

B flavor and time-dependent CP violating measurement with Belle II

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for proponents

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Outline

- Proponents and collaborating colleagues
- Importance of CP violation measurements
- Attempts to be made at Belle II in coming years
- Summary

Proponents

French Group

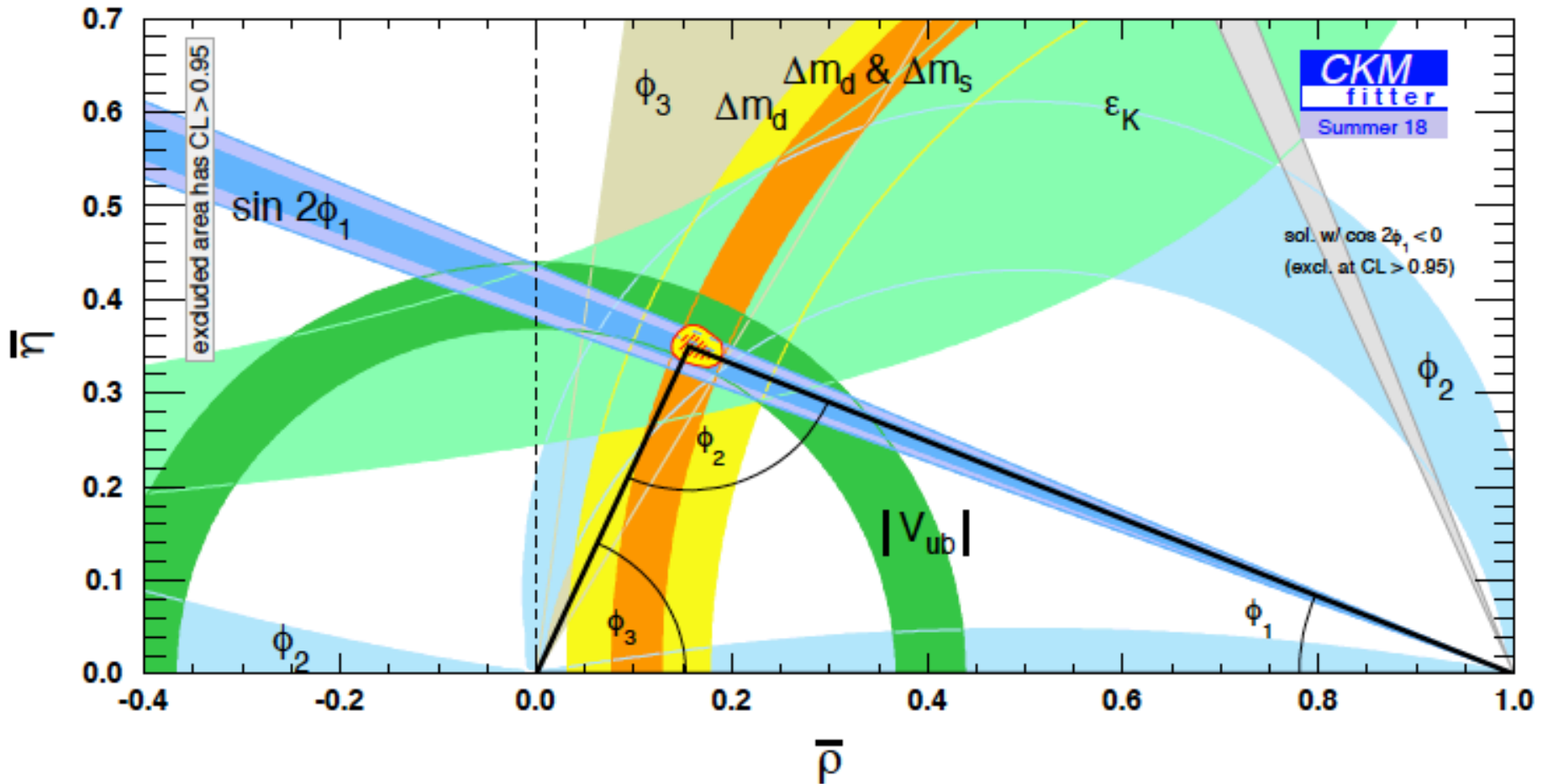
- Jerome Baudot
- Isabelle Ripp-Baudot
- Reem Rasheed
- Tristan Fillinger
- Sviatoslav Bilokin
- Giulio Dujany

Japanese Group

- Kenkichi Miyabayashi
- Alessandro Gaz
- Yosuke Yusa
- Yutaka Ushiroda
- Hikaru Tanigawa
- Miho Fujii

Belle II time-dep. CPV group includes also IPMU, Tokyo, MPI and other colleagues.

BaBar & Belle legacy; unitarity triangle

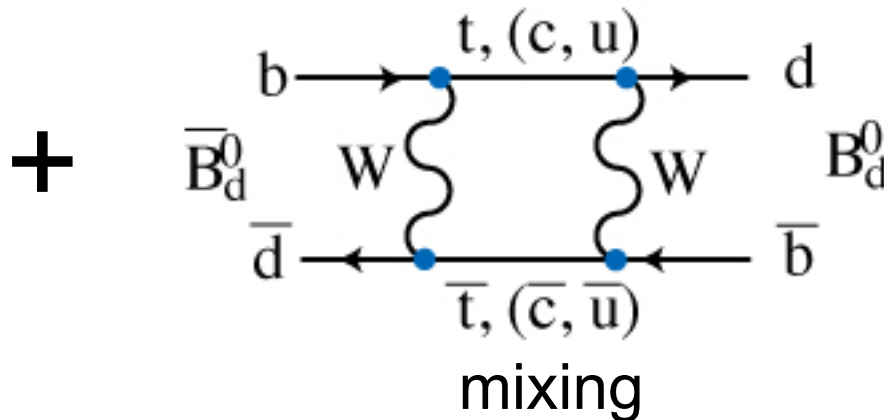
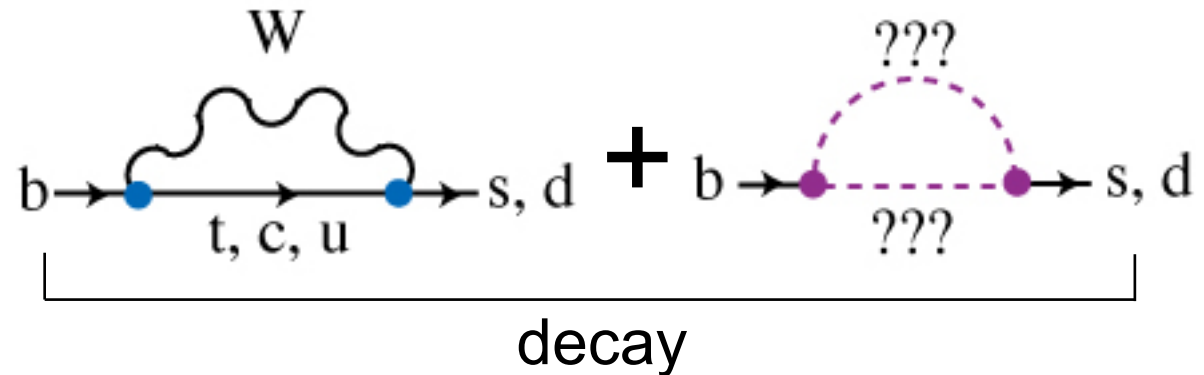


Entire mission was within B decay studies.

How to open the next door?

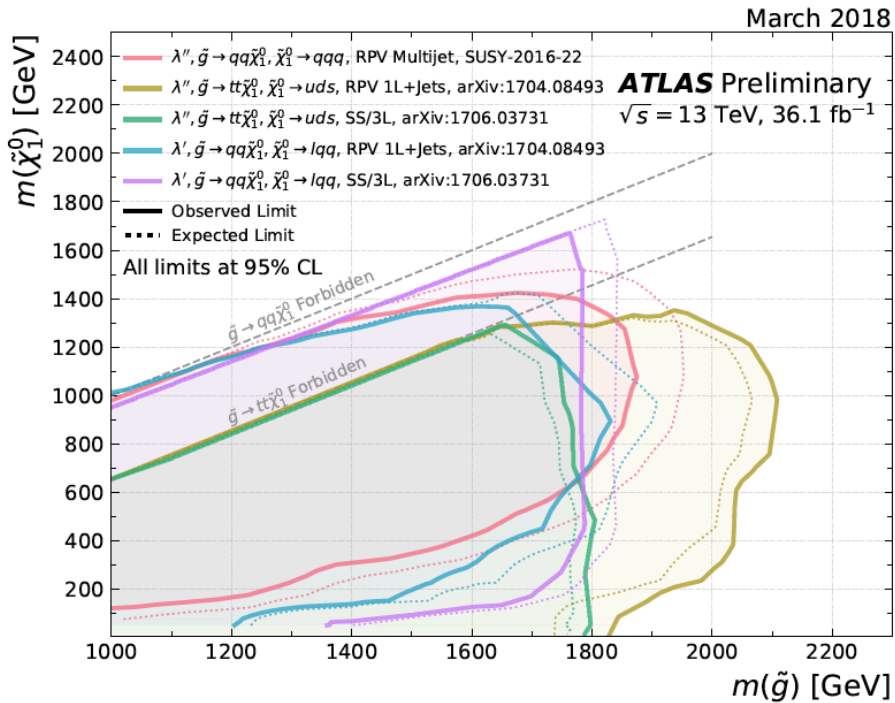
- Approach to the physics beyond the SM (i.e. New Physics, NP) via quantum effects.

Amplitude giving
Observable =

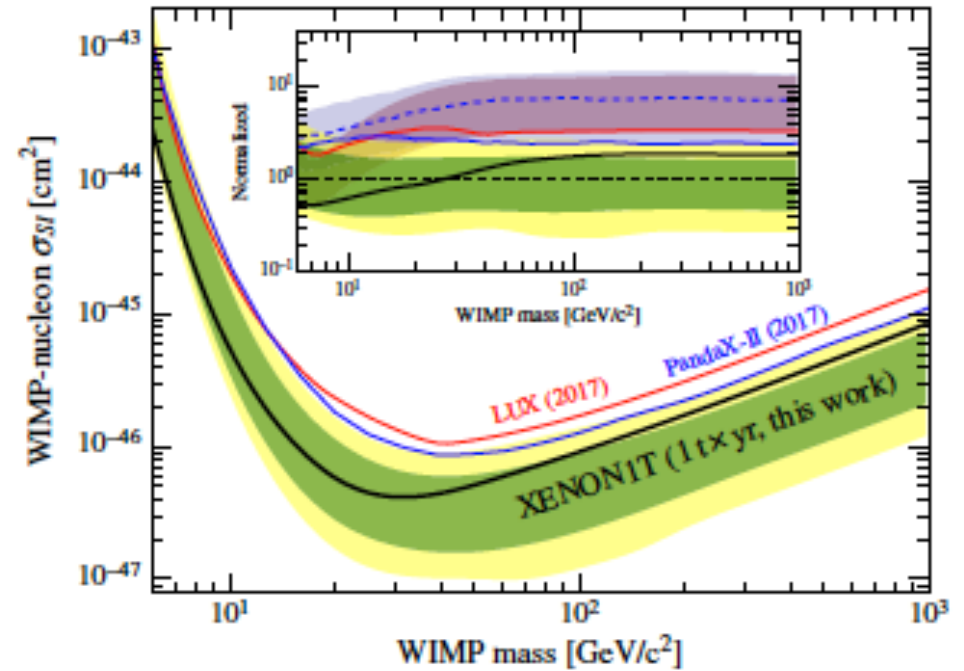


So far, no signature of SUSY, WIMP, ..

XENON1T, PRL121,111302(2018)

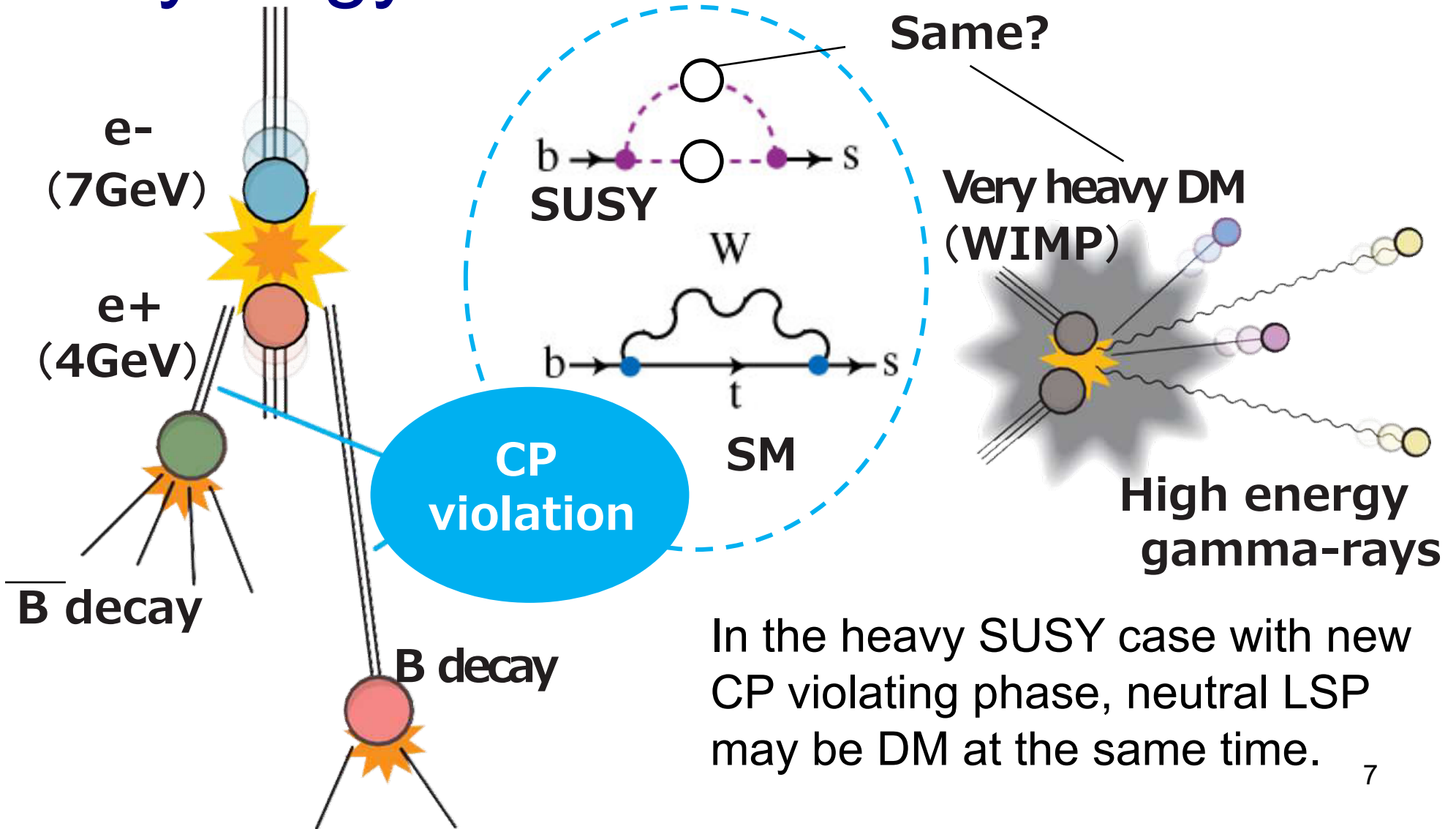


$M(\text{SUSY}) > \text{TeV}$



Mass window for under ground exp. is 10 GeV ~ 100 GeV.

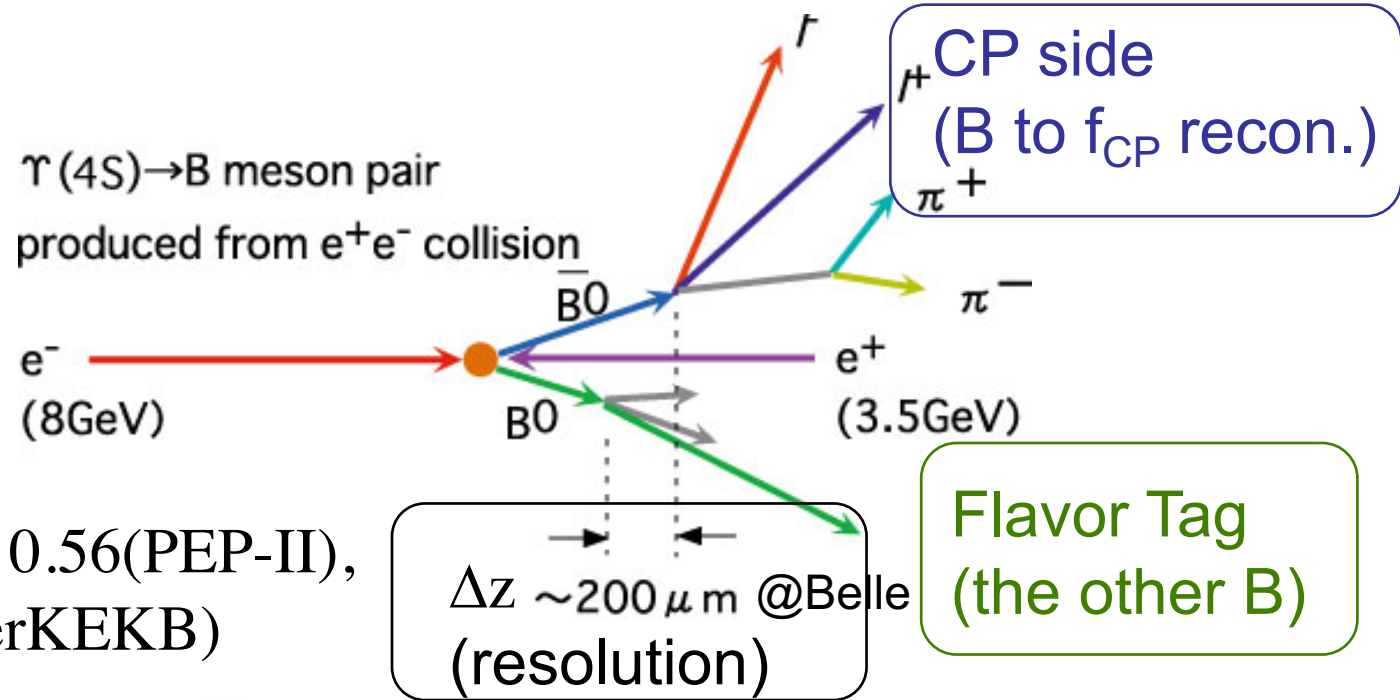
Possible scenario; Synergy with other measurements



Requirement to do time-dep. CPV

In order to see CPV by interference between decay and mixing.

$\Upsilon(4S) \rightarrow B$ meson pair
produced from e^+e^- collision



$$\Delta z = \beta \gamma c \Delta t,$$

$$\beta \gamma = 0.425 (\text{KEKB}), 0.56 (\text{PEP-II}), 0.284 (\text{SuperKEKB})$$

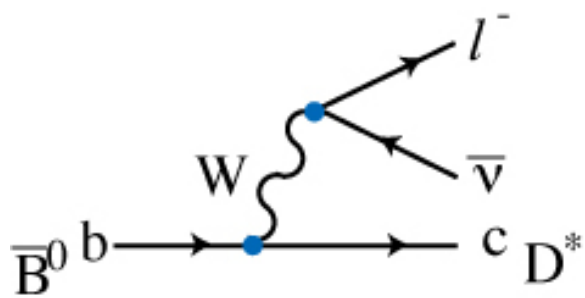
$$A_{\text{CP}}(\Delta t) = \frac{\Gamma(\bar{B}^0(\Delta t) \rightarrow f_{\text{CP}}) - \Gamma(B^0(\Delta t) \rightarrow f_{\text{CP}})}{\Gamma(\bar{B}^0(\Delta t) \rightarrow f_{\text{CP}}) + \Gamma(B^0(\Delta t) \rightarrow f_{\text{CP}})} = S_{f_{\text{CP}}} \sin(\Delta m \Delta t) + A_{f_{\text{CP}}} \cos(\Delta m \Delta t)$$

$$S_{f_{\text{CP}}} = \frac{2 \text{Im}(\lambda)}{|\lambda|^2 + 1} \quad A_{f_{\text{CP}}} = \frac{|\lambda|^2 - 1}{|\lambda|^2 + 1} \quad \lambda = \frac{q}{p} \frac{\bar{A}(f_{\text{CP}})}{A(f_{\text{CP}})}$$

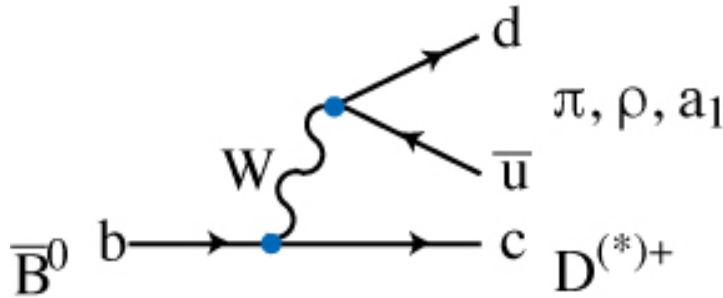
$$-C_{f_{\text{CP}}} = A_{f_{\text{CP}}} \quad |\lambda| = 1 \text{ if no DCPV}$$

In the coming two years

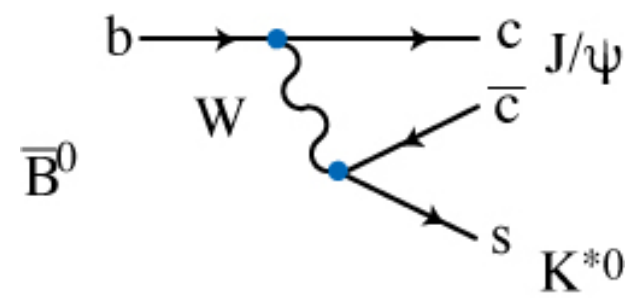
- At first = currently, understanding detector and validation of analysis procedure are main issues.
- Before looking at CP eigenstate modes' Δt distribution, flavor-specific B decay modes (tree diagram) are to be visited for establish vertex resolution and flavor tagging.



$B^0 \rightarrow D^* l \nu$;
semileptonic

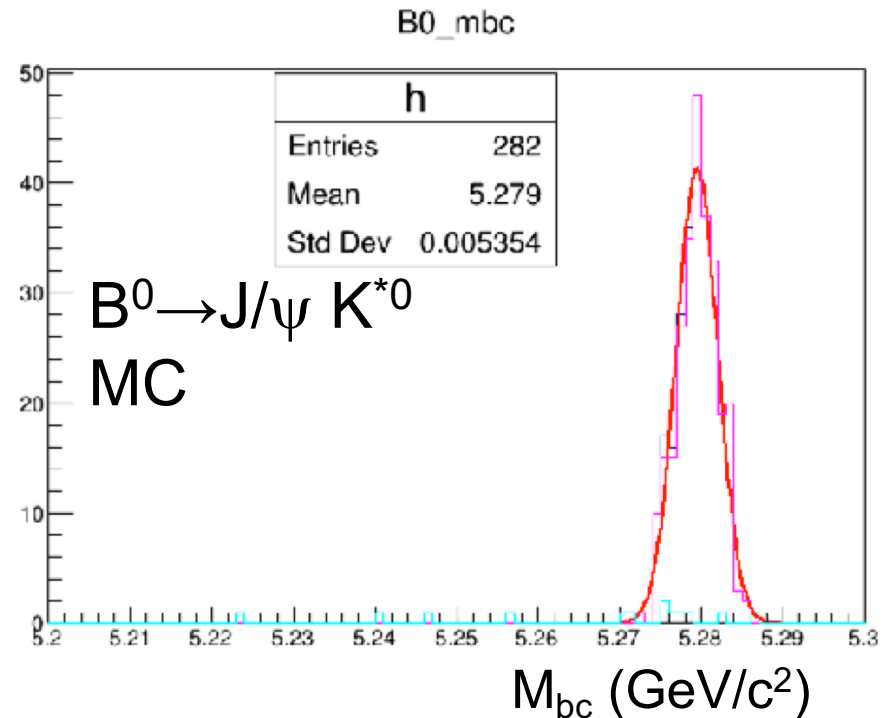
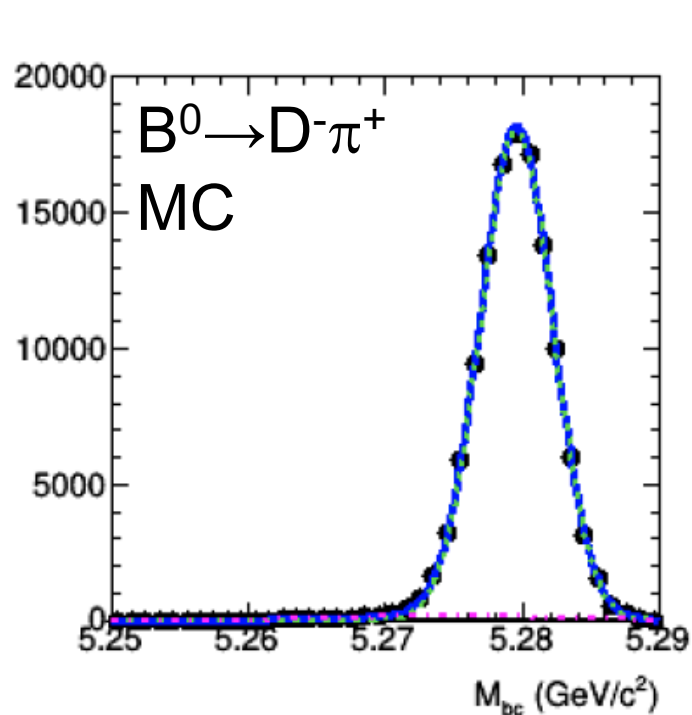


$B^0 \rightarrow D^{(*)} \pi, \rho, a_1$;
hadronic



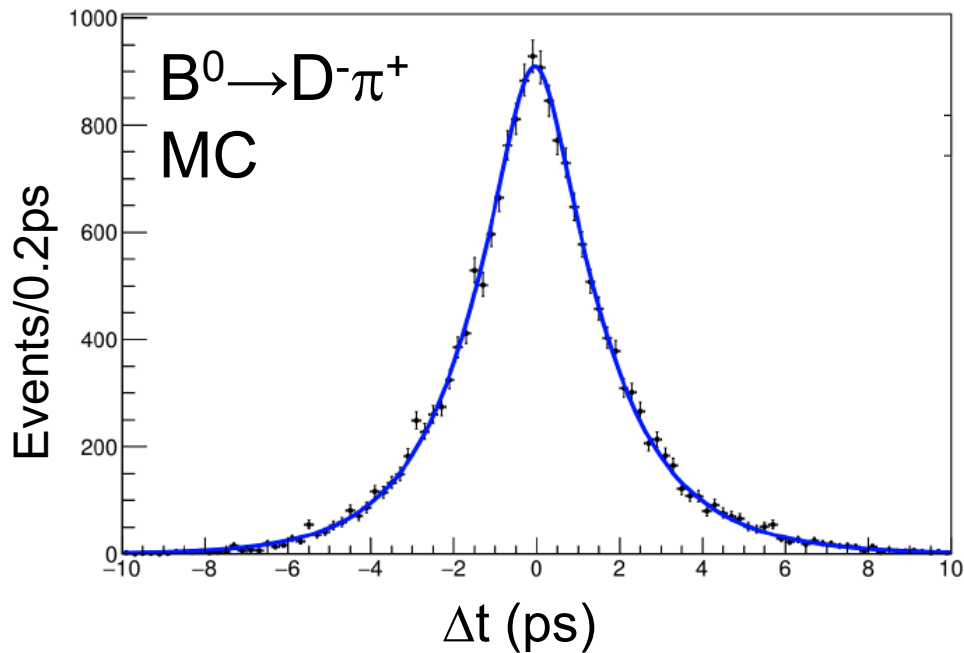
$B^0 \rightarrow J/\psi K^{*0}$

Reconstruction of B decays

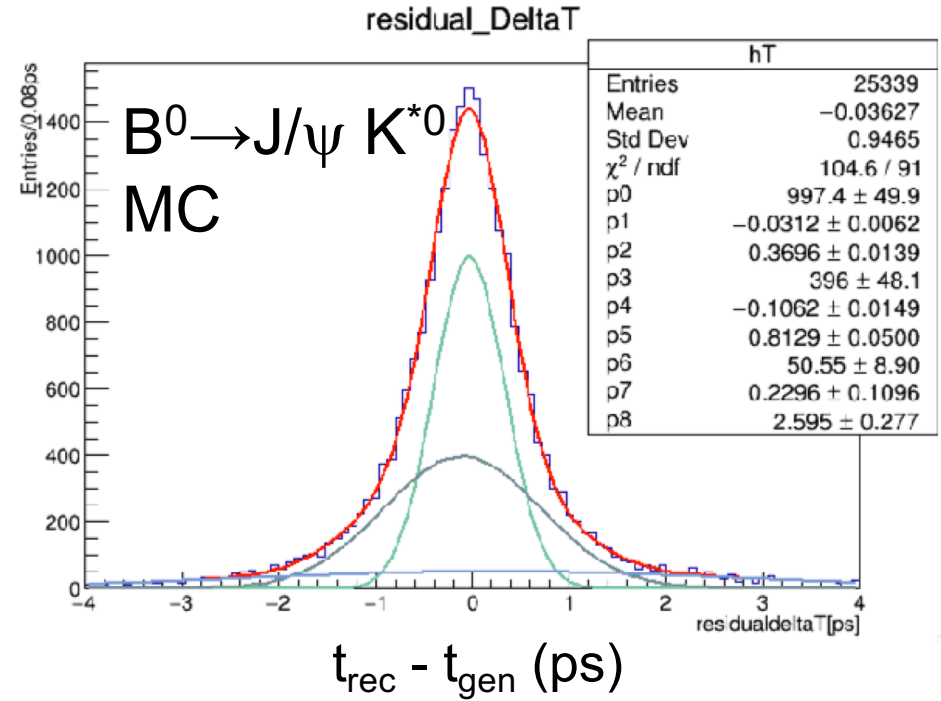


In addition to the hadronic modes mentioned above, for $B^0 \rightarrow D^{*-} l^+ \nu$, partial reconstruction technique with slow pion and lepton is introduced to maximize statistics from early data.

Δt reconstruction, resolution



Extraction of lifetime is possible.



Vertex difference between $J/\psi \rightarrow \mu^+ \mu^-$ and $K^{*0} \rightarrow K^- \pi^+$ is sensitive to Data/MC difference.

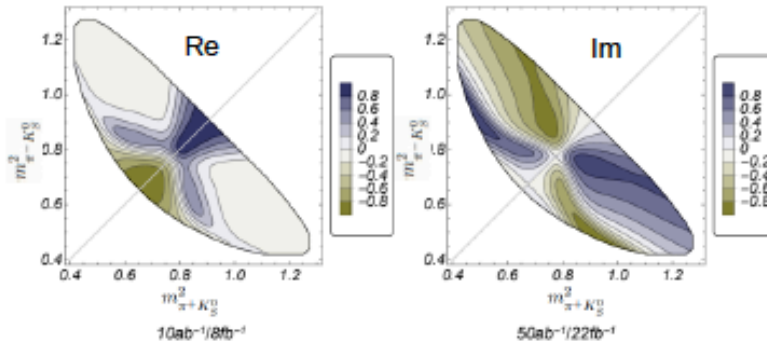
~10/fb accumulation of data enables us to start to evaluate decay vertex reconstruction performance and Δt resolution.

Not only simple extension but also new attempts for physics

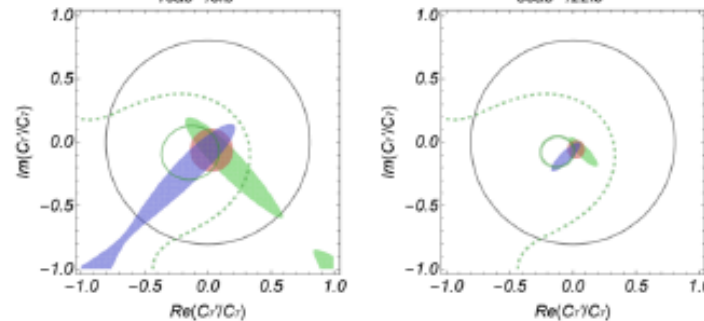
Potential of $B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma$ in Belle data

- **New:** We can separate the Dalitz space as in arxiv:1802.09433

Normalized decay amplitude of $K_1(1270)$ including all intermediate resonances



Prospect for the Wilson coefficient determination using S^+ and S^-



- Using only one channel, we can constrain both Re and Im C_7'

$B^0 \rightarrow K_S \pi^+ \pi^- \gamma$ case, dividing $M(K_S \pi^+) > M(K_S \pi^-)$ or else, possibility to constrain both Re and Im parts of C_7' effective operator.

Showing the feasibility with Belle data is also in the scope.

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Proposed by Strasbourg colleagues, S. Bilokin, et al.

Summary(1)

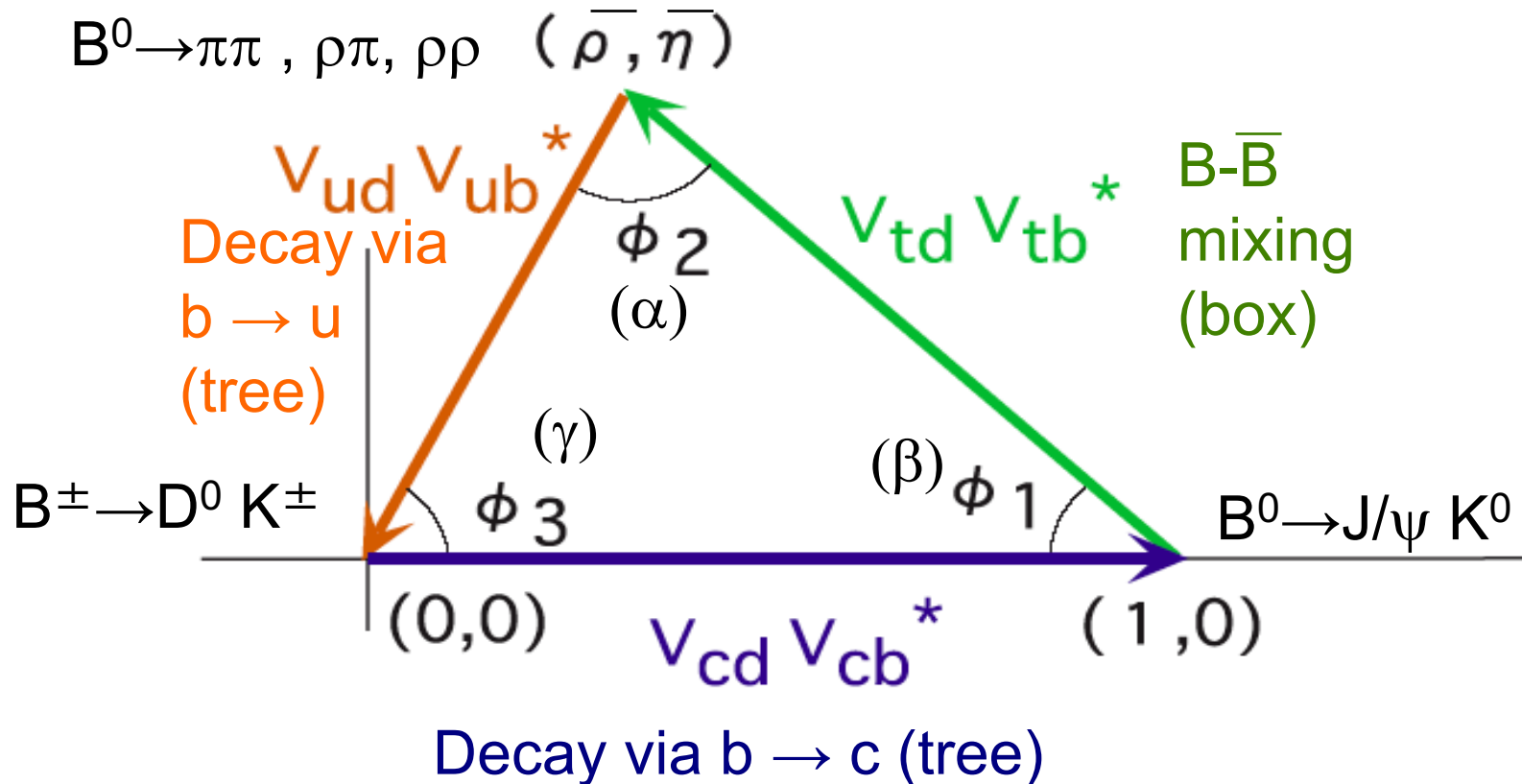
- Search for NP via quantum effects now very important.
 - No signature of SUSY up to ~ 1 TeV at LHC, so far.
 - No WIMP direct detection reported from underground exp.
- Measurements of time-dep. CP violation in penguin B decays will play a crucial role in wider scope.
 - New CP phase in heavy SUSY? \rightarrow is it also DM particle?
(to be searched for in high energy cosmic gamma rays.)

Summary(2)

- In the coming a couple of years, understanding detector and establishing analysis machinery are the key issues.
 - Actively working on $B^0 \rightarrow D^{*-} l^+ \nu$, $D^{(*)} \pi$ (or ρ , a_1), $J/\psi K^{*0}$.
 - Then CP eigenstate modes.
- Innovative ideas are also to be tackled.
 - For example, dividing $B^0 \rightarrow K_S \pi^+ \pi^- \gamma$ by Dalitz plane.
- Collaborative effort already started.
 - For Belle analysis, KM gave an instruction to S. Bilokin.
 - R. Rasheed has a month stay planned in Nagoya to work together with A. Gaz.

Backup slides

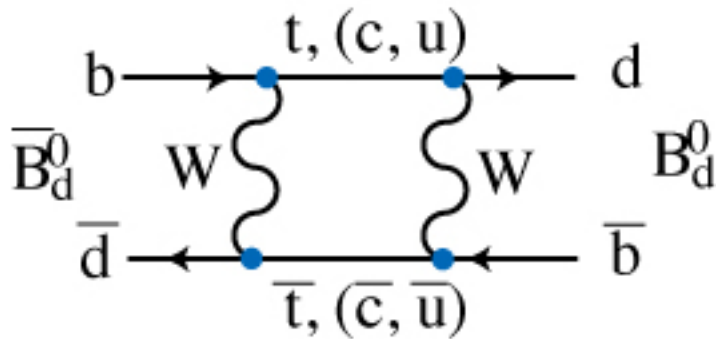
BaBar & Belle legacy; KM Unitarity triangle



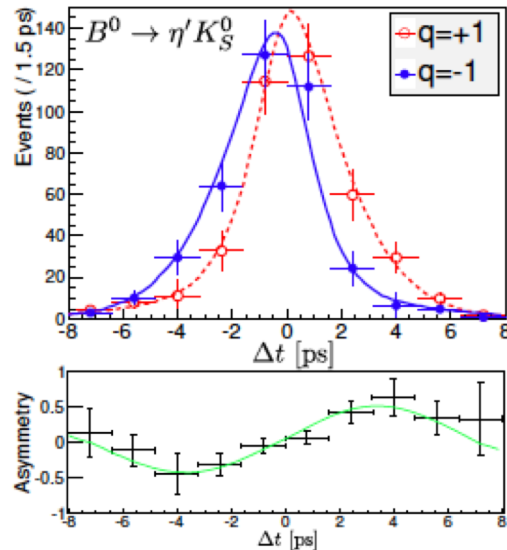
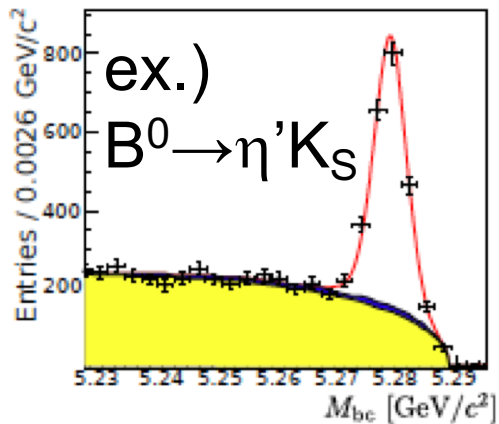
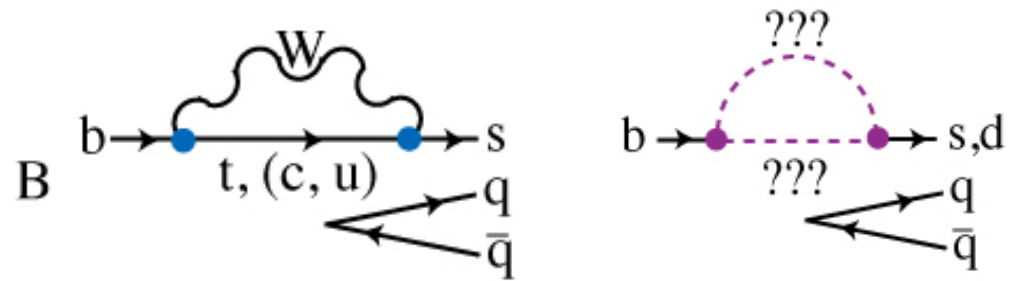
Comprehensive test of Kobayasi-Maskawa scheme;
All needed information got by B decay studies.

Time-dependent CP violation in Rare B decays

Mixing

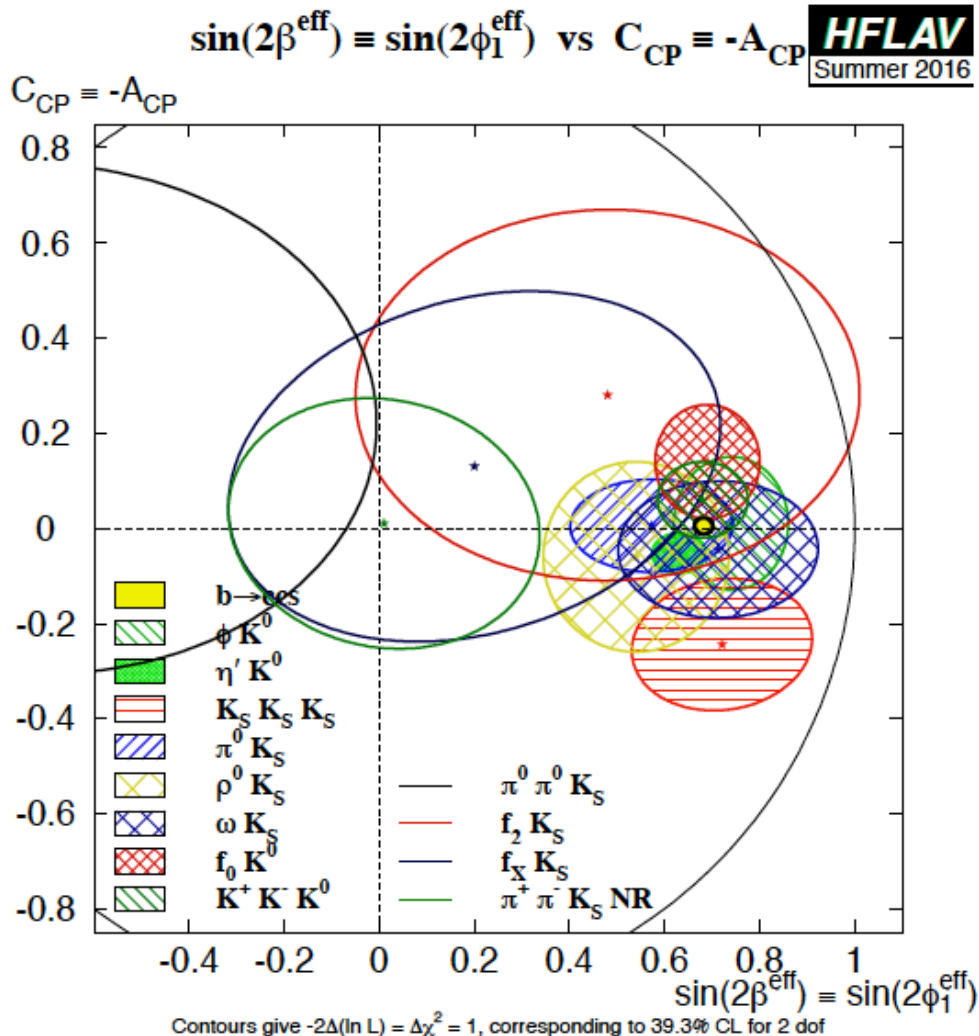


Decay via penguin diagram



In SM, expected to be same as $B^0 \rightarrow J/\psi K^0$, while NP with additional CP violating phase may cause deviation.

Current situation



Still precision is statistically dominated.



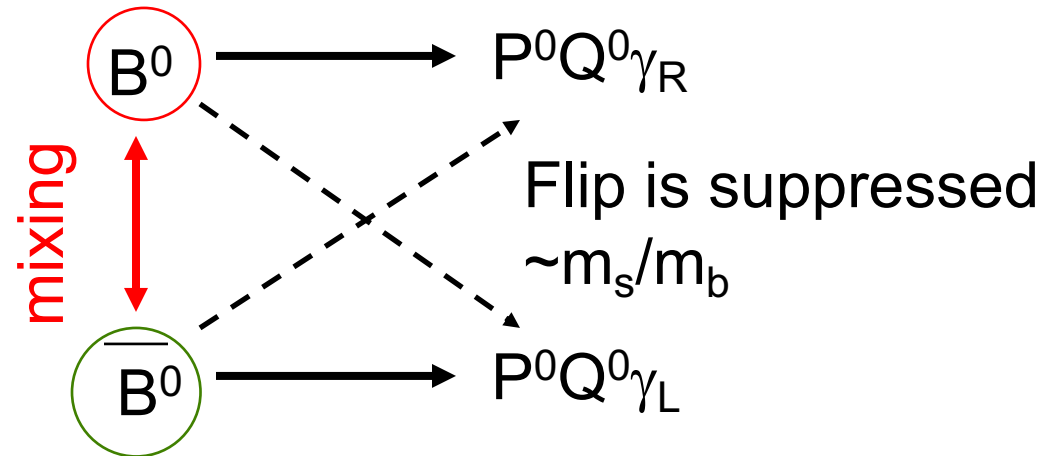
To obtain sensitivity CP violation of $O(10^{-2})$, we need $O(10\text{ab}^{-1})$ integrated lumi. to be got by SuperKEKB and Belle II.

CP violation in radiative B decay such as $B^0 \rightarrow K_S \pi^0 \gamma$

In SM, the γ oppositely circular polarized between B^0 and \bar{B}^0 .

↓
Small CP violation expected;
 $S_{K\pi\gamma} \sim 2(m_s/m_b)\sin 2\phi_1 \sim 0.03$
 $A_{K\pi\gamma} \sim 0.01$

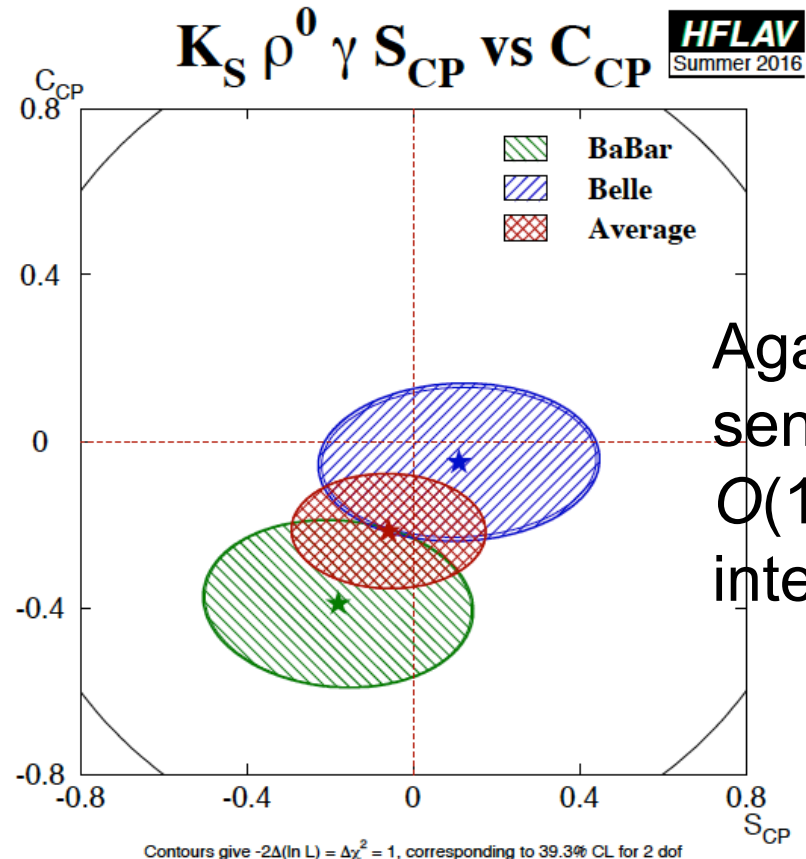
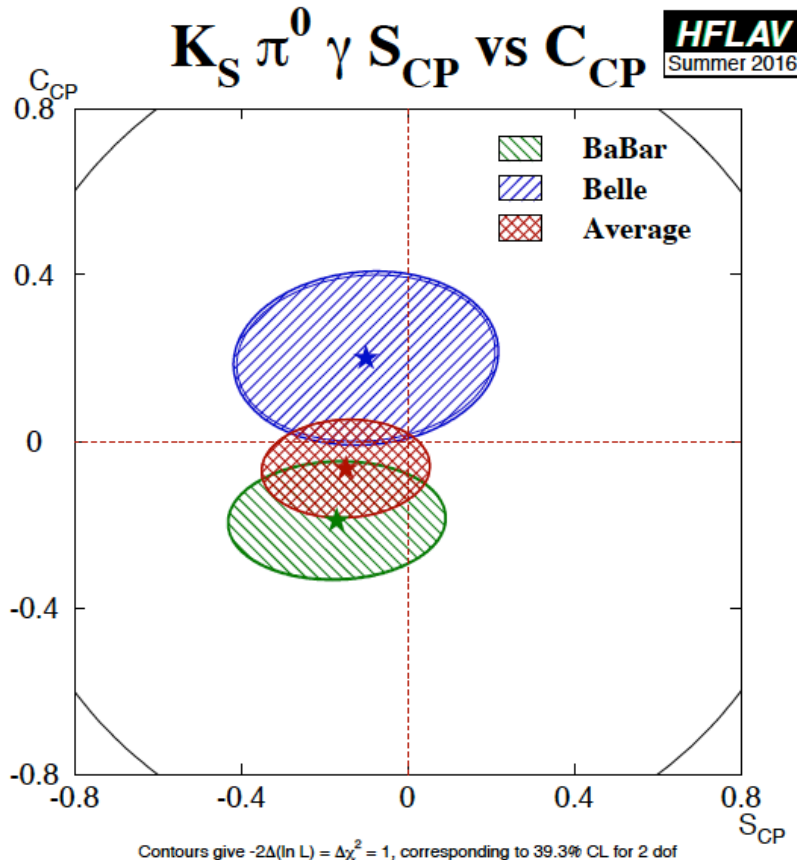
↓
Large mixing-induced CP violation is a signature of NP with right-handed coupling.



This holds for any P^0, Q^0

D.Atwood, T.Gershon, M.Hazumi and A.Soni PRD71,076003(2005)

Current status; Radiative B decays



Again, $O(10^{-2})$ sensitivity needs $O(10\text{ab}^{-1})$ integrated lumi.

If significant CP violation \rightarrow what happens on sterile neutrino search?
 If both positive, GUT with right-handed coupling?