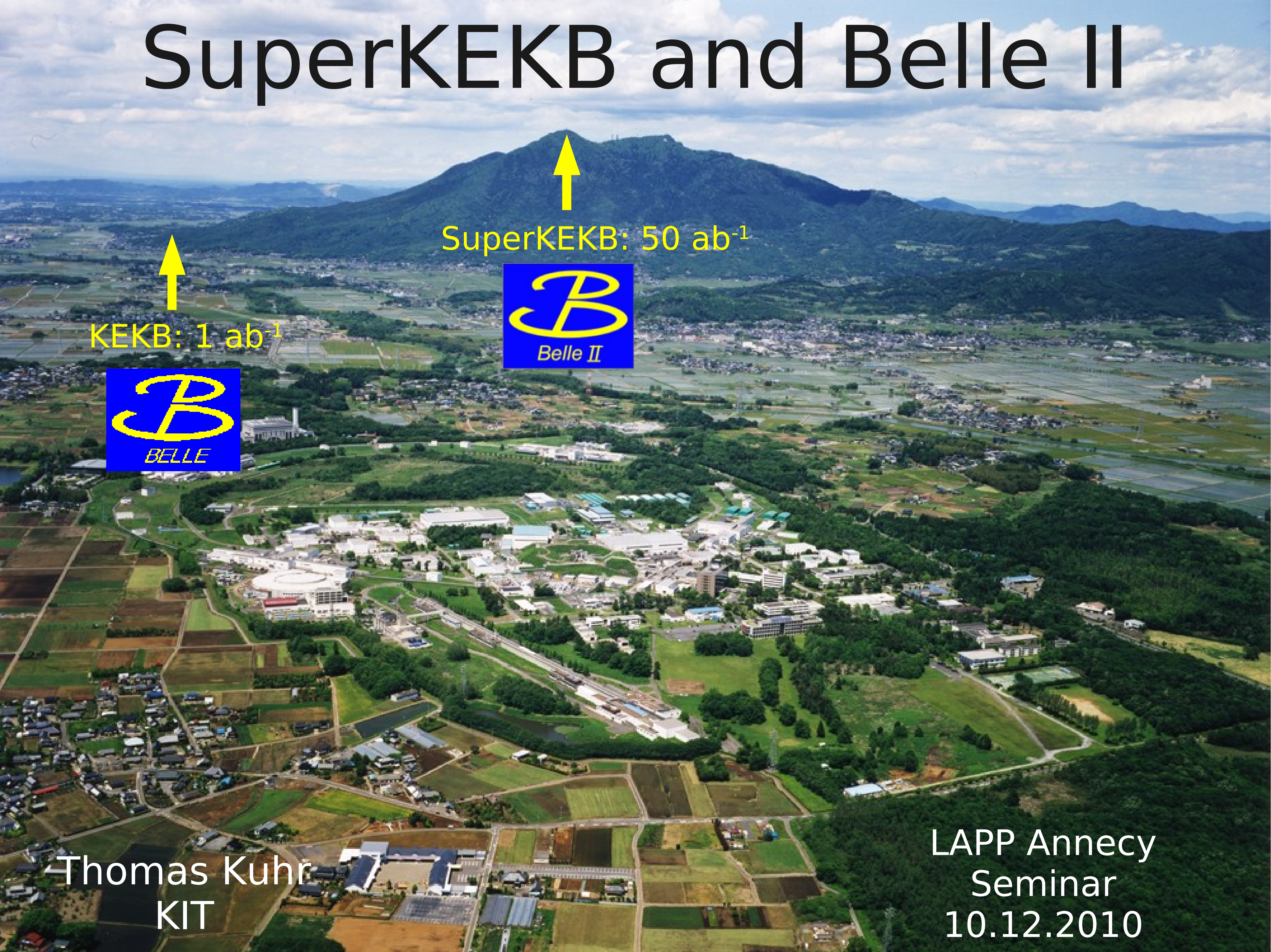
SuperKEKB and Belle II

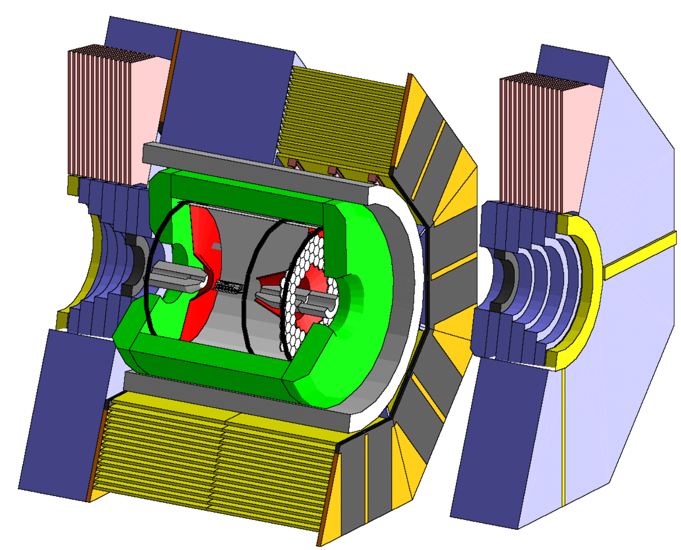


Thomas Kuhr
KIT

LAPP Annecy
Seminar
10.12.2010

Outline

- KEKB and Belle
- Physics at a Super B Factory
- SuperKEKB Accelerator
- Belle II Detector
- Computing at Belle II
- Status of Project
- Summary



Motivation for B Factories

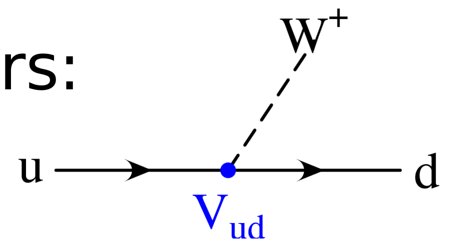
- 1964, Cronin, Fitch: Discovery of CP violation in K^0 system, small effect $O(10^{-3})$

- ➢ 1972, Kobayashi, Maskawa:
  - ➔ CP violation possible, if there are 6 quark flavors
- ✔ 1974, Burton, Richter: Discovery of charm quark
- ✔ 1977, E288: Discovery of bottom quark
- ✔ 1995, CDF, D0: Discovery of top quark

➔ CP violation?

(C)KM-Matrix

- Flavor changing coupling of W to quark pairs:



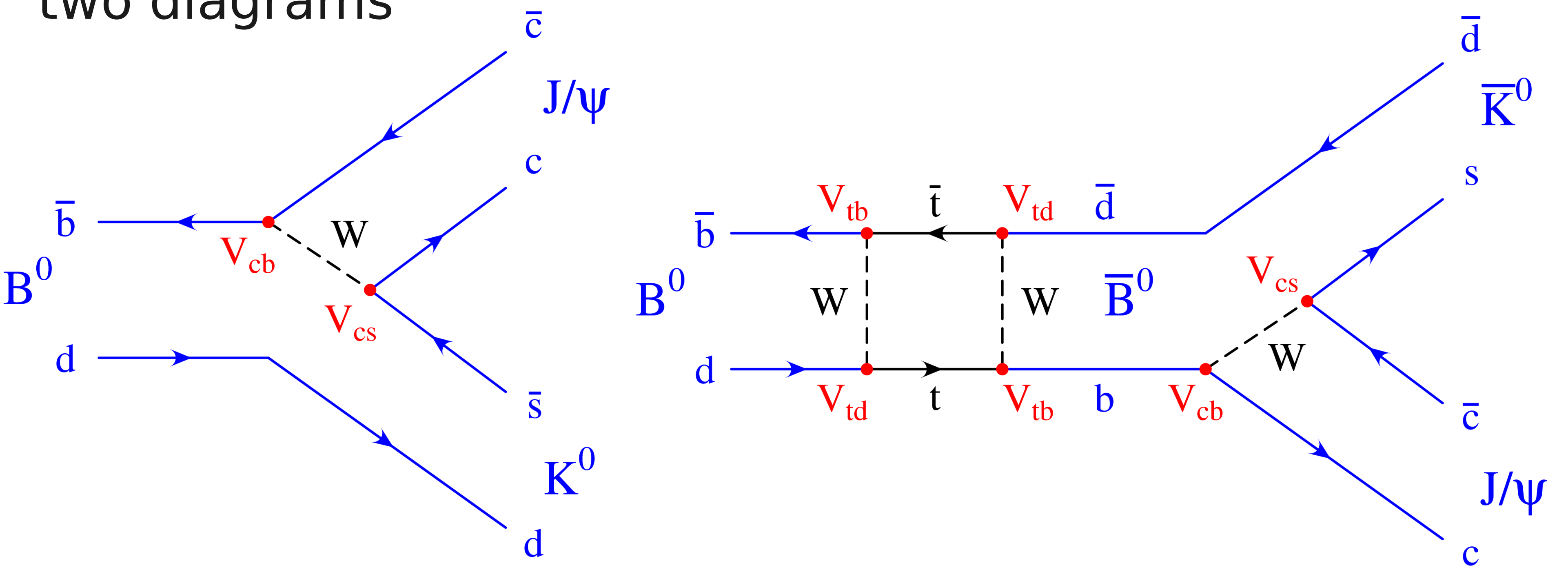
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

- Complex elements V_{ij}
- → 18 parameters
- Unitarity ($VV^\dagger = 1$) + quark phases
- → 4 free par.:
  3 angles + 1 phase (~~CP~~)

- CP violation determined by just one parameter
- Prediction of large CP violation in B^0 system
  - Experimental verification needed → B factories

Measurement of CP Violation

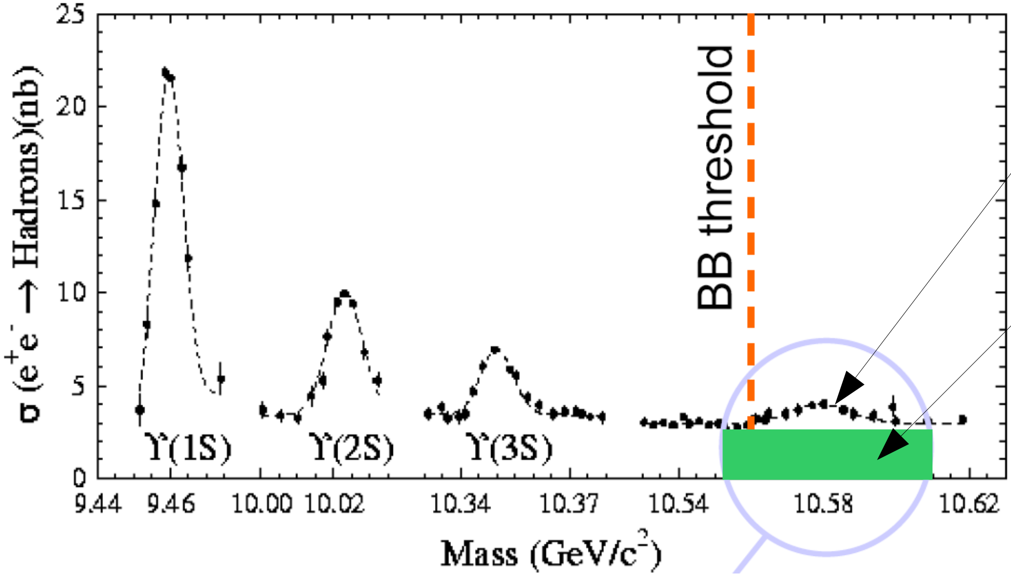
- Measurement of phase requires interference between two diagrams



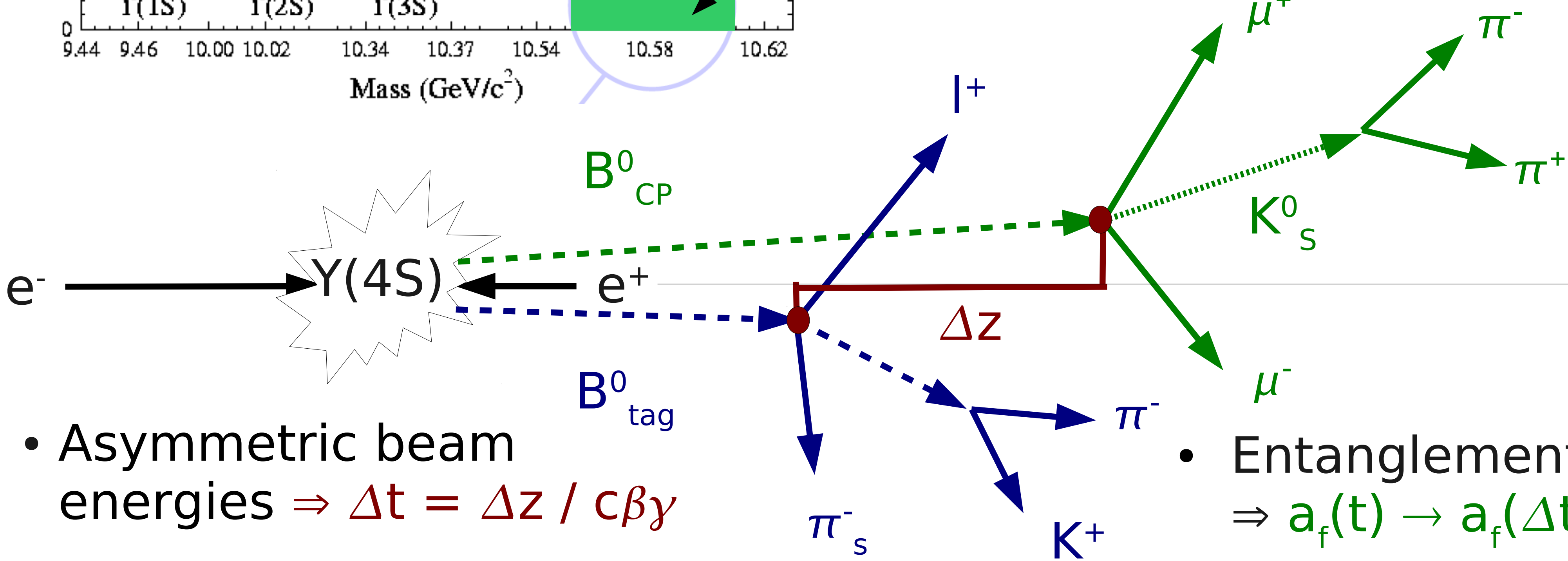
➢ Time dependent asymmetry measurement:

$$a_f(t) = \frac{\Gamma(\bar{B}^0 \to f) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to f) + \Gamma(B^0 \to f)} \approx -\xi_f \sin(2\phi_1) \sin(\Delta m t)$$

Time Dependent $\cancel{CP}$ Measurement

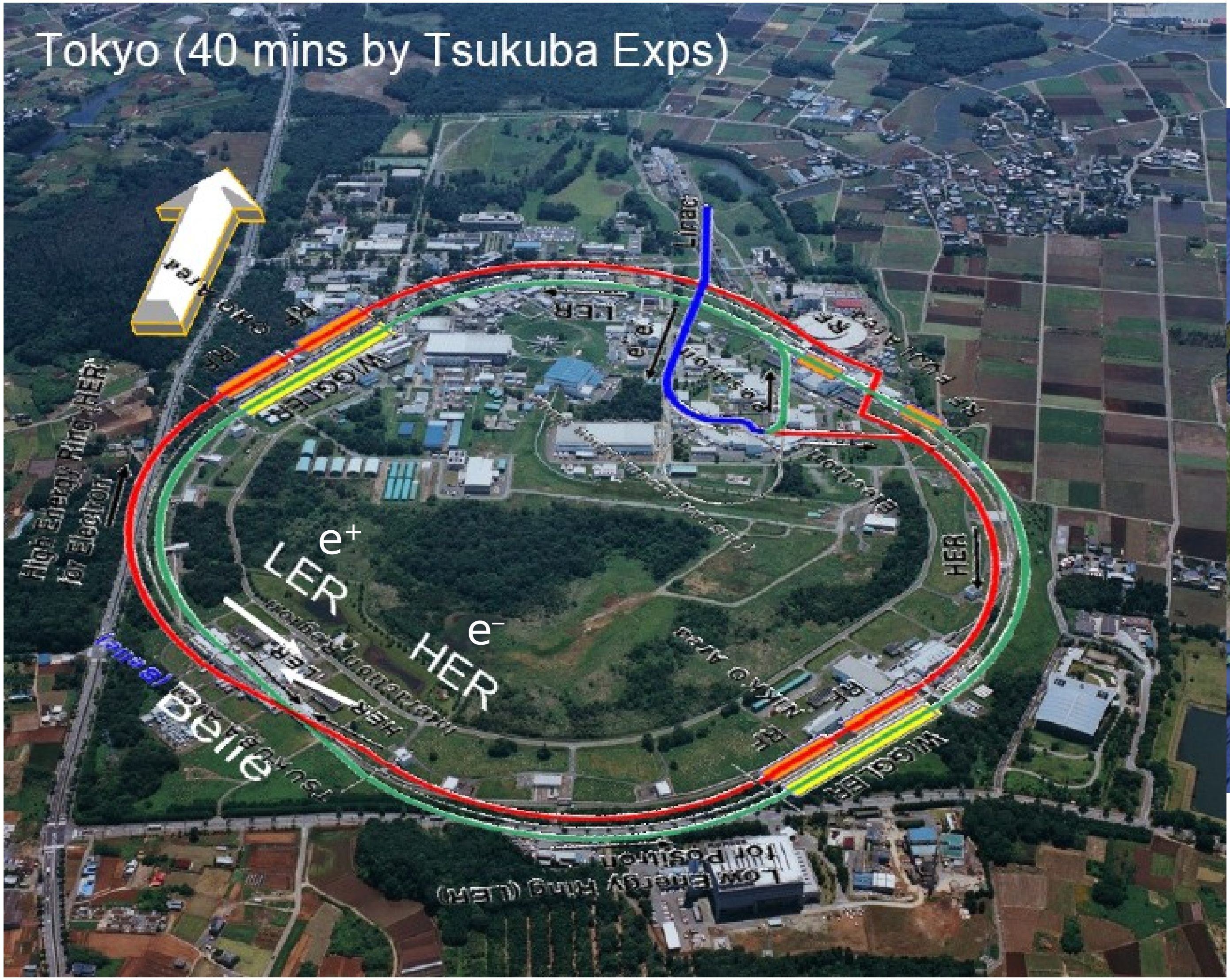


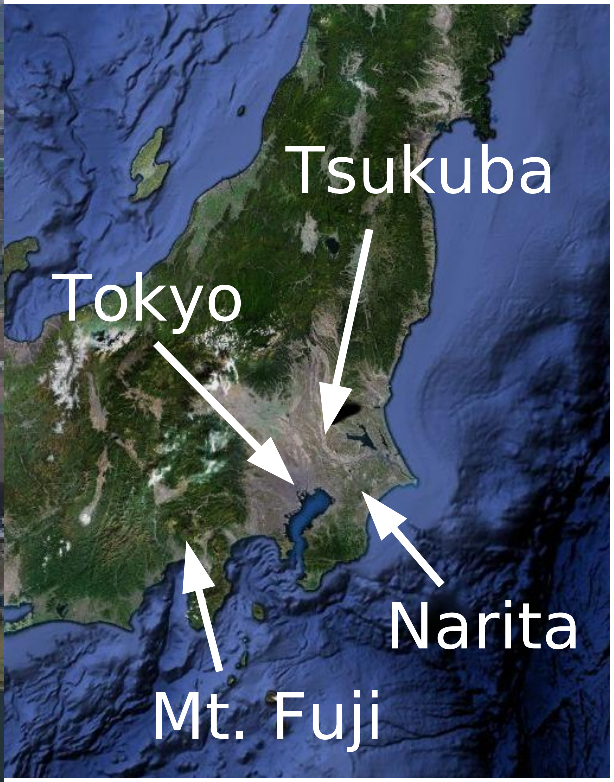
- $e^+e^- \rightarrow Y(4S) \rightarrow B^0\bar{B}^0$ (50%)
  $\rightarrow B^+B^-$ (50%)
- Continuum background



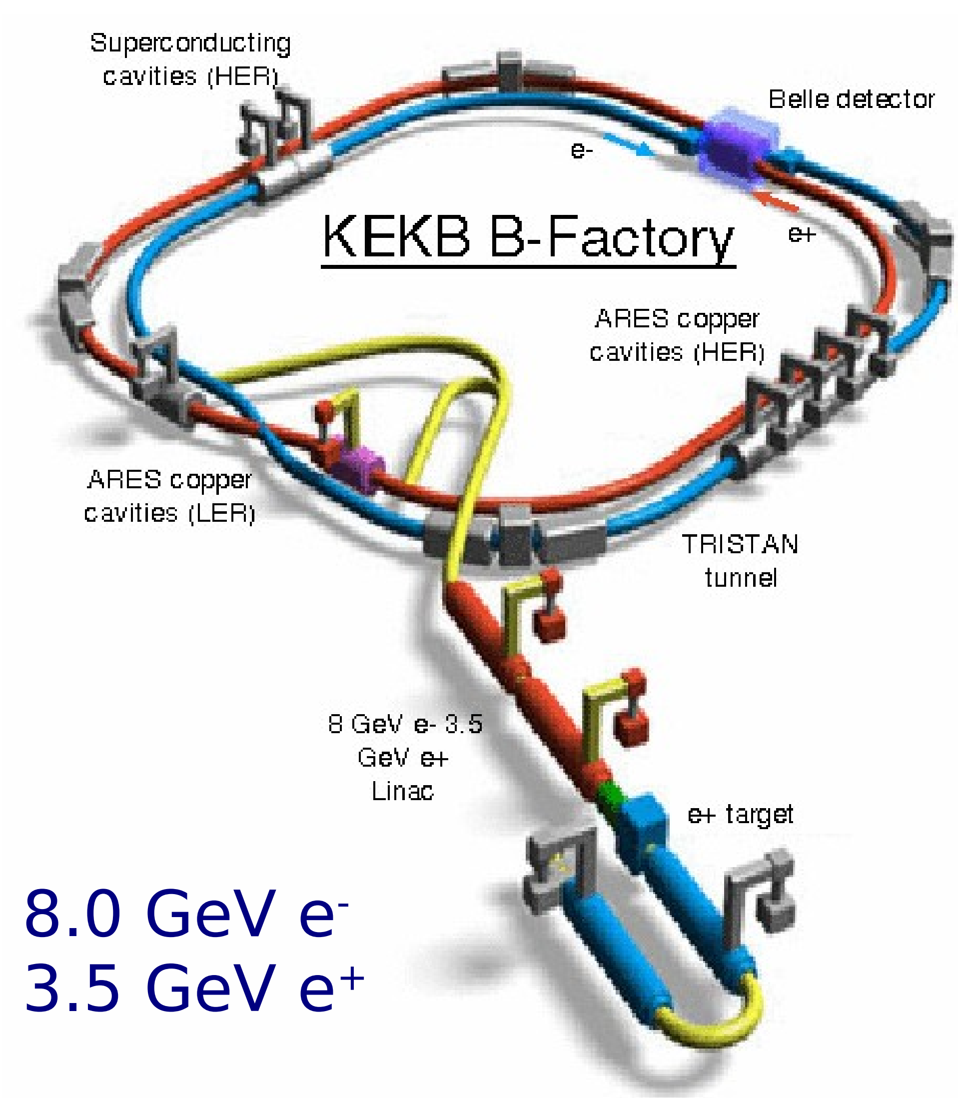
- Asymmetric beam energies $\Rightarrow \Delta t = \Delta z \,/\, c\beta\gamma$
- Entanglement $\Rightarrow a_f(t) \rightarrow a_f(\Delta t)$

KEK Site

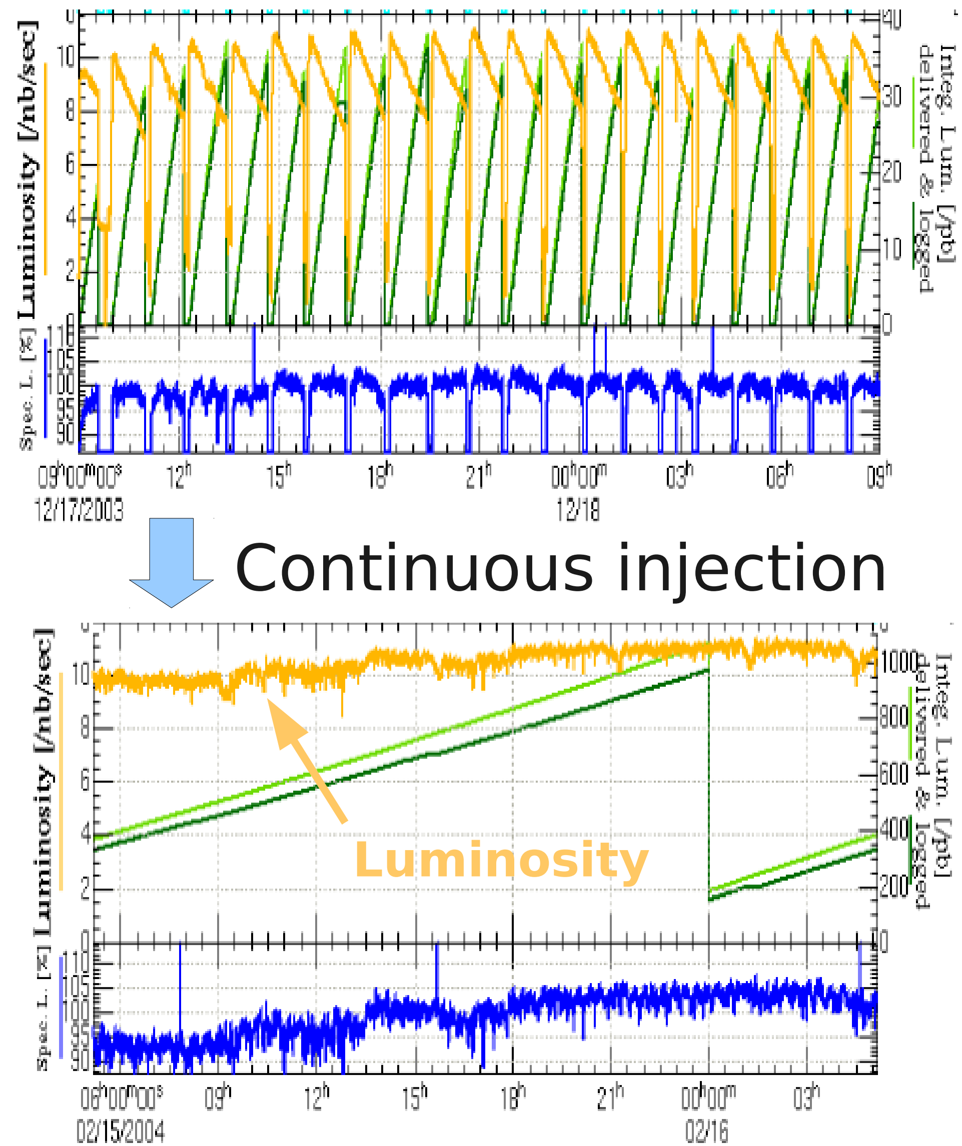

Tokyo (40 mins by Tsukuba Exps)
Linac
e+
LER
e−
HER
Belle
WIGGLER
RF
High Energy Ring (HER) for Electron
Low Energy Ring (LER) for Positron


Tsukuba
Tokyo
Narita
Mt. Fuji

KEKB Accelerator

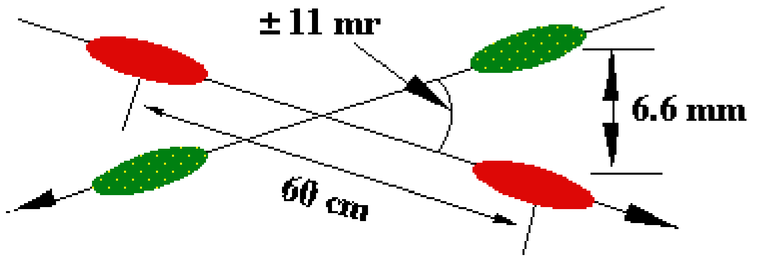


8.0 GeV e^-
3.5 GeV e^+

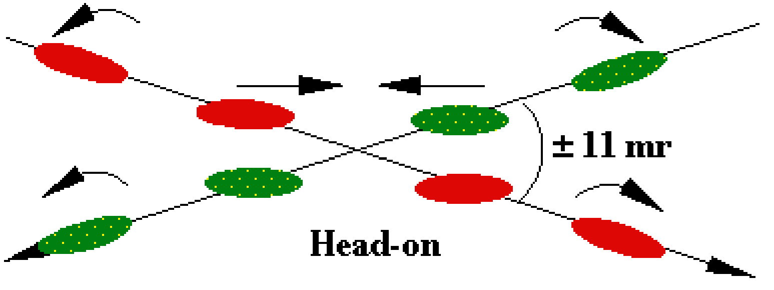


Crab Cavities

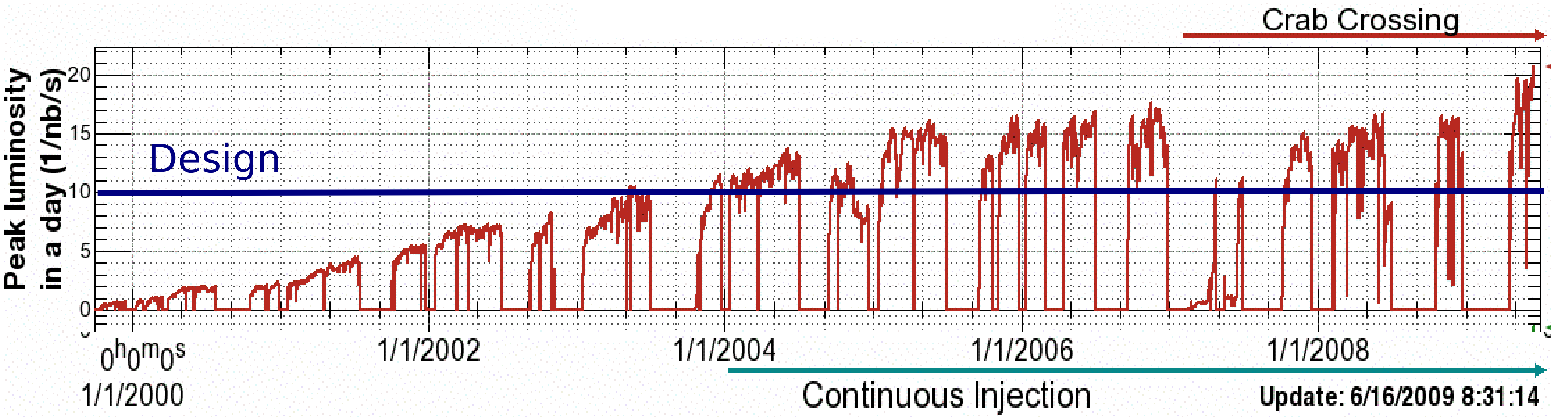
- 22 mrad crossing angle between beams



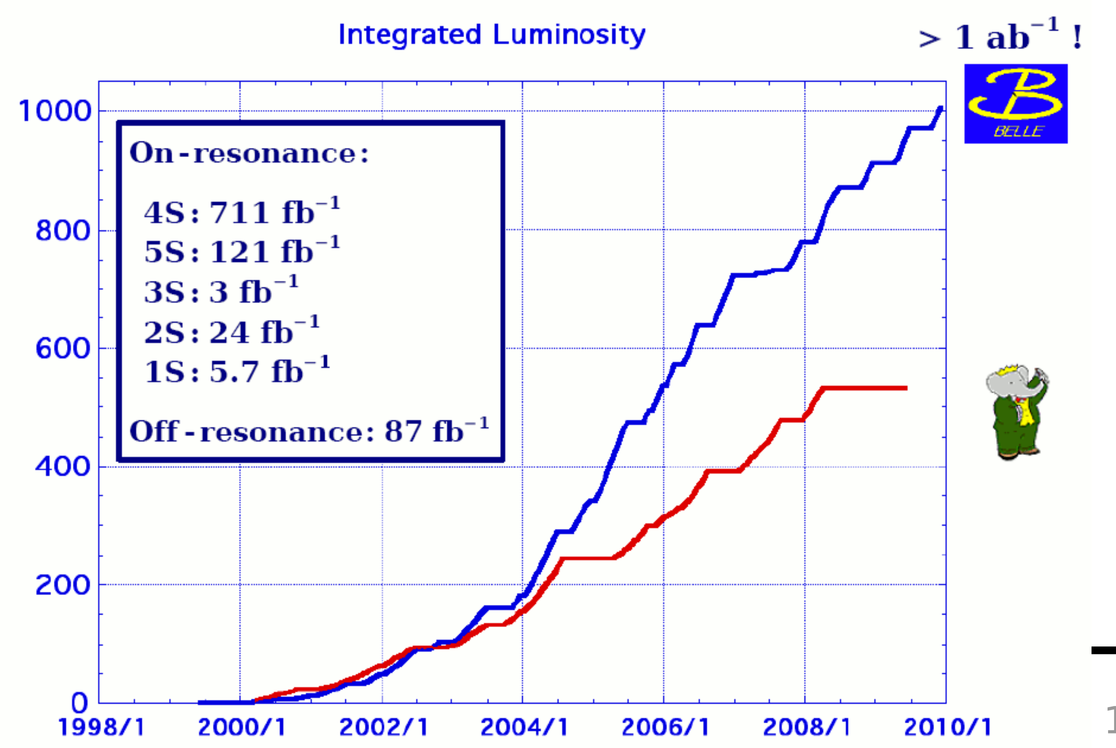
- Rotate bunches to have head-on collisions



KEKB Performance



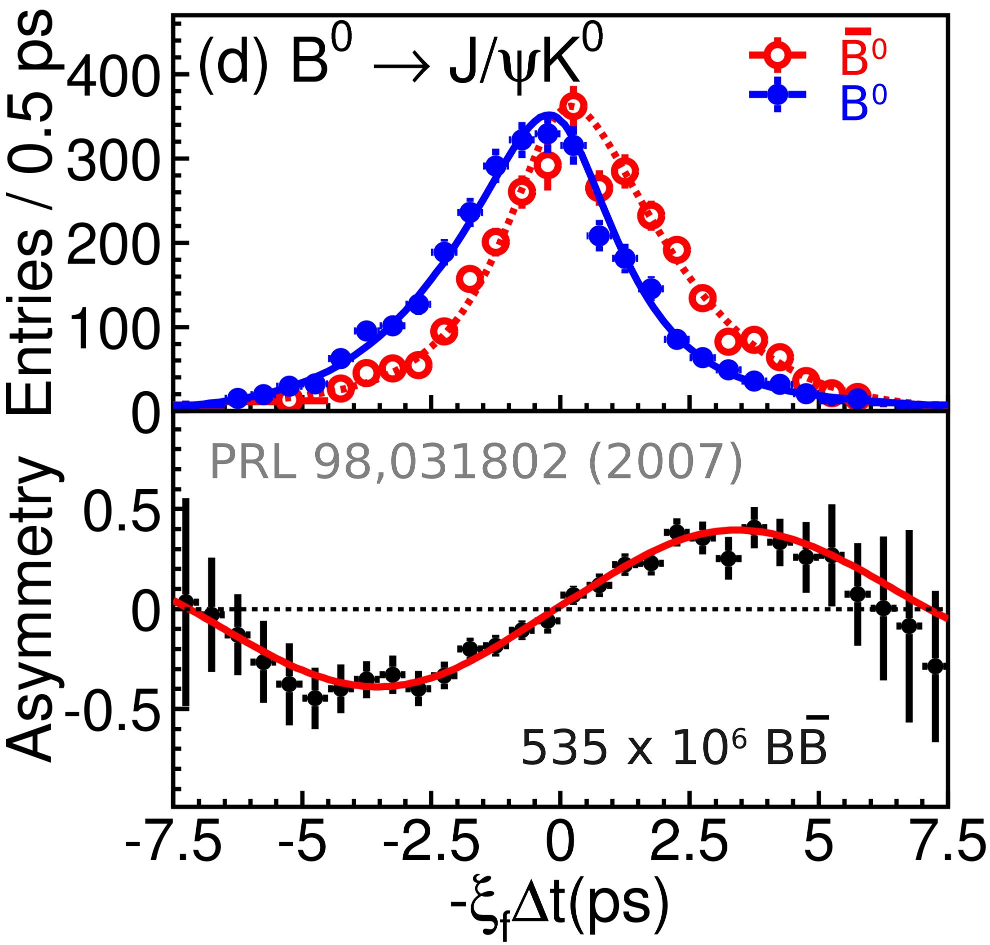
- World record luminosity: $2.1 \times 10^{34}\ cm^{-2}s^{-1}$ → Twice design
- 1 ab^{-1} of integrated luminosity

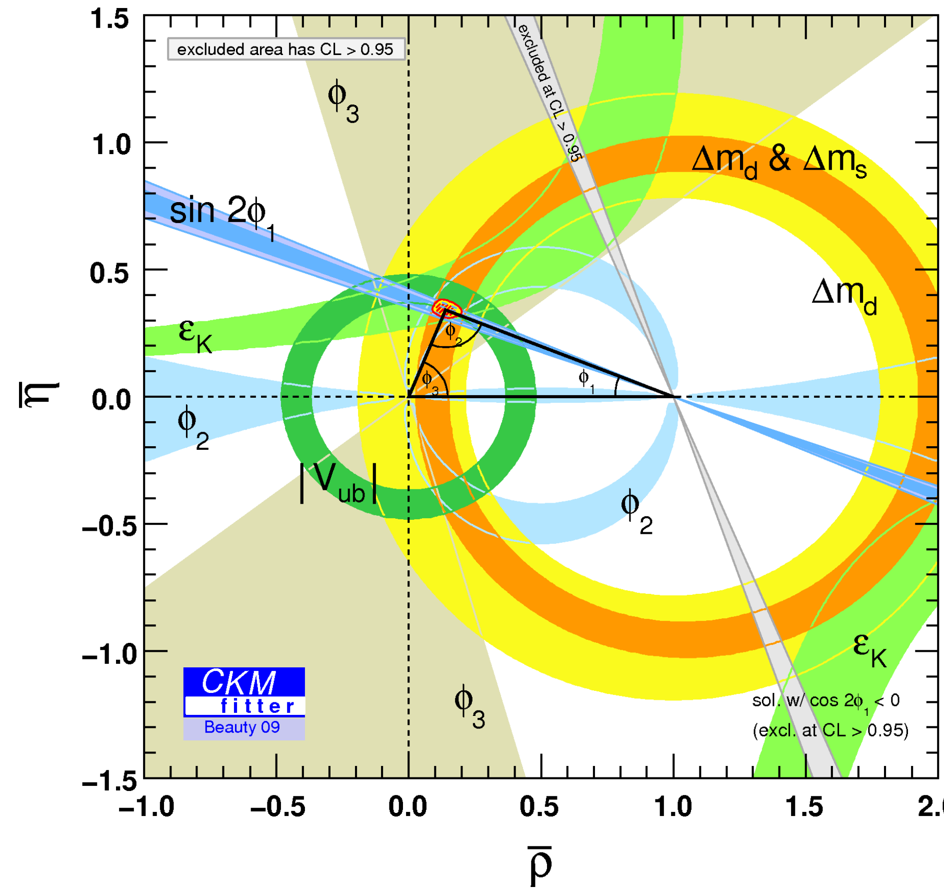


World Record Luminosity

$L_{max} = 2.1 \times 10^{34}\ cm^{-2}s^{-1}$

Physics Objective of Belle





✔ Confirmation of KM mechanism of $\not{CP}$ in the Standard Model

Baryon Asymmetry in the Universe

- Big bang: Equal amount of matter and antimatter
- Today: Only matter left

- Requirements (1967, Sakharov):
  - Baryon number violation
  - Departure from thermal equilibrium
  - C and CP violation

✗ CP violation in the SM by many orders of magnitude too small to generate observed asymmetry

➢ Need sources of CP violation beyond the SM

➔ Super B factory

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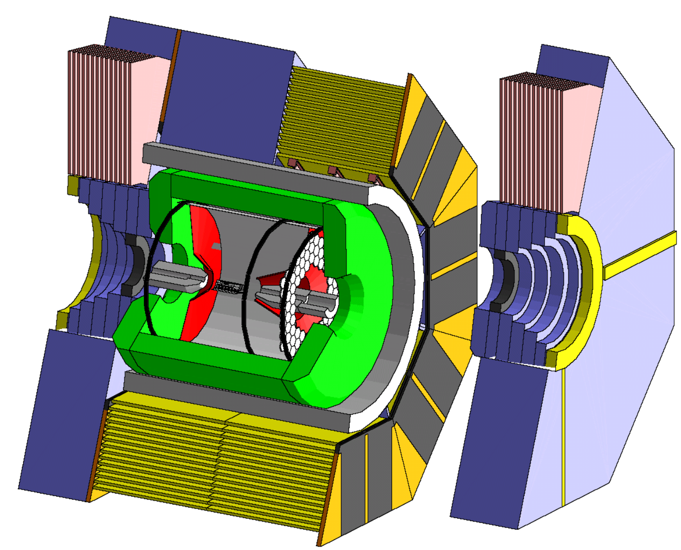
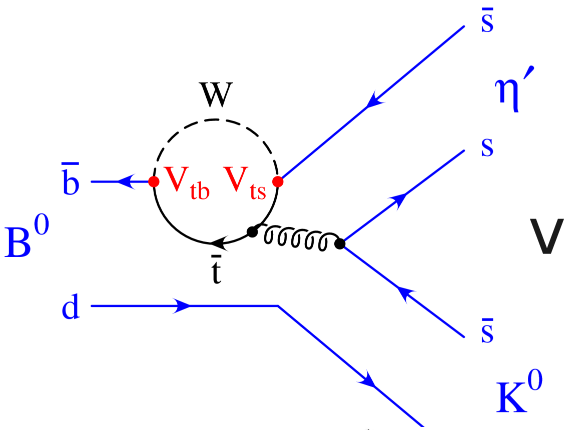
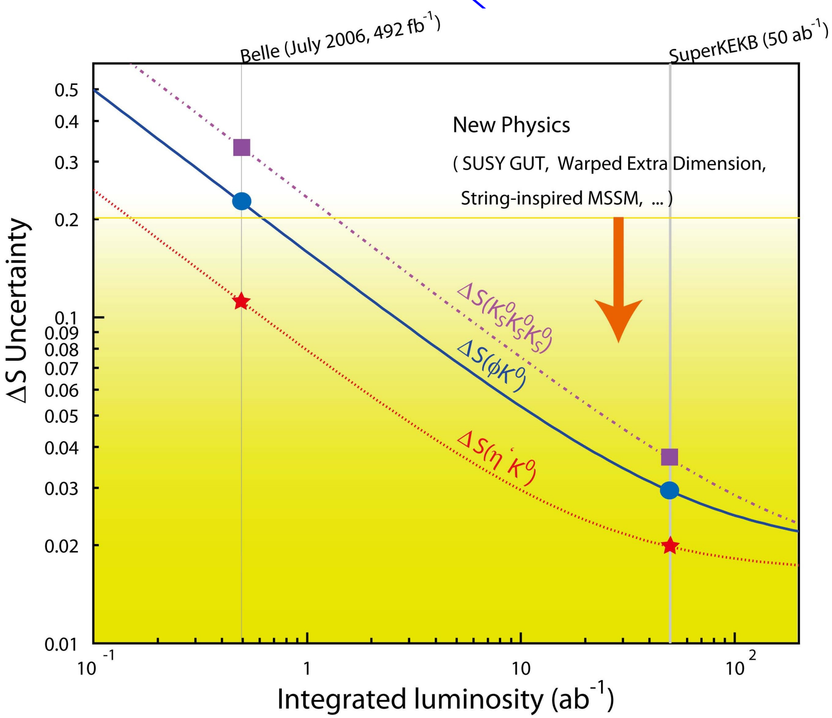
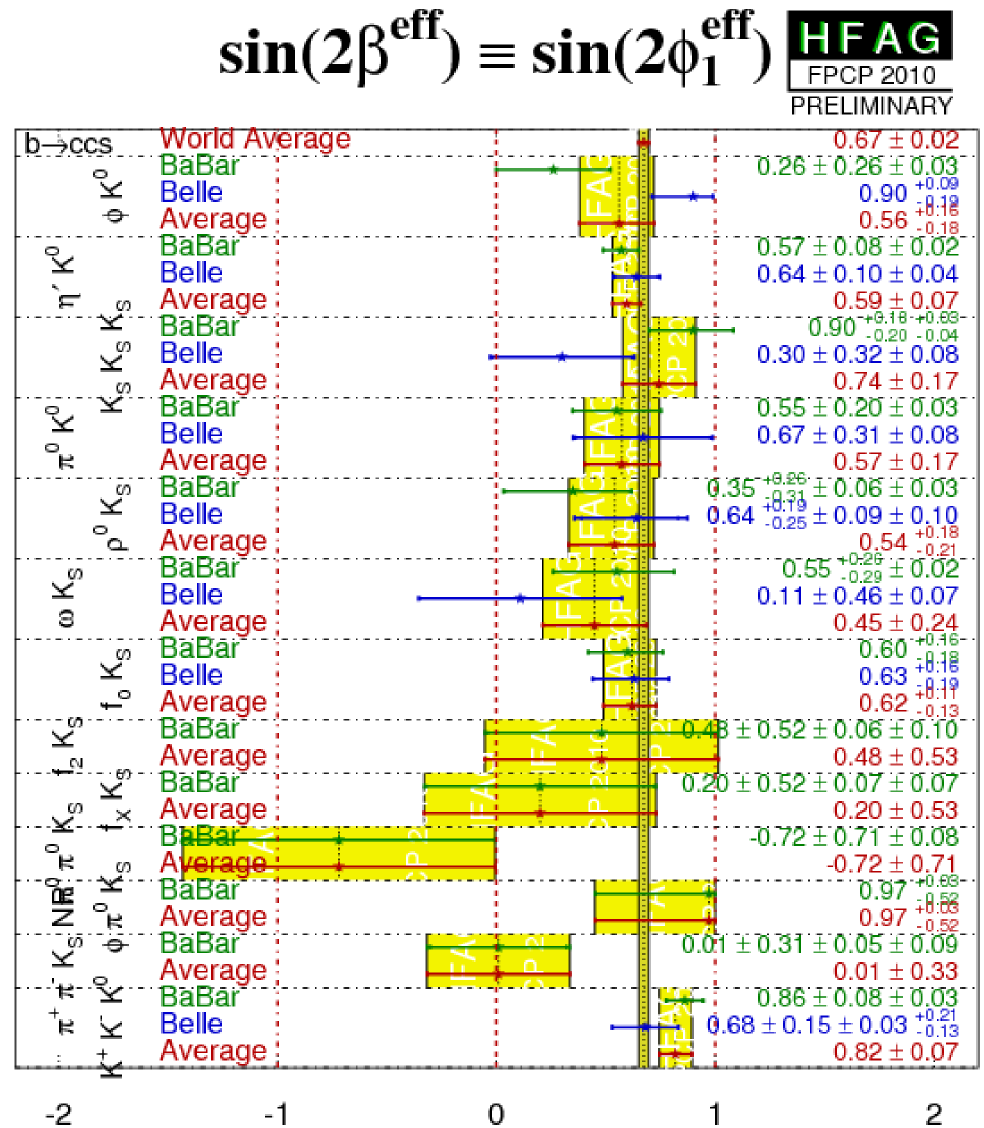


Time Dependent ~~CP~~ in $b \to q\bar{q}s$ Decays

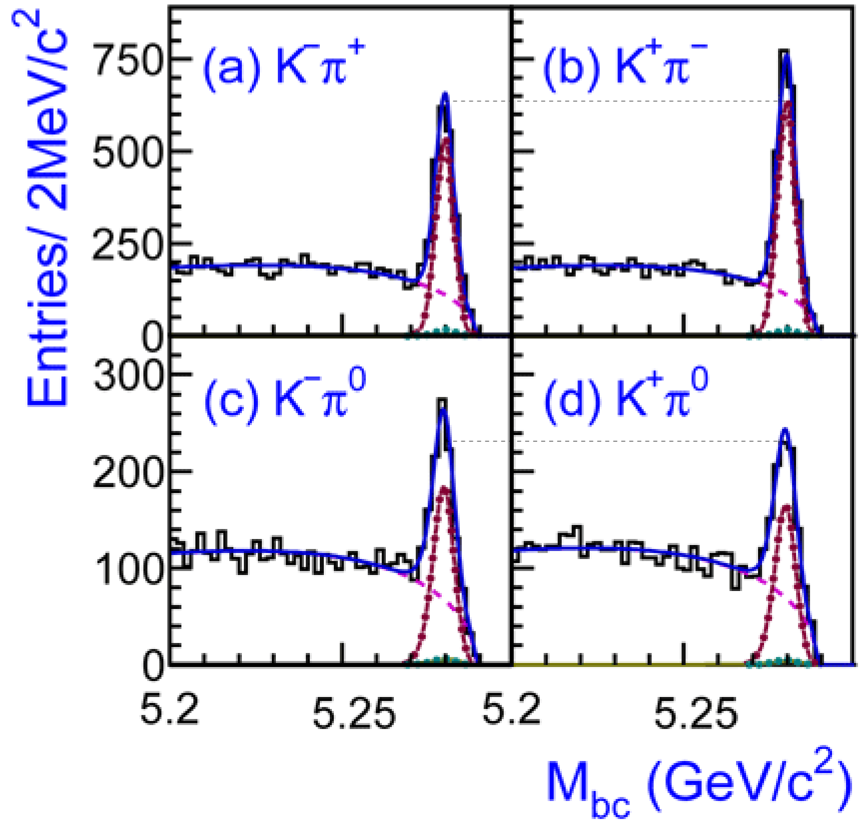


Tendency to lower values than in $b \to c\bar{c}s$





Direct $\cancel{CP}$ in $B \to K\pi$

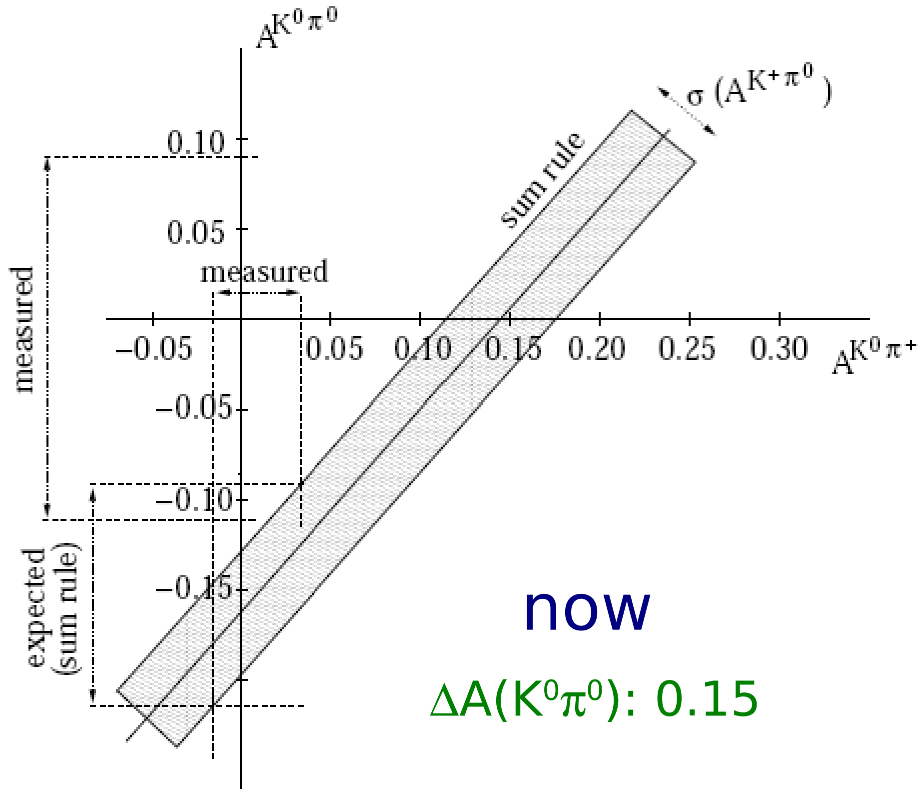


$\bar{B}^0$ vs. B^0

B^- vs. B^+

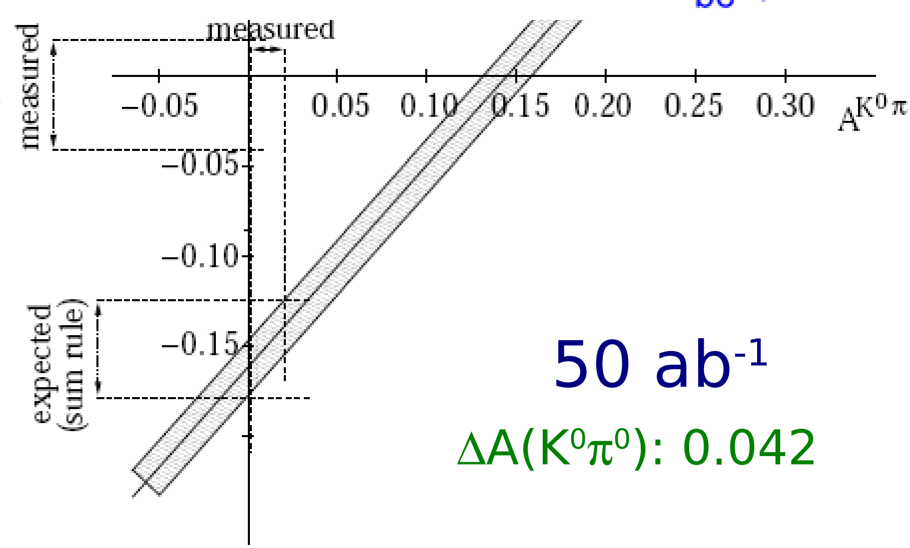
Sum rule:

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



now

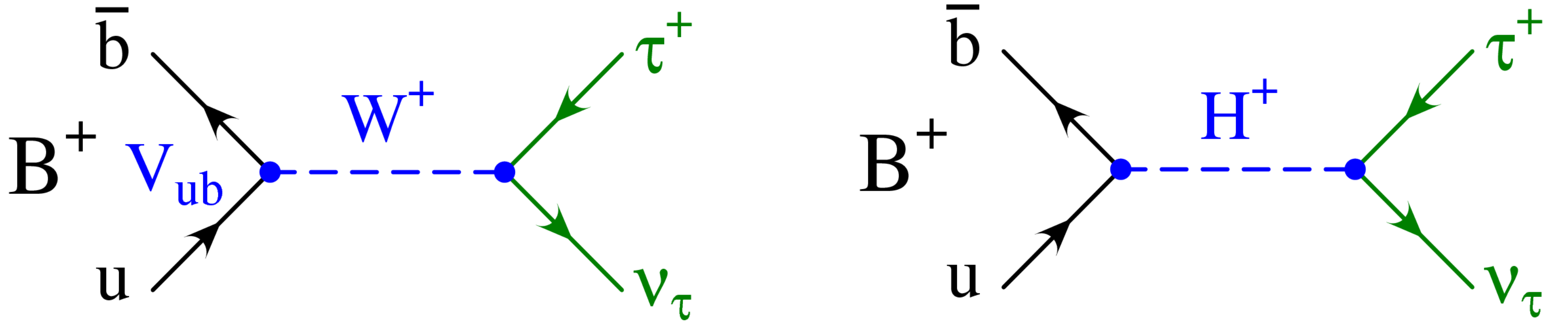
$\Delta A(K^0\pi^0)$: 0.15



50 ab^{-1}

$\Delta A(K^0\pi^0)$: 0.042

Rare Decays: B → $\tau\nu$



- SM:

$$\mathcal{B}(B^+ \to \tau^+\nu) = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

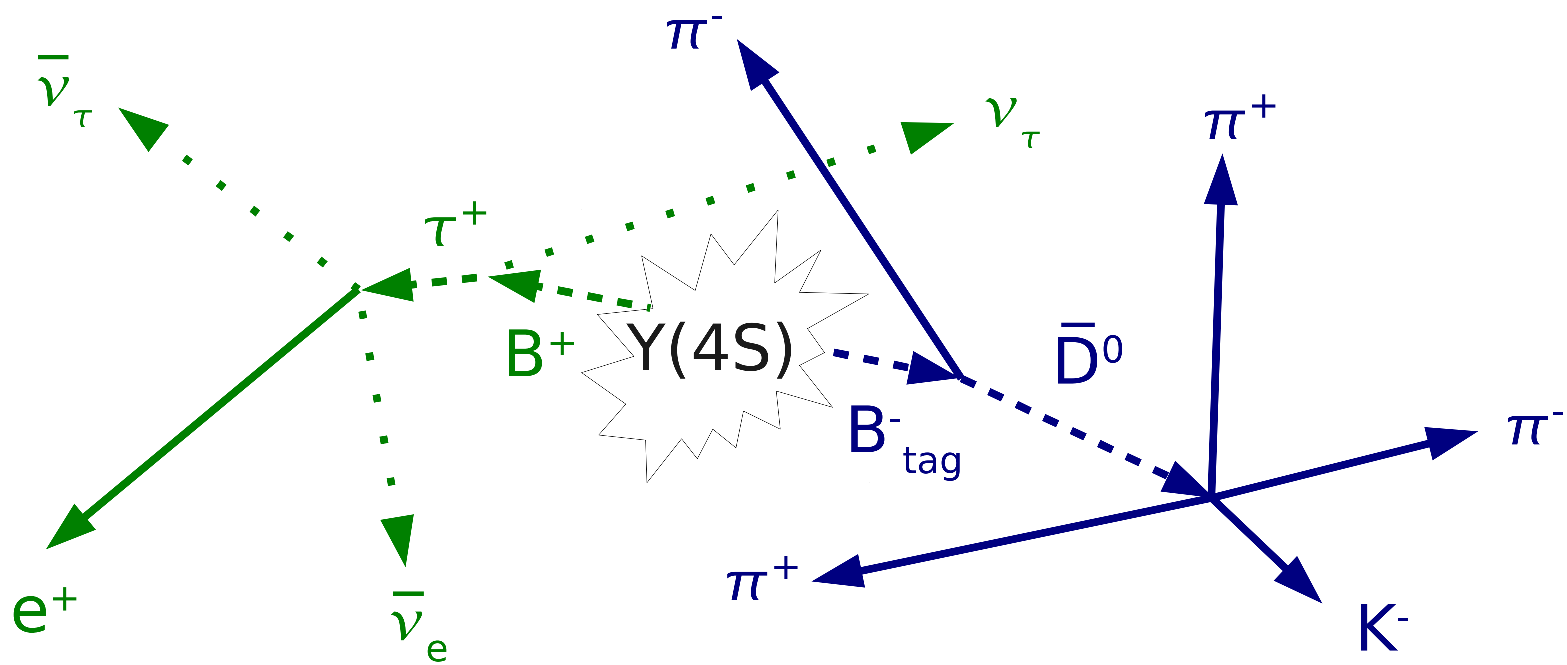
→ V_{ub} from other measurements → Measurement of f_B

- Two Higgs doublet model:

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

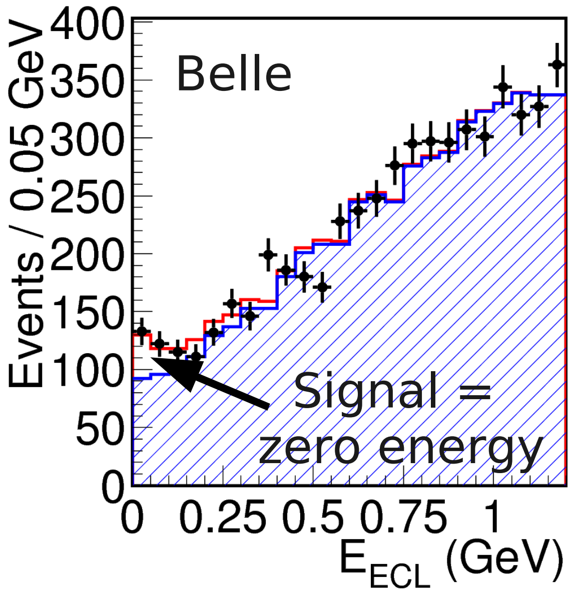
→ f_B from lattice QCD → H^+ discovery or limit on H^+ mass

Full Reconstruction

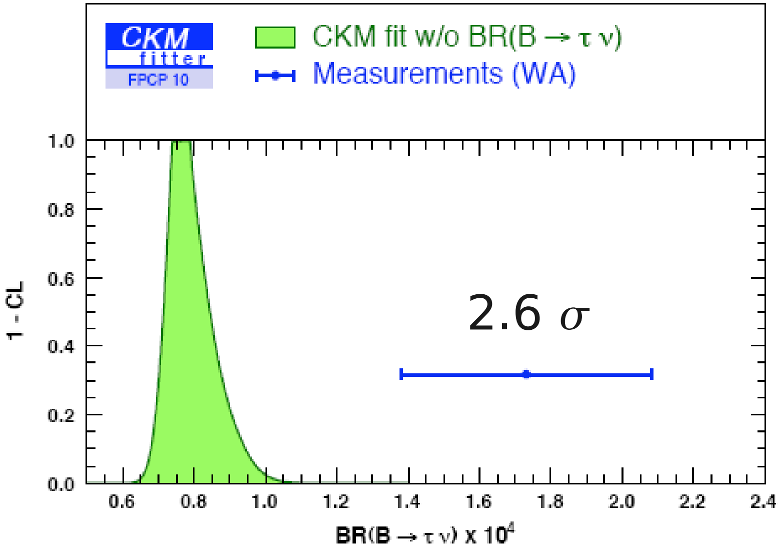


- Hundreds of exclusive decay modes → efficiency O(0.1%)
  - ➔ Type and momentum of other B known
  - ➔ Remaining particles belong to other B

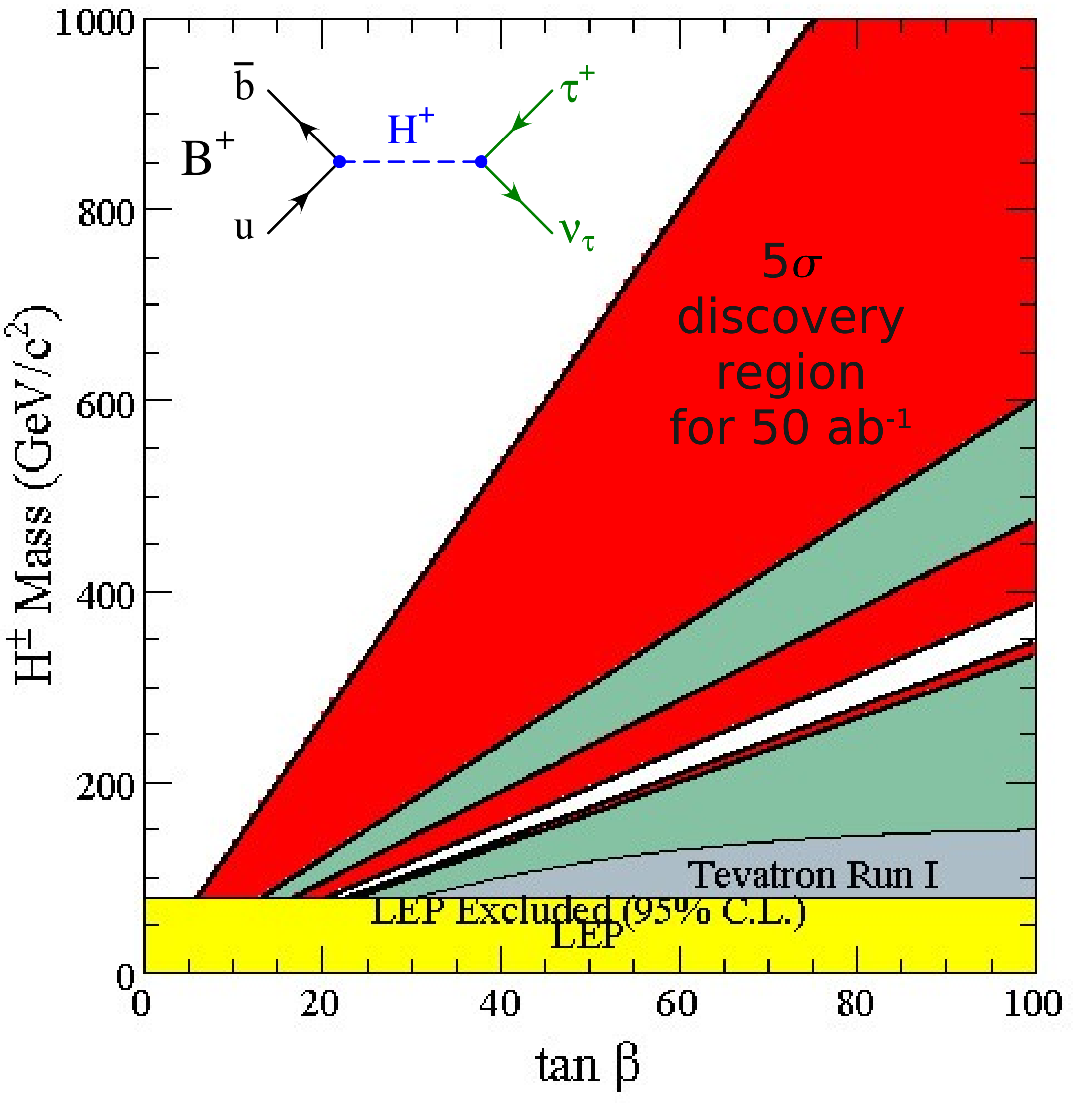
B → $\tau\nu$



Belle
Events / 0.05 GeV
Signal = zero energy
E_{ECL} (GeV)



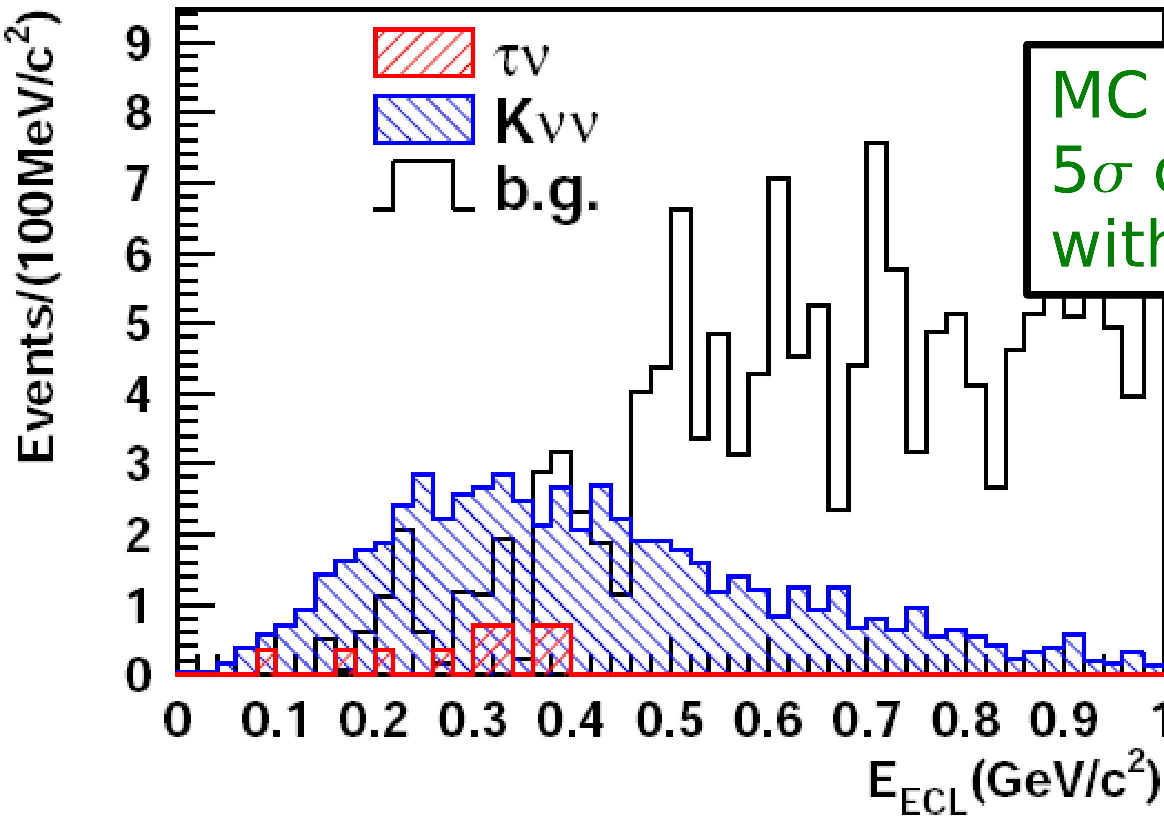
CKM fitter
FPCP 10
CKM fit w/o BR(B → τ ν)
Measurements (WA)
1 - CL
2.6 σ
BR(B → τ ν) x 10^4



$H^{\pm}$ Mass (GeV/c^2)
tan β
B+
$\bar{b}$
u
H^+
τ^+
ν_τ
5σ discovery region for 50 ab-1
Tevatron Run I
LEP Excluded (95% C.L.)
LEP

$B \to K\nu\nu$

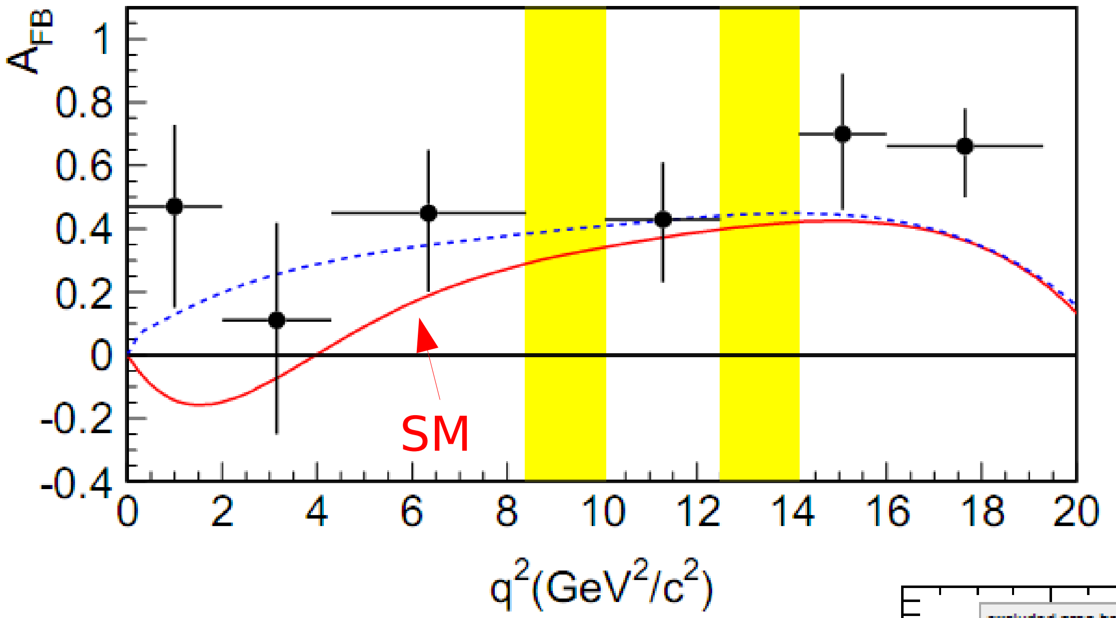
- Theoretically clean mode
  - SM: $B(B^+ \to K^+\nu\nu) = (3.8\,^{+1.2}_{-0.6}) \times 10^{-6}$



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

Signature
sensitive to
light dark matter

More Places to Look for New Physics

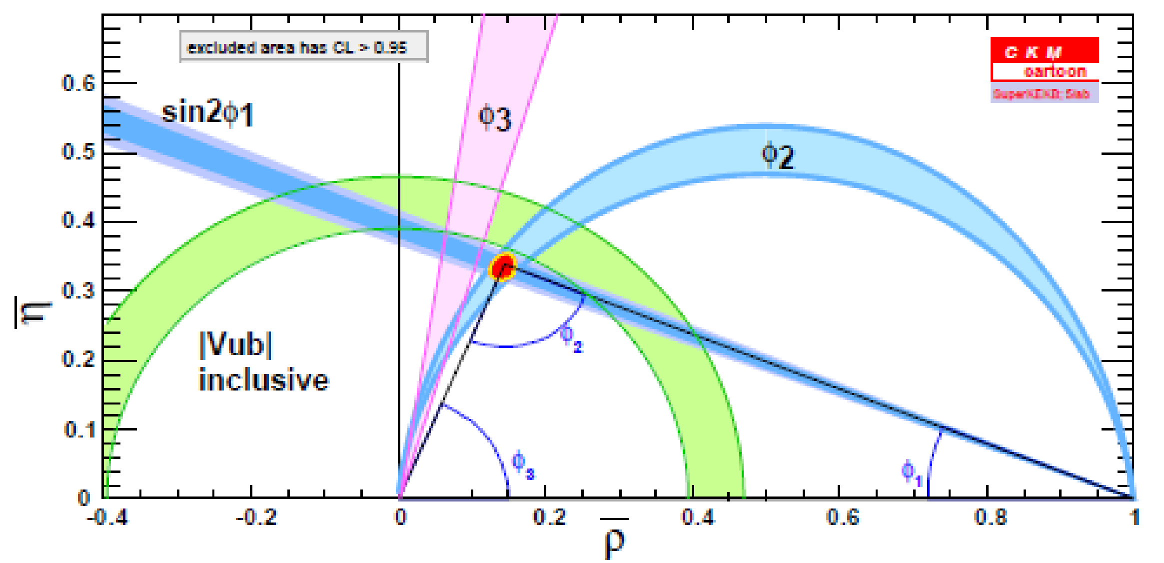


$B \rightarrow K^{(*)}l^+l^-$ FB asymmetry

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

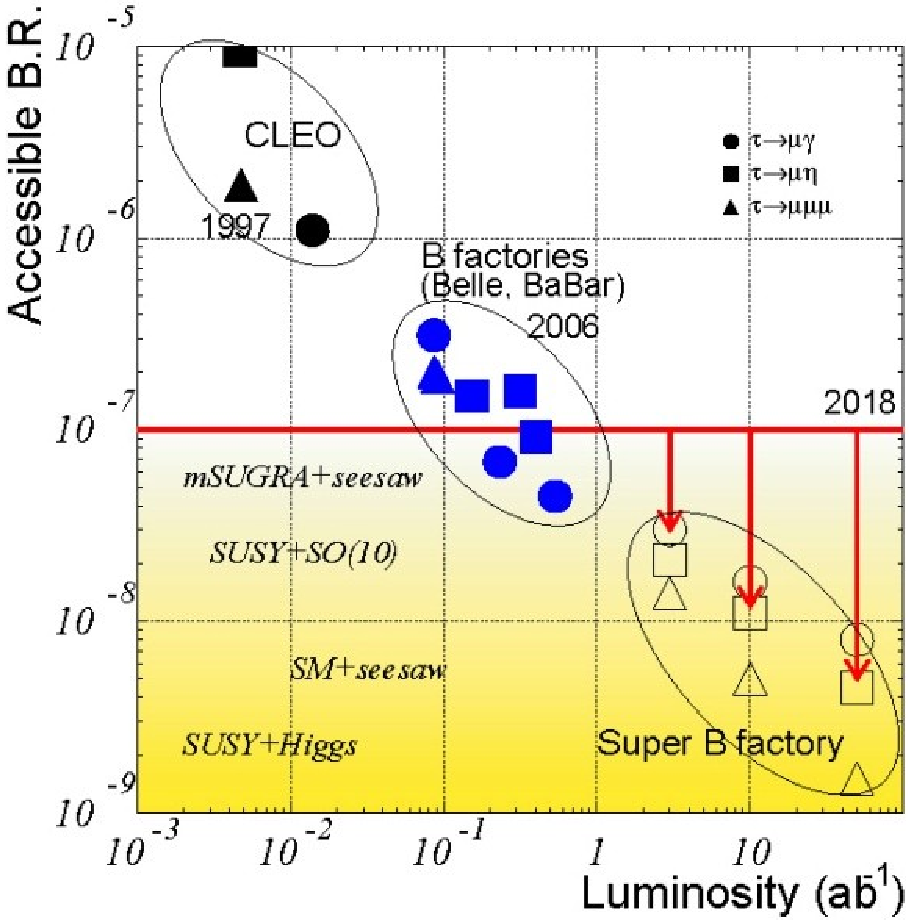
Precision angle measurements

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



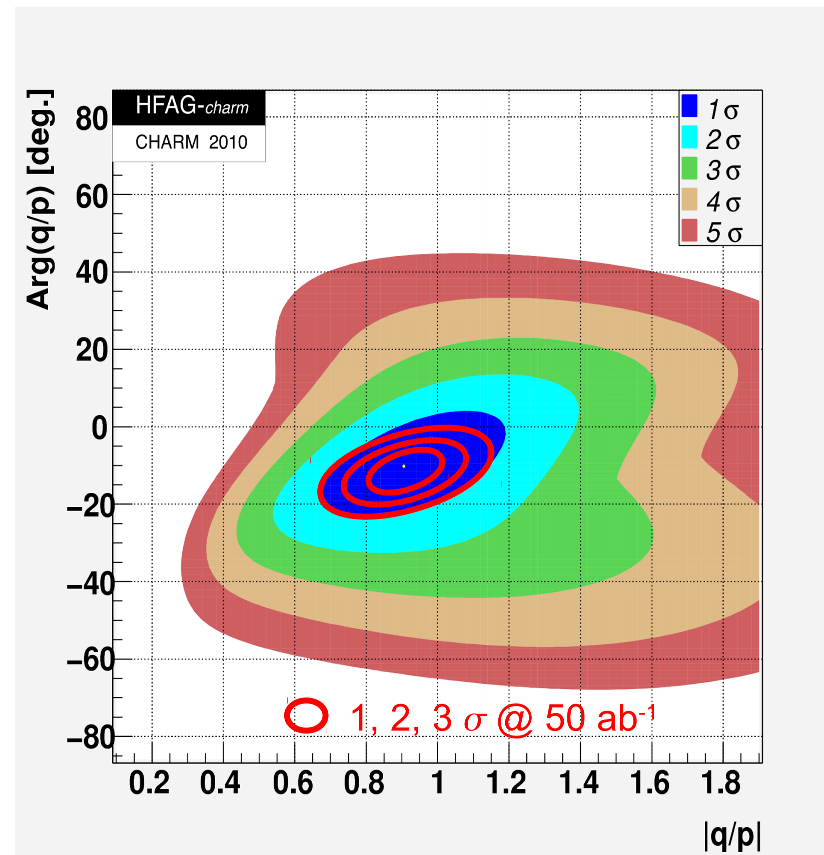
Even More Places to Look for New Physics

Lepton flavor violation



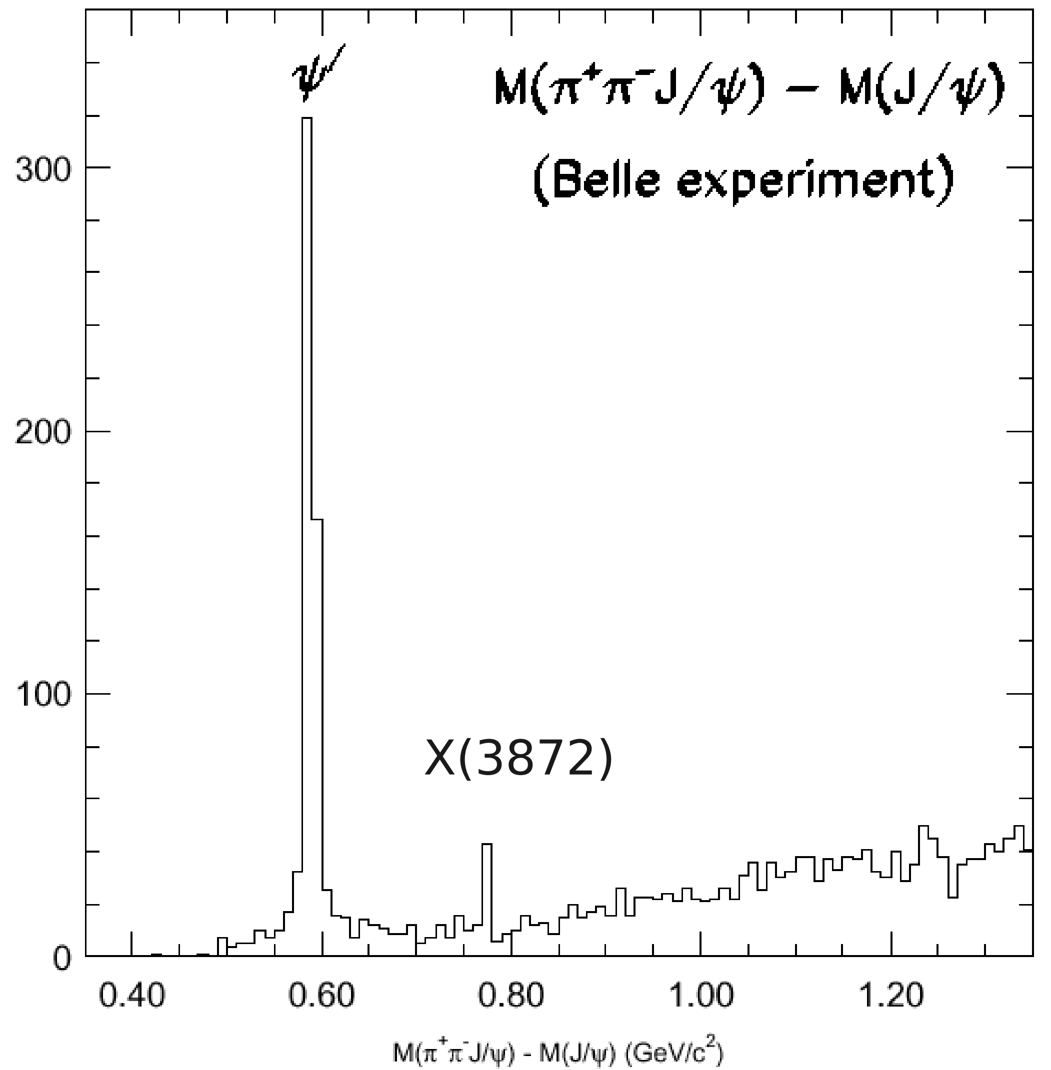
B(τ → μγ) 90% CL upper limit [10^{-9}]:
45 (~0.5 ab^{-1}) → 5 (50 ab^{-1})

CP violation in D^0 mixing



Precision of |q/p|:
0.16 (~0.5 ab^{-1}) → 0.05 (50 ab^{-1})

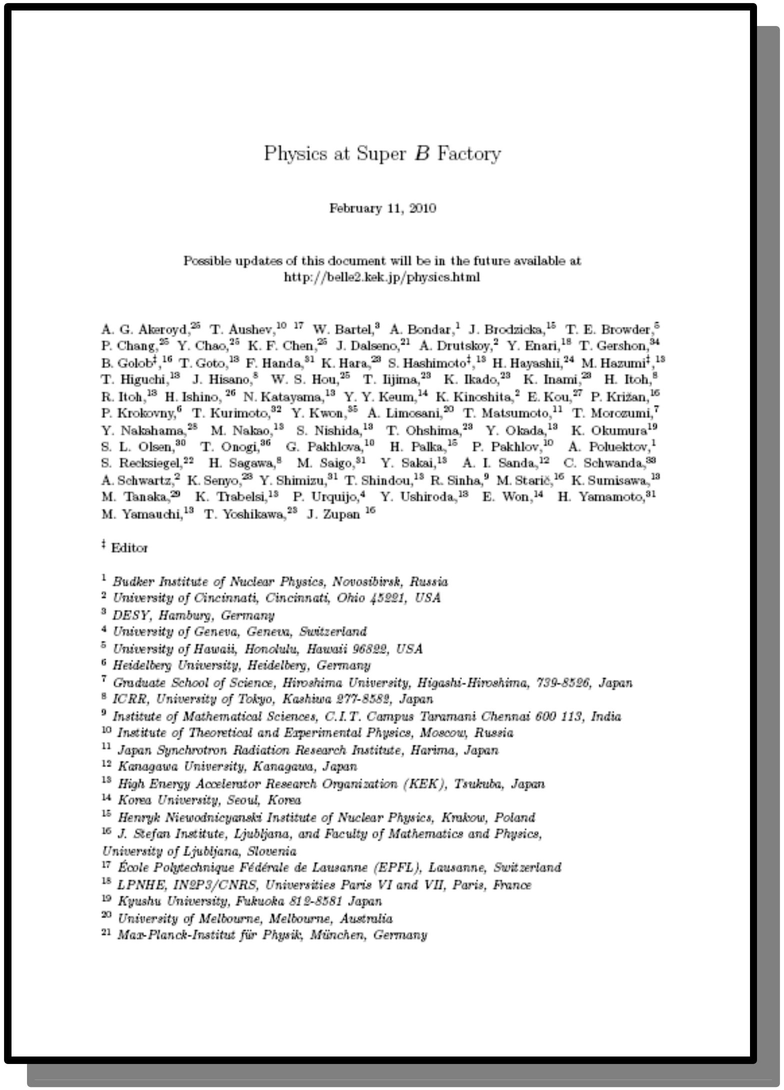
The Unexpected



Belle II experiment

?

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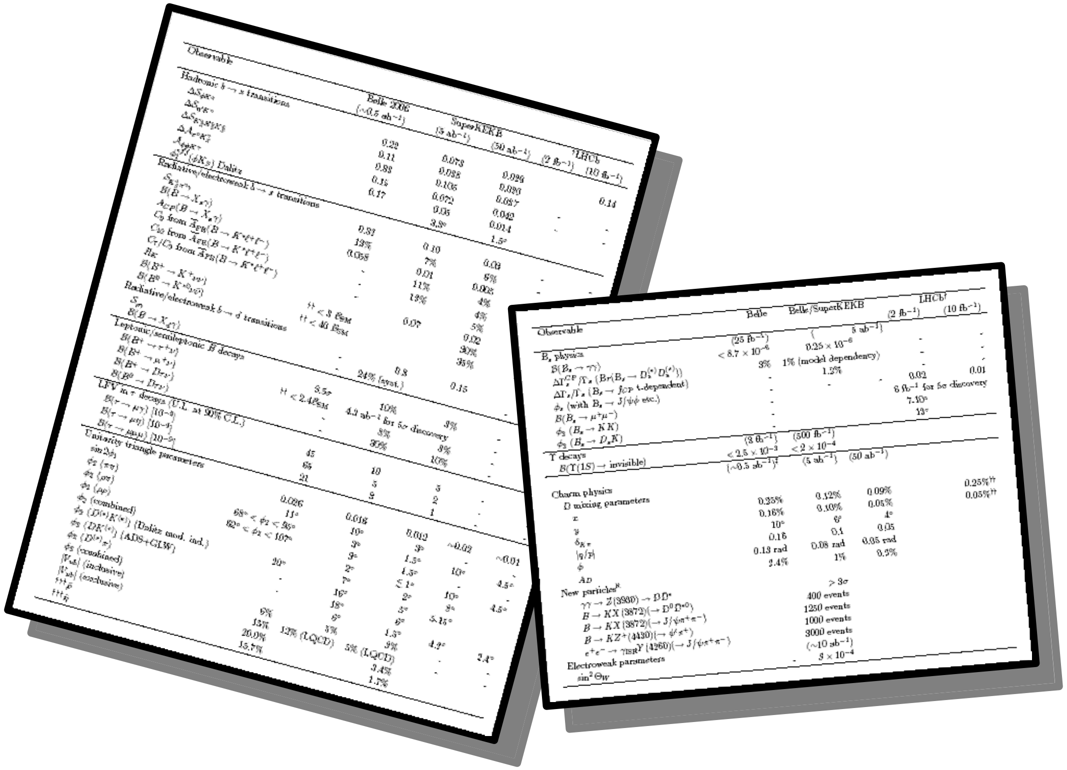
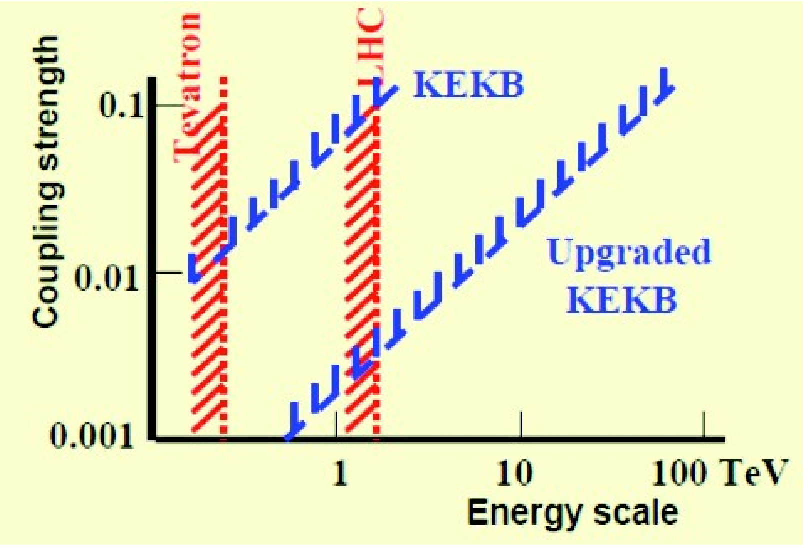
A. G. Akeroyd et al.
KEK-REPORT-2009-12, Feb 2010,
arXiv:1002.5012 [hep-ex]



Flavor Physics in the LHC Era



- Complementary to direct search for NP at LHC
- Partly complementary to LHCb physics program

➔ “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

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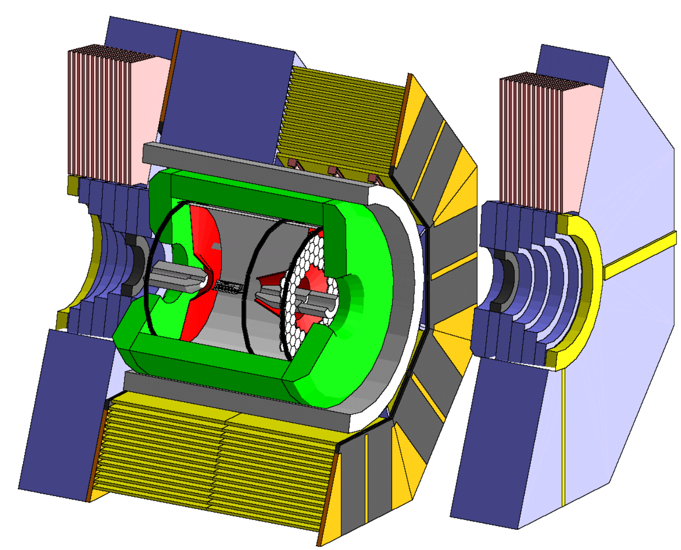
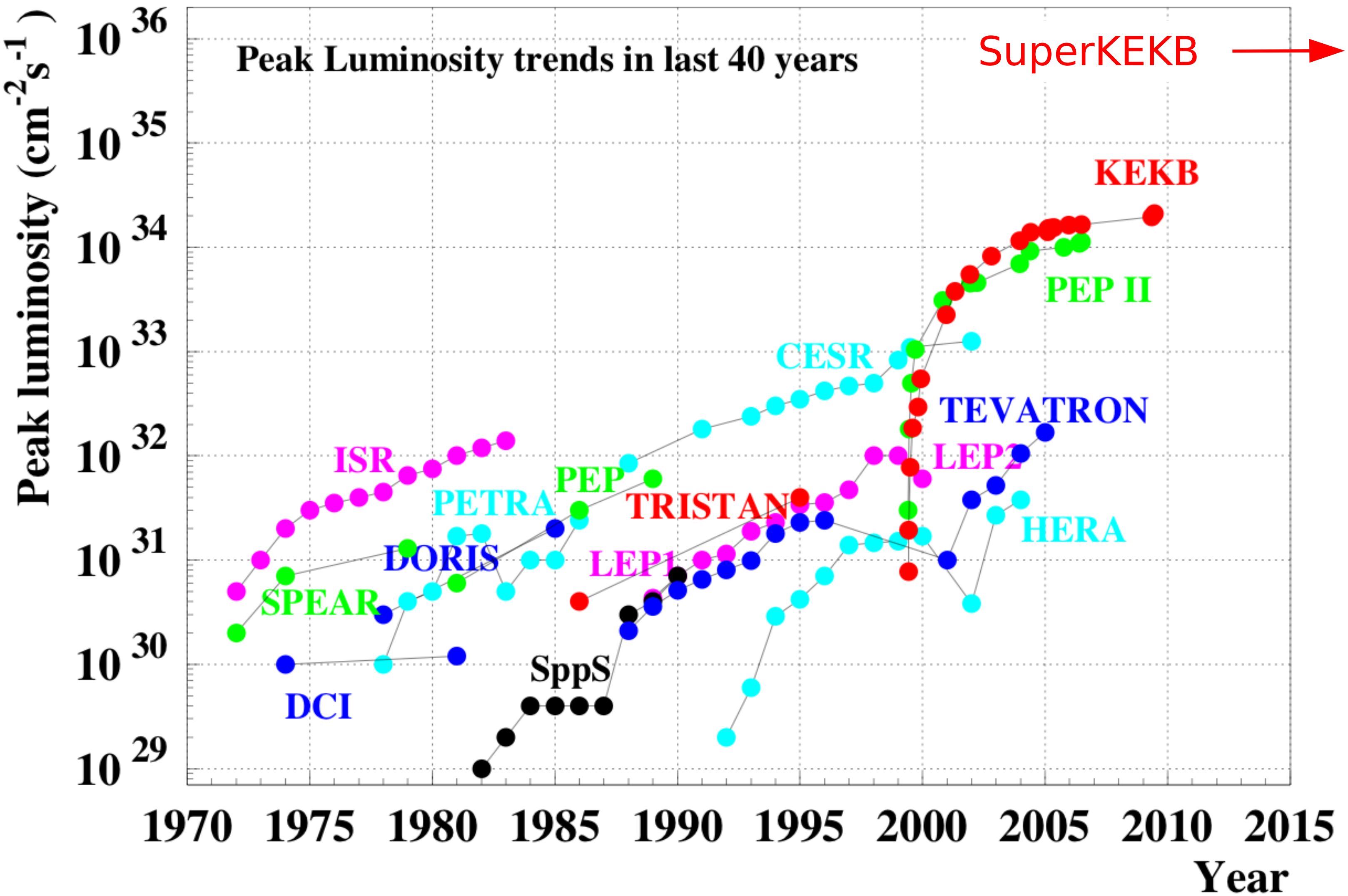


Aim For 50 ab^{-1}



SuperKEKB → 8 x 10^{35} cm^{-2} s^{-1}

Accelerator Design: Nano Beam Scheme

Lorentz factor

Beam current

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

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

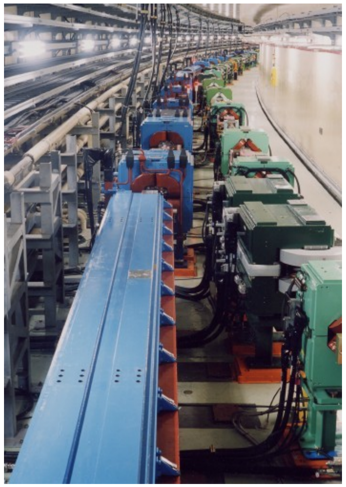
Geometrical reduction factors (crossing angle, hourglass effect)

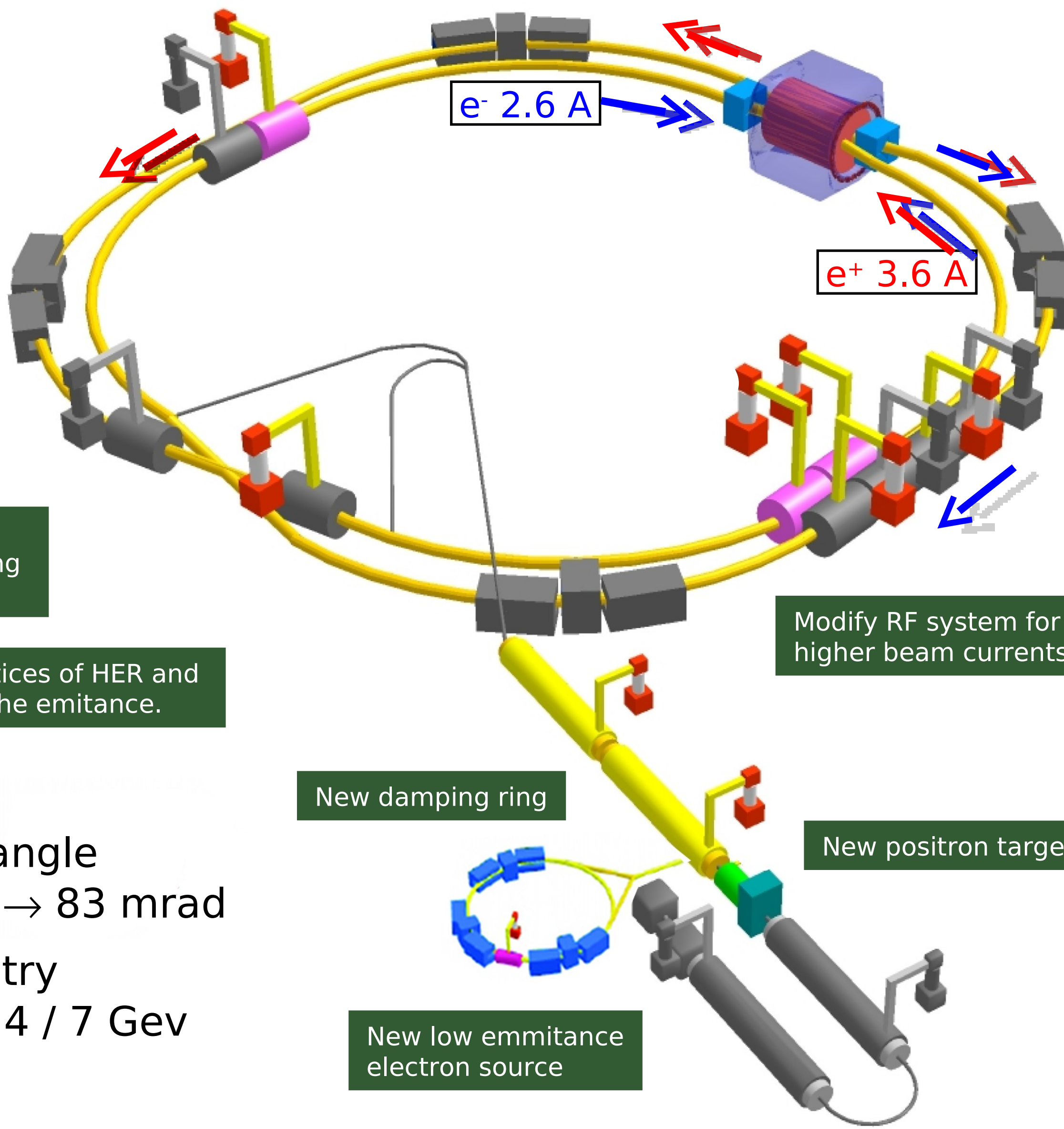
Beam aspect ratio at IP

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	0.27/0.30	0.09/0.08	3.2/4.3	3.6/2.6	**80×10^{34}**

SuperKEKB Upgrade





Belle II

New IR

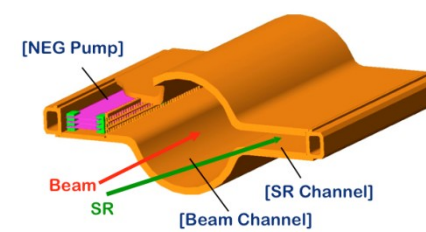
New Superconducting / permanent final focusing quads near the IP

Replace short dipoles with long ones in LER

Redesign the lattices of HER and LER to squeeze the emitance.

Modify RF system for higher beam currents

TiN coated beam pipe with antechambers



New damping ring

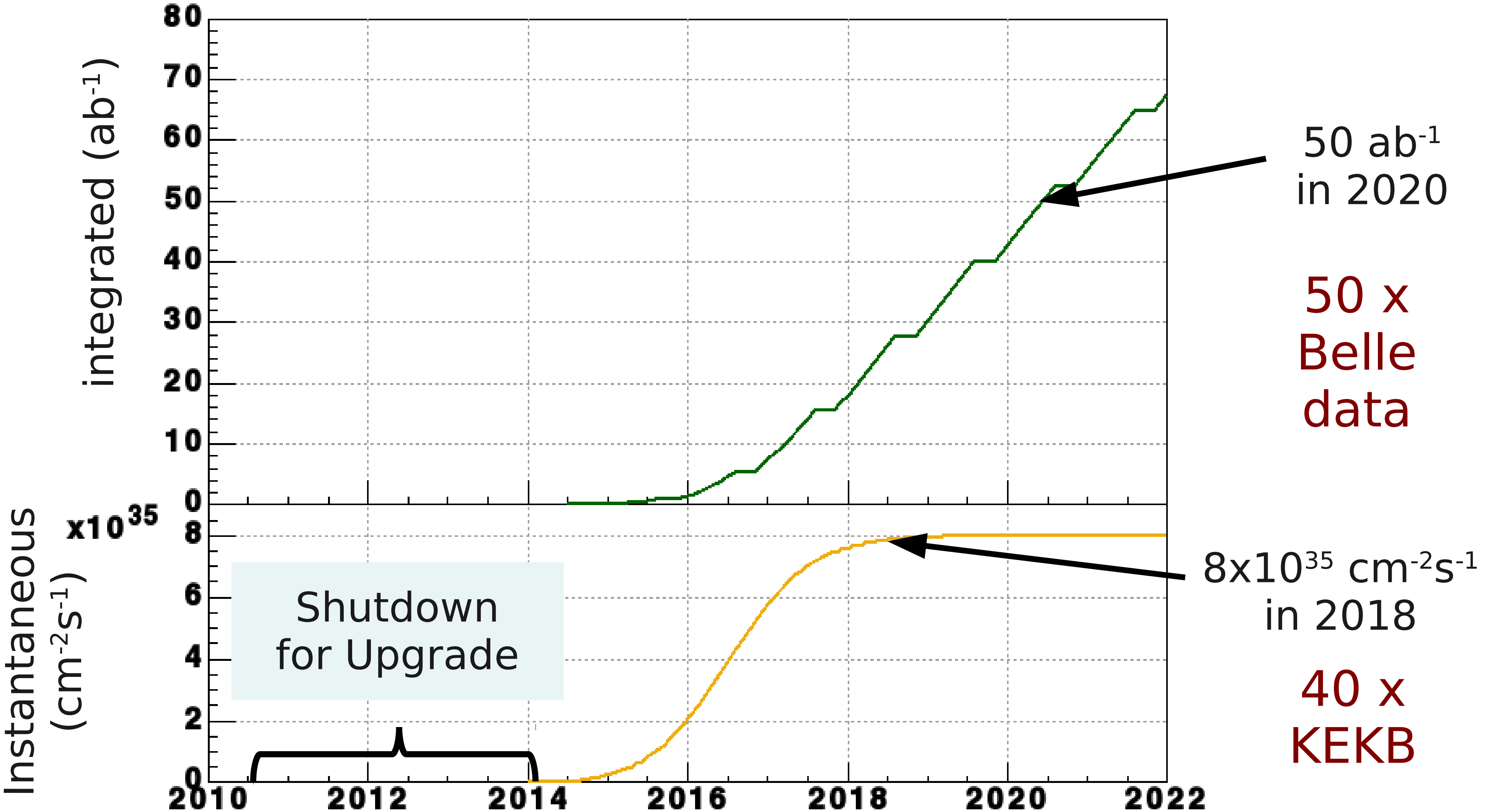
New positron target

New low emmitance electron source

Larger crossing angle
$2\phi = 22 \text{ mrad} \rightarrow 83 \text{ mrad}$

Smaller asymmetry
$3.5 / 8 \text{ GeV} \rightarrow 4 / 7 \text{ Gev}$

Projection of Luminosity



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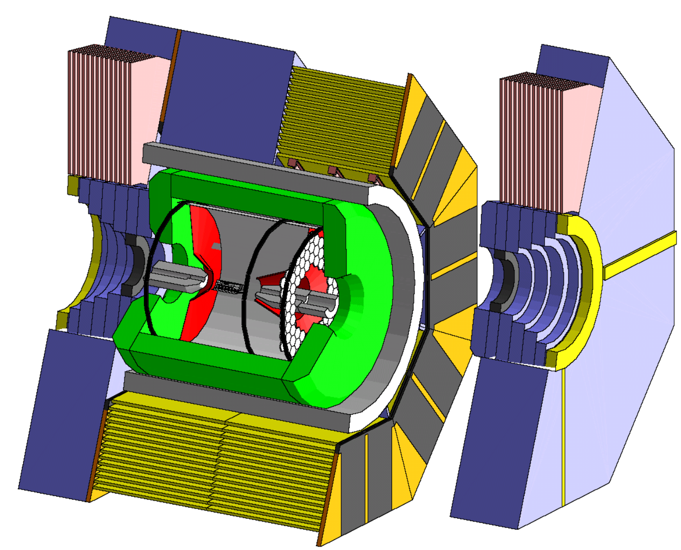
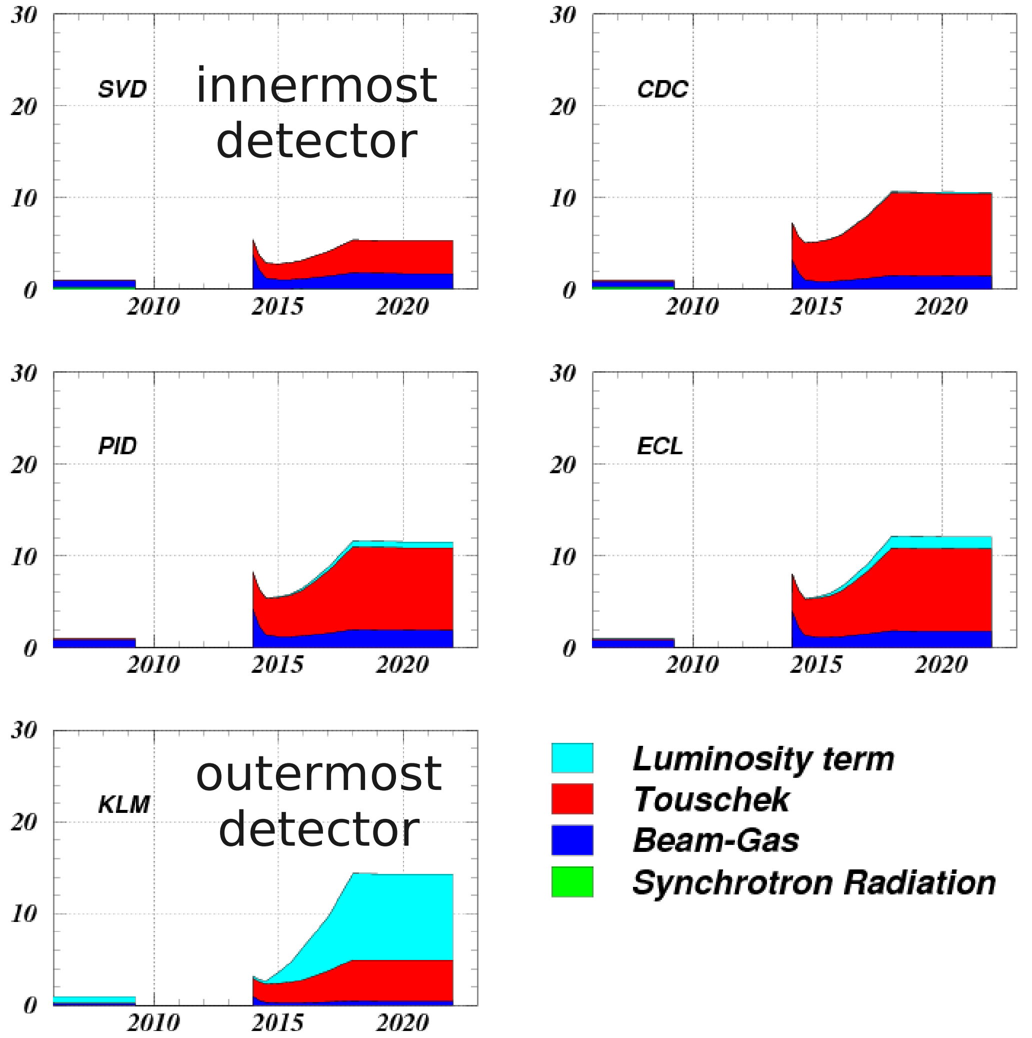


Background Estimates

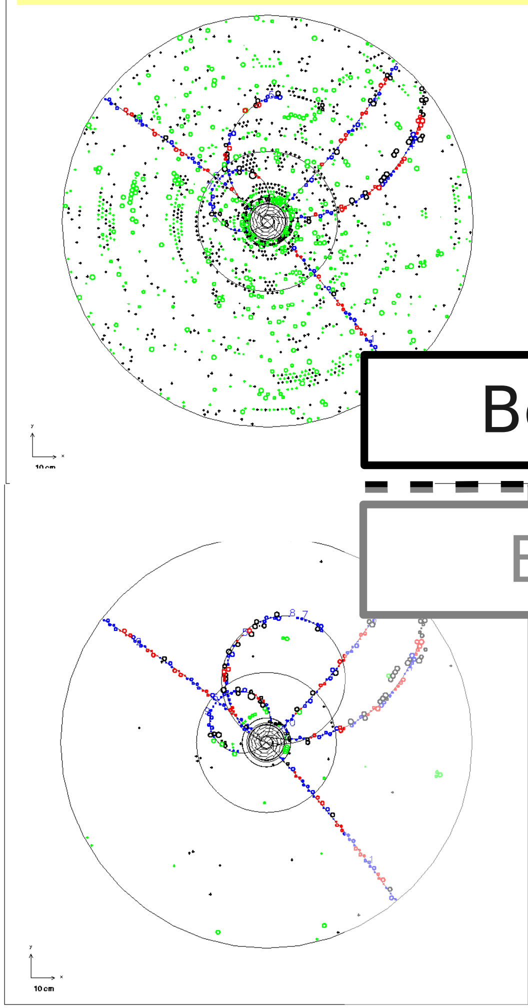


Projected background level in units of background level in the Belle detector

Belle II detector has to provide equal or even better performance despite 10-20 times higher background

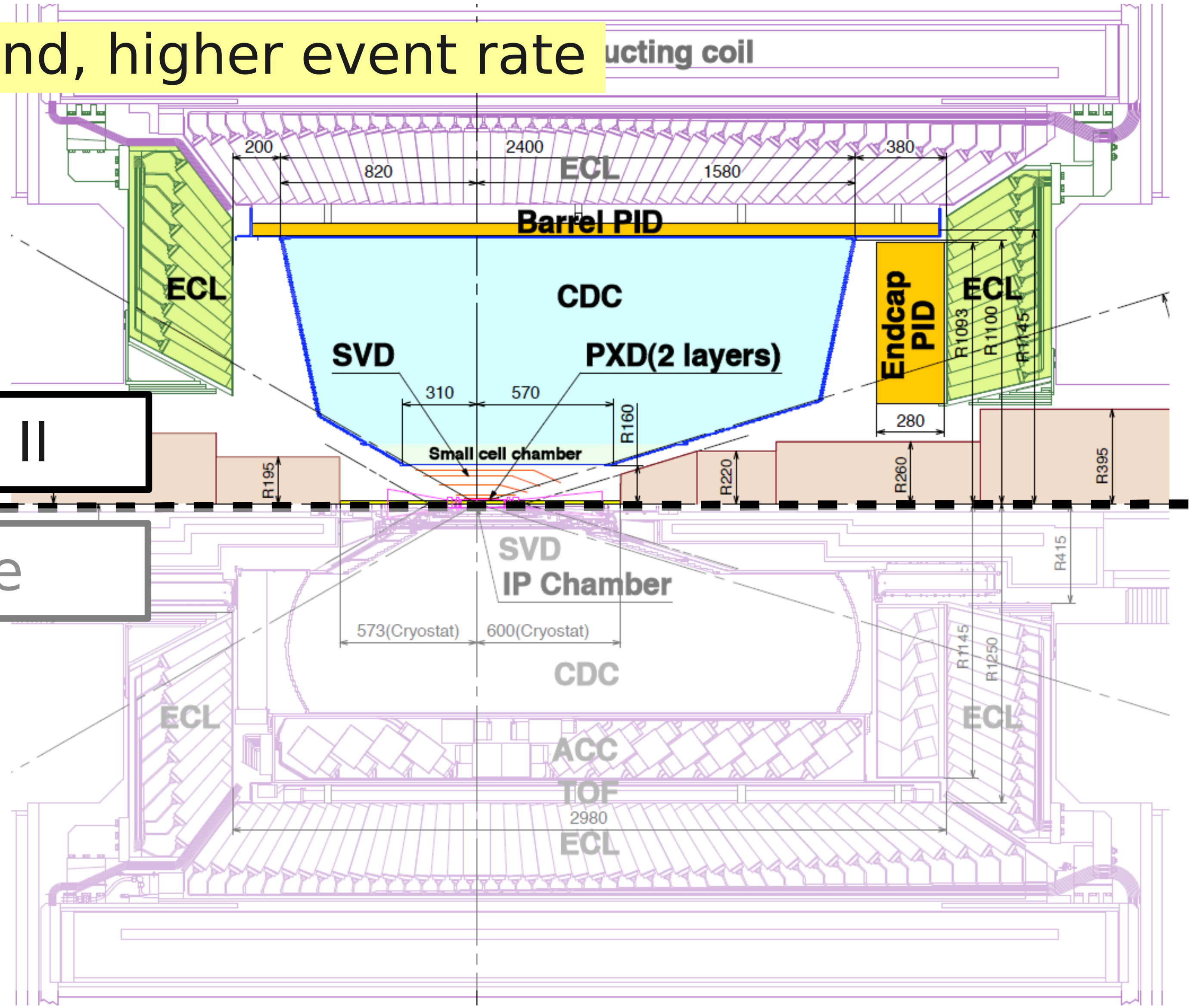
Belle II Detector

- ➔ Higher background, higher event rate



Belle II

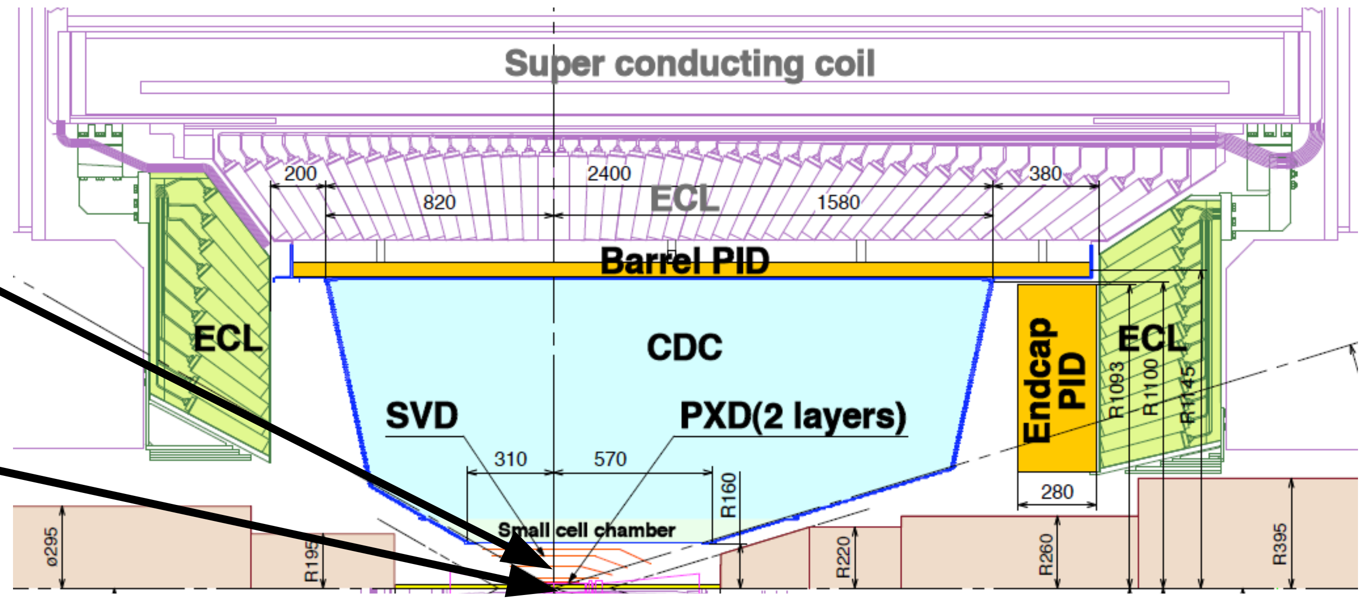
Belle

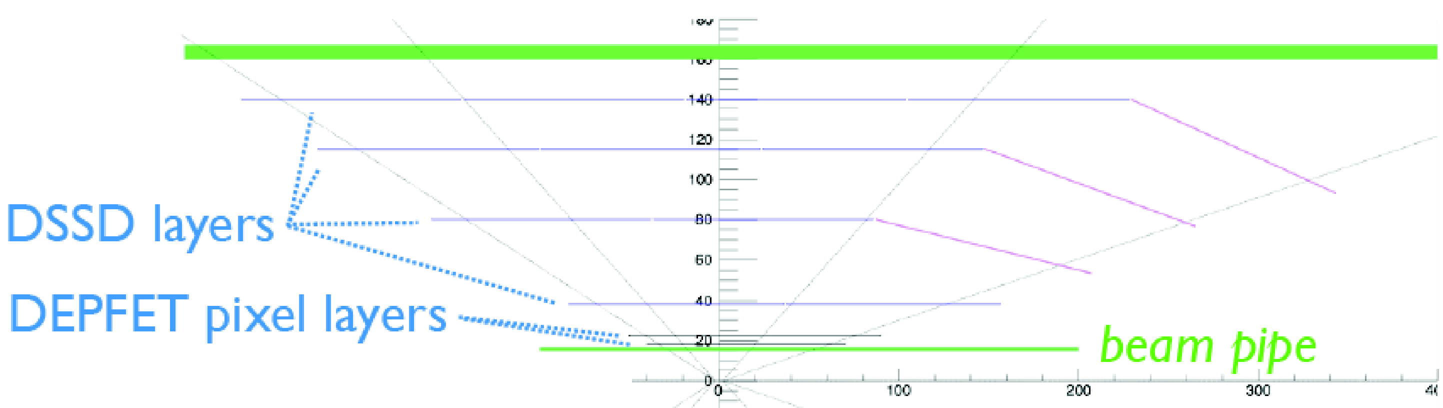


Vertex Detectors

4 layer silicon strip detector

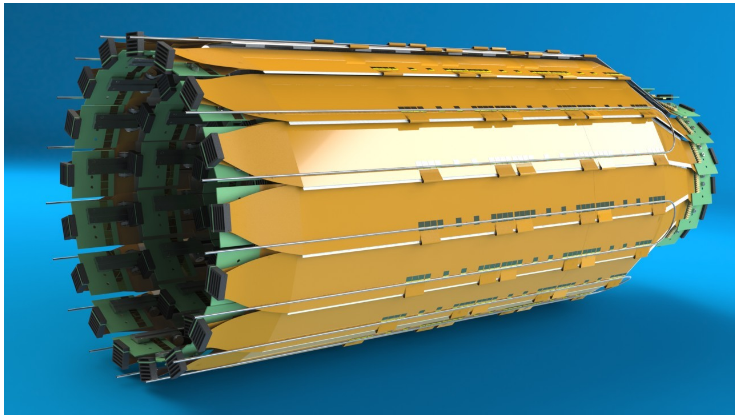
2 layer DEPFET pixel detector

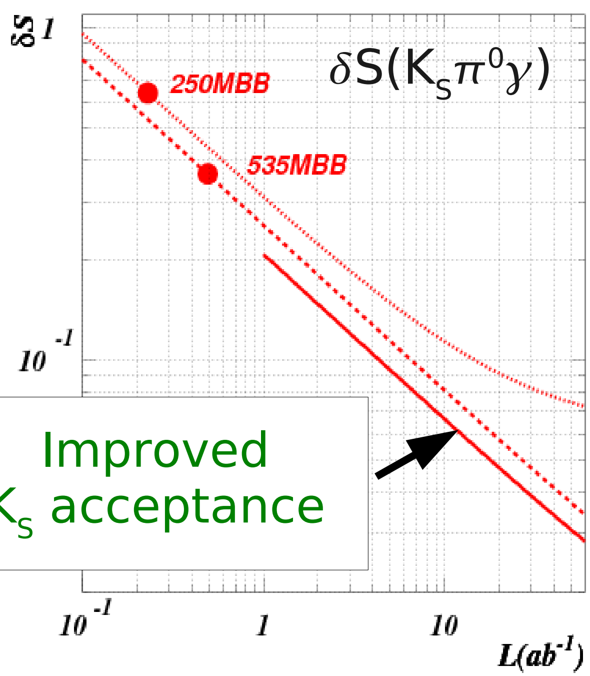




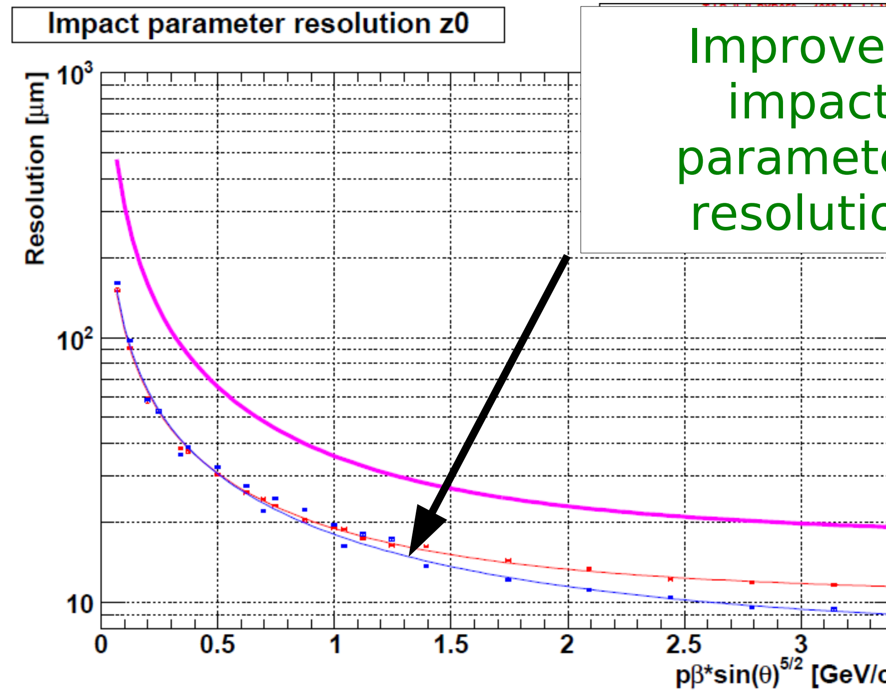
- ➔ Improved vertex resolution
- • Larger radius
- ➔ Better K_S efficiency

Vertex Detectors





Improved K_S acceptance



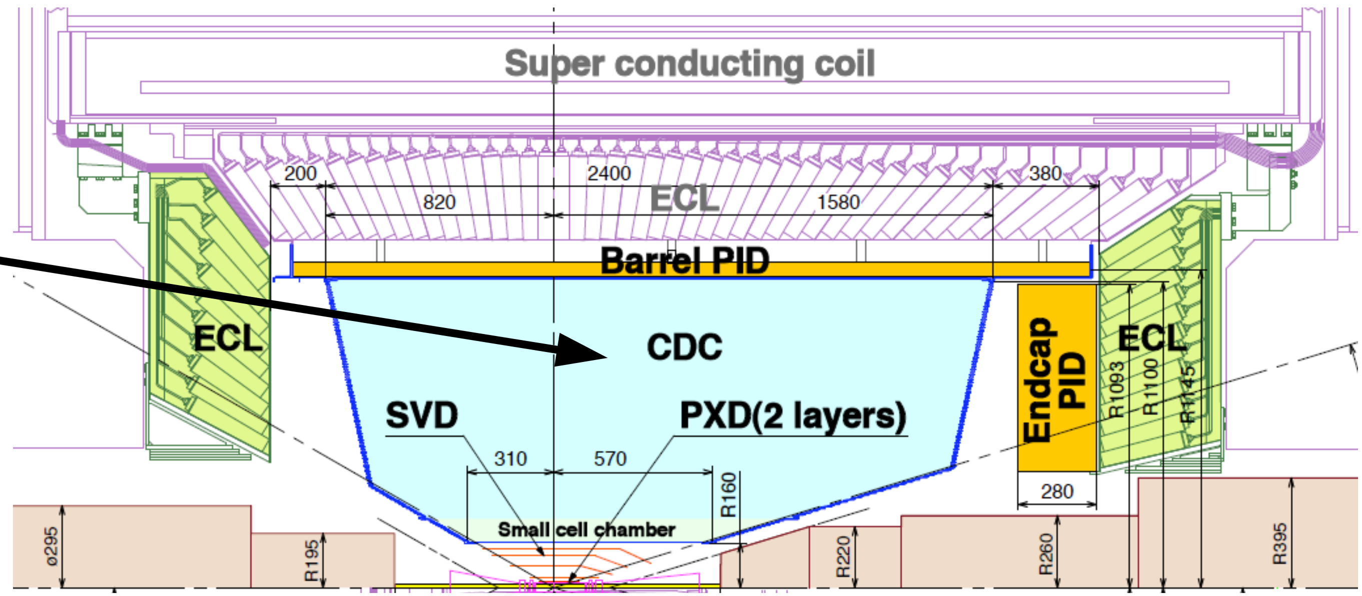
Improved impact parameter resolution

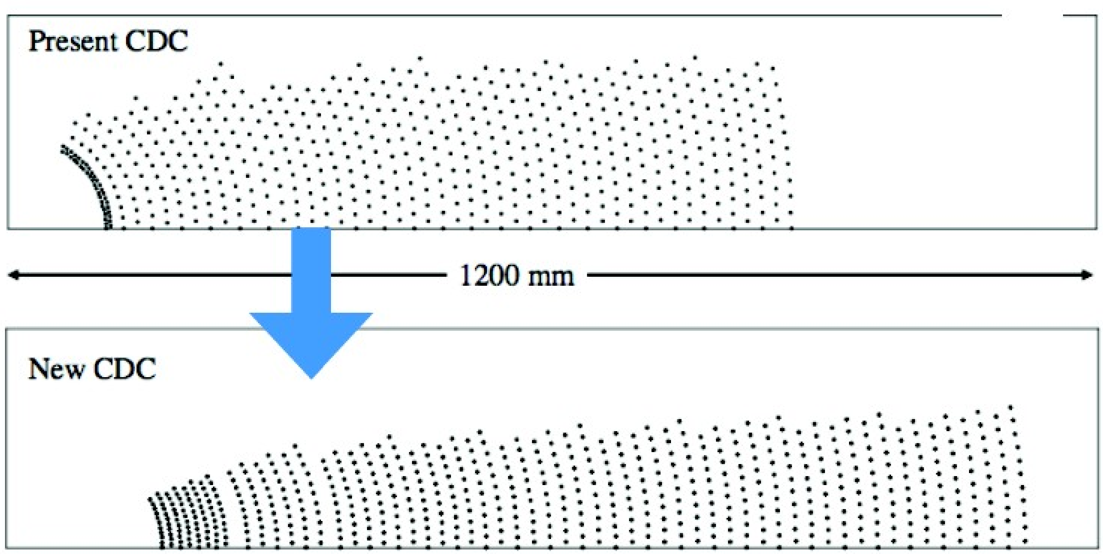
Belle

Belle II

Drift Chamber

Drift Chamber





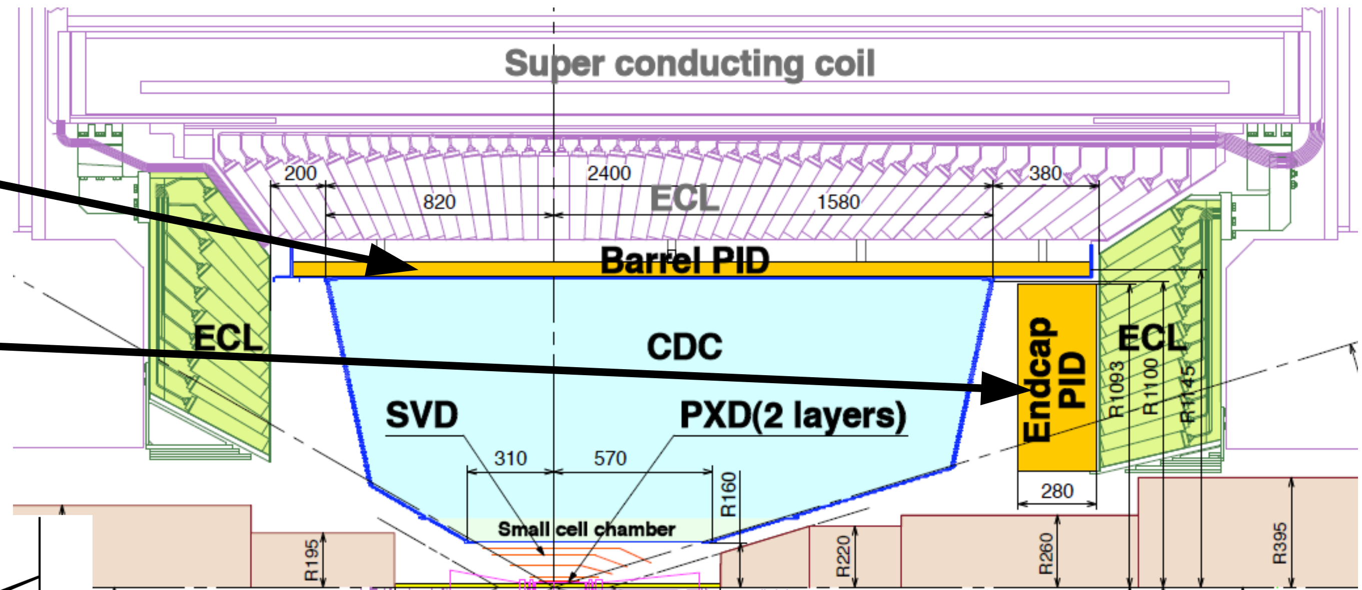
- Smaller cells
- Larger radius

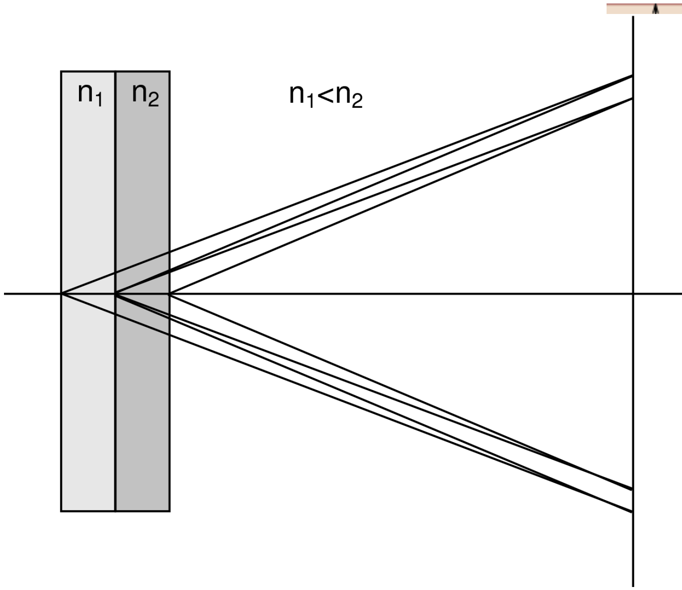
→ Better momentum resolution

Particle Identification

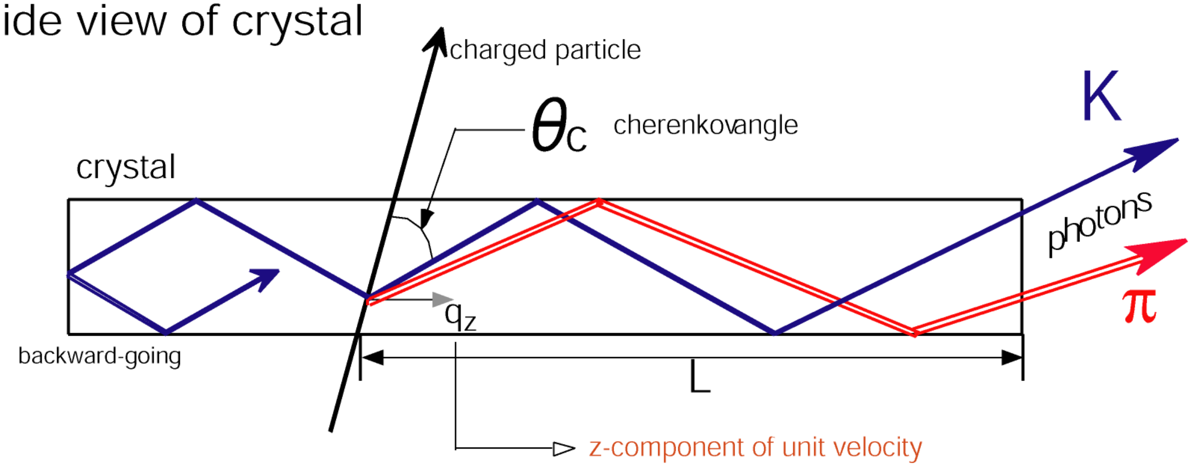
Time of propagation

“Focusing” RICH





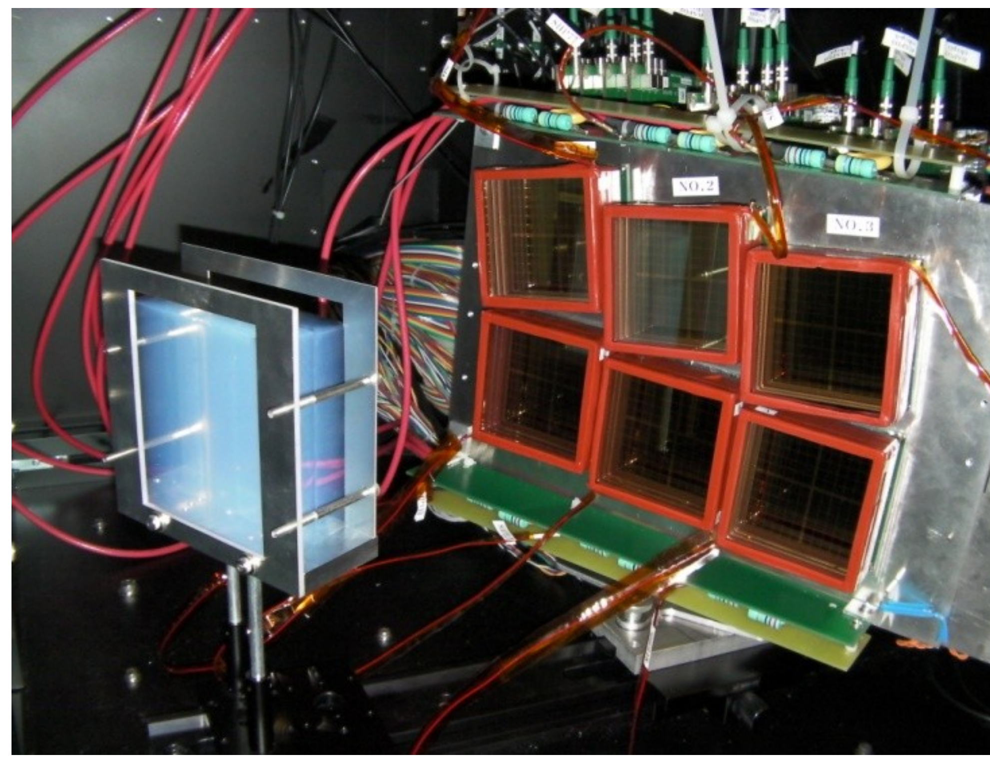
Side view of crystal



→ Improved particle identification

Particle Identification

Endcap PID (ARICH):
96% kaon efficiency
at 1% pion fake prob.
at 4 GeV

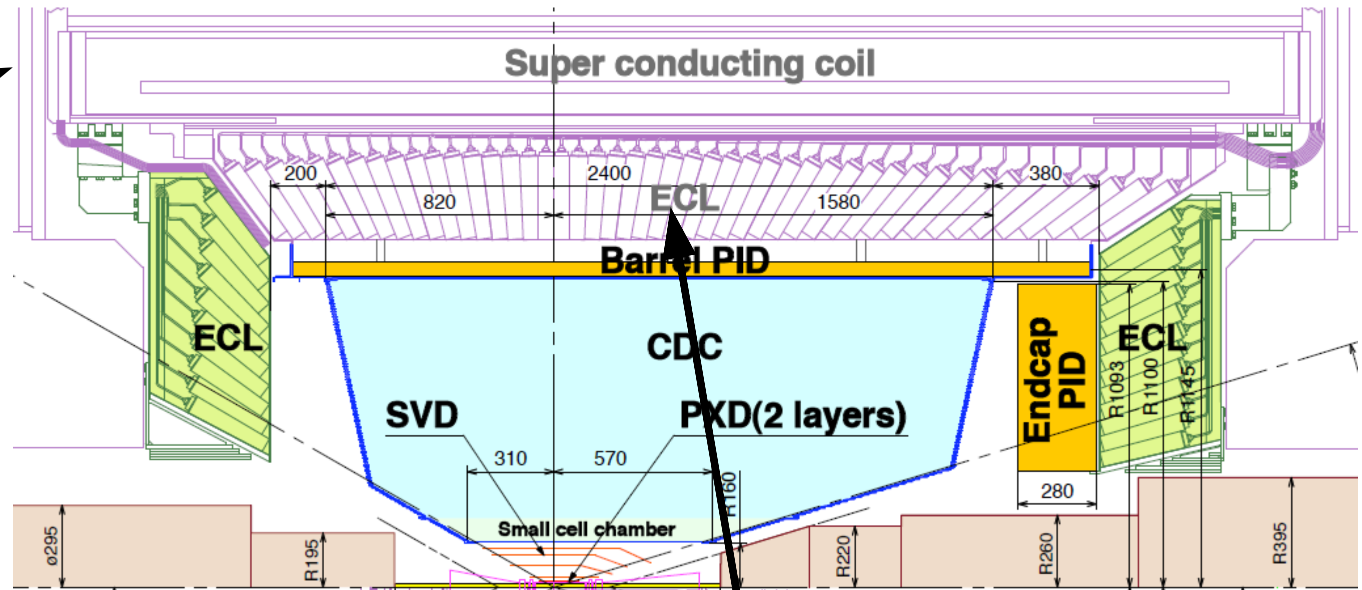


Barrel PID (TOP):
>99% kaon efficiency
at <0.5% pion fake prob.
for B → $\rho\gamma$

Calorimeter, K_L and Muon Detection

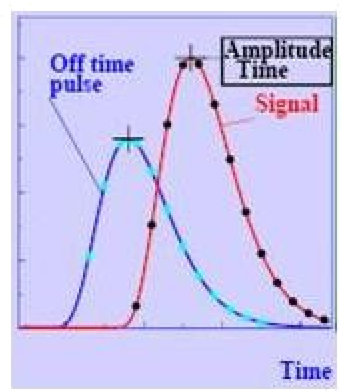
K_L and μ Detector

- Scintillators in end-caps
- ➔ Improved beam background tolerance

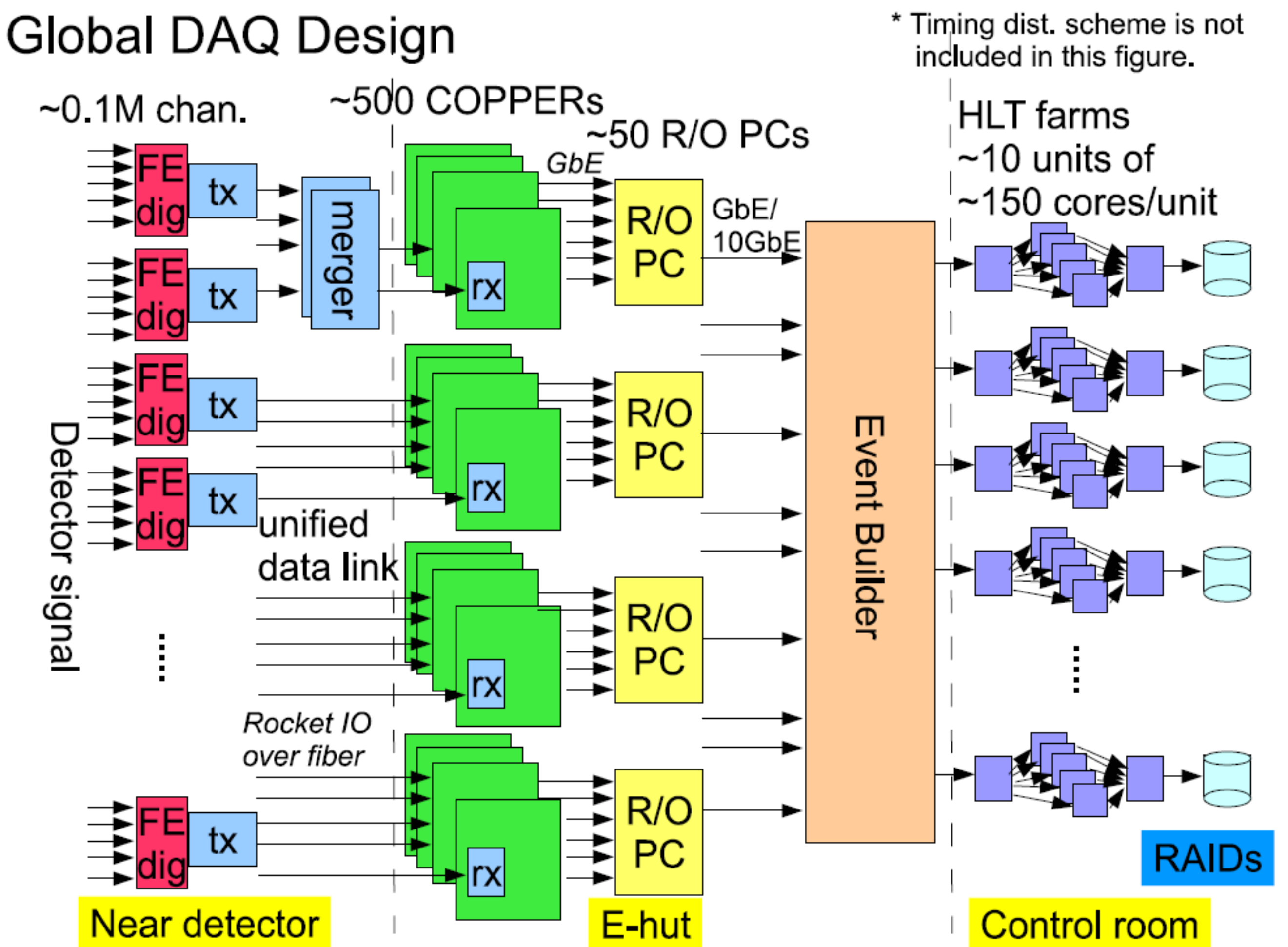


Electromagnetic Calorimeter

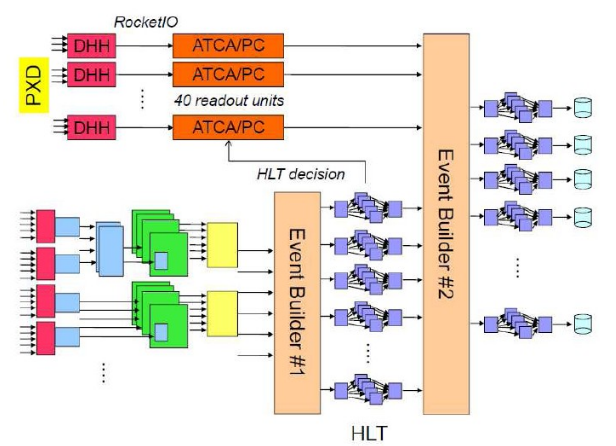
- Wave form sampling
- ➔ Better signal to background separation



Data Acquisition / High Level Trigger



- Designed for input rate of 30 kHz
- One challenge: PXD event data reduction
  1 MB → ~200 kB
  (all other Belle II detectors together ~100 kB)



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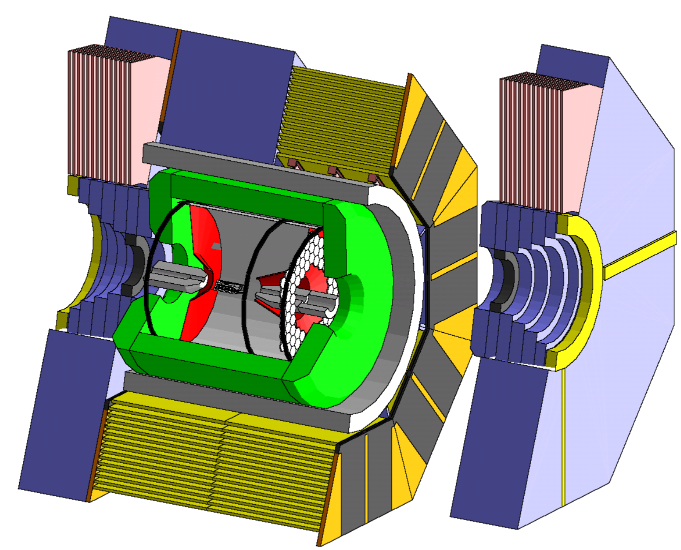
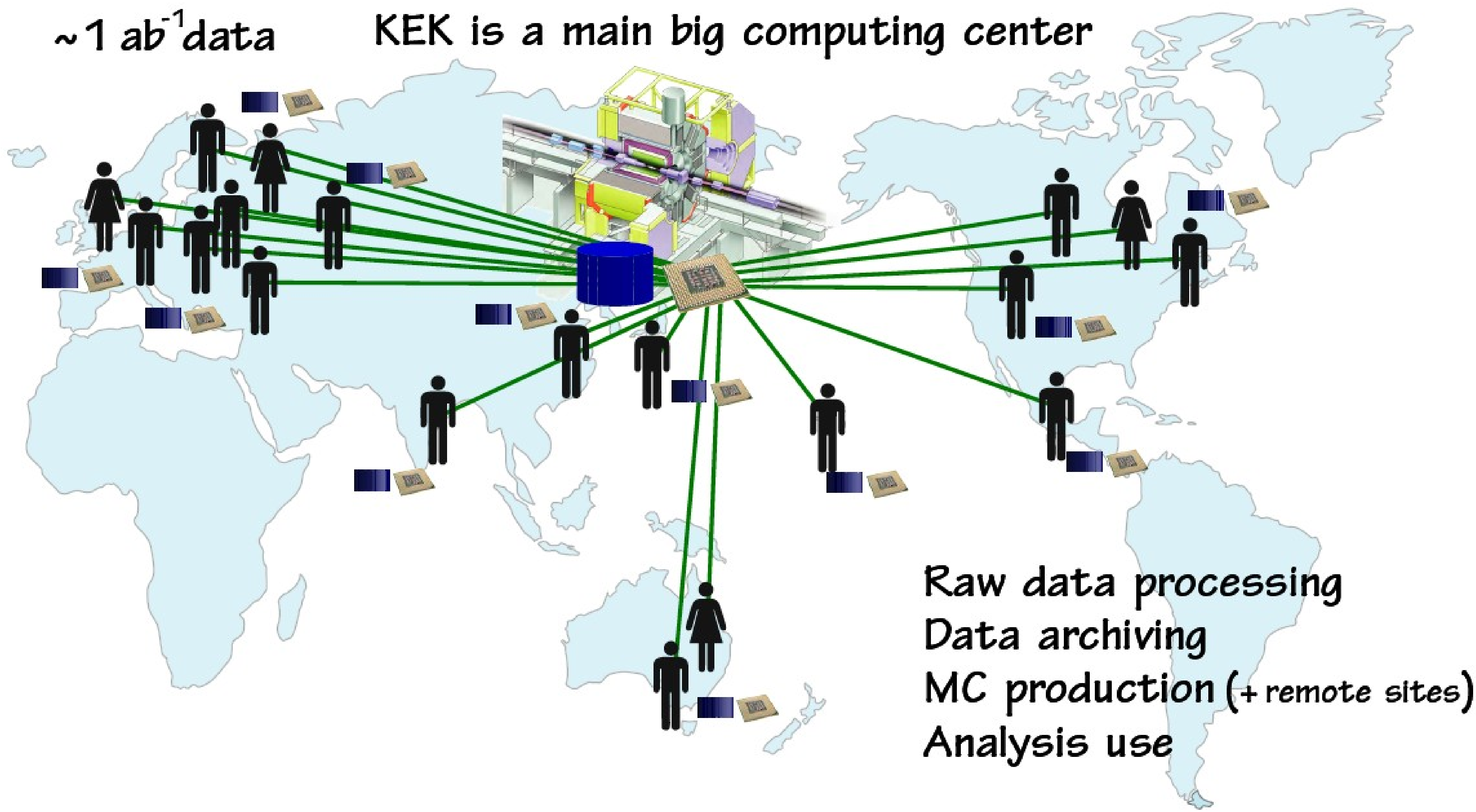


Estimated Data Rates

Experiment	Event Size [kB]	Rate [Hz]	Rate [MB/s]
High rate scenario for Belle II DAQ:			
Belle II	300	6,000	1,800
LCG TDR (2005):			
ALICE (HI)	12,500	100	1,250
ALICE (pp)	1,000	100	100
ATLAS	1,600	200	320
CMS	1,500	150	225
LHCb	25	2,000	50

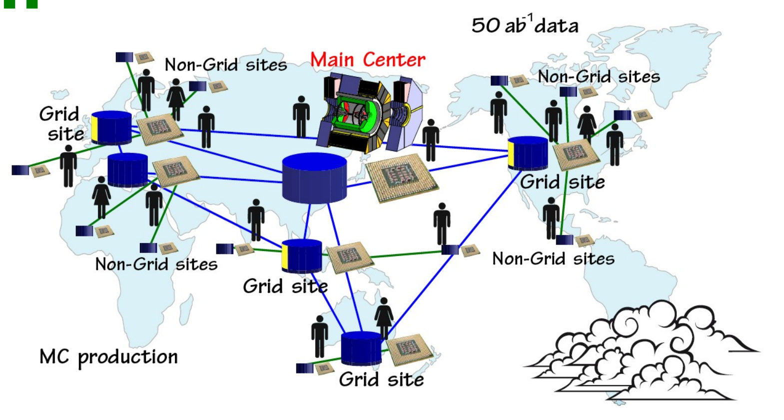
Belle Computing: Centralized at KEK



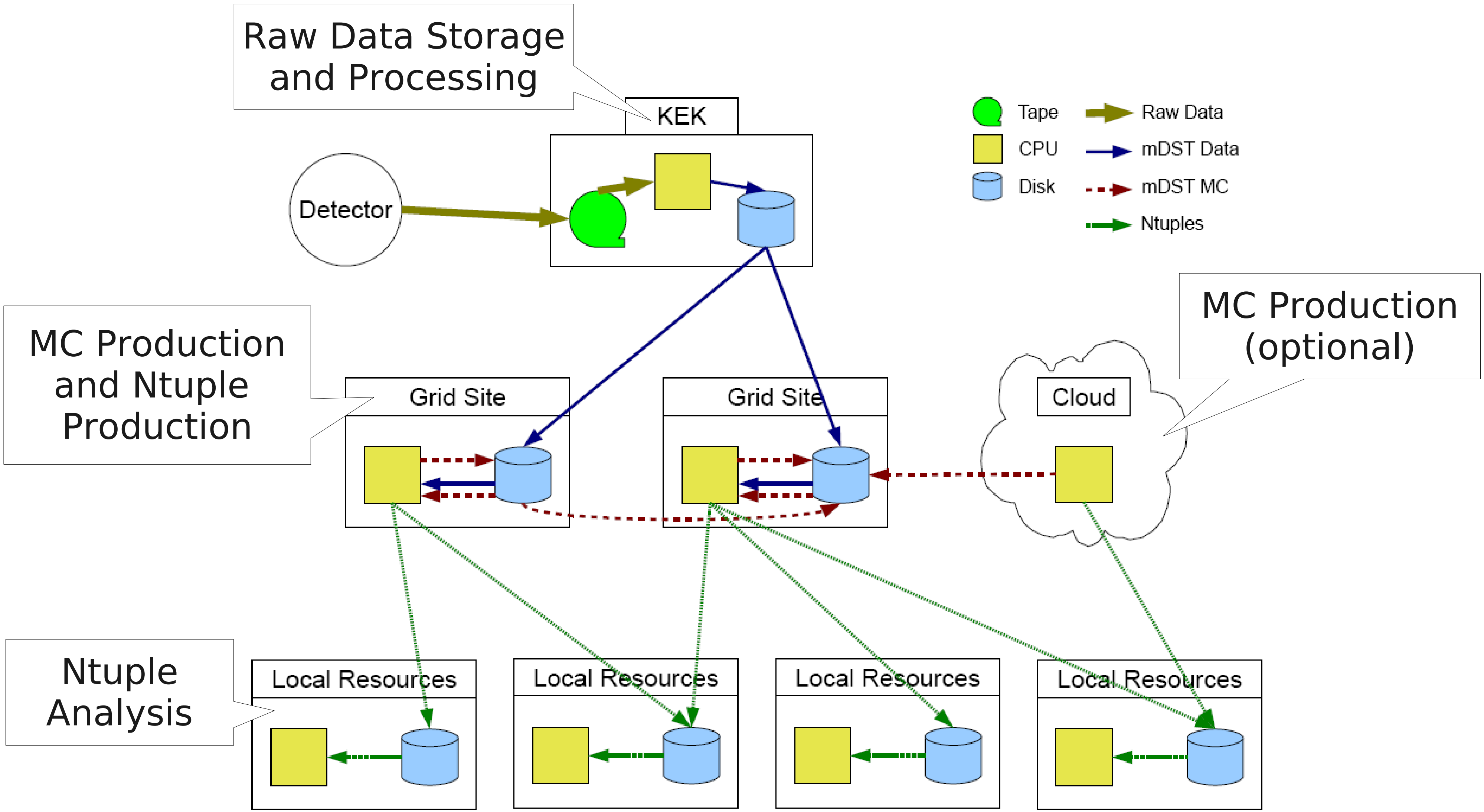
Considerations for Belle II Computing

- 50 times more data in ~10 years
  - ➔ O(50) times more computing resources

- Can not expect KEK to provide all resources
- *Have to enable all Belle II member institutes to contribute*
  - ➔ **Distributed computing system** based on grid services (gLite)
  - ➢ Can benefit from existing LCG infrastructure
  - ➢ Profit from experience of LHC experiments and their well-established and matured solutions



Belle II Computing Model

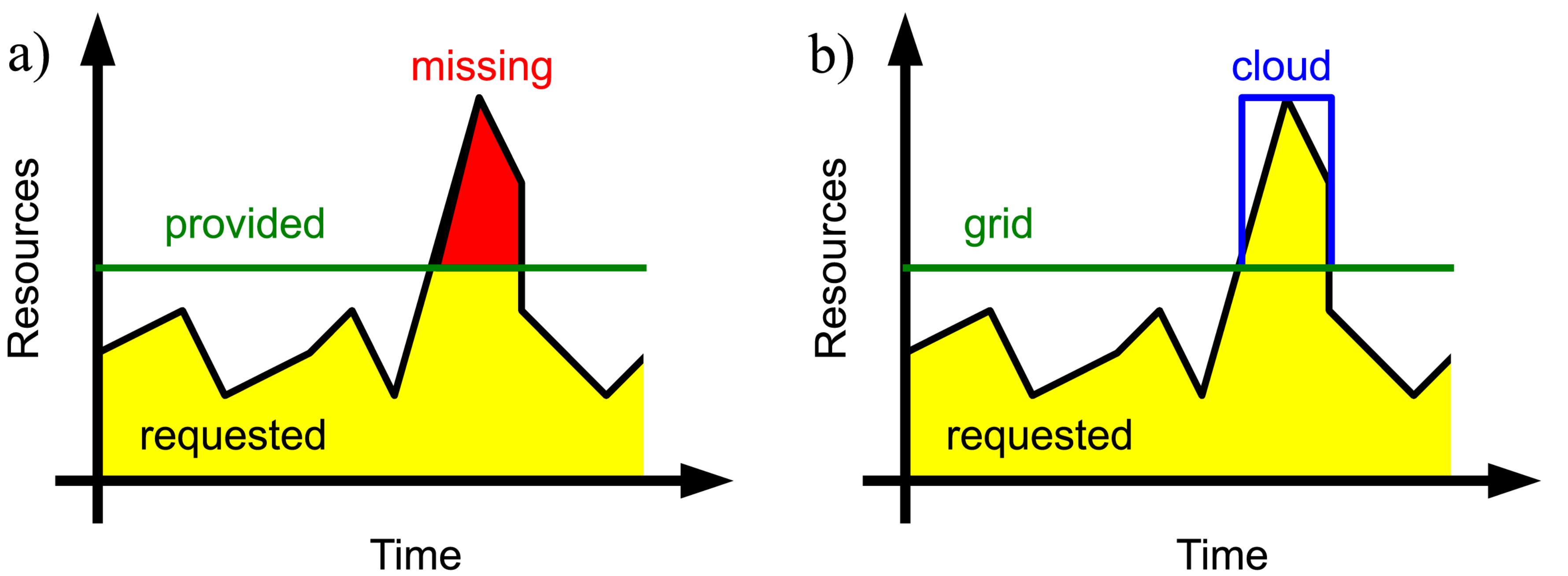


Cloud Computing

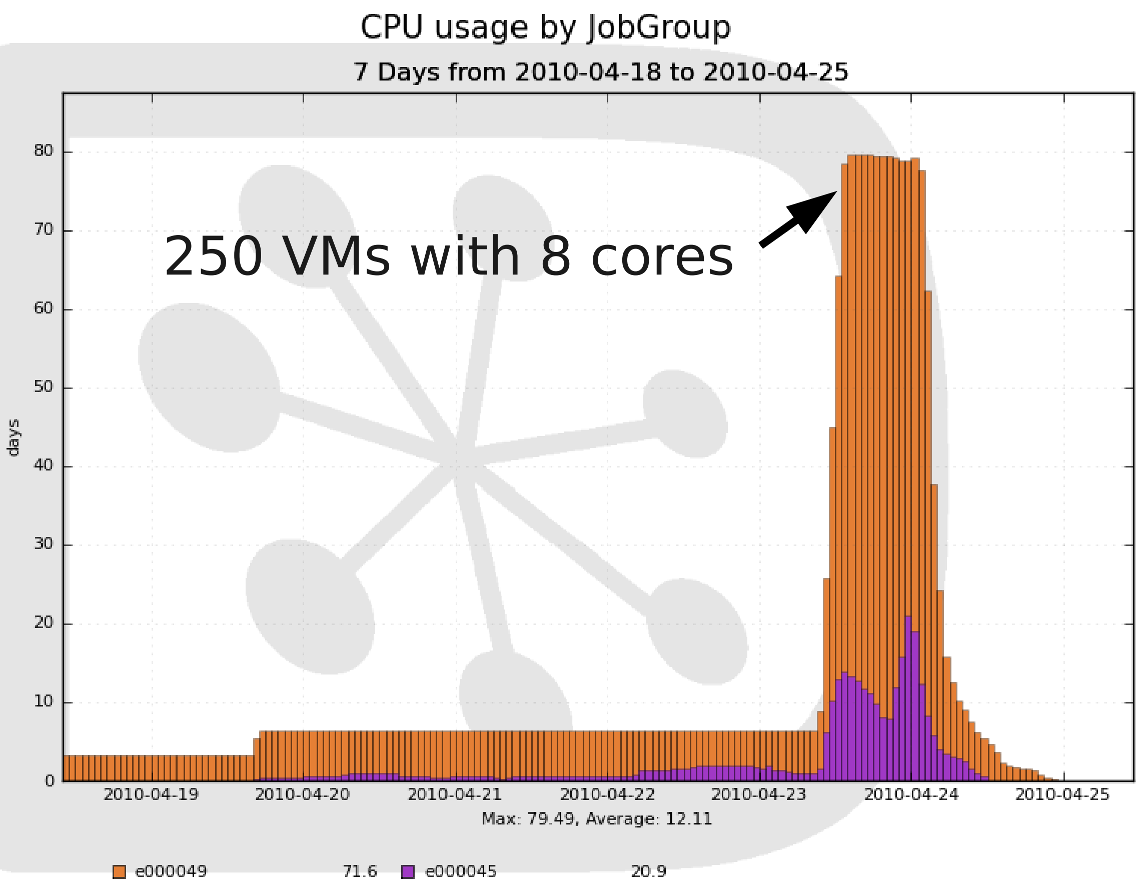
- Resource demands vary with time
- Fair-share can solve this issue only to some extent

➔ Cloud computing allows to buy resources on demand

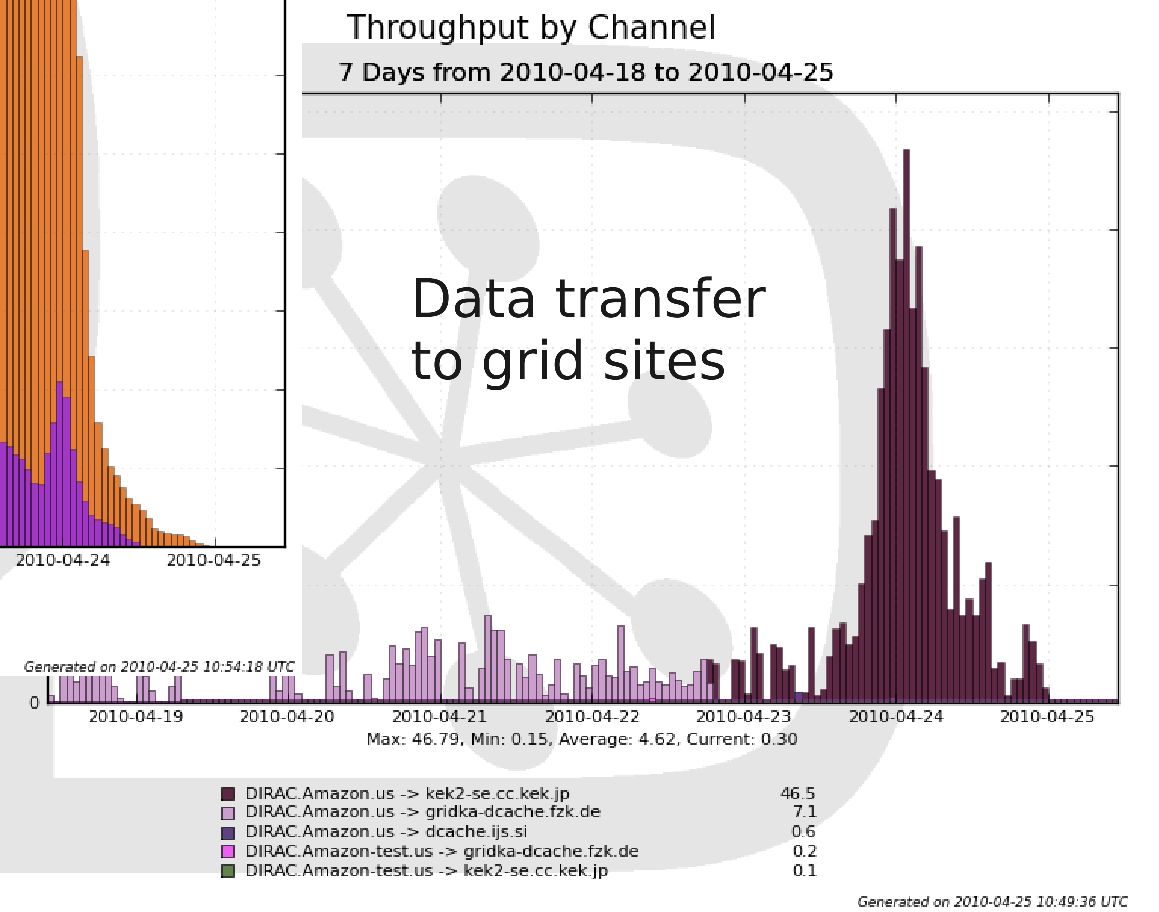
  - Well suited to absorb peaks in varying resource demand



Belle MC Production on the Cloud



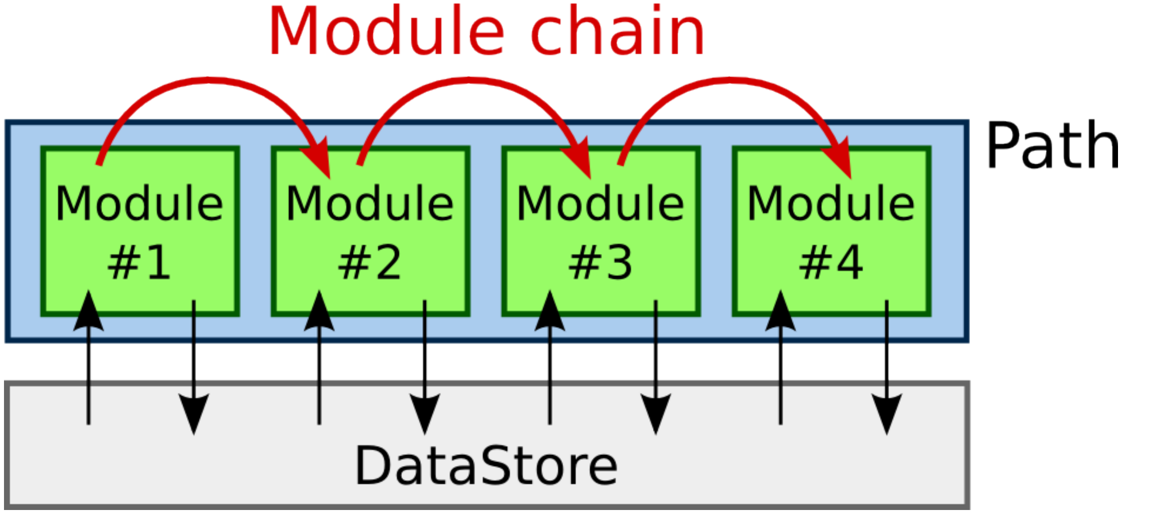
- 170M events (3.6 TB) produced in 6 days



- Amazon Spot Instances
  → 0.20 USD / 10k events

Framework

- Inspired by frameworks of Belle (basf) + other experiments
- ✔ Used for simulation, reconstruction, analysis, and DAQ
- ✔ ROOT I/O as data format
- ✔ Software bus with dynamically loaded modules
- ✔ Python steering
- ✔ Parallel processing



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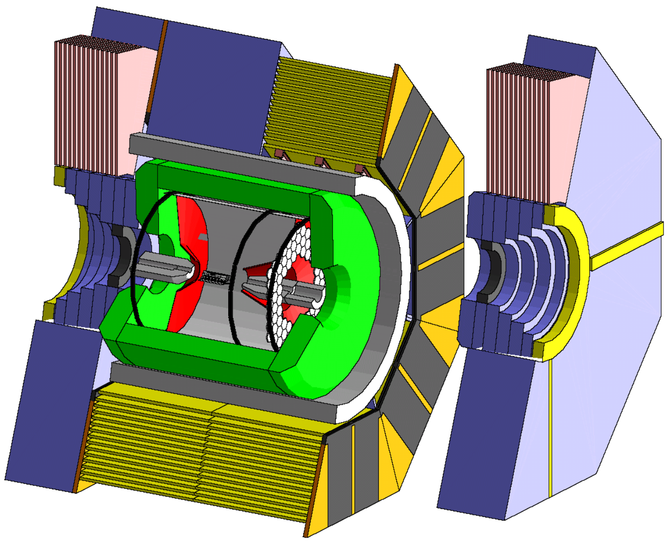


Technical Design Report

TDR published

T. Abe et al.
KEK-REPORT-2010-1, Oct 2010,
arXiv:1011.0352 [hep-ex]
(~470 pages)

TDR review in May:
The committee is very impressed by the TDR produced by the Belle II collaboration, and does not have any major technical concern.

Belle II Collaboration

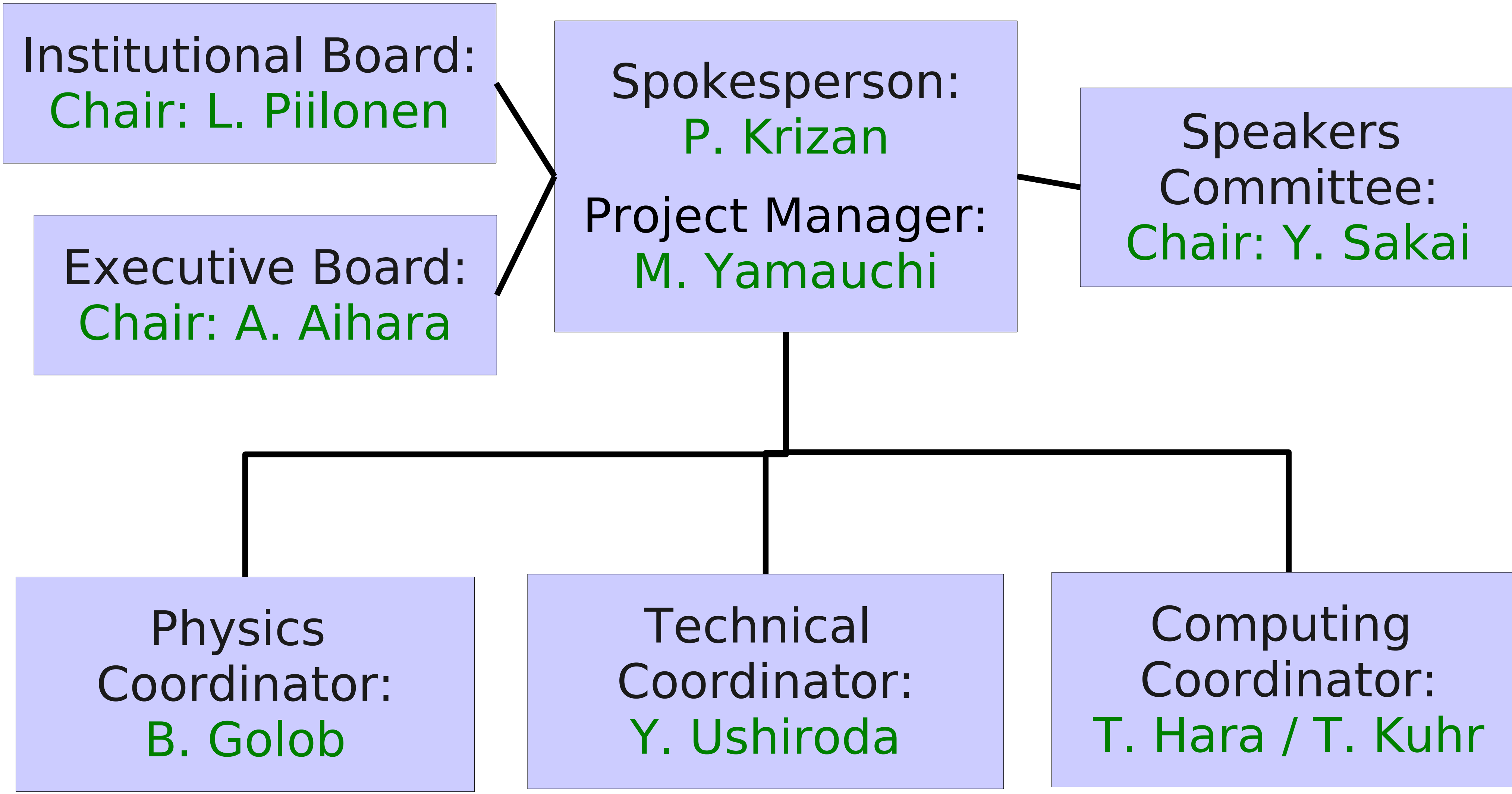
- June 2004: Letter of Intent
- March 2008: First proto collaboration meeting
- December 2008: New collaboration founded

→ ~350 members
55 institutes from 13 countries

International Collaboration

You are welcome to join!

Belle II Organization



Funding

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

Press Release

大学共同利用機関法人 KEK 高エネルギー加速器研究機構

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>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."

[Media Contact] Youhei Morita,
Head of Public Relations Office, KEK
tel. +81-29-879-6047

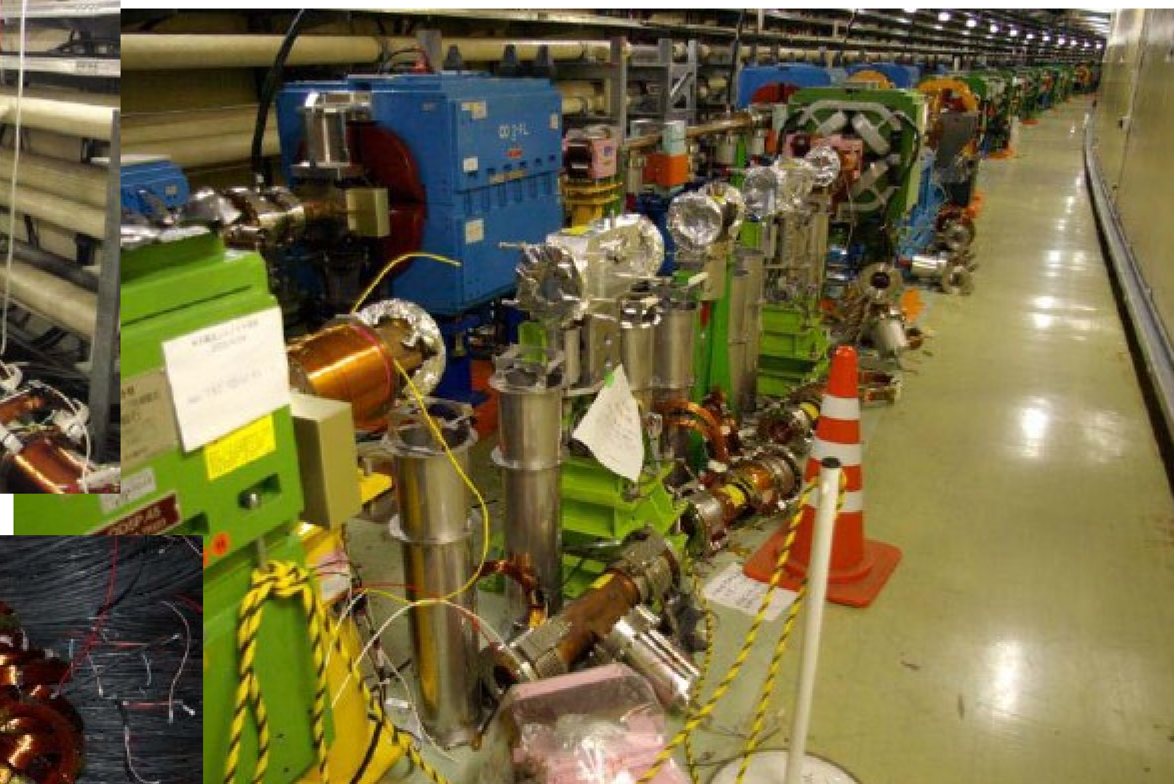
Approval Process

- ✔ Review by MEXT (Ministry for Education, Culture, Sports, Science and Technology) in July
- ✔ Positive decision by MEXT in August
- Approval by Ministry of Finance expected in December
- Approval by Diet expected in March 2011
- If approved by Diet:
  SuperKEKB groundbreaking ceremony in April 2011

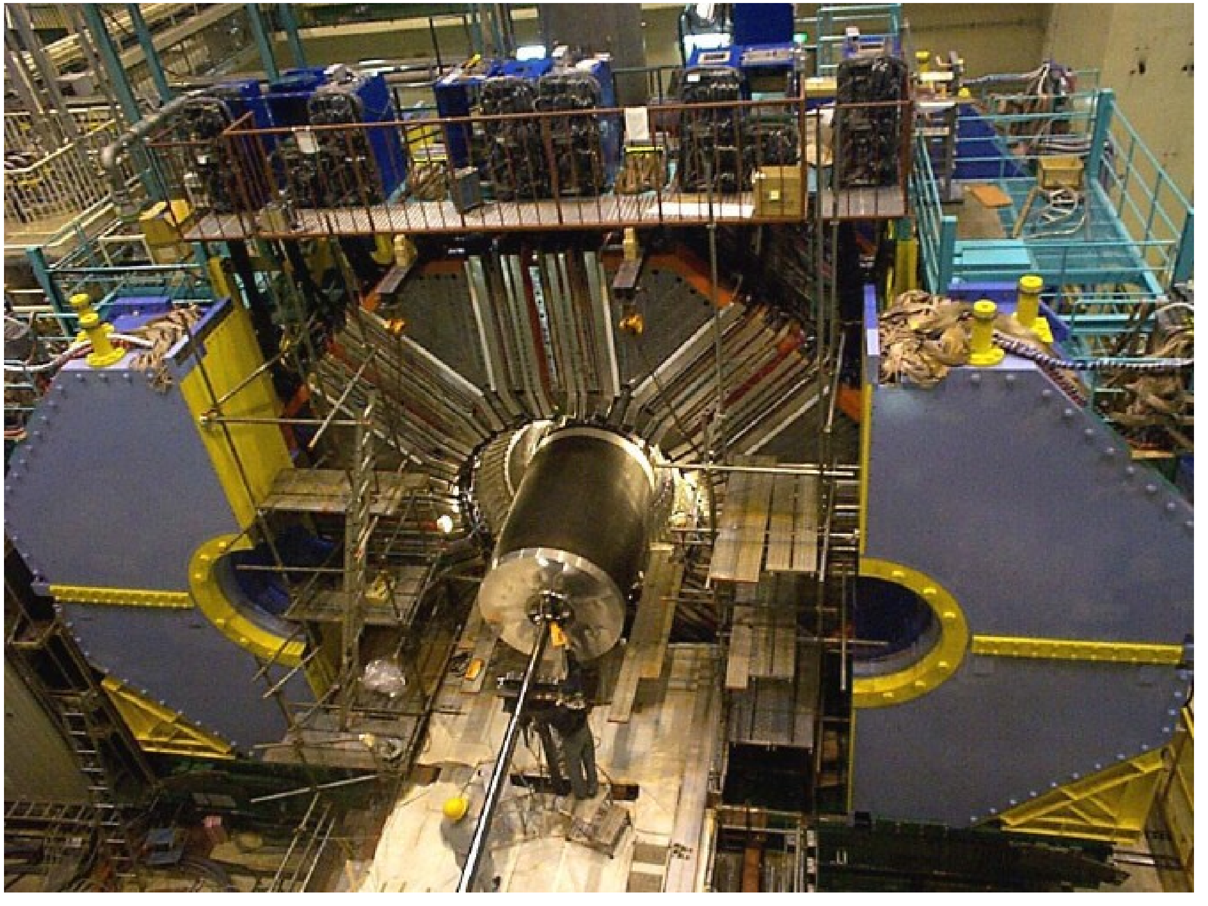
KEKB and Belle Shutdown

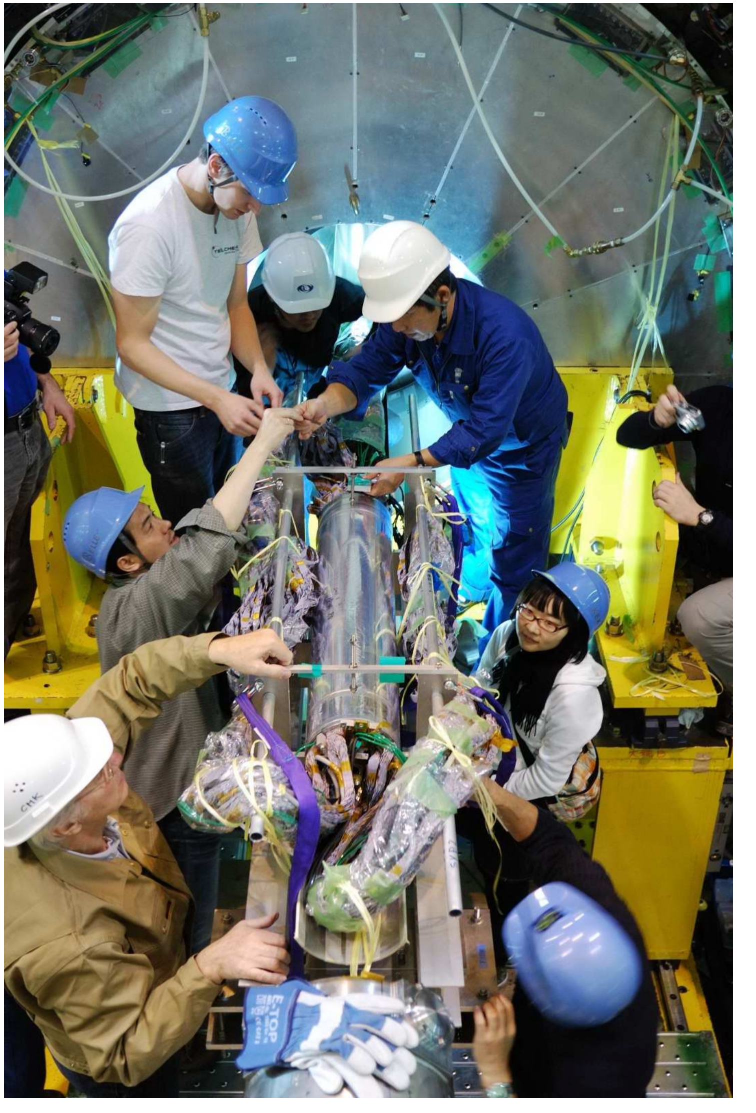
- ✔ KEKB and Belle shutdown on June 30th to start upgrade

KEKB Disassembly



Belle Disassembly





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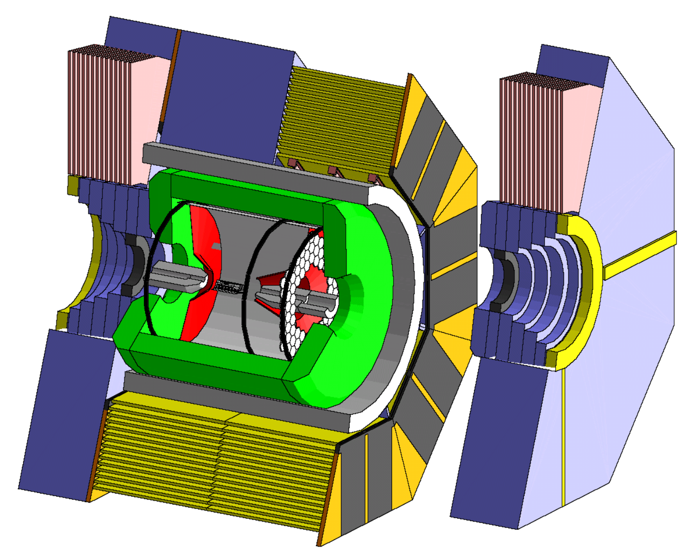
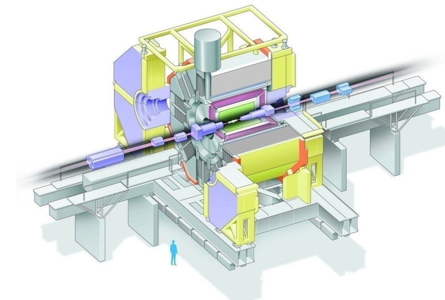
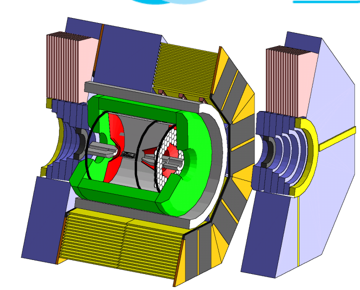


Summary

- ✔ Belle/KEKB performed remarkably well and confirmed the KM theory
- ✗ But we know there has to be more CPV
- ➢ Still many places where NP can hide
- ➔ Need much more data to find or exclude this NP
- ✔ 50 ab^{-1} in 2020 possible with nano-beam scheme at SuperKEKB
- ✔ Belle II detector and computing system are designed for conditions at next generation B factory
- ➔ Looking forward to friendly competition with SuperB and LHCb





http://belle2.kek.jp

Backup

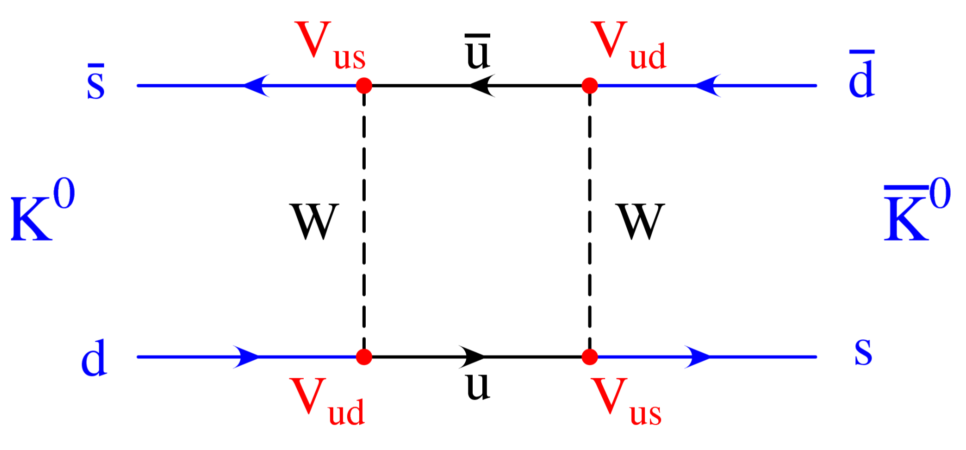
Wolfenstein Parametrization

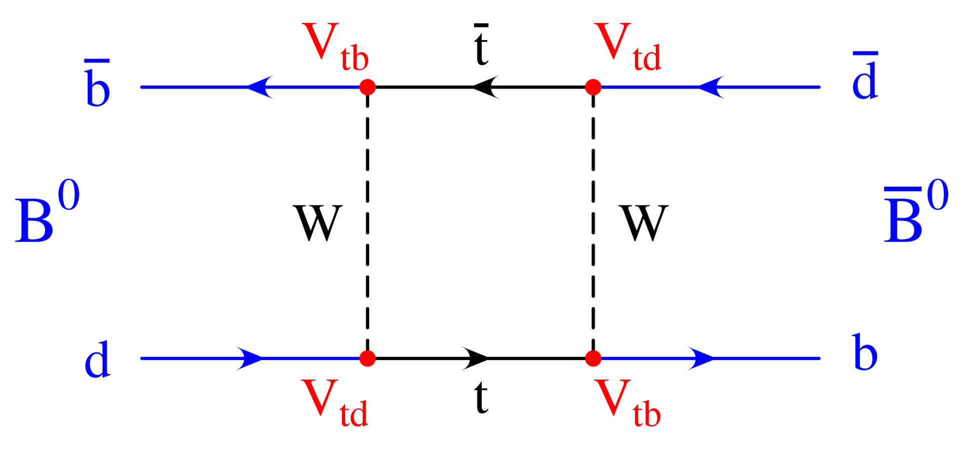
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$\lambda \approx 0.22$, $A \approx 0.82$

$\rho \approx 0.22$, $\eta \approx 0.34$

$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

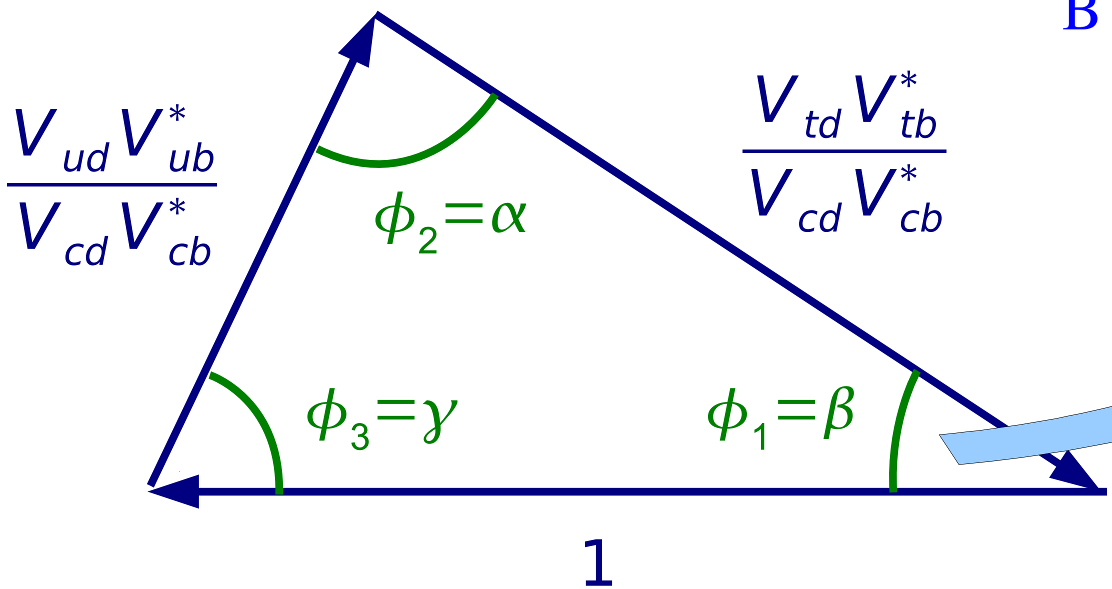


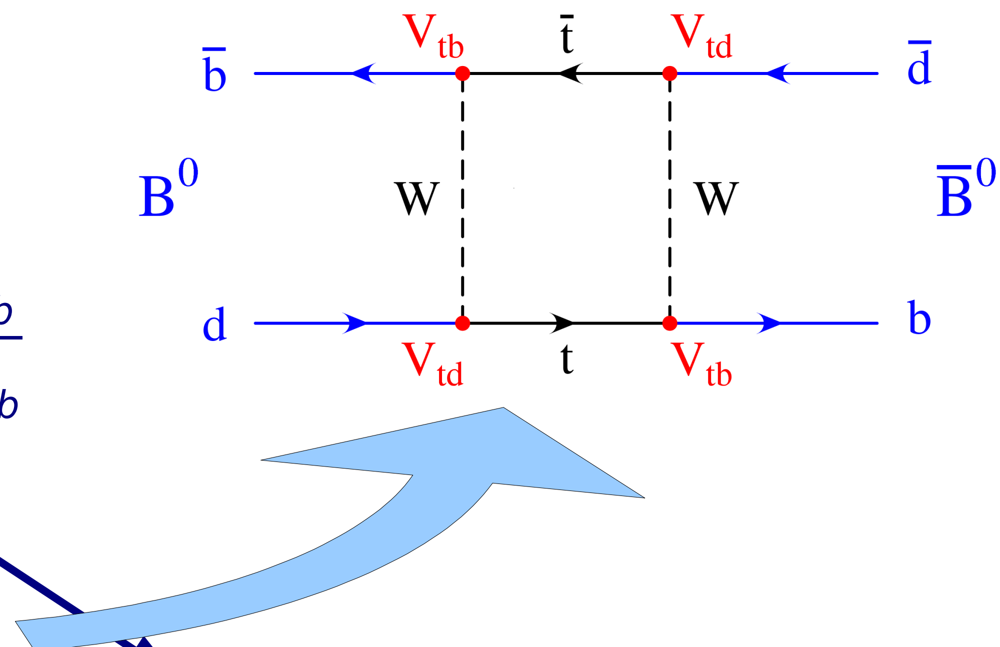


Unitarity Triangle

Graphical representation of unitarity condition: $\sum_i V_{ij} V^*_{ik} = \delta_{jk}$

- e.g. for j=1, k=3: $V_{ud} V^*_{ub} + V_{cd} V^*_{cb} + V_{td} V^*_{tb} = 0$

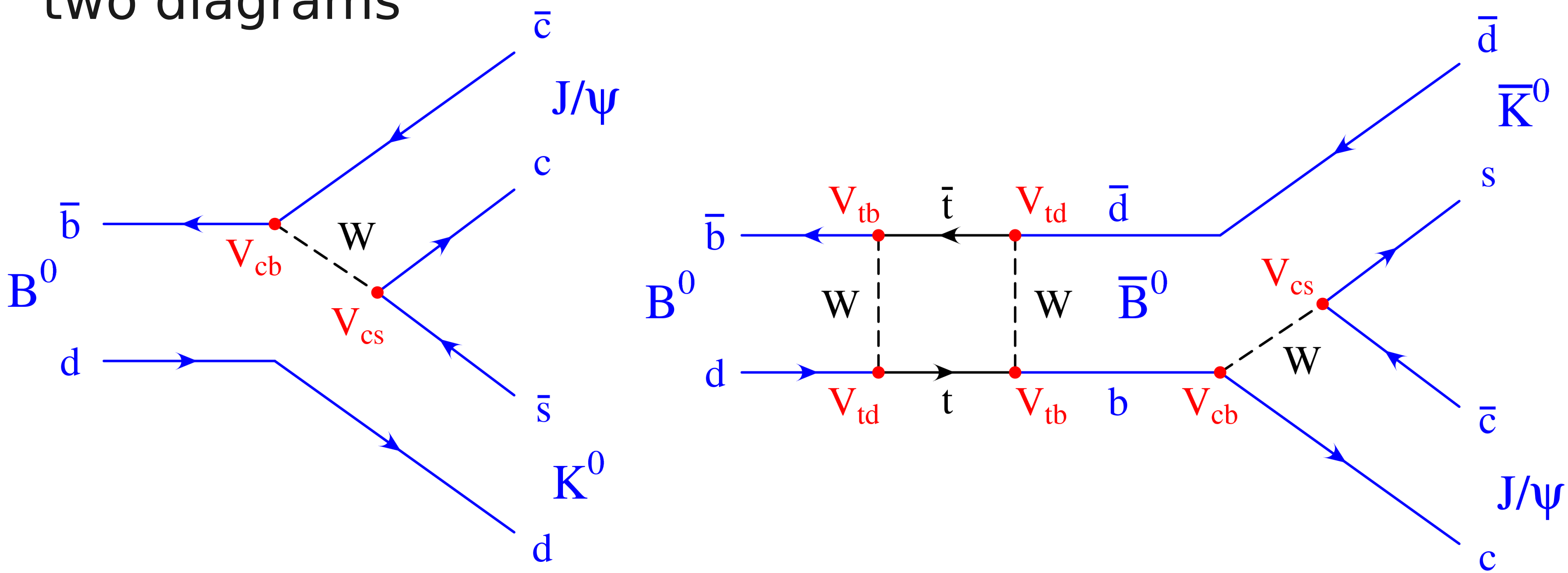




SM ⇒
closed triangle

Interference

- Measurement of phase requires interference between two diagrams



➢ Same final state only due to K^0 mixing:

- $K^0/\overline{K}^0 \rightarrow K^0_S \rightarrow \pi^+\pi^-$ $\quad$ $CP(2\pi)=+1 \Rightarrow CP(J/\psi K^0_S) =: \xi_f = -1$
- $K^0/\overline{K}^0 \rightarrow K^0_L \rightarrow 3\pi$ $\quad$ $CP(3\pi)=-1 \Rightarrow CP(J/\psi K^0_L) =: \xi_f = +1$

Time Dependent Asymmetry

$$a_f(t) = \frac{\Gamma(\bar{B}^0 \to f) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to f) + \Gamma(B^0 \to f)}$$

$$= \frac{(1 - |\lambda_f|^2)\cos(\Delta m t) - 2\mathrm{Im}(\lambda_f)\sin(\Delta m t)}{1 + |\lambda_f|^2}$$

$$= A\cos(\Delta m t) + S\sin(\Delta m t)$$

Decay to
CP eigenstate f

Interference

Decay

Mixing

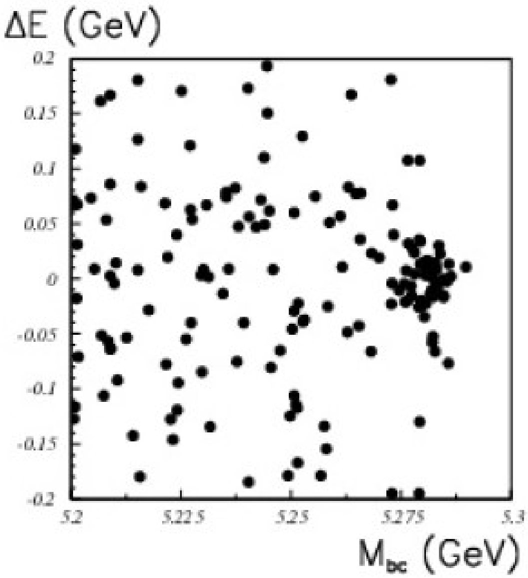
$$|B_L^0\rangle = p|B^0\rangle + q|\bar{B}^0\rangle$$
$$|B_H^0\rangle = p|B^0\rangle - q|\bar{B}^0\rangle$$

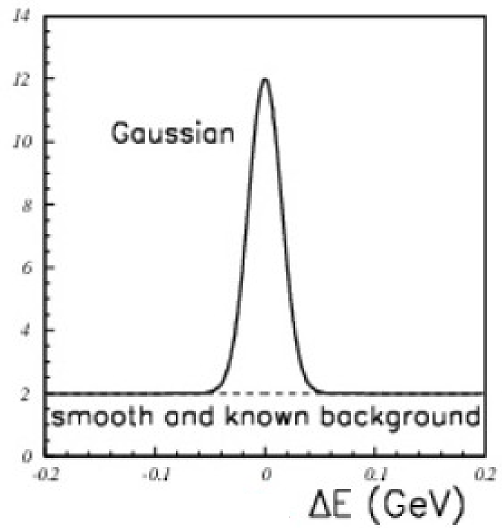
$$\boxed{\lambda_f = \frac{q}{p}\frac{\bar{A}_f}{A_f} = \xi_f \frac{q}{p}\frac{\bar{A}_{\bar{f}}}{A_f}}$$

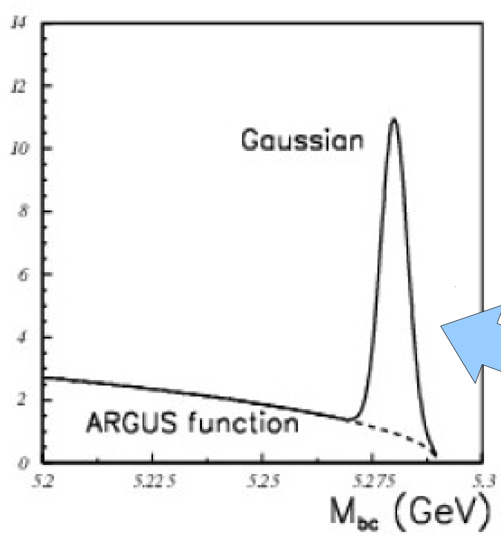
Decay
amplitude
A_f

SM: $S = -\xi_f \sin(2\phi_1)$

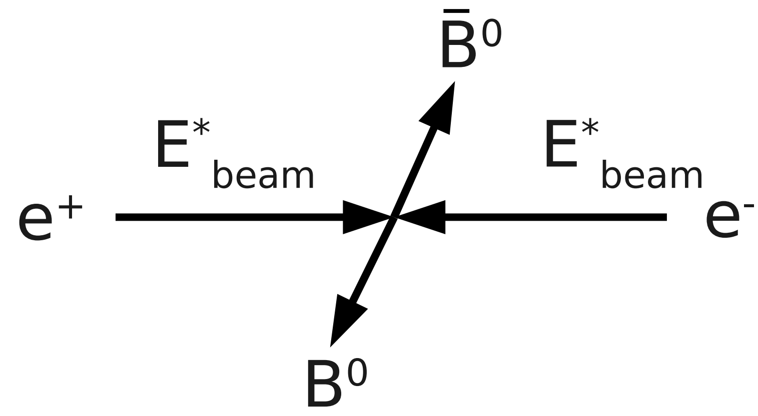
B^0 Reconstruction







In Y(4S) CMS:

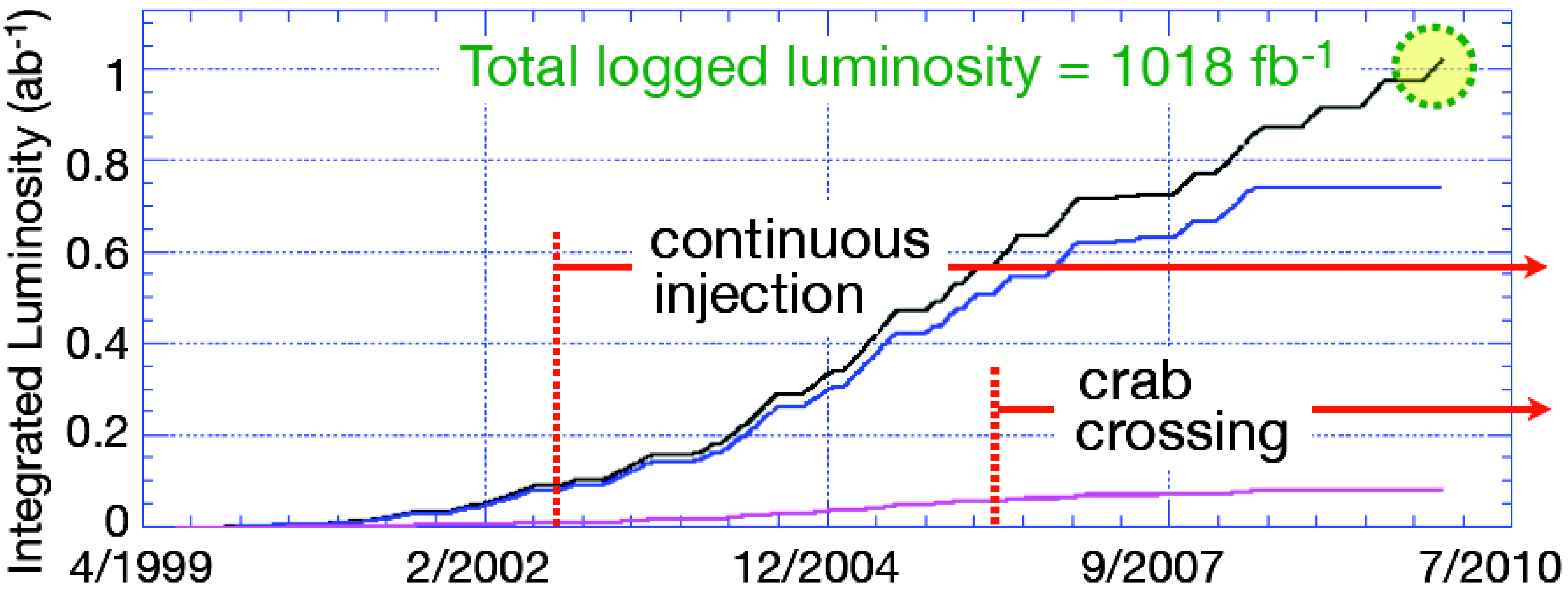


$$\Delta E = \left(\sum_{\text{daughters}} E_i^\star \right) - E_{beam}^\star$$

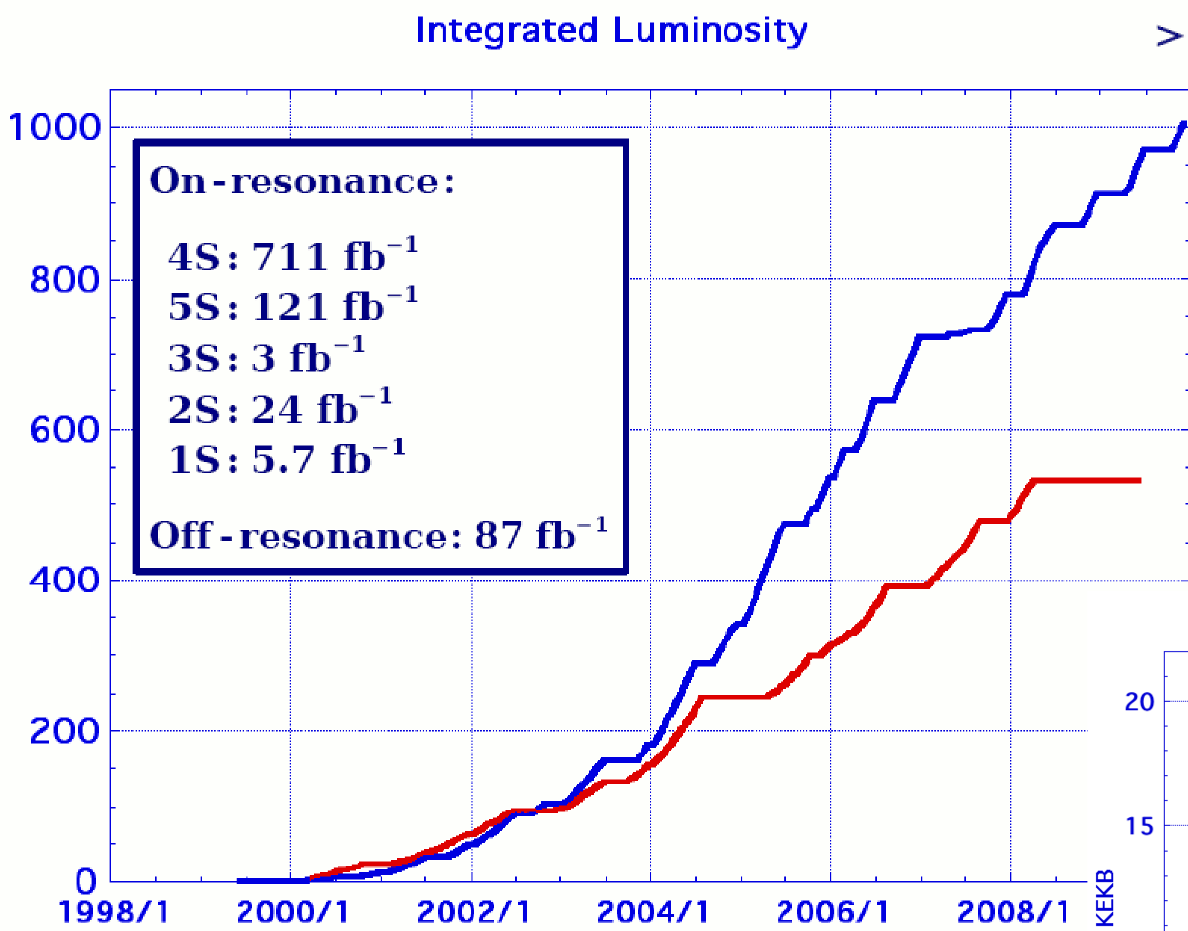
$$M_{bc} = \sqrt{{E_{beam}^\star}^2 - \left(\sum_{\text{daughters}} \vec{p}_i^\star \right)^2}$$

Energy and momentum of B mesons determined by beam energy

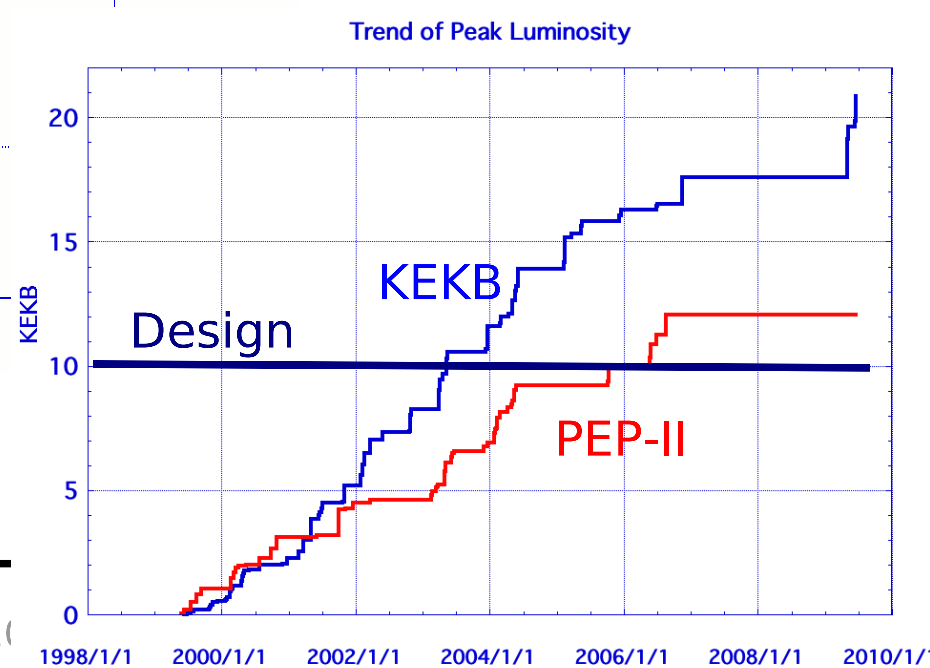
Integrated Luminosity



Comparison KEKB/PEP-II



$> 1\ ab^{-1}$!



Physics at Belle II

Observable	Belle 2006	SuperKEKB		†LHCb	
	(~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
$\mathcal{B}(B^+ \to K^+ \nu\nu)$	†† $< 3\ \mathcal{B}_{\mathrm{SM}}$		30%	-	-
$\mathcal{B}(B^0 \to K^{*0} \nu\bar{\nu})$	†† $< 40\ \mathcal{B}_{\mathrm{SM}}$		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 ($\sim$0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})	†LHCb (2 fb^{-1})	†LHCb (10 fb^{-1})
Leptonic/semileptonic B decays					
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%	-	-
$\mathcal{B}(B^+ \to \mu^+\nu)$	†† $< 2.4\mathcal{B}_{\rm SM}$	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)	-	-
††† $\bar{\rho}$	20.0%		3.4%		
††† $\bar{\eta}$	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})			
$\mathcal{B}(\Upsilon(1S) \to \text{invisible})$	$< 2.5 \times 10^{-3}$	$< 2 \times 10^{-4}$			
	(~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		(~10 ab^{-1})			
$\sin^2\Theta_W$	-	3×10^{-4}			

Belle II Detector Components

Component	Type	Configuration	Readout	Performance
Beam pipe	Beryllium double-wall	Cylindrical, inner radius 10 mm, 10 μm Au, 0.6 mm Be, 1 mm coolant (paraffin), 0.4 mm Be		
PXD	Silicon pixel (DEPFET)	Sensor size: 15×100 (120) mm^2 pixel size: 50×50 (75) μm^2 2 layers: 8 (12) sensors	10 M	impact parameter resolution $\sigma_{z_0} \sim 20\ \mu$m (PXD and SVD)
SVD	Double sided Silicon strip	Sensors: rectangular and trapezoidal Strip pitch: 50(p)/160(n) - 75(p)/240(n) μm 4 layers: 16/30/56/85 sensors	245 k	
CDC	Small cell drift chamber	56 layers, 32 axial, 24 stereo r = 16 - 112 cm - 83 $\leq z \leq$ 159 cm	14 k	$\sigma_{r\phi} = 100\ \mu$m, $\sigma_z = 2$ mm $\sigma_{p_t}/p_t = \sqrt{(0.2\% p_t)^2 + (0.3\%/\beta)^2}$ $\sigma_{p_t}/p_t = \sqrt{(0.1\% p_t)^2 + (0.3\%/\beta)^2}$ (with SVD) $\sigma_{dE/dx} = 5\%$
TOP	RICH with quartz radiator	16 segments in ϕ at $r \sim 120$ cm 275 cm long, 2 cm thick quartz bars with 4x4 channel MCP PMTs	8 k	$N_{p.e.} \sim 20$, $\sigma_t = 40$ ps K/π separation : efficiency > 99% at < 0.5% pion fake prob. for $B \to \rho\gamma$ decays
ARICH	RICH with aerogel radiator	4 cm thick focusing radiator and HAPD photodetectors for the forward end-cap	78 k	$N_{p.e.} \sim 13$ K/π separation at 4 GeV/c: efficiency 96% at 1% pion fake prob.
ECL	CsI(Tl) (Towered structure)	Barrel: $r = 125$ - 162 cm End-cap: $z =$ -102 cm and +196 cm	6624 1152 (F) 960 (B)	$\frac{\sigma E}{E} = \frac{0.2\%}{E} \oplus \frac{1.6\%}{\sqrt[4]{E}} \oplus 1.2\%$ $\sigma_{pos} = 0.5$ cm/$\sqrt{E}$ (E in GeV)
KLM	barrel: RPCs end-caps: scintillator strips	14 layers (5 cm Fe + 4 cm gap) 2 RPCs in each gap 14 layers of $(7-10) \times 40$ mm^2 strips read out with WLS and G-APDs	θ: 16 k, ϕ: 16 k 17 k	$\Delta\phi = \Delta\theta = 20$ mradian for K_L $\sim$ 1 % hadron fake for muons $\Delta\phi = \Delta\theta = 10$ mradian for K_L $\sigma_p/p = 18\%$ for 1 GeV/c K_L

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	