Belle の最新結果とBelle II 実験

西田 昌平

KEK

高エネルギー物理 春の学校 @ 彦根ビューホテル

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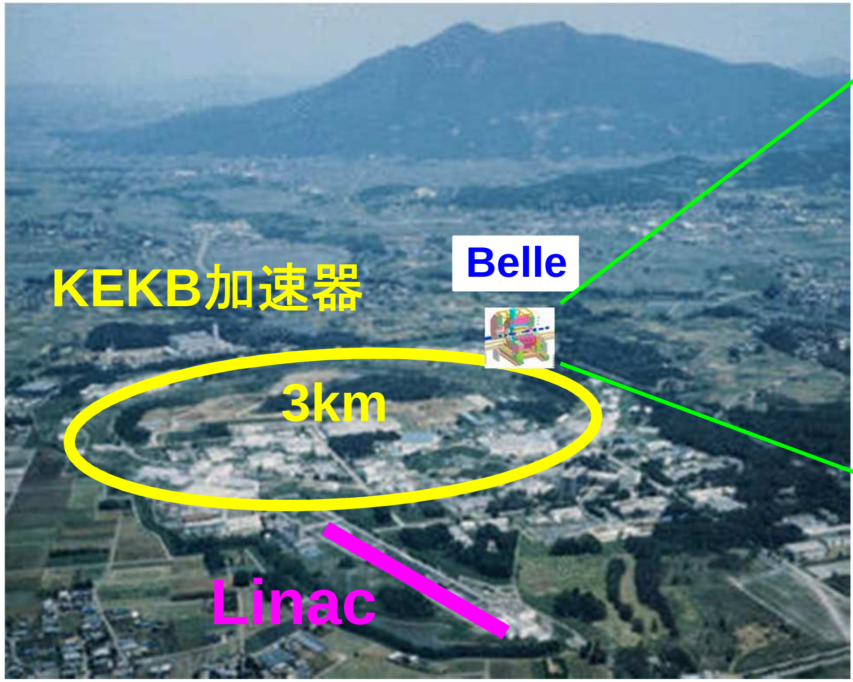
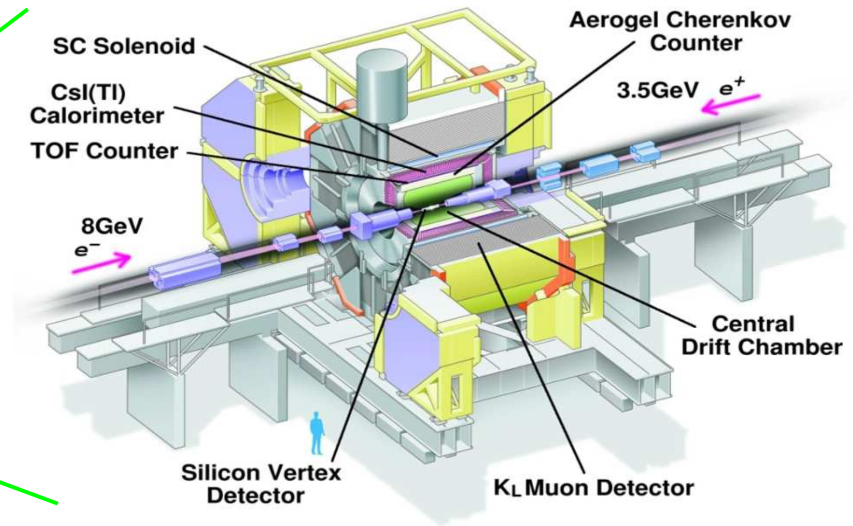
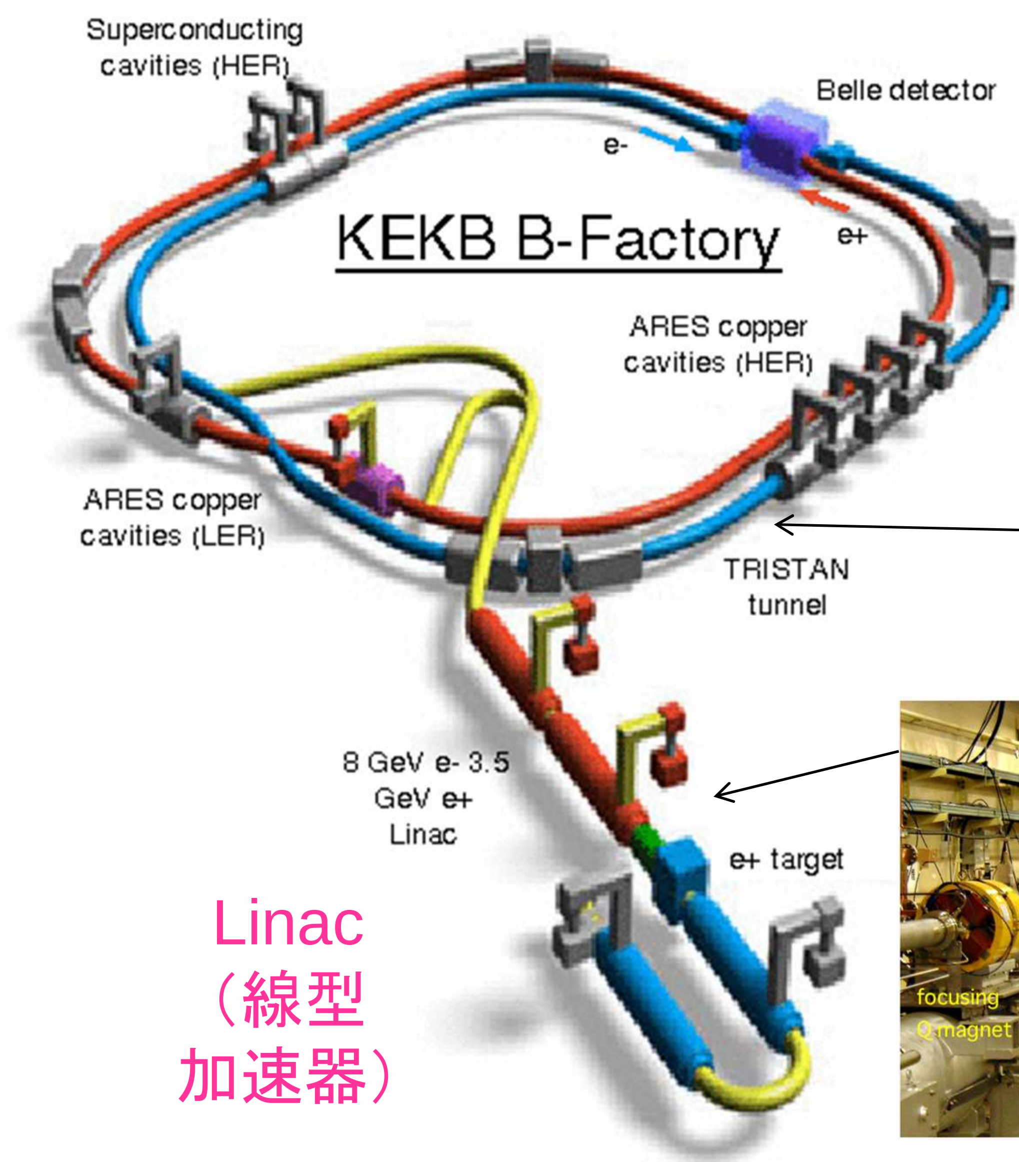
Belle実験

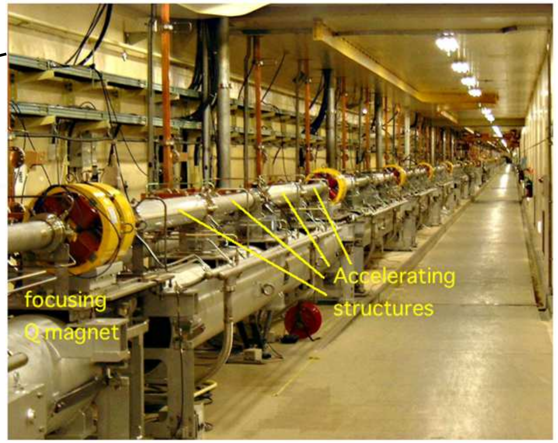




- 高エネルギー加速器研究機構（KEK）で行われている（いた）実験。1999年に運転を開始。
- KEKB加速器で作り出した大量のB中間子をBelle検出器で測定。「Bファクトリー（工場）実験」。
- KEKB加速器は世界最高のルミノシティ（衝突性能）を有する加速器。
- 15ヶ国、400人の国際共同実験。
- B中間子系でのCP対称性の破れを発見し（2001年）、小林益川理論を証明。

KEKB加速器





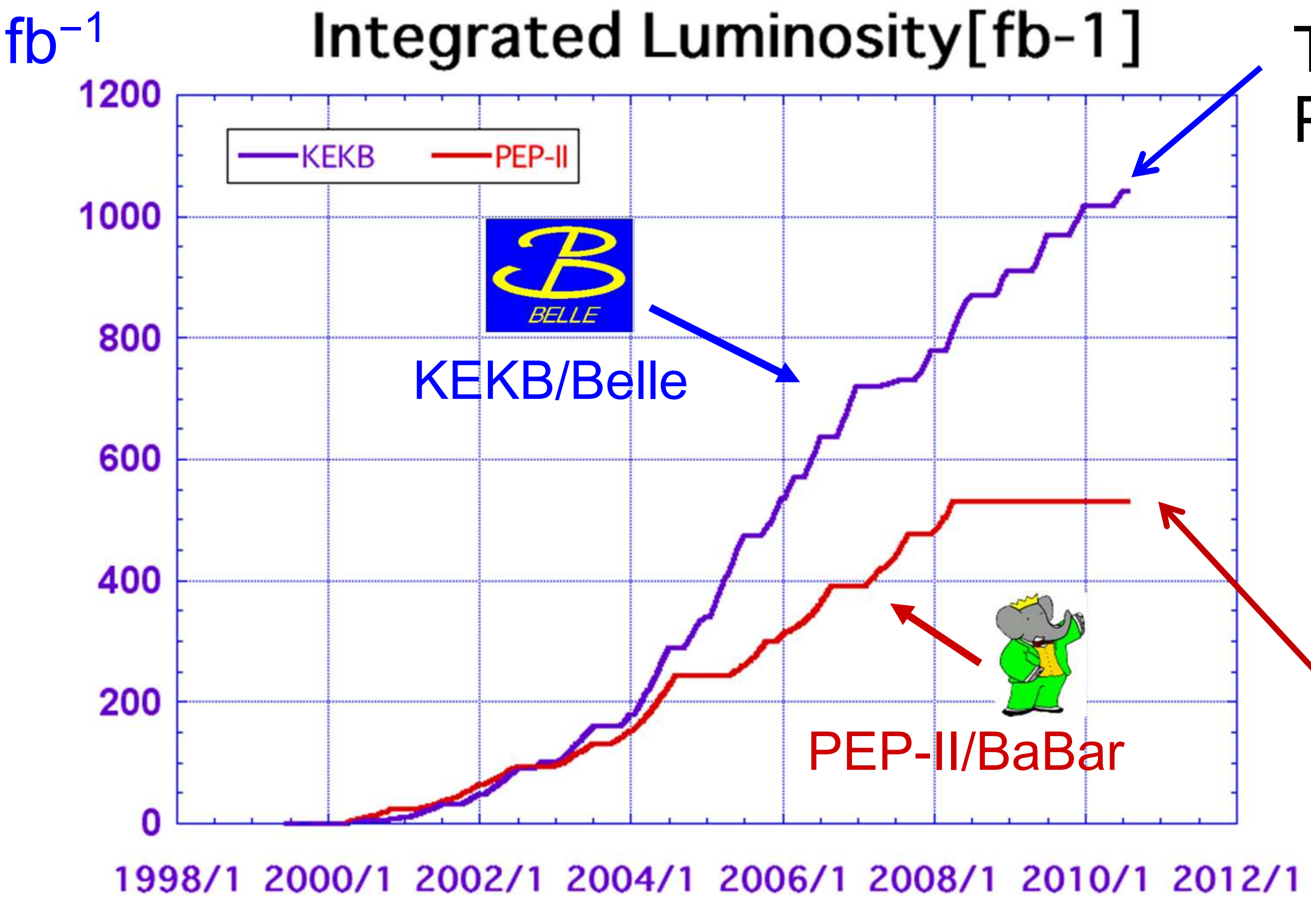
- 電子陽電子衝突型加速器（陽電子3.5 GeV, 電子 8 GeV）
- 周長 3km
- 最大電流：陽電子2.0A, 電子1.4A

Luminosity

$e^+e^- \to \Upsilon(4S) \to B\bar{B}$ (1.1nb)

1 fb^{-1} ~10^6 $B\bar{B}$ @ $\Upsilon(4S)$

World Record!!



Total ~1020 fb^{-1}

Peak 2.11×10^{34} cm^{-2} s^{-1}

On resonance:

- $\Upsilon(5S)$: 121 fb^{-1} ← B_s
- $\Upsilon(4S)$: 711 fb^{-1}
- $\Upsilon(3S)$: 3 fb^{-1}
- $\Upsilon(2S)$: 24 fb^{-1}
- $\Upsilon(1S)$: 6 fb^{-1}

Off resonance, scan:

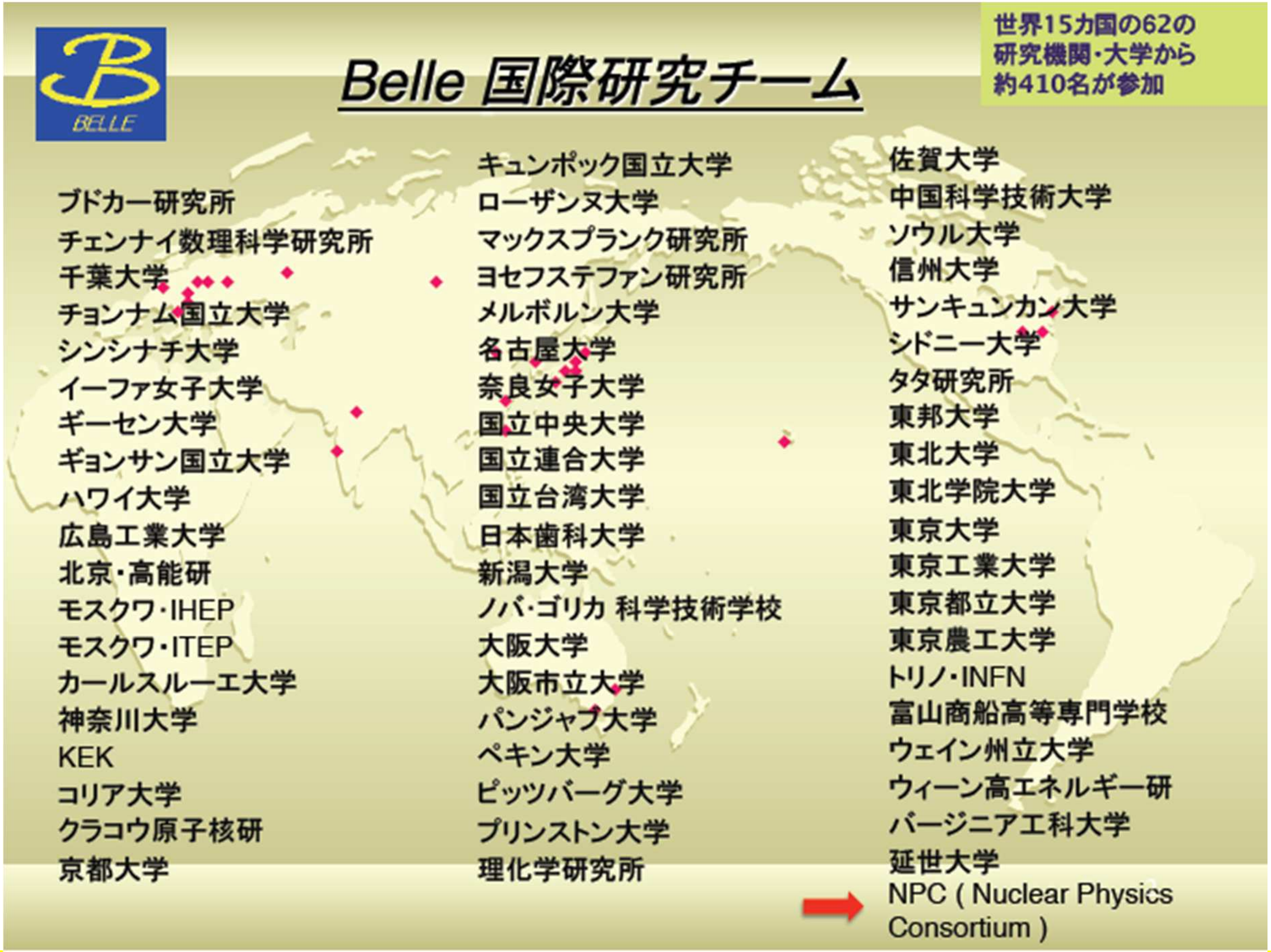
~ 100 fb^{-1}

Total 550 fb^{-1}

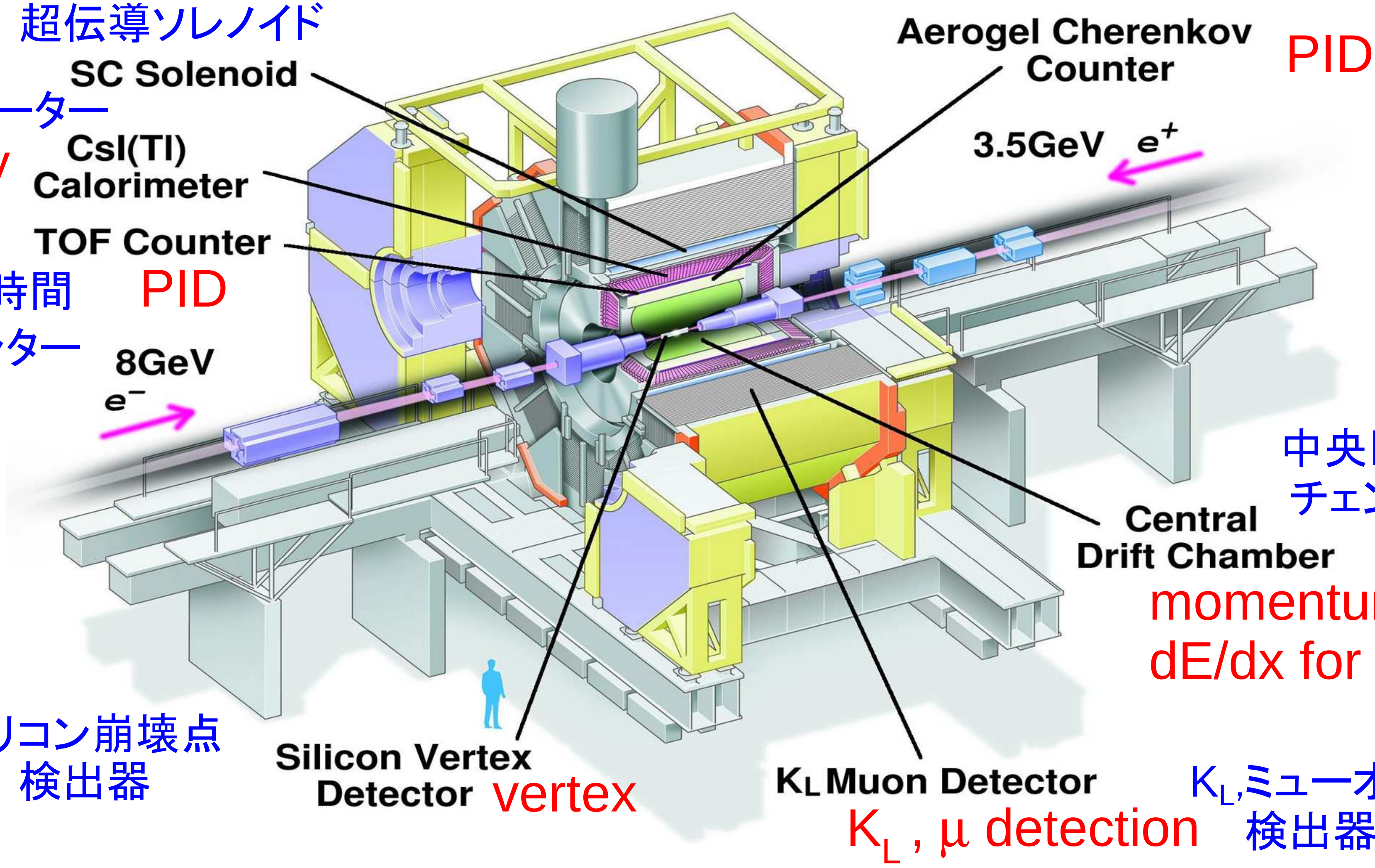
Peak 1.21×10^{34} cm^{-2} s^{-1}

(BaBar@SLAC)

Belle Collaboration



Belle検出器



エアロジェルチェレンコフカウンター
Aerogel Cherenkov Counter
PID
超伝導ソレノイド
SC Solenoid
カロリメーター
energy
CsI(Tl) Calorimeter
TOF Counter
飛行時間カウンター
PID
3.5GeV e+
8GeV e−
中央ドリフトチェンバー
Central Drift Chamber
momentum
dE/dx for PID
シリコン崩壊点検出器
Silicon Vertex Detector
vertex
KL Muon Detector
KL,ミューオン検出器
KL , μ detection

End of KEKB Operation

The operation of KEKB & Belle has ended on June 30, 2010.

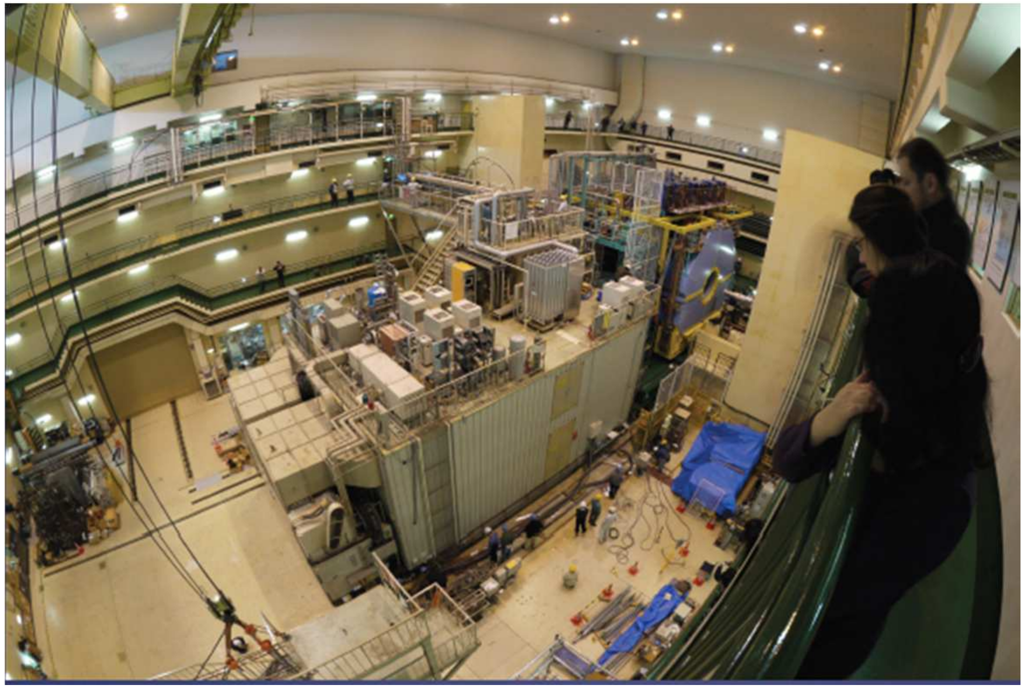
⇒ Start of the upgrade to SuperKEKB & Belle II

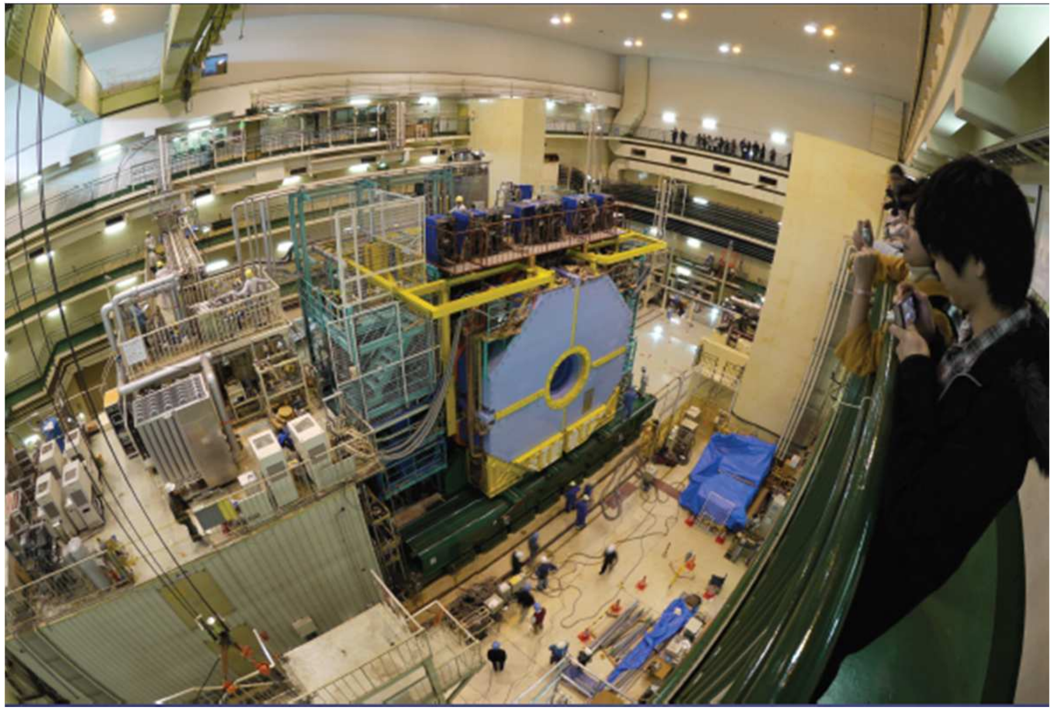
KEKB Control Room

Belle Control Room

BaBar (PEP II) ended the operation in 2008.

Belle 解体





sin2ϕ_1 の測定

標準模型におけるCP対称性の破れ

小林益川理論(1973)

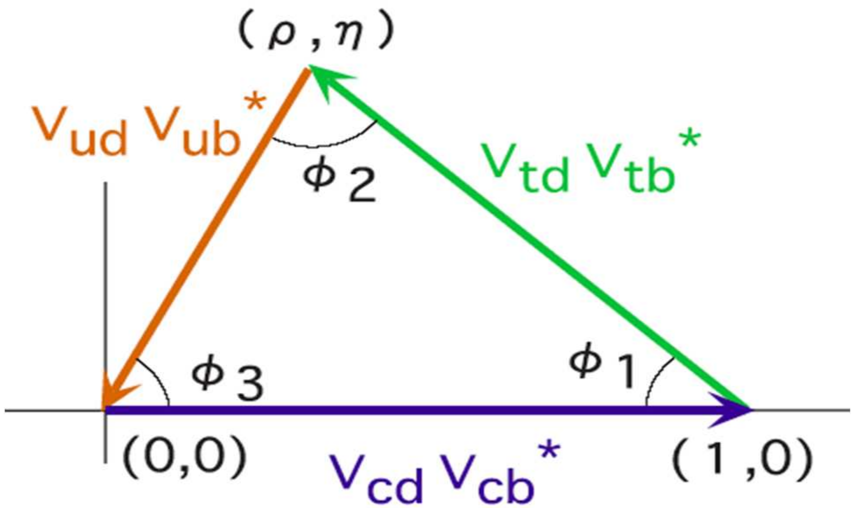
> クォークの遷移行列に複素位相があれば、
> 弱い相互作用でCP対称性の破れが生じる

CKM行列：クォークの遷移を表すユニタリー行列

$$V=\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

行列のままではわかりづらいので、ユニタリティの関係を複素平面上に書く。

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$



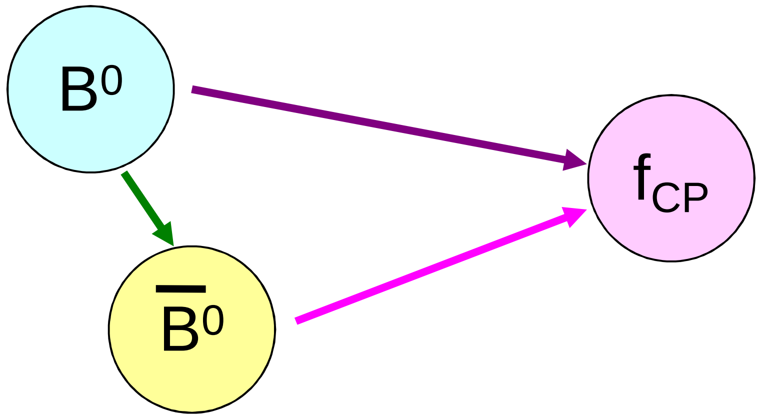
ユニタリティ三角形の辺と角度の精密測定がBelle実験の大きな目的。

時間に依存したCP非対称性

このうち、ϕ_1 が最も基本的な測定。

共通のCP固有状態 f_{CP} への崩壊

CP対称性の破れは、B^0 と $\overline{B}^0$ の崩壊の時間分布の差として表れる



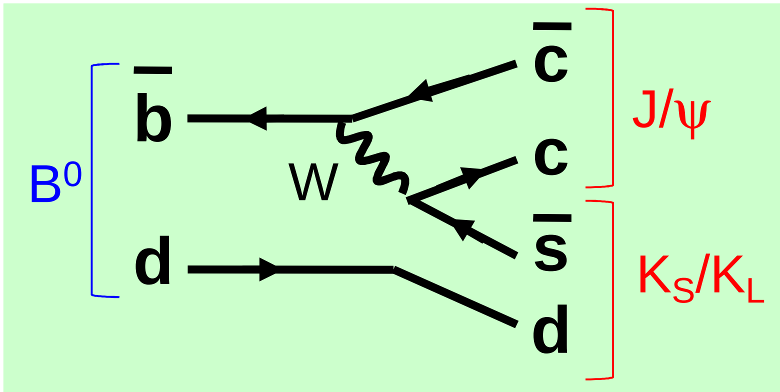
$$A_{CP}(\Delta t) = \frac{\Gamma(\overline{B}^0(\Delta t) \to f_{CP}) - \Gamma(B^0(\Delta t) \to f_{CP})}{\Gamma(\overline{B}^0(\Delta t) \to f_{CP}) + \Gamma(B^0(\Delta t) \to f_{CP})}$$
$$= S \sin(\Delta m \Delta t) + A \cos(\Delta m \Delta t)$$

S : mixing induced CPV
A : direct CPV

特に $B^0 \to J/\psi K_{S/L}$ の場合は、

$S = -\xi \sin(2\phi_1)$ (ξ : CP eigenstate)
$A = 0$

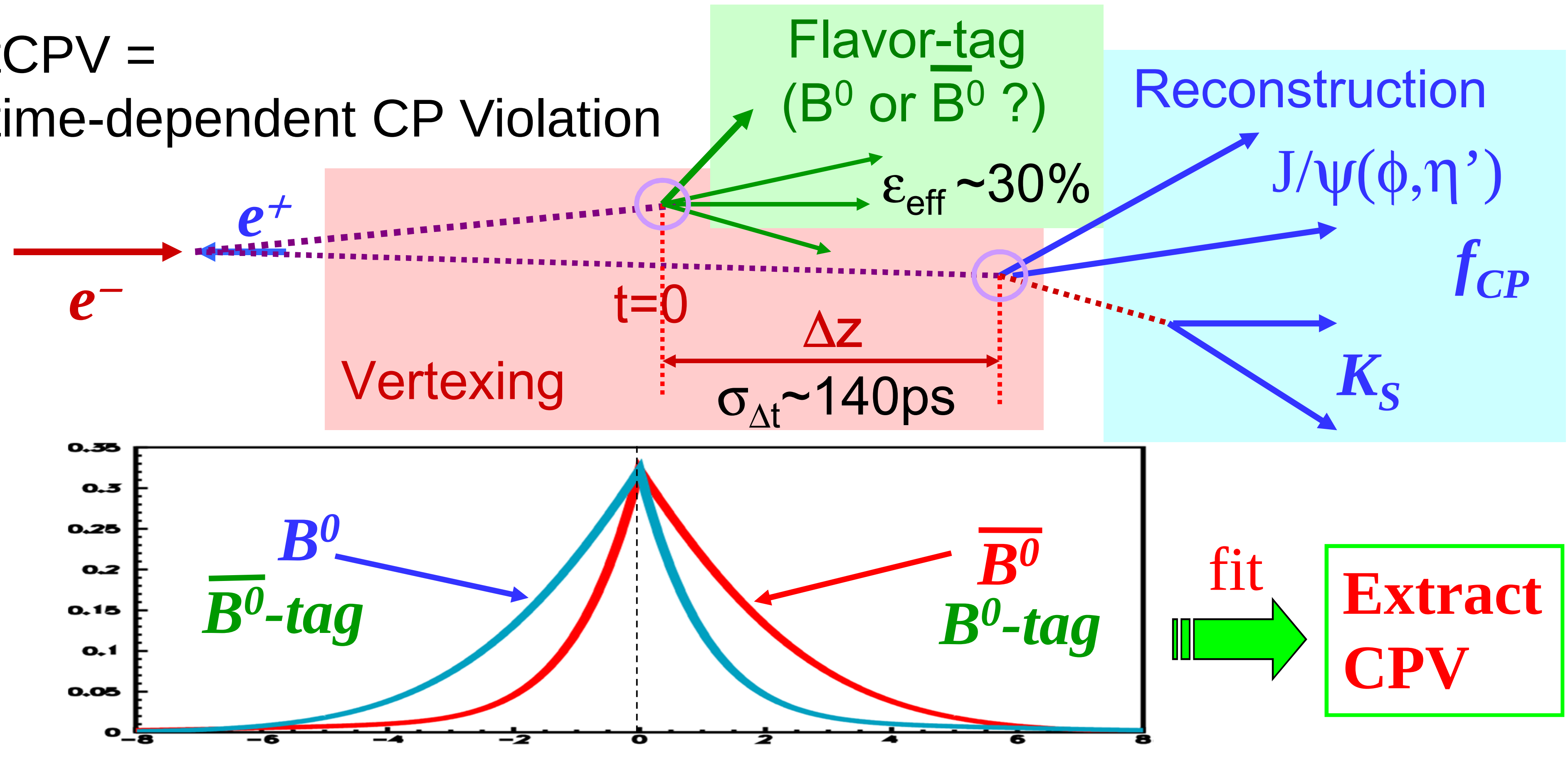
(Golden mode)



時間に依存したCP非対称性

Measure position instead of time (B life time ~1.6ps)

tCPV =
time-dependent CP Violation

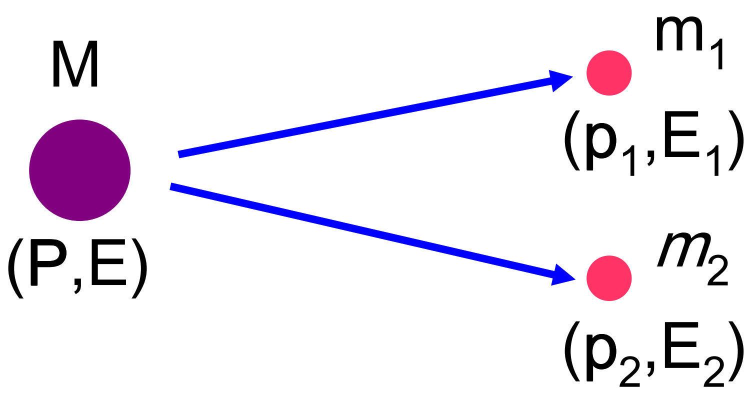


$\Delta t \approx \Delta z / c\beta\gamma$

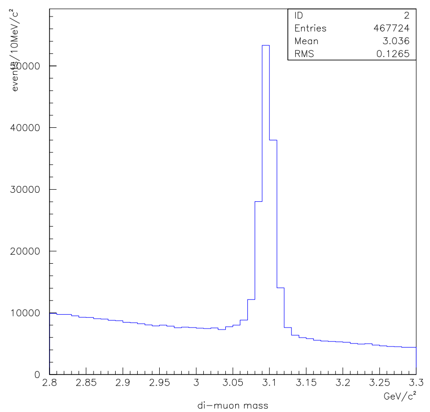
βγ=0.425 (KEKB)

B中間子の再構成

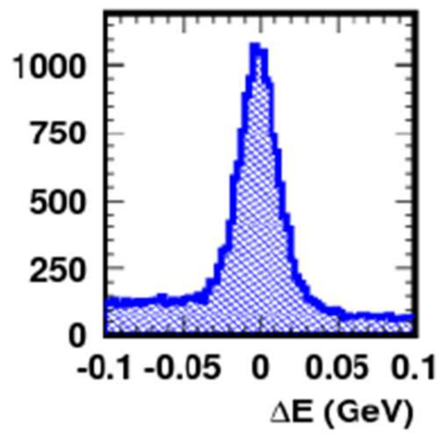
In an usual case:

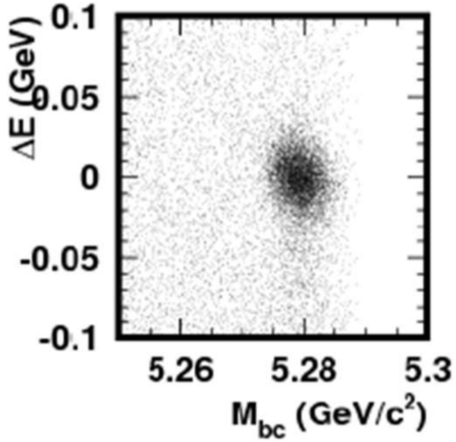


$$M^2 = E^2 - |P|^2$$
$$= (E_1+E_2)^2 - |p_1+p_2|^2$$



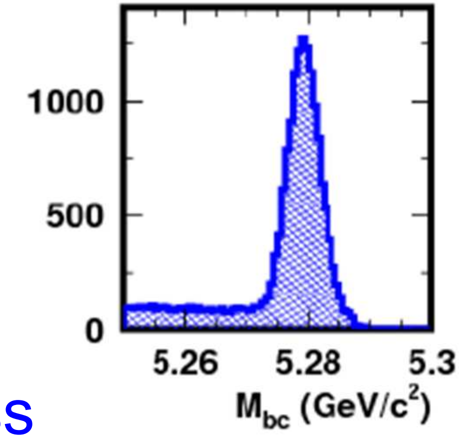
B mesons are produced almost at rest.





Energy Difference

$$\Delta E = \sum E_i - E_{\mathrm{CM}}/2$$



Beam Constrained Mass

$$M_{\mathrm{bc}} = \sqrt{(E_{\mathrm{CM}}/2)^2 - (\sum p_i)^2}$$

Signal Reconstruction

Golden mode: $\sin 2\phi_1$ with $B^0 \to J/\psi K^0$

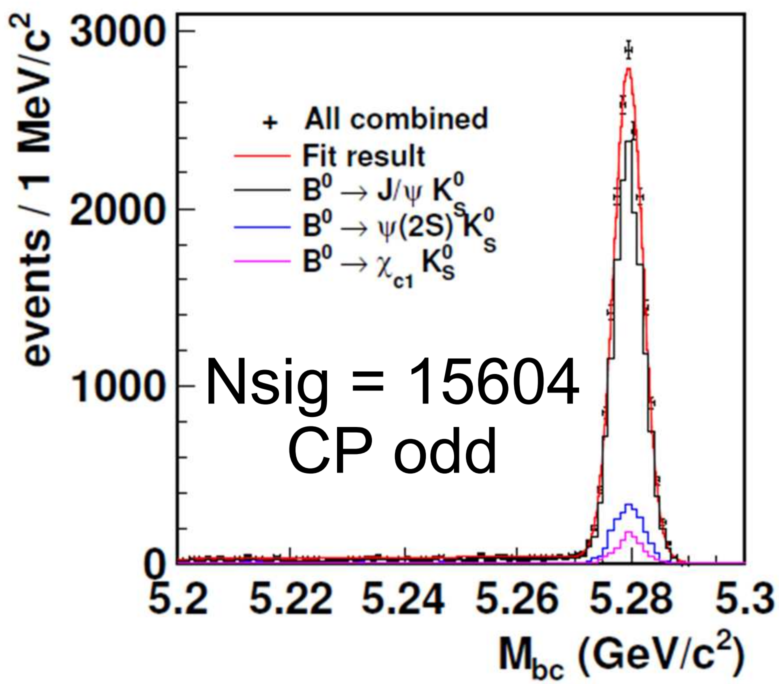
$$A_{CP}(\Delta t) = S \sin(\Delta m \Delta t) + A \cos(\Delta m \Delta t)$$

$$S = -\xi \sin(2\phi_1), \quad A = 0$$

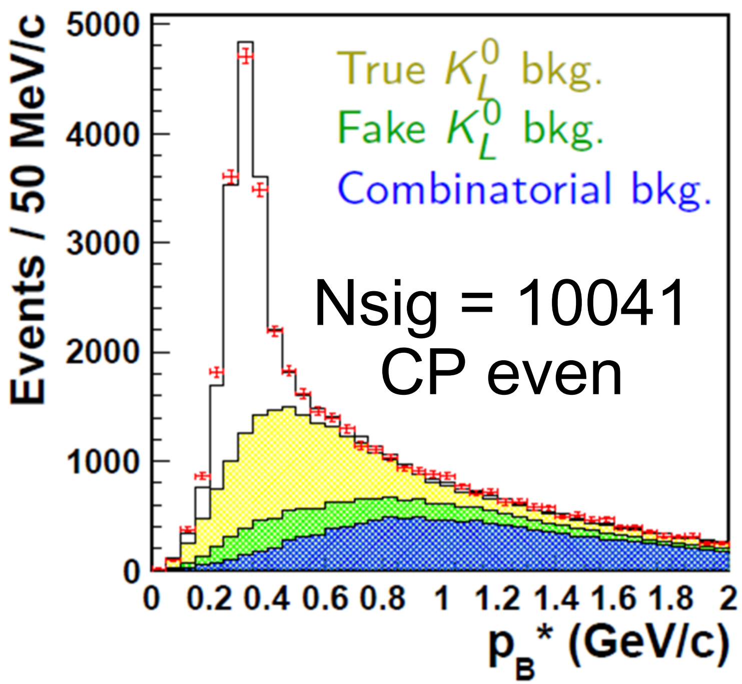
772M $B\bar{B}$

- Belle の全データを利用
- Reprocess で tracking efficiency 向上(+50%)

$B^0 \to J/\psi K_S$ etc.

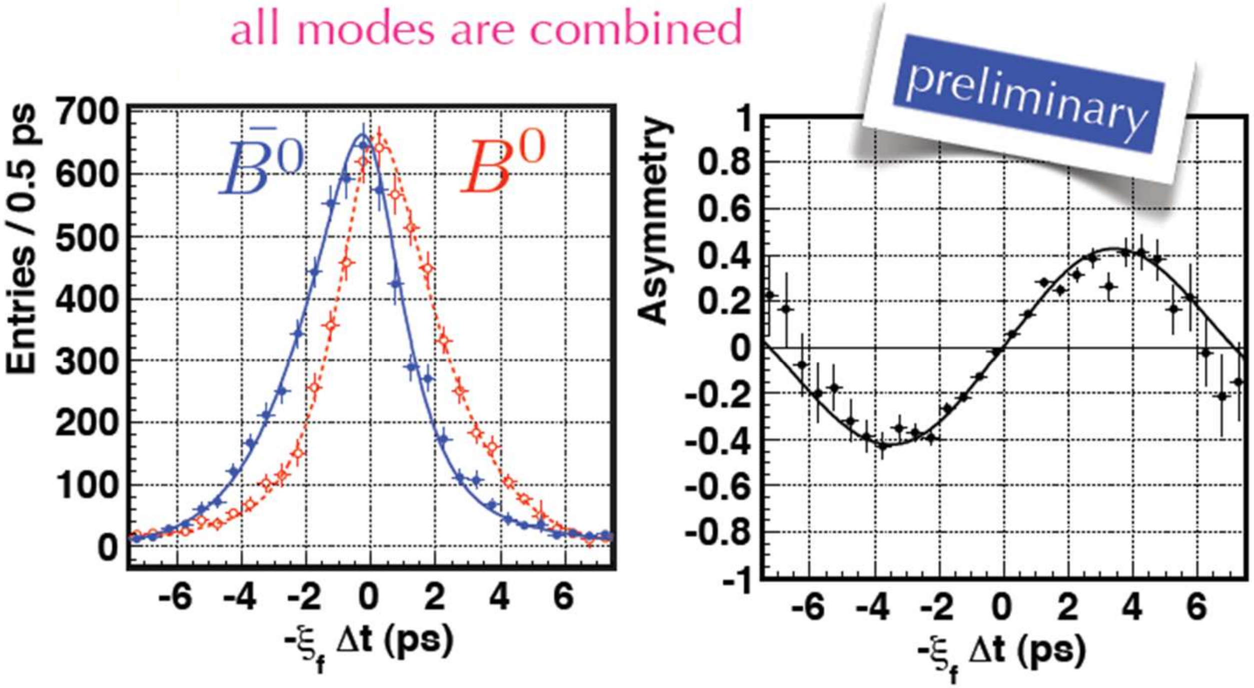


$B^0 \to J/\psi K_L$



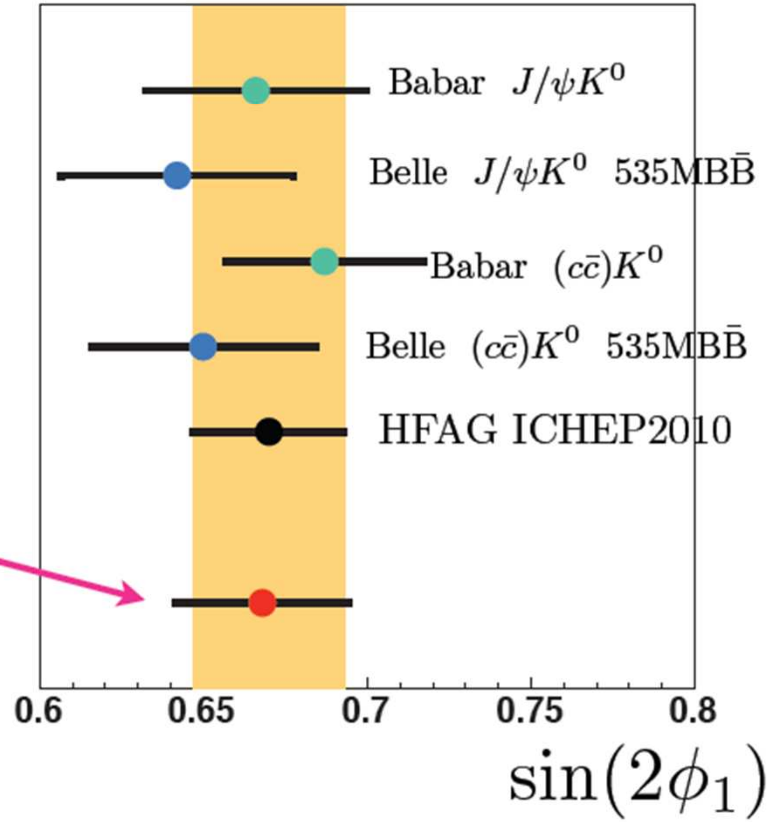
Measurement of sin2ϕ_1

all modes are combined



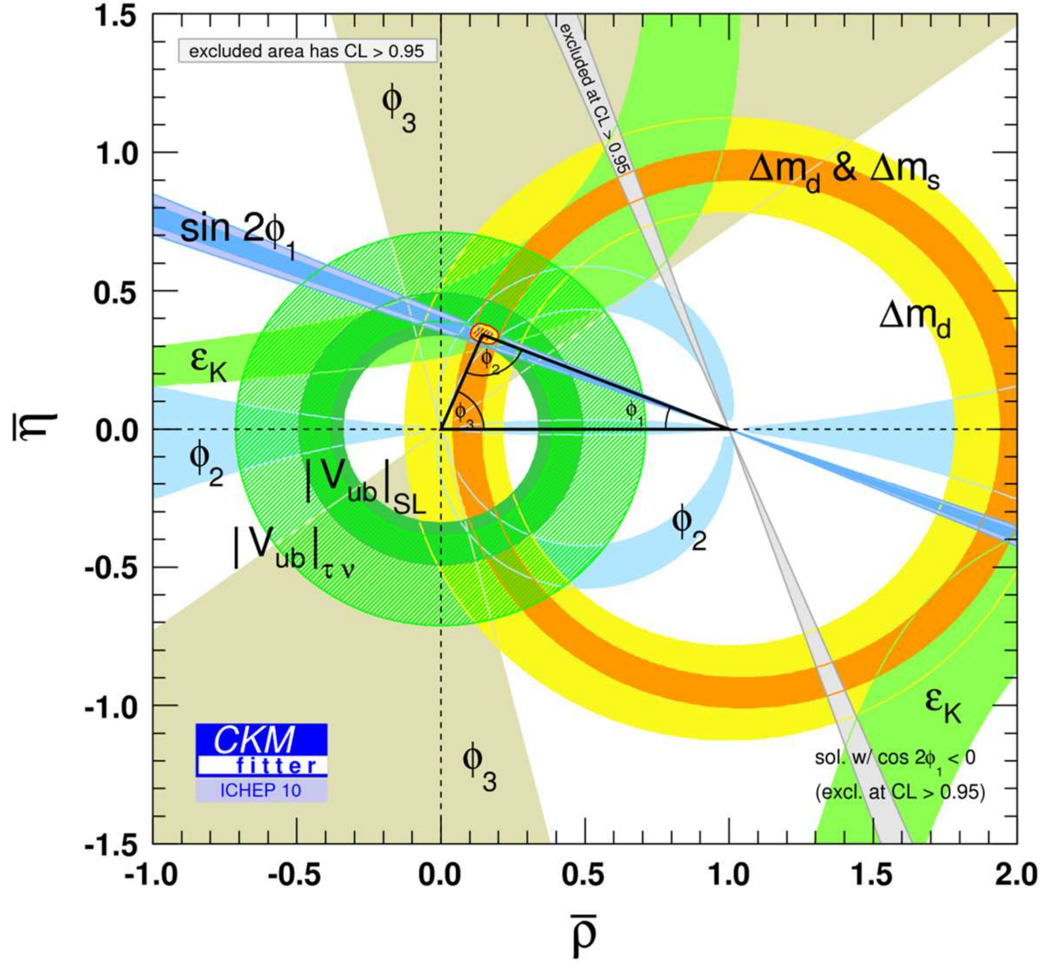
$$\mathcal{S} = 0.668 \pm 0.023\ \text{(stat.)} \pm 0.013\ \text{(syst.)}$$
$$\mathcal{A} = 0.007 \pm 0.016\ \text{(stat.)} \pm 0.013\ \text{(syst.)}$$

World's most precise measurement



Unitarity Triangle

Present constraints on UT.



Belle and BaBar confirmed

- CP Violation in the B meson system
- CKM mechanism as a source of the CP Violation.

2008 Nobel Prize in Physics

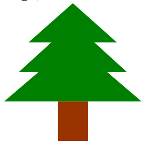
Makoto Kobayashi

Toshihide Maskawa

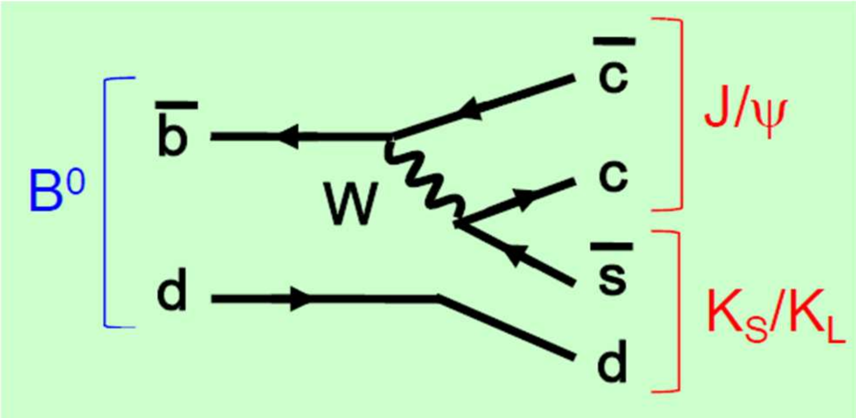
Next target of B factories is the search and study of New Physics

Measurement of $\sin 2\phi_1$

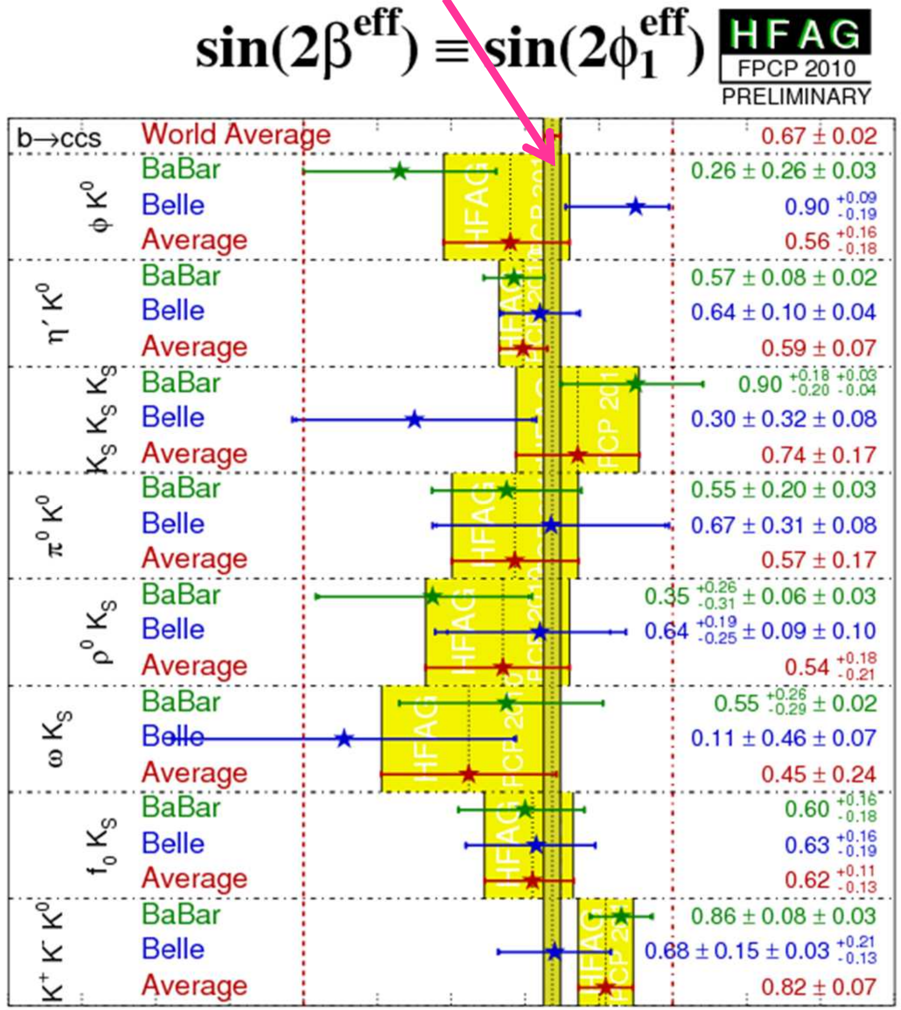
$\sin 2\phi_1$を精度よく計ると、新物理の寄与が起こりうる過程と比較できる。



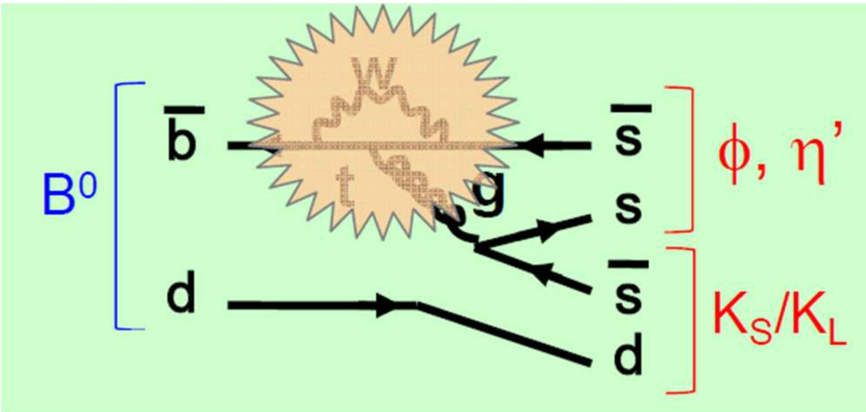
$b \to c$ ($B \to J/\psi K^0$)



sin2φ1 from b→ccs (reference)



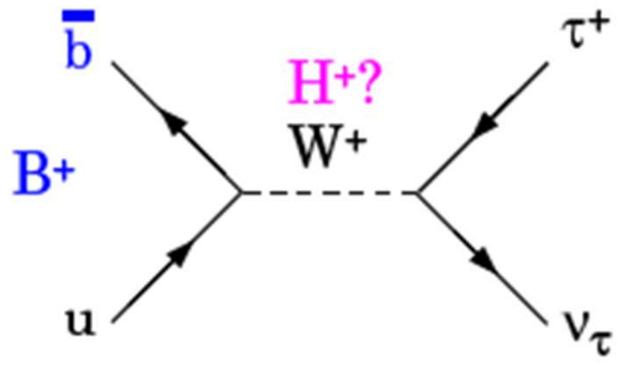
$b \to s$ ($B \to \phi K^0, \eta' K^0$)



$B \to \tau\nu$

B→τν

- Possible contribution of charged Higgs (H^+) in tree level.
- In the SM: $\mathcal{B}(B\to\tau\nu_\tau) = (1.20 \pm 0.25)\times 10^{-4}$



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

$|V_{ub}|=(4.32\pm0.16\pm0.29)\times10^{-3}$ From inclusive semileptonic B decays HFAG ICHEP08

f_B=190±13MeV, From LQCD HPQCD arXiv:0902.1815

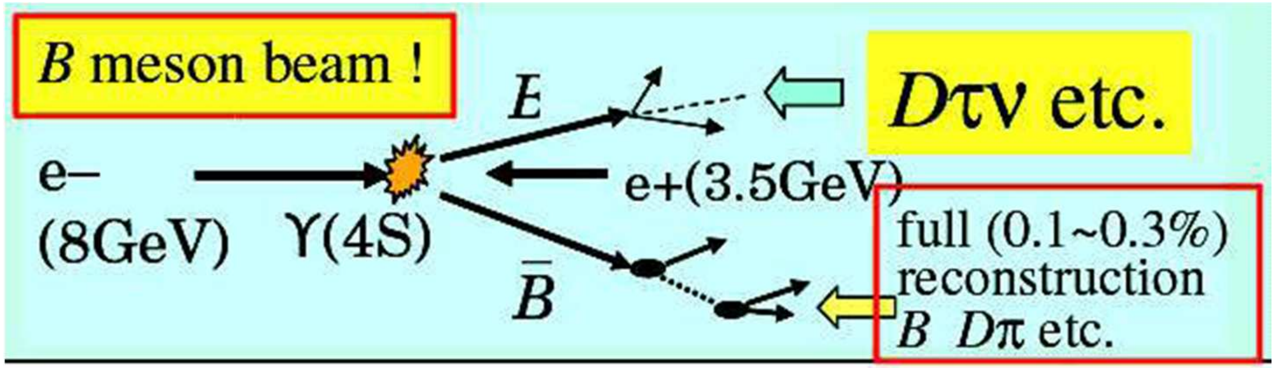
B decay constant ↔ Lattice QCD

However, experimentally very challenging due to more than 1 neutrino in the final state

$B^+ \to \tau^+\nu_\tau$

$\tau^+ \to e^+\nu_e\bar{\nu}_\tau$

$\to \pi^+\bar{\nu}_\tau$

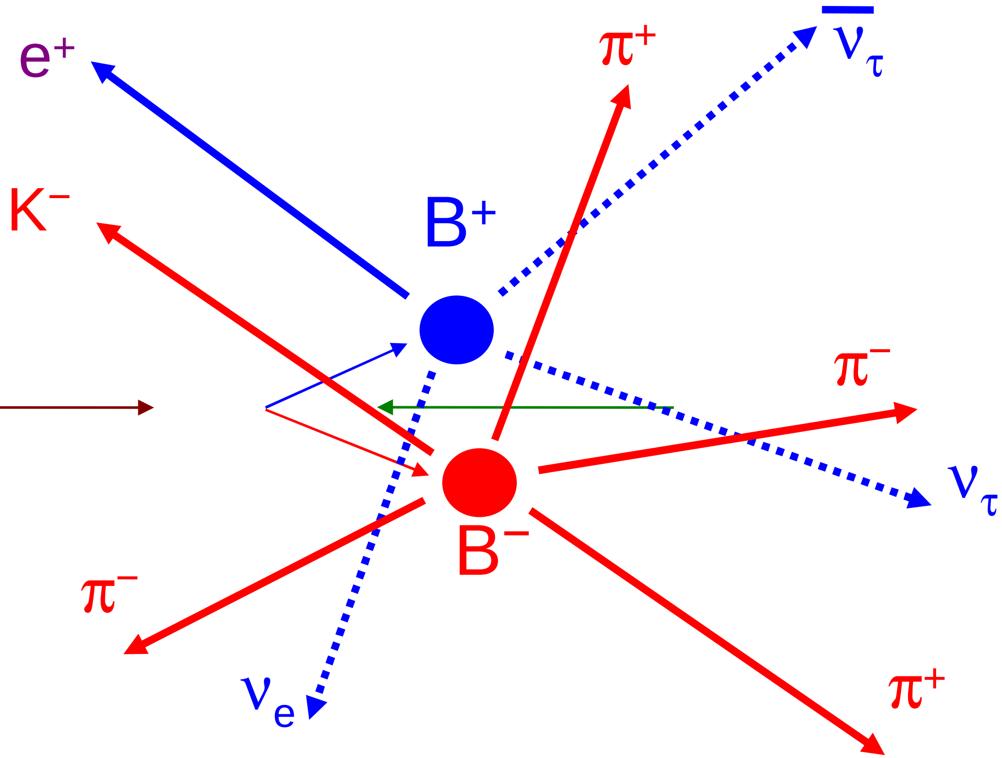


Tag one of the B mesons
- Fully reconstruct using hadronic mode.
- Tag with B semi-leptonic decays.

B→τν

$B^+ \to \tau^+ \nu_\tau$
$\tau^+ \to e^+ \nu_e \bar{\nu}_\tau$

B^- の方をちゃんと再構成する



$B^+ \to \tau^+ \nu_\tau$崩壊であれば、B^- の子供以外の検出可能な粒子はe^+だけ！

→ 荷電粒子の他には何もないということを要求する

B→τν

hadronic tags

449M $\bar{B}B$

$$BF(B \to \tau\nu) = [\mathbf{1.79}^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(syst)] \times 10^{-4}$$

first evidence 3.5σ

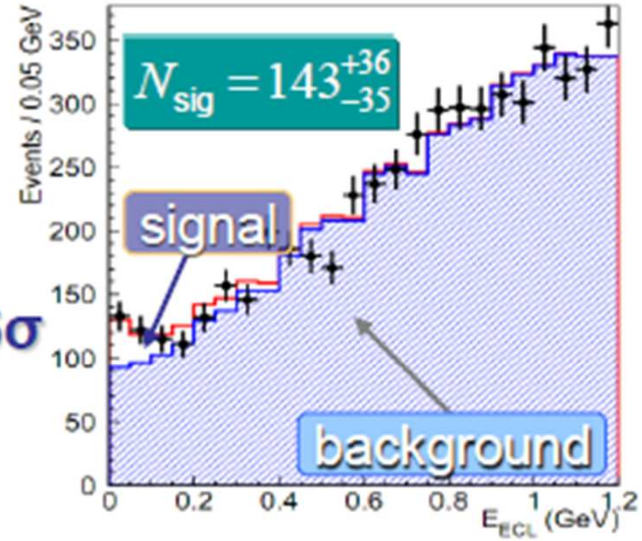
↑ significance

Belle Collab., PRL **97**, 251802 (2006)

semileptonic tags

NEW 657M $\bar{B}B$

3.6σ



$$BF(B \to \tau\nu) = [\mathbf{1.54}^{+0.38}_{-0.37}(stat)^{+0.29}_{-0.31}(syst)] \times 10^{-4}$$

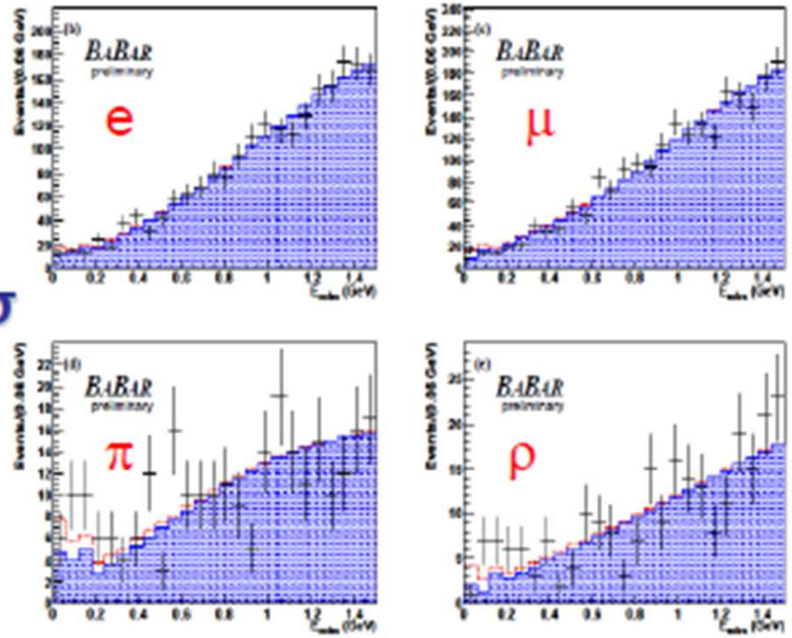
Belle Collab., arXiv: 1006.4201 submitted to PRD-RC

hadronic tags

NEW, *preliminary*

468 M $\bar{B}B$

3.3σ



$$BF(B \to \tau\nu) = [\mathbf{1.80}^{+0.57}_{-0.54}(stat) \pm 0.26] \times 10^{-4}$$

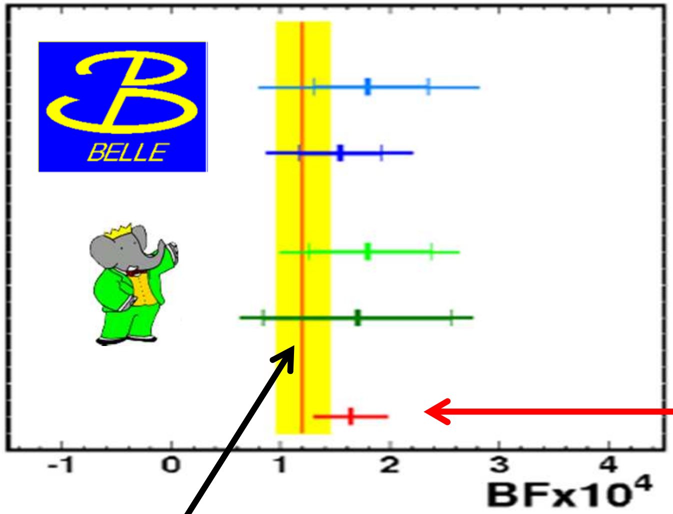
BaBar Collab., arXiv: 1008.0104

semileptonic tags

$$BF(B \to \tau\nu) = [\mathbf{1.7 \pm 0.8}(stat) \pm 0.2] \times 10^{-4}$$ 2.3σ

BaBar Collab., PRD **81**, 051101 (2010)

slide from M.Rozanska
@Charged Higgs 2010



$[1.79^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(syst)]\times10^{-4}$ hadronic tag

$[1.54^{+0.38}_{-0.37}(stat)^{+0.29}_{-0.31}(syst)]\times10^{-4}$ semileptonic tag

$[1.80^{+0.57}_{-0.54}(stat)\pm0.26(syst)]\times10^{-4}$ hadronic tag

$[1.7\pm0.8(stat)\pm0.2(syst)]\times10^{-4}$ semileptonic tag

HFAG $(1.64\pm0.39)\times10^{-4}$

Consistent with the SM: $(1.20 \pm 0.25)\times10^{-4}$

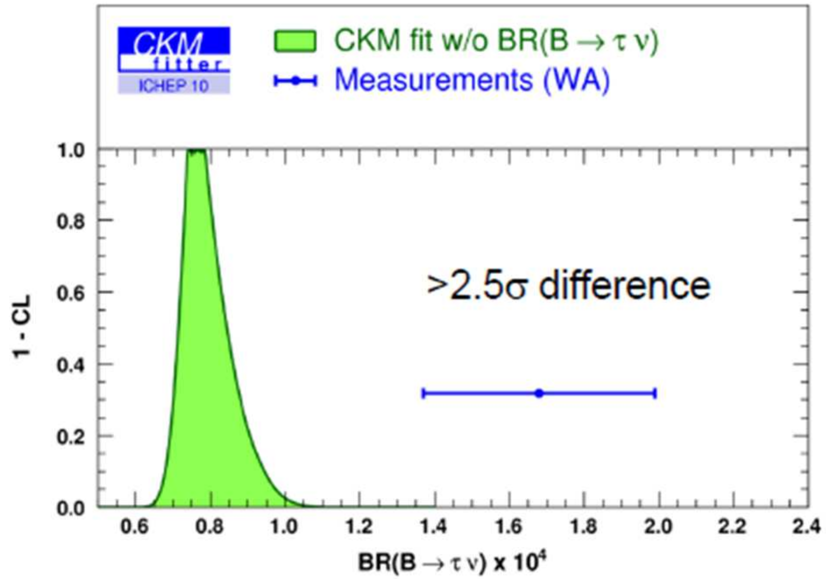
SM prediction

Alternative approach is to extract the B.F. from CKM fit (excluding direct meas.).

$BF(B\to\tau\nu)_{SM(CKM)} = [0.763^{+0.114}_{-0.061}]\times10^{-4}$ (CKMfitter)

$BF(B\to\tau\nu)_{SM(UT)} = [0.805\pm0.071]\times10^{-4}$ (UT fit)

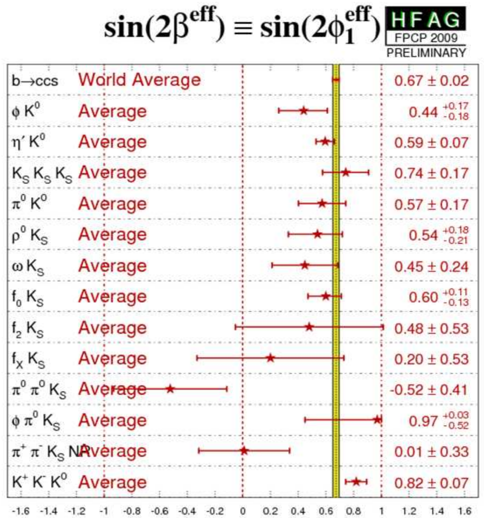
Tension!



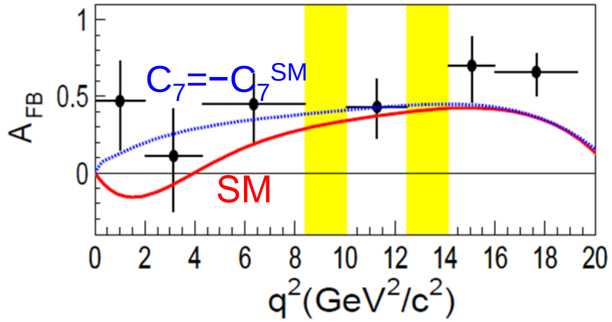
SuperKEKB & Belle II

Belleにおける新物理の兆候

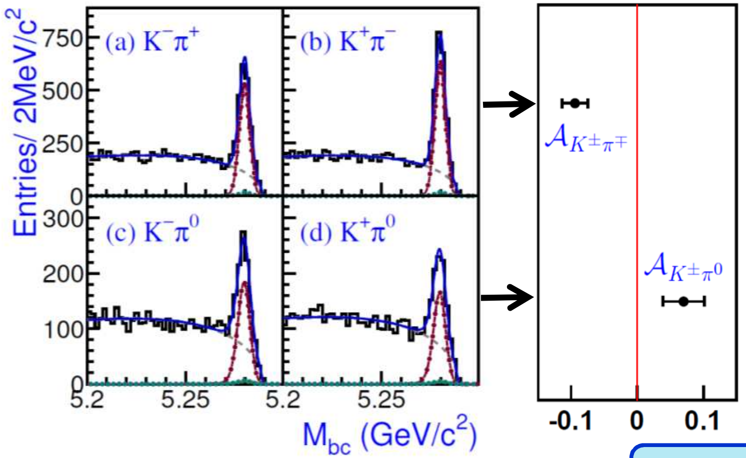
b→s遷移でCP非対称性に異常？



B→K*ℓ⁺ℓ⁻の前後方非対称性に異常？



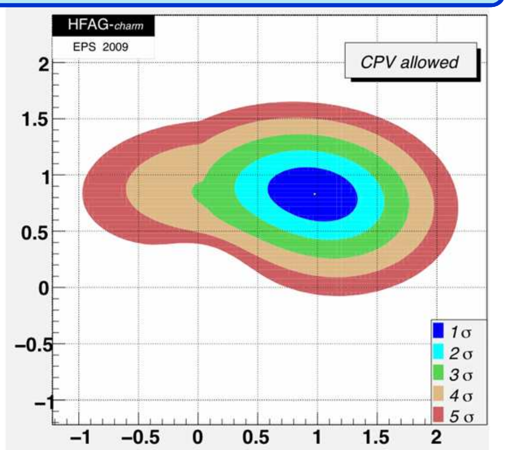
B⁰ とB±でCP非対称性の大きさに差異

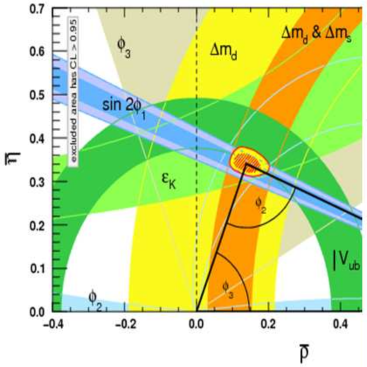


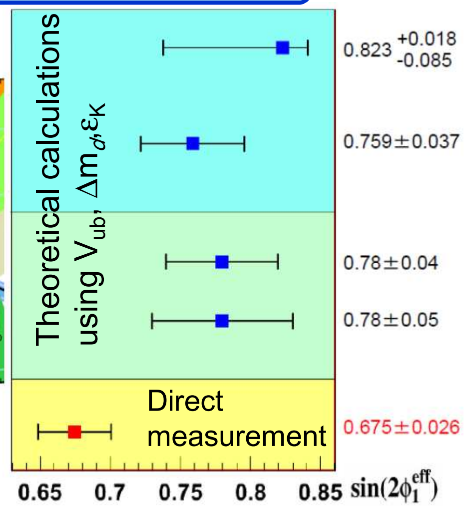
Belleでも新物理の信号が見え始めている？

ユニタリティー三角形に矛盾？

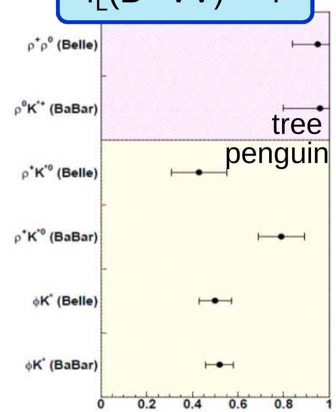
予想外に大きなD⁰-D̄⁰混合







$f_L(B\to VV) \neq 1$

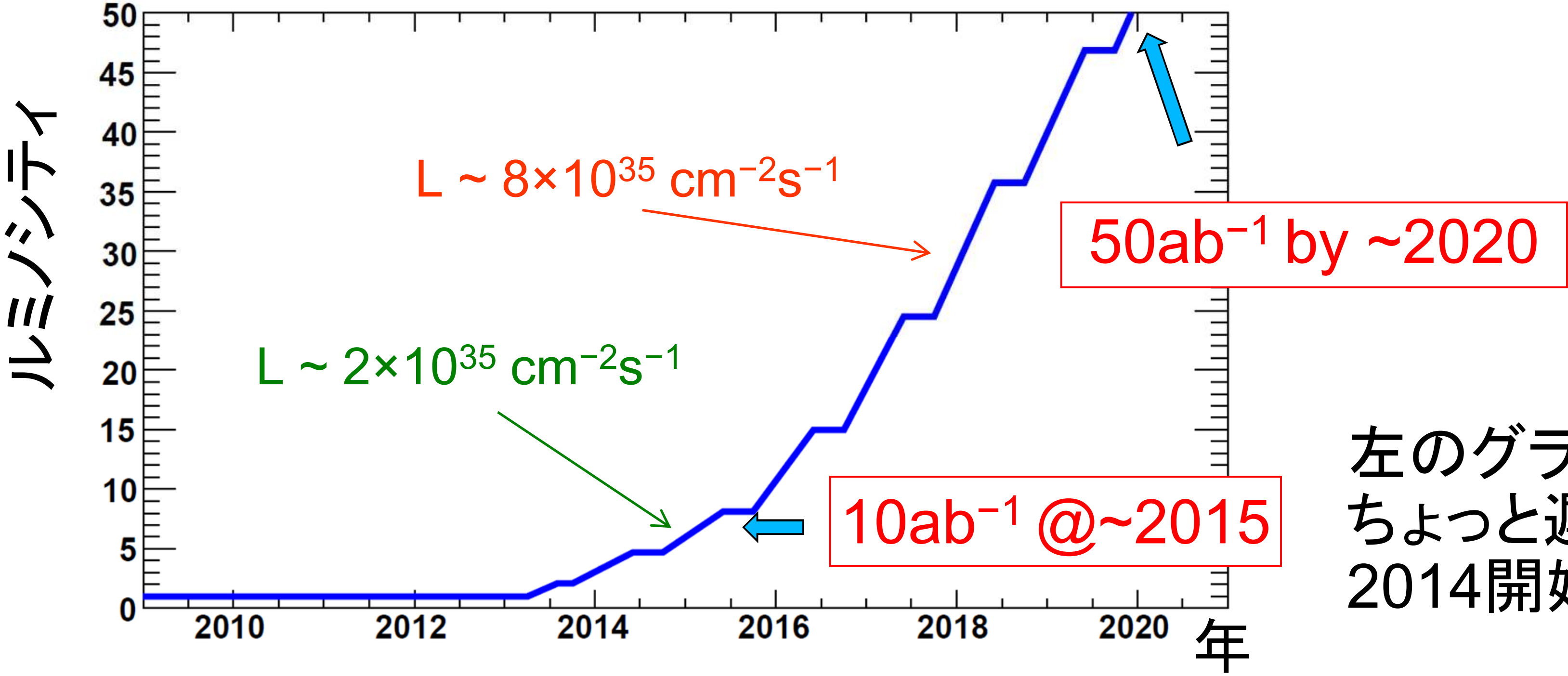


…..

SuperKEKB & Belle II

- (LHCで発見されると期待される)TeVスケールの新物理の解明。
- 小林益川行列のCP位相以外の、新しいCP位相の探索。
- これまでの「兆候？」の検証

➡ SuperKEKB加速器&Belle II実験



左のグラフより
ちょっと遅れてます
2014開始。

新物理の識別

Belle II では新物理が関与するモードを精査

➡ 超対称性理論のどの模型がもっとも正しいか、複数の角度から検証

代表的なSUSY模型 →

Belle II（又は他の実験）での観測量 ↓

	mSUGRA	MSSM+ν_R		SU(5)+ν_R		U(2) FS	…
		degenerate	non-degenerate	degenerate	non-degenerate		
$A_{CP}(s\gamma)$						✓	
$S(K^*\gamma)$				✓	✓	✓	
$S(\rho\gamma)$				✓	✓	✓	
$S(\phi K_S)$				✓	✓	✓	
$S(B_s \to J/\psi\,\phi)$				✓	✓	✓	
$\mu \to e\gamma$		✓		✓	✓	?	
$\tau \to \mu\gamma$		✓	✓	✓	✓	?	
$\tau \to e\gamma$			✓		✓	?	
⋮							

✔:標準模型からのずれ [based on T.Goto et.al. PRD77, 095010(2008)]

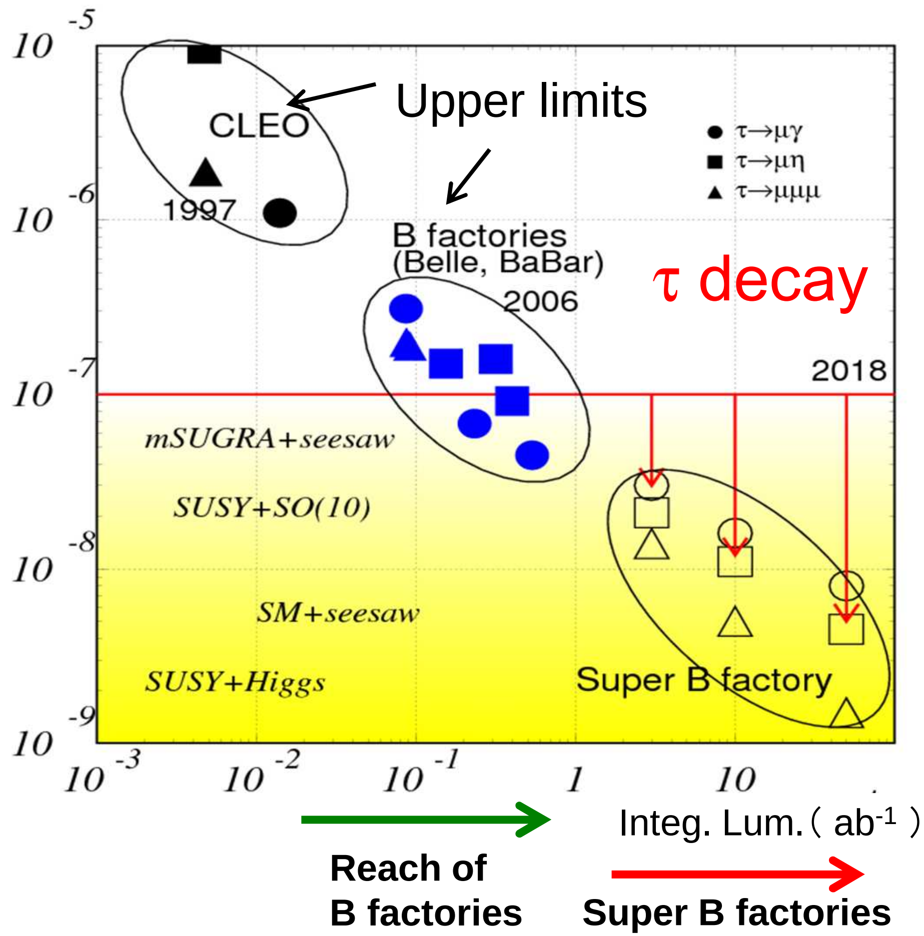
Physics with 50 ab^{-1}

Two recent publications:

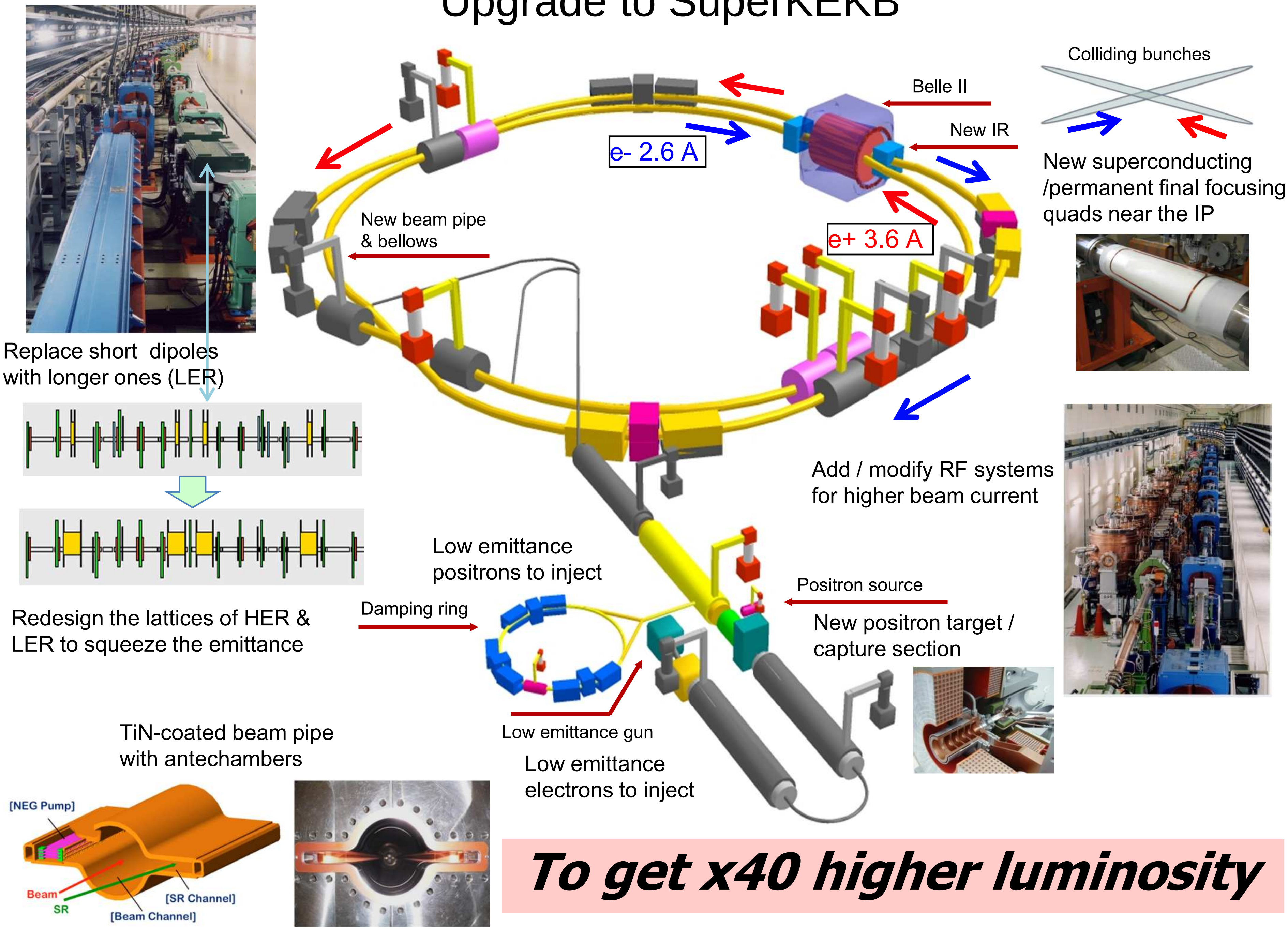
- Physics at Super B Factory (Belle II) arXiv:1002.5012
- SuperB Progress Reports: Physics (SuperB) arXiv:1008.1541

In addition to the topics in this talk,

- Photon polarization of $B \to K^* \gamma$.
- $B \to K^{(*)} \nu\nu$.
- CPV in D.
- LFV in τ decay.
- …

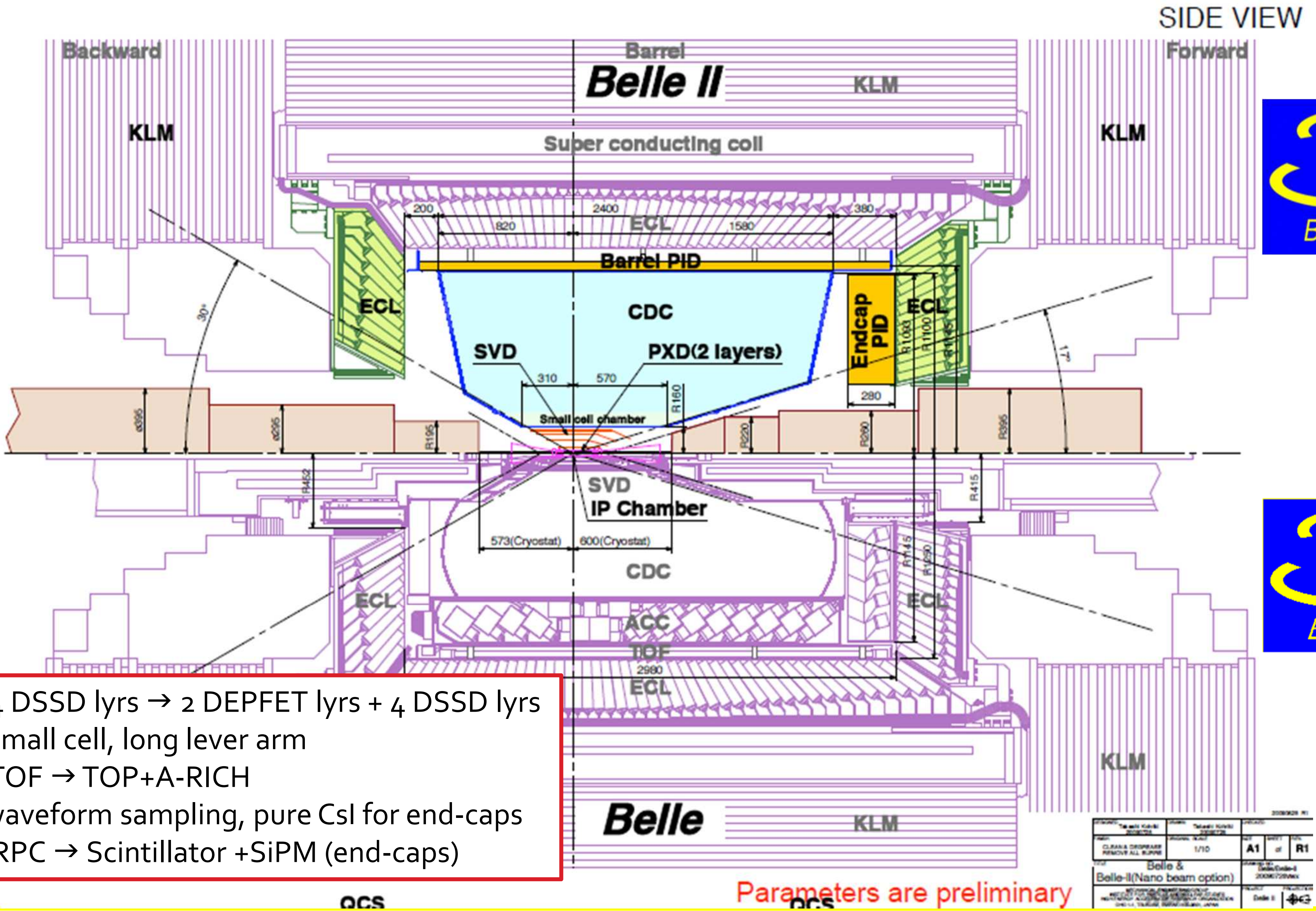


Upgrade to SuperKEKB



To get x40 higher luminosity

Belle II Detector



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)

まとめ

- 1999年に始まったBelle実験は2010年に運転終了
- sin2ϕ_1 の新測定（Belleの最終結果）
- B→τνなど新物理に感度のある崩壊
- Belle 2 へ（LHCで発見される新物理の識別）

Backup

Signal Reconstruction

$CP = -1$ modes:

Mode	Signal yield
$B \to J/\psi K_S^0$, $J/\psi \to l^+l^-$	12681 ± 114
$B \to \psi(2S) K_S^0$, $\psi(2S) \to l^+l^-$	908 ± 31
$\psi(2S) \to J/\psi \pi^+\pi^-$	1072 ± 33
$B \to \chi_{c1} K_S^0$, $\chi_{c1} \to J/\psi\gamma$	943 ± 33

$CP = +1$ mode:

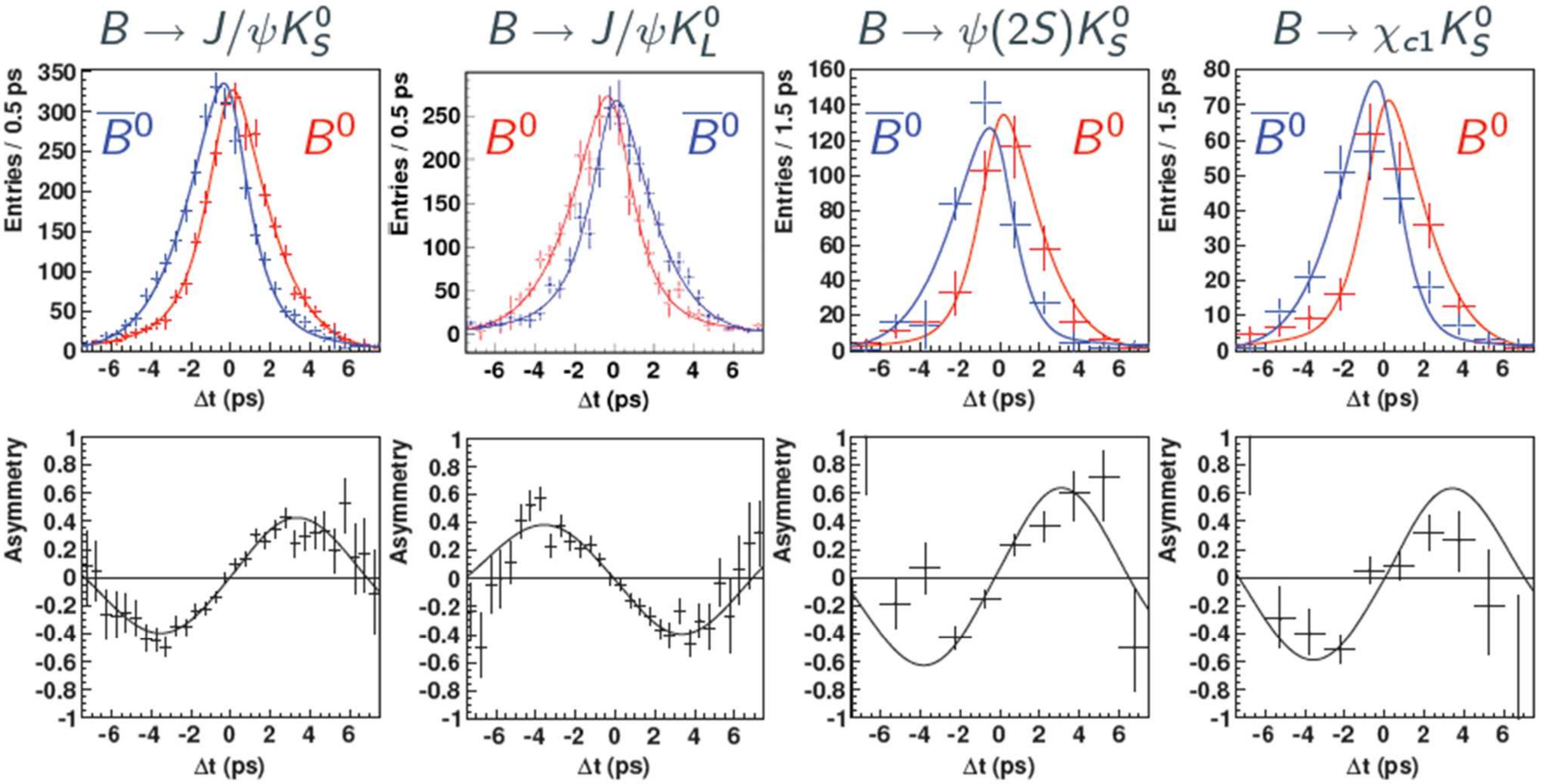
$B \to J/\psi K_L^0$ Signal yield: 10041 ± 154

Missing information about K_L^0 momentum:
K_L^0 cluster reconstructed in ECL or KLM,
match it with the K_L^0 direction from
kinematical constraints.

Measurement of sin2ϕ_1

Good tag only, background subtracted.

Belle preliminary



$S = 0.671 \pm 0.029$ $A = -0.014 \pm 0.021$

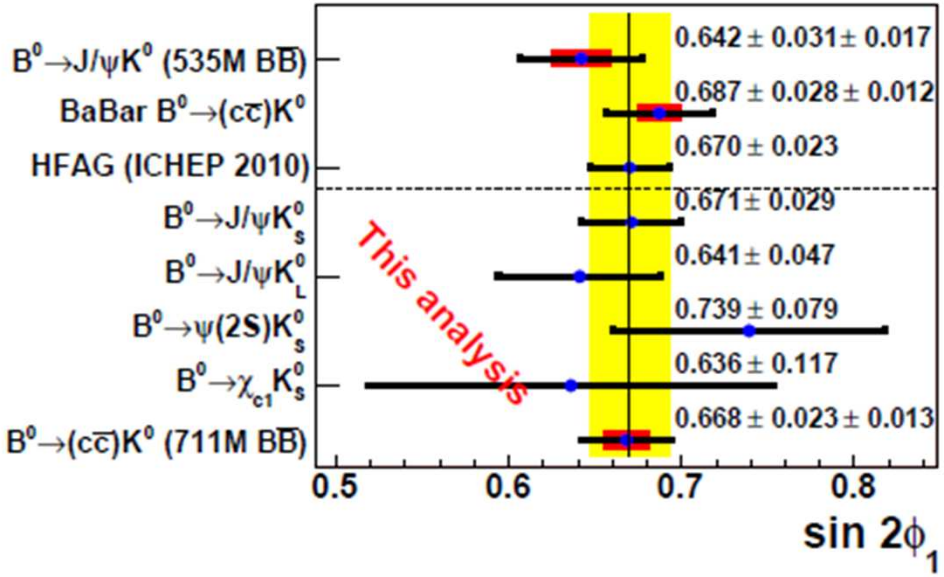
$S = 0.641 \pm 0.047$ $A = 0.019 \pm 0.026$

$S = 0.739 \pm 0.079$ $A = 0.103 \pm 0.055$

$S = 0.636 \pm 0.117$ $A = -0.023 \pm 0.083$

CP violation is observed in all modes

Measurement of sin2ϕ_1



Belle preliminary

Systematic errors:

	ΔS	ΔA
Vertexing	$^{+0.008}_{-0.009}$	±0.008
Flavor tagging	$^{+0.004}_{-0.003}$	±0.003
Resolution function	±0.007	±0.001
Physics parameters	±0.001	< 0.001
Fit bias	±0.004	±0.005
$J/\psi K^0_S$ signal fraction	±0.002	±0.001
$J/\psi K^0_L$ signal fraction	±0.004	$^{+0.000}_{-0.002}$
$\psi(2S)K^0_S$ signal fraction	< 0.001	< 0.001
$\chi_{c1}K^0_S$ signal fraction	< 0.001	< 0.001
Background Δt	±0.001	< 0.001
Tag-side interference	±0.001	±0.008
Total	±0.013	±0.013

Significant improvement in sys. error (vertexing, resolution function)

Combination of four modes:

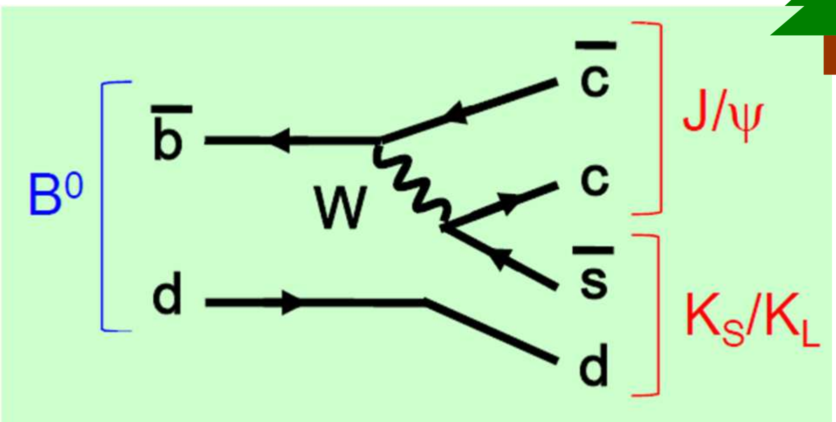
$$S = 0.668 \pm 0.023 \pm 0.013\ (\text{syst})$$

$$A = 0.007 \pm 0.016 \pm 0.013\ (\text{syst})$$

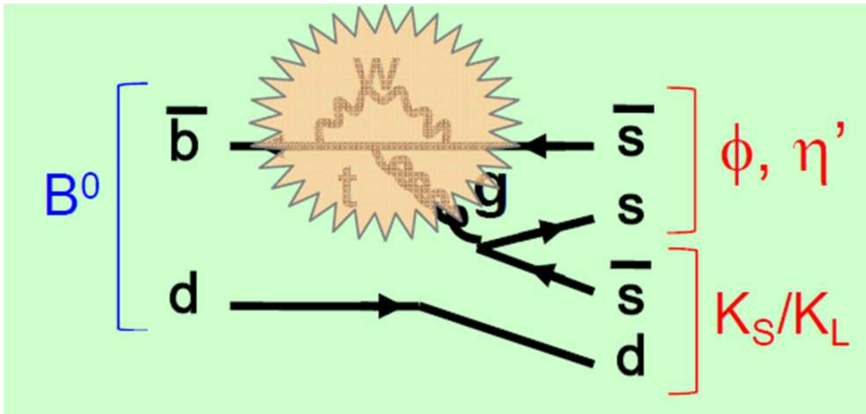
Expect tension in CKM fit to be loosened

CP Violation in b→s

b→c ($B \to J/\psi K^0$)



b→s ($B \to \phi K^0, \eta' K^0$)

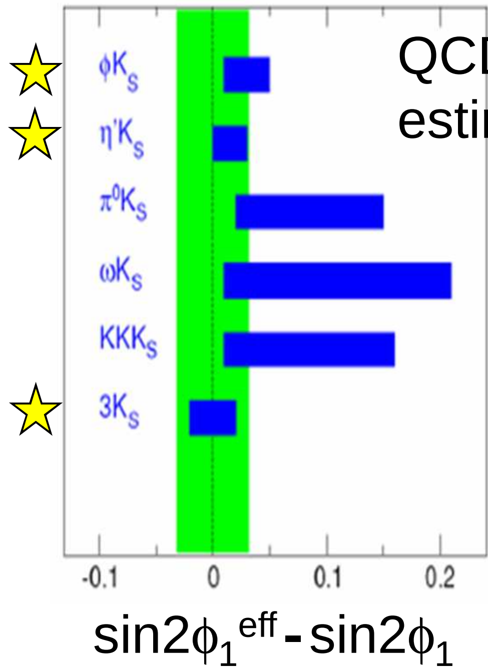


In the SM,

$S = -\xi \sin(2\phi_1)$

for b→s processes, but possible discrepancy due to non-SM contribution.

- The theoretical uncertainty (within SM) depends on the final states.
- $B \to K^0K^0K^0$, ϕK^0, $\eta' K^0$ are the cleanest modes (δS_{theory} ~a few %).



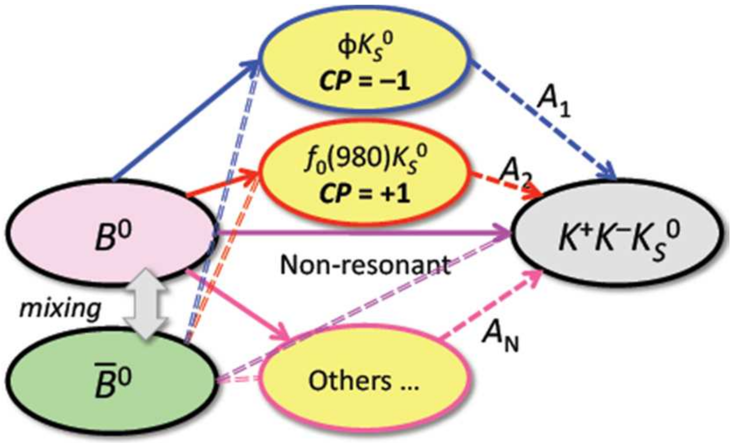
QCDF estimates

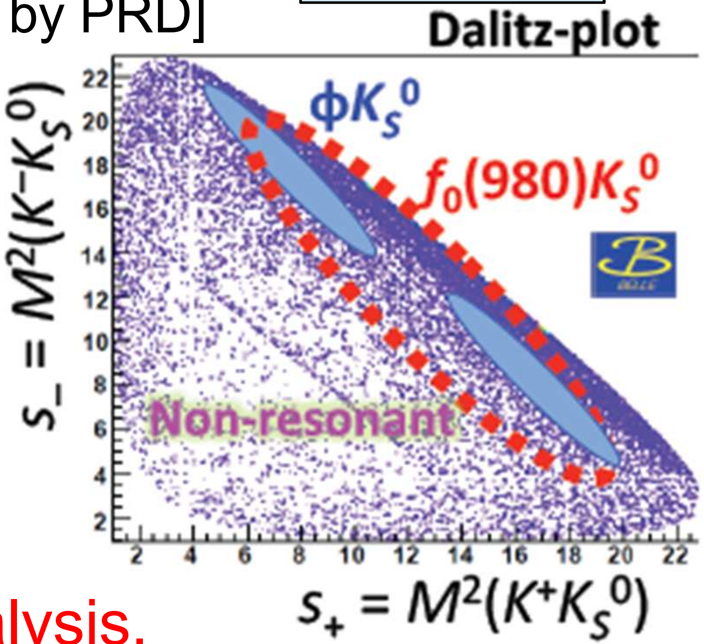
$B \to K^+K^-K_S$

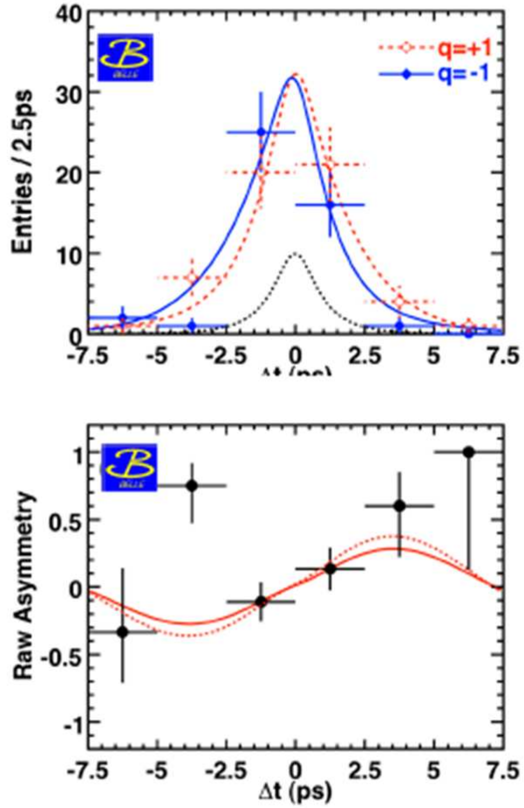
New Belle result on $B \to K^+K^-K_S$

[arXiv:1007.3848, accepted by PRD]

657M $B\bar{B}$







ϕ mass region

- Time dependent Dalitz analysis.
- Measure ϕ_1^{eff} associated with individual intermediate state.
- Multiple solutions; preferred one chosen with external information.

ϕK_S: $\phi_1^{eff} = (32.2 \pm 9.0 \pm 2.6 \pm 1.4)°$

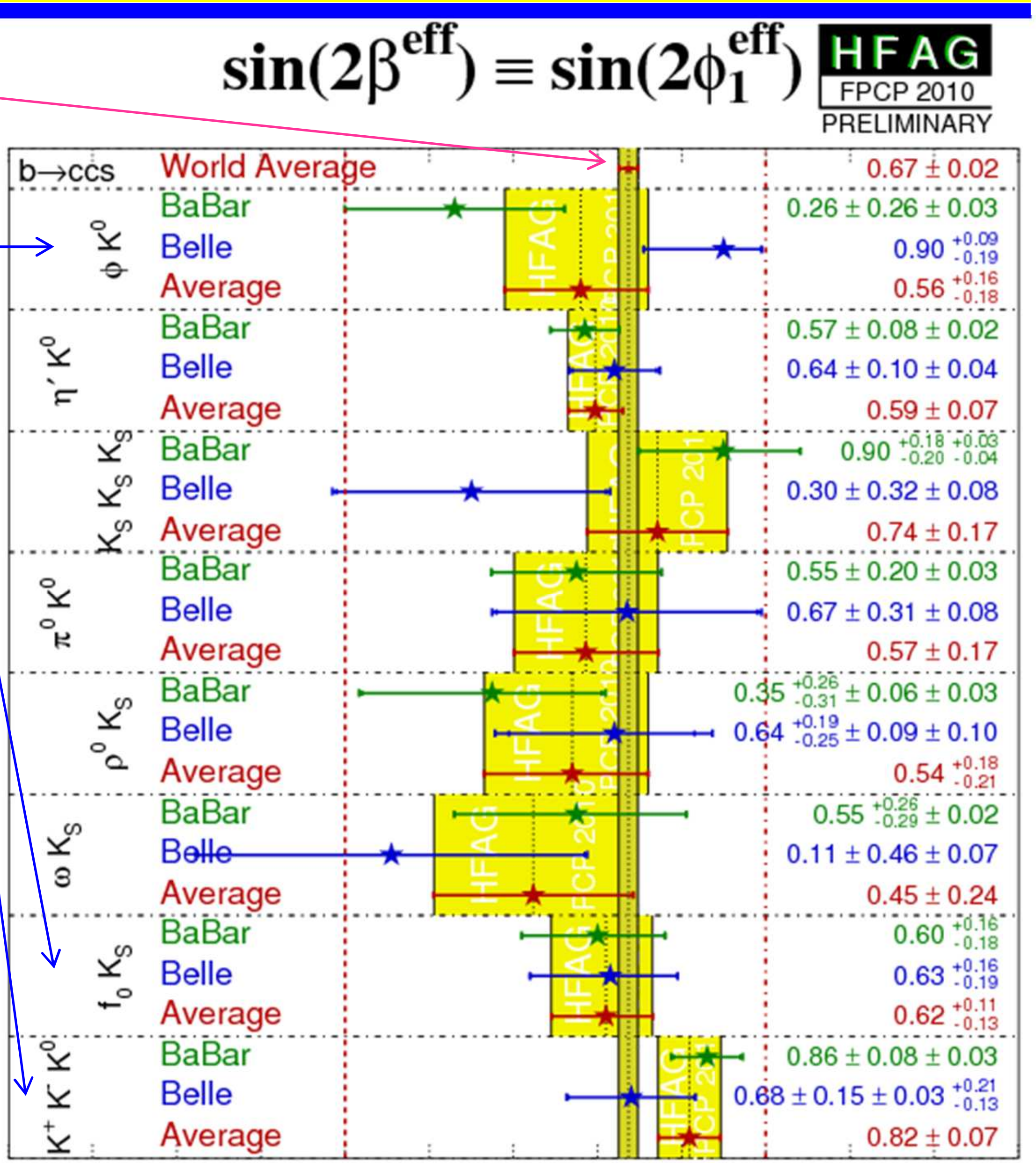
$f_0(890)K_S$: $\phi_1^{eff} = (31.3 \pm 9.0 \pm 3.4 \pm 4.0)°$

$\phi_1 = (21.1 \pm 0.9)°$

CP Violation in b→s

sin2ϕ_1 from b→ccs (reference)

new Belle result



- Now in a good agreement with the SM.
- New CPV effect can be seen with much larger data (note: predicted $\delta\Delta\sin2\phi_1$~ O(%))

Super B Factories

- Although there exist interesting possible hints for the NP at the present B factories, all the results are consistent with the SM.
- NP should exist at the higher energy scale, possibly in TeV region considering the hierarchy problem → LHC will discover it.
- Super B factories can help the identification of the NP, i.e. whether it is SUSY or others, or how SUSY breaking occurs.

SUSY scenario →

Observables @ Super B factories or other experiments ↓

	mSUGRA	MSSM+ν_R		SU(5)+ν_R		U(2) FS
		degenerate	non-degenerate	degenerate	non-degenerate	
$A_{CP}(s\gamma)$						✓
$S(K^*\gamma)$				✓	✓	✓
$S(\rho\gamma)$				✓	✓	✓
$S(\phi K_S)$				✓	✓	✓
$S(B_s \to J/\psi\ \phi)$				✓	✓	✓
$\mu \to e\gamma$		✓		✓	✓	?
$\tau \to \mu\gamma$		✓	✓	✓	✓	?
$\tau \to e\gamma$			✓		✓	?

[based on T.Goto et.al. PRD77, 095010(2008)]

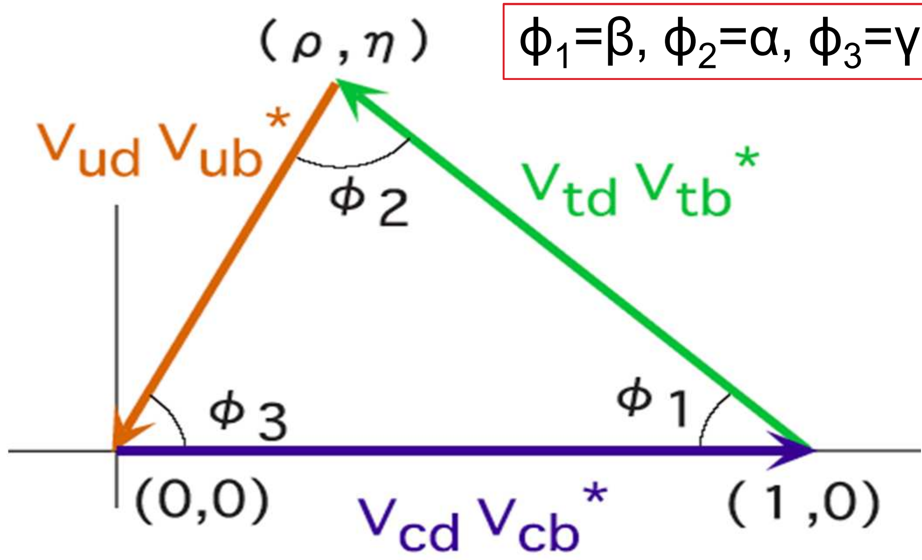
Unitarity Matrix

CKM matrix is unitary:

$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$

- This relation becomes a triangle in the complex plane = Unitarity Triangle
- Other triangles tend to be “collapsed”.
- Non-zero ϕ_1 or ϕ_3
  = Complex phase in the CKM matrix
  = Strong support of KM mechanism.

$\phi_1=\beta,\ \phi_2=\alpha,\ \phi_3=\gamma$

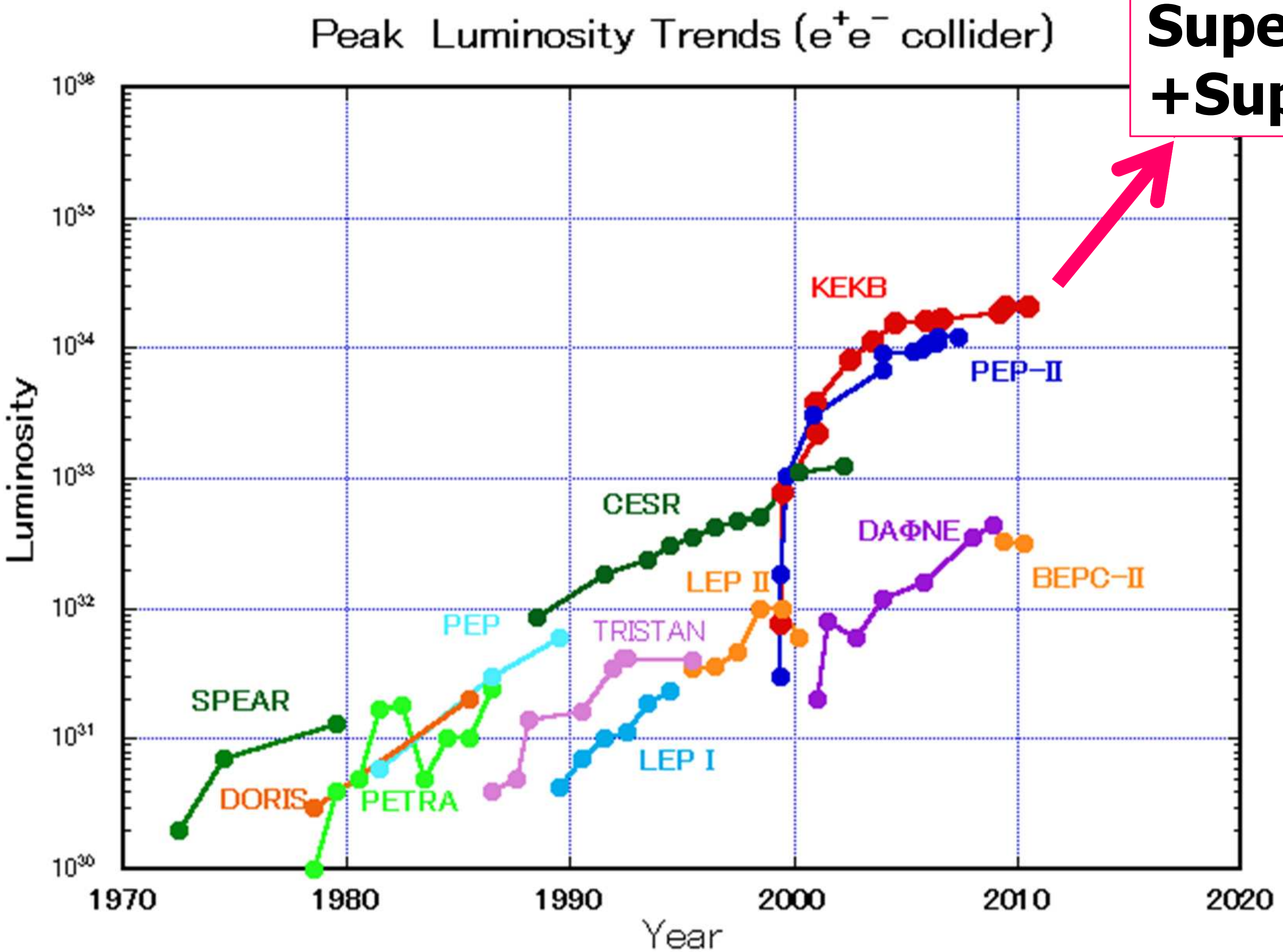


$$V=\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

- Precise measurement of Unitarity Triangle is one of the main goal of B factory experiments.
- Various B decay modes can be used to measure the angles and sides of the triangle.

Super B Factories

Increase the luminosity by ~2 orders of magnitudes!!



SuperKEKB +SuperB

Japan (KEK)

Italy (INFN)

Target

SuperKEKB
$50\ ab^{-1}$
$8 \times 10^{35}\ cm^{-2}\ s^{-1}$

Super B
$75\ ab^{-1}$
$1 \times 10^{36}\ cm^{-2}\ s^{-1}$

Nano Beam Scheme

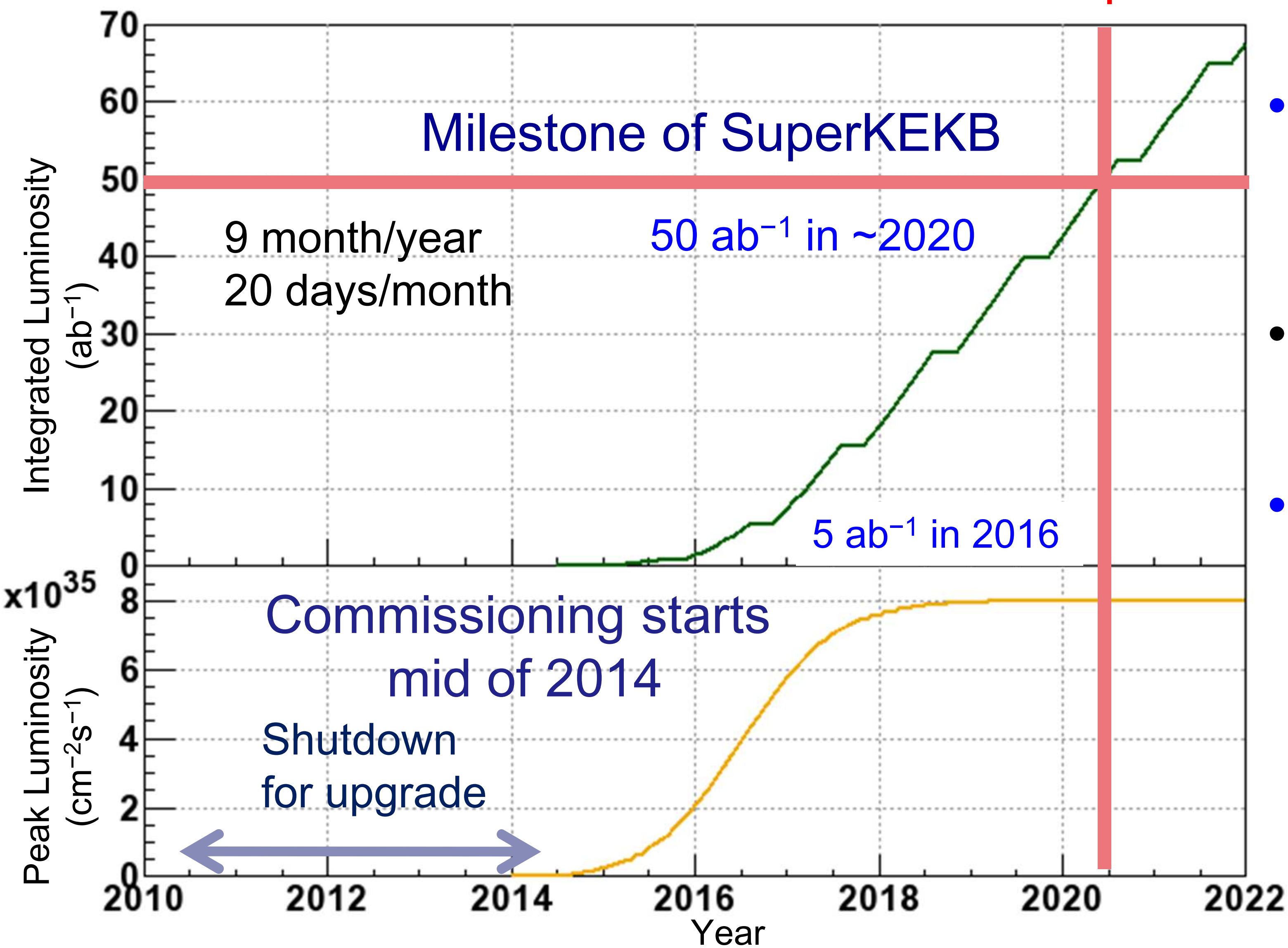
	KEKB		SuperKEKB		SuperB		Units
	LER	HER	LER	HER	LER	HER	
Beam Energy	3.5	8	4	7	4.18	6.7	GeV
Half crossing angle	11		41.5		33		mrad
Beta func. @ IP (x/y)	1200 / 5.9		32 / 0.27	25 / 0.31	26 / 0.253	32 / 0.205	mm
Beam current	1.64	1.19	3.60	2.60	1.892	2.447	A
Luminosity [$\times 10^{34}$]	2.1		80		100		$cm^{-1}s^{-1}$

[detailed tables are in backup slides]

- Collision with very small spot-size beam.
- Increase beam current (moderately)
- Larger crossing angle.
- Change beam energy to symmetric side (to solve LER short lifetime).
- SuperB has plan to run at τ-charm threshold with ~ 10^{35} $cm^{-1}s^{-1}$

SuperKEKB Schedule

SuperKEKB is approved!



- 10 billion yen (~90 million EUR) for machine.
- Continue efforts to obtain additional funds.
- Funds from several non-Japanese agencies.

Nobel Prize

2008 Nobel Prize in Physics

Makoto Kobayashi
Toshihide Maskawa

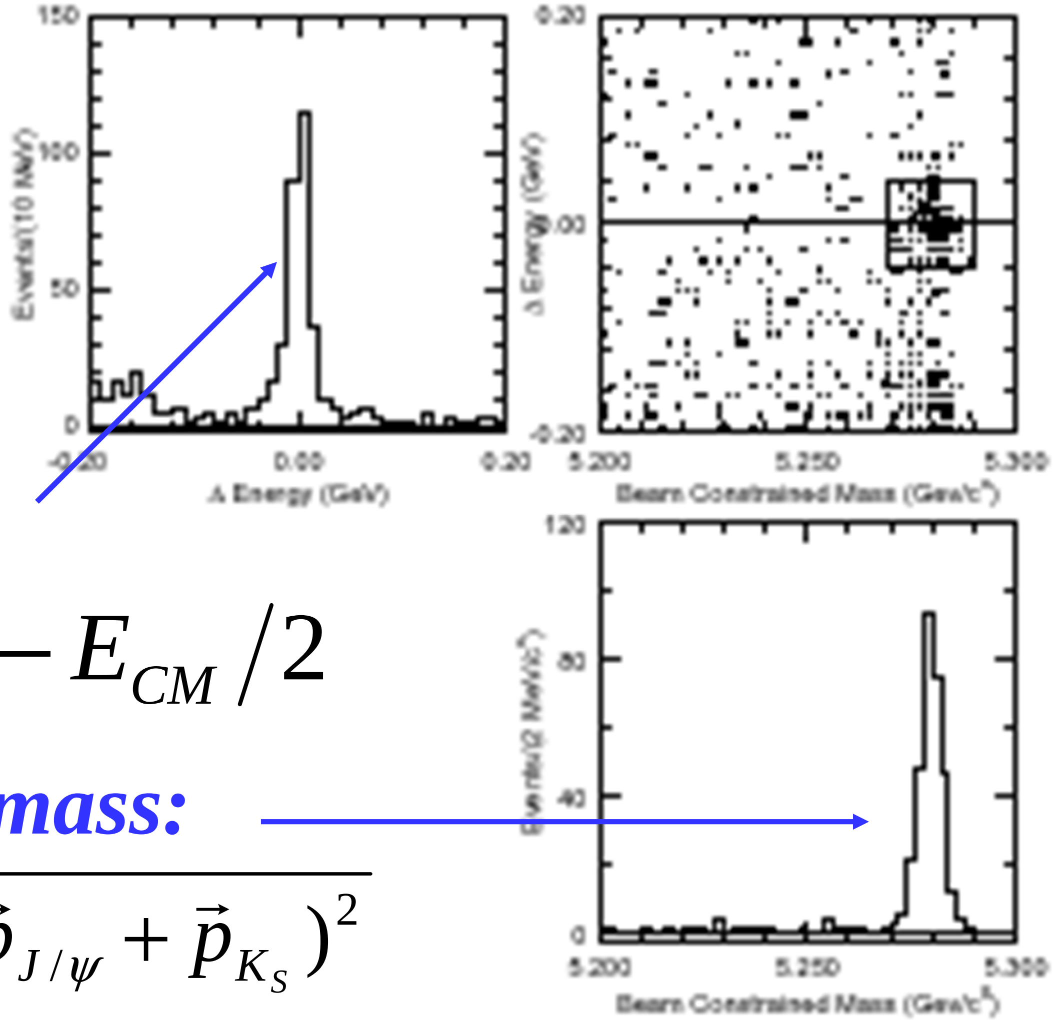
for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature

CP Violation

The spontaneous broken symmetries that Nambu studied, differ from the broken symmetries described by **Makoto Kobayashi** and **Toshihide Maskawa**. These spontaneous occurrences seem to have existed in nature since the very beginning of the universe and came as a complete surprise when they first appeared in particle experiments in 1964. It is only in recent years that scientists have come to fully confirm the explanations that Kobayashi and Maskawa made in 1972. It is for this work that they are now awarded the Nobel Prize in Physics. They explained broken symmetry within the framework of the Standard Model, but required that the Model be extended to three families of quarks. These predicted, hypothetical new quarks have recently appeared in physics experiments. As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier.

Press release by the Royal Swedish Academy of Science

Utilize special kinematics at $\Upsilon(4S)$



Energy difference:

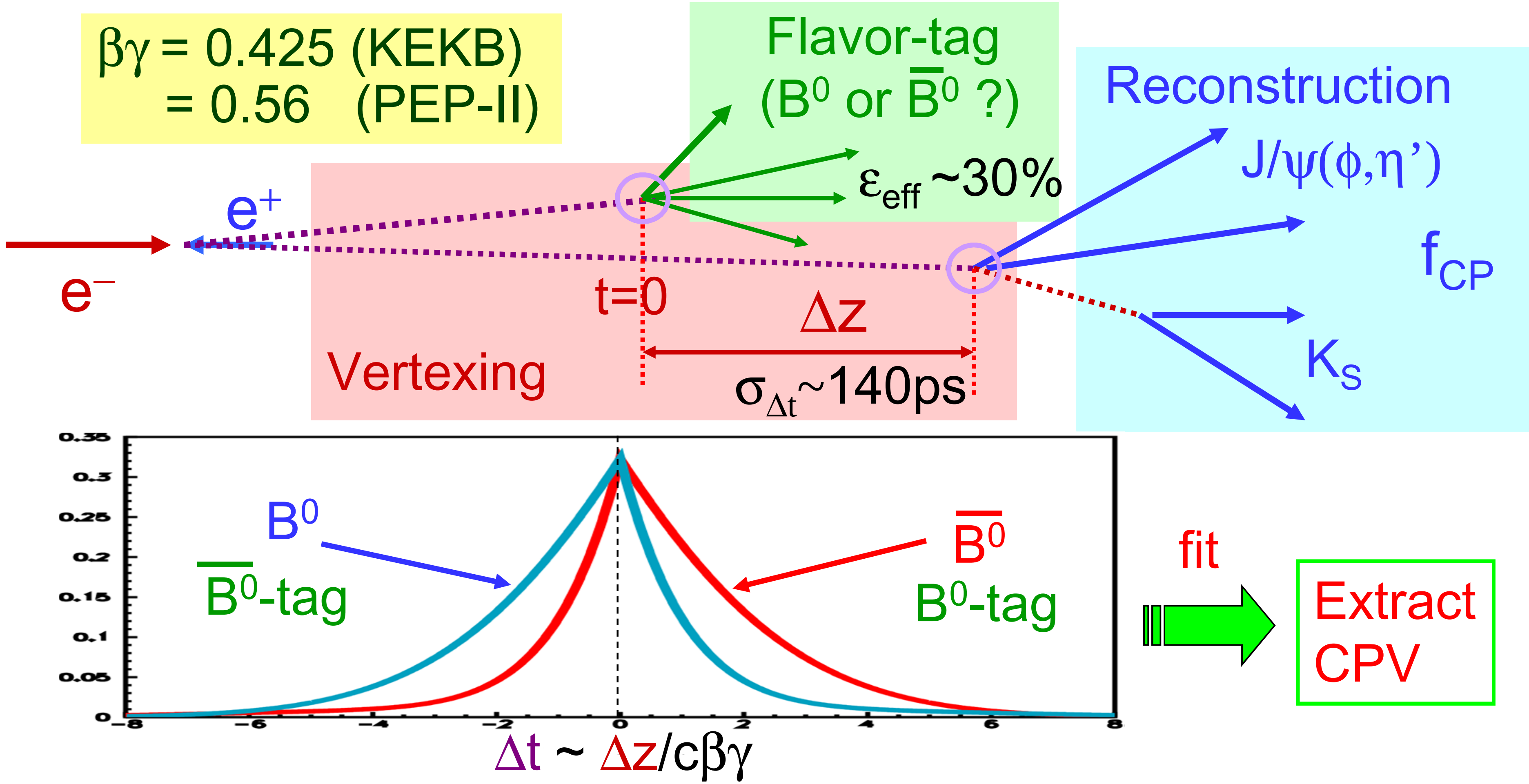
$$\Delta E \equiv E_{J/\psi} + E_{K_S} - E_{CM}/2$$

Beam-constrained mass:

$$M_{\rm bc} = \sqrt{(E_{CM}/2)^2 - (\vec{p}_{J/\psi} + \vec{p}_{K_S})^2}$$

Asymmetric Collider

- Asymmetric energy to study time-dependent CP Violation (tCPV)
- Measure position instead of time (B lifetime ~1.6ps)

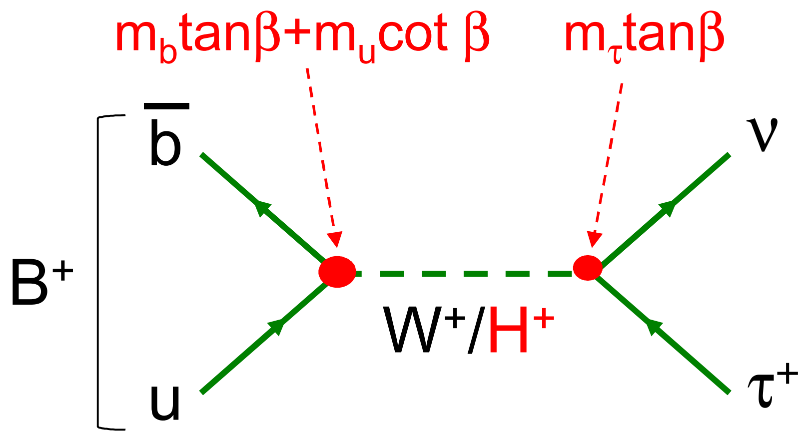


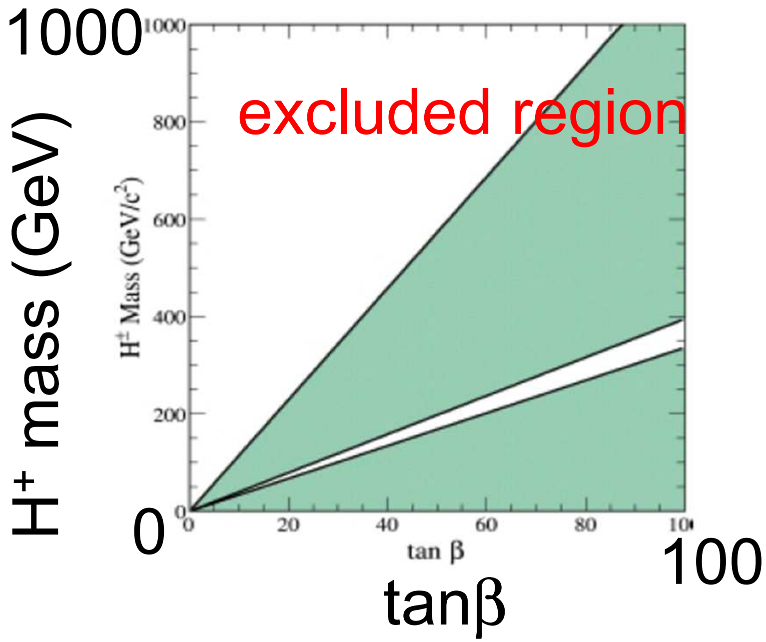
B→τν

Limit to charged Higgs mass.

$$Br(B \to l\nu) = BR_{SM} \times \left(1 - \tan^2\beta \frac{m_B^2}{m_H^2} \right)^2$$

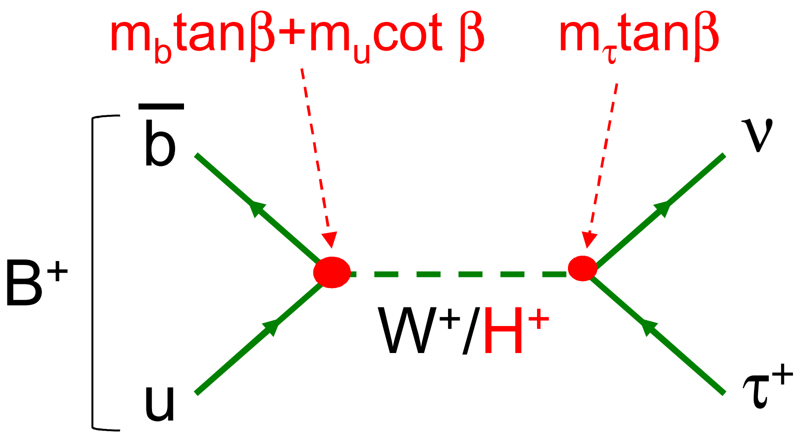
(Type II '2HDM')





Unique opportunity to study b-H^+-u interaction

$B \to \tau\nu$



$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{SM} \times r_H$$

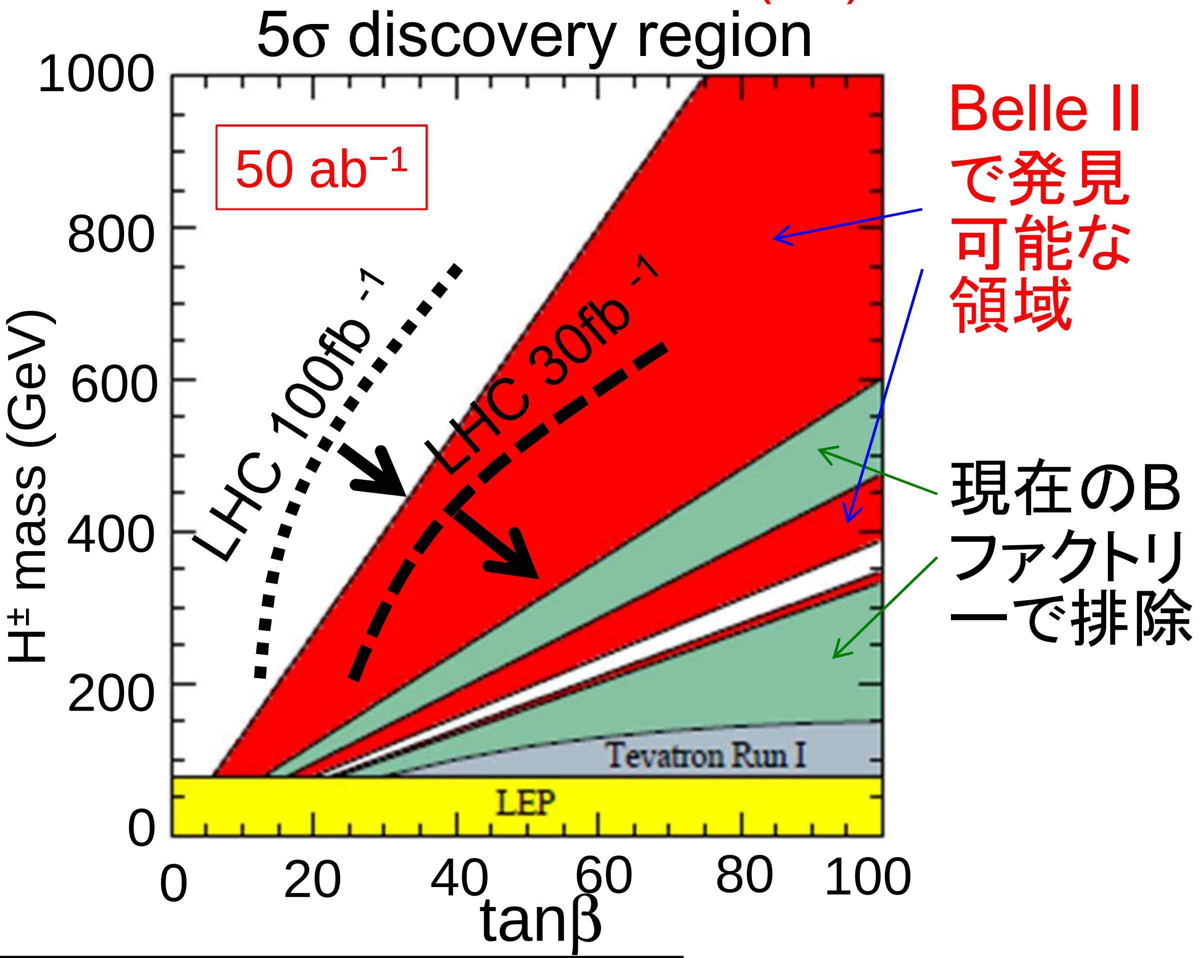
$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

$\mathcal{B}(B \to \tau\nu) = (1.53 \pm 0.33) \times 10^{-4}$
[ICHEP2008]

$\sigma \sim 2\%$ @50 ab^{-1}

f_B と $|V_{ub}|$ の誤差を数%まで減らすことが重要（右図はともに 2.5% を仮定）

- 標準模型では W-消滅過程
- SUSYでは荷電ヒッグス(H^+)の寄与



b-H^+-u 結合を測定する唯一の手段

$B \to K^{(*)}\nu\nu$

arXiv:1002.5012

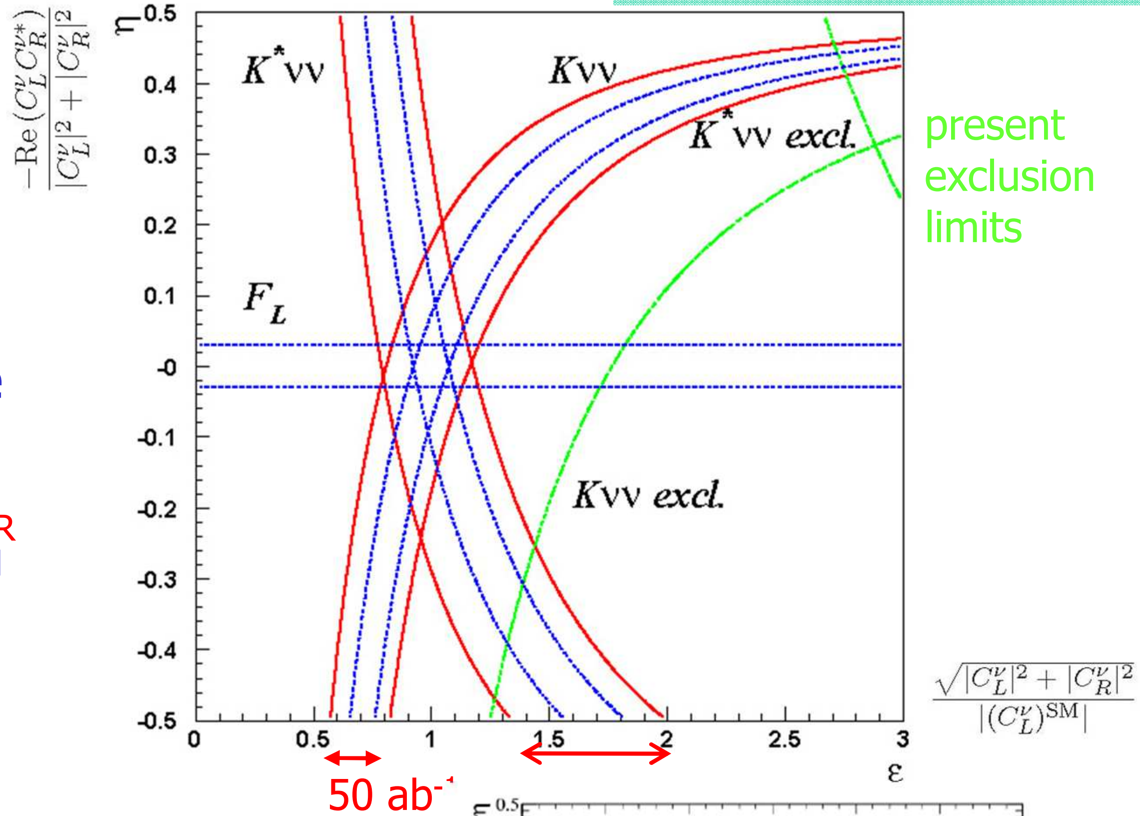
adopted from W. Altmannshofer et al., JHEP 0904, 022 (2009)

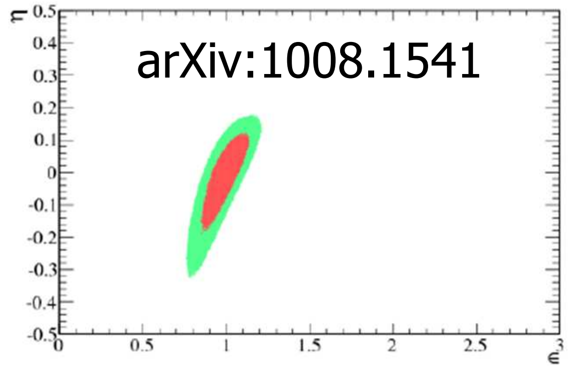
$B \to K\nu\nu$, $\mathcal{B} \sim 4\cdot10^{-6}$
$B \to K^*\nu\nu$, $\mathcal{B} \sim 6.8\cdot10^{-6}$

SM: penguin+box

Look for departure from the expected value → information on couplings C^ν_R and C^ν_L compared to $(C^\nu_L)^{SM}$

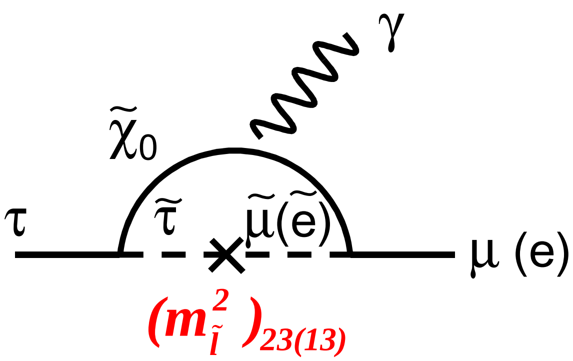
Again: fully reconstruct one of the B mesons, look for signal (+nothing else) in the rest of the event.



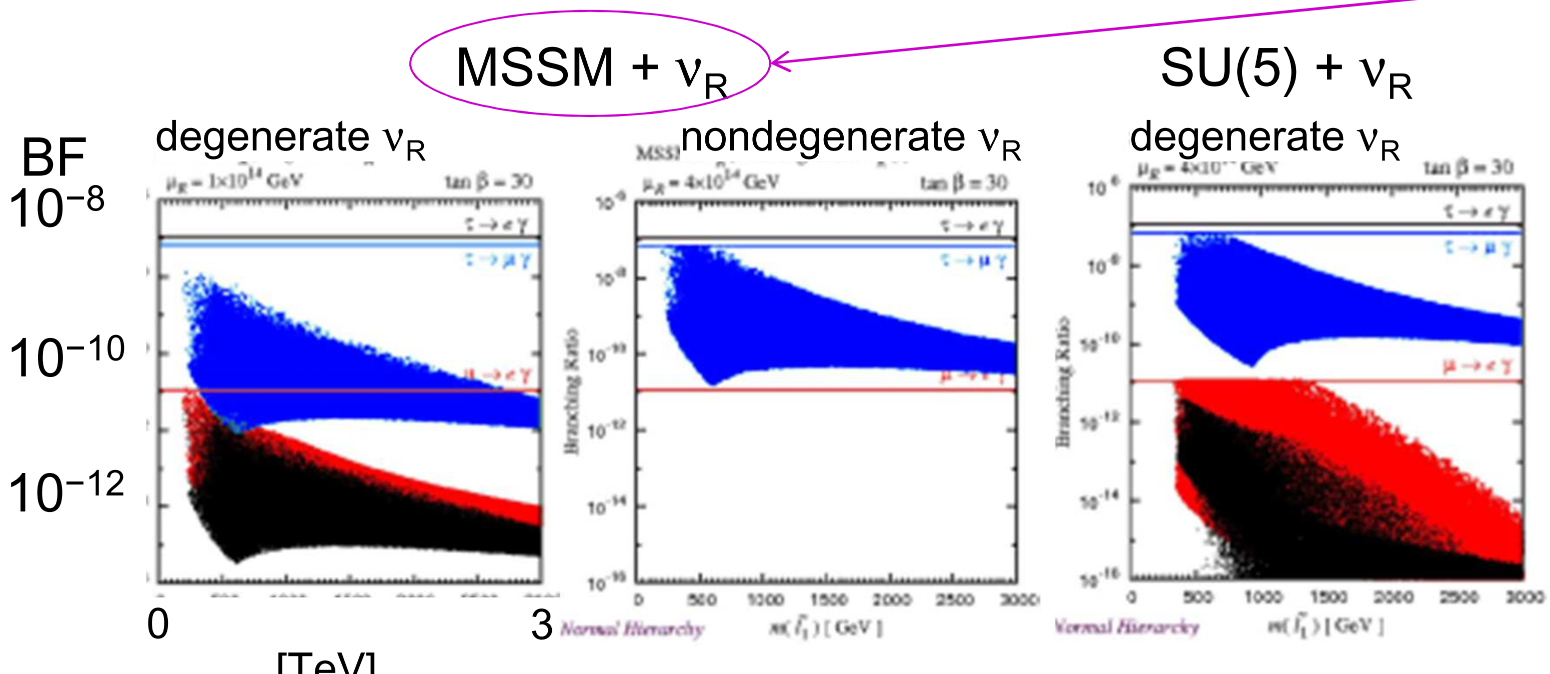


τ LFV

- レプトンフレーバーの破れ(LFV):標準模型では禁止
- 多くの新物理モデルでは予言されている
- Bファクトリーでは、大量の τ 対が作られる（τ ファクトリー）。
- τ の崩壊:第3世代と第2(1)世代の混合



クォークセクターには新物理の効果があまり現れないモデル



$\tau \rightarrow \mu\gamma$

$\tau \rightarrow e\gamma$

$\mu \rightarrow e\gamma$

horizontal axis = lightest charged slepton mass

Nano Beam Scheme

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

Lorentz factor

Beam current

Beam-beam parameter

Lumi. reduction factor (crossing angle)&
Tune shift reduction factor (hour glass effect)
0.8 ~ 1 (short bunch)

Classical electron radius

Beam size ratio@IP
1 ~ 2 % (flat beam)

Vertical beta function@IP

(1) Smaller β_y^*
(2) Increase beam currents
(3) Increase ξ_y

"Nano-Beam" scheme

Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

SuperKEKB

parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	ϕ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	5.0	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^* / β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0886	0.0830	
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

M. Iwasaki, ICHEP2010