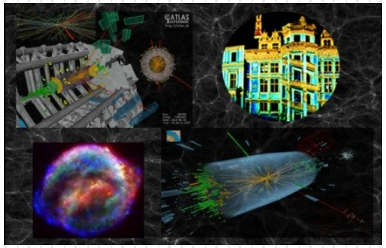
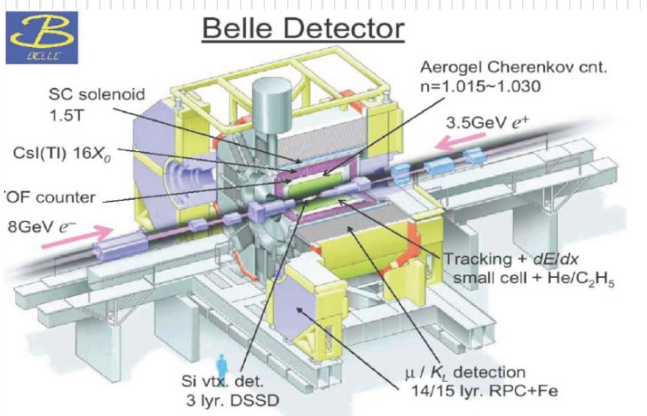


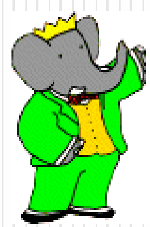
25th Recontres de Blois 2013,
Particle Physics and Cosmology

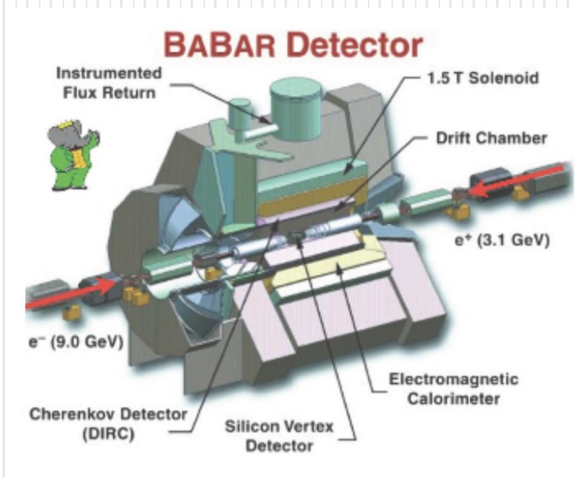
Flavor Physics at e^+e^- collider status and outlook



Hisaki Hayashii
Nara, Japan

for





26-31, May, 2013, Blois, France

2013/5/30

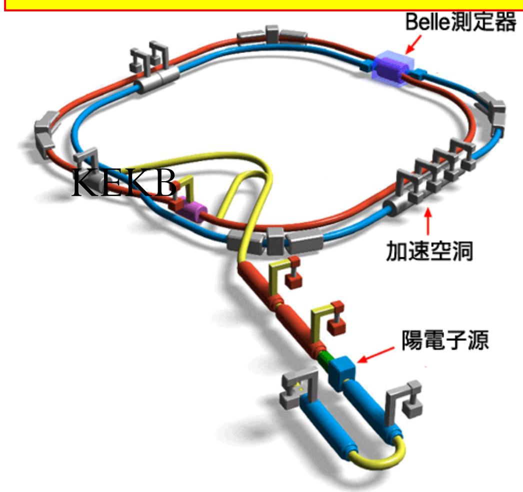
Outline

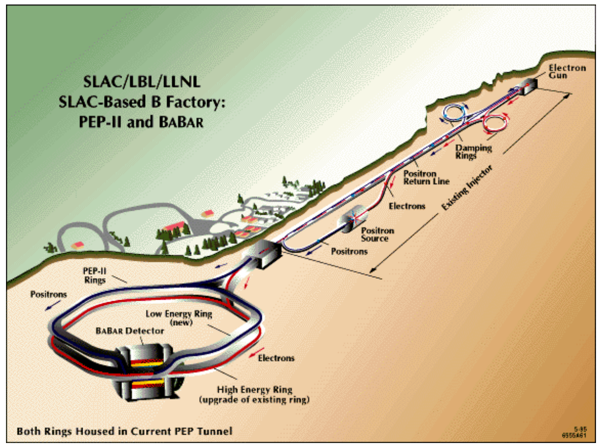
See also
- "Charged Higgs constraints from flavor physics", R.Itoh
- " Search for rare decays of B mesons at B-factories", R.Cheaib

- Introduction
- Rare B decays and constraints for charged Higgs
  - $B \to X_s \gamma$
  - $B \to \tau \nu$
  - $B \to D^{(*)} \tau \nu$
- CP violation in the B system and the unitarity triangle
  - angles: ϕ_1, ϕ_2, ϕ_3
  - V_{ub}
- Other rare decays $B \to h \bar{\nu} \nu$
- Belle II status

Introduction: Belle and Babar, the luminosity frontier asymmetric B factories

Belle and BaBar shaped flavor Physics to a large degree in the previous decade.





Exp.	Resonance	Luminosity(fb^{-1}) (On/off peak)
BaBar	Υ(4S)	424.2 /43.9
	Υ(3S)	28.0/2.6
	Υ(2S)	13.6/1.4
	SCAN	0/4
Belle	Υ(5S)	121.1/1.7
	Υ(4S)	703.3/89.4
	Υ(3S)	2.9/0.2
	Υ(2S)	24.9/1.7
	Υ(1S)	5.7/1.8
	SCAN	0/25.6

$\sqrt{s}=10.58$ GeV

$e^+ \rightarrow \Upsilon(4s) \leftarrow e^-$

$\Upsilon(4s)$ → B, $\bar{B}$

$\Delta z \sim c\beta\gamma\tau_B \sim 200$mm

BaBar Total : 518 fb^{-1}

Belle Total: 978.3 fb^{-1}

BaBar+Belle: 1496 fb^{-1}

BaBar	$p(e^-)=9$ GeV	$p(e^+)=3.1$ GeV	$\beta\gamma=0.56$
Belle	$p(e^-)=8$ GeV	$p(e^+)=3.5$ GeV	$\beta\gamma=0.42$

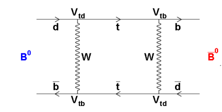
Introduction: Flavor Physics – big questions

- SM flavor problem
  - Hierarchy of mass and mixing angles. Free parameters in SM.
- NP flavor problem
  - The effective Lagrangian analysis for FCNC processes

$$L_{eff} = L_{SM} + \sum_i \frac{C_i}{\Lambda^2} O_i + \ldots (\Lambda : \text{NP scale})$$

indicates that the flavor && CPV scale is higher than the TeV scale, the scale of the EW hierarchy.

Constraints on ΔF=2 (Mixing)



KEK-FF 2013.3 by Z.Ligeti

$$L_{eff} = L_{SM} + \sum_i \frac{C_i}{\Lambda^2} O_i + \ldots (\Lambda : \text{NP scale})$$

Dimension 6

	Operator	Bounds on Λ [TeV] ($C=1$) Re	Bounds on Λ [TeV] ($C=1$) Im	Bounds on C ($\Lambda = 1$ TeV) Re	Bounds on C ($\Lambda = 1$ TeV) Im	Observables
K^0	$(\bar{s}_L\gamma^\mu d_L)^2$	9.8×10^2	1.6×10^4	9.0×10^{-7}	3.4×10^{-9}	$\Delta m_K;\ \epsilon_K$
	$(\bar{s}_R d_L)(\bar{s}_L d_R)$	1.8×10^4	3.2×10^5	6.9×10^{-9}	2.6×10^{-11}	$\Delta m_K;\ \epsilon_K$
D^0	$(\bar{c}_L\gamma^\mu u_L)^2$	1.2×10^3	2.9×10^3	5.6×10^{-7}	1.0×10^{-7}	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
	$(\bar{c}_R u_L)(\bar{c}_L u_R)$	6.2×10^3	1.5×10^4	5.7×10^{-8}	1.1×10^{-8}	$\Delta m_D;\ \lvert q/p\rvert, \phi_D$
B^0	$(\bar{b}_L\gamma^\mu d_L)^2$	5.1×10^2	9.3×10^2	3.3×10^{-6}	1.0×10^{-6}	$\Delta m_{B_d};\ S_{\psi K_S}$
	$(\bar{b}_R d_L)(\bar{b}_L d_R)$	1.9×10^3	3.6×10^3	5.6×10^{-7}	1.7×10^{-7}	$\Delta m_{B_d};\ S_{\psi K_S}$
B^0_s	$(\bar{b}_L\gamma^\mu s_L)^2$	1.1×10^2	2.2×10^2	7.6×10^{-5}	1.7×10^{-5}	$\Delta m_{B_s};\ S_{\psi\phi}$
	$(\bar{b}_R s_L)(\bar{b}_L s_R)$	3.7×10^2	7.4×10^2	1.3×10^{-5}	3.0×10^{-6}	$\Delta m_{B_s};\ S_{\psi\phi}$

[update of Isidori, Perez, Nir, 1002.0900]

- If NP has O(1) coupling, NP scales are in the 10^2-10^5 TeV range.
- If NP has O(α_W) coupling, NP scales are 10-10^4 TeV.
- If NP in the 1 TeV range, the effective coupling should be < 10^{-5} – 10^{-11}.

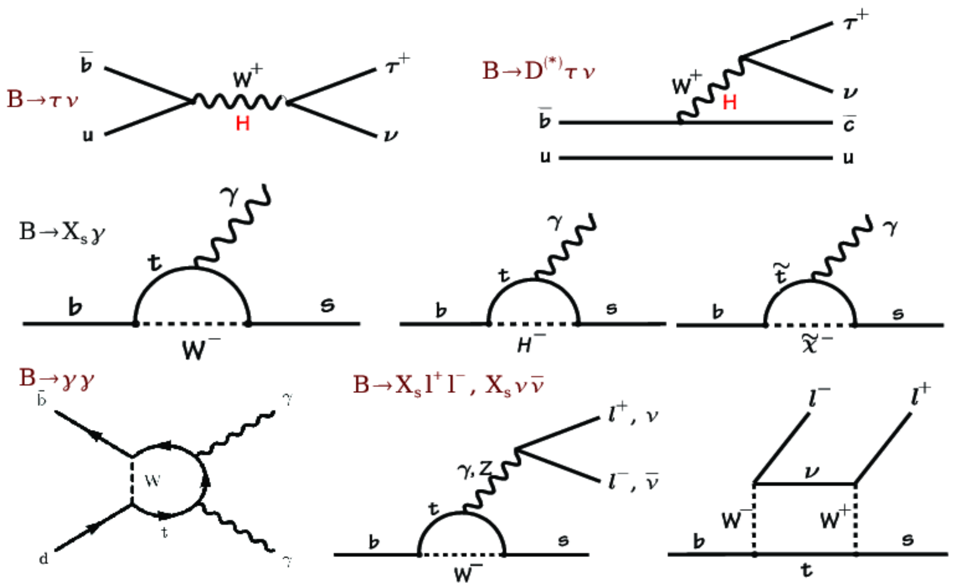
TeV scale NP must have very special features. Constrain model building.
Flavor may be sensitive for physics in high mass scale.

Rare B decays and constraint for charged Higgs

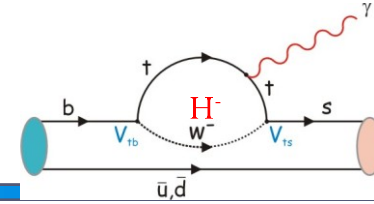
■Charged Higgs bosons are assumed in many of the Extension of the SM. Among them, 2HDM is one of the simplest extension of the SM.

■The 2HDM (Type II) resembles the Higgs sector in the Minimum SUSY Standard Model (MSSM).

■ Since the H^+ coupling is proportional to the fermion mass, $B \to \tau\nu$, $B \to D^{(*)}\tau\nu$ as well as $B \to X_s\gamma$ are ideal place to look for Charged Higgs bosons.



$B \to X_s\gamma$



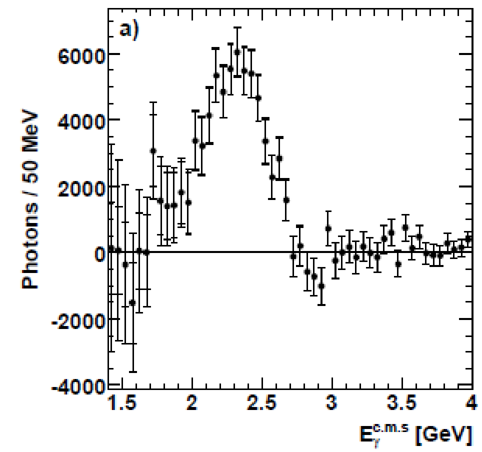
Belle, PRL103, 241801(2009),605 fb^{-1}

- Radiative decays are sensitive to charged Higgs contribution in the loop in the radiative penguin.
- Analysis: Tags of other B reduce background extensively.
- Experiments (extrapolate to E_γ>1.6GeV at B-rest frame)
- World average including the recent BaBar results is

$$B(B \to X_s\gamma) = (3.43 \pm 0.21 \pm 0.07) \times 10^{-4}$$

stat.+sys.

Extrapolation error



- Theory :

SM:

$$B(B \to X_s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$$

(NNLO: M.Misiak etal. PRL 98(022002) 2007)

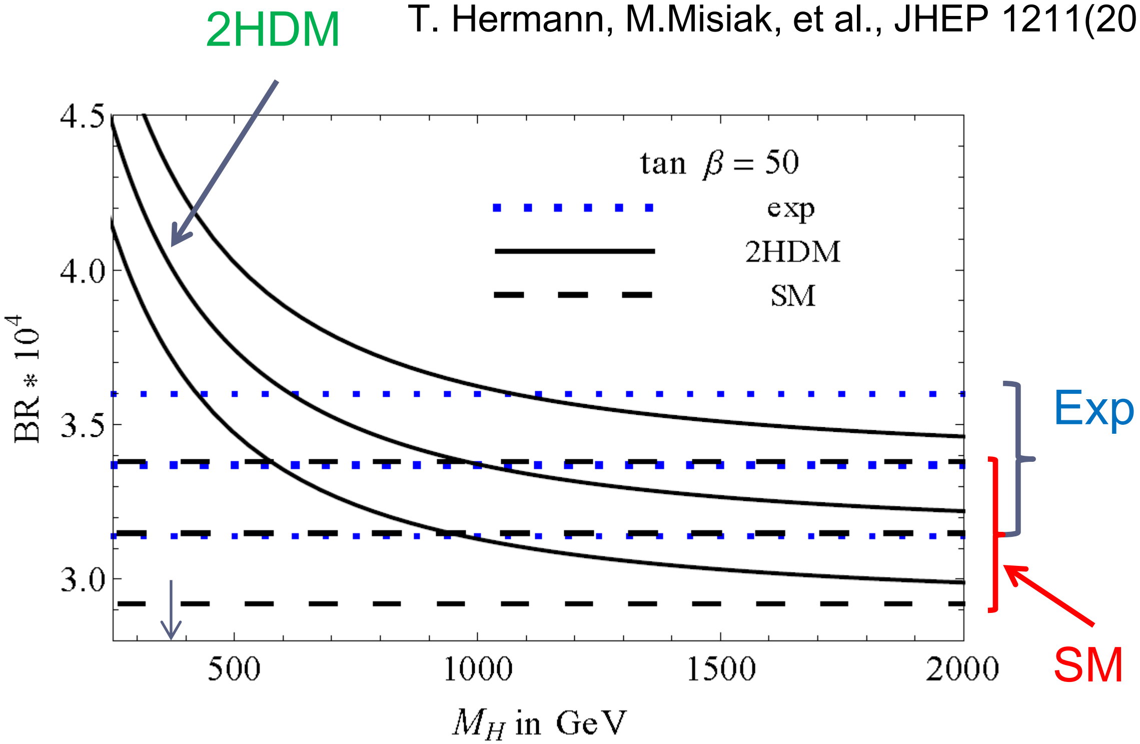
Method	Br (10^{-6})	E_γ(th.) (GeV)	year
Belle (un+lepton-tag)	345 ±15 ±40	>1.7	2009
Babar(lepton-tag)	321± 15 ±29	>1.8	2012
Babar(Hadron-tag)	366 ± 85 ± 60	>1.9	2008
Belle (sum exclusive)	336 ± 53±42	>2.2	2001
BaBar(sum exclusive)	329 ± 19±48	>1.9	2012

Phys.Rev.D86,1120008(2012)
Phys.Rev.D86,052012(2012)

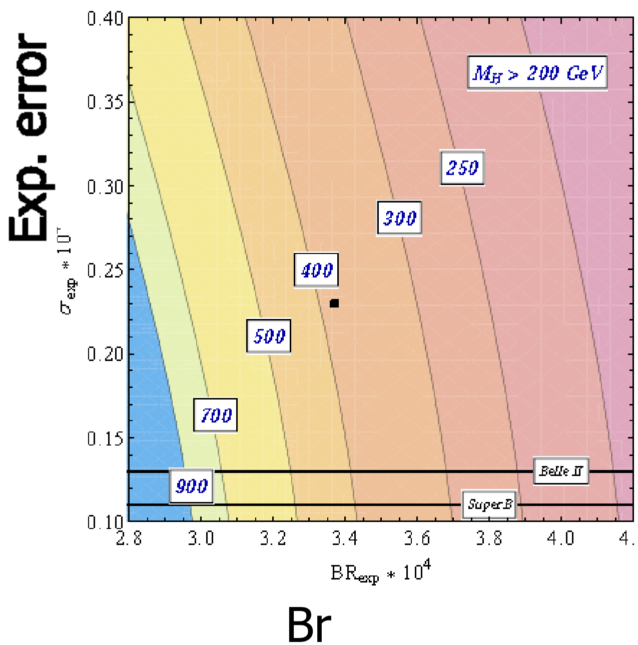
Charged Higgs limit from $B \rightarrow X_s\gamma$

Next Next Leading order calculation for 2HDM

T. Hermann, M.Misiak, et al., JHEP 1211(2012) 036



M_H lower limit @ 95% C.L.



$$M_{H^\pm} \geq 380 \ \ GeV \ \ at \ \ 95\% \, C.L.$$

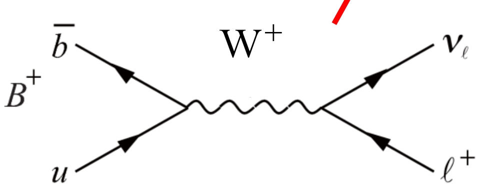
(This limit is independent of tanβ for tan β >2)

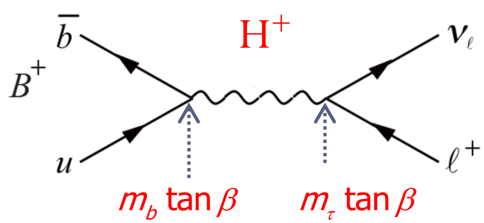
Charged Higgs in b⟶τ transition

- In the (semi-)leptonic B decay to τ lepton, there is a charged Higgs contribution in Tree level. Theoretically clean.
- The effective Hamiltonian (SM + 2HDM(Type II))

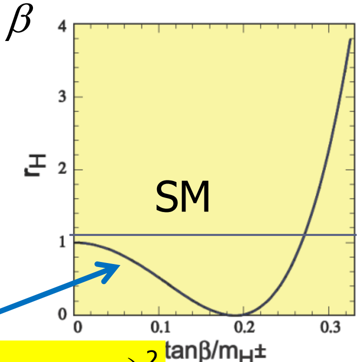
$$\mathcal{H}_{eff}^{b\to q} = \frac{G_F}{\sqrt{2}} V_{qb} \left\{ (\bar{q}_L \gamma^\mu b_L)(\bar{\nu}_L \gamma_\mu \tau_L) + C_\tau^{NP} (\bar{q}_R b_L)(\bar{\nu}_L \tau_R) + h.c. \right\}$$

SM





$$\propto C_\tau^{NR} = -\frac{m_b m_\tau}{M_H^2} \tan^2\beta$$



- Br of B⟶τ ν_τ in SM

$$\mathcal{B}_{SM}(B^- \to \tau^- \bar{\nu}_\tau) = \frac{G_F^2 m_B m_\tau^2}{8\pi} \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B |V_{ub}|^2 \tau_B$$
$$= (1.01 \pm 0.29) \times 10^{-4}$$

using WA values for

$$|V_{ub}| = (3.95 \pm 0.38_{\exp} \pm 0.39_{th}) \times 10^{-4}$$
$$f_B = (0.191 \pm 0.009) GeV$$

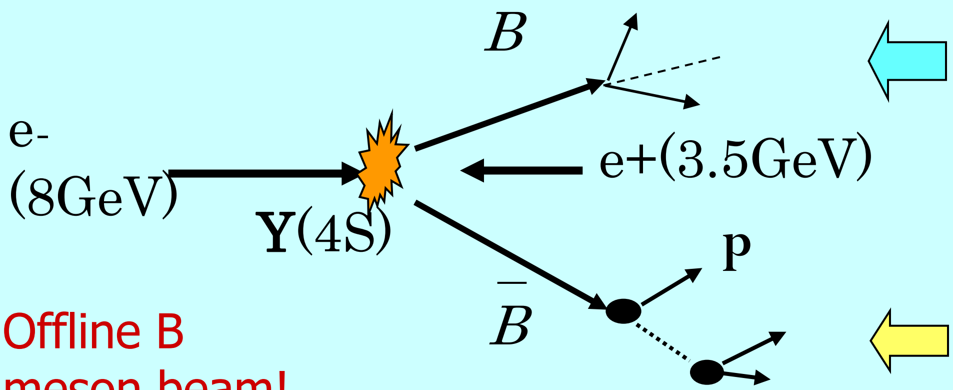
- NP(2HDM) effects)

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

Exp: at least two ν's in the final state.

Full reconstruction tagging

Idea: fully reconstruct one of the B's to tag B flavor/charge, determine its momentum, and exclude decay products of this B from further analysis



Offline B meson beam!

Decays of interest
- $B \to X_u\, l\, \nu$,
- $B \to \tau\, \nu$
- $B \to D\tau\nu$, $\tau\nu$

full reconstruction
$B \to D\pi$ etc. (0.1-0.3%)

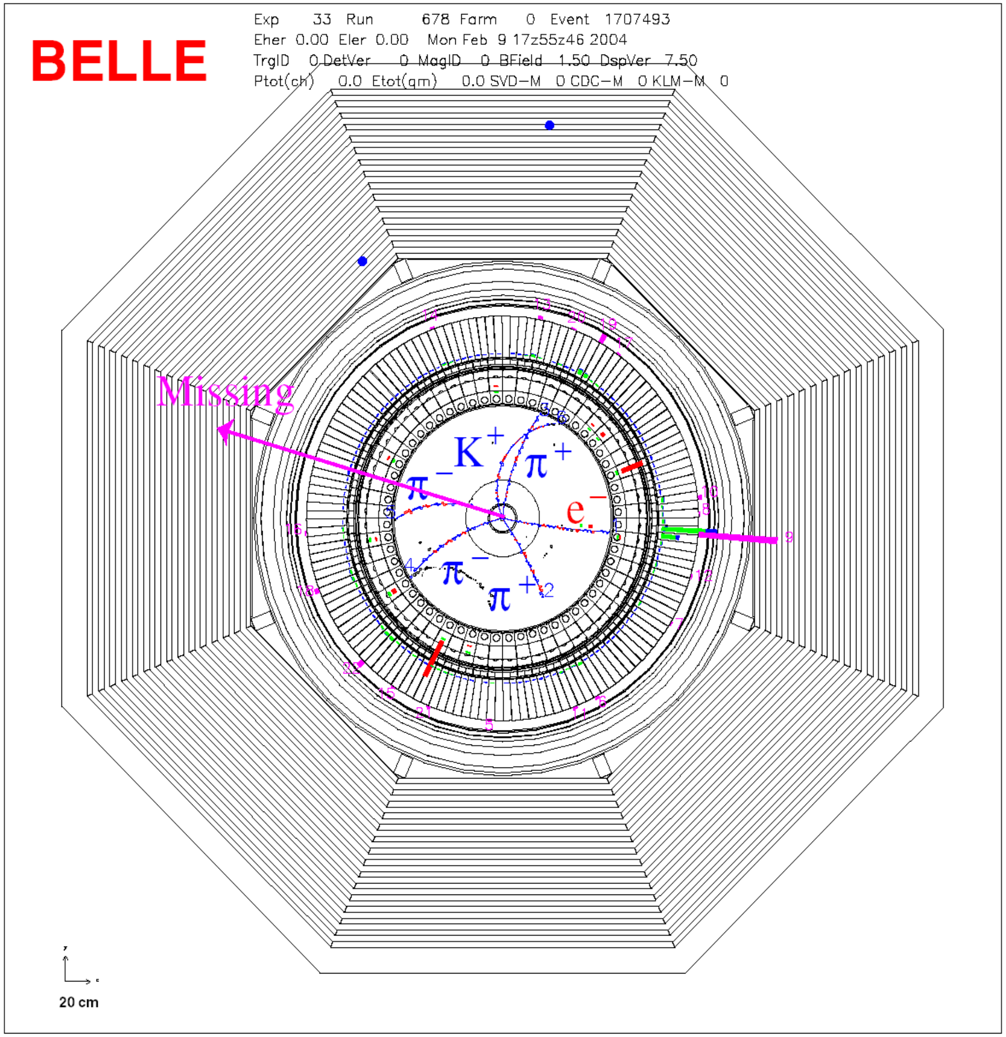
Reduce background and allows us to obtain kinematical constraints.

Powerful tool for B decays with neutrinos, used in several analyses in this talk
→unique feature at B factories

$B^- \rightarrow \tau^- \nu_\tau$ candidates with full reconstruction tag.

Example of a missing energy decay

$$B^+ \longrightarrow D^0\pi^+$$
$$(\longrightarrow K\pi^-\pi^+\pi^-)$$
$$B^- \longrightarrow \tau(\longrightarrow e\nu\bar{\nu})\nu$$

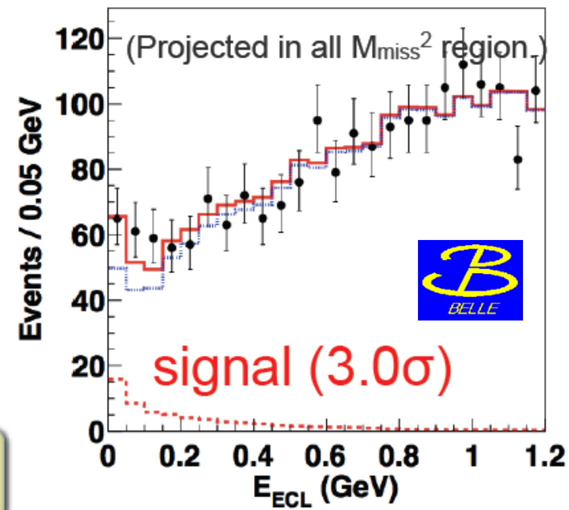


$B^- \to \tau^- \nu_\tau$

Method: tag one B with full reconstruction, look for the $B^- \to \tau^- \nu_\tau$ in the rest of the event.

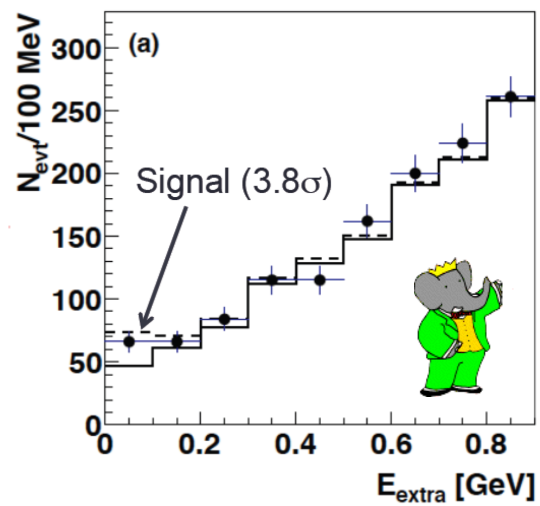
Main discriminating variable on the signal side: remaining energy in the calorimeter, not associated with any charged tracks or photons

→ Signal at $E_{ECL} = 0$



Belle $Br(B \to \tau\nu) = [0.72\ ^{+0.27}_{-0.25} \pm 0.11] \times 10^{-4}$

BaBar $Br(B \to \tau\nu) = [1.83\ ^{+0.53}_{-0.49} \pm 0.24] \times 10^{-4}$

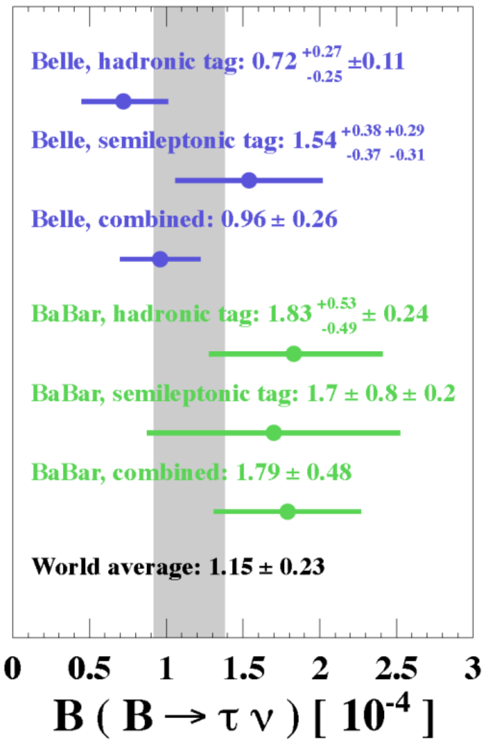


All measurements are combined

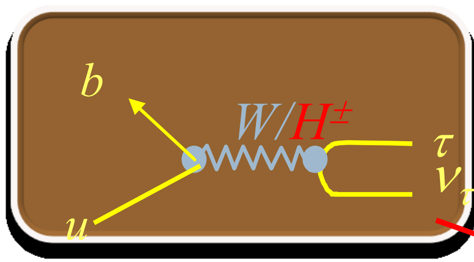
$$Br(B \to \tau\nu) = (1.15 \pm 0.23) \cdot 10^{-4}$$

$$r_H = \frac{BF(B \to \tau\nu)_{meas}}{BF(B \to \tau\nu)_{SM}} = 1.14 \pm 0.40$$

Charged Higgs limits from B → $\tau^- \nu_\tau$

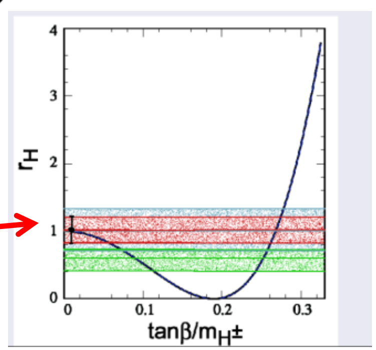


$$r_H = \frac{BF(B \to \tau\nu)}{BF(B \to \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

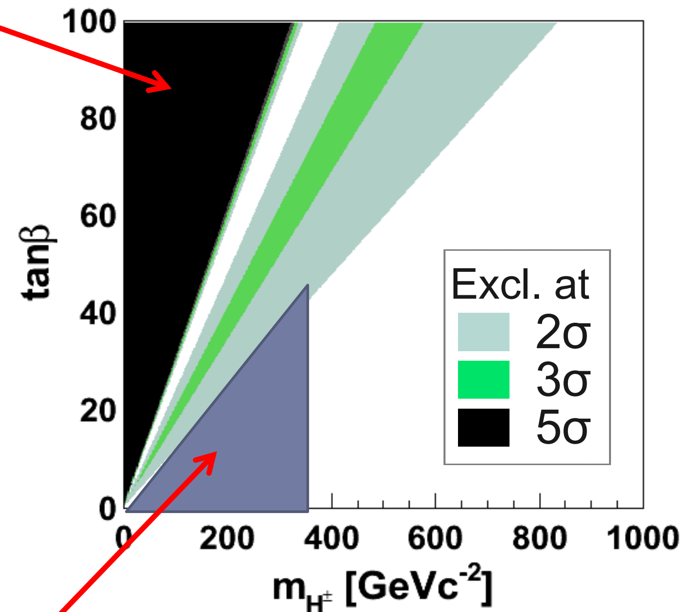


B factories: Exclusion plot

Stringent constraint on M_H and tanβ is obtained.



Exp



B→Xs γ

$B \to D^{(*)} \tau\nu$ decays from BaBar

$B \to D^{(*)} \tau\nu$ are another processes sensitive to H^-

$$\mathcal{R}(D) = \frac{\mathcal{B}(B \to D\tau\nu_\tau)}{\mathcal{B}(B \to Dl\nu_\tau)}$$

$$\mathcal{R}(D^*) = \frac{\mathcal{B}(B \to D^*\tau\nu_\tau)}{\mathcal{B}(B \to D^*l\nu_\tau)}$$

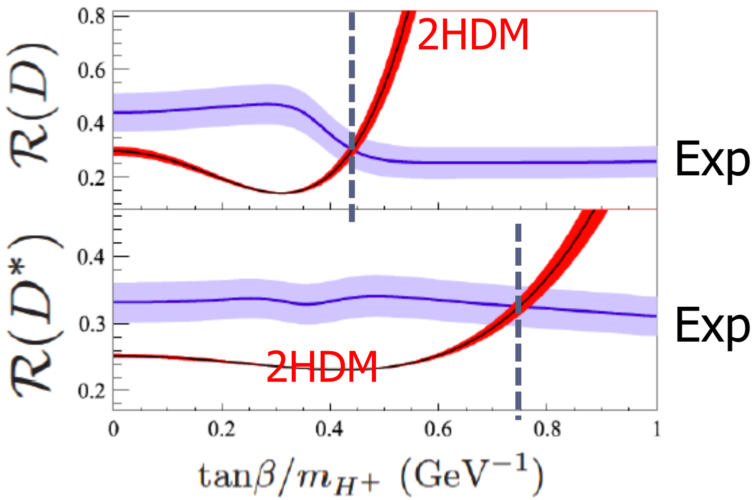
$$\mathcal{R}(D)_{\rm exp} = 0.440 \pm 0.072 \qquad \mathcal{R}(D^*)_{\rm exp} = 0.332 \pm 0.030$$

2.0σ   2.7σ

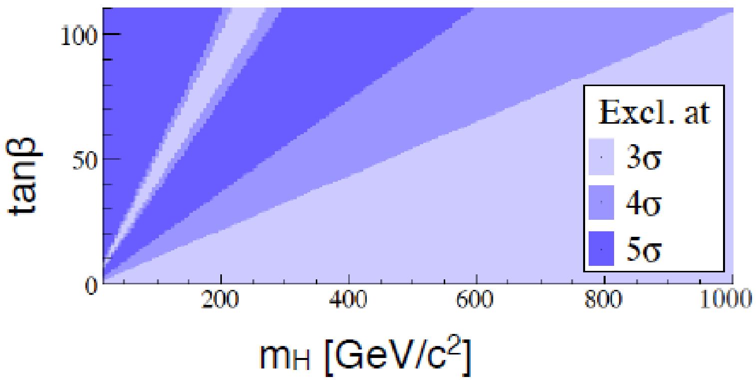
$$\mathcal{R}(D)_{\rm SM} = 0.297 \pm 0.017 \qquad \mathcal{R}(D^*)_{\rm SM} = 0.252 \pm 0.003$$

SM expectations in S. Fajfer, J. Kamenik, I. Nisandzic, PRD 85, 094025 (2012).

$\tan\beta/m_H$ values do not agree for R(D) and R(D*).



Blue: this result, red: Type-II 2HDM.



Combined result: Type II 2HDM is excluded at 99.8% C.L. for any value of tanβ and charged Higgs mass

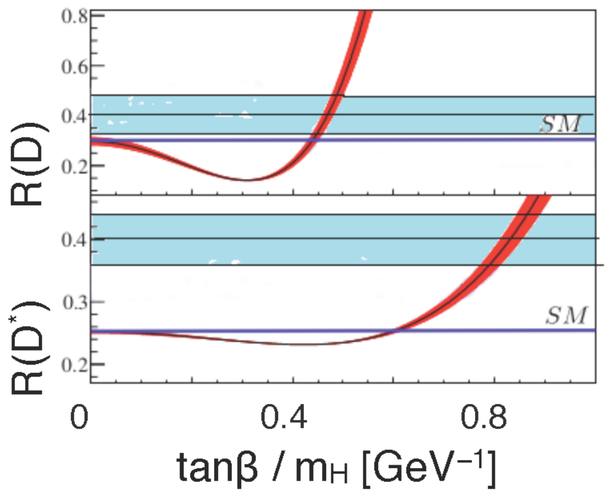
$B \to D^{(*)} \tau\nu$ decays from Belle

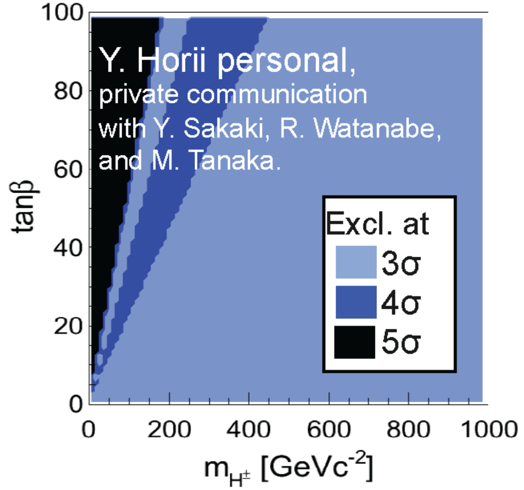
- Average of the results

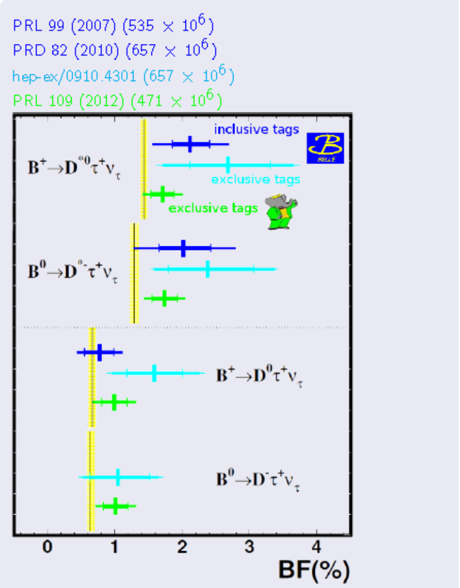
$$R(D) = 0.430 \pm 0.091$$
$$R(D^*) = 0.405 \pm 0.047$$

Deviation from SM

$1.4\,\sigma$, $3.0\,\sigma$ } $3.3\,\sigma$





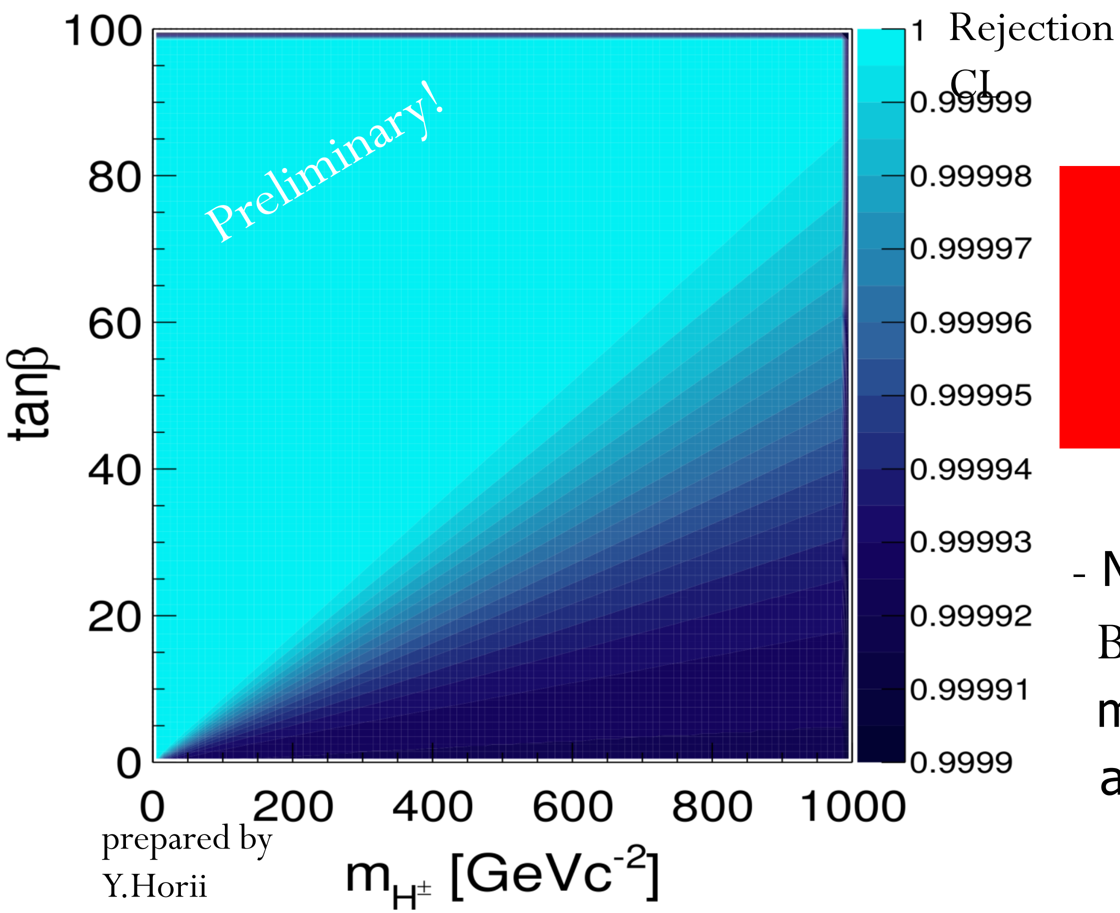


Similar tendency with BaBar. Belle+BaBar combined fit results (Itoh's talk) show 2HDM Type II is rejected at more than 3σ.

c) Constraint on Charged Higgs with all modes combined by global fit

Belle + BaBar : $B \to \tau\nu$ + $B \to D\tau\nu$ + $B \to D^*\tau\nu$

* Correlation in $D^{(*)}\tau\nu$ measurements : BaBar - included in the fit, Belle - not considered.
* $\tan\beta/m_H$ dependence in $D^{(*)}\tau\nu$ measurements is omitted both for BaBar and Belle..

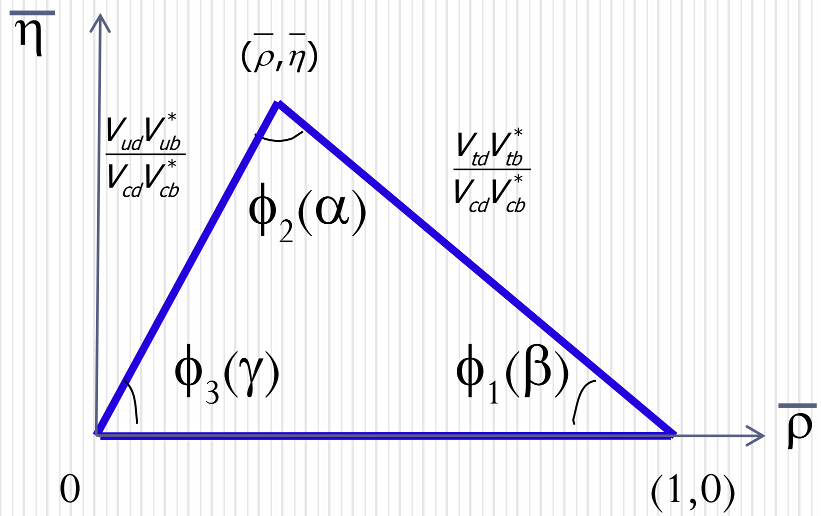


prepared by Y.Horii

2HDM Type II is rejected at more than 99.99% CL in the shown range by $B \to \tau\nu$ + $B \to D^{(*)}\tau\nu$

- New Belle results of $B \to D\tau\nu$ and $B \to D^*\tau\nu$ measurements will become available soon.
  - stay tuned.

CP violation in the B system and the unitarity triangle (UT)



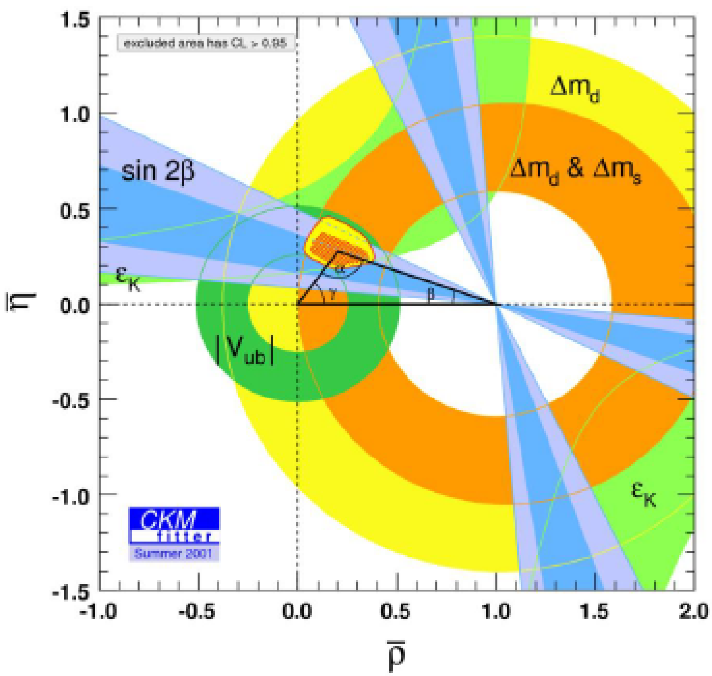
Mixing matrix should be unitary within KM mechanism, but New Physics can change it.

Measure three angles and two sides → Over constraint

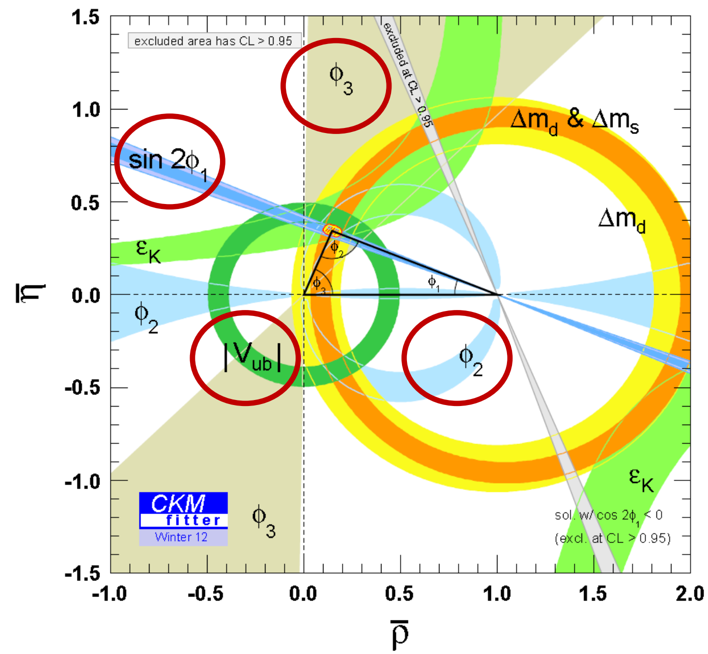
CP violation in the B system and UT

- CP violation in the B system: from the discovery (2001) and a precision measurement (2012)

EPS 2001

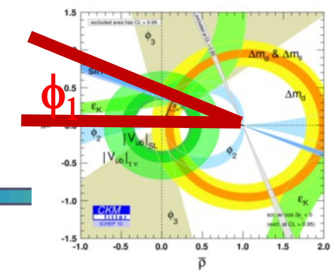


2012 winter

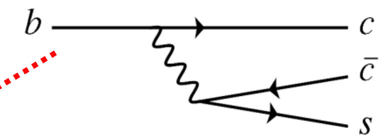


Significant improvements in ten years.
In this talk I present recent results for observables marked by

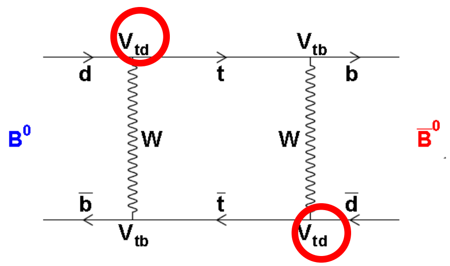
$\sin 2\phi_1$ (=$\sin 2\beta$) measurements

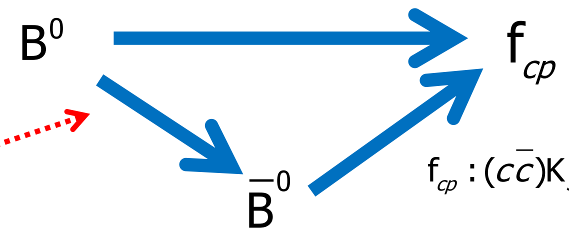


- ϕ_1 from CP violation measurements in $B^0 \to c\bar{c}\, K^0$
- Measuring the CP phase in the B-$\overline{\text{B}}$ mixing



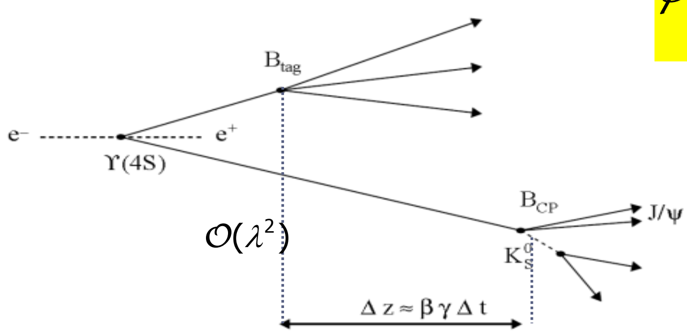
$$\phi_1 = \beta = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$$





$f_{cp} : (c\bar{c})K_{S(L)} = (J/\psi)K_{S(L)}, \psi' K_{S(L)}, \ldots$

- Observable: time-dependent decay rate of a B or a $\overline{\text{B}}$ meson decaying into common *CP* eigenstate

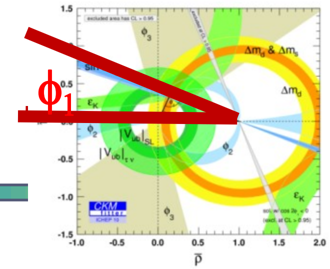


$$\mathcal{P}(\Delta t) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}\left\{1 + q\left[S_{CP}\sin(\Delta m_d \Delta t) + A_{CP}\cos(\Delta m_d \Delta t)\right]\right\}$$

$S_{cp} = \eta_{CP}\sin\phi_1$, *mixing CP*, (η_{CP} : *CP* eigen value of f_{cp})

A_{cp} : *direct CP*, small

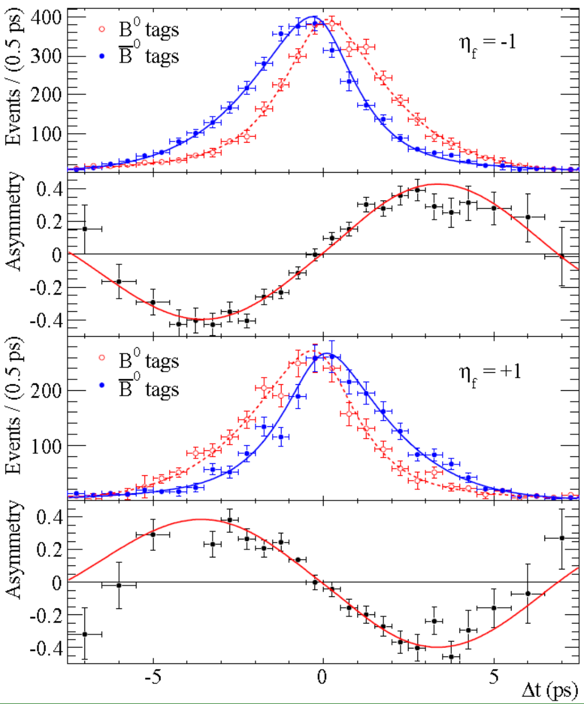
Final measurement of $\sin 2\phi_1$ ($=\sin 2\beta$)



ϕ_1 from CP violation measurements in $B^0 \to c\bar{c}\, K^0$

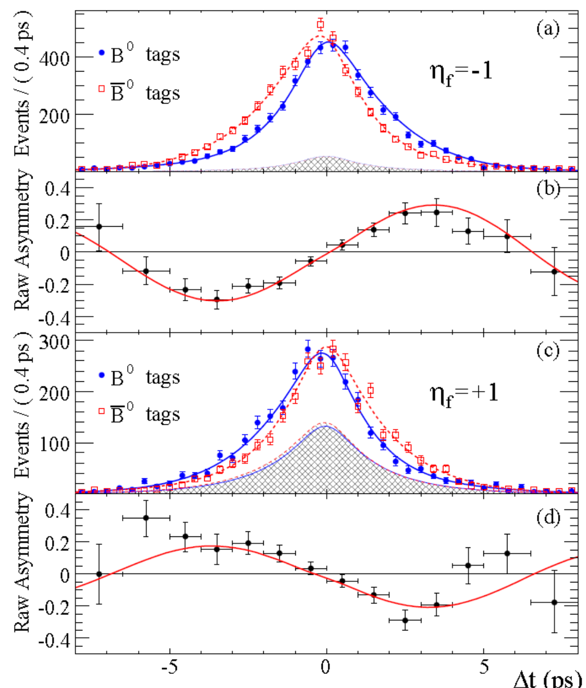
$c\bar{c} = J/\psi,\ \psi(2S),\ \chi_{c1}$, $711\,\text{fb}^{-1}$, 25k events

$c\bar{c} = J/\psi,\ \psi(2S),\ \eta_c, \chi_{c1}$, $426\,\text{fb}^{-1}$



$(c\bar{c})K_S$

$(c\bar{c})K_L$



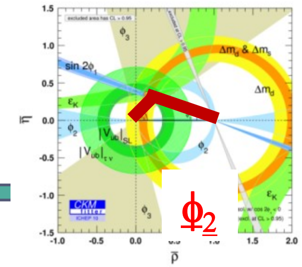
Belle, 710 fb^{-1}, PRL 108, 171802 (2012)

BaBar, PRD 79, 072009 (2009)

Belle: $\sin 2\phi_1 = 0.668 \pm 0.023 \pm 0.012$
BaBar: $\sin 2\phi_1 = 0.687 \pm 0.028 \pm 0.012$

precision of ~4%!

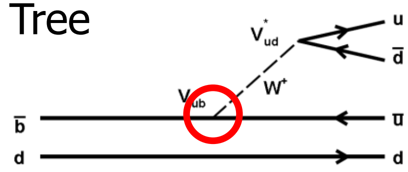
$\phi_2(=\alpha)$ measurements



- ϕ_2 from CP violation measurements in $B^0 \to \pi\pi, \rho\rho, \rho\pi$
- Measuring the CP phase in B-B mixing and that in decay.

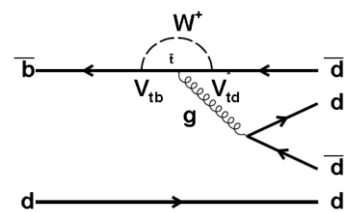
$$\phi_2 = \alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ub}V_{ud}^*}\right)$$

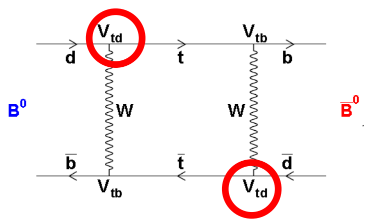
Tree

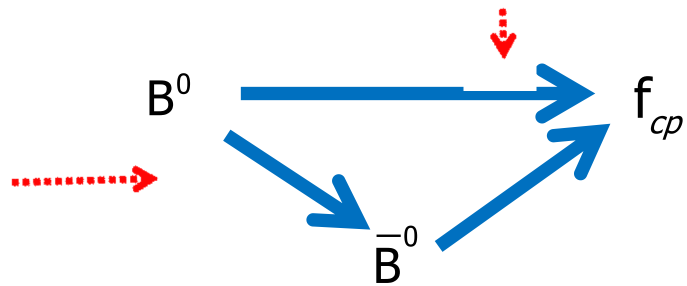


+

penguin





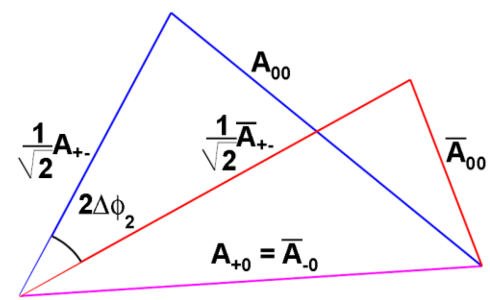


$f_{cp} = \pi\pi,\ \rho\rho,\ \rho\pi$

- Penguin process can contribute in the same order

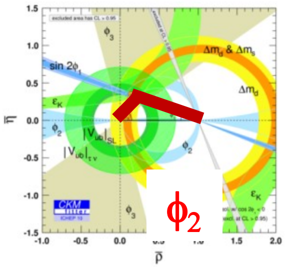
➡ Need an iso-spin analysis to extract ϕ_2

$$\phi_2 = \phi_2^{eff.} - \Delta\phi_2$$



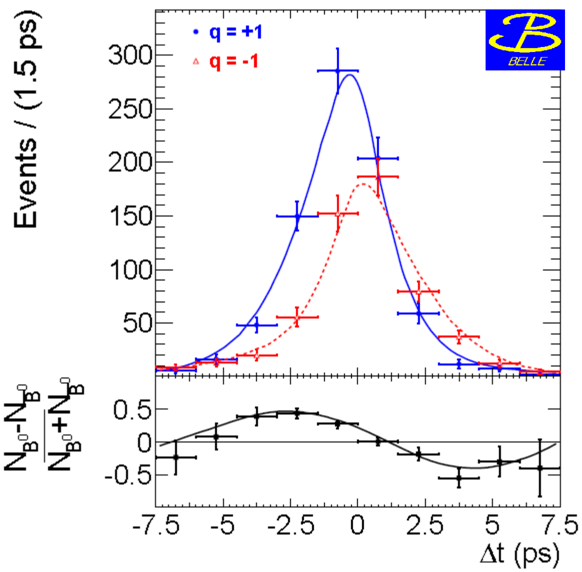
M. Gronau and D. London, PRL 65 3381 (1990)

Final measurement of $\phi_2(\alpha)$ in $B \to \pi^+\pi^-$



Belle, arXiv:1302.0551

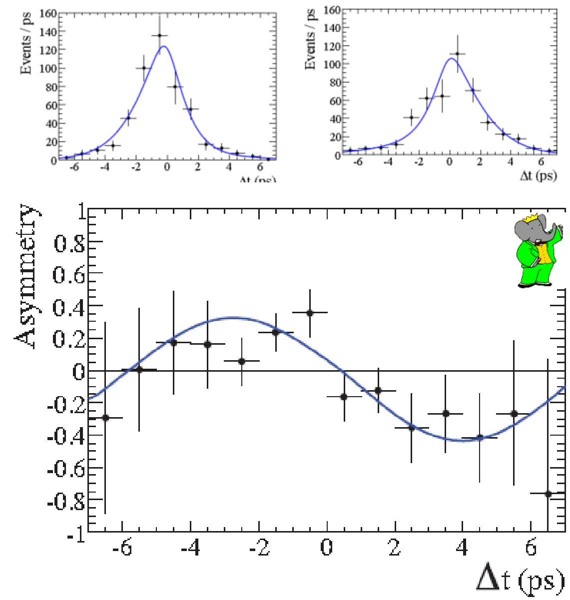
772×10^6 $B\bar{B}$ pairs



$$S_{cp}^{\pi\pi} = -0.64 \pm 0.08 \pm 0.03$$
$$A_{cp}^{\pi\pi} = +0.33 \pm 0.06 \pm 0.03$$

BaBar, PRD 87 052009(2013)

467×10^6 $B\bar{B}$ pairs



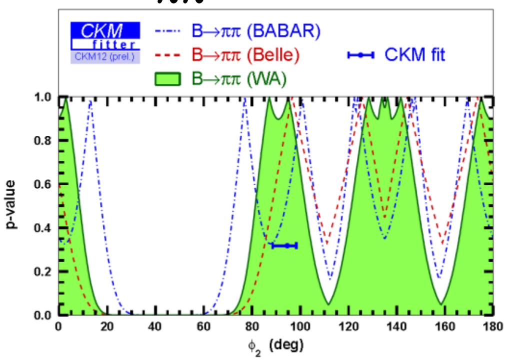
$$S_{cp}^{\pi\pi} = -0.68 \pm 0.10 \pm 0.03$$
$$A_{cp}^{\pi\pi} = +0.25 \pm 0.08 \pm 0.02$$

Clear mixing induced CP violation and presence of penguins. $\mathcal{A}_{CP}^{\pi^+\pi^-} \neq 0$

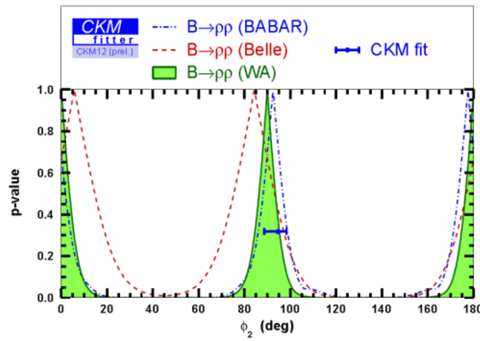
$$\mathcal{P}(\Delta t) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}}\left\{1 + q\left[\mathcal{S}_{CP}\sin(\Delta m_d \Delta t) + \mathcal{A}_{CP}\cos(\Delta m_d \Delta t)\right]\right\}$$

Improved measurement of ϕ_2 in $B \to \pi\pi, \rho\rho, \rho\pi$

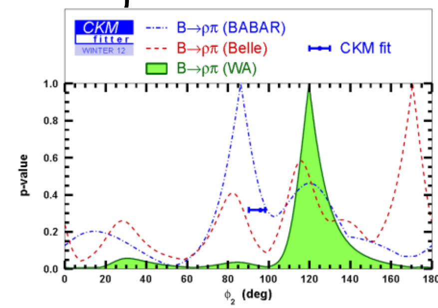
$\pi\pi$



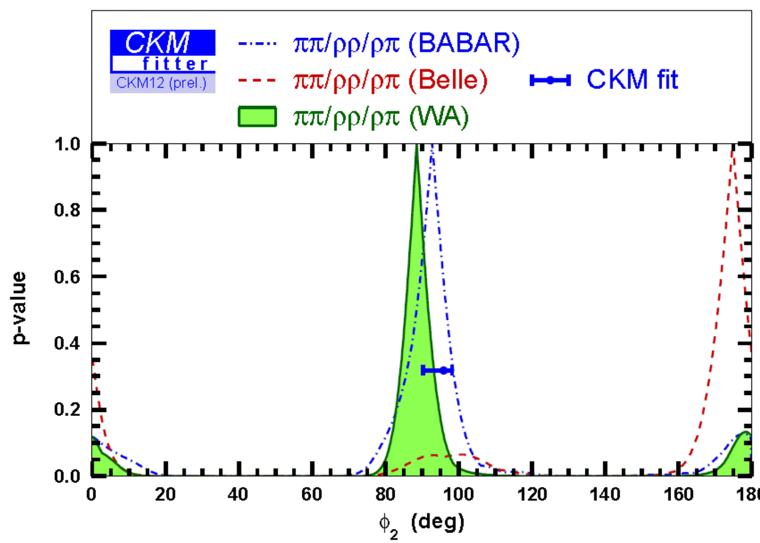
$\rho\rho$



$\rho\pi$



Combined $\pi\pi$, $\rho\rho$, $\rho\pi$

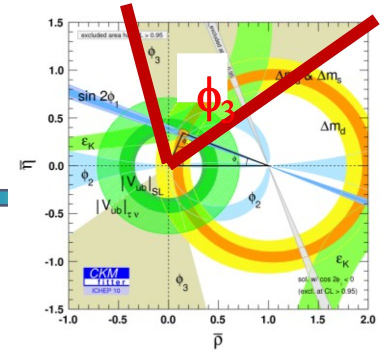


- Tight constraint from $\rho\rho$.
- $\rho\pi$? To be settled

Still to be updated for the final version: new results expected from Belle on $\rho^+\rho^-$, $\rho\pi$

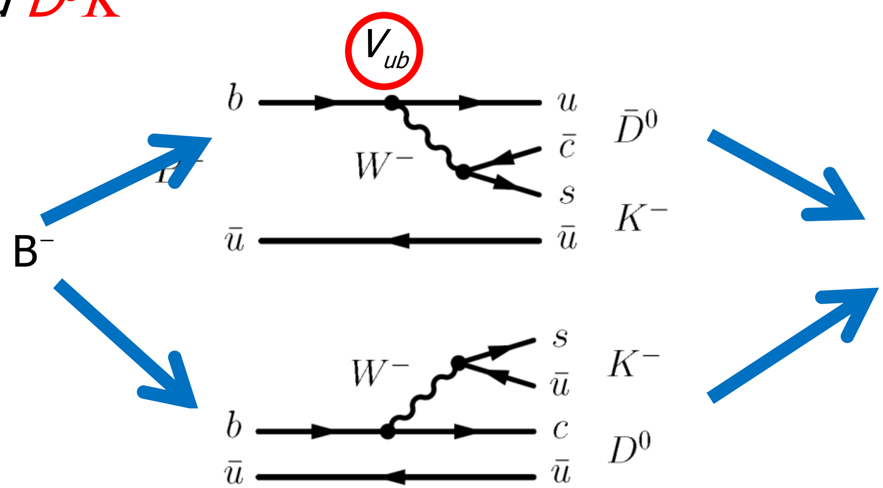
$$\phi_2 = \alpha = (88.5 \pm^{4.7}_{4.4})^\circ$$

ϕ_3 (=γ) measurements



- ϕ_3 from direct CP violation measurements in $B^- \to D^0K^-$ and $\bar{D}^0K^-$

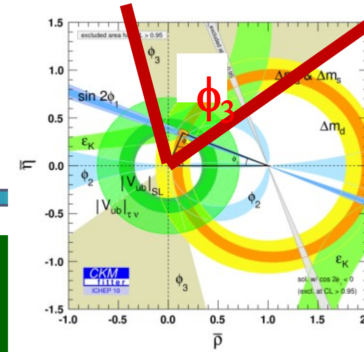
$$\phi_3 = \gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{ud}V_{cb}^*}\right)$$



$K_S\pi^+\pi^-$ + K^-	GGSZ
(K^+K^- or $K_S\pi^0$) + K^-	GLW
($K^+\pi^-$) + K^-	ADS

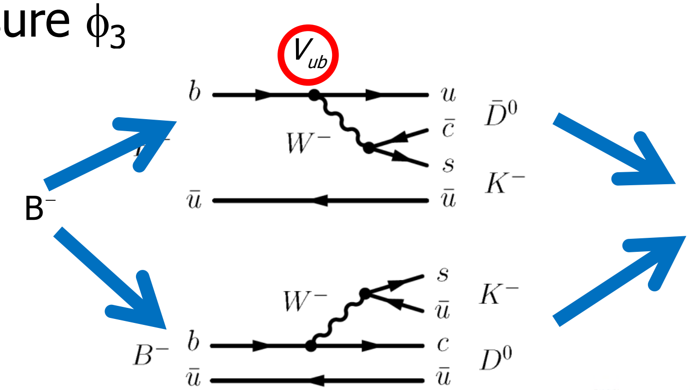
- Measuring CP phase in tree level.
- Most difficult to measure experimentally.
- Three methods have been proposed depending on the D^0 decay modes.

ϕ_3 (=γ) with Dalitz analysis



A. Giri et al., PRD68, 054018 (2003)
A. Bondar et al (Belle), Proc. BINP Meeting on Dalitz Analyses, 2002

- GGSZ method: The best way to measure ϕ_3

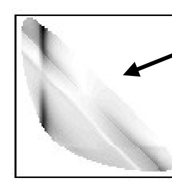
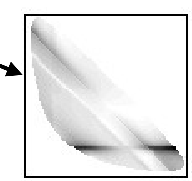


$K_S\pi^+\pi^-$ + K^-

$$|M_\pm(m_+^2, m_-^2)|^2 = |f_D(m_+^2, m_-^2) + re^{i\delta_B \pm i\phi_3} f_D(m_-^2, m_+^2)|^2$$

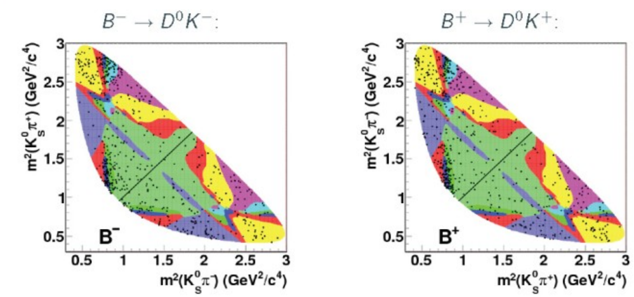
- Need 3-body $D^0 \to K_S\pi^+\pi^-$ Dalitz amplitude

-Parameterize by a model using Belle D decay data.

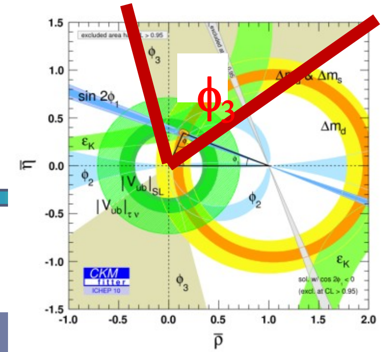
$= \Big|$  $+ re^{i\delta_B \pm i\phi_3}$  $\Big|^2$

-Model independent method. use CLEOc data.

Belle, PRD81, 112002, (2010), 605 fb^{-1}



ϕ_3 (=γ) results

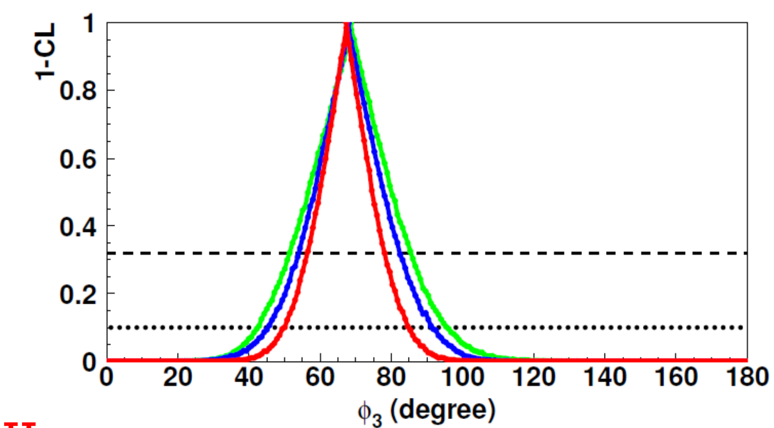


- CCSZ method

Exp	Treatment of Dalitz	ϕ_3	Ref.
Belle	Parameterize	$(78 \pm 12 \pm 4 \pm 9)^o$	PRD81,112002,(2010)
BaBar	Parameterize	$(68 \pm 14 \pm 4 \pm 3)^o$	PRL 105,121801(2010)
Belle	Model indep.	$(77.3 \pm 15 \pm 4.1 \pm 4.3)^o$	PRD85,112014(2012)

- Combined ϕ_3 value for all methods.

ϕ_3 =(67 ± 11) degrees



- At B factories, the measurement of ϕ_3 finally turned out to be much better than expected!
- Statistical error is dominated
- Systematic can be reduced in future with BESIII data.

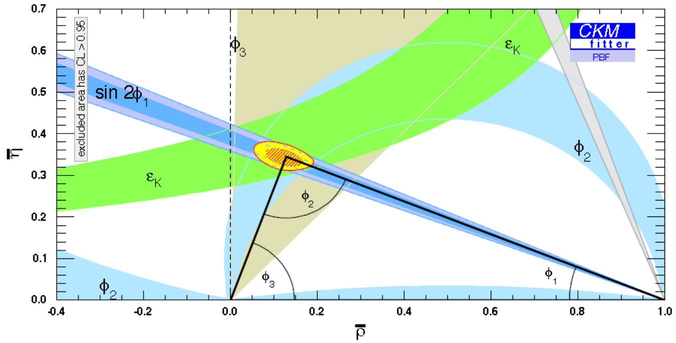
Expected accuracy ϕ_3 in Belle II: ~ 2 deg.

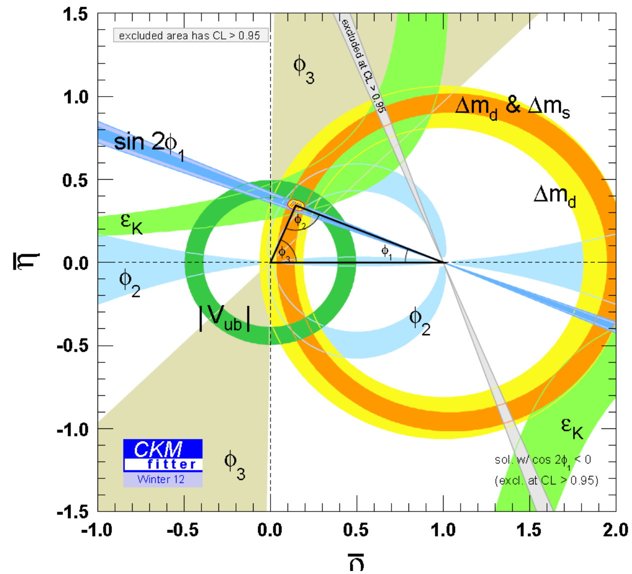
Current status of unitarity triangle

- Remarkable agreement.

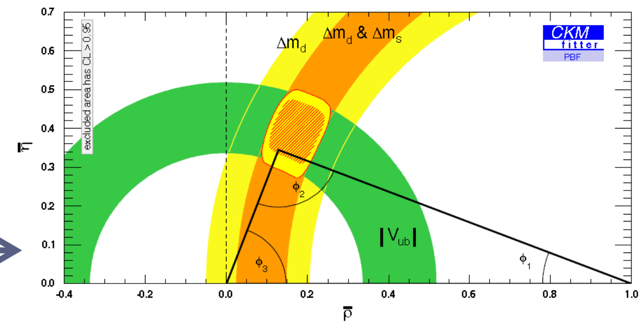
But

- Note that UT apex (ρ, η) position is determined best from sin ϕ_1 and ϕ_2.



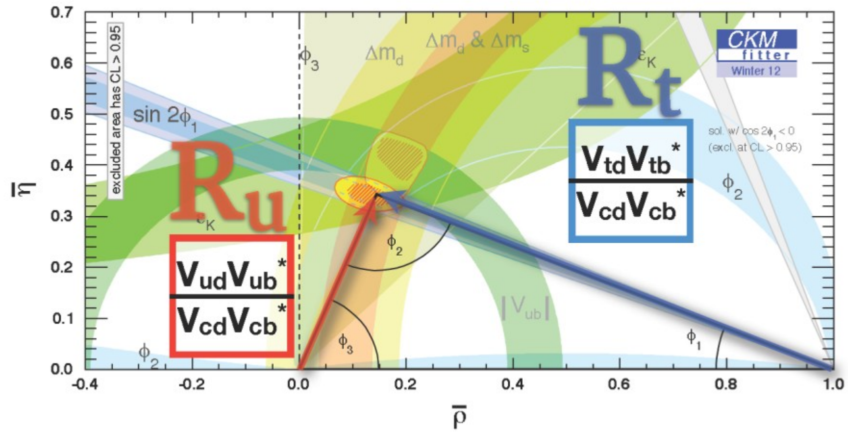


- Less constraints from the side measurements.



UT current and future

- Even there is a tension between the apex determined from angles and sides.



still 10-20% NP allowed

- It is important to determine UT only from Tree level observables (ϕ_3, V_{ud}, V_{cb}) and check the consistency of the observables in loop (ϕ_1,ϕ_2, $\Delta m_d/\Delta m_s$, ε_k)

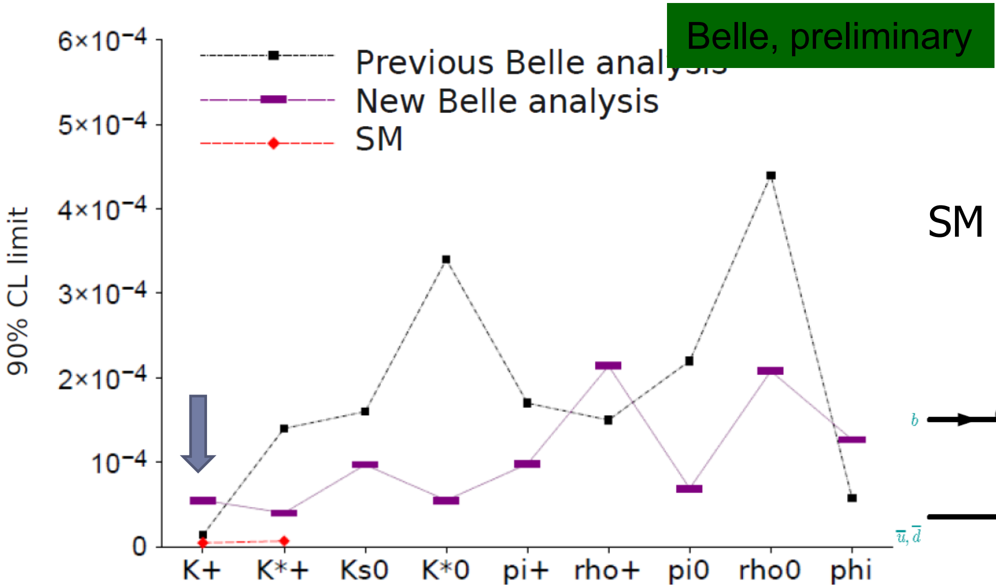
- Crucial for a search of NP in the loop, which has a high sensitivity for the physics in multi-TeV and even higher ($\mathcal{O}$(1TeV) – $\mathcal{O}$(100 TeV)) [Z.Ligeti, Hewett, 2012]

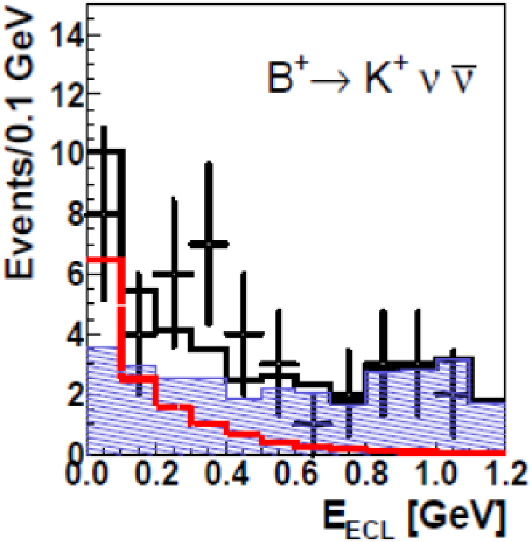
$B \to h\nu\nu$ decays (h=K, K*, π, ρ, ϕ)

Other example sensitive to the loop diagram.

Method: again tag one B with full reconstruction, search for signal in the remaining energy in the calorimeter, at $E_{ECL} = 0$

Recent update from Belle

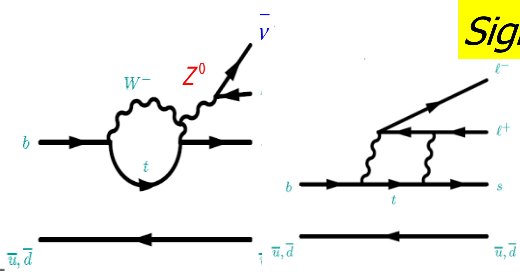




$$N_{sig} = 13.3^{+7.4}_{-6.6}(stat) \pm 2.3(sys)$$

$$Significance = 2\sigma$$

SM contribution



$$Br(B^+ \to K^+\nu\bar{\nu}) \langle 5.5\times10^{-5}\,(Belle)\ \ arxiv.1303.3719$$

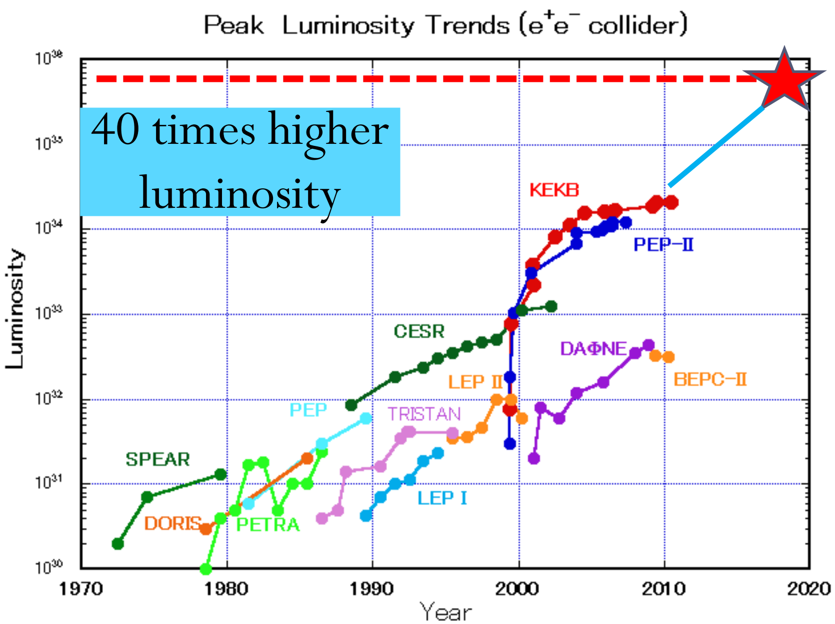
$$\langle 3.7\times10^{-5}\,(BaBar)\ arxiv.1303.7465$$

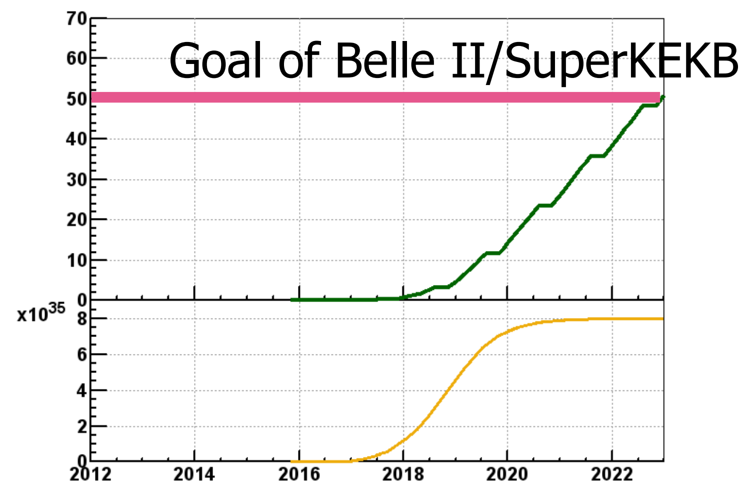
$$SM : Br(B^+ \to K^+\nu\bar{\nu}) = (4.5\times0.7)\times10^{-6}$$

Already achieving to the same order of the SM expectations

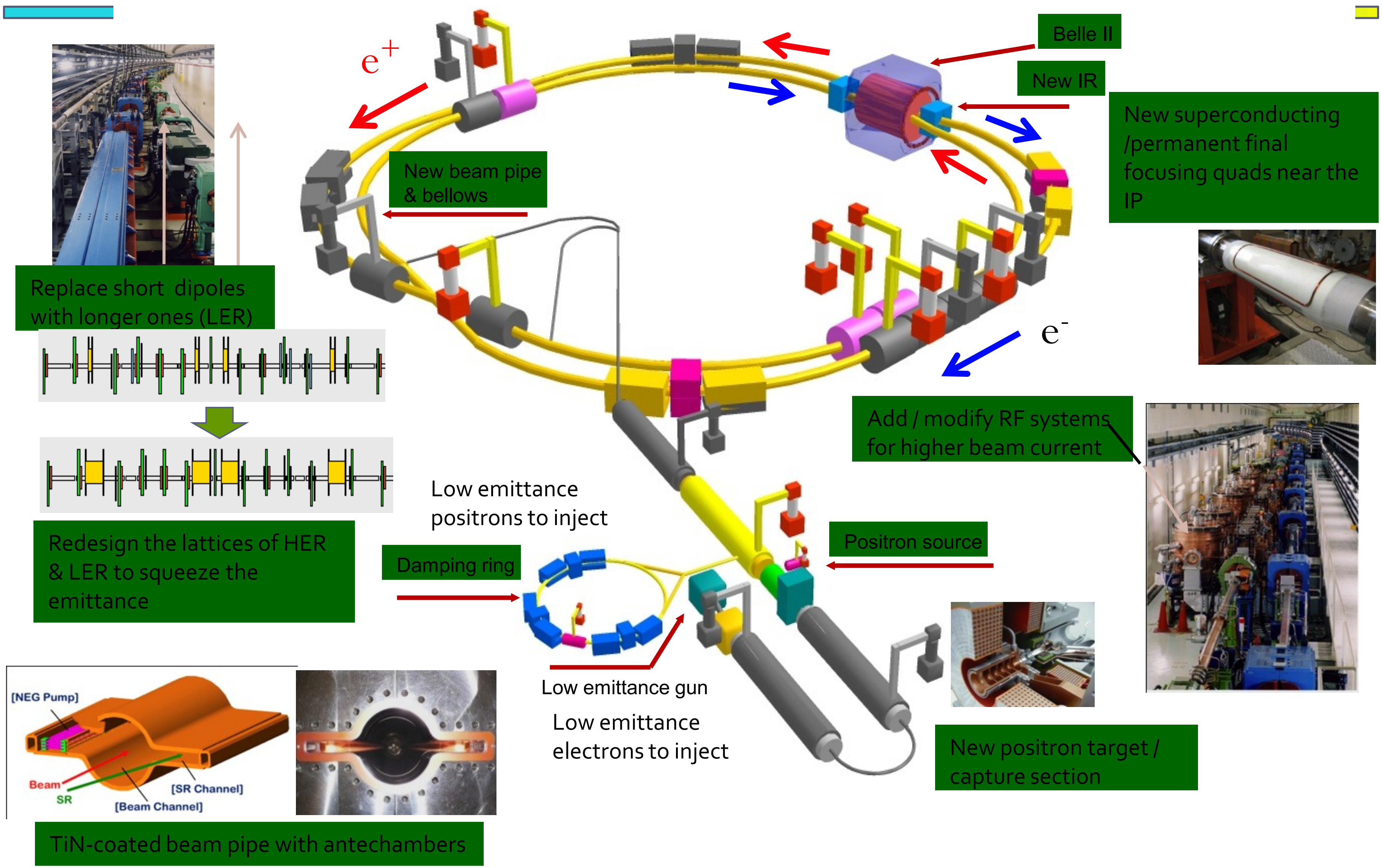
What next ?

- Need more data !
- In Belle II/Super KEKB
  - 40 times more luminosity 8×10^{35} cm^{-2} s^{-1}
  - Start physics run in 2016
  - Accumulate 50 ab^{-1} within next decades.





SuperKEKB status: Many components are installed

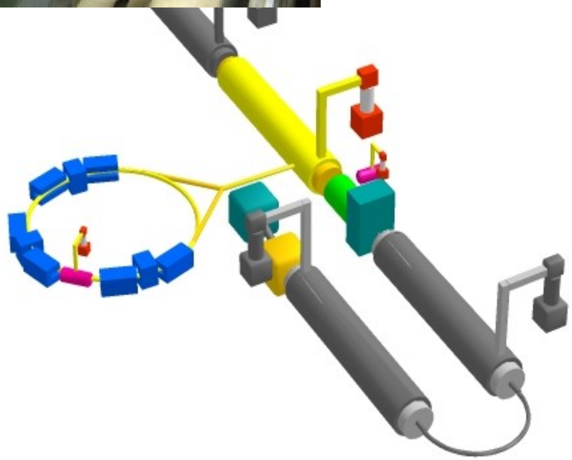


Super KEKB Construction status.

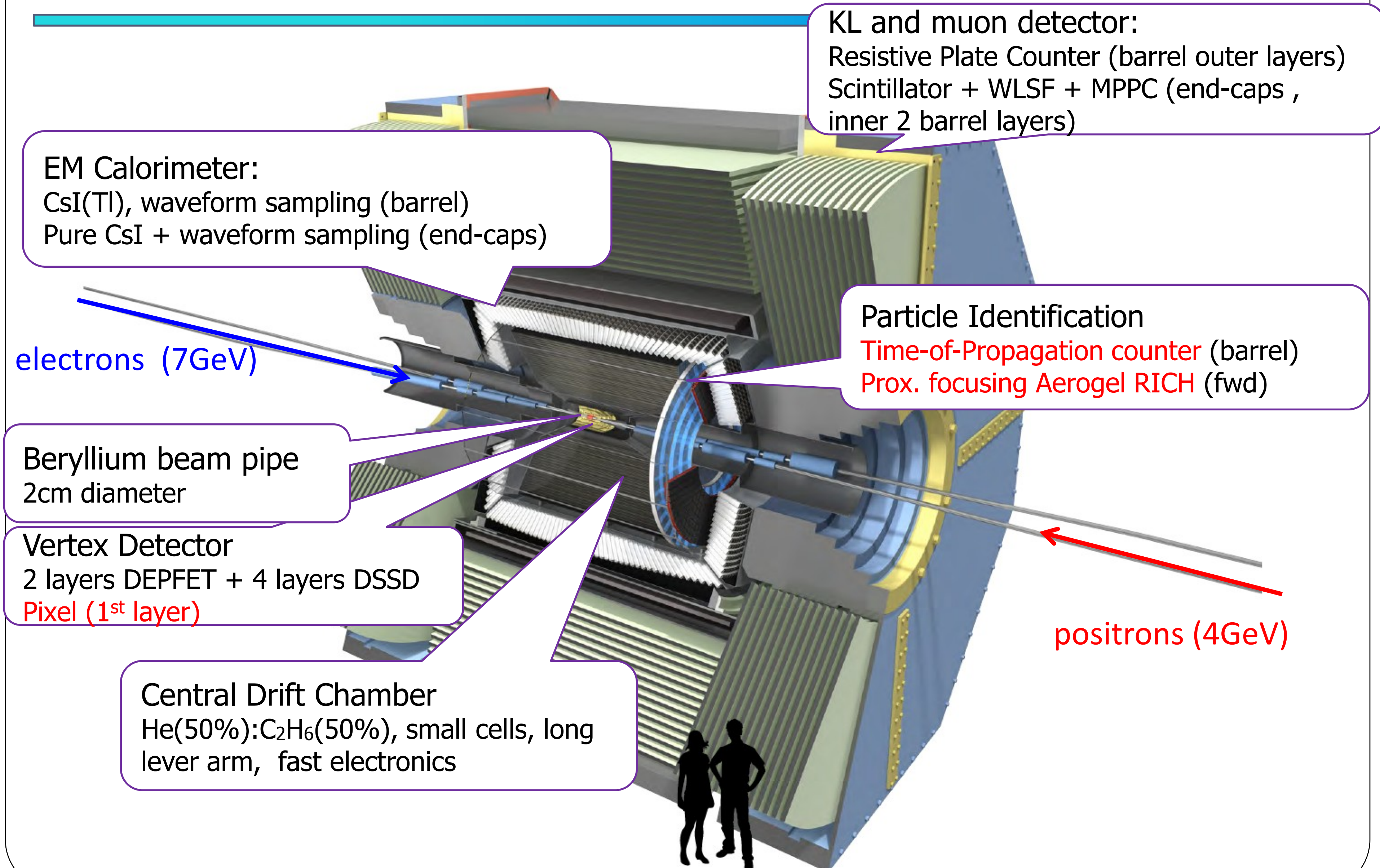
Installation of 100 new long LER bending magnets done

Installation of HER wiggler chambers in Oho straight section is done.

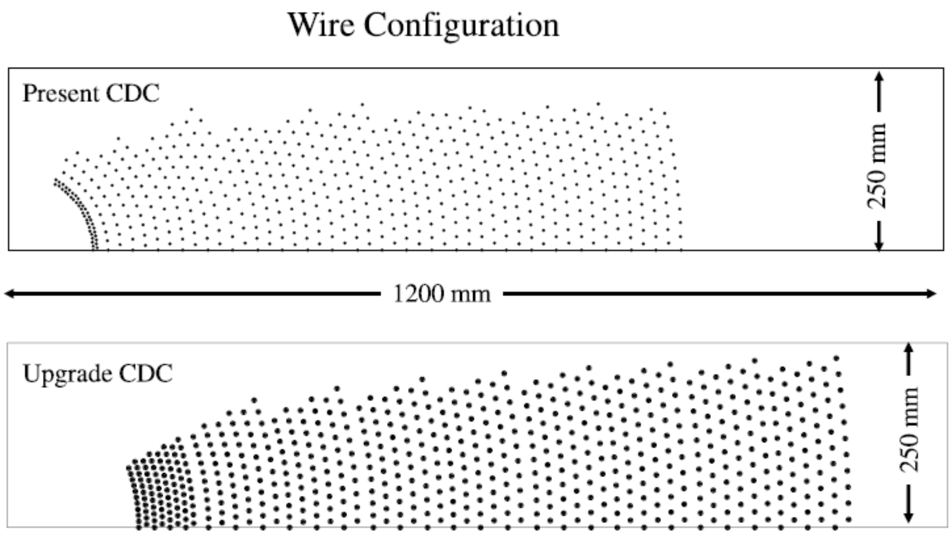
Damping ring tunnel: built!



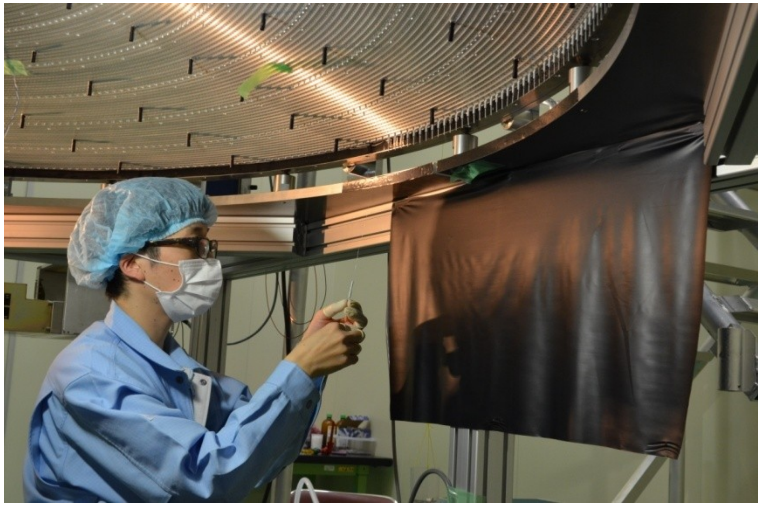
Belle II Detector



Belle II CDC



Much bigger than in Belle!



Wire stringing in a clean room

- 70 thousands of wires,
- 1 year of work…

Key observables and expected accuracy

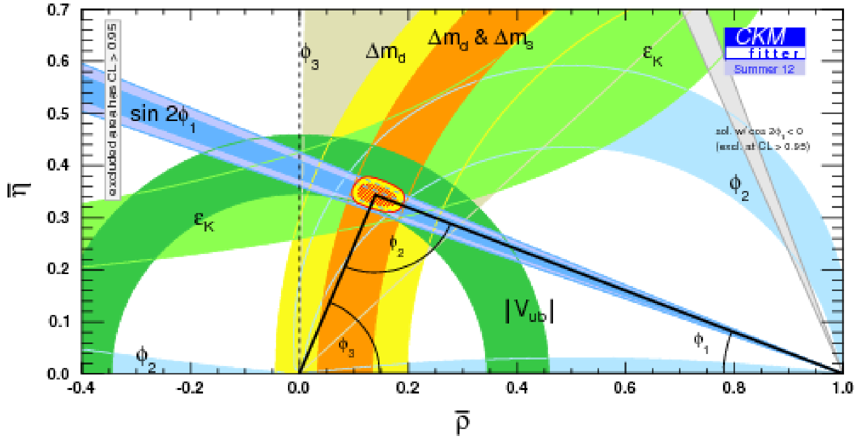
- Include observables (i) sensitive to different NP, (ii) measurement can improve order of magnitude, (iii) not limited by hadronic uncertainty.

	Precision at 50 ab^{-1}
ϕ_3 from *CP* asymmetry in tree-level vs $S_{\psi Ks}$ and $\Delta m_d/\Delta m_s$	2^o
tauonic (semi)-leptonic decays: $B\to\tau\nu$, $B\to D^{(*)}\tau\nu$	3%
Difference of *CP* asymmetry in $S_{\psi Ks}$ and $S_{\phi Ks}$	2%
Search for *CP* violation in D0 –$\bar{D}$0 mixing (arg(p/q))	2^o
CP asymmetry in the radiative decay $B\to K^*\gamma$	0.5%
CP asymmetry in semileptonic decays A_{sl}	0.5%
Rare decay searches $B\to h\,\nu\nu$ ($h=K, K^*, \pi, \rho, \phi$), $B\to\mu\nu$	5σ discovery
Lepton flavor violation in $\tau\to\mu\gamma$, 3μ and similar modes	10^{-9}-10^{-10}
FB asymmetry in $B\to K^*ll$	4% for C_9,C_{10}

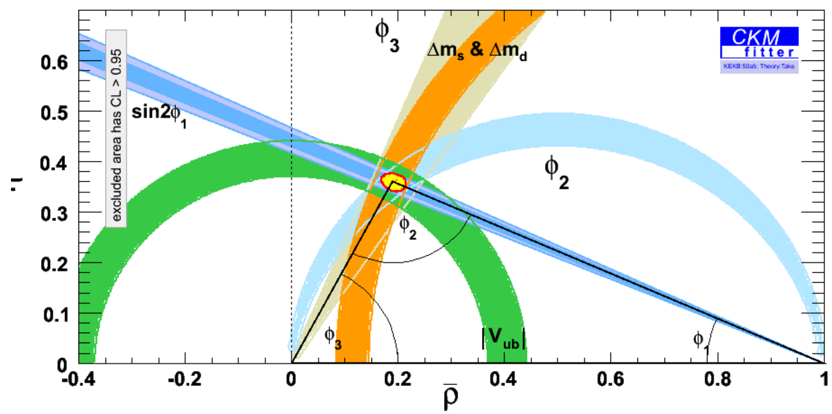
- Broad program and Complementary to LHCb
- Any one of these measurements has the potential to establish new physics.

Expected improvements: Unitarity Triangle

Now (2012)

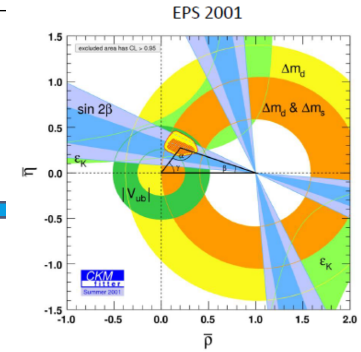


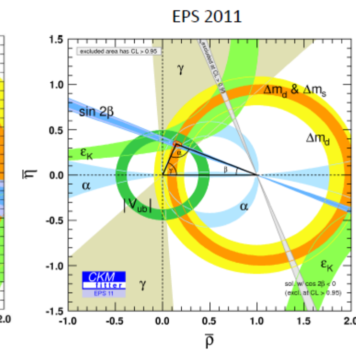
2022



No change of the center value is assumed.

Summary





- There is a stringent limit for the charged Higgs mass in 2HDM from rare-B decay. $B \to \to D^{(*)}\tau\nu$ measurements have $>3\sigma$ deviations from SM predictions. They cannot be explained also by 2HDM Type II at more than 99.5% C.L. for any value of tanβ and charged Higgs mass.
- UT triangle: still 10-20% NP is possible.
- Belle II with L x40 is planning to start physics run in 2016.
- Many key observables, sensitive to NP, the precision can be improved by order of magnitude in Belle II.
- Flavor is crucial for the search for NP indirectly, that has an sensitivity for multi-TeV region or higher (high reach) .

Expect a new, exciting era of discoveries, complementary to LHC(b)

Backup

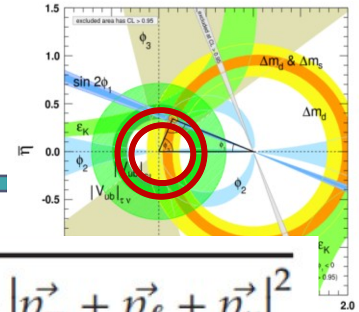
Key Observables and expected Accuracy

Observable	Expected th. accuracy	Expected exp. uncertainty	Facility
CKM matrix			
$\|V_{us}\|$ $[K \to \pi \ell \nu]$	**	0.1%	K-factory
$\|V_{cb}\|$ $[B \to X_c \ell \nu]$	**	1%	Belle II
$\|V_{ub}\|$ $[B_d \to \pi \ell \nu]$	*	4%	Belle II
$\sin(2\phi_1)$ $[c\bar{c}K_S^0]$	***	$8 \cdot 10^{-3}$	Belle II/LHCb
ϕ_2		1.5°	Belle II
ϕ_3	***	3°	BelleII/LHCb
CPV			
$S(B_s \to \psi\phi)$	**	0.01	LHCb
$S(B_s \to \phi\phi)$	**	0.05	LHCb
$S(B_d \to \phi K)$	***	0.05	Belle II/LHCb
$S(B_d \to \eta' K)$	***	0.02	Belle II
$S(B_d \to K^*(\to K_S^0\pi^0)\gamma))$	***	0.03	Belle II
$S(B_s \to \phi\gamma))$	***	0.05	LHCb
$S(B_d \to \rho\gamma))$		0.15	Belle II
A_{SL}^d	***	0.001	LHCb
A_{SL}^s	***	0.001	LHCb
$A_{CP}(B_d \to s\gamma)$	*	0.005	Belle II
rare decays			
$\mathcal{B}(B \to \tau\nu)$	**	3%	Belle II
$\mathcal{B}(B \to D\tau\nu)$		3%	Belle II
$\mathcal{B}(B_d \to \mu\nu)$	**	6%	Belle II
$\mathcal{B}(B_s \to \mu\mu)$	***	10%	LHCb
zero of $A_{FB}(B \to K^*\mu\mu)$	**	0.05	LHCb
$\mathcal{B}(B \to K^{(*)}\nu\nu)$	***	30%	Belle II
$\mathcal{B}(B \to s\gamma)$		4%	Belle II
$\mathcal{B}(B_s \to \gamma\gamma)$		$0.25 \cdot 10^{-6}$	Belle II (with 5 ab^{-1})
$\mathcal{B}(K \to \pi\nu\nu)$	**	10%	K-factory
$\mathcal{B}(K \to e\pi\nu)/\mathcal{B}(K \to \mu\pi\nu)$	***	0.1%	K-factory
charm and τ			
$\mathcal{B}(\tau \to \mu\gamma)$	***	$3 \cdot 10^{-9}$	Belle II
$\|q/p\|_D$	***	0.03	Belle II
$arg(q/p)_D$	***	1.5°	Belle II

→Need both LHCb and super B factories to cover all aspects of precision flavour physics

- B. Golob, KEK FF Workshop, Feb. 2012

$|V_{ub}|$ from $B^0 \to \pi^- / l^+ \nu$ exclusive decays



- Full reconstruction of other side B.→ neutrino mom.
- Yield: 2d fit in M_{bc}=M_{ES} and ΔE, in bins of q^2

$$m_{bc} = \sqrt{E^2_{beam} - |\vec{p_\pi} + \vec{p_\ell} + \vec{p_\nu}|^2}$$
$$\Delta E = E_{beam} - (E_\pi + E_\ell + E_\nu)$$

$\mathcal{B}$=(1.41±0.05±0.07)·10^{-4}

BaBar, PRD83, 032007 (2011)

$\mathcal{B}$=(1.42±0.05±0.07)·10^{-4}

BaBar, PRD83, 052011 (2011)

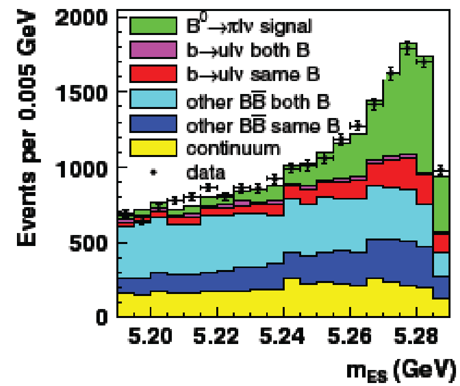
$\mathcal{B}$=(1.49±0.04±0.07)·10^{-4}

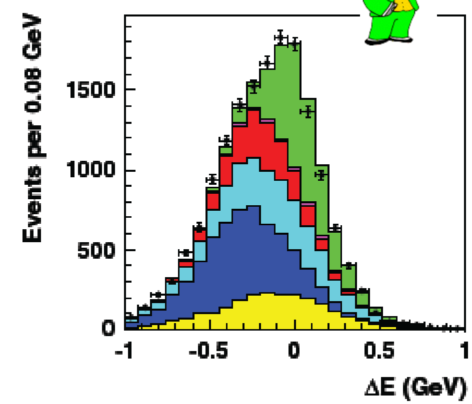
Belle, PRD83, 071101 (2011)

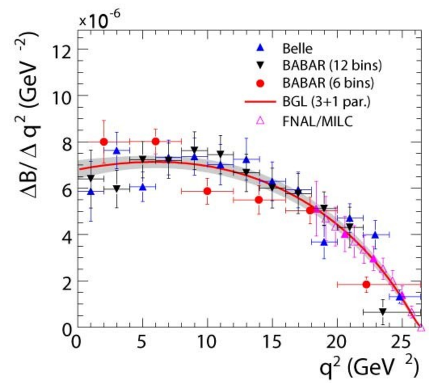
$\mathcal{B}$=(1.49±0.09±0.07)·10^{-4}

Belle, preliminary

New results using full reconstruction hadron tag







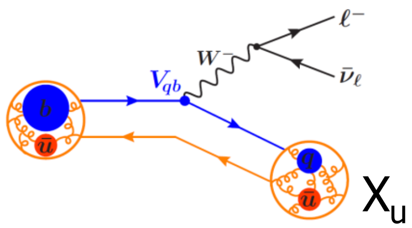
$|V_{ub}|$ extraction: fit data + LQCD points in $q^2 = (p_\ell + p_\nu)^2 = (p_B - p_\pi)^2$

Belle + BaBar + FNAL/MILC

$|V_{ub}|$ = (3.23 ± 0.30)·10^{-3}

Good shape but

$|V_{ub}|$ from inclusive decays $B \to X_u \ell^+ \nu$



The other possibility: inclusive b→u measurement by measuring momentum spectrum in semileptonic b→u decays, or by using tagged events (e.g. fully reconstruct one of the B's, and then measure the rate vs mass of the hadronic system X_u)

Inclusive decays vs exclusive decays differ at a level of 3σ

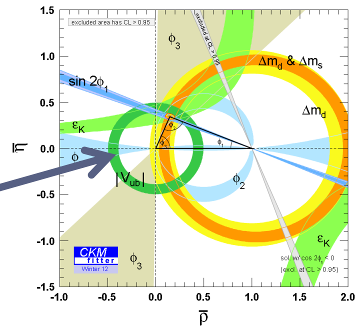
$|V_{ub}|_{inc} = (4.42 \pm 0.20\,(\text{exp}) \pm 0.15(\text{th}))\text{x}10^{-3}$

$|V_{ub}|_{excl} = (3.23 \pm 0.16(\text{exp}) \pm 0.25(\text{th}))\text{x}10^{-3}$

→ Tension between inclusive and exclusive decays is still there - and not understood

The average of inc. and excl. is used in a global (CKM) fit.

$|V_{ub}|_{fit} = (3.95 \pm 0.38(\text{exp}) \pm 0.39(\text{th}))\text{x}10^{-3}$

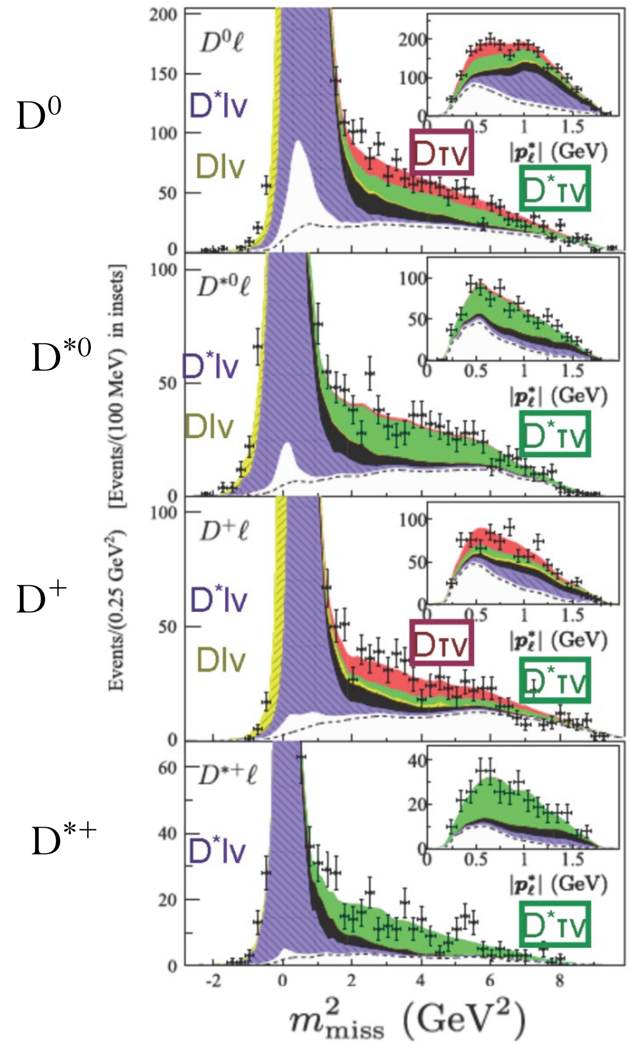


$B \longrightarrow D^{(*)}\tau\nu$ from BaBar

- $B \rightarrow D^{(*)}\tau\nu$ are another processes sensitive to H^-
- PRL 109, 101802 (2012)+ arxiv:1303.0571
- Full data (471MBB). Full reconstruction other B.
- Measure both neutral and charged modes.
- Final selection from missing mass and lepton momentum. $m^2_{\text{miss}}, |\, p_l^* \,|$
- Results

$$\mathcal{R}(D) = \frac{\mathcal{B}(B \to D\tau\nu_\tau)}{\mathcal{B}(B \to Dl\nu_\tau)} = 0.440 \pm 0.058 \pm 0.042$$

$$\mathcal{R}(D) = \frac{\mathcal{B}(B \to D^*\tau\nu_\tau)}{\mathcal{B}(B \to D^*l\nu_\tau)} = 0.332 \pm 0.024 \pm 0.018$$

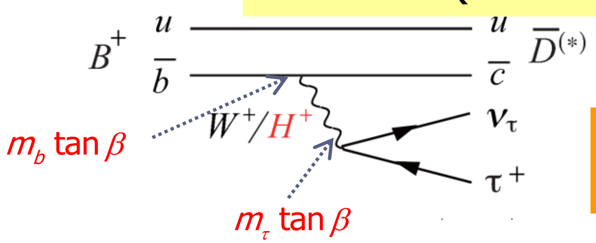


B⟶Dτν and B⟶D*τν

- B→D(*) τν are another processes sensitive to the charged Higgs
- Ratios to B→D(*) lν,(l=e,μ) are measured.
  - Several uncertainties, B⟶D form factor, |Vcb|, tagging eff. are cancel.
  - Small theoretical uncertainty. Large Br in SM (~ 1%)

$$\mathcal{R}(D) = \frac{\mathcal{B}(B \to D\tau\nu_\tau)}{\mathcal{B}(B \to Dl\nu_\tau)}$$

$$\mathcal{R}(D^*) = \frac{\mathcal{B}(B \to D^*\tau\nu_\tau)}{\mathcal{B}(B \to D^*l\nu_\tau)}$$



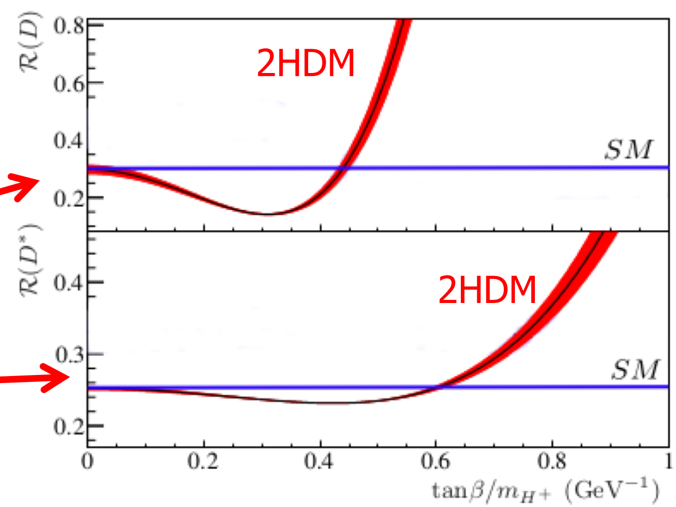
$$C_\tau^{NR} = -\frac{m_b m_\tau}{M_H^2}\tan^2\beta$$

$$R(D) = R_{SM}(D)(1 + 1.5\mathrm{Re}(C_\tau^{NR}) + 1.1|C_\tau^{NR}|^2)$$

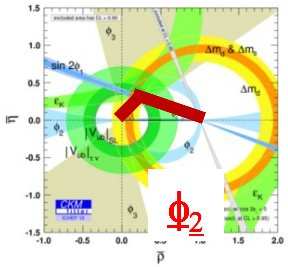
$$R_{SM}(D) = 0.297 \pm 0.017$$

$$R(D^*) = R_{SM}(D^*)(1 + 0.12\mathrm{Re}(C_\tau^{NR}) + 0.05|C_\tau^{NR}|^2)$$

$$R_{SM}(D^*) = 0.252 \pm 0.003$$



S.Fajfer, J. Kamenik, I. Nisandzic, PRD 85, 094025 (2012)

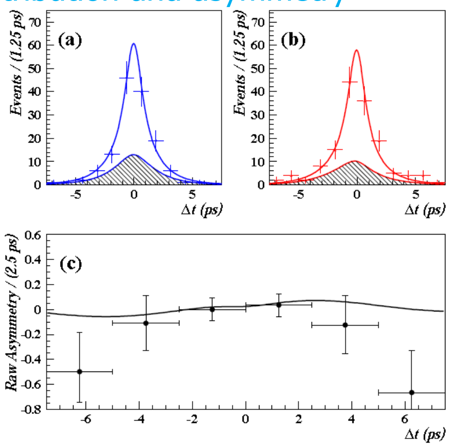


Measurement of ϕ_2 in $B \to \rho^+\rho^-$

Belle, PRD 76 011104(2007)

Update to 535 million $B\bar{B}$ pairs

Δt distribution and asymmetry

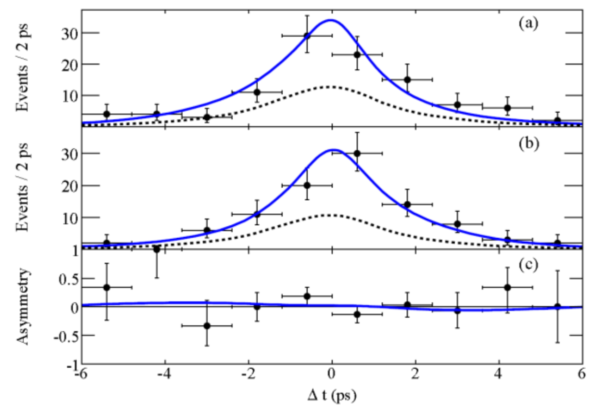


$$S_{CP} = +0.19 \pm 0.30 \pm 0.07$$
$$A_{CP} = +0.16 \pm 0.21 \pm 0.07$$

BaBar, PRD 76 052007(2007)

384 million $B\bar{B}$ pairs

Δt distribution and asymmetry



$$S_{CP} = -0.17 \pm 0.20^{+0.05}_{-0.06}$$
$$A_{CP} = -0.01 \pm 0.15 \pm 0.06$$

$\rho\rho$ mode has a high sensitivity to ϕ_2, since $Br(\rho^0\rho^0)$ is small.

$$Br(B^0 \to \rho^0\rho^0) = (0.92 \pm 0.32 \pm 0.14) \times 10^{-6}\ (BaBar : 2008)$$
$$= (1.02 \pm 0.30 \pm 0.22) \times 10^{-6}\ (Belle : 2012)$$

Preliminary.arxiv:12
12.4015