ICHEP 2012
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Physics with the BelleII Detector

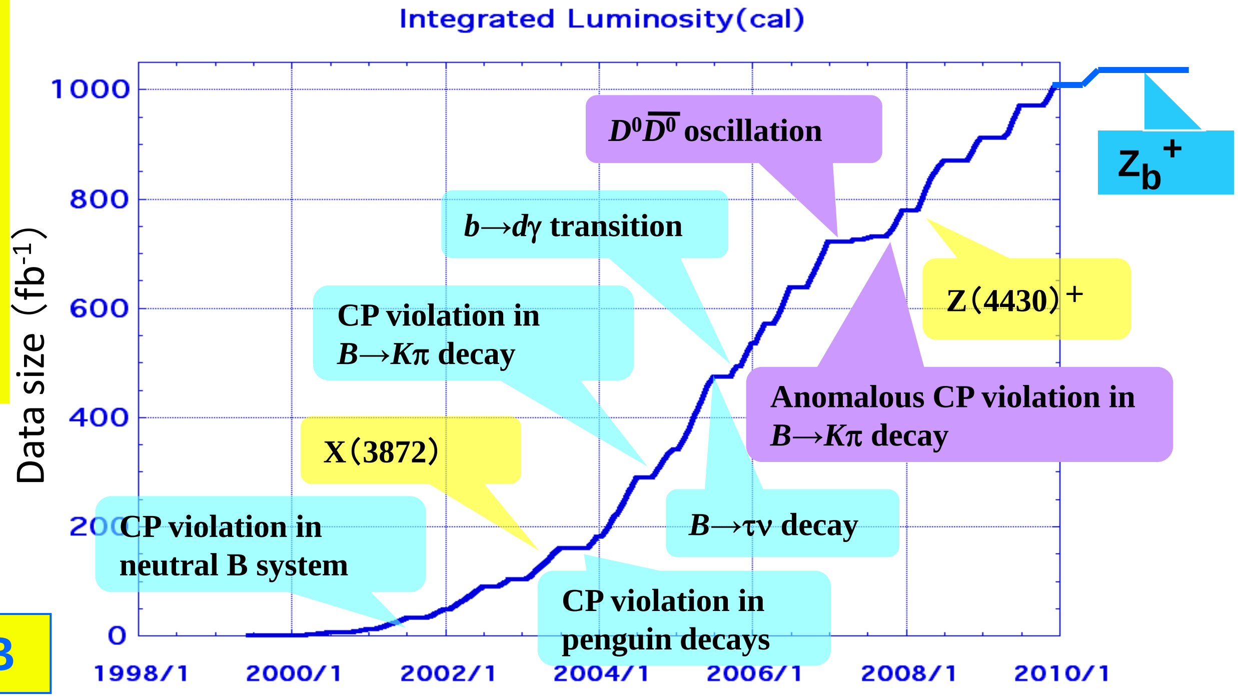
M.Danilov

Institute for Theoretical and Experimental Physics
Moscow
(Representing the BELLE II Collaboration)

Excellent KEKB performance allowed BELLE experiment to obtain many exciting results

Discoveries are still coming!

Next step is SuperKEKB



Ground breaking ceremony for SuperKEKB on November 11, 2011

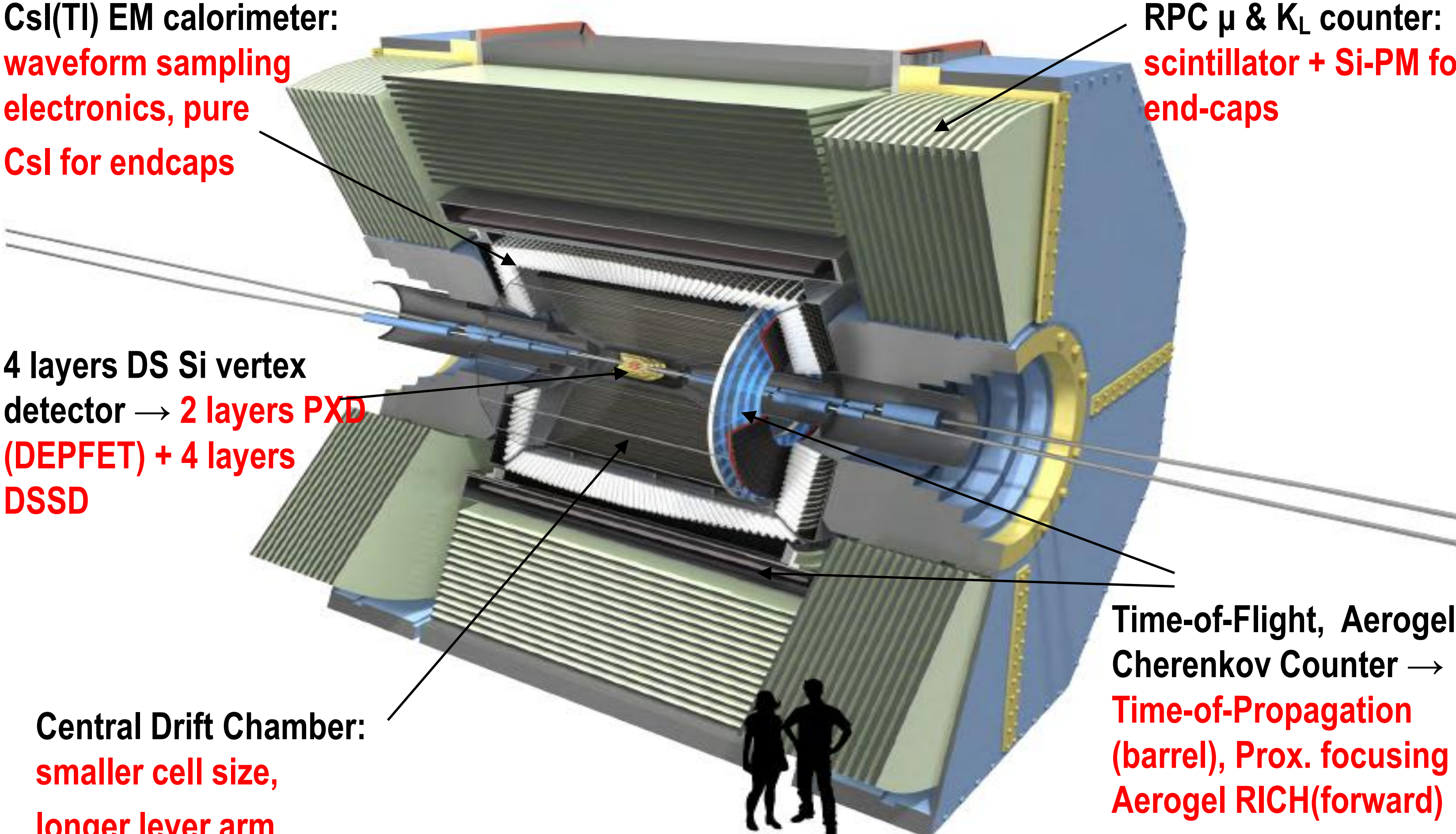
Upgrade of KEKB and Belle in progress (Talk by M.Sevior)

TDR published: arXiv:1011.0352v1 [physics.ins-det]

Belle II will start data taking in 2015

Aim at $10ab^{-1}$ by 2018 and $50ab^{-1}$ by 2022

BELLEII DETECTOR



CsI(TI) EM calorimeter:
waveform sampling electronics, pure CsI for endcaps

RPC μ & K_L counter:
scintillator + Si-PM for end-caps

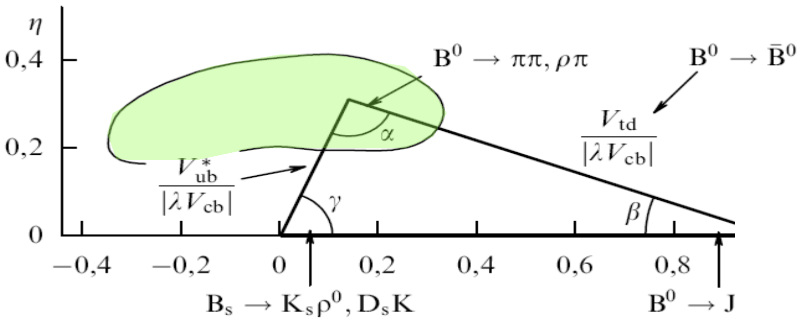
4 layers DS Si vertex detector → 2 layers PXD (DEPFET) + 4 layers DSSD

Time-of-Flight, Aerogel Cherenkov Counter →
Time-of-Propagation (barrel), Prox. focusing Aerogel RICH(forward)

Central Drift Chamber:
smaller cell size, longer lever arm

Precision of Unitarity Triangle measurements improved dramatically

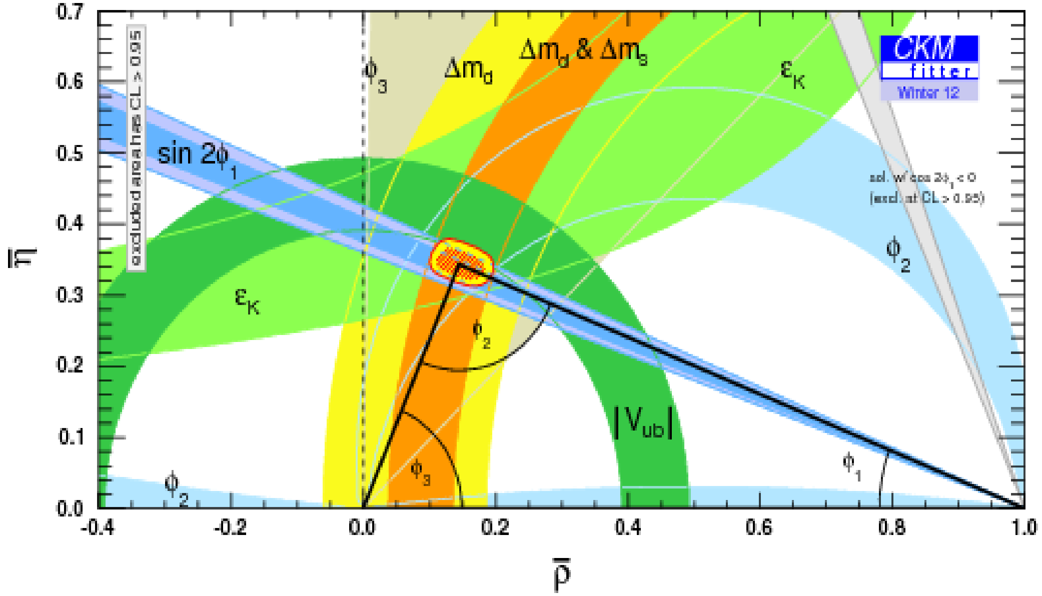
ARGUS & CLEO era



Belle & BaBar era

Belle precise measurement

$\sin2\varphi_1 = 0.667 \pm 0.023 \pm 0.012$



CKM Fitter 2012:

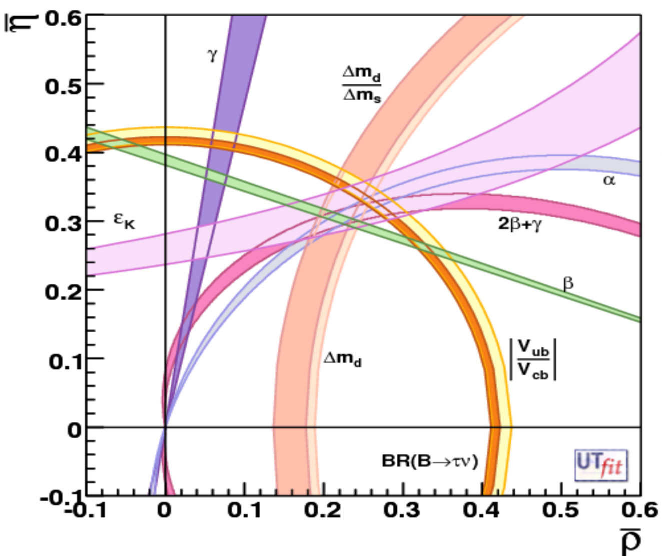
Indirect prediction	$\sin(2\phi_1) = 0.824^{+0.024}_{-0.028}$
World Average measurement	$\sin(2\phi_1) = 0.691 \pm 0.020$
	Large deviation

Precise measurements of UT are still highly important !!!

Expected sensitivity for UT parameters at 50ab^{-1} (arXiv:1002.5012)

Observable	Belle 2006 (~0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})	†LHCb (2 fb^{-1})	†LHCb (10 fb^{-1})
Unitarity triangle parameters					
$\sin 2\phi_1$	0.026	0.016	0.012	~0.02	~0.01
ϕ_2 ($\pi\pi$)	11°	10°	3°	-	-
ϕ_2 ($\rho\pi$)	$68° < \phi_2 < 95°$	3°	1.5°	10°	4.5°
ϕ_2 ($\rho\rho$)	$62° < \phi_2 < 107°$	3°	1.5°	-	-
ϕ_2 (combined)		2°	$\lesssim 1°$	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%		

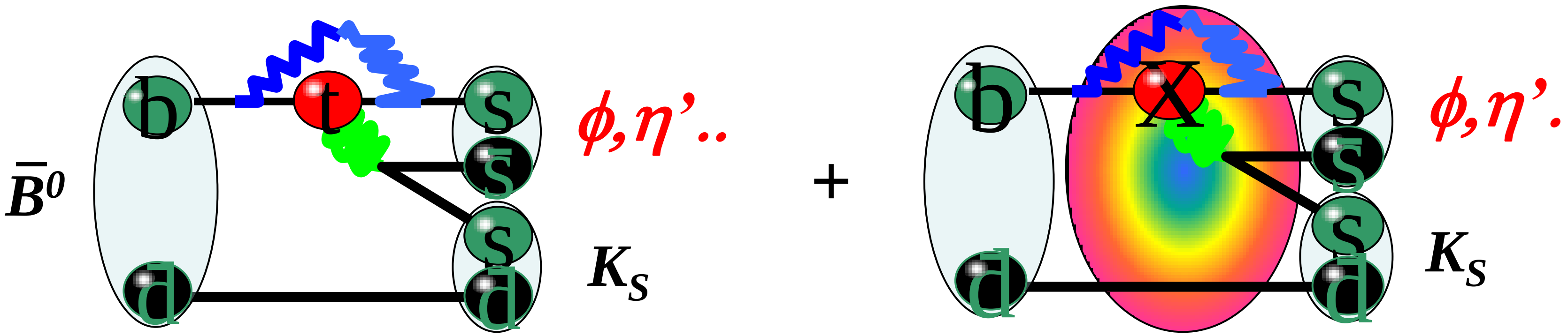
BELLEII in many cases is more sensitive to UT parameters than LHCb

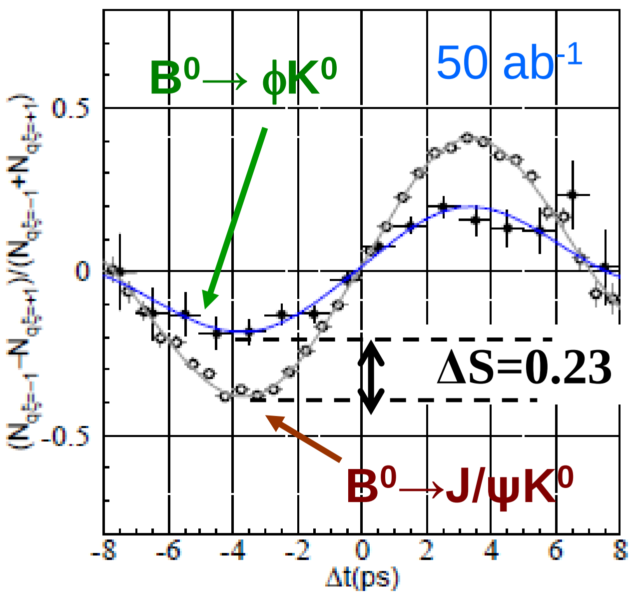


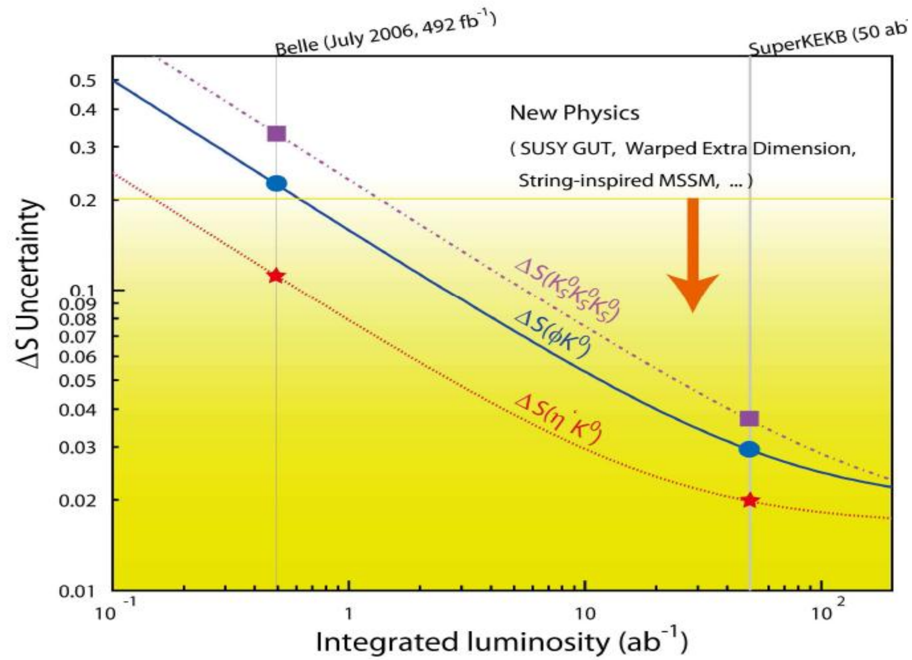
UT with present central values but with 50ab^{-1} errors

New phases can lead to inconsistency of UT.

New Source of CPV in $b \to sq\bar{q}$

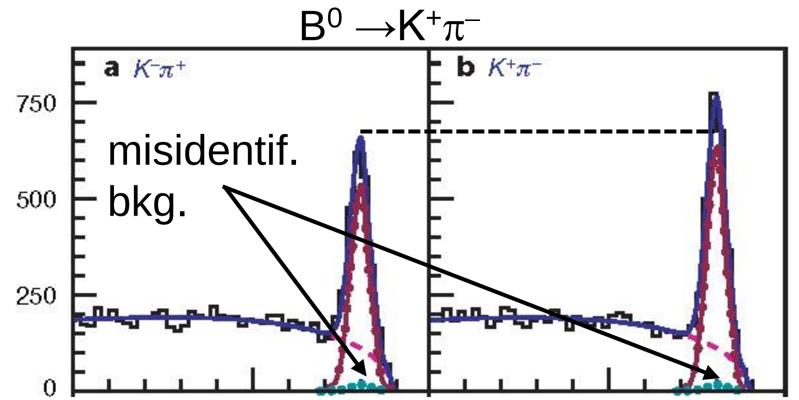






Prospect $\delta(S_{b \to s}) \sim$ **0.02** @ 50ab^{-1}

Direct CPV



Belle, Nature 452, 332 (2008), 480 fb^{-1}

DCPV puzzle:

tree+penguin processes, $B^{+(0)} \to K^+\pi^{0(-)}$

$\Delta A_{K\pi} = A(K^+\pi^-) - A(K^+\pi^0) = -0.127 \pm 0.022$

P. Chang, EPS'11

model independent sum rule:

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

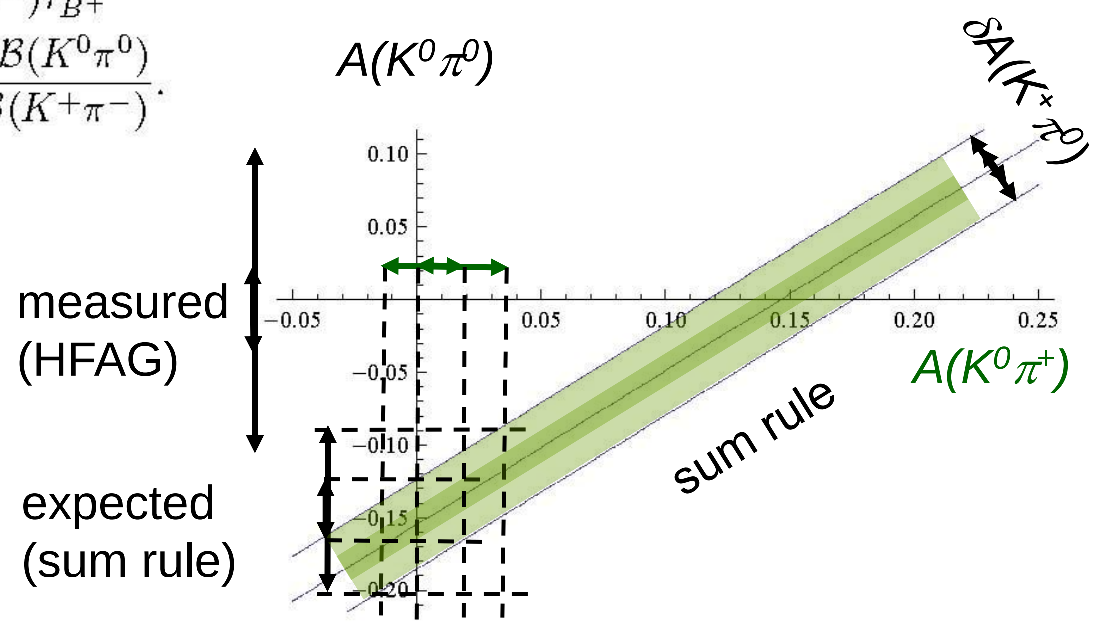
$$\mathcal{A}_f(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)\tau_{B^0}}{\mathcal{B}(K^+\pi^-)\tau_{B^+}} + \mathcal{A}_f(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}.$$

M. Gronau, PLB627, 82 (2005);
D. Atwood, A. Soni, PRD58, 036005 (1998)

$A(K^0\pi^+) = 0.009 \pm 0.025$
$A(K^+\pi^0) = 0.050 \pm 0.025$
$A(K^+\pi^-) = -0.098 \pm 0.012$
$A(K^0\pi^0) = -0.01 \pm 0.10$

Belle II 50 ab^{-1}

HFAG, Summer'11



t-dependent CPV

$B \rightarrow K^* (\rightarrow K_S\pi^0)\gamma$
t-dependent CPV

SM:
$S_{CP}^{K^*\gamma} \sim -(2m_s/m_b)\sin 2\phi_1 \sim -0.04$

Left-Right Symmetric Models:
$S_{CP}^{K^*\gamma} \sim 0.67 \cos 2\phi_1 \sim 0.5$

D. Atwood et al., PRL79, 185 (1997)
B. Grinstein et al., PRD71, 011504 (2005)

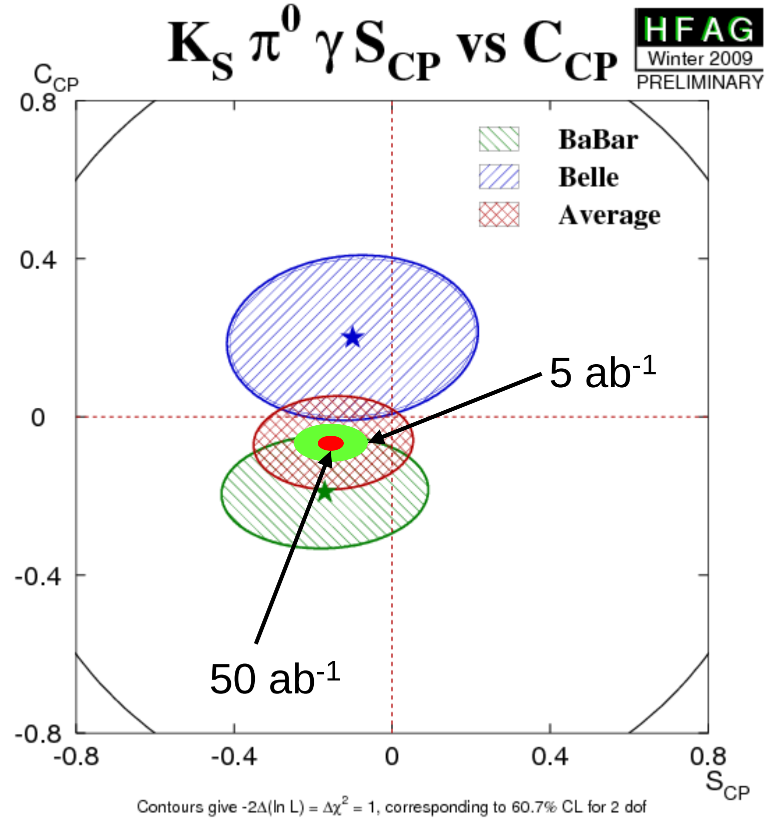
$S_{CP}^{Ks\pi0\gamma} = -0.15 \pm 0.20$
$A_{CP}^{Ks\pi0\gamma} = -0.07 \pm 0.12$

HFAG, Summer'11

$\sigma(S_{CP}^{Ks\pi0\gamma})=$ 0.09 @ 5 ab^{-1}
0.03 @ 50 ab^{-1}
(~SM prediction)

t-dependent decays rate of $B \rightarrow f_{CP}$;
S and A: CP violating parameters

$$P(B^0 \rightarrow f;\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}[1 + S_{CP}^f \sin(\Delta m \Delta t) + A_{CP}^f \cos(\Delta m \Delta t)]$$



Example of complementarity: MSSM searches

$$m_{\tilde{q}} = m_{\tilde{g}} = 1\,TeV$$

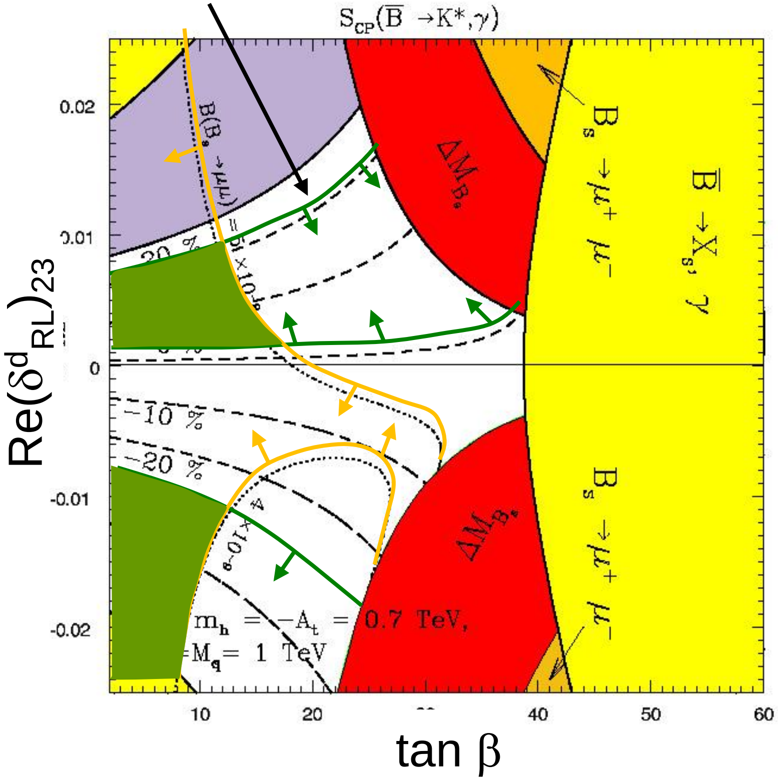
$S(K_S\pi^0\gamma) \sim -0.4\pm0.1$
$S(K_S\pi^0\gamma) \sim 0.1\pm0.1$

Belle II constraints shown @ 5 ab^{-1}

LHCb: $Br(B_s \to \mu^+\mu^-) \sim (4\text{-}5)\times10^{-9}$ (@ 3 fb^{-1})

Belle II/LHCb combination:
stringent limits on $Re(\delta^d_{RL})_{23}$, $\tan\beta$

contours of $S(K_S\pi^0\gamma)$

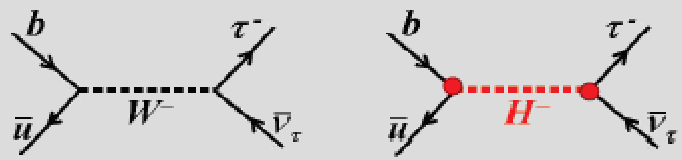


A.G. Akeroyd et al., arXiv:1002.5012

Charged Higgs in B decays

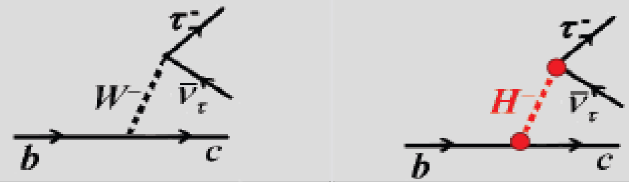
leptonic

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



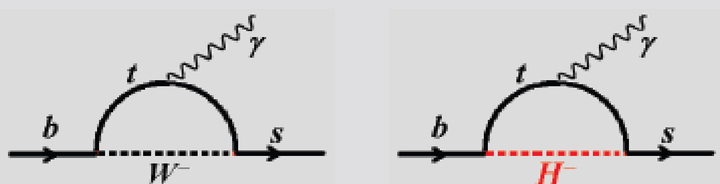
semileptonic

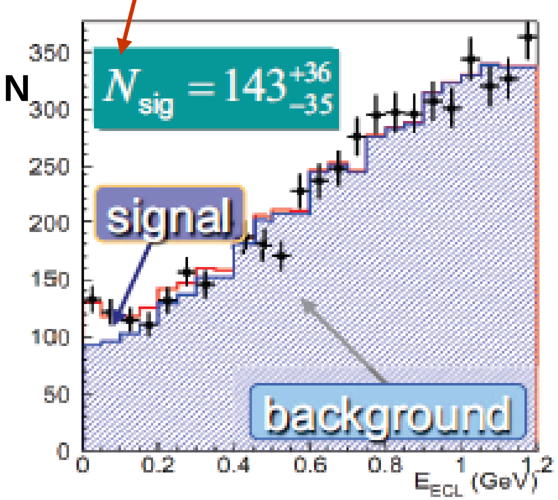
- $B \to D^{(*)} \tau \nu_\tau$



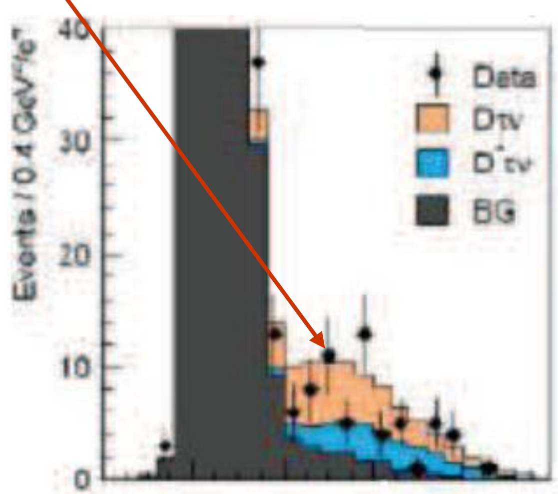
inclusive radiative

- $B \to X_s \gamma$

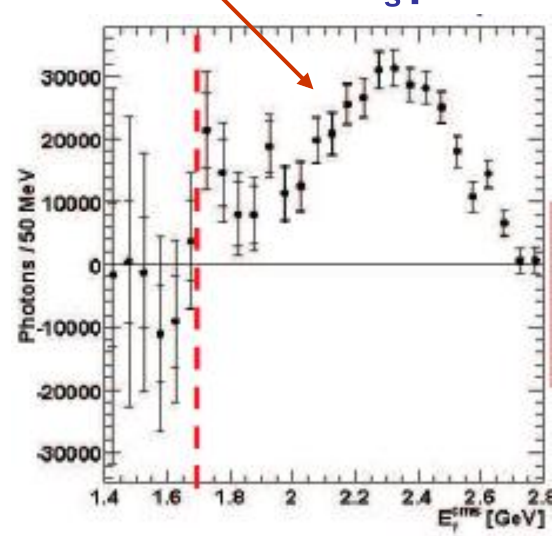




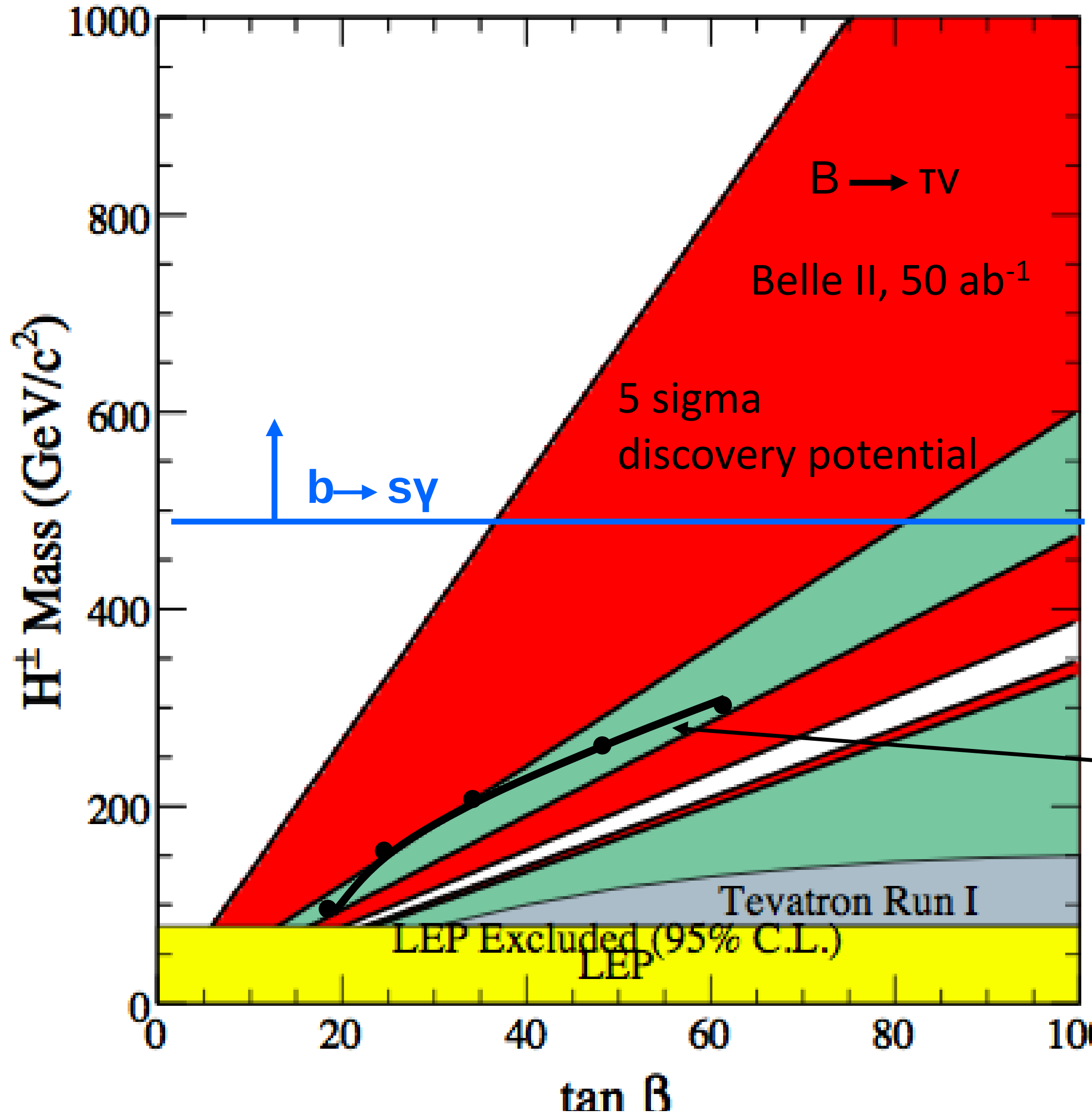
B→ $D^0 \tau \nu$



B → $X_s \gamma$



Expected sensitivity at Belle

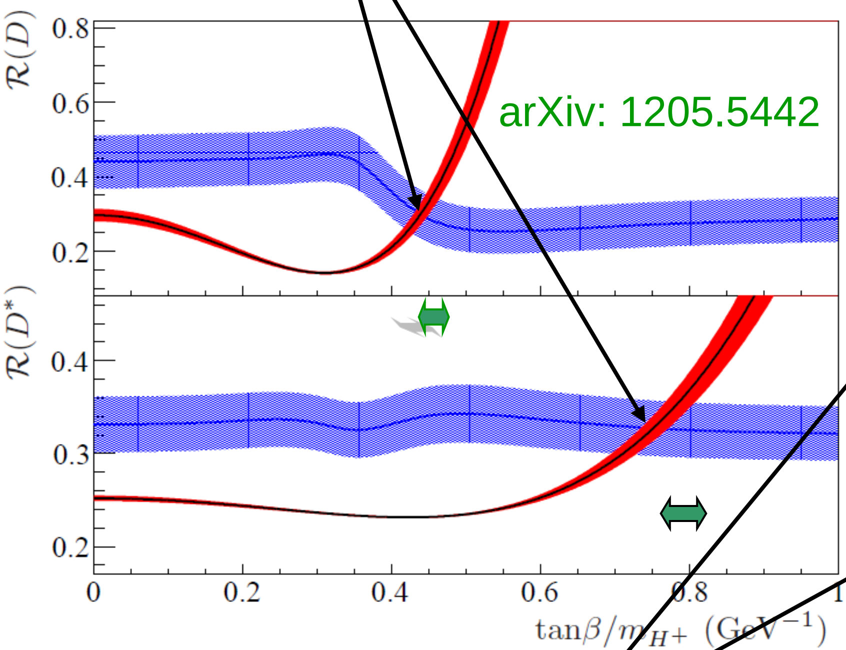


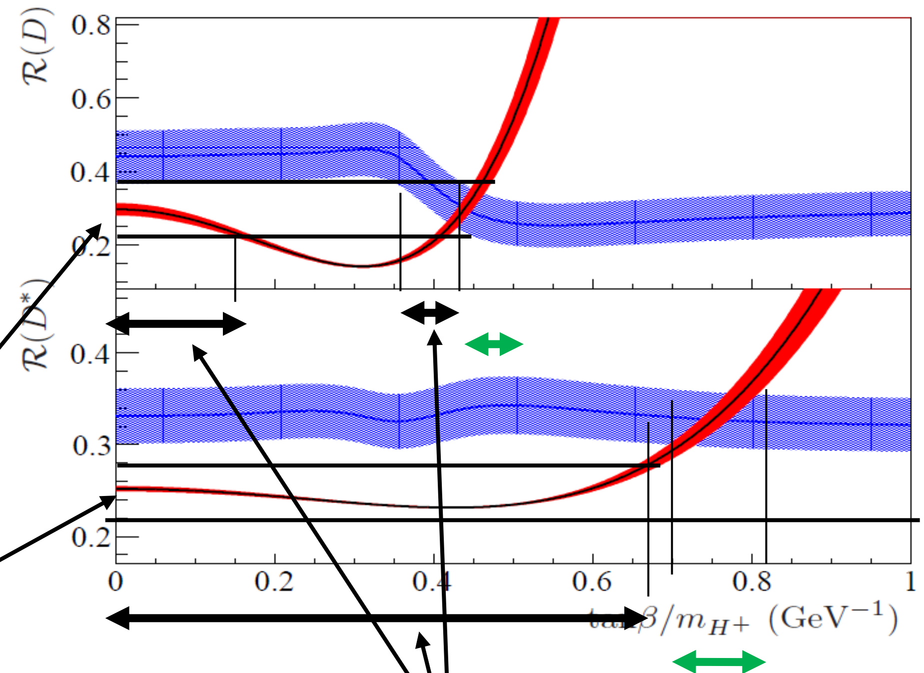
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/PublicPlotsHG10

Belle II is sensitive to a wide range of Higgs masses and tan β
Belle II sensitivity is higher than in direct searches at LHC

B→ D(*)τν

Recent BaBar result excludes Type II 2DHM since allowed regions for D and D* decays do not overlap

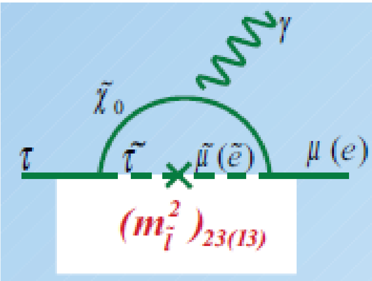




With SM predictions constraints would be weaker
We underestimated the sensitivity of these channels!

May be we underestimate sensitivity of other channels as well!

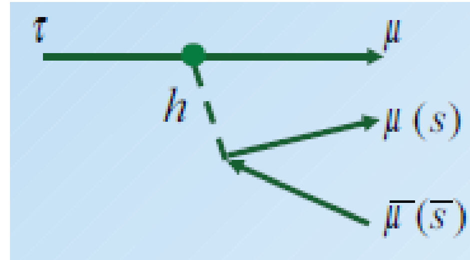
LFV and New Physics



SUSY + Seasaw

Bkg. $e^+e^- \to \gamma\tau^+\tau^-$

UL ~1/√L

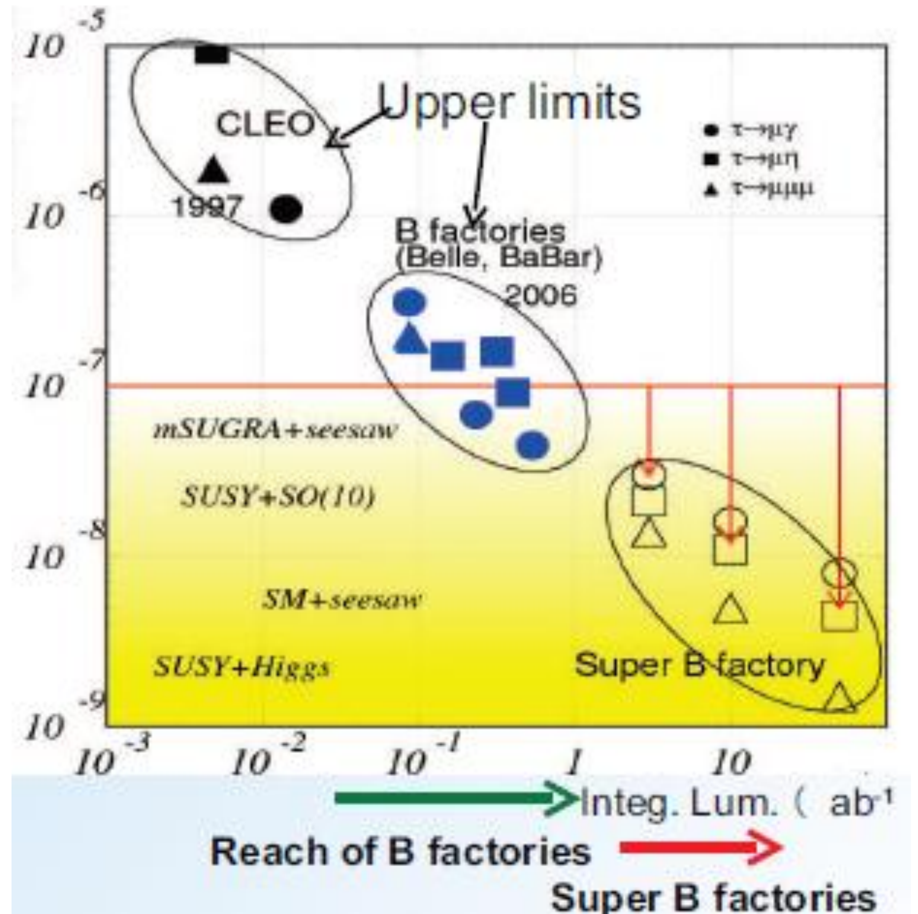


Higgs mediated decays. Important for MSUSY>>EW scale

Bkg. free. UL~1/L

Different models predict different relations for μ and tau decays

model	Br(τ→μγ)	Br(τ→ℓℓℓ)
mSUGRA+seesaw	10^{-7}	10^{-9}
SUSY+SO(10)	10^{-8}	10^{-10}
SM+seesaw	10^{-9}	10^{-10}
Non-Universal Z′	10^{-9}	10^{-8}
SUSY+Higgs	10^{-10}	10^{-7}



Belle II sensitivity for LFV covers predictions of many models

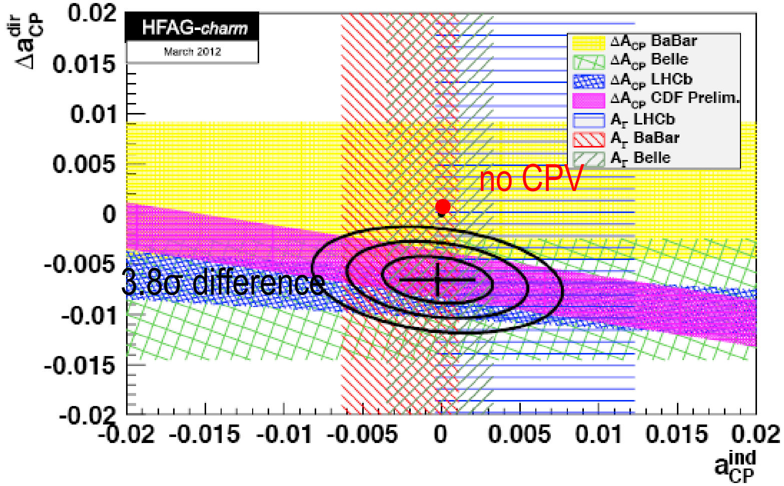
CP Violation in Charm Decays Sensitive to New Physics

Naively CPV in D mesons in SM ≤$O(10^{-3})$

Is large (~1%) ΔAcp sign of New Physics?

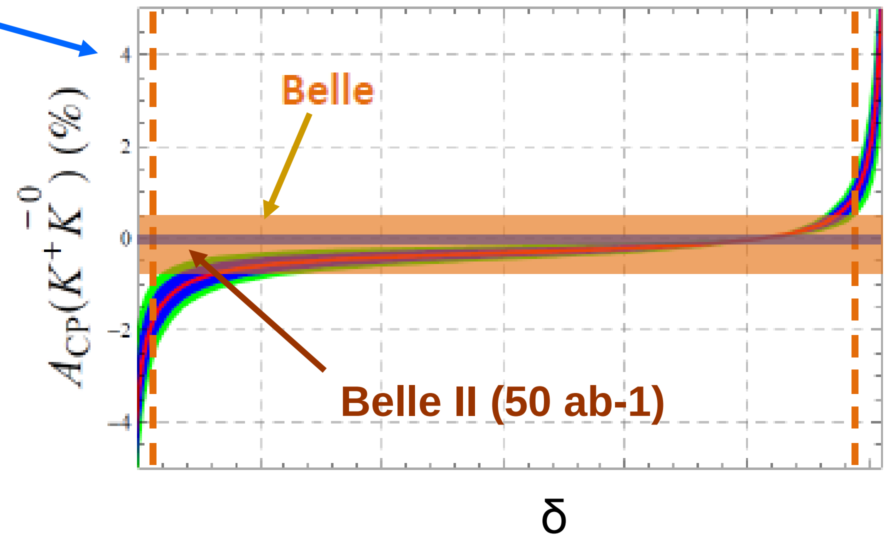
May be not - small penguin contribution could solve the problem

[Bhattacharya, Gronau, Rosner arXiv:1201.2351]



$A_{CP}(D^0 \to K^+K^-) - A_{CP}(D^0 \to \pi^+\pi^-) = \Delta a_{CP\ direct} + \Delta t/\tau\ a_{CP\ indirect}$

Can be checked using D decays to neutral Kaons and pions



Many channels needed to observe NP

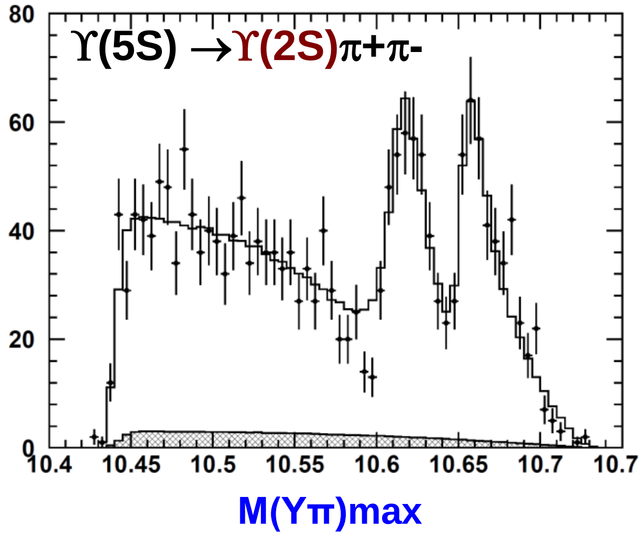
Belle II sensitivity ~0.1% in many decays

$D^0 \to K_S^0 \pi^0$	± 0.05
$D^0 \to K_S^0 \eta$	± 0.10
$D^0 \to K_S^0 \eta'$	± 0.10
$D^0 \to \pi^+\pi^-$	± 0.07
$D^0 \to K^+K^-$	± 0.05

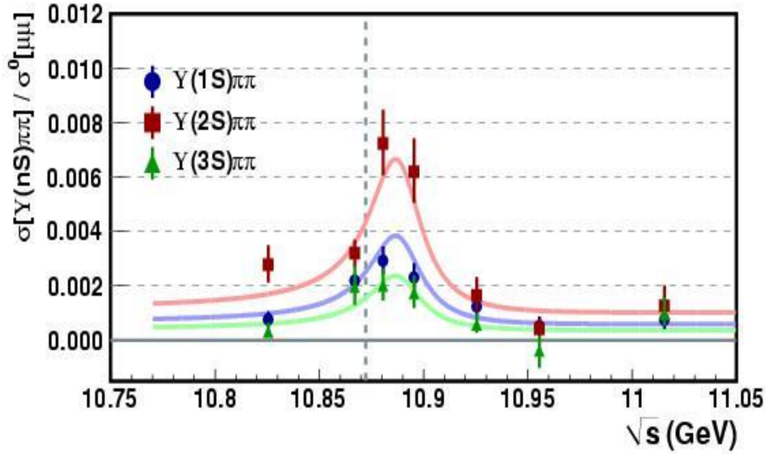
Belle II can study CPV in many D decays including neutral. Complimentary to LHCb

Spectroscopy issues for Belle II

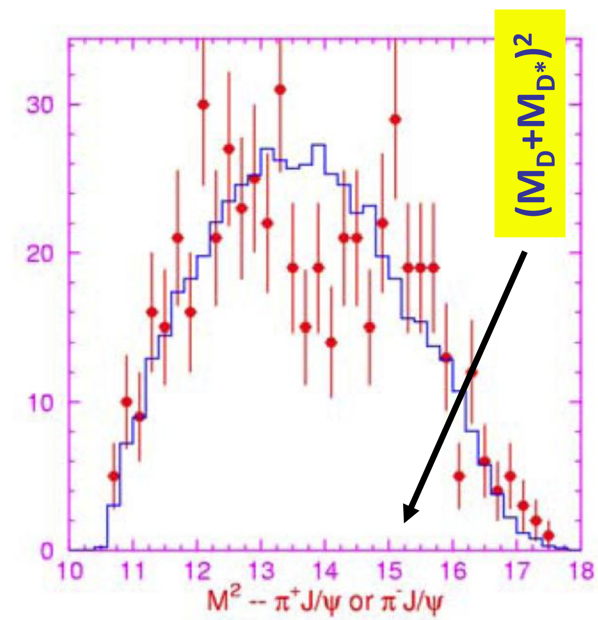
Belle discovered Zb$^+$



Do they come from a new resonance?
Peak in **ϒπ+π-** **is** 2σ away from **ϒ(5S)**



Is there Zc$^+$ analogue of Zb$^+$ in Y(4260)→π+π-J/ψ?
Hint but inconclusive. Need more data!



Many other questions:
Remaining narrow states (η_2)
Search for new (exotic) states
Properties of discovered states
Exclusive ϒ decays
Searches for new particles
…

Methods and processes where Super B factory can provide important insight into NP complementary to other experiments:

(shown are expected sensitivities @ 50 ab-1)

Belle II

E_{miss}:

$\mathcal{B}(B \to \tau\nu)$, $\mathcal{B}(B \to X_c\tau\nu)$, $\mathcal{B}(B \to h\nu\nu)$,...

±3% ±3% ±30%

Inclusive:

$\mathcal{B}(B \to s\gamma)$, $A_{CP}(B \to s\gamma)$, $\mathcal{B}(B \to s\ell\ell)$, ...

±6% $\pm 5 \cdot 10^{-3}$ $\pm 1 \cdot 10^{-7}$

Neutrals:

$S(B \to K_S\pi^0\gamma)$, $S(B \to \eta' K_S)$, $S(B \to K_SK_SK_S)$, $\mathcal{B}(\tau \to \mu\gamma)$, $\mathcal{B}(B_s \to \gamma\gamma)$, ...

±0.03 ±0.02 ±0.03 $\pm 3 \cdot 10^{-9}$ $\pm 3 \cdot 10^{-7}$

Missing mass technique: *Spectroscopy(Zb,…), Inclusive Production (Double Charm),*

Detailed description of physics program at Super B factories at:

A.G. Akeroyd et al., arXiv: 1002.5012

Physics at Super B Factory

Belle II

SuperB

B. O'Leary et al., arXiv: 1008.1541

Super$B$
Progress Reports
Physics

SUMMARY

Construction of SuperKEKB/Belle II started

Start of commissioning in 2015

Luminosity goals: $L=8\times10^{35}$ $cm^{-2}s^{-1}$;

$10ab^{-1}$ by 2018, $50ab^{-1}$ by 2022

Exciting physics program

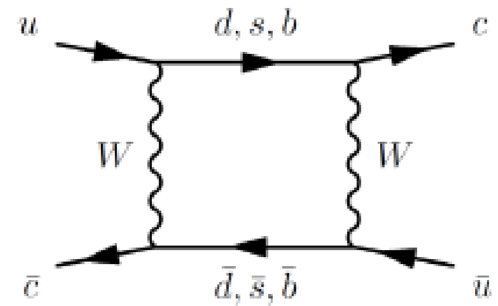
Upgraded detector capable to reach the physics goals

Experienced worldwide collaboration

Backup Slides

D mixing and CPV

- Mass & flavor eigenstates differ:
  - $|D_{1,2}> = p|D^0> \pm q|\overline{D^0}>$
  - Note: if $p \neq q$, CP is violated.



- Mixing parameterized by mass/width splittings:

$$x \equiv \frac{(m_1 - m_2)}{\Gamma} \quad y \equiv \frac{(\Gamma_1 - \Gamma_2)}{2\Gamma}$$

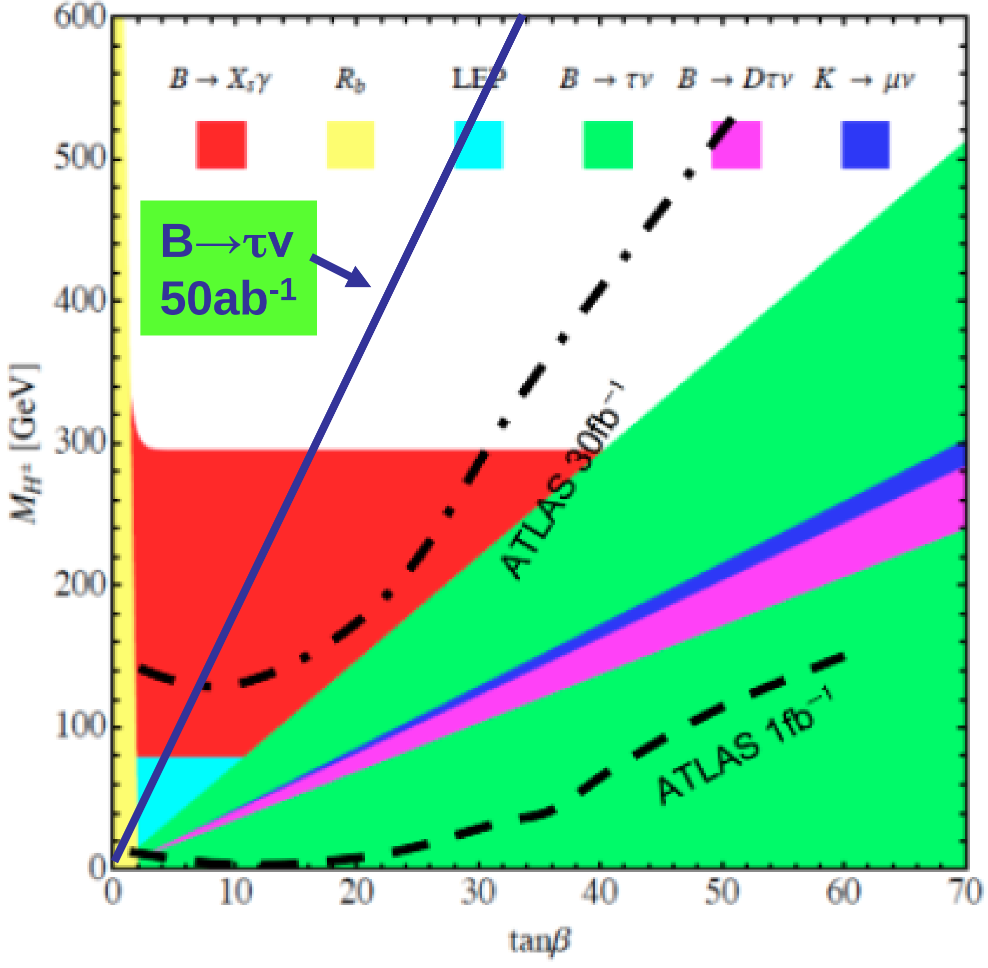
- Three sources: $A_{CP}(D \to f) = \frac{\Gamma(D \to f) - \Gamma(\bar{D} \to \bar{f})}{\Gamma(D \to f) + \Gamma(\bar{D} \to \bar{f})} = a_f^d + a_f^m + a_f^i$
  - Mixing (a_f^m):

    $|q/p| \neq 1$
  - Decay (a_f^d):

    $|\mathcal{A}(D \to f)/\mathcal{A}(\bar{D} \to \bar{f})| \neq 1$
  - Interference between mixing and direct:

$$\phi = \arg\left(\frac{\mathrm{qA}(\bar{\mathrm{D}} \to \bar{\mathrm{f}})}{\mathrm{pA}(\mathrm{D} \to \mathrm{f})}\right)$$

B factory provides much better constraints on $H^{\pm}$ than LHC with $30fb^{-1}$ and 14TeV



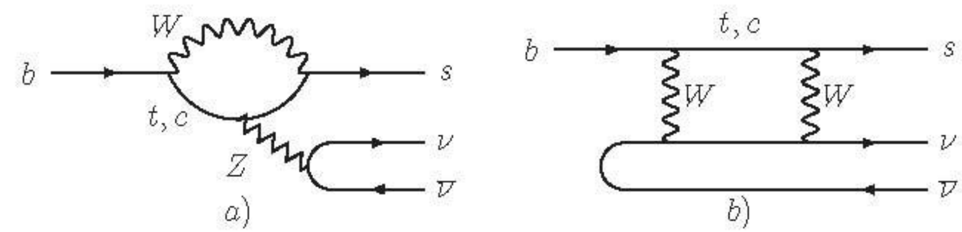
2HDM(II) U.Haisch arXiv:0805.2141

E_{miss} measurements

$B \to h\nu\nu$

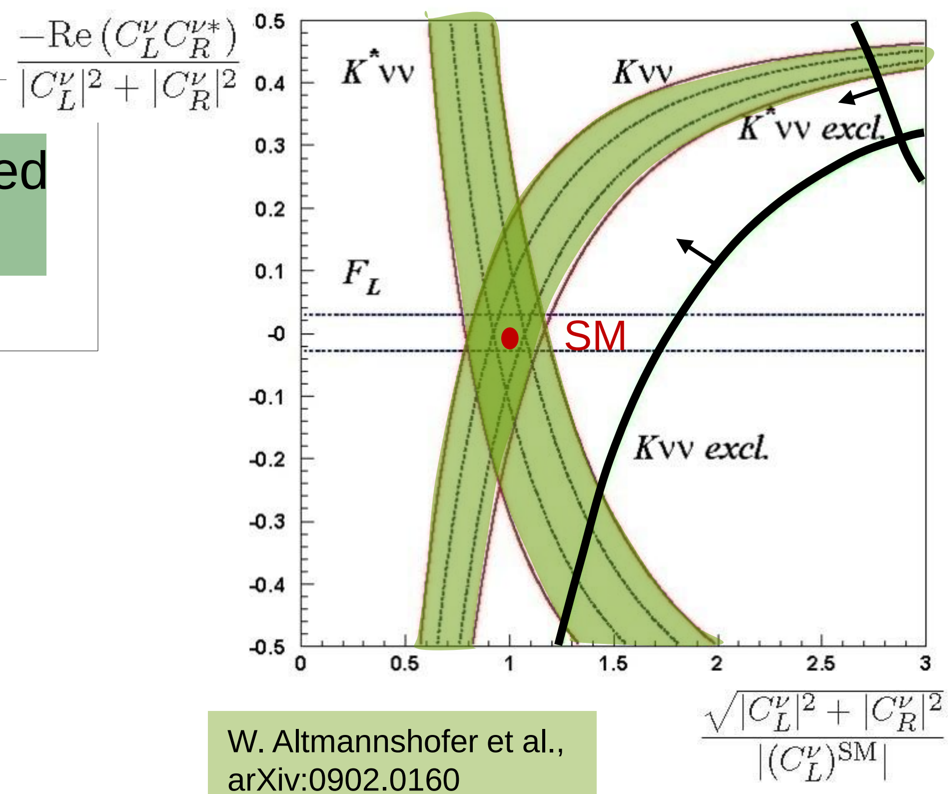
$B_{sig}B_{tag} \to (h\nu\nu)(X\ell\nu)$ semil. tag

$\to (h\nu\nu)(X)$ hadr. tag



$\mathcal{B}(B^+ \to K^{(*)+}\nu\nu)$ can be measured to ±30% with 50 ab^{-1};

limits on right-handed currents



W. Altmannshofer et al., arXiv:0902.0160