PANIC July 28, 2011

Superb prospects: Physics at Belle II/SuperKEKB

cf G. Varner, talk 3H-1
SuperKEKB & Belle II projects

Kay Kinoshita
University of Cincinnati
Belle II Collaboration

Belle (1999-2010)

Primary goal: establish unitarity & complex phase of CKM matrix

Kobayashi & Maskawa (1973)

- propose 3rd generation of particles
- Explain CP violation in K, predict for B

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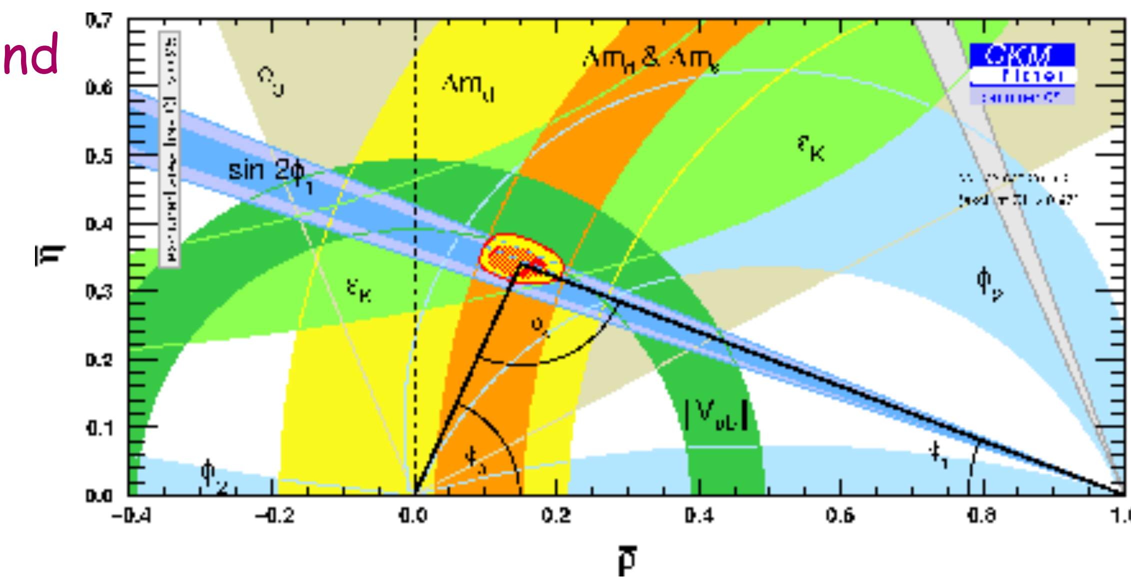
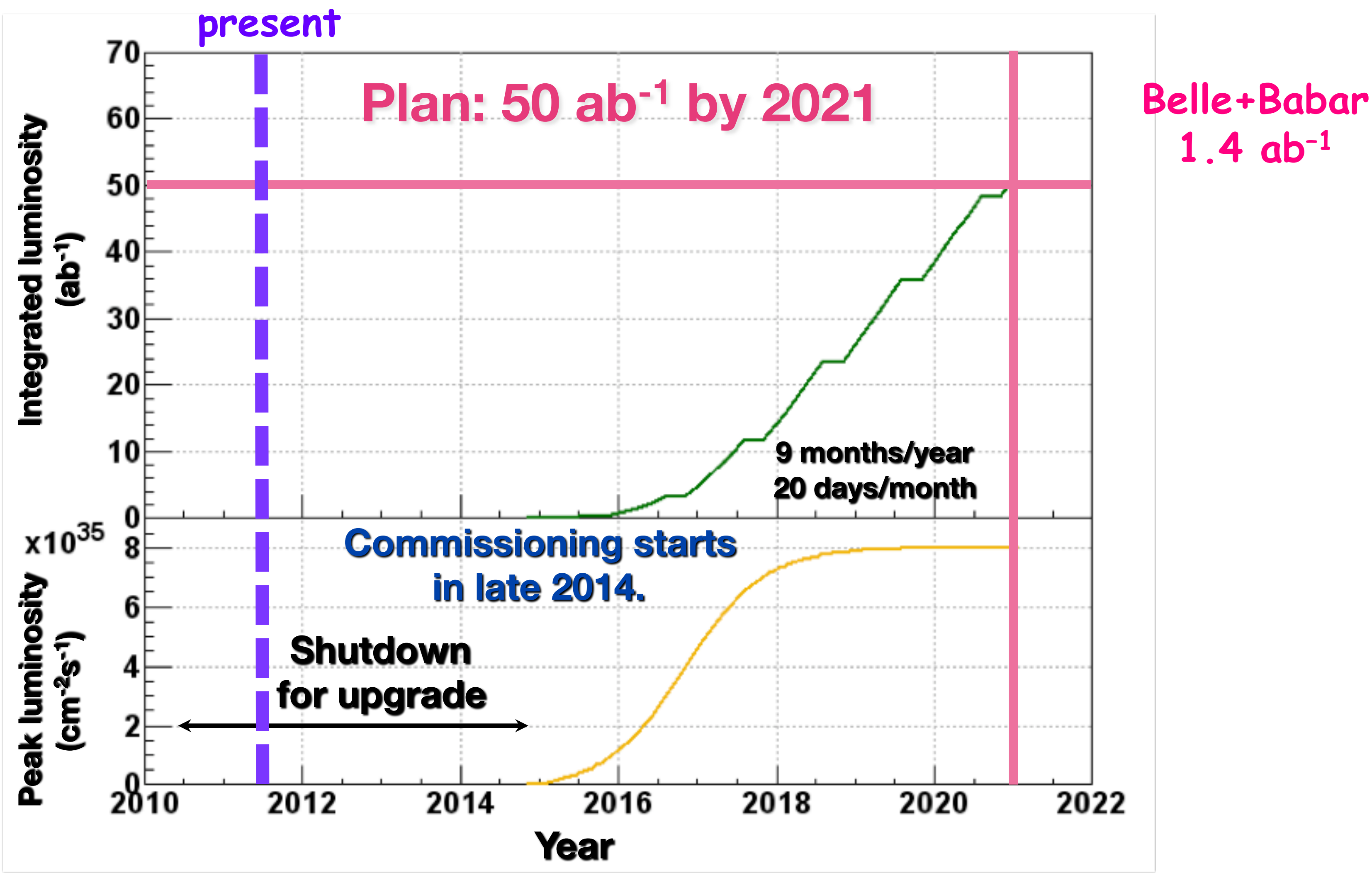
B-Factories (1999-)

- CP asymmetry manifested in diverse processes in B decay -> many measurements, (over)constrain CKM, found consistent with unitarity



Future: SuperKEKB/Belle II



Advantages of e^+e^-: γ, K_L detection; hermeticity -> neutrinos

This talk: focus on prospects that are unique to high-lum e^+e^-

Why a Super-B-factory? Role of Flavor in SM history

Flavor – (i.e. wrt weak interaction) essential properties:

- L-R asymmetry
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Discovery & phenomenology

- maximal P violation [V-A]
- unitarity: GIM → charm
- CP violation -> Kobayashi-Maskawa -> 3rd generation
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Bottom line: flavor in SM imposes cancellations & precise relationships that both test SM and constrain New Physics (NP) to higher mass scales

- "Unitarity triangle" [18 dof -> 4 dof]
- lepton universality

Search for Right-Handed Currents

Right-handed currents

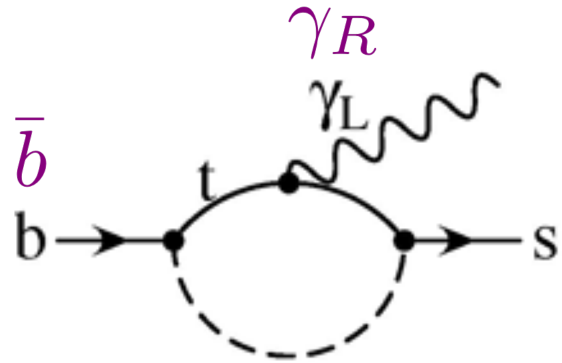
in SM

$B^0 \to X_s\gamma$ is

~flavor-specific (γ polarization)

-> low CP-asymmetry, O(3%)

O(0) for $B^0 \to X_d\gamma$



Atwood, Gronau, Soni (PRL 79, 185 (1997))
Atwood, Gershon, Hazumi, Soni (PRD 71, 076003 (2005))

large asymmetry

<->

right-handed current

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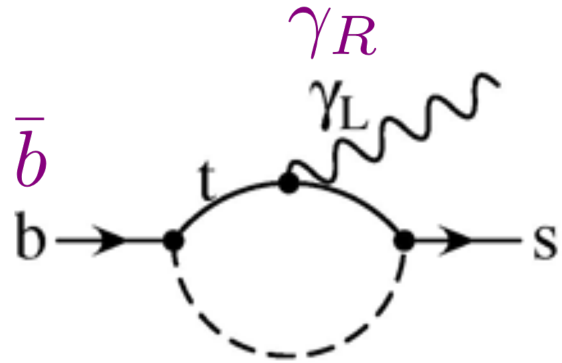

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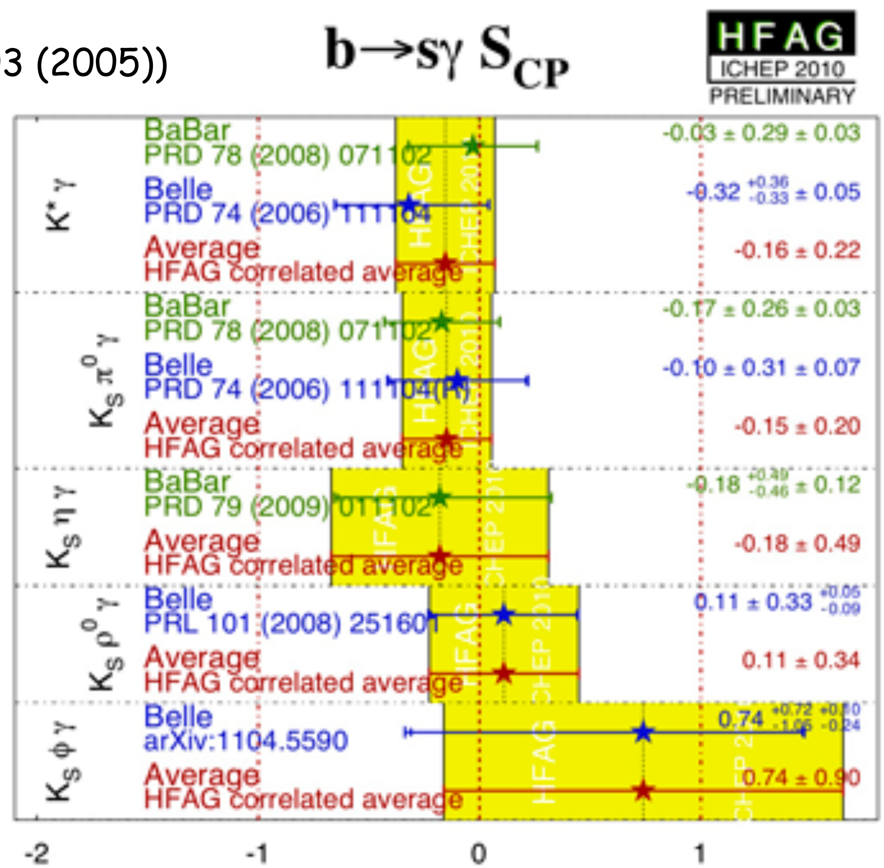
large asymmetry
<->
right-handed current

Current results:
consistent with no
RH currents (S<~30%)

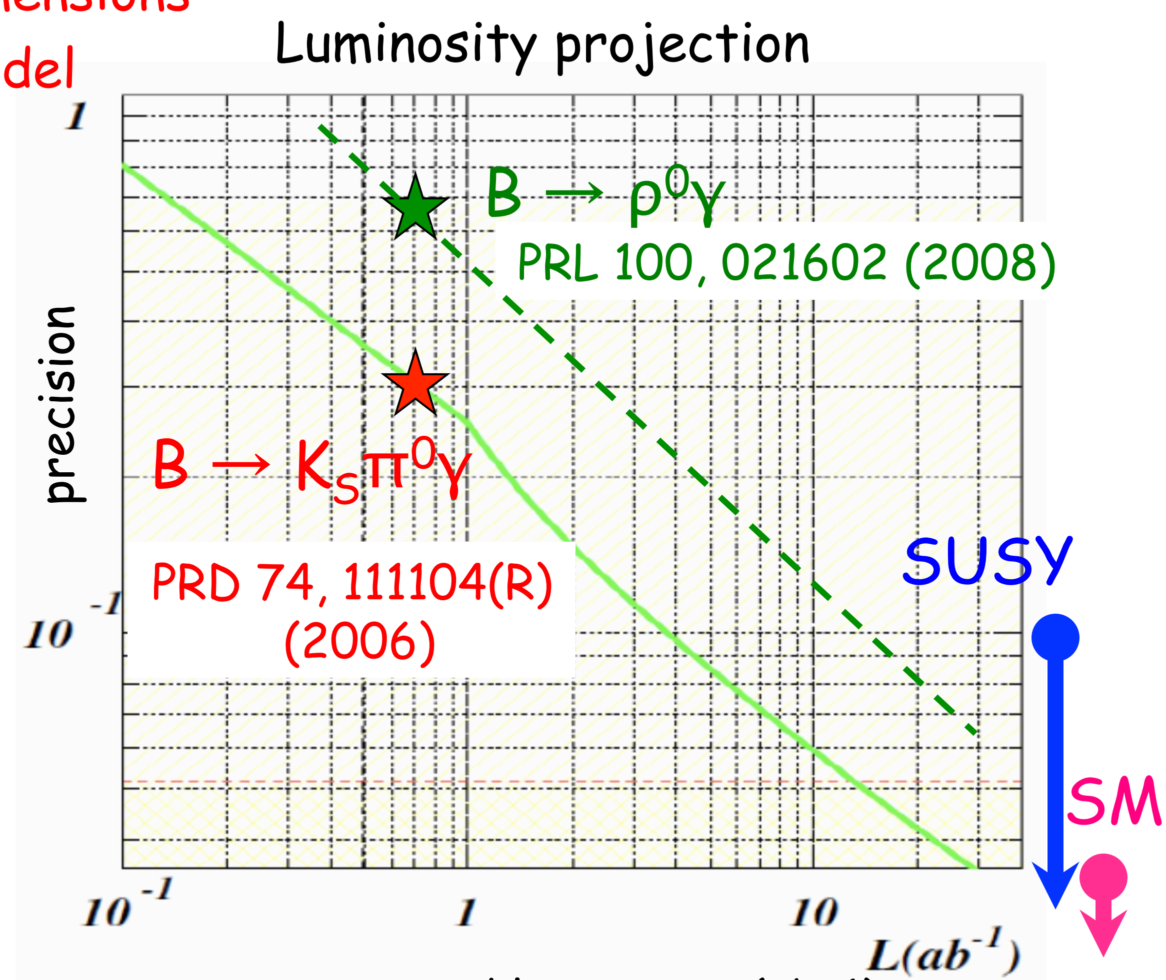


Right-handed currents

Possible contributions from NP

- O(1): Warped extra dimensions
- O(1): L-R symmetric model
- O(0.1): SUSY SU(5)

Luminosity projection



Integrated luminosity (ab−1)

with 50 ab^{-1}

$\Delta S(K^{*0}\gamma) = 0.027$

$\Delta S(\rho^0\gamma) = 0.075$

Search for CP Anomalies

CP asymmetry: "standard" $\sin 2\varphi_1$ ($\sin 2\beta$)

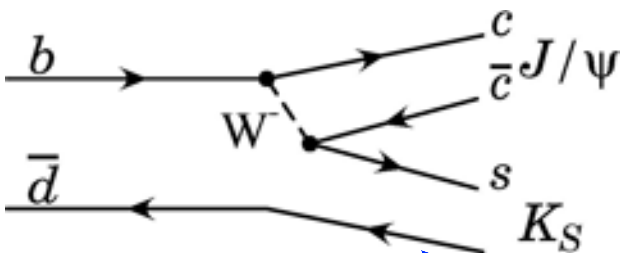
for $B \to J/\psi\, K_s$

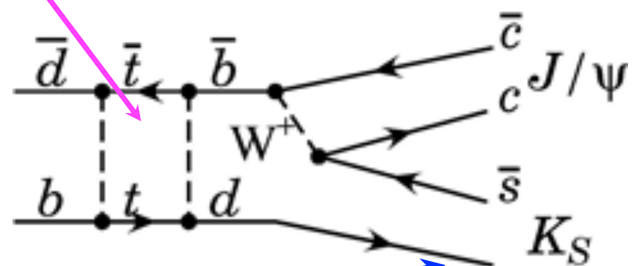
tree (real V_{ij}) $\propto V_{cb}^{*} V_{cs}$

mixing+tree $\propto V_{tb}^{*2} V_{td}^{2} V_{cb} V_{cs}^{*}$

well-measured rate

phase = $\arg(V_{tb}^{*2} V_{td}^{2}) = 2\varphi_1$





identical hadronic processes -> same |Amplitude|

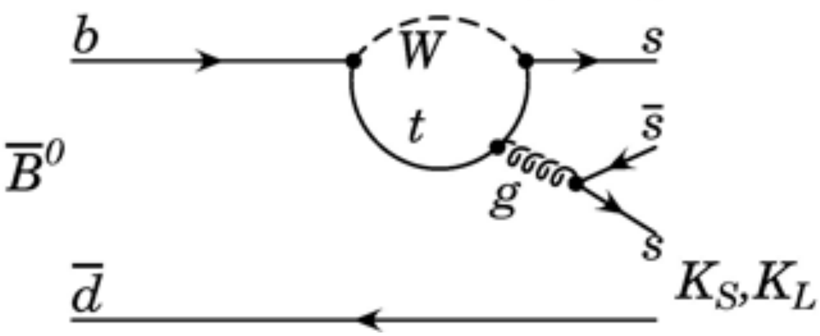
$V_{cb}^{*} V_{cs}$ real => zero phase difference

=> relative phase = $2\varphi_1$, CP asymmetry ~ $\sin 2\varphi_1$

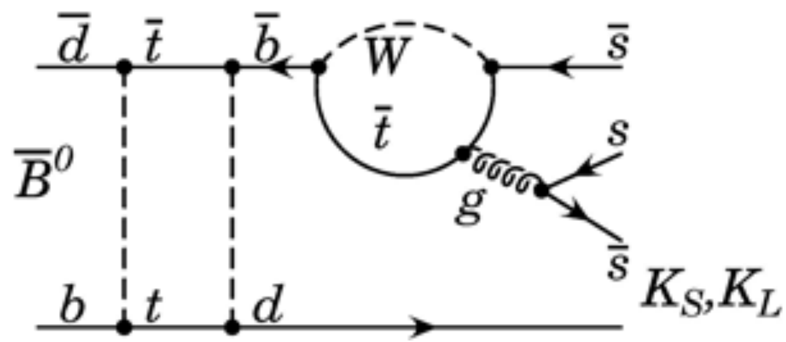
CP asymmetry: "other" $\sin 2\varphi_1$

for b -> $s\bar{s}s$: identical reasoning

Direct (real V_{ij}) $\propto V_{tb}^{*}V_{ts}$

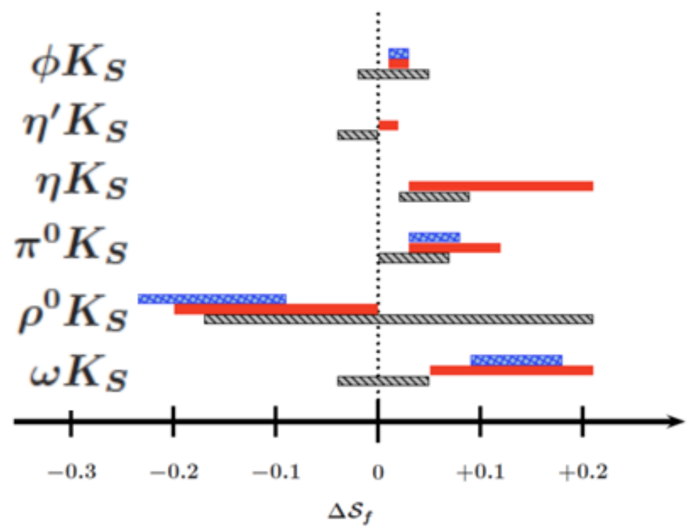


mixing+direct $\propto V_{tb}^{*2}V_{td}^{2}V_{tb}V_{ts}^{*}$



$V_{tb}^{*}V_{ts}$ real => zero phase difference

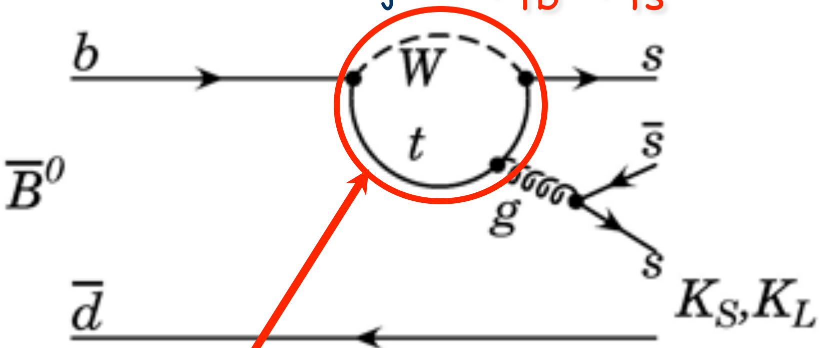
$\Rightarrow$relative phase = $2\varphi_1$,
CP asymmetry ~ $\sin 2\varphi_1$
w minor theory corrections



CP asymmetry: "other" $\sin 2\varphi_1$

for b -> $s\bar{s}s$: identical reasoning

tree (real V_{ij}) $\propto V_{tb}^{*} V_{ts}$



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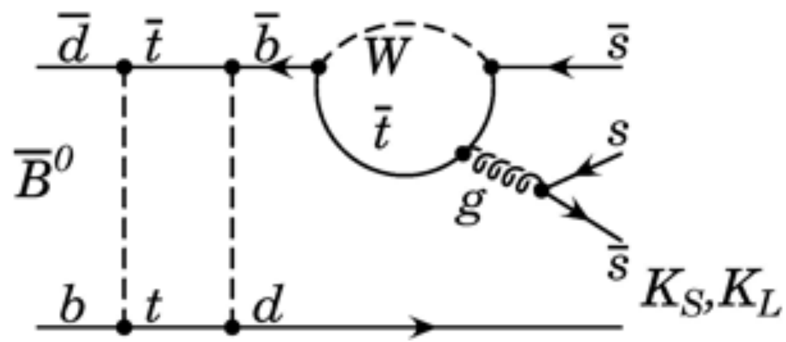

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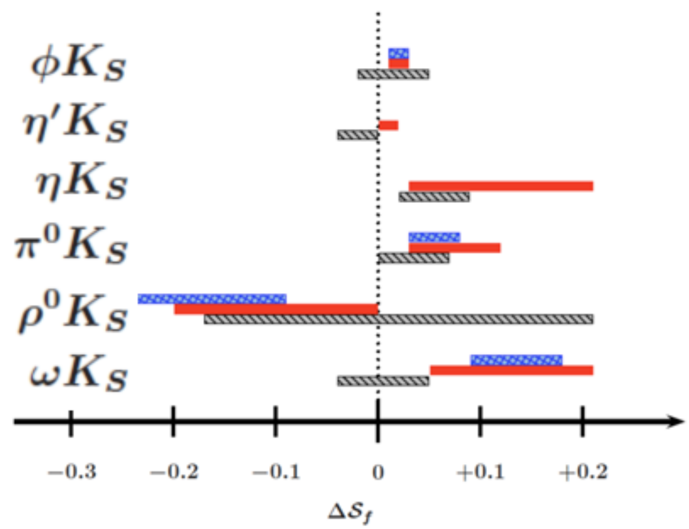


NP process w complex phase φ_{new}
---> CP asymmetry ≠ $\sin(2\varphi_1)$

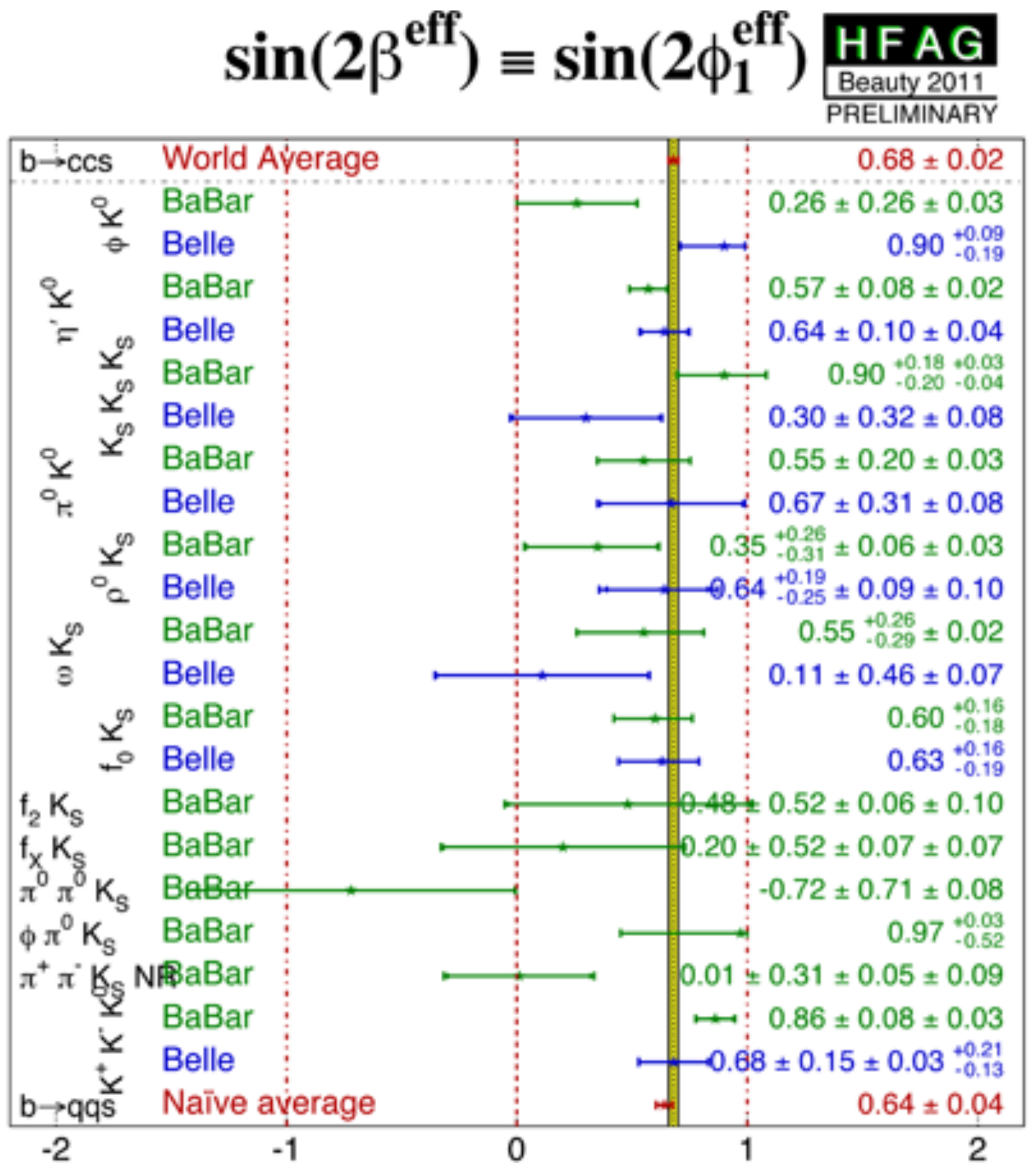
Average "sin2φ_1" from b->s penguins

Naïve World Average
$\sin 2\varphi_1(b\text{->}sq\bar{q}) = 0.64 \pm 0.04$

Compare to $c\bar{c}s$:
$\sin 2\varphi_1(b\text{->}c\bar{c}s) = 0.679 \pm 0.020$

CL = 0.28 (1.1σ)

Sensitivity to NP depends on
- statistics
- reduced systematics
- theory corrections



Leptons

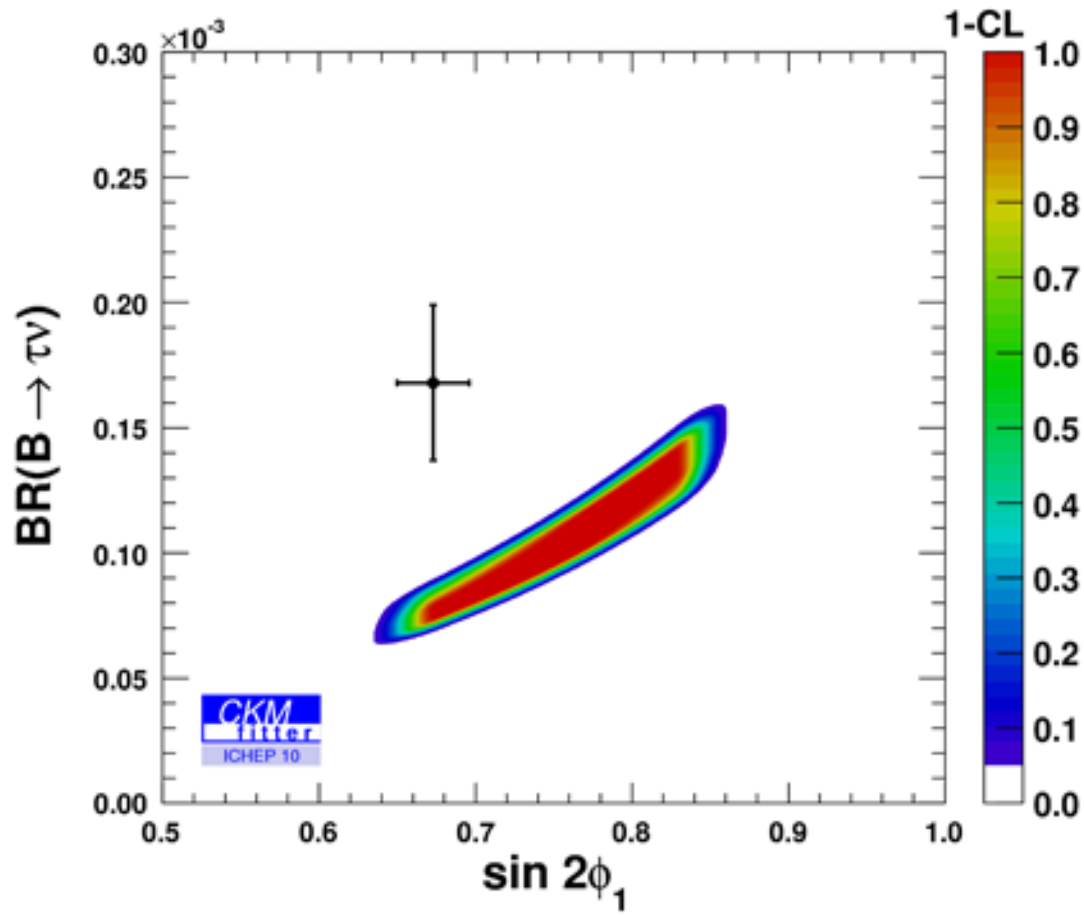
Precision measurement & Universality

In SM, B -> $\tau\nu_\tau$ BF is predicted precisely

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

CKMfitter:
2.8σ "tension"

B(B -> $\tau\nu_\tau$), sin2φ1
vs
all other CKM constraints

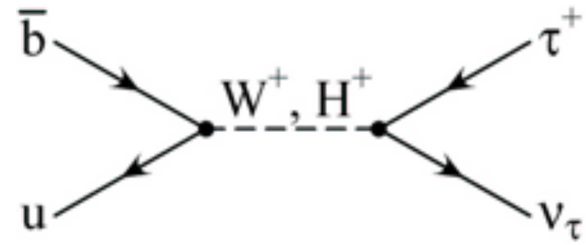


$B^+ \to \tau^+ \nu_\tau$: constraints on charged Higgs

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

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

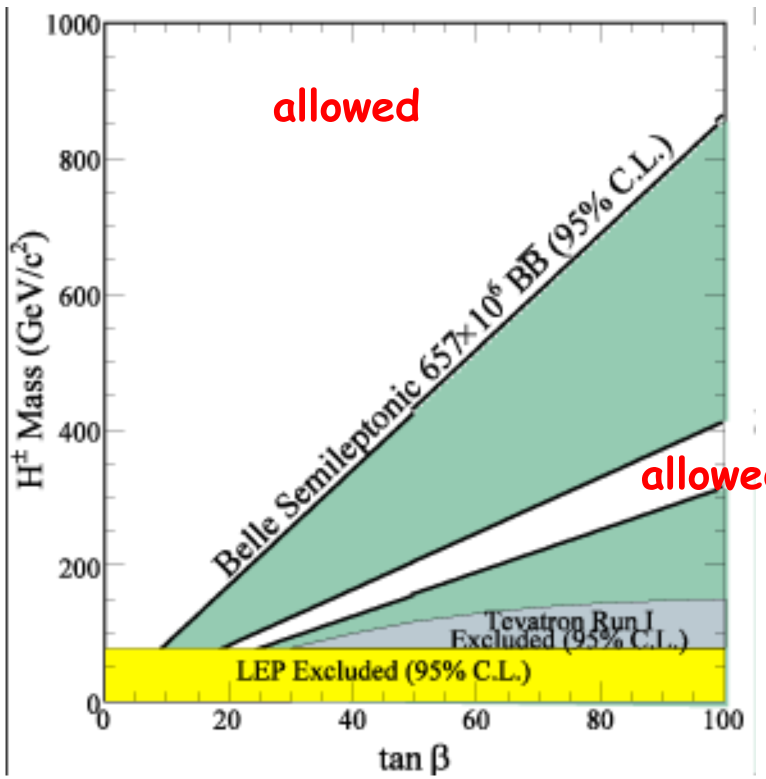
(2HDM)



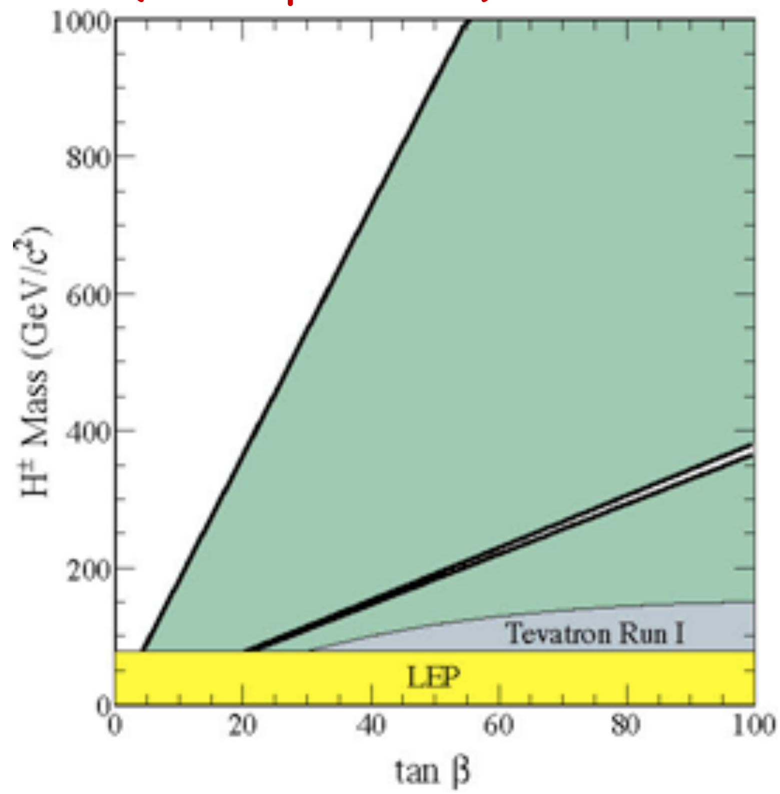
{WS Hou, PRD 48, 2342 (1993)}

(Belle) 0.65 ab^{-1}

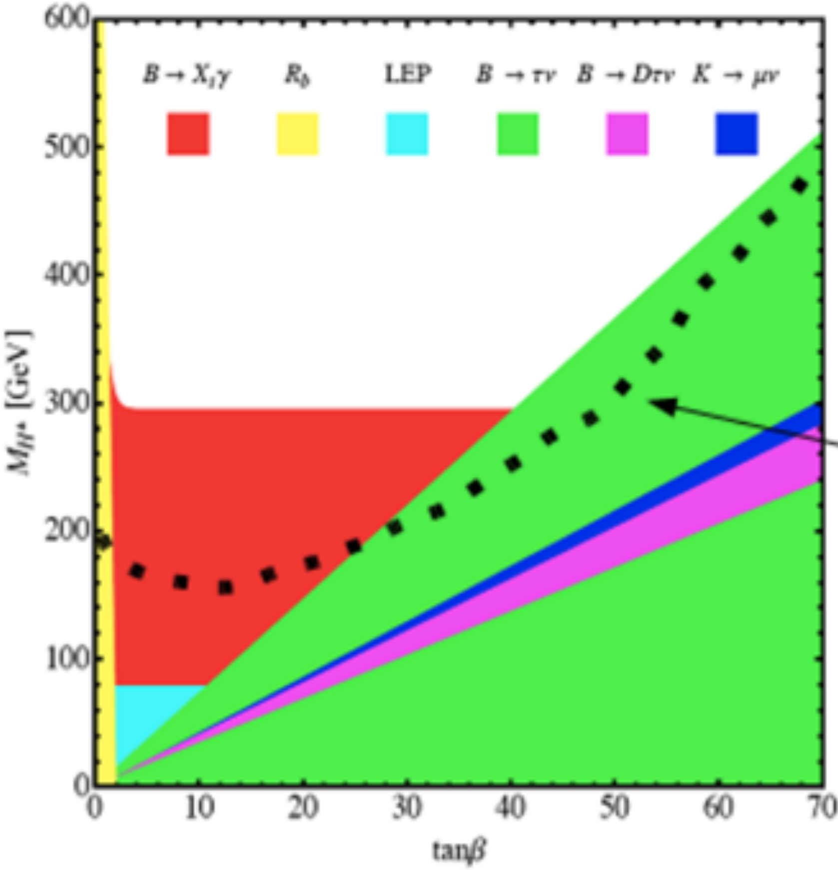
$\mathcal{B}(B \to \tau\nu) = (1.7 \pm 0.4 \pm 0.4) \times 10^{-4}$



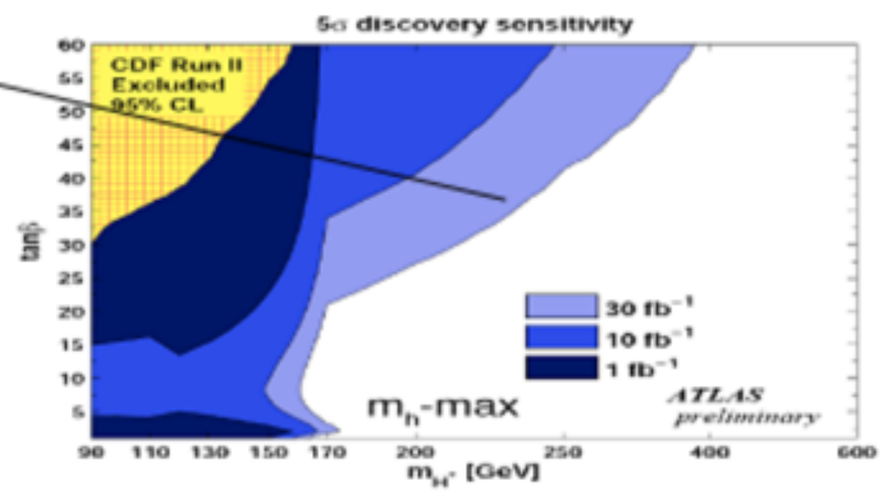
(extrapolation) 50 ab^{-1}



B Factories versus LHC (ATLAS) for the charged Higgs



Current flavour constraints are already very competitive with LHC expected direct search sensitivity for charged Higgs



U. Haisch, hep-ph/0805.2141; ATLAS curve added by *Steve Robertson*

Also see (MSSM),D. Eriksson,F.Mahmoudi and 0.Stal

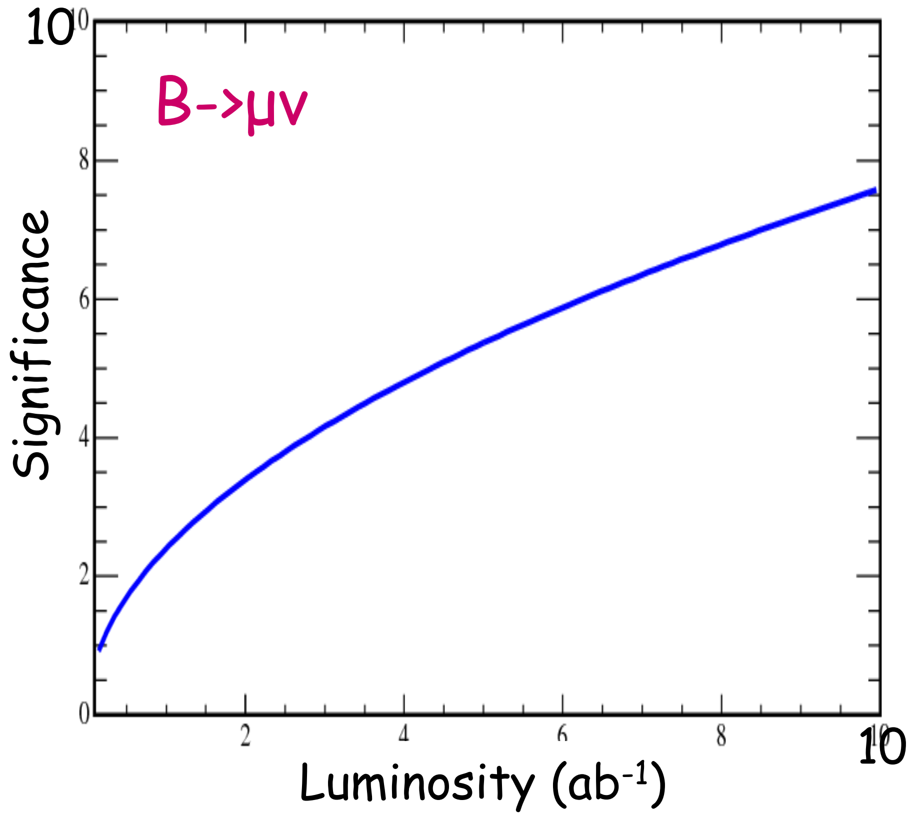
B→μν

SM:

B(B->τν) = 1.6×10^{-4}

B(B-> μν) = 7.1×10^{-7} observation with ~5 ab^{-1}

B(B-> eν) = 1.7×10^{-11}



B→μν

SM:

$B(B\to\tau\nu) = 1.6\times10^{-4}$

$B(B\to \mu\nu) = 7.1\times10^{-7}$ observation with ~5 ab^{-1}

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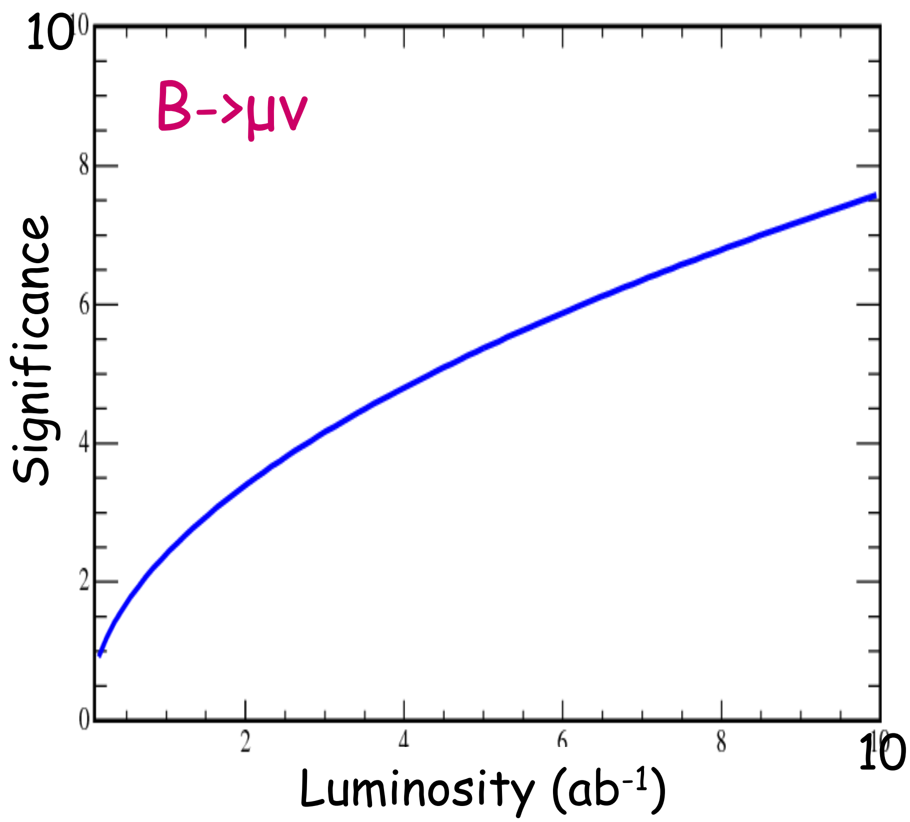
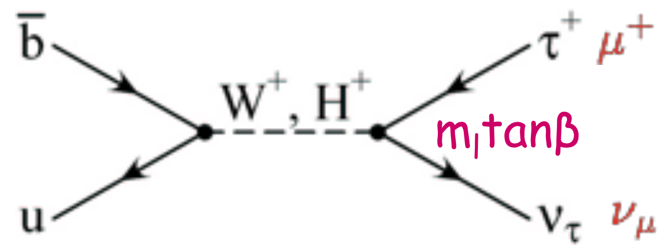


Universality

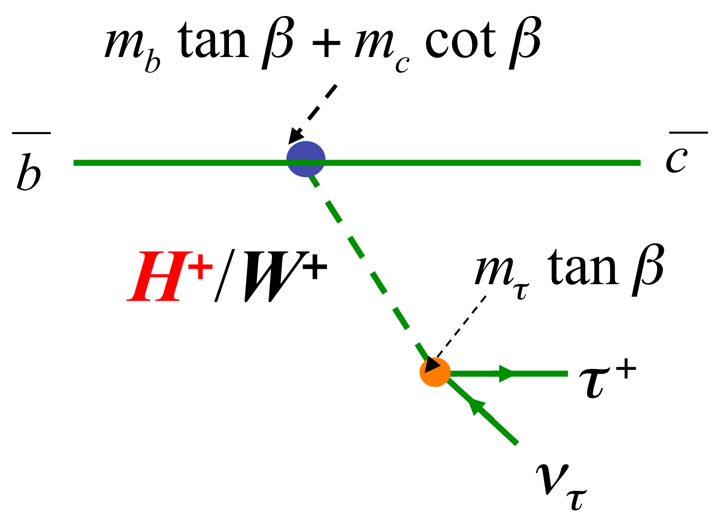


$$\frac{B\to\tau\nu}{B\to \mu\nu}$$

deviations from SM sensitive to NP

B → D$^{(*)}$ τ ν

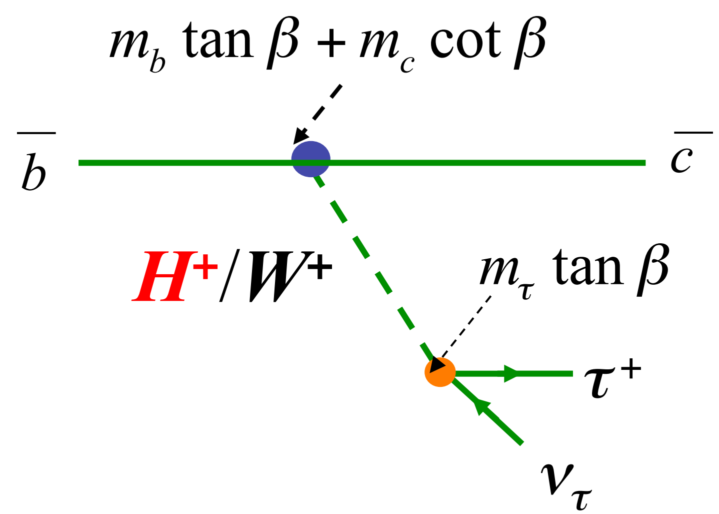
- Lepton universality via semileptonic decays



  - Ratio (τ/μ) is sensitive to charged Higgs (similar to B→τ ν)

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

- Lepton universality via semileptonic decays

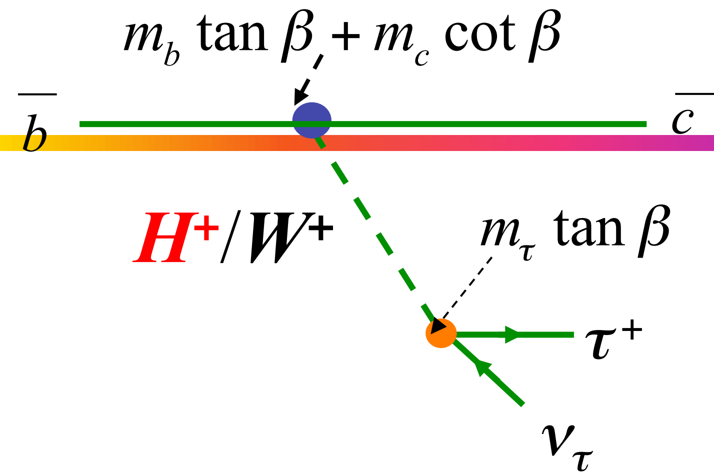


  - Ratio (τ/μ) is sensitive to charged Higgs (similar to $B \to \tau \nu$)

$B \to \tau X$ decays probe NP in different ways:

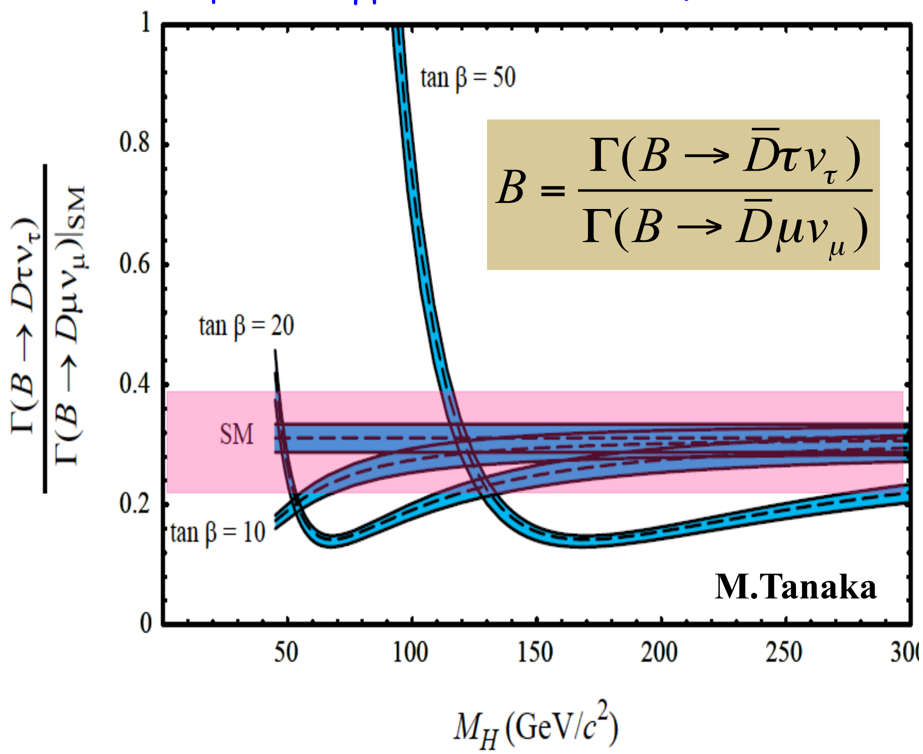
- $B \to \tau \nu$: H-b-u vertex
- $B \to D\tau\nu$: H-b-c vertex

B → D$^{(*)}$ τ ν

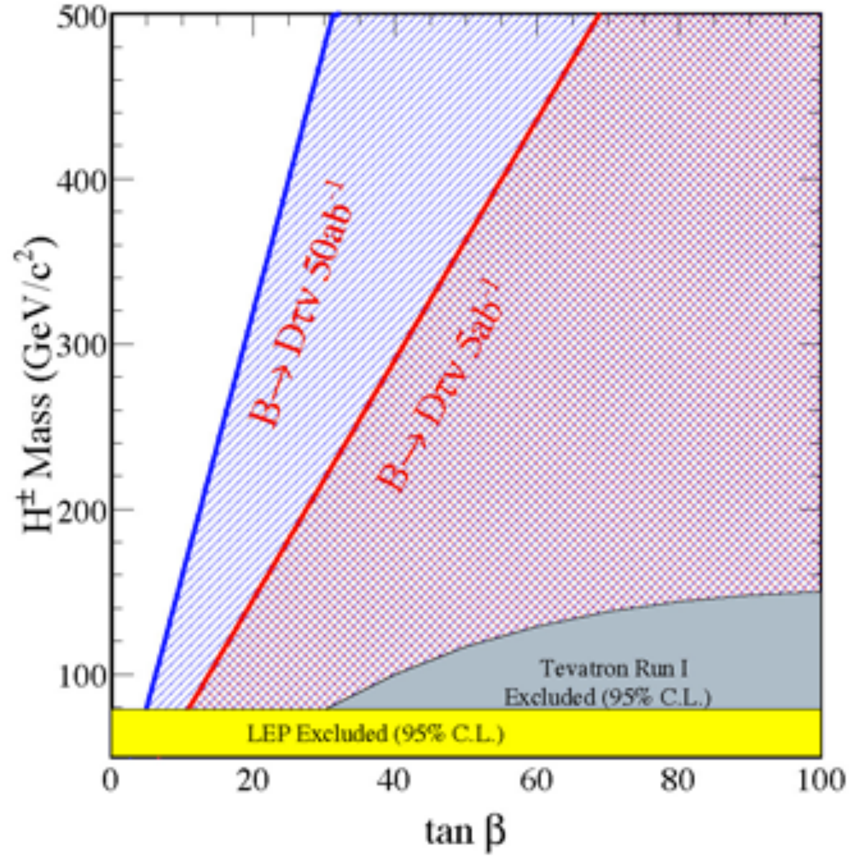


- B(B->D^{*-}τν)/B(B->D$^{*-}\ell\nu$)
  = R_τ = 0.29±0.10 [PDG 2011]

R_τ vs M_H, various tanβ



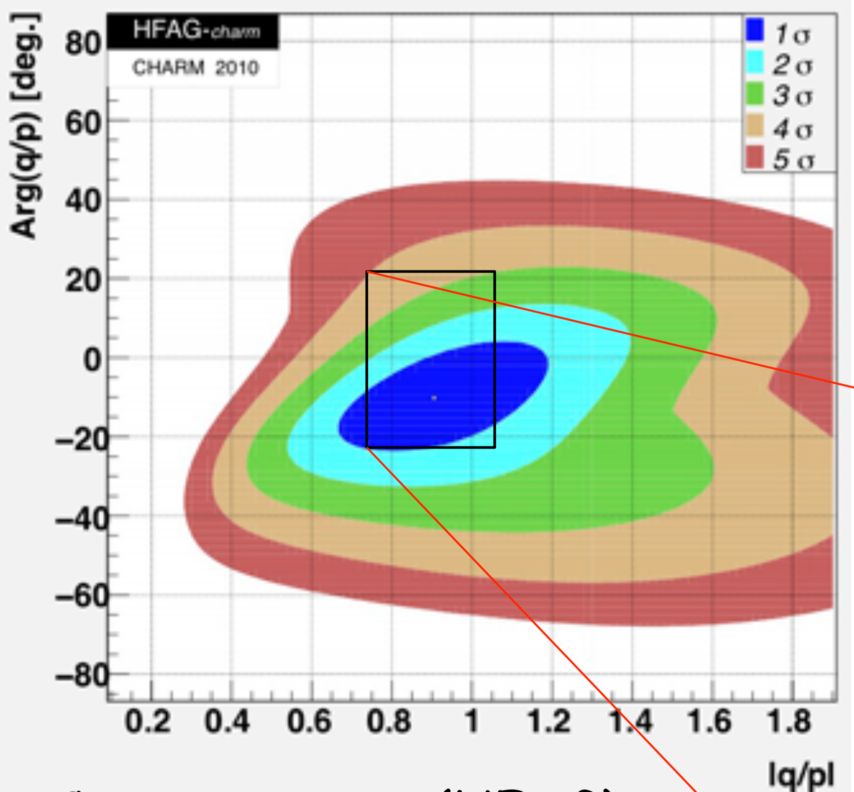
M_H vs tanβ sensitivity



Charm

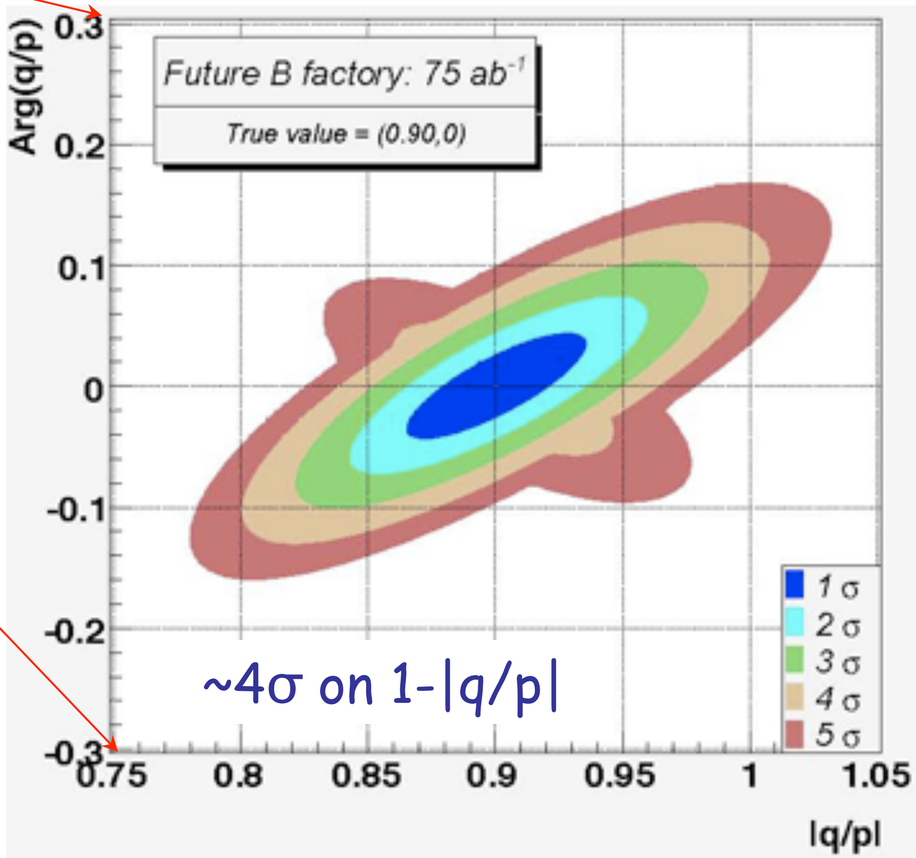
- Mixing/CP

D mixing/CP violation



Current status (HFAG)

MC 75 ab^{-1} |q/p|=0.9



~4σ on 1-|q/p|

what we need:

Billions and Billions of B's!

SuperKEKB & Belle II
(cf G. Varner, talk 3H-1)

Summary

- B-factories 1999-2010, >1.4x10^9 B pairs:
  established CKM as source of CP asymmetry in weak interaction
  multiple measurements on CKM with increasing precision
  -> probe New Physics at ~ few hundred GeV scale
  + discoveries: D mixing, new hadronic states
  possible hints of NP: Kπ CP asymmetry, imperfect CKM fit

- ~10^2X luminosity will probe significantly into >1 TeV mass scale
  precision CKM, CP, lepton universality, LFV
- SuperKEKB/Belle II well underway
  complementary to LHC in sensitivity