Searching for New Physics in Flavor Physics

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FCPPL workshop 2016
IPHC Strasbourg, 30 March-1 April 2016

Members of the team

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New application (separated from Richard/Zhao group):
focusing more on Flavour Physics and BSM

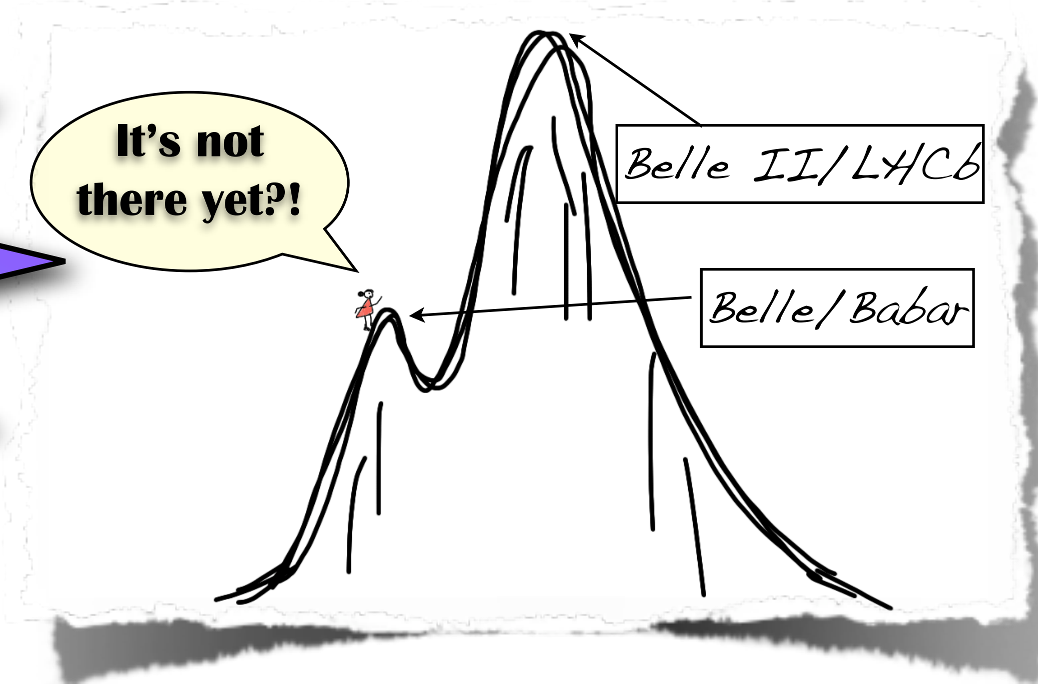
Discovery in Flavour Physics

Well motivated. But we need to improve the sensitivity?

- New physics models predict naturally deviation from SM in flavour and CP violating phenomena.
- But then, what is the indication of the non-appearance of new physics? And where/how to search it now?

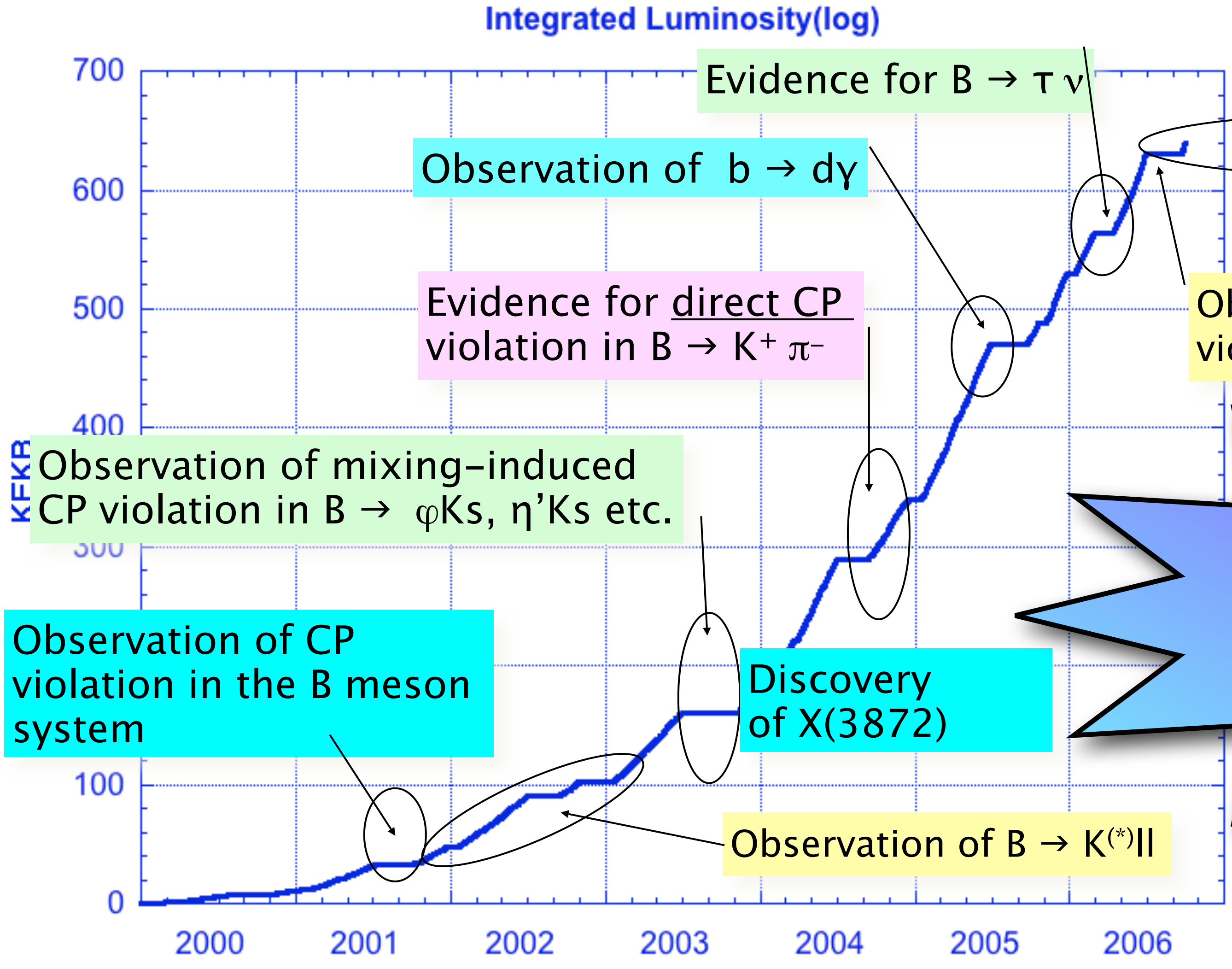
Increase the sensitivity to new physics by an order of magnitude!

High luminosity machines!



Legacy of Babar/Belle

Many $2\text{-}3\sigma$ seen, disappeared, unclear etc…



Evidence for $B \to \tau \nu$

Evidence for D^0 mixing

Observation of $b \to d\gamma$

Confirmation of g-2
$\sim 3\sigma$ deviation

Evidence for direct CP
violation in $B \to K^+ \pi^-$

Observation of direct CP
violation in $B \to \rho^+ \rho^-$

Observation of mixing-induced
CP violation in $B \to \phi K_s, \eta' K_s$ etc.

Observation of CP
violation in the B meson
system

Discovery
of X(3872)

Observation of $B \to K^{(*)}ll$

LHCb/Belle II will tell us what they are !!

Slide taken from talk
by T. Browder

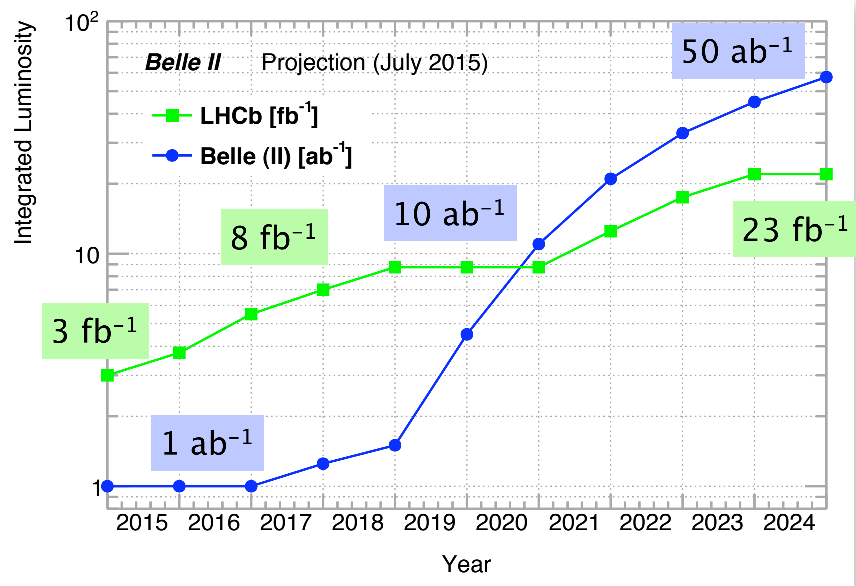
Similarly, LHCb sees several interesting anomalies !!!

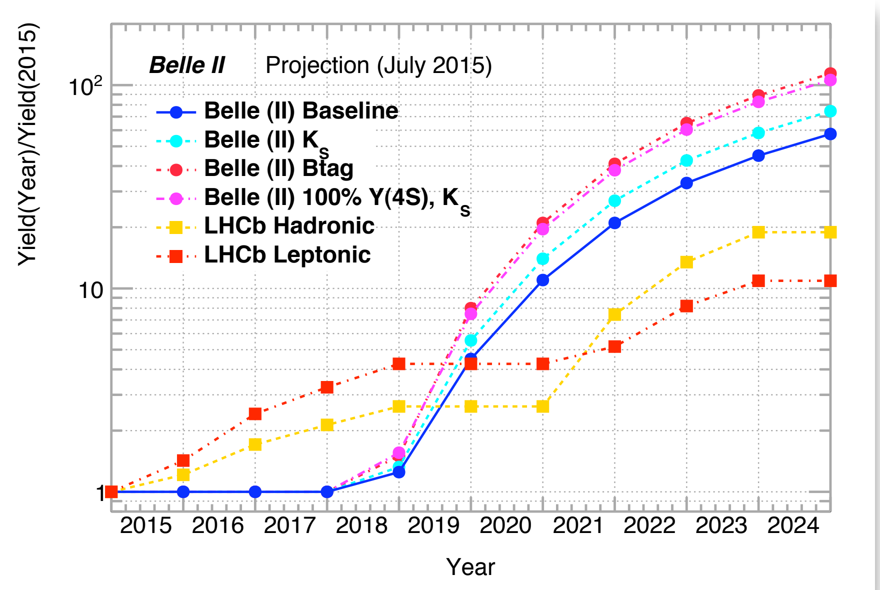
LHCb and Belle II

Competition or complementary ???

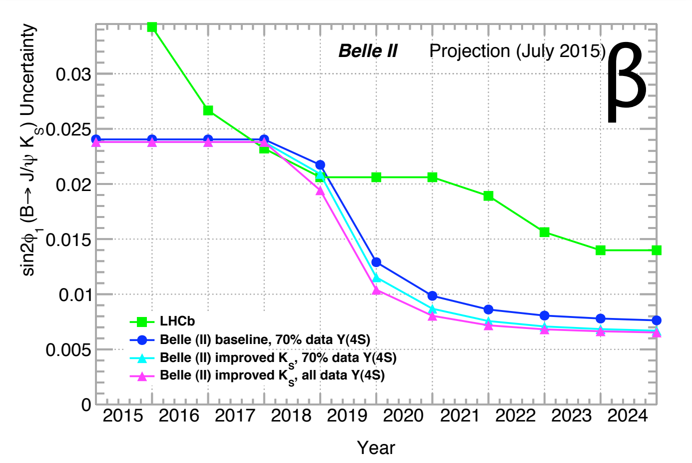
Future increase of the luminosity

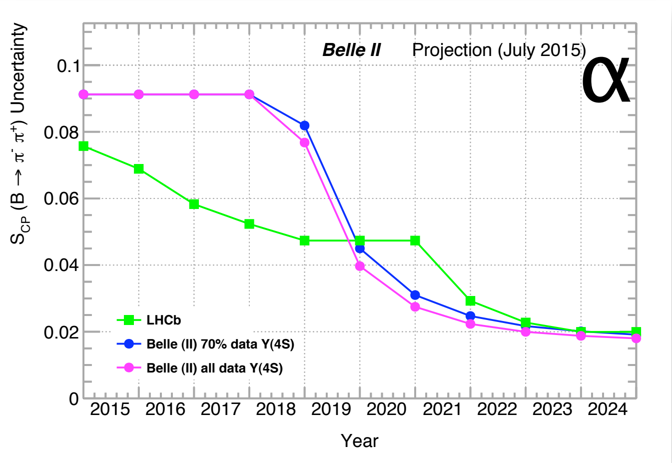
BELLE2-NOTE-PH-2015-004

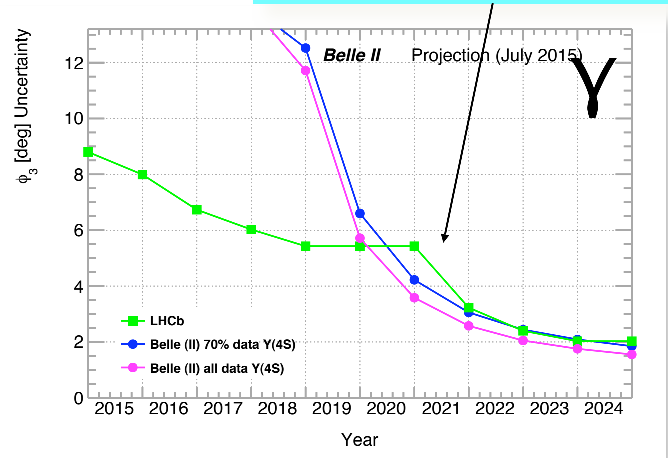




Future reductions of the errors





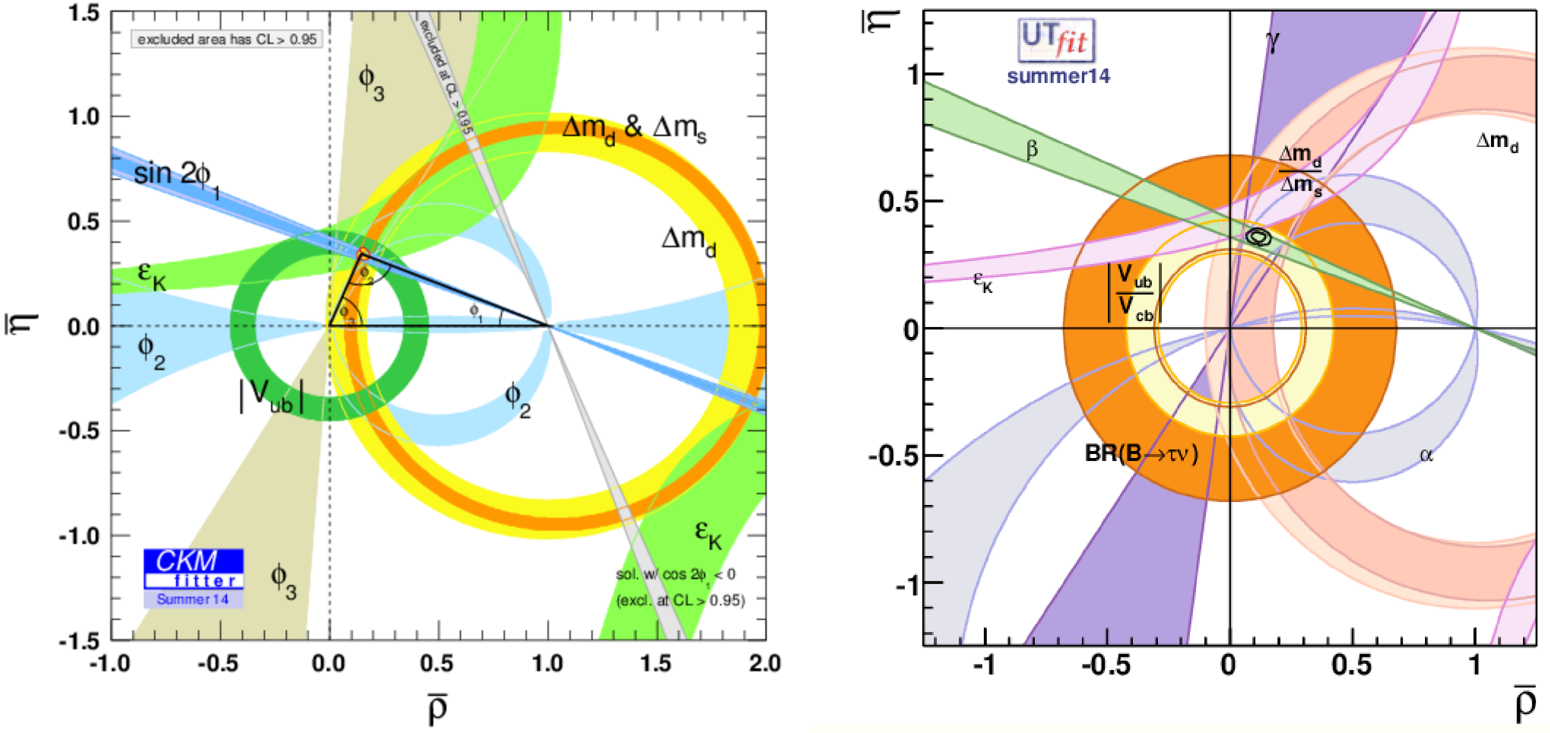


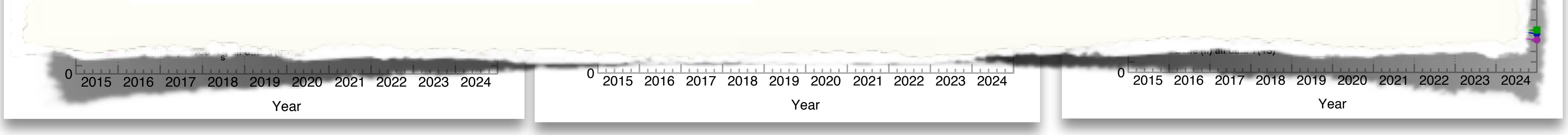
BESIII inputs crucial!

LHCb and Belle II

Competition or complementary ???

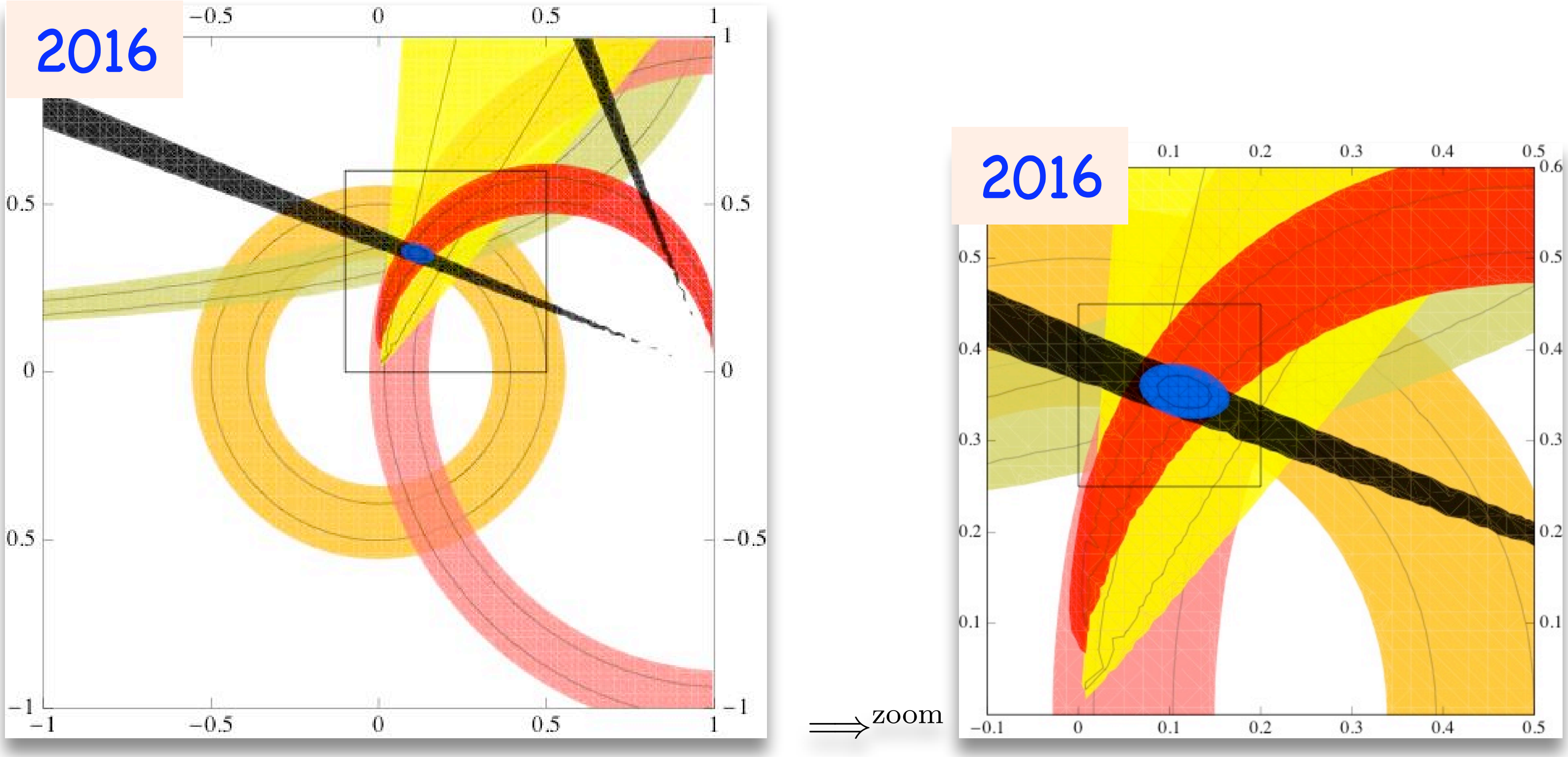
Can we expect a discovery of New Physics with the Unitarity Triangle ?!





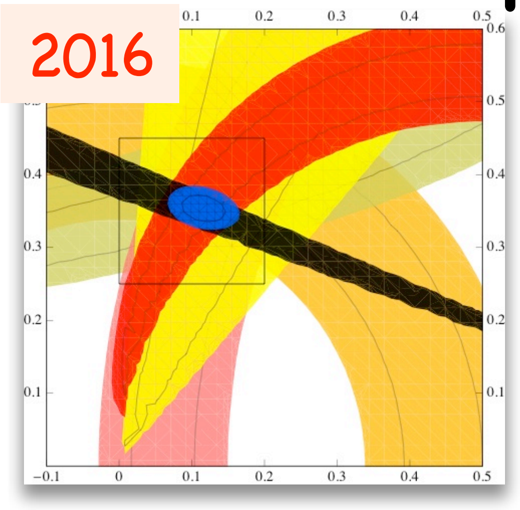
Future prospect of the UT triangle

Current status: good agreement



What would happen in 10 years time??

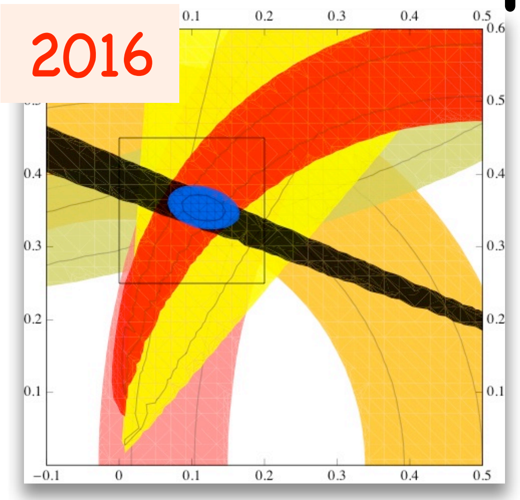
Future prospect of the UT triangle



50ab-1
Belle II

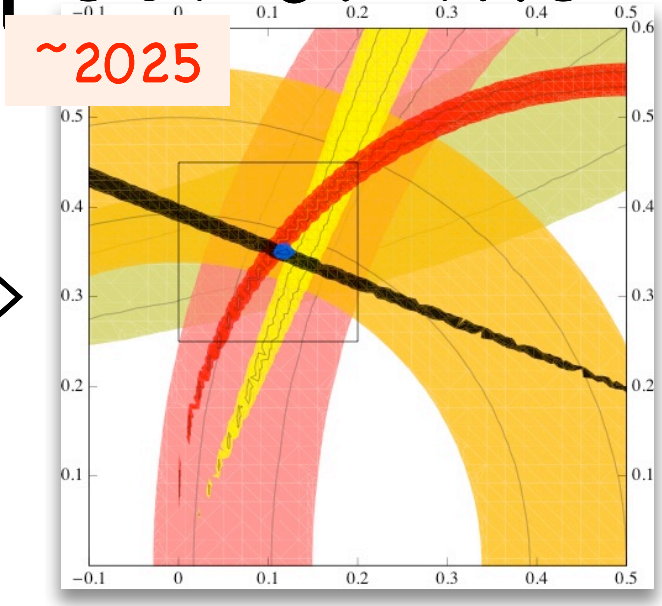
E.K.& F. Le Diberder
for B2TiP working group

Future prospect of the UT triangle



2016

50ab−1
Belle II



~2025

E.K.& F. Le Diberder
for B2TiP working group

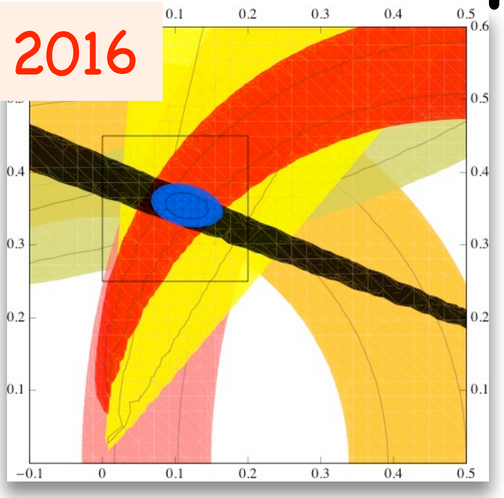
1.4σ level agreement!

If the central value remains the same
(though unlikely)...

Future prospect of the UT triangle

E.K.& F. Le Diberder
for B2TiP working group

2016



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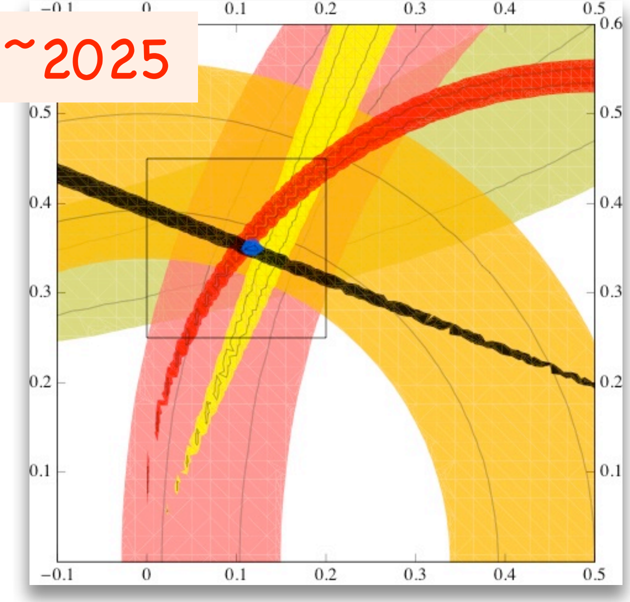
Belle II

~2025



1.4σ level agreement!

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50ab−1
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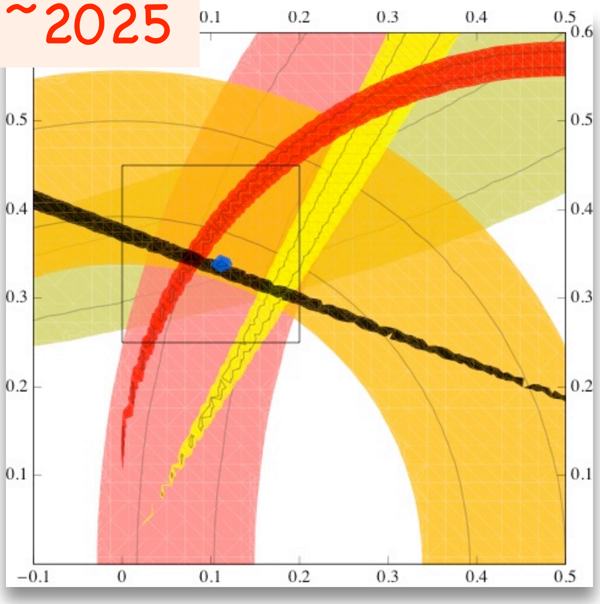
~2025



8σ level discrepancy!

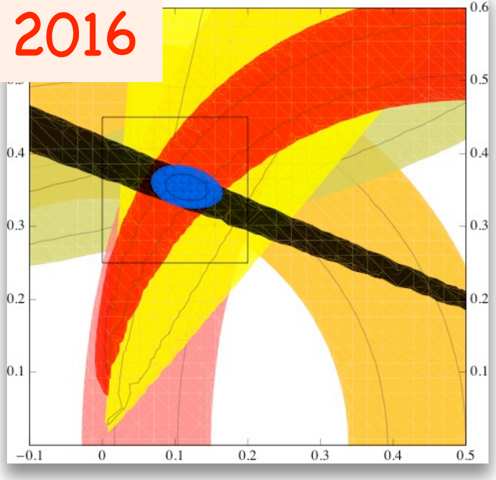
If all the central values a little go lower...

**Is this 8σ an "odd case"???
(the answer is NO!)**

Future prospect of the UT triangle

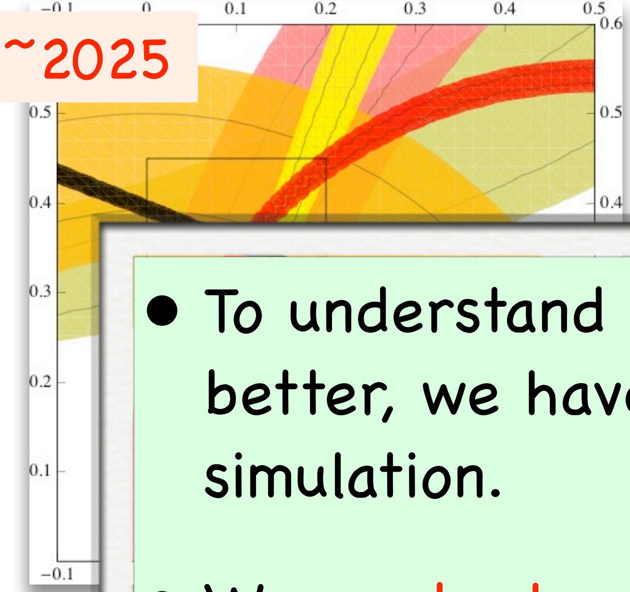
E.K. with F. Le Diberder
(preliminary)

2016



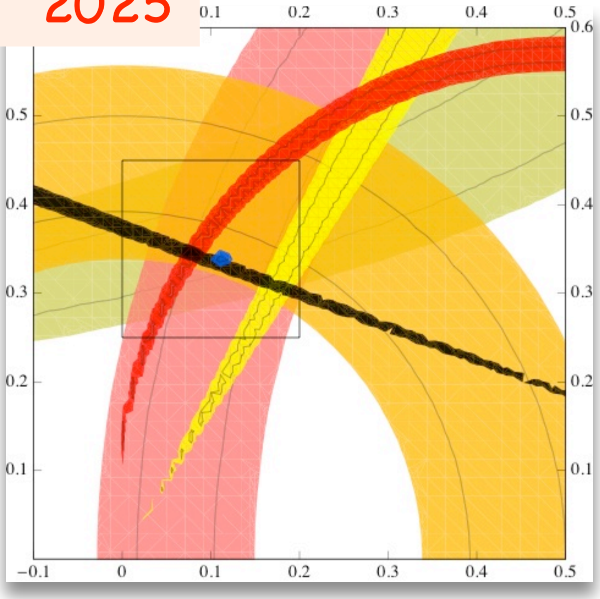
50ab−1
Belle II

~2025



50ab−1
Belle II

~2025



If the ce

8σ le
discrep

If all the central values a little go lower…

- To understand this “8σ” effect better, we have run a Monte Carlo simulation.
- We randomly sample the central values (1000 trials) assuming Gaussian measurements and compute the significance.
- The result shows that **the chance to observe deviation more than 5σ significance is currently 52 % !**

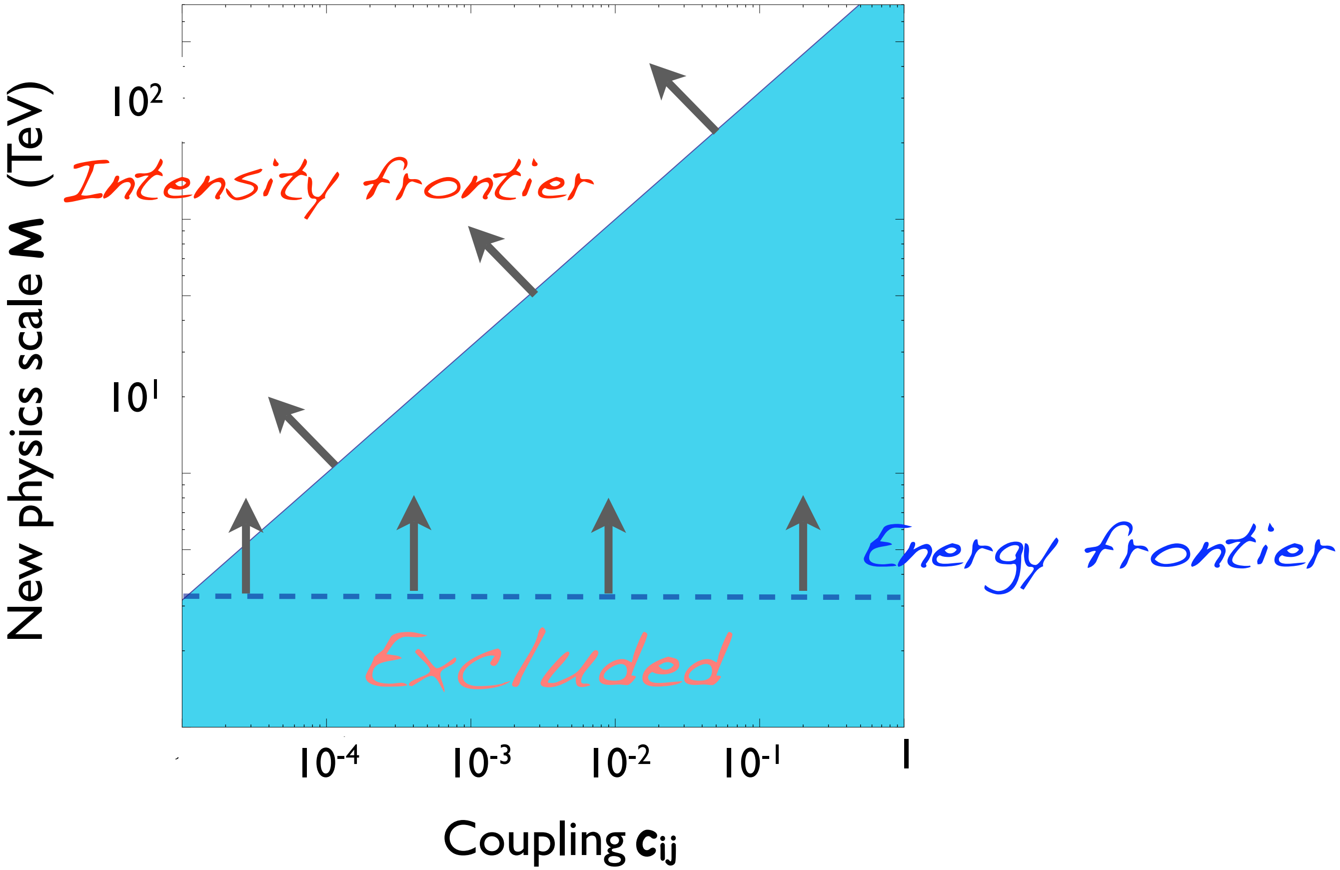
Our 2016 project

Flavour and High-P_T

Competition or complementary ???

$$\Delta_{NP} = (\text{exp.} - \text{SM}) \pm \sqrt{(\sigma_{exp})^2+(\sigma_{SM})^2}$$
$$= c/(M_{NP})^{n=2}$$

complementarity



Left-Right Symmetric Model (LRSM)

EK, C.-D. Lu and F.-S. Yu (JHEP 2013)
Thesis of F.-S. Yu (China-France co-supervision)

Extended gauge group

$$SU(2)_L \times SU(2)_R \times U(1)_{\tilde{Y}} \to SU(2)_L \times U(1)_Y \to U(1)_{\rm EM}.$$

[Pati,Salam,1974;Mohapatra,Pati,1975;Mohapatra,Sejanovic,1975]

Two step Symmetry breakings

$$\langle\Phi\rangle = \begin{pmatrix} \kappa & 0 \\ 0 & \kappa' e^{i\omega} \end{pmatrix}, \quad \langle\Delta_L\rangle = \begin{pmatrix} 0 & 0 \\ v_L e^{i\theta_L} & 0 \end{pmatrix}, \quad \langle\Delta_R\rangle = \begin{pmatrix} 0 & 0 \\ v_R & 0 \end{pmatrix}$$

$$\kappa, \kappa', v_L \ll v_R$$

Right handed mass very large

W boson with left- and right-handed couplings (W$_L$ & W$_R$)

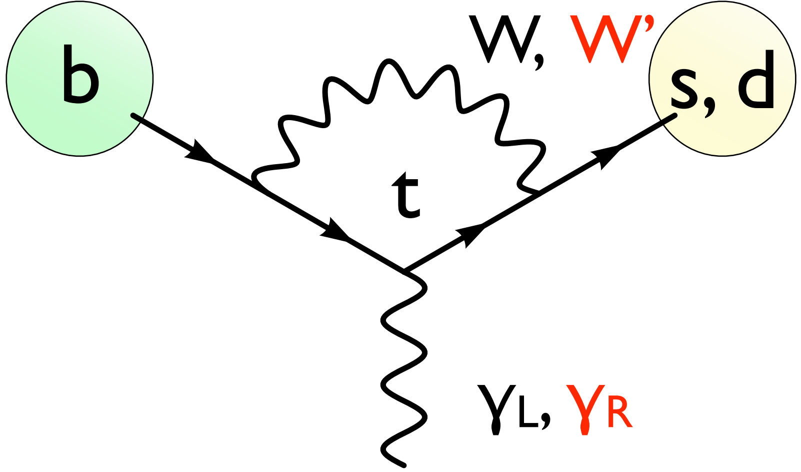
$$\begin{pmatrix} W_L^- \\ W_R^- \end{pmatrix} = \begin{pmatrix} \cos\zeta & -\sin\zeta e^{iw} \\ \sin\zeta e^{-iw} & \cos\zeta \end{pmatrix} \begin{pmatrix} W_1^- \\ W_2^- \end{pmatrix}$$

$$\sin\zeta \approx \frac{g_L}{g_R}\frac{|\kappa||\kappa'|}{v_R^2} = \frac{g_L}{g_R}\frac{1}{2}\epsilon^2 \sin 2\beta \approx \frac{M_{W_1}^2}{M_{W_2}^2}\frac{g_R}{g_L}\sin 2\beta.$$

Mass eigenstates W$_1$ & W$_2$ are a mixture of left and right W's

Searching signals of LRSM

Flavour physics signal

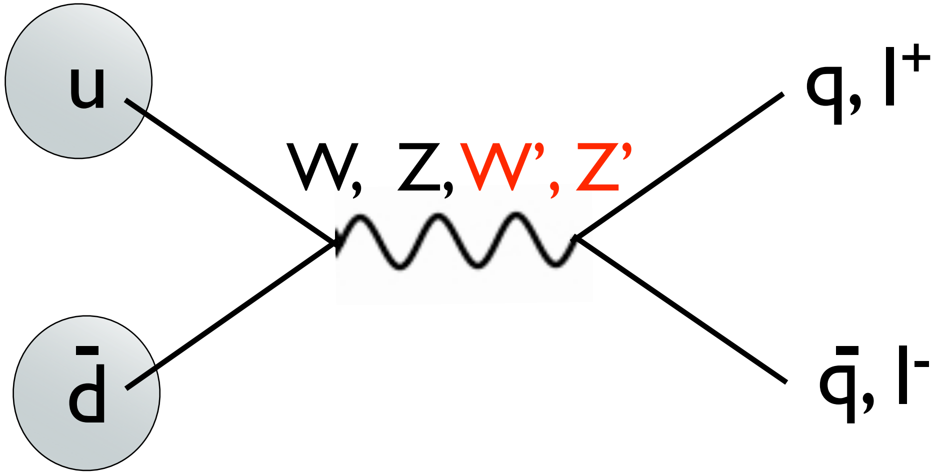


W: b →s/dγ_L (left-handed polarization)

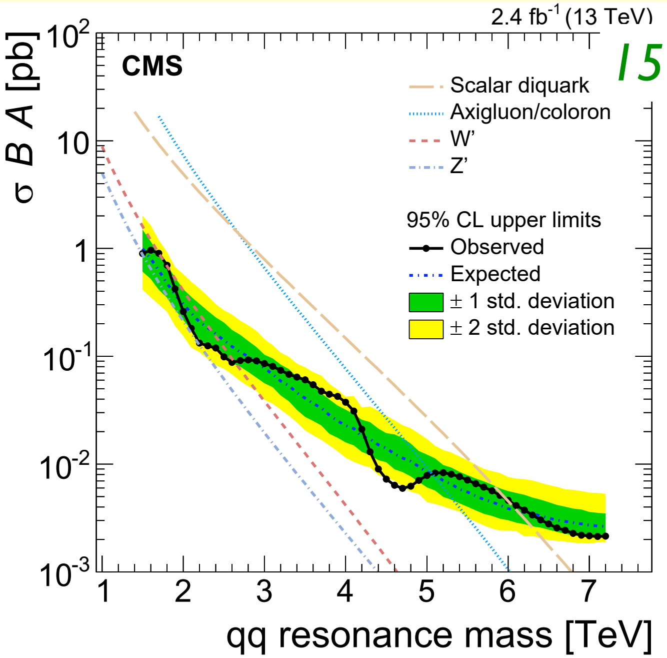
W': b →s/dγ_R (right-handed polarization)

In the previous years, we have been investigating methods to measure the photon polarization of b->s/d γ decays (find details in our FCPPL report and also backup slides)

ATLAS/CMS signal



Generic resonance search with dijets



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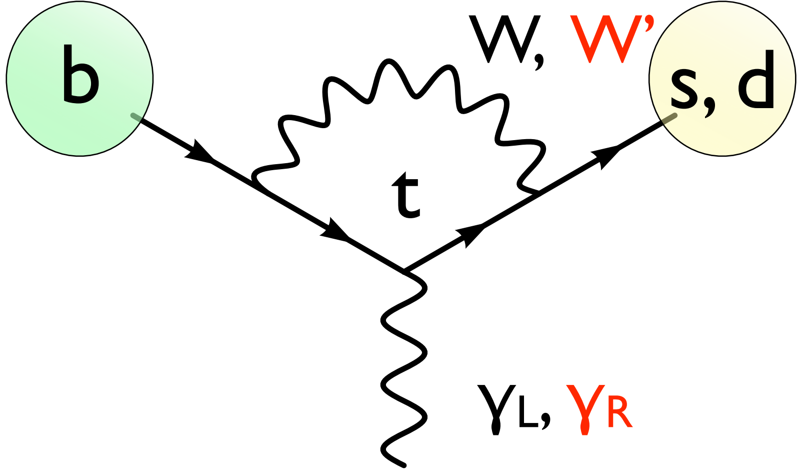
Searching signals of LRSM

Flavour physics signal



W: b →s/dγ_L (left-handed polarization)

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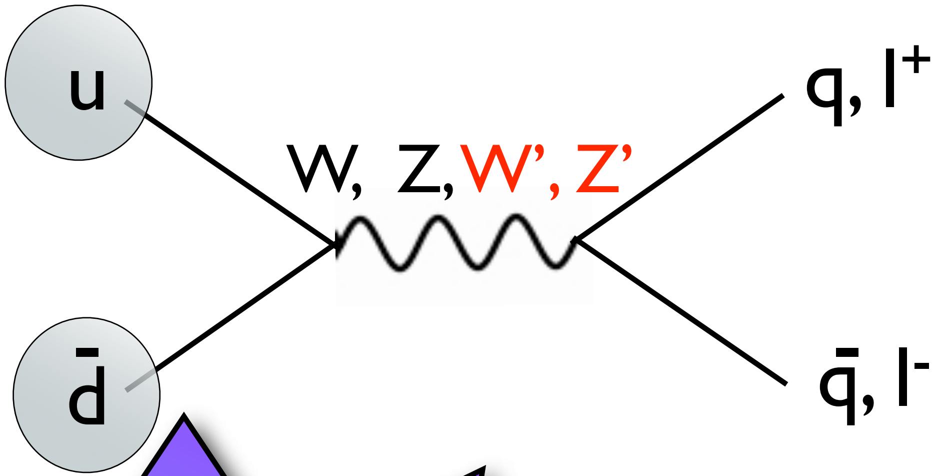
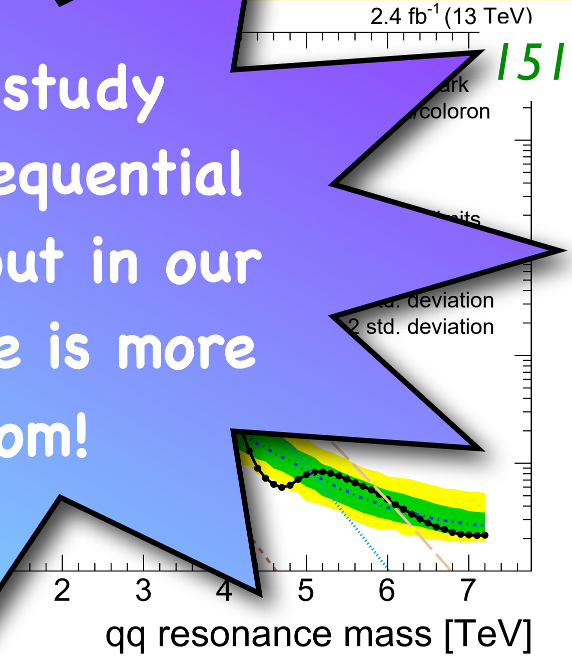
ATLAS/CMS signal



Gene sonan search with dijets



1512.01224

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Generic study assumes “sequential couplings” but in our model there is more freedom!

Right-handed CKM matrix

Langacker-Sankar model (‘89):

proposed to avoid constraints from various low energy experiments.

$$V^R_{(A)} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_\alpha & \pm s_\alpha \\ 0 & s_\alpha & \mp c_\alpha \end{pmatrix}, \qquad V^R_{(B)} = \begin{pmatrix} 0 & 1 & 0 \\ c_\alpha & 0 & \pm s_\alpha \\ s_\alpha & 0 & \mp c_\alpha \end{pmatrix},$$

-Top could couple Strange/Bottom
-Up-Down coupling is one

We studied previously

EK, C.-D. Lu and F.-S. Yu (JHEP 2013)

-Top could couple Down/Bottom
-Up-Down coupling is zero

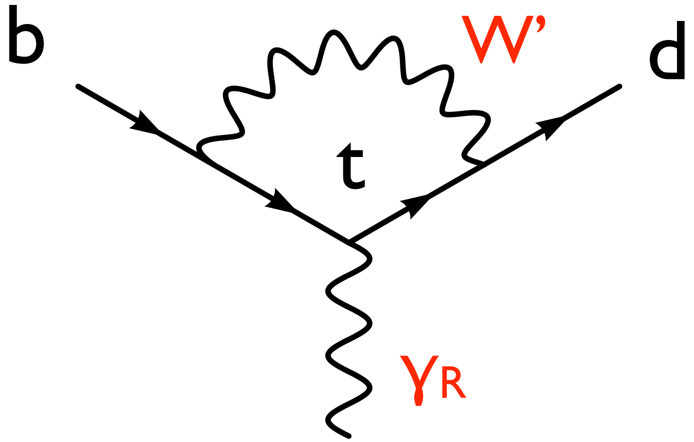
Our 2016 project

with new collaborators
T. Abe & M. Nojiri (KEK)

Searching signals of LRSM

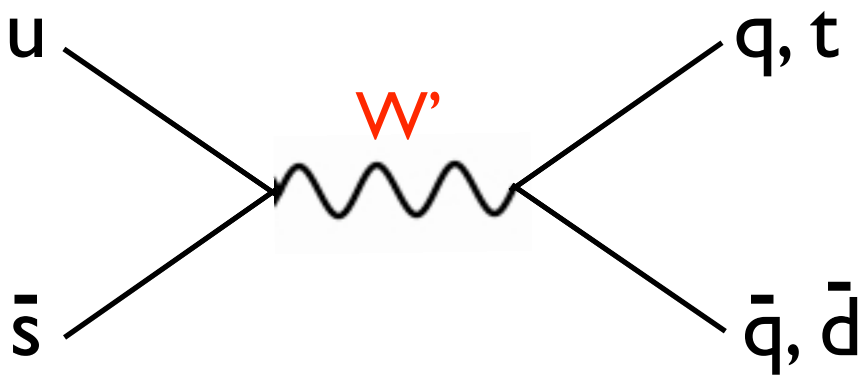
$$V^R_{(B)} = \begin{pmatrix} 0 & \boxed{1} & 0 \\ c_\alpha & 0 & \pm s_\alpha \\ s_\alpha & 0 & \mp c_\alpha \end{pmatrix}$$

Flavour physics signal

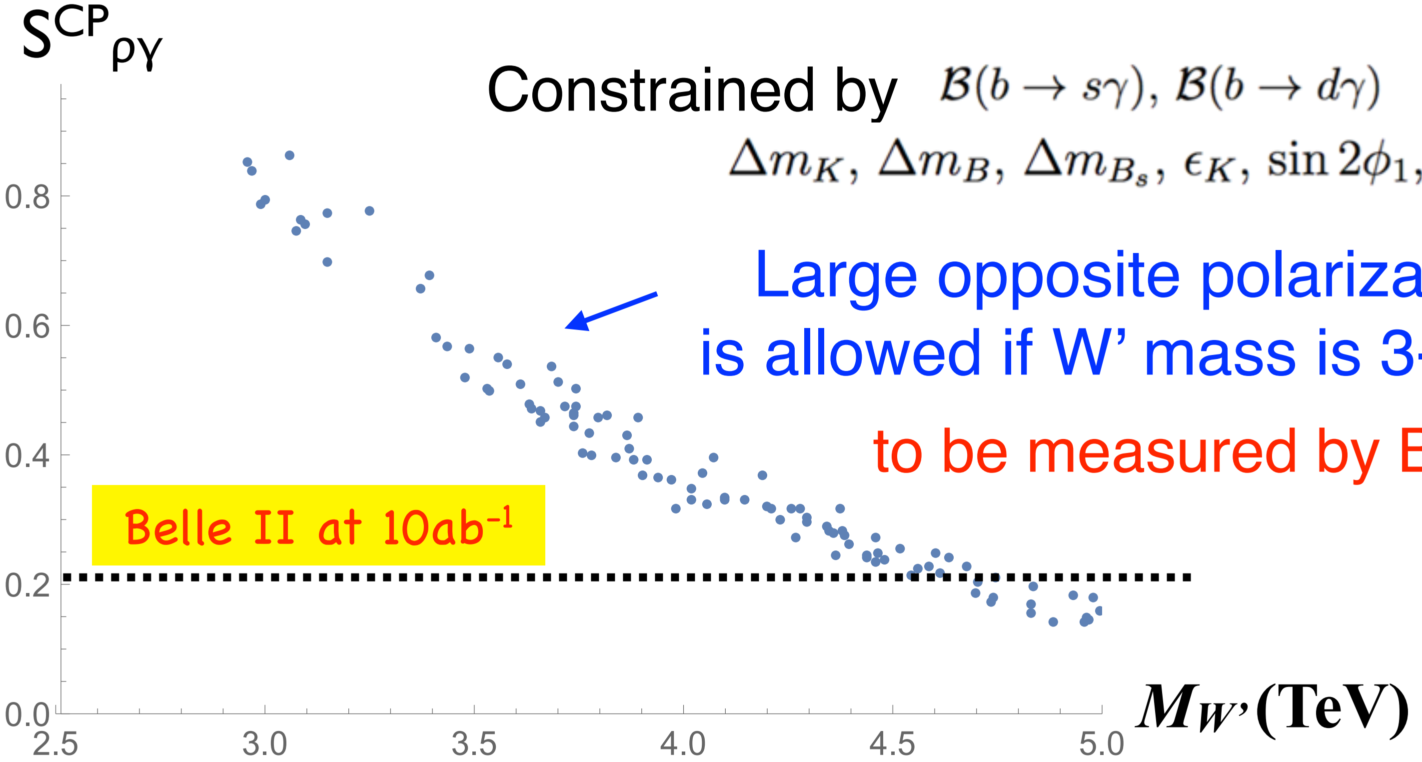


B→ργ photon polarization measurement at Belle II

ATLAS/CMS signal



Djets signal or single top (without bottom associated)??



Constrained by $\mathcal{B}(b \to s\gamma)$, $\mathcal{B}(b \to d\gamma)$

Δm_K, Δm_B, Δm_{B_s}, ϵ_K, $\sin 2\phi_1$, ϕ_s

Large opposite polarization is allowed if W' mass is 3-4TeV

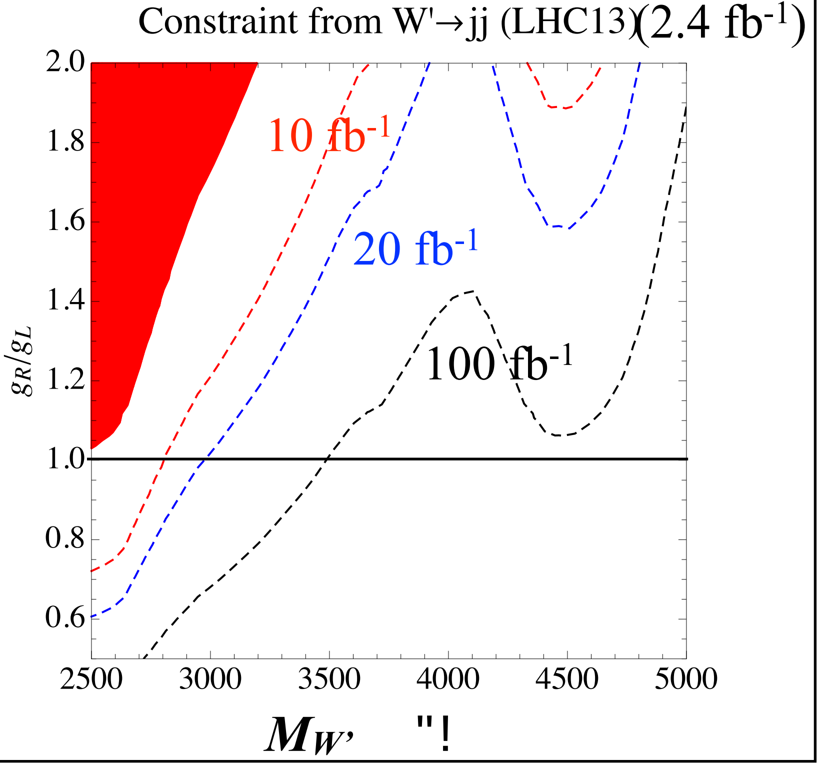
to be measured by Belle II

Belle II at 10ab^{-1}

Very preliminary results
T. Abe, E.K. M. Nojiri
and F.-S. Yu

Flavour physics signal

ATLAS/CMS signal



Conclusions

- Having two high luminosity experiments (LHCb&Belle II) in very good shapes, flavour physics will keep being a powerful tool to search for signals beyond the SM.
- Our new project considers Left-Right symmetric model with a particular right-handed CKM matrix and study both the flavour and high-pT signals from this model.
- We found that $S^{CP}_{\rho\gamma}$ (a new Belle II golden channel) can lead us a clear signal if Mw' is 3-4 TeV.
- We found that the same model would lead to a signal for the ATLAS/CMS resonance search with dijet. We also investigate the single top final state so as to distinguish different models.

Backup

Time-dependent CP asymmetry in $\bar{B} \to f_{CP}\gamma$ and $\bar{B} \to B \to f_{CP}\gamma$

[Atwood, Gronau, Soni, 1997']

$$\begin{tikzcd}
 & B \arrow[r, "m_s(m_b)"] & K_{\rm res}\gamma_{L(R)} \arrow[dr] & \\
\overline{B}(t=0) \arrow[ur, "\frac{p}{q}f_-(t)"] \arrow[dr, "f_+(t)"'] & & & (n\pi)K_S\gamma_{L(R)} \\
 & \overline{B} \arrow[r, "m_b(m_s)"] & \overline{K}_{\rm res}\gamma_{L(R)} \arrow[ur] &
\end{tikzcd}$$

$$A_{CP}(t) \equiv \frac{\Gamma(\overline{B}(t) \to f_{CP}\gamma) - \Gamma(B(t) \to f_{CP}\gamma)}{\Gamma(\overline{B}(t) \to f_{CP}\gamma) + \Gamma(B(t) \to f_{CP}\gamma)} \approx S_{f_{CP}\gamma}\sin(\Delta m t)$$

- Indirect measurement of photon polarization

$$S^{\rm SM}_{K_S\pi^0\gamma} = -(2.3 \pm 1.6)\%, \qquad S^{\rm exp}_{K_S\pi^0\gamma} = -0.16 \pm 0.23$$

[Ball,Jones,Zwicky,PRD2007']

[HFAG, 2013']

- In the future Belle II experiment, the error of *S* will be significantly reduced down to 2%.

$B^0 \rightarrow K_{\mathrm{res}}\gamma \rightarrow K_S\rho^0\gamma \rightarrow K_S\pi^+\pi^-\gamma$

$S_{\rho Ks\gamma}$ is determined by the dilution factor:

$$\mathcal{D} = \frac{\mathcal{S}_{\pi^+\pi^-K_S\gamma}}{\mathcal{S}_{\rho K_S\gamma}}$$

Non-CP eigenstates may contribute

$$= \frac{\sum_{\lambda=L,R}|A_\lambda^{\rho K_S}|^2 - |A_\lambda^{K^{*+}\pi^-}|^2 - |A_\lambda^{(K\pi)_0^+\pi^-}|^2 + 2\mathrm{Re}[A_\lambda^{*\rho K_S}A_\lambda^{K^{*+}\pi^-}] + 2\mathrm{Re}[A_l^{*\rho K_S}A_\lambda^{(K\pi)_0^+\pi^-}]}{\sum_{\lambda=L,R}|A_\lambda^{\rho K_S}|^2 + |A_\lambda^{*K^{*+}\pi^-}|^2 + |A_\lambda^{*(K\pi)_0^+\pi^-}|^2 + 2\mathrm{Re}[A_\lambda^{*\rho K_S}A_\lambda^{K^{*+}\pi^-}] + 2\mathrm{Re}[A_\lambda^{*\rho K_S}A_\lambda^{(K\pi)_0^+\pi^-}]}$$

↑ ↑

Including *S*-wave *Kπ* resonances

↓

[Akar, Ben-Haim, Hebinger, **Kou, FSY**, in preparation available LAL-report-15-75]

	Babar 2015	Belle 2008 without $(K\pi)_0$
$\mathcal{S}_{K_S^0\pi^+\pi^-\gamma}$	$0.14 \pm 0.25 \pm 0.03$	$0.09 \pm 0.27^{+0.04}_{-0.07}$
$\mathcal{D}_{K_S^0\rho^0\gamma}$	$-0.78^{+0.19}_{-0.17}$	$0.83^{+0.19}_{-0.03}$
$\mathcal{S}_{K_S^0\rho^0\gamma}$	$-0.18 \pm 0.32^{+0.06}_{-0.05}$	$0.11 \pm 0.33^{+0.05}_{-0.09}$