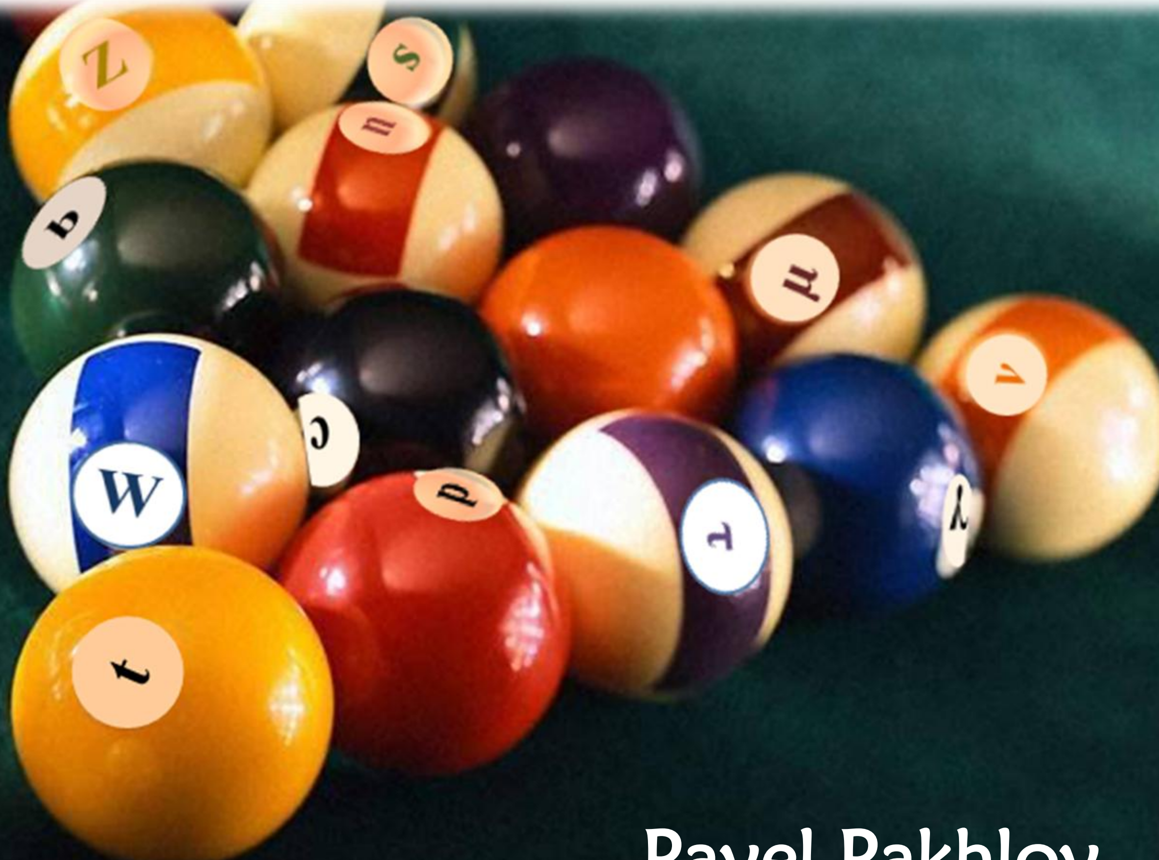
Flavor physics at Super B factories era



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MEPhI, Moscow

International conference on particle physics and astrophysics,

Milan Hotel 4*, Moscow, 5-10 October 2015

Flavor physics in the SM …

bosonic sector of the SM:

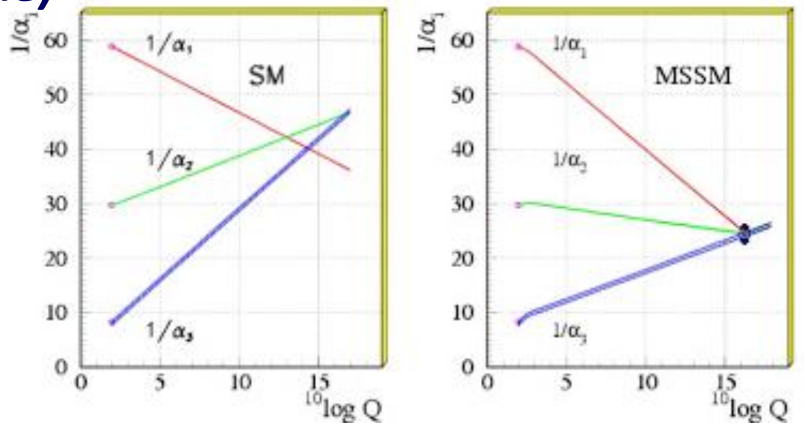
5 free parameters:

one defines the scale (vacuum expectation value)

+ 4 dimensionless coupling constants

$$@1\mathrm{GeV}: g' \sim 0.3,\quad g \sim 0.6,\quad g_s \sim 0.6,\quad \lambda \sim 1$$

Ideally, we have to accept one scale parameter, and expect that dimensionless parameters are some geometrical constants; there is a hint that three gauge constants are related to each other...



fermionic (flavor) sector (without neutrino):

3 Yukawa constants for charged leptons:

6 Yukawa constants for quarks

4 quark-mixing parameters

$$Y_t \sim 10^0,\quad Y_b \sim 10^{-2}, Y_c \sim 10^{-2},$$
$$Y_s \sim 10^{-3}, Y_u \sim 10^{-5}, Y_d \sim 10^{-5},$$
$$Y_\tau \sim 10^{-2}, Y_\mu \sim 10^{-3}, Y_e \sim 10^{-6},$$
$$|V_{ud}| \sim 1, |V_{us}| \sim 0.2, |V_{cb}| \sim 0.04,$$
$$|V_{ub}| \sim 0.004, \delta_{\mathrm{KM}} \sim 1$$

This is a really miraculous part of the SM.
There is no idea

- why do we have many (3) generations?
- why are these 13 constants such as they are?
- why is there a hierarchy & smallness structure?
- why is the mixing matrix almost unit, but not exactly?

All these "*Whys?*": The SM flavor puzzle

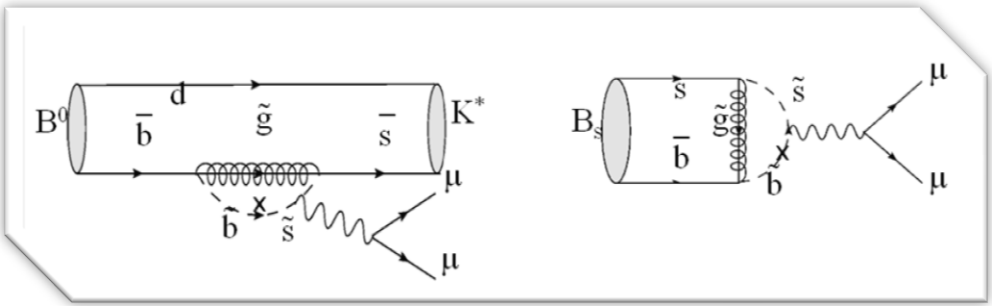
… and beyond

Beyond SM:

13 parameters are too many for a fundamental theory, but not too many to check consistency of the SM predictions for decay/oscillation/CP violation patterns:

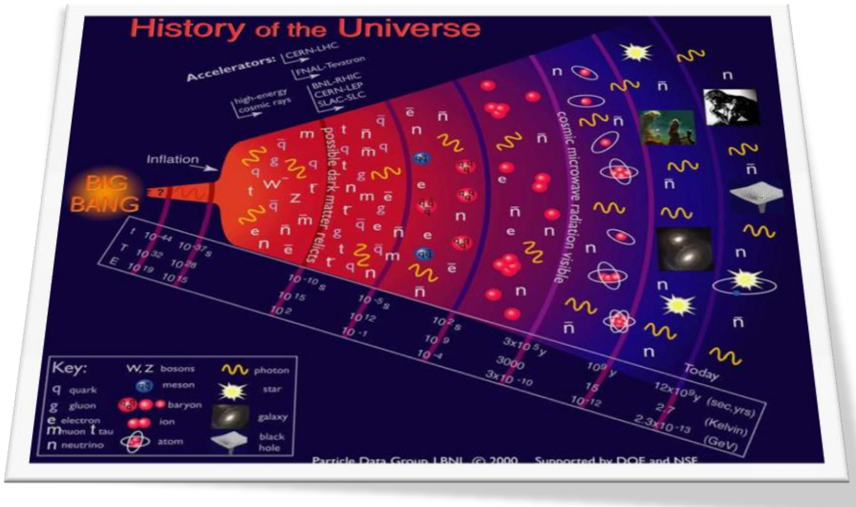
500 decays modes (Br’s and UL’s) for B
200 decays for D
40 decays for K (some with BR’s ~ 10^{-12}!)

non-SM particles (even very heavy) run around in loops



Cosmology:

needs CP-violation



to produce baryonic asymmetry of the Universe; the only known source of CP violation is a flavor sector of the SM (though it is too small…)

Flavor physics:
<u>SM</u>: in the heart of quark interactions
<u>Cosmology</u>: related to matter-antimatter asymmetry
<u>Beyond SM</u>: measurements are sensitive to New particles

Physics at (Super) B factories

SM

- **B and D decays:**
  access to (almost all, including complex phase) CKM matrix elements

beyond SM

- **B and D decays:**
  mixing, CP Violation, rare decays
- **Tau leptons:**
  search for Lepton Flavor Violation
- **Direct search for light sterile particles:**
  sterile neutrino, dark photons, axions etc.

Direct searches for New particles & forbidden decays; indirect check for consistency of SM-pattern

QCD

- **Hadron spectroscopy:**
  quarkonium, charm and light mesons & baryons
- **γγ –physics:**
  γγ-width, Form-Factors

Important inputs to QCD models

QCD exotics

- **Quarkonium-like states + more exotics?**
  New spectroscopy beyond standard quark model

Beyond SM at Super B factories

Physics beyond the Standard Model must exist. New Physics is required to provide us with Dark Matter, to add CP violation for cosmology, to cut off UV divergences…

If New Physics will be found at LHC

its flavor and CP violating couplings should be studied at Flavor experiments

If New Physics will NOT be found at LHC

flavor experiments give a chance to observe NP manifestation even for the mass scale >TeV

Flavor Physics studies processes via box&loop diagrams:

- FCNC ($b \to s$, $b \to d$)
- mixing (box diagram)
- CP Violation (box, box+loop, box+tree, etc…)

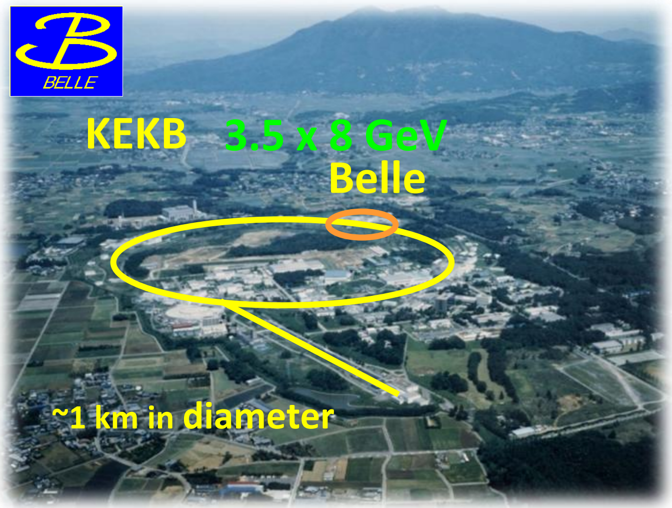
New particles (e.g. SUSY) even at high mass scale can compete with SM

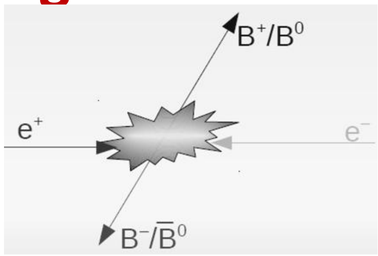
Benefits of Super B factories at e^+e^- colliders

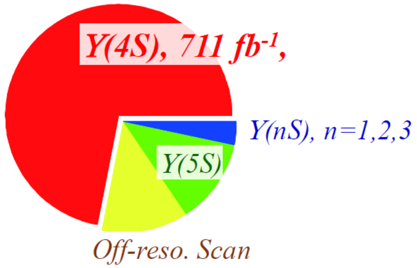
- Low backgrounds, high trigger efficiency, high γ and π^0 reconstruction efficiency, high flavor tagging efficiency with low dilution
- Negligible trigger bias and good kinematic resolution (due to low background)
- Dalitz analyses, absolute branching fractions
- Missing mass and missing energy measurements
- Systematics differ from LHCb

e^+e^- asymmetric B-factories

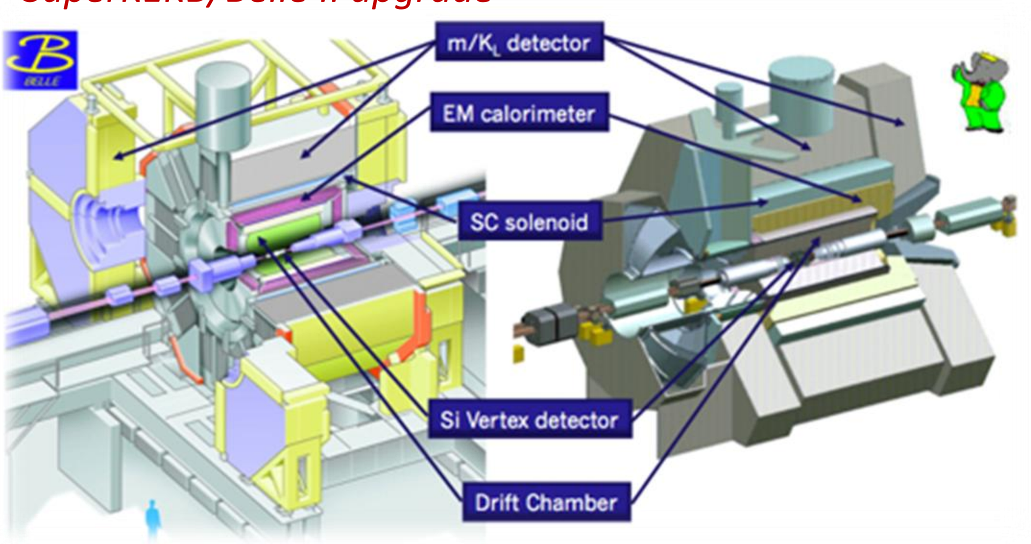
world highest luminosities

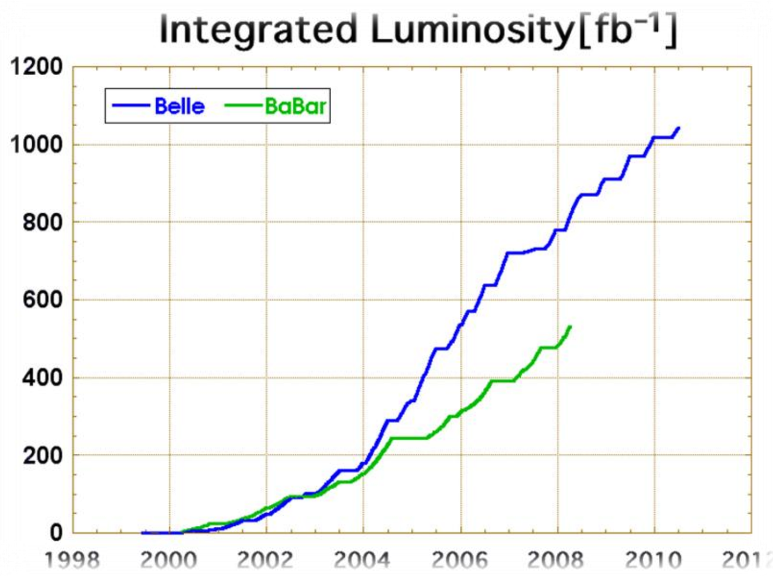






Completed data taking on June, 2010 to start
SuperKEKB/Belle II upgrade





B factories: 10+ years of success

PHYSICS HIGHLIGHTS:

- From the first observation to precise measurement of indirect CP violation;
- Measurements of CKM matrix elements and angles of the Unitarity triangle;
- First observation of direct CP violation in B decays;
- Measurements of rare B decays:
  - $b \to s\gamma$: probe of new sources of CPV and constraints on NP from branching
  - $B \to D^{(*)}\tau\nu$, $B \to \tau\nu$: sensitive to tree non-SM Higgs contribution
  - $b \to sll$: new physics can modify the helicity structure
- Observation of DDbar mixing + many charm studies;
- Search for rare τ decays;
- Direct searches for dark photons, light Higgs, etc,
- New hadron spectroscopy and many others…

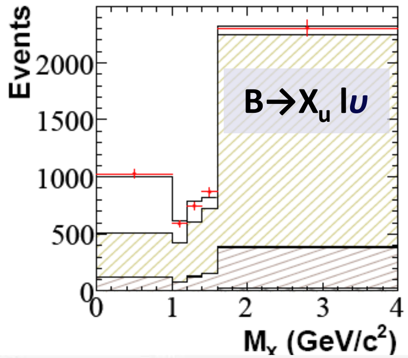
All these were possible because of

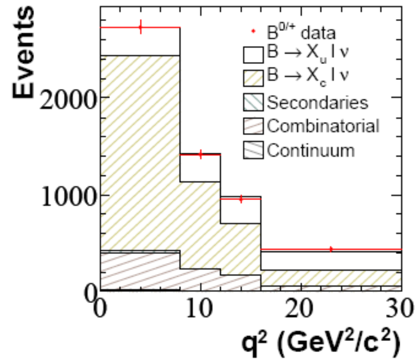
Unique capabilities of B-factories:

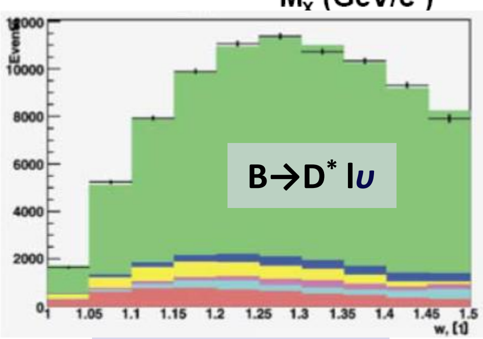
- very clean environment,
- kinematical constraints,
- detection of neutrals,
- hermecity of the detector (detection of neutrino)

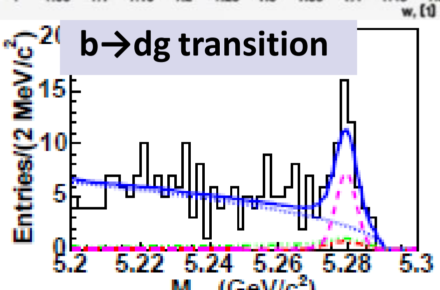
From CPV observation to precise KM test

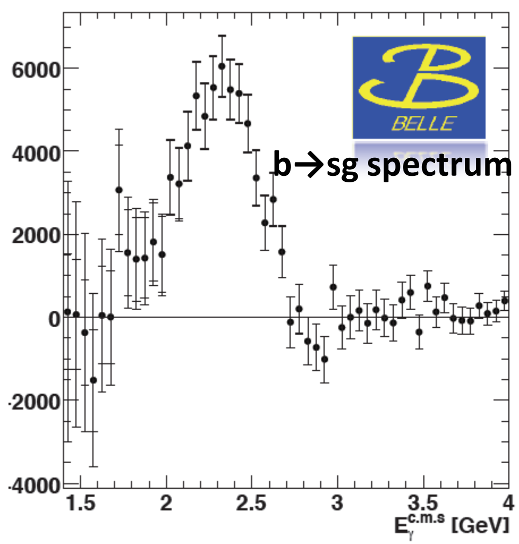
- **Angle $\varphi_1(\beta)$ is measured with 1° accuracy; angles $\varphi_2(\alpha)$ and $\varphi_3(\gamma)$ ~ 5-15° accuracy**
- **Accuracies for V_{cb} ~ 3%; V_{ub} ~ 10%; V_{td} ~ 7%; V_{ts} ~ 6%; V_{td}/V_{ts} ~ 3% (Δm_s)**



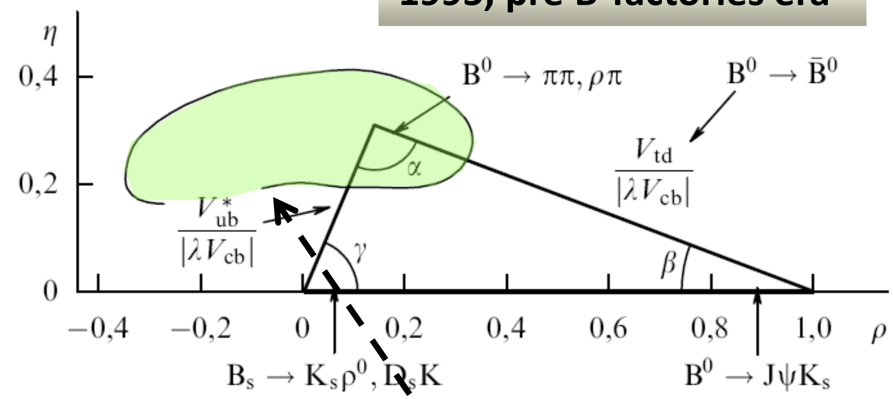






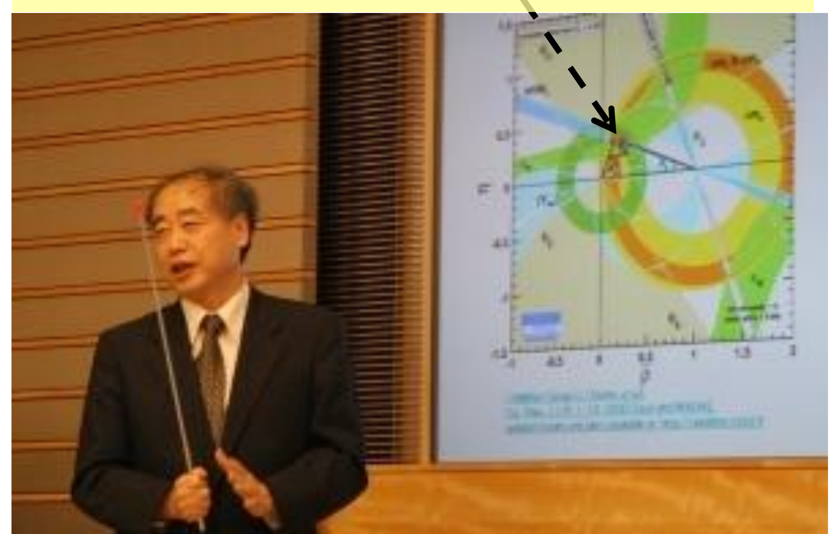


1995, pre B-factories era



The allowed area for upper apex is squeezed by almost 2 orders of magnitude

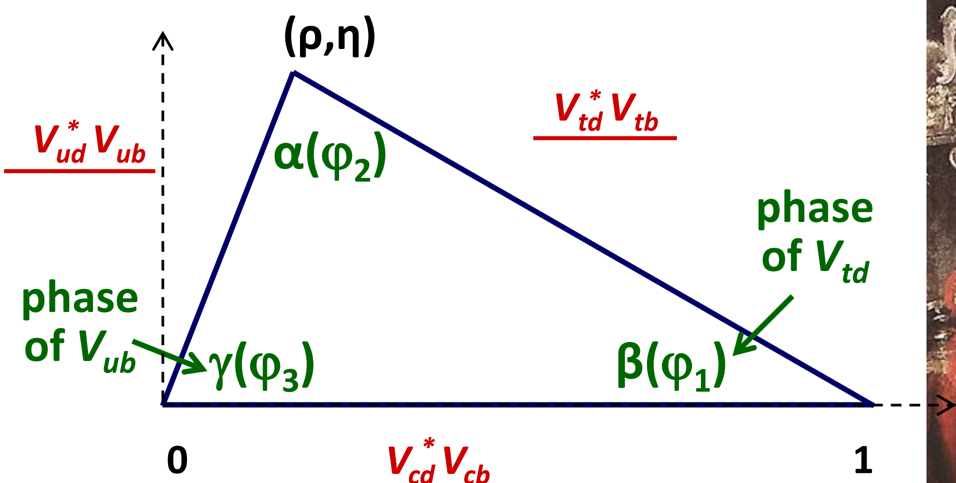
Belle & BaBar + LHCb + Tevatron + huge contribution from theory



Search for New Physics in CP violation pattern

Unitarity triangle

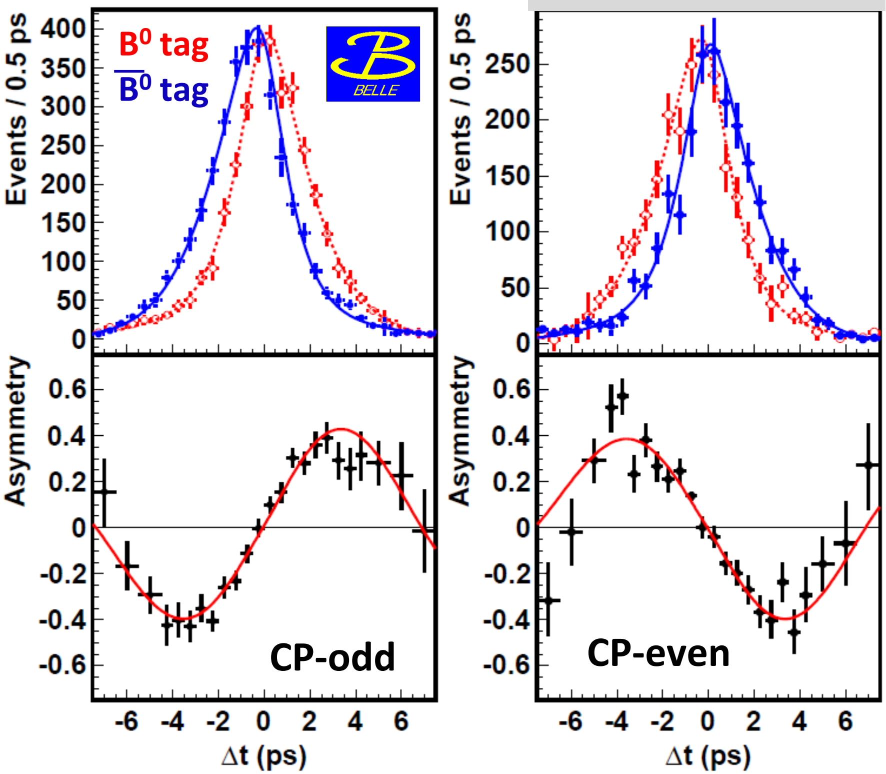
$$V_{ud}^{*}V_{ub} \quad + \quad V_{cd}^{*}V_{cb} \quad + \quad V_{td}^{*}V_{tb} \quad = \quad 0$$



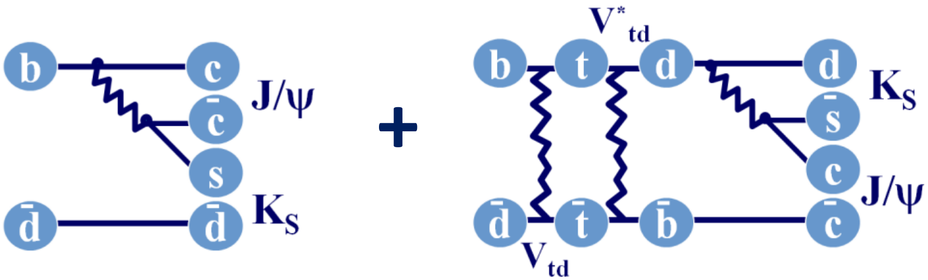
Precise measurement of sin(2β) in $B^0 \to c\bar{c}K^0$

$772 \times 10^6\ B\bar{B}$ pairs

PRL 108 171208 (2012)



$\Upsilon(4S) \to B^0\bar{B}^0 \to f_{CP} f_{tag}$



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

SM: $S_f = -\sin 2\beta$ and $A_f = 0$

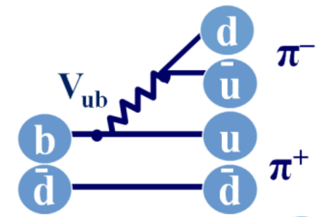
Belle 2012: $B \to J/\psi K^0_s$, $\psi(2S)K^0_s$, $\chi_{c1}K^0_s$ & $B \to J/\psi K^0_L$

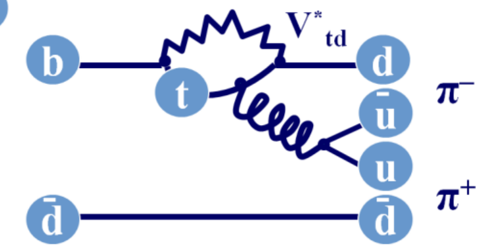
sin(2β) = 0.667 ± 0.023 ± 0.012 (0.9°)

A_f = 0.006 ± 0.016 ± 0.012 (direct CPV)

Belle II		sin(2β)	LHCb	
5 ab^{-1}	50 ab^{-1}		8 fb^{-1} (2018)	50 fb^{-1}
0.4°	0.3°		0.6°	0.3°

α measurements: $B^0 \to \pi\,\pi$





The decay amplitudes $B \to \pi^+\pi^-(\rho^+\rho^-)$ include:

- tree term $T \sim V_{ub}^* V_{ud}$ (dominant)
- penguin term $P \sim V_{tb}^* V_{td}$ (suppressed, but not small)

Parameter S of indirect CPV related to effective α (α_{eff}) shifted by extra angle

$$S = \sin 2\alpha + 2r\cos\delta \sin(\alpha+\beta)\cos 2\alpha + O(r^2)$$

δ – the relative strong phase between T and P amplitudes

r < 1 – ratio of P to T amplitude

$$S = \sqrt{1-C^2}\,\sin(2\alpha_{eff}) \qquad \alpha_{eff} = \alpha + \theta$$

To extract α additional inputs required

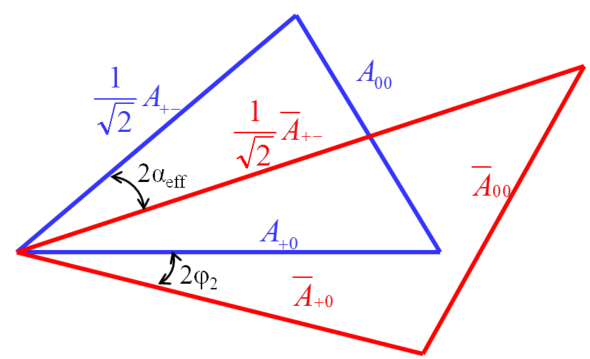
The cleanest method is isospin analysis (Gronau and London)

We need to measure all 6 BR's of B^0 and B^+ to $\pi\pi$ decays: $\pi^+\pi^-$, $\pi^0\pi^0$, $\pi^+\pi^0$

Need neutral modes!

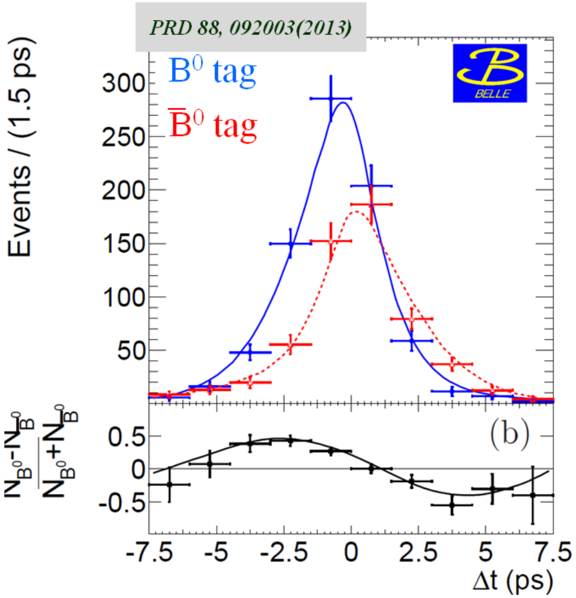
$$A_{+-} + \sqrt{2}\,A_{00} = \sqrt{2}\,A_{+0}$$
$$\bar{A}_{+-} + \sqrt{2}\,\bar{A}_{00} = \sqrt{2}\,\bar{A}_{+0}$$

$$A_{+-} = A(B^0 \to \pi^+\pi^-) = e^{-i\alpha}\,T^{+-} + P$$
$$\sqrt{2}\,A_{00} = \sqrt{2}\,A(B^0 \to \pi^0\pi^0) = e^{-i\alpha}\,T^{00} + P$$
$$\sqrt{2}\,A_{+0} = \sqrt{2}\,A(B^+ \to \pi^+\pi^0) = e^{-i\alpha}\,(T^{00} + T^{+-})$$



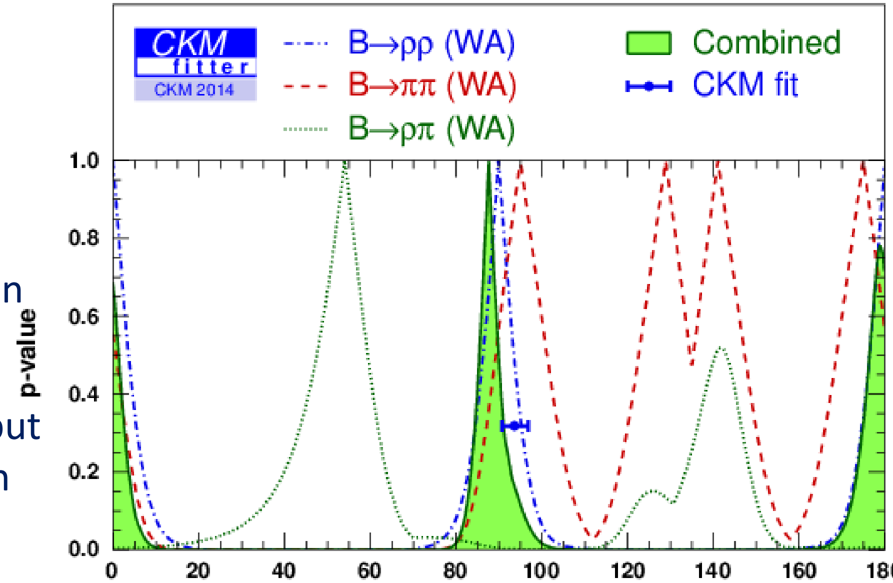
Isospin triangles

α: experimental results



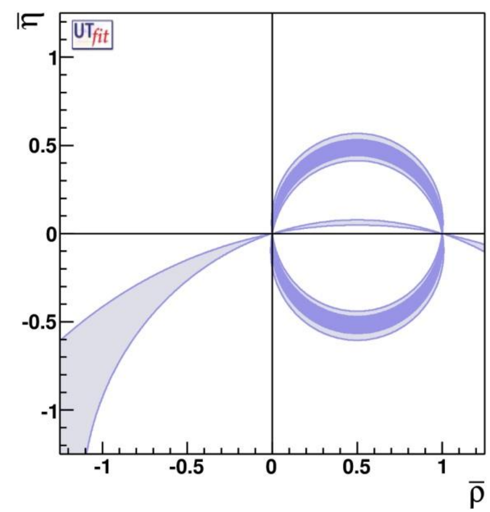
$B^0 \to \rho^0\rho^0$
- angular analysis
- purely CP=+1 final state
- small Br, small penguin contribution

$B^0 \to \rho^\pm\pi^\pm$
not CP eigenstate, but B^0 can decay to both $\rho^+\pi^-$ and $\rho^-\pi^+$



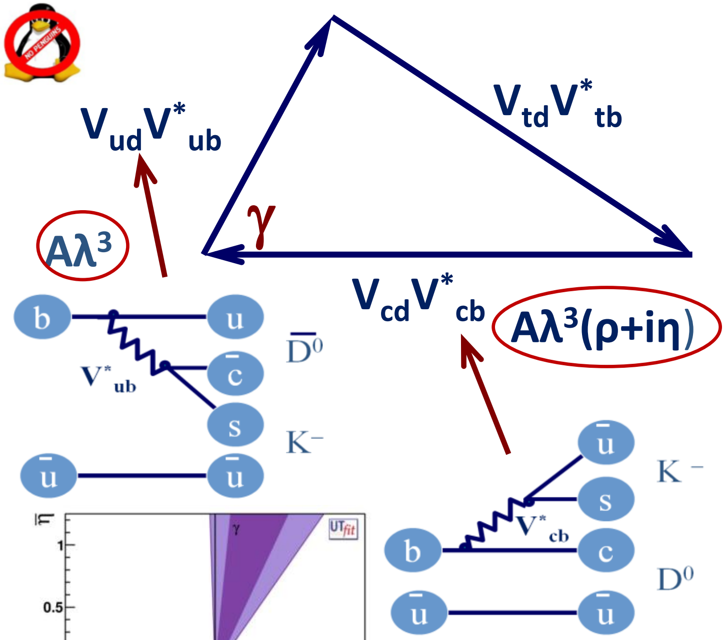
$B^0 \to \pi^+ \pi^-$
$S_{CP} = -0.64 \pm 0.06 \pm 0.03$
$A_{CP} = +0.33 \pm 0.06 \pm 0.03$

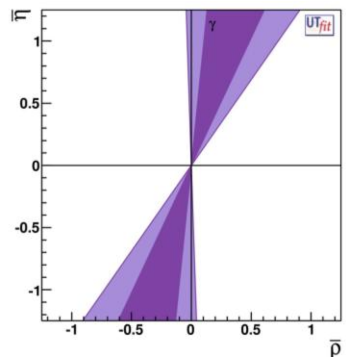
α[WA,all]$=(87.7^{+3.5}_{-3.3})°$

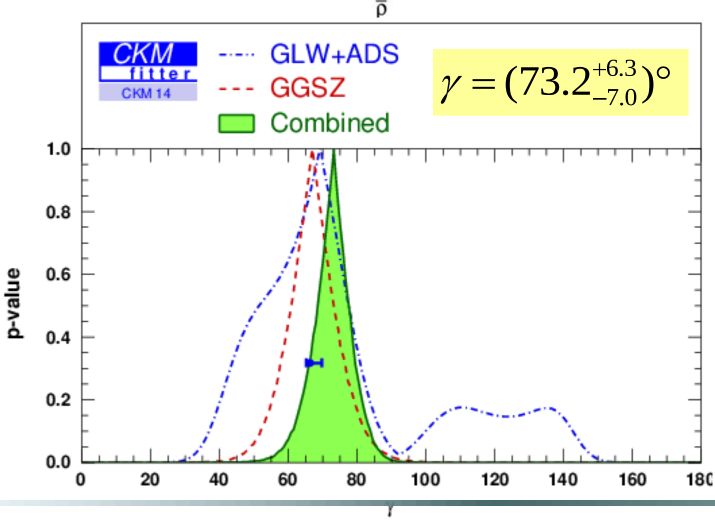


- **Complicated analysis (especially for $\rho^0\rho^0$)**
  - **method was checked many times by Belle & BaBar**
  - **Belle & BaBar consistent results**
- **Statistics limited (not systematic)**
- **B factories only (a lot of neutrals in the final states)**
- **Expected errors : 5 ab^{-1} to be 2°, 50 ab^{-1} to be 1°**

Direct CPV and γ







B→DK: the angle between two amplitudes is really γ, but the final states are different $D^0 \neq \overline{D}^0$

GLW, GGSZ methods:

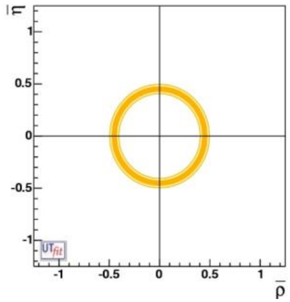
use D^0 decays into two or three-body CP eigenstates. 3-body requires Dalitz analysis.

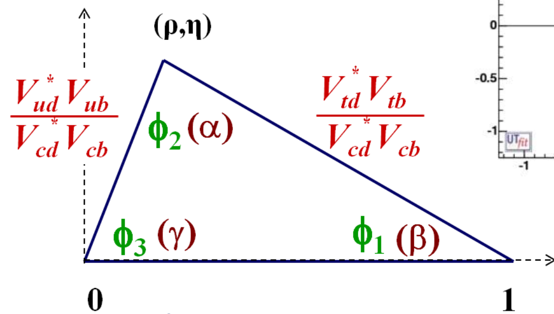
The accuracy of present measurements are limited by statistics (we really study VERY rare decay). The systematic and model uncertainties are much smaller.

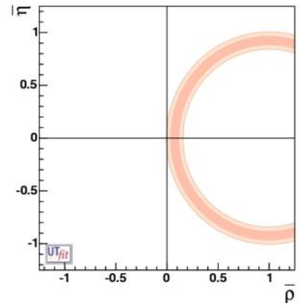
Sensitivity of Belle II and LHCb upgrade

Decay mode	LHCb upgrade		Belle II
$B \to DK$ with $D \to hh'$, $D \to K\pi\pi\pi$	$1.3°$	[15]	$2.0°$
$B \to DK$ with $D \to K^0_S\pi\pi$	$1.9°$	[15]	$2.0°$
$B \to DK$ with $D \to 4\pi$	$1.7°$		–
$B \to DK\pi$ with $D \to hh'$, $D \to K^0_S\pi\pi$	$1.5°$	[16]	–
$B \to DK\pi\pi$ with $D \to hh'$	$3.0°$		–
Combined	$1.1°$		$1.5°$
Time-dependent $B^0_s \to D^\mp_s K^\pm$	$2.4°$	[15]	–

Sides of UT







~$|V_{td}/V_{ts}|$

B_d and B_s mixing: $\Delta m_d/\Delta m_s$

@ Hadron colliders

Radiative decays: $b \to s\gamma$, $b \to d\gamma$

@ B factories

~$|V_{ub}/V_{cb}|$

Inclusive semileptonic decays

$|V_{cb}|$ $B \to X_c\, l\, \nu$

$|V_{ub}|$ $B \to X_u\, l\, \nu$

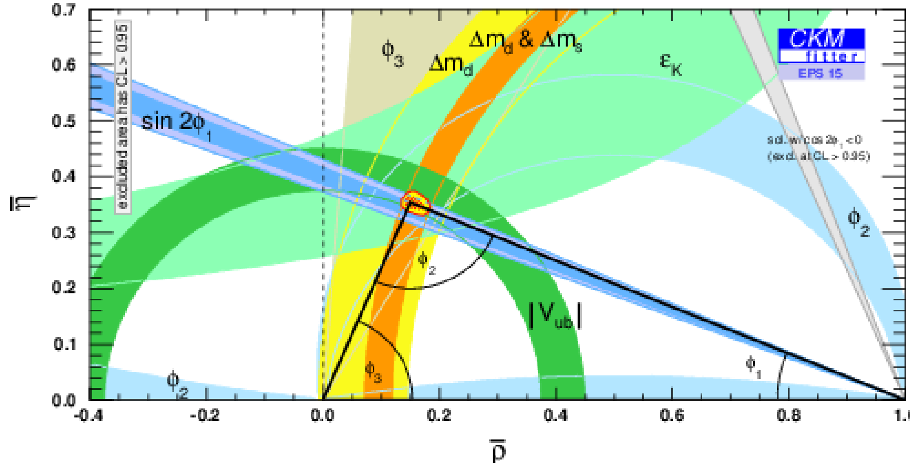
Exclusive semileptonic decays

$|V_{cb}|$ $B \to D^{(*)} l\, \nu$

$|V_{ub}|$ $B \to \pi\, l\, \nu$

Observables	Belle (2014)	Belle II $5\ \mathrm{ab}^{-1}$	Belle II $50\ \mathrm{ab}^{-1}$
$|V_{cb}|$ incl.	$\pm 2.4\%$	$\pm 1.0\%$	
$|V_{cb}|$ excl.	$\pm 3.6\%$	$\pm 1.8\%$	$\pm 1.4\%$
$|V_{ub}|$ incl.	$\pm 6.5\%$	$\pm 3.4\%$	$\pm 3.0\%$
$|V_{ub}|$ excl. (had. tag.)	$\pm 10.8\%$	$\pm 4.7\%$	$\pm 2.4\%$
$|V_{ub}|$ excl. (untag.)	$\pm 9.4\%$	$\pm 4.2\%$	$\pm 2.2\%$

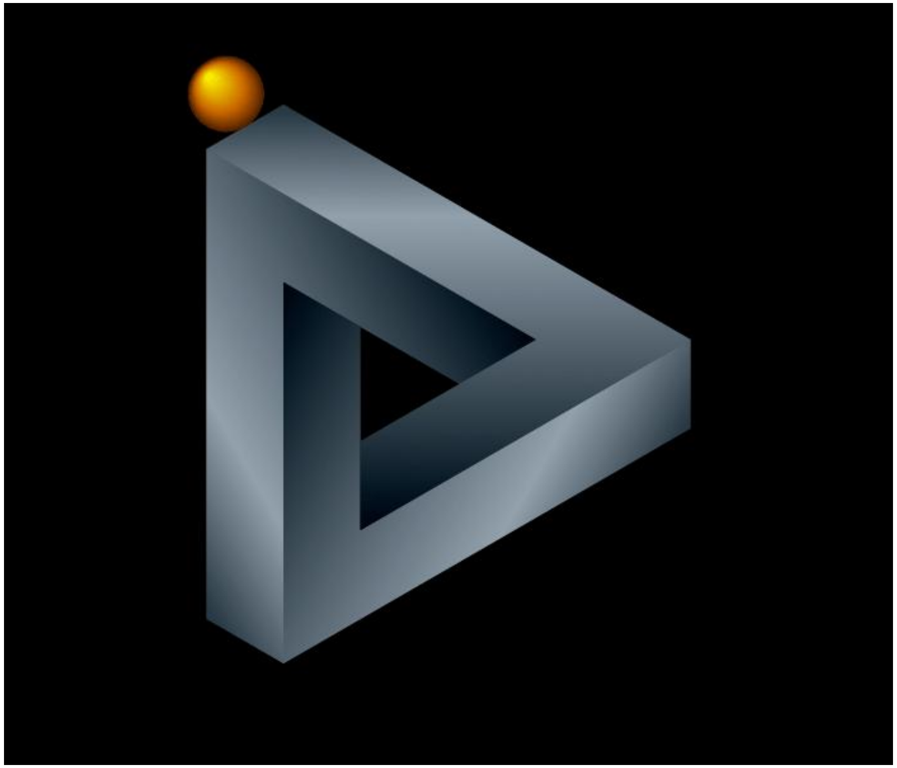
and consistency check

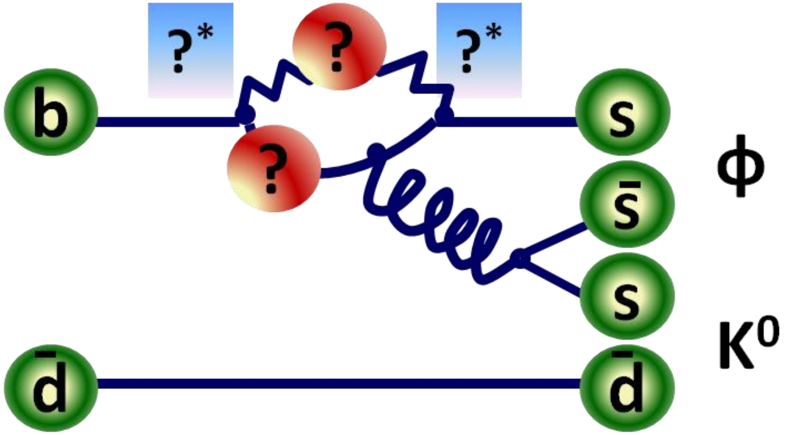


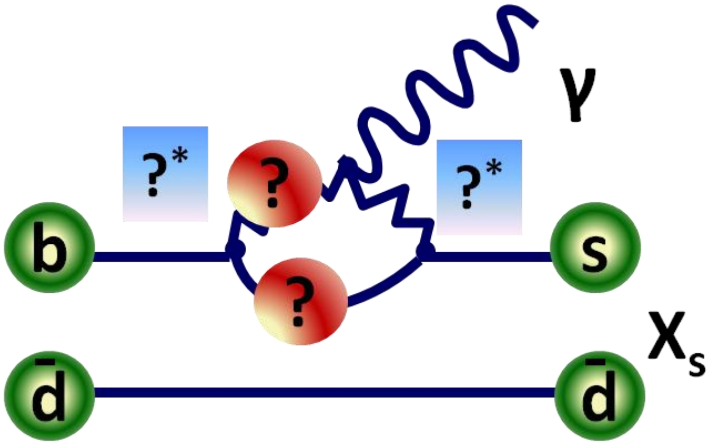
Combined constraints in the $(\bar{\rho}, \bar{\eta})$ plane from UT angles&side measurements

In 5 years: the square of the allowed region will be reduced by at least 2 order of magnitude: precision consistency check!

Search for New physics beyond Unitarity triangle

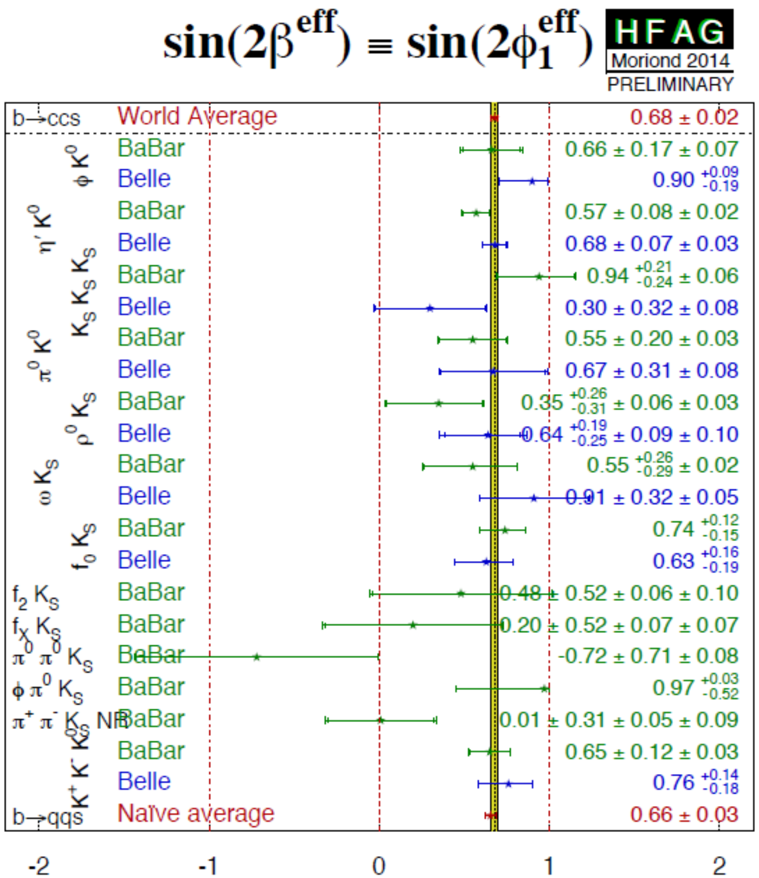


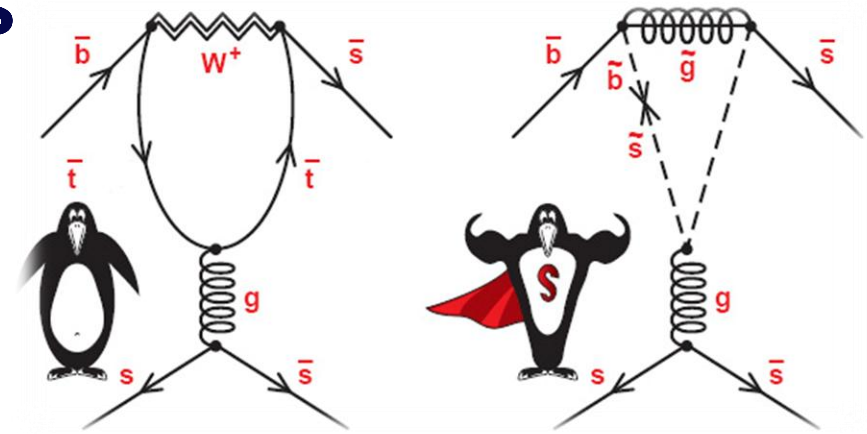




Search for SuperPenguins

CP asymmetry should be ~ sin2φ_1
No tree contribution!
Theoretical uncertainty ~ 0.01-0.03 much smaller than the current exp. errors!





sin2 $\varphi^{\rm eff} \neq$ sin2φ_1 ?

2006: exciting 3.5 σ discrepancy!

now: disappointing nice agreement

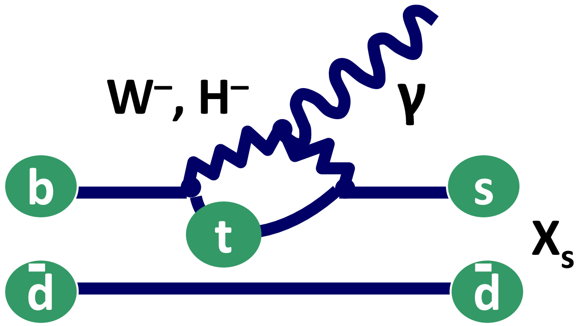
$$\sin 2\beta = 0.68 \pm 0.02 \approx 0.66 \pm 0.03 = \sin 2\phi^{\rm eff}$$ $$A_{CP} \approx 0$$

Belle II:

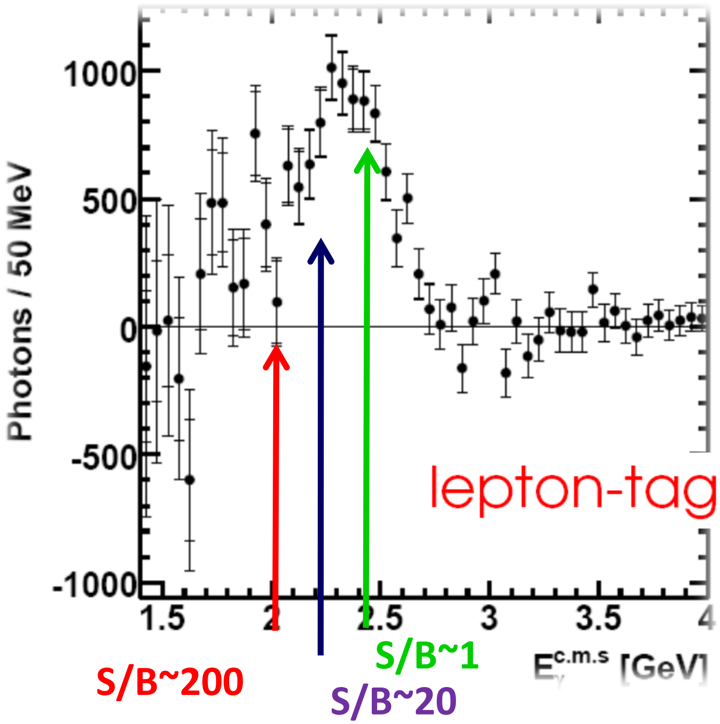
Expected errors for the golden modes

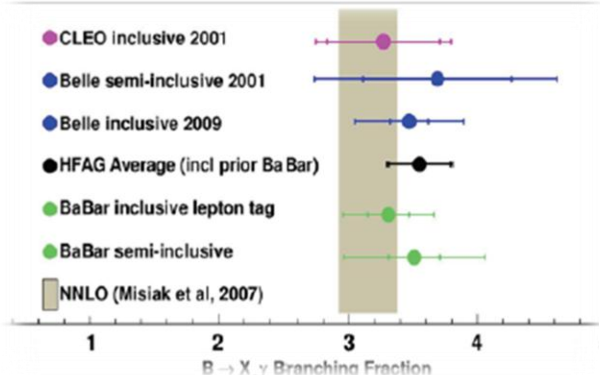
Mode	5 ab^{-1}		50 ab^{-1}	
	$\sigma(\mathcal{S})$	$\sigma(\mathcal{A})$	$\sigma(\mathcal{S})$	$\sigma(\mathcal{A})$
$\eta' K^0$	0.028	0.020	0.011	0.009
ϕK^0_S	0.053	0.070	0.018	0.023
$K_S K_S K_S$	0.101	0.064	0.033	0.021

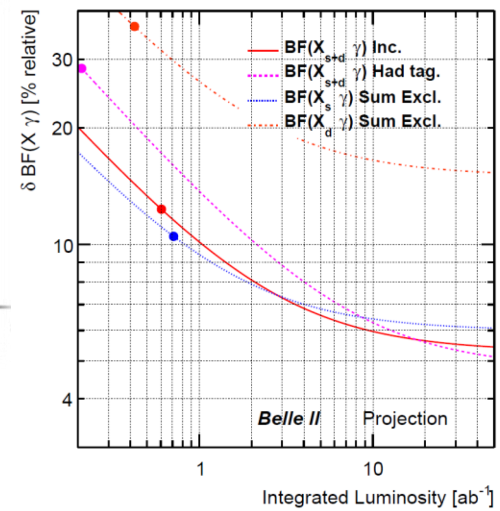
$Br(B \to X_s\,\gamma)$

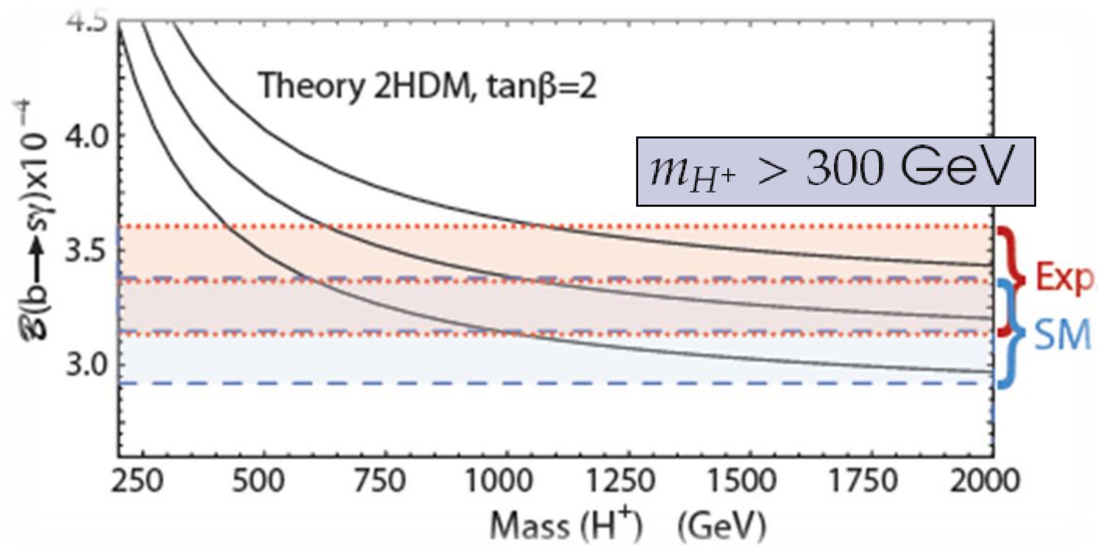


To reduce model uncertainty need to measure from as smaller E_γ as possible

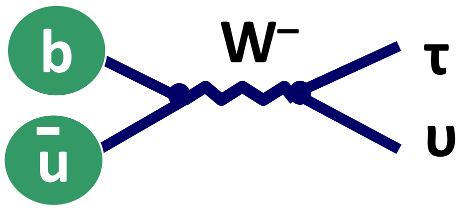


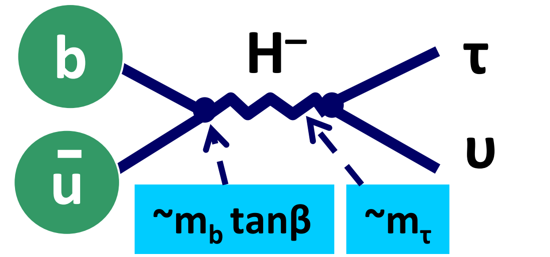






Purely leptonic decay

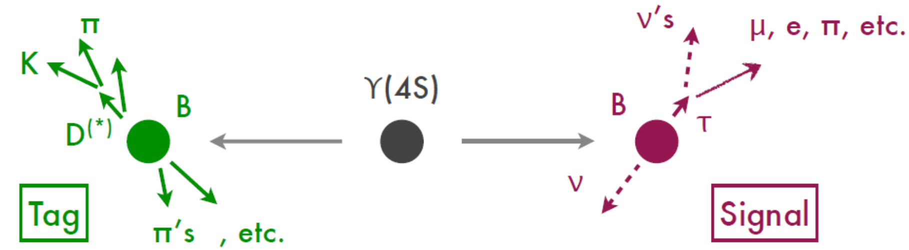


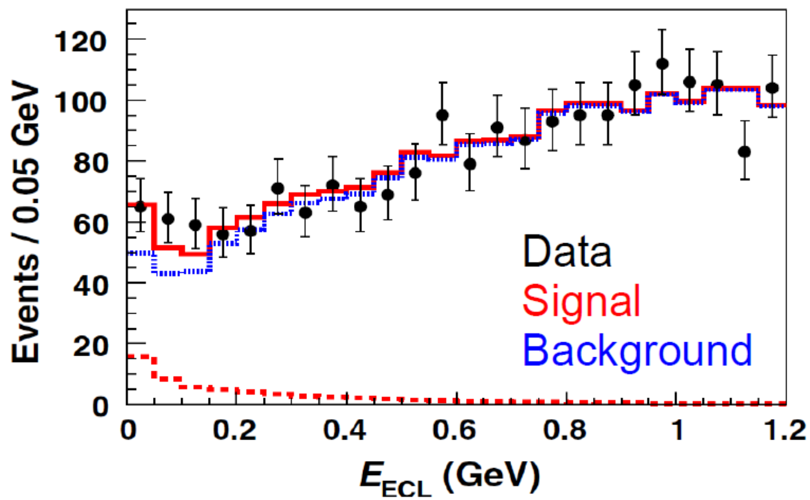


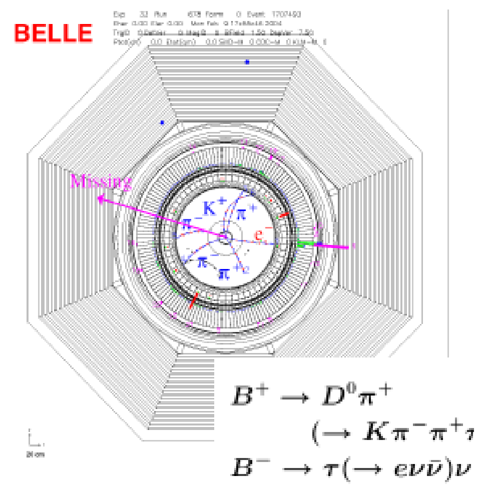
$$\mathcal{B}(B^+ \to \tau^+\nu) = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left(1-\frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

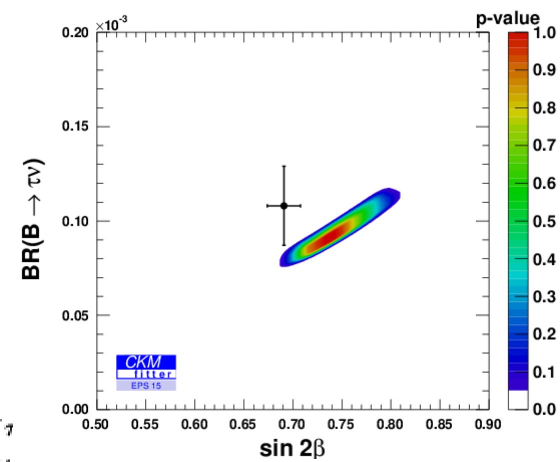
$$\mathcal{B}(B^+ \to \tau^+\nu) = \mathcal{B}(B^+ \to \tau^+\nu)_{SM}\left(1-\frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

Reconstruct one B fully in hadronic or semileptonic decay, see one track from τ-decay, check that there is no extra energy deposition in the event







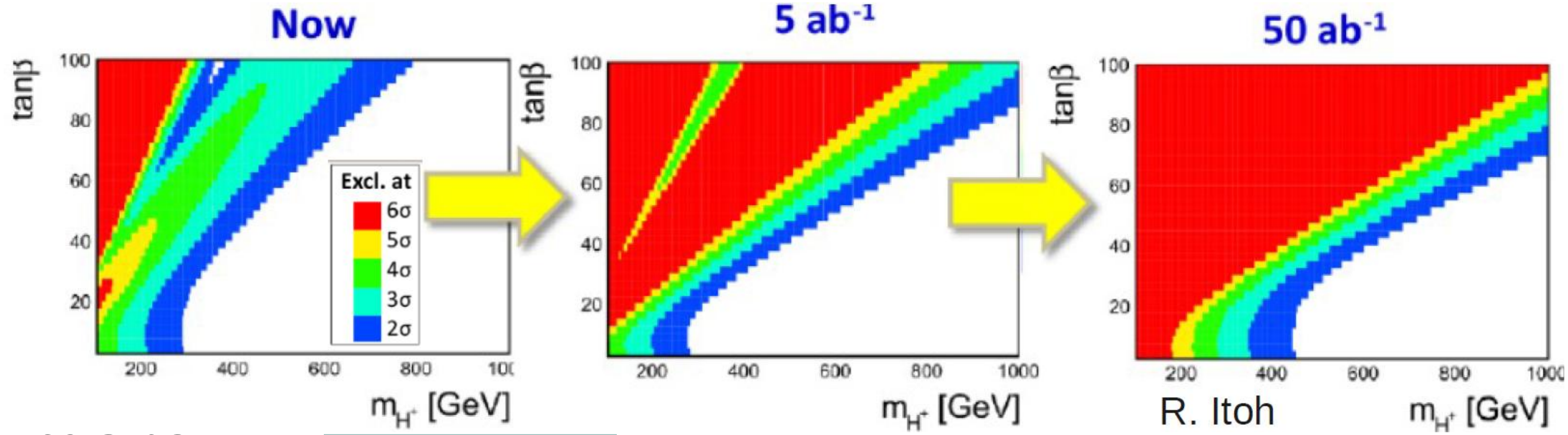


WA: Br(B → τν) = (1.14 ± 0.22)×10⁻⁴

Belle II: Improve accuracy by ~5

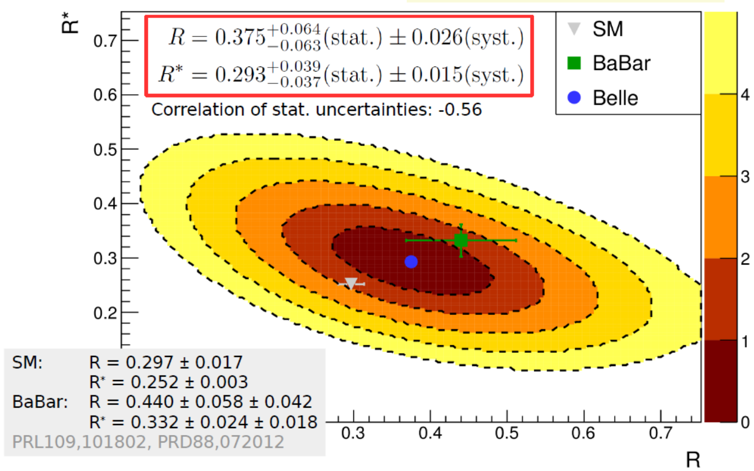
New physics: virtual particles in B-decays *vs* direct searches

Br($B \to \tau\nu$) constrains m_{H^+} - $\tan\beta$ plane and rule out certain charged Higgs models



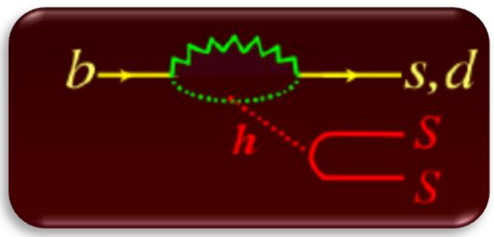
+ more

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



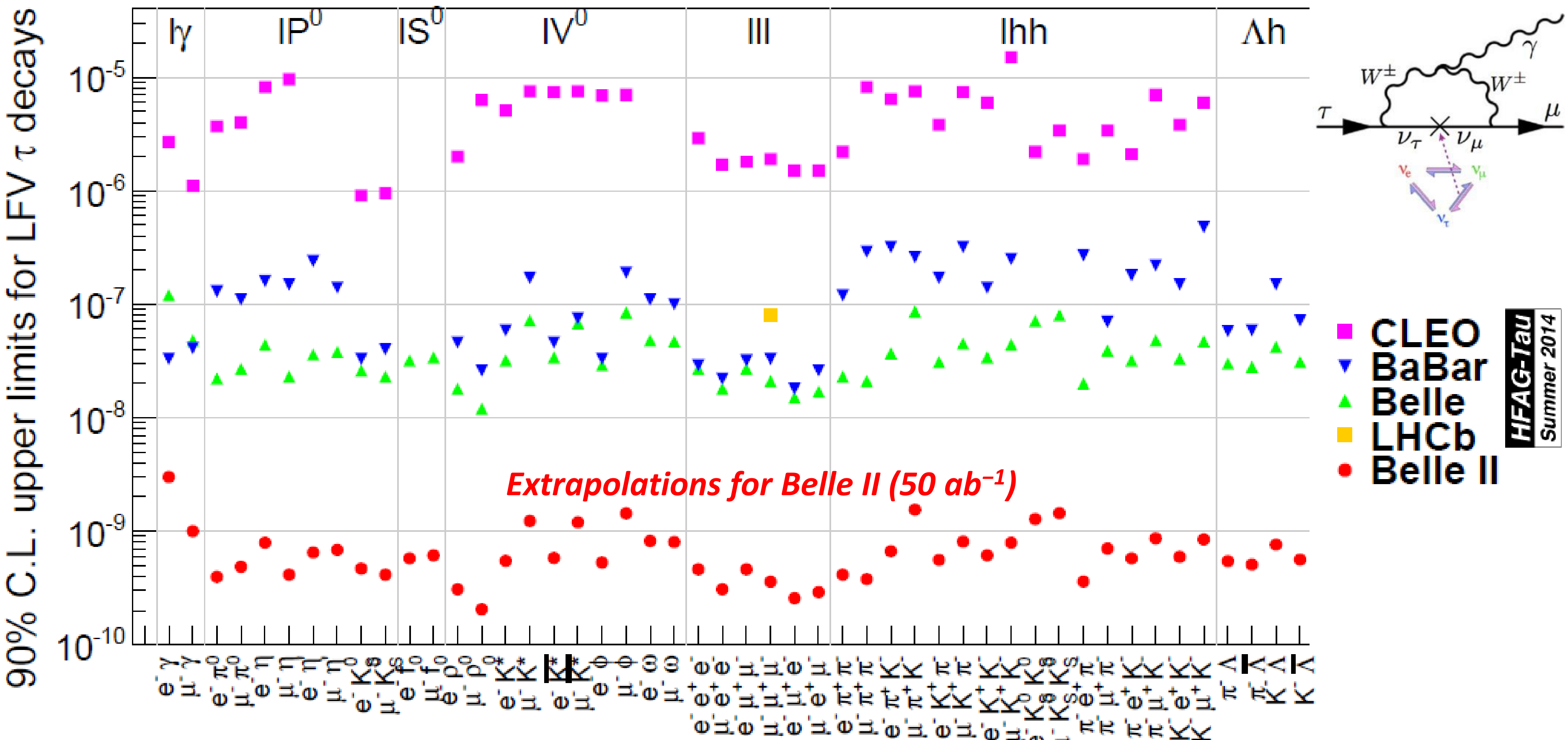
$B \to K^{(*)} \ell^+\ell^-$

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



sensitive to NP at LHC scale and above

LFV τ decays



- Lepton Flavor Violation is highly suppressed in the SM (e.g. Br(τ→μγ) ~ 10^{-40}):
- LFV τ decays are clean and ambiguous probes for New Physics effects
- **Belle II :** Sensitivity for LFV decay rates is over **100 times higher** than Belle for the cleanest channels (τ→3l) and over **10 times higher** for other modes, such as τ→lγ (due to irreducible background contributions)

Much more to be done at Belle II

	Observables	Belle or LHCb* (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}	LHCb 8 fb^{-1}(2018)	LHCb 50 fb^{-1}
UT angles	$\sin 2\beta$	$0.667 \pm 0.023 \pm 0.012 (0.9^\circ)$	0.4°	0.3°	0.6°	0.3°
	α [$^\circ$]	85 ± 4 (Belle+BaBar)	2	1		
	γ [$^\circ$] ($B \to D^{(*)}K^{(*)}$)	68 ± 14	6	1.5	4	1
	$2\beta_s(B_s \to J/\psi\phi)$ [rad]	$0.07 \pm 0.09 \pm 0.01^*$			0.025	0.009
Gluonic penguins	$S(B \to \phi K^0)$	$0.90^{+0.09}_{-0.19}$	0.053	0.018	0.2	0.04
	$S(B \to \eta' K^0)$	$0.68 \pm 0.07 \pm 0.03$	0.028	0.011		
	$S(B \to K^0_S K^0_S K^0_S)$	$0.30 \pm 0.32 \pm 0.08$	0.100	0.033		
	$\beta_s^{\rm eff}(B_s \to \phi\phi)$ [rad]	$-0.17 \pm 0.15 \pm 0.03^*$			0.12	0.03
	$\beta_s^{\rm eff}(B_s \to K^{*0}\bar{K}^{*0})$ [rad]	–			0.13	0.03
Direct CP in hadronic Decays	$\mathcal{A}(B \to K^0\pi^0)$	$-0.05 \pm 0.14 \pm 0.05$	0.07	0.04		
UT sides	$\lvert V_{cb}\rvert$ incl.	$41.6 \cdot 10^{-3}(1 \pm 2.4\%)$	1.2%			
	$\lvert V_{cb}\rvert$ excl.	$37.5 \cdot 10^{-3}(1 \pm 3.0\%_{\rm ex.} \pm 2.7\%_{\rm th.})$	1.8%	1.4%		
	$\lvert V_{ub}\rvert$ incl.	$4.47 \cdot 10^{-3}(1 \pm 6.0\%_{\rm ex.} \pm 2.5\%_{\rm th.})$	3.4%	3.0%		
	$\lvert V_{ub}\rvert$ excl. (had. tag.)	$3.52 \cdot 10^{-3}(1 \pm 10.8\%)$	4.7%	2.4%		
Leptonic and Semi-tauonic	$\mathcal{B}(B \to \tau\nu)$ [10^{-6}]	$96(1 \pm 26\%)$	10%	5%		
	$\mathcal{B}(B \to \mu\nu)$ [10^{-6}]	< 1.7	20%	7%		
	$R(B \to D\tau\nu)$ [Had. tag]	$0.440(1 \pm 16.5\%)^\dagger$	5.6%	3.4%		
	$R(B \to D^*\tau\nu)^\dagger$ [Had. tag]	$0.332(1 \pm 9.0\%)^\dagger$	3.2%	2.1%	...	
Radiative	$\mathcal{B}(B \to X_s\gamma)$	$3.45 \cdot 10^{-4}(1 \pm 4.3\% \pm 11.6\%)$	7%	6%		
	$A_{CP}(B \to X_{s,d}\gamma)$ [10^{-2}]	$2.2 \pm 4.0 \pm 0.8$	1	0.5		
	$S(B \to K^0_S\pi^0\gamma)$	$-0.10 \pm 0.31 \pm 0.07$	0.11	0.035		
	$2\beta_s^{\rm eff}(B_s \to \phi\gamma)$	–			0.13	0.03
	$S(B \to \rho\gamma)$	$-0.83 \pm 0.65 \pm 0.18$	0.23	0.07		
	$\mathcal{B}(B_s \to \gamma\gamma)$ [10^{-6}]	< 8.7	0.3	–		
Electroweak penguins	$\mathcal{B}(B \to K^{*+}\nu\overline{\nu})$ [10^{-6}]	< 40	< 15	30%		
	$\mathcal{B}(B \to K^+\nu\overline{\nu})$ [10^{-6}]	< 55	< 21	30%		
	C_7/C_9 ($B \to X_s\ell\ell$)	~20%	10%	5%		
	$\mathcal{B}(B_s \to \tau\tau)$ [10^{-3}]	–	< 2	–		
	$\mathcal{B}(B_s \to \mu\mu)$ [10^{-9}]	$2.9^{+1.1}_{-1.0}{}^*$			0.5	0.2

	Observables	Belle or LHCb* (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}	LHCb 2018	LHCb 50 fb^{-1}
Charm Rare	$\mathcal{B}(D_s \to \mu\nu)$	$5.31 \cdot 10^{-3}(1 \pm 5.3\% \pm 3.8\%)$	2.9%	0.9%		
	$\mathcal{B}(D_s \to \tau\nu)$	$5.70 \cdot 10^{-3}(1 \pm 3.7\% \pm 5.4\%)$	3.5%	2.3%		
	$\mathcal{B}(D^0 \to \gamma\gamma)$ [10^{-6}]	< 1.5	30%	25%		
Charm CP	$A_{CP}(D^0 \to K^+K^-)$ [10^{-4}]	$-32 \pm 21 \pm 9$	11	6		
	$\Delta A_{CP}(D^0 \to K^+K^-)$ [10^{-3}]	3.4^*			0.5	0.1
	A_Γ [10^{-2}]	0.22	0.1	0.03	0.02	0.005
	$A_{CP}(D^0 \to \pi^0\pi^0)$ [10^{-2}]	$-0.03 \pm 0.64 \pm 0.10$	0.29	0.09		
	$A_{CP}(D^0 \to K^0_S\pi^0)$ [10^{-2}]	$-0.21 \pm 0.16 \pm 0.09$	0.08	0.03		
Charm Mixing	$x(D^0 \to K^0_S\pi^+\pi^-)$ [10^{-2}]	$0.56 \pm 0.19 \pm {}^{0.07}_{0.13}$	0.14	0.11		
	$y(D^0 \to K^0_S\pi^+\pi^-)$ [10^{-2}]	$0.30 \pm 0.15 \pm {}^{0.05}_{0.08}$	0.08	0.05		
	$\lvert q/p\rvert(D^0 \to K^0_S\pi^+\pi^-)$	$0.90 \pm {}^{0.16}_{0.15} \pm {}^{0.08}_{0.06}$	0.10	0.07		
	$\phi(D^0 \to K^0_S\pi^+\pi^-)$ [$^\circ$]	$-6 \pm 11 \pm {}^{4}_{5}$	6	4		
Tau	$\tau \to \mu\gamma$ [10^{-9}]	< 45	< 14.7	< 4.7		
	$\tau \to e\gamma$ [10^{-9}]	< 120	< 39	< 12		
	$\tau \to \mu\mu\mu$ [10^{-9}]	< 21.0	< 3.0	< 0.3		

+ charm spectroscopy, rare D decays, ϒ(5S) physics, quarkonium(+like)

Super B factory and LHCb are complementary to each other

Belle II vs Belle

KEKB: The energy asymmetry 8 GeV (e^-) × 3.5 GeV (e^+) ($\beta\gamma$=0.425)

- **sin(2β) the main goal of the experiment : measurement of Δt of two B mesons with high precision**

SuperKEKB: The energy asymmetry 7 GeV (e^-) × 4 GeV (e^+) ($\beta\gamma$= 0.28)

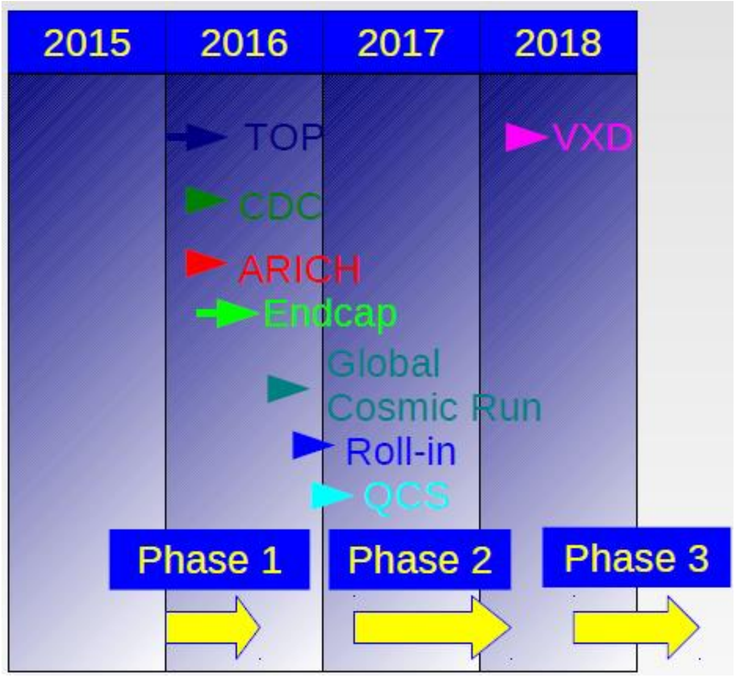
- **modes with neutrino in the final state (e.g. $B\to\tau\nu$): better hemeticity**

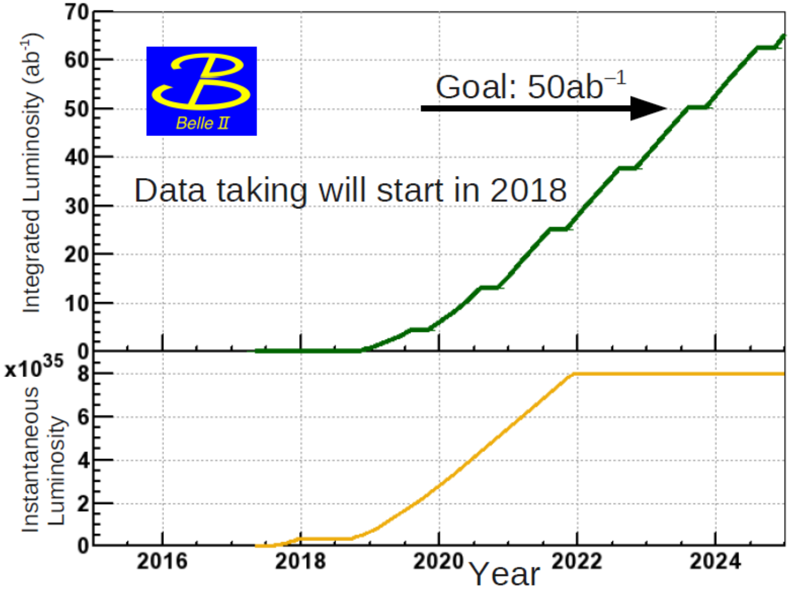
Belle II:

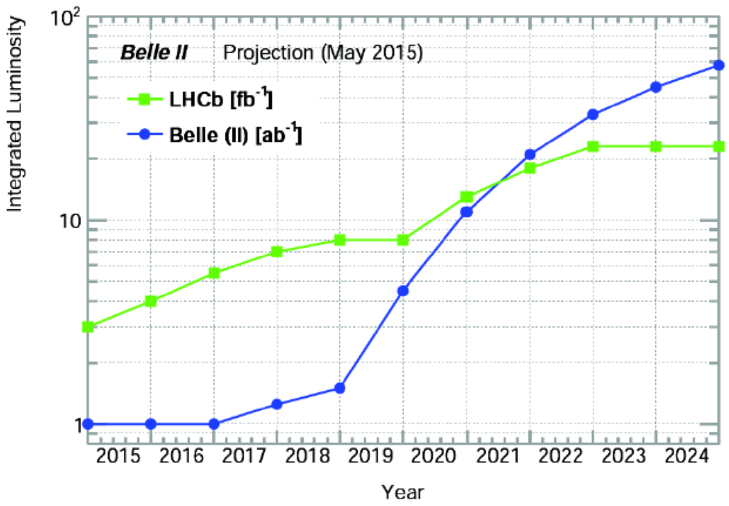
- A smaller beam pipe radius (1.5 cm to 1.0 cm) allows for the innermost silicon detector layer to be positioned closer to the IP (2.0 cm to 1.3 cm)
  - **significantly improve the resolution in the z direction**
- Significantly increased outer radius of the SVD (from 8.8 to 14.0 cm)
  - **more K^0_S for the time-dependent using K^0_S vertexing**
- Higher reconstruction efficiency of D^* slow pions and better flavor tagging
- PID improvements
  - **improve K/π separation, flavor tagging, rare charmless decays or $b\to s\gamma$ efficiencies, background rejection**
- Improvements to the KLM
  - **higher hadronic veto efficiencies used in missing energy analyses ($B\to\tau\nu$)**

Schedule & expectations

- SuperKEKB will start circulating beams in 2016
- 3 phases in commissioning → operation
  - Phase 1: Without Belle II detector
  - Phase 2: Belle II is rolled in, but without vertex detector
  - Phase 3: Full Belle II operation
- Physics data taking will start in 2018





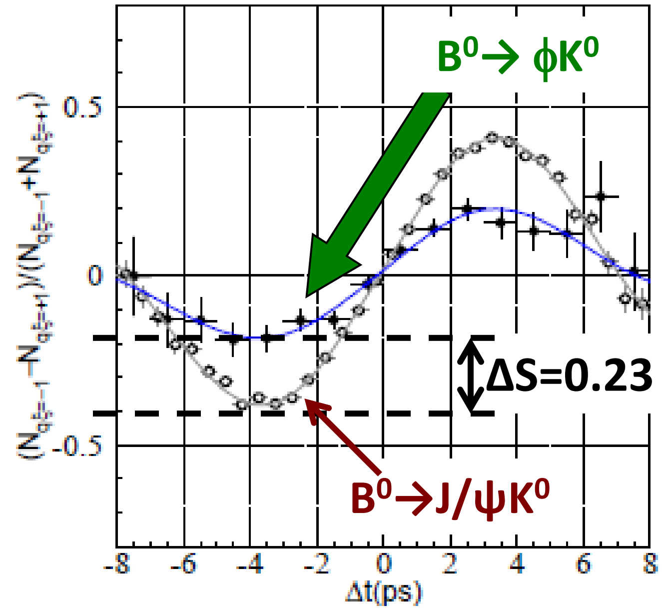


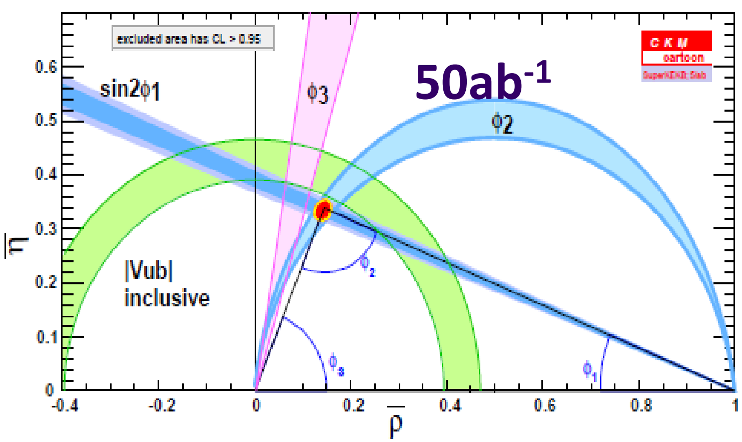
Summary

Physics beyond the Standard Model has successfully avoided detection up to now. But we are sure it is somewhere nearby.

Up to now the sensitivity to New Physics amplitude was ~10% of those from the SM; in 5-10 years it will be improved by an order of magnitude.

- **Rich physics program for Belle II**
- **Belle II will start data taking in 2018**
- **Belle II goal of 50/ab will provide great sensitivity and complimentary to LHCb information in many areas of flavor, CP and related fields**





- **We hope to observe something like THIS in 5-7 years**

UT 2014		Belle II
α	4° (WA)	1°
β	0.8° (WA)	0.2°
γ	8.5° (WA) 14°(Belle)	1-1.5°

Where is New Physics?

It must be somewhere nearby.

T H A N K   Y O U !